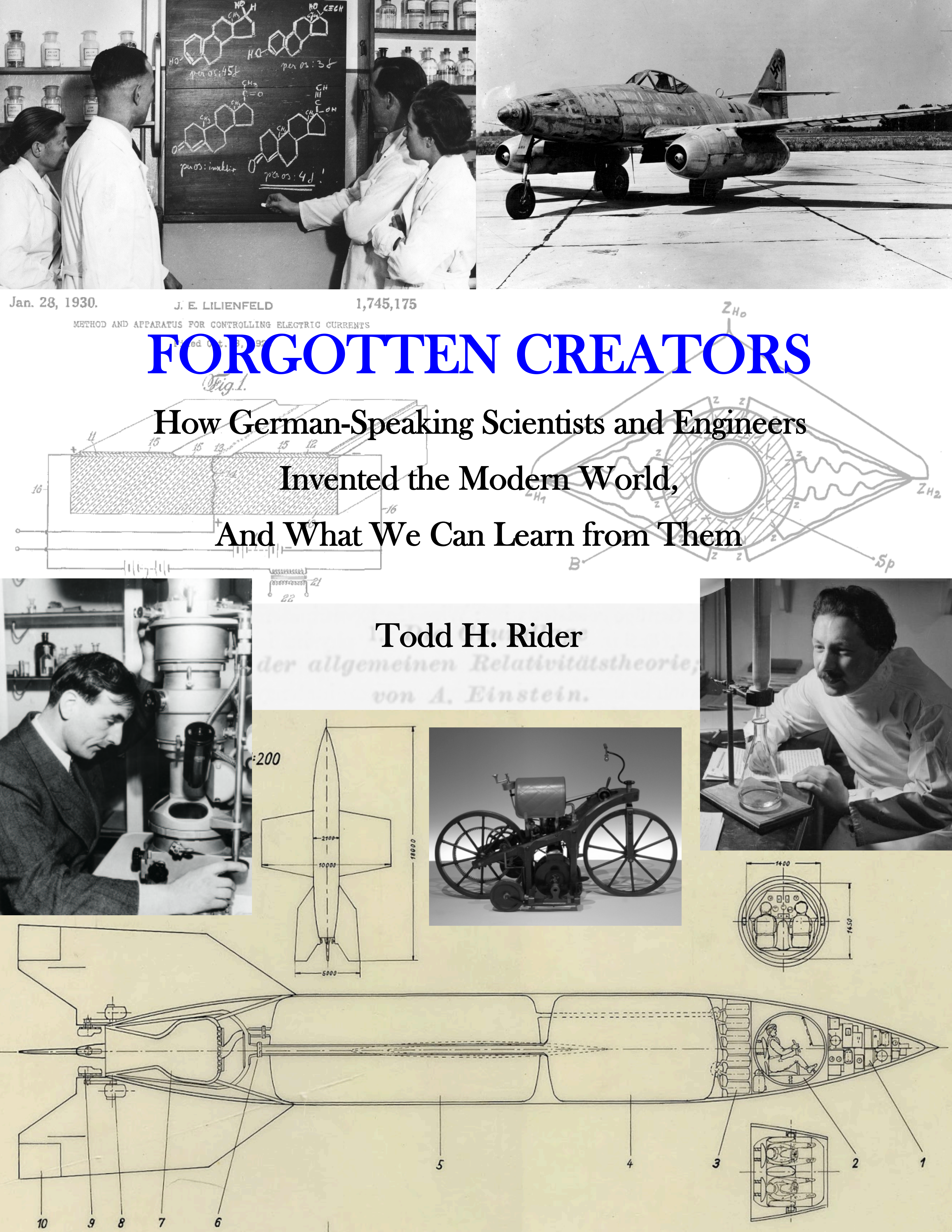
FORGOTTEN CREATORS

How German-Speaking Scientists and Engineers
Invented the Modern World,
And What We Can Learn from Them

Todd H. Rider


Jan. 28, 1930.
J. E. LILIENFELD
1,745,175
METHOD AND APPARATUS FOR CONTROLLING ELECTRIC CURRENTS
Fig.1.
der allgemeinen Relativitätstheorie;
von A. Einstein.
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Lebe mit deinem Jahrhundert, aber sei nicht sein Geschöpf; leiste deinen Zeitgenossen, aber was sie bedürfen, nicht was sie loben.

Live with your century, but do not be its creature; create for your contemporaries, not what they praise, but rather what they need.

Friedrich Schiller, *On the Aesthetic Education of Man*, Letter 9 (1794)

FORGOTTEN CREATORS

How German-Speaking Scientists and Engineers Invented the Modern World, And What We Can Learn from Them

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Comments from Reviewers

“Todd H. Rider’s *Forgotten Creators* is a monumental treatise about and an exciting intellectual journey through the contributions of scientists and technologists in Germany and other Central European countries and German-speaking areas to universal progress. It is thoroughly researched, meticulously documented, and presented in an easy-to-perceive way. The pre-war and pre-Nazi German system of science support has lessons that would be difficult to emulate but worthy to ponder about even today. The long-range tragic consequences in science caused by National Socialism are well demonstrated as are the benefits in the West and in the East from the exodus of Jewish scientists before and the importation of others from Germany following World War II. The book is a virtually bottomless well for mining reliable information in the history of science and technology. The ‘forgotten creators’ are no longer forgotten. Todd is to be congratulated for his accomplishment and thanked for sharing it so generously with the international community.”

István Hargittai, Professor Emeritus of Chemistry, Budapest University of Technology and Economics,
author of *Buried Glory*, *Candid Science*, *Drive and Curiosity*, *Great Minds*,
Judging Edward Teller, *Martians of Science*, and *The Road to Stockholm*

“It was really with a great feeling of appreciation that I discovered the various chapters (physics, mathematics, biology, medicine, etc.) of this monumental work (over 6,000 pages!) by Todd H. Rider, which is dedicated to the German contributions to the advancement of scientific knowledge in the modern world. Thousands of valuable pieces of information all collected in a unique source make this book a precious tool both for reading and for research.”

Umberto Bartocci, Professor Emeritus of Mathematics and Mathematical History, University of Perugia

“Todd H. Rider’s *Forgotten Creators* is an encyclopedic consideration of Germany’s central place in the advancement of science and technology between 1800 and 1945. Drawing upon a wide range of sources, Rider has summarized that effort in a survey that will impress the reader just as much for the breadth of German intellectual achievement as for the influence that achievement has had upon the modern world.”

George W. Cully, retired Director, Office of History at Air University, Maxwell Air Force Base, Alabama

“The scope and ambition of *Forgotten Creators* is really incredible. It is a work of great scholarship, an effective narrative with many historical quotes by scientists and their contemporaries that make it a very engaging read. It is richly illustrated with so many photos of researchers, where they worked, maps, patents, etc. I think this book will be of great value to historians of science and public policy institutions. I also think that as the center of economic and scientific innovation seems to be shifting from West to East, many forward-thinking people in Asia will be reading this book closely as they consider their own path ahead.”

Brian Dempsey, President, Massachusetts Association of Biology Teachers

“The current fragmentation of scientific disciplines up to the point of marginalization raises the question whether examples from history do exist to overcome this situation. Todd Rider attempts an answer, posing the counter question: ‘Which lessons can be learned from the most productive German-speaking inventors of the nineteenth and early twentieth century?’ His intention is not only to start a discussion on the chances to successfully transfer former educational conditions to the present scientific system but also to remember the inventors. *Forgotten Creators*, published online, is an impressive compilation of German achievements, covering the natural sciences, mathematics, and engineering until WWII.”

Gernot Eilers, German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety

“Todd H. Rider reminds us with *Forgotten Creators* that many key technologies like jet flight, helicopters, rocket propelled gliders, guided missiles, night vision, special alloys and welding methods, or simply synthetic rubber or polymer products that are common today were actually developed in the first half of the twentieth century in Central Europe under the control of Germany. These technologies belonged among the most valuable treasures the Allies won in the Second World War and triggered a strategic arms race among the newly emerging superpowers in the subsequent decades of the Cold War (which some say had started already in 1945 in St. Georgen/Gusen, Austria). An indispensable new reference book for all who are interested in the history of technology and the twentieth century.”

Rudolf A. Haunschmied, Gusen Memorial Committee, author of *St. Georgen—Gusen—Mauthausen*

"Todd Rider's fundamental work, *Forgotten Creators*, is a formidable counter against the oblivion or even 'cancel science' regarding pre-Nazi and Nazi Germany. This era's technical and scientific achievements, although mostly along the sad Heraclid dictum '*bellum omnium pater*,' have their impacts even today. Apparently lots of documents of this period are still classified. I am convinced that the tenacious author will bring those to light and underpin his *magnum opus* further."

Manfred Höfert, former Head of Radioprotection at CERN, Geneva, Switzerland

"Todd Rider's *Forgotten Creators* is a really amazing overview of German technical history. Even contemporary historians will discover a lot of new references."

Rainer Karlsch, Institute for Contemporary History, Berlin, author of *Leuna: 100 Jahre Chemie*, *Sowjetische Demontagen in Deutschland 1944–1949*, *Playing the Game: The History of Adidas*, *Uranbergbau im Kalten Krieg*, *Uran für Moskau*, *Hitlers Bombe*, and *Für und Wider "Hitlers Bombe"*

"The book *Forgotten Creators* is a really impressive book, as Todd H. Rider tries to mention all relevant German-speaking scientists and engineers and their scientific fields up to 1945 in this mammoth project. In this form, nobody has dared to do this before. The author deserves my full respect for this. I am pleased that we were able to support him in his research."

Thomas Köhler, Peenemünde Historical-Technical Museum historian and head of the archive, author of *Vernichtender Fortschritt: Serienfertigung und Kriegseinsatz der Peenemünder "Vergeltungswaffen"*

"*Forgotten Creators* is an examination of mid-twentieth-century German science and technology, studying the question of how this era came to be so productive. Using extensive reproduction of original materials and source accounts, the author is not only able to provide an overview of what is known about wartime activities, but is also able to indicate avenues for future historical research. The careful and comprehensive referencing permits the materials presented to be used in academic studies. A notable feature of this work is the fluid format provided by online publication, allowing revisions and new materials to be added. An especially important emphasis of the book is what can be learned from both the German-speaking scientists and the World War II era in general that could improve scientific productivity and creativity now."

Thomas Kunkle, Los Alamos National Laboratory, retired

"*Forgotten Creators* shows us some aspects of the German culture in form and content: it reflects the spirit of the German soul in the best of the senses, focused on the recent history of science mainly in Germany and the U.S. The style reminds me of some of the biggest creations of German culture: ambitious, brave, sublime, erudite, extensive, rigorous in the analyses and exhorting in the discourses. Great! It grasps the sociological problems of science nowadays, and it offers lucid pessimistic views and wise observations of the facts. There are two different leitmotivs: 1) the modern decline of our scientific and technical advances; 2) the highest importance of German science in the most important contributions of the twentieth century scientific and technological advances. Hence, the author posits interesting hypotheses that relate the decline of science and the recent history of Germany and its influence in the world. Risk-taking interpretations that are worth reading and thinking about."

Martín López-Corredoira, Instituto de Astrofísica de Canarias,
author of *The Twilight of the Scientific Age*

"In the book *Forgotten Creators*, Todd H. Rider presents interesting perspectives that contribute to rethinking the story of the German nuclear project, as well as the role that heavy water had in it. The book also confirms the importance of the military actions carried out against heavy water production at Vemork."

Gunhild Lurås, Heavy Water Exhibition Curator,
Norwegian Industrial Workers Museum, Vemork

"Todd Rider has done a heroic job of bringing 'secret Nazi research' out of tinfoil-hat territory and into the realm of rigorous scholarship by compiling the vast primary-source material on a subject that has generally daunted mainstream historical research. And that shadowy field is only a sliver of the vast sweep of German science and technology covered in this monumental work. *Forgotten Creators* is a triumph of exactingly documented fact-finding and analysis, but it also rewards both the casual reader and the serious researcher with dynamic cross-referencing, side-by-side translations, and splendid illustrations. Rider has achieved a difficult balancing act—opening up new areas of inquiry while staying within the ever-accumulating evidence."

Diane McWhorter, biographer of Wernher von Braun and 2002 Pulitzer Prize winner

"Encyclopedia. This was the very first word coming to my mind when reading Todd H. Rider's book. In one publication the reader is given the opportunity to review official documents as well as getting familiar with stories told by people who were involved in the development of modern technology. The book serves as a compendium of knowledge for all who are passionate about any kind of research and inventions, not only about the ones which saw the light during the Second World War and the German national socialism era. There is no doubt that many of German speaking scientists presented in the book have strongly contributed to the colossal technological progress and the development of new disciplines of science. However, when you read the book, I would encourage you not to focus on these magnificent discoveries only. Names like Wernher von Braun, Hubertus Strughold, and Otto Ambros trigger a negative connotation to many as their activities during the period of Nazi Germany are still not completely transparent. Read, think about it, and draw your own conclusions."

Marek Michalski, author of *Labor Camp Treblinka I*,
researcher for the Treblinka Museum and Gross-Rosen Museum

"With his work, based on very comprehensive, thoroughly researched sources, Todd Rider has presented an astonishing study of the history of German science, especially in the first half of the twentieth century, which also reveals many connections that have been unjustly forgotten or little noticed. This also applies to numerous persons whose achievements are hardly known."

Günter Nagel, author of *Wissenschaft für den Krieg*, *Himmlers Waffenforscher*,
Atomversuche in Deutschland, and *Das geheime deutsche Uranprojekt 1939–1945*

"A very valuable part of the book is devoted to the development of nuclear weapons in Germany during WWII, 1939–1945. While the histories of both the US/British Manhattan Project and the Soviet atomic project have been to a large extent declassified, little is actually known about the German work. Rider has done historians a favor by marshalling all of the evidence he could find in US, German, and Russian archives regarding the German atomic project. The inescapable conclusion is that the Germans were much farther advanced in nuclear weapons development than is generally thought."

Lee Pondrom, Professor Emeritus of Physics, University of Wisconsin-Madison,
author of *The Soviet Atomic Project: How the Soviet Union Obtained the Atomic Bomb*

"Todd Rider's book *Forgotten Creators*, the creation of which I was able to observe and support for more than two years, is extraordinary in every respect. The sheer size of the book shows how important the role of German-speaking scientists was in the development of new technological advances. But it also shows the author's will to present as complete an account of this history as possible. He has succeeded in doing so. The work therefore serves both as an introductory book and as a reference book. It is highly recommended."

Georg Ribienski, Documentation Center Manager, Jonastalverein historical society, Thuringia

"Todd Rider has created an incredible document that details the technical contributions of Central Europeans in the nineteenth and twentieth centuries. The scope and scholarship are breathtaking. This document contains useful insights into how innovation and progress actually occur, as well as useful lessons that should be implemented by leaders in corporations, government agencies, and other organizations. It is past time to eliminate or minimize bureaucratic practices that obstruct innovation."

William C. Schneck, Jr., Colonel (ret.), U.S. Army Corps of Engineers (USAR)

"*Forgotten Creators* by Todd Rider is an extraordinary work of detailed research and new insights into the technological advances contributed by German-speaking scientists. His lengthy and in-depth study of history often overlooked or not even seen in more cursory reviews is a refreshing read. His attempt to create the fullest account possible has resulted in a fine reference book that also serves to introduce new research for the reader. Rider's contention, right up front in the Executive Summary—that inventions and discoveries had their highest concentration of revolutionary innovations from scientists and engineers from the German-speaking central European research world in the nineteenth and early twentieth centuries—demands the reader's attention. He then fills an enormous amount of over 6,000 pages with supporting details. Amazing subject matter and new revolutionary insights dug up through meticulous research make *Forgotten Creators* a 'must read' for serious historians and curious researchers alike."

D. Ray Smith, Oak Ridge Historian, retired Y-12 Historian, author, and newspaper columnist

"Todd Rider's extensively researched and amazingly detailed book opens a new world for everybody interested in the history of science. Never before has anyone dug as deeply into the sources as Todd has, such that he even discovered interesting details about our father, then a young officer, and revealed some new aspects about him to us, his children. We are very grateful for Todd's interest, dedication, and thorough research."

Andrea (Stoelzel) Edwards and Bernhard Stoelzel,
children of former Peenemünde staff member Heinz Stoelzel

"This is a truly fascinating work! Dr. Rider has produced an insightful and comprehensive survey of a highly scientifically productive domain in spacetime. It is well worth understanding why that was, and what aspects of that culture should be preserved or revived."

David Strozzi, Lawrence Livermore National Laboratory

"This truly voluminous study provides an in-depth overview of techno-scientific achievements and innovations which originated from the German-speaking world. It is a rich and fascinating history of the transnational circulation of knowledge over a period of no less than two centuries."

Helmuth Trischler, Head of Research, Deutsches Museum, Munich, author of *Luft- und Raumfahrtforschung in Deutschland 1900–1970* and *Building Europe on Expertise: Innovators, Organizers, Networkers*

"A most important and deserving book. Todd Rider's research on the German rocket and nuclear programs in World War II is especially impressive because of the number and depth of the sources cited and the meticulousness of their evaluation. Really pioneering work has been done here!"

Matthias Uhl, Deutsches Historisches Institut, Moscow, author of
Stalins V-2: Der Technologietransfer der deutschen Fernlenkwaffentechnik and
Die Organisation des Terrors: Der Dienstkalender Heinrich Himmlers 1943–1945

"Todd Rider's compendium traces the phenomenal and explosive contribution of the Central European scientific culture of the first half of the twentieth century to the modern world. The multinational renaissance was ended by the Second World War, but the participants became scientific refugees in the victorious states, driving technology around the world during the Cold War. A unique and valuable resource!"

Mark Wade, author of *Encyclopedia Astronautica*, http://www.astronautix.com

"Todd Rider has produced a meticulously researched and cogently argued *tour de force* on the men and the circumstances that drove the modern German Renaissance in science and technology. Brought out of the long shadow of the Third Reich, the story of this Golden Age of human enquiry is convincingly shown to have as much relevance to our present times as it did then. A remarkable achievement."

Stephen Walton, Senior Curator, U.K. Imperial War Museum

Executive Summary

Wo ich schaffe, bin ich wahr. Where I create, I am true.

Rainer Maria Rilke. 8 August 1903. Letter to Lou Andreas-Salomé.

Chapter 1: Why We Should Remember What Was Forgotten. As shown in this chapter, the world does not appear to be producing truly revolutionary scientific innovations at the same rate it once did (certainly if measured in terms of revolutionary innovations per researcher or per amount of funding). Instead the academic research sector seems increasingly fixated on maximizing its rate of publishing papers regardless of their quality, redundancy, or relevance; the corporate research sector appears more and more focused on very low-risk, immediately marketable products; and the government research sector seems increasingly incapacitated by bureaucracy and budget cuts. Rather than trying to create solutions for these modern systemic problems from scratch, one may study what conditions facilitated the successes of innovators in other times and places.

Many people like to believe that their own country has been the most innovative, and indeed, inventions and discoveries have been made around the world and throughout history. Yet as illustrated by the examples in this book, the highest concentration (or at the very least, one of the highest concentrations) of revolutionary innovations appears to have come from scientists and engineers who were trained in the predominantly German-speaking central European research world in the nineteenth and early twentieth centuries. Unfortunately, the history of those innovations has been significantly obscured by World Wars I and II, the Cold War, language barriers, and cultural stereotypes, leaving the modern world less aware of the details and less able to fully reproduce the research conditions that led to so many revolutionary achievements. Therefore the objectives of this book are to:

- Elucidate the major creators and creations produced by that German-speaking world in various fields of science and engineering (Chapters 2–9 and Appendices A–E).
- Determine the systemic factors that promoted so much revolutionary innovation in that particular place and time (Chapter 10).
- Evaluate the previous successes and failures of transferring that scientific knowledge and those systemic methods to other research systems (Chapter 11).
- Propose methods by which modern governments, organizations, and/or individuals could better emulate the success of the earlier German-speaking research world (Chapter 12).

A variety of study scopes and methods would be possible and enlightening, but this book focuses on revolutionary innovators who were educated in that earlier German-speaking world[1] between approximately 1800 and 1945, as well as their subsequent careers (in some cases to the dawn of the twenty-first century). As explained in detail in this chapter, this study does not argue that the modern research system has produced no revolutionary innovations, but rather that it can and should be improved. This study is not intended to support nationalist or ethnic bragging rights, the Third Reich, or any notion that research conditions in the German-speaking world were ever perfect. At best this book can only give a concise overview of a vast field encompassing the actions of thousands of scientists and engineers across many countries over a period of two centuries, as well as investigations into that time period by countless subsequent scholars.

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[1] Defined herein as German, Austrian, and Swiss researchers; eastern European and other researchers who trained in the German-speaking world; and scientists and engineers in the closely coupled Dutch research system.

The German-speaking world produced remarkable numbers of revolutionary innovators and innovations in a wide range of fields, as enumerated in eight chapters:

Chapter 2: Creators and Creations in Biology and Medicine
Advances from genetics to antibiotics

Chapter 3: Creators and Creations in Chemistry and Materials Science
Breakthroughs from color film to synthetic rubber

Chapter 4: Creators and Creations in Earth and Space Science
Discoveries about the universe from continental drift to stellar distances

Chapter 5: Creators and Creations in Physics and Mathematics
Revolutionary ideas from relativity to quantum mechanics

Chapter 6: Creators and Creations in Electrical and Electromagnetic Engineering
Inventions from semiconductors to computers

Chapter 7: Creators and Creations in Mechanical Engineering
Systems from automobiles to submarines

Chapter 8: Creators and Creations in Nuclear Science and Engineering
Reactions and applications from fission to fusion

Chapter 9: Creators and Creations in Aerospace Engineering
Vehicles from jet planes to moon rockets

Chapter 10: Creating the Creators. Based on evidence presented in this chapter, a number of specific factors within the German-speaking world promoted revolutionary innovation:

1. Science was socially glorified, from children's activities and amateur science clubs to prestigious jobs and government-lauded scientific heroes.

2. A century-long steady exponential increase in funding gave scientists, employers, and sponsors much more freedom to pursue higher-risk and/or longer-term research.

3. Many Ph.D. students were encouraged to propose their own research topics and to pursue them independently.

4. Scientists received their final degrees nearly a decade earlier in life, and independent research funding up to two decades earlier, than modern scientists do.

5. Scientists who made major contributions to multiple disciplines, and fraternization among scientists from different disciplines, were much more common than in the modern world.

6. Instead of peer review, an autocratic yet farsighted scientific management culture of "enlightened despots" granted stable jobs and funding to the most promising creators and creations.

7. Both scientists and sponsors used a systems analysis approach to focus on the most important problems and the most effective innovations to address those problems.

8. The lack of natural resources spurred the creation of a wide range of innovative alternatives.

9. International rivalry (both economic and military) was a powerful driving force for innovation.
10. German-speaking companies were less afraid of losing their own innovations to each other than of being outstripped by foreign countries, giving them a strong motivation to innovate.

Chapter 11: Immortalizing the Creations and Forgetting the Creators. As documented in this chapter, the modern world eagerly adopted the creations of the earlier German-speaking world, yet ultimately largely forgot both the creators and the systemic approaches that had made such creations possible. Over the course of waves that occurred before, during, and after the Third Reich, all of the creations, most of the creators, and some of the systemic approaches were transferred from the German-speaking world to the United States and other countries in a German scientific diaspora. Those countries spent many decades fully perfecting and mass-producing the innovations that had been created by the earlier German-speaking world, resulting in our modern world of jet aircraft, electronics, and pharmaceuticals. Most of the creators who had already died or who remained in German-speaking areas were largely forgotten by the non-German-speaking world, which often mistakenly attributed their creations to whichever non-German-speaking individuals or organizations had acquired their technical information. Most of the creators who emigrated out of German-speaking areas led well-funded but quiet lives perfecting their creations and were also ultimately forgotten. Especially during the 1940s–1960s, the United States and other countries practiced some of the general approaches that had made the earlier German-speaking world successful, thereby cultivating new innovators and innovations of their own.

By the 1970s, most of the German-speaking creators had retired or died, their creations had been refined to the point of diminishing incremental returns, and global research systems had abandoned most of the German-like practices they had adopted, significantly reducing their efficiency at producing entirely new innovators and innovations. The Cold War as a strong motivating force for innovation had also relaxed around 1970, and any truly revolutionary new innovators (or innovations) that were produced by the global research system found it increasingly difficult to obtain proper support as time went by. From the 1990s onward, with the Cold War over and officials both public and private haggling over every research dollar while spending heavily or even wastefully in other areas, the academic, corporate, and government research sectors each became increasingly dysfunctional in their own ways.

Chapter 12: Learning from the Creators. Based on the successes of the earlier German-speaking world, this final chapter offers lessons that could be applied at any scale from the national level down to an individual's career. At a nationwide or statewide level, the following policies could improve the ability of the modern scientific system to produce revolutionary innovators and innovations:

1. The social and financial status of science research should be elevated greatly. Better quality and greater variety of educational science experiment kits for children should be produced and more widely advertised and used. Student science competitions (especially ones like science fairs that emulate real scientific research) should be given much greater emphasis, and the winners of those competitions should be very publicly praised and rewarded. The salaries and working conditions of science and other teachers should be improved in order to attract very talented people to those positions and to recognize and reward the most effective teachers. Important scientific discoveries and inventions, as well as the people responsible for them, should be given much more coverage in television news programs, movies, newspapers, magazines, and popular internet sites.

2. If the amount of funding and permanent job positions better matched the number of graduating students and career researchers (by increasing funding wherever possible, or otherwise by limiting the number of students going into research), scientists would be able to spend much more of their time and energy doing productive research, and much less of their time and energy pursuing elusive funding and positions. It would also be much more acceptable to sponsors, institutions, and the scientists themselves for researchers to pursue longer-term work without an immediately demonstrable payoff, as well as more innovative higher-risk work that would be less guaranteed to yield results than very incremental, low-risk work.

3. Science students should be trained from an early age to be very creative and very self-reliant researchers. Students should be strongly encouraged to select their own research topics and methods. Research advisors should provide as much advice and assistance as is necessary (but only what is necessary) to ensure that their students are pursuing productive research topics using suitable methods. Research advisors should not use students as unpaid or low-wage labor to benefit the advisors' own research grants or lists of publications.

4. The average age at which scientists receive their final degree and obtain independent research funding should be reduced back toward their early to mid-twenties. That would greatly increase the number of productive working years during which those scientists have the greatest creativity, the most energy, and the fewest non-research obligations.

5. The system should train and reward at least some percentage of multidisciplinary scientists who can make major contributions in multiple fields, apply knowledge and methods from one field to another, and use their broader view to guide fields away from less productive areas and toward more productive ones. All scientists should be strongly encouraged to make their research comprehensible to people outside their field, and to interact with scientists in other fields in a variety of environments, in order to cross-pollinate ideas among different fields.

6. While there is certainly a place for methodical peer review, entrusting virtually all funding and hiring decisions to peer review risks overlooking those creative new scientists and ideas that are so revolutionary that they cannot easily and immediately get broad consensus from the scientific status quo. The modern research system should set aside some percentage of research funding to be allocated by "enlightened despots" who are good at identifying potentially revolutionary innovators and innovations. Such enlightened despots should have the clear authority to grant financial and political support to any people or projects they deem worthy, and to grant that support for many years without having to demonstrate that there is an immediate payoff, or even that all funded research will eventually pay off. Wherever possible, any remaining peer review should be done by reviewers unaware of the researchers' names and affiliations, so that they can more fairly evaluate the actual research in question.

7. By using systems analysis, key decision makers in government, industry, and academia could help focus more resources on the most important problems and potential solutions. If individual scientists were taught to practice systems analysis, they could use that method to guide their careers and their research projects in more promising directions, and to ensure that no potentially useful regions of the conceptual "phase space" had been overlooked.

8. In the face of dwindling natural resources and the rising long-term costs of climate change, pollution, and waste, government-funded programs and government regulations for industrial programs should prioritize the development of very innovative methods of reducing the consumption of natural resources and minimizing the creation of waste products.

9. Peaceful economic rivalry and regional pride could constructively motivate nations or states to accelerate their research programs. Regional high-tech centers could promote interactions among programs they contain, and rival high-tech centers could compete for the best scientists, projects, research funding, and economic income from resulting inventions and products.
10. Companies should view very innovative, longer-term research and development (R&D) as a worthwhile investment in staying ahead of competitors, not a financial liability whose resulting products could be copied by competitors that did not fund their own R&D. Improved tax, patent, regulatory, or other government incentives could make it much more lucrative for the first company that develops any given major innovation, and/or less lucrative for copycats.

In addition to the above lessons for national or state research systems, Chapter 12 also offers additional lessons for individual companies, organizations, and laboratories; for individual scientists and engineers; and for scholars who study past, present, and potential future innovation systems.

The appendices focus on some potentially quite advanced creations of the German-speaking world during World War II that are currently much less well understood by modern historians, and whose complexities necessitate a considerably longer treatment than could be given in Chapters 2–9:

> **Appendix A** presents archival documents that suggest that Germany had the largest and most advanced biotechnology programs in the world at that time, was developing neural interfaces to control prosthetic limbs and weapons systems, possessed a significant offensive program in biological warfare, and discovered advanced V-series nerve agents during the war.
>
> **Appendix B** gives an overview of evidence that transistors and other microelectronics innovations may have originated in the German-speaking world, and that information on those technologies may have been transferred to and exploited by Allied countries after the war.
>
> **Appendix C** presents documents that appear to show that the German-speaking world developed and tested a variety of directed-energy technologies, including particle beams, electromagnetic pulse weapons, major steps toward lasers, focused sound waves for applications ranging from ultrasound imaging to acoustic weapons, and electromagnetic railguns.
>
> **Appendix D** provides considerable evidence that Germany may have developed and even successfully tested fission bombs during the war (which would have made it the first country in world history to possess nuclear weapons), and that it may have even had a megaton-level hydrogen bomb in an advanced stage of development when the war ended.
>
> **Appendix E** presents archival documents that appear to show that wartime Germany made considerable progress toward developing the aerospace technologies that have formed the "nuclear triad" for most of the postwar decades: intercontinental jet bombers, intercontinental ballistic missiles, and submarine-launched missiles.

Although the evidence in the appendices does not constitute conclusive proof, it should prompt further archival research to clarify the true extent of those wartime programs.

The **Bibliography** of over 400 pages covers relevant books, articles, government reports, and archival documents.

To maximize the audience, longevity, and impact of this book, it is available for free on the internet. Hopefully it will spur discussion, learning, and further work in the important areas that it covers. Suggestions for improvements are very welcome.

For creators
everywhere,
past, present,
and future.

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It is a strange feeling to be so completely dependent on the help of other people. However, at least it teaches one to be grateful, and I hope I shall never forget that. In ordinary life we hardly realize that we receive a great deal more than we give, and that it is only with gratitude that life becomes rich. It is very easy to overestimate the importance of our own achievements in comparison with what we owe to others.

Dietrich Bonhoeffer. 13 September 1943 letter to his parents.
Eberhard Bethge, ed. 2016. *Widerstand und Ergebung: Briefe und Aufzeichnungen aus der Haft* [*Resistance and Resignation: Letters and Papers from Prison*]. Gütersloh: Gütersloher Verlag.

As a child, I read about scientists and engineers (including some of those in this book) who tackled the most important problems that were within their power, and as a result produced revolutionary discoveries and inventions that changed the world. Inspired by those examples, I have spent most of my life endeavoring to pursue innovative scientific research projects of my own (p. 6314). Over the years, unfortunately, I have personally witnessed how the modern U.S. research system is dysfunctional in many different ways, and how that dysfunction can discourage the initiation of potentially revolutionary research projects and also prematurely terminate innovative projects that have been initiated.

Eventually it dawned on me that perhaps the most important research problem is the research system itself—even modest improvements in the research system could have large effects on countless individual innovators, and amplified through them, an enormous impact on the whole world. Rather than relying on the very limited data set of my own personal experiences or even those of my colleagues, I decided to examine a far larger data set, the history of science, in hopes of better understanding the problems with and potential solutions for the modern research system.

This book is the result of that effort. It is very much a work in progress, imperfect and incomplete, yet I offer it in hopes that it will inspire ideas, discussion, and further work in the areas that it covers. **If readers have any suggestions for corrections, improvements, or additions, please send me an email (ToddHRider@gmail.com or thor@riderinstitute.org), and I will try to incorporate those suggestions into a future improved edition.**

Just as the modern world is entirely dependent upon the creations of numerous earlier inventors and scientists, this book would not have been possible without all of the earlier research and publications of large numbers of scholars and investigators (such as those listed in the Bibliography), as well as the documents, information, suggestions, and assistance that many of those people have provided directly to me. I would especially like to thank:

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Chapter 1

Why We Should Remember What Was Forgotten

Heiße Magister, heiße Doktor gar	I'm called a Master, even Doctor too
Und ziehe schon an die zehen Jahr	And now I've nearly ten years through
Herauf, herab und quer und krumm	Pulled my students by their noses to and fro
Meine Schüler an der Nase herum—	And up and down, across, about
Und sehe, daß wir nichts wissen können!	And see there's nothing we can know!
Das will mir schier das Herz verbrennen.	That all but burns my heart right out.
Zwar bin ich gescheiter als all die Laffen,	True, I am more clever than all the vain creatures,
Doktoren, Magister, Schreiber und Pfaffen;	The doctors and masters, writers and preachers;
Mich plagen keine Skrupel noch Zweifel,	No doubts plague me, nor scruples as well.
Fürchte mich weder vor Hölle noch Teufel—	I'm not afraid of devil or hell.
Dafür ist mir auch alle Freud entrissen,	To offset that, all joy is rent from me.
Bilde mir nicht ein, was Rechts zu wissen,	I do not imagine I know aught that's right;
Bilde mir nicht ein, ich könnte was lehren,	I do not imagine I could teach what might
Die Menschen zu bessern und zu bekehren.	Convert and improve humanity.

Johann von Goethe. 1808. *Faust Part One.* Nacht, Faust.
English verse translation adapted from George Madison Priest.

Science and engineering have changed the world in countless ways. While some scientific discoveries and engineering inventions may be harmful or dangerous if misused, on the whole they appear to have improved our lives. Very few people who are alive now would voluntarily choose to give up indoor plumbing, electric lights, rapid transportation, and modern medicine. Based on such historical precedents, we have good reason to hope that science and engineering could make our lives even better in the future. Thus it is in the best interests of everyone, even those who are not scientists and engineers, for the scientific research and development system to function as well as possible.

The ultimate goal of this book is to help improve our understanding of the past, the present, and the potential future of scientific research and development, and through that improved understanding, to enhance the effectiveness of the research and development system in bringing new discoveries and inventions to our lives and those of our children and grandchildren.

1.1. This chapter begins by evaluating the state of scientific innovation in the modern world:

  1.1.1. Problems with the modern innovation system from everyday experience.

  1.1.2. Problems with the modern innovation system from published analyses.

  1.1.3. Problems with modern academic research.

  1.1.4. Problems with modern corporate research.

  1.1.5. Problems with modern government research.

1.2. Then this chapter turns to consider scientific innovation in the earlier German-speaking world:

  1.2.1. Studying the earlier German-speaking world can help to improve the modern innovation system.

  1.2.2. The scope and framework of this book are explained.

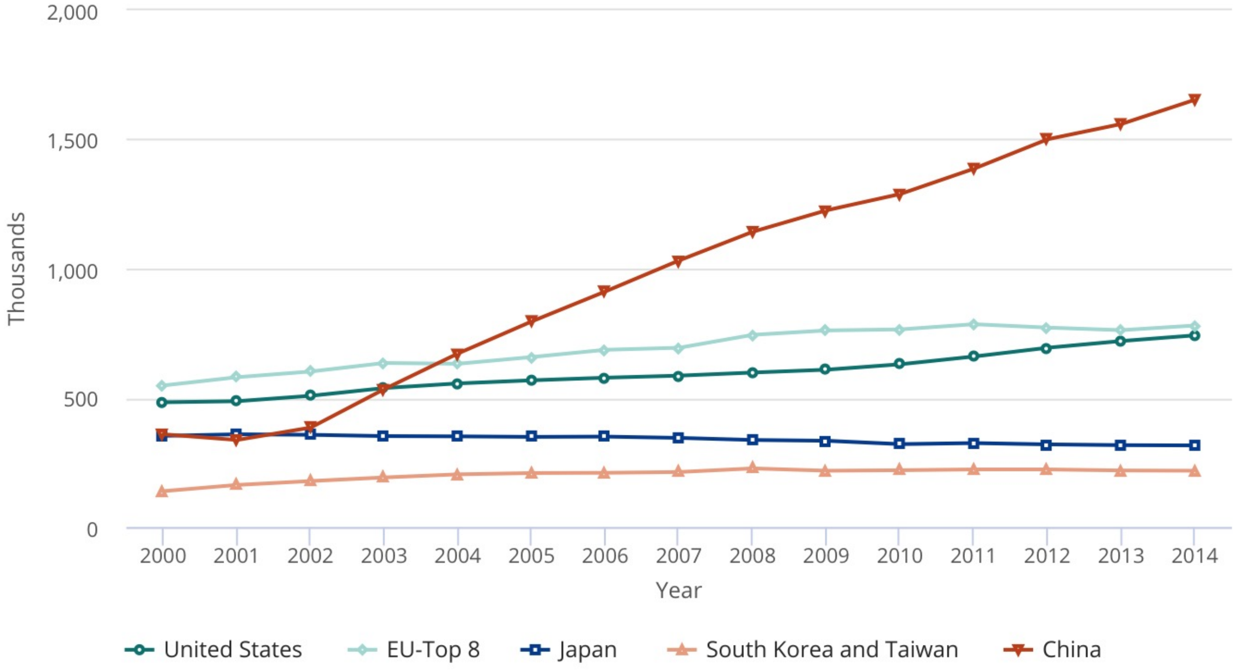
  1.2.3. A number of disclaimers are presented for clarity and precision.

1.1 Scientific Innovation in the Modern World

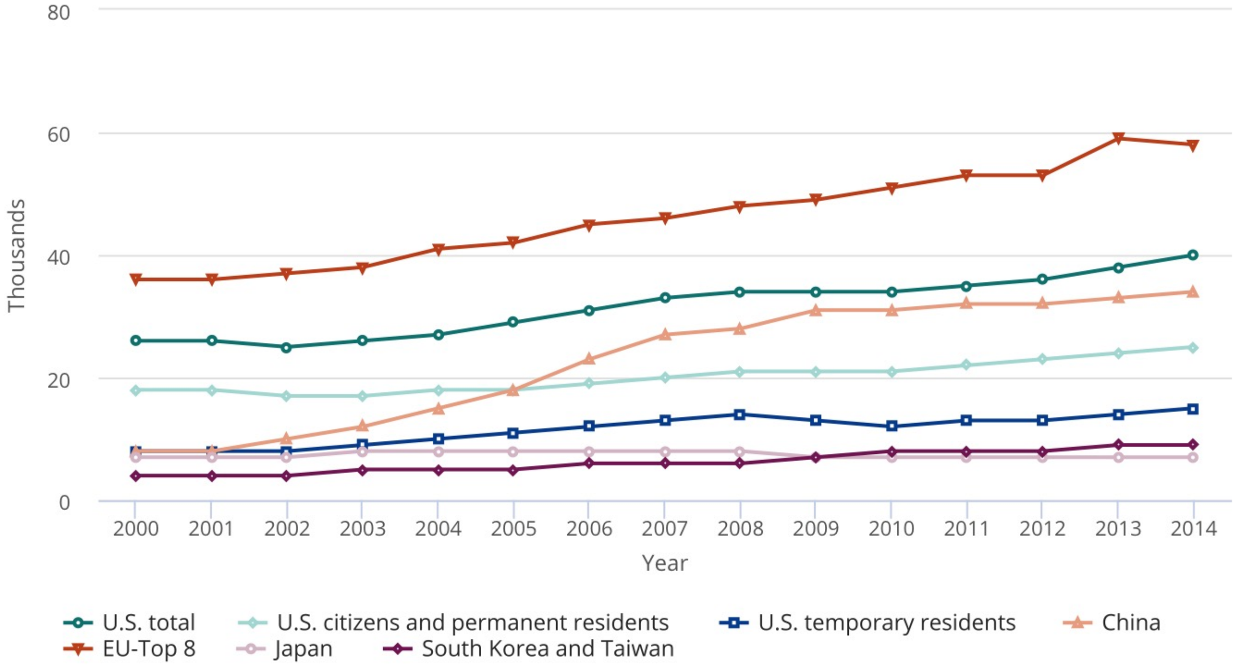
Upon superficial inspection, the modern scientific research and development system seems to be operating very successfully [AAAS2 2018; NSF 2018; Nelson 1993; OECD 2018]:

- Each year, over 750,000 bachelor's degrees in science and engineering fields are awarded in the United States, and over 4 million worldwide, as shown in Fig. 1.1(a).
- Likewise, each year over 40,000 science and engineering doctoral degrees are awarded in the United States, and over 200,000 worldwide, as illustrated in Fig. 1.1(b).
- Some of those degree recipients go into other work, but many join the pool of people who are currently doing scientific research, which is over 1.3 million researchers in the United States and growing, and over 7 million researchers worldwide and growing, as graphed in Fig. 1.2(a).
- Each year, those researchers receive an estimated total (both public and private funding) of \$500 billion in the United States and over \$1.7 trillion worldwide for research and development (R&D), as shown in Fig. 1.2(b).
- With that funding, each year they produce over 2 million new journal articles worldwide, as illustrated in Fig. 1.3(a).
- Also with that funding, each year they produce over 3.3 million new patent applications worldwide, as graphed in Fig. 1.3(b).
- Along the way, modern researchers have produced recent popular products such as smartphones, a wide variety of internet sites for social networking and sales, computer-generated visual effects, new computer games, 3D printers, and pharmaceuticals ranging from Viagra to opioids.

Yet upon closer examination, the modern research system appears to have serious problems, as suggested by several different lines of evidence that are considered in the following sections.



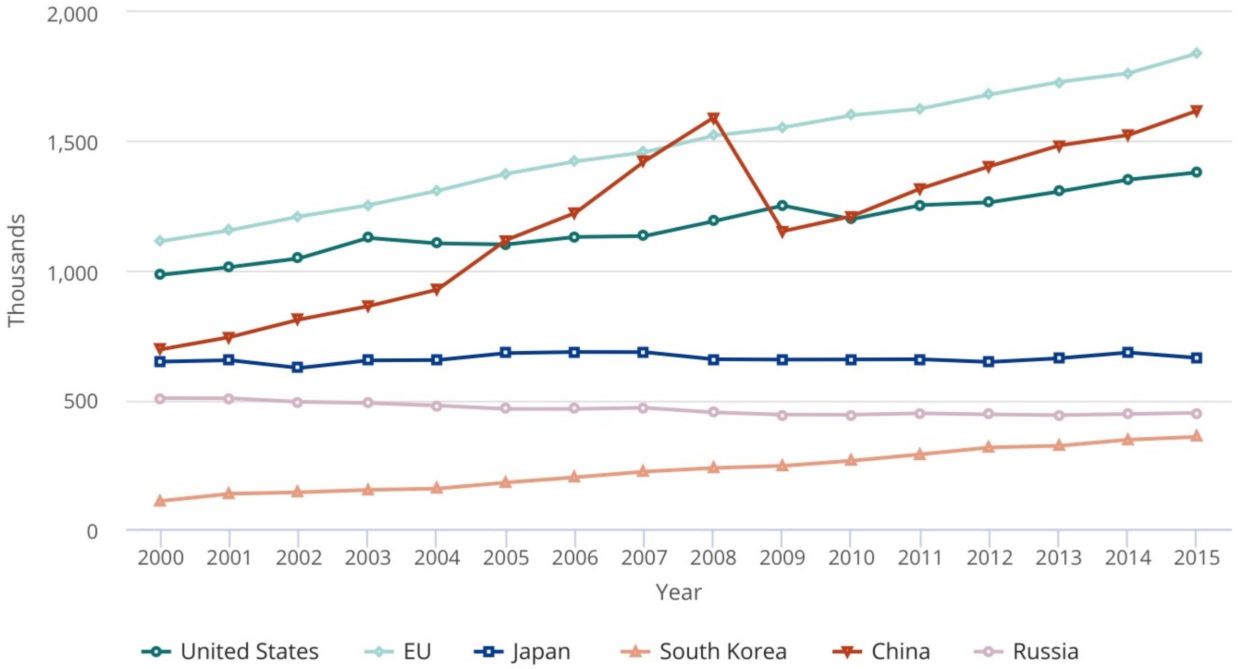
(a) Bachelor's degrees awarded in science and engineering fields in various countries



(b) Doctoral degrees awarded in science and engineering fields in various countries

Figure 1.1: Number of (a) bachelor's degrees and (b) doctoral degrees awarded in science and engineering fields in various countries each year; note that many countries (such as India) are not included in the graphs [https://www.nsf.gov/statistics/2018/nsb20181/figures].

(a) Estimated number of researchers in various countries



(b) Total R&D spending of various countries in purchasing power parity (PPP) dollars

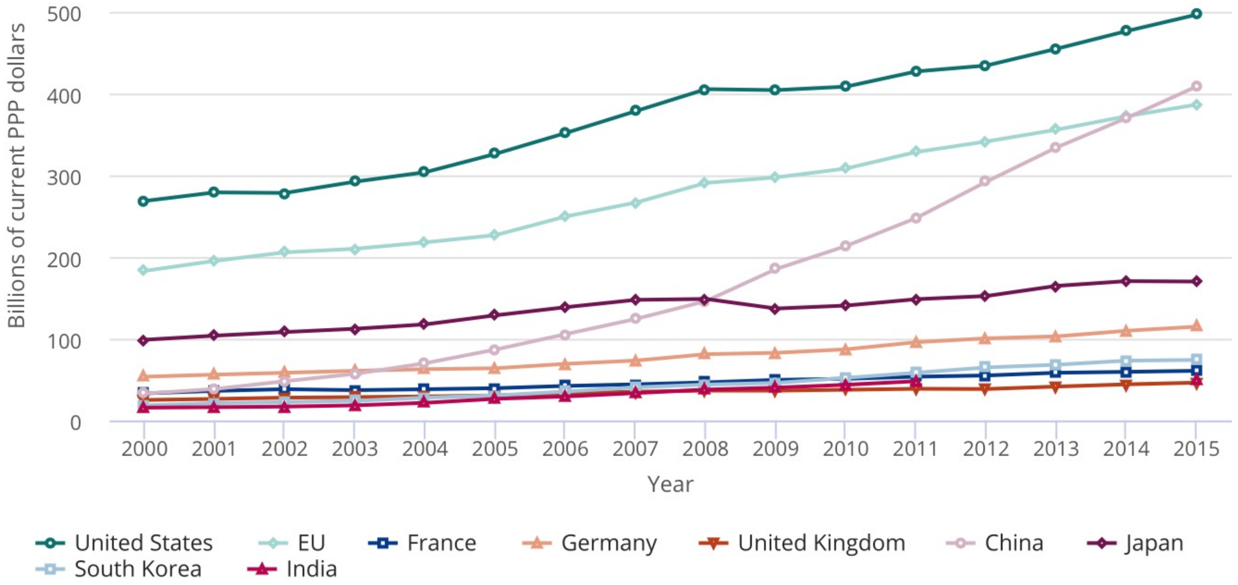
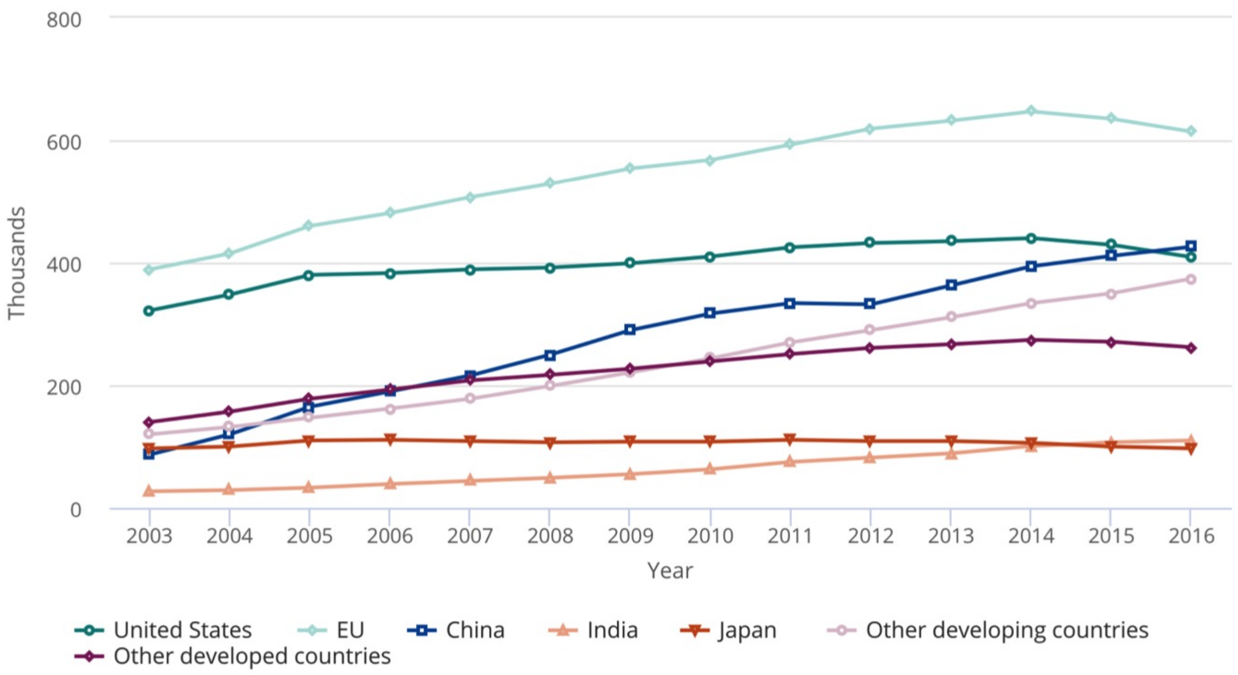
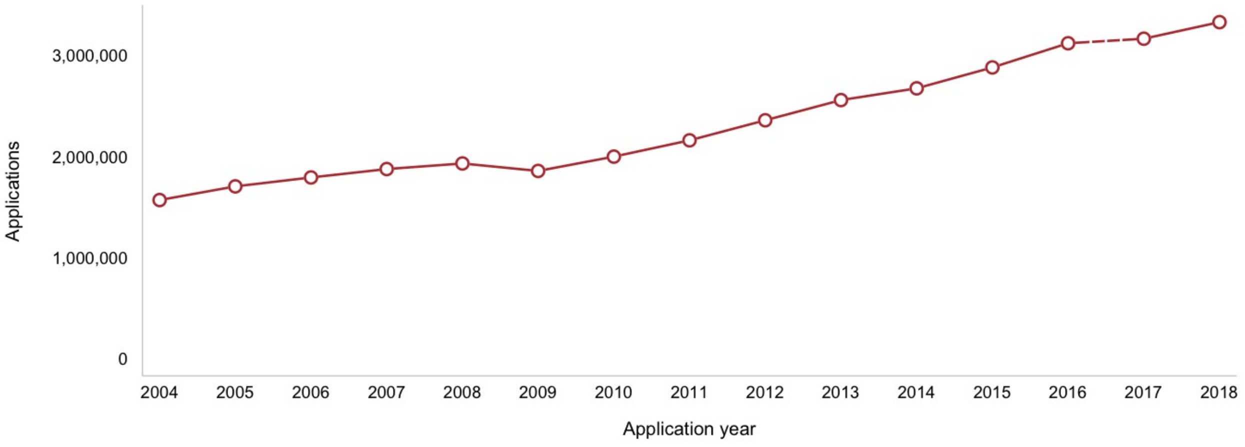


Figure 1.2: Research system sizes as measured by (a) estimated number of researchers in various countries, and (b) total R&D spending of various countries in purchasing power parity (PPP) dollars [https://www.nsf.gov/statistics/2018/nsb20181/figures]. (In the upper graph, the apparent 2008–2009 drop in researchers in China is just an artifact of a change in how Chinese researchers were counted before vs. after that time; by either method of counting, the number of Chinese researchers steadily increased throughout the time period of the graph.)



(a) Science and engineering articles by various countries



(b) Total patent applications filed worldwide

Figure 1.3: Annual production of (a) science and engineering articles by various countries, and (b) total patent applications filed worldwide [https://www.nsf.gov/statistics/2018/nsb20181/figures; https://www.wipo.int/edocs/pubdocs/en/wipo_pub_941_2019.pdf].

1.1.1 Problems from Everyday Experience

At least in the developed world, most of the technologies encountered in people's daily lives have not changed much over the last half century. We still travel around in very similar automobiles and jet planes, spend too much time in front of color video screens (even if they are nicer now and come in more sizes), and struggle to cure cancer. Only a few visible technologies have changed significantly over the last 50 years: virtually everyone has a phone in their pocket instead of on their desk, and anyone can use a computer instead of just workers in large offices. In contrast, there were large numbers of completely transformative technological changes over any 50-year span during the nineteenth century and for most of the twentieth century: electric lighting and appliances, indoor plumbing and air-conditioning, trains and automobiles, vaccines and antibiotics, jets and helicopters, transistors and lasers, nuclear power and weapons, submarines on the ocean floor and astronauts on the moon. By the standards of everyday experience, in absolute terms the rate of modern scientific innovation seems much lower now than it had been decades ago, despite the record-breaking amounts of funding, people, and papers involved in the modern system. Certainly the rate of revolutionary innovation per dollar or per person working in the system appears to be far lower now than in the past.

The longtime science journalist Michael Hanlon summed up this apparent decline [Hanlon 2014]:

> Yet there once was an age when speculation matched reality. It spluttered to a halt more than 40 years ago. Most of what has happened since has been merely incremental improvements upon what came before. That true age of innovation—I'll call it the Golden Quarter—ran from approximately 1945 to 1971. Just about everything that defines the modern world either came about, or had its seeds sown, during this time. The Pill. Electronics. Computers and the birth of the internet. Nuclear power. Television. Antibiotics. Space travel... The Green Revolution in agriculture... Mass aviation... Cheap, reliable and safe automobiles. High-speed trains. We put a man on the Moon, sent a probe to Mars, beat smallpox and discovered the double-spiral key of life. The Golden Quarter was a unique period of less than a single human generation, a time when innovation appeared to be running on a mix of dragster fuel and dilithium crystals.
>
> Today, progress is defined almost entirely by consumer-driven, often banal improvements in information technology. The US economist Tyler Cowen, in his essay *The Great Stagnation* (2011), argues that, in the US at least, a technological plateau has been reached. Sure, our phones are great, but that's not the same as being able to fly across the Atlantic in eight hours or eliminating smallpox. As the US technologist Peter Thiel once put it: "We wanted flying cars, we got 140 characters."
>
> But it could have been so much better. If the pace of change had continued, we could be living in a world where Alzheimer's was treatable, where clean nuclear power had ended the threat of climate change, where the brilliance of genetics was used to bring the benefits of cheap and healthy food to the bottom billion, and where cancer really was on the back foot. Forget colonies on the Moon; if the Golden Quarter had become the Golden Century, the battery in your magic smartphone might even last more than a day.

As illustrated by additional data in the next section, Hanlon's diagnosis of an innovation decline appears to be correct. However, like most people in the modern world, he incorrectly perceived most modern innovations as having come from the United States during the first few decades after World War II. As this book shows, the specific innovations that he cited, and the highly creative scientists and engineers who produced them, can actually be traced to a different time and place.

1.1.2 Problems from Published Analyses

Using more quantitative and detailed methods of analysis, various researchers have studied the rate of production of major scientific and technological innovations and published their conclusions that the rate has indeed been declining over the last several decades. A few examples are shown in Figs. 1.4–1.5.

Stanford researchers Nicholas Bloom, Charles I. Jones, John Van Reenen, and Michael Webb conducted a detailed study [Bloom et al. 2020]. They found that between 1930 and 2000, the number of researchers in the United States increased by a factor of 23, whereas the U.S. economic growth rate due to research innovation fell by a factor of approximately 1.78, so the productive innovation rate per researcher fell by a factor of 41. (See Fig. 1.4 top.) In other words, according to this study, the average researcher in 1930 produced 41 times more innovation than the average researcher in 2000. The same study found similar declines in innovation productivity as measured in specific fields such as medicine, electronics, and agriculture:

> [W]e proceed to measure research productivity in many different contexts. Our robust finding is that research productivity is falling sharply everywhere we look. Taking the US aggregate number as representative, research productivity falls in half every 13 years: ideas are getting harder and harder to find. Put differently, just to sustain constant growth in GDP per person, the United States must double the amount of research effort every 13 years to offset the increased difficulty of finding new ideas. [...] A first-order fact of growth empirics is that research productivity is falling sharply. [...]
>
> Akcigit and Kerr (2018) suggests that "follow on" innovations may be smaller than original innovations and provide evidence that research productivity declines with firm size. Incumbent firms may shift to "defensive" R&D to protect their market position, and this could cause research productivity to decline; Dinopoulos and Syropoulos (2007) provides a model along these lines. Or perhaps declines in basic research spending, potentially related to the US decline in publicly-funded research as a share of GDP, have negatively impacted overall research productivity. Clearly this would have important policy implications.

U.S. Navy physicist Jonathan Huebner published an earlier analysis of the number of revolutionary innovations per person per year. (See Fig. 1.4 middle.) Although his data sources and methods of analysis were significantly different than those of Bloom et al., Huebner also found a steep decline in the number of innovations per person per year over the last several decades [Huebner 2005]:

> There is a general consensus that technology is advancing exponentially, and that this advance will continue into the distant future. The basic assumption behind this view is that either there is no limit to technological advance, or if there is a limit, then we are far from reaching it. The history of technological innovation from the end of the Dark Ages to the present time is examined, and evidence is provided that we are closer to a technological limit than many people realize.

> There are two different technological limits. The first limit is a physical one, due to the laws of physics, such as the impossibility of building a perpetual motion machine. The second limit is economic; it is physically possible to dig a canal from the Pacific Ocean to the Atlantic Ocean across the continental United States, but it is not economically feasible. This paper addresses the economic limit, as we will reach this limit before the physical limit. [...]
>
> In conclusion, the evidence presented indicates that the rate of innovation reached a peak over a hundred years ago and is now in decline. This decline is most likely due to an economic limit of technology or a limit of the human brain that we are approaching. We are now approximately 85% of the way to this limit, and the pace of technological development will diminish with each passing year.

Molecular geneticist Jan Vijg analyzed the historical innovation rate too [Vijg 2011]. (See Fig. 1.4 bottom.) Whereas Bloom et al. and Huebner presented their results as declines in the number of innovations per person per year, Vijg simply plotted the total number of innovations per year (not also per person). According to Vijg, that total innovation rate has fallen markedly for several decades, even though the population has greatly increased during that time. Thus Vijg's statement about innovation decline is even stronger than those by Bloom et al. and Huebner. Vijg explained [Vijg 2011, p. 31]:

> Of the more than 300 macro-inventions listed in the table, fewer than 50 were made before 500 BC, with over 100 only from the last 100 years. What this tells us is that inventions accumulated faster in more recent times, which confirms the expectations of most futurologists and is undoubtedly something most of us would intuitively expect. Sometimes intuition is right and when plotting the number of new inventions since 500 BC, we do indeed see an exponential increase[....] The same is true when plotting not the accumulated number of inventions, but the number of new inventions per year, i.e. a measure for inventiveness [Fig. 1.4 bottom]. However, from this graph we can also see the beginning of a decline around 1970 with no sign of a restoration yet[....]

In the most extensive study yet, management professors Michael Park, Erin Leahey, and Russell Funk statistically analyzed millions of journal articles and patents. (See Fig. 1.5.) They demonstrated a pronounced decline over recent decades in the average amount of innovation (the CD_5 or Coefficient of Disruption 5 years after publication) per paper or per patent [Park et al. 2023]:

> Recent decades have witnessed exponential growth in the volume of new scientific and technological knowledge, thereby creating conditions that should be ripe for major advances. Yet contrary to this view, studies suggest that progress is slowing in several major fields. Here, we analyse these claims at scale across six decades, using data on 45 million papers and 3.9 million patents from six large-scale datasets, together with a new quantitative metric—the CD index—that characterizes how papers and patents change networks of citations in science and technology. We find that papers and patents are increasingly less likely to break with the past in ways that push science and technology in new directions. This pattern holds universally across fields and is robust across multiple different citation- and text-based metrics.

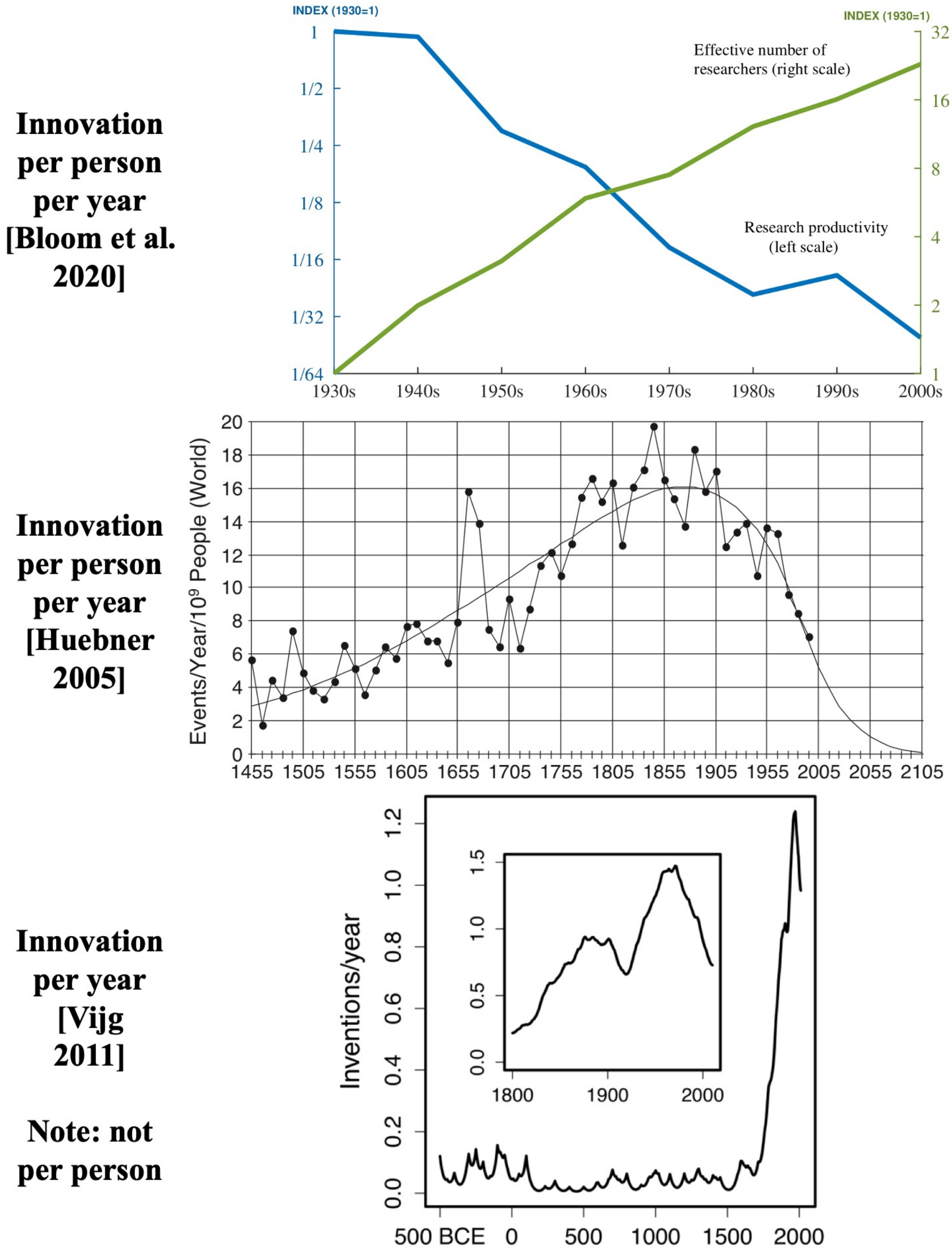
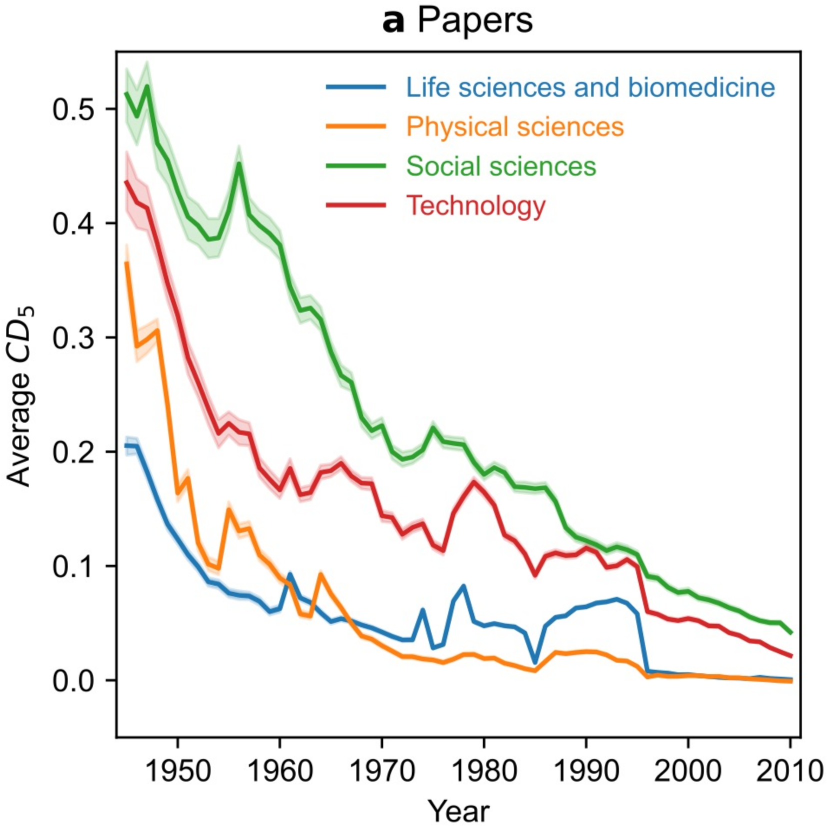


Figure 1.4: Examples of independent analyses indicating a modern decline in number of new scientific innovations per person per year [Bloom et al. 2020; Huebner 2005; Vijg 2011].

Innovation per journal article [Park et al. 2023]



Innovation per patent [Park et al. 2023]

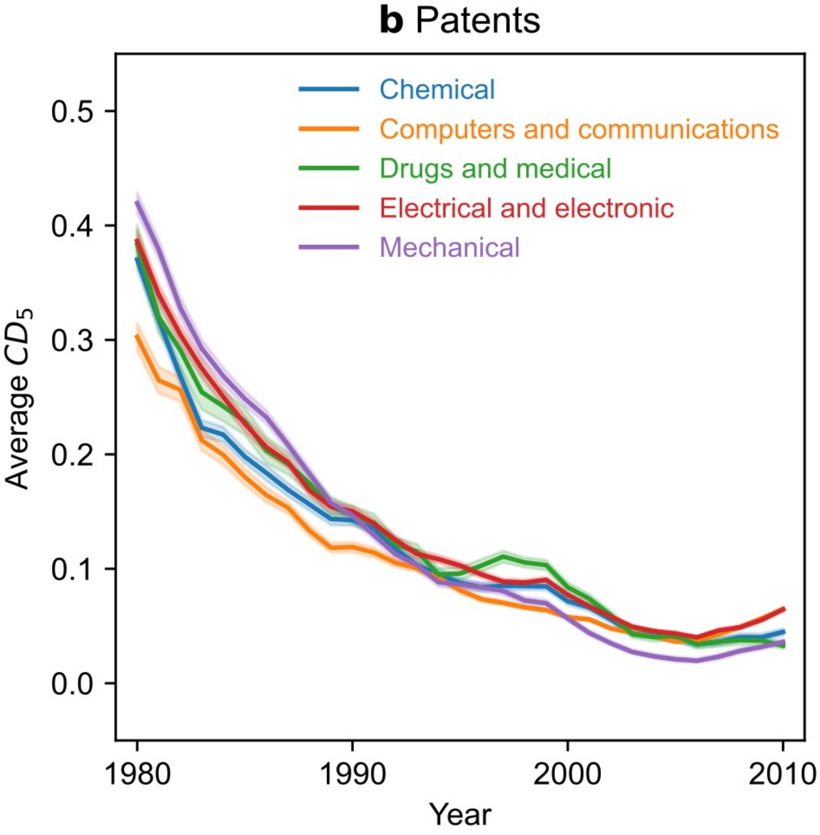


Figure 1.5: Further examples of independent analyses indicating a modern decline in the amount of innovation (the CD_5 or Coefficient of Disruption 5 years after publication) per journal article or per patent [Park et al. 2023].

These four analyses showing a significant decline in the number of revolutionary innovations per person per year, or even the total number of revolutionary innovations per year, are not isolated studies or outlier results. Some other analysts warning of the recent innovation decline include:

- Marc Andreessen, a venture capitalist [Andreessen 2020]
- Ashish Arora, Sharon Belenzon, and Andrea Patacconi, economists [Arora et al. 2015, 2019]
- Robert Atkinson, an economist [Atkinson 2014a, 2014b; Foote and Atkinson 2019]
- Professor Jeremy Baumberg, a nanotechnology researcher at Cambridge University [Baumberg 2018]
- Professors Jay Bhattacharya and Mikko Packalen [Bhattacharya and Packalen 2020]
- Professors Kevin J. Boudreau, Eva C. Guinan, Karim R. Lakhani, and Christoph Riedl [Boudreau et al. 2016]
- Donald Braben, a retired British Petroleum research manager [Braben 1994, 2004, 2008, 2014]
- Bill Buxton, a *Bloomberg Businessweek* writer [Buxton 2008]
- Nicholas Carr, a *Wall Street Journal* writer and book author [Carr 2012, 2015]
- ETH Zürich professors Peter Cauwels and Didier Sornette [Cauwels and Sornette 2020]
- Professors Johan S. G. Chu and James A. Evans [Chu and Evans 2021]
- Patrick Collison and Michael Nielsen, Silicon Valley venture capitalists [Collison and Nielsen 2018; Collison and Cowen 2019; Noah Smith 2020]
- Tyler Cowen, an economist [Collison and Cowen 2019; Cowen 2011; Cowen and Southwood 2019]
- Steve Denning, a *Forbes* writer [Denning 2013]
- Ross Douthat, a *New York Times* columnist [Douthat 2020]
- Elizabeth Dzeng, a scholar at Cambridge University [Dzeng 2014]
- Judy Estrin, a veteran Silicon Valley entrepreneur [Estrin 2008; NYT 2008-09-01, p. C4]
- Justin Fox, a former *Harvard Business Review* editorial director [Fox 2012]

- Robert Gordon, an economist [Gordon 2000, 2012, 2016]
- Lynn Gref, a retired NASA and Defense Department manager [Gref 2010]
- Jonathan Gruber and Simon Johnson, MIT economists [Gruber and Johnson 2019]
- John Horgan, a science journalist [Horgan 2015]
- Greg Ip, chief economics commentator for the *Wall Street Journal* [Ip 2016]
- Walter Isaacson, historian of science [Isaacson 2019]
- Leslie Kwoh, a *Wall Street Journal* writer [Kwoh 2012]
- Martín López-Corredoira, an astrophysicist [López-Corredoira 2013]
- Michael Mandel, a *Bloomberg Businessweek* writer [Mandel 2009]
- Chris Matthews, a *Fortune* magazine writer [Matthews 2015]
- Derek de Solla Price, an historian of science [Price 1986]
- Simon Ramo, a retired TRW cofounder [Ramo 1980a, 1983, 1988]
- Richard Rosenbloom, a Harvard Business School professor [Rosenbloom and Spencer 1996]
- Daniel Sarewitz, an Arizona State University science policy professor [Sarewitz 2016]
- William Spencer, a former Sematech CEO [Rosenbloom and Spencer 1996]
- Neal Stephenson, a science fiction author [Stephenson 2011]
- Peter Thiel, a technology investor [Thiel 2011, 2016, 2023]
- Derek Thompson, a journalist at *The Atlantic* [Derek Thompson 2021]
- Dietrich Vollrath, a University of Houston professor [Vollrath 2020]
- A high-ranking panel from the American Academy of Arts & Sciences [AAAS1 2014]
- A high-ranking panel from MIT [MIT 2015]
- A high-ranking panel from the U.S. National Academy of Sciences [NAS 2007, 2010]

1.1.3 Problems with Modern Academic Research

While universities have produced innovators, discoveries, and inventions for centuries, many observers have reported widespread problems with the modern academic system.[1] Examples include:

(a) Professors at many universities are generally evaluated primarily or exclusively for research, so they tend to neglect teaching. Professors who are deemed to invest too much effort in teaching may even be denied tenure or otherwise punished, while other professors often delegate teaching to poorly paid adjunct professors or graduate students.

(b) The modern academic system seems to be extremely focused on publishing as many papers as possible, even if they are highly repetitive of previous papers by the same researchers, do little to actually advance their field, and often are of dubious quality (or even plagiarized or faked entirely).[2] Researchers openly talk about maximizing the number of "minimum publishable units." Academics are so judged by their continuous high production rate of papers that they cannot really afford to get negative results. For that reason, they tend to pursue experiments (1) with a readily predictable and immediate payoff, (2) with insufficient optimization for repeatability, (3) with very little risk or innovation, and (4) preferably without focusing on truly practical applications that would take much longer to perfect. Likewise, academics usually cannot afford the time to publish any negative results if they do happen to get them (which would be very helpful to warn others of dead ends or misconceptions). The result appears to be an exponentially increasing deluge of repetitious, minimally innovative, or even spurious papers.

(c) Although it is considered to be by far the most important product of the system, this output of papers seems to end up largely unread and unutilized because (1) the number of papers is so incomprehensibly vast, (2) the papers are inaccessible to most of the world due to exorbitant online journal paywalls or the cost or obscurity of the printed volumes in which they appear, and (3) most academic researchers are too busy frantically writing their own papers to spend much time reading, trying to replicate, or applying other researchers' papers.

(d) Instead of multidisciplinary cross-pollination or even proper perspective within a given field, modern academia seems to demand extreme microspecialization. To compound the problem, researchers in each subfield appear to continually develop more and more unnecessarily specialized vocabulary, and this "tower of Babel" effect makes it much more difficult for (1) students to learn a given field, (2) researchers in different fields to communicate or spread ideas, (3) the public to understand and appreciate the work, and (4) the work to have any impact in the real world beyond the virtually inaccessible specialized literature.

---

[1] E.g., Aitkenhead 2013; Alberts et al. 2014; Armstrong 1997; Baumberg 2018; Begley 2009; Belluz et al. 2016a, 2016b; Bhattacharya and Packalen 2020; Blumenstyk 2014; Brenner 2014; Brezis 2007; Carey 2015; Carr 2009; Childress 2019; Chu and Evans 2021; Dzeng 2014; *Economist* 2010; Farrow 2019; Feighery 2013; Frey 2003; Garner 2006; Gee 2017; Gillies 2008; Godlee et al. 1998; Horrobin 1990; Ietto-Gillies 2008; Junod 2013; Kendzior 2015; Kennefick 2009; Lin 2014; López-Corredoira 2013; Maddox 1995; Mahoney 1997; Merton 1968; O'Shaughnessy 2012; Peters and Ceci 1982; Racker 1989; Ritchie 2020; Rothwell and Martyn 2000; Sandal 2011a, 2011b, 2016; Scott 2012; Taschner 2007; Tarver 2007; Warner 2020; Ziman 1995.

[2] E.g., Begley and Ellis 2012; Buranyi 2017; Errington et al. 2021a, 2021b; Francis 2020; Schneider 2016, 2017, 2020.

(e) Universities now seem to be bottomless pits for tuition, research grants, donations, university-hosted conference fees, and other funding, with tuition rising far faster than inflation for many decades, university faculty and staff endlessly pursuing wealthy donors and sponsor grants full-time, untapped university endowments mounting ever higher, and an explosion of administrators, extravagant campus architectural projects, ever more expensive athletic programs and facilities, and other costs with at best a tenuous connection to actual research and education.

(f) For decades there has been an exponential multiplication of professors and postdocs who want to be professors. Although this process began as a way to build up an academic system from minimal roots, in the modern environment in which the number of positions for professors has been relatively constant for years, it now functions for all practical purposes as a pyramid or Ponzi scheme that primarily benefits those who got in earlier. Those entering the system more recently tend to work very long hours to make the whole system function, are paid quite poorly, and have very dim career prospects.

Many observers (such as those cited) have reported these problems, but the most colorful summation was provided by Mark Tarver, a former professor at the University of Leeds [Tarver 2007]:

> Teaching was not the only criterion of assessment. Research was another and, from the point of view of getting promotion, more important. Teaching being increasingly dreadful, research was both an escape ladder away from the coal face and a means of securing a raise. The mandarins in charge of education decreed that research was to be assessed, and that meant counting things. Quite what things and how wasn't too clear, but the general answer was that the more you wrote, the better you were. So lecturers began scribbling with the frenetic intensity of battery hens on overtime, producing paper after paper, challenging increasingly harassed librarians to find the space for them. New journals and conferences blossomed and conference hopping became a means to self-promotion. Little matter if your effort was read only by you and your mates. It was there and it counted.
>
> Today this ideology is totally dominant all over the world, including North America. You can routinely find lecturers with more than a hundred published papers and you marvel at these paradigms of human creativity. These are people, you think, who are fit to challenge Mozart who wrote a hundred pieces or more of music. And then you get puzzled that, in this modern world, there should be so many Mozarts—almost one for every department.
>
> The more prosaic truth emerges when you scan the titles of these epics. First, the author rarely appears alone, sharing space with two or three others. Often the collaborators are Ph.D. students who are routinely doing most of the spade work on some low grant in the hope of climbing the greasy pole. Dividing the number of titles by the author's actual contribution probably reduces those hundred papers to twenty-five. Then looking at the titles themselves, you'll see that many of the titles bear a striking resemblance to each other. "Adaptive Mesh Analysis" reads one and "An Adaptive Algorithm for Mesh Analysis" reads another. Dividing the total remaining by the average number of repetitions halves the list again. Mozart disappears before your very eyes.

> But the last criterion is often the hardest. Is the paper important? Is it something people will look back on and say "That was a landmark." Applying this last test requires historical hindsight—not an easy thing. But when it is applied, very often the list of one hundred papers disappears altogether. Placed under the heat of forensic investigation the list finally evaporates and what you are left with is the empty set.
>
> And this, really, is not a great surprise, because landmark papers in any discipline are few and far between. Mozarts are rare and to be valued, but the counterfeit academic Mozarts are common and a contributory cause to global warming and deforestation.

[For the history of these trends, see for example: Buranyi 2017; Francis 2020.]

Because of all of the above problems, and because it is now more efficient and far cheaper for students to do much of their academic coursework online, utilizing the best recorded lectures and curriculum materials, it is currently unclear how universities should or will change in the coming decades.

1.1.4 Problems with Modern Corporate Research

Decades ago, corporate research programs made sizeable investments in very innovative, longer-term research and development projects, ultimately leading to products ranging from revolutionary microelectronics to whole new classes of pharmaceuticals. Unfortunately, corporate research (even including start-up companies and venture capitalists) now appears to be hobbled by several widespread problems, such as:[3]

(a) With top management and investors seemingly focused only on tomorrow's stock prices and next year's products, companies are generally only interested in developing very near-term, very low-risk (non-innovative) products.

(b) There appears to be a strong financial incentive for companies to take whatever amount of innovation does exist in their R&D pipeline and spread that innovation out for as many years as possible over a long succession of slightly improved products, in order to ensure planned obsolescence of each product and profitable sales of the next version of the product. There seems to be a strong disincentive to release as much innovation as possible as quickly as possible, which would spur the need for much more extensive and accelerated innovative research programs to refill the pipeline with future products.

(c) Research and development for any period of time is apparently viewed as an immediate financial loss for the company, not an investment in the company's future, and scaled back or entirely replaced with the hope of finding some other company's research that can be bought out or simply imitated. It is presumably much more lucrative to wait for someone else to invest in developing an innovative product, then just copy that product and try to capture as much of the market share as possible.

---

[3] E.g., Arora 2015; Buxton 2008; Denning 2013, 2014; Hsueh 2015; Kwoh 2012; Lyons 2016, 2018; Matthews 2015; Mittra 2009; O'Neill 2012; Pearlstein 2018; Ramo 1980a, 1983, 1988; Rosenbloom and Spencer 1996; Slywotzky 2009; Terkel 2011; NYT 2011-05-02, 2015-05-20, 2016-06-30.

(d) Companies tend to be very unstable, with an endless series of mergers, acquisitions, or internal reorganizations that can completely redirect any research and development priorities on an almost annual basis.

(e) Profits for top management and investors seem to grow ever larger while rewards and working conditions for the actual research and development employees have stagnated at low levels or even worsened in recent years. Upper management tends to view the workers as disposable, interchangeable cogs in the machine that can be frequently and easily replaced, not skilled experts whose abilities should be cultivated, allowed to reach their maximum potential, and rewarded with and for longtime service.

Simon Ramo, cofounder of TRW, saw these problems arise in the 1970s [Ramo 1980a, pp. 55–56]:

> New technology is by its nature speculative. Risk taking is part of the task of management in the private sector but in periods of diminishing rewards smaller risks will be favored. This means priority will go to sticking to existing technology and making only small changes in techniques of manufacture and in the products themselves. Managers of R&D in American corporations are now reporting a heavy shift in emphasis to short-term programs either to produce safe, non-speculative, incremental improvements or else to learn how to comply with new government environmental and safety regulations. Basic research has been disappearing from private U.S. industry. Another factor is that principal executives, while not disinterested in long-term investments that may enhance the company's position after they have retired, have a natural desire to see results while they are still in the driver's seat. They are increasingly less motivated to make risky, long-term investments as their concern grows about U.S. economic-political stability over the lengthening period required to see a speculative investment through to successful completion. [...]
>
> After World War II there was a burgeoning in the United States of new technological industries: computers, agricultural technology, instant copiers, telecommunications, jet transport, semiconductors, nuclear reactors, spacecraft, fast foods, new chemicals and pharmaceuticals, and many more. Some of these product areas are now approaching maturity. We need new ideas and enterprises as well as continued enhancement and expansion of the fields in which we have a strong position.

The problems succinctly diagnosed by Ramo in 1980 have only worsened in the several decades since then, as shown by the references about corporate research cited above.

As with Michael Hanlon (see p. 42), most or all of the innovations that Ramo attributed to the United States during the first few decades after World War II can actually be traced to a different time and place, as this book shows.

1.1.5 Problems with Modern Government Research

Although government-run or government-funded laboratories played major roles in developing revolutionary innovations (nuclear technology, radar, space flight, guidance systems, etc.) many decades ago, they now seem to be mired in a number of problems.[4] In general the problems include:

(a) Each lab appears to be strongly focused on some core technology that was very innovative roughly three-quarters of a century ago when the lab was founded, but that is now very mature and for which government funding is steadily declining.

(b) Because of their previously reliable government funding and potentially dangerous core technologies, government labs tended to develop very risk-averse management cultures in which it is generally much safer politically to do nothing than to support any progress or change.

(c) Any new work at government labs seems to be highly constrained by a wide variety of internal and external regulations that have greatly increased in number and severity over the last 75 or so years.

(d) As funding for government labs has declined in recent years, not only have their research staff sizes decreased, but the surviving staff members have had to devote larger and larger fractions of their time to pursuing outside resources instead of actually conducting research. In many cases, the staff members spend much of their time writing proposals to try to obtain funding from outside sponsors. In other cases, the surviving staff are no longer allowed to conduct their own research, but rather must spend their time selecting and managing outside contractors to do the research.

(e) In cases where government labs have attempted to reform their structures and their areas of research, those reforms often mimic some of the worst practices of modern industry, for example either by focusing on very short-term, non-innovative, low-risk work or else by investing in a rapid succession of poorly thought-out “get rich quick” schemes.

(f) For all of the preceding reasons, government labs often have great difficulty attracting and retaining talented scientific professionals, and may instead accumulate mediocre personnel to fill out available positions, with some of those mediocre personnel ultimately rising to management positions at all levels as managerial openings become available over time.

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[4] E.g., Alvarez 2014; GAO 2016; Gref 2010; Harris and Benincasa 2014; King 2011; Kramer 2016; Lucibella and Levine 2010; Mann 2011; McCurdy 1993; Nesbit 2016; Odenwald 1995; Sisk 2015; Steinbock 2015; Trento and Trento 1987; Trigaux 2015; Young 2015a, 2015b; NYT 2011-01-23, 2011-09-11.

Howard McCurdy, professor of public affairs at American University, summarized these problems in his detailed analysis of NASA's management history [McCurdy 1993, pp. 1–2]:

> The people who ran the National Aeronautics and Space Administration (NASA) when the agency was young developed methods of doing business that allowed them to carry out extraordinarily difficult tasks. NASA civil servants discovered ways to circumvent bureaucratic restrictions and avoid failure when it threatened to occur. They adopted an organizational philosophy suited to the scientific and technological missions they were asked to perform. NASA acquired a reputation as a high-performance government organization.
>
> As NASA grew older, it changed. Beliefs about how the agency should be run persisted, but no longer did those beliefs elicit the behavior that characterized the early years. NASA grew more bureaucratic. It became more concerned with maintaining its survival. In the eyes of some people, its performance declined. The onset of maturity changed NASA. The agency that embarked upon the 1990s was a different one than the NASA that sent astronauts to the Moon. The NASA story helps reveal forces that work to mollify the capabilities of high-performance organizations in the public sector. Unlike business firms, whose fundamental outlooks tend to persist over long periods of time, NASA's organizational culture blossomed and lost strength within just thirty years. The NASA experience suggests that high-performance cultures within the public sector are inherently unstable, given the conditions with which they must deal.

Thus government-run or government-funded laboratories fell into increasing dysfunction over the course of several decades, just as the academic and corporate research sectors did.

1.2 Scientific Innovation in the Earlier German-Speaking World

Trying to imagine completely new methods of improving the innovation system would be rather challenging (though not impossible), and any new methods might have inadequacies or even major adverse consequences that would not be discovered until they were tested in practice. As a more tractable alternative, studying the conditions that facilitated the major successes of earlier scientists and engineers in history can offer road-tested insights into how to maximize the productivity of modern researchers. Although inventions and discoveries have been made throughout the world and throughout history, high concentrations of major innovations within a given place and time should indicate especially conducive conditions for cultivating innovators and innovations.

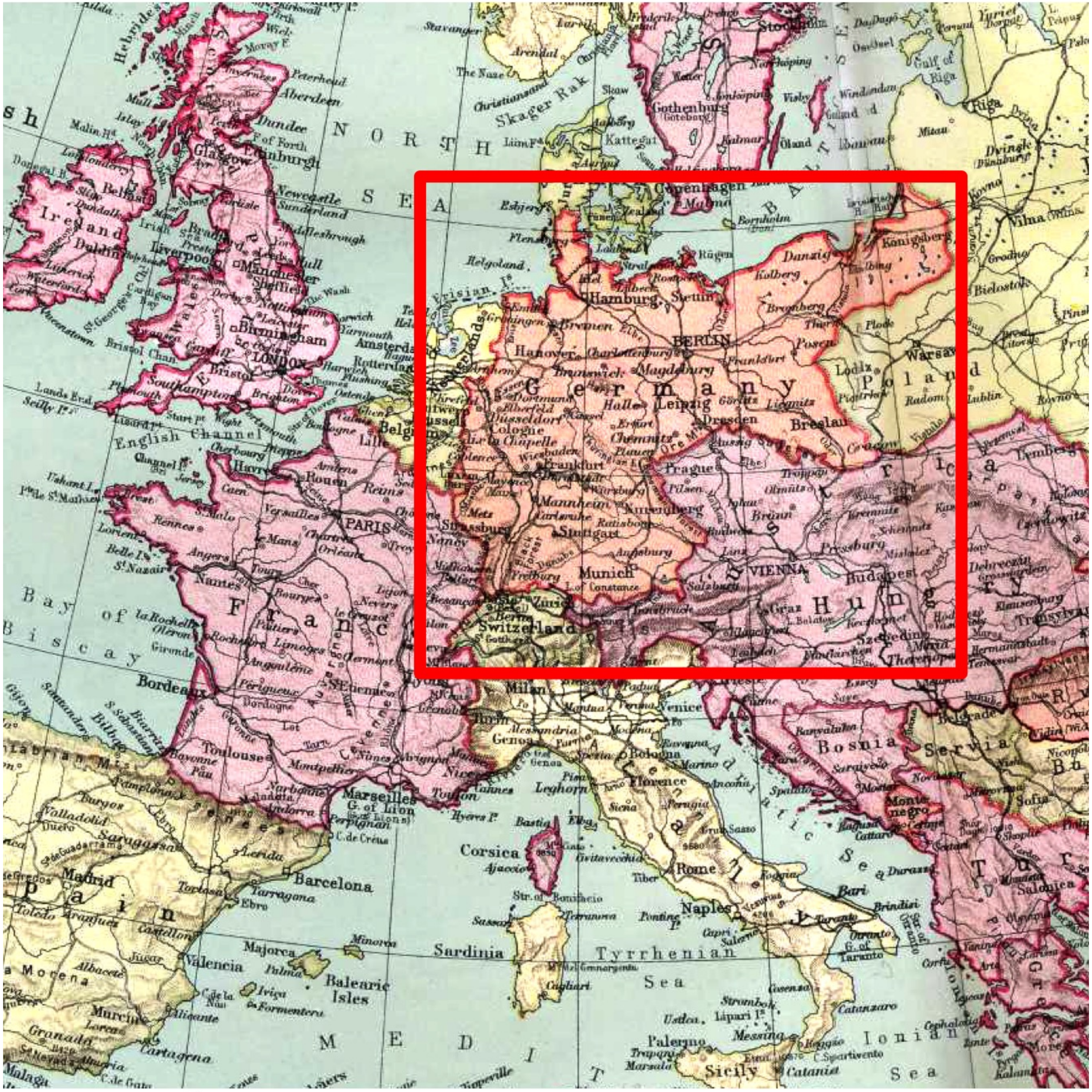
1.2.1 Motivation for Studying the Earlier German-Speaking World

One of the highest concentrations (and arguably the highest concentration) of revolutionary discoveries and inventions came from scientists and engineers who were trained in the predominantly German-speaking central European research world in the nineteenth and early twentieth centuries. For the purposes of this study, that world is defined as containing German, Austrian, and Swiss researchers, eastern European and other researchers who were educated and/or worked in the German-speaking world, and scientists and engineers in the closely coupled Dutch research system. (Some historians of science have previously classified the Dutch system as part of the greater German-speaking scientific world [e.g., Laurie Brown et al. 1995, p. 17].) Figure 1.6 presents a map of Europe in 1914 to help visualize the relevant geographical areas.

This book focuses on scientists and engineers who received some or all of their training in that world between approximately 1800, when the German-speaking scientific world first began to take recognizable form, and 1945, when that world was essentially destroyed and then subsequently slowly rebuilt. For completeness, this book also includes all the accomplishments of those who were educated before 1945 but continued to make significant contributions after 1945.

As shown in Table 1.1, of the 99 people who received Nobel Prizes in Physics, Chemistry, and Physiology or Medicine through 1932, or prior to the Third Reich and all the problems it caused, half (49) were trained in the German-speaking research world. The other Nobel laureates were divided among a number of other research systems, including the United Kingdom, the United States, France, Sweden, Italy, etc., so the German-speaking world had by far the largest share.

Predominantly German-speaking scientific world of the nineteenth and early twentieth centuries


Germany
Hamburg
Bremen
BERLIN
Magdeburg
Leipzig
Dresden
Breslau
Frankfurt
Stuttgart
Munich
Prague
VIENNA
Budapest
Switzerland
Danzig
Königsberg
Warsaw
Poland
PARIS
France
LONDON
Edinburgh
Ireland
Copenhagen
Milan
Venice
Florence
Rome
Naples
Corsica
Sardinia
Sicily
Madrid
Barcelona
Spain
Bosnia
Servia
North Sea
English Channel
Bay of Biscay
Tyrrhenian Sea

Germany

Poland

Switzerland

Austria

Hungary, esp. Budapest

Czechia (Bohemia/Moravia)

Netherlands—closely coupled

Outsiders who came for education and/or work

Figure 1.6: As shown on this 1914 map, the predominantly German-speaking scientific world of the nineteenth and early twentieth centuries included modern Germany, Poland, Switzerland, Austria, Hungary (especially Budapest), Czechia (Bohemia/Moravia), the Netherlands (closely coupled to the German world), and people who came from elsewhere for scientific education and/or work.

Year	**Physics Nobel**	**Chemistry Nobel**	**Physiology/Med. Nobel**
1901	**Wilhelm Röntgen**	**Jacobus van 't Hoff**	**Emil von Behring**
1902	**Hendrik Lorentz** **Pieter Zeeman**	**Emil Fischer**	Ronald Ross
1903	Henri Becquerel Pierre Curie Marie Curie	Svante Arrhenius	Niels Finsen
1904	Lord Rayleigh	William Ramsay	Ivan Pavlov
1905	**Philipp Lenard**	**Adolf von Baeyer**	**Robert Koch**
1906	J. J. Thomson	Henri Moissan	Camillo Golgi Ramón y Cajal
1907	**Albert Michelson**	**Eduard Buchner**	Alphonse Laveran
1908	Gabriel Lippmann	Ernest Rutherford	**Élie Metchnikoff** **Paul Ehrlich**
1909	Guglielmo Marconi **Karl Braun**	**Wilhelm Ostwald**	**Theodor Kocher**
1910	**Johannes van der Waals**	**Otto Wallach**	**Albrecht Kossel**
1911	**Wilhelm Wien**	Marie Curie	Allvar Gullstrand
1912	Gustaf Dalén	Victor Grignard Paul Sabatier	Alexis Carrel
1913	**Heike Kamerlingh Onnes**	**Alfred Werner**	Charles Richet
1914	**Max von Laue**	Theodore Richards	**Róbert Bárány**
1915	William Henry Bragg William Lawrence Bragg	**Richard Willstätter**	—
1916	—	—	—
1917	Charles Barkla	—	—
1918	**Max Planck**	**Fritz Haber**	—
1919	**Johannes Stark**	—	Jules Bordet
1920	Charles Guillaume	**Walther Nernst**	August Krogh
1921	**Albert Einstein**	Frederick Soddy	—
1922	Niels Bohr	Francis Aston	A. V. Hill **Otto Meyerhof**
1923	Robert Millikan	**Fritz Pregl**	Frederick Banting John Macleod
1924	Manne Siegbahn	—	**Willem Einthoven**
1925	**James Franck** **Gustav Hertz**	**Richard Zsigmondy**	—
1926	Jean Perrin	Theodor Svedberg	**Johannes Fibiger**
1927	Arthur Compton Charles Wilson	**Heinrich Wieland**	**Julius Wagner-Jauregg**
1928	Owen Richardson	**Adolf Windaus**	Charles Nicolle
1929	Louis de Broglie	Arthur Harden **Hans von Euler-Chelpin**	**Christiaan Eijkman** Frederick Hopkins
1930	C. V. Raman	**Hans Fischer**	**Karl Landsteiner**
1931	—	**Carl Bosch** **Friedrich Bergius**	**Otto Warburg**
1932	**Werner Heisenberg**	**Irving Langmuir**	Charles Sherrington Edgar Douglas Adrian

Table 1.1: Prior to the Third Reich (1901–1932), 99 scientists won Nobel Prizes in Physics, Chemistry, and Physiology or Medicine. Of those scientists, 49 were trained in the German-speaking world. That figure includes **38 native German speakers (German, Austro-Hungarian, or Swiss), 7 Dutch scientists, and 4 others who were educated in the German world.** Marie Curie won two Nobel Prizes in the table, and prizes were not awarded in years with dashes.

Highly innovative scientists and engineers who were educated in that German-speaking world prior to 1945 (**creators**, as they are called throughout this book) produced a huge number of revolutionary discoveries and inventions (**creations**) that have shaped the modern world:

- Biomedical advances from genetics to antibiotics
- Chemical breakthroughs from color film to synthetic rubber
- Discoveries about the universe from continental drift to stellar distances
- Revolutionary physics from relativity to quantum mechanics
- Electrical inventions from semiconductors to computers
- Mechanical systems from automobiles to submarines
- Nuclear reactions and applications from fission to fusion
- Aerospace vehicles from jet planes to moon rockets

Almost all of the inventions cited by Hanlon (p. 42) and Ramo (p. 52) as examples of post-1945 U.S. innovation actually originated from pre-1945 German-speaking creators.

A wide range of scientific experts from outside the early German-speaking research world and after its downfall have testified about its scientific success. For example, Sir Brian Pippard from the Cavendish Laboratory of the University of Cambridge wrote [Laurie Brown et al. 1995, p. 7]:

> It cannot be doubted that in physics, as in nearly every branch of scholarship, Germany at this time [early twentieth century[5]] led the world. The universities and their researchers were highly esteemed by their own people, their learned journals were eagerly followed everywhere, and there was an abundance of local societies to meet the needs of amateurs.

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[5] Wherever I insert my own editorial comments into quoted text, I put my comments in square brackets and in blue to make them clearly distinguishable.

John Cornwell, another British scholar from the University of Cambridge, similarly observed [Cornwell 2003, p. 7]:

> By the end of the first decade of the twentieth century, Germany had become the international Mecca of science. Researchers, basic and applied, flocked to German universities from all over the world; learned German to read the leading science journals and to participate in conferences and seminars.

As an example of an American perspective, David Hounshell, a Carnegie Mellon University professor and historian of science, wrote [Rosenbloom and Spencer 1996, pp. 19–20]:

> During the last third of the nineteenth century and the first decade and a half of the twentieth century, a preponderance of U.S. physicists and chemists earned graduate degrees in Germany. These scientists not only observed a different system of graduate education in German universities but also witnessed the evolution of a nationwide system of scientific research and industrial-academic relations that had begun after German unification in 1871. By the beginning of World War I, Germany possessed the world's most complex and advanced research system, comprised of university research programs, government- and industry-sponsored research institutes, and industrial R&D programs. These components were linked by research scientists committed to advancing science and, as necessary to this goal, technology and industry.

Despite the deleterious impact of two World Wars and the intervening economic Depression on the German-speaking world, U.S. Army Air Forces General Curtis LeMay was so impressed by the scientific innovations the United States found in German-speaking areas in 1945 that he wrote [LeMay 1946, p. 17]:

> At Wright Field, O[hio]., German scientists are now assisting American scientists in translating great masses of captured German scientific documents. These documents reveal, as the materiel at Freeman Field indicates, the extent to which German science had out-distanced American science in basic and applied scientific research and in aircraft development. It has been estimated that the Germans were 10 to 15 years ahead of us in fundamental research.

L. B. Kilgore from the U.S. Technical Industrial Intelligence Division (TIID) confirmed the very high level of the German-language scientific achievements found by the United States after the wars; in fact, he admitted that their quantity and quality were almost beyond description [L. B. Kilgore, Proposal for a Compendium of German War Time Technology, Draft No. 2, 10 January 1947, NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss]:

> The accumulation of the technical industrial information, which has resulted from the detailed investigations of the German industry for the past two years by this office, has reached such enormous proportions that it has become difficult to inform the public of the possible benefits available to it. This accumulation of information not only represents the greatest transfer of mass intelligence ever made from one country to another, but it also represents one of the most valuable acquisitions ever made by this country.

A 1946 U.S. Senate report on the establishment of the National Science Foundation noted that even the major scientific accomplishments of the United States during World War II were directly derived from earlier German-speaking creators [NSF 1946, p. 6]:

> It should be somewhat humiliating to us to realize that the revolutionary sulfa drugs had their beginning in German research laboratories; that atom splitting was discovered in Berlin; that the basic pioneer work that has led to radio and radar and the enormous American electronic industries was that of a German professor. Penicillin came from England [where it was purified by Ernst Chain, a German refugee]; DDT from Germany and Switzerland.

Although the Soviet Union was much less vocal with its praise of the German-speaking scientific world, its actions spoke volumes. Beginning in 1945, the Soviet Union removed thousands of scientists and many hundreds of whole laboratories and factories from German-speaking territory, and historians have shown that the subsequent Soviet nuclear, aircraft, rocket, electronics, and other development programs owed a huge debt to the German-speaking scientists and scientific information.[6]

Unfortunately, the history of the German-speaking creators and their transformative creations has been greatly obscured by a combination of factors including:

- World War I and its aftermath
- World War II and its aftermath
- The Cold War and its secrecy requirements
- Language barriers
- Pervasive and long-standing cultural stereotypes of German-speaking scientists in the rest of the world (villainous as in James Bond and Indiana Jones stories, insane as in Frankenstein films and other mad scientist stories, and/or foolish and ridiculous as in *Hogan's Heroes* and *Dr. Strangelove*)

The creators who invented so much of the modern world have been largely forgotten (especially by non-German speakers), leaving the modern world less aware of key details in its history and less able to fully reproduce the research conditions that led to so many revolutionary achievements.

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[6] E.g., Albrecht et al. 1992; von Ardenne 1990, 1997; Barkleit 2008; Barwich and Barwich 1970; Fengler 2014; Fengler and Sachse 2012; Graham 1993; Heinemann-Gruder 1992; Holloway 1994; Karlsch and Laufer 2002; Kozyrev 2005; Kruglov 2002; Jürgen Michels 1997; Mick 2000; Nagel 2016; Naimark 1995; Oleynikov 2000; Pondrom 2018; Przybilski 1999, 2002a, 2002b; Riabev 2002a; Riehl and Seitz 1993; Siddiqi 2009; Sokolov 1955; Uhl 2001; Zeman and Karlsch 2008; *News Chronicle* 1945-10-15 p. 1; NYT 1945-10-15 p. 4, 1945-10-31 p. 6, 1946-01-29 p. 1, 1946-11-28 p. 16, 1946-12-06 p. 17, 1947-02-24 p. 1, 1948-05-26 p. 3, 1948-12-28 p. 10b; *Spokane Daily Chronicle* 1948-03-16 p. 6; *Sydney Morning Herald* 1946-04-20 p. 2; *Times* 1945-05-15, 1945-05-18.

1.2.2 Scope and Outline of this Book

Due to the length of this book, all of the sections and appendices are designed to be as self-contained as possible (even though that necessitates some degree of overlap and redundancy among some sections). Please use this outline or the Table of Contents to find whatever section interests you the most, and jump straight to that without any shame.

Motivated by the reasons explained earlier in this chapter, this book presents an overview and analysis of the historical German-speaking scientific world. The revolutionary creators and creations that world produced are divided into eight very broad fields over the next eight chapters:

Chapter 2: Biology and medicine

Chapter 3: Chemistry and materials science

Chapter 4: Earth and space science

Chapter 5: Physics and mathematics

Chapter 6: Electrical and electromagnetic engineering

Chapter 7: Mechanical engineering

Chapter 8: Nuclear science and engineering

Chapter 9: Aerospace engineering

Before delving into those specific fields, it would be useful to lay out the general approach of Chapters 2–9:

- The main objective of these chapters is to illustrate both the vast number and the profound modern impact of creators and creations arising from the earlier German-speaking world.
- In order to make such a broad overview accessible within a finite number of pages and a limited amount of readers' time and attention, the presentation in these chapters is primarily visual using figures, with accompanying pages of relatively brief text to put the figures in their proper context and to refer interested readers to sources of much more detailed information.
- The sections throughout Chapters 2–9 are based on information from general sources[7] as well as additional information from more specialized references on individual science and engineering fields as listed in the Bibliography.
- Within each of the eight fields covered by Chapters 2–9, creators and creations are grouped into specific topics to facilitate an overview of the details. There is considerable overlap for some of the fields, topics, creators, and creations, and it would easily be possible to categorize the same material in many other ways.

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[7] Especially ACLS 2000; Albrecht et al. 1992; Ash and Söllner 1996; Bar-Zohar 1967; Bower 1987; Bunch and Hellemans 2004; Challoner 2009; Cornwell 2003; Crim 2018; EB 1911, 2010; Gillispie 1970–1990; Gimbel 1990a; Glatt 1994; Hall 2019a; István Hargittai 2006, 2011; Linda Hunt 1991; Impey et al. 2008; Jacobsen 2014; Koertge 2007; Kurowski 1982; Lasby 1971; Lusar 1956, 1971; Medawar and Pyke 2000; Mick 2000; Murray 2003; Nachmansohn 1979; NDB 1953–2020; Neufeld 2012; Nouzille and Huwart 1999; O'Reagan 2014, 2019; Porter 1994; Charles Walker 1946; Peter Watson 2010; Weitensfelder 2009.

- German-derived creations for some topics are less studied and less well understood by modern historians than those for other topics. For a handful of especially important yet historically murky topics, evidence for German-language innovations in those areas is briefly mentioned in these chapters, then presented in much more detail in Appendices A–E.

- In order to give some context for the major German-speaking creators, each section also briefly mentions some major creators in that field who were outside the German-speaking world, how relevant information was imported into the German-speaking world from other innovation systems, and how the German-speaking creators' inventions and discoveries were exported to the rest of the world. A common theme for many of the sections is that non-German-speaking (especially French and British) scientists initially dominated a given field up to the mid-nineteenth century or so, German-speaking scientists adopted that work as a starting point and entered the field sometime during the nineteenth century, and by 1945 German-speaking scientists had contributed most of the major new innovations in that field and were far ahead of their competitors (in many cases by a decade or more).

- The coverage of fields, innovators, and innovations in Chapters 2–9 is reasonably thorough but certainly not exhaustive. Hopefully those that have been included here are at least sufficient to elucidate both the impact of the German-speaking creators and the systemic principles underlying their successes.

Chapter 10 investigates why the earlier German-speaking scientific world was able to produce so many revolutionary creators and creations even though it had far fewer researchers than the modern scientific world, far less funding, and a long string of dire political challenges. Its success is even more remarkable when one considers the fact that over the course of a century or so, the German-speaking scientific world went from being far behind to being far ahead of its competitors in so many different fields. Systemic innovation-promoting factors that are examined include the social status of science and scientists, the growth rate of research funding, some characteristics of the education system, the popularity of interdisciplinary scientific work, the style of scientific management, the employment of systems analysis, incentives due to natural resource constraints, and incentives due to economic and military rivalries with other countries.

Chapter 11 considers how the global community adopted so many creations from the earlier German-speaking world while forgetting so many of their creators. In different waves that occurred before, during, and after the Third Reich, many thousands of German-speaking scientists, hundreds of thousands of tons of documents on their innovations, and complete inventions and even the factories to produce them were transferred to the United States, the Soviet Union, the United Kingdom, France, and other countries. Along with those creators and creations, some innovation-promoting systemic approaches were also transferred from the earlier German-speaking world to other countries, where they facilitated further scientific innovation during the Cold War. Chapter 11 explores which general approaches were adopted, and how they were ultimately abandoned.

Chapter 12 focuses on what the modern scientific research system can learn from the earlier German-speaking world. Based on the perspective accumulated in Chapters 1–11, Chapter 12 offers suggestions for:

- State or national innovation systems that would like to increase their production of revolutionary research

- Individual companies, organizations, or laboratories that would like to pursue more innovative research

- Individuals who are now trying to pursue careers in innovative research in the existing state of the global system

- Scholars who would like to further study the past, present, and potential future of revolutionary scientific innovators and innovations

The appendices focus on some potentially quite advanced creations of the German-speaking world during World War II that are currently much less well understood by modern historians, and whose complexities necessitate a considerably longer treatment than could be given in Chapters 2–9:

> **Appendix A** presents archival documents that suggest that Germany had the largest and most advanced biotechnology programs in the world at that time, was developing neural interfaces to control prosthetic limbs and weapons systems, possessed a significant offensive program in biological warfare, and discovered advanced V-series nerve agents during the war.
>
> **Appendix B** gives an overview of evidence that transistors and other microelectronics innovations may have originated in the German-speaking world, and that information on those technologies may have been transferred to and exploited by Allied countries after the war.
>
> **Appendix C** presents documents that appear to show that the German-speaking world developed and tested a variety of directed-energy technologies, including particle beams, electromagnetic pulse weapons, major steps toward lasers, focused sound waves for applications ranging from ultrasound imaging to acoustic weapons, and electromagnetic railguns.
>
> **Appendix D** provides considerable evidence that Germany may have developed and even successfully tested fission bombs during the war (which would have made it the first country in world history to do so), and that it may have even had a megaton-level hydrogen bomb in an advanced stage of development when the war ended.
>
> **Appendix E** presents archival documents that appear to show that wartime Germany made considerable progress toward developing the aerospace technologies that have formed the “nuclear triad” for most of the postwar decades: intercontinental jet bombers, intercontinental ballistic missiles, and submarine-launched missiles.

Although the evidence in the appendices does not constitute conclusive proof, it should prompt further archival research to clarify the true extent of those wartime programs.

The primary motivation for this study is one of practical modern self-interest, to identify factors that might improve present and future scientific productivity. However, there is also an underlying historical obligation. The names of Marco Polo, Christopher Columbus, Neil Armstrong and Buzz Aldrin, and other pioneers are remembered by the modern world. The German-speaking scientists and engineers who played such vital roles in creating our modern world deserve to be remembered as well.

1.2.3 Disclaimers

Before proceeding, it would be prudent to note several disclaimers, caveats, and assumptions, many of which are graphically illustrated in Fig. 1.7:

1. It should be emphasized that this study does not argue that the modern research system has produced no revolutionary innovations. Rather, this study proceeds based on the assumption (derived from the analyses of other scholars such as those cited in Section 1.1) that compared to earlier times, the modern system appears to have produced fewer revolutionary innovations per year, or at least fewer revolutionary innovations per year per person in the system, or fewer innovations per year per amount of money spent on the system.

    (a) One should certainly consider the possibility that the apparent decline in the innovation rate is only an artifact of how revolutionary innovation is defined. One should also bear in mind the possibility that it may appear that there has been a recent decline in innovation simply because there are large numbers of current innovations whose true impact can only be correctly viewed and judged in hindsight, many decades from now. Nonetheless, it seems unlikely that the recent innovation decline is merely an artifact of our perception. Whereas once the world changed dramatically every few years, due to discoveries that were made only a few years before their impact was felt, now the world appears to have been largely free of similarly revolutionary changes for half a century, with only a few exceptions.

    (b) Similarly, this study does not argue that non-revolutionary R&D is not important. Typically it takes far fewer people, far less time, and far less money to first come up with a revolutionary innovation than it does to then take that existing innovation and fully develop it all the way to a mature product. Therefore one would expect an optimally efficient research and development system to devote only a relatively small fraction of its people and funding to creating revolutionary new innovations, and most of its resources to perfecting previously created innovations. However, relative to previous periods that produced and perfected many revolutionary innovations, the modern system seems to be (i) devoting a smaller fraction of its resources to creating new innovations, and/or (ii) constructively advancing a smaller fraction of such innovations all the way through to later-stage development.

2. Having concluded that the modern innovation rate has declined, this study proceeds on the assumption that it is possible that the modern innovation rate **can** be increased. One cannot discount the possibility that we are simply nearing the physical limits of innovation. Perhaps most things that can be invented or discovered, within the constraints of human resources and interests, have already been invented or discovered. In that case, the innovation decline is due to the well of possibilities gradually running dry. On the other hand, on many previous occasions humanity has believed that it had reached the limits of innovation, and on each occasion it was mistaken (for example, during the Roman Empire; before each succeeding wave of the Industrial Revolution; once classical physics was mature but before quantum and relativistic physics were discovered; the state of medicine prior to the development of anesthetics, antiseptics, and antibiotics; etc.). Therefore, we should adopt the assumption that we are not now at an actual physical limit for innovation, and at least try to increase the innovation rate to see if any physical limits are encountered.

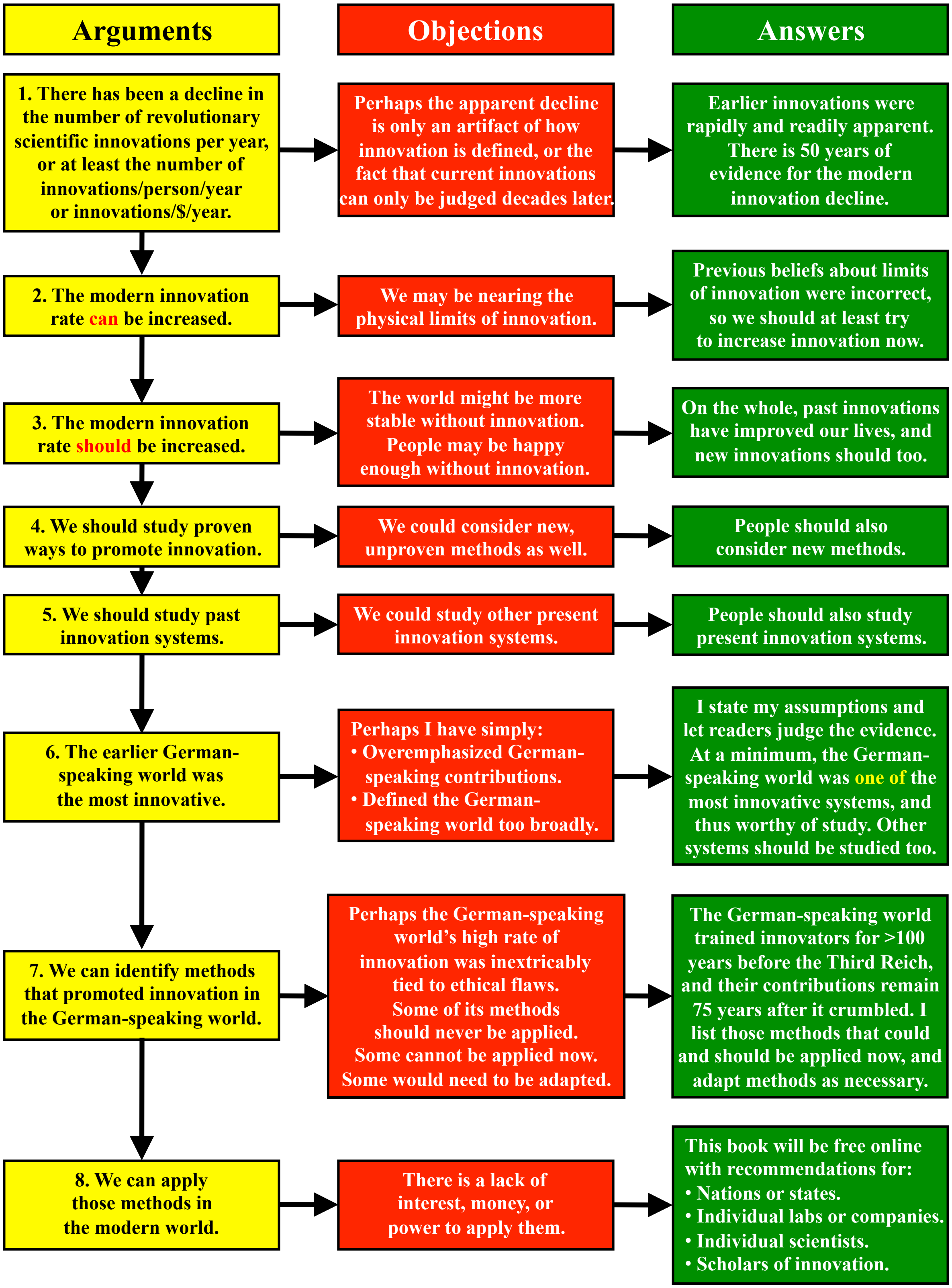
Arguments
Objections
Answers
1. There has been a decline in the number of revolutionary scientific innovations per year, or at least the number of innovations/person/year or innovations/$/year.
Perhaps the apparent decline is only an artifact of how innovation is defined, or the fact that current innovations can only be judged decades later.
Earlier innovations were rapidly and readily apparent. There is 50 years of evidence for the modern innovation decline.
2. The modern innovation rate can be increased.
We may be nearing the physical limits of innovation.
Previous beliefs about limits of innovation were incorrect, so we should at least try to increase innovation now.
3. The modern innovation rate should be increased.
The world might be more stable without innovation. People may be happy enough without innovation.
On the whole, past innovations have improved our lives, and new innovations should too.
4. We should study proven ways to promote innovation.
We could consider new, unproven methods as well.
People should also consider new methods.
5. We should study past innovation systems.
We could study other present innovation systems.
People should also study present innovation systems.
6. The earlier German-speaking world was the most innovative.
Perhaps I have simply: • Overemphasized German-speaking contributions. • Defined the German-speaking world too broadly.
I state my assumptions and let readers judge the evidence. At a minimum, the German-speaking world was one of the most innovative systems, and thus worthy of study. Other systems should be studied too.
7. We can identify methods that promoted innovation in the German-speaking world.
Perhaps the German-speaking world's high rate of innovation was inextricably tied to ethical flaws. Some of its methods should never be applied. Some cannot be applied now. Some would need to be adapted.
The German-speaking world trained innovators for >100 years before the Third Reich, and their contributions remain 75 years after it crumbled. I list those methods that could and should be applied now, and adapt methods as necessary.
8. We can apply those methods in the modern world.
There is a lack of interest, money, or power to apply them.
This book will be free online with recommendations for: • Nations or states. • Individual labs or companies. • Individual scientists. • Scholars of innovation.

Figure 1.7: Flowchart of the key arguments underlying this book, some possible objections, and answers to those objections.

3. Moreover, this study operates on the assumption that the modern innovation rate **should** be increased. Someone may object that the world might be more stable without innovation, or that people are currently happy enough without further innovation, and those objections do have some merit. Yet on the whole, past innovations have improved our lives. How many people would prefer to forsake modern technology and medicine and live as people did in the year 1900, or 1800, or 1200? Thus this study proceeds with the belief that at least on balance, new innovations will also improve people's lives and are morally and socially desirable.

4. Rather than trying to reinvent the wheel, this study focuses on studying already proven ways to promote innovation. It does not consider new, unproven methods to promote innovation, although other scholars certainly should propose and evaluate new methods as well.

5. Among those proven ways to promote innovation, this study specifically considers past innovation systems. With mountains of historical documentation and many decades of hindsight, it is more straightforward to fully evaluate past innovation systems and their ultimate impact than to properly evaluate present innovation systems around the world. Nevertheless, other scholars should be and are evaluating various current innovation systems worldwide, and there is much to learn from those studies.

6. Out of all past innovation systems, I wanted to focus on the most productive one, whatever that was. I eventually came to the conclusion that the German-speaking world was the most innovative, based on the number and the importance of the creators and creations summarized in Chapters 2–9 and the appendices, as well as considerable reading about other historical innovation systems. Readers are entirely welcome to disagree with my conclusion, but hopefully my presentation shows that the German-speaking world was at the very least **one of** the most innovative systems, and thus imminently worthy of detailed study.

    (a) Some readers may feel that I have overemphasized the contributions of the German-speaking world relative to those of other historical innovation systems. It is not at all my intent to belittle the scientific contributions of other places or times, which have been made by innovators ranging from Archimedes to Louis Pasteur to Rosalind Franklin. Ideally it would be desirable to analyze factors that have promoted innovation in all places and times, but in order to keep the scope manageable, I had to pick one innovation system, and I chose the German-speaking world of the nineteenth and early twentieth centuries. Nevertheless, I highly recommend that readers of this book seek out or even conduct their own studies of scientific innovations from other places and times. Such other studies may even find some of the same contributing factors as this study, or they may identify additional useful systemic methods for promoting innovation.

    (b) Other readers may object that I have inflated the accomplishments of the German-speaking world by defining that world too broadly. Admittedly, the topic I have chosen, revolutionary scientific innovations in the German-speaking world of the nineteenth and early twentieth centuries, has very fuzzy boundaries. One should certainly recognize that this topic could be defined in many other possible ways, with the boundaries of the topic set at other limits. I have chosen to define the boundaries very broadly in order to analyze as much data as possible. Another advantage of defining the boundaries so broadly in this study is that if some readers prefer to set different limits for the boundaries, it would be much easier for them to simply exclude some of the data I provide in order to shrink the boundaries than it would be for them to collect the large amounts of new data that would be required to expand the boundaries. The three major categories of boundaries used in defining the scope of this study are:

i. Spatial boundaries. Depending on personal preferences and definitions, the German-speaking world could be defined to include the Netherlands and parts of eastern Europe, as other scholars have done previously and I have done here, or those could be excluded. Even within that German-speaking world, there could be important differences in innovation systems in different regions, as that world was hardly homogeneous. Moreover, people, ideas, and methods flowed back and forth across national borders, and thus the German-speaking scientific world was never truly independent of the scientific communities in other regions. To deal with these difficulties, I have tried to define and analyze the system as a scientist would analyze a physical system: choosing a well-defined if somewhat arbitrary boundary around that system, studying what happens within that system, and keeping track of what flows into and out of that system across the boundary.

ii. Temporal boundaries. The German-speaking scientific world had a very long and very slow rise, with no clear beginning point. It was definitely booming by the time of German unification in 1871. In order to capture most of the rise, this book considers scientists and discoveries well before that date, back to around 1800, but other beginning dates could equally well be chosen. Likewise, the end date of the German-speaking world to be studied could easily be defined in different ways. When the Third Reich began in 1933, roughly 25% of scientists (mostly of Jewish background) left the German-speaking world, and conditions greatly changed for those who remained in it. By 1945, that world had been destroyed by a combination of the Third Reich's behavior, the Allied military campaign, and Allied removals of scientists and scientific material from the German-speaking world. The slow reconstitution of scientific systems in West and East Germany (and later in reunified Germany) and in Austria after 1945 is beyond the scope of this book, although the book does track the post-1945 worldwide contributions of scientists who had been educated primarily or entirely in the German-speaking world before 1945. Finally, of course, it must be recognized that national borders, governments, and population ethnic compositions changed repeatedly over the time period covered in this book.

iii. Intellectual boundaries. There are no clear-cut definitions for, and no obvious boundary between, truly revolutionary and more evolutionary (progress by incremental improvements) scientific work. I have tried to focus on the more revolutionary and innovative inventions and discoveries, as generally recognized in the sources listed in the Bibliography. The result cannot help but be somewhat arbitrary and definitely incomplete, yet I hope that it will serve as a representative selection to facilitate the overarching analysis in this book. In order to keep the scope manageable, I have excluded the social sciences—psychology, linguistics, philosophy, economics, and others—from this book; that is simply my personal choice, and there would undoubtedly be much to learn from other researchers who do address those areas. Also largely excluded are scientific failures and mediocrity in the areas covered by this book, simply because there is so little available literature and data on them compared to what exists for the much more visible successes. (I do not know how to readily rectify this deficiency, but I do at least want to acknowledge it.)

(c) This study is not intended to make an argument for nationalist or ethnic bragging rights. The scientific research world in question spanned several nations, and even several very different types of government within a single nation's history. The scientists had a wide variety of ancestral backgrounds. The key to their success appears to lie in their intellectual approach, not their nationality or ethnicity.

(d) This study does not mean to imply that there is anything unique or magical about the German language—speaking German does not make scientists smarter. "German-speaking" is used throughout this book as the most convenient phrase to describe a geographical region in central Europe, centered on the German-speaking countries of Germany, Austria, and Switzerland, but also spilling over to surrounding areas to which they were most closely coupled during the time period in question (especially the Netherlands and parts of Czechoslovakia, Poland, and Hungary). "German-speaking" is also employed throughout this book to describe scientists and engineers who received part or all of their training in that region, regardless of whether German was their primary language, or even the language in which most of their education and research were conducted. Thus "German-speaking" is used to denote a population of scientists who were molded by the research world in this central region of Europe, in order to facilitate the study of those scientists and of common factors in their training that may have contributed to their ultimate success.

(e) Similarly, the label "scientists" is used throughout this book as shorthand to denote people who contributed to scientific discoveries or technological inventions, even though those people included not only degreed scientists but also engineers, mathematicians, medical doctors, veterinarians, technicians, military personnel, and individuals with only incomplete or no formal scientific education who made important contributions.

(f) As a final note on definitions, "forgotten" is employed in this book's title to succinctly encapsulate the apparent overall trend regarding general worldwide awareness of these scientists. Of course I realize that some of these scientists (such as Albert Einstein, Edward Teller, and Wernher von Braun) became household names, that modern scientists will recognize many more names in some of these fields, and that huge numbers of books, articles, and encyclopedia entries have been written about various German-speaking scientists (as cited in the Bibliography). Nevertheless, I believe that most readers will find it as surprisingly enlightening as I have (i) to learn about many of the creators and creations that are included in this book, (ii) to realize that this limited portion of geography and time could produce revolutionary creators and creations with such overwhelming numbers and importance, and (iii) to consider what innovation-promoting approaches our modern world may be able to learn from that history. (One should also note that the problem of innovators not being properly recognized or remembered is not exclusive to German-speaking creators.)

(g) It is certainly not my intent to claim that all major innovations have come from German-speaking scientists, or even that all elements and steps in any given innovation have come from German-speaking scientists. Yet I believe the examples cited in this book show that the number of major innovative contributions by German-speaking scientists in the nineteenth and twentieth centuries was astoundingly large, and that those contributions have had a remarkably profound and long-lasting impact on our modern world. As already mentioned, even if the German-speaking world was only one of the top innovation systems and not the greatest one, then it warrants a detailed analysis to see what we can learn from it.

7. This study assumes that we can identify useful methods that promoted innovation in the earlier German-speaking world.
    (a) This study is at best a concise overview of a vast field encompassing the actions of thousands of scientists and engineers across many countries over a period of two centuries (including the post-1945 careers many of them had), as well as investigations of those innovators and their innovations by countless subsequent scholars. For much more information on people and projects that can only be briefly mentioned here, please consult the cited references and even their references. Due to space limits, this book cannot include all scientific fields or all creations and creators within each field. Nonetheless, hopefully the sizable numbers of fields, creations, and creators that have been included are sufficient to elucidate both the impact of the German-speaking creators and the systemic principles underlying their successes. Much more work on these topics could and should be conducted, however.

    (b) I do not mean to imply that the earlier German-speaking world was entirely different or unique; some of its innovation-promoting factors may also have been successfully implemented at other times and places, or may already be a part of the modern research system.

    (c) For those innovation-promoting factors that are different, one must recognize the larger differences that existed between the earlier German-speaking world and the modern world. A strategy that facilitated innovation in the older German-speaking world may need to be suitably adapted to operate successfully in the modern world. Other factors that promoted innovation in the earlier German-speaking world may not be possible or even desirable to implement now. Nonetheless, I hope that enough strategies can be identified and adapted to be beneficial.

    (d) Some people may only be familiar with research programs that were conducted during the Third Reich, or might wonder if perhaps the German-speaking world's high rate of innovation was inextricably tied to ethical flaws. In no way is this study an argument that the Third Reich had inherently superior scientific research approaches. This study focuses on innovators who were trained in the scientific world that existed for more than a century prior to the Third Reich, and many of them lived their entire productive careers before the Third Reich. For those creators whose productive careers extended beyond 1933, their careers and the scientific research world itself were greatly impacted or destroyed by the Third Reich.[8] The key is the earlier research world, which had a long and illustrious history prior to the Third Reich, and which produced creators and creations whose impact is still felt at least three-quarters of a century after the Third Reich crumbled.

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[8] The Third Reich drove out, fired, imprisoned, and/or killed a large fraction of the creators. Most of the remaining creators were mistreated and misused, even if some of their creations did receive lavish funding. The Third Reich also caused huge numbers of its students (many of whom would have become future scientists) and some of its existing scientists to die fighting in the war, made the schools and universities highly ideological and dysfunctional, and made scientists focus their energies solely on developing military projects without also refilling the research pipeline by training the next generation of creators and making new discoveries in fundamental science. Even if the Third Reich had won the war, the German-speaking scientific world that had been so carefully cultivated by earlier generations would have been destroyed.

   (e) This study does not claim that research conditions in the earlier German-speaking world were ever perfect, even before the Third Reich came along. Throughout the time period and geographical areas in question, there were plenty of examples of interpersonal conflicts, discrimination, bureaucratic obstruction, overlooked innovators, insufficient job opportunities and funding, and other problems. Nonetheless, despite these pervasive and persistent human problems, the amount of revolutionary innovation per scientist in the earlier German-speaking world seems to compare quite favorably with that in the modern world.

   (f) Both to keep the scope and length manageable and also to concentrate on topics that have not been well addressed previously, this study is focused only on the factual questions of what innovations were created, what innovators created them, and what factors facilitated the development of those innovators and innovations. This study cannot even begin to address the large number of related ethical questions—whether certain innovations should have been created, how they should have been used, how innovators were treated by or behaved during the Third Reich, how Allied countries treated the German-speaking world after World Wars I and II, etc. There is a vast body of existing literature on such moral questions, and I highly recommend that all readers seek out those books and study them.[9]

8. The ultimate objective of this study is to make these methods of improving innovation available to the modern world. Yet I recognize that there may be a lack of interest, funding, or power to apply them. Accordingly, I have tried to do everything possible to ensure that this book will ultimately find a receptive audience at some time, place, and level.

   (a) I have divided the concluding recommendations into those that would require support from entire nations or states, those that could be implemented by individual organizations or laboratories, those that could be useful for individual scientists, and those that should be considered by scholars of innovation systems.

   (b) In order to maximize the potential audience, longevity, and impact of this study, I decided to make the document freely available on the internet instead of publishing it as a printed book, which might be expensive and difficult to obtain and might rapidly go out of print, as so many of the cited references have. An online resource also has the advantage that it can be periodically updated with corrections or additional information. In choosing this path, I am following the model of other researchers who have made large amounts of technical information freely available online, for example Carey Sublette's website (http://nuclearweaponarchive.org), Mark Wade's website (http://www.astronautix.com), and the website of the Stichting Centrum voor Duitse Verbindingen en aanverwante Technologieën (http://www.cdvandt.org).

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[9] E.g., Bar-Zohar 1967; Beyerchen 1977; Black 2012a, 2012b, 2017; Borkin 1978; Bower 1987; Campbell and Harsch 2013; Cornwell 2003; Crim 2018; Deichmann 1996; Joseph Fisher 2017; Friedrich et al. 2017; Geissler 1998a, 1998b, 1999; Gellermann 1986; Georg 2012; Gimbel 1986, 1990a, 1990b, 1990c; Gröhler 1989; Guillemin 2005; Friedrich Hansen 1993; István Hargittai 2006; Harris Paxman 2002; Haunschmied et al. 2007; Hayes 2001; Heim et al. 2009; Hentschel and Hentschel 1996; Linda Hunt 1991; Jacobsen 2014; Jeffreys 2008; Karlsch and Laufer 2002; Kaszeta 2020; Kater 1989; Keynes 2019; Klee 2001; Kurowski 1982; Lasby 1971; Leff 2019; Le Maner and Sellier 2001; Julian Lewis 2002; Lichtblau 2014; Macrakis 1993; Milton Mayer 2017; Medawar and Pyke 2000; Mick 2000; Nachmansohn 1979; Nash 2013; Michael Neufeld 1995, 2002, 2003, 2007; Plumpe 1990; Posner and Ware 2000; Pringle 2006; Renneberg and Walker 1993; Sasuly 1947; Schambach 2011; Sellier 2003; Simpson 1988; Spitz 2005; Stoltzenberg 1994, 2005; Sutton 1976; Szöllösi-Janze 2001, 2015; Tucker 2006; Wachsmann 2015; Bernd Wagner 2000; Jens-Christian Wagner 2011, 2015; Wallace 2004; Whitman 2018.

   (c) For the same reasons, I decided to write this document in English, which currently is arguably the most widely accessible international language. I would be happy to offer advice or assistance with translating the contents into other languages if that would be of interest.

9. Here are a few final points:

   (a) **I have deliberately left a blank space where images of some creators or creations should go.** Those are people or projects that I felt were important enough that they should definitely be shown in this book, yet I have not yet been able to locate a suitable image that I have permission to use, despite my searches in Europe and in the United States. If readers have any relevant images and could send them to me, I would be very grateful and will include them in future editions of this book. Even where a suitable photo cannot be located, I believe that leaving a blank space pays tribute both to the scientific importance of that creator or creation and to how that historical fact has been very nearly forgotten.

   (b) Similarly, some first names, nationalities, or dates of birth and death are indicated as unknown if I have not been able to find them. Relevant information from readers would be very welcome.

   (c) Throughout the book, I have made a deliberate choice to quote experts and source documents on various topics as much as possible, rather than asking readers to accept my own account of innovators, innovations, events, and their importance. While the resulting text may not flow as smoothly as a unified narration, I hope that the presentation benefits far more from the objectivity and the persuasive amount of data that are afforded by this approach.

   (d) Lengthy or tangential sets of evidence have been placed in the appendices to avoid interrupting the flow of the discussion in the main chapters of the book.

      i. In order not to obscure the book's arguments by simply referring readers to numerous documents that may be difficult to obtain, relevant excerpts from a large number of key sources are presented in the appendices.

      ii. All or parts of some key documents are presented as photographs, which I have tried to make as clear and readable as possible, subject to the constraints of the original documents and the book format.

      iii. To make the contents computer-searchable for readers and internet search engines, most documents have been retyped (with annotations as appropriate).

      iv. Where I have retyped documents, I have tried to preserve the formatting of the original documents (underlining, etc.) as much as possible.

      v. To avoid variant spellings that would not come up in a computer text search, I have silently corrected some obvious typographical errors in some of the quoted source documents. U.S. and U.K. documents that were typed during and shortly after World War II were often careless in their spellings of the German names of people and places.

  vi. Neither archival documents nor cited reference works are guaranteed to be unbiased or free from error. In the text, and especially in Appendices A–E, I quote sources that I believe are worthy of serious consideration.[10] Some readers may come to different conclusions about the accuracy or interpretation of some of those sources. By making this collection of sources freely available, I hope to facilitate such discussions.

  vii. In order to avoid increasing the length of this already enormous book by a factor of several fold, I have abridged portions of the documents that seemed less relevant, as denoted by [...] in the quoted text.

  viii. Where I wanted to add emphasis to passages in quoted documents to draw the attention of readers, I have displayed those passages in red. Even passages not in red are relevant too, though, which is why I have taken the time to type them up and include them as well.

  ix. To add my own commentary regarding quoted documents yet clearly distinguish my commentary from the text of the source documents, [my commentary appears in blue text inside square brackets].

  x. Key sources not in English are presented in both their original language and a parallel English translation.

  xi. Citations direct interested readers to the original sources of these documents in case readers would like to verify their authenticity and read them in full.

  xii. Each source quote has been placed in the most relevant section, but it may be germane to other sections as well, as indicated by cross-references.

(e) The Bibliography is organized into a number of broad categories, instead of being one long list with everything mixed together. Hopefully any difficulties in figuring out in which category a citation may be found are greatly outweighed by the convenience to those who are interested in easily perusing all references on a given topic.

(f) Even though there is a tremendous amount of available literature in this field, many lifetimes could be spent pursuing answers to all of the important questions that remain. Those answers may lie in personal collections or official archives anywhere around the world, if new investigators are willing to take up the quest.

(g) Because the body of information on German-speaking innovators is both so large and so incomplete, this book cannot help but be incomplete and imperfect. **For readers who find that specific assumptions, definitions, information, arguments, or conclusions I have given are incorrect or incomplete, I would welcome any suggestions for improvements to future editions (ToddHRider@gmail.com or thor@riderinstitute.org).**

(h) At the very least, hopefully this book will spur discussion, learning, and further work in the important areas that it covers.

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[10] In recent decades, the topic of advanced German wartime research has been plagued by some completely bogus documents and information. I have tried my best to exclude that here. Please let me know if you think I have included something that is bogus or excluded something that is real. Some references that are cited in the Bibliography but not quoted in the text are included simply for completeness, not as any endorsement of their quality.

Chapter 2

Creators and Creations in Biology and Medicine

O dieses ist das Tier, das es nicht giebt.
Sie wußtens nicht und habens jeden Falls
—sein Wandeln, seine Haltung, seinen Hals,
bis in des stillen Blickes Licht—geliebt.

Zwar *war* es nicht.
Doch weil sie's liebten, ward
ein reines Tier. Sie ließen immer Raum.
Und in dem Raume, klar und ausgespart,
erhob es leicht sein Haupt und brauchte kaum

zu sein. Sie nährten es mit keinem Korn,
nur immer mit der Möglichkeit, es sei.
Und die gab solche Stärke an das Tier,

daß es aus sich ein Stirnhorn trieb.
Ein Horn.
Zu einer Jungfrau kam es weiß herbei—
und war im Silber-Spiegel und in ihr.

Oh this is the animal that never was.
They didn't know that and dared nonetheless
to love its transformations, its bearing, its gait,
till in the tranquil gaze of light, it lived.

Really it never *was.*
Yet as they loved it, it
became a pure creature. They always left room.
And in that space, empty and set aside,
it lightly raised its head and scarcely needed

to be. They nourished it with no corn,
only and always with the possibility of being.
And that gave such strength to the creature,

that it grew a horn on its forehead.
One horn.
It came to a young woman, all white—
and was in the silver mirror and in her.

Rainer Maria Rilke. 1923.
Die Sonette an Orpheus [*Sonnets to Orpheus*]
Part II, 4. Leipzig: IM Insel.

This chapter gives an overview of some innovations in biology and medicine that have played major roles in the modern world and that were discovered or invented by scientists, doctors, and engineers who were trained in the predominantly German-speaking central European research world in the nineteenth and early twentieth centuries. As may be seen from the examples cited in this chapter, the large number, profound impact, and lasting nature of those contributions are quite striking.

Over the course of the nineteenth century, intellectual leadership in biology and medical research began to pass from primarily French and British scientists to largely German-speaking scientists.[1] France was weakened by nearly a century of continual political upheaval that followed the French Revolution. As extraordinarily farsighted and productive as Louis Pasteur and those gathered around him were, it is difficult to identify a widespread culture of comparable biologists in France by the late nineteenth century. Since previous centuries, at any given time the United Kingdom maintained a relatively small number of scientists who made enormously important biology and medical contributions; such British biologists still existed in the late nineteenth century (e.g., Charles Darwin, Alfred Russel Wallace, and Joseph Lister), yet their modest numbers became overwhelmed by the large numbers of talented German-speaking biologists. By the mid- to late-nineteenth century, German-speaking creators were also producing microscopes with the greatest clarity at high magnifications (Section 6.9), and that gave a further advantage to German-speaking biologists and doctors.

As covered in this chapter, creators from the German-speaking world made major contributions to:

2.1. Cellular and molecular biology

2.2. Microbiology and immunology

2.3. Neuroscience

2.4. Cardiovascular medicine

2.5. Vitamins and hormones

2.6. Developmental biology and embryology

2.7. Aerospace medicine and other aspects of physiology

2.8. Botany

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[1] In addition to specific references that are cited in different areas throughout this chapter, this chapter makes use of general biographical and project information from: ACLS 2000; Albrecht et al. 1992; Ash and Söllner 1996; Bar-Zohar 1967; Bower 1987; Bunch and Hellemans 2004; Challoner 2009; Cornwell 2003; Crim 2018; EB 1911, 2010; Gillispie 1970–1990; Gimbel 1990a; Glatt 1994; Hall 2019a; István Hargittai 2006, 2011; Linda Hunt 1991; Impey et al. 2008; Jacobsen 2014; Koertge 2007; Kurowski 1982; Lasby 1971; Lusar 1956, 1971; Medawar and Pyke 2000; Mick 2000; Murray 2003; Nachmansohn 1979; NDB 1953–2020; Neufeld 2012; Nouzille and Huwart 1999; O'Reagan 2014, 2019; Porter 1994; Charles Walker 1946; Peter Watson 2010; Weitensfelder 2009.

For general overviews of large portions of the history of biology and medicine in the German-speaking world, see: Deichmann 1996; Gedeon 2006; Henry Harris 1999; Jahn 2004; Junker 2004; Kohler 2008; Lagerkvist 1998, 2003, 2005; Magner 2002; Morange 2020; von Schwerin 2013; Simmons 2002.

I have deliberately left a blank space where images of some creators or creations should go. Those are people or projects that I felt were important enough that they should definitely be shown in this book, yet I have not yet been able to locate a suitable image that I have permission to use, despite my searches in Europe and in the United States. If readers have any relevant images and could send them to me, I would be very grateful and will include them in future editions of this book. Even where a suitable photo cannot be located, I believe that leaving a blank space pays tribute both to the scientific importance of that creator or creation and to how that historical fact has been very nearly forgotten.

German-speaking creators also made numerous contributions to other biomedicine-related areas listed in Chapters 3 (chemistry), 6 (optical and electron microscopy), and 8 (nuclear medicine).

A widely held view among historians of science is that German-speaking scientists lagged significantly behind other parts of the world in the field of biotechnology [Szöllösi-Janze 2001, pp. 112–114]. As shown in this chapter and in Appendix A, German-speaking scientists actually led the world in developing most of the knowledge, tools, methods, and applications of biotechnology: culture of prokaryotic (bacteria) and eukaryotic (yeast, animal, and plant) cells for laboratory and industrial applications, DNA extraction and study, immunoassays, enzymes, etc.

Even American and British officials overseeing the transfer of science and technology from Germany to the United States after World War II were shocked by the quantity and quality of biology-related innovations, and they recorded some of them for history. For example, in September 1945, R. P. Linstead and T. J. Betts, the British and American chairs of the Combined Intelligence Objectives Subcommittee (CIOS), listed a number of important German innovations regarding pharmaceuticals [AFHRA A5186 electronic version pp. 904–1026, Ch. 4, p. 57]:

> In the field of new pharmaceuticals a wide range of new products were discovered by CIOS investigators. In the majority of instances, German testing methods were inadequate to provide conclusive proof of their efficacy. The following pharmaceuticals were of special interest.
>
> 1. A method of producing inactive insulin by emincing fresh glands in alcohol. This process results in much higher yields than those obtained by conventional methods.
> 2. Improved analgesics and hypnotics.
> 3. The use of DDD (German designation, ME-1700) as an insecticide. Germans claims that this product is more effective than DDT are currently being investigated. If these claims are substantiated, the product would prove of great value since it can be produced more cheaply than DDT, and is less toxic to warm blooded animals.
> 4. The development of peristone or synthetic blood plasma.
> 5. A new sulpha compound which had been synthesized, but not tested clinically.
>
> The Germans were discovered to be using automatic machinery for filling and sealing ampules. The advantages of this machinery are many: it eliminates the imperfect sterilization, low output, inaccurate dosage, loss through spilling and high operating cost which is characteristic of hand methods.

In a lengthy magazine article published in the United States in 1946, journalist Charles Lester Walker gave a much longer list of examples he had learned from U.S. government personnel overseeing the technology transfer [Charles Walker 1946]:

> In matters of food, medicine, and branches of the military art the finds of the search teams were no less impressive. And in aeronautics and guided missiles they proved to be downright alarming. One of the food secrets the Nazis had discovered was a way to

sterilize fruit juices without heat. The juice was filtered, then cooled, then carbonated and stored under eight atmospheres of carbon-dioxide pressure. Later the carbon-dioxide was removed, the juice passed through another filter—which, this time, germ-proofed it—and then was bottled. Some thing, perhaps, for American canners to think about.

Milk pasteurization by ultra-violet light has always failed in other countries, but the Germans had found how to do it by using light tubes of great length, and simultaneously how to enrich the milk with vitamin D.

At a plant in Kiel, British searchers of the Joint Intelligence Objectives Committee found that cheese was being made—"good quality Hollander and Tilitser"—by a new method at unheard-of speed. "Eighty minutes from the renneting to the hooping of the curd," report the investigators. The cheese industry around the world had never been able to equal that.

Butter (in a creamery near Hamburg) was being produced by something long wished for by American butter makers: a continuous butter making machine. An invention of dairy equipment manufacturers in Stuttgart, it took up less space than American churns and turned out fifteen hundred pounds an hour. The machine was promptly shipped to this country to be tested by the American Butter Institute.

Among other food innovations was a German way of making yeast in almost limitless quantities. The waste sulfite liquor from the beechwood used to manufacture cellulose was treated with an organism known to bacteriologists as candida arborea at temperatures higher than ever used in yeast manufacture before. The finished product served as both animal and human food. Its caloric value is four times that of lean meat, and it contains twice as much protein.

The Germans also had developed new methods of preserving food by plastics and new, advanced refrigeration techniques. Refrigeration and air-conditioning on German U-boats had become so efficient that the submarines could travel from Germany to the Pacific, operate there for two months, and then return to Germany without having to take on fresh water for the crew. A secret plastics mixture (among its ingredients were polyvinyl acetate, chalk, and talc) was used to coat bread and cheese. A loaf fresh from the oven was dipped, dried, redipped, then heated half an hour at 285 degrees. It would be unspoiled and good to eat eight months later.

"As for medical secrets in this collection," one Army-surgeon has remarked, "some of them will save American medicine years of research; some of them are revolutionary[...]"

German medical researchers had discovered a way to produce synthetic blood plasma. Called capain, it was made on a commercial scale and equalled natural plasma, in results. Another discovery was periston, a substitute for the blood liquid. An oxidation production of adrenalin (adrenichrome) was produced in quantity successfully only by the Nazis and was used with good results in combating high blood pressure (of which 750,000 persons die annually in the United States). Today we have the secret of manufacture and considerable supply.

2.1 Cellular and Molecular Biology

Scientists from the greater German-speaking world were responsible for many of the major discoveries and innovations in cellular and molecular biology.[2] For convenience, in this section the creators and creations in cellular and molecular biology are divided into five (somewhat arbitrary and overlapping) categories:

2.1.1. Cell biology

2.1.2. DNA and genetics

2.1.3. Cancer

2.1.4. Proteins and enzymes

2.1.5. Mitochondria, respiration, and metabolism

The impressive history of cell biology in the German-speaking world is very well documented. One could also make a strong case that scientists from the German-speaking world essentially founded the whole field of molecular biology, dealing with the structures, natural functions, and artificial manipulation of important biological molecules such as DNA (deoxyribonucleic acid), RNA (ribonucleic acid), and proteins. This section provides a brief summary; see Appendix A for some relevant archival documents.

2.1.1 Cell Biology

As shown in Figs. 2.1–2.6, the majority of important pioneers of cell biology were from the predominantly German-speaking scientific world. One should certainly not overlook the importance of some British microscopists such as Robert Hooke (English, 1635–1703) and Robert Brown (Scottish, 1773–1858), as well as some French microscopists such as Henri Dutrochet (1776–1847) and François-Vincent Raspail (1794–1878) [Henry Harris 1999]. Nonetheless, over the course of the nineteenth century, those relatively small numbers of British and French microscopists were overwhelmed by the rapidly rising numbers and discoveries of German-speaking biologists, as well as the improved tools for microscopy that were also coming out of the German-speaking world (Section 6.9).

Although this book focuses primarily on scientific history from around 1800 onward, it would be impossible not to mention Antonie van Leeuwenhoek (Dutch, 1632–1723), who created the first known microscope and used it to observe numerous types of single-celled and multicellular organisms [Dobell 1960]. See pp. 1260 and 1267 for more information.

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[2] For good overviews of portions of the history of cellular and molecular biology in the German-speaking world, see especially: Deichmann 1996; Dominguez-Lacasa 2005; Gausemeier 2005; Gedeon 2006; Henry Harris 1999; Holmes 1993; Höxtermann and Sucker 1989; Jahn 2004; Junker 2004; Kohler 2008; Krebs 1981; 2005; Magner 2002; Perutz 1989, 1998; von Schwerin 2013; Simmons 2002 Stoff 2012.

Johann Purkinje (Austrian/Czech, 1787–1869, Fig. 2.1) was arguably the founder of histology, the microscopic study of cells from different tissues in the body. He used the improved microscopes that were becoming available during the nineteenth century to study features of cells, especially those from the central and peripheral nervous systems. Purkinje (and independently, Wilhelm His Sr., p. 377) invented the first practical microtome for making extremely thin slices from animal organs or plants, and used that method to more easily visualize tissue structures under the microscope. He also developed the use of balsam tree sap to seal microscope slides and preserve them indefinitely. The *Encyclopedia Britannica* explained some of his scientific innovations and discoveries [EB 2010]:

> [P]ioneer Czech experimental physiologist whose investigations in the fields of histology, embryology, and pharmacology helped create a modern understanding of the eye and vision, brain and heart function, mammalian reproduction, and the composition of cells.
>
> Considered the founder of laboratory training in connection with university teaching in Germany, Purkinje is best known for his discovery of large nerve cells with many branching extensions found in the cortex of the cerebellum of the brain (Purkinje cells; 1837) and of the fibrous tissue that conducts the pacemaker stimulus along the inside walls of the ventricles to all parts of the heart (Purkinje fibres; 1839). In describing young animal embryos, he introduced protoplasm as a scientific term.
>
> First to use the microtome (a mechanical device for slicing thin tissue sections), glacial acetic acid, potassium bichromate, and Canada balsam in the preparation of tissue samples for microscopic examination. Purkinje also described the experimental effects on humans of camphor, opium, belladonna, and turpentine (1829) and the visual images produced by poisoning with digitalis and belladonna. He discovered the sweat glands of the skin (1833) and the germinal vesicle, or nucleus of the unripe ovum, that now bears his name (1825), recognized fingerprints as a means of identification (1823), and noted the protein-digesting power of pancreatic extracts (1836).

Building on the work of Purkinje, Johannes Peter Müller (German states, 1801–1858, Fig. 2.1) expanded the field of histology, studying both the macroscopic and the microscopic features of tissues from a wide variety of animal and human samples. In addition to his own research, he had an enormous scientific impact through the students whom he trained; he was the doctoral advisor for future luminaries such as Hermann von Helmholtz, Jakob Henle, Robert Remak, Theodor Schwann, and Rudolf Virchow.

Franz Meyen (Prussian, 1804–1840, Fig. 2.1), a botanist and microscopist, published a series of plant physiology books in the 1830s in which he wrote that plants were divided into many similar cells, and that new cells arose from the division of existing cells. Both of those discoveries were foundational to the field of cell biology.

Matthias Schleiden (German 1804–1881, Fig. 2.2) studied a variety of plants and plant tissues under the microscope and was another of the first scientists to recognize that larger organisms are divided into many similar cells. He studied the cell nucleus, cell division, and other aspects of cells. Oxford University's *Biographical Dictionary of Scientists* listed some of his discoveries [Porter 1994, pp. 607–608]:

> German botanist who, with Theodor Schwann, is best known for the establishment of the cell theory. [...]

> Schleiden was the first to recognize their importance as the fundamental units of living organisms when, in 1838, he announced that the various parts of plants consist of cells or derivatives of cells. [...]
>
> Schleiden also researched into other aspects of cells. He recognized the importance of the nucleus (which he called the cytoblast) in cell division[...] In addition, he noted the active movement of intracellular material in plant tissues[...]

Rudolph Wagner (German states, 1805–1864, Fig. 2.2) conducted microscopic research on the central and peripheral nervous systems, egg cells, and other tissues.

Jakob Henle (German, 1809–1885, Fig. 2.2) studied with Johannes Müller before having his own successful career studying and cataloging the macroscopic and microscopic features of tissues from a wide variety of organs.

Theodor Schwann (German, 1810–1882, Fig. 2.2) showed that animal tissues were composed of cells with nuclei and other features, just as Meyen and Schleiden had shown for plants. He studied a wide range of tissues under the microscope and classified cells by their features and apparent functions. Oxford University's *Biographical Dictionary of Scientists* described some of his research [Porter 1994, p. 611]:

> In 1834, Schwann began to investigate digestive processes and two years later isolated from the lining of the stomach a chemical responsible for protein digestion, which he called pepsin. This was the first enzyme to be isolated from animal tissue[...] Schwann then studied fermentation and between 1836 and 1837 showed that the fermentation of sugar is a result of the life processes of living yeast cells (he later coined the term metabolism to denote the chemical changes that occur in living tissue). [...]
>
> Giving numerous examples from many different types of animal tissues, Schwann in his *Microscopical Researches* concluded that all organisms (both animals and plants) consist entirely of cells or of products of cells and that the life of each individual cell is subordinated to that of the whole organism. The cell theory soon became widely accepted and is today recognized as being one of the most important concepts in biology.
>
> Schwann also discovered the cells (now called Schwann cells) that make up the myelin sheath surrounding peripheral nerve axons, and the striated muscle in the upper region of the oesophagus. In addition, he noted that an egg is a single cell that eventually develops into a complex organism—a basic principle in embryology.

Gabriel Gustav Valentin (German, 1810–1883, Fig. 2.3) worked with Purkinje and then moved to Switzerland, where he continued to study the histology of many different organs.

Rudolf von Kölliker (Swiss, 1817–1905, Fig. 2.3) catalogued important characteristics and structures of cells from skeletal or striated muscle, smooth muscle, skin, both, blood vessels, the central and peripheral nervous systems, and other tissues. He also investigated tissues in a wide variety of animals and embryos. The American Council of Learned Societies summarized some of his contributions [ACLS 2000, p. 495]:

> [...A]warded Ph.D. at Zurich for determining cellular nature of spermatozoa of invertebrates (1841); awarded M.D. from Heidelberg (1842). [...R]ecognized cellular nature of

> muscle fibers (1846)[...] Published *Mikroskopische Anatomie* (1850–54), which presented study of tissue in terms of cell theory; Koelliker's classification of tissues, presented in *Handbuch der Gewebelehre des Menschen* (1852), became accepted throughout Europe. Also employed cell theory in interpreting development of the embryo; demonstrated that same types of developmental processes occur in both invertebrates and vertebrates; viewed the egg as single cell. Suggested that the nucleus transmitted inherited characteristics (1841) and foreshadowed De Vries's theory of mutations; helped substantiate doctrine of the neuron as basic unit of nervous system (*circa* 1884) [...] he helped establish histology and cytology as independent branches of science.

Joseph von Gerlach (German, 1820–1896, Fig. 2.3) was one of the main developers of modern microscope stains, which stain different substances different colors and make it much easier to see cellular features that would otherwise be essentially transparent structures within a transparent fluid. He was also one of the originators of photomicrography, so that microscopic structures could be shown by actual photographs instead of hand-drawn sketches.

Rudolf Virchow (German, 1821–1902, Fig. 2.4) greatly elaborated on the earlier work by Schwann and others, publishing voluminous writings on the microscopic features of various cells and tissues, as well as their roles in the origins of numerous diseases such as cancer and arthritis. He also made fundamental contributions in many other fields. The *Encyclopedia Britannica* gave some idea of the diversity of Virchow's interests and achievements [EB 2010]:

> German pathologist and statesman, one of the most prominent physicians of the 19th century. He pioneered the modern concept of pathological processes by his application of the cell theory to explain the effects of disease in the organs and tissues of the body. He emphasized that diseases arose, not in organs or tissues in general, but primarily in their individual cells. Moreover, he campaigned vigorously for social reforms and contributed to the development of anthropology as a modern science. [...]
>
> As an intern at the Charité Hospital, he studied pathological histology and in 1845 published a paper in which he described one of the two earliest reported cases of leukemia. This paper became a classic. [...]
>
> Early in 1848 Virchow was appointed by the Prussian government to investigate an outbreak of typhus fever in Upper Silesia; his subsequent report laid the blame for the outbreak on social conditions and on the government.
>
> In 1859 he was elected to the Berlin City Council, on which, for the rest of his life, he focused on public health matters, such as sewage disposal, the design of hospitals, meat inspection, and school hygiene. He supervised the design of two large new Berlin hospitals, the Friedrichshain and the Moabit, opened a nursing school in the Friedrichshain Hospital, and designed the new Berlin sewer system.
>
> His work on the role of animal parasites, especially trichina, in causing disease in humans was fundamental and led to his own public interest in meat inspection. In 1874 he introduced a standardized technique for performing autopsies, by the use of which the whole body was examined in detail, often revealing unsuspected lesions.
>
> In 1865 Virchow discovered pile dwellings in northern Germany, and in 1870 he started

> to excavate hill forts. [...H]e accompanied Schliemann to Troy in 1879 and to Egypt in 1888.

Max Schultze (German, 1825–1874, Fig. 2.5) studied cellular structures and developed methods of classifying different types of cells.

Karl Wilhelm von Kupffer (Baltic German, 1829–1902, Fig. 2.5) conducted wide-ranging work in histology, studying cells from the central nervous system, kidneys, pancreas, spleen, blood vessels, and other tissues, as well as from embryos.

By studying plant cells under the microscope, Wilhelm Pfeffer (German, 1845–1920, Fig. 2.5) discovered the importance of osmotic pressure, and he developed methods to measure it.

Paul Mayer (German, 1848–1923, Fig. 2.5) further improved and systematized the microscope staining methods that had been introduced by Joseph von Gerlach and others.

A number of German-speaking scientists helped to develop methods of isolating cells from larger organisms and using "tissue culture" techniques to keep those cells alive and even get them to reproduce under laboratory conditions (Fig. 2.6).[3]

Wilhelm Roux (German, 1850–1924) conducted the first animal cell tissue culture experiments in 1885, removing medullary plate cells from a chicken embryo and keeping them alive in culture for 13 days.

Paul Grawitz (German, 1850–1932) experimented with tissue culture of additional animal cell types in the 1890s.

Gottlieb Haberlandt (Austrian, 1854–1945) developed plant cell tissue culture and also discovered totipotency, the ability of some "stem" cells to give rise to any type of specialized cell in an organism, in 1902. He was the father of Ludwig Haberlandt, who invented oral contraceptives (p. 354).

Paul Alfred Weiss (Austrian, 1898–1989) moved to the United States in 1930 and helped to develop improved methods for animal tissue culture there.

At the Friedrich Loeffler Institute, Friedrich Hecke (German?, 18??–19??), successfully demonstrated the first practical cultivation of viruses in tissue culture: foot-and-mouth disease virus (1930) and hog cholera virus (1932). Growing viruses in tissue culture is an immensely powerful technique that is now widely utilized to conduct preliminary tests of the properties of viruses and potential treatments for viruses much more rapidly and cheaply than can be done in animals. Tissue culture of viruses also became an important and widespread method of preparing "safe" versions of viruses to make vaccines that will protect humans or animals against the real version of the virus.

Other German-speaking scientists who contributed to cell biology are listed in other sections in this chapter, if their work was especially applicable to DNA, neuroscience, embryology, botany, or other areas.

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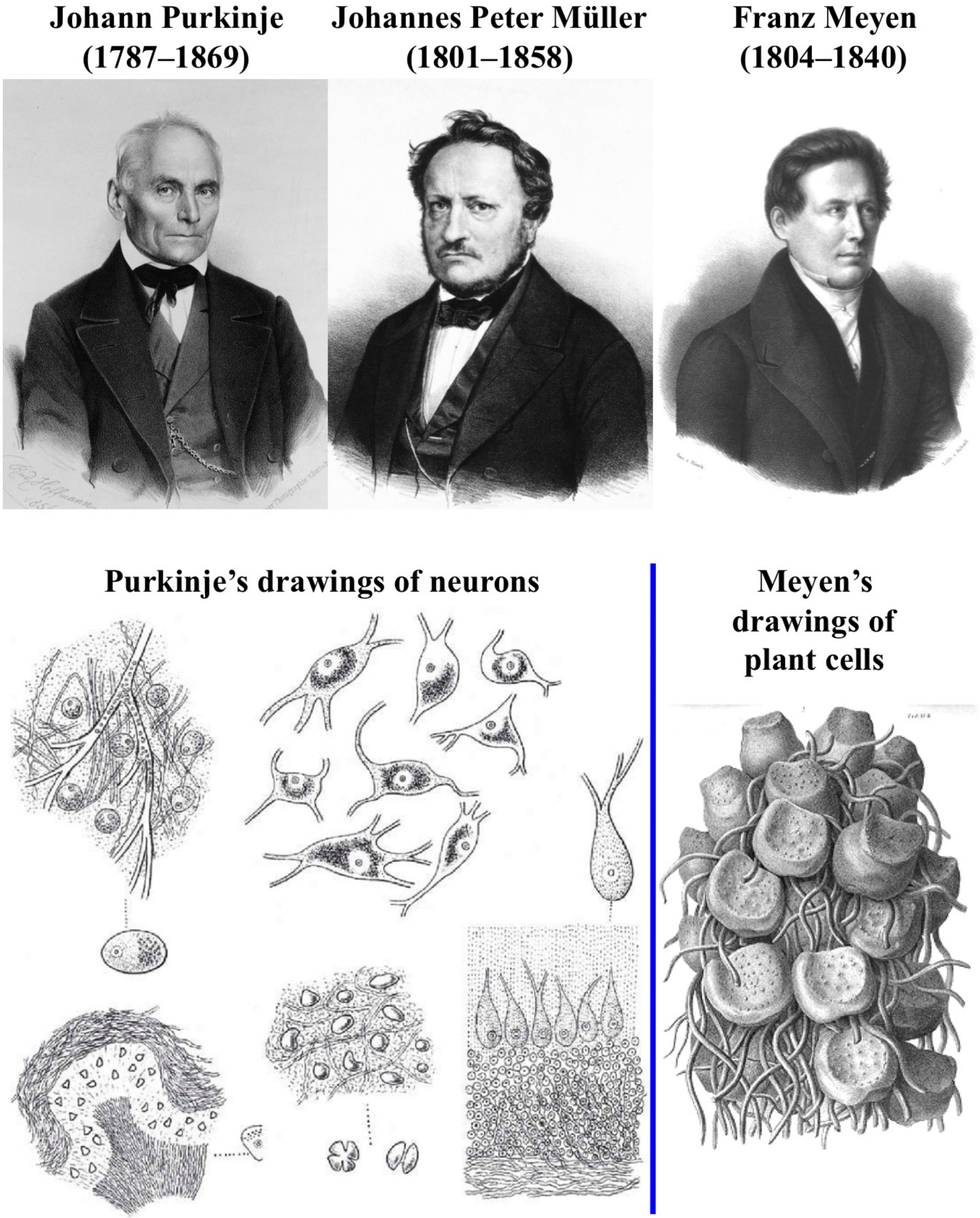
[3] Ross Harrison (American, 1870–1959) began testing animal cell tissue culture methods in the United States in 1907, and is much better known in the English-speaking world than the earlier German-speaking tissue culture pioneers. It would be quite helpful for someone to write a deeply researched history of the early development of animal and plant tissue culture in the German-speaking world, including the work by and influence of Wilhelm Roux, Paul Grawitz, Gottlieb Haberlandt, Paul Alfred Weiss, Friedrich Hecke, and others.



Johann Purkinje (1787–1869)

Johannes Peter Müller (1801–1858)

Franz Meyen (1804–1840)

Purkinje's drawings of neurons

Meyen's drawings of plant cells

Figure 2.1: Johann Purkinje, Johannes Müller, and Franz Meyen pioneered the study of cell biology.

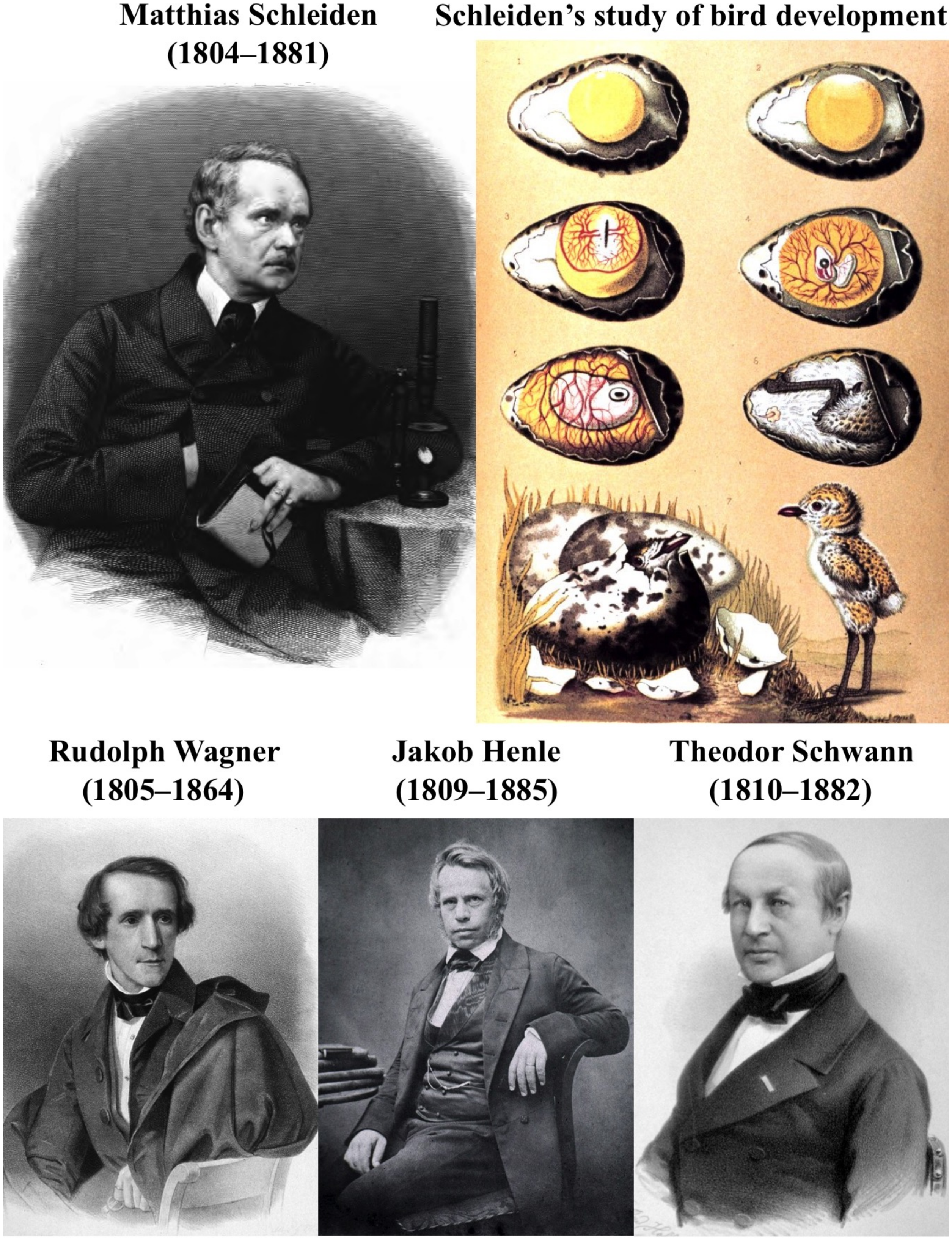
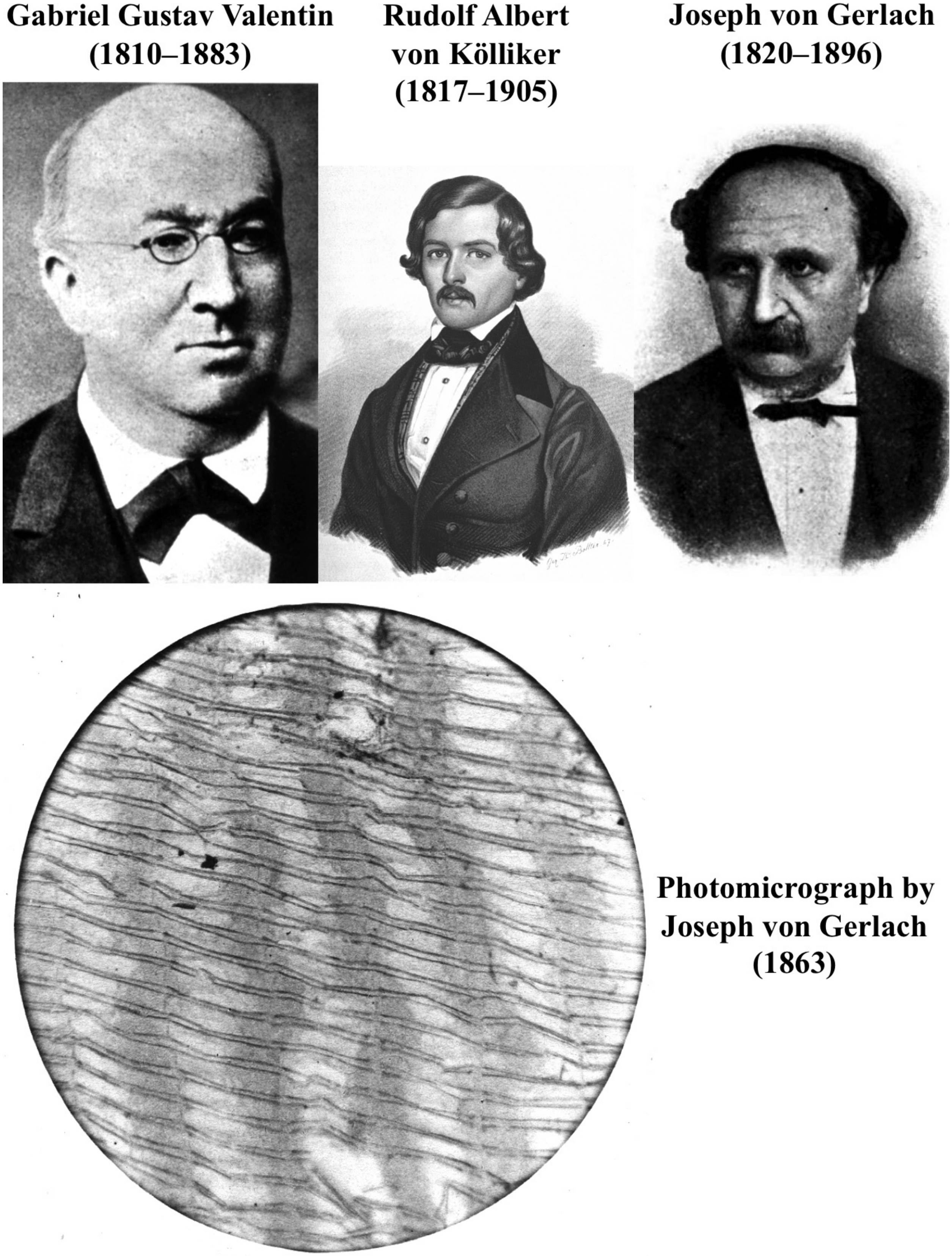

Matthias Schleiden
(1804–1881)
Schleiden's study of bird development
Rudolph Wagner
(1805–1864)
Jakob Henle
(1809–1885)
Theodor Schwann
(1810–1882)

Figure 2.2: Other creators who made major contributions to cell biology included Matthias Schleiden, Rudolph Wagner, Jakob Henle, and Theodor Schwann.



Gabriel Gustav Valentin (1810–1883)

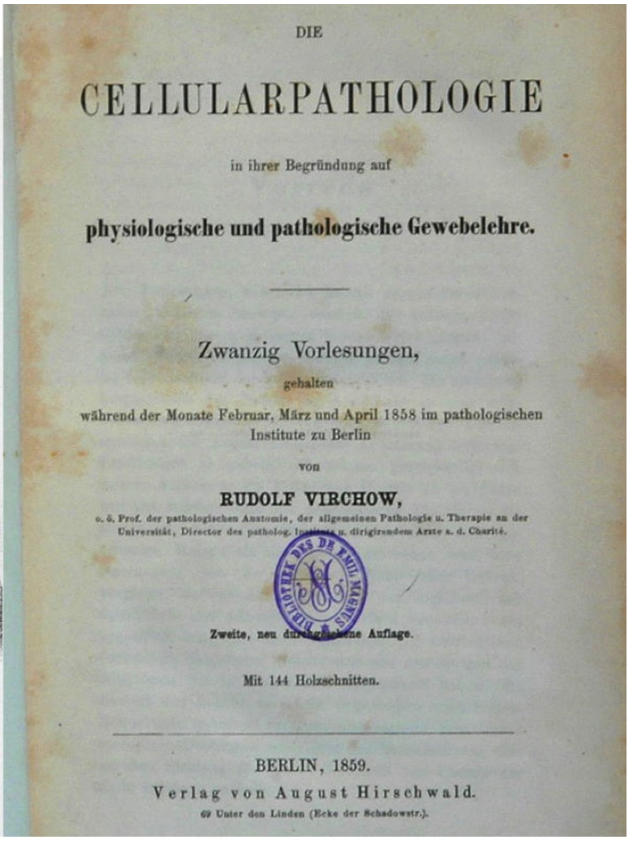
Rudolf Albert von Kölliker (1817–1905)

Joseph von Gerlach (1820–1896)

Photomicrograph by Joseph von Gerlach (1863)

Figure 2.3: Other creators who made major contributions to cell biology included Gabriel Gustav Valentin, Rudolf von Kölliker, and Joseph von Gerlach.

Rudolf Virchow (1821–1902)



DIE

CELLULARPATHOLOGIE

in ihrer Begründung auf

physiologische und pathologische Gewebelehre.

Zwanzig Vorlesungen,
gehalten
während der Monate Februar, März und April 1858 im pathologischen
Institute zu Berlin
von

RUDOLF VIRCHOW,
o. ö. Prof. der pathologischen Anatomie, der allgemeinen Pathologie u. Therapie an der
Universität, Director des patholog. Instituts u. dirigirendem Arzte a. d. Charité.

BIBLIOTHEK DES DR EMIL MAGNUS

Zweite, neu durchgesehene Auflage.

Mit 144 Holzschnitten.

BERLIN, 1859.
Verlag von August Hirschwald.
69 Unter den Linden (Ecke der Schadowstr.).

Fig. 56.

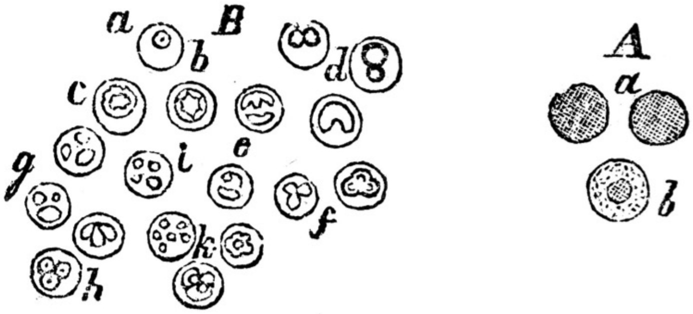


Fig. 64.

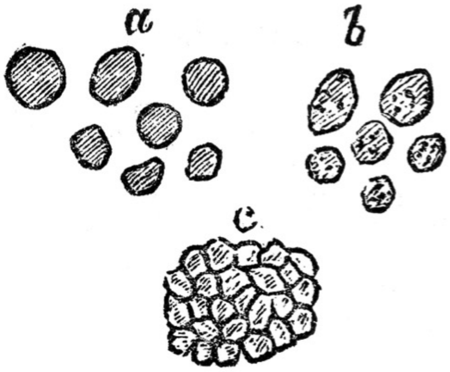


Fig. 66.

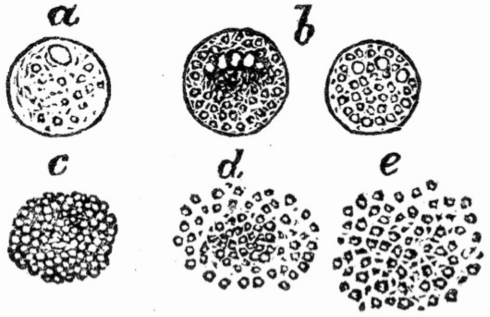


Figure 2.4: Rudolf Virchow was another pioneer of cell biology.

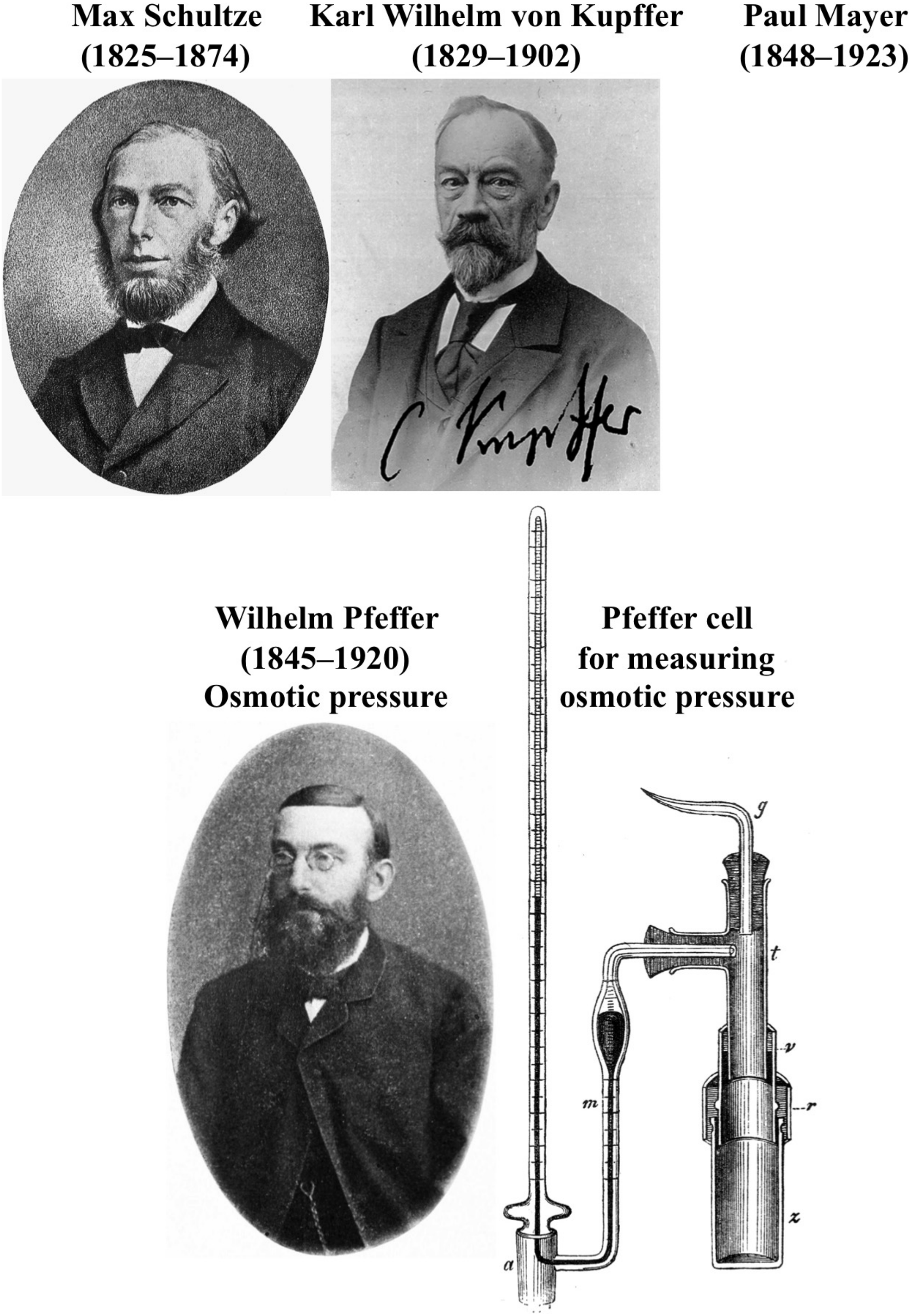
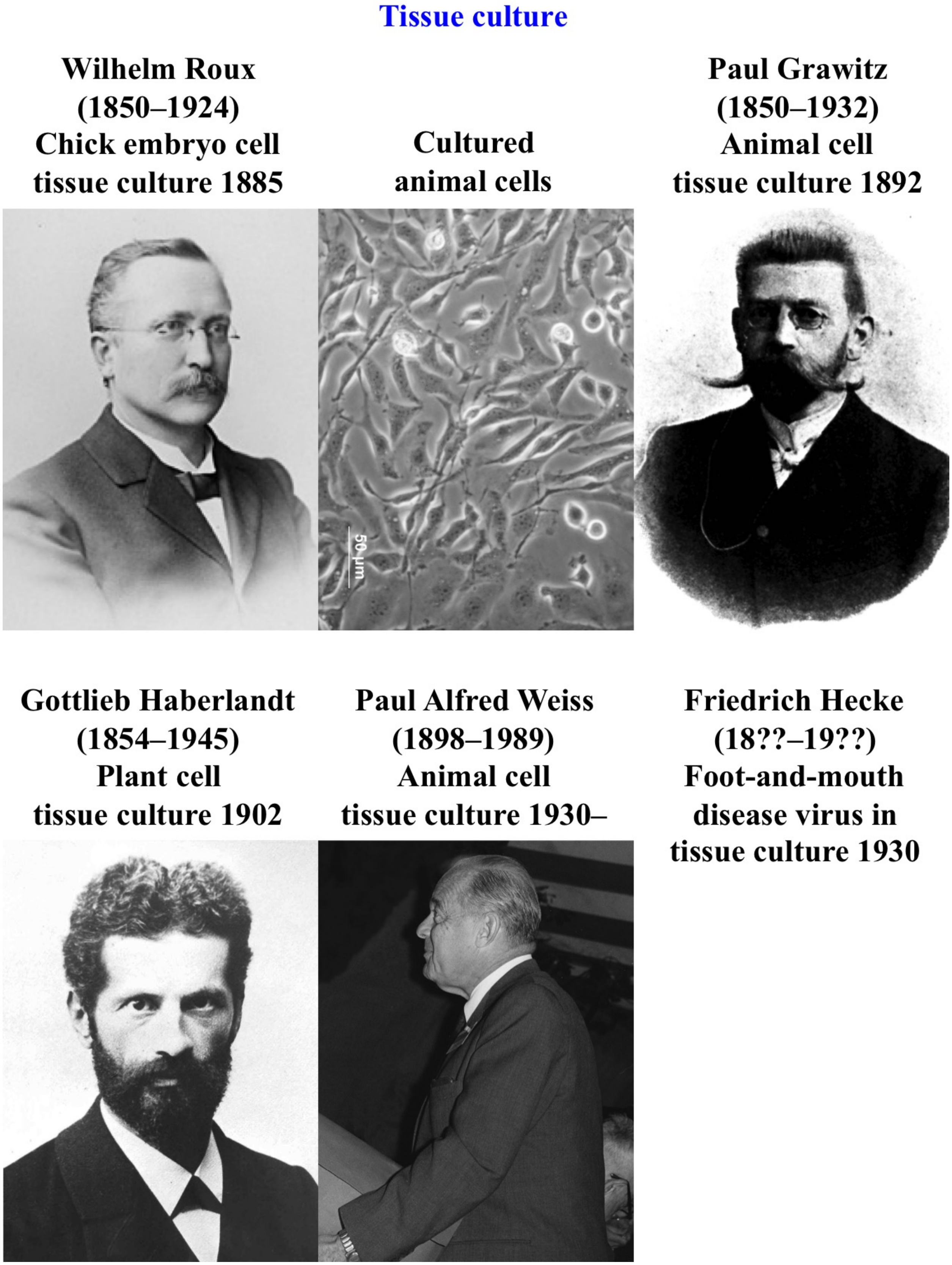

Max Schultze
(1825–1874)
Karl Wilhelm von Kupffer
(1829–1902)
Paul Mayer
(1848–1923)
Wilhelm Pfeffer
(1845–1920)
Osmotic pressure
Pfeffer cell
for measuring
osmotic pressure
g
t
v
r
m
z
a

Figure 2.5: Other creators who made major contributions to cell biology included Max Schultze, Karl Wilhelm von Kupffer, Paul Mayer, and Wilhelm Pfeffer.



Tissue culture

Wilhelm Roux
(1850–1924)
Chick embryo cell
tissue culture 1885

Cultured
animal cells

Paul Grawitz
(1850–1932)
Animal cell
tissue culture 1892

Gottlieb Haberlandt
(1854–1945)
Plant cell
tissue culture 1902

Paul Alfred Weiss
(1898–1989)
Animal cell
tissue culture 1930–

Friedrich Hecke
(18??–19??)
Foot-and-mouth
disease virus in
tissue culture 1930

Figure 2.6: Wilhelm Roux, Paul Grawitz, Paul Alfred Weiss, and Friedrich Hecke helped to develop tissue culture methods for growing animal cells in the laboratory, while Gottlieb Haberlandt developed plant cell tissue culture.

2.1.2 DNA and Genetics

As shown in Fig. 2.7, DNA (deoxyribonucleic acid) is divided into several chromosomes in the nucleus of a cell. DNA forms a double-stranded helix, in which each strand is composed of a sequence of four possible bases or nucleotides: adenine (A), cytosine (C), guanine (G), and thymine (T). Each A on one strand is electrostatically attracted to a T on the other strand, and each C is attracted to a G. The bases of a strand are connected via a chain of alternating sugar and phosphate groups. RNA (ribonucleic acid) is very similar but uses a uracil (U) base instead of T.

German-speaking scientists founded and dominated the field of DNA and genetics research until World War II (with the exception of a few early foreign scientific competitors, chiefly the American Thomas Hunt Morgan and his students).[4] See Figs. 2.8–2.24. The dissemination of their discoveries (and in many cases, the diaspora of the scientists themselves) before, during, and after the war seeded research in this field around the world.

Franz Andreas Bauer (Austrian, 1758–1840) studied plants under the microscope and painted what he saw. He was the first or one of the first scientists to observe and depict the nuclei of cells (before the Scottish scientist Robert Brown, who is usually given credit in English-language science history books).

Franz Unger (Austrian, 1800–1870) worked in the fields of paleontology, plant physiology, and microscopy. He proposed that elements inside plant cells carry hereditary traits, and those ideas later influenced Gregor Mendel. He also suggested that the descendants of species could gradually evolve into other species over generations—before Charles Darwin, who garnered much more attention.

Hugo von Mohl (German, 1805–1872) studied plant cells under the microscope too. He was responsible for naming the contents of the cell the "protoplasm." He was also the first or one of the first scientists to observe mitosis, or the division of one cell and its nucleus into two cells, each with its own nucleus.

Robert Remak (Prussian, 1815–1865) observed and confirmed the process of mitosis for cell division, and in addition was one of the founders of the field of developmental biology and embryology.

Carl Wilhelm von Nägeli (Swiss, 1817–1891) studied the division of nuclei in cellular mitosis, as well as the fusion of nuclei in plant pollination.

Harald Bagge (German, 1817–1895) noted that in mitosis, the division of the nucleus occurs before the division of the cell.

Franz Leydig (German, 1821–1908) also studied the process of mitosis for various cell types.

As is now well known, Gregor Mendel (Austrian, 1822–1884) discovered the rules of genetics using plants he grew at his monastery, and meticulously documented his discoveries and explanations in a lengthy book. See Fig. 2.8. It is less well known that Mendel also conducted research in several other fields, including astronomy and meteorology. Oxford University's *Biographical Dictionary of*

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[4] Bateson 1909; Bielka 2002; Brandt 2004; Corcos and Monaghan 1993; Deichmann 1996; Dostál 2016; Edelson 1999; Ernst Fischer 1988; Gamow 1953, 1967, 1970; Gausemeier 2015; Harwood 1987, 1993; Henig 2000; Jahn 2004; Junker 2004; Knippers 2017; Kohler 1994; Lagerkvist 1998; Magner 2002; Mawer 2006; Mayr 1984; Morange 2020; Müller-Wille and Brandt 2016; Müller-Wille and Rheinberger 2012; Olby 1994; Pasternak 2004; von Schwerin 2004; Segrè 2011; Sloan and Fogel 2011; Stubbe 1965; Timoféeff-Ressovsky 1935; Weinberg 1908; Gareth Williams 2019.

Scientists summarized Mendel's research on genetics [Porter 1994, p. 475]:

> Mendel began the experiments that led to his discovery of the basic laws of heredity in 1856. Much of his work was performed on the edible pea (*Pisum* sp.), which he grew in the monastery garden. He carefully self-pollinated and wrapped (to prevent accidental pollination by insects) each individual plant, collected the seeds produced by the plants, and studied the offspring of these seeds. [...] Mendel also studied other characteristics in pea plants, such as flower colour, seed shape and flower position, finding that, as with height, simple laws governed the inheritance of these traits. From his findings Mendel concluded that each parent plant contributes a factor that determines a particular trait and that the pairs of factors in the offspring do not give rise to an amalgamation of traits. These conclusions, in turn, led him to formulate his famous law of segregation and law of independent assortment of characters, which are now recognized as two of the fundamental laws of heredity.
>
> Mendel reported his findings to the Brünn Society for the Study of Natural Science in 1865 and in the following year he published *Experiments with Plant Hybrids*, a paper that summarized his results.

Wilhelm Hofmeister (German, 1824–1877) was the first or one of the first scientists to identify and study individual chromosomes within the nuclei of plant cells.

August Weismann (German, 1834–1914) proposed methods by which cellular material could be inherited from one generation to the next and could lead to the evolution of species. He studied cell division and was the first to distinguish between mitosis (cell division that leads to two identical cells with the same numbers of chromosomes as the original cell) and meiosis (cell division that creates sperm and egg cells with half the numbers of chromosomes as the original cell).

Wilhelm von Waldeyer-Hartz (German, 1836–1921) studied and gave the name "chromosomes" to the individual components of the nucleus.

Johannes Friedrich Miescher (Swiss, 1844–1895) purified DNA (which he called nuclein) from cellular nuclei and suggested that the DNA could be involved in heredity. See Fig. 2.9. Historian of science Lois Magner explained Miescher's research [Magner 2002, pp. 422–423]:

> After receiving his M.D. degree (1868), Miescher began his remarkable studies of the physiological chemistry of pus cells [white blood cells], which were obtained by washing out used bandages from the surgical clinic. Given the high rate of postsurgical infection found in European hospitals at the time, a plethora of pus cells was always available. Attempting to purify pus cell nuclei, Miescher subjected his preparations to an acid extract of pig gastric mucosa (a crude preparation of the protein-digesting enzyme called pepsin). After this treatment, Miescher obtained an organic acid that had a remarkably high phosphorus content. The solubility properties of this substance, and its resistance to pepsin, suggested that it was a previously unknown cell constituent. Although this novel material was not well characterized, it was given the name *nuclein*. Later Miescher demonstrated that nuclein could also be isolated from salmon sperm. [...]
>
> [H]e did suggest that if some substance in the sperm were the specific cause of fertilization, it would have to be nuclein. [...] Privately, Miescher speculated on the possible role of nuclein in the transmission of heritable traits.

Walther Flemming (German, 1843–1905) was the one who dubbed the usual process of cell division "mitosis." Beginning in 1873, he conducted extensive studies of the structure and behavior of chromosomes in various cell types and in cell division, as shown in Fig. 2.10.

Eduard Strasburger (Polish/German, 1844–1912) studied the chromosome distribution in mitotic and meiotic cell division, and coined the words "nucleoplasm" and "cytoplasm" for the contents of the nucleus and the rest of the cell.

Hugo de Vries (Dutch, 1848–1935) rediscovered the rules of genetics after Mendel, and attributed the inherited traits to microscopic particles he called "pangenes," which was later shorted to "genes." He dubbed changes in genes "mutations," and explained the importance of mutations for evolution. He was also the first scientist to propose that homologous recombination or crossing over occurs between two chromosomes of the same type during meiosis.

Oskar Hertwig (German, 1849–1922) studied and reported details of the processes of mitosis and meiosis, and stated that DNA (nuclein) was the material that carried hereditary traits. He was the father of Paula Hertwig, who also conducted DNA research.

Wilhelm Roux (1850–1924) studied the role of chromosomes in fertilization and cell division. He was also one of the founders of the field of developmental biology.

Richard Altmann (German, 1852–1900) built on Miescher's work to purify DNA (nuclei), confirming that the substance was acidic and naming it "nucleic acid" in 1889.

Carl Rabl (Austrian, 1853–1917) tracked individual chromosomes through the stages of replication and cell division.

Albrecht Kossel (German, 1853–1927), shown in Fig. 2.11, determined the chemical composition of nucleic acids purified from cells. He showed that nucleic acids contain five different bases: adenine, cytosine, guanine, thymine, and uracil (including both DNA and RNA). Kossel found that those bases were connected via linkages of sugars and phosphates. He also isolated and studied proteins that bind to nucleic acids in the nucleus, which were determined to be histones and other accessory proteins [Mary Ellen Jones 1953]. For these discoveries, he won the Nobel Prize in Physiology or Medicine in 1910. Professor the Count K. A. H. Mörner, Rector of the Royal Caroline Institute, explained the revolutionary importance of Kossel's research on both nucleic acids and proteins [https://www.nobelprize.org/prizes/medicine/1910/ceremony-speech/]:

> The cells of the organism exhibit on the one hand certain special characteristics according to the organs to which they belong and on the other hand general, shared characteristics as well. It has long been known, and is easy to demonstrate, that the main mass of their organic substance consists of materials belonging to the group of protein bodies. They are however dissimilar in different cases. The development of protein chemistry in general, and of the specialized knowledge of the protein bodies occurring in cells and of the combined forms in which they appear, is therefore an important link in the chain of knowledge of cell chemistry and consequently also a factor of great importance in research on cellular life and functions.
>
> [...] Professor Kossel has since then enlarged the knowledge by the discovery of new, related substances, and in particular he has, by means of extensive work using new methods which he himself elaborated, carried the knowledge of the quantitative rela-

> tionships of these substances in the protein molecule further than is the case for the other protein breakdown products.
>
> There are several kinds of proteins. One group which is included here are the so-called protamines obtained from the milt of fish. Kossel has made a detailed study of these. For these a relatively simple structure has been discovered inasmuch as the number of dissimilar atom groups in them is not very great. They therefore present simpler relationships than proteins in general, and consist mainly of substances belonging to the group which I have just called basic breakdown products of protein. For certain protamines Kossel, thanks to his methods of determination, has in fact been able to establish the quantitative relationships of the building blocks making up these protamines, a goal which we seem to be far from attaining where the other proteins are concerned. [...]
>
> One protein group, first observed by Kossel, consists of the so-called histones. They stand between the protamines and what is termed ordinary protein. This group, again, is important because of its occurrence as a component of certain cells, and has also been studied in detail by Kossel.
>
> Professor Kossel has made an extensive and important study of the problem of the protein compounds in cells. As we have already mentioned, the proteins are very complex bodies. Within the cells the relationships are further complicated by the fact that the proteins there are combined in varying degrees with other substances such as those grouped under the name of "nucleic acids". These, too, are far from simple in structure. They form phosphorus-containing organic substances which, together with a form of phosphoric acid, usually contain purine bodies, pyrimidine bodies and a form of sugar or related substance. Professor Kossel has devoted a great part of his activity to these problems. It is not practicable to give an account of the details without taking up too much time, and they must therefore be passed over on this occasion. I will restrict myself to remarking that these nucleic acids by their presence in the cells and their relation to the protein bodies found there, certainly possess a great biological significance; and furthermore I should like to emphasize that it is to Kossel and his pupils especially that we owe our present advanced knowledge of these problems.

Wilhelm Weinberg (German, 1862–1937) rediscovered and extended Mendel's work on rules of genetic inheritance. No later than 1907, he discovered the principle of genetic equilibrium of alleles (different versions of a gene) within a population that was later rediscovered by the British mathematician G. H. Hardy. See Fig. 2.12. English-language science books have tended to credit Hardy and not Weinberg's earlier work, or at most to call it the Hardy-Weinberg principle.

Theodor Boveri (German, 1862–1915) had an enormously productive and underrated scientific career. He discovered and named the centrosome that guides chromosomes apart when a nucleus divides. He also demonstrated that proper embryonic development requires the presence of the normal number of chromosomes for a given species. He made many important discoveries regarding the role of mutations to the chromosomes in causing cancer.

Karl Correns (German, 1864–1933) was another scientist who rediscovered and extended Mendel's work on rules of genetic inheritance. In addition, he found that plant cells inherit their properties not only from genes in the nucleus, but also from genes in chloroplasts and mitochondria.

Phoebus Levene (Baltic Jewish, 1869–1940) worked with Albrecht Kossel and Hermann Emil Fischer. He continued and extended Kossel's research on the chemical composition and structure of DNA and RNA.

Erich Tschermak von Seysenegg (Austrian, 1871–1962) also rediscovered and extended Mendel's work on rules of genetic inheritance.

Hans Winkler (German, 1877–1945) described the total inheritance of a cell by combining the words gene and chromosome to create a new word, "genome," in 1920. He also introduced the new word "heteroploid" to describe an abnormal number of chromosomes.

Richard Goldschmidt (German, 1878–1958) made many contributions in the fields of genetics, evolution, and developmental biology.

Charlotte Auerbach (German, 1899–1994) pioneered the study of the chemical mutagenesis of DNA. Among other discoveries, she found that mustard gas could cause mutations and therefore could be carcinogenic in addition to its dangerous corrosive effects on organisms.

Curt Stern (German, 1902–1981) demonstrated homologous recombination or crossing over between chromosomes in fruit flies and spent much of his career focusing on human genetics and its implications for medicine.

In the early 1930s, Alfred Kühn (German, 1885–1968) and Adolf Butenandt (German, 1903–1995) led a closely knit research community that induced and analyzed mutations in insects and other species, and used that data to demonstrate that individual genes produce individual proteins (sometimes called the "one gene, one enzyme hypothesis") [Egelhaaf 1996; Grossbach 1996, 2009]. Some other key members of the same research community included:

- Hans Bauer (German, 1904–1988)
- Erich Becker (German, 19??–1942)
- Ernst Caspari (German, 1909–1988)
- Helmut Döring (German, 19??–1942)
- Georg Gottschewski (German, 1906–1975)
- Karl Henke (German, 1895–1956)
- Paula Hertwig (German, 1889–1983, daughter of Oscar Hertwig)
- Lothar Löffler (German, 1901–1983) chemical and radiation-induced mutations in invertebrates and vertebrates
- Karl Pirschle (German, 1900–1945)
- Ernst Plagge (German, 1911–1945)
- Hans Stubbe (German, 1902–1989)

See Figs. 2.13–2.14. Unfortunately, several members of that genetics research community had to flee to other countries in the 1930s to escape antisemitism and political repression. Other members were drafted into the military after the war started, and several died in the war. Thus this particular research community had largely ceased to function by around 1940.

By using the publications by Alfred Kühn and the others as a roadmap, the U.S. scientists George Beadle and Edward Tatum later demonstrated the same "one gene, one enzyme" principle; for that work they won the 1958 Nobel Prize in Physiology or Medicine and are prominently discussed in most modern genetics textbooks. All of the earlier research by Alfred Kühn and other German-speaking scientists was essentially ignored, and they have been largely forgotten.

In a revolutionary 1935 paper (Fig. 2.15), Max Delbrück (German, 1906–1981), Nikolai Timoféeff-Ressovsky (Russian but worked in Germany 1925–1945, lived 1900–1981), and Karl Günter Zimmer (German, 1911–1988) at the Kaiser Wilhelm Society in Berlin described and demonstrated the structure of chromosomal DNA, methods and consequences of inducing point mutations in DNA, and forced genetic recombination of different pieces of DNA [Ernst Fischer 1988; Segrè 2011; Sloan and Fogel 2011; Timoféeff-Ressovsky, Zimmer, and Delbrück 1935]. The methods and objectives that Timoféeff-Ressovsky, Zimmer, and Delbrück stated at the beginning of their paper essentially defined the new field of molecular biology [Sloan and Fogel 2011, p. 222]:

> In the following paper, we attempt to construct a general picture of the nature of the gene and of mutation, on the basis of experimental investigations of the mutation processes in *Drosophila* and a physical analysis of the results of those experiments. Compared to previous hypotheses about the nature of the gene and of gene mutation, we believe we have taken a step forward, in that our ideas are constructed only from the experimental results of mutation research, and therefore from an area of research that concerns events directly involving the genes themselves. [...]
>
> Thus, we hope to arrive at a theory of the mutation process and gene structure that will be experimentally well-founded and that will have experimentally verifiable implications. Of course, we are far from regarding our ideas as conclusive; rather, we see their value lying in the extending of earlier approaches through the use of the concepts of physics.
>
> This paper represents a collaboration between genetics and physics.

Erwin Chargaff (Austrian, 1905–2002) made many experimental measurements of the chemical composition of DNA and discovered guanine-cytosine (G-C) and adenine-thymine (A-T) base-pairing, which was critical for working out the correct structure of double-stranded DNA.

As shown in Fig. 2.16, in 1940 (under wartime conditions and 13 years before the discovery by Rosalind Franklin, Francis Crick, and James Watson), Hans Friedrich-Freksa (German, 1906–1973) proposed a double-stranded self-complementary model of DNA structure and replication [Friedrich-Freksa 1940]. Apparently the war prevented him from taking that work even further.

By 1942, despite even more severe wartime hindrances, Gerhard Schramm (German, 1910–1969) identified the genome of the tobacco mosaic virus as RNA, showed that its protein subunits are identical, and mutated the RNA to create mutant proteins.[5] See Fig. 2.17.

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[5] Schramm 1941; Schramm 1943; Schramm and Dannenberg 1944; Schramm and Müller 1940; Schramm and Müller 1942; Schramm and Rebensburg 1942.

George Gamow (Russian but educated and worked in Germany, lived 1904–1968) made several insightful proposals and worked with other scientists to determine the genetic code, the rules for what sequences of DNA or RNA nucleotides tell cells to produce what sequences of amino acids in proteins [Segrè 2011].

J. Heinrich Matthaei (German, 1929–) also played a major role in deciphering the genetic code. In 1961, he demonstrated that a synthetic poly-uridine RNA made cells produce a poly-phenylalanine protein, so the RNA sequence UUU codes for a phenylalanine amino acid. After that initial breakthrough, Matthaei continued to decipher parts of the genetic code.

Heinz-Günter Wittmann (German, 1927–1990) made a number of important discoveries regarding the genetic code, ribosomes, the proteome of *E. coli*, and other aspects of genetics and genomics.

Werner Arber (Swiss, 1929–) harnessed natural DNA restriction enzymes to cut and splice DNA, for which he won the Nobel Prize in Physiology or Medicine in 1978. Professor Peter Reichard of the Karolinska Medico-Chirurgical Institute explained the importance of Arber's innovations [https://www.nobelprize.org/prizes/medicine/1978/ceremony-speech/]:

> We can compare the DNA of a single human cell with a book containing all the information for the development and function of the cell. [...]
>
> Restriction enzymes are the tools which make it possible to open the sealed book. Werner Arber discovered these enzymes in the early 1960s when he analyzed an apparently obscure phenomenon in bacteria, discovered 10 years earlier by Bertani and Weigle, called host-controlled modification. In a series of simple but elegant experiments Arber showed that this phenomenon was caused by a change in DNA and apparently served to protect the host from foreign genes. Foreign DNA is degraded, and Arber postulated that bacteria contain restriction enzymes with the capacity to recognize and bind to recurring structural elements of DNA. At these locations the DNA-helix is severed: the pages of the book are separated. [...]
>
> The application of restriction enzymes has revolutionized the genetics of higher organisms and completely changed our ideas of the organisation of their genes. In contrast to the DNA of bacteria, the DNA of higher organisms is not a contiguous structure coding for one protein. Instead, genes contain "quiet" regions alternating with regions containing the genetic code. Restriction enzymes have also been used for genetic engineering. With their aid we can selectively remove parts of the genetic material and transplant genes into a foreign background. In this way genes from higher organisms have been transferred to bacteria, and in certain cases such bacteria can be used to produce human hormones. In the near future we can expect many products of medical importance to be synthesized.

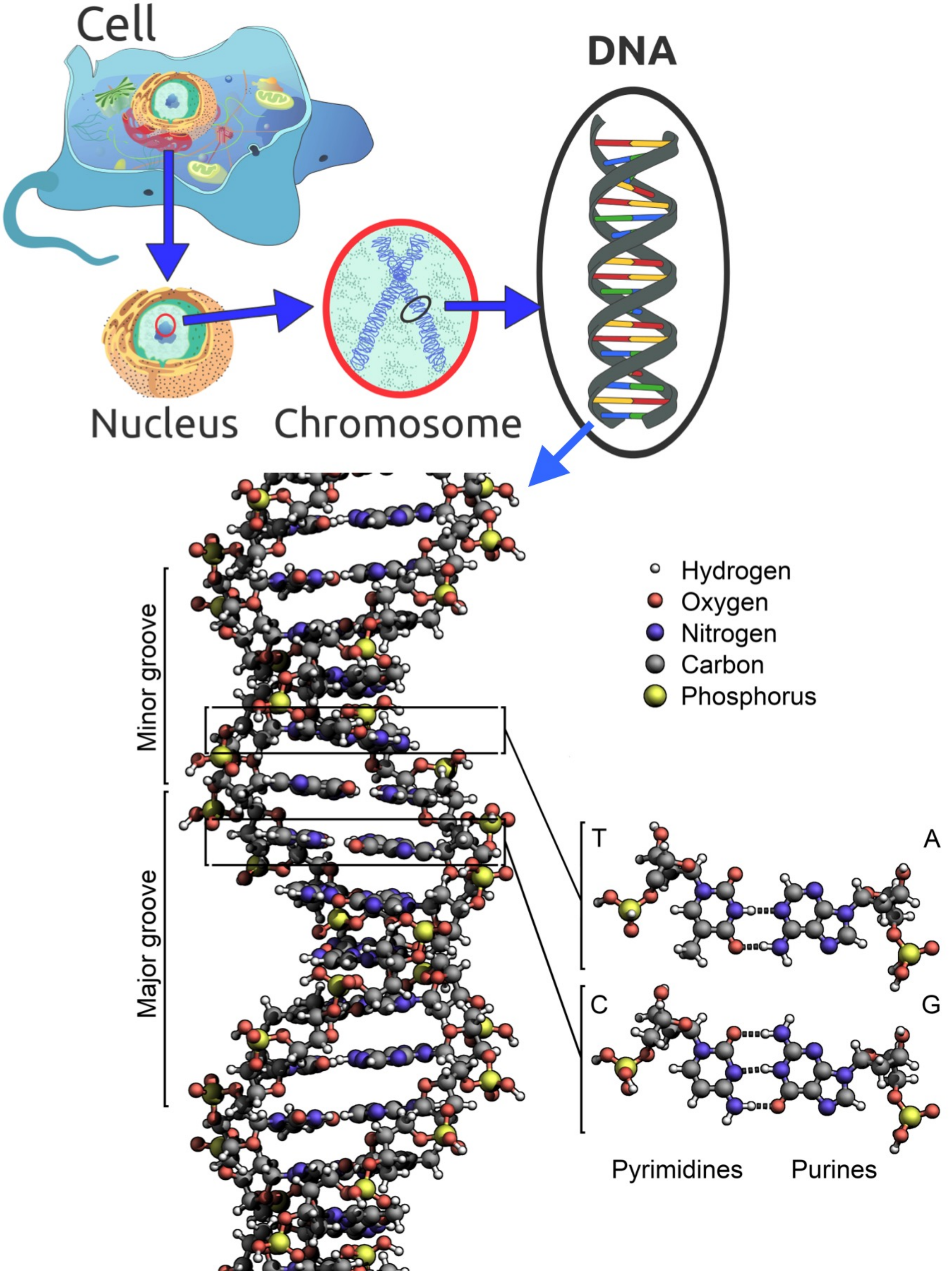

Cell
DNA
Nucleus
Chromosome
Hydrogen
Oxygen
Nitrogen
Carbon
Phosphorus
Minor groove
Major groove
T
A
C
G
Pyrimidines
Purines

Figure 2.7: DNA is divided into several chromosomes in the nucleus of a cell. DNA forms a double-stranded helix, in which each strand is composed of a sequence of four possible bases or nucleotides (A, C, G, and T). Each A on one strand is electrostatically attracted to a T on the other strand, and each C is attracted to a G. RNA is very similar but uses a U base instead of T.

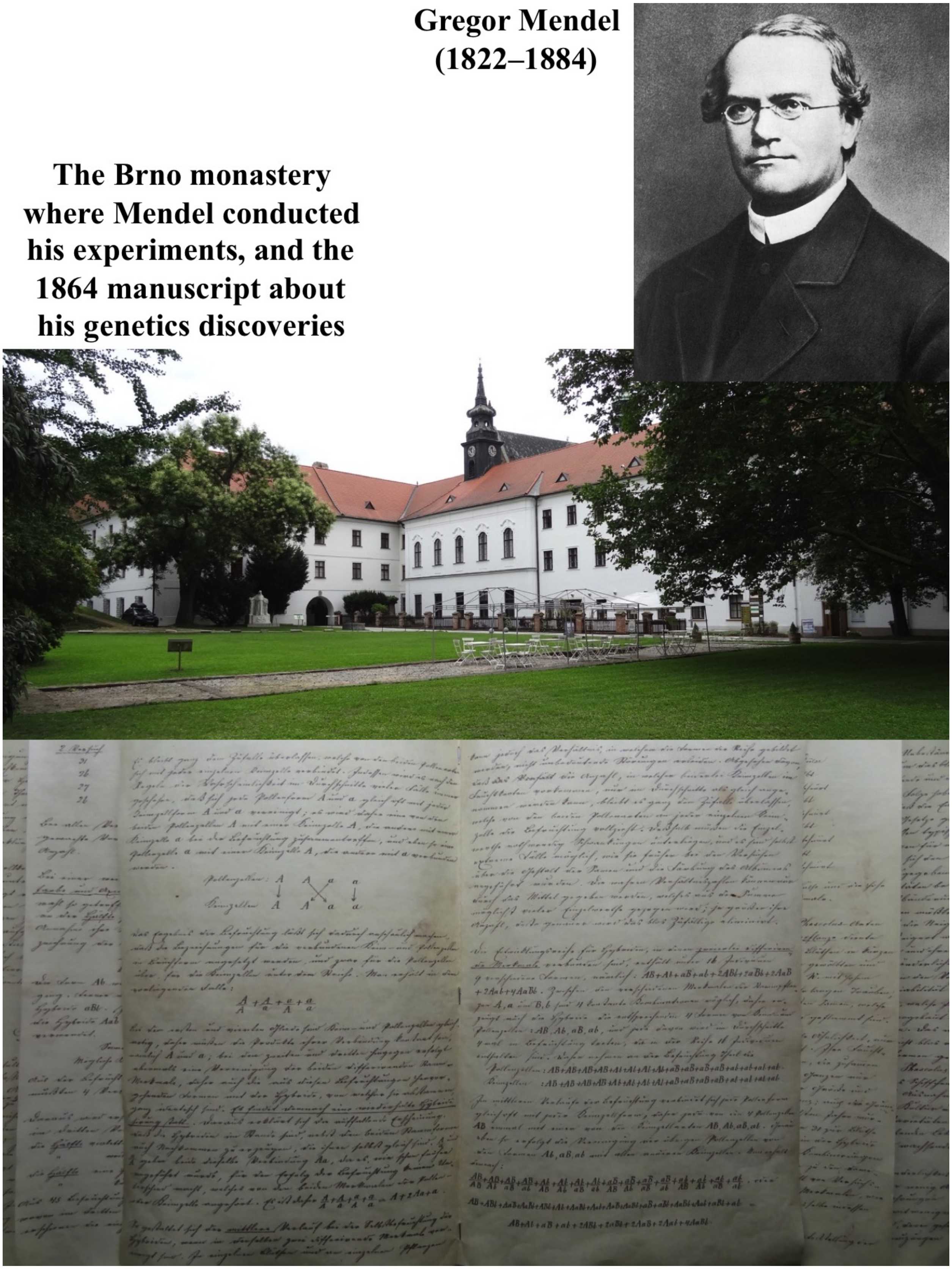
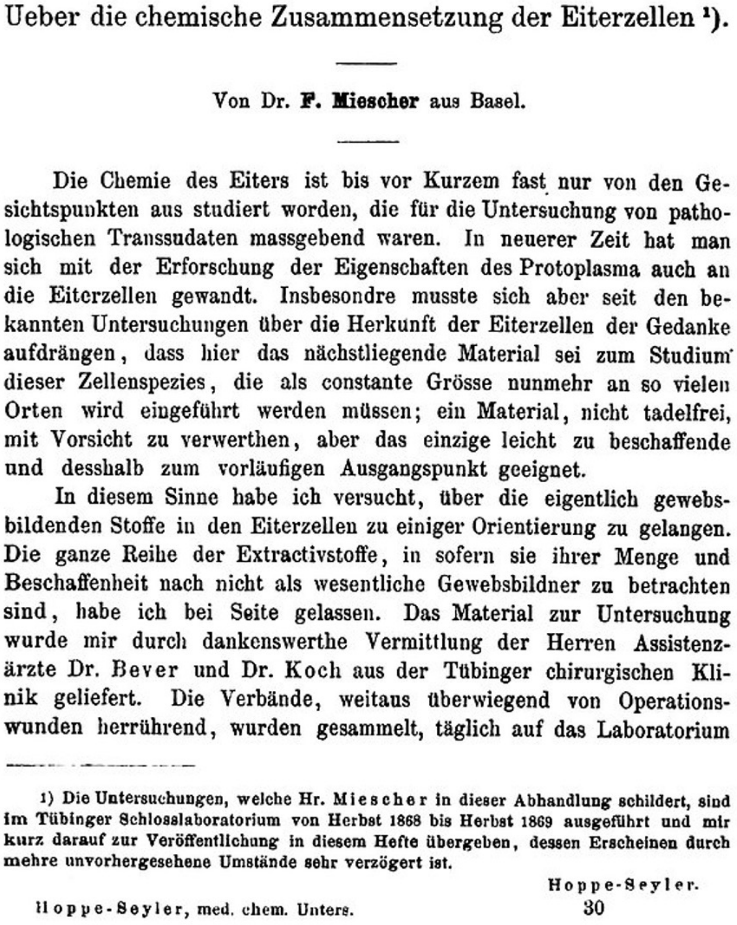

Gregor Mendel
(1822–1884)
The Brno monastery where Mendel conducted his experiments, and the 1864 manuscript about his genetics discoveries

Figure 2.8: Gregor Mendel discovered the rules of genetics using plants he grew at his monastery.

***Medicinisch-chemische Untersuchungen* 4:441–460 (1871)**



Ueber die chemische Zusammensetzung der Eiterzellen 1).

Von Dr. **F. Miescher** aus Basel.

Die Chemie des Eiters ist bis vor Kurzem fast nur von den Gesichtspunkten aus studiert worden, die für die Untersuchung von pathologischen Transsudaten massgebend waren. In neuerer Zeit hat man sich mit der Erforschung der Eigenschaften des Protoplasma auch an die Eiterzellen gewandt. Insbesondre musste sich aber seit den bekannten Untersuchungen über die Herkunft der Eiterzellen der Gedanke aufdrängen, dass hier das nächstliegende Material sei zum Studium dieser Zellenspezies, die als constante Grösse nunmehr an so vielen Orten wird eingeführt werden müssen; ein Material, nicht tadelfrei, mit Vorsicht zu verwerthen, aber das einzige leicht zu beschaffende und desshalb zum vorläufigen Ausgangspunkt geeignet.

In diesem Sinne habe ich versucht, über die eigentlich gewebsbildenden Stoffe in den Eiterzellen zu einiger Orientierung zu gelangen. Die ganze Reihe der Extractivstoffe, in sofern sie ihrer Menge und Beschaffenheit nach nicht als wesentliche Gewebsbildner zu betrachten sind, habe ich bei Seite gelassen. Das Material zur Untersuchung wurde mir durch dankenswerthe Vermittlung der Herren Assistenzärzte Dr. Bever und Dr. Koch aus der Tübinger chirurgischen Klinik geliefert. Die Verbände, weitaus überwiegend von Operationswunden herrührend, wurden gesammelt, täglich auf das Laboratorium

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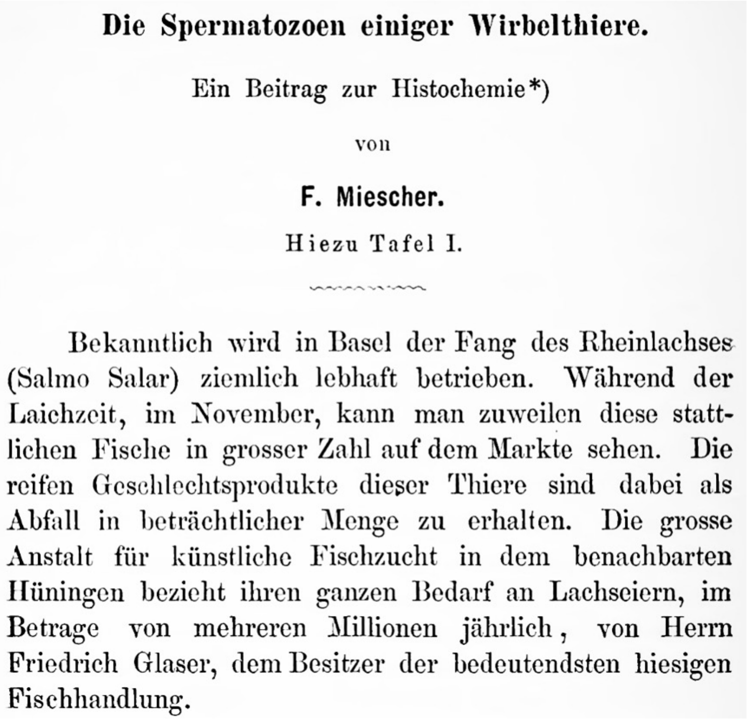
1) Die Untersuchungen, welche Hr. Miescher in dieser Abhandlung schildert, sind im Tübinger Schlosslaboratorium von Herbst 1868 bis Herbst 1869 ausgeführt und mir kurz darauf zur Veröffentlichung in diesem Hefte übergeben, dessen Erscheinen durch mehre unvorhergesehene Umstände sehr verzögert ist.

Hoppe-Seyler.

Hoppe-Seyler, med. chem. Unters. 30

Johannes Friedrich Miescher (1844–1895) extracted and purified DNA from human white blood cells and proposed that DNA is involved in heredity (1868–1869).



Die Spermatozoen einiger Wirbelthiere.

Ein Beitrag zur Histochemie*)

von

F. Miescher.

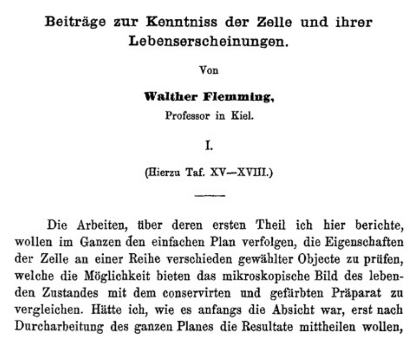
Hiezu Tafel I.

Bekanntlich wird in Basel der Fang des Rheinlachses (Salmo Salar) ziemlich lebhaft betrieben. Während der Laichzeit, im November, kann man zuweilen diese stattlichen Fische in grosser Zahl auf dem Markte sehen. Die reifen Geschlechtsprodukte dieser Thiere sind dabei als Abfall in beträchtlicher Menge zu erhalten. Die grosse Anstalt für künstliche Fischzucht in dem benachbarten Hüningen bezieht ihren ganzen Bedarf an Lachseiern, im Betrage von mehreren Millionen jährlich, von Herrn Friedrich Glaser, dem Besitzer der bedeutendsten hiesigen Fischhandlung.

***Bericht über die Verhandlungen der Naturforschenden Gesellschaft in Basel* 6:138–208 (1874)**

Figure 2.9: Johannes Friedrich Miescher purified and studied DNA from cell nuclei in 1869.

Walther Flemming (1843–1905) made detailed observations of chromosomes during mitosis (1873 onward, published 1878 onward)



Beiträge zur Kenntniss der Zelle und ihrer Lebenserscheinungen.

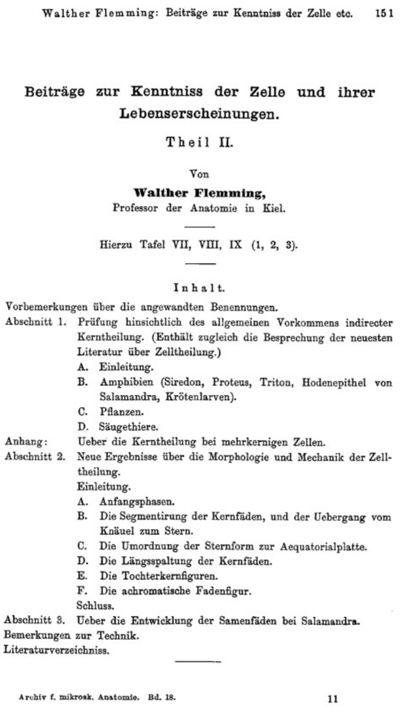
Von

Walther Flemming,
Professor in Kiel.

I.

(Hierzu Taf. XV—XVIII.)

Die Arbeiten, über deren ersten Theil ich hier berichte, wollen im Ganzen den einfachen Plan verfolgen, die Eigenschaften der Zelle an einer Reihe verschieden gewählter Objecte zu prüfen, welche die Möglichkeit bieten das mikroskopische Bild des lebenden Zustandes mit dem conservirten und gefärbten Präparat zu vergleichen. Hätte ich, wie es anfangs die Absicht war, erst nach Durcharbeitung des ganzen Planes die Resultate mittheilen wollen,



Walther Flemming: Beiträge zur Kenntniss der Zelle etc. 151

Beiträge zur Kenntniss der Zelle und ihrer Lebenserscheinungen.

Theil II.

Von

Walther Flemming,
Professor der Anatomie in Kiel.

Hierzu Tafel VII, VIII, IX (1, 2, 3).

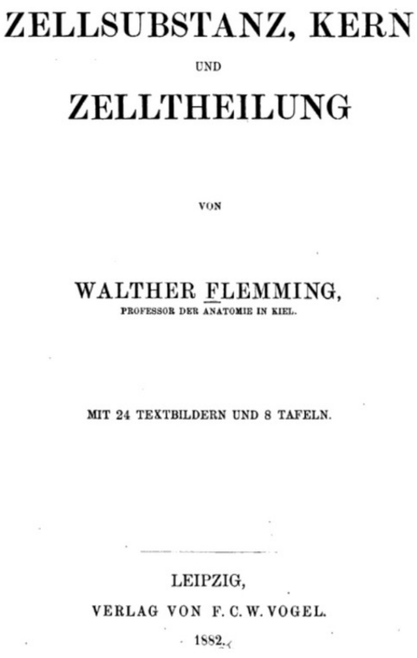
Inhalt.

Vorbemerkungen über die angewandten Benennungen.
Abschnitt 1. Prüfung hinsichtlich des allgemeinen Vorkommens indirecter Kerntheilung. (Enthält zugleich die Besprechung der neuesten Literatur über Zelltheilung.)
- A. Einleitung.
- B. Amphibien (Siredon, Proteus, Triton, Hodenepithel von Salamandra, Krötenlarven).
- C. Pflanzen.
- D. Säugethiere.

Anhang: Ueber die Kerntheilung bei mehrkernigen Zellen.
Abschnitt 2. Neue Ergebnisse über die Morphologie und Mechanik der Zelltheilung.
Einleitung.
- A. Anfangsphasen.
- B. Die Segmentirung der Kernfäden, und der Uebergang vom Knäuel zum Stern.
- C. Die Umordnung der Sternform zur Aequatorialplatte.
- D. Die Längsspaltung der Kernfäden.
- E. Die Tochterkernfiguren.
- F. Die achromatische Fadenfigur.

Schluss.
Abschnitt 3. Ueber die Entwicklung der Samenfäden bei Salamandra.
Bemerkungen zur Technik.
Literaturverzeichniss.

Archiv f. mikrosk. Anatomie. Bd. 18. 11



ZELLSUBSTANZ, KERN
UND
ZELLTHEILUNG

VON

WALTHER FLEMMING,
PROFESSOR DER ANATOMIE IN KIEL.

MIT 24 TEXTBILDERN UND 8 TAFELN.

LEIPZIG,
VERLAG VON F. C. W. VOGEL.
1882.

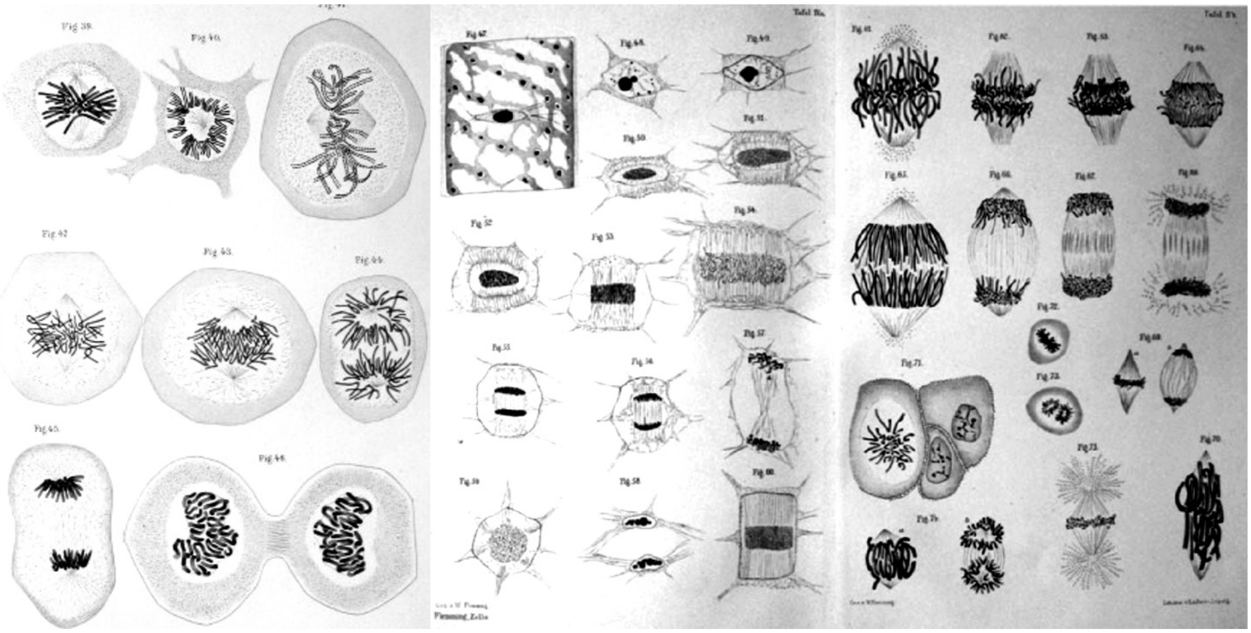
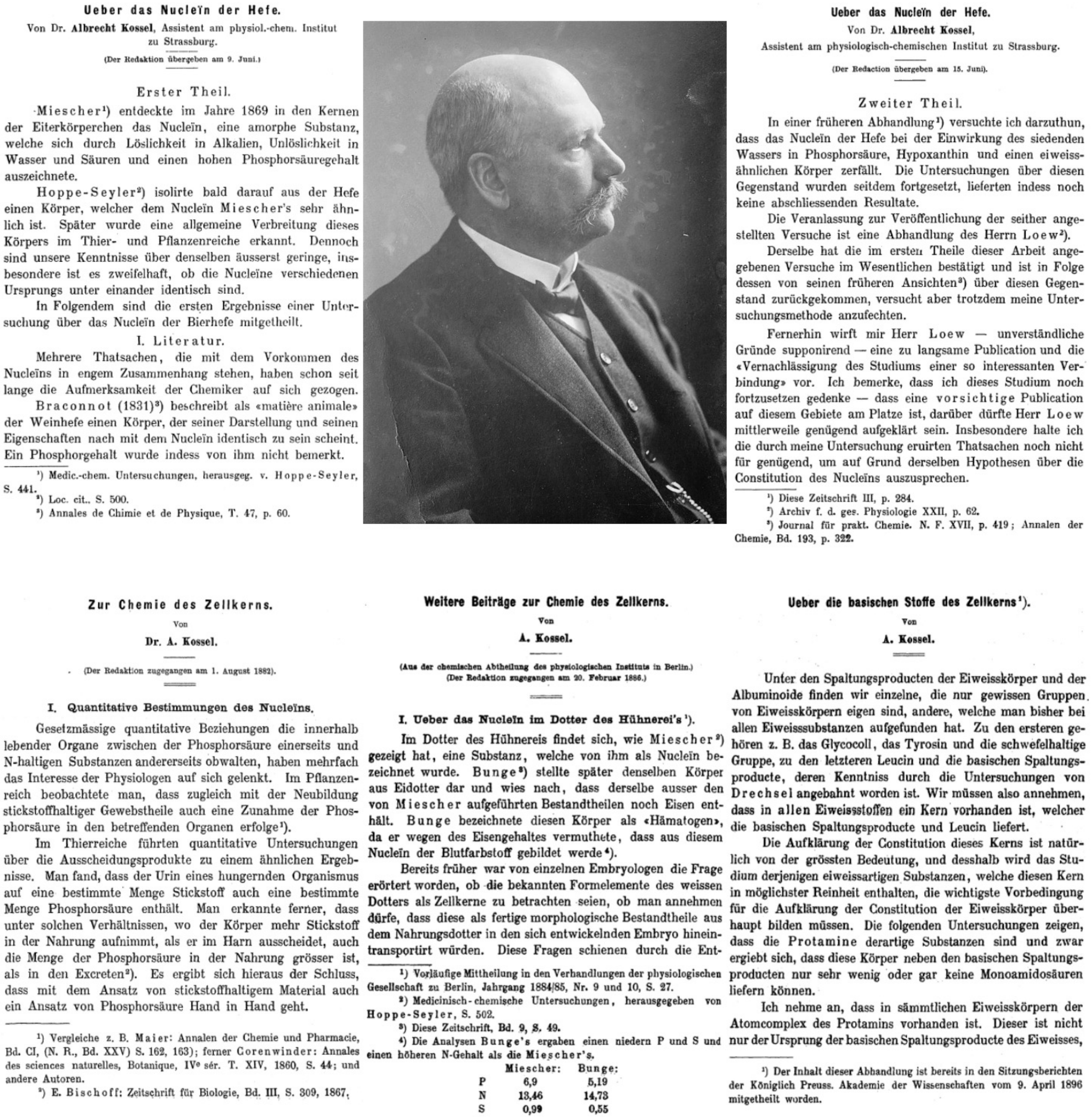


Fig 39.
Fig 40.
Fig 42.
Fig 43.
Fig 44.
Fig 45.
Fig 46.
Flemming, Zelle

Figure 2.10: Walther Flemming made detailed observations of chromosomes during mitotic cell division from 1873 onward.

Beginning in the 1870s, Albrecht Kossel (1853–1927) showed that DNA and RNA contain five different bases (adenine, cytosine, guanine, thymine, and uracil), demonstrated that those bases are connected via linkages of sugars and phosphates, and isolated and studied proteins that bind to nucleic acids in the nucleus (histones and other accessory proteins). He won the 1910 Nobel Prize in Physiology or Medicine.



Ueber das Nucleïn der Hefe.

Von Dr. **Albrecht Kossel**, Assistent am physiol.-chem. Institut zu Strassburg.

(Der Redaktion übergeben am 9. Juni.)

Erster Theil.

Miescher[1] entdeckte im Jahre 1869 in den Kernen der Eiterkörperchen das Nucleïn, eine amorphe Substanz, welche sich durch Löslichkeit in Alkalien, Unlöslichkeit in Wasser und Säuren und einen hohen Phosphorsäuregehalt auszeichnete.

Hoppe-Seyler[2] isolirte bald darauf aus der Hefe einen Körper, welcher dem Nucleïn Miescher's sehr ähnlich ist. Später wurde eine allgemeine Verbreitung dieses Körpers im Thier- und Pflanzenreiche erkannt. Dennoch sind unsere Kenntnisse über denselben äusserst geringe, insbesondere ist es zweifelhaft, ob die Nucleïne verschiedenen Ursprungs unter einander identisch sind.

In Folgendem sind die ersten Ergebnisse einer Untersuchung über das Nucleïn der Bierhefe mitgetheilt.

I. Literatur.

Mehrere Thatsachen, die mit dem Vorkommen des Nucleïns in engem Zusammenhang stehen, haben schon seit lange die Aufmerksamkeit der Chemiker auf sich gezogen.

Braconnot (1831)[3] beschreibt als «matière animale» der Weinhefe einen Körper, der seiner Darstellung und seinen Eigenschaften nach mit dem Nucleïn identisch zu sein scheint. Ein Phosphorgehalt wurde indess von ihm nicht bemerkt.

---

[1] Medic.-chem. Untersuchungen, herausgeg. v. Hoppe-Seyler, S. 441.

[2] Loc. cit., S. 500.

[3] Annales de Chimie et de Physique, T. 47, p. 60.

Ueber das Nucleïn der Hefe.

Von Dr. **Albrecht Kossel**,
Assistent am physiologisch-chemischen Institut zu Strassburg.

(Der Redaction übergeben am 15. Juni).

Zweiter Theil.

In einer früheren Abhandlung[1] versuchte ich darzuthun, dass das Nucleïn der Hefe bei der Einwirkung des siedenden Wassers in Phosphorsäure, Hypoxanthin und einen eiweissähnlichen Körper zerfällt. Die Untersuchungen über diesen Gegenstand wurden seitdem fortgesetzt, lieferten indess noch keine abschliessenden Resultate.

Die Veranlassung zur Veröffentlichung der seither angestellten Versuche ist eine Abhandlung des Herrn Loew[2].

Derselbe hat die im ersten Theile dieser Arbeit angegebenen Versuche im Wesentlichen bestätigt und ist in Folge dessen von seinen früheren Ansichten[3] über diesen Gegenstand zurückgekommen, versucht aber trotzdem meine Untersuchungsmethode anzufechten.

Fernerhin wirft mir Herr Loew — unverständliche Gründe supponirend — eine zu langsame Publication und die «Vernachlässigung des Studiums einer so interessanten Verbindung» vor. Ich bemerke, dass ich dieses Studium noch fortzusetzen gedenke — dass eine vorsichtige Publication auf diesem Gebiete am Platze ist, darüber dürfte Herr Loew mittlerweile genügend aufgeklärt sein. Insbesondere halte ich die durch meine Untersuchung eruirten Thatsachen noch nicht für genügend, um auf Grund derselben Hypothesen über die Constitution des Nucleïns auszusprechen.

---

[1] Diese Zeitschrift III, p. 284.

[2] Archiv f. d. ges. Physiologie XXII, p. 62.

[3] Journal für prakt. Chemie. N. F. XVII, p. 419; Annalen der Chemie, Bd. 193, p. 322.

Zur Chemie des Zellkerns.

Von

Dr. A. Kossel.

(Der Redaktion zugegangen am 1. August 1882).

I. Quantitative Bestimmungen des Nucleïns.

Gesetzmässige quantitative Beziehungen die innerhalb lebender Organe zwischen der Phosphorsäure einerseits und N-haltigen Substanzen andererseits obwalten, haben mehrfach das Interesse der Physiologen auf sich gelenkt. Im Pflanzenreich beobachtete man, dass zugleich mit der Neubildung stickstoffhaltiger Gewebstheile auch eine Zunahme der Phosphorsäure in den betreffenden Organen erfolge[1].

Im Thierreiche führten quantitative Untersuchungen über die Ausscheidungsprodukte zu einem ähnlichen Ergebnisse. Man fand, dass der Urin eines hungernden Organismus auf eine bestimmte Menge Stickstoff auch eine bestimmte Menge Phosphorsäure enthält. Man erkannte ferner, dass unter solchen Verhältnissen, wo der Körper mehr Stickstoff in der Nahrung aufnimmt, als er im Harn ausscheidet, auch die Menge der Phosphorsäure in der Nahrung grösser ist, als in den Excreten[2]. Es ergibt sich hieraus der Schluss, dass mit dem Ansatz von stickstoffhaltigem Material auch ein Ansatz von Phosphorsäure Hand in Hand geht.

---

[1] Vergleiche z. B. Maier: Annalen der Chemie und Pharmacie, Bd. CI, (N. R., Bd. XXV) S. 162, 163); ferner Corenwinder: Annales des sciences naturelles, Botanique, IVe sér. T. XIV, 1860, S. 44; und andere Autoren.

[2] E. Bischoff: Zeitschrift für Biologie, Bd. III, S. 309, 1867.

Weitere Beiträge zur Chemie des Zellkerns.

Von

A. Kossel.

(Aus der chemischen Abtheilung des physiologischen Instituts in Berlin.)
(Der Redaktion zugegangen am 20. Februar 1886.)

I. Ueber das Nucleïn im Dotter des Hühnerei's[1].

Im Dotter des Hühnereis findet sich, wie Miescher[2] gezeigt hat, eine Substanz, welche von ihm als Nucleïn bezeichnet wurde. Bunge[3] stellte später denselben Körper aus Eidotter dar und wies nach, dass derselbe ausser den von Miescher aufgeführten Bestandtheilen noch Eisen enthält. Bunge bezeichnete diesen Körper als «Hämatogen», da er wegen des Eisengehaltes vermuthete, dass aus diesem Nucleïn der Blutfarbstoff gebildet werde[4].

Bereits früher war von einzelnen Embryologen die Frage erörtert worden, ob die bekannten Formelemente des weissen Dotters als Zellkerne zu betrachten seien, ob man annehmen dürfe, dass diese als fertige morphologische Bestandtheile aus dem Nahrungsdotter in den sich entwickelnden Embryo hineintransportirt würden. Diese Fragen schienen durch die Ent-

---

[1] Vorläufige Mittheilung in den Verhandlungen der physiologischen Gesellschaft zu Berlin, Jahrgang 1884/85, Nr. 9 und 10, S. 27.

[2] Medicinisch-chemische Untersuchungen, herausgegeben von Hoppe-Seyler, S. 502.

[3] Diese Zeitschrift, Bd. 9, S. 49.

[4] Die Analysen Bunge's ergaben einen niedern P und S und einen höheren N-Gehalt als die Miescher's.

	Miescher:	Bunge:
P	6,9	5,19
N	13,46	14,73
S	0,99	0,55

Ueber die basischen Stoffe des Zellkerns[1].

Von

A. Kossel.

Unter den Spaltungsproducten der Eiweisskörper und der Albuminoide finden wir einzelne, die nur gewissen Gruppen von Eiweisskörpern eigen sind, andere, welche man bisher bei allen Eiweisssubstanzen aufgefunden hat. Zu den ersteren gehören z. B. das Glycocoll, das Tyrosin und die schwefelhaltige Gruppe, zu den letzteren Leucin und die basischen Spaltungsproducte, deren Kenntniss durch die Untersuchungen von Drechsel angebahnt worden ist. Wir müssen also annehmen, dass in allen Eiweissstoffen ein Kern vorhanden ist, welcher die basischen Spaltungsproducte und Leucin liefert.

Die Aufklärung der Constitution dieses Kerns ist natürlich von der grössten Bedeutung, und desshalb wird das Studium derjenigen eiweissartigen Substanzen, welche diesen Kern in möglichster Reinheit enthalten, die wichtigste Vorbedingung für die Aufklärung der Constitution der Eiweisskörper überhaupt bilden müssen. Die folgenden Untersuchungen zeigen, dass die Protamine derartige Substanzen sind und zwar ergiebt sich, dass diese Körper neben den basischen Spaltungsproducten nur sehr wenig oder gar keine Monoamidosäuren liefern können.

Ich nehme an, dass in sämmtlichen Eiweisskörpern der Atomcomplex des Protamins vorhanden ist. Dieser ist nicht nur der Ursprung der basischen Spaltungsproducte des Eiweisses,

---

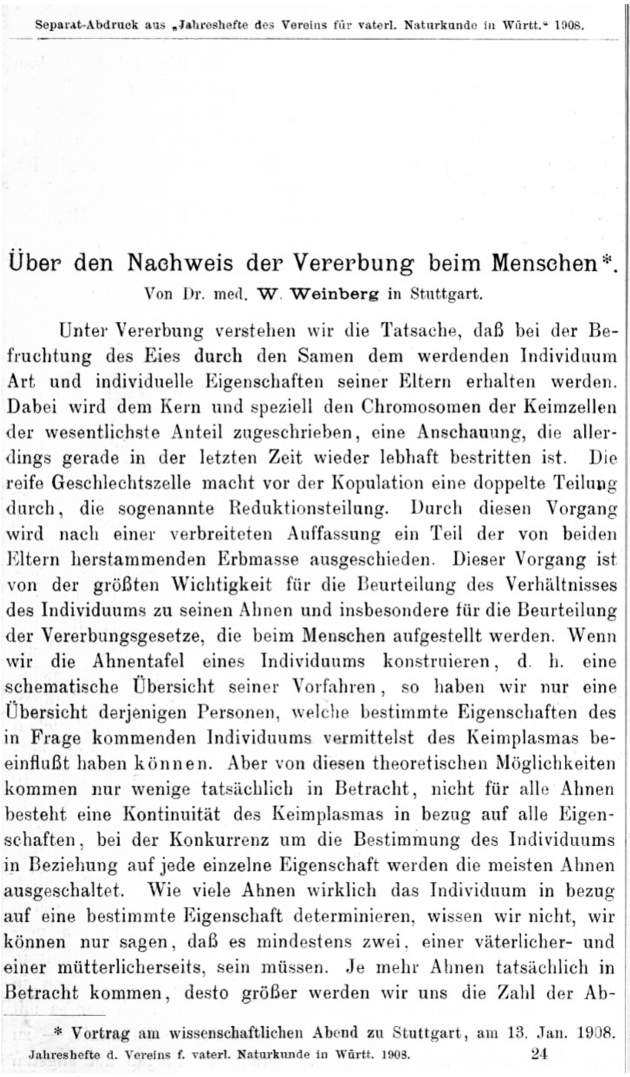
[1] Der Inhalt dieser Abhandlung ist bereits in den Sitzungsberichten der Königlich Preuss. Akademie der Wissenschaften vom 9. April 1896 mitgetheilt worden.

Figure 2.11: Albrecht Kossel identified A, C, G, T, and U bases in DNA and RNA; identified amino acids in proteins; and won the 1910 Nobel Prize in Physiology or Medicine.

Wilhelm Weinberg
(1862–1937)

Discovered the equilibrium distribution of alleles (different versions of a gene) within a population (1907 or earlier)

***Jahreshefte des Vereins für vaterländische Naturkunde in Württemberg* 64:369–382 (1908)**



Separat-Abdruck aus „Jahreshefte des Vereins für vaterl. Naturkunde in Württ." 1908.

Über den Nachweis der Vererbung beim Menschen*.

Von Dr. med. **W. Weinberg** in Stuttgart.

Unter Vererbung verstehen wir die Tatsache, daß bei der Befruchtung des Eies durch den Samen dem werdenden Individuum Art und individuelle Eigenschaften seiner Eltern erhalten werden. Dabei wird dem Kern und speziell den Chromosomen der Keimzellen der wesentlichste Anteil zugeschrieben, eine Anschauung, die allerdings gerade in der letzten Zeit wieder lebhaft bestritten ist. Die reife Geschlechtszelle macht vor der Kopulation eine doppelte Teilung durch, die sogenannte Reduktionsteilung. Durch diesen Vorgang wird nach einer verbreiteten Auffassung ein Teil der von beiden Eltern herstammenden Erbmasse ausgeschieden. Dieser Vorgang ist von der größten Wichtigkeit für die Beurteilung des Verhältnisses des Individuums zu seinen Ahnen und insbesondere für die Beurteilung der Vererbungsgesetze, die beim Menschen aufgestellt werden. Wenn wir die Ahnentafel eines Individuums konstruieren, d. h. eine schematische Übersicht seiner Vorfahren, so haben wir nur eine Übersicht derjenigen Personen, welche bestimmte Eigenschaften des in Frage kommenden Individuums vermittelst des Keimplasmas beeinflußt haben können. Aber von diesen theoretischen Möglichkeiten kommen nur wenige tatsächlich in Betracht, nicht für alle Ahnen besteht eine Kontinuität des Keimplasmas in bezug auf alle Eigenschaften, bei der Konkurrenz um die Bestimmung des Individuums in Beziehung auf jede einzelne Eigenschaft werden die meisten Ahnen ausgeschaltet. Wie viele Ahnen wirklich das Individuum in bezug auf eine bestimmte Eigenschaft determinieren, wissen wir nicht, wir können nur sagen, daß es mindestens zwei, einer väterlicher- und einer mütterlicherseits, sein müssen. Je mehr Ahnen tatsächlich in Betracht kommen, desto größer werden wir uns die Zahl der Ab-

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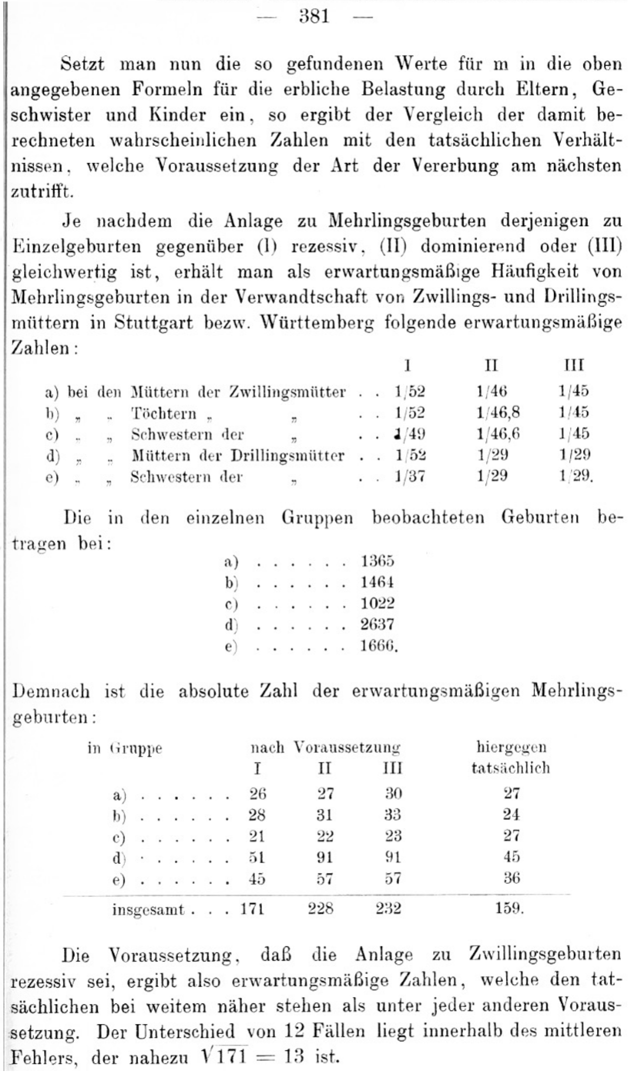
* Vortrag am wissenschaftlichen Abend zu Stuttgart, am 13. Jan. 1908.



Setzt man nun die so gefundenen Werte für m in die oben angegebenen Formeln für die erbliche Belastung durch Eltern, Geschwister und Kinder ein, so ergibt der Vergleich der damit berechneten wahrscheinlichen Zahlen mit den tatsächlichen Verhältnissen, welche Voraussetzung der Art der Vererbung am nächsten zutrifft.

Je nachdem die Anlage zu Mehrlingsgeburten derjenigen zu Einzelgeburten gegenüber (I) rezessiv, (II) dominierend oder (III) gleichwertig ist, erhält man als erwartungsmäßige Häufigkeit von Mehrlingsgeburten in der Verwandtschaft von Zwillings- und Drillingsmüttern in Stuttgart bezw. Württemberg folgende erwartungsmäßige Zahlen:

	I	II	III
a) bei den Müttern der Zwillingsmütter . .	1/52	1/46	1/45
b) „ „ Töchtern „ „ . .	1/52	1/46,8	1/45
c) „ „ Schwestern der „ . .	1/49	1/46,6	1/45
d) „ „ Müttern der Drillingsmütter . .	1/52	1/29	1/29
e) „ „ Schwestern der „ . .	1/37	1/29	1/29.

Die in den einzelnen Gruppen beobachteten Geburten betragen bei:

a)	1365
b)	1464
c)	1022
d)	2637
e)	1666.

Demnach ist die absolute Zahl der erwartungsmäßigen Mehrlingsgeburten:

in Gruppe	nach Voraussetzung			hiergegen
	I	II	III	tatsächlich
a)	26	27	30	27
b)	28	31	33	24
c)	21	22	23	27
d)	51	91	91	45
e)	45	57	57	36
insgesamt . . .	171	228	232	159.

Die Voraussetzung, daß die Anlage zu Zwillingsgeburten rezessiv sei, ergibt also erwartungsmäßige Zahlen, welche den tatsächlichen bei weitem näher stehen als unter jeder anderen Voraussetzung. Der Unterschied von 12 Fällen liegt innerhalb des mittleren Fehlers, der nahezu $\sqrt{171} = 13$ ist.

Figure 2.12: No later than 1907, Wilhelm Weinberg discovered the equilibrium distribution of alleles (different versions of a gene) within a population of a species.

Individual genes encode individual proteins (1933 or earlier)
Alfred Kühn (1885–1968)
Ernst Caspari (1909–1988)
Caspari (2nd from left) with others from Kühn's genetics lab

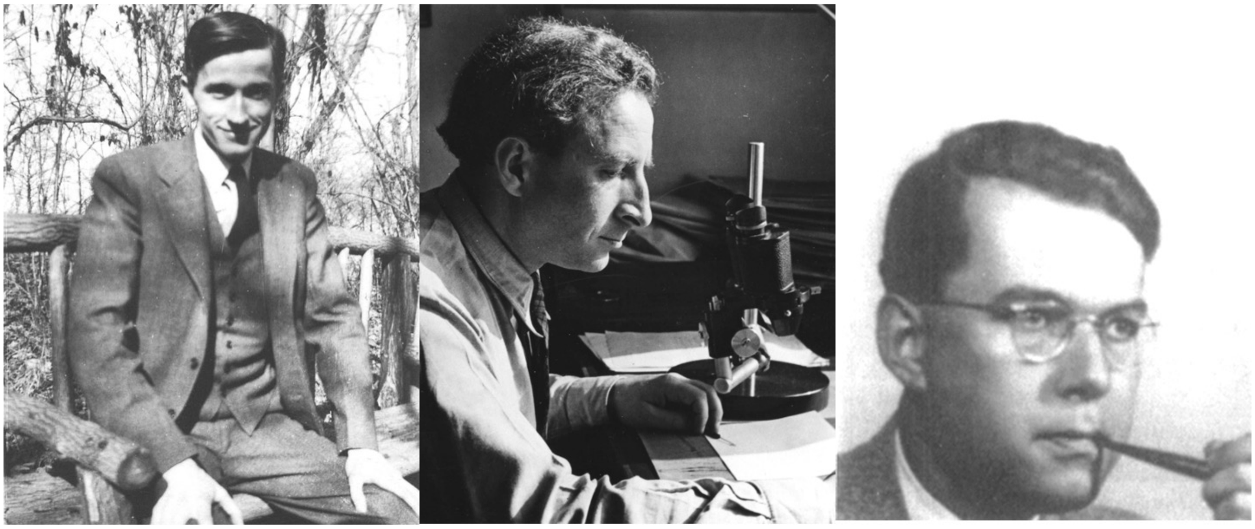
Figure 2.13: In 1933 or earlier, Alfred Kühn, Ernst Caspari, and other members of Kühn's research group discovered that individual genes encode individual proteins.

Individual genes
encode
individual proteins
(1933 or earlier)

Adolf Butenandt (1903–1995)

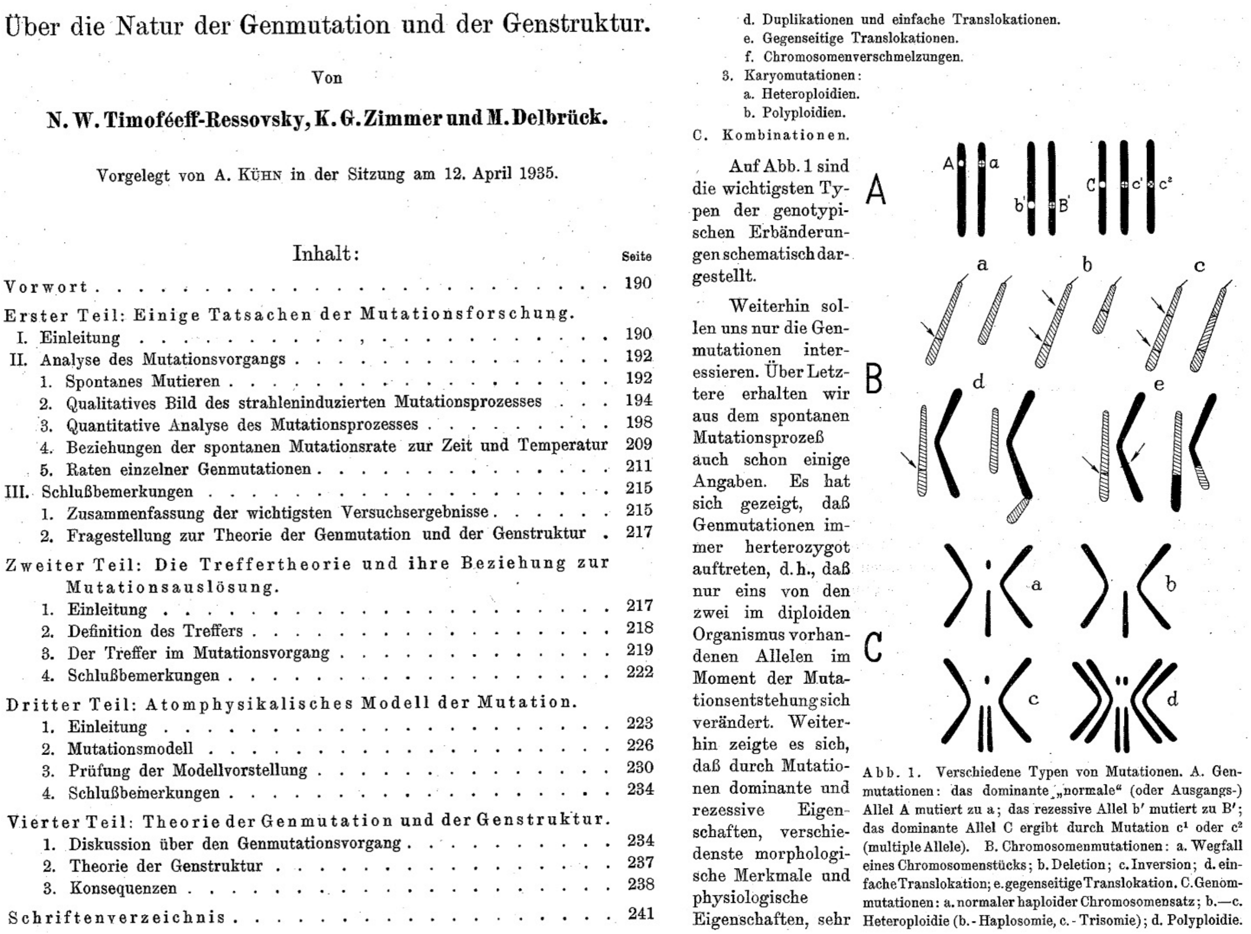
Figure 2.14: In 1933 or earlier, Adolf Butenandt and other researchers discovered that individual genes encode individual proteins.

Max Delbrück (1906–1981) **Nikolai Timoféeff-Ressovsky (1900–1981)** **Karl Günter Zimmer (1911–1988)**



Chromosome/gene structure and mutations (1935 or earlier)

***Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen* pp. 189–245 (1935)**



Über die Natur der Genmutation und der Genstruktur.

Von

N. W. Timoféeff-Ressovsky, K. G. Zimmer und M. Delbrück.

Vorgelegt von A. Kühn in der Sitzung am 12. April 1935.

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f. Chromosomenverschmelzungen.
3. Karyomutationen:
a. Heteroploidien.
b. Polyploidien.
C. Kombinationen.

Auf Abb. 1 sind die wichtigsten Typen der genotypischen Erbänderungen schematisch dargestellt.

Weiterhin sollen uns nur die Genmutationen interessieren. Über Letztere erhalten wir aus dem spontanen Mutationsprozeß auch schon einige Angaben. Es hat sich gezeigt, daß Genmutationen immer herterozygot auftreten, d. h., daß nur eins von den zwei im diploiden Organismus vorhandenen Allelen im Moment der Mutationsentstehung sich verändert. Weiterhin zeigte es sich, daß durch Mutationen dominante und rezessive Eigenschaften, verschiedenste morphologische Merkmale und physiologische Eigenschaften, sehr

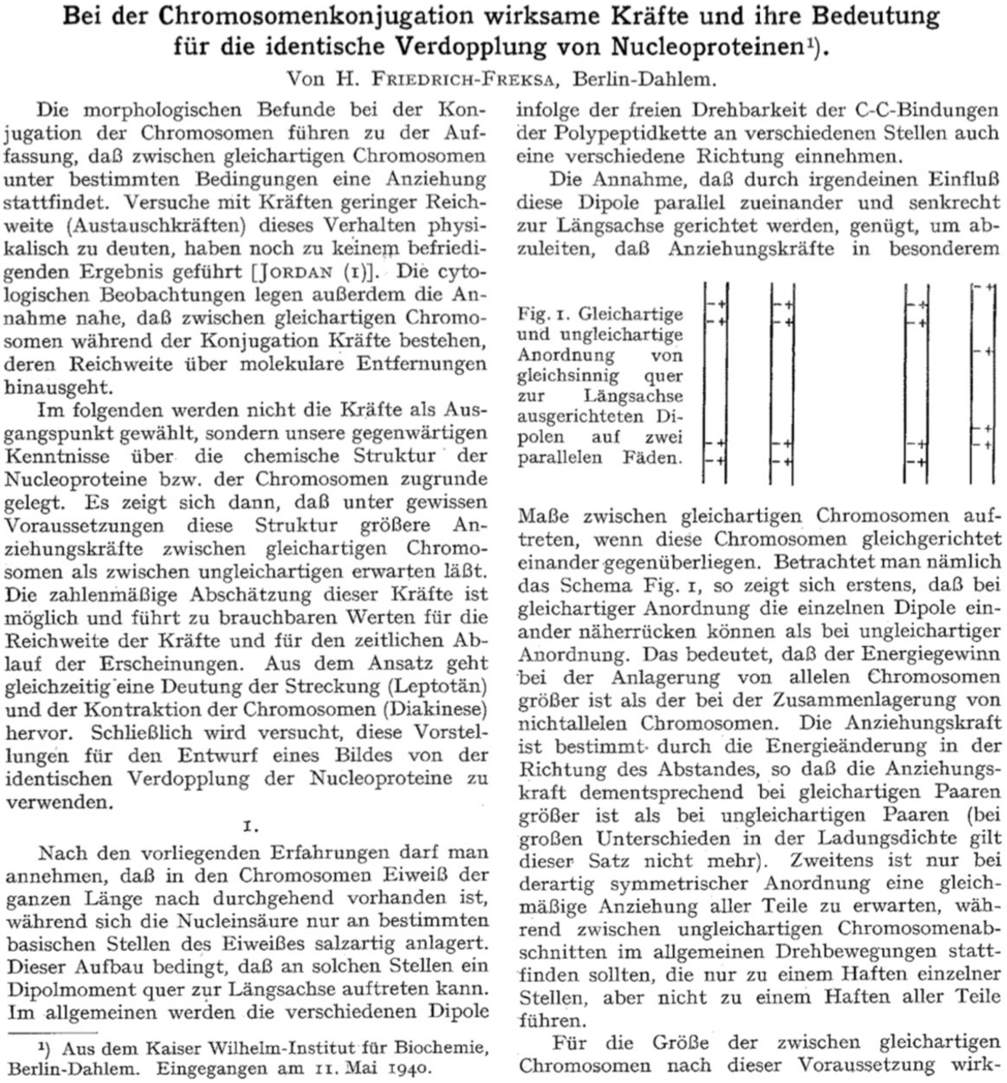
Abb. 1. Verschiedene Typen von Mutationen. A. Genmutationen: das dominante „normale“ (oder Ausgangs-) Allel A mutiert zu a; das rezessive Allel b' mutiert zu B'; das dominante Allel C ergibt durch Mutation c^1 oder c^2 (multiple Allele). B. Chromosomenmutationen: a. Wegfall eines Chromosomenstücks; b. Deletion; c. Inversion; d. einfache Translokation; e. gegenseitige Translokation. C. Genommutationen: a. normaler haploider Chromosomensatz; b.—c. Heteroploidie (b. - Haplosomie, c. - Trisomie); d. Polyploidie.

Figure 2.15: In 1935, Max Delbrück, Nikolai Timoféeff-Ressovsky, and Karl Günter Zimmer published a detailed and advanced paper on chromosomes and gene structures, as well as methods and effects of mutating or recombining them [Timoféeff-Ressovsky, Zimmer, and Delbrück 1935].

Hans Friedrich-Freksa
(1906–1973)

Proposed that the structure of DNA is double-stranded with electrostatic attraction between complementary sequences

Die Naturwissenschaften
28:24:376–379 (1940)



Bei der Chromosomenkonjugation wirksame Kräfte und ihre Bedeutung für die identische Verdopplung von Nucleoproteinen[1]).

Von H. Friedrich-Freksa, Berlin-Dahlem.

Die morphologischen Befunde bei der Konjugation der Chromosomen führen zu der Auffassung, daß zwischen gleichartigen Chromosomen unter bestimmten Bedingungen eine Anziehung stattfindet. Versuche mit Kräften geringer Reichweite (Austauschkräften) dieses Verhalten physikalisch zu deuten, haben noch zu keinem befriedigenden Ergebnis geführt [Jordan (1)]. Die cytologischen Beobachtungen legen außerdem die Annahme nahe, daß zwischen gleichartigen Chromosomen während der Konjugation Kräfte bestehen, deren Reichweite über molekulare Entfernungen hinausgeht.

Im folgenden werden nicht die Kräfte als Ausgangspunkt gewählt, sondern unsere gegenwärtigen Kenntnisse über die chemische Struktur der Nucleoproteine bzw. der Chromosomen zugrunde gelegt. Es zeigt sich dann, daß unter gewissen Voraussetzungen diese Struktur größere Anziehungskräfte zwischen gleichartigen Chromosomen als zwischen ungleichartigen erwarten läßt. Die zahlenmäßige Abschätzung dieser Kräfte ist möglich und führt zu brauchbaren Werten für die Reichweite der Kräfte und für den zeitlichen Ablauf der Erscheinungen. Aus dem Ansatz geht gleichzeitig eine Deutung der Streckung (Leptotän) und der Kontraktion der Chromosomen (Diakinese) hervor. Schließlich wird versucht, diese Vorstellungen für den Entwurf eines Bildes von der identischen Verdopplung der Nucleoproteine zu verwenden.

I.

Nach den vorliegenden Erfahrungen darf man annehmen, daß in den Chromosomen Eiweiß der ganzen Länge nach durchgehend vorhanden ist, während sich die Nucleinsäure nur an bestimmten basischen Stellen des Eiweißes salzartig anlagert. Dieser Aufbau bedingt, daß an solchen Stellen ein Dipolmoment quer zur Längsachse auftreten kann. Im allgemeinen werden die verschiedenen Dipole infolge der freien Drehbarkeit der C-C-Bindungen der Polypeptidkette an verschiedenen Stellen auch eine verschiedene Richtung einnehmen.

Die Annahme, daß durch irgendeinen Einfluß diese Dipole parallel zueinander und senkrecht zur Längsachse gerichtet werden, genügt, um abzuleiten, daß Anziehungskräfte in besonderem Maße zwischen gleichartigen Chromosomen auftreten, wenn diese Chromosomen gleichgerichtet einander gegenüberliegen. Betrachtet man nämlich das Schema Fig. 1, so zeigt sich erstens, daß bei gleichartiger Anordnung die einzelnen Dipole einander näherrücken können als bei ungleichartiger Anordnung. Das bedeutet, daß der Energiegewinn bei der Anlagerung von allelen Chromosomen größer ist als der bei der Zusammenlagerung von nichtallelen Chromosomen. Die Anziehungskraft ist bestimmt durch die Energieänderung in der Richtung des Abstandes, so daß die Anziehungskraft dementsprechend bei gleichartigen Paaren größer ist als bei ungleichartigen Paaren (bei großen Unterschieden in der Ladungsdichte gilt dieser Satz nicht mehr). Zweitens ist nur bei derartig symmetrischer Anordnung eine gleichmäßige Anziehung aller Teile zu erwarten, während zwischen ungleichartigen Chromosomenabschnitten im allgemeinen Drehbewegungen stattfinden sollten, die nur zu einem Haften einzelner Stellen, aber nicht zu einem Haften aller Teile führen.

Für die Größe der zwischen gleichartigen Chromosomen nach dieser Voraussetzung wirk-

Fig. 1. Gleichartige und ungleichartige Anordnung von gleichsinnig quer zur Längsachse ausgerichteten Dipolen auf zwei parallelen Fäden.

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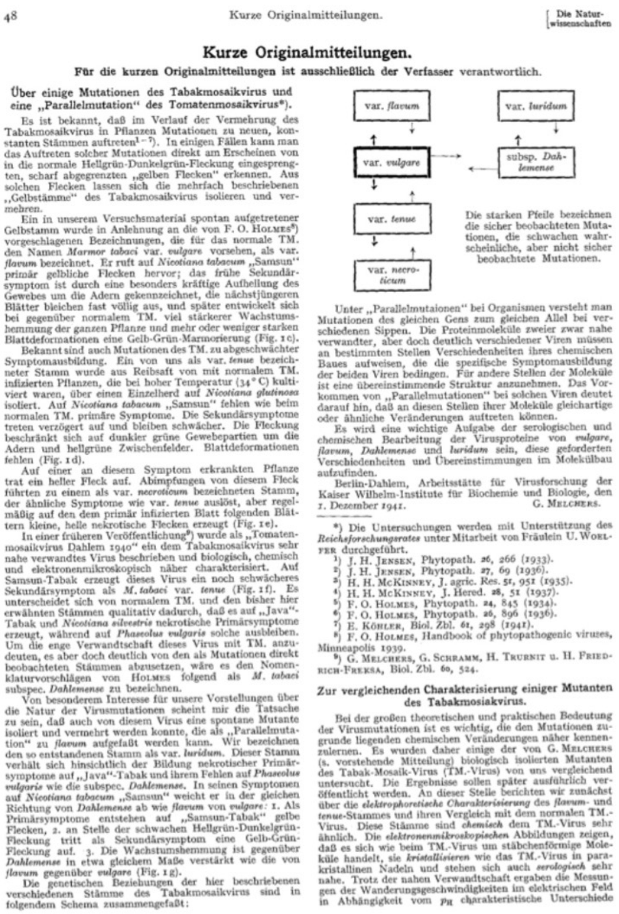
[1] Aus dem Kaiser Wilhelm-Institut für Biochemie, Berlin-Dahlem. Eingegangen am 11. Mai 1940.

Figure 2.16: No later than 1940, Hans Friedrich-Freksa proposed that the structure of DNA is double-stranded with electrostatic attraction between complementary sequences on the strands [Friedrich-Freksa 1940].

Gerhard Schramm (1910–1969) RNA, translation to proteins, and genetic engineering of viruses

Experimented with tobacco mosaic virus (1940–1942):

- **Identified RNA genome**
- **Showed protein subunits are identical**
- **Mutated RNA to create mutant proteins**



48 Kurze Originalmitteilungen. [Die Naturwissenschaften

Kurze Originalmitteilungen.

Für die kurzen Originalmitteilungen ist ausschließlich der Verfasser verantwortlich.

Über einige Mutationen des Tabakmosaikvirus und eine „Parallelmutation" des Tomatenmosaikvirus[*].

Es ist bekannt, daß im Verlauf der Vermehrung des Tabakmosaikvirus in Pflanzen Mutationen zu neuen, konstanten Stämmen auftreten[1–7]. In einigen Fällen kann man das Auftreten solcher Mutationen direkt am Erscheinen von in die normale Hellgrün-Dunkelgrün-Fleckung eingesprengten, scharf abgegrenzten „gelben Flecken" erkennen. Aus solchen Flecken lassen sich die mehrfach beschriebenen „Gelbstämme" des Tabakmosaikvirus isolieren und vermehren.

Ein in unserem Versuchsmaterial spontan aufgetretener Gelbstamm wurde in Anlehnung an die von F. O. Holmes[8] vorgeschlagenen Bezeichnungen, die für das normale TM. den Namen *Marmor tabaci* var. *vulgare* vorsehen, als var. *flavum* bezeichnet. Er ruft auf *Nicotiana tabacum* „Samsun" primär gelbliche Flecken hervor; das frühe Sekundärsymptom ist durch eine besonders kräftige Aufhellung des Gewebes um die Adern gekennzeichnet, die nächstjüngeren Blätter bleichen fast völlig aus, und später entwickelt sich bei gegenüber normalem TM. viel stärkerer Wachstumshemmung der ganzen Pflanze und mehr oder weniger starken Blattdeformationen eine Gelb-Grün-Marmorierung (Fig. 1c).

Bekannt sind auch Mutationen des TM. zu abgeschwächter Symptomausbildung. Ein von uns als var. *tenue* bezeichneter Stamm wurde aus Reibsaft von mit normalem TM. infizierten Pflanzen, die bei hoher Temperatur (34° C) kultiviert waren, über einen Einzelherd auf *Nicotiana glutinosa* isoliert. Auf *Nicotiana tabacum* „Samsun" fehlen wie beim normalen TM. primäre Symptome. Die Sekundärsymptome treten verzögert auf und bleiben schwächer. Die Fleckung beschränkt sich auf dunkler grüne Gewebepartien um die Adern und hellgrüne Zwischenfelder. Blattdeformationen fehlen (Fig. 1d).

Auf einer an diesem Symptom erkrankten Pflanze trat ein heller Fleck auf. Abimpfungen von diesem Fleck führten zu einem als var. *necroticum* bezeichneten Stamm, der ähnliche Symptome wie var. *tenue* auslöst, aber regelmäßig auf den dem primär infizierten Blatt folgenden Blättern kleine, helle nekrotische Flecken erzeugt (Fig. 1e).

In einer früheren Veröffentlichung[9] wurde als „Tomatenmosaikvirus Dahlem 1940" ein dem Tabakmosaikvirus sehr nahe verwandtes Virus beschrieben und biologisch, chemisch und elektronenmikroskopisch näher charakterisiert. Auf Samsun-Tabak erzeugt dieses Virus ein noch schwächeres Sekundärsymptom als *M. tabaci* var. *tenue* (Fig. 1f). Es unterscheidet sich von normalem TM. und den bisher hier erwähnten Stämmen qualitativ dadurch, daß es auf „Java"-Tabak und *Nicotiana silvestris* nekrotische Primärsymptome erzeugt, während auf *Phaseolus vulgaris* solche ausbleiben. Um die enge Verwandtschaft dieses Virus mit TM. anzudeuten, es aber doch deutlich von den als Mutationen direkt beobachteten Stämmen abzusetzen, wäre es den Nomenklaturvorschlägen von Holmes folgend als *M. tabaci* subspec. *Dahlemense* zu bezeichnen.

Von besonderem Interesse für unsere Vorstellungen über die Natur der Virusmutationen scheint mir die Tatsache zu sein, daß auch von diesem Virus eine spontane Mutante isoliert und vermehrt werden konnte, die als „Parallelmutation" zu *flavum* aufgefaßt werden kann. Wir bezeichnen den so entstandenen Stamm als var. *luridum*. Dieser Stamm verhält sich hinsichtlich der Bildung nekrotischer Primärsymptome auf „Java"-Tabak und ihrem Fehlen auf *Phaseolus vulgaris* wie die subspec. *Dahlemense*. In seinen Symptomen auf *Nicotiana tabacum* „Samsun" weicht er in der gleichen Richtung von *Dahlemense* ab wie *flavum* von *vulgare*: 1. Als Primärsymptome entstehen auf „Samsun-Tabak" gelbe Flecken, 2. an Stelle der schwachen Hellgrün-Dunkelgrün-Fleckung tritt als Sekundärsymptom eine Gelb-Grün-Fleckung auf. 3. Die Wachstumshemmung ist gegenüber *Dahlemense* in etwa gleichem Maße verstärkt wie die von *flavum* gegenüber *vulgare* (Fig. 1g).

Die genetischen Beziehungen der hier beschriebenen verschiedenen Stämme des Tabakmosaikvirus sind in folgendem Schema zusammengefaßt:

Die starken Pfeile bezeichnen die sicher beobachteten Mutationen, die schwachen wahrscheinliche, aber nicht sicher beobachtete Mutationen.

Unter „Parallelmutaionen" bei Organismen versteht man Mutationen des gleichen Gens zum gleichen Allel bei verschiedenen Sippen. Die Proteinmoleküle zweier zwar nahe verwandter, aber doch deutlich verschiedener Viren müssen an bestimmten Stellen Verschiedenheiten ihres chemischen Baues aufweisen, die die spezifische Symptomausbildung der beiden Viren bedingen. Für andere Stellen der Moleküle ist eine übereinstimmende Struktur anzunehmen. Das Vorkommen von „Parallelmutationen" bei solchen Viren deutet darauf hin, daß an diesen Stellen ihrer Moleküle gleichartige oder ähnliche Veränderungen auftreten können.

Es wird eine wichtige Aufgabe der serologischen und chemischen Bearbeitung der Virusproteine von *vulgare*, *flavum*, *Dahlemense* und *luridum* sein, diese geforderten Verschiedenheiten und Übereinstimmungen im Molekülbau aufzufinden.

Berlin-Dahlem, Arbeitsstätte für Virusforschung der Kaiser Wilhelm-Institute für Biochemie und Biologie, den 1. Dezember 1941.

G. Melchers.

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[*] Die Untersuchungen werden mit Unterstützung des *Reichsforschungsrates* unter Mitarbeit von Fräulein U. Woelfer durchgeführt.

[1] J. H. Jensen, Phytopath. **26**, 266 (1933).

[2] J. H. Jensen, Phytopath. **27**, 69 (1936).

[3] H. H. McKinney, J. agric. Res. **51**, 951 (1935).

[4] H. H. McKinney, J. Hered. **28**, 51 (1937).

[5] F. O. Holmes, Phytopath. **24**, 845 (1934).

[6] F. O. Holmes, Phytopath. **26**, 896 (1936).

[7] E. Köhler, Biol. Zbl. **61**, 298 (1941).

[8] F. O. Holmes, Handbook of phytopathogenic viruzes, Minneapolis 1939.

[9] G. Melchers, G. Schramm, H. Trurnit u. H. Friedrich-Freksa, Biol. Zbl. **60**, 524.

Zur vergleichenden Charakterisierung einiger Mutanten des Tabakmosiakvirus.

Bei der großen theoretischen und praktischen Bedeutung der Virusmutationen ist es wichtig, die den Mutationen zugrunde liegenden chemischen Veränderungen näher kennenzulernen. Es wurden daher einige der von G. Melchers (s. vorstehende Mitteilung) biologisch isolierten Mutanten des Tabak-Mosaik-Virus (TM.-Virus) von uns vergleichend untersucht. Die Ergebnisse sollen später ausführlich veröffentlicht werden. An dieser Stelle berichten wir zunächst über die *elektrophoretische Charakterisierung* des *flavum*- und *tenue*-Stammes und ihren Vergleich mit dem normalen TM.-Virus. Diese Stämme sind *chemisch* dem TM.-Virus sehr ähnlich. Die *elektronenmikroskopischen* Abbildungen zeigen, daß es sich wie beim TM.-Virus um stäbchenförmige Moleküle handelt, sie *kristallisieren* wie das TM.-Virus in parakristallinen Nadeln und stehen sich auch *serologisch* sehr nahe. Trotz der nahen Verwandtschaft ergaben die Messungen der Wanderungsgeschwindigkeiten im elektrischen Feld in Abhängigkeit vom p_H charakteristische Unterschiede

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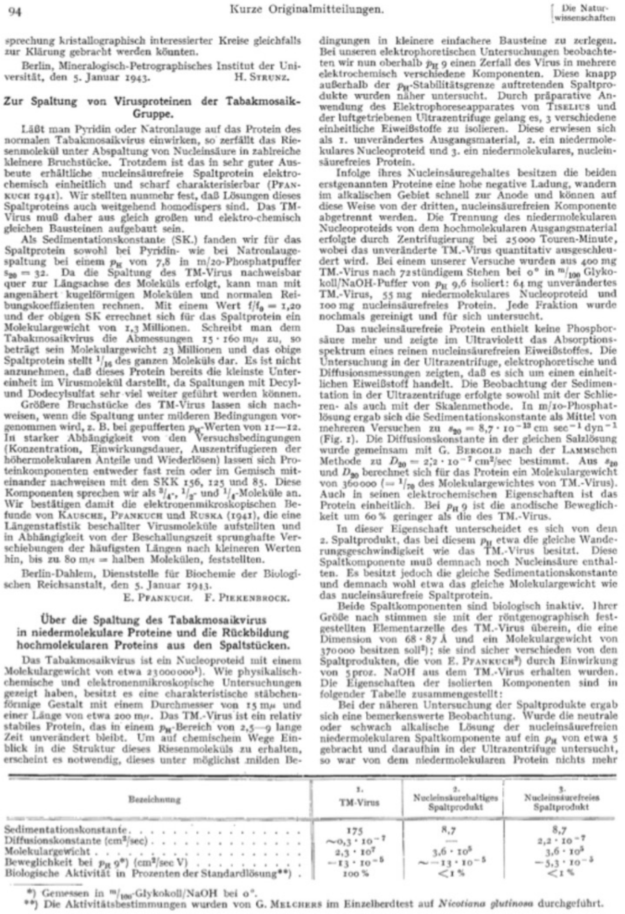

94 Kurze Originalmitteilungen. [Die Naturwissenschaften

sprechung kristallographisch interessierter Kreise gleichfalls zur Klärung gebracht werden könnten.

Berlin, Mineralogisch-Petrographisches Institut der Universität, den 5. Januar 1943.

H. Strunz.

Zur Spaltung von Virusproteinen der Tabakmosaik-Gruppe.

Läßt man Pyridin oder Natronlauge auf das Protein des normalen Tabakmosaikvirus einwirken, so zerfällt das Riesenmolekül unter Abspaltung von Nucleinsäure in zahlreiche kleinere Bruchstücke. Trotzdem ist das in sehr guter Ausbeute erhältliche nucleinsäurefreie Spaltprotein elektrochemisch einheitlich und scharf charakterisierbar (Pfankuch 1941). Wir stellten nunmehr fest, daß Lösungen dieses Spaltproteins auch weitgehend homodispers sind. Das TM-Virus muß daher aus gleich großen und elektro-chemisch gleichen Bausteinen aufgebaut sein.

Als Sedimentationskonstante (SK.) fanden wir für das Spaltprotein sowohl bei Pyridin- wie bei Natronlaugespaltung bei einem p_H von 7,8 in m/20-Phosphatpuffer $s_{20} = 32$. Da die Spaltung des TM-Virus nachweisbar quer zur Längsachse des Moleküls erfolgt, kann man mit angenähert kugelförmigen Molekülen und normalen Reibungskoeffizienten rechnen. Mit einem Wert $f/f_0 = 1,20$ und der obigen SK errechnet sich für das Spaltprotein ein Molekulargewicht von 1,3 Millionen. Schreibt man dem Tabakmosaikvirus die Abmessungen 15 · 160 mμ zu, so beträgt sein Molekulargewicht 23 Millionen und das obige Spaltprotein stellt $^{1}/_{16}$ des ganzen Moleküls dar. Es ist nicht anzunehmen, daß dieses Protein bereits die kleinste Untereinheit im Virusmolekül darstellt, da Spaltungen mit Decyl- und Dodecylsulfat sehr viel weiter geführt werden können.

Größere Bruchstücke des TM-Virus lassen sich nachweisen, wenn die Spaltung unter milderen Bedingungen vorgenommen wird, z. B. bei gepufferten p_H-Werten von 11—12. In starker Abhängigkeit von den Versuchsbedingungen (Konzentration, Einwirkungsdauer, Auszentrifugieren der höhermolekularen Anteile und Wiederlösen) lassen sich Proteinkomponenten entweder fast rein oder im Gemisch miteinander nachweisen mit den SKK 156, 125 und 85. Diese Komponenten sprechen wir als $^{3}/_{4}$-, $^{1}/_{2}$- und $^{1}/_{4}$-Moleküle an. Wir bestätigen damit die elektronenmikroskopischen Befunde von Kausche, Pfankuch und Ruska (1941), die eine Längenstatistik beschallter Virusmoleküle aufstellten und in Abhängigkeit von der Beschallungszeit sprunghafte Verschiebungen der häufigsten Längen nach kleineren Werten hin, bis zu 80 mμ = halben Molekülen, feststellten.

Berlin-Dahlem, Dienststelle für Biochemie der Biologischen Reichsanstalt, den 5. Januar 1943.

E. Pfankuch. F. Piekenbrock.

Über die Spaltung des Tabakmosaikvirus in niedermolekulare Proteine und die Rückbildung hochmolekularen Proteins aus den Spaltstücken.

Das Tabakmosaikvirus ist ein Nucleoproteid mit einem Molekulargewicht von etwa 23000000[1]. Wie physikalisch-chemische und elektronenmikroskopische Untersuchungen gezeigt haben, besitzt es eine charakteristische stäbchenförmige Gestalt mit einem Durchmesser von 15 mμ und einer Länge von etwa 200 mμ. Das TM.-Virus ist ein relativ stabiles Protein, das in einem p_H-Bereich von 2,5—9 lange Zeit unverändert bleibt. Um auf chemischem Wege Einblick in die Struktur dieses Riesenmoleküls zu erhalten, erscheint es notwendig, dieses unter möglichst milden Bedingungen in kleinere einfachere Bausteine zu zerlegen. Bei unseren elektrophoretischen Untersuchungen beobachteten wir nun oberhalb p_H 9 einen Zerfall des Virus in mehrere elektrochemisch verschiedene Komponenten. Diese knapp außerhalb der p_H-Stabilitätsgrenze auftretenden Spaltprodukte wurden näher untersucht. Durch präparative Anwendung des Elektrophoreseapparates von Tiselius und der luftgetriebenen Ultrazentrifuge gelang es, 3 verschiedene einheitliche Eiweißstoffe zu isolieren. Diese erwiesen sich als 1. unverändertes Ausgangsmaterial, 2. ein niedermolekulares Nucleoproteid und 3. ein niedermolekulares, nucleinsäurefreies Protein.

Infolge ihres Nucleinsäuregehaltes besitzen die beiden erstgenannten Proteine eine hohe negative Ladung, wandern im alkalischen Gebiet schnell zur Anode und können auf diese Weise von der dritten, nucleinsäurefreien Komponente abgetrennt werden. Die Trennung des niedermolekularen Nucleoproteids von dem hochmolekularen Ausgangsmaterial erfolgte durch Zentrifugierung bei 25000 Touren-Minute, wobei das unveränderte TM.-Virus quantitativ ausgeschleudert wird. Bei einem unserer Versuche wurden aus 400 mg TM.-Virus nach 72stündigem Stehen bei 0° in $^{m}/_{100}$ Glykokoll/NaOH-Puffer von p_H 9,6 isoliert: 64 mg unverändertes TM.-Virus, 55 mg niedermolekulares Nucleoproteid und 100 mg nucleinsäurefreies Protein. Jede Fraktion wurde nochmals gereinigt und für sich untersucht.

Das nucleinsäurefreie Protein enthielt keine Phosphorsäure mehr und zeigte im Ultraviolett das Absorptionsspektrum eines reinen nucleinsäurefreien Eiweißstoffes. Die Untersuchung in der Ultrazentrifuge, elektrophoretische und Diffusionsmessungen zeigten, daß es sich um einen einheitlichen Eiweißstoff handelt. Die Beobachtung der Sedimentation in der Ultrazentrifuge erfolgte sowohl mit der Schlieren- als auch mit der Skalenmethode. In m/10-Phosphatlösung ergab sich die Sedimentationskonstante als Mittel von mehreren Versuchen zu $s_{20} = 8,7 \cdot 10^{-13}$ cm sec^{-1} dyn^{-1} (Fig. 1). Die Diffusionskonstante in der gleichen Salzlösung wurde gemeinsam mit G. Bergold nach der Lammschen Methode zu $D_{20} = 2,2 \cdot 10^{-7}$ cm^2/sec bestimmt. Aus s_{20} und D_{20} berechnet sich für das Protein ein Molekulargewicht von 360000 (= $^{1}/_{70}$ des Molekulargewichtes von TM.-Virus). Auch in seinen elektrochemischen Eigenschaften ist das Protein einheitlich. Bei p_H 9 ist die anodische Beweglichkeit um 60% geringer als die des TM.-Virus.

In dieser Eigenschaft unterscheidet es sich von dem 2. Spaltprodukt, das bei diesem p_H etwa die gleiche Wanderungsgeschwindigkeit wie das TM.-Virus besitzt. Diese Spaltkomponente muß demnach noch Nucleinsäure enthalten. Es besitzt jedoch die gleiche Sedimentationskonstante und demnach wohl etwa das gleiche Molekulargewicht wie das nucleinsäurefreie Spaltprotein.

Beide Spaltkomponenten sind biologisch inaktiv. Ihrer Größe nach stimmen sie mit der röntgenographisch festgestellten Elementarzelle des TM.-Virus überein, die eine Dimension von 68 · 87 Å und ein Molekulargewicht von 370000 besitzen soll[2]; sie sind sicher verschieden von den Spaltprodukten, die von E. Pfankuch[3] durch Einwirkung von 5proz. NaOH aus dem TM.-Virus erhalten wurden. Die Eigenschaften der isolierten Komponenten sind in folgender Tabelle zusammengestellt:

Bei der näheren Untersuchung der Spaltprodukte ergab sich eine bemerkenswerte Beobachtung. Wurde die neutrale oder schwach alkalische Lösung der nucleinsäurefreien niedermolekularen Spaltkomponente auf ein p_H von etwa 5 gebracht und daraufhin in der Ultrazentrifuge untersucht, so war von dem niedermolekularen Protein nichts mehr

Bezeichnung	1. TM-Virus	2. Nucleinsäurehaltiges Spaltprodukt	3. Nucleinsäurefreies Spaltprodukt
Sedimentationskonstante	175	8,7	8,7
Diffusionskonstante (cm²/sec)	$\sim 0,3 \cdot 10^{-7}$	—	$2,2 \cdot 10^{-7}$
Molekulargewicht	$2,3 \cdot 10^{7}$	$3,6 \cdot 10^{5}$	$3,6 \cdot 10^{5}$
Beweglichkeit bei p_H 9*) (cm²/sec V)	$-13 \cdot 10^{-5}$	$\sim -13 \cdot 10^{-5}$	$-5,3 \cdot 10^{-5}$
Biologische Aktivität in Prozenten der Standardlösung**)	100 %	<1 %	<1 %

*) Gemessen in $^{m}/_{100}$-Glykokoll/NaOH bei 0°.

**) Die Aktivitätsbestimmungen wurden von G. Melchers im Einzelherdtest auf *Nicotiana glutinosa* durchgeführt.

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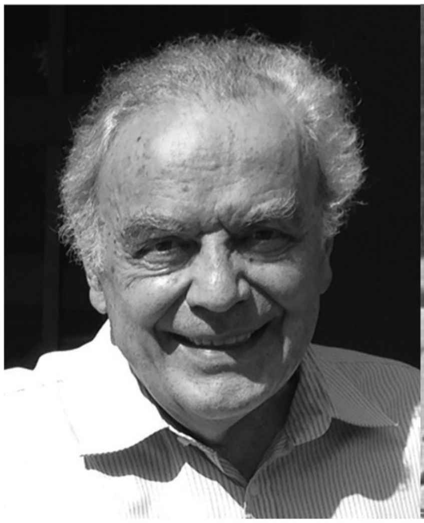
Figure 2.17: Gerhard Schramm identified the genome of the tobacco mosaic virus as RNA, showed that its protein subunits are identical, and mutated the RNA to create mutant proteins [Schramm and Rebensburg 1942; Schramm 1943].

DNA

Richard Altmann
(1852–1900)
Nucleic acid
1889

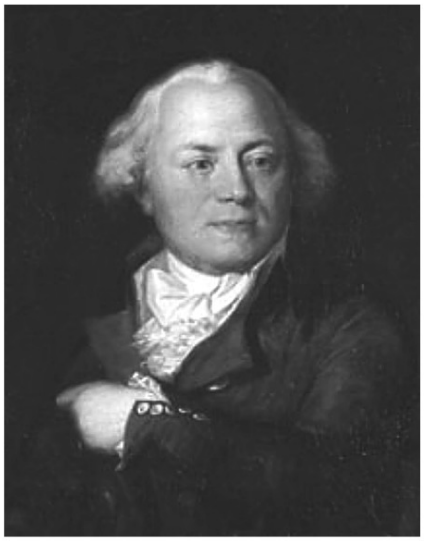
Werner Arber
(1929–)
DNA restriction
enzymes



Charlotte Auerbach
(1899–1994)
Chemical mutagenesis
of DNA

Harald Bagge
(1817–1895)
Cell nucleus
and mitosis

Franz Andreas Bauer
(1758–1840)
Nuclear
structure



Hans Bauer
(1904–1988)
Genetics and
mutations

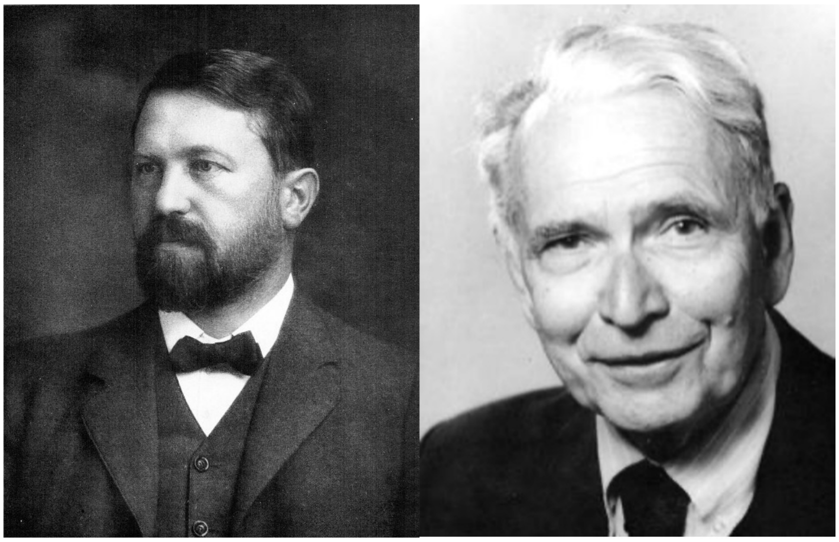
Figure 2.18: Other creators who made significant contributions to knowledge about DNA included Richard Altmann, Werner Arber, Charlotte Auerbach, Harald Bagge, Franz Andreas Bauer, and Hans Bauer.

DNA

Erich Becker
(19??–1942)
Genetics and
mutations

Theodor Boveri
(1862–1915)
Chromosome structure/
abnormalities, mitosis

Erwin Chargaff
(1905–2002)
G-C and A-T
base-pairing in DNA



Karl Correns
(1864–1933)
Genetics and
chloroplasts

Hugo de Vries
(1848–1935)
Genetics and
mutations

Helmut Döring
(19??–1942)
Genetics and
mutations

Figure 2.19: Other creators who made significant contributions to knowledge about DNA included Erich Becker, Theodor Boveri, Erwin Chargaff, Karl Correns, Hugo de Vries, and Helmut Döring.

DNA

George Gamow
(1904–1968)
Genetic code

Richard Goldschmidt
(1878–1958)
Genetics, evolution, and
developmental biology

Richard Goldschmidt

Georg Gottschewski
(1906–1975)
Genetics and
mutations

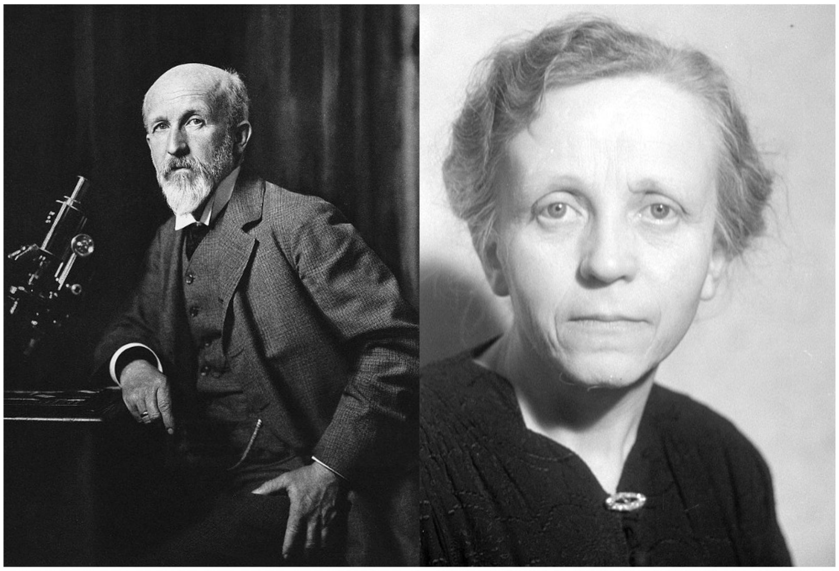
Figure 2.20: Other creators who made significant contributions to knowledge about DNA included George Gamow, Richard Goldschmidt, and Georg Gottschewski.

DNA

Karl Henke
(1895–1956)
Genetics and mutations

Oscar Hertwig
(1849–1922)
Mitosis, meiosis, genes

Paula Hertwig
(1889–1983)
Genetics and mutations



Wilhelm Hofmeister
(1824–1877)
Individual chromosomes

Phoebus Levene
(1869–1940)
DNA and RNA nucleotides

Franz Leydig
(1821–1908)
Mitosis and chromosomes

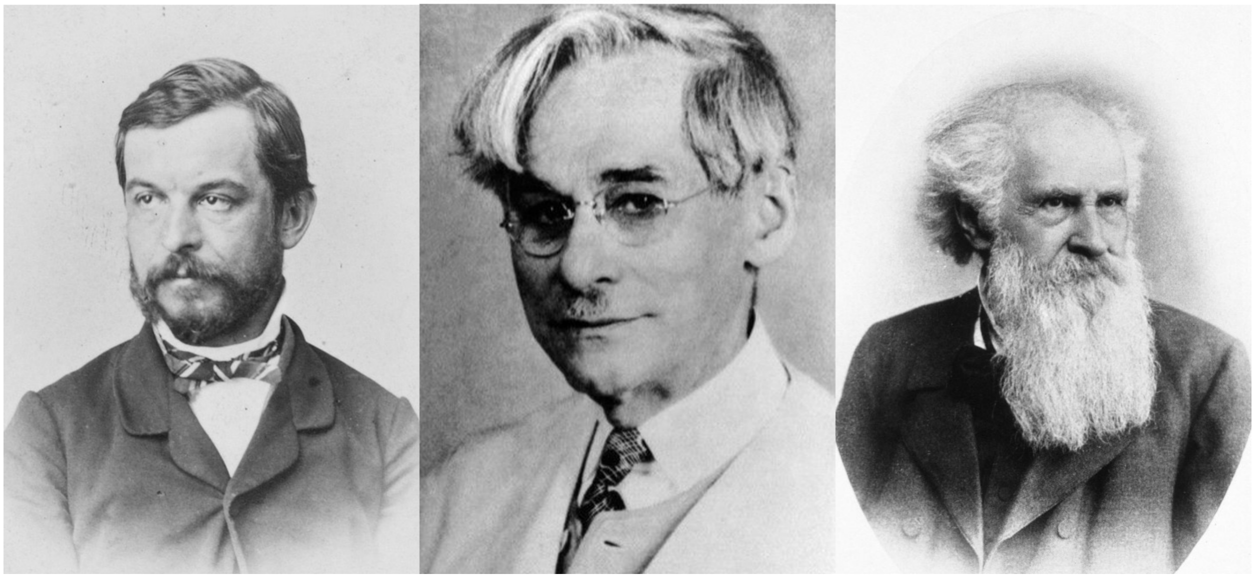


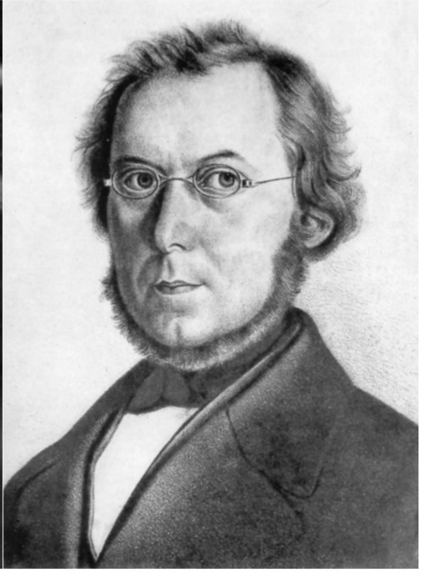
Figure 2.21: Other creators who made significant contributions to knowledge about DNA included Karl Henke, Oscar Hertwig, Paula Hertwig, Wilhelm Hofmeister, Phoebus Levene, and Franz Leydig.

DNA

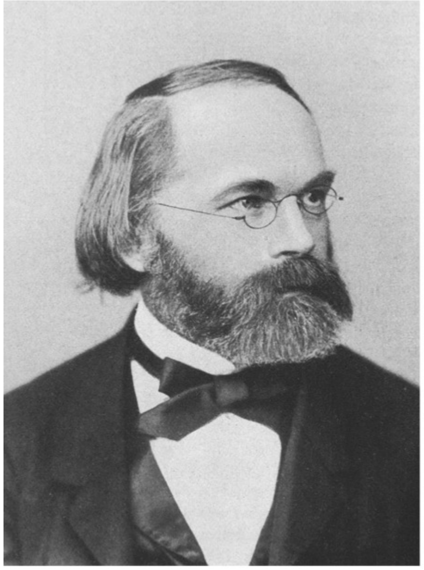
Lothar Löffler
(1901–1983)
Genetics and
mutations

J. Heinrich
Matthaei
(1929–)
Genetic code

Hugo von Mohl
(1805–1872)
Mitosis and
cell biology



Carl Wilhelm
von Nägeli
(1817–1891)
Mitosis



Karl Pirschle
(1900–1945)
Genetics and
mutations

Ernst Plagge
(1911–1945)
Genetics and
mutations

Figure 2.22: Other creators who made significant contributions to knowledge about DNA included Lothar Löffler, J. Heinrich Matthaei, Hugo von Mohl, Carl Wilhelm von Nägeli, Karl Pirschle, and Ernst Plagge.

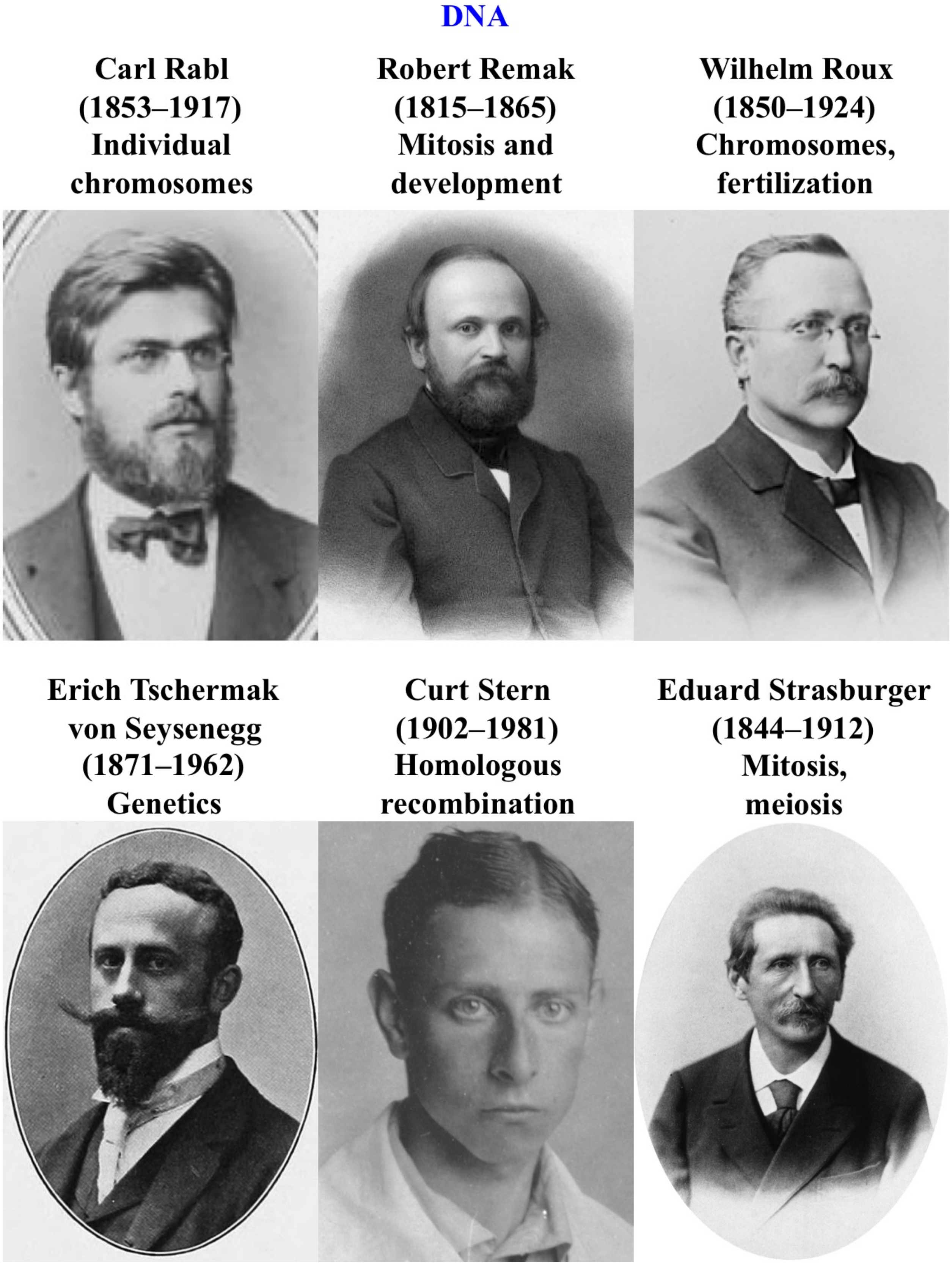

DNA
Carl Rabl
(1853–1917)
Individual chromosomes
Robert Remak
(1815–1865)
Mitosis and development
Wilhelm Roux
(1850–1924)
Chromosomes, fertilization
Erich Tschermak von Seysenegg
(1871–1962)
Genetics
Curt Stern
(1902–1981)
Homologous recombination
Eduard Strasburger
(1844–1912)
Mitosis, meiosis

Figure 2.23: Other creators who made significant contributions to knowledge about DNA included Carl Rabl, Robert Remak, Wilhelm Roux, Erich Tschermak von Seysenegg, Curt Stern, and Eduard Strasburger.

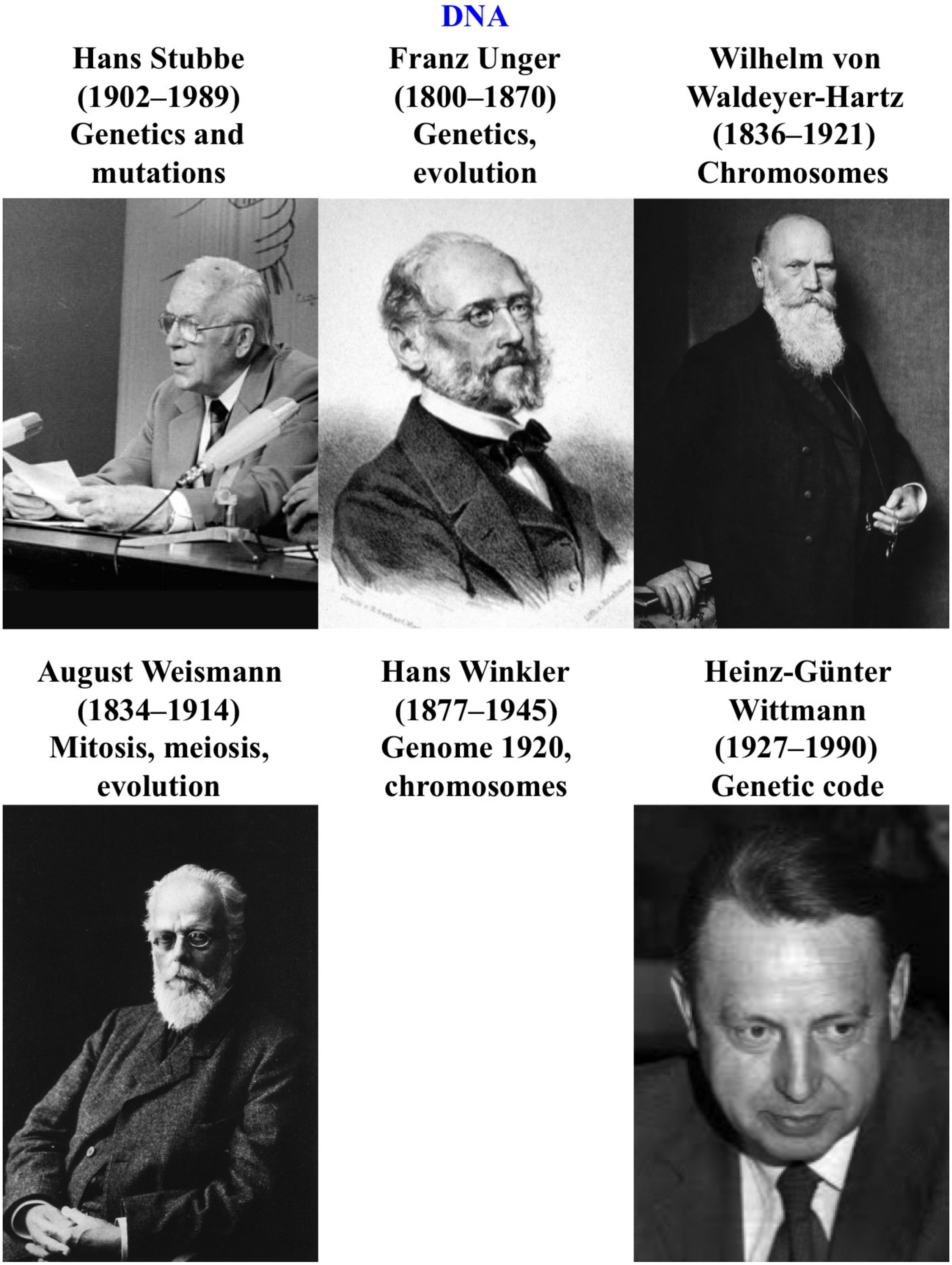

DNA
Hans Stubbe (1902–1989) Genetics and mutations
Franz Unger (1800–1870) Genetics, evolution
Wilhelm von Waldeyer-Hartz (1836–1921) Chromosomes
August Weismann (1834–1914) Mitosis, meiosis, evolution
Hans Winkler (1877–1945) Genome 1920, chromosomes
Heinz-Günter Wittmann (1927–1990) Genetic code

Figure 2.24: Other creators who made significant contributions to knowledge about DNA included Hans Stubbe, Franz Unger, Wilhelm von Waldeyer-Hartz, August Weismann, Hans Winkler, and Heinz-Günter Wittmann.

2.1.3 Cancer

German-speaking scientists dominated the early field of cancer research and cancer prevention (Figs. 2.25–2.32).[6] This field is far larger, and had far more German-speaking creators and discoveries, than can be properly covered in this brief section. Historian of science Robert Proctor gave an overview of some of the remarkably early and remarkably numerous cancer-related discoveries in the German-speaking world [Proctor 1999, pp. 17–19, 281–283]:

> German cancer research—and medical research more generally—was the most advanced in the world by the time of the *Machtergreifung* (1933). German scientists were the first to discover skin cancers caused by coal tar distillates, and the first to show that uranium mining could cause lung cancer (both in the 1870s). Germans were the first to identify a bladder cancer hazard of aniline dye manufacture (in 1895),[14] a lung cancer hazard from chromate manufacture (1911),[15] and a skin cancer hazard of sunlight exposure (1894).[16] German physicians were the first to diagnose an X-ray-induced cancer (in 1902) and the first to prove, by animal experimentation, that X-rays could cause leukemia (1906). They were even the first to suggest that domestic indoor radon might prove to be a health hazard, in 1907.[17]
>
> There are many other examples one can name[18]—and in the interest of completeness (and at the risk of tedium), I shall continue. Johannes Müller in the 1830s pioneered the microscopic analysis of malignancies, identifying tumors as composed of cells, and Rudolf Virchow in Berlin in the 1860s developed the theory of cancer as caused by local "irritations."[19] Germans were pioneers of cancer transplant research,[20] and early in the development of the theory of dose-response latency (*Latenzzeit*).[21] Germans were among the first to propose a major role for hormones in carcinogenesis[22] and were early on aware of what is sometimes today called the "xenoestrogen hypothesis"—the idea that powerful petrochemical carcinogens such as methylcholanthrene may work by mimicking the body's natural hormones.[23] It was a Munich pathologist (Max Borst) who first classified tumors according to their histogenesis, the method used today by the World Health Organization to classify cancers.[24]
>
> The list goes on: Germans were the first to utilize tissue stains as chemotherapeutic agents (in 1922),[25] and were the first to inject thorotrast (thorium dioxide) into patients to improve the contrast in X-ray photographic plates (1928).[26] German geneticists were the first to show that colon cancer could be inherited as a dominant trait, and it was a German zoologist—Theodor H. Boveri—who first proposed that chromosomal abnormalities might be responsible for the onset of malignancies (1902).[27] Germany was the site of the first international congress of cancer research (Heidelberg and Frankfurt, in 1906)[28] and the first country to establish a permanent journal devoted exclusively to cancer research.[29] Germany pioneered the optical diagnosis of cancer, being home to the development of not just X-rays and the colposcope but also the rectal endoscope—a candlelit version of which was introduced in Frankfurt in 1807.[30] German was arguably, at least for a time, the *language* of international cancer research[...] Germans were also

---

[6] Deichmann 1996; Eckart 2000; Haustein 2004; Höxtermann and Sucker 1989; Jahn 2004; Junker 2004; Koesling and Schülke 2010; Kohler 2008; Magner 2002; Possehl 1989; Proctor 1999; Raviña and Kubinyi 2011; Schnalke and Atzl 2010; Schneider 1972; Simmons 2002; Sneader 2005; Wagner and Mauerberger 2012; Weatherall 1991.

> apparently the first to suggest that secondhand tobacco smoke might be a cause of lung cancer—in 1928.[32]
>
> German scientists in the mid-1930s elaborated on this scientific base. The Reich Anticancer Committee (Reichsausschuss für Krebsbekämpfung) established in 1931 was enlarged, and an ambitious new journal, the *Monatsschrift für Krebsbekämpfung* (Monthly journal for the struggle against cancer), published by the notoriously antisemitic J. F. Lehmann publishing house, was launched in 1933 to coordinate the anticancer effort. More than a thousand medical doctoral theses explored cancer in one form or another in the twelve years of Nazi rule; only diseases of the blood attracted more attention. Cancer registries were established, including the first German registries to record cancer morbidity (incidence) and not just mortality (deaths). Efforts were made to strengthen prevention-oriented public health measures, including occupational safeguards, laws against the adulteration of food and drugs, bans on smoking, and programs to reduce the use of cancer-causing cosmetics, to name only a few.[7]

---

[7] Proctor's endnotes referred to the following cancer researchers:

14. Ludwig Rehn (German, 1849–1930).

15. E. Pfeil (German?, 18??–19??).

16. Paul Gerson Unna (German, 1850–1929).

17. Albert Frieben (German?, 18??–19??), Kurt Ziegler (German?, 18??–19??), Heinrich W. Schmidt (German?, 18??–19??), Ekkehard Schmid (German?, 18??–19??), and Nikolaus von Jagić (German/Austrian, 1875–1956).

18. Richard von Volkmann (German, 1830–1889) and Martha Schmidtmann (German 1892–1981).

19. Johannes Peter Müller (German states, 1801–1858) and Rudolf Virchow (German, 1821–1902).

20. Arthur Hanau (Swiss, 18??–19??).

21. Kurt Rostoski (German?, 18??–19??), Erich Saupe (German?, 1893–19??), and Christian Georg Schmorl (German, 1861–1932); Otto Teutschlaender (German?, 18??–19??).

22. Jens Paulsen (German, 18??–19??).

23. Karl Heinrich Bauer (German, 1890–1978) and Adolf Butenandt (German, 1903–1995).

24. Max Borst (German, 1869–1946).

25. Rudolf Roosen (German?, 18??–19??).

26. Theodor Blühbaum (German?, 18??–19??), Karl Frik (German, 1878–1944), and Helmut Kalkbrenner (German?, 18??–19??).

27. Otto Jüngling (German, 1884–1944) and Theodor Boveri (German, 1862–1915). As shown in Fig. 2.25, Boveri conducted extensive studies of cell division (mitosis), chromosome structure, and chromosome abnormalities. In 1902 he realized that cancer can be caused by pro-mitotic (cell-division-inducing) mutations from radiation, chemicals, or viruses.

28. George Meyer (German?, 18??–19??).

29. *Zeitschrift für Krebsforschung.*

Several other prominent German-speaking cancer researchers should also be mentioned here.

Johannes Fibiger (Danish but studied under Robert Koch and Emil von Behring, lived 1867–1928) conducted important clinical trials on diagnostics and therapeutics for diptheria. He won the Nobel Prize in Physiology or Medicine in 1926 for experiments showing that infectious pathogenic organisms can induce cancer. Although his specific conclusions regarding those pathogens (he focused on helminths) were later found to be incorrect, his experiments spurred a great deal of cancer research by other scientists, and his general conclusions have ultimately proven correct, especially with regard to the role of viruses in causing certain types of cancer. Professor W. Wernstedt, Dean of the Royal Caroline Institute, described Fibiger's research [https://www.nobelprize.org/prizes/medicine/1926/ceremony-speech/]:

> *But Fibiger's discovery had a still greater significance.* The possibility of experimentally producing cancer gave to the particular research into this illness an invaluable and badly needed method, lacking until this time, allowing the elucidation of some of the obscure points in the problem of cancer. Fibiger's discovery also gave remarkable impetus to research. Whereas research had, in many respects, entered upon a period of stagnation, Fibiger's discovery marked the beginning of a new era, of a new epoch in the history of cancer, to which the fruitful research made by him gave fresh vigour. From his discoveries we have continued to march forward and have gained valuable ideas as to the nature of this illness.

Arnold Graffi (Austrian/German, 1910–2006) discovered some of the mechanisms by which chemicals and viruses can cause cancer, and helped to develop chemotherapeutic methods to target cancer cells for destruction.

Paul Grawitz (German, 1850–1932) studied various types of cancers, and renal cell carcinoma is named Grawitz's tumor after him.

Rudolf Krönlein (Swiss, 1847–1910) pioneered many types of surgical operations, including surgeries to remove certain kinds of tumors.

Fritz Lickint (German, 1898–1960) began medical studies of smokers vs. nonsmokers in the 1920s, published evidence that smoking causes cancer in 1929, and published a >1200 page medical book on the detailed pathology caused by smoking in 1939. His discoveries led to public health campaigns against smoking, first in Germany and much later worldwide [Haustein 2004]. See Fig. 2.26.

Hans Sachs (German, 1877–1945) studied interactions between the immune system and cancer.

Otto Heinrich Warburg (German, 1883–1970) discovered important metabolic changes that distinguish cancer cells from normal cells.

Creators from the German-speaking world also developed sunscreen lotion, which reduces the incidence of skin cancer.[8]

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30. Leopold Schönbauer (Austrian, 1888–1963) and Erna Schmidt-Überreiter (German?, 18??–19??).

32. Ernst Schönherr (German?, 18??–19??).

[8] Eder and Freund 1922; Hammer 1891; Hausser and Vahle 1922; Urbach 2001; Vogt 2008; von Weiher 1983;

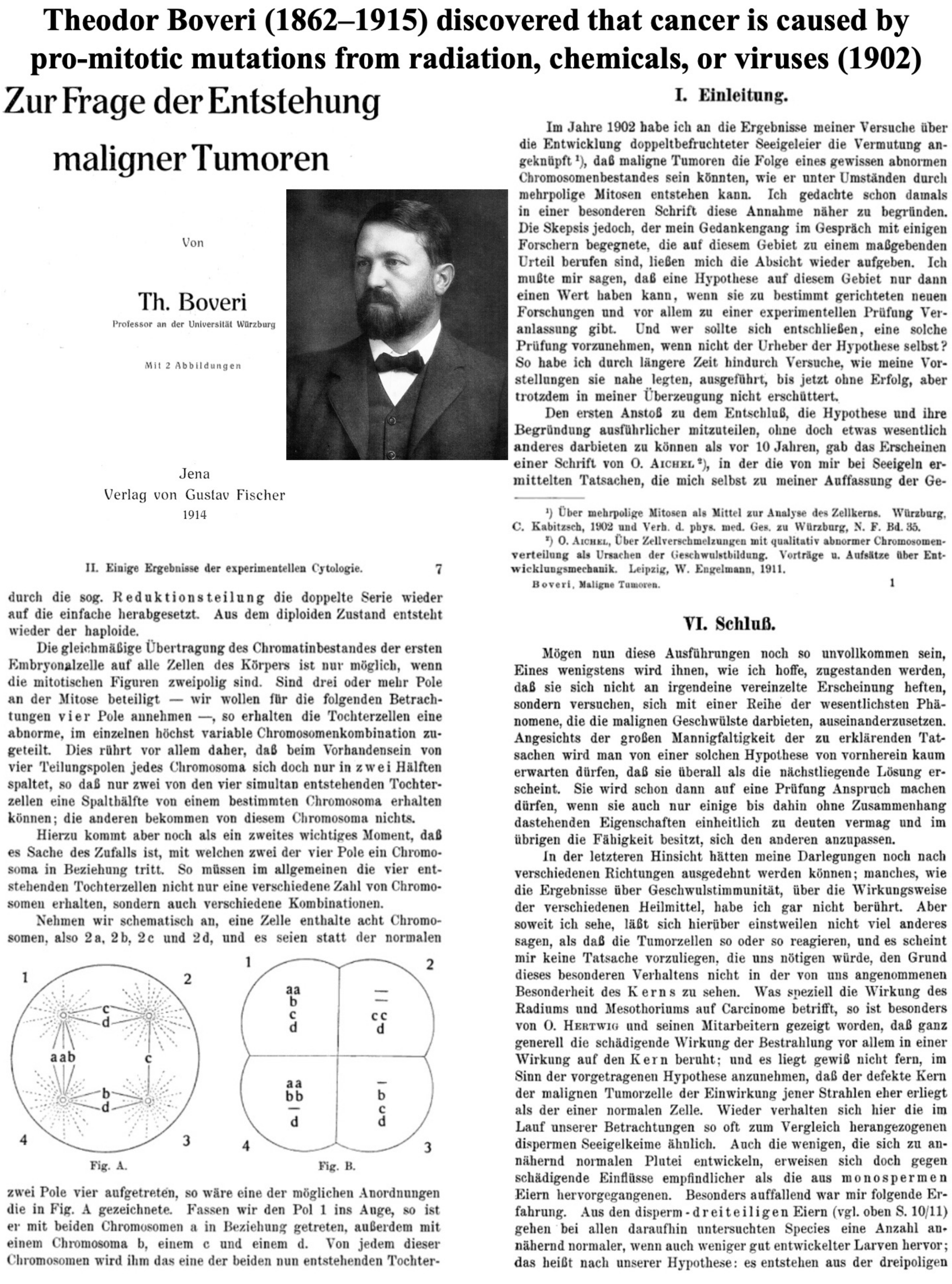
During the period 1889–1891, Erik Johan Widmark (Swedish but closely coupled to the German-speaking research world, 1850–1909) and Friedrich Hammer (German, 1860–1943) demonstrated via a series of experiments that ultraviolet light causes sunburns and suntans, and that those effects could be reduced by coating the skin with a protective layer of certain natural plant extracts. See Fig. 2.33.

In 1922, Josef Maria Eder (Austrian, 1855–1944) and Leopold Freund (Austrian, 1868–1943) invented the first chemical sunscreen, which was marketed as Antilux. See Fig. 2.34. Freund also invented and successfully demonstrated radiation therapy in 1896 (p. 1509).

In 1938, Franz Greiter (Austrian, 1919–1985) developed an improved sunscreen that was ultimately marketed as Piz Buin Gletscher Crème, as shown in Fig. 2.35.

During the period 1922–1956, Karl Wilhelm Hausser (German, 1887–1933), his wife Isolde (Ganswindt) Hausser (German, 1889–1951), Wilhelm Vahle (German?, 18??–19??), Friedrich Ellinger (German, 1900–1962), and Rudolf Schulze (German, 1906–1974) developed increasingly sophisticated methods of measuring the sun protection factor (SPF) offered by sunscreens, as well as the cellular damage caused by ultraviolet exposure. See Fig. 2.35. Isolde Hausser was the daughter of Hermann Ganswindt (pp. 1643, 1801, and 1953), ran a department at the Kaiser Wilhelm Institute for Medical Research, and also made important contributions to radiation therapy for cancer.

Widmark 1889.



Theodor Boveri (1862–1915) discovered that cancer is caused by pro-mitotic mutations from radiation, chemicals, or viruses (1902)

Zur Frage der Entstehung maligner Tumoren

Von

Th. Boveri
Professor an der Universität Würzburg

Mit 2 Abbildungen

Jena
Verlag von Gustav Fischer
1914

II. Einige Ergebnisse der experimentellen Cytologie. 7

durch die sog. Reduktionsteilung die doppelte Serie wieder auf die einfache herabgesetzt. Aus dem diploiden Zustand entsteht wieder der haploide.

Die gleichmäßige Übertragung des Chromatinbestandes der ersten Embryonalzelle auf alle Zellen des Körpers ist nur möglich, wenn die mitotischen Figuren zweipolig sind. Sind drei oder mehr Pole an der Mitose beteiligt — wir wollen für die folgenden Betrachtungen vier Pole annehmen —, so erhalten die Tochterzellen eine abnorme, im einzelnen höchst variable Chromosomenkombination zugeteilt. Dies rührt vor allem daher, daß beim Vorhandensein von vier Teilungspolen jedes Chromosoma sich doch nur in zwei Hälften spaltet, so daß nur zwei von den vier simultan entstehenden Tochterzellen eine Spalthälfte von einem bestimmten Chromosoma erhalten können; die anderen bekommen von diesem Chromosoma nichts.

Hierzu kommt aber noch als ein zweites wichtiges Moment, daß es Sache des Zufalls ist, mit welchen zwei der vier Pole ein Chromosoma in Beziehung tritt. So müssen im allgemeinen die vier entstehenden Tochterzellen nicht nur eine verschiedene Zahl von Chromosomen erhalten, sondern auch verschiedene Kombinationen.

Nehmen wir schematisch an, eine Zelle enthalte acht Chromosomen, also 2 a, 2 b, 2 c und 2 d, und es seien statt der normalen zwei Pole vier aufgetreten, so wäre eine der möglichen Anordnungen die in Fig. A gezeichnete. Fassen wir den Pol 1 ins Auge, so ist er mit beiden Chromosomen a in Beziehung getreten, außerdem mit einem Chromosoma b, einem c und einem d. Von jedem dieser Chromosomen wird ihm das eine der beiden nun entstehenden Tochter-

Fig. A.

Fig. B.

I. Einleitung.

Im Jahre 1902 habe ich an die Ergebnisse meiner Versuche über die Entwicklung doppeltbefruchteter Seeigeleier die Vermutung angeknüpft [1]), daß maligne Tumoren die Folge eines gewissen abnormen Chromosomenbestandes sein könnten, wie er unter Umständen durch mehrpolige Mitosen entstehen kann. Ich gedachte schon damals in einer besonderen Schrift diese Annahme näher zu begründen. Die Skepsis jedoch, der mein Gedankengang im Gespräch mit einigen Forschern begegnete, die auf diesem Gebiet zu einem maßgebenden Urteil berufen sind, ließen mich die Absicht wieder aufgeben. Ich mußte mir sagen, daß eine Hypothese auf diesem Gebiet nur dann einen Wert haben kann, wenn sie zu bestimmt gerichteten neuen Forschungen und vor allem zu einer experimentellen Prüfung Veranlassung gibt. Und wer sollte sich entschließen, eine solche Prüfung vorzunehmen, wenn nicht der Urheber der Hypothese selbst? So habe ich durch längere Zeit hindurch Versuche, wie meine Vorstellungen sie nahe legten, ausgeführt, bis jetzt ohne Erfolg, aber trotzdem in meiner Überzeugung nicht erschüttert.

Den ersten Anstoß zu dem Entschluß, die Hypothese und ihre Begründung ausführlicher mitzuteilen, ohne doch etwas wesentlich anderes darbieten zu können als vor 10 Jahren, gab das Erscheinen einer Schrift von O. AICHEL [2]), in der die von mir bei Seeigeln ermittelten Tatsachen, die mich selbst zu meiner Auffassung der Ge-

---

[1]) Über mehrpolige Mitosen als Mittel zur Analyse des Zellkerns. Würzburg, C. Kabitzsch, 1902 und Verh. d. phys. med. Ges. zu Würzburg, N. F. Bd. 35.

[2]) O. AICHEL, Über Zellverschmelzungen mit qualitativ abnormer Chromosomenverteilung als Ursachen der Geschwulstbildung. Vorträge u. Aufsätze über Entwicklungsmechanik. Leipzig, W. Engelmann, 1911.

Boveri, Maligne Tumoren. 1

VI. Schluß.

Mögen nun diese Ausführungen noch so unvollkommen sein, Eines wenigstens wird ihnen, wie ich hoffe, zugestanden werden, daß sie sich nicht an irgendeine vereinzelte Erscheinung heften, sondern versuchen, sich mit einer Reihe der wesentlichsten Phänomene, die die malignen Geschwülste darbieten, auseinanderzusetzen. Angesichts der großen Mannigfaltigkeit der zu erklärenden Tatsachen wird man von einer solchen Hypothese von vornherein kaum erwarten dürfen, daß sie überall als die nächstliegende Lösung erscheint. Sie wird schon dann auf eine Prüfung Anspruch machen dürfen, wenn sie auch nur einige bis dahin ohne Zusammenhang dastehenden Eigenschaften einheitlich zu deuten vermag und im übrigen die Fähigkeit besitzt, sich den anderen anzupassen.

In der letzteren Hinsicht hätten meine Darlegungen noch nach verschiedenen Richtungen ausgedehnt werden können; manches, wie die Ergebnisse über Geschwulstimmunität, über die Wirkungsweise der verschiedenen Heilmittel, habe ich gar nicht berührt. Aber soweit ich sehe, läßt sich hierüber einstweilen nicht viel anderes sagen, als daß die Tumorzellen so oder so reagieren, und es scheint mir keine Tatsache vorzuliegen, die uns nötigen würde, den Grund dieses besonderen Verhaltens nicht in der von uns angenommenen Besonderheit des Kerns zu sehen. Was speziell die Wirkung des Radiums und Mesothoriums auf Carcinome betrifft, so ist besonders von O. HERTWIG und seinen Mitarbeitern gezeigt worden, daß ganz generell die schädigende Wirkung der Bestrahlung vor allem in einer Wirkung auf den Kern beruht; und es liegt gewiß nicht fern, im Sinn der vorgetragenen Hypothese anzunehmen, daß der defekte Kern der malignen Tumorzelle der Einwirkung jener Strahlen eher erliegt als der einer normalen Zelle. Wieder verhalten sich hier die im Lauf unserer Betrachtungen so oft zum Vergleich herangezogenen dispermen Seeigelkeime ähnlich. Auch die wenigen, die sich zu annähernd normalen Plutei entwickeln, erweisen sich doch gegen schädigende Einflüsse empfindlicher als die aus monospermen Eiern hervorgegangenen. Besonders auffallend war mir folgende Erfahrung. Aus den disperm-dreiteiligen Eiern (vgl. oben S. 10/11) gehen bei allen daraufhin untersuchten Species eine Anzahl annähernd normaler, wenn auch weniger gut entwickelter Larven hervor; das heißt nach unserer Hypothese: es entstehen aus der dreipoligen

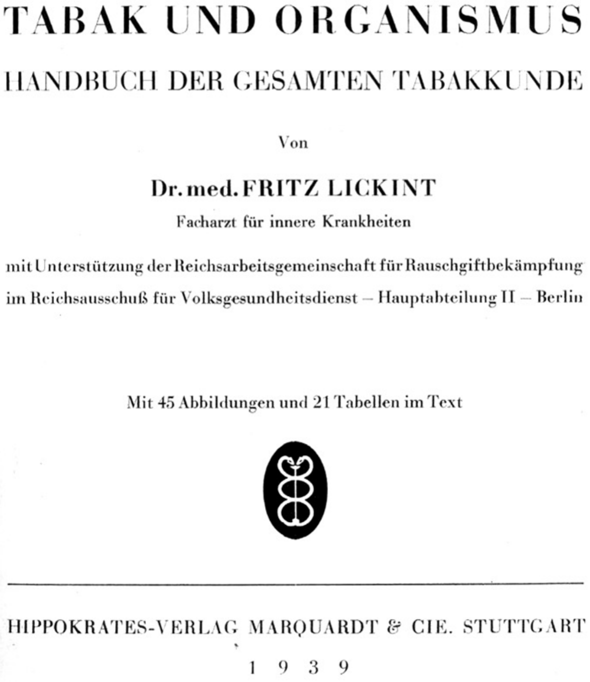
Figure 2.25: Theodor Boveri discovered in 1902 that cancer can be caused by pro-mitotic (cell-division-inducing) mutations from radiation, chemicals, or viruses.

Fritz Lickint (1898–1960)

Began studies of smokers vs. nonsmokers (1920s)

Published evidence that smoking causes cancer (1929)

Published >1200 page medical book on detailed pathology (1939)



TABAK UND ORGANISMUS

HANDBUCH DER GESAMTEN TABAKKUNDE

Von

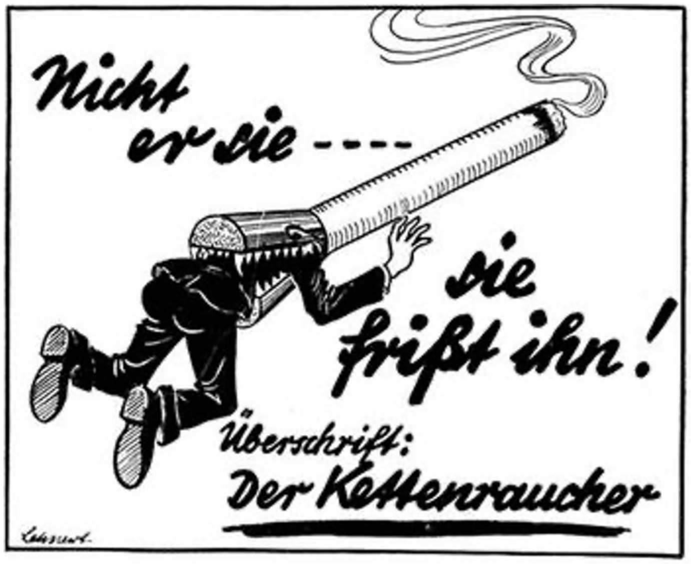
Dr. med. FRITZ LICKINT

Facharzt für innere Krankheiten

mit Unterstützung der Reichsarbeitsgemeinschaft für Rauschgiftbekämpfung
im Reichsausschuß für Volksgesundheitsdienst – Hauptabteilung II – Berlin

Mit 45 Abbildungen und 21 Tabellen im Text

HIPPOKRATES-VERLAG MARQUARDT & CIE. STUTTGART
1939



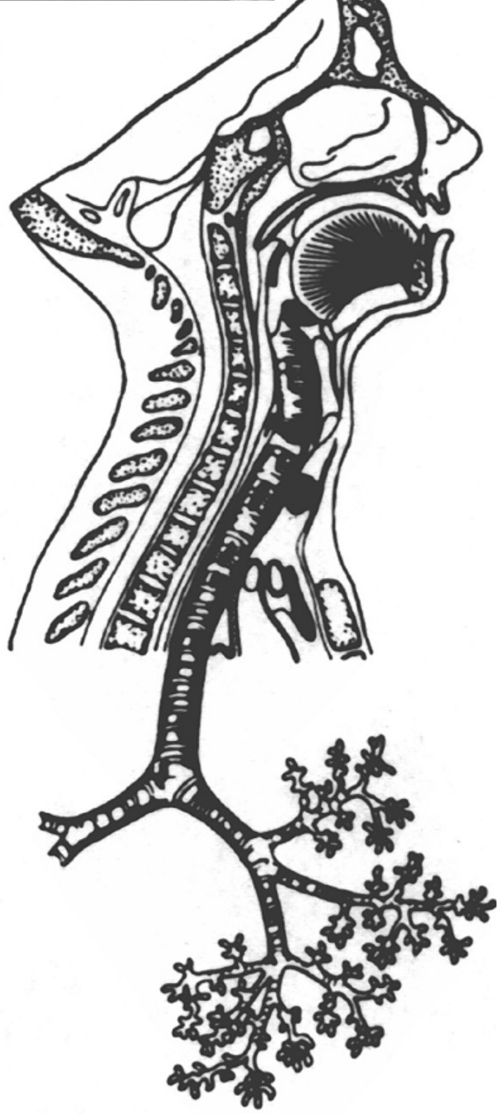


Figure 2.26: Fritz Lickint began medical studies of smokers vs. nonsmokers in the 1920s, published evidence that smoking causes cancer in 1929, and published a >1200 page medical book on the detailed pathology caused by smoking in 1939. His discoveries led to public health campaigns against smoking, first in Germany and much later worldwide.

Cancer

Karl Heinrich Bauer
(1890–1978)

Theodor Blühbaum
(18??–19??)

Max Borst
(1869–1946)

Adolf Butenandt
(1903–1995)

Johannes Fibiger
(1867–1928)

Albert Frieben
(18??–19??)

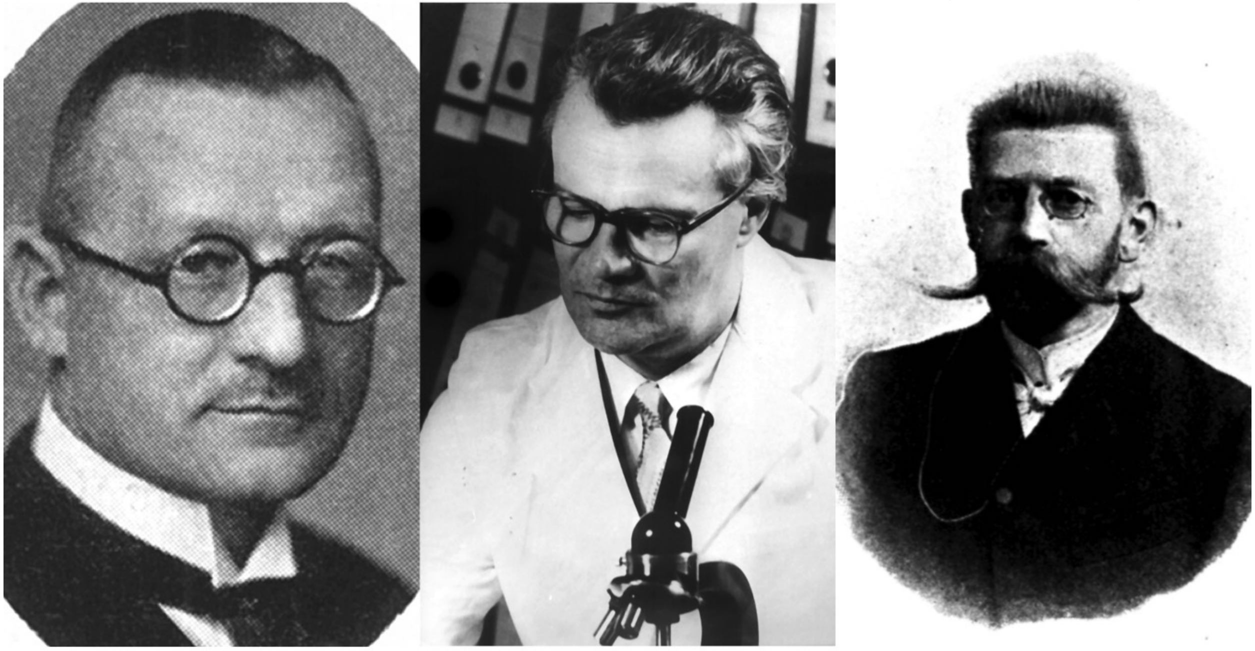
Figure 2.27: Other creators who made significant contributions to knowledge about cancer included Karl Heinrich Bauer, Theodor Blühbaum, Max Borst, Adolf Butenandt, Johannes Fibiger, and Albert Frieben.

Cancer

Karl Frik
(1878–1944)

Arnold Graffi
(1910–2006)

Paul Grawitz
(1850–1932)



Arthur Hanau
(18??–19??)

Nikolaus von Jagić
(1875–1956)

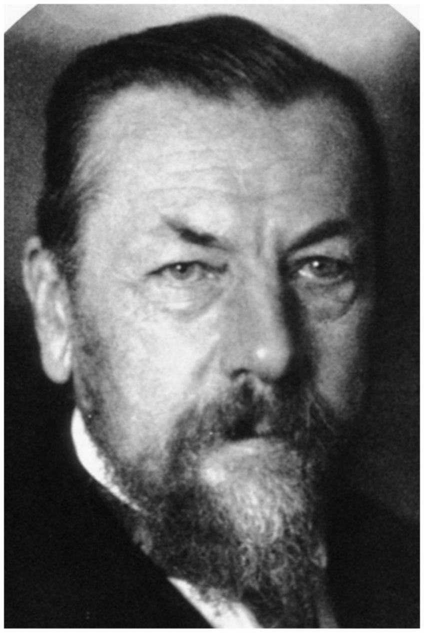
Otto Jüngling
(1884–1944)

Figure 2.28: Other creators who made significant contributions to knowledge about cancer included Karl Frik, Arnold Graffi, Paul Grawitz, Arthur Hanau, Nikolaus von Jagić, and Otto Jüngling.

Cancer

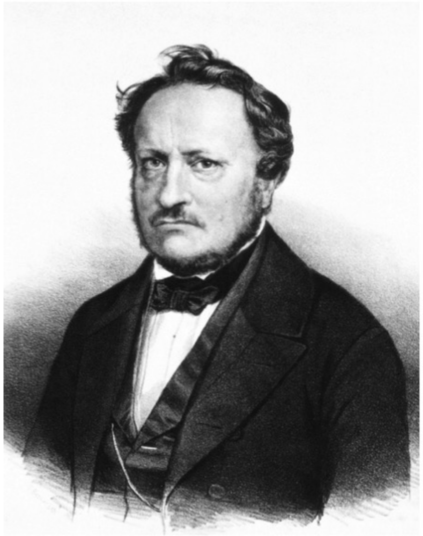
Helmut Kalkbrenner (18??–19??)

Rudolf Krönlein (1847–1910)



George Meyer (18??–19??)

Johannes Peter Müller (1801–1858)



Jens Paulsen (18??–19??)

E. Pfeil (18??–19??)

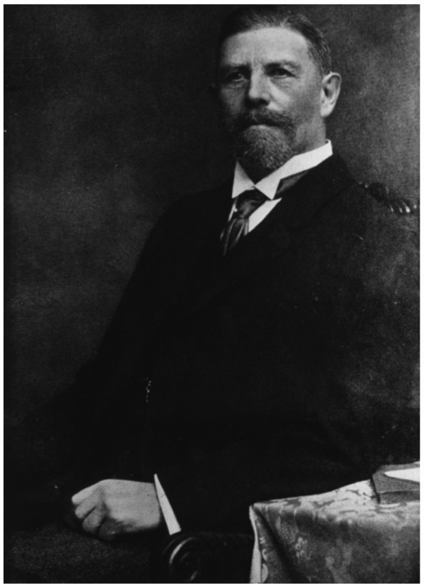
Figure 2.29: Other creators who made significant contributions to knowledge about cancer included Helmut Kalkbrenner, Rudolf Krönlein, George Meyer, Johannes Peter Müller, Jens Paulsen, and E. Pfeil.

Cancer

Ludwig Rehn
(1849–1930)

Rudolf Roosen
(18??–19??)

Kurt Rostoski
(18??–19??)



Hans Sachs
(1877–1945)

Erich Saupe
(1893–19??)

Ekkehard Schmid
(18??–19??)

Figure 2.30: Other creators who made significant contributions to knowledge about cancer included Ludwig Rehn, Rudolf Roosen, Kurt Rostoski, Hans Sachs, Erich Saupe, and Ekkehard Schmid.

Cancer

**Heinrich W.
Schmidt
(18??–19??)**

**Erna
Schmidt-Überreiter
(18??–19??)**

**Martha
Schmidtmann
(1892–1981)**

**Christian Georg
Schmorl
(1861–1932)**

**Leopold
Schönbauer
(1888–1963)**

**Ernst
Schönherr
(18??–19??)**

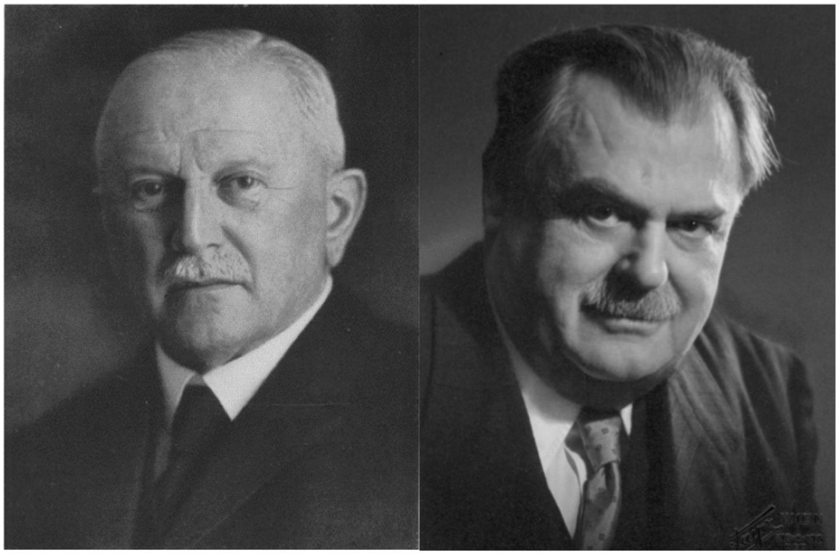
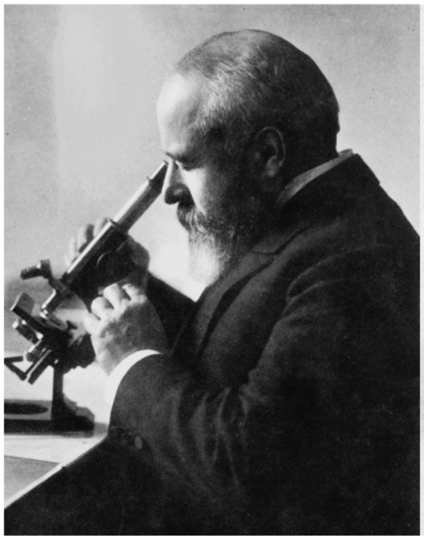


Figure 2.31: Other creators who made significant contributions to knowledge about cancer included Heinrich W. Schmidt, Erna Schmidt-Überreiter, Martha Schmidtmann, Christian Georg Schmorl, Leopold Schönbauer, and Ernst Schönherr.

Cancer

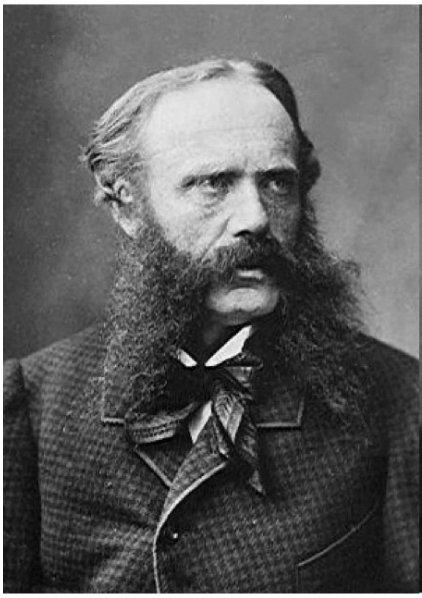
Otto Teutschlaender (18??–19??)

Paul Gerson Unna (1850–1929)



Rudolf Virchow (1821–1902)

Richard von Volkmann (1830–1889)



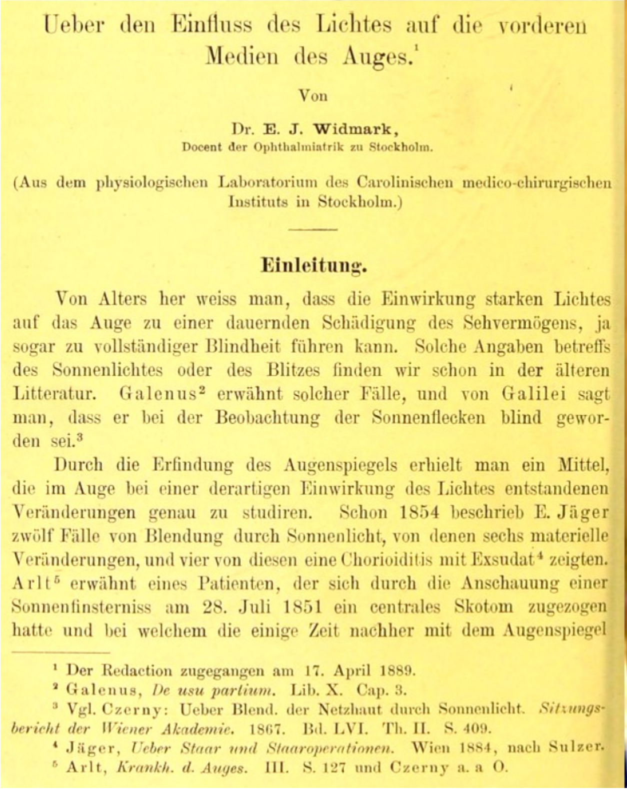
Otto Heinrich Warburg (1883–1970)

Kurt Ziegler (18??–19??)

Figure 2.32: Other creators who made significant contributions to knowledge about cancer included Otto Teutschlaender, Paul Gerson Unna, Rudolf Virchow, Richard von Volkmann, Otto Heinrich Warburg, and Kurt Ziegler.

Ultraviolet light causes sunburns and sun tans (1889–1891)

Erik Johan Widmark (1850–1909) Friedrich Hammer (1860–1943)



Ueber den Einfluss des Lichtes auf die vorderen Medien des Auges.[1]

Von

Dr. E. J. Widmark,
Docent der Ophthalmiatrik zu Stockholm.

(Aus dem physiologischen Laboratorium des Carolinischen medico-chirurgischen Instituts in Stockholm.)

Einleitung.

Von Alters her weiss man, dass die Einwirkung starken Lichtes auf das Auge zu einer dauernden Schädigung des Sehvermögens, ja sogar zu vollständiger Blindheit führen kann. Solche Angaben betreffs des Sonnenlichtes oder des Blitzes finden wir schon in der älteren Litteratur. Galenus[2] erwähnt solcher Fälle, und von Galilei sagt man, dass er bei der Beobachtung der Sonnenflecken blind geworden sei.[3]

Durch die Erfindung des Augenspiegels erhielt man ein Mittel, die im Auge bei einer derartigen Einwirkung des Lichtes entstandenen Veränderungen genau zu studiren. Schon 1854 beschrieb E. Jäger zwölf Fälle von Blendung durch Sonnenlicht, von denen sechs materielle Veränderungen, und vier von diesen eine Chorioiditis mit Exsudat[4] zeigten. Arlt[5] erwähnt eines Patienten, der sich durch die Anschauung einer Sonnenfinsterniss am 28. Juli 1851 ein centrales Skotom zugezogen hatte und bei welchem die einige Zeit nachher mit dem Augenspiegel

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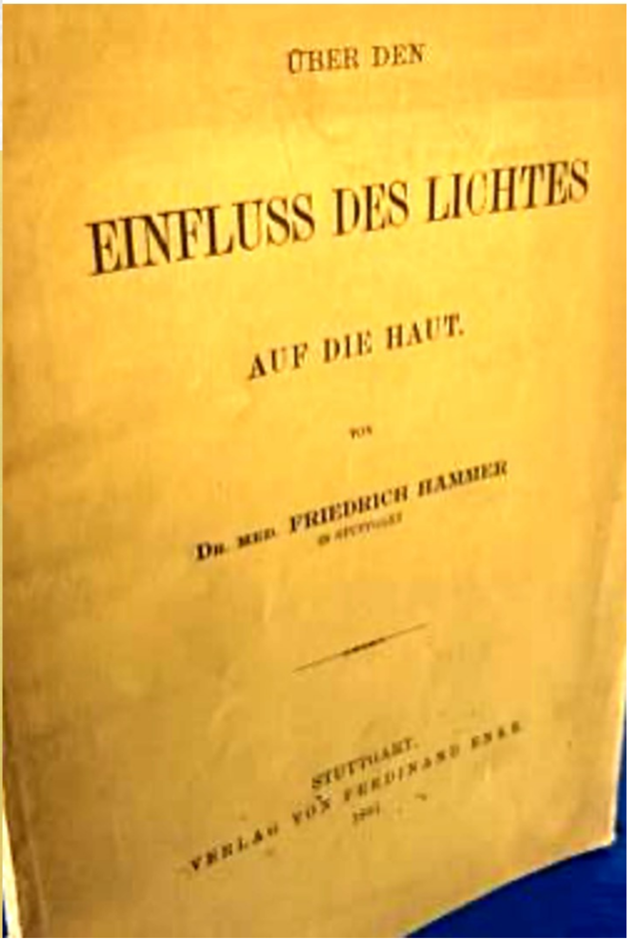
[1] Der Redaction zugegangen am 17. April 1889.

[2] Galenus, *De usu partium.* Lib. X. Cap. 3.

[3] Vgl. Czerny: Ueber Blend. der Netzhaut durch Sonnenlicht. *Sitzungsbericht der Wiener Akademie.* 1867. Bd. LVI. Th. II. S. 409.

[4] Jäger, *Ueber Staar und Staaroperationen.* Wien 1884, nach Sulzer.

[5] Arlt, *Krankh. d. Auges.* III. S. 127 und Czerny a. a O.



ÜBER DEN
EINFLUSS DES LICHTES
AUF DIE HAUT.

VON

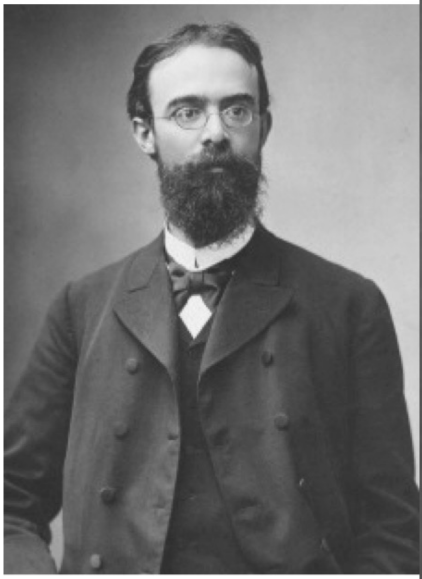
DR. MED. FRIEDRICH HAMMER

STUTTGART.
VERLAG VON FERDINAND ENKE

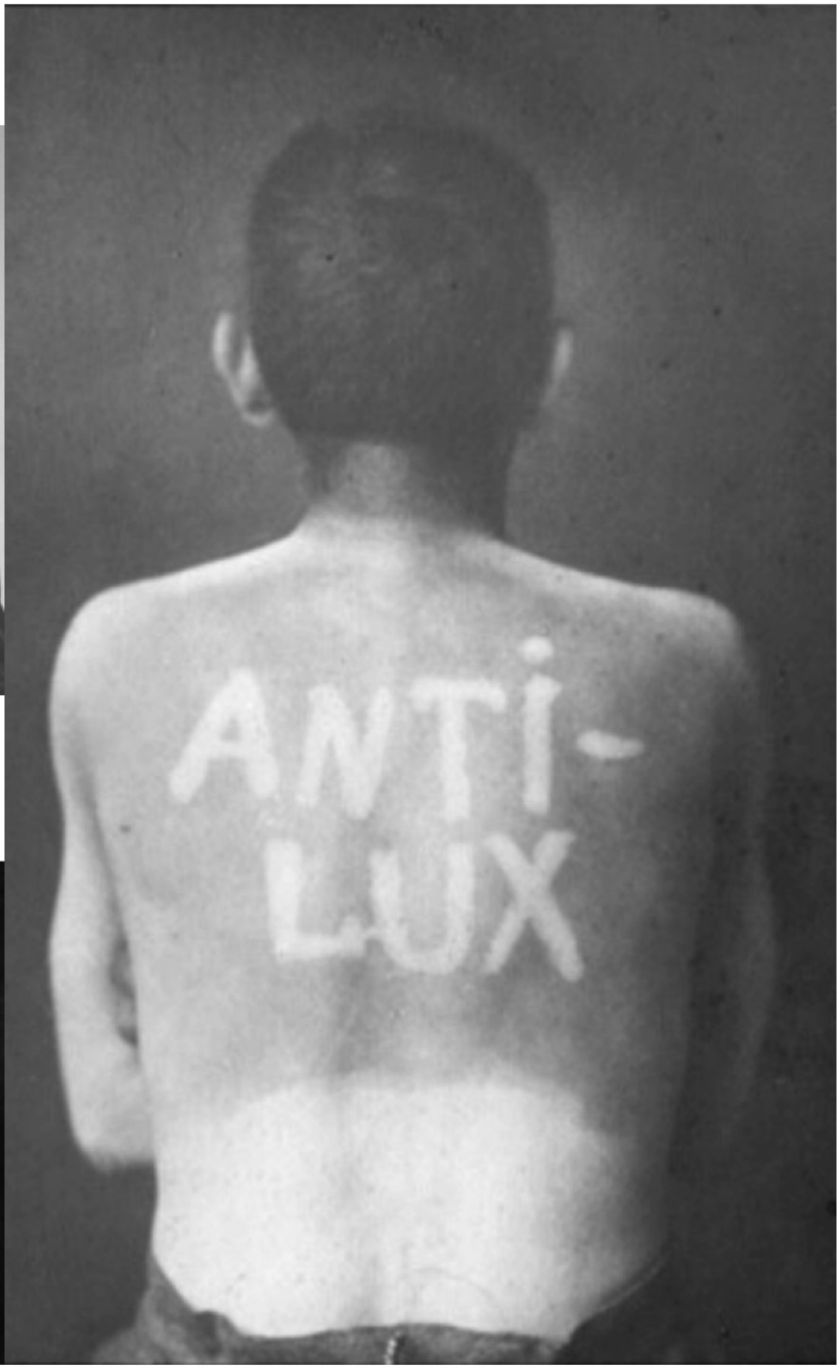
Figure 2.33: During the period 1889–1891, Erik Johan Widmark and Friedrich Hammer demonstrated that ultraviolet light causes sunburns and suntans.

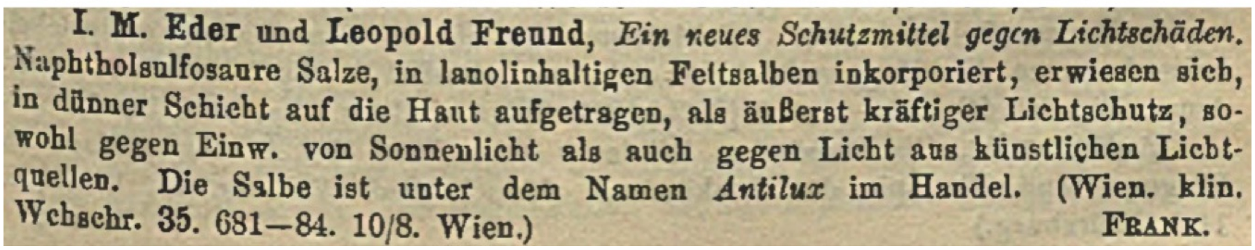
First chemical sunscreen: Antilux (1922)

Josef Maria Eder
(1855–1944)



Leopold Freund
(1868–1943)





I. M. **Eder** und **Leopold Freund**, *Ein neues Schutzmittel gegen Lichtschäden.* Naphtholsulfosaure Salze, in lanolinhaltigen Feltsalben inkorporiert, erwiesen sich, in dünner Schicht auf die Haut aufgetragen, als äußerst kräftiger Lichtschutz, sowohl gegen Einw. von Sonnenlicht als auch gegen Licht aus künstlichen Lichtquellen. Die Salbe ist unter dem Namen *Antilux* im Handel. (Wien. klin. Wchschr. 35. 681—84. 10/8. Wien.) FRANK.

Figure 2.34: In 1922, Josef Maria Eder and Leopold Freund invented the first chemical sunscreen, which was marketed as Antilux.

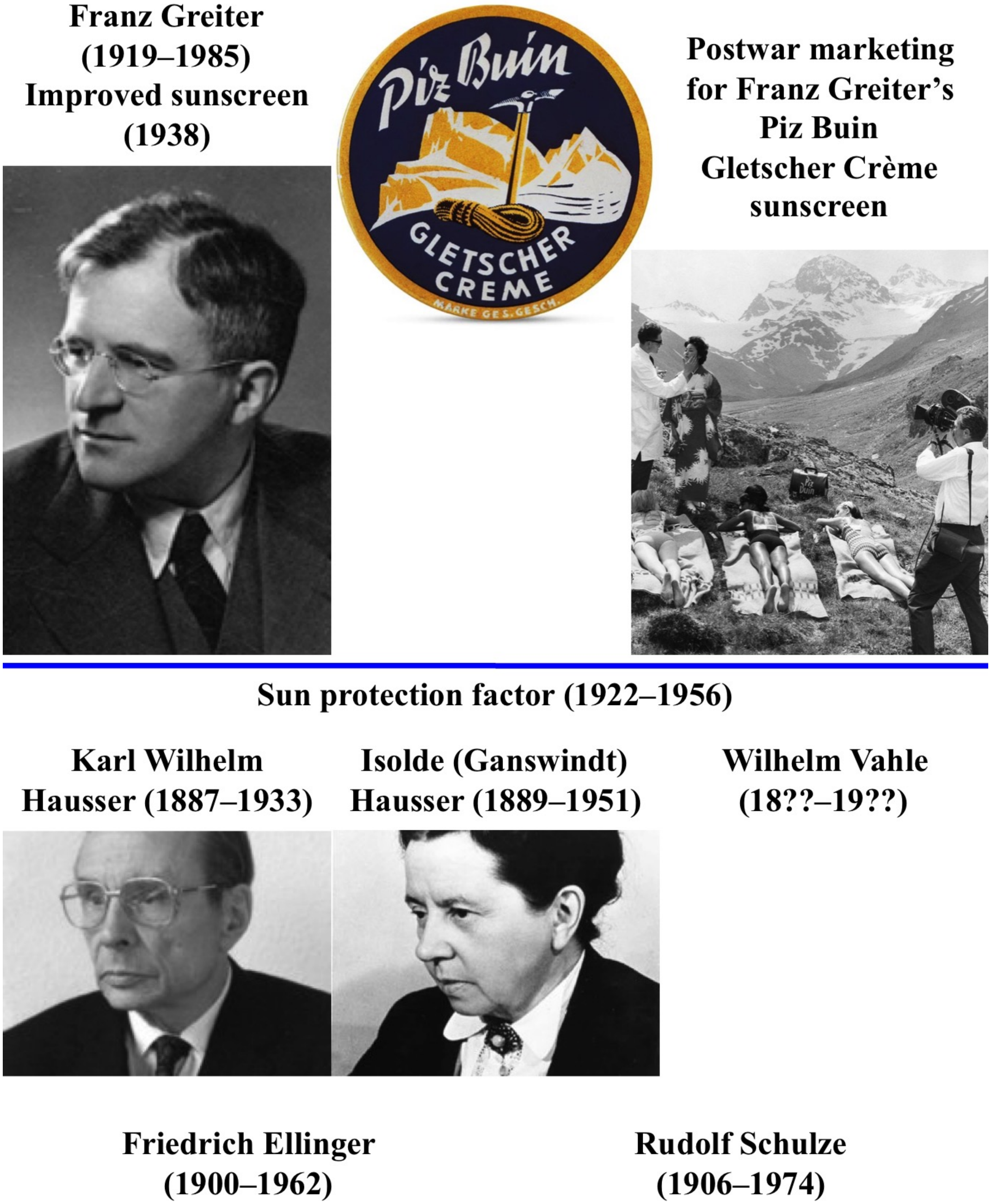

Franz Greiter
(1919–1985)
Improved sunscreen
(1938)
Piz Buin
GLETSCHER
CREME
MARKE GES.GESCH.
Postwar marketing
for Franz Greiter's
Piz Buin
Gletscher Crème
sunscreen
Piz Buin
Sun protection factor (1922–1956)
Karl Wilhelm
Hausser (1887–1933)
Isolde (Ganswindt)
Hausser (1889–1951)
Wilhelm Vahle
(18??–19??)
Friedrich Ellinger
(1900–1962)
Rudolf Schulze
(1906–1974)

Figure 2.35: In 1938, Franz Greiter developed an improved sunscreen that was ultimately marketed as Piz Buin Gletscher Crème. During the period 1922–1956, Karl Wilhelm Hausser, his wife Isolde (Ganswindt) Hausser, Wilhelm Vahle, Friedrich Ellinger, and Rudolf Schulze developed increasingly sophisticated methods of measuring the sun protection factor (SPF) offered by sunscreens.

2.1.4 Proteins and Enzymes

Figures 2.36–2.37 show the 20 standard amino acids and how those are joined together to make proteins. Many proteins are enzymes, essentially tiny biological machines that are specialized to do a particular task. As presented in Figs. 2.38–2.46, creators from the German-speaking world made many critical contributions to our knowledge about proteins and enzymes.[9]

Johann Purkinje (Austrian/Czech, 1787–1869, Fig. 2.40) was most famous for his contributions to cell biology and microscopy (p. 78), yet in 1836 he also discovered that pancreatic extracts contained enzymes that digested proteins.

Theodor Schwann (German, 1810–1882, Fig. 2.40), another cell biologist (p. 79), also discovered protein-digesting enzymes in 1836. He identified the enzyme pepsin from the stomach lining and studied its properties. He then went on to investigate the enzymatic processes of fermentation.

Wilhelm Kühne (German, 1837–1900) coined the word "enzyme." He studied the protein-digesting enzyme trypsin from the pancreas (drawing upon the earlier work by Purkinje and Schwann), and he also studied proteins in muscle. See Fig. 2.41.

Franz Hofmeister (Austrian, 1850–1922) established many methods of protein chemistry that are still used today (Fig. 2.42). He discovered the peptide bonds in proteins, the effect of various salts on proteins, differing protein solubilities, methods of protein purification, and methods of protein crystallization [Abernethy 1967].

Hermann Emil Fischer (German, 1852–1919, Fig. 2.38) studied enzymes involved in the synthesis of sugars and purine molecules, and made numerous other contributions to organic chemistry. He won the Nobel Prize in Chemistry in 1902 (p. 469). One of his students, Max Bergmann, built upon Fischer's work on proteins and enzymes by developing methods to analyze and synthesize proteins.

Albrecht Kossel (German, 1853–1927, Fig. 2.43) found that proteins were composed of individual amino acids. He determined the chemical composition of DNA and RNA too [Mary Ellen Jones 1953]. For his discoveries regarding proteins and nucleic acids, he won the Nobel Prize in Physiology or Medicine in 1910 (p. 90). In a 1911 lecture, Kossel demonstrated his remarkably early and detailed knowledge of protein structure [Olby 1994, p. 77]:

> [W]e must remember that the proteins are composed of *Bausteine* [building blocks, i.e. amino acids] united in very different ways[...] The number of *Bausteine* which can take part in the formation of the proteins is about as large as the number of letters in the alphabet. When we consider that through the combination of letters an infinitely large number of thoughts may be expressed, we can understand how vast a number of the properties of the organism may be recorded in the small space which is occupied by the protein molecules. [...] We may also comprehend how great and important the task is to determine the structure of the proteins and why the biochemist has devoted himself with so much industry to their analysis.

---

[9] Deichmann 1996; Dominguez-Lacasa 2005; Gausemeier 2005; Gedeon 2006; Henry Harris 1999; Holmes 1993; Höxtermann and Sucker 1989; Jahn 2004; Junker 2004; Kohler 2008; Krebs 1981; 2005; Magner 2002; Perutz 1989, 1998; von Schwerin 2013; Simmons 2002 Stoff 2012.

Eduard Buchner (German, 1860–1917, Fig. 2.38) discovered cell-free enzymes for fermentation, for which he won the Nobel Prize in Chemistry in 1907. Professor the Count K. A. H. Mörner, President of the Royal Swedish Academy of Sciences, praised the revolutionary nature of Buchner's discoveries [https://www.nobelprize.org/prizes/chemistry/1907/ceremony-speech/]:

> Under these circumstances it can easily be understood that a great sensation was created when E. Buchner, after many years' work, succeeded in showing that alcoholic fermentation could be produced from the juices expressed from yeast cells, free from live cells. He demonstrated incontrovertibly that this fermentation was due to a ferment produced by the yeast cells, from which it can be separated. Fermentation is not a direct expression of life by yeast cells; the cells can be killed and destroyed, while the ferment remains.
>
> By Buchner's work, the fermentation mentioned and various other processes analogous to it have been freed from the shackles which previously held them and which prevented any progress in research. Now, no special difficulty is encountered in obtaining from yeast cells and various other cells an ample amount of powerfully active cell substance which is free from live cells. Numerous clarifying investigations into its properties have also been made, partly by Buchner himself and partly by others. Hitherto inaccessible territories have now been brought into the field of chemical research, and vast new prospects have now been opened up to chemical science.

Friedrich Kutscher (German, 1866–1942, Fig. 2.40) conducted important early research on the molecular structures of amino acids, proteins, and nucleic acids. In his early career, he worked closely with Albrecht Kossel.

Richard Willstätter (German, 1872–1942, Fig. 2.40) is best known for his discoveries regarding the molecular structures of chlorophyll, for which he won the Nobel Prize in Chemistry in 1915 (p. 407). However, he subsequently went on to conduct extensive investigations of the nature and properties of enzymes.

Hans von Euler-Chelpin (German, 1873–1964, Fig. 2.38) made many discoveries regarding enzymes and won the Nobel Prize in Chemistry in 1929. Professor H.G. Söderbaum, Chairman of the Nobel Committee for Chemistry, explained von Euler-Chelpin's work [https://www.nobelprize.org/prizes/chemistry/1929/ceremony-speech/]:

> In the same measure as research in this department has made new conquests, a clearer and clearer insight has been gained into the importance of this discovery. In particular the work of von Euler and his pupils during the last few years greatly contributed to the unravelling of the mechanism of phosphorization.
>
> The primary function of phosphoric acid in fermentation consists, according to von Euler, in the fact that in cooperation with an enzyme it gives rise to glucose monophosphate, identical with the monophosphate discovered by Harden and Robison. This phosphate afterwards undergoes a mutation in the presence of co-zymase, inasmuch as a glucose diphosphate and an active glucose are formed, after which the latter yields the necessary material for the subsequent stages of the fermentation.

> This demonstration of the part of mutase played by the co-zymase, or in other words of the identity of co-zymase and co-mutase, is of fundamental importance, for it has fully revealed the central position in the process of fermentation of the complementary enzyme in question.
>
> The researches of von Euler and his pupils have further led to the concentration of the co-zymase and to a far more exact study of its properties than had been previously possible. They have been able to determine approximately its molecular weight, which has been found to be about 490; and they have also been able to draw certain definite conclusions concerning its chemical nature, which make it highly probable that we have here what the chemists call a pentosenucleoside. The production of a co-zymase with a high activity has also shown in a brilliant manner the character of that enzyme as a specific activator.

As illustrated in Fig. 2.45, Leonor Michaelis (German, 1875–1949) and Maud Menten (Canadian, worked in Germany, 1879–1960) studied the chemical reaction rates of enzymes. Their experimental and theoretical methods of analyzing enzyme-catalyzed reaction rates (Michaelis-Menten kinetics, Michaelis-Menten graphs, the Michaelis-Menten equation, etc.) are still widely used in biology and chemistry.

Otto Röhm (German, 1876–1939), shown in Fig. 2.44, pioneered the industrial use of enzymes for applications such as leather production (1906), washing detergents (1914), pharmaceuticals (1920), and juice processing (1934). In many ways, he could be regarded as the founder of the entire field of industrial biotechnology (see Appendix A for more examples). Röhm also invented transparent polymethylacrylic plastic (plexiglass) in 1928 (p. 654). With the businessman Otto Haas (German, 1872–1960), he founded the company of Röhm and Haas to capitalize on his inventions. Haas moved to Philadelphia to establish a branch of the company there, thereby bringing knowledge of Röhm's biotechnology methods to the United States.

Building upon the earlier work of Eduard Buchner, Carl Neuberg (German, 1877–1956, Fig. 2.40) meticulously worked out many of the key enzymatic steps and mechanisms involved in fermentation and other biochemical pathways.

Max Bergmann (German, 1886–1944) received his Ph.D. under Hermann Emil Fischer in 1911. Bergmann spent his entire career creating methods of determining the amino acid sequences of natural proteins and of artificially synthesizing proteins with specific amino acid sequences (Fig. 2.46). Such methods have been widely used ever since to analyze and synthesize proteins in laboratories. In 1933, Bergmann moved to the United States, where he attracted new students to harness and extend his research. Leonidas Zervas (1902–1980) was Greek but was educated and worked in Germany. He worked closely with Bergmann in Germany and in the U.S. after Bergmann moved there; later he continued his protein research in Greece.

Kurt Felix (German, 1888–1960, Fig. 2.38) conducted important research on proteins at the University of Munich from the 1920s onward.

Felix Haurowitz (Czech, 1896–1987, Fig. 2.39) made a number of protein structural studies and discoveries about antibodies (immunoglobulins) as well as hemoglobin.

In the 1930s and early 1940s, German-speaking scientists developed several egg protein substitutes that consisted of protein extracted and processed on an industrial scale from cultured yeast, animal blood plasma (Plenora), fish (Eiweiss), and milk (Milei) [BIOS 236; BIOS 1417; BIOS 1481; BIOS 1513]. See p. 521.

Klaus H. Hofmann (German/Swiss, 1911–1995, Fig. 2.39) chemically synthesized analogs of amino acids, studied the mechanisms of protein-cleaving trypsin and RNA-cleaving RNaseA enzymes, chemically synthesized peptide hormones, and made other discoveries regarding protein structures and functions. He also did important work on steroid hormones.

Max Perutz (Austrian, 1914–2002, Fig. 2.40) developed and demonstrated methods of determining detailed three-dimensional protein structures [Medawar and Pyke 2000; Perutz 1989, 1998]. He won the 1962 Nobel Prize in Chemistry for working out the structure of the hemoglobin protein (Fig. 2.47).

Edmond Fischer (Swiss, 1920–, Fig. 2.38) made important discoveries regarding protein phosphorylation and dephosphorylation, the methods by which cells regulate the activity of proteins by attaching or removing charged phosphate groups on the proteins. Along with Edwin Krebs, he won the Nobel Prize in Physiology or Medicine in 1992 for that work. Professor Hans Jörnvall of the Nobel Assembly of the Karolinska Institute explained the scientific importance of these discoveries [https://www.nobelprize.org/prizes/medicine/1992/ceremony-speech/]:

> And now phosphorylation: one or several small phosphate groups are coupled to a protein, changing its properties. If the parallel with our human workers is pursued further, one could perhaps compare phosphorylation with ballet shoes. Despite their small size they have dramatic effects on their wearer! The shape of the foot is altered and after that, work is like a dance. Edmond Fischer and Edwin Krebs, this year's Laureates, described this principle in the fifties. They showed how muscles liberate an energy-rich form of sugar from its storage form by phosphorylation of a protein. After that, science gradually gained insight into the fact that this constitutes a general principle manifested in all cellular activities. Today, a considerable part of world bioscience involves protein phosphorylation.
>
> Why this regulation via coupling of small groups? One advantage is that the process is reversible, i.e. the shoes can be taken off and put on, a process which can be repeated again and again. Thus, proteins can be regulated in both directions. Another is that the reactions can be carried out in successive steps, creating a cascade that amplifies the end effect. Much like the hydraulic amplification in a brake: a gentle touch of the pedal can stop even a heavy car. In the world of proteins, Krebs and his collaborators paved the way for this knowledge by studying also the preceding protein in the chain of phosphorylations, while Fischer concentrated his efforts along other lines and, as recently as some years ago, reported the purification of a special type of phosphate-removing protein.
>
> Yet another advantage is that the regulation can be affected by different signals. The system that Fischer and Krebs first studied can be activated either by means of a stress hormone released when we become frightened and our muscles prepare us for escape, or by an act of will when we wish to run for other reasons. Phosphate groups are in these

> two cases attached in response to separate signals, much as they are in all other cellular response systems. What relevance does this have to medicine? The easiest answer is that we all know of the consequences in society from imbalances in economic chain reactions! We are now in a position to start perceiving how illnesses, including common diseases like hypertension and tumors, are accompanied by imbalances in phosphorylations.

Werner Adolf Immerwahr (German, 1924–2006, Fig. 2.39) left Germany during World War II, changed his name to Vernon Ingram, and ultimately became a well-known biology professor at MIT. With support from Max Perutz and other members of the German-speaking scientific diaspora, he spent most of his career studying the roles of proteins in diseases. In the 1950s, Immerwahr/Ingram showed that a mutation changing a single amino acid in hemoglobin was responsible for causing sickle-cell anemia, a hereditary blood disease. Later he studied some of the key proteins involved in neurodegenerative illnesses such as Alzheimer's disease.

Günter Blobel (German, 1936–2018, Fig. 2.38) discovered that many proteins contain a "postal address code" that tells cells where to send the protein so it can do its job. For that discovery, he won the Nobel Prize in Physiology or Medicine in 1999. The Royal Swedish Academy of Sciences summarized his work [https://www.nobelprize.org/prizes/medicine/1999/blobel/facts/]:

> Proteins, molecules composed of chains of amino acids, play a crucial role in life processes in our cells. Proteins are continuously being transported through membranes or walls that both separate the cell from its surroundings and separate the inner parts of the cell, the organelles. In 1975 Günter Blobel showed that in certain cases amino acids in a protein serve as an address label that determines where a protein is to be delivered. Amino acid sequences determine whether a protein is to be passed through the membrane out of the cell or into an organelle or is to be built in the membrane.

For closely related work, see Section 2.1.5 for enzymes involved in metabolism, Section 2.4.1 for hemoglobin protein in red blood cells, and Appendix A for industrial biotechnology methods and applications.

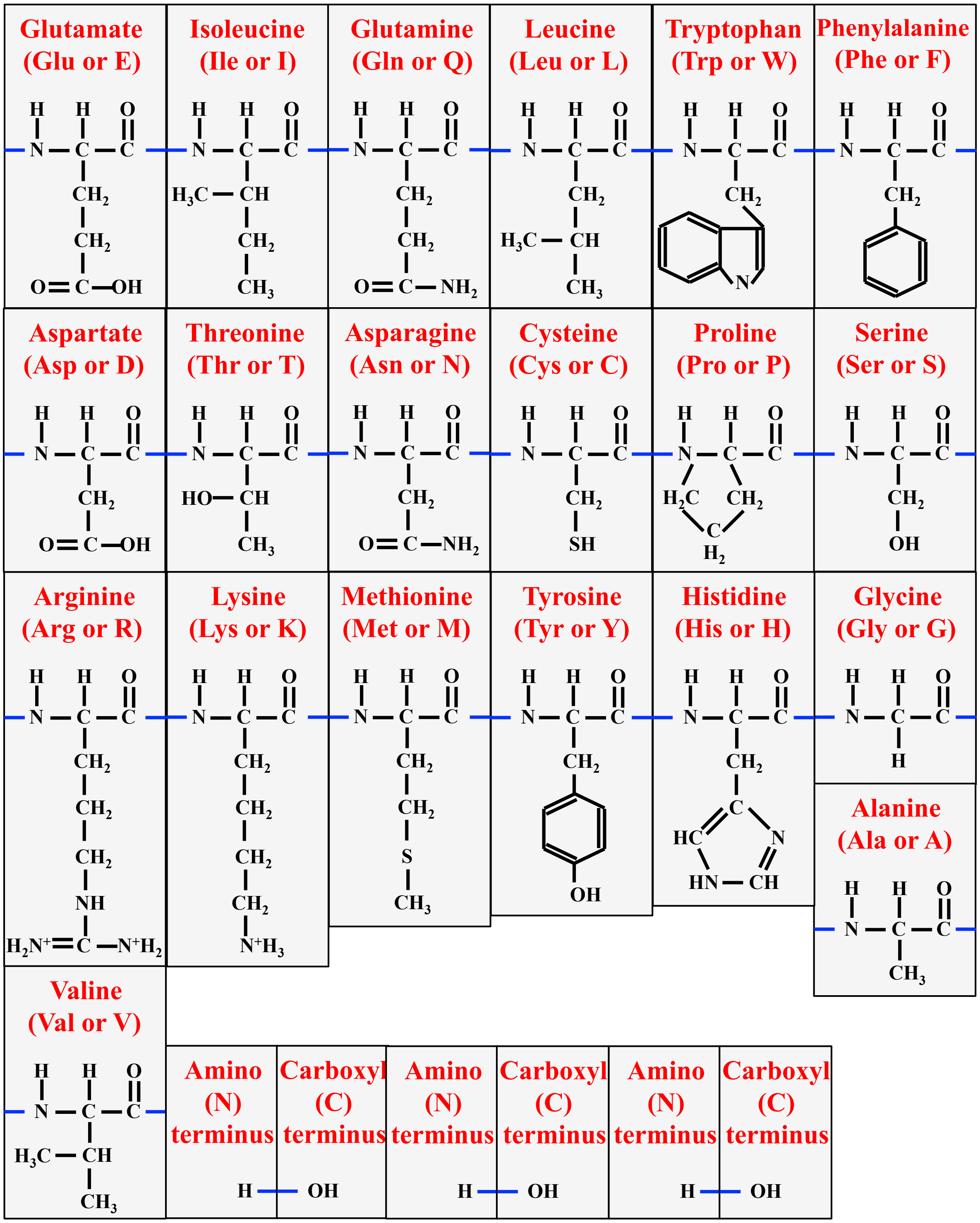

Glutamate (Glu or E)
Isoleucine (Ile or I)
Glutamine (Gln or Q)
Leucine (Leu or L)
Tryptophan (Trp or W)
Phenylalanine (Phe or F)
Aspartate (Asp or D)
Threonine (Thr or T)
Asparagine (Asn or N)
Cysteine (Cys or C)
Proline (Pro or P)
Serine (Ser or S)
Arginine (Arg or R)
Lysine (Lys or K)
Methionine (Met or M)
Tyrosine (Tyr or Y)
Histidine (His or H)
Glycine (Gly or G)
Alanine (Ala or A)
Valine (Val or V)
Amino (N) terminus
Carboxyl (C) terminus
Amino (N) terminus
Carboxyl (C) terminus
Amino (N) terminus
Carboxyl (C) terminus
H
OH
H
OH
H
OH

Figure 2.36: Proteins are composed of 20 standard amino acids arranged in different sequences.

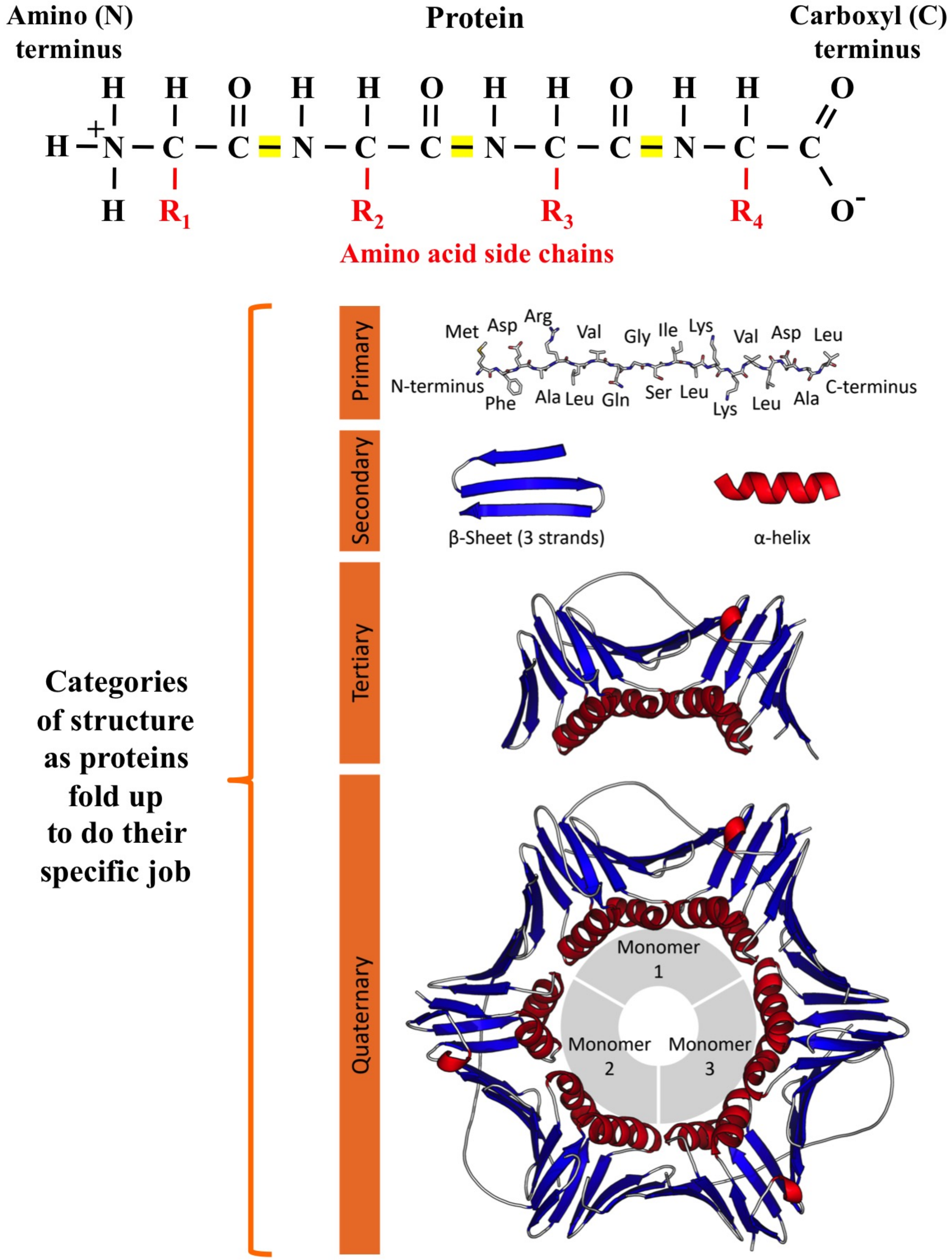

Amino (N) terminus
Protein
Carboxyl (C) terminus
H H O H H O H H O H H O
H N C C N C C N C C N C C
H R1 R2 R3 R4 O-
Amino acid side chains
Categories of structure as proteins fold up to do their specific job
Primary
Met Asp Arg Val Gly Ile Lys Val Asp Leu
N-terminus
Phe Ala Leu Gln Ser Leu Lys Leu Ala
C-terminus
Secondary
β-Sheet (3 strands)
α-helix
Tertiary
Quaternary
Monomer 1
Monomer 2
Monomer 3

Figure 2.37: Most proteins must fold up in a specific way to do their particular job. The structure of a protein is described at different levels: primary (amino acid sequence), secondary (folding of small regions into β-sheet or α-helix structures, tertiary (folded structure of the complete amino acid sequence), and quaternary (assembly of separate monomeric subunits of amino acid sequences to form a complete multimeric protein).

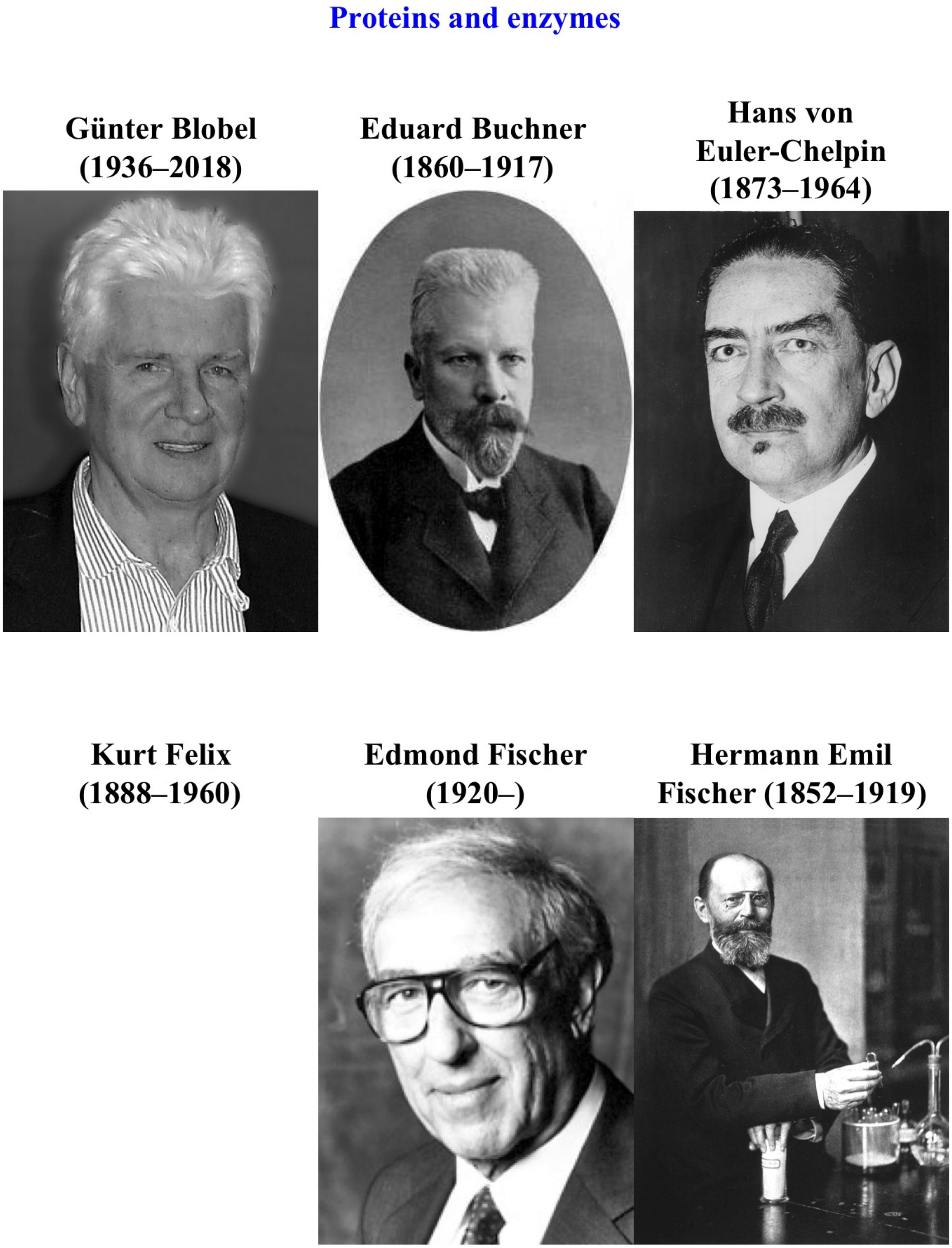

Proteins and enzymes
Günter Blobel (1936–2018)
Eduard Buchner (1860–1917)
Hans von Euler-Chelpin (1873–1964)
Kurt Felix (1888–1960)
Edmond Fischer (1920–)
Hermann Emil Fischer (1852–1919)

Figure 2.38: Some creators who made significant contributions to knowledge about proteins and enzymes included Günter Blobel, Eduard Buchner, Hans von Euler-Chelpin, Kurt Felix, Edmond Fischer, and Hermann Emil Fischer.

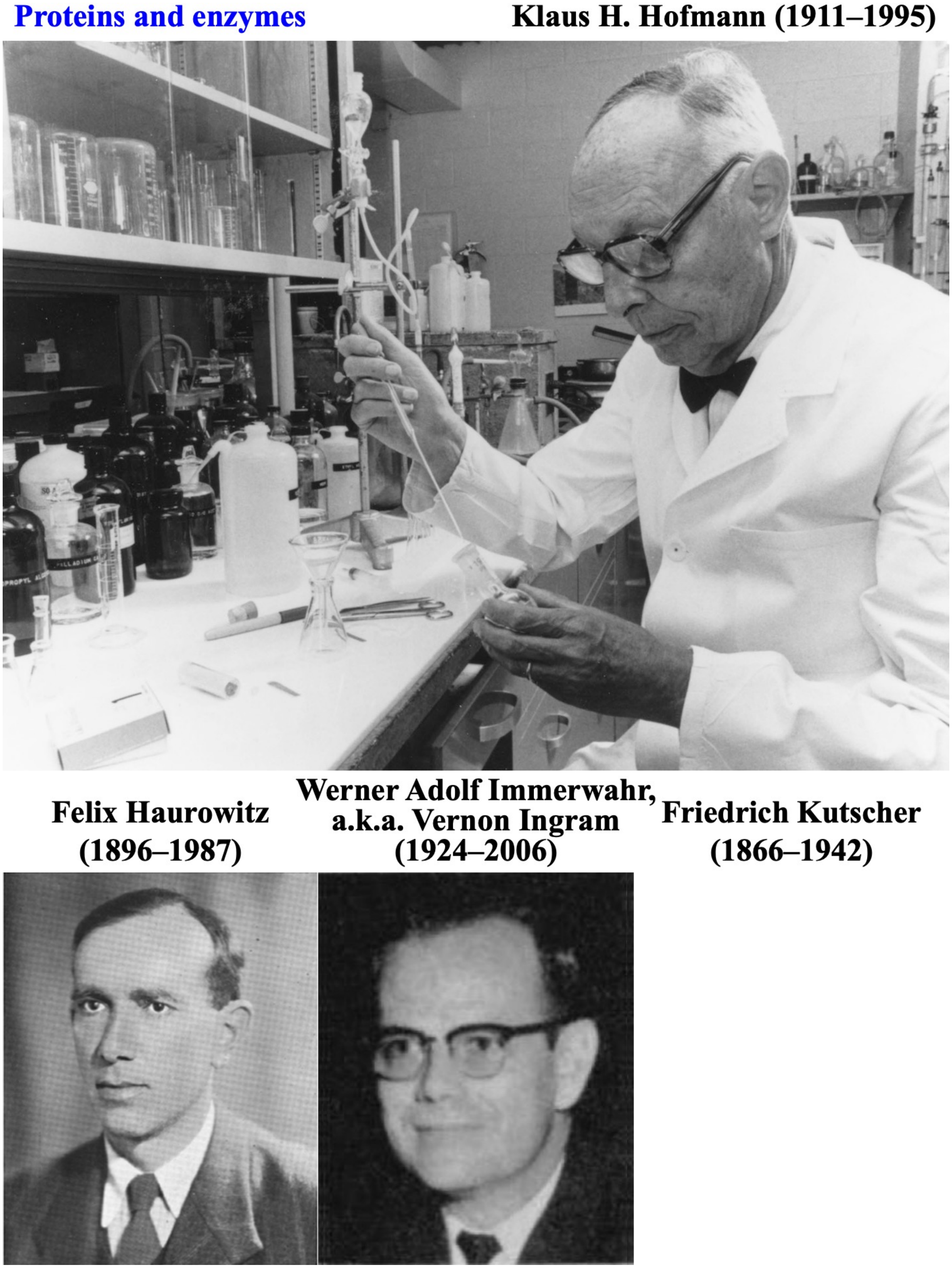
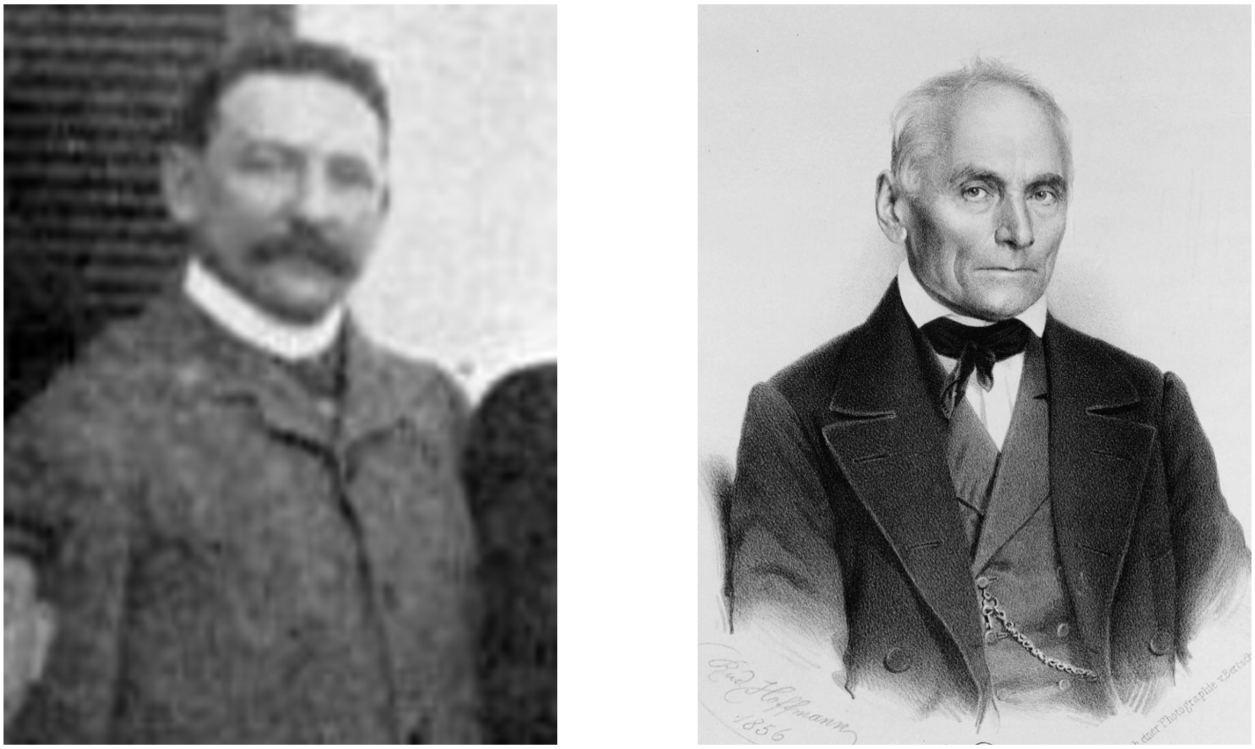

Proteins and enzymes
Klaus H. Hofmann (1911–1995)
Felix Haurowitz (1896–1987)
Werner Adolf Immerwahr, a.k.a. Vernon Ingram (1924–2006)
Friedrich Kutscher (1866–1942)

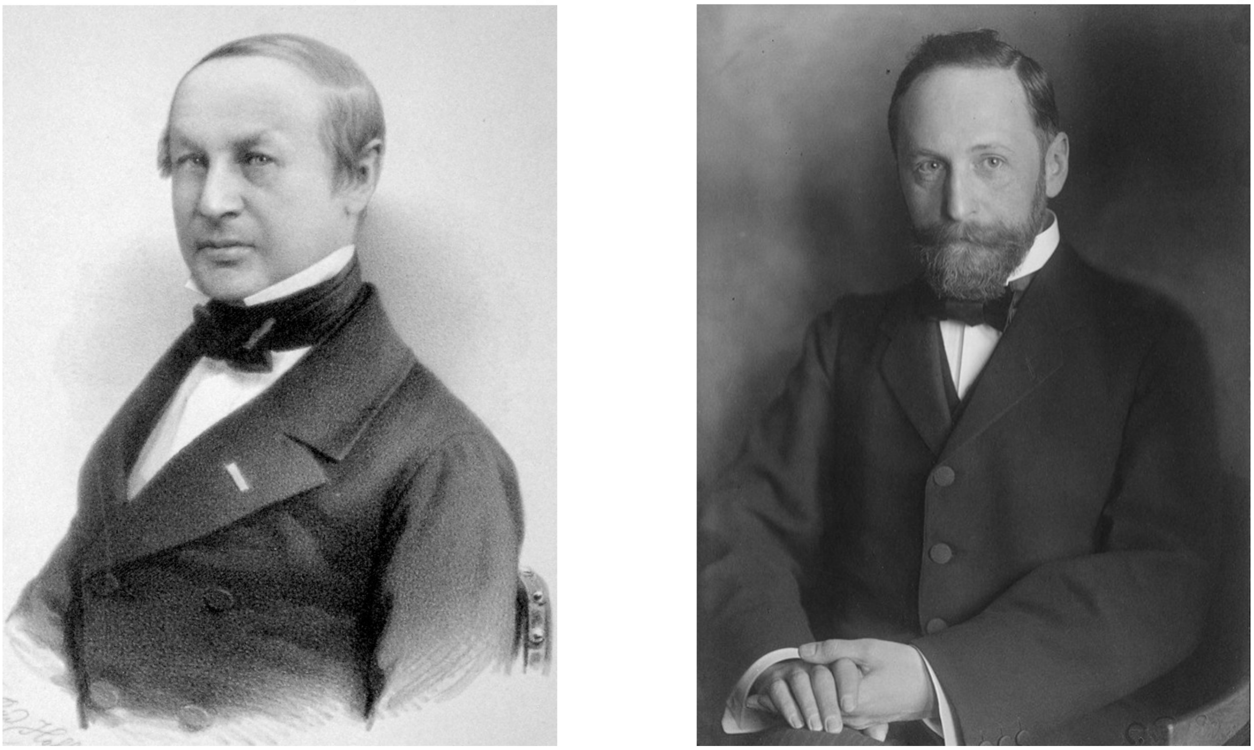
Figure 2.39: Other creators who made significant contributions to knowledge about proteins and enzymes included Felix Haurowitz, Klaus H. Hofmann, Werner Adolf Immerwahr/Vernon Ingram, and Friedrich Kutscher.

Proteins and enzymes



Carl Neuberg (1877–1956)

Johann Purkinje (1787–1869)

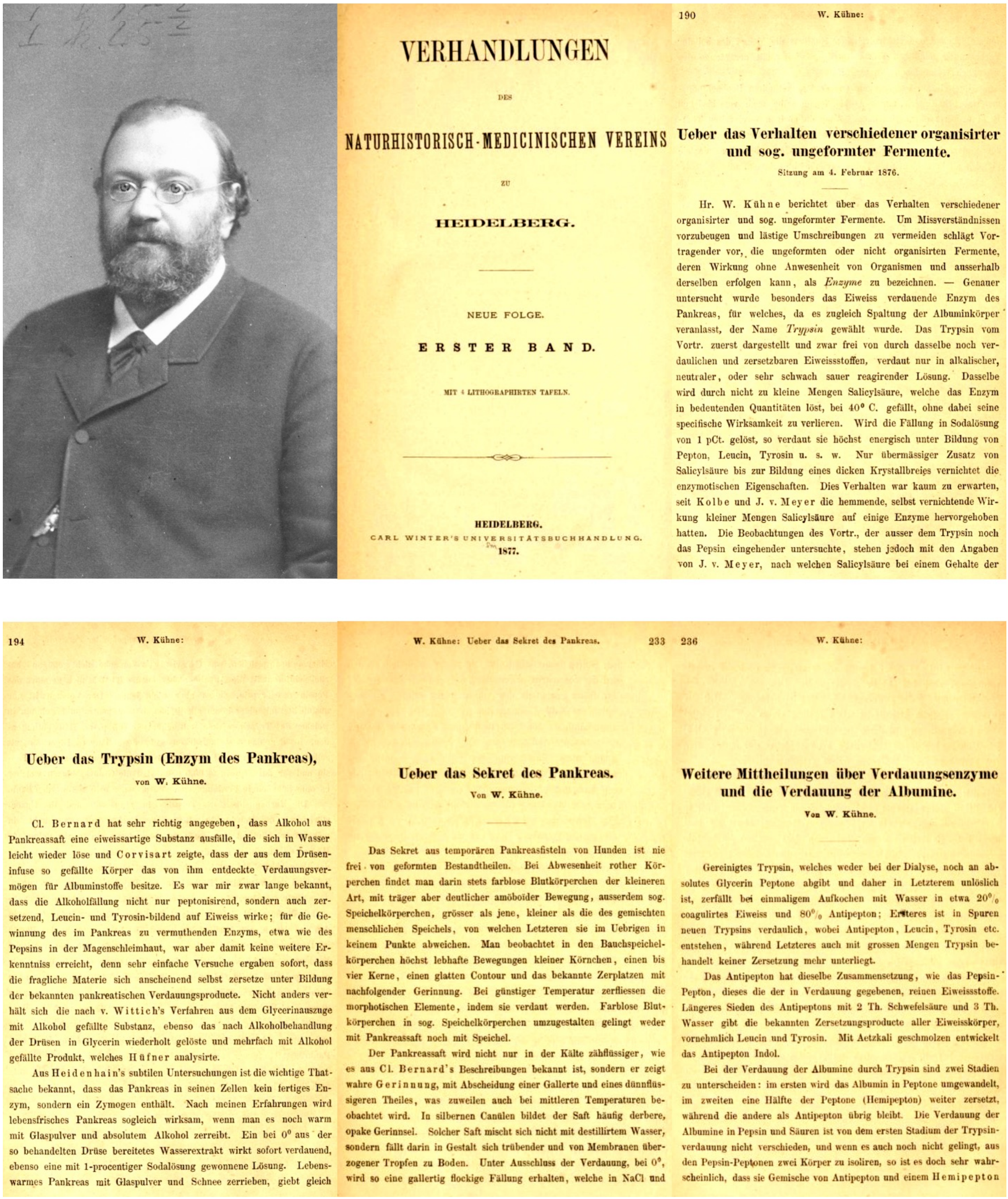


Theodor Schwann (1810–1882)

Richard Willstätter (1872–1942)

Figure 2.40: Other creators who made significant contributions to knowledge about proteins and enzymes included Carl Neuberg, Johann Purkinje, Theodor Schwann, and Richard Willstätter.

Wilhelm Kühne (1837–1900) discovered myosin protein in muscles (1864) and the digestive protein (protease) trypsin (1875), and coined the word "enzyme."



VERHANDLUNGEN
DES
NATURHISTORISCH-MEDICINISCHEN VEREINS
ZU
HEIDELBERG.

NEUE FOLGE.
ERSTER BAND.
MIT 4 LITHOGRAPHIRTEN TAFELN.

HEIDELBERG.
CARL WINTER'S UNIVERSITÄTSBUCHHANDLUNG.
1877.

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190 W. Kühne:

Ueber das Verhalten verschiedener organisirter und sog. ungeformter Fermente.

Sitzung am 4. Februar 1876.

Hr. W. Kühne berichtet über das Verhalten verschiedener organisirter und sog. ungeformter Fermente. Um Missverständnissen vorzubeugen und lästige Umschreibungen zu vermeiden schlägt Vortragender vor, die ungeformten oder nicht organisirten Fermente, deren Wirkung ohne Anwesenheit von Organismen und ausserhalb derselben erfolgen kann, als *Enzyme* zu bezeichnen. — Genauer untersucht wurde besonders das Eiweiss verdauende Enzym des Pankreas, für welches, da es zugleich Spaltung der Albuminkörper veranlasst, der Name *Trypsin* gewählt wurde. Das Trypsin vom Vortr. zuerst dargestellt und zwar frei von durch dasselbe noch verdaulichen und zersetzbaren Eiweissstoffen, verdaut nur in alkalischer, neutraler, oder sehr schwach sauer reagirender Lösung. Dasselbe wird durch nicht zu kleine Mengen Salicylsäure, welche das Enzym in bedeutenden Quantitäten löst, bei 40° C. gefällt, ohne dabei seine specifische Wirksamkeit zu verlieren. Wird die Fällung in Sodalösung von 1 pCt. gelöst, so verdaut sie höchst energisch unter Bildung von Pepton, Leucin, Tyrosin u. s. w. Nur übermässiger Zusatz von Salicylsäure bis zur Bildung eines dicken Krystallbreies vernichtet die enzymotischen Eigenschaften. Dies Verhalten war kaum zu erwarten, seit Kolbe und J. v. Meyer die hemmende, selbst vernichtende Wirkung kleiner Mengen Salicylsäure auf einige Enzyme hervorgehoben hatten. Die Beobachtungen des Vortr., der ausser dem Trypsin noch das Pepsin eingehender untersuchte, stehen jedoch mit den Angaben von J. v. Meyer, nach welchen Salicylsäure bei einem Gehalte der

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194 W. Kühne:

Ueber das Trypsin (Enzym des Pankreas),

von W. Kühne.

Cl. Bernard hat sehr richtig angegeben, dass Alkohol aus Pankreassaft eine eiweissartige Substanz ausfälle, die sich in Wasser leicht wieder löse und Corvisart zeigte, dass der aus dem Drüseninfuse so gefällte Körper das von ihm entdeckte Verdauungsvermögen für Albuminstoffe besitze. Es war mir zwar lange bekannt, dass die Alkoholfällung nicht nur peptonisirend, sondern auch zersetzend, Leucin- und Tyrosin-bildend auf Eiweiss wirke; für die Gewinnung des im Pankreas zu vermuthenden Enzyms, etwa wie des Pepsins in der Magenschleimhaut, war aber damit keine weitere Erkenntniss erreicht, denn sehr einfache Versuche ergaben sofort, dass die fragliche Materie sich anscheinend selbst zersetze unter Bildung der bekannten pankreatischen Verdauungsproducte. Nicht anders verhält sich die nach v. Wittich's Verfahren aus dem Glycerinauszuge mit Alkohol gefällte Substanz, ebenso das nach Alkoholbehandlung der Drüsen in Glycerin wiederholt gelöste und mehrfach mit Alkohol gefällte Produkt, welches Hüfner analysirte.

Aus Heidenhain's subtilen Untersuchungen ist die wichtige Thatsache bekannt, dass das Pankreas in seinen Zellen kein fertiges Enzym, sondern ein Zymogen enthält. Nach meinen Erfahrungen wird lebensfrisches Pankreas sogleich wirksam, wenn man es noch warm mit Glaspulver und absolutem Alkohol zerreibt. Ein bei 0^0 aus der so behandelten Drüse bereitetes Wasserextrakt wirkt sofort verdauend, ebenso eine mit 1-procentiger Sodalösung gewonnene Lösung. Lebenswarmes Pankreas mit Glaspulver und Schnee zerrieben, giebt gleich

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W. Kühne: Ueber das Sekret des Pankreas. 233

Ueber das Sekret des Pankreas.

Von W. Kühne.

Das Sekret aus temporären Pankreasfisteln von Hunden ist nie frei von geformten Bestandtheilen. Bei Abwesenheit rother Körperchen findet man darin stets farblose Blutkörperchen der kleineren Art, mit träger aber deutlicher amöboïder Bewegung, ausserdem sog. Speichelkörperchen, grösser als jene, kleiner als die des gemischten menschlichen Speichels, von welchen Letzteren sie im Uebrigen in keinem Punkte abweichen. Man beobachtet in den Bauchspeichelkörperchen höchst lebhafte Bewegungen kleiner Körnchen, einen bis vier Kerne, einen glatten Contour und das bekannte Zerplatzen mit nachfolgender Gerinnung. Bei günstiger Temperatur zerfliessen die morphotischen Elemente, indem sie verdaut werden. Farblose Blutkörperchen in sog. Speichelkörperchen umzugestalten gelingt weder mit Pankreassaft noch mit Speichel.

Der Pankreassaft wird nicht nur in der Kälte zähflüssiger, wie es aus Cl. Bernard's Beschreibungen bekannt ist, sondern er zeigt wahre Gerinnung, mit Abscheidung einer Gallerte und eines dünnflüssigeren Theiles, was zuweilen auch bei mittleren Temperaturen beobachtet wird. In silbernen Canülen bildet der Saft häufig derbere, opake Gerinnsel. Solcher Saft mischt sich nicht mit destillirtem Wasser, sondern fällt darin in Gestalt sich trübender und von Membranen überzogener Tropfen zu Boden. Unter Ausschluss der Verdauung, bei 0°, wird so eine gallertig flockige Fällung erhalten, welche in NaCl und

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236 W. Kühne:

Weitere Mittheilungen über Verdauungsenzyme und die Verdauung der Albumine.

Von W. Kühne.

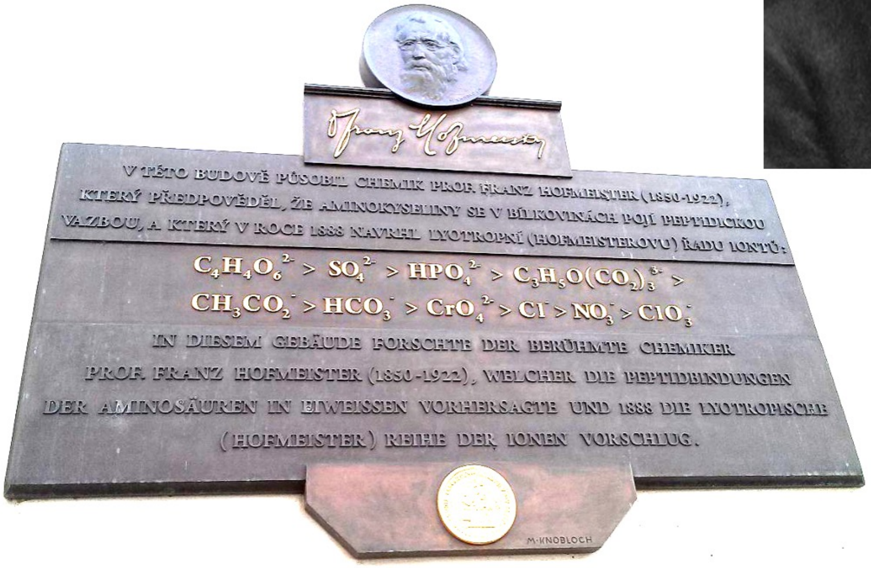
Gereinigtes Trypsin, welches weder bei der Dialyse, noch an absolutes Glycerin Peptone abgibt und daher in Letzterem unlöslich ist, zerfällt bei einmaligem Aufkochen mit Wasser in etwa $20^0/_0$ coagulirtes Eiweiss und $80^0/_0$ Antipepton; Ersteres ist in Spuren neuen Trypsins verdaulich, wobei Antipepton, Leucin, Tyrosin etc. entstehen, während Letzteres auch mit grossen Mengen Trypsin behandelt keiner Zersetzung mehr unterliegt.

Das Antipepton hat dieselbe Zusammensetzung, wie das Pepsin-Pepton, dieses die der in Verdauung gegebenen, reinen Eiweissstoffe. Längeres Sieden des Antipeptons mit 2 Th. Schwefelsäure und 3 Th. Wasser gibt die bekannten Zersetzungsproducte aller Eiweisskörper, vornehmlich Leucin und Tyrosin. Mit Aetzkali geschmolzen entwickelt das Antipepton Indol.

Bei der Verdauung der Albumine durch Trypsin sind zwei Stadien zu unterscheiden: im ersten wird das Albumin in Peptone umgewandelt, im zweiten eine Hälfte der Peptone (Hemipepton) weiter zersetzt, während die andere als Antipepton übrig bleibt. Die Verdauung der Albumine in Pepsin und Säuren ist von dem ersten Stadium der Trypsinverdauung nicht verschieden, und wenn es auch noch nicht gelingt, aus den Pepsin-Peptonen zwei Körper zu isoliren, so ist es doch sehr wahrscheinlich, dass sie Gemische von Antipepton und einem Hemipepton

Figure 2.41: Wilhelm Kühne discovered myosin protein in muscles (1864) and the digestive protein (protease) trypsin (1875), and coined the word "enzyme."

Franz Hofmeister (1850–1922)
Peptide bonds in proteins
Effect of salts on proteins
Protein solubility
Protein purification
Protein crystallization

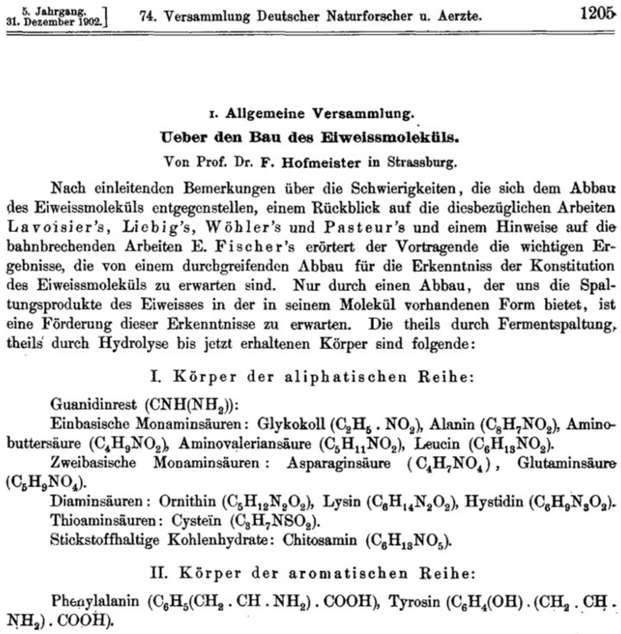


Franz Hofmeister

V TÉTO BUDOVĚ PŮSOBIL CHEMIK PROF. FRANZ HOFMEISTER (1850-1922), KTERÝ PŘEDPOVĚDĚL, ŽE AMINOKYSELINY SE V BÍLKOVINÁCH POJÍ PEPTIDICKOU VAZBOU, A KTERÝ V ROCE 1888 NAVRHL LYOTROPNÍ (HOFMEISTEROVU) ŘADU IONTŮ:

$C_4H_4O_6^{2-} > SO_4^{2-} > HPO_4^{2-} > C_3H_5O(CO_2)_3^{3-} >$
$CH_3CO_2^- > HCO_3^- > CrO_4^{2-} > Cl^- > NO_3^- > ClO_3^-$

IN DIESEM GEBÄUDE FORSCHTE DER BERÜHMTE CHEMIKER PROF. FRANZ HOFMEISTER (1850-1922), WELCHER DIE PEPTIDBINDUNGEN DER AMINOSÄUREN IN EIWEISSEN VORHERSAGTE UND 1888 DIE LYOTROPISCHE (HOFMEISTER) REIHE DER IONEN VORSCHLUG.



5. Jahrgang. 31. Dezember 1902.] 74. Versammlung Deutscher Naturforscher u. Aerzte. 1205

1. Allgemeine Versammlung.

Ueber den Bau des Eiweissmoleküls.

Von Prof. Dr. **F. Hofmeister** in Strassburg.

Nach einleitenden Bemerkungen über die Schwierigkeiten, die sich dem Abbau des Eiweissmoleküls entgegenstellen, einem Rückblick auf die diesbezüglichen Arbeiten Lavoisier's, Liebig's, Wöhler's und Pasteur's und einem Hinweise auf die bahnbrechenden Arbeiten E. Fischer's erörtert der Vortragende die wichtigen Ergebnisse, die von einem durchgreifenden Abbau für die Erkenntniss der Konstitution des Eiweissmoleküls zu erwarten sind. Nur durch einen Abbau, der uns die Spaltungsprodukte des Eiweisses in der in seinem Molekül vorhandenen Form bietet, ist eine Förderung dieser Erkenntnisse zu erwarten. Die theils durch Fermentspaltung, theils durch Hydrolyse bis jetzt erhaltenen Körper sind folgende:

I. Körper der aliphatischen Reihe:

Guanidinrest ($CNH(NH_2)$):

Einbasische Monaminsäuren: Glykokoll ($C_2H_5 . NO_2$), Alanin ($C_8H_7NO_2$), Aminobuttersäure ($C_4H_9NO_2$), Aminovaleriansäure ($C_5H_{11}NO_2$), Leucin ($C_6H_{13}NO_2$).

Zweibasische Monaminsäuren: Asparaginsäure ($C_4H_7NO_4$), Glutaminsäure ($C_5H_9NO_4$).

Diaminsäuren: Ornithin ($C_5H_{12}N_2O_2$), Lysin ($C_6H_{14}N_2O_2$), Hystidin ($C_6H_9N_3O_2$).

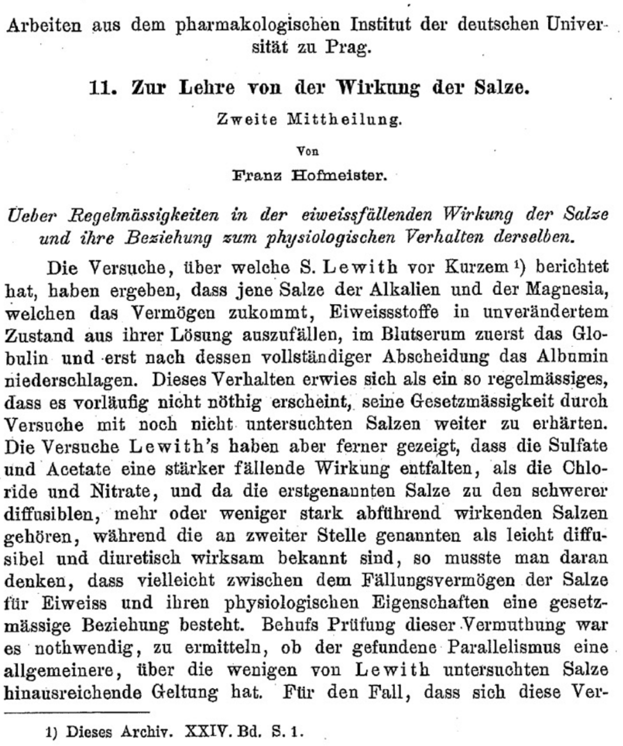
Thioaminsäuren: Cysteïn ($C_3H_7NSO_2$).

Stickstoffhaltige Kohlenhydrate: Chitosamin ($C_6H_{13}NO_5$).

II. Körper der aromatischen Reihe:

Phenylalanin ($C_6H_5(CH_2 . CH . NH_2) . COOH$), Tyrosin ($C_6H_4(OH) . (CH_2 . CH . NH_2) . COOH$).

XVII.



Arbeiten aus dem pharmakologischen Institut der deutschen Universität zu Prag.

11. Zur Lehre von der Wirkung der Salze.

Zweite Mittheilung.

Von

Franz Hofmeister.

Ueber Regelmässigkeiten in der eiweissfällenden Wirkung der Salze und ihre Beziehung zum physiologischen Verhalten derselben.

Die Versuche, über welche S. Lewith vor Kurzem 1) berichtet hat, haben ergeben, dass jene Salze der Alkalien und der Magnesia, welchen das Vermögen zukommt, Eiweissstoffe in unverändertem Zustand aus ihrer Lösung auszufällen, im Blutserum zuerst das Globulin und erst nach dessen vollständiger Abscheidung das Albumin niederschlagen. Dieses Verhalten erwies sich als ein so regelmässiges, dass es vorläufig nicht nöthig erscheint, seine Gesetzmässigkeit durch Versuche mit noch nicht untersuchten Salzen weiter zu erhärten. Die Versuche Lewith's haben aber ferner gezeigt, dass die Sulfate und Acetate eine stärker fällende Wirkung entfalten, als die Chloride und Nitrate, und da die erstgenannten Salze zu den schwerer diffusiblen, mehr oder weniger stark abführend wirkenden Salzen gehören, während die an zweiter Stelle genannten als leicht diffusibel und diuretisch wirksam bekannt sind, so musste man daran denken, dass vielleicht zwischen dem Fällungsvermögen der Salze für Eiweiss und ihren physiologischen Eigenschaften eine gesetzmässige Beziehung besteht. Behufs Prüfung dieser Vermuthung war es nothwendig, zu ermitteln, ob der gefundene Parallelismus eine allgemeinere, über die wenigen von Lewith untersuchten Salze hinausreichende Geltung hat. Für den Fall, dass sich diese Ver-

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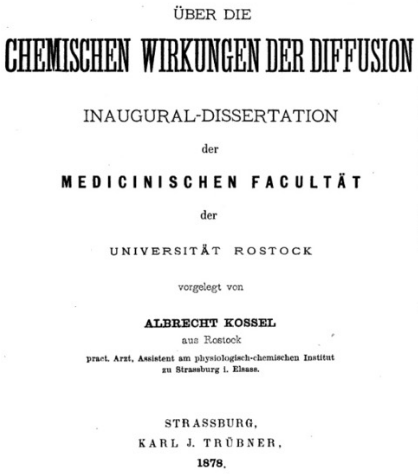
1) Dieses Archiv. XXIV. Bd. S. 1.

Figure 2.42: Franz Hofmeister established much of protein chemistry. He discovered the peptide bonds in proteins, the effect of various salts on proteins, differing protein solubilities, methods of protein purification, and methods of protein crystallization.

Beginning in the 1870s, Albrecht Kossel (1853–1927) showed that proteins are composed of amino acids, and isolated and characterized the individual amino acids.



ÜBER DIE

CHEMISCHEN WIRKUNGEN DER DIFFUSION

INAUGURAL-DISSERTATION

der

MEDICINISCHEN FACULTÄT

der

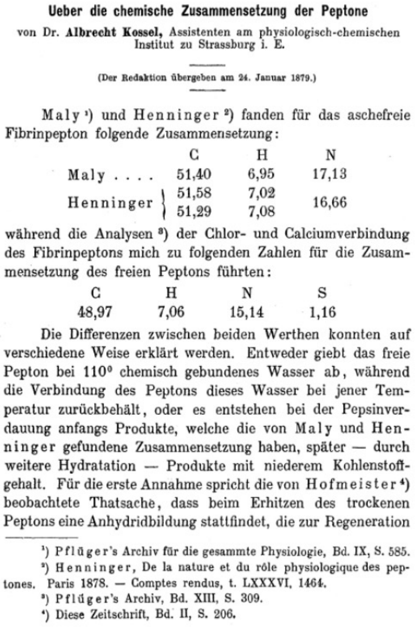
UNIVERSITÄT ROSTOCK

vorgelegt von

ALBRECHT KOSSEL
aus Rostock

pract. Arzt, Assistent am physiologisch-chemischen Institut
zu Strassburg i. Elsass.

STRASSBURG,
KARL J. TRÜBNER,
1878.



Ueber die chemische Zusammensetzung der Peptone

von Dr. **Albrecht Kossel,** Assistenten am physiologisch-chemischen Institut zu Strassburg i. E.

(Der Redaktion übergeben am 24. Januar 1879.)

Maly [1]) und Henninger [2]) fanden für das aschefreie Fibrinpepton folgende Zusammensetzung:

	C	H	N
Maly	51,40	6,95	17,13
Henninger	51,58	7,02	16,66
	51,29	7,08	

während die Analysen [3]) der Chlor- und Calciumverbindung des Fibrinpeptons mich zu folgenden Zahlen für die Zusammensetzung des freien Peptons führten:

C	H	N	S
48,97	7,06	15,14	1,16

Die Differenzen zwischen beiden Werthen konnten auf verschiedene Weise erklärt werden. Entweder giebt das freie Pepton bei 110° chemisch gebundenes Wasser ab, während die Verbindung des Peptons dieses Wasser bei jener Temperatur zurückbehält, oder es entstehen bei der Pepsinverdauung anfangs Produkte, welche die von Maly und Henninger gefundene Zusammensetzung haben, später — durch weitere Hydratation — Produkte mit niederem Kohlenstoffgehalt. Für die erste Annahme spricht die von Hofmeister [4]) beobachtete Thatsache, dass beim Erhitzen des trockenen Peptons eine Anhydridbildung stattfindet, die zur Regeneration

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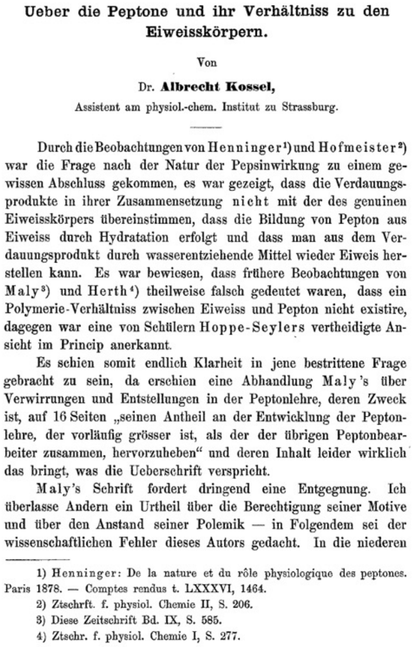
[1]) Pflüger's Archiv für die gesammte Physiologie, Bd. IX, S. 585.

[2]) Henninger, De la nature et du rôle physiologique des peptones. Paris 1878. — Comptes rendus, t. LXXXVI, 1464.

[3]) Pflüger's Archiv, Bd. XIII, S. 309.

[4]) Diese Zeitschrift, Bd. II, S. 206.



Ueber die Peptone und ihr Verhältniss zu den Eiweisskörpern.

Von

Dr. **Albrecht Kossel,**
Assistent am physiol.-chem. Institut zu Strassburg.

Durch die Beobachtungen von Henninger [1]) und Hofmeister [2]) war die Frage nach der Natur der Pepsinwirkung zu einem gewissen Abschluss gekommen, es war gezeigt, dass die Verdauungsprodukte in ihrer Zusammensetzung nicht mit der des genuinen Eiweisskörpers übereinstimmen, dass die Bildung von Pepton aus Eiweiss durch Hydratation erfolgt und dass man aus dem Verdauungsprodukt durch wasserentziehende Mittel wieder Eiweis herstellen kann. Es war bewiesen, dass frühere Beobachtungen von Maly [3]) und Herth [4]) theilweise falsch gedeutet waren, dass ein Polymerie-Verhältniss zwischen Eiweiss und Pepton nicht existire, dagegen war eine von Schülern Hoppe-Seylers vertheidigte Ansicht im Princip anerkannt.

Es schien somit endlich Klarheit in jene bestrittene Frage gebracht zu sein, da erschien eine Abhandlung Maly's über Verwirrungen und Entstellungen in der Peptonlehre, deren Zweck ist, auf 16 Seiten „seinen Antheil an der Entwicklung der Peptonlehre, der vorläufig grösser ist, als der der übrigen Peptonbearbeiter zusammen, hervorzuheben" und deren Inhalt leider wirklich das bringt, was die Ueberschrift verspricht.

Maly's Schrift fordert dringend eine Entgegnung. Ich überlasse Andern ein Urtheil über die Berechtigung seiner Motive und über den Anstand seiner Polemik — in Folgendem sei der wissenschaftlichen Fehler dieses Autors gedacht. In die niederen

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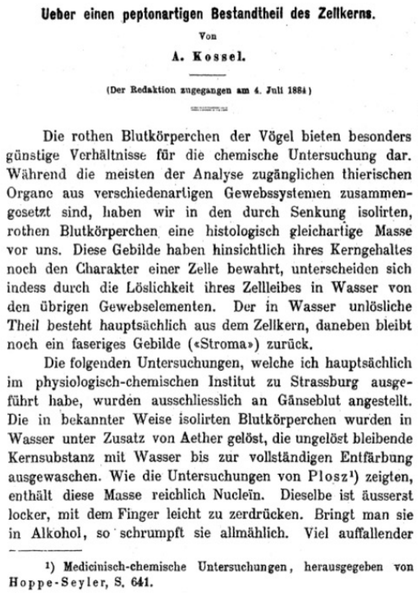
1) Henninger: De la nature et du rôle physiologique des peptones. Paris 1878. — Comptes rendus t. LXXXVI, 1464.

2) Ztschrft. f. physiol. Chemie II, S. 206.

3) Diese Zeitschrift Bd. IX, S. 585.

4) Ztschr. f. physiol. Chemie I, S. 277.



Ueber einen peptonartigen Bestandtheil des Zellkerns.

Von

A. Kossel.

(Der Redaktion zugegangen am 4. Juli 1884.)

Die rothen Blutkörperchen der Vögel bieten besonders günstige Verhältnisse für die chemische Untersuchung dar. Während die meisten der Analyse zugänglichen thierischen Organe aus verschiedenartigen Gewebssystemen zusammengesetzt sind, haben wir in den durch Senkung isolirten, rothen Blutkörperchen eine histologisch gleichartige Masse vor uns. Diese Gebilde haben hinsichtlich ihres Kerngehaltes noch den Charakter einer Zelle bewahrt, unterscheiden sich indess durch die Löslichkeit ihres Zellleibes in Wasser von den übrigen Gewebselementen. Der in Wasser unlösliche Theil besteht hauptsächlich aus dem Zellkern, daneben bleibt noch ein faseriges Gebilde («Stroma») zurück.

Die folgenden Untersuchungen, welche ich hauptsächlich im physiologisch-chemischen Institut zu Strassburg ausgeführt habe, wurden ausschliesslich an Gänseblut angestellt. Die in bekannter Weise isolirten Blutkörperchen wurden in Wasser unter Zusatz von Aether gelöst, die ungelöst bleibende Kernsubstanz mit Wasser bis zur vollständigen Entfärbung ausgewaschen. Wie die Untersuchungen von Plosz [1]) zeigten, enthält diese Masse reichlich Nucleïn. Dieselbe ist äusserst locker, mit dem Finger leicht zu zerdrücken. Bringt man sie in Alkohol, so schrumpft sie allmählich. Viel auffallender

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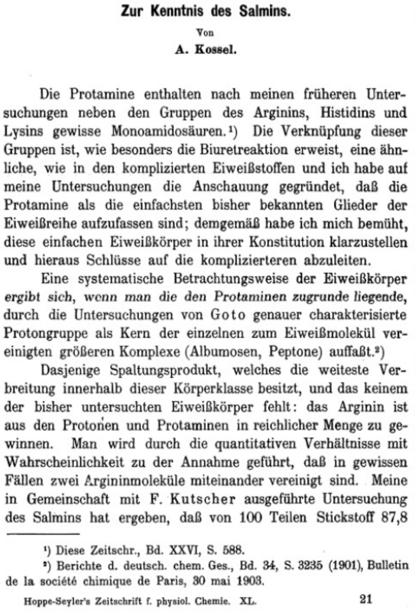
[1]) Medicinisch-chemische Untersuchungen, herausgegeben von Hoppe-Seyler, S. 461.



Zur Kenntnis des Salmins.

Von

A. Kossel.

Die Protamine enthalten nach meinen früheren Untersuchungen neben den Gruppen des Arginins, Histidins und Lysins gewisse Monoamidosäuren. [1]) Die Verknüpfung dieser Gruppen ist, wie besonders die Biuretreaktion erweist, eine ähnliche, wie in den komplizierten Eiweißstoffen und ich habe auf meine Untersuchungen die Anschauung gegründet, daß die Protamine als die einfachsten bisher bekannten Glieder der Eiweißreihe aufzufassen sind; demgemäß habe ich mich bemüht, diese einfachen Eiweißkörper in ihrer Konstitution klarzustellen und hieraus Schlüsse auf die komplizierteren abzuleiten.

Eine systematische Betrachtungsweise der Eiweißkörper *ergibt sich, wenn man die den Protaminen zugrunde liegende,* durch die Untersuchungen von Goto genauer charakterisierte Protongruppe als Kern der einzelnen zum Eiweißmolekül vereinigten größeren Komplexe (Albumosen, Peptone) auffaßt. [2])

Dasjenige Spaltungsprodukt, welches die weiteste Verbreitung innerhalb dieser Körperklasse besitzt, und das keinem der bisher untersuchten Eiweißkörper fehlt: das Arginin ist aus den Protonen und Protaminen in reichlicher Menge zu gewinnen. Man wird durch die quantitativen Verhältnisse mit Wahrscheinlichkeit zu der Annahme geführt, daß in gewissen Fällen zwei Argininmoleküle miteinander vereinigt sind. Meine in Gemeinschaft mit F. Kutscher ausgeführte Untersuchung des Salmins hat ergeben, daß von 100 Teilen Stickstoff 87,8

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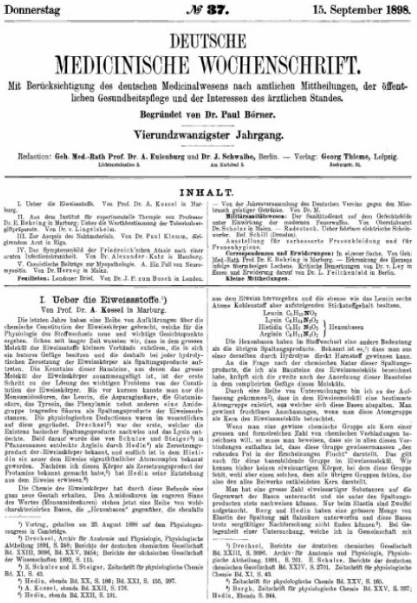
[1]) Diese Zeitschr., Bd. XXVI, S. 588.

[2]) Berichte d. deutsch. chem. Ges., Bd. 34, S. 3235 (1901), Bulletin de la société chimique de Paris, 30 mai 1903.

Hoppe-Seyler's Zeitschrift f. physiol. Chemie. XL. 21



Donnerstag № 37. 15. September 1898.

DEUTSCHE
MEDICINISCHE WOCHENSCHRIFT.

Mit Berücksichtigung des deutschen Medicinalwesens nach amtlichen Mittheilungen, der öffentlichen Gesundheitspflege und der Interessen des ärztlichen Standes.

Begründet von Dr. Paul Börner.

Vierundzwanzigster Jahrgang.

Redaction: Geh. Med.-Rath Prof. Dr. A. Eulenburg und Dr. J. Schwalbe, Berlin. — Verlag: Georg Thieme, Leipzig.

INHALT.

I. Ueber die Eiweissstoffe.[1])
Von Prof. Dr. A. Kossel in Marburg.

Figure 2.43: Beginning in the 1870s, Albrecht Kossel showed that proteins are composed of amino acids, and isolated and characterized the individual amino acids.

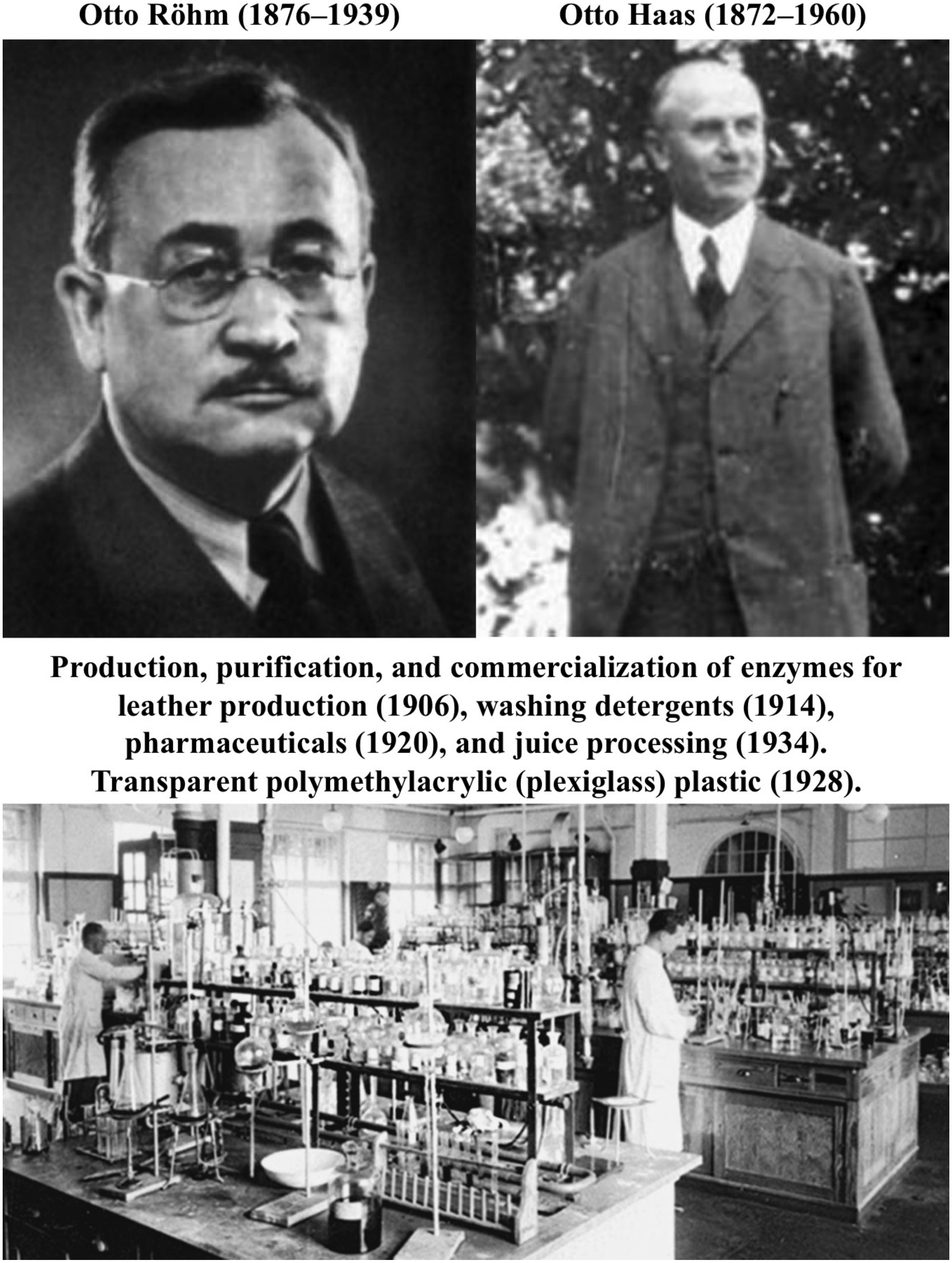

Otto Röhm (1876–1939)
Otto Haas (1872–1960)
Production, purification, and commercialization of enzymes for leather production (1906), washing detergents (1914), pharmaceuticals (1920), and juice processing (1934).
Transparent polymethylacrylic (plexiglass) plastic (1928).

Figure 2.44: Otto Röhm and Otto Haas founded Röhm and Haas, which was probably the world's first biotechnology company. Röhm developed methods to produce and purify enzymes for leather production (1906), washing detergents (1914), pharmaceuticals (1920), and juice processing (1934). He also invented transparent polymethylacrylic (plexiglass) plastic (1928). Haas led a branch of the company in the United States, transferring the biotechnology knowledge and methods there.

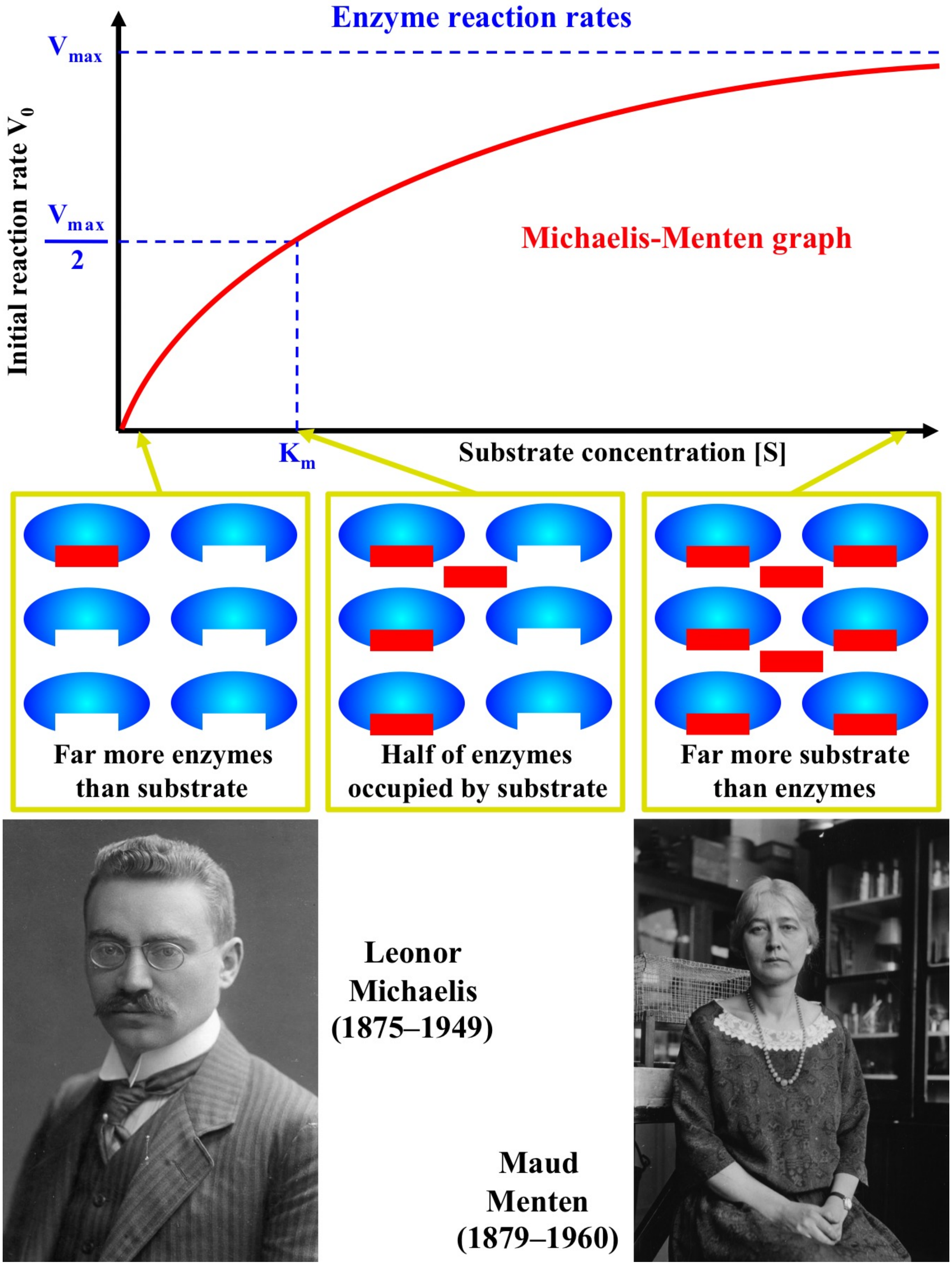

Enzyme reaction rates
V_{max}
Initial reaction rate V_0
$\frac{V_{max}}{2}$
Michaelis-Menten graph
K_m
Substrate concentration [S]
Far more enzymes than substrate
Half of enzymes occupied by substrate
Far more substrate than enzymes
Leonor Michaelis (1875–1949)
Maud Menten (1879–1960)

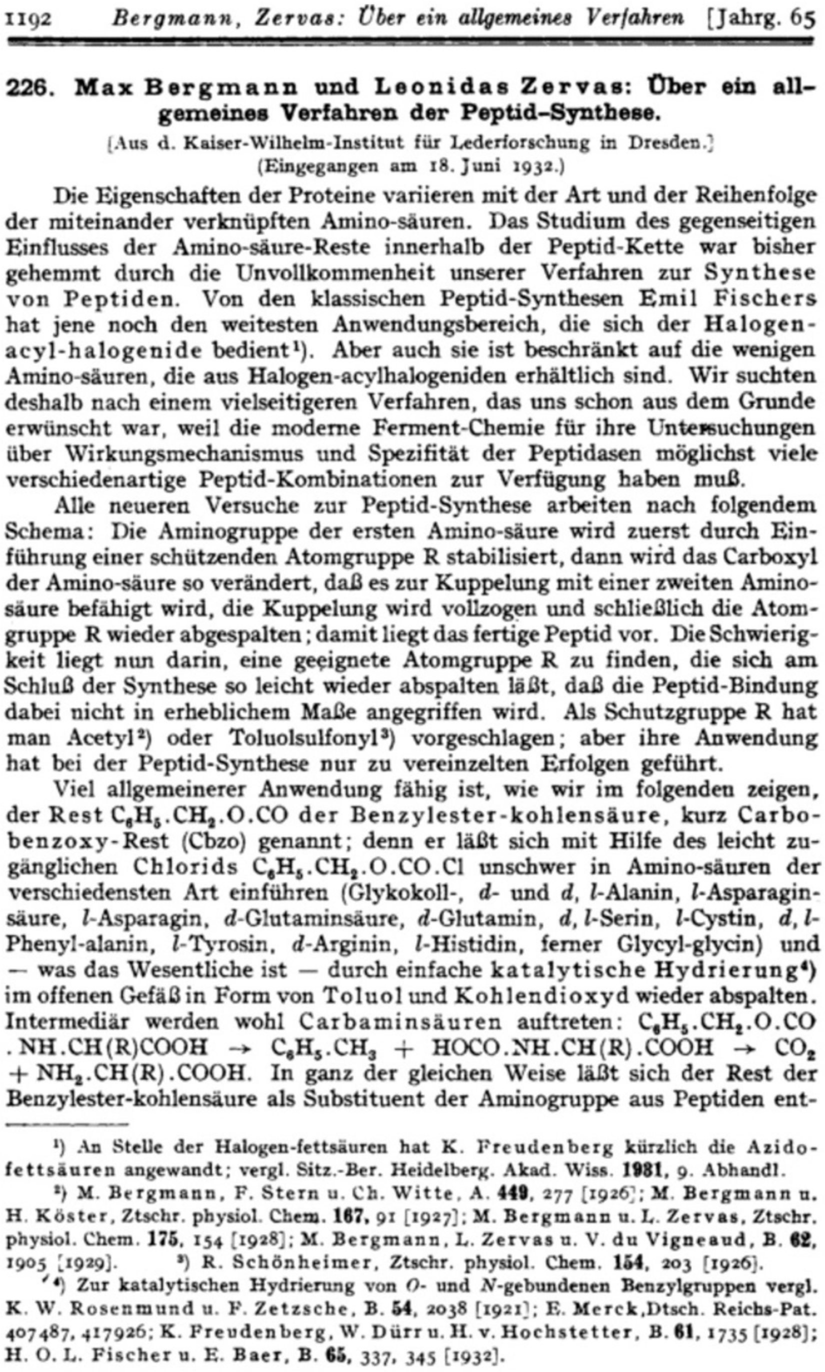
Figure 2.45: Leonor Michaelis and Maud Menten studied the chemical reaction rates of enzymes.

Starting in the 1910s, Max Bergmann created methods of:

- **Determining the amino acid sequences of natural proteins.**
- **Artificially synthesizing proteins with specific amino acid sequences.**

Max Bergmann
(1886–1944)

Leonidas Zervas
(1902–1980)



1192 *Bergmann, Zervas: Über ein allgemeines Verfahren* [Jahrg. 65

226. Max Bergmann und Leonidas Zervas: Über ein allgemeines Verfahren der Peptid-Synthese.

[Aus d. Kaiser-Wilhelm-Institut für Lederforschung in Dresden.]
(Eingegangen am 18. Juni 1932.)

Die Eigenschaften der Proteine variieren mit der Art und der Reihenfolge der miteinander verknüpften Amino-säuren. Das Studium des gegenseitigen Einflusses der Amino-säure-Reste innerhalb der Peptid-Kette war bisher gehemmt durch die Unvollkommenheit unserer Verfahren zur Synthese von Peptiden. Von den klassischen Peptid-Synthesen Emil Fischers hat jene noch den weitesten Anwendungsbereich, die sich der Halogen-acyl-halogenide bedient[1]). Aber auch sie ist beschränkt auf die wenigen Amino-säuren, die aus Halogen-acylhalogeniden erhältlich sind. Wir suchten deshalb nach einem vielseitigeren Verfahren, das uns schon aus dem Grunde erwünscht war, weil die moderne Ferment-Chemie für ihre Untersuchungen über Wirkungsmechanismus und Spezifität der Peptidasen möglichst viele verschiedenartige Peptid-Kombinationen zur Verfügung haben muß.

Alle neueren Versuche zur Peptid-Synthese arbeiten nach folgendem Schema: Die Aminogruppe der ersten Amino-säure wird zuerst durch Einführung einer schützenden Atomgruppe R stabilisiert, dann wird das Carboxyl der Amino-säure so verändert, daß es zur Kuppelung mit einer zweiten Amino-säure befähigt wird, die Kuppelung wird vollzogen und schließlich die Atomgruppe R wieder abgespalten; damit liegt das fertige Peptid vor. Die Schwierigkeit liegt nun darin, eine geeignete Atomgruppe R zu finden, die sich am Schluß der Synthese so leicht wieder abspalten läßt, daß die Peptid-Bindung dabei nicht in erheblichem Maße angegriffen wird. Als Schutzgruppe R hat man Acetyl[2]) oder Toluolsulfonyl[3]) vorgeschlagen; aber ihre Anwendung hat bei der Peptid-Synthese nur zu vereinzelten Erfolgen geführt.

Viel allgemeinerer Anwendung fähig ist, wie wir im folgenden zeigen, der Rest $C_6H_5.CH_2.O.CO$ der Benzylester-kohlensäure, kurz Carbobenzoxy-Rest (Cbzo) genannt; denn er läßt sich mit Hilfe des leicht zugänglichen Chlorids $C_6H_5.CH_2.O.CO.Cl$ unschwer in Amino-säuren der verschiedensten Art einführen (Glykokoll-, *d*- und *d, l*-Alanin, *l*-Asparaginsäure, *l*-Asparagin, *d*-Glutaminsäure, *d*-Glutamin, *d, l*-Serin, *l*-Cystin, *d, l*-Phenyl-alanin, *l*-Tyrosin, *d*-Arginin, *l*-Histidin, ferner Glycyl-glycin) und — was das Wesentliche ist — durch einfache katalytische Hydrierung[4]) im offenen Gefäß in Form von Toluol und Kohlendioxyd wieder abspalten. Intermediär werden wohl Carbaminsäuren auftreten: $C_6H_5.CH_2.O.CO.NH.CH(R)COOH \rightarrow C_6H_5.CH_3 + HOCO.NH.CH(R).COOH \rightarrow CO_2 + NH_2.CH(R).COOH$. In ganz der gleichen Weise läßt sich der Rest der Benzylester-kohlensäure als Substituent der Aminogruppe aus Peptiden ent-

---

[1]) An Stelle der Halogen-fettsäuren hat K. Freudenberg kürzlich die Azido-fettsäuren angewandt; vergl. Sitz.-Ber. Heidelberg. Akad. Wiss. **1981**, 9. Abhandl.

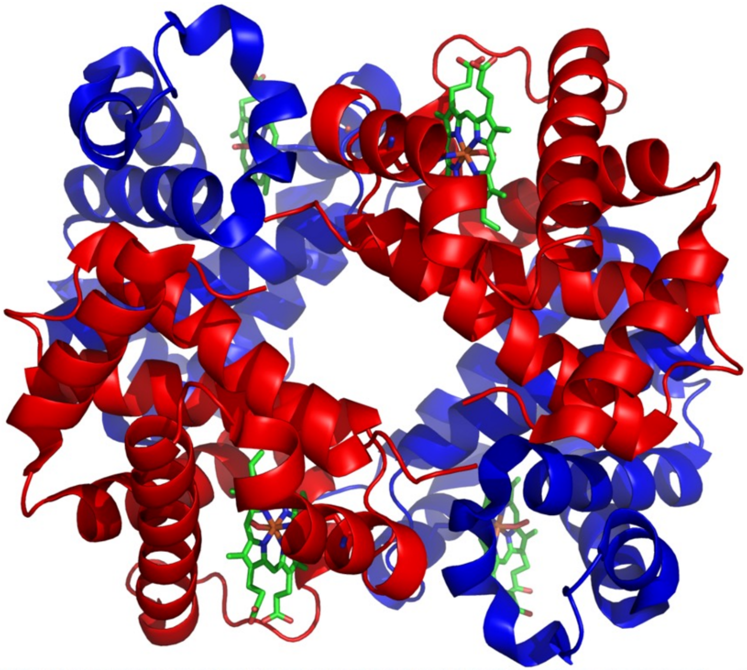
[2]) M. Bergmann, F. Stern u. Ch. Witte, A. **449**, 277 [1926]; M. Bergmann u. H. Köster, Ztschr. physiol. Chem. **167**, 91 [1927]; M. Bergmann u. L. Zervas, Ztschr. physiol. Chem. **175**, 154 [1928]; M. Bergmann, L. Zervas u. V. du Vigneaud, B. **62**, 1905 [1929]. [3]) R. Schönheimer, Ztschr. physiol. Chem. **154**, 203 [1926].

[4]) Zur katalytischen Hydrierung von *O*- und *N*-gebundenen Benzylgruppen vergl. K. W. Rosenmund u. F. Zetzsche, B. **54**, 2038 [1921]; E. Merck, Dtsch. Reichs-Pat. 407487, 417926; K. Freudenberg, W. Dürr u. H. v. Hochstetter, B. **61**, 1735 [1928]; H. O. L. Fischer u. E. Baer, B. **65**, 337, 345 [1932].

Berichte der deutschen chemischen Gesellschaft
65:7:1192–1201 (1932)

Figure 2.46: Starting in the 1910s, Max Bergmann created methods of (1) determining the amino acid sequences of natural proteins, and (2) artificially synthesizing proteins with specific amino acid sequences. He was later assisted by his student Leonidas Zervas.

Max Perutz (1914–2002) developed and demonstrated methods of determining detailed 3D protein structures such as hemoglobin.



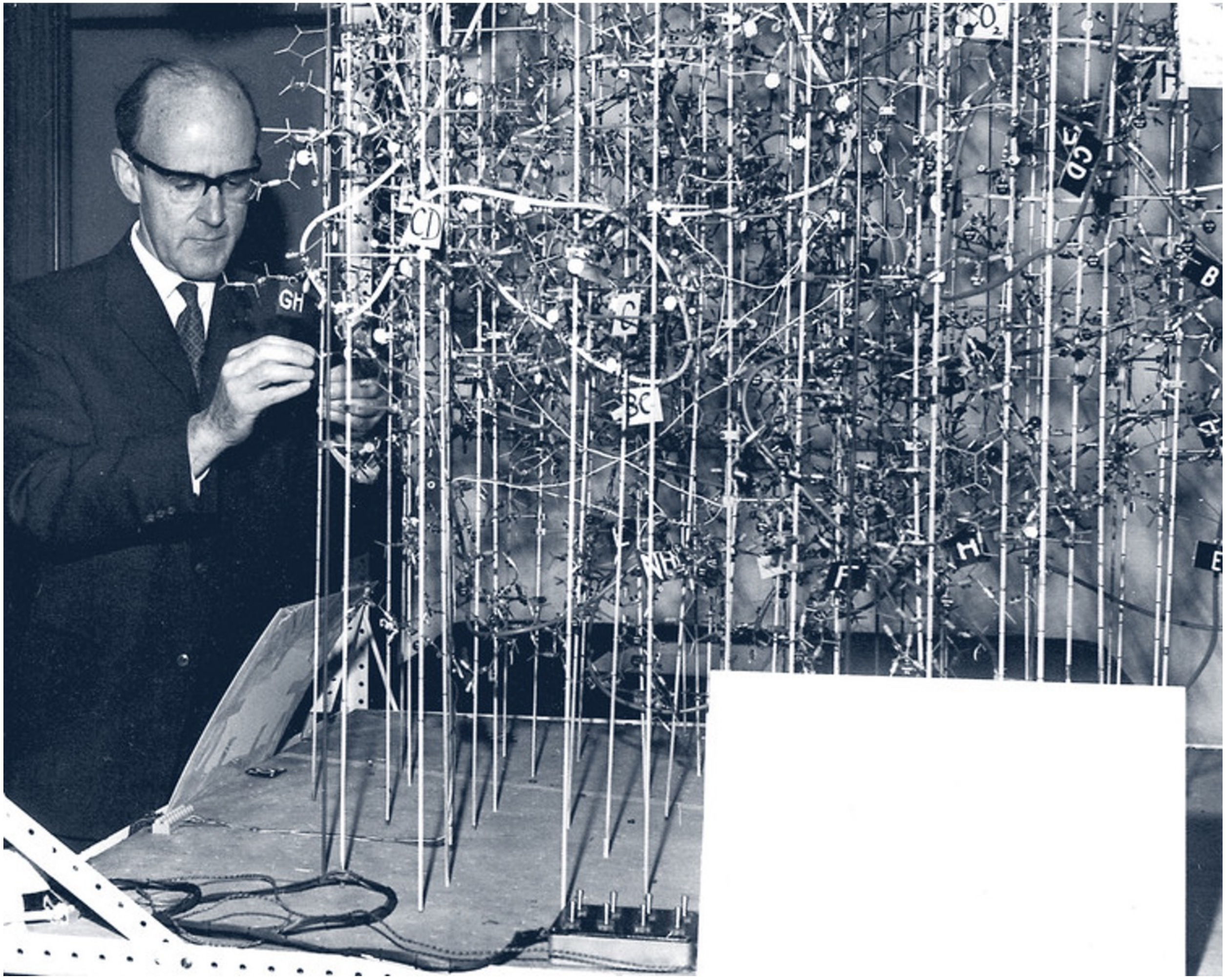


Figure 2.47: Max Perutz developed and demonstrated methods of determining detailed 3D protein structures such as hemoglobin.

2.1.5 Mitochondria, Cellular Respiration, and Metabolism

The creators discussed in this section worked on various aspects of the interrelated topics of mitochondria, cellular respiration, and other associated metabolic reactions:

- As illustrated in Figs. 2.48–2.49, mitochondria are the "power plants" within animal cells, plant cells, and fungi. In a process called cellular respiration, mitochondria carry out a series of chemical reactions to combine sugar and oxygen molecules to produce energy, carbon dioxide, and water.
- As shown in Fig. 2.50, the breaking down of sugars into half-sugars (such as pyruvate) and smaller molecules (glycolysis), and likewise the building up of sugars from smaller molecules (gluconeogenesis), involve many chemical steps, each carried out by a different enzyme.
- The Krebs or citric acid cycle within mitochondria converts half-sugars (containing carbon, hydrogen, and oxygen atoms) into hydrogens and carbon dioxide molecules. Each step is carried out by a different enzyme, as listed in Fig. 2.51.

German-speaking scientists played leading roles in discovering and understanding mitochondria, cellular respiration, and related metabolic reactions (Figs. 2.53–2.56).[10]

Justus von Liebig (German, 1803–1873, Fig. 2.55) was the first or one of the first scientists to propose the biochemical concept of cellular respiration.

Rudolf von Kölliker (Swiss, 1817–1905, Fig. 2.54) closely studied cells with high-resolution microscopes and discovered mitochondria sometime before 1888.

Completely independently, Richard Altmann (German, 1852–1900, Fig. 2.54) examined cells under the microscope and discovered mitochondria sometime before 1890.

In the 1910s, Fritz Pregl developed micro-pipetting and micro-analysis tools and methods that are now used in virtually all biology and chemistry laboratories [Pregl 1917]. See pp. 155 and 473. Pregl's micro tools and methods made it possible to conduct accurate measurements and manipulations of biochemical processes such as cellular respiration and fermentation, fundamentally enabling all of the other work in this field (and many other fields of biology and chemistry). Pregl won the Nobel Prize in Chemistry in 1923.

Gustav Embden (German, 1874–1933, Fig. 2.54), Otto Fritz Meyerhof (German, 1884–1951, Fig. 2.55), and Jakub Parnas (Austrian/Polish, 1884–1949, Fig. 2.55) discovered and explained what is now called the Embden-Meyerhof-Parnas pathway for glycolysis, the downward pathway on the left side of Fig. 2.50. They also conducted related research on muscle metabolism, liver biochemistry, and fermentation. For these discoveries, Meyerhof won the Nobel Prize in Physiology and Medicine in 1922. Professor J.E. Johansson, Chairman of the Nobel Committee for Physiology or Medicine, explained some of Meyerhof's research [https://www.nobelprize.org/prizes/medicine/1922/ceremony-speech/]:

> It is at this stage in the development of the question that Meyerhof's contribution comes in. In his investigations concerning the respiration of the tissues (1918) he came

---

[10] Deichmann 1996; Dominguez-Lacasa 2005; Gausemeier 2005; Gedeon 2006; Henry Harris 1999; Holmes 1993; Höxtermann and Sucker 1989; Jahn 2004; Junker 2004; Kohler 2008; Krebs 1981; 2005; Magner 2002; Perutz 1989, 1998; von Schwerin 2013; Simmons 2002 Stoff 2012.

> to devote his attention to the things that take place in the surviving muscle, and in this connection also to the objections that had been raised against the conclusions of Fletcher and Hopkins and their interpretation of the "lactic acid maximum" of the muscle. He showed that these objections do not really affect the result of the recently cited calculations of Hill. Most important of all, however, was his parallel determination of the lactic acid metabolism and the oxygen consumption during the recovery of the muscle, which yielded the result that the oxygen consumption does not correspond to more than 1/3–1/4 of the simultaneous lactic acid metabolism. Evidently the greater part of the lactic acid disappears in some other way than through combustion. In another parallel determination—the development of heat and the oxygen consumption—the development of heat exhibited a deficit in comparison with what could be calculated from the simultaneously observed oxygen consumption. From this the conclusion may be drawn that the combustion of lactic acid in the muscle is combined with some other process, an endothermic one, in the course of which part of the heat developed in the combustion is used up. Meyerhof also made a parallel determination of the carbohydrates and lactic acid in the resting and in the working muscle, also in the recovery period after fatigue; he found: when lactic acid is stored in the muscle, an equivalent quantity of carbohydrates, chiefly glycogen, disappears, while when lactic acid disappears, the quantity of carbohydrates in the muscle is increased by an amount equivalent to the difference between the total amount of lactic acid that has disappeared and the quantity oxidized corresponding to the oxygen consumption.
>
> Hence the processes which we have to take into account in the muscles are: (1) the formation of lactic acid from carbohydrates; (2) the combustion of lactic acid to carbonic acid and water; and (3) the reversion of lactic acid to carbohydrates. But these processes are not confined to the uninjured muscle. Meyerhof has also traced them in finely chopped muscle substance kept moist in a suitable liquid, and in that case found them take place 10–29 times more rapidly than in the well-known muscle preparation. In such a dilution it is also possible to study the effect of different factors such as the concentration of hydrogen ions, the presence of phosphates, etc.; and in particular it has been possible to make clear to what extent the various processes are connected with one another or can be varied in relation to one another. A matter of extremely great interest is the establishment of the fact that the combustion of lactic acid in the muscle cannot take place without a simultaneous formation of lactic acid from carbohydrates, and that the combustion of lactic acid is connected with the formation of carbohydrates in such a way that out of four molecules of lactic acid one is oxidized, while the three others are reverted to carbohydrates. lt is not inconceivable that the reversion does not always extend so far as to produce carbohydrates; but the ideal course of the process may be regarded as precisely defined by Meyerhof, and it has been represented by him in the form of a scheme of chemical reaction. In this scheme, too, can well be fitted the lactacidogen discovered by Embden as a connecting link between glycogen and lactic acid.

Otto Heinrich Warburg (German, 1883–1970, Fig. 2.56) studied many different aspects of cellular respiration during his long career, including the heme-based cytochrome reactions that harness energy taken from the Krebs cycle. He won the Nobel Prize in Physiology or Medicine in 1931 for some of his discoveries regarding the biochemical reactions in respiration. Professor E. Hammarsten of the Nobel Committee for Physiology or Medicine announced the award [https://www.nobelprize.org/prizes/medicine/1931/ceremony-speech/]:

> It had been known, since the days of Davy and Berzelius, that many metals possess the power of initiating or accelerating various reactions, including combustion. Starting from the possibility that had indeed been envisaged earlier, Warburg assumed that intracellular combustion might also be regarded as being due to catalysis by metals, i.e. that it might be initiated by some metallic compound. Definite proof that he was on the track of this well-hidden secret of Nature was obtained by the use of exact measurements of combustion in living cells or, as Warburg calls it, cell respiration. The quantitatively measured variations in the process of combustion under different conditions threw light on the nature of the respiratory ferment. Its tendency to enter into compounds with substances which combine with iron showed that it is itself an iron compound, and that its effects are due to iron. The correspondence between the effects of light on cellular combustion inhibited by carbon monoxide and on carbon-monoxide compounds of certain pigments closely related to blood pigments led, with the aid of a detailed mathematical analysis to the conclusion that the respiratory ferment is a red pigment containing iron, and that it is closely related to our own blood pigment. This was the first demonstration of an effective catalyst, a ferment, in the living organism, and this identification is the more important because it throws light on a process of general significance in the maintenance of life.
>
> Professor Warburg. From the start, your research has been focussed on problems of central importance. Your bold ideas, but above all, your keen intelligence and rare perfection in the art of exact measurement have won for you exceptional successes, and for the science of biology some of its most valuable material.
>
> I take the liberty of mentioning those two of your discoveries, which seem to be of the greatest value.
>
> The medical world expects great things from your experiments on cancer and other tumours, experiments which seem already to be sufficiently far advanced to be able to furnish an explanation for at least one cause of the destructive and unlimited growth of these tumours.
>
> Your discovery about the nature and effect of the ferment of respiration, which the Caroline Institute is rewarding this year with Alfred Nobel's Prize for Physiology or Medicine, has added a link of brilliant achievement to the chain that binds for all time[...]

Albert Szent-Györgyi (Hungarian, 1893–1986, Fig. 2.55) discovered several key components and reactions within the larger Krebs cycle, as well as the main biochemical steps involved in muscle contraction. He also won a Nobel Prize for his discoveries regarding vitamin C (p. 348). The *Encyclopedia Britannica* summarized his research [EB 2010]:

> Hungarian biochemist whose discoveries concerning the roles played by certain organic compounds, especially vitamin C, in the oxidation of nutrients by the cell brought him the 1937 Nobel Prize for Medicine or Physiology. [...]
>
> Szent-Györgyi then turned to the study of organic compounds known to play a part in the conversion of carbohydrate breakdown products to carbon dioxide, water, and

> other substances necessary for the production of usable energy by the cell. His work laid the foundations for Sir Hans Krebs's elucidation of the complete conversion cycle (the Krebs cycle) two years later.
>
> Devoting himself to a study of the biochemistry of muscular action, he discovered a protein in muscle that he named "actin," demonstrated that it—in combination with the muscle protein myosin—is responsible for muscular contraction, and showed that the compound adenosine triphosphate (ATP) is the immediate source of energy necessary for muscle contraction. Immigrating to the United States in 1947, he was immediately appointed director of the Institute for Muscle Research, Woods Hole, Mass., where he conducted research into the causes of cell division and, hence, cancer.

The married researchers Carl Cori (Austrian/Czech, 1896–1984) and Gerty Cori (Austrian/Czech, 1896–1957), shown in Fig. 2.53, discovered how the process of glycolysis could be reversed, gluconeogenesis (the upward pathway on the right side of Fig. 2.50). The coupled processes of glycolysis in muscle and gluconeogenesis in the liver are now called the Cori cycle. For their discoveries, Carl and Gerty Cori won the Nobel Prize in Physiology or Medicine in 1947. Professor H. Theorell of the Royal Caroline Institute explained the importance of their work [https://www.nobelprize.org/prizes/medicine/1947/ceremony-speech/]:

> After a great deal of preliminary work during the years 1932–1936, Professor Cori and his wife showed that if ground-up muscle was washed with water, the washed residue could still promote the disappearance of free phosphoric acid, which, as could be expected, was due to its being bound to sugar. But the washing had effected a change; the sugar phosphoric acid then formed exhibited certain singular properties. The Cori's were soon able to prove by means of crystallization and determination of the constitution of the new compound that the characteristic properties of this phosphoric acid ester, the so-called Cori ester were due to the fact that phosphoric acid was linked to the first carbon atom of the sugar instead of to its sixth. A layman would probably think that such a detail could only be of interest for hairsplitting specialists; but the grain of mustard seed may grow up into a great tree, if it is sown in suitable soil. From this apparently insignificant startingpoint the Cori's and their co-workers, in a long series of masterly studies, have thrown clear light on the previously unknown interplay between glucose, phosphoric acid and glycogen. The reason why the Cori ester is found only in *washed* muscle is that with the washing water an enzyme is removed, i.e. a protein substance with a special catalytic effect, which moves phosphoric acid from one end of the sugar molecule, the 1-position to the opposite, the previously known 6-position.
>
> An enzyme crystallized by the Cori's and Green, phosphorylase, plays a chief part in the mechanism. It is met with in many different tissues and can be prepared from, e.g., muscle, liver or yeast. If the phosphorylase is allowed to act on glycogen in the presence of phosphoric acid, the whole glycogen molecule is split up, with the simultaneous appearance of glucose molecules bound to phosphoric acid. This substance is indeed the Cori ester. The same process may, however, also proceed in the opposite direction, so that glycogen is formed from the Cori ester. The direction of the reaction is determined by the relative amounts of the components. For glycogen synthesis to start, a small amount of glycogen must be present as a nucleus upon which to build. Thus, if under extreme conditions it should happen that all the glycogen were broken down, the individual in question would lose for all time the capacity to form glycogen. Such

> a thing cannot happen, however, thanks to an ingenious protective mechanism discovered by the Cori's. When the glycogen supply threatens to come to an end, an enzyme intervenes, which for the time being inactivates the glycogen-splitting phosphorylase and thus preserves the last traces of the glycogen. Nature's wealth of invention is truly amazing!
>
> For a chemist, synthesis is the definite proof of how a substance is built up. Professor and Doctor Cori have accomplished the astounding feat of synthesizing glycogen in a test tube with the help of a number of enzymes which they have prepared in a pure state and whose mode of action they have revealed. This synthesis would be impossible by methods of organic chemistry alone, since the six carbon atoms of the various glucose molecules might conceivably be bound to one another in a chaotic mass of combinations. The Cori enzymes made this synthesis possible, because the enzymes favour certain modes of linkage. In spite of this, the difficulties were formidable; the first isolated phosphorylases formed unbranched compounds resembling starch, and only with the help of further enzymes were the branched chains characteristic of glycogen obtained.
>
> Blood and tissues contain free glucose. The chemical changes in metabolism are always initiated by its being coupled to phosphoric acid, which is transferred from a nitrogenous phosphoric acid compound usually called ATP. The reaction is promoted by the enzyme *hexokinase*. Two years ago a great sensation was aroused in the scientific world when the Cori's, together with Price, Colowick and Slein, announced that this hexokinase reaction was promoted by insulin but checked by another hormone in extracts from the anterior lobe of the pituitary gland, the hypophysis. The experiments have been confirmed and extended this year. This discovery is of fundamental significance. We have long known that the secreting organs—the pituitary gland, the thyroid gland, the accessory thyroid glands, the suprarenal glands, the pancreas, the sex-glands, and a number of others—exercise a decisive influence on our vital functions. But the perpetual question, which we meet already in Luther's catechism: "How does it take place?" has remained unanswered until the discovery—published by Cori's Institute—that hormones intervene chemically in the hexokinase reaction. A wide new field of physiology was thereby linked up with the domain of chemistry. In the near future it will be possible to express a further part of the mystical "vital force" in chemical formulae.

Karl Lohmann (German, 1898–1978, Fig. 2.55) discovered adenosine triphosphate (ATP) in 1929. Mitochondria convert the energy stored in sugar molecules to energy stored in ATP molecules. ATP is then used as an energy source to power a wide variety of enzymes and other processes inside cells.

Fritz Lipmann (German, 1899–1986, Fig. 2.55) discovered coenzyme A, which plays critical roles both in the Krebs cycle and in the synthesis and consumption of fats. For this accomplishment, he won the Nobel Prize in Physiology or Medicine in 1953. Professor E. Hammarsten of the Royal Caroline Institute noted [https://www.nobelprize.org/prizes/medicine/1953/ceremony-speech/]:

> [...] Lipmann announced his discovery of coenzyme A. Now suddenly everything fitted perfectly—the last notch of a combination lock fell into its place.
>
> Coenzyme A is a compound with a rather small molecule, which, when united with the enzyme-protein, acquires the property of binding acetic acid. Acetic acid is normally

> quite unreactive but when bound in this way it becomes labile and reactive and represents the previously mystical 2-carbon compound which combines with a 4-carbon compound to form citric acid. A new way for the transmission of energy in the cell was demonstrated by this discovery.
>
> Recently the acetyl phosphate made a come-back, when Lipmann with his usual keen insight showed that it is used as the active 2-carbon compound in certain bacteria. Far from feeling triumphant Lipmann wrote in his otherwise very serious scientific paper that he was quite happy about this finding.
>
> That Lipmann's discovery has an even wider scope became clear when he and others found that other acids than acetic acid are activated by coenzyme A bound to other enzyme proteins.

Hans Adolf Krebs (1900–1981, Fig. 2.54) combined the results of his own experimental investigations with those from earlier researchers to work out the complete Krebs cycle, or citric acid cycle. He won the Nobel Prize in Physiology or Medicine in 1953, and Professor E. Hammarsten of the Royal Caroline Institute praised the scientific insight of Krebs [https://www.nobelprize.org/prizes/medicine/1953/ceremony-speech/]:

> It was Krebs who discovered how these individual reactions are linked to each other in a cyclic process. He brought us a clear understanding of the essential principle of how the released energy is used for the building up processes which take place within the cell.
>
> This energy is liberated by the oxidation of a 2-carbon compound to carbonic acid and water. This 2-carbon compound is derived from the foodstuffs and is introduced into the Krebs cycle. The nature of this compound and the mechanism of its incorporation were discovered by Fritz Lipmann. But for the moment let us not be concerned with this discovery since at that time it had not yet been made. In the beginning Krebs was quite alone with his idea, and when he first presented it, it was criticized by many. But soon he found an even greater number of supporters who were joined by his previous critics. Krebs' idea was that the mysterious 2-carbon compound is added on to a known substance with 4 carbon atoms yielding a 6-carbon compound. The 2-carbon compound, bound in this way, is then degraded stepwise to carbonic acid, water, and energy. When this degradation is completed, the 4-carbon compound is again free to react with another 2-carbon molecule, which starts a new period in the oxidation cycle. Krebs could show that the 6-carbon compound formed at the onset of this cycle is citric acid which contains three carboxyl groups. The cycle is therefore also called the tricarboxylic acid cycle. [...]
>
> Out of the chaos of isolated reactions Krebs succeeded in extracting the basic system for the essential pathway of oxidation process within the cell. His penetrating intuition was so clear and true and his grasp of the problem so keen from the start that none of his original ideas had to be revised.

Hans Kornberg (German, 1928–, Fig. 2.54) received his Ph.D. under Hans Krebs. Together, Kornberg and Krebs discovered the glyoxylate cycle, an alternate version of the Krebs cycle that occurs in some microorganisms and plants.

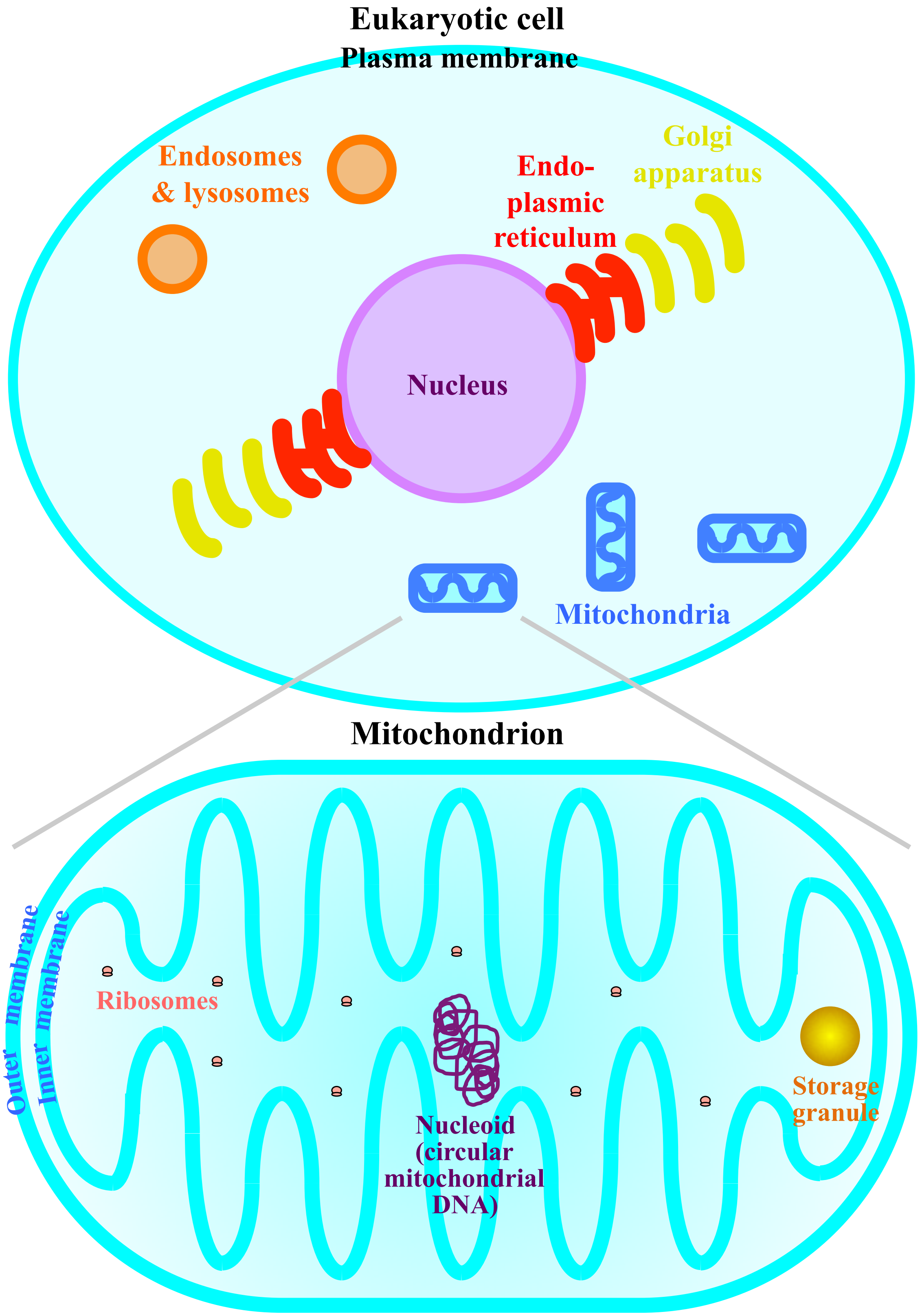

Eukaryotic cell
Plasma membrane
Endosomes
& lysosomes
Endo-
plasmic
reticulum
Golgi
apparatus
Nucleus
Mitochondria
Mitochondrion
Outer membrane
Inner membrane
Ribosomes
Nucleoid
(circular
mitochondrial
DNA)
Storage
granule

Figure 2.48: Mitochondria are the "power plants" within animal cells, plant cells, and fungi.

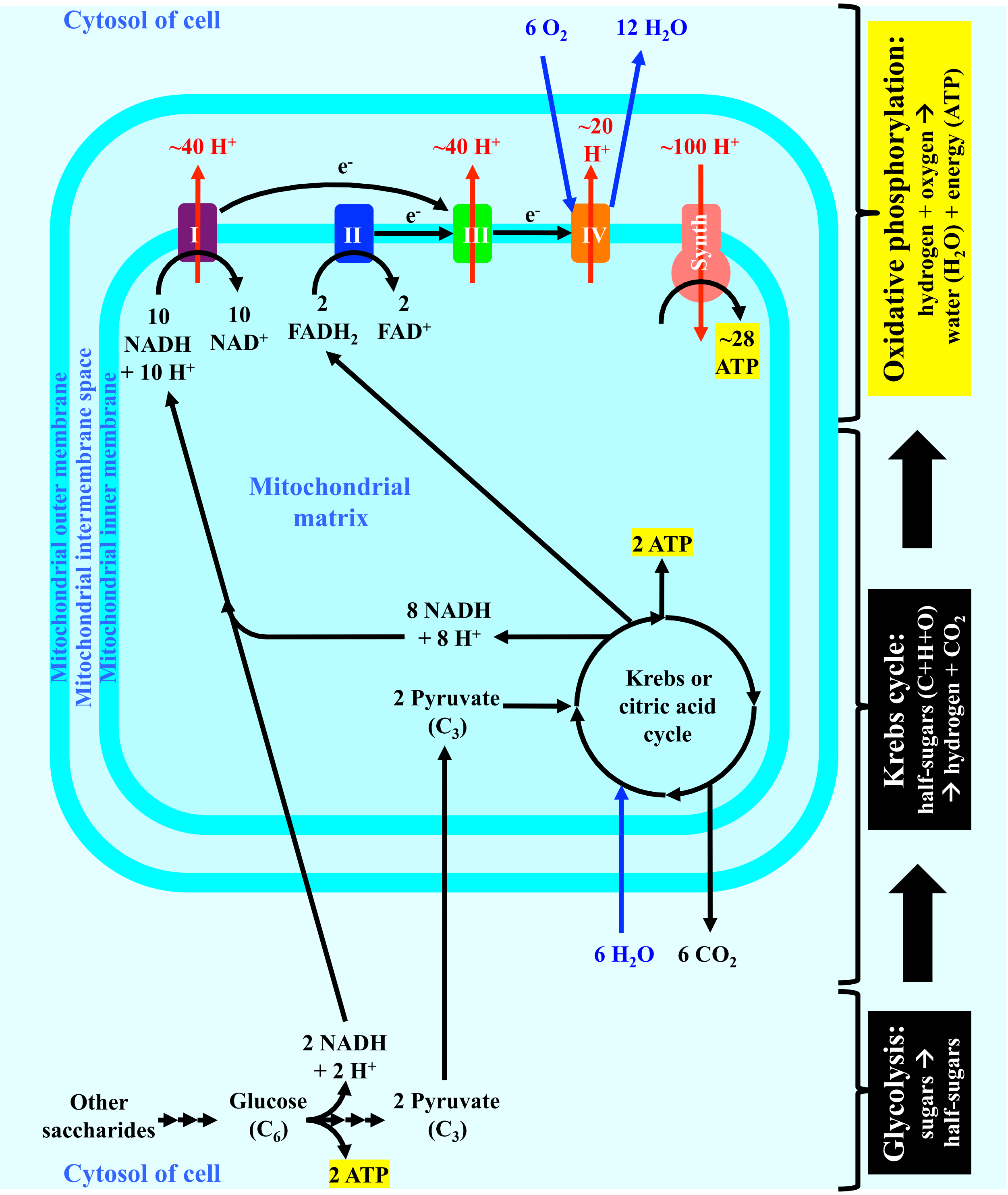

Cytosol of cell
6 O_2
12 H_2O
~40 H^+
e^-
~40 H^+
~20 H^+
~100 H^+
I
II
e^-
III
e^-
IV
Synth
10 NADH + 10 H^+
10 NAD^+
2 $FADH_2$
2 FAD^+
~28 ATP
Mitochondrial outer membrane
Mitochondrial intermembrane space
Mitochondrial inner membrane
Mitochondrial matrix
2 ATP
8 NADH + 8 H^+
2 Pyruvate (C_3)
Krebs or citric acid cycle
6 H_2O
6 CO_2
2 NADH + 2 H^+
Other saccharides
Glucose (C_6)
2 Pyruvate (C_3)
Cytosol of cell
2 ATP
Oxidative phosphorylation: hydrogen + oxygen → water (H_2O) + energy (ATP)
Krebs cycle: half-sugars (C+H+O) → hydrogen + CO_2
Glycolysis: sugars → half-sugars

Figure 2.49: In cellular respiration, mitochondria carry out a series of chemical reactions to combine sugar and oxygen molecules to produce energy, carbon dioxide, and water.

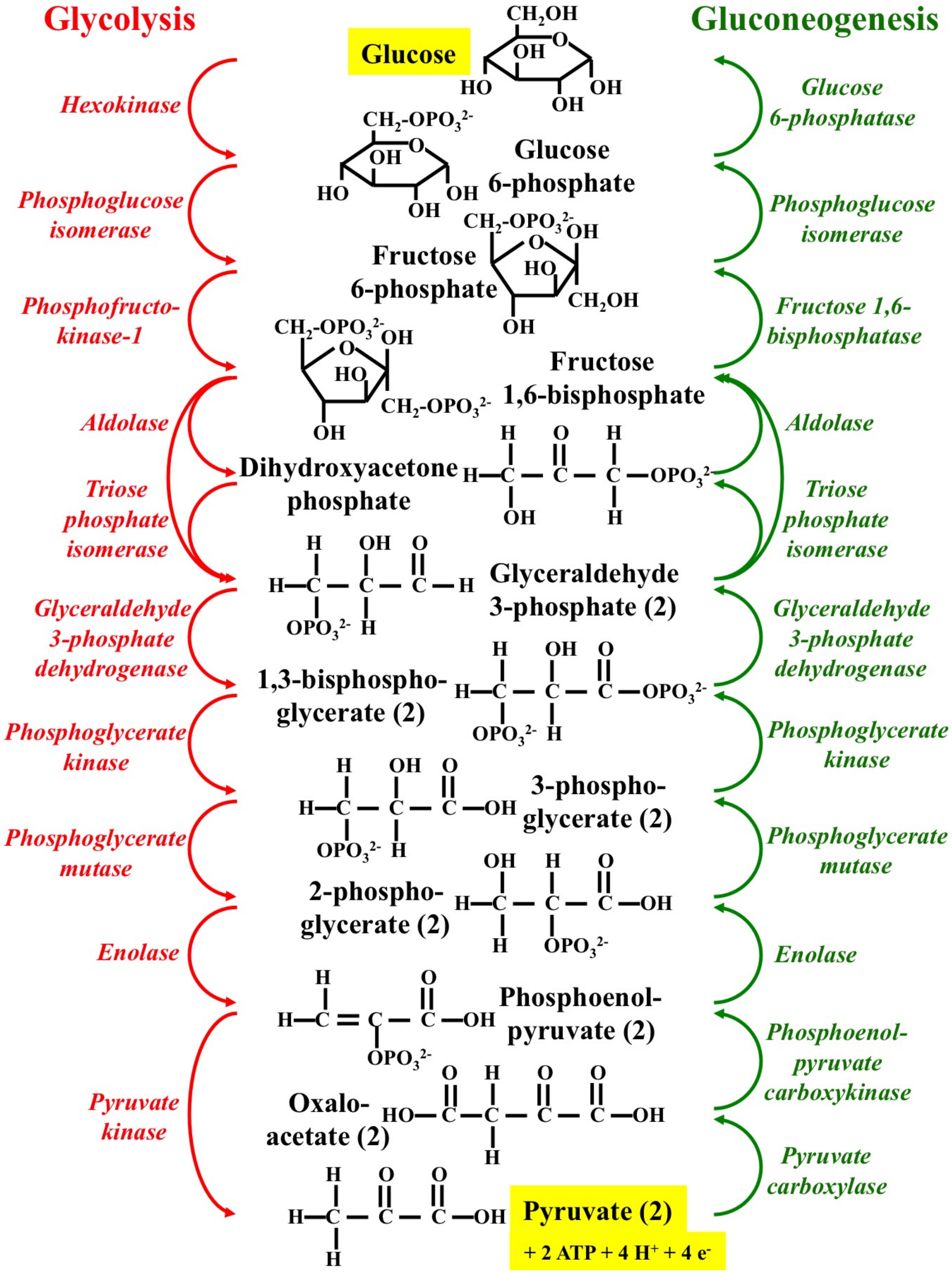

Glycolysis
Gluconeogenesis
Glucose
Hexokinase
Glucose 6-phosphatase
Glucose 6-phosphate
Phosphoglucose isomerase
Phosphoglucose isomerase
Fructose 6-phosphate
Phosphofructo-kinase-1
Fructose 1,6-bisphosphatase
Fructose 1,6-bisphosphate
Aldolase
Aldolase
Dihydroxyacetone phosphate
Triose phosphate isomerase
Triose phosphate isomerase
Glyceraldehyde 3-phosphate (2)
Glyceraldehyde 3-phosphate dehydrogenase
Glyceraldehyde 3-phosphate dehydrogenase
1,3-bisphospho-glycerate (2)
Phosphoglycerate kinase
Phosphoglycerate kinase
3-phospho-glycerate (2)
Phosphoglycerate mutase
Phosphoglycerate mutase
2-phospho-glycerate (2)
Enolase
Enolase
Phosphoenol-pyruvate (2)
Phosphoenol-pyruvate carboxykinase
Oxalo-acetate (2)
Pyruvate kinase
Pyruvate carboxylase
Pyruvate (2)
+ 2 ATP + 4 H+ + 4 e-

Figure 2.50: Breaking down sugars into smaller molecules (glycolysis), or building up sugars from smaller molecules (gluconeogenesis), involve many chemical steps, each carried out by a different enzyme.

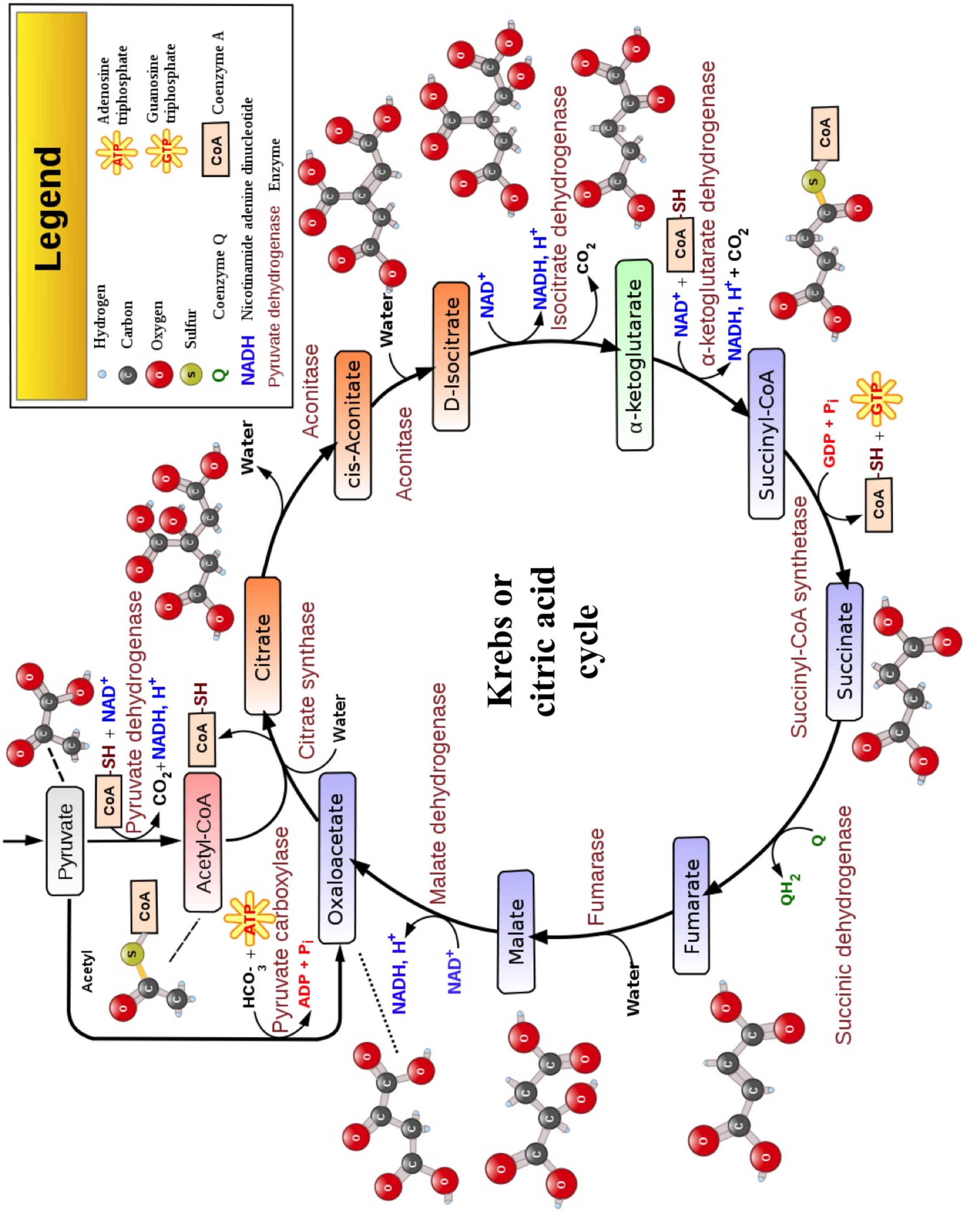
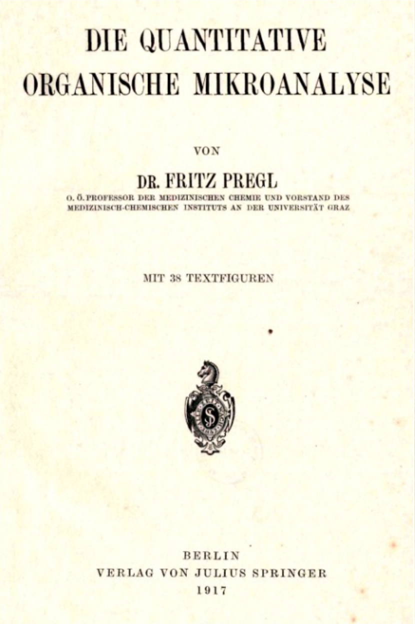

Legend
Hydrogen
Carbon
Oxygen
Sulfur
Q Coenzyme Q
NADH Nicotinamide adenine dinucleotide
Pyruvate dehydrogenase Enzyme
ATP Adenosine triphosphate
GTP Guanosine triphosphate
CoA Coenzyme A
Krebs or citric acid cycle
Pyruvate
CoA-SH + NAD+
Pyruvate dehydrogenase
CO2+NADH, H+
Acetyl-CoA
CoA-SH
Acetyl
Citrate
Citrate synthase
Water
Water
cis-Aconitate
Aconitase
Aconitase
Water
D-Isocitrate
NAD+
NADH, H+
Isocitrate dehydrogenase
CO2
α-ketoglutarate
NAD+ + CoA-SH
α-ketoglutarate dehydrogenase
NADH, H+ + CO2
Succinyl-CoA
GDP + Pi
CoA-SH + GTP
Succinyl-CoA synthetase
Succinate
Q
QH2
Succinic dehydrogenase
Fumarate
Fumarase
Water
Malate
Malate dehydrogenase
NAD+
NADH, H+
Oxaloacetate
HCO3- + ATP
ADP + Pi
Pyruvate carboxylase

Figure 2.51: The Krebs or citric acid cycle within mitochondria converts half-sugars (containing carbon, hydrogen, and oxygen atoms) into hydrogens and carbon dioxide molecules. Each step is carried out by a different enzyme.

Fritz Pregl (1869–1930) developed micro-pipetting and micro-analysis tools and methods (1910s)



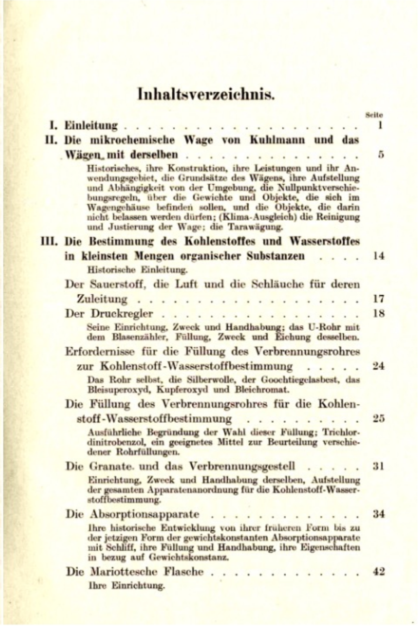
DIE QUANTITATIVE
ORGANISCHE MIKROANALYSE

VON

DR. FRITZ PREGL
O. Ö. PROFESSOR DER MEDIZINISCHEN CHEMIE UND VORSTAND DES
MEDIZINISCH-CHEMISCHEN INSTITUTS AN DER UNIVERSITÄT GRAZ

MIT 38 TEXTFIGUREN

BERLIN
VERLAG VON JULIUS SPRINGER
1917



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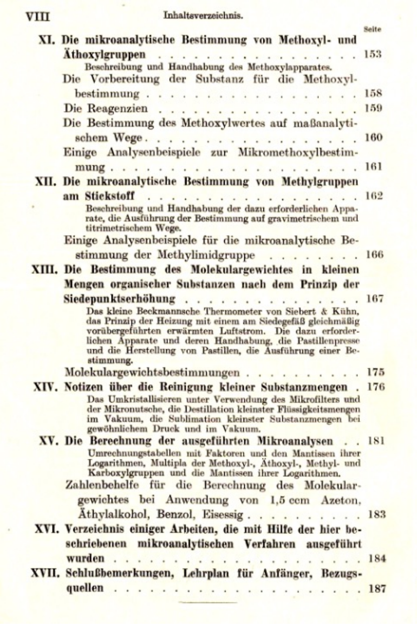

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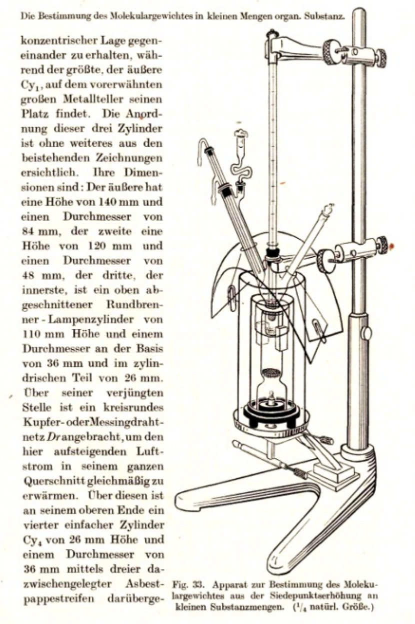
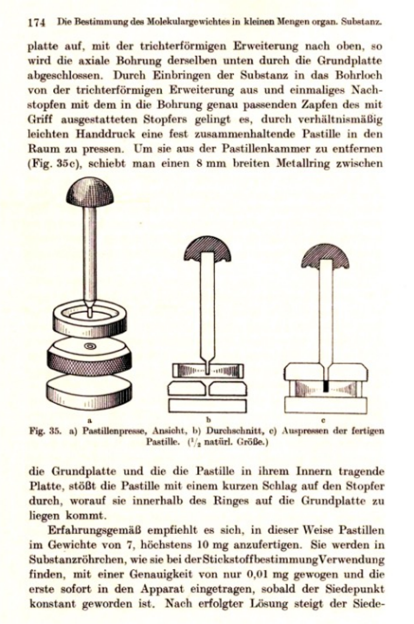


Die Bestimmung des Molekulargewichtes in kleinen Mengen organ. Substanz.

konzentrischer Lage gegeneinander zu erhalten, während der größte, der äußere Cy_1, auf dem vorerwähnten großen Metallteller seinen Platz findet. Die Anordnung dieser drei Zylinder ist ohne weiteres aus den beistehenden Zeichnungen ersichtlich. Ihre Dimensionen sind: Der äußere hat eine Höhe von 140 mm und einen Durchmesser von 84 mm, der zweite eine Höhe von 120 mm und einen Durchmesser von 48 mm, der dritte, der innerste, ist ein oben abgeschnittener Rundbrenner-Lampenzylinder von 110 mm Höhe und einem Durchmesser an der Basis von 36 mm und im zylindrischen Teil von 26 mm. Über seiner verjüngten Stelle ist ein kreisrundes Kupfer- oder Messingdrahtnetz *Dr* angebracht, um den hier aufsteigenden Luftstrom in seinem ganzen Querschnitt gleichmäßig zu erwärmen. Über diesen ist an seinem oberen Ende ein vierter einfacher Zylinder Cy_4 von 26 mm Höhe und einem Durchmesser von 36 mm mittels dreier dazwischengelegter Asbestpappestreifen darüberge-

Fig. 33. Apparat zur Bestimmung des Molekulargewichtes aus der Siedepunktserhöhung an kleinen Substanzmengen. ($^1/_4$ natürl. Größe.)



174 Die Bestimmung des Molekulargewichtes in kleinen Mengen organ. Substanz.

platte auf, mit der trichterförmigen Erweiterung nach oben, so wird die axiale Bohrung derselben unten durch die Grundplatte abgeschlossen. Durch Einbringen der Substanz in das Bohrloch von der trichterförmigen Erweiterung aus und einmaliges Nachstopfen mit dem in die Bohrung genau passenden Zapfen des mit Griff ausgestatteten Stopfers gelingt es, durch verhältnismäßig leichten Handdruck eine fest zusammenhaltende Pastille in den Raum zu pressen. Um sie aus der Pastillenkammer zu entfernen (Fig. 35c), schiebt man einen 8 mm breiten Metallring zwischen die Grundplatte und die die Pastille in ihrem Innern tragende Platte, stößt die Pastille mit einem kurzen Schlag auf den Stopfer durch, worauf sie innerhalb des Ringes auf die Grundplatte zu liegen kommt.

Erfahrungsgemäß empfiehlt es sich, in dieser Weise Pastillen im Gewichte von 7, höchstens 10 mg anzufertigen. Sie werden in Substanzröhrchen, wie sie bei der Stickstoffbestimmung Verwendung finden, mit einer Genauigkeit von nur 0,01 mg gewogen und die erste sofort in den Apparat eingetragen, sobald der Siedepunkt konstant geworden ist. Nach erfolgter Lösung steigt der Siede-

a b c

Fig. 35. a) Pastillenpresse, Ansicht, b) Durchschnitt, c) Auspressen der fertigen Pastille. ($^1/_2$ natürl. Größe.)

Figure 2.52: In the 1910s, Fritz Pregl developed micro-pipetting and micro-analysis tools and methods that are now used in virtually all biology and chemistry laboratories [Pregl 1917].

Mitochondria and cellular respiration

Gerty Cori (1896–1957) Carl Cori (1896–1984)

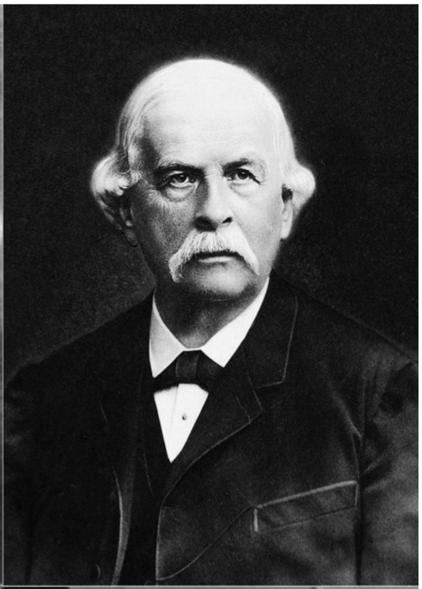
Figure 2.53: Gerty Cori and Carl Cori made significant contributions to knowledge about mitochondria and cellular respiration.

Mitochondria and cellular respiration

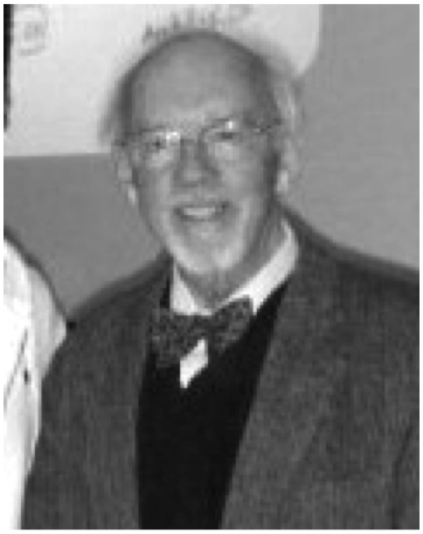
Richard Altmann
(1852–1900)
Mitochondria
<1890

Gustav Embden
(1874–1933)
Embden-Meyerhof-Parnas pathway

Rudolph Albert
von Kölliker
(1817–1905)
Mitochondria <1888



Hans Kornberg (1928–)
Glyoxylate cycle



Hans Krebs (1900–1981)
Krebs cycle, glyoxylate cycle

Figure 2.54: Other creators who made significant contributions to knowledge about mitochondria and cellular respiration included Richard Altmann, Gustav Embden, Rudolf Albert von Kölliker, Hans Kornberg, and Hans Krebs.

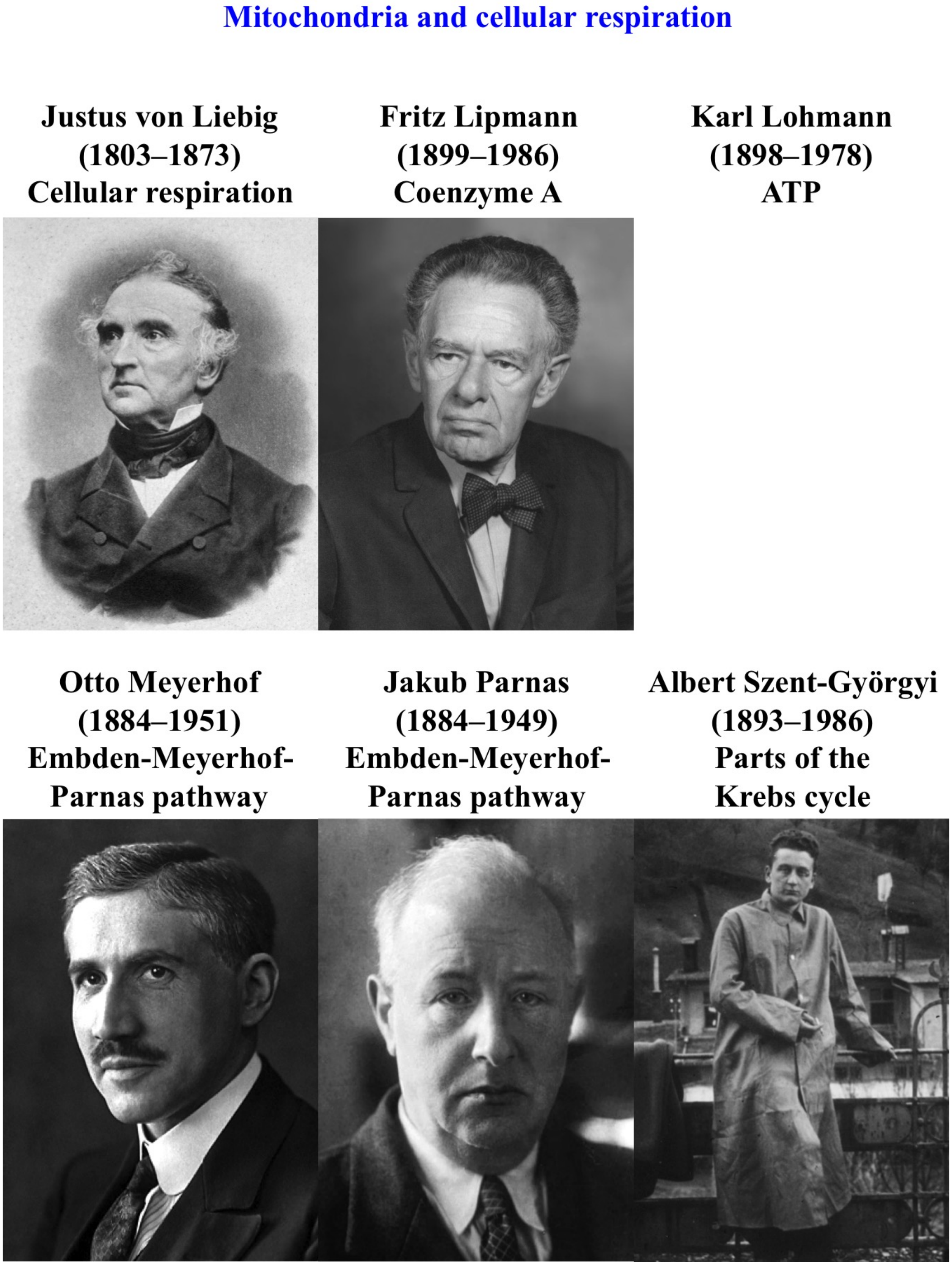

Mitochondria and cellular respiration
Justus von Liebig
(1803–1873)
Cellular respiration
Fritz Lipmann
(1899–1986)
Coenzyme A
Karl Lohmann
(1898–1978)
ATP
Otto Meyerhof
(1884–1951)
Embden-Meyerhof-Parnas pathway
Jakub Parnas
(1884–1949)
Embden-Meyerhof-Parnas pathway
Albert Szent-Györgyi
(1893–1986)
Parts of the Krebs cycle

Figure 2.55: Other creators who made significant contributions to knowledge about mitochondria and cellular respiration included Justus von Liebig, Fritz Lipmann, Karl Lohmann, Otto Meyerhof, Jakub Parnas, and Albert Szent-Györgi.

Mitochondria and cellular respiration

Otto Warburg (1883–1970)
Cellular respiration

Figure 2.56: Otto Warburg made significant contributions to knowledge about mitochondria and cellular respiration.

2.2 Microbiology and Immunology

Microbiology covers different categories of microorganisms, most of which include important pathogenic and nonpathogenic examples. German-speaking scientists made large numbers of important discoveries for all categories of microorganisms, as well as in the immunology:

> 2.2.1. Bacteria are individual prokaryotic (simple) cells that can reproduce themselves, but often like to live on the nutrients available inside a host organism (such as a person).
>
> 2.2.2. Viruses are rogue genes (generally packaged with other components) that need to hijack a cell to reproduce.
>
> 2.2.3. Prions are rogue proteins that need to hijack a cell to reproduce.
>
> 2.2.4. Fungi are small eukaryotic (complex) cells, surrounded by cell walls but otherwise not unlike eukaryotic animal cells.
>
> 2.2.5. Protozoa are simple animals composed of a single eukaryotic cell.
>
> 2.2.6. Helminths are multi-celled eukaryotic worms that start off like microorganisms but may grow to significant size.
>
> 2.2.7. Immunology, a closely related topic, is how the cells and proteins that make up the body's immune system fight infections by pathogenic microorganisms.

As a supplement to the material in this section, Appendix A gives information on offensive biological weapons research that may have been conducted in the Germany during World War II (as opposed to merely defensive work, aimed at protecting against biological weapons).[11] According to official histories, Germany did not pursue biological weapons during World War II. However, Appendix A presents evidence that suggests that Germany may have actually made major advances in biological warfare research and development during this time, and that German-speaking scientists may have subsequently transferred those methods and materials to postwar biological warfare programs in the United States, the Soviet Union, and other countries. While bioweapon development may not be viewed as an honorable field of research (harnessing microbiological knowledge to cause diseases instead of to cure them), the revolutionary nature of the actual science is noteworthy, and the long-term impact on Cold War military programs, modern concerns about bioterrorism, and even research on clinical pathogens and therapeutics has been profound. Many details remain murky and further historical investigation is definitely needed.

---

[11] See for example: Barenblatt 2004; Blome 1941; Michael Carroll 2004; Deichmann 1996; Geißler 1998a, 1998b; Gold 1997; Haagen 1941; Friedrich Hansen 1993; Sheldon Harris 2002; Kater 1989; Keremidis 2013; Klee 2001; Leitenberg and Zilinskas 2012; Posner and Ware 2000; Regis 1999; Reinhardt 2013; Vivien Spitz 2005; Tokyo War Crimes Trial 1950; U.S. Army 1956.

2.2.1 Bacteria

Bacteriology is the study of bacteria and the infections they can cause. The upper part of Fig. 2.57 shows the structure of a typical bacterium or prokaryotic cell. It is in the range of 0.5-5 μm (microns or millionths of a meter) long, near the limit of what can be readily seen with an optical microscope and roughly 10 times smaller than human and other eukaryotic (complex) cells; that is why microbiology in the German-speaking world was greatly aided by improvements in microscopes that also occurred in the German-speaking world (Section 6.9).

Prokaryotic cells are surrounded by a plasma membrane (like eukaryotic cells), but for extra protection against harsh environmental conditions or attack by a host's immune system, they add a sturdy cell wall and then for some bacteria also a capsule of polysaccharide slime. Different categories of bacteria have different types of cell walls, as illustrated in Figs. 2.57 (bottom) and 2.58.

While there were certainly contributions from scientists elsewhere (most notably Louis Pasteur (French, 1822–1895), who was personally responsible for a long list of revolutionary discoveries), scientists in the greater German-speaking world arguably played the greatest role in the development of bacteriology.[12]

Antonie van Leeuwenhoek (Dutch, 1632–1723) created the first known microscope and used it to observe a variety of microscopic organisms. In 1762, Marcus Antonius von Plenciz (Austrian, 1705–1786) published a book, *Opera medico-physica*, in which he persuasively argued that many diseases were caused by microorganisms, and he even divided those diseases into different categories by how the organisms were apparently spread. Friedrich Henle (Bavarian, 1809–1885) also publicly advocated for the germ theory of disease in 1840; one of his students was Robert Koch, who went on to make countless contributions to bacteriology.

---

[12] Allen 2014; Barlow and Barlow 1971; Thomas Brock 1999; Drews 2010; Gerber 1966; Goschler 2009; Gradmann 2009; Hinz-Wessels 2008; Hulverscheidt and Laukötter 2009; Hüntelmann 2008, 2011; Lagerkvist 2003; Schlegel 2004; Semmelweis 1981; Stichnothe-Botschafter 2013; Weiss 2005.

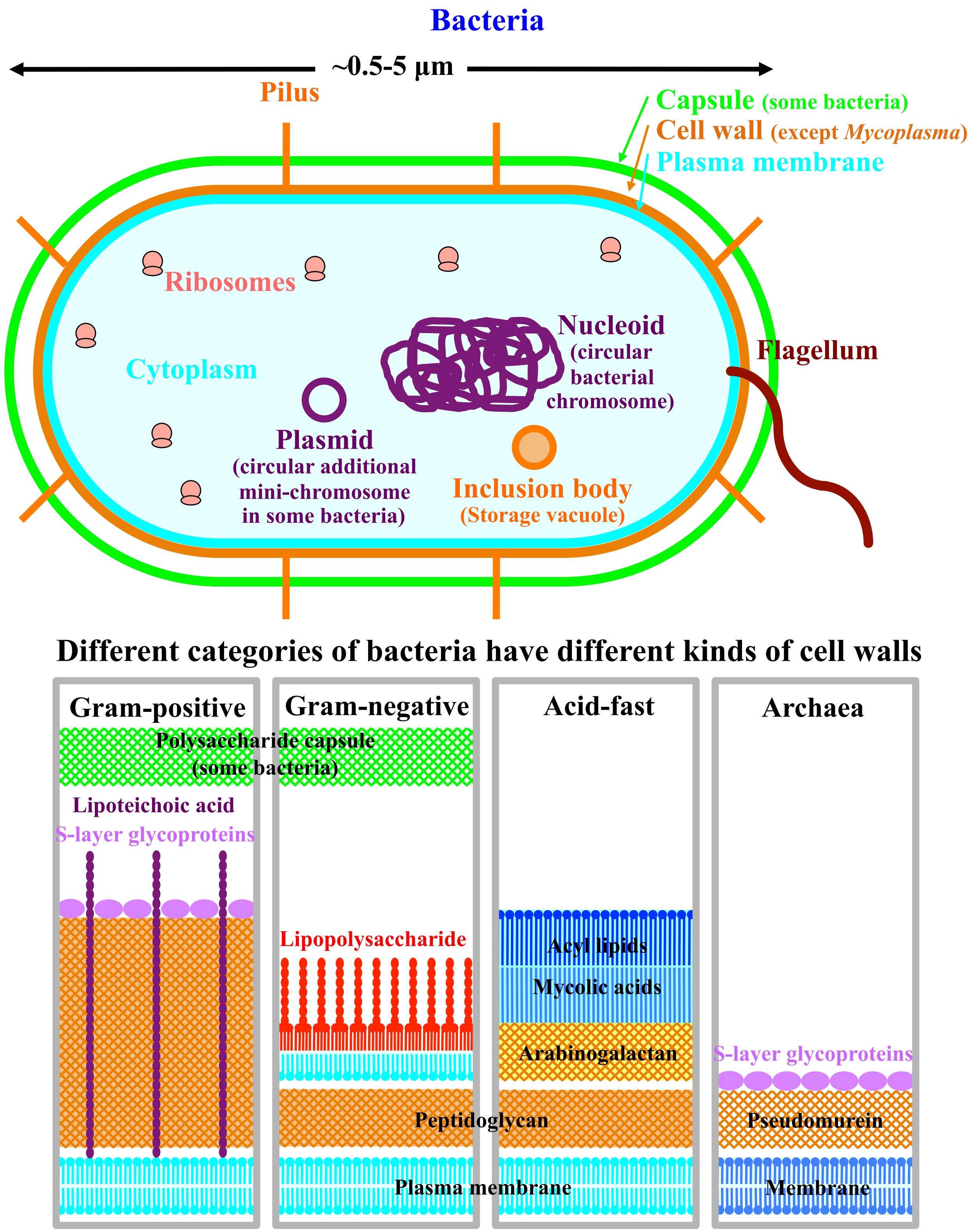

Bacteria
~0.5-5 µm
Pilus
Capsule (some bacteria)
Cell wall (except *Mycoplasma*)
Plasma membrane
Ribosomes
Cytoplasm
Nucleoid (circular bacterial chromosome)
Flagellum
Plasmid (circular additional mini-chromosome in some bacteria)
Inclusion body (Storage vacuole)
Different categories of bacteria have different kinds of cell walls
Gram-positive
Gram-negative
Acid-fast
Archaea
Polysaccharide capsule (some bacteria)
Lipoteichoic acid
S-layer glycoproteins
Lipopolysaccharide
Acyl lipids
Mycolic acids
Arabinogalactan
S-layer glycoproteins
Peptidoglycan
Pseudomurein
Plasma membrane
Membrane

Figure 2.57: Typical prokaryotic or bacterial cell, showing the overall structure (top), and the layers of the cell wall for different categories of bacteria (bottom).

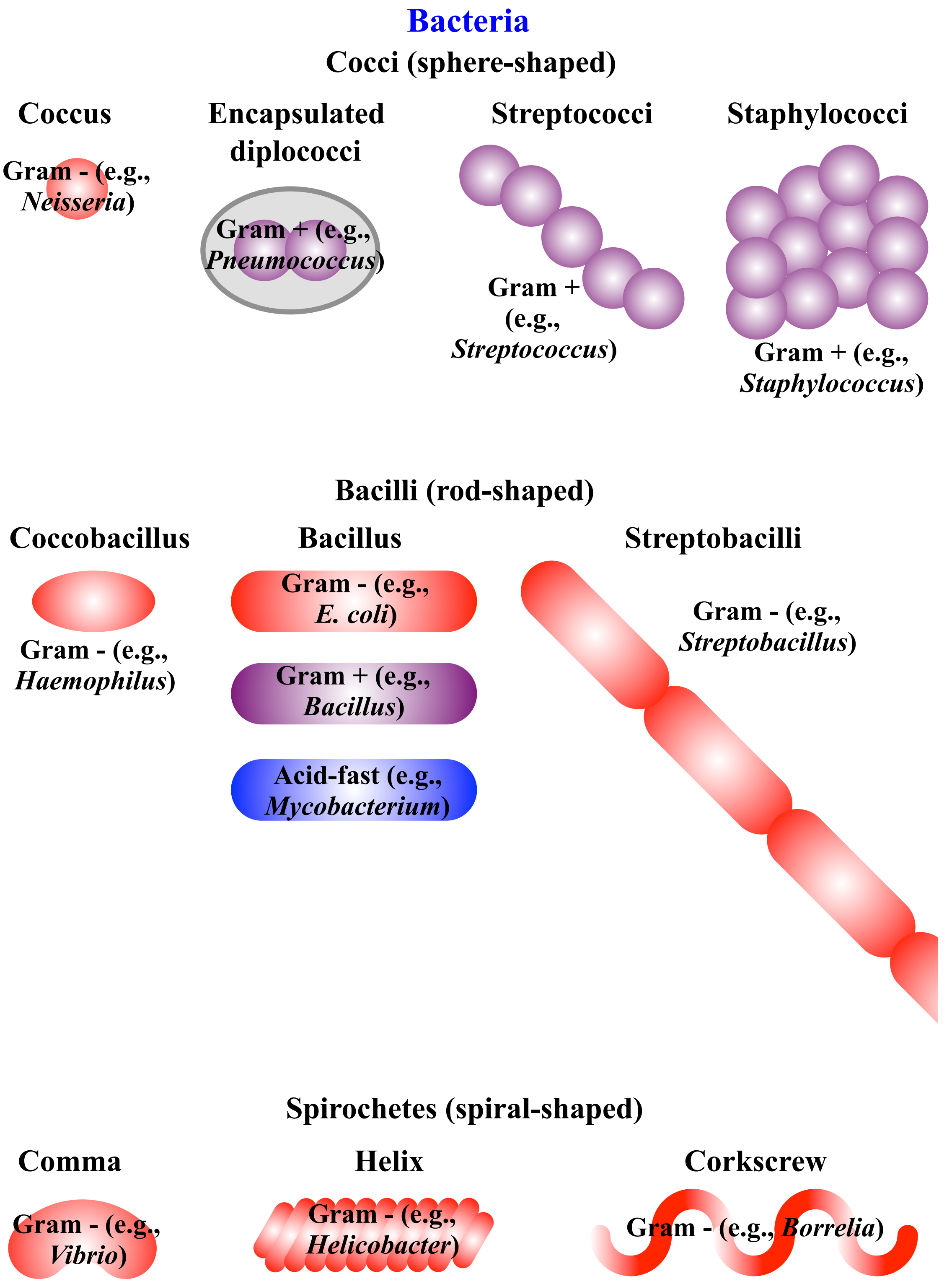

Bacteria
Cocci (sphere-shaped)
Coccus
Gram - (e.g., *Neisseria*)
Encapsulated diplococci
Gram + (e.g., *Pneumococcus*)
Streptococci
Gram + (e.g., *Streptococcus*)
Staphylococci
Gram + (e.g., *Staphylococcus*)
Bacilli (rod-shaped)
Coccobacillus
Gram - (e.g., *Haemophilus*)
Bacillus
Gram - (e.g., *E. coli*)
Gram + (e.g., *Bacillus*)
Acid-fast (e.g., *Mycobacterium*)
Streptobacilli
Gram - (e.g., *Streptobacillus*)
Spirochetes (spiral-shaped)
Comma
Gram - (e.g., *Vibrio*)
Helix
Gram - (e.g., *Helicobacter*)
Corkscrew
Gram - (e.g., *Borrelia*)

Figure 2.58: Bacteria may be classified by both their cell wall type and their shape: cocci or spherical bacteria, bacilli or rod-shaped bacteria, and spirochetes or spiral-shaped bacteria. Bacteria may also be connected in different ways: individual bacteria, joined pairs [diplo-], chains [strepto-] of bacteria, and clumps [staphylo-] of bacteria.

In 1847, Ignaz Semmelweis (Austrian, 1818–1865, Fig. 2.59) went further than these earlier scientists by introducing and demonstrating the importance of antiseptics (especially a dilute solution of calcium hypochlorite or bleach) in preventing the spread of disease-causing organisms, such as a *Streptococcus* strain that was causing puerperal fever or “childbed fever” in Vienna hospitals at the time. Semmelweis demonstrated that his antiseptic methods greatly reduced infection rates at the hospitals where he worked, yet he struggled the rest of his life to persuade hospitals elsewhere of the importance of antiseptics. Two decades later, in 1867, Joseph Lister (British, 1827–1912) published similar results and achieved far more more success and fame in promoting antiseptics, specifically phenol or “carbolic acid” as he called it. Ironically, phenol soon fell out of favor as an antiseptic due to its toxicity, whereas Semmelweis’s preferred solution of dilute hypochlorite bleach is still widely used to disinfect surfaces and linens in hospitals.

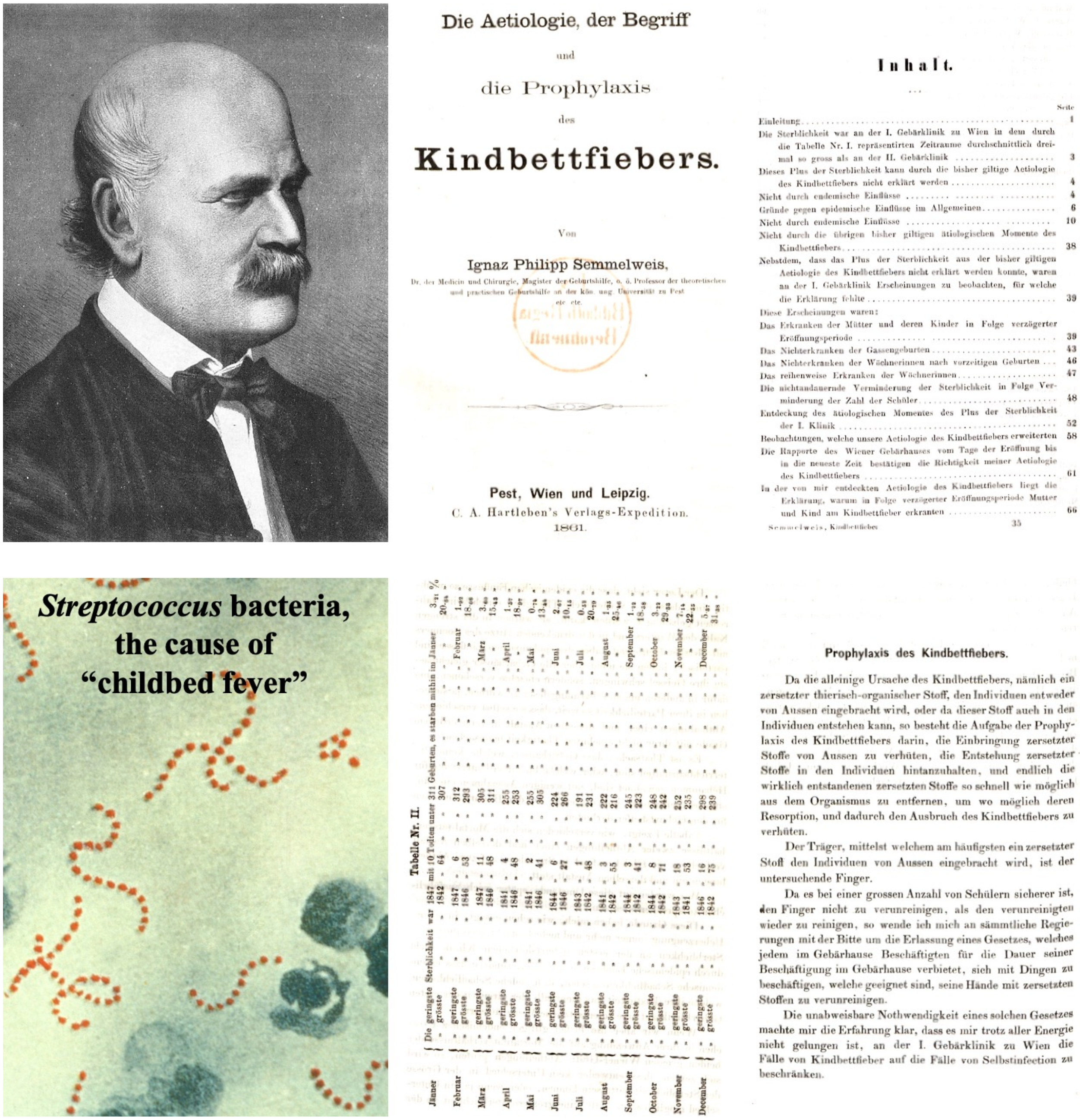
With newly improved microscopes (Section 6.9), it became much easier to see organisms as small as bacteria. However, a remaining problem was that most bacteria are essentially clear, and surrounded by essentially clear liquid or other sample material. Therefore, scientists in the German-speaking world developed methods that stained bacteria different colors than the surrounding sample material, making it much easier to visualize their shapes and identify them under the microscope. Scientists who developed important early microscope staining techniques for bacteria included Karl Weigert (German, 1845–1904), Paul Ehrlich (German, 1854–1915), and Robert Koch (German, 1843–1910), as shown in Fig. 2.60.

In 1872, Ferdinand Cohn (German, 1828–1898, Fig. 2.61) created the modern classification system for bacterial shapes (spheres or cocci, rods or bacilli, spirals or spirochetes, etc.).

Based on the earlier stains, Hans Christian Gram (Danish but worked and made his discovery in Germany, 1853–1938, Fig. 2.60) developed the “Gram staining” method in Berlin in 1884 while working with Carl Friedländer (German, 1847–1887, Fig. 2.65). Gram staining is still widely used to distinguish between bacteria with two different types of cell walls, “Gram-positive” bacteria that turn purple with this technique and “Gram-negative” bacteria that turn red. The ability to distinguish between Gram-positive and Gram-negative bacteria, and among bacteria with different shapes, was and remains a powerful method to identify bacteria under the microscope (Fig. 2.58).

Ignaz Semmelweis (1818–1865) developed and demonstrated antiseptics to prevent bacterial infections (1847).

Semmelweis made his discovery nearly two decades before Joseph Lister's much better known work (1865), and Semmelweis's chlorine-bleach-based solution was safer and more modern than Lister's phenol solution.



Die Aetiologie, der Begriff
und
die Prophylaxis
des
Kindbettfiebers.

Von
Ignaz Philipp Semmelweis,
Dr. der Medicin und Chirurgie, Magister der Geburtshilfe, ö. ö. Professor der theoretischen und practischen Geburtshilfe an der kön. ung. Universität zu Pest
etc. etc.

Pest, Wien und Leipzig.
C. A. Hartleben's Verlags-Expedition.
1861.

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Dieses Plus der Sterblichkeit kann durch die bisher giltige Aetiologie des Kindbettfiebers nicht erklärt werden 4
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Tabelle Nr. II.

Jänner	Die geringste Sterblichkeit war	1847	mit 10 Todten	unter 311	Geburten, es starben mithin im Jänner	3·21 %
	» grösste » »	1842	» 64 »	» 307	» » » » » »	20·84 »
Februar	» geringste » »	1847	» 6 »	» 312	» » » » » Februar	1·92 »
	» grösste » »	1846	» 53 »	» 293	» » » » » »	18·09 »
März	» geringste » »	1847	» 11 »	» 305	» » » » » März	3·60 »
	» grösste » »	1846	» 48 »	» 311	» » » » » »	15·43 »
April	» geringste » »	1841	» 4 »	» 255	» » » » » April	1·57 »
	» grösste » »	1846	» 48 »	» 253	» » » » » »	18·97 »
Mai	» geringste » »	1841	» 2 »	» 255	» » » » » Mai	0·78 »
	» grösste » »	1846	» 41 »	» 305	» » » » » »	13·44 »
Juni	» geringste » »	1844	» 6 »	» 224	» » » » » Juni	2·67 »
	» grösste » »	1846	» 27 »	» 266	» » » » » »	10·15 »
Juli	» geringste » »	1843	» 1 »	» 191	» » » » » Juli	0·52 »
	» grösste » »	1842	» 48 »	» 231	» » » » » »	20·79 »
August	» geringste » »	1841	» 3 »	» 222	» » » » » August	1·35 »
	» grösste » »	1842	» 55 »	» 216	» » » » » »	25·46 »
September	» geringste » »	1844	» 3 »	» 245	» » » » » September	1·22 »
	» grösste » »	1842	» 41 »	» 223	» » » » » »	18·38 »
October	» geringste » »	1844	» 8 »	» 248	» » » » » October	3·22 »
	» grösste » »	1842	» 71 »	» 242	» » » » » »	29·33 »
November	» geringste » »	1843	» 18 »	» 252	» » » » » November	7·14 »
	» grösste » »	1841	» 53 »	» 235	» » » » » »	22·55 »
December	» geringste » »	1846	» 16 »	» 298	» » » » » December	5·37 »
	» grösste » »	1842	» 75 »	» 239	» » » » » »	31·38 »

Prophylaxis des Kindbettfiebers.

Da die alleinige Ursache des Kindbettfiebers, nämlich ein zersetzter thierisch-organischer Stoff, den Individuen entweder von Aussen eingebracht wird, oder da dieser Stoff auch in den Individuen entstehen kann, so besteht die Aufgabe der Prophylaxis des Kindbettfiebers darin, die Einbringung zersetzter Stoffe von Aussen zu verhüten, die Entstehung zersetzter Stoffe in den Individuen hintanzuhalten, und endlich die wirklich entstandenen zersetzten Stoffe so schnell wie möglich aus dem Organismus zu entfernen, um wo möglich deren Resorption, und dadurch den Ausbruch des Kindbettfiebers zu verhüten.

Der Träger, mittelst welchem am häufigsten ein zersetzter Stoff den Individuen von Aussen eingebracht wird, ist der untersuchende Finger.

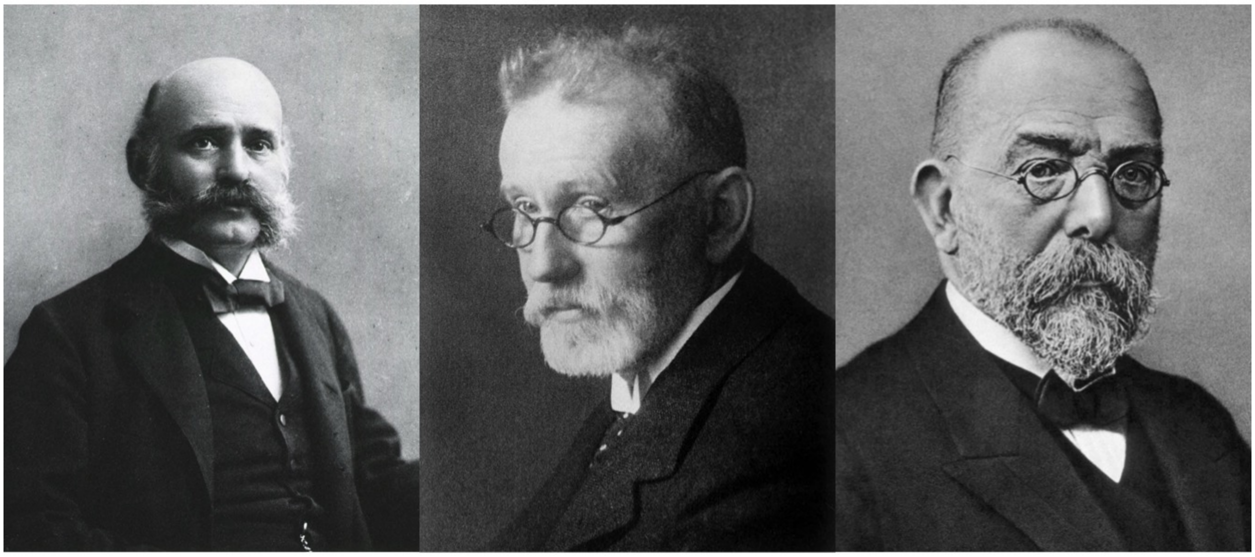
Da es bei einer grossen Anzahl von Schülern sicherer ist, den Finger nicht zu verunreinigen, als den verunreinigten wieder zu reinigen, so wende ich mich an sämmtliche Regierungen mit der Bitte um die Erlassung eines Gesetzes, welches jedem im Gebärhause Beschäftigten für die Dauer seiner Beschäftigung im Gebärhause verbietet, sich mit Dingen zu beschäftigen, welche geeignet sind, seine Hände mit zersetzten Stoffen zu verunreinigen.

Die unabweisbare Nothwendigkeit eines solchen Gesetzes machte mir die Erfahrung klar, dass es mir trotz aller Energie nicht gelungen ist, an der I. Gebärklinik zu Wien die Fälle von Kindbettfieber auf die Fälle von Selbstinfection zu beschränken.

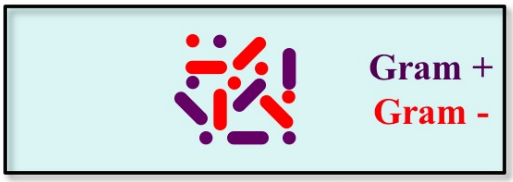
Figure 2.59: Ignaz Semmelweis discovered the importance of antiseptics in preventing the spread of pathogens, such as a *Streptococcus* strain that caused "childbed fever."

Microscope stains for bacteria

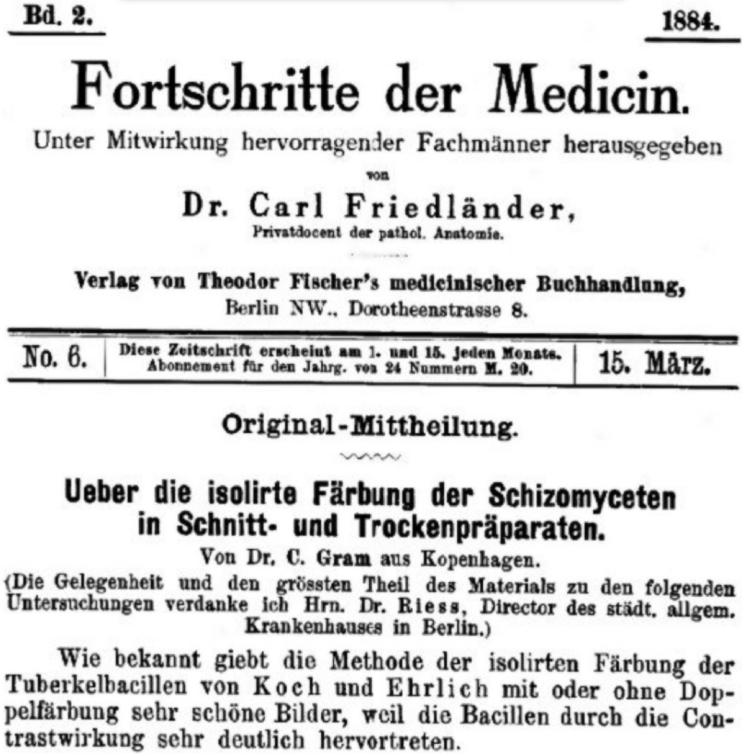
Karl Weigert (1845–1904) **Paul Ehrlich (1854–1915)** **Robert Koch (1843–1910)**



Schematic illustration of Gram stain for bacteria



Hans Christian Gram (1853–1938)



Bd. 2. 1884.

Fortschritte der Medicin.

Unter Mitwirkung hervorragender Fachmänner herausgegeben
von
Dr. Carl Friedländer,
Privatdocent der pathol. Anatomie.

Verlag von Theodor Fischer's medicinischer Buchhandlung,
Berlin NW., Dorotheenstrasse 8.

No. 6. | Diese Zeitschrift erscheint am 1. und 15. jeden Monats. Abonnement für den Jahrg. von 24 Nummern M. 20. | 15. März.

Original-Mittheilung.

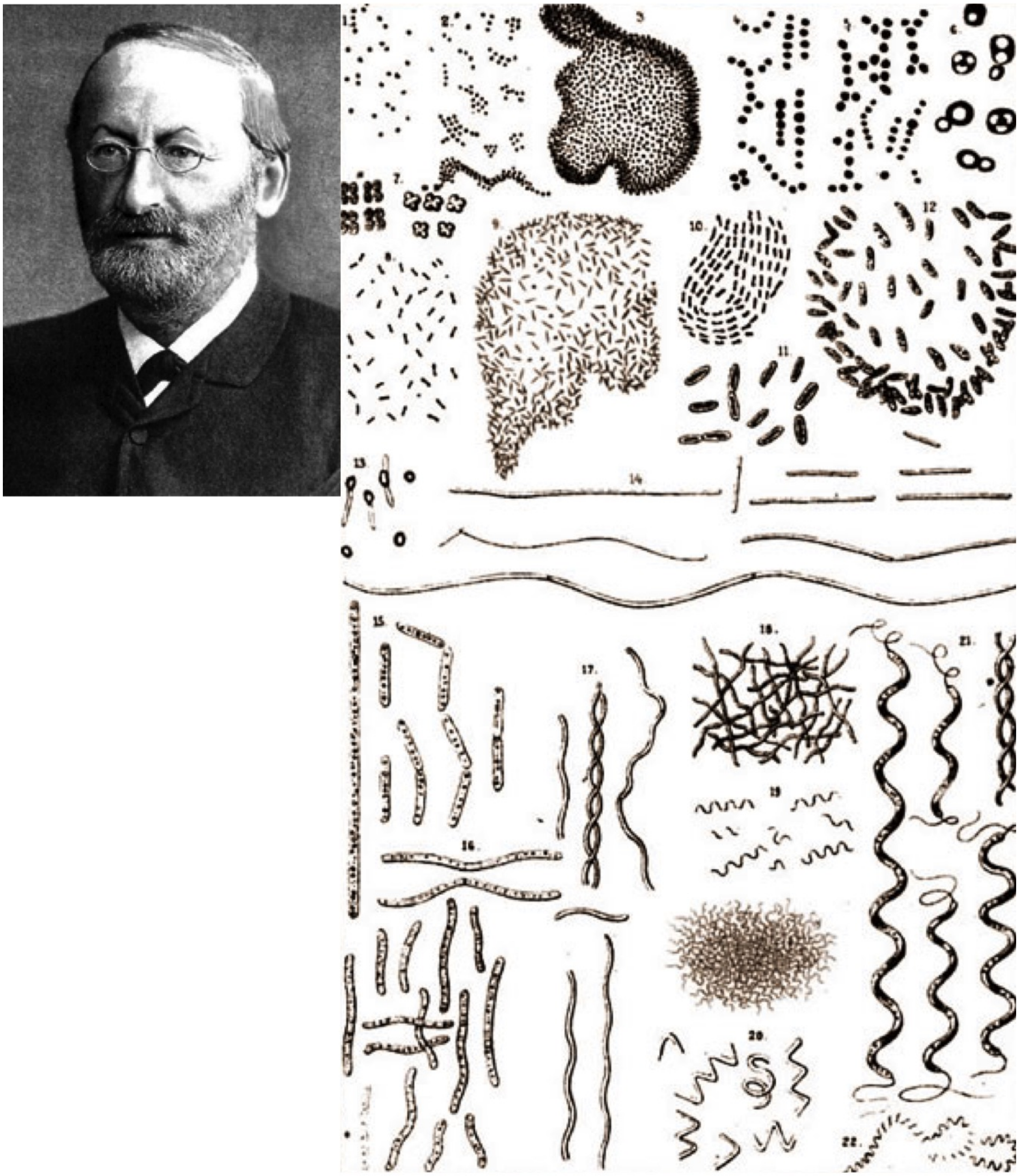
Ueber die isolirte Färbung der Schizomyceten in Schnitt- und Trockenpräparaten.

Von Dr. C. Gram aus Kopenhagen.

(Die Gelegenheit und den grössten Theil des Materials zu den folgenden Untersuchungen verdanke ich Hrn. Dr. Riess, Director des städt. allgem. Krankenhauses in Berlin.)

Wie bekannt giebt die Methode der isolirten Färbung der Tuberkelbacillen von Koch und Ehrlich mit oder ohne Doppelfärbung sehr schöne Bilder, weil die Bacillen durch die Contrastwirkung sehr deutlich hervortreten.

Figure 2.60: Creators who developed methods of staining bacteria to identify them under the microscope included Karl Weigert, Paul Ehrlich, Robert Koch, and Hans Christian Gram. Gram staining is still widely used to distinguish between bacteria with two different types of cell walls, "Gram positive" bacteria that turn purple and "Gram negative" bacteria that turn red.



Ferdinand Cohn (1828–1898) established the modern categories for bacteria shapes (1872)

Figure 2.61: Ferdinand Cohn established the modern categories for bacteria shapes.

As soon as German-speaking scientists developed improved microscopes and staining techniques for bacteria, those and other German-speaking scientists immediately began to use those methods to identify the bacteria responsible for different diseases. In fact, German-speaking scientists identified almost all of the bacteria that were responsible for major bacterial infections at that time:

- Theodor Escherich (German/Austrian, 1857–1911, Fig. 2.62) discovered the common intestinal bacteria *Escherichia coli* (*E. coli*) in 1885. Some strains of *E. coli* produce toxins and cause food-borne disease outbreaks. Nonpathogenic *E. coli* are now widely used as genetically engineered "workhorses" in biotechnology.

- Albert Fraenkel (German, 1848–1916, Fig. 2.62) discovered *Streptococcus pneumoniae*, the cause of bacteria pneumonia, in 1884.

- Alexandre Yersin (Swiss, 1863–1943, Fig. 2.62) discovered *Yersinia pestis* bacteria, the cause of bubonic, pneumonic, and septicemic plague, in 1894.

- Robert Koch (Fig. 2.63) discovered *Bacillus anthracis*, the cause of anthrax, in 1877; *Staphylococcus* strains, the cause of staph skin infections, in 1878; *Mycobacterium tuberculosis*, the cause of tuberculosis, in 1882; and *Vibrio cholerae*, the cause of cholera, in 1883. Koch received the Nobel Prize in Physiology or Medicine in 1905.

  Professor the Count K. A. H. Mörner, Rector of the Royal Caroline Institute, went into detail about Koch's achievements [https://www.nobelprize.org/prizes/medicine/1905/ceremony-speech/]:

  > In 1876 Koch entered the field of bacteriological research with an investigation of anthrax, and two years later he produced his classical investigations into diseases from wound infections. With the views set out there and the way he formulated the questions, he had a fundamental effect on the further development of bacteriology, and the ideas he expressed there recur as a leading motive in his subsequent research and form the foundation of modern bacteriology, as they do of the axioms of hygiene which are derived from it.
  >
  > He stressed that, if bacteria caused a disease, then they must always be demonstrable in it, and they should develop in a way such that this would account for the pathological process.
  >
  > He further stressed that the capacity to produce disease could not be a general property of bacteria or one common to them all. On the contrary it should be expected in this respect to find specific properties distinguishing individual bacteria. Even if they resemble other bacteria in their form, etc. they must still be different from one another by virtue of this biological property: in other words, every disease must have its special bacterium, and to combat the disease, it would be necessary to look for clues in the biology of the bacterium. Koch therefore not only set himself the task of examining the problem of whether diseases were caused by bacteria, but also endeavoured to discover the special micro-organisms of the particular diseases and to get to know more about them: this was a problem which, in the circumstances then prevailing, seemed to offer very little hope of being solved. In the way Koch solved this problem he was just as much, if not more, of a pioneer, then he already

was in the abovementioned precision which he had given to the formulation of the problem.

To start with, developing a general methodology is as valuable as finding the correct technique for every special case. Koch's genius has blazed new trails in this respect and has given present-day research its form. To give a detailed description of this is beyond the scope of this account. I only want to mention that he had moreover already given a significant development to techniques in staining and microscopic investigation as well as in the field of experiment in his earliest work. Shortly after this he produced the important method, which is still generally the usual one, of spreading the material under investigation in a solid nutrient medium to allow each individual among the micro-organisms present to develop into a fixed colony, from which it is possible, in further research, to go on to obtain what is known as a pure culture.

Shortly after the publication of his investigations into diseases from wound infections Koch was appointed to the new Institution, the "Gesundheitsamt" (Department of Health), in Berlin. There he started work on some of the most important human diseases, namely, tuberculosis, diphtheria and typhus. He worked on the former one himself. The two latter investigations he left to his first two pupils and assistants, Loeffler and Gaffky. For all three diseases the specific bacteria were discovered and studied in detail.

To give an account of the work which Koch carried out, or accomplished through his pupils, and also to mention the work which derives more indirectly from Koch, would nearly be the same as describing the development of bacteriology over the last few decades. I will content myself with naming some of the most important discoveries and items of research which, in addition to those already named, are more directly linked with Koch's name. At the head of the German Cholera Commission Koch investigated the parasitic aetiology of cholera in Egypt and India, and discovered the cholera bacillus and the conditions necessary for its life. Experience thus gained found practical application in the development of measures taken to prevent and combat this devastating disease. In addition Koch made important investigations concerning plague in humans, malaria, tropical dysentery, and the Egyptian eye disease (trachoma) among others, and now finally concerning typhus recurrens in tropical Africa. He has also carried out work of exceptional importance, concerning a host of destructive tropical cattle diseases, such as rinderpest, Surra disease, Texas fever, and finally concerning coast fever in cattle and the trypanosome disease carried by the tsetse fly.

Through the perfection he gave to methods of culturing and identifying micro-organisms, he has been able to carry out his work with regard to disinfectants and methods of disinfection so important for practical hygiene, and advice concerning the early detection and combating of certain epidemic diseases such as cholera, typhus and malaria.

- Arthur Nicolaier (German, 1862–1942) discovered *Clostridium tetani*, the cause of tetanus, in 1884. Émile van Ermengem (Belgian but closely coupled to the German research world, 1851–1932) discovered the closely related *Clostridium botulinum*, the cause of botulism, in 1896. See Fig. 2.64.

- Carl Friedländer and T. A. Edwin Klebs (German, 1834–1913) discovered *Klebsiella pneumoniae*, a cause of bacterial pneumonia, in 1882. See Fig. 2.65.

- T. A. Edwin Klebs and Friedrich Löffler (German, 1852–1915) discovered *Corynebacterium diptheriae*, the cause of diptheria, in 1883. See Fig. 2.65.

- Albert Neisser (German, 1855–1916) discovered *Neisseria gonorrhoeae*, the cause of gonorrhea, in 1879. Anton Weichselbaum (Austrian, 1845–1920) discovered the closely related *Neisseria meningitidis*, the cause of bacterial meningitis, in 1887. See Fig. 2.66.

- Erich Hoffmann (German, 1868–1959) and Fritz Schaudinn (German, 1871–1906) discovered *Treponema pallidum*, the cause of syphilis, in 1903. See Fig. 2.66.

- *Salmonella* species cause various illnesses (Fig. 2.67). Karl Joseph Eberth (German, 1835–1926) discovered *Salmonella typhi*, the cause of typhoid fever, in 1880; Georg Gaffky (German, 1850–1918) confirmed that finding in 1884. August Gaertner (1848–1934) discovered *Salmonella enteritidis*, the cause of salmonellosis, in 1888. Hugo Schottmüller (German, 1867–1936) discovered *Salmonella paratyphi*, the cause of paratyphoid fever, in 1900.

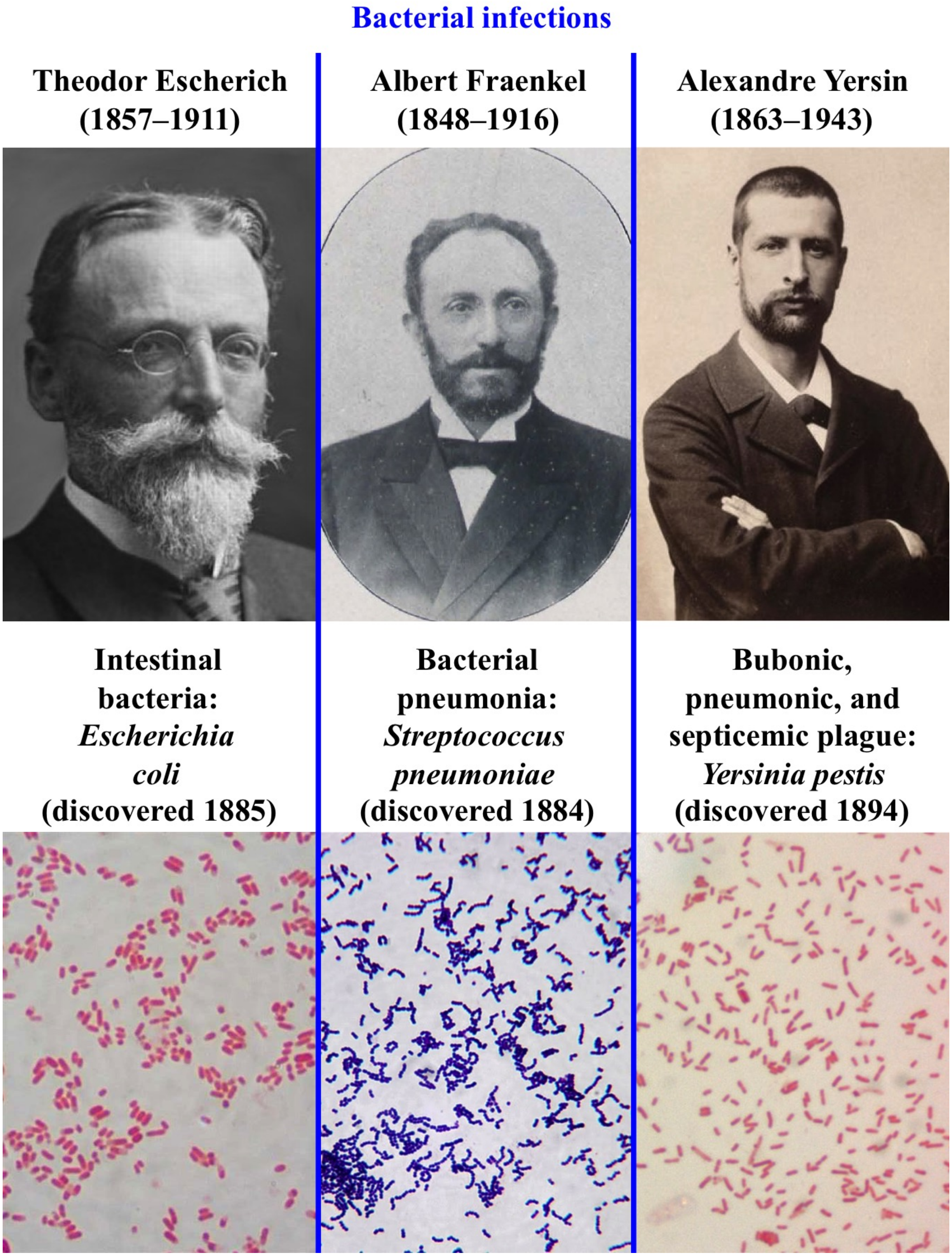

Bacterial infections
Theodor Escherich
(1857–1911)
Albert Fraenkel
(1848–1916)
Alexandre Yersin
(1863–1943)
Intestinal bacteria: *Escherichia coli* (discovered 1885)
Bacterial pneumonia: *Streptococcus pneumoniae* (discovered 1884)
Bubonic, pneumonic, and septicemic plague: *Yersinia pestis* (discovered 1894)

Figure 2.62: Theodor Escherisch discovered *Escherischia coli* (*E. coli*) bacteria, Albert Fraenkel discovered *Streptococcus pneumoniae*, and Alexandre Yersin discovered *Yersinia pestis*.

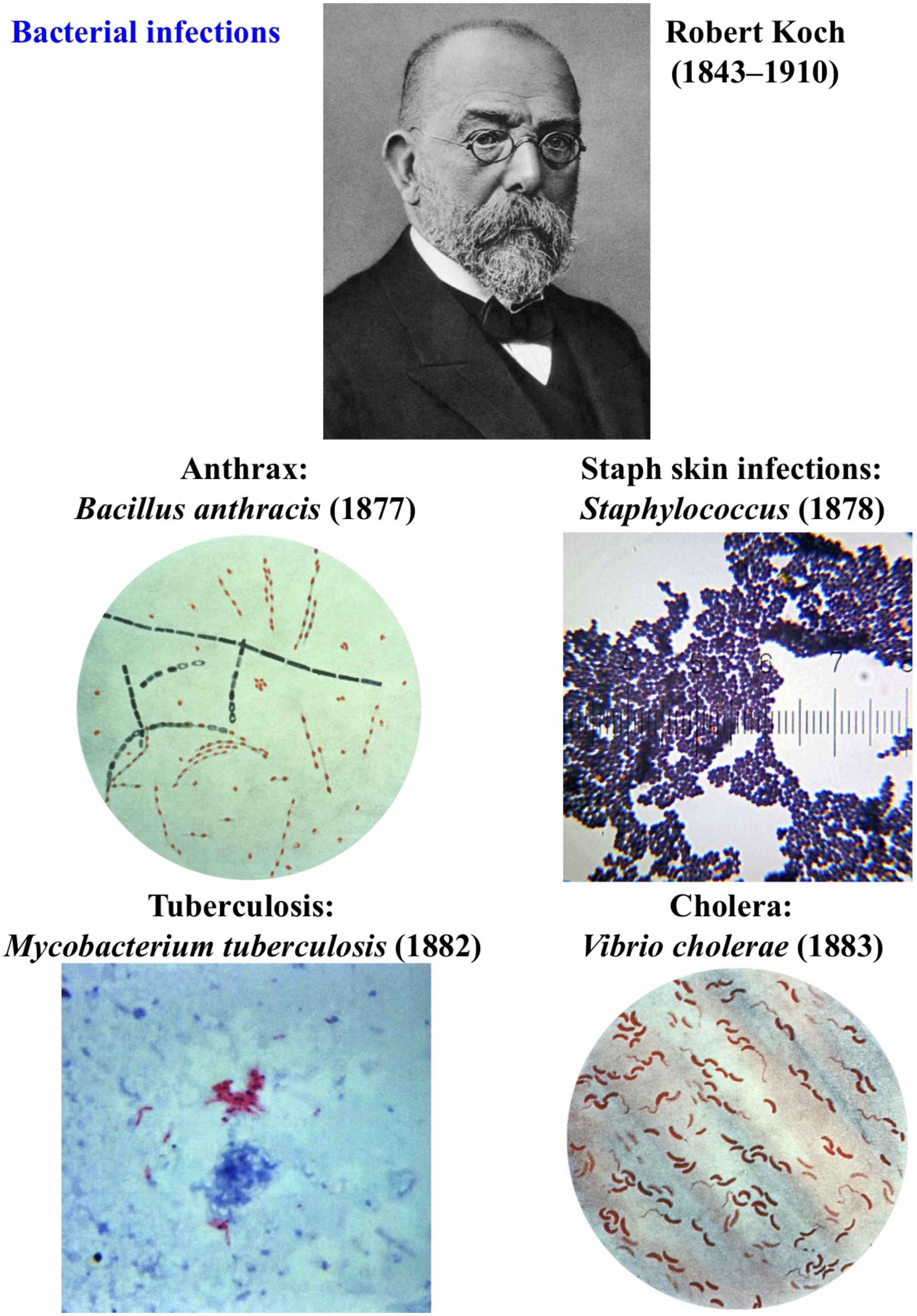
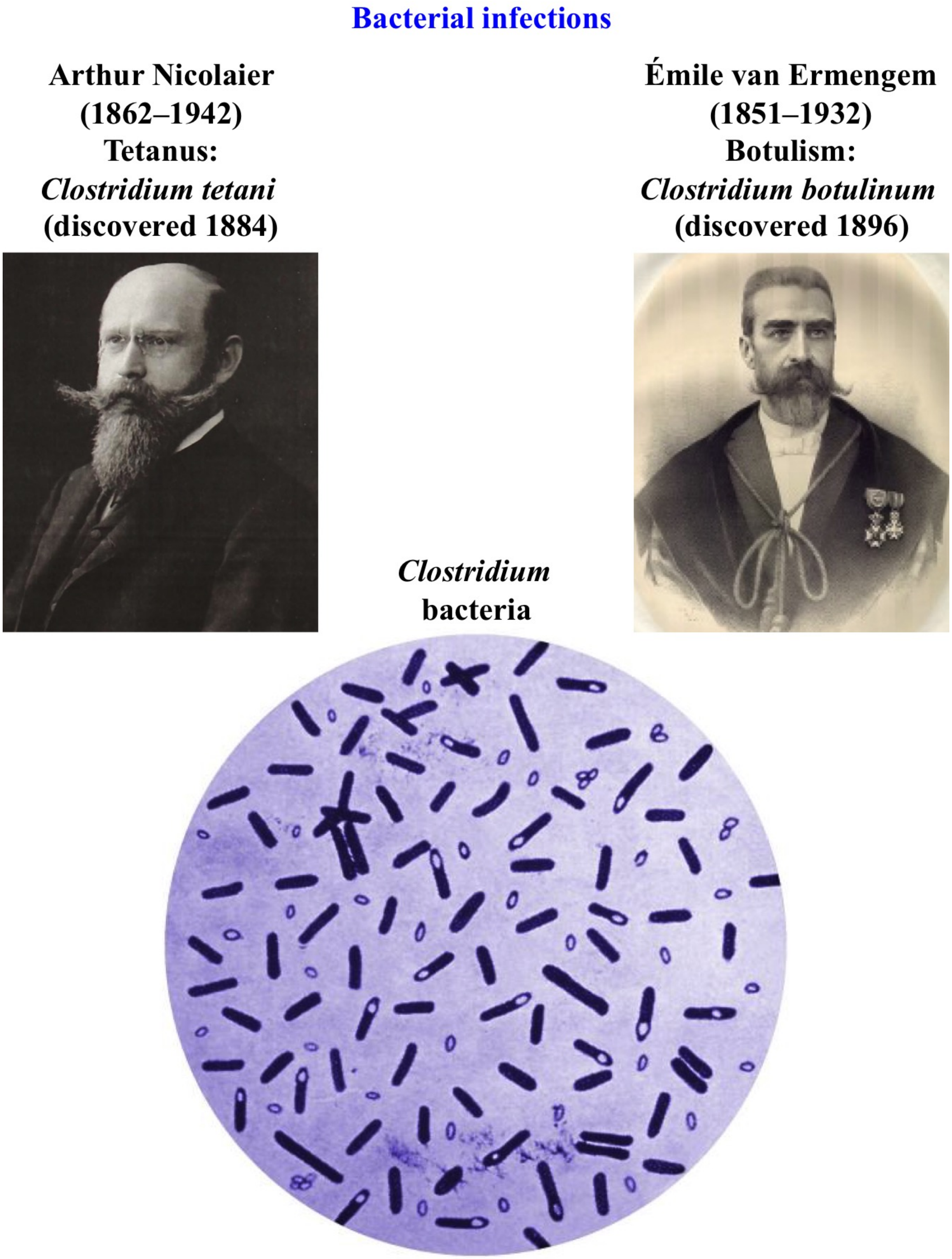

Bacterial infections
Robert Koch
(1843–1910)
Anthrax:
Bacillus anthracis (1877)
Staph skin infections:
Staphylococcus (1878)
Tuberculosis:
Mycobacterium tuberculosis (1882)
Cholera:
Vibrio cholerae (1883)

Figure 2.63: Robert Koch discovered *Bacillus anthracis*, *Staphylococcus*, *Mycobacterium tuberculosis*, and *Vibrio cholera* bacteria.



Bacterial infections

Arthur Nicolaier
(1862–1942)
Tetanus:
Clostridium tetani
(discovered 1884)

Émile van Ermengem
(1851–1932)
Botulism:
Clostridium botulinum
(discovered 1896)

Clostridium
bacteria

Figure 2.64: Arthur Nicolaier discovered *Clostridium tetani* and Émile van Ermengem discovered the closely related *Clostridium botulinum*.

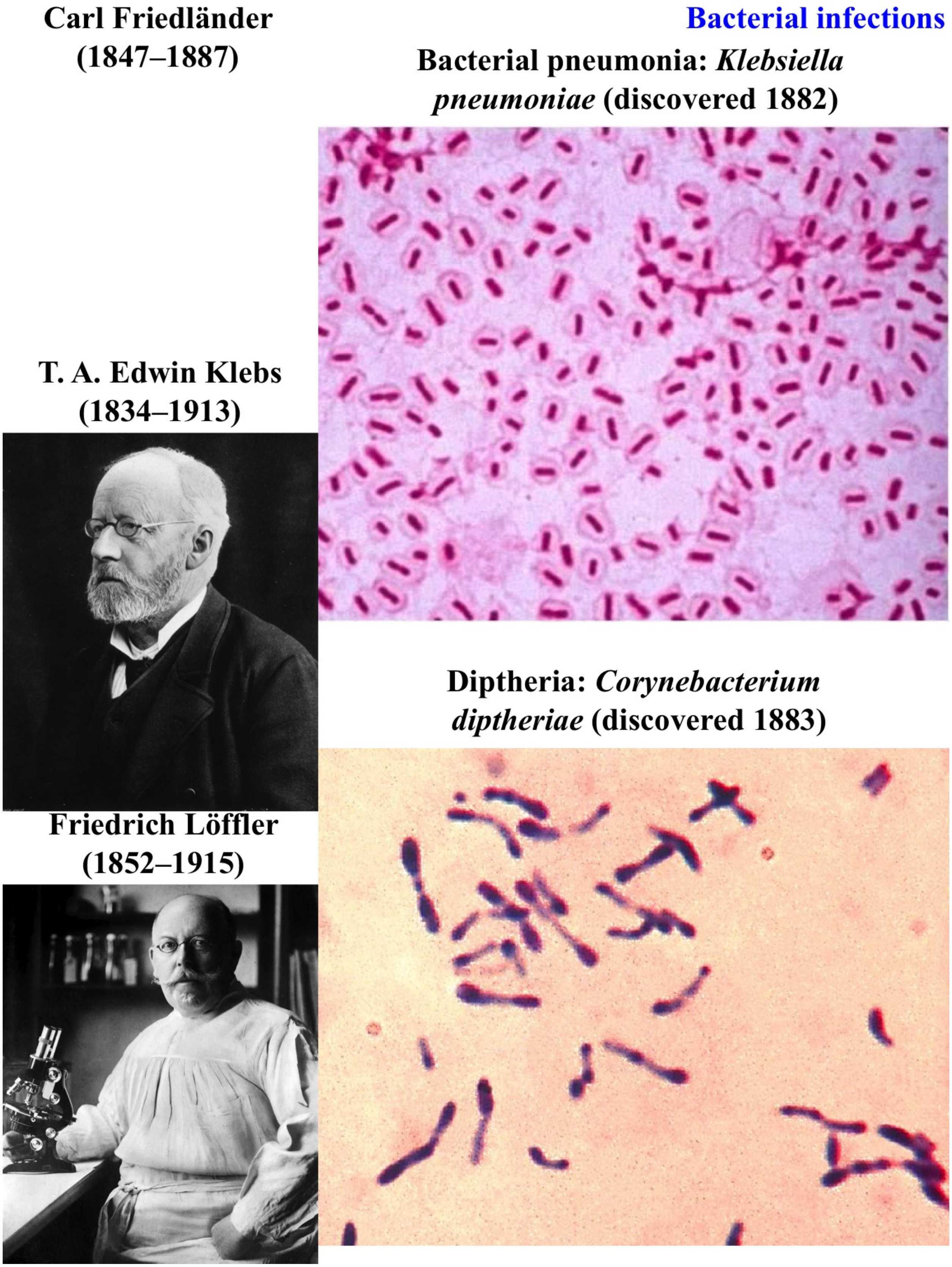

Carl Friedländer
(1847–1887)
Bacterial infections
Bacterial pneumonia: *Klebsiella pneumoniae* (discovered 1882)
T. A. Edwin Klebs
(1834–1913)
Diptheria: *Corynebacterium diptheriae* (discovered 1883)
Friedrich Löffler
(1852–1915)

Figure 2.65: Carl Friedländer and T. A. Edwin Klebs discovered *Klebsiella pneumoniae*. Klebs and Friedrich Löffler discovered *Corynebacterium diptheriae*.

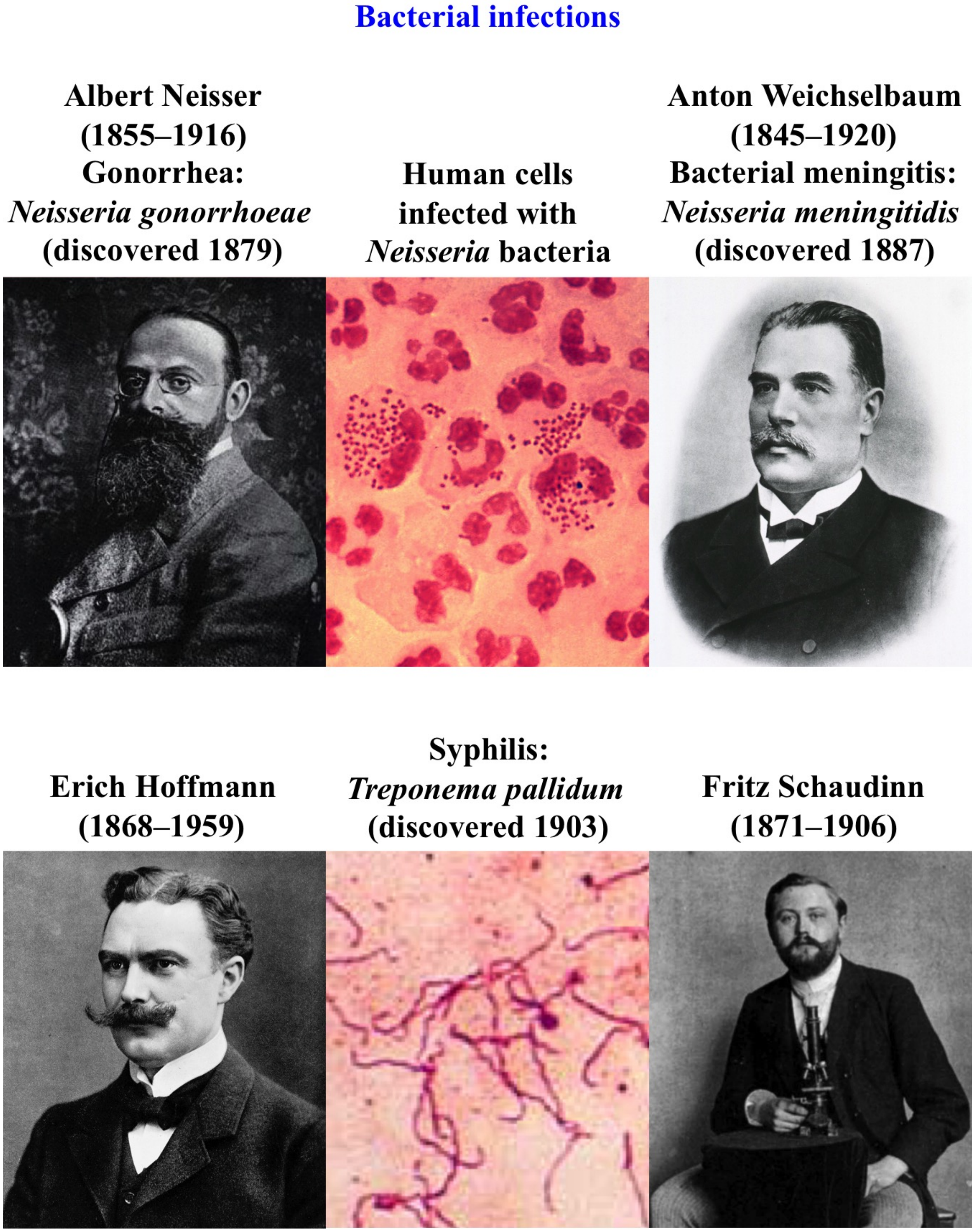
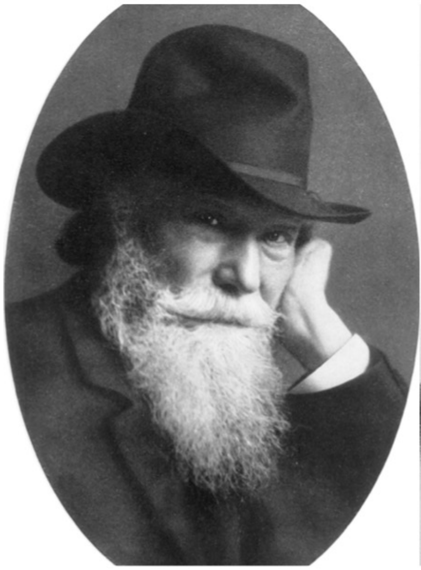

Bacterial infections
Albert Neisser (1855–1916) Gonorrhea: *Neisseria gonorrhoeae* (discovered 1879)
Human cells infected with *Neisseria* bacteria
Anton Weichselbaum (1845–1920) Bacterial meningitis: *Neisseria meningitidis* (discovered 1887)
Erich Hoffmann (1868–1959)
Syphilis: *Treponema pallidum* (discovered 1903)
Fritz Schaudinn (1871–1906)

Figure 2.66: Albert Neisser discovered *Neisseria gonorrhoeae* and Anton Weichselbaum discovered the closely related *Neisseria meningitidis* bacteria. Erich Hoffmann and Fritz Schaudinn discovered *Treponema pallidum*.

Bacterial infections

Karl Eberth
(1835–1926)
Typhoid fever:
Salmonella
***typhi* (1880)**



Georg Gaffky
(1850–1918)
Confirmed
typhoid fever:
***Salmonella typhi* (1884)**

Salmonella

August Gaertner
(1848–1934)
Salmonellosis:
Salmonella
***enteritidis* (1888)**

Hugo Schottmüller
(1867–1936)
Paratyphoid fever:
Salmonella
***paratyphi* (1900)**

Figure 2.67: Karl Eberth and Georg Gaffky discovered *Salmonella typhi*, August Gaertner discovered *Salmonella enteritidis*, and Hugo Schottmüller discovered *Salmonella paratyphi* bacteria.

German-speaking scientists also developed methods to cultivate bacteria and other microorganisms, as shown in Figs. 2.68–2.73:

- Working together with Robert Koch, Julius Petri (German, 1852–1921) invented Petri dishes in 1881. In that same year, spouses Fanny Hesse (born of German parents in the United States, lived in Germany, 1850–1934) and Walther Hesse (German, 1846–1911) developed agar nutrient gel to fill those dishes [Brock 1999; Schlegel 2004]. The agar provides a solid surface that does not decay to a messy liquid as microorganisms grow on it. Agar-filled Petri dishes are now virtually ubiquitous in biology laboratories for culturing microorganisms.

- By 1890, Carl Wehmer (1858–1935) was using yeast fermentation to produce citric acid, fumaric acid, and other substances [Benninga 1990]. See Fig. 2.69.

- Franz Schardinger (Austrian, 1853–1920) used bacterial fermentation to produce acetone (1903–1904). See Fig. 2.70 for some of his publications demonstrating his methods and results.

- In 1910, Chaim Azriel Weizmann (Belarus, educated and worked in Germany and Switzerland, 1874–1952) began internationally popularizing Schardinger's methods of using bacterial fermentation to produce acetone. (Sometimes international credit was given to Weizmann for popularizing these methods, but not to Schardinger for first inventing, demonstrating, and publishing these methods.)

- In the early twentieth century, bioreactors for the continuous liquid culture of microorganisms were developed by scientists at Benkiser, Boehringer, I.G. Farben, Phrix, Röhm and Haas, and other German companies and laboratories (Figs. 2.71–2.71). For more detailed information, see pp. 2401–2404, 2412.

- In the 1940s, the use of bioreactors for the continuous liquid culture of microorganisms was internationally popularized by German-speaking refugees such as Ernst Chain (German, 1906–1979, working in the United Kingdom) and Leo Szilard (Hungarian, 1898–1964, working in the United States, p. 183)[13], and also by Allied investigators who wrote numerous reports on the German biotechnology industry (pp. 2401–2404, 2412).

- Bioreactors are now used worldwide for a wide variety of industrial-scale production of microorganisms and products derived from them.

- See Appendix A for additional examples.

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[13] See for example: Ronald Clark 1985; István Hargittai 2006; Lanouette and Silard 1992; Weart and Szilard 1978.

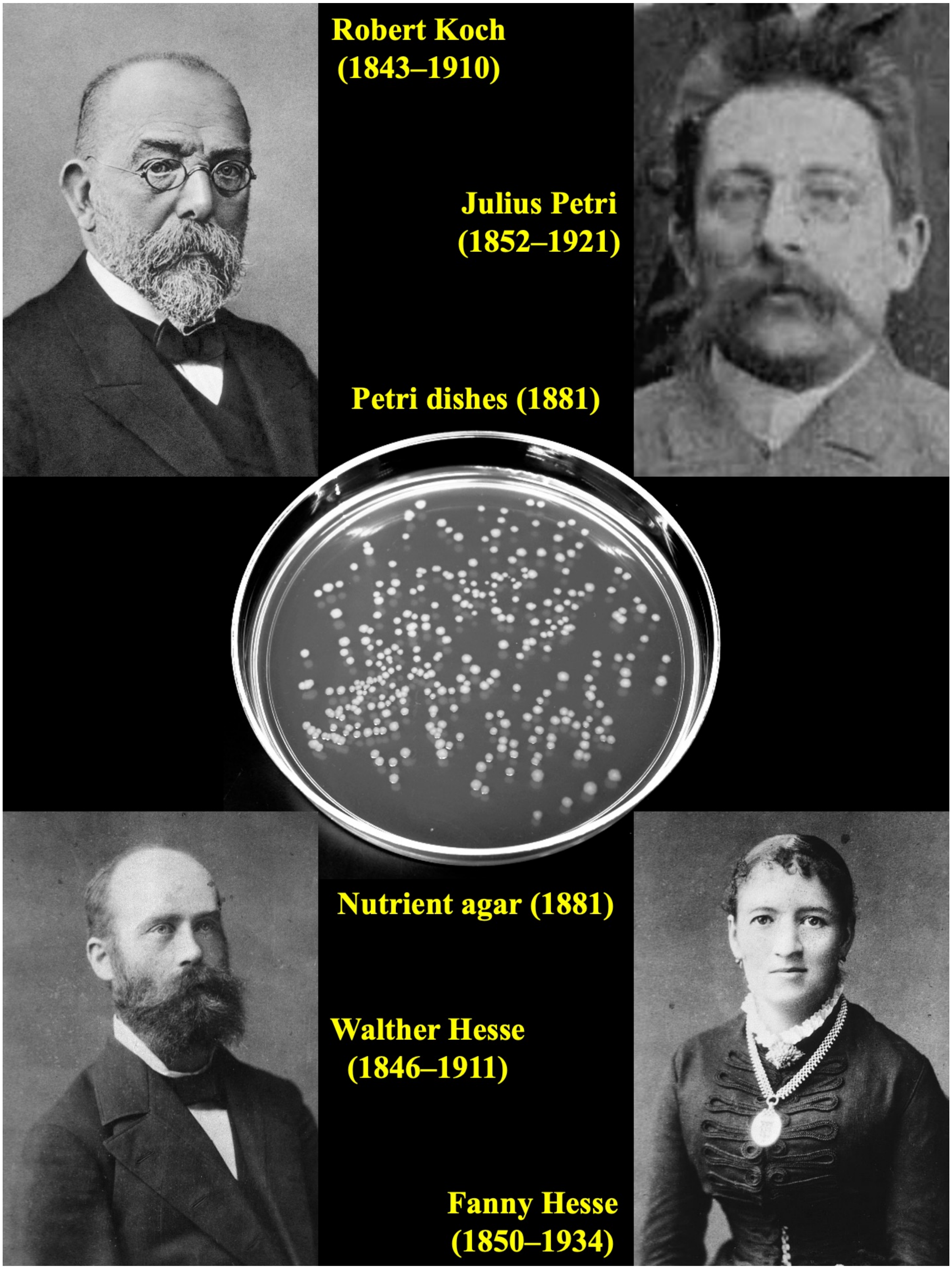
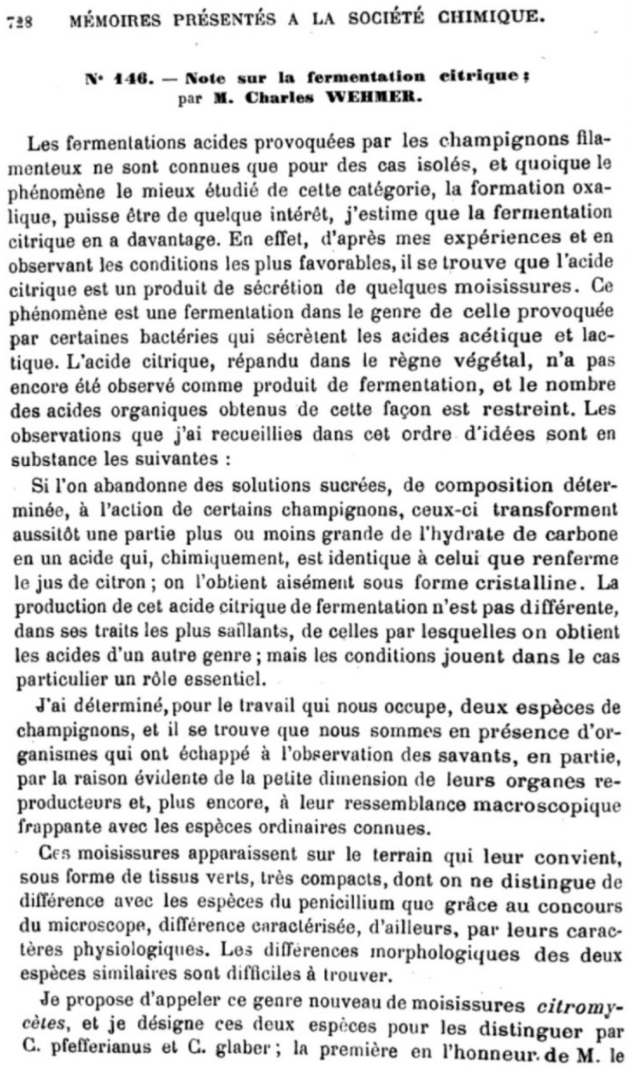

Robert Koch
(1843–1910)
Julius Petri
(1852–1921)
Petri dishes (1881)
Nutrient agar (1881)
Walther Hesse
(1846–1911)
Fanny Hesse
(1850–1934)

Figure 2.68: In 1881, Robert Koch and Julius Petri invented Petri dishes, and Fanny and Walther Hesse created nutrient agar to culture microorganisms on solid surfaces that would not decay to liquid.

By 1890, Carl Wehmer (1858–1935) was using yeast fermentation to produce citric acid, fumaric acid, and other substances.



728 MÉMOIRES PRÉSENTÉS A LA SOCIÉTÉ CHIMIQUE.

N° 146. — Note sur la fermentation citrique ;
par M. Charles WEHMER.

Les fermentations acides provoquées par les champignons filamenteux ne sont connues que pour des cas isolés, et quoique le phénomène le mieux étudié de cette catégorie, la formation oxalique, puisse être de quelque intérêt, j'estime que la fermentation citrique en a davantage. En effet, d'après mes expériences et en observant les conditions les plus favorables, il se trouve que l'acide citrique est un produit de sécrétion de quelques moisissures. Ce phénomène est une fermentation dans le genre de celle provoquée par certaines bactéries qui sécrètent les acides acétique et lactique. L'acide citrique, répandu dans le règne végétal, n'a pas encore été observé comme produit de fermentation, et le nombre des acides organiques obtenus de cette façon est restreint. Les observations que j'ai recueillies dans cet ordre d'idées sont en substance les suivantes :

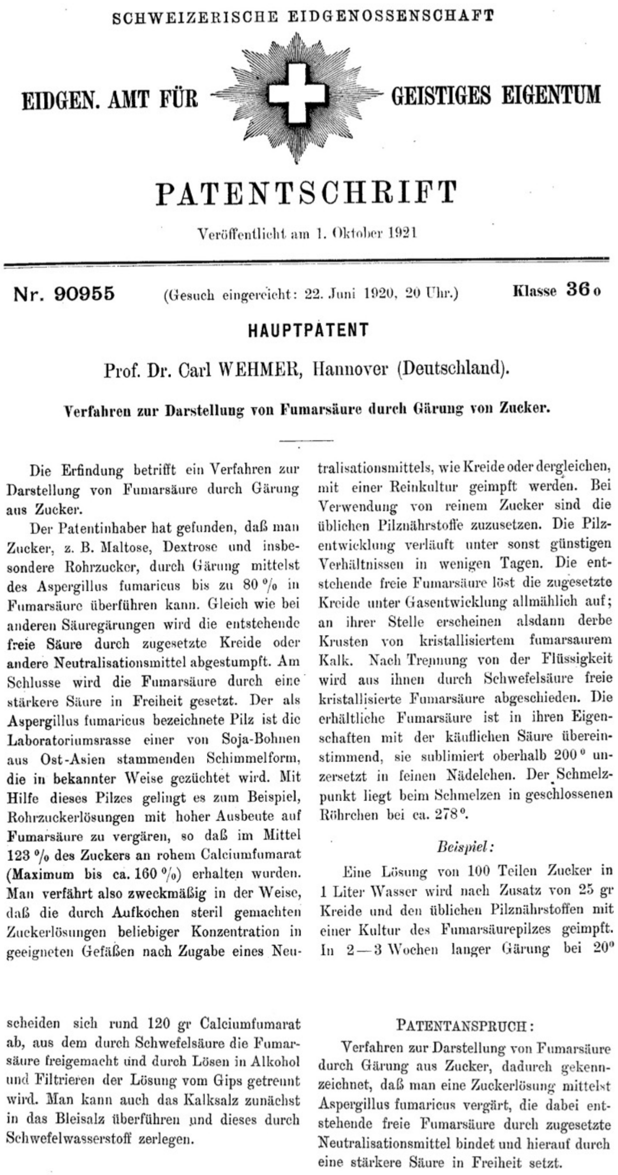
Si l'on abandonne des solutions sucrées, de composition déterminée, à l'action de certains champignons, ceux-ci transforment aussitôt une partie plus ou moins grande de l'hydrate de carbone en un acide qui, chimiquement, est identique à celui que renferme le jus de citron ; on l'obtient aisément sous forme cristalline. La production de cet acide citrique de fermentation n'est pas différente, dans ses traits les plus saillants, de celles par lesquelles on obtient les acides d'un autre genre ; mais les conditions jouent dans le cas particulier un rôle essentiel.

J'ai déterminé, pour le travail qui nous occupe, deux espèces de champignons, et il se trouve que nous sommes en présence d'organismes qui ont échappé à l'observation des savants, en partie, par la raison évidente de la petite dimension de leurs organes reproducteurs et, plus encore, à leur ressemblance macroscopique frappante avec les espèces ordinaires connues.

Ces moisissures apparaissent sur le terrain qui leur convient, sous forme de tissus verts, très compacts, dont on ne distingue de différence avec les espèces du penicillium que grâce au concours du microscope, différence caractérisée, d'ailleurs, par leurs caractères physiologiques. Les différences morphologiques des deux espèces similaires sont difficiles à trouver.

Je propose d'appeler ce genre nouveau de moisissures *citromycètes*, et je désigne ces deux espèces pour les distinguer par C. pfefferianus et C. glaber ; la première en l'honneur de M. le

Bulletin de la Société Chimique de France
9:728–730 (1893)



SCHWEIZERISCHE EIDGENOSSENSCHAFT

EIDGEN. AMT FÜR GEISTIGES EIGENTUM

PATENTSCHRIFT

Veröffentlicht am 1. Oktober 1921

Nr. 90955 (Gesuch eingereicht: 22. Juni 1920, 20 Uhr.) **Klasse 36 o**

HAUPTPATENT

Prof. Dr. Carl WEHMER, Hannover (Deutschland).

Verfahren zur Darstellung von Fumarsäure durch Gärung von Zucker.

Die Erfindung betrifft ein Verfahren zur Darstellung von Fumarsäure durch Gärung aus Zucker.

Der Patentinhaber hat gefunden, daß man Zucker, z. B. Maltose, Dextrose und insbesondere Rohrzucker, durch Gärung mittelst des Aspergillus fumaricus bis zu 80 % in Fumarsäure überführen kann. Gleich wie bei anderen Säuregärungen wird die entstehende freie Säure durch zugesetzte Kreide oder andere Neutralisationsmittel abgestumpft. Am Schlusse wird die Fumarsäure durch eine stärkere Säure in Freiheit gesetzt. Der als Aspergillus fumaricus bezeichnete Pilz ist die Laboratoriumsrasse einer von Soja-Bohnen aus Ost-Asien stammenden Schimmelform, die in bekannter Weise gezüchtet wird. Mit Hilfe dieses Pilzes gelingt es zum Beispiel, Rohrzuckerlösungen mit hoher Ausbeute auf Fumarsäure zu vergären, so daß im Mittel 123 % des Zuckers an rohem Calciumfumarat (Maximum bis ca. 160 %) erhalten wurden. Man verfährt also zweckmäßig in der Weise, daß die durch Aufkochen steril gemachten Zuckerlösungen beliebiger Konzentration in geeigneten Gefäßen nach Zugabe eines Neutralisationsmittels, wie Kreide oder dergleichen, mit einer Reinkultur geimpft werden. Bei Verwendung von reinem Zucker sind die üblichen Pilznährstoffe zuzusetzen. Die Pilzentwicklung verläuft unter sonst günstigen Verhältnissen in wenigen Tagen. Die entstehende freie Fumarsäure löst die zugesetzte Kreide unter Gasentwicklung allmählich auf; an ihrer Stelle erscheinen alsdann derbe Krusten von kristallisiertem fumarsaurem Kalk. Nach Trennung von der Flüssigkeit wird aus ihnen durch Schwefelsäure freie kristallisierte Fumarsäure abgeschieden. Die erhältliche Fumarsäure ist in ihren Eigenschaften mit der käuflichen Säure übereinstimmend, sie sublimiert oberhalb 200° unzersetzt in feinen Nädelchen. Der Schmelzpunkt liegt beim Schmelzen in geschlossenen Röhrchen bei ca. 278°.

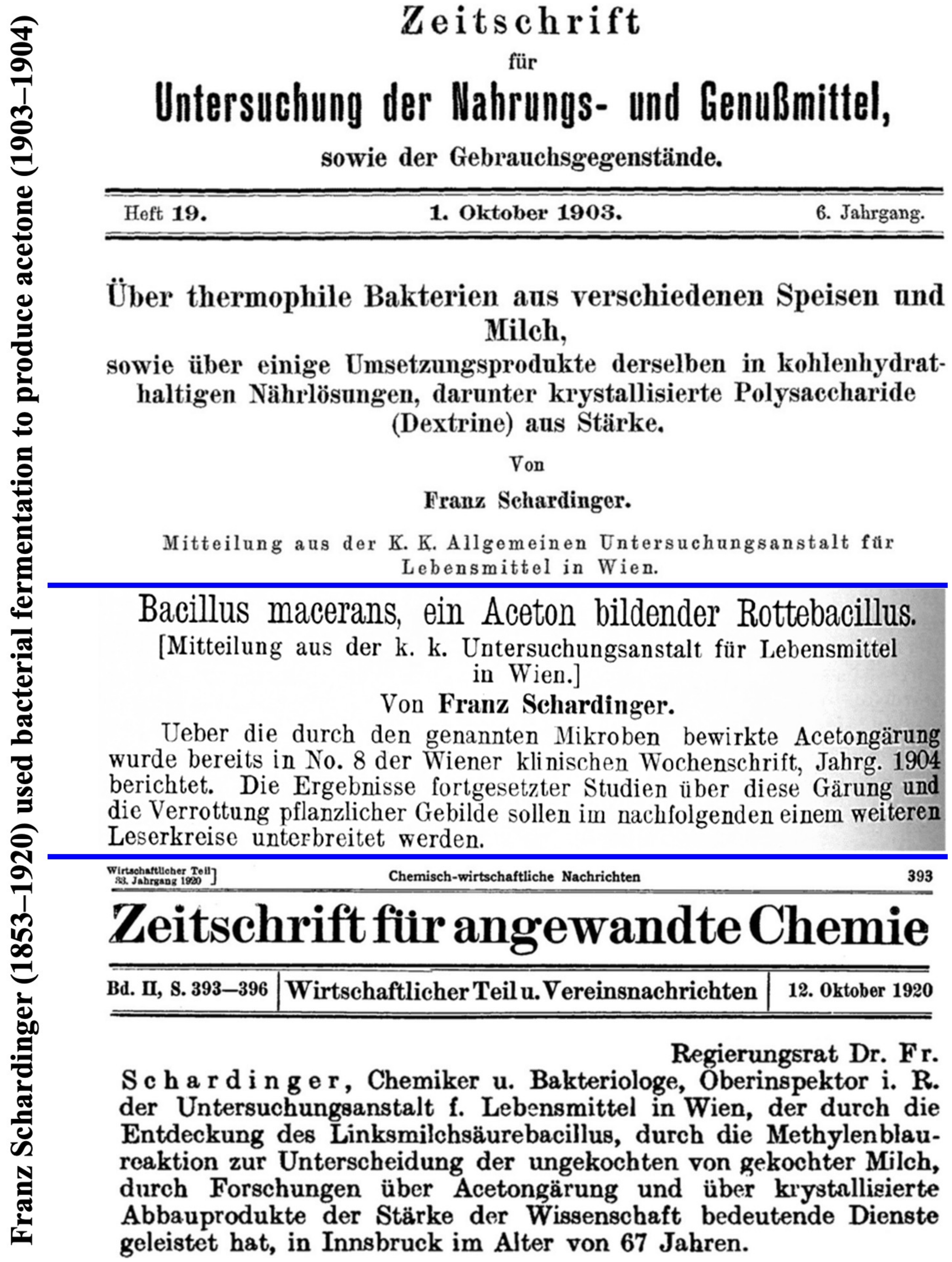
Beispiel:

Eine Lösung von 100 Teilen Zucker in 1 Liter Wasser wird nach Zusatz von 25 gr Kreide und den üblichen Pilznährstoffen mit einer Kultur des Fumarsäurepilzes geimpft. In 2—3 Wochen langer Gärung bei 20° scheiden sich rund 120 gr Calciumfumarat ab, aus dem durch Schwefelsäure die Fumarsäure freigemacht und durch Lösen in Alkohol und Filtrieren der Lösung vom Gips getrennt wird. Man kann auch das Kalksalz zunächst in das Bleisalz überführen und dieses durch Schwefelwasserstoff zerlegen.

PATENTANSPRUCH:

Verfahren zur Darstellung von Fumarsäure durch Gärung aus Zucker, dadurch gekennzeichnet, daß man eine Zuckerlösung mittelst Aspergillus fumaricus vergärt, die dabei entstehende freie Fumarsäure durch zugesetzte Neutralisationsmittel bindet und hierauf durch eine stärkere Säure in Freiheit setzt.

Figure 2.69: By 1890, Carl Wehmer (1858–1935) was using yeast fermentation to produce citric acid, fumaric acid, and other substances.



Franz Schardinger (1853–1920) used bacterial fermentation to produce acetone (1903–1904)

Zeitschrift
für
Untersuchung der Nahrungs- und Genußmittel,
sowie der Gebrauchsgegenstände.

Heft 19. 1. Oktober 1903. 6. Jahrgang.

Über thermophile Bakterien aus verschiedenen Speisen und Milch,
sowie über einige Umsetzungsprodukte derselben in kohlenhydrathaltigen Nährlösungen, darunter krystallisierte Polysaccharide (Dextrine) aus Stärke.

Von
Franz Schardinger.

Mitteilung aus der K. K. Allgemeinen Untersuchungsanstalt für Lebensmittel in Wien.

Bacillus macerans, ein Aceton bildender Rottebacillus.
[Mitteilung aus der k. k. Untersuchungsanstalt für Lebensmittel in Wien.]
Von **Franz Schardinger.**

Ueber die durch den genannten Mikroben bewirkte Acetongärung wurde bereits in No. 8 der Wiener klinischen Wochenschrift, Jahrg. 1904 berichtet. Die Ergebnisse fortgesetzter Studien über diese Gärung und die Verrottung pflanzlicher Gebilde sollen im nachfolgenden einem weiteren Leserkreise unterbreitet werden.

Wirtschaftlicher Teil
33. Jahrgang 1920 Chemisch-wirtschaftliche Nachrichten 393

Zeitschrift für angewandte Chemie

Bd. II, S. 393—396 | Wirtschaftlicher Teil u. Vereinsnachrichten | 12. Oktober 1920

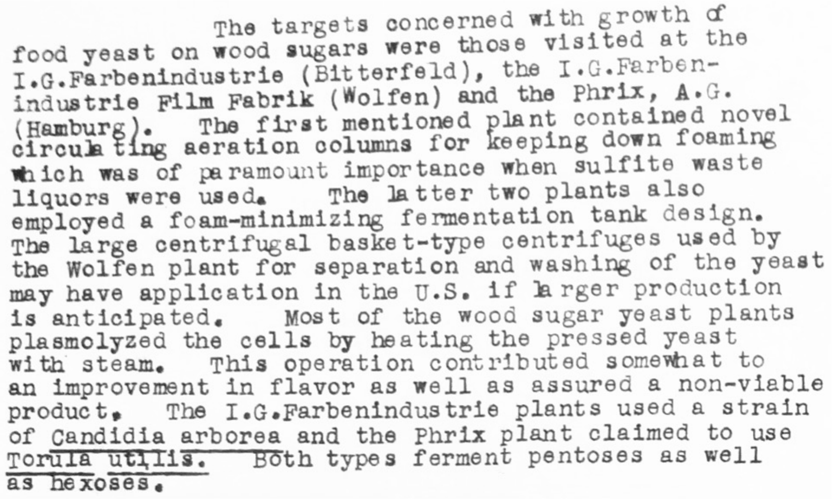
Regierungsrat Dr. Fr. Schardinger, Chemiker u. Bakteriologe, Oberinspektor i. R. der Untersuchungsanstalt f. Lebensmittel in Wien, der durch die Entdeckung des Linksmilchsäurebacillus, durch die Methylenblaureaktion zur Unterscheidung der ungekochten von gekochter Milch, durch Forschungen über Acetongärung und über krystallisierte Abbauprodukte der Stärke der Wissenschaft bedeutende Dienste geleistet hat, in Innsbruck im Alter von 67 Jahren.

Figure 2.70: Franz Schardinger used bacterial fermentation to produce acetone (1903–1904).

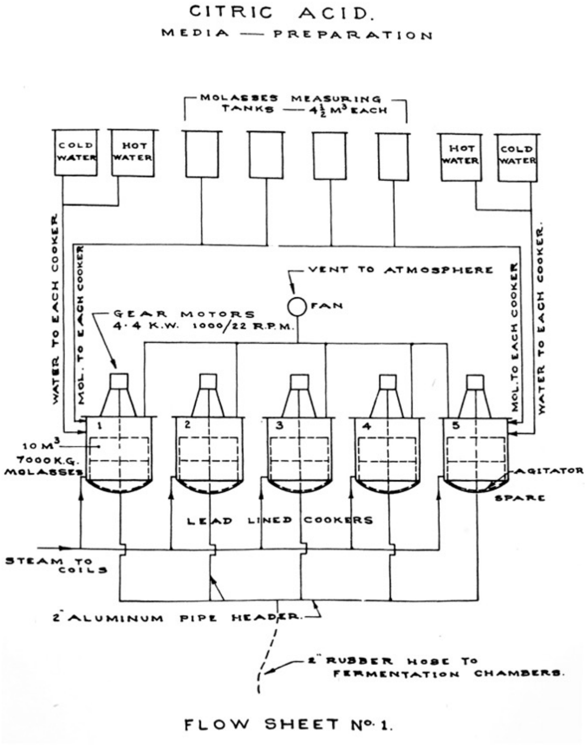
Bioreactors for continuous liquid culture

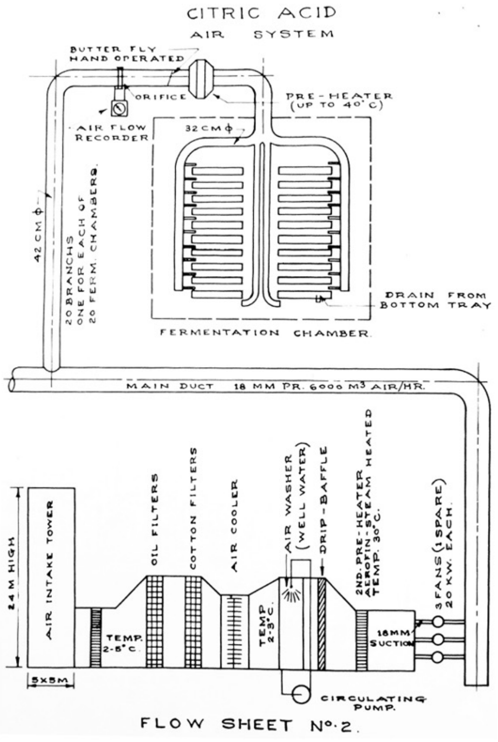
FIAT 195. ***Yeast and Nutrition Targets in Germany.***

BIOS 1776. ***Yeast and Citric Acid Production from Sugar Beet Molasses in Germany.***



The targets concerned with growth of food yeast on wood sugars were those visited at the I.G.Farbenindustrie (Bitterfeld), the I.G.Farbenindustrie Film Fabrik (Wolfen) and the Phrix, A.G. (Hamburg). The first mentioned plant contained novel circulating aeration columns for keeping down foaming which was of paramount importance when sulfite waste liquors were used. The latter two plants also employed a foam-minimizing fermentation tank design. The large centrifugal basket-type centrifuges used by the Wolfen plant for separation and washing of the yeast may have application in the U.S. if larger production is anticipated. Most of the wood sugar yeast plants plasmolyzed the cells by heating the pressed yeast with steam. This operation contributed somewhat to an improvement in flavor as well as assured a non-viable product. The I.G.Farbenindustrie plants used a strain of Candidia arborea and the Phrix plant claimed to use Torula utilis. Both types ferment pentoses as well as hexoses.


CITRIC ACID.
MEDIA — PREPARATION
MOLASSES MEASURING TANKS — 4½ M³ EACH
COLD WATER
HOT WATER
HOT WATER
COLD WATER
VENT TO ATMOSPHERE
FAN
GEAR MOTORS 4·4 K.W. 1000/22 R.P.M.
WATER TO EACH COOKER
MOL. TO EACH COOKER
MOL. TO EACH COOKER
WATER TO EACH COOKER
1
2
3
4
5
10 M³ 7000 KG. MOLASSES
AGITATOR
SPARE
LEAD LINED COOKERS
STEAM TO COILS
2" ALUMINUM PIPE HEADER
2" RUBBER HOSE TO FERMENTATION CHAMBERS
FLOW SHEET No. 1.


CITRIC ACID
AIR SYSTEM
BUTTER FLY HAND OPERATED
ORIFICE
AIR FLOW RECORDER
PRE-HEATER (UP TO 40° C)
32 CM ϕ
42 CM ϕ
20 BRANCHS ONE FOR EACH OF 20 FERM. CHAMBERS
DRAIN FROM BOTTOM TRAY
FERMENTATION CHAMBER
MAIN DUCT 18 MM PR. 6000 M³ AIR/HR.
24 M HIGH
AIR INTAKE TOWER
5X5M
TEMP. 2-5° C.
OIL FILTERS
COTTON FILTERS
AIR COOLER
TEMP 2-3° C.
AIR WASHER (WELL WATER)
DRIP-BAFFLE
2ND. PRE-HEATER AEROFIN-STEAM HEATED TEMP. 30° C.
18MM SUCTION
3 FANS (1 SPARE) 20 KW. EACH.
CIRCULATING PUMP.
FLOW SHEET No. 2.

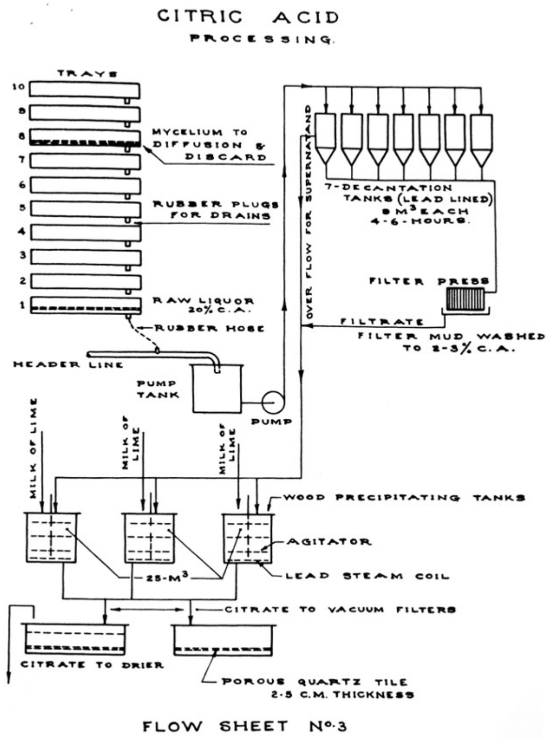
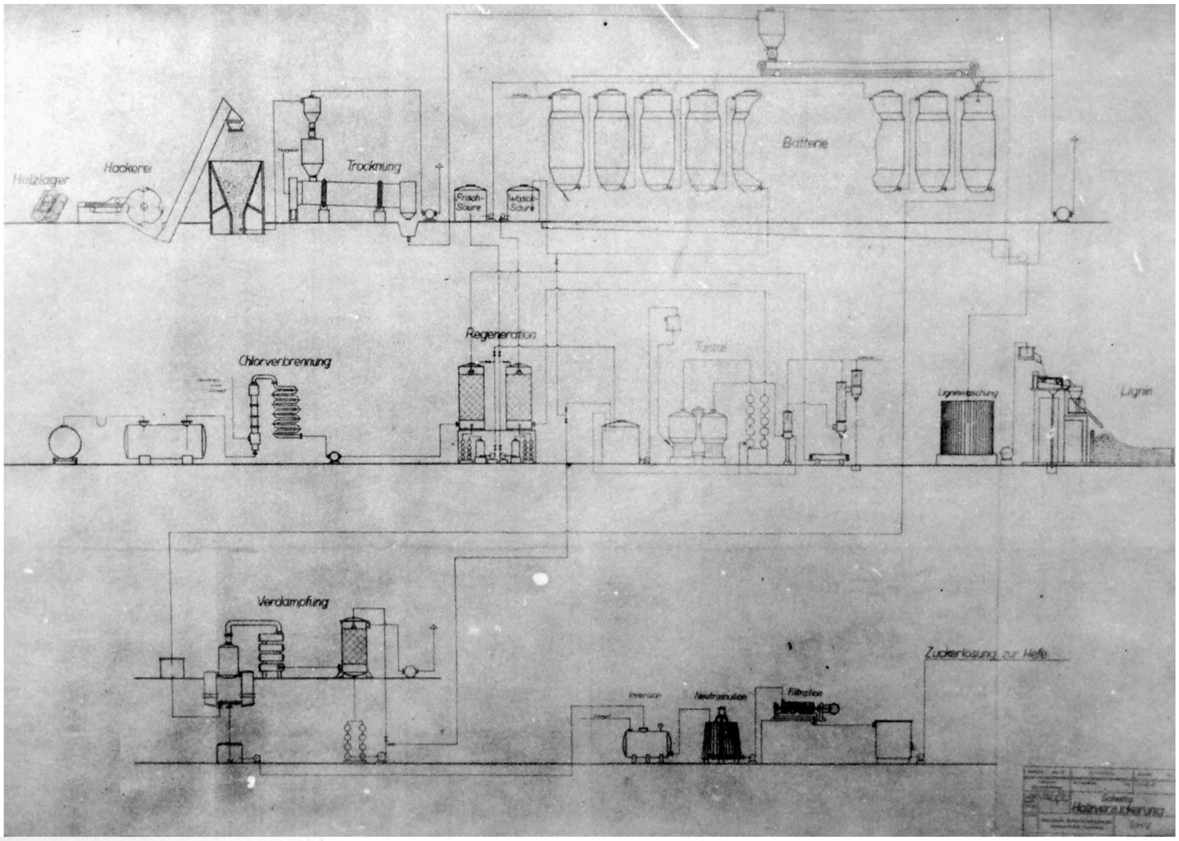
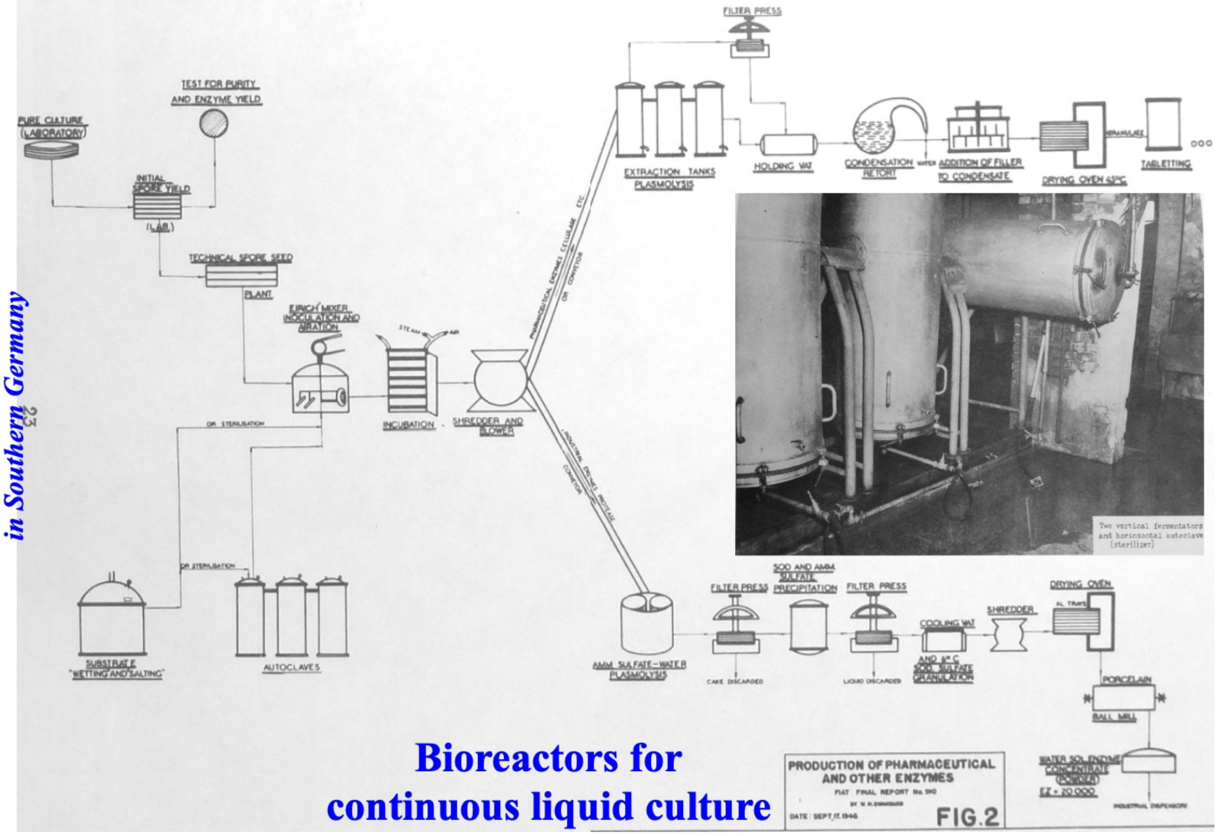

CITRIC ACID
PROCESSING.
TRAYS
10
9
8
7
6
5
4
3
2
1
MYCELIUM TO DIFFUSION & DISCARD
RUBBER PLUGS FOR DRAINS
RAW LIQUOR 20% C.A.
RUBBER HOSE
HEADER LINE
PUMP TANK
PUMP
OVER FLOW FOR SUPERNATAND
7-DECANTATION TANKS (LEAD LINED) 8 M³ EACH 4-6-HOURS.
FILTER PRESS
FILTRATE
FILTER MUD WASHED TO 2-3% C.A.
MILK OF LIME
MILK OF LIME
MILK OF LIME
WOOD PRECIPITATING TANKS
AGITATOR
LEAD STEAM COIL
25-M³
CITRATE TO VACUUM FILTERS
CITRATE TO DRIER
POROUS QUARTZ TILE 2·5 C.M. THICKNESS
FLOW SHEET No. 3

Figure 2.71: In the early twentieth century, bioreactors for the continuous liquid culture of microorganisms were developed by scientists at several German companies. These methods were later popularized internationally by Allied investigators who wrote numerous reports on the German biotechnology industry. [FIAT 195; BIOS 1776]

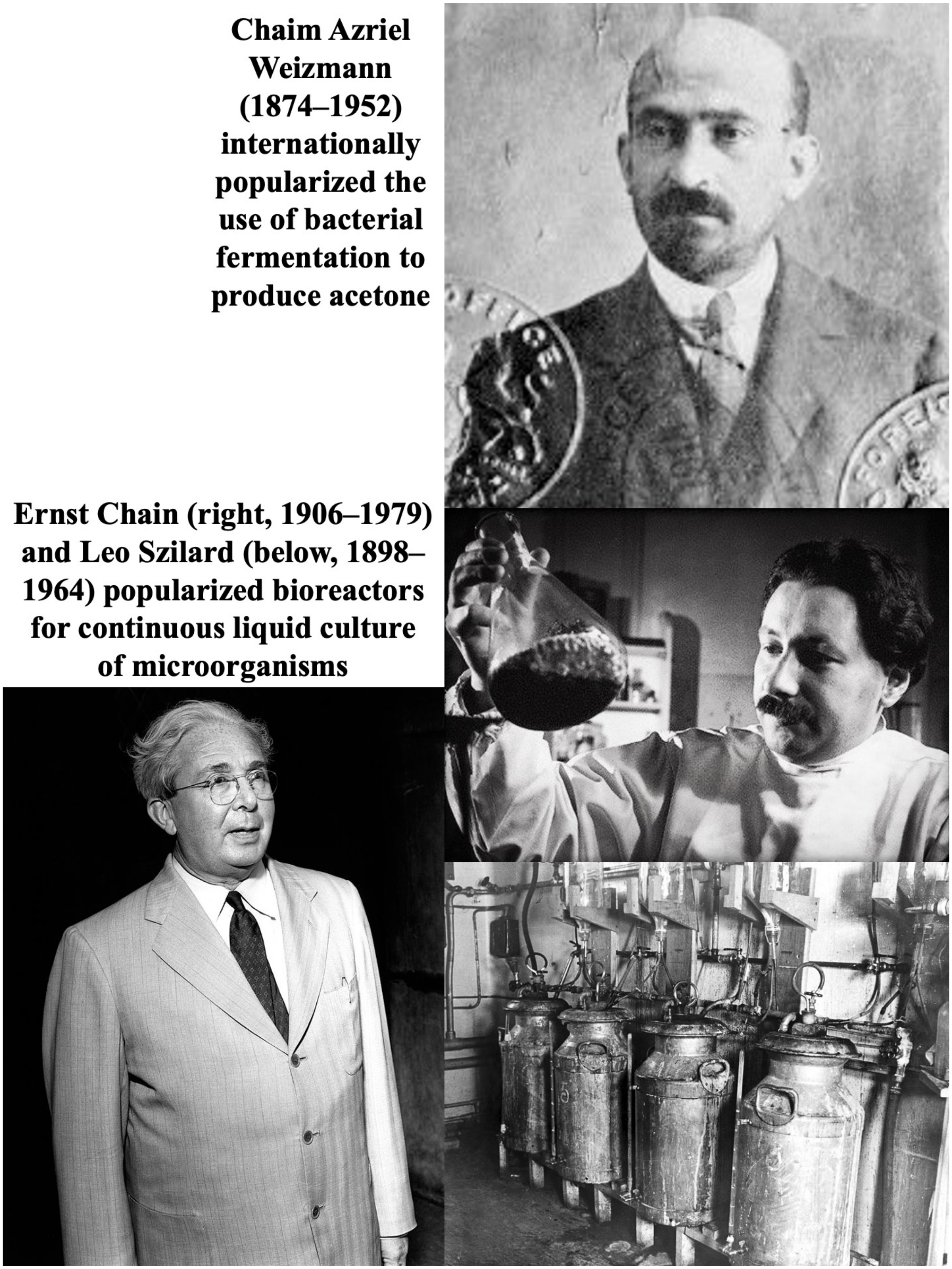

Holzlager
Hackerei
Trocknung
Frisch-Säure
Wasch-Säure
Batterie
Chlorverbrennung
Regeneration
Lignin
Verdampfung
Inversion
Neutralisation
Filtration
Zuckerlösung zur Hefe
Holzverzuckerung

BIOS 236. *Developments in Pure and Applied Microbiology (American, British and French Zones) During World War II*


FILTER PRESS
TEST FOR PURITY AND ENZYME YIELD
PURE CULTURE (LABORATORY)
INITIAL SPORE YIELD (LAB.)
TECHNICAL SPORE SEED
PLANT
EIRICH MIXER INOCULATION AND AERATION
STEAM
AIR
INCUBATION
SHREDDER AND BLOWER
OR STERILISATION
SUBSTRATE "WETTING AND SALTING"
AUTOCLAVES
EXTRACTION TANKS PLASMOLYSIS
HOLDING VAT
CONDENSATION RETORT
WATER
ADDITION OF FILLER TO CONDENSATE
DRYING OVEN 45°C
GRANULES
TABLETTING
Two vertical fermentators and horizontal autoclave (sterilizer)
AMM. SULFATE–WATER PLASMOLYSIS
FILTER PRESS
CAKE DISCARDED
SOD. AND AMM. SULFATE PRECIPITATION
FILTER PRESS
LIQUID DISCARDED
COOLING VAT
AND 6° C SOD. SULFATE GRANULATION
SHREDDER
DRYING OVEN
AL TRAYS
PORCELAIN BALL MILL
WATER SOL. ENZYME CONCENTRATE (POWDER) EZ = 20.000
INDUSTRIAL DISPENSORY
PRODUCTION OF PHARMACEUTICAL AND OTHER ENZYMES
FIAT FINAL REPORT No. 910
DATE: SEPT. 17. 1946
FIG. 2
Bioreactors for continuous liquid culture

FIAT 910. *Production of Pharmaceutical and Industrial Enzymes in Southern Germany*

Figure 2.72: In the early twentieth century, bioreactors for the continuous liquid culture of microorganisms were developed by scientists at several German companies. These methods were later popularized internationally by Allied investigators who wrote numerous reports on the German biotechnology industry. [BIOS 236; FIAT 910]



Chaim Azriel Weizmann (1874–1952) internationally popularized the use of bacterial fermentation to produce acetone

Ernst Chain (right, 1906–1979) and Leo Szilard (below, 1898–1964) popularized bioreactors for continuous liquid culture of microorganisms

Figure 2.73: In 1910, Chaim Azriel Weizmann began internationally popularizing Schardinger's methods of using bacterial fermentation to produce acetone. In the 1940s, Ernst Chain and Leo Szilard internationally popularized bioreactors for continuous liquid culture of microorganisms.

Julius Wagner-Jauregg (Austrian, 1857–1940) showed that some bacterial infections could be successfully treated by infecting the patient with malaria parasites to induce a high fever, then later curing the malaria with quinine. This method was called pyrotherapy (Fig. 2.74). He won the Nobel Prize in Physiology or Medicine in 1927, although his method became obsolete with the development of antibiotics in the following years. The Royal Swedish Academy of Sciences noted [https://www.nobelprize.org/prizes/medicine/1927/wagner-jauregg/facts/]:

> General paralysis is a stage in syphilis when the brain and psyche are attacked and the patient ends up in a lethargic and paralytic state that can end in death. As far back as antiquity, people noted that mental illnesses could be ameliorated by fevers. In 1917 Julius Wagner-Jauregg exposed patients to malaria-infected blood and could in this way cure or alleviate general paralysis. The malaria was of a type that was comparatively innocuous, and consequently the patient's health could be improved.

Scientists from the German-speaking world played leading roles in developing antibiotics to treat or prevent bacterial infections.[14] The process of discovering and developing suitable antibiotic molecules was challenging because they needed to be effective at killing bacterial cells yet not kill human cells, and they also had to be produced and purified with sufficiently quantity and quality. Some of the major scientists are shown in Figs. 2.75–2.78.

Paul Ehrlich (German, 1854–1915) discovered Salvarsan in 1909 and successfully used it to treat syphilis, caused by the sexually transmitted bacterium *Treponema pallidum* [Hüntelmann 2011]. He won the Nobel Prize in Physiology or Medicine in 1908 for his earlier work on immunology (see p. 222).

Gerhard Domagk (German, 1895–1964) discovered and demonstrated sulfa antibiotics, the first broad-spectrum antibiotics, in 1932 [Domagk 1935; Grundmann 2004; Hager 2006]. In 1939, he won the Nobel Prize in Physiology or Medicine for that work.

Even by the standard of other Nobel Prize awards, Professor N. Svartz, member of the Royal Caroline Institute, gave extremely high praise for Domagk's discoveries [https://www.nobelprize.org/prizes/medicine/1939/ceremony-speech/]:

> During the investigations conducted by Domagk and his co-workers 4-sulphonamide-2', 4'-diaminoazobenzene hydrochloride, among other substances, was tested. This preparation was subsequently named Prontosil. The earliest published experiments with Prontosil were begun in December 1932. The lethal dose, for mice, of a certain strain of haemolytic streptococci, which had been isolated from a patient suffering from blood poisoning, had previously been determined. A number of mice were injected with 10 times the lethal dose of this bacterial strain, and approximately half of them were given a specific quantity of Prontosil 1 1/2 hours after being infected.

---

[14] Bud 2006; Ronald Clark 1985; Domagk 1935; Gradmann and Simon 2010; Grundmann 2004; Hager 2006; Hüntelmann 2011; Jahn 2004; Junker 2004; Koesling and Schülke 2010; Kohler 2008; Lax 2004; Magner 2002; Possehl 1989; Raviña and Kubinyi 2011; Schneider 1972; von Schwerin 2013; Sneader 2005; Weatherall 1991.

> On 24th December, 1932, it was found that in an experiment begun on 20th December, 1932, all the controls had died, whereas all the mice which had been given Prontosil were alive and well. This was the basis of the discovery which was destined to bring undreamed-of advances in chemotherapy. [...]
>
> In addition, brilliant results have been obtained with certain infections not due to streptococci, namely gonorrhoea and epidemic meningitis, and, as already mentioned, an effect has also been shown with staphylococcal infections.
>
> This preparation, which is so effective against various coccal infections, has also been used with success in the case of certain infections due to bacilli, e.g. cold infections. Sulphonamide is therefore now the best known remedy against infections of the urinary passages due to colon bacilli. Preparations of this group are also effective against undulant fever as well as, to a lesser extent, other bacillary infections which will not be enumerated here. [...]
>
> Professor Gerhard Domagk was awarded the 1939 Nobel Prize for Physiology or Medicine for the discovery of the antibacterial effects of Protonsil. Protonsil was the first of the so-called sulpha preparations, which have proved to represent one of the greatest therapeutic advances in the history of medicine.

Ernst Chain (German, 1906–1979) purified penicillin, another broad-spectrum antibiotic, in 1940, making it available for human use. He won the Nobel Prize in Physiology or Medicine in 1945 for that work [Ronald Clark 1985; Lax 2004]. Alexander Fleming (Scottish, 1881–1955) shared in that Nobel Prize; he is famous for having earlier discovered penicillin-producing fungal cells, but he had been unable to purify the penicillin or to scale up its production—both problems were solved by Chain. Howard Florey (Australian, 1898–1968) also shared in the Prize; he appears to have focused largely on testing penicillin in animals and humans, leaving most of the actual production and purification of penicillin to Chain. The Royal Caroline Institute noted [https://www.nobelprize.org/prizes/medicine/1945/chain/facts/]:

> After Alexander Fleming's 1928 discovery that a certain mold produced a substance called penicillin that inhibited the growth of bacteria, it was not a major leap to think that penicillin could be used as a pharmaceutical. However, the substance proved to be unstable and difficult to produce in pure form. Ernst Boris Chain, Howard Florey, and their colleagues succeeded in systematically producing a pure form of penicillin at the beginning of the 1940s and in investigating its properties in more detail. Additional efforts led to a pharmaceutical that could be produced in larger quantities.

Richard Kuhn (Austrian, 1900–1967) produced and tested synthetic antibiotics during World War II, identifying a promising antibiotic (dubbed "3065") and paving the way for later industrial parallel synthesis, screening, and structure-activity relationship testing to identify and optimize new drug molecules [CIOS ER 1, 75, 159]. Kuhn won the Nobel Prize in chemistry in 1938 for unrelated research on vitamins (p. 347).

Pyrotherapy
to treat
bacterial infections

Julius Wagner-Jauregg
(1857–1940)
(dressed in black)

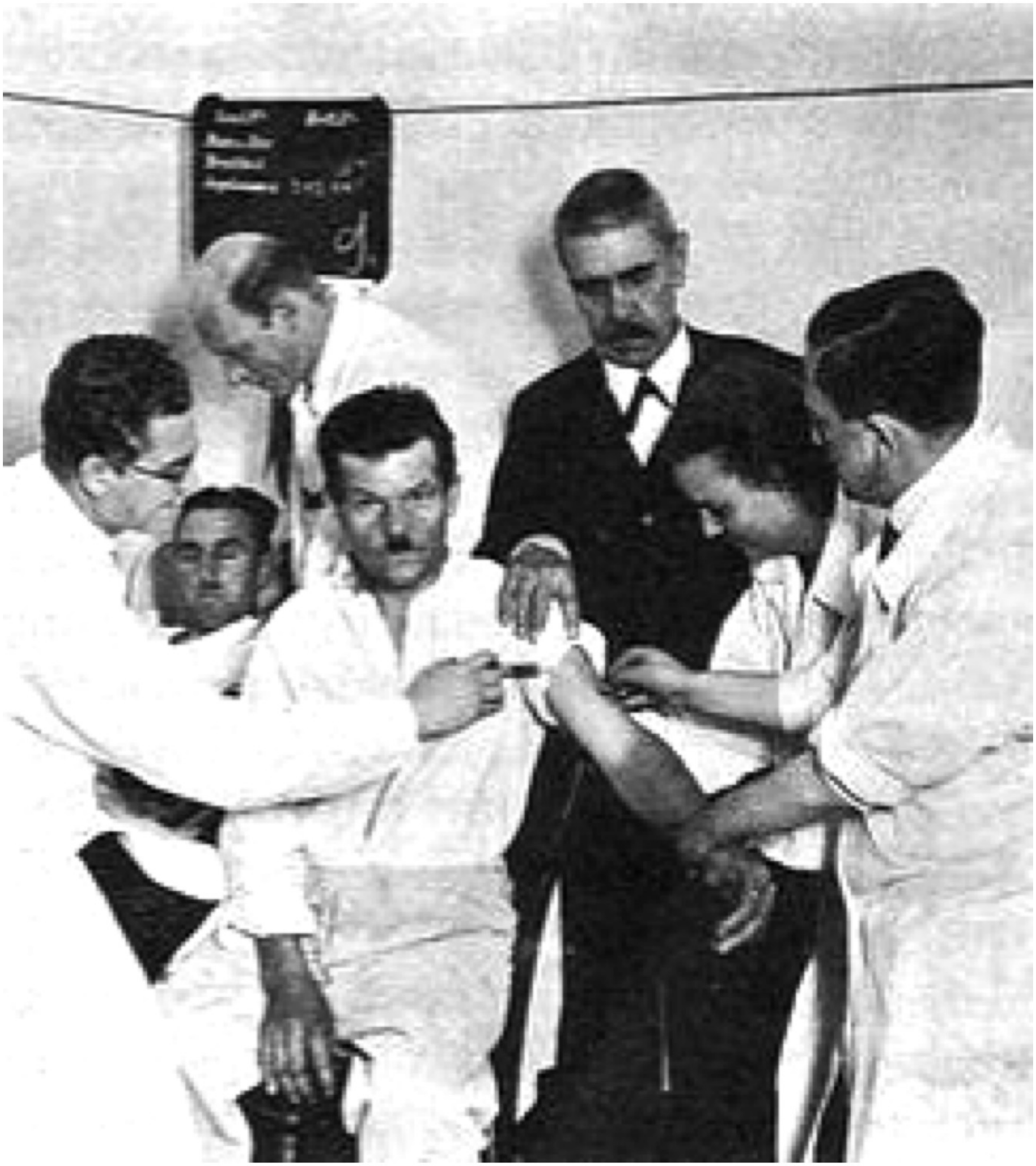
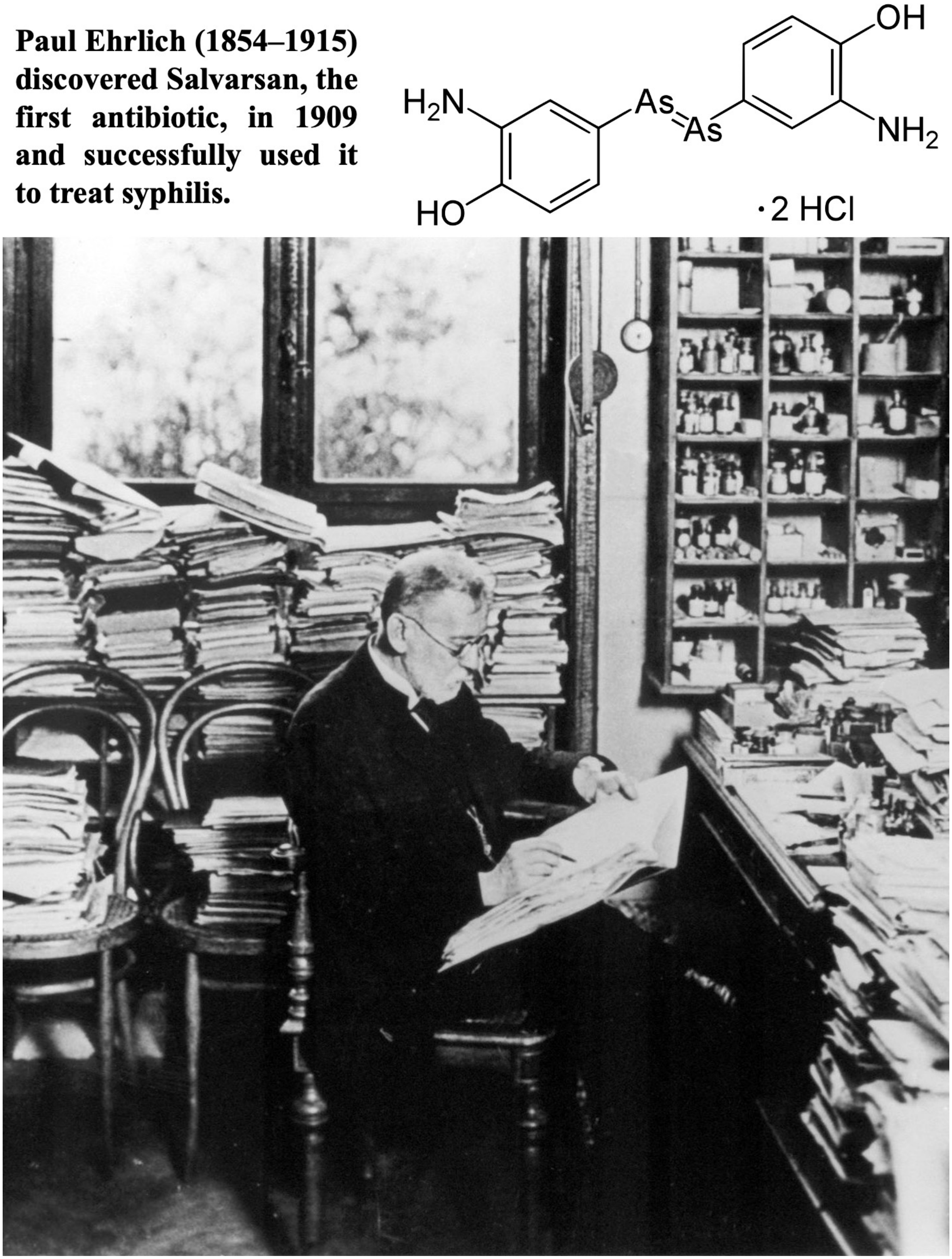
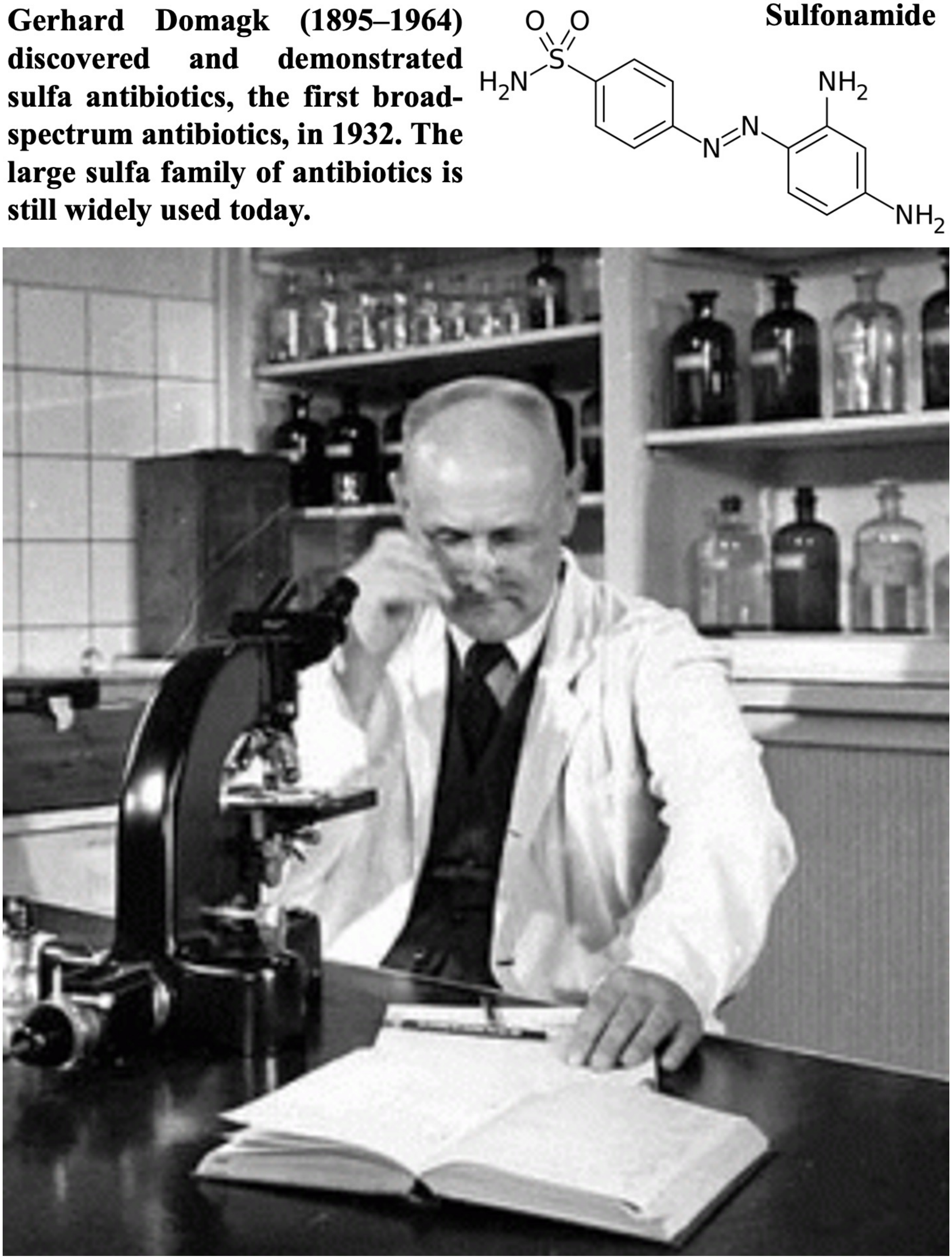


Figure 2.74: Julius Wagner-Jauregg successfully treated bacterial infections by infecting the patient with malaria parasites to induce a high fever (pyrotherapy), then later curing the malaria with quinine. He won the Nobel Prize in Physiology or Medicine in 1927.



Paul Ehrlich (1854–1915) discovered Salvarsan, the first antibiotic, in 1909 and successfully used it to treat syphilis.

Figure 2.75: Paul Ehrlich discovered Salvarsan, the first antibiotic, in 1909 and successfully used it to treat syphilis.



Gerhard Domagk (1895–1964) discovered and demonstrated sulfa antibiotics, the first broad-spectrum antibiotics, in 1932. The large sulfa family of antibiotics is still widely used today.

Figure 2.76: Gerhard Domagk discovered and demonstrated sulfa antibiotics, the first broad-spectrum antibiotics, in 1932. The large sulfa family of antibiotics is still widely used today.

Ernst Chain (1906–1979) purified penicillin in 1940, taking penicillin from an effect that could only be demonstrated in Petri dishes to an effective antibiotic that could be mass-produced and administered to people.

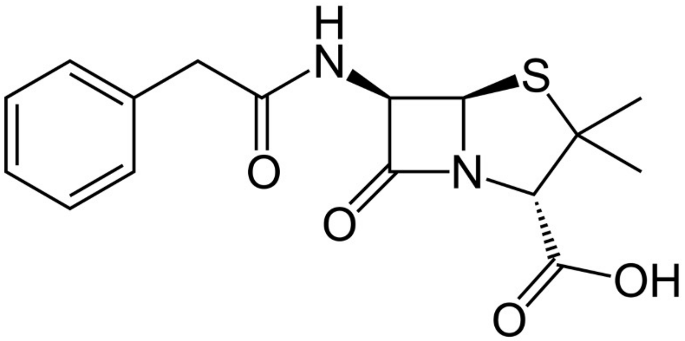
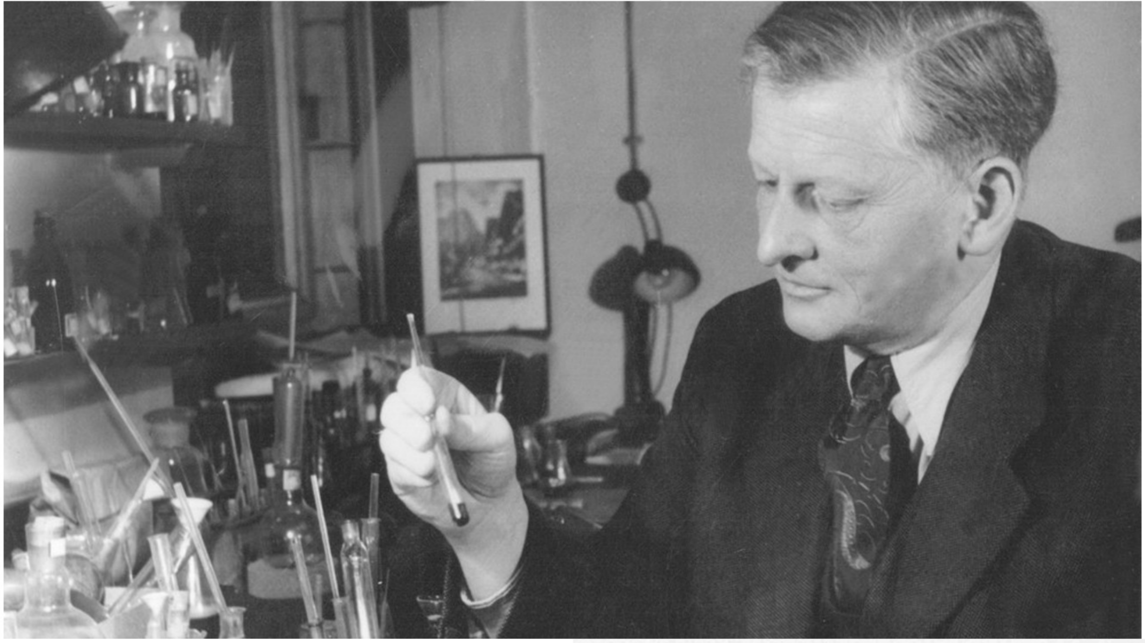
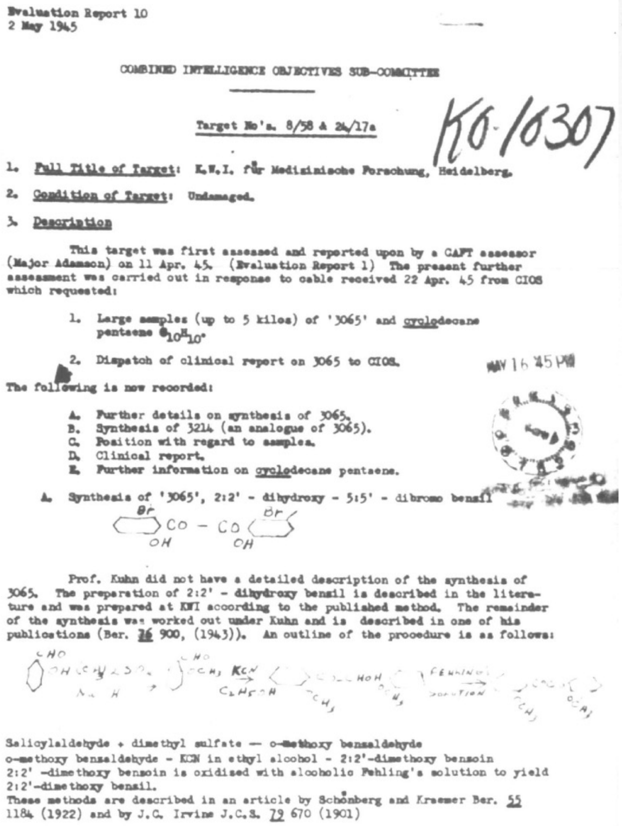


Figure 2.77: Ernst Chain purified penicillin in 1940, taking penicillin from an effect that could only be demonstrated in Petri dishes to an effective antibiotic that could be mass-produced and administered to people.

Richard Kuhn (1900–1967) produced and tested synthetic antibiotics such as "3065" during WWII, using massively parallel chemical synthesis and testing to carry out very modern methods of structure-activity relationship (SAR) optimization of the molecules.





Evaluation Report 10
2 May 1945

COMBINED INTELLIGENCE OBJECTIVES SUB-COMMITTEE

Target No's. 8/58 & 24/17a

KO-10307

1. Full Title of Target: K.W.I. für Medizinische Forschung, Heidelberg.

2. Condition of Target: Undamaged.

3. Description

This target was first assessed and reported upon by a CAFT assessor (Major Adamson) on 11 Apr. 45. (Evaluation Report 1) The present further assessment was carried out in response to cable received 22 Apr. 45 from CIOS which requested:

1. Large samples (up to 5 kilos) of '3065' and cyclodecane pentaene $C_{10}H_{10}$.
2. Dispatch of clinical report on 3065 to CIOS.

MAY 16 '45 PM

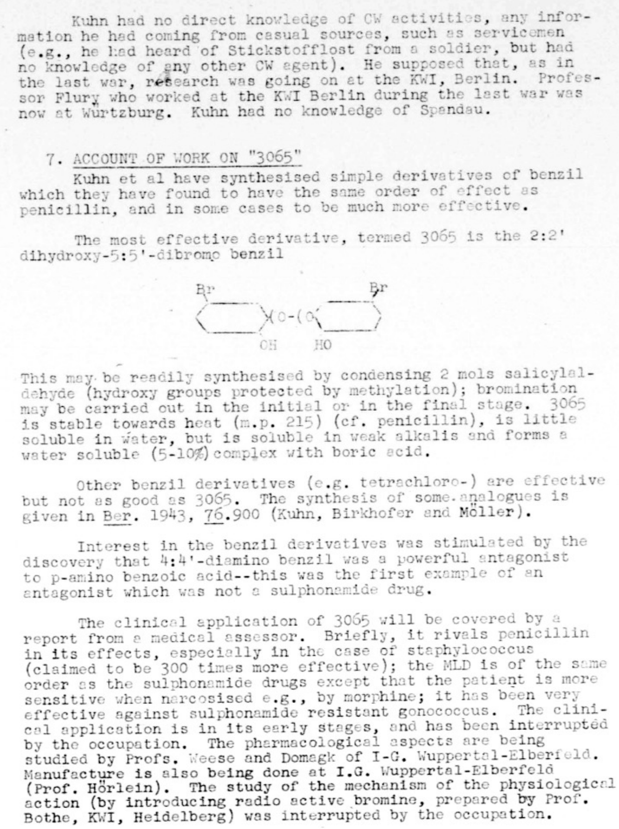
The following is now recorded:

A. Further details on synthesis of 3065.
B. Synthesis of 3214 (an analogue of 3065).
C. Position with regard to samples.
D. Clinical report.
E. Further information on cyclodecane pentaene.

A. Synthesis of '3065', 2:2' - dihydroxy - 5:5' - dibromo benzil

Prof. Kuhn did not have a detailed description of the synthesis of 3065. The preparation of 2:2' - dihydroxy benzil is described in the literature and was prepared at KWI according to the published method. The remainder of the synthesis was worked out under Kuhn and is described in one of his publications (Ber. 76 900, (1943)). An outline of the procedure is as follows:

Salicylaldehyde + dimethyl sulfate — o-methoxy benzaldehyde
o-methoxy benzaldehyde - KCN in ethyl alcohol - 2:2'-dimethoxy benzoin
2:2' -dimethoxy benzoin is oxidised with alcoholic Fehling's solution to yield 2:2'-dimethoxy benzil.
These methods are described in an article by Schönberg and Kraemer Ber. 55 1184 (1922) and by J.C. Irvine J.C.S. 79 670 (1901)



Kuhn had no direct knowledge of CW activities, any information he had coming from casual sources, such as servicemen (e.g., he had heard of Stickstofflost from a soldier, but had no knowledge of any other CW agent). He supposed that, as in the last war, research was going on at the KWI, Berlin. Professor Flury who worked at the KWI Berlin during the last war was now at Würtzburg. Kuhn had no knowledge of Spandau.

7. ACCOUNT OF WORK ON "3065"

Kuhn et al have synthesised simple derivatives of benzil which they have found to have the same order of effect as penicillin, and in some cases to be much more effective.

The most effective derivative, termed 3065 is the 2:2' dihydroxy-5:5'-dibromo benzil

This may be readily synthesised by condensing 2 mols salicylaldehyde (hydroxy groups protected by methylation); bromination may be carried out in the initial or in the final stage. 3065 is stable towards heat (m.p. 215) (cf. penicillin), is little soluble in water, but is soluble in weak alkalis and forms a water soluble (5-10%) complex with boric acid.

Other benzil derivatives (e.g. tetrachloro-) are effective but not as good as 3065. The synthesis of some analogues is given in Ber. 1943, 76.900 (Kuhn, Birkhofer and Möller).

Interest in the benzil derivatives was stimulated by the discovery that 4:4'-diamino benzil was a powerful antagonist to p-amino benzoic acid--this was the first example of an antagonist which was not a sulphonamide drug.

The clinical application of 3065 will be covered by a report from a medical assessor. Briefly, it rivals penicillin in its effects, especially in the case of staphylococcus (claimed to be 300 times more effective); the MLD is of the same order as the sulphonamide drugs except that the patient is more sensitive when narcosised e.g., by morphine; it has been very effective against sulphonamide resistant gonococcus. The clinical application is in its early stages, and has been interrupted by the occupation. The pharmacological aspects are being studied by Profs. Weese and Domagk of I-G. Wuppertal-Elberfeld. Manufacture is also being done at I.G. Wuppertal-Elberfeld (Prof. Hörlein). The study of the mechanism of the physiological action (by introducing radio active bromine, prepared by Prof. Bothe, KWI, Heidelberg) was interrupted by the occupation.

Figure 2.78: Richard Kuhn produced and tested synthetic antibiotics such as "3065" during WWII, using massively parallel chemical synthesis and testing to carry out very modern methods of structure-activity relationship (SAR) optimization of the molecules.

2.2.2 Viruses

As shown in Fig. 2.79, viruses usually consist of just a few genes, packaged into a capsid made of proteins. The majority of viruses use RNA to encode their genome, although some viruses use DNA just as cells do. Some viruses wrap themselves in a protective envelope membrane to try to hide from their host's immune system, and some do not.

Viruses can range in size from smaller than 20 nm (for parvoviruses) to larger than 350 nm (for smallpox), with ∼50 nm as a typical average size. That means that virtually all viruses are too small to be seen with even the best possible light microscope, and therefore early virology researchers had to content themselves by proving that samples contained something that was infectious but too small to see. It also means that when German-speaking scientists invented electron microscopes, which could see things as small as viruses, that was a major step forward for virology.

Figure 2.80 shows how a typical virus replicates. Viruses do not have the machinery to replicate themselves, so they must invade a suitable host cell (human, animal, plant, or even bacterial cell, depending on the particular type of virus) and force the infected host cell to produce more copies of the virus. The small number of viral genes tell the host cell what to do and block the host cell from fighting off the infection. Most RNA viruses replicate outside the cellular nucleus as shown in the figure, and most DNA viruses replicate inside the nucleus.

German-speaking scientists made a large number of important discoveries in the early history of virology.[15] As with bacteriology, the most notable contributions to virology outside the German-speaking world came from Louis Pasteur, whose development of the rabies vaccine was a scientific tour de force that was probably decades ahead of its time.

Peter Plett (German states, 1766–1823) developed and successfully demonstrated a cowpox-based vaccine for smallpox virus beginning in the late 1780s, and first reported his results in 1790. Edward Jenner (English, 1749–1823) rediscovered the same thing several years later, and published his first results in 1798. Yet Jenner became famous as the discoverer of smallpox vaccine, and Plett has been virtually forgotten [Plett 2006]. See Fig. 2.81.

Advances in knowledge about the actual nature of viruses required specific viruses that could be tested in a variety of ways under laboratory conditions, and that were important enough to justify the expense of doing so. The German-speaking world identified and began unlocking the mysteries of two such model viruses roughly in parallel: tobacco mosaic virus (TMV), which infects tobacco plants (considered a valuable crop), and foot-and-mouth disease virus (FMDV), which infects cattle, pigs, sheep, goats, and deer.

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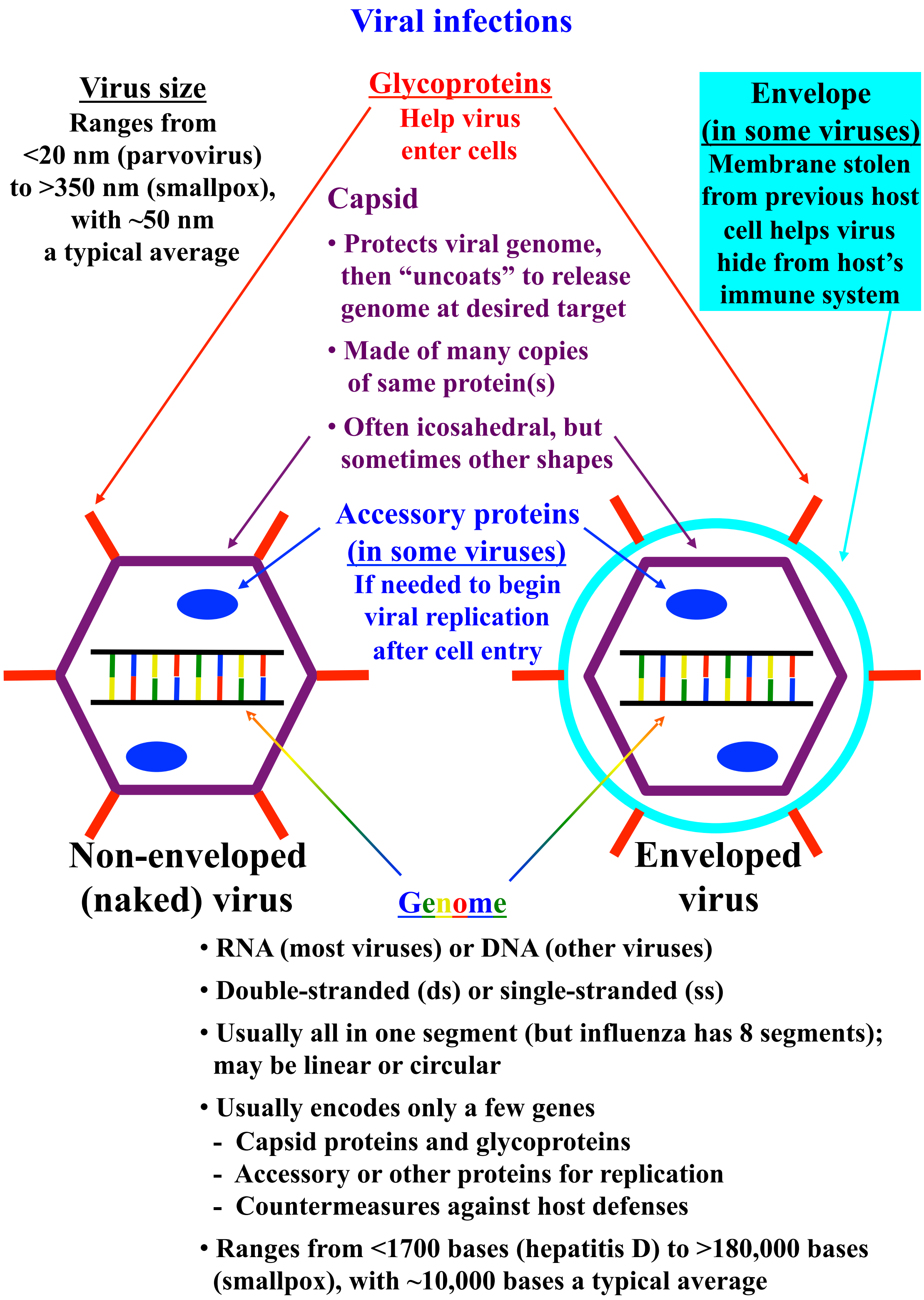
[15] Brandis 1957; Eberle 2015; Fast and Riebe 2011; Haagen 1941; Hinz-Wessels and Thiel 2010; Horzinek 1997; Loeffler and Frosch 1897, 1898; Loeffler 1919; Mettenleiter 2005, 2017; Müssemeier 1957; Riebe and Möhlmann 2012; Rott 1999; Rott and Siddell 1998; Wirtz 1998.



Viral infections

Virus size

Ranges from
<20 nm (parvovirus)
to >350 nm (smallpox),
with ~50 nm
a typical average

Glycoproteins

Help virus
enter cells

Envelope
(in some viruses)

Membrane stolen
from previous host
cell helps virus
hide from host's
immune system

Capsid

- **Protects viral genome, then "uncoats" to release genome at desired target**
- **Made of many copies of same protein(s)**
- **Often icosahedral, but sometimes other shapes**

Accessory proteins
(in some viruses)

If needed to begin
viral replication
after cell entry

Non-enveloped
(naked) virus

Enveloped
virus

Genome

- **RNA (most viruses) or DNA (other viruses)**
- **Double-stranded (ds) or single-stranded (ss)**
- **Usually all in one segment (but influenza has 8 segments); may be linear or circular**
- **Usually encodes only a few genes**
  - **Capsid proteins and glycoproteins**
  - **Accessory or other proteins for replication**
  - **Countermeasures against host defenses**
- **Ranges from <1700 bases (hepatitis D) to >180,000 bases (smallpox), with ~10,000 bases a typical average**

Figure 2.79: General structures of typical non-enveloped and enveloped viruses.

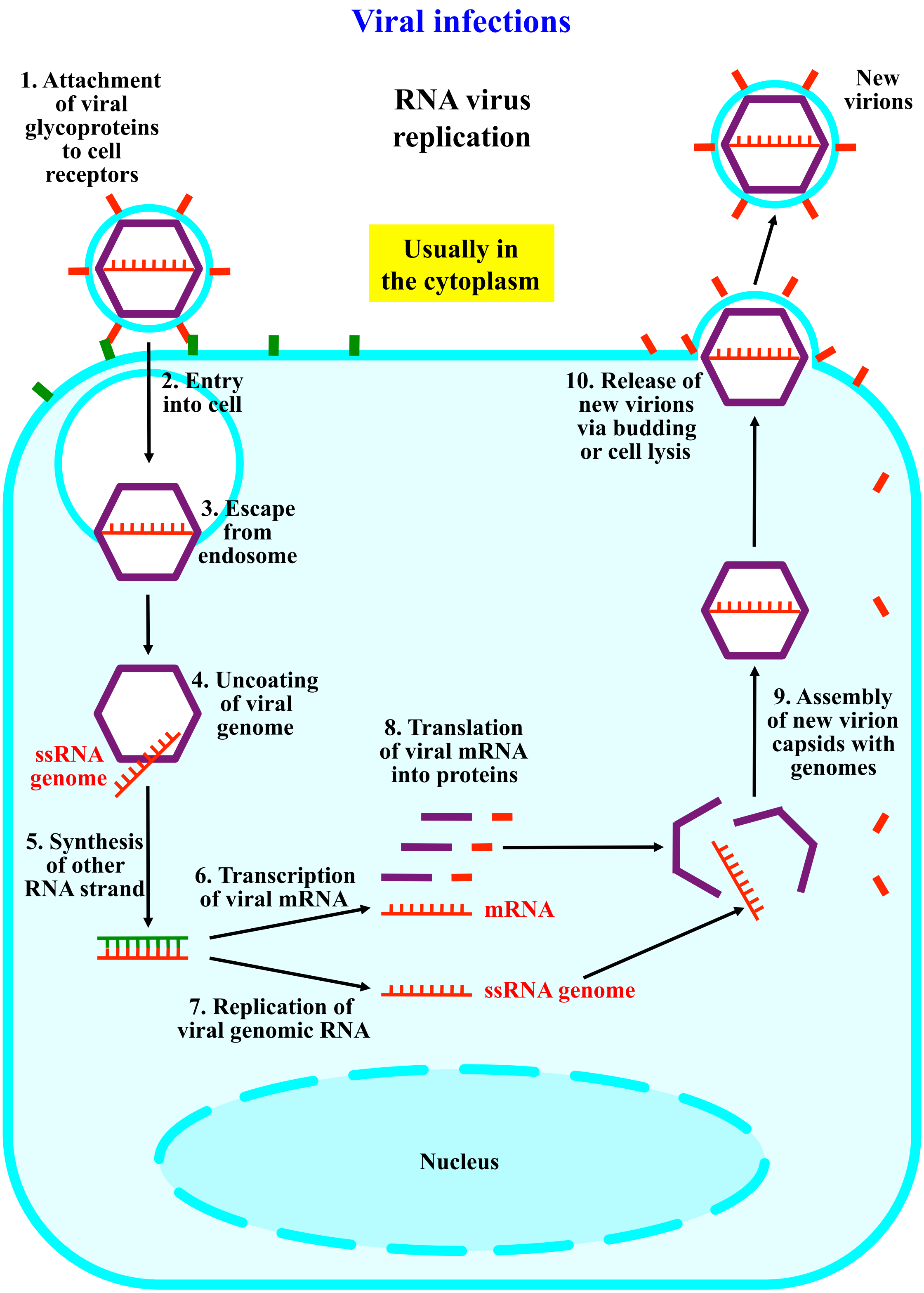
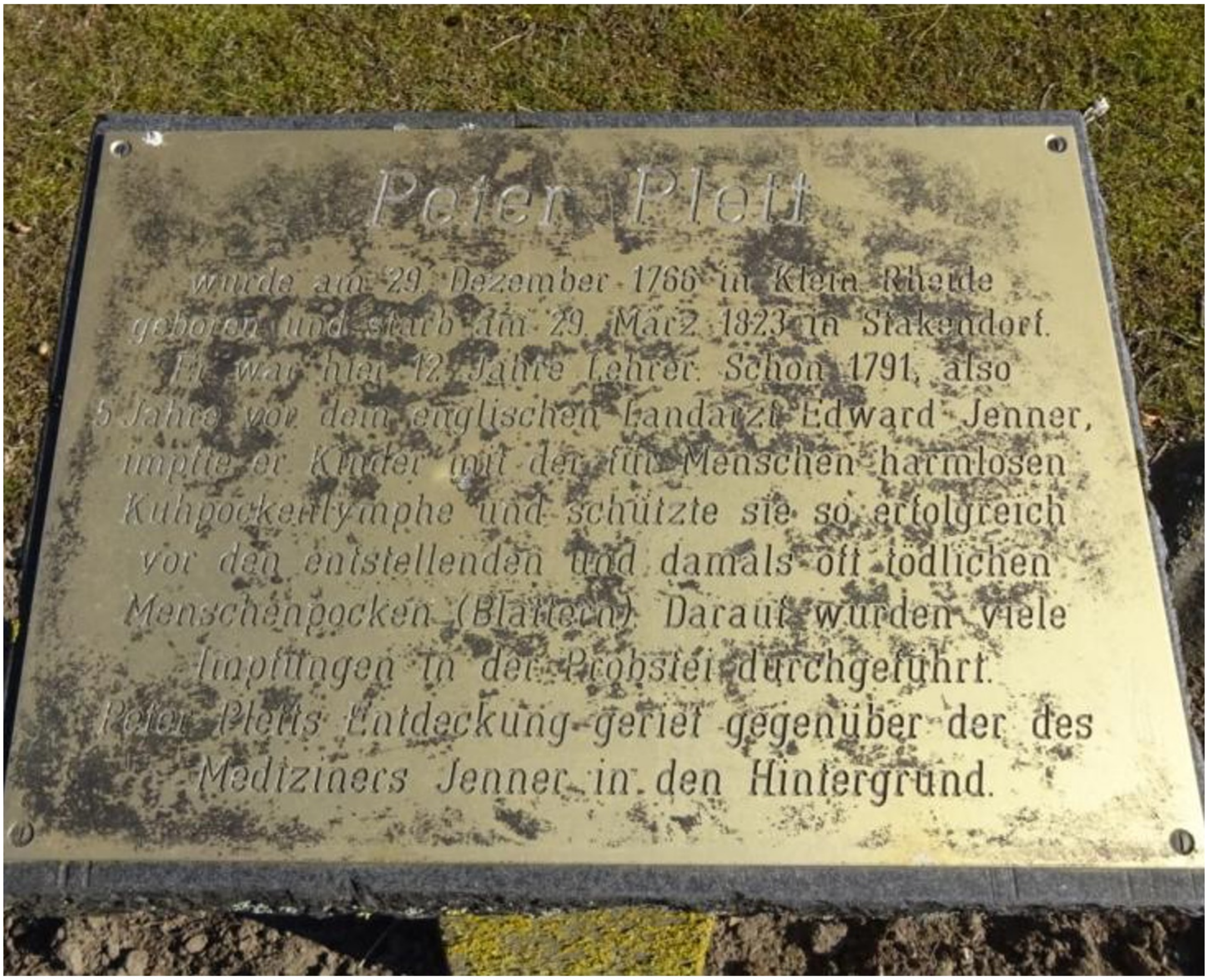

Viral infections
RNA virus replication
1. Attachment of viral glycoproteins to cell receptors
New virions
Usually in the cytoplasm
2. Entry into cell
3. Escape from endosome
10. Release of new virions via budding or cell lysis
4. Uncoating of viral genome
ssRNA genome
8. Translation of viral mRNA into proteins
9. Assembly of new virion capsids with genomes
5. Synthesis of other RNA strand
6. Transcription of viral mRNA
mRNA
ssRNA genome
7. Replication of viral genomic RNA
Nucleus

Figure 2.80: Replication of a typical RNA virus. Most RNA viruses replicate outside the cell nucleus, and most DNA viruses replicate inside the cell nucleus (using the nucleus's own enzymes).

Peter Plett (1766–1823) developed and successfully demonstrated a cowpox-based vaccine for smallpox virus beginning in the late 1780s, roughly a decade before Edward Jenner.



Peter Plett

wurde am 29. Dezember 1766 in Klein Rheide
geboren und starb am 29. März 1823 in Stakendorf.
Er war hier 12 Jahre Lehrer. Schon 1791, also
5 Jahre vor dem englischen Landarzt Edward Jenner,
impfte er Kinder mit der für Menschen harmlosen
Kuhpockenlymphe und schützte sie so erfolgreich
vor den entstellenden und damals oft tödlichen
Menschenpocken (Blattern). Darauf wurden viele
Impfungen in der Probstei durchgeführt.
Peter Pletts Entdeckung geriet gegenüber der des
Mediziners Jenner in den Hintergrund.

Figure 2.81: Peter Plett (1766–1823) developed and successfully demonstrated a cowpox-based vaccine for smallpox virus beginning in the late 1780s, roughly a decade before Edward Jenner.

As shown in Fig. 2.82, scientists who studied tobacco mosaic virus included:

- Adolf Eduard Mayer (German, 1843–1942) discovered the tobacco mosaic virus (TMV), a virus that infects tobacco plants, in 1886. He found that the pathogen was too small to be seen with a microscope (unlike bacteria) and was uncertain about its exact nature.

- In a series of experiments in the 1890s, Martinus Beijerinck (Dutch, 1851–1931) demonstrated that TMV was not a bacterium–it was much smaller, could not be cultured in nutrient medium, and only replicated in tobacco plants. He coined the term "virus" to describe this type of pathogen.

- Gerhard Schramm (1910–1969) conducted a series of remarkably advanced experiments in the late 1930s and early 1940s to investigate the molecular composition and functions of TMV. He demonstrated TMV's nucleic acid components could be separated from its protein components, and that the nucleic acid (RNA) by itself was infectious in plants and therefore carried genetic information. He also showed that he could make individual mutations in the nucleic acid, leading to corresponding changes in the proteins and viruses that were produced in infected plants—thus nucleic acids contained genes that encoded protein sequences. He also showed that the proteins forming the viral structure around the nucleic acid were all identical, suggesting how they assembled into symmetrical geometric structures. His experiments might have gone even further if he had not been hampered by shortages and restrictions in wartime Germany.[16]

- Heinz Fränkel-Conrat (German, 1910–1999) independently replicated and extended many of Schramm's experiments on the molecular biology of TMV in the United States after the war.

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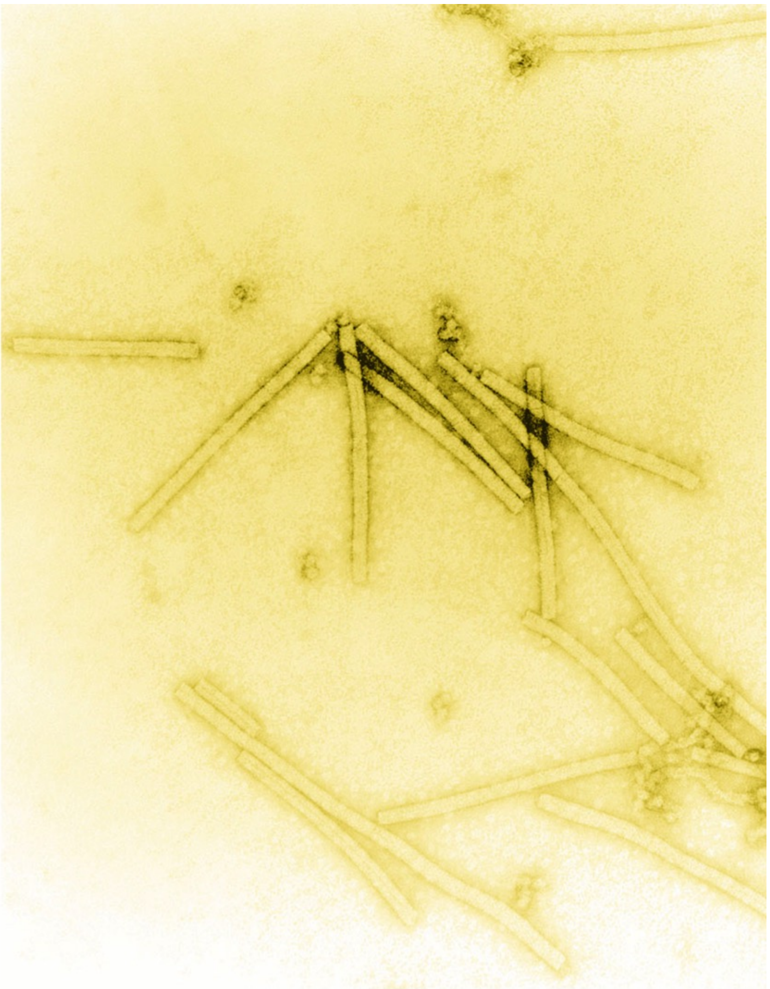
[16] Schramm 1941; Schramm 1943; Schramm and Dannenberg 1944; Schramm and Müller 1940; Schramm and Müller 1942; Schramm and Rebensburg 1942.

Viral infections

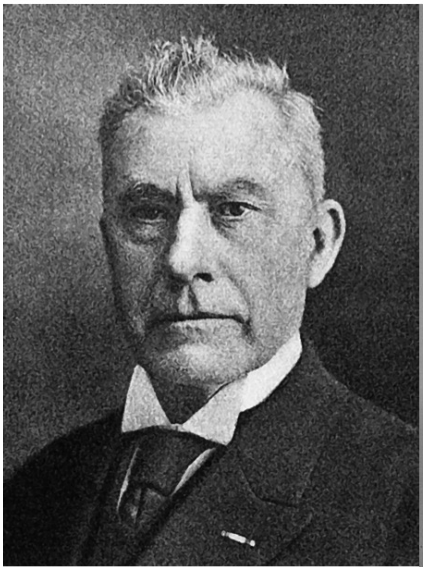
Tobacco mosaic virus



Adolf Eduard Mayer (1843–1942)

Dr. Adolf Mayer

Martinus Beijerinck (1851–1931)



Gerhard Schramm (1910–1969)

Heinz Fränkel-Conrat (1910–1999)

Figure 2.82: Scientists who studied tobacco mosaic virus included Adolf Eduard Mayer, Martinus Beijerinck, Gerhard Schramm, and Heinz Fränkel-Conrat.

Scientists who studied foot-and-mouth disease virus (FMDV) included:[17]

- Friedrich Löffler (German, 1852–1915, Fig. 2.83) and Paul Frosch (German, 1860–1928, Fig. 2.83), who had both worked with Robert Koch, discovered foot-and-mouth disease virus (FMDV) in 1897, demonstrating that the pathogen was not a bacterium. Löffler went on to help create what became known as the Friedrich Löffler Institute on Riems island on the Baltic coast of Germany, where experiments on FMDV and other animal viruses could be conducted in isolation.

- Carl Hecker (German?, 1868–1910, Fig. 2.83) immediately developed the first FMDV animal models (smaller animals that could be infected with the virus and therefore used to test potential treatments) and anti-FMDV immune serum during the period 1897–1899.

- Otto Waldmann (German, 1885–1955, Fig. 2.84) was the head of the FLI during the period 1919–1948. In addition to his administrative duties, he was very active scientifically. Working with Julius Pape (German?, 18??–19??), he developed a guinea pig model of FMDV in 1920. Together with Gottfried Pyl (19??–19??) and Carl Köbe (19??–19??), he developed a highly effective FMDV vaccine in 1938.

- Some other especially noteworthy scientists working on FMDV at FLI were Erich Traub (German, 1906–1985, Fig. 2.84), who was Waldmann's deputy for several years before becoming a consultant to U.S. animal labs after the war, and Friedrich Hecke (German?, 18??–19??), who developed a remarkably early and advanced tissue culture model of FMDV infection in 1930. In 1943, FLI scientists also developed a complement-binding immunoassay that could distinguish between different FMDV strains within less than one day.

German discoveries regarding FMDV were transferred to and utilized by the rest of the world. See for example FIAT 900, *The Waldmann Vaccine (Against Aphthous Stomatitis)*.

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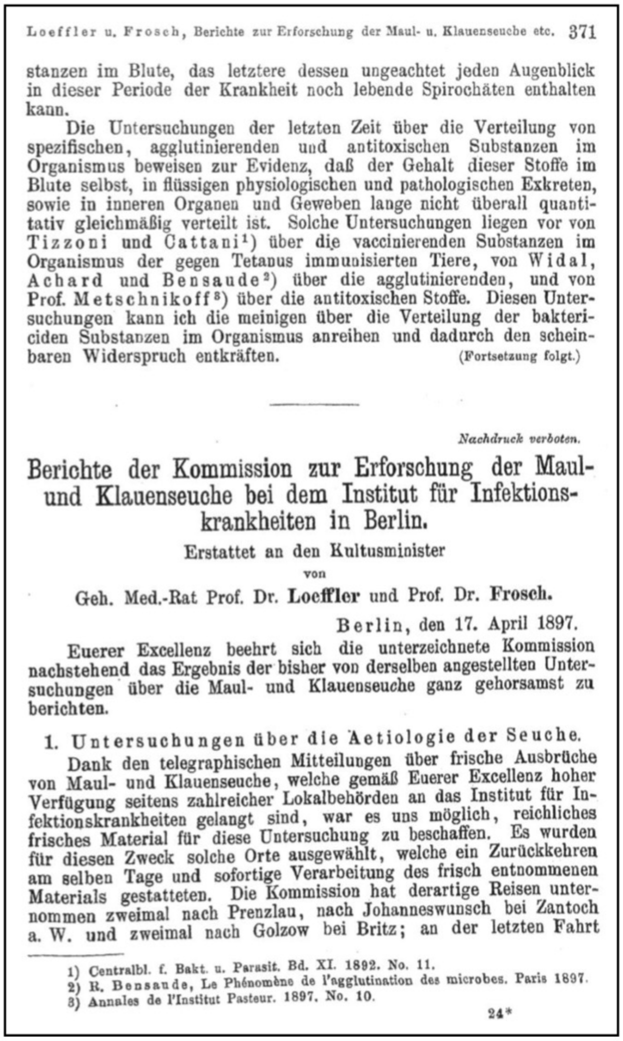
[17] Eberle 2015; Fast and Riebe 2011; Hinz-Wessels and Thiel 2010; Horzinek 1997; Loeffler and Frosch 1897, 1898; Loeffler 1919; Mettenleiter 2005, 2017; Müssemeier 1957; Riebe and Möhlmann 2012; Rott 1999; Rott and Siddell 1998; Wirtz 1998.



Loeffler u. Frosch, Berichte zur Erforschung der Maul- u. Klauenseuche etc. 371

stanzen im Blute, das letztere dessen ungeachtet jeden Augenblick in dieser Periode der Krankheit noch lebende Spirochäten enthalten kann.

Die Untersuchungen der letzten Zeit über die Verteilung von spezifischen, agglutinierenden und antitoxischen Substanzen im Organismus beweisen zur Evidenz, daß der Gehalt dieser Stoffe im Blute selbst, in flüssigen physiologischen und pathologischen Exkreten, sowie in inneren Organen und Geweben lange nicht überall quantitativ gleichmäßig verteilt ist. Solche Untersuchungen liegen vor von Tizzoni und Cattani[1]) über die vaccinierenden Substanzen im Organismus der gegen Tetanus immunisierten Tiere, von Widal, Achard und Bensaude[2]) über die agglutinierenden, und von Prof. Metschnikoff[3]) über die antitoxischen Stoffe. Diesen Untersuchungen kann ich die meinigen über die Verteilung der baktericiden Substanzen im Organismus anreihen und dadurch den scheinbaren Widerspruch entkräften. (Fortsetzung folgt.)

Nachdruck verboten.

Berichte der Kommission zur Erforschung der Maul- und Klauenseuche bei dem Institut für Infektionskrankheiten in Berlin.

Erstattet an den Kultusminister

von

Geh. Med.-Rat Prof. Dr. **Loeffler** und Prof. Dr. **Frosch.**

Berlin, den 17. April 1897.

Euerer Excellenz beehrt sich die unterzeichnete Kommission nachstehend das Ergebnis der bisher von derselben angestellten Untersuchungen über die Maul- und Klauenseuche ganz gehorsamst zu berichten.

1. Untersuchungen über die Aetiologie der Seuche.

Dank den telegraphischen Mitteilungen über frische Ausbrüche von Maul- und Klauenseuche, welche gemäß Euerer Excellenz hoher Verfügung seitens zahlreicher Lokalbehörden an das Institut für Infektionskrankheiten gelangt sind, war es uns möglich, reichliches frisches Material für diese Untersuchung zu beschaffen. Es wurden für diesen Zweck solche Orte ausgewählt, welche ein Zurückkehren am selben Tage und sofortige Verarbeitung des frisch entnommenen Materials gestatteten. Die Kommission hat derartige Reisen unternommen zweimal nach Prenzlau, nach Johanneswunsch bei Zantoch a. W. und zweimal nach Golzow bei Britz; an der letzten Fahrt

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1) Centralbl. f. Bakt. u. Parasit. Bd. XI. 1892. No. 11.
2) R. Bensaude, Le Phénomène de l'agglutination des microbes. Paris 1897.
3) Annales de l'Institut Pasteur. 1897. No. 10.

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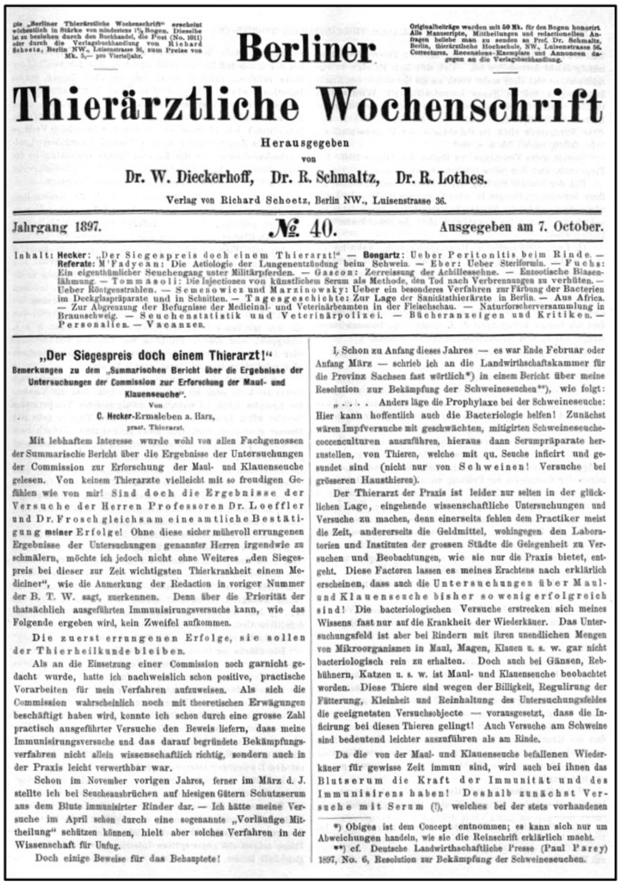
Viral infections

Foot-and-mouth disease virus (FMDV, discovered 1897)



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Originalbeiträge werden mit 50 Mk. für den Bogen honorirt. Alle Manuscripte, Mittheilungen und redactionellen Anfragen beliebe man zu senden an Prof. Dr. Schmaltz, Berlin, thierärztliche Hochschule, NW., Luisenstrasse 56. Correcturen, Recensions-Exemplare und Annoncen dagegen an die Verlagsbuchhandlung.

Berliner
Thierärztliche Wochenschrift
Herausgegeben
von
Dr. W. Dieckerhoff, Dr. R. Schmaltz, Dr. R. Lothes.
Verlag von Richard Schoetz, Berlin NW., Luisenstrasse 36.

Jahrgang 1897. № 40. Ausgegeben am 7. October.

Inhalt: **Hecker**: „Der Siegespreis doch einem Thierarzt!“ — **Bongartz**: Ueber Peritonitis beim Rinde. — **Referate**: M'Fadyean: Die Aetiologie der Lungenentzündung beim Schwein. — Eber: Ueber Steriformin. — Fuchs: Ein eigenthümlicher Seuchengang unter Militärpferden. — Gascon: Zerreissung der Achillessehne. — Enzootische Blasenlähmung. — Tommasoli: Die Injectionen von künstlichem Serum als Methode, den Tod nach Verbrennungen zu verhüten. — Ueber Röntgenstrahlen. — Semenowicz und Marzinowsky: Ueber ein besonderes Verfahren zur Färbung der Bacterien im Deckglaspräparate und in Schnitten. — Tagesgeschichte: Zur Lage der Sanitätsthierärzte in Berlin. — Aus Africa. — Zur Abgrenzung der Befugnisse der Medicinal- und Veterinärbeamten in der Fleischschau. — Naturforscherversammlung in Braunschweig. — Seuchenstatistik und Veterinärpolizei. — Bücheranzeigen und Kritiken. — Personalien. — Vacanzen.

„Der Siegespreis doch einem Thierarzt!“

Bemerkungen zu dem „Summarischen Bericht über die Ergebnisse der Untersuchungen der Commission zur Erforschung der Maul- und Klauenseuche“.

Von

C. Hecker-Ermsleben a. Harz,

pract. Thierarzt.

Mit lebhaftem Interesse wurde wohl von allen Fachgenossen der Summarische Bericht über die Ergebnisse der Untersuchungen der Commission zur Erforschung der Maul- und Klauenseuche gelesen. Von keinem Thierarzte vielleicht mit so freudigen Gefühlen wie von mir! Sind doch die Ergebnisse der Versuche der Herren Professoren Dr. Loeffler und Dr. Frosch gleichsam eine amtliche Bestätigung **meiner** Erfolge! Ohne diese sicher mühevoll errungenen Ergebnisse der Untersuchungen genannter Herren irgendwie zu schmälern, möchte ich jedoch nicht ohne Weiteres „den Siegespreis bei dieser zur Zeit wichtigsten Thierkrankheit einem Mediciner“, wie die Anmerkung der Redaction in voriger Nummer der B. T. W. sagt, zuerkennen. Denn über die Priorität der thatsächlich ausgeführten Immunisirungsversuche kann, wie das Folgende ergeben wird, kein Zweifel aufkommen.

Die zuerst errungenen Erfolge, sie sollen der Thierheilkunde bleiben.

Als an die Einsetzung einer Commission noch garnicht gedacht wurde, hatte ich nachweislich schon positive, practische Vorarbeiten für mein Verfahren aufzuweisen. Als sich die Commission wahrscheinlich noch mit theoretischen Erwägungen beschäftigt haben wird, konnte ich schon durch eine grosse Zahl practisch ausgeführter Versuche den Beweis liefern, dass meine Immunisirungsversuche und das darauf begründete Bekämpfungsverfahren nicht allein wissenschaftlich richtig, sondern auch in der Praxis leicht verwerthbar war.

Schon im November vorigen Jahres, ferner im März d. J. stellte ich bei Seucheausbrüchen auf hiesigen Gütern Schutzserum aus dem Blute immunisirter Rinder dar. — Ich hätte meine Versuche im April schon durch eine sogenannte „Vorläufige Mittheilung“ schützen können, hielt aber solches Verfahren in der Wissenschaft für Unfug.

Doch einige Beweise für das Behauptete!

I. Schon zu Anfang dieses Jahres — es war Ende Februar oder Anfang März — schrieb ich an die Landwirthschaftskammer für die Provinz Sachsen fast wörtlich*) in einem Bericht über meine Resolution zur Bekämpfung der Schweineseuchen**), wie folgt:

„. . . . Anders läge die Prophylaxe bei der Schweineseuche: Hier kann hoffentlich auch die Bacteriologie helfen! Zunächst wären Impfversuche mit geschwächten, mitigirten Schweineseuchecoccenculturen auszuführen, hieraus dann Serumpräparate herzustellen, von Thieren, welche mit qu. Seuche inficirt und gesundet sind (nicht nur von Schweinen! Versuche bei grösseren Hausthieren).

Der Thierarzt der Praxis ist leider nur selten in der glücklichen Lage, eingehende wissenschaftliche Untersuchungen und Versuche zu machen, denn einerseits fehlen dem Practiker meist die Zeit, andererseits die Geldmittel, wohingegen den Laboratorien und Instituten der grossen Städte die Gelegenheit zu Versuchen und Beobachtungen, wie sie nur die Praxis bietet, entgeht. Diese Factoren lassen es meines Erachtens nach erklärlich erscheinen, dass auch die Untersuchungen über Maul- und Klauenseuche bisher so wenig erfolgreich sind! Die bacteriologischen Versuche erstrecken sich meines Wissens fast nur auf die Krankheit der Wiederkäuer. Das Untersuchungsfeld ist aber bei Rindern mit ihren unendlichen Mengen von Mikroorganismen in Maul, Magen, Klauen u. s. w. gar nicht bacteriologisch rein zu erhalten. Doch auch bei Gänsen, Rebhühnern, Katzen u. s. w. ist Maul- und Klauenseuche beobachtet worden. Diese Thiere sind wegen der Billigkeit, Regulirung der Fütterung, Kleinheit und Reinhaltung des Untersuchungsfeldes die geeignetsten Versuchsobjecte — vorausgesetzt, dass die Inficirung bei diesen Thieren gelingt! Auch Versuche am Schweine sind bedeutend leichter auszuführen als am Rinde.

Da die von der Maul- und Klauenseuche befallenen Wiederkäuer für gewisse Zeit immun sind, wird auch bei ihnen das Blutserum die Kraft der Immunität und des Immunisirens haben! Deshalb zunächst Versuche mit Serum (!), welches bei der stets vorhandenen

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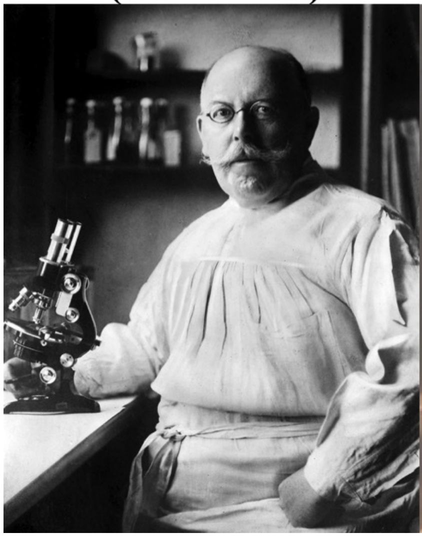
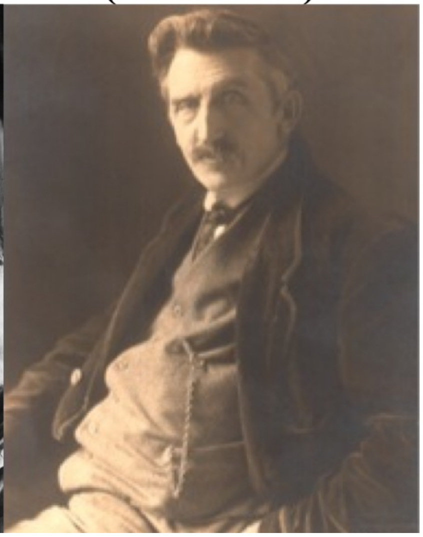
*) Obiges ist dem Concept entnommen; es kann sich nur um Abweichungen handeln, wie sie die Reinschrift erklärlich macht.

**) cf. Deutsche Landwirthschaftliche Presse (Paul Parey) 1897, No. 6, Resolution zur Bekämpfung der Schweineseuchen.

Friedrich Löffler (1852–1915)



Paul Frosch (1860–1928)



Carl Hecker (1868–1910)

Figure 2.83: Scientists who studied foot-and-mouth disease virus included Friedrich Löffler, Paul Frosch, and Carl Hecker.

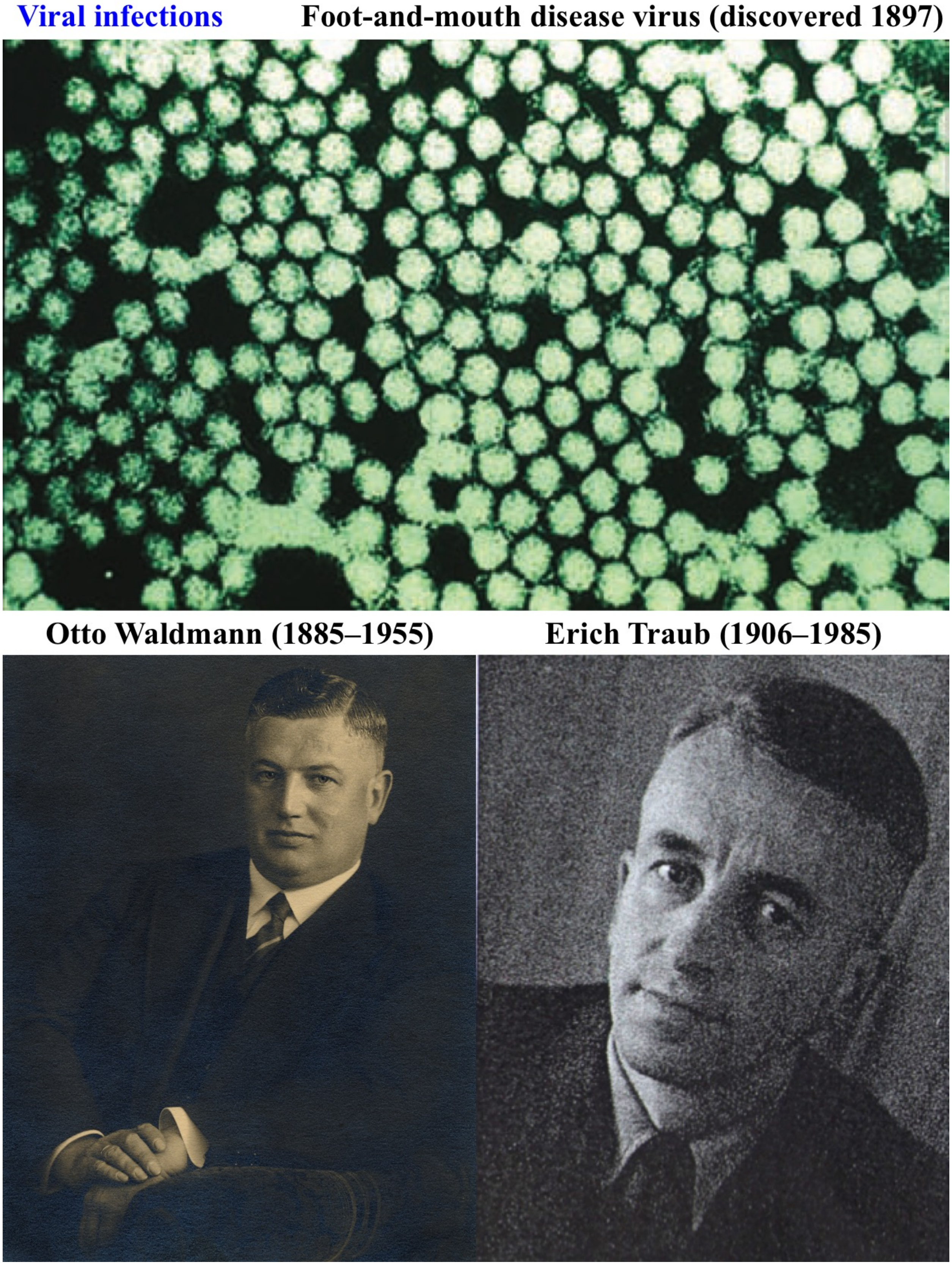

Viral infections
Foot-and-mouth disease virus (discovered 1897)
Otto Waldmann (1885–1955)
Erich Traub (1906–1985)

Figure 2.84: Scientists who studied foot-and-mouth disease virus included Otto Waldmann and Erich Traub.

Figure 2.85 shows an electron microscope image of poliovirus, the cause of polio. Poliovirus was discovered in 1908 by Karl Landsteiner (Austrian, 1868–1943) and Erwin Popper (Austrian, 1879–1955). Marguerite Vogt (German, 1913–2007) developed methods to grow poliovirus and polyoma virus in tissue culture, and also pursued cancer research.

As shown in Fig. 2.86, some other German-speaking scientists who made important early contributions to virology included:

- Max Delbrück (German, 1906–1981) did important early work on bacteriophages, viruses that infect bacteria. He won the Nobel Prize in Physiology or Medicine in 1969. Professor Sven Gad of the Royal Caroline Institute emphasized the importance of the discoveries of Delbrück and his coworkers [https://www.nobelprize.org/prizes/medicine/1969/ceremony-speech/]:

  > The honour in the first place goes to Delbrück who transformed bacteriophage research from vague empiricism to an exact science. He analyzed and defined the conditions for precise measurement of the biological effects. Together with Luria he elaborated the quantitative methods and established the statistical criteria for evaluation which made the subsequent penetrating studies possible. [...]
  >
  > The research proceeded along the lines Delbrück had set for a little more than ten years. During this period the bacteriophage life cycle was mapped out in detail. The various phases of the replication process were dissected and studied separately. [...]
  >
  > Their discoveries have also had great importance for the geneticists. It is mainly through studies of bacteriophages that the mechanisms of the genetic regulation of the vital processes have been revealed.
  >
  > Last but not least, bacteriophage research has given us the better insight in the nature of viruses which is necessary for the understanding and combat of virus diseases of higher beings. A long time has passed since the discoveries were made. However, their general biological and medical importance was only gradually recognized and only in later years has the wide range of their applicability become fully evident.

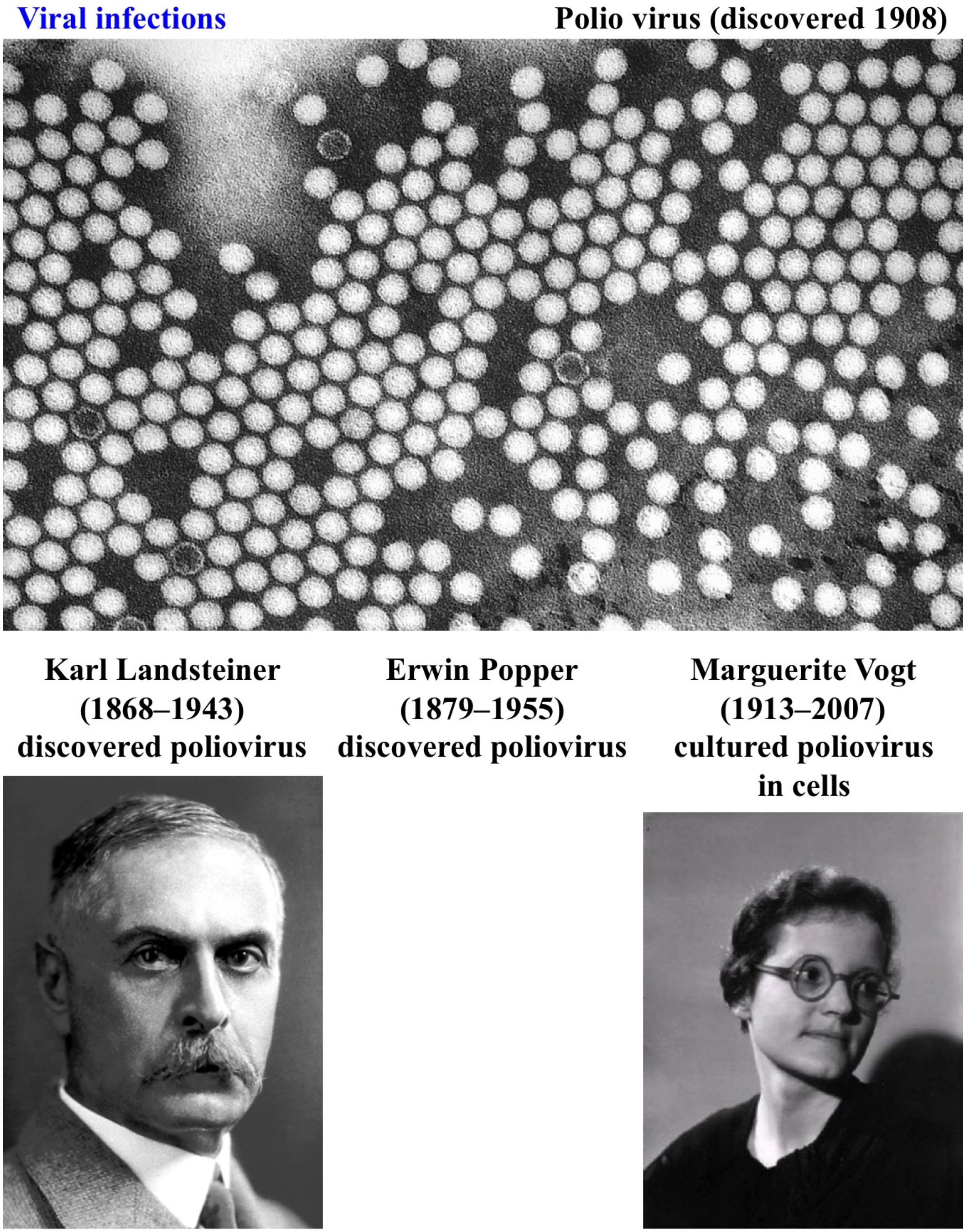
- Eugen Haagen (German, 1898–1972) was an expert on a wide variety of viral infections and wrote a handbook on viruses, *Viruskrankheiten des Menschen*, that became a standard for many years.

- Emil Pfeiffer (German, 1846–1921) was the first scientist to study what later came to be named the Epstein-Barr virus—decades before Michael Epstein and Yvonne Barr. The disease caused by the virus, infectious mononucleosis, is sometimes called Pfeiffer's disease.

- Helmut Ruska (German, 1908–1973) developed electron microscopy methods of viewing viruses, since viruses are too small to be seen by ordinary light microscopes.[18]

---

[18] von Ardenne and Pyl 1940; Gelderblom and Krüger 2014; Gentile and Gelderblom 2014; Krüger 2000; Pfankuch and Ruska 1947; Helmut Ruska 1939; Helmut Ruska and Poppe 1947; Simmons 2002, pp. 270–274.



Viral infections

Polio virus (discovered 1908)

Karl Landsteiner
(1868–1943)
discovered poliovirus

Erwin Popper
(1879–1955)
discovered poliovirus

Marguerite Vogt
(1913–2007)
cultured poliovirus
in cells

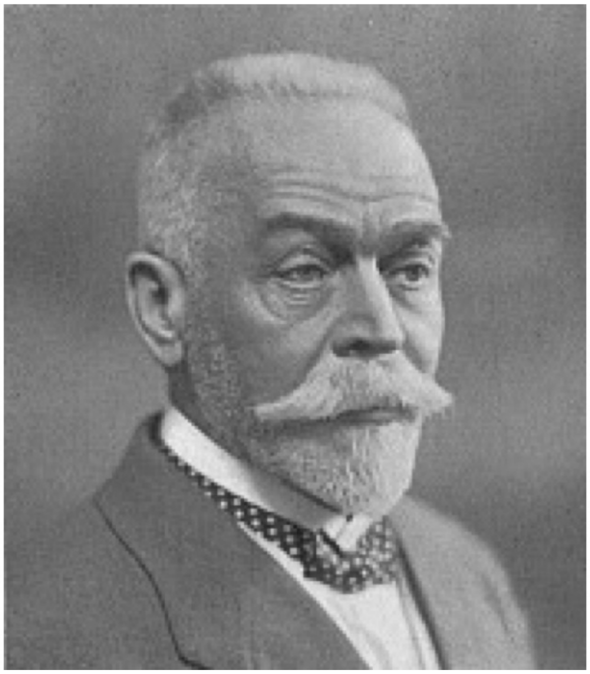
Figure 2.85: Poliovirus was discovered by Karl Landsteiner and Erwin Popper, and cultured in cells by Marguerite Vogt.

Viral infections

Max Delbrück (1906–1981)
Bacteriophages

Eugen Haagen (1898–1972)
Viral handbook

Emil Pfeiffer (1846–1921)
Epstein-Barr virus



Helmut Ruska (1908–1973)
Electron microscopy for viruses

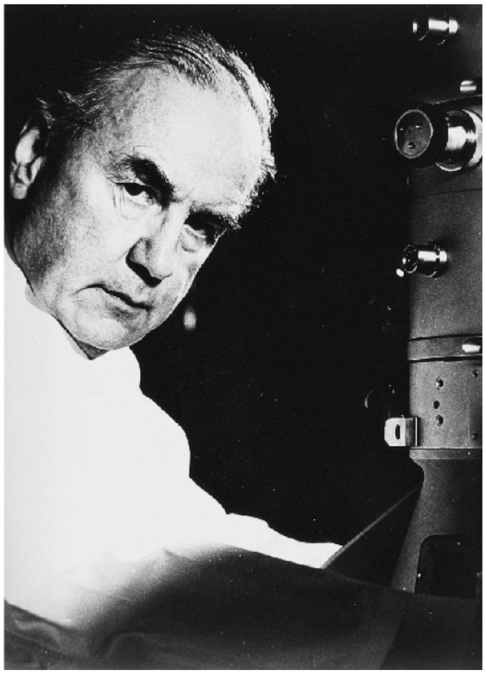


Figure 2.86: Some other German-speaking scientists who made important early contributions to virology included Max Delbrück, Eugen Haagen, Emil Pfeiffer, and Helmut Ruska.

2.2.3 Prions

Prions are just rogue proteins and not real live microorganisms, but they can spread from one animal or human host to another and kill their hosts, so they are usually classified as part of microbiology. The normal, healthy form and the pathogenic form of a prion protein (PrP) have the same amino acid sequence as each other, but they are folded up differently, as shown in Fig. 2.87 (top). Figure 2.87 (bottom) illustrates how pathogenic prions can recruit initially healthy PrP proteins to convert them into more prions. Pathogenic prions, shown in red, tend to accumulate to form large clumps, called fibrils or plaques. Some pathogenic prions can break off from the clumps and bind to healthy prion proteins (green) normally found in the host animal or person. The pathogenic prions refold the initially healthy prion proteins into the pathogenic shape, thus gaining more converts for their cause and multiplying exponentially. If even a small number of pathogenic prions are introduced into a healthy animal or human host (for example, if the new host consumes prion-containing meat from a previous infected host), over time they can convert most of the host's prions into the pathogenic form. Because of their unique folded structure, pathogenic prions are able to survive everything from cooking of meat to lying on the ground exposed to the elements for years.

The best-known prions are formed from a protein commonly found in neurons, so when they become pathogenic, they slowly make brain tissue look like Swiss cheese, killing brain cells and leaving only holes where the cells used to be, as shown in Fig. 2.88 (top). Such prion infections are called bovine spongiform encephalopathy or mad cow disease in cattle, chronic wasting disease in deer and elk, scrapie in sheep and goats, and Creutzfeldt-Jakob disease or Kuru in humans, although they can be transmitted from one species to another.

Prion infections were discovered and studied by (Fig. 2.88):

- Hans Gerhard Creutzfeldt (German, 1885–1964), who along with Jakob identified human cases of the disease in 1920.

- Alfons Maria Jakob (German, 1884–1931), who along with Creutzfeldt diagnosed human cases of the disease in 1920.

- Friedrich Meggendorfer (German, 1880–1953), who identified an inherited familial form of Creutzfeldt-Jakob disease in 1930.

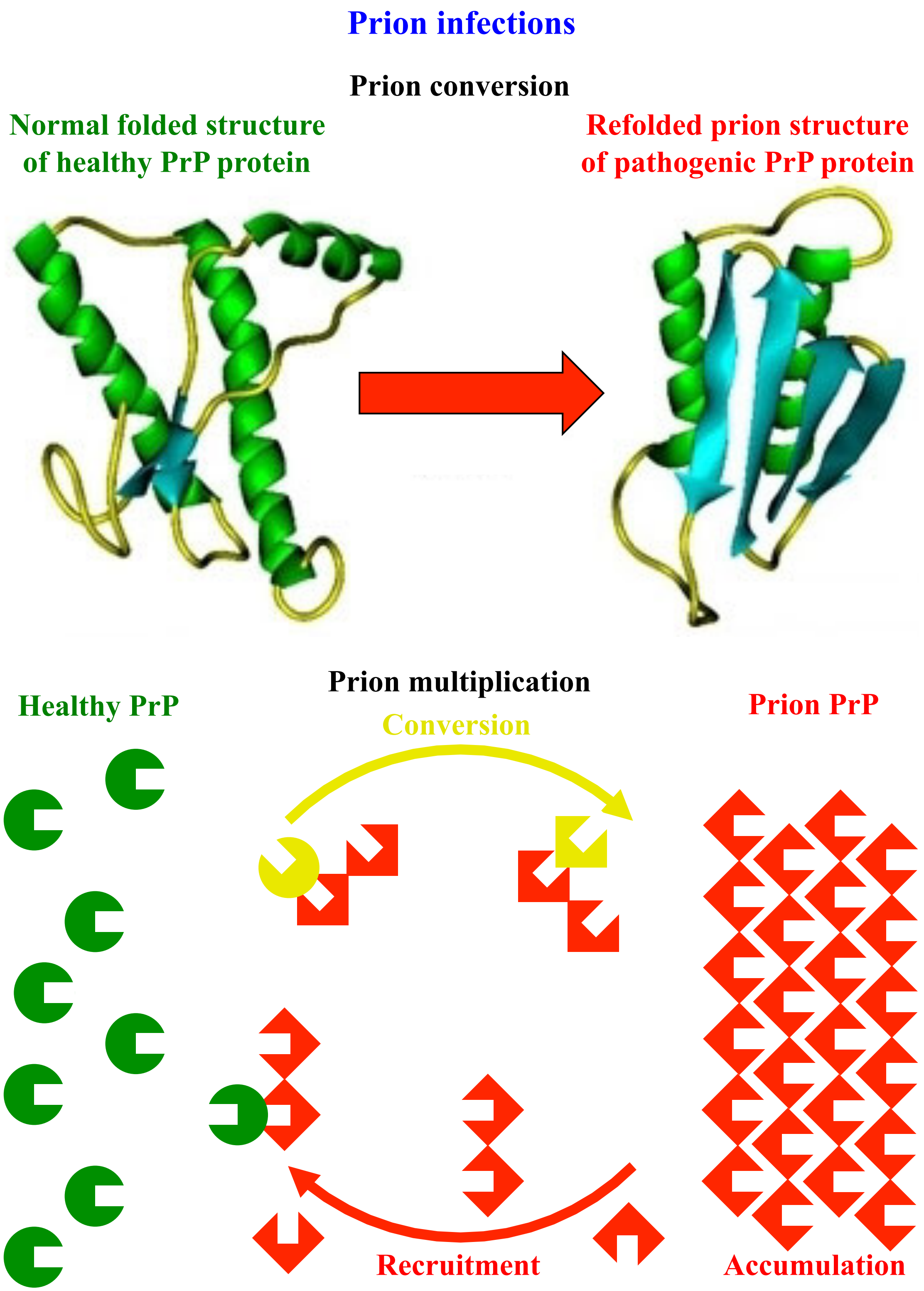

Prion infections
Prion conversion
Normal folded structure of healthy PrP protein
Refolded prion structure of pathogenic PrP protein
Prion multiplication
Healthy PrP
Conversion
Prion PrP
Recruitment
Accumulation

Figure 2.87: The mechanism of pathogenic prion formation, showing (above) how a healthy PrP protein can be refolded to be a pathogenic PrP protein, and (below) how pathogenic prions can recruit initially healthy PrP proteins to convert them into more prions.

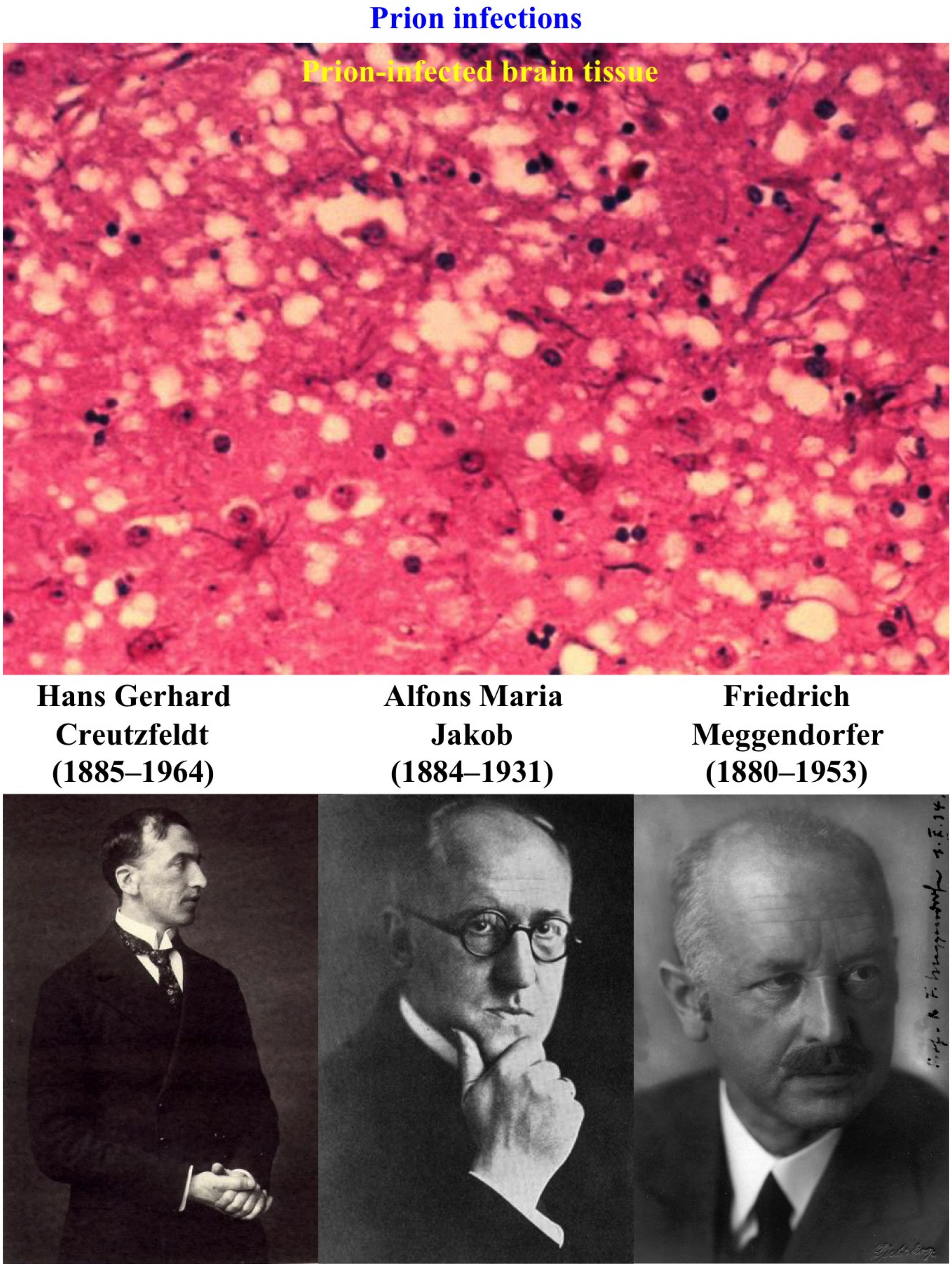

Prion infections
Prion-infected brain tissue
Hans Gerhard Creutzfeldt (1885–1964)
Alfons Maria Jakob (1884–1931)
Friedrich Meggendorfer (1880–1953)

Figure 2.88: Hans Gerhard Creutzfeldt, Alfons Maria Jakob, and Friedrich Meggendorfer discovered prion infections, which tend to kill brain cells and leave lots of holes in brain tissue.

2.2.4 Fungi

As shown in Fig. 2.89, fungal cells look very similar to plant cells, but are smaller and without chloroplasts. Animal, plant, and fungal cell membranes contain different types of sterols. Plant and fungal cells both have cell walls, but of different composition. There are many nonpathogenic species of fungi that live in the environment, but also some pathogenic ones that can infect humans, animals, or plants.

Scientists from the German-speaking world made many important discoveries regarding fungal infections; Fig. 2.90 shows some examples.

Johann Schönlein (German states, 1793–1864) discovered human infections by the pathogenic fungus *Trichophyton*. *Trichophyton* and similar fungal species cause fungal skin (tinea) infections, including nail infections, scalp infections, athlete's foot, jock itch, and ringworm on the body. They secrete a keritinase enzyme that breaks down the keratin structural protein in skin, nails, and hair, then live off the resulting nutrients.

Abraham Buschke (German, 1868–1943) and Otto Busse (German, 1867–1922) discovered infections by *Cryptococcus*. *Cryptococcus* species take the form of yeast both inside and outside humans; like some bacteria, they are coated with a protective polysaccharide layer. If inhaled, they cause a mild lung infection and then head for the central nervous system, where they can cause a potentially fatal fungal mengingoencephalitis.

Heinrich Anton de Bary (German, 1831–1888) discovered fungal infections in plants.

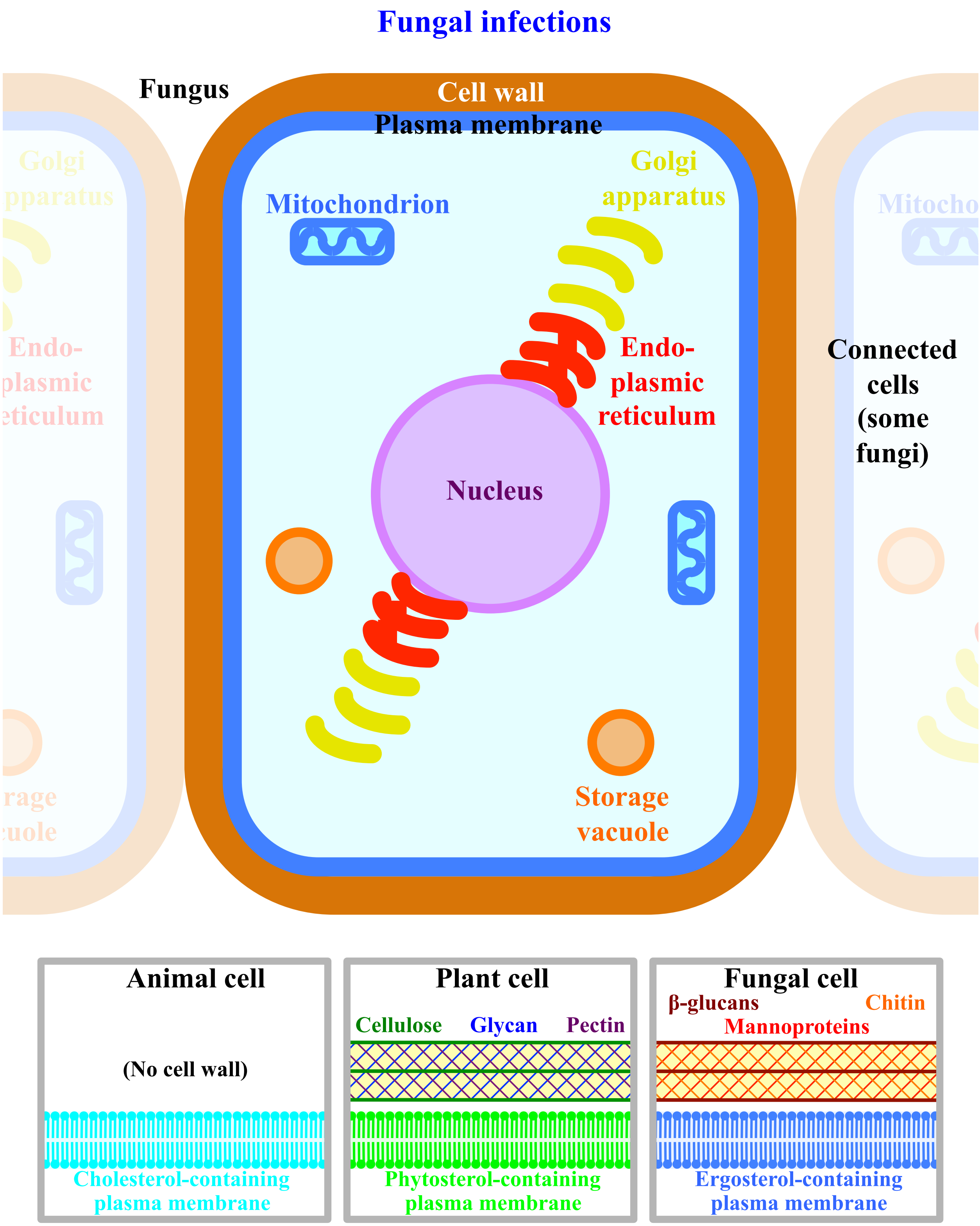

Fungal infections
Fungus
Cell wall
Plasma membrane
Mitochondrion
Golgi apparatus
Endo-plasmic reticulum
Nucleus
Storage vacuole
Connected cells (some fungi)
Animal cell
(No cell wall)
Cholesterol-containing plasma membrane
Plant cell
Cellulose
Glycan
Pectin
Phytosterol-containing plasma membrane
Fungal cell
β-glucans
Chitin
Mannoproteins
Ergosterol-containing plasma membrane

Figure 2.89: Fungal cells look very similar to plant cells, but smaller and without chloroplasts. Animal, plant, and fungal cell membranes contain different types of sterols. Plant and fungal cells both have cell walls, but of different composition.

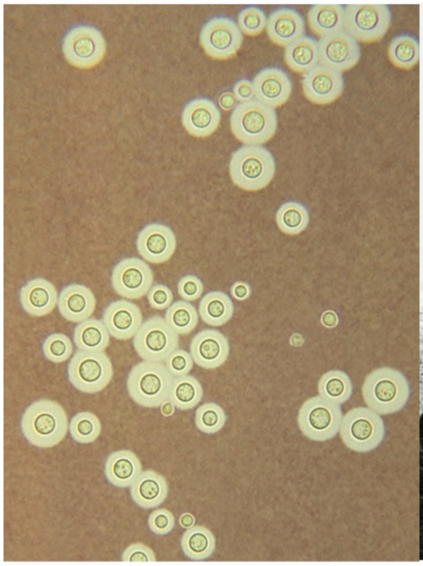
Fungal infections

Trichophyton
pathogenic fungi

Johann Schönlein
(1793–1864)
Fungal infections
in humans

Heinrich Anton
de Bary (1831–1888)
Fungal infections
in plants

Cryptococcus
pathogenic fungi



Abraham Buschke
(1868–1943)

Otto Busse
(1867–1922)

Figure 2.90: Johann Schönlein discovered human infections by the pathogenic fungus *Trichophyton*, and Abraham Buschke and Otto Busse discovered infections by *Cryptococcus*. Heinrich Anton de Bary discovered fungal infections in plants.

2.2.5 Protozoa

Protozoa or protists are single-celled animals, so they are eukaryotic cells that are relatively similar to human cells (Fig. 2.91). Pathogenic protozoa can take up residence in humans and cause disease either from inside or from outside our cells, whereas non-pathogenic protozoa just live harmlessly in the environment. Most protozoa can form spore-like cysts that are ∼10-20 μm wide and can lie dormant during harsh conditions in the environment, then in better conditions can hatch and grow to their mature forms, which are usually ∼20-400 μm long. Most pathogenic protozoa are transmitted from person to person either by insect bites (e.g., *Plasmodium* or malaria), *Trypanosoma*, etc.) or by ingesting contaminated water (e.g., amoeba species, *Giardia*, etc.).

Whereas German-speaking scientists made most of the major discoveries in all other categories of pathogenic microorganisms (bacteria, viruses, prions, fungi, and helminths), they made fewer important discoveries regarding pathogenic protozoa.

Many the major discoveries regarding pathogenic protozoa were made by French, British, and American doctors, presumably because those countries had large populations of citizens or subjects living in tropical or semi-tropical regions that are especially conducive to the growth of pathogenic protozoa and the insects that carry them. Historically, German-speaking countries had far less presence in such regions.

Nonetheless, Otto Bütschli (German, 1848–1920), shown in Fig. 2.92, did develop a method of categorizing protozoa that has been widely used ever since.

Perhaps most importantly, Hans Andersag (born in Italy but educated and worked in Germany, 1902–1955) developed chloroquine and related treatments for malaria in 1934, as shown in Fig. 2.93. Information on chloroquine and other antimalarial drugs was transferred to the United States and other countries during and after World War II [e.g., Pou et al. 2012; BIOS 1387]. Chloroquine-based drugs have been used worldwide ever since.

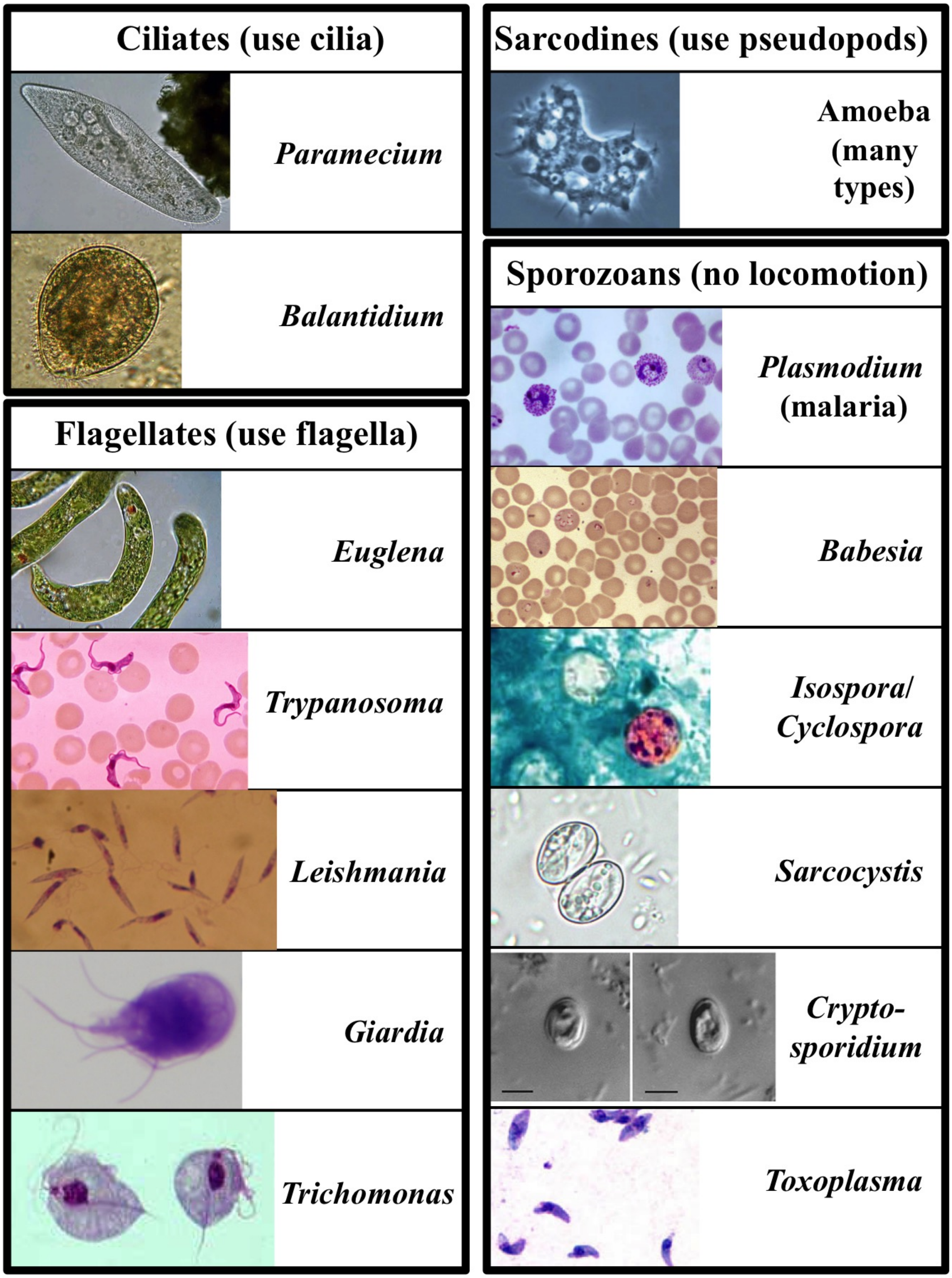

Ciliates (use cilia)
Paramecium
Balantidium
Flagellates (use flagella)
Euglena
Trypanosoma
Leishmania
Giardia
Trichomonas
Sarcodines (use pseudopods)
Amoeba (many types)
Sporozoans (no locomotion)
Plasmodium (malaria)
Babesia
Isospora/ Cyclospora
Sarcocystis
Crypto-sporidium
Toxoplasma

Figure 2.91: Protozoa or protists can be classified by their method of locomotion: ciliates use many hair-like cilia, flagellates use one or more whip-like flagella, sarcodines use pseudopods that can easily be reshaped, and sporozoans have no visible means of locomotion and simply follow the movement of the fluid they are in.

Otto Bütschli (1848–1920): classification of protozoa

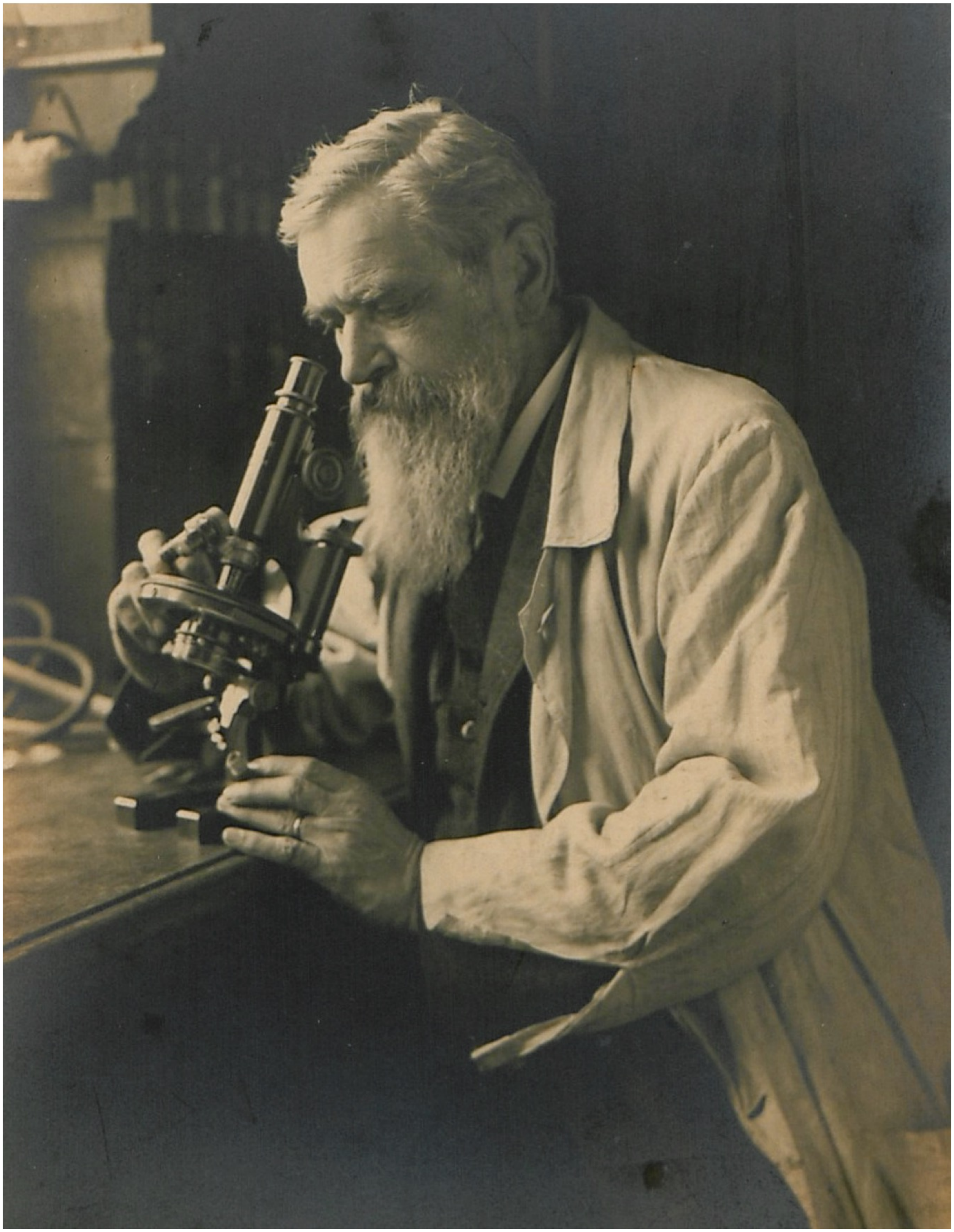
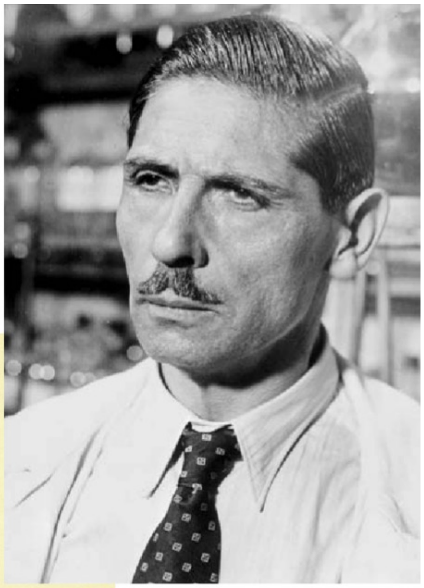
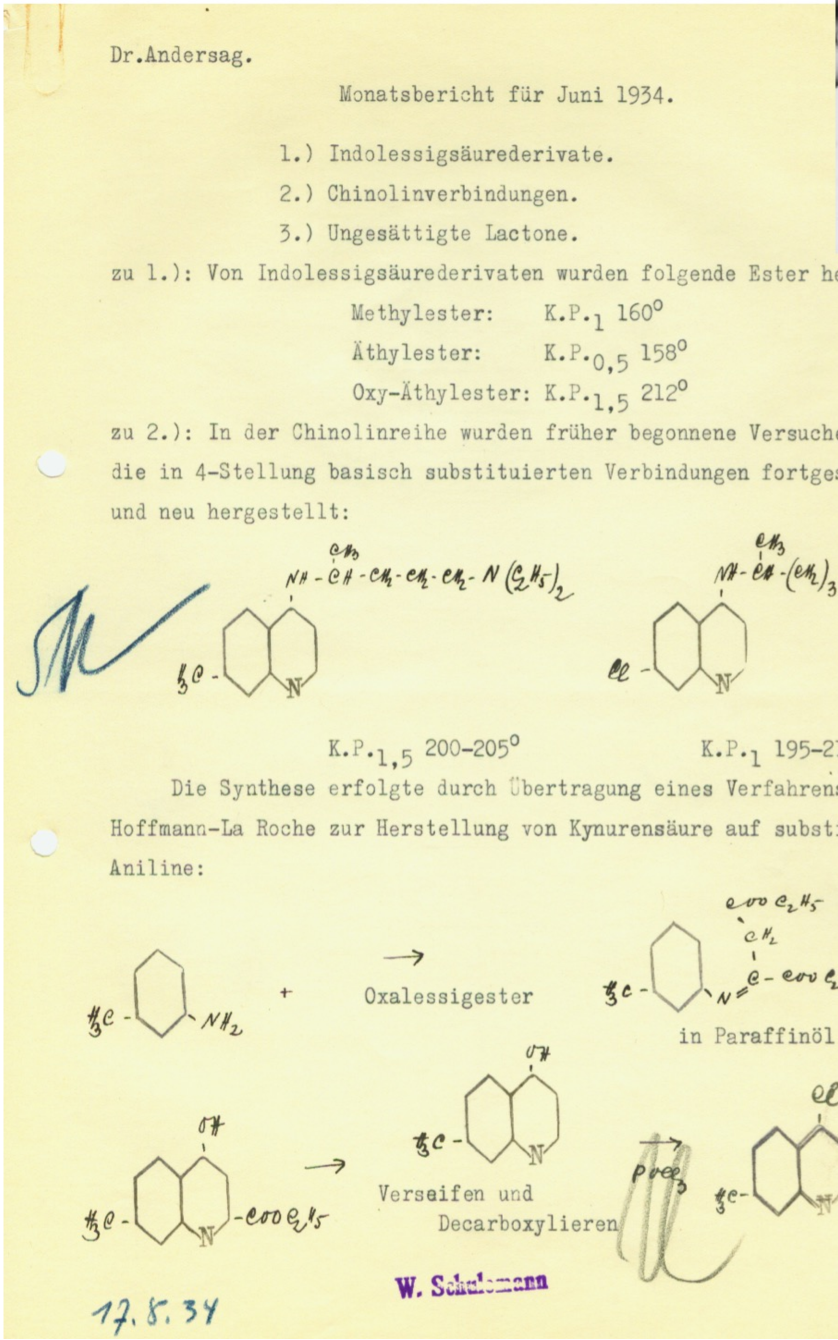


Figure 2.92: Otto Bütschli developed a system to classify protozoa or protists.

Hans Andersag
(1902–1955)
developed chloroquine
and related treatments
for malaria (1934)





Dr.Andersag.

Monatsbericht für Juni 1934.

1.) Indolessigsäurederivate.
2.) Chinolinverbindungen.
3.) Ungesättigte Lactone.

zu 1.): Von Indolessigsäurederivaten wurden folgende Ester hergestell

Methylester: K.P.$_{1}$ 160°
Äthylester: K.P.$_{0,5}$ 158°
Oxy-Äthylester: K.P.$_{1,5}$ 212°

zu 2.): In der Chinolinreihe wurden früher begonnene Versuche über die in 4-Stellung basisch substituierten Verbindungen fortgesetzt und neu hergestellt:

NH-CH(CH3)-CH2-CH2-CH2-N(C2H5)2
H3C-
N
NH-CH(CH3)-(CH2)3-N(C2H5)2
Cl-
N

K.P.$_{1,5}$ 200-205°   K.P.$_{1}$ 195-210°

Die Synthese erfolgte durch Übertragung eines Verfahrens von Hoffmann-La Roche zur Herstellung von Kynurensäure auf substituierte Aniline:

H3C-
NH2
+
Oxalessigester
COO C2H5
CH2
C-COO C2H5
N=
in Paraffinöl bei 250°
OH
H3C-
N
-COO C2H5
Verseifen und Decarboxylieren
POCl3
Cl

W. Schulemann

17.8.34

Figure 2.93: Hans Andersag developed chloroquine and related treatments for malaria in 1934.

2.2.6 Helminths

Helminths are worms. Most helminths are non-pathogenic and live in the environment. However, certain pathogenic types of helminths can invade the body of an animal or human, usually when the helminth is a microscopic egg or larva, then slowly grow to considerable size inside their new host. As shown in Fig. 2.94, helminths may be divided into three broad categories based on their shapes and structures: nematodes (roundworms), trematodes (flatworms or flukes), and cestodes (segmented tape worms). Different types of helminths attach themselves inside different organs (usually the gastrointestinal tract, but sometimes elsewhere), siphon nutrients from their host, and produce fertilized eggs that are excreted in the host's waste to infect other animals or people.

German-speaking scientists made important discoveries regarding helminth infections (Fig. 2.95).

Rudolf Virchow (1821–1902) discovered *Trichinella* nematodes, a serious problem in undercooked meat that is consumed by humans or domesticated animals.

Hans Vogel (1900–1980) discovered both *Opisthorchis* liver flukes and *Echinococcus* tapeworms.

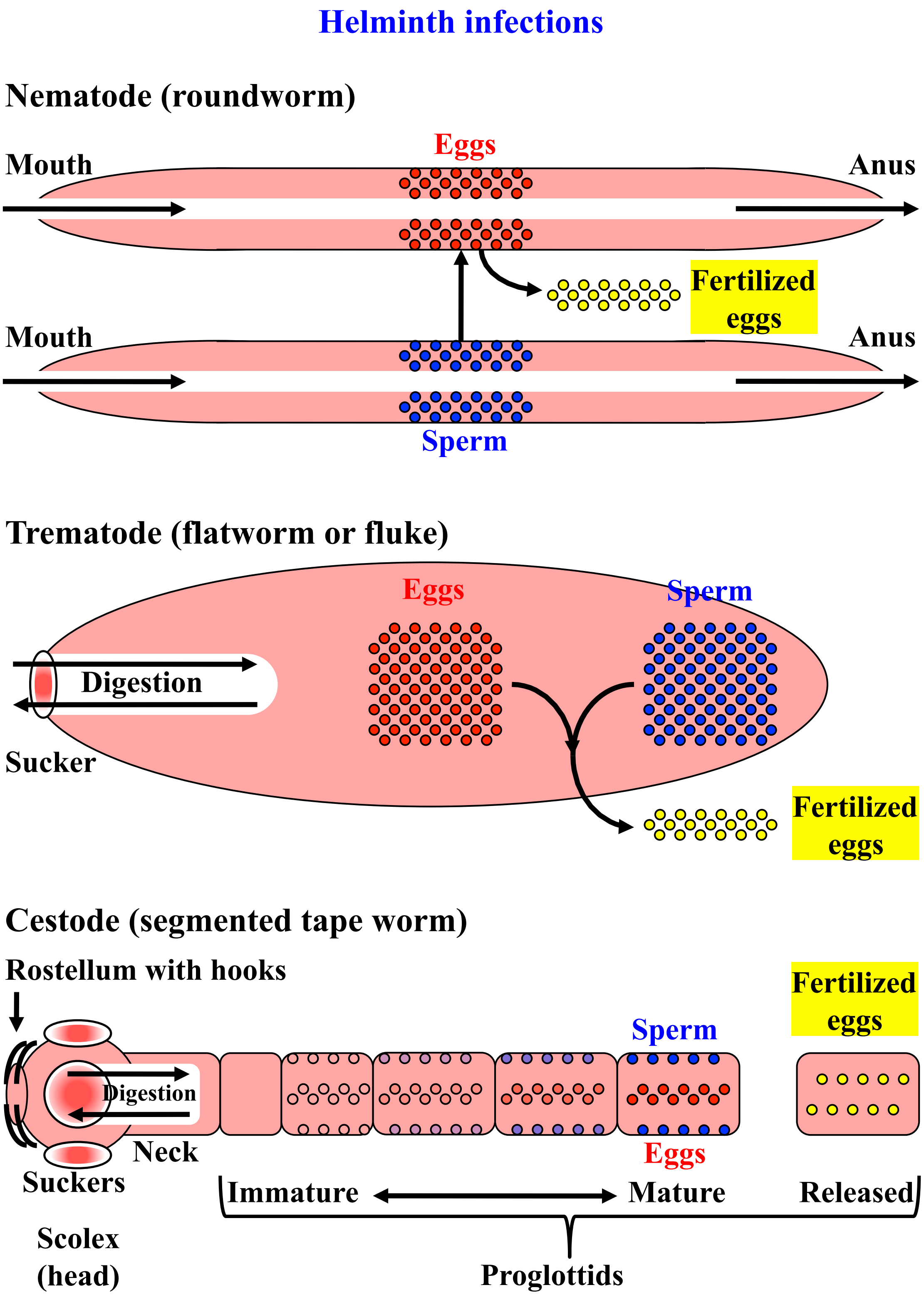

Helminth infections
Nematode (roundworm)
Eggs
Mouth
Anus
Fertilized eggs
Mouth
Anus
Sperm
Trematode (flatworm or fluke)
Eggs
Sperm
Digestion
Sucker
Fertilized eggs
Cestode (segmented tape worm)
Rostellum with hooks
Fertilized eggs
Sperm
Digestion
Neck
Eggs
Suckers
Immature
Mature
Released
Scolex (head)
Proglottids

Figure 2.94: Helminths include: nematodes or roundworms; trematodes, flatworms, or flukes; and cestodes or segmented tapeworms.

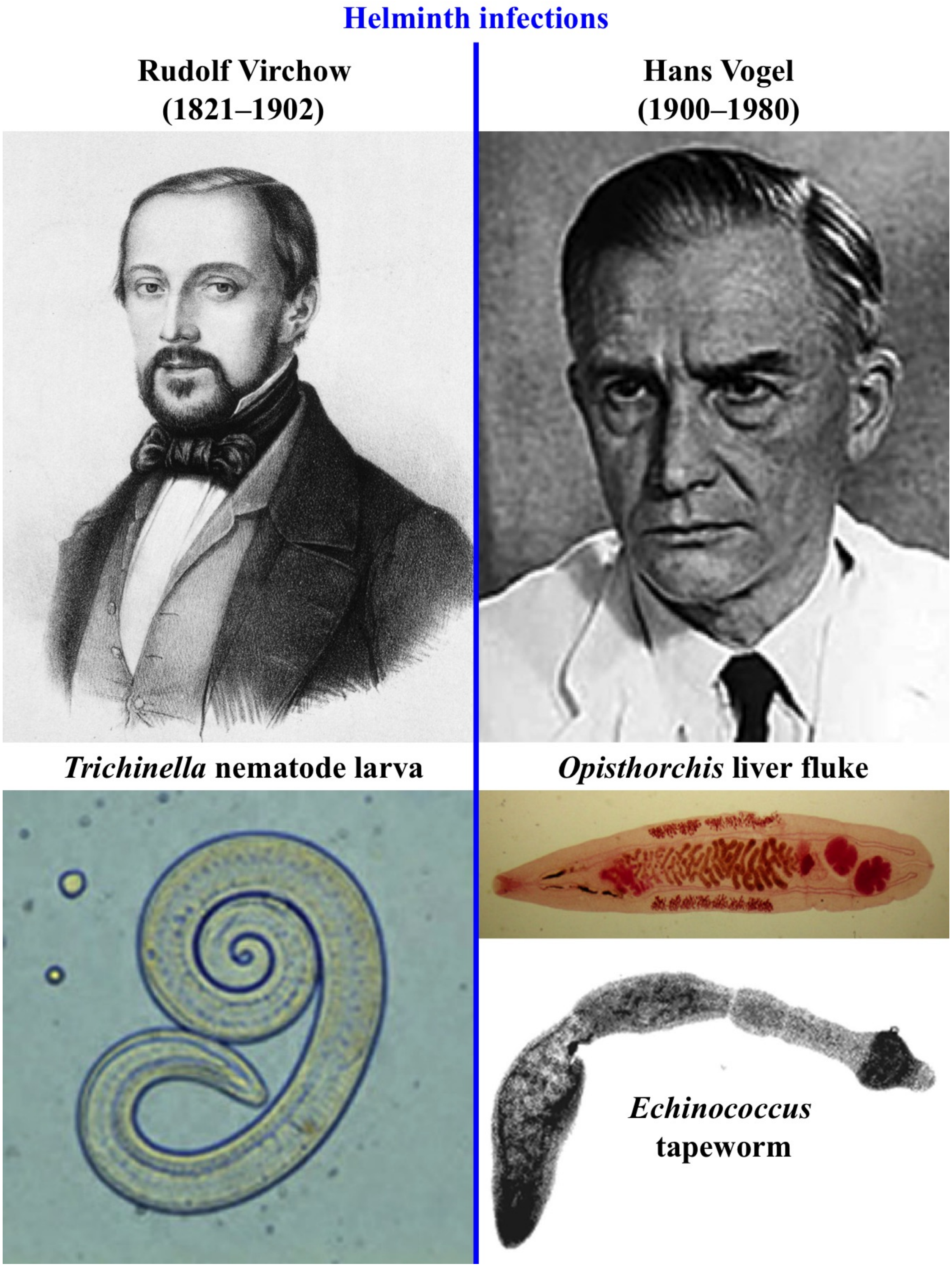

Helminth infections
Rudolf Virchow
(1821–1902)
Hans Vogel
(1900–1980)
Trichinella nematode larva
Opisthorchis liver fluke
Echinococcus
tapeworm

Figure 2.95: Rudolf Virchow discovered *Trichinella* nematodes, and Hans Vogel discovered *Opisthorchis* liver flukes and *Echinococcus* tapeworms.

2.2.7 Immunology

The immune system has many different ways to recognize and attack pathogenic organisms or anything else that does not appear to be normal component of the host. Some of the major types of immune system responses to pathogen infections are shown in Fig. 2.96 and include:

- T lymphocytes peer inside other cells to see if they have been infected by pathogens. If so, the T lymphocytes or T cells kill those cells and hopefully also the pathogens inside them. T cells can even activate the apoptosis pathway to persuade infected cells to kill themselves if the infected cells don't feel guilty enough to do the deed on their own. The most effective pathogens are those that can hide inside cells without being detected until it is too late to stop their evil scheme.

- B lymphocytes try to find and clobber pathogens outside our cells. B lymphocytes or B cells make antibodies, proteins that can be tailored to bind to specific pathogens but not anything else. Different B cells have different antibodies on their surface. If the antibodies on the surface of a B cell detect and bind to a specific invading pathogen, that B cell will start replicating and cranking out lots of those same antibodies to attack the pathogens. Sneaky pathogens try to avoid that response by hiding inside our cells or inside other protective enclosures, and/or by frequently changing their outer appearance so a given set of antibodies will no longer recognize them.

- Other immune system cells such as natural killer (NK) cells and macrophages destroy cells that fail to show proper identification, since they assume that those may be pathogen cells, host cells that are infected but trying to hide it, host cells that are becoming cancer cells, or other cells that are up to no good.

- Complement proteins act both by themselves and in conjunction with antibodies to bind to the surface of a pathogen and interfere with its operation.

Creators from the German-speaking world made huge contributions to the field of immunology, the study of how the immune system works and how it can be harnessed [19] Historically, immunology has been divided into cellular immunity (how cells respond to pathogens) and humoral immunity (how proteins such as antibodies and complement respond to pathogens). There is actually not a clear distinction between cellular and humoral immunity—B cells produce and release antibody proteins, antibodies and complement proteins can guide immune cells to pathogens, and there are other close interactions between cellular and humoral immunity. Nonetheless, because the distinction between cellular and humoral immunity was important during the history of the development of immunology, those terms will be used here.

---

[19] Michael Carroll 2004; Deichmann 1996; Dominguez-Lacasa 2005; Gausemeier 2005; Gedeon 2006; Gradmann and Simon 2010; Jahn 2004; Junker 2004; Koesling and Schülke 2010; Kohler 2008; Magner 2002; Raviña and Kubinyi 2011; Possehl 1989; Schnalke and Atzl 2010; Schneider 1972; von Schwerin 2013; Simmons 2002; Sneader 2005; Weatherall 1991.

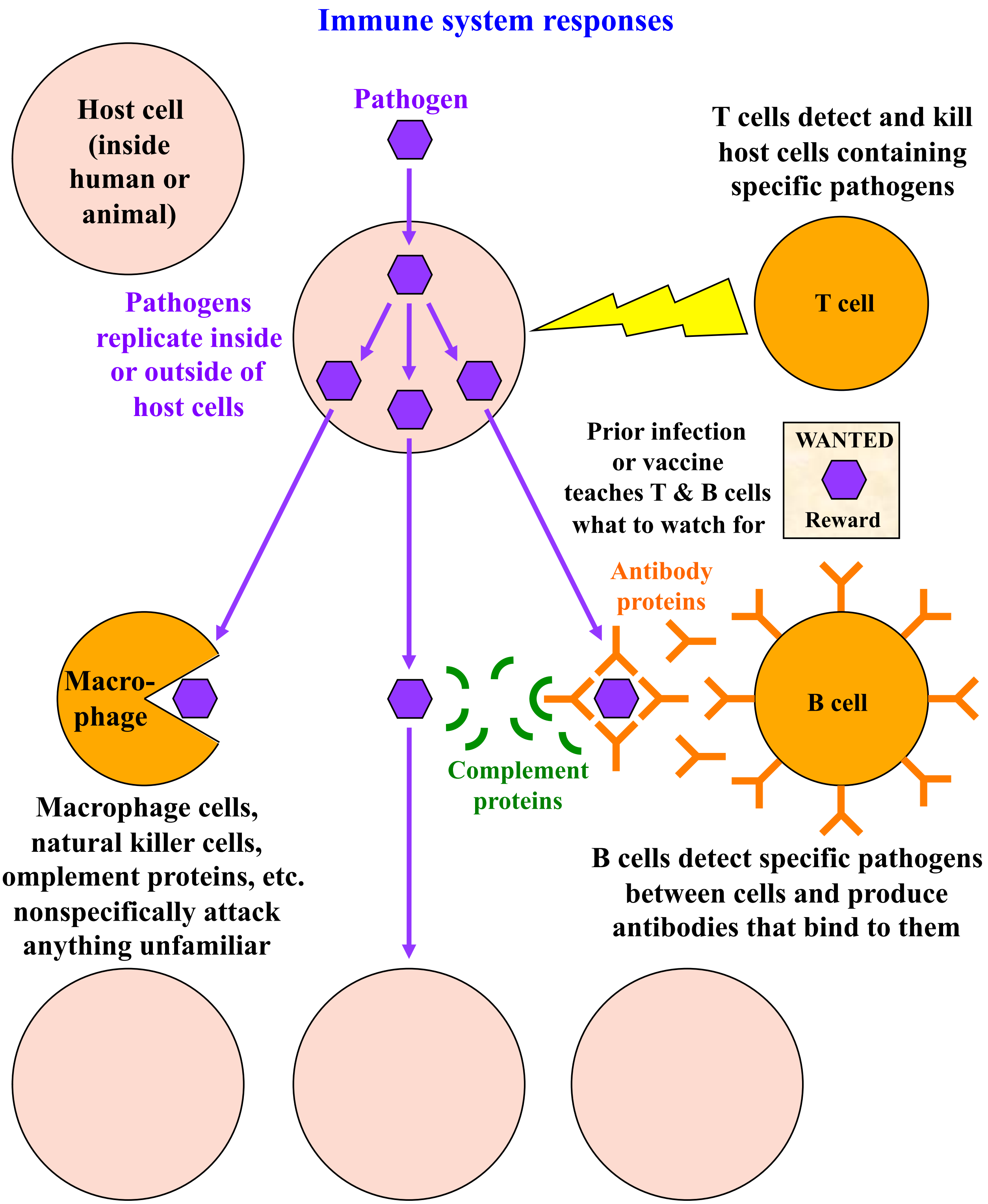

Immune system responses
Host cell (inside human or animal)
Pathogen
T cells detect and kill host cells containing specific pathogens
Pathogens replicate inside or outside of host cells
T cell
Prior infection or vaccine teaches T & B cells what to watch for
WANTED
Reward
Antibody proteins
Macro-phage
B cell
Complement proteins
Macrophage cells, natural killer cells, omplement proteins, etc. nonspecifically attack anything unfamiliar
B cells detect specific pathogens between cells and produce antibodies that bind to them

Figure 2.96: Immune system responses against infections by pathogenic microorganisms include highly pathogen-specific responses by T cells (which attack infected host cells) and B cells (which produce antibody proteins), as well as nonspecific responses by other cells and proteins that attack anything unfamiliar.

Cellular immunity

Figure 2.97 shows examples of creators who played major roles in deciphering cellular immunity.

Rudolf Virchow (German, 1821–1902) arguably made the first contributions to cellular immunity with his discoveries regarding the structure and reproduction of cells, cellular pathologies such as cancer, and cellular responses to pathologies. He strongly supported the work of later researchers such as Élie Metchnikoff on cellular immunity.

Carl Friedrich Wilhelm Claus (1835–1899) discovered and named phagocytes, cells that eat pathogens or other unwanted substances in the body.

Élie Metchnikoff (Russian but educated in Germany, 1845–1916) studied the structure and behavior of phagocytes or macrophage cells. For that research, he won the 1908 Nobel Prize in Physiology or Medicine. Professor the Count K. A. H. Mörner, Rector of the Royal Caroline Institute, noted the importance of his work [https://www.nobelprize.org/prizes/medicine/1908/ceremony-speech/]:

> Elie Metchnikoff was the first to take up consciously and purposefully, by means of experiments, the study of the question so fundamental to the question of immunity; by what means does the organism vanquish the disease-bearing microbes attacking the organism in which they have succeeded in establishing themselves and developing? At first his experiments were restricted to the lower animals. This was the case in his important work concerning a kind of infection in certain microscopic aquatic animals, the so-called water fleas. If the guiding principles behind these investigations were not known they could appear to be remote from any medical interest. They were, however, the first links in a chain of investigations leading to phenomena of immunity, also in mammals and in humans. These investigations opened the way for Metchnikoff's theory of phagocytosis. According to this theory, the microorganisms are destroyed by the activity of cells in the organism. Certain kinds of cells in the bodies of humans and animals, namely, are supposed to have, in addition to other functions, the task of catching and destroying disease-producing microbes which have succeeded in penetrating the organism, and also of rendering certain bacterial poisons harmless.
>
> I cannot here give a report on the comprehensive work and valuable observations which go to make up this theory of phagocytosis. But an important aspect of this research is that it makes a special study of certain types of cells, and that first of all the importance of the cells for the phenomena of immunity is emphasized. One can safely predict that even if other features are of more immediate importance in this doctrine, nevertheless the abundant actual observations which have been made with regard to the importance of the cells to the problem of immunity will always remain of great and permanent value. In the doctrine of immunity, as in other provinces of biology, the activity of the cells, which are considered as being the focus of organic life, remains a factor of the highest importance. The research of recent years into the question of immunity has thrown the importance of Metchnikoff's work into strong relief. As a recognition of Metchnikoff's accomplishment in initiating modern research into the question of immunity, the direction and development of which, particularly in its early stages, he profoundly influenced, the Caroline Institute wishes to honour him with this year's Nobel Prize.

Completely independently of Metchnikoff and at approximately the same time, Johann Muellendorf (German, 18??–19??) also studied macrophages and cellular immunity.

Niels Jerne (Dutch/Danish, 1911–1994) won the 1984 Nobel Prize in Physiology or Medicine for his work on both cellular and humoral immunity. Professor Hans Wigzell of the Karolinska Institute explained his discoveries [https://www.nobelprize.org/prizes/medicine/1984/ceremony-speech/]:

> Niels Jerne is the great theoretician in modern immunology. He entered the immunological arena comparatively late in his life and was 44 years old when in 1955 he published his first important theory of the construction of the immune system. Jerne proposed that the well-known capacity of the immune defence to recognize myriades of foreign molecules was something predetermined, already existing in the body when the very first contact with a foreign structure was made. What then happened was merely a selection amongst the naturally occurring antibody population resulting in an increase in production of exactly those antibodies which happened to have a good fit for the structure. Jerne's theory stood in great contrast to prevailing theories at that time, but it was rapidly confirmed and extended. We now know that Darwin's laws about natural selection indeed apply to the cells of the immune system: Those cells which happen to have received the property to produce a wanted antibody type will upon vaccination be rewarded with regard to proliferative capacity and survival.
>
> Jerne took another known feature of the immune defence as the starting point for his next important theory, in 1971. The immune system always expresses a very strong defence of the private and unique features of the tissues within one individual. This behaviour creates great problems whenever attempts are made to transplant tissue from one individual to another. Jerne assumed that the molecules in the tissues that cause these reactions, the so-called transplantation antigens, must have their normal functions within the body of the individual. He proposed that one function of these molecules could be to serve as a specific driving force for the cells of the immune system, thus creating a large number of cells from which cells especially suitable to defend the tissues of the host would become selected. Special organs, such as the thymus, were assumed to serve as a combination of greenhouse and university for these cells. In this theory Jerne did predict to a great extent how the specificity of the cellmediated immunity is generated.
>
> In the third great theory, in 1974, Niels Jerne introduced us to the mirror halls of immunology. The immune system is visualized somewhat like a gigantic computer where constant communication and regulation takes place in between the different components, the cells. The number of cells in such a network system in an adult human being exceeds 1012 (one million millions); and the system has through its capacity to produce billions of different forms of antibodies an enormous inbuilt richness with regard to structural variations. Jerne proposed that this should allow the creation of multiple complementary situations where certain antibodies would have select capacity to combine with their mirror images. Some antibodies would according to the theory then even mimic foreign molecules against which other antibodies would normally be produced during immunization. Jerne postulated that pairs of antibodies and their mirror images would spontaneously be produced during the development of the immune system, thus creating the possibilities for communication networks and regulatory equlibria. During immunization the foreign molecules would enter the mirror halls of immunology where the

> different pairs of antibodies and cells would perform their interdependent piruettes and separate the partners chasing away the mirror images. This change in equilibrium would then serve as a driving force, resulting in immunity. It is now well documented that network forces of the fascinating type that Jerne predicted do indeed exist inbuilt in our own immune systems. The theory also predicted the almost mind-boggling possibility that antibodies of the mirror image-type could replace the foreign material completely when inducing immunity. This is now a proven reality. Thus, it is for instance possible to induce a long lasting immunity against hepatitis virus by immunization with mirror image antibodies to the antibodies against hepatitis virus without ever using the virus in the vaccination.
>
> In conclusion, Niels Jerne has via his visionary theories enabled modern immunology to make major leaps of progress. Several concepts in immunology now considered as self-evident have their roots in some of his pioneering thoughts.

Rolf Zinkernagel (Swiss, 1944–) made important discoveries regarding T cells, for which he won the Nobel Prize in Physiology or Medicine in 1996 (along with Peter Doherty). The Royal Swedish Academy of Sciences summarized this work [https://www.nobelprize.org/prizes/medicine/1996/zinkernagel/facts/]:

> When the body's cells are attacked by viruses, the immune system begins killing the infected cells. By studying mice, Rolf Zinkernagel and Peter Doherty proved in 1973 how the immune system recognizes virus-ridden cells. A kind of white blood cell, T-cells, kills the virus-ridden cells, but only if they recognize both the foreign substances, viruses, and certain substances from the body's own cells. The discovery has provided an important basis for vaccines and medicines for infectious diseases, but also for inflammatory diseases and cancer.

Cellular immunity
Rudolf Virchow
(1821–1902)
Carl Claus
(1835–1899)
Johann Muellendorf
(18??–19??)
Élie Metchnikoff
(1845–1916)
Niels Jerne
(1911–1994)
Rolf Zinkernagel
(1944–)

Figure 2.97: Creators who made significant contributions to knowledge about cellular immune responses included Rudolf Virchow, Carl Claus, Johann Muellendorf, Élie Metchnikoff, Niels Jerne, and Rolf Zinkernagel.

Humoral immunity

Figure 2.98–2.99 shows examples of creators who played major roles in discovering and elucidating humoral immunity.

Joseph Fodor (Hungarian, 18??–19??) discovered the first indications of complement protein activity in 1886.

Hans Buchner (German, 1850–1902) demonstrated and studied complement proteins in 1891. He was the older brother of Eduard Buchner (p. 129).

Paul Ehrlich (German, 1854–1915) made important discoveries regarding the humoral immune system and how it could be harnessed. He won the 1908 Nobel Prize in Physiology or Medicine for that work. Professor the Count K. A. H. Mörner, Rector of the Royal Caroline Institute, praised Ehrlich's discoveries [https://www.nobelprize.org/prizes/medicine/1908/ceremony-speech/]:

> It has been shown that protection against disease can be of two kinds. It can consist in the ability to destroy microbes or to inhibit their further development. This is a bacteria-destroying immunity. But there is also a protection of another kind, one which acts against the bacteria products. The damage which the disease-producing microorganisms cause, namely, is conditioned by the poisons which these organisms produce and which are distributed by the body fluids. A certain kind of immunity occurs against this danger as well, namely the so-called poison immunity. The best known example of this is the use of anti-diphtheria serum, when, through serum injection, substances are introduced into the organism which act as antitoxins against the diphtheria poison. It has been discovered that poisons which are produced by bacteria have the property, as have many other substances also, of causing the production of elements in the organism which have an antagonistic effect especially and exclusively directed against the substance which caused the production of the elements. This we call the formation of antibodies. After immunity has been achieved, such antibodies are found in the humors of the organism. Furthermore, it has been possible to show that these antibodies are of great importance, not only as regards protection against disease-producing microorganisms themselves, but also, above all, as regards protection against the toxic products of these organisms. [...]
>
> A man who has been responsible for important scientific progress as organizer and leader in this field deserves to be mentioned among the first of those who have dedicated themselves to a study of immunity, is the research scientist Paul Ehrlich, already famous for his other biological work, and the Professorial Staff of the Caroline Institute wishes to honour him too with this year's Nobel Prize for his work in the sphere of immunity.

Emil von Behring (German, 1854–1917) demonstrated that therapeutic antibodies could be produced by one individual and administered to another individual to combat a particular pathogen. For that work, he won the Nobel Prize in Physiology or Medicine in 1901. Professor the Count K. A. H. Mörner, Rector of the Royal Caroline Institute, explained the importance of von Behring's research [https://www.nobelprize.org/prizes/medicine/1901/ceremony-speech/]:

> In general, the disease-causing bacteria produce poisons which in their turn give rise to

> a toxic condition in the individual in which they develop. And it is precisely because of these poisons that the bacteria are so dangerous. Nevertheless, it has been shown that the poisons, under certain conditions, will lead the organism to produce substances which render them harmless and which prevent the development of the bacteria. When such a condition of "immunity" has been built up, the individual can become insensitive to the bacteria in question and resistant to the poisons. [...]
>
> Blood fluid—or blood serum—from an individual who has been immunized with poisons from a certain bacterium, can, namely, when introduced into the organs of another individual, confer resistance upon him against the bacterium in question. Upon this fact modern serum therapy is based.
>
> Up until now, serum therapy has had particularly splendid triumphs in the case of diphtheria, but its significance is not limited to this disease but extends much further. The field which is opened up for research by the development of serum therapy has therefore—for the present—no discernible limits. Much ground has been gained already and we are justified in expecting a great deal of important progress.
>
> The pioneer in this new area of medical research, Professor Emil von Behring, has been chosen by the Professorial Staff of the Caroline Institute as the recipient of this year's Nobel Prize for Medicine.

Richard Pfeiffer (German, 1858–1945) made many important discoveries in microbiology and immunology during his long career. He developed both therapeutic antibodies and vaccines for several bacterial infections, including cholera and typhoid.

Julius Morgenroth (German, 1871–1924) worked closely with Paul Ehrlich and also conducted his own research on immunology and therapeutics for infections.

Fritz Breinl (German?, 1888–1936) and Felix Haurowitz (Czech, 1896–1987) conducted experiments on antibody formation and developed theoretical models of the process.

To complete the story even though this is a little later than the primary time period for this book, Georges Köhler (German, 1946–1995) developed the hybridoma method for producing large amounts of identical (monoclonal) antibodies for diagnostic or therapeutic applications (along with César Milstein). For that innovation, he won the Nobel Prize in Physiology or Medicine in 1984. Professor Hans Wigzell of the Karolinska Institute noted [https://www.nobelprize.org/prizes/medicine/1984/ceremony-speech/]:

> At the same time the young researcher Georges Köhler struggled in Basel in Switzerland to study normal antibody-producing cells in tissue culture. His research was in part frustrating as he could only get very few cells to survive for short periods of time. Köhler knew of the important studies of Milstein, and it seemed logical to see if normal antibody-forming cells could be fused with tumor cells to produce long-lived hybrid cell lines. If this was indeed possible the experiments of Milstein would indicate that they should then continue to produce their antibodies. At the same time the normally evil feature of tumor cells, the capacity to proliferate for ever, would now be turned into a

very beneficial feature. Köhler went to Milstein's laboratory and together they wrestled with the problems and managed to solve them in a hectic two year period, 1975–1976. By that time they had succeeded to develop a technique allowing them at will to fish up exactly those rare antibody-producing cells that they wanted from a sea of cells. These cells were fused with tumor cells creating hybrid cells with eternal life and capacity to produce the very same antibody in high quantity. Köhler and Milstein called these hybrid cells hybridomas, and as all cells in a given hybridoma come from one single hybrid cell, the antibodies made are monoclonal.

Köhler's, and Milstein's development of the hybridoma technique for production of monoclonal antibodies have in less than a decade revolutionized the use of antibodies in health care and research. Rare antibodies with a tailor-made-like fit for a given structure can now be made in large quantities. The hybridoma cells can be stored in tissue banks and the very same monoclonal antibody can be used all over the world with a guarantee for eternal supply. The precision in diagnosis is greatly improved, and entirely new possibilities for therapy have been opened up via the hybridoma technique. Rare molecules present in trace amounts in complex solution can now be purified in an efficient manner using monoclonal antibodies. In all, it is therefore correct to describe the hybridoma technique discovered by Georges Köhler and César Milstein as one of the major methodological advances in medicine during this century.

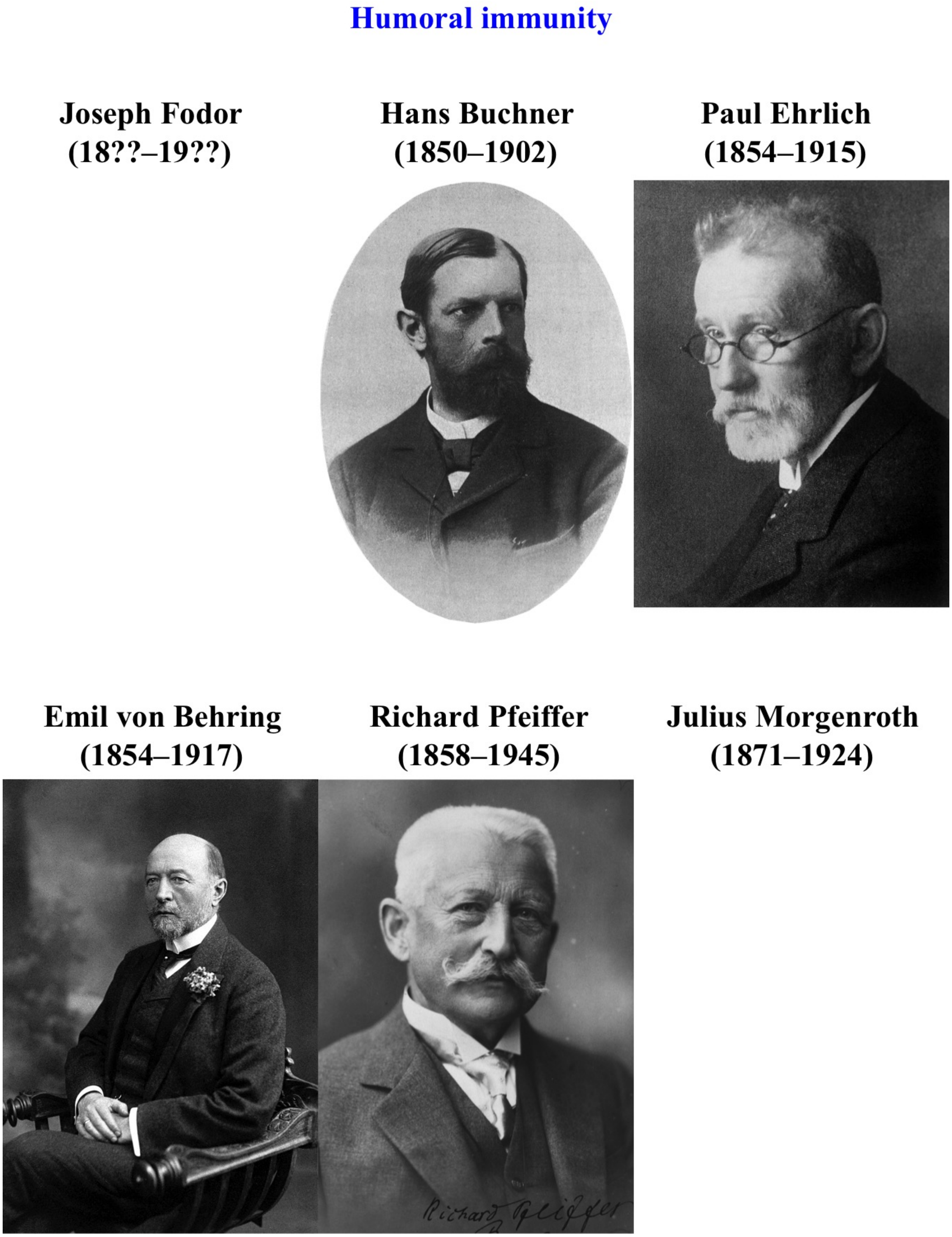

Humoral immunity
Joseph Fodor
(18??–19??)
Hans Buchner
(1850–1902)
Paul Ehrlich
(1854–1915)
Emil von Behring
(1854–1917)
Richard Pfeiffer
(1858–1945)
Julius Morgenroth
(1871–1924)

Figure 2.98: Creators who made significant contributions to knowledge about humoral (protein) immune responses included Joseph Fodor, Hans Buchner, Paul Ehrlich, and Emil von Behring.

Humoral immunity

Fritz Breinl
(1888–1936)

Felix Haurowitz
(1896–1987)

Georges Köhler
(1946–1995)

Figure 2.99: Other creators who made significant contributions to knowledge about humoral (protein) immune responses included Richard Pfeiffer, Julius Morgenroth, Fritz Breinl, and Felix Haurowitz.

Immunoassays

As illustrated in Fig. 2.100, immunoassays use antibodies (produced by B cells) that bind to specific pathogens but nothing else. Each antibody is a Y-shaped protein, with an identical pathogen binding site at the top of each prong of the Y. If the corresponding pathogen is not present in a sample, nothing happens, but if it is, antibodies and pathogens bind to each other and create a detectable clump. Immunoassays are now used for a wide variety of medical diagnostics and biotechnology applications.

Creators from the German-speaking world, shown in Fig. 2.100, developed immunoassays to test for the presence of specific pathogens *in vitro* (in test tubes):

- Max von Gruber (Austrian, 1853–1927) discovered the agglutination reaction, in which antibodies and pathogens clump together, in 1896.
- Rudolf Kraus (Austrian, 1868–1932) used the agglutination reaction to create an antibody assay for specific bacterial precipitins in 1897.
- August von Wasserman (German, 1866–1925) used similar methods to create a complement fixation test for syphilis bacteria in 1906.
- Similar *in vitro* immunoassays were rapidly developed for a wide variety of other pathogens or other targets for detection.

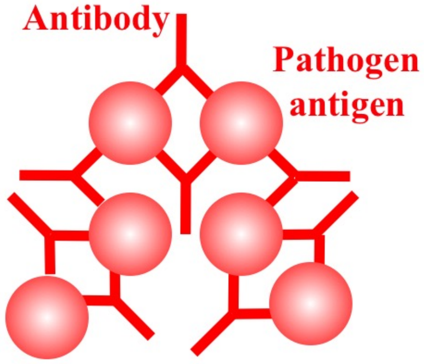
As shown in Fig. 2.101, creators from the German-speaking world also developed immunoassays to test for the presence of specific pathogens *in vivo* (directly in the body of a patient):

- Clemens von Pirquet (Austrian, 1874–1929) developed the skin test for tuberculosis in 1906, and it has been widely used ever since.
- Béla Schick (Hungarian, educated and worked in Austria, 1877–1967) developed a skin test for diphtheria susceptibility in 1910. The method became known as the Schick skin test and was used worldwide.
- Similar *in vivo* immunoassays were quickly developed for a wide variety of other pathogens or allergic reactions.

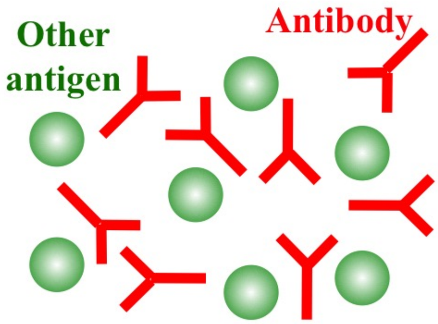
In vitro immunoassays

Distinguish antigens (components) from pathogens vs. non-pathogens, or from one pathogen vs. other pathogens

Antibody proteins form visible clumps if they recognize a specific pathogen antigen



Antibody proteins do not form clumps if they do not recognize any pathogen antigens



Max von Gruber (1853–1927) Agglutination reaction (1896)

Rudolf Kraus (1868–1932) Bacterial precipitin antibody assay (1897)

August von Wasserman (1866–1925) Complement fixation test for syphilis (1906)

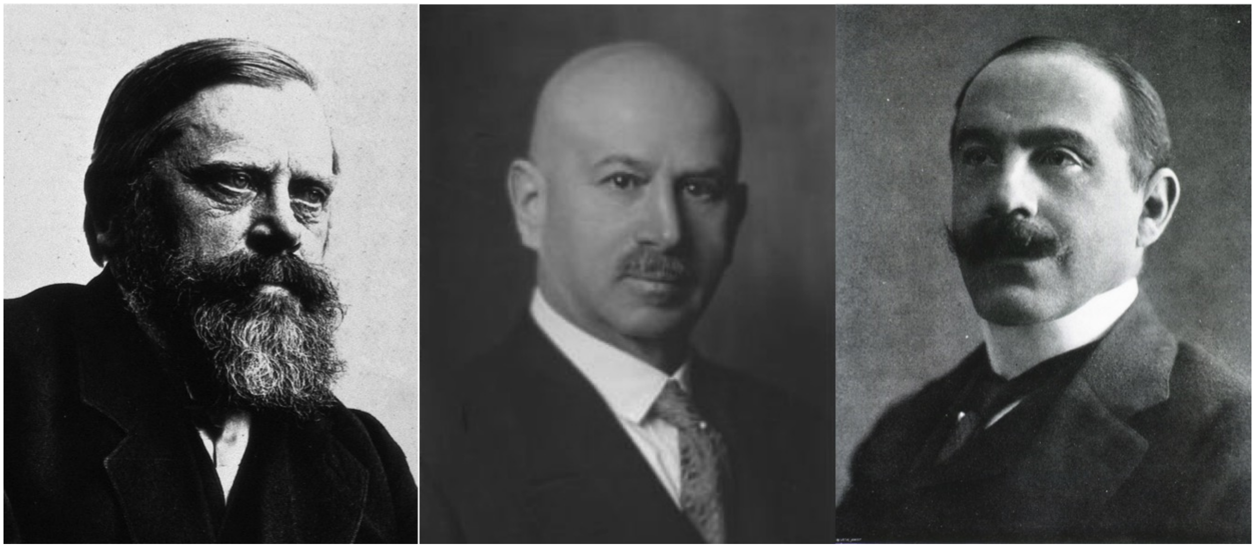


Figure 2.100: Max von Gruber, Rudolf Kraus, and August von Wasserman harnessed components of the immune system to create *in vitro* (in the lab) immunoassays for specific pathogens.

Clemens von Pirquet (1874–1929) Tuberculosis skin test (1906)
In vivo immunoassays
Béla Schick (1877–1967) Skin test for diphtheria susceptibility (1910)
Schick skin test

Figure 2.101: Clemens von Pirquet and Béla Schick harnessed components of the immune system to create *in vivo* (in the body) immunoassays for specific pathogens.

Vaccines and adjuvants

Vaccines are another way to artificially harness the immune system. Vaccines teach the immune system what specific pathogens to keep watch for, like showing a “wanted” poster to the police (Fig. 2.96). A good vaccine looks like a certain pathogen to the immune system, yet does not do any pathogenic mischief itself. Most vaccines use killed versions of the target pathogen, artificially weakened versions of the target pathogen, or individual pieces of the target pathogen.

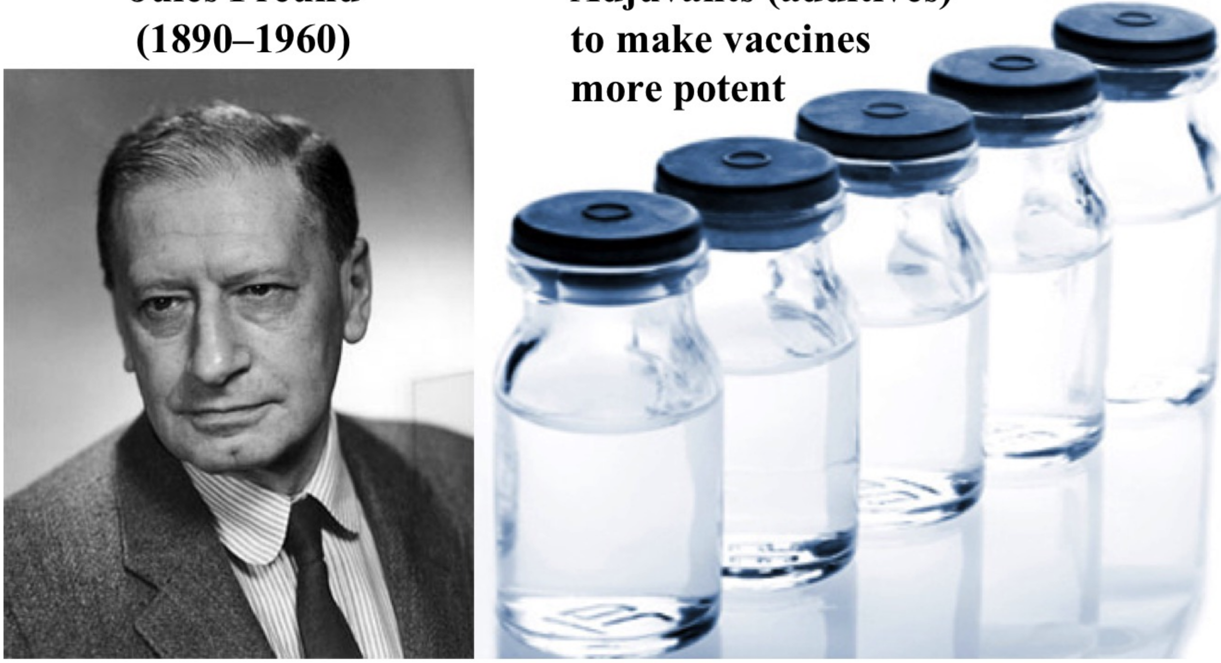
As already noted, German-speaking creators produced many of the first vaccines. (Louis Pasteur in Paris played an enormous role too of course.) Peter Plett developed and demonstrated the first cowpox-based vaccine for smallpox (p. 191). Otto Waldmann, Gottfried Pyl, and Carl Köbe created a vaccine for foot-and-mouth disease virus (p. 197). Poliovirus was discovered by Karl Landsteiner and Erwin Popper, and cultured in cells by Marguerite Vogt, which were essential steps to creating vaccines for polio (p. 201). Many other examples could be cited as well.

German-speaking creators also developed methods to make vaccines more effective, as shown in Fig. 2.102. Jules Freund (Hungarian, educated and worked in Austria and Germany, 1890–1960) introduced chemical adjuvants (additives) to make vaccines more potent. In 1957, Jean Lindemann (Swiss, 1924–2015) discovered (along with Alick Isaacs) interferon, a natural hormone that can provoke a strong immune system response.

Immunology

Jules Freund
(1890–1960)

Adjuvants (additives)
to make vaccines
more potent



Jean Lindenmann
(1924–2015)

Interferon to provoke a strong
immune system response (discovered 1957)

HUMAN LE
3 M
LC
LEUKOCYTE INT
3 MILLION I. U.
LOT P - 7923
E INTERFERON
I. U.
7923

Figure 2.102: Jules Freund developed adjuvants (additives) to make vaccines more potent. Jean Lindemann discovered that interferon could provoke a strong immune system response.

2.3 Neuroscience

German-speaking scientists largely dominated the early history of neuroscience, the study of how the brain, senses, nerves, and muscles work.[20] Neuroscience is a very large and diverse field; for convenience, it is divided into several (overlapping) subfields in this section:

2.3.1. Brain regions

2.3.2. Neurons

2.3.3. Neurotransmitters

2.3.4. Animal behavior

2.3.5. Circadian rhythms

2.3.6. Electroencephalography (EEG)

2.3.7. Neuropathology and neuropsychiatry

2.3.8. Psychology and psychotherapy

2.3.9. Analgesics and anesthetics

2.3.10. Vision

2.3.11. Hearing and balance

2.3.12. Touch

2.3.13. Taste

2.3.14. Smell

2.3.1 Brain Regions

Apart from the French physician Pierre Paul Broca (1824–1880), most of the scientists who worked to decipher which regions of the brain perform which functions came from the greater German-speaking world (Figs. 2.103–2.106).

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[20] Bielka 2002; Deichmann 1996; Dominguez-Lacasa 2005; Finger 1994; Gausemeier 2005; Gedeon 2006; Jahn 2004; Junker 2004; Koesling and Schülke 2010; Kohler 2008; Magner 2002; Pasternak 2004; Possehl 1989; Raviña and Kubinyi 2011; Schnalke and Atzl 2010; Schneider 1972; von Schwerin 2013; Simmons 2002; Roger Smith 1997; Sneader 2005; Weatherall 1991.

Franz Joseph Gall (German states, 1758–1828) and Johann Spurzheim (German states, 1776–1832) were two of the first scientists to systematically investigate the localization of brain functions.

Friederich Goltz (German, 1834–1902) used surgical methods to study the functions of regions of the cerebral cortex in dogs' brains.

Gustav Fritsch (German, 1838–1927) and Eduard Hitzig (German, 1838–1907) used electrical stimulation to investigate the functions of different areas of dogs' brains.

Hermann Munk (German, 1839–1912) studied the functions of different parts of the brains in dogs and monkeys.

Carl Wernicke (German, 1848–1905) identified the region of the human brain that is involved in comprehending language, now known as Wernicke's area.

Constantin von Monakow (Russian, studied and worked in Switzerland, 1853–1930) spent his career studying neuroanatomy and neural functions.

Jacques Loeb (German, 1859–1924) applied electrical stimulation to localized areas of dogs' brains and conducted experiments in other areas of biology. He moved to the United States and became a champion of improving science research there.

Korbinian Brodmann (German, 1868–1918) identified 52 distinct regions of the cerebral cortex, which are now called Brodmann areas. Brodmann studied the macroscopic and microscopic features of each area, as well as its functions.

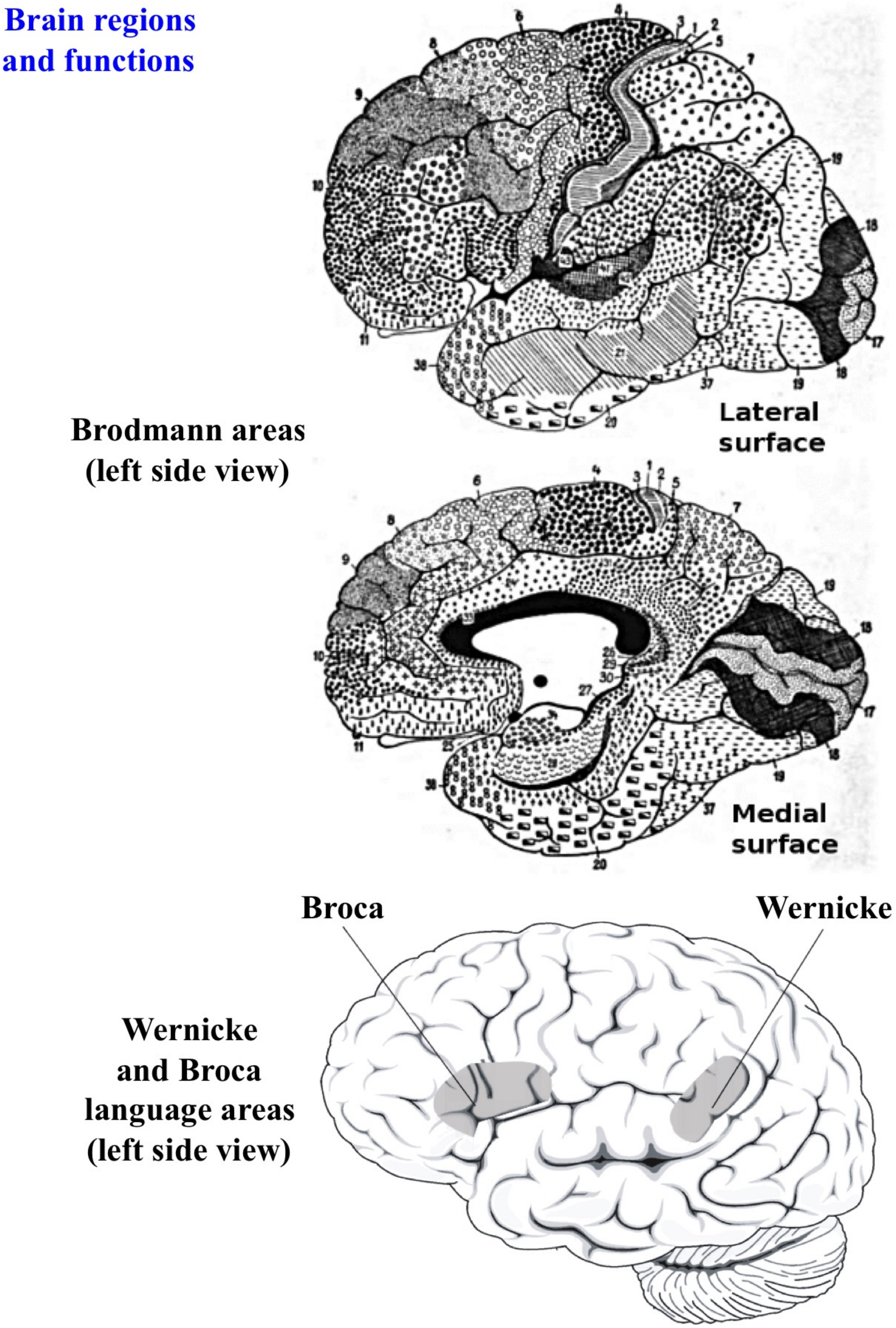
The spouses Oskar Vogt (German, 1870–1959) and Cécile Vogt-Mugnier (French but worked in Germany, 1875–1962) were pioneers in neuroanatomy and electrical stimulation of the brain. They were assisted by Max Borcherdt (German?, 18??–19??) and Louise Bosse (German?, 18??–19??), among others.

Walter Rudolf Hess (Swiss, 1881–1973) was another pioneer in using electrodes for mapping the locations and functions of brain regions. For that work, he won the Nobel Prize in Physiology or Medicine in 1949. Professor H. Olivecrona of the Royal Caroline Institute explained Hess's research [https://www.nobelprize.org/prizes/medicine/1949/ceremony-speech/]:

> Although we have long been aware of the function of the midbrain as a higher center of the autonomous nervous system, we have only now, through the research of Walter Rudolf Hess, had the localization of these functions mapped out in detail. Through the use of a refined and accurate technique he has succeeded in applying stimulation to or causing the destruction of very small areas, and thus he has been able to study the effect of the stimulus, as well as of the disappearance of a function. For his experiments he has used cats into which, under anesthesia, a thin metal wire has been introduced. The wire has been electrically insulated along its entire length except at the very end, which has been placed in the center of the brain area which is being studied. When the animal has regained consciousness and has recovered entirely from the effect of narcosis, it is possible to stimulate the area of the midbrain where the end of the needle is situated by

> conducting a weak electric current through the metal wire. There were various effects, depending upon the location of the needle-end, each effect always connected to one definite center of stimulation. By electrical stimulation of certain strictly limited parts of the midbrain it was possible to reproduce spontaneous autonomous functions. By stimulating one definite part, the animal was caused to curl up and go into a sleep from which it could be awakened just as easily as from natural sleep. Stimulation of other areas gave rise to defensive reactions which would normally occur if the cat were threatened by a dog: the hairs on the back stood up on end, the tail was ruffled, the cat spat and, if the stimulus was not discontinued, it attacked. Other localizations of the stimulus caused evacuation of the intestines or the bladder, accompanied by the characteristic body postures. From other areas, blood circulation and respiration could be influenced. It was common to all these experiments with stimuli that they released complex functions, not limited to the reactions characteristic of the autonomic nervous system, such as evacuation of the intestines, secretion of saliva, changes of the pupils, and the like, but were accompanied by reactions of the skeletal muscles necessary and appropriate to the autonomic function, such as characteristic body postures, attempts at escape or attack, and so forth. It was apparent from these facts that in the midbrain we have higher centers of autonomic functions which coordinate these with reactions of the skeletal musculature adapted to the individual functions. An ingenious method made possible the exact determination of the anatomic localization after the discontinuance of the experiment, and thus the anatomic substrata of complex autonomic functions could be mapped out. Through his research Hess has brilliantly answered a number of difficult questions regarding the localization of body functions in the brain.

Johannes Dusser de Barenne (Dutch, 1885–1940) injected strychnine into different regions of the cerebral cortex in order to determine their functions.


Brain regions
and functions
Brodmann areas
(left side view)
Lateral
surface
Medial
surface
Broca
Wernicke
Wernicke
and Broca
language areas
(left side view)
1
2
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4
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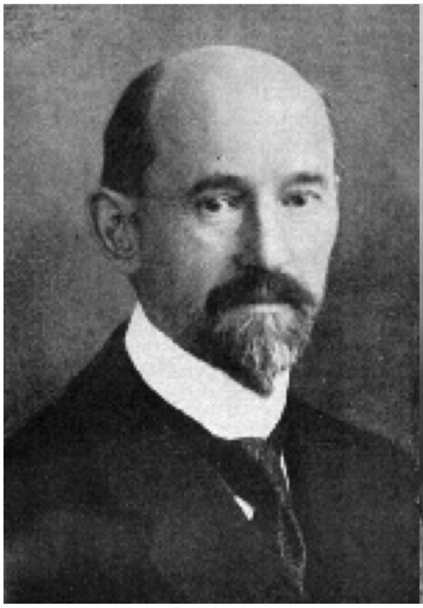
Figure 2.103: Creators from the German-speaking world made significant contributions to knowledge about the regional organization of the brain.

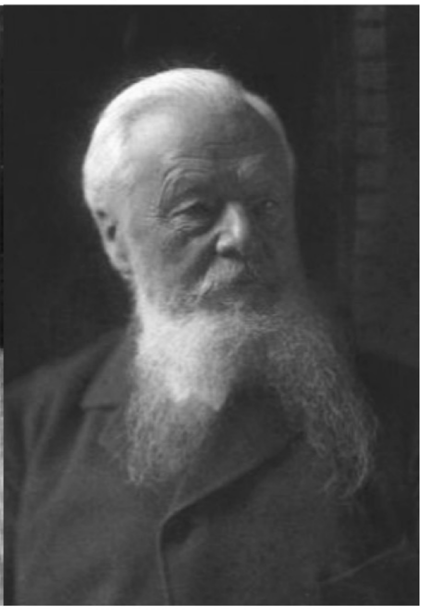
Brain regions and functions

Korbinian Brodmann (1868–1918)

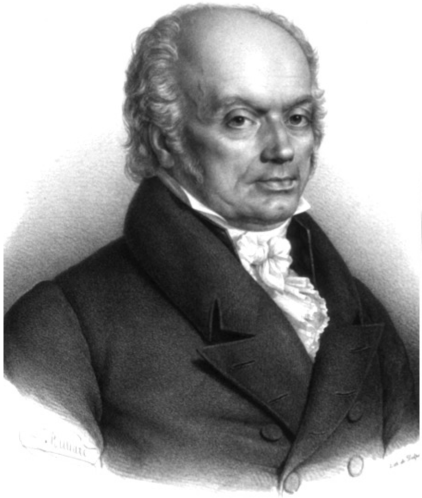


Johannes Dusser de Barenne (1885–1940)

Gustav Fritsch (1838–1927)



Franz Joseph Gall (1758–1828)



Friederich Goltz (1834–1902)

Walter Rudolf Hess (1881–1973)

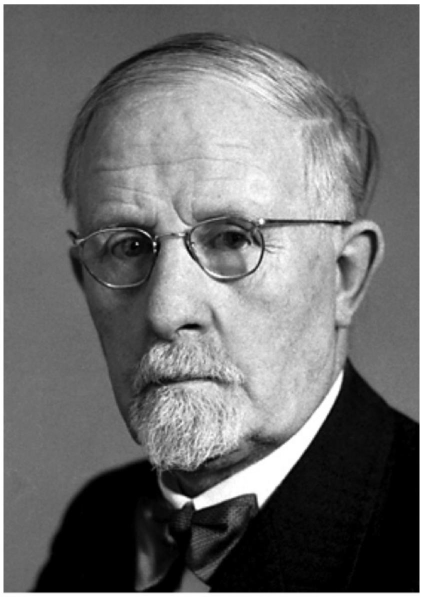


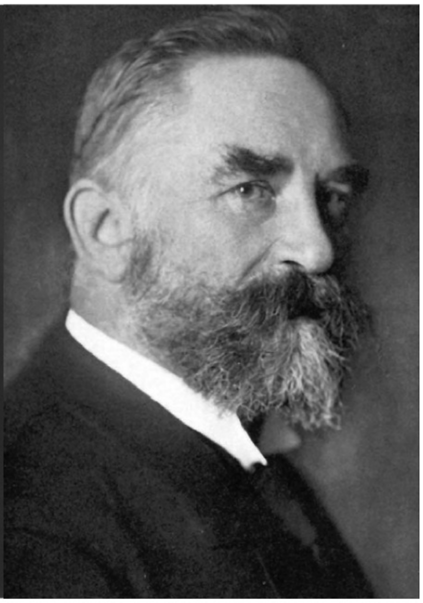
Figure 2.104: Creators who made significant contributions to knowledge about the regional organization of the brain included Korbinian Brodmann, Johannes Dusser de Barenne, Gustav Fritsch, Franz Joseph Gall, Friederich Goltz, and Walter Hess.

Brain regions and functions

Eduard Hitzig (1838–1907)

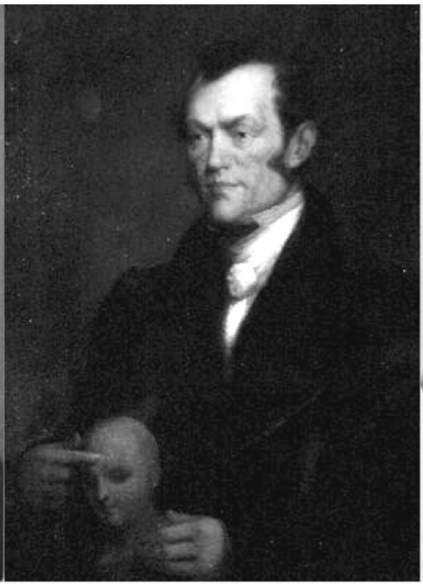
Jacques Loeb (1859–1924)

Constantin von Monakow (1853–1930)



Hermann Munk (1839–1912)

Johann Spurzheim (1776–1832)

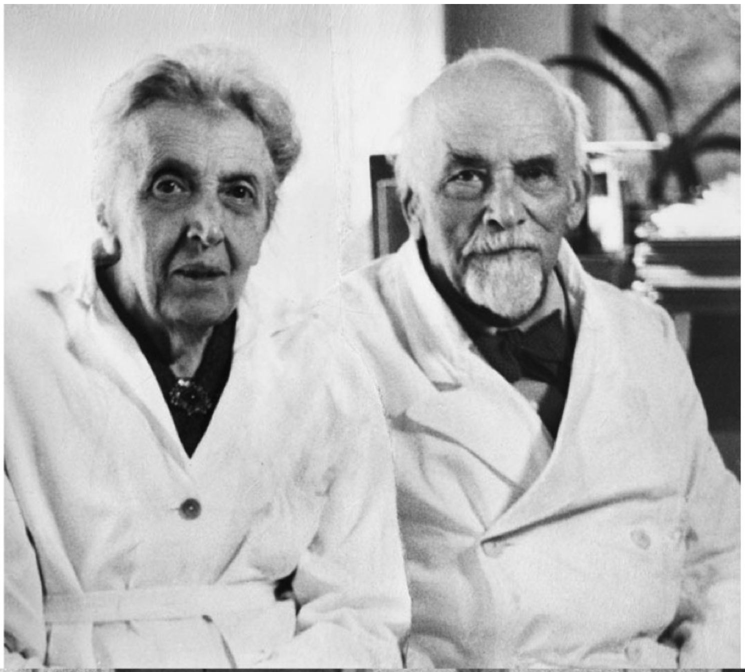


Carl Wernicke (1848–1905)

Figure 2.105: Other creators who made significant contributions to knowledge about the regional organization of the brain included Eduard Hitzig, Jacques Loeb, Constantin von Monakow, Hermann Munk, Johann Spurzheim, and Carl Wernicke.

Brain regions and functions

Cécile Vogt-Mugnier (1875–1962)



Oskar Vogt (1870–1959)

Berlin neuroscience laboratory (ca. 1903); from left: Korbinian Brodmann, Cécile Vogt-Mugnier, Oskar Vogt, Louise Bosse, Max Borcherdt, and Max Lewandowsky

Figure 2.106: Other creators who made significant contributions to knowledge about the regional organization of the brain included Cécile Vogt-Mugnier, Oskar Vogt, Max Borcherdt, Louise Bosse, and Max Lewandowsky.

2.3.2 Neurons

The brain is composed of cells, and the predominant types of brain cells are called neurons, as illustrated in Fig. 2.107. (There are also glial cells, which assist and care for the neurons, and also appear to play direct roles in thinking that are still not well understood.) Thought impulses or signals travel within a given neuron as an electrical signal, called an action potential. Signals are usually sent from one neuron to other neurons as chemical molecules or neurotransmitters that are released by one neuron and detected by its immediate neighbors.

Other than the extraordinarily farsighted and far-reaching work of the Spanish scientist Santiago Ramón y Cajal (1852–1934) and the staining methods of the Italian histologist Camillo Golgi (1843–1926), most of the early research on individual neurons occurred in the German-speaking world.

Johann Purkinje (Austrian/Czech, 1787–1869) discovered what are now called Purkinje cells in the cerebelllum. He also discovered what are now called Purkinje fibers that conducted electrical impulses in the heart.

Rudolf Wagner (German states, 1805–1864) studied neurons, neuroanatomy, and electric eels.

Rudolf von Kölliker (Swiss, 1817–1905) employed staining methods to study neuron pathways in the inner brain and the spinal cord.

Leopold Auerbach (German, 1828–1897) discovered what is now called Auerbach's plexus, a bundle of neurons linked to the gastrointestinal tract.

Heinrich Wilhelm von Waldeyer-Hartz (German, 1836–1921) conducted research on neurons and in fact coined the word "neuron" to describe individual brain cells.

Heinrich Lissauer (German, 1861–1891) discovered what is now called Lissauer's tract, neural fibers in the posterolateral tract of the spinal cord.

Ludwig Guttmann (German, 1899–1980) pioneered the treatment of spinal injuries.

Emil du Bois-Reymond (German, 1818–1896) discovered the action potential (the propagation of an electrical signal in a neuron) in 1843.

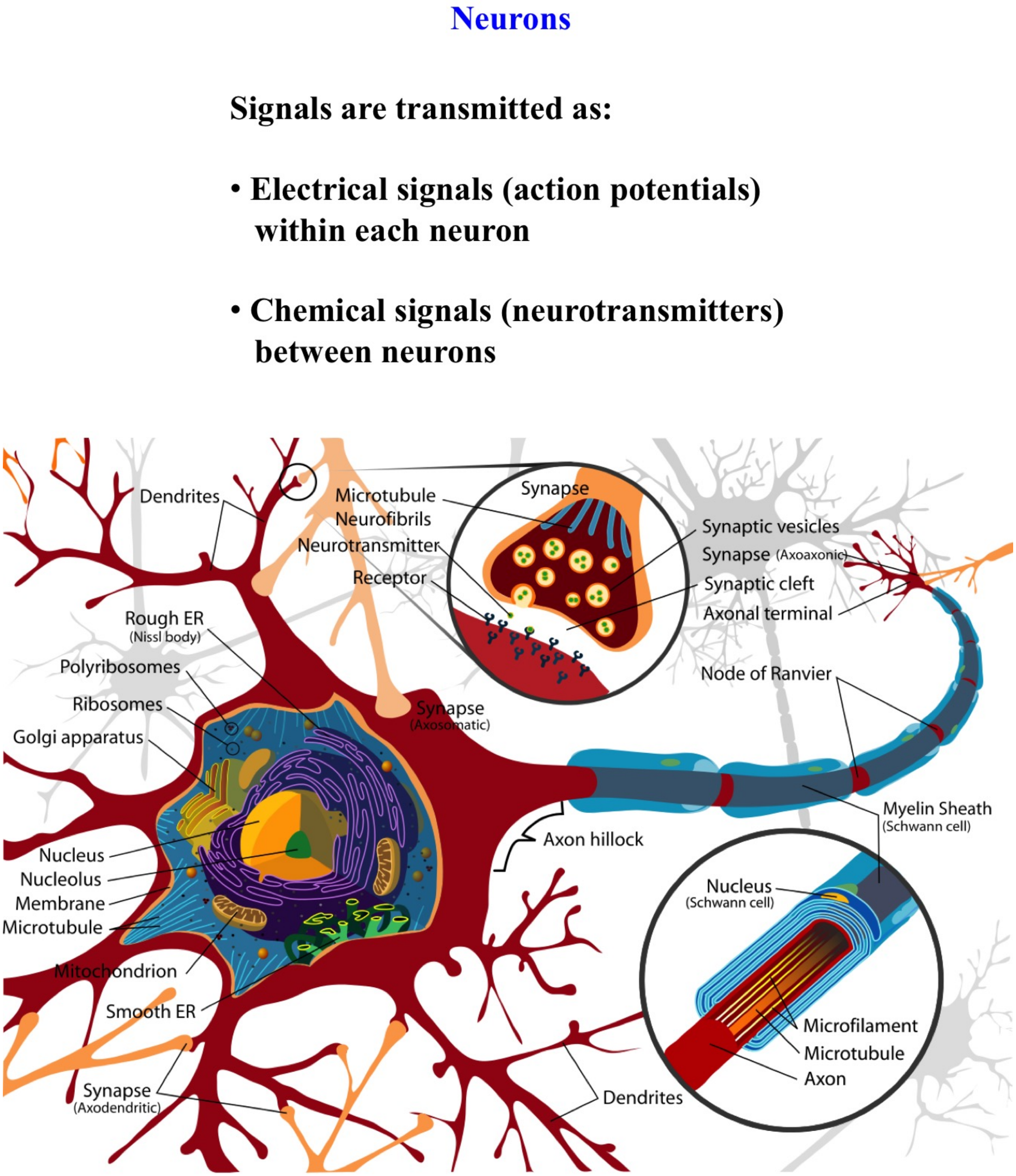
Hermann von Helmholtz (German, 1821–1894) measured the conduction velocity of action potentials in 1850.

In 1902, Julius Bernstein (German, 1839–1917) realized that the action potential involved calcium ions passing through the cellular membrane.

In 1949, Bernhard Katz (German, 1911–2003) also considered the effect of other types of ions on the action potential.

Bert Sakmann (German, 1942–) and Erwin Neher (German, 1944–) invented and used the patch clamp technique to measure the electrical current from individual ion channels in neurons and other cell types (Fig. 2.110). For that work, they won the Nobel Prize in Physiology or Medicine in 1991. Professor Sten Grillner of the Karolinska Institute explained their discoveries [https://www.nobelprize.org/prizes/medicine/1991/ceremony-speech/]:

> Ions are transported through ion channels, which can be specific to one type of ion like sodium or potassium. Every single ion channel consists of one protein molecule or a molecular complex, which forms the walls of a thin channel, connecting the interior of the cell with its exterior. The ion channel has such a small diameter that it corresponds to the width of only one single ion, and it is thus incredibly small. The ion channel is opened or closed as its molecule changes shape. When, for example, the ion channel molecule for sodium is opened, sodium ions in a long row will pass through the minute ion channel into the cell, because there are more sodium ions outside the cell than on the inside. Since ions are electrically charged, an electric current will also pass through the open ion channel. This year's Laureates, Erwin Neher and Bert Sakmann, succeeded in making a conclusive demonstration that ion channels exist, by developing a technique by which the miniscule currents, flowing through a single ion channel molecule, could be measured. These are currents of a thousandth of a billionth of an ampère. The technique is nevertheless, in principle very simple. A thin glass-tube filled with fluid is used as a recording electrode. The tip of the tube is pulled out to a width of only some thousandth of a millimeter. When it is brought in very close contact with the cell membrane, they form as it were, a chemical unity with each other. The ion channels, which are present in the cell membrane under the pipette opening, will then form the only connection between the interior of the cell and its outside. When one of the channels is opened a very small current will flow, which can be measured through the ingenious technique of Neher and Sakmann. We can thus measure exactly when a single ion channel is opened or closed, that is when a single molecule changes its shape. This is a totally unique level of resolution. This technique was combined with the new methods for biochemical microsurgery on single molecules, through which different parts of the ion channel molecules can be modified or exchanged. Through this procedure, it has been possible to elucidate the function of the different parts of the molecule, for instance, what makes an ion channel select only one type of ion, or be sensitive to a particular type of chemical transmitter. This technique has in one single blow changed our ability to study the different ion channels, which influence the life of every little cell. Thousands of laboratories throughout the entire world now use this technique to understand the roles ion channels may play in different tissues in animals or plants. Ion channels are, for instance, engaged when the cells in the pancreas secrete insulin, when the heart is contracting, or when we think or remember something. A number of diseases are either influenced or caused by a modified ion channel function. Many drugs act directly on the specific type of ion channel, which is of importance in a particular disease. Examples include anxiety, cardiovascular disease, epilepsy, and diabetes. Our life as a unique individual actually starts with an activation of the ion channels in the egg cell by the sperm at the instant of conception. This prevents other competing sperms from gaining access to the egg cell.



Neurons

Signals are transmitted as:

- **Electrical signals (action potentials) within each neuron**
- **Chemical signals (neurotransmitters) between neurons**

Dendrites
Microtubule
Neurofibrils
Neurotransmitter
Receptor
Synapse
Synaptic vesicles
Synapse (Axoaxonic)
Synaptic cleft
Axonal terminal
Rough ER
(Nissl body)
Polyribosomes
Ribosomes
Golgi apparatus
Synapse
(Axosomatic)
Node of Ranvier
Myelin Sheath
(Schwann cell)
Axon hillock
Nucleus
Nucleolus
Membrane
Microtubule
Nucleus
(Schwann cell)
Mitochondrion
Smooth ER
Microfilament
Microtubule
Axon
Synapse
(Axodendritic)
Dendrites

Figure 2.107: Structure of a typical neuron. Signals are transmitted as electrical signals (action potentials) within each neuron and chemical signals (neurotransmitters) between neurons.

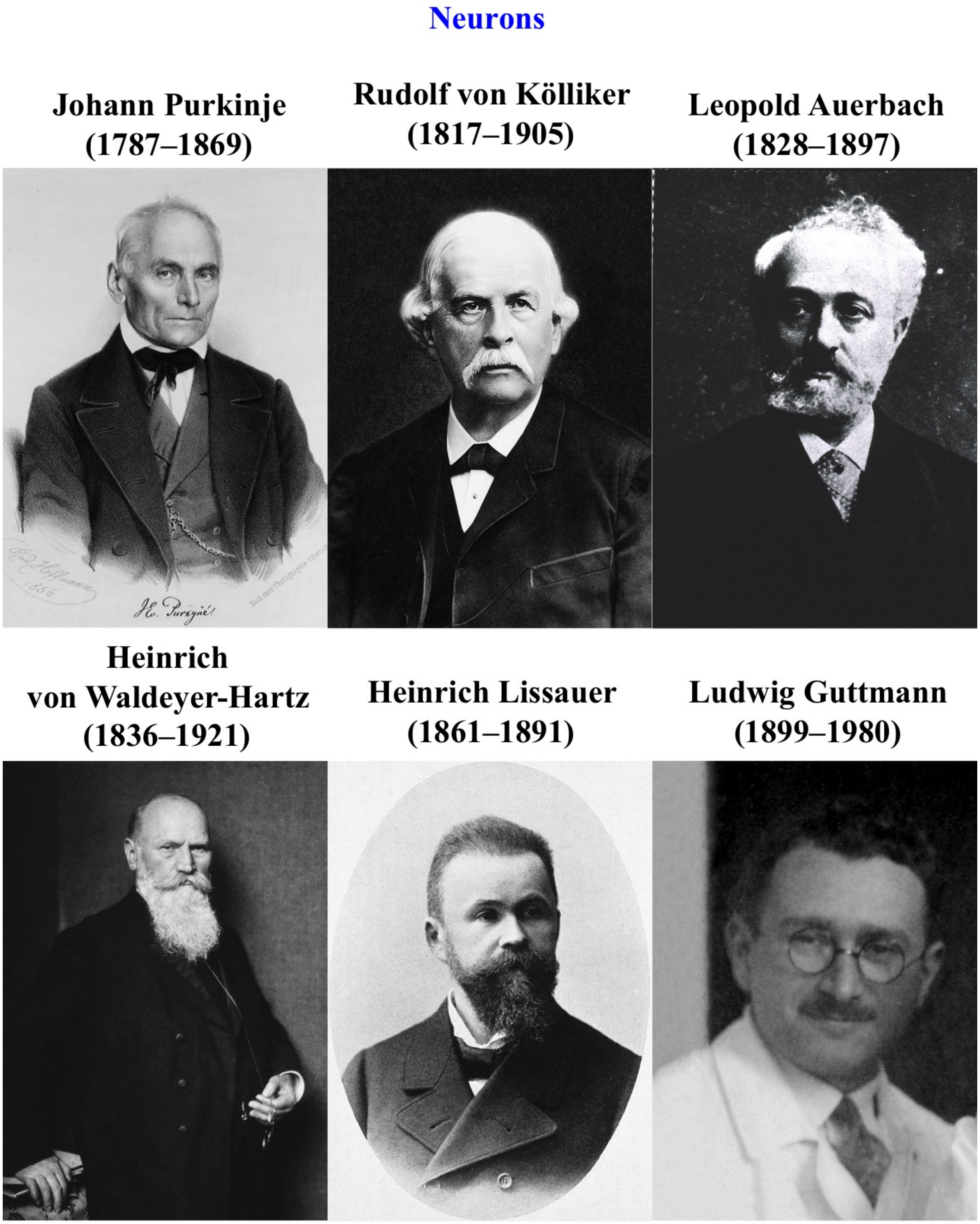

Neurons
Johann Purkinje (1787–1869)
Rudolf von Kölliker (1817–1905)
Leopold Auerbach (1828–1897)
Heinrich von Waldeyer-Hartz (1836–1921)
Heinrich Lissauer (1861–1891)
Ludwig Guttmann (1899–1980)

Figure 2.108: Scientists from the German-speaking world who made significant contributions to knowledge about neurons included Johann Purkinje, Rudolf von Kölliker, Leopold Auerbach, Heinrich von Waldeyer-Hartz, Heinrich Lissauer, and Ludwig Guttmann.

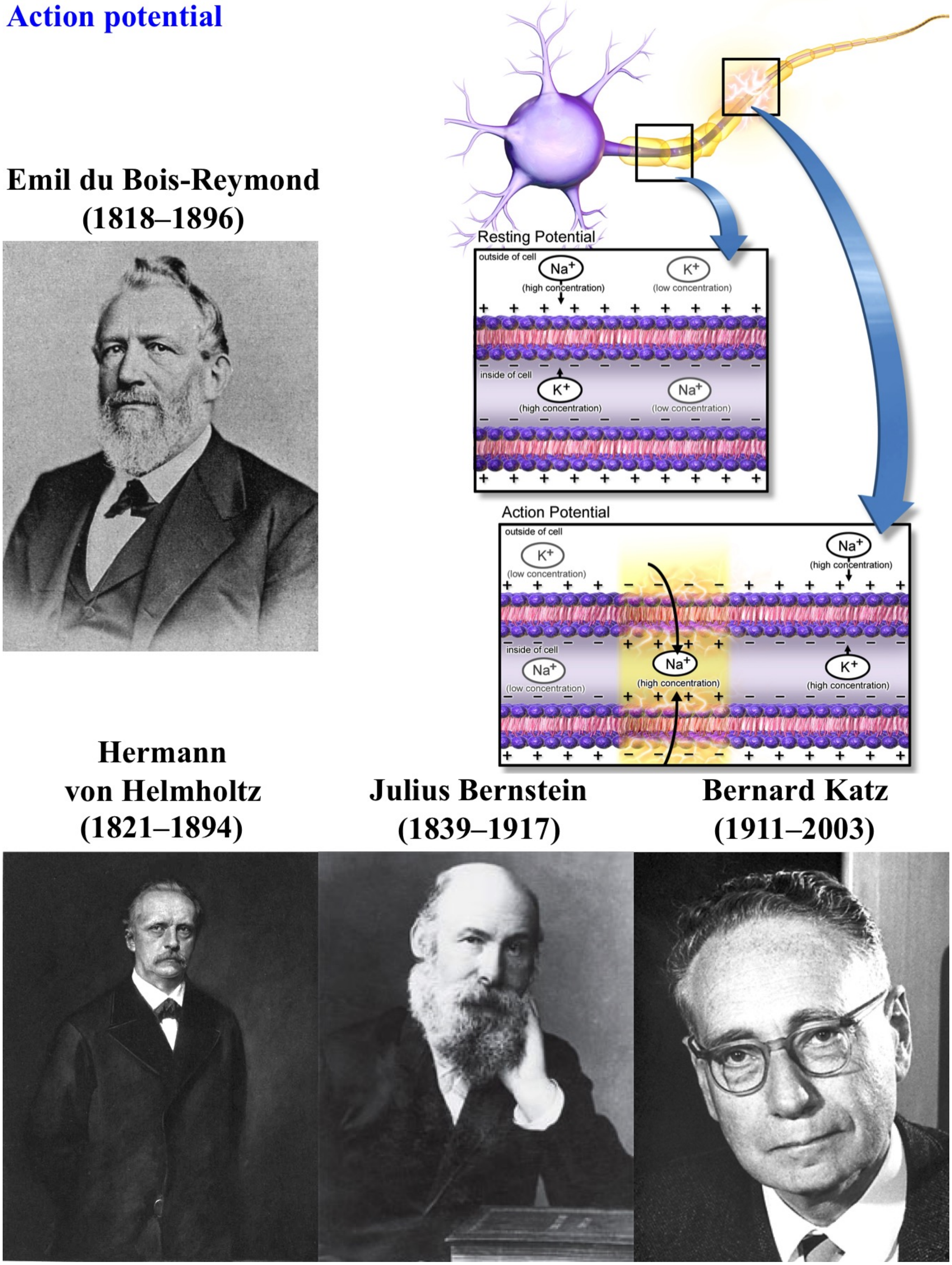
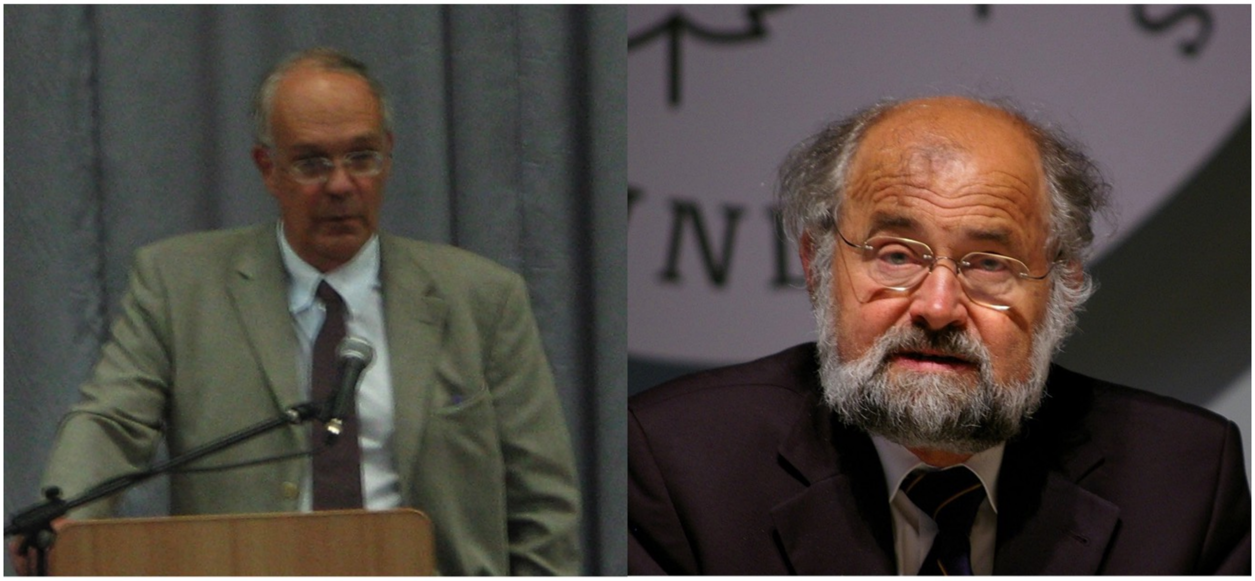

Action potential
Emil du Bois-Reymond
(1818–1896)
Resting Potential
outside of cell
Na+
(high concentration)
K+
(low concentration)
inside of cell
K+
(high concentration)
Na+
(low concentration)
Action Potential
outside of cell
K+
(low concentration)
Na+
(high concentration)
inside of cell
Na+
(low concentration)
Na+
(high concentration)
K+
(high concentration)
Hermann
von Helmholtz
(1821–1894)
Julius Bernstein
(1839–1917)
Bernard Katz
(1911–2003)

Figure 2.109: Scientists from the German-speaking world who made significant contributions to knowledge about electrical action potential signals within neurons included Emil du Bois-Reymond, Hermann von Helmholtz, Julius Bernstein, and Bernard Katz.



Bert Sakmann (1942–) **Erwin Neher (1944–)**

Patch clamp setup for measuring electrical current from individual ion channels in cells

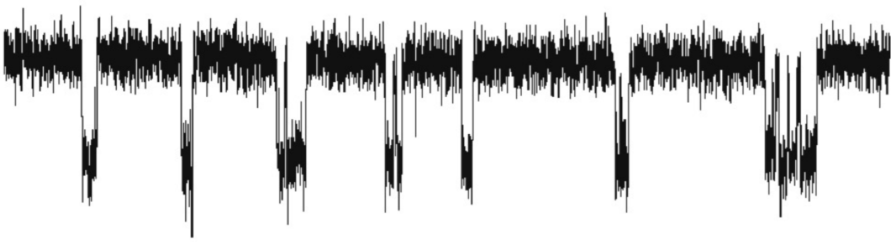


Figure 2.110: Bert Sakmann and Erwin Neher developed the patch clamp technique to measure the electrical current from individual ion channels in neurons and other cell types.

2.3.3 Neurotransmitters

As shown in Fig. 2.111, chemical molecules or neurotransmitters carry signals across the synapse (gap) between the end (axon) of one neuron and the beginning (dendrite) of the next neuron. Different types of neurons produce and respond to different types of neurotransmitters, such as acetylcholine, dopamine, histamine, and norepinephrine.

Scientists from the German-speaking world made many significant contributions to knowledge about neurotransmitters (Figs. 2.112–2.113).

Hermann Blaschko (German, 1900–1993) worked out the synthetic pathway for dopamine, norepinephrine, and epinephrine in 1939 (independently of Peter Holtz).

Daniel Bovet (Swiss, 1907–1992) discovered antihistamines, drugs that block histamine-mediated signals and that have been widely used since then to control allergic reactions. He won the Nobel Prize in Physiology or Medicine in 1957. Professor B. Uvnäs of the Royal Caroline Institute noted [https://www.nobelprize.org/prizes/medicine/1957/ceremony-speech/]:

> Daniel Bovet concentrated his research on the problem of pharmacologically blocking the amines mentioned above, and he succeeded in producing substances which specifically inhibited their effects.
>
> As early as 1937, Bovet and Staub succeeded in producing the first antihistamine, thymoxidiethylamine, capable of preventing anaphylactic shock in animals which, unneutralized, was fatal. This first histamine antagonist was, it is true, too toxic to be used clinically, but virtually every antihistamine that is used throughout the world today to oppose symptoms of allergy is derived from it. [...]
>
> For a number of years, Bovet and his co-workers studied in animals the relationships between chemical structure and biological effect, as could be observed in the alkaloids of curare and ergot. Proceeding by systematic variations and successive simplifications of chemical structure, work which involved the elaboration of new methods of biological testing and the production of hundreds of new synthetic chemical compounds, they succeeded, by degrees, in obtaining simple chemical compounds which proved themselves, from the point of view of specificity and the absence of undesirable side-effects, much more useful than naturally occurring substances.
>
> The interest which the appearance of products capable of paralysing muscle presents in practical medicine is bound to the evolution of modern surgery, which has made it possible to perform more and more complicated surgical procedures. Operations of this type often require complete muscular relaxation. Anaesthesia must therefore be deep and long, and for this reason it carries risks which can be more dangerous than the surgery itself. We owe to Bovet's research the general muscle relaxants which we use today. We can, in this way, use a light level of anaesthetic and reduce the hazards to which the patient is subjected. Sympatholytic compounds have not yet found any application in general medicine. The future will tell whether the hopes placed in them will be fulfilled and whether they will be of value in the treatment of hypertension and

> other vascular conditions for which we think a reduction in nervous control would be desirable.
>
> Apart from the importance of Bovet's work in experimental neuropharmacology, his observations have exerted a very stimulating influence in one rapidly growing branch of pharmacology: I speak of psychopharmacology. Biological amines are the transmitters of nerve impulses in the different tracts of the brain, just as they are the chemical agents which link nerve fibres to peripheral organs. In other words, it should be possible to find drugs which specifically affect brain function.

Edith Bülbring (German, 1903–1990) studied the effects of acetylcholine, epinephrine, and serotonin on muscles.

Wilhelm Feldberg (German, 1900–1993) conducted experiments involving histamine, acetylcholine, and other neurotransmitters.

Peter Holtz (German, 1902–1970) worked out the synthetic pathway for dopamine, norepinephrine, and epinephrine in 1939 (independently of Hermann Blaschko).

Bernhard Katz (German, 1911–2003) studied how acetylcholine is released from neurons at synapses. For his discoveries, he won the Nobel Prize in Physiology or Medicine in 1970. Professor Börje Uvnäs of the Nobel Committee for Physiology or Medicine explained Katz's research [https://www.nobelprize.org/prizes/medicine/1970/ceremony-speech/]:

> Bernhard Katz was specially interested in the electrical events which occur when impulses in motor nerves induce muscle activity by acting at motor end-plates. These special structures in the muscle with condenser-like properties are charged by the nerve impulses and their discharge in turn activates the muscle. Through the discovery of the existence of "miniature end-plate potentials" Katz demonstrated that the messenger substance between the motor nerve and the muscle end-plate, acetylcholine, was released from the nerve terminals in small quanta, small packages if you like.

Max Lewandowsky (German, 1876–1916) studied epinephrine and other neurotransmitters, and named the "blood-brain barrier" that only allows certain substances in the bloodstream to enter the brain.

Otto Loewi (German, 1873–1961) discovered the neurotransmitter acetylcholine. For that accomplishment, he won the Nobel Prize in Physiology or Medicine in 1936. Professor G. Liljestrand of the Royal Caroline Institute praised Loewi's research [https://www.nobelprize.org/prizes/medicine/1936/ceremony-speech/]:

> While the idea that nerve stimulation could be brought about by the release of certain substances was not entirely new, it is nevertheless thanks to Loewi that the idea was brought from the realm of unproven hypotheses on to the firm ground of certain experience. He first used a heart with its nerve trunk, removed from a frog or toad, connecting up the heart chamber with a small glass container in which was a small quantity of a suitable nutrient fluid. If the nerve trunk was stimulated by electrical means, the number and strength of heart beats altered according to circumstances there are, namely,

> in the nerve trunk fibres from both the sympathetic and the parasympathetic systems. If after such stimulation Loewi transferred the fluid which had been pumped in and out of the heart into another similarly prepared heart, he found that the fluid itself had taken on properties capable of producing changes in the activity of the organ corresponding to those which had earlier been produced by the nerve stimulation. Through this very simple but ingenious experiment it was proved that the nerve stimulus can release substances having the action characteristic for the nerve stimulation and further observations left no doubt whatever that the nerve stimulus itself was passed on to the organ by chemical means.
>
> Painstaking work now began with the object of determining the nature of the substances concerned—it was soon apparent that different substances were involved in the stimulation of the two different kinds of nerves. This task would appear hopeless considering the incredibly small quantities in which the substances are released. Chemical methods alone were of no avail. But Loewi carried out instead a model analysis, using those activities which were obtained in the living organism under changing conditions. With the sympathicus substance he was able to prove in this way that, in a series of important points such as destruction through oxidation and under the effects of certain kinds of irradiation, as well as in regard to its action, it corresponded absolutely with adrenaline. As regards the parasympathetic substance, the task was more difficult on account of its rapid breaking down in the presence of blood and tissue—this supports the contention made previously that the parasympathetic nerves act locally whereas the action of the sympathetic nerves is more widespread. Loewi and Navratil discovered that the breaking down could be prevented by the addition of the vegetable base physostigmine and this made it possible to work out a method which later made the detection of the substance very much easier. After considerable work, Loewi was able to determine the nature of this substance too, and to prove that the parasympathetic substance was identical with acetylcholine.

David Nachmansohn (German, 1899–1983) focused on acetylcholine, especially at junctions between neurons and muscles.

Marthe Vogt (German, 1903–2003) was appointed head of the chemical division of the Kaiser Wilhelm Institute for Brain Research when she was only 28 years old; she later fled the Third Reich and continued her work in the United Kingdom. During her long career, she studied epinephrine, acetylcholine, and other neurotransmitters.

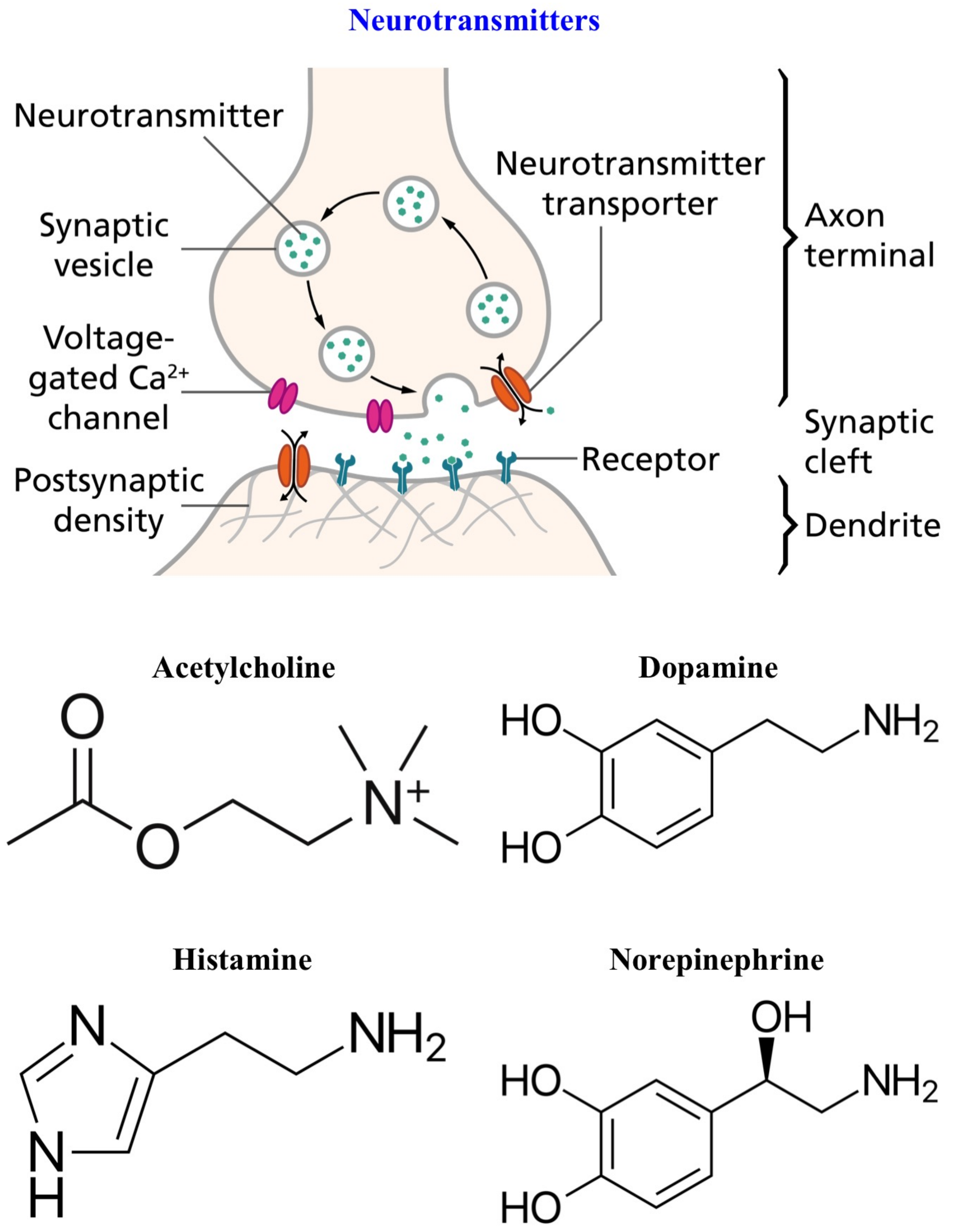

Neurotransmitters
Neurotransmitter
Synaptic vesicle
Voltage-gated Ca2+ channel
Postsynaptic density
Neurotransmitter transporter
Receptor
Axon terminal
Synaptic cleft
Dendrite
Acetylcholine
O
O
N+
Dopamine
HO
HO
NH2
Histamine
N
N
H
NH2
Norepinephrine
OH
HO
HO
NH2

Figure 2.111: Chemical molecules or neurotransmitters carry signals across the synapse (gap) between the end (axon) of one neuron and the beginning (dendrite) of the next neuron. Different types of neurons produce and respond to different types of neurotransmitters, such as acetylcholine, dopamine, histamine, and norepinephrine.

Neurotransmitters

Hermann Blaschko
(1900–1993)

Daniel Bovet
(1907–1992)

Edith Bülbring
(1903–1990)

Wilhelm Feldberg
(1900–1993)

Bernard Katz
(1911–2003)

Max Lewandowsky
(1876–1916)

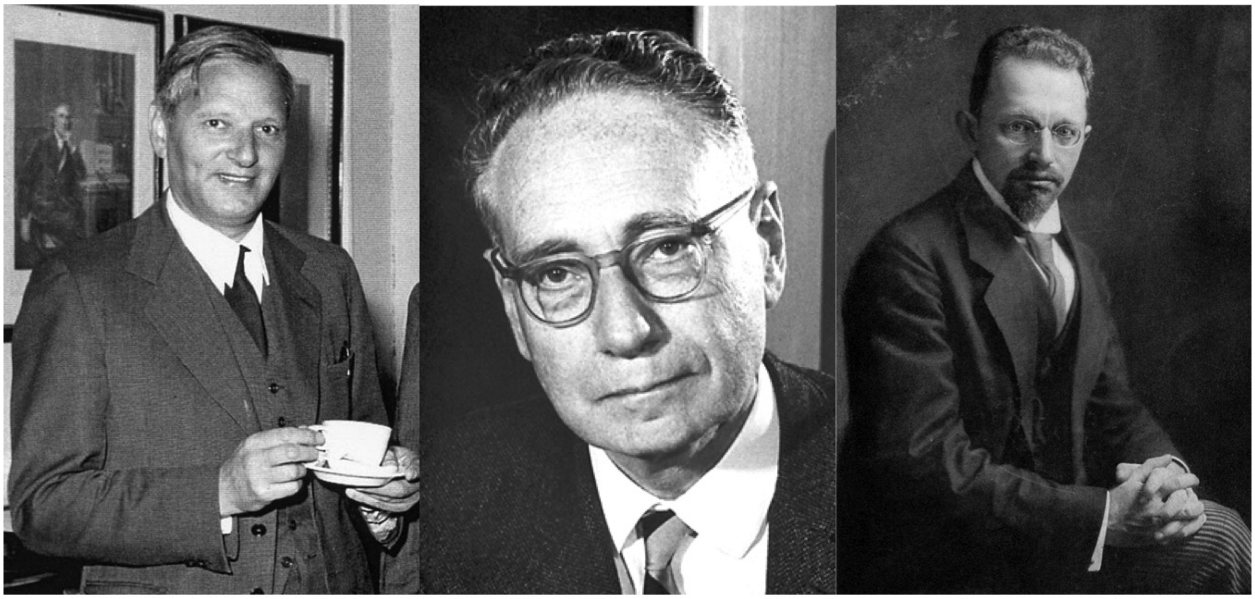


Figure 2.112: Scientists from the German-speaking world who made significant contributions to knowledge about neurotransmitters included Hermann Blaschko, Daniel Bovet, Edith Bülbring, Wilhelm Feldberg, Bernard Katz, and Max Lewandowsky.

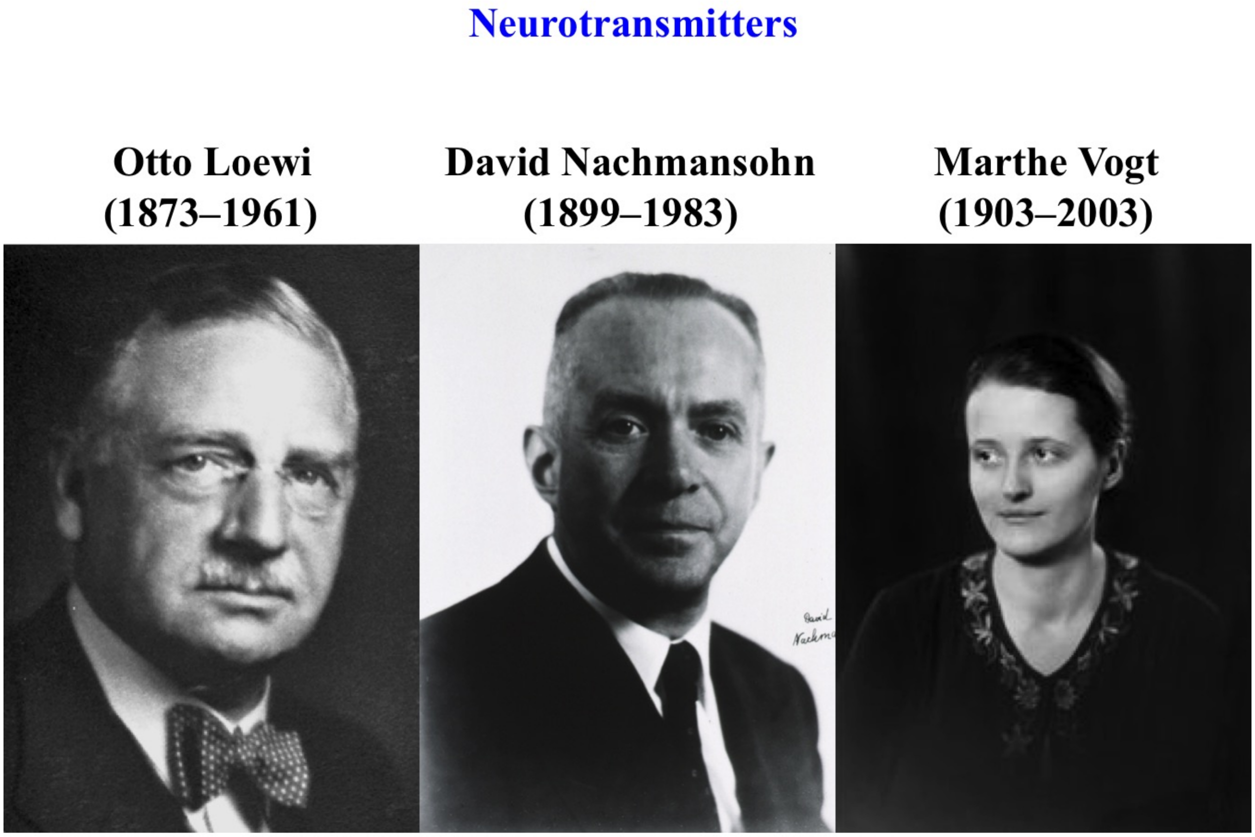

Neurotransmitters
Otto Loewi
(1873–1961)
David Nachmansohn
(1899–1983)
Marthe Vogt
(1903–2003)

Figure 2.113: Other scientists from the German-speaking world who made significant contributions to knowledge about neurotransmitters included Otto Loewi, David Nachmansohn, and Marthe Vogt.

2.3.4 Animal Behavior

Several scientists from the German-speaking world made especially noteworthy contributions to knowledge about animal behavior (Figs. 2.114–2.117):

- Carl Hagenbeck (German, 1844–1913) designed, patented, and built the first modern zoos, giving the animals much larger and much more realistic environments and separating visiting humans from the animals by height or unbridged gaps instead of bars or glass. He also spent a great deal of his time studying and training animals, and his more natural, modern zoos made animals available for others to study.

- Ernst Mayr (German, 1904–2005) spent decades studying bird behavior and bird evolution, as well as the more general principles of evolution.

- Karl von Frisch (Austrian, 1886–1982) studied the behavior of bees, for which he won the Nobel Prize in Physiology or Medicine in 1973.

- Erich von Holst (Baltic German, 1908–1962) studied the neuroscience and muscle movements of birds, flying insects, worms, and other animals.

- Konrad Lorenz (Austrian, 1903–1989) monitored and analyzed the behavior of birds. For that work, he won the Nobel Prize in Physiology or Medicine in 1973. Lorenz worked with Tinbergen for part of his research.

- Konrad Most (German, 18??–19??) developed systematic methods for training police and military dogs, and published them in his 1910 book, *Abrichtung des Hundes*, or *Training of Dogs* [Burch and Pickel 1990].

- Carl Spitz (German, 1894–1976), one of Konrad Most's students, moved to the United States, where he trained "Toto" (real name Terry) for *The Wizard of Oz*, as well as other dogs featured in films. Spitz also ran the U.S. program for training military dogs during World War II [http://akc.libraryhost.com/repositories/2/archival_objects/11098].

- Nikolaas Tinbergen (Dutch, 1907–1988) observed and tested the behavior of a wide variety of animals, including birds, fish, and bees. For his discoveries, he won the Nobel Prize in Physiology or Medicine in 1973. Tinbergen worked with Lorenz for part of his research.

Professor Börje Cronholm of the Karolinska Institute explained the importance of the work of von Frisch, Tinbergen, and Lorenz [https://www.nobelprize.org/prizes/medicine/1973/ceremony-speech/]:

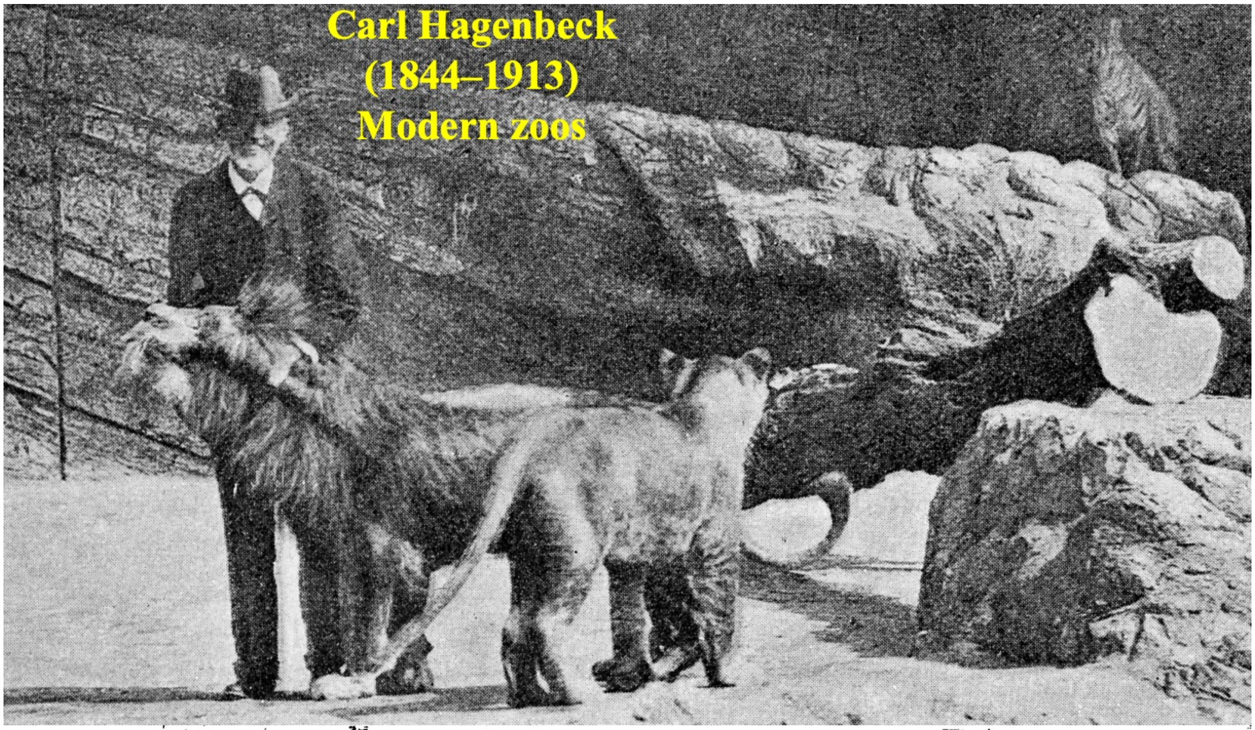
> For more than sixty years: Karl von Frisch has devoted himself to studies of the very complicated behavior of honeybees. Above all, he has elucidated what has rightly been called 'the language of bees'. When a bee has found flowers containing nectar, it performs a special dance when returning to the hive. The dance informs the bees in the hive of the existence of food, often also about the direction where the flowers will be found and about the distance to them. The foraging bee is able to indicate the direction of the

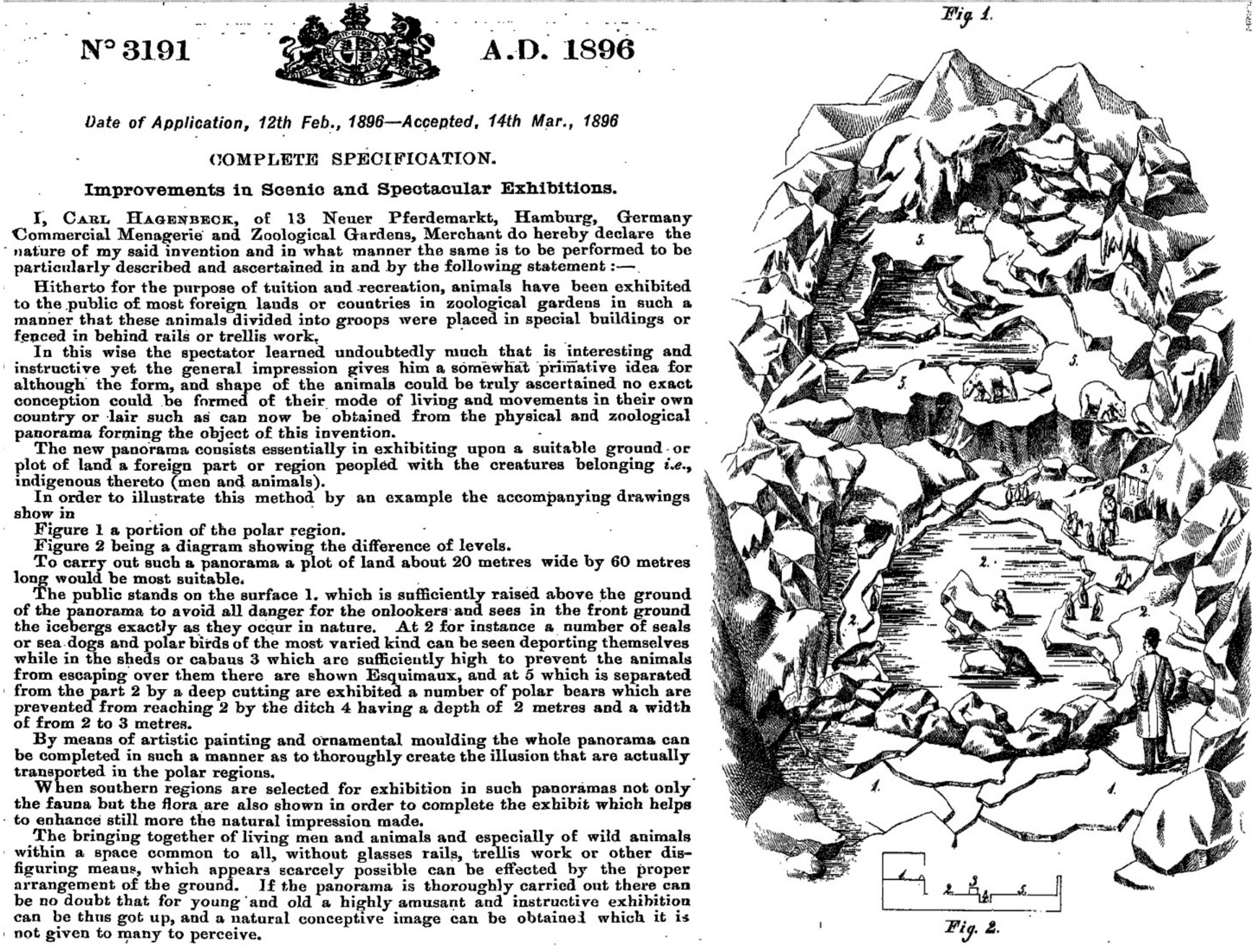
food source in relation to the sun by means of analyzing polarized, ultraviolet light from the sky, light that is invisible to us. The honeybees do not learn, either to dance or to understand the message of the dance. Both the dancing and the appropriate reactions to it are genetically programmed behavior patterns.

Konrad Lorenz has studied among many other things the fixed action patterns of various birds. His experiments with inexperienced animals, e.g. young birds from an incubator, are of great importance in this context. In these young birds he observed behavior patterns that could not reasonably have been learnt but were to be interpreted as being genetically programmed. He also found that experiences of young animals during a critical period could be decisive for their future development. Newborn ducks and geese follow the first moving object that they catch sight of, and later on they will follow those particular objects only. Normally, they will follow their mother, but they may be seduced to follow almost any moving object or creature. This phenomenon has been called 'imprinting'.

While Konrad Lorenz has above all been a systematic observer of animal behavior, Nikolaas Tinbergen has to a large extent tested various hypotheses by means of comprehensive, careful, and quite often ingenious experiments. Among other things, he has used dummies to measure the strength of different key stimuli as regards their ability to elicit corresponding fixed action patterns. He made the important observation that 'supranormal' stimuli eliciting more intense behavior than those of natural conditions, may be produced by exaggerating certain characteristics.

The discoveries made by this year's Nobel prize laureates were based on studies of insects, fishes and birds and might thus seem to be of only minor importance for human physiology or medicine. However, their discoveries have been a prerequisite for the comprehensive research that is now pursued also on mammals. Studies are devoted to the existence of genetically programmed behavior patterns, their organization, maturation and their elicitation by key stimuli. There are also studies concerning the importance of specific experiences during critical periods for the normal development of the individual. Research into the behavior of monkeys have demonstrated that serious and to a large extent lasting behavior disturbances may be the result when a baby grows up in isolation without contact with its mother and siblings or with adequate substitutes. Another important research field concerns the effects of abnormal psychosocial situations on the individual. They may lead not only to abnormal behavior but also to serious somatic illness such as arterial hypertension and myocardial infarction. One important conclusion is that the psychosocial situation of an individual cannot be too adverse to its biological equipment without serious consequences. This holds true for all species, also for that which in shameless vanity has baptized itself 'Homo sapiens'.





N° 3191 A.D. 1896

Date of Application, 12th Feb., 1896—Accepted, 14th Mar., 1896

COMPLETE SPECIFICATION.

Improvements in Scenic and Spectacular Exhibitions.

I, Carl Hagenbeck, of 13 Neuer Pferdemarkt, Hamburg, Germany Commercial Menagerie and Zoological Gardens, Merchant do hereby declare the nature of my said invention and in what manner the same is to be performed to be particularly described and ascertained in and by the following statement :—

Hitherto for the purpose of tuition and recreation, animals have been exhibited to the public of most foreign lands or countries in zoological gardens in such a manner that these animals divided into groops were placed in special buildings or fenced in behind rails or trellis work.

In this wise the spectator learned undoubtedly much that is interesting and instructive yet the general impression gives him a somewhat primative idea for although the form, and shape of the animals could be truly ascertained no exact conception could be formed of their mode of living and movements in their own country or lair such as can now be obtained from the physical and zoological panorama forming the object of this invention.

The new panorama consists essentially in exhibiting upon a suitable ground or plot of land a foreign part or region peopled with the creatures belonging *i.e.*, indigenous thereto (men and animals).

In order to illustrate this method by an example the accompanying drawings show in

Figure 1 a portion of the polar region.

Figure 2 being a diagram showing the difference of levels.

To carry out such a panorama a plot of land about 20 metres wide by 60 metres long would be most suitable.

The public stands on the surface 1. which is sufficiently raised above the ground of the panorama to avoid all danger for the onlookers and sees in the front ground the icebergs exactly as they occur in nature. At 2 for instance a number of seals or sea dogs and polar birds of the most varied kind can be seen deporting themselves while in the sheds or cabaus 3 which are sufficiently high to prevent the animals from escaping over them there are shown Esquimaux, and at 5 which is separated from the part 2 by a deep cutting are exhibited a number of polar bears which are prevented from reaching 2 by the ditch 4 having a depth of 2 metres and a width of from 2 to 3 metres.

By means of artistic painting and ornamental moulding the whole panorama can be completed in such a manner as to thoroughly create the illusion that are actually transported in the polar regions.

When southern regions are selected for exhibition in such panoramas not only the fauna but the flora are also shown in order to complete the exhibit which helps to enhance still more the natural impression made.

The bringing together of living men and animals and especially of wild animals within a space common to all, without glasses rails, trellis work or other disfiguring means, which appears scarcely possible can be effected by the proper arrangement of the ground. If the panorama is thoroughly carried out there can be no doubt that for young and old a highly amusant and instructive exhibition can be thus got up, and a natural conceptive image can be obtained which it is not given to many to perceive.

Figure 2.114: Carl Hagenbeck designed, patented, and built the first modern zoos, giving the animals much larger and much more realistic environments and separating visiting humans from the animals by height or unbridged gaps instead of bars or glass.

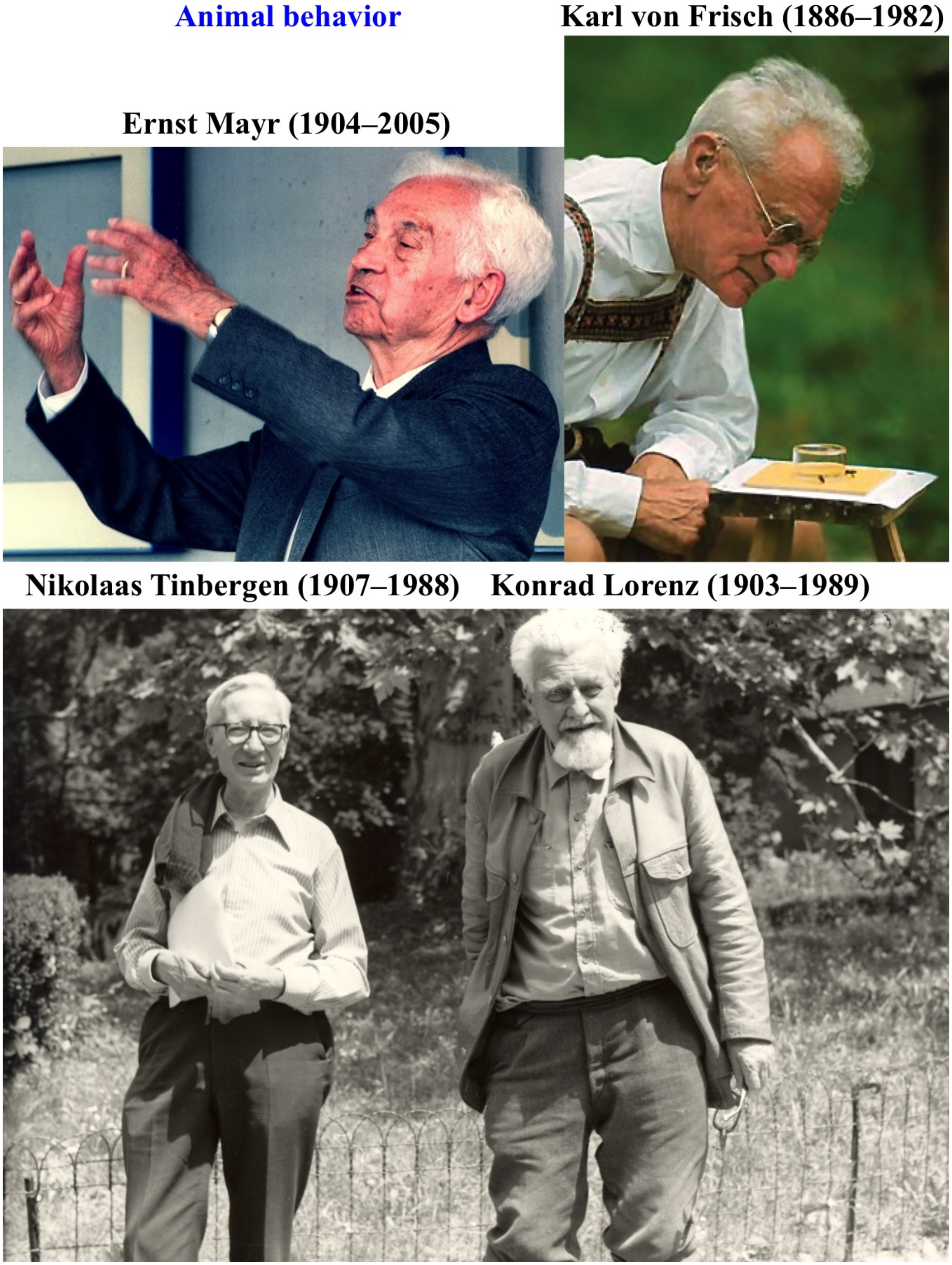

Animal behavior
Karl von Frisch (1886–1982)
Ernst Mayr (1904–2005)
Nikolaas Tinbergen (1907–1988)
Konrad Lorenz (1903–1989)

Figure 2.115: Some scientists from the German-speaking world who made significant contributions to knowledge about animal behavior included Ernst Mayr, Karl von Frisch, Nikolaas Tinbergen, and Konrad Lorenz.

Erich von Holst (1908–1962) studied the neuroscience and muscle movements of birds, flying insects, worms, and other animals

Figure 2.116: Erich von Holst studied the neuroscience and muscle movements of birds, flying insects, worms, and other animals.

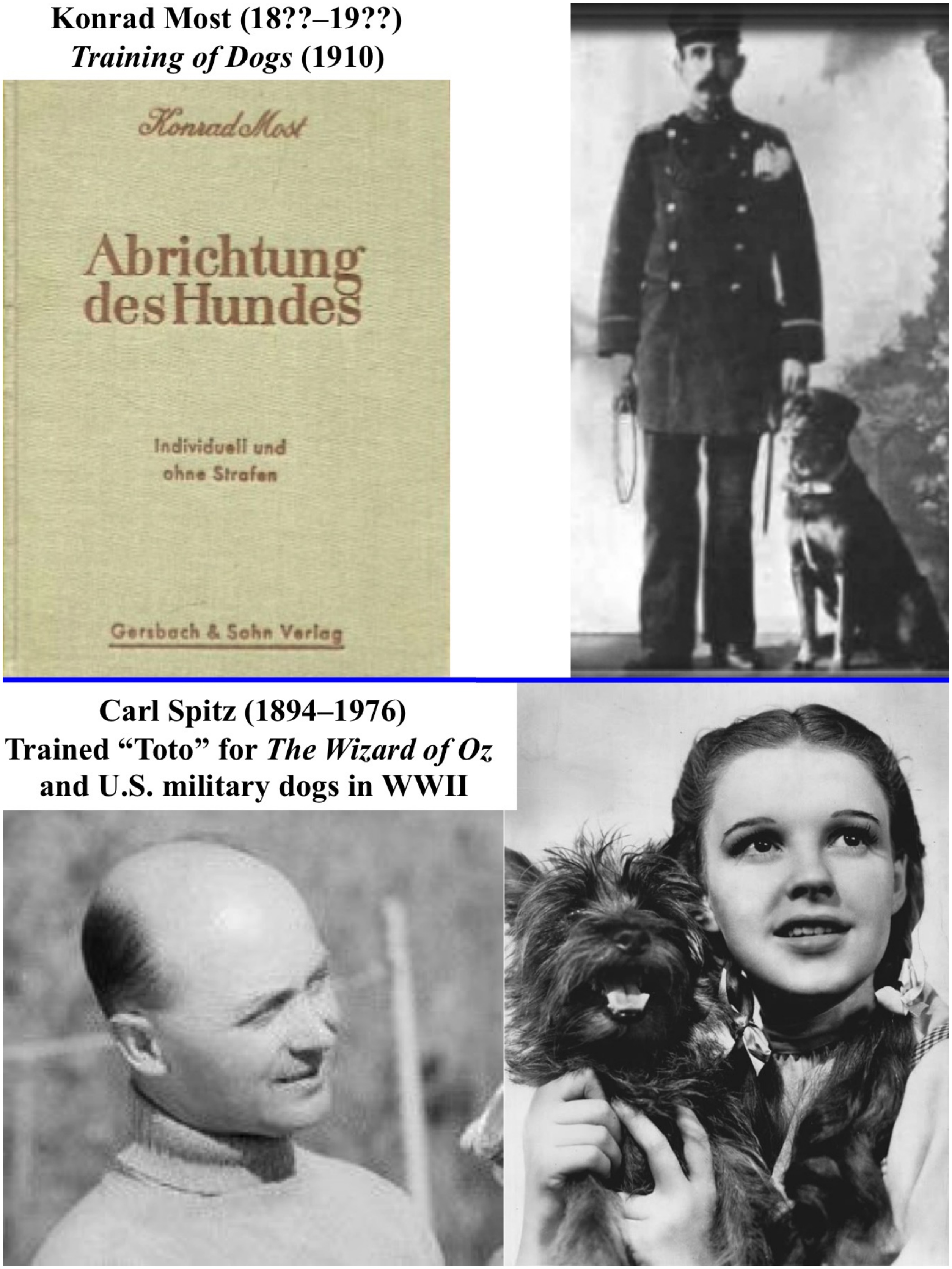

Konrad Most (18??–19??)
Training of Dogs (1910)
Konrad Most
Abrichtung des Hundes
Individuell und ohne Strafen
Gersbach & Sohn Verlag
Carl Spitz (1894–1976)
Trained "Toto" for The Wizard of Oz and U.S. military dogs in WWII

Figure 2.117: Konrad Most developed systematic methods for training police and military dogs, and published them in his 1910 book, *Training of Dogs*. Carl Spitz, one of Most's students, moved to the United States, where he trained the dog that appeared as "Toto" for *The Wizard of Oz* and U.S. military dogs during World War II.

2.3.5 Circadian Rhythms

Scientists from the German-speaking world discovered and studied circadian rhythms, neural clocks that tell an organism what time of day to be awake, even in the absence of a visible day and night (Fig. 2.118):

- Jürgen Aschoff (German, 1913–1998) studied circadian rhythms in a wide variety of species, including humans.
- Ingeborg Beling (German, 1904–1988) discovered circadian rhythms in bees.
- Erwin Bünning (German, 1906–1990), working with Hans Kalmus, discovered circadian rhythms in fruit flies in 1935.
- Auguste Forel (Swiss, 1848–1931) discovered circadian rhythms in ants.
- Franz Halberg (Romanian/Austrian, 1919–2013) coined the term "circadian" in 1959 and studied circadian rhythms in multiple species.
- Hans Kalmus (Austrian, 1906–1988), working with Erwin Bünning, discovered circadian rhythms in fruit flies in 1935.
- Oskar Wahl (German?, 19??–19??) discovered circadian rhythms in bees.

2.3.6 Electroencephalography (EEG)

As shown in Figs. 2.119–2.120, scientists from the greater German-speaking world developed electroencephalography (EEG):

- Hans Berger (German, 1873–1941) invented electroencephalography.
- Napoleon Cybulski (Polish, 1854–1919) and Adolf Beck (Polish/Austrian, 1863–1942) also carried out early experiments in electroencephalography.
- Hans Helmut Kornhuber (1928–2009) and Lüder Deecke (1938–) discovered the Bereitschaftspotential (readiness potential) using electroencephalography.

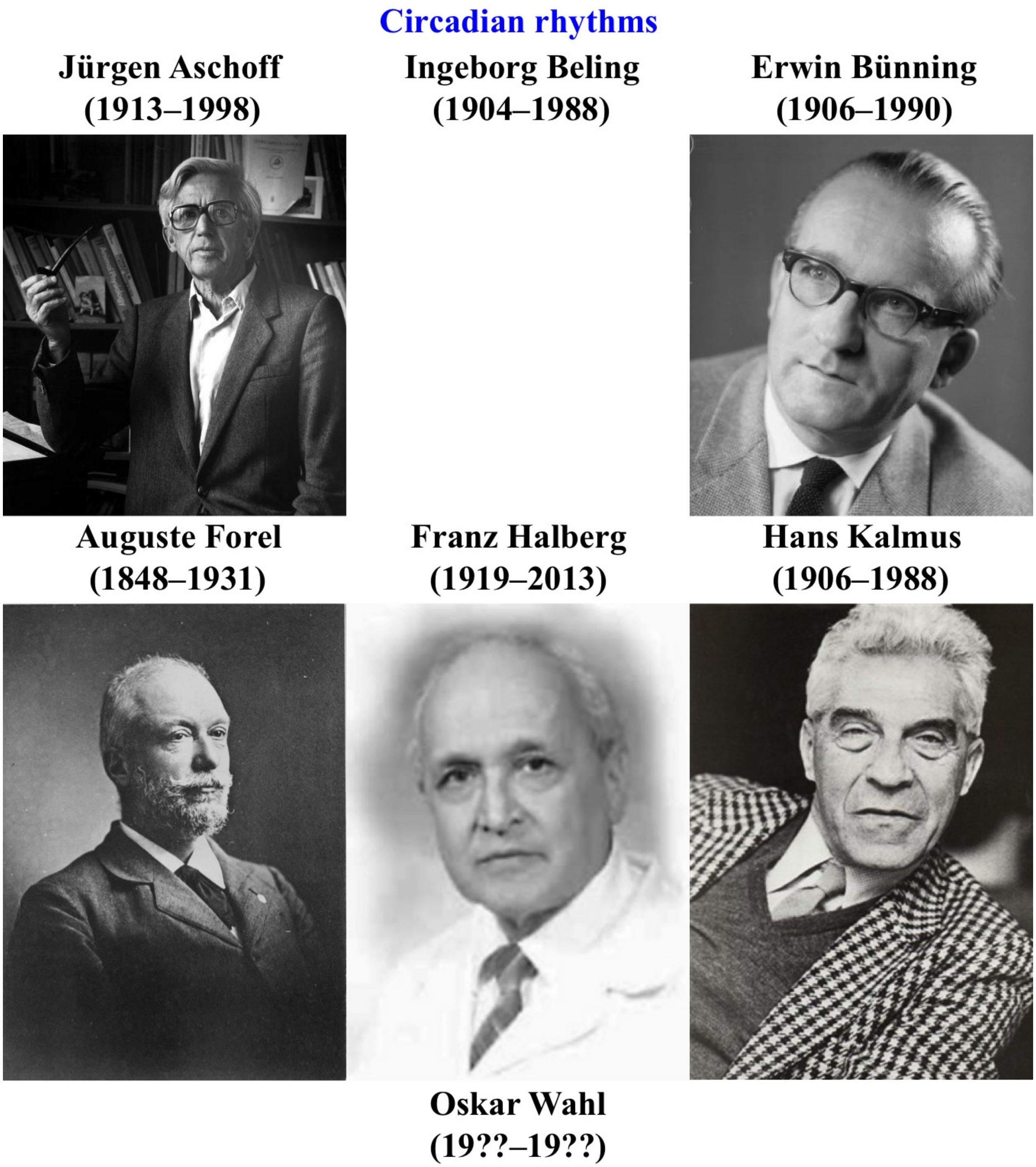

Circadian rhythms
Jürgen Aschoff
(1913–1998)
Ingeborg Beling
(1904–1988)
Erwin Bünning
(1906–1990)
Auguste Forel
(1848–1931)
Franz Halberg
(1919–2013)
Hans Kalmus
(1906–1988)
Oskar Wahl
(19??–19??)

Figure 2.118: Scientists from the German-speaking world who made significant contributions to knowledge about circadian rhythms included Jürgen Aschoff, Ingeborg Beling, Erwin Bünning, Auguste Forel, Franz Halberg, Hans Kalmus, and Oskar Wahl.

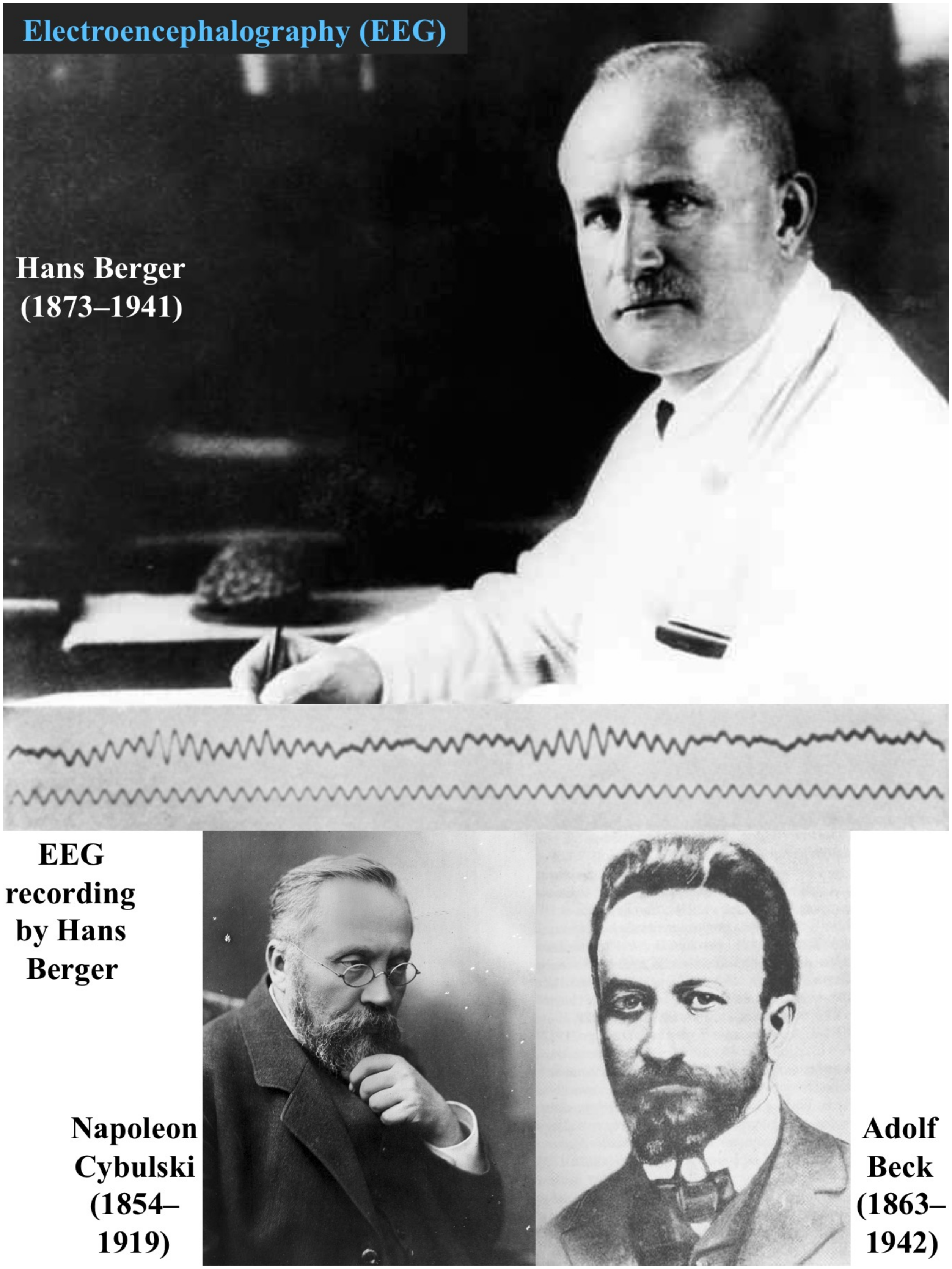

Electroencephalography (EEG)
Hans Berger (1873–1941)
EEG recording by Hans Berger
Napoleon Cybulski (1854–1919)
Adolf Beck (1863–1942)

Figure 2.119: Scientists from the German-speaking world who helped to develop electroencephalography (EEG) included Hans Berger, Napoleon Cybulski, and Adolf Beck.

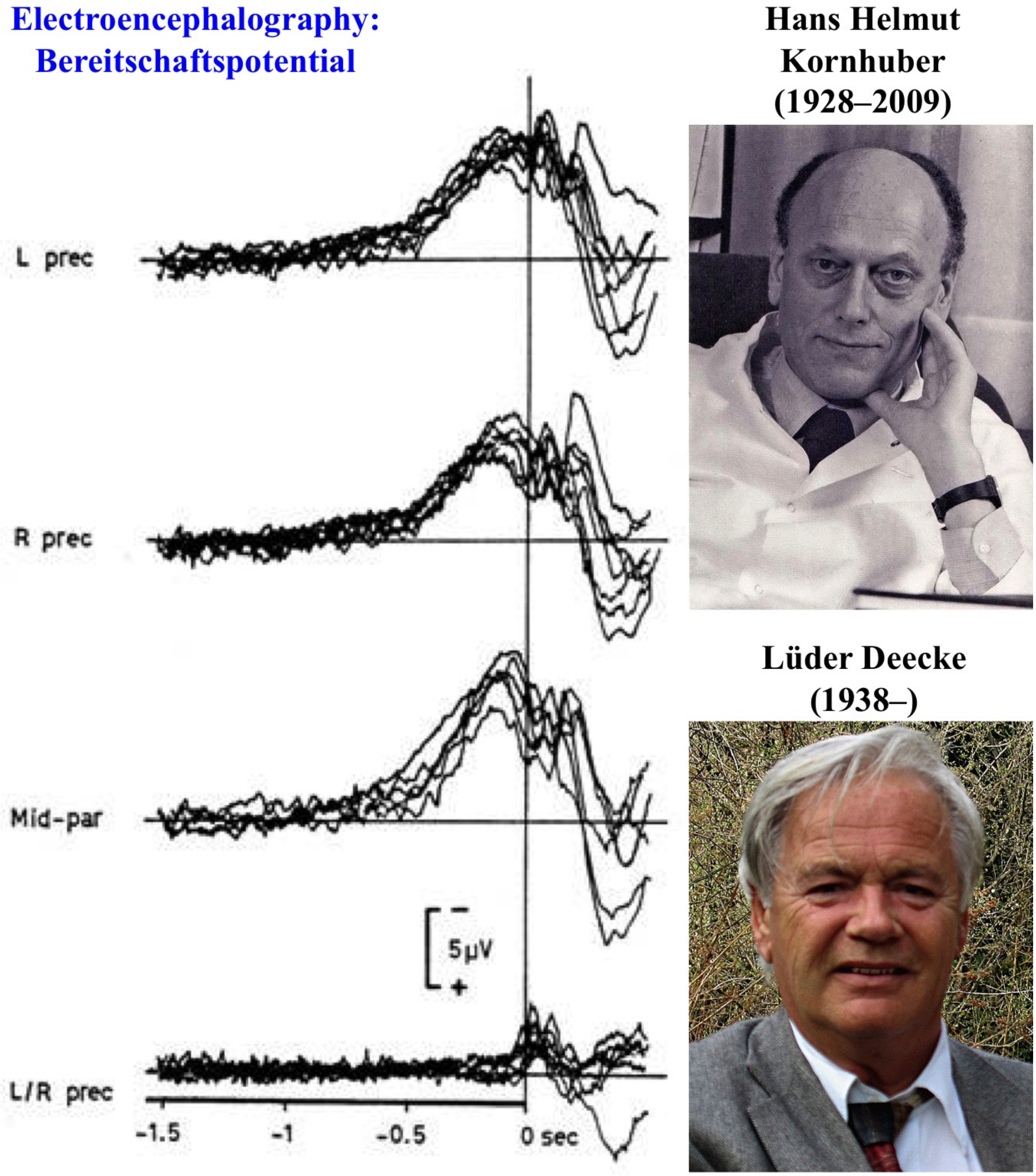


Figure 2.120: Hans Helmut Kornhuber and Lüder Deecke discovered the Bereitschaftspotential (readiness potential) using electroencephalography.

2.3.7 Neuropathology and Neuropsychiatry

Creators from the German-speaking world made numerous and profound contributions to neuropathology and neuropsychiatry, including the discovery and diagnosis of dyslexia, autism and Asperger's syndrome, Alzheimer's disease, and other aspects (Figs. 2.121–2.123).

A. Dyslexia

The physician Adolf Kussmaul (German, 1822–1902) discovered dyslexia in 1877; he called it Wortblindheit, or word-blindness. He also demonstrated the anti-inflammatory effects of acetanilide (p. 269) and made numerous other medical discoveries (p. 401).

Apparently quite independently, another physician, Oswald Berkhan (German, 1834–1917), (re)discovered dyslexia in 1881.

Rudolf Berlin (German, 1833–1897), an ophthalmologist, coined the name dyslexia in 1887 and studied patients with the condition.

B. Autism and Asperger's syndrome

Eugen Bleuler (Swiss, 1857–1939) was a psychiatrist who studied a wide range of conditions and coined the terms schizophrenia (1908) and autism (1910). He defined autism in terms of apparent psychological withdrawal from the world.

Leo Kanner (Austrian, 1894–1981) was a psychiatrist and physician who studied and worked in Germany, then moved to the United States in the 1920s. In 1938, he began studying autistic children, and he published a detailed report on childhood autism in 1943.

Hans Asperger (Austrian, 1906–1980), a pediatric physician, diagnosed and extensively studied Asperger's syndrome and autism beginning in the 1930s. He published numerous papers on the subject from 1938 onward. Kanner and Asperger appear to have worked entirely independently; it is unclear whether one influenced the other.

C. Alzheimer's disease

Alzheimer's disease, which kills neurons and leaves protein plaques in the cerebral cortex (Fig. 2.122), was first identified in 1901 by observations of a patient with an early-onset form of the disease: Auguste Deter (German, 1850–1906).

The psychiatrists Alois Alzheimer (German, 1864–1915, after whom the disease is named) and Emil Kraepelin (German, 1856–1926) studied Deter while she was alive and discovered the protein plaques in her brain after she died.

Alzheimer also studied other dementia patients, and Kraepelin separately made important discoveries regarding manic depression and schizophrenia.

D. Other discoveries in neuropathology and neuropsychiatry

Wilhelm Erb (German, 1840–1921) made innovative discoveries related to a number of areas of neuropathology, including myasthenia gravis, progressive muscular atrophy, spinal paralysis, the effects of polio, the effects of syphilis, electrodiagnostics, and electrotherapeutics.

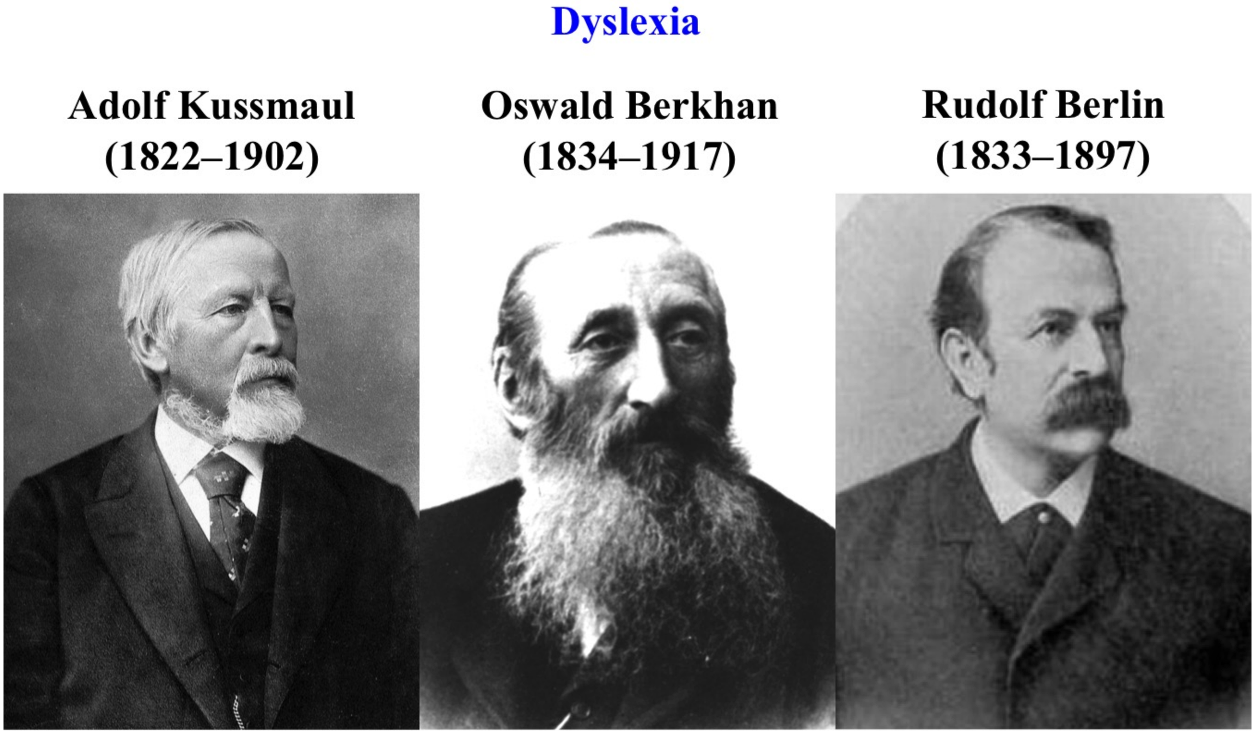
Edward Flatau (Polish, worked in Germany, 1868–1932) studied meningitis, migraines, and other types of neuropathologies.

Nikolaus Friedreich (German, 1825–1882) identified Friedreich's ataxia, an inherited neurodegenerative disease, in 1863.

Franz Josef Kallmann (German, 1897–1965) studied the effects of heredity vs. environment in the pathogenesis of neural diseases.

Richard Lindenberg (German, 1911–1992) was an expert on neuropathology, came to the United States as part of Operation Paperclip, and was called upon to examine the bullet wound in John F. Kennedy's head after his assassination.

Franz Nissl (German, 1860–1919) developed the Nissl staining method for labeling neurons on microscope slides in order to identify neuropathologies.



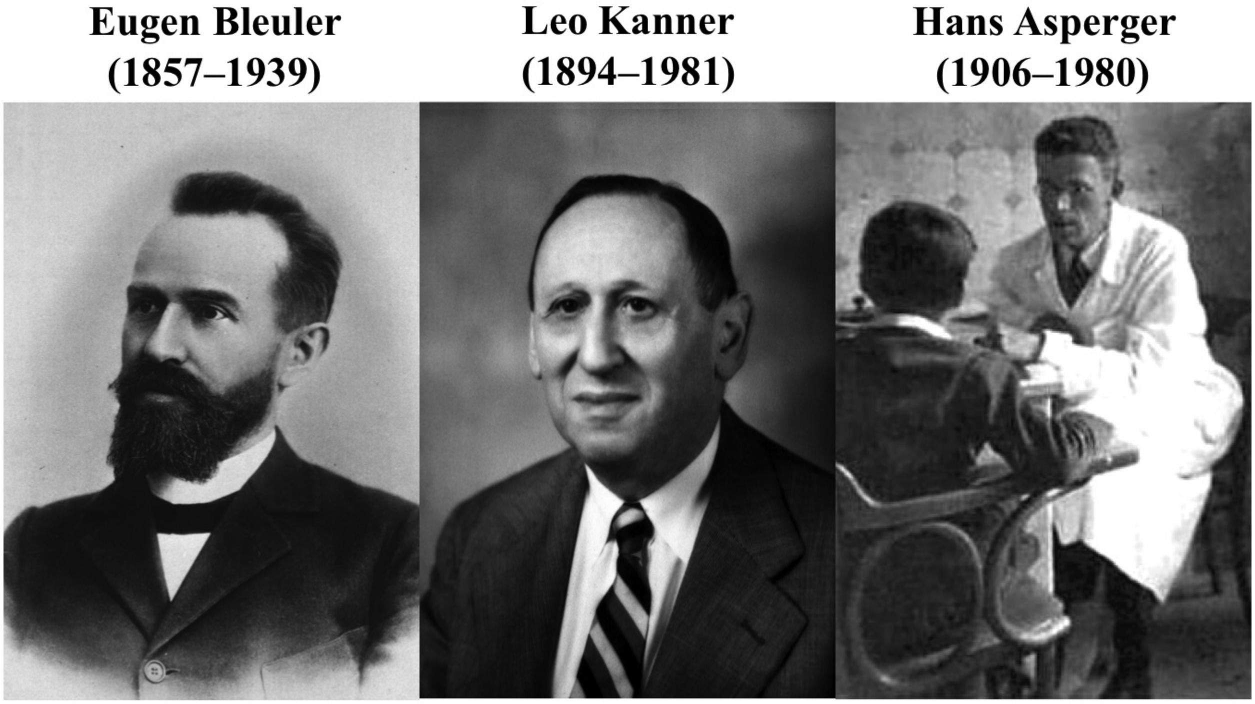
Dyslexia

Adolf Kussmaul (1822–1902)

Oswald Berkhan (1834–1917)

Rudolf Berlin (1833–1897)

Autism and Asperger's syndrome



Eugen Bleuler (1857–1939)

Leo Kanner (1894–1981)

Hans Asperger (1906–1980)

Figure 2.121: Adolf Kussmaul, Oswald Berkhan, and Rudolf Berlin discovered and studied dyslexia. Eugen Bleuler, Leo Kanner, and Hans Asperger discovered and studied autism and Asperger's syndrome.

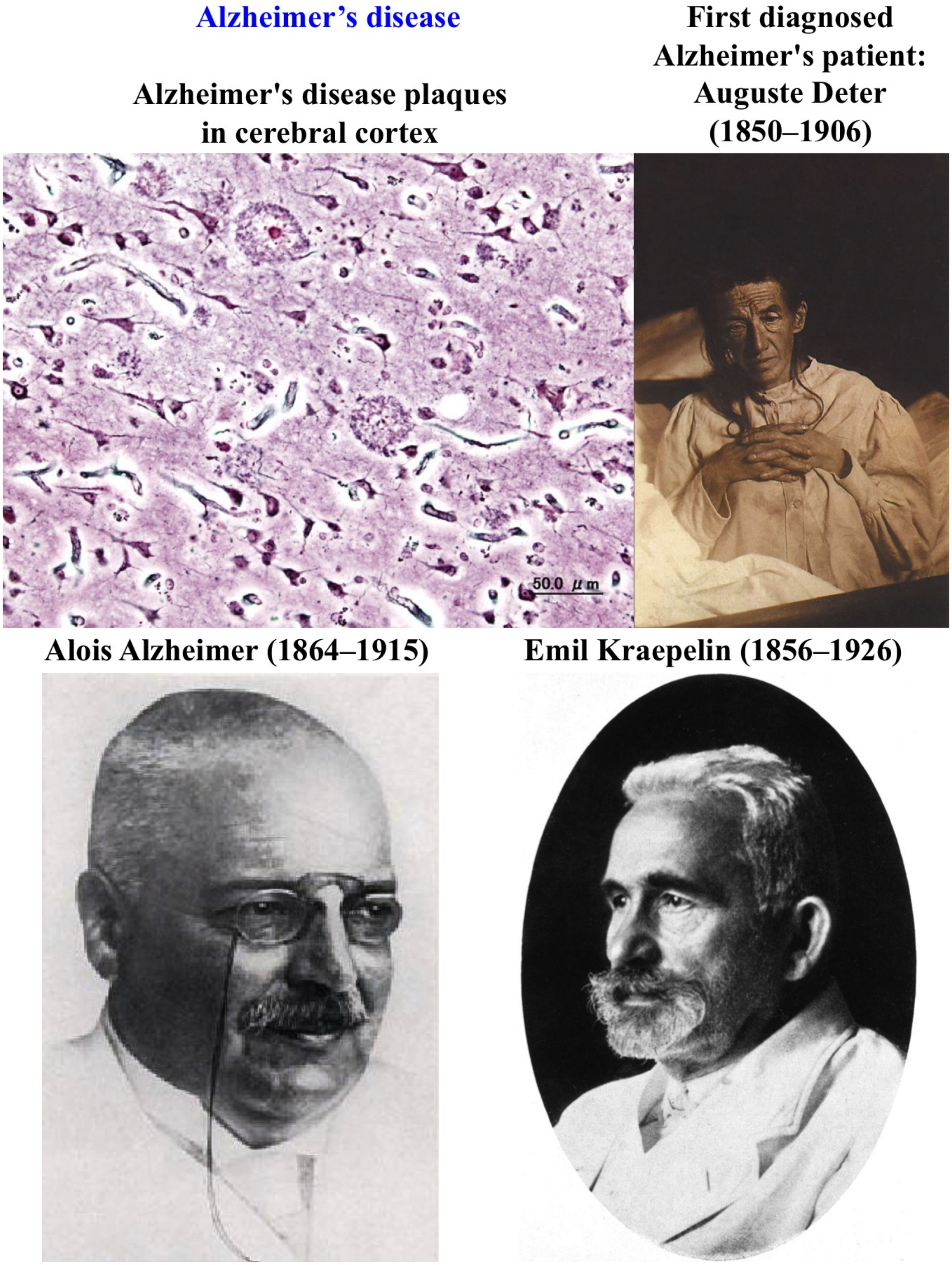
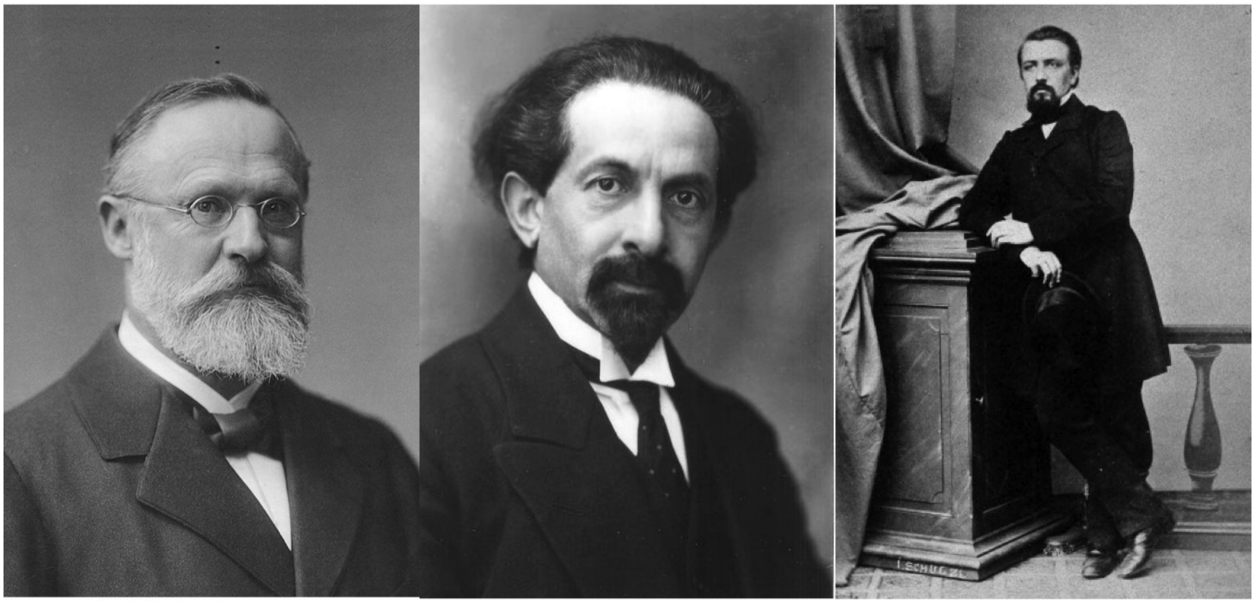

Alzheimer’s disease
Alzheimer's disease plaques in cerebral cortex
First diagnosed Alzheimer's patient: Auguste Deter (1850–1906)
50.0 µm
Alois Alzheimer (1864–1915)
Emil Kraepelin (1856–1926)

Figure 2.122: Alois Alzheimer and Emil Kraepelin discovered and studied Alzheimer’s disease.

Neuropathology and neuropsychiatry

Wilhelm Erb (1840–1921) **Edward Flatau (1868–1932)** **Nikolaus Friedreich (1825–1882)**



Franz Josef Kallmann (1897–1965) **Richard Lindenberg (1911–1992)** **Franz Nissl (1860–1919)**

Figure 2.123: Some other creators who made significant contributions to knowledge about neuropathology and neuropsychiatry included Wilhelm Erb, Edward Flatau, Nikolaus Friedreich, Franz Josef Kallmann, Richard Lindenberg, and Franz Nissl.

2.3.8 Psychology and Psychotherapy

Although this book does not attempt to properly cover the social sciences such as psychology (due to length constraints), it is impossible to resist mentioning at least a few of the most important German-speaking developers of psychology and psychotherapy (Figs. 2.124–2.125):

- Wilhelm Wundt (German, 1832–1920) is generally regarded as the founder of experimental psychology. He examined patients and conducted experiments in a wide variety of areas, including learning, reaction times, and sensory perception. He trained many younger experimental psychologists in his laboratory (Fig. 2.124). He also wrote a highly influential three-volume survey of physiological psychology and a ten-volume work on cultural psychology.

- Ludwig Wilhelm Stern (German, 1871–1938) devised the intelligence quotient (IQ) and also made major contributions to developmental child psychology, differential psychology, forensic psychology, and other areas.

- Josef Breuer (Austrian, 1842–1925) developed psychotherapy or the “talking cure” in the 1880s while working with his most famous patient, whom he referred to as “Anna O.” (actually Bertha Pappenheim, Austrian, 1859–1936).

- Sigmund Freud (Austrian, 1856–1939) first collaborated with and was later estranged from Joseph Breuer. He adopted the idea of psychotherapy from Breuer and greatly extended and popularized it.

- Carl Jung (Swiss, 1875–1961) initially collaborated with and later quarreled with Freud. He pursued psychotherapy but also developed his own ideas about the collective unconscious, biologically innate or culturally inspired ideas and feelings that are generally unspoken yet shared by many people within a group.

- Hermann Rorschach (Swiss, 1884–1922) combined his interests in psychiatry and art to create his now-famous inkblot test, which evaluates what subconscious ideas patients most readily identify with a series of abstract images. He wrote a textbook on psychodiagnostics and may well have achieved even more if he had not died at age 37 from a ruptured appendix.

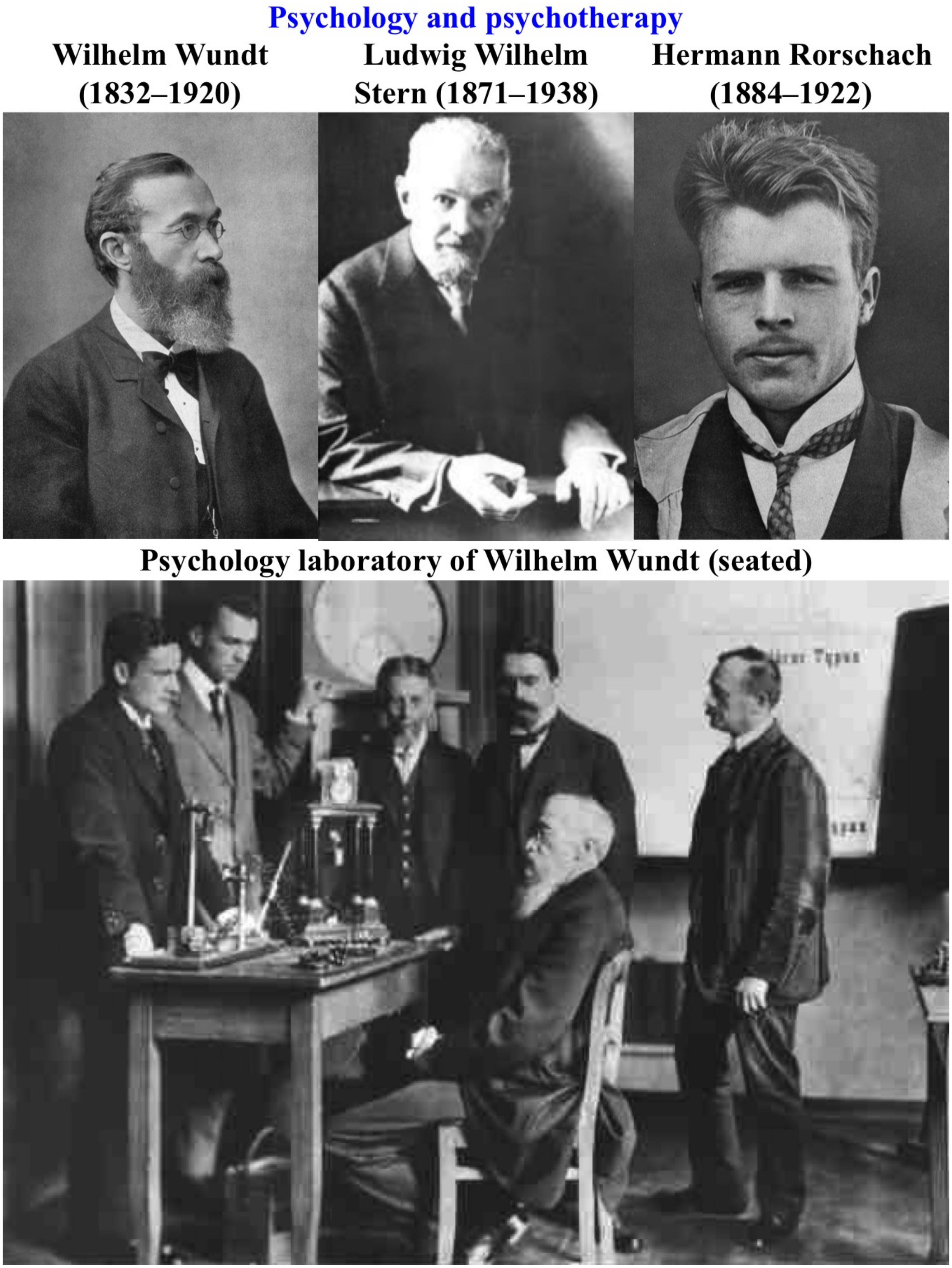

Psychology and psychotherapy
Wilhelm Wundt (1832–1920)
Ludwig Wilhelm Stern (1871–1938)
Hermann Rorschach (1884–1922)
Psychology laboratory of Wilhelm Wundt (seated)

Figure 2.124: Creators who helped to develop psychology and psychotherapy included Wilhelm Wundt, Ludwig Wilhelm Stern, and Hermann Rorschach.

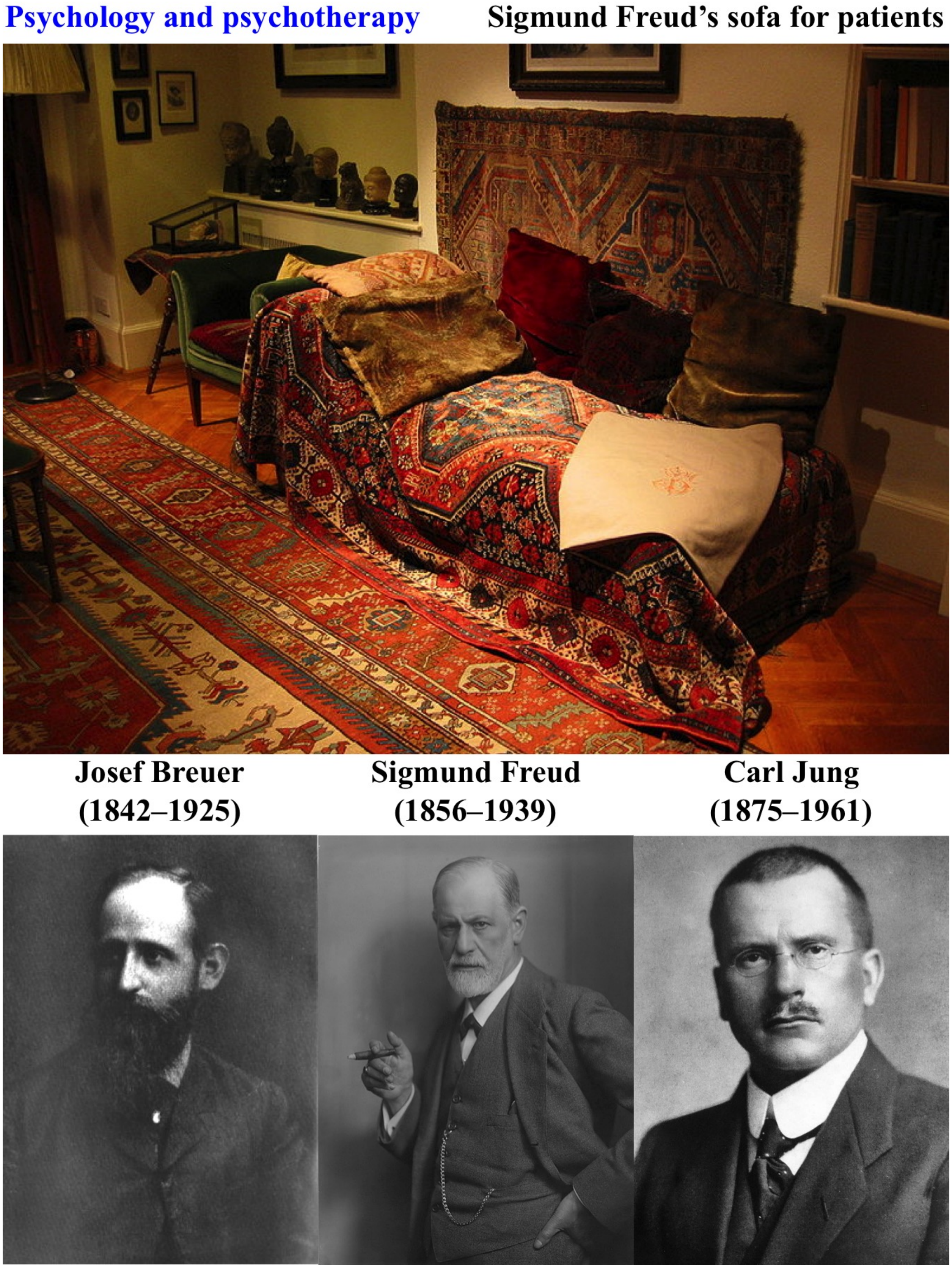

Psychology and psychotherapy
Sigmund Freud's sofa for patients
Josef Breuer (1842–1925)
Sigmund Freud (1856–1939)
Carl Jung (1875–1961)

Figure 2.125: Creators who helped to develop psychology and psychotherapy included Josef Breuer, Sigmund Freud (with his famous sofa for patients, also shown), and Carl Jung.

2.3.9 Analgesics and Anesthetics

German-speaking scientists developed a wide range of neural-related drugs and treatments, including opioids, non-steroidal anti-inflammatory drugs, local and general anesthetics, barbiturates, benzodiazepines, psychoactive drugs, and electroconvulsive therapy.[21]

While the use of natural opium goes back thousands of years, opioid drug molecules were developed by German-speaking scientists in the nineteenth and early twentieth centuries (Figs. 2.126–2.127):

- Friedrich Sertürner (German states, 1783–1841) purified and identified morphine in 1804.
- Max Bockmühl (German, 1882–1949) and Gustav Ehrhart (German, 1894–1971) created methadone and over 300 other synthetic opioids.
- Heinrich Dreser (German, 1860–1924) and Felix Hoffmann (German, 1868–1946) synthesized and demonstrated heroin and codeine.

Many major non-steroidal anti-inflammatory drugs (NSAIDs) also came from German-speaking scientists (Figs. 2.127–2.129):

- Ludwig Knorr (German, 1859–1921) created an aspirin-like non-steroidal anti-inflammatory drug called phenazone in 1887.
- Friedrich Carl Duisberg (German, 1861–1935), the head of research at the Friedrich Bayer company, initiated and managed the search for fever-reducing drugs, leading to the discovery and production of aspirin in 1897.
- Arthur Eichengrün (German, 1867–1949) was in charge of the chemical synthesis group that produced aspirin, as well as a silver protein stain/antibiotic and other novel drugs.
- Felix Hoffmann (German, 1868–1946) worked with Eichengrün to synthesize aspirin and other drug molecules.
- Heinrich Dreser (German, 1860–1924) was in charge of the pharmacology testing group that demonstrated the efficacy of aspirin, codeine, and other drugs.
- Charles Frédéric Gerhardt (German states, 1816–1856) synthesized acetanilide (later known as Antifebrin) in 1843. It was derived from aniline dyes and was the first example of the class of drugs that ultimately included paracetamol (acetaminophen).
- In 1886, Adolf Kussmaul (German, 1822–1902), Arnold Cahn (German?, 18??–??), and Paul Hepp (German?, 18??–??) demonstrated the efficacy of acetanilide (Antifebrin) in humans.
- Joseph von Mering (German, 1849–1908) synthesized and demonstrated paracetamol (acetaminophen) and the closely related phenacetin (acetophenetidin) sometime prior to 1887.
- Harmon Northrop Morse (American but educated in Germany, 1848–1920) also synthesized paracetamol or acetaminophen but apparently did not pursue it further.

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[21] Gedeon 2006; Jahn 2004; Jeffreys 2004; Junker 2004; Koesling and Schülke 2010; Kohler 2008; Magner 2002; Ohler 2017; Possehl 1989; Raviña and Kubinyi 2011; Schnalke and Atzl 2010; Schneider 1972; von Schwerin 2013; Sneader 2005; Verg 1988; Weatherall 1991.

German-speaking creators played important roles in the development of local and general anesthetics (Figs. 2.130):

- In the early 1880s, Carl Koller (Austrian, 1857–1944) tested cocaine and other substances as anesthetics for eye surgery.
- Alfred Einhorn (German, 1856–1917) developed Procaine/Novocain in 1905.
- Heinrich Braun (German, 1862–1934) also helped to develop Procaine/Novocain, as well as other local and general anesthetics in the early 1900s.

Barbiturate drugs can be used as sedatives or hypnotics for inducing relaxation or sleep, anticonvulsants for treating seizures, or general anesthetics for surgery. German-speaking creators developed and demonstrated the first barbiturates such as barbital/Veronal and phenobarbital/Luminal (Fig. 2.131):

- In 1864, Adolf von Baeyer (German, 1835–1917) synthesized barbituric acid, the parent compound of the barbiturate family.
- In 1882, Max Guthzeit (German, 1847–1915) and Max Conrad (German, 1848–1920) synthesized small quantities of barbital, a derivative of barbituric acid, but apparently did not study it further.
- Franz Joseph Emil Fischer (German, 1877–1947) and Alfred Dilthey (German, 1877–1915) synthesized large quantities of barbital in 1902 and phenobarbital in 1904.
- Joseph von Mering (German, 1849–1908) demonstrated the sedative and hypnotic effects of barbital in 1902 and phenobarbital in 1904.
- In 1912, Alfred Hauptmann (German, 1881–1948) discovered that phenobarbital could be used as an anticonvulsant to treat or prevent epileptic seizures.

[See also FIAT 914.]

In the 1950s, Leo Sternbach (Austrian, 1908–2005) developed benzodiazepine tranquilizers such as chlordiazepoxide/Librium, diazepam/Valium, flunitrazepam/Rohypnol, and many others. See Fig. 2.132.

The German-speaking world was important in the development of psychoactive drugs (Fig. 2.133):

- Albert Hofmann (Swiss, 1906–2008) synthesized lysergic acid diethylamide (LSD) in 1938 and studied its psychedelic properties in the early 1940s.
- Lazăr Edeleanu (Romanian but worked in Germany, 1861–1941) synthesized amphetamine in 1887. Methamphetamine, a more potent derivative, was packaged as Pervitin and used as a stimulant by German troops during World War II.

Creators who developed electrostimulation and electroconvulsive therapy included:

- Gustav Fritsch (German, 1838–1927, Fig. 2.104) and Eduard Hitzig (German, 1838–1907, Fig. 2.105) demonstrated the effects of electrical stimulation in the brains of dogs.
- Jacques Loeb (German, 1859–1924, Fig. 2.105) also applied electrical stimulation to localized areas of dogs' brains.
- Oskar Vogt (German, 1870–1959, Fig. 2.106) and Cécile Vogt-Mugnier (French but worked in Germany, 1875–1962, Fig. 2.106) conducted experiments to study the effects of electrostimulation of the brain.
- Walter Hess (Swiss, 1881–1973, Fig. 2.104) studied electrostimulation in the brains of cats and other subjects.
- Ladislas Meduna (Hungarian, 1896–1964, Fig. 2.134) tested metrazol and other drugs to induce convulsions in psychiatric patients for therapeutic purposes.
- Ugo Cerletti (Italian but studied in Germany, 1877–1963, Fig. 2.134) demonstrated and popularized electroconvulsive therapy.
- Friedrich Meggendorfer (German, 1880–1953, Fig. 2.134) also prominently demonstrated electroconvulsive therapy.

Opioids

Friedrich Sertürner
(1783–1841)
Morphine

Max Bockmühl
(1882–1949)

Gustav Ehrhart
(1894–1971)

Methadone and >300 other synthetic opioids

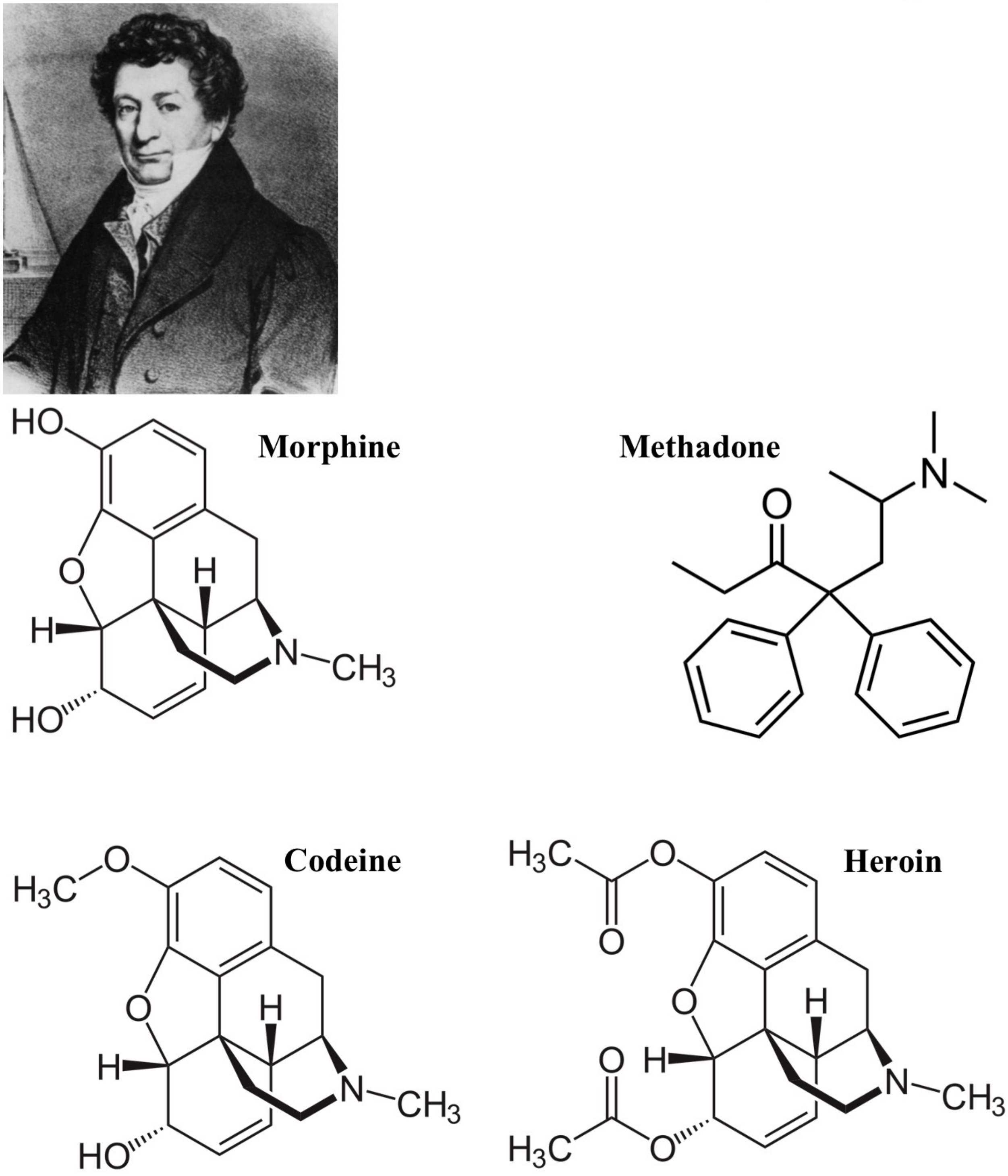

HO
Morphine
O
H
H
N
CH3
HO
Methadone
O
N
H3C
O
Codeine
O
H
H
N
CH3
HO
H3C
O
O
Heroin
O
H
H
N
CH3
O
H3C
O
O

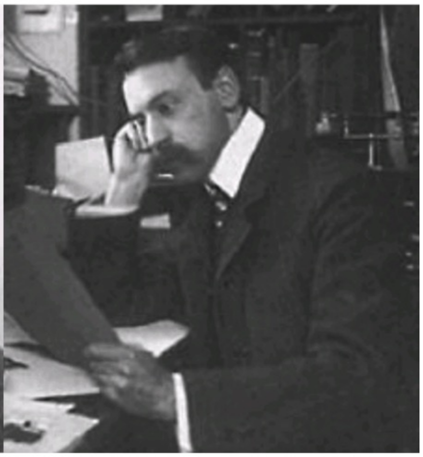
Figure 2.126: Scientists from the German-speaking world who helped to develop opioid drugs included Friedrich Sertürner, Max Bockmühl, and Gustav Ehrhart.

Nonsteroidal anti-inflammatory drugs (NSAIDs) and opioids

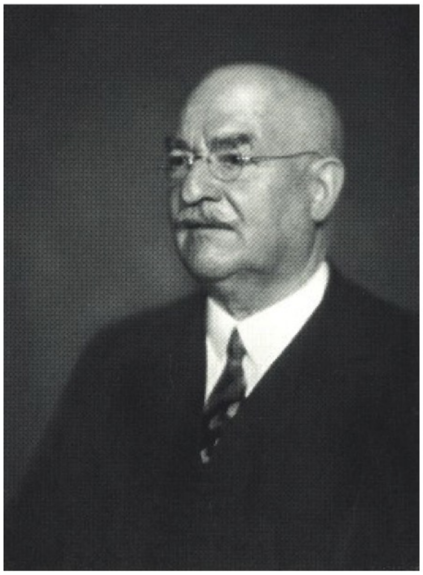
Heinrich Dreser (1860–1924) Aspirin, heroin, codeine

Felix Hoffmann (1868–1946) Aspirin, heroin, codeine

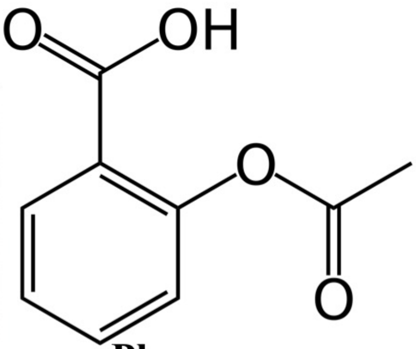
Arthur Eichengrün (1867–1949) Aspirin



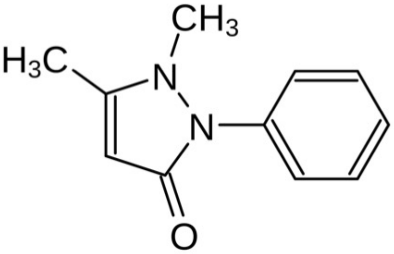
Friedrich Carl Duisberg (1861–1935) Aspirin



Aspirin



Phenazone



Ludwig Knorr (1859–1921) Phenazone

Figure 2.127: Scientists from the German-speaking world who helped to develop nonsteroidal anti-inflammatory drugs (NSAIDs) included Heinrich Dreser, Felix Hoffmann, Arthur Eichengrün, Friedrich Carl Duisberg, and Ludwig Knorr. Dreser and Hoffmann also helped to develop opioid drugs.

Nonsteroidal anti-inflammatory drugs (NSAIDs) and opioids

Heinrich Dreser (second from right) and others in Bayer laboratory (1897)

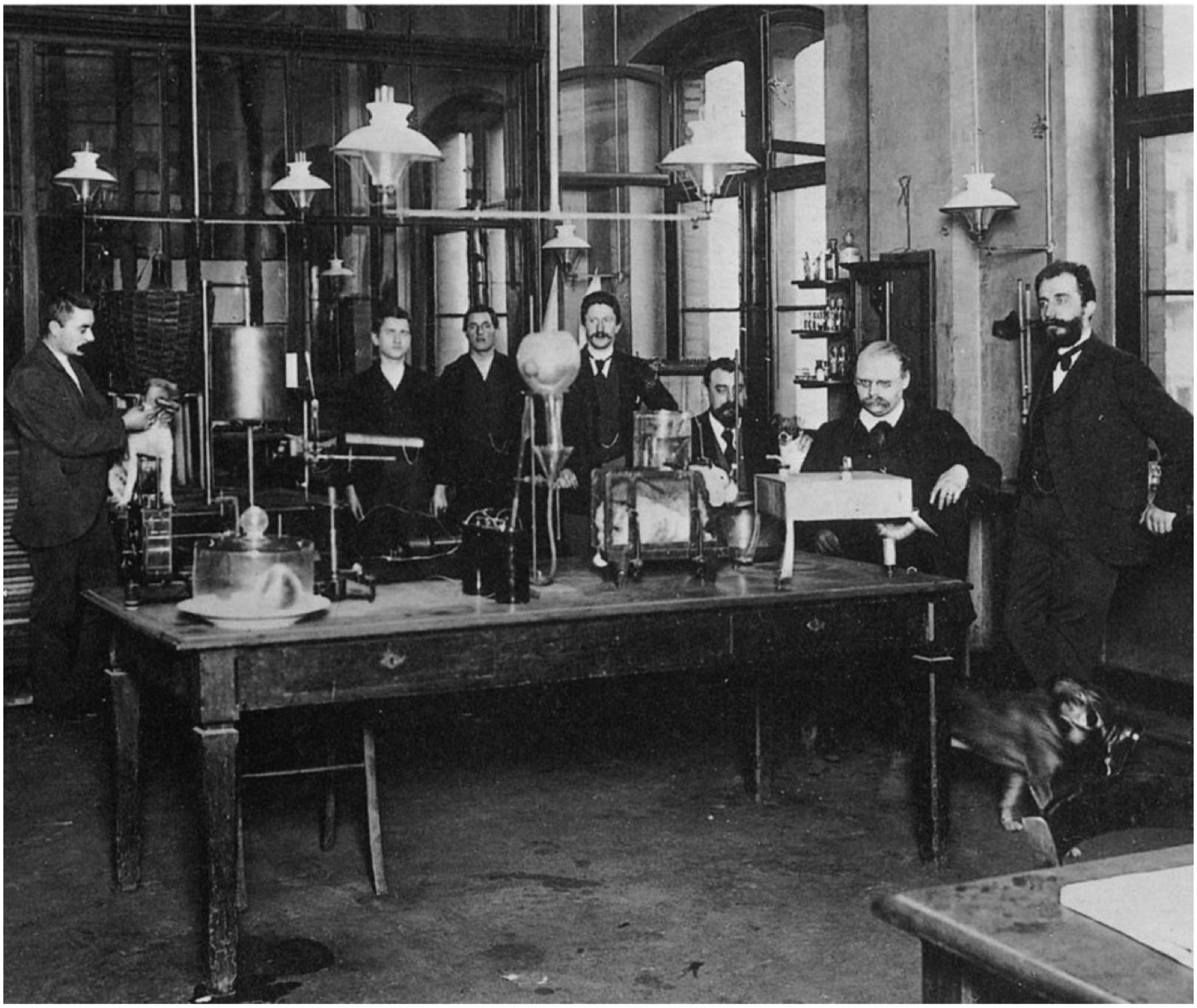


Figure 2.128: Heinrich Dreser (second from right) and others in Bayer laboratory (1897).

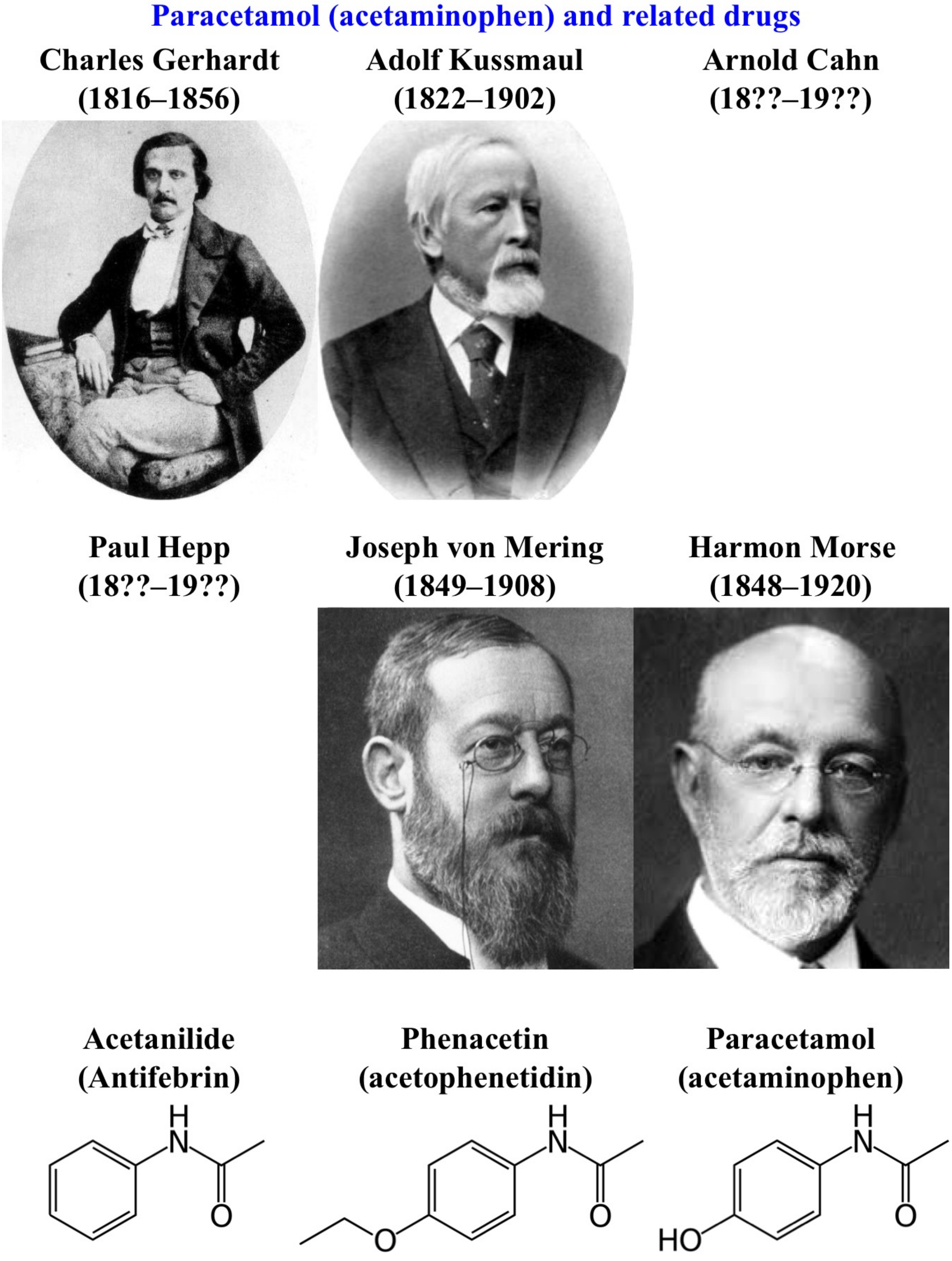
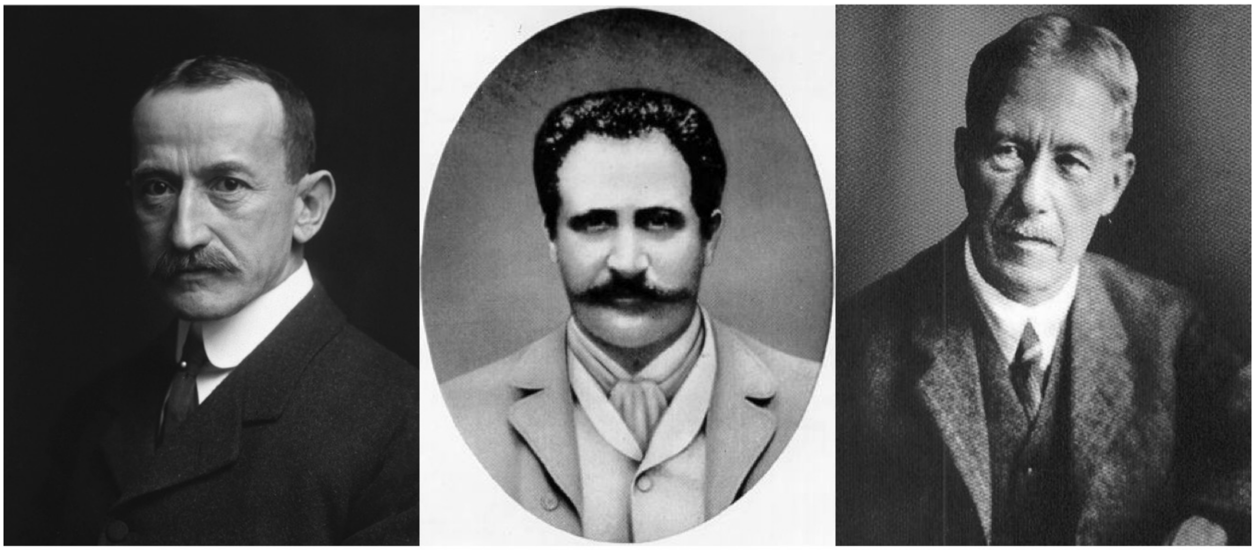

Paracetamol (acetaminophen) and related drugs
Charles Gerhardt
(1816–1856)
Adolf Kussmaul
(1822–1902)
Arnold Cahn
(18??–19??)
Paul Hepp
(18??–19??)
Joseph von Mering
(1849–1908)
Harmon Morse
(1848–1920)
Acetanilide
(Antifebrin)
Phenacetin
(acetophenetidin)
Paracetamol
(acetaminophen)
H
N
O
HO

Figure 2.129: Paracetamol (acetaminophen) and the closely related drugs acetanilide (Antifebrin) and phenacetin (acetophenetidin) were first synthesized and tested by Charles Gerhardt, Adolf Kussmaul, Arnold Cahn, Paul Hepp, Joseph von Mering, and Harmon Morse.

Anesthetics

Carl Koller (1857–1944) Cocaine and other eye anesthetics	Alfred Einhorn (1856–1917) Procaine/Novocain (1905)	Heinrich Braun (1862–1934) Procaine, other general and local anesthetics



Cocaine **Procaine/Novocain**

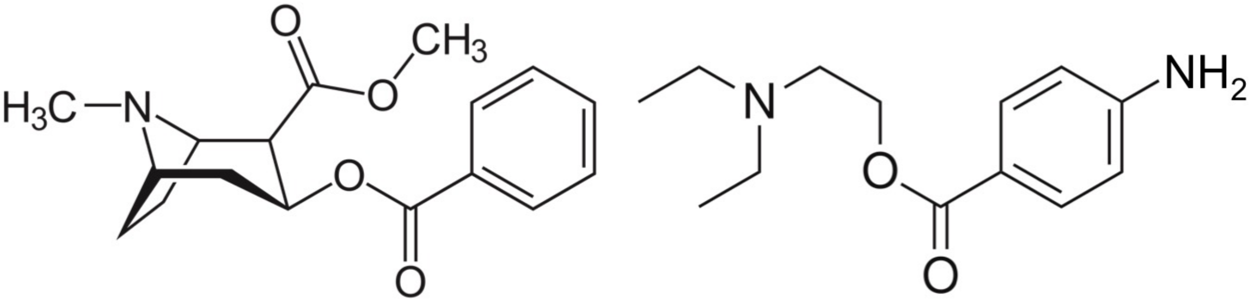
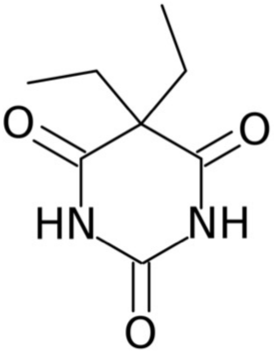


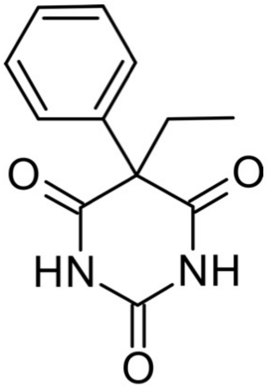
Figure 2.130: Scientists from the German-speaking world who helped to develop anesthetics such as procaine/novocain included Carl Koller, Alfred Einhorn, and Heinrich Braun.

Barbiturates

Barbital or Veronal (1882)



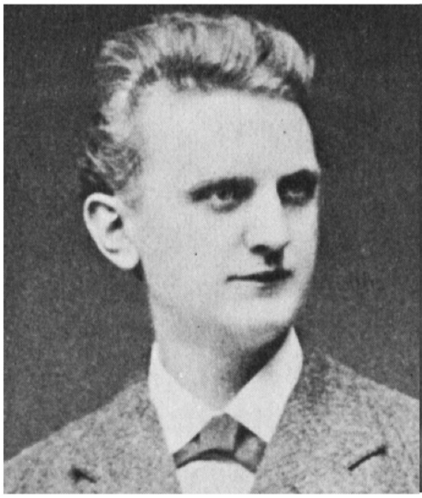
Phenobarbital or Luminal (1904)



Adolf von Baeyer (1835–1917)

Max Guthzeit (1847–1915)

Max Conrad (1848–1920)



Joseph von Mering (1849–1908)

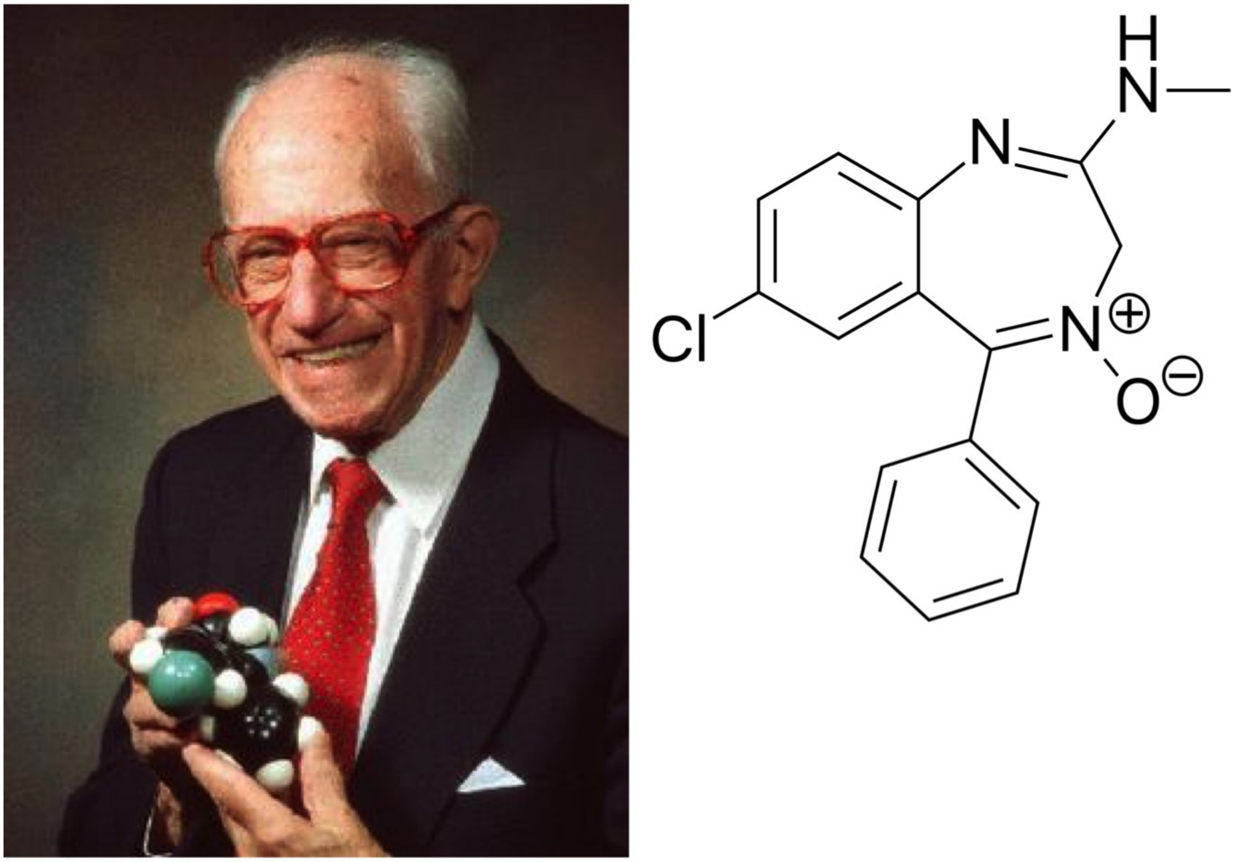
Franz Joseph Emil Fischer (1877–1947)

Alfred Dilthey (1877–1915)

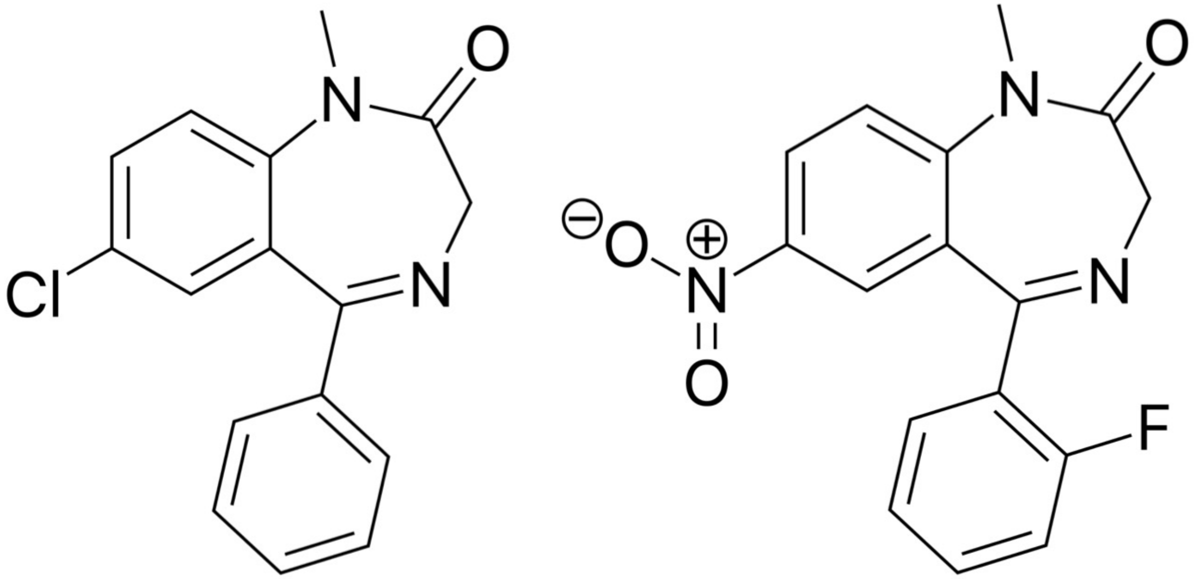
Alfred Hauptmann (1881–1948)

Figure 2.131: Creators who developed barbiturates such as barbital/Veronal and phenobarbital/Luminal included Adolf von Baeyer, Max Guthzeit, Max Conrad, Joseph von Mering, Franz Joseph Emil Fischer, Alfred Dilthey, and Alfred Hauptmann.

Benzodiazepines



Leo Sternbach (1908–2005) **Chlordiazepoxide/Librium (1955)**



Diazepam/Valium (1950s) **Flunitrazepam/Rohypnol (1950s)**

Figure 2.132: In the 1950s, Leo Sternbach developed benzodiazepine tranquilizers such as chlordiazepoxide/Librium, diazepam/Valium, flunitrazepam/Rohypnol, and many others.

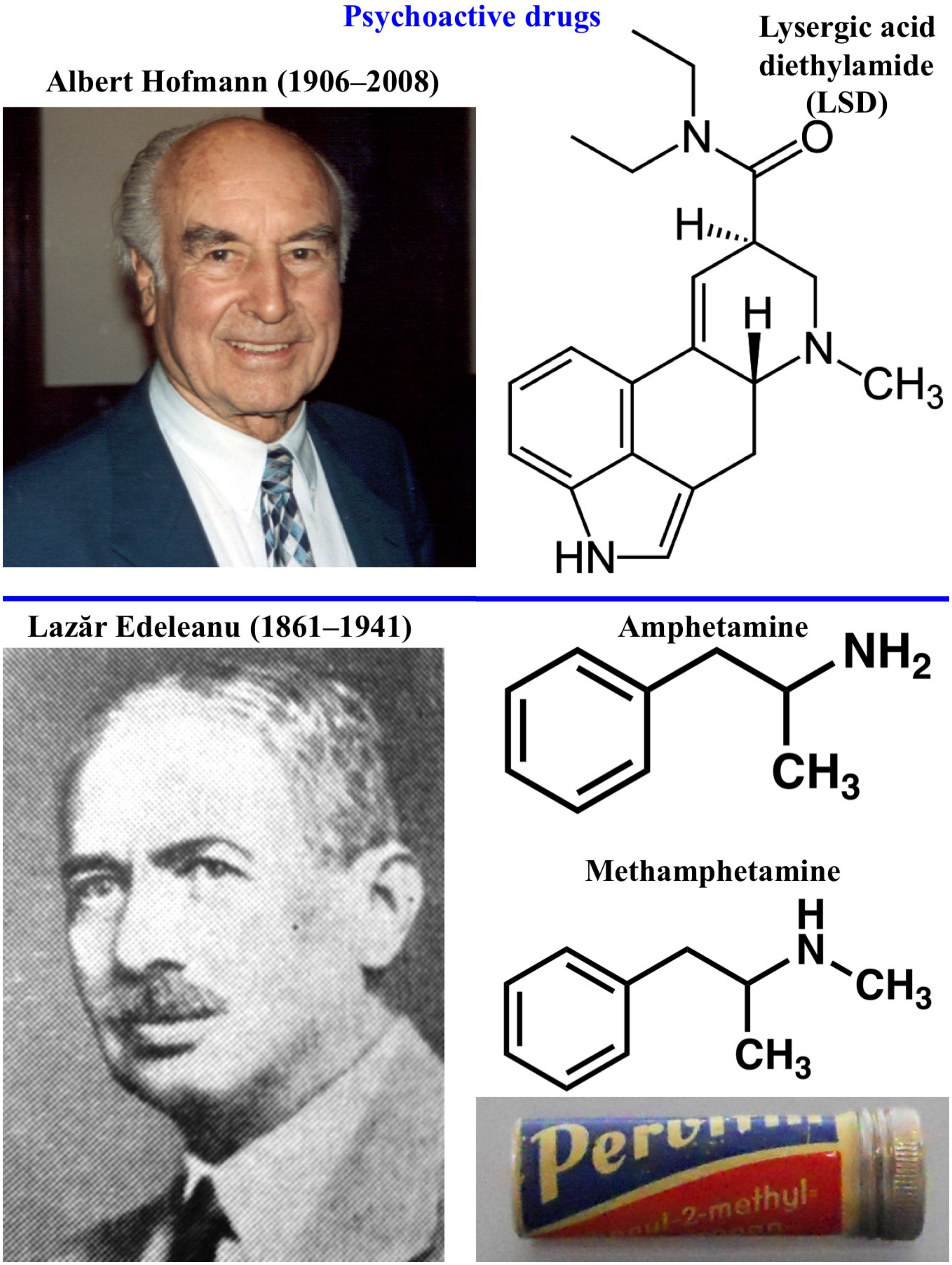

Psychoactive drugs
Albert Hofmann (1906–2008)
Lysergic acid diethylamide (LSD)
Lazăr Edeleanu (1861–1941)
Amphetamine
Methamphetamine
2-methyl-

Figure 2.133: Scientists from the German-speaking world who helped to develop psychoactive drugs included Albert Hofmann and Lazăr Edeleanu.

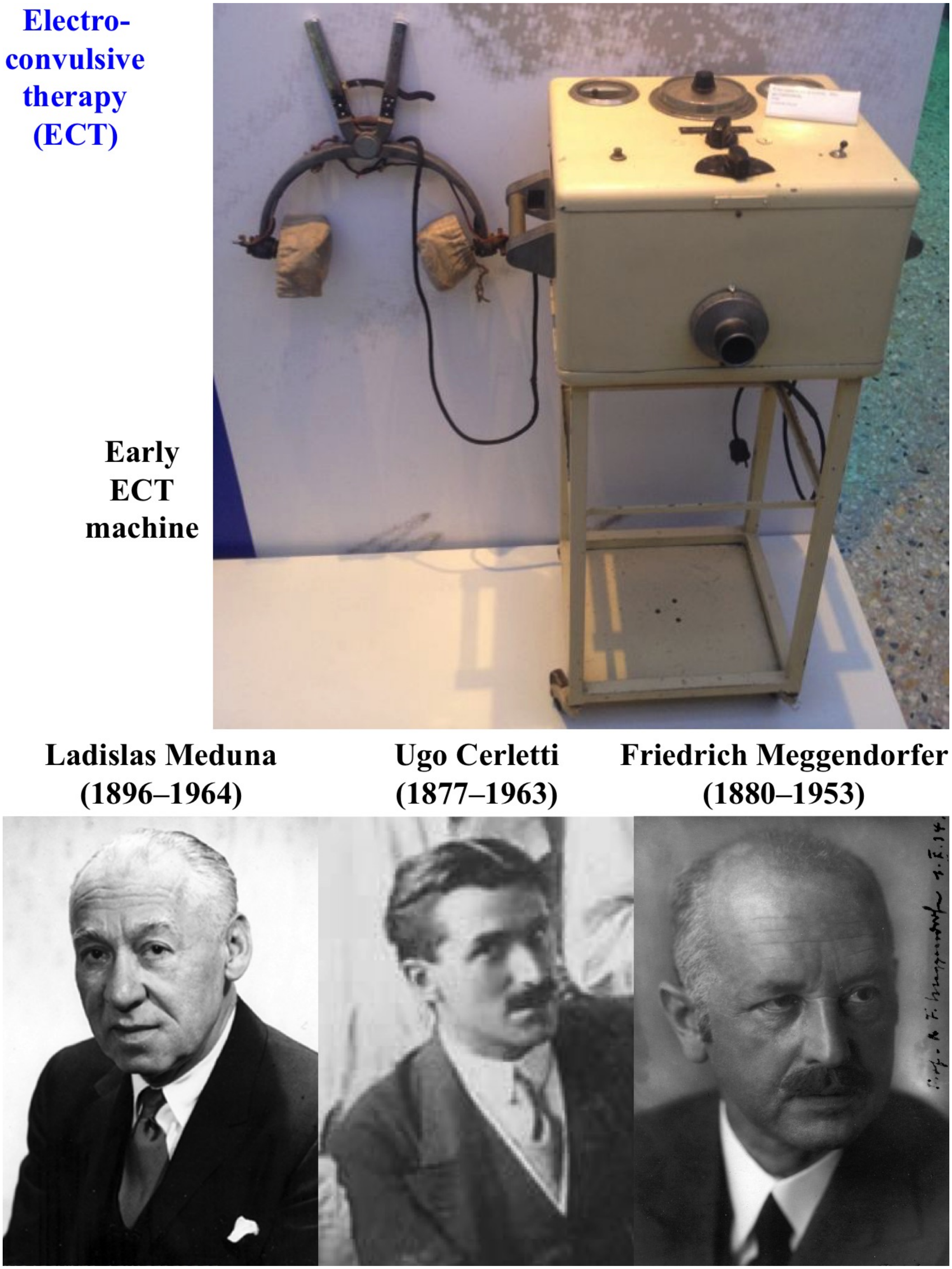

Electro-convulsive therapy (ECT)
Early ECT machine
Ladislas Meduna (1896–1964)
Ugo Cerletti (1877–1963)
Friedrich Meggendorfer (1880–1953)

Figure 2.134: Scientists who helped to develop electroconvulsive therapy (ECT) included Ladislas Meduna, Ugo Cerletti, and Friedrich Meggendorfer.

2.3.10 Vision

Figures 2.135–2.136 show the anatomy of the eye and the retina at the back of the eye. The retina contains three different types of cone cells to detect colored light (red, green, and blue), and also rod cells that are more sensitive but cannot distinguish colors (only black and white, but they are important for vision in dim light).

A large number of scientists from the German-speaking world made important discoveries regarding vision (Figs. 2.137–2.143).

In 1583, Felix Platter (Swiss, 1536–1614) conducted experiments on image formation with the lens of the eye.

In 1604, Johannes Kepler (Weil der Stadt, 1571–1630) provided the theoretical explanation for image formation on the retina by the lens of the eye.

In 1619, Chrisoph Scheiner (German states, 1575–1650) carried out detailed experiments demonstrating image formation on the retina by the lens of the eye.

In 1674, Antonie van Leeuwenhoek (Dutch, 1632–1723) conducted the first examination of structures in the eye with a microscope.

In his 1747 *Primae lineae physiologiae* [*Primer of Physiology*], Albrecht von Haller (Swiss, 1708–1777) proposed a general theoretical framework for how the eyes and brain process visual signals.

Johann Gottfried Zinn (German states, 1727–1759) published the first book on the detailed anatomy of the human eye, *Descriptio anatomica oculi humani* [*Anatomical Description of the Human Eye*], in 1765.

Johann Wolfgang von Goethe (German states, 1749–1832) carried out considerable experimental and theoretical work on the human perception of colors.

In 1791, Samuel Thomas von Sömmerring (German states, 1755–1830) discovered the macula lutea and the fovea in the retina.

Franz Joseph Gall (German states, 1758–1828) and Johann Spurzheim (German states, 1776–1832) described the connections from the eye to parts of the brain—the lateral geniculate nucleus and the superior colliculus in the midbrain—in 1809.

Karl Friedrich Burdach (German states, 1776–1847) studied the visual connections to the lateral geniculate nucleus and the superior colliculus in more detail in 1822.

Jakob Henle (German, 1809–1885) and Theodor Meynert (German/Austrian, 1833–1892) later confirmed the discoveries of Gall, Spurzheim, and Burdach regarding the connections to the lateral geniculate nucleus and the superior colliculus.

In the 1820s, Johann Purkinje (Austrian/Czech, 1787–1869) conducted a wide variety of experiments on vision and on factors that influence it.

In 1828, Gottfried Treviranus (German states, 1776–1837) discovered the rod photoreceptor cells in the retina.

Alfred Wilhelm Volkmann (German, 1801–1877) studied the neural connections of the visual system.

August Seebeck (German states, 1805–1849) conducted detailed studies of color blindness in 1837.

Johannes Peter Müller (German states, 1801–1858) gave a written description of the microscopic structure of the retina in 1838.

In 1839, Friedrich Heinrich Bidder (Baltic German, 1810–1894) realized that the retina is "backwards," with light having to pass through several layers of other cells to reach the photoreceptor cells.

In 1840, Heinrich Müller (German states, 1820–1864) identified the different layers of cells within the retina.

In 1851, Hermann von Helmholtz (German, 1821–1894) invented the ophthalmoscope to examine the inside of the eye; ophthalmoscopes have been widely used ever since. Von Helmholtz also conducted numerous experiments on color vision, depth perception, and motion perception. His *Handbuch der Physiologischen Optik* [*Handbook of Physiological Optics*] (1867) remained an important reference work for nearly a century.

In 1852, Rudolf Albert von Kölliker (Swiss, 1817–1905) discovered cone photoreceptor cells in the retina. Heinrich Müller confirmed that discovery in 1856.

In the 1850s, Albrecht von Gräfe (Prussian, 1828–1870) conducted detailed tests of the visual fields and described visual defects due to damage in certain parts of the brain.

In 1865, Hermann Rudolph Aubert (German, 1826–1892) published a book explaining that visual acuity and color discrimination are greatest at the center of the retina and decrease toward the edges of the retina.

In 1866, Max Schultze (German, 1825–1874) realized that cones provide color vision and rods provide black-and-white night vision.

Franz Christian Boll (German, 1849–1879) discovered rhodopsin, the light-detecting molecule in photoreceptor cells, in 1876.

In 1877, Wilhelm Kühne (German, 1837–1900) and Carl Anton Ewald (German, 1845–1915) confirmed the presence of rhodopsin in human photoreceptor cells.

Beginning in 1874, Paul Flechsig (German, 1847–1929) studied the visual processing areas of the brain.

Hermann Munk (German, 1839–1912) discovered the visual area of the occipital cortex at the back of the brain in 1878.

Hermann Wilbrand (German, 1851–1935) confirmed the location of the visual area in the occipital cortex in 1881.

August Leopold von Reuss (Austrian, 1841–1924) developed and extensively used tests for color blindness, and also measured the curvature of the cornea.

In the 1870s, Karl Ewald Hering (German, 1834–1918) proposed detailed theoretical explanations of color vision.

In 1881, Franciscus Donders (Dutch, 1818–1889) also presented a detailed explanation of color vision.

Ludwig Mauthner (Austrian, 1840–1894) made numerous contributions to knowledge about the eye, eye surgery, and the visual areas of the brain.

Constantin von Monakow (Russian, studied and worked in Switzerland, 1853–1930) conducted experimental studies of the visual areas of the brain.

In 1884, Jacques Loeb (German, 1859–1924) applied electrical stimulation to localized areas of dogs' brains to study the visual cortex.

In 1890, Adolf Beck (Polish/Austrian, 1863–1942) placed electrodes in rabbits' and dogs' brains to measure the electrical signals that were stimulated in the occipital lobe by bright lights.

Arthur König (German, 1856–1901) measured the light absorption characteristics of rhodopsin molecules in 1894.

Mieczylsław Minkowski (Polish/Swiss, 1884–1972) studied in detail the connections from the eyes to the lateral geniculate nucleus in the brain.

In the 1920s, Erwin Schrödinger (Austrian, 1887–1961) made detailed theoretical studies of color vision, including the quantum physics of the molecular detection of light of different wavelengths.

Creators who made important advances in eye surgery included (Fig. 2.144):

- Georg Beer (Austrian, 1763–1821) pioneered cataract surgery.
- Albrecht von Gräfe (Prussian, 1828–1870) developed treatments for glaucoma and cataracts.
- Carl Koller (Austrian, 1857–1944) also worked on glaucoma and cataract therapies.
- Gerhard Meyer-Schwickerath (German, 1920–1992) invented photocoagulation to treat retinal detachment.

Eye charts to measure visual acuity were developed by (Fig. 2.145):

- Heinrich Küchler (German, 1811–1873), who created the first eye charts using symbols.

- Eduard Jäger von Jaxtthal (Austrian, 1818–1884), who developed improved eye charts and also discovered diabetic retinopathy.
- Herman Snellen (Dutch, 1834–1908), who further improved and finalized eye charts.

Scientists from the greater German-speaking world also developed modern corrective lenses for vision (Fig. 2.146):

- Franciscus Donders (Dutch, 1818–1889) made the first eyeglass lenses for astigmatism in 1860.
- Adolf Gaston Eugen Fick (German, 1852–1937) invented glass contact lenses in 1888.
- Heinrich Wöhlk (German, 1913–1991) created plastic contact lenses in 1940.
- Otto Wichterle (Moravian, 1913–1998) and Drahoslav Lím (Czech, 1925–2003) developed soft contact lenses in the 1950s.

Vision

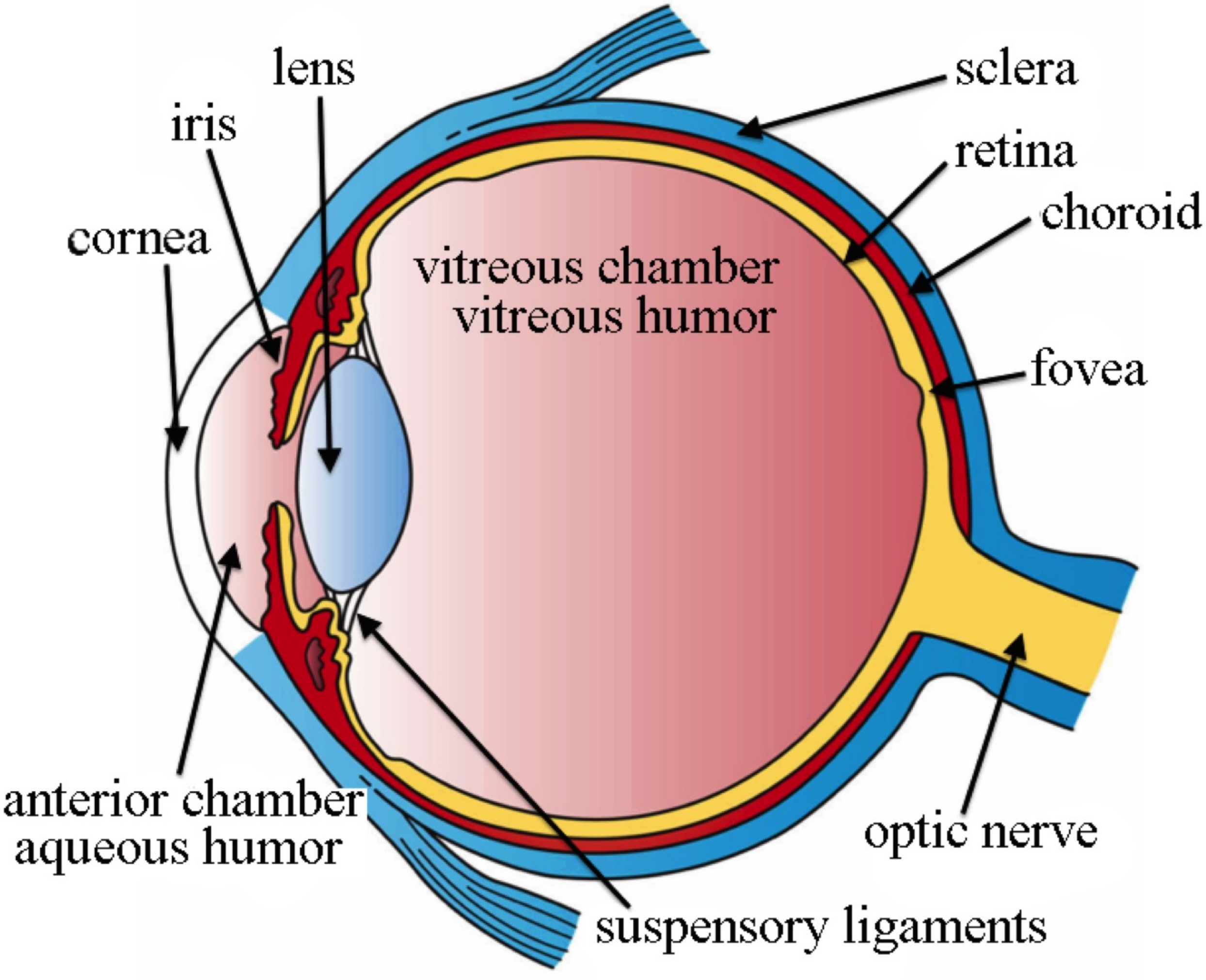

lens
iris
cornea
sclera
retina
choroid
vitreous chamber
vitreous humor
fovea
anterior chamber
aqueous humor
optic nerve
suspensory ligaments

Figure 2.135: The anatomy of the eye.

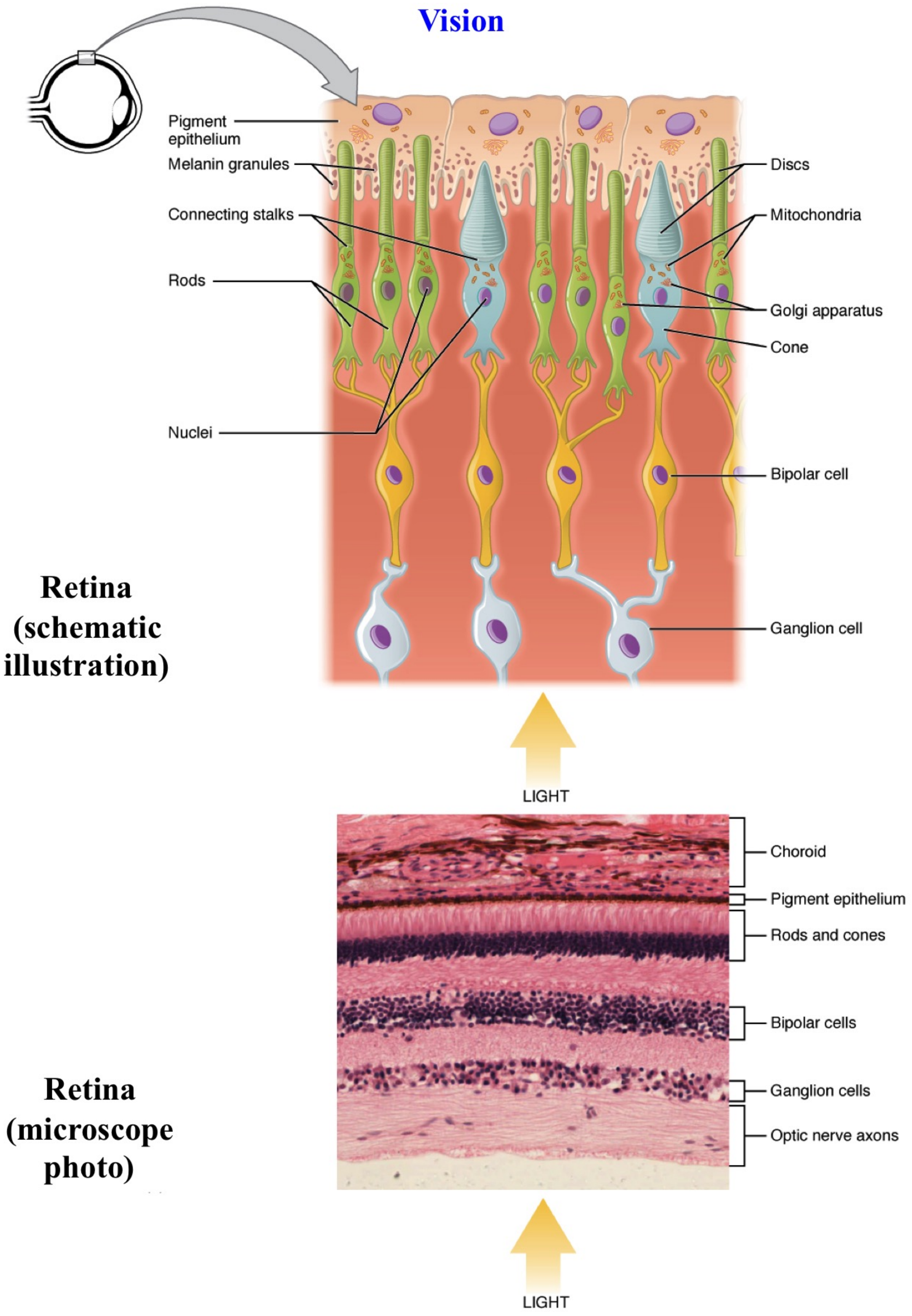

Vision
Pigment epithelium
Melanin granules
Connecting stalks
Rods
Nuclei
Discs
Mitochondria
Golgi apparatus
Cone
Bipolar cell
Ganglion cell
Retina (schematic illustration)
LIGHT
Choroid
Pigment epithelium
Rods and cones
Bipolar cells
Ganglion cells
Optic nerve axons
Retina (microscope photo)
LIGHT

Figure 2.136: In the eye, the retina contains three different types of cone cells to detect colored light (red, green, and blue), and also rod cells that are more sensitive but cannot distinguish colors (only black and white).

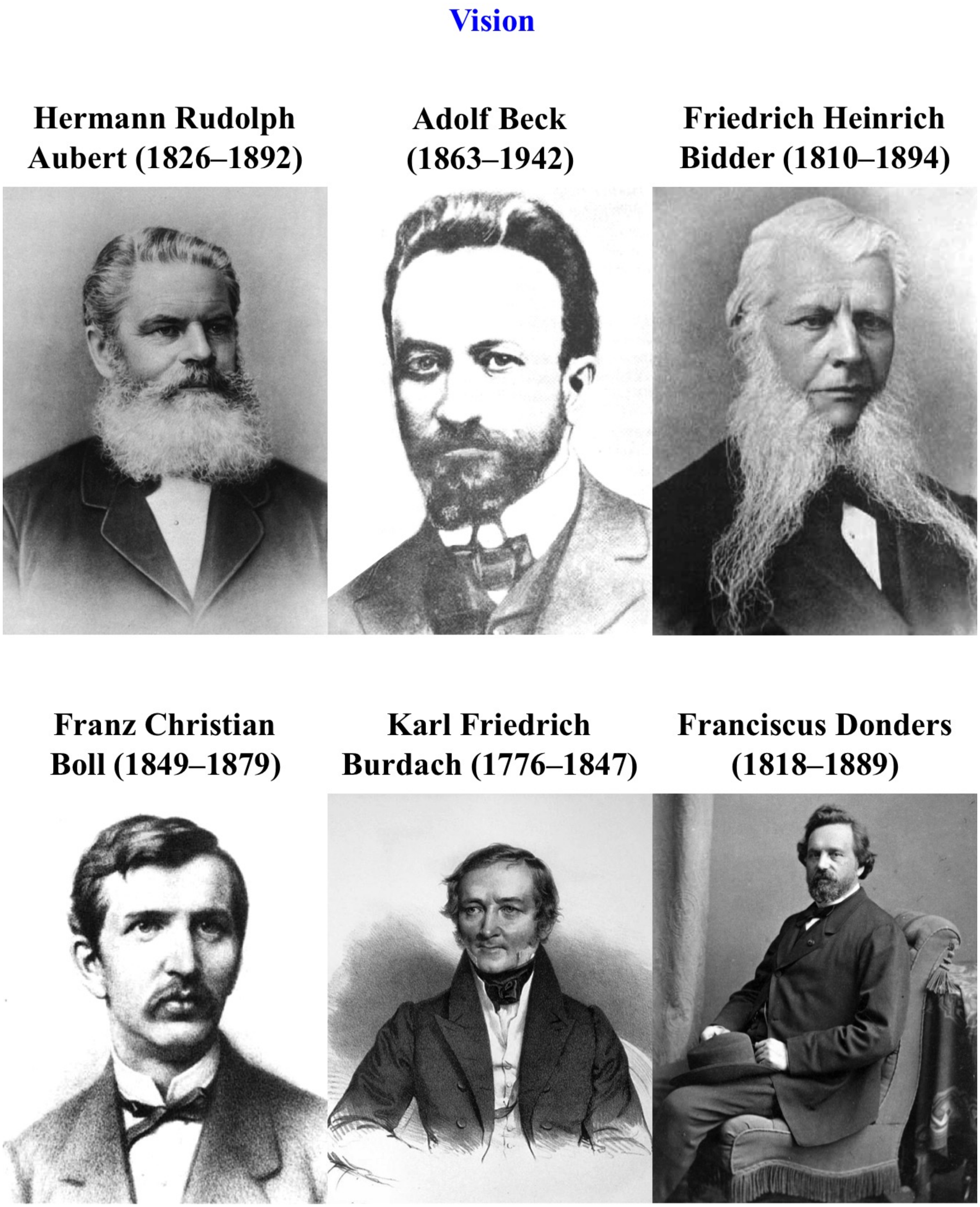

Vision
Hermann Rudolph Aubert (1826–1892)
Adolf Beck (1863–1942)
Friedrich Heinrich Bidder (1810–1894)
Franz Christian Boll (1849–1879)
Karl Friedrich Burdach (1776–1847)
Franciscus Donders (1818–1889)

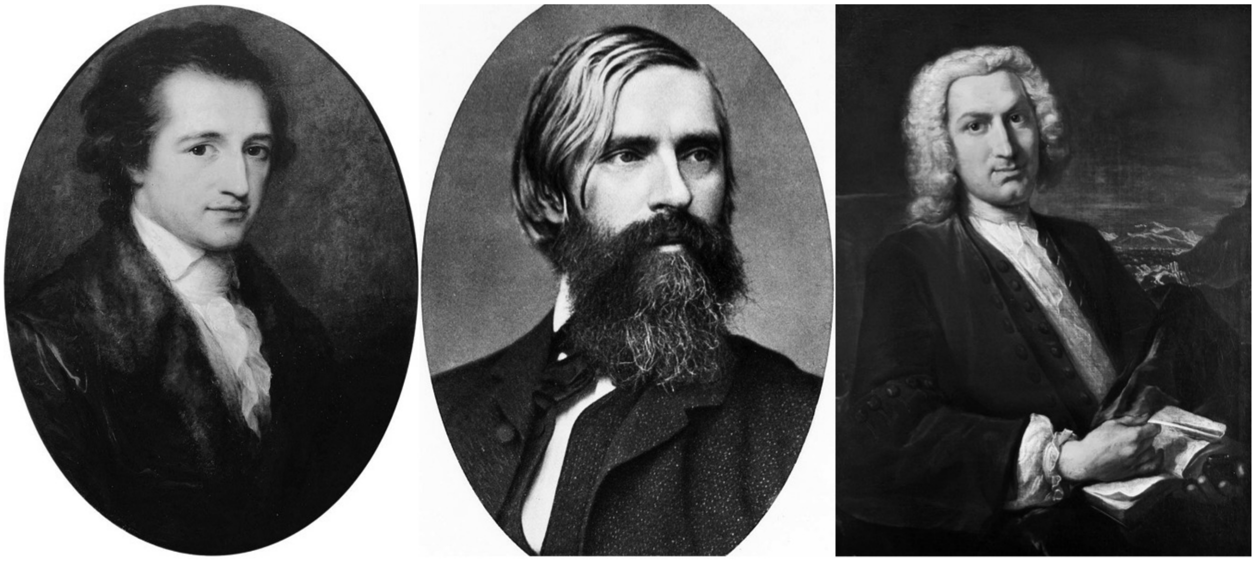
Figure 2.137: Creators who made important discoveries regarding vision included Hermann Rudolph Aubert, Adolf Beck, Friedrich Heinrich Bidder, Franz Christian Boll, Karl Friedrich Burdach, and Franciscus Donders.

Vision

Carl Anton Ewald (1845–1915)

Paul Flechsig (1847–1929)

Franz Joseph Gall (1758–1828)



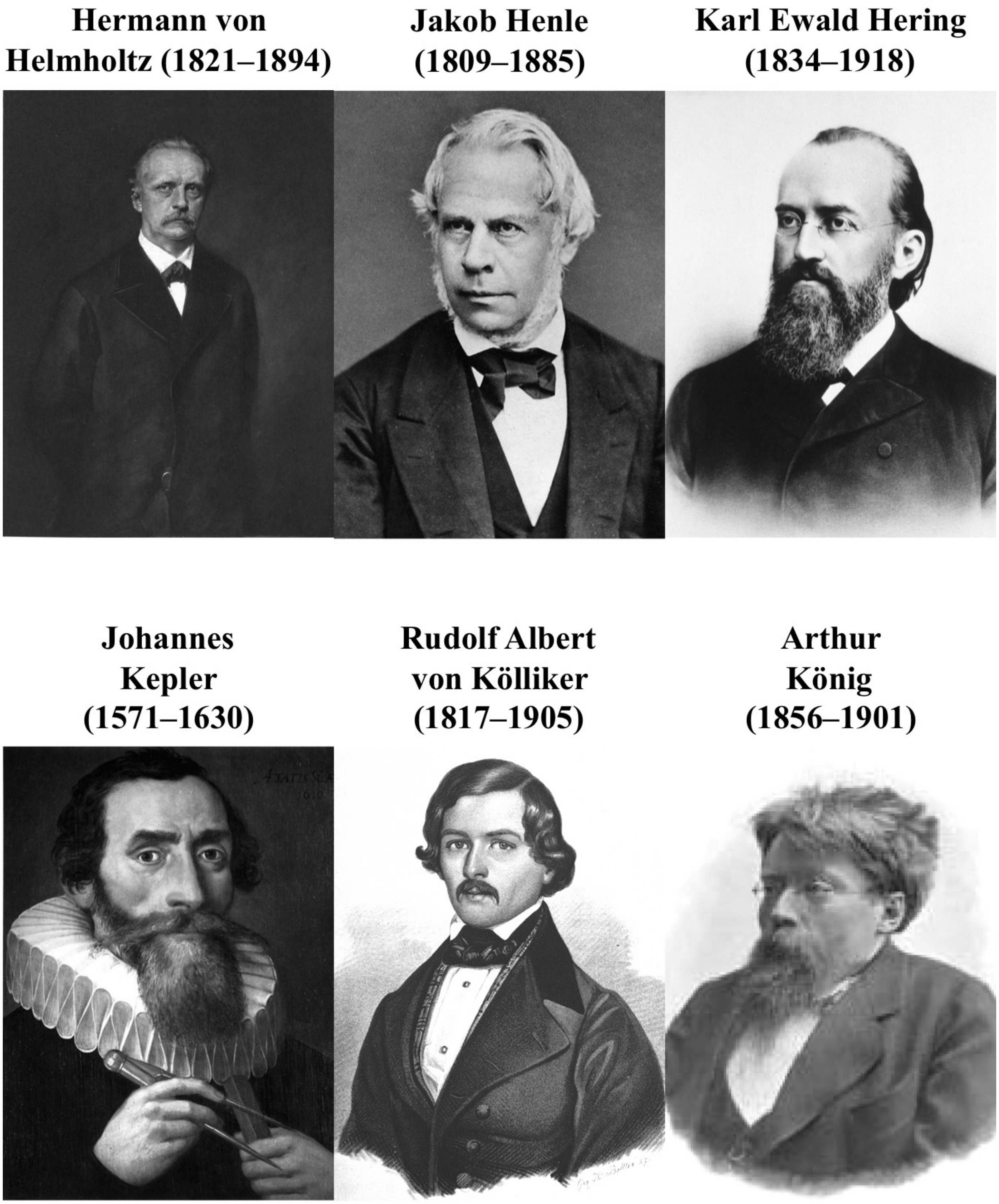
Johann Wolfgang von Goethe (1749–1832)

Albrecht von Gräfe (1828–1870)

Albrecht von Haller (1708–1777)

Figure 2.138: Other creators who made important discoveries regarding vision included Carl Anton Ewald, Paul Flechsig, Franz Joseph Gall, Johann Wolfgang von Goethe, Albrecht von Gräfe, and Albrecht von Haller.

Vision


Hermann von Helmholtz (1821–1894)

Jakob Henle (1809–1885)

Karl Ewald Hering (1834–1918)

Johannes Kepler (1571–1630)

Rudolf Albert von Kölliker (1817–1905)

Arthur König (1856–1901)

Figure 2.139: Other creators who made important discoveries regarding vision included Hermann von Helmholtz, Jakob Henle, Karl Ewald Hering, Johannes Kepler, Rudolf Albert von Kölliker, and Arthur König.

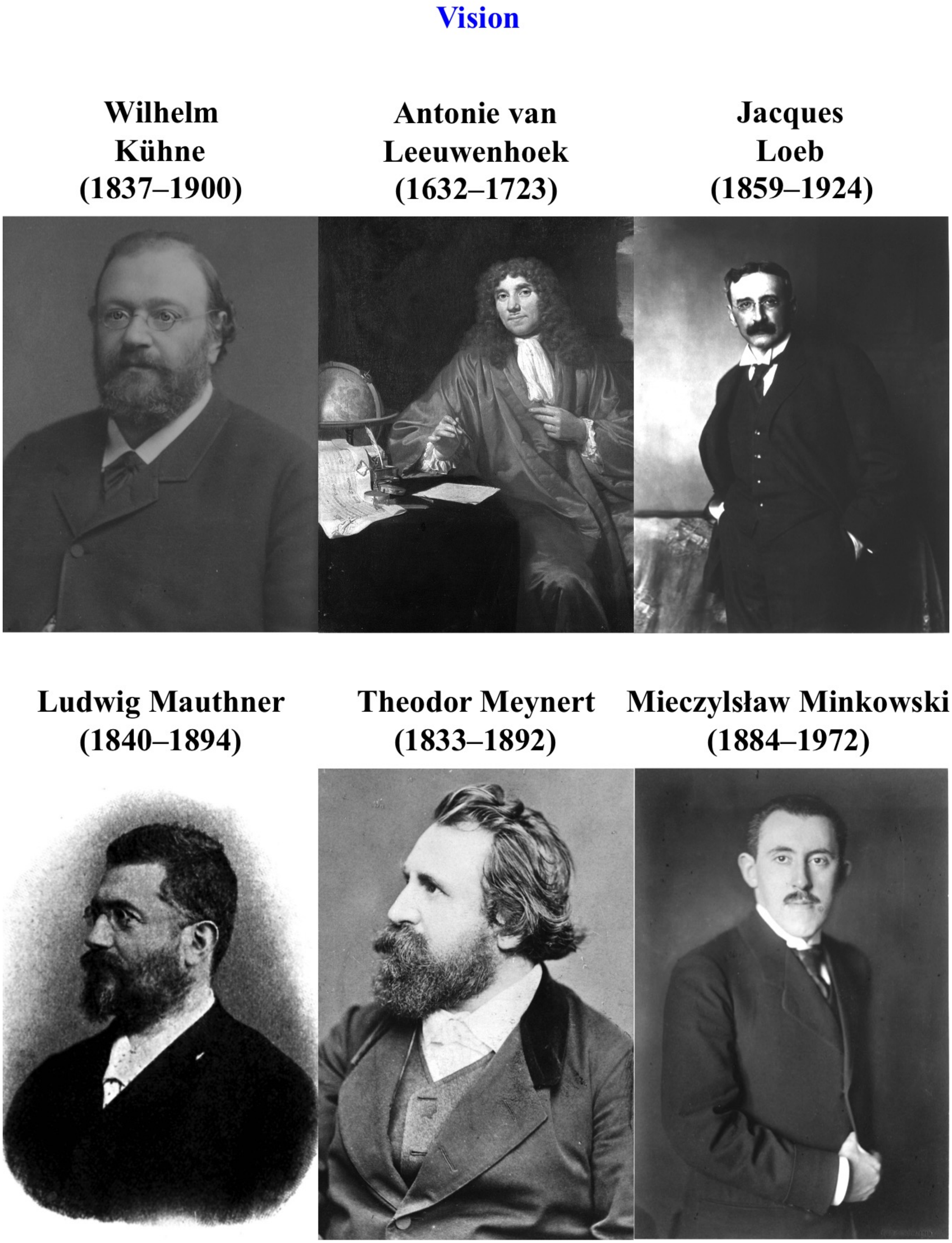

Vision
Wilhelm Kühne (1837–1900)
Antonie van Leeuwenhoek (1632–1723)
Jacques Loeb (1859–1924)
Ludwig Mauthner (1840–1894)
Theodor Meynert (1833–1892)
Mieczylsław Minkowski (1884–1972)

Figure 2.140: Other creators who made important discoveries regarding vision included Wilhelm Kühne, Antonie van Leeuwenhoek, Jacques Loeb, Ludwig Mauthner, Theodor Meynert, and Mieczylsław Minkowski.

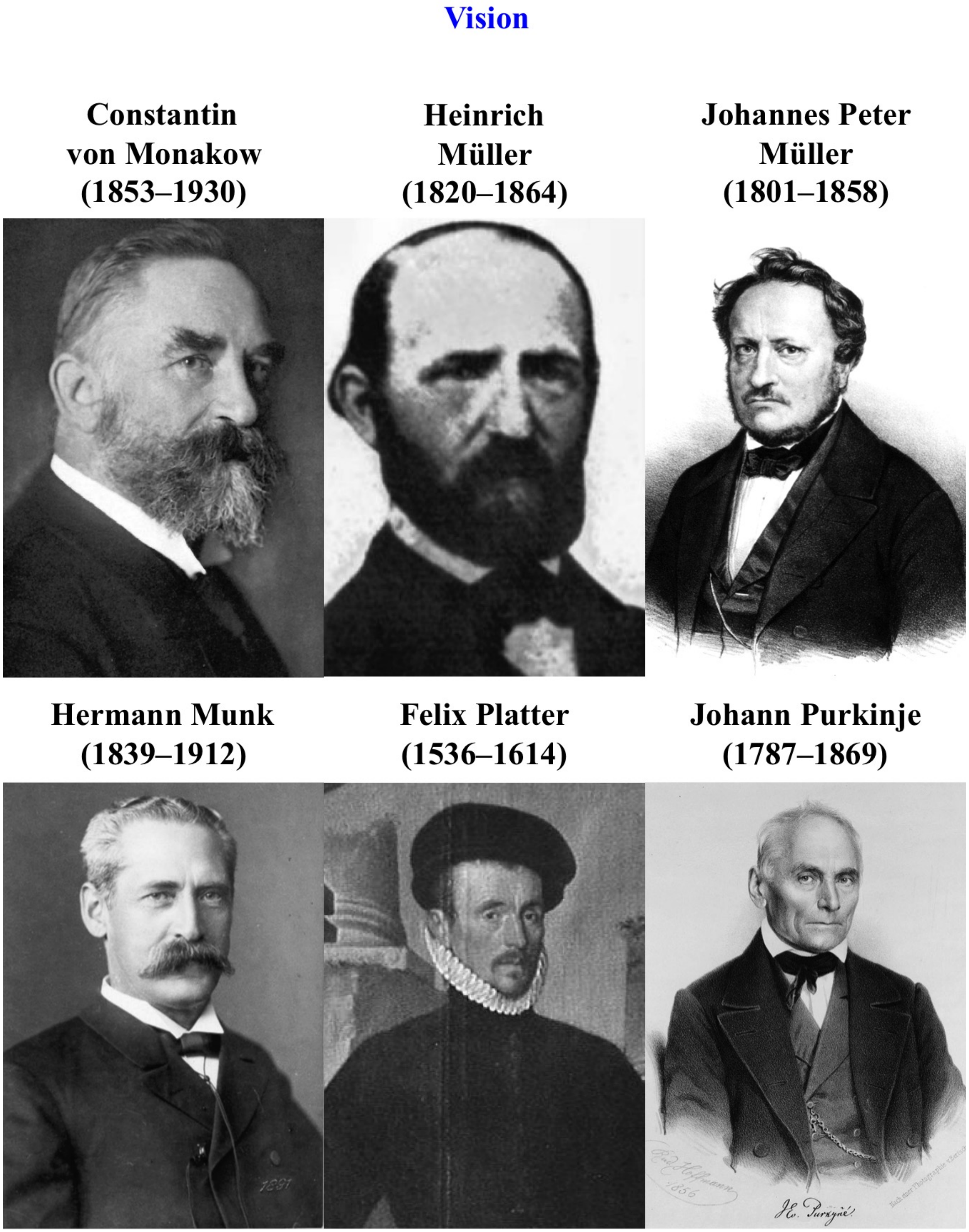
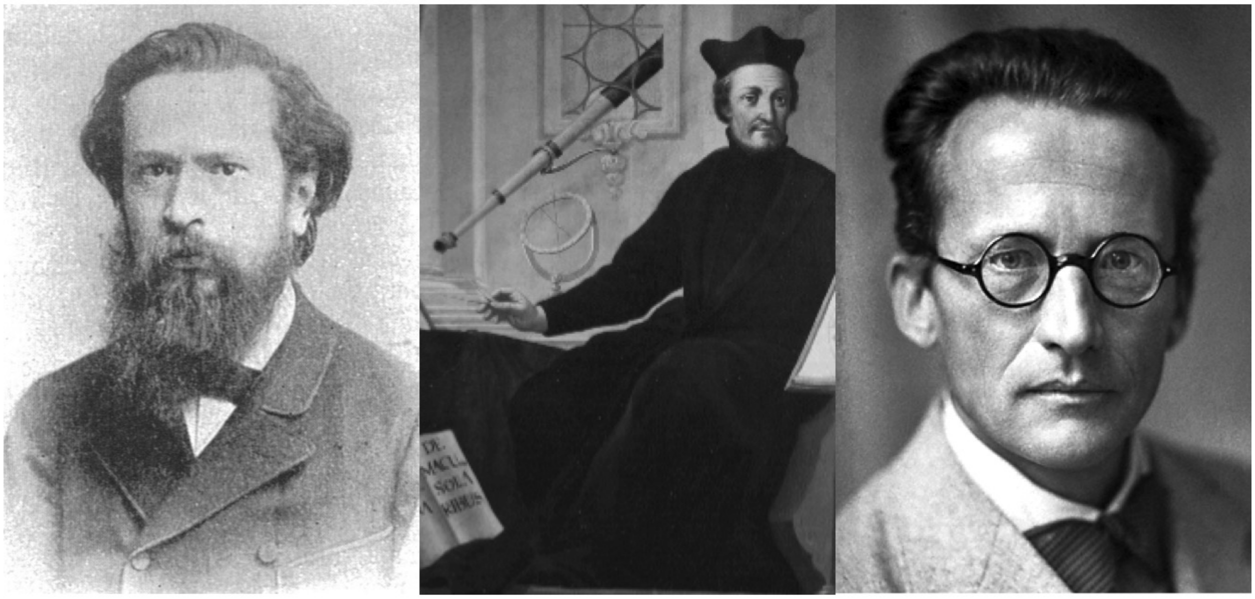

Vision
Constantin von Monakow (1853–1930)
Heinrich Müller (1820–1864)
Johannes Peter Müller (1801–1858)
Hermann Munk (1839–1912)
Felix Platter (1536–1614)
Johann Purkinje (1787–1869)
1881
J.E. Purkyně

Figure 2.141: Other creators who made important discoveries regarding vision included Constantin von Monakow, Heinrich Müller, Johannes Peter Müller, Hermann Munk, Felix Platter, and Johann Purkinje.

Vision

August Leopold von Reuss (1841–1924) **Chrisopher Scheiner (1575–1650)** **Erwin Schrödinger (1887–1961)**



Max Schultze (1825–1874) **August Seebeck (1805–1849)** **Samuel Thomas von Sömmerring (1755–1830)**

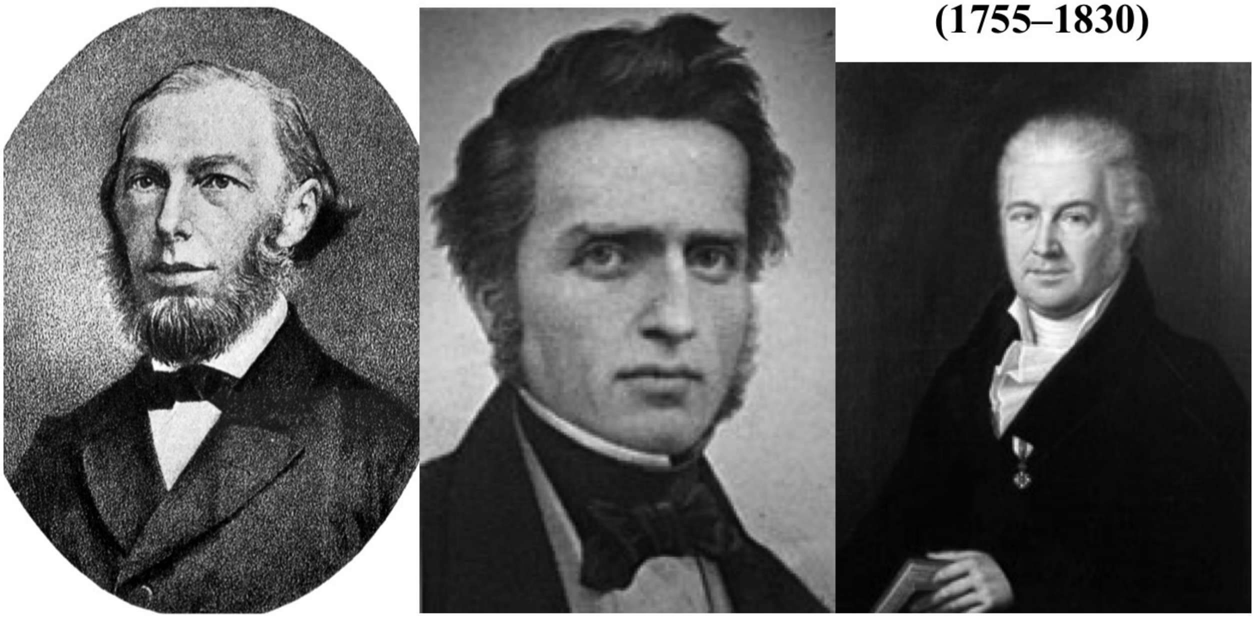


Figure 2.142: Other creators who made important discoveries regarding vision included August Leopold von Reuss, Chrisopher Scheiner, Erwin Schrödinger, Max Schultze, August Seebeck, and Samuel Thomas von Sömmerring.

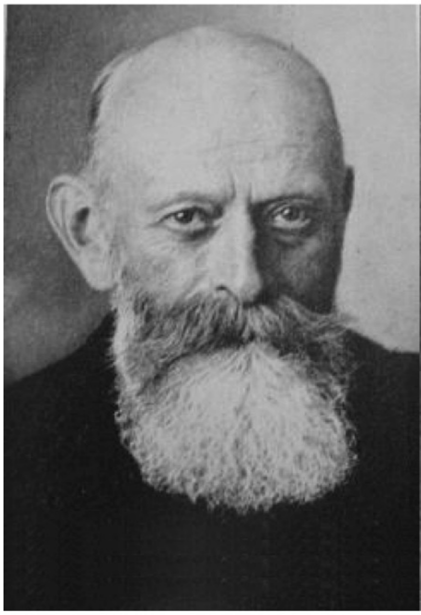
Vision

Johann Spurzheim (1776–1832)

Gottfried Treviranus (1776–1837)

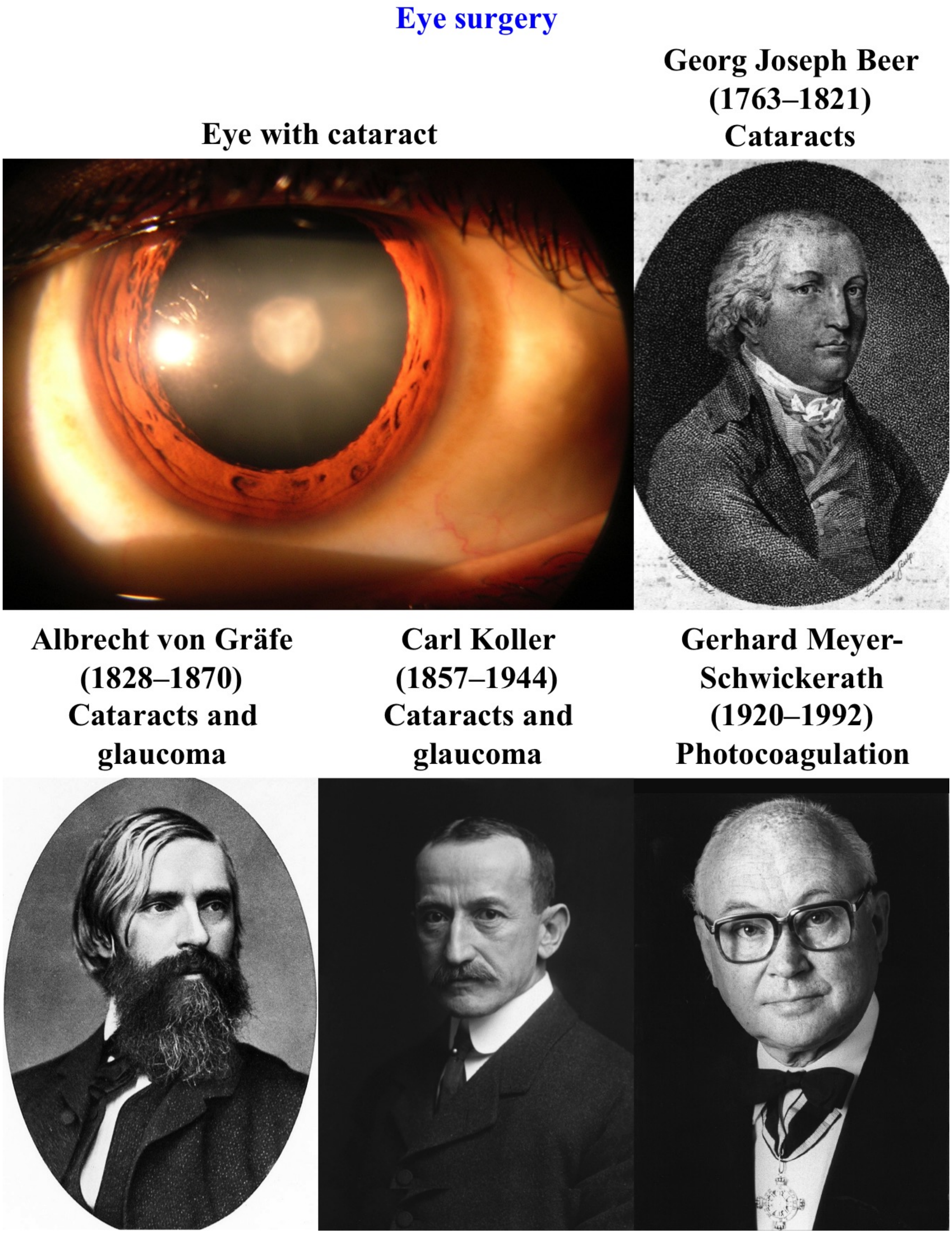
Alfred Wilhelm Volkmann (1801--1877)

Hermann Wilbrand (1851–1935)



Johann Gottfried Zinn (1727–1759)

Figure 2.143: Other creators who made important discoveries regarding vision included Johann Spurzheim, Gottfried Treviranus, Alfred Wilhelm Volkmann, Hermann Wilbrand, and Johann Gottfried Zinn.



Eye surgery

Eye with cataract

Georg Joseph Beer
(1763–1821)
Cataracts

Albrecht von Gräfe
(1828–1870)
Cataracts and glaucoma

Carl Koller
(1857–1944)
Cataracts and glaucoma

Gerhard Meyer-Schwickerath
(1920–1992)
Photocoagulation

Figure 2.144: Scientists from the German-speaking world who made important advances in eye surgery included Georg Beer, Albrecht von Gräfe, Carl Koller, and Gerhard Meyer-Schwickerath.

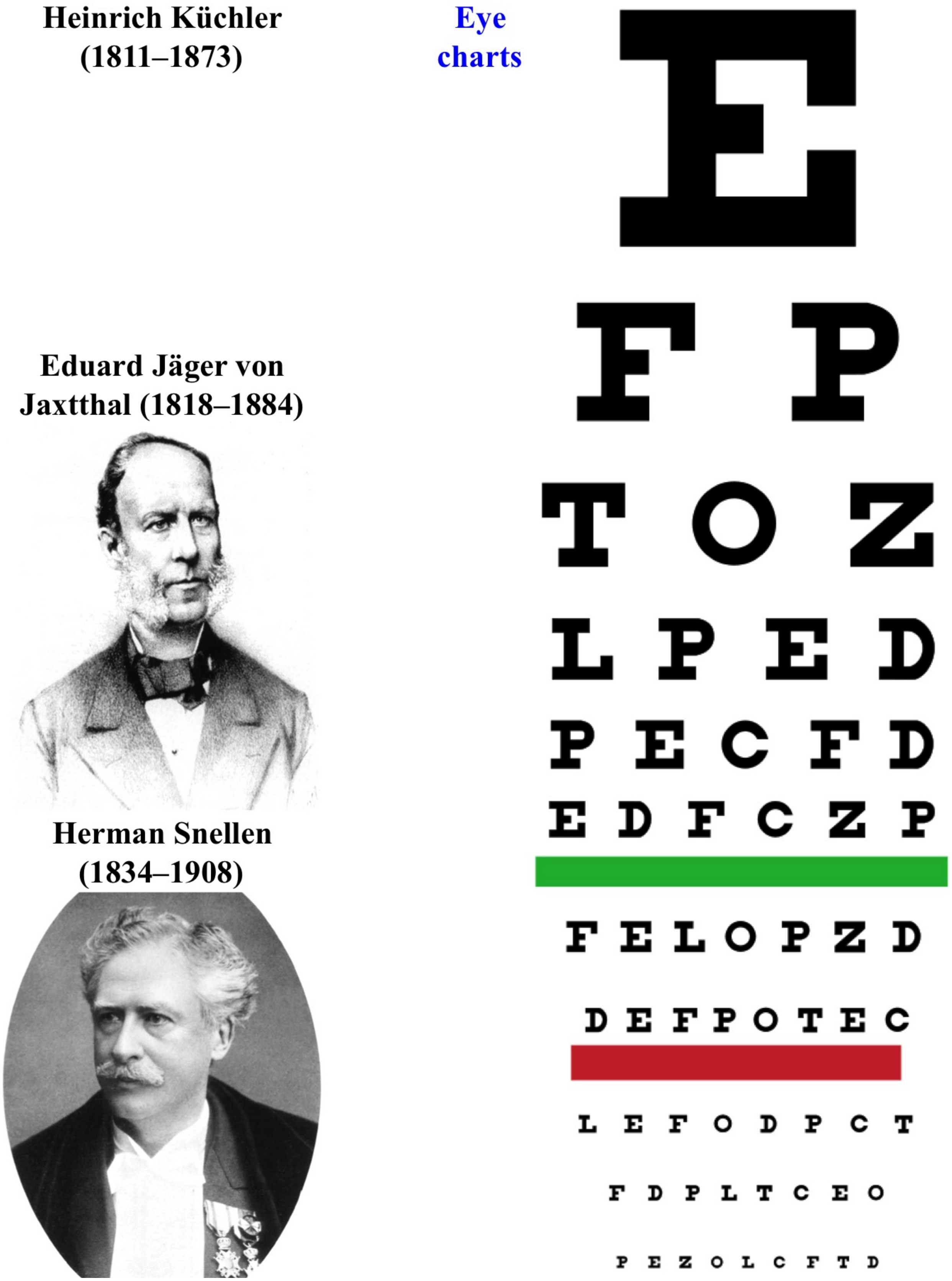

Heinrich Küchler (1811–1873)
Eye charts
Eduard Jäger von Jaxtthal (1818–1884)
Herman Snellen (1834–1908)
E
F P
T O Z
L P E D
P E C F D
E D F C Z P
F E L O P Z D
D E F P O T E C
L E F O D P C T
F D P L T C E O
P E Z O L C F T D

Figure 2.145: Heinrich Küchler, Eduard Jäger von Jaxtthal, and Herman Snellen developed eye charts for measuring visual acuity.

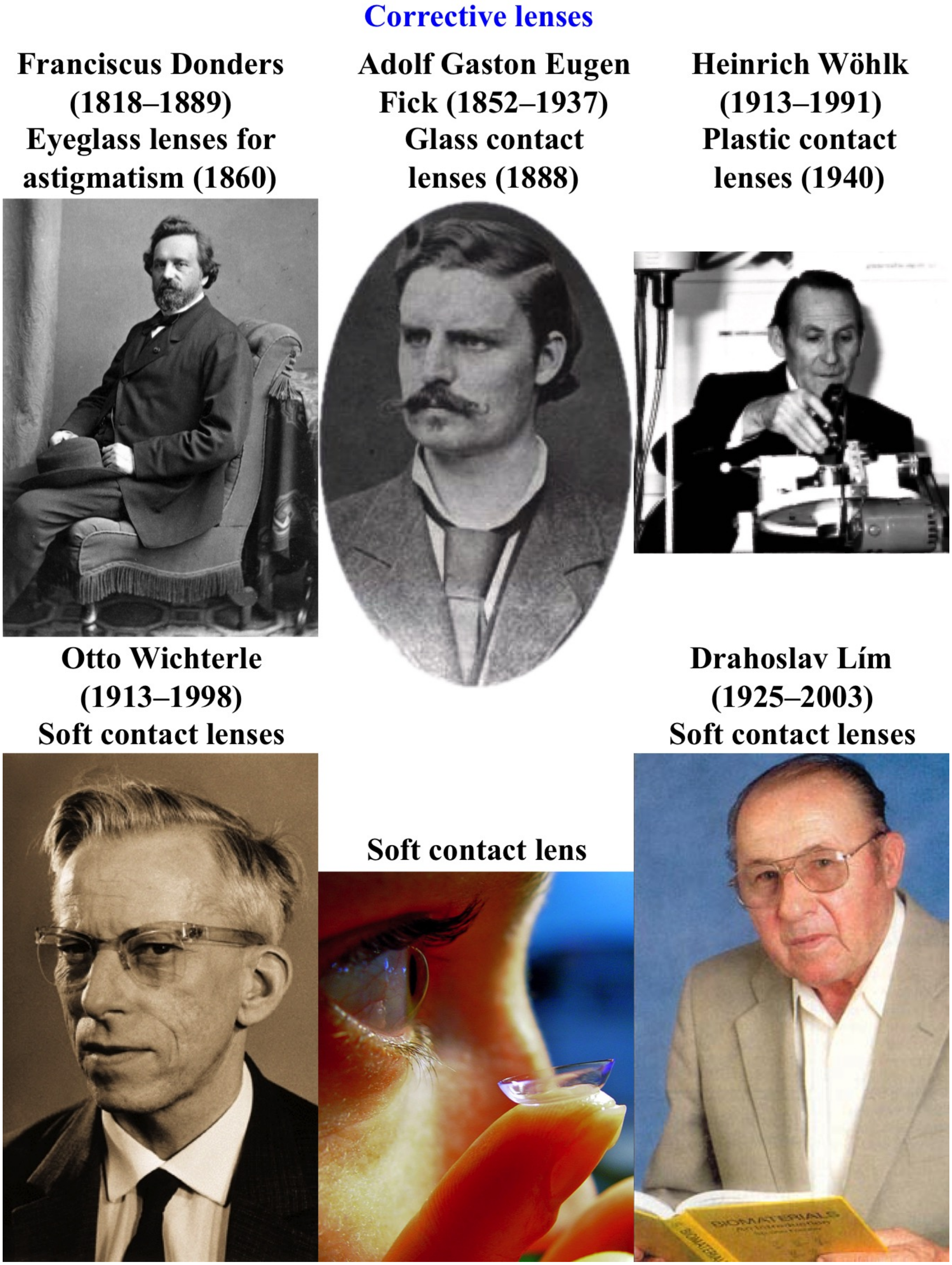

Corrective lenses
Franciscus Donders (1818–1889) Eyeglass lenses for astigmatism (1860)
Adolf Gaston Eugen Fick (1852–1937) Glass contact lenses (1888)
Heinrich Wöhlk (1913–1991) Plastic contact lenses (1940)
Otto Wichterle (1913–1998) Soft contact lenses
Drahoslav Lím (1925–2003) Soft contact lenses
Soft contact lens

Figure 2.146: Scientists from the German-speaking world who helped to develop corrective lenses for vision included Franciscus Donders, Adolf Gaston Eugen Fick, Heinrich Wöhlk, Otto Wichterle, and Drahoslav Lím.

2.3.11 Hearing and Balance

As shown in Fig. 2.147, different structures in the ear provide both the sense of hearing and the sense of balance.

Hearing

Much of the earliest scientific work on ear anatomy was conducted by Italian physicians from the Renaissance and thereafter (perhaps because this area was at the intersection of Renaissance Italy's keen interests in both music and anatomy). However, later scientific work on hearing shifted steadily to the German-speaking world. Creators from the German-speaking world who made important contributions to knowledge about the sense of hearing are shown in Figs. 2.148–2.152.

In 1605, Kaspar Bauhin (Swiss, 1560–1624) proposed that varying cavity sizes within the ear could act as selective resonators to allow different parts of the ear to detect different frequencies of sound waves. That hypothesis later proved to be correct for the cochlea.

Théophile Bonet (Swiss, 1620–1689) conducted or reviewed over 3000 autopsies and reported that hearing loss could be caused by damage to small ossicles, by brain tumors, and by other factors affecting the ear and auditory parts of the brain.

Johannes Bohn (German states, 1640–1718) and Günther Christoph Schelhammer (German states, 1649–1716) separately and correctly realized that sound waves must be transferred from the air to other media in the ear in order to be detected.

Albrecht von Haller (Swiss, 1708–1777) proposed that varying cavity sizes within the cochlea in particular could act as selective resonators to allow different parts of the cochlea to detect different frequencies. He also traced the path of nerves from the ear to regions of the brain.

Rudolf Albert von Kölliker (Swiss, 1817–1905) traced nerve connections between the ear and the brain.

Heinrich Adolf Rinne (German states, 1819–1868) studied the processes by which complex sounds are detected by the ear, transmitted through nerves, and reconstructed in the brain.

Friedrich Eduard Rudolf Voltolini (German, 1819–1889) studied the responses of hair cells to sound waves of different frequencies and different amplitudes.

Hermann von Helmholtz (German, 1821–1894) conducted experimental and theoretical work to demonstrate in detail how varying cavity sizes within the cochlea could act as selective resonators to allow different parts of the cochlea to detect different frequencies.

In 1851, Ernst Heinrich Weber (German, 1795–1878) correctly analyzed, synthesized, and reported all the available information to date on how sound waves were transmitted through air, the ear drum, the ossicles, and the fluid in the cochlea in order to be detected.

Also in 1851, Ernst Reissner (Baltic German, 1824–1878) discovered the membrane in the cochlea that is now called Reissner's membrane. In addition, he studied the development of the ear in animal embryos.

In 1858, Max Schultze (German, 1825–1874) traced the auditory nerve fibers to hair cell regions of the cochlea.

Otto Friedrich Karl Deiters (German states, 1834–1863), Paul Flechsig (German, 1847–1929), Constantin von Monakow (Russian, studied and worked in Switzerland, 1853–1930), Hans Held (German, 1866–1942), and Stjepan Poljak/Stephen Polyak (Austrian/Croatian, 1889–1955) worked individually to trace in detail the nerve connections between the ear and the brain.

Christian Andreas Victor Hensen (German, 1835–1924) discovered what is now called Hensen's duct or canal in the ear. He also measured vibrations in the membrane of the cochlea.

In 1864, Adam Politzer (Austrian, 1835–1920) made automated chart recordings of vibrations in the ossicles induced by sound waves.

Ernst Mach (Austrian, 1838–1916) studied several aspects of the ear, hearing, and sound waves, including conducting experiments on how the brain can focus on particular sounds or voices out of many simultaneous ones.

Hermann Munk (German, 1839–1912) conducted experiments on the regions of the brain that analyze signals from the ears. Adolf Beck (Polish/Austrian, 1863–1942) placed electrodes in dogs' brains to measure the electrical signals that were stimulated by sounds that the dogs heard.

Carl Hasse (German, 1841–1922), Ernst Julius Richard Ewald (German, 1855–1921), and Max Friedrich Meyer (German, 1873–1967) separately conducted experiments to study how the membrane and hair cells of the cochlea detect different frequencies and amplitudes of sound waves.

Beginning in 1890, J. Habermann (German?, 18??–19??) conducted human autopsies to identify the mechanisms by which loud sounds cause hearing damage. In 1907, Karl Wittmaack (German, 1876–1972) used guinea pigs to confirm the mechanisms of hearing damage by loud sounds.

Georg von Békésy (Hungarian, 1899–1972) used strobe photography to study cochlear function in great detail. For that work, he won the Nobel Prize in Physiology or Medicine in 1961. Professor C.G. Bernhard of the Royal Caroline Institute explained von Békésy's research [https://www.nobelprize.org/prizes/medicine/1961/ceremony-speech/]:

> Von Békésy has provided us with the knowledge of the physical events at all strategically important points in the transmission system of the ear. This does not mean that the properties of the oscillating systems of the ear have not been an object of study and theoretical considerations by scientists before von Békésy. The field of physiological acoustics has a noble ancestry, in which the theories of von Helmholtz hold an authoritative position.
>
> Von Békésy's distinction is, however, to have recorded the events in this fragile biological miniature system. Authorities in this field evaluate the elaborate technique which he developed for this purpose as being worthy of a genius. By microdissection he reaches anatomical structures difficult of access, uses advanced teletechnique for stimulation and recording, and employs high magnification stroboscopic microscopy for making apparent complex membrane movements, the amplitudes of which are measured in thousandths of the millimeter.
>
> Among von Békésy's important contributions to our knowledge of sound transmission in the middle ear should be mentioned the elucidation of the vibration patterns of the eardrum and of the interplay of the ossicle movements. His technical and theoretical mastery has reached its peak in those investigations which led to the fundamental

> discoveries concerning the dynamics of the inner ear. Experimental and clinical data had confirmed von Helmholtz's assumption that the frequency of the sound waves determines the location along the basilar membrane at which stimulation occurs. The physical characteristics of the pattern of the membrane vibrations and the conditions for its appearance had, however, previously only been the object of theoretical considerations. Von Békésy succeeded in unveiling the features of the vibration pattern. He found that movements of the stirrup footplate evoke a wave complex in the basilar membrane, which travels from the stiffer basal part to the more flexible part in the apex of the cochlea. The crest of the largest wave first increases, thereafter quickly decreases. The position of the maximal amplitude was found to be dependent on the frequency of the stimulating sound waves in such a way that the highest crest of the travelling wave appears near the apex of the cochlea at low-frequency tones and near its base at high frequencies. The conditions for the appearance of these specific vibration patterns were determined in model experiments.
>
> Von Békésy then turned to the question of how the hair cells are stimulated. With a thin needle, the point of which touched the basilar membrane, different parts of the membrane could be set in vibrations in various directions. The point of the needle simultaneously served as an electrode for recording the electrical potentials from the receptor cells. It was found that a local pressure on the basilar membrane is transformed into strong shearing forces which act on the hair cells in various degrees.
>
> Thus, von Békésy has given us a clear picture of how the cochlea functions mechanically and his discoveries serve as a basis for our conception of the cochlea as a frequency analyzer.
>
> We have now reached the last strategic point of the system, that is to say the point at which the mechanical energy is transformed into the physicochemical processes which result in nerve impulses. As in the case of other sense organs, the knowledge about the electrical processes in the inner ear constitutes the foundation for further research. Von Békésy has discovered, on the one hand, the so-called endocochlear potential indicating the existence of a large potential difference over the receptor membrane at rest and, on the other hand, slow potential shifts taking place upon stimulation of the hair cells. These discoveries contribute most significantly to the analysis of the relation between the mechanical and the electrical phenomena in the receptors which are involved in the transformation of sound into nerve impulses.
>
> The work of von Békésy has greatly influenced the development of audiology and its clinical application. Thus, the development of refined diagnostic methods has made possible great advances in the treatment of diseases of the ear.

Karl Eberhard Zwicker (German, 1924–1990) investigated how the brain analyzes sounds, and he also conducted further studies of cochlear function.

German-speaking scientists also invented electric hearing aids, as shown in Fig. 2.153. Werner von Siemens invented the first (non-portable) hearing aid in 1878. At the Siemens company, Louis Weber invented the first compact portable hearing aid in 1911. The development of microelectronics by German-speaking scientists (Appendix B) ultimately allowed hearing aids to be reduced in size to fit entirely within the ear.

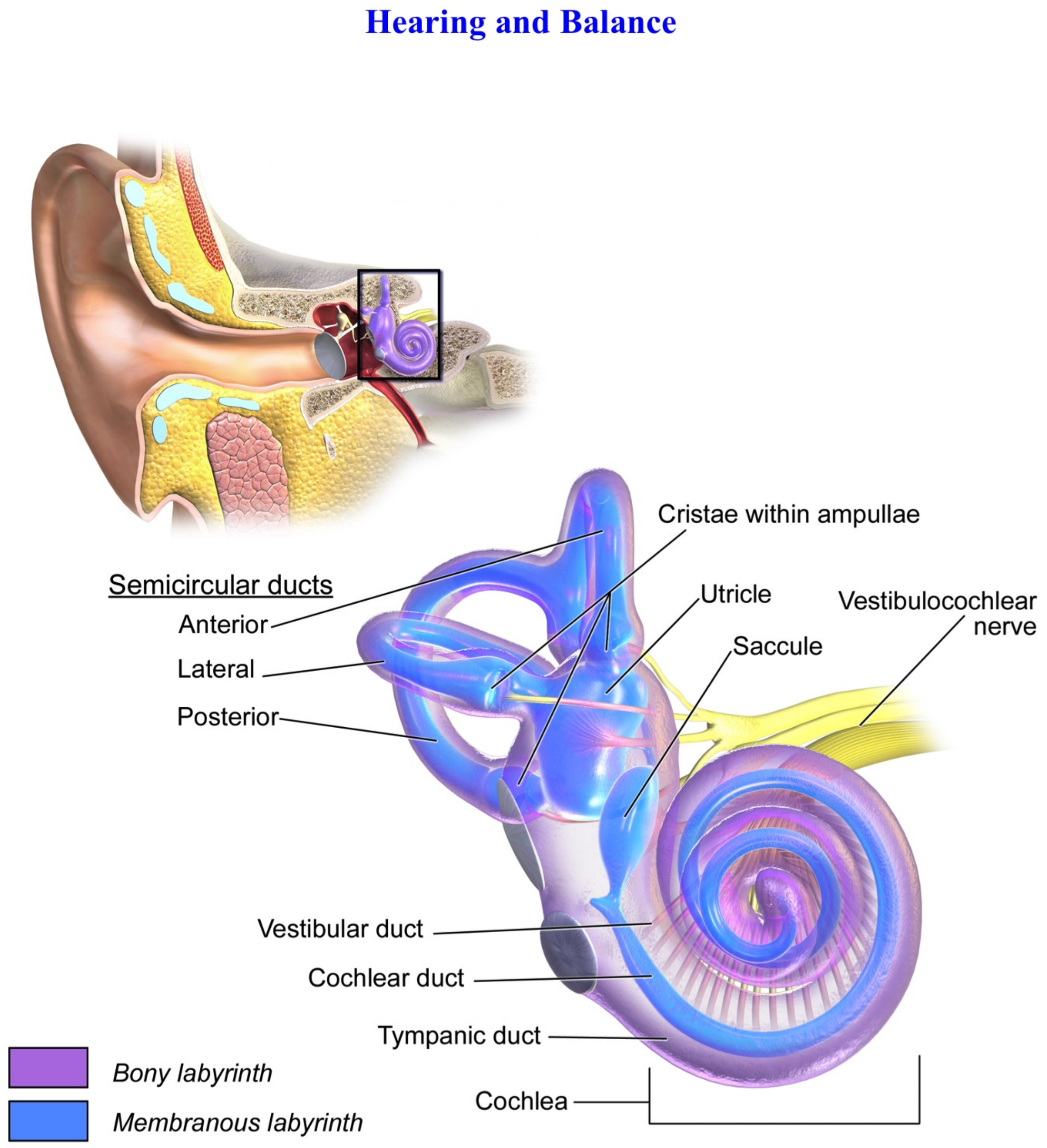
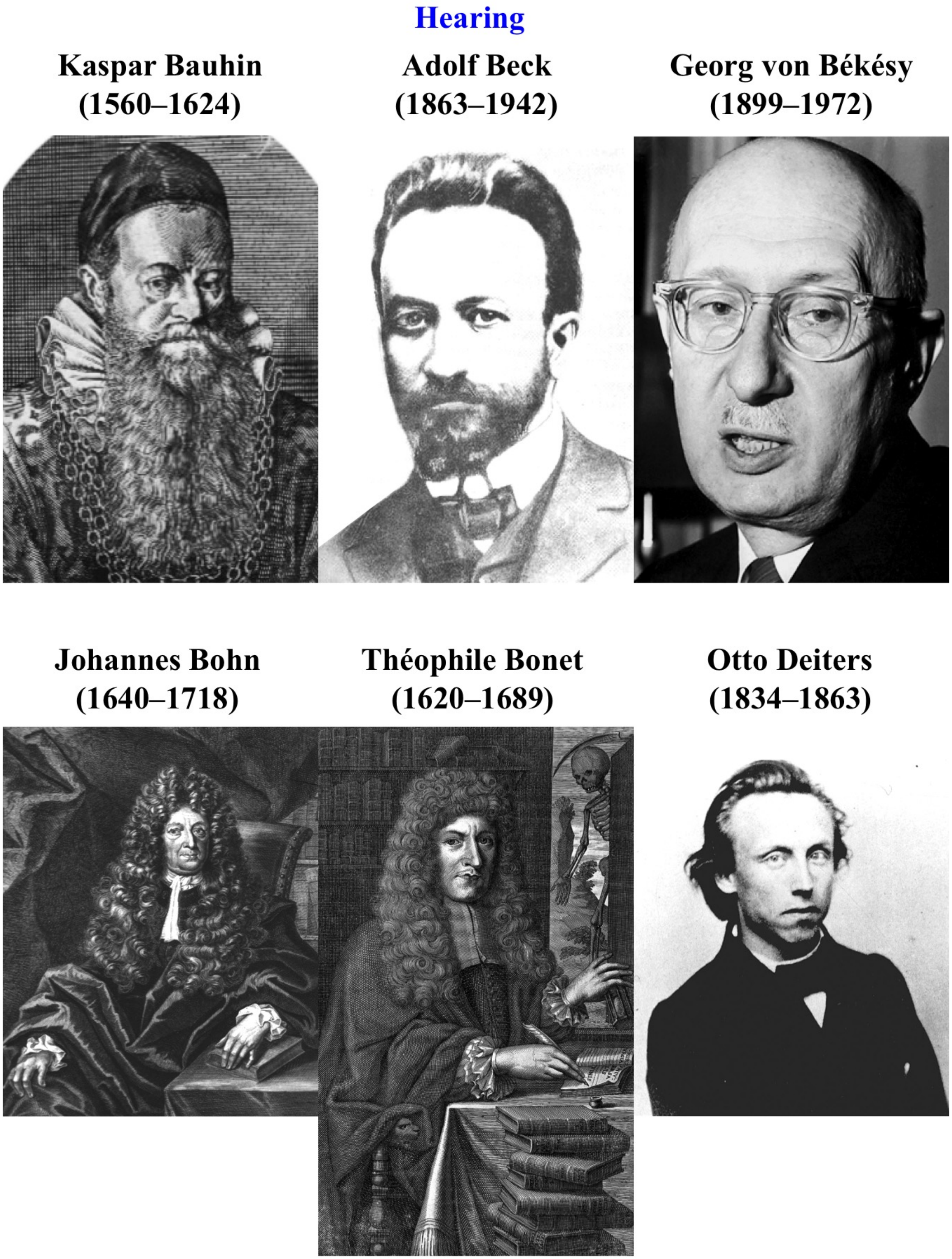

Hearing and Balance
Cristae within ampullae
Semicircular ducts
Anterior
Lateral
Posterior
Utricle
Saccule
Vestibulocochlear nerve
Vestibular duct
Cochlear duct
Tympanic duct
Cochlea
Bony labyrinth
Membranous labyrinth

Figure 2.147: Different structures in the ear provide both the sense of hearing and the sense of balance.



Hearing

Kaspar Bauhin (1560–1624)

Adolf Beck (1863–1942)

Georg von Békésy (1899–1972)

Johannes Bohn (1640–1718)

Théophile Bonet (1620–1689)

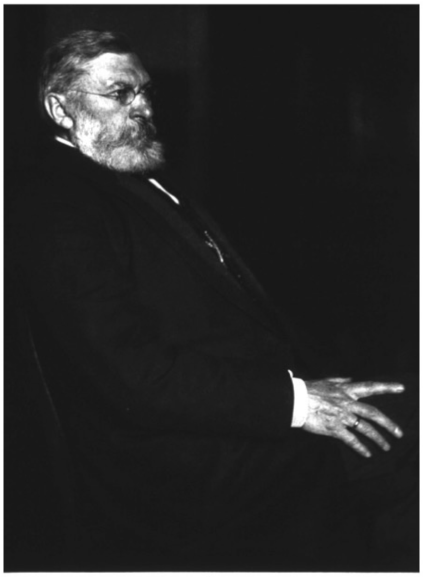
Otto Deiters (1834–1863)

Figure 2.148: Creators who made important contributions to knowledge about the sense of hearing included Kaspar Bauhin, Adolf Beck, Georg von Békésy, Johannes Bohn, Théophile Bonet, and Otto Deiters.

Hearing

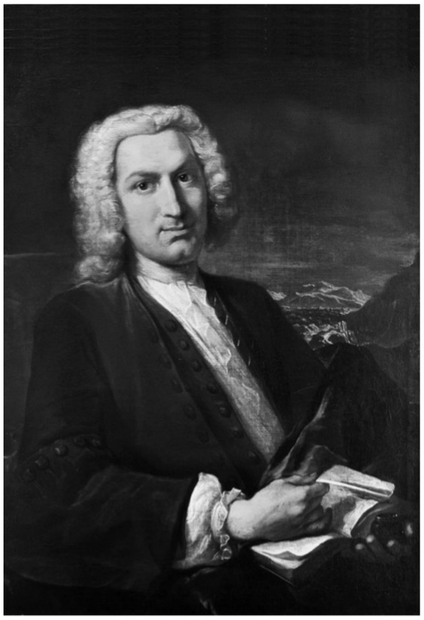
Ernst Ewald
(1855–1921)

Paul Flechsig
(1847–1929)



J. Habermann
(18??–19??)

Albrecht von Haller
(1708–1777)



Carl Hasse
(1841–1922)

Hans Held
(1866–1942)

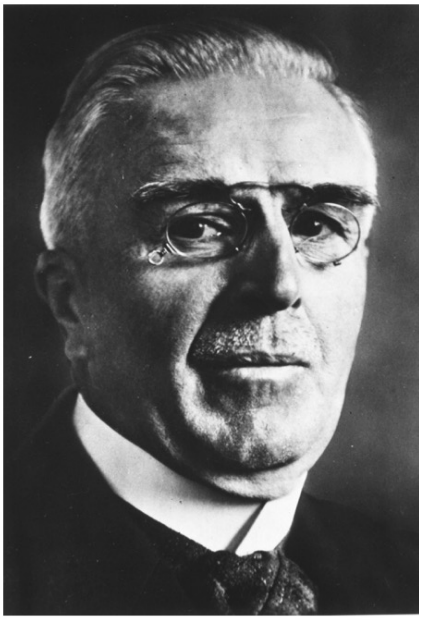
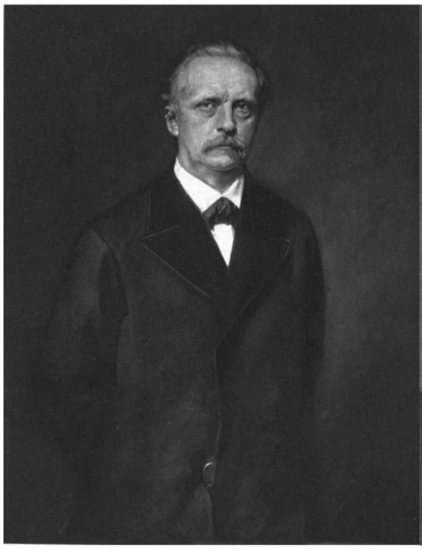


Figure 2.149: Creators who made important contributions to knowledge about the sense of hearing included Ernst Ewald, Paul Flechsig, J. Habermann, Albrecht von Haller, Carl Hasse, and Hans Held.

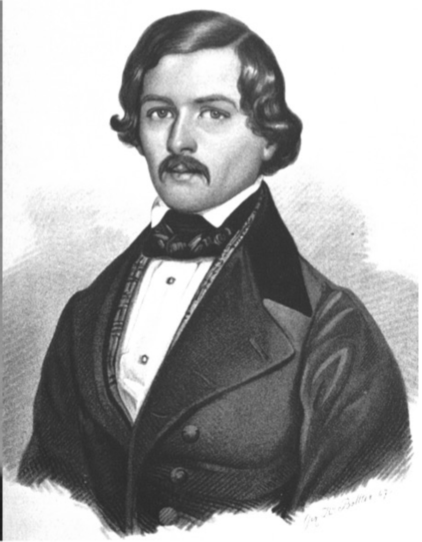
Hearing

Hermann
von Helmholtz
(1821–1894)



Christian Andreas
Victor Hensen
(1835–1924)

Rudolf Albert
von Kölliker
(1817–1905)



Ernst
Mach
(1838–1916)

Max Friedrich
Meyer
(1873–1967)

Constantin
von Monakow
(1853–1930)

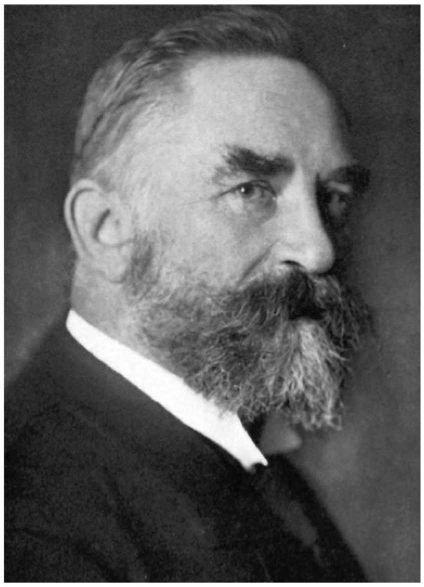


Figure 2.150: Creators who made important contributions to knowledge about the sense of hearing included Hermann von Helmholtz, Christian Andreas Victor Hensen, Rudolf Albert von Kölliker, Ernst Mach, Max Friedrich Meyer, and Constantin von Monakow.

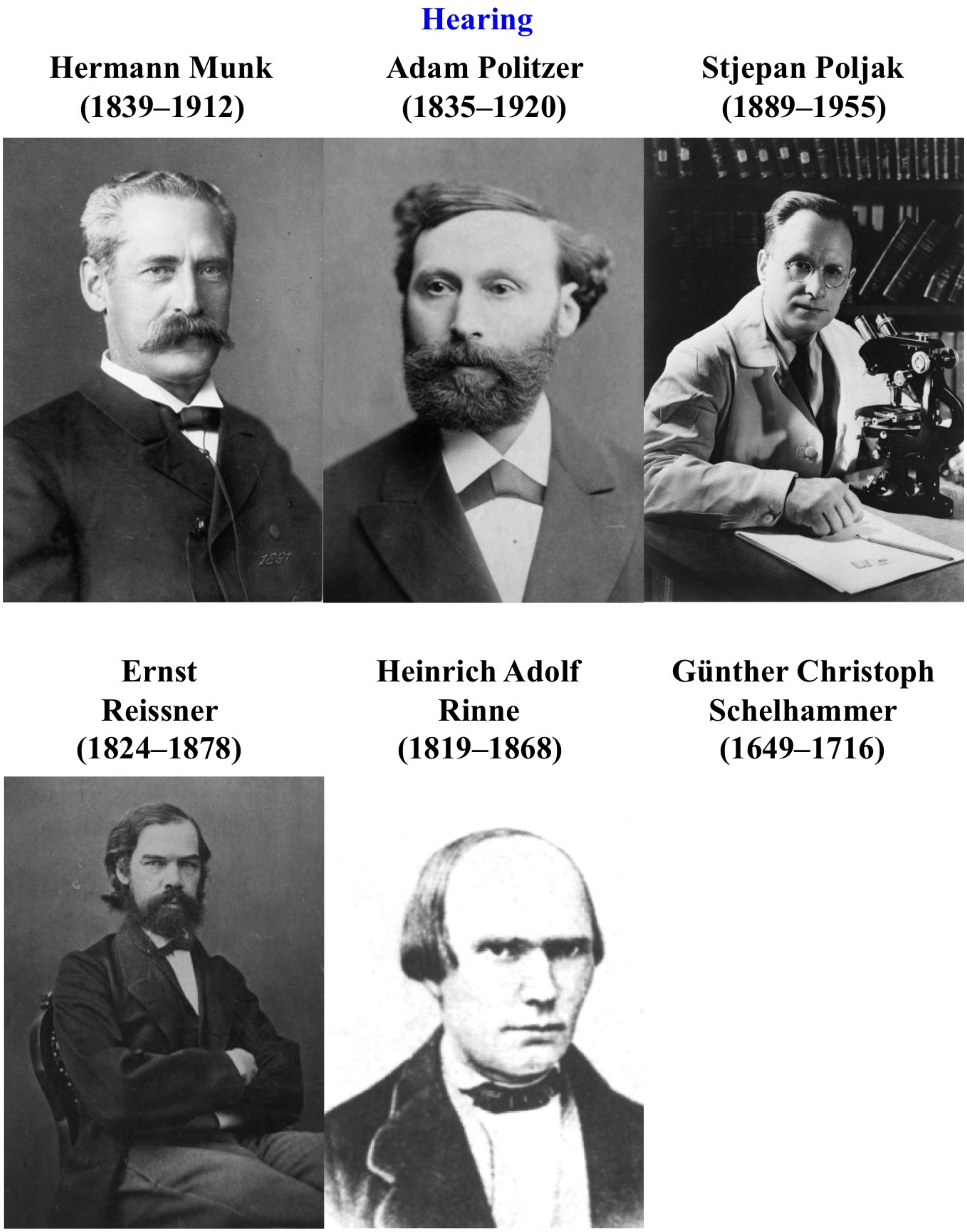

Hearing
Hermann Munk (1839–1912)
Adam Politzer (1835–1920)
Stjepan Poljak (1889–1955)
Ernst Reissner (1824–1878)
Heinrich Adolf Rinne (1819–1868)
Günther Christoph Schelhammer (1649–1716)

Figure 2.151: Creators who made important contributions to knowledge about the sense of hearing included Hermann Munk, Adam Politzer, Stjepan Poljak, Ernst Reissner, Heinrich Adolf Rinne, and Günther Christoph Schelhammer.

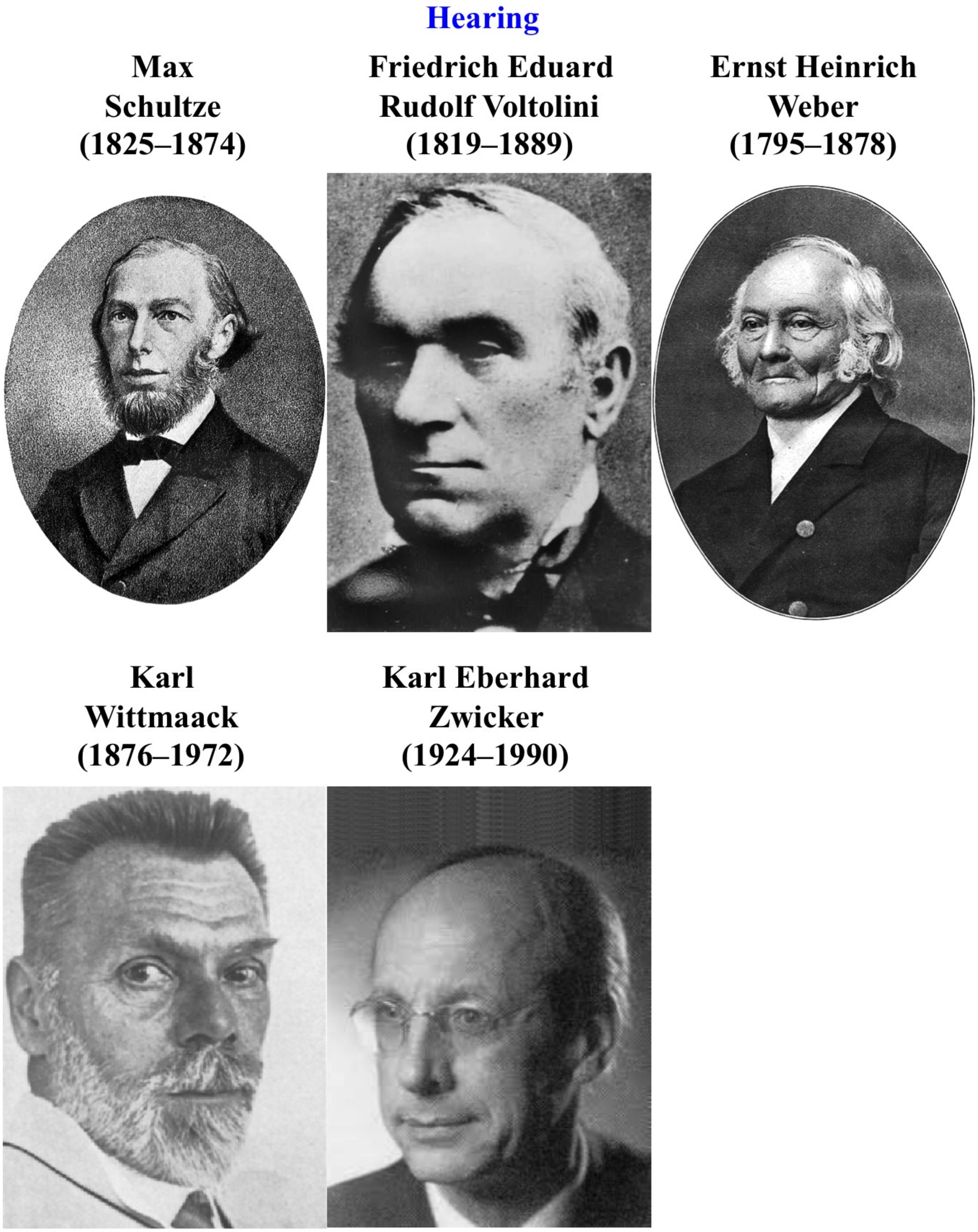
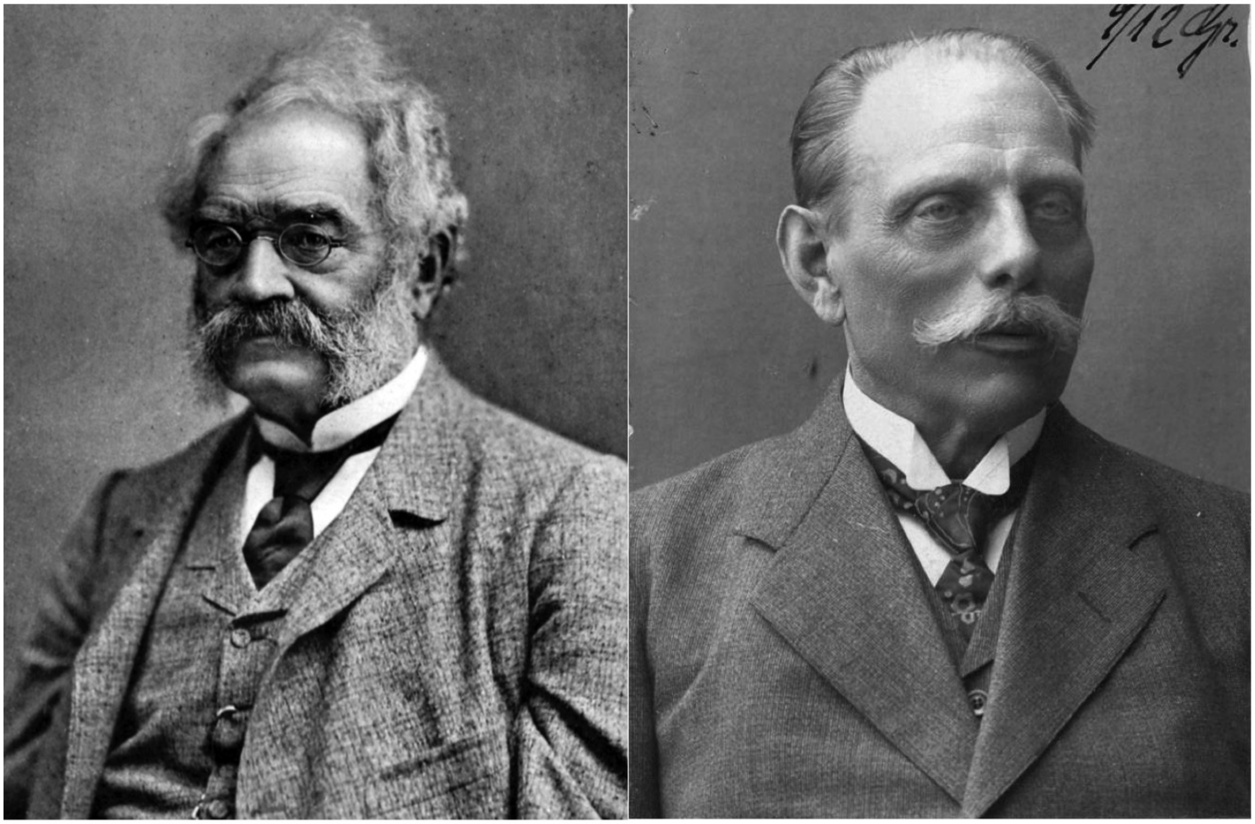

Hearing
Max Schultze (1825–1874)
Friedrich Eduard Rudolf Voltolini (1819–1889)
Ernst Heinrich Weber (1795–1878)
Karl Wittmaack (1876–1972)
Karl Eberhard Zwicker (1924–1990)

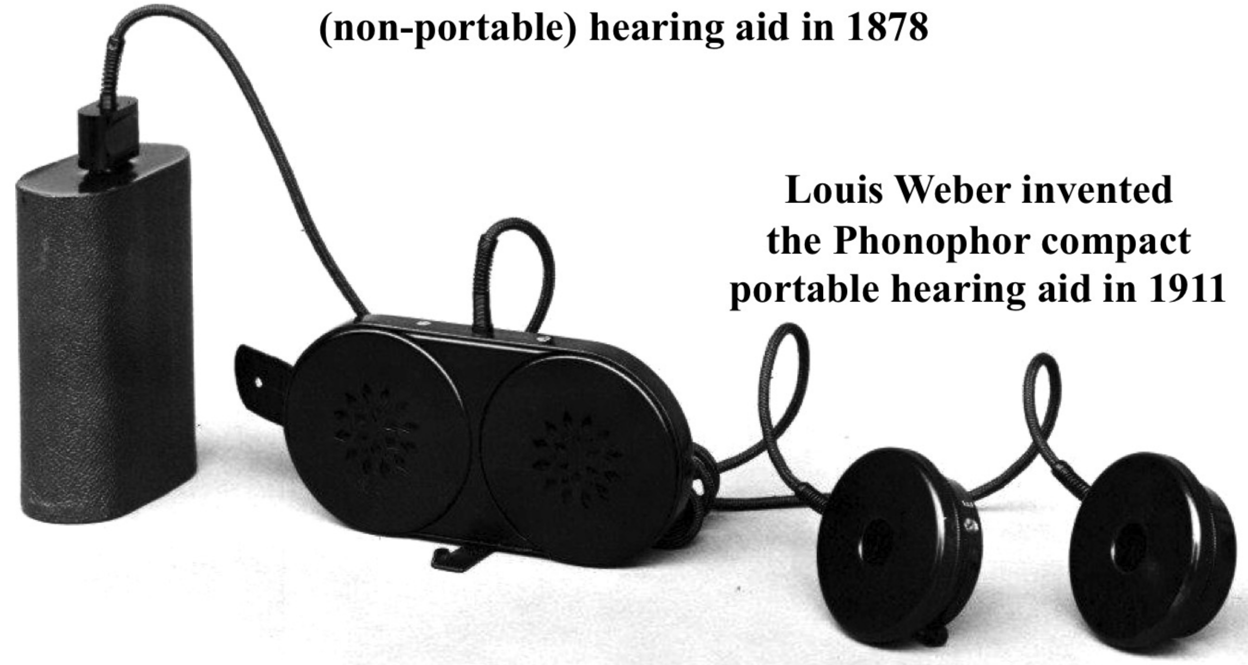
Figure 2.152: Creators who made important contributions to knowledge about the sense of hearing included Max Schultze, Friedrich Eduard Rudolf Voltolini, Ernst Heinrich Weber, Karl Wittmaack, and Karl Eberhard Zwicker.

Electric hearing aids

Werner von Siemens (1816–1892) **Louis Weber (18??–19??)**



Werner von Siemens invented the first (non-portable) hearing aid in 1878



Louis Weber invented
the Phonophor compact
portable hearing aid in 1911

Figure 2.153: Werner von Siemens invented the first (non-portable) hearing aid in 1878. At the Siemens company, Louis Weber invented the first compact portable hearing aid in 1911.

Balance

As shown in Fig. 2.154, major discoveries regarding the sense of balance or vestibular system were entirely dominated by creators from the German-speaking world.

In 1870, Friedrich Goltz (German, 1834–1902) discovered that the semicircular canals in the inner ear sense balance and position and transmit that information to the brain.

In 1873, Ernst Mach (Austrian, 1838–1916) and Josef Breuer (Austrian, 1842–1925), working independently of each other, both determined how fluid motion in the semicircular canals detects balance and position.

Ernst Julius Richard Ewald (German, 1855–1921) conducted experiments on the semicircular canals of pigeons to study the details of their fluid flow and detection.

Róbert Bárány (Austro-Hungarian, 1876–1936) measured the effects of temperature on fluid flow and thus sensation in the semicircular canals of human patients. For that research, he won the Nobel Prize in Physiology or Medicine in 1914. Professor G. Holmgren of the Caroline Institute praised Bárány's research as well as the earlier discoveries of Breuer and Ewald [https://www.nobelprize.org/prizes/medicine/1914/press-release/]:

> Later, a number of physiologists, especially Breuer and Ewald, studied the physiology of the inner ear and increased our knowledge of it in a high degree. Otologists also made daily observations in this field without, however, appreciating their significance and adapting them to the service of otology.
>
> After Bárány, in May 1905, had communicated his observations on caloric nystagmus to the Austrian Otological Society, there followed during the next ten years a tremendous, almost revolutionary development of otology, in which Bárány's work was both the foundation and the central theme; many other research workers also contributed, in particular the younger generation of otologists in Vienna (Alexander, Neumann, Ruttin and others).
>
> The starting-point of the work appeared, at first, to be quite simple. For a long time otologists had been aware that the syringing of a patient's ears often caused dizziness—some doctors had even observed nystagmus. But it was not known by what agency this came about or which organ released the phenomenon. Bárány made a systematic study of the question and found that syringing of the ear regularly produced nystagmus of a certain type. This nystagmus was connected with a feeling of giddiness. The explanation came to him quite by chance. A patient whose ears he was syringing said to him one day that he experienced a strong sensation of vertigo when the syringing water was too cold. Bárány then used very warm fluid in the syringe and the patient again complained of severe vertigo. Bárány noted the appearance of nystagmus here too, but its direction was the exact opposite to the one previously observed. The explanation was now clear. The decisive factor was the temperature of the syringing fluid and it was soon also clear that the phenomenon, the so-called caloric reaction, proceeded from the semi-circular canals, in which the endolymph increases in specific gravity with cooling, showing a

tendency to sink, whereas with warming the specific gravity decreases and the fluid shows a tendency to rise. The flux, or tendency to flux, which then appears in the endolymph of the semi-circular canals produces the reaction. [...]

Bárány also studied systematically the other vestibular reactions. He provided an explanation for the vestibular phenomena occurring after rotation which was in sharp contrast to what had been thought before and established the clinical and physiological importance of the so-called rotatory reaction. By means of the so-called fistula test he made the "pneumatic hammer" of the physiologist Ewald available for clinical use and he gave the galvanic reaction the secondary place which it now occupies.

He also studied the remaining phenomena of the vestibular syndrome, both the subjective and the objective ones, and systematized them. Here he was chiefly concerned with developing the question of the so-called vestibular reaction movements. First of all he established that vestibular disturbances of equilibrium, which were already known, occur in a regular manner, in a certain relationship to the existing nystagmus, so that change of position, or tendency to change of position, always occurs in the same plane but in an opposite direction to the existing nystagmus. From this follows the interesting and clinically extraordinarily important fact that existing vestibular imbalance changes direction with an alteration in the head position. These imbalances, which may stem from the muscular apparatus of the trunk, correspond with other analogous phenomena in all the other muscles which are directed by the will. With an appropriate series of experiments it can be shown how each extremity, or part of an extremity, deviates from a certain position, or tends to deviate, in the same plane but in an opposite direction to the nystagmus caused, or already present. This previously quite unknown phenomenon has become, through Bárány's so-called pointing test, an integral part of the examination methods of ear and nerve specialists.

Attempts to explain the phenomena drew Bárány in a new and promising direction leading to important investigations into the function of the cerebellum. Bárány thinks that constant impulses are going out from the cortex of the cerebellum to all the muscles controlled by the will which are thus held in a constant, and under normal circumstances, uniform state of tension (tonus). This tonus is influenced by the stimulation of the vestibular apparatus in the regular manner already indicated. If one applies the simple test (Bárány's so-called pointing test) of raising the outstretched arm from a downward position upwards opposite a suitably situated, fixed object, e.g. a graduated disc (Boivie), it will be found that with repeated attempts every normal individual reaches approximately the same spot each time with either open or closed eyes. If the same test is repeated after stimulation of the vestibular apparatus, i.e. after syringing an ear with cold or warm water, the subject will point wrongly with closed eyes and always in the same way, that is to say, in the same plane in which the nystagmus occurs, but in an opposite direction. The reaction will be the same, mutatis mutandis, if the arm is moved in the horizontal plane or if the test is made with the leg, forearm, lower leg, trunk, head, etc. Bárány has illustrated this in an excellent manner. Let us imagine a horse walking and being led by two stretched reins. The horse can be led out of its direct path either by a stronger pull on one rein or by a loosening of the other. In Bárány's pointing test the cortex of the cerebrum represents the active force—the horse—while the cerebellar cortex supplies the tonus; one must assume that it has a centre for the tonus which is directed against the sagittal axis of the body, i.e. "inwards" and also a centre for the tonus away from this axis, i.e. "outwards". When the arm is directed into the horizontal plane one must assume that, as regards tonus, it is being influenced by one centre for tonus in an upward direction and one for tonus in a downward direction. Consequently one must assume for each joint in the body the presence of four of such tonus centres in the cerebellar cortex, one for each of four possible movement directions. By close study of cases of isolated damage to the cerebellar cortex and by suitable development and adaptation of the Trendelenburg method, by which the cortical centre can be temporarily paralysed by freezing, Bárány also succeeded in establishing the presence and position of some of these centres and thereby inaugurating a kind of topical cerebellar diagnostics of a very promising nature. Although by its very nature this study presents great difficulties, the solution of which requires considerable time, many of the points raised have already been confirmed from different sources, while others must be left open.

After the outbreak of war Bárány's efforts were partly directed into other channels which must be touched upon lightly here although they are not directly within the framework of the work for which the Nobel Prize has been awarded. As a doctor in Przemysl he soon became aware that the usual methods of treating infected cranial wounds gave very unsatisfactory results. In almost all cases where projectiles had penetrated into the brain taking with them infected particles of skin and clothing, infection occurred which sooner or later led to death. Bárány assumed that the so-called open methods of treating wounds generally current at the time were directly favorable to this infection and attempted in suitable cases, after careful cleansing of the cavity, to close the wound with a primary suture, thereby preventing continuing infection from outside. With this method of treatment, which, although Bárány was unaware of it, was also beginning to be used in Germany and, particularly, in France, he obtained immediately a considerable and obvious improvement in his results and when Bárány came back in the middle of the war from a prisoner-of-war camp in Russia he applied himself exclusively to introducing the new method to the surgeons of his own country. At first he met with definite and tough resistance, but, when the experience of other countries became known and when Austrian surgeons had tried the method themselves, when also Bárány's great work on this theme was completed and published, opinion changed and he was able to add another great triumph to those previously achieved.

During the long period which he spent as a prisoner of war without any kind of literature, laboratory facilities or other scientific aids, Bárány was unable to proceed with this great work or with research into the vestibular mechanism. His speculative mind resorted then to the question of consciousness and its anatomical-physiological explanation to which he afterwards related a great part of his work, the first results of which have already been published.

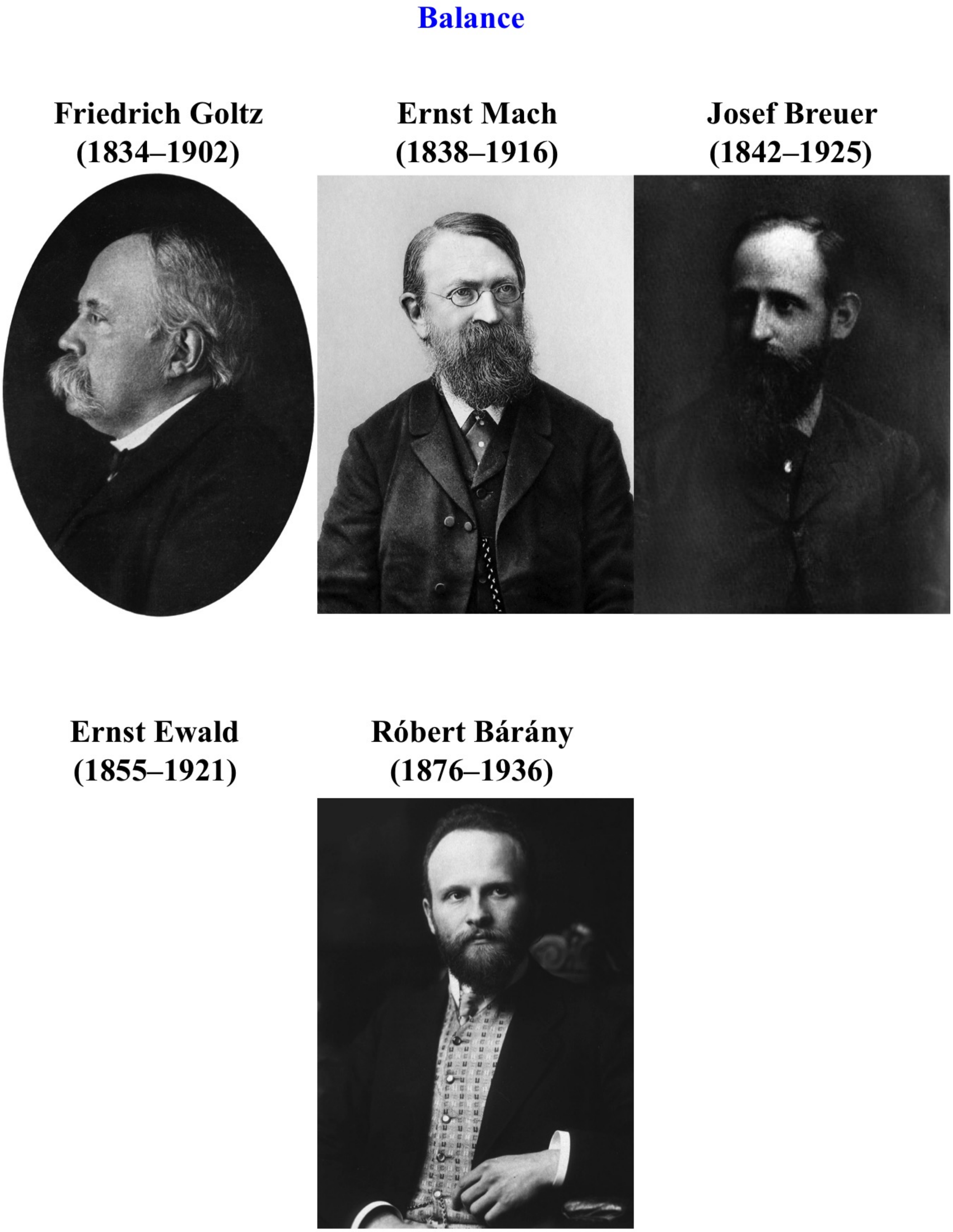

Balance
Friedrich Goltz
(1834–1902)
Ernst Mach
(1838–1916)
Josef Breuer
(1842–1925)
Ernst Ewald
(1855–1921)
Róbert Bárány
(1876–1936)

Figure 2.154: Creators who made important contributions to knowledge about the sense of balance included Friedrich Goltz, Ernst Mach, Josef Breuer, Ernst Ewald, and Róbert Bárány.

2.3.12 Touch

As illustrated in Fig. 2.155, the sense of touch, or somatosensory system, employs a variety of sensory receptor cells that detect pressure, pain, heat, cold, and other stimuli. Most aspects of the somatosensory system were discovered and studied by scientists from the German-speaking world (Figs. 2.155–2.157).

In 1719, Abraham Vater (German states, 1684–1751) identified vibration- and pressure-sensitive corpuscles in the skin, later called Vater-Pacini corpuscles (after Filippo Pacini, who rediscovered them over a century later with much greater fame).

Ernst Heinrich Weber (German, 1795–1878) conducted many experiments on touch and wrote a book on touch in 1834. He developed the two-point method of determining the minimum detectable distance between touched points on different regions the body, measured the sensitivity to changes in touch pressure, and demonstrated how temperature detection interacted with other aspects of the sense of touch.

Johannes Peter Müller (German states, 1801–1858) realized that different types of nerve endings sensed different aspects of touch (pressure, heat, cold, pain, etc.), and wrote about that in his 1840 *Handbuch der Physiologie* [*Handbook of Physiology*].

Rudolf Wagner (German states, 1806–1864) analyzed the sense of touch in his 1844 *Handwörterbuch der Physiologie* [*Dictionary of Physiology*]. Along with Georg Meissner, in 1852 he also discovered Meissner's corpuscles, which detect light touch.

Hermann von Helmholtz (German, 1821–1894) measured the speed of conduction of nerve impulses related to various aspects of the sense of touch.

Moritz Schiff (German, 1823–1896) conducted experiments that differentiated between the detection of touch/pressure and pain, and also studied how those signals were transmitted through the spinal cord.

In 1852, Georg Meissner (German, 1829–1905) as well as Rudolf Wagner discovered Meissner's corpuscles, mechanoreceptors that sense light touch.

Wilhelm Wundt (German, 1832–1920) studied differences in the detection and transmission of touch sensations vs. pain.

In 1859, Wilhelm Krause (German, 1833–1910) discovered Krause's corpuscles or Krause end bulbs, which sense mechanical stimuli in mucous membranes and joints.

In 1875, Friedrich Sigmund Merkel (German, 1845–1919) discovered Merkel discs or Merkel cells, another type of mechanoreceptors that sense light touch.

Maximilian von Frey (Austrian, 1852–1932) conducted experiments to correlate different receptors with different types of touch stimuli.

Alfred Goldscheider (German, 1858–1935) determined specific locations on the skin that had receptors for heat, cold, touch, and pain.

Friedrich Kiesow (German, 1858–1940) identified regions that were sensitive to touch but not to pain.

Otfrid Foerster (German, 1873–1941) published a highly detailed map of dermatomes (regions of the skin connected to the same sensory neuron) in 1933, based on decades of experiments. He also mapped the sensory-motor regions of the cerebral cortex.

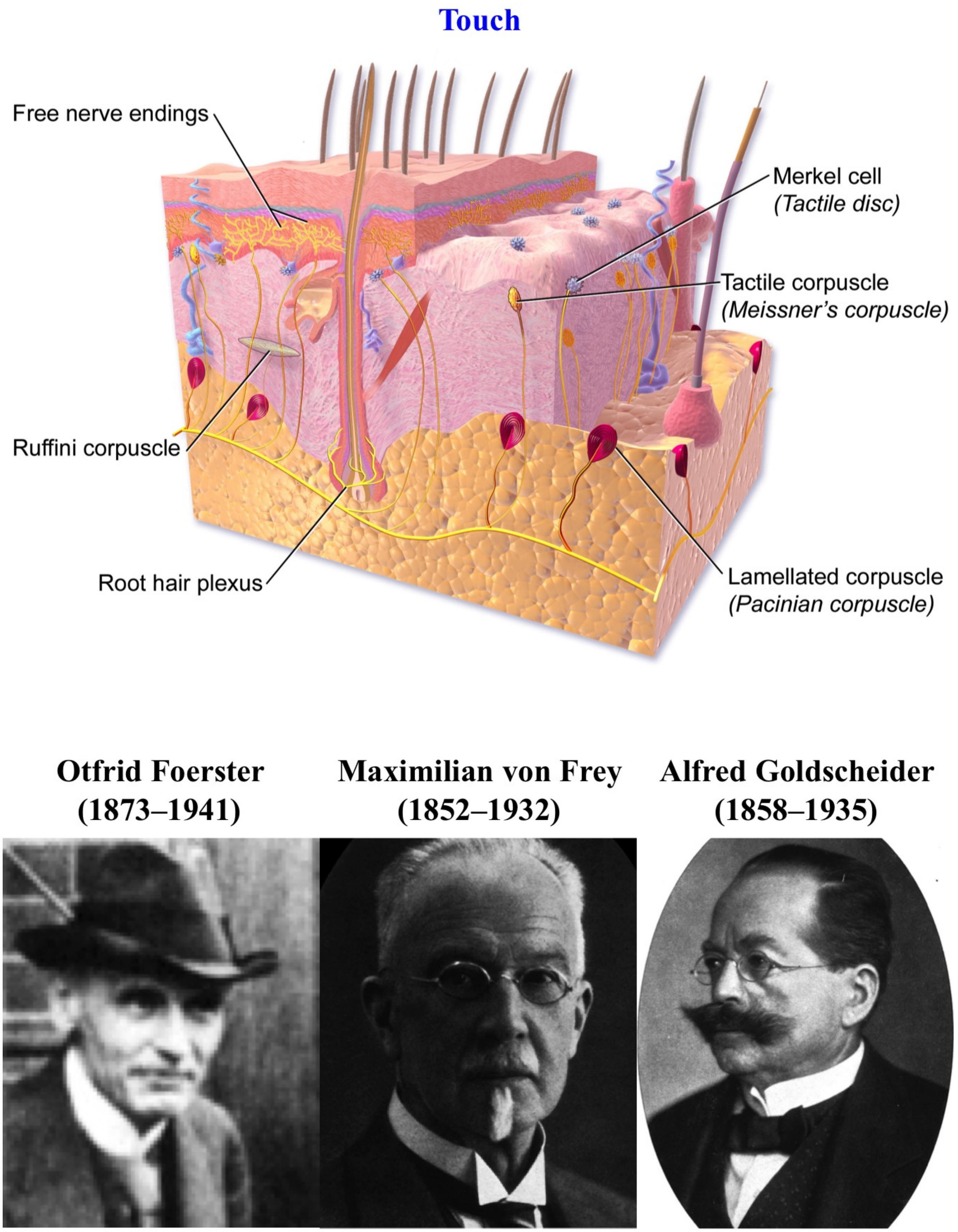
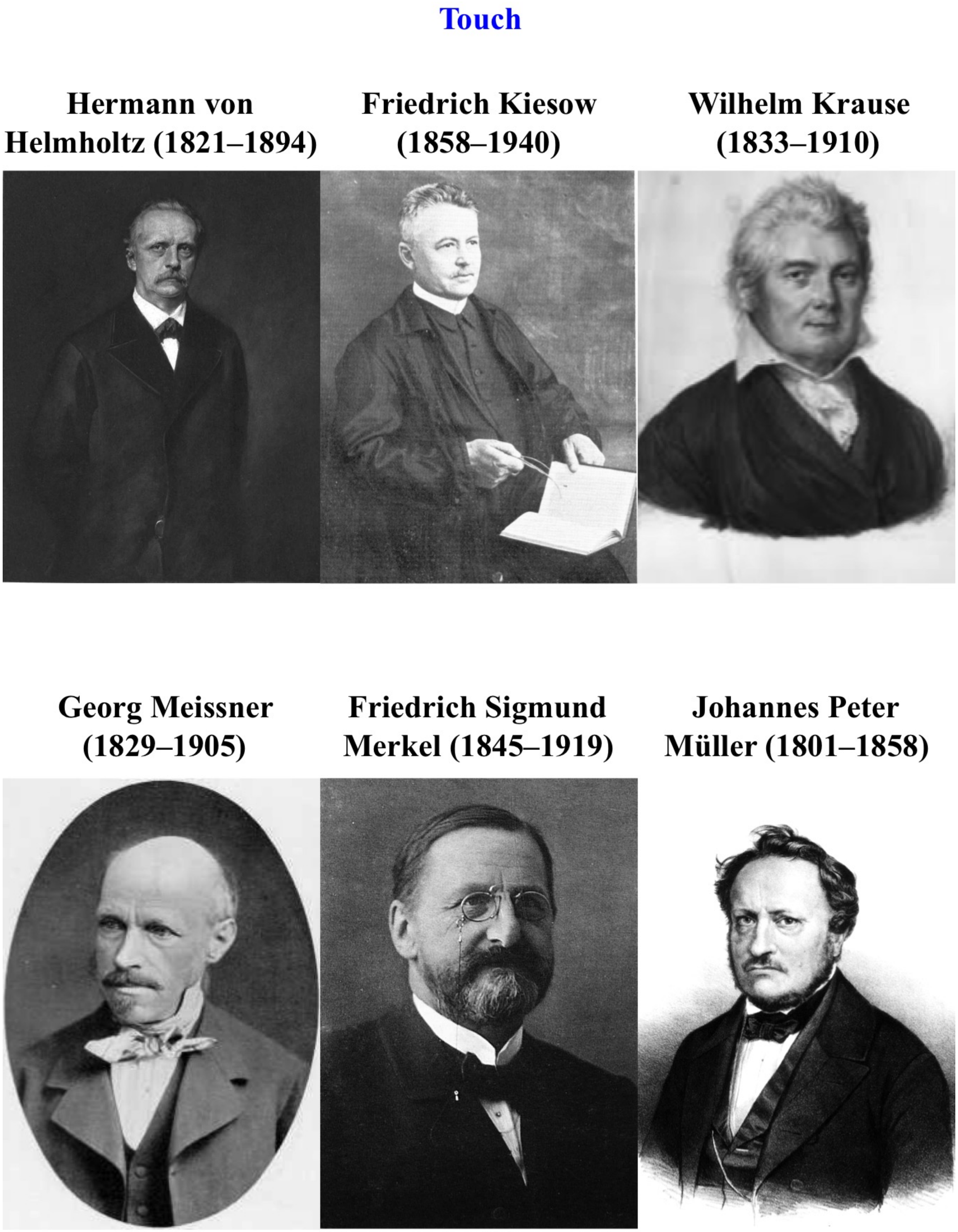

Touch
Free nerve endings
Merkel cell
(Tactile disc)
Tactile corpuscle
(Meissner's corpuscle)
Ruffini corpuscle
Root hair plexus
Lamellated corpuscle
(Pacinian corpuscle)
Otfrid Foerster
(1873–1941)
Maximilian von Frey
(1852–1932)
Alfred Goldscheider
(1858–1935)

Figure 2.155: The sense of touch, or somatosensory system, employs a variety of sensory receptor cells that detect pressure, pain, temperature, and other stimuli. Creators who made important contributions to knowledge about the sense of touch included Otfrid Foerster, Maximilian von Frey, and Alfred Goldscheider.



Touch

Hermann von Helmholtz (1821–1894)

Friedrich Kiesow (1858–1940)

Wilhelm Krause (1833–1910)

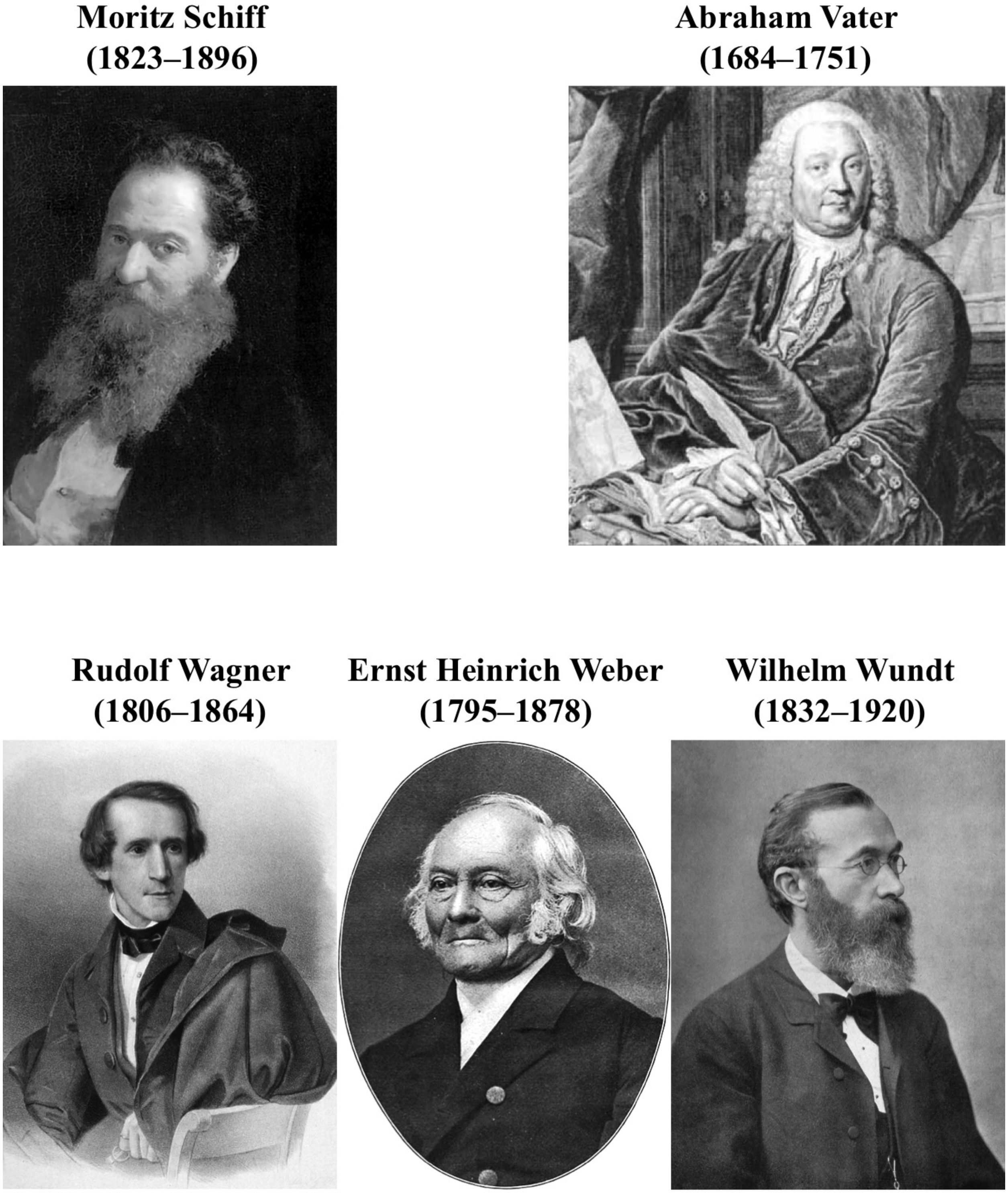
Georg Meissner (1829–1905)

Friedrich Sigmund Merkel (1845–1919)

Johannes Peter Müller (1801–1858)

Figure 2.156: Other creators who made important contributions to knowledge about the sense of touch included Hermann von Helmholtz, Friedrich Kiesow, Wilhelm Krause, Georg Meissner, Friedrich Sigmund Merkel, and Johannes Peter Müller.

Touch



Moritz Schiff (1823–1896)

Abraham Vater (1684–1751)

Rudolf Wagner (1806–1864)

Ernst Heinrich Weber (1795–1878)

Wilhelm Wundt (1832–1920)

Figure 2.157: Other creators who made important contributions to knowledge about the sense of touch included Moritz Schiff, Abraham Vater, Rudolf Wagner, Ernst Heinrich Weber, and Wilhelm Wundt.

2.3.13 Taste

Scientists from the German-speaking world made important contributions to knowledge about the sense of taste or gustation (Figs. 2.158–2.160).

In his 1747 *Primae lineae physiologiae* [*Primer of Physiology*], Albrecht von Haller (Swiss, 1708–1777) classified detectable tastes into categories and proposed that they were detected by specialized structures in the tongue.

In 1752, Johann Sulzer (Swiss, 1720–1779) discovered that electricity from a primitive battery with zinc and copper electrodes could induce sensations of taste in the tongue.

Ernst Heinrich Weber (German, 1795–1878) demonstrated that temperature affects the sensitivity of the tongue to different tastes.

Johannes Peter Müller (German states, 1801–1858) discovered that different fundamental tastes can interact with each other in complex flavors.

Gabriel Valentin (German, 1810–1883) assembled and analyzed information on the sense of taste in his 1844 *Lehrbuch der Physiologie des Menschen* [*Textbook of Human Physiology*] and his 1846 *Grundriss der Physiologie des Menschen* [*Outline of Human Physiology*] .

Maximilian Ritter von Vintschgau (Austrian, 1832–1913) refined the earlier lists of tastes to the primary tastes of sour, sweet, salty, and bitter in 1880.

Wilhelm Wundt (German, 1832–1920) also classified the primary tastes in 1880.

In 1867, Gustav Schwalbe (German, 1844–1916) discovered taste buds in the tongues of humans and other mammals.

Ludimar Hermann (German, 1838–1914) studied the development of taste buds in dogs in 1884.

Napoleon Cybulski (Polish, 1854–1919) and Adolf Beck (Polish/Austrian, 1863–1942) demonstrated that different receptors in the tongue respond to different primary tastes.

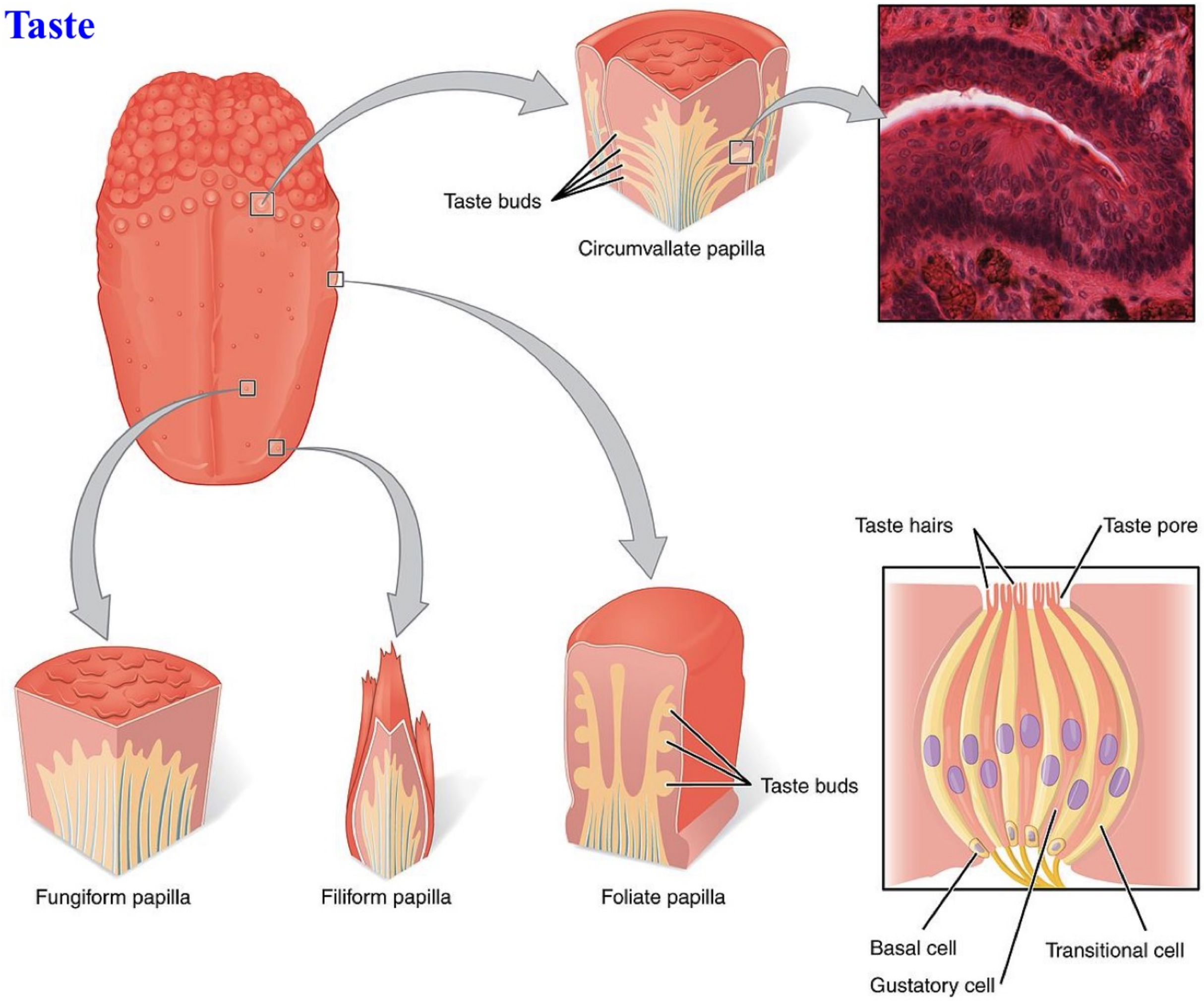
Fedor Krause (German, 1857–1937) traced the nerves carrying signals from the taste buds to the brain.

In 1894, Friedrich Kiesow (German, 1858–1940) showed that the sensory reaction times of the tongue were different for the different primary tastes.

Hans Henning (German, 1885–1946) studied the fundamental tastes and their interactions.

Walter Börnstein (German, 1890–19??) discovered how the brain analyzes taste signals in 1928, and synthesized all of the accumulated data and theories on taste in 1940.

Taste


Taste buds
Circumvallate papilla
Taste hairs
Taste pore
Taste buds
Fungiform papilla
Filiform papilla
Foliate papilla
Basal cell
Gustatory cell
Transitional cell

Adolf Beck
(1863–1942)

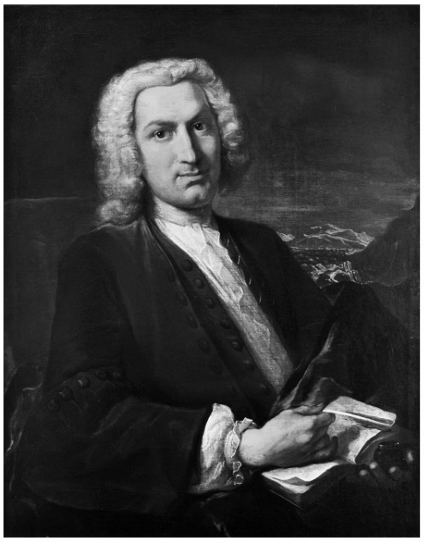
Walter Börnstein
(1890–19??)

Napoleon Cybulski
(1854–1919)

Figure 2.158: Creators who made important contributions to knowledge about the sense of taste included Adolf Beck, Walter Börnstein, and Napoleon Cybulski.

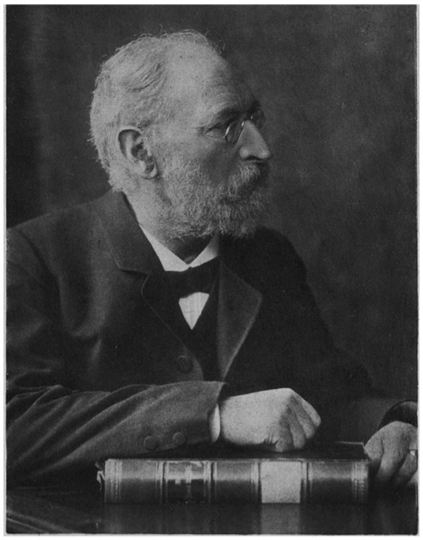
Taste

Albrecht von Haller
(1708–1777)

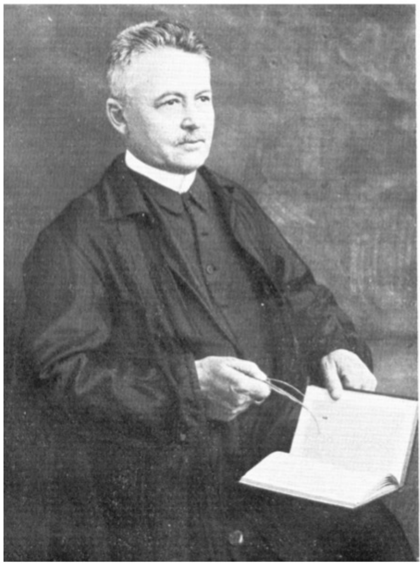


Hans Henning
(1885–1946)

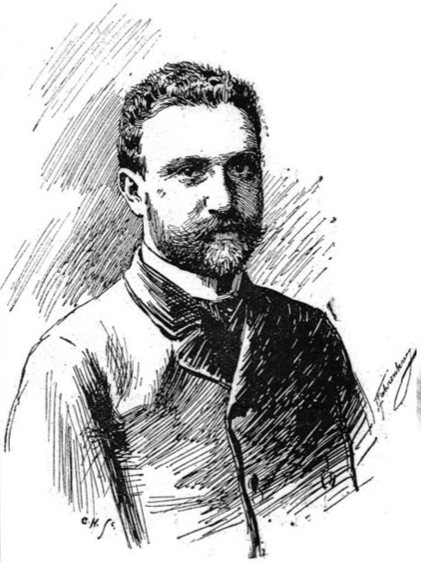
Ludimar Hermann
(1838–1914)



Friedrich Kiesow
(1858--1940)



Fedor Krause
(1857--1937)



Johannes Peter
Müller (1801–1858)

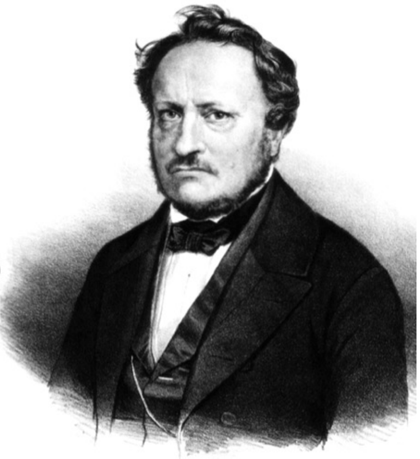


Figure 2.159: Other creators who made important contributions to knowledge about the sense of taste included Albrecht von Haller, Hans Henning, Ludimar Hermann, Friedrich Kiesow, Fedor Krause, and Johannes Peter Müller.

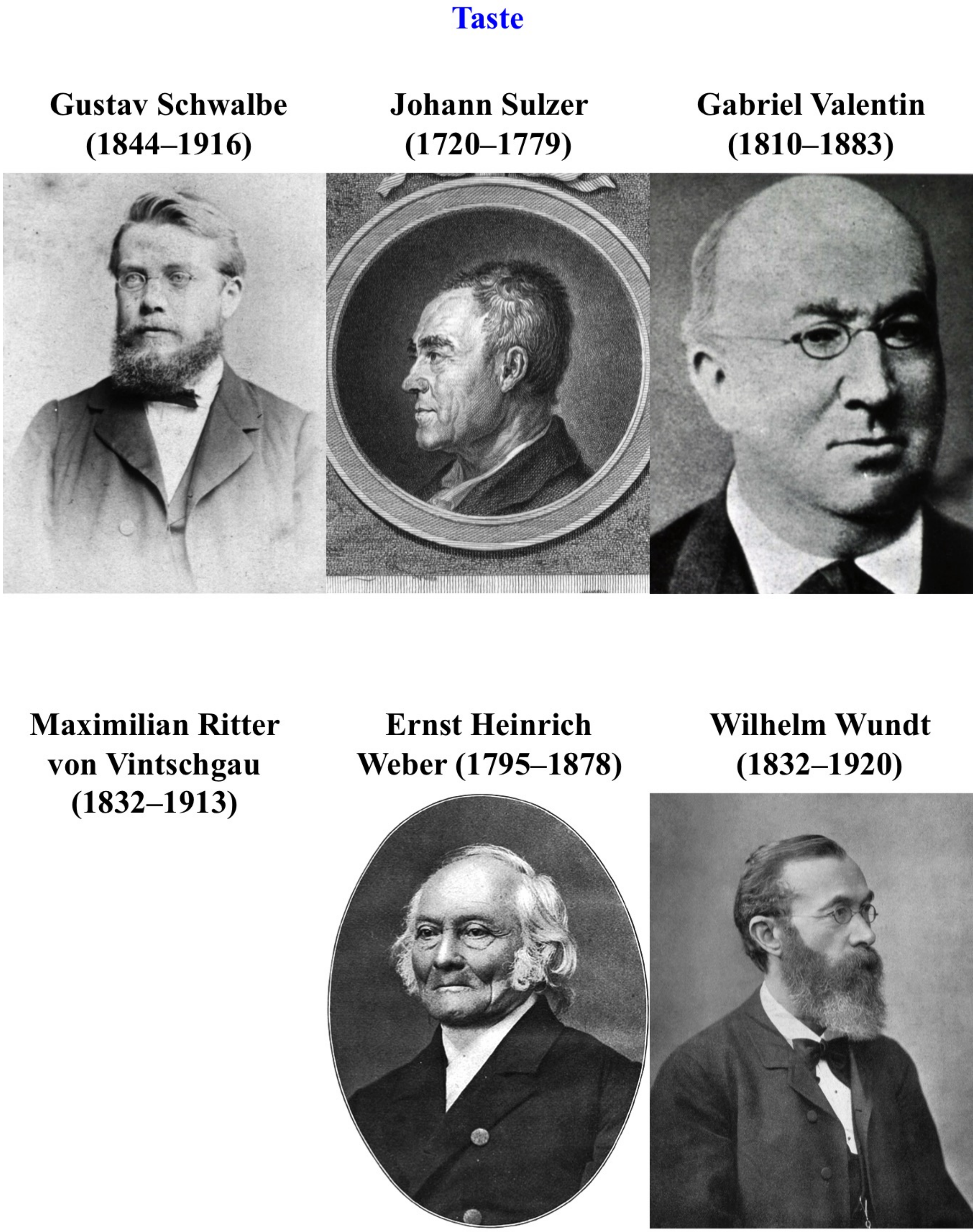

Taste
Gustav Schwalbe (1844–1916)
Johann Sulzer (1720–1779)
Gabriel Valentin (1810–1883)
Maximilian Ritter von Vintschgau (1832–1913)
Ernst Heinrich Weber (1795–1878)
Wilhelm Wundt (1832–1920)

Figure 2.160: Other creators who made important contributions to knowledge about the sense of taste included Gustav Schwalbe, Johann Sulzer, Gabriel Valentin, Maximilian Ritter von Vintschgau, Ernst Heinrich Weber, and Wilhelm Wundt.

2.3.14 Smell

Scientists from the German-speaking world made important contributions to knowledge about the sense of smell or olfaction (Figs. 2.161–2.162).

Albrecht von Haller (Swiss, 1708–1777) wrote one of the earliest scientific discussions of olfaction in his 1747 *Primae lineae physiologiae* [*Primer of Physiology*] and 1757–1766 eight-volume *Elementa physiologieae* [*Elements of Physiology*].

Johannes Peter Müller (German states, 1801–1858) analyzed the scientific basis of olfaction in his 1838 *Handbuch der Physiologie des Menschen* [*Handbook of Human Physiology*].

Rudolf Wagner (German states, 1806–1864) also analyzed the scientific basis of olfaction in his 1844 *Handwörterbuch der Physiologie* [*Dictionary of Physiology*].

In 1847, Ernst Heinrich Weber (German, 1795–1878) discovered that olfaction was much more sensitive to odorant molecules dispersed in air than in water, giving important clues about the mechanism by which any olfactory receptors must operate.

Conrad Eckhard (German, 1822–1905) discovered olfactory receptor cells in the nasal epithelium of frogs in 1855.

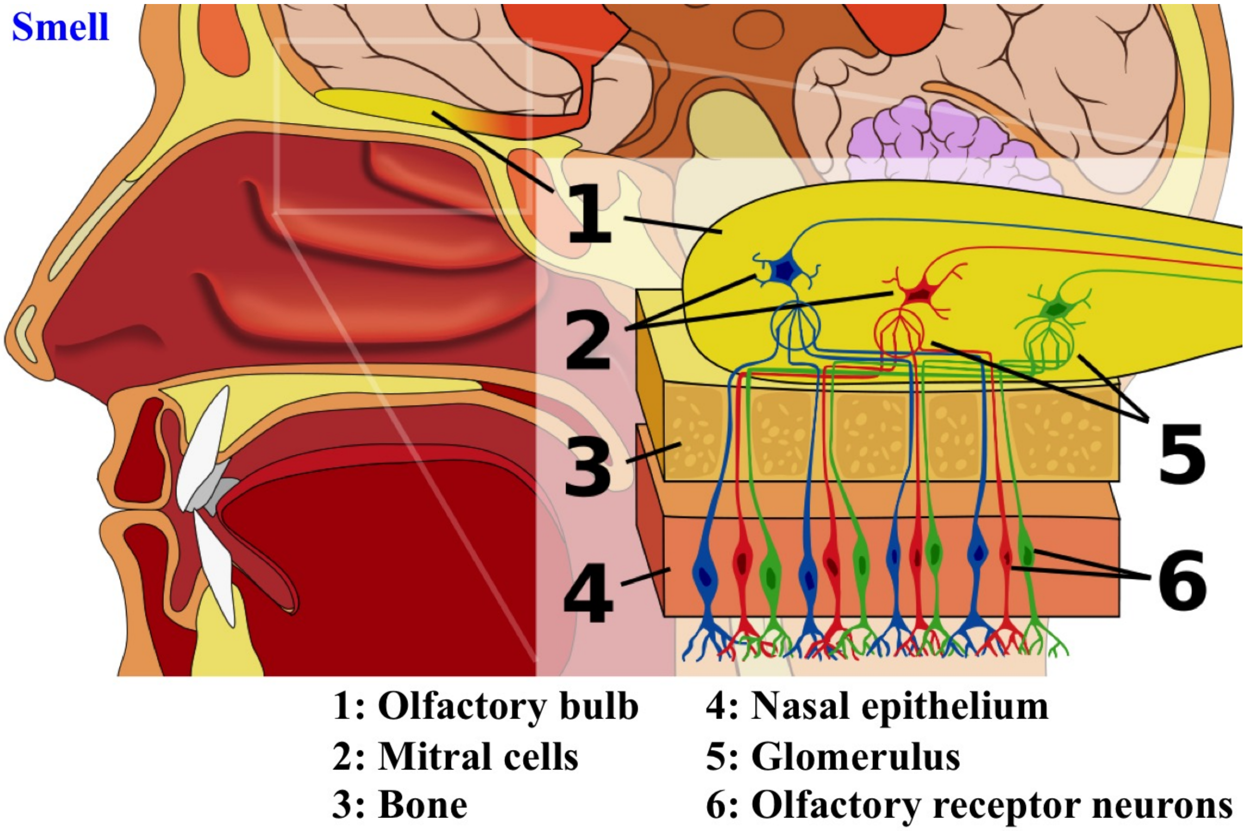
Max Schultze (German, 1825–1874) discovered olfactory receptor cells in the nasal epithelium of humans and other mammals in 1856.

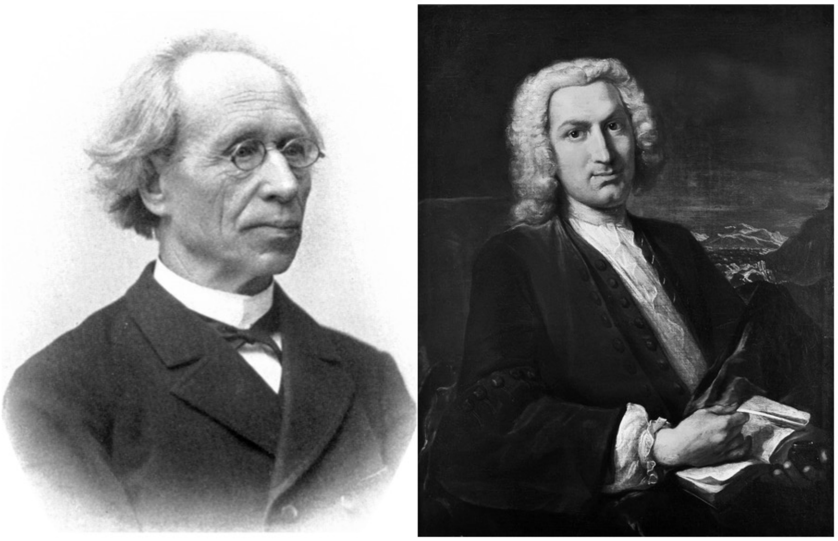
Maximilian Ritter von Vintschgau (Austrian, 1832–1913) conducted experiments to study the differences between the senses of olfaction and taste.

In 1895, Hendrik Zwaardemaker (Dutch, 1857–1930) developed a system for classifying detectable odors into categories.

In 1916, Hans Henning (German, 1885–1946) developed an alternative system for classifying detectable odors into categories.

As shown in Fig. 2.163, G. Krum (German?, 18??–19??) invented facial tissues or “paper handkerchiefs” in 1894, 30 years before the first Kleenex tissues in the United States.


Smell
1
2
3
4
5
6
1: Olfactory bulb
2: Mitral cells
3: Bone
4: Nasal epithelium
5: Glomerulus
6: Olfactory receptor neurons



Conrad Eckhard (1822–1905)

Albrecht von Haller (1708–1777)

Hans Henning (1885–1946)

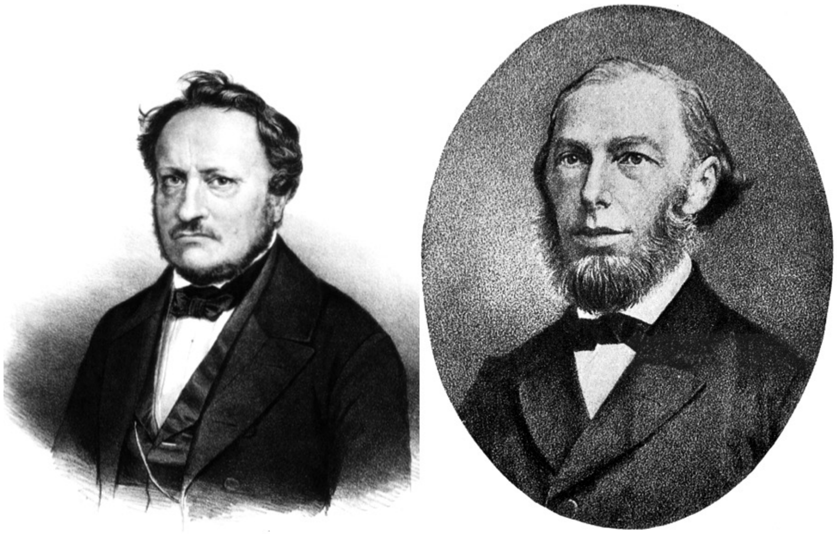
Figure 2.161: Creators who made important contributions to knowledge about the sense of smell or olfaction included Conrad Eckhard, Albrecht von Haller, and Hans Henning.

Smell

Johannes Peter Müller (1801–1858)

Max Schultze (1825–1874)

Maximilian Ritter von Vintschgau (1832–1913)



Rudolf Wagner (1806–1864)

Ernst Heinrich Weber (1795–1878)

Hendrik Zwaardemaker (1857–1930)

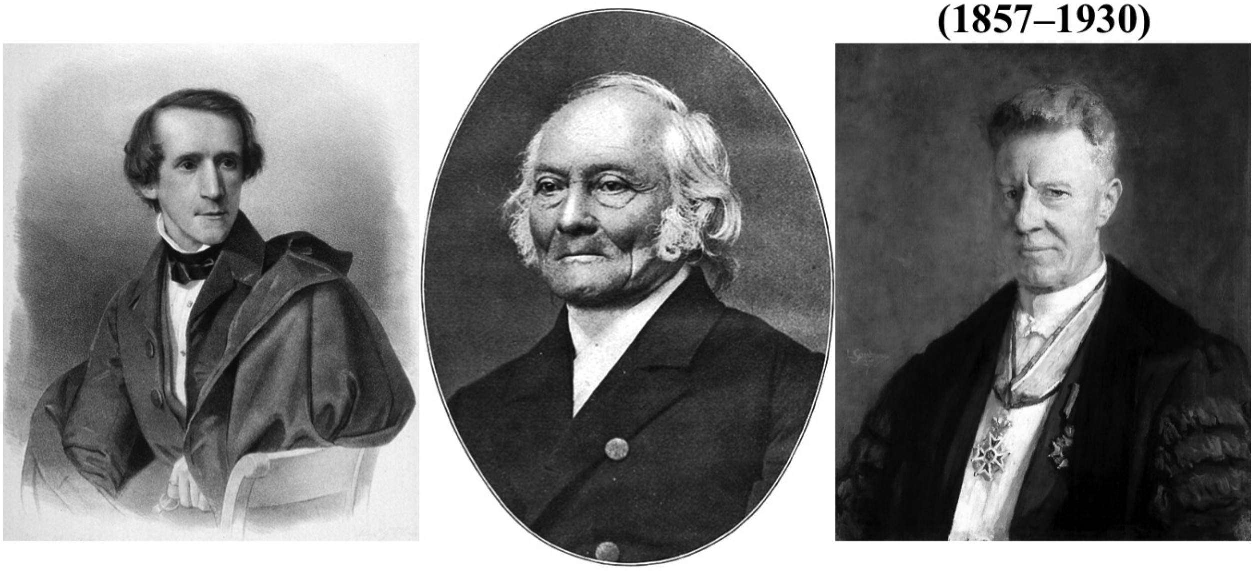
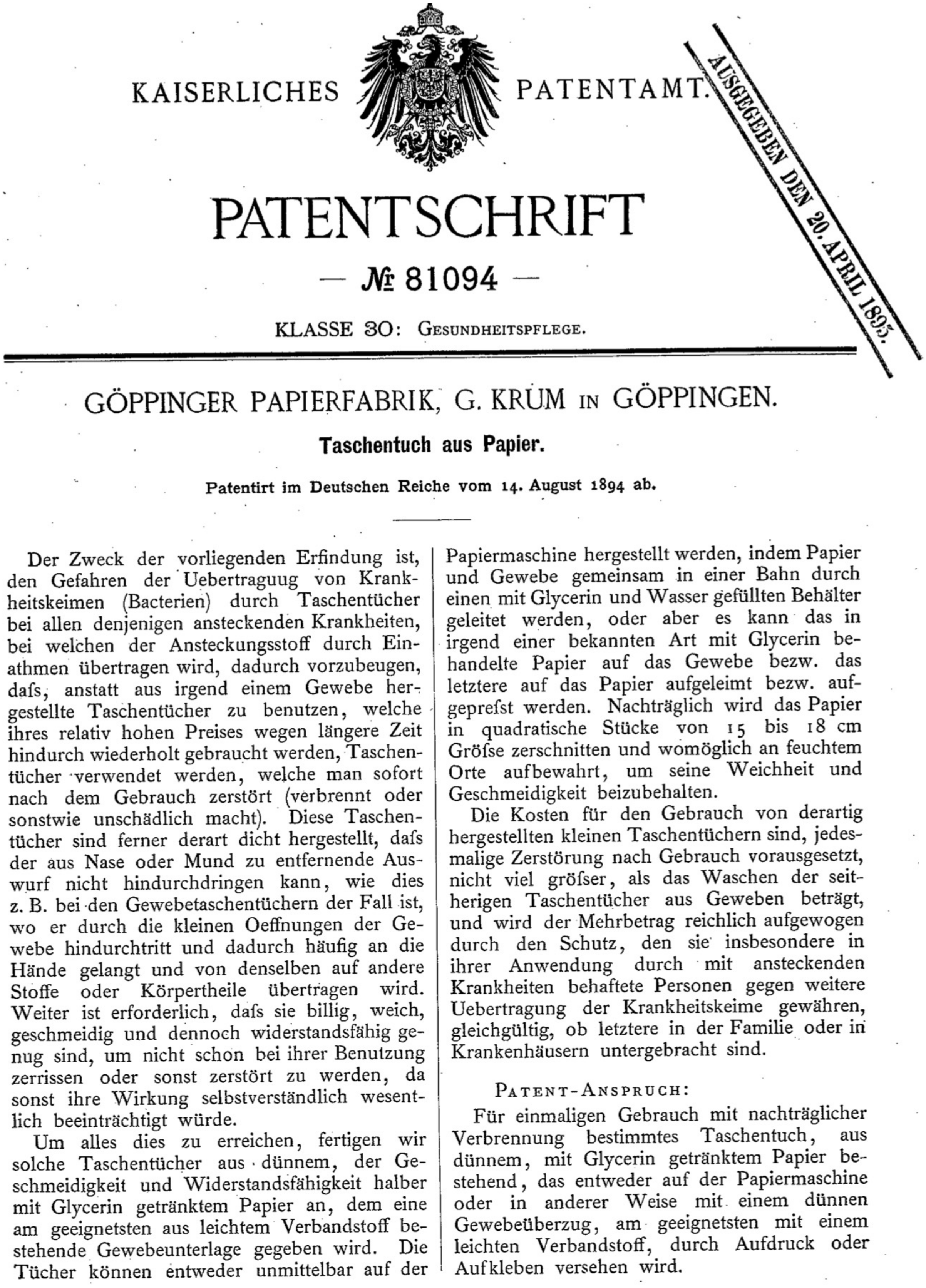


Figure 2.162: Other creators who made important contributions to knowledge about the sense of smell or olfaction included Johannes Peter Müller, Max Schultze, Maximilian Ritter von Vintschgau, Rudolf Wagner, Ernst Heinrich Weber, and Hendrik Zwaardemaker.



KAISERLICHES PATENTAMT.

AUSGEGEBEN DEN 20. APRIL 1895.

PATENTSCHRIFT

— № 81094 —

KLASSE 30: GESUNDHEITSPFLEGE.

GÖPPINGER PAPIERFABRIK, G. KRUM IN GÖPPINGEN.

Taschentuch aus Papier.

Patentirt im Deutschen Reiche vom 14. August 1894 ab.

Der Zweck der vorliegenden Erfindung ist, den Gefahren der Uebertraguug von Krankheitskeimen (Bacterien) durch Taschentücher bei allen denjenigen ansteckenden Krankheiten, bei welchen der Ansteckungsstoff durch Einathmen übertragen wird, dadurch vorzubeugen, daſs, anstatt aus irgend einem Gewebe hergestellte Taschentücher zu benutzen, welche ihres relativ hohen Preises wegen längere Zeit hindurch wiederholt gebraucht werden, Taschentücher verwendet werden, welche man sofort nach dem Gebrauch zerstört (verbrennt oder sonstwie unschädlich macht). Diese Taschentücher sind ferner derart dicht hergestellt, daſs der aus Nase oder Mund zu entfernende Auswurf nicht hindurchdringen kann, wie dies z. B. bei den Gewebetaschentüchern der Fall ist, wo er durch die kleinen Oeffnungen der Gewebe hindurchtritt und dadurch häufig an die Hände gelangt und von denselben auf andere Stoffe oder Körpertheile übertragen wird. Weiter ist erforderlich, daſs sie billig, weich, geschmeidig und dennoch widerstandsfähig genug sind, um nicht schon bei ihrer Benutzung zerrissen oder sonst zerstört zu werden, da sonst ihre Wirkung selbstverständlich wesentlich beeinträchtigt würde.

Um alles dies zu erreichen, fertigen wir solche Taschentücher aus dünnem, der Geschmeidigkeit und Widerstandsfähigkeit halber mit Glycerin getränktem Papier an, dem eine am geeignetsten aus leichtem Verbandstoff bestehende Gewebeunterlage gegeben wird. Die Tücher können entweder unmittelbar auf der Papiermaschine hergestellt werden, indem Papier und Gewebe gemeinsam in einer Bahn durch einen mit Glycerin und Wasser gefüllten Behälter geleitet werden, oder aber es kann das in irgend einer bekannten Art mit Glycerin behandelte Papier auf das Gewebe bezw. das letztere auf das Papier aufgeleimt bezw. aufgepreſst werden. Nachträglich wird das Papier in quadratische Stücke von 15 bis 18 cm Gröſse zerschnitten und womöglich an feuchtem Orte aufbewahrt, um seine Weichheit und Geschmeidigkeit beizubehalten.

Die Kosten für den Gebrauch von derartig hergestellten kleinen Taschentüchern sind, jedesmalige Zerstörung nach Gebrauch vorausgesetzt, nicht viel gröſser, als das Waschen der seitherigen Taschentücher aus Geweben beträgt, und wird der Mehrbetrag reichlich aufgewogen durch den Schutz, den sie insbesondere in ihrer Anwendung durch mit ansteckenden Krankheiten behaftete Personen gegen weitere Uebertragung der Krankheitskeime gewähren, gleichgültig, ob letztere in der Familie oder in Krankenhäusern untergebracht sind.

PATENT-ANSPRUCH:

Für einmaligen Gebrauch mit nachträglicher Verbrennung bestimmtes Taschentuch, aus dünnem, mit Glycerin getränktem Papier bestehend, das entweder auf der Papiermaschine oder in anderer Weise mit einem dünnen Gewebeüberzug, am geeignetsten mit einem leichten Verbandstoff, durch Aufdruck oder Aufkleben versehen wird.

Figure 2.163: G. Krum invented facial tissues or “paper handkerchiefs” in 1894.

2.4 Cardiovascular Medicine

Scientists from the German-speaking world made many of the major discoveries and inventions in cardiovascular medicine, including:[22]

2.4.1. Hemoglobin and its properties

2.4.2. Blood pressure measurement

2.4.3. The heart-lung machine

2.4.4. Blood types and transfusions

2.4.5. Cardiovascular disease

2.4.6. Cardiovascular diagnostics

2.4.7. Cardiovascular therapeutics

2.4.8. Synthetic blood plasma

2.4.9. Transfer of cardiovascular medical innovations to other countries

2.4.1 Hemoglobin

As shown in Figs. 2.164–2.166, many scientists were involved in discovering and working out the details of how hemoglobin in red blood cells transports oxygen.

In 1840, Friedrich Ludwig Hünefeld (German, 1799–1882) discovered hemoglobin and demonstrated that it could carry oxygen.

Soon after that, in 1842, Julius Robert von Mayer (German, 1814–1878) proposed that oxidative chemical reactions provided the energy for cells throughout the body, suggesting that was the purpose of transporting oxygen through the bloodstream.

In 1851, Otto Funke (German, 1828–1879) purified hemoglobin from red blood cells and converted it into a crystalline form to measure its properties. He also investigated blood cells in the spleen.

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[22] Boettcher et al. 2003; Gedeon 2006; Jahn 2004; Junker 2004; Koesling and Schülke 2010; Kohler 2008; Magner 2002; Possehl 1989; Raviña and Kubinyi 2011; Schnalke and Atzl 2010; Schneider 1972; von Schwerin 2013; Simmons 2002; Sneader 2005; Weatherall 1991; Zimmer 2003.

Felix Hoppe-Seyler (German, 1825–1895) used and greatly extended Friedrich Ludwig Hünefeld's techniques to measure the binding of hemoglobin to oxygen.

Julius Lothar Meyer (German, 1830–1895) studied how carbon monoxide can displace oxygen from hemoglobin, leading to carbon monoxide poisoning. Meyer also developed and published the periodic table of the elements (p. 441).

Hans Fischer (German, 1881–1945) discovered how to chemically synthesize heme (or haemin), the iron-binding porphyrin molecule that combines with proteins to form hemoglobin. For that work, he won the 1930 Nobel Prize in Chemistry. Professor H. G. Söderbaum, Chairman of the Nobel Committee for Chemistry, described Fischer's accomplishments [https://www.nobelprize.org/prizes/chemistry/1930/ceremony-speech/]:

> This is the road which Professor Hans Fischer of Munich travelled, to reach his destination with perseverance and determination; not only did he determine completely the constitution of haemin and all its decomposition products: he also prepared the blood pigments from their simplest constituents by synthesis, a scientific achievement which would scarcely have been considered possible even a generation ago. By this synthesis he crowned his researches which both in extent and in the unbelievable difficulties associated with them deserve to be called a gigantic labour.
>
> Moreover, these researches were not wholly restricted to blood pigments. Closely related pigments occur in Nature and not only in the blood. These include the pigments in the bile, of which bilirubin is the best characterized to date. Its constitution, too, has been determined by Fischer who established the connection between this bile pigment and the blood pigment. Further, it was discovered that the pigment in the pinions of certain birds is the copper salt of a porphyrin, whereas the pigment which forms the dark spots on the eggs of a large number of wild birds, the so-called ooporphyrin, has been found to be blood pigment without iron. Even if I add that Fischer has demonstrated the occurrence of haemin in yeast, all this is overshadowed by the fact that, chemically speaking, the pigment of green plants, i.e. chlorophyll, is closely related with the red blood pigment, and even derives, as Fischer has shown, from exactly the same parent substance, as regards the porphyrins. [...]

Felix Haurowitz (Czech, 1896–1987) also made a number of structural studies and discoveries about hemoglobin and its various forms during the late 1920s and 1930s in Prague, before that research was ended by the war.

Rudolf Lemberg (German, 1896–1975) fled the Third Reich and conducted similar studies of hemoglobin in Australia in the 1930s–1950s.

Hermann Lehmann (German, 1910–1985), another refugee from the Third Reich, settled in the United Kingdom and studied hemoglobin and red blood cell abnormalities such as sickle cell anemia in the 1940s–1960s.

Max Perutz (Austrian, 1914–2002) worked out the structure of the hemoglobin protein, for which he won the 1962 Nobel Prize in Chemistry. The Royal Swedish Academy of Sciences briefly summarized his research [https://www.nobelprize.org/prizes/chemistry/1962/perutz/facts/]:

> When X-rays pass through a crystalline structure, the patterns formed can be captured as photographic images, which are then used to determine the crystal's structure. During the 1930s, this method was used to map increasingly large and complex molecules. Max Perutz began to map the structure of hemoglobin, for example—the protein that allows blood to transport energy-giving oxygen to the body's muscles. His study, completed in 1959, was later followed by further studies of the hemoglobin molecule and its function.

Werner Adolf Immerwahr (German, 1924–2006) left Germany during World War II, changed his name to Vernon Ingram, and ultimately became a well-known biology professor at MIT. With support from Max Perutz and other members of the German-speaking scientific diaspora, he spent most of his career studying the roles of proteins in diseases. In the 1950s, Immerwahr/Ingram showed that a mutation changing a single amino acid in hemoglobin was responsible for causing sickle-cell anemia, a hereditary blood disease. Later he studied some of the key proteins involved in neurodegenerative illnesses such as Alzheimer's disease.

2.4.2 Blood Pressure Measurement

As shown in Fig. 2.167, scientists from the German-speaking world created instruments for measuring blood pressure.

In 1854, Karl von Vierordt (German, 1818–1884) developed and demonstrated an instrument called a sphygmograph (somewhat like a graphing seismometer) for blood pressure measurement.

Building on the work of von Vierordt, in 1881 Samuel Siegfried von Basch (Austrian, 1837–1905) developed the more practical sphygmomanometer for blood pressure measurement.

Beginning in 1901, Heinrich Jacob von Recklinghausen (German, 1867–1942) refined von Basch's sphygmomanometer to create the modern instrument for blood pressure measurement.

2.4.3 Heart-Lung Machine

In 1885, Maximilian von Frey (Austrian, 1852–1932) and Max von Gruber (Austrian, 1853–1927) invented and demonstrated the heart-lung machine (Fig. 2.168). It could oxygenate blood and circulate that through a patient whose heart had been temporarily stopped for heart surgery. Their approach gradually spread worldwide.

The design of heart-lung machines was later improved by Willem Kolff (Dutch, 1911–2009, p. 339), who also invented renal dialysis machines.

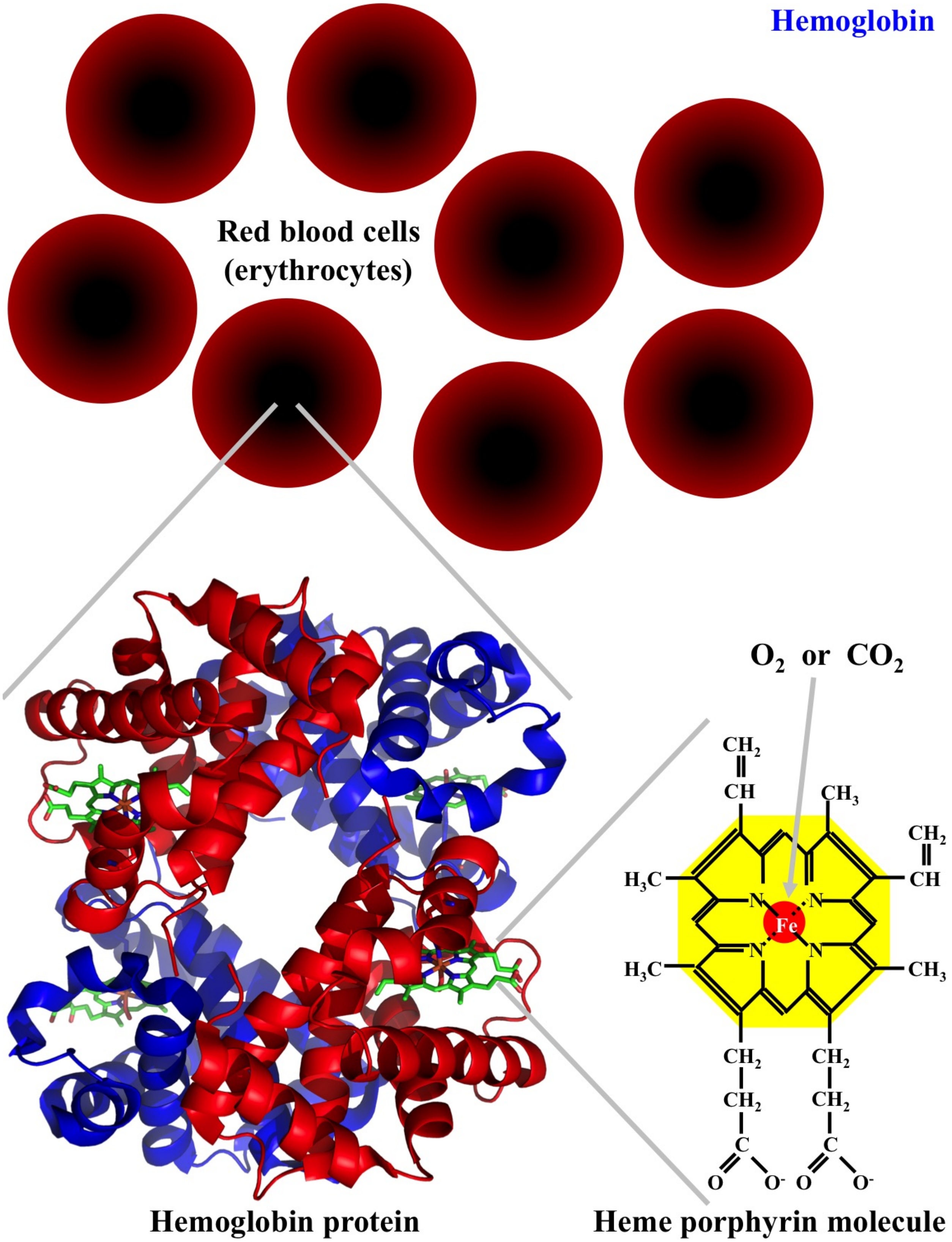

Hemoglobin
Red blood cells (erythrocytes)
O_2 or CO_2
CH_2
CH
CH_3
CH_2
CH
H_3C
N
N
Fe
N
N
H_3C
CH_3
CH_2
CH_2
CH_2
CH_2
C
C
O
O^-
O
O^-
Hemoglobin protein
Heme porphyrin molecule

Figure 2.164: Red blood cells contain hemoglobin protein, which in turn contains heme molecules that can carry oxygen.

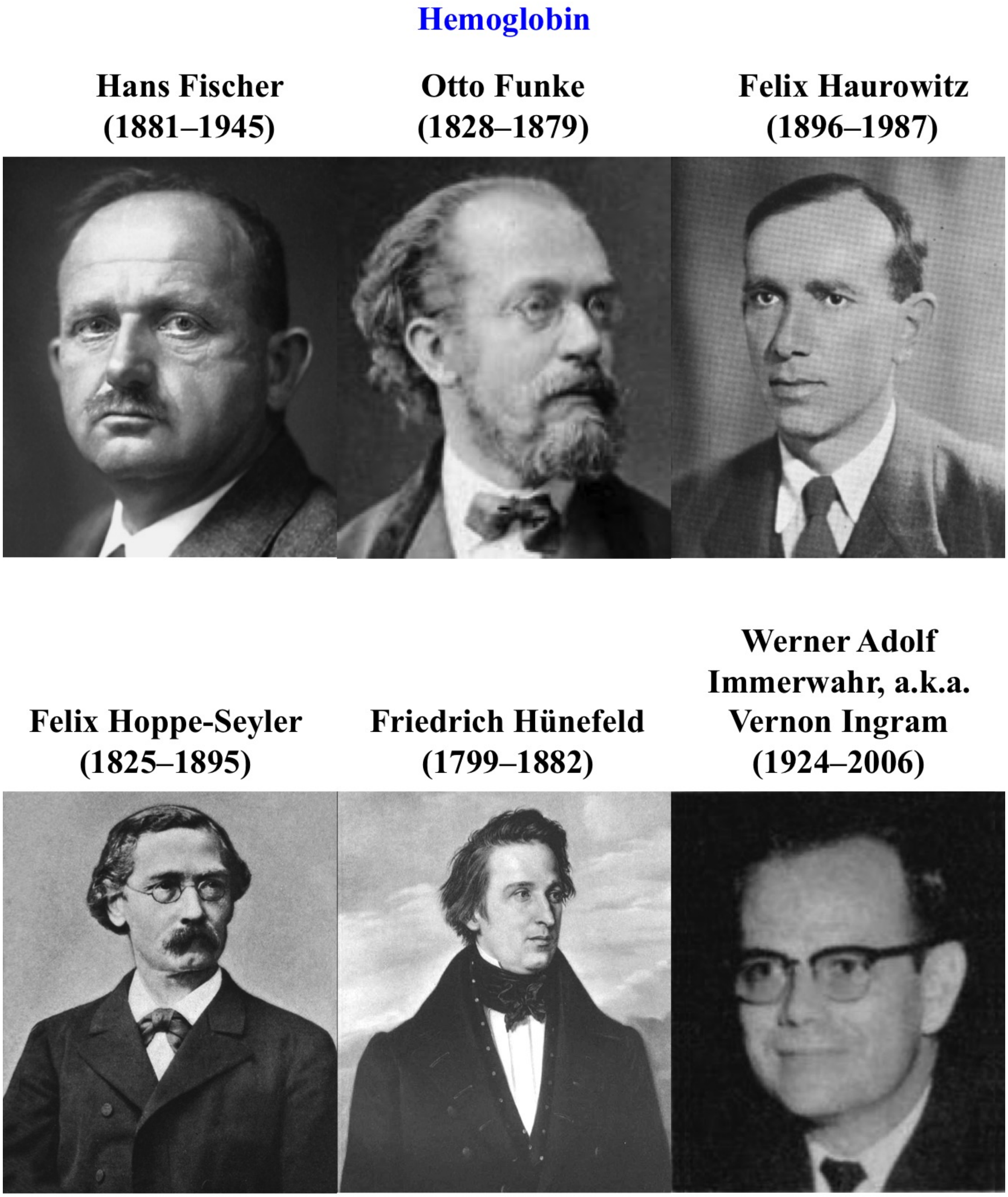
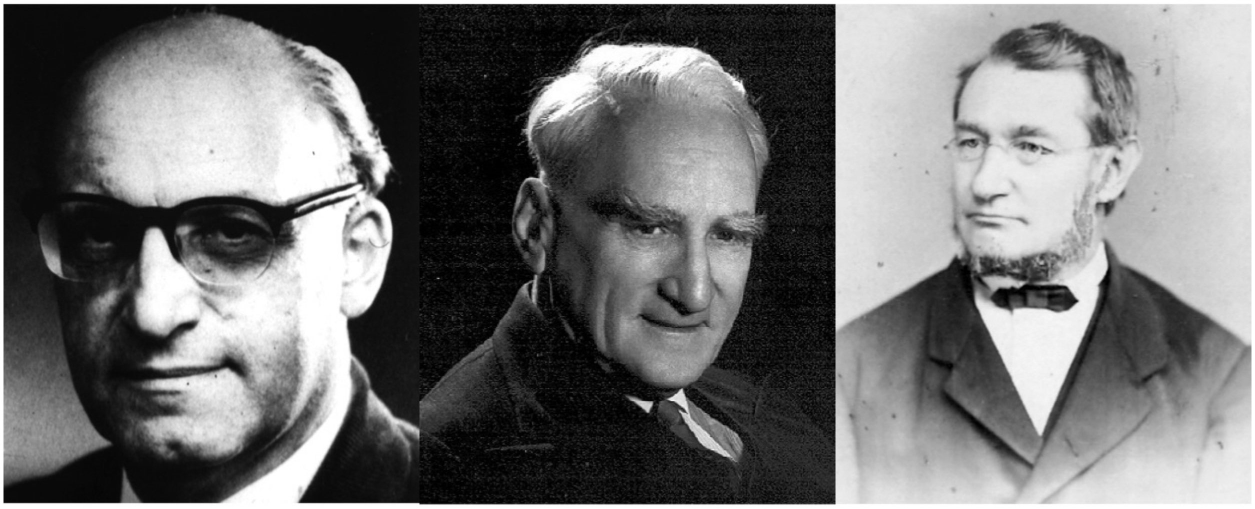

Hemoglobin
Hans Fischer (1881–1945)
Otto Funke (1828–1879)
Felix Haurowitz (1896–1987)
Felix Hoppe-Seyler (1825–1895)
Friedrich Hünefeld (1799–1882)
Werner Adolf Immerwahr, a.k.a. Vernon Ingram (1924–2006)

Figure 2.165: Some creators who made important contributions to knowledge about hemoglobin included Hans Fischer, Otto Funke, Felix Haurowitz, Felix Hoppe-Seyler, Friedrich Ludwig Hünefeld, and Werner Adolf Immerwahr, also known as Vernon Ingram.

Hemoglobin

Hermann Lehmann (1910–1985) **Rudolf Lemberg (1896–1975)** **Julius von Mayer (1814–1878)**



Julius Lothar Meyer (1830–1895) **Max Perutz (1914–2002)**

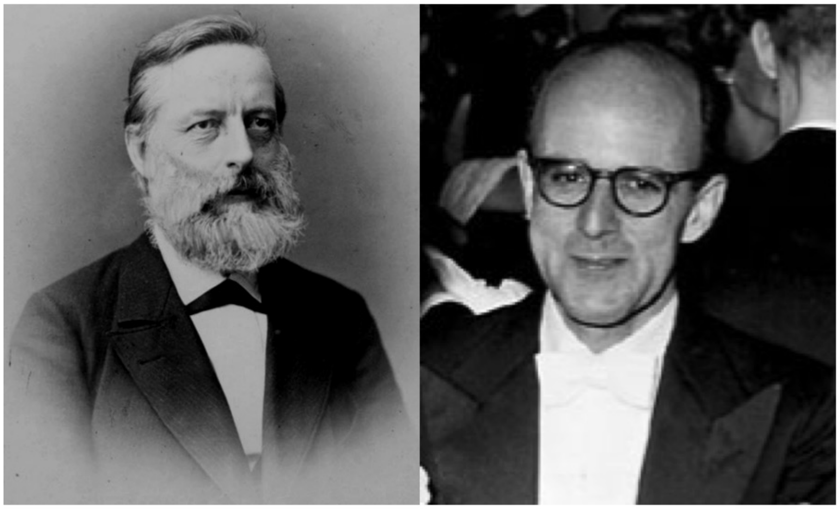


Figure 2.166: Other creators who made important contributions to knowledge about hemoglobin included Hermann Lehmann, Rudolf Lemberg, Julius von Mayer, Julius Lothar Meyer, and Max Perutz.

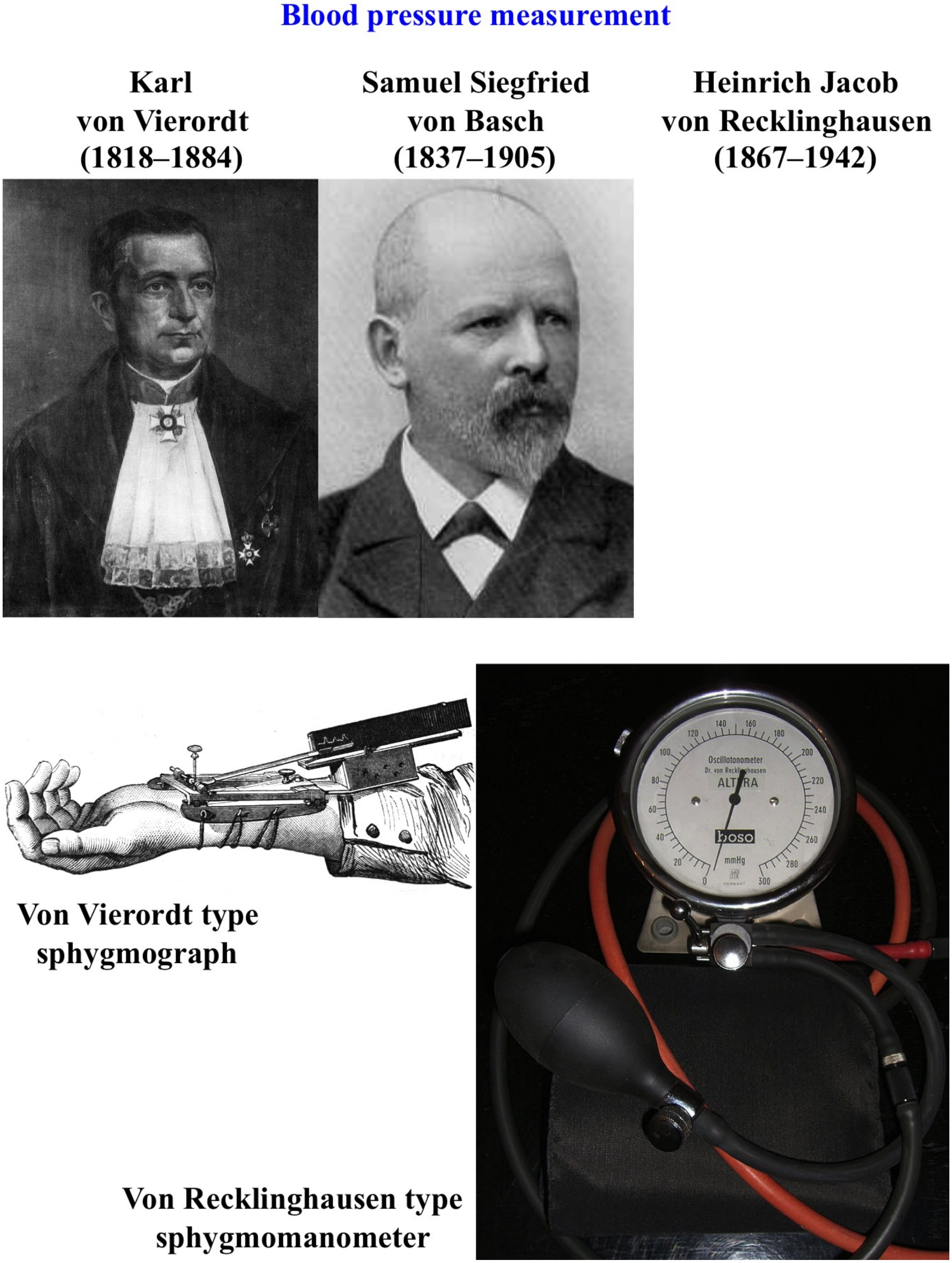
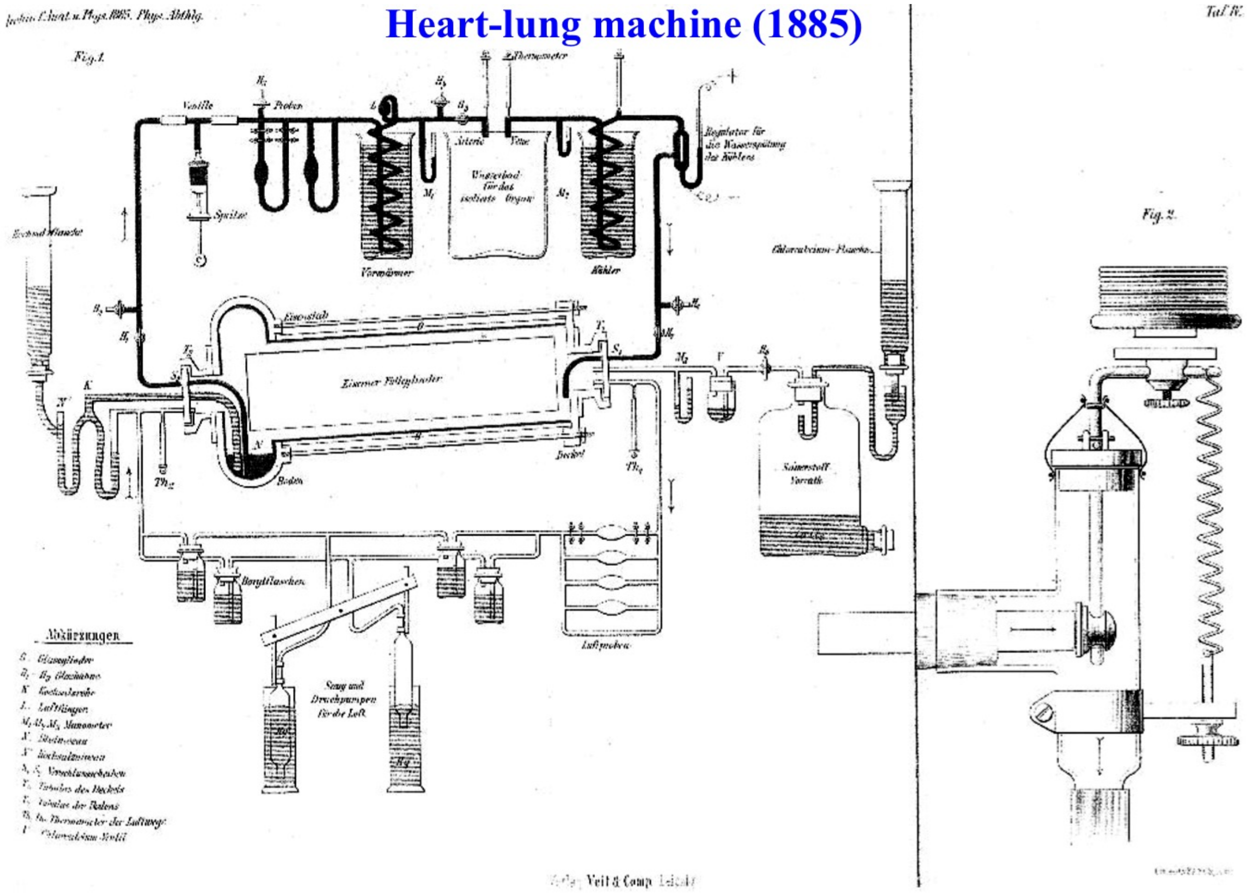
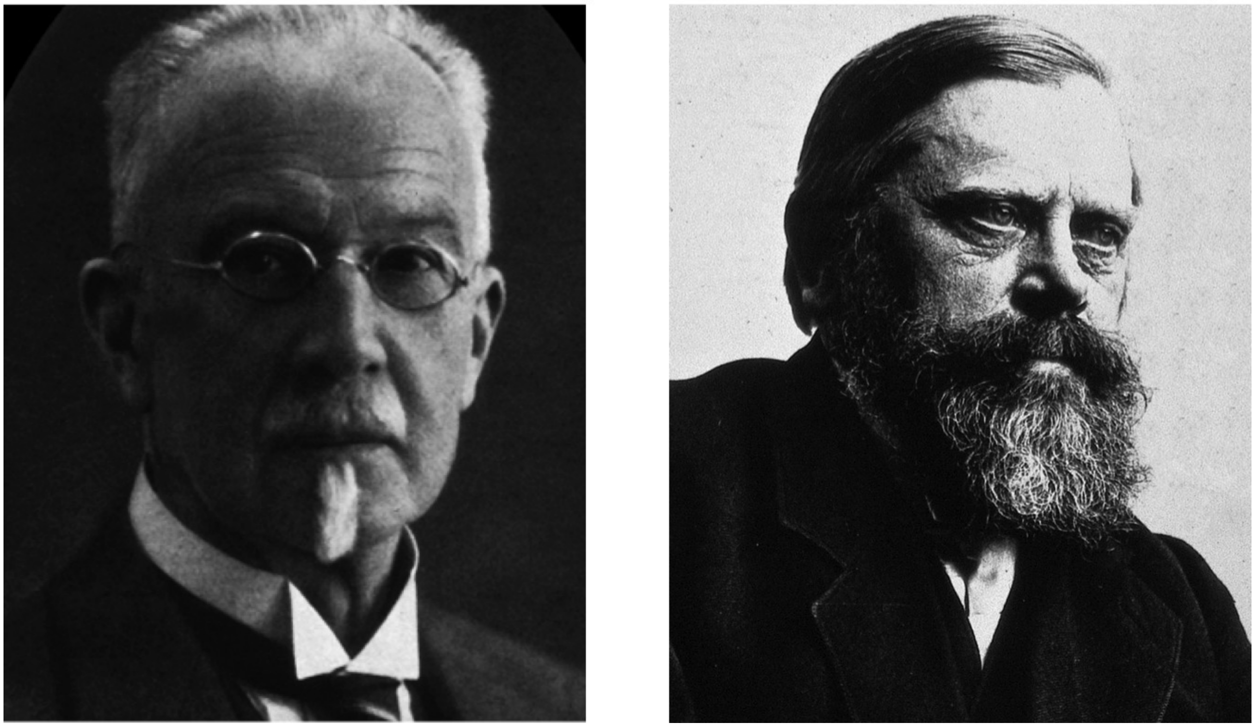

Blood pressure measurement
Karl von Vierordt (1818–1884)
Samuel Siegfried von Basch (1837–1905)
Heinrich Jacob von Recklinghausen (1867–1942)
Von Vierordt type sphygmograph
Von Recklinghausen type sphygmomanometer
Oscillotonometer
Dr. von Recklinghausen
ALTERA
boso
mmHg

Figure 2.167: Karl von Vierordt, Samuel Siegfried von Basch, and Heinrich von Recklinghausen developed instruments for measuring blood pressure.



Heart-lung machine (1885)

Fig. 1.
Fig. 2.
Thermometer
Ventile
Proben
Spritze
Arterie
Vene
Wasserbad für das isolirte Organ
Vorwärmer
Kühler
Regulator für die Wasserspülung des Kühlers
Eiserner Fellgehäuse
Boden
Deckel
Sauerstoff Vorrath
Barytflaschen
Saug und Druckpumpen für die Luft
Luftproben
Abkürzungen
Veit & Comp. Leipzig



Maximilian von Frey (1852–1932)

Max von Gruber (1853–1927)

Figure 2.168: Maximilian von Frey and Max von Gruber invented and demonstrated the heart-lung machine in 1885.

2.4.4 Blood Types and Transfusions

Scientists from the greater German-speaking world discovered blood types and made blood transfusions safe and practical (Figs. 2.169–2.170).

Karl Landsteiner (Austrian, 1868–1943) identified blood types in 1900 and helped conduct the first matched transfusion in 1907. For that breakthrough, he won the Nobel Prize in Physiology or Medicine in 1930. Professor G. Hedrén, Chairman of the Nobel Committee for Physiology or Medicine, explained [https://www.nobelprize.org/prizes/medicine/1930/ceremony-speech/]:

> Thirty years ago, in 1900, in the course of his serological studies Landsteiner observed that when, under normal physiological conditions, blood serum of a human was added to normal blood of another human the red corpuscles in some cases coalesced into larger or smaller clusters. This observation of Landsteiner was the starting-point of his discovery of the human blood groups. In the following year, i.e. 1901, Landsteiner published his discovery that in man, blood types could be classified into three groups according to their different agglutinating properties. These agglutinating properties were identified more closely by two specific blood-cell structures, which can occur either singly or simultaneously in the same individual. A year later von Decastello and Sturli showed that there was yet another blood group. The number of blood groups in man is therefore four.
>
> Landsteiner's discovery of the blood groups was immediately confirmed but it was a long time before anyone began to realize the great importance of the discovery. The first incentive to pay greater attention to this discovery was provided by von Dungern and Hirszfeld when in 1910 they published their investigations into the hereditary transmission of blood groups.

Working independently of Landsteiner, Jan Janský (Czech/Austrian, 1873–1921) also identified and studied blood types.

In 1910, Emil von Dungern (German, 1867–1961) and Ludwik Hirszfeld (Polish, studied and worked in Germany then Switzerland, 1884–1954) discovered the heritability of ABO blood types.

Alfred Beck (German, 1889–1973) developed efficient equipment for blood transfusions.

2.4.5 Cardiovascular Disease

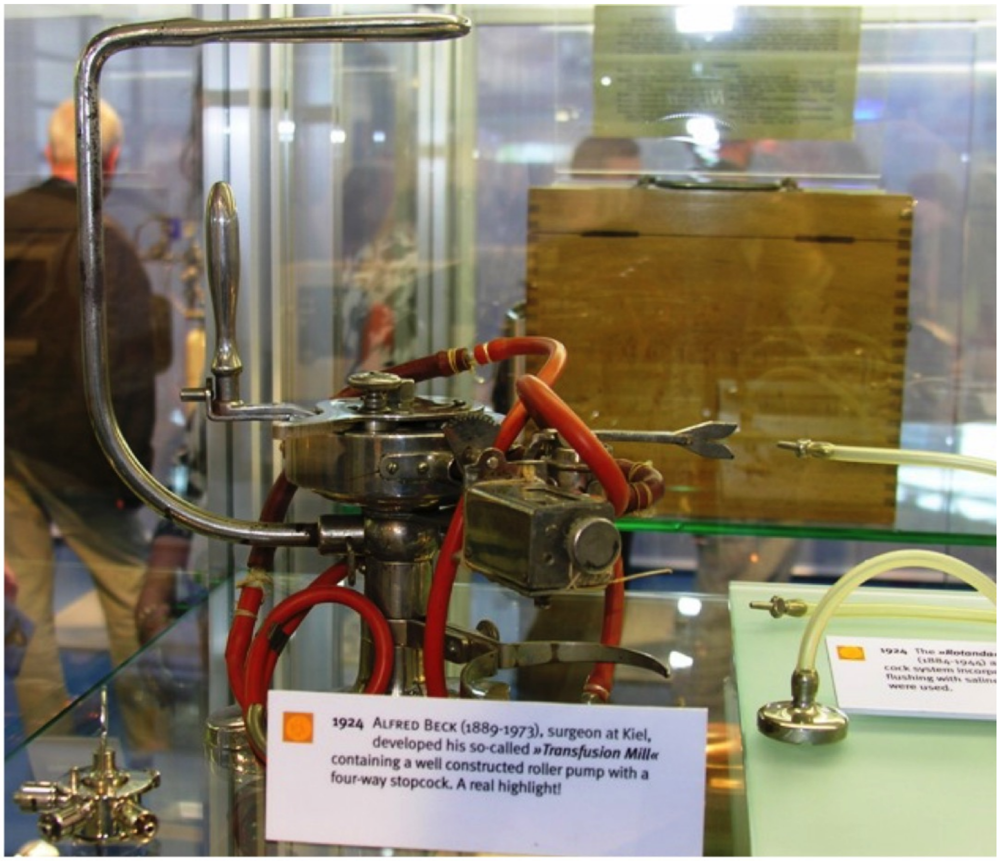
German-speaking scientists also made important contributions to knowledge about cardiovascular disease (Fig. 2.171).

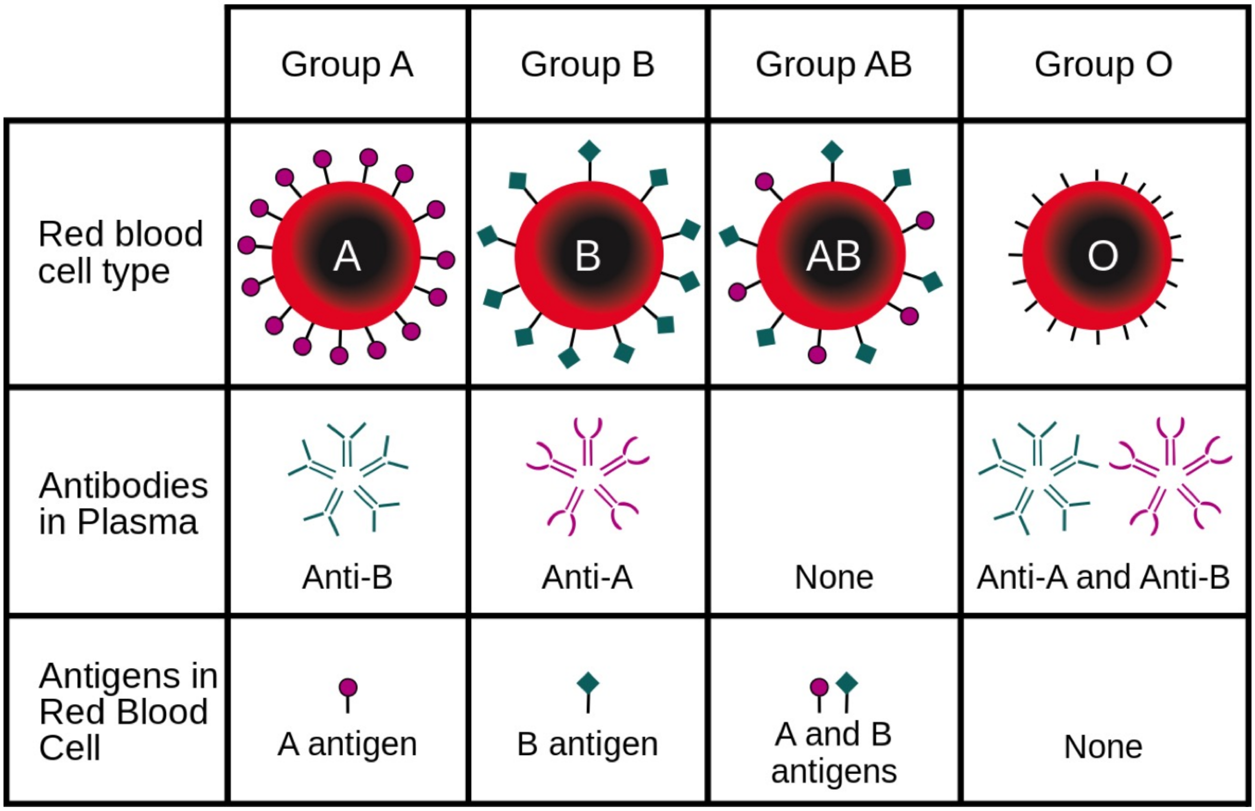
Ludwig Aschoff (German, 1866–1942) identified and studied many pathophysiological conditions of the heart. His son Jürgen Aschoff conducted research on circadian rhythms (p. 258).

In 1931, Rudolf Schoenheimer (German, 1898–1941) published the results of a series of animal experiments in which he discovered and analyzed the link between dietary intake of cholesterol and atherosclerosis.

Konrad Bloch (German, 1912–2000) and Feodor Lynen (German, 1911–1979) won the Nobel Prize in Physiology or Medicine in 1964 for their work on cholesterol and fatty acid metabolism, which also had many implications for cardiovascular disease. For more information, see p. 356.

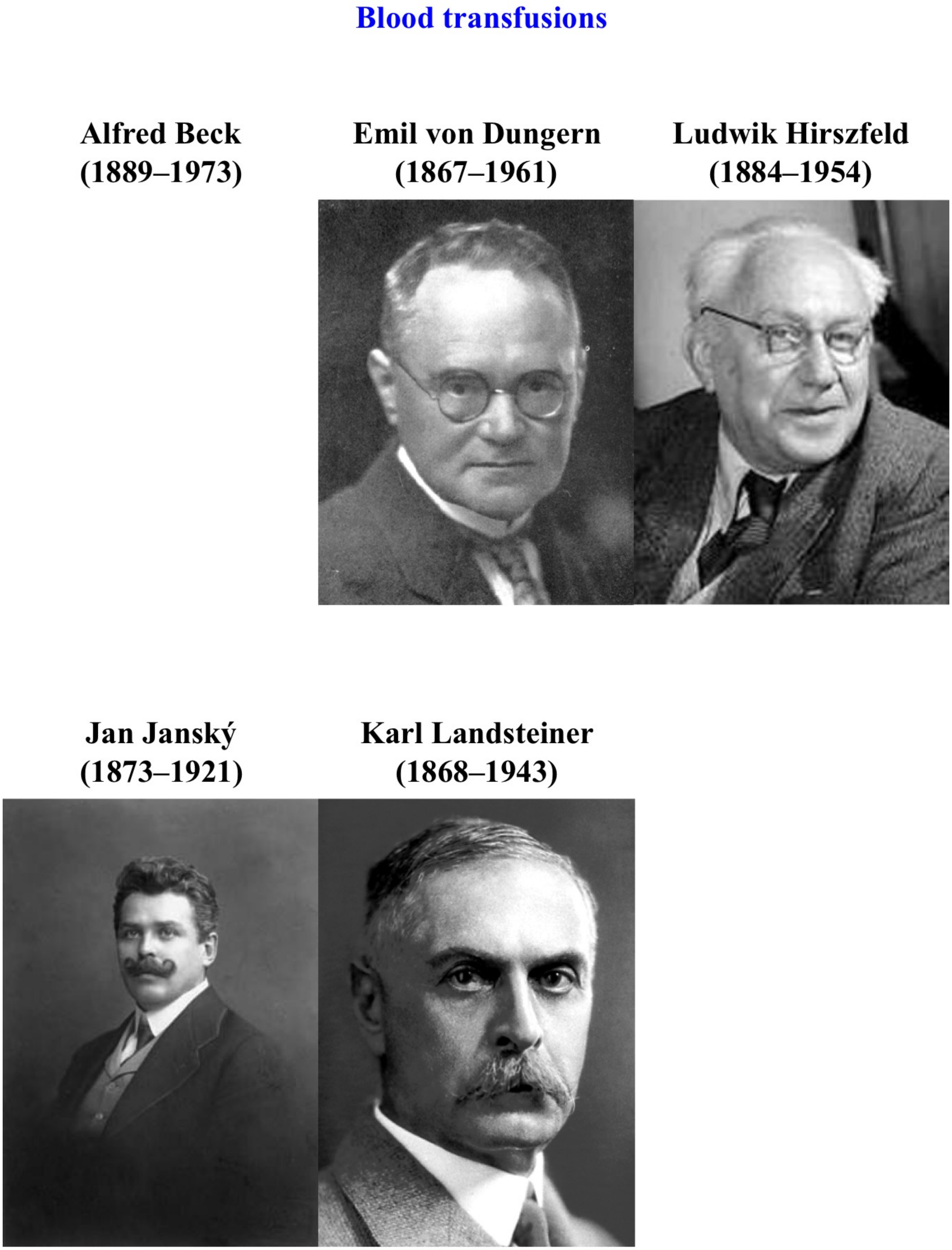
Blood transfusions


1924 Alfred Beck (1889-1973), surgeon at Kiel, developed his so-called »Transfusion Mill« containing a well constructed roller pump with a four-way stopcock. A real highlight!



	Group A	Group B	Group AB	Group O
Red blood cell type	A	B	AB	O
Antibodies in Plasma	Anti-B	Anti-A	None	Anti-A and Anti-B
Antigens in Red Blood Cell	A antigen	B antigen	A and B antigens	None

Figure 2.169: Creators from the German-speaking world developed efficient equipment for blood transfusions and determined compatible blood groups for transfusions.



Blood transfusions
Alfred Beck
(1889–1973)
Emil von Dungern
(1867–1961)
Ludwik Hirszfeld
(1884–1954)
Jan Janský
(1873–1921)
Karl Landsteiner
(1868–1943)

Figure 2.170: Creators who determined compatible blood groups for transfusions and developed efficient equipment for transfusions included Alfred Beck, Emil von Dungern, Ludwik Hirszfeld, Jan Janský, and Karl Landsteiner.

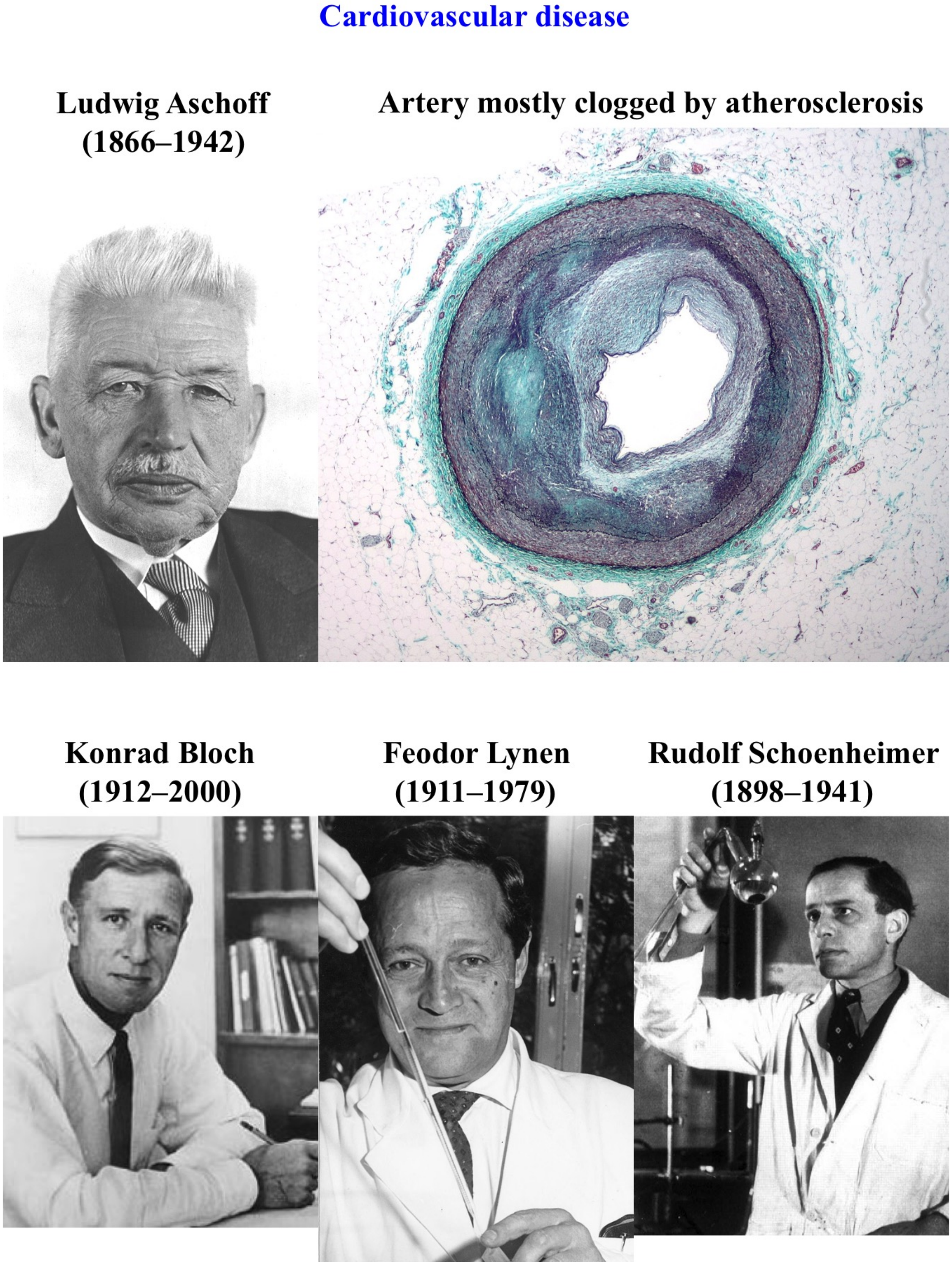

Cardiovascular disease
Ludwig Aschoff (1866–1942)
Artery mostly clogged by atherosclerosis
Konrad Bloch (1912–2000)
Feodor Lynen (1911–1979)
Rudolf Schoenheimer (1898–1941)

Figure 2.171: Scientists from the German-speaking world who made important contributions to knowledge about cardiovascular disease included Ludwig Aschoff, Konrad Bloch, Feodor Lynen, and Rudolf Schoenheimer.

2.4.6 Cardiovascular Diagnostics

Creators from the greater German-speaking world developed the major types of cardiovascular diagnostics (Fig. 2.172).

In 1893, Wilhelm His Jr. (Swiss, 1863–1934) discovered what is now called the “bundle of His,” tissue that conducts and coordinates electrical impulses telling the heart muscle to beat.

Building on His’s discovery, in 1903, Willem Einthoven (Dutch, 1860–1927) invented the first practical electrocardiogram (ECG or EKG) for recording electrical signals from the heart. He received the Nobel Prize in Physiology or Medicine in 1924 for that work. Professor J.E. Johansson, Chairman of the Nobel Committee for Physiology or Medicine, explained Einthoven’s invention [https://www.nobelprize.org/prizes/medicine/1924/ceremony-speech/]:

> Einthoven’s name is linked partly with the design of a physical instrument, the *string galvanometer*, partly with the so-called *electrocardiogram*, a record of the electrical potential fluctuations at the surface of the body, which accompany the heart beat. The heart beat, like the piston movement of a steam engine, is a cyclic process. Behind this process lies, in the first place, a similarly cyclic process in the heart muscle.

Carl Hellmuth Hertz (German, 1920–1990), the son of Gustav Hertz (p. 893) and great nephew of Heinrich Hertz (p. 854), developed echocardiography, which uses ultrasonic waves and acoustic signal recording and imaging methods to analyze heart function. He obtained the first echocardiogram in 1953, and later he also developed inkjet printing.

See also p. 1250 for the early development of ultrasound imaging by the German-speaking world.

Cardiovascular diagnostics

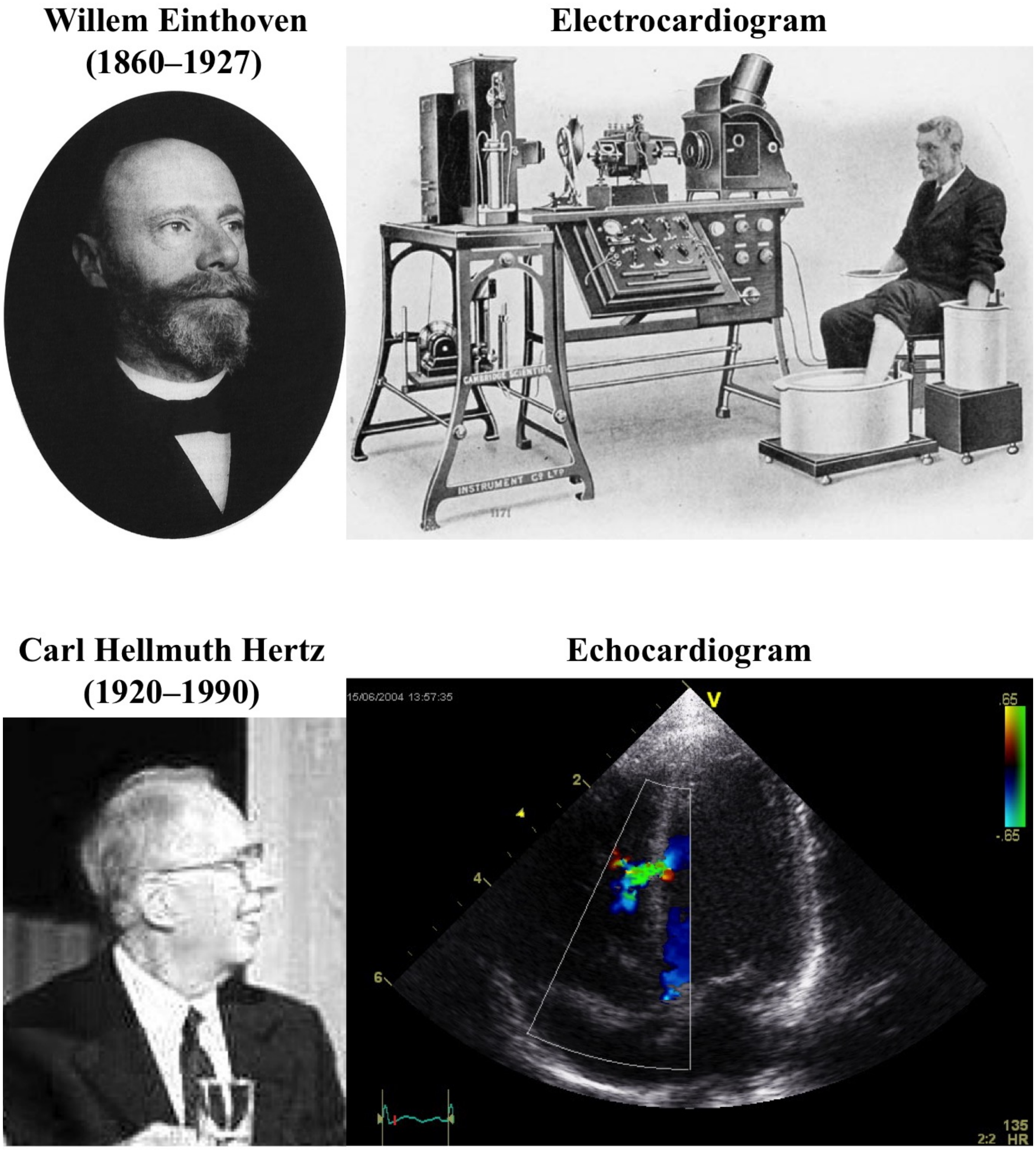

Willem Einthoven
(1860–1927)
Electrocardiogram
CAMBRIDGE SCIENTIFIC
INSTRUMENT Co LTD
1171
Carl Hellmuth Hertz
(1920–1990)
Echocardiogram
15/06/2004 13:57:35
V
.65
-.65
2
4
6
135
2:2 HR

Figure 2.172: Willem Einthoven developed the electrocardiogram in 1895, and Carl Hellmuth Hertz developed the echocardiogram in 1953.

2.4.7 Cardiovascular Therapeutics

Scientists from the greater German-speaking world also developed many important cardiovascular therapeutics, including both devices and medications (Fig. 2.173).

In 1929, Werner Forßmann (German, 1904–1979) invented and successfully demonstrated the cardiac catheter. For that revolutionary innovation, he won the Nobel Prize in Physiology or Medicine in 1956. Professor G. Liljestrand, Secretary of the Nobel Committee for Physiology or Medicine, praised his work [https://www.nobelprize.org/prizes/medicine/1956/ceremony-speech/]:

> As far as man is concerned, these methods were for a long time only partly applicable. Thus, it was possible to record the pressure in the peripheral arteries—and this is what is usually meant when we speak of the blood pressure—as well as in the superficial veins. These values reflect to some extent the conditions in the left ventricle and the right atrium. But measurements of the right ventricular pressure, which is of essential importance for the work of the right side of the heart, was impracticable. Similarly, it was possible, for determination of the oxygen content, to take samples of the arterial blood, but not of the mixed venous blood in the right side of the heart, which gives the average value for the body as a whole. It was, in fact, necessary to resort to indirect methods. These have yielded valuable results, although they have somewhat undeservedly—as is often the case—been overshadowed by the subsequent conquests. One of the factors limiting the applicability of these indirect methods was, however, that they required the active cooperation of the experimental subject or patient, and this was at times associated with difficulties or was altogether unfeasible.
>
> As late as 1928, there were good reasons for the statement in a textbook that in man, one was "naturally" confined to the use of the indirect methods. Consequently, it was highly surprising when, already in the following year, Werner Forssmann at the surgical clinic in Eberswalde was able to show—by making, with the intrepidity of youth, by no means harmless experiments on himself—that a narrow catheter could be advanced from a cubital vein into the right atrium itself, a distance of almost two-thirds of a metre. Obviously, this constituted a remarkable advance.

Willem Kolff (Dutch, 1911–2009) invented, developed, and successfully demonstrated the renal dialysis machine during World War II. After the war, his technology rapidly spread around the world, and Kolff moved to the United States, where he continued to develop improved dialysis machines, as well as improved heart-lung machines.

Arthur Stoll (Swiss, 1887–1971) led a research team at Sandoz in Basel that developed some of the earliest and most important heart medications, including cardiac glycosides, alkaloids, and soluble calcium salts.

German-speaking scientists developed early blood pressure medications such as adrenochrome (p. 340) and pentaerythritol tetranitrate (PETN, p. 535). After World War II, those discoveries were adopted by other countries [e.g., CIOS ER 115–116]. Much more archival research should be conducted to elucidate the history of the development of blood pressure medications in the German-speaking world, along with the direct and indirect effects that knowledge had on drug development in other countries.

2.4.8 Synthetic Blood Plasma

As shown in Figs. 2.174–2.176, by the early 1940s, at least two synthetic blood plasma substitutes were developed and successfully tested in the German-speaking world [Brinkman et al. 1945; Hüsselmann 1952; Schoen 1949; NYT 1945-09-21 p. 5, 1947-05-25 p. 42, 1951-02-08 p. 35, 1951-05-20 p. E9]. This work was decades ahead of its time, since perfecting synthetic blood substitutes for battlefield use is still a subject of great military and medical interest.

Periston was developed and tested by Walter Reppe (German, 1892–1969, see p. 474), Hellmut Weese (German, 1897–1954), and G. Hecht (German?, 18??–19??). It was a saline-glucose solution containing completely synthetic polymers of polyvinyl pyrrolidone suspended as a colloid. Periston was far more than a laboratory experiment—it was successfully employed in hundreds of thousands of patients in wartime and early postwar Germany, due to the very large numbers of patients and the shortage of real human blood plasma. The *New York Times* reported the history and successes of periston [NYT 1951-05-20]:

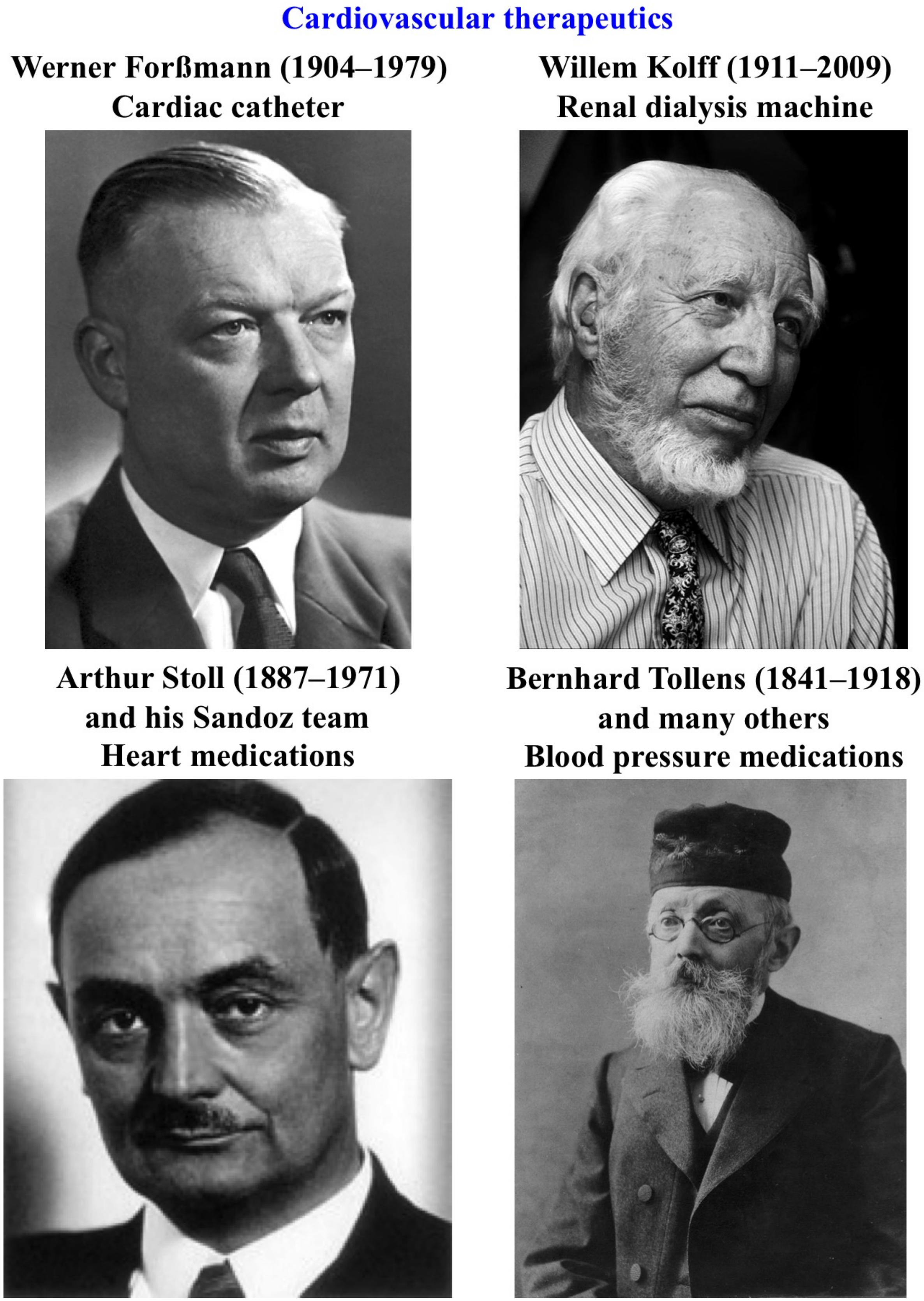
> Confronted in 1939 with a serious shortage of blood, the German Government encouraged Drs. G. Hecht and H. Weese, among others, to develop a blood plasma substitute. Hecht and Weese rejected gum solutions and sought instead a colloid which would not slip easily through the membranes of the kidneys, as salt solutions do, and which would readily absorb water. The quest ended with a product which was christened "Periston" and which is chemically called polyvinyl pyrrolidon.
>
> This polyvinyl pyrrolidon is an artificial compound synthesized from acetylene, ammonia and formaldehyde. The molecule so obtained is coupled with others, a process called polymerization, which means coupling of small molecules to form big ones. Rubber is a polymer, and so is many a synthetic fiber. Since polymers are big molecules, they are not easily lost by slipping through membranes of the kidneys and out of the blood stream.
>
> Periston or PVP, as it was also known, was used successfully during the recent war in the treatment of 500,000 German battlefront casualties. Since the war the preparation has been widely used in Germany in surgical clinics because there is still a shortage of blood for transfusions.

Another synthetic blood plasma was capain, which was a saline solution containing polypeptide fragments that had been hydrolyzed from casein (purified milk protein), as well as glucose and other ingredients. It was also manufactured on a commercial scale and used successfully in humans (pp. 76 and 342).

2.4.9 Transfer of Cardiovascular Medical Innovations to Other Countries

Many innovations in cardiovascular medicine—such as blood pressure measurement, the heart-lung machine, blood type matching, and the electrocardiogram—were rapidly adopted worldwide after they were invented or discovered by scientists in the German-speaking world in the late nineteenth and early twentieth centuries.

All of the remaining innovations in cardiovascular medicine were transferred from the German-speaking world to other countries after World War II. For examples see Fig. 2.174 and FIAT 779, *Work on Physiology of the Circulatory System and on Electrophysiology.*



Cardiovascular therapeutics

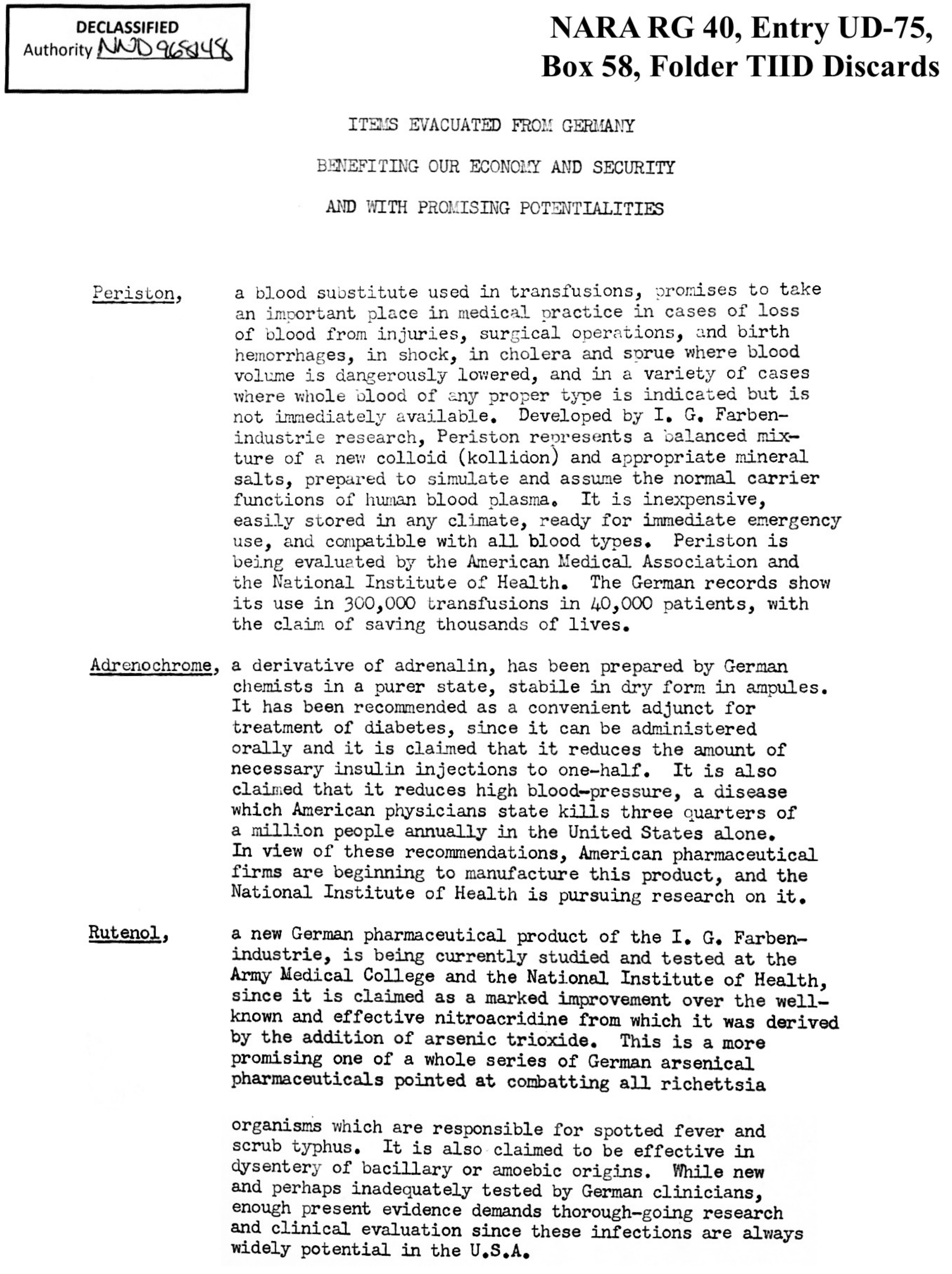
Werner Forßmann (1904–1979)
Cardiac catheter

Willem Kolff (1911–2009)
Renal dialysis machine

Arthur Stoll (1887–1971)
and his Sandoz team
Heart medications

Bernhard Tollens (1841–1918)
and many others
Blood pressure medications

Figure 2.173: Werner Forßmann invented the cardiac catheter. Willem Kolff created the renal dialysis machine. Arthur Stoll led a Sandoz team that discovered heart medications. Bernhard Tollens and many others developed blood pressure medications, such as PETN and adrenochrome.



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Authority NND 968148

NARA RG 40, Entry UD-75,
Box 58, Folder TIID Discards

ITEMS EVACUATED FROM GERMANY

BENEFITING OUR ECONOMY AND SECURITY

AND WITH PROMISING POTENTIALITIES

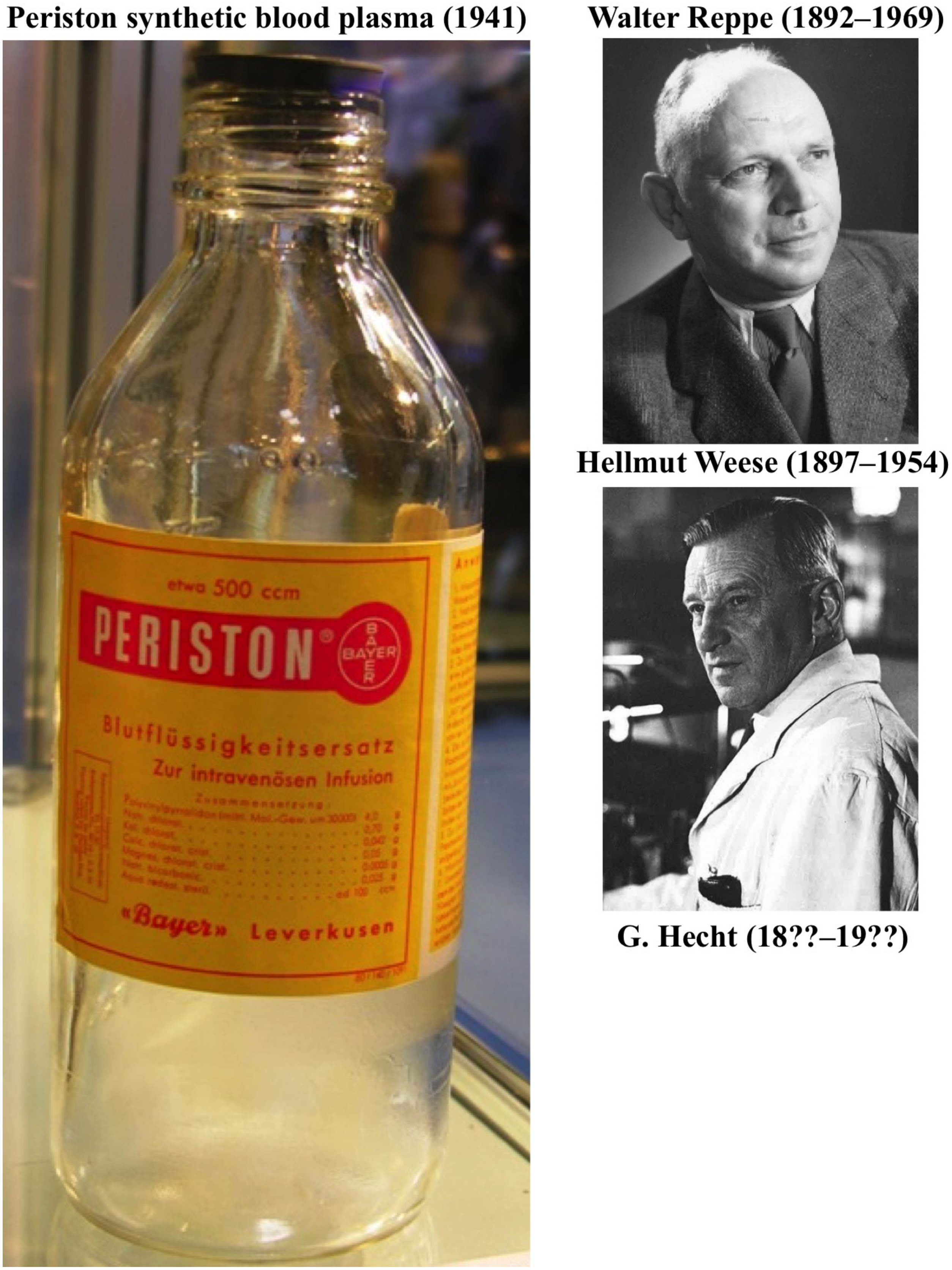
Periston, a blood substitute used in transfusions, promises to take an important place in medical practice in cases of loss of blood from injuries, surgical operations, and birth hemorrhages, in shock, in cholera and sprue where blood volume is dangerously lowered, and in a variety of cases where whole blood of any proper type is indicated but is not immediately available. Developed by I. G. Farbenindustrie research, Periston represents a balanced mixture of a new colloid (kollidon) and appropriate mineral salts, prepared to simulate and assume the normal carrier functions of human blood plasma. It is inexpensive, easily stored in any climate, ready for immediate emergency use, and compatible with all blood types. Periston is being evaluated by the American Medical Association and the National Institute of Health. The German records show its use in 300,000 transfusions in 40,000 patients, with the claim of saving thousands of lives.

Adrenochrome, a derivative of adrenalin, has been prepared by German chemists in a purer state, stabile in dry form in ampules. It has been recommended as a convenient adjunct for treatment of diabetes, since it can be administered orally and it is claimed that it reduces the amount of necessary insulin injections to one-half. It is also claimed that it reduces high blood-pressure, a disease which American physicians state kills three quarters of a million people annually in the United States alone. In view of these recommendations, American pharmaceutical firms are beginning to manufacture this product, and the National Institute of Health is pursuing research on it.

Rutenol, a new German pharmaceutical product of the I. G. Farbenindustrie, is being currently studied and tested at the Army Medical College and the National Institute of Health, since it is claimed as a marked improvement over the well-known and effective nitroacridine from which it was derived by the addition of arsenic trioxide. This is a more promising one of a whole series of German arsenical pharmaceuticals pointed at combatting all richettsia

organisms which are responsible for spotted fever and scrub typhus. It is also claimed to be effective in dysentery of bacillary or amoebic origins. While new and perhaps inadequately tested by German clinicians, enough present evidence demands thorough-going research and clinical evaluation since these infections are always widely potential in the U.S.A.

Figure 2.174: The German-speaking world developed a variety of medicines and medical products that were transferred to other countries after World War II, as shown for example by this document [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].


etwa 500 ccm
PERISTON®
BAYER
Blutflüssigkeitsersatz
Zur intravenösen Infusion
«Bayer» Leverkusen

Periston synthetic blood plasma (1941)

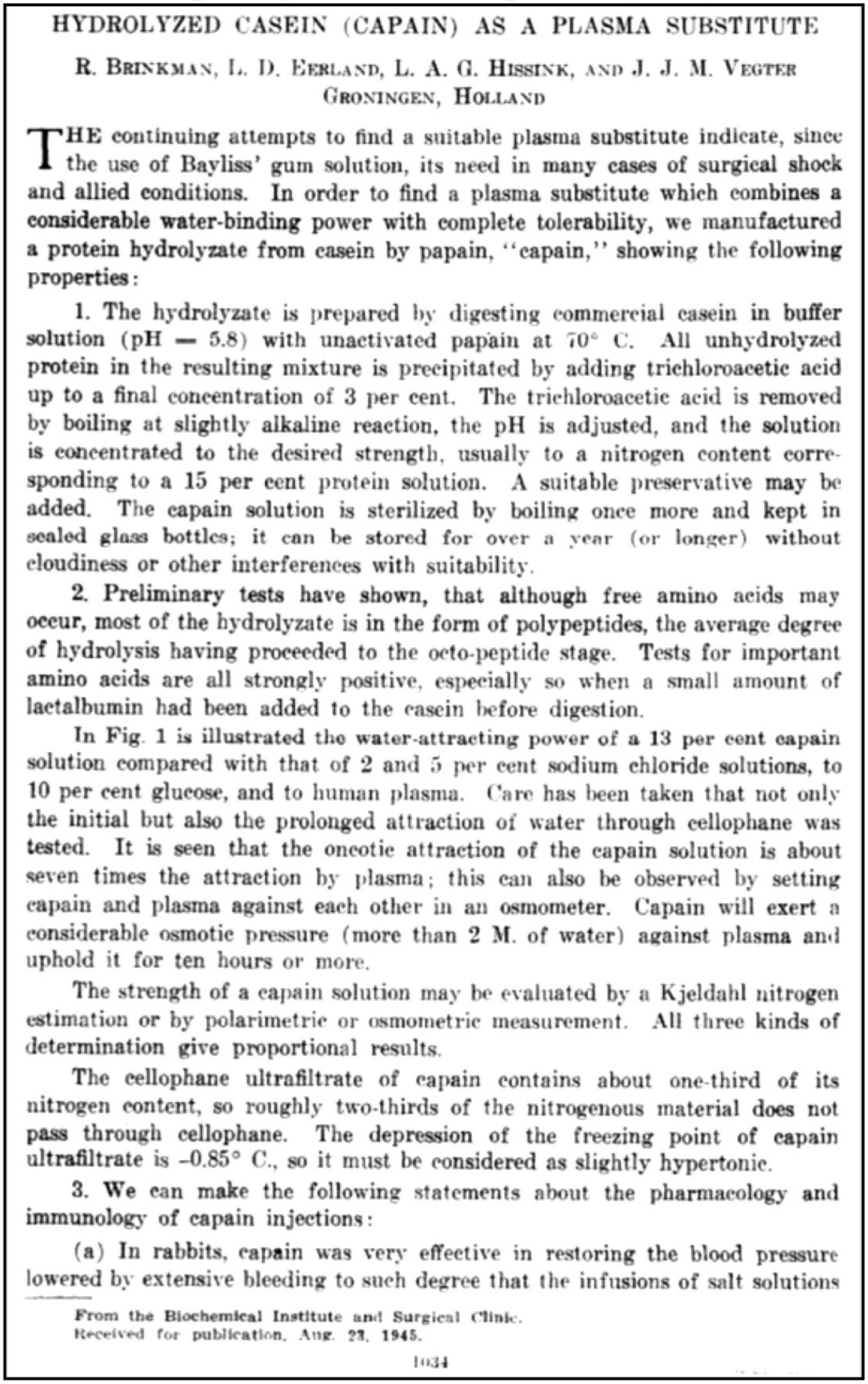
Walter Reppe (1892–1969)

Hellmut Weese (1897–1954)

G. Hecht (18??–19??)

Figure 2.175: Creators from the German-speaking world developed and successfully used periston as a synthetic blood plasma substitute.

Capain synthetic blood plasma (1943)



HYDROLYZED CASEIN (CAPAIN) AS A PLASMA SUBSTITUTE

R. Brinkman, L. D. Eerland, L. A. G. Hissink, and J. J. M. Vegter
Groningen, Holland

The continuing attempts to find a suitable plasma substitute indicate, since the use of Bayliss' gum solution, its need in many cases of surgical shock and allied conditions. In order to find a plasma substitute which combines a considerable water-binding power with complete tolerability, we manufactured a protein hydrolyzate from casein by papain, "capain," showing the following properties:

1. The hydrolyzate is prepared by digesting commercial casein in buffer solution (pH — 5.8) with unactivated papain at 70° C. All unhydrolyzed protein in the resulting mixture is precipitated by adding trichloroacetic acid up to a final concentration of 3 per cent. The trichloroacetic acid is removed by boiling at slightly alkaline reaction, the pH is adjusted, and the solution is concentrated to the desired strength, usually to a nitrogen content corresponding to a 15 per cent protein solution. A suitable preservative may be added. The capain solution is sterilized by boiling once more and kept in sealed glass bottles; it can be stored for over a year (or longer) without cloudiness or other interferences with suitability.

2. Preliminary tests have shown, that although free amino acids may occur, most of the hydrolyzate is in the form of polypeptides, the average degree of hydrolysis having proceeded to the octo-peptide stage. Tests for important amino acids are all strongly positive, especially so when a small amount of lactalbumin had been added to the casein before digestion.

In Fig. 1 is illustrated the water-attracting power of a 13 per cent capain solution compared with that of 2 and 5 per cent sodium chloride solutions, to 10 per cent glucose, and to human plasma. Care has been taken that not only the initial but also the prolonged attraction of water through cellophane was tested. It is seen that the oncotic attraction of the capain solution is about seven times the attraction by plasma; this can also be observed by setting capain and plasma against each other in an osmometer. Capain will exert a considerable osmotic pressure (more than 2 M. of water) against plasma and uphold it for ten hours or more.

The strength of a capain solution may be evaluated by a Kjeldahl nitrogen estimation or by polarimetric or osmometric measurement. All three kinds of determination give proportional results.

The cellophane ultrafiltrate of capain contains about one-third of its nitrogen content, so roughly two-thirds of the nitrogenous material does not pass through cellophane. The depression of the freezing point of capain ultrafiltrate is –0.85° C., so it must be considered as slightly hypertonic.

3. We can make the following statements about the pharmacology and immunology of capain injections:

(a) In rabbits, capain was very effective in restoring the blood pressure lowered by extensive bleeding to such degree that the infusions of salt solutions

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From the Biochemical Institute and Surgical Clinic.
Received for publication, Aug. 23, 1945.

Figure 2.176: Creators from the German-speaking world also developed and successfully used capain as a synthetic blood plasma substitute.

2.5 Vitamins and Hormones

Vitamins are essential biochemical molecules that the human body needs yet cannot make for itself (at least in sufficient quantities), so they must be acquired from foods or other sources. Hormones are biochemical molecules that cells in the body use to send various signals to each other; many belong to the family of steroid hormones derived from cholesterol, but other hormones do not. There are a number of biochemical connections between vitamin molecules and hormone molecules, and hence there was considerable overlap in these research areas. Creators from the greater German-speaking world made many major discoveries and innovations regarding:

2.5.1. Vitamins

2.5.2. Steroid hormones

2.5.3. Nonsteroidal hormones

2.5.1 Vitamins

It is helpful to cover the basics of vitamin molecules, in order to better understand the importance of the original discoveries and scientific studies of those vitamins. Vitamins may be divided into those that are hydrophobic (do not like to be in water) and therefore fat-soluble, and those that are hydrophilic (like to be in water) and therefore water-soluble.

Fat-soluble vitamins can accumulate in body fat and are difficult to dissolve in water and eliminate in urine. Thus they can last a long time in the body, but they can also have toxic effects if they are consumed in excess. As shown in Fig. 2.177, some major fat-soluble vitamins include:

- Vitamin A (retinol) can be derived from certain plants such as carrots, sweet potato, pumpkin, spinach, kale, etc., or fats from animals that have previously ingested such plants. Retinol and its related forms are essential components of light-detecting rhodopsin molecules in the eye and of some DNA-regulating transcription factors in cell nuclei. Too little vitamin A can cause blindness and sterility; too much can cause liver damage or birth defects.

- Vitamin D (cholecalciferol) can be made from cholesterol in human skin exposed to enough sunlight; otherwise it can be derived from certain mushrooms, alfalfa, or animals that have previously ingested such foods. Vitamin D acts on the intestine and bones to maintain sufficient levels of calcium and phosphorus. Insufficient vitamin D can cause bone demineralization and deformation (rickets). Excessive vitamin D can cause nausea or kidney stones.

- Vitamin E (tocopherol) is found in vegetable oils, which are used to make many foods. It acts as an antioxidant to prevent oxidative damage to cells, so its absence can increase oxidative damage, especially in red blood cells that carry lots of oxygen and in neurons that use lots of oxygen. Too much vitamin E can interfere with proper blood clotting.

- Vitamin K (phylloquinone) can be derived from leafy green vegetables such as spinach, collard greens, broccoli, and Brussels sprouts. Vitamin K is also made by the bacteria that naturally live inside the gastrointestinal tract. Vitamin K is used as a coenzyme to modify a number of human proteins, most of which play key roles in blood clotting. Too little vitamin K can hinder blood clotting, and too much can potentially harm red blood cells.

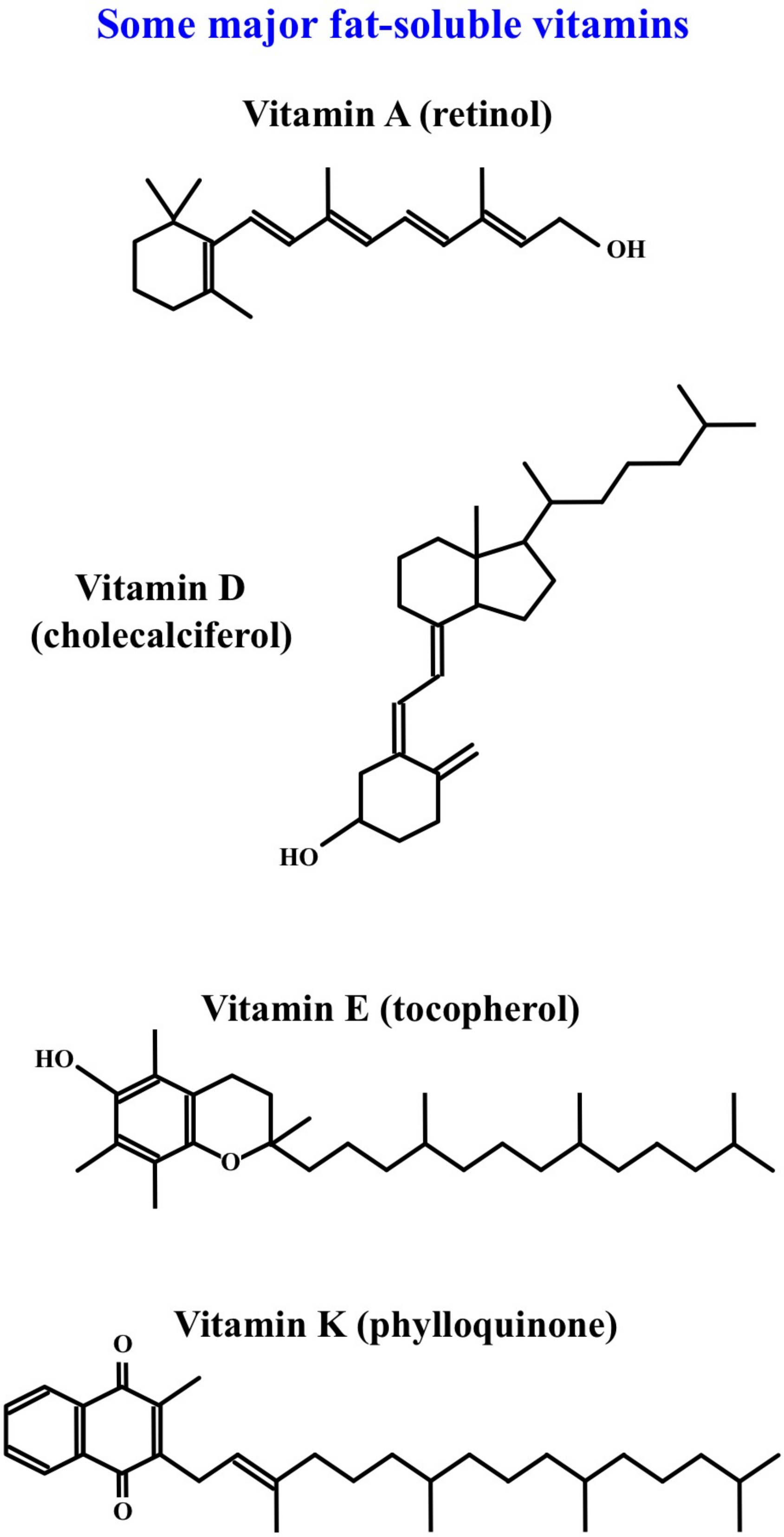
Some major fat-soluble vitamins
Vitamin A (retinol)
OH
Vitamin D (cholecalciferol)
HO
Vitamin E (tocopherol)
HO
O
Vitamin K (phylloquinone)
O
O

Figure 2.177: Some major fat-soluble vitamins include vitamins A (retinol), D (cholecalciferol), E (tocopherol), and K (phylloquinone).

Water-soluble vitamins are not stored in body fat and are readily eliminated in urine. As a result, one can quickly become deficient in these vitamins if they are not consumed regularly, yet it is difficult to overdose on them. Water-soluble vitamins are especially important for the synthesis of biomolecules such as amino acids and nucleotides, and for metabolism to produce energy by breaking down fats and sugars. Thus the effects of water-soluble vitamin deficiencies are most pronounced in rapidly dividing cells that need lots of biomolecular synthesis and energetic metabolism (e.g., blood-cell-producing bone marrow, mucous membrane and skin cells, and developing embryos), and in neurons in the central or peripheral nervous system that are damaged if their steady energetic metabolism is interrupted. As shown in Fig. 2.178, some major water-soluble vitamins include:

- Vitamin B_1 (thiamine) can be derived from whole grains, legumes, nuts, or fungi, or from products (e.g., liver, eggs) from animals that have consumed those foods. It is a precursor for thiamine pyrophosphate, which prepares sugars for the energy-producing citric acid cycle. Thiamine deficiency can damage the central nervous system, a condition called beriberi.
- Vitamin B_2 (riboflavin) is found in leafy vegetables, legumes, and products (milk, eggs, liver) from animals that have consumed those foods. Cells use it to produce two major electron and proton transport proteins.
- Vitamin B_3 (niacin) can be derived from grains, cereal, nuts, milk, and meat. It is an essential precursor of two other electron and proton transport proteins.
- Vitamin B_5 (pantothenic acid) is found in a very wide variety of plant- and animal-derived foods and is a component of coenzyme A, which carries several molecules through metabolic pathways.
- Vitamin B_6 (pyridoxine) is also found in a wide range of plant- and animal-derived foods, and is a precursor of pyridoxal 5'-phosphate, a cofactor for a number of metabolic reactions.
- Vitamin B_7 or H (biotin) is found in a great variety of plant- and animal-derived foods and is also produced by bacteria in the human intestine, so biotin deficiency is virtually unheard of. Biotin is an important cofactor or component of several different carboxylase enzymes.
- Vitamin B_9 or M (folic acid or folate) is most plentiful in leafy green vegetables. It is a precursor of tetrahydrofolate, a coenzyme essential for amino acid and nucleotide synthesis.
- Vitamin C (ascorbic acid) is abundant in most fruits. It is an essential cofactor for a number of enzymes, including those involved in collagen synthesis, and may play a role as an antioxidant to prevent cellular damage from free oxygen radicals.

Because there are such profound human health implications from having too little or too much of a given vitamin, the discoveries of individual vitamins and their properties were major milestones in biology and medicine, and many of those discoveries were recognized with Nobel Prizes. Figures 2.179–2.180 show some scientists who made important discoveries about vitamins.[23]

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[23] Jahn 2004; Junker 2004; Kohler 2008; Magner 2002; von Schwerin 2013; Sneader 2005; Stoff 2012; Weatherall 1991.

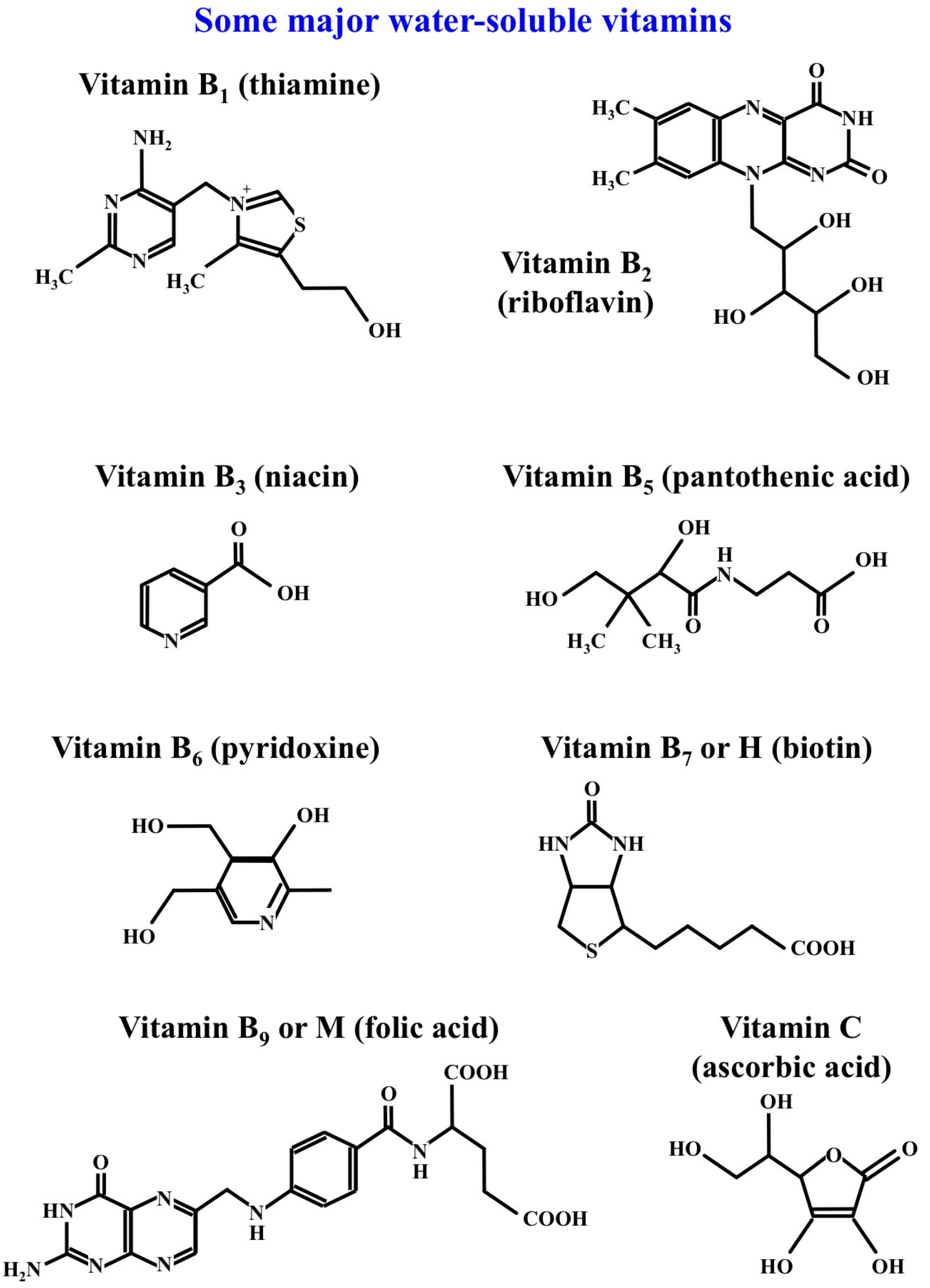

Some major water-soluble vitamins
Vitamin B$_1$ (thiamine)
Vitamin B$_2$ (riboflavin)
Vitamin B$_3$ (niacin)
Vitamin B$_5$ (pantothenic acid)
Vitamin B$_6$ (pyridoxine)
Vitamin B$_7$ or H (biotin)
Vitamin B$_9$ or M (folic acid)
Vitamin C (ascorbic acid)

Figure 2.178: Some major water-soluble vitamins include vitamins B$_1$ (thiamine), B$_2$ (riboflavin), B$_3$ (niacin), B$_5$ (pantothenic acid), B$_6$ (pyridoxine), B$_7$ or H (biotin), B$_9$ or M (folic acid), and C (ascorbic acid).

Christiaan Eijkman (Dutch, 1858–1930) discovered vitamin B_1 and its importance for preventing beriberi. For that discovery, he won the Nobel Prize in Physiology or Medicine in 1929. Professor G. Liljestrand, a member of the Royal Caroline Institute, described Eijkman's discovery and its implications [https://www.nobelprize.org/prizes/medicine/1929/ceremony-speech/]:

> It was the analysis of the nature of the food used in cases of polyneuritis in hens that led Eijkman to his discovery. As a rule, analysis and synthesis complete each other, and indeed the employment of both these avenues of approach has been of decisive importance also for the development of the science of vitamins. [...]
>
> Many years have passed, since Eijkman found the antineuritic principle in food, but the great importance of this work has been appreciated but slowly. Today, however, the outstanding significance of the discovery is universally acknowledged not only for our understanding and our attempt to combat beriberi, but also because it has indicated a way of investigating and controlling many other deficiency diseases.

Albert Eschenmoser (Swiss, 1925–) artificially synthesized vitamin B_{12}, the vitamin with the most complex molecular structure. Eschenmoser also developed methods of synthesizing artificial nucleic acids that differ from natural DNA and RNA.

Casimir (Kazimierz) Funk (Polish, educated in Switzerland and worked in Germany before moving to United States, 1884–1967) first coined the word "vitamin" (or "vital amine") and helped to identify the molecular structures and/or dietary effects of vitamins B_1, B_2, B_3, C, and D. He also did important early work on steroid hormones. Despite his many important discoveries regarding vitamins and hormones, he never won a Nobel Prize.

Paul Karrer (Swiss, 1889–1971) conducted research that helped to identify vitamins A, B_2, C, and E. He won the Nobel Prize in Chemistry in 1937. Professor W. Palmær, Chairman of the Nobel Committee for Chemistry, stated [https://www.nobelprize.org/prizes/chemistry/1937/ceremony-speech/]:

> The Royal Academy of Sciences has decided also to award to Professor Paul Karrer in Zurich one half of the Nobel Prize in Chemistry this year in recognition of his researches concerning carotenoids and flavins, and the vitamins A and B_2. [...]
>
> Karrer has thus succeeded in elucidating completely the nature of two of the vitamins, hitherto considered as so mysterious, and one of them is now produced artificially. A characteristic of this scientist is his open eye to the great and important problems as well as to their kernels, and the independent way in which he attacks the problems and pursues his new departures with the aid of his own methods.

Richard Kuhn (Austrian, 1900–1967) made major discoveries regarding the chemical structures and synthesis of vitamins A, B_2, and B_6, for which he won the Nobel Prize in Chemistry in 1938. He also synthesized antibiotics (p. 190) and nerve agents (p. 585) and conducted a wide variety of other innovative biochemical work during his career. The Royal Swedish Academy of Sciences described Kuhn's vitamin discoveries [https://www.nobelprize.org/prizes/chemistry/1938/kuhn/facts/]:

> Kuhn investigated theoretical problems of organic chemistry (stereochemistry of aliphatic and aromatic compounds; syntheses of polyenes and cumulenes; constitution and colour; the acidity of hydrocarbons), as well as extensive fields in biochemistry (carotenoids; flavins; vitamins and enzymes).

> For a period of twenty years Kuhn investigated compounds containing double bonds which proved to be of great interest in connection with the study of the chemical nature of the carotenoids. He discovered eight new types of these and was able to analyse their constitution. He also carried out important work on vitamin B2 and the antidermatitis vitamin B6. For his work in this important field Kuhn was awarded the Nobel Prize for Chemistry in 1938.

Feodor Lynen (German, 1911–1979) made important discoveries regarding vitamin B_7, cholesterol, and fatty acid metabolism. He won the Nobel Prize in Physiology or Medicine in 1964. His work regarding cholesterol and hormones is discussed on p. 356.

Tadeusz Reichstein (Polish, educated and worked in Switzerland, 1897–1996) discovered a method to synthesize vitamin C that is now called the Reichstein process and is still widely used. He won the Nobel Prize in Physiology or Medicine in 1950 for his research on cortisone (p. 356).

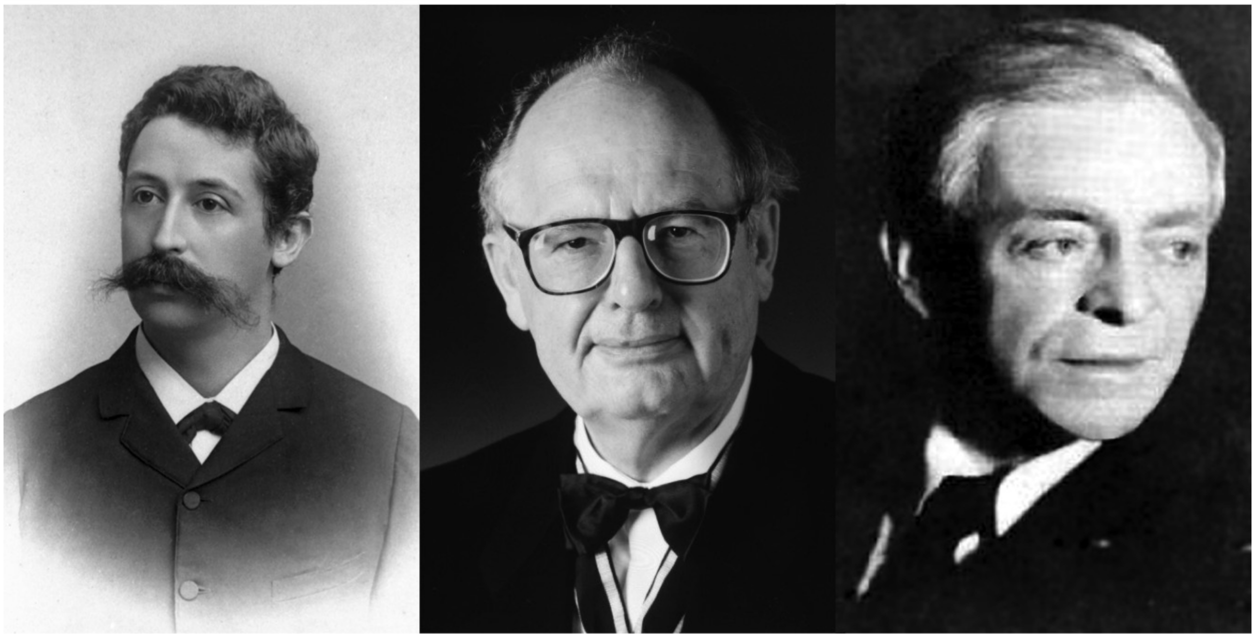
Albert Szent-Györgyi (Hungarian, 1893–1986) was the first to purify vitamin C, and he also made important discoveries regarding other vitamins, muscle metabolism, and the Krebs cycle. He won the Nobel Prize in Physiology or Medicine in 1937. Professor E. Hammarsten, a member of the Royal Caroline Institute, explained the importance of Szent-Györgyi's work on vitamin C and other vitamins [https://www.nobelprize.org/prizes/medicine/1937/ceremony-speech/]:

> The magnificent series of Szent-Györgyi's discoveries commenced in 1933. They were carried out and pursued at Szeged with extraordinary rapidity and precision. His clear vision for essentials induced him, in spite of his isolation of ascorbic acid and of his identification of it with the so-termed vitamin C—a feat that was justly hailed with enthusiasm—to hand over to others for the time being the tempting pursuit of the further development of that discovery, and to devote the whole of his energy to the problem of combustion, notwithstanding the difficulties it presented. [...]
>
> It is of especially great importance that at least two vitamins—C and B_2, and possibly B_1, and P—are in cooperation in the oxidation chain and are catalysts, illustrating the way in which these vitamins act in the organism.

Adolf Windaus (German, 1876–1959) made important discoveries regarding the structures and synthesis of vitamin D and cholesterol, for which he won the Nobel Prize in Chemistry in 1928. Professor H. G. Söderbaum, Secretary of the Royal Swedish Academy of Sciences, discussed Windaus's discoveries [https://www.nobelprize.org/prizes/chemistry/1928/ceremony-speech/]:

> Another sterol which Windaus has studied in detail, is ergosterol, which occurs partly in ergot and partly in yeast. The research carried out in recent years, in which Windaus himself has also played a leading part, has revealed the very important fact that, on being irradiated with ultraviolet light, this ergosterol assumes exactly the same properties as the antirachitic vitamin, "vitamin D", i.e. it will cure rachitis (rickets). For example, it has been found that 5 mg of irradiated ergosterol has the same action in this respect as 1 litre of good cod-liver oil. It can be considered proved, therefore, that ergosterol, or possibly a sterol, the physiological effects of which correspond completely with those of ergosterol, constitutes the antirachitic provitamin, i.e. the mother substance of vitamin D. [...] For there is no doubt that your work on sterols, vegetable cardiac poisons and other closely related substances merits in the same high degree such an award as the work which we have just recognized.

Vitamins



Christiaan Eijkman (1858–1930) Vitamin B_1

Albert Eschenmoser (1925–) Synthesized vitamin B_{12}, nucleic acids, etc.

Casimir Funk (1884–1967) Vitamins B_1, B_2, B_3, C, D

Paul Karrer (1889–1971) Vitamins A, B_2, C, E

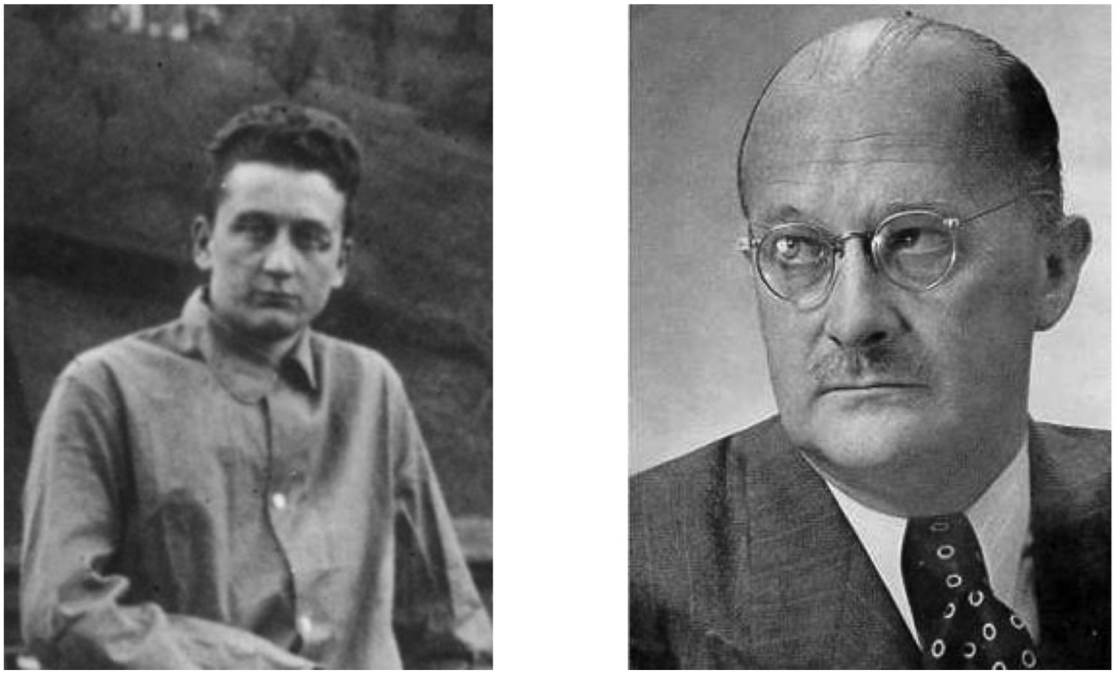
Richard Kuhn (1900–1967) Vitamins A, B_2, B_6

Figure 2.179: Creators who made major discoveries about vitamins included Christiaan Eijkman, Albert Eschenmoser, Casimir Funk, Paul Karrer, and Richard Kuhn.

Vitamins

Feodor Lynen (1911–1979)
Vitamin B_7, cholesterol

Tadeusz Reichstein (1897–1996)
Vitamin C, cortisone



Albert Szent-Györgyi (1893–1986)
Vitamin C, muscle, Krebs cycle

Adolf Windaus (1876–1959)
Vitamin D, cholesterol

Figure 2.180: Creators who made major discoveries about vitamins also included Feodor Lynen, Tadeusz Reichstein, Albert Szent-Györgyi, and Adolf Windaus.

2.5.2 Steroid Hormones

Many hormones belong to the family of steroid hormones; several examples are shown in Fig. 2.181. Steroid hormones are all derived from cholesterol. Various steroid hormones are produced by certain organs, pass through the bloodstream, and enter target cells elsewhere in the body to deliver their signals. The best-known steroid hormones are the male hormone testosterone, produced by the testes, and female hormones progesterone and estradiol (estrogen), produced by the ovaries. However, the large family of steroid hormones also includes non-sexual hormones, such as cortisone, an anti-inflammatory hormone produced by the adrenal glands in response to stress, and aldosterone, produced by the adrenal glands to regulate blood pressure.

Both the natural science and the practical applications of steroid hormones were developed almost entirely by creators from the greater German-speaking world.[24] Figures 2.182–2.191 show some of the key individuals who were involved. The discoveries regarding these hormones had revolutionary, immediate, and long-lasting implications, making possible the creation of:

- Pregnancy tests
- Hormonal contraceptives
- Menopause treatments
- Anabolic steroids
- Anti-inflammatory steroid drugs
- Blood pressure medications
- Therapeutics for high cholesterol
- Etc.

Arnold Adolph Berthold (German states, 1803–1861) demonstrated the existence of sexual hormones by removing the testes from roosters and then successfully re-implanting them in other regions of some of the birds, showing that the testes produced substances that passed through the blood to affect sexual characteristics.

Austrian gynecologists Rudolf Chrobak (1843–1910) and Emil Knauer (1867–1935) built upon that work, as reported by professor of pharmacology Walter Sneader [Sneader 2005, p. 173]:

---

[24] Butenandt 1931; Dominguez-Lacasa 2005; Gausemeier 2005; Jahn 2004; Junker 2004; Karlson 1990; Koesling and Schülke 2010; Kohler 2008; Magner 2002; Marks 2010; Possehl 1989; Raviña and Kubinyi 2011; Schieder and Trunk 2004; Schneider 1972; von Schwerin 2013; Sneader 2005; Stoff 2012; Taschwer 2016; Weatherall 1991.

> During the period of enthusiasm for organotherapy at the end of the nineteenth century, the Viennese gynaecologist Rudolf Chrobak gave tablets prepared from cows' ovaries to his patients in an attempt to overcome the undesirable effects that ensued after surgical removal of their ovaries. Chrobak then asked his assistant, Emil Knauer, to investigate the effects of transplantation of ovarian tissue in animals. He began by extirpating the ovaries of rabbits and showing that this led to involution of the uterus and cessation of the oestrus cycles. However, when he reimplanted the ovaries elsewhere in the animals, normal ovarian function was restored. His work inspired others to administer desiccated ovaries or extracts of these to patients in the hope of relieving menopausal disorders.

In 1912, Eugen Steinach (Austrian, 1861–1944) went further than the same-sex experiments of Berthold and Knauer. He demonstrated that transplanting the testes from male to female guinea pigs caused the female guinea pigs to develop male characteristics.

Heinrich Wieland (German, 1877–1957) won the 1927 Nobel Prize in Chemistry for his research on the biochemical synthesis of bile acids, which are chemically related to cholesterol and therefore shed knowledge on this whole family of molecules. Professor H. G. Söderbaum, Secretary of the Royal Swedish Academy of Sciences, summarized the methods and the importance of Wieland's research [https://www.nobelprize.org/prizes/chemistry/1927/ceremony-speech/]:

> Wieland succeeded in producing from bile a saturated acid which can be regarded as the mother substance or parent acid of the bile acids, and which he studied and characterized in detail. When Windaus then produced this same parent acid, cholanic acid, from cholesterol by means of a complicated and very ingenious series of experiments, this indicated very clearly the close relationship between cholesterol and the bile acids. It should be pointed out in this connection that Wieland's investigations into bile acids themselves gave a deeper insight of the mechanism of the action of the bile in the resorption of food in the intestines. [...]
>
> Professor Wieland. The decision of the Royal Academy of Sciences to award you the Nobel Prize in Chemistry for your work on bile acids and related substances, is only a just recognition of the solution of a problem which is without doubt one of the most difficult which organic chemistry has had to tackle.
>
> The complex composition of the compounds investigated, the large number of atoms contained in the molecules of these compounds, the fact that the material was often very difficult to produce, even in small quantities, these were obstacles which could only be overcome with such striking success through a remarkable skill in experimentation and a rare capacity for finding new ways and means.

During the 1930s, four different groups working in parallel within the German-speaking world almost simultaneously purified, identified, and chemically synthesized the various male and female sexual hormones:

1. In Germany, Adolf Butenandt (German, 1903–1995) purified and identified several natural sex hormones in the 1930s [Butenandt 1931; Karlson 1990; Schieder and Trunk 2004]. He won the 1939 Nobel Prize in Chemistry for that work. The Royal Swedish Academy of Sciences emphasized the significance of the research of Butenandt and his collaborators [https://www.nobelprize.org/prizes/chemistry/1939/butenandt/facts/]:

> Hormones are substances that transfer signals between the body's cells and organs and regulate bodily functions. In the 1930s Adolf Butenandt contributed to the mapping of several hormones that specifically apply to men and women, respectively. After determining the composition of the female sex hormone estrogen, he was able to determine the structure for this hormone and a related hormone, estriol. He was also able to produce a male sex hormone in pure form for the first time and to determine its chemical composition. It was named androsterone.

Butenandt worked at several universities and then became head of the Kaiser Wilhelm Institute for Biochemistry. During that time, he worked with a team of other hormone experts in his academic laboratories, including Hans Dannenbaum (German?, 18??–19??), Günther Hanisch (German?, 18??–19??), Helmut Kudszus (German?, 18??–19??), and Kurt Tscherning (German?, 18??–19??). Butenandt also worked closely with the Schering pharmaceutical company to commercialize production of both naturally derived and chemically synthesized hormones for a variety of purposes (Figs. 2.183–2.186). Some especially noteworthy scientists at Schering included:

- Max Dohrn (German, 1874–1943, chemist) who worked on everything from sex hormones to insulin to sulfonamide antibiotics.

- Fritz Hildebrandt (German, 1887–1961, pharmacologist).

- Walter Hohlweg (Austrian, 1902–1992, endocrinologist) and Hans-Herloff Inhoffen (German, 1906–1992, Schering chemist), who developed an orally effective form of estrogen. Inhoffen also chemically synthesized vitamins A and D.

- Carl Kaufmann (German, 1900–1980, gynecologist), who worked on female sexual hormones and their relevance for treating menstrual disorders and cancers.

- Johannes Schultze (German?, ??–??, chemist), an expert on the chemical synthesis of steroid hormones.

- Erwin Schwenk (Austrian, 1887–1976, chemist), who moved to Schering's U.S. branch and set up similar work there.

2. In Switzerland, Leopold Ružička (Austro-Hungarian/Croatian, studied in Germany and worked in Switzerland, 1887–1976) chemically synthesized sex hormones in the 1930s. For that work, he also won the 1939 Nobel Prize in Chemistry. The Royal Swedish Academy of Sciences summarized the results of Ružička and his collaborators [https://www.nobelprize.org/prizes/chemistry/1939/ruzicka/facts/]:

> Terpenes are a large and varied group of substances that range from rubber and the solvent turpentine to the cholesterol in our blood. Leopold Ruzicka studied fragrances in perfumes and became interested in how they were related to other substances. In the mid-1920s he came to the conclusion that the substances were composed of the same building block, terpene isoprene. By manipulating cholesterol molecules, Leopold Ruzicka succeeded in producing the male sex hormone androsterone and later demonstrated that testosterone also could be produced from cholesterol.

Just as Butenandt collaborated with the German pharmaceutical company Schering, Ružička collaborated with the Swiss pharmaceutical company CIBA (Chemische Industrie Basel) [Ratmoko 2010]. Chemists at Ciba who were especially important for steroid hormone synthesis included Max Hartmann (Swiss, 1884–1952), Karl Miescher (Swiss, 1892–1974), Ernst Tschopp (Swiss?, ??–19??), and Albert Wettstein (Swiss, 1907–1974). See Fig. 2.187.

3. At the University of Vienna, the chemist Karl Slotta (German, 1895–1987) led a group that also included gynecologist Erich Fels (German, 1897–1981) and chemist Heinrich Ruschig (German, 1906–1994); see Fig. 2.188. They too were at the forefront of discovering, synthesizing, and testing various steroid hormones.

4. At the University of Amsterdam and the collaborating Organon pharmaceutical company, physician Ernst Laqueur (German, 1880–1947) led a group that also included Kåroly Gyula David (Hungarian, 1905–1945, killed in the Gusen concentration camp), Elisabeth Dingemanse (Dutch, 1886–1952), John (Johann) Freud (Hungarian, ??–??), Bernard Josephy (German, 18??–19??), and Otto Mühlbock (German, 1906–1979) [Oudshoorn 1991], as shown in Fig. 2.189. They published numerous papers and patented a variety of hormonal compounds, running neck-and-neck with the German, Swiss, and Austrian groups.

In 1927, the gynecologists Selmar Aschheim (German, 1878–1965) and Bernhard Zondek (German, 1891–1966) developed the first pregnancy test, measuring hormone changes in urine with the onset of pregnancy [Sneader 2005, p. 174]. The test involved injecting a woman's urine into an immature female mouse (Fig. 2.190). If the woman was not pregnant, no changes were noted in the mouse. If the woman was pregnant, the mouse visibly went into heat from the extra hormones, even though it was not mature enough to produce its own hormones. This test was adopted worldwide (often with rabbits instead of mice) and used for decades until it was replaced by *in vitro* immunoassays (which had also been invented by German-speaking scientists—see p. 228). This test detected human chorionic gonadotropin (hCG), which Aschheim and Zondek also purified and identified. While hCG is a protein hormone and not a steroid, its function is directly tied to steroid hormones, so it is included in this section.

Based on the latest discoveries about female sexual hormones, Ludwig Haberlandt (Austrian, 1885–1932) proposed hormonal birth control in 1921, successfully demonstrated it in animals during the 1920s, and tried to initiate human trials beginning in 1930 (Fig. 2.191). Although Haberlandt's hormonal contraceptive was never officially approved for that purpose in humans, it appears to have unofficially achieved considerable use from the 1930s onward. Historian Lara Marks recounted Haberlandt's struggles and achievements [Marks 2010, pp. 47–48]:

> [H]e had successfully conducted a series of animal experiments by 1927, proving the contraceptive value of ovarian and placental extracts. By the late 1920s he was negotiating with the German-based pharmaceutical firms E. Merck and I. G. Farben to produce a progesterone-based hormonal contraceptive. Neither of these companies, however, were willing to take on the project. Despite the increasing use of contraception among couples in these years, research into contraception remained highly taboo. Haberlandt himself was denied promotion in his own academic institution because of the hostility of the Catholic lobby to his contraceptive work. Despite these difficulties, in 1928 Haberlandt secured an agreement to develop his hormonal contraceptive with Gedeon Richter, a Hungarian company producing hormones, based in Budapest. By 1930 the company

> had commercially registered a compound called Infecundin. Haberlandt faced problems getting the product tested on humans because he was not a clinician. Although he approached a number of physicians to try out the drug as a hormonal contraceptive in women, no one was willing to support it.
>
> Though Haberlandt himself died prematurely in 1932, his product was tested at a women's hospital in Innsbruck in 1934. The results of this research were never published. The drug, however, had its commercial registration renewed in 1940 and 1950. Infecundin, or a similar substance called Profecundin, is also rumoured to have been promoted in Germany during 1942. [...I]n 1966 Gedeon Richter, by then a state-owned company, promoted Infecundin as the first Hungarian contraceptive pill.

Carl Djerassi (Austrian/Bulgarian, 1923–2015), having trained in the German-speaking world, studied the details of Haberlandt's work, and worked with other German-speaking pioneers from the early days of hormone research, proceeded to commercialize hormonal birth control in Mexico and the United States in the 1950s. Lara Marks described direct links between Djerassi and the earlier work by Haberlandt and other German-speaking hormone researchers [Marks 2010, pp. 67–68]:

> [...] Emerik Somlo [...] had started off his career in Mexico in 1928 as a representative for the Hungarian company Gedeon Richter, which at that time was negotiating its agreement with Haberlandt in Europe to produce an oral contraceptive. In Mexico Somlo had established a lucrative trade for Gedeon Richter due to the almost total absence of other drug houses. He soon realized he could push the business even further with the establishment of a laboratory within Mexico. Refused funding by Gedeon Richter to finance such a project, Somlo collaborated with a young German Jewish chemist, Frederico Lehmann, to set up the laboratory and their own company, Laboratorios Hormona, in 1933. Much of the production of this firm was built up through the expertise of refugee European scientists recruited to the company in the 1930s. Feeling the ravages of fascism, these scientists brought with them many of the advances in hormone knowledge and production in Europe in the interwar period. [...]
>
> In 1945 Somlo hired a Hungarian Jewish chemist, George Rosenkrantz [at Somlo and Lehman's new company Syntex...] Trained in technical sciences and chemical engineering at the Eidgenossische Technische Hochschule (Technical School of the Confederation) in Zurich in the 1930s, Rosenkrantz had worked alongside leading experts in the chemical synthesis of male hormones. His supervisor, Leopold Ruzicka, for instance, had received the Nobel Prize in 1939 as a result of his work on male hormones with Adolf Butenandt, one of the discoverers of oestrone. [...]
>
> In 1948, Rosenkrantz was joined in these efforts by a young American (born in Vienna), the Jewish Carl Djerassi. Recruite together with a number of other scientists, some of whom had trained with Rosenkrantz in Zurich, Djerassi had a strong background in steroidal chemistry. After leaving Europe in 1938, he had obtained a doctorate from the University of Wisconsin in 1945. His graduate work had focused on the chemical conversion of the male hormone, testosterone, into the female hormone, oestrogen. Djerassi subsequently worked for the American subsidiary of the Swiss company CIBA, which held the patent for cholesterol, whence he joined Syntex. Employed by Syntex as part of its drive to fulfill its industrial potential and expand its range of steroidal intermedi-

> aries, Djerassi not only brought with him industrial expertise and a knowledge of steroid chemistry, but also a desire to establish an academic and scientific reputation.

Marks also noted [Marks 2010, p. 11]:

> In a recent paper Djerassi calls himself 'The mother of the pill'. Such mythology partly stems from the fact that much of the early history of the oral contraceptive was written by the scientists and medical experts involved in its initial development, who had an interest in promoting themselves as its inventors.

Tadeusz Reichstein (Polish, educated and worked in Switzerland, 1897–1996) won the Nobel Prize in Physiology or Medicine in 1950 for identifying cortisone, a steroid hormone that is not sex-related, but rather produced in response to stress. Professor G. Liljestrand of the Royal Caroline Institute announced the award [https://www.nobelprize.org/prizes/medicine/1950/ceremony-speech/]:

> Professor Tadeus Reichstein. To you and your co-workers we owe the first isolation of four active hormones from the adrenal cortex, the first synthesis of one of them, the proof of the steroid nature of said hormones, and numerous details on the structure and properties of these important bodies. In this way the wearisome road to synthesis was smoothed, and new medicaments created. Your discoveries in this field are of fundamental importance.

Konrad Bloch (German, 1912–2000) and Feodor Lynen (German, 1911–1979) won the Nobel Prize in Physiology or Medicine in 1964 for their work on cholesterol and fatty acid metabolism, which also had many implications for the biochemistry of hormones. Professor S. Bergström of the Nobel Committee for Physiology or Medicine explained some of their research [https://www.nobelprize.org/prizes/medicine/1964/ceremony-speech/]:

> At an early stage Bloch made another discovery of fundamental importance in showing that cholesterol is the precursor of bile acids and of one of the female sex hormones. These discoveries opened up a new field of research that has engaged a great number of scientists in different disciplines. We know now that all substances of steroid nature in our body are formed from cholesterol.
>
> Mainly through the basic biochemical work of this year's prizewinners do we know today in detail how cholesterol and fatty acids are synthesized and metabolized in the body. These processes comprise series of reactions with a great number of individual steps. For instance, the formation of cholesterol from acetic acid is a process involving some thirty different steps. Derangements of this complicated mechanism of formation and metabolism of lipids are in many cases responsible for the genesis of some of our most important diseases, especially in the cardiovascular field. A detailed knowledge of the mechanisms of lipid metabolism is necessary to deal with these medical problems in a rational manner.
>
> The importance of the work of Bloch and Lynen lies in the fact that we now know the reactions which have to be studied in relation to inherited and other factors. We can now predict that we, through further research in this field in the near future, can expect to be able to do individual specific therapy against the diseases that in the developed countries are the most common cause of death.

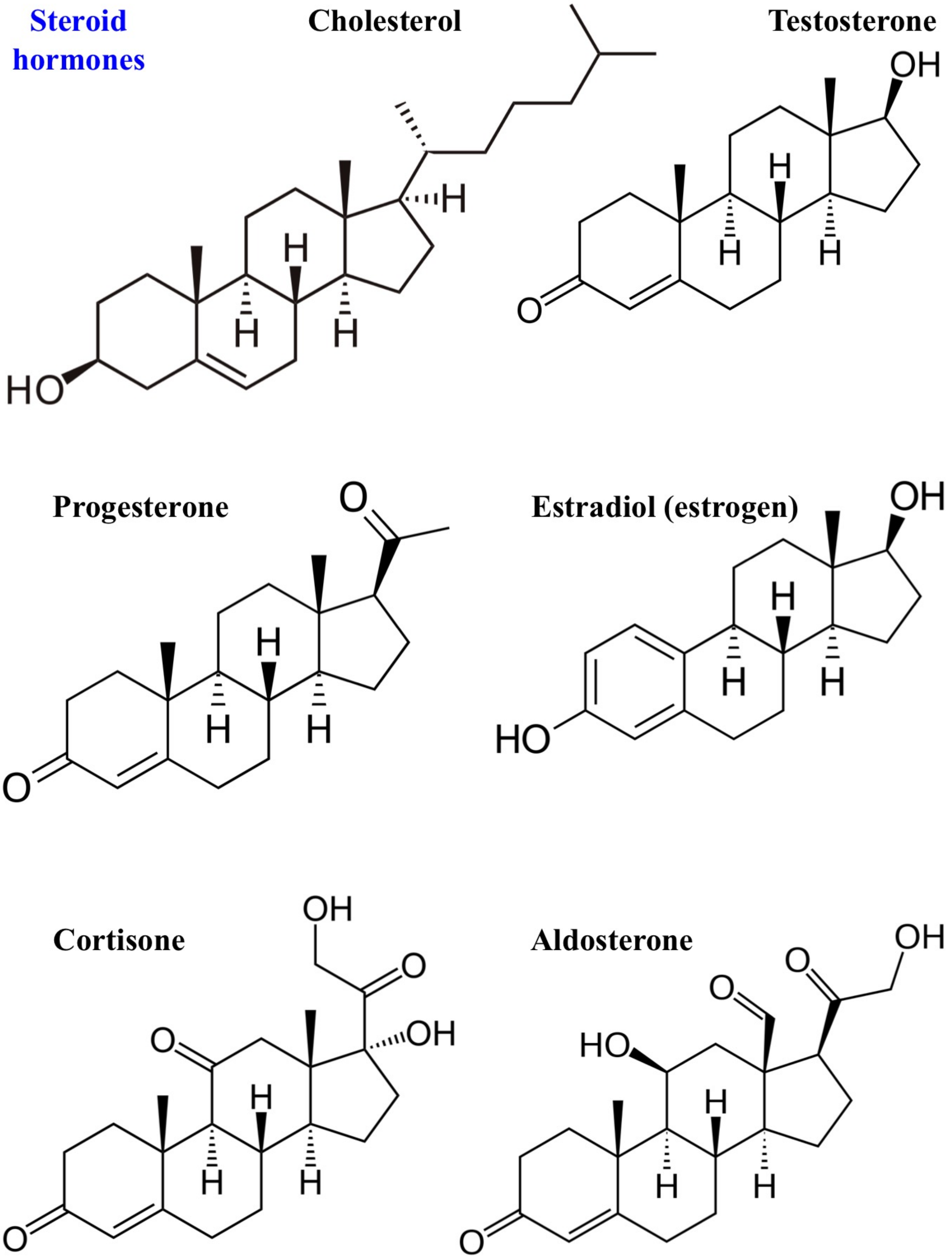
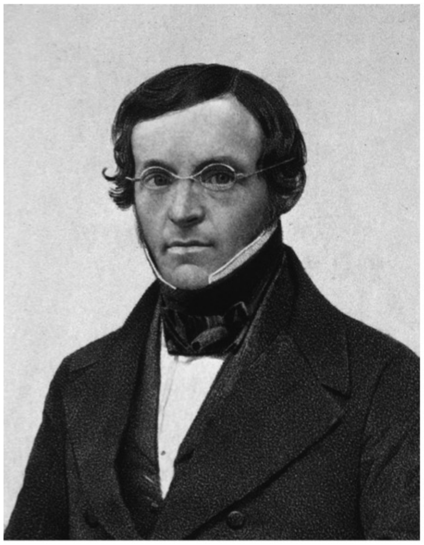

Steroid hormones
Cholesterol
Testosterone
Progesterone
Estradiol (estrogen)
Cortisone
Aldosterone

Figure 2.181: Steroid hormones are derived from cholesterol and include hormones such as testosterone, progesterone, estradiol (estrogen), cortisone, and aldosterone.

Steroid hormones

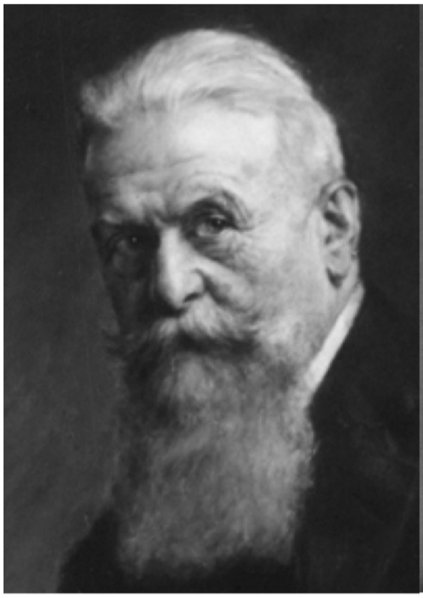
Arnold Berthold
(1803–1861)



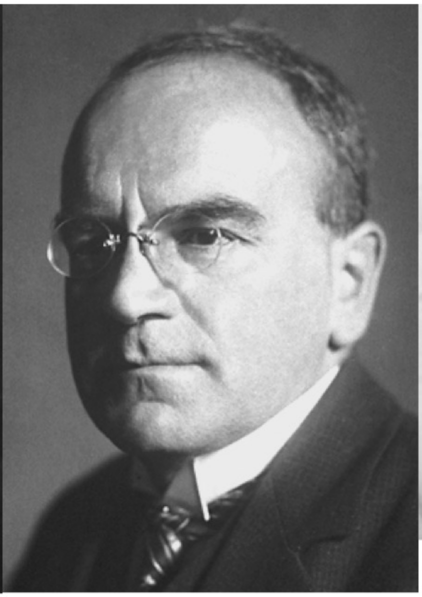
Rudolf Chrobak
(1843–1910)

Emil Knauer
(1867–1935)

Eugen Steinach
(1861–1944)



Heinrich Wieland
(1877–1957)

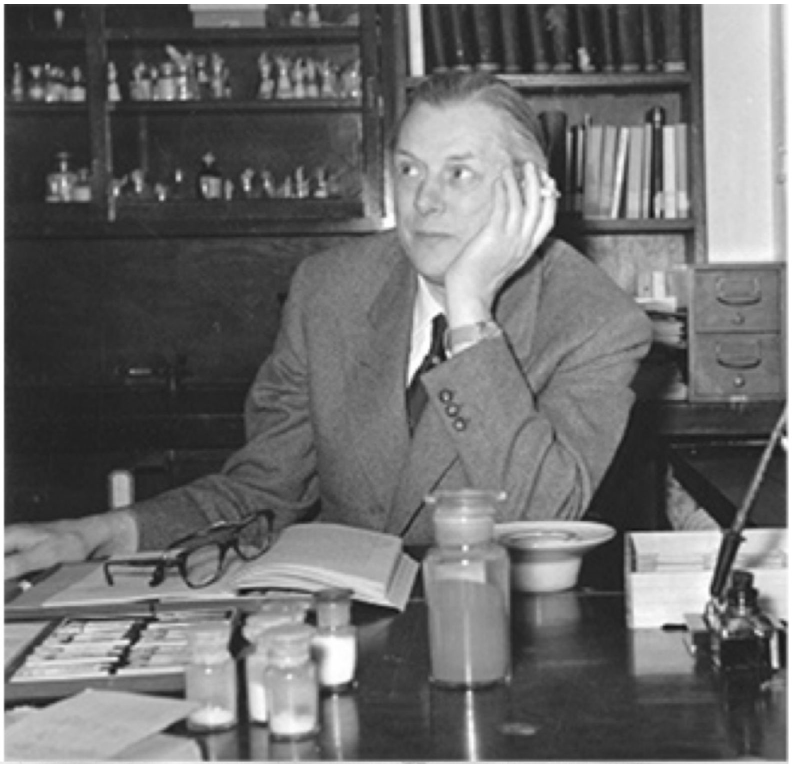


Konrad Bloch
(1912–2000)

Figure 2.182: Some of the creators who made important contributions to knowledge about steroid hormones included Arnold Berthold, Rudolf Chrobak, Emil Knauer, Eugen Steinach, Heinrich Wieland, and Konrad Bloch.

Steroid hormones: Butenandt/Schering

Adolf Butenandt
(1903–1995)



Chemical synthesis
of steroid hormones
(Schering, 1937–1938);
from the left:
??, Johannes Schultze,
Walter Hohlweg, ??

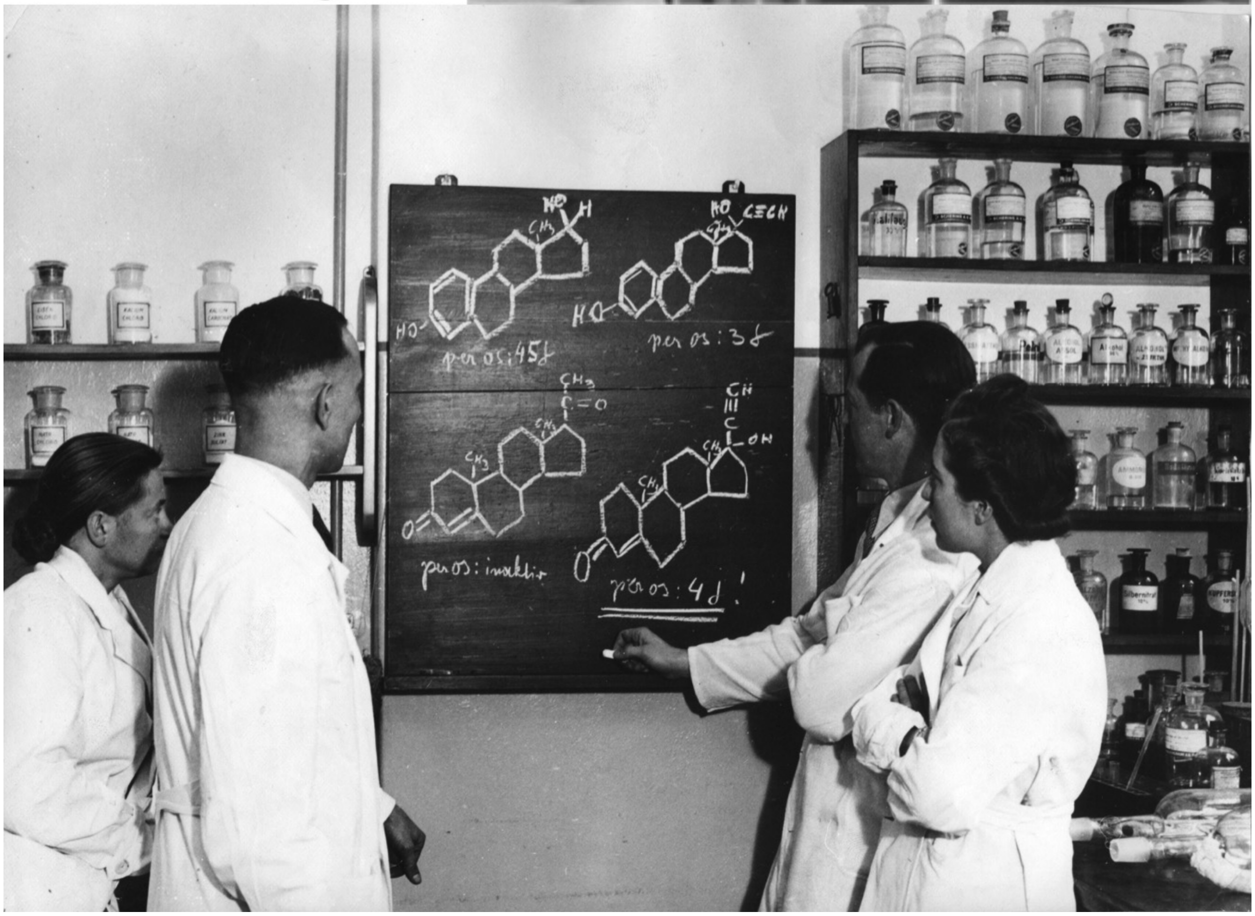

HO
CH₃
H
HO
C≡CH
HO
per os: 45γ
per os: 3γ
CH₃
C=O
CH₃
CH₃
CH
C
OH
CH₃
CH₃
O
per os: inaktiv
O
per os: 4γ!

Figure 2.183: Adolf Butenandt led a research group that collaborated with Schering to purify, study, and synthesize steroid hormones.

Steroid hormones: Butenandt/Schering
Hans Dannenbaum
(19??–19??)
Max Dohrn
(1874–1943)
Günther Hanisch
(19??–19??)
Fritz Hildebrandt
(1887–1961)
Walter Hohlweg
(1902–1992)
Hans-Herloff Inhoffen
(1906–1992)

Figure 2.184: The steroid hormone R&D group run by Butenandt and Schering included Hans Dannenbaum, Max Dohrn, Günther Hanisch, Fritz Hildebrandt, Walter Hohlweg, and Hans-Herloff Inhoffen.

Steroid hormones: Butenandt/Schering

Carl Kaufmann
(1900–1980)

Helmut Kudszus
(19??–19??)

Johannes Schultze
(19??–19??)

Erwin Schwenk
(1887–1976)

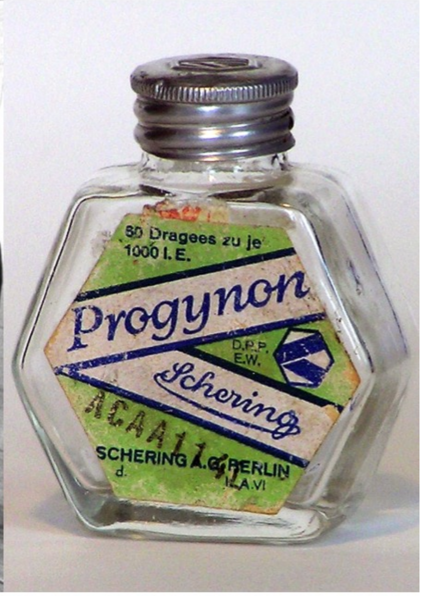
Kurt Tscherning
(19??–19??)

Figure 2.185: The steroid hormone R&D group run by Butenandt and Schering also included Carl Kaufmann, Helmut Kudszus, Johannes Schultze, Erwin Schwenk, and Kurt Tscherning.

Steroid hormones: Butenandt/Schering

Preparing pig ovaries and pituitary glands to extract hormones at Schering in Berlin (ca. 1928)

Purified estrogen (first sold by Schering in 1928)


50 Dragees zu je
1000 I.E.
Progynon
D.P.P.
E.W.
Schering
SCHERING A.G. BERLIN

Johannes Schultze working on chemical synthesis of steroid hormones at Schering (1935)

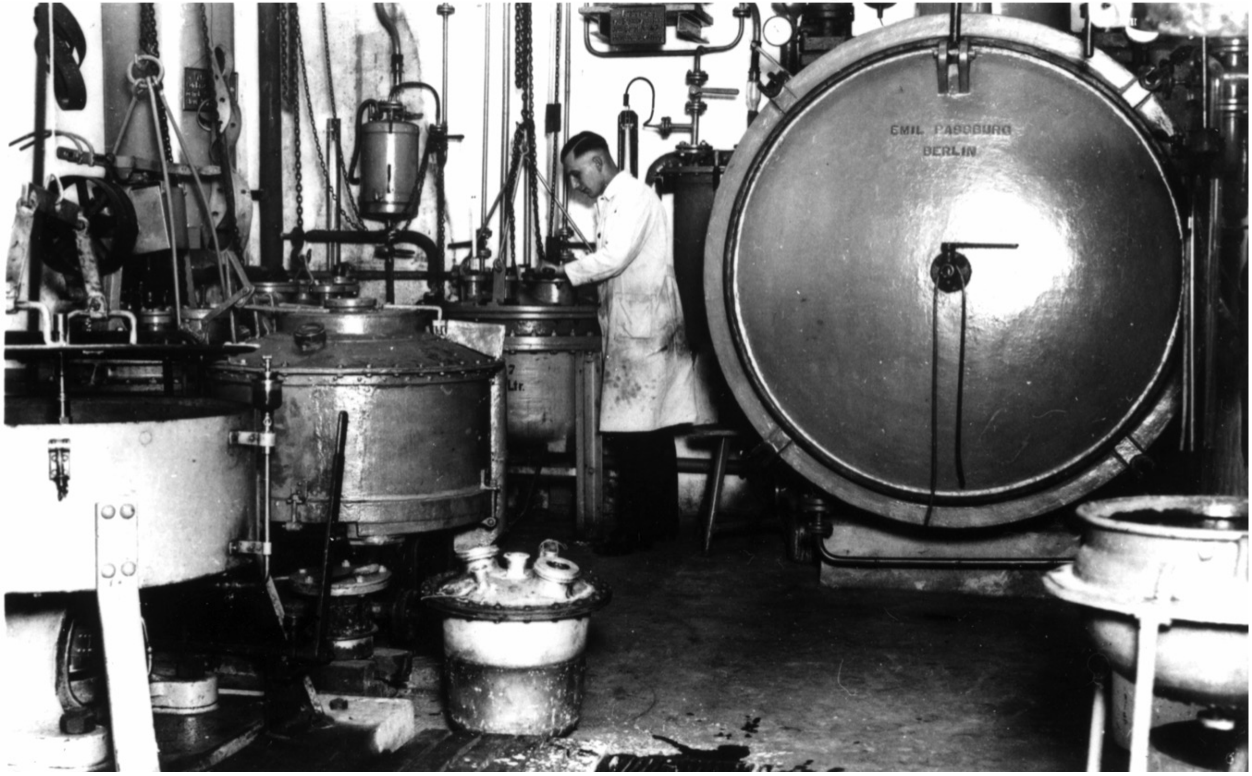

EMIL PASSBURG
BERLIN

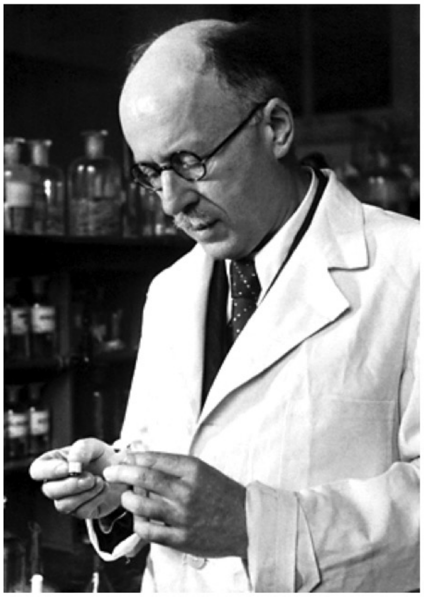
Figure 2.186: The steroid hormone R&D group run by Butenandt and Schering purified steroid hormones from animals and then developed methods to chemically synthesize them.

Steroid hormones: ETH Zurich/CIBA

Leopold Ružička
(1887–1976)

Max Hartmann
(1884–1952)

Karl Miescher
(1892–1974)



Albert Wettstein
(1907–1974)

Ernst Tschopp
(19??–19??)

Figure 2.187: The steroid hormone R&D group at ETH Zurich and CIBA was run by Leopold Ružička and also included Max Hartmann, Karl Miescher, Ernst Tschopp, and Albert Wettstein.

Steroid hormones: University of Vienna

Karl Slotta (1895–1987)

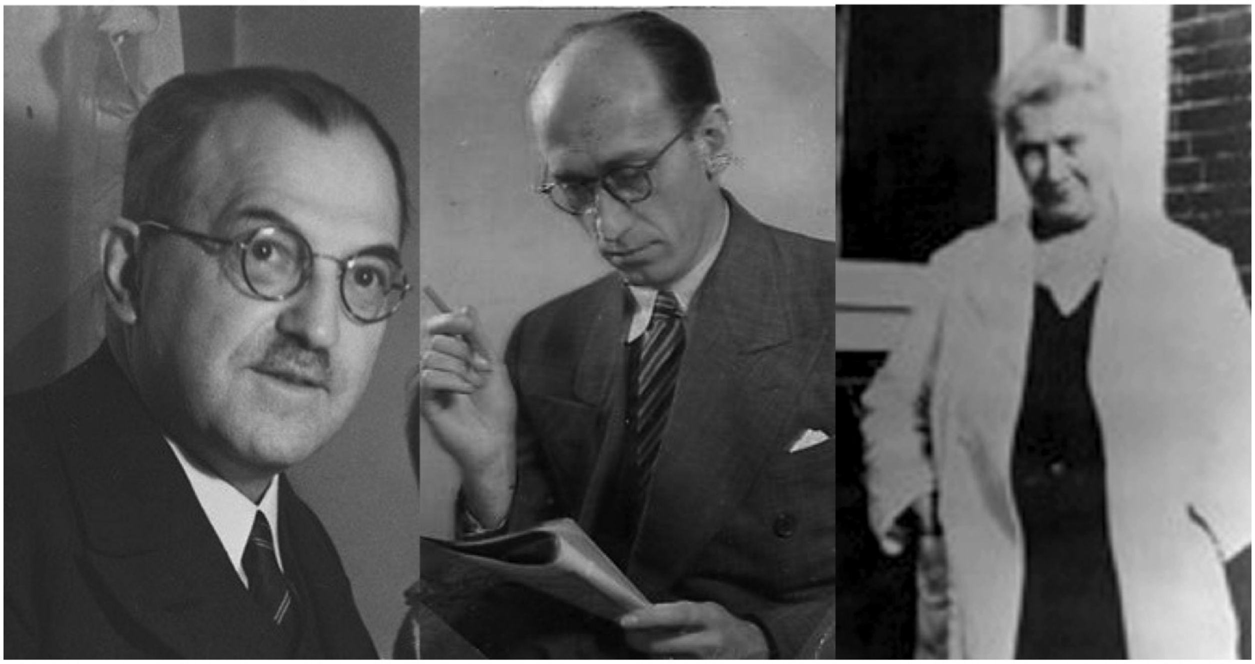
Erich Fels (1897–1981)

Heinrich Ruschig (1906–1994)

Figure 2.188: The steroid hormone R&D group at the University of Vienna was run by Karl Slotta and also included Erich Fels and Heinrich Ruschig.

Steroid hormones: University of Amsterdam/Organon

Ernst Laqueur (1880–1947) **Kåroly Gyula David (1905–1945)** **Elisabeth Dingemanse (1886–1952)**



John (Johann) Freud (19??–19??) **Bernard Josephy (18??–19??)** **Otto Mühlbock (1906–1979)**

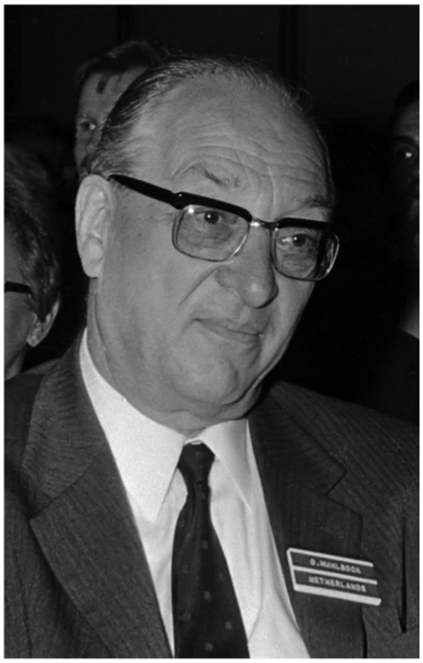
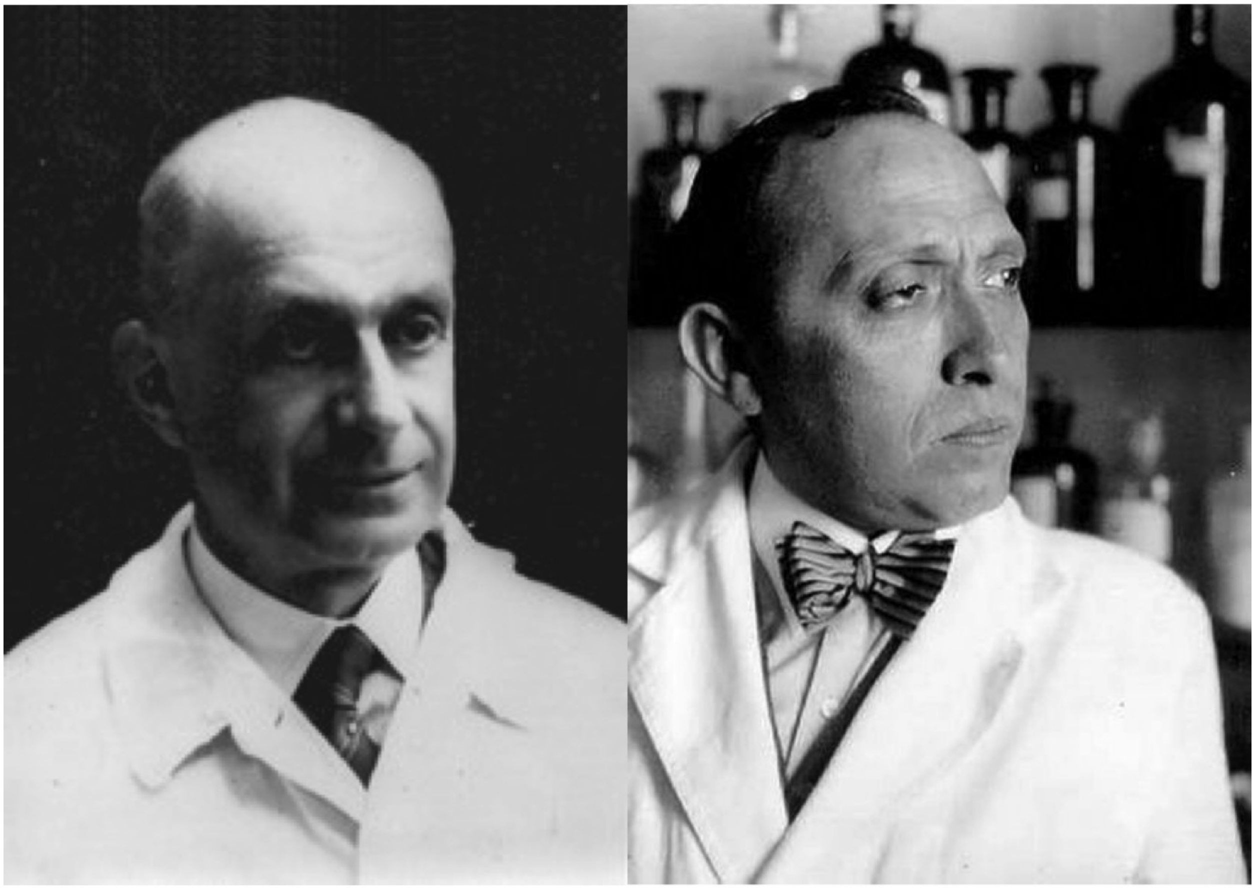


Figure 2.189: The steroid hormone R&D group at the University of Amsterdam and Organon was run by Ernst Laqueur and also included Kåroly Gyula David, Elisabeth Dingemanse, John (Johann) Freud, Bernard Josephy, and Otto Mühlbock.

Hormone-based pregnancy test (1927)

Selmar Aschheim (1878–1965) **Bernhard Zondek (1891–1966)**



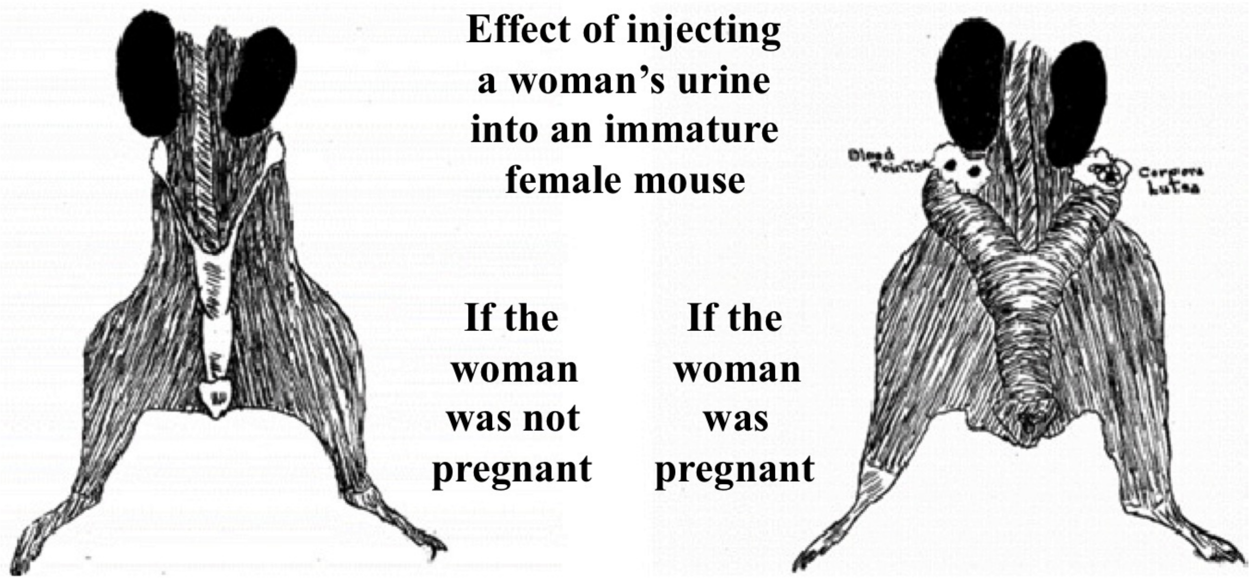

Effect of injecting a woman's urine into an immature female mouse
If the woman was not pregnant
If the woman was pregnant
Blood Follicles
Corpora lutea

Figure 2.190: Other German-speaking scientists who made important contributions to knowledge about steroid hormones included Selman Ascheim and Bernhard Zondek.

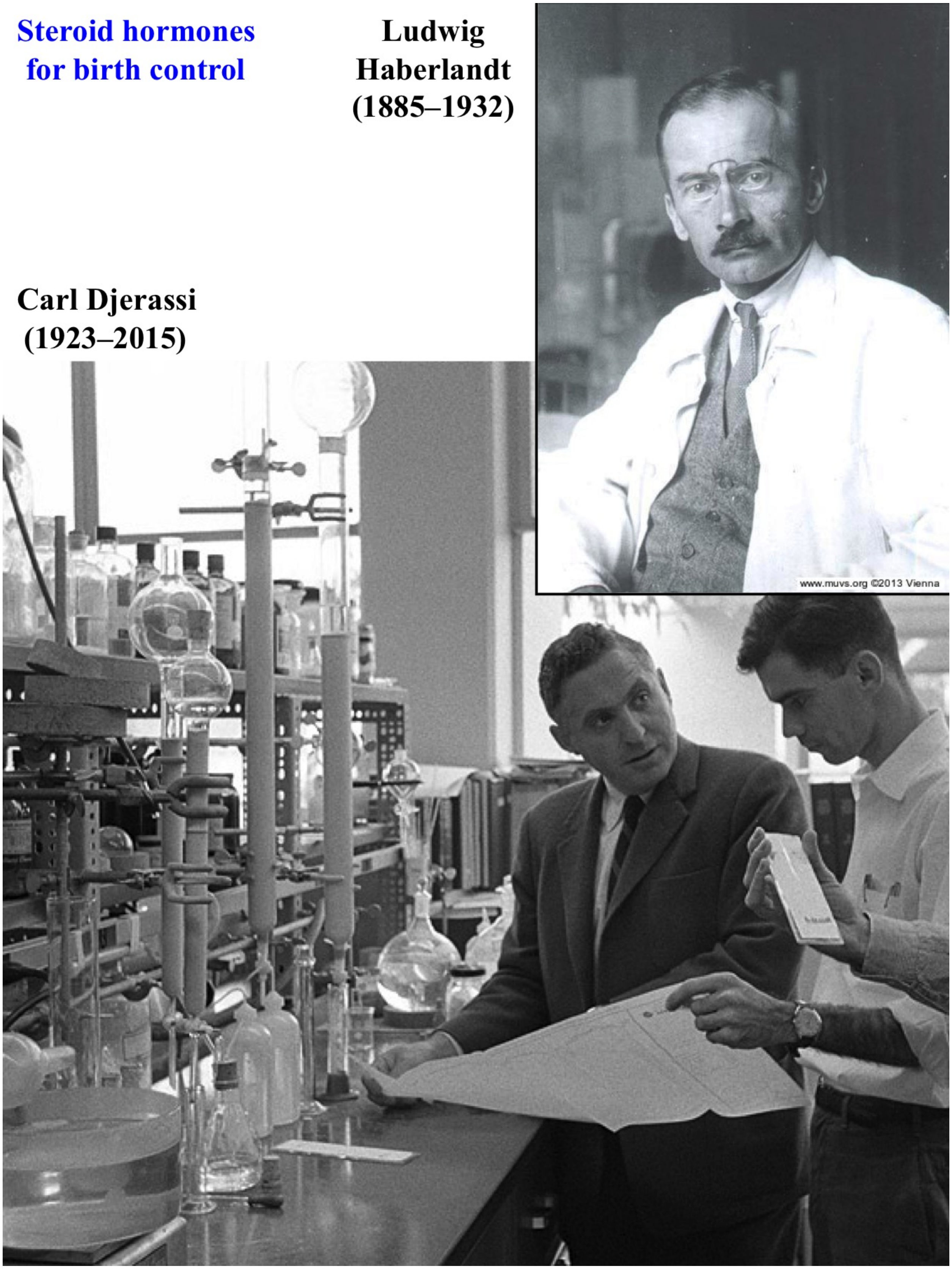

Steroid hormones for birth control
Ludwig Haberlandt (1885–1932)
Carl Djerassi (1923–2015)
www.muvs.org ©2013 Vienna

Figure 2.191: Ludwig Haberlandt proposed hormonal birth control in 1921, demonstrated it in animals in 1930, and helped to develop oral contraceptives that entered commercial human use in Europe in the 1930s. Carl Djerassi (shown with a student) commercialized a version of Haberlandt's oral contraceptive in North America in the 1950s and achieved much greater fame.

2.5.3 Nonsteroidal Hormones

Creators from the greater German-speaking world also made many major discoveries about nonsteroidal hormones, such as thyroid hormone, adrenaline, and insulin.[25] For closely related work on neurotransmitters, see p. 245.

Some important scientists who studied thyroid hormone production are shown in Fig. 2.192.

Theodor Billroth (Prussian/Austrian, 1829–1894) pioneered a wide variety of surgical techniques in the neck, including the thyroid, and the abdomen. Even the American Council of Learned Societies deemed his work especially noteworthy, well over a century later [ACLS 2000, p. 99]:

> Billroth, the son of a clergyman, took a doctorate in medicine at Berlin (1952) and directed the surgical clinic at Zurich (1860–67) and the University of Vienna (to 1894). [...] His *Die allgemeine chirurgische Pathologie und Chirurgie in fünfzig Vorlesungen* (1863) is a classic surgical textbook. He helped introduce antisepsis on the Continent, and was the first to resect the esophagus (1872), to perform total laryngectomy (1873), and to resect a cancerous pylorus (1881). His methods of resection, although modified, remained in use for many years. Plastic surgery, especially of the face, was another of his specialties. His pupils spread his teaching all over the Continent.

One of Billroth's students, Emil Theodor Kocher (Swiss, 1841–1917), greatly expanded on his initial work and elucidated the principles of thyroid disease and successful treatment. For these achievements, Kocher won the 1909 Nobel Prize in Physiology or Medicine. Professor the Count K. A. H. Mörner, Rector of the Royal Caroline Institute emphasized the importance of Kocher's work [https://www.nobelprize.org/prizes/medicine/1909/ceremony-speech/]:

> Not only the thyroid, but also various other glands such as the adrenals and the pancreas play a characteristic part in the processes within the organism by elaborating a secretion peculiar to each gland, which is not excreted, but is diffused throughout the organism and is of the greatest importance to it. [...]
>
> However, it is not only the treatment of the goitre which has been the subject of Kocher's research on the goitre. He has also carried out extensive investigations into the causes of the endemic occurrence of goitre in certain regions and into the cretinism connected with disturbances in thyroid function.
>
> In the thyroid, as already indicated, other diseases can occur in addition to those which arise with the ordinary goitre. To these as well Kocher has devoted successful work, as a result of which it has been possible to define with more and more certainty the method of treatment best suited to each case; in addition, on the basis of Kocher's work a broader, deeper knowledge of the pathology of the thyroid has been achieved.

Eugen Baumann (German, 1846–1896) demonstrated that thyroxine was the hormone produced by the thyroid gland.

---

[25] Bliss 2007; Jahn 2004; Junker 2004; Koesling and Schülke 2010; Kohler 2008; Magner 2002; Mellinghoff 1971, 1972; Possehl 1989; Raviña and Kubinyi 2011; Schneider 1972; von Schwerin 2013; Simmons 2002; Sneader 2005; Stoff 2012; Weatherall 1991.

Scientists who made major discoveries about the hormone adrenaline or epinephrine are shown in Fig. 2.193:

- In 1895, Napoleon Cybulski (Polish, 1854–1919) and his student Władysław Szymonowicz (Polish, 1869–1939) first isolated and identified adrenaline.
- Otto von Fürth (Austrian, 1867–1938) independently purified adrenaline in 1898.
- In 1899, Max Lewandowsky (German, 1876–1916) showed that injecting adrenaline extract into animals immediately elicited strong responses from nerves and muscles.
- Friedrich Stolz (German, 1860–1936) first used chemical methods to synthesize adrenaline in 1904.
- Ernst Joseph Friedmann (German, 1877–1956) worked out the molecular structure of adrenaline in 1906.

Another important hormone is insulin. Glucose, a simple form of sugar, is circulated through the blood to feed cells in the body, but too much glucose can actually damage cells, a condition called diabetes. Part of the pancreas monitors the level of glucose in the blood and, when necessary, sends out insulin to tell other organs to lower the amount of glucose. Thus the discovery of insulin had enormous implications both for understanding the cause of diabetes and for successfully treating it.

As shown in Figs. 2.194–2.195, German-speaking scientists made virtually all of the key discoveries regarding the role of insulin in controlling and preventing diabetes.[26]

In 1869, Paul Langerhans (German, 1847–1888) discovered the clumps of cells in the pancreas that produce insulin, which are now called the islets of Langerhans.

Joseph von Mering (German, 1849–1908) and Oskar Minkowski (Baltic German, studied and worked in Germany, 1858–1931) demonstrated in 1889 that surgically removing the pancreas of a dog caused diabetes, and therefore that a product of the pancreas was essential for controlling and preventing diabetes. (Josef von Mering also helped to discover barbiturates—see p. 277).

Georg Ludwig Zülzer (German, 1870–1949), working together with Max Dohrn (German, 1874–1943, a prolific chemist who also helped to synthesize steroid hormones and antibiotics) and Anton Marxer (German, 1880–19??) at Schering, conducted the first experiments demonstrating that insulin could be purified from calf pancreas (in an extract called Acomatol) and used to treat diabetic symptoms, beginning in rabbits in 1903 and humans in 1906 [Mellinghoff 1971, 1972]. Their first insulin preparations demonstrably worked to control the symptoms of diabetes in humans, but they also produced some inflammatory reactions due to the presence of impurities from animal pancreas remaining in the preparations.

Zülzer and his colleagues continued working steadily to improve their insulin production process in order to eliminate any remaining impurities. They were on the verge of achieving a marketable final product, yet unfortunately their experiments were terminated in 1914 when medical personnel and facilities were conscripted into caring for soldiers wounded in World War I. With the four years of war, followed immediately by years of crippling national reparations payments and economic depression, Zülzer was unable to renew his experiments.

---

[26] Bliss 2007, pp. 25–31; Meienhofer 1963; Mellinghoff 1971, 1972; von Schwerin et al. 2013, pp. 151–155; Sneader 2005, pp. 164–166.

Erich Leschke (German, 1887–1933) also developed and demonstrated injectable forms of insulin purified from animal pancreases, producing a doctoral thesis on the topic in 1911 (*Über die Wirkung des Pankreasextraktes auf pankreasdiabetische und auf normale Tiere*, or *On the Effect of Pancreatic Extract on Pancreatic-Diabetic and Normal Animals*).

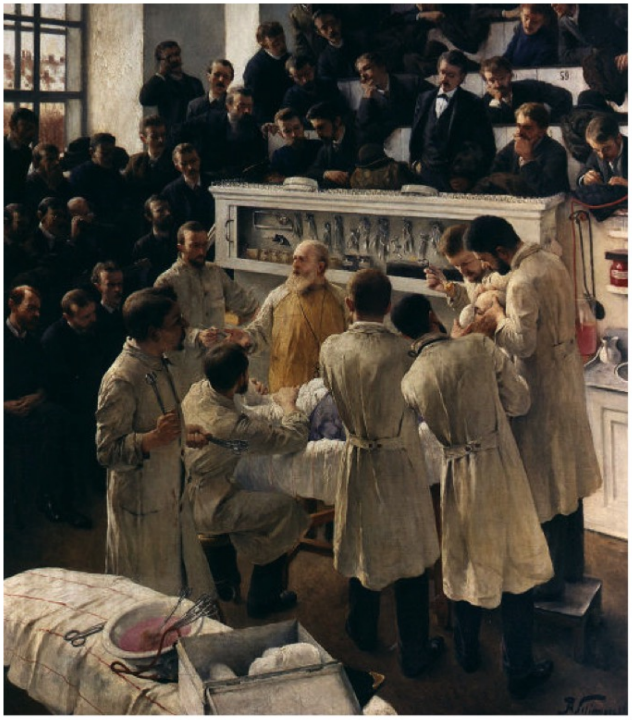
By closely following the steps of the insulin purification process that were described in detail in Zülzer's published papers and patents, Frederick Banting (Canadian, 1891–1941) and John Macleod (Scottish, 1876–1935) replicated his work and used Zülzer's own methods to eliminate any remaining impurities in insulin in 1922. They were awarded the Nobel Prize in Physiology or Medicine the very next year, in 1923, and have been lauded in the history books ever since. Zülzer has been all but forgotten.

It seems quite likely that if World War I had not intervened, Zülzer (and perhaps Dohrn, Marxer, or Leschke) would have won the Nobel Prize for that achievement. In any event, without all of the discoveries from Langerhans, von Mering, Minkowski, Zülzer, Dohrn, Marxer, Leschke, and other scientists in the German-speaking world who labored for half a century to go from discovering insulin to purifying it, the now-widespread use of insulin to treat diabetes would have begun far later than it did.

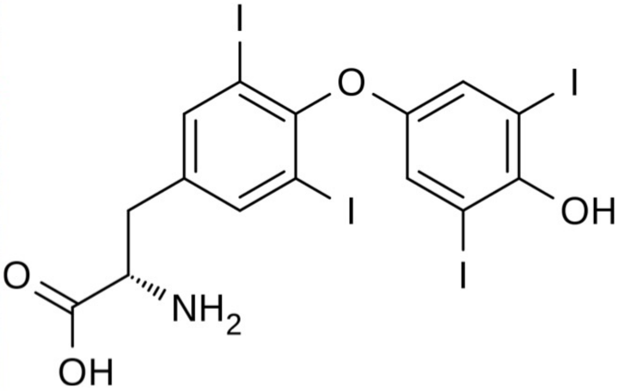
To avoid the necessity of purifying natural insulin from animals, Helmut Zahn (German, 1916–2004) at Aachen University began working on methods of artificially synthesizing insulin after World War II, based on protein synthesis techniques that had been pioneered in 1932 by Max Bergmann (German, 1886–1944, p. 130). Zahn and his coworkers successfully produced and demonstrated the first synthetic insulin in 1963 [Meienhofer 1963]. (By using Bergmann's methods, the University of Pittsburgh also produced synthetic insulin somewhat later.) That synthetic insulin was also the first application of an artificially created protein, a major milestone in biotechnology. All of the insulin used worldwide is now produced by biotechnological processes.

Thyroid hormones

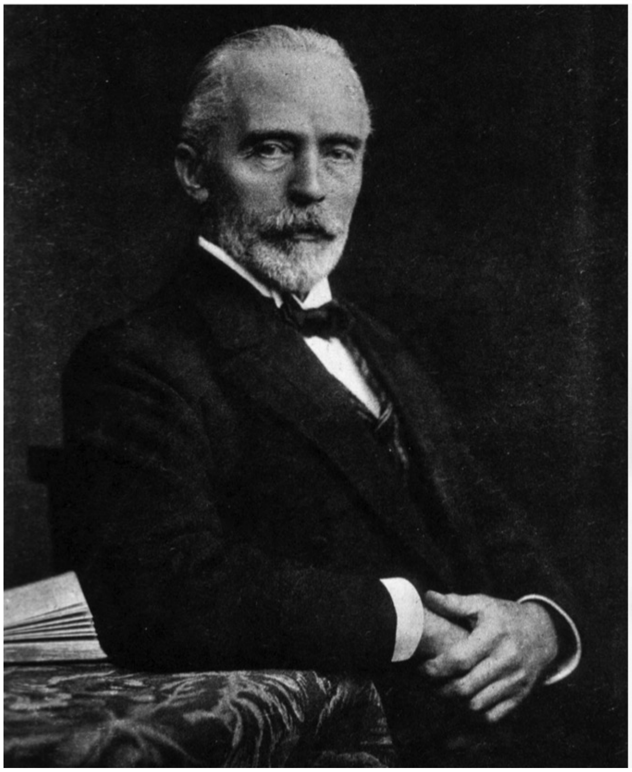
Theodor Billroth (1829–1894)



Thyroid hormone thyroxine (T_4)



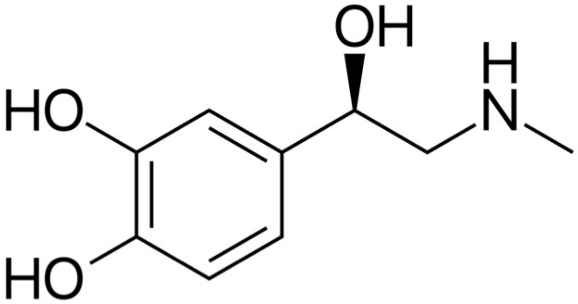
Emil Theodor Kocher (1841–1917)



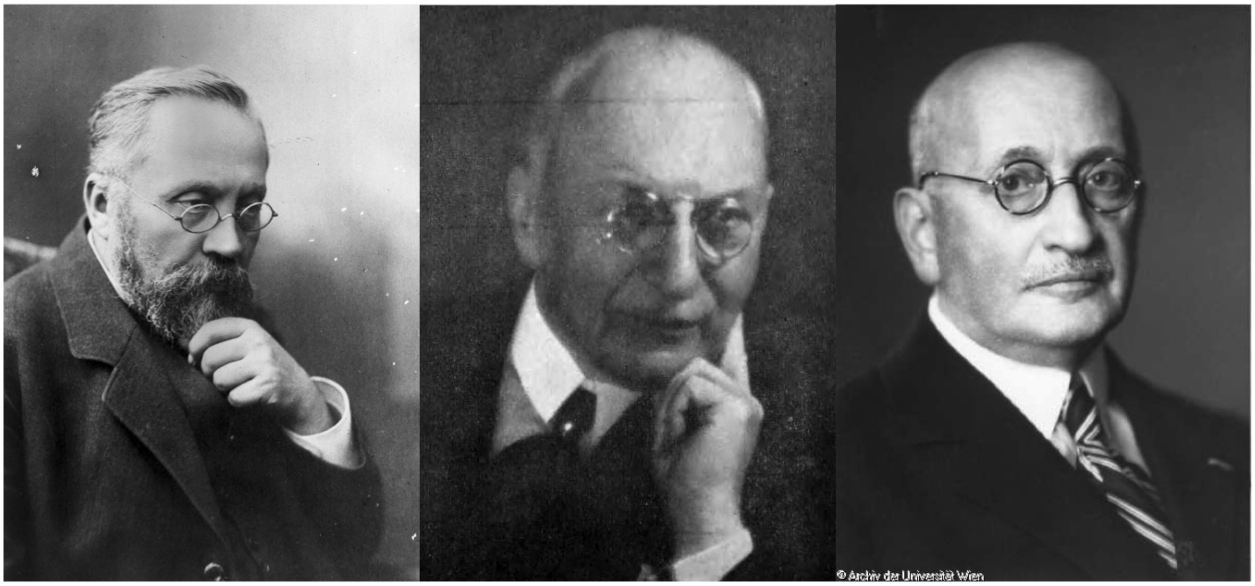
Eugen Baumann (1846–1896)

Figure 2.192: German-speaking scientists who made major discoveries about thyroid hormone production included Theodor Billroth, Emil Theodor Kocher, and Eugen Baumann.

Adrenaline
or
epinephrine



Napoleon Cybulski (1854–1919) **Władysław Szymonowicz (1869–1939)** **Otto von Fürth (1867–1938)**


© Archiv der Universität Wien

Friedrich Stolz (1860–1936) **Ernst Joseph Friedmann (1877–1956)** **Max Lewandowsky (1876–1916)**

Figure 2.193: German-speaking scientists who made major discoveries about adrenaline or epinephrine included Napoleon Cybulski, Władysław Szymonowicz, Otto von Fürth, Friedrich Stolz, Ernst Joseph Friedmann, and Max Lewandowsky.

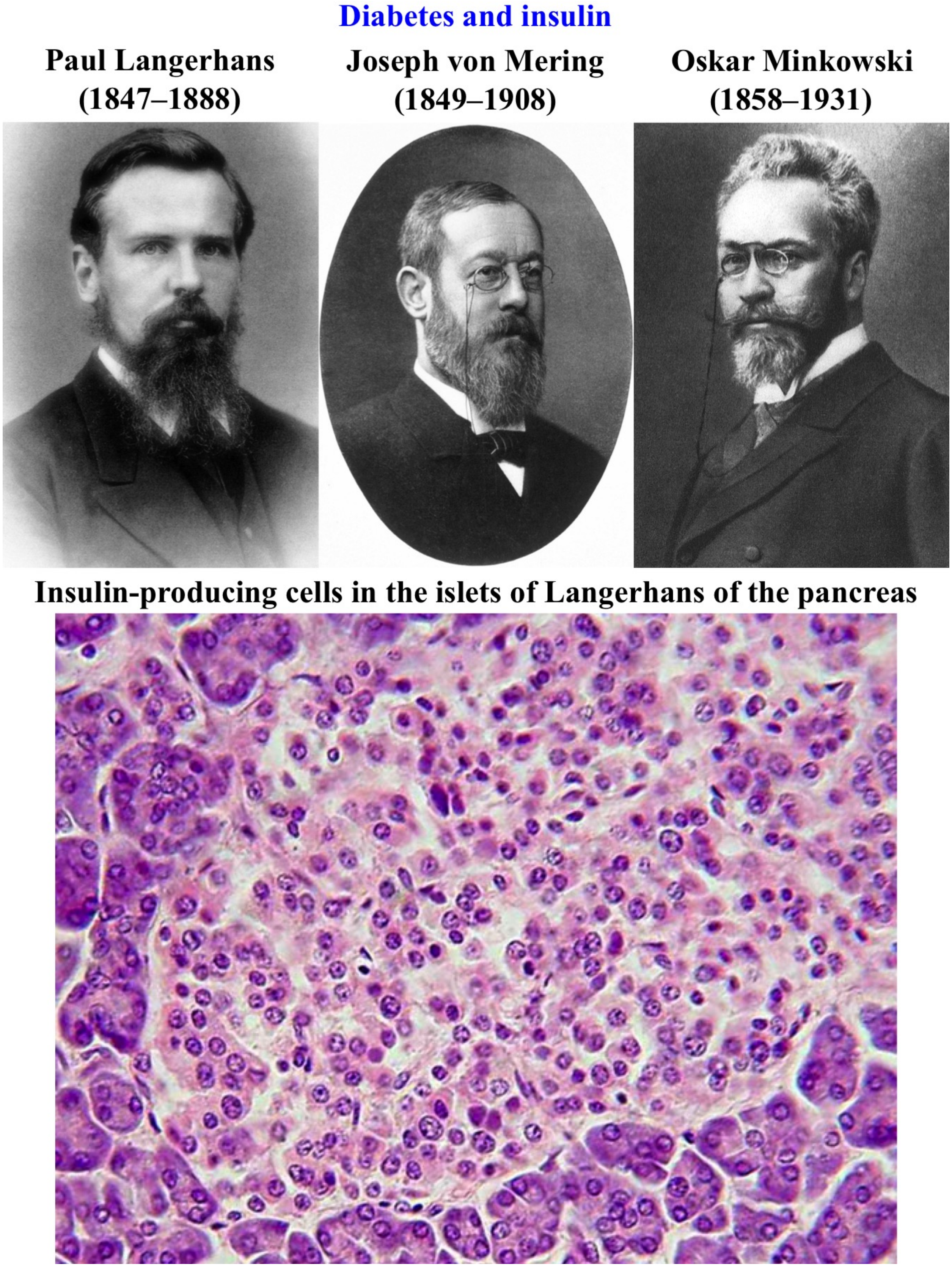

Diabetes and insulin
Paul Langerhans (1847–1888)
Joseph von Mering (1849–1908)
Oskar Minkowski (1858–1931)
Insulin-producing cells in the islets of Langerhans of the pancreas

Figure 2.194: Creators who made key discoveries regarding the role of insulin in controlling diabetes included Paul Langerhans, Joseph von Mering, and Oskar Minkowski.

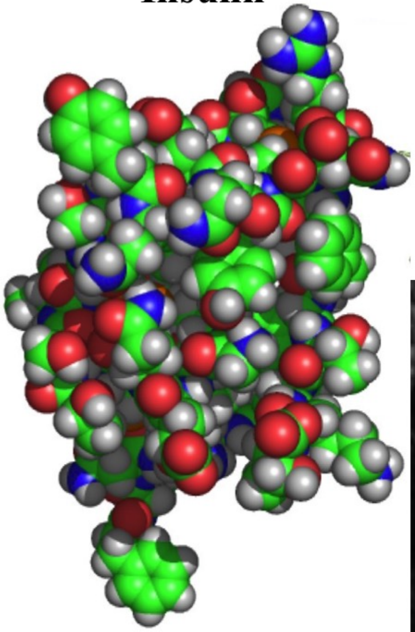
Diabetes and insulin

Georg Ludwig Zülzer
(1870–1949)

Max Dohrn
(1874–1943)

Anton Marxer
(1880–19??)

Insulin



Erich Leschke
(1887–1933)

Helmut Zahn
(1916–2004)

Figure 2.195: Other creators who made key discoveries regarding the role of insulin in controlling diabetes included Georg Ludwig Zülzer, Max Dohrn, Anton Marxer, Erich Leschke, and Helmut Zahn.

2.6 Developmental Biology and Embryology

Creators from the German-speaking world pioneered developmental biology (Section 2.6.1), as well as techniques to aid childbirth and neonatal babies (Section 2.6.2).

2.6.1 Developmental Biology

Developmental biology is the study of how a fertilized egg cell multiplies and becomes the many highly specialized and highly organized cells of a whole organism (Figs. 2.196–2.197). Scientists from the greater German-speaking world virtually monopolized the field of developmental biology and embryology for more than a century.[27] In awarding the 1935 Nobel Prize in Physiology or Medicine to Hans Spemann, Professor G. Häggquist of the Royal Caroline Institute emphasized how completely it was German-speaking scientists who had created and who continued to dominate the field of developmental biology [https://www.nobelprize.org/prizes/medicine/1935/ceremony-speech/]:

> Developmental mechanics seeks to establish the inner causal connection between the developmental processes. Wilhelm Roux founded this branch of science at the end of the 80's of the last century. Although Roux himself, Driesch, and many others have enriched our knowledge with interesting facts, it was really Spemann and his school who first established developmental mechanics as a current branch of science which has revealed laws and relationships which encompass the entire biological world.
>
> In his technical work, Spemann can be called a micro-surgeon. His instruments are simple: glass rods drawn to a point, glass tubes which can be used as fine pipettes, or loops of children's hair. His experimental material consisted of the eggs of newts and frogs. An egg cell of this kind is a little ball of living matter with a diameter of 1–1.5 mm. Normally after fertilization it develops by continued segmentation until it changes into a small hollow sphere whose wall consists of small cells. Subsequently this hollow sphere invaginates rather as if you were to take a burst rubber ball and squeeze it together in the hand; only the difference is that the walls grow together so that the orifice of the now double-walled sphere will be small and cleftshaped. After that, a further layer of cells grows between the two walls of the sphere. These three layers are called *ectoderm*, *mesoderm*, and *endoderm* from outside inwards respectively. The orifice is called the *blastopore*. Then in front of this blastopore there arise from the ectoderm the primordia of the brain and spinal cord. Beneath the primordial brain an invagination of the ectoderm against the entoderm is formed, later to become the mouth. The mesoderm will form the skeleton (in the first place the dorsal strip, then the notochord) and muscles. The endoderm forms gut.
>
> Much thought has been given to the nature of the forces and causality regulating this development. It is at this point that Spemann's researches begin. He used eggs of various animal species which differ in colour, and with his simple instruments transplanted small pieces of tissue in different stages of development. [...]

---

[27] Deichmann 1996; Gausemeier 2005; Gilbert and Barresi 2016; Jahn 2004; Junker 2004; Kohler 2002, 2006; Magner 2002; Mayr 1984; Miller 1988; Richards 2004, 2009; Schnalke and Atzl 2010; Simmons 2002; Roger Smith 1997; Taschwer 2016.

> [...] Spemann has revealed conditions in the developmental process which are of deep significance. A mountain of difficulties rears up before him who seeks to wrest from Nature, secrets connected with the origin and development of a new individual. Spemann has opened this mountain and has brought to light rich treasures of knowledge. Moreover, a group of disciples has followed him, who can carry his thoughts forward and continue the work at such time as the master himself grows weary. [...]
>
> Herr Geheimrat [Spemann]. You are a student of Theodor Boveri, and occupy the Chair once held by Professor August Weismann. These are two names of vast reputation evoking feelings of gratitude and admiration in anyone engaged in biological research. They are, however, also names imposing on the student and successor responsibilities for carrying on a great tradition. You, Herr Geheimrat, have been successful in upholding this proud scientific tradition. You have, with new tools, continued where Weismann and Boveri had to stop, and have paved new ways in biology. August Weismann managed, although ignorant of Mendel's observations, to outline the significance of the nucleus as bearer of heredity; Boveri laid, together with Oscar Hertwig, the foundation of our knowledge of the fertilization phenomena; and you, Herr Geheimrat, have discovered secret forces regulating the early development of the fertilized egg. You have also created a school of scientists from whom Science can expect further valuable contributions. As a result of this you have occupied a place in the first rank of great cultural personalities in which your country is so rich.

Figures 2.198–2.202 show some of the most important scientists in developmental biology. Their research methods and results were so complex, and there was so much overlap in their careers and their discoveries, that these creators are simply mentioned in alphabetical order here. For much more detail on all of these scientists and their research, please see the cited references.

Karl Ernst von Baer (Baltic German, 1792–1876) discovered the early blastula stage of development, studied the germ layers (ectoderm, mesoderm, and endoderm) of the following gastrula stage in a variety of vertebrates, and discovered the notochord (the early developmental stage of the spinal column).

Carl Bergmann (German states, 1814–1865) studied comparative anatomy and formulated what is now called "Bergmann's rule"—the observation that species generally tend to be larger in colder climates and smaller in warmer climates.

Theodor Boveri (German, 1862–1915) showed that chromosomes carry the inherited traits of an organism, and that proper embyonic development requires the normal number of chromosomes for an organism.

Hans Driesch (German, 1867–1941) demonstrated that embryonic cells in the early blastula stage are totipotent and can become any part of the resulting animal, or completely separate animals if they are split apart and allowed to resume development. In a sense, Driesch's successful experiments splitting apart the cells of one developing embryo to create many identical embryos were the earliest demonstration of cloning.

Karl Gegenbaur (German, 1826–1903) was one of the pioneers of comparative anatomy and developmental morphology, and published highly influential textbooks showing the evolutionary relationships among structures in different species.

Salome Gluecksohn-Waelsch (German, 1907–2007) was the founder of developmental genetics, the study of how specific genes influence the development of an embryo and the differentiation of initially totipotent cells into highly specialized cell types committed to different fates.

Ernst Haeckel (German, 1834–1919) was a student of Karl Gegenbaur, and also conducted extensive studies in comparative embryology among a variety of species.

Curt Herbst (German, 1866–1946) demonstrated the importance of ion concentrations for differentiation and development in embryos.

Oscar Hertwig (German, 1849–1922) stated in 1885 that nucleic acid (DNA) is responsible for inherited characteristics, meticulously documented cellular events during fertilization, and made other contributions to developmental biology. He was the older brother of Richard Hertwig.

Richard Hertwig (German, 1850–1937) was the younger brother of Oscar Hertwig, and he also elucidated the process of fertilization and conducted other studies in developmental biology.

Wilhelm His Sr. (Swiss, 1831–1904) documented the development of the central and peripheral nervous system, described endothelial tissue layers, and (along with Johann Purkinje, p. 78) was one of the inventors of the microtome, which has become a widely used instrument for preparing thin slices of animal or plant tissues for microscope slides. He was the father of Wilhelm His Jr. (p. 335).

Johannes Holtfreter (German, 1901–1992) conducted a long series of experiments demonstrating how organizer or inducer regions of an embryo produce chemical gradients that control the body plan or location and layout of organs.

Johann Friedrich Wilhelm Krause (German, 1833–1910) made a variety of contributions to developmental biology and human anatomy, including studies of the peripheral nervous system.

Hilde Mangold (German, 1898–1924) made discoveries that led to a Nobel Prize (for her supervisor Hans Spemann in 1935), although unfortunately she did not live to share in that award. Developmental biologists Scott Gilbert and Michael Barresi briefly recounted her story [Gilbert and Barresi 2016, p. 347]:

> The most spectacular transplantation experiments were published by Spemann and his doctoral student Hilde Mangold in 1924. They showed that, of all the tissues in the early gastrula, only one has its fate autonomously determined. This self-determining tissue is the dorsal lip of the blastopore—the tissue derived from the gray crescent cytoplasm opposite the point of sperm entry. When this tissue was transplanted into the presumptive belly skin region of another gastrula, it not only continued to be dorsal blastopore lip but also initiated gastrulation and embryogenesis in the surrounding tissue! [...]
>
> Hilde Proescholdt Mangold died in a tragic accident in 1924, when her kitchen's gasoline

> heater exploded. She has 26 years old, and her paper was just about to be published. Hers is one of the very few doctoral theses in biology that have directly resulted in the awarding of a Nobel Prize.

Otto Mangold (German, 1891–1962), the husband of Hilde Mangold, also made important contributions to developmental biology, especially with regard to the differentiation of initially totipotent embryonic cells into highly specialized, committed cell types.

Johann Friedrich Meckel (Prussian Saxony, 1781–1833) was one of the first scientists to make a systematic study of birth defects and abnormalities that occur during the development of an embryo.

Heinz (or Heinrich) Christian Pander (Baltic German, 1794–1865) discovered and studied the three germ layers (ectoderm, mesoderm, and endoderm) in chick embryos.

Martin Heinrich Rathke (German states, 1793–1860) carefully studied the developmental biology of a wide variety of vertebrate and invertebrate species, and was the first to identify many features in their development.

Karl Bogislaus Reichert (German, 1811–1883) investigated and reported on the development of a number of different structures in vertebrate embryos.

Robert Remak (Prussian, 1815–1865) studied and described in detail the three germ layers (ectoderm, mesoderm, and endoderm) of the gastrula.

Wilhelm Roux (German, 1850–1924) conducted experiments on the development of the skeletal and cardiovascular systems in vertebrate embryos.

Hans Spemann (German, 1869–1941) worked with Hilde Mangold and others on a wide range of topics in developmental biology. For experiments that Hilde Mangold carried out, Spemann won the Nobel Prize in Physiology or Medicine in 1935 (p. 375). In 1936, Spemann published *Experimentelle Beiträge zu einer Theorie der Entwicklung* (translated into English in 1938 as *Embryonic Development and Induction*), a book that included a detailed and scientifically accurate description of experimental methods for cloning adult animals by removing the nucleus of an egg cell and replacing it with the nucleus from a cell of an adult to be cloned. It is not clear how far experiments with that approach actually progressed in Germany before the end of World War II; much more archival research should be performed to investigate that matter. In any event, Spemann's approach was successfully used by other scientists to create cloned animals in the decades after the war.

Walther (or Walter) Vogt (German, 1888–1941) was the first to use a vital (nontoxic) dye for fate mapping of cells in developing embryos, in order to determine which types of cells arise from a particular earlier cell that was injected with the tracking dye.

Heinrich Wilhelm von Waldeyer-Hartz (German, 1836–1921) discovered the developmental stages for many structures in the head, including teeth, tonsils, and hair.

Else Wehmeier (German?, 19??–??) conducted important experiments demonstrating the action of organizer or inducer regions in an embryo.

August Weismann (German, 1834–1914) studied reproduction and development in sea urchins as a very simple animal model, and made many important contributions regarding chromosomes and heredity.

Paul Alfred Weiss (Austrian, 1898–1989) studied cellular differentiation and tissue regeneration in cultured cells and in whole amphibians.

Caspar Friedrich Wolff (Brandenburg, 1733–1794) founded the fields of animal and plant developmental biology. He studied plant, chick, human, and other embryos and made important discoveries regarding early developmental stages, developmental abnormalities, and the development of organ systems such as the gastrointestinal tract.

Although it was somewhat later than the primary time period covered by this book, Christiane Nüsslein-Volhard (German, 1942–) and Eric Wieschaus (U.S. but worked in Germany, 1947–) studied the genetic control of embryonic development. For that work, they won the Nobel Prize in Physiology or Medicine in 1995. Professor Björn Vennström of the Nobel Committee at the Karolinska Institute explained their discoveries [https://www.nobelprize.org/prizes/medicine/1995/ceremony-speech/]:

> Insect larvae have segments; recall the larva of a butterfly! Each segment has its own developmental program. Think about the wasp, with its head, the central section, and the striped posterior ("tail") region: every part develops from a specific segment in the larva. Christiane Nüsslein-Volhard and Eric Wieschaus decided to find all the genes that cause the larva to develop exactly 14 segments, since the segments determine the body plan. Their chances of success were unclear. Nobody had done anything similar before, and a hopelessly large number of genes could be involved. They began their work, using a simple but ingenious experimental approach. After having tested more than half of the approximately 20000 genes of the fly, they found three groups of genes that govern segmentation. The first group of genes provides a basis for segmentation along the body axis. The next group of genes governs the development of every second segment, whereas the third group refines the structure of the individual segments.
>
> Christiane Nüsslein-Volhard and Eric Wieschaus had opened a Pandora's box filled with a seemingly unmanageable jumble of genes, and transformed their hope for success into a reality. They showed that it really was possible to identify and classify genes that govern early embryogenesis in a rational way. The genes they found were surprisingly few: only 15. This success has paved the way for other developmental biologists to make pioneering discoveries.

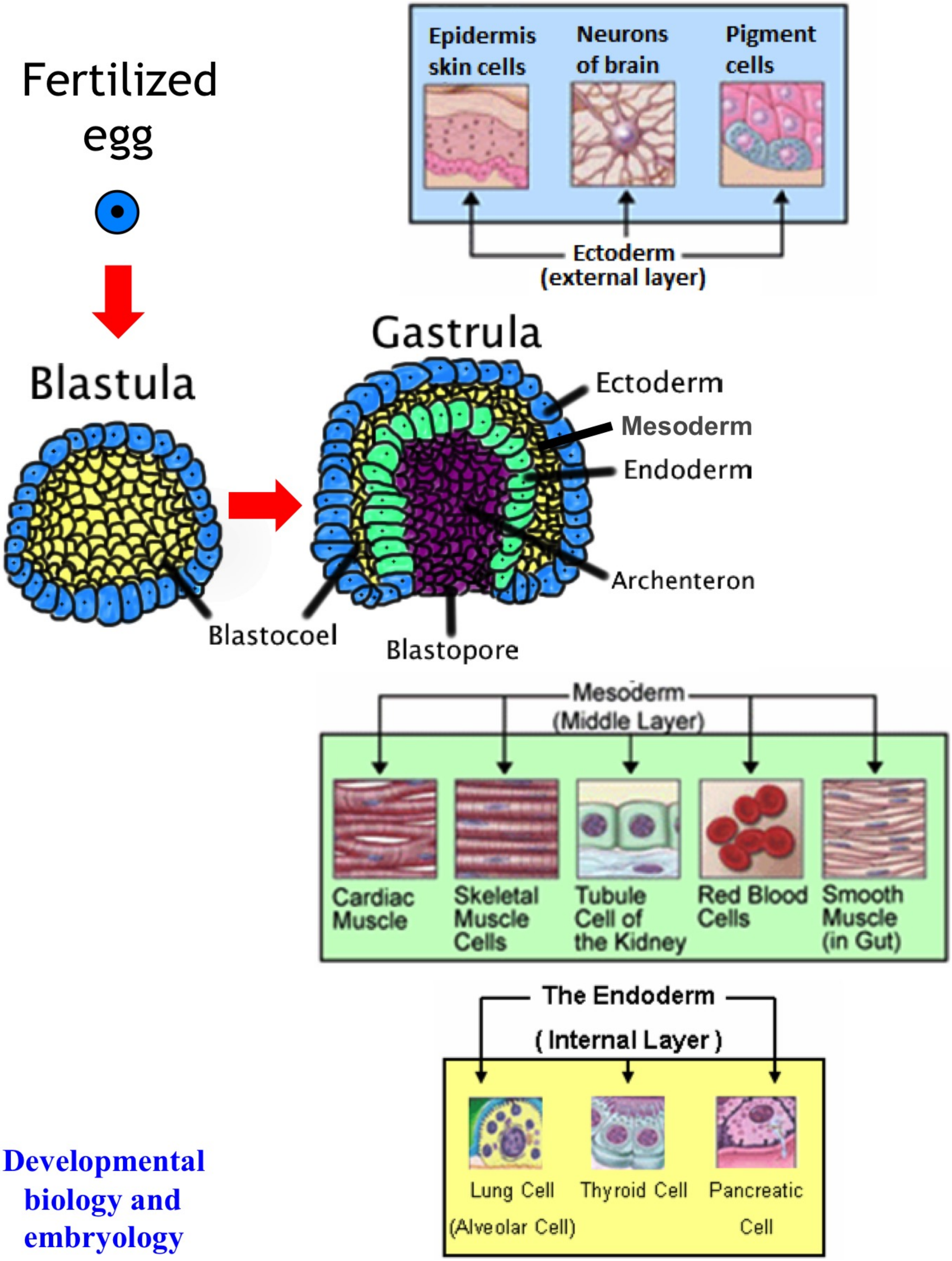

Fertilized egg
Epidermis skin cells
Neurons of brain
Pigment cells
Ectoderm (external layer)
Blastula
Gastrula
Ectoderm
Mesoderm
Endoderm
Archenteron
Blastocoel
Blastopore
Mesoderm (Middle Layer)
Cardiac Muscle
Skeletal Muscle Cells
Tubule Cell of the Kidney
Red Blood Cells
Smooth Muscle (in Gut)
The Endoderm (Internal Layer)
Lung Cell (Alveolar Cell)
Thyroid Cell
Pancreatic Cell
Developmental biology and embryology

Figure 2.196: Most animals have similar early stages of development. A fertilized egg divides to become a hollow ball of cells called a blastula. The cells of the blastula further multiply and rearrange themselves to form a gastrula with three germ layers (ectoderm, mesoderm, and endoderm). The cells of those three layers multiply and differentiate to form different types of tissues.

Developmental biology and embryology

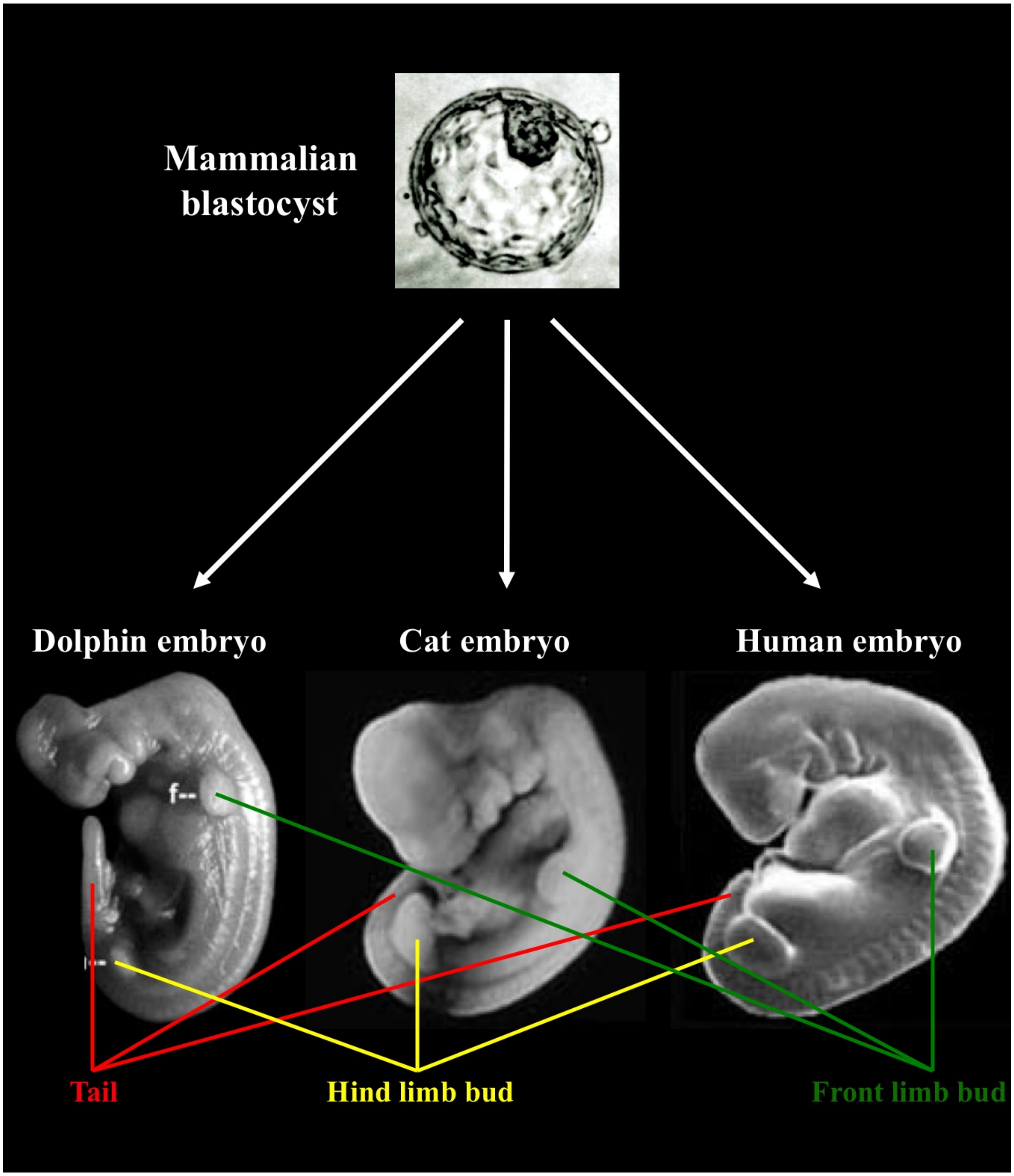

Mammalian blastocyst
Dolphin embryo
Cat embryo
Human embryo
f--
l--
Tail
Hind limb bud
Front limb bud

Figure 2.197: The embryos of many species have similar anatomical features (tails, limb buds, etc.), even though some of them may lose those features before they are born.

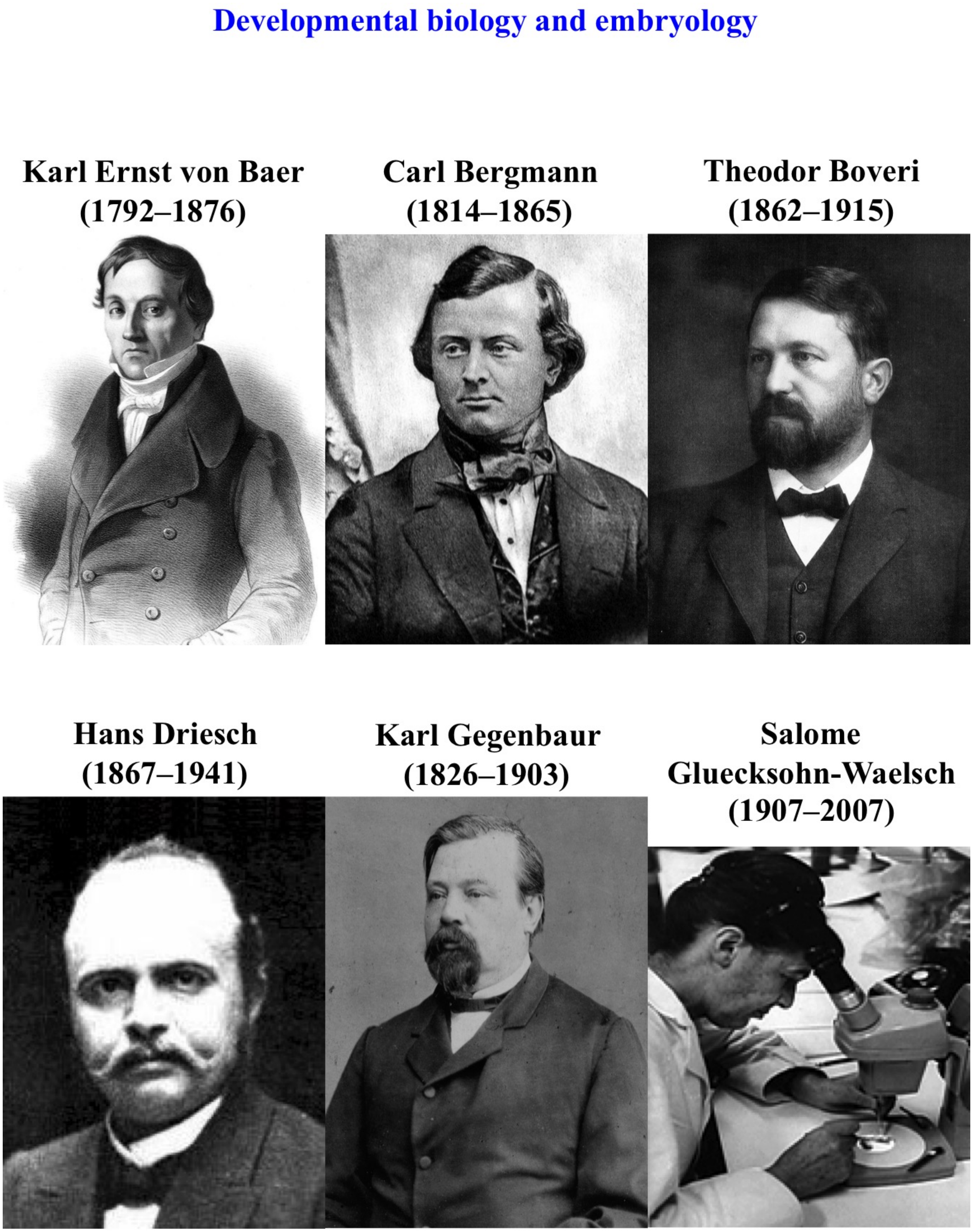

Developmental biology and embryology
Karl Ernst von Baer (1792–1876)
Carl Bergmann (1814–1865)
Theodor Boveri (1862–1915)
Hans Driesch (1867–1941)
Karl Gegenbaur (1826–1903)
Salome Gluecksohn-Waelsch (1907–2007)

Figure 2.198: Creators who made important contributions to developmental biology and embryology included Karl Ernst von Baer, Carl Bergmann, Theodor Boveri, Hans Driesch, Karl Gegenbaur, and Salome Gluecksohn-Waelsch.

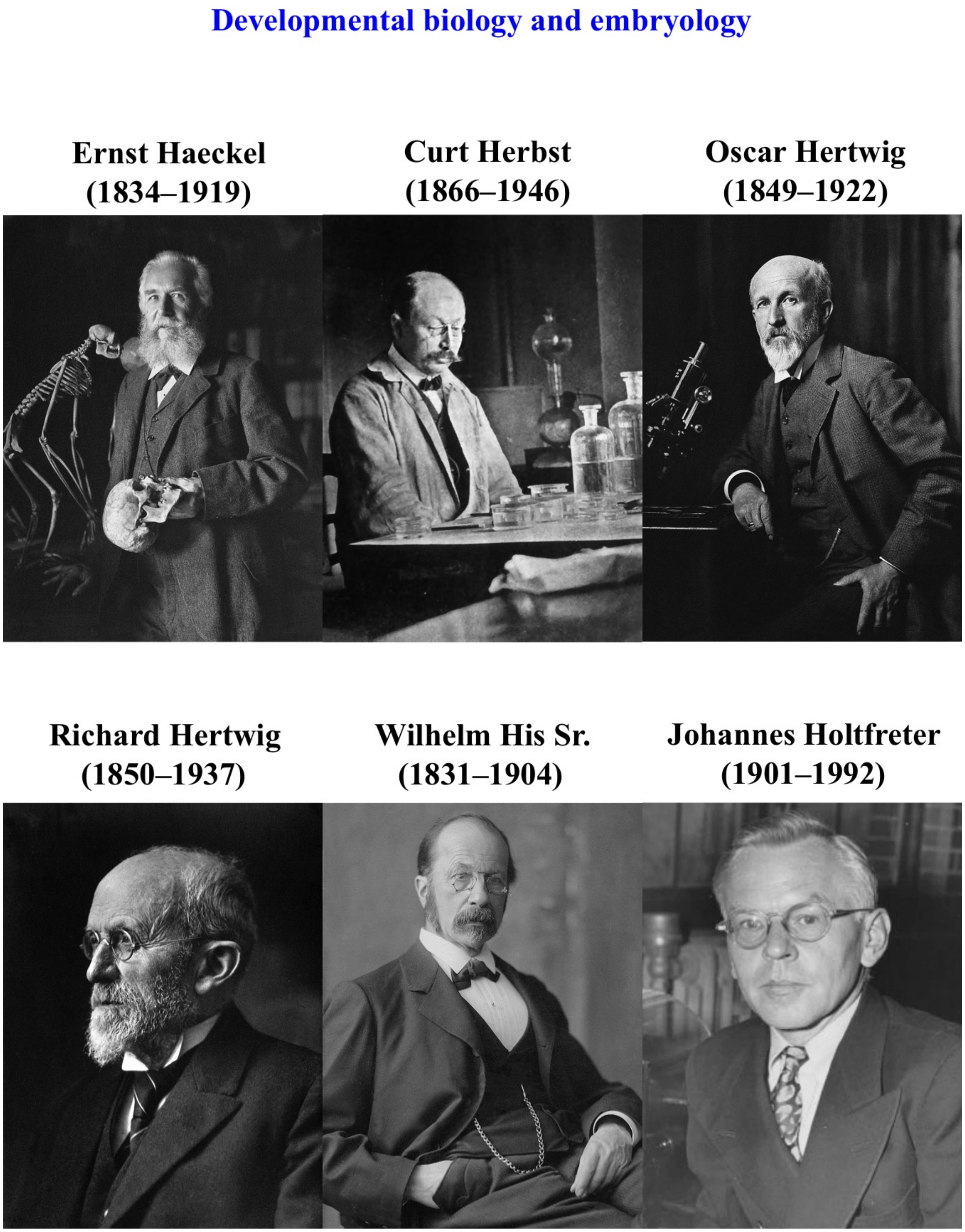
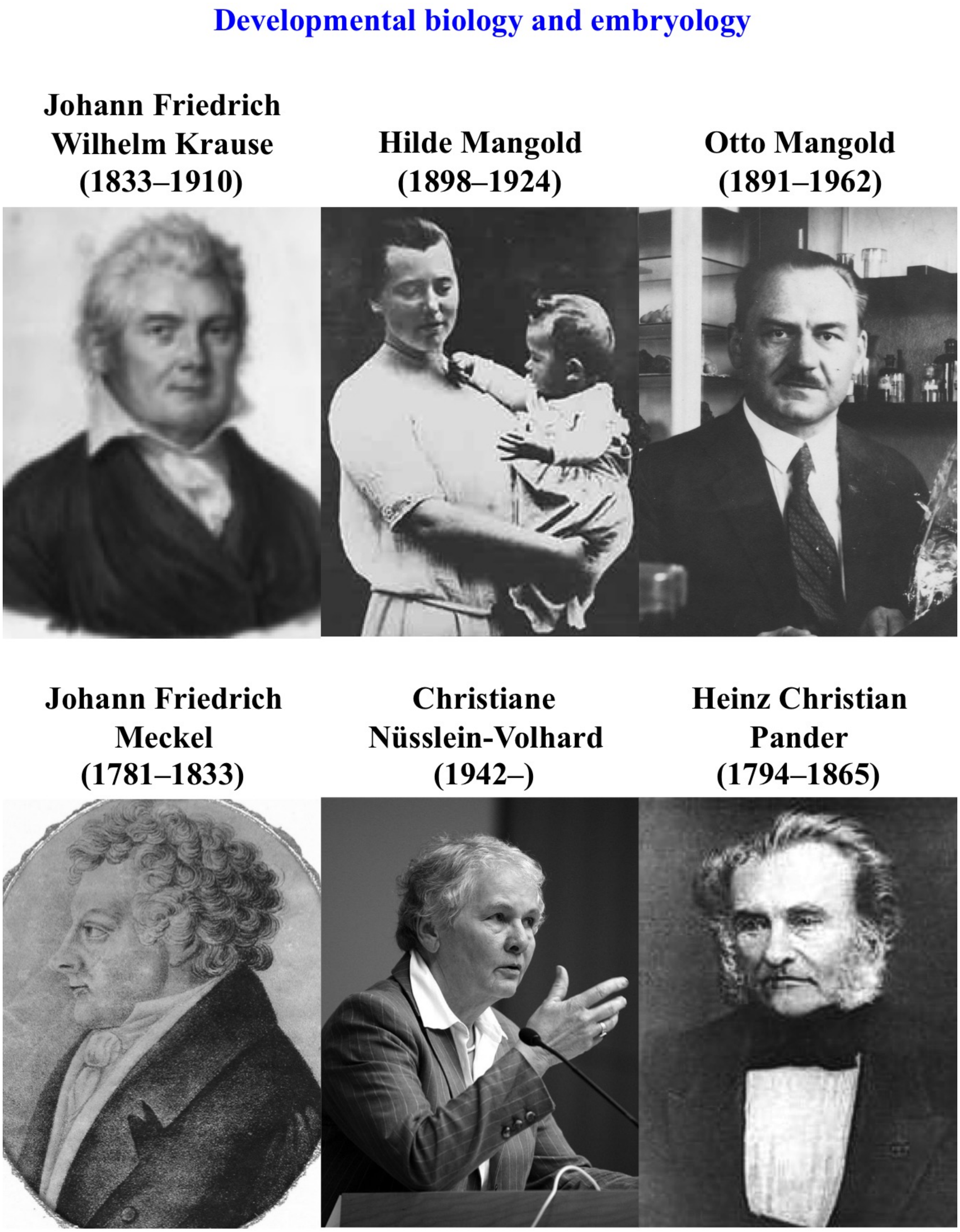

Developmental biology and embryology
Ernst Haeckel (1834–1919)
Curt Herbst (1866–1946)
Oscar Hertwig (1849–1922)
Richard Hertwig (1850–1937)
Wilhelm His Sr. (1831–1904)
Johannes Holtfreter (1901–1992)

Figure 2.199: Creators who made important contributions to developmental biology and embryology also included Ernst Haeckel, Curt Herbst, Oscar Hertwig, Richard Hertwig, Wilhelm His Sr., and Johannes Holtfreter.



Developmental biology and embryology

Johann Friedrich Wilhelm Krause (1833–1910)

Hilde Mangold (1898–1924)

Otto Mangold (1891–1962)

Johann Friedrich Meckel (1781–1833)

Christiane Nüsslein-Volhard (1942–)

Heinz Christian Pander (1794–1865)

Figure 2.200: Creators who made important contributions to developmental biology and embryology also included Johann Friedrich Wilhelm Krause, Hilde Mangold, Otto Mangold, Johann Friedrich Meckel, Christiane Nüsslein-Volhard, and Heinz Christian Pander.

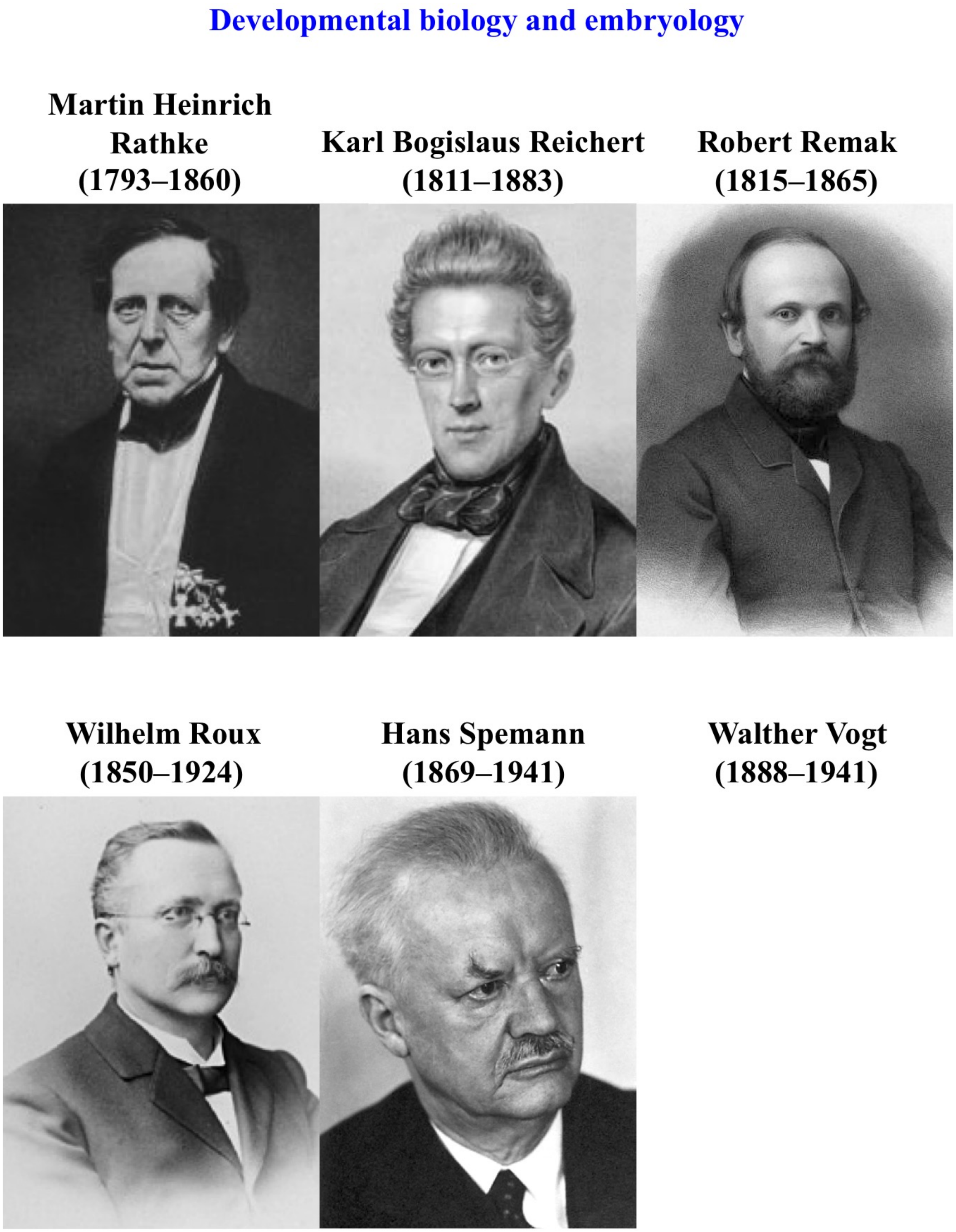
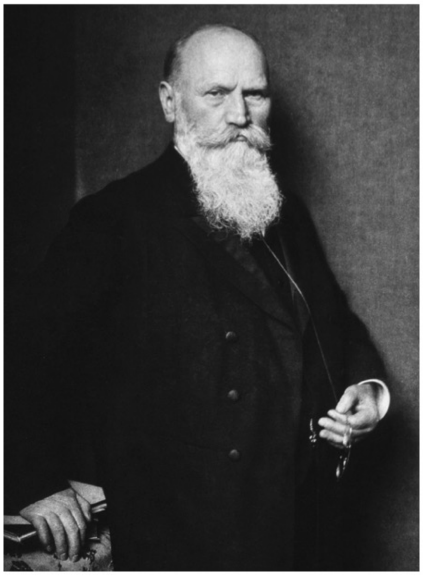

Developmental biology and embryology
Martin Heinrich Rathke (1793–1860)
Karl Bogislaus Reichert (1811–1883)
Robert Remak (1815–1865)
Wilhelm Roux (1850–1924)
Hans Spemann (1869–1941)
Walther Vogt (1888–1941)

Figure 2.201: Creators who made important contributions to developmental biology and embryology also included Martin Heinrich Rathke, Karl Bogislaus Reichert, Robert Remak, Wilhelm Roux, Hans Spemann, and Walther Vogt.

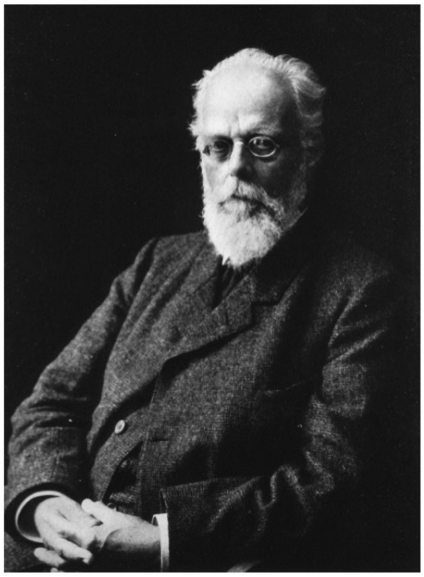
Developmental biology and embryology

Heinrich Wilhelm
von Waldeyer-Hartz
(1836–1921)



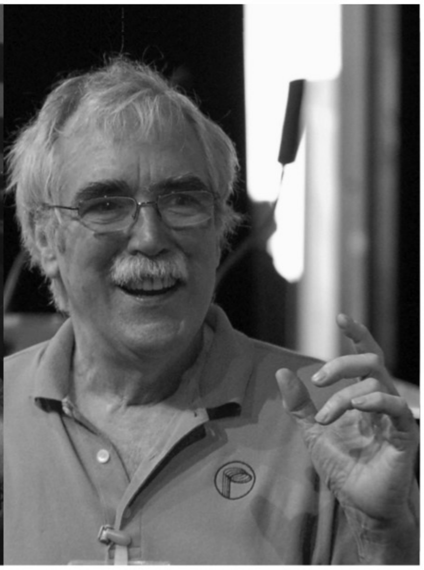
Else Wehmeier
(19??–??)

August Weismann
(1834–1914)



Paul Alfred Weiss
(1898–1989)

Eric Wieschaus
(1947–)



Caspar Friedrich
Wolff
(1733–1794)

Figure 2.202: Creators who made important contributions to developmental biology and embryology also included Heinrich Wilhelm von Waldeyer-Hartz, Else Wehmeier, August Weismann, Paul Alfred Weiss, Eric Wieschaus, and Caspar Friedrich Wolff.

2.6.2 Caesarean Sections and Neonatal Incubators

Scientists from the German-speaking world also pioneered techniques to aid childbirth and neonatal babies.

Although caesarean sections had been occasionally performed since ancient times, mothers usually did not survive the procedure. In 1881, Ferdinand Adolf Kehrer (German, 1837–1914, Fig. 2.203) first used a horizontal incision low on the abdomen that greatly reduced bleeding and maternal mortality.

In 1882, Max Sänger (German, 1853–1903, Fig. 2.203) demonstrated that the uterus could be sutured after a caesarean section to preserve the mother's ability to have future children.

Hermann Johannes Pfannenstiel (German, 1862–1909, Fig. 2.203) made further improvements to the surgical methods of caesarean sections in 1900. That final form of the technique, known as the Pfannenstiel incision, is still used today.

Caesarean sections were greatly aided by antiseptics (p. 165), anesthetics (p. 276), and later antibiotics (pp. 187–190), all of which were also developed by German-speaking creators.

In 1835, Johann Georg von Ruehl (Baltic German, 1769–1846, Fig. 2.204) invented and used the first neonatal incubators for premature babies. Such incubators became known as Ruehl's cradle and spread throughout Europe over the following decades.

Michael Cohn, later known as Martin Couney (German, 1870–1950, Fig. 2.204), moved to the United States and improved, mass-produced, and popularized incubators.

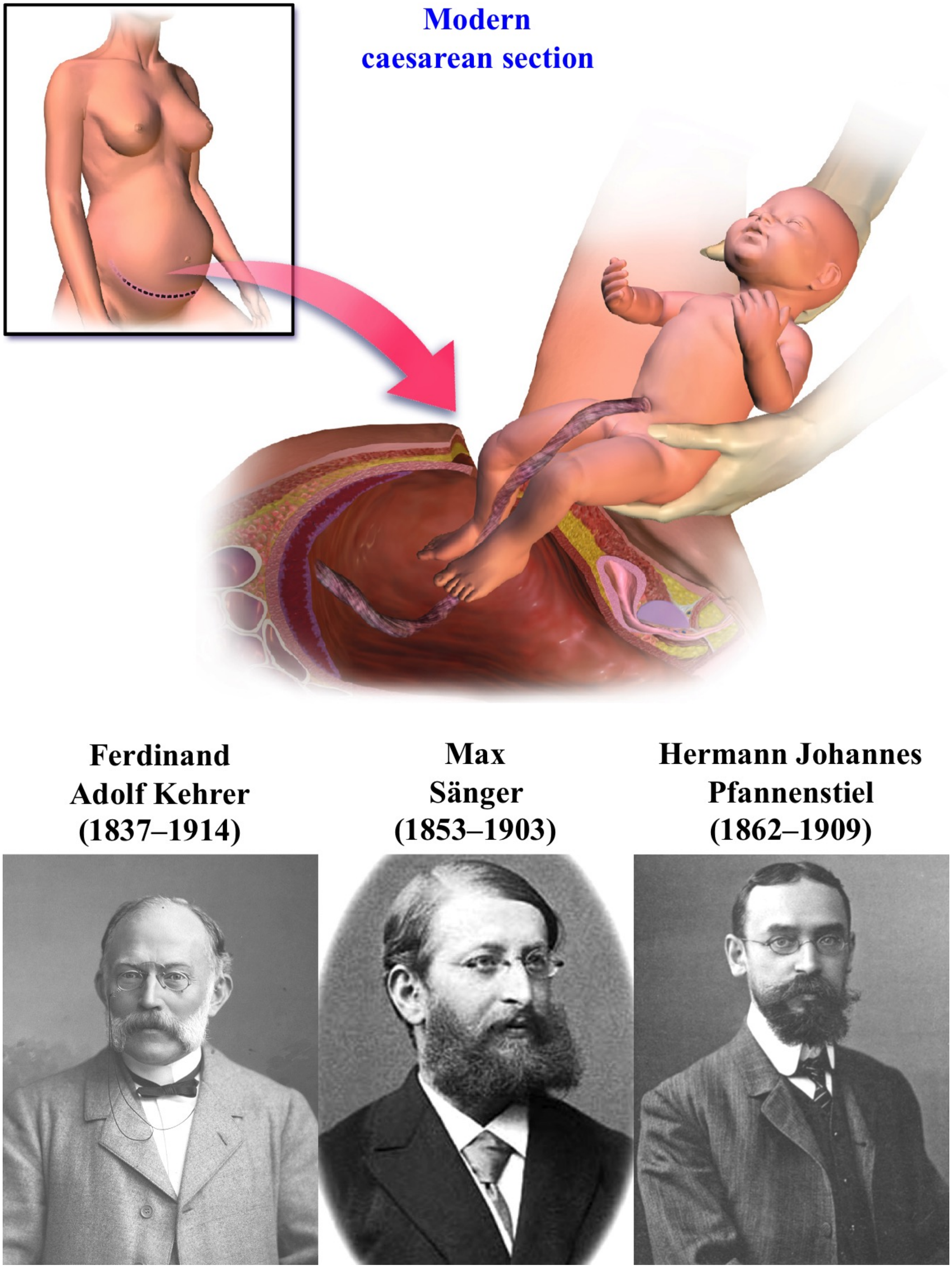

Modern
caesarean section
Ferdinand
Adolf Kehrer
(1837–1914)
Max
Sänger
(1853–1903)
Hermann Johannes
Pfannenstiel
(1862–1909)

Figure 2.203: Beginning in 1881, Ferdinand Adolf Kehrer, Max Sänger, and Hermann Johannes Pfannenstiel developed the modern surgical methods of safe caesarean sections.

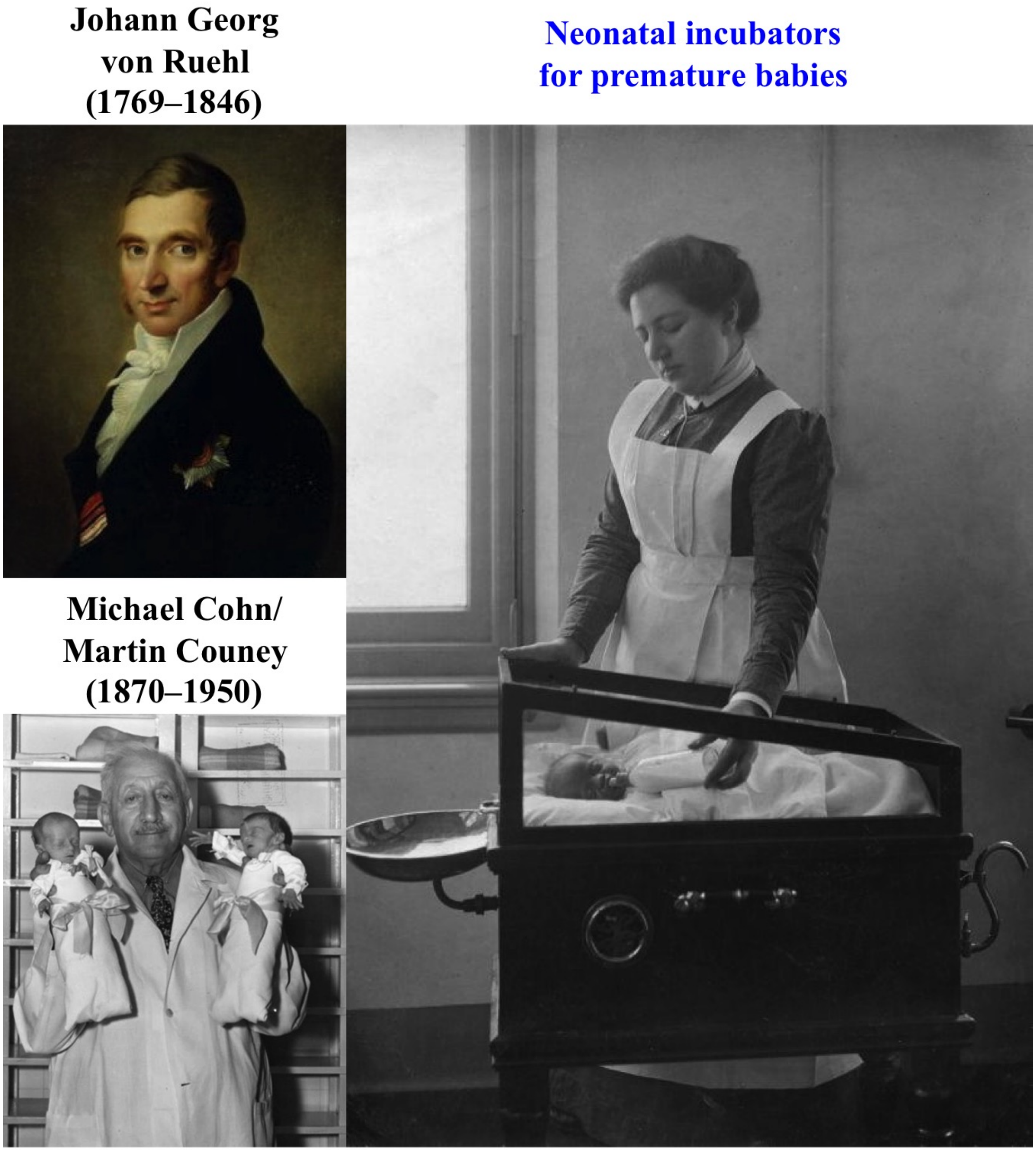

Johann Georg
von Ruehl
(1769–1846)
Neonatal incubators
for premature babies
Michael Cohn/
Martin Couney
(1870–1950)

Figure 2.204: Johann Georg von Ruehl invented and demonstrated neonatal incubators in 1835. Michael Cohn, also known as Martin Couney, later improved, mass-produced, and popularized incubators.

2.7 Aerospace Medicine, Prostheses, and Other Physiology

In addition to those areas already discussed in this chapter, scientists from the greater German-speaking world also made many important contributions to other topics in physiology, including:[28]

2.7.1. Aerospace medicine

2.7.2. Prostheses

2.7.3. Other aspects of anatomy, physiology, and zoology

2.7.1 Aerospace Medicine

As shown in Figs. 2.205–2.206, a number of German-speaking scientists made important early discoveries regarding high-altitude or aerospace medicine. Some major examples include:

- Arthur Berson (German, 1859–1942), a balloonist and meteorologist, conducted important research on the physiological effects of high altitudes. He used both high-altitude balloons and ground-based low-pressure chambers for that work, and he collaborated with Hermann von Schrötter, Reinhard Süring, and Nathan Zuntz.

- Arnold Durig (Austrian, 1872–1961) was a physician who conducted experiments on himself at high altitudes on mountains. He was a student of Nathan Zuntz.

- Adolf Löwy (German, 1862–1937), a physician, conducted experiments both on high mountains and in ground-based low-pressure chambers. He collaborated with Nathan Zuntz.

- Hermann von Schrötter (Austrian, 1870–1928) was a physician who designed a pressurized balloon cabin for very high altitudes. He studied physiological effects in balloons, on mountains, in ground-based pressure chambers, and in deep-sea divers. At various times he worked with Arthur Berson, Arnold Durig, Adolf Löwy, Reinhard Süring, and Nathan Zuntz.

- Reinhard Süring (German, 1866–1950) was a meteorologist who also studied the physiological effects of high altitudes using balloons and ground-based pressure chambers. He worked with Arthur Berson, Hermann von Schrötter, and Nathan Zuntz.

- Nathan Zuntz (German, 1847–1920), a physiologist, was the earliest of those listed here, and was essentially the founder of both high-altitude medicine and sports medicine. Over his long career, he trained and/or collaborated with Arthur Berson, Arnold Durig, Adolf Löwy, Hermann von Schrötter, and Reinhard Süring.

---

[28] Campbell et al. 2007; Campbell and Harsch 2013, 2019; Deichmann 1996; Gedeon 2006; Harsch 2000a, 2000b, 2004, 2006a, 2006b, 2007a, 2007b, 2015, 2017, 2018, 2019; Harsch and Kriebel 2006; Harsch et al. 2008; Kater 1989; Klee 2001; Posner and Ware 2000; Schnalke and Atzl 2010; Simmons 2002; Vivien Spitz 2005; Strughold 1950.

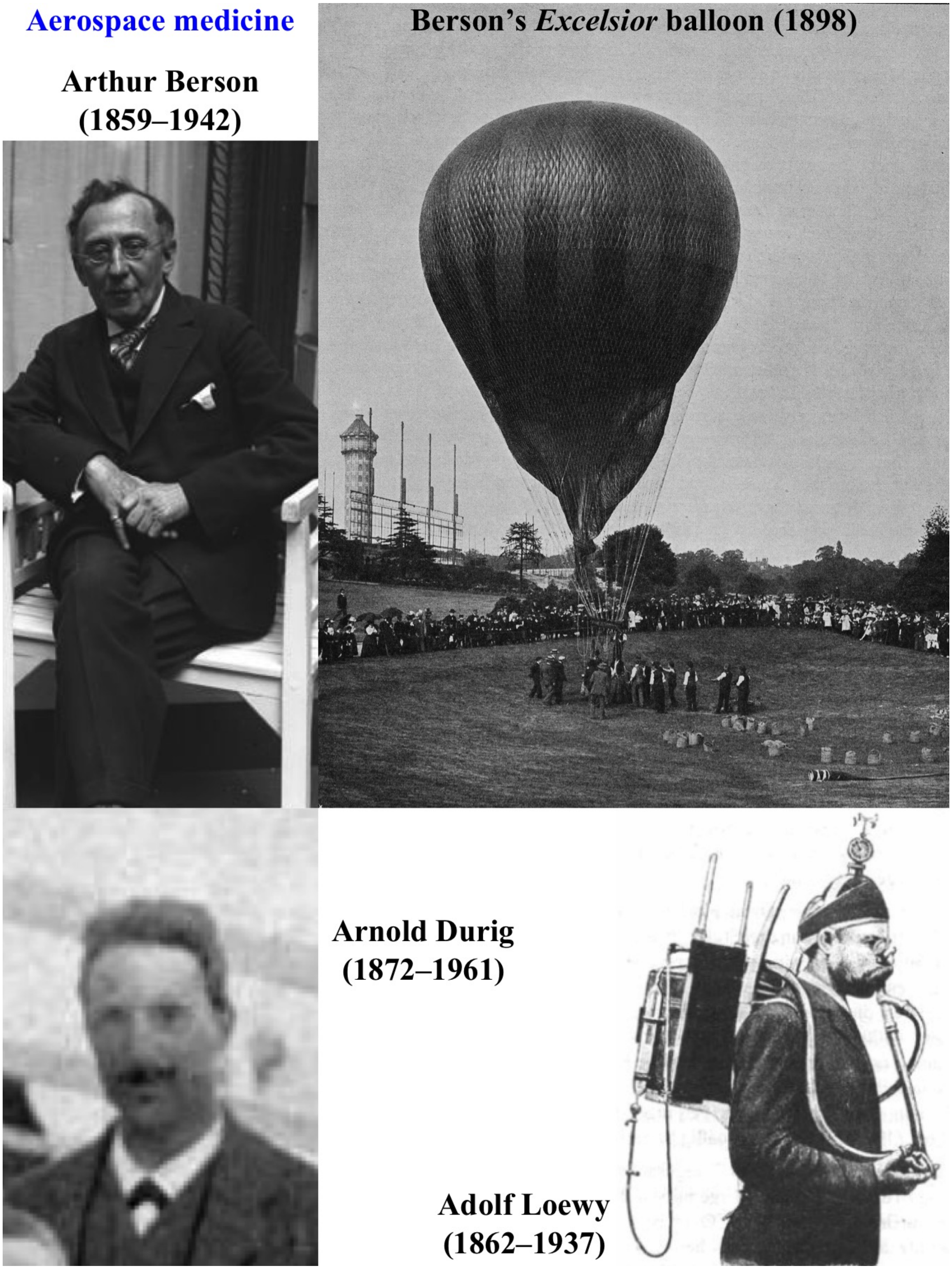

Aerospace medicine
Arthur Berson
(1859–1942)
Berson's *Excelsior* balloon (1898)
Arnold Durig
(1872–1961)
Adolf Loewy
(1862–1937)

Figure 2.205: Some creators who made important early discoveries in aerospace medicine included Arthur Berson, Arnold Durig, and Adolf Loewy.

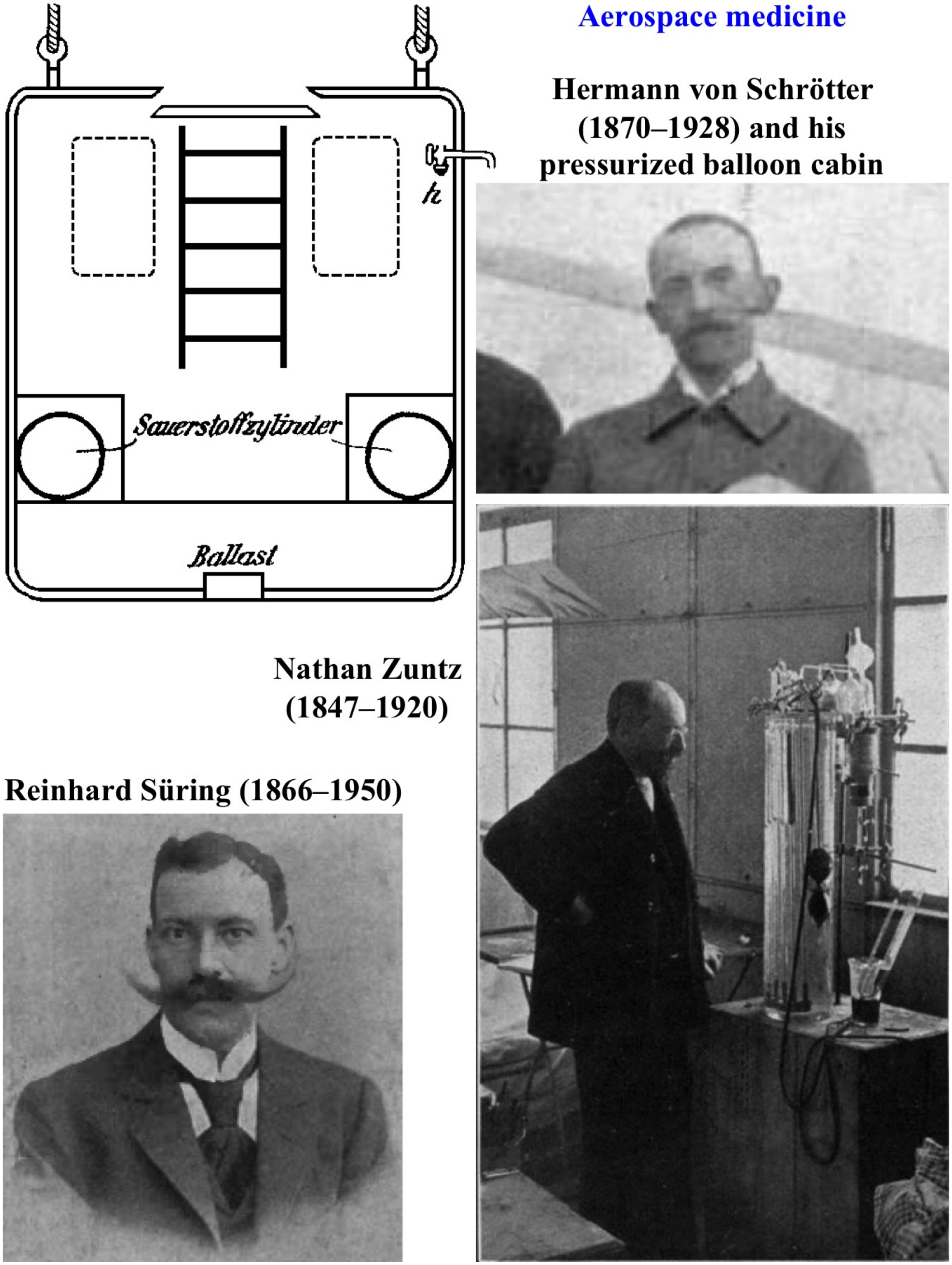

Aerospace medicine
Hermann von Schrötter (1870–1928) and his pressurized balloon cabin
h
Sauerstoffzylinder
Ballast
Nathan Zuntz (1847–1920)
Reinhard Süring (1866–1950)

Figure 2.206: Other creators who made important early discoveries in aerospace medicine included Hermann von Schrötter, Reinhard Süring, and Nathan Zuntz.

During World War II, Germany had a very large group of aerospace medicine researchers working on problems related to high-altitude aircraft, jets, rocket planes, ejection seats, and even piloted missiles and rockets. Those experts were rapidly scooped up by Allied countries at the end of the war, forming the basis for modern aerospace medicine in those countries. A large fraction of German aerospace medicine experts went to the United States, where they founded programs at the U.S. Air Force School of Aviation Medicine and the U.S. Naval Medical Research Institute (Figs. 2.207–2.208). Their expertise was invaluable for postwar military aviation, as well as for the later manned space program. Especially prominent members of this group of U.S.-based German aerospace medical experts included:

- Theodor Benzinger (German, 1905–1999) worked directly with the first U.S. astronauts to prepare them for spaceflight, yet is now nearly forgotten; if he is remembered at all by the modern world, it is for inventing the ear thermometer. Aerospace medicine expert Viktor Harsch summarized Benzinger's career path [Harsch 2007a]:

  > Theodore Benzinger was a pilot-physician who performed pioneering research—often involving self-experimentation—in areas related to flight at high altitude during World War II. Of greatest historical interest to those of us in aerospace medicine is his work on the effects of rapid decompression and related oxygen equipment. Benzinger was born in Stuttgart, Germany, on 28th August 1905. He studied medicine and natural sciences at the universities of Tuebingen, Munich, and Berlin. From 1934 to 1944, Benzinger headed the aeromedical laboratory "EMed" in Rechlin, where he was instrumental in conducting studies related to stratospheric flight, including self-experimentation with rapid decompression up to 19,000 m (62,320 ft). His Rechlin experiments made an important contribution to understanding the physiology and life-support requirements for high-altitude aviation and later work under space-equivalent conditions. Following World War II, Benzinger joined the staff of the U.S. Army Air Forces Aeromedical Center in Heidelberg. In 1947 he was recruited by "Operation Paperclip" to work at the U.S. Naval Medical Research Institute (NMRI) in Bethesda, MD, where he worked on various aspects of human physiology. He died as a U.S. citizen in Bethesda, MD, on 26th October 1999.

- Konrad Büttner (German, 1903–1970) specialized in environmental conditions from the lower atmosphere to the upper atmosphere to radiation in space. He worked closely with Theodor Benzinger, Hubertus Strughold, and other German-speaking scientists to apply that expertise to aerospace medicine.

- Fritz Haber (German, 1912–1998, not to be confused with the earlier chemist of the same name) was the brother of Heinz Haber. Both during and after World War II, he worked on aerospace projects and aerospace medicine. He and his brother proposed simulating zero-gravity conditions for short periods of time by sending astronaut trainees on parabolic flights in aircraft, and that became standard practice.

- Heinz Haber (German, 1913–1990) was the brother of Fritz Haber. He was a physicist and pilot, and worked on everything from nuclear power to aerospace projects, including parabolic flights for zero-gravity training.

- Hubertus Strughold (German, 1898–1986) was the leader of the German aerospace medicine experts both during and after the war. He tested himself in large centrifuges and pressure chambers in the 1930s and early 1940s, and headed the postwar programs to protect, equip, and train astronauts. In his biography, aerospace medicine experts Mark Campbell and Viktor Harsch wrote [Campbell and Harsch 2013, pp. 7, 10–11]:

  > Dr. Hubertus Strughold (1898–1986) is known as the “Father of Space Medicine”. The Space Medicine Branch of the Aerospace Medical Association initiated the “Hubertus Strughold Award” in 1963, given to the person each year for the greatest achievement in space medicine. [...]
  >
  > Dr. Hubertus Strughold became the first and only Professor of Space Medicine in 1958. Under his leadership, the school became a major center for basic and clinical investigations into the physiological and behavioral effects of spaceflight and the space environment. [...]
  >
  > Frequently misunderstood and a decade ahead of everyone else, but pressing forward with what he knew to be true and important; unwavering in his principles, beliefs, and ideas. As an example, Dr. Strughold never joined the Nazi party or allowed his staff to do so at a time when it would not only be advantageous to his career, but actually dangerous to not do so. He was as anti-Nazi as you could possibly be in his position without being arrested or executed. He specialized in aviation medicine at such an early time that he was discredited by his colleagues for his expansive ideas on future aeronautical possibilities. He then was a pioneer in the advancement of space medicine when the only activity was short unmanned suborbital flights using captured V-2s. He was pivotal in developing this discipline to such an extent that the U.S. was well prepared for the Mercury program in 1959. Finally, he was an advocate of the possibility of life on Mars and kept a “Mars jar” on his desk during the 1950s. This jar was growing lichen in an atmosphere of extremely dry, low pressure CO_2. [...]
  >
  > It is important that future debate of Dr. Strughold’s World War II activities be carried on with documented and well referenced facts[...]

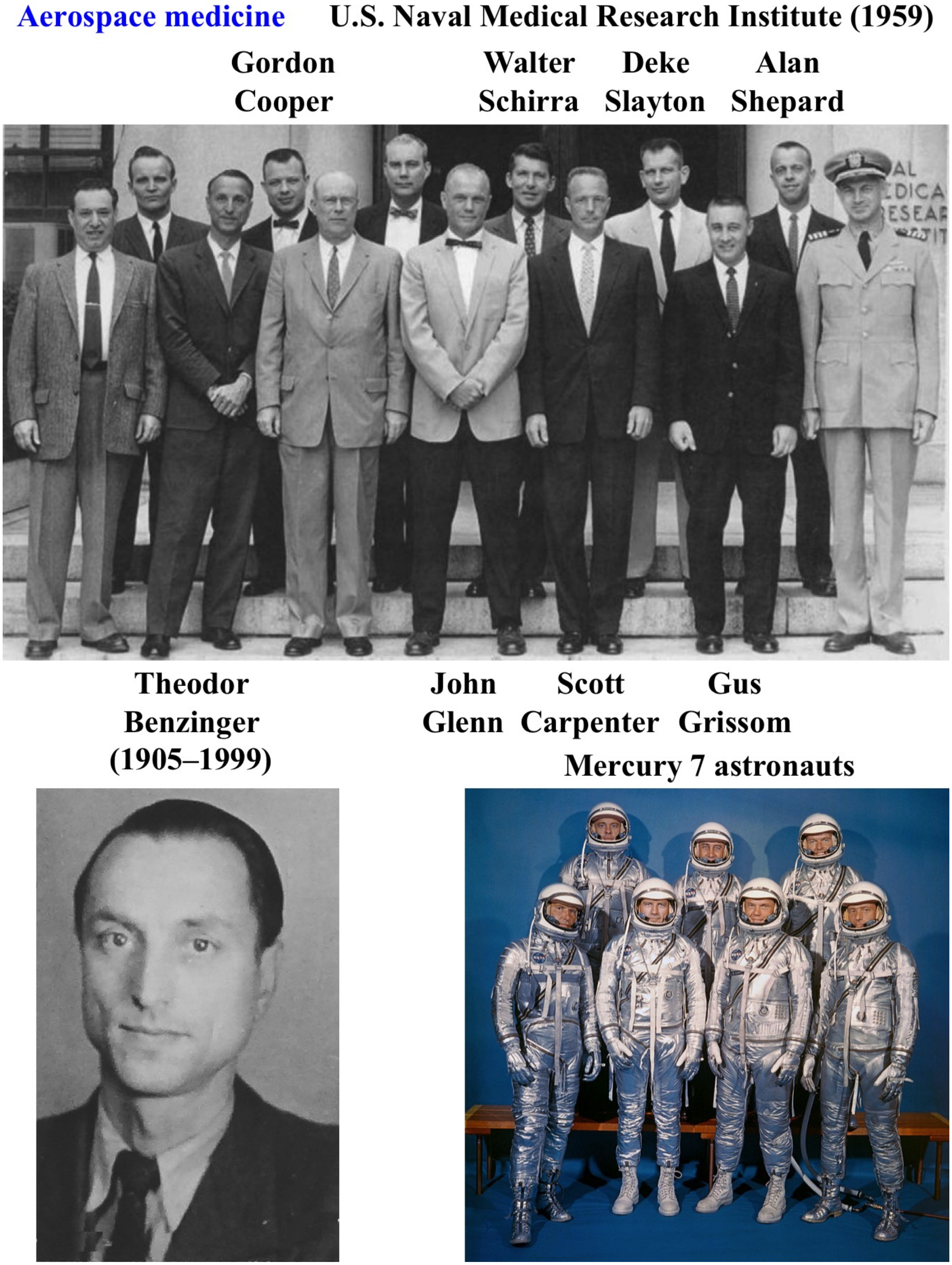

Aerospace medicine
U.S. Naval Medical Research Institute (1959)
Gordon Cooper
Walter Schirra
Deke Slayton
Alan Shepard
Theodor Benzinger (1905–1999)
John Glenn
Scott Carpenter
Gus Grissom
Mercury 7 astronauts

Figure 2.207: The Mercury 7 astronauts with Theodor Benzinger at the U.S. Naval Medical Research Institute.

Aerospace medicine

U.S. School of Aviation Medicine
Randolph Air Force Base, Texas (1959)

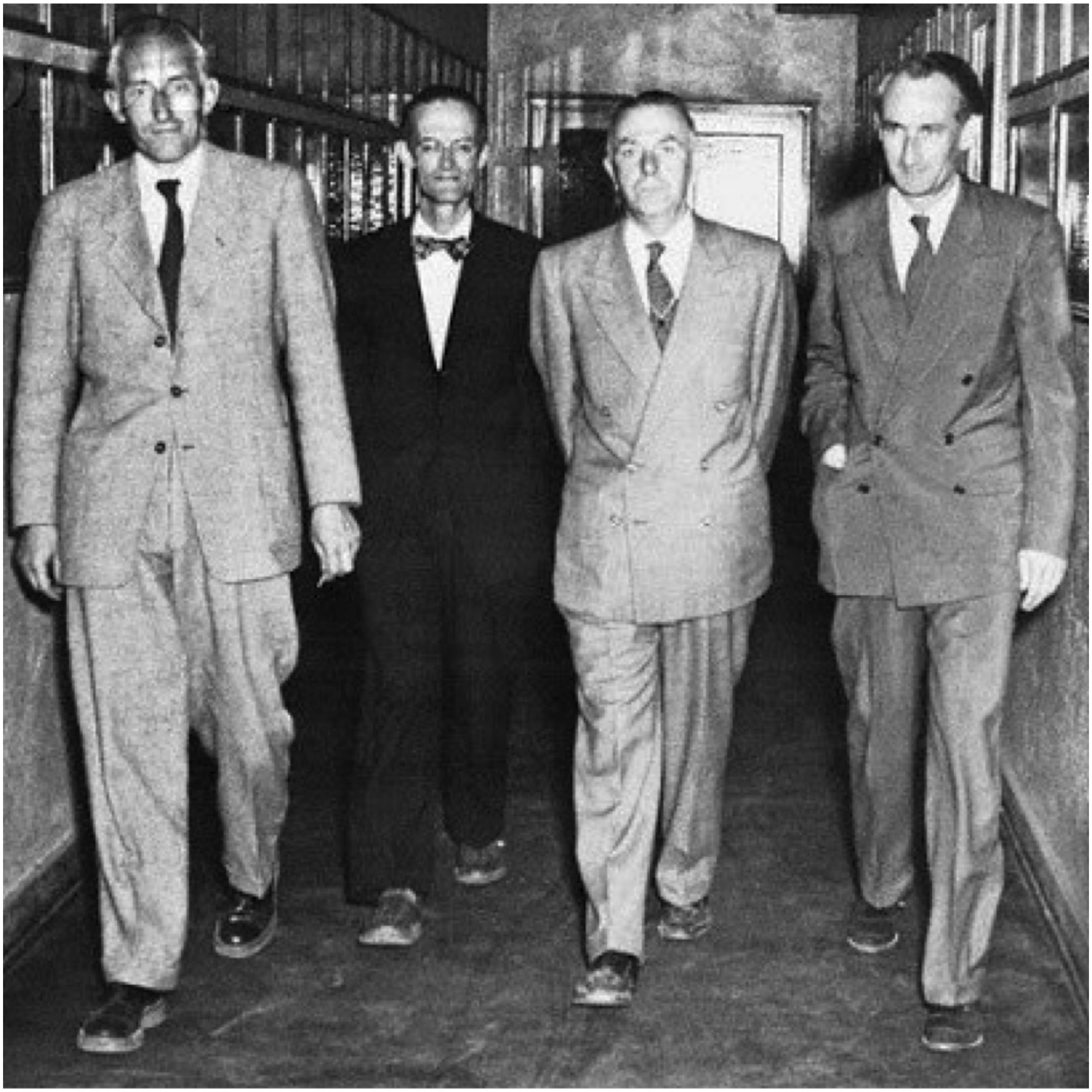

Fritz Haber (1912–1998)
Konrad Buettner (1903–1970)
Hubertus Strughold (1898–1986)
Heinz Haber (1913–1990)

Figure 2.208: Fritz Haber, Konrad Buettner, Hubertus Strughold, and Heinz Haber at the U.S. School of Aviation Medicine.

2.7.2 Prostheses

Due to the combination of strong support for scientific innovation and the large numbers of people with war injuries, the German-speaking world led the development of prosthetic limbs from the beginning of the nineteenth century onward.

While simple, rigid artificial limbs had been used since antiquity, in 1808, Albrecht Ludwig Berblinger (German states, 1770–1829) developed the first prosthetic legs with movable joints, which made the legs much more practical to use (Fig. 2.209). Berblinger also made early attempts at developing manned gliders [Harsch and Kriebel 2006].

In the 1890s, Jakob Riedinger (German, 1861–1917, Fig. 2.210) developed a corresponding prosthetic arm with movable joints, the "Würzburg working arm." In addition, from the 1890s through World War I, he established and helped to run national programs to treat and assist the disabled.

During World War I, Ferdinand Sauerbruch (German, 1875–1951) invented the first prosthetic arms that could be controlled by residual arm stump muscles, a particularly useful design that became known as the "Sauerbruch arm" (Fig. 2.210). In 1904, Sauerbruch also invented a pressurized chamber (the "Sauerbruch chamber") for much more safely opening the thorax of a patient to conduct operations on the heart or lungs.

Georg Schlesinger (German, 1874–1949, Fig. 2.210) worked with both Jakob Riedinger and Ferdinand Sauerbruch to design and build improved prosthetic arms and legs during and after World War I. Schlesinger also spent much of his career improving the standardization, testing, and calibration of machine tools.

During and after World War II, Ulrich Henschke (German, 1914–1980) and Hans Mauch (German, 1906–1984) developed the Swing-aNd-Stance (S-N-S) hydraulically controlled prosthetic leg, which has been used worldwide for many decades since then (Fig. 2.211). They also worked on prosthetic arms, vision systems for the blind, methods of interfacing electronics to the human nervous system, aerospace medicine, and aviation controls and simulators. In addition, Henschke developed brachytherapy methods for treating cancer. Mauch also played a key role in the early development of jet engines and jet aircraft (p. 1764). For much more information on Henschke and Mauch, see Section A.2.

Albrecht Ludwig Berblinger (1770–1829)

First prosthetic legs with movable joints

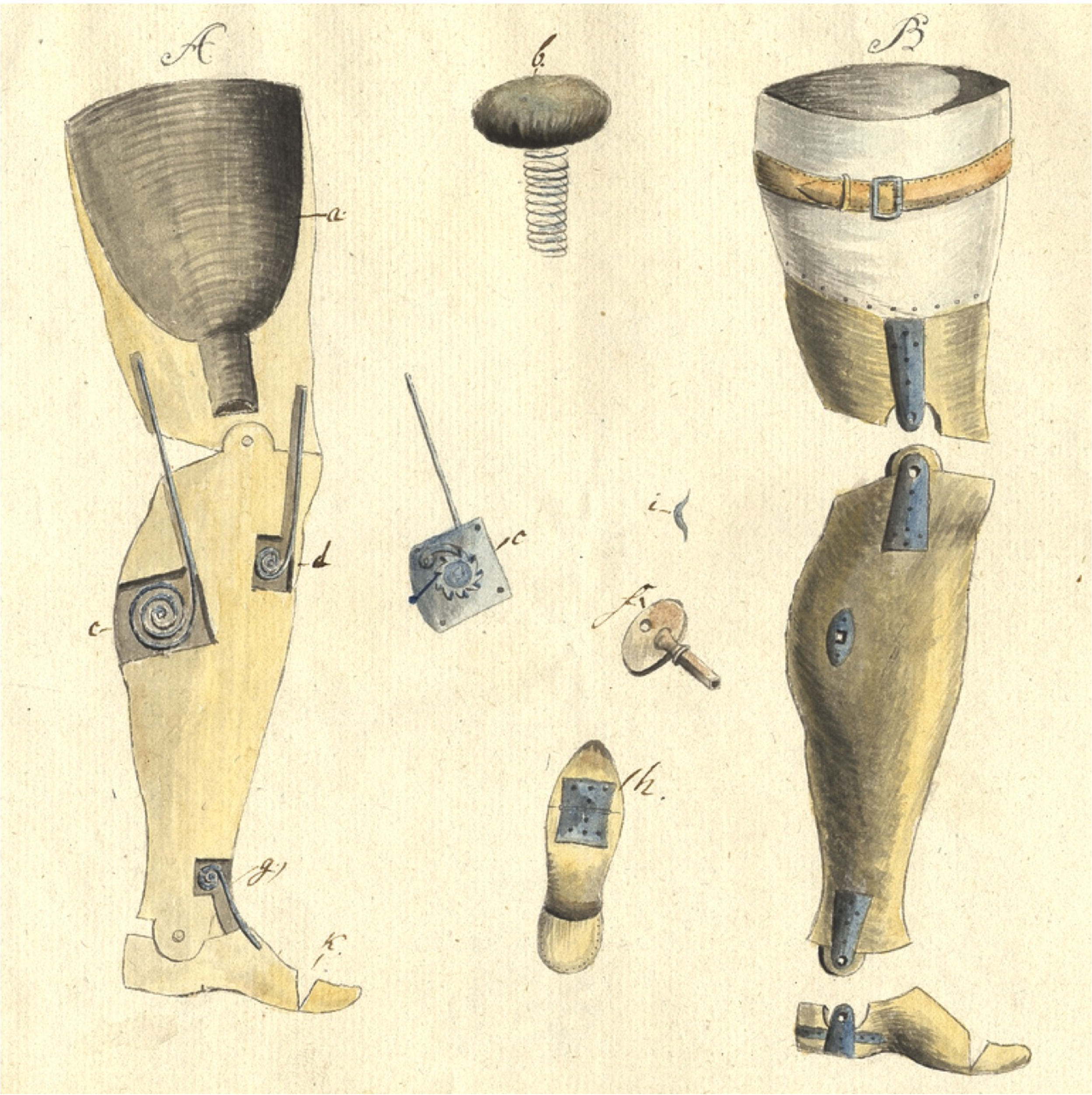


Figure 2.209: Albrecht Ludwig Berblinger developed the first prosthetic legs with movable joints.

Jakob Riedinger
(1861–1917)
Georg Schlesinger
(1874–1949)
Ferdinand Sauerbruch
(1875–1951)

Sauerbruch arm controlled by residual arm stump muscles

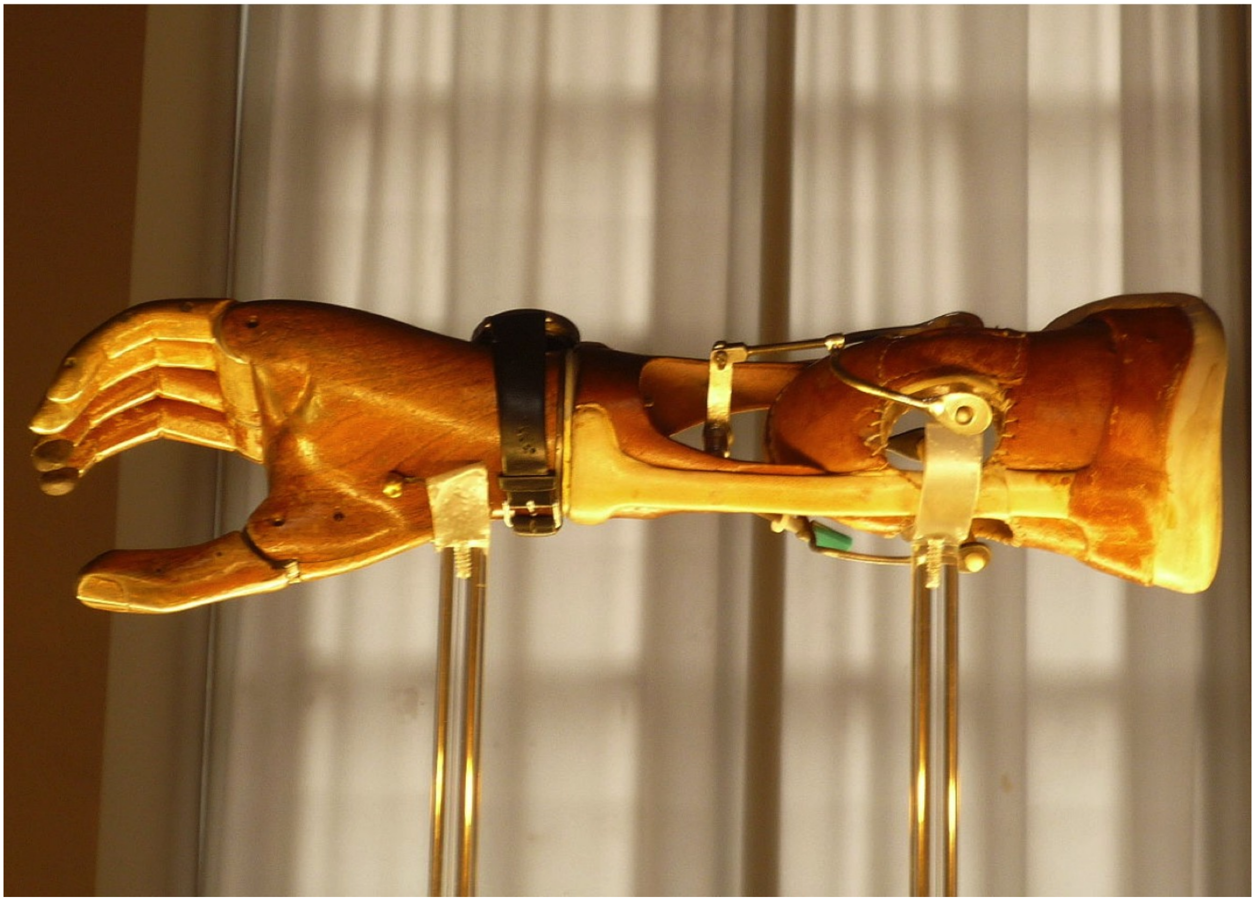


Figure 2.210: Jakob Riedinger developed the first prosthetic arms with movable joints. Ferdinand Sauerbruch invented the first prosthetic arms that could be controlled by residual arm stump muscles. Georg Schlesinger worked with both Riedinger and Sauerbruch.

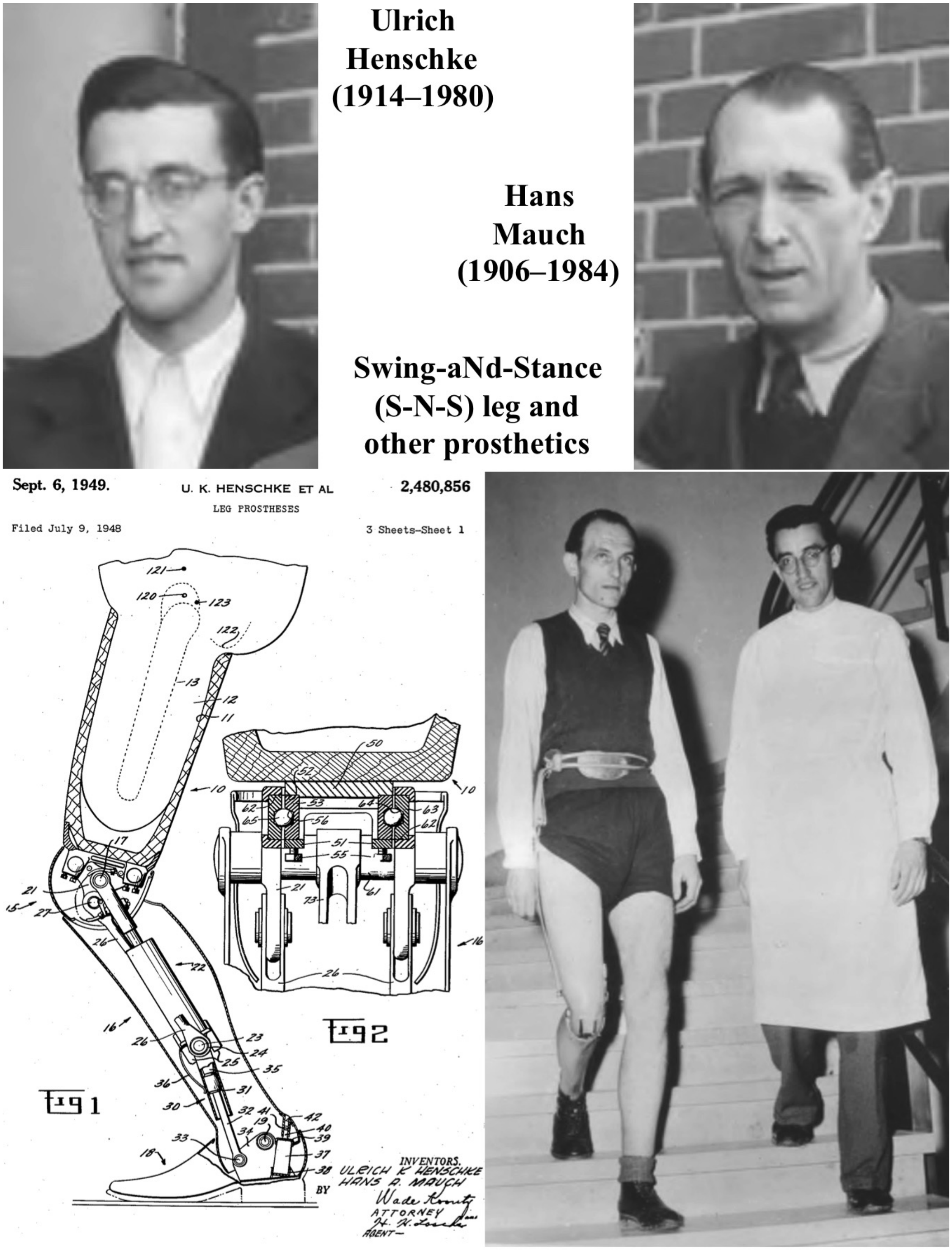

Ulrich Henschke (1914–1980)
Hans Mauch (1906–1984)
Swing-aNd-Stance (S-N-S) leg and other prosthetics
Sept. 6, 1949.
U. K. HENSCHKE ET AL
2,480,856
LEG PROSTHESES
Filed July 9, 1948
3 Sheets-Sheet 1
121
120
123
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Fig 1
Fig 2
INVENTORS.
ULRICH K HENSCHKE
HANS A. MAUCH
BY
Wade Koontz
ATTORNEY
H. H. Loeske
AGENT

Figure 2.211: Ulrich Henschke and Hans Mauch developed the Swing-aNd-Stance (S-N-S) leg and other prostheses. Lower right: An amputee (left) and Henschke (right) demonstrating the leg while walking down stairs. For more information, see Section A.2.

2.7.3 Miscellaneous Anatomy, Physiology, and Zoology

Scientists from the greater German-speaking world also made many important contributions regarding other aspects of anatomy, physiology, and zoology. A few illustrative examples are shown in Figs. 2.212–2.214 and discussed below:

Theodor Billroth (German/Austrian, 1829–1894) established and taught many of the key principles of modern gastrointestinal surgery (Fig. 2.212).

Ernst von Brücke (German, 1819–1892) conducted research on the anatomy and physiology of everything from chameleons' color changes to human language.

Karl Friedrich Burdach (German states, 1776–1847) studied the anatomy and physiology of the brain and other organs, and popularized the term "biology" for the study of organisms.

Julius Cohnheim (German, 1839–1884) made important discoveries in immunology, inflammation, neuromuscular junctions, histology, and other areas.

Johann Friedrich Dieffenbach (German states, 1792–1847) greatly advanced reconstructive and plastic surgery.

Gustav Gärtner (Austrian, 1855–1937) did important work in renal physiology, blood pressure measurement, nutrition, and other areas.

Leopold Gmelin (German states, 1788–1853) conducted research on digestive physiology, biochemistry, cellular pigments, and other topics.

Willi Hennig (German, 1913–1976) performed extensive work in comparative zoology and founded the field of phylogenetic systematics or cladistics.

Rudolf Albert von Kölliker (Swiss, 1817–1905) made discoveries in comparative zoology, embryology, histology, and the anatomy and physiology of many human organs.

Adolf Kussmaul (German, 1822–1902) was a pioneering physician who gave the first descriptions of mesenteric embolism, polyarteritis nodosa, progressive bulbar paralysis, the labored breathing of diabetic ketoacidosis, and the early emotional effects of mercury poisoning. He also worked to develop novel techniques such as esophagoscopy, gastric lavage, gastroscopy, and pleural tapping. He discovered dyslexia (p. 261) and the anti-inflammatory effects of acetanilide (p. 269) too.

Carl Ludwig (German, 1816–1895) wrote a textbook on human physiology (1852–1856) and worked in many areas of physiology, including blood pressure, renal physiology, and anesthesia.

Johannes Peter Müller (German states, 1801–1858) made several important discoveries in physiology and other fields of biology, and published his *Handbuch der Physiologie des Menschen* (*Handbook of Human Physiology*) during the period 1833–1840.

Friedrich Tiedemann (German states, 1781–1861) made contributions to neuroanatomy, osteology, cancer, evolution, and other topics.

Theodor Billroth (in yellow, 1829–1894) pioneered abdominal surgery

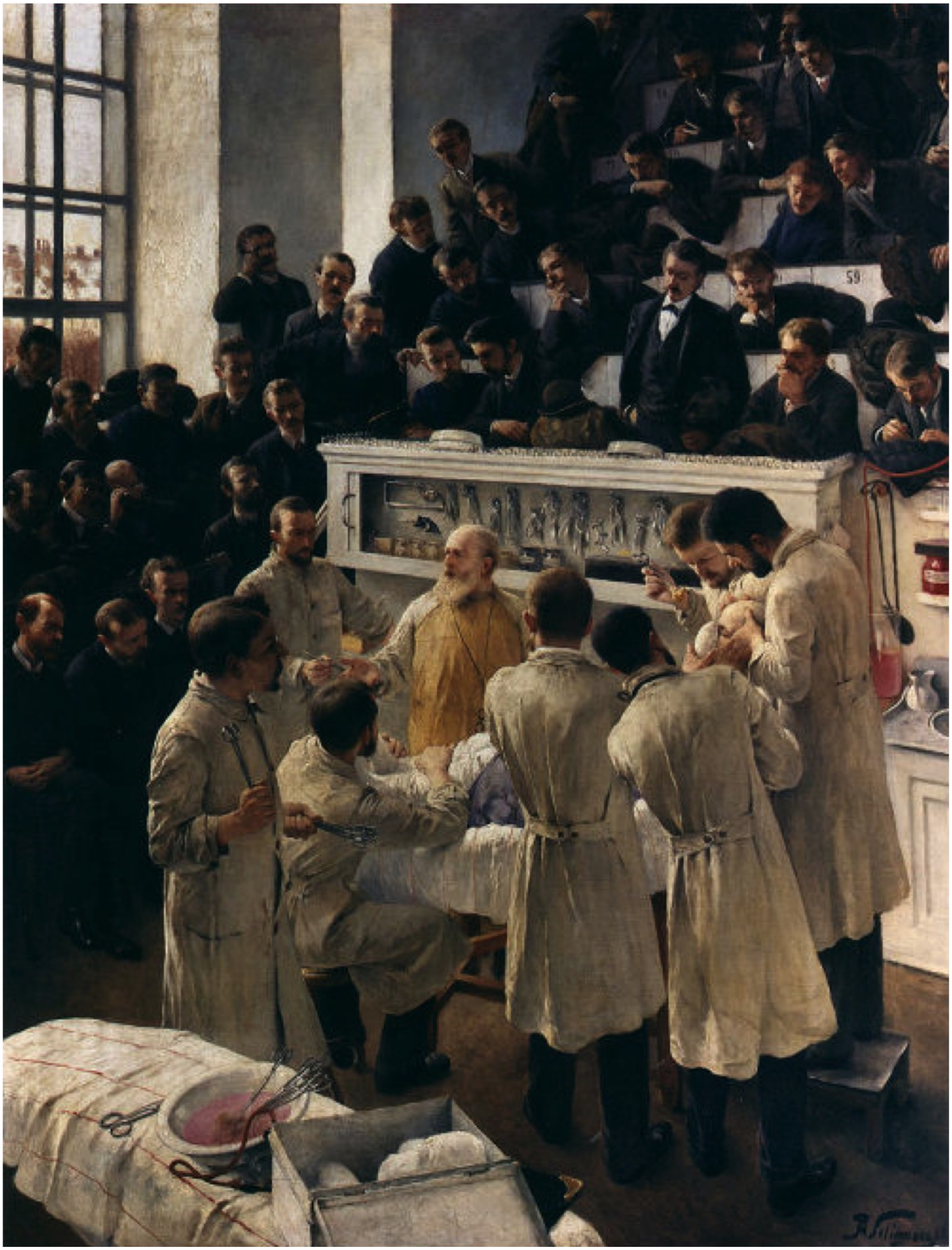


Figure 2.212: Theodor Billroth pioneered abdominal surgery.

Miscellaneous anatomy and physiology

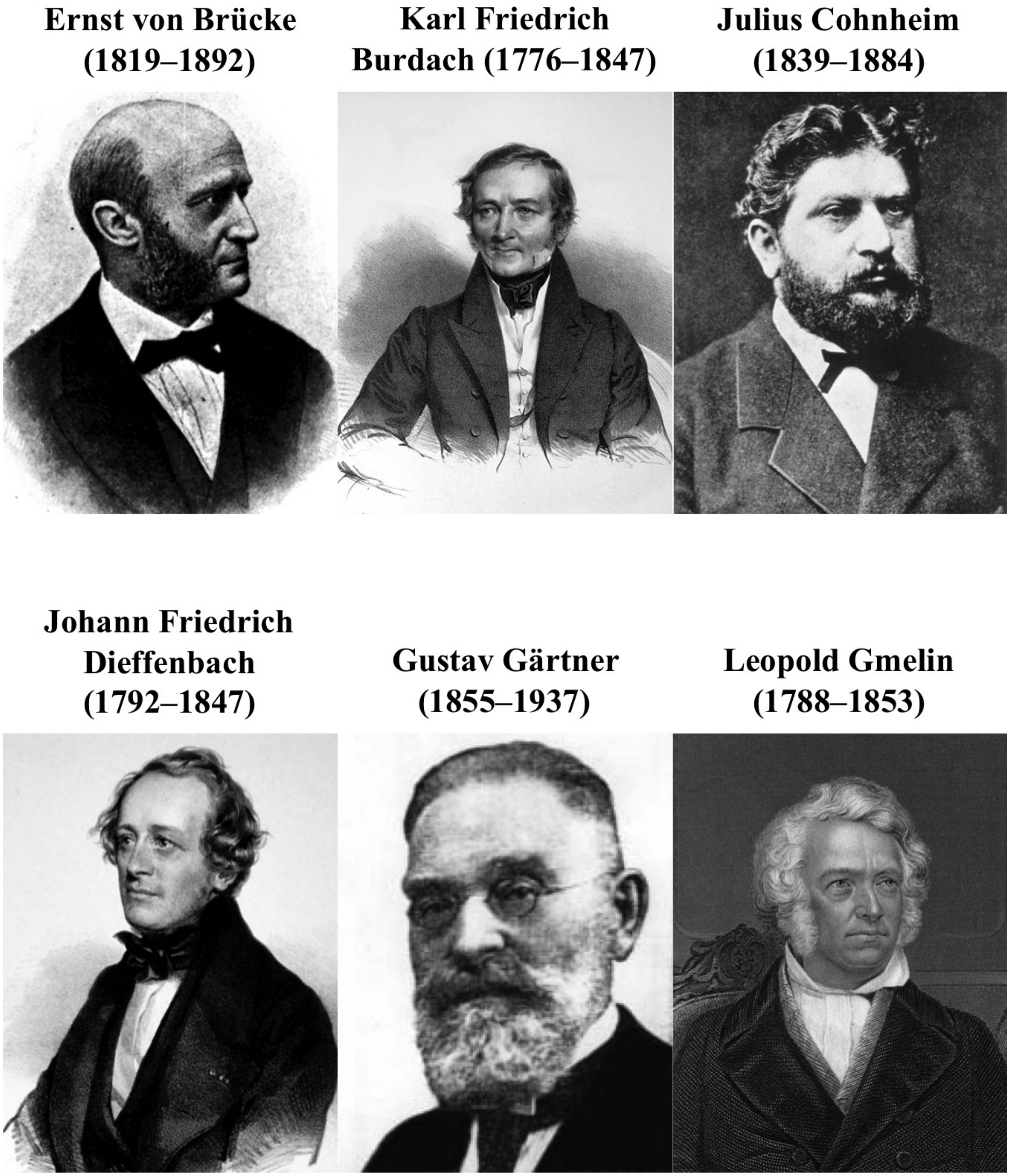
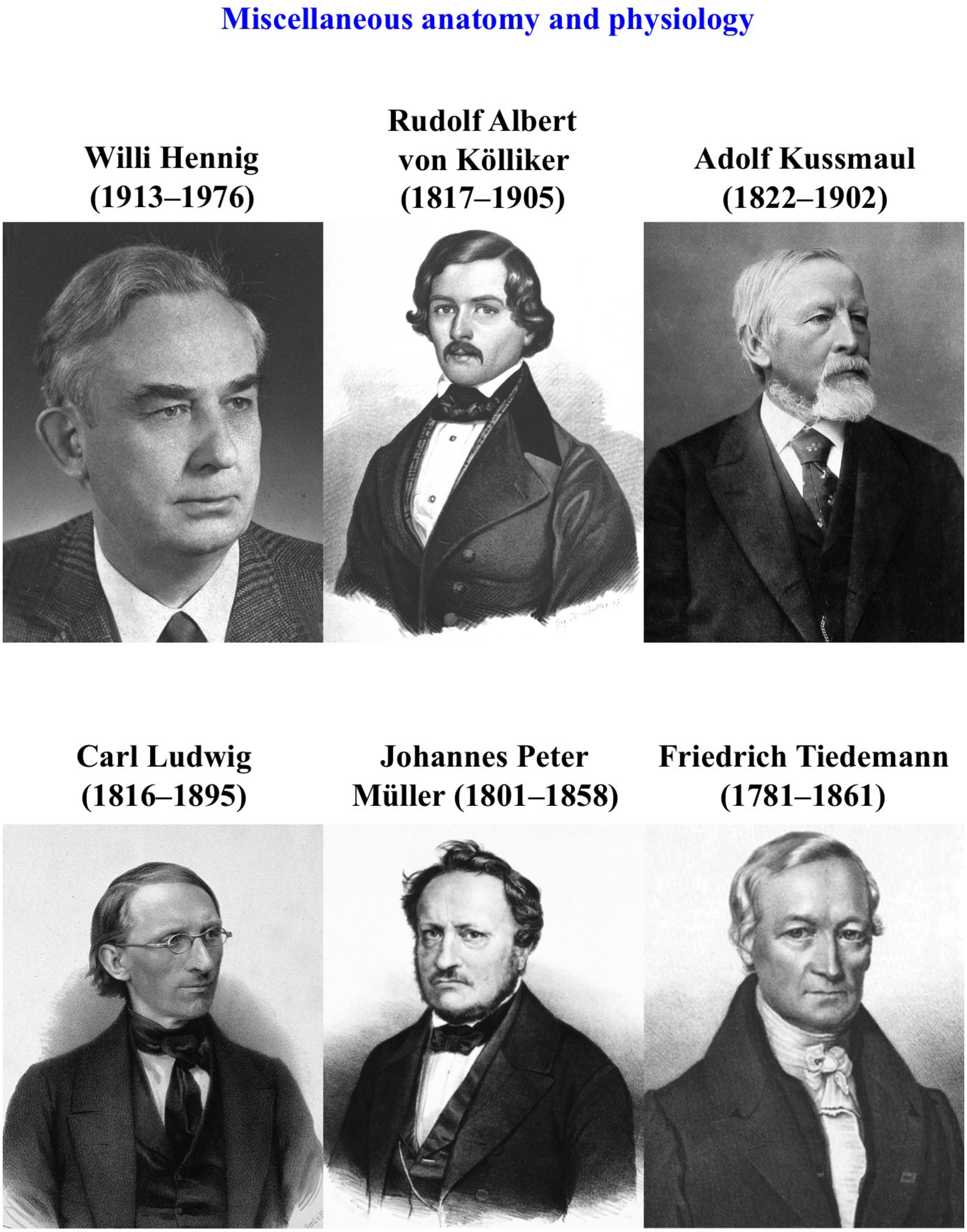

Ernst von Brücke (1819–1892)
Karl Friedrich Burdach (1776–1847)
Julius Cohnheim (1839–1884)
Johann Friedrich Dieffenbach (1792–1847)
Gustav Gärtner (1855–1937)
Leopold Gmelin (1788–1853)

Figure 2.213: Other creators who made significant contributions to knowledge about anatomy and physiology included Ernst von Brücke, Karl Friedrich Burdach, Julius Cohnheim, Johann Friedrich Dieffenbach, Gustav Gärtner, and Leopold Gmelin.



Miscellaneous anatomy and physiology

Willi Hennig (1913–1976)

Rudolf Albert von Kölliker (1817–1905)

Adolf Kussmaul (1822–1902)

Carl Ludwig (1816–1895)

Johannes Peter Müller (1801–1858)

Friedrich Tiedemann (1781–1861)

Figure 2.214: Other creators who made significant contributions to knowledge about anatomy and physiology included Willi Hennig, Rudolf Albert von Kölliker, Adolf Kussmaul, Carl Ludwig, Johannes Peter Müller, and Friedrich Tiedemann.

2.8 Botany

Scientists from the greater German-speaking world made many important discoveries in botany, including:[29]

2.8.1. How chlorophyll facilitates the process of photosynthesis.

2.8.2. Other aspects of plant physiology and genetics.

2.8.1 Photosynthesis

As shown in Fig. 2.215, plant cells are similar to animal cells, but they are surrounded by a cell wall and also possess chloroplasts. The chloroplasts contain chlorophyll, a specialized porphyrin molecule that absorbs light energy, which is then converted into stored chemical energy in a process called photosynthesis. The structure of chlorophyll and the biochemical steps involved in photosynthesis are quite complex, and a number of scientists were involved in elucidating their details (Figs. 2.216–2.218). Due to the overlapping and scientifically complex nature of their work, these creators are simply listed alphabetically below with very brief descriptions of their contributions.

Hans Fischer (German, 1881–1945) won the Nobel Prize in Chemistry in 1930 for his discoveries regarding the structure and synthesis of chlorophyll (as well as heme from hemoglobin–see p. 324). In awarding Fischer the Nobel Prize, Professor H.G. Söderbaum, Chairman of the Nobel Committee for Chemistry of the Royal Swedish Academy of Sciences, praised his work [https://www.nobelprize.org/prizes/chemistry/1930/ceremony-speech/]:

> [...] Even if I add that Fischer has demonstrated the occurrence of haemin in yeast, all this is overshadowed by the fact that, chemically speaking, the pigment of green plants, i.e. chlorophyll, is closely related with the red blood pigment, and even derives, as Fischer has shown, from exactly the same parent substance, as regards the porphyrins.
>
> This shows that Nature in spite of her extravagant diversity was sufficiently economical to use exactly the same building material when constructing these two substances which are so greatly different in appearance and occurrence.
>
> Having completed his work on the blood pigments and their components by the haemin synthesis, Fischer turned with undiminished energy to research into chlorophyll. In this field, where a scientist has previously gained a Nobel Prize, but where much work remained to be done, conditions are even more complicated and the difficulties as a consequence are even greater than in the other field. Nevertheless, Fischer obtained results which are so important that the Academy has considered it fitting to include them in the award.

---

[29] Bateson 1909; Corcos and Monaghan 1993; Deichmann 1996; Dostal 2016; Edelson 1999; Goppelsröder 1901; Henig 2000; Jahn 2004; Junker 2004; Kaplan and Cooke 1996; Magner 2002; Mawer 2006; Miller 1988; Richards 2004; Taschwer 2016; Wulf 2015.

James Franck (German, 1882–1964) was a quantum and nuclear physicist who spent his whole career studying various ways that light can interact with matter; he won the Nobel Prize in Physics in 1925 for part of that work, as discussed on p. 893. As just one aspect of that general interest, Franck conducted important experimental and theoretical analyses of the physics underlying photosynthetic interactions between light and chlorophyll molecules.

Friedrich Goppelsröder (Swiss, 1837–1919) demonstrated one-dimensional chromatography methods both in filter paper and in capillary tubes in 1861, and continued working to improve and to apply chromatography for several decades [Schönbein 1861; Goppelsröder 1861]. In particular, he used chromatography to separate and analyze the colored pigments from a wide variety of plant leaves [Goppelsröder 1901]. Some of the later scientists listed in this section ultimately found that some of those separated pigments were various forms of chlorophyll and related photosynthetic pigments. See pp. 711–714.

Like Hans Fischer but much earlier, Felix Hoppe-Seyler (German, 1825–1895) also purified and analyzed both hemoglobin and chlorophyll, and his studies became the foundation for the later work by Fischer and others.

Robert Huber (German, 1937–), Johann Deisenhofer (German, 1943–), and Hartmut Michel (German, 1948–) identified the mechanisms of photosynthesis in certain types of bacteria that can convert sunlight. Photosynthetic bacteria are environmentally important in their own right, and they were also the ancestors of photosynthetic plant chloroplasts. For this research, Huber, Deisenhofer, and Michel won the Nobel Prize in Chemistry in 1988. Professor Bo G. Malmström of the Royal Swedish Academy of Sciences explained the importance of their discoveries [https://www.nobelprize.org/prizes/chemistry/1988/ceremony-speech/]:

> For a long time it has been impossible to prepare membrane-bound proteins in a form allowing the determination of the detailed structure in three dimensions. [...] But the situation had actually drastically changed in 1982, when Hartmut Michel thanks to systematic experiments succeeded in preparing highly ordered crystals of a photosynthetic reaction center from a bacterium. With these crystals he could in the period 1982–1985, in collaboration with Johann Deisenhofer and Robert Huber, determine the structure of the reaction center in atomic detail.
>
> The structural determination awarded has led to a giant leap in our understanding of fundamental reactions in photosynthesis, the most important chemical reaction in the biosphere of our earth. But it has also consequences far outside the field of photosynthesis research. Not only photosynthesis and respiration are associated with membrane-bound proteins but also many other central biological functions, e. g. the transport of nutrients into cells, hormone action or nerve impulses. Proteins participating in these processes must span biological membranes, and the structure of the reaction center has delineated the structural principles for such proteins. Michel's methodological contribution has, in addition, the consequence that there is now hope that we can determine detailed structures also for many other membrane proteins. Not least important is the fact that the reaction center structure has given theoretical chemists an indispensable tool in their efforts to understand how biologic electron transfer over very large distances on a molecular scale can occur as rapidly as in one billionth (American English, trillionth) of a second. In a longer perspective it is possible that such research can lead to important energy technology in the form of artificial photosynthesis.

Jan Ingenhousz (Dutch, worked in Austria, lived 1730–1799) demonstrated that plant leaves produce oxygen when in the light and carbon dioxide when in the dark, and that part of a plant's mass must come from the air.

Hans Kornberg (German, 1928–) studied photosynthetic pathways in bacteria and related those to photosynthetic molecules and reactions in plants.

Max Rudolf Lemberg (German, 1896–1975) spent his career investigating the structure and function of porphyrins, including those for chlorophyll, hemoglobin, and several cytochromes.

Hilde Levi (German, 1909–2003), a quantum and nuclear physicist, worked with James Franck to purify chlorophyll molecules and analyze the light absorption and emission spectra of chlorophyll.

Julius von Mayer (German, 1814–1878) clearly articulated and was an important early advocate of the general principle of photosynthesis, that plants convert absorbed light energy into stored chemical energy.

Helmut Metzner (German, 1925–1999) made highly accurate measurements of photosynthetic reactions that refined our understanding of the detailed processes involved.

Julius von Sachs (German, 1832–1897) demonstrated that photosynthesis in leaves produces starch molecules, a key discovery in understanding the fundamental role of photosynthesis.

Nicolas-Théodore de Saussure (Swiss, 1767–1845) made careful experimental measurements demonstrating that photosynthetic reactions require both water and carbon dioxide as input materials.

Cornelius Bernardus van Niel (Dutch, 1897–1985) pioneered the study of photosynthetic pathways in bacteria. His work was later continued by Hans Kornberg, Robert Huber, Johann Deisenhofer, and Hartmut Michel.

Otto Heinrich Warburg (German, 1883–1970) investigated the catalytic mechanism and quantum efficiency involved in photosynthesis. He should not be confused with his distant older cousin Otto Warburg (1859–1938), who made other contributions to botany (p. 414). Otto Heinrich Warburg won the Nobel Prize in Physiology or Medicine in 1931 for his work on cellular respiration, which is essentially photosynthesis with all of its biochemical steps run in reverse (p. 147).

Building upon the earlier work by Friedrich Goppelsröder, Richard Willstätter (German, 1872–1942) identified different types of chlorophyll and other plant pigment molecules and determined their empirical formulas. For those discoveries, he won the Nobel Prize in Chemistry in 1915. At the award ceremony, Professor O. Hammarsten, Chairman of the Nobel Committee for Chemistry of the Royal Swedish Academy of Sciences, described the importance of Willstätter's work [https://www.nobelprize.org/prizes/chemistry/1915/press-release/]:

> The difficulties, however, which confront research scientists in this field have been so great that until very recently they have prevented a successful study of the problem of chlorophyll. Willstätter is the first, jointly with several of his students, to have been successful in overcoming these difficulties by working out new and very valuable methods and by extensive investigations carried out with masterly experimental skill. By the new and important discoveries resulting from these investigations he has been able to elucidate in all its essential parts the question of the chemical nature of chlorophyll. [...]

The most important part of Willstätter's investigations is, nevertheless, that relating to the detection of the chemical structure of chlorophyll. He has shown that chlorophyll is an ester, which on saponification with alkali can be split up into a previously unknown alcohol called "phytol", which represents about one third of the molecule, and a colour component called "chlorophyllin", containing magnesium, which forms the remaining part. He has more closely investigated these two components both individually and for their transformation and decomposition products. Furthermore, he has found that this splitting-up of chlorophyll into the two mentioned main components can also take place as a result of the action of an enzyme occurring in the leaves, which he has called "chlorophyllase", and hence he has been able to elucidate the nature of the crystallized chlorophyll. [...]

A very important section of Willstätter's work on the chemical structure of chlorophyll is represented by his investigations into the colour components, the "chlorophyllin", and other "phyllins" and derivatives formed from it. These investigations are of particular interest with regard to the question of the relationship between blood pigment and chlorophyll. [...]

He has also prepared in a pure state and studied exhaustively the yellow pigments, the so-called carotenoids, which occur together with chlorophyll in the leaves of plants. By means of the results obtained regarding both these yellow pigments and the chlorophylls he has paved the way for new biological researches into the part played by the different leaf pigments in the assimilation of carbonic acid.

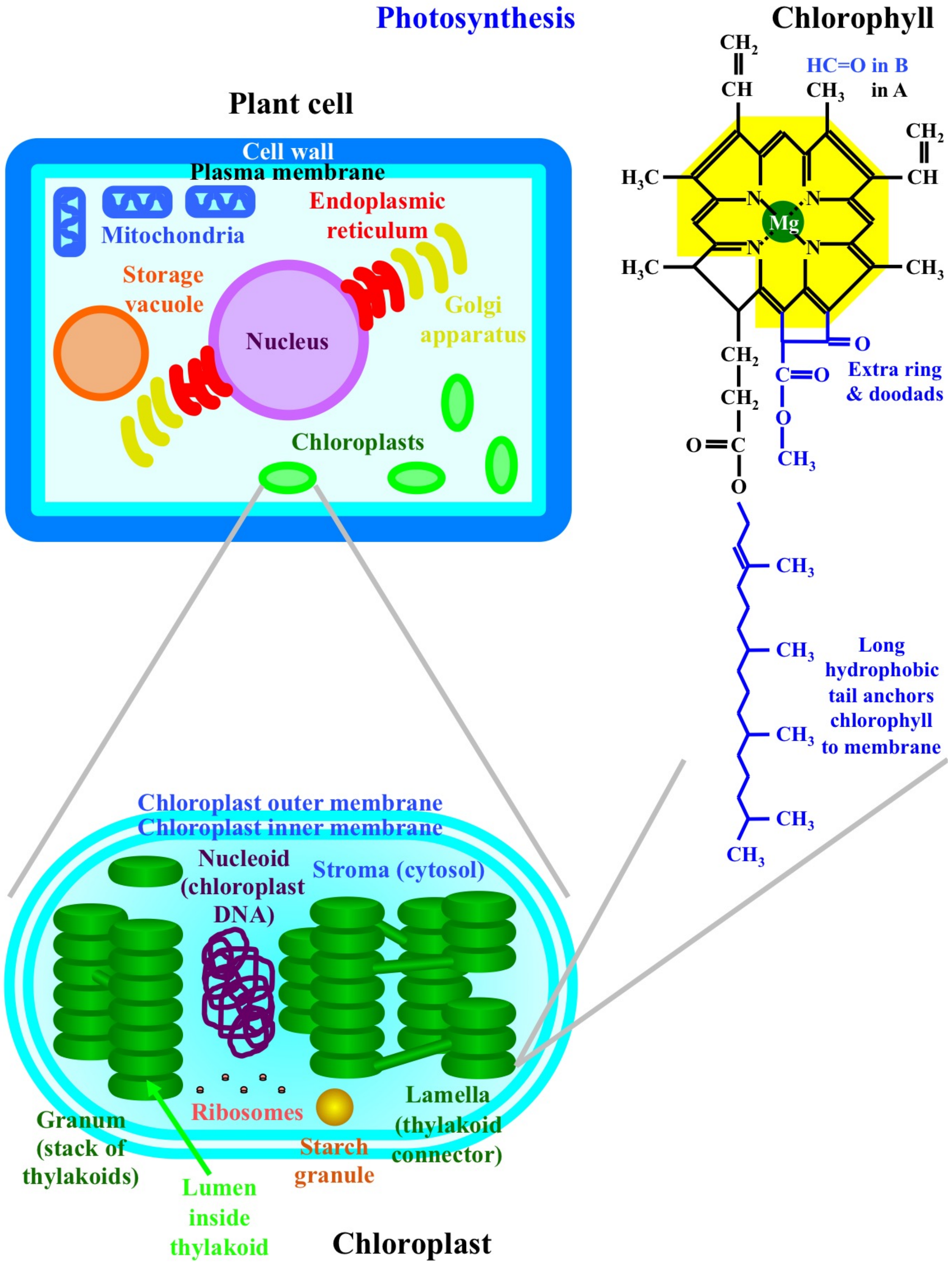
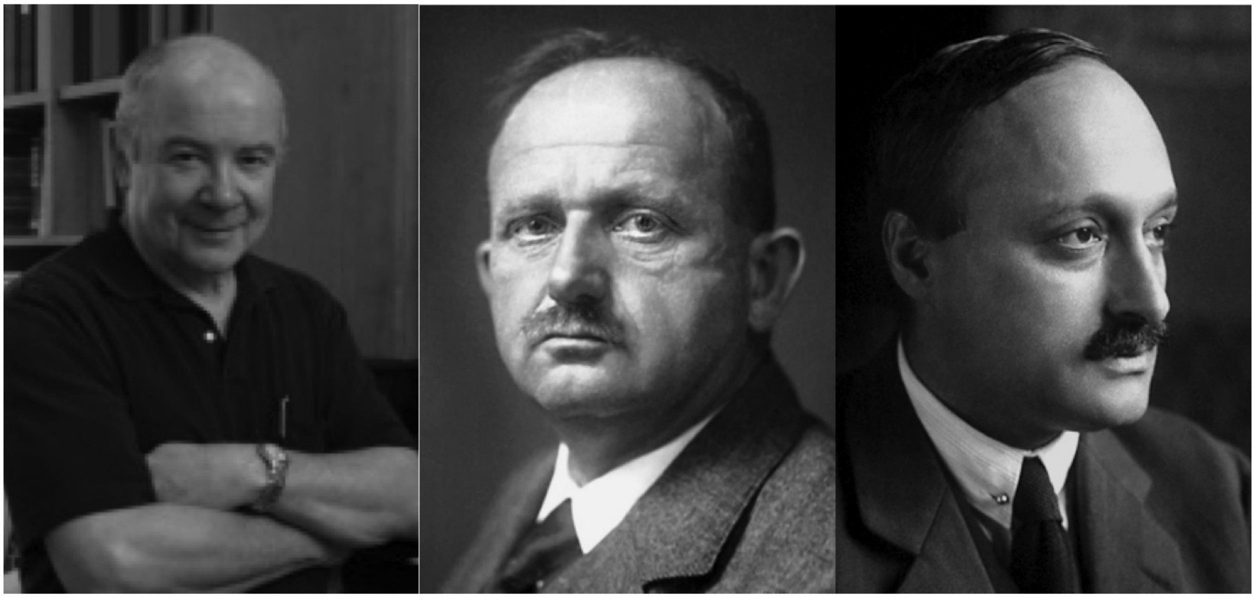

Photosynthesis
Chlorophyll
Plant cell
Cell wall
Plasma membrane
Mitochondria
Endoplasmic reticulum
Storage vacuole
Nucleus
Golgi apparatus
Chloroplasts
CH_2
CH
HC=O in B
CH_3 in A
CH_2
CH
H_3C
N
N
Mg
N
N
H_3C
CH_3
CH_2
CH_2
O
C=O
O
CH_3
Extra ring & doodads
O=C
O
CH_3
CH_3
CH_3
CH_3
CH_3
Long hydrophobic tail anchors chlorophyll to membrane
Chloroplast outer membrane
Chloroplast inner membrane
Nucleoid (chloroplast DNA)
Stroma (cytosol)
Granum (stack of thylakoids)
Lumen inside thylakoid
Ribosomes
Starch granule
Lamella (thylakoid connector)
Chloroplast

Figure 2.215: Plant cells are similar to animal cells, but they are surrounded by a cell wall and also possess chloroplasts. The chloroplasts contain chlorophyll, specialized porphyrin molecules that absorb light energy, which is then converted into stored chemical energy.

Photosynthesis

Johann Deisenhofer (1943–) **Hans Fischer (1881–1945)** **James Franck (1882–1964)**



Friedrich Goppelsröder (1837–1919) **Felix Hoppe-Seyler (1825–1895)** **Robert Huber (1937–)**

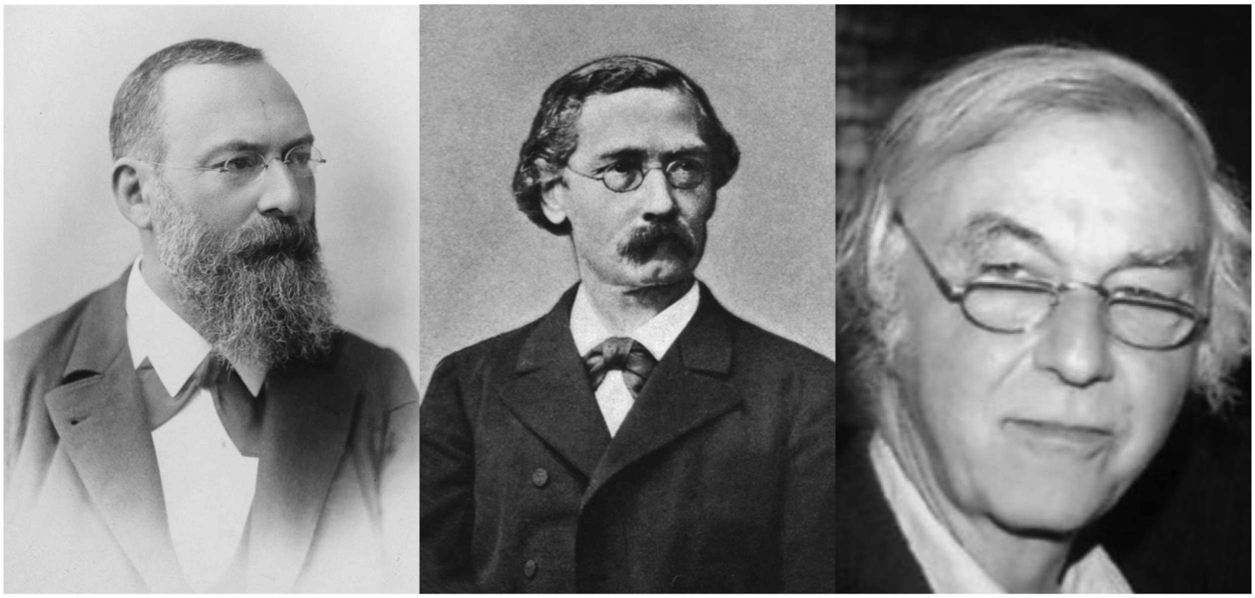


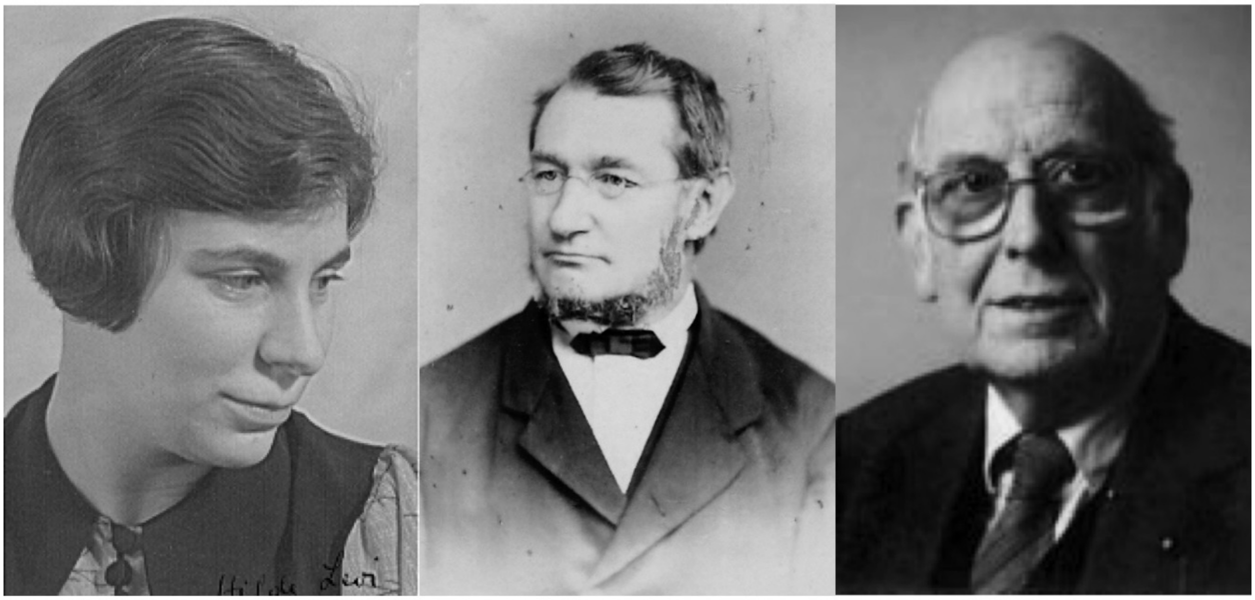
Figure 2.216: Some creators who made significant contributions to knowledge about photosynthesis included Johann Deisenhofer, Hans Fischer, James Franck, Friedrich Goppelsröder, Felix Hoppe-Seyler, and Robert Huber.

Photosynthesis

Jan Ingenhousz (1730–1799)

Hans Kornberg (1928–)

Max Rudolf Lemberg (1896–1975)



Hilde Levi (1909–2003)

Julius von Mayer (1814–1878)

Helmut Metzner (1925–1999)

Figure 2.217: Other creators who made significant contributions to knowledge about photosynthesis included Jan Ingenhousz, Hans Kornberg, Max Rudolf Lemberg, Hilde Levi, Julius von Mayer, and Helmut Metzner.

Photosynthesis
Hartmut Michel (1948–)
Julius von Sachs (1832–1897)
Nicolas-Théodore de Saussure (1767–1845)
Cornelius Bernardus van Niel (1897–1985)
Otto Heinrich Warburg (1883–1970)
Richard Willstätter (1872–1942)

Figure 2.218: Other creators who made significant contributions to knowledge about photosynthesis included Hartmut Michel, Julius von Sachs, Nicolas-Théodore de Saussure, Cornelius Bernardus van Niel, Otto Heinrich Warburg, and Richard Willstätter.

2.8.2 Other Aspects of Botany

There were a huge number of scientists in the predominantly German-speaking scientific world who made important discoveries regarding plant properties other than photosynthesis. This section can only briefly mention a few illustrative examples (Figs. 2.219–2.222).

Willem Hendrik Arisz (Dutch, 1888–1975) contributed to many areas of botany over his long career, but is perhaps best remembered for his work on the mechanisms of phototropism.

Franz Andreas Bauer (Austrian, 1758–1840) discovered plant cell structures under the microscope and produced thousands of highly detailed color paintings and drawings of the microscopic and macroscopic features of a vast variety of plants.

Martinus Beijerinck (Dutch, 1851–1931) discovered nitrogen fixation, the process by which bacteria living in root nodules of plants convert atmospheric nitrogen gas into ammonia that plants can absorb and utilize.

Alexander Braun (German, 1805–1877) made important discoveries regarding plant morphology, phyllotaxis, plant cell structure, and other aspects of botany.

Ferdinand Cohn (German, 1828–1898) investigated algae and plants under the microscope, recognized that algae are simple single-celled plants, and conducted experiments on plant physiology.

Friedrich Johann Franz Czapek (Austrian/Czech, 1868–1921) studied and synthesized new biochemical discoveries that were applicable to plants in his highly influential three-volume reference work, *Biochemie der Pflanzen*.

Heinrich Anton de Bary (Germany, 1831–1888) identified and studied plant pathogens such as the fungi that cause potato (late) blight and stem (wheat) rust, showed that lichens are a symbiosis of algae and fungi, and studied other aspects of algae and plant physiology.

Augustin de Candolle (Swiss, 1778–1841) developed and published a hugely detailed system of classifying plants and proposing their potential evolutionary relationships. He also demonstrated intrinsic circadian rhythms in plants kept under conditions of constant light.

Gottlieb Haberlandt (Austrian, 1854–1945) developed plant cell tissue culture and also discovered totipotency, the ability of some "stem" cells to give rise to any type of specialized cell in an organism, in 1902. He was the father of Ludwig Haberlandt, who developed oral contraceptives (p. 354).

Wilhelm Hofmeister (German, 1824–1877) discovered the alternation of generations in plants, was one of the first scientists to observe and record plant chromosomes under the microscope, greatly advanced the study of plant embryology, and proposed a theory for the evolution of plant species. His botanical discoveries were so numerous and so revolutionary that he deserves far more fame than he has generally received [Kaplan and Cooke 1996].

Alexander von Humboldt (Prussian, 1769–1859), traveled the world conducting scientific studies, and essentially founded the field of botanical geography. He also made other contributions to botany, as well as geography, meteorology, archaeology, and other subjects [Wulf 2015].

Gregor Mendel (Austrian, 1822–1884) discovered the rules of genetics using plants he grew at his monastery (p. 96). He also studied asexual reproduction in hawkweed and identified several new species of plants.[30]

Franz Meyen (Prussian, 1804–1840, Fig. 2.1), a botanist and microscopist, published a very important series of plant physiology books in the 1830s. Among other critical insights during his short life, he wrote that plants were divided into many similar cells, and that new cells arose from the division of existing cells.

Hugo von Mohl (German, 1805–1872) observed the structure of plant cells under the microscope and recorded cell division in algae in 1835. He also spent decades observing and cataloging the microscopic and macroscopic structures of a wide range of plants.

Ernst Münch (German, 1876–1946) made major discoveries in plant physiology, tree breeds and species, pine resin, and plant pathology (including blue stain fungi and disease resistance). He is best remembered for his pressure flow hypothesis of nutrient transport in plants.

Wilhelm Pfeffer (German, 1845–1920) was responsible for important findings regarding growth, movement, and metabolism in plants. He also discovered the significance of osmotic pressure, and he developed methods to measure it.

Wilhelm Ruhland (German, 1878–1960) had a long career conducting botanical research, but his greatest contribution was writing the 18-volume *Handbuches der Pflanzenphysiologie*, which was finally published at the end of his life.

Matthias Schleiden (German 1804–1881, Fig. 2.2) studied a variety of plants and plant tissues under the microscope and was one of the first scientists to recognize that larger organisms are divided into many similar cells. He studied the cell nucleus, cell division, and other aspects of plant cells.

Eduard Strasburger (Polish, studied and worked in Germany, 1844–1912) studied the embryology of gymnosperms and angiosperms, monitored plant chromosomes in cell division, and made other contributions to plant physiology and cell biology.

Gottfried Reinhold Treviranus (Bremen, 1776–1837) proposed a theory of plant evolution and studied the relationships among plant species. He was the older brother of Ludolph Treviranus.

Ludolph Christian Treviranus (Bremen, 1779–1864) made a wide variety of contributions to plant taxonomy, embryology, and physiology. He was the younger brother of Gottfried Treviranus.

Otto Warburg (German, 1859–1938) was an important expert on tropical agriculture. He should not be confused with his distant younger cousin Otto Heinrich Warburg (1883–1970, p. 407).

Frits Warmolt Went (Dutch, 1903–1990) studied plant hormones. In 1927, he discovered the role of the plant hormone auxin in phototropism.

Fritz von Wettstein (Austrian, 1895–1945) made a number of important discoveries regarding chloroplast genetics and plant chromosomes. He was the son of Richard Wettstein von Westersheim.

Richard Wettstein von Westersheim (Austrian, 1863–1931) developed and published an extremely detailed system of classifying plants, and was the father of Fritz von Wettstein.

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[30] Bateson 1909; Corcos and Monaghan 1993; Dostal 2016; Edelson 1999; Henig 2000; Mawer 2006.

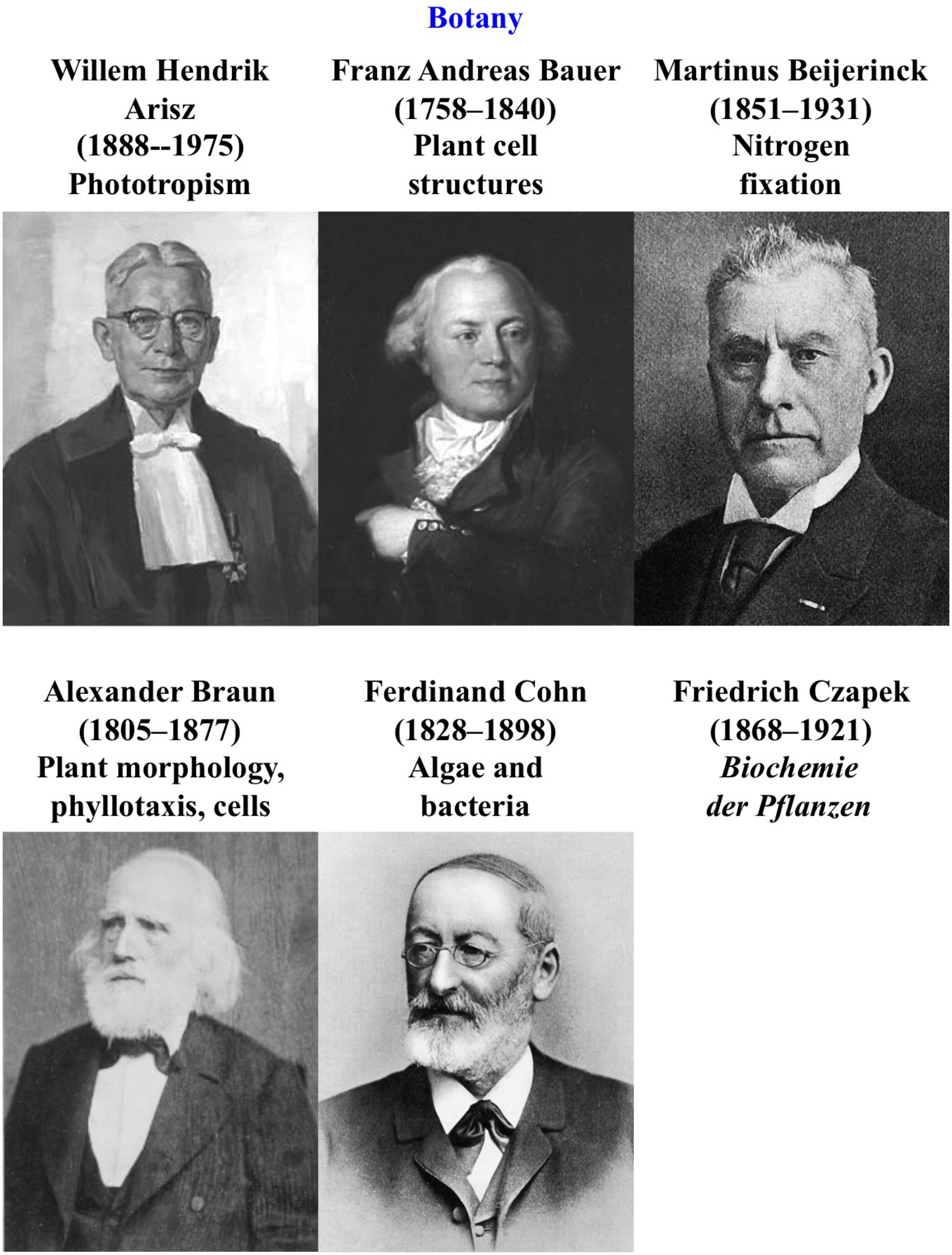

Botany
Willem Hendrik Arisz (1888--1975) Phototropism
Franz Andreas Bauer (1758–1840) Plant cell structures
Martinus Beijerinck (1851–1931) Nitrogen fixation
Alexander Braun (1805–1877) Plant morphology, phyllotaxis, cells
Ferdinand Cohn (1828–1898) Algae and bacteria
Friedrich Czapek (1868–1921) *Biochemie der Pflanzen*

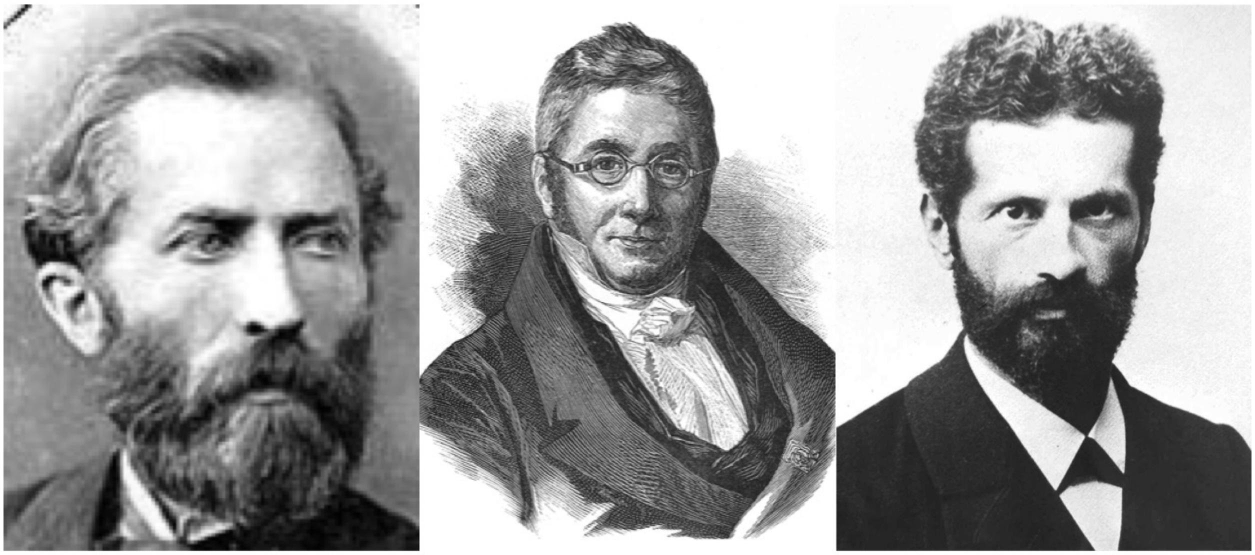
Figure 2.219: Some creators who made significant contributions to knowledge about botany included Willem Hendrik Arisz, Franz Andreas Bauer, Martinus Beijerinck, Alexander Braun, Ferdinand Cohn, and Friedrich Czapek.

Botany

Anton de Bary
(1831–1888)
Algae, lichens,
plant diseases

Augustin de Candolle
(1778–1841)
Plant classification,
circadian rhythms

Gottlieb Haberlandt
(1854--1945)
Plant tissue culture
and plant stem cells



Wilhelm Hofmeister
(1824–1877)
Alternation of
generations in plants

Alexander
von Humboldt
(1769–1859)
Botanical geography

Franz Meyen
(1804–1840)
Plant physiology
and cell division

Figure 2.220: Other creators who made significant contributions to knowledge about botany included Anton de Bary, Augustin de Candolle, Gottlieb Haberlandt, Wilhelm Hofmeister, Alexander von Humboldt, Gregor Mendel (shown on p. 96), and Franz Meyen.

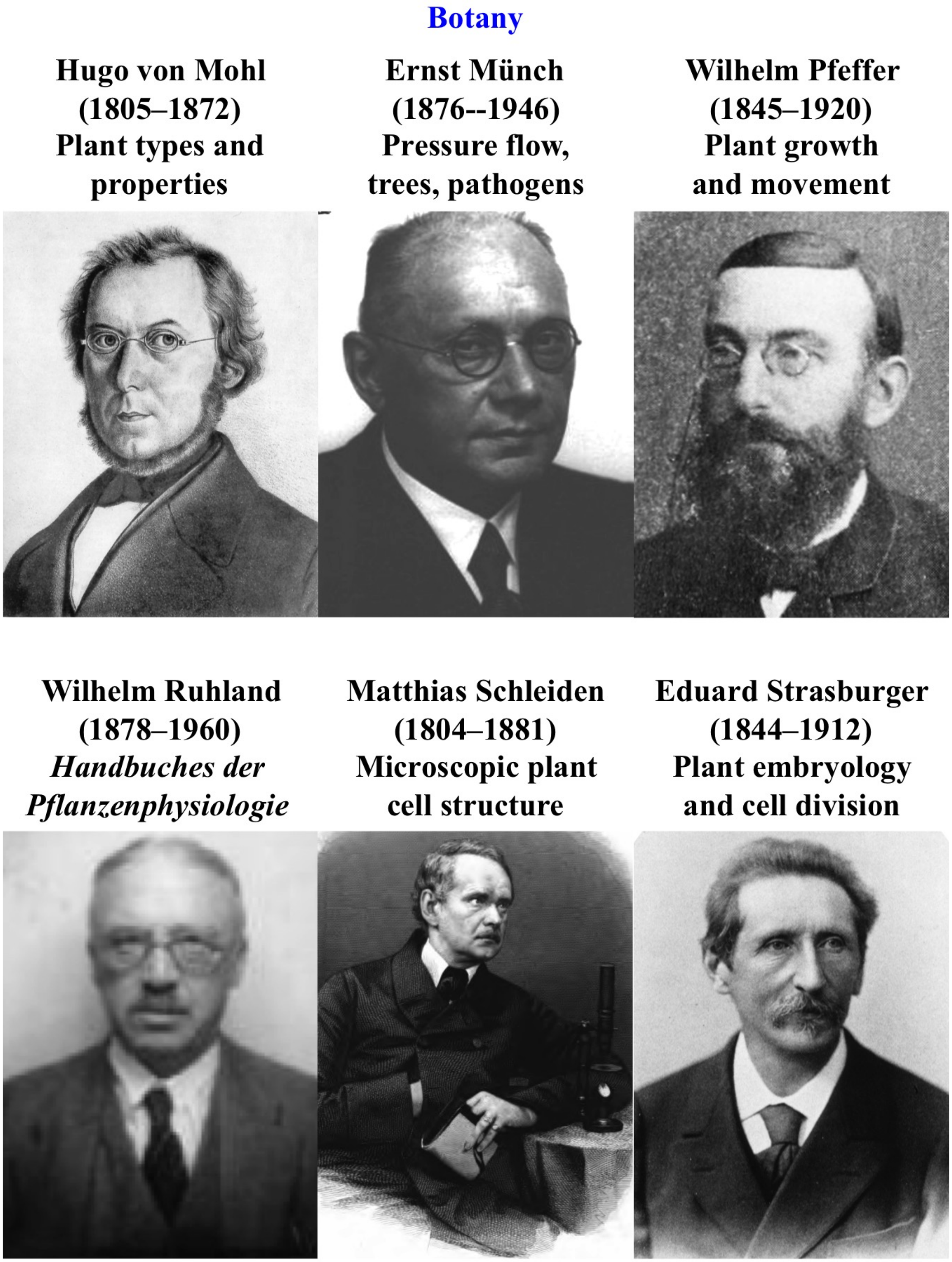

Botany
Hugo von Mohl
(1805–1872)
Plant types and properties
Ernst Münch
(1876--1946)
Pressure flow, trees, pathogens
Wilhelm Pfeffer
(1845–1920)
Plant growth and movement
Wilhelm Ruhland
(1878–1960)
Handbuches der Pflanzenphysiologie
Matthias Schleiden
(1804–1881)
Microscopic plant cell structure
Eduard Strasburger
(1844–1912)
Plant embryology and cell division

Figure 2.221: Other creators who made significant contributions to knowledge about botany included Hugo von Mohl, Ernst Münch, Wilhelm Pfeffer, Wilhelm Ruhland, Matthias Schleiden, and Eduard Strasburger.

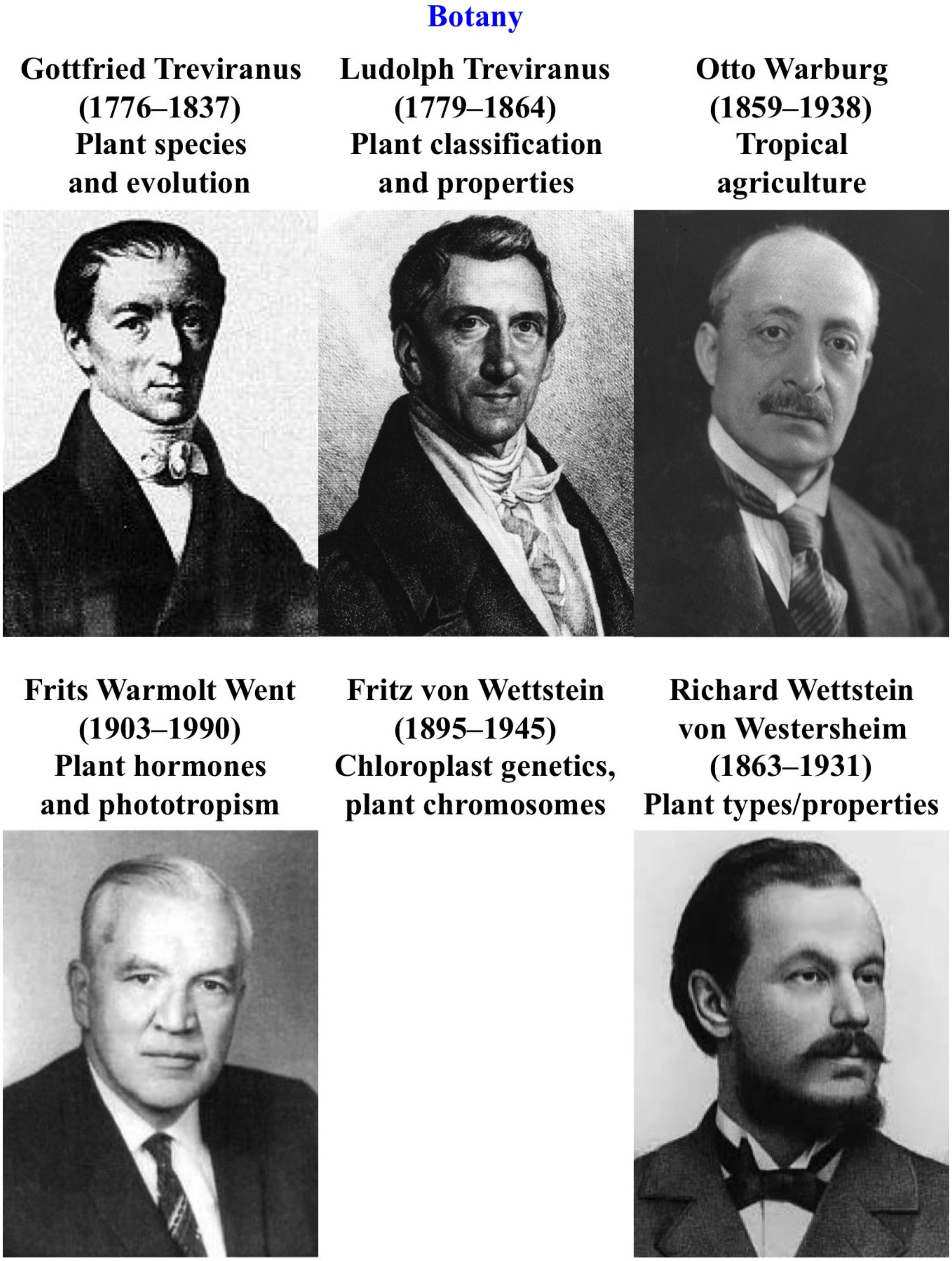

Botany
Gottfried Treviranus
(1776–1837)
Plant species
and evolution
Ludolph Treviranus
(1779–1864)
Plant classification
and properties
Otto Warburg
(1859–1938)
Tropical
agriculture
Frits Warmolt Went
(1903–1990)
Plant hormones
and phototropism
Fritz von Wettstein
(1895–1945)
Chloroplast genetics,
plant chromosomes
Richard Wettstein
von Westersheim
(1863–1931)
Plant types/properties

Figure 2.222: Other creators who made significant contributions to knowledge about botany included Gottfried Treviranus, Ludolph Treviranus, Otto Warburg, Frits Warmolt Went, Fritz von Wettstein, and Richard Wettstein von Westersheim.

Chapter 3

Creators and Creations in Chemistry and Materials Science

Alle Arnzneien sind auf der Erde, aber es fehlen die Menschen, die sie pflücken würden. Sie sind zur Ernte gereift, aber die Schnitter sind nicht gekommen. Wenn einmal die Schnitter der rechten Arznei da sein werden, dann werden wir ohne Hinderung durch leere Sophistik die Aussätzigen reinigen und die Blinden sehend machen. Denn diese Kraft liegt in der Erde und sie wächst überall. [...]

All the remedies are on earth, but we lack the people to gather them. They are ready to be harvested, but the reapers have not come. But one day the reapers of the right remedies shall come, and undeterred by empty sophistry we will cleanse the lepers and make the blind see. For this power is concealed in the earth, and it grows everywhere. [...]

Die Natur ist so sorgfältig und genau in ihren Dingen, daß man sie ohne große Kunst nicht verwenden kann; denn sie bringt nichts an den Tag, was an sich vollendet wäre. Alles hat der Mensch zu vollenden. Diese Vollendung heißt: Alchemie... Und der ist ein Alchemist, der alles, was in der Natur den Menschen zum Nutzen wächst, zu seinem von ihr bestimmten Ende führt. [...] Deswegen soll mehr Fleiß darauf verwendet werden, um mehr daraus zu gestalten! [...]

Nature is so careful and exact in her creations that they cannot be used without great skill; for she does not produce anything that is perfect in itself. Man must bring everything to perfection. This work of bringing things to their perfection is called alchemy... And he is an alchemist who carries what nature grows for the use of man to its destined end. [...] For this reason more diligence should be spent on alchemy, in order to obtain still greater results! [...]

Gott hat Eisen geschaffen, aber nicht das, was daraus gemacht werden soll... Das Weitere hat Er dem Feuer anbefohlen und dem Vulcanus, der des Feuers Herr ist... Daraus folgt, daß das Eisen zuerst von seinen Schlacken gereinigt und dann zu dem geschmiedet werden muß, was aus ihm entsehen soll. Das nennt sich Alchemie, das ist der Schmelzer—der Schmied—, der Vulcanus heißt. Was das Feuer tut, ist Alchemie—auch im Ofen, oder auch im Küchenherd.	God created iron but not that which is to be made of it... He enjoined fire, and Vulcan, who is the lord of fire, to do the rest... From this it follows that iron must be cleansed of its dross before it can be forged. This process is alchemy; its founder is the smith Vulcan. What is accomplished by fire is alchemy—whether in the furnace or in the kitchen stove.

Paracelsus. ca. 1536. In Jolande Jacobi, ed. 2002. *Paracelsus: Lebendiges Erbe.* St. Goar: Reichl. pp. 96–97. English translation adapted from Norbert Guterman.

As with biology, during the nineteenth century, intellectual leadership in chemistry and materials science passed from scientists in other countries (primarily France, the United Kingdom, and Sweden) to German-speaking scientists.[1]

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[1] In addition to specific references that are cited in different areas throughout this chapter, this chapter makes use of general biographical and project information from: ACLS 2000; Albrecht et al. 1992; Ash and Söllner 1996; Bar-Zohar 1967; Bower 1987; Bunch and Hellemans 2004; Challoner 2009; Cornwell 2003; Crim 2018; EB 1911, 2010; Gillispie 1970–1990; Gimbel 1990a; Glatt 1994; Hall 2019a; István Hargittai 2006, 2011; Linda Hunt 1991; Impey et al. 2008; Jacobsen 2014; Koertge 2007; Kurowski 1982; Lasby 1971; Lusar 1956, 1971; Medawar and Pyke 2000; Mick 2000; Murray 2003; Nachmansohn 1979; NDB 1953–2020; Neufeld 2012; Nouzille and Huwart 1999; O'Reagan 2014, 2019; Porter 1994; Charles Walker 1946; Peter Watson 2010; Weitensfelder 2009.

For coverage of major portions of the history of chemistry and materials science in the German-speaking world, see: Abelshauser et al. 2004; Brock 1993; Bugge 1955; Coffey 2008; Deichmann 2001; Drummer and Zwilling 2007; Engels et al. 1989; Farber 1961; Haber 1958, 1971; Ihde 1984; Johnson 1990; Kahlert 2002; Karlsch2016; Lesch 2000; Maier 2015; Marsch 1994a; Neufeldt 2003; Partington 1935, 1957, 1964; Peppas 2013; Rosner 2004; Sasuly 1947; Scerri 2006; Schwenk 2000; Soukup 2007; Teltschik 1992; Ungewitter 1938; Weeks and Leicester 1968; Welsch 1981; Werner 2017.

I have deliberately left a blank space where images of some creators or creations should go. Those are people or projects that I felt were important enough that they should definitely be shown in this book, yet I have not yet been able to locate a suitable image that I have permission to use, despite my searches in Europe and in the United States. If readers have any relevant images and could send them to me, I would be very grateful and will include them in future editions of this book. Even where a suitable photo cannot be located, I believe that leaving a blank space pays tribute both to the scientific importance of that creator or creation and to how that historical fact has been very nearly forgotten.

As covered in this chapter, creators from the predominantly German-speaking central European research world then made enormous contributions to:

3.1. Inorganic chemistry

3.2. Organic chemistry

3.3. The chemistry of foods and drinks

3.4. Chemical explosives

3.5. Chemical warfare agents and pesticides

3.6. Physical chemistry

3.7. Film photography

3.8. Materials science

3.9. Other aspects of chemistry

German-speaking creators also made numerous contributions to other chemistry-related areas such as biochemistry (Chapter 2), earth science (Chapter 4), quantum and statistical physics (Chapter 5), and nuclear chemistry (Chapter 8).

In 1946, the American journalist Charles Lester Walker provided a useful contemporary perspective on chemistry- and materials-related creations that were transferred out of the German-speaking world [Charles Walker 1946]:

> Mica was another thing. None is mined in Germany, so during the war our Signal Corps was mystified. Where was Germany getting it?
>
> One day certain piece of mica was handed to one of our experts in the U.S. Bureau of Mines for analysis and opinion. “Natural mica,” he reported, “and no impurities.”
>
> But the mica was synthetic. The Kaiser Wilhelm Institute for Silicate Research had discovered how to make it and—something which had always eluded scientists—in large sheets.
>
> We know now, thanks to FIAT teams, that ingredients of natural mica were melted in crucibles of carbon capable of taking 2,350 degrees of heat, and then—this was the real secret—cooled in a special way. Complete absence of vibration was the first essential. Then two forces directly perpendicular to each other were applied. One, vertically, was a controlled gradient of temperature in the cooling. At right angles to this, horizontally, was introduced a magnetic field. This forced the formation of the crystals in large laminated sheets on that plane.

> "You see this . . ." the head of Communications Unit, TIIB, said to me. It was metal, and looked like a complicated doll's house with the roof off. "It is the chassis or frame, for a radio. To make the same thing, Americans would machine cut, hollow, shape, fit—a dozen different processes. This is done on a press in one operation. It is called the 'cold extrusion' process. We do it with some soft, splattery metals. But by this process the Germans do it with cold steel!
>
> Thousands of parts now made as castings or drop forgings or from malleable iron can now be made this way. The production speed increase is a little matter of one thousand per cent."
>
> This one war secret alone, many American steel men believe, will revolutionize dozens of our metal fabrication industries.
>
> In textiles the war secrets collection has produced so many revelations, that American textile men are a little dizzy. There is a German rayon-weaving machine, discovered a year ago by the American 'Knitting Machine' Team, which increases production in relation to floor space by one hundred and fifty percent. Their "Links-Links" loom produces a ladderless, runproof hosiery. New German needle-making machinery, it is thought, will revolutionize that business in both the United Kingdom and the United States. There is a German method for pulling the wool from sheepskins without injury to hide or fiber, by use of an enzyme. Formerly the "puller"—a trade secret—was made from animal pancreas from American packing horses. During the war the Nazis made it from a mold called aspergil paraciticus, which they seeded in bran. It results not only in better wool, but in ten per cent greater yield.
>
> Another discovery was a way to put a crimp in viscose rayon fibers which gives them the appearance, warmth, wear resistance, and reaction-to-dyes of wool. The secret here, our investigators found, was the addition to the cellulose of twenty-five per cent fish protein.
>
> But of all the industrial secrets, perhaps, the biggest windfall came from the laboratories and plants of the great German cartel, I. G. Farbenindustrie. Never before, it is claimed, was there such a store-house of secret information. It covers liquid and solid fuels, metallurgy, synthetic rubber, textiles, chemicals, plastics. drugs, dyes. One American dye authority declares:
>
> *It includes the production know-how and the secret formulas for over fifty thousand dyes. Many of them are faster and better than ours. Many are colors we were never able to make. The American dye industry will be advanced at least ten years.*

A 29 July 1945 press release from the U.S. Foreign Economic Administration confirmed Walker's assessment of how advanced German science and engineering were, and also cited many additional examples, mainly in chemistry and materials science [NARA RG 40, Entry UD-75, Box 12, Folder Publicity, Advance Release FEA-575]:

Among the new developments uncovered so far are the following:

A plane with a ceiling several thousand feet higher than any American plane.

Process for welding side seams on tin cans by machine instead of by hand, as in this country.

New applications of radiation devices in fields not heretofore explored in the U.S.

New and improved X-ray tubes for cancer therapy and industrial purposes.

Flexible high tension cables that withstand double the voltage of American made cables of the same size.

Tungsten substitutes for use in the manufacture of armor-piercing shells and cutting tools for machining metals.

Power circuit breakers with construction details unfamiliar in the U.S.

New uses of waste cellulose materials for the manufacture of fats for animal feed.

Improved techniques in the fermentation of yeast from wood sugar in the production of both human and cattle food.

Improved techniques for the production of synthetic petroleum products.

Hydrogenation plants operating at extremely high pressures.

New catalysts permitting the Germans to convert oil to high octane gasoline more quickly than was known here.

Details on German refinements in the gas synthesis method of producing liquid fuels and lubricants from coal.

New processing methods in the field of synthetic rubber.

New data on continuous polymerization processes in plastics manufacture.

New data on acetylene and electro-chemical processes.

Information on high temperature alloys unknown in the U.S.

Production of high grade nitro-cellulose from lower grade wood pulp with stability superior to the same product made from high grade pulp in the U.S.

Gottfried Plumpe, a historian of science who wrote one of the most comprehensive studies of I.G. Farben's chemical research programs [Plumpe 1990], summarized his findings about why the German chemical industry was so innovative [Caron 1995, pp. 163–173]:

> When the companies merged to form the IG Farben in 1926 they had a total of 25 large laboratories employing over 3,700 people. [...]
>
> Cooperation with external researchers and research institutes traditionally played an important role in developing the innovative potential of the company. It is no exaggeration to say that there was a close network of cooperation between chemical companies and universities, and that this formed the basis for the development of the German chemical industry. Outstanding examples from the years prior to the merger include the synthesis of indigo and ammonia, the development of the first medicines and chemotherapy. Famous names from this period include Adolf von Baeyer, Fritz Haber, Wilhelm Filehne, Paul Ehrlich and Hermann Staudinger.
>
> The basic research carried out by external institutes was essential for industrial R&D. The universities also ensured a supply of qualified personnel both for the research laboratories and for the production plants. A close and trusting relationship between the company and universities was thus an integral part of IG Farben's research strategy. The importance accorded to this is reflected by the fact that the Board of Management itself rook charge of maintaining these contacts. The founding fathers of IG, men like Carl Duisberg, Carl Bosch and Arthur von Weinberg, regarded themselves at least partially as scientists and undertook this task personally. In 1931, when the Central Committee was set up, it was agreed unanimously that one of its nine members should have special responsibility for these research contacts.
>
> IG Farben has often been accused of having no uniform R&D strategy, unlike the Anglo-American corporations. I do not believe that this is true. IG management most definitely did have a basic objective—we need only think of its declared aim of becoming a diversified company capable of synthesizing all organic products. Given the size of the company and above all the diversity of its activities this objective could never manifest itself in the form of a single "grand design". The most important factor behind the company's R&D policy was the fact that all members of the management team shared the basic conviction that R&D was essential for the company's future and that there was general agreement on the basic aims.
>
> In the relatively prosperous years following the merger, when the company was earning high profits, this meant that almost every project received authorization and financial support. Costs expanded accordingly, with research expenses reaching ten per cent of sales in the 1920s, the highest level in the company's short history.
>
> [...] About a third of all university graduates working for IG were employed in research. In 1929/30 there were about 1,100 scientists on the payroll. By 1932 the number had fallen by about 100, partly through redundancies and partly through natural wastage. During the 1930s the number of researchers gradually rose again, reaching a high point of 1,300 in 1940. During the war it fell back to 1,000. This decline becomes more significant if we compare it with the development of the total workforce. In 1929 research scientists

> represented just one per cent of the workforce. This rose to 1.5 per cent during the Depression because considerably more labourers and clerical staff lost their jobs than researchers. By 1939 researchers only represented 0.8 per cent of the workforce and by 1944 this had dropped to 0.5 per cent. [...]
>
> It is never as easy to quantify the results of R&D and their economic impact as it is to describe organizational structures. It is a well-known fact that the number of patents is only a very rough indicator because it says nothing about the importance of the processes and products they refer to. Nevertheless, the figures give some indication of activity. IG Farben obtained an extremely large number of patents, roughly corresponding to its spending on R&D.
>
> The number of patent applications rose in the 1920s, dropped during the Depression and then increased again through the 1930s. Between 1928 and 1930 IG Farben submitted more than 2,000 patent applications a year in Germany and almost 10,000 worldwide. In the thirties IG Farben had more patents than any other company in the world. At the start of 1939 it held over 5,000 patents in Germany and about 34,000 in other major countries throughout the world, including 5,300 in the USA, about 4,000 in the UK, 3,700 in France, 2,300 in Italy and nearly 900 in Japan. The majority—a good third of the German patents—concerned dyestuffs, while 13 per cent were for organic intermediates and solvents, about 10 per cent each were for inorganic products and medicines, eight per cent for photographic products and fibres and about six per cent for the hydrogenation of mineral oil.

Plumpe also gave an overview of the wide range of innovations that came from the German chemical industry [Caron 1995, pp. 163–173]:

> A few details of the innovations made by IG Farben should give a clearer idea of what all this meant. In the 1920s by far the largest project was the synthesis of mineral oil, which was brought to a successful conclusion in 1932. The basic principle comprised catalytic hydrogenation of solid carbon from lignite or hard coal, yielding aviation and motor fuel, lubricants and hydrogenation gas. The high energy requirement meant that these processes were less economical than those based on petrochemical feedstocks, and they were only used in Germany during the Nazi period. However, the R&D work in this field provided a wealth of material that was of wider use to the petrochemical industry and is still important today.
>
> The second most important project was the synthesis of rubber, a project which the companies had worked on prior to the merger and which was taken up again in 1926. The project was largely abandoned during the Depression, but in 1935 came the breakthrough with the development of styrene butadiene rubber. A modified form of this synthetic rubber is the most important commodity rubber produced today. IG Farben was also a pioneer in the development of plastics. Its achievements include polystyrene (1929), the development of polyvinylchloride (PVC) into a usable engineering plastic (1931) and the discovery of polyurethane in 1937. IG also developed a polyamide-based synthetic fibre (Perlon) at around the same time as Du Pont (1935) and in 1941 it produced the first polyacrylonitrile fibre.

Until the discovery of penicillin, IG was also a world leader in the field of chemotherapy. Milestones in this field include the development of antimalarial drugs based on quinolone derivatives, for example, Plasmochin (1924), Atebrin (1930) and, above all, the first antibacterial sulphonamide (1935). A pioneering innovation in the field of crop protection, phosphoric acid ester (mid-1930s), also belongs to the IG era.

The development of organic intermediates was extremely important for many areas of the chemical industry from dyestuffs through pharmaceuticals and crop protection agents to films and plastics. The products developed are too numerous to be listed here, but it is no exaggeration to say that the success of IG was largely due to its dominant position in this field and that the organic intermediates were the foundation stone for the development of modern chemical technology. In order to give a complete picture of the breadth of research in the IG Farben, its work on inorganic and metal chemistry and its pioneering role in the development of colour photography should also be mentioned.

Since there are no precise data on the contribution made by new products to the company's sales and earnings, it is not easy to quantify their importance, and above all their economic impact. However, I feel that the company's steady diversification is evidence of the importance of research in its development. Even when the merger was agreed in 1926 the name "Farbenindustrie" (dyestuffs industry) was hardly appropriate for the company as a whole. Nitrogen fertilizers were already generating a larger proportion of sales than dyestuffs, and the establishment of new commercial activities based on successful innovations accelerated this trend, making IG Farben one of the most diversified chemical companies by the 1940s.

3.1 Inorganic Chemistry

German-speaking scientists made a huge number of important discoveries in inorganic chemistry, including:[2]

3.1.1. Identifying large numbers of the elements.

3.1.2. Creating the periodic table of the elements.

3.1.3. Making a wide variety of other chemical innovations.

3.1.1 Discoveries of Elements

Once chemists realized in the eighteenth century that chemicals were composed of distinctive elements, there was an international race to purify, characterize, and name as many chemical elements as possible. Several important scientists in that race were in Sweden, France, and the United Kingdom, but arguably the largest share of element discoveries came from scientists in the German-speaking world. The major German-speaking discoveries are summarized below. Note that some elements are listed more than once, if they were independently discovered by different scientists, or first discovered earlier but then characterized in much more detail later.

Carl Wilhelm Scheele (Pomerania, 1742–1786), shown in Fig. 3.1, was the earliest and most successful German-speaking discover of elements. He discovered at least ten elements: hydrogen (1771), nitrogen (1771), oxygen (1771), fluorine (1771), phosphorus (1774), chlorine (1774), manganese (1774), molybdenum (1778), barium (1774), and tungsten (1781).

As illustrated in Fig. 3.2, Martin Klaproth (German states, 1743–1817) discovered six elements: titanium (1795), strontium (1791), zirconium (1789), tellurium (1798), cerium (1803), and uranium (1789).

Friedrich Wöhler (German, 1800–1882) discovered five elements: beryllium (1828), aluminum (1827), silicon (1850), titanium (1850), and yttrium (1828); see Fig. 3.3. He was the first to synthesize several important inorganic molecules such as silane, silicon nitride, and calcium carbide. By synthesizing urea and other organic molecules, he was also one of the founders of organic chemistry and biochemistry.

Robert Bunsen (German, 1811–1899) and Gustav Kirchhoff (German, 1824–1887), shown together in Fig. 3.4, discovered cesium in 1860 and rubidium in 1861 using novel methods of spectroscopic analysis. Bunsen also created the carbon-zinc battery; with Peter Desaga (German, 1812–1879), he created the Bunsen burner.

---

[2] Brock 1993; Bugge 1955; Coffey 2008; Engels et al. 1989; Farber 1961; Ihde 1984; Johnson 1990; Kahlert 2002; Maier 2015; Neufeldt 2003; Partington 1935, 1957, 1964; Scerri 2006; Weeks and Leicester 1968; Werner 2017.

As shown in Fig. 3.5, Jean de Marignac (Swiss, 1817–1894) measured atomic weights with greater precision than others had previously and also discovered three elements: samarium (1880), gadolinium (1880), and ytterbium (1878).

Berta Karlik (Austrian, 1904–1990) and Traude Bernert (Austrian, 1915–1998) discovered short-lived astatine in natural ore samples in 1942; see Fig. 3.5.

Carl Auer von Welsbach (Austrian, 1858–1929, Figs. 3.6 and 6.15), was phenomenally successful on fronts in science, engineering, and business. He discovered four elements: praseodymium (1885), neodymium (1885), ytterbium (1905), and lutetium (1905). He also invented the gaslight mantle (1885), osmium wire (1890), metal filament incandescent lamps (1898), and the flint metal lighter (1903). Based on those inventions and discoveries, he founded the Auergesellschaft, Treibacher Industrie, and Osram companies.

As illustrated in Fig. 3.7, Otto Berg (German, 1873–1939), Walter Noddack (German, 1893–1960), and Ida Tacke Noddack (German, 1896–1978) discovered rhenium and technetium in 1925. In 1934, Ida Tacke Noddack also correctly predicted both neutron-induced uranium fission and methods of producing and purifying neptunium and plutonium, which do not exist naturally (p. 1537).

Other German-speaking discoverers of elements are shown in Figs. 3.8–3.11:

- Hennig Brand (German states, 1630–1692, Fig. 3.8) discovered phosphorus in 1669.

- Clemens Winkler (German, 1838–1904, Fig. 3.8) discovered germanium in 1886.

- Albertus Magnus (German states, 1193–1280, Fig. 3.8) discovered arsenic in 1250.

- Carl Jacob Löwig (German, 1803–1890, Fig. 3.8) discovered bromine in 1825.

- Karl Ernst Claus (Baltic German, 1796–1864, Fig. 3.8) discovered ruthenium in 1844.

- Friedrich Stromeyer (German states, 1776–1835) and Karl Hermann (German states, 1765–1846) discovered cadmium in 1817; see Fig. 3.9.

- Ferdinand Reich (German, 1799–1882) and Hieronymous Theodor Richter (German, 1824–1898) discovered indium in 1863; see Fig. 3.9.

- Franz-Joseph Müller von Reichenstein (Austrian, 1740–1825) discovered tellurium in 1782; see Fig. 3.10.

- Jacques-Louis Soret (Swiss, 1827–1890) and Marc Delafontaine (Swiss, 1838–1911) discovered holmium in 1878; see Fig. 3.10.

- Dirk Coster (Dutch, 1889–1950) and George de Hevesy (Hungarian, 1885–1966) discovered hafnium in 1922; see Fig. 3.10.

- Georgius Agricola, also known as Georg Bauer (German states, 1494–1555, Fig. 3.10), discovered bismuth around 1540. He conducted extensive work on metallurgy.

- Friedrich Ernst Dorn (German, 1848–1916, Fig. 3.11) discovered radon in 1900.

- Gerhard Carl Schmidt (German, 1865–1949, Fig. 3.11) discovered the radioactivity of thorium in 1898; Marie Curie later confirmed that result.

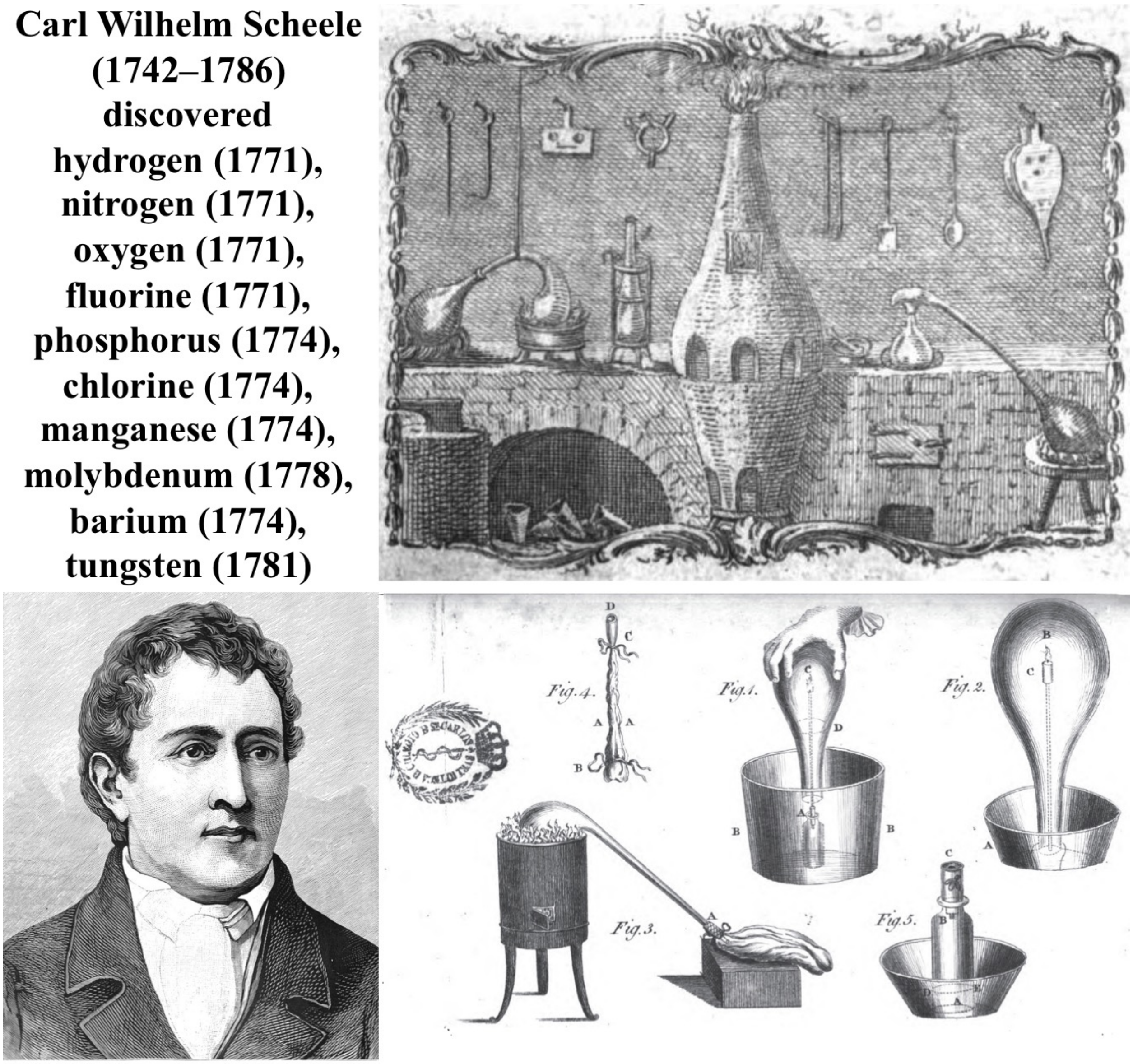
- Kasimir Fajans (Polish, 1887–1975) and Oswald Helmuth Göhring (German, 1889–1915) discovered the first isotope of protactinium in 1913; see Fig. 3.11.

- Otto Hahn (German, 1879–1968) and Lise Meitner (Austrian, 1878–1968) discovered a longer-lived protactinium isotope in 1917; see Fig. 3.11.

German-speaking scientists also discovered all three of the building blocks of atoms: electrons, protons, and neutrons (Section 5.2.3).

Even in English-speaking countries and after so much time, the symbol for the atomic number (the number of protons in the nucleus, or the number of electrons in a neutral atom) is still Z, for the German word "Zahl" or number.

**Carl Wilhelm Scheele
(1742–1786)
discovered
hydrogen (1771),
nitrogen (1771),
oxygen (1771),
fluorine (1771),
phosphorus (1774),
chlorine (1774),
manganese (1774),
molybdenum (1778),
barium (1774),
tungsten (1781)**



1 H Hydrogen
7 N Nitrogen
8 O Oxygen
9 F Fluorine
15 P Phosphorus

17 Cl Chlorine
25 Mn Manganese
42 Mo Molybdenum
56 Ba Barium
74 W Tungsten

Figure 3.1: Carl Wilhelm Scheele discovered ten elements during the period 1771–1781.

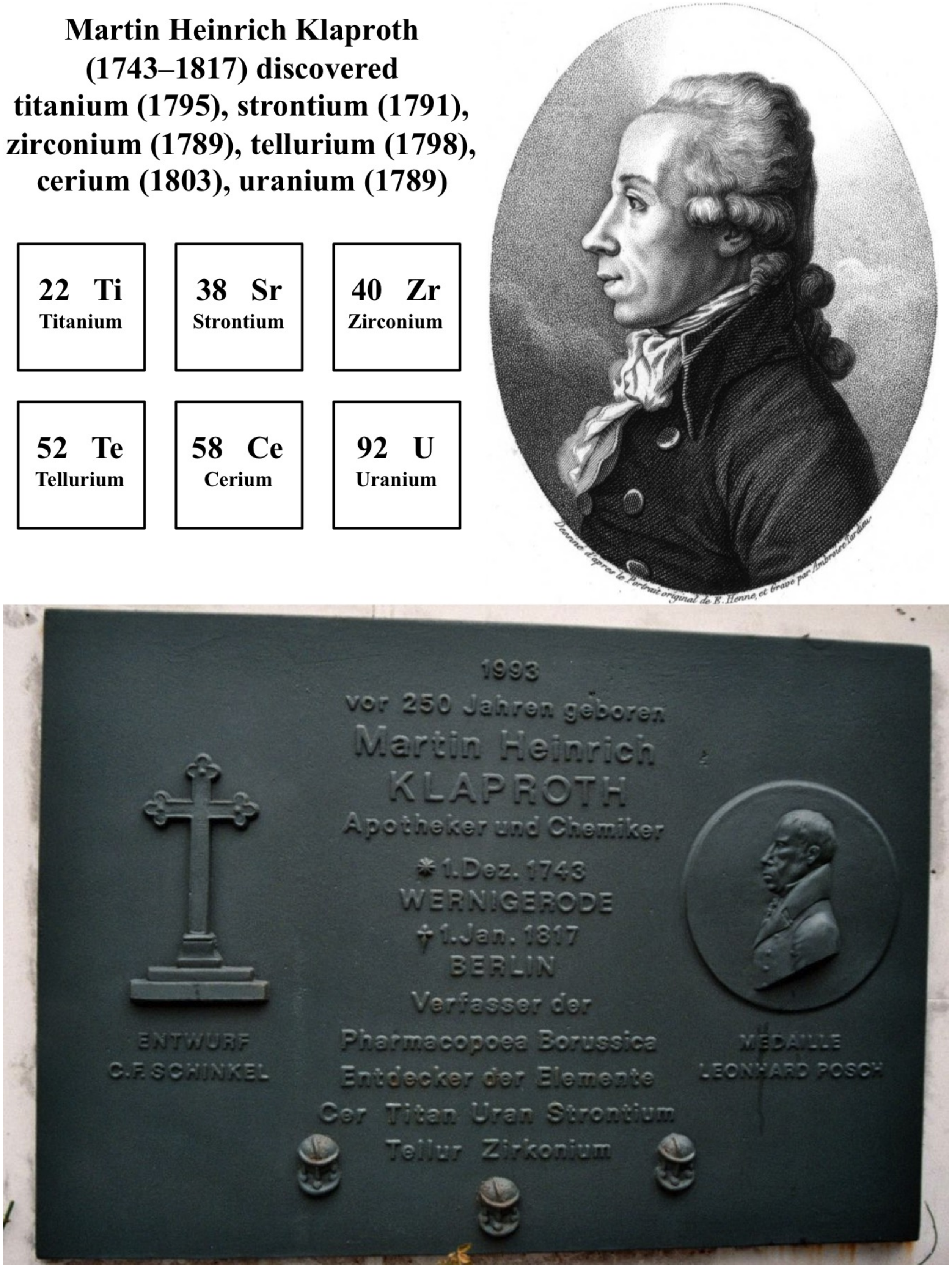

Martin Heinrich Klaproth
(1743–1817) discovered
titanium (1795), strontium (1791),
zirconium (1789), tellurium (1798),
cerium (1803), uranium (1789)
22 Ti
Titanium
38 Sr
Strontium
40 Zr
Zirconium
52 Te
Tellurium
58 Ce
Cerium
92 U
Uranium
Dessiné d'après le Portrait original de E. Henne, et gravé par Ambroise Tardieu
1993
vor 250 Jahren geboren
Martin Heinrich
KLAPROTH
Apotheker und Chemiker
*1. Dez. 1743
WERNIGERODE
†1. Jan. 1817
BERLIN
Verfasser der
Pharmacopoea Borussica
Entdecker der Elemente
Cer Titan Uran Strontium
Tellur Zirkonium
ENTWURF
C.F. SCHINKEL
MEDAILLE
LEONHARD POSCH

Figure 3.2: Martin Klaproth discovered six elements (including uranium) during the period 1789–1803.

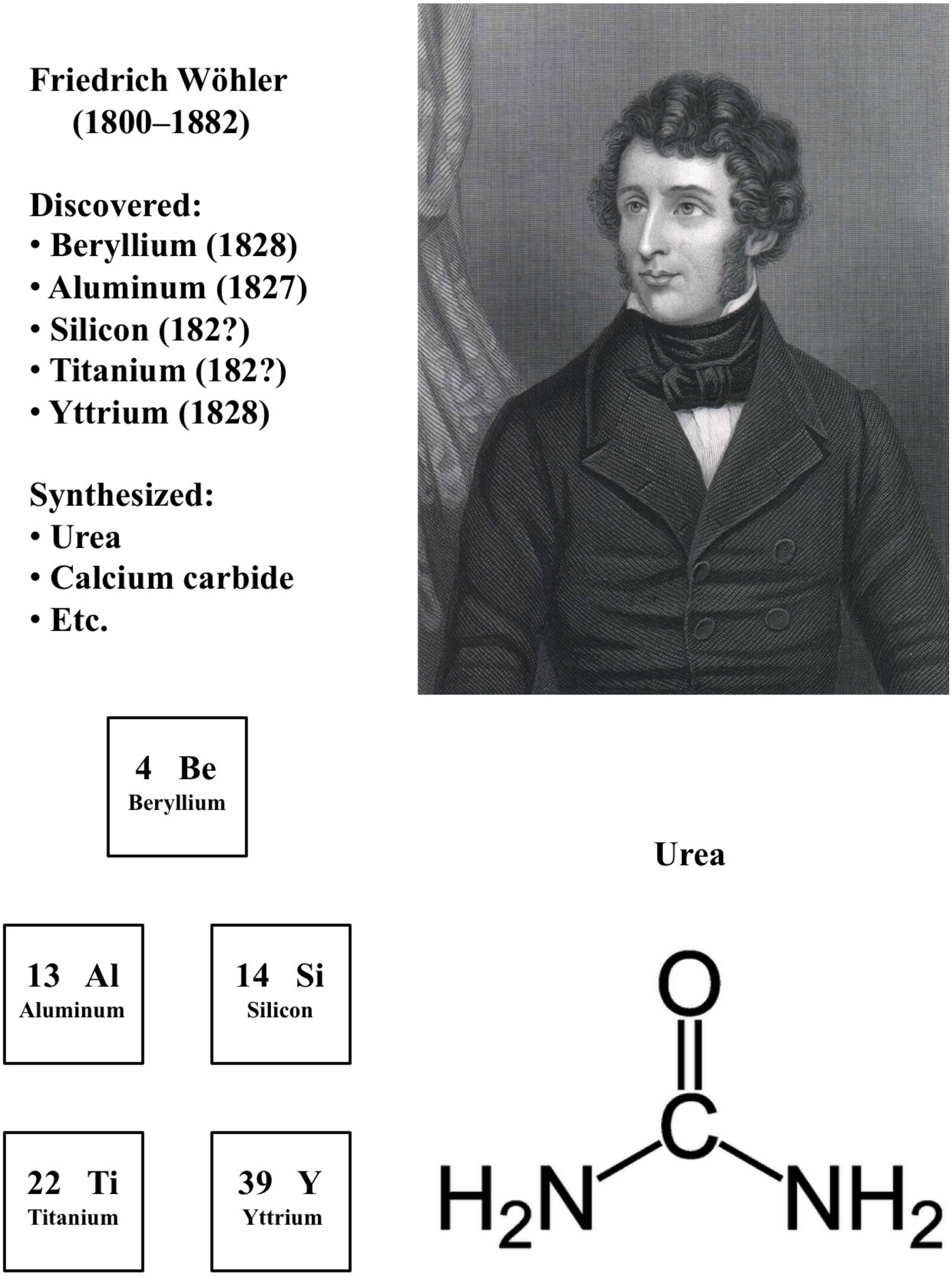

Friedrich Wöhler
(1800–1882)
Discovered:
• Beryllium (1828)
• Aluminum (1827)
• Silicon (182?)
• Titanium (182?)
• Yttrium (1828)
Synthesized:
• Urea
• Calcium carbide
• Etc.
4 Be
Beryllium
13 Al
Aluminum
14 Si
Silicon
22 Ti
Titanium
39 Y
Yttrium
Urea
O
C
H2N
NH2

Figure 3.3: Friedrich Wöhler discovered five elements, and was also the first to synthesize important molecules such as urea and calcium carbide.

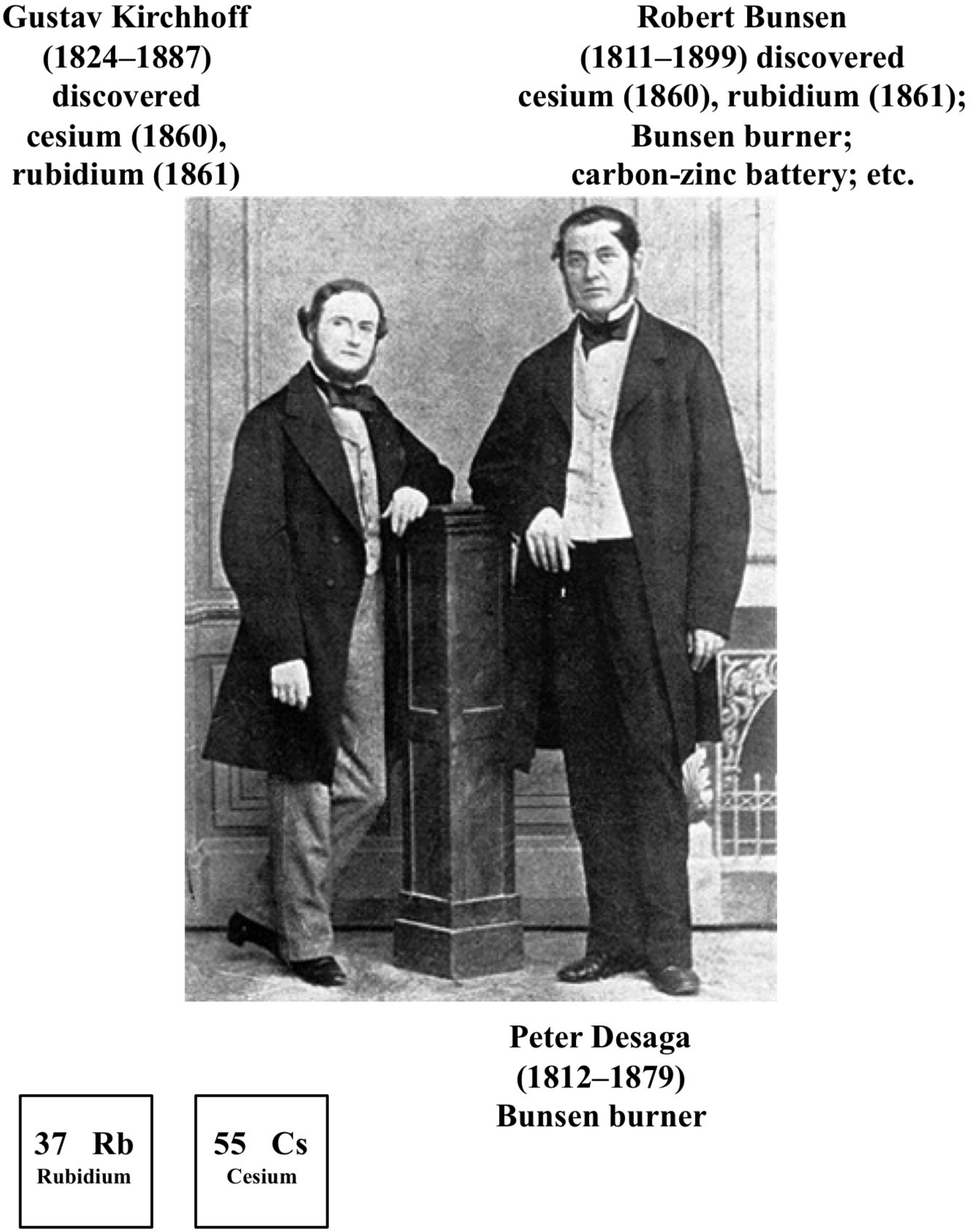

Gustav Kirchhoff (1824–1887) discovered cesium (1860), rubidium (1861)
Robert Bunsen (1811–1899) discovered cesium (1860), rubidium (1861); Bunsen burner; carbon-zinc battery; etc.
Peter Desaga (1812–1879) Bunsen burner
37 Rb
Rubidium
55 Cs
Cesium

Figure 3.4: Robert Bunsen and Gustav Kirchhoff discovered cesium in 1860 and rubidium in 1861 using novel methods of spectroscopic analysis. Bunsen also created the carbon-zinc battery; with Peter Desaga he created the Bunsen burner.

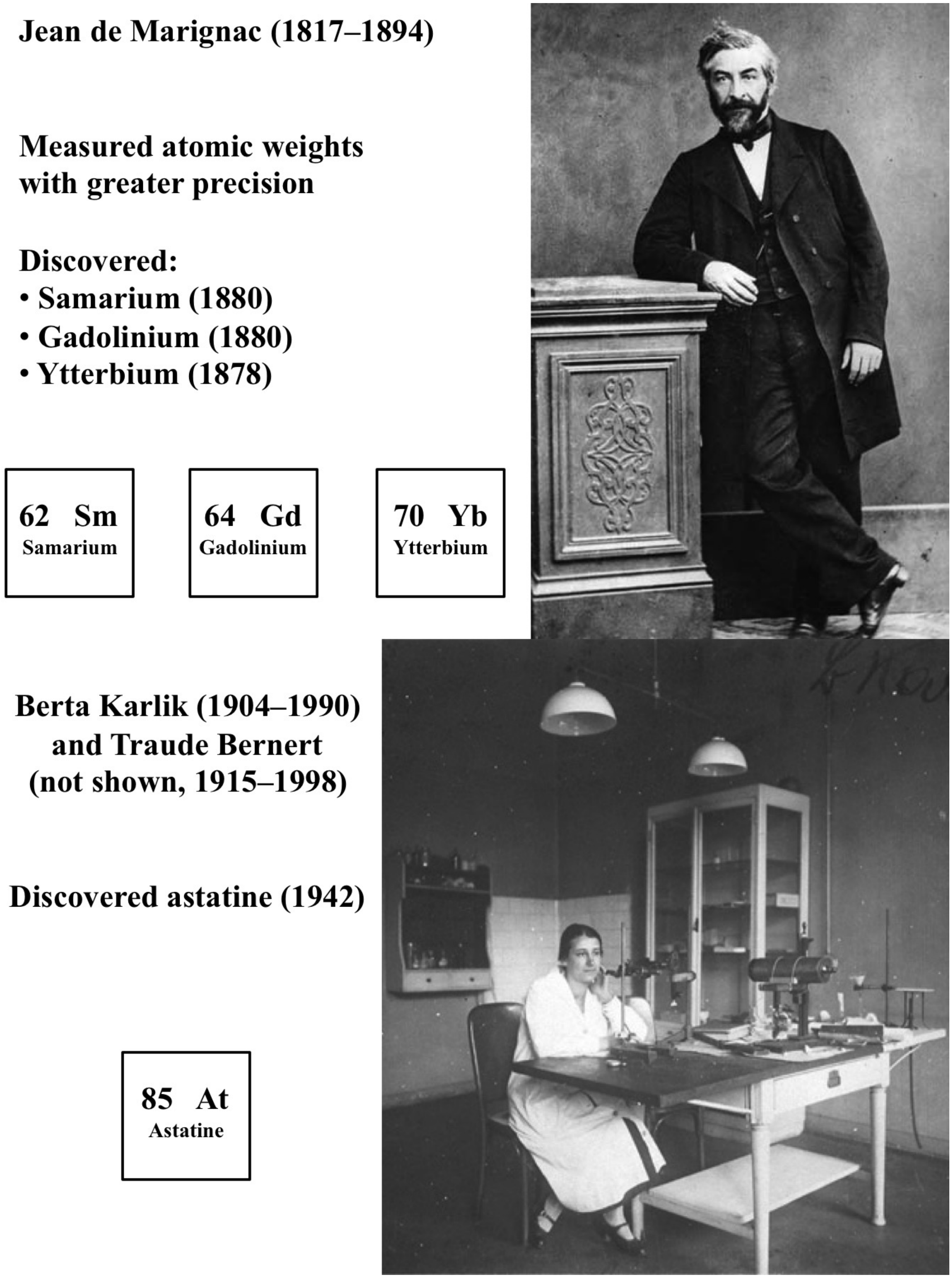

Jean de Marignac (1817–1894)
Measured atomic weights with greater precision
Discovered:
• Samarium (1880)
• Gadolinium (1880)
• Ytterbium (1878)
62 Sm Samarium
64 Gd Gadolinium
70 Yb Ytterbium
Berta Karlik (1904–1990) and Traude Bernert (not shown, 1915–1998)
Discovered astatine (1942)
85 At Astatine

Figure 3.5: Jean de Marignac measured atomic weights with greater precision and discovered samarium, gadolinium, and ytterbium 1878–1880. Berta Karlik and Traude Bernert discovered short-lived astatine in natural ore samples in 1942.

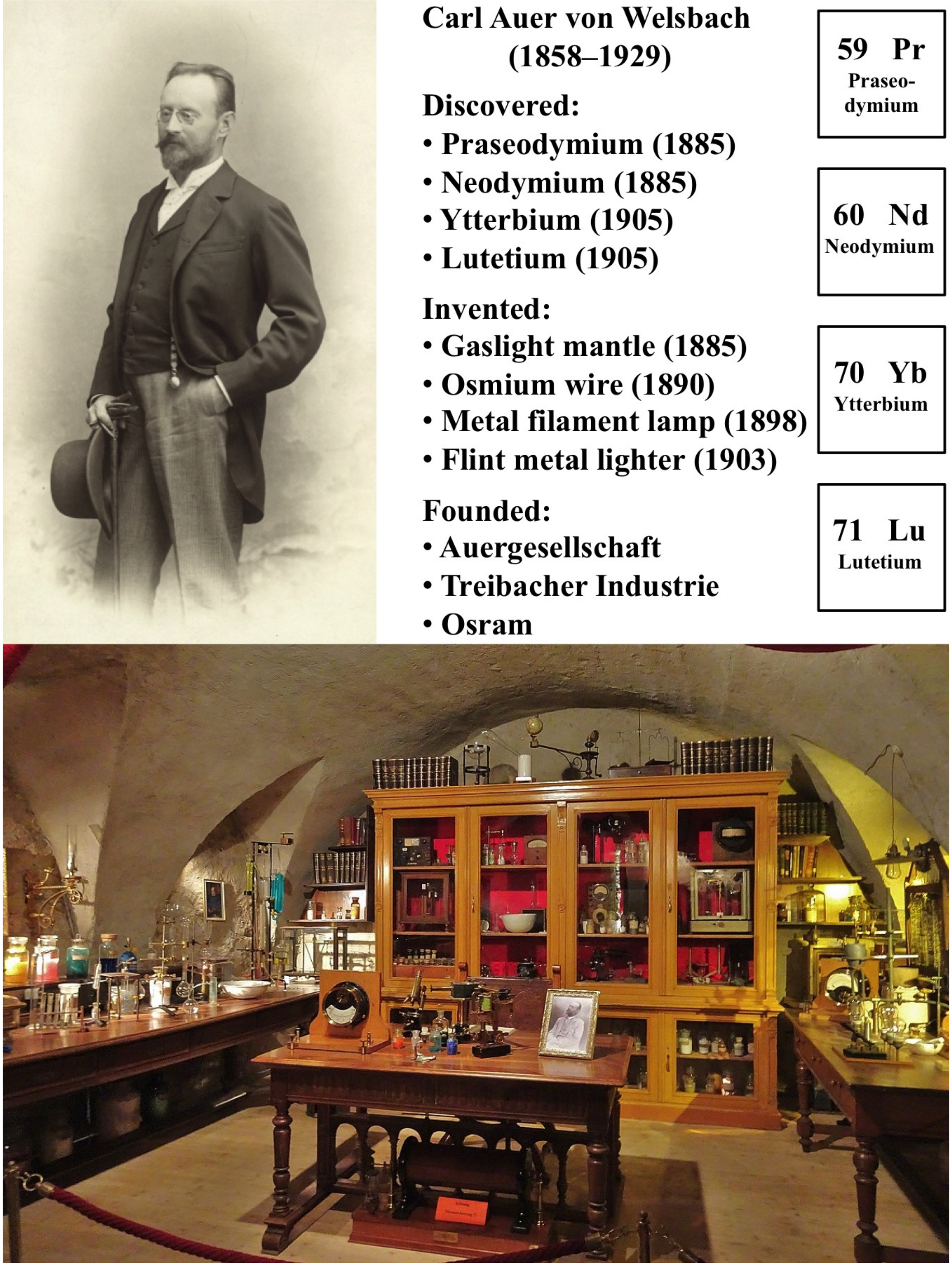

Carl Auer von Welsbach
(1858–1929)
Discovered:
• Praseodymium (1885)
• Neodymium (1885)
• Ytterbium (1905)
• Lutetium (1905)
Invented:
• Gaslight mantle (1885)
• Osmium wire (1890)
• Metal filament lamp (1898)
• Flint metal lighter (1903)
Founded:
• Auergesellschaft
• Treibacher Industrie
• Osram
59 Pr
Praseo-
dymium
60 Nd
Neodymium
70 Yb
Ytterbium
71 Lu
Lutetium

Figure 3.6: Carl Auer von Welsbach discovered four elements; invented the gaslight mantle, osmium wire, the metal filament incandescent lamp, and the flint metal lighter; and founded Auergesellschaft, Treibacher Industrie, and Osram.

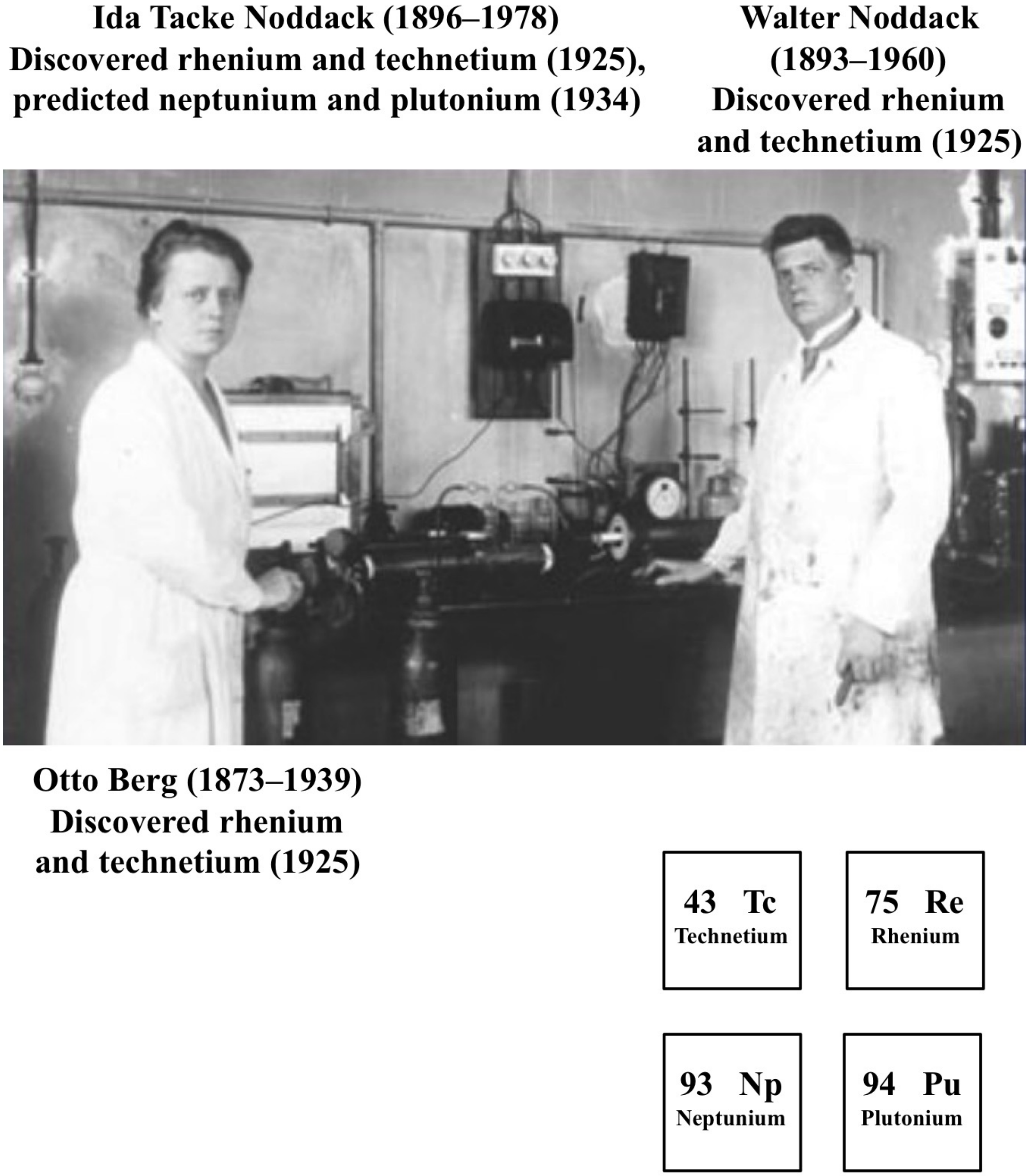

Ida Tacke Noddack (1896–1978)
Discovered rhenium and technetium (1925),
predicted neptunium and plutonium (1934)
Walter Noddack
(1893–1960)
Discovered rhenium
and technetium (1925)
Otto Berg (1873–1939)
Discovered rhenium
and technetium (1925)
43 Tc
Technetium
75 Re
Rhenium
93 Np
Neptunium
94 Pu
Plutonium

Figure 3.7: Otto Berg, Walter Noddack, and Ida Tacke Noddack discovered rhenium and technetium in 1925. In 1934, Ida Tacke Noddack also correctly predicted how to produce neptunium and plutonium, which do not exist naturally.

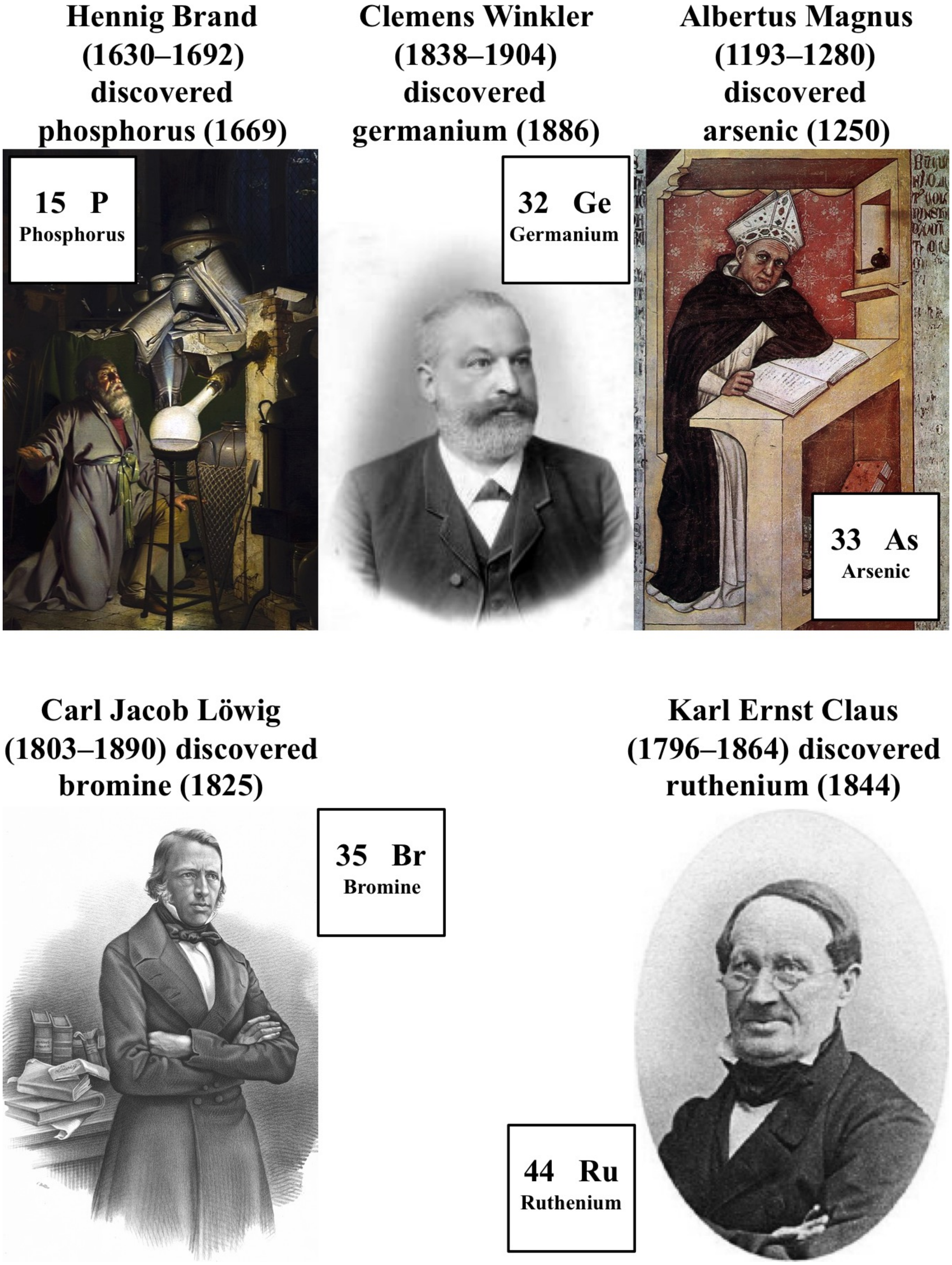

Hennig Brand (1630–1692) discovered phosphorus (1669)
15 P
Phosphorus
Clemens Winkler (1838–1904) discovered germanium (1886)
32 Ge
Germanium
Albertus Magnus (1193–1280) discovered arsenic (1250)
33 As
Arsenic
Carl Jacob Löwig (1803–1890) discovered bromine (1825)
35 Br
Bromine
Karl Ernst Claus (1796–1864) discovered ruthenium (1844)
44 Ru
Ruthenium

Figure 3.8: Hennig Brand discovered phosphorus in 1669. Clemens Winkler discovered germanium in 1886. Albertus Magnus discovered arsenic in 1250. Carl Jacob Löwig discovered bromine in 1825. Karl Ernst Claus discovered ruthenium in 1844.

Johann Friedrich Stromeyer (1776–1835) discovered cadmium (1817)

48 Cd
Cadmium

Karl Hermann (1765–1846) discovered cadmium (1817)

Ferdinand Reich (1799–1882) discovered indium (1863)

49 In
Indium

Hieronymous Theodor Richter (1824–1898) discovered indium (1863)

Figure 3.9: Friedrich Stromeyer and Karl Hermann discovered cadmium in 1817. Ferdinand Reich and Hieronymous Theodor Richter discovered indium in 1863.

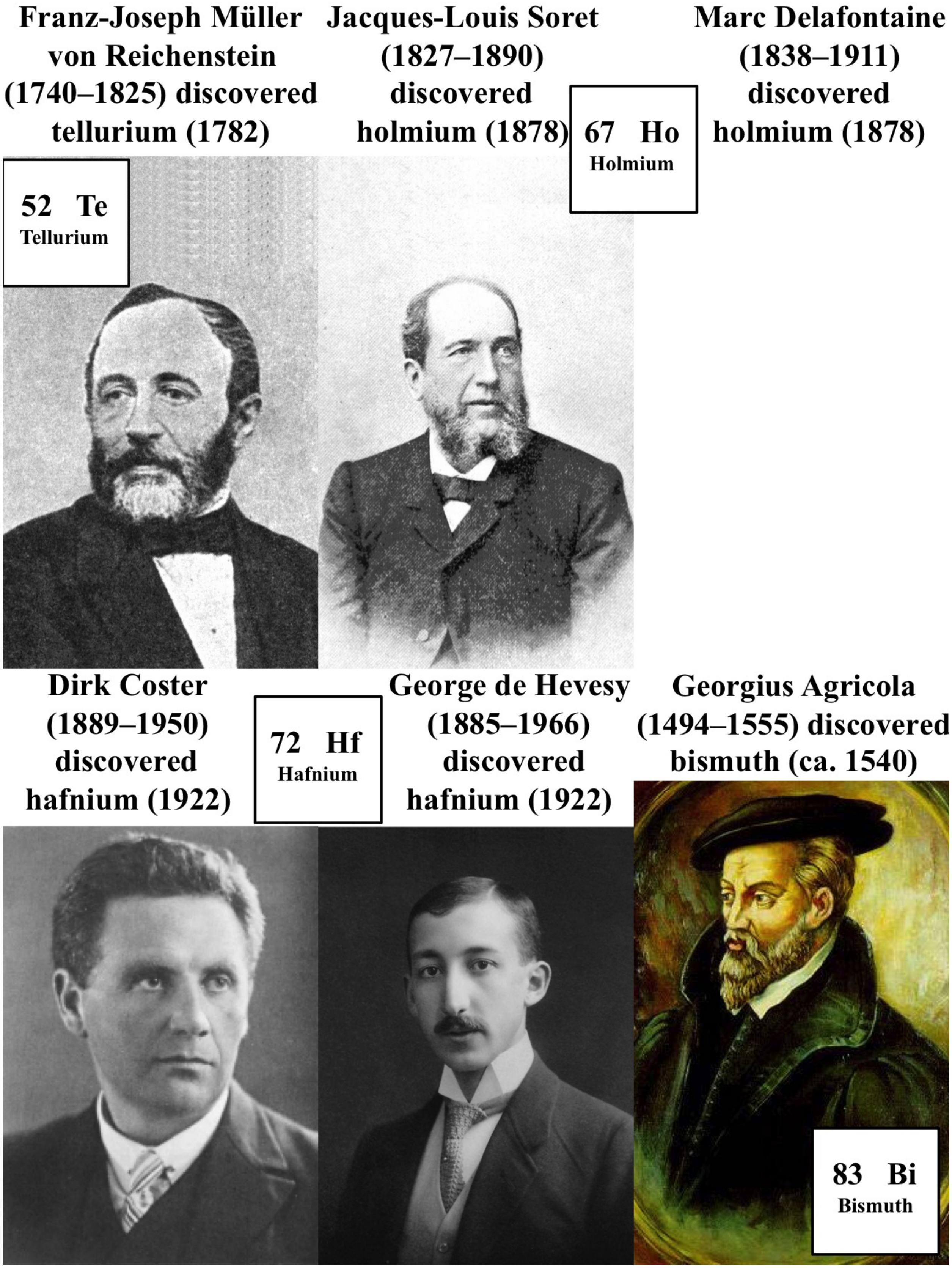

Franz-Joseph Müller von Reichenstein (1740–1825) discovered tellurium (1782)
Jacques-Louis Soret (1827–1890) discovered holmium (1878)
67 Ho Holmium
Marc Delafontaine (1838–1911) discovered holmium (1878)
52 Te Tellurium
Dirk Coster (1889–1950) discovered hafnium (1922)
72 Hf Hafnium
George de Hevesy (1885–1966) discovered hafnium (1922)
Georgius Agricola (1494–1555) discovered bismuth (ca. 1540)
83 Bi Bismuth

Figure 3.10: Franz-Joseph Müller von Reichenstein discovered tellurium in 1782. Jacques-Louis Soret and Marc Delafontaine discovered holmium in 1878. Dirk Coster and George de Hevesy discovered hafnium in 1922. Georgius Agricola discovered bismuth around 1540.

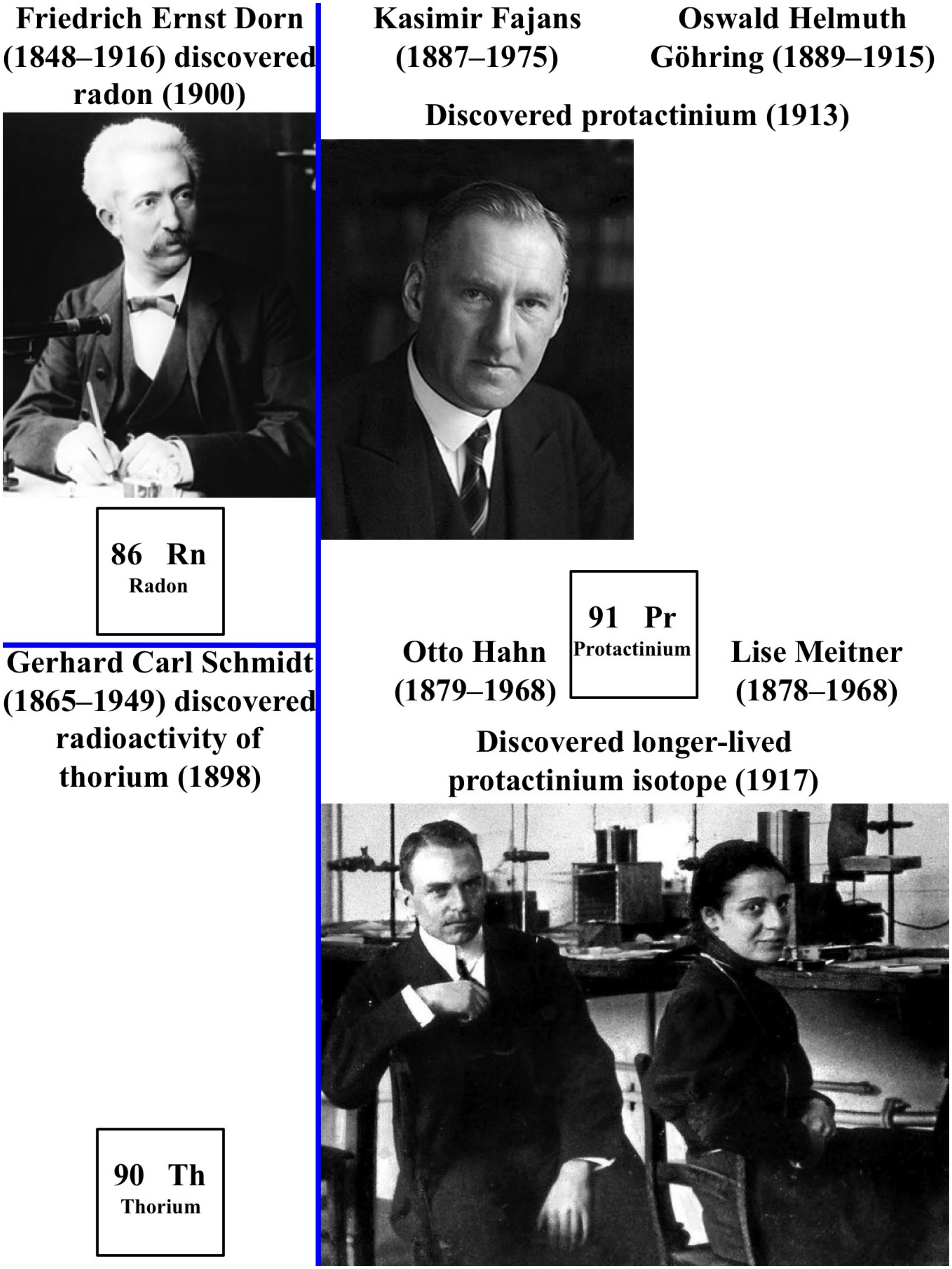

Friedrich Ernst Dorn (1848–1916) discovered radon (1900)
86 Rn
Radon
Gerhard Carl Schmidt (1865–1949) discovered radioactivity of thorium (1898)
90 Th
Thorium
Kasimir Fajans (1887–1975)
Oswald Helmuth Göhring (1889–1915)
Discovered protactinium (1913)
Otto Hahn (1879–1968)
91 Pr
Protactinium
Lise Meitner (1878–1968)
Discovered longer-lived protactinium isotope (1917)

Figure 3.11: Friedrich Dorn discovered radon in 1900. Gerhard Schmidt discovered the radioactivity of thorium in 1898. Kasimir Fajans and Oswald Göhring discovered the first isotope of protactinium in 1913. Otto Hahn and Lise Meitner discovered a longer-lived protactinium isotope in 1917.

3.1.2 Creation of the Periodic Table of the Elements

Johann Wolfgang Döbereiner (German states, 1780–1849), shown in Fig. 3.12, was the first to realize that elements could be grouped by similar chemical properties. Among elements that were known then in 1829, he found three examples of each type, later dubbed triads. He also discovered platinum catalysts and used those to invent an improved lamp, which became widely used as the world's first fluid-filled instant lighter.

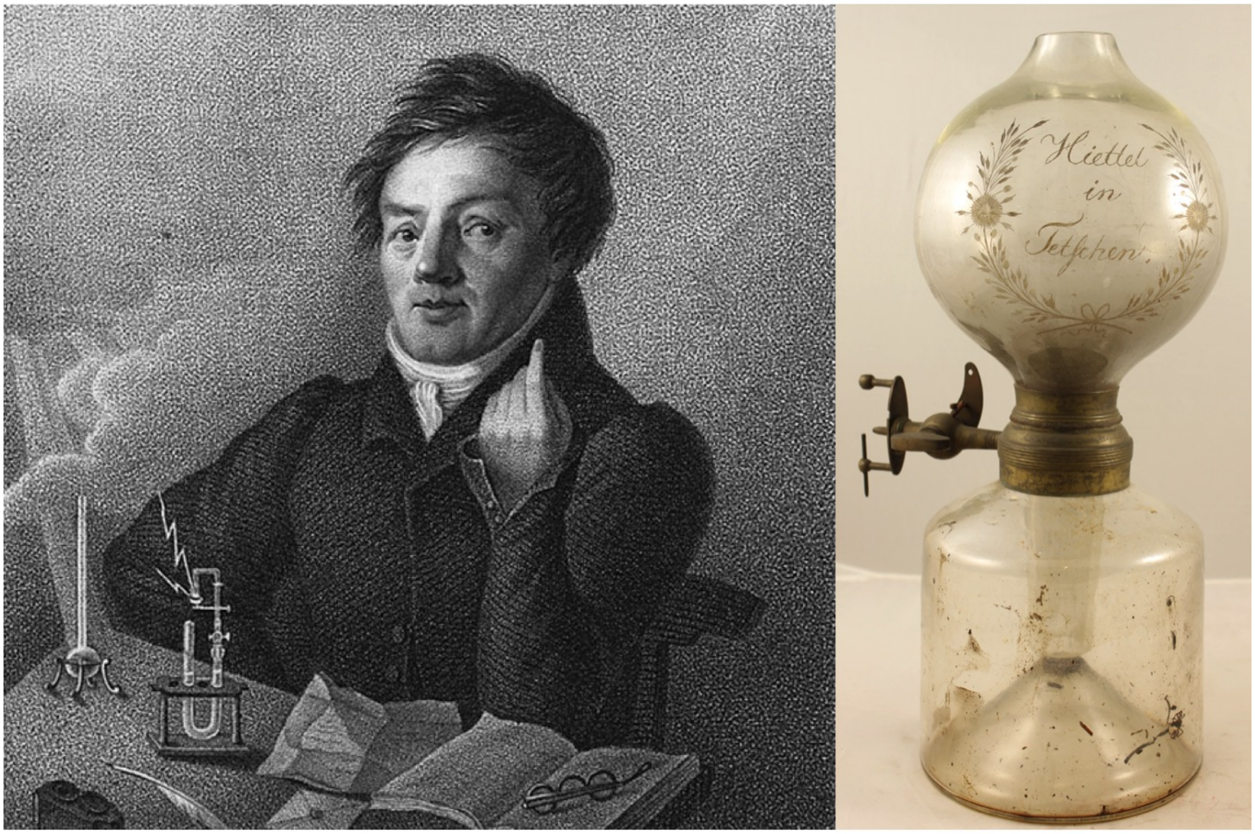
As illustrated in Fig. 3.13, Leopold Gmellin (German states, 1788–1853) expanded Döbereiner's triads into a connected table of known elements in 1843. Some other pioneers of periodic properties of the elements included Max Joseph von Pettenkofer (German, 1818–1901, who also made important contributions to urban hygiene), Peter Kremers (German?, 18??–19??), and Ernst Lenssen (German?, 1837–1870?).

Julius Lothar Meyer (German, 1830–1895) produced the first truly scientific periodic table of the elements in 1862 and published it in his 1864 chemistry textbook, as shown in Fig. 3.14. Meyer's 1864 textbook discussed in detail how the known elements fit into a periodic table that explained all of the measured masses, densities, and valences of the elements (Fig. 3.15). It also predicted new elements that would fill in gaps in the periodic table. Meyer presented data demonstrating the periodic properties of atomic volumes, with peaks corresponding to the beginning of each row of the periodic table. In 1868 he updated his periodic table with additional elements that had been newly discovered (Fig. 3.16).

Dmitri Mendeleev (Russian, 1834–1907) left Russia to study chemistry with Robert Bunsen and Gustav Kirchhoff in Heidelberg in 1860–1861, studied in Switzerland, and then returned to Russia. During his chemistry studies in Germany and Switzerland, Mendeleev almost certainly would have been exposed to the early periodic tables of Döbereiner, Gmellin, and others (though of course the available documents do not record students' discussions from that time). Moreover, it is highly likely that Mendeleev would have heard about the early work of Julius Lothar Meyer, especially since Meyer also studied with Bunsen and Kirchhoff in Heidelberg around the same time that Mendeleev was there. In addition to any personal transfers of information, Meyer's 1864 chemistry textbook that publicly presented and explained the periodic table was widely circulated in Europe, and copies would presumably have been available in Russia after Mendeleev returned home.

After returning to Russia, Mendeleev did not even begin to work on his version of the periodic table until 1869, nine years after his personal immersion in the academic world of German chemistry, and five years after the publication of Meyer's detailed textbook that explained the organization, contents, and scientific evidence for the periodic table. Then Mendeleev did not finalize his version of a periodic table for another decade, until 1879 [Scerri 2006, pp. 105, 112]. Mendeleev never even attempted to offer a credible explanation for how his version of the periodic table resulted from his earlier studies and the earlier researchers. Rather, he quite incredibly claimed that the entire periodic table simply came to him suddenly in a dream, that he had never heard of any earlier versions of the periodic table, and that the entire concept of a periodic table was his alone.

While Mendeleev is widely called the originator of the period table nowadays, the evidence clearly demonstrates that Döbereiner's and Gmellin's work preceded Mendeleev's by decades, and that Julius Lothar Meyer produced and published highly detailed versions of the periodic table backed by large amounts of experimental evidence and accurate predictions years before Mendeleev, even including details that Mendeleev's later table did not. Furthermore, the available evidence suggests that Mendeleev simply plagiarized his "discovery" from the earlier German-speaking scientists.



Johann Wolfgang Döbereiner (1780–1849)
Discovered platinum catalyst (18??)

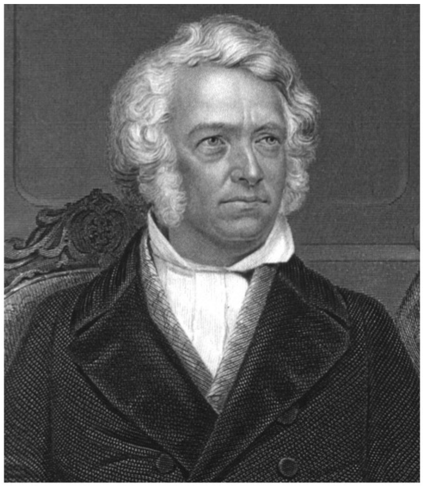
Döbereiner's lamp
(18??)

Döbereiner's periodic arrangement of elements into triads (1829)

Li	Ca	P	S	Cl
Na	Sr	As	Se	Br
K	Ba	Sb	Te	I

Figure 3.12: Johann Wolfgang Döbereiner was the first to realize that elements could be grouped by similar chemical properties. Among elements that were then known in 1829, he found three examples of each type, later dubbed triads. He also discovered platinum catalysts and invented an improved lamp.

Leopold Gmelin
(1788–1853)
expanded
Döbereiner's triads
into a connected table of
known elements (1843)



O N H
F Cl Br I Li Na K
S Se Te Mg Ca Sr Ba
P As Sb Be Ce La
C B Bi Zr Th Al
Ti Ta W Sn Cd Zn
Mo V Cr U Mn Ni Fe
Bi Pb Ag Hg Cu
Os Ir Rh Pt Pd Au

Some other pioneers of periodic properties of the elements:

Max Joseph von
Pettenkofer (1818–1901)
(also urban hygiene)

Peter Kremers
(18??–19??)

Ernst Lenssen
(1837–19??)

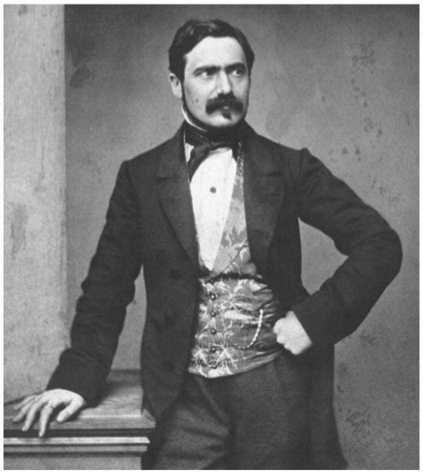
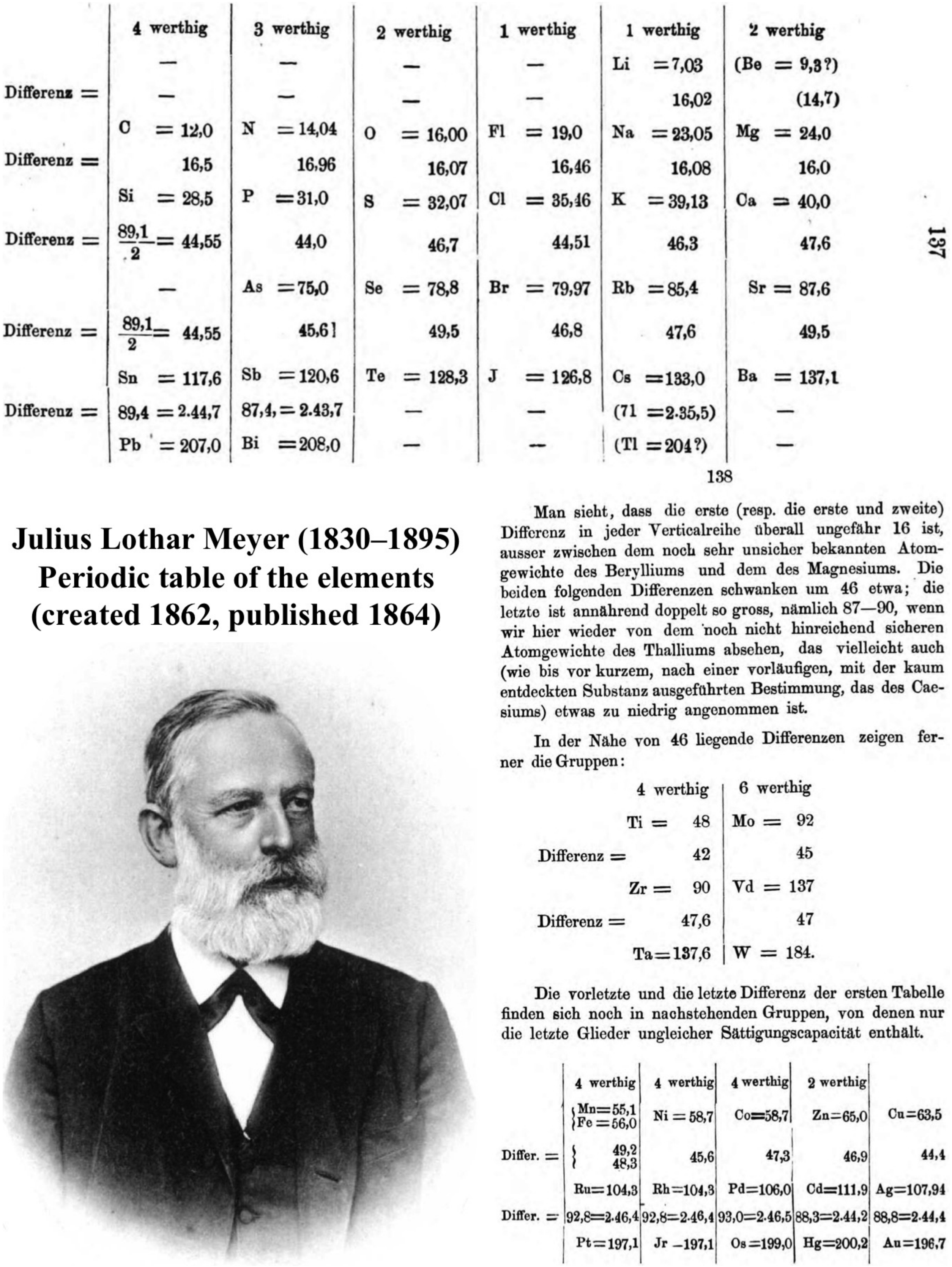


Figure 3.13: Leopold Gmelin expanded Döbereiner's triads into a connected table of known elements in 1843. Some other pioneers of periodic properties of the elements included Max Joseph von Pettenkofer, Peter Kremers, and Ernst Lenssen.



	4 werthig	3 werthig	2 werthig	1 werthig	1 werthig	2 werthig
	—	—	—	—	Li = 7,03	(Be = 9,3?)
Differenz =	—	—	—	—	16,02	(14,7)
	C = 12,0	N = 14,04	O = 16,00	Fl = 19,0	Na = 23,05	Mg = 24,0
Differenz =	16,5	16,96	16,07	16,46	16,08	16,0
	Si = 28,5	P = 31,0	S = 32,07	Cl = 35,46	K = 39,13	Ca = 40,0
Differenz =	$\frac{89,1}{2}$ = 44,55	44,0	46,7	44,51	46,3	47,6
	—	As = 75,0	Se = 78,8	Br = 79,97	Rb = 85,4	Sr = 87,6
Differenz =	$\frac{89,1}{2}$ = 44,55	45,6	49,5	46,8	47,6	49,5
	Sn = 117,6	Sb = 120,6	Te = 128,3	J = 126,8	Cs = 133,0	Ba = 137,1
Differenz =	89,4 = 2.44,7	87,4, = 2.43,7	—	—	(71 = 2.35,5)	—
	Pb = 207,0	Bi = 208,0	—	—	(Tl = 204?)	—

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Julius Lothar Meyer (1830–1895)
Periodic table of the elements
(created 1862, published 1864)

Man sieht, dass die erste (resp. die erste und zweite) Differenz in jeder Verticalreihe überall ungefähr 16 ist, ausser zwischen dem noch sehr unsicher bekannten Atomgewichte des Berylliums und dem des Magnesiums. Die beiden folgenden Differenzen schwanken um 46 etwa; die letzte ist annährend doppelt so gross, nämlich 87—90, wenn wir hier wieder von dem noch nicht hinreichend sicheren Atomgewichte des Thalliums absehen, das vielleicht auch (wie bis vor kurzem, nach einer vorläufigen, mit der kaum entdeckten Substanz ausgeführten Bestimmung, das des Caesiums) etwas zu niedrig angenommen ist.

In der Nähe von 46 liegende Differenzen zeigen ferner die Gruppen:

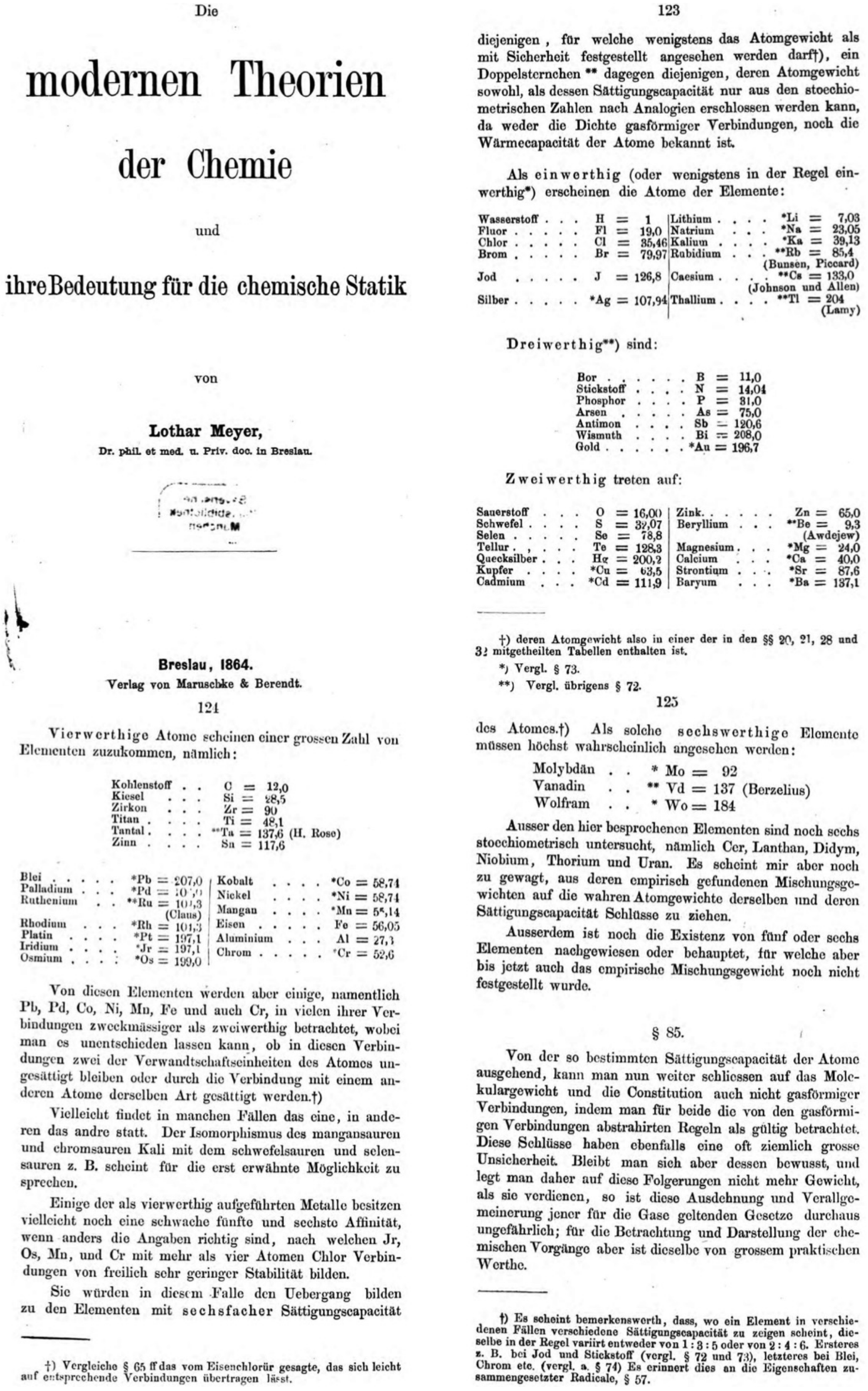
	4 werthig	6 werthig
	Ti = 48	Mo = 92
Differenz =	42	45
	Zr = 90	Vd = 137
Differenz =	47,6	47
	Ta = 137,6	W = 184.

Die vorletzte und die letzte Differenz der ersten Tabelle finden sich noch in nachstehenden Gruppen, von denen nur die letzte Glieder ungleicher Sättigungscapacität enthält.

	4 werthig	4 werthig	4 werthig	2 werthig	
	Mn = 55,1 Fe = 56,0	Ni = 58,7	Co = 58,7	Zn = 65,0	Cu = 63,5
Differ. =	49,2 48,3	45,6	47,3	46,9	44,4
	Ru = 104,3	Rh = 104,3	Pd = 106,0	Cd = 111,9	Ag = 107,94
Differ. =	92,8 = 2.46,4	92,8 = 2.46,4	93,0 = 2.46,5	88,3 = 2.44,2	88,8 = 2.44,4
	Pt = 197,1	Jr – 197,1	Os = 199,0	Hg = 200,2	Au = 196,7

Figure 3.14: Julius Lothar Meyer produced the first scientific periodic table of the elements in 1862 and published it in his 1864 chemistry textbook.

Lothar Meyer's 1864 chemistry textbook showed in detail how the known elements fit into a periodic table that explained all of the measured masses, densities, and valences of the elements. It also predicted new elements that would fill in gaps in the periodic table.



Die

modernen Theorien

der Chemie

und

ihre Bedeutung für die chemische Statik

von

Lothar Meyer,
Dr. phil. et med. u. Priv. doc. in Breslau.

Breslau, 1864.
Verlag von Maruschke & Berendt.

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diejenigen, für welche wenigstens das Atomgewicht als mit Sicherheit festgestellt angesehen werden darf†), ein Doppelsternchen ** dagegen diejenigen, deren Atomgewicht sowohl, als dessen Sättigungscapacität nur aus den stoechiometrischen Zahlen nach Analogien erschlossen werden kann, da weder die Dichte gasförmiger Verbindungen, noch die Wärmecapacität der Atome bekannt ist.

Als einwerthig (oder wenigstens in der Regel einwerthig*) erscheinen die Atome der Elemente:

Wasserstoff	H	= 1	Lithium	*Li	= 7,03
Fluor	Fl	= 19,0	Natrium	*Na	= 23,05
Chlor	Cl	= 35,46	Kalium	*Ka	= 39,13
Brom	Br	= 79,97	Rubidium	**Rb	= 85,4 (Bunsen, Piccard)
Jod	J	= 126,8	Caesium	**Cs	= 133,0 (Johnson und Allen)
Silber	*Ag	= 107,94	Thallium	**Tl	= 204 (Lamy)

Dreiwerthig**) sind:

Bor	B	= 11,0
Stickstoff	N	= 14,04
Phosphor	P	= 31,0
Arsen	As	= 75,0
Antimon	Sb	= 120,6
Wismuth	Bi	= 208,0
Gold	*Au	= 196,7

Zweiwerthig treten auf:

Sauerstoff	O	= 16,00	Zink	Zn	= 65,0
Schwefel	S	= 32,07	Beryllium	**Be	= 9,3 (Awdejew)
Selen	Se	= 78,8			
Tellur	Te	= 128,3	Magnesium	*Mg	= 24,0
Quecksilber	Hg	= 200,2	Calcium	*Ca	= 40,0
Kupfer	*Cu	= 63,5	Strontium	*Sr	= 87,6
Cadmium	*Cd	= 111,9	Baryum	*Ba	= 137,1

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†) deren Atomgewicht also in einer der in den §§ 20, 21, 28 und 32 mitgetheilten Tabellen enthalten ist.

*) Vergl. § 73.

**) Vergl. übrigens § 72.

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Vierwerthige Atome scheinen einer grossen Zahl von Elementen zuzukommen, nämlich:

Kohlenstoff	C	= 12,0
Kiesel	Si	= 28,5
Zirkon	Zr	= 90
Titan	Ti	= 48,1
Tantal	**Ta	= 137,6 (H. Rose)
Zinn	Sn	= 117,6

Blei	*Pb	= 207,0	Kobalt	*Co	= 58,74
Palladium	*Pd	= [illegible]	Nickel	*Ni	= 58,74
Ruthenium	**Ru	= 104,3 (Claus)	Mangan	*Mn	= [illegible]
Rhodium	*Rh	= 104,3	Eisen	Fe	= 56,05
Platin	*Pt	= 197,1	Aluminium	Al	= 27,3
Iridium	*Jr	= 197,1	Chrom	*Cr	= 52,6
Osmium	*Os	= 199,0			

Von diesen Elementen werden aber einige, namentlich Pb, Pd, Co, Ni, Mn, Fe und auch Cr, in vielen ihrer Verbindungen zweckmässiger als zweiwerthig betrachtet, wobei man es unentschieden lassen kann, ob in diesen Verbindungen zwei der Verwandtschaftseinheiten des Atomes ungesättigt bleiben oder durch die Verbindung mit einem anderen Atome derselben Art gesättigt werden.†)

Vielleicht findet in manchen Fällen das eine, in anderen das andre statt. Der Isomorphismus des mangansauren und chromsauren Kali mit dem schwefelsauren und selensauren z. B. scheint für die erst erwähnte Möglichkeit zu sprechen.

Einige der als vierwerthig aufgeführten Metalle besitzen vielleicht noch eine schwache fünfte und sechste Affinität, wenn anders die Angaben richtig sind, nach welchen Jr, Os, Mn, und Cr mit mehr als vier Atomen Chlor Verbindungen von freilich sehr geringer Stabilität bilden.

Sie würden in diesem Falle den Uebergang bilden zu den Elementen mit sechsfacher Sättigungscapacität

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†) Vergleiche § 65 ff das vom Eisenchlorür gesagte, das sich leicht auf entsprechende Verbindungen übertragen lässt.

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des Atomes.†) Als solche sechswerthige Elemente müssen höchst wahrscheinlich angesehen werden:

Molybdän	* Mo	= 92
Vanadin	** Vd	= 137 (Berzelius)
Wolfram	* Wo	= 184

Ausser den hier besprochenen Elementen sind noch sechs stoechiometrisch untersucht, nämlich Cer, Lanthan, Didym, Niobium, Thorium und Uran. Es scheint mir aber noch zu gewagt, aus deren empirisch gefundenen Mischungsgewichten auf die wahren Atomgewichte derselben und deren Sättigungscapacität Schlüsse zu ziehen.

Ausserdem ist noch die Existenz von fünf oder sechs Elementen nachgewiesen oder behauptet, für welche aber bis jetzt auch das empirische Mischungsgewicht noch nicht festgestellt wurde.

§ 85.

Von der so bestimmten Sättigungscapacität der Atome ausgehend, kann man nun weiter schliessen auf das Molekulargewicht und die Constitution auch nicht gasförmiger Verbindungen, indem man für beide die von den gasförmigen Verbindungen abstrahirten Regeln als gültig betrachtet. Diese Schlüsse haben ebenfalls eine oft ziemlich grosse Unsicherheit. Bleibt man sich aber dessen bewusst, und legt man daher auf diese Folgerungen nicht mehr Gewicht, als sie verdienen, so ist diese Ausdehnung und Verallgemeinerung jener für die Gase geltenden Gesetze durchaus ungefährlich; für die Betrachtung und Darstellung der chemischen Vorgänge aber ist dieselbe von grossem praktischen Werthe.

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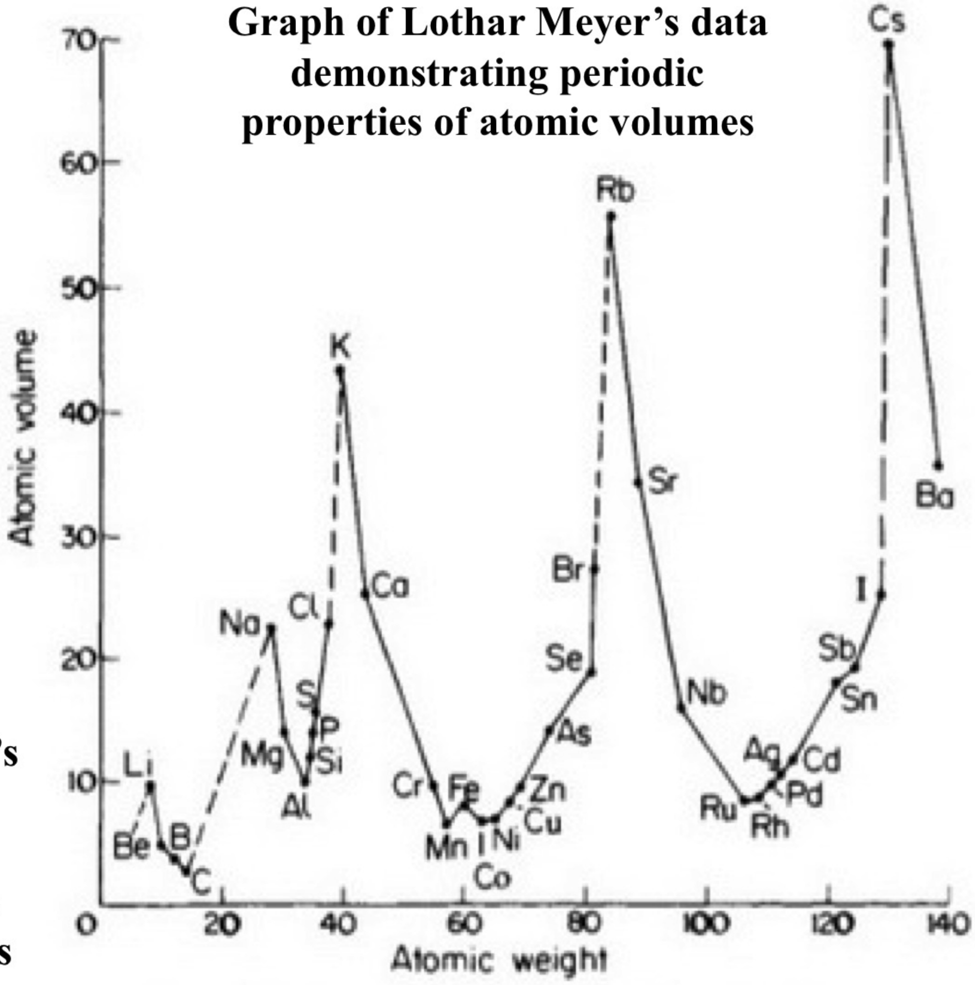
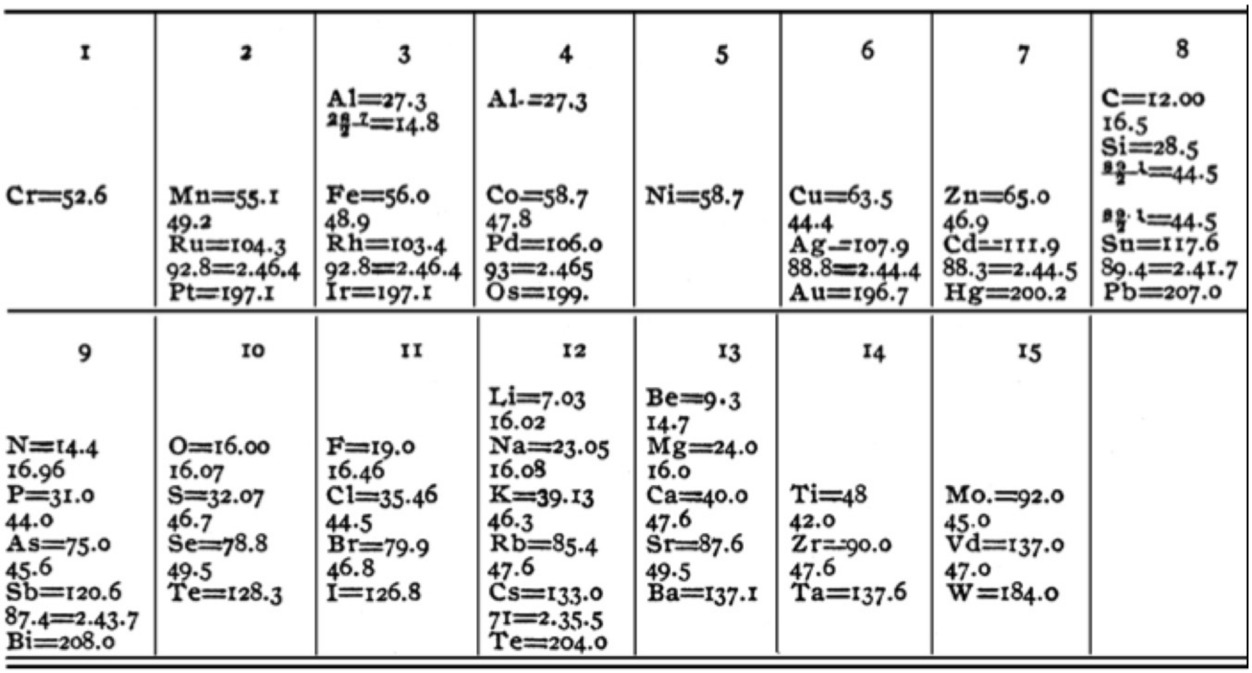
†) Es scheint bemerkenswerth, dass, wo ein Element in verschiedenen Fällen verschiedene Sättigungscapacität zu zeigen scheint, dieselbe in der Regel variirt entweder von 1 : 3 : 5 oder von 2 : 4 : 6. Ersteres z. B. bei Jod und Stickstoff (vergl. § 72 und 73), letzteres bei Blei, Chrom etc. (vergl. a. § 74) Es erinnert dies an die Eigenschaften zusammengesetzter Radicale, § 57.

Figure 3.15: Lothar Meyer's 1864 chemistry textbook showed in detail how the known elements fit into a periodic table that explained all of the measured masses, densities, and valences of the elements. It also predicted new elements that would fill in gaps in the periodic table.



Lothar Meyer's 1868 update to his 1864 periodic table of the elements



1	2	3	4	5	6	7	8
		Al=27.3 $\frac{28}{2}$-1=14.8	Al.=27.3				C=12.00 16.5 Si=28.5 $\frac{89}{2}$-1=44.5
Cr=52.6	Mn=55.1 49.2 Ru=104.3 92.8=2.46.4 Pt=197.1	Fe=56.0 48.9 Rh=103.4 92.8=2.46.4 Ir=197.1	Co=58.7 47.8 Pd=106.0 93=2.465 Os=199.	Ni=58.7	Cu=63.5 44.4 Ag=107.9 88.8=2.44.4 Au=196.7	Zn=65.0 46.9 Cd=111.9 88.3=2.44.5 Hg=200.2	$\frac{89}{2}$·1=44.5 Sn=117.6 89.4=2.41.7 Pb=207.0

9	10	11	12	13	14	15	
N=14.4 16.96 P=31.0 44.0 As=75.0 45.6 Sb=120.6 87.4=2.43.7 Bi=208.0	O=16.00 16.07 S=32.07 46.7 Se=78.8 49.5 Te=128.3	F=19.0 16.46 Cl=35.46 44.5 Br=79.9 46.8 I=126.8	Li=7.03 16.02 Na=23.05 16.08 K=39.13 46.3 Rb=85.4 47.6 Cs=133.0 71=2.35.5 Te=204.0	Be=9.3 14.7 Mg=24.0 16.0 Ca=40.0 47.6 Sr=87.6 49.5 Ba=137.1	Ti=48 42.0 Zr=90.0 47.6 Ta=137.6	Mo.=92.0 45.0 Vd=137.0 47.0 W=184.0	

Figure 3.16: Lothar Meyer presented data demonstrating the periodic properties of atomic volumes, with peaks corresponding to the beginning of each row of the periodic table. In 1868 he updated his periodic table with newly discovered elements.

3.1.3 Other Important Contributions to Inorganic Chemistry

Fritz Haber (German, 1868–1934) invented and Carl Bosch (German, 1874–1940) scaled up the Haber-Bosch process for chemically synthesizing ammonia on an industrial scale for fertilizers and explosives (rather than having to rely on limited natural sources, such as harvesting bat guano from caves) [Hager 2008; Stoltzenberg 1994, 2005; Szöllösi-Janze 2015]. See Fig. 3.17. Haber won the 1918 Nobel Prize in Chemistry for this work. Å. G. Ekstrand, President of the Royal Swedish Academy of Sciences, praised Haber's accomplishment [https://www.nobelprize.org/prizes/chemistry/1918/ceremony-speech/]:

> Geheimrat Professor Haber. This country's Academy of Sciences has awarded you the 1918 Nobel Prize for Chemistry in recognition of your great services in the solution of the problem of directly combining atmospheric nitrogen with hydrogen. A solution to this problem has been repeatedly attempted before, but you were the first to provide the industrial solution and thus to create an exceedingly important means of improving the standards of agriculture and the well-being of mankind. We congratulate you on this triumph in the service of your country and the whole of humanity.

In 1962, Rudolf Hoppe (German, 1922–2014) created the first chemical compounds containing noble gases, which had previously been believed to be chemically inert. See Fig. 3.18.

As shown in Figs. 3.19–3.22, many other German-speaking scientists made important contributions to inorganic chemistry:

Richard Abegg (German, 1869–1910, Fig. 3.19) pioneered valence theory (including what is now know as Abegg's rule) and also measured the effects of solutes on freezing point depression, osmotic pressure, and other properties.

Wilhelm Biltz (German, 1877–1943, Fig. 3.19) made careful measurements of many inorganic molecular weights and vapor pressures.

Otto Linné Erdmann (German states, 1804–1869, Fig. 3.19) conducted experiments with nickel and indigo and also measured a number of atomic weights.

Otto Robert Fricke (German, 1895–1950, Fig. 3.19) was especially known for his work with oxide hydrates.

Wilhelm Hampe (German, 18??–19??, Fig. 3.19) studied the properties of metal-halogen compounds.

Siegfried Herzog (German, 1918–2011, Fig. 3.19) conducted research on a variety of compounds containing metals or transition metals.

Kurt Issleib (German, 1919–1994, Fig. 3.20) created and studied a wide range of phosphorus compounds, including phosphorus-containing drug molecules.

Wilhelm Klemm (German, 1896–1985, Fig. 3.20) made important discoveries in many areas of inorganic chemistry, including intermetallic compounds, rare earths, transition elements, oxides, fluorides, and magnetochemistry. As a student, teacher, or collaborator, he worked with many other major inorganic chemists, such as Wilhelm Biltz, Rudolf Hoppe, Eduard Zintl, and others.

Wilhelm Manchot (German, 1869–1945, Fig. 3.20) was especially known for his work on a variety of carbon monoxide reactions, but he also conducted research on silicides and other areas of inorganic chemistry.

Eilhard Mitscherlich (German states, 1794–1863, Fig. 3.20) discovered isomorphism in crystals, experimented with several acids and salts, studied catalysis, and measured the vapor pressures of many volatile compounds.

Paul Pfeiffer (German, 1875–1951, Fig. 3.20) conducted research on ionic compounds and crystals. He discovered salen ligands (complex molecular structures) as well as the Pfeiffer effect of molecules on optical rotation of polarized light.

Carl Friedrich Rammelsberg (German, 1813–1899, Fig. 3.20) studied phosphoric acid and made a large number of important discoveries in chemical mineralogy that were relevant to both geology and industrial mining.

Günther Rienäcker (German, 1904–1989, Fig. 3.21) focused especially on heterogeneous catalysts, their mechanisms, and their applications.

Otto Ruff (German, 1871–1939, Fig. 3.21) was noted for his work in fluorine chemistry, high-temperature chemistry, and several other areas of inorganic chemistry.

Robert Schwarz (German, 1887–1963, Fig. 3.21) conducted important research on the chemistry of silicon, germanium, halogens, and peroxides.

Arthur Simon (German, 1893–1962, Fig. 3.21) harnessed Raman spectroscopy to determine molecular structures. He also developed an electric furnace and a cryostat for chemical experiments.

Georg Ernst Stahl (German states, 1659–1734, Fig. 3.21) conducted some of the first detailed chemical studies of reduction-oxidation reactions and fermentation reactions.

Alfred Stock (German, 1876–1946, Fig. 3.21) studied a number of areas of inorganic chemistry, including boron hydrides, silicon hydrides, beryllium, and mercury toxicity. He created the Stock system (e.g., "iron(II) chloride" for $FeCl_2$) for naming binary chemical compounds that is still in use today.

Erich Thilo (German, 1898–1977, Fig. 3.22) created and studied novel inorganic polymers composed of silicates, as opposed to more conventional carbon-based polymers.

Hans von Wartenberg (German, 1880–1960, Fig. 3.22) developed techniques and compiled a large amount of important data regarding high-temperature chemistry. He also did important work in silicon chemistry.

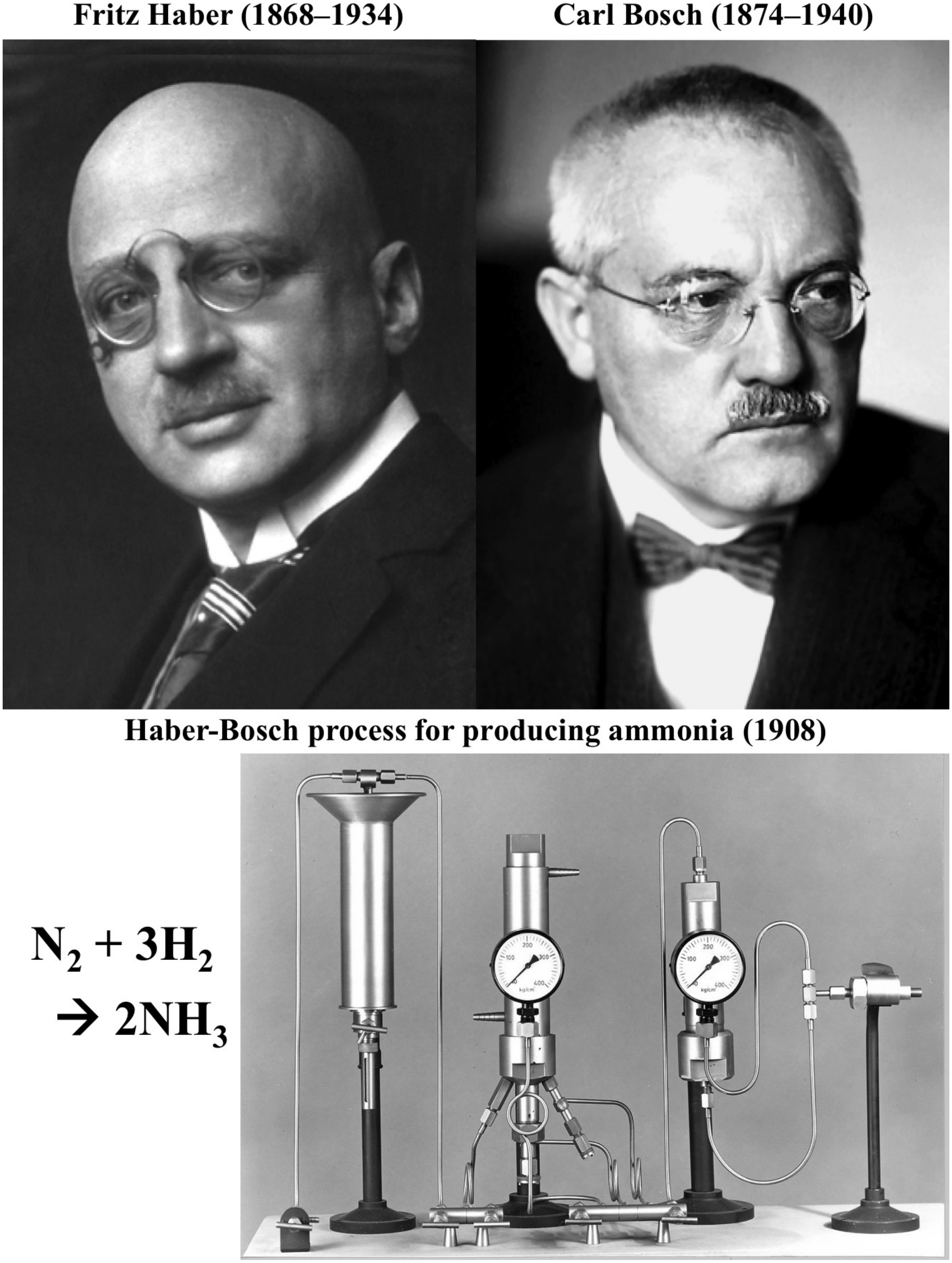
Alfred Werner (Swiss, 1866–1919, Fig. 3.22) won the Nobel Prize in Chemistry in 1913 for his discoveries regarding the coordination chemistry of bonding and stereochemistry in inorganic molecules. T. Nordström, President of the Royal Swedish Academy of Sciences, explained the importance of Werner's work [https://www.nobelprize.org/prizes/chemistry/1913/ceremony-speech/]:

> The number of atoms or groups of atoms which can be linked in a first sphere with the elementary atom functioning as centre, or which in other words can be coordinated into complex radicals under direct linkage with an atom, Werner calls the coordination number. This is a dearly defined numerical concept which is superior to other numerical

> concepts designed to characterize affinity saturation in that it is to some extent independent of the nature and valence of the interconnected elementary atoms, in so far as it has the same value for the great majority of elements. Only two such numerical values have been demonstrated as yet, i.e. four for some elements, and six for the others.
>
> By this approach of which only some principal characteristics can be mentioned here, Werner explains the structure and origin of complex inorganic compounds. By widening and deepening the concept of valence which incorporates his view he has succeeded in bringing atomistic and molecular compounds together under a common point of view. He has drawn a large number of diverse compounds into the range of his comprehensive expert mental work and has thereby been able to establish a uniform system for large groups of inorganic compounds. Werner's approach has also exerted significant influence on research in organic chemistry.
>
> Werner's theory has been supported in an extremely important and valuable manner by the stereochemical researches which he carried out as a sideline, mostly in connection with his work on the constitution of chemical compounds.
>
> By virtue of his theory of the asymmetrical carbon atom, van't Hoff became the real founder of the stereochemistry of organic compounds, and it is Werner's indisputable merit to have introduced this approach to inorganic chemistry as well. Even in his earlier investigations into certain metal ammonias he was able to show that numerous cases of isomerism in complex cobalt and platinum compounds could only be satisfactorily explained by steric approach. For complex radicals of a certain type he put forward a steric theory—the octahedron theory—which predicted that certain of these compounds must occur in two stereoisomeric forms, a prediction which has been confirmed by experiment. By far the greatest interest in this field attaches also to the discovery he made in the last few years, that certain cobalt, chromium, iron, and radium compounds with an asymmetrical metal atom in the complex radical can be divided into two forms which behave like mirror images and show differences of the same kind as those in organic mirror-image isomers, i.e. they are optical antipodes of each other. This discovery is a splendid support for Werner's theory. It has been called the most important discovery in chemistry in recent times, and his stereochemical work makes him the founder of inorganic stereochemistry.
>
> As to Werner's research work as a whole we can with good reason agree with the remark of an eminent research worker, that Werner's theoretical and experimental work in inorganic chemistry has opened up new paths of chemical research and is of positively revolutionary significance. It is substantially his researches which have during the last few decades set the trend of development in inorganic chemistry and have newly inspired this branch of science which had been somewhat neglected during the last quarter of the 19th century, by giving it new impulses which have borne fruit in numerous different special studies by various research workers.

Lothar Wöhler (German, 1870–1952, Fig. 3.22) spent his career studying oxidative reactions for explosives, catalysts, and other applications.

Eduard Zintl (German, 1898–1941, Fig. 3.22) made important discoveries regarding intermetallic compounds; his name remains associated with Zintl phases and Zintl ions.



Fritz Haber (1868–1934)
Carl Bosch (1874–1940)
Haber-Bosch process for producing ammonia (1908)

$$N_2 + 3H_2 \rightarrow 2NH_3$$

Figure 3.17: Fritz Haber invented and Carl Bosch scaled up the Haber-Bosch process for producing ammonia for fertilizers and explosives.

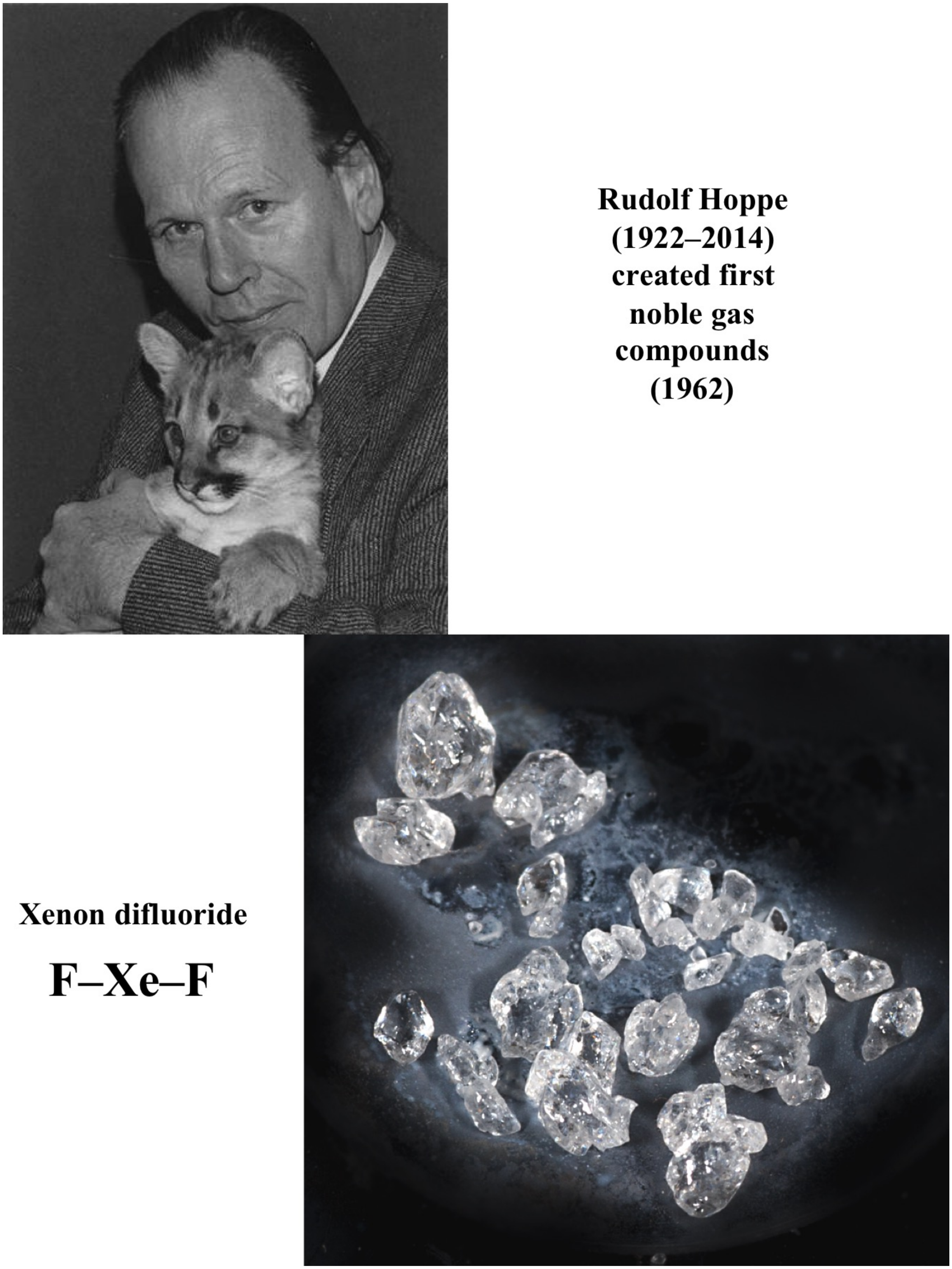
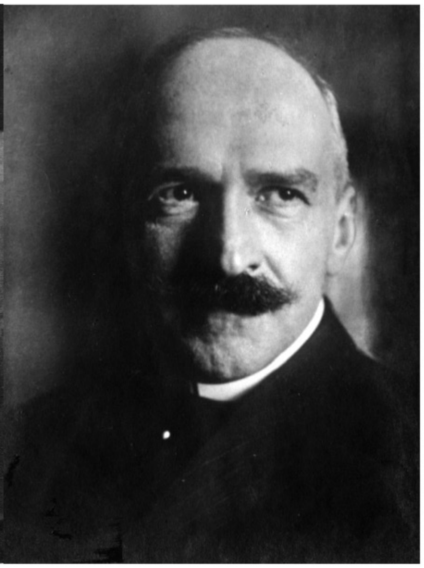

Rudolf Hoppe
(1922–2014)
created first
noble gas
compounds
(1962)
Xenon difluoride
F–Xe–F

Figure 3.18: In 1962, Rudolf Hoppe created the first chemical compounds containing noble gases, which had previously been believed to be chemically inert.

Richard Abegg
(1869–1910)
Valence theory, freezing point depression

Wilhelm Blitz
(1877–1943)
Inorganic molecular weights and vapor pressures

Otto Linné Erdmann
(1804–1869)
Nickel, indigo, atomic weights



Otto Robert Fricke
(1895–1950)
Oxide hydrates

Wilhelm Hampe
(18??–19??)
Properties of metal-halogen compounds

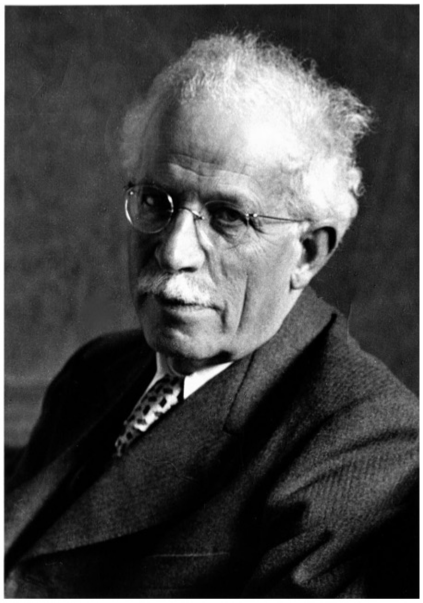
Siegfried Herzog
(1918–2011)
Metal compounds

Figure 3.19: Other creators who made important contributions to inorganic chemistry included Richard Abegg, Wilhelm Blitz, Otto Linné Erdmann, Robert Fricke, Wilhelm Hampe, and Siegfried Herzog.

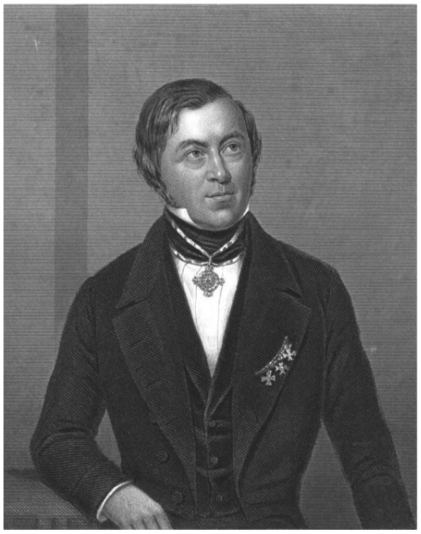
Kurt Issleib
(1919–1994)
Phosphorus
compounds

Wilhelm Klemm
(1896–1985)
Intermetallic
compounds,
rare earths,
transition elements

Wilhelm Manchot
(1869–1945)
Carbon monoxide
reactions



Eilhard Mitscherlich
(1794–1863)
Isomorphism
in crystals



Paul Pfeiffer
(1875–1951)
Ionic compounds
and crystals

Carl Friedrich
Rammelsberg
(1813–1899)
Phosphoric acid,
crystals

Figure 3.20: Other creators who made important contributions to inorganic chemistry included Kurt Issleib, Wilhelm Klemm, Wilhelm Manchot, Eilhard Mitscherlich, Paul Pfeiffer, and Carl Friedrich Rammelsberg.

Günther Rienäcker (1904–1989) Heterogeneous catalysts

Otto Ruff (1871–1939) Fluorine chemistry

Robert Schwarz (1887–1963) Chemistry of silicon, germanium, halogens, and peroxides

Arthur Simon (1893–1962) Raman spectroscopy to determine molecular structures

Georg Ernst Stahl (1659–1734) Reduction-oxidation reactions, fermentation

Alfred Stock (1876–1946) Boron hydrides, silicon hydrides, beryllium, mercury toxicity, Stock system for naming compounds

Figure 3.21: Other creators who made important contributions to inorganic chemistry included Günther Rienäcker, Otto Ruff, Robert Schwarz, Arthur Simon, Georg Ernst Stahl, and Alfred Stock.

Erich Thilo
(1898–1977)
Silicate polymers

Hans von Wartenberg
(1880–1960)
Silicon chemistry,
high-temperature
chemistry

Alfred Werner
(1866–1919)
Coordination chemistry
Nobel Prize in
Chemistry 1913

Lothar Wöhler
(1870–1952)
Explosives and
other oxidative
reactions

Eduard Zintl
(1898–1941)
Intermetallic
compounds

Figure 3.22: Other creators who made important contributions to inorganic chemistry included Erich Thilo, Hans von Wartenberg, Alfred Werner, Lothar Wöhler, and Eduard Zintl.

3.2 Organic Chemistry

German-speaking scientists dominated the development of organic chemistry, or the chemistry of molecules that contain significant numbers of carbon atoms.[3] Organic chemistry is especially important since carbon-rich molecules include everything from biological molecules and pharmaceuticals to synthetic polymers and dyes.

This section covers some of the German-speaking creators and their creations that were involved in:

3.2.1. Synthetic dyes and the origins of organic chemistry

3.2.2. General organic chemistry

3.2.3. Organometallic chemistry

3.2.4. Synthetic fuels

3.2.5. Liquid crystals

3.2.6. Technology transfer out of the German-speaking world

3.2.1 Synthetic Dyes and the Origins of Organic Chemistry

One of the strongest motivations for the development of organic chemistry in the German-speaking world was the creation of synthetic fabric dyes that could be cheaper than natural dyes and could come in a greater variety of colors. That industry was quite lucrative, yet it also led to the generation of many would-be dyes that had pharmaceutical, explosive, or other desirable properties. All of those applications drove the need to understand the science of organic molecules and reactions, and to develop methods of synthesizing and mass-producing any desired organic molecule.

Ulrich Wengenroth, a scientific historian at the Deutsches Museum in Munich, summarized the importance of the German-speaking world for organic chemistry, and vice versa [Landes et al. 2010, pp. 290–291]:

> The showcase of German science-based industry was undoubtedly organic chemistry. From the 1880s until well after World War II German companies held a commanding position in most products based on carbon hydrates, especially when it came to high-value products like pharmaceuticals. The success story began with synthetic dyestuffs in the 1880s. Although the first synthetic dyestuffs were created in France and England, the latter in a laboratory set up by a student of the German chemist Liebig, it was German firms, supported by academic chemists from universities and engineers from

---

[3] Abelshauser et al. 2004; Brock 1993; Bugge 1955; Coffey 2008; Deichmann 2001; Drummer and Zwilling 2007; Engels et al. 1989; Farber 1961; Haber 1958, 1971; Ihde 1984; Johnson 1990; Kahlert 2002; Karlsch2016; Lesch 2000; Maier 2015; Marsch 1994a; Neufeldt 2003; Partington 1935, 1957, 1964; Peppas 2013; Rosner 2004; Sasuly 1947; Schwenk 2000; Soukup 2007; Teltschik 1992; Ungewitter 1938; Welsch 1981; Werner 2017.

> polytechnics, that turned synthetic dyestuffs into an industry with a highly methodical and scientific approach. The main strategy was always the same: analyze a natural product and then find ways to synthesize it cheaply from the tar derivatives the heavy industries and gasworks would abundantly supply. The overabundant supply of first-rate human capital for industrial research, plus the additional incentive of not having access to natural resources for colonies, created a situation that proved to be immensely fortunate. Only the Swiss chemical industry, also with a good supply of academically trained scientists and no colonies, could match the progress of German organic chemistry. It was one of the first examples after the Industrial Revolution when the absence of natural resources proved to be beneficial. Apart from the availability of highly qualified human capital, the German dyestuffs industry benefited from having hit a treasure trove of potential products, and the most innovative entrepreneurs were smart enough to see and fully utilize that potential.
>
> Serendipity had it that hydrocarbons are at the root of three major product families: dyestuffs, synthetic materials, and pharmaceuticals. In looking for one, chemists would inevitably find the others. They just had to find out what the properties of the respective stuff were they had hit upon. This was done by massive testing on a hitherto unprecedented scale by hundreds of professionals in the laboratories of the big three (Hoechst, Bayer, BASF) of the German chemical industry. In the words of Carl Duisberg, head of Bayer, there was "nowhere any trace of a flash of genius" in the labs, just academic toil and screening. Eventually his company found more than 10,000 synthetic dyestuffs before the eve of World War I, 2,000 of which were marketed. At the same time they had hit on dyestuffs that wouldn't dye but could cure ills. Many twentieth-century drugs are "failed dyes," Valium being just the most profitable among them. Next to drugs a host of synthetic materials was found "on the way" and gave rise to ever more scrutiny when laboratories were testing newly synthesized chemicals.
>
> Charts of tar-based products show a wide spectrum from explosives to anesthesia, Bakelite, and a number of synthetic dyestuffs and their intermediates. [...] It took the German chemical industry's competitors decades and the scrapping of all property rights in the wake of the wars slowly to erode the position it had built by the turn of the century.

Two of the most important founders of organic chemistry were Friedrich Wöhler and Justus von Liebig, who were friends and research collaborators throughout most of their careers. They also educated and inspired a huge number of younger chemists who went on to make major discoveries themselves.

Friedrich Wöhler (German, 1800–1882), shown in Fig. 3.23, synthesized urea, discovered compound radicals, and made other discoveries that helped to establish the field of organic chemistry. As the years went by, he spent more and more of his time educating and mentoring chemistry students, to whom he was quite devoted and helpful. Oxford University's *Biographical Dictionary of Scientists* summarized some of his research history [Porter 1994, pp. 731–732]:

> In Wöhler's first research in 1827 he isolated metallic aluminium by heating its chloride with potassium; he then prepared many different aluminium salts. In 1828 he used the same procedure to isolate beryllium. Also in 1828 he carried out the reaction for which he is best known. He heated ammonium thiocyanate—a crystalline, inorganic substance—and converted it to urea (carbamide), an organic substance previously obtained only

> from natural sources. Until that time there had been a basic misconception in scientific thinking that the chemical changes undergone by substances in living organisms were not governed by the same laws as were inanimate substances[...]
>
> Wöhler worked with Justus von Liebig on a number of important investigations. In 1830, they proved the polymerism of cyanates and fulminates, and two years later announced a series of studies of benzaldehyde (benzenecarbaldehyde) and the benzoyl (benzenecarboxyl) radical. In 1837, they investigated uric acid and its derivatives. Wöhler also discovered quinone (cyclohexadiene-1,4-dione), hydroquinone or quinol (benzene-1,4-diol) and quinhydrone (a molecular complex composed of equimolar amounts of quinone and hydroquinone).
>
> In the inorganic field Wöhler isolated boron and silicon and prepared silicon nitride and hydride. He prepared phosphorus by the modern method, and discovered calcium carbide and showed that it can be reacted with water to produce acetylene (ethene) [...]

Justus von Liebig (German, 1803–1873) collaborated with Wöhler for much of his career, for example in discovering compound radicals. As illustrated in Fig. 3.24, he taught large number of students in his laboratory, creating generations of later chemists. The *Encyclopedia Britannica* described his research [EB 2010]:

> [T]he radical theory that Liebig did much to develop was the first major attempt at systematization in organic chemistry.
>
> Liebig's studies in organic chemistry were greatly aided by the simple method he developed for the analytical determination of carbon and hydrogen. He also developed a method for the analytical determination of halogens, published important work on polybasic organic acids, and did much to support the hydrogen theory of acids. [...]
>
> After 1838 Liebig's interest shifted from pure organic chemistry to the chemistry of plants and animals. He made a large number of analyses of tissues and body fluids and carried out a study of the nitrogenous products of the animal organism. [...] He [...] showed that plants took carbon dioxide, water, and ammonia from the air and soil.

As shown in Fig. 3.25, Otto Unverdorben (German, 1806–1873), Friedlieb Ferdinand Runge (German, 1795–1867), Carl Fritzsche (German, 1808–1871), and August Wilhelm von Hofmann (German, 1818–1892) synthesized aniline, which can be chemically modified to produce a wide variety of colored dyes, explosives, and drugs. In 1820, Runge was also the first scientist to extract and identify caffeine. Even the American Council of Learned Societies praised von Hofmann's contributions and impact [ACLS 2000, pp. 432–433]:

> He obtained his doctorate in 1841 and taught at the University of Bonn. In 1845, under the sponsorship of Prince Albert, he went to England, where he became director of the Royal College of Chemistry, London. He stayed there until 1865, when he was given the chemistry chair at the University of Berlin. [...]
>
> Hofmann's influence on British and German chemistry was profound. He was responsible for continuing the method of science teaching by laboratory instruction that had been

> established and popularized by Liebig at Giessen and for transporting it to England and Berlin. He created his own school of chemists who were interested primarily in experimental organic chemistry and its industrial applications. Much of his experimentation had to do with coal tar and its derivatives. In 1843 he established that many substances obtainable from coal tar naphtha and its derivatives were all of a single nitrogenous base, aniline. His discoveries—and those of his school—laid the foundation for the coal tar products industries. He also did important work on the chemistry of dyes.

Heinrich Caro (German, 1834–1910), Carl Gräbe (German, 1841–1927), and Carl Theodore Liebermann (German, 1842–1914), shown in Fig. 3.26, synthesized alizarin red dye in 1868.

Adolf von Baeyer (German, 1835–1917), Karl Heumann (German, 1850–1894), Johannes Pfleger (German, 1867–1957), and Rudolf Knietsch (German, 1854–1906) synthesized indigo dye. Adolf von Baeyer won the Nobel Prize in Chemistry in 1905. See Fig. 3.27. Professor A. Lindstedt, President of the Royal Swedish Academy of Sciences, explained the importance of von Baeyer's work [https://www.nobelprize.org/prizes/chemistry/1905/ceremony-speech/]:

> Among the living research workers who have contributed directly or indirectly to the unique development of the tar-dyestuff industry the place of honour goes to the Professor at Munich University, Adolf von Baeyer, for his researches into the composition of indigo as well as into the triphenyl methane dyestuffs.
>
> Indigo, the gorgeous pigment of the indigo plant, has been considered the most important of all organic pigments on account of its beauty and colour fastness, and the annual tribute which the West used to pay India for it amounted to a very considerable sum. To reproduce the pigment by synthetic methods and make it more easily obtainable was therefore an exceptionally inviting task for chemical research.
>
> The complex and unique composition of indigo, however, made this also one of the hardest of tasks. Here there could be no question of one of those casual discoveries, which by happy accident seem to achieve half the work. Years of work were required for even von Baeyer's acumen and experimental skill to achieve the necessary insight into the pigment's chemical composition and to be able to manufacture it from simpler constituents. Even after the purely scientific part of the work had been completed it still took a number of years to make the results obtained from research applicable to technology. [...]
>
> Simultaneously with his analyses within the indigo group, analyses moreover which exerted a far-reaching influence upon the development of organic chemistry and directed research into new channels, von Baeyer was active with no less success in another sphere of the chemistry of organic dyestuffs. The stimulus was given by his discovery of a new group of beautifully coloured compounds, the so-called phthaleins, of which only the eosin pigments, highly important to industry, and the rhodamin dyes derived from them, may have particular mention here. In a series of masterly experiments von Baeyer demonstrated several years ago the chemical nature of the phthaleins and showed that, just like the already known rosaniline dyes, they may be classified as derivatives of the hydrocarbon triphenylmethane. In recent years—more exactly, from 1900 on—von Baeyer has resumed his work on triphenylmethane, and from this a new conception

> of the chemical composition of pigments and in general of the connection between the optical properties of organic substances and their interior atomic structure has been to a high degree prepared.
>
> The dyestuffs studied by von Baeyer belong to the main category of organic substances usually classified under the name of aromatic compounds, which differ decisively from the other organic substances—the so-called aliphatic or fatty acid series—both in their properties and in their behaviour in reaction. In fact this difference has been considered so great that it has caused the division of the whole of organic chemistry into two separate halves: the chemistry of aliphatic, and of aromatic substances. Nevertheless, one of the main tasks of scientific research is to try to bridge the gulfs dividing different sciences, or different branches of the same science. In this respect, too, von Baeyer has carried out notable work in his research, remarkable alike from the experimental as well as from the theoretical point of view, on the so-called hydroaromatic compounds. With these compounds, he has found the transitional form between the two main series just mentioned and by application of the new conception and the new method to the terpenes and the species of camphor occurring in nature and also important for technology, he has opened up fields for synthetic work which were previously inaccessible.

There were many other German-speaking chemists who developed thousands of other artificial dyes. Peter Griess (German, 1829–1888), Otto Nikolaus Witt (German/Swiss, 1853–1915), and Paul Friedländer (German, 1857–1923), depicted in Fig. 3.28, are just a few additional examples of important dye creators.

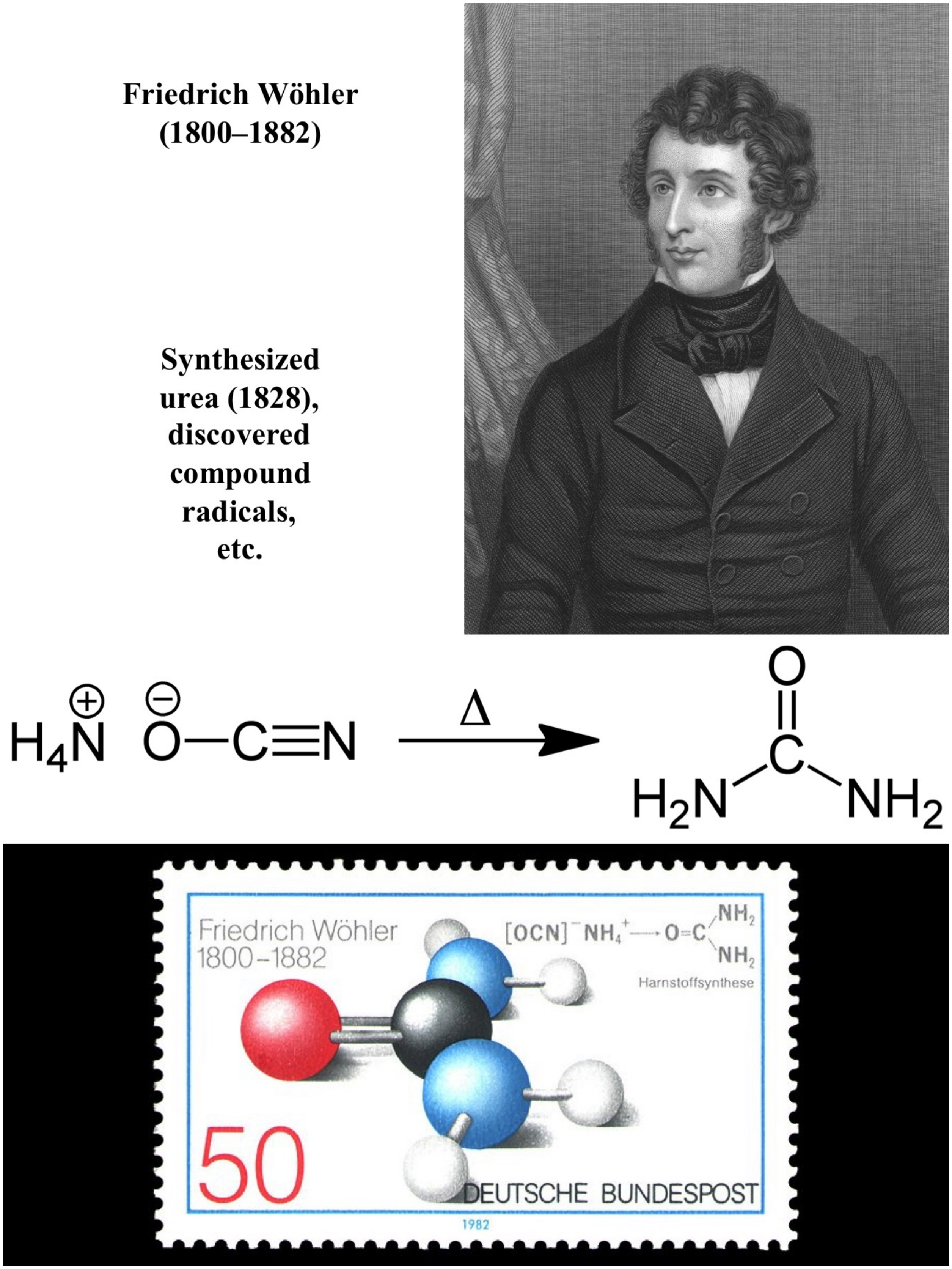
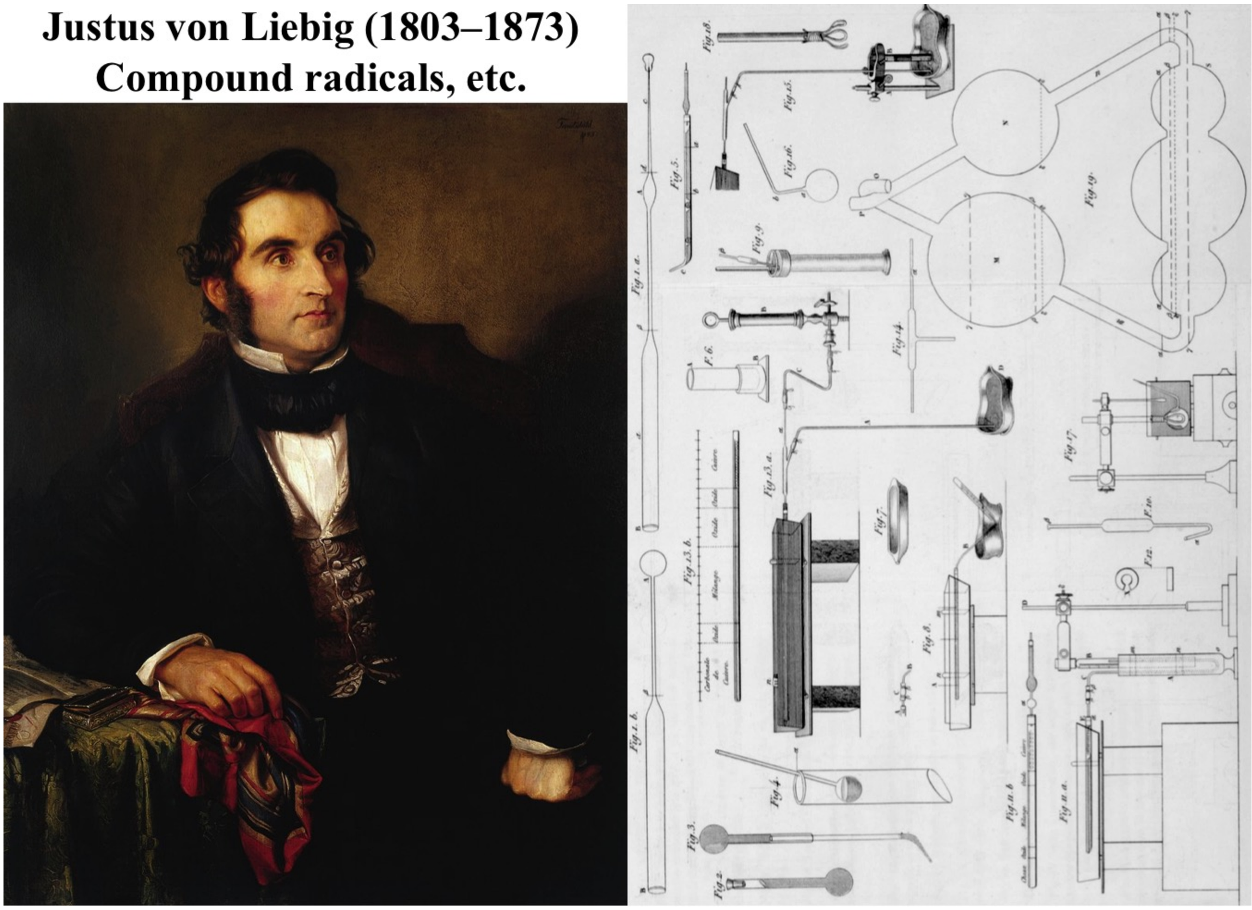

Friedrich Wöhler
(1800–1882)
Synthesized urea (1828), discovered compound radicals, etc.
$H_4\overset{\oplus}{N}$ $\overset{\ominus}{O}-C\equiv N$
Δ
O
C
H_2N
NH_2
Friedrich Wöhler
1800–1882
$[OCN]^-NH_4^+ \longrightarrow O{=}C(NH_2)_2$
Harnstoffsynthese
50
DEUTSCHE BUNDESPOST
1982

Figure 3.23: Friedrich Wöhler synthesized urea, discovered compound radicals, and made other discoveries that helped to found the field of organic chemistry.


Justus von Liebig (1803–1873)
Compound radicals, etc.

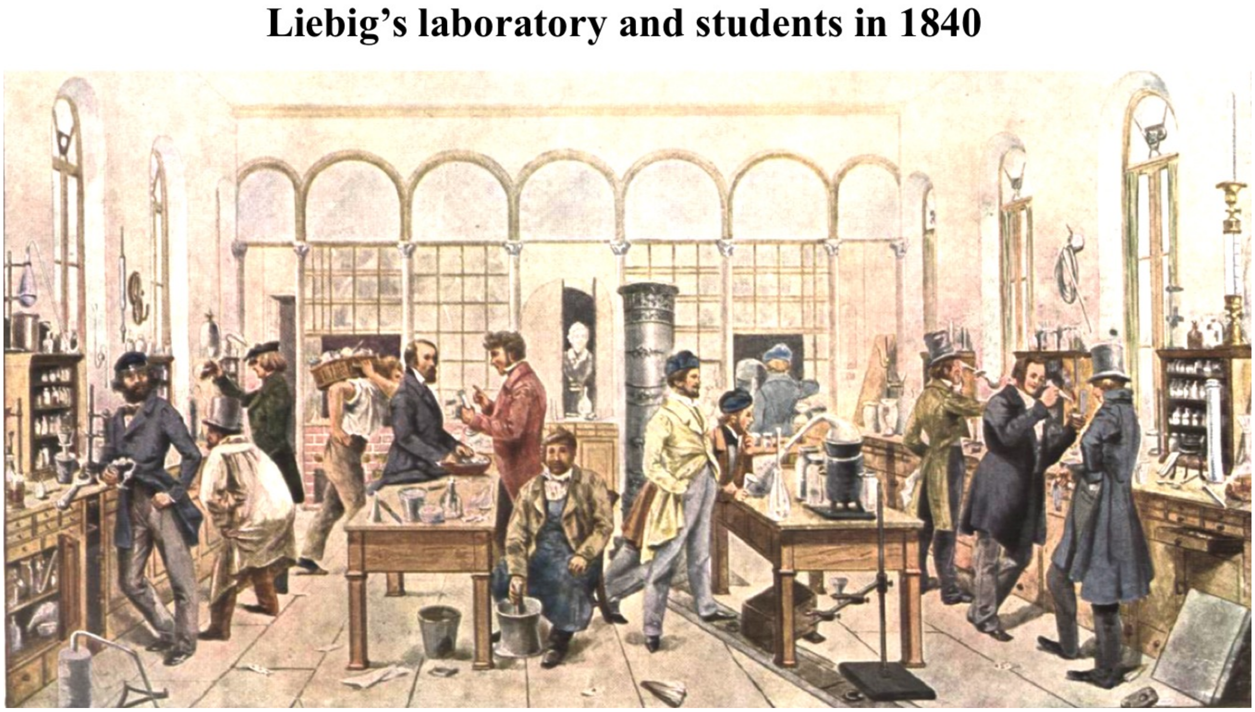

Liebig's laboratory and students in 1840

Figure 3.24: Justus von Liebig collaborated with Wöhler for part of his career, for example in discovering compound radicals. He taught large number of students in his laboratory, creating generations of later chemists.

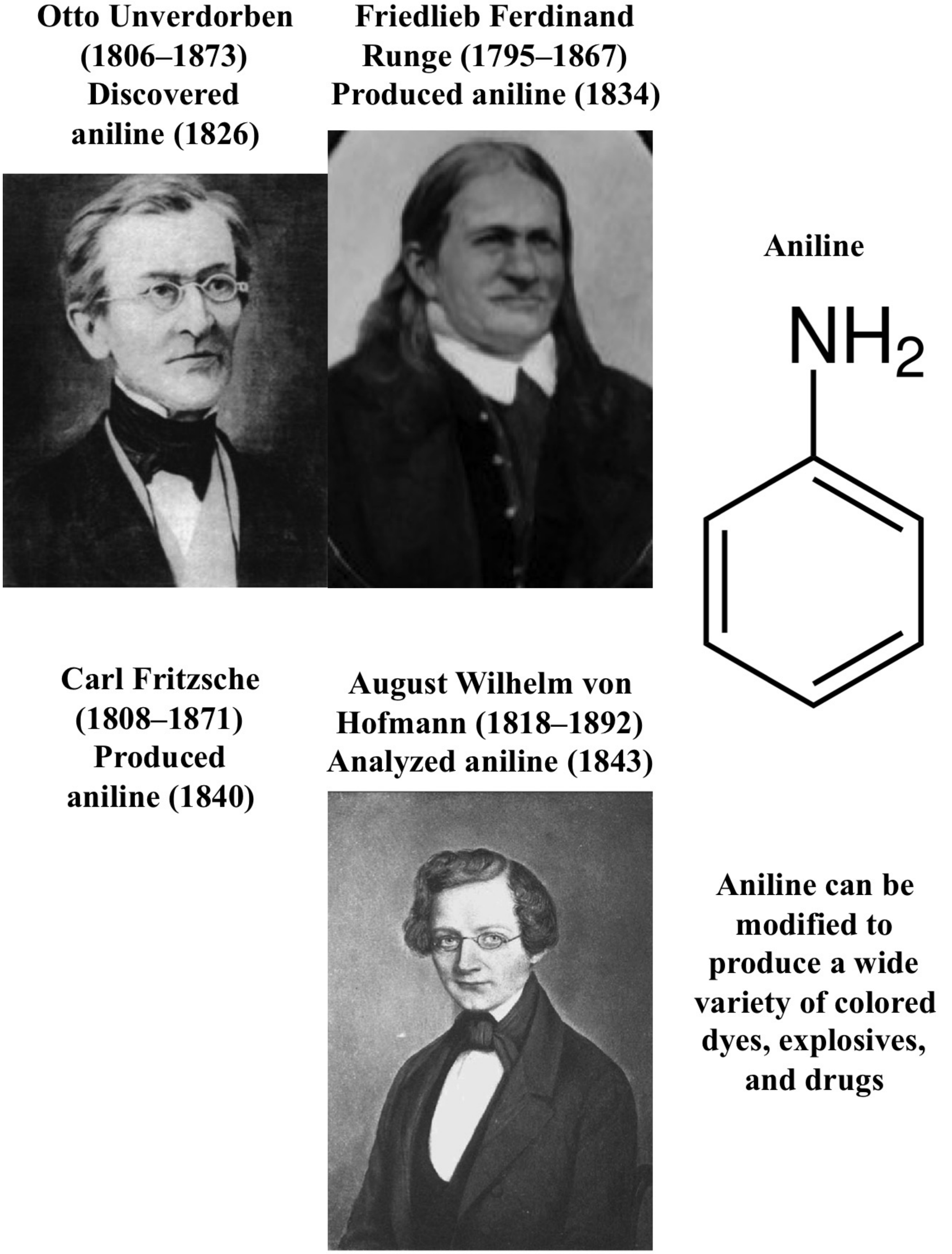

Otto Unverdorben (1806–1873) Discovered aniline (1826)
Friedlieb Ferdinand Runge (1795–1867) Produced aniline (1834)
Aniline
NH2
Carl Fritzsche (1808–1871) Produced aniline (1840)
August Wilhelm von Hofmann (1818–1892) Analyzed aniline (1843)
Aniline can be modified to produce a wide variety of colored dyes, explosives, and drugs

Figure 3.25: Otto Unverdorben, Friedlieb Ferdinand Runge, Carl Fritzsche, and August Wilhelm von Hofmann synthesized aniline, which can be chemically modified to produce a wide variety of colored dyes, explosives, and drugs.

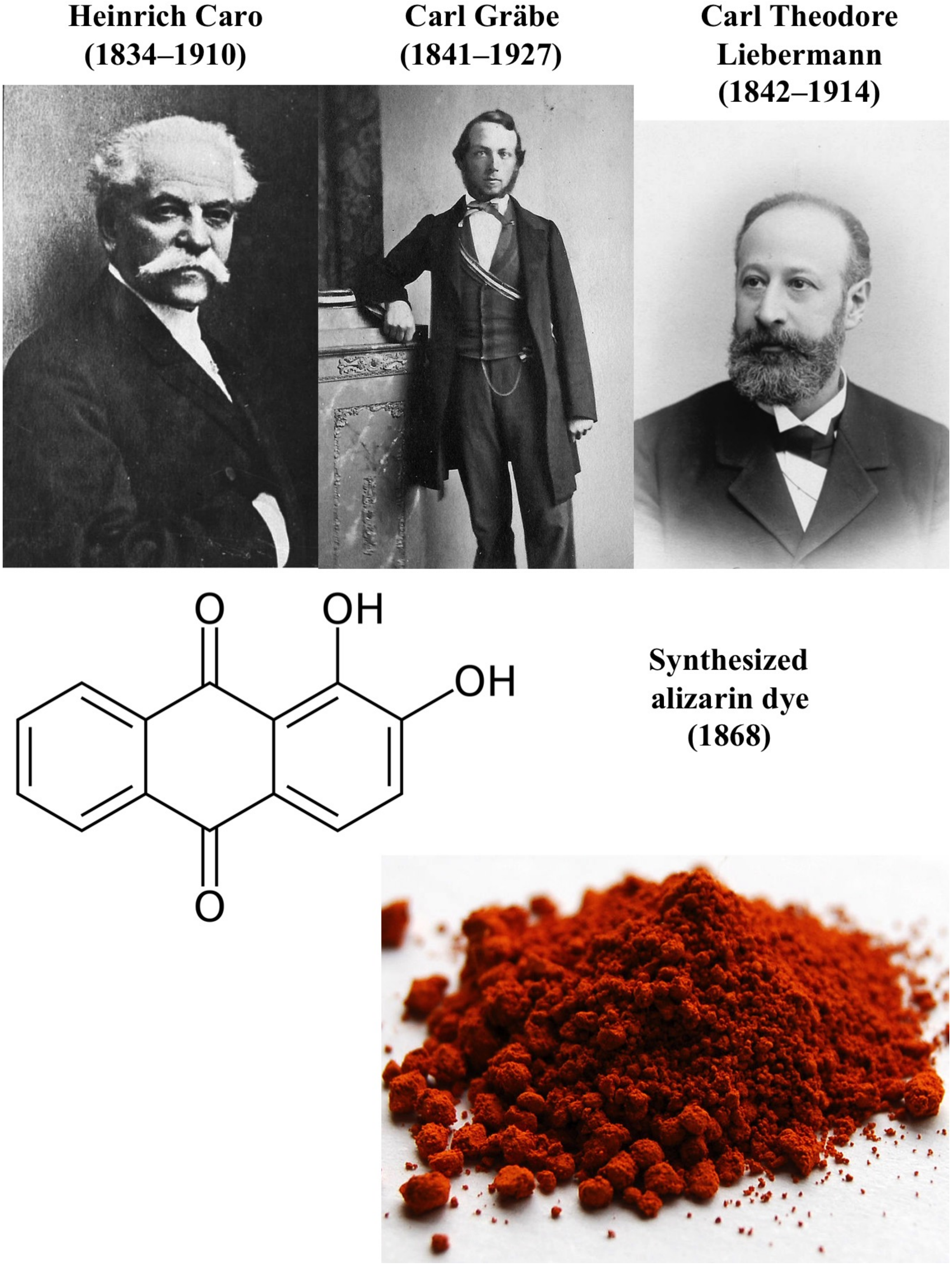

Heinrich Caro
(1834–1910)
Carl Gräbe
(1841–1927)
Carl Theodore
Liebermann
(1842–1914)
O
OH
OH
O
Synthesized
alizarin dye
(1868)

Figure 3.26: Heinrich Caro, Carl Gräbe, and Carl Theodore Liebermann synthesized alizarin red dye in 1868.

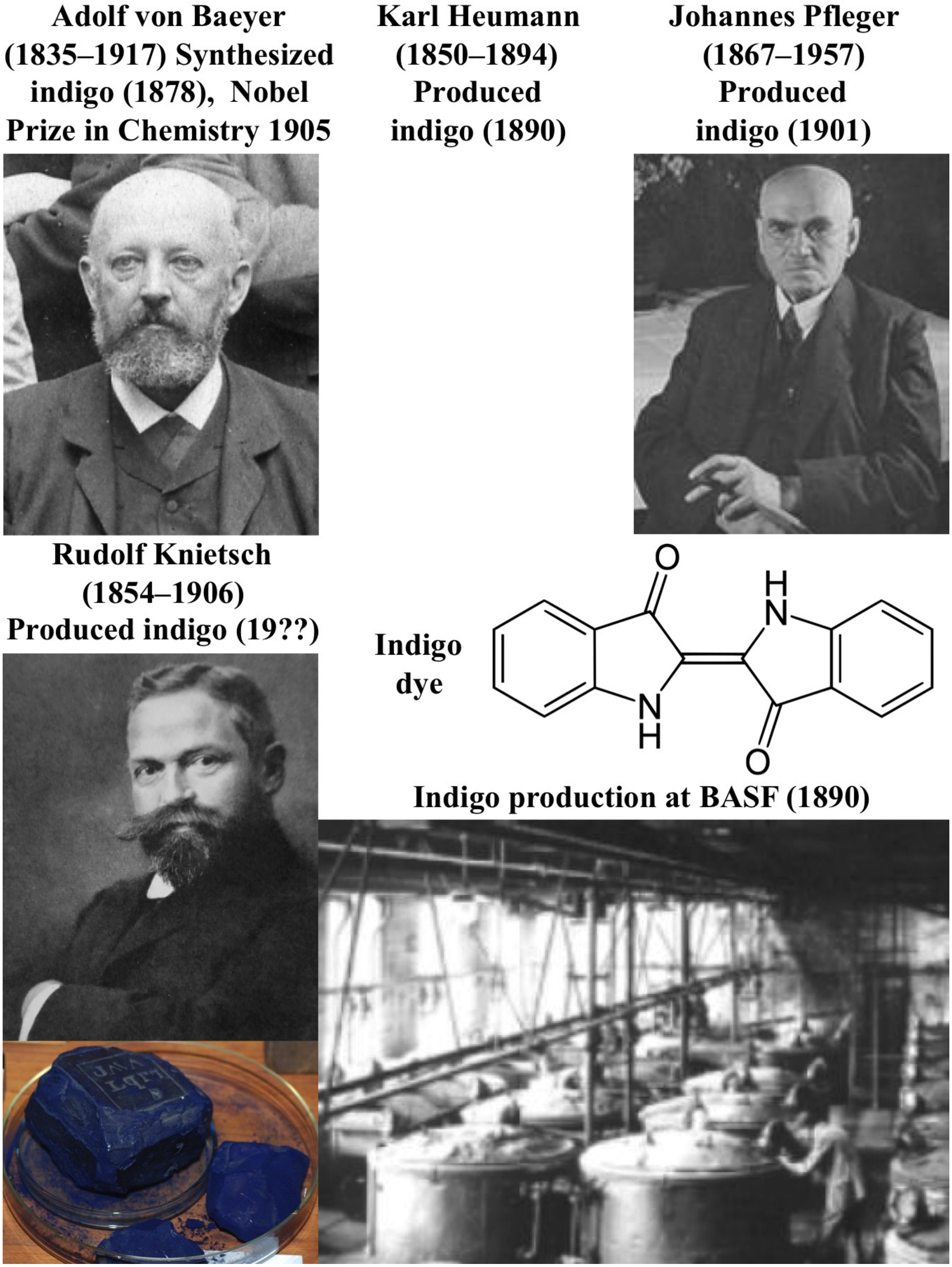

Adolf von Baeyer (1835–1917) Synthesized indigo (1878), Nobel Prize in Chemistry 1905
Karl Heumann (1850–1894) Produced indigo (1890)
Johannes Pfleger (1867–1957) Produced indigo (1901)
Rudolf Knietsch (1854–1906) Produced indigo (19??)
Indigo dye
O
H
N
NH
H
O
Indigo production at BASF (1890)

Figure 3.27: Adolf von Baeyer, Karl Heumann, Johannes Pfleger, and Rudolf Knietsch synthesized indigo dye. Adolf von Baeyer won the Nobel Prize in Chemistry in 1905.

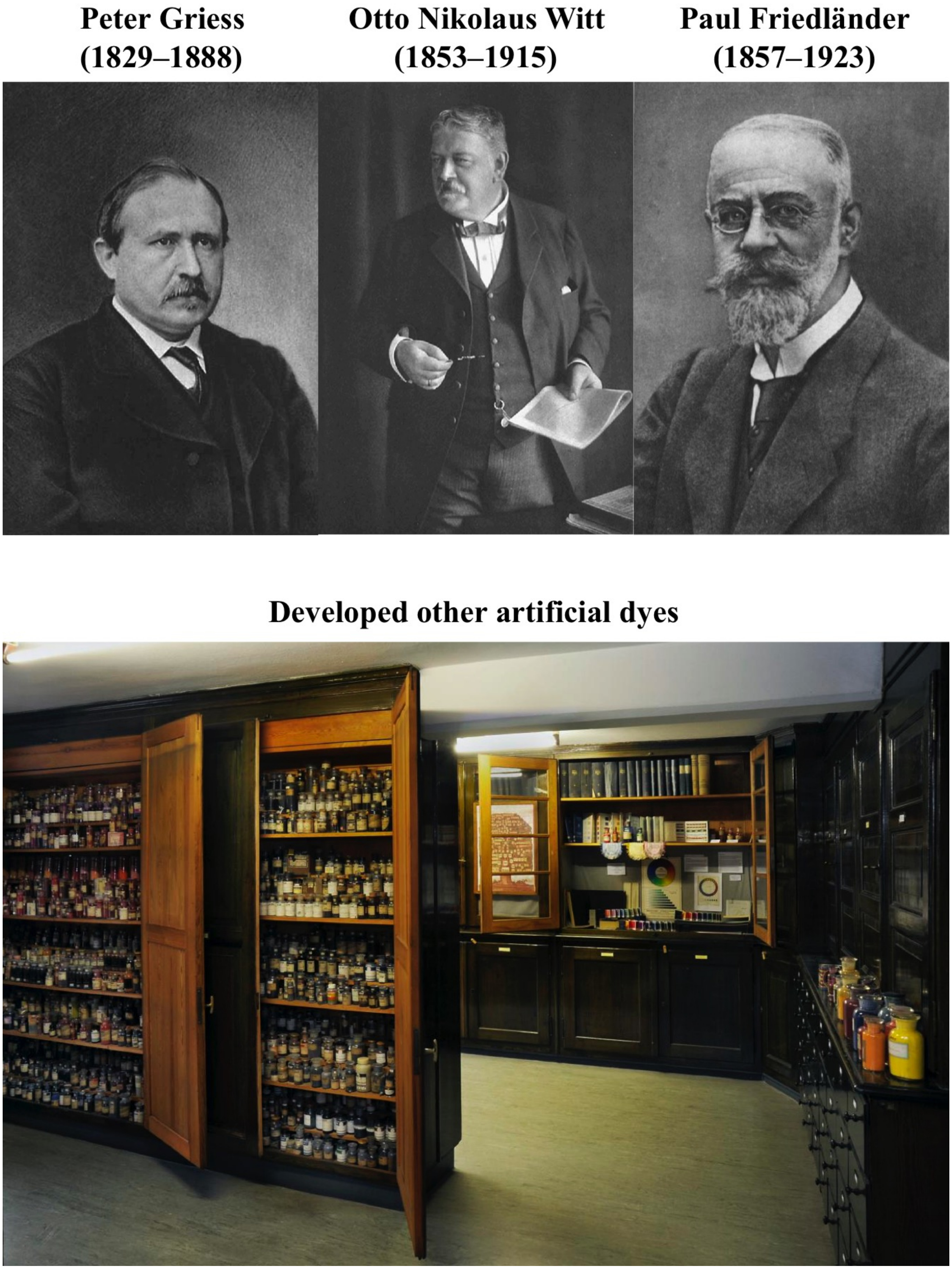

Peter Griess
(1829–1888)
Otto Nikolaus Witt
(1853–1915)
Paul Friedländer
(1857–1923)
Developed other artificial dyes

Figure 3.28: Peter Griess, Otto Nikolaus Witt, and Paul Friedländer developed other artificial dyes.

3.2.2 General Organic Chemistry

An enormous number of German-speaking scientists made important contributions to organic chemistry. This section can only briefly mention some examples (Figs. 3.29–3.47). For simplicity, they are mainly in alphabetical order.

Karl von Auwers (German, 1863–1939, Fig. 3.29) received his Ph.D. under August Wilhelm von Hofmann and in turn was the doctoral adviser of Georg Wittig and Karl Ziegler. He is best remembered for developing Auwers synthesis in 1908.

Eugen Bamberger (German, 1857–1932, Fig. 3.29) also received his Ph.D. under August Wilhelm von Hofmann. He discovered the Bamberger rearrangement in 1894.

Ernst Beckmann (German, 1853–1923) developed the Beckmann rearrangement (1886), shown in Fig. 3.30, which later proved extremely useful for making Nylon and several important drugs. He also invented the Beckmann freezing-point apparatus and thermometer.

Friedrich Beilstein (German, 1838–1906, Fig. 3.30) created the encyclopedic *Beilstein's Handbook of Organic Chemistry* in 1881 and continued to update its collection of organic molecules and information during his lifetime. Other chemists have continued to update and maintain *Beilstein's Handbook* to this day.

Ernst Bergmann (1903–1975, Fig. 3.31) received his Ph.D. under Wilhelm Schlenk at the University of Berlin in 1927 and conducted important research in organic and fluorine chemistry. Soon after the founding of the modern nation of Israel, he became the head scientist of the Israeli program to develop nuclear weapons. (This is another example of German-speaking scientists being responsible for developing nuclear weapons in several different countries.)

Julius von Braun (Polish/German, 1875–1939, Fig. 3.31) was a doctoral student of Otto Wallach and made several discoveries such as the von Braun reaction and the Rosenmund-von Braun reaction.

Julius Bredt (German, 1855–1937, Fig. 3.31) determined the structure of camphor and is also known for Bredt's rule and the Bredt distributor.

Hans Theodor Bucherer (German, 1869–1949, Fig. 3.31) received his Ph.D. under Johannes Wislicenus and went on to discover the Bucherer reaction, Bucherer carbazole synthesis, and the Bucherer-Bergs reaction.

George Büchi (German, 1921–1998, Fig. 3.31) is especially remembered for his studies of photochemical organic reactions.

Ernst Büchner (1850–1924, Fig. 3.31) spent his career working in organic chemistry and developed the Büchner flask and the Büchner funnel, both of which are now widely used for filtration in chemistry and biology experiments.

Robert Bunsen (German, 1811–1899, Fig. 3.32) conducted research in organic chemistry in addition to his well-known work in inorganic chemistry. He worked with organic arsenides, discovered an antidote for arsenic poisoning (iron oxide hydrate) and studied organic photochemistry.

Rainer Ludwig Claisen (German, 1851–1930, Fig. 3.33) developed many incredibly useful experimental methods that have been widely employed in organic chemistry ever since, including Claisen condensation, the Claisen reaction, the Claisen rearrangement, the Claisen flask, etc.

Rudolf Criegee (German, 1902–1975, Fig. 3.32) studied the oxidation of organic molecules and the properties of cyclic reactions. He discovered the Criegee rearrangement and the Criegee intermediate.

Theodor Curtius (German, 1857–1928, Fig. 3.32) discovered the Curtius rearrangement and several novel molecules, including hydrazine, an extremely important rocket fuel.

Walter Dieckmann (German, 1869–1925, Fig. 3.33) is most famous for developing Dieckmann condensation, a step that ever since then has been widely utilized in the synthesis of organic molecules.

Otto Diels (German, 1876–1954) and Kurt Alder (German, 1902–1958) developed Diels-Alder reactions (1928), which are very useful for producing polymers and other complex organic molecules. They both won the Nobel Prize in Chemistry in 1950. See Fig. 3.34. Professor A. Fredga of the Nobel Committee for Chemistry explained the importance of their work [https://www.nobelprize.org/prizes/chemistry/1950/ceremony-speech/]:

> Professor Diels, Professor Alder. More than two decades have passed since the day when you sent in the first paper on "Syntheses in the Hydroaromatic Series" to the Editor of the *Annals*. Much has happened since then—in Science, as well as in the world.
>
> The reciprocal addition of the unsaturated compounds was at that time still somewhat mysterious. The chemistry of the high polymer compounds belonged for the most part to the future. You found it necessary to stress that the new substances which you obtained so easily were not molecular compounds but were really new molecules, stable and firmly bonded. New simple bonds had come into being of the old, well-known kind. This identification has paved the way to a right understanding of the polymerization phenomena of the unsaturated compounds, and through it you have very greatly advanced the development of high polymer chemistry and technics.
>
> In this treatise you have even indicated how highly promising the consequences of the low molecular compounds were for the future of chemistry. In the past years the synthesis of dienes has, to be sure, achieved more than you could either foresee or predict when you wrote your paper. But the general trend, the prophetic leading ideas are already to be found in it.
>
> You mention there the possibilities for discussion of several theoretically interesting questions concerning the forces of attraction in polycyclic systems. You also mention the practical consequences. The possibility of the synthetic production of complicated natural substances or of compounds similar to them is, in your view, immediately in prospect. Finally you indicate the possibility that this astonishingly rapid and smoothly running reaction could also play a significant part in the processes of Nature.
>
> Since 1928 the synthesis of dienes has been developed in various directions by numerous workers, and its significance has become more and more obvious. You have yourselves, partly together, partly independently, worked with great success in the field you have

> opened up. The external circumstances were not always of the best for reasons which we all know. We have been told that you, Professor Diels, were in the past years unable to do any experimental work. And yet your thoughts played keenly upon scientific problems and we hope that you will soon have the opportunity of approaching the problems experimentally as well. You, Professor Alder, in spite of limited facilities for work, are again fully active. During the past year you have, by your splendid work on the steric and energetic conditions in the polycyclic systems, successfully maintained your position as the leading research worker in this field.

André Dreiding (Swiss, 1919–2013, Fig. 3.32) developed Dreiding stereomodel kits for physically building and showing organic molecular structures.

Richard August Carl Emil Erlenmeyer (German, 1825–1909, Fig. 3.32) had a long career working in many different areas of organic chemistry and biochemistry, but he is best remembered for the Erlenmeyer flask and the Erlenmeyer rule.

Hermann von Fehling (1812–1885, Fig. 3.32) is famous for developing Fehling's solution for detecting sugars, which has since been widely used everywhere from public school classrooms to hospital laboratories.

Hermann Emil Fischer (German, 1852–1919, Fig. 3.35) is remembered for many innovations such as Fischer esterification and Fischer projection. He won the Nobel Prize in Chemistry in 1902 for his work on the synthesis of sugars and purines. Professor Hj. Théel, President of the Swedish Royal Academy of Sciences, praised his research [https://www.nobelprize.org/prizes/chemistry/1902/ceremony-speech/]:

> With surprisingly acute judgement and with brilliant discernment in choosing his ways and means Fischer not only reproduced synthetically natural grape- and fruit-sugars, but also some thirty other sugars and an abundance of closely related compounds. Whereas of the naturally occurring, simple sugars only those with 5-6 carbon atoms have been found, Fischer synthesized a continuous series containing from 2 to 9 carbon atoms. Furthermore, by his elegant method of making glucosides artificially, he has also added to the achievements of organic synthesis this group which is so extraordinarily important for vegetable physiology. [...]
>
> Even since 1776 when Scheele found uric acid in urinary calculus, several substances closely related to it such as xanthine, adenine and guanine, etc. have been detected in animal secretions. The same group additionally includes theobromine, theophylline and caffeine which occur in the vegetable kingdom and constitute the stimulants in our staple beverages cocoa, coffee and tea. With the keen perception of the excellent scientist and a masterly technique Professor Fischer brought order and clarity to this field as well. He demonstrated that all those substances are derivatives of the same parent substance, purine, which he had discovered. He successfully prepared them from one another and from simpler constituents in such a way that here, too, the synthesized chain goes back to inorganic carbon, hydrogen and oxygen, and besides these he prepared a large number of new, closely related substances so that the purine derivatives studied by Fischer must now number about 150. The intrinsic composition of each has been fully determined.

Wilhelm Rudolph Fittig (German, 1835–1910, Fig. 3.35) worked in several areas of organic chemistry during his career and discovered several new molecules and new types of organic reactions. His name is most closely associated with the Fittig reaction for the synthesis of alkylbenzene molecules.

Hermann Frasch (1851–1914, Fig. 3.35) spent most of his career using organic chemistry to improve processes in oil refining.

Karl Fries (German, 1875–1962, Fig. 3.35) received his Ph.D. under Theodor Zincke and is best known for discovering the Fries rearrangement of phenolic ester molecules.

Ludwig Gattermann (1860–1920, Fig. 3.35) wrote a widely used textbook of experimental methods in organic synthesis. He also discovered new methods such as the Gattermann reaction.

Carl Glaser (German, 1841–1935, Fig. 3.35) developed Glaser coupling, which was later used to synthesize indigo dye and other important organic molecules.

Irma Goldberg (Russian but educated in Switzerland and worked in Switzerland and Germany, 1871–<1939, Fig. 3.36) worked with and married Fritz Ullmann. She developed several synthetic dye molecules and is remembered for the Goldberg amidation reaction.

Fritz Haber (German, 1868–1934, Fig. 3.36) studied carbon-carbon and carbon-hydrogen bond strengths and other topics in organic chemistry, in addition to his better known work on ammonia synthesis in inorganic chemistry (for which he won the 1918 Nobel Prize in Chemistry—see p. 447).

Arthur Hantzsch (German, 1857–1935, Fig. 3.36) developed Hantzsch pyridine synthesis and Hantzsch pyrrole synthesis.

Kurt Hoesch (German, 1882–1932, Fig. 3.36) focused on the synthesis of phenylketone molecules and developed the Hoesch reaction for that purpose.

Erich Hückel (German, 1896–1980, Fig. 3.36) is famous for the Hückel molecular orbital theory, as well as his contributions to physical chemistry such as the Debye-Hückel theory for electrolysis.

Rolf Huisgen (German, 1920–, Fig. 3.36) studied the reaction mechanisms involved in each step of synthesizing organic molecules, and personally developed the Huisgen reaction.

Claire Hunsdiecker (German, 1903–1995, Fig. 3.37) and Heinz Hunsdiecker (German, 1904–1981, Fig. 3.37) received their Ph.D.s in chemistry, married, and spent their lives conducting research in organic chemistry. They are best known for the Hunsdiecker reaction.

Oskar Georg Friedrich Jacobsen (German, 1840–1889, Fig. 3.37) studied the distillation and components of coal tar, discovered the Jacobsen rearrangement, and pioneered the field of marine chemistry.

Karl Kastner (1783–1857, Fig. 3.37) helped to establish chemistry as a proper academic field of study. He taught Justus von Liebig, who in turn educated a huge number of important chemists.

August Kekulé (German, 1829–1896) figured out the chemical bonds and structure of benzene (1865) and other organic molecules; see Fig. 3.38.

Heinrich Kiliani (German, 1855–1945, Fig. 3.37) studied digitalis and carbohydrate chemistry, and developed (along with Emil Fischer) the Kiliani-Fischer synthesis of sugar molecules.

Emil Knoevenagel (German, 1865–1921, Fig. 3.37) focused on experimental methods of synthesizing organic molecules and is remembered for the Knoevenagel condensation reaction.

Ludwig Knorr (German, 1859–1921, Fig. 3.39) developed processes such as Knorr quinoline synthesis and Knorr pyrrole synthesis, and synthesized phenazone, an aspirin-like drug molecule (p. 269).

Hermann Kolbe (German, 1818–1884, Fig. 3.39) helped to formalize the field of organic chemistry and coined the term "synthesis." His name is associated with Kolbe electrolysis, Kolbe nitrile synthesis, and the Kolbe-Schmitt reaction.

Wilhelm Körner (1839–1925, Fig. 3.39) studied many aromatic compounds as well as biochemical molecules from plants.

Albert Ladenburg (1842–1911, Fig. 3.39) purified scopolamine (which is now used to treat nausea) and synthesized other alkaloid drug molecules.

Carl Mannich (German, 1877–1947, Fig. 3.39) worked in several different areas of organic chemistry, including keto bases and alcohol bases, and remains best known for the Mannich reaction.

Hans Meerwein (German, 1879–1965, Fig. 3.39) developed or determined the mechanisms of several key organic synthesis reactions, leading to his name being associated with methods such as Meerwein arylation, Meerwein's salt, Meerwein-Ponndorf-Verley reduction, and the Wagner-Meerwein rearrangement.

Jakob Meisenheimer (German, 1876–1934, Fig. 3.40) synthesized and determined the structures of a number of organic molecules, most notably the class of molecules that are now known as the Meisenheimer complex.

Julius Lothar Meyer (German, 1830–1895, Fig. 3.40) made his greatest contribution to chemistry by developing the periodic table of the elements (p. 444), but he also did important work in organic chemistry, such as studying the structure of benzene.

Karl Meyer (German, 1899–1990, Fig. 3.40) did fundamental research on polysaccharide molecules such as hyaluronan, a component of many human cells and some bacteria.

Kurt Hans Meyer (German, 1883–1952, Fig. 3.40) received his Ph.D. under Arthur Hantzsch and studied a wide variety of organic reactions over the course of his career.

Viktor Meyer (German, 1848–1897, Fig. 3.40) worked in both organic and inorganic chemistry. Among other accomplishments, he discovered thiophene and developed the Viktor Meyer apparatus for measuring vapor densities.

Eilhard Mitscherlich (German, 1794–1863, Fig. 3.40) did important research in the fields of crystallography, inorganic chemistry, and organic chemistry. In organic chemistry, he is best known for his experiments on benzene derivatives.

Costin D. Nenitzescu (Romanian, educated in Switzerland and Germany, 1902–1970, Fig. 3.41) studied under Hans Fischer and went on to a long career synthesizing and identifying organic molecules. Nenitzescu synthesis is named for him.

George Olah (Oláh György, Hungarian, 1927–2017, Fig. 3.41) won the Nobel Prize in Chemistry in 1994 for his work on carbocations. Professor Salo Gronowitz of the Royal Swedish Academy of Sciences explained his discoveries [https://www.nobelprize.org/prizes/chemistry/1994/ceremony-speech/]:

> Because it was not possible to detect carbocations with spectroscopic methods, different scientists interpreted their experiments differently, and a scientific feud took place in organic chemistry during the 1960s and 1970s.
>
> Through a series of brilliant experiments Professor George Olah solved the problem. He created methods to prepare long-lived carbocations in high concentrations, which made it possible to study their structure, stability and reactions with spectroscopic methods. He achieved this by using special solvents, which did not react with the cations. He observed that in these solvents at low temperatures, carbocations could be prepared with the aid of superacids, acids eighteen powers of ten stronger than concentrated sulfuric acid. Through Olah's pioneering work he and the scientists who followed in his footsteps could obtain detailed knowledge about the structure and reactivity of carbocations. Olah's discovery resulted in a complete revolution for scientific studies of carbocations, and his contributions occupy a prominent place in all modern textbooks of organic chemistry.
>
> Olah found that there are two groups of carbocations, the trivalent ones called carbenium ions, in which the positive carbon atom is surrounded by three atoms, and those in which the positive carbon is surrounded by five atoms, called carbonium ions. The disputed existence of these penta-coordinated carbocations was the reason for the scientific feud. By providing convincing proof that penta-coordinated carbocations exist, Olah demolished the dogma that carbon in organic compounds could at most be tetra-coordinated, or bind a maximum of four atoms. This had been one of the cornerstones of structural organic chemistry since the days of Kekulé in the 1860s.
>
> Olah found that the superacids were so strong that they could donate a proton to simple saturated hydrocarbons, and that these penta-coordinated carbonium ions could undergo further reactions. This fact has contributed to a better understanding of the most important reactions in petrochemistry. His discoveries have led to the development of methods for the isomerization of straight chain alkanes, which have low octane numbers when used in combustion engines, to produce branched alkanes with high octane numbers. Furthermore, these branched alkanes are important as starting materials in industrial syntheses. Olah has also shown that with the aid of superacids it is possible to prepare larger hydrocarbons with methane as the building block. With superacid catalysis it is also possible to crack heavy oils and liquefy coal under surprisingly mild conditions.

Wilhelm Ostwald (1853–1932, Fig. 3.41) made a number of important contributions in organic chemistry, catalytic chemistry, and physical chemistry. He won the Nobel Prize in Chemistry in 1909 (p. 913).

Hans von Pechmann (German, 1850–1902, Fig. 3.41) synthesized or discovered several new organic molecules and is remembered for Pechmann condensation and Pechmann pyrazole synthesis.

Fritz Pregl (Austrian, 1869–1930, Fig. 2.52) developed important methods for quantitative organic microanalysis that have been widely used ever since. For that work, he won the Nobel Prize in Chemistry in 1923. Professor O. Hammarsten, Chairman of the Nobel Committee for Chemistry, announced the award [https://www.nobelprize.org/prizes/chemistry/1923/ceremony-speech/]:

> The improvement consists of the fact that Pregl converted previously used methods for quantitative analysis of relatively large quantities of substances to micro-analytical methods. This has made it possible to carry out these analyses of such small quantities of substances, the analysis of which would previously have been impossible, with exactly the same accuracy, but with great savings in time, labour, and expense. [...]
>
> Pregl's micro-analysis can be equally well applied in all fields of organic chemistry. It has already proved itself in a great number of cases, and has stood the test in this country as well. It opens promising prospects for research in the future, particularly in the vast field of biochemistry. There is every reason to hope that micro-analysis will make possible fruitful study of a great number of substances which so far, in some respects at least, have been practically inaccessible to exact chemical investigation. Such substances, for instance, include enzymes, vitamins and hormones, the extremely great significance of which for the vital processes is well known.

Vladimir Prelog (Austro-Hungarian/Croatian, 1906–1998, Fig. 3.41) made many important discoveries regarding the stereochemistry of organic molecules and the shapes of enzymes, for which he won the Nobel Prize in Chemistry in 1975. Professor Arne Fredga of the Royal Academy of Sciences explained his research [https://www.nobelprize.org/prizes/chemistry/1975/ceremony-speech/]:

> Professor Prelog has worked in many fields of stereochemistry, and often the problems have been connected with the geometrical shapes of the molecules and their influence on the course of the reactions. [...]
>
> Professor Prelog has also made important contributions to enzyme chemistry. He has studied enzymatic reactions on small molecules and in particular oxidation or reduction processes. The experiments may be more or less successful depending on how the enzyme and the other molecule fit together geometrically. By systematic experiments with various small molecules of well-defined shapes, it was possible to construct a "map" of the active part of the enzyme molecule. The results have recently been confirmed in a special case by Swedish scientists using x-ray methods.
>
> Professor Prelog has also with ingenuity and penetration discussed and analysed the fundamental concepts of stereochemistry, not least the conditions for chirality in large and complicated molecules.

Prelog also built up long-lasting research programs in the Kaštel/Pliva pharmaceutical company, leading to work on antibiotics from sulfa drugs to azithromycin.

Robert Pschorr (German, 1868–1930, Fig. 3.42) worked on the synthesis of complex organic molecules and is best known for Pschorr cyclization.

Rudolf Pummerer (Austrian, 1882–1973, Fig. 3.42) focused on the chemistry of sulfoxides and free radicals, and remains known for the Pummerer rearrangement.

Sergey Reformatsky (Russian but educated in Germany, 1860–1934, Fig. 3.42) studied organic synthesis and metal catalysts, and is remembered for the Reformatsky reaction.

Karl Reichenbach (German states, 1788–1869, Fig. 3.42) discovered many useful organic molecules, including phenol and paraffin.

Walter Reppe (German, 1892–1969, Fig. 3.42) was an enormously influential figure in applied organic chemistry, both in Germany and in other countries (through postwar reports on his chemical methods). His work focused on turning Germany's large natural supply of coal into acetylene, and then converting the acetylene into a vast variety of useful chemical molecules, a process that became known as Reppe chemistry.

Karl Wilhelm Rosenmund (German, 1884–1965, Fig. 3.42) received his Ph.D. under Otto Diels. His name is associated with Rosenmund reduction and the Rosenmund-von Braun reaction.

Otto Ruff (German, 1871–1939, Fig. 3.43) conducted important work in high-temperature chemistry, the chemistry of sugars, polymers, and other areas of organic chemistry. He is best known for Ruff degradation.

Traugott Sandmeyer (Swiss, 1854–1922, Fig. 3.43) was an expert at synthesizing complex organic molecules. He is still remembered for the Sandmeyer reaction and Sandmeyer synthesis.

Rudolf Schmitt (German, 1830–1898, Fig. 3.43), along with his Ph.D. advisor Adolph Kolbe, discovered the Kolbe-Schmitt reaction. He also conducted research on salicylic acid and other areas of organic chemistry.

As illustrated in Fig. 3.44, Carl Schotten (German, 1853–1910) and Eugen Baumann (German, 1846–1896) developed Schotten-Baumann reactions (1883), which are used to synthesize a wide variety of useful organic molecules.

Hermann Staudinger (German, 1881–1965, Fig. 3.43) made an enormous number of contributions in the fields of organic chemistry, polymers, and colloids. He discovered ketene molecules and the Staudinger reaction, and won the Nobel Prize in Chemistry in 1953. Professor A. Fredga, a member of the Nobel Committee for Chemistry, praised his work [https://www.nobelprize.org/prizes/chemistry/1953/ceremony-speech/]:

> Professor Staudinger. More than thirty years ago you expressed the view that a chemical molecule can attain an almost arbitrary size and that such macromolecules are of great importance in our world. Your view was based on logical reasoning. You drew attention to the fact that what are termed high polymers are formed when for some reason or another an anticipated ring closure fails to occur. You thus submitted an argument which an organic chemist cannot ignore. Moreover, in extensive and painstaking series of studies you have provided experimental proof.

Johann Stobbe (German, 1860–1938, Fig. 3.33) is best known for developing Stobbe condensation, a step that ever since then has been widely utilized in the synthesis of organic molecules.

Adolph Strecker (German, 1822–1871), Friedrich Gustav Carl Emil Erlenmeyer, Jr. (German, 1864–1921), Fritz Arndt (German, 1885–1969), and Bernd Eistert (German, 1902–1978) developed methods to artificially synthesize amino acids, the building blocks of proteins. See Fig. 3.45.

Johannes Thiele (German, 1865–1918, Fig. 3.43) synthesized a number of novel types of organic molecules and is still known for the Thiele tube.

Bernhard Tollens (German, 1841–1918, Fig. 3.43) determined the structures of several sugar molecules and developed the Tollens reagent.

Alfred Treibs (German, 1899–1983, Fig. 3.46) founded organic geochemistry. He discovered porphyrin molecules in petroleum, proving that petroleum originated from ancient plants and animals.

Fritz Ullmann (German, 1865–1939, Fig. 3.46) worked with and married Irma Goldberg. He developed several synthetic dye molecules and is remembered for the Ullmann reaction and Ullmann condensation. He also edited the *Enzyklopädie der Technischen Chemie*, which has been updated by others since then and is still in use today.

Jacobus Hendricus van 't Hoff (Dutch, 1852–1911, Fig. 3.46) made many important discoveries in the stereochemistry of organic molecules as well as in physical chemistry. He won the Nobel Prize in Chemistry in 1901. C.T. Odhner, President of the Royal Swedish Academy of Sciences, described his research [https://www.nobelprize.org/prizes/chemistry/1901/ceremony-speech/]:

> As a result of his investigations in the fields of atomic and molecular theory van 't Hoff has made the most important discoveries in theoretical chemistry since Dalton's time.
>
> With regard to atomic theory van 't Hoff, following an idea put forward by Pasteur, advanced the hypothesis that the elementary atoms have attachment points geometrically oriented in space—a hypothesis which in so far as carbon compounds are concerned led to the theory of the asymmetry of carbon atoms and to the founding of stereochemistry.
>
> Still more revolutionary were van 't Hoff's discoveries in the field of molecular theory. van 't Hoff's investigations showed that the law, which has been named after the Italian Avogadro, according to which the number of gas molecules in a given volume is the same for all gases at the same pressure and temperature, embraces not only substances in the gaseous phase but also those in solution, provided that their pressure, known as osmotic pressure, is taken into account in the same way as the gas pressure in the case of gases. He proved that gas pressure and osmotic pressure are identical, and thereby that the molecules themselves in the gaseous phase and in solutions are also identical. As a result of this the concept of the molecule in chemistry was found to be definite and universally valid to a degree hitherto undreamed-of. He also discovered how to express the state of chemical equilibrium in reactions and the electromotive force which a reaction can produce; he explained how the transition occurs between the various modifications of the elements, between hydrates of differing water contents, how double salts are formed, etc.
>
> By applying these simple principles, which were originally borrowed from mechanics and thermodynamics, van 't Hoff became one of the founders of chemical dynamics.

Jacob Volhard (1834–1910, Fig. 3.46) and his student Hugo Erdmann discovered the Volhard-Erdmann cyclization reaction. Volhard also trained several other students who went on to make great discoveries, most notably Hermann Staudinger.

Otto Wallach (German, 1847–1931, Fig. 3.46) focused on organic molecules that are alicyclic, or both aliphatic and cyclic. His name is associated with the Wallach rearrangement, Wallach degradation, and Wallach's rule. He won the Nobel Prize in Chemistry 1910, and Professor O. Montelius, President of the Royal Swedish Academy of Sciences, praised his research [https://www.nobelprize.org/prizes/chemistry/1910/ceremony-speech/]:

> Through this pioneering work Wallach opened up a new field for research, which could be investigated further with good hope of success. And it is true that this field was immediately tackled by a great number of research scientists in various countries. Organic chemistry, during the decade that followed, was characterized by the study of the so-called alicyclic compounds, among which the terpenes and the closely related types of camphor with their derivatives played the most important part. Wallach himself, by overcoming considerable difficulties with admirable success and though perseverance, made continuous progress in the field opened up by himself. An extraordinarily large number of compounds were prepared by him and he also determined their structure. Apart from the terpenes proper, he also investigated and scientifically characterized various previously known or newly discovered natural products, such as alcohols, ketones, sesquiterpenes and polyterpenes belonging to the terpene series, which in part are also of great significance in biological and technical respects. For this reason the alicyclic series has, since the middle of the eighties, assumed such size and importance as to make it the equal of the other three main series within organic chemistry. Wallach contributed more towards this than any other research scientist.
>
> Wallach's research activity did not only decisively influence theoretic chemistry, but also chemical industry, namely that branch of the industry which processes essential oils.

Conrad Willgerodt (German, 1841–1930, Fig. 3.46) studied the chemistry of ketones, discovered iodosobenzene, and is still remembered for the Willgerodt reaction.

Johannes Wislicenus (German, 1835–1902, Fig. 3.47) made a number of important discoveries regarding the stereochemistry of organic molecules.

Georg Wittig (German, 1897–1987, Fig. 3.47) is famous for the Wittig reaction and the Wittig rearrangement. He developed a new method to produce alkenes, or hydrocarbon molecules containing double bonds, for which he won the Nobel Prize in Chemistry in 1979. Professor Bengt Lindberg of the Royal Academy of Sciences explained the importance of Wittig's work [https://www.nobelprize.org/prizes/chemistry/1979/ceremony-speech/]:

> Georg Wittig has provided many significant contributions in organic chemistry. The most important of these is the discovery of the synthetic method which bears his name, the Wittig reaction. In this, phosphorus ylides, a type of compound which he discovered, are allowed to react with carbonyl compounds. An exchange of groups takes place and the result is a compound in which two carbon atoms have been joined by a double bond. Since many natural products with biological activity contain such bonds, this elegant

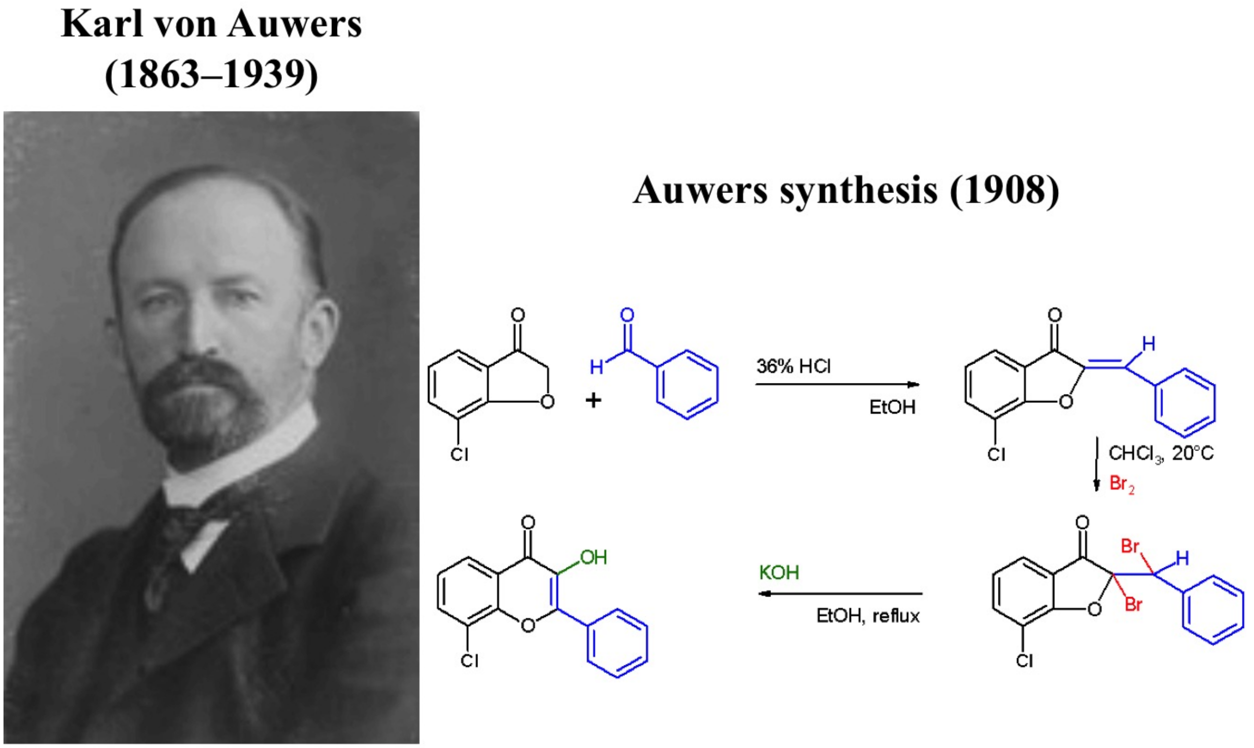
> method has found wide-spread use, for example in the industrial synthesis of vitamin A.

Alfred Wohl (German, 1863–1933, Fig. 3.47) worked in sugar chemistry, developed novel catalysts, and is remembered for Wohl degradation, the Wohl-Aue reaction, and the Wohl-Ziegler reaction.

Ludwig Wolff (German, 1857–1919, Fig. 3.47) received his Ph.D. under Rudolph Fittig and conducted important research in organic chemistry; his name is now associated with the Wolff rearrangement and the Wolff reduction.

Charles Adolphe Wurtz (Franco-German, studied in Germany, 1817–1884, Fig. 3.47) discovered the aldol reaction, what is now called the Wurtz reaction, ethylamine, and ethylene glycol.

Ernst Carl Theodor Zincke (German, 1843–1928, Fig. 3.47) received his Ph.D. under Friedrich Wöhler, and in turn was the doctoral advisor of Otto Hahn. He made many organic chemistry discoveries for which he is remembered, such as Zincke reaction, Zincke nitration, Zincke-Suhl reaction, etc.


Karl von Auwers
(1863–1939)
Auwers synthesis (1908)
36% HCl
EtOH
CHCl3, 20°C
Br2
KOH
EtOH, reflux
O
H
Cl
OH
Br

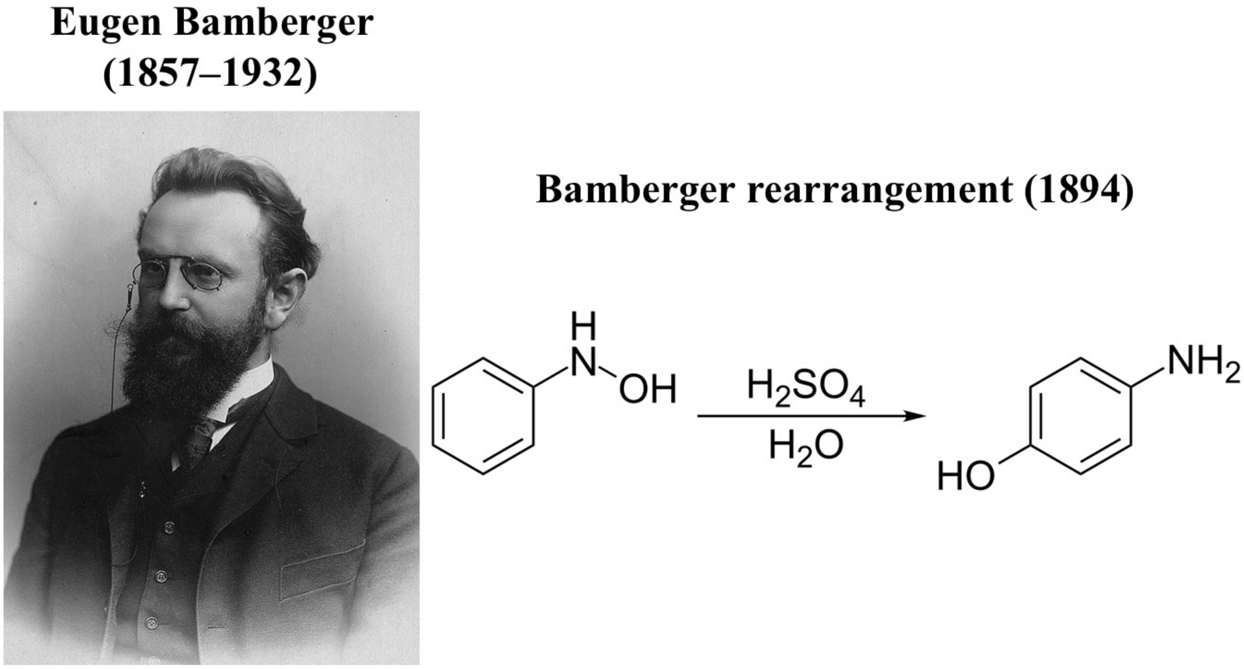
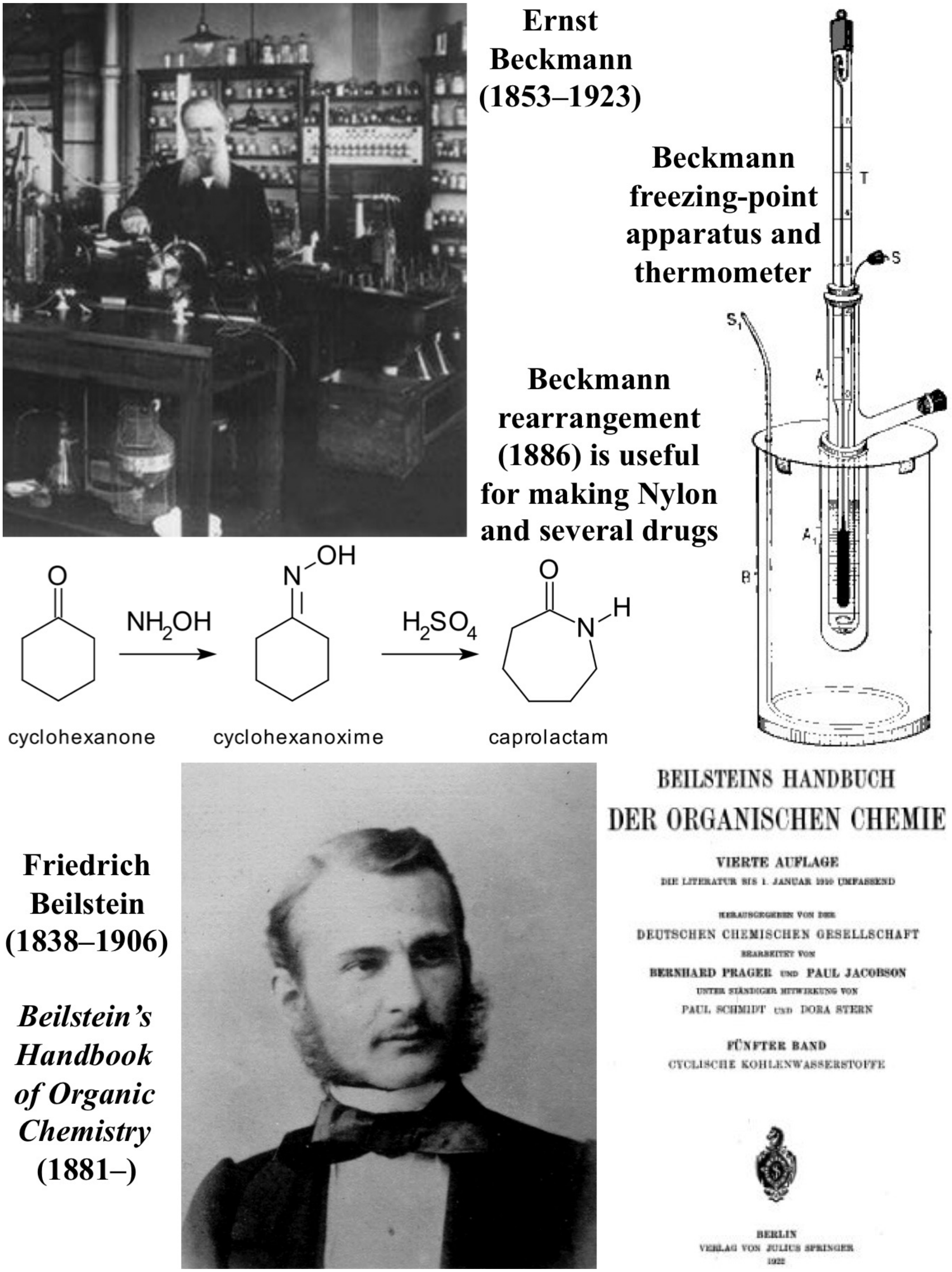

Eugen Bamberger
(1857–1932)
Bamberger rearrangement (1894)
H
N
OH
H2SO4
H2O
NH2
HO

Figure 3.29: Karl von Auwers developed Auwers synthesis in 1908, and Eugen Bamberger discovered the Bamberger rearrangement in 1894.



Ernst Beckmann (1853–1923)

Beckmann freezing-point apparatus and thermometer

Beckmann rearrangement (1886) is useful for making Nylon and several drugs

Friedrich Beilstein (1838–1906)

***Beilstein's Handbook of Organic Chemistry* (1881–)**

BEILSTEINS HANDBUCH
DER ORGANISCHEN CHEMIE

VIERTE AUFLAGE
DIE LITERATUR BIS 1. JANUAR 1910 UMFASSEND

HERAUSGEGEBEN VON DER
DEUTSCHEN CHEMISCHEN GESELLSCHAFT
BEARBEITET VON
BERNHARD PRAGER UND PAUL JACOBSON
UNTER STÄNDIGER MITWIRKUNG VON
PAUL SCHMIDT UND DORA STERN

FÜNFTER BAND
CYCLISCHE KOHLENWASSERSTOFFE

BERLIN
VERLAG VON JULIUS SPRINGER
1922

Figure 3.30: Ernst Beckmann developed the Beckmann rearrangement (1886), which later proved extremely useful for making Nylon and several drugs. He also invented the Beckmann freezing-point apparatus and thermometer. Friedrich Beilstein created the encyclopedic *Beilstein's Handbook of Organic Chemistry*.

Ernst Bergmann (1903–1975) Organic & fluorine chemistry, Israeli nuclear program

Julius von Braun (1875–1939) von Braun reaction, Rosenmund-von Braun reaction

Julius Bredt (1855–1937) Bredt's rule, Bredt distributor, structure of camphor

Hans Theodor Bucherer (1869–1949) Bucherer reaction, Bucherer carbazole synthesis, Bucherer-Bergs reaction

George Büchi (1921–1998) Photochemical organic reactions

Ernst Büchner (1850–1924) Büchner flask, Büchner funnel

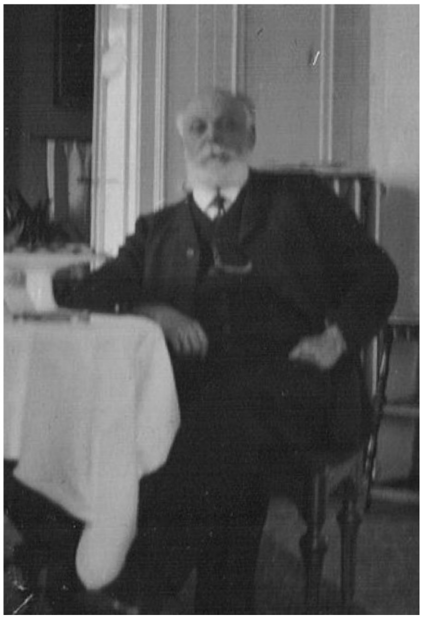


Figure 3.31: Other creators who made important contributions to organic chemistry included Ernst Bergmann, Julius von Braun, Julius Bredt, Hans Theodor Bucherer, George Büchi, and Ernst Büchner.

Robert Bunsen
(1811–1899)
Organic arsenides,
organic photochemistry

Rudolf Criegee
(1902–1975)
Criegee rearrangement,
Criegee intermediate

Theodor Curtius
(1857–1928)
Hydrazine, Curtius
rearrangement

André Dreiding
(1919–2013)
Organic
molecular
structures

Richard August Carl
Emil Erlenmeyer
(1825–1909)
Erlenmeyer rule,
Erlenmeyer flask

Hermann von Fehling
(1812–1885)
Fehling's solution
for detecting
sugars

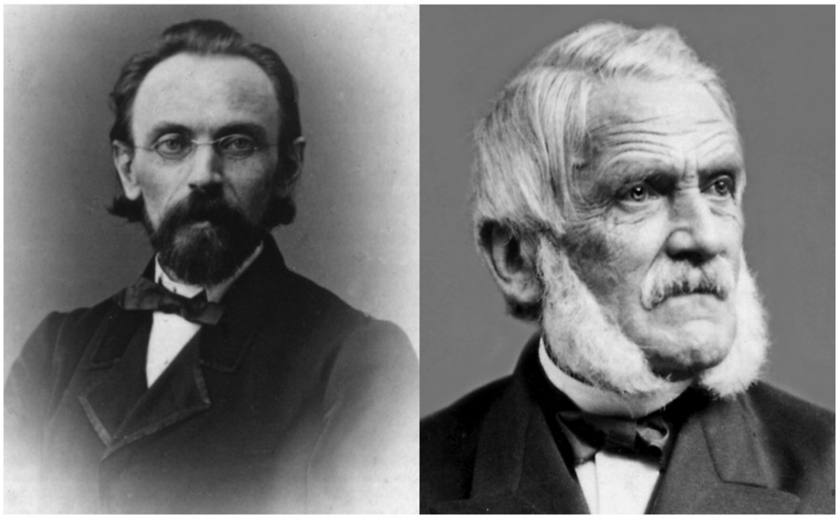


Figure 3.32: Other creators who made important contributions to organic chemistry included Robert Bunsen, Rudolf Criegee, Theodor Curtius, André Dreiding, Richard August Carl Emil Erlenmeyer, and Hermann von Fehling.

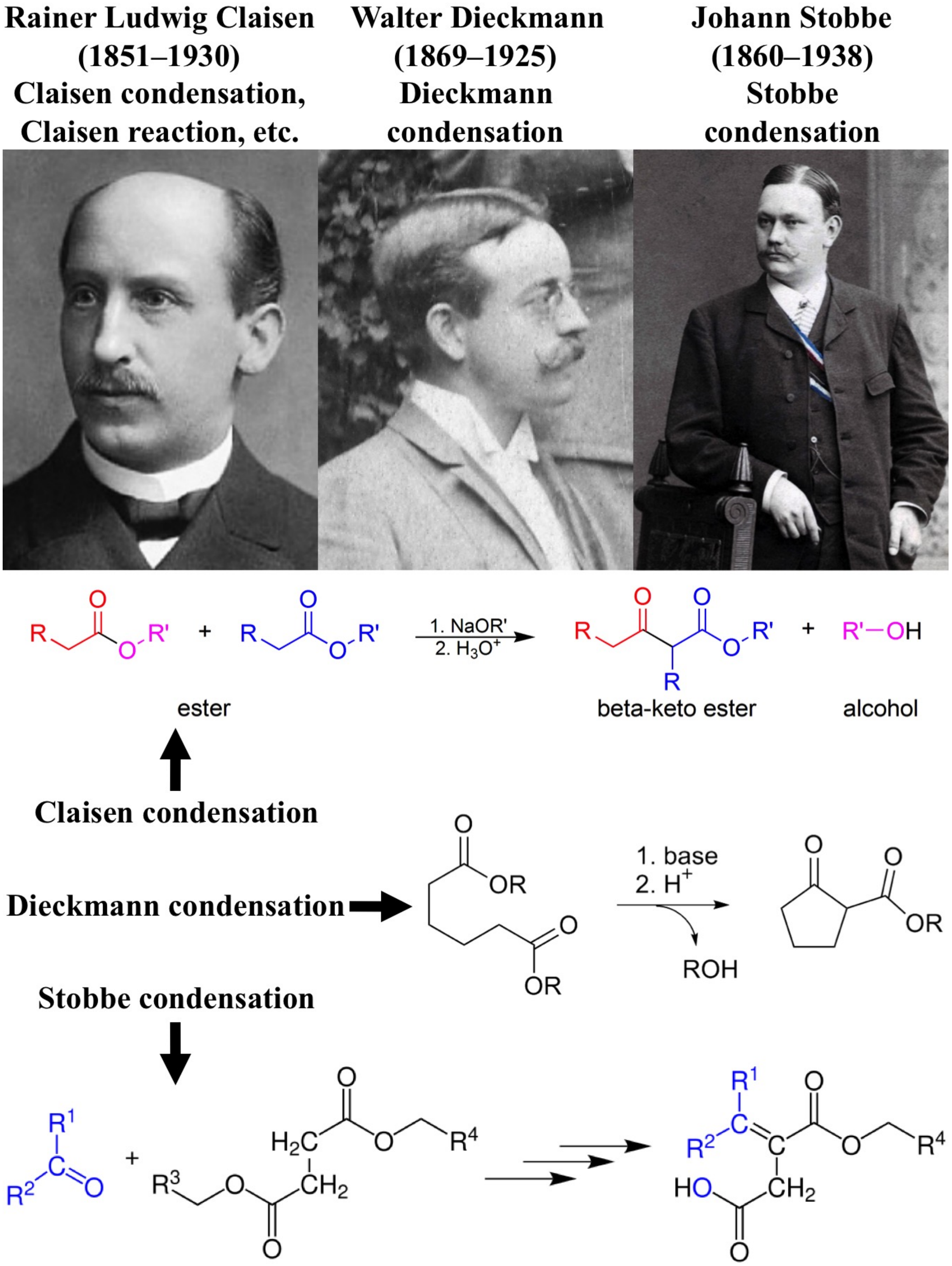
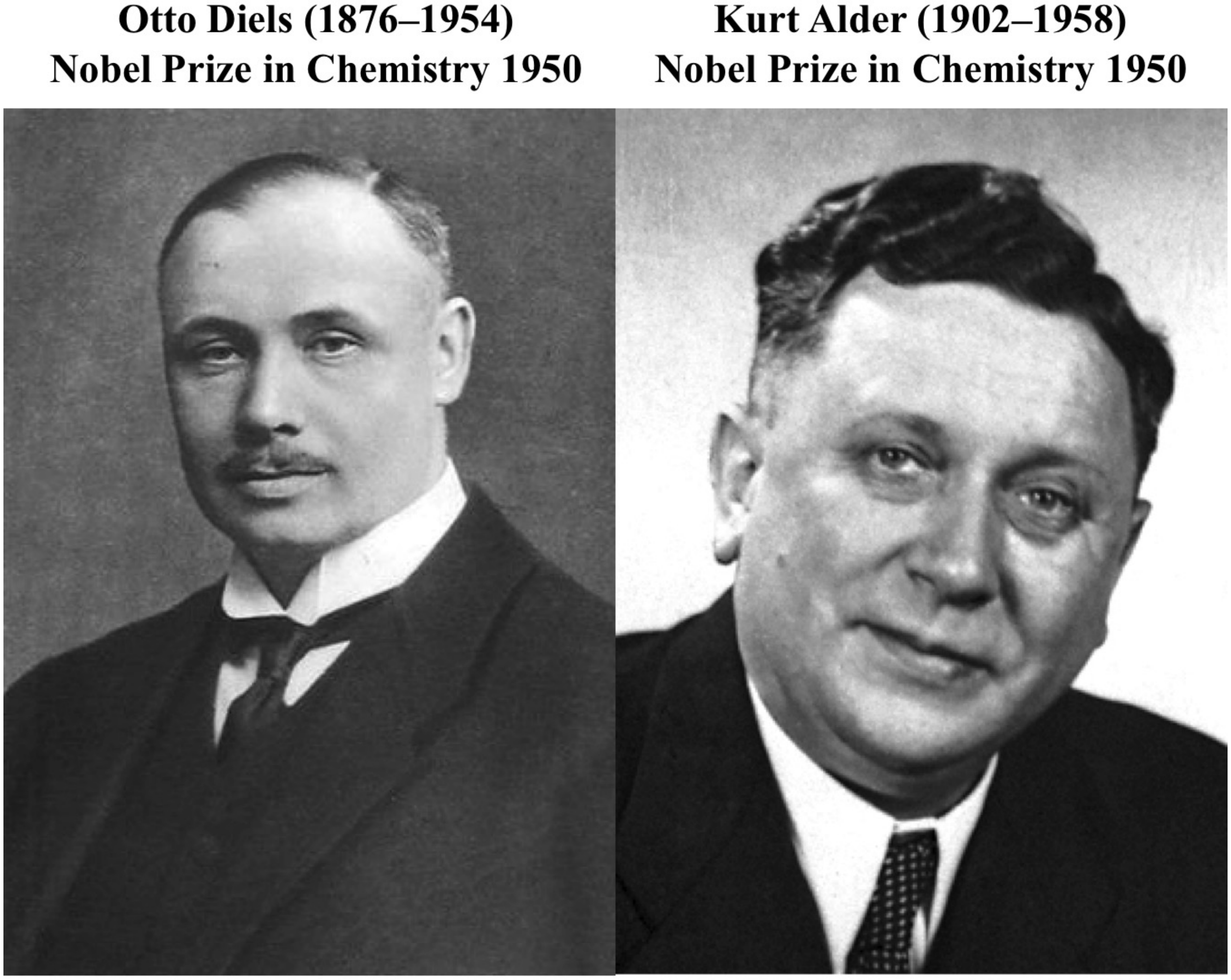
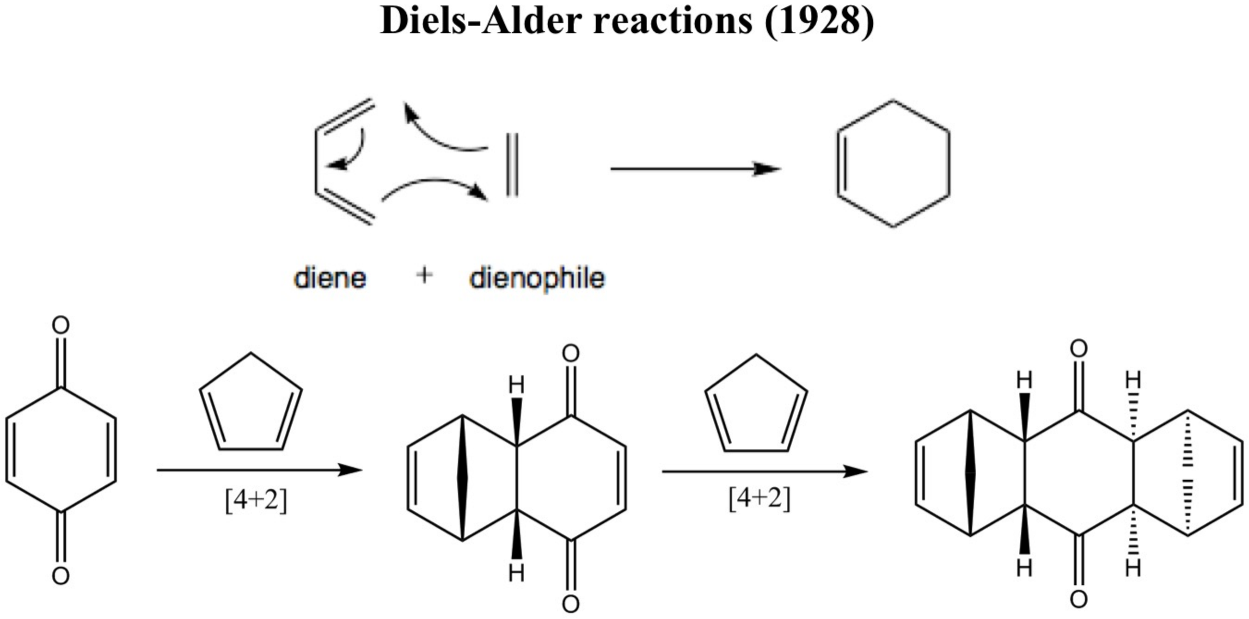

Rainer Ludwig Claisen
(1851–1930)
Claisen condensation,
Claisen reaction, etc.
Walter Dieckmann
(1869–1925)
Dieckmann
condensation
Johann Stobbe
(1860–1938)
Stobbe
condensation
1. NaOR'
2. H3O+
ester
beta-keto ester
alcohol
Claisen condensation
Dieckmann condensation
1. base
2. H+
ROH
Stobbe condensation

Figure 3.33: Rainer Ludwig Claisen, Walter Dieckmann, and Johann Stobbe developed condensation reactions that have been widely used to synthesize organic molecules ever since.



Otto Diels (1876–1954)
Nobel Prize in Chemistry 1950

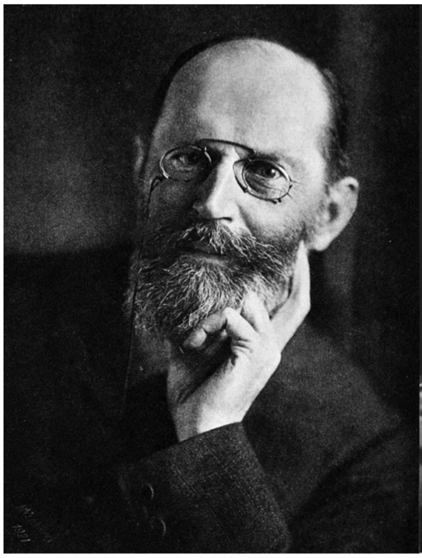
Kurt Alder (1902–1958)
Nobel Prize in Chemistry 1950



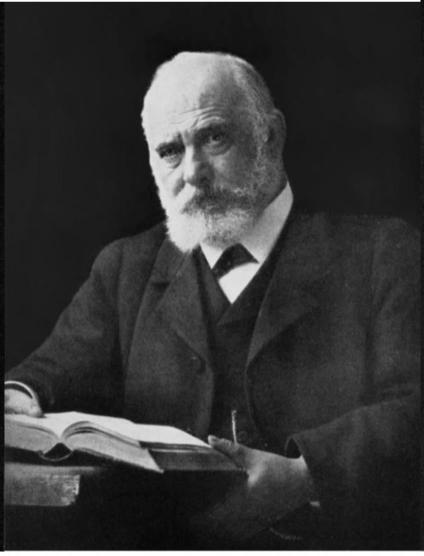
Diels-Alder reactions (1928)

Figure 3.34: Otto Diels and Kurt Alder developed Diels-Alder reactions (1928), which are very useful for producing polymers and other complex organic molecules. They both won the Nobel Prize in Chemistry in 1950.

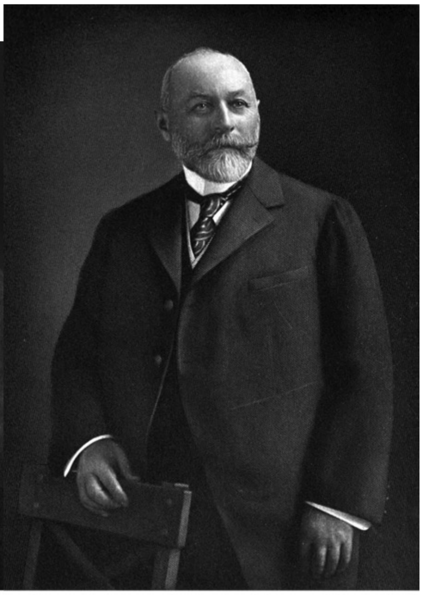
Hermann Emil Fischer
(1852–1919)
Fischer esterification,
Fischer projection, etc.



Wilhelm Rudolph
Fittig (1835–1910)
Many types of
organic reactions



Hermann Frasch
(1851–1914)
Oil refining



Karl Fries
(1875–1962)
Fries rearrangement

Ludwig Gattermann
(1860–1920)
Gattermann
reaction, etc.

Carl Glaser
(1841–1935)
Glaser coupling

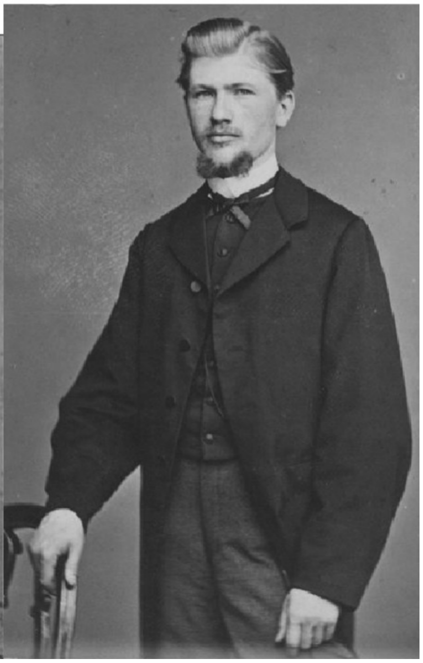


Figure 3.35: Other creators who made important contributions to organic chemistry included Hermann Emil Fischer, Wilhelm Rudolph Fittig, Hermann Frasch, Karl Fries, Ludwig Gattermann, and Carl Glaser.

Irma Goldberg
(1871–<1939)
Goldberg
amidation
reaction

Fritz Haber
(1868–1934)
Carbon-carbon and
carbon-hydrogen
bond strength, etc.

Arthur
Hantzsch
(1857–1935)
Hantzsch
synthesis

Kurt Hoesch
(1882–1932)
Hoesch
reaction

Erich Hückel
(1896–1980)
Hückel Molecular
Orbital Theory, etc.

Rolf Huisgen
(1920–)
Huisgen
reaction

Figure 3.36: Other creators who made important contributions to organic chemistry included Irma Goldberg, Fritz Haber, Arthur Hantzsch, Kurt Hoesch, Erich Hückel, and Rolf Huisgen.

Cläre Hunsdiecker
(1903–1995)
Hunsdiecker
reaction

Heinz Hunsdiecker
(1904–1981)
Hunsdiecker
reaction

Oskar Georg
Friedrich Jacobsen
(1840–1889)
Jacobsen
rearrangement

Karl Kastner
(1783–1857)
Helped establish
academic chemistry,
taught von Liebig

Heinrich Kiliani
(1855–1945)
Kiliani-Fischer
synthesis
of sugars

Emil Knoevenagel
(1865–1921)
Knoevenagel
condensation

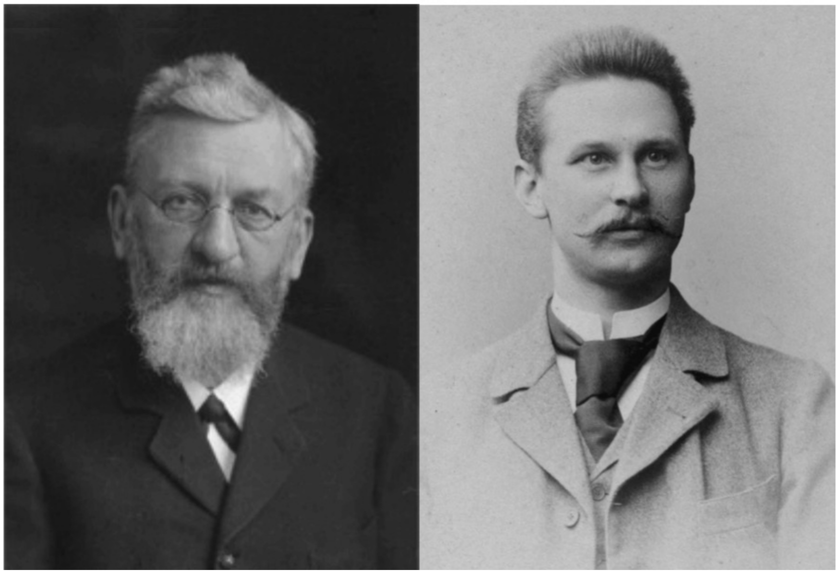
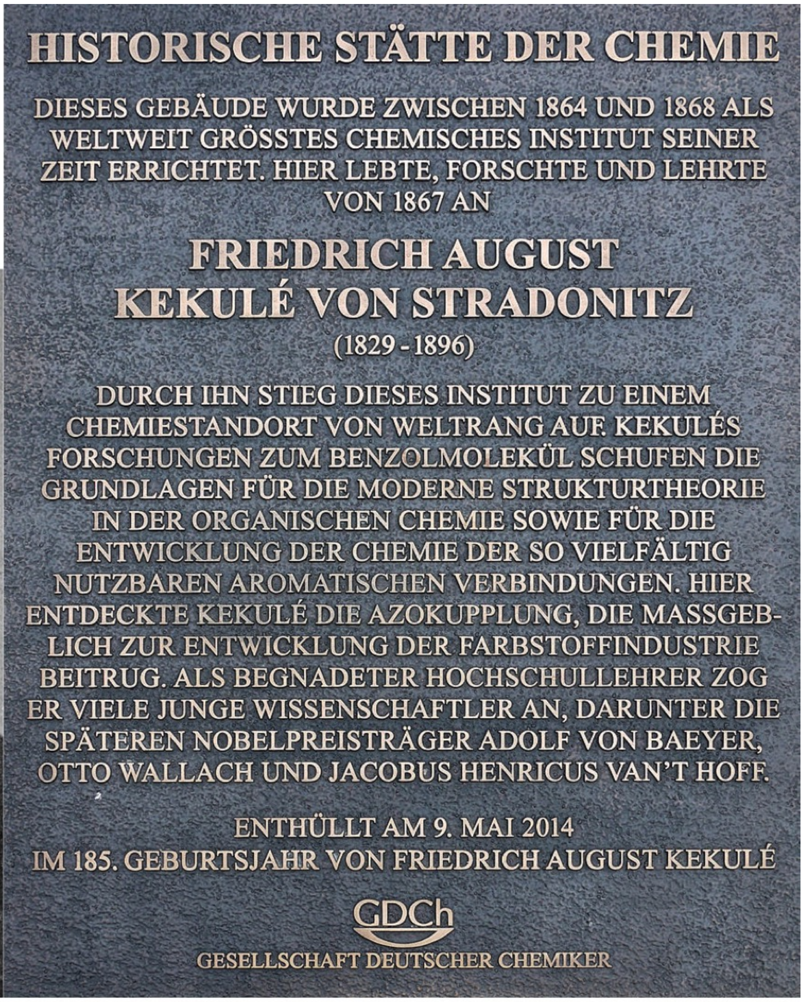


Figure 3.37: Other creators who made important contributions to organic chemistry included Cläre Hunsdiecker, Heinz Hunsdiecker, Oskar Georg Friedrich Jacobsen, Karl Kastner, and Heinrich Kiliani, and Emil Knoevenagel.

August Kekulé
(1829–1896)



HISTORISCHE STÄTTE DER CHEMIE

DIESES GEBÄUDE WURDE ZWISCHEN 1864 UND 1868 ALS WELTWEIT GRÖSSTES CHEMISCHES INSTITUT SEINER ZEIT ERRICHTET. HIER LEBTE, FORSCHTE UND LEHRTE VON 1867 AN

FRIEDRICH AUGUST
KEKULÉ VON STRADONITZ
(1829 - 1896)

DURCH IHN STIEG DIESES INSTITUT ZU EINEM CHEMIESTANDORT VON WELTRANG AUF. KEKULÉS FORSCHUNGEN ZUM BENZOLMOLEKÜL SCHUFEN DIE GRUNDLAGEN FÜR DIE MODERNE STRUKTURTHEORIE IN DER ORGANISCHEN CHEMIE SOWIE FÜR DIE ENTWICKLUNG DER CHEMIE DER SO VIELFÄLTIG NUTZBAREN AROMATISCHEN VERBINDUNGEN. HIER ENTDECKTE KEKULÉ DIE AZOKUPPLUNG, DIE MASSGEBLICH ZUR ENTWICKLUNG DER FARBSTOFFINDUSTRIE BEITRUG. ALS BEGNADETER HOCHSCHULLEHRER ZOG ER VIELE JUNGE WISSENSCHAFTLER AN, DARUNTER DIE SPÄTEREN NOBELPREISTRÄGER ADOLF VON BAEYER, OTTO WALLACH UND JACOBUS HENRICUS VAN'T HOFF.

ENTHÜLLT AM 9. MAI 2014
IM 185. GEBURTSJAHR VON FRIEDRICH AUGUST KEKULÉ

GDCh
GESELLSCHAFT DEUTSCHER CHEMIKER

Chemical bonds and structure of
benzene (1865) and other organic molecules

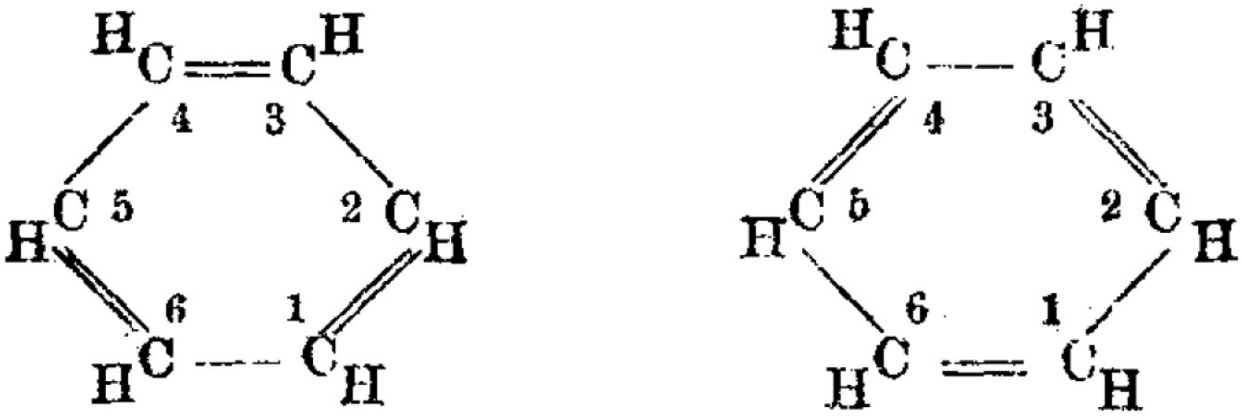
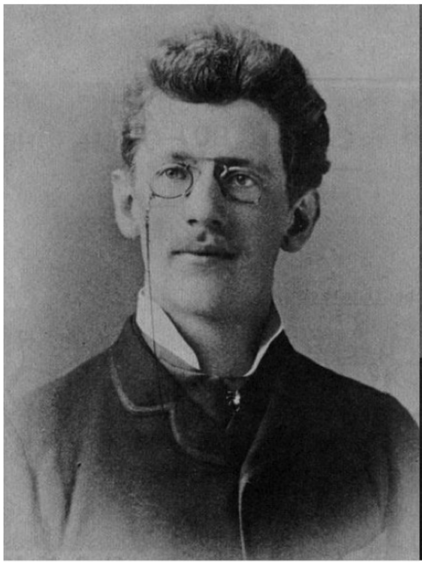


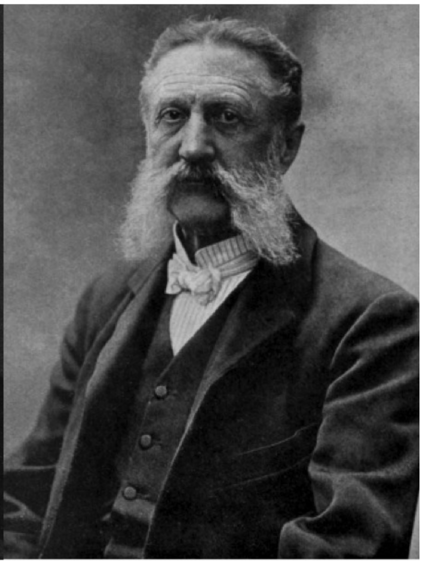
Figure 3.38: August Kekulé figured out the chemical bonds and structure of benzene (1865) and other organic molecules.

Ludwig Knorr
(1859–1921)
Knorr synthesis,
Phenazone

Hermann Kolbe
(1818–1884)
Kolbe electrolysis,
Kolbe nitrile synthesis,
Kolbe-Schmitt reaction

Wilhelm Körner
(1839–1925)
Aromatic
compounds





Albert Ladenburg
(1842–1911)
Synthesized alkaloids,
purified scopolamine

Carl Mannich
(1877–1947)
Mannich reaction

Hans Meerwein
(1879–1965)
Meerwein arylation,
Meerwein's salt, etc.

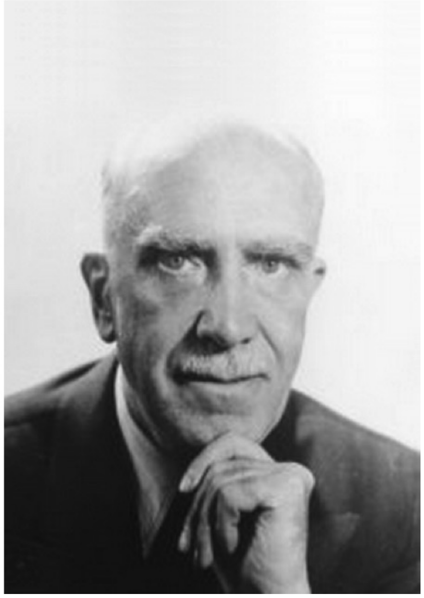


Figure 3.39: Other creators who made important contributions to organic chemistry included Ludwig Knorr, Hermann Kolbe, Wilhelm Körner, Albert Ladenburg, Carl Mannich, and Hans Meerwein.

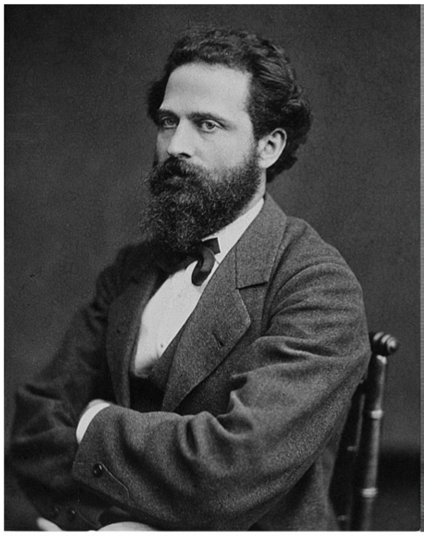
Jakob Meisenheimer
(1876–1934)
Meisenheimer complex

Julius Lothar Meyer
(1830–1895)
Benzene structure, etc.

Karl Meyer
(1899–1990)
Polysaccharides

Kurt Hans Meyer
(1883–1952)
Organic reactions

Viktor Meyer
(1848–1897)
Thiophene, etc.



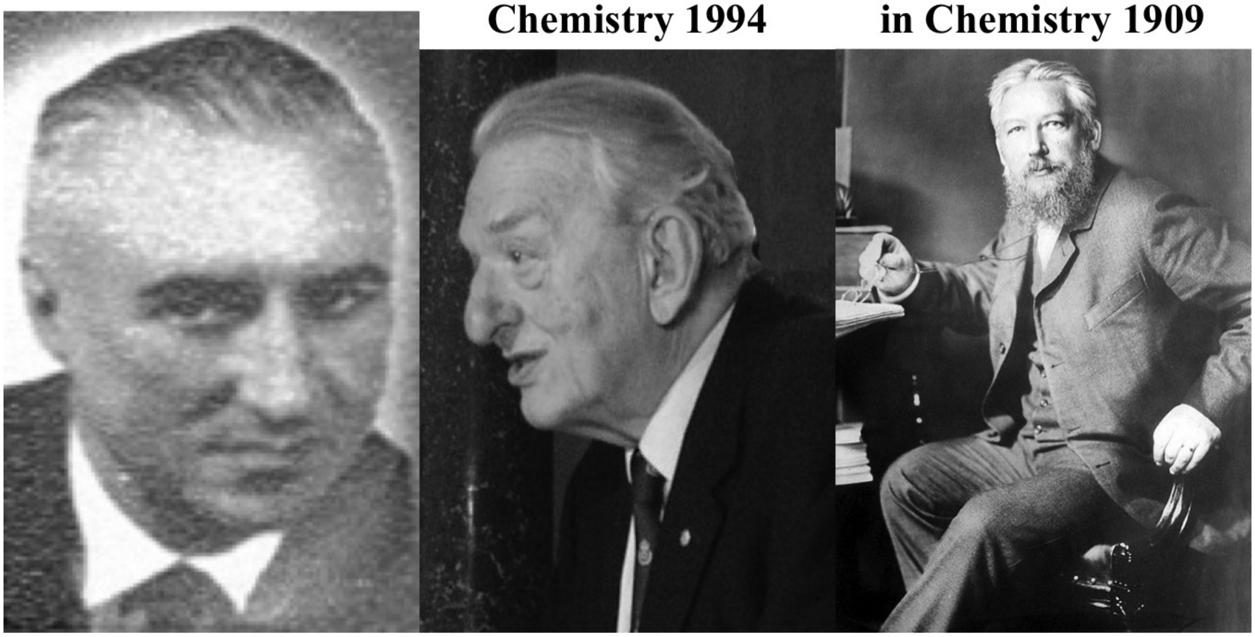
Eilhard Mitscherlich
(1794–1863)
Benzene derivatives

Figure 3.40: Other creators who made important contributions to organic chemistry included Jakob Meisenheimer, Julius Lothar Meyer, Karl Meyer, Kurt Hans Meyer, Viktor Meyer, and Eilhard Mitscherlich.

Costin D. Nenitzescu (1902–1970) Nenitzescu synthesis

George Olah (1927–2017) Carbocations, Nobel Prize in Chemistry 1994

Wilhelm Ostwald (1853–1932) Physical chemistry, catalysis, Nobel Prize in Chemistry 1909



Hans von Pechmann (1850–1902) Pechmann condensation, Pechmann pyrazole synthesis, etc.

Fritz Pregl (1869–1930) Quantitative organic microanalysis, Nobel Prize in Chemistry 1923

Vladimir Prelog (1906–1998) Stereochemistry, Nobel Prize in Chemistry 1975

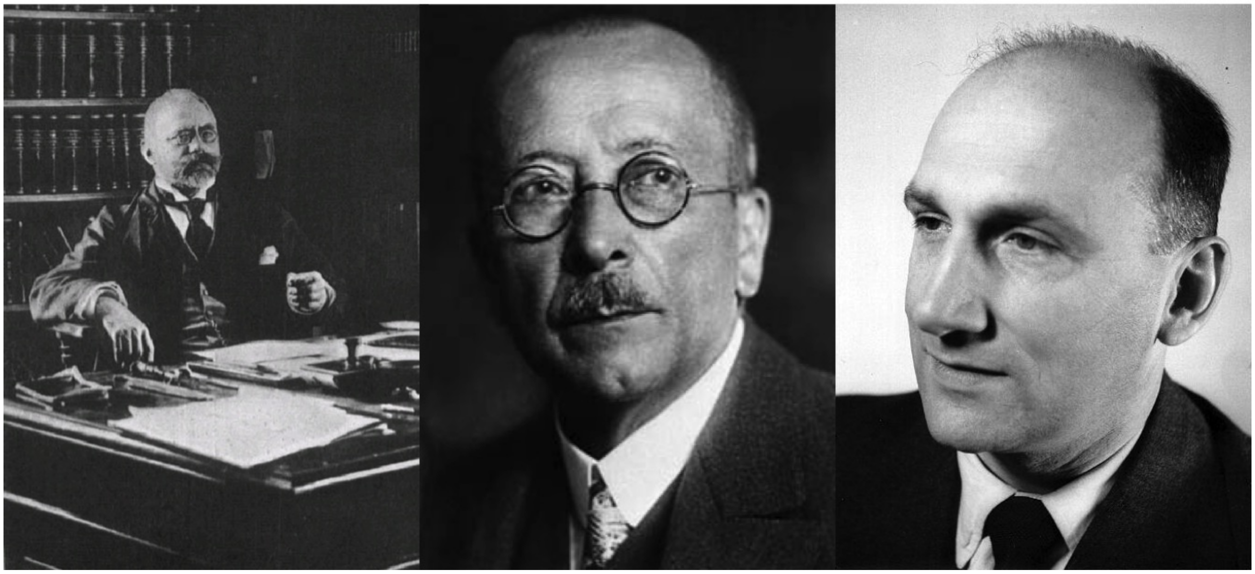
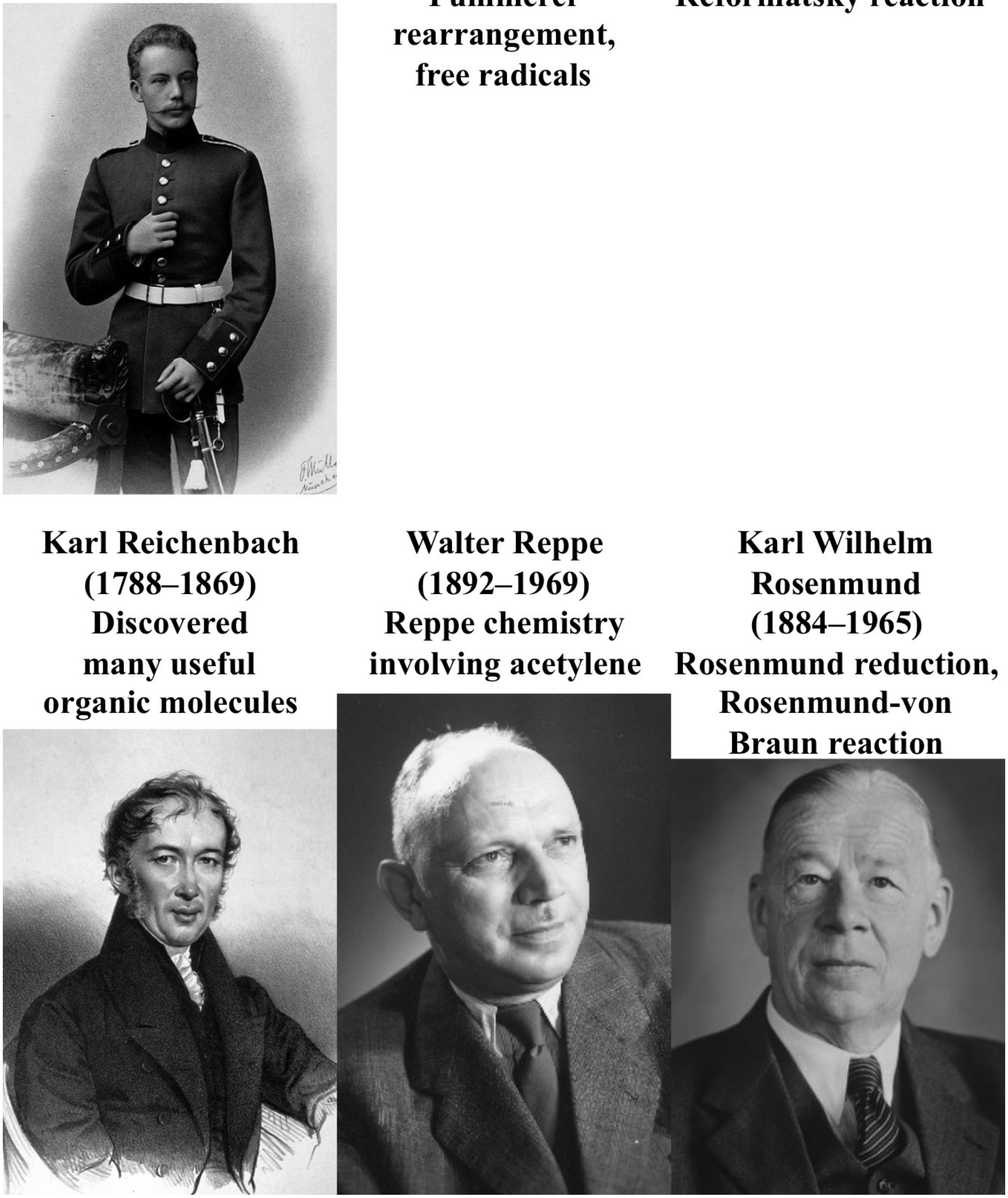


Figure 3.41: Other creators who made important contributions to organic chemistry included Costin D. Nenitzescu, George Olah, Wilhelm Ostwald, Hans von Pechmann, Fritz Pregl, and Vladimir Prelog.



Robert Pschorr
(1868–1930)
Pschorr cyclization

Rudolf
Pummerer
(1882–1973)
Pummerer
rearrangement,
free radicals

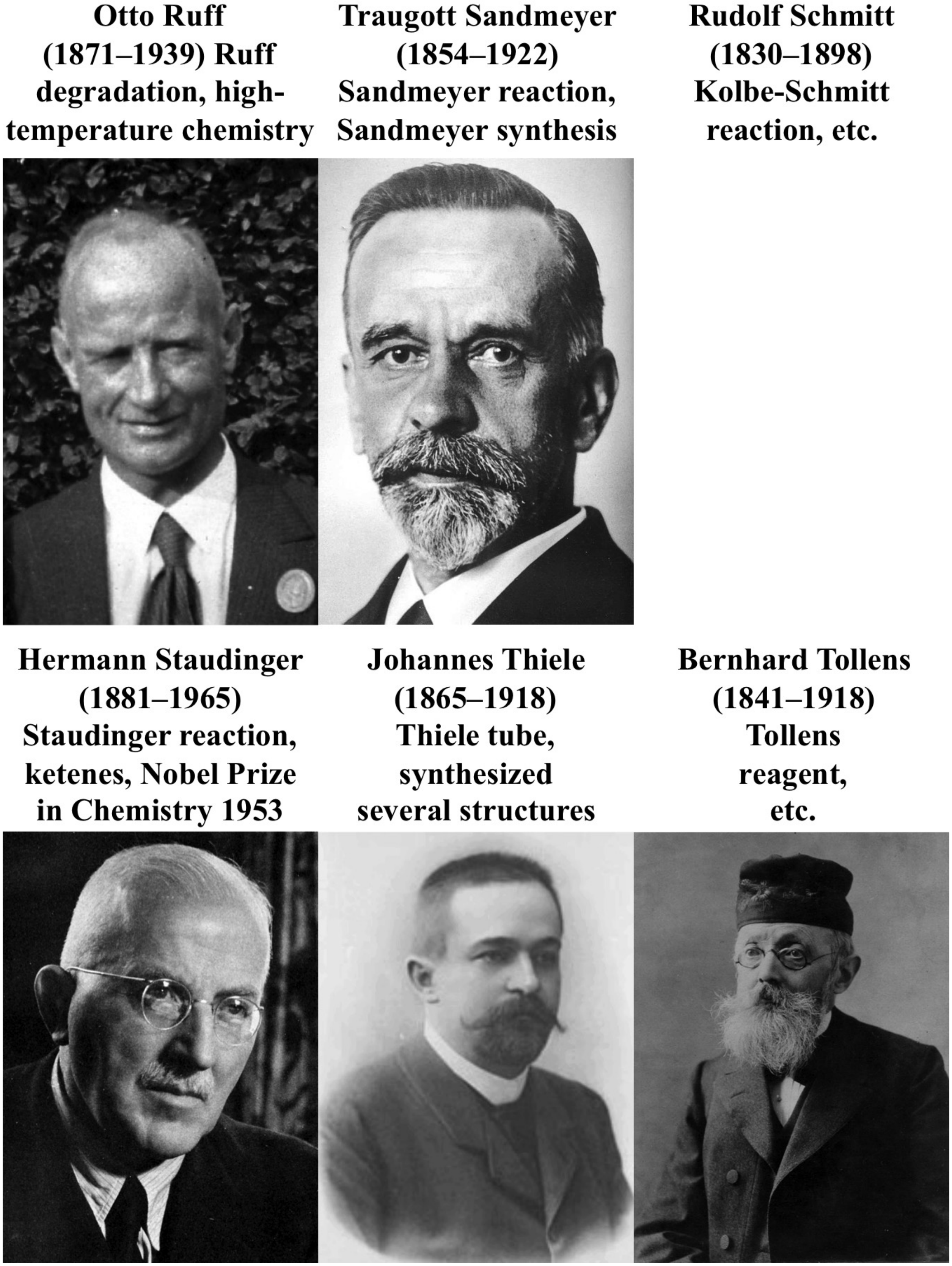
Sergey Reformatsky
(Russian but educated
in Germany, 1860–1934)
Reformatsky reaction

Karl Reichenbach
(1788–1869)
Discovered
many useful
organic molecules

Walter Reppe
(1892–1969)
Reppe chemistry
involving acetylene

Karl Wilhelm
Rosenmund
(1884–1965)
Rosenmund reduction,
Rosenmund-von
Braun reaction

Figure 3.42: Other creators who made important contributions to organic chemistry included Robert Pschorr, Rudolf Pummerer, Sergey Reformatsky, Karl Reichenbach, Walter Reppe, and Karl Wilhelm Rosenmund.



Otto Ruff (1871–1939) Ruff degradation, high-temperature chemistry

Traugott Sandmeyer (1854–1922) Sandmeyer reaction, Sandmeyer synthesis

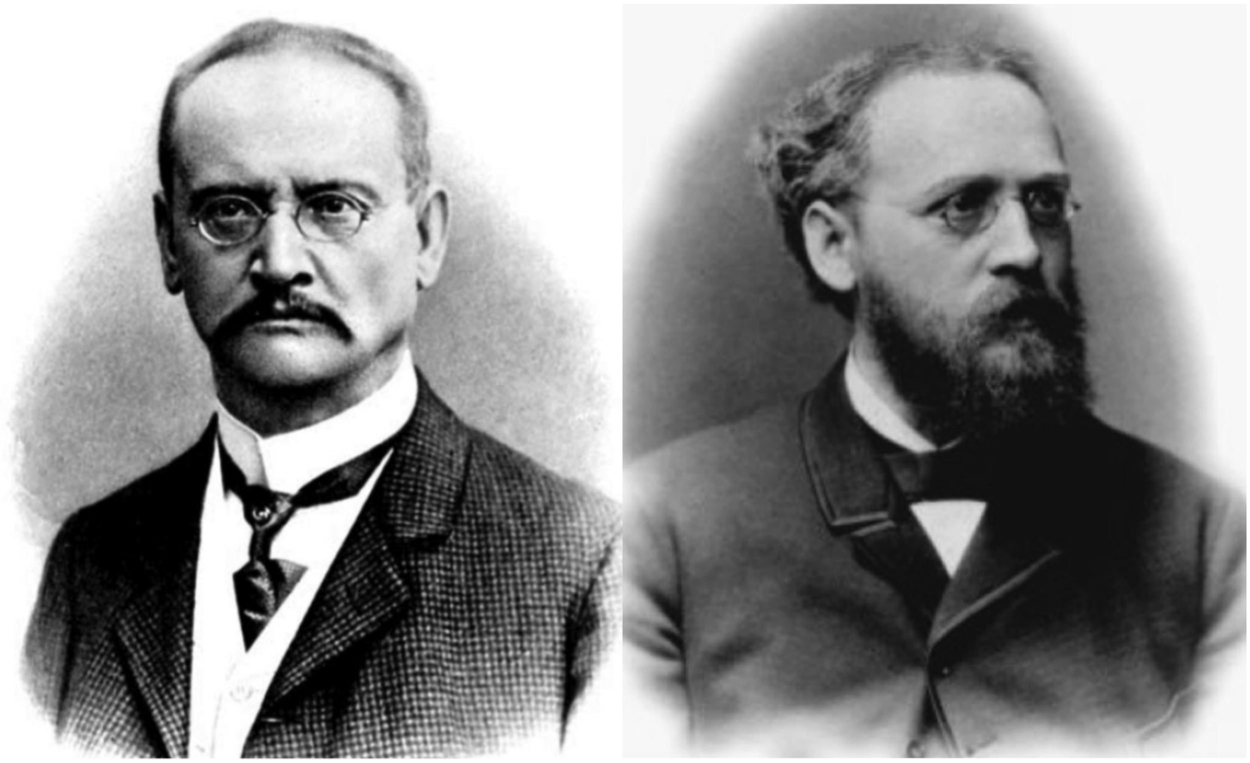
Rudolf Schmitt (1830–1898) Kolbe-Schmitt reaction, etc.

Hermann Staudinger (1881–1965) Staudinger reaction, ketenes, Nobel Prize in Chemistry 1953

Johannes Thiele (1865–1918) Thiele tube, synthesized several structures

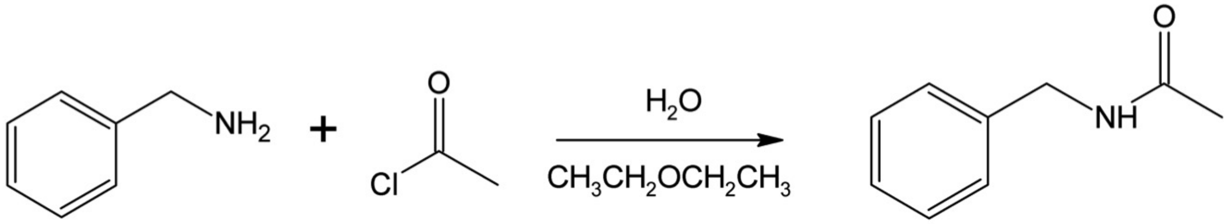
Bernhard Tollens (1841–1918) Tollens reagent, etc.

Figure 3.43: Other creators who made important contributions to organic chemistry included Otto Ruff, Traugott Sandmeyer, Rudolf Schmitt, Hermann Staudinger, Johannes Thiele, and Bernhard Tollens.



Carl Schotten (1853–1910)

Eugen Baumann (1846–1896)



Schotten-Baumann reactions (1883)

NH$_2$
+
O
Cl
H$_2$O
CH$_3$CH$_2$OCH$_2$CH$_3$
O
NH

Figure 3.44: Carl Schotten and Eugen Baumann developed Schotten-Baumann reactions (1883), which are used to synthesize a wide variety of useful organic molecules.

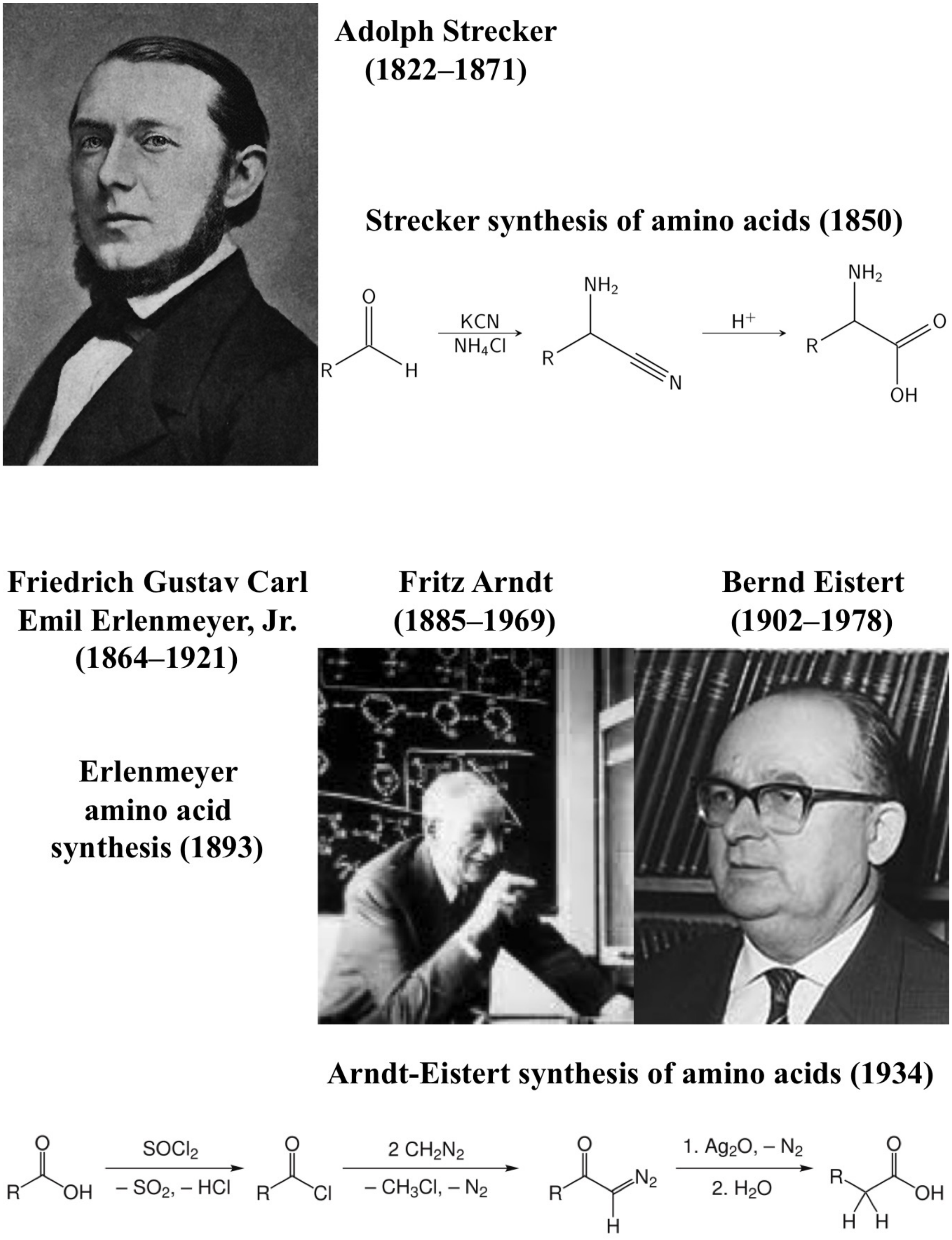
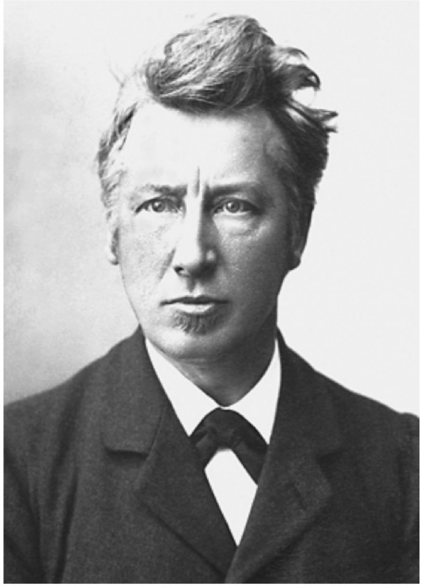

Adolph Strecker
(1822–1871)
Strecker synthesis of amino acids (1850)
O
R
H
KCN
NH₄Cl
NH₂
R
N
H⁺
NH₂
R
O
OH
Friedrich Gustav Carl
Emil Erlenmeyer, Jr.
(1864–1921)
Fritz Arndt
(1885–1969)
Bernd Eistert
(1902–1978)
Erlenmeyer
amino acid
synthesis (1893)
Arndt-Eistert synthesis of amino acids (1934)
O
R
OH
SOCl₂
– SO₂, – HCl
O
R
Cl
2 CH₂N₂
– CH₃Cl, – N₂
O
R
N₂
H
1. Ag₂O, – N₂
2. H₂O
O
R
OH
H H

Figure 3.45: Adolph Strecker, Friedrich Gustav Carl Emil Erlenmeyer, Jr., Fritz Arndt, and Bernd Eistert developed methods to artificially synthesize amino acids, the building blocks of proteins.

Alfred Treibs (1899–1983) Founded organic geochemistry

Fritz Ullmann (1865–1939) Ullmann reaction, Ullmann condensation, *Enzyklopädie der Technischen Chemie*

Jacobus Hendricus van't Hoff (1852–1911) Physical chemistry, stereochemistry, Nobel Prize in Chemistry 1901



Jacob Volhard (1834–1910) Volhard-Erdmann cyclization reaction

Otto Wallach (1847–1931) Wallach rearrangement, Wallach degradation, Wallach's rule, Nobel Prize in Chemistry 1910

Conrad Willgerodt (1841–1930) Willgerodt reaction

Figure 3.46: Other creators who made important contributions to organic chemistry included Alfred Treibs, Fritz Ullmann, Jacobus Hendricus van't Hoff, Jacob Volhard, Otto Wallach, and Conrad Willgerodt.

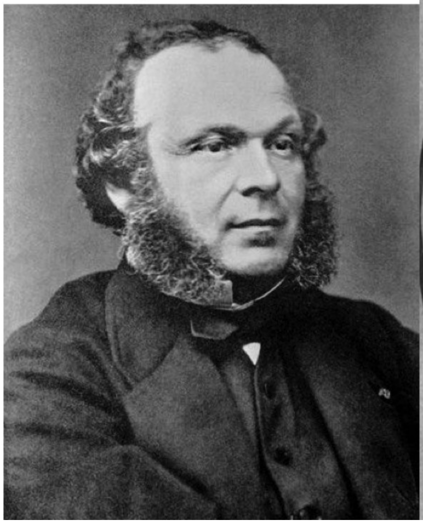
Johannes Wislicenus (1835–1902) Stereochemistry of organic molecules

Georg Wittig (1897–1987) Wittig reaction, Wittig rearrangement, Nobel Prize in Chemistry 1979

Alfred Wohl (1863–1933) Wohl degradation, Wohl-Aue reaction, Wohl-Ziegler reaction

Ludwig Wolff (1857–1919) Wolff rearrangement, Wolff reduction

Adolphe Wurtz (1817–1884) Aldol reaction, Wurtz reaction, ethylamine, ethylene glycol



Ernst Carl Theodor Zincke (1843–1928) Zincke reaction, Zincke nitration, Zincke-Suhl reaction

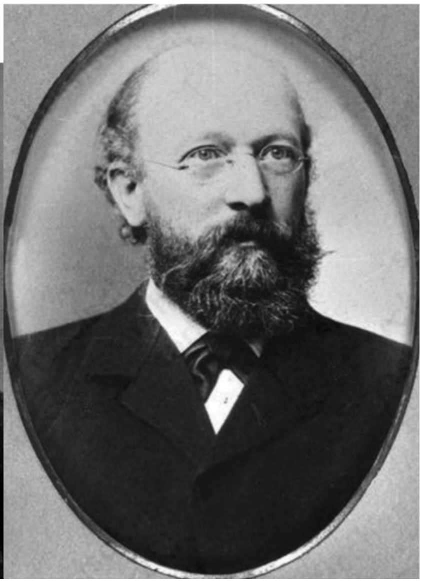


Figure 3.47: Other creators who made important contributions to organic chemistry included Johannes Wislicenus, Georg Wittig, Alfred Wohl, Ludwig Wolff, Adolphe Wurtz, and Ernst Carl Theodor Zincke.

3.2.3 Organometallic Chemistry

German-speaking scientists made many important contributions to organometallic chemistry, the study of carbon-rich organic molecules bound to metal atoms.[4] Organometallic compounds are especially useful in catalyzing reactions for the large-scale production of many industrial chemical products. Knowledge about them is also useful for understanding the natural catalytic properties of many enzymes.

Ludwig Mond (German, 1839–1909, Fig. 3.48) founded the field of organometallic chemistry and was one of the pioneers of industrial chemistry. He discovered metal carbonyls such as nickel tetracarbonyl (1890) and used his discovery to make a fortune purifying nickel in the United Kingdom. He also ran an industrial research program that made several other important chemical discoveries. Oxford University's *Biographical Dictionary of Scientists* summarized some of his research history [Porter 1994, pp. 492–493]:

> He studied chemistry at Marburg (under Adolf Wilhelm Hermann Kolbe) and Heidelberg (under Robert Bunsen) [...]
>
> In 1879, Mond became interested in the production of ammonia, an intermediate in the Solvay process which was increasingly being used as an artificial fertilizer. One outcome was the development of the Mond producer gas process, in which carbon monoxide and hydrogen are produced by alternately passing air and steam over heated coal or coke (and the hydrogen used to convert nitrogen into ammonia). [...] An interesting extension of this work was the attempt, with the assistance of K. Langer, to turn the energy of the fuel directly into electrical energy. This early fuel cell, which used porous plates moistened with sulphuric acid, was not developed further at that time. [...]
>
> One unexpected result of the producer gas process came from Mond's observation that nickel is corroded by gases containing carbon monoxide. This led, in 1889, to the discovery of nickel carbonyl, $Ni(CO)_4$, one of the first organometallic compounds. After two years' work, with Langer and Quincke, he had developed a new extraction process for nickel.

Johann (John) Ulric Nef (Swiss, 1862–1915, Fig. 3.48) received his Ph.D. under Adolf von Baeyer at the University of Munich, then spent his career in the United States. He studied carbene molecules, discovered Nef synthesis and the Nef reaction, and applied those methods to organic compounds containing metal ions. The American Council of Learned Societies summarized some of his other contributions to organic chemistry [ACLS 2000, pp. 636–637]:

> A great experimentalist and pioneer in theoretical organic chemistry, whose theoretical work clearly contains the germs of the present concepts of free radicals, transition states, and polymerization. Topics studied included the apparently bivalent carbon compounds and their dissociation, and the action of alkali and alkaline oxidizing agents on the sugars.

---

[4] Abelshauser et al. 2004; Brock 1993; Bugge 1955; Coffey 2008; Deichmann 2001; Drummer and Zwilling 2007; Engels et al. 1989; Farber 1961; Haber 1958, 1971; Ihde 1984; Johnson 1990; Kahlert 2002; Lesch 2000; Maier 2015; Marsch 1994a; Neufeldt 2003; Partington 1935, 1957, 1964; Peppas 2013; Rosner 2004; Sasuly 1947; Schwenk 2000; Soukup 2007; Teltschik 1992; Ungewitter 1938; Welsch 1981; Werner 2017.

Wilhelm Schlenk (German, 1879–1943, Fig. 3.48) discovered organolithium compounds and studied organomagnesium compounds. He remains known for the Schlenk equilibrum, the Schlenk flask, and the Schlenk line.

Franz Hein (German, 1892–1976, Fig. 3.48) focused on organometallic chemistry for his whole career, studying organic compounds containing bismuth, chromium, magnesium, and other metal ions. *ABC Geschichte der Chemie* succinctly listed some of Hein's scientific accomplishments [Engels et al. 1989, p. 204]:

> Umfangreiche Arbeiten auf dem Gebiet der Organometall-Komplexchemie. Entdeckung einer Klasse chromiumorg. Verbindungen (1919); Arbeiten über Metallalkyle (darunter Quecksilberalkyle), Chromium(III)-dihalogen-alkoholate, Organometall-Eisentetracarbonyle, Komplexe des Chromiums mit 2,2'-Dipyridyl; Chromiumphenylverbindungen; Maskierung von Metallionen durch Komplexbildung; Bestimmungsmethode für Wasserstoff mittels $AgMnO_4$.

> Extensive work in the field of organometallic complex chemistry. Discovery of a class of chromium-organic compounds (1919); work on metal alkyls (including mercury alkyls), chromium(III) dihaloalcohols, organometallic iron tetracarbonyls, complexes of chromium with 2,2'-dipyridyl; chromium phenyl compounds; masking of metal ions by complexation; determination method for hydrogen using $AgMnO_4$.

Walter Otto Hieber (German, 1895–1976, Fig. 3.48) made a variety of important discoveries in organometallic chemistry, including organic molecules containing iron, manganese, osmium, rhenium, and other metals. His name remains attached to the Hieber base reaction. He was the doctoral adviser of Ernst Otto Fischer and Erwin Weiss (see below).

Karl Ziegler (German, 1898–1973, Fig. 3.49) won the Nobel Prize in Chemistry in 1963 for his work on organometallic chemistry and its application to polymer production. Professor A. Fredga of the Nobel Committee for Chemistry praised Ziegler's innovations in that area [https://www.nobelprize.org/prizes/chemistry/1963/ceremony-speech/]:

> Professor Ziegler has found entirely new methods of polymerization. Studying organometallic compounds, he discovered that organoaluminium compounds, which are easy to prepare, are particularly suitable for work on the industrial scale. Peculiar electrical forces operate around an aluminium-carbon bond in a hydrocarbon chain: reactive molecules are drawn in and sandwiched between the carbon atom and the aluminium atom, thus increasing the length of the chain. All this happens much more quietly than in free-radical reactions. When the chain is long enough, we detach the aluminium and thus stop the further growth of the molecule. The combination of aluminium compounds with other metallic compounds gives Ziegler catalysts. These can be used to control polymerizations and to obtain molecular chains of the required length. However, many systematic experiments—and indeed some accidental findings—were necessary to reach this stage. Ziegler catalysts, now widely used, have simplified and rationalized polymerization processes, and have given us new and better synthetic materials.

Similarly, Ernst Otto Fischer (German, 1918–2007, Fig. 3.49) won the Nobel Prize in Chemistry in 1973 for his research on organometallic chemistry (along with Geoffrey Wilkinson). Fischer studied ferrocene, created cobaltocene in 1953, and synthesized bis(benzene) chromium together with his student Walter Hafner in 1955. Professor Ingvar Lindqvist of the Royal Academy of Sciences explained Fischer's discoveries [https://www.nobelprize.org/prizes/chemistry/1973/ceremony-speech/]:

> It seems to be appropriate to put forward these views when speaking of this year's Nobel laureates in chemistry, professors Fischer and Wilkinson. The facts were available for all the chemists of the world to see, but the right interpretation was lacking. Once the correct hypothesis was arrived at by fantasy or intuition, it readily lent itself to simple processes of logical deduction. I am of course referring to the way in which they together with the former Nobel laureate Woodward reached the conclusion that certain compounds could not be understood without the introduction of a new concept, namely that of the sandwich compound. This expression applies to the structure of these compounds, which can be thought of as a metal atom—the filling—sandwiched between two flat molecules. Now the science of chemistry involves, of course, more than flashes of visionary inspiration, and both Fischer and Wilkinson did not hesitate to confirm and develop the concept of the sandwich compound by an intensive experimental effort. This they did by the successful synthesis of a large number of compounds which were analogous to the initially discovered ferrocene (named by Woodward in analogy with benzene), but with other metals than iron, and with other flat molecules than the cyclopentadienyl group found in ferrocene. Amongst other things, Fischer managed to surprise chemists by preparing a sandwich of chromium between two benzene molecules. The culinary exploits were pursued further with the progress to open sandwiches, having a flat molecule on one side of the metal atom, and with only small molecules such as carbonyl, methyl or ethyl groups on the other side. [...]
>
> It is a fact that every discovery within the realm of fundamental chemical research has potential applications. The very circumstance of the stability of sandwich compounds has led to involved theoretical discussions, which have also played their part in important advances in theoretical and applied research on catalysis.

Walter Hafner (German, 1927–2004, Fig. 3.49) received his Ph.D. under Ernst Otto Fischer. He and Fischer synthesized bis(benzene) chromium in 1955. Later Hafner harnessed palladium as a catalyst in organometallic reactions for industrial chemical production.

Erwin Weiss (German, 1926–2019, Fig. 3.49) did his Ph.D. studies under Walter Hieber and analyzed the structure of bis(benzene) chromium soon after it was synthesized by Ernst Otto Fischer and Walter Hafner. He spent the rest of his career investigating organic molecules containing lithium, sodium, potassium, rubidium, caesium, magnesium, copper, and other metal ions.

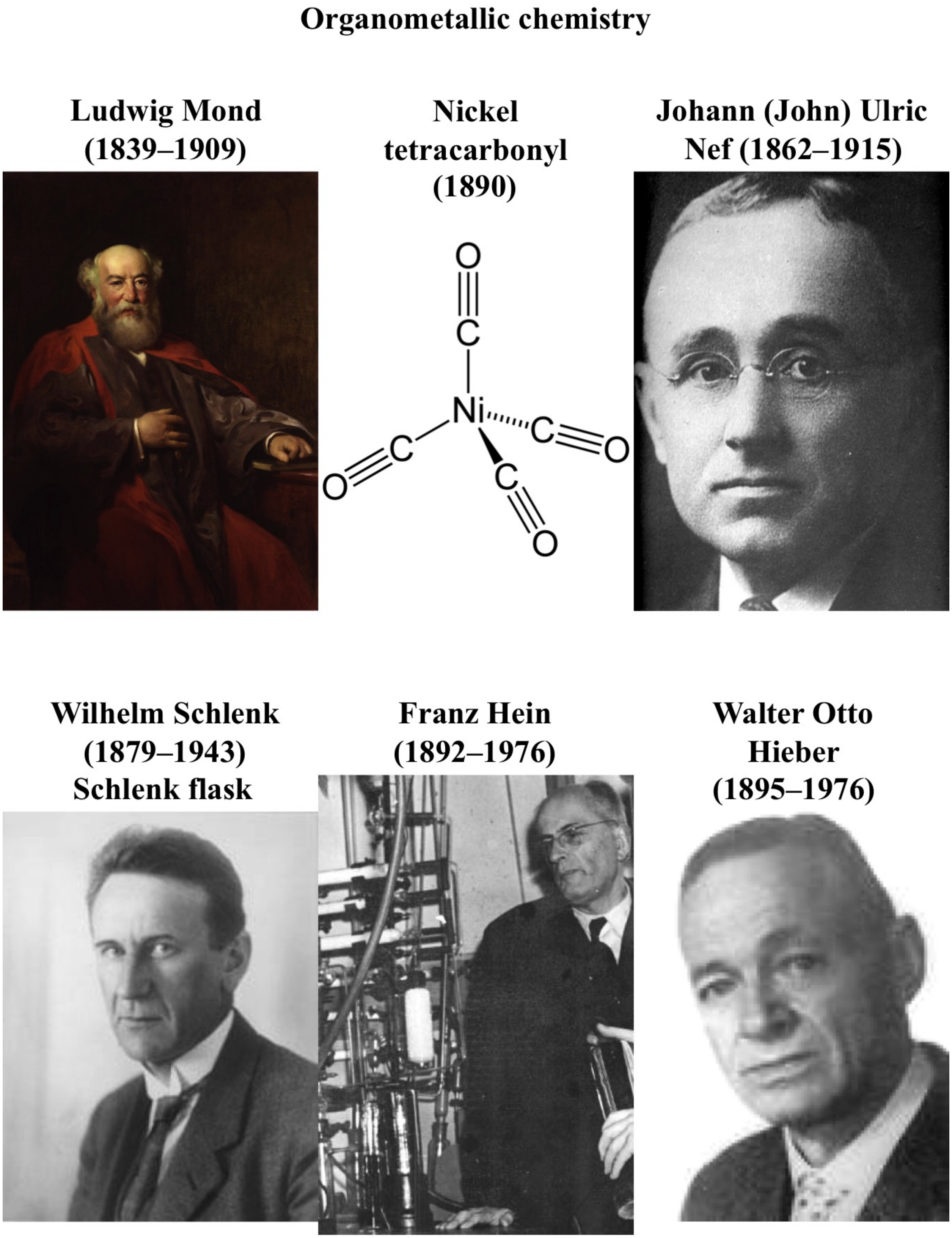

Organometallic chemistry
Ludwig Mond (1839–1909)
Nickel tetracarbonyl (1890)
Johann (John) Ulric Nef (1862–1915)
O
C
Ni
C
O
C
O
C
O
Wilhelm Schlenk (1879–1943) Schlenk flask
Franz Hein (1892–1976)
Walter Otto Hieber (1895–1976)

Figure 3.48: Some creators who made important contributions to organometallic chemistry included Ludwig Mond, Johann (John) Ulric Nef, Wilhelm Schlenk, Franz Hein, and Walter Otto Hieber.

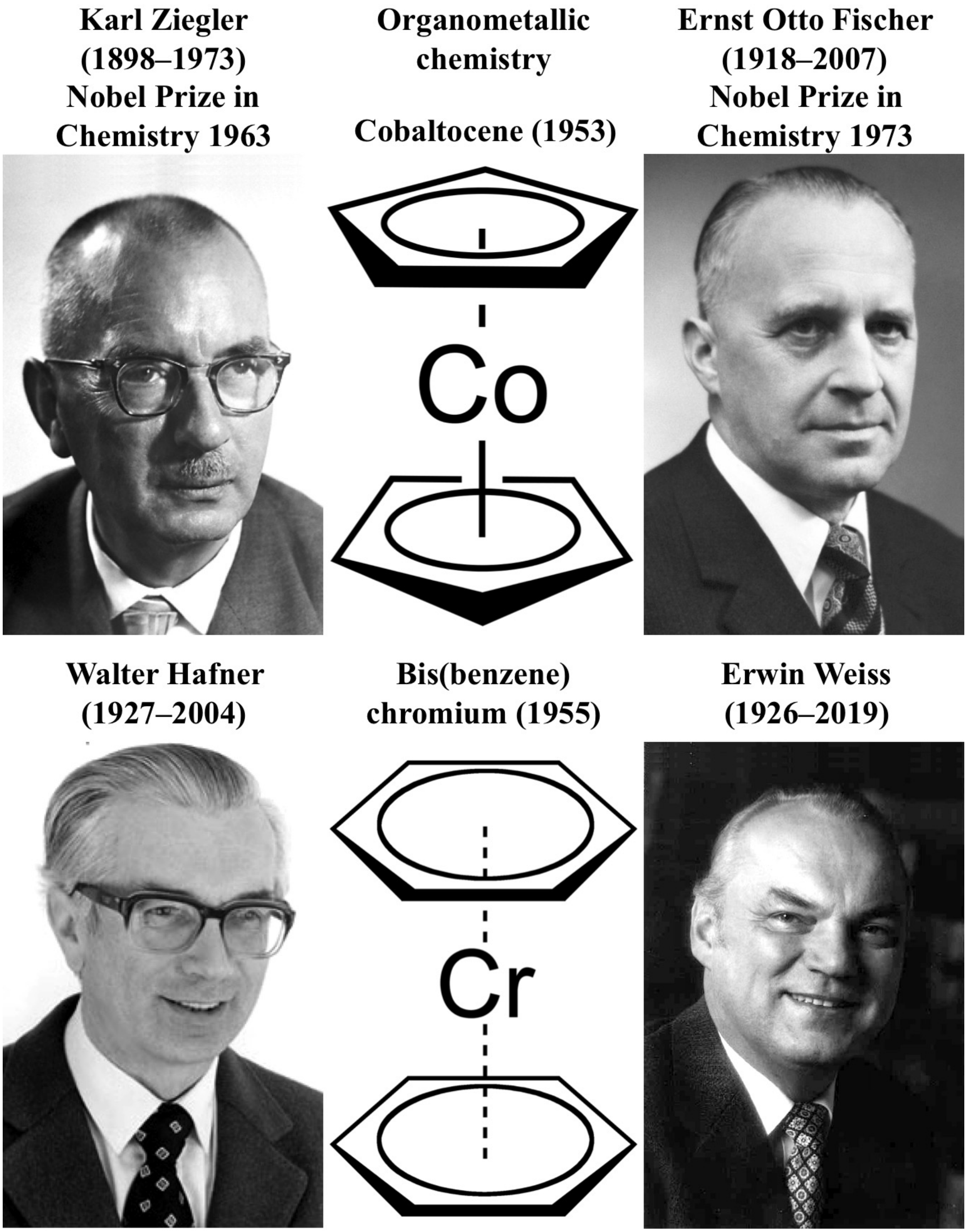

Karl Ziegler
(1898–1973)
Nobel Prize in
Chemistry 1963
Organometallic
chemistry
Cobaltocene (1953)
Co
Ernst Otto Fischer
(1918–2007)
Nobel Prize in
Chemistry 1973
Walter Hafner
(1927–2004)
Bis(benzene)
chromium (1955)
Cr
Erwin Weiss
(1926–2019)

Figure 3.49: Other creators who made important contributions to organometallic chemistry included Karl Ziegler, Ernst Otto Fischer, Walter Hafner, and Erwin Weiss.

3.2.4 Synthetic Fuels

The German-speaking world had large deposits of coal but little oil, natural gas, or most other natural resources. Therefore, especially when imported resources were embargoed or too expensive, there was a strong incentive to harness organic chemistry to convert coal into synthetic liquid fuels, synthetic gaseous fuels, synthetic motor oil, and a variety of other synthetic hydrocarbon products.[5]

In 1913, Friedrich Bergius (German, 1884–1949) created and Carl Bosch (German, 1874–1940) scaled up the Bergius high-pressure process for producing synthetic liquid fuels from coal, for which they both won the Nobel Prize in Chemistry 1931. See Fig. 3.50. Professor W. Palmær, Member of the Nobel Committee for Chemistry, announced the award [https://www.nobelprize.org/prizes/chemistry/1931/ceremony-speech/]:

> You, Professor Bosch, were the first to enrich the chemical industry with this powerful tool, for the production of ammonia from the elements. Between the presentation of the scientific bases of this synthesis and its industrial exploitation lay a mighty chasm, which you bridged, inter alia, by the brilliant invention and construction of the high-pressure apparatus. By doing so, you made it possible for nitrogen to be made available to mankind in inexhaustible quantities, in a form suitable for agriculture, and even at lower prices than hitherto. Furthermore, you developed high-pressure methods for the production of other important substances. By virtue of this, the Academy wishes to thank you and congratulate you, and requests you to receive the distinction from the hands of His Majesty the King.
>
> General Director Bergius. You undertook to tackle a problem which, in its importance for humanity, can be compared with the solution of the nitrogen question. You have shown how, by the injection of hydrogen under pressure, pit coal, brown coal, and other carbon-bearing materials can be processed to liquid fuels which are considered indispensable in modern life for the propulsion of ships and vehicles. You have thereby obviated the danger which threatened of exhaustion of petroleum deposits, an event which must have happened sooner or later. In your work, you arrived at the high-pressure method quite independently. On the basis of your work, a powerful industry has already been formed.

Similarly, in 1925, Franz Fischer (German, 1877–1947) and Hans Tropsch (Austrian, 1889–1935) created the Fischer-Tropsch process for synthesizing fuels and other hydrocarbons, as shown in Fig. 3.51. The chemist and chemical historian Aaron Ihde explained [Ihde 1984, p. 683]:

> Perhaps of even greater interest in this connection is the Fischer-Tropsch process developed in the twenties by the Germans Franz Fischer (1877–1947) and Hans Tropsch (1889–1935). Water gas [$CO + H_2$] passed over suitable metal oxide catalysts at about 200^o C. and moderate pressure is converted into hydrocarbons suitable for motor fuels. The process was ready for commercial production of hydrocarbons after 1935 and was an important factor in the German war effort, as evidenced by the attention given to synthetic oil plants by Allied bombers. The hydrocarbons thus produced also were oxidized to fatty acids to help Germany overcome a shortage of food fats.

At the end of World War II, Allied countries seized all information on German synthetic fuel production processes. Due to limited worldwide resources and concerns about global warming and pollution, such synthetic fuels or related approaches may have a renewed importance in the future.

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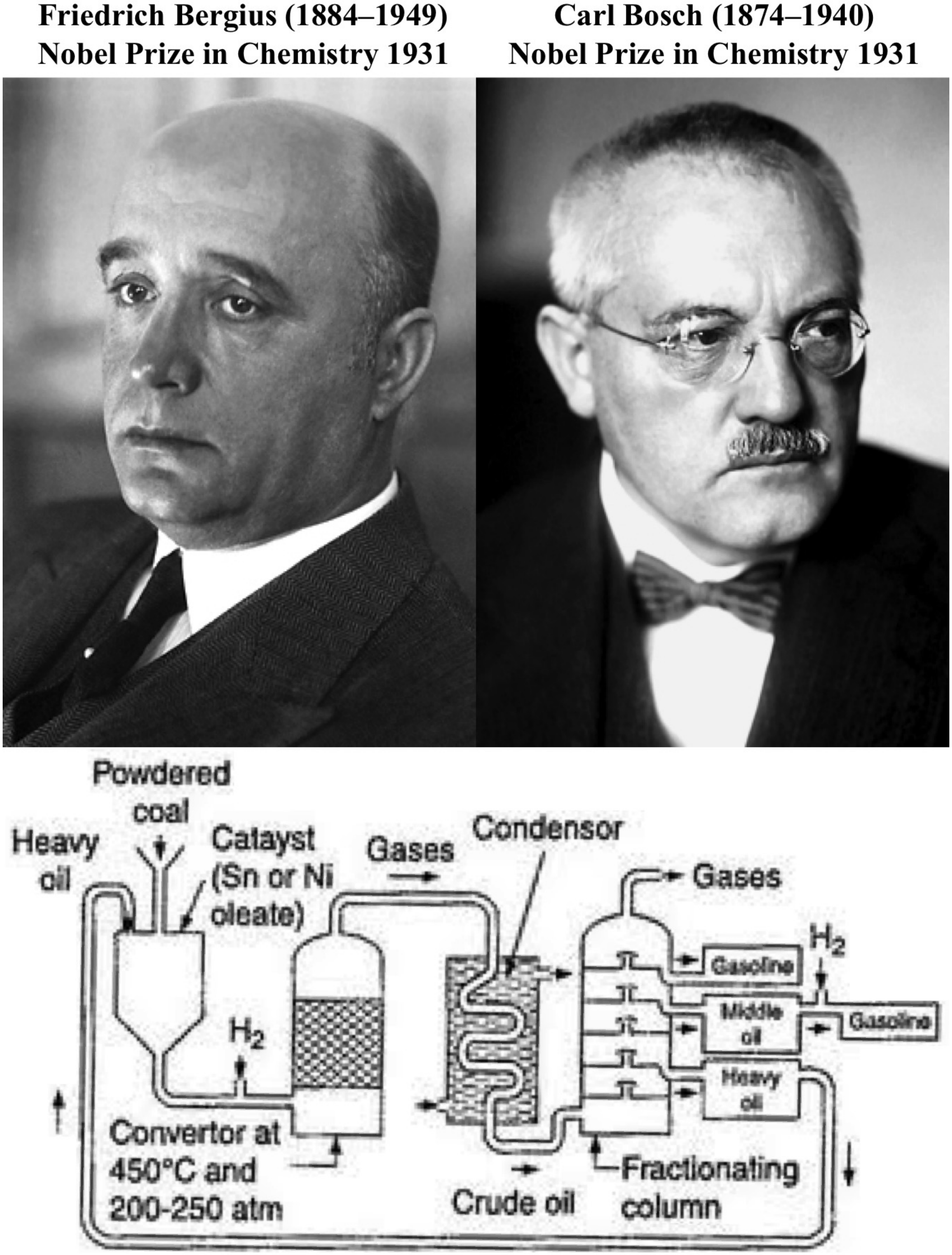
[5] See for example: Becker 1981; Gimbel 1990a; Hasche 1945; Kastens et al. 1952; Krammer 1978, 1981; Lampe 1977; Albert Miller 1945; Schroeder 1945; Sheldon 1945; Stranges 1984; Vieter 1980.

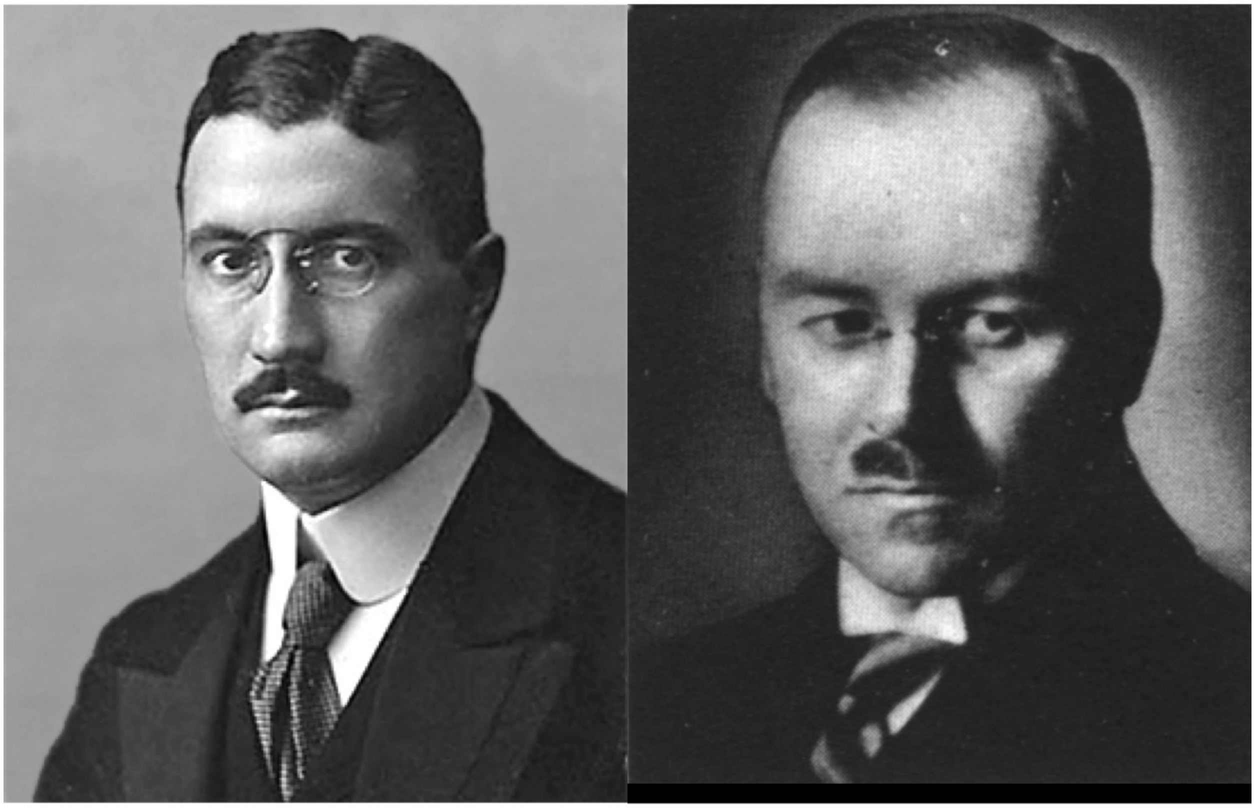


Friedrich Bergius (1884–1949)
Nobel Prize in Chemistry 1931

Carl Bosch (1874–1940)
Nobel Prize in Chemistry 1931

Powdered coal
Heavy oil
Catayst (Sn or Ni oleate)
Gases
Condensor
Gases
H_2
Gasoline
Middle oil
Gasoline
Heavy oil
H_2
Convertor at 450°C and 200-250 atm
Crude oil
Fractionating column

Figure 3.50: Friedrich Bergius created and Carl Bosch scaled up the Bergius process for producing synthetic fuels (1913), for which they both won the Nobel Prize in Chemistry 1931.



Franz Fischer (1877–1947) **Hans Tropsch (1889–1935)**

Fischer-Tropsch process for hydrocarbon synthesis (1925)

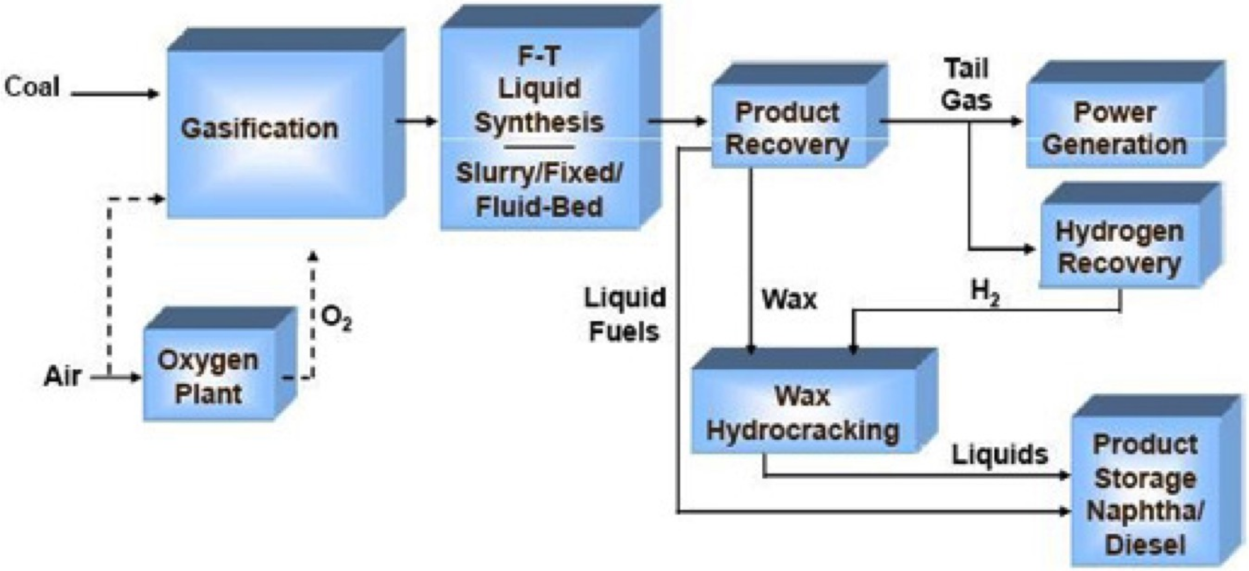

Coal
Gasification
F-T Liquid Synthesis
Slurry/Fixed/ Fluid-Bed
Product Recovery
Tail Gas
Power Generation
Hydrogen Recovery
H_2
Liquid Fuels
Wax
Wax Hydrocracking
Liquids
Product Storage Naphtha/ Diesel
Air
Oxygen Plant
O_2

Figure 3.51: In 1925, Franz Fischer and Hans Tropsch created the Fischer-Tropsch process for producing synthetic fuels and other hydrocarbons.

3.2.5 Liquid Crystals

Scientists from the German-speaking world discovered and developed liquid crystals, which can respond to changing temperatures, voltages, pressure, or other conditions by changing their optical properties.[6] One simple application of liquid crystals is to create materials that change colors over a custom-designed range of temperatures. More importantly, electrically controlled liquid crystals are now widely used in electronic display panels from watches to television screens (Fig. 3.52).

Friedrich Reinitzer (Austrian, 1857–1927), a biochemist, discovered liquid crystals in 1888. He noticed the liquid crystal properties of cholesteryl benzoate that he had purified from plants, and he continued to study those properties for several years.

After first discovering liquid crystals, in 1888 Reinitzer enlisted the assistance of Otto Lehmann (German, 1855–1922) in further analyzing and experimenting with them. Lehmann was a physicist and already an expert on the optical properties of materials that could rotate the polarization of light or bend light differently depending on its direction of polarization. Lehmann spent the rest of his life studying the optical properties of liquid crystals in conjunction with polarizers, the temperature-sensitive phase transitions of liquid crystals, and the microscopic and chemical properties of liquid crystals. He was the one who named them "liquid crystals," and he produced a string of publications that firmly established this field, explored its applications, and promoted it to other scientists. For all of his research on liquid crystals, Lehmann was repeatedly nominated for a Nobel Prize, but unfortunately he never won.

Inspired by the pioneering work of Reinitzer and Lehmann, Daniel Vorländer (German, 1867–1941) spent his career synthesizing and analyzing hundreds of different liquid crystal compounds. He also trained a number of students in this field.

Based on the decades of work by Reinitzer, Lehmann, Vorländer, and other scientists that they inspired and/or trained,[7] by the end of World War II, there was a large body of research on the synthesis, properties, and applications of liquid crystals. After the war, all of that information and many of the relevant researchers were seized and harnessed by Allied countries. For example, liquid crystals and some of their applications were described in BIOS 1688, *Radiological Activities in Germany*, p. 12:

> 6. Thermo-Colour Methods
> Berthold attempted to apply Thermo-Colour materials, developed by Dr. Penzig of I.G. Farben in 1939, to non-destructive methods of testing. With these materials it is possible to detect small changes of temperature of the order of a few degrees in temperature ranges up to 360^{o}C. It was Berthold's intention to apply the method to inspect the fit or surface contact of cast inserts, duplex bearings, etc.

As a result of that technology transfer, in the decades after World War II, liquid crystals slowly began appearing in commercial products in Allied countries—first novelty mood rings, then small liquid crystal displays for watches and calculators, and finally larger liquid crystal displays for everything from smart phones to computers to wall-sized television screens. Much more archival research should be conducted to elucidate the full history of liquid crystal research in the German-speaking world, as well as the transfer and influence of that research in other countries.

---

[6] Bruce et al. 1997; Dunmur and Sluckin 2011; Kelker 1973; Kelker 1988; Kelker and Scheurle 1969; Lehmann 1889; Lehmann 1904; Lehmann 1911; Mitov 2014; Reinitzer 1888; Sluckin et al. 2004; Stegemeyer 1994; Weygand 1943.

[7] For example, Hans Kelker (German, 19??–??), Horst Sackmann (German, 1921–1993), Horst Stegemeyer (German, 1931–), and others.

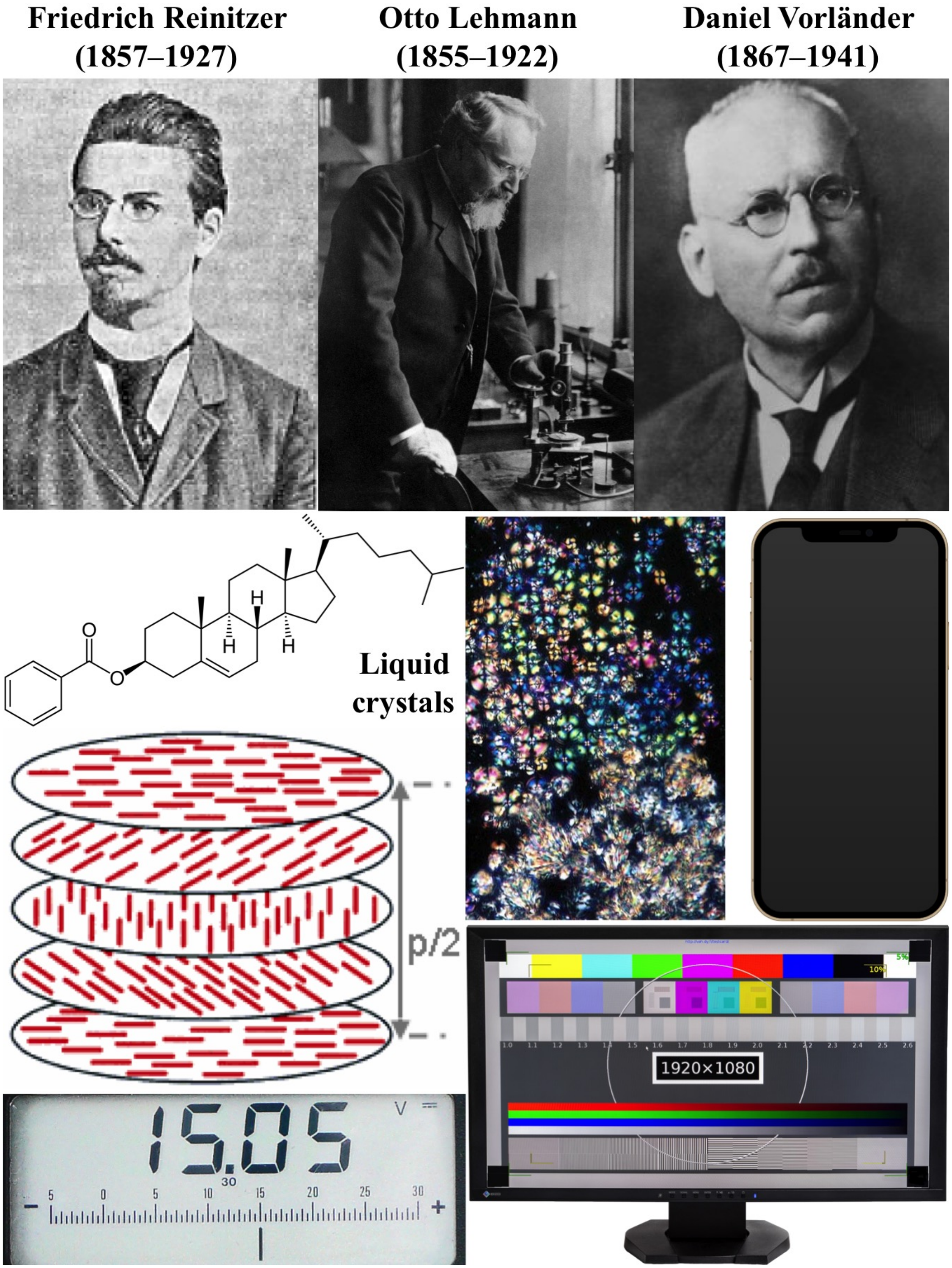

Friedrich Reinitzer
(1857–1927)
Otto Lehmann
(1855–1922)
Daniel Vorländer
(1867–1941)
O
O
H
H
H
Liquid
crystals
p/2
15.05
V
30
- 5 0 5 10 15 20 25 30 +
1920×1080

Figure 3.52: Friedrich Reinitzer, Otto Lehmann, and Daniel Vorländer discovered and developed liquid crystals, which are now widely used in electronic display panels from watches and phones to television sets and computer screens.

3.2.6 Technology Transfer out of the German-Speaking World

Many chemical innovations were transferred from the German-speaking world to other countries before World War II, in the form of published papers and patents, commercial transactions, foreign students who visited the German-speaking world, German and Austrian assets seized by other countries during World War I, and chemists who left the German-speaking world to seek careers elsewhere and/or to flee the rising tide of antisemitism and National Socialism.

All remaining chemical innovations, of which there were still a huge number, were seized by Allied countries at the end of World War II. For some examples, see pp. 421–423, as well as the large number of chemistry-related BIOS ER, BIOS, BIOS Misc., BIOS Overall, CIOS ER, CIOS, FIAT, *FIAT Review*, JIOA, NavTecMisEu LR, and NavTecMisEu reports in the Bibliography.

In September 1945, R. P. Linstead and T. J. Betts, the British and American chairs of the Combined Intelligence Objectives Subcommittee (CIOS), gave a very incomplete yet still highly impressive list of important German innovations in synthetic chemistry that had been found by U.S. and U.K. investigators [AFHRA A5186 electronic version pp. 904–1026, Ch. 4, pp. 54–56]:

> The German war time economy was based on its abundant supplies of coal and therefore coke; water gas; on calcium carbide from coke and lime, leading to acetylene; on nitrogen and hydrogen, leading to ammonia; and on salt, leading to chlorine and caustic soda. From these basic products the entire German chemical industry was erected by the following catalytic processes:
>
> 1. Hydrogenation of coal, tar, and oils, and their subsequent conversion into motor fuels, and diesel oils with its long line of by-products such as lubricants, lower aliphatic hydrocarbons and olefines and compounds containing oxygen, like phenol and its homologues.
> 2. The variety of processes of catalytic conversion of CO and H_2 in different proportions leading to methanol, ethanol and their homologues up to long chain fatty alcohols.
>   (a) The synthesis of isobutanol and its conversion to isobutylene and isooctane.
>   (b) The production of hydrocarbons according to the Fischer-Tropsch synthesis leading to aliphatics and olefines from low to very high chain length. Further conversion of the olefines so obtained by addition of CO and H_2 of the type of the oxo reactions or with CO and water according to the fatty acid synthesis of Reppe.
> 3. The reactions of acetylene and ethylene and their many derivatives leading to solvents, plastics, rubber and synthetic fibres.
> 4. The latest types of aliphatic reactions of acetylene and olefine with CO.
>
> Of particular significance is the manufacture of synthetic rubber (BUNA) by the Reppe process, which uses only 1/3 of the quantity of carbide and acetylene required in the conventional process. The discovery of the "Koresine" tacking process is regarded as being of primary importance. The application of this process to the synthetic rubber industry in the U.S. resulted in increased production, and did much to eliminate the threat of a cut in tire production during the critical phase of combat operations.

> The development of plastics covered a very large number of polymer products, among which the polyisocyanates and polyurethanes (Demodurs), the superpolyamides of the Igamid and Perlon types (German nylon) consisting of dibasic acids, diamides, the polyethylenes (Lupolenes), the vinylchloride polymers (Igelites), the vinylacetate polymers (Nowiliths), as well as their derivatives, represent outstanding achievements.

Similarly, Linstead and Betts listed a number of important German innovations for synthetic fuels and oils that had been found by U.S. and U.K. investigators [AFHRA A5186 electronic version pp. 904–1026, Ch. 4, pp. 59–60]:

> The two principal features of the German synthetic fuels and lubricants industry consisted of the hydrogenation of coal, coal tar, and coal tar products; and the Fischer-Tropsch process for the production of fuel from water gas.
>
> The acquisition of a vast amount of specific German data has been one of the significant accomplishments resulting from exploitation of intelligence in this field. Should the U.S. or Great Britain be faced with another national emergency, adequate supplies of fuels and lubricants will be much more assured as the result of this information.
>
> The DHD process for obtaining aviation fuels by hydrogenation and conversion to aromatics is a development hitherto unknown in this detail.
>
> The Germans were discovered to have adopted new methods which permitted the successful hydrogenation of brown coal from Rhineland reserves. They had also perfected a novel process for producing water gas from brown coal.
>
> Interrogation of German authorities and examination of documents and plants revealed that the Fischer-Tropsch process could not be expected to yield more than 15 to 20% of fuel and oil requirements of the German economy. However, the Fischer-Tropsch process has a certain advantage of yielding crude chemicals which possess a considerable potential for further refining.
>
> The Germans have recently developed a new iron catalyst which could be used to supplant catalysts of conventional cobalt type.
>
> The following additional discoveries resulting from investigation of the German fuel and oil industry are worthy of mention:
>
> 1. New high grade aviation lubricants obtained by polymerization of ethylene.
> 2. New methods of testing fuels and lubricants.
> 3. Fairly complete specifications for German fuels and lubricating oils.
> 4. Details of German shale oil distillations and the refining of these distillates.
>
> Many laboratory improvements were encountered which had not been applied to industrial use, but which will prove of value in U.S. and British development work.

The organic chemistry methods, discoveries, and expertise that were transferred out of the German-speaking world created our modern world of consumer products from colored fabrics and plastic materials to pharmaceuticals and liquid crystal display screens.

3.3 Chemistry of Foods and Drinks

In food and drink production, as in many other areas, the German-speaking world possessed very limited natural resources. When key food and drink ingredients from foreign sources became too expensive during peacetime, and especially when key ingredients were embargoed and unavailable during World Wars I and II, German-speaking scientists developed a number of highly innovative food substitutes and related synthetic products and preservatives. This is a large field, and only a few examples are briefly discussed in this section, including:

3.3.1. Synthetic flavors

3.3.2. Synthetic drinks

3.3.3. Synthetic fats

3.3.4. Synthetic protein products

3.3.5. Preservatives

Several of the above innovations, those related to biotechnology, are covered in more detail in Appendix A.

Even after the wars, several of these innovative food and drink products continued to be used both in German-speaking countries and in other countries around the world that adopted the innovations, especially in cases where the innovative product was cheaper or better than the original food, drink, or ingredient. The strong interest by other countries in these innovations is demonstrated by the large number of BIOS, CIOS, and FIAT reports that Allied countries wrote about them.

3.3.1 Synthetic Flavors

Karl Reimer (German, 1845–1883), Wilhelm Haarmann (German, 1847–1931), and Ferdinand Tiemann (German, 1848–1899) found the molecular structure of natural vanillin flavor from vanilla beans, and developed purely chemical methods of synthesizing it in 1874, as illustrated in Fig. 3.53. In the modern world, most vanillin flavor is chemically synthesized using these same or similar methods, since chemical synthesis is less expensive than growing and processing vanilla beans.

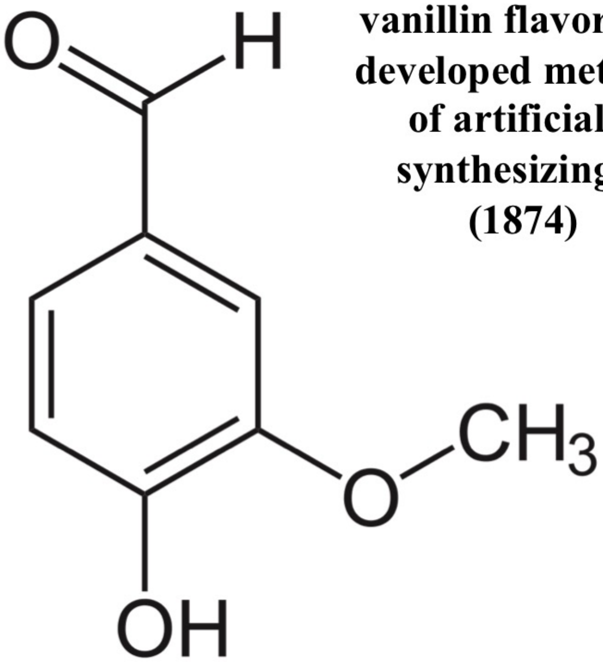
In 1879, Constantin Fahlberg (Russian but studied and worked in Germany, 1850–1910) discovered the artificial sweetener saccharin. By the 1880s, saccharin was synthesized on a large scale in Germany (Fig. 3.54), and it has been sold around the world ever since [BIOS 1576].

During World War I, Hermann Staudinger (German, 1881–1965) and Paul Immerwahr (German, 1886–1926) developed an artificial substitute for scarce black pepper: ground nutshells soaked in chemically synthesized piperine or piperine derivatives (the key ingredient of real black pepper) [Vaupel 2010, 2011]. See Fig. 3.55.

By World War II, the German-speaking world had developed a number of other artificial spices, such as synthetic allspice, cinnamon, cloves, cardamom, and nutmeg [Vaupel 2011; CIOS XXXII-47; FIAT 244].

Artificial vanillin

Karl Reimer (1845–1883) **Wilhelm Haarmann (1847–1931)**

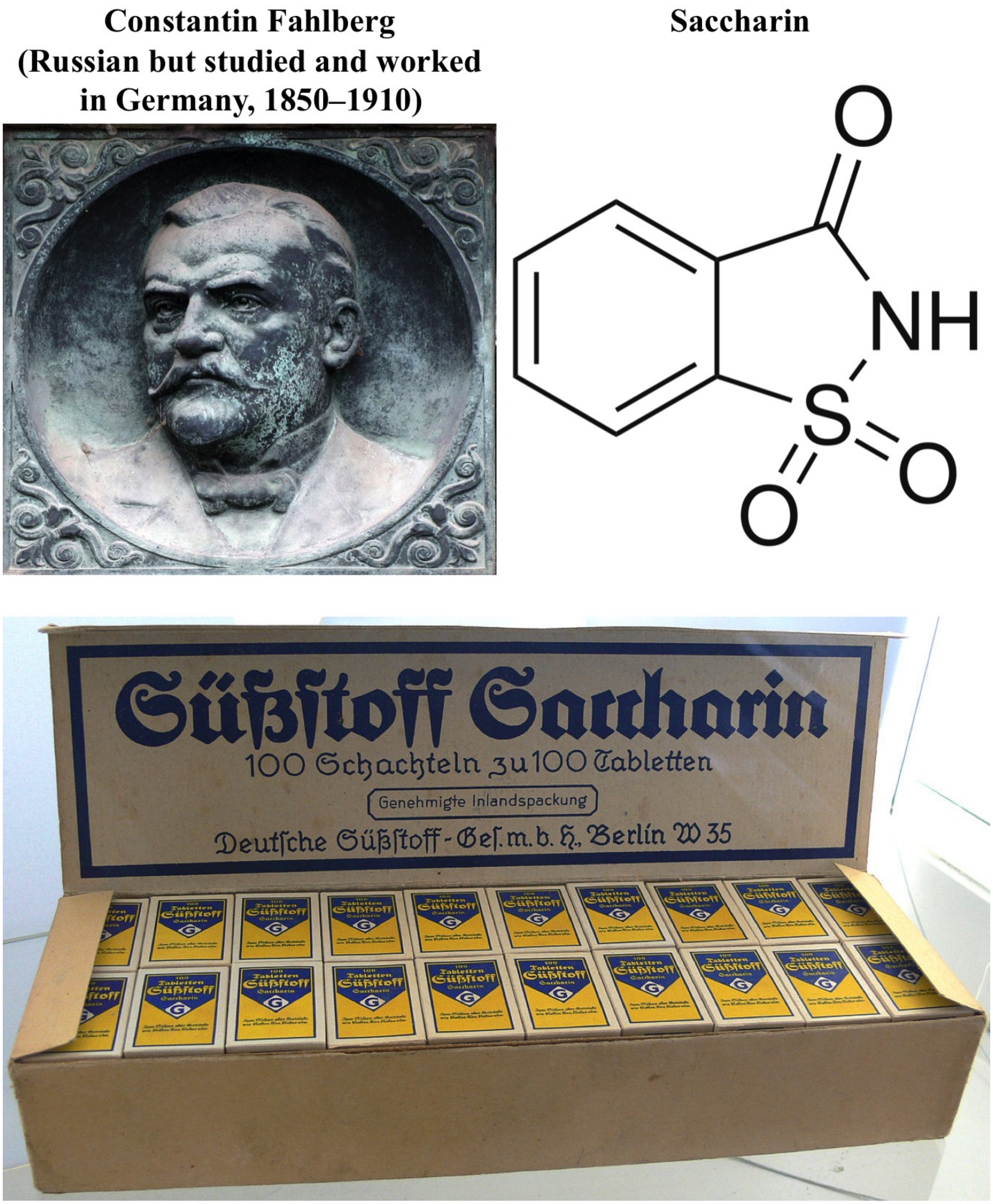


Found molecular structure of natural vanillin flavor and developed methods of artificially synthesizing it (1874)

Ferdinand Tiemann (1848–1899)

Figure 3.53: Karl Reimer, Wilhelm Haarmann, and Ferdinand Tiemann found the molecular structure of natural vanillin flavor and developed methods of artificially synthesizing it in 1874.

Artificial sweetener

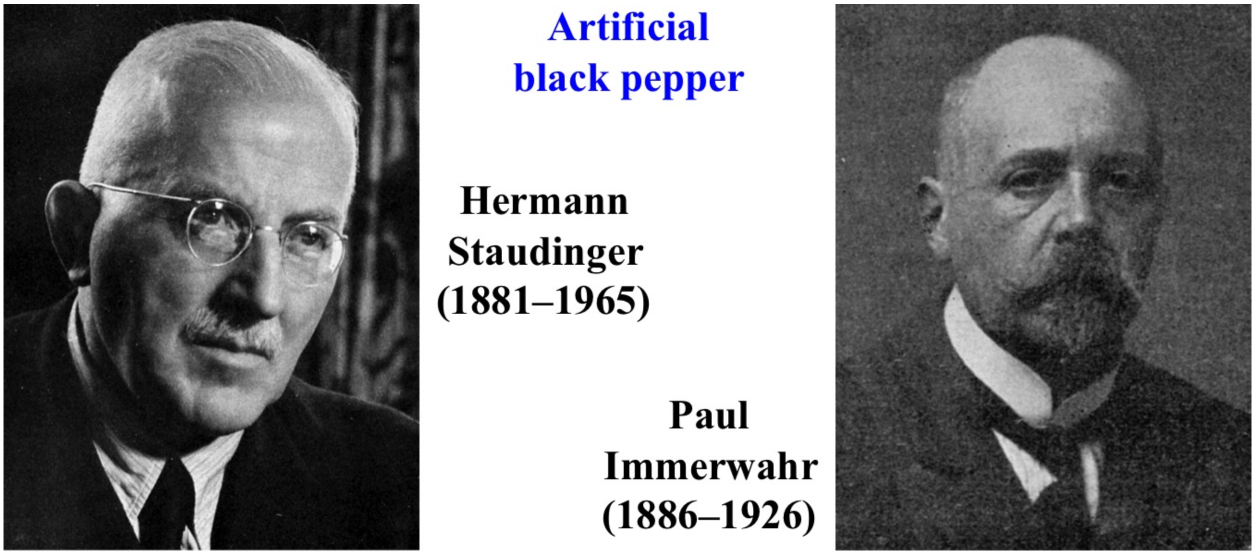


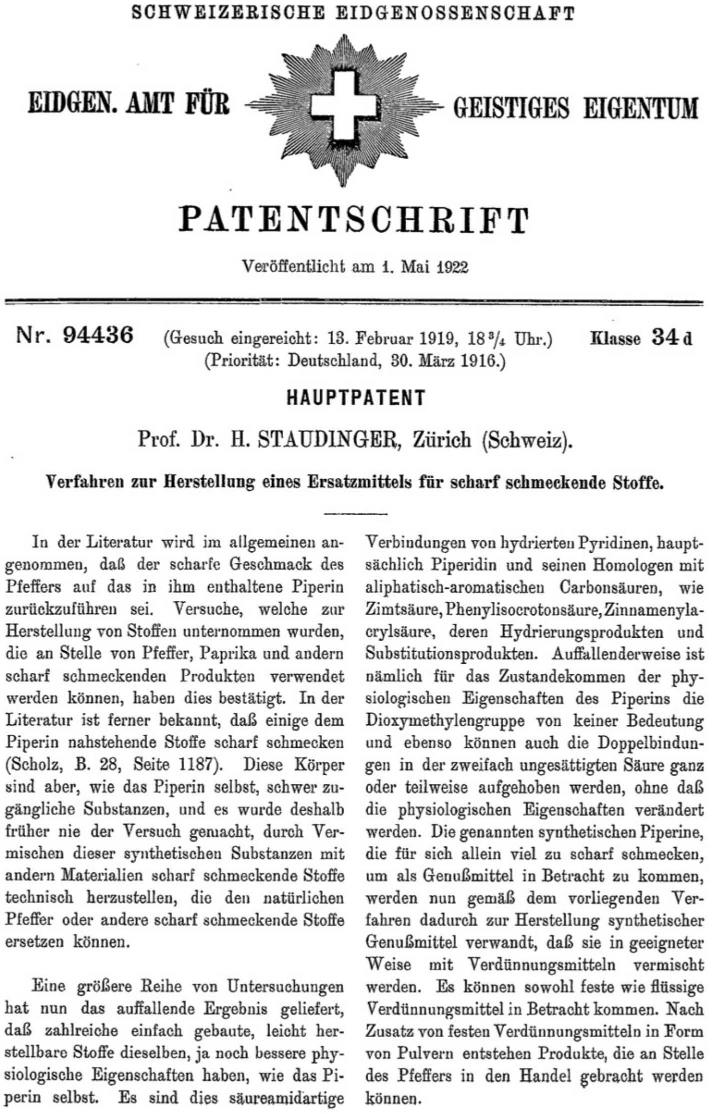
Constantin Fahlberg (Russian but studied and worked in Germany, 1850–1910)

Saccharin

O
NH
S
O
O
Süßſtoff Saccharin
100 Schachteln zu 100 Tabletten
Genehmigte Inlandspackung
Deutſche Süßſtoff-Geſ.m.b.H., Berlin W 35
100 Tabletten Süßstoff Saccharin

Figure 3.54: Constantin Fahlberg discovered the artificial sweetener saccharin in 1879. By the 1880s, saccharin was synthesized on a large scale in Germany.





SCHWEIZERISCHE EIDGENOSSENSCHAFT

EIDGEN. AMT FÜR GEISTIGES EIGENTUM

PATENTSCHRIFT

Veröffentlicht am 1. Mai 1922

Nr. 94436 (Gesuch eingereicht: 13. Februar 1919, $18\frac{3}{4}$ Uhr.) Klasse 34 d
(Priorität: Deutschland, 30. März 1916.)

HAUPTPATENT

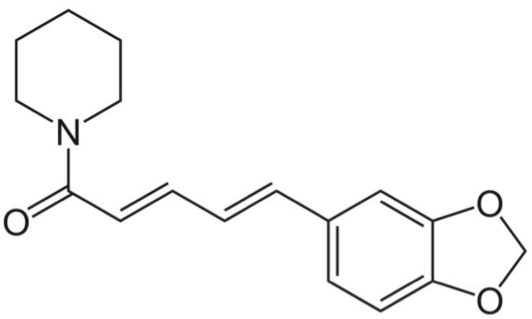
Prof. Dr. H. STAUDINGER, Zürich (Schweiz).

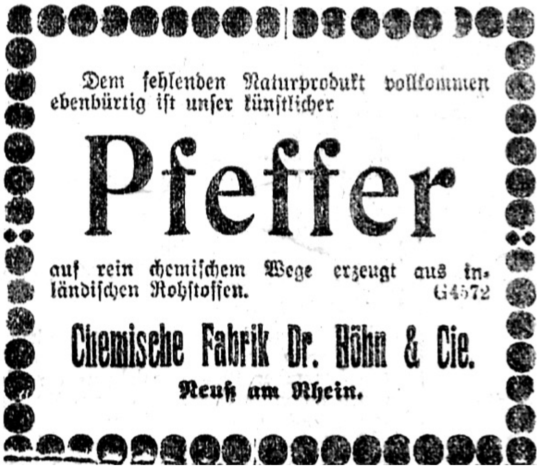
Verfahren zur Herstellung eines Ersatzmittels für scharf schmeckende Stoffe.

In der Literatur wird im allgemeinen angenommen, daß der scharfe Geschmack des Pfeffers auf das in ihm enthaltene Piperin zurückzuführen sei. Versuche, welche zur Herstellung von Stoffen unternommen wurden, die an Stelle von Pfeffer, Paprika und andern scharf schmeckenden Produkten verwendet werden können, haben dies bestätigt. In der Literatur ist ferner bekannt, daß einige dem Piperin nahstehende Stoffe scharf schmecken (Scholz, B. 28, Seite 1187). Diese Körper sind aber, wie das Piperin selbst, schwer zugängliche Substanzen, und es wurde deshalb früher nie der Versuch gemacht, durch Vermischen dieser synthetischen Substanzen mit andern Materialien scharf schmeckende Stoffe technisch herzustellen, die den natürlichen Pfeffer oder andere scharf schmeckende Stoffe ersetzen können.

Eine größere Reihe von Untersuchungen hat nun das auffallende Ergebnis geliefert, daß zahlreiche einfach gebaute, leicht herstellbare Stoffe dieselben, ja noch bessere physiologische Eigenschaften haben, wie das Piperin selbst. Es sind dies säureamidartige Verbindungen von hydrierten Pyridinen, hauptsächlich Piperidin und seinen Homologen mit aliphatisch-aromatischen Carbonsäuren, wie Zimtsäure, Phenylisocrotonsäure, Zinnamenylacrylsäure, deren Hydrierungsprodukten und Substitutionsprodukten. Auffallenderweise ist nämlich für das Zustandekommen der physiologischen Eigenschaften des Piperins die Dioxymethylengruppe von keiner Bedeutung und ebenso können auch die Doppelbindungen in der zweifach ungesättigten Säure ganz oder teilweise aufgehoben werden, ohne daß die physiologischen Eigenschaften verändert werden. Die genannten synthetischen Piperine, die für sich allein viel zu scharf schmecken, um als Genußmittel in Betracht zu kommen, werden nun gemäß dem vorliegenden Verfahren dadurch zur Herstellung synthetischer Genußmittel verwandt, daß sie in geeigneter Weise mit Verdünnungsmitteln vermischt werden. Es können sowohl feste wie flüssige Verdünnungsmittel in Betracht kommen. Nach Zusatz von festen Verdünnungsmitteln in Form von Pulvern entstehen Produkte, die an Stelle des Pfeffers in den Handel gebracht werden können.

Piperine





Dem fehlenden Naturprodukt vollkommen ebenbürtig iſt unſer künſtlicher

Pfeffer

auf rein chemiſchem Wege erzeugt aus inländiſchen Rohſtoffen.
G4572

Chemiſche Fabrik Dr. Höhn & Cie.

Neuß am Rhein.

Figure 3.55: During World War I, Hermann Staudinger and Paul Immerwahr developed an artificial substitute for scarce black pepper: ground nutshells soaked in chemically synthesized piperine or piperine derivatives (the key ingredient of real black pepper).

3.3.2 Synthetic Drinks

During wartime, caffeine was an important stimulant, yet its natural sources—tea leaves and coffee beans—were difficult to obtain due to embargoes. Therefore, many German-speaking chemists developed artificial methods of producing caffeine (Fig. 3.56). Most of those methods involved direct chemical synthesis of caffeine by a long series of reactions [BIOS 306; BIOS 449; BIOS 1404; CIOS XXVI-9; FIAT 71; FIAT 885]. However, some especially ingenious (or desperate) scientists also developed and demonstrated methods to farm large quantities of snake urine, which contains an especially high concentration of uric acid, and then convert that uric acid to caffeine [BIOS 449; see p. 2354].

Amalie Melitta Bentz (German, 1873–1950) invented paper coffee filters and the corresponding brewing system in 1908 (Fig. 3.57). She founded the Melitta coffee company.

In the 1930s, Hermann Staudinger (German, 1881–1965), Tadeusz Reichstein (Polish, educated and worked in Switzerland, 1897–1996), Max Kerschbaum (German?, 18??–10??), Eligius Freudl (Austrian, 1875–1951), and other chemists developed Coffarom and other instant coffee mixes derived from synthetic ingredients [Priesner 2014, 2016; FIAT 244; FIAT 407]. See Fig. 3.58.

In parallel during the 1930s, Max Rudolf Morgenthaler (Swiss, 1901–1980) and other chemists developed Nescafé, an instant coffee mix derived from coffee bean extracts and other natural ingredients [Priesner 2014, 2016]. See Fig. 3.59.

During World War II, German-speaking scientists also made a number of improvements to the processing and sterilization of fruit juices that were adopted by other countries after the war [e.g., Kertesz 1946; FIAT 50].

3.3.3 Synthetic Fats

In the 1930s and early 1940s, many German-speaking scientists developed artificial methods to produce lipids or fats for foods, soaps, fuels, and other products.

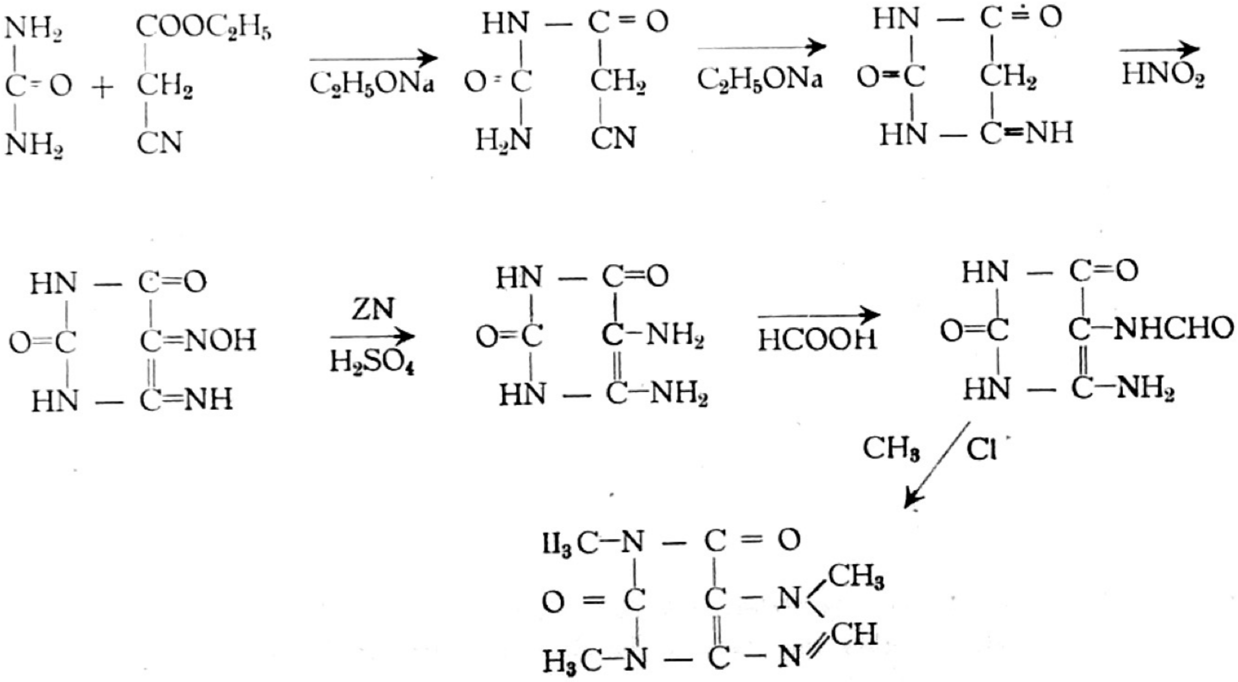
Glycerin, sterols, fatty acids, and triglycerides were produced from chemical synthesis on an industrial scale and sold for food products and other applications [BIOS 86; BIOS 805; FIAT 213; FIAT 407]. See Fig. 3.60.

Fats were produced and purified from various strains of cultured algae and fungi using biotechnology methods [BIOS 236; BIOS 691; FIAT 371]. In addition to the food applications, this appears to have been the origin of algal and other microbial biofuel technologies. See Fig. 3.61.

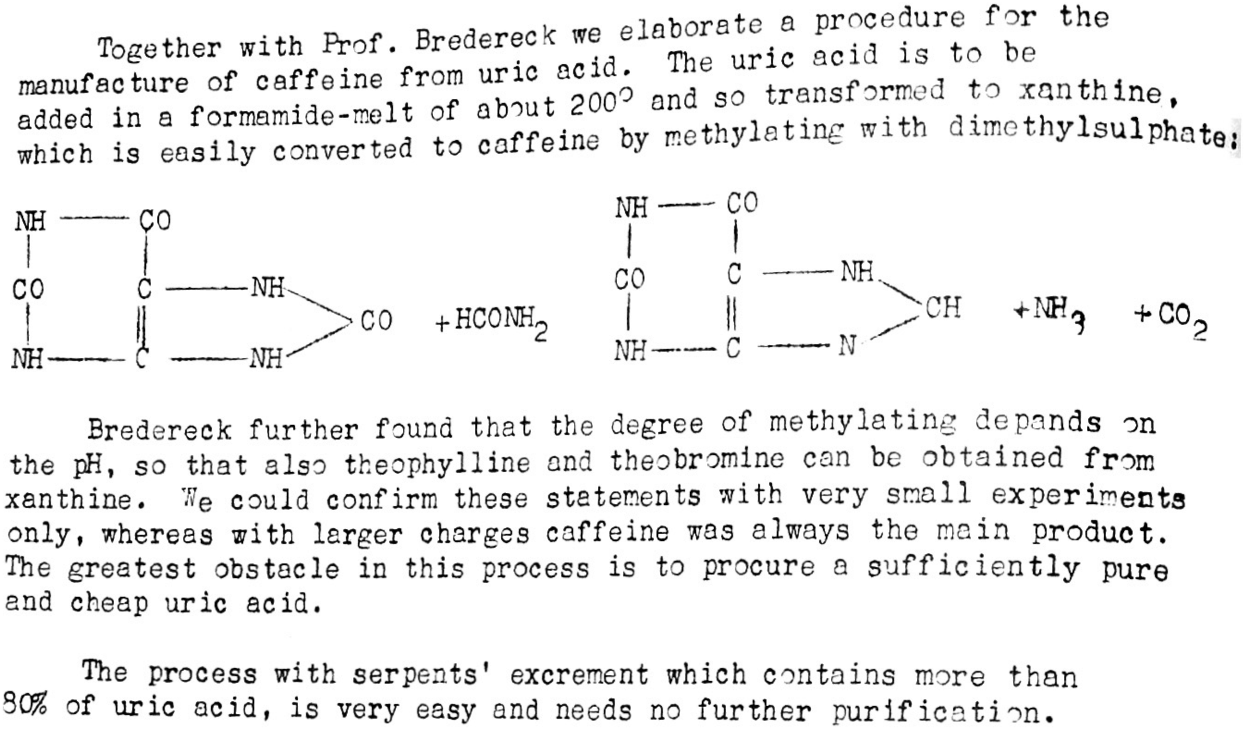
Artificially produced fats were used to make a variety of food products, including cooking oil, cooking fat (shortening), margarine, creamer, salad oil, chocolate [Clarke 1946], synthetic human milk (infant formula) [FIAT 107], etc. [See also Gemmill 1946 for examples of other innovations in butter production.]

Artificial caffeine

From chemical synthesis [FIAT 885]



From conversion of uric acid from snake urine [BIOS 449]



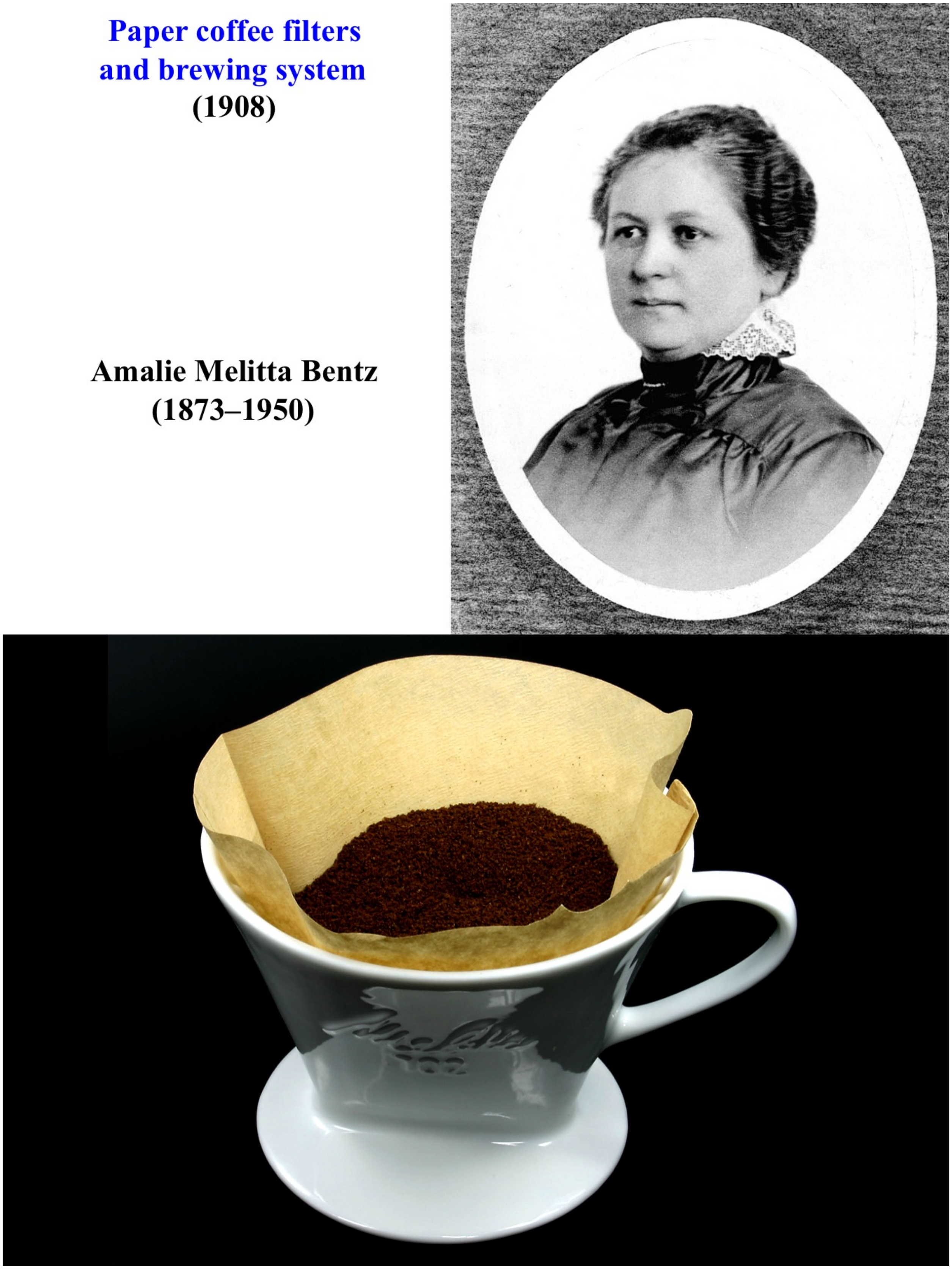
Together with Prof. Bredereck we elaborate a procedure for the manufacture of caffeine from uric acid. The uric acid is to be added in a formamide-melt of about 200° and so transformed to xanthine, which is easily converted to caffeine by methylating with dimethylsulphate:

$+HCONH_2$
$+NH_3$
$+CO_2$

Bredereck further found that the degree of methylating depands on the pH, so that also theophylline and theobromine can be obtained from xanthine. We could confirm these statements with very small experiments only, whereas with larger charges caffeine was always the main product. The greatest obstacle in this process is to procure a sufficiently pure and cheap uric acid.

The process with serpents' excrement which contains more than 80% of uric acid, is very easy and needs no further purification.

Figure 3.56: German-speaking chemists developed artificial methods of producing caffeine, including from direct chemical synthesis [FIAT 885] and from the conversion of uric acid harvested from snake urine [BIOS 449].

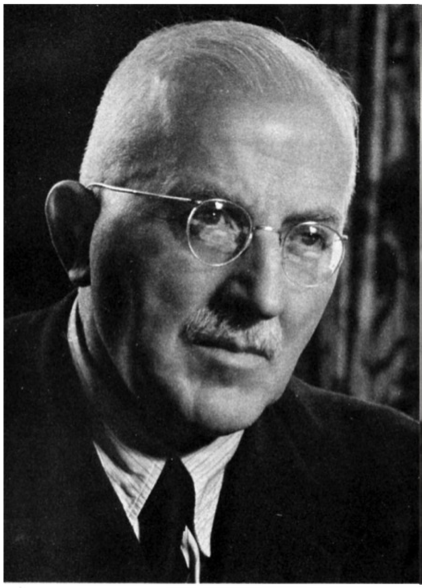


Paper coffee filters
and brewing system
(1908)
Amalie Melitta Bentz
(1873–1950)

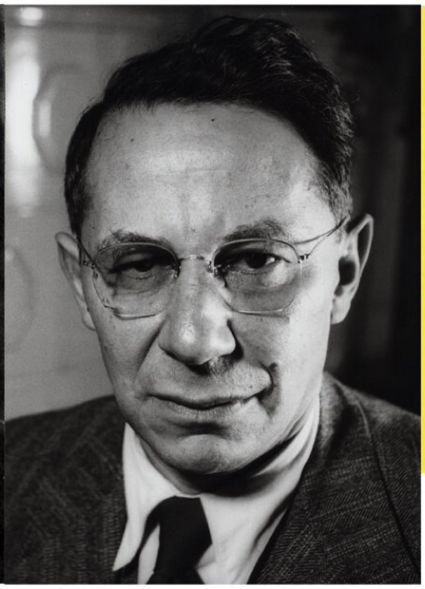
Figure 3.57: Amalie Melitta Bentz invented paper coffee filters and the corresponding brewing system in 1908.

Instant coffee: Coffarom

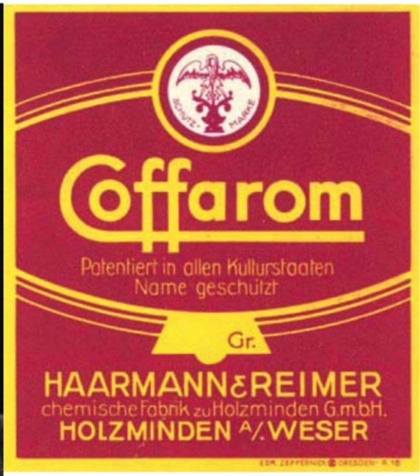
Hermann Staudinger (1881–1965)



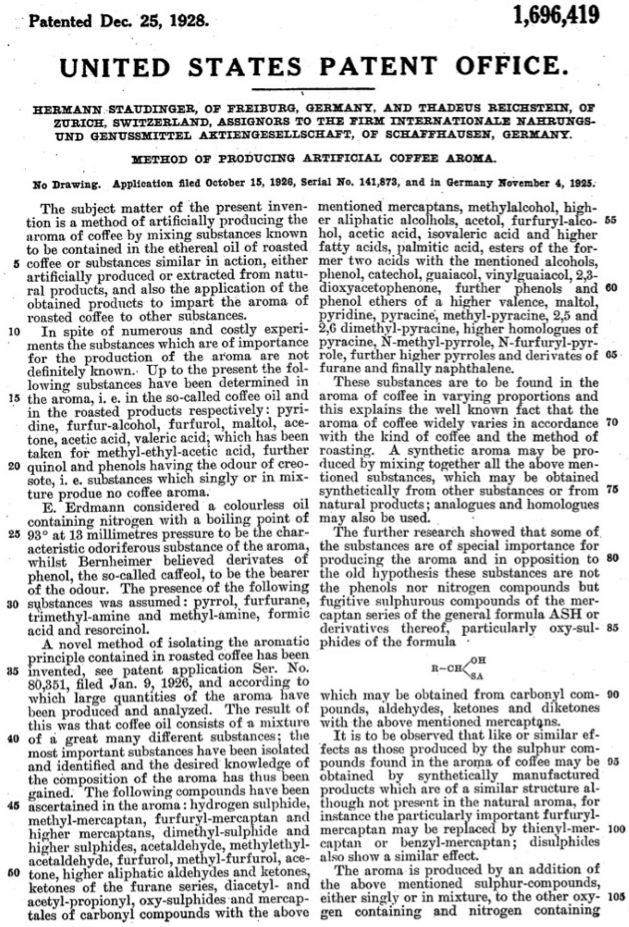
Tadeusz Reichstein (1897–1996)



Max Kerschbaum (18??–19??)



Eligius Freudl (1875–1951)



Patented Dec. 25, 1928. 1,696,419

UNITED STATES PATENT OFFICE.

HERMANN STAUDINGER, OF FREIBURG, GERMANY, AND THADEUS REICHSTEIN, OF ZURICH, SWITZERLAND, ASSIGNORS TO THE FIRM INTERNATIONALE NAHRUNGS- UND GENUSSMITTEL AKTIENGESELLSCHAFT, OF SCHAFFHAUSEN, GERMANY.

METHOD OF PRODUCING ARTIFICIAL COFFEE AROMA.

No Drawing. Application filed October 15, 1926, Serial No. 141,873, and in Germany November 4, 1925.

The subject matter of the present invention is a method of artificially producing the aroma of coffee by mixing substances known to be contained in the ethereal oil of roasted coffee or substances similar in action, either artificially produced or extracted from natural products, and also the application of the obtained products to impart the aroma of roasted coffee to other substances.

In spite of numerous and costly experiments the substances which are of importance for the production of the aroma are not definitely known. Up to the present the following substances have been determined in the aroma, i. e. in the so-called coffee oil and in the roasted products respectively: pyridine, furfur-alcohol, furfurol, maltol, acetone, acetic acid, valeric acid, which has been taken for methyl-ethyl-acetic acid, further quinol and phenols having the odour of creosote, i. e. substances which singly or in mixture produe no coffee aroma.

E. Erdmann considered a colourless oil containing nitrogen with a boiling point of 93° at 13 millimetres pressure to be the characteristic odoriferous substance of the aroma, whilst Bernheimer believed derivates of phenol, the so-called caffeol, to be the bearer of the odour. The presence of the following substances was assumed: pyrrol, furfurane, trimethyl-amine and methyl-amine, formic acid and resorcinol.

A novel method of isolating the aromatic principle contained in roasted coffee has been invented, see patent application Ser. No. 80,351, filed Jan. 9, 1926, and according to which large quantities of the aroma have been produced and analyzed. The result of this was that coffee oil consists of a mixture of a great many different substances; the most important substances have been isolated and identified and the desired knowledge of the composition of the aroma has thus been gained. The following compounds have been ascertained in the aroma: hydrogen sulphide, methyl-mercaptan, furfuryl-mercaptan and higher mercaptans, dimethyl-sulphide and higher sulphides, acetaldehyde, methylethyl-acetaldehyde, furfurol, methyl-furfurol, acetone, higher aliphatic aldehydes and ketones, ketones of the furane series, diacetyl- and acetyl-propionyl, oxy-sulphides and mercaptales of carbonyl compounds with the above mentioned mercaptans, methylalcohol, higher aliphatic alcohols, acetol, furfuryl-alcohol, acetic acid, isovaleric acid and higher fatty acids, palmitic acid, esters of the former two acids with the mentioned alcohols, phenol, catechol, guaiacol, vinylguaiacol, 2,3-dioxyacetophenone, further phenols and phenol ethers of a higher valence, maltol, pyridine, pyracine, methyl-pyracine, 2,5 and 2,6 dimethyl-pyracine, higher homologues of pyracine, N-methyl-pyrrole, N-furfuryl-pyrrole, further higher pyrroles and derivates of furane and finally naphthalene.

These substances are to be found in the aroma of coffee in varying proportions and this explains the well known fact that the aroma of coffee widely varies in accordance with the kind of coffee and the method of roasting. A synthetic aroma may be produced by mixing together all the above mentioned substances, which may be obtained synthetically from other substances or from natural products; analogues and homologues may also be used.

The further research showed that some of the substances are of special importance for producing the aroma and in opposition to the old hypothesis these substances are not the phenols nor nitrogen compounds but fugitive sulphurous compounds of the mercaptan series of the general formula ASH or derivatives thereof, particularly oxy-sulphides of the formula

$$\mathrm{R{-}CH}\left\langle\begin{matrix}\mathrm{OH}\\ \mathrm{SA}\end{matrix}\right.$$

which may be obtained from carbonyl compounds, aldehydes, ketones and diketones with the above mentioned mercaptans.

It is to be observed that like or similar effects as those produced by the sulphur compounds found in the aroma of coffee may be obtained by synthetically manufactured products which are of a similar structure although not present in the natural aroma, for instance the particularly important furfuryl-mercaptan may be replaced by thienyl-mercaptan or benzyl-mercaptan; disulphides also show a similar effect.

The aroma is produced by an addition of the above mentioned sulphur-compounds, either singly or in mixture, to the other oxygen containing and nitrogen containing

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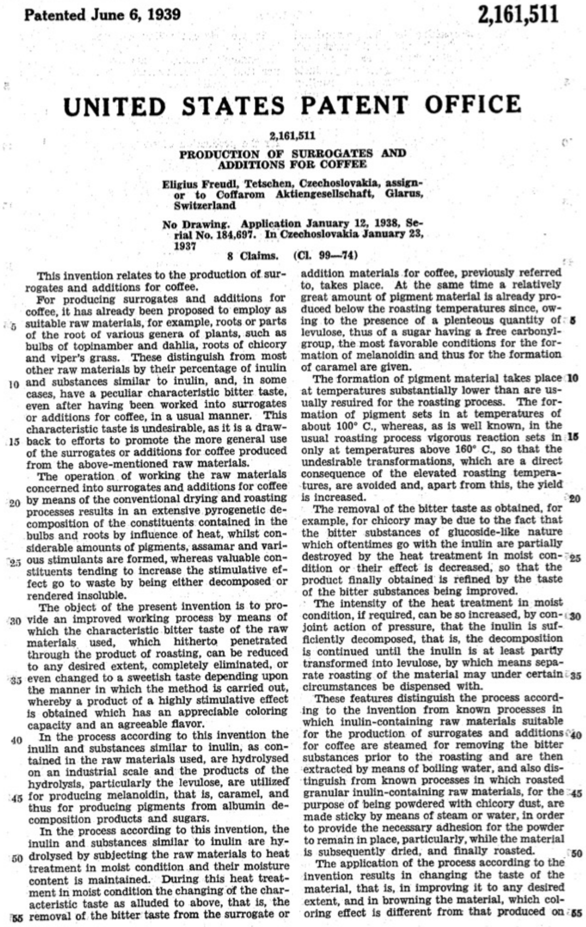


Patented June 6, 1939 2,161,511

UNITED STATES PATENT OFFICE

2,161,511

PRODUCTION OF SURROGATES AND ADDITIONS FOR COFFEE

Eligius Freudl, Tetschen, Czechoslovakia, assignor to Coffarom Aktiengesellschaft, Glarus, Switzerland

No Drawing. Application January 12, 1938, Serial No. 184,697. In Czechoslovakia January 23, 1937

8 Claims. (Cl. 99—74)

This invention relates to the production of surrogates and additions for coffee.

For producing surrogates and additions for coffee, it has already been proposed to employ as suitable raw materials, for example, roots or parts of the root of various genera of plants, such as bulbs of topinamber and dahlia, roots of chicory and viper's grass. These distinguish from most other raw materials by their percentage of inulin and substances similar to inulin, and, in some cases, have a peculiar characteristic bitter taste, even after having been worked into surrogates or additions for coffee, in a usual manner. This characteristic taste is undesirable, as it is a drawback to efforts to promote the more general use of the surrogates or additions for coffee produced from the above-mentioned raw materials.

The operation of working the raw materials concerned into surrogates and additions for coffee by means of the conventional drying and roasting processes results in an extensive pyrogenetic decomposition of the constituents contained in the bulbs and roots by influence of heat, whilst considerable amounts of pigments, assamar and various stimulants are formed, whereas valuable constituents tending to increase the stimulative effect go to waste by being either decomposed or rendered insoluble.

The object of the present invention is to provide an improved working process by means of which the characteristic bitter taste of the raw materials used, which hitherto penetrated through the product of roasting, can be reduced to any desired extent, completely eliminated, or even changed to a sweetish taste depending upon the manner in which the method is carried out, whereby a product of a highly stimulative effect is obtained which has an appreciable coloring capacity and an agreeable flavor.

In the process according to this invention the inulin and substances similar to inulin, as contained in the raw materials used, are hydrolysed on an industrial scale and the products of the hydrolysis, particularly the levulose, are utilized for producing melanoidin, that is, caramel, and thus for producing pigments from albumin decomposition products and sugars.

In the process according to this invention, the inulin and substances similar to inulin are hydrolysed by subjecting the raw materials to heat treatment in moist condition and their moisture content is maintained. During this heat treatment in moist condition the changing of the characteristic taste as alluded to above, that is, the removal of the bitter taste from the surrogate or addition materials for coffee, previously referred to, takes place. At the same time a relatively great amount of pigment material is already produced below the roasting temperatures since, owing to the presence of a plenteous quantity of levulose, thus of a sugar having a free carbonyl-group, the most favorable conditions for the formation of melanoidin and thus for the formation of caramel are given.

The formation of pigment material takes place at temperatures substantially lower than are usually resuired for the roasting process. The formation of pigment sets in at temperatures of about 100° C., whereas, as is well known, in the usual roasting process vigorous reaction sets in only at temperatures above 160° C., so that the undesirable transformations, which are a direct consequence of the elevated roasting temperatures, are avoided and, apart from this, the yield is increased.

The removal of the bitter taste as obtained, for example, for chicory may be due to the fact that the bitter substances of glucoside-like nature which oftentimes go with the inulin are partially destroyed by the heat treatment in moist condition or their effect is decreased, so that the product finally obtained is refined by the taste of the bitter substances being improved.

The intensity of the heat treatment in moist condition, if required, can be so increased, by conjoint action of pressure, that the inulin is sufficiently decomposed, that is, the decomposition is continued until the inulin is at least partly transformed into levulose, by which means separate roasting of the material may under certain circumstances be dispensed with.

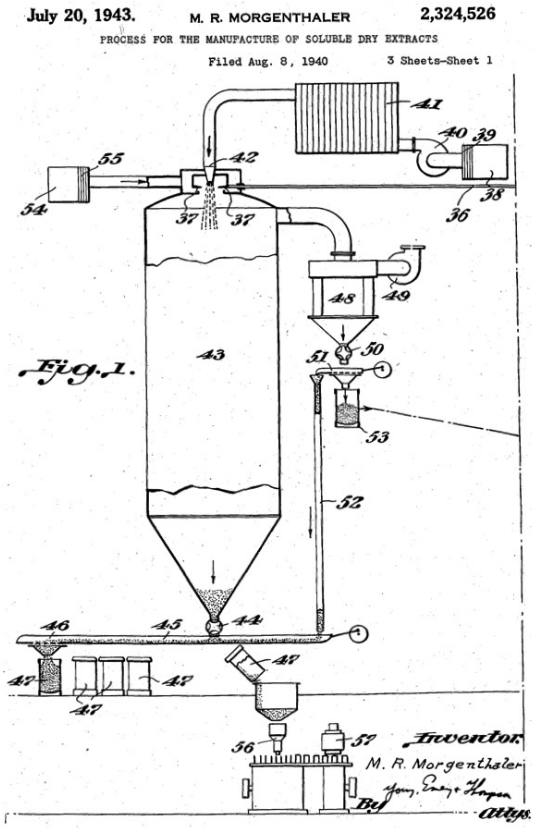
These features distinguish the process according to the invention from known processes in which inulin-containing raw materials suitable for the production of surrogates and additions for coffee are steamed for removing the bitter substances prior to the roasting and are then extracted by means of boiling water, and also distinguish from known processes in which roasted granular inulin-containing raw materials, for the purpose of being powdered with chicory dust, are made sticky by means of steam or water, in order to provide the necessary adhesion for the powder to remain in place, particularly, while the material is subsequently dried, and finally roasted.

The application of the process according to the invention results in changing the taste of the material, that is, in improving it to any desired extent, and in browning the material, which coloring effect is different from that produced on

Figure 3.58: In the 1930s, Hermann Staudinger, Tadeusz Reichstein, Max Kerschbaum, Eligius Freudl, and other chemists developed Coffarom, an instant coffee derived from synthetic ingredients.

Instant coffee: Nescafé

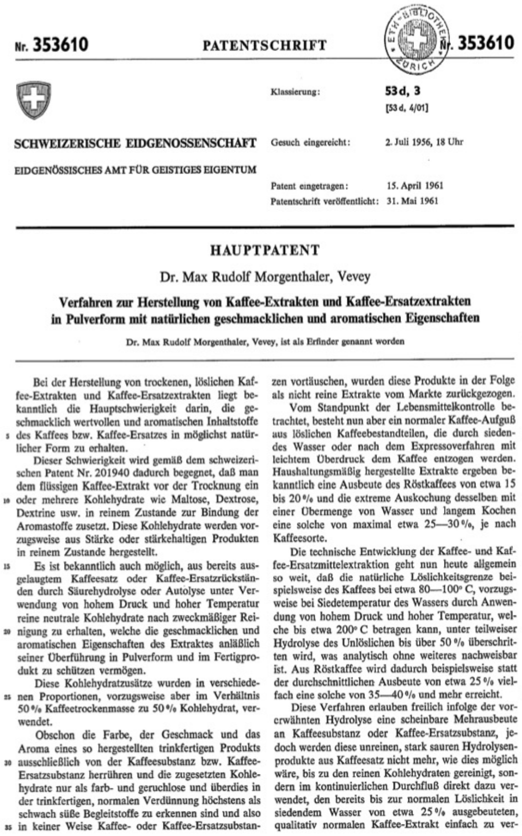
Max Rudolf Morgenthaler (1901–1980)



July 20, 1943. M. R. MORGENTHALER **2,324,526**

PROCESS FOR THE MANUFACTURE OF SOLUBLE DRY EXTRACTS

Filed Aug. 8, 1940 3 Sheets-Sheet 1



Nr. 353610 PATENTSCHRIFT **Nr. 353610**

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EIDGENÖSSISCHES AMT FÜR GEISTIGES EIGENTUM

Klassierung: **53d, 3**
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HAUPTPATENT

Dr. Max Rudolf Morgenthaler, Vevey

Verfahren zur Herstellung von Kaffee-Extrakten und Kaffee-Ersatzextrakten in Pulverform mit natürlichen geschmacklichen und aromatischen Eigenschaften

Dr. Max Rudolf Morgenthaler, Vevey, ist als Erfinder genannt worden

Bei der Herstellung von trockenen, löslichen Kaffee-Extrakten und Kaffee-Ersatzextrakten liegt bekanntlich die Hauptschwierigkeit darin, die geschmacklich wertvollen und aromatischen Inhaltstoffe des Kaffees bzw. Kaffee-Ersatzes in möglichst natürlicher Form zu erhalten.

Dieser Schwierigkeit wird gemäß dem schweizerischen Patent Nr. 201940 dadurch begegnet, daß man dem flüssigen Kaffee-Extrakt vor der Trocknung ein oder mehrere Kohlehydrate wie Maltose, Dextrose, Dextrine usw. in reinem Zustande zur Bindung der Aromastoffe zusetzt. Diese Kohlehydrate werden vorzugsweise aus Stärke oder stärkehaltigen Produkten in reinem Zustande hergestellt.

Es ist bekanntlich auch möglich, aus bereits ausgelaugtem Kaffeesatz oder Kaffee-Ersatzrückständen durch Säurehydrolyse oder Autolyse unter Verwendung von hohem Druck und hoher Temperatur reine neutrale Kohlehydrate nach zweckmäßiger Reinigung zu erhalten, welche die geschmacklichen und aromatischen Eigenschaften des Extraktes anläßlich seiner Überführung in Pulverform und im Fertigprodukt zu schützen vermögen.

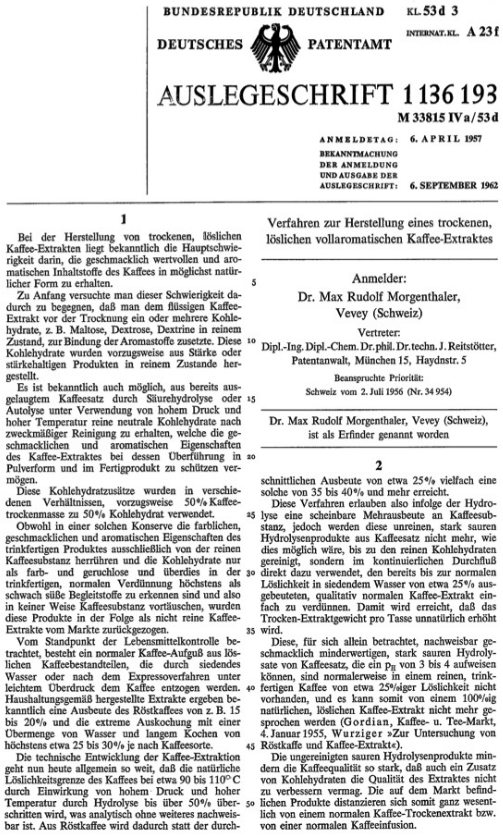
Diese Kohlehydratzusätze wurden in verschiedenen Proportionen, vorzugsweise aber im Verhältnis 50 % Kaffeetrockenmasse zu 50 % Kohlehydrat, verwendet.

Obschon die Farbe, der Geschmack und das Aroma eines so hergestellten trinkfertigen Produkts ausschließlich von der Kaffeesubstanz bzw. Kaffee-Ersatzsubstanz herrühren und die zugesetzten Kohlehydrate nur als farb- und geruchlose und überdies in der trinkfertigen, normalen Verdünnung höchstens als schwach süße Begleitstoffe zu erkennen sind und also in keiner Weise Kaffee- oder Kaffee-Ersatzsubstanzen vortäuschen, wurden diese Produkte in der Folge als nicht reine Extrakte vom Markte zurückgezogen.

Vom Standpunkt der Lebensmittelkontrolle betrachtet, besteht nun aber ein normaler Kaffee-Aufguß aus löslichen Kaffeebestandteilen, die durch siedendes Wasser oder nach dem Expressoverfahren mit leichtem Überdruck dem Kaffee entzogen werden. Haushaltungsmäßig hergestellte Extrakte ergeben bekanntlich eine Ausbeute des Röstkaffees von etwa 15 bis 20 % und die extreme Auskochung desselben mit einer Übermenge von Wasser und langem Kochen eine solche von maximal etwa 25—30 %, je nach Kaffeesorte.

Die technische Entwicklung der Kaffee- und Kaffee-Ersatzmittelextraktion geht nun heute allgemein so weit, daß die natürliche Löslichkeitsgrenze beispielsweise des Kaffees bei etwa 80—100° C, vorzugsweise bei Siedetemperatur des Wassers durch Anwendung von hohem Druck und hoher Temperatur, welche bis etwa 200° C betragen kann, unter teilweiser Hydrolyse des Unlöslichen bis über 50 % überschritten wird, was analytisch ohne weiteres nachweisbar ist. Aus Röstkaffee wird dadurch beispielsweise statt der durchschnittlichen Ausbeute von etwa 25 % vielfach eine solche von 35—40 % und mehr erreicht.

Diese Verfahren erlauben freilich infolge der vorerwähnten Hydrolyse eine scheinbare Mehrausbeute an Kaffeesubstanz oder Kaffee-Ersatzsubstanz, jedoch werden diese unreinen, stark sauren Hydrolysenprodukte aus Kaffeesatz nicht mehr, wie dies möglich wäre, bis zu den reinen Kohlehydraten gereinigt, sondern im kontinuierlichen Durchfluß direkt dazu verwendet, den bereits bis zur normalen Löslichkeit in siedendem Wasser von etwa 25 % ausgebeuteten, qualitativ normalen Kaffee-Extrakt einfach zu ver-



BUNDESREPUBLIK DEUTSCHLAND KL. 53d 3

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DEUTSCHES PATENTAMT

AUSLEGESCHRIFT 1 136 193

M 33815 IVa/53d

ANMELDETAG: 6. APRIL 1957

BEKANNTMACHUNG DER ANMELDUNG UND AUSGABE DER AUSLEGESCHRIFT: 6. SEPTEMBER 1962

Verfahren zur Herstellung eines trockenen, löslichen vollaromatischen Kaffee-Extraktes

Anmelder:
Dr. Max Rudolf Morgenthaler,
Vevey (Schweiz)

Vertreter:
Dipl.-Ing. Dipl.-Chem. Dr. phil. Dr. techn. J. Reitstötter,
Patentanwalt, München 15, Haydnstr. 5

Beanspruchte Priorität:
Schweiz vom 2. Juli 1956 (Nr. 34 954)

Dr. Max Rudolf Morgenthaler, Vevey (Schweiz), ist als Erfinder genannt worden

1

Bei der Herstellung von trockenen, löslichen Kaffee-Extrakten liegt bekanntlich die Hauptschwierigkeit darin, die geschmacklich wertvollen und aromatischen Inhaltstoffe des Kaffees in möglichst natürlicher Form zu erhalten.

Zu Anfang versuchte man dieser Schwierigkeit dadurch zu begegnen, daß man dem flüssigen Kaffee-Extrakt vor der Trocknung ein oder mehrere Kohlehydrate, z. B. Maltose, Dextrose, Dextrine in reinem Zustand, zur Bindung der Aromastoffe zusetzte. Diese Kohlehydrate wurden vorzugsweise aus Stärke oder stärkehaltigen Produkten in reinem Zustande hergestellt.

Es ist bekanntlich auch möglich, aus bereits ausgelaugtem Kaffeesatz durch Säurehydrolyse oder Autolyse unter Verwendung von hohem Druck und hoher Temperatur reine neutrale Kohlehydrate nach zweckmäßiger Reinigung zu erhalten, welche die geschmacklichen und aromatischen Eigenschaften des Kaffee-Extraktes bei dessen Überführung in Pulverform und im Fertigprodukt zu schützen vermögen.

Diese Kohlehydratzusätze wurden in verschiedenen Verhältnissen, vorzugsweise 50 % Kaffeetrockenmasse zu 50 % Kohlehydrat verwendet.

Obwohl in einer solchen Konserve die farblichen, geschmacklichen und aromatischen Eigenschaften des trinkfertigen Produktes ausschließlich von der reinen Kaffeesubstanz herrühren und die Kohlehydrate nur als farb- und geruchlose und überdies in der trinkfertigen, normalen Verdünnung höchstens als schwach süße Begleitstoffe zu erkennen sind und also in keiner Weise Kaffeesubstanz vortäuschen, wurden diese Produkte in der Folge als nicht reine Kaffee-Extrakte vom Markte zurückgezogen.

Vom Standpunkt der Lebensmittelkontrolle betrachtet, besteht ein normaler Kaffee-Aufguß aus löslichen Kaffeebestandteilen, die durch siedendes Wasser oder nach dem Expressoverfahren unter leichtem Überdruck dem Kaffee entzogen werden. Haushaltungsgemäß hergestellte Extrakte ergeben bekanntlich eine Ausbeute des Röstkaffees von z. B. 15 bis 20 % und die extreme Auskochung mit einer Übermenge von Wasser und langem Kochen von höchstens etwa 25 bis 30 % je nach Kaffeesorte.

Die technische Entwicklung der Kaffee-Extraktion geht nun heute allgemein so weit, daß die natürliche Löslichkeitsgrenze des Kaffees bei etwa 90 bis 110° C durch Einwirkung von hohem Druck und hoher Temperatur durch Hydrolyse bis über 50 % überschritten wird, was analytisch ohne weiteres nachweisbar ist. Aus Röstkaffee wird dadurch statt der durchschnittlichen Ausbeute von etwa 25 % vielfach eine solche von 35 bis 40 % und mehr erreicht.

2

Diese Verfahren erlauben also infolge der Hydrolyse eine scheinbare Mehrausbeute an Kaffeesubstanz, jedoch werden diese unreinen, stark sauren Hydrolysenprodukte aus Kaffeesatz nicht mehr, wie dies möglich wäre, bis zu den reinen Kohlehydraten gereinigt, sondern im kontinuierlichen Durchfluß direkt dazu verwendet, den bereits bis zur normalen Löslichkeit in siedendem Wasser von etwa 25 % ausgebeuteten, qualitativ normalen Kaffee-Extrakt einfach zu verdünnen. Damit wird erreicht, daß das Trocken-Extraktgewicht pro Tasse unnatürlich erhöht wird.

Diese, für sich allein betrachtet, nachweisbar geschmacklich minderwertigen, stark sauren Hydrolysate von Kaffeesatz, die ein p_H von 3 bis 4 aufweisen können, sind normalerweise in einem reinen, trinkfertigen Kaffee von etwa 25%iger Löslichkeit nicht vorhanden, und es kann somit von einem 100%ig natürlichen, löslichen Kaffee-Extrakt nicht mehr gesprochen werden (Gordian, Kaffee- u. Tee-Markt, 4. Januar 1955, Wurziger »Zur Untersuchung von Röstkaffe und Kaffee-Extrakt«).

Die ungereinigten sauren Hydrolysenprodukte mindern die Kaffeequalität so stark, daß auch ein Zusatz von Kohlehydraten die Qualität des Extraktes nicht zu verbessern vermag. Die auf dem Markt befindlichen Produkte distanzieren sich somit ganz wesentlich von einem normalen Kaffee-Trockenextrakt bzw. von einer normalen Kaffeeinfusion.

Figure 3.59: In the 1930s, Max Rudolf Morgenthaler and other chemists developed Nescafé, an instant coffee derived from natural ingredients.

Production of fats via industrial chemical synthesis

[BIOS 805]

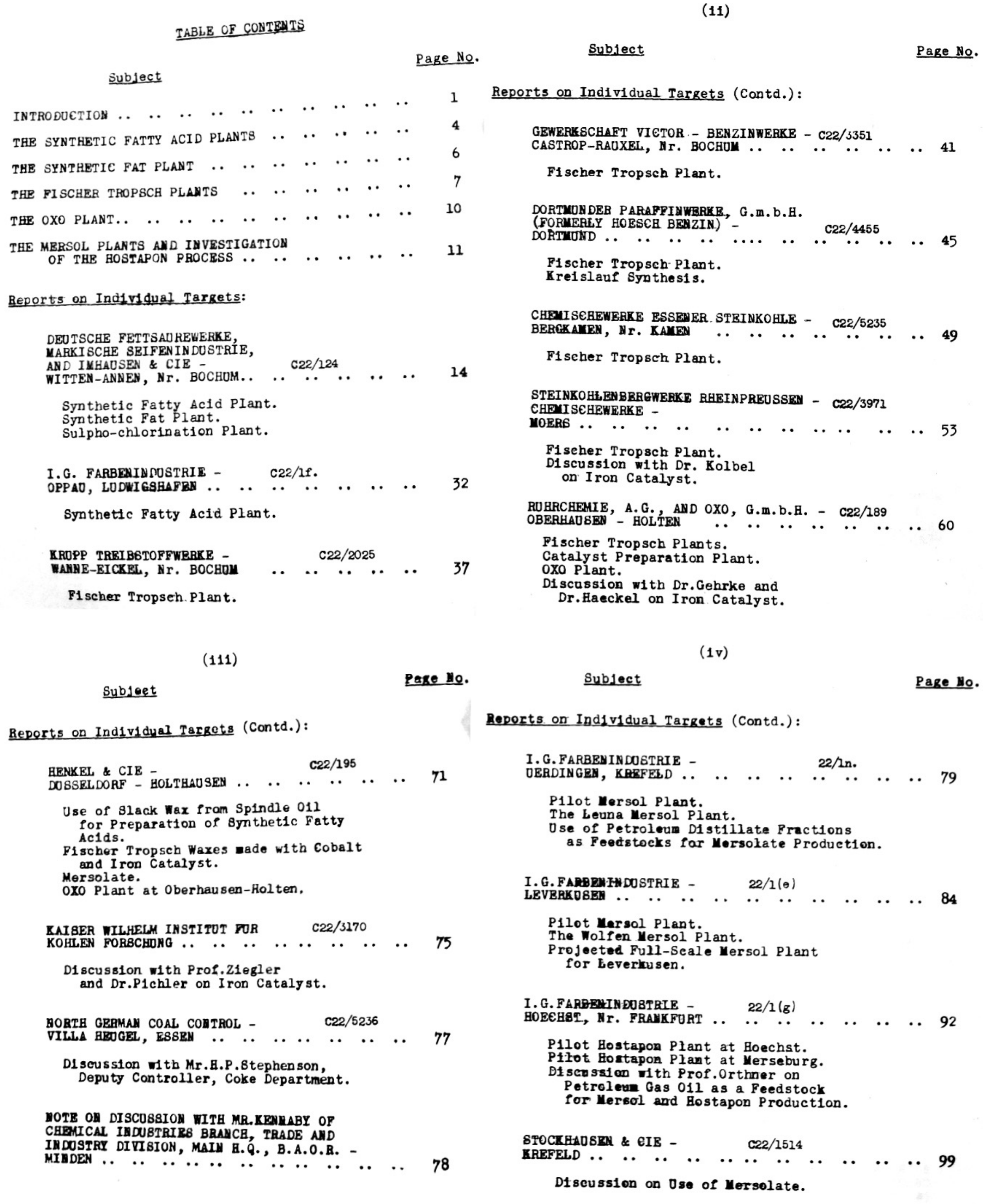

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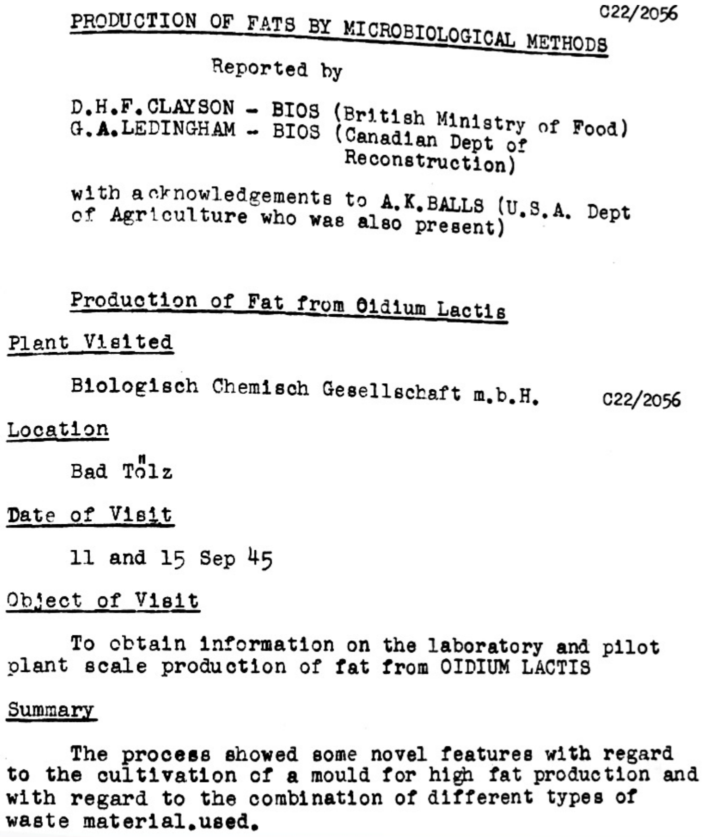
Figure 3.60: In the 1930s and early 1940s, German-speaking scientists developed methods to produce fats via industrial chemical synthesis [BIOS 805].

Production of fats via biotechnology

From cultured yeast [BIOS 236]



C22/2056

PRODUCTION OF FATS BY MICROBIOLOGICAL METHODS

Reported by

D.H.F.CLAYSON - BIOS (British Ministry of Food)
G.A.LEDINGHAM - BIOS (Canadian Dept of Reconstruction)

with acknowledgements to A.K.BALLS (U.S.A. Dept of Agriculture who was also present)

Production of Fat from Oidium Lactis

Plant Visited

Biologisch Chemisch Gesellschaft m.b.H. C22/2056

Location

Bad Tölz

Date of Visit

11 and 15 Sep 45

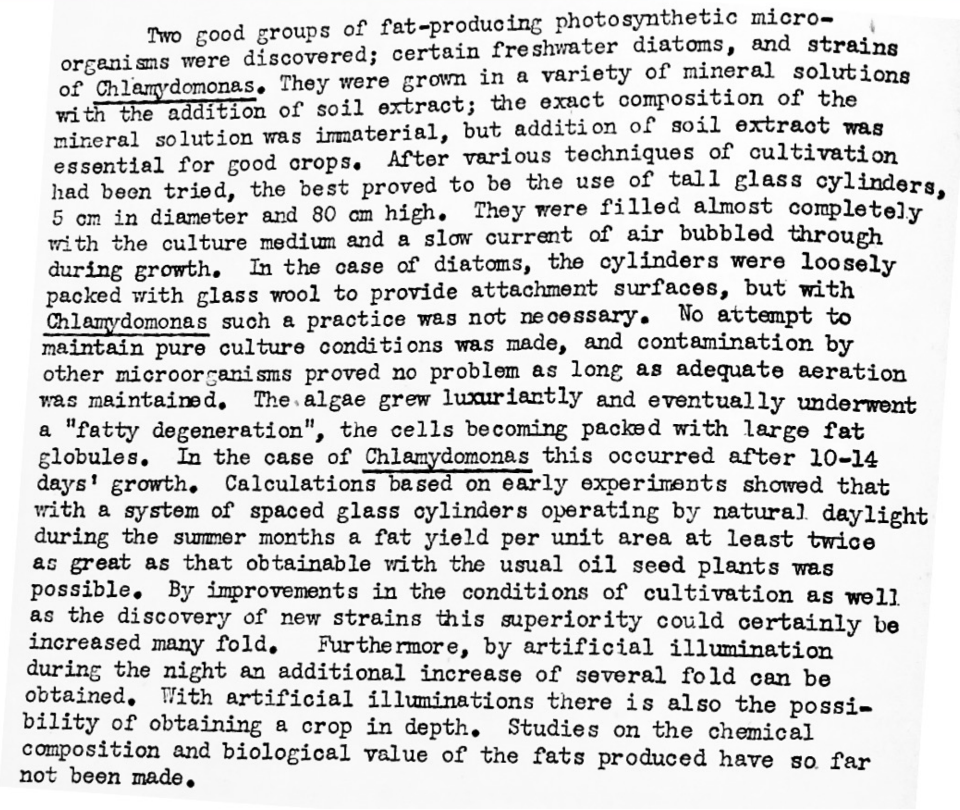
Object of Visit

To obtain information on the laboratory and pilot plant scale production of fat from OIDIUM LACTIS

Summary

The process showed some novel features with regard to the cultivation of a mould for high fat production and with regard to the combination of different types of waste material.used.

From cultured algae [BIOS 691]



Two good groups of fat-producing photosynthetic micro-organisms were discovered; certain freshwater diatoms, and strains of Chlamydomonas. They were grown in a variety of mineral solutions with the addition of soil extract; the exact composition of the mineral solution was immaterial, but addition of soil extract was essential for good crops. After various techniques of cultivation had been tried, the best proved to be the use of tall glass cylinders, 5 cm in diameter and 80 cm high. They were filled almost completely with the culture medium and a slow current of air bubbled through during growth. In the case of diatoms, the cylinders were loosely packed with glass wool to provide attachment surfaces, but with Chlamydomonas such a practice was not necessary. No attempt to maintain pure culture conditions was made, and contamination by other microorganisms proved no problem as long as adequate aeration was maintained. The algae grew luxuriantly and eventually underwent a "fatty degeneration", the cells becoming packed with large fat globules. In the case of Chlamydomonas this occurred after 10-14 days' growth. Calculations based on early experiments showed that with a system of spaced glass cylinders operating by natural daylight during the summer months a fat yield per unit area at least twice as great as that obtainable with the usual oil seed plants was possible. By improvements in the conditions of cultivation as well as the discovery of new strains this superiority could certainly be increased many fold. Furthermore, by artificial illumination during the night an additional increase of several fold can be obtained. With artificial illuminations there is also the possibility of obtaining a crop in depth. Studies on the chemical composition and biological value of the fats produced have so far not been made.

Figure 3.61: In the 1930s and early 1940s, German-speaking scientists developed methods to produce fats via biotechnology using cultured yeast or algae cells [BIOS 236; BIOS 691].

3.3.4 Synthetic Protein Products

Likewise in the 1930s and early 1940s, German-speaking scientists developed several egg protein substitutes that consisted of protein extracted and processed on an industrial scale from (Fig. 3.62):

- Cultured strains of yeast that produced the variety of amino acids needed by humans, as developed by Andreas Lembke (German, 1911–2002) and other scientists [BIOS 236; BIOS 691; FIAT 491].
- Animal blood plasma (a final product called Plenora), as developed by scientists at the Rugamer & Co. Plenora-Werke in Hamburg [BIOS 1417; FIAT 491].
- Fish (a final product called Eiweiss), as developed by Peter Paul Hiltner (German, 19??–19??) and other scientists [BIOS 1481; FIAT 491].
- Milk (a final product called Milei), as developed by Georg Demmler (German, 19??–19??) and other scientists [BIOS 32; BIOS 275; BIOS 1513; BIOS 1782; FIAT 491].

3.3.5 Preservatives

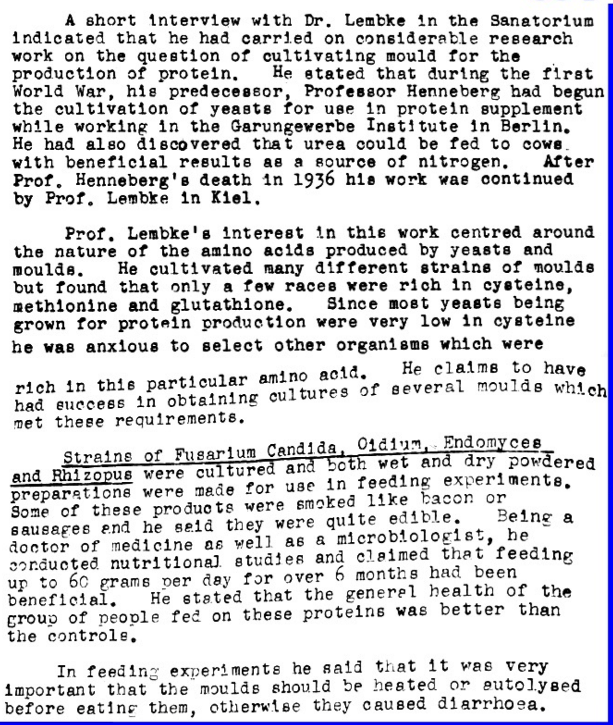
In order to preserve valuable food stocks for storage and transport during both peacetime and wartime, German-speaking scientists developed many important food preservatives that work by chelating (trapping) metal ions that are needed by degradative enzymes and bacteria. These preservatives have been widely used ever since, and include for example:

- Ascorbic acid (vitamin C), which was identified in 1930 by Albert Szent-Györgyi (Hungarian, 1893–1986) and mass-produced via chemical synthesis in 1933 by Tadeusz Reichstein (Polish, educated and worked in Switzerland, 1897–1996, Fig. 3.63).
- Benzoic acid, which was first analyzed in 1832 by Friedrich Wöhler (German, 1800–1882) and Justus von Liebig (German, 1803–1873, Fig. 3.63).
- Citric acid, which was first produced from fermentation in fungi in 1890 by Carl Wehmer (German, 1858–1935, Fig. 3.63) [Benninga 1990, p. 140].
- Sorbic acid, which was discovered in 1859 by August Wilhelm von Hofmann (German, 1818–1892, Fig. 3.63).
- Ethylenediaminetetraacetic acid (EDTA), an extremely effective chelator, which was synthesized and demonstrated in 1935 by Ferdinand Münz (Austrian, 1888–1969, Fig. 3.64) Schahinian 2018.

In 1940, German-speaking scientists also developed and successfully implemented the use of ultraviolet light to sterilize drinks so that they could be packaged for safe long-term storage without requiring refrigeration [BIOS 770; FIAT 50; FIAT 107; FIAT 257]. Some of the most important scientists in the project were Andreas Lembke (German, 1911–2002), Hellmuth Bayha (German?, 19??–19??), Karl Krammer (German?, 19??–19??), and Eugen Sauter (German?, 19??–19??). For more information, see pp. 2367–2373.

Artificial egg protein

Protein derived from cultured yeast [BIOS 236]



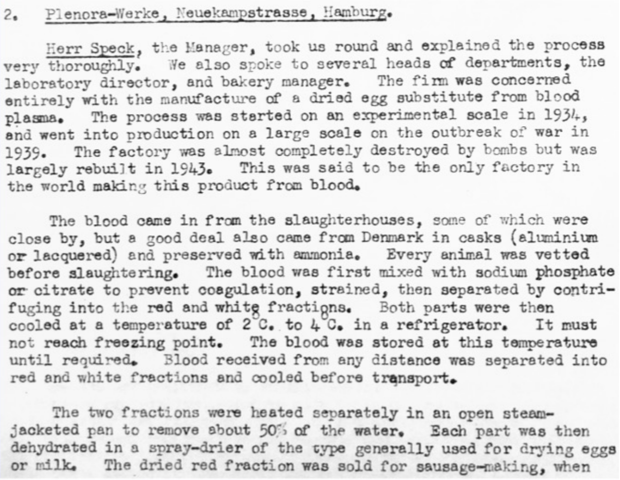
A short interview with Dr. Lembke in the Sanatorium indicated that he had carried on considerable research work on the question of cultivating mould for the production of protein. He stated that during the first World War, his predecessor, Professor Henneberg had begun the cultivation of yeasts for use in protein supplement while working in the Garungewerbe Institute in Berlin. He had also discovered that urea could be fed to cows with beneficial results as a source of nitrogen. After Prof. Henneberg's death in 1936 his work was continued by Prof. Lembke in Kiel.

Prof. Lembke's interest in this work centred around the nature of the amino acids produced by yeasts and moulds. He cultivated many different strains of moulds but found that only a few races were rich in cysteine, methionine and glutathione. Since most yeasts being grown for protein production were very low in cysteine he was anxious to select other organisms which were rich in this particular amino acid. He claims to have had success in obtaining cultures of several moulds which met these requirements.

Strains of Fusarium Candida, Oidium, Endomyces and Rhizopus were cultured and both wet and dry powdered preparations were made for use in feeding experiments. Some of these products were smoked like bacon or sausages and he said they were quite edible. Being a doctor of medicine as well as a microbiologist, he conducted nutritional studies and claimed that feeding up to 60 grams per day for over 6 months had been beneficial. He stated that the general health of the group of people fed on these proteins was better than the controls.

In feeding experiments he said that it was very important that the moulds should be heated or autolysed before eating them, otherwise they caused diarrhoea.

Plenora derived from animal blood plasma [BIOS 1417]



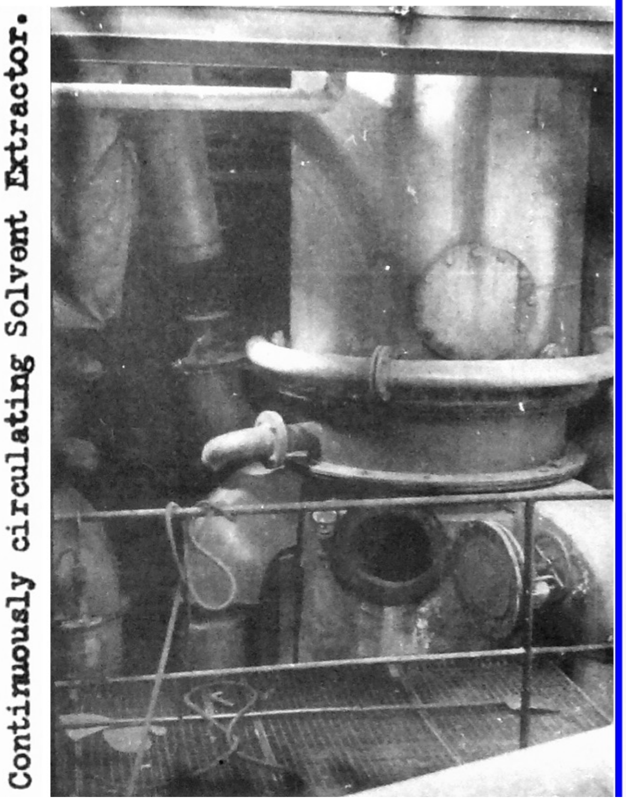
2. Plenora-Werke, Neuekampstrasse, Hamburg.

Herr Speck, the Manager, took us round and explained the process very thoroughly. We also spoke to several heads of departments, the laboratory director, and bakery manager. The firm was concerned entirely with the manufacture of a dried egg substitute from blood plasma. The process was started on an experimental scale in 1934, and went into production on a large scale on the outbreak of war in 1939. The factory was almost completely destroyed by bombs but was largely rebuilt in 1943. This was said to be the only factory in the world making this product from blood.

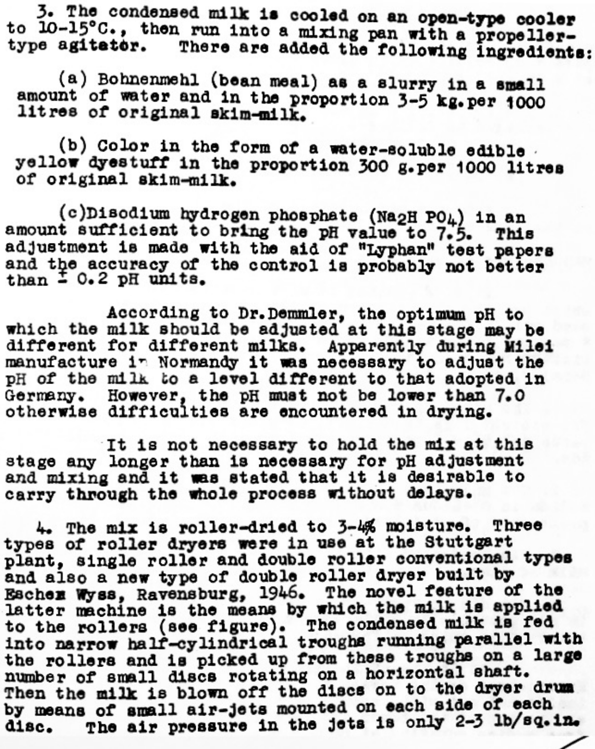
The blood came in from the slaughterhouses, some of which were close by, but a good deal also came from Denmark in casks (aluminium or lacquered) and preserved with ammonia. Every animal was vetted before slaughtering. The blood was first mixed with sodium phosphate or citrate to prevent coagulation, strained, then separated by contrifuging into the red and white fractions. Both parts were then cooled at a temperature of 2°C. to 4°C. in a refrigerator. It must not reach freezing point. The blood was stored at this temperature until required. Blood received from any distance was separated into red and white fractions and cooled before transport.

The two fractions were heated separately in an open steam-jacketed pan to remove about 50% of the water. Each part was then dehydrated in a spray-drier of the type generally used for drying eggs or milk. The dried red fraction was sold for sausage-making, when

Eiweiss derived from fish [BIOS 1481]



Milei derived from milk [BIOS 1513]



3. The condensed milk is cooled on an open-type cooler to 10-15°C., then run into a mixing pan with a propeller-type agitator. There are added the following ingredients:-

(a) Bohnenmehl (bean meal) as a slurry in a small amount of water and in the proportion 3-5 kg.per 1000 litres of original skim-milk.

(b) Color in the form of a water-soluble edible yellow dyestuff in the proportion 300 g.per 1000 litres of original skim-milk.

(c)Disodium hydrogen phosphate ($Na_2H\ PO_4$) in an amount sufficient to bring the pH value to 7.5. This adjustment is made with the aid of "Lyphan" test papers and the accuracy of the control is probably not better than ± 0.2 pH units.

According to Dr.Demmler, the optimum pH to which the milk should be adjusted at this stage may be different for different milks. Apparently during Milei manufacture in Normandy it was necessary to adjust the pH of the milk to a level different to that adopted in Germany. However, the pH must not be lower than 7.0 otherwise difficulties are encountered in drying.

It is not necessary to hold the mix at this stage any longer than is necessary for pH adjustment and mixing and it was stated that it is desirable to carry through the whole process without delays.

4. The mix is roller-dried to 3-4% moisture. Three types of roller dryers were in use at the Stuttgart plant, single roller and double roller conventional types and also a new type of double roller dryer built by Escher Wyss, Ravensburg, 1946. The novel feature of the latter machine is the means by which the milk is applied to the rollers (see figure). The condensed milk is fed into narrow half-cylindrical troughs running parallel with the rollers and is picked up from these troughs on a large number of small discs rotating on a horizontal shaft. Then the milk is blown off the discs on to the dryer drum by means of small air-jets mounted on each side of each disc. The air pressure in the jets is only 2-3 lb/sq.in.

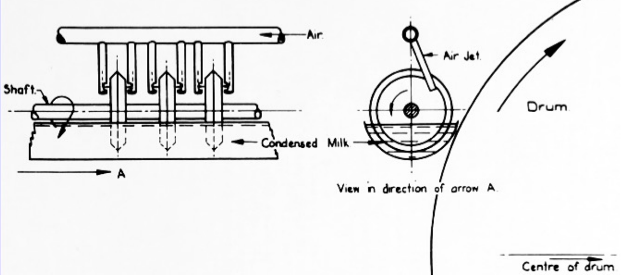


Figure 3.62: In the 1930s and early 1940s, German-speaking scientists developed several egg protein substitutes that consisted of protein extracted and processed on an industrial scale from cultured yeast, animal blood plasma (Plenora), fish (Eiweiss), and milk (Milei) [BIOS 236; BIOS 1417; BIOS 1481; BIOS 1513].

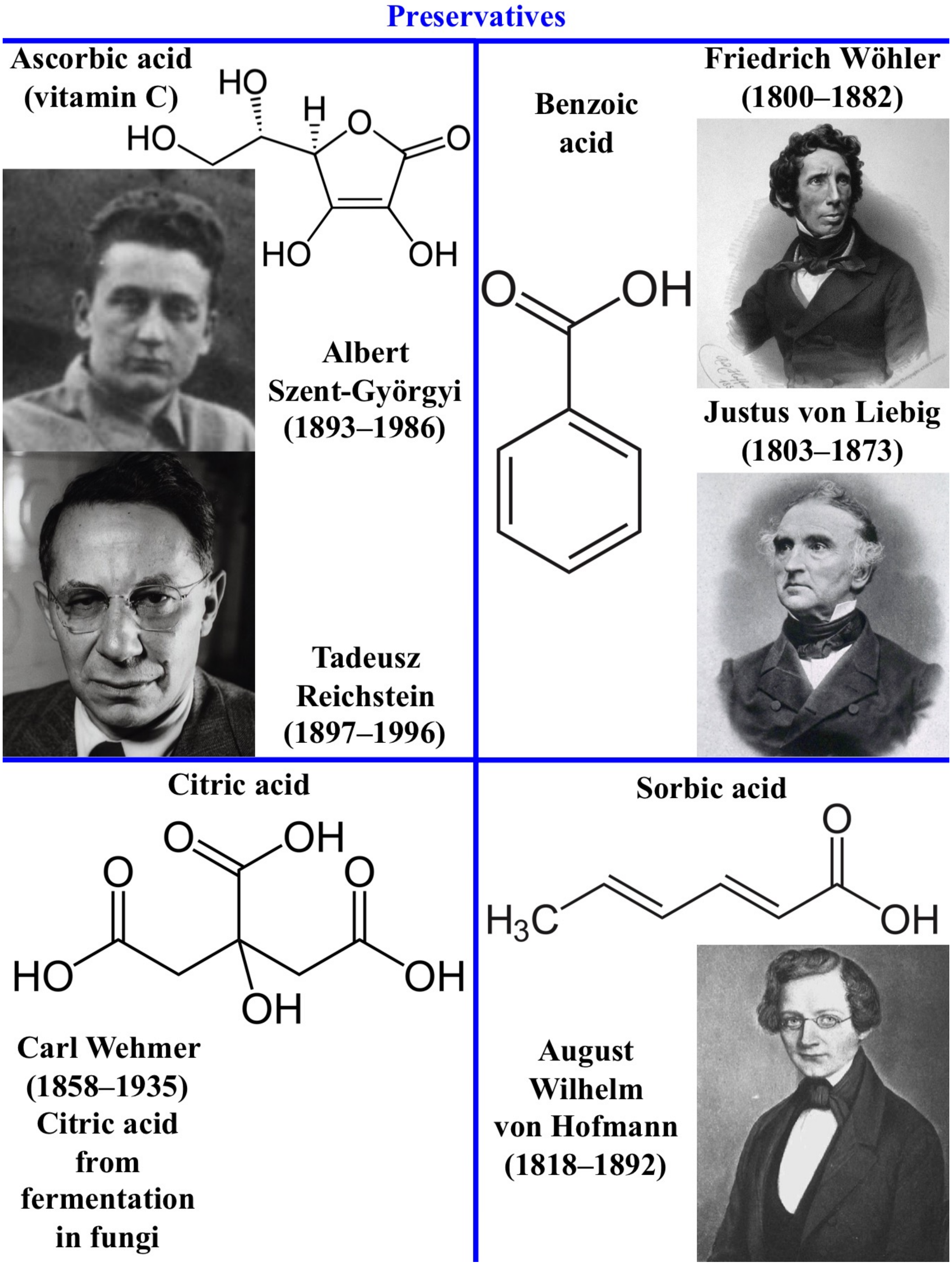
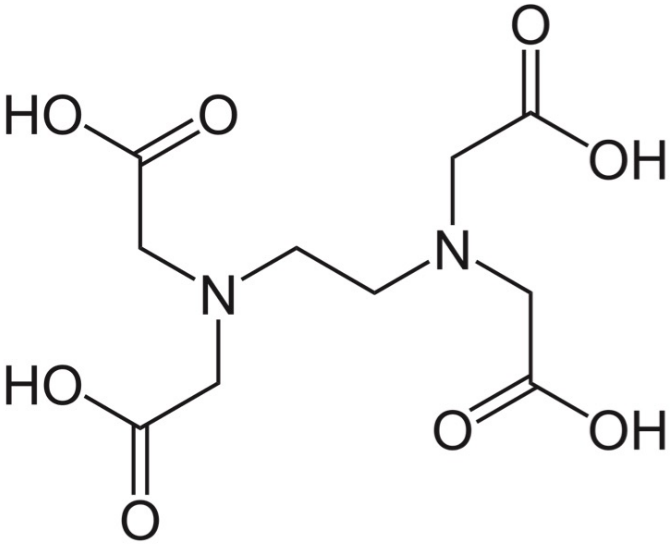

Preservatives
Ascorbic acid
(vitamin C)
HO
H
HO
O
O
HO
OH
Albert
Szent-Györgyi
(1893–1986)
Tadeusz
Reichstein
(1897–1996)
Benzoic
acid
O
OH
Friedrich Wöhler
(1800–1882)
Justus von Liebig
(1803–1873)
Citric acid
O
OH
O
O
HO
OH
OH
Carl Wehmer
(1858–1935)
Citric acid
from
fermentation
in fungi
Sorbic acid
O
H3C
OH
August
Wilhelm
von Hofmann
(1818–1892)

Figure 3.63: German-speaking scientists developed many important food preservatives, including ascorbic acid (vitamin C, identified by Albert Szent-Györgyi and mass-produced by Tadeusz Reichstein), benzoic acid (first analyzed by Friedrich Wöhler and Justus von Liebig), citric acid (first produced from fermentation in fungi by Carl Wehmer), and sorbic acid (discovered by August Wilhelm von Hofmann).

Preservative: EDTA

Ferdinand Münz (1888–1969)

Ethylenediaminetetraacetic acid (EDTA) preservative (1935)



EDTA works by chelating (trapping) metal ions (M) that are needed by degradative enzymes and bacteria

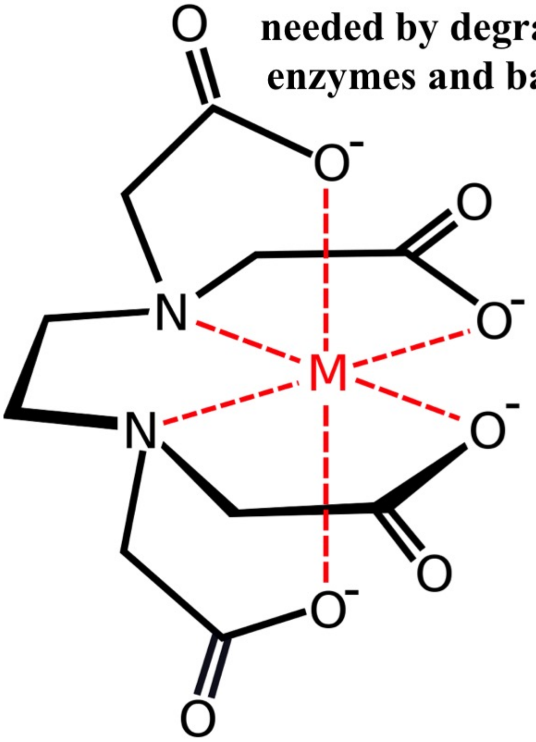


Figure 3.64: In 1935, Ferdinand Münz created the synthetic preservative ethylenediaminetetraacetic acid (EDTA), which works by chelating (trapping) metal ions that are needed by degradative enzymes and bacteria.

3.4 Explosives

Scientists from the German-speaking world were responsible for most of the major innovations in modern explosives, including:[8]

3.4.1. Explosive chemical compounds

3.4.2. Fuel-air explosives

3.4.3. Shaped explosive charges

3.4.4. Radio control and electric timers for explosives

3.4.1 Explosive Chemical Compounds

German-speaking chemists developed most of the major modern explosive chemical compounds.

The first known high explosive was fulminating gold, a complex mixture of compounds containing gold, ammonia, and chlorine. Fulminating gold was produced and demonstrated by Sebalt Schwertzer (German states, 1552–1598) and Johann Thölde/Thölden (German states, 1565–1614). Historical portraits of Schwertzer and Thölde(n) do not appear to exist, but Fig. 3.65 shows illustrations of typical alchemists from that time and place.

As illustrated in Fig. 3.66, Christian Schönbein (German states, 1799–1868), Rudolf Christian Böttger (German, 1806–1881), Friedrich Julius Otto (German, 1809–1870), and Wilhelm Lenk von Wolfsberg (Austrian, 1809–1894) developed nitrocellulose or guncotton explosive.

Johann F. E. Schultze (German?, 18??–19??), Max Duttenhofer (German, 1843–1903), and Frederick Volkmann (German?, 18??–19??) developed smokeless powder, shown in Fig. 3.67. Smokeless powder is essentially an improved nitrocellulose material in flake or powder form, and has been widely used as propellant for small solid rockets.

Johann Rudolf Glauber (German states, 1604–1670) discovered picric acid around 1648, and Hermann Sprengel (German states, 1834–1906) produced large quantities of picric acid as an explosive in 1871 (Fig. 3.68). Sprengel also produced safety explosives (binary explosives that can be safely stored as separate components, then mixed shortly before use) and other explosive-related products.

As shown in Fig. 3.69, Julius Wilbrand (German, 1839–1906) first synthesized trinitrotoluene (TNT) in 1863, Paul Hepp (German, 18??–19??) improved the synthesis in 1880, and Karl Häussermann (German, 1853–1918) used TNT as an explosive in 1889. Science historian Peter Krehl described their contributions [Krehl 2009, p. 404]:

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[8] George Brown 1998; Field 2017; Kennedy 1990; Krehl 2009; Walters and Zukas 1989.

> 1891: Karl Häussermann, a German chemist, discovers the explosive properties of trinitrotoluene [...], later known as TNT. The substance was first crudely synthesized by the German chemist Julius Wilbrand [...]; pure TNT was first prepared by the German chemist Paul Hepp in 1880. Häussermann, who undertook the manufacture of TNT on an industrial scale, was also the first to suggest its military use: pressed into shells, it can withstand the shock developed by the propellant when a shell is fired from a gun barrel. In 1902, TNT was adopted for use by the German army.

The chemist and chemical historian Aaron Ihde added [Ihde 1984, p. 706]:

> During World War I TNT and picric acid explosives were brought into large-scale use. The Germans, with their flourishing coal tar chemicals industry, were prepared for the production of high explosives. The French and British were not nearly as well prepared.

Wilhelm Michler (German, 1846–1889), Carl Meyer (German, 18??–19??), Karel Hendrik Mertens (Dutch, 18??–19??), and Pieter van Romburgh (Dutch, 1855–1945) developed tetryl explosive beginning in 1877 (Fig. 3.70). The chemist Simon Field summarized the story [Field 2017, pp. 81–82]:

> In 1877, German chemists Wilhelm Michler and Carl Meyer invented the compound tetryl, or 2,4,6-trinitrophenylmethylnitramine. It took until 1886 before its structure was established by Dutch chemist Karel Hendrik Mertens. Another Dutch chemist, Pieter van Romburgh later (in 1889) proved the structure by synthesizing it from picryl chloride and potassium methylnitramine.
>
> Tetryl was the first of the nitramine class of high explosives, which includes many of the most explosive compounds currently in use. [...] Nitramines are characterized by the two nitrogen atoms connected together, with one of them then connected to two oxygen atoms.
>
> Tetryl was used in both World Wars as a booster, and by itself in some of the smaller caliber shells.

As illustrated in Fig. 3.71, Georg Friedrich Henning (German, 1863–1945) first synthesized hexogen in 1898, and Edmund von Herz (German, 18??–19??) patented hexogen as an explosive in 1919. Hexogen was named for its six-sided central ring, surrounded by three symmetrical nitro groups. Later it became much more widely known as "Research Department Explosive" or RDX in the United Kingdom and United States. During the Third Reich, German chemists extended the approach of hexogen to create octogen, an eight-sided central ring with four symmetrical nitro groups. Octogen later became better known as HMX.

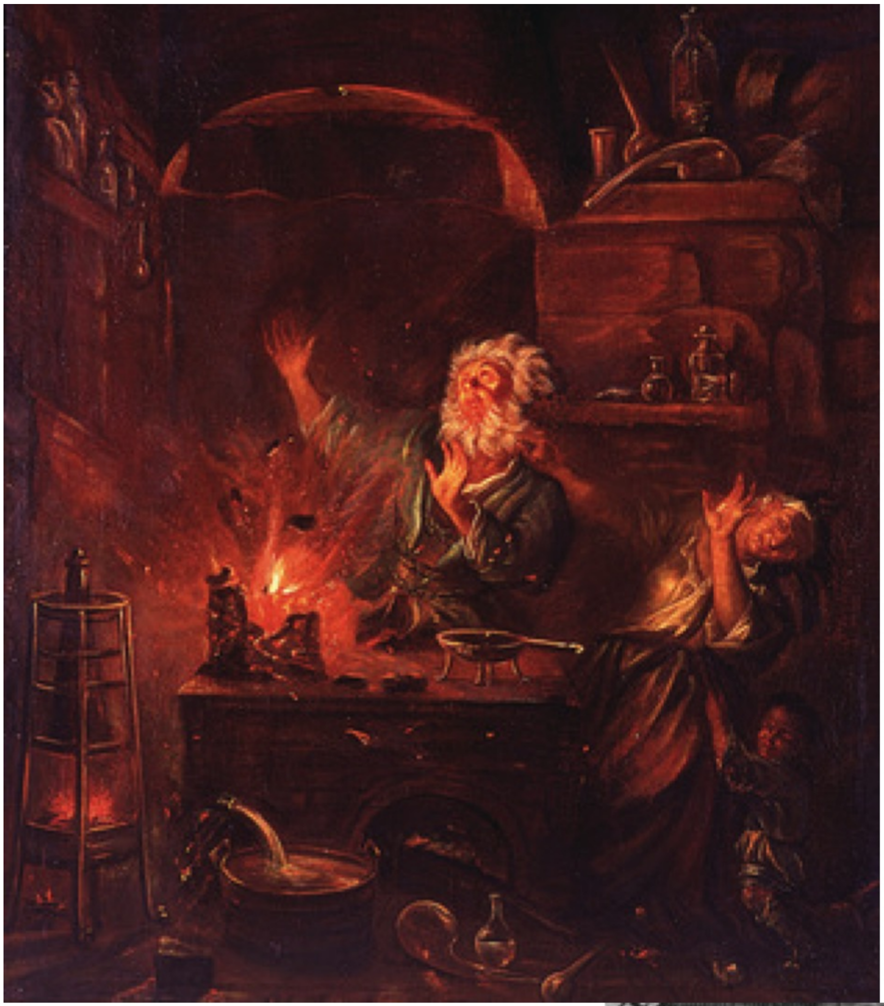
Figure 3.72 shows that nitroglycerin and dynamite were also closely connected to the German-speaking research world. Ascanio Sobrero (Italian but studied under Justus Liebig, 1812–1888) developed nitroglycerin explosive in 1847. Nitroglycerin is extremely powerful but quite sensitive to physical shock. In 1867, Alfred Nobel (Swedish but worked in Germany, 1833–1996) developed dynamite, which is clay soaked with nitroglycerin, in order to make the nitroglycerin less sensitive to shock and therefore much easier to transport and use.

Bernhard Tollens (German, 1841–1918) and Peter Wigand (German, 18??–19??), shown in Fig. 3.73, developed pentaerythritol tetranitrate (PETN) explosive in 1891. The general public nowadays is more familiar with Semtex plastic explosive, which is a mixture of PETN and RDX with a small amount of plasticizer and binder. PETN is also used as a blood pressure medication.

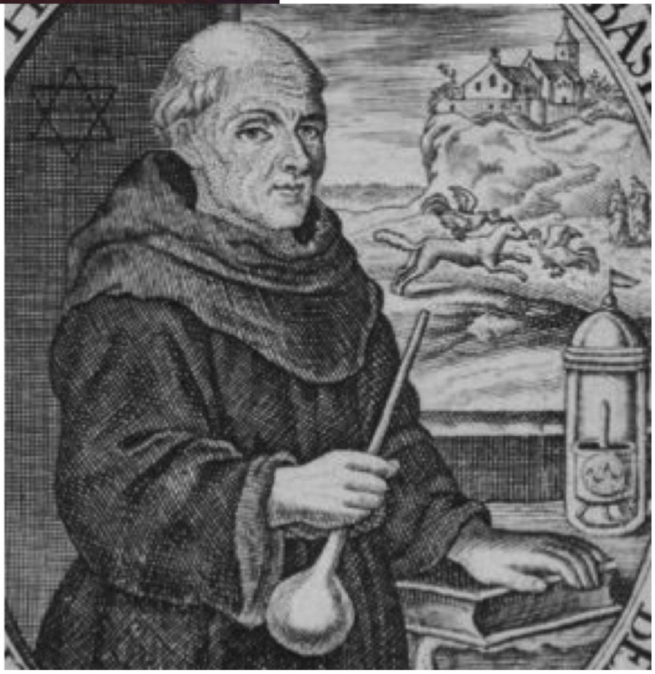
Figure 3.74 presents examples of German-speaking scientists who made important contributions to the mathematical theory of explosions. Walther Nernst (German, 1864–1941) and Max Bodenstein (German, 1871–1942) worked out the theory of explosive chain reactions; Nernst won the Nobel Prize in Chemistry in 1920 (p. 913). Heinrich Mache (Austrian, 1876–1954) and Ludwig Flamm (Austrian, 1885–1964) developed the theory of explosive gas mixtures.

Over two years after World War II ended in Europe, the U.S. War Department General Staff (WDGS) Intelligence Division wrote a report summarizing what they had learned about "New Explosives Developed by the Germans" during the war. Even after so many decades, that report remains classified and unavailable to the public. Why? What new explosive compounds or methods were described in that report, or in others like it that may still be buried in classified archives? See Fig. 3.75.

Fulminating gold explosive



Sebalt Schwertzer (1552–1598)



Johann Thölde(n) (1565–1614)

Figure 3.65: Sebalt Schwertzer and Johann Thölde(n) developed and demonstrated fulminating gold explosive.

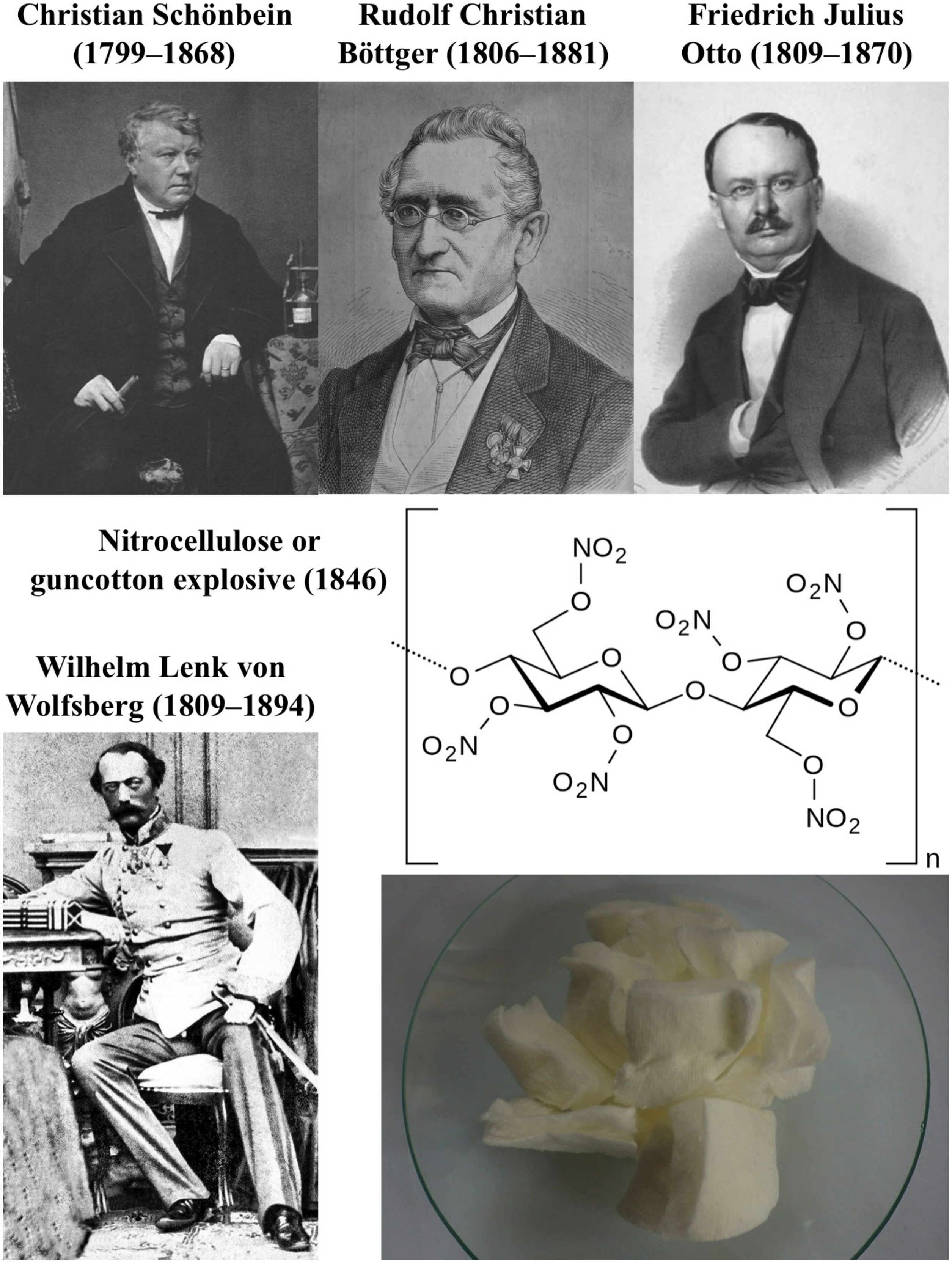
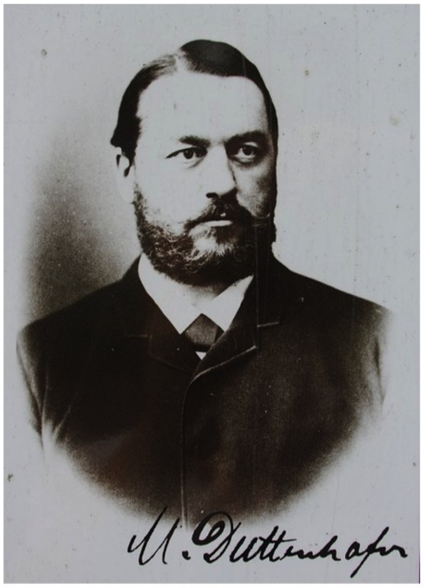

Christian Schönbein (1799–1868)
Rudolf Christian Böttger (1806–1881)
Friedrich Julius Otto (1809–1870)
Nitrocellulose or guncotton explosive (1846)
Wilhelm Lenk von Wolfsberg (1809–1894)
NO2
O2N
O
O2N
O
O
O
O
O2N
O
O
O
O2N
O
O
O
O2N
NO2
n

Figure 3.66: Christian Schönbein, Rudolf Christian Böttger, Friedrich Julius Otto, and Wilhelm Lenk von Wolfsberg developed nitrocellulose or guncotton explosive.

Johann F. E. Schultze
(18??–18??)

Max Duttenhofer
(1843–1903)

Frederick Volkmann
(18??–19??)



Smokeless powder

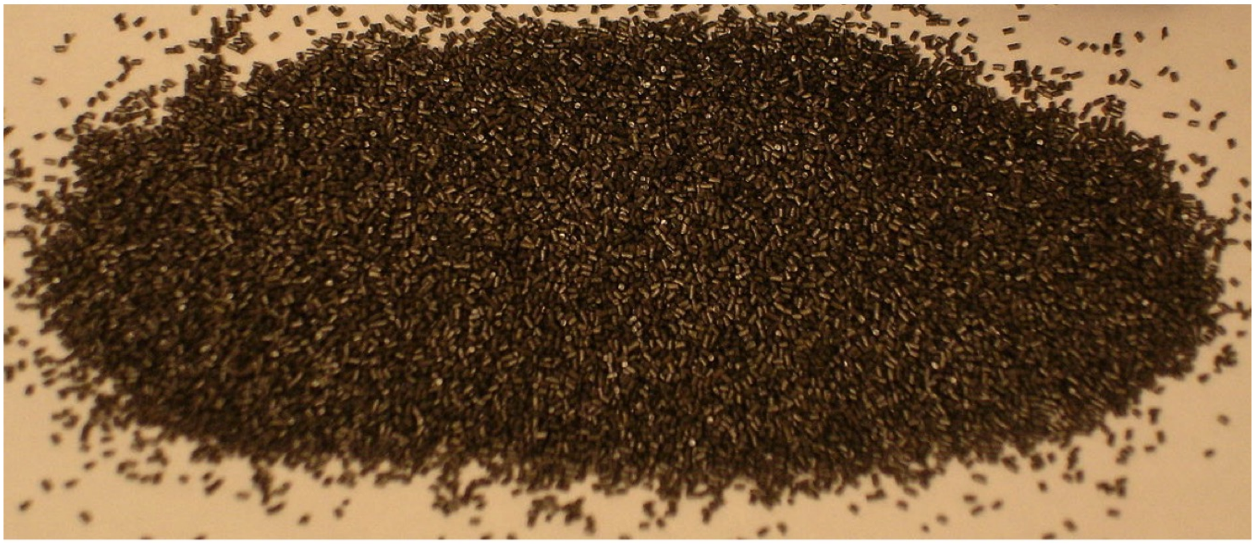
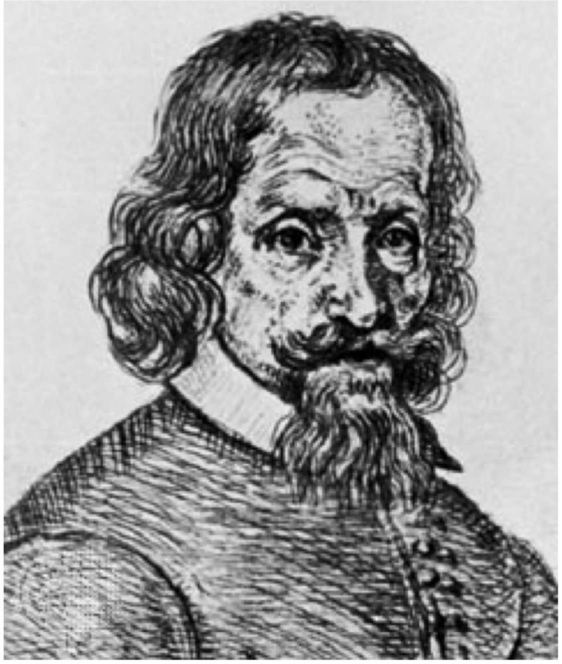
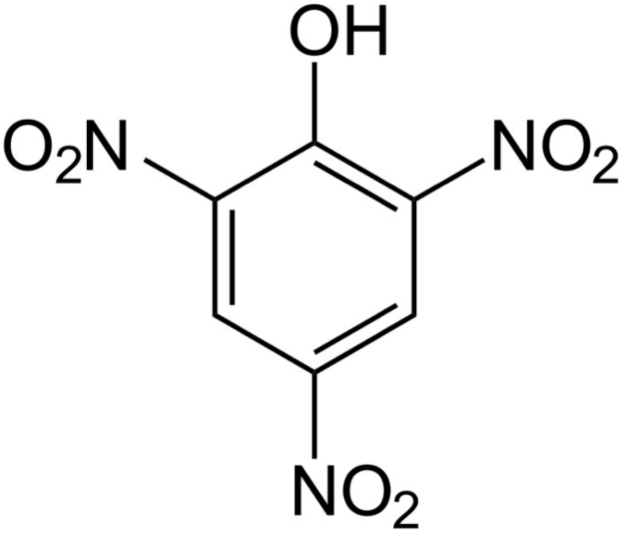


Figure 3.67: Johann F. E. Schultze, Max Duttenhofer, and Frederick Volkmann developed smokeless powder.

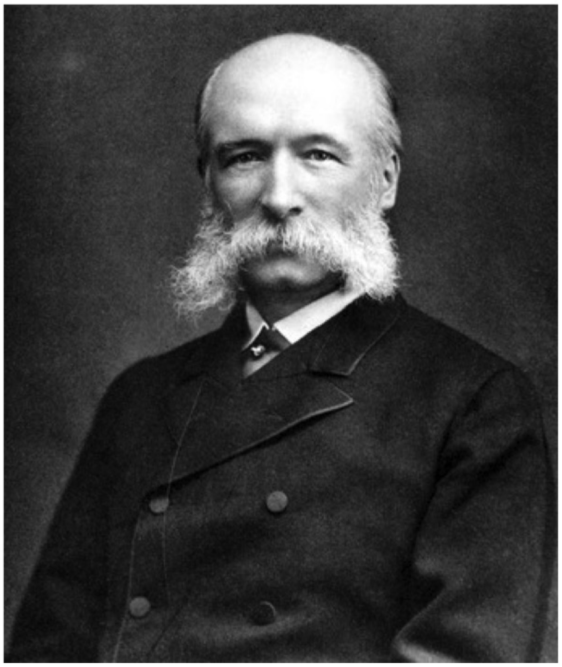
Johann Rudolf Glauber (1604–1670) discovered picric acid (ca. 1648)

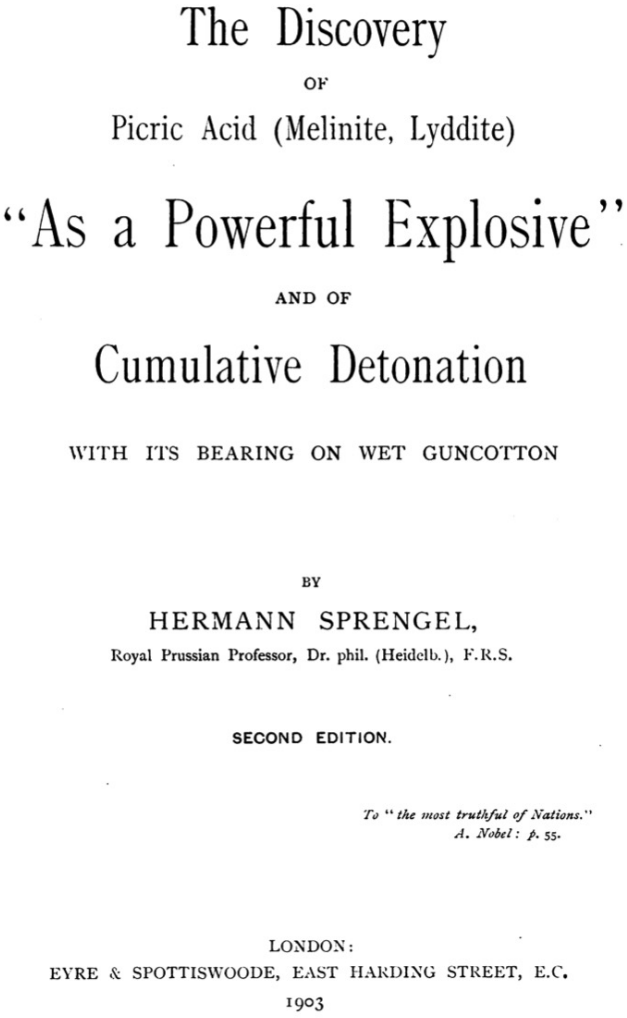


Picric acid explosive



Hermann Sprengel (1834–1906) produced picric acid as explosive (1871)





The Discovery
OF
Picric Acid (Melinite, Lyddite)
"As a Powerful Explosive"
AND OF
Cumulative Detonation
WITH ITS BEARING ON WET GUNCOTTON

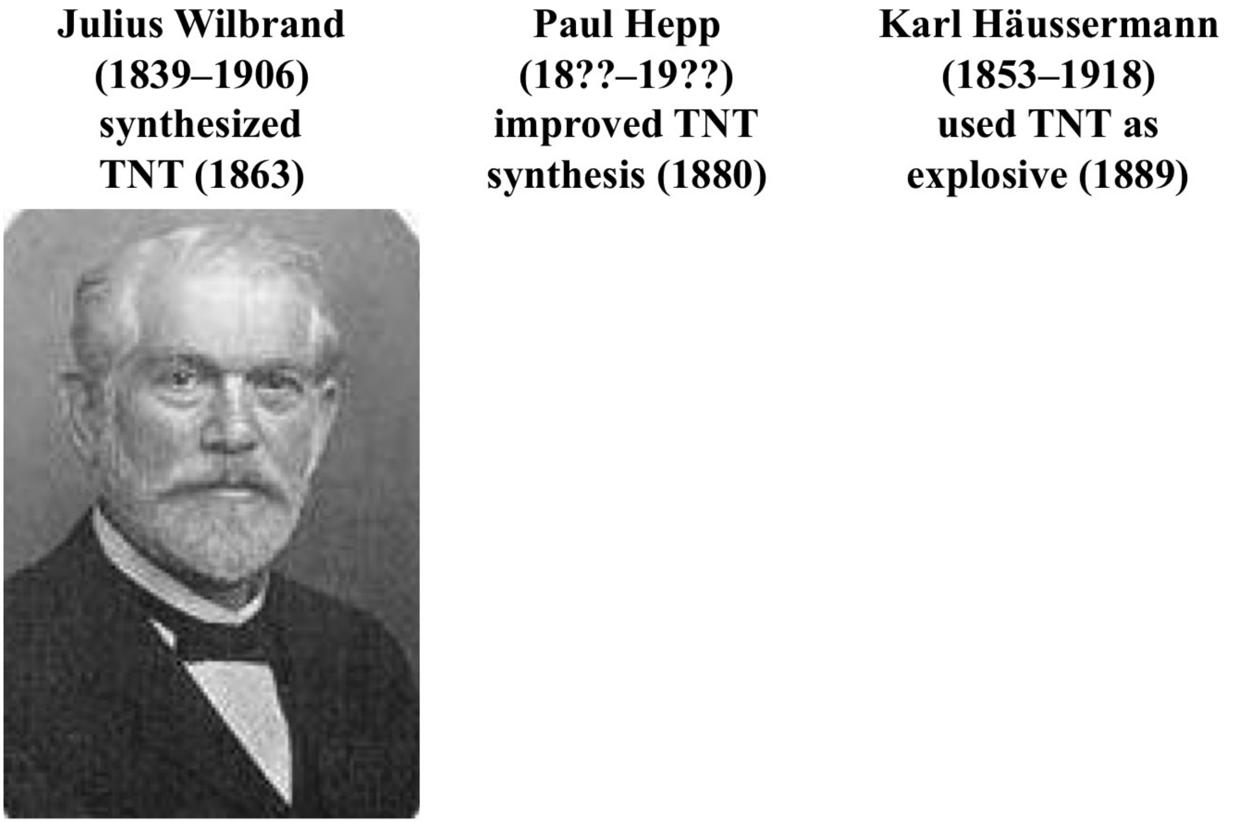
BY
HERMANN SPRENGEL,
Royal Prussian Professor, Dr. phil. (Heidelb.), F.R.S.

SECOND EDITION.

To "the most truthful of Nations."
A. Nobel: p. 55.

LONDON:
EYRE & SPOTTISWOODE, EAST HARDING STREET, E.C.
1903

Figure 3.68: Johann Rudolf Glauber discovered picric acid around 1648, and Hermann Sprengel produced large quantities of picric acid as an explosive in 1871.


Julius Wilbrand
(1839–1906)
synthesized
TNT (1863)
Paul Hepp
(18??–19??)
improved TNT
synthesis (1880)
Karl Häussermann
(1853–1918)
used TNT as
explosive (1889)

Trinitrotoluene (TNT) explosive

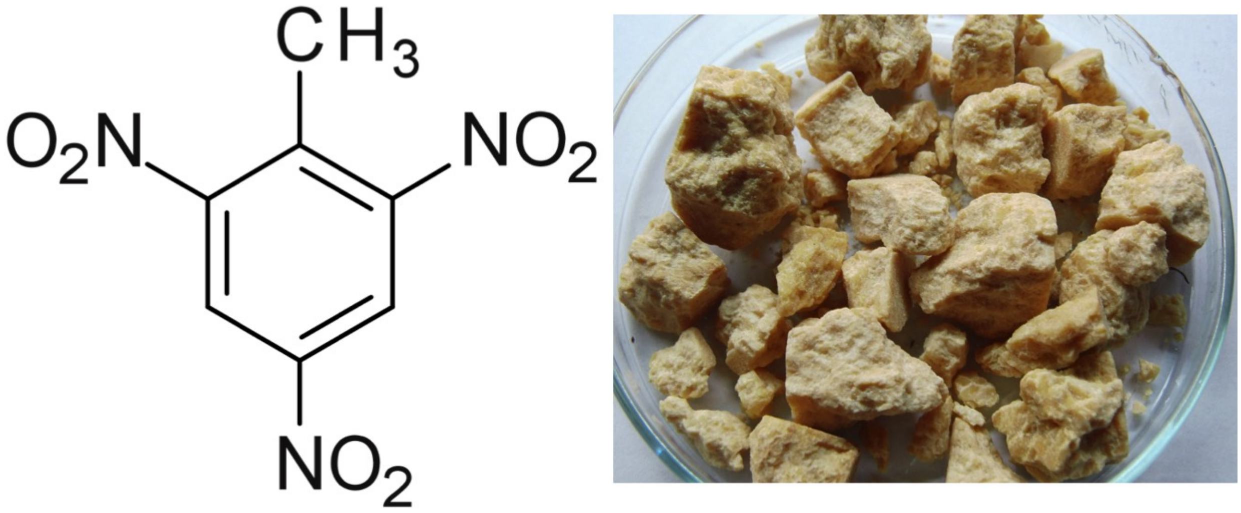
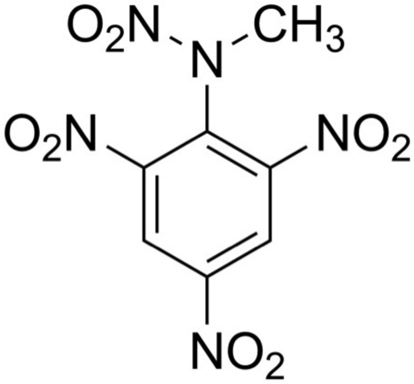

CH_3
O_2N
NO_2
NO_2

Figure 3.69: Julius Wilbrand synthesized trinitrotoluene (TNT) in 1863, Paul Hepp improved the synthesis in 1880, and Karl Häussermann used TNT as an explosive in 1889.

Wilhelm Michler
(1846–1889)

Carl Meyer
(18??–19??)

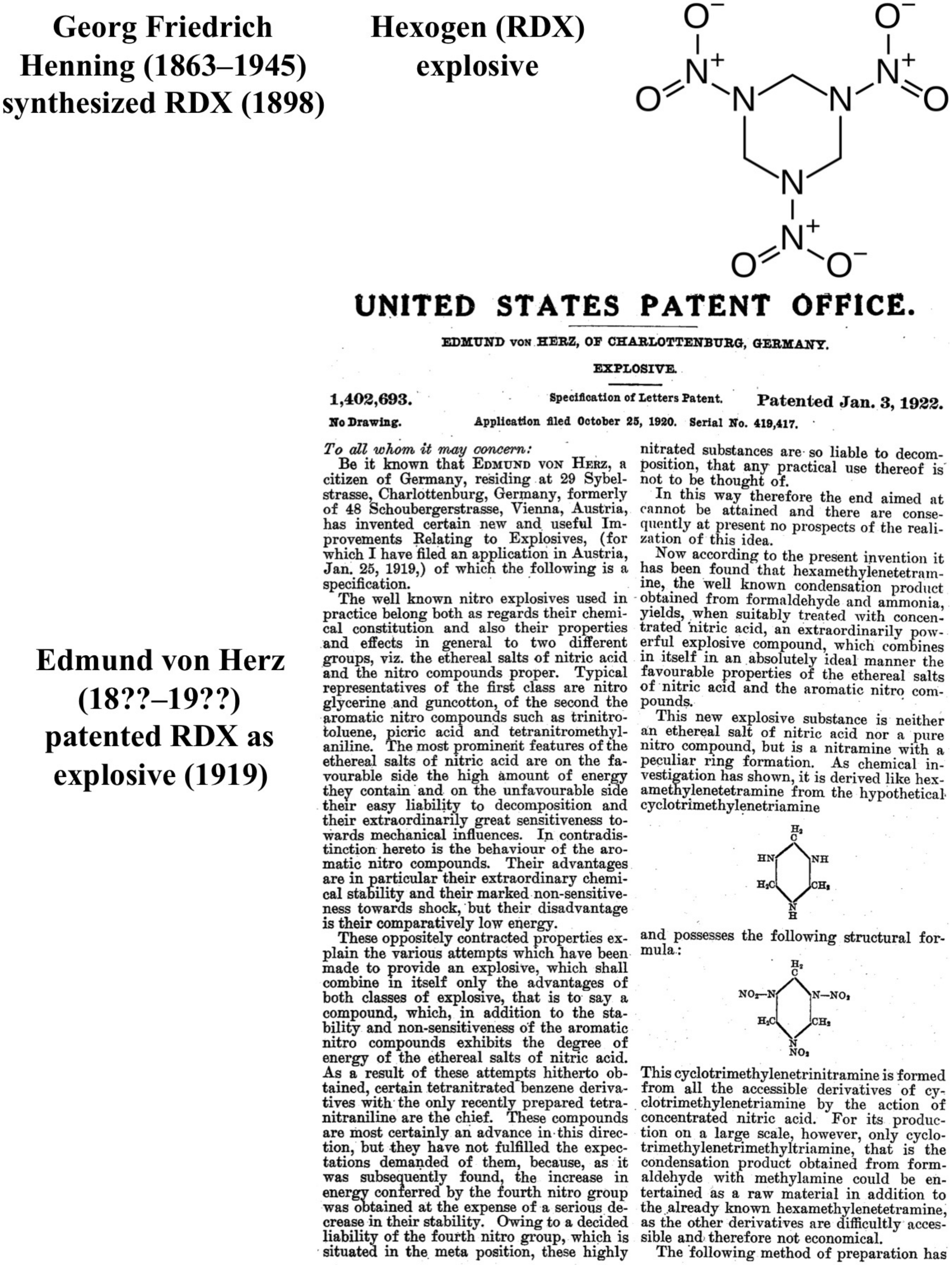
Tetryl explosive (1877)



Karel Hendrik Mertens
(18??–19??)

Pieter van Romburgh
(1855–1945)

Figure 3.70: Wilhelm Michler, Carl Meyer, Karel Hendrik Mertens, and Pieter van Romburgh developed tetryl explosive beginning in 1877.



Georg Friedrich Henning (1863–1945) synthesized RDX (1898)

Hexogen (RDX) explosive

Edmund von Herz (18??–19??) patented RDX as explosive (1919)

UNITED STATES PATENT OFFICE.

EDMUND VON HERZ, OF CHARLOTTENBURG, GERMANY.

EXPLOSIVE.

1,402,693. Specification of Letters Patent. Patented Jan. 3, 1922.

No Drawing. Application filed October 25, 1920. Serial No. 419,417.

To all whom it may concern:

Be it known that Edmund von Herz, a citizen of Germany, residing at 29 Sybelstrasse, Charlottenburg, Germany, formerly of 48 Schoubergerstrasse, Vienna, Austria, has invented certain new and useful Improvements Relating to Explosives, (for which I have filed an application in Austria, Jan. 25, 1919,) of which the following is a specification.

The well known nitro explosives used in practice belong both as regards their chemical constitution and also their properties and effects in general to two different groups, viz. the ethereal salts of nitric acid and the nitro compounds proper. Typical representatives of the first class are nitro glycerine and guncotton, of the second the aromatic nitro compounds such as trinitrotoluene, picric acid and tetranitromethylaniline. The most prominent features of the ethereal salts of nitric acid are on the favourable side the high amount of energy they contain and on the unfavourable side their easy liability to decomposition and their extraordinarily great sensitiveness towards mechanical influences. In contradistinction hereto is the behaviour of the aromatic nitro compounds. Their advantages are in particular their extraordinary chemical stability and their marked non-sensitiveness towards shock, but their disadvantage is their comparatively low energy.

These oppositely contracted properties explain the various attempts which have been made to provide an explosive, which shall combine in itself only the advantages of both classes of explosive, that is to say a compound, which, in addition to the stability and non-sensitiveness of the aromatic nitro compounds exhibits the degree of energy of the ethereal salts of nitric acid. As a result of these attempts hitherto obtained, certain tetranitrated benzene derivatives with the only recently prepared tetranitraniline are the chief. These compounds are most certainly an advance in this direction, but they have not fulfilled the expectations demanded of them, because, as it was subsequently found, the increase in energy conferred by the fourth nitro group was obtained at the expense of a serious decrease in their stability. Owing to a decided liability of the fourth nitro group, which is situated in the meta position, these highly nitrated substances are so liable to decomposition, that any practical use thereof is not to be thought of.

In this way therefore the end aimed at cannot be attained and there are consequently at present no prospects of the realization of this idea.

Now according to the present invention it has been found that hexamethylenetetramine, the well known condensation product obtained from formaldehyde and ammonia, yields, when suitably treated with concentrated nitric acid, an extraordinarily powerful explosive compound, which combines in itself in an absolutely ideal manner the favourable properties of the ethereal salts of nitric acid and the aromatic nitro compounds.

This new explosive substance is neither an ethereal salt of nitric acid nor a pure nitro compound, but is a nitramine with a peculiar ring formation. As chemical investigation has shown, it is derived like hexamethylenetetramine from the hypothetical cyclotrimethylenetriamine

and possesses the following structural formula:

This cyclotrimethylenetrinitramine is formed from all the accessible derivatives of cyclotrimethylenetriamine by the action of concentrated nitric acid. For its production on a large scale, however, only cyclotrimethylenetrimethyltriamine, that is the condensation product obtained from formaldehyde with methylamine could be entertained as a raw material in addition to the already known hexamethylenetetramine, as the other derivatives are difficultly accessible and therefore not economical.

The following method of preparation has

Figure 3.71: Georg Friedrich Henning synthesized hexogen or RDX in 1898, and Edmund von Herz patented RDX as an explosive in 1919.

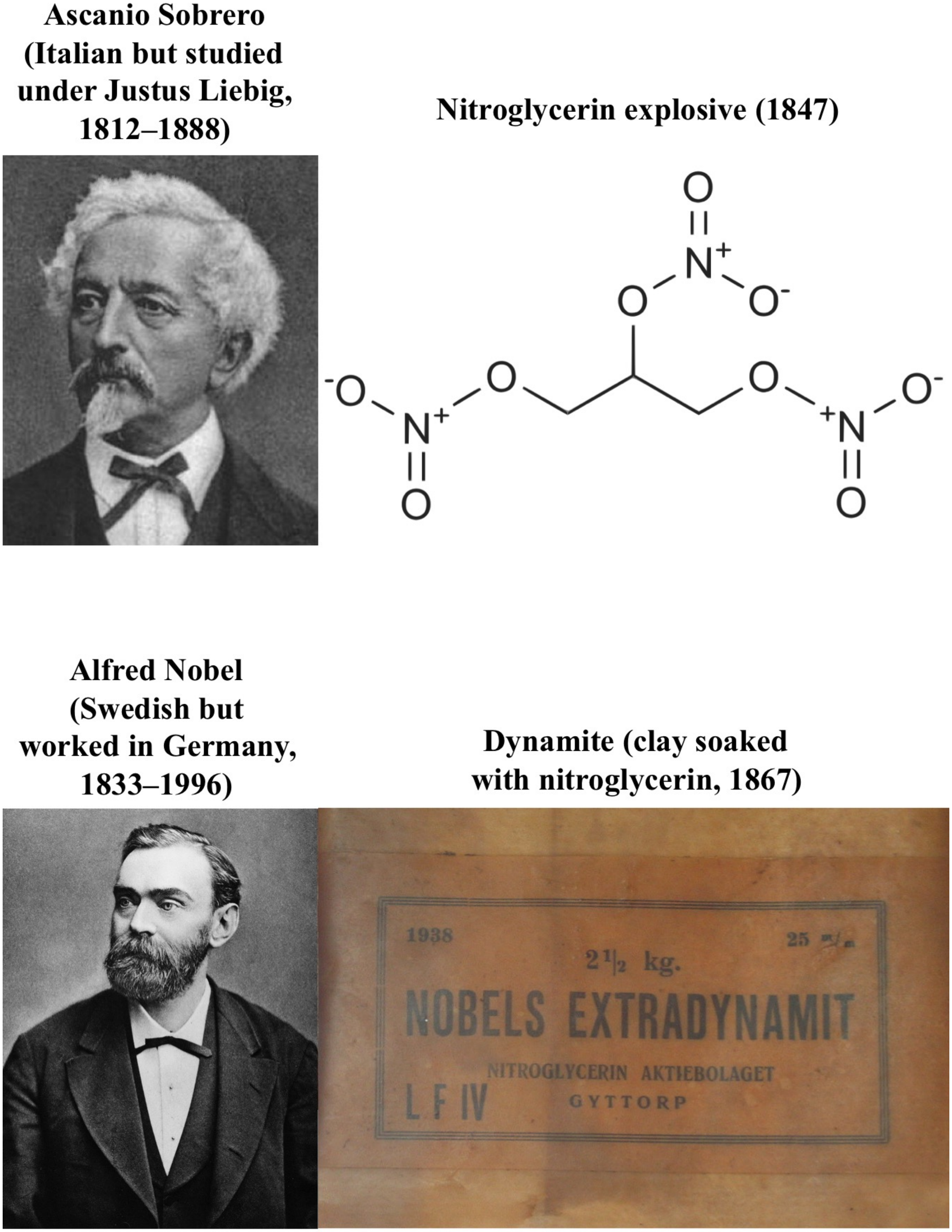
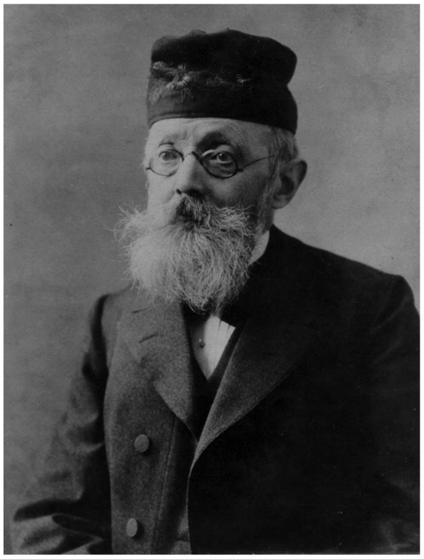
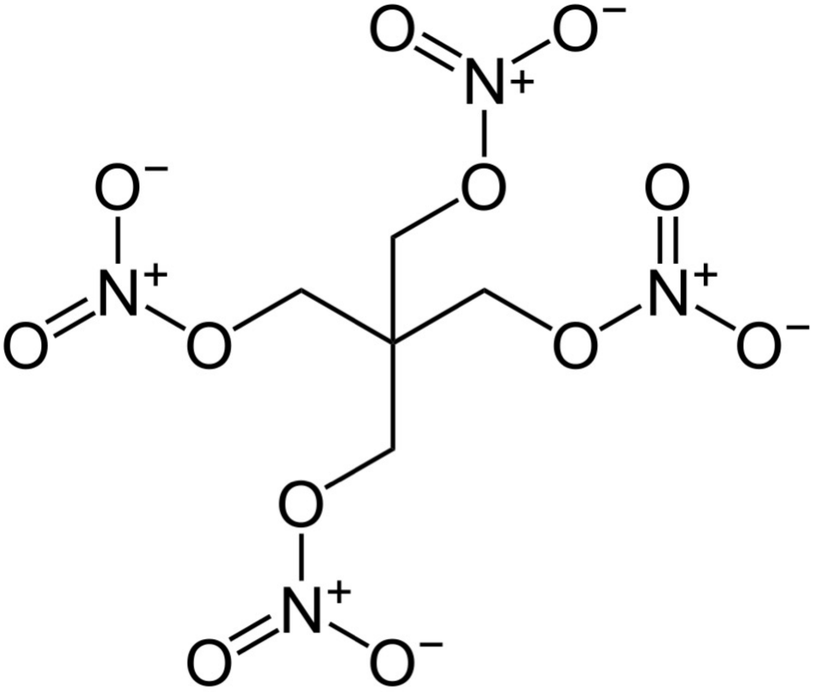

Ascanio Sobrero (Italian but studied under Justus Liebig, 1812–1888)
Nitroglycerin explosive (1847)
O
N+
O
O-
-O
N+
O
O
O
O-
+N
O
Alfred Nobel (Swedish but worked in Germany, 1833–1996)
Dynamite (clay soaked with nitroglycerin, 1867)
1938
25 m/m
2½ kg.
NOBELS EXTRADYNAMIT
NITROGLYCERIN AKTIEBOLAGET
L F IV
GYTTORP

Figure 3.72: Ascanio Sobrero, who studied under Justus Liebig, developed nitroglycerin explosive in 1847. Alfred Nobel developed dynamite (clay soaked with nitroglycerin) in 1867.

Bernhard Tollens
(1841–1918)



Pentaerythritol tetranitrate
(PETN) explosive (1891)



Peter Wigand
(18??–19??)

Semtex plastic explosive is a mixture
of PETN, RDX, and polymers

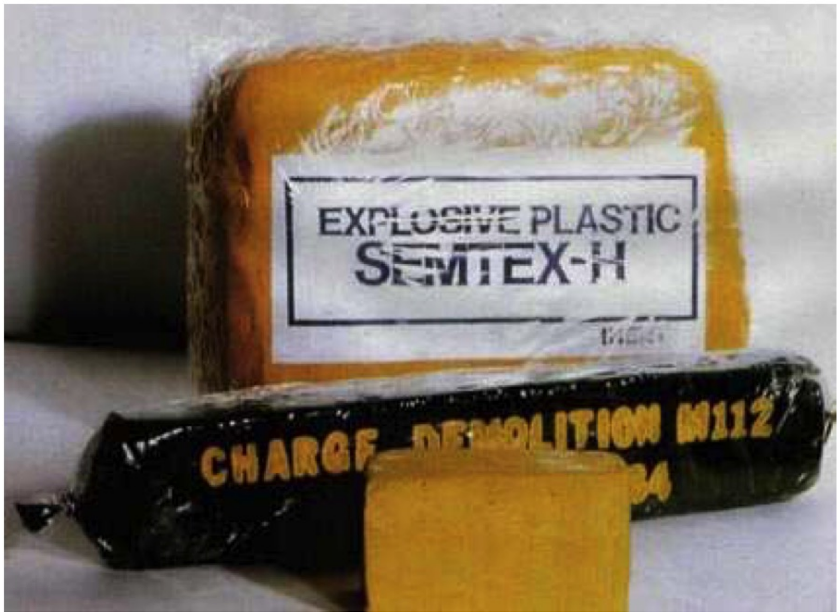
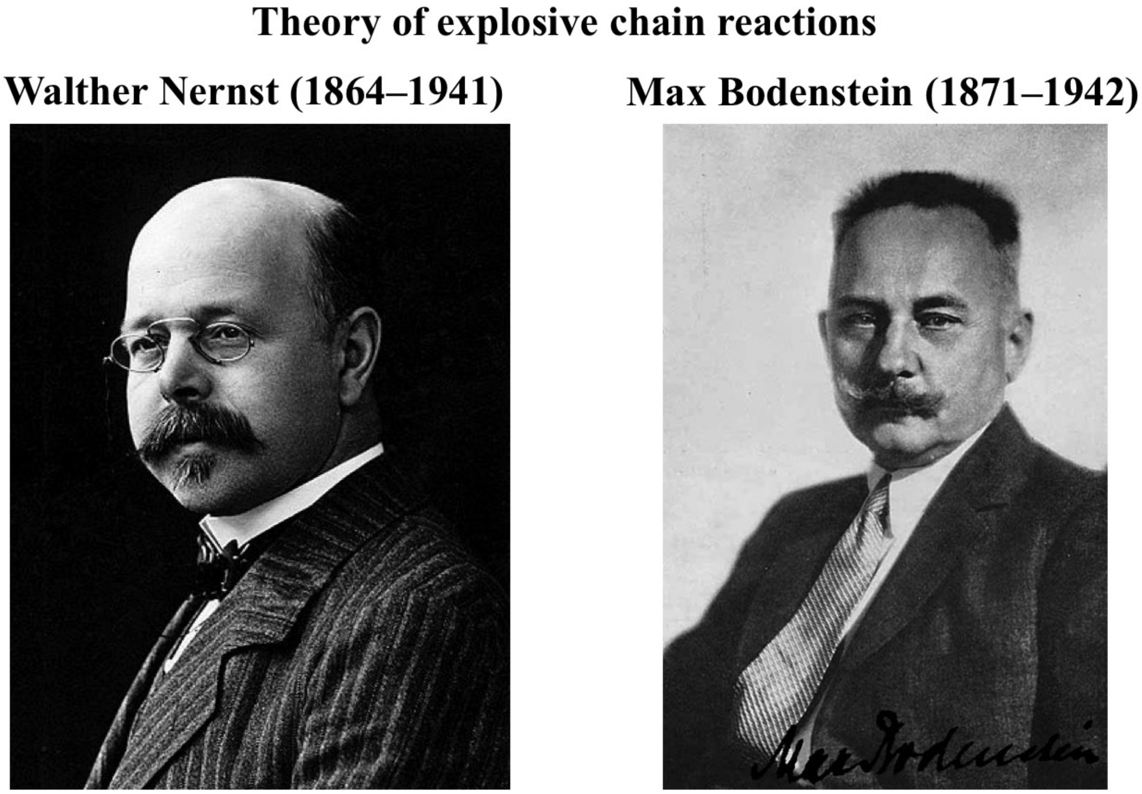

EXPLOSIVE PLASTIC
SEMTEX-H
CHARGE DEMOLITION M112

Figure 3.73: Bernhard Tollens and Peter Wigand developed pentaerythritol tetranitrate (PETN) explosive in 1891. Semtex plastic explosive is a mixture of PETN, RDX, and polymers. PETN is also used as a blood pressure medication.


Theory of explosive chain reactions
Walther Nernst (1864–1941)
Max Bodenstein (1871–1942)

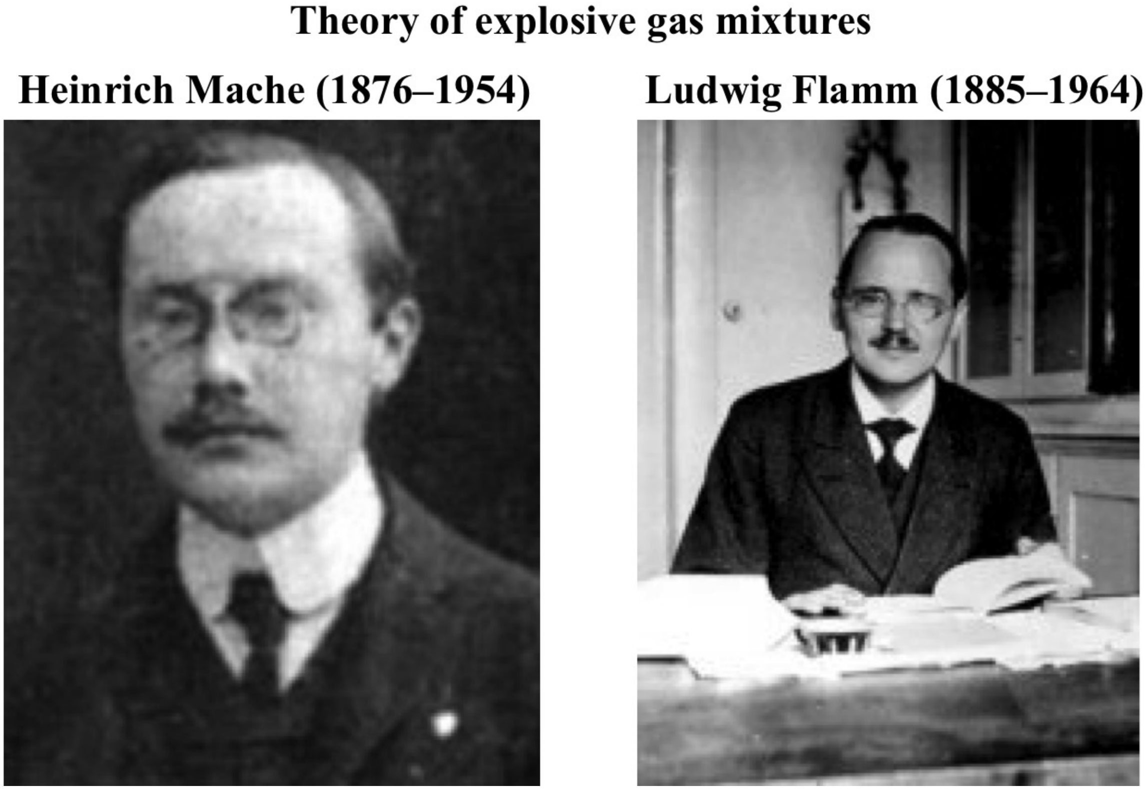

Theory of explosive gas mixtures
Heinrich Mache (1876–1954)
Ludwig Flamm (1885–1964)

Figure 3.74: Walther Nernst and Max Bodenstein worked out the theory of explosive chain reactions. Heinrich Mache and Ludwig Flamm developed the theory of explosive gas mixtures.

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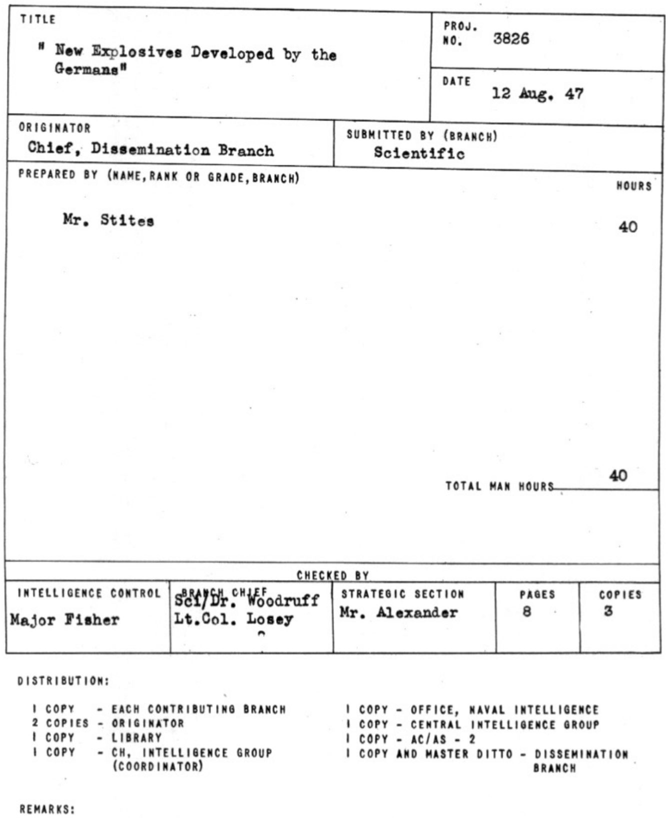

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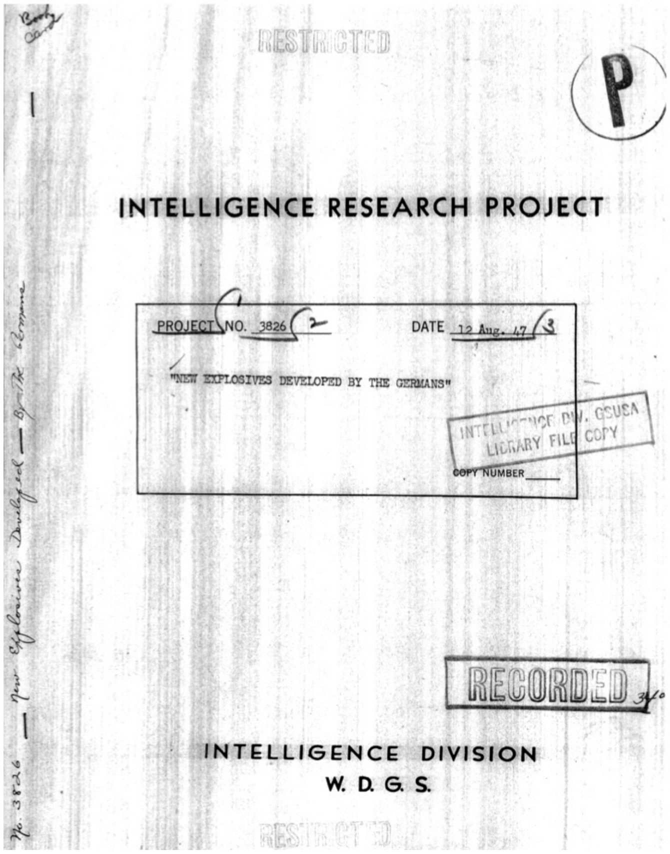

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No. 3826 — New Explosives Developed — By The Germans

Figure 3.75: Over two years after World War II ended in Europe, the U.S. War Department General Staff (WDGS) Intelligence Division wrote a report summarizing what they had learned about "New Explosives Developed by the Germans" during the war. Even after so many decades, that report remains classified and unavailable to the public. Why? What information is in the report? [NARA RG 319, Entry NM3-82, Box 2899, Folder Project 3826]

3.4.2 Fuel-Air Explosives

German-speaking scientists also invented and developed fuel-air explosives [von Haken 1933; Karlsch 2007b; Stevens 2007, pp. 103–111; CIOS ER 201]. While fuel-air explosives use conventional chemical explosive compounds, they disperse those explosive compounds widely before the detonation, and allow the compounds to combust with oxygen in the air. Therefore, fuel-air explosives can cause damage to a much larger area than would be possible with normally packaged bombs of the same explosive compounds.

The earliest known description of a fuel-air explosive bomb is a patent application filed on 6 April 1933 by Kurd von Haken (German?, 18??–19??), DE680483, Fliegerbombe für Kohlenstaubexplosionen [Airborne Bombs for Coal Dust Explosions] (Fig. 3.76):

> In der Zeichnung ist der Fliegerbombenkörper in Abb. 1 schematisch im Schnitt dargestellt. Abb. 2 betrifft ein offenes Fallschirmchen mit dem Zeitzünder. In Abb. 3 ist die Zeitwirkung der Explosion einer Gruppe solcher Bomben auf ein Druckwellenempfangsgerät auf der Seite in einiger Entfernung dargestellt. Es bedeutet 4 die Bombe mit Kohlenstaub, gegebenenfalls mit flockig in diesem verteilten Feuerwerkpulversätzen, 5 ein etwa barometrisch einstellbares Gerät zum Auslösen des Fallschirmes, 6 die durch irgendein an sich bekanntes Mittel von mehreren Flugzeugen aus für alle Bomben gleichzeitig einzustellende Zündvorrichtung, die zu den einzelnen Zündern 7 führt, die mit etwa mittels einer Taschenlampenbatterie 8 auszulösende Zeitzünderchen 9 versehen sind. Die Zeitzünderchen 9 sind von den von ihnen zu zündenden Zündsätzen für den Kohlenstaub 10 umgeben, an die ein sie zerstäubender Sprengstoffkörper 11 sich anschließt. 12 ist das Fallschirmchen für diese Zeitzünder, die in zusammengelegtern Zustande in besonderen Kammern 13 der leicht zu zerteilenden Bombe angeordnet sind. 14 ist der Initialsprengkörper zum Zerstäuben der ganzen Bombe. 15 ist ein Fallschirm, gegebenenfalls mit propellerförmig angeordneten Öffnungen 16 versehen, damit die Bombe in Drehung gerät und so in begrenztem Maße durch die Schwingungen der Fallschirme gehemmt wird. 12' ist das Fallschirmchen mit dem Zeitzünder in geöffnetem Zustande.

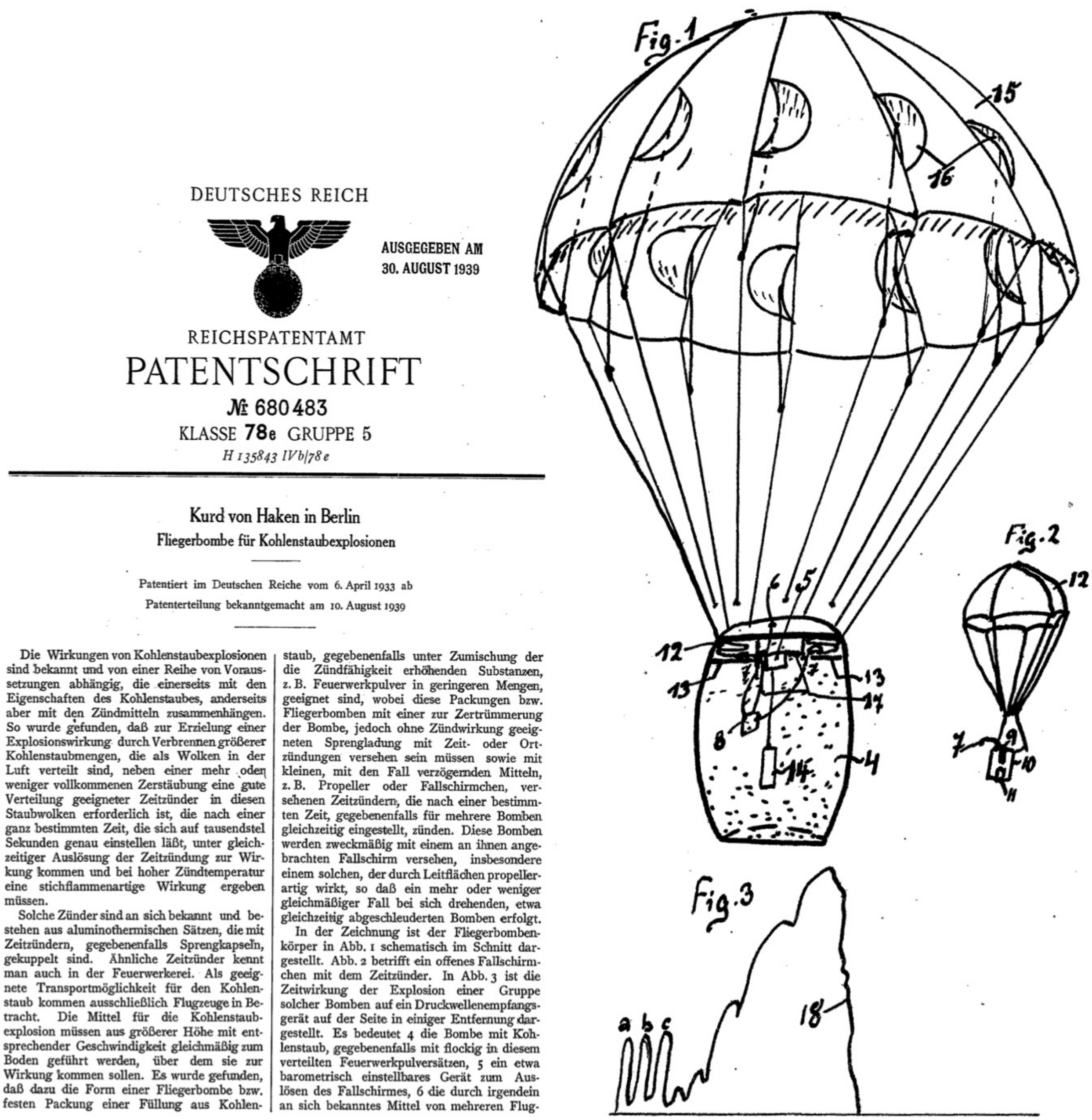
> In the drawing, the aerial bomb is shown schematically in section in Fig. 1. Fig. 2 concerns an open parachute with the time fuse. Figure 3 shows the time effect of the explosion of a group of such bombs on a pressure wave receiving device on the side at some distance. 4 means the bomb with pulverized coal dust, possibly with a flare in the distributed fireworks powder etching, 5 an approximately barometrically adjustable device for triggering the parachute, 6 which, by means of a means known per se from a plurality of airplanes, which are provided with timers 7 to be triggered by means of a torch battery 8, for example. The timers 9 are of the ignitions to be lit by them. For the carbon dust 10, to which an explosive body, which atomizes them, follows. 12 is the parachute for these time igniters, which are arranged in a combined state in particular chambers 13 of the easy-to-split bomb. 14 is the atomic bubble for atomizing the whole bomb. 15 is a parachute, provided if necessary with propeller-shaped openings 16, so that the bomb is turned and thus limited to a certain degree by the vibrations of the parachutes. 12' is the parachute with the time fuse in the opened state.

Beim etwa gleichzeitigen Abwurf einer Reihe von Bomben öffnen sich nicht alle Bombenfallschirme gleichzeitig, so daß die Bomben in verschiedener Höhe und in verschiedener Zeit über einer mehr oder weniger großen Zielfläche, z.B. 1 qkm, verteilt sind, im Gesamtgewicht von etwa 10 t. Bei der Primärzerstäubungdurch Zünden der Sprengkörper 14 bilden sich um die Bomben eine Reihe Staubwolken, die in langsamem Falle weiter sinken. Die kleinen Fallschirmchen mit den kleinen Zeitzündern öffnen sich gleichzeitig oder früher durch Auslösung einex Hilfsvorrichtung 17 vom Manometer aus und verteilen sich in gleichmäßigem Falle in diesen Staubwolken, so daß sie auch annähernd gleichzeitig zur Explosion kommen. Auf dem Zeitmeßgerät zeichnen sich dann, je nach der Entfernung der Bomben 1, 2, 3 und der Zündkörperchen 1 bis 10, drei Wellen *a, b, c* für die Zerstäubung und etwa fünf kleine Wellen, von der Explosion der Zündkörperchen herrührend, ab. Um die detonierenden Zündkörperchen herum wirkt sich progressiv steigernd eine große Druckwelle 18 aus, die im Zusammenhang mit der Großluftbewegung mit Überschallgeschwindigkeit auf große Entfernung zur Wirkung gelangt.

When a series of bombs are dropped at the same time, not all of the bombshells open at the same time, so that the bombs are at different heights and at different times over a more or less large target area, for example, 1 square kilometer, with a total weight of approximately 10 t. In primary sputtering by igniting the explosive bodies 14, a series of dust clouds form around the bombs, which sink further in a slow case. The little parachutes with the small time fuses open at the same time or earlier by triggering an auxiliary device from the manometer and distributing themselves in this case evenly in the dust clouds, so that they also almost explode at the same time. According to the distance of the bombs 1, 2, 3 and the ignition body 1 to 10, three waves *a, b, c* for the atomization and about five small waves, which originate from the explosion of the ignition cores, are then distinguished on the time-measuring device. Around the detonating detonators, a large pressure wave 18 acts progressively increasing, which in conjunction with the shock wave arrives at a great distance with a supersonic velocity.

Currently it is not clear what role (if any) Kurd von Haken played in the subsequent development and testing of his ideas for fuel-air explosives.

Kurd von Haken (18??–19??) invented fuel-air explosives



DEUTSCHES REICH

AUSGEGEBEN AM
30. AUGUST 1939

REICHSPATENTAMT
PATENTSCHRIFT
№ 680483
KLASSE 78e GRUPPE 5
H 135843 IVb/78e

Kurd von Haken in Berlin
Fliegerbombe für Kohlenstaubexplosionen

Patentiert im Deutschen Reiche vom 6. April 1933 ab
Patenterteilung bekanntgemacht am 10. August 1939

Die Wirkungen von Kohlenstaubexplosionen sind bekannt und von einer Reihe von Voraussetzungen abhängig, die einerseits mit den Eigenschaften des Kohlenstaubes, anderseits aber mit den Zündmitteln zusammenhängen. So wurde gefunden, daß zur Erzielung einer Explosionswirkung durch Verbrennen größerer Kohlenstaubmengen, die als Wolken in der Luft verteilt sind, neben einer mehr oder weniger vollkommenen Zerstäubung eine gute Verteilung geeigneter Zeitzünder in diesen Staubwolken erforderlich ist, die nach einer ganz bestimmten Zeit, die sich auf tausendstel Sekunden genau einstellen läßt, unter gleichzeitiger Auslösung der Zeitzündung zur Wirkung kommen und bei hoher Zündtemperatur eine stichflammenartige Wirkung ergeben müssen.

Solche Zünder sind an sich bekannt und bestehen aus aluminothermischen Sätzen, die mit Zeitzündern, gegebenenfalls Sprengkapseln, gekuppelt sind. Ähnliche Zeitzünder kennt man auch in der Feuerwerkerei. Als geeignete Transportmöglichkeit für den Kohlenstaub kommen ausschließlich Flugzeuge in Betracht. Die Mittel für die Kohlenstaubexplosion müssen aus größerer Höhe mit entsprechender Geschwindigkeit gleichmäßig zum Boden geführt werden, über dem sie zur Wirkung kommen sollen. Es wurde gefunden, daß dazu die Form einer Fliegerbombe bzw. festen Packung einer Füllung aus Kohlenstaub, gegebenenfalls unter Zumischung der die Zündfähigkeit erhöhenden Substanzen, z. B. Feuerwerkpulver in geringeren Mengen, geeignet sind, wobei diese Packungen bzw. Fliegerbomben mit einer zur Zertrümmerung der Bombe, jedoch ohne Zündwirkung geeigneten Sprengladung mit Zeit- oder Ortzündungen versehen sein müssen sowie mit kleinen, mit den Fall verzögernden Mitteln, z. B. Propeller oder Fallschirmchen, versehenen Zeitzündern, die nach einer bestimmten Zeit, gegebenenfalls für mehrere Bomben gleichzeitig eingestellt, zünden. Diese Bomben werden zweckmäßig mit einem an ihnen angebrachten Fallschirm versehen, insbesondere einem solchen, der durch Leitflächen propellerartig wirkt, so daß ein mehr oder weniger gleichmäßiger Fall bei sich drehenden, etwa gleichzeitig abgeschleuderten Bomben erfolgt.

In der Zeichnung ist der Fliegerbombenkörper in Abb. 1 schematisch im Schnitt dargestellt. Abb. 2 betrifft ein offenes Fallschirmchen mit dem Zeitzünder. In Abb. 3 ist die Zeitwirkung der Explosion einer Gruppe solcher Bomben auf ein Druckwellenempfangsgerät auf der Seite in einiger Entfernung dargestellt. Es bedeutet 4 die Bombe mit Kohlenstaub, gegebenenfalls mit flockig in diesem verteilten Feuerwerkpulversätzen, 5 ein etwa barometrisch einstellbares Gerät zum Auslösen des Fallschirmes, 6 die durch irgendein an sich bekanntes Mittel von mehreren Flug-

Figure 3.76: Kurd von Haken filed a patent application on fuel-air explosives in 1933.

Using von Haken's patent, Mario Zippermayr (Austrian, 1899–1979) and other scientists developed and tested fuel-air explosives during World War II, as shown in Figs. 3.77–3.90 [CIOS ER 201, NavTecMisEu 548-45]. Historian Rainer Karlsch explained the development program [Karlsch 2007b]:

> During the war a group of scientists under the direction of the Austrian physicist Mario Zippermayr made use of the patent belonging to Kurd von Haken. They improved the concept of the coal dust bomb. [...]
>
> Zippermayr's activities for the Air Force and the establishment of his research institute probably did not begin until 1942. The swift progress of the group is therefore even more astounding. Zippermayr was not, however, the scientific "brain" of the group, but rather its loyal Nazi manager.
>
> According to reports by the US Forces Austria Counter-Intelligence Corps, his group had 35 individuals employed in locations in Vienna and in Lofer, Tyrol. The most important research project was the development of a highly explosive warhead with which the anti-aircraft missiles 'Enzian' (Gentian) and 'Schmetterling' (Butterfly) were to be fitted.
>
> The project work was accelerated in the second half of 1944, after the landing of the Allies at Normandy and the assassination attempt on Hitler. At that point the SS took over the most modern weapons development projects, and tried to bring these weapons to a usable stage of development. Among the many exotic ideas there were also some technically very demanding projects such as the development of nerve gases, missiles and nuclear explosives.
>
> Himmler's organization also had an influence on the project of SS officer Mario Zippermayr, and in this case the cooperation between researchers and the SS was probably especially close. The researchers were on a promising path, as Zippermayr reported in October 1944 in a report for the Reichsforschungsrat (Research Advisory Council) labeled "Geheime Kommandosache" (Secret Commando Matter). He referred to experiments that took place in the spring of 1943 with 60 kilograms of a mixture of coal dust and liquid oxygen in the vicinity of the air base Zwölfaxing near Vienna. The explosions broke windows up to 1.5 kilometers away. As far as 3.5 kilometers away, windows and doors that had been pulled to were pushed open by the explosions.
>
> The project was given the code name "Witches Cauldron" [Hexenkessel]. Contributors to the project were scientists from Dynamit Nobel Corporation, Rheinmetall-Borsig, the Ballistic Institute in Gatow, as well as specialists from the brown coal industry and from the Zippermayr group. Probably there was at least one more SS research group that conducted similar experiments in Silesia and in other locations.
>
> According to information that reached British intelligence early in 1945, a test north of Berlin achieved a destructive radius of approximately 600 meters. The heat and pressure wave ignited trees in the target area and knocked them over. The air force could have made good use of such a weapon. The plan was to target these at aircraft formations via anti-aircraft missiles. As far as we know, these missiles were never used, however.

> But the new bomb could have been used against large surface target areas. This was a very real danger. According to American secret service reports, the German military possessed at war's end 5-ton "liquid air bombs," as the thermobaric bombs were called then. In the National Archive in Washington, there is a document naming a plant in Nordhausen, in the Harz region, where the V-2 missiles were produced, as the location for the production of even larger "oxygen bombs" (yet another name for these same bombs). [See pp. 556–557.] An actual use of the bombs never occurred.
>
> Even as late as the capitulation, the victors possessed only vague secret service information about the super bomb. Nevertheless, there was an interest in the immediate study and development of this technology, of course under conditions of utmost secrecy. For this reason, Zippermayr was repeatedly questioned by the Chemical Warfare Service, beginning on 3 August 1945. During a later interrogation in 1949, he told the Americans that with his bomb—whether with pulverized coal dust or with gas or other liquids—he could achieve the area destruction of a small atomic bomb. Furthermore, the production of such a bomb would be much cheaper.
>
> In contrast to other prominent German weapons industry researchers, there was reluctance to transport the SS man Zippermayr to the United States. However, several of his colleagues were offered the opportunity to continue their research in America in the context of "Operation Paperclip." Apparently the Soviets also benefited from the knowledge produced by the Zippermayr group. According to an American report, Heinrich Mache, a professor at the Technical University in Vienna, was forced to conduct experiments with coal dust explosives in October 1945 under Soviet supervision.
>
> The terrible fruits of the Zippermayr group did not just remain in the arsenals. They were used as "enhanced blast weapons" in the Vietnam War and in 1969 in Soviet-Chinese border conflicts at the Ussuri River. This name comes from the fact that the temperatures achieved by these bombs were not extreme. This changed in the late 1980s when the reaction temperature was raised substantially through added metallic particles, primarily aluminum, but also through other metals, as well as through oxygen. The principle of the thermobaric bomb, however, remained the same and is one example for the fact that it was not just in the case of missiles and jet planes that the victors in the Second World War made use of the knowledge of the defeated powers. That the technology behind the "father of all bombs" is old hat should not obscure the fact that this is a weapon of mass destruction that should be forbidden.

Note that the use of powdered aluminum in explosives to enhance the temperature and blast (as described above) was also developed in wartime Germany; see pp. 5692–5695 [BIOS 27; BIOS 100; BIOS 1261]. Thus the "thermobaric" and "enhanced blast weapons" built by the United States and other countries after the war were entirely derived from technologies that had previously been designed and demonstrated in Germany and Austria, based on information and materials obtained from German-speaking scientists, as well as the direct assistance of many of those scientists themselves (as shown below).

An August 1949 JIOA document, Immigration of Austrian Scientists to Soviet Zone, listed several key members of Zippermayr's team [NARA RG 319, Entry A1-134A, Box 31, Folder 02/006 430]:

> FRITSCHE, Doz. Dr. Ing. Volker, Technische Hochschule, Vienna. Formerly with the Zippermayr Laboratory engaged in research in use of coal dust as antiaircraft explosive. Member of the Electro-technical Institute, Technische Hochschule. Reportedly making survey for Russians on high frequency prospecting for oil.
>
> HOENIG, Dr Alfred, Scheffsnoth 8, Zell am See, Austria. Formerly worked at Zippermayr Institute engaged in research on coal dust explosives. Chemical Corps and Air Corps interestd. Chemical expert interviewed subject and ZIPPERMAYER, and agreed that their theories were basically sound and could not be permitted to reach potential U.S. enemies. It will be recommended that these two with KILLIAN be employed in U. S. HOENIG fears that he might be kidnapp[blacked out]
>
> KILLIAN, Karl, Hattlegasse 40, Hitzing, Vienna XIII, Austria. Mathematician and aerodynamics expert who formerly worked with ZIPPERMAYER and HOENIG on Pfeil aircraft, torpedoes designed to be released from great heights and torpedoes with luminous underwater trails. Being considered along with HOENIG and ZIPPERMAYER for employment in U. S. by Chemical Corps.
>
> MACHE, Prof. Dr. Heinrich, Pokenvgasse 25, Vienna XIX/117. Professor at Technische Hochschule, Vienna and regular member of Austrian Academy of Science. In October 1945, conducted experiments with coal dust explosives under Soviet orders. Specialist on discharge of electric energy in gases.
>
> ZIPPERMAYR, Prof. Dr. Mario, Lofer Au 3, Zell am See, Austria. Stateless. Chemist. NSDAP member and SD from 1937 to 1945. Headed Zippermayr [blacked out] in coal dust explosives. [blacked out]. See HOENIG and KILLIAN.
>
> BE[ETZ?], Dr.—Halle, Germany. Formerly with Zippermayr Institute engaged in research on methods of transmitting course of enemy bombers to night fighters and on dust explosions.
>
> MELDAU, Dr. Ing—Last reported at Spremberg, Germany. Formerly with Zippermayr Institute engaged in research on coal dust explosives.

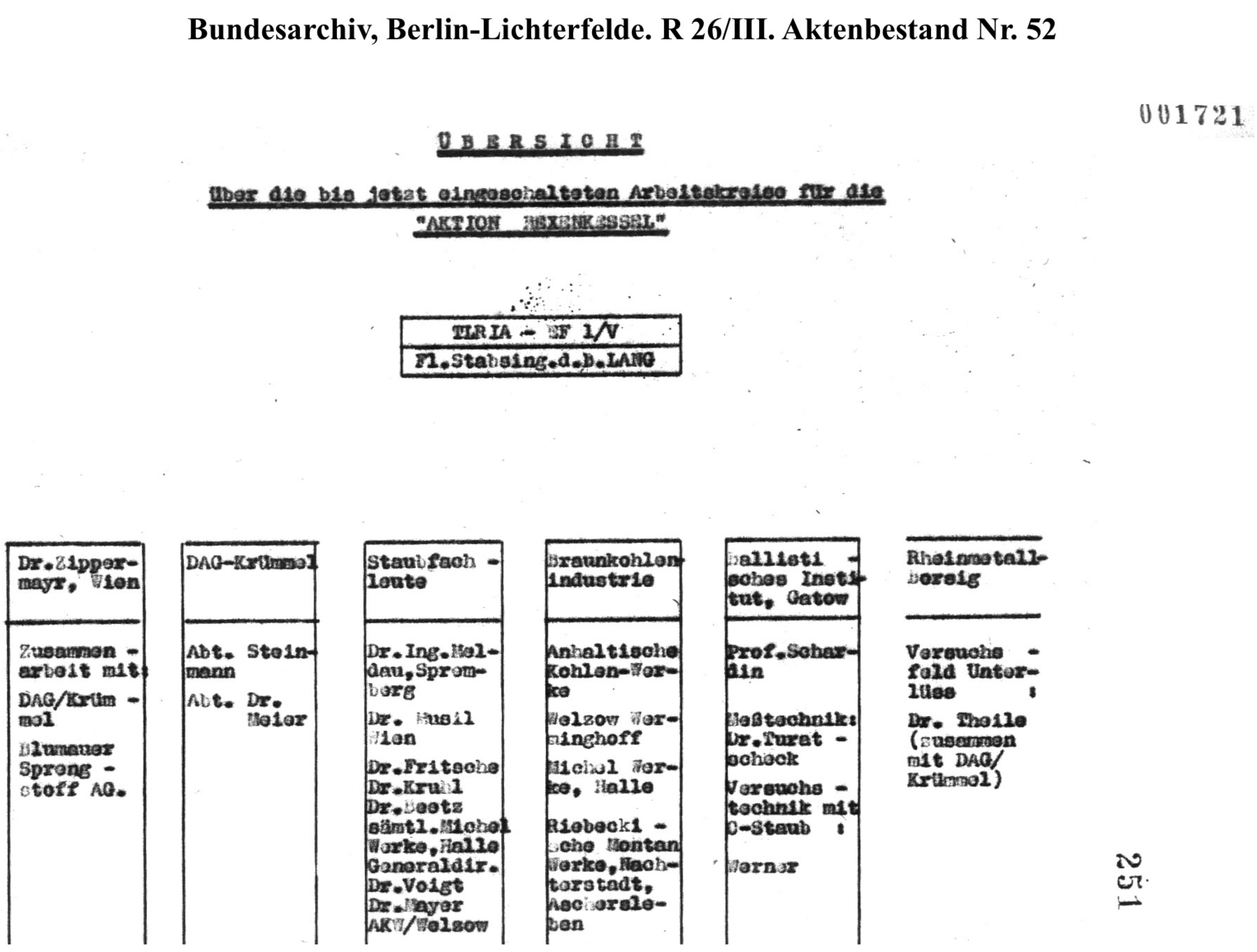
Zippermayr and some of the other scientists were extensively interrogated after the war, and some were taken to work for the United States, Russia, or other countries.

Zippermayr's Austrian group was part of a much larger wartime program to develop, test, and mass-produce fuel-air explosives (pp. 544–545).

There were several reports of successful tests of fuel-air explosives during the war. Some archival documents even mentioned fuel-air explosives actually being used on the Eastern front during the war. See pp. 546–555, 2615–2623, 4396–4397.

By the end of the war, at least 7000 workers had mass-produced 5-ton fuel-air explosive bombs and stockpiled them (pp. 556–557). There were also stockpiles of fuel-air explosives in an assortment of smaller sizes. Those stockpiled bombs were probably taken by Allied countries after the war.

Much more historical research on this topic could be quite enlightening.



Bundesarchiv, Berlin-Lichterfelde. R 26/III. Aktenbestand Nr. 52

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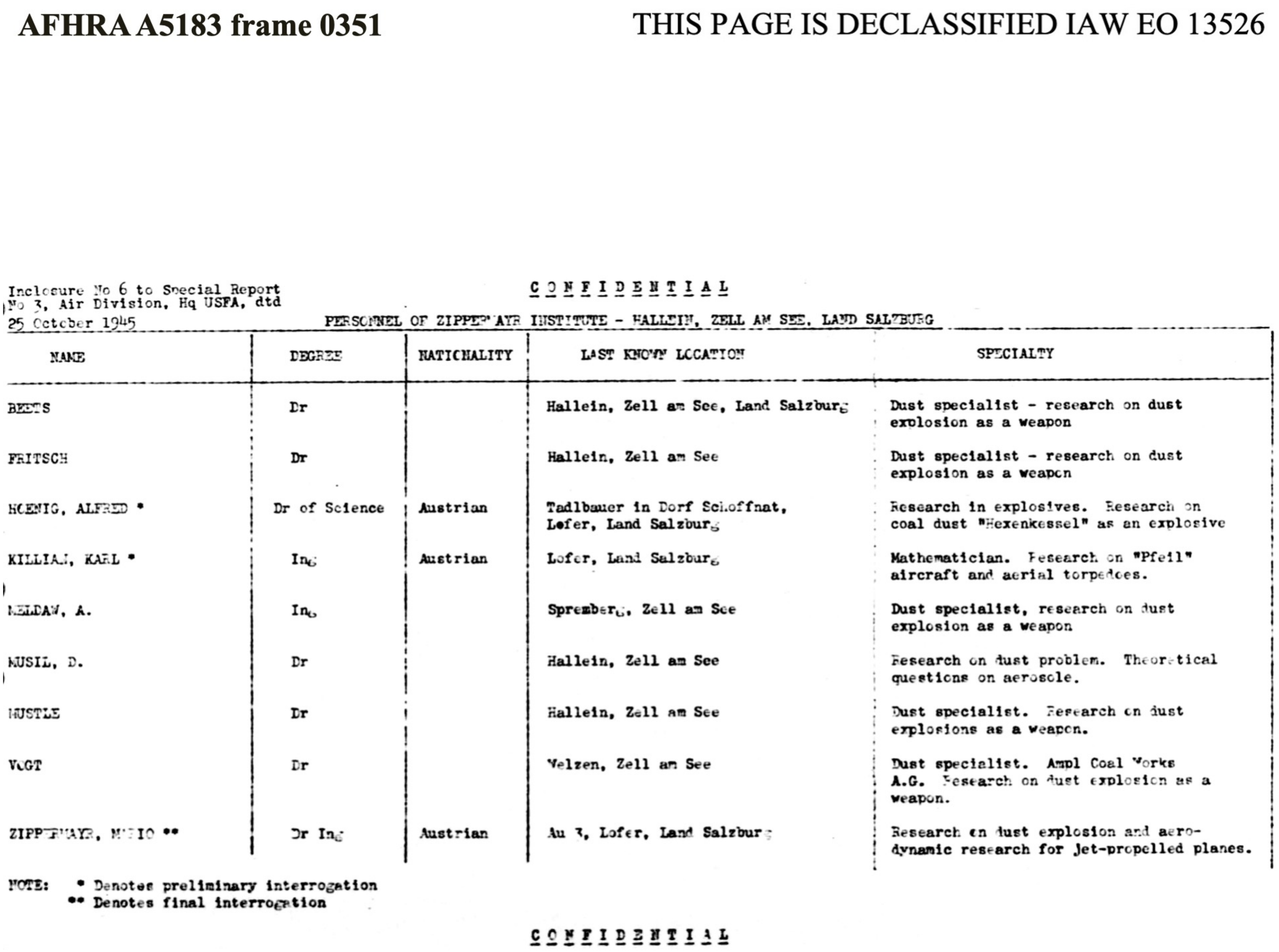
ÜBERSICHT

Über die bis jetzt eingeschalteten Arbeitskreise für die "AKTION HEXENKESSEL"

TLR IA - EF 1/V
Fl.Stabsing.d.B.LANG

Dr.Zippermayr, Wien	DAG-Krümmel	Staubfachleute	Braunkohlenindustrie	Ballistisches Institut, Gatow	Rheinmetall-Borsig
Zusammenarbeit mit: DAG/Krümmel Blumauer Sprengstoff AG.	Abt. Steinmann Abt. Dr. Meier	Dr.Ing.Meldau, Spremberg Dr. Musil Wien Dr.Fritsche Dr.Kruhl Dr.Beetz sämtl.Michel Werke, Halle Generaldir. Dr.Voigt Dr.Mayer AKW/Welsow	Anhaltische Kohlen-Werke Welzow Werminghoff Michel Werke, Halle Riebeckische Montan Werke, Nachterstadt, Aschersleben	Prof.Schardin Meßtechnik: Dr.Turetschek Versuchstechnik mit C-Staub: Werner	Versuchsfeld Unterlüss: Dr. Theile (zusammen mit DAG/Krümmel)

Figure 3.77: A large program, including a group led by Mario Zippermayr, developed and tested fuel-air explosives during the war [Bundesarchiv, Berlin-Lichterfelde, R 26/III, Aktenbestand Nr. 52].



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Inclosure No 6 to Special Report
No 3, Air Division, Hq USFA, dtd
25 October 1945

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PERSONNEL OF ZIPPERMAYR INSTITUTE - HALLEIN, ZELL AM SEE, LAND SALZBURG

NAME	DEGREE	NATIONALITY	LAST KNOWN LOCATION	SPECIALTY
BEETS	Dr		Hallein, Zell am See, Land Salzburg	Dust specialist - research on dust explosion as a weapon
FRITSCH	Dr		Hallein, Zell am See	Dust specialist - research on dust explosion as a weapon
HOENIG, ALFRED *	Dr of Science	Austrian	Tadlbauer in Dorf Schoffnat, Lofer, Land Salzburg	Research in explosives. Research on coal dust "Hexenkessel" as an explosive
KILLIAN, KARL *	Ing	Austrian	Lofer, Land Salzburg	Mathematician. Research on "Pfeil" aircraft and aerial torpedoes.
MELDAW, A.	Ing		Spremberg, Zell am See	Dust specialist, research on dust explosion as a weapon
MUSIL, D.	Dr		Hallein, Zell am See	Research on dust problem. Theoretical questions on aerosole.
MUSTLE	Dr		Hallein, Zell am See	Dust specialist. Research on dust explosions as a weapon.
VOGT	Dr		Velzen, Zell am See	Dust specialist. Ampl Coal Works A.G. Research on dust explosion as a weapon.
ZIPPERMAYR, MARIO **	Dr Ing	Austrian	Au 3, Lofer, Land Salzburg	Research on dust explosion and aerodynamic research for Jet-propelled planes.

NOTE: * Denotes preliminary interrogation
** Denotes final interrogation

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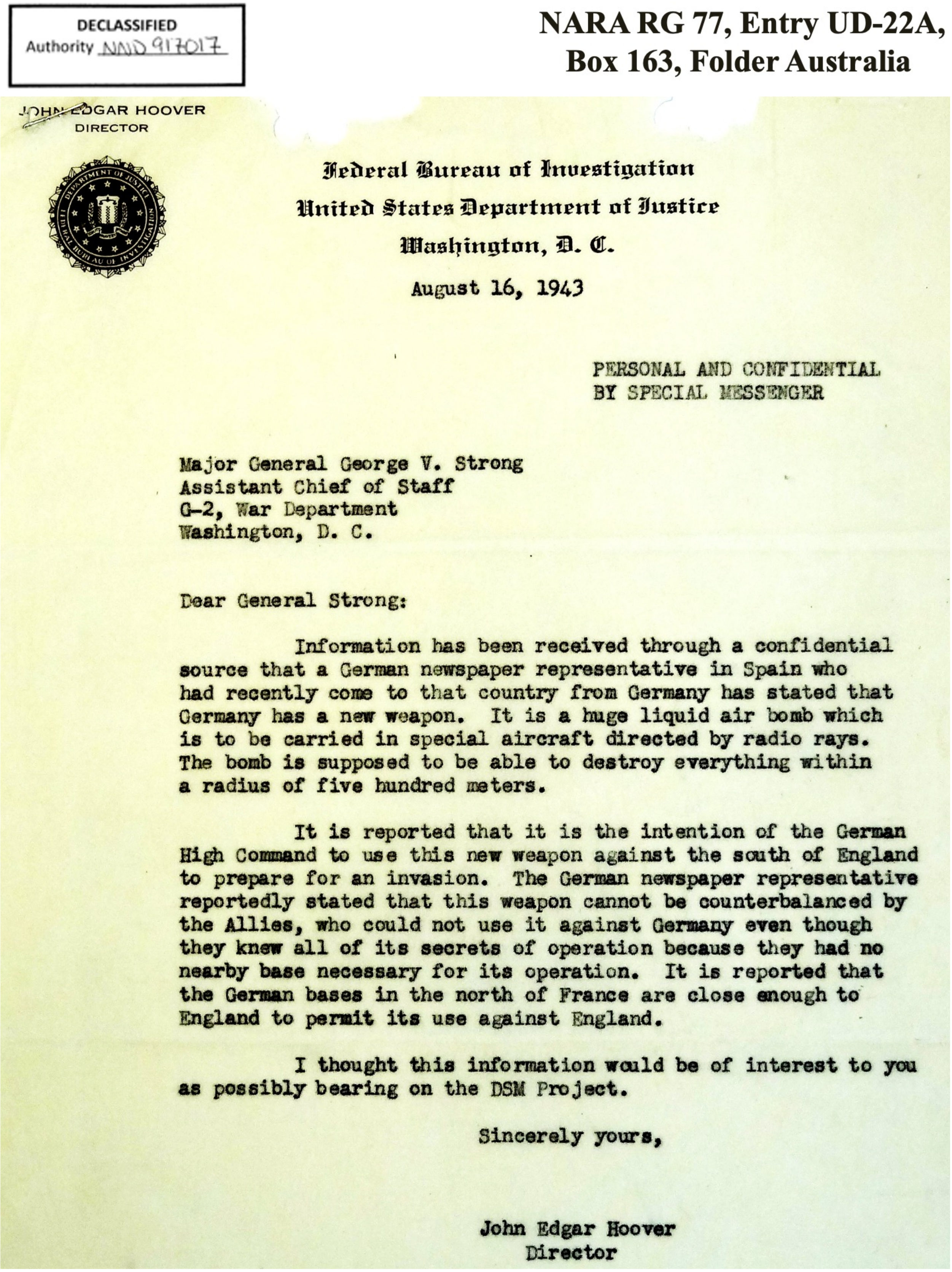
Figure 3.78: A large program, including a group led by Mario Zippermayr, developed and tested fuel-air explosives during the war [AFHRA A5183 frame 0351].



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NARA RG 77, Entry UD-22A, Box 163, Folder Australia

JOHN EDGAR HOOVER
DIRECTOR

Federal Bureau of Investigation
United States Department of Justice
Washington, D. C.

August 16, 1943

PERSONAL AND CONFIDENTIAL
BY SPECIAL MESSENGER

Major General George V. Strong
Assistant Chief of Staff
G-2, War Department
Washington, D. C.

Dear General Strong:

Information has been received through a confidential source that a German newspaper representative in Spain who had recently come to that country from Germany has stated that Germany has a new weapon. It is a huge liquid air bomb which is to be carried in special aircraft directed by radio rays. The bomb is supposed to be able to destroy everything within a radius of five hundred meters.

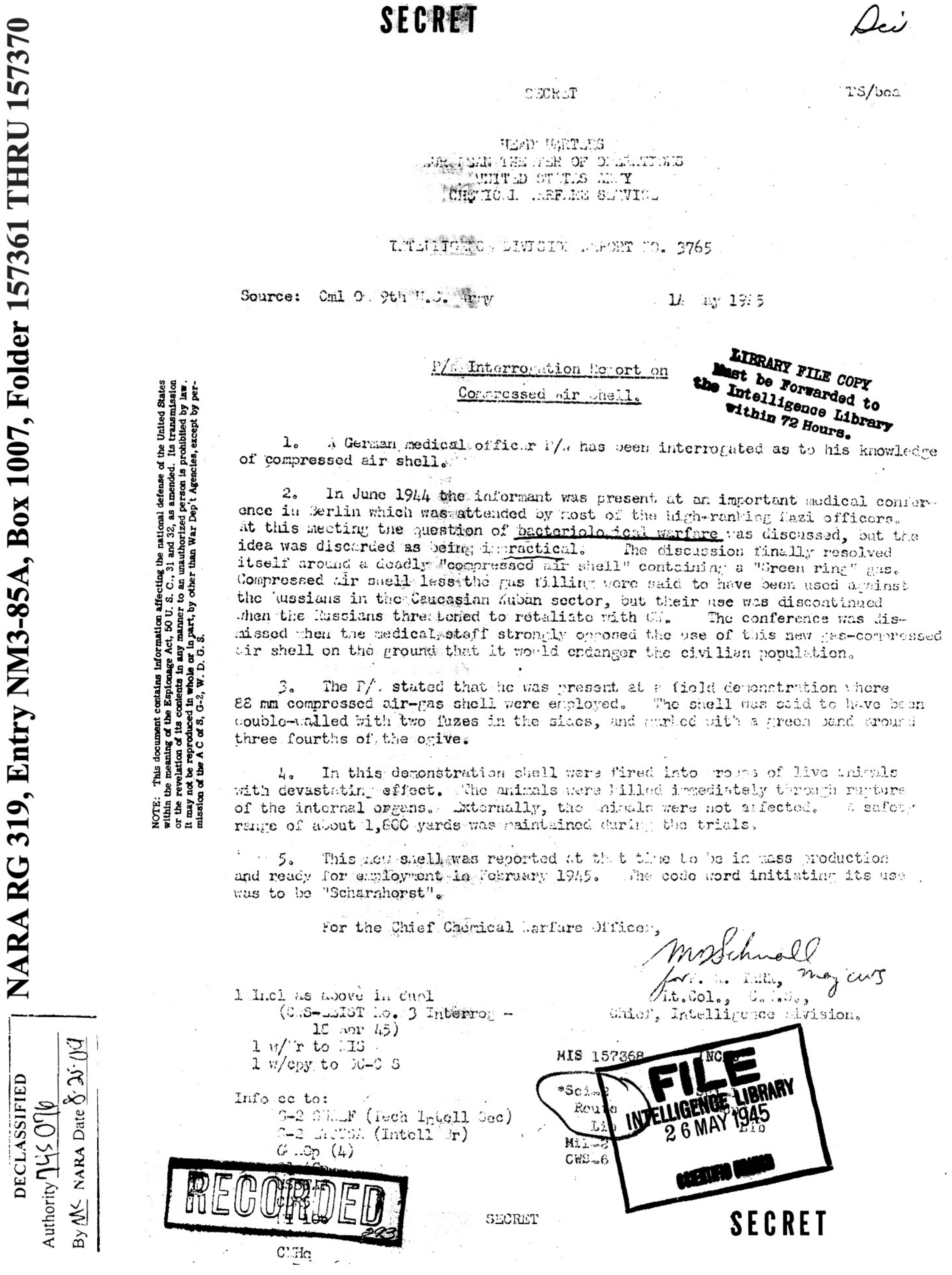
It is reported that it is the intention of the German High Command to use this new weapon against the south of England to prepare for an invasion. The German newspaper representative reportedly stated that this weapon cannot be counterbalanced by the Allies, who could not use it against Germany even though they knew all of its secrets of operation because they had no nearby base necessary for its operation. It is reported that the German bases in the north of France are close enough to England to permit its use against England.

I thought this information would be of interest to you as possibly bearing on the DSM Project.

Sincerely yours,

John Edgar Hoover
Director

Figure 3.79: J. Edgar Hoover. 16 August 1943 [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].



NARA RG 319, Entry NM3-85A, Box 1007, Folder 157361 THRU 157370

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Authority 745096
By MC NARA Date 8-25-09

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HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
CHEMICAL WARFARE SERVICE

INTELLIGENCE DIVISION REPORT NO. 3765

Source: Cml O. 9th U.S. Army 14 May 1945

P/W Interrogation Report on
Compressed Air Shell.

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the Intelligence Library
within 72 Hours.

1. A German medical officer P/W has been interrogated as to his knowledge of compressed air shell.

2. In June 1944 the informant was present at an important medical conference in Berlin which was attended by most of the high-ranking Nazi officers. At this meeting the question of bacteriological warfare was discussed, but the idea was discarded as being impractical. The discussion finally resolved itself around a deadly "compressed air shell" containing a "Green ring" gas. Compressed air shell less the gas filling were said to have been used against the Russians in the Caucasian Kuban sector, but their use was discontinued when the Russians threatened to retaliate with CW. The conference was dismissed when the medical staff strongly opposed the use of this new gas-compressed air shell on the ground that it would endanger the civilian population.

3. The P/W stated that he was present at a field demonstration where 88 mm compressed air-gas shell were employed. The shell was said to have been double-walled with two fuzes in the sides, and marked with a green band around three fourths of the ogive.

4. In this demonstration shell were fired into groups of live animals with devastating effect. The animals were killed immediately through rupture of the internal organs. Externally, the animals were not affected. A safety range of about 1,800 yards was maintained during the trials.

5. This new shell was reported at that time to be in mass production and ready for employment in February 1945. The code word initiating its use was to be "Scharnhorst".

For the Chief Chemical Warfare Officer,

M D Schnall
for [illegible], maj CWS
Lt.Col., C.W.S.,
Chief, Intelligence Division.

1 Incl as above in dupl
(CWS-EIST No. 3 Interrog -
18 Apr 45)
1 w/Tr to MIS
1 w/cpy to OC-C S

Info cc to:
G-2 SHAEF (Tech Intell Sec)
G-2 ETOUSA (Intell Br)
G ..Op (4)

CWHq

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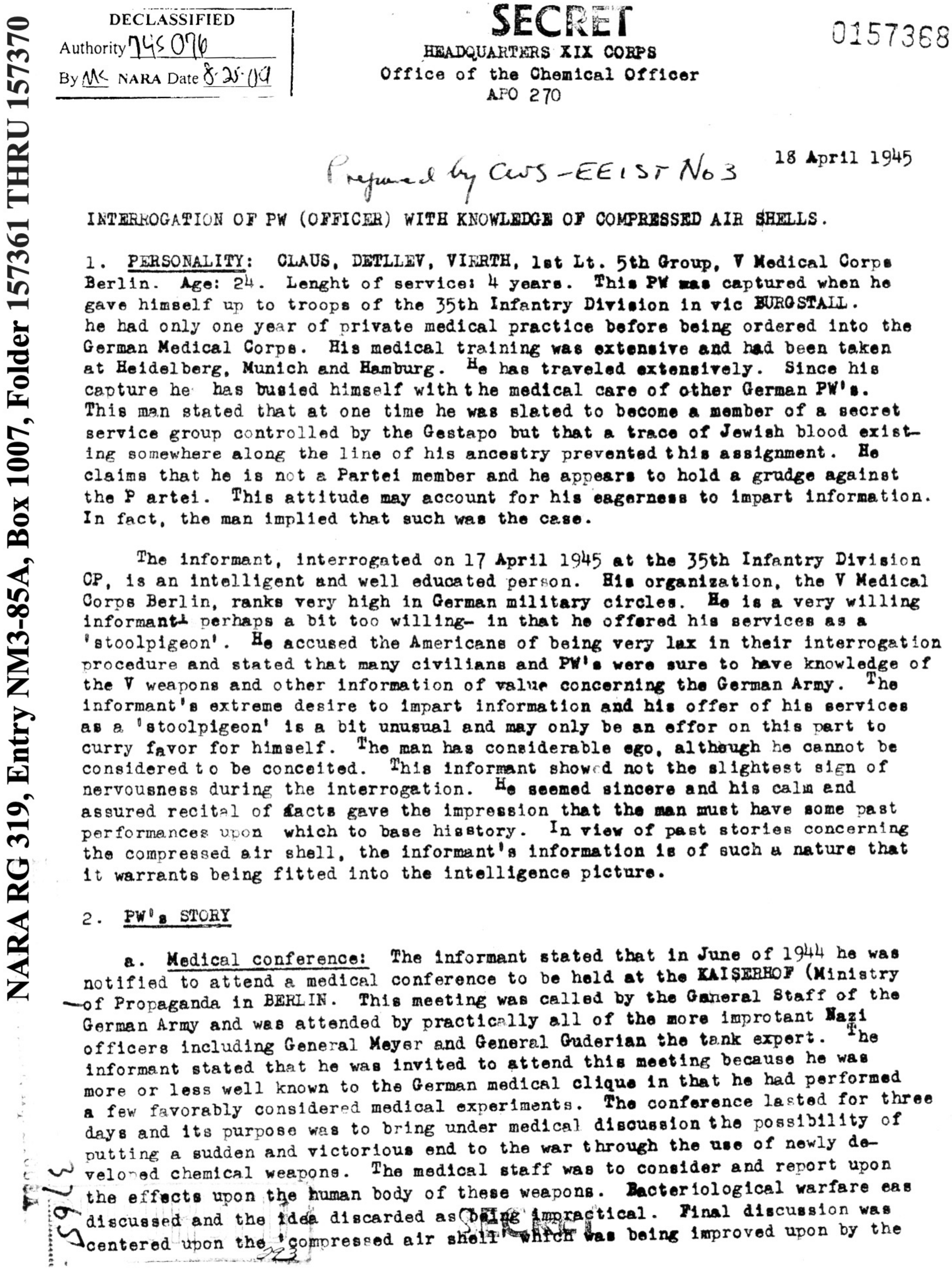
Figure 3.80: A reported test of a fuel-air explosive (or possibly a chemical agent) [NARA RG 319, Entry NM3-85A, Box 1007, Folder 157361 THRU 157370].



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HEADQUARTERS XIX CORPS
Office of the Chemical Officer
APO 270

0157368

Prepared by CWS-EEIST No 3

18 April 1945

INTERROGATION OF PW (OFFICER) WITH KNOWLEDGE OF COMPRESSED AIR SHELLS.

1. PERSONALITY: CLAUS, DETLLEV, VIERTH, 1st Lt. 5th Group, V Medical Corps Berlin. Age: 24. Lenght of service: 4 years. This PW was captured when he gave himself up to troops of the 35th Infantry Division in vic BURGSTALL. he had only one year of private medical practice before being ordered into the German Medical Corps. His medical training was extensive and had been taken at Heidelberg, Munich and Hamburg. He has traveled extensively. Since his capture he has busied himself with the medical care of other German PW's. This man stated that at one time he was slated to become a member of a secret service group controlled by the Gestapo but that a trace of Jewish blood existing somewhere along the line of his ancestry prevented this assignment. He claims that he is not a Partei member and he appears to hold a grudge against the Partei. This attitude may account for his eagerness to impart information. In fact, the man implied that such was the case.

The informant, interrogated on 17 April 1945 at the 35th Infantry Division CP, is an intelligent and well educated person. His organization, the V Medical Corps Berlin, ranks very high in German military circles. He is a very willing informant- perhaps a bit too willing- in that he offered his services as a 'stoolpigeon'. He accused the Americans of being very lax in their interrogation procedure and stated that many civilians and PW's were sure to have knowledge of the V weapons and other information of value concerning the German Army. The informant's extreme desire to impart information and his offer of his services as a 'stoolpigeon' is a bit unusual and may only be an effor on this part to curry favor for himself. The man has considerable ego, although he cannot be considered to be conceited. This informant showed not the slightest sign of nervousness during the interrogation. He seemed sincere and his calm and assured recital of facts gave the impression that the man must have some past performances upon which to base hisstory. In view of past stories concerning the compressed air shell, the informant's information is of such a nature that it warrants being fitted into the intelligence picture.

2. PW's STORY

a. Medical conference: The informant stated that in June of 1944 he was notified to attend a medical conference to be held at the KAISERHOF (Ministry of Propaganda in BERLIN. This meeting was called by the General Staff of the German Army and was attended by practically all of the more improtant Nazi officers including General Meyer and General Guderian the tank expert. The informant stated that he was invited to attend this meeting because he was more or less well known to the German medical clique in that he had performed a few favorably considered medical experiments. The conference lasted for three days and its purpose was to bring under medical discussion the possibility of putting a sudden and victorious end to the war through the use of newly developed chemical weapons. The medical staff was to consider and report upon the effects upon the human body of these weapons. Bacteriological warfare eas discussed and the idea discarded as being impractical. Final discussion was centered upon the 'compressed air shell' which was being improved upon by the

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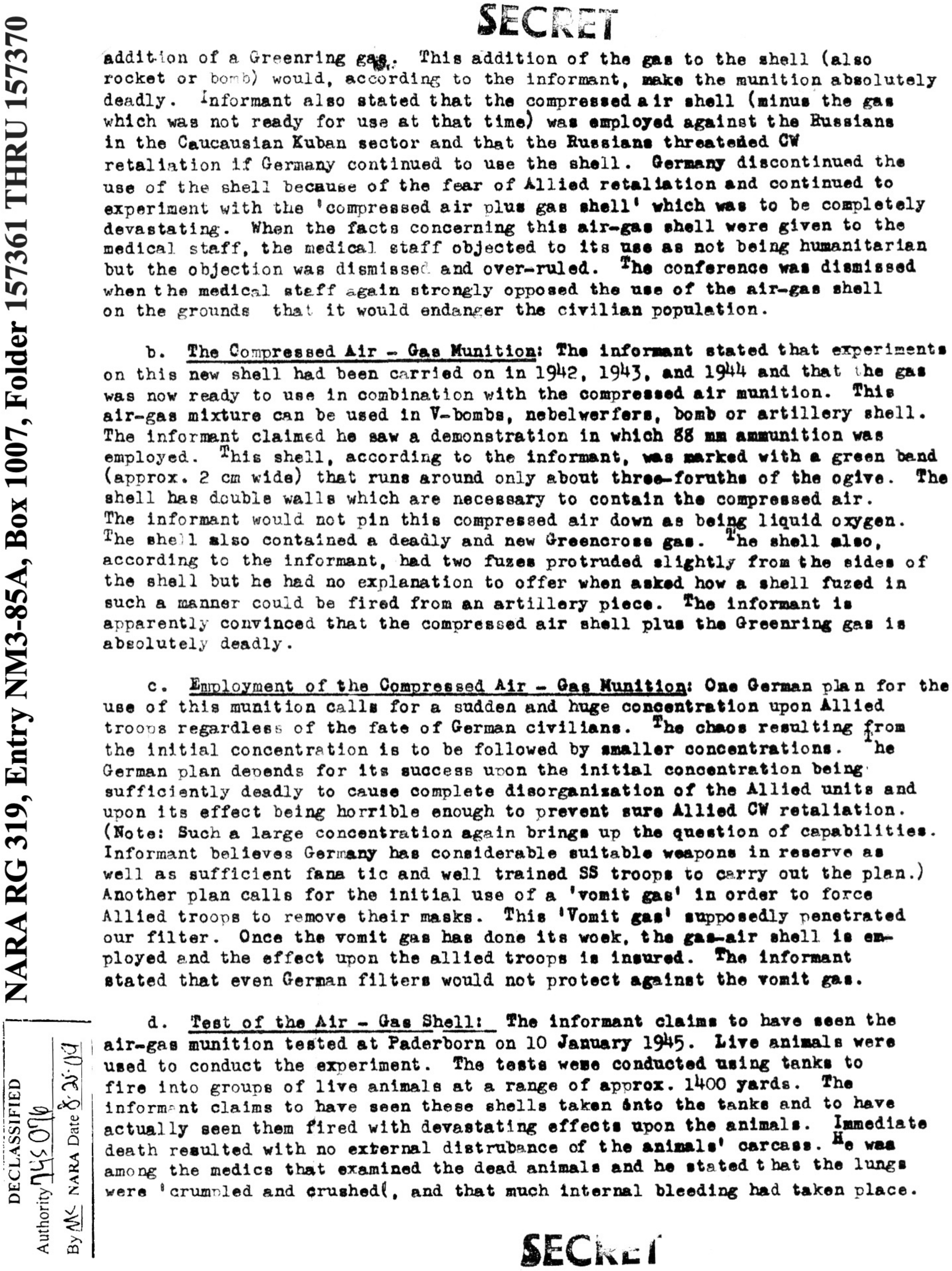
Figure 3.81: A reported test of a fuel-air explosive (or possibly a chemical agent) [NARA RG 319, Entry NM3-85A, Box 1007, Folder 157361 THRU 157370].



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addition of a Greenring gas. This addition of the gas to the shell (also rocket or bomb) would, according to the informant, make the munition absolutely deadly. Informant also stated that the compressed air shell (minus the gas which was not ready for use at that time) was employed against the Russians in the Caucausian Kuban sector and that the Russians threatened CW retaliation if Germany continued to use the shell. Germany discontinued the use of the shell because of the fear of Allied retaliation and continued to experiment with the 'compressed air plus gas shell' which was to be completely devastating. When the facts concerning this air-gas shell were given to the medical staff, the medical staff objected to its use as not being humanitarian but the objection was dismissed and over-ruled. The conference was dismissed when the medical staff again strongly opposed the use of the air-gas shell on the grounds that it would endanger the civilian population.

b. The Compressed Air - Gas Munition: The informant stated that experiments on this new shell had been carried on in 1942, 1943, and 1944 and that the gas was now ready to use in combination with the compressed air munition. This air-gas mixture can be used in V-bombs, nebelwerfers, bomb or artillery shell. The informant claimed he saw a demonstration in which 88 mm ammunition was employed. This shell, according to the informant, was marked with a green band (approx. 2 cm wide) that runs around only about three-foruths of the ogive. The shell has double walls which are necessary to contain the compressed air. The informant would not pin this compressed air down as being liquid oxygen. The shell also contained a deadly and new Greencross gas. The shell also, according to the informant, had two fuzes protruded slightly from the sides of the shell but he had no explanation to offer when asked how a shell fuzed in such a manner could be fired from an artillery piece. The informant is apparently convinced that the compressed air shell plus the Greenring gas is absolutely deadly.

c. Employment of the Compressed Air - Gas Munition: One German plan for the use of this munition calls for a sudden and huge concentration upon Allied troops regardless of the fate of German civilians. The chaos resulting from the initial concentration is to be followed by smaller concentrations. The German plan depends for its success upon the initial concentration being sufficiently deadly to cause complete disorganisation of the Allied units and upon its effect being horrible enough to prevent sure Allied CW retaliation. (Note: Such a large concentration again brings up the question of capabilities. Informant believes Germany has considerable suitable weapons in reserve as well as sufficient fanatic and well trained SS troops to carry out the plan.) Another plan calls for the initial use of a 'vomit gas' in order to force Allied troops to remove their masks. This 'Vomit gas' supposedly penetrated our filter. Once the vomit gas has done its woek, the gas-air shell is employed and the effect upon the allied troops is insured. The informant stated that even German filters would not protect against the vomit gas.

d. Test of the Air - Gas Shell: The informant claims to have seen the air-gas munition tested at Paderborn on 10 January 1945. Live animals were used to conduct the experiment. The tests wese conducted using tanks to fire into groups of live animals at a range of approx. 1400 yards. The informant claims to have seen these shells taken onto the tanks and to have actually seen them fired with devastating effects upon the animals. Immediate death resulted with no external distrubance of the animals' carcass. He was among the medics that examined the dead animals and he stated that the lungs were 'crumpled and crushed', and that much internal bleeding had taken place.

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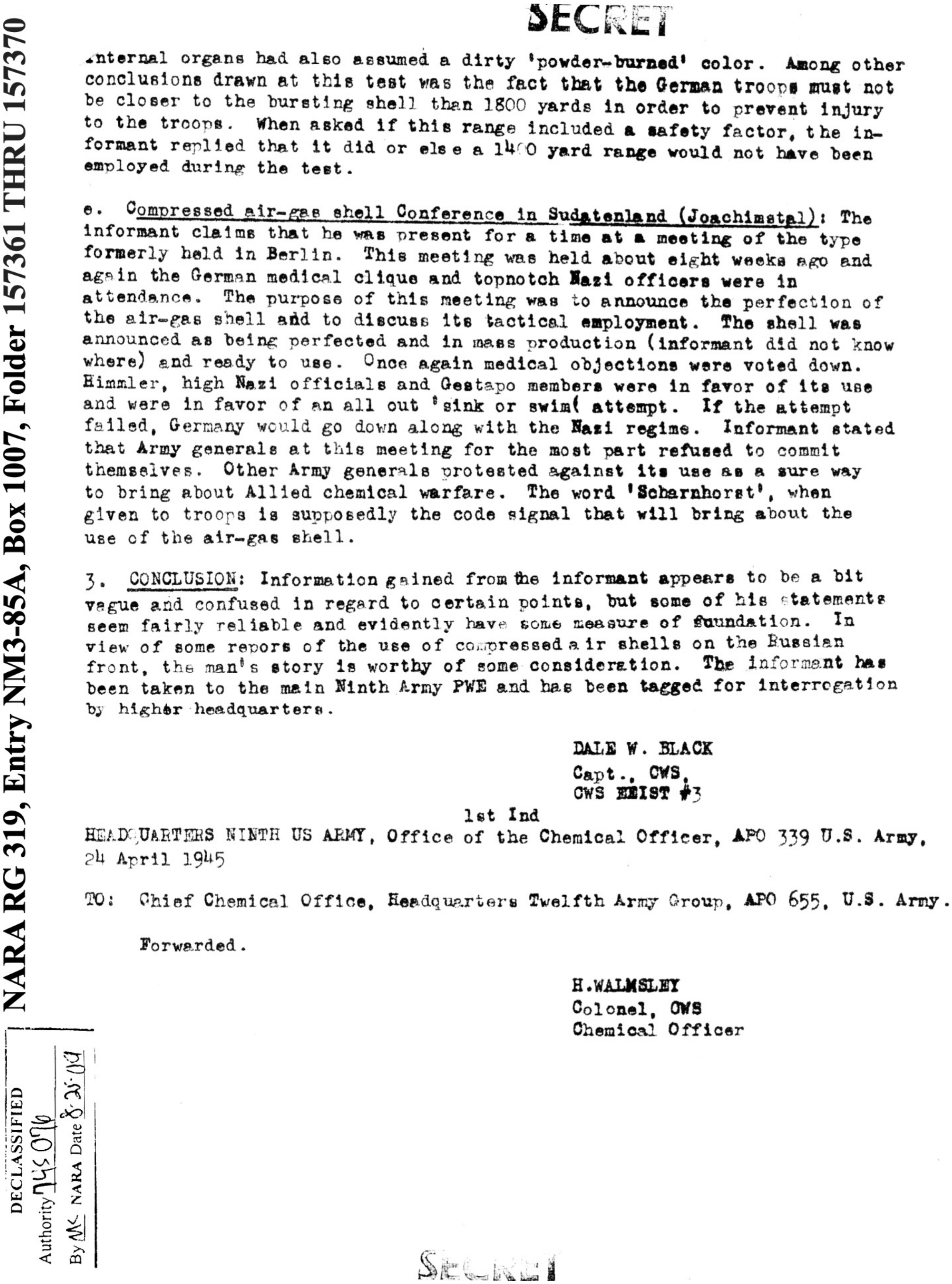
By NK NARA Date 8-25-03

Figure 3.82: A reported test of a fuel-air explosive (or possibly a chemical agent) [NARA RG 319, Entry NM3-85A, Box 1007, Folder 157361 THRU 157370].



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internal organs had also assumed a dirty 'powder-burned' color. Among other conclusions drawn at this test was the fact that the German troops must not be closer to the bursting shell than 1800 yards in order to prevent injury to the troops. When asked if this range included a safety factor, the informant replied that it did or else a 1400 yard range would not have been employed during the test.

e. Compressed air-gas shell Conference in Sudatenland (Joachimstal): The informant claims that he was present for a time at a meeting of the type formerly held in Berlin. This meeting was held about eight weeks ago and again the German medical clique and topnotch Nazi officers were in attendance. The purpose of this meeting was to announce the perfection of the air-gas shell and to discuss its tactical employment. The shell was announced as being perfected and in mass production (informant did not know where) and ready to use. Once again medical objections were voted down. Himmler, high Nazi officials and Gestapo members were in favor of its use and were in favor of an all out 'sink or swim(attempt. If the attempt failed, Germany would go down along with the Nazi regime. Informant stated that Army generals at this meeting for the most part refused to commit themselves. Other Army generals protested against its use as a sure way to bring about Allied chemical warfare. The word 'Scharnhorst', when given to troops is supposedly the code signal that will bring about the use of the air-gas shell.

3. CONCLUSION: Information gained from the informant appears to be a bit vague and confused in regard to certain points, but some of his statements seem fairly reliable and evidently have some measure of foundation. In view of some repors of the use of compressed air shells on the Russian front, the man's story is worthy of some consideration. The informant has been taken to the main Ninth Army PWE and has been tagged for interrogation by higher headquarters.

DALE W. BLACK
Capt., CWS,
CWS EEIST #3

1st Ind

HEADQUARTERS NINTH US ARMY, Office of the Chemical Officer, APO 339 U.S. Army, 24 April 1945

TO: Chief Chemical Office, Headquarters Twelfth Army Group, APO 655, U.S. Army.

Forwarded.

H.WALMSLEY
Colonel, CWS
Chemical Officer

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NARA RG 319, Entry NM3-85A, Box 1007, Folder 157361 THRU 157370

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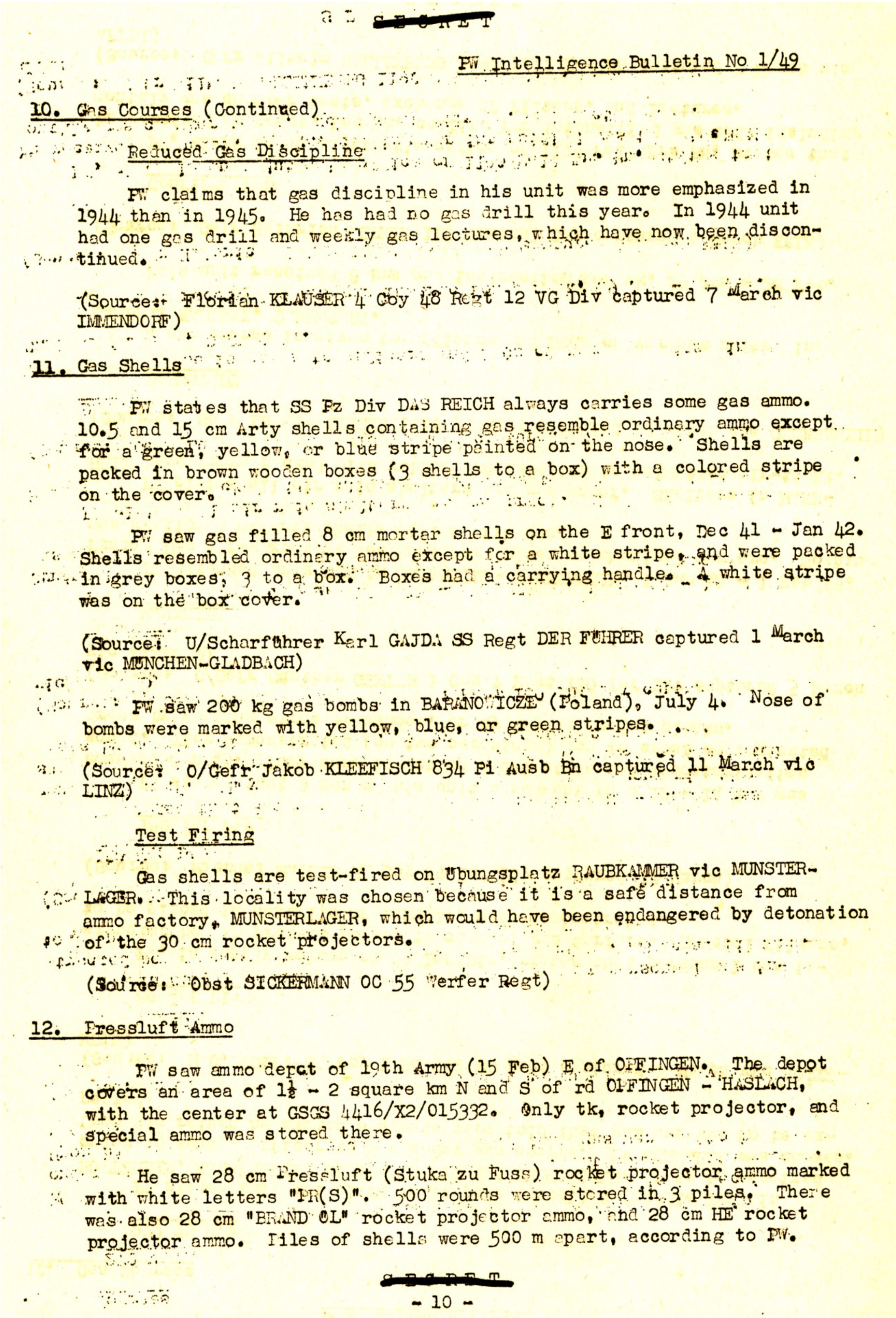
By MC NARA Date 8-25-09

Figure 3.83: A reported test of a fuel-air explosive (or possibly a chemical agent) [NARA RG 319, Entry NM3-85A, Box 1007, Folder 157361 THRU 157370].

PW Intelligence Bulletin No 1/49, AFHRA folder 506.61951 Nos. 1/47--1/56 13 Mar--9 Apr 1945, IRIS 207526 THIS PAGE IS DECLASSIFIED IAW EO 13526



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PW Intelligence Bulletin No 1/49

10. Gas Courses (Continued)

Reduced Gas Discipline

PW claims that gas discipline in his unit was more emphasized in 1944 than in 1945. He has had no gas drill this year. In 1944 unit had one gas drill and weekly gas lectures, which have now been discontinued.

(Source: Florian KLAUSER 4 Coy 48 Regt 12 VG Div captured 7 March vic IMMENDORF)

11. Gas Shells

PW states that SS Pz Div DAS REICH always carries some gas ammo. 10.5 and 15 cm Arty shells containing gas resemble ordinary ammo except for a green, yellow, or blue stripe painted on the nose. Shells are packed in brown wooden boxes (3 shells to a box) with a colored stripe on the cover.

PW saw gas filled 8 cm mortar shells on the E front, Dec 41 - Jan 42. Shells resembled ordinary ammo except for a white stripe, and were packed in grey boxes, 3 to a box. Boxes had a carrying handle. A white stripe was on the box cover.

(Source: U/Scharführer Karl GAJDA SS Regt DER FÜHRER captured 1 March vic MÜNCHEN-GLADBACH)

PW saw 200 kg gas bombs in BARANOWICZE (Poland), July 4. Nose of bombs were marked with yellow, blue, or green stripes.

(Source: O/Gefr Jakob KLEEFISCH 834 Pi Ausb Bn captured 11 March vic LINZ)

Test Firing

Gas shells are test-fired on Übungsplatz RAUBKAMMER vic MUNSTERLAGER. This locality was chosen because it is a safe distance from ammo factory, MUNSTERLAGER, which would have been endangered by detonation of the 30 cm rocket projectors.

(Source: Obst SICKERMANN OC 55 Werfer Regt)

12. Pressluft Ammo

PW saw ammo depot of 19th Army (15 Feb) E of OFFINGEN. The depot covers an area of 1½ - 2 square km N and S of rd OFFINGEN - HASLACH, with the center at GSGS 4416/X2/015332. Only tk, rocket projector, and special ammo was stored there.

He saw 28 cm Pressluft (Stuka zu Fuss) rocket projector ammo marked with white letters "PR(S)". 500 rounds were stored in 3 piles. There was also 28 cm "BRAND ÖL" rocket projector ammo, and 28 cm HE rocket projector ammo. Piles of shells were 500 m apart, according to PW.

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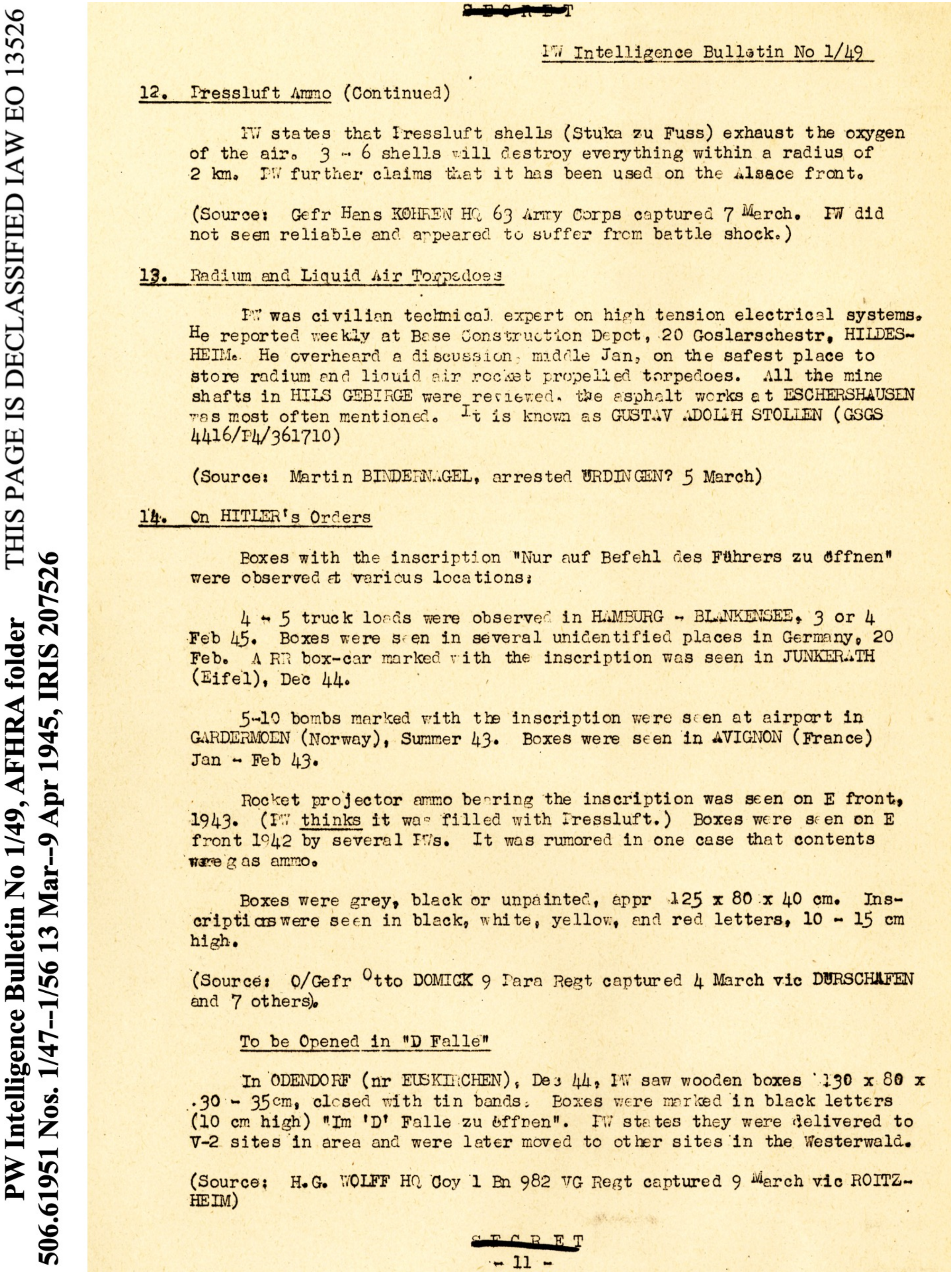
Figure 3.84: Reports of stockpiled fuel-air explosives and other weapons. PW Intelligence Bulletin No 1/49 [AFHRA folder 506.61951 Nos. 1/47–1/56 13 Mar–9 Apr 1945, IRIS 207526; AFHRA A5185 frames 840–841].



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PW Intelligence Bulletin No 1/49, AFHRA folder
506.61951 Nos. 1/47--1/56 13 Mar--9 Apr 1945, IRIS 207526

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PW Intelligence Bulletin No 1/49

12. Pressluft Ammo (Continued)

PW states that Pressluft shells (Stuka zu Fuss) exhaust the oxygen of the air. 3 - 6 shells will destroy everything within a radius of 2 km. PW further claims that it has been used on the Alsace front.

(Source: Gefr Hans KOHREN HQ 63 Army Corps captured 7 March. PW did not seem reliable and appeared to suffer from battle shock.)

13. Radium and Liquid Air Torpedoes

PW was civilian technical expert on high tension electrical systems. He reported weekly at Base Construction Depot, 20 Goslarschestr, HILDESHEIM. He overheard a discussion, middle Jan, on the safest place to store radium and liquid air rocket propelled torpedoes. All the mine shafts in HILS GEBIRGE were reviewed. the asphalt works at ESCHERSHAUSEN was most often mentioned. It is known as GUSTAV ADOLPH STOLLEN (GSGS 4416/P4/361710)

(Source: Martin BINDERNAGEL, arrested URDINGEN? 5 March)

14. On HITLER's Orders

Boxes with the inscription "Nur auf Befehl des Führers zu öffnen" were observed at various locations:

4 - 5 truck loads were observed in HAMBURG - BLANKENSEE, 3 or 4 Feb 45. Boxes were seen in several unidentified places in Germany, 20 Feb. A RR box-car marked with the inscription was seen in JUNKERATH (Eifel), Dec 44.

5-10 bombs marked with the inscription were seen at airport in GARDERMOEN (Norway), Summer 43. Boxes were seen in AVIGNON (France) Jan - Feb 43.

Rocket projector ammo bearing the inscription was seen on E front, 1943. (PW thinks it was filled with Pressluft.) Boxes were seen on E front 1942 by several PWs. It was rumored in one case that contents were gas ammo.

Boxes were grey, black or unpainted, appr 125 x 80 x 40 cm. Inscriptions were seen in black, white, yellow, and red letters, 10 - 15 cm high.

(Source: O/Gefr Otto DOMICK 9 Para Regt captured 4 March vic DURSCHAFEN and 7 others).

To be Opened in "D Falle"

In ODENDORF (nr EUSKIRCHEN), Dec 44, PW saw wooden boxes 130 x 80 x 30 - 35cm, closed with tin bands. Boxes were marked in black letters (10 cm high) "Im 'D' Falle zu öffnen". PW states they were delivered to V-2 sites in area and were later moved to other sites in the Westerwald.

(Source: H.G. WOLFF HQ Coy 1 Bn 982 VG Regt captured 9 March vic ROITZHEIM)

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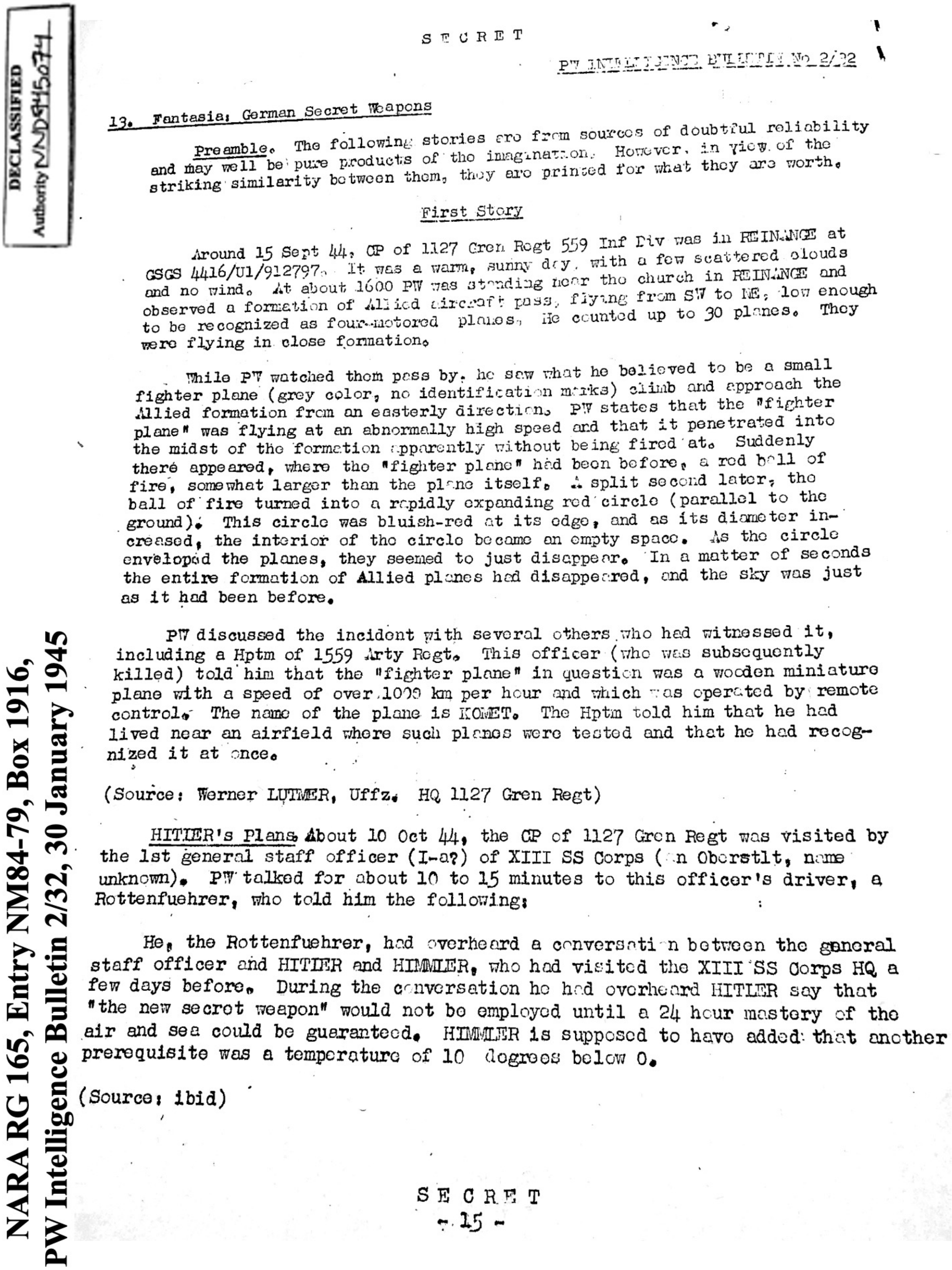
Figure 3.85: Reports of stockpiled fuel-air explosives and other weapons. PW Intelligence Bulletin No 1/49 [AFHRA folder 506.61951 Nos. 1/47–1/56 13 Mar–9 Apr 1945, IRIS 207526; AFHRA A5185 frames 840–841].



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PW INTELLIGENCE BULLETIN No 2/32

13. Fantasia: German Secret Weapons

Preamble. The following stories are from sources of doubtful reliability and may well be pure products of the imagination. However, in view of the striking similarity between them, they are printed for what they are worth.

First Story

Around 15 Sept 44, CP of 1127 Gren Regt 559 Inf Div was in REINANGE at GSGS 4416/U1/912797. It was a warm, sunny day, with a few scattered clouds and no wind. At about 1600 PW was standing near the church in REINANGE and observed a formation of Allied aircraft pass, flying from SW to NE, low enough to be recognized as four-motored planes. He counted up to 30 planes. They were flying in close formation.

While PW watched them pass by, he saw what he believed to be a small fighter plane (grey color, no identification marks) climb and approach the Allied formation from an easterly direction. PW states that the "fighter plane" was flying at an abnormally high speed and that it penetrated into the midst of the formation apparently without being fired at. Suddenly there appeared, where the "fighter plane" had been before, a red ball of fire, somewhat larger than the plane itself. A split second later, the ball of fire turned into a rapidly expanding red circle (parallel to the ground). This circle was bluish-red at its edge, and as its diameter increased, the interior of the circle became an empty space. As the circle enveloped the planes, they seemed to just disappear. In a matter of seconds the entire formation of Allied planes had disappeared, and the sky was just as it had been before.

PW discussed the incident with several others who had witnessed it, including a Hptm of 1559 Arty Regt. This officer (who was subsequently killed) told him that the "fighter plane" in question was a wooden miniature plane with a speed of over 1000 km per hour and which was operated by remote control. The name of the plane is KOMET. The Hptm told him that he had lived near an airfield where such planes were tested and that he had recognized it at once.

(Source: Werner LUTMER, Uffz. HQ 1127 Gren Regt)

HITLER's Plans. About 10 Oct 44, the CP of 1127 Gren Regt was visited by the 1st general staff officer (I-a?) of XIII SS Corps (an Oberstlt, name unknown). PW talked for about 10 to 15 minutes to this officer's driver, a Rottenfuehrer, who told him the following:

He, the Rottenfuehrer, had overheard a conversation between the general staff officer and HITLER and HIMMLER, who had visited the XIII SS Corps HQ a few days before. During the conversation he had overheard HITLER say that "the new secret weapon" would not be employed until a 24 hour mastery of the air and sea could be guaranteed. HIMMLER is supposed to have added that another prerequisite was a temperature of 10 degrees below 0.

(Source: ibid)

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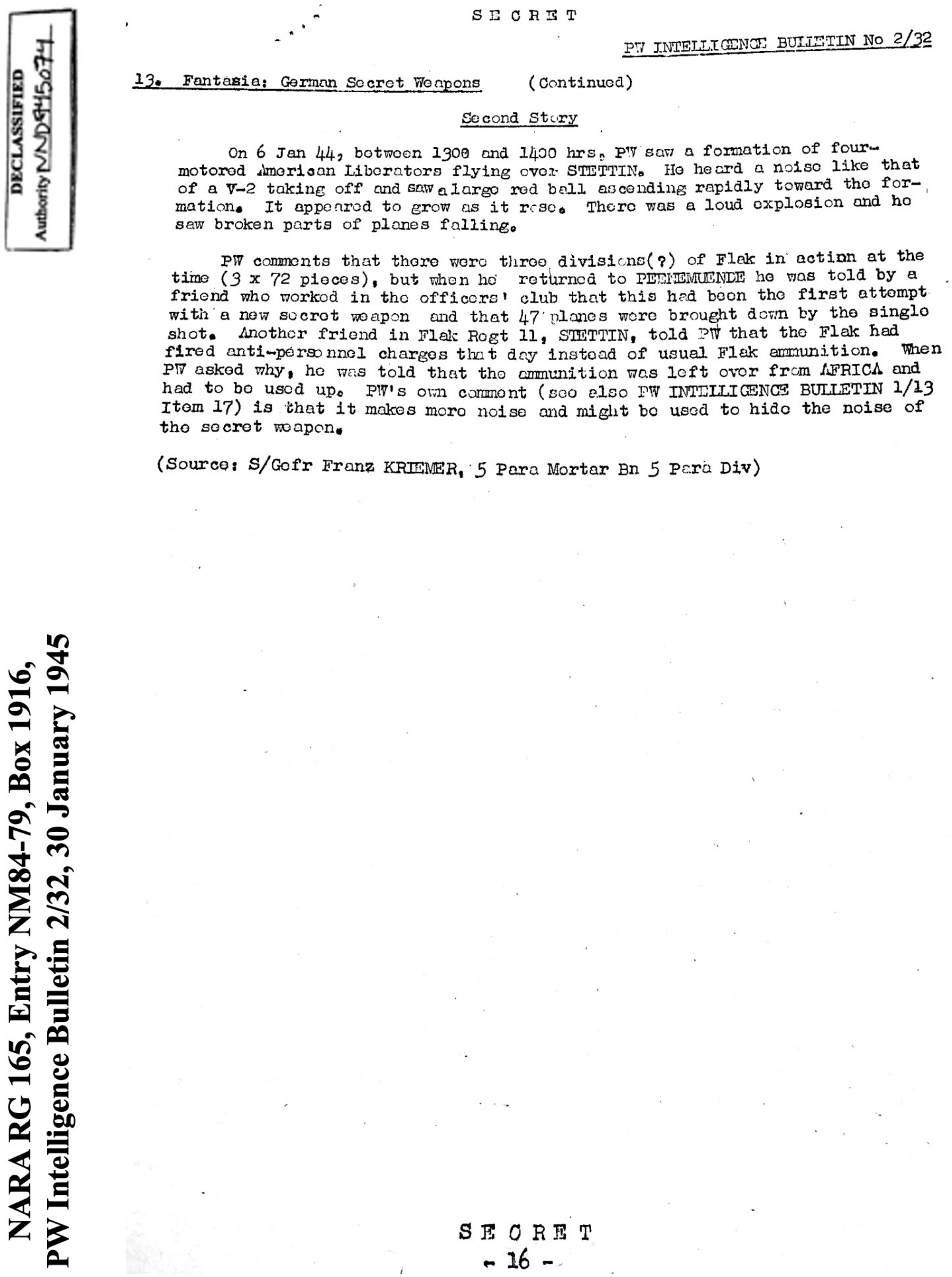
NARA RG 165, Entry NM84-79, Box 1916,
PW Intelligence Bulletin 2/32, 30 January 1945

Figure 3.86: A reported test of a fuel-air explosive. PW Intelligence Bulletin 2/32, 30 January 1945. [NARA RG 165, Entry NM84-79, Box 1916].



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PW INTELLIGENCE BULLETIN No 2/32

13. Fantasia: German Secret Weapons (Continued)

Second Story

On 6 Jan 44, between 1300 and 1400 hrs, PW saw a formation of four-motored American Liberators flying over STETTIN. He heard a noise like that of a V-2 taking off and saw a large red ball ascending rapidly toward the formation. It appeared to grow as it rose. There was a loud explosion and he saw broken parts of planes falling.

PW comments that there were three divisions(?) of Flak in action at the time (3 x 72 pieces), but when he returned to PEENEMUENDE he was told by a friend who worked in the officers' club that this had been the first attempt with a new secret weapon and that 47 planes were brought down by the single shot. Another friend in Flak Regt 11, STETTIN, told PW that the Flak had fired anti-personnel charges that day instead of usual Flak ammunition. When PW asked why, he was told that the ammunition was left over from AFRICA and had to be used up. PW's own comment (see also PW INTELLIGENCE BULLETIN 1/13 Item 17) is that it makes more noise and might be used to hide the noise of the secret weapon.

(Source: S/Gefr Franz KRIEMER, 5 Para Mortar Bn 5 Para Div)

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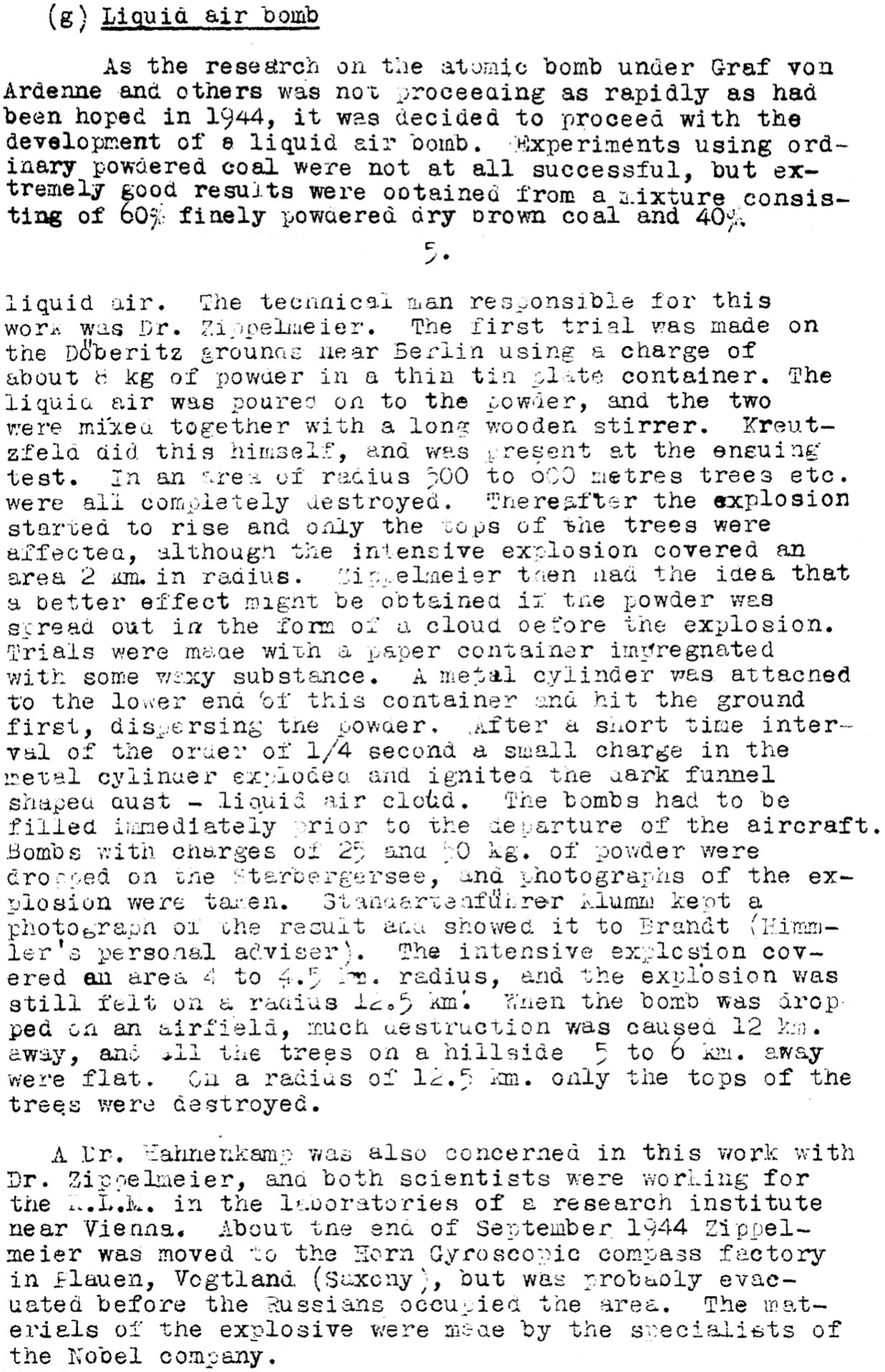
NARA RG 165, Entry NM84-79, Box 1916,
PW Intelligence Bulletin 2/32, 30 January 1945

Figure 3.87: A reported test of a fuel-air explosive. PW Intelligence Bulletin 2/32, 30 January 1945. [NARA RG 165, Entry NM84-79, Box 1916].

BIOS 142. *Information Obtained from Targets of Opportunity in the Sonthofen Area.*



(g) Liquid air bomb

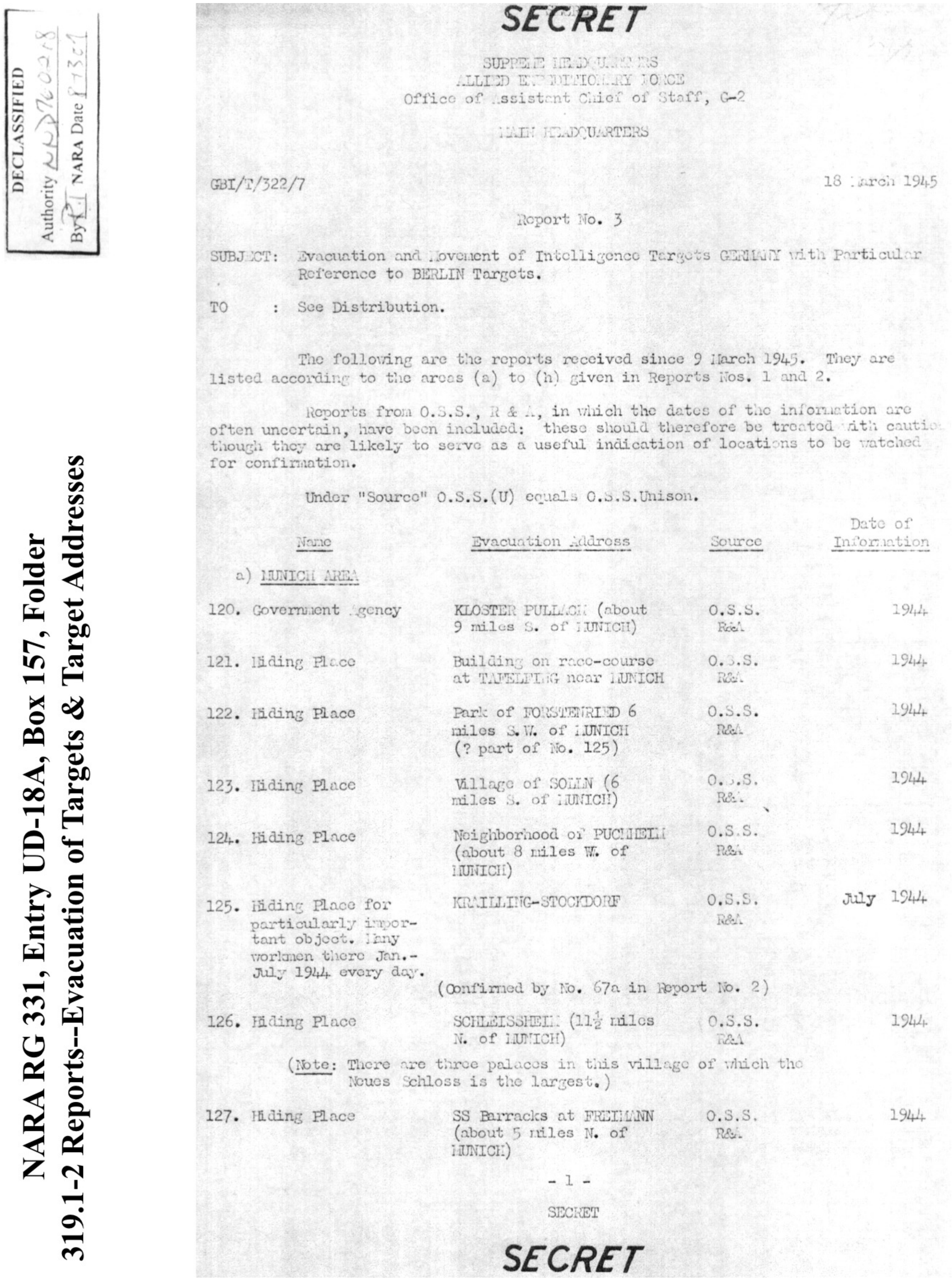
As the research on the atomic bomb under Graf von Ardenne and others was not proceeding as rapidly as had been hoped in 1944, it was decided to proceed with the development of a liquid air bomb. Experiments using ordinary powdered coal were not at all successful, but extremely good results were obtained from a mixture consisting of 60% finely powdered dry brown coal and 40%

5.

liquid air. The technical man responsible for this work was Dr. Zippelmeier. The first trial was made on the Döberitz grounds near Berlin using a charge of about 8 kg of powder in a thin tin plate container. The liquid air was poured on to the powder, and the two were mixed together with a long wooden stirrer. Kreutzfeld did this himself, and was present at the ensuing test. In an area of radius 500 to 600 metres trees etc. were all completely destroyed. Thereafter the explosion started to rise and only the tops of the trees were affected, although the intensive explosion covered an area 2 km. in radius. Zippelmeier then had the idea that a better effect might be obtained if the powder was spread out in the form of a cloud before the explosion. Trials were made with a paper container impregnated with some waxy substance. A metal cylinder was attached to the lower end of this container and hit the ground first, dispersing the powder. After a short time interval of the order of 1/4 second a small charge in the metal cylinder exploded and ignited the dark funnel shaped dust - liquid air cloud. The bombs had to be filled immediately prior to the departure of the aircraft. Bombs with charges of 25 and 50 kg. of powder were dropped on the Starbergersee, and photographs of the explosion were taken. Standartenführer Klumm kept a photograph of the result and showed it to Brandt (Himmler's personal adviser). The intensive explosion covered an area 4 to 4.5 km. radius, and the explosion was still felt on a radius 12.5 km. When the bomb was dropped on an airfield, much destruction was caused 12 km. away, and all the trees on a hillside 5 to 6 km. away were flat. On a radius of 12.5 km. only the tops of the trees were destroyed.

A Dr. Hahnenkamp was also concerned in this work with Dr. Zippelmeier, and both scientists were working for the R.L.M. in the laboratories of a research institute near Vienna. About the end of September 1944 Zippelmeier was moved to the Horn Gyroscopic compass factory in Plauen, Vogtland (Saxony), but was probably evacuated before the Russians occupied the area. The materials of the explosive were made by the specialists of the Nobel company.

Figure 3.88: Reported tests of fuel-air explosives [BIOS 142, pp. 4–5]. The tests sound real although the blast radii (reported secondhand and from memory) seem exaggerated for the amounts of explosives and dispersal methods described. The “waxy substance” coating the container was probably to keep the coal dust from sticking to the container.



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Authority NND 760218
By RT NARA Date 8-13-01

NARA RG 331, Entry UD-18A, Box 157, Folder
319.1-2 Reports--Evacuation of Targets & Target Addresses

SECRET

SUPREME HEADQUARTERS
ALLIED EXPEDITIONARY FORCE
Office of Assistant Chief of Staff, G-2

MAIN HEADQUARTERS

GBI/T/322/7 18 March 1945

Report No. 3

SUBJECT: Evacuation and Movement of Intelligence Targets GERMANY with Particular Reference to BERLIN Targets.

TO : See Distribution.

The following are the reports received since 9 March 1945. They are listed according to the areas (a) to (h) given in Reports Nos. 1 and 2.

Reports from O.S.S., R & A, in which the dates of the information are often uncertain, have been included: these should therefore be treated with caution though they are likely to serve as a useful indication of locations to be watched for confirmation.

Under "Source" O.S.S.(U) equals O.S.S.Unison.

Name	Evacuation Address	Source	Date of Information
a) MUNICH AREA			
120. Government Agency	KLOSTER PULLACH (about 9 miles S. of MUNICH)	O.S.S. R&A	1944
121. Hiding Place	Building on race-course at TAFELFING near MUNICH	O.S.S. R&A	1944
122. Hiding Place	Park of FORSTENRIED 6 miles S.W. of MUNICH (? part of No. 125)	O.S.S. R&A	1944
123. Hiding Place	Village of SOLLN (6 miles S. of MUNICH)	O.S.S. R&A	1944
124. Hiding Place	Neighborhood of PUCHHEIM (about 8 miles W. of MUNICH)	O.S.S. R&A	1944
125. Hiding Place for particularly important object. Many workmen there Jan.-July 1944 every day.	KRAILLING-STOCKDORF	O.S.S. R&A	July 1944
	(Confirmed by No. 67a in Report No. 2)		
126. Hiding Place	SCHLEISSHEIM (11½ miles N. of MUNICH)	O.S.S. R&A	1944
	(Note: There are three palaces in this village of which the Neues Schloss is the largest.)		
127. Hiding Place	SS Barracks at FREIMANN (about 5 miles N. of MUNICH)	O.S.S. R&A	1944

- 1 -

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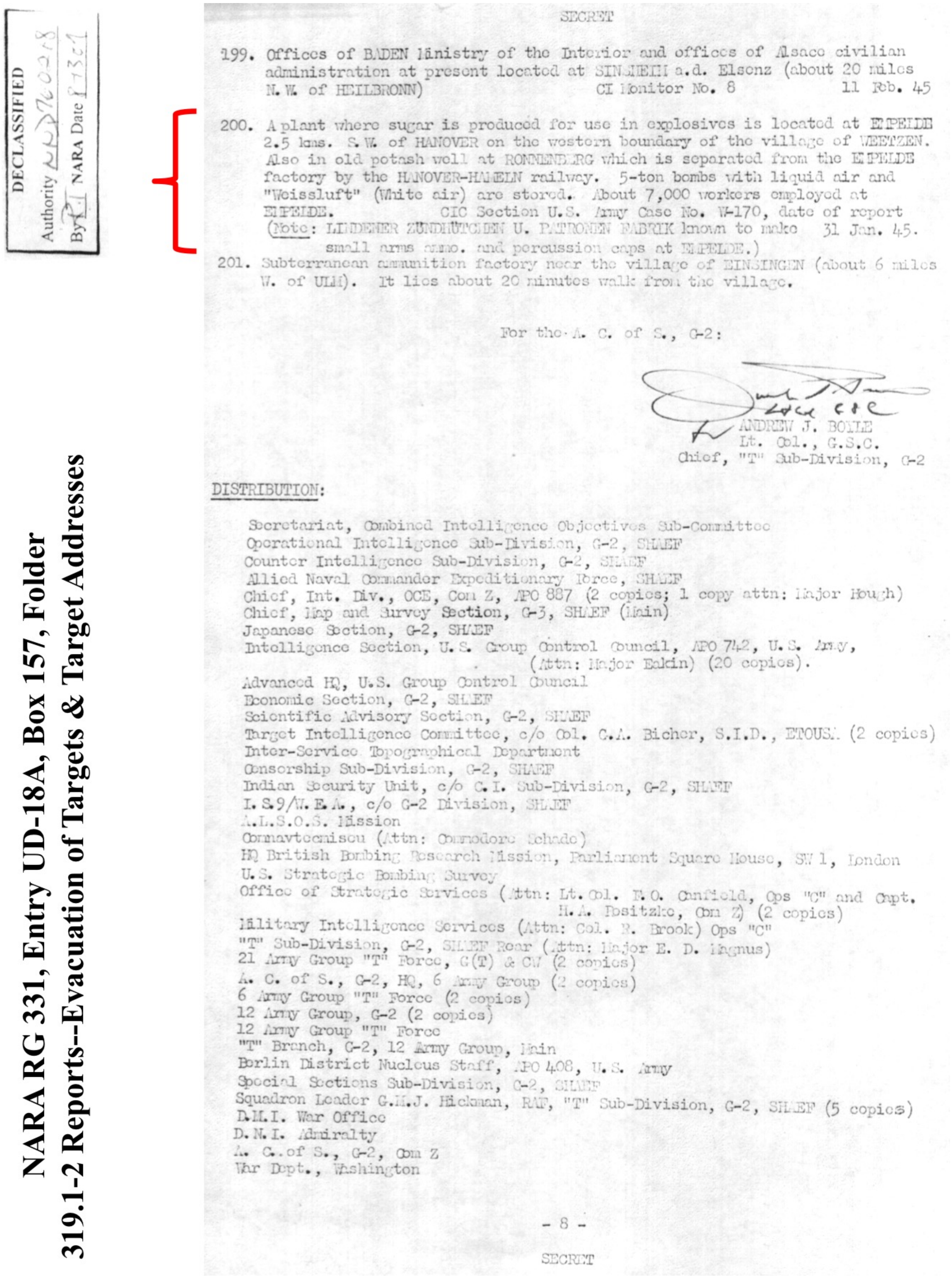
SECRET

Figure 3.89: By the end of the war, at least 7000 workers had mass-produced 5-ton fuel-air explosive bombs and stockpiled them [NARA RG 331, Entry UD-18A, Box 157, Folder 319.1-2 Reports—Evacuation of Targets & Target Addresses].



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Authority NND760218
By RI NARA Date 8-13-01

NARA RG 331, Entry UD-18A, Box 157, Folder 319.1-2 Reports--Evacuation of Targets & Target Addresses

SECRET

199. Offices of BADEN Ministry of the Interior and offices of Alsace civilian administration at present located at SINSHEIM a.d. Elsenz (about 20 miles N. W. of HEILBRONN) CI Monitor No. 8 11 Feb. 45

200. A plant where sugar is produced for use in explosives is located at EMPELDE 2.5 kms. S. W. of HANOVER on the western boundary of the village of WEETZEN. Also in old potash well at RONNENBERG which is separated from the EMPELDE factory by the HANOVER-HAMELN railway. 5-ton bombs with liquid air and "Weissluft" (White air) are stored. About 7,000 workers employed at EMPELDE. CIC Section U.S. Army Case No. W-170, date of report 31 Jan. 45.
(Note: LINDENER ZÜNDHÜTCHEN U. PATRONEN FABRIK known to make small arms ammo. and percussion caps at EMPELDE.)

201. Subterranean ammunition factory near the village of EINSINGEN (about 6 miles W. of ULM). It lies about 20 minutes walk from the village.

For the A. C. of S., G-2:

ANDREW J. BOYLE
Lt. Col., G.S.C.
Chief, "T" Sub-Division, G-2

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A. C. of S., G-2, Com Z
War Dept., Washington

- 8 -

SECRET

Figure 3.90: By the end of the war, at least 7000 workers had mass-produced 5-ton fuel-air explosive bombs and stockpiled them [NARA RG 331, Entry UD-18A, Box 157, Folder 319.1-2 Reports—Evacuation of Targets & Target Addresses].

3.4.3 Shaped Explosive Charges

Similarly, German-speaking scientists led the development of shaped (or hollow) explosive charges, which concentrate the force of an explosion in a particular direction—for example in the forward direction to penetrate tank armor upon impact (Fig. 3.91), or radially inward in an implosion bomb to compress nuclear fuel (Sections D.8–D.9).[9]

Franz von Baader (German states, 1765–1841, Fig. 3.92) designed and utilized shaped charges for mining.

Gustav Bloem (German?, 18??–19??, Fig. 3.92) invented metal-lined shaped charges as detonator caps.

Carl Julius Cranz (German, 1858–1945, Fig. 3.92) worked on many aspects of ballistics and supported Franz Rudolf Thomanek and others in developing militarily useful shaped charges.

Rolf Engel (German, 1912–1993, Fig. 3.92) was an expert on rockets, explosives, shaped charges, and implosion designs. He worked on secretive weapons projects for the German military during World War II and for the French military after the war.

Ernst Richard Escales (German, 1863–1924, Fig. 3.92) published handbooks and journals about a wide variety of explosives and explosive techniques, including shaped charges.

Max von Förster (German, 1845–1905, Fig. 3.92) designed, tested, and published descriptions of shaped explosive charges.

Hellmuth von Huttern (German?, 19??–19??, Fig. 3.93) worked with Franz Rudolf Thomanek in developing the first prototypes for military shaped charge weapons.

Heinrich Langweiler (German?, 19??–19??, Fig. 3.93) led the team that developed the Faustpatrone and Panzerfaust anti-tank weapons [BIOS 99; BIOS 100]. See also p. 2131.

Hans Mohaupt (Swiss, 1915–2001, Fig. 3.93) brought the concept of shaped explosive charges to the United States, leading to the design of the bazooka.

Egon Neumann (German, 18??–19??, Fig. 3.93) developed sophisticated shaped charge explosives in 1910 and helped to publicize the general concept [George Brown 1998, p. 166; Walters and Zukas 1989, pp. 12–13].

Hubert Schardin (German, 1902–1965, Fig. 3.93) worked for the Luftwaffe as an expert on the design and experimental measurement of shaped explosive charges and implosion bombs [Krehl 2009, pp. 1160–1162; Nagel 2012a, p. 149 ff.]. After the war, he worked for the French military.

Erich Schumann (German, 1898–1985, Fig. 3.93) ran a Heereswaffenamt (Army Ordnance Office) program to design and conduct experimental measurements of shaped explosive charges and implosion bombs [Karlsch 2005; Nagel 2012a].

---

[9] George Brown 1998; DOD 1953; DOW 1945a; Field 2017; Karlsch 2005; Kennedy 1990; Krehl 2009; Mrazek 1970; Nagel 2012a; Simon 1947a; Walters and Zukas 1989; BIOS 99; BIOS 100.

Alfred Stettbacher (Swiss, 1888–1961, Fig. 3.94) designed and tested shaped charges.

Franz Rudolf Thomanek (Austrian, 1913–1990, Fig. 3.94) began designing and developing hollow-charge antitank weapons in 1932 and worked on them until 1945.

Walter Trinks (German, 1910–1995, Fig. 3.94) worked closely with Erich Schumann as part of the Heereswaffenamt (Army Ordnance Office) program to design and conduct experimental measurements of shaped explosive charges and implosion bombs [Karlsch 2005; Nagel 2012a].

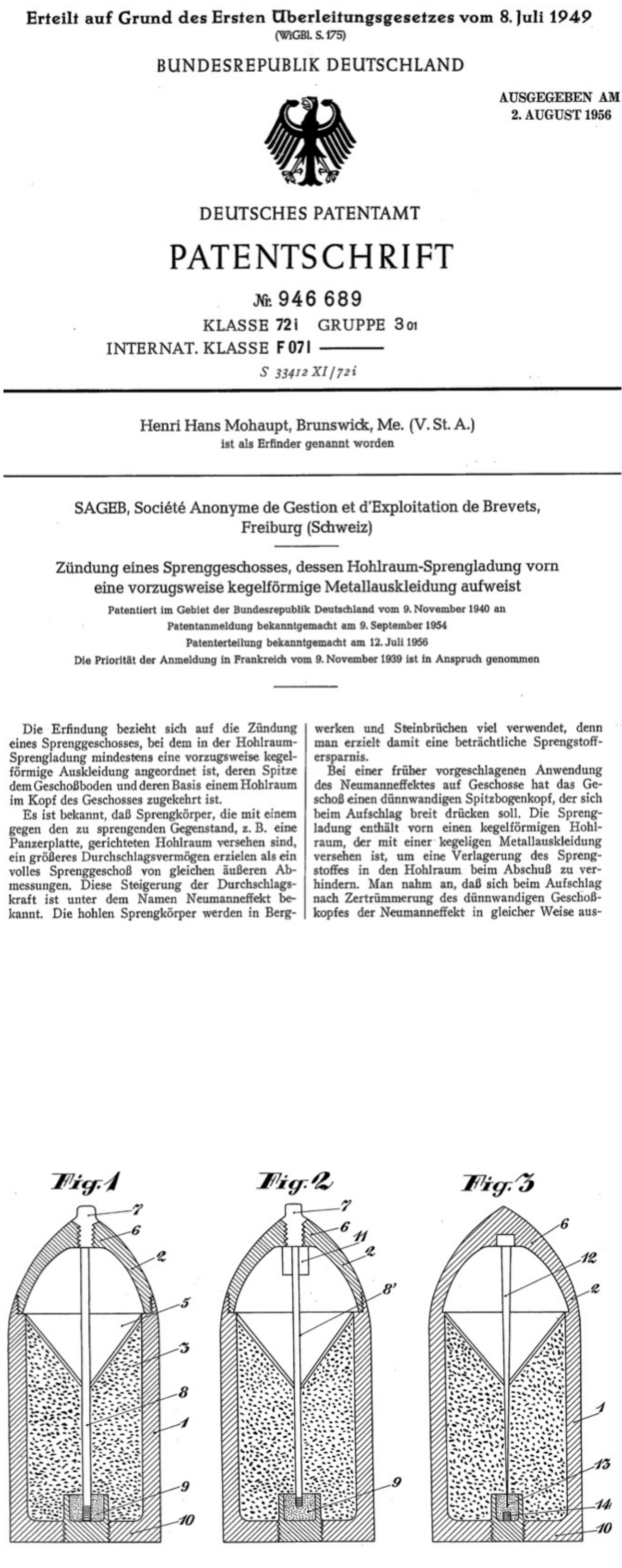
The chemist Simon Field [Field 2017, pp. 131–132, 136] emphasized the contributions of many of the above scientists to the development of shaped explosive charges:

> In 1792 the twenty-six-year-old German Catholic philospher, theologist, and mining engineer Franz Xaver von Baader came up with a way of saving gunpowder in mines. The idea was to make a conical of mushroom-shaped hollow in the front of the gunpowder charge. His reasoning was not recorded, and it is not clear what effect it had, if any, but it was used in Norway and later in the mines of the Harz Mountains in Germany[...]
>
> Things were a little different ninety-one years later, in 1883. The chief company engineer of the nitrocellulose factor of Wolff and Co. in Walsrode, Germany, was a man named Max von Förster. Von Förster tested a hypothesis "to give the detonating gases of guncotton a certain direction aiming toward the target" through a series of experiments with hollowed-out charges. "Estimated on the whole, it appears that the effect of the hollow cartridge of the same size and less weight is superior to the full one of more weight." [...]
>
> In 1883 Gustav Bloem patented a metal detonator cap with a hollow in it, to get a "concentration of the effect of the explosion in an axial direction." This was the first lined cavity shaped charge.
>
> [...] Dr. Franz Rudolph Thomanek, on February 4, 1938, discovered the importance of the metal lining. [...] Between then and 1943, Thomanek experimented with different hollow shapes and different liner thicknesses, including tapering the thickness.
>
> In Zurich in 1937 a Swiss engineer, Dr. Henry Hans Mohaupt, also came up with a metal-lined hollow cavity shaped charge, and tried to get the British government to pay him for the expense of developing it. [...]
>
> Mohaupt brought his idea to the United States on October 18, 1940. First developed as a rifle grenade, the idea morphed into a rocket-propelled munition with a shaped charge armor-piercing warhead that became known as the "bazooka" [...]

A small group of German soldiers successfully used two innovations, troop gliders (p. 1689) and shaped explosive charges, to land at and penetrate through the thick reinforced concrete walls of Fort Eben-Emael in Belgium in May 1940 [Mrazek 1970].

For more information on the use of shaped charges and implosion for German nuclear weapons during World War II, see Section D.8.

Shaped explosive charges



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
2. AUGUST 1956

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 946 689

KLASSE **72i** GRUPPE 3 01
INTERNAT. KLASSE **F 07 l** ———
S 33412 XI/72i

Henri Hans Mohaupt, Brunswick, Me. (V. St. A.)
ist als Erfinder genannt worden

SAGEB, Société Anonyme de Gestion et d'Exploitation de Brevets,
Freiburg (Schweiz)

Zündung eines Sprenggeschosses, dessen Hohlraum-Sprengladung vorn eine vorzugsweise kegelförmige Metallauskleidung aufweist

Patentiert im Gebiet der Bundesrepublik Deutschland vom 9. November 1940 an
Patentanmeldung bekanntgemacht am 9. September 1954
Patenterteilung bekanntgemacht am 12. Juli 1956
Die Priorität der Anmeldung in Frankreich vom 9. November 1939 ist in Anspruch genommen

Die Erfindung bezieht sich auf die Zündung eines Sprenggeschosses, bei dem in der Hohlraum-Sprengladung mindestens eine vorzugsweise kegelförmige Auskleidung angeordnet ist, deren Spitze dem Geschoßboden und deren Basis einem Hohlraum im Kopf des Geschosses zugekehrt ist.

Es ist bekannt, daß Sprengkörper, die mit einem gegen den zu sprengenden Gegenstand, z. B. eine Panzerplatte, gerichteten Hohlraum versehen sind, ein größeres Durchschlagsvermögen erzielen als ein volles Sprenggeschoß von gleichen äußeren Abmessungen. Diese Steigerung der Durchschlagskraft ist unter dem Namen Neumanneffekt bekannt. Die hohlen Sprengkörper werden in Bergwerken und Steinbrüchen viel verwendet, denn man erzielt damit eine beträchtliche Sprengstoffersparnis.

Bei einer früher vorgeschlagenen Anwendung des Neumanneffektes auf Geschosse hat das Geschoß einen dünnwandigen Spitzbogenkopf, der sich beim Aufschlag breit drücken soll. Die Sprengladung enthält vorn einen kegelförmigen Hohlraum, der mit einer kegeligen Metallauskleidung versehen ist, um eine Verlagerung des Sprengstoffes in den Hohlraum beim Abschuß zu verhindern. Man nahm an, daß sich beim Aufschlag nach Zertrümmerung des dünnwandigen Geschoßkopfes der Neumanneffekt in gleicher Weise aus-

Fig. 1
7
6
2
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3
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9
10
Fig. 2
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11
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8'
9
Fig. 3
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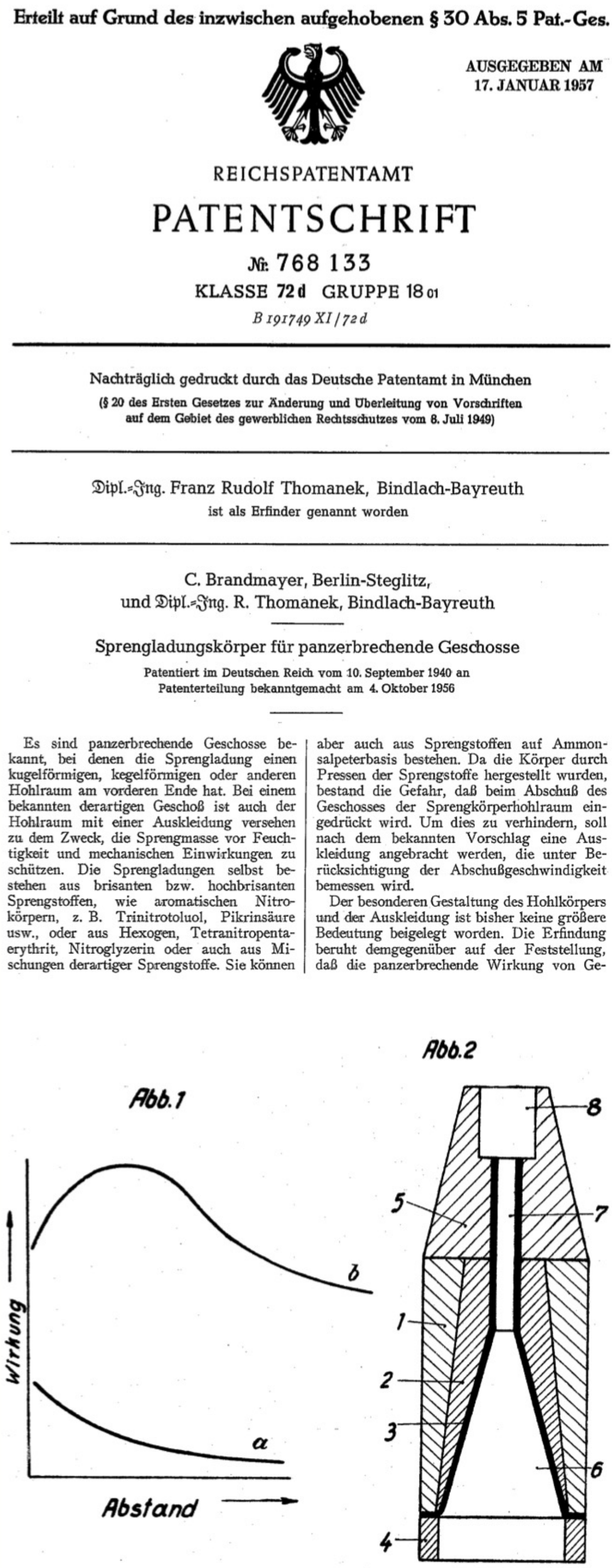
13
14
10



Erteilt auf Grund des inzwischen aufgehobenen § 30 Abs. 5 Pat.-Ges.

AUSGEGEBEN AM
17. JANUAR 1957

REICHSPATENTAMT

PATENTSCHRIFT

№ 768 133

KLASSE **72d** GRUPPE 18 01
B 191749 XI/72d

Nachträglich gedruckt durch das Deutsche Patentamt in München
(§ 20 des Ersten Gesetzes zur Änderung und Überleitung von Vorschriften auf dem Gebiet des gewerblichen Rechtsschutzes vom 8. Juli 1949)

Dipl.-Ing. Franz Rudolf Thomanek, Bindlach-Bayreuth
ist als Erfinder genannt worden

C. Brandmayer, Berlin-Steglitz,
und Dipl.-Ing. R. Thomanek, Bindlach-Bayreuth

Sprengladungskörper für panzerbrechende Geschosse

Patentiert im Deutschen Reich vom 10. September 1940 an
Patenterteilung bekanntgemacht am 4. Oktober 1956

Es sind panzerbrechende Geschosse bekannt, bei denen die Sprengladung einen kugelförmigen, kegelförmigen oder anderen Hohlraum am vorderen Ende hat. Bei einem bekannten derartigen Geschoß ist auch der Hohlraum mit einer Auskleidung versehen zu dem Zweck, die Sprengmasse vor Feuchtigkeit und mechanischen Einwirkungen zu schützen. Die Sprengladungen selbst bestehen aus brisanten bzw. hochbrisanten Sprengstoffen, wie aromatischen Nitrokörpern, z. B. Trinitrotoluol, Pikrinsäure usw., oder aus Hexogen, Tetranitropentaerythrit, Nitroglyzerin oder auch aus Mischungen derartiger Sprengstoffe. Sie können aber auch aus Sprengstoffen auf Ammonsalpeterbasis bestehen. Da die Körper durch Pressen der Sprengstoffe hergestellt wurden, bestand die Gefahr, daß beim Abschuß des Geschosses der Sprengkörperhohlraum eingedrückt wird. Um dies zu verhindern, soll nach dem bekannten Vorschlag eine Auskleidung angebracht werden, die unter Berücksichtigung der Abschußgeschwindigkeit bemessen wird.

Der besonderen Gestaltung des Hohlkörpers und der Auskleidung ist bisher keine größere Bedeutung beigelegt worden. Die Erfindung beruht demgegenüber auf der Feststellung, daß die panzerbrechende Wirkung von Ge-

Figure 3.91: German-speaking scientists led the development of shaped explosive charges, as illustrated by these examples of patents from Hans Mohaupt and Franz Rudolf Thomanek.

Shaped explosive charges

Franz von Baader (1765–1841)

Gustav Bloem (18??–19??)

Carl Julius Cranz (1858–1945)

Rolf Engel (1912–1993)

Ernst Richard Escales (1863–1924)

Max von Förster (1845–1905)

Figure 3.92: German-speaking scientists who were responsible for the development of shaped explosive charges included Franz von Baader, Gustav Bloem, Carl Julius Cranz, Rolf Engel, Ernst Richard Escales, and Max von Förster.

Shaped explosive charges

Hellmuth von Huttern
(19??–19??)

Heinrich Langweiler
(19??–19??)

Hans Mohaupt
(1915–2001)

Egon Neumann
(18??–19??)

Hubert Schardin
(1902–1965)

Erich Schumann
(1898–1985)

Figure 3.93: Other German-speaking scientists who were responsible for the development of shaped explosive charges included Hellmuth von Huttern, Heinrich Langweiler, Hans Mohaupt, Egon Neumann, Hubert Schardin, and Erich Schumann.

Shaped explosive charges

Alfred Stettbacher (1888–1961)

Franz Rudolf Thomanek (1913–1990)

Walter Trinks (1910–1995)

Figure 3.94: Other German-speaking scientists who were responsible for the development of shaped explosive charges included Alfred Stettbacher, Franz Rudolf Thomanek, and Walter Trinks.

3.4.4 Radio Control and Electric Timers for Explosives

In addition to developing explosives, German-speaking creators invented precise electrical means of detonating the explosives, including radio control and electric timers.

Ferdinand Schneider (German, 1866–1955) invented radio-controlled mines in 1904 and patented them in many countries, directly inspiring subsequent copies and implementations. See Fig. 3.95. Schneider also created many other electrical inventions, including radio systems, radio-synchronized clocks, depth charges, audiovisual equipment, and wind turbines.

As shown in Fig. 3.96, Herbert Rühlemann (German, 1902–19??) invented time-delay electric bomb fuses in the 1920s. Ernst Marquard (German, 1897–1980) helped to further develop them during World War II.

Bombs equipped with such time-delay fuses can be set to detonate hours, days, or even longer after they are dropped. Because people in the targeted region do not know what times the fuses are programmed for, they do not know if it is safe to begin clearing and repairing the damage from the attack. Thus time-delay bombs can cause much more chaos and institutional paralysis than bombs that detonate immediately upon impact, especially when bombs with many different time settings are dropped at once.

Both Rühlemann and Marquard aided ordnance development in the United States after the war.

Ferdinand Schneider (1866–1955)

Radio-controlled mines (1904) + many other electrical inventions

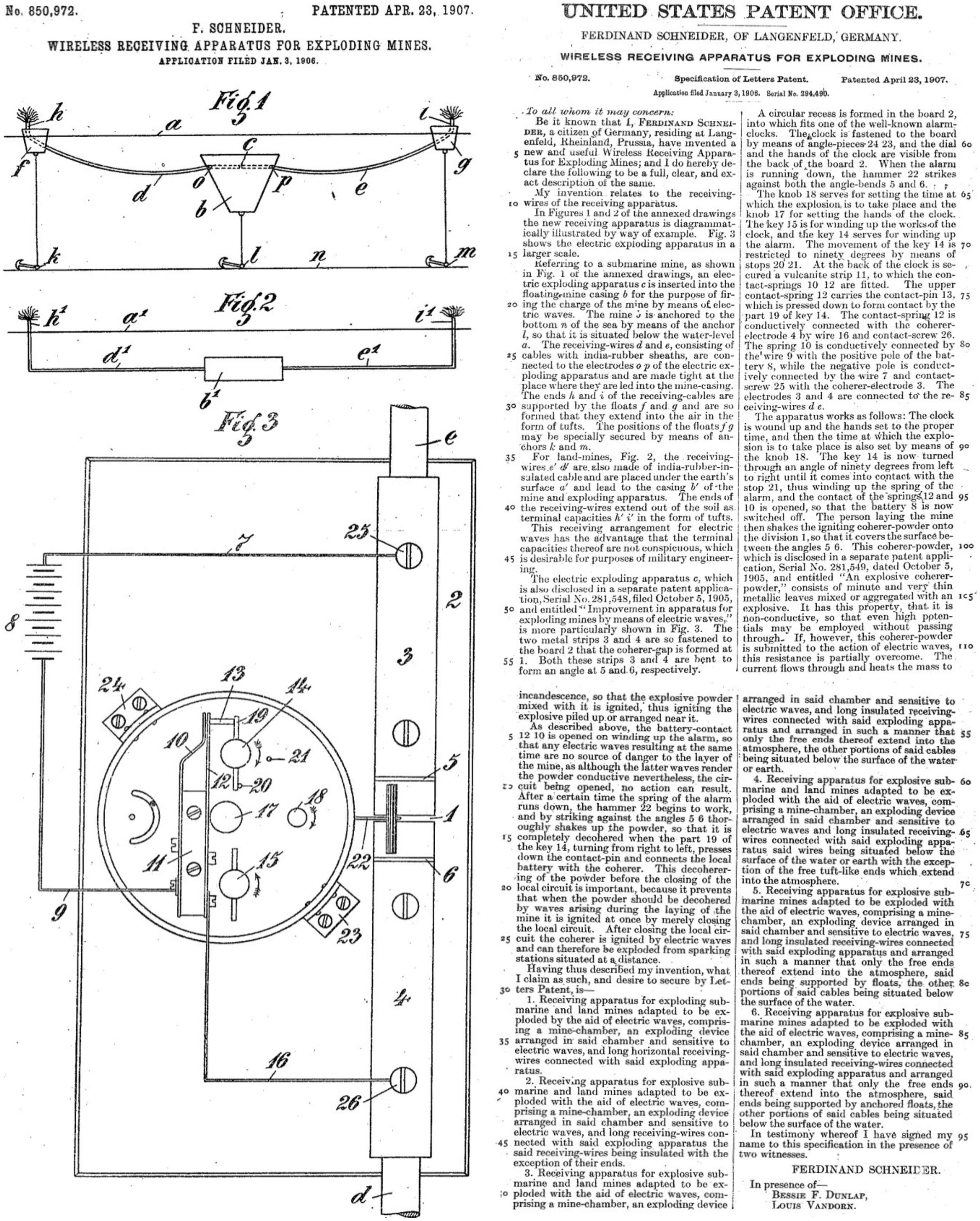


Fig.1
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Fig.2
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j
i^1
d^1
e^1
b^1
Fig.3
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20
5
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26
d

No. 850,972. PATENTED APR. 23, 1907.

F. SCHNEIDER.

WIRELESS RECEIVING APPARATUS FOR EXPLODING MINES.

APPLICATION FILED JAN. 3, 1906.

UNITED STATES PATENT OFFICE.

FERDINAND SCHNEIDER, OF LANGENFELD, GERMANY.

WIRELESS RECEIVING APPARATUS FOR EXPLODING MINES.

No. 850,972. Specification of Letters Patent. Patented April 23, 1907.

Application filed January 3, 1906. Serial No. 294,490.

To all whom it may concern:

Be it known that I, FERDINAND SCHNEIDER, a citizen of Germany, residing at Langenfeld, Rheinland, Prussia, have invented a new and useful Wireless Receiving Apparatus for Exploding Mines; and I do hereby declare the following to be a full, clear, and exact description of the same.

My invention relates to the receiving-wires of the receiving apparatus.

In Figures 1 and 2 of the annexed drawings the new receiving apparatus is diagrammatically illustrated by way of example. Fig. 3 shows the electric exploding apparatus in a larger scale.

Referring to a submarine mine, as shown in Fig. 1 of the annexed drawings, an electric exploding apparatus *c* is inserted into the floating-mine casing *b* for the purpose of firing the charge of the mine by means of electric waves. The mine *j* is anchored to the bottom *n* of the sea by means of the anchor *l*, so that it is situated below the water-level *a*. The receiving-wires *d* and *e*, consisting of cables with india-rubber sheaths, are connected to the electrodes *o p* of the electric exploding apparatus and are made tight at the place where they are led into the mine-casing. The ends *h* and *i* of the receiving-cables are supported by the floats *f* and *g* and are so formed that they extend into the air in the form of tufts. The positions of the floats *f g* may be specially secured by means of anchors *k* and *m*.

For land-mines, Fig. 2, the receiving-wires *e′ d′* are also made of india-rubber-insulated cable and are placed under the earth's surface *a′* and lead to the casing *b′* of the mine and exploding apparatus. The ends of the receiving-wires extend out of the soil as terminal capacities *h′ i′* in the form of tufts.

This receiving arrangement for electric waves has the advantage that the terminal capacities thereof are not conspicuous, which is desirable for purposes of military engineering.

The electric exploding apparatus *c*, which is also disclosed in a separate patent application, Serial No. 281,548, filed October 5, 1905, and entitled "Improvement in apparatus for exploding mines by means of electric waves," is more particularly shown in Fig. 3. The two metal strips 3 and 4 are so fastened to the board 2 that the coherer-gap is formed at 1. Both these strips 3 and 4 are bent to form an angle at 5 and 6, respectively.

A circular recess is formed in the board 2, into which fits one of the well-known alarm-clocks. The clock is fastened to the board by means of angle-pieces 24 23, and the dial and the hands of the clock are visible from the back of the board 2. When the alarm is running down, the hammer 22 strikes against both the angle-bends 5 and 6.

The knob 18 serves for setting the time at which the explosion is to take place and the knob 17 for setting the hands of the clock. The key 15 is for winding up the works of the clock, and the key 14 serves for winding up the alarm. The movement of the key 14 is restricted to ninety degrees by means of stops 20 21. At the back of the clock is secured a vulcanite strip 11, to which the contact-springs 10 12 are fitted. The upper contact-spring 12 carries the contact-pin 13, which is pressed down to form contact by the part 19 of key 14. The contact-spring 12 is conductively connected with the coherer-electrode 4 by wire 16 and contact-screw 26. The spring 10 is conductively connected by the wire 9 with the positive pole of the battery 8, while the negative pole is conductively connected by the wire 7 and contact-screw 25 with the coherer-electrode 3. The electrodes 3 and 4 are connected to the receiving-wires *d e*.

The apparatus works as follows: The clock is wound up and the hands set to the proper time, and then the time at which the explosion is to take place is also set by means of the knob 18. The key 14 is now turned through an angle of ninety degrees from left to right until it comes into contact with the stop 21, thus winding up the spring of the alarm, and the contact of the springs 12 and 10 is opened, so that the battery 8 is now switched off. The person laying the mine then shakes the igniting coherer-powder onto the division 1, so that it covers the surface between the angles 5 6. This coherer-powder, which is disclosed in a separate patent application, Serial No. 281,549, dated October 5, 1905, and entitled "An explosive coherer-powder," consists of minute and very thin metallic leaves mixed or aggregated with an explosive. It has this property, that it is non-conductive, so that even high potentials may be employed without passing through. If, however, this coherer-powder is submitted to the action of electric waves, this resistance is partially overcome. The current flows through and heats the mass to incandescence, so that the explosive powder mixed with it is ignited, thus igniting the explosive piled up or arranged near it.

As described above, the battery-contact 12 10 is opened on winding up the alarm, so that any electric waves resulting at the same time are no source of danger to the layer of the mine, as although the latter waves render the powder conductive nevertheless, the circuit being opened, no action can result. After a certain time the spring of the alarm runs down, the hammer 22 begins to work, and by striking against the angles 5 6 thoroughly shakes up the powder, so that it is completely decohered when the part 19 of the key 14, turning from right to left, presses down the contact-pin and connects the local battery with the coherer. This decohering of the powder before the closing of the local circuit is important, because it prevents that when the powder should be decohered by waves arising during the laying of the mine it is ignited at once by merely closing the local circuit. After closing the local circuit the coherer is ignited by electric waves and can therefore be exploded from sparking stations situated at a distance.

Having thus described my invention, what I claim as such, and desire to secure by Letters Patent, is—

1. Receiving apparatus for exploding submarine and land mines adapted to be exploded by the aid of electric waves, comprising a mine-chamber, an exploding device arranged in said chamber and sensitive to electric waves, and long horizontal receiving-wires connected with said exploding apparatus.

2. Receiving apparatus for explosive submarine and land mines adapted to be exploded with the aid of electric waves, comprising a mine-chamber, an exploding device arranged in said chamber and sensitive to electric waves, and long receiving-wires connected with said exploding apparatus the said receiving-wires being insulated with the exception of their ends.

3. Receiving apparatus for explosive submarine and land mines adapted to be exploded with the aid of electric waves, comprising a mine-chamber, an exploding device arranged in said chamber and sensitive to electric waves, and long insulated receiving-wires connected with said exploding apparatus and arranged in such a manner that only the free ends thereof extend into the atmosphere, the other portions of said cables being situated below the surface of the water or earth.

4. Receiving apparatus for explosive submarine and land mines adapted to be exploded with the aid of electric waves, comprising a mine-chamber, an exploding device arranged in said chamber and sensitive to electric waves and long insulated receiving-wires connected with said exploding apparatus said wires being situated below the surface of the water or earth with the exception of the free tuft-like ends which extend into the atmosphere.

5. Receiving apparatus for explosive submarine mines adapted to be exploded with the aid of electric waves, comprising a mine-chamber, an exploding device arranged in said chamber and sensitive to electric waves, and long insulated receiving-wires connected with said exploding apparatus and arranged in such a manner that only the free ends thereof extend into the atmosphere, said ends being supported by floats, the other portions of said cables being situated below the surface of the water.

6. Receiving apparatus for explosive submarine mines adapted to be exploded with the aid of electric waves, comprising a mine-chamber, an exploding device arranged in said chamber and sensitive to electric waves, and long insulated receiving-wires connected with said exploding apparatus and arranged in such a manner that only the free ends thereof extend into the atmosphere, said ends being supported by anchored floats, the other portions of said cables being situated below the surface of the water.

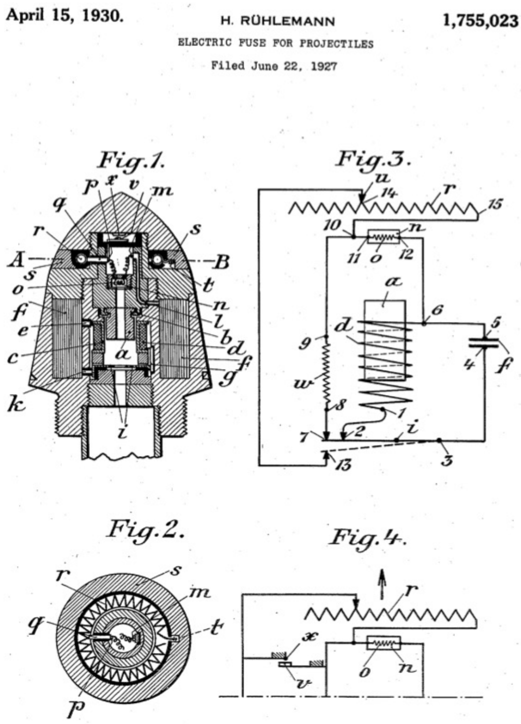
In testimony whereof I have signed my name to this specification in the presence of two witnesses.

FERDINAND SCHNEIDER.

In presence of—
BESSIE F. DUNLAP,
LOUIS VANDORN.

Figure 3.95: Ferdinand Schneider invented radio-controlled mines in 1904; he also created many other electrical inventions.

Time-delay electric bomb fuses



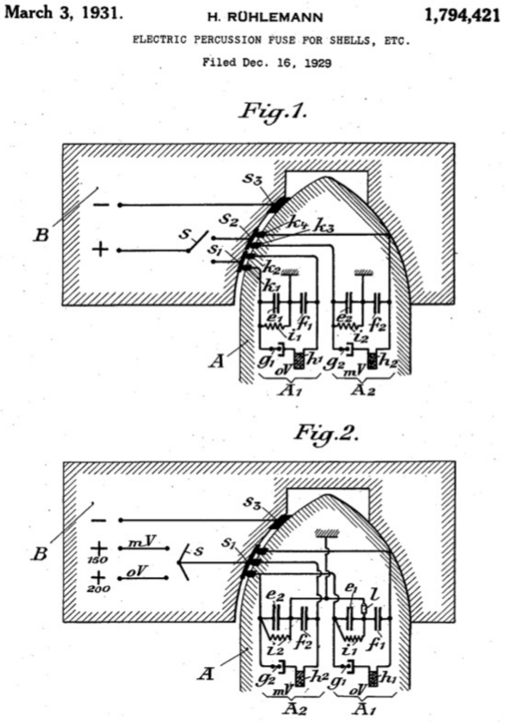
April 15, 1930. H. RÜHLEMANN 1,755,023

ELECTRIC FUSE FOR PROJECTILES

Filed June 22, 1927

Fig. 1.
Fig. 3.
Fig. 2.
Fig. 4.
p x v m q r s A B o t n f l e b c d a g k i
n 14 r 15 10 11 o 12 a 6 5 d 9 4 f w 8 2 1 7 i 3 13
r s m q t p
r x v o n

Herbert Rühlemann (1902–19??)

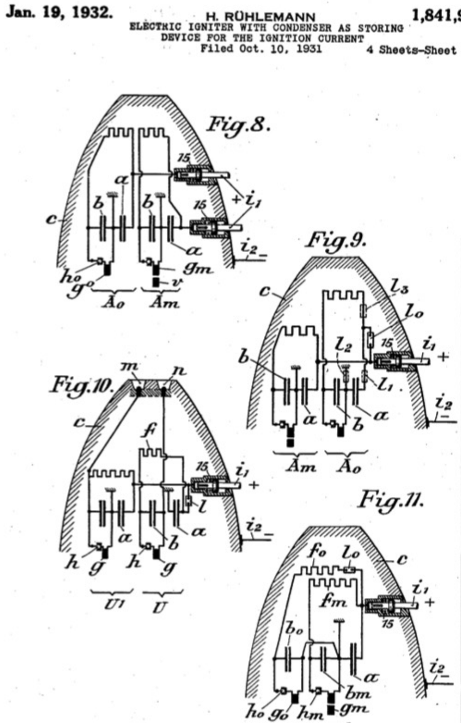


March 3, 1931. H. RÜHLEMANN 1,794,421

ELECTRIC PERCUSSION FUSE FOR SHELLS, ETC.

Filed Dec. 16, 1929

Fig. 1.
Fig. 2.
B − + s s3 s2 s1 k4 k3 k2 k1 e1 f1 e2 f2 i1 i2 g1 oV h1 g2 mV h2 A A1 A2
B − + 150 + 200 mV oV s s3 s1 e2 e1 l f2 f1 i2 i1 g2 h2 g1 h1 mV oV A A2 A1



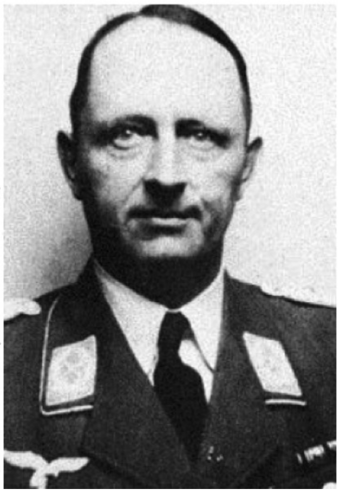
Jan. 19, 1932. H. RÜHLEMANN 1,841,983

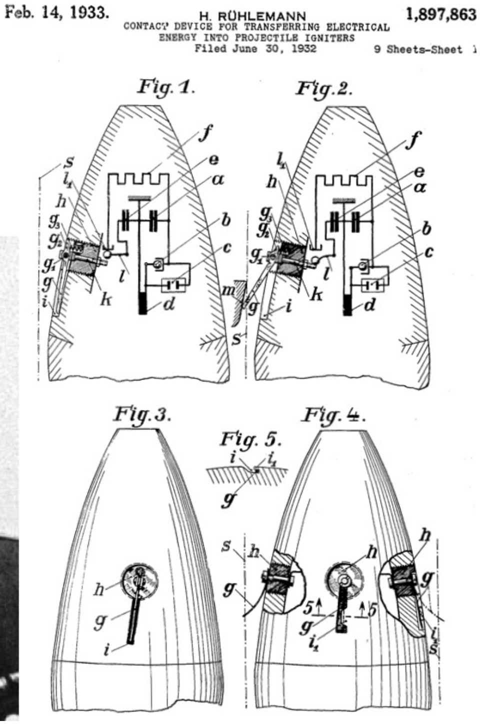
ELECTRIC IGNITER WITH CONDENSER AS STORING DEVICE FOR THE IGNITION CURRENT

Filed Oct. 10, 1931 4 Sheets-Sheet 3

Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
c b a 15 i1 + i2 − ho go gm v Ao Am
c l3 lo b l2 15 i1 + l1 a b i2 Am Ao
m n c f 15 i1 + l a b h g h g i2 U1 U
fo lo c i1 + fm 15 bo a i2 ho go hm bm gm

Ernst Marquard (1897–1980)





Feb. 14, 1933. H. RÜHLEMANN 1,897,863

CONTACT DEVICE FOR TRANSFERRING ELECTRICAL ENERGY INTO PROJECTILE IGNITERS

Filed June 30, 1932 9 Sheets-Sheet 1

Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
s l1 h g3 g2 g1 g i k l f e a b c d m s
l1 h g3 g2 g1 g i k l f e a b c d
h g i
i l1 g
s h g 5 h 5 g i1 h g l s

Figure 3.96: Herbert Rühlemann invented time-delay electric bomb fuses in the 1920s, Ernst Marquard helped to further develop them during World War II, and both aided ordnance development in the United States after the war.

3.5 Chemical Warfare Agents and Pesticides

German-speaking scientists dominated the development of chemical warfare agents and pesticides, including:[10]

3.5.1. First-generation chemical weapons

3.5.2. Insecticides

3.5.3. G-series nerve agents

3.5.4. V-series nerve agents

3.5.5. Other chemical weapons

Figure 3.97 illustrates the chemical structures of some major chemical warfare agents and pesticides.

Figures 3.98–3.110 show some of the German-speaking scientists who were involved in developing and testing chemical warfare agents and pesticides.

3.5.1 First-Generation Chemical Weapons

Several compounds became famous or infamous after their first use in World War I (Fig. 3.97). They were developed by German-speaking scientists, but then later copied and used by other countries.

The cyanide-containing Prussian blue pigment was developed in the German-speaking world around 1700. Hydrogen cyanide gas derived from the Prussian blue pigment was called Prussic acid. It was deployed to some extent on WWI battlefields, but was also used as an insecticide. In World War II, it was called Zyklon B and used in the gas chambers of the Holocaust, yet even long after the wars, it was still used for government executions in the United States.

Chlorine gas, two chlorine atoms bonded together, was used on World War I battlefields, and is caustic to lungs, eyes, and other sensitive tissues with which it comes into contact.

In phosgene gas, the two chlorine atoms were coupled to a carbon atom and an oxygen atom, making the molecule more readily absorbed by tissues and hence even more toxic.

In mustard agent, the two chlorine atoms were linked to a hydrocarbon chain. This hydrocarbon chain gave mustard agent an oily feel, made it persist on surfaces for long periods of time instead of rapidly dispersing like a gas, and allowed it to penetrate through skin so that it could attack even people wearing gas masks.

---

[10] Friedrich et al. 2017; Gellermann 1986; Gröhler 1989; Hager 2008; Harris and Paxman 2002; Hein Hofmann 2008; Kaszeta 2020; Pfingsten 2003; Stoltzenberg 1994, 2005; Szöllösi-Janze 2015; Tucker 2006; Zecha 2000; BIOS 110; BIOS 542; BIOS 714; BIOS 760; BIOS 761; BIOS 782; CIOS ER 33; CIOS II-1; CIOS IX-4; CIOS XI-12; CIOS XXI-4; CIOS XXIV-19; CIOS XXVI-49; CIOS XXVII-34; CIOS XXVIII-59; CIOS XXX-19; CIOS XXXI-86; CIOS XXXII-13.

The U.S. chemical weapons expert Jonathan Tucker described how Fritz Haber (German, 1868–1934) and other German scientists developed the first generation of chemical warfare agents [Tucker 2006, pp. 10–12, 18–19]:

> Because Germany possessed the world's most advanced chemical industry, it enjoyed an inherent advantage in this type of warfare. [...]
>
> The individual who became responsible for developing chemical weapons for the German War Office was Professor Fritz Haber, a brilliant young chemist and ardent Prussian nationalist who directed the Kaiser Wilhelm Institute for Physical Chemistry in Berlin. [...]
>
> In late 1914, Haber had the idea of loading artillery shells with chlorine, which the German chemical industry produced in large quantities for the production of dyestuffs. When a shortage of artillery shells ruled out this method of delivery, he proposed instead that chlorine be released directly from pressurized gas cylinders, allowing the wind to carry the poisonous cloud over the enemy's trenches. [...]
>
> In mid-January [1915], Haber ordered the chemist Otto Hahn and several other colleagues to help prepare the chlorine attack. [...] The German chemists helped to organize a special unit for gas warfare called Pioneer Regiment 36. [...]
>
> In December 1915, the Germans fired shells containing phosgene, a gas used in the dye industry that was eighteen times more toxic than chlorine. [...]
>
> In an effort to circumvent the Allied use of protective masks and respirators, Haber and his colleagues developed a new chemical warfare agent that attacked the skin as well as the lungs. Called "mustard" because of its sharp, garlicky odor, it was an oily liquid that was readily absorbed through the skin, giving rise after several hours to severe chemical burns and blisters. In July 1917, once again at Ypres, the Germans began firing mustard-filled shells containing an explosive burster charge that shattered the liquid agent into a fine mist that was colorless or light yellow. Like phosgene, the effects of mustard were insidious: symptoms developed only after a delay of three to twenty-four hours (with a mean of ten to twelve hours), so that troops often did not realize that they had been exposed to the agent until it was too late.
>
> [...] Mustard soon became the most dreaded of chemical weapons and was dubbed "the king of the war gases." Not only was it highly persistent, clinging to clothing and equipment and contaminating the battlefield for days or even weeks, but its ability to penetrate the skin forced troops to augment their respirators with cumbersome oilskin capes, goggles, and leather or rubber garments. This protective gear could be worn only for short periods, however, because it caused heat stress and seriously impaired fighting efficiency.

Fritz Haber won the 1918 Nobel Prize in Chemistry for unrelated work to chemically synthesize ammonia on an industrial scale (p. 447).

During World War I, Fritz Wilhelm Lommel (German, 1875–1968) and Georg Wilhelm Steinkopf (German, 1879–1949) developed a chemical method for the large-scale synthesis of mustard agent. Ever since then, mustard agent has commonly been known in the German-speaking world as LOST, combining the first two letters of their last names.

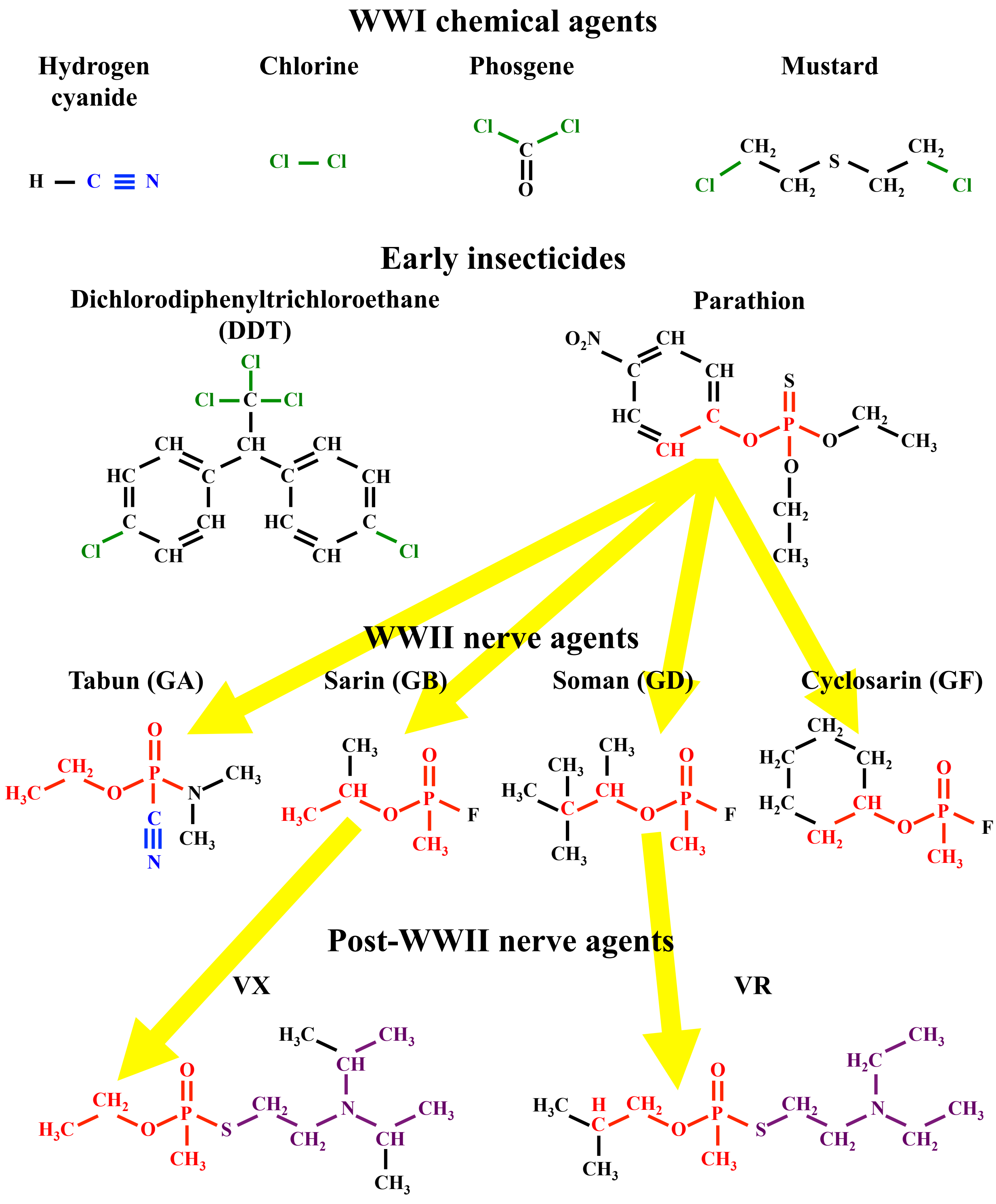
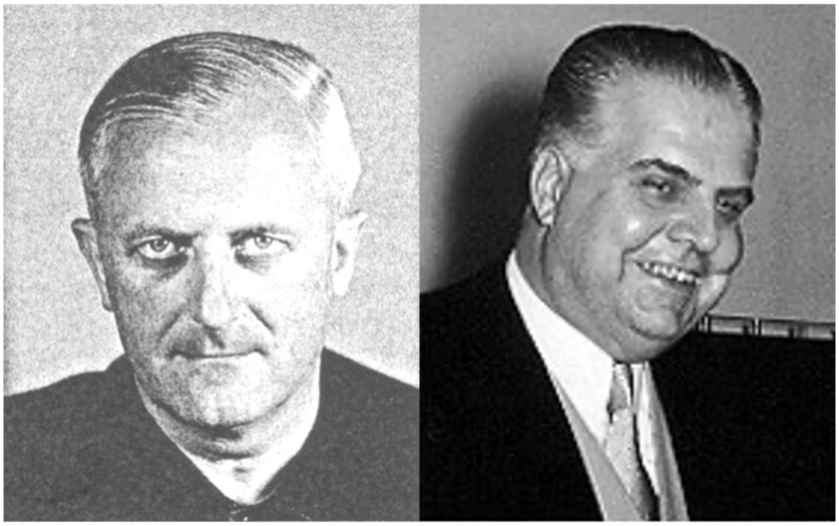

WWI chemical agents
Hydrogen cyanide
Chlorine
Phosgene
Mustard
Early insecticides
Dichlorodiphenyltrichloroethane (DDT)
Parathion
WWII nerve agents
Tabun (GA)
Sarin (GB)
Soman (GD)
Cyclosarin (GF)
Post-WWII nerve agents
VX
VR

Figure 3.97: Chemical warfare agents and pesticides, including chemical agents used during World War I, some important early insecticides, nerve agents produced during World War II, and related nerve agents produced after World War II.

Wolfgang Alt
(19??–19??)

Otto Ambros
(1901–1990)
I.G. Farben

Otto Bayer
(1902–1982)
Leverkusen



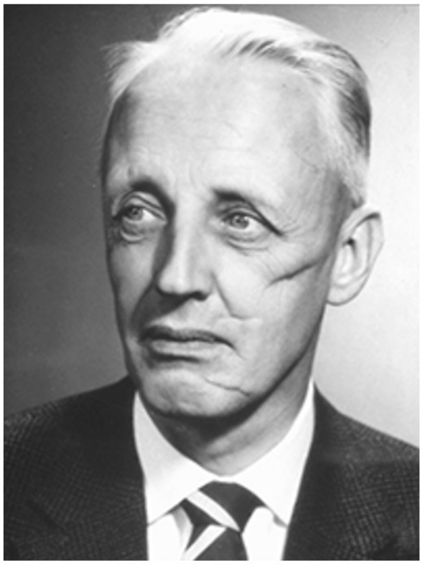
?? von Bock
(19??–19??)
Dyhernfurth –1945;
USSR 1945--

Gerhard L. Bottger
(19??–19??)

Kurt Brand
(19??–19??)

Figure 3.98: Some creators who were involved in developing and testing chemical warfare agents and pesticides included Wolfgang Alt, Otto Ambros, Otto Bayer, ?? von Bock, Gerhard L. Bottger, and Kurt Brand.

Rudolf Criegee
(1902–1975)
Chemisches Institut
TU Karlsruhe

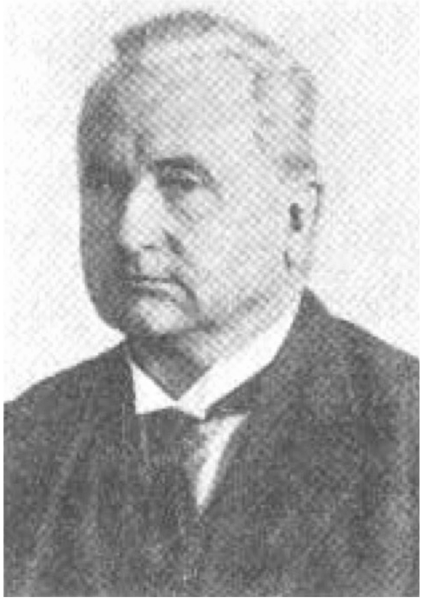


Gerhard Ehlers
(19??–19??)

Harry Endler
(19??–19??)

?? Fischer
(19??–19??)

Ferdinand Flury
(1877–1947)



?? Gebauer
(19??–19??)

Figure 3.99: Other creators who were involved in developing and testing chemical warfare agents and pesticides included Rudolf Criegee, Gerhard Ehlers, Harry Endler, ?? Fischer, Ferdinand Flury, and ?? Gebauer.

Siegfried Glupe
(1909–19??)
Army Ordnance Office

Eberhard Gross
(19??–19??)
IG Farben

Max Gruber
(19??–19??)
Gendorf Anorgana

Fritz Haber
(1868–1934)
WW I gases

Otto Hahn
(1879–1968)
WW I gases

Rudolf Hanslian
(1883–1954)

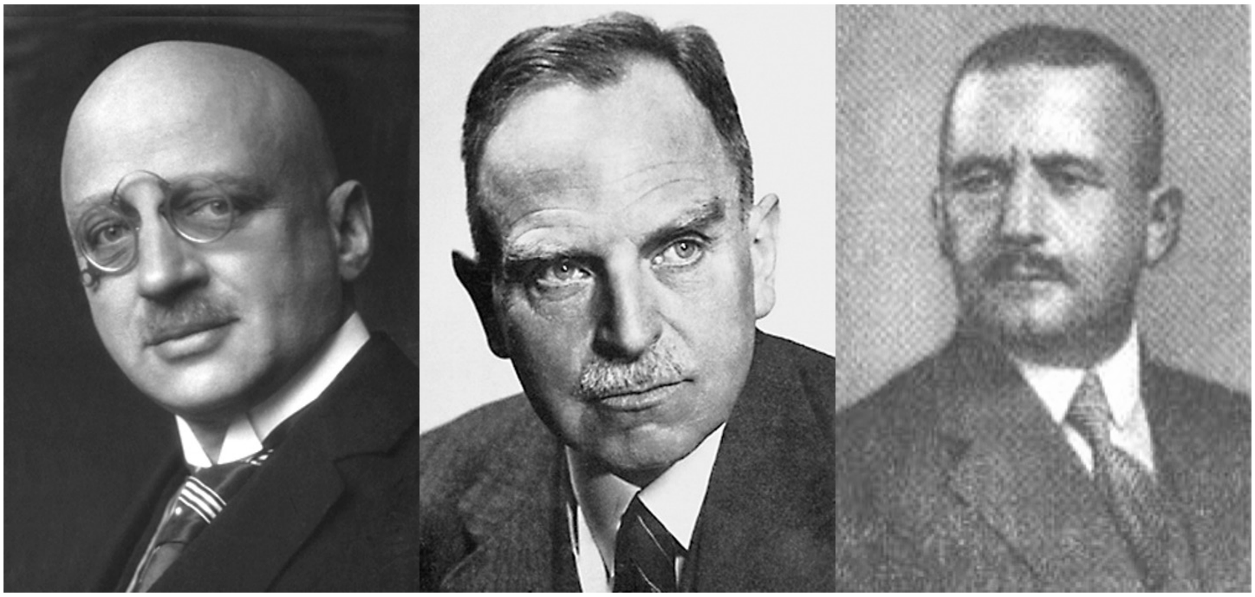


Figure 3.100: Other creators who were involved in developing and testing chemical warfare agents and pesticides included Siegfried Glupe, Eberhard Gross, Max Gruber, Fritz Haber, Otto Hahn, and Rudolf Hanslian.

Paul Hartmann
(19??–19??)

?? Heinman
(19??–19??)

Hans Henke
(19??–19??)

Walter Hirsch
(19??–19??)

August Hirt
(1898–1945)
Testing

Friedrich Wilhelm
Hoffmann (1910–1967)
Organic synthesis

Figure 3.101: Other creators who were involved in developing and testing chemical warfare agents and pesticides included Paul Hartmann, ?? Heinman, Hans Henke, Walter Hirsch, August Hirt, and Friedrich Wilhelm Hoffmann.

Heinrich Hörlein
(1882–1954)

?? Hoyer
(19??–19??)

Erich Hückel
(1896–1980)
New organophosphate nerve agents

?? Jannsen
(19??–19??)

?? Jung
(19??–19??)

L. Klebert
(19??–19??)
Leverkusen

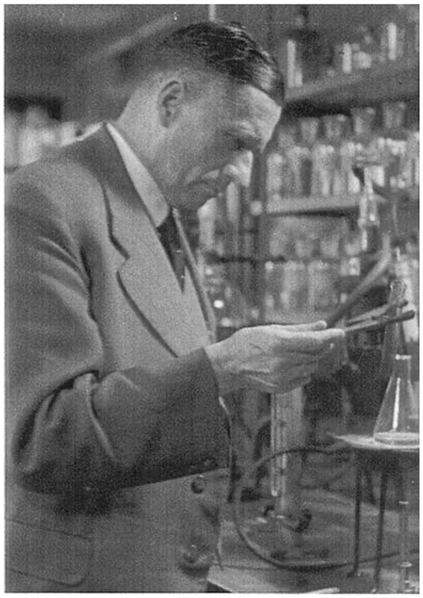
Figure 3.102: Other creators who were involved in developing and testing chemical warfare agents and pesticides included Heinrich Hörlein, ?? Hoyer, Erich Hückel, ?? Jannsen, ?? Jung, and L. Klebert.

Wilhelm Kleinhans
(19??–19??)

Jürgen von Klenk
(1909–19??)

Otto Klimmer
(19??–19??)

Carl Krauch
(1887–1968)



Gerda von Krüger
(19??–19??)
1932 organophosphate nerve agent DFP

Richard Kuhn
(1900–1967)
Soman, etc.

Figure 3.103: Other creators who were involved in developing and testing chemical warfare agents and pesticides included Wilhelm Kleinhans, Jürgen von Klenk, Otto Klimmer, Carl Krauch, Gerda von Krüger, and Richard Kuhn.

Hans Kükenthal
(19??–19??)
insecticide testing

Karl Küpper
(19??–19??)
Schrader's assistant

Willy Lange
(19??–19??)
1932 organophosphate nerve agent DFP

J. von der Linde
(19??–19??)

Fritz Wilhelm Lommel
(1875–1968)
Mass production of mustard agent

Walter Lorenz
(19??–19??)
VX-like agents

Figure 3.104: Other creators who were involved in developing and testing chemical warfare agents and pesticides included Hans Kükenthal, Karl Küpper, Willy Lange, J. von der Linde, Fritz Wilhelm Lommel, and Walter Lorenz.

Paul Hermann Müller
(1899–1965)
DDT

Wilhelm Neumann
(1898–1965)

?? Nold
(19??–19??)

Hermann Ochsner
(1892–1951)

H. Oettel
(19??–19??)

Albert Palm
(19??–1994)
Dyhernfurth

Figure 3.105: Other creators who were involved in developing and testing chemical warfare agents and pesticides included Paul Hermann Müller, Wilhelm Neumann, ?? Nold, Hermann Ochsner, H. Oettel, and Albert Palm.

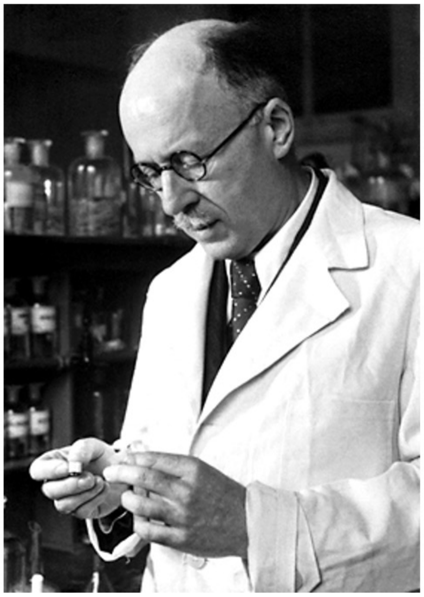
Karl Quasebart
(1882–19??)

Karl Rath
(19??–19??)

?? Rhein
(19??–19??)

Gerhard Ritter
(1902–19??)

Leopold Ružička
(1887–1976)
Pyrethroid insecticides



Wilhelm Sandermann
(1909–1994)

Figure 3.106: Other creators who were involved in developing and testing chemical warfare agents and pesticides included Karl Quasebart, Karl Rath, ?? Rhein, Gerhard Ritter, Leopold Ružička, and Wilhelm Sandermann.

Ernst Schegk
(19??–19??)
VX-like agents

Walther Schieber
(1896–1960)

Hanshelmut Schlör
(19??–19??)
VX-like agents

?? Schmall
(19??–19??)

Siegfried Schmidt
(19??–19??)
Army Ordnance Office

Gerhard Schrader
(1903–1990)
Insecticides, tabun,
sarin, VX-like agents

Figure 3.107: Other creators who were involved in developing and testing chemical warfare agents and pesticides included Ernst Schegk, Walther Schieber, Hanshelmut Schlör, ?? Schmall, Siegfried Schmidt, and Gerhard Schrader.

Erich Schumann
(1898–1985)
Army Ordnance Office
Chemical, biological, and nuclear weapons

Joseph Sextel
(19??–19??)

Leopold von Sicherer
(19??–19??)
Chemical munitions

Hermann Staudinger
(1881–1965)
Pyrethroid insecticides

Georg Wilhelm Steinkopf
(1879–1949)
Mass production of mustard agent

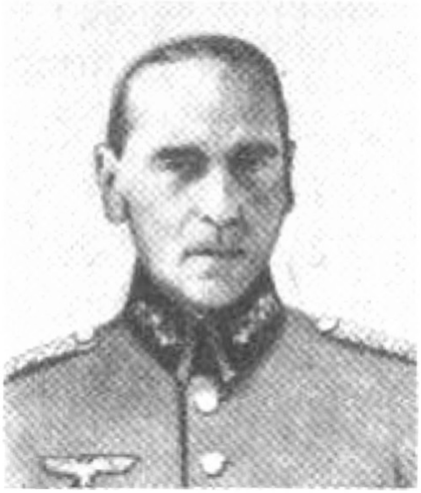
Hugo Stoltzenberg
(1883–1974)

Figure 3.108: Other creators who were involved in developing and testing chemical warfare agents and pesticides included Erich Schumann, Joseph Sextel, Leopold von Sicherer, Hermann Staudinger, Georg Wilhelm Steinkopf, and Hugo Stoltzenberg.

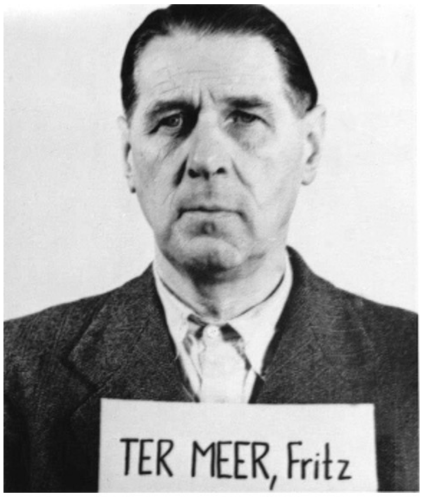
Gerhard Strauss
(19??–19??)

Ernst August Struss
(19??–19??)

Friedrich von Tempelhoff
(1878–1941)



Fritz ter Meer
(1884–1967)



?? Tolkmitt
(19??–19??)

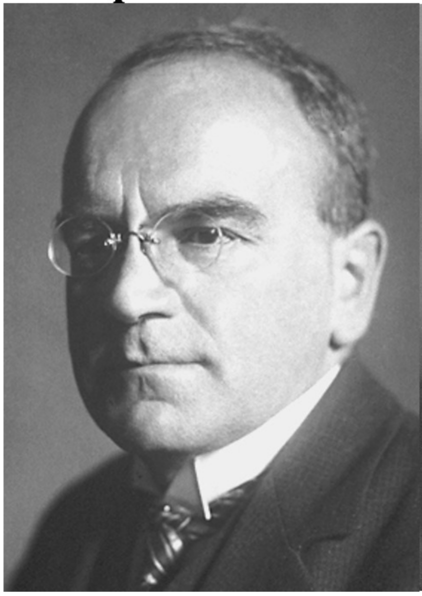
?? Vogel
(19??–19??)

Figure 3.109: Other creators who were involved in developing and testing chemical warfare agents and pesticides included Gerhard Strauss, Ernst August Struss, Friedrich von Tempelhoff, Fritz ter Meer, ?? Tolkmitt, and ?? Vogel.

Theodor Wagner-Jauregg (1903–1992) Paperclip

Heinrich Wieland (1877–1957) adamsite riot control agent, alpha amanitin

Richard Willstätter (1872–1942) Chemical warfare filters



Karl Wimmer (1910–1946) Testing

Wolfgang Wirth (1898–1996) Testing

Othmar Zeidler (1850–1911) DDT

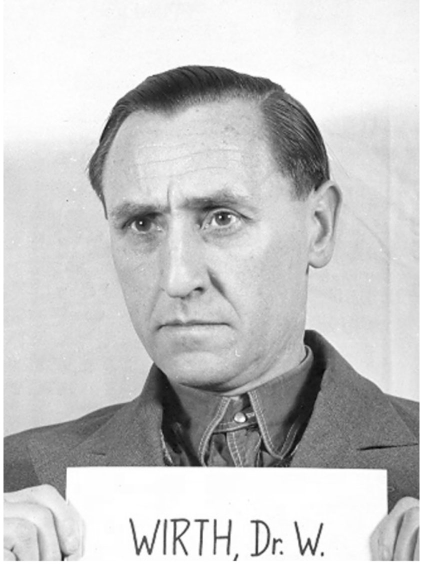


Figure 3.110: Other creators who were involved in developing and testing chemical warfare agents and pesticides included Theodor Wagner-Jauregg, Heinrich Wieland, Richard Willstätter, Karl Wimmer, Wolfgang Wirth, and Othmar Zeidler.

3.5.2 Insecticides

The German-speaking world also produced the most important early insecticides, which had a worldwide impact and became the prototypes for improved insecticides. Dichloro-diphenyl-trichloromethylmethane (DDT, Fig. 3.97), with five chlorines coupled to two benzene rings, was first produced in 1874 by Othmar Zeidler (Austrian, 1850–1911). Paul Hermann Müller (Swiss, 1899–1965) discovered DDT's insecticidal properties in 1939. DDT was rapidly transferred from the German-speaking world to many other countries [Brooks 1974, pp. 7–17] and was widely used to curtail insect-borne diseases in the 1940s–1960s. Müller won the Nobel Prize in Physiology or Medicine in 1948 for DDT, drawing the praise of Professor G. Fischer, a member of the Staff of Professors of the Royal Caroline Institute [https://www.nobelprize.org/prizes/medicine/1948/ceremony-speech/]:

> The story of DDT illustrates the often wondrous ways of science when a major discovery has been made. A scientist, working with flies and Colorado beetles discovers a substance that proves itself effective in the battle against the most serious diseases in the world. Many there are who will say he was lucky, and so he was. Without a reasonable slice of luck hardly any discoveries whatever would be made. But the results are not simply based on luck. The discovery of DDT was made in the course of industrious and certainly sometimes monotonous labour; the real scientist is he who possesses the capacity to understand, interpret and evaluate the meaning of what at first sight may seem to be an unimportant discovery.
>
> Dr. Paul Müller. I have tried to give a brief survey of the historical development of DDT. Your discovery of the strong contact insecticidal action of dichloro-diphenyl-trichloromethylmethane is of the greatest importance in the field of medicine. Thanks to you, preventive medicine is now able to fight many diseases carried by insects on a way totally different from that employed heretofore. Your discovery furthermore has, throughout the world, stimulated successful research into newer insecticides.

DDT was phased out starting in the 1960s due to concerns about environmental side effects, as most famously articulated in Rachel Carson's 1962 book, *Silent Spring*. However, it was replaced by other insecticides that came from the German-speaking world.

Scientists in the German-speaking world developed a number of chemical derivatives of DDT that appeared (and in some cases still appear) to be safer. One was dichlorodiphenyldichloroethane (DDD), also known a ME-1700. Others were difluorodiphenyltrichloroethane (DFDT, also known as Lauseto) and monofluorodiphenyltrichloroethane (MFDT), which as of 2019 were still being considered as attractive and relatively safe insecticides [Zhu et al. 2019].

Hermann Staudinger (German, 1881–1965) and Leopold Ružička (Austro-Hungarian/Croatian, studied in Germany and worked in Switzerland, 1887–1976) identified pyrethroid insecticide molecules in 1924, and pyrethroid insecticides have been widely used from the 1960s onward as a safer replacement for DDT. Staudinger won the Nobel Prize in Chemistry in 1953 for his work on polymers (p. 474), and Ružička won the Nobel Prize in Chemistry in 1939 for his work on hormones (p. 353).

Other early insecticides had an even more profound impact. Organophosphate compounds, containing both a phosphorus atom and several carbons, were developed as insecticides by Paul Gerhard Schrader (German, 1903–1990). Parathion (Fig. 3.97) was one of the earliest and best-known examples, and numerous variations such as malathion were subsequently produced and used to the present day. Yet because some of the early organophosphate insecticides had some toxicity to humans as well as insects, they proved to be the key to developing more modern chemical warfare agents—rapidly acting nerve agents.

3.5.3 G-Series Nerve Agents

Scientists in the Third Reich produced and tested a wide variety of organophosphate nerve agents, and created several especially potent ones (which were given postwar codenames beginning with G for German): tabun (GA), sarin (GB), soman (GD), ethylsarin (GE), cyclosarin (GF), and isopentylsarin (GH). (The code name GC was not used, to avoid confusion with the U.S. code name for phosgene, CG [Tucker 2006, p. 105]. GG was likely skipped because of the double letters.) See Fig. 3.97. Schrader created all of the agents just listed, except for soman which was developed by Richard Kuhn (Austrian, 1900–1967). After their initial discovery and testing, the agents were mass-produced by I.G. Farben at several industrial plants led by the chemist Otto Ambros (German, 1901–1990). These G-series nerve agents were exclusively possessed by the Third Reich and were stockpiled but never used, due to fear that Allied nations would retaliate with much cruder but still effective first-generation chemical weapons such as mustard agent (pp. 2632–2651).

Jonathan Tucker described the sophistication of nerve agent research, development, and production during the Third Reich [Tucker 2006, pp. 42, 45, 47–48, 50–51]:

> Code-named "Hochwerk," it would eventually cover an area 1.5 kilometers long by 700 meters wide. [...]
>
> Because of shortages of key equipment and manpower, it took two years and an expenditure of 120 million reichsmarks to complete the Hochwerk plant at Dyhernfurth, which the Anorgana company headed by Ambros began to operate in the spring of 1942. The sprawling production complex included buildings for manufacturing basic chemical ingredients, intermediates, and final products; numerous warehouses and storage tanks; a bombproof bunker that could hold 1,000 tons of bulk agent; filling lines for loading Tabun into artillery shells and aerial bombs; a well-equipped medical clinic with a staff of trained physicians; and barracks for the plant workers. To reduce exposure to air raids, the main production facility was built partially underground and camouflaged with trees planted on the roof.
>
> Because of Tabun's extreme toxicity, the design of the Hochwerk facility included special features to protect the plant workers against exposure. Each kettle was housed in an enclosed operating chamber formed of two spaced glass walls. Between the glass walls, a ventilation system produced greater than atmospheric pressure, so that the flow of air was always toward the reaction kettle. Inside the operating chamber, the air above the kettle was continuously changed by means of a separate ventilating duct, creating negative pressure. This pressure differential meant that the air contaminated with Tabun fumes was retained inside the operating chamber. All pipes used to transfer solutions containing Tabun were double-walled, and their outer surfaces were sprayed frequently with a weak solution of ammonia and water to neutralize minor leaks. After each production run, the kettles were decontaminated with steam and ammonia.
>
> No technicians were allowed to enter the operating chambers while the production of Tabun was under way. Instead, the operators opened and closed valves with long-handled mechanical levers that penetrated the double glass walls through rubber-sealed gaskets. [...]

> Although the standard Germany Army gas mask protected against breathing contaminate air, Tabun could also be absorbed through the skin. For this reason, all mechanics who entered the sealed production chambers to perform repairs and maintenance wore not only a respirator but a protective suit, cap, boots, and gloves, encapsulating the entire body. The suit consisted of two layers of rubber separated by a layer of cloth, making it cumbersome and unbearably hot in summer. Despite these precautions, about a dozen fatal accidents occurred during the two and a half years of Tabun production, most of them affecting mechanics performing overhauls of the plant. In one incident, seven pipe fitters were struck in the face by a pressurized stream of liquid Tabun that forced itself between their respirators and rubberized suits. [...]
>
> All seven victims were given intramuscular injections of atropine and a new drug called Sympotal, but five did not respond to the antidotes and died. [...]
>
> Dyhernfurth had its own munition-loading facility, which was built underground and equipped with ventilation shafts. Steel artillery shells and bomb casings were manufactured in a separate building and place on conveyor belts that transported them to the filling plant. Liquid Tabun pumped from underground storage tanks was loaded into empty 105 mm and 150 mm artillery shells, 250-kilogram aerial bombs, and artillery rockets. [...] To compensate for Tabun's lack of volatility, the bombs contained a central "burster" tube filled with a high explosive that, detonated on impact with the ground, would shatter the liquid agent into a mist of tiny droplets, poisoning enemy soldiers through inhalation and skin contact.
>
> Once an aerial bomb had been loaded with Tabun, the filling port was closed with a plug that incorporated a tightening pin. Using a wrench, a technician applied seating pressure to the pin, causing it to shear off and leave the plug in a sealed position, flush with the surface of the weapon. The sealing plug and adjacent surface were then coated with a slow-drying pink lacquer that would turn a deep carmine if Tabun lead through the plug. Near the base of the bomb or shell, workers painted three green rings around the munition to indicate its contents, along with stenciled numbers providing the date of manufacture and a code letter indicating the ratio of Tabun to chlorobenzene. [...]
>
> The forced laborers were assigned the most menial, backbreaking, and dangerous tasks at the Tabun plant, including construction, maintenance, and loading munitions with the liquid agent. On the filling line, they wore protective clothing similar to a deep-sea diving suit, with a helmetlike mask covering the entire head and a hose providing a supply of fresh air. [...]

While Gerhard Schrader synthesized tabun, sarin, and hundreds of other possible nerve agents and pesticides, Jonathan Tucker described the role that Richard Kuhn also played in the program [Tucker 2006, pp. 54, 62–63]:

> In early 1943, Colonel Schmidt of the Army Ordnance Office asked Professor Richard Kuhn, the director of the Institute of Chemistry at the Kaiser Wilhelm Institute for Medical Research in Heidelberg, to analyze the effects of nerve agents on the central and peripheral nervous systems. [...]

> Based on these insights, Kuhn's research team developed a standardized assay that measured the ability of nerve agents to inhibit purified cholinesterase enzymes in the test tube. Over the next two years, they used this assay to screen a variety of candidate nerve agents, some of their own invention and others synthesized by the German Army chemists at Spandau Citadel. [...]
>
> [D]uring the spring of 1944, Richard Kuhn, working at the Kaiser Wilhelm Institute in Heidelberg, made a striking discovery. He was continuing his research for the German Army by screening a wide variety of organophosphorus compounds—some of which he had synthesized himself—for the ability to inhibit cholinesterase. Because of the Nazi obsession with secrecy, his research was "compartmented": he was not put into contact with other scientists in the nerve agent field and was completely unaware of Schrader's work.
>
> When Kuhn replaced the isopropyl alcohol used to make Sarin with a more complex alcohol known as pinacolyl, the resulting substance (which he called Compound 25075) had a camphorlike odor and was roughly twice as potent as Sarin in inhibiting cholinesterase. The War Office code-named this new compound "Soman," and Kuhn synthesized small amounts in the laboratory.
>
> Toxicological testing of Soman in animals by Dr. Gross at IG Elberfeld revealed that the new agent was twice as toxic as Sarin by inhalation, readily penetrated into the skin, and passed rapidly from the bloodstream into the brain, enhancing its lethal effects. Even more striking, Soman inactivated cholinesterase irreversibly within two minutes, severely limiting the effectiveness of atropine as an antidote. Over the next several months, Kuhn and his colleagues tested about fifty analogues of Sarin and Soman for their ability to inhibit cholinesterase in his test-tube system. The most promising compounds were then tested on dogs and apes. [...]

Unlike the view in conventional history books, both Axis and Allied forces very nearly used chemical weapons in World War II. Germany stockpiled and very seriously considered using its chemical weapons (both the newer ones like nerve agents and the older ones like mustard agent) against Allied targets, especially to halt Russian advances on the Eastern Front. The United States and United Kingdom stockpiled and very seriously considered using their own copies of the chemical weapons that Germany had invented in the previous war (mustard and phosgene) with the explicit goal of killing millions of civilians in German cities. The threats by both sides to use chemical weapons played an enormously important role in how and why the war was waged as it actually was. For more information, see pp. 2632–2651.

The G-series nerve agents and information on how to produce them were removed from Germany at the end of the war, and G-series agents have been mass-produced by a wide range of nations ever since. For example, the postwar U.S./U.K. chemical warfare program was directly copied from the wartime German program, making extensive use of German scientists, information, and materials [Tucker 2006, p. 116]:

> In addition to Schieber, EUCOM hired about thirty German chemical warfare experts, some of whom were later transferred to Edgewood Arsenal to continue their work on

> American soil. [...] Several of the German chemical weapons specialists recruited by Porton Down later moved to the United States, where they were granted U.S. citizenship and prominent positions.

Similarly, the postwar Soviet chemical warfare program was also directly copied from the wartime German program [Tucker 2006, pp. 106–107, 145]:

> In September 1946, with the aid of captured German scientists, Soviet engineers and pipe fitters had systematically dismantled the Tabun and Sarin plants at Dyhernfurth, which the Red Army had seized as war booty, and shipped the production equipment to Stalingrad. [...]
>
> To assist in rebuilding the nerve agent production lines, the Soviets brought to Stalingrad about a dozen German chemists and process engineers from Dyhernfurth who had been captured by the Red Army. The most senior of the German scientists were Dr. von Bock, the former production manager. Soon after his arrival, he was ordered to write a detailed technical report on Tabun production and was questioned at length about the metal corrosion problems associated with the manufacture of Sarin.
>
> The Sarin plant at Stalingrad started out as a copy of the one at Dyhernfurth, but for reasons of national pride [Zaharovich] Soborovsky and [Boris] Libman tried to improve on the German production process. In so doing, they ran into serious technical problems that resulted in lengthy delays. [...] Although the development had begun in 1948, it was not until 1959—more than a decade later—that Chemical Works No. 91 was churning out large amounts of Sarin with a satisfactory level of purity and stability.

For additional examples of the transfer of chemical weapons technologies from the German-speaking world to Allied countries, see:

> BIOS 110. *Drägerwerk Factories at Lübeck, Hamburg and Uetersen.* [Protective clothing, respiration filters, sensors, etc. for chemical warfare]
>
> BIOS 542. *Interrogation of Certain German Personalities Connected with Chemical Warfare.*
>
> BIOS 714. *The Development of New Insecticides and Chemical Warfare Agents.* [original edition; revised edition only covers insecticides and is less than half as long!]
>
> BIOS 760. *German War-Time Development in Fluid Turbulence with Particular Reference to the Lower Atmosphere and the Meteorology of Chemical Warfare.*
>
> BIOS 761. *German Bursting Coloured Smoke Shell. Interrogation of Dipl. Ing. C. von Watzdorf and Dr. W. Sauermilch.*
>
> BIOS 782. *Interrogation of Professor Ferdinand Flury and Dr. Wolfgang Wirth on the Toxicology of Chemical Warfare Agents.*

CIOS ER 33. *Interview with Dr. Klebert, Dr. Redies and Dr. Knonradi: Synthetic Rubber, Chemical Warfare.*

CIOS II-1. *German Chemical Warfare Activities in Paris Area.*

CIOS IX-4. *Interviews on Chemical Warfare.*

CIOS XI-12. *Production and Use of Aerosols.* [Chemical warfare aerosol production, medical treatment aerosols]

CIOS XXI-4. *Miscellaneous Chemical Warfare Information, I.G. Leverkusen.*

CIOS XXIV-19. *Anorgana G.m.b.H. Werke Gendorf.* [Chemical warfare, periston]

CIOS XXVI-49. *Heeresgasschutzschule I, Celle.* [chemical warfare]

CIOS XXVII-34. *War Gas Production and Miscellaneous Chemical Warfare Information, Anorgana G.m.b.H., Gendorf.*

CIOS XXVIII-59. *Aviation Medicine, General Medicine, Veterinary Medicine, and Chemical Warfare.*

CIOS XXX-19. *Chemical Warfare, I.G. Farbenindustrie AG, Frankfurt/Main.*

CIOS XXXI-86. *Chemical Warfare Installations in the Munsterlager Area.* [very long and very detailed, including personnel and molecular structures]

CIOS XXXII-13. *Production of Smoke, Incendiary and Chemical Warfare Weapons.*

NARA Still Pictures, RG 111 SCA---Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941-1954. Captured German Equipment, German, Box 3347, Book 8, SC 231579.

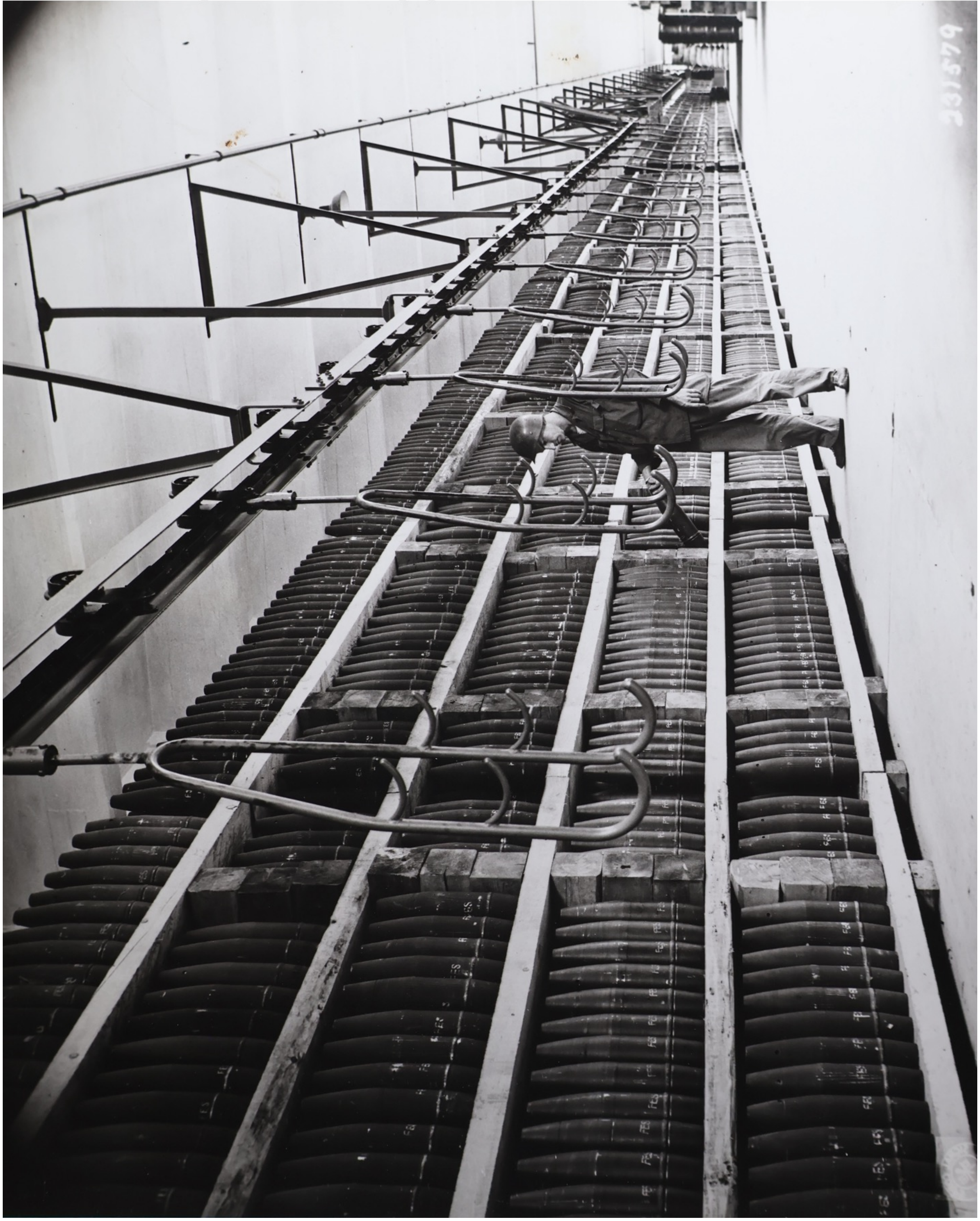


Figure 3.111: Stockpiled German chemical weapons found by U.S. forces in 1945. [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3347, Book 8, SC 231579.]

3.5.4 V-Series Nerve Agents

A significant innovation in nerve agents first became publicly known after the war. Although G-series agents were relatively small molecules that dispersed fairly rapidly, if they were coupled to an oily hydrocarbon chain, they could persist on surfaces for long periods of time and also readily penetrate through human skin. These improved nerve agents became known as the V-series (for venomous); VX was the favorite in the United States and United Kingdom, and the similarly acting VR was the favorite in the Soviet Union (Fig. 3.97). Officially, the invention of this category of nerve agents was credited to postwar researchers not from the German-speaking world. In 1952, Ranajit Ghosh and J. F. Newman at the UK Imperial Chemical Industries (ICI) Plant Protection Laboratory produced a potent V-series agent, Amiton, that had been intended as an insecticide. Almost simultaneously, Lars-Erik Tammelin of the Swedish Institute of Chemical Defense produced similar compounds that came to be known as Tammelin esters.

In fact, V-series agents appear to have been invented, produced, and tested in Germany during World War II.

The chemical approach of coupling a toxic gas molecule to an oily hydrocarbon chain—in order to make the agent persist on surfaces and penetrate through human skin—is exactly the same strategy that German chemists used during World War I to upgrade chlorine gas to mustard agent (Fig. 3.97).

German chemists would be expected to consider the same approach to upgrade nerve agents during World War II. Making the most toxic German chemical agents persist much longer in the environment, so that they could be used to contaminate areas and block a Soviet advance (see p. 2633 for such plans), would be a very obvious and very high-priority goal.

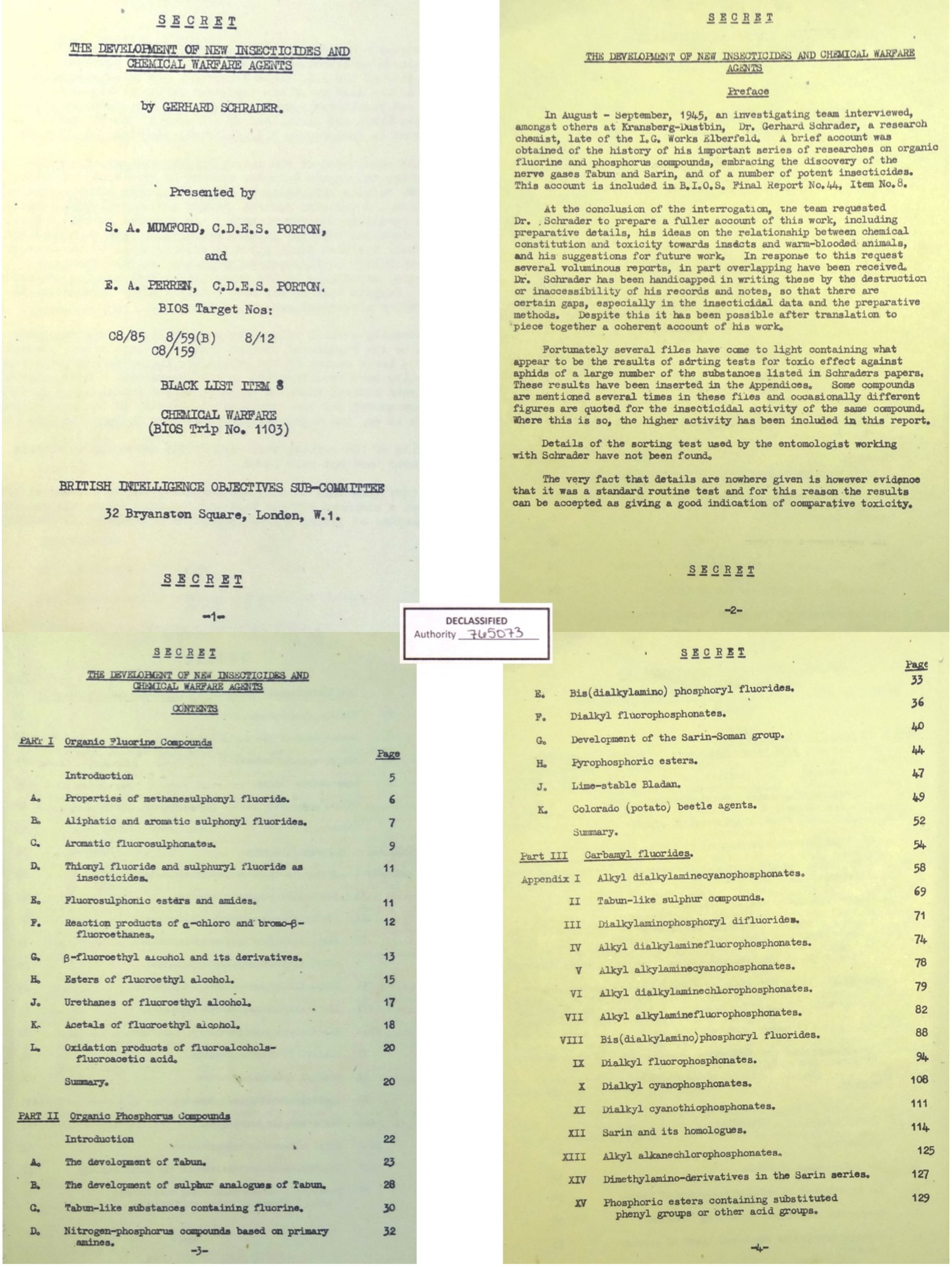
Indeed, in 1945 Gerhard Schrader gave U.K. and U.S. officials detailed information on many hundreds of nerve agents that he had developed and tested during the war [BIOS 714; see Fig. 3.112 and Section A.4]. Schrader's report included a wide variety of V-series agents, composed of G-series agents coupled to an oily hydrocarbon chain. Furthermore, many of Schrader's agents possessed the same molecular features as VX and VR, such as using a nitrogen atom to attach two branches of hydrocarbons to the toxic part of the molecule. After the war, Schrader, Ernst Schegk, and Hanshelmut Schlör of Bayer in Leverkusen (part of I.G. Farben during the war) filed patents on linking an oily hydrocarbon chain to a toxic organophosphate structure, although postwar restrictions both delayed public acknowledgement of that work and compelled them to focus on insecticide applications instead of chemical warfare applications; see Fig. 3.113 and Section A.4.

In the United States (and likely in other countries as well), German experts such as Friedrich Wilhelm Hoffmann (1910–1967) were employed after the war to mass produce V-series agents. Hoffmann was also deeply involved in the postwar U.S. development (or perhaps the postwar transfer/recapitulation of wartime German work) of the Agent Orange defoliant, dioxin, various other toxins, attempts to harness LSD, and other chemical agents.[11]

It is quite possible that Richard Kuhn or others also developed V-series agents in Germany during the war. Much more archival research is needed to clarify the history of the development and dissemination of knowledge about V-series agents.

---

[11] Albarelli 2009; Jacobsen 2014, pp. 384–389; Lindemann 2016; Möller et al. 2014; Sandermann 1984; Sorge 2017.



SECRET

THE DEVELOPMENT OF NEW INSECTICIDES AND CHEMICAL WARFARE AGENTS

by GERHARD SCHRADER.

Presented by

S. A. MUMFORD, C.D.E.S. PORTON,

and

E. A. PERREN, C.D.E.S. PORTON.

BIOS Target Nos:

C8/85 8/59(B) 8/12
C8/159

BLACK LIST ITEM 8

CHEMICAL WARFARE
(BIOS Trip No. 1103)

BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE

32 Bryanston Square, London, W.1.

SECRET

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THE DEVELOPMENT OF NEW INSECTICIDES AND CHEMICAL WARFARE AGENTS

Preface

In August - September, 1945, an investigating team interviewed, amongst others at Kransberg-Dustbin, Dr. Gerhard Schrader, a research chemist, late of the I.G. Works Elberfeld. A brief account was obtained of the history of his important series of researches on organic fluorine and phosphorus compounds, embracing the discovery of the nerve gases Tabun and Sarin, and of a number of potent insecticides. This account is included in B.I.O.S. Final Report No.44, Item No.8.

At the conclusion of the interrogation, the team requested Dr. Schrader to prepare a fuller account of this work, including preparative details, his ideas on the relationship between chemical constitution and toxicity towards insects and warm-blooded animals, and his suggestions for future work. In response to this request several voluminous reports, in part overlapping have been received. Dr. Schrader has been handicapped in writing these by the destruction or inaccessibility of his records and notes, so that there are certain gaps, especially in the insecticidal data and the preparative methods. Despite this it has been possible after translation to piece together a coherent account of his work.

Fortunately several files have come to light containing what appear to be the results of sorting tests for toxic effect against aphids of a large number of the substances listed in Schraders papers. These results have been inserted in the Appendices. Some compounds are mentioned several times in these files and occasionally different figures are quoted for the insecticidal activity of the same compound. Where this is so, the higher activity has been included in this report.

Details of the sorting test used by the entomologist working with Schrader have not been found.

The very fact that details are nowhere given is however evidence that it was a standard routine test and for this reason the results can be accepted as giving a good indication of comparative toxicity.

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THE DEVELOPMENT OF NEW INSECTICIDES AND CHEMICAL WARFARE AGENTS

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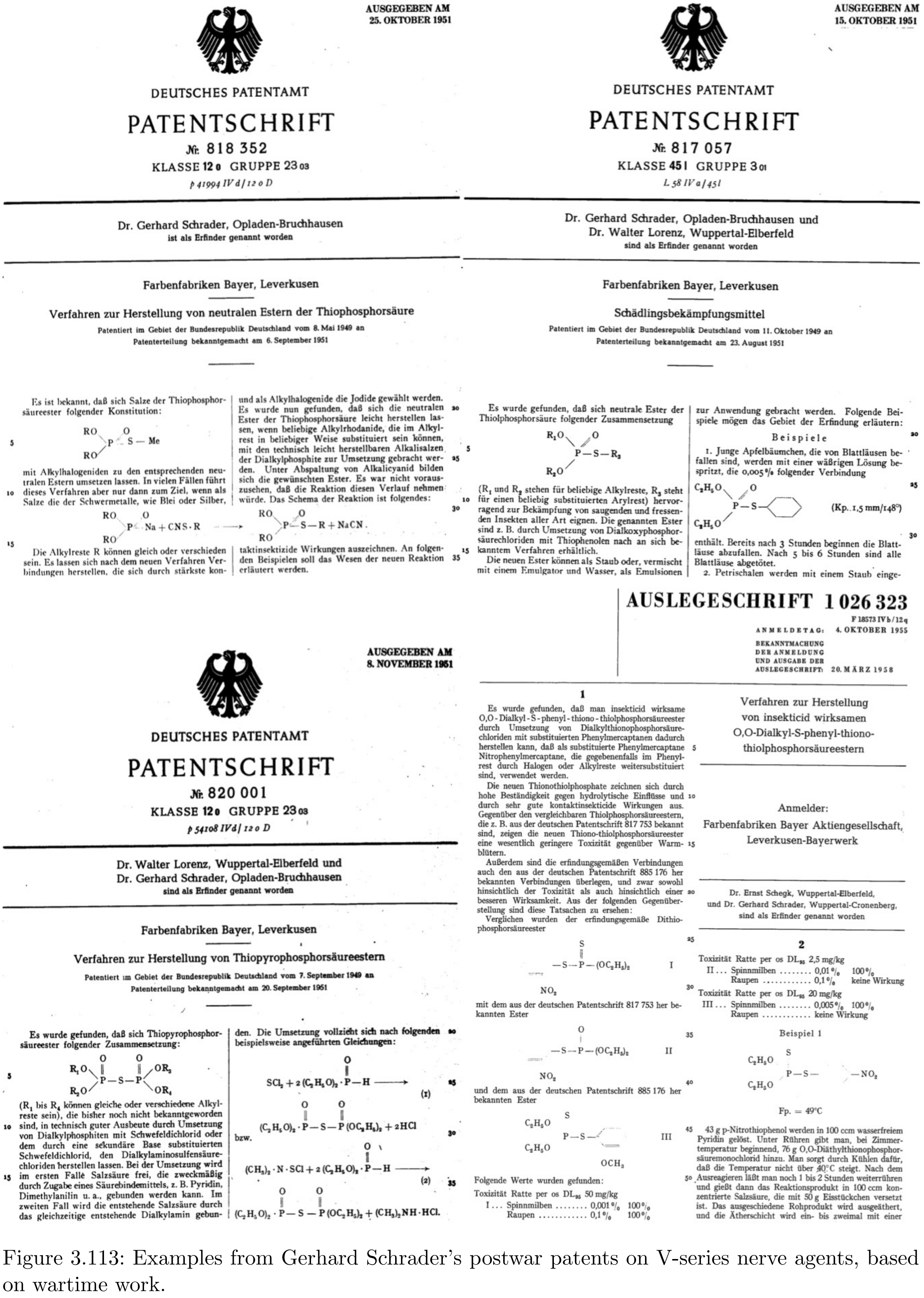
Figure 3.112: Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



AUSGEGEBEN AM
25. OKTOBER 1951

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 818 352

KLASSE 12o GRUPPE 23 03

p 41994 IVd/12o D

Dr. Gerhard Schrader, Opladen-Bruchhausen
ist als Erfinder genannt worden

Farbenfabriken Bayer, Leverkusen

Verfahren zur Herstellung von neutralen Estern der Thiophosphorsäure

Patentiert im Gebiet der Bundesrepublik Deutschland vom 8. Mai 1949 an
Patenterteilung bekanntgemacht am 6. September 1951

Es ist bekannt, daß sich Salze der Thiophosphorsäureester folgender Konstitution:

$(RO)_2P(O)S-Me$

mit Alkylhalogeniden zu den entsprechenden neutralen Estern umsetzen lassen. In vielen Fällen führt dieses Verfahren aber nur dann zum Ziel, wenn als Salze die der Schwermetalle, wie Blei oder Silber, und als Alkylhalogenide die Jodide gewählt werden. Es wurde nun gefunden, daß sich die neutralen Ester der Thiophosphorsäure leicht herstellen lassen, wenn beliebige Alkylrhodanide, die im Alkylrest in beliebiger Weise substituiert sein können, mit den technisch leicht herstellbaren Alkalisalzen der Dialkylphosphite zur Umsetzung gebracht werden. Unter Abspaltung von Alkalicyanid bilden sich die gewünschten Ester. Es war nicht vorauszusehen, daß die Reaktion diesen Verlauf nehmen würde. Das Schema der Reaktion ist folgendes:

$$(RO)_2P(O)Na + CNS \cdot R \longrightarrow (RO)_2P(O)-S-R + NaCN.$$

Die Alkylreste R können gleich oder verschieden sein. Es lassen sich nach dem neuen Verfahren Verbindungen herstellen, die sich durch stärkste kontaktinsektizide Wirkungen auszeichnen. An folgenden Beispielen soll das Wesen der neuen Reaktion erläutert werden.

AUSGEGEBEN AM
15. OKTOBER 1951

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 817 057

KLASSE 45l GRUPPE 3 01

L 58 IVa/45l

Dr. Gerhard Schrader, Opladen-Bruchhausen und
Dr. Walter Lorenz, Wuppertal-Elberfeld
sind als Erfinder genannt worden

Farbenfabriken Bayer, Leverkusen

Schädlingsbekämpfungsmittel

Patentiert im Gebiet der Bundesrepublik Deutschland vom 11. Oktober 1949 an
Patenterteilung bekanntgemacht am 23. August 1951

Es wurde gefunden, daß sich neutrale Ester der Thiolphosphorsäure folgender Zusammensetzung

$(R_1O)(R_2O)P(O)-S-R_3$

(R_1 und R_2 stehen für beliebige Alkylreste, R_3 steht für einen beliebig substituierten Arylrest) hervorragend zur Bekämpfung von saugenden und fressenden Insekten aller Art eignen. Die genannten Ester sind z. B. durch Umsetzung von Dialkoxyphosphorsäurechloriden mit Thiophenolen nach an sich bekanntem Verfahren erhältlich.

Die neuen Ester können als Staub oder, vermischt mit einem Emulgator und Wasser, als Emulsionen zur Anwendung gebracht werden. Folgende Beispiele mögen das Gebiet der Erfindung erläutern:

Beispiele

1. Junge Apfelbäumchen, die von Blattläusen befallen sind, werden mit einer wäßrigen Lösung bespritzt, die 0,005 % folgender Verbindung

(Kp. 1,5 mm/148°)

enthält. Bereits nach 3 Stunden beginnen die Blattläuse abzufallen. Nach 5 bis 6 Stunden sind alle Blattläuse abgetötet.

2. Petrischalen werden mit einem Staub einge-

AUSGEGEBEN AM
8. NOVEMBER 1951

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 820 001

KLASSE 12o GRUPPE 23 03

p 54108 IVd/12o D

Dr. Walter Lorenz, Wuppertal-Elberfeld und
Dr. Gerhard Schrader, Opladen-Bruchhausen
sind als Erfinder genannt worden

Farbenfabriken Bayer, Leverkusen

Verfahren zur Herstellung von Thiopyrophosphorsäureestern

Patentiert im Gebiet der Bundesrepublik Deutschland vom 7. September 1949 an
Patenterteilung bekanntgemacht am 20. September 1951

Es wurde gefunden, daß sich Thiopyrophosphorsäureester folgender Zusammensetzung:

$(R_1O)(R_2O)P(O)-S-P(O)(OR_3)(OR_4)$

(R_1 bis R_4 können gleiche oder verschiedene Alkylreste sein), die bisher noch nicht bekanntgeworden sind, in technisch guter Ausbeute durch Umsetzung von Dialkylphosphiten mit Schwefeldichlorid oder dem durch eine sekundäre Base substituierten Schwefeldichlorid, den Dialkylaminosulfensäurechloriden herstellen lassen. Bei der Umsetzung wird im ersten Falle Salzsäure frei, die zweckmäßig durch Zugabe eines Säurebindemittels, z. B. Pyridin, Dimethylanilin u. a., gebunden werden kann. Im zweiten Fall wird die entstehende Salzsäure durch das gleichzeitige entstehende Dialkylamin gebunden. Die Umsetzung vollzieht sich nach folgenden beispielsweise angeführten Gleichungen:

$$SCl_2 + 2\,(C_2H_5O)_2 \cdot P(O)-H \longrightarrow (C_2H_5O)_2 \cdot P(O)-S-P(O)(OC_2H_5)_2 + 2\,HCl \quad (1)$$

bzw.

$$(CH_3)_2 \cdot N \cdot SCl + 2\,(C_2H_5O)_2 \cdot P(O)-H \longrightarrow (C_2H_5O)_2 \cdot P(O)-S-P(O)(OC_2H_5)_2 + (CH_3)_2NH \cdot HCl. \quad (2)$$

AUSLEGESCHRIFT 1 026 323

F 18573 IVb/12q

ANMELDETAG: 4. OKTOBER 1955

BEKANNTMACHUNG
DER ANMELDUNG
UND AUSGABE DER
AUSLEGESCHRIFT: 20. MÄRZ 1958

Verfahren zur Herstellung
von insekticid wirksamen
O,O-Dialkyl-S-phenyl-thiono-
thiolphosphorsäureestern

Anmelder:
Farbenfabriken Bayer Aktiengesellschaft,
Leverkusen-Bayerwerk

Dr. Ernst Schegk, Wuppertal-Elberfeld,
und Dr. Gerhard Schrader, Wuppertal-Cronenberg,
sind als Erfinder genannt worden

1

Es wurde gefunden, daß man insekticid wirksame O,O-Dialkyl-S-phenyl-thiono-thiolphosphorsäureester durch Umsetzung von Dialkylthionophosphorsäurechloriden mit substituierten Phenylmercaptanen dadurch herstellen kann, daß als substituierte Phenylmercaptane Nitrophenylmercaptane, die gegebenenfalls im Phenylrest durch Halogen oder Alkylreste weitersubstituiert sind, verwendet werden.

Die neuen Thionothiolphosphate zeichnen sich durch hohe Beständigkeit gegen hydrolytische Einflüsse und durch sehr gute kontaktinsekticide Wirkungen aus. Gegenüber den vergleichbaren Thiolphosphorsäureestern, die z. B. aus der deutschen Patentschrift 817 753 bekannt sind, zeigen die neuen Thiono-thiolphosphorsäureester eine wesentlich geringere Toxizität gegenüber Warmblütern.

Außerdem sind die erfindungsgemäßen Verbindungen auch den aus der deutschen Patentschrift 885 176 her bekannten Verbindungen überlegen, und zwar sowohl hinsichtlich der Toxizität als auch hinsichtlich einer besseren Wirksamkeit. Aus der folgenden Gegenüberstellung sind diese Tatsachen zu ersehen:

Verglichen wurden der erfindungsgemäße Dithiophosphorsäureester

$-S-P(S)-(OC_2H_5)_2$ I
NO_2

mit dem aus der deutschen Patentschrift 817 753 her bekannten Ester

$-S-P(O)-(OC_2H_5)_2$ II
NO_2

und dem aus der deutschen Patentschrift 885 176 her bekannten Ester

$(C_2H_5O)_2P(S)-S-$ III
OCH_3

Folgende Werte wurden gefunden:

Toxizität Ratte per os DL_{95} 50 mg/kg
I ... Spinnmilben .... 0,001 % 100 %
Raupen .... 0,1 % 100 %

2

Toxizität Ratte per os DL_{95} 2,5 mg/kg
II ... Spinnmilben .... 0,01 % 100 %
Raupen .... 0,1 % keine Wirkung

Toxizität Ratte per os DL_{95} 20 mg/kg
III ... Spinnmilben .... 0,005 % 100 %
Raupen .... keine Wirkung

Beispiel 1

$(C_2H_5O)_2P(S)-S-$ $-NO_2$

Fp. = 49°C

43 g p-Nitrothiophenol werden in 100 ccm wasserfreiem Pyridin gelöst. Unter Rühren gibt man, bei Zimmertemperatur beginnend, 76 g O,O-Diäthylthionophosphorsäuremonochlorid hinzu. Man sorgt durch Kühlen dafür, daß die Temperatur nicht über 40°C steigt. Nach dem Ausreagieren läßt man noch 1 bis 2 Stunden weiterrühren und gießt dann das Reaktionsprodukt in 100 ccm konzentrierte Salzsäure, die mit 50 g Eisstückchen versetzt ist. Das ausgeschiedene Rohprodukt wird ausgeäthert, und die Ätherschicht wird ein- bis zweimal mit einer

Figure 3.113: Examples from Gerhard Schrader's postwar patents on V-series nerve agents, based on wartime work.

3.5.5 Other Chemical Weapons

German-speaking scientists discovered and developed other categories of chemical weapons too. For example, R. P. Linstead and T. J. Betts, the British and American chairs of the Combined Intelligence Objectives Subcommittee (CIOS), described "N-Stoff" or chlorine trifluoride, a highly corrosive and incendiary German chemical weapon, in a September 1945 report [AFHRA A5186 electronic version pp. 904–1026, Ch. 4, p. 54]:

> A new method was discovered for the manufacture of chlorine trifluoride. The value of this compound is said to lie in its powerful oxidizing properties which causes organic materials to burst into flame immediately on contact. It also has a quality of liberating fluorine which attacks glass and rapidly obscures vision in planes or military vehicles.

Chemical weapons expert Dan Kaszeta provided more background information on N-Stoff/chlorine trifluoride [Kaszeta 2020, p. 39]:

> The Falkenhagen site was already in use for production of chemical warfare materiel unrelated to the nerve agent programme. In 1938, ground had been broken there for a complex to produce Chlorine Trifluoride (ClF_3), which the Army had nicknamed "N-stoff"—literally "substance N". It is a particularly vile substance. A very strong oxidizer, it is both extremely corrosive and poisonous and could be more readily considered to be an incendiary weapon. It burns many different things, even in the absence of oxygen and even ignites glass on contact. It reacts with water, including moisture on the skin. The German military had considered Chlorine Trifluoride as a possible weapon to attack fortifications such as the Maginot Line because it will burn through concrete.

Germany may have actually employed 5-kilogram shells of chlorine trifluoride[12] on the Eastern Front. An English translation of an Allied-intercepted 9 December 1944 Japanese message from Stockholm to Tokyo reported [NARA RG 457, Entry A1-9004, Japanese Army Attaché Messages Translations, SRA 14,200 thru 15,000. SRA 14628–14632. Photos in Pellas 2020, pp. 15–17]:

> [...] It is a fact that in June of 1942 the German Army tried out an utterly new type of weapon against the Russians at a location 150 kilometers southeast of Kursk. Although it was the entire 19th Infantry Regiment of the Russians which was thus attacked, only a few bombs (each round up to 5 kilograms) sufficed to utterly wipe them out to the last man. [...]
>
> The following is according to a statement by Lieutenant-Colonel UE(?K?)I KENJI, advisor to the attaché in Hungary and formerly (?on duty?) in this country, who by chance saw the actual scene immediately after the above took place:
>
> "All the men and the horses (?within the area of?) the explosion of the shells were charred black and even their ammunition had all been detonated."
>
> Moreover, it is a fact that the same type of war material was tried out in the Crimea, too. At that time the Russians claimed that this was poison-gas, and protested that if Germany were ever again to use it, Russia, too, would use poison-gas. [...]

A number of other German chemical agents with incendiary, freezing, neuropharmacological, and other properties were also reported.

---

[12] Or perhaps fuel-air explosive shells or another novel weapon?

3.6 Physical Chemistry

Due to the dominance of creators from the greater German-speaking world both in the field of chemistry and in the field of physics, it is not surprising that they founded and led the area of physical chemistry, the intersection between chemical and physical phenomena.[13] Physical chemistry encompasses many topics such as thermochemistry, electrochemistry, photochemistry, and physical methods for analytical chemistry.

Some important creators in physical chemistry are shown in Figs. 3.114–3.123 and discussed in alphabetical order in Section 3.6.1.

Electrochemical battery and fuel cell technologies are discussed in more detail in Section 3.6.2.

For closely related creators and creations in quantum physics and statistical physics, see Sections 5.4 and 5.5, respectively.

3.6.1 General Physical Chemistry

Hermann Aron (German, 1845–1913) developed an improved lead-acid rechargeable battery in 1880, and it became widely used thereafter. He also developed improved methods of measuring electrical voltage and current [Katzir 2009, 2013].

Svante Arrhenius (1859–1927) was Swedish but studied and worked in Germany and Austria. In fact, throughout most of his education and career, he encountered considerable opposition to his scientific innovations in Sweden, but was given strong support and assistance by creators such as Ludwig Boltzmann, Rudolf Clausius, Friedrich Kohlrausch, Wilhelm Ostwald, and Jacobus van 't Hoff. Arrhenius was one of the founders of the field of physical chemistry and won the Nobel Prize in Chemistry in 1903 for his theoretical insights into electrolytic dissociation. H. R. Törnebladh, President of the Royal Swedish Academy of Sciences, explained the importance of Arrhenius's work [https://www.nobelprize.org/prizes/chemistry/1903/ceremony-speech/]:

> Around 1880 Svante Arrhenius—then studying for a doctorate in science—arrived, as a result of his researches into the movement of electric current through solutions, at a new explanation of the causes of chemical phenomena, i.e. he attributed them to electrical charges contained in the constituents of reacting substances. Electricity was thus introduced as a decisive factor into the theory of chemistry[...]
>
> In the time of Berzelius this notion rested on a qualitative basis only, whereas Arrhenius's theory determined it quantitatively, thus allowing it to be treated mathematically. In his doctor's thesis, twenty years ago, Arrhenius had deduced from this principle all known laws governing chemical changes, but despite this the new theory was very little understood. It so conflicted with current ideas as to disprove them. According to this theory, for instance, common salt, sodium chloride, when dissolved in water splits up to

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[13] For more information on this area, see especially: Brock 1993; Laurie Brown et al. 1995; Bugge 1955; Coffey 2008; Engels et al. 1989; Farber 1961; Gamow 1966; Ihde 1984; Johnson 1990; Jones 2008; Jungnickel and McCormmach 1986, 2017; Kragh 2002; L'Annunziata 2016; von Meÿenn 1997; Ingo Müller 2007; Neufeldt 2003; Partington 1957, 1964; Teichmann et al. 2008; Weber 1988.

> a varying extent, in other words it is *dissociated* into its constituent parts which are diametrically opposed but charged with electricity, i.e. into *ions of chlorine* and of *sodium*, the only chemically effective substances in a solution of common salt. The theory also claimed that when an acid and a base react upon one another, water is the primary product and salt the secondary, and not reversely, as was then generally believed. Ideas so contrary to those current at that time could not be accepted immediately. A struggle lasting more than ten years and an enormous number of new experiments were required before the new theory was accepted by everyone. During this long battle over Arrhenius's theory of dissociation tremendous advances were made in chemistry and ever closer links were established between chemistry and physics—to the great benefit of both sciences.

Emil Bauer (Swiss, 1873–1944) developed novel fuel cells, such as a fuel cell using molten silver as the electrolyte. Together with Hans Preis, he developed the first fuel cell with a solid electrolyte, in this case one made of paste and metal oxides.

Henri Bernard Beer (Dutch, 1909–1994) invented improved electrodes made of titanium coated with mixed metal oxides containing metals such as rhodium, platinum, iridium, or ruthenium.

Jürgen Otto Besenhard (German, 1944–2006) played a major role in developing lithium batteries. It could be beneficial for historians to conduct much more archival research to investigate just how far back the history of the development of lithium batteries goes, and what contributions various scientists from the greater German-speaking world made during that development process.

Ludwig Boltzmann (Austrian, 1844–1906) developed an extensive framework of statistical physics equations for describing the thermodynamic behavior of large numbers of particles in solids, liquids, or gases [Boltzmann 1964]. As part of that work, he gave a precise mathematical definition of entropy for the second law of thermodynamics. In addition to its importance to physics, Boltzmann's work had enormous implications for chemical equilibria and chemical reactions.

Robert Bunsen (German, 1811–1899) made many important discoveries in physical chemistry. He invented the Bunsen cell battery using carbon electrodes (instead of more expensive platinum electrodes as had been used previously). He studied photochemical reactions, and he employed electrolysis to purify different metals. With Gustav Kirchhoff, he used spectroscopy to analyze and identify chemical elements.

Alexander Classen (German, 1843–1934) made important contributions to electrochemistry, including electrolytic gravimetry and rotating electrodes. The American Council of Learned Societies noted [ACLS 2000, p. 194]:

> First to make thorough study of electrogravimetric analysis (*Quantitative Analyse auf elektrolytischem Weg*, 1881); his innovative methods, which became standard practice, included use of warm solutions, introduction of measuring devices into the circuit, and substitution of storage cells for galvanic cells.

In 1850, Rudolf Clausius (German, 1822–1888) was the first to clearly articulate the second law of thermodynamics, that entropy cannot decrease, or equivalently that heat flows from regions of higher temperature to regions of lower temperature. He also did important work on phase transitions and other aspects of physical chemistry.

Peter Debye (Dutch, 1884–1966) studied and worked in Germany and Switzerland for many years. He developed statistical models of the behavior of molecules, chemical solutions, and crystalline solids. For his work, he won the Nobel Prize in Chemistry in 1936 (p. 914).

Manfred Eigen (German, 1927–2019) developed methods of measuring very fast chemical reactions. He won the Nobel Prize in Chemistry in 1967 for those innovations. Professor H. A. Ölander of the Nobel Committee for Chemistry announced the award [https://www.nobelprize.org/prizes/chemistry/1967/ceremony-speech/]:

> Professor Dr. Manfred Eigen. Although chemists had long been talking of instantaneous reactions, they had no way of determining the actual reaction rates. There were many very important reactions of this type, such as the neutralization of acids with alkalis. Thanks to you, chemists now have a whole range of methods that can be used to follow these rapid processes, so that this large gap in our chemical knowledge has now been filled.

Tibor Erdey-Grúz (Hungarian, 1902–1976) studied the electrochemistry of ionic conductivity, corrosion, and catalysis. Together with Max Volmer, he developed an equation describing the relation between voltage and current in electrolytic solutions.

Richard Ernst (Swiss, 1933–) developed nuclear magnetic resonance (NMR) spectroscopy methods that are useful for studying chemical molecules and biological systems. For that work, he won the Nobel Prize in Chemistry in 1991. Professor Sture Forsén of the Royal Swedish Academy of Sciences praised his research [https://www.nobelprize.org/prizes/chemistry/1991/ceremony-speech/]:

> Professor Ernst,
>
> You have played a leading role in several of the most significant methodological developments that have taken place in the field of NMR spectroscopy over the past two decades; developments that have had a lasting impact on the way modern chemistry is conducted. You have, in an admirable way, combined excellent experimental know-how with extraordinary theoretical insight. In recognition of your services to chemistry, and to natural science as a whole, the Royal Swedish Academy of Sciences has decided to confer upon you this year's Nobel Prize for Chemistry.

Joseph von Fraunhofer (German states, 1787–1826) invented the spectroscope and was the first to use spectroscopy to analyze chemical elements. Robert Bunsen and Gustav Kirchhoff later built upon his work on spectroscopic chemical analysis. Von Fraunhofer also made important innovations in the production of high-quality glass. See pp. 680, 961, and 1260.

In 1885, Carl Gassner (German, 1855–1942) demonstrated and patented the world's first dry batteries, which used zinc, carbon, and a paste electrolyte. See Fig. 3.126.

Heinz Gerischer (German, 1919–1994) began his research on electrochemistry during World War II and continued in that field for the rest of his career, making a number of major discoveries regarding electrode kinetics, electrode reactions, and electrode diagnostics. He also made important contributions to photochemistry.

Michael Grätzel (German, 1944–) invented dye-sensitized photoelectrochemical cells for converting sunlight to electricity more cheaply and efficiently than had previously been possible.

Theodor Grotthuß (German states, 1785–1822) conducted early experiments on electrolysis and developed the first theory of charge transport in electrolytes (now called the Grotthuß mechanism) in 1806. He also developed important early theoretical explanations of photochemical reactions.

Fritz Haber (German, 1868–1934) made tremendously important contributions not only to most other areas of chemistry, but also to physical chemistry, particularly with regard to electrochemistry, combustion, and chemical bond energies [Hager 2008; Stoltzenberg 1994; Szöllösi-Janze 2015]. He won the Nobel Prize in Chemistry in 1918 for his development of industrial-scale ammonia synthesis (p. 447).

Wilhelm Heinrich Heintz (German, 1817–1880) analyzed the physical structure of molecules, including fatty acids, uric acid, amines, and others. He also studied chemical reaction kinetics and the properties of a number of metals.

Frederik Wilhelm Hellesen (Danish but closely tied to the German-speaking research world, 1836–1892) produced dry zinc-carbon batteries in 1887.

Hermann von Helmholtz (German, 1821–1894) made foundational contributions to the thermodynamics of chemical reactions, most notably by defining what came to be known as the Helmholtz free energy. In 1847, he published a more detailed treatment of the first law of thermodynamics, *Über die Erhaltung der Kraft* (*On the Conservation of Energy*), and also studied the thermodynamics of fluids. Von Helmholtz also made major discoveries in biology (pp. 239, 282, 297, 311) and physics (p. 859) [Cahan 2018].

Gerhard Herzberg (German, 1904–1999) made important discoveries regarding molecular structures, molecular spectroscopy, and highly reactive free radical molecules. He won the Nobel Prize in Chemistry in 1971 for his work in those areas. Professor Stig Claesson of the Royal Swedish Academy of Sciences explained the importance of Herzberg's research [https://www.nobelprize.org/prizes/chemistry/1971/ceremony-speech/]:

> Herzberg began as a physicist and his first contributions to molecular spectroscopy were published at the end of the 1920's. In such investigations one measures how molecules absorb light-energy—also outside the visible region—i.e. in the ultraviolet and infrared. Since light-energy is packaged as quanta, these measurements can provide accurate information about energy contents in molecules. From this information their size, shape and other properties can be derived. Such calculations must be based on the description of matter given by quantum mechanics. The development of this subject during the 1920's and 30's is regarded as one of the most exciting periods in the history of physical science. Herzberg's elegant experimental investigations combined with his theoretical insight into their interpretation contributed to the progress of quantum mechanics while being decisive for the rapid development of molecular spectroscopy.
>
> One may now ask why Herzberg—originally a physicist and even famous as an astrophysicist—finally was awarded the Nobel Prize in chemistry.
>
> The explanation is that around 1950 molecular spectroscopy had progressed so far that one could begin to study even complicated systems of great chemical interest. This is brilliantly demonstrated by Herzberg's pioneering investigations of free radicals. Knowledge of their properties is of fundamental importance to our understanding of

> how chemical reactions proceed.
>
> For a chemical reaction to occur the original molecules must in some way break up into fragments which rearrange to form the new molecules. These fragments, or intermediates, are called free radicals.
>
> Free radicals are very difficult to study due to their short life-times—measured in millionths of a second. Herzberg therefore had ample opportunity to repeatedly demonstrate his exceptional experimental skill when the necessary spectroscopic technique was worked out.
>
> Herzberg has so far performed extensive precision determinations of the properties of over thirty free radicals among which are to be found the radicals methyl and methylene—well known from organic chemistry. Among his exciting discoveries may be mentioned that radicals drastically change their shape with increasing energy. For example, methylene is linear in its ground state but bent in states of higher energy. Many of the most important results were only achieved after several years' work and some of the most exciting as late as at the end of the 1960's. One can therefore note that this year's prize is truly an award for contributions of great current interest.

In 1840, Germain Hess (Swiss, 1802–1850) formulated what is now known as Hess's law, a form of the first law of thermodynamics (conservation of energy) applied to a series of chemical reactions. He also studied the thermodynamics of the dissolution of various salts in water.

Jaroslav Heyrovský (Austrian/Czech, 1890–1967) developed polarographic and electroanalytic methods of analyzing chemical samples. For those innovations, he won the Nobel Prize in Chemistry in 1959. The Royal Swedish Academy of Sciences summarized his work [https://www.nobelprize.org/prizes/chemistry/1959/ceremony-speech/]:

> Chemical and electrical phenomena are often associated, as in the case of redox reactions, when electrons are emitted and absorbed. In 1922 Jaroslav Heyrovský discovered a method for analyzing the occurrence and content of various substances in solutions using electrical measurements. The solution is analyzed with two electrodes, one of which is a dropping mercury electrode. At a voltage specific for different substances, redox reactions cause the current to rapidly increase to a level dependent on the concentration of the substance.

Johann Wilhelm Hittorf (German, 1824–1914) conducted very careful electrolytic experiments to measure the mobilities of different ions in solution, the values of which are now called Hittorf ion transport numbers. He was also one of the earliest scientists to experiment with high-voltage tubes and electron beams (p. 862).

Roald Hoffmann (born Roald Safran, Polish, 1937–) made important discoveries regarding the behavior of electrons in chemical bonds, for which he won the Nobel Prize in Chemistry in 1981. The Royal Swedish Academy of Sciences described his research [https://www.nobelprize.org/prizes/chemistry/1981/ceremony-speech/]:

> In chemical reactions, molecules composed of atoms meet and form new compounds. Electrons orbiting around the atoms' nuclei play an important role here. After Kenichi

> Fukui proved that the properties of the electron orbits that most weakly bound to the atom are critical in chemical reactions, Roald Hoffmann went on to further develop these theories from the mid-1960s. Independently of one another, Roald Hoffmann and Kenichi Fukui both demonstrated how the symmetrical properties of electron orbitals explain the course of chemical reactions.

Erich Hückel (German, 1896–1980) developed the Hückel molecular orbital theory to explain double and triple covalent bonds in molecules. He also worked with Peter Debye to create the Debye-Hückel theory of electrolytic solutions. Oxford University's *Biographical Dictionary of Scientists* summarized some of his research accomplishments [Porter 1994, pp. 350–351]:

> Debye and Hückel suggested that strong electrolytes dissociate completely into ions, explaining the deviations from expected behaviour in terms of attraction and repulsion between the ions. In a series of highly mathematical investigations they found formulae for calculating the electrical and thermodynamic properties of electrolytic solutions, principally dilute solutions of strong electrolytes. [...]
>
> In 1930, Hückel began his work on aromaticity, the basis of the chemical behaviour of benzene, pyridine and similar compounds. The benzene molecule is held together by electrons that are delocalized and contribute to one large hexagonal bond above and below the plane of the molecule. This accounts for its planar shape and its ability to preserve its structure through chemical reactions. Hückel developed a mathematical approximation for the evaluation of certain integrals in the calculations concerned with the exact nature of the bonding in benzene.
>
> Later in the 1930s, he extended his research to other chemical systems that appear to possess the same kind of aromatic nature as benzene (although usually to a lower degree). From this study emerged the Hückel rule for monocyclic systems[...]
>
> Hückel also carried out research into unsaturated compounds (those with double or triple bonds) and into the chemistry of free radical compounds (those with a free, non-bonding electron).

In 1899, Ernst Waldemar Jungner (Swedish but closely tied to the German-speaking research world, 1869–1924) created nickel-cadmium, nickel-iron, and silver cadmium rechargeable batteries (Fig. 3.127). He also developed improved fuel cells and electrolytic systems. Nickel-cadmium and other rechargeable batteries were mass-produced and harnessed for a variety of applications in the German-speaking world.

Karl Kellner (Austrian, 1851–1905) developed an industrial electrolytic process for producing chlorine gas and sodium hydroxide, both of which were useful reagents for manufacturing other commercial chemical products.

Gustav Kirchhoff (German, 1824–1887) derived equations to predict the heat of reaction in thermochemistry. Working with Robert Bunsen, he used spectroscopy to analyze and identify chemical elements. Kirchhoff made major discoveries in many areas of chemistry, physics, and engineering (see also pp. 427, 858, 915, 945, and 957).

Friedrich Kohlrausch (German, 1840–1910), the son of Rudolf Kohlrausch (p. 859), was an experimentalist who worked on a wide range of topics in chemistry, physics, and physical chemistry over his career. He developed and used accurate methods of measuring the electrical conductivity of electrolytes, and he also studied the properties of mercury. In addition, he developed experimental techniques and instruments for measuring thermal conductivity, elasticity, magnetic fields, and optical properties.

Walter Kohn (Austrian, 1923–2016) developed new methods to calculate the behavior of electrons in large molecules and in solid materials. For that work, he won the Nobel Prize in Chemistry in 1998, as explained by Professor Björn Roos of the Royal Swedish Academy of Sciences [https://www.nobelprize.org/prizes/chemistry/1998/ceremony-speech/]:

> In two landmark articles from 1964 and 1965, Walter Kohn showed an alternative way in which quantum mechanical equations can be approximated. He showed that there is a one-to-one correspondence between the energy of a quantum mechanical system and its electron density, which is a function of three positional coordinates only and is, therefore, much easier to handle than the complicated wave function, which depend on the positions of all electrons. He also developed a method which made it possible to construct a set of equations, which could be used to determine the energy and electron density. This approach, called density functional theory, has developed during the last ten years into a versatile computational tool with many applications in chemistry. Due to its simplicity, it can be applied to larger molecules than the wave function based methods. Density functional theory has made it possible to study the mechanisms of chemical reactions in enzymes, for example when water is transformed into oxygen in photosynthesis.

Hermann Kolbe (German, 1818–1884) developed methods of using electrolysis with carboxylic acids and fatty acids, now called Kolbe electrolysis. He was also one of the founders of organic chemistry (p. 471).

Karl Kordesch (Austrian, 1922–2011) worked on advanced battery programs in wartime and early postwar Austria, then came to the United States as part of Operation Paperclip. Drawing upon his experience with advanced battery research in Austria, he headed the battery development program at the U.S. Army's Fort Monmouth laboratory, then headed two Union Carbide groups to develop fuel cells and batteries in parallel. He and the other members of his Union Carbide battery group filed the first patents on alkaline (manganese dioxide) dry batteries (Fig. 3.129). He also invented hydrazine-air fuel cells and developed thin carbon electrodes that revolutionized hydrogen-oxygen fuel cells (Fig. 3.130). In view of the great importance that the United States placed on importing Kordesch in Operation Paperclip, putting him in charge of a battery development program for the Army, and placing him in charge simultaneously of two different programs at Union Carbide, it seems highly likely that Kordesch's postwar U.S. projects were based on earlier discoveries by him or others in Austria and Germany. It is difficult to trace that history from the publicly available documentation, but more archival research in this area could be quite enlightening.

Irving Langmuir (American but studied in Germany, 1881–1957) did important work on surface chemistry, the study of chemical reactions that occur at the surface of a liquid or solid. For his discoveries, he won the Nobel Prize in Chemistry in 1932. The Royal Swedish Academy of Sciences described Langmuir's research [https://www.nobelprize.org/prizes/chemistry/1932/langmuir/facts/]:

> Chemical reactions often take place more easily next to surfaces where substances in different phases, such as solids and gases, come in contact. In studies of incandescent

> light bulbs with rarefied hydrogen gas, Irving Langmuir discovered that a layer of hydrogen atoms only one atom thick formed on the inside of the incandescent light bulb. Further studies of oil films and other materials led him in 1917 to a theory postulating that surfaces resemble a chessboard on which every square can be occupied by only one atom or molecule. As a result, atoms or molecules that wind up next to each other can more easily react with one another.

Max Le Blanc (German, 1865–1943) created many innovations in electrochemistry, including the hydrogen electrode for pH measurement, control of voltage during electrolysis to selectively deposit different metals, and improved methods of measuring voltages and currents in solutions.

Johann Josef Loschmidt (Austrian, 1821–1895) studied the physical structures and sizes of molecules. He developed methods to determine the number of gas molecules within a given volume of air. In his honor, that number for standard temperature and pressure is now called the Loschmidt constant, approximately 2.69×10^{25} molecules/m^3 at 0^oC and 1 atmosphere of pressure. Loschmidt also used the then-new second law of thermodynamics in theoretical explanations of the behavior of chemical compounds and solutions.

Julius von Mayer (German, 1814–1878) expressed the first law of thermodynamics, the law of conservation of energy (including heat energy and work), in 1841. He was also the first to find equations for the specific heat of an ideal gas, or the relationship between the amount of heat energy absorbed by a substance and the corresponding temperature rise for that substance. He was one of the first to attempt a scientific analysis of photosynthesis, and he created Mayer's reagent for detecting alkaloids.

Karl Friedrich Mohr (German, 1806–1879) developed improved methods of volumetric analysis and chemical titration. In an 1837 journal article, he became the first known scientist to state the first law of thermodynamics (conservation of energy) [Mohr 1837]:

> Ausser den bekannten 54 chemischen Elementen gibt es in der Natur der Dinge nur noch ein Agens, und dieses heisst Kraft; es kann unter den passenden Verhältnissen als Bewegung, chemische Affinität, Cohäsion, Elektricität, Licht, Wärme und Magnetismus hervortreten, und aus jeder dieser Erscheinungsarten können alle übrigen hervorgebracht werden.

> Apart from the known 54 chemical elements, there is only one agent in the physical world, and this is called energy; it can appear under the appropriate conditions as motion, chemical affinity, cohesion, electricity, light, heat, and magnetism, and from any one of these forms it can be transformed into any of the others.

Ludwig Mond (German, 1839–1909) developed and improved electrochemical methods for extracting and depositing nickel and other metals. Mond also founded the field of organometallic chemistry (p. 497).

Adolph Müller (German, 1852–1928) was responsible for first producing lead-acid storage batteries on an industrial scale in Germany in 1886. His battery company became known as Accumulatoren Fabrik Aktiengesellschaft Berlin-Hagen (AFA) until 1945, and as VARTA (Vertrieb, Aufladung, Reparatur transportabler Akkumulatoren) after 1945.

Walther Nernst (German, 1864–1941) was one of the founders of the field of physical chemistry. He made important discoveries regarding the statistical physics underlying thermodynamics, chemical reactions, electrochemistry, and the physics of solids. He derived the Nernst equation relating voltages and ion concentrations in electrochemistry. In 1905, he discovered the third law of thermodynamics (as a system approaches absolute zero temperature, its entropy approaches a constant value), for which he won the Nobel Prize in Chemistry in 1920 (p. 913).

Wilhelm Ostwald (German, 1853–1932) was another founder of the field of physical chemistry. He developed statistical methods that were applicable to thermodynamic processes in both chemistry and physics. He also made key discoveries regarding the dissociation constants of electrolytes (Ostwald's dilution law) and polymorphism in solid materials (Ostwald's rule). Ostwald's work earned him the Nobel Prize in Chemistry in 1909 (p. 913).

In 1842, Johann Christian Poggendorff (German, 1796–1877) invented an improved battery, now called the Poggendorff cell, that used chromic acid as the electrolyte. Poggendorff also developed and used a number of sensitive instruments for measuring voltage, current, and other parameters in electrochemistry experiments.

John Polanyi (German/Hungarian, 1929–) is the son of Michael Polanyi. He won the Nobel Prize in Chemistry in 1986 for developing methods of using infrared chemiluminescence and other techniques to make high-speed measurements of chemical reactions as they occur. The Royal Swedish Academy of Sciences explained his work [https://www.nobelprize.org/prizes/chemistry/1986/ceremony-speech/]:

> Chemical reactions in which molecules comprised of atoms collide and form new compounds represent one of nature's fundamental processes. At the end of the 1950s John Polanyi began developing methods to carefully study the dynamics of chemical reactions. During chemical reactions, the newly formed molecules are sometimes infused with energy that then is emitted in the form of infrared light. By measuring this very weak radiation, the quantum mechanical energy state of the molecules can be determined and the reaction mapped.

Michael Polanyi (Hungarian, 1891–1976) made major discoveries in many areas of physical chemistry, including the kinetics of chemical reactions, X-ray diffraction, the adsorption of gases by solids, fiber diffraction analysis, and the theory of dislocations in materials under plastic deformation. He also made important contributions in a number of other fields, including medicine, economics, philosophy, and epistemology. He was the father of John Polanyi. The American Council of Learned Societies summarized his contributions to physical chemistry [ACLS 2000, p. 717]:

> Earned his Ph.D. from the University of Budapest in 1917 with a dissertation on the thermodynamics of gas adsorption. In 1920 he was hired by the Kaiser Wilhelm Institute for Fiber Chemistry in Berlin, where he did research on plant fibers, using X-ray diffraction. At the Kaiser Wilhelm Institute for Physical Chemistry, which he joined in 1923, he established his well-known dislocation theory. His work with Eugene Wigner concerned the uncertainty principle for angular momentum and the absolute rate of unimolecular dissociation. In 1933 he immigrated to England, where his main work was in reaction kinetics. At the University of Manchester, he helped develop the theory of bimolecular activation energy and the theory of absolute rates of reaction; he also did studies on ionic reactions in solution, on bond dissociation energies, and on the mechanism of polymerization.

Hans Preis (Swiss, 18??–19??) worked together with Emil Bauer to develop the first fuel cell with a solid electrolyte, in this case one made of paste and metal oxides.

Johann Ritter (Prussian/Bavarian, 1776–1810) built the first or one of the first electrolysis cells around 1800 and studied the electrolysis of water. He also built and conducted experiments with very early batteries. In addition, Ritter discovered ultraviolet light in 1801 (p. 961).

Beginning in 1896, Paul Schmidt (German, 1868–1948, not to be confused with the later designer of the V-1 cruise missile's pulsejet engine) mass-produced zinc-carbon dry batteries and founded the Daimon electronics company.

Christian Schönbein (German states, 1799–1868) invented and demonstrated the first fuel cells (using hydrogen and oxygen) no later than 1838, as shown in Fig. 3.124. He also discovered ozone and did groundbreaking work in explosives (p. 528) and chromatography (p. 711).

Wilhelm Sinsteden (German, 1803–1891) invented and demonstrated lead-acid rechargeable batteries during the period 1850–1854, published his results in 1854 (Fig. 3.125), and studied many other areas of electricity and electrical components.

While Otto Stern (German, 1888–1969) is more famous for his physics experiments (p. 897), he made several important contributions to physical chemistry. He discovered what is now known as the Stern electrochemical double layer, developed the Stern-Volmer equation for photochemical reaction kinetics with Max Volmer, and studied entropy and statistical effects in chemical systems.

Ignatz Stroof (German, 1838–1920) developed industrial-scale electrolysis systems for producing chemical elements of high purity.

Julius Tafel (Swiss, 1862–1918) made several discoveries in electrochemistry that are now named after him, such as the Tafel equation relating voltage and the electrochemical reaction rate, the Tafel mechanism for catalytic hydrogen production, and the Tafel rearrangement for electrochemical hydrocarbon synthesis.

Jacobus van 't Hoff (Dutch, 1852–1911) was another founder of the field of physical chemistry, making vital discoveries regarding chemical affinity, chemical equilibrium, chemical kinetics, chemical thermodynamics, osmotic pressure in solutions, and stereochemistry. In 1901, he became the first winner of the Nobel Prize in Chemistry (p. 475).

Max Volmer (German, 1885–1965) made several contributions to physical chemistry. One was discovering what is now known as Volmer diffusion of adsorbed molecules. Working with Tibor Erdey-Grúz, he also developed an equation describing the relation between voltage and current in electrolytic solutions. With Otto Stern, he developed the Stern-Volmer equation describing the kinetics of photochemical reactions. Moreover, Volmer played an important role in the wartime German nuclear program (Section 8.8) and the postwar Soviet nuclear program (Section 8.9).

In 1874, Emil Wohlwill (German, 1835–1912) invented what is now known as the Wohlwill process, an electrochemical process for refining gold or silver to very high purity, which is still used today. He was the father of Heinrich Wohlwill.

Heinrich Wohlwill (German, 1874–1943) was the son of Emil Wohlwill. He invented an electrolytic process for purifying and recycling copper, and became the technical director of Norddeutsche Affinerie to apply that process on an industrial scale. Unfortunately he was taken to the Theresienstadt concentration camp in 1942 and died there in 1943.

Kurt Wüthrich (Swiss, 1938–) developed methods to use nuclear magnetic resonance (NMR) to study large molecules. For that work, he won the Nobel Prize in Chemistry in 2002. Professor Astrid Gräslund of the Royal Swedish Academy of Sciences emphasized the importance of his innovations [https://www.nobelprize.org/prizes/chemistry/2002/ceremony-speech/]:

> Using nuclear magnetic resonance, or NMR, a method that Kurt Wüthrich has further refined, it is now possible to determine the three-dimensional structure of protein molecules in a water solution. NMR is one of the chemist's best methods for examining molecules, and it has been used extensively for small molecules since the mid-20th century. But large molecules like proteins involve special problems. One of the fine points of NMR is that it enables us to see individual signals, for example, from each hydrogen nucleus in a molecule. But because a protein can contain thousands of hydrogen nuclei, how do you know which signal belongs to which nucleus?
>
> Wüthrich devised a way of systematically determining how each signal fits together with its special hydrogen nucleus. In the bargain, he was also able to determine a large number of pairwise distances between hydrogen nuclei. This enabled him to calculate a three-dimensional structure for the protein molecule. It is something like drawing a picture of a house if you know a large number of distances in the house. So thanks to Wüthrich's discovery, we can now use NMR to examine and depict proteins in their natural environment, surrounded by water like in a cell.

Physical chemistry

Hermann Aron
(1845–1913)

Svante Arrhenius
(1859–1927)

Emil Bauer
(1873–1944)

Henri Bernard Beer
(1909–1994)

Jürgen Besenhard
(1944–2006)

Ludwig Boltzmann
(1844–1906)

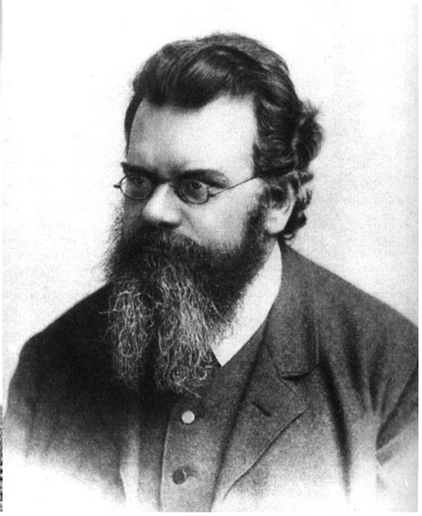


Figure 3.114: Some creators who made important contributions to physical chemistry included Hermann Aron, Svante Arrhenius, Emil Bauer, Henri Bernard Beer, Jürgen Besenhard, and Ludwig Boltzmann.

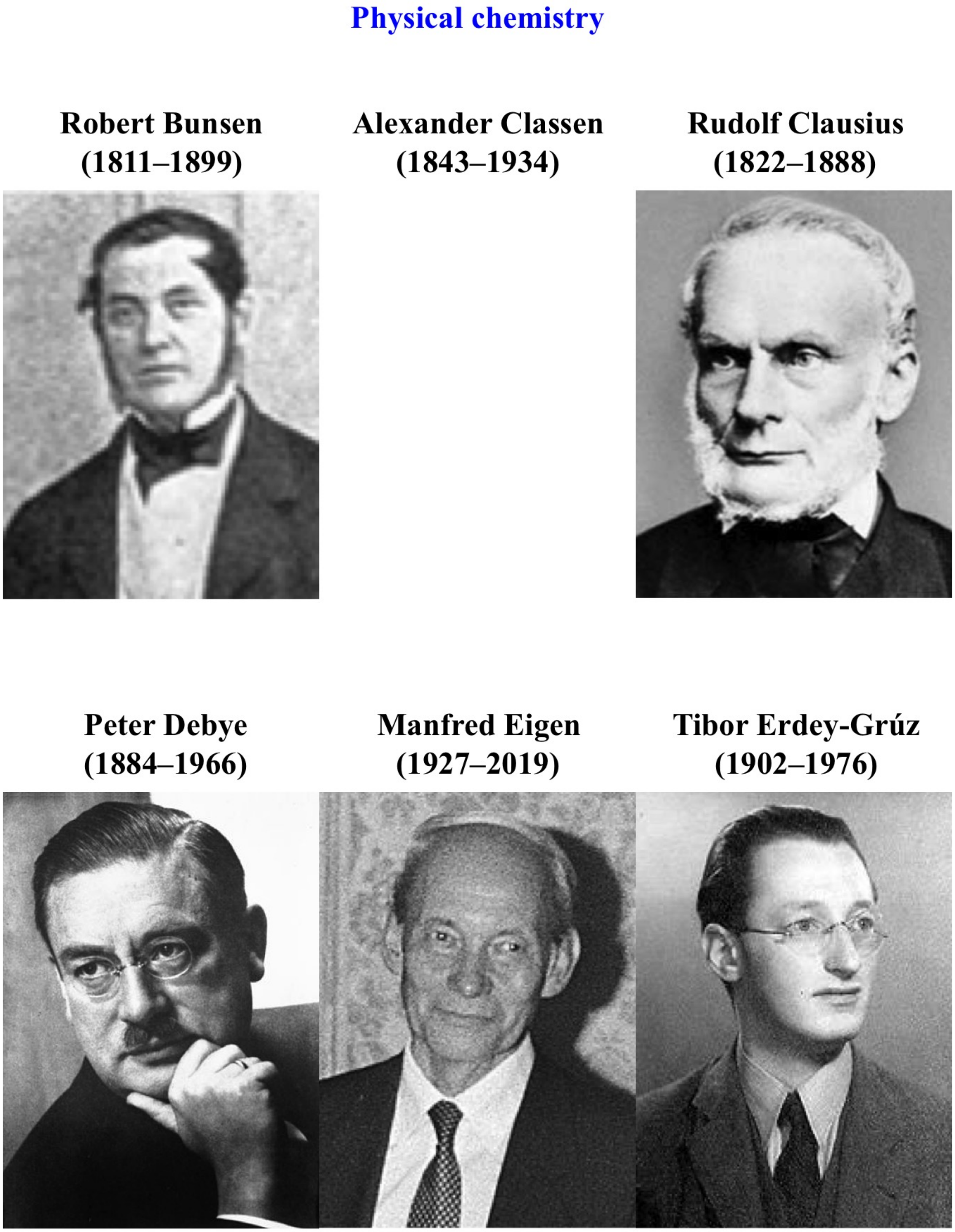

Physical chemistry
Robert Bunsen
(1811–1899)
Alexander Classen
(1843–1934)
Rudolf Clausius
(1822–1888)
Peter Debye
(1884–1966)
Manfred Eigen
(1927–2019)
Tibor Erdey-Grúz
(1902–1976)

Figure 3.115: Other creators who made important contributions to physical chemistry included Robert Bunsen, Alexander Classen, Rudolf Clausius, Peter Debye, Manfred Eigen, and Tibor Erdey-Grúz.

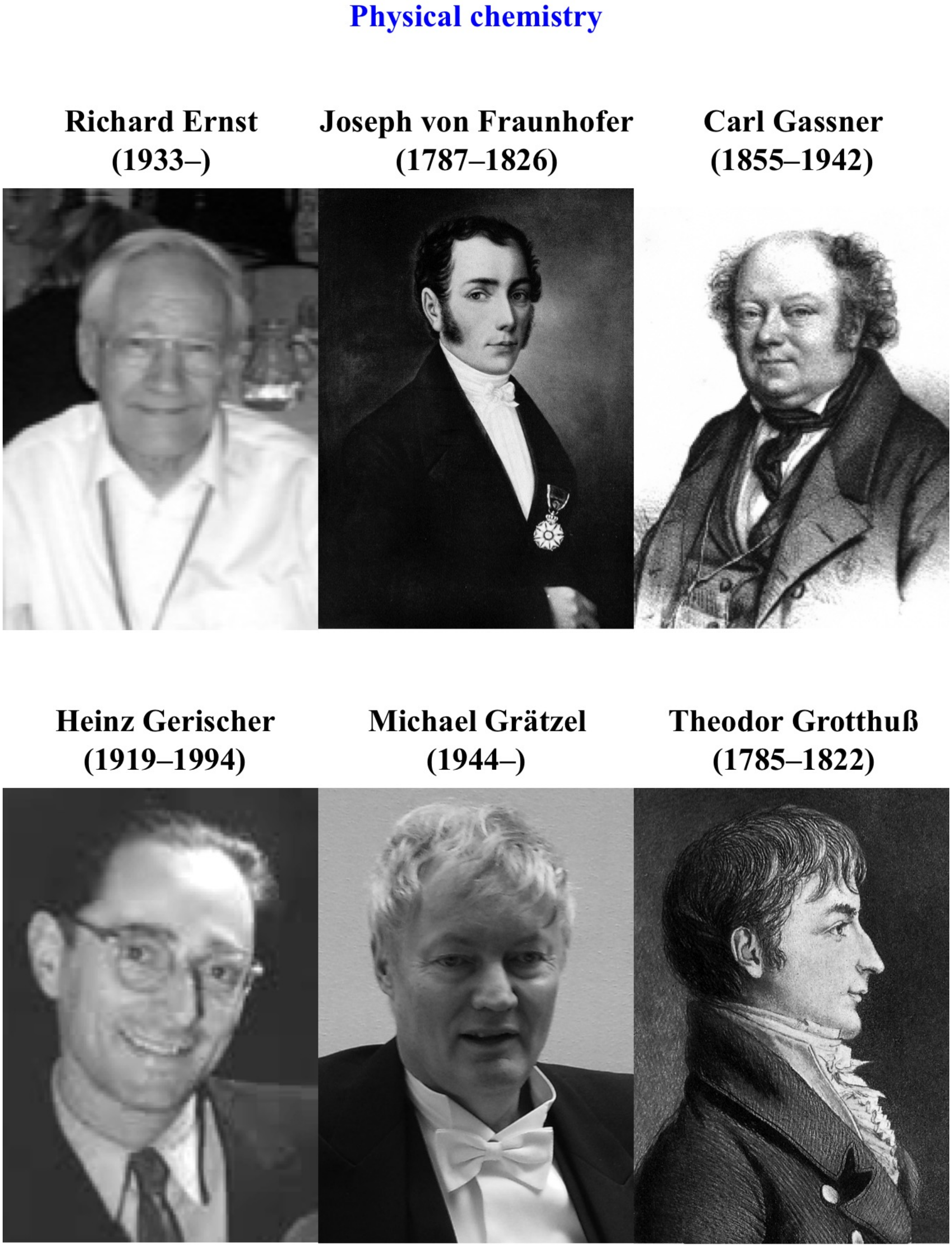

Physical chemistry
Richard Ernst
(1933–)
Joseph von Fraunhofer
(1787–1826)
Carl Gassner
(1855–1942)
Heinz Gerischer
(1919–1994)
Michael Grätzel
(1944–)
Theodor Grotthuß
(1785–1822)

Figure 3.116: Other creators who made important contributions to physical chemistry included Richard Ernst, Joseph von Fraunhofer, Carl Gassner, Heinz Gerischer, Michael Grätzel, and Theodor Grotthuß.

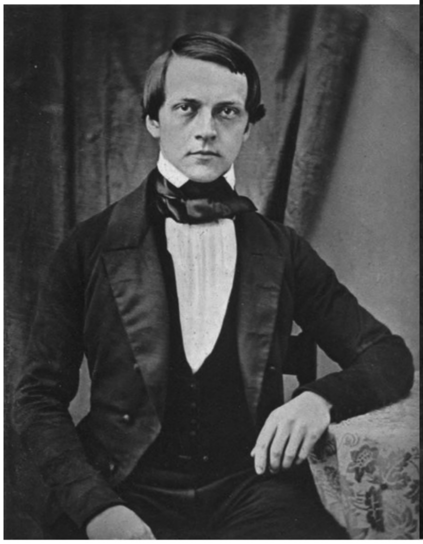
Physical chemistry

Fritz Haber
(1868–1934)

Wilhelm Heintz
(1817–1880)

Frederik Wilhelm
Hellesen
(1836–1892)

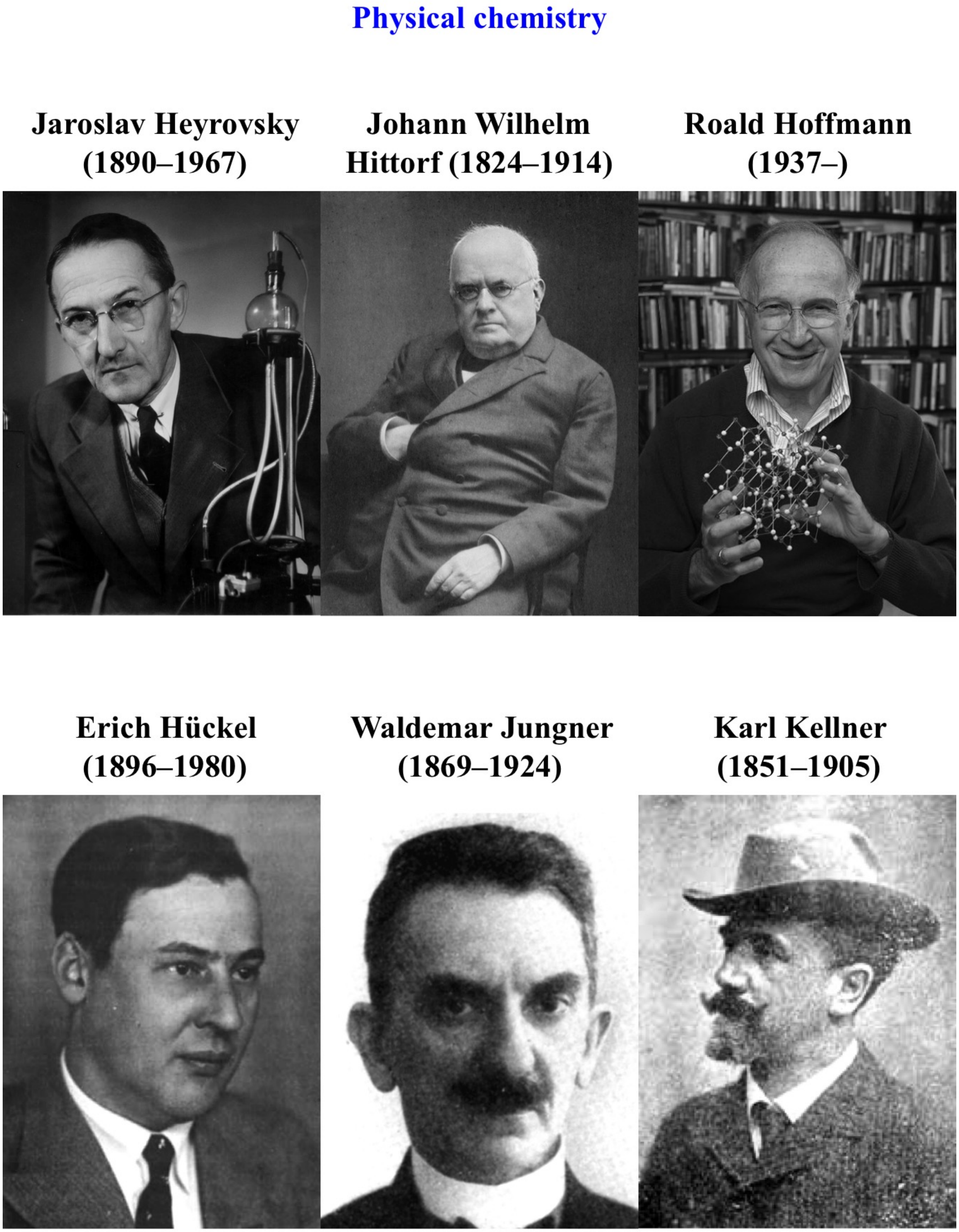
Hermann
von Helmholtz
(1821–1894)



Gerhard Herzberg
(1904–1999)

Germain Hess
(1802–1850)

Figure 3.117: Other creators who made important contributions to physical chemistry included Fritz Haber, Wilhelm Heintz, Frederik Wilhelm Hellesen, Hermann von Helmholtz, Gerhard Herzberg, and Germain Hess.



Physical chemistry
Jaroslav Heyrovsky (1890–1967)
Johann Wilhelm Hittorf (1824–1914)
Roald Hoffmann (1937–)
Erich Hückel (1896–1980)
Waldemar Jungner (1869–1924)
Karl Kellner (1851–1905)

Figure 3.118: Other creators who made important contributions to physical chemistry included Jaroslav Heyrovský, Johann Wilhelm Hittorf, Roald Hoffmann, Erich Hückel, Waldemar Jungner, and Karl Kellner.

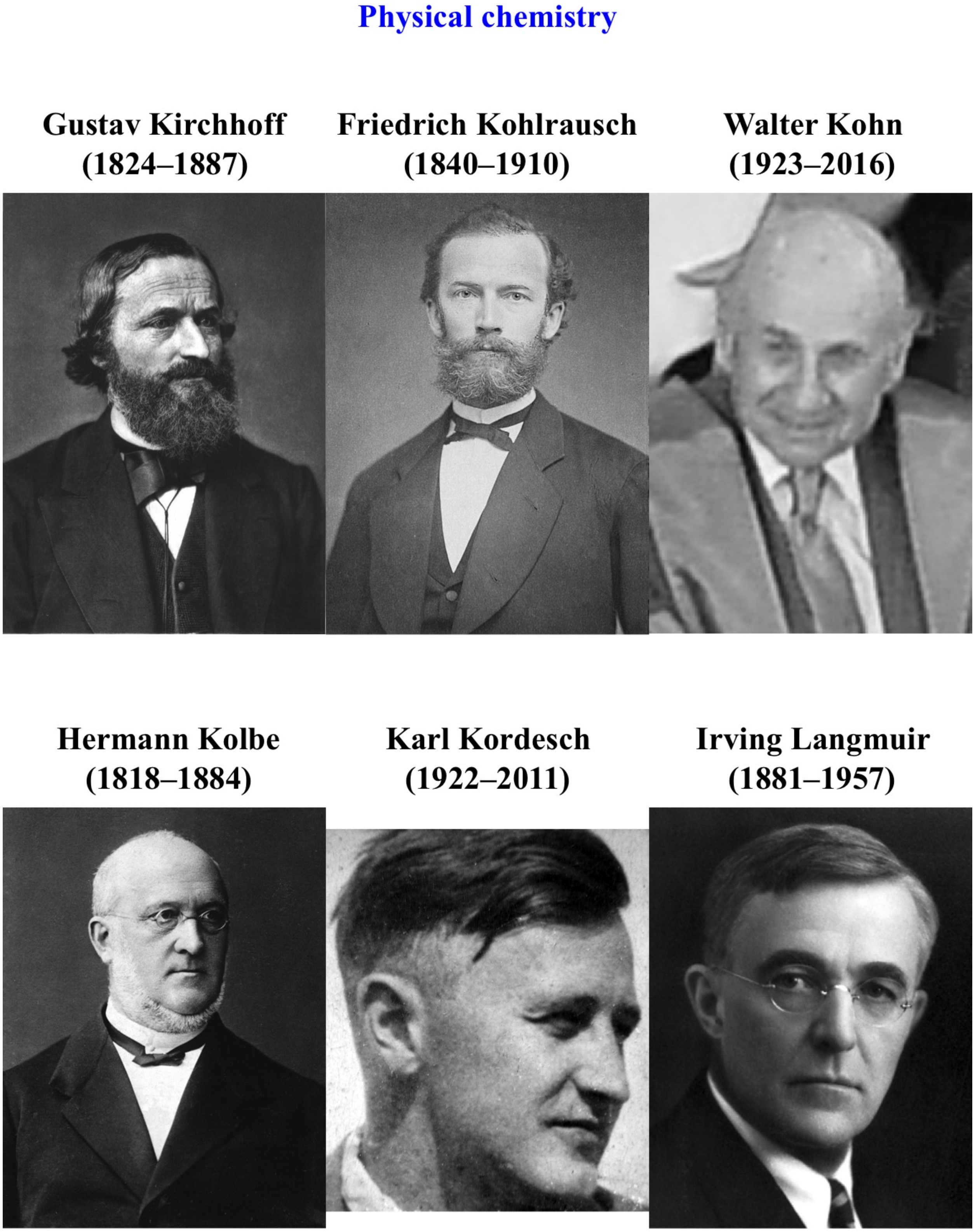

Physical chemistry
Gustav Kirchhoff (1824–1887)
Friedrich Kohlrausch (1840–1910)
Walter Kohn (1923–2016)
Hermann Kolbe (1818–1884)
Karl Kordesch (1922–2011)
Irving Langmuir (1881–1957)

Figure 3.119: Other creators who made important contributions to physical chemistry included Gustav Kirchhoff, Friedrich Kohlrausch, Walter Kohn, Hermann Kolbe, Karl Kordesch, and Irving Langmuir.

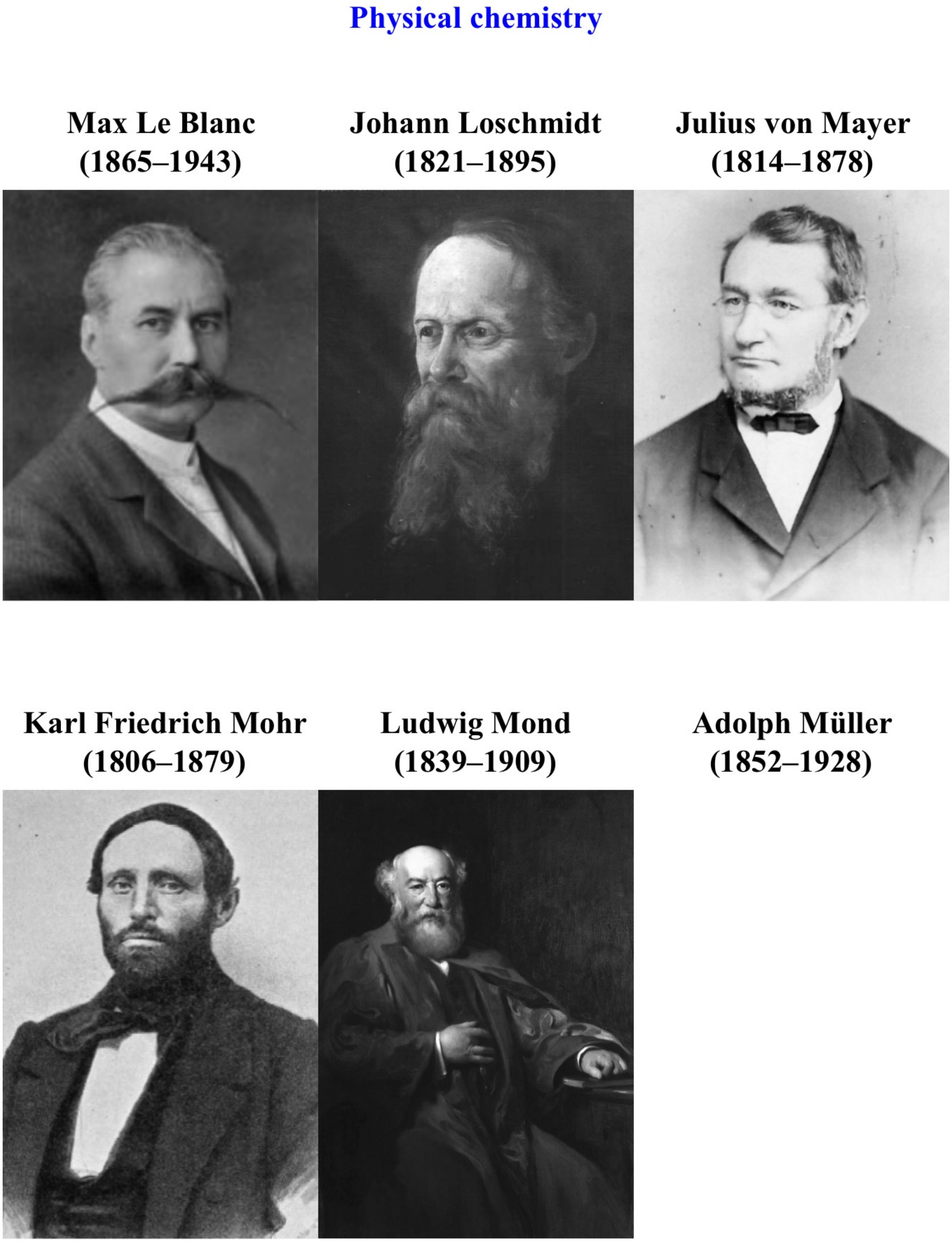
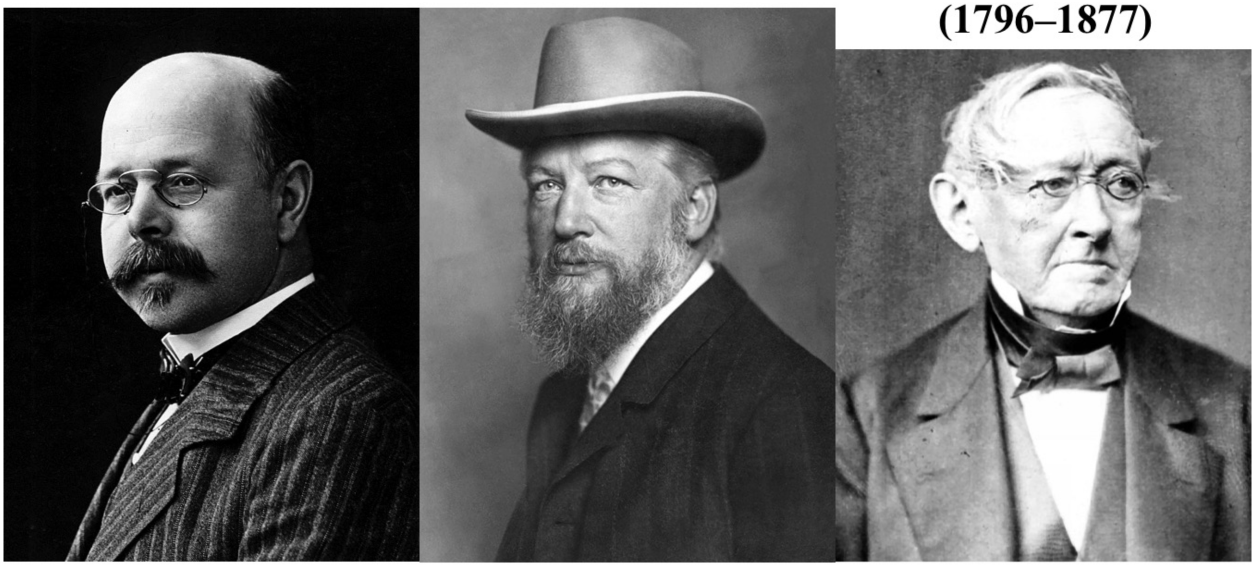

Physical chemistry
Max Le Blanc (1865–1943)
Johann Loschmidt (1821–1895)
Julius von Mayer (1814–1878)
Karl Friedrich Mohr (1806–1879)
Ludwig Mond (1839–1909)
Adolph Müller (1852–1928)

Figure 3.120: Other creators who made important contributions to physical chemistry included Max Le Blanc, Johann Loschmidt, Julius von Mayer, Karl Friedrich Mohr, Ludwig Mond, and Adolph Müller.

Physical chemistry



**Walther Nernst
(1864–1941)**

**Wilhelm Ostwald
(1853–1932)**

**Johann Christian
Poggendorff
(1796–1877)**

**John Polanyi
(1929–)**

**Michael Polanyi
(1891–1976)**

**Hans Preis
(18??–19??)**

Figure 3.121: Other creators who made important contributions to physical chemistry included Walther Nernst, Wilhelm Ostwald, Johann Christian Poggendorff, John Polanyi, Michael Polanyi, and Hans Preis.

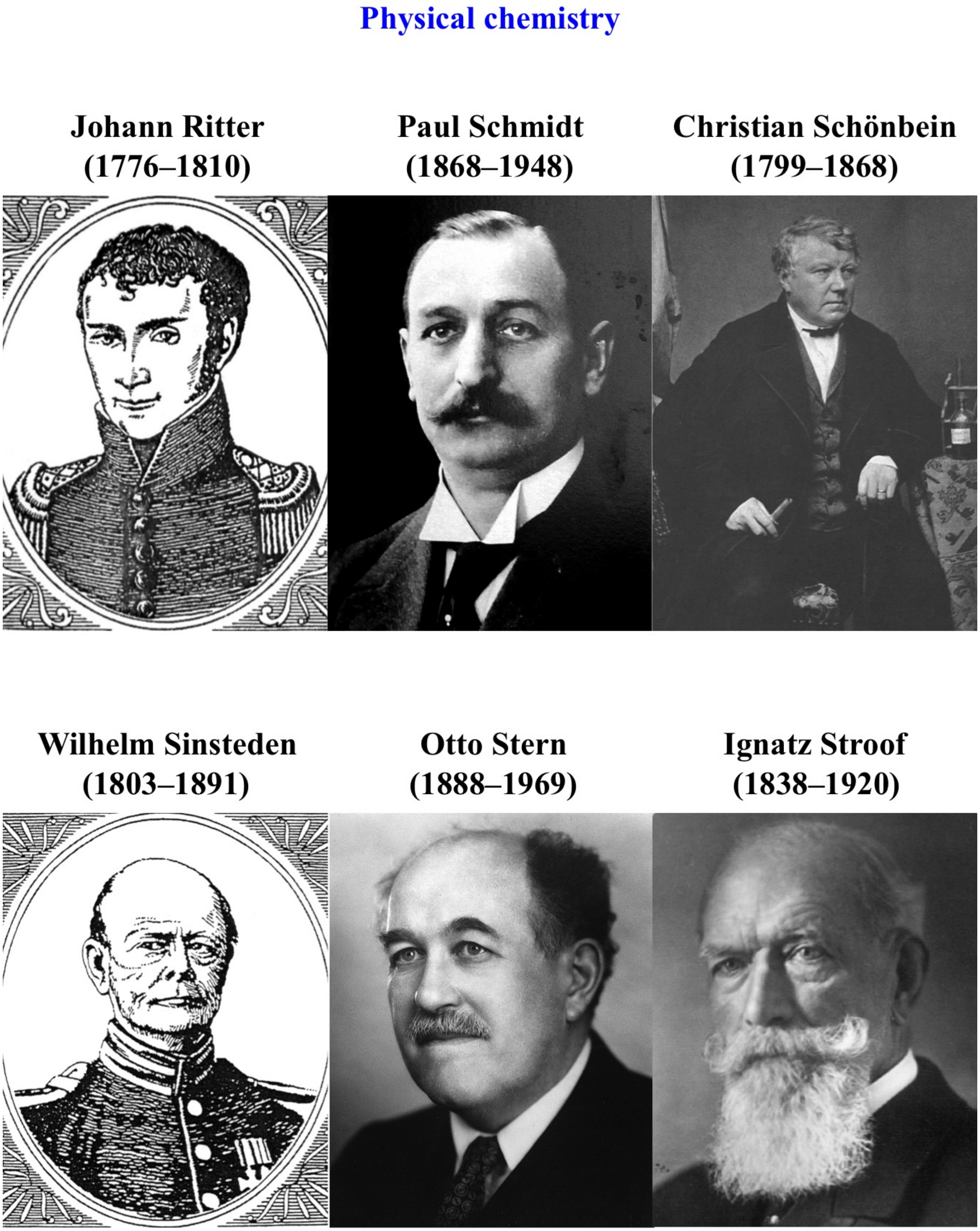

Physical chemistry
Johann Ritter
(1776–1810)
Paul Schmidt
(1868–1948)
Christian Schönbein
(1799–1868)
Wilhelm Sinsteden
(1803–1891)
Otto Stern
(1888–1969)
Ignatz Stroof
(1838–1920)

Figure 3.122: Other creators who made important contributions to physical chemistry included Johann Ritter, Paul Schmidt, Christian Schönbein, Wilhelm Sinsteden, Otto Stern, and Ignatz Stroof.

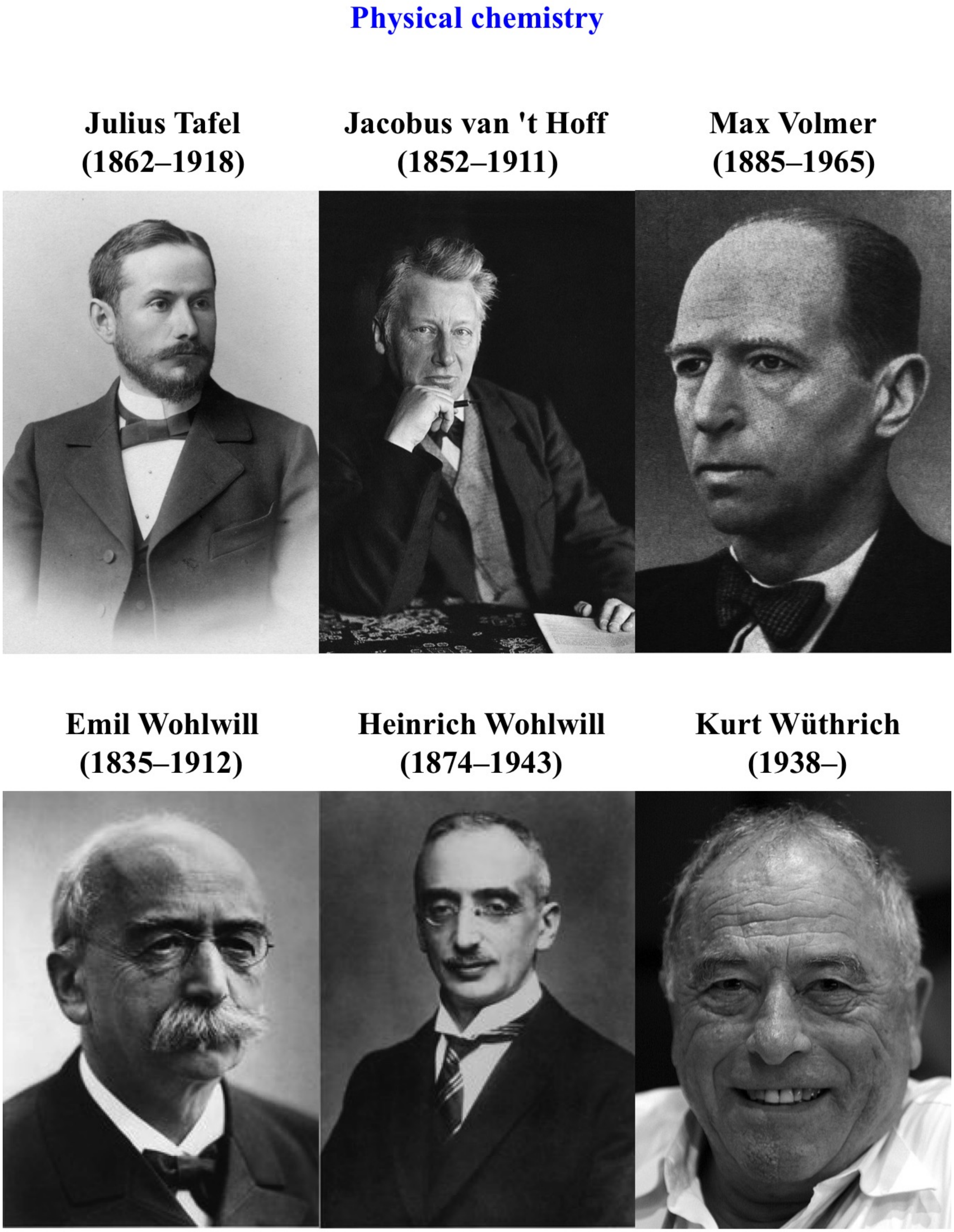

Physical chemistry
Julius Tafel (1862–1918)
Jacobus van 't Hoff (1852–1911)
Max Volmer (1885–1965)
Emil Wohlwill (1835–1912)
Heinrich Wohlwill (1874–1943)
Kurt Wüthrich (1938–)

Figure 3.123: Other creators who made important contributions to physical chemistry included Julius Tafel, Jacobus van 't Hoff, Max Volmer, Emil Wohlwill, Heinrich Wohlwill, and Kurt Wüthrich.

3.6.2 Batteries and Fuel Cells

Most modern battery and fuel cell technologies were invented and developed in the German-speaking world, as discussed above for individual creators and as shown in Figs. 3.124–3.130. Advanced German battery technologies were used for everything from the world's first hybrid electric automobiles in 1900 (p. 1353) to electric submarines in World Wars I and II (p. 1458).

Many of those battery technologies were transferred out of the German-speaking world before 1945 in the form of patents, commercial transactions, and immigrant scientists. However, there were a number of additional, advanced battery and fuel cell technologies that were transferred out of the German-speaking world in the immediate aftermath of World War II (Fig. 3.128), as shown by numerous reports such as:

> BIOS 307. *German Secondary Batteries (with Special Reference to Those Used by Army Signals).*
>
> BIOS 362. *German Primary Battery Industry.*
>
> BIOS 384. *German Battery Electric Vehicles and the German Storage Battery Industry.*
>
> BIOS 467. *German Secondary Battery Industry.*
>
> BIOS 490. *Primary Battery Development by the Chemische-Physikalische Versuchsanstalt, Danisch Nienhof.*
>
> BIOS 557. *Visits to Radio Targets in Germany.*
>
> BIOS 1097. *German Battery Electric Road Vehicles.*
>
> CIOS XXX-53. *German Development of the Primary Battery.*
>
> CIOS XXXII-81. *The Manufacture of Hard Rubber Parts for Storage Batteries.*
>
> FIAT 615. *Battery Production Capacities for Automotive Purposes in Germany.*
>
> FIAT 670. *Survey of a New Storage Battery.*
>
> FIAT 800. *Nickel Cadmium Storage Batteries in Germany.*
>
> NavTecMisEu 210-45. *Submarine Batteries The Accumulaturen Fabrik AG Hagen—Hannover Plants.*
>
> NavTecMisEu 211-45. *Torpedo Propulsion Batteries (Secondary) The Accumulatoren Fabrik, AG Hagon—Hannover Plants.*
>
> NavTecMisEu 212-45. *Aircraft Batteries (Lead and Alkaline) The Accumulatoren Fabrick AG Hagon—Hannover Plants.*

NavTecMisEu 213-45. *Manufacture of Hard Rubber Parts for Storage Batteries and Battery Ventilating Equipment for German Submarines.*

NavTecMisEu 283-45. *German Development of the Primary Battery.*

NavTecMisEu 310-45. *German Submarine Battery Installation and Battery Ventilation.*

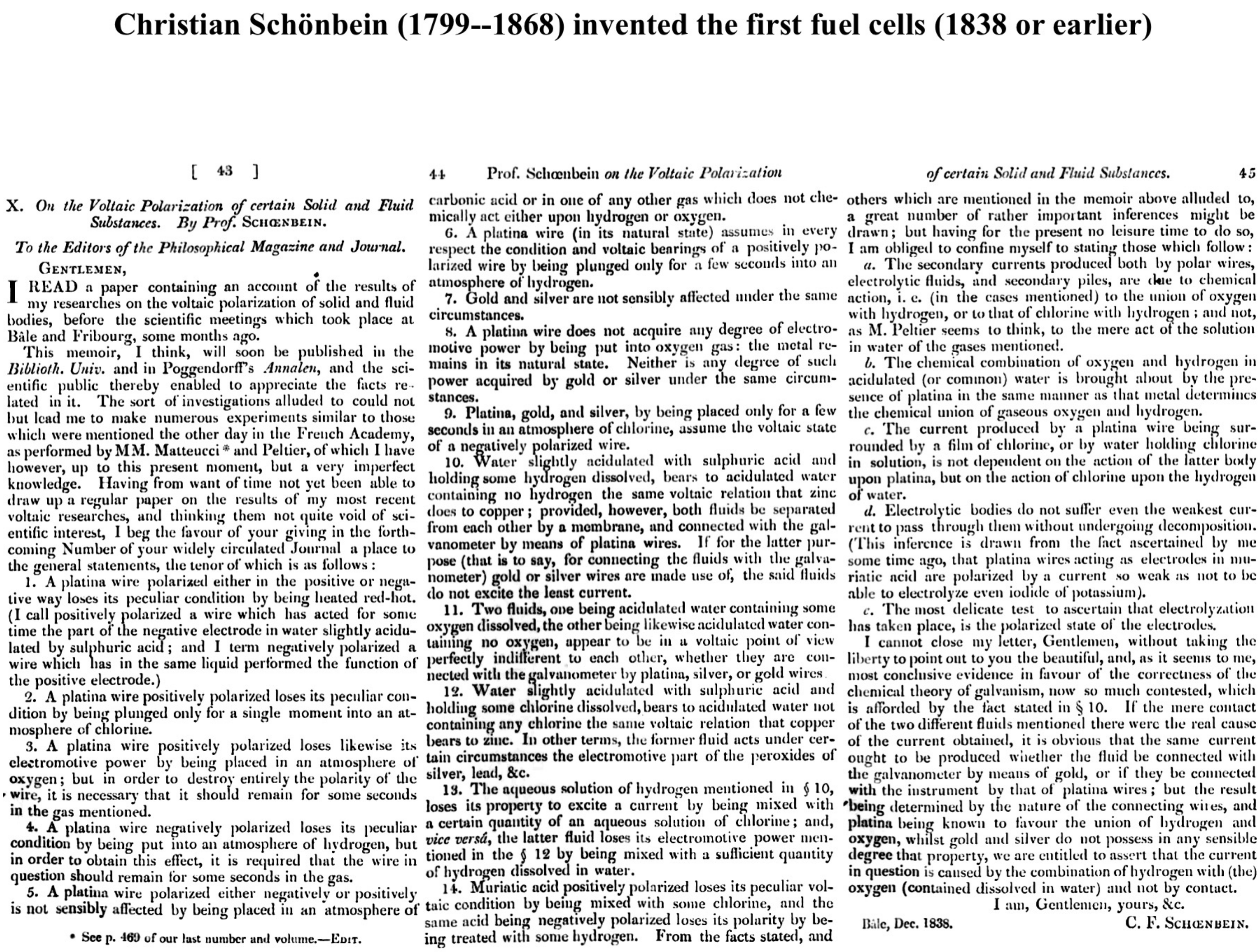
Karl Kordesch and many other German-speaking experts on advanced battery and fuel cell technologies were also transferred along with all of that information.

In addition to battery and fuel cell technologies, many other physical-chemistry-based technologies were transferred too, such as physical methods of making chemical measurements. See for example:

BIOS 1007. *Instrumentation and Control in the German Chemical Industry.* [Magnetic oxygen recorder, CO_2 recorder, etc.]

BIOS 1321. *Control Instruments in the German Chemical Industry.* [Chemical control in production, infrared chemical analyzer, etc.]

FIAT 708. *A Survey of the Use of Infra-Red Spectra in Chemical Analysis in Germany.*



Christian Schönbein (1799--1868) invented the first fuel cells (1838 or earlier)

X. *On the Voltaic Polarization of certain Solid and Fluid Substances. By Prof.* Schœnbein.

To the Editors of the Philosophical Magazine and Journal.

Gentlemen,

I READ a paper containing an account of the results of my researches on the voltaic polarization of solid and fluid bodies, before the scientific meetings which took place at Bâle and Fribourg, some months ago.

This memoir, I think, will soon be published in the *Biblioth. Univ.* and in Poggendorff's *Annalen*, and the scientific public thereby enabled to appreciate the facts related in it. The sort of investigations alluded to could not but lead me to make numerous experiments similar to those which were mentioned the other day in the French Academy, as performed by MM. Matteucci * and Peltier, of which I have however, up to this present moment, but a very imperfect knowledge. Having from want of time not yet been able to draw up a regular paper on the results of my most recent voltaic researches, and thinking them not quite void of scientific interest, I beg the favour of your giving in the forthcoming Number of your widely circulated Journal a place to the general statements, the tenor of which is as follows:

1. A platina wire polarized either in the positive or negative way loses its peculiar condition by being heated red-hot. (I call positively polarized a wire which has acted for some time the part of the negative electrode in water slightly acidulated by sulphuric acid; and I term negatively polarized a wire which has in the same liquid performed the function of the positive electrode.)

2. A platina wire positively polarized loses its peculiar condition by being plunged only for a single moment into an atmosphere of chlorine.

3. A platina wire positively polarized loses likewise its electromotive power by being placed in an atmosphere of oxygen; but in order to destroy entirely the polarity of the wire, it is necessary that it should remain for some seconds in the gas mentioned.

4. A platina wire negatively polarized loses its peculiar condition by being put into an atmosphere of hydrogen, but in order to obtain this effect, it is required that the wire in question should remain for some seconds in the gas.

5. A platina wire polarized either negatively or positively is not sensibly affected by being placed in an atmosphere of

carbonic acid or in one of any other gas which does not chemically act either upon hydrogen or oxygen.

6. A platina wire (in its natural state) assumes in every respect the condition and voltaic bearings of a positively polarized wire by being plunged only for a few seconds into an atmosphere of hydrogen.

7. Gold and silver are not sensibly affected under the same circumstances.

8. A platina wire does not acquire any degree of electromotive power by being put into oxygen gas: the metal remains in its natural state. Neither is any degree of such power acquired by gold or silver under the same circumstances.

9. Platina, gold, and silver, by being placed only for a few seconds in an atmosphere of chlorine, assume the voltaic state of a negatively polarized wire.

10. Water slightly acidulated with sulphuric acid and holding some hydrogen dissolved, bears to acidulated water containing no hydrogen the same voltaic relation that zinc does to copper; provided, however, both fluids be separated from each other by a membrane, and connected with the galvanometer by means of platina wires. If for the latter purpose (that is to say, for connecting the fluids with the galvanometer) gold or silver wires are made use of, the said fluids do not excite the least current.

11. Two fluids, one being acidulated water containing some oxygen dissolved, the other being likewise acidulated water containing no oxygen, appear to be in a voltaic point of view perfectly indifferent to each other, whether they are connected with the galvanometer by platina, silver, or gold wires.

12. Water slightly acidulated with sulphuric acid and holding some chlorine dissolved, bears to acidulated water not containing any chlorine the same voltaic relation that copper bears to zinc. In other terms, the former fluid acts under certain circumstances the electromotive part of the peroxides of silver, lead, &c.

13. The aqueous solution of hydrogen mentioned in § 10, loses its property to excite a current by being mixed with a certain quantity of an aqueous solution of chlorine; and, *vice versâ*, the latter fluid loses its electromotive power mentioned in the § 12 by being mixed with a sufficient quantity of hydrogen dissolved in water.

14. Muriatic acid positively polarized loses its peculiar voltaic condition by being mixed with some chlorine, and the same acid being negatively polarized loses its polarity by being treated with some hydrogen. From the facts stated, and

others which are mentioned in the memoir above alluded to, a great number of rather important inferences might be drawn; but having for the present no leisure time to do so, I am obliged to confine myself to stating those which follow:

a. The secondary currents produced both by polar wires, electrolytic fluids, and secondary piles, are due to chemical action, i. e. (in the cases mentioned) to the union of oxygen with hydrogen, or to that of chlorine with hydrogen; and not, as M. Peltier seems to think, to the mere act of the solution in water of the gases mentioned.

b. The chemical combination of oxygen and hydrogen in acidulated (or common) water is brought about by the presence of platina in the same manner as that metal determines the chemical union of gaseous oxygen and hydrogen.

c. The current produced by a platina wire being surrounded by a film of chlorine, or by water holding chlorine in solution, is not dependent on the action of the latter body upon platina, but on the action of chlorine upon the hydrogen of water.

d. Electrolytic bodies do not suffer even the weakest current to pass through them without undergoing decomposition. (This inference is drawn from the fact ascertained by me some time ago, that platina wires acting as electrodes in muriatic acid are polarized by a current so weak as not to be able to electrolyze even iodide of potassium).

e. The most delicate test to ascertain that electrolyzation has taken place, is the polarized state of the electrodes.

I cannot close my letter, Gentlemen, without taking the liberty to point out to you the beautiful, and, as it seems to me, most conclusive evidence in favour of the correctness of the chemical theory of galvanism, now so much contested, which is afforded by the fact stated in § 10. If the mere contact of the two different fluids mentioned there were the real cause of the current obtained, it is obvious that the same current ought to be produced whether the fluid be connected with the galvanometer by means of gold, or if they be connected with the instrument by that of platina wires; but the result being determined by the nature of the connecting wires, and platina being known to favour the union of hydrogen and oxygen, whilst gold and silver do not possess in any sensible degree that property, we are entitled to assert that the current in question is caused by the combination of hydrogen with (the) oxygen (contained dissolved in water) and not by contact.

I am, Gentlemen, yours, &c.

Bâle, Dec. 1838. C. F. Schœnbein.

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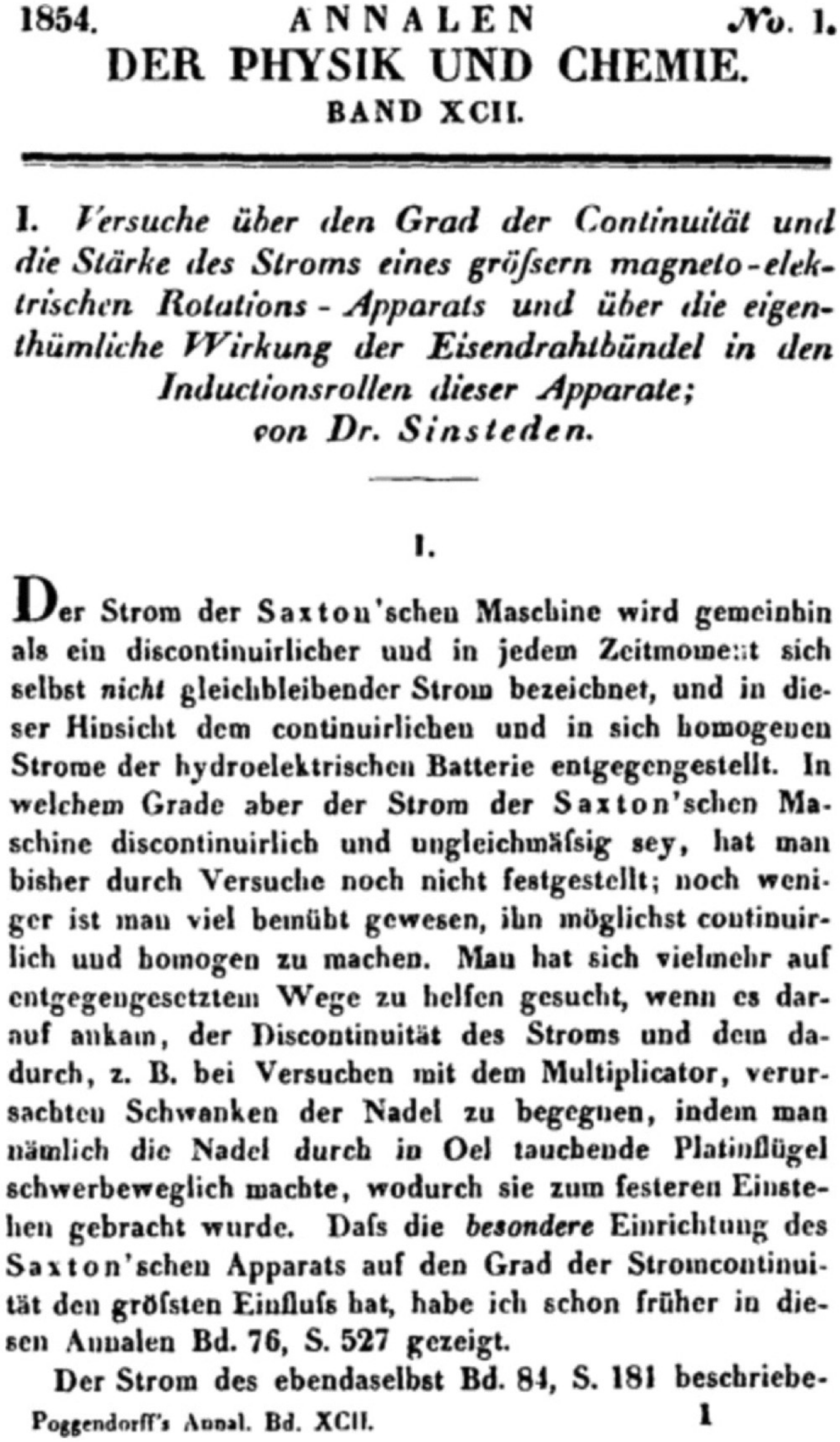
* See p. 469 of our last number and volume.—Edit.

Figure 3.124: Christian Schönbein invented and demonstrated the first fuel cells in 1838 or earlier [Schönbein 1839].

Wilhelm Sinsteden (1803–1891) invented lead-acid rechargeable batteries (1854 or earlier)



1854. ANNALEN No. 1.

DER PHYSIK UND CHEMIE.

BAND XCII.

I. *Versuche über den Grad der Continuität und die Stärke des Stroms eines gröſsern magneto-elektrischen Rotations-Apparats und über die eigenthümliche Wirkung der Eisendrahtbündel in den Inductionsrollen dieser Apparate;*

von Dr. Sinsteden.

1.

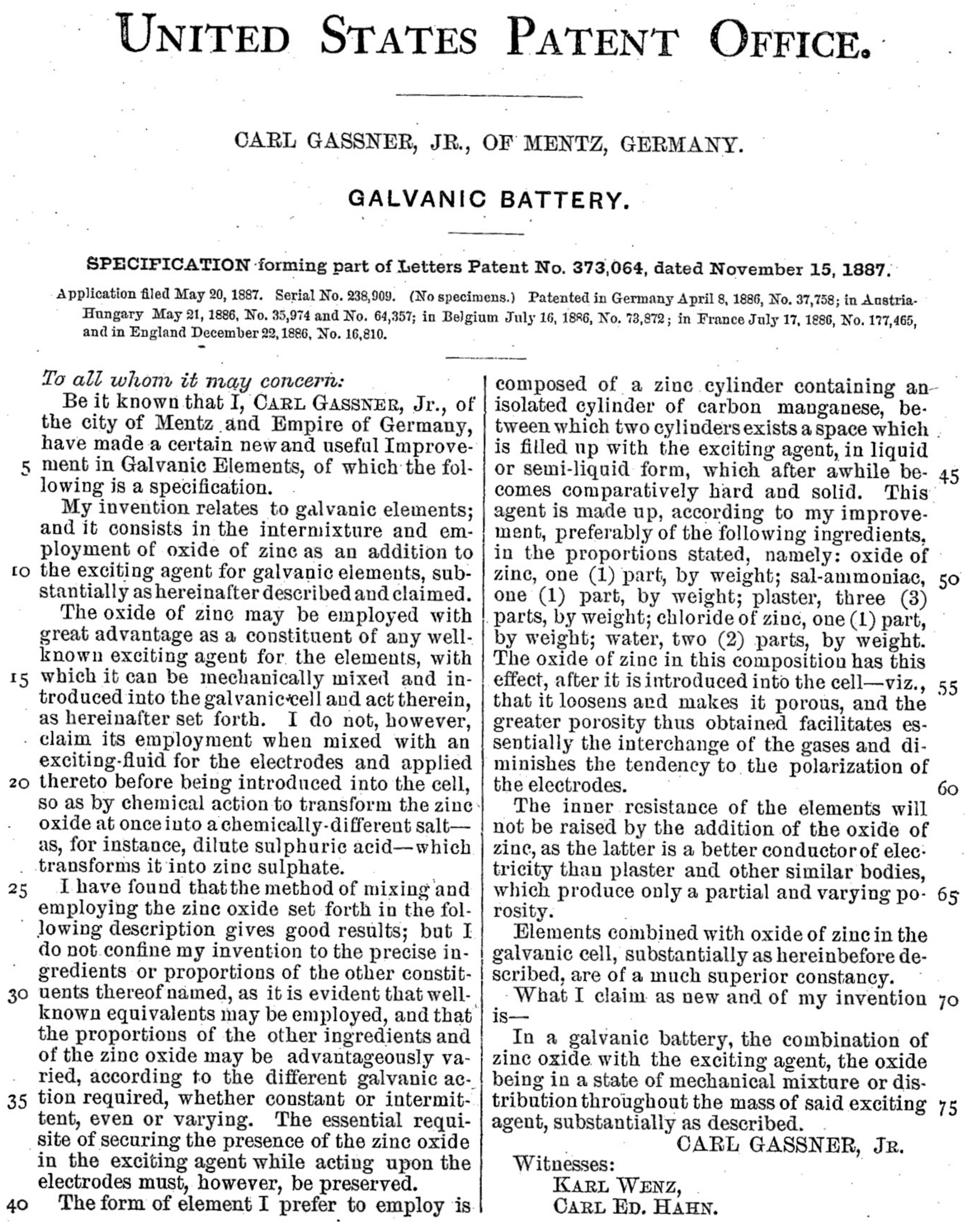
Der Strom der Saxton'schen Maschine wird gemeinhin als ein discontinuirlicher und in jedem Zeitmoment sich selbst *nicht* gleichbleibender Strom bezeichnet, und in dieser Hinsicht dem continuirlichen und in sich homogenen Strome der hydroelektrischen Batterie entgegengestellt. In welchem Grade aber der Strom der Saxton'schen Maschine discontinuirlich und ungleichmäſsig sey, hat man bisher durch Versuche noch nicht festgestellt; noch weniger ist man viel bemüht gewesen, ihn möglichst continuirlich und homogen zu machen. Man hat sich vielmehr auf entgegengesetztem Wege zu helfen gesucht, wenn es darauf ankam, der Discontinuität des Stroms und dem dadurch, z. B. bei Versuchen mit dem Multiplicator, verursachten Schwanken der Nadel zu begegnen, indem man nämlich die Nadel durch in Oel tauchende Platinflügel schwerbeweglich machte, wodurch sie zum festeren Einstehen gebracht wurde. Daſs die *besondere* Einrichtung des Saxton'schen Apparats auf den Grad der Stromcontinuität den gröſsten Einfluſs hat, habe ich schon früher in diesen Annalen Bd. 76, S. 527 gezeigt.

Der Strom des ebendaselbst Bd. 84, S. 181 beschriebe-

Poggendorff's Annal. Bd. XCII. 1

Figure 3.125: Wilhelm Sinsteden invented and demonstrated lead-acid rechargeable batteries in 1854 or earlier [Sinsteden 1854].

Carl Gassner (1855–1942) invented zinc-carbon dry batteries (1885)



UNITED STATES PATENT OFFICE.

CARL GASSNER, JR., OF MENTZ, GERMANY.

GALVANIC BATTERY.

SPECIFICATION forming part of Letters Patent No. 373,064, dated November 15, 1887.

Application filed May 20, 1887. Serial No. 238,909. (No specimens.) Patented in Germany April 8, 1886, No. 37,758; in Austria-Hungary May 21, 1886, No. 35,974 and No. 64,357; in Belgium July 16, 1886, No. 73,872; in France July 17, 1886, No. 177,465, and in England December 22, 1886, No. 16,810.

To all whom it may concern:

Be it known that I, CARL GASSNER, Jr., of the city of Mentz and Empire of Germany, have made a certain new and useful Improvement in Galvanic Elements, of which the following is a specification.

My invention relates to galvanic elements; and it consists in the intermixture and employment of oxide of zinc as an addition to the exciting agent for galvanic elements, substantially as hereinafter described and claimed.

The oxide of zinc may be employed with great advantage as a constituent of any well-known exciting agent for the elements, with which it can be mechanically mixed and introduced into the galvanic cell and act therein, as hereinafter set forth. I do not, however, claim its employment when mixed with an exciting-fluid for the electrodes and applied thereto before being introduced into the cell, so as by chemical action to transform the zinc oxide at once into a chemically-different salt—as, for instance, dilute sulphuric acid—which transforms it into zinc sulphate.

I have found that the method of mixing and employing the zinc oxide set forth in the following description gives good results; but I do not confine my invention to the precise ingredients or proportions of the other constituents thereof named, as it is evident that well-known equivalents may be employed, and that the proportions of the other ingredients and of the zinc oxide may be advantageously varied, according to the different galvanic action required, whether constant or intermittent, even or varying. The essential requisite of securing the presence of the zinc oxide in the exciting agent while acting upon the electrodes must, however, be preserved.

The form of element I prefer to employ is composed of a zinc cylinder containing an isolated cylinder of carbon manganese, between which two cylinders exists a space which is filled up with the exciting agent, in liquid or semi-liquid form, which after awhile becomes comparatively hard and solid. This agent is made up, according to my improvement, preferably of the following ingredients, in the proportions stated, namely: oxide of zinc, one (1) part, by weight; sal-ammoniac, one (1) part, by weight; plaster, three (3) parts, by weight; chloride of zinc, one (1) part, by weight; water, two (2) parts, by weight. The oxide of zinc in this composition has this effect, after it is introduced into the cell—viz., that it loosens and makes it porous, and the greater porosity thus obtained facilitates essentially the interchange of the gases and diminishes the tendency to the polarization of the electrodes.

The inner resistance of the elements will not be raised by the addition of the oxide of zinc, as the latter is a better conductor of electricity than plaster and other similar bodies, which produce only a partial and varying porosity.

Elements combined with oxide of zinc in the galvanic cell, substantially as hereinbefore described, are of a much superior constancy.

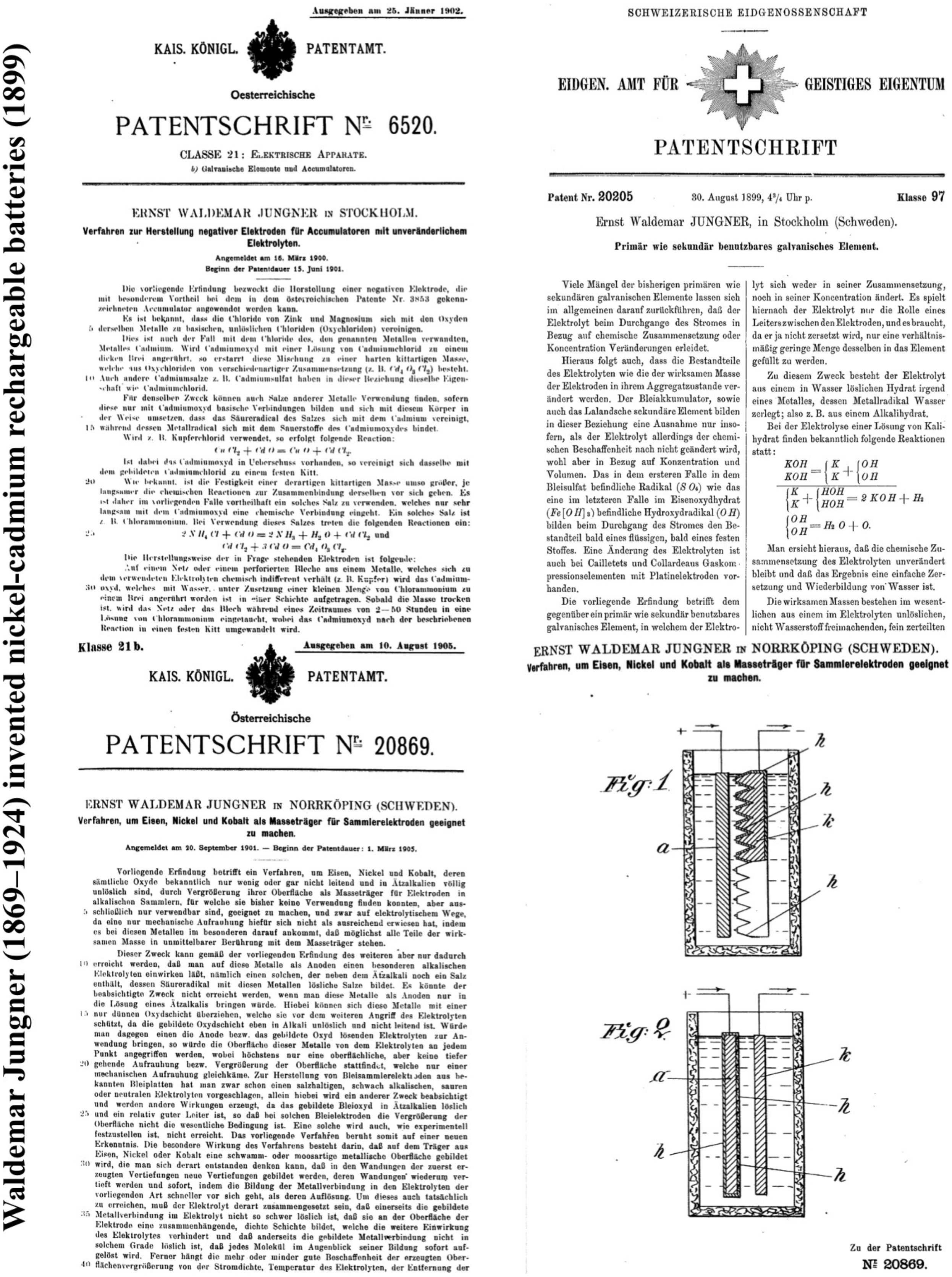
What I claim as new and of my invention is—

In a galvanic battery, the combination of zinc oxide with the exciting agent, the oxide being in a state of mechanical mixture or distribution throughout the mass of said exciting agent, substantially as described.

CARL GASSNER, JR.

Witnesses:
KARL WENZ,
CARL ED. HAHN.

Figure 3.126: Carl Gassner demonstrated and patented zinc-carbon dry batteries in 1885.



Waldemar Jungner (1869–1924) invented nickel-cadmium rechargeable batteries (1899)

Ausgegeben am 25. Jänner 1902.

KAIS. KÖNIGL. PATENTAMT.

Oesterreichische

PATENTSCHRIFT Nr. 6520.

CLASSE 21: Elektrische Apparate.
b) Galvanische Elemente und Accumulatoren.

ERNST WALDEMAR JUNGNER in STOCKHOLM.

Verfahren zur Herstellung negativer Elektroden für Accumulatoren mit unveränderlichem Elektrolyten.

Angemeldet am 16. März 1900.
Beginn der Patentdauer 15. Juni 1901.

Die vorliegende Erfindung bezweckt die Herstellung einer negativen Elektrode, die mit besonderem Vortheil bei dem in dem österreichischen Patente Nr. 3853 gekennzeichneten Accumulator angewendet werden kann.

Es ist bekannt, dass die Chloride von Zink und Magnesium sich mit den Oxyden derselben Metalle zu basischen, unlöslichen Chloriden (Oxychloriden) vereinigen.

Dies ist auch der Fall mit dem Chloride des, den genannten Metallen verwandten, Metalles Cadmium. Wird Cadmiumoxyd mit einer Lösung von Cadmiumchlorid zu einem dicken Brei angerührt, so erstarrt diese Mischung zu einer harten kittartigen Masse, welche aus Oxychloriden von verschiedenartiger Zusammensetzung (z. B. $Cd_4O_3Cl_2$) besteht. Auch andere Cadmiumsalze z. B. Cadmiumsulfat haben in dieser Beziehung dieselbe Eigenschaft wie Cadmiumchlorid.

Für denselben Zweck können auch Salze anderer Metalle Verwendung finden, sofern diese nur mit Cadmiumoxyd basische Verbindungen bilden und sich mit diesem Körper in der Weise umsetzen, dass das Säureradical des Salzes sich mit dem Cadmium vereinigt, während dessen Metallradical sich mit dem Sauerstoffe des Cadmiumoxydes bindet.

Wird z. B. Kupferchlorid verwendet, so erfolgt folgende Reaction:

$$CuCl_2 + CdO = CuO + CdCl_2.$$

Ist dabei das Cadmiumoxyd in Ueberschuss vorhanden, so vereinigt sich dasselbe mit dem gebildeten Cadmiumchlorid zu einem festen Kitt.

Wie bekannt, ist die Festigkeit einer derartigen kittartigen Masse umso größer, je langsamer die chemischen Reactionen zur Zusammenbindung derselben vor sich gehen. Es ist daher im vorliegenden Falle vortheilhaft ein solches Salz zu verwenden, welches nur sehr langsam mit dem Cadmiumoxyd eine chemische Verbindung eingeht. Ein solches Salz ist z. B. Chlorammonium. Bei Verwendung dieses Salzes treten die folgenden Reactionen ein:

$$2NH_4Cl + CdO = 2NH_3 + H_2O + CdCl_2 \text{ und}$$
$$CdCl_2 + 3CdO = Cd_4O_3Cl_2.$$

Die Herstellungsweise der in Frage stehenden Elektroden ist folgende:

Auf einem Netz oder einem perforierten Bleche aus einem Metalle, welches sich zu dem verwendeten Elektrolyten chemisch indifferent verhält (z. B. Kupfer) wird das Cadmiumoxyd, welches mit Wasser, unter Zusetzung einer kleinen Menge von Chlorammonium zu einem Brei angerührt worden ist in einer Schichte aufgetragen. Sobald die Masse trocken ist, wird das Netz oder das Blech während eines Zeitraumes von 2—50 Stunden in eine Lösung von Chlorammonium eingetaucht, wobei das Cadmiumoxyd nach der beschriebenen Reaction in einen festen Kitt umgewandelt wird.

Klasse 21 b. Ausgegeben am 10. August 1905.

KAIS. KÖNIGL. PATENTAMT.

Österreichische

PATENTSCHRIFT Nr. 20869.

ERNST WALDEMAR JUNGNER in NORRKÖPING (SCHWEDEN).

Verfahren, um Eisen, Nickel und Kobalt als Masseträger für Sammlerelektroden geeignet zu machen.

Angemeldet am 20. September 1901. — Beginn der Patentdauer: 1. März 1905.

Vorliegende Erfindung betrifft ein Verfahren, um Eisen, Nickel und Kobalt, deren sämtliche Oxyde bekanntlich nur wenig oder gar nicht leitend und in Ätzalkalien völlig unlöslich sind, durch Vergrößerung ihrer Oberfläche als Masseträger für Elektroden in alkalischen Sammlern, für welche sie bisher keine Verwendung finden konnten, aber ausschließlich nur verwendbar sind, geeignet zu machen, und zwar auf elektrolytischem Wege, da eine nur mechanische Aufrauhung hiefür sich nicht als ausreichend erwiesen hat, indem es bei diesen Metallen im besonderen darauf ankommt, daß möglichst alle Teile der wirksamen Masse in unmittelbarer Berührung mit dem Masseträger stehen.

Dieser Zweck kann gemäß der vorliegenden Erfindung des weiteren aber nur dadurch erreicht werden, daß man auf diese Metalle als Anoden einen besonderen alkalischen Elektrolyten einwirken läßt, nämlich einen solchen, der neben dem Ätzalkali noch ein Salz enthält, dessen Säureradikal mit diesen Metallen lösliche Salze bildet. Es könnte der beabsichtigte Zweck nicht erreicht werden, wenn man diese Metalle als Anoden nur in die Lösung eines Ätzalkalis bringen würde. Hiebei können sich diese Metalle mit einer nur dünnen Oxydschicht überziehen, welche sie vor dem weiteren Angriff des Elektrolyten schützt, da die gebildete Oxydschicht eben in Alkali unlöslich und nicht leitend ist. Würde man dagegen einen die Anode bezw. das gebildete Oxyd lösenden Elektrolyten zur Anwendung bringen, so würde die Oberfläche dieser Metalle von dem Elektrolyten an jedem Punkt angegriffen werden, wobei höchstens nur eine oberflächliche, aber keine tiefer gehende Aufrauhung bezw. Vergrößerung der Oberfläche stattfindet, welche nur einer mechanischen Aufrauhung gleichkäme. Zur Herstellung von Bleisammlerelektroden aus bekannten Bleiplatten hat man zwar schon einen salzhaltigen, schwach alkalischen, sauren oder neutralen Elektrolyten vorgeschlagen, allein hiebei wird ein anderer Zweck beabsichtigt und werden andere Wirkungen erzeugt, da das gebildete Bleioxyd in Ätzalkalien löslich und ein relativ guter Leiter ist, so daß bei solchen Bleielektroden die Vergrößerung der Oberfläche nicht die wesentliche Bedingung ist. Eine solche wird auch, wie experimentell festzustellen ist, nicht erreicht. Das vorliegende Verfahren beruht somit auf einer neuen Erkenntnis. Die besondere Wirkung des Verfahrens besteht darin, daß auf dem Träger aus Eisen, Nickel oder Kobalt eine schwamm- oder moosartige metallische Oberfläche gebildet wird, die man sich derart entstanden denken kann, daß in den Wandungen der zuerst erzeugten Vertiefungen neue Vertiefungen gebildet werden, deren Wandungen wiederum vertieft werden und sofort, indem die Bildung der Metallverbindung in den Elektrolyten der vorliegenden Art schneller vor sich geht, als deren Auflösung. Um dieses auch tatsächlich zu erreichen, muß der Elektrolyt derart zusammengesetzt sein, daß einerseits die gebildete Metallverbindung im Elektrolyt nicht so schwer löslich ist, daß sie an der Oberfläche der Elektrode eine zusammenhängende, dichte Schichte bildet, welche die weitere Einwirkung des Elektrolytes verhindert und daß anderseits die gebildete Metallverbindung nicht in solchem Grade löslich ist, daß jedes Molekül im Augenblick seiner Bildung sofort aufgelöst wird. Ferner hängt die mehr oder minder gute Beschaffenheit der erzeugten Oberflächenvergrößerung von der Stromdichte, Temperatur des Elektrolyten, der Entfernung der

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SCHWEIZERISCHE EIDGENOSSENSCHAFT

EIDGEN. AMT FÜR GEISTIGES EIGENTUM

PATENTSCHRIFT

Patent Nr. 20205 30. August 1899, 4¾ Uhr p. **Klasse 97**

Ernst Waldemar JUNGNER, in Stockholm (Schweden).

Primär wie sekundär benutzbares galvanisches Element.

Viele Mängel der bisherigen primären wie sekundären galvanischen Elemente lassen sich im allgemeinen darauf zurückführen, daß der Elektrolyt beim Durchgange des Stromes in Bezug auf chemische Zusammensetzung oder Koncentration Veränderungen erleidet.

Hieraus folgt auch, dass die Bestandteile des Elektrolyten wie die der wirksamen Masse der Elektroden in ihrem Aggregatzustande verändert werden. Der Bleiakkumulator, sowie auch das Lalandsche sekundäre Element bilden in dieser Beziehung eine Ausnahme nur insofern, als der Elektrolyt allerdings der chemischen Beschaffenheit nach nicht geändert wird, wohl aber in Bezug auf Konzentration und Volumen. Das in dem ersteren Falle in dem Bleisulfat befindliche Radikal (SO_4) wie das eine im letzteren Falle im Eisenoxydhydrat ($Fe[OH]_3$) befindliche Hydroxydradikal (OH) bilden beim Durchgang des Stromes den Bestandteil bald eines flüssigen, bald eines festen Stoffes. Eine Änderung des Elektrolyten ist auch bei Cailletets und Collardeaus Gaskompressionselementen mit Platinelektroden vorhanden.

Die vorliegende Erfindung betrifft dem gegenüber ein primär wie sekundär benutzbares galvanisches Element, in welchem der Elektrolyt sich weder in seiner Zusammensetzung, noch in seiner Koncentration ändert. Es spielt hiernach der Elektrolyt nur die Rolle eines Leiters zwischen den Elektroden, und es braucht, da er ja nicht zersetzt wird, nur eine verhältnismäßig geringe Menge desselben in das Element gefüllt zu werden.

Zu diesem Zweck besteht der Elektrolyt aus einem in Wasser löslichen Hydrat irgend eines Metalles, dessen Metallradikal Wasser zerlegt; also z. B. aus einem Alkalihydrat.

Bei der Elektrolyse einer Lösung von Kalihydrat finden bekanntlich folgende Reaktionen statt:

$$\begin{array}{l} \begin{matrix}KOH\\KOH\end{matrix} = \left\{\begin{matrix}K\\K\end{matrix}\right. + \left\{\begin{matrix}OH\\OH\end{matrix}\right. \\ \hline \left\{\begin{matrix}K\\K\end{matrix}\right. + \left\{\begin{matrix}HOH\\HOH\end{matrix}\right. = 2KOH + H_2 \\ \left\{\begin{matrix}OH\\OH\end{matrix}\right. = H_2O + O. \end{array}$$

Man ersieht hieraus, daß die chemische Zusammensetzung des Elektrolyten unverändert bleibt und daß das Ergebnis eine einfache Zersetzung und Wiederbildung von Wasser ist.

Die wirksamen Massen bestehen im wesentlichen aus einem im Elektrolyten unlöslichen, nicht Wasserstoff freimachenden, fein zerteilten

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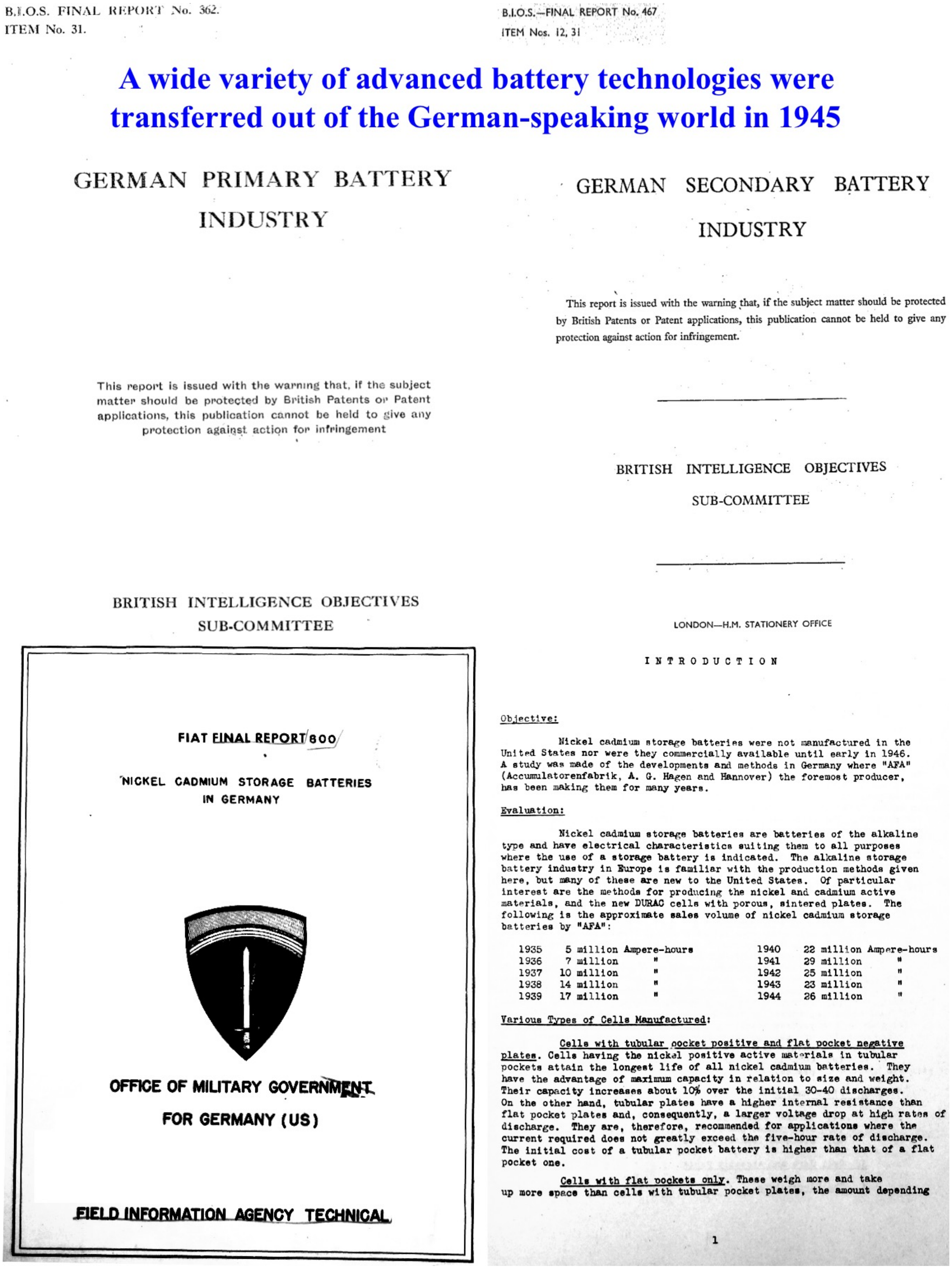
ERNST WALDEMAR JUNGNER in NORRKÖPING (SCHWEDEN).

Verfahren, um Eisen, Nickel und Kobalt als Masseträger für Sammlerelektroden geeignet zu machen.

Zu der Patentschrift
Nr. 20869.

Figure 3.127: Waldemar Jungner invented nickel-cadmium rechargeable batteries in 1899.



A wide variety of advanced battery technologies were transferred out of the German-speaking world in 1945

B.I.O.S. FINAL REPORT No. 362.
ITEM No. 31.

GERMAN PRIMARY BATTERY
INDUSTRY

This report is issued with the warning that, if the subject matter should be protected by British Patents or Patent applications, this publication cannot be held to give any protection against action for infringement

BRITISH INTELLIGENCE OBJECTIVES
SUB-COMMITTEE

B.I.O.S.—FINAL REPORT No. 467
ITEM Nos. 12, 31

GERMAN SECONDARY BATTERY
INDUSTRY

This report is issued with the warning that, if the subject matter should be protected by British Patents or Patent applications, this publication cannot be held to give any protection against action for infringement.

BRITISH INTELLIGENCE OBJECTIVES
SUB-COMMITTEE

LONDON—H.M. STATIONERY OFFICE

FIAT FINAL REPORT 800

NICKEL CADMIUM STORAGE BATTERIES
IN GERMANY

OFFICE OF MILITARY GOVERNMENT
FOR GERMANY (US)

FIELD INFORMATION AGENCY TECHNICAL

INTRODUCTION

Objective:

Nickel cadmium storage batteries were not manufactured in the United States nor were they commercially available until early in 1946. A study was made of the developments and methods in Germany where "AFA" (Accumulatorenfabrik, A. G. Hagen and Hannover) the foremost producer, has been making them for many years.

Evaluation:

Nickel cadmium storage batteries are batteries of the alkaline type and have electrical characteristics suiting them to all purposes where the use of a storage battery is indicated. The alkaline storage battery industry in Europe is familiar with the production methods given here, but many of these are new to the United States. Of particular interest are the methods for producing the nickel and cadmium active materials, and the new DURAC cells with porous, sintered plates. The following is the approximate sales volume of nickel cadmium storage batteries by "AFA":

1935	5 million Ampere-hours	1940	22 million Ampere-hours
1936	7 million "	1941	29 million "
1937	10 million "	1942	25 million "
1938	14 million "	1943	23 million "
1939	17 million "	1944	26 million "

Various Types of Cells Manufactured:

Cells with tubular pocket positive and flat pocket negative plates. Cells having the nickel positive active materials in tubular pockets attain the longest life of all nickel cadmium batteries. They have the advantage of maximum capacity in relation to size and weight. Their capacity increases about 10% over the initial 30-40 discharges. On the other hand, tubular plates have a higher internal resistance than flat pocket plates and, consequently, a larger voltage drop at high rates of discharge. They are, therefore, recommended for applications where the current required does not greatly exceed the five-hour rate of discharge. The initial cost of a tubular pocket battery is higher than that of a flat pocket one.

Cells with flat pockets only. These weigh more and take up more space than cells with tubular pocket plates, the amount depending

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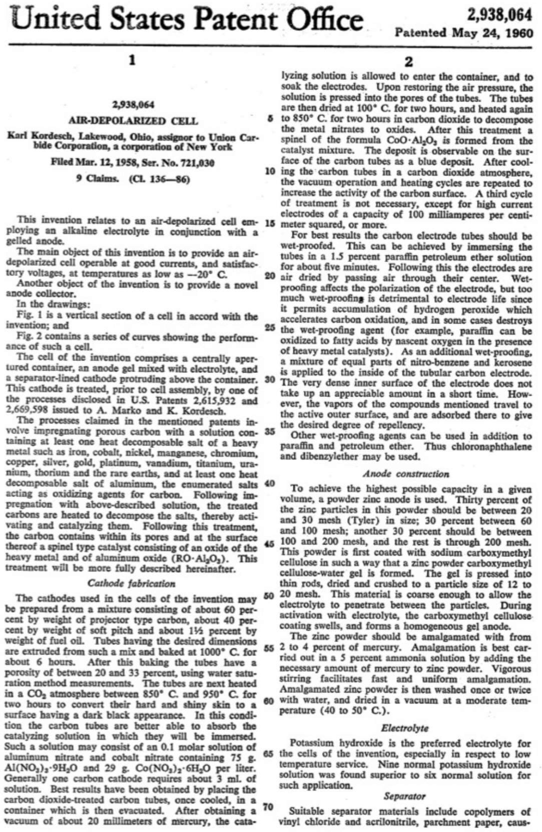
Figure 3.128: A wide variety of advanced battery technologies were transferred out of the German-speaking world in 1945, as shown by numerous BIOS, CIOS, FIAT, NavTecMisEu, and other reports.

Karl Kordesch (1922–2011) invented alkaline dry batteries (1957 or earlier)



United States Patent Office

2,938,064
Patented May 24, 1960

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2,938,064
AIR-DEPOLARIZED CELL
Karl Kordesch, Lakewood, Ohio, assignor to Union Carbide Corporation, a corporation of New York
Filed Mar. 12, 1958, Ser. No. 721,030
9 Claims. (Cl. 136—86)

This invention relates to an air-depolarized cell employing an alkaline electrolyte in conjunction with a gelled anode.

The main object of this invention is to provide an air-depolarized cell operable at good currents, and satisfactory voltages, at temperatures as low as —20° C.

Another object of the invention is to provide a novel anode collector.

In the drawings:

Fig. 1 is a vertical section of a cell in accord with the invention; and

Fig. 2 contains a series of curves showing the performance of such a cell.

The cell of the invention comprises a centrally apertured container, an anode gel mixed with electrolyte, and a separator-lined cathode protruding above the container. This cathode is treated, prior to cell assembly, by one of the processes disclosed in U.S. Patents 2,615,932 and 2,669,598 issued to A. Marko and K. Kordesch.

The processes claimed in the mentioned patents involve impregnating porous carbon with a solution containing at least one heat decomposable salt of a heavy metal such as iron, cobalt, nickel, manganese, chromium, copper, silver, gold, platinum, vanadium, titanium, uranium, thorium and the rare earths, and at least one heat decomposable salt of aluminum, the enumerated salts acting as oxidizing agents for carbon. Following impregnation with above-described solution, the treated carbons are heated to decompose the salts, thereby activating and catalyzing them. Following this treatment, the carbon contains within its pores and at the surface thereof a spinel type catalyst consisting of an oxide of the heavy metal and of aluminum oxide ($RO \cdot Al_2O_3$). This treatment will be more fully described hereinafter.

Cathode fabrication

The cathodes used in the cells of the invention may be prepared from a mixture consisting of about 60 percent by weight of projector type carbon, about 40 percent by weight of soft pitch and about 1½ percent by weight of fuel oil. Tubes having the desired dimensions are extruded from such a mix and baked at 1000° C. for about 6 hours. After this baking the tubes have a porosity of between 20 and 33 percent, using water saturation method measurements. The tubes are next heated in a CO_2 atmosphere between 850° C. and 950° C. for two hours to convert their hard and shiny skin to a surface having a dark black appearance. In this condition the carbon tubes are better able to absorb the catalyzing solution in which they will be immersed. Such a solution may consist of an 0.1 molar solution of aluminum nitrate and cobalt nitrate containing 75 g. $Al(NO_3)_3 \cdot 9H_2O$ and 29 g. $Co(NO_3)_2 \cdot 6H_2O$ per liter. Generally one carbon cathode requires about 3 ml. of solution. Best results have been obtained by placing the carbon dioxide-treated carbon tubes, once cooled, in a container which is then evacuated. After obtaining a vacuum of about 20 millimeters of mercury, the catalyzing solution is allowed to enter the container, and to soak the electrodes. Upon restoring the air pressure, the solution is pressed into the pores of the tubes. The tubes are then dried at 100° C. for two hours, and heated again to 850° C. for two hours in carbon dioxide to decompose the metal nitrates to oxides. After this treatment a spinel of the formula $CoO \cdot Al_2O_3$ is formed from the catalyst mixture. The deposit is observable on the surface of the carbon tubes as a blue deposit. After cooling the carbon tubes in a carbon dioxide atmosphere, the vacuum operation and heating cycles are repeated to increase the activity of the carbon surface. A third cycle of treatment is not necessary, except for high current electrodes of a capacity of 100 milliamperes per centimeter squared, or more.

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For best results the carbon electrode tubes should be wet-proofed. This can be achieved by immersing the tubes in a 1.5 percent paraffin petroleum ether solution for about five minutes. Following this the electrodes are air dried by passing air through their center. Wet-proofing affects the polarization of the electrode, but too much wet-proofing is detrimental to electrode life since it permits accumulation of hydrogen peroxide which accelerates carbon oxidation, and in some cases destroys the wet-proofing agent (for example, paraffin can be oxidized to fatty acids by nascent oxygen in the presence of heavy metal catalysts). As an additional wet-proofing, a mixture of equal parts of nitro-benzene and kerosene is applied to the inside of the tubular carbon electrode. The very dense inner surface of the electrode does not take up an appreciable amount in a short time. However, the vapors of the compounds mentioned travel to the active outer surface, and are adsorbed there to give the desired degree of repellency.

Other wet-proofing agents can be used in addition to paraffin and petroleum ether. Thus chloronaphthalene and dibenzylether may be used.

Anode construction

To achieve the highest possible capacity in a given volume, a powder zinc anode is used. Thirty percent of the zinc particles in this powder should be between 20 and 30 mesh (Tyler) in size; 30 percent between 60 and 100 mesh; another 30 percent should be between 100 and 200 mesh, and the rest is through 200 mesh. This powder is first coated with sodium carboxymethyl cellulose in such a way that a zinc powder carboxymethyl cellulose-water gel is formed. The gel is pressed into thin rods, dried and crushed to a particle size of 12 to 20 mesh. This material is coarse enough to allow the electrolyte to penetrate between the particles. During activation with electrolyte, the carboxymethyl cellulose coating swells, and forms a homogeneous gel anode.

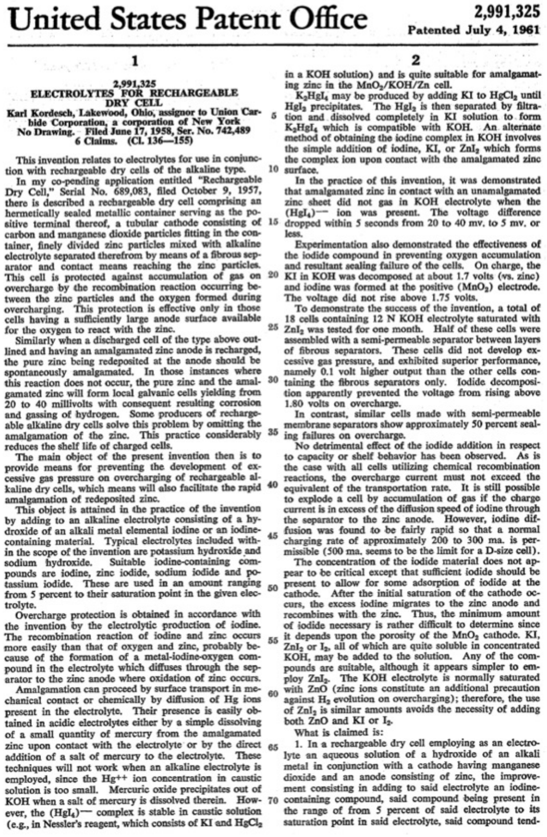
The zinc powder should be amalgamated with from 2 to 4 percent of mercury. Amalgamation is best carried out in a 5 percent ammonia solution by adding the necessary amount of mercury to zinc powder. Vigorous stirring facilitates fast and uniform amalgamation. Amalgamated zinc powder is then washed once or twice with water, and dried in a vacuum at a moderate temperature (40 to 50° C.).

Electrolyte

Potassium hydroxide is the preferred electrolyte for the cells of the invention, especially in respect to low temperature service. Nine normal potassium hydroxide solution was found superior to six normal solution for such application.

Separator

Suitable separator materials include copolymers of vinyl chloride and acrilonitrile, parchment paper, caus-



United States Patent Office

2,991,325
Patented July 4, 1961

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2,991,325
ELECTROLYTES FOR RECHARGEABLE DRY CELL
Karl Kordesch, Lakewood, Ohio, assignor to Union Carbide Corporation, a corporation of New York
No Drawing. Filed June 17, 1958, Ser. No. 742,489
6 Claims. (Cl. 136—155)

This invention relates to electrolytes for use in conjunction with rechargeable dry cells of the alkaline type.

In my co-pending application entitled "Rechargeable Dry Cell," Serial No. 689,083, filed October 9, 1957, there is described a rechargeable dry cell comprising an hermetically sealed metallic container serving as the positive terminal thereof, a tubular cathode consisting of carbon and manganese dioxide particles fitting in the container, finely divided zinc particles mixed with alkaline electrolyte separated therefrom by means of a fibrous separator and contact means reaching the zinc particles. This cell is protected against accumulation of gas on overcharge by the recombination reaction occurring between the zinc particles and the oxygen formed during overcharging. This protection is effective only in those cells having a sufficiently large anode surface available for the oxygen to react with the zinc.

Similarly when a discharged cell of the type above outlined and having an amalgamated zinc anode is recharged, the pure zinc being redeposited at the anode should be spontaneously amalgamated. In those instances where this reaction does not occur, the pure zinc and the amalgamated zinc will form local galvanic cells yielding from 20 to 40 millivolts with consequent resulting corrosion and gassing of hydrogen. Some producers of rechargeable alkaline dry cells solve this problem by omitting the amalgamation of the zinc. This practice considerably reduces the shelf life of charged cells.

The main object of the present invention then is to provide means for preventing the development of excessive gas pressure on overcharging of rechargeable alkaline dry cells, which means will also facilitate the rapid amalgamation of redeposited zinc.

This object is attained in the practice of the invention by adding to an alkaline electrolyte consisting of a hydroxide of an alkali metal elemental iodine or an iodine-containing material. Typical electrolytes included within the scope of the invention are potassium hydroxide and sodium hydroxide. Suitable iodine-containing compounds are iodine, zinc iodide, sodium iodide and potassium iodide. These are used in an amount ranging from 5 percent to their saturation point in the given electrolyte.

Overcharge protection is obtained in accordance with the invention by the electrolytic production of iodine. The recombination reaction of iodine and zinc occurs more easily than that of oxygen and zinc, probably because of the formation of a metal-iodine-oxygen compound in the electrolyte which diffuses through the separator to the zinc anode where oxidation of zinc occurs.

Amalgamation can proceed by surface transport in mechanical contact or chemically by diffusion of Hg ions present in the electrolyte. Their presence is easily obtained in acidic electrolytes either by a simple dissolving of a small quantity of mercury from the amalgamated zinc upon contact with the electrolyte or by the direct addition of a salt of mercury to the electrolyte. These techniques will not work when an alkaline electrolyte is employed, since the Hg^{++} ion concentration in caustic solution is too small. Mercuric oxide precipitates out of KOH when a salt of mercury is dissolved therein. However, the $(HgI_4)^{--}$ complex is stable in caustic solution (e.g., in Nessler's reagent, which consists of KI and $HgCl_2$

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in a KOH solution) and is quite suitable for amalgamating zinc in the $MnO_2/KOH/Zn$ cell.

K_2HgI_4 may be produced by adding KI to $HgCl_2$ until HgI_2 precipitates. The HgI_2 is then separated by filtration and dissolved completely in KI solution to form K_2HgI_4 which is compatible with KOH. An alternate method of obtaining the iodine complex in KOH involves the simple addition of iodine, KI, or ZnI_2 which forms the complex ion upon contact with the amalgamated zinc surface.

In the practice of this invention, it was demonstrated that amalgamated zinc in contact with an unamalgamated zinc sheet did not gas in KOH electrolyte when the $(HgI_4)^{--}$ ion was present. The voltage difference dropped within 5 seconds from 20 to 40 mv. to 5 mv. or less.

Experimentation also demonstrated the effectiveness of the iodide compound in preventing oxygen accumulation and resultant sealing failure of the cells. On charge, the KI in KOH was decomposed at about 1.7 volts (vs. zinc) and iodine was formed at the positive (MnO_2) electrode. The voltage did not rise above 1.75 volts.

To demonstrate the success of the invention, a total of 18 cells containing 12 N KOH electrolyte saturated with ZnI_2 was tested for one month. Half of these cells were assembled with a semi-permeable separator between layers of fibrous separators. These cells did not develop excessive gas pressure, and exhibited superior performance, namely 0.1 volt higher output than the other cells containing the fibrous separators only. Iodide decomposition apparently prevented the voltage from rising above 1.80 volts on overcharge.

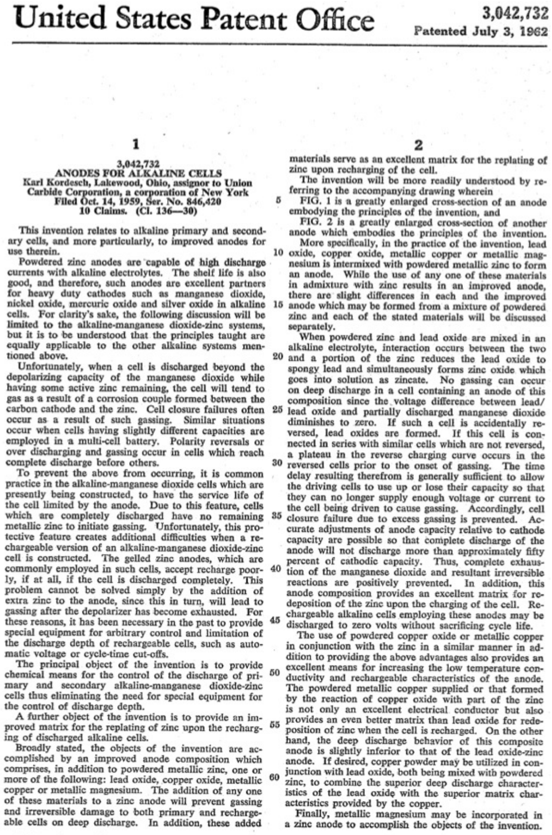
In contrast, similar cells made with semi-permeable membrane separators show approximately 50 percent sealing failures on overcharge.

No detrimental effect of the iodide addition in respect to capacity or shelf behavior has been observed. As is the case with all cells utilizing chemical recombination reactions, the overcharge current must not exceed the equivalent of the transportation rate. It is still possible to explode a cell by accumulation of gas if the charge current is in excess of the diffusion speed of iodine through the separator to the zinc anode. However, iodine diffusion was found to be fairly rapid so that a normal charging rate of approximately 200 to 300 ma. is permissible (500 ma. seems to be the limit for a D-size cell).

The concentration of the iodide material does not appear to be critical except that sufficient iodide should be present to allow for some adsorption of iodide at the cathode. After the initial saturation of the cathode occurs, the excess iodine migrates to the zinc anode and recombines with the zinc. Thus, the minimum amount of iodide necessary is rather difficult to determine since it depends upon the porosity of the MnO_2 cathode. KI, ZnI_2 or I_2, all of which are quite soluble in concentrated KOH, may be added to the solution. Any of the compounds are suitable, although it appears simpler to employ ZnI_2. The KOH electrolyte is normally saturated with ZnO (zinc ions constitute an additional precaution against H_2 evolution on overcharging); therefore, the use of ZnI_2 is similar amounts avoids the necessity of adding both ZnO and KI or I_2.

What is claimed is:

1. In a rechargeable dry cell employing as an electrolyte an aqueous solution of a hydroxide of an alkali metal in conjunction with a cathode having manganese dioxide and an anode consisting of zinc, the improvement consisting in adding to said electrolyte an iodine-containing compound, said compound being present in the range of from 5 percent of said electrolyte to its saturation point in said electrolyte, said compound tend-



United States Patent Office

3,042,732
Patented July 3, 1962

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3,042,732
ANODES FOR ALKALINE CELLS
Karl Kordesch, Lakewood, Ohio, assignor to Union Carbide Corporation, a corporation of New York
Filed Oct. 14, 1959, Ser. No. 846,420
10 Claims. (Cl. 136—30)

This invention relates to alkaline primary and secondary cells, and more particularly, to improved anodes for use therein.

Powdered zinc anodes are capable of high discharge currents with alkaline electrolytes. The shelf life is also good, and therefore, such anodes are excellent partners for heavy duty cathodes such as manganese dioxide, nickel oxide, mercuric oxide and silver oxide in alkaline cells. For clarity's sake, the following discussion will be limited to the alkaline-manganese dioxide-zinc systems, but it is to be understood that the principles taught are equally applicable to the other alkaline systems mentioned above.

Unfortunately, when a cell is discharged beyond the depolarizing capacity of the manganese dioxide while having some active zinc remaining, the cell will tend to gas as a result of a corrosion couple formed between the carbon cathode and the zinc. Cell closure failures often occur as a result of such gassing. Similar situations occur when cells having slightly different capacities are employed in a multi-cell battery. Polarity reversals or over discharging and gassing occur in cells which reach complete discharge before others.

To prevent the above from occurring, it is common practice in the alkaline-manganese dioxide cells which are presently being constructed, to have the service life of the cell limited by the anode. Due to this feature, cells which are completely discharged have no remaining metallic zinc to initiate gassing. Unfortunately, this protective feature creates additional difficulties when a rechargeable version of an alkaline-manganese dioxide-zinc cell is constructed. The gelled zinc anodes, which are commonly employed in such cells, accept recharge poorly, if at all, if the cell is discharged completely. This problem cannot be solved simply by the addition of extra zinc to the anode, since this in turn, will lead to gassing after the depolarizer has become exhausted. For these reasons, it has been necessary in the past to provide special equipment for arbitrary control and limitation of the discharge depth of rechargeable cells, such as automatic voltage or cycle-time cut-offs.

The principal object of the invention is to provide chemical means for the control of the discharge of primary and secondary alkaline-manganese dioxide-zinc cells thus eliminating the need for special equipment for the control of discharge depth.

A further object of the invention is to provide an improved matrix for the replating of zinc upon the recharging of discharged alkaline cells.

Broadly stated, the objects of the invention are accomplished by an improved anode composition which comprises, in addition to powdered metallic zinc, one or more of the following: lead oxide, copper oxide, metallic copper or metallic magnesium. The addition of any one of these materials to a zinc anode will prevent gassing and irreversible damage to both primary and rechargeable cells on deep discharge. In addition, these added

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materials serve as an excellent matrix for the replating of zinc upon recharging of the cell.

The invention will be more readily understood by referring to the accompanying drawing wherein

FIG. 1 is a greatly enlarged cross-section of an anode embodying the principles of the invention, and

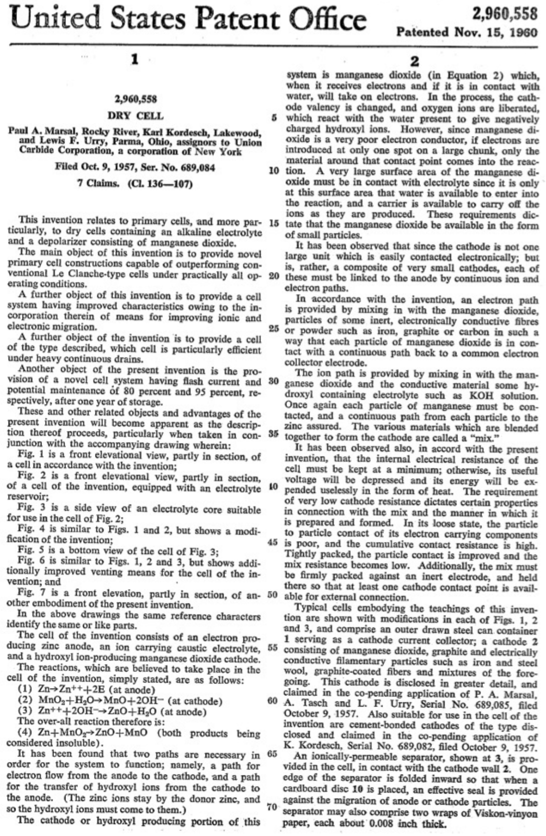
FIG. 2 is a greatly enlarged cross-section of another anode which embodies the principles of the invention.

More specifically, in the practice of the invention, lead oxide, copper oxide, metallic copper or metallic magnesium is intermixed with powdered metallic zinc to form an anode. While the use of any one of these materials in admixture with zinc results in an improved anode, there are slight differences in each and the improved anode which may be formed from a mixture of powdered zinc and each of the stated materials will be discussed separately.

When powdered zinc and lead oxide are mixed in an alkaline electrolyte, interaction occurs between the two and a portion of the zinc reduces the lead oxide to spongy lead and simultaneously forms zinc oxide which goes into solution as zincate. No gassing can occur on deep discharge in a cell containing an anode of this composition since the voltage difference between lead/lead oxide and partially discharged manganese dioxide diminishes to zero. If such a cell is accidentally reversed, lead oxides are formed. If this cell is connected in series with similar cells which are not reversed, a plateau in the reverse charging curve occurs in the reversed cells prior to the onset of gassing. The time delay resulting therefrom is generally sufficient to allow the driving cells to use up or lose their capacity so that they can no longer supply enough voltage or current to the cell being driven to cause gassing. Accordingly, cell closure failure due to excess gassing is prevented. Accurate adjustments of anode capacity relative to cathode capacity are possible so that complete discharge of the anode will not discharge more than approximately fifty percent of cathodic capacity. Thus, complete exhaustion of the manganese dioxide and resultant irreversible reactions are positively prevented. In addition, this anode composition provides an excellent matrix for redeposition of the zinc upon the charging of the cell. Rechargeable alkaline cells employing these anodes may be discharged to zero volts without sacrificing cycle life.

The use of powdered copper oxide or metallic copper in conjunction with the zinc in a similar manner in addition to providing the above advantages also provides an excellent means for increasing the low temperature conductivity and rechargeable characteristics of the anode. The powdered metallic copper supplied or that formed by the reaction of copper oxide with part of the zinc is not only an excellent electrical conductor but also provides an even better matrix than lead oxide for redeposition of zinc when the cell is recharged. On the other hand, the deep discharge behavior of this composite anode is slightly inferior to that of the lead oxide-zinc anode. If desired, copper powder may be utilized in conjunction with lead oxide, both being mixed with powdered zinc, to combine the superior deep discharge characteristics of the lead oxide with the superior matrix characteristics provided by the copper.

Finally, metallic magnesium may be incorporated in a zinc anode to accomplish the objects of the invention.



United States Patent Office

2,960,558
Patented Nov. 15, 1960

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2,960,558
DRY CELL
Paul A. Marsal, Rocky River, Karl Kordesch, Lakewood, and Lewis F. Urry, Parma, Ohio, assignors to Union Carbide Corporation, a corporation of New York
Filed Oct. 9, 1957, Ser. No. 689,084
7 Claims. (Cl. 136—107)

This invention relates to primary cells, and more particularly, to dry cells containing an alkaline electrolyte and a depolarizer consisting of manganese dioxide.

The main object of this invention is to provide novel primary cell constructions capable of outperforming conventional Le Clanche-type cells under practically all operating conditions.

A further object of this invention is to provide a cell system having improved characteristics owing to the incorporation therein of means for improving ionic and electronic migration.

A further object of the invention is to provide a cell of the type described, which cell is particularly efficient under heavy continuous drains.

Another object of the present invention is the provision of a novel cell system having flash current and potential maintenance of 80 percent and 95 percent, respectively, after one year of storage.

These and other related objects and advantages of the present invention will become apparent as the description thereof proceeds, particularly when taken in conjunction with the accompanying drawing wherein:

Fig. 1 is a front elevational view, partly in section, of a cell in accordance with the invention;

Fig. 2 is a front elevational view, partly in section, of a cell of the invention, equipped with an electrolyte reservoir;

Fig. 3 is a side view of an electrolyte core suitable for use in the cell of Fig. 2;

Fig. 4 is similar to Figs. 1 and 2, but shows a modification of the invention;

Fig. 5 is a bottom view of the cell of Fig. 3;

Fig. 6 is similar to Figs. 1, 2 and 3, but shows additionally improved venting means for the cell of the invention; and

Fig. 7 is a front elevation, partly in section, of another embodiment of the present invention.

In the above drawings the same reference characters identify the same or like parts.

The cell of the invention consists of an electron producing zinc anode, an ion carrying caustic electrolyte, and a hydroxyl ion-producing manganese dioxide cathode.

The reactions, which are believed to take place in the cell of the invention, simply stated, are as follows:

(1) $Zn \rightarrow Zn^{++} + 2E$ (at anode)
(2) $MnO_2 + H_2O \rightarrow MnO + 2OH^-$ (at cathode)
(3) $Zn^{++} + 2OH^- \rightarrow ZnO + H_2O$ (at anode)

The over-all reaction therefore is:

(4) $Zn + MnO_2 \rightarrow ZnO + MnO$ (both products being considered insoluble).

It has been found that two paths are necessary in order for the system to function; namely, a path for electron flow from the anode to the cathode, and a path for the transfer of hydroxyl ions from the cathode to the anode. (The zinc ions stay by the donor zinc, and so the hydroxyl ions must come to them.)

The cathode or hydroxyl producing portion of this

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system is manganese dioxide (in Equation 2) which, when it receives electrons and if it is in contact with water, will take on electrons. In the process, the cathode valency is changed, and oxygen ions are liberated, which react with the water present to give negatively charged hydroxyl ions. However, since manganese dioxide is a very poor electron conductor, if electrons are introduced at only one spot on a large chunk, only the material around that contact point comes into the reaction. A very large surface area of the manganese dioxide must be in contact with electrolyte since it is only at this surface area that water is available to enter into the reaction, and a carrier is available to carry off the ions as they are produced. These requirements dictate that the manganese dioxide be available in the form of small particles.

It has been observed that since the cathode is not one large unit which is easily contacted electronically; but is, rather, a composite of very small cathodes, each of these must be linked to the anode by continuous ion and electron paths.

In accordance with the invention, an electron path is provided by mixing in with the manganese dioxide, particles of some inert, electronically conductive fibres or powder such as iron, graphite or carbon in such a way that each particle of manganese dioxide is in contact with a continuous path back to a common electron collector electrode.

The ion path is provided by mixing in with the manganese dioxide and the conductive material some hydroxyl containing electrolyte such as KOH solution. Once again each particle of manganese must be contacted, and a continuous path from each particle to the zinc assured. The various materials which are blended together to form the cathode are called a "mix."

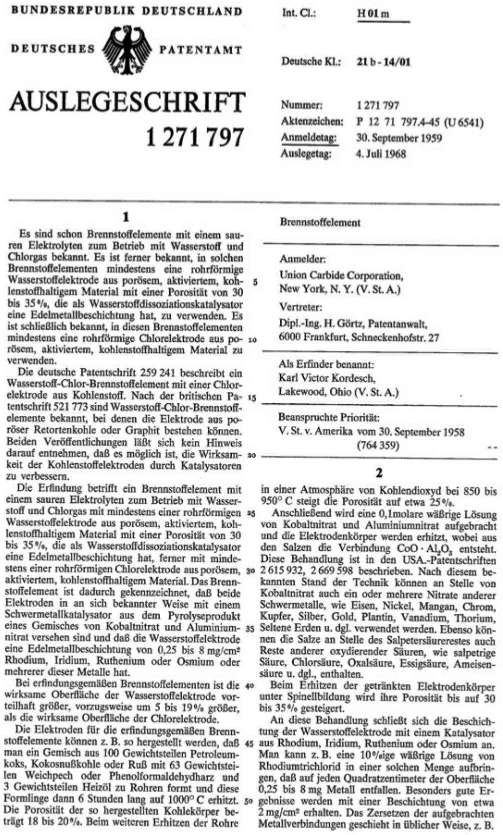
It has been observed also, in accord with the present invention, that the internal electrical resistance of the cell must be kept at a minimum; otherwise, its useful voltage will be depressed and its energy will be expended uselessly in the form of heat. The requirement of very low cathode resistance dictates certain properties in connection with the mix and the manner in which it is prepared and formed. In its loose state, the particle to particle contact of its electron carrying components is poor, and the cumulative contact resistance is high. Tightly packed, the particle contact is improved and the mix resistance becomes low. Additionally, the mix must be firmly packed against an inert electrode, and held there so that at least one cathode contact point is available for external connection.

Typical cells embodying the teachings of this invention are shown with modifications in each of Figs. 1, 2 and 3, and comprise an outer drawn steel can container 1 serving as a cathode current collector; a cathode 2 consisting of manganese dioxide, graphite and electrically conductive filamentary particles such as iron and steel wool, graphite-coated fibers and mixtures of the foregoing. This cathode is disclosed in greater detail, and claimed in the co-pending application of P. A. Marsal, A. Tasch and L. F. Urry, Serial No. 689,085, filed October 9, 1957. Also suitable for use in the cell of the invention are cement-bonded cathodes of the type disclosed and claimed in the co-pending application of K. Kordesch, Serial No. 689,082, filed October 9, 1957.

An ionically-permeable separator, shown at 3, is provided in the cell, in contact with the cathode wall 2. One edge of the separator is folded inward so that when a cardboard disc 10 is placed, an effective seal is provided against the migration of anode or cathode particles. The separator may also comprise two wraps of Viskon-vinyon paper, each about 0.008 inch thick.

Figure 3.129: Karl Kordesch, an Austrian battery expert who was brought to the United States as part of Operation Paperclip, invented alkaline dry batteries in 1957 or earlier.

Karl Kordesch (1922–2011) invented improved fuel cells



BUNDESREPUBLIK DEUTSCHLAND

DEUTSCHES PATENTAMT

AUSLEGESCHRIFT
1 271 797

Int. Cl.: H 01 m

Deutsche Kl.: 21 b - 14/01

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Anmeldetag: 30. September 1959
Auslegetag: 4. Juli 1968

Brennstoffelement

Anmelder:
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Beanspruchte Priorität:
V. St. v. Amerika vom 30. September 1958
(764 359)

1

Es sind schon Brennstoffelemente mit einem sauren Elektrolyten zum Betrieb mit Wasserstoff und Chlorgas bekannt. Es ist ferner bekannt, in solchen Brennstoffelementen mindestens eine rohrförmige Wasserstoffelektrode aus porösem, aktiviertem, kohlenstoffhaltigem Material mit einer Porosität von 30 bis 35%, die als Wasserstoffdissoziationskatalysator eine Edelmetallbeschichtung hat, zu verwenden. Es ist schließlich bekannt, in diesen Brennstoffelementen mindestens eine rohrförmige Chlorelektrode aus porösem, aktiviertem, kohlenstoffhaltigem Material zu verwenden.

Die deutsche Patentschrift 259 241 beschreibt ein Wasserstoff-Chlor-Brennstoffelement mit einer Chlorelektrode aus Kohlenstoff. Nach der britischen Patentschrift 521 773 sind Wasserstoff-Chlor-Brennstoffelemente bekannt, bei denen die Elektrode aus poröser Retortenkohle oder Graphit bestehen können. Beiden Veröffentlichungen läßt sich kein Hinweis darauf entnehmen, daß es möglich ist, die Wirksamkeit der Kohlenstoffelektroden durch Katalysatoren zu verbessern.

Die Erfindung betrifft ein Brennstoffelement mit einem sauren Elektrolyten zum Betrieb mit Wasserstoff und Chlorgas mit mindestens einer rohrförmigen Wasserstoffelektrode aus porösem, aktiviertem, kohlenstoffhaltigem Material mit einer Porosität von 30 bis 35%, die als Wasserstoffdissoziationskatalysator eine Edelmetallbeschichtung hat, ferner mit mindestens einer rohrförmigen Chlorelektrode aus porösem, aktiviertem, kohlenstoffhaltigem Material. Das Brennstoffelement ist dadurch gekennzeichnet, daß beide Elektroden in an sich bekannter Weise mit einem Schwermetallkatalysator aus dem Pyrolyseprodukt eines Gemisches von Kobaltnitrat und Aluminiumnitrat versehen sind und daß die Wasserstoffelektrode eine Edelmetallbeschichtung von 0,25 bis 8 mg/cm^2 Rhodium, Iridium, Ruthenium oder Osmium oder mehrerer dieser Metalle hat.

Bei erfindungsgemäßen Brennstoffelementen ist die wirksame Oberfläche der Wasserstoffelektrode vorteilhaft größer, vorzugsweise um 5 bis 19% größer, als die wirksame Oberfläche der Chlorelektrode.

Die Elektroden für die erfindungsgemäßen Brennstoffelemente können z. B. so hergestellt werden, daß man ein Gemisch aus 100 Gewichtsteilen Petroleumkoks, Kokosnußkohle oder Ruß mit 63 Gewichtsteilen Weichpech oder Phenolformaldehydharz und 3 Gewichtsteilen Heizöl zu Rohren formt und diese Formlinge dann 6 Stunden lang auf 1000° C erhitzt. Die Porosität der so hergestellten Kohlekörper beträgt 18 bis 20%. Beim weiteren Erhitzen der Rohre

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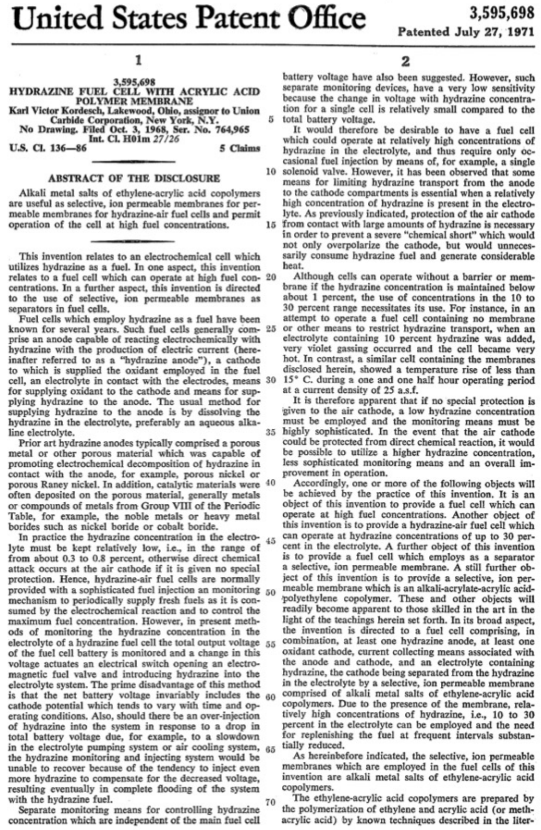
in einer Atmosphäre von Kohlendioxyd bei 850 bis 950° C steigt die Porosität auf etwa 25%.

Anschließend wird eine 0,1molare wäßrige Lösung von Kobaltnitrat und Aluminiumnitrat aufgebracht und die Elektrodenkörper werden erhitzt, wobei aus den Salzen die Verbindung $CoO \cdot Al_2O_3$ entsteht. Diese Behandlung ist in den USA.-Patentschriften 2 615 932, 2 669 598 beschrieben. Nach diesem bekannten Stand der Technik können an Stelle von Kobaltnitrat auch ein oder mehrere Nitrate anderer Schwermetalle, wie Eisen, Nickel, Mangan, Chrom, Kupfer, Silber, Gold, Plantin, Vanadium, Thorium, Seltene Erden u. dgl. verwendet werden. Ebenso können die Salze an Stelle des Salpetersäurerestes auch Reste anderer oxydierender Säuren, wie salpetrige Säure, Chlorsäure, Oxalsäure, Essigsäure, Ameisensäure u. dgl., enthalten.

Beim Erhitzen der getränkten Elektrodenkörper unter Spinellbildung wird ihre Porosität bis auf 30 bis 35% gesteigert.

An diese Behandlung schließt sich die Beschichtung der Wasserstoffelektrode mit einem Katalysator aus Rhodium, Iridium, Ruthenium oder Osmium an. Man kann z. B. eine 10%ige wäßrige Lösung von Rhodiumtrichlorid in einer solchen Menge aufbringen, daß auf jeden Quadratzentimeter der Oberfläche 0,25 bis 8 mg Metall entfallen. Besonders gute Ergebnisse werden mit einer Beschichtung von etwa 2 mg/cm^2 erhalten. Das Zersetzen der aufgebrachten Metallverbindungen geschieht in üblicher Weise, z. B.



United States Patent Office 3,595,698
Patented July 27, 1971

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3,595,698
HYDRAZINE FUEL CELL WITH ACRYLIC ACID POLYMER MEMBRANE
Karl Victor Kordesch, Lakewood, Ohio, assignor to Union Carbide Corporation, New York, N.Y.
No Drawing. Filed Oct. 3, 1968, Ser. No. 764,965
Int. Cl. H01m *27/26*
U.S. Cl. 136—86 5 Claims

ABSTRACT OF THE DISCLOSURE

Alkali metal salts of ethylene-acrylic acid copolymers are useful as selective, ion permeable membranes for permeable membranes for hydrazine-air fuel cells and permit operation of the cell at high fuel concentrations.

This invention relates to an electrochemical cell which utilizes hydrazine as a fuel. In one aspect, this invention relates to a fuel cell which can operate at high fuel concentrations. In a further aspect, this invention is directed to the use of selective, ion permeable membranes as separators in fuel cells.

Fuel cells which employ hydrazine as a fuel have been known for several years. Such fuel cells generally comprise an anode capable of reacting electrochemically with hydrazine with the production of electric current (hereinafter referred to as a "hydrazine anode"), a cathode to which is supplied the oxidant employed in the fuel cell, an electrolyte in contact with the electrodes, means for supplying oxidant to the cathode and means for supplying hydrazine to the anode. The usual method for supplying hydrazine to the anode is by dissolving the hydrazine in the electrolyte, preferably an aqueous alkaline electrolyte.

Prior art hydrazine anodes typically comprised a porous metal or other porous material which was capable of promoting electrochemical decomposition of hydrazine in contact with the anode, for example, porous nickel or porous Raney nickel. In addition, catalytic materials were often deposited on the porous material, generally metals or compounds of metals from Group VIII of the Periodic Table, for example, the noble metals or heavy metal borides such as nickel boride or cobalt boride.

In practice the hydrazine concentration in the electrolyte must be kept relatively low, i.e., in the range of from about 0.3 to 0.8 percent, otherwise direct chemical attack occurs at the air cathode if it is given no special protection. Hence, hydrazine-air fuel cells are normally provided with a sophisticated fuel injection an monitoring mechanism to periodically supply fresh fuels as it is consumed by the electrochemical reaction and to control the maximum fuel concentration. However, in present methods of monitoring the hydrazine concentration in the electrolyte of a hydrazine fuel cell the total output voltage of the fuel cell battery is monitored and a change in this voltage actuates an electrical switch opening an electromagnetic fuel valve and introducing hydrazine into the electrolyte system. The prime disadvantage of this method is that the net battery voltage invariably includes the cathode potential which tends to vary with time and operating conditions. Also, should there be an over-injection of hydrazine into the system in response to a drop in total battery voltage due, for example, to a slowdown in the electrolyte pumping system or air cooling system, the hydrazine monitoring and injecting system would be unable to recover because of the tendency to inject even more hydrazine to compensate for the decreased voltage, resulting eventually in complete flooding of the system with the hydrazine fuel.

Separate monitoring means for controlling hydrazine concentration which are independent of the main fuel cell

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battery voltage have also been suggested. However, such separate monitoring devices, have a very low sensitivity because the change in voltage with hydrazine concentration for a single cell is relatively small compared to the total battery voltage.

It would therefore be desirable to have a fuel cell which could operate at relatively high concentrations of hydrazine in the electrolyte, and thus require only occasional fuel injection by means of, for example, a single solenoid valve. However, it has been observed that some means for limiting hydrazine transport from the anode to the cathode compartments is essential when a relatively high concentration of hydrazine is present in the electrolyte. As previously indicated, protection of the air cathode from contact with large amounts of hydrazine is necessary in order to prevent a severe "chemical short" which would not only overpolarize the cathode, but would unnecessarily consume hydrazine fuel and generate considerable heat.

Although cells can operate without a barrier or membrane if the hydrazine concentration is maintained below about 1 percent, the use of concentrations in the 10 to 30 percent range necessitates its use. For instance, in an attempt to operate a fuel cell containing no membrane or other means to restrict hydrazine transport, when an electrolyte containing 10 percent hydrazine was added, very violet gassing occurred and the cell became very hot. In contrast, a similar cell containing the membranes disclosed herein, showed a temperature rise of less than 15° C. during a one and one half hour operating period at a current density of 25 a.s.f.

It is therefore apparent that if no special protection is given to the air cathode, a low hydrazine concentration must be employed and the monitoring means must be highly sophisticated. In the event that the air cathode could be protected from direct chemical reaction, it would be possible to utilize a higher hydrazine concentration, less sophisticated monitoring means and an overall improvement in operation.

Accordingly, one or more of the following objects will be achieved by the practice of this invention. It is an object of this invention to provide a fuel cell which can operate at high fuel concentrations. Another object of this invention is to provide a hydrazine-air fuel cell which can operate at hydrazine concentrations of up to 30 percent in the electrolyte. A further object of this invention is to provide a fuel cell which employs as a separator a selective, ion permeable membrane. A still further object of this invention is to provide a selective, ion permeable membrane which is an alkali-acrylate-acrylic acid-polyethylene copolymer. These and other objects will readily become apparent to those skilled in the art in the light of the teachings herein set forth. In its broad aspect, the invention is directed to a fuel cell comprising, in combination, at least one hydrazine anode, at least one oxidant cathode, current collecting means associated with the anode and cathode, and an electrolyte containing hydrazine, the cathode being separated from the hydrazine in the electrolyte by a selective, ion permeable membrane comprised of alkali metal salts of ethylene-acrylic acid copolymers. Due to the presence of the membrane, relatively high concentrations of hydrazine, i.e., 10 to 30 percent in the electrolyte can be employed and the need for replenishing the fuel at frequent intervals substantially reduced.

As hereinbefore indicated, the selective, ion permeable membranes which are employed in the fuel cells of this invention are alkali metal salts of ethylene-acrylic acid copolymers.

The ethylene-acrylic acid copolymers are prepared by the polymerization of ethylene and acrylic acid (or methacrylic acid) by known techniques described in the liter-

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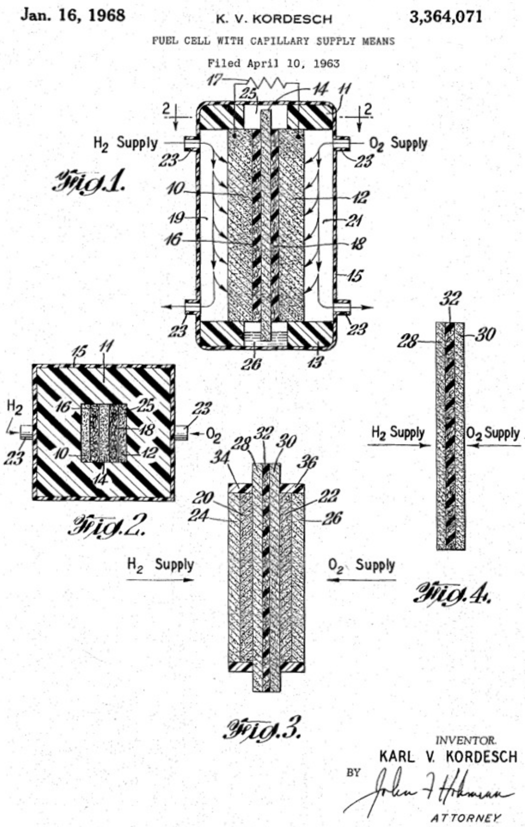
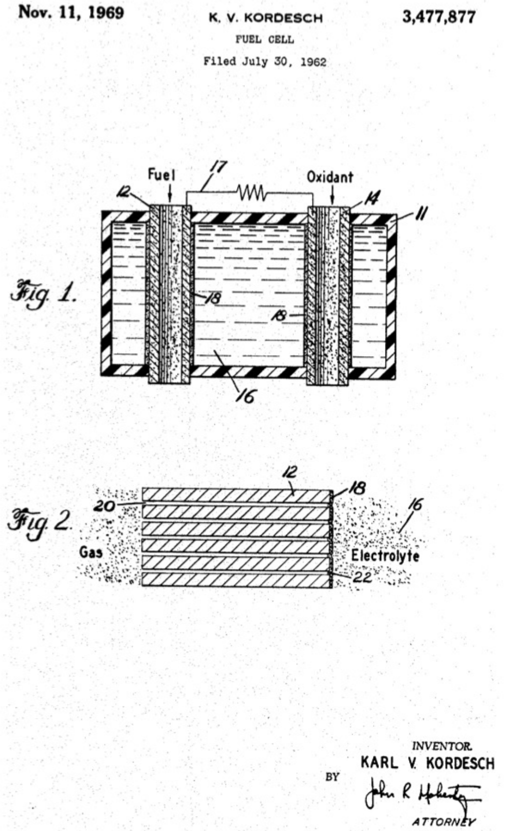


Jan. 16, 1968 K. V. KORDESCH 3,364,071
FUEL CELL WITH CAPILLARY SUPPLY MEANS
Filed April 10, 1963

INVENTOR.
KARL V. KORDESCH
BY
ATTORNEY



Nov. 11, 1969 K. V. KORDESCH 3,477,877
FUEL CELL
Filed July 30, 1962

INVENTOR.
KARL V. KORDESCH
BY
ATTORNEY

Figure 3.130: Karl Kordesch also invented improved fuel cells.

3.7 Film Photography

While early film photography was being developed and practiced in France, the United Kingdom, the United States, and other countries, most of the key technological advances were made in the German-speaking world (Section 3.7.1) and then transferred to other countries (Section 3.7.2).[14] See Figs. 3.131–3.144.

Even the American chemist and chemical historian Aaron Ihde admitted [Ihde 1984, p. 464]:

> The German industry held a virtual monopoly until World War I as a supplier of photographic chemicals, optical glass, and high quality cameras.

3.7.1 Development of Photography

In 1717, Johann Heinrich Schulze (German states, 1687–1744, Fig. 3.132) discovered that light causes some silver solutions to become darker. He used that process to reproduce clear images such as words, although he found that the images in the silver solutions faded with time. Schulze published his results in books that were freely circulated within the European chemical community, thus launching the field of chemical photography.

Building upon Schulze's research, in 1777 Carl Wilhelm Scheele (German states, 1742–1786, Fig. 3.132) developed a chemical fixer for silver solutions to make the light-induced images permanent and to prevent further light from altering the images. Scheele also discovered the need for working with light-sensitive silver solutions in red light until they were fixed. Scheele's research findings, like the earlier discoveries of Schulze, were circulated within the community of European chemists. Thus Schulze and Scheele were responsible for establishing the fundamental chemical and physical principles upon which film photography has been based ever since.

It appears that the German-speaking scientific world reduced the discoveries of Schulze and Scheele to practical and commercial applications by the early nineteenth century. No later than 1839, the brothers Friedrich Wilhelm Enzmann (German states, 1802–1866, Fig. 3.131) and Carl Heinrich Enzmann (German states, 18??–18??) were producing and selling cameras and photographic film as a regular commercial business.

These early German developments in photography spread to other countries, where they were adopted and further publicized by other scientists such as Louis Daguerre (French, 1787–1851) and William Henry Fox Talbot (English, 1800–1877). Especially in the English-speaking world, some historians erroneously assigned credit for the invention of photography to those later scientists, although the original discoveries and inventions clearly arose earlier and in the German-speaking world.

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[14] See for example: Flueckiger 2020; Gill and Mustroph 2014, 2015a, 2015b; BIOS 61; BIOS 252; BIOS 262; BIOS 397; BIOS 435; BIOS 484; BIOS 492; BIOS 658; BIOS 772; BIOS 773; BIOS 1180; BIOS 1355; BIOS 1605; BIOS 1627; BIOS Overall 19; CIOS ER 217; CIOS ER 345; CIOS XII-22; CIOS XIII-5; CIOS XVII-10; CIOS XXVI-7; CIOS XXVI-61; CIOS XXX-15; CIOS XXX-17; FIAT 153; FIAT 351; FIAT 355; FIAT 356; FIAT 357; FIAT 358; FIAT 359; FIAT 360; FIAT 678; FIAT 698; FIAT 721; FIAT 891; FIAT 893; FIAT 943; FIAT 953; FIAT 976; FIAT 977; JIOA 13; NavTecMisEu 96-45; NavTecMisEu 140-45.

In 1873, Hermann Wilhelm Vogel (German, 1834–1898, not to be confused with the astronomer Hermann Carl Vogel) invented dye color sensitization, which enabled photographic emulsions to be made sensitive to different colors of light, and thereby led to color photography. His results were widely publicized (Fig. 3.133) and became the basis of almost all color photography. *Chronologie Chemie* described Vogel's revolutionary innovation [Neufeldt 2003, p. 74]:

Die Entdeckung der optischen Sensibilisierung photographischer Schichten, so daß diese außer für blau auch für weitere Spektralbereiche lichtempfindlich werden, führt zu naturgetreuen Schattierungen in der Schwarz-Weiß-Photographie. Vogel beobachtet dieses Phänomen zuerst am Farbstoff Korallin, die Weiterentwicklung führt zur Sensibilisierung für grünes und gelbes Licht (orthochromatische Filme) und schließlich mit Hilfe der Polymethin-Farbstoffe zur Sensibilisierung für den gesamten sichtbaren Spektralbereich (panchromatische Filme).	The discovery of optical sensitization of photographic layers, so that they become light-sensitive to other spectral ranges in addition to blue, led to lifelike shading in black-and-white photography. Vogel first observed this phenomenon with the dye coralline; further development led to sensitization for green and yellow light (orthochromatic films) and finally, with the help of polymethine dyes, to sensitization for the entire visible spectral range (panchromatic films).

Ferdinand Hurter (Swiss, 1844–1898, Fig. 3.131) worked to make photography more rigorously systematic, such as defining and measuring film speed, optical density, and other properties.

As shown in Fig. 3.134, Ottomar Anschütz (German, 1846–1907) invented high-speed camera shutters in 1881 and compact portable cameras in 1896.

Momme Andresen (German/Danish, 1857–1951) invented new and improved chemical developers and fixers for photography from the 1880s onward. He helped to build what became known as the Agfa photography company (derived and rebranded from the earlier Aktiengesellschaft für Anilinfabrikation) and employed other chemists such as Ernst Leupold (German, 18??–19??). See Fig. 3.135.

As shown in Fig. 3.136, the brothers Max Skladanowsky (German, 1863–1939) and Emil Skladanowsky (German, 1866–1945) created the Bioscop motion picture camera and projector in 1892 and presented the first public films in 1895.

Adolf Miethe (German, 1862–1927) produced high-quality color photographs using a three-color process beginning in 1901 (Fig. 3.137). He also invented the first practical flash powder for photography.

Raphael Eduard Liesegang (German, 1869–1947, Fig. 3.132) conducted numerous experimental and theoretical analyses of the photochemistry of both black-and-white photography and color photography.

Rudolf Fischer (German, 1881–1957) invented Agfa color film in 1911 (Fig. 3.138). He worked closely with Wilhelm Siegrist (German, 1881–19??) for part of that period.

In 1913, Oskar Barnack (German, 1879–1936) invented the first modern 35 mm still camera, which later was dubbed Leica (for Leitz Camera); see Fig. 3.139. The *Encyclopedia Britannica* described his invention [EB 2010]:

> [D]esigner of the first precision miniature camera to become available commercially, the Leica I, which was introduced in 1924 by the Ernst Leitz optical firm at Wetzlar, Ger.
>
> Barnack was a master mechanic and inventor who joined the Leitz optical firm in 1911. Barnack had completed a prototype of the Leica by 1913, but World War I and the postwar chaos in Germany delayed production. The success of the Leica I promoted the use of 35-millimetre and other small cameras. Barnack determined the standard 24 × 36-millimetre picture size for 35-millimetre film and was partly responsible for the Leitz Elmar lens.

As shown in Fig. 3.140, Max Hagedorn (German, 18??–19??) created improved film stock from 1924 onward.

Ernst Bauer (German, 18??–19??), Wilhelm Schneider (German, 18??–19??), and Gustav Wilmanns (German, 18??–19??) invented Agfa Neu improved color film in 1935. Their technology was showcased in films such as *Frauen sind doch bessere Diplomaten* (Fig. 3.141) and became the basis for most color film around the world after World War II.

Joseph Joshua Weiss (Austrian, 1905–1972, Fig. 3.132) carried out a series of analyses on the photochemical reaction mechanisms in photographic film.

Artur Fischer (German, 1919–2016, Fig. 3.131) invented a system for synchronizing a photo flash with the camera shutter.

The German-speaking world also developed very high-quality optical components and optical devices that were important for photography (p. 680 and Section 6.9).

3.7.2 Transfer of Photography-Related Technologies

As illustrated by the examples above, a wide variety of advanced technologies, components, and methods for photography were created in the German-speaking world. Some were transferred to other countries via patents, publications, and commerce before World War II, but many of the most advanced photographic technologies were only transferred after the war. For some examples of transferred technologies, see Figs. 3.142–3.144 and the following reports:

> BIOS 61. *Weapons Section of the LFA, Volkenrode, with Notes on Photographic Methods Used in German Ballistics.*
>
> BIOS 252. *I. G. Photopapier Fabrik (AGFA), Leverkusen, Near Cologne.*
>
> BIOS 262. *German Photographic Film Base Industry.*
>
> BIOS 397. *Agfa Colour.*

BIOS 435. *Ozalid Light-Sensitive Materials, Kalle & Co., Wiesbaden—Biebrich (I.G. Farbenindustrie A.G.).*

BIOS 484. *The German Printing Industry.*

BIOS 492. *Explosives Work and Associated Photographic Technique.*

BIOS 658. *German Photographic Industry.*

BIOS 772. *Manufacture of Diazo Chemicals, Kalle & Co., Wiesbaden/Biebrich.*

BIOS 773. *Manufacture of Photographic Developing Substances at I.G. Farbenfabrik, Wolfen.*

BIOS 1180. *German Between-Lens Photographic Shutter Production.*

BIOS 1355. *Further Investigation of Agfa Filmfabrik (Photographic Plant), Wolfen, Near Leipzig.*

BIOS 1605. *I.G. Farbenindustrie. The Manufacture of Intermediates and "Colour Formers" for Agfa Farbenfilm.*

BIOS 1627. *German Organic and Inorganic Photographic Chemicals Manufacture.*

BIOS Overall 19. *Photographic Industry.*

CIOS ER 217. *Report on Manufacture of Air Photography Apparatus.*

CIOS ER 345. *Report on: I.G. Agfa, Wolfen; I.G. Farben, Wolfen.*

CIOS XII-22. *Electronic Test Instruments Spark and Flash Discharge Photographic Equipment Philips, Eindhoven.*

CIOS XIII-5. *Photographic Lenses and Optical Instruments.*

CIOS XVII-10. *Gervart Photo Material Manufacturer, Antwerp.*

CIOS XXVI-7. *Focke Wulf Photo Reproduction Department, Bad Eilsen.*

CIOS XXVI-61. *Film Production and Methods, Agfa Film Fabrik Plant, Wolfen.*

CIOS XXX-15. *Agfa Film Factory, Wolfen.*

CIOS XXX-17. *I.G. Farben, Agfa Subsidiary, Wolfen.*

FIAT 153. *Punching of Spinnerets, I.G. Farbenindustrie, Agfa Camera Werke, Munich.*

FIAT 351. *Photosensitive Products, Kalle & Company.*

FIAT 355. *Interviews with Technical Personnel, Agfa, Wolfen.*

FIAT 356. *Report on Photographic Silver Nitrate as Manufactured by Degussa, Frankfurt/M.*

FIAT 357. *Photographic Gelatin Plants.*

FIAT 358. *The Manufacture of Photosensitive Products at the Schleussner Film Werke.*

FIAT 359. *Report on Goebel, A. G. Darmstadt.* [photosensitive materials]

FIAT 360. *Report on AGFA Photo Paper Plant, at Leverkusen.*

FIAT 678. *Status of Exploitation of Photography and Optics in Germany.*

FIAT 698. *Photographing a Single Fuel Injection.*

FIAT 721. *Agfacolor Negative-Positive Method for Professional Motion Pictures.*

FIAT 891. *Duxochrome Photo Color Prints.*

FIAT 893. *Introduction to Technical Photographic X-Ray.*

FIAT 943. *The Manufacture of Agfacolor Material.*

FIAT 953. *Color Photography.*

FIAT 976. *Agfa Color Process.*

FIAT 977. *Color Reproduction by Color Photography.*

JIOA 13. *Photo-Mapping and Map Reproduction.*

NavTecMisEu 96-45. *Investigation of Film Production and Methods at the Agfa Film Fabrik Plant, Wolfen, Germany.*

NavTecMisEu 140-45. *Agfa Paper Formulae.*

Scientists from the German-speaking world also developed technologies for electronic photography and transferred those technologies to other countries, especially after World War II. See Sections 6.3, 6.5, and 6.6. Over the course of several decades after World War II, German-derived chemical film technologies for photography were slowly and ultimately almost completely eclipsed by German-derived electronic photography technologies.

Photography

Carl Heinrich Enzmann (18??–18??)

Friedrich Wilhelm Enzmann (1802–1866)

Artur Fischer (1919–2016)

Ferdinand Hurter (1844–1898)

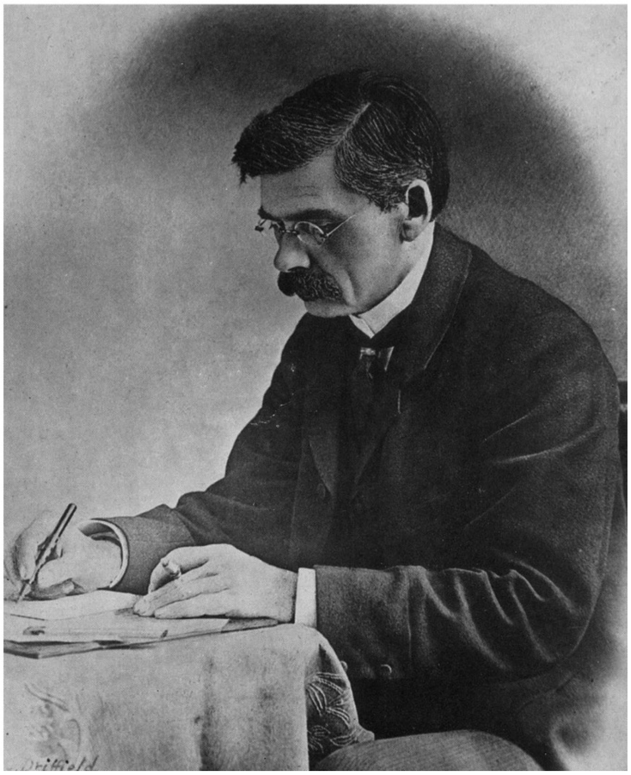


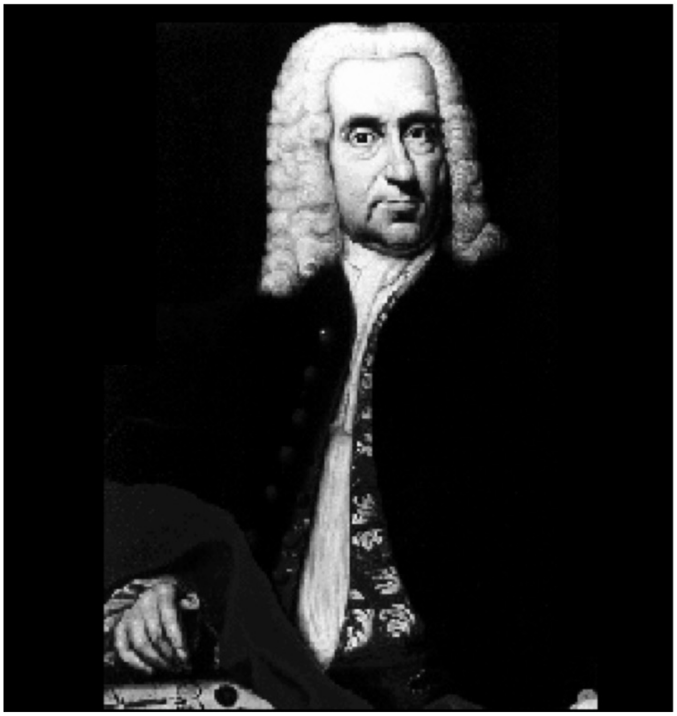
Figure 3.131: Some creators who made important contributions to photography included Carl Heinrich Enzmann, Friedrich Wilhelm Enzmann, Artur Fischer, and Ferdinand Hurter.

Photography

Raphael Eduard Liesegang (1869–1947)

Carl Wilhelm Scheele (1742–1786)

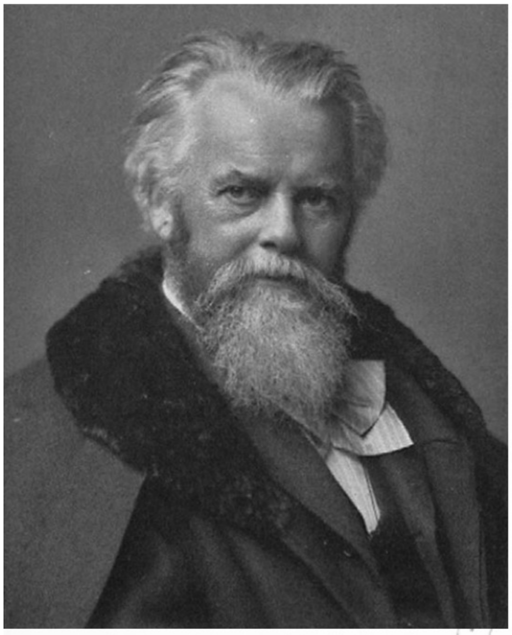
Johann Heinrich Schulze (1687–1744)

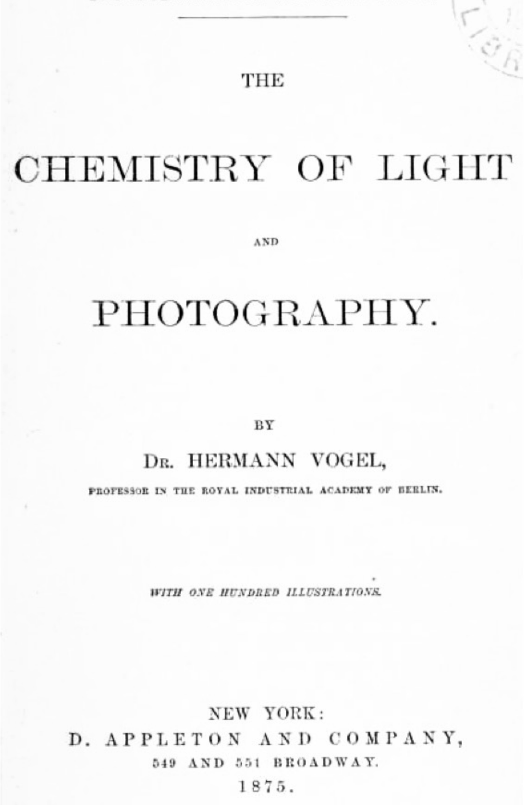


Joseph Joshua Weiss (1905–1972)

Figure 3.132: Other creators who made important contributions to photography included Raphael Eduard Liesegang, Carl Wilhelm Scheele, Johann Heinrich Schulze, and Joseph Joshua Weiss.

Hermann Wilhelm
Vogel (1834–1898)
invented dye sensitization
for color photography (1873)





THE INTERNATIONAL SCIENTIFIC SERIES.

THE

CHEMISTRY OF LIGHT

AND

PHOTOGRAPHY.

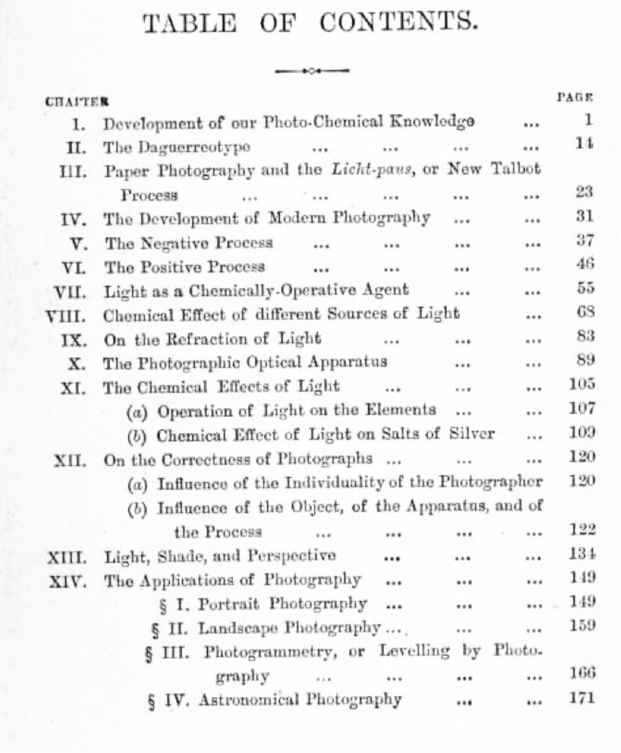
BY

DR. HERMANN VOGEL,

PROFESSOR IN THE ROYAL INDUSTRIAL ACADEMY OF BERLIN.

WITH ONE HUNDRED ILLUSTRATIONS.

NEW YORK:
D. APPLETON AND COMPANY,
549 AND 551 BROADWAY.
1875.



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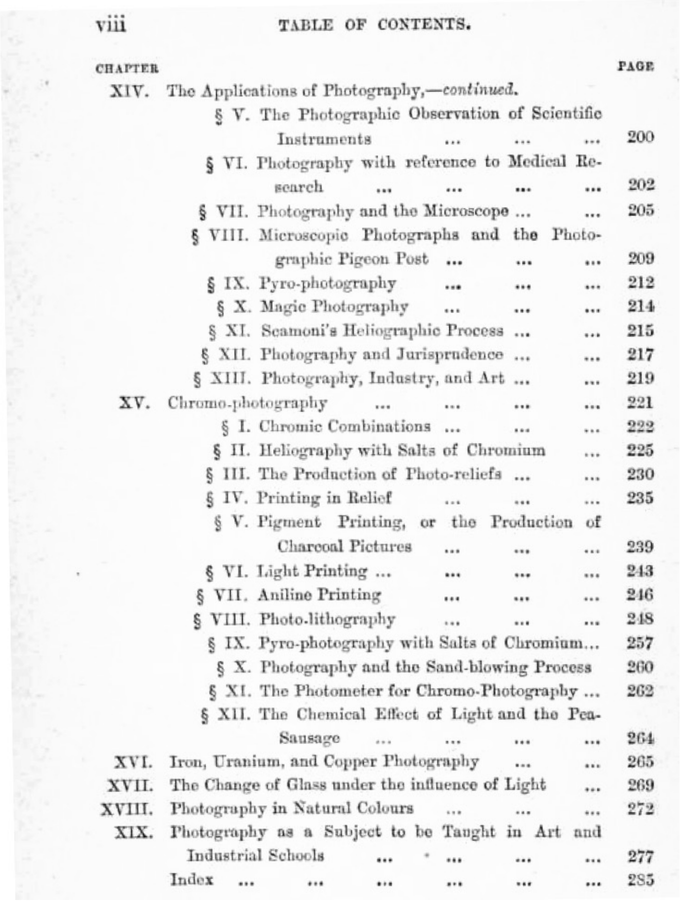

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Figure 3.133: Hermann Wilhelm Vogel invented dye sensitization for color photography in 1873.

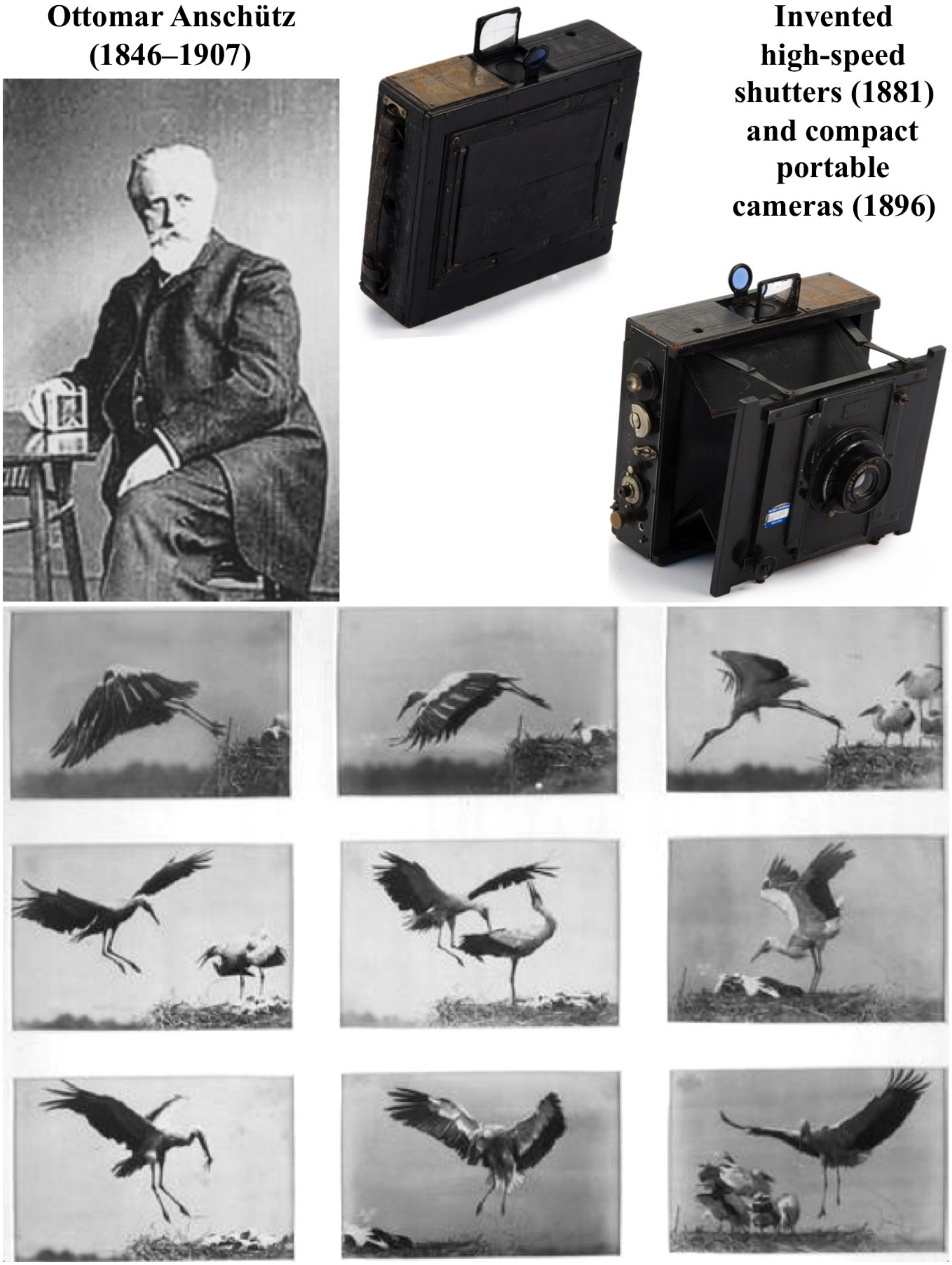
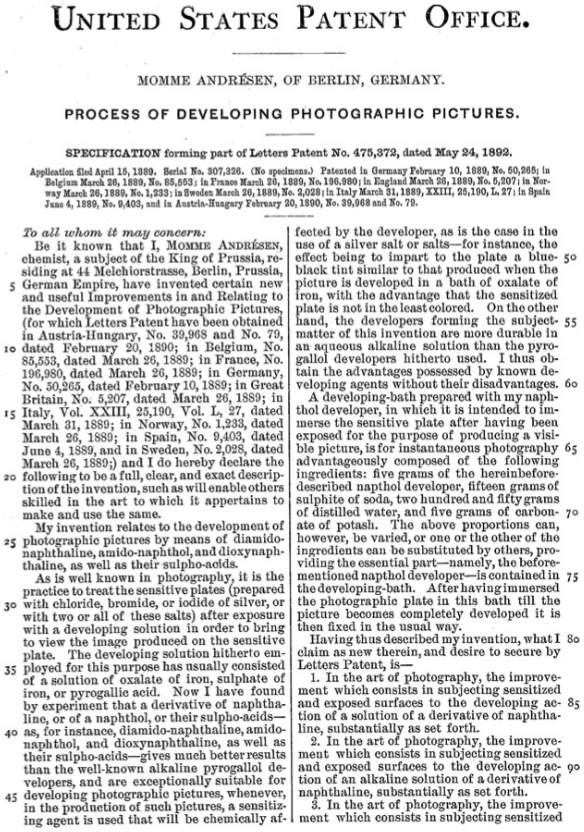

Ottomar Anschütz
(1846–1907)
Invented
high-speed
shutters (1881)
and compact
portable
cameras (1896)

Figure 3.134: Ottomar Anschütz invented high-speed shutters in 1881 and compact portable cameras in 1896.

Momme Andresen (1857–1951)

Ernst Leupold (18??–19??)

Chemical developers and fixers for photography



UNITED STATES PATENT OFFICE.

MOMME ANDRÉSEN, OF BERLIN, GERMANY.

PROCESS OF DEVELOPING PHOTOGRAPHIC PICTURES.

SPECIFICATION forming part of Letters Patent No. 475,372, dated May 24, 1892.

Application filed April 15, 1889. Serial No. 307,326. (No specimens.) Patented in Germany February 10, 1889, No. 50,265; in Belgium March 26, 1889, No. 85,553; in France March 26, 1889, No. 196,980; in England March 26, 1889, No. 5,207; in Norway March 26, 1889, No. 1,233; in Sweden March 26, 1889, No. 2,028; in Italy March 31, 1889, XXIII, 25,190, L, 27; in Spain June 4, 1889, No. 9,403, and in Austria-Hungary February 20, 1890, No. 39,968 and No. 79.

To all whom it may concern:

Be it known that I, MOMME ANDRÉSEN, chemist, a subject of the King of Prussia, residing at 44 Melchiorstrasse, Berlin, Prussia, German Empire, have invented certain new and useful Improvements in and Relating to the Development of Photographic Pictures, (for which Letters Patent have been obtained in Austria-Hungary, No. 39,968 and No. 79, dated February 20, 1890; in Belgium, No. 85,553, dated March 26, 1889; in France, No. 196,980, dated March 26, 1889; in Germany, No. 50,265, dated February 10, 1889; in Great Britain, No. 5,207, dated March 26, 1889; in Italy, Vol. XXIII, 25,190, Vol. L, 27, dated March 31, 1889; in Norway, No. 1,233, dated March 26, 1889; in Spain, No. 9,403, dated June 4, 1889, and in Sweden, No. 2,028, dated March 26, 1889;) and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

My invention relates to the development of photographic pictures by means of diamido-naphthaline, amido-naphthol, and dioxynaphthaline, as well as their sulpho-acids.

As is well known in photography, it is the practice to treat the sensitive plates (prepared with chloride, bromide, or iodide of silver, or with two or all of these salts) after exposure with a developing solution in order to bring to view the image produced on the sensitive plate. The developing solution hitherto employed for this purpose has usually consisted of a solution of oxalate of iron, sulphate of iron, or pyrogallic acid. Now I have found by experiment that a derivative of naphthaline, or of a naphthol, or their sulpho-acids—as, for instance, diamido-naphthaline, amido-naphthol, and dioxynaphthaline, as well as their sulpho-acids—gives much better results than the well-known alkaline pyrogallol developers, and are exceptionally suitable for developing photographic pictures, whenever, in the production of such pictures, a sensitizing agent is used that will be chemically affected by the developer, as is the case in the use of a silver salt or salts—for instance, the effect being to impart to the plate a blue-black tint similar to that produced when the picture is developed in a bath of oxalate of iron, with the advantage that the sensitized plate is not in the least colored. On the other hand, the developers forming the subject-matter of this invention are more durable in an aqueous alkaline solution than the pyrogallol developers hitherto used. I thus obtain the advantages possessed by known developing agents without their disadvantages.

A developing-bath prepared with my naphthol developer, in which it is intended to immerse the sensitive plate after having been exposed for the purpose of producing a visible picture, is for instantaneous photography advantageously composed of the following ingredients: five grams of the hereinbefore-described napthol developer, fifteen grams of sulphite of soda, two hundred and fifty grams of distilled water, and five grams of carbonate of potash. The above proportions can, however, be varied, or one or the other of the ingredients can be substituted by others, providing the essential part—namely, the before-mentioned napthol developer—is contained in the developing-bath. After having immersed the photographic plate in this bath till the picture becomes completely developed it is then fixed in the usual way.

Having thus described my invention, what I claim as new therein, and desire to secure by Letters Patent, is—

1. In the art of photography, the improvement which consists in subjecting sensitized and exposed surfaces to the developing action of a solution of a derivative of naphthaline, substantially as set forth.

2. In the art of photography, the improvement which consists in subjecting sensitized and exposed surfaces to the developing action of an alkaline solution of a derivative of naphthaline, substantially as set forth.

3. In the art of photography, the improvement which consists in subjecting sensitized

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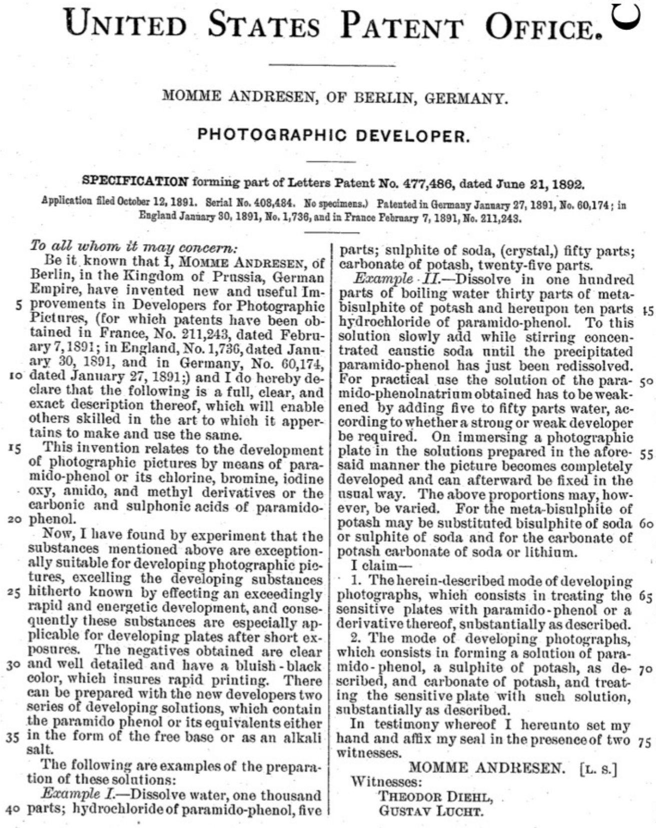


UNITED STATES PATENT OFFICE.

MOMME ANDRESEN, OF BERLIN, GERMANY.

PHOTOGRAPHIC DEVELOPER.

SPECIFICATION forming part of Letters Patent No. 477,486, dated June 21, 1892.

Application filed October 12, 1891. Serial No. 408,484. No specimens.) Patented in Germany January 27, 1891, No. 60,174; in England January 30, 1891, No. 1,736, and in France February 7, 1891, No. 211,243.

To all whom it may concern:

Be it known that I, MOMME ANDRESEN, of Berlin, in the Kingdom of Prussia, German Empire, have invented new and useful Improvements in Developers for Photographic Pictures, (for which patents have been obtained in France, No. 211,243, dated February 7, 1891; in England, No. 1,736, dated January 30, 1891, and in Germany, No. 60,174, dated January 27, 1891;) and I do hereby declare that the following is a full, clear, and exact description thereof, which will enable others skilled in the art to which it appertains to make and use the same.

This invention relates to the development of photographic pictures by means of paramido-phenol or its chlorine, bromine, iodine oxy, amido, and methyl derivatives or the carbonic and sulphonic acids of paramido-phenol.

Now, I have found by experiment that the substances mentioned above are exceptionally suitable for developing photographic pictures, excelling the developing substances hitherto known by effecting an exceedingly rapid and energetic development, and consequently these substances are especially applicable for developing plates after short exposures. The negatives obtained are clear and well detailed and have a bluish-black color, which insures rapid printing. There can be prepared with the new developers two series of developing solutions, which contain the paramido phenol or its equivalents either in the form of the free base or as an alkali salt.

The following are examples of the preparation of these solutions:

Example I.—Dissolve water, one thousand parts; hydrochloride of paramido-phenol, five parts; sulphite of soda, (crystal,) fifty parts; carbonate of potash, twenty-five parts.

Example II.—Dissolve in one hundred parts of boiling water thirty parts of meta-bisulphite of potash and hereupon ten parts hydrochloride of paramido-phenol. To this solution slowly add while stirring concentrated caustic soda until the precipitated paramido-phenol has just been redissolved. For practical use the solution of the paramido-phenolnatrium obtained has to be weakened by adding five to fifty parts water, according to whether a strong or weak developer be required. On immersing a photographic plate in the solutions prepared in the aforesaid manner the picture becomes completely developed and can afterward be fixed in the usual way. The above proportions may, however, be varied. For the meta-bisulphite of potash may be substituted bisulphite of soda or sulphite of soda and for the carbonate of potash carbonate of soda or lithium.

I claim—

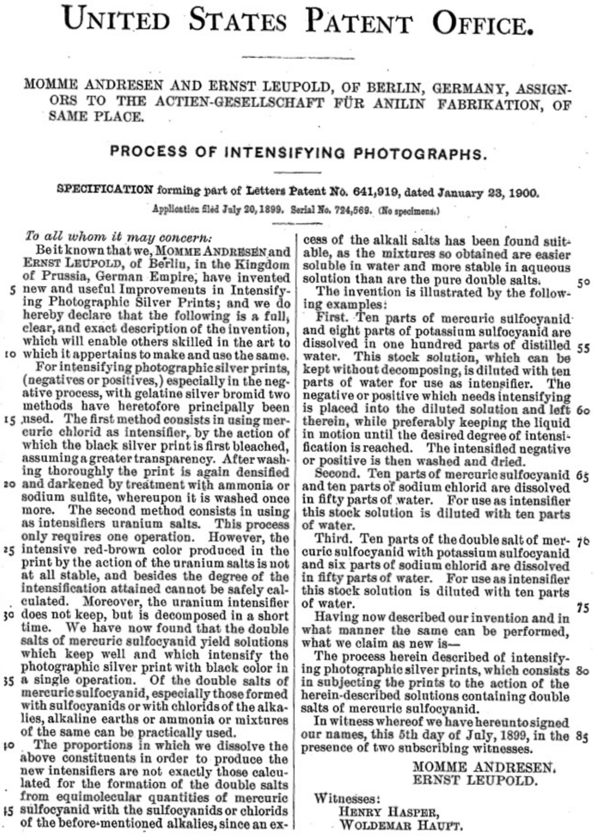
1. The herein-described mode of developing photographs, which consists in treating the sensitive plates with paramido-phenol or a derivative thereof, substantially as described.

2. The mode of developing photographs, which consists in forming a solution of paramido-phenol, a sulphite of potash, as described, and carbonate of potash, and treating the sensitive plate with such solution, substantially as described.

In testimony whereof I hereunto set my hand and affix my seal in the presence of two witnesses.

MOMME ANDRESEN. [L. S.]

Witnesses:
THEODOR DIEHL,
GUSTAV LUCHT.



UNITED STATES PATENT OFFICE.

MOMME ANDRESEN AND ERNST LEUPOLD, OF BERLIN, GERMANY, ASSIGNORS TO THE ACTIEN-GESELLSCHAFT FÜR ANILIN FABRIKATION, OF SAME PLACE.

PROCESS OF INTENSIFYING PHOTOGRAPHS.

SPECIFICATION forming part of Letters Patent No. 641,919, dated January 23, 1900.

Application filed July 20, 1899. Serial No. 724,569. (No specimens.)

To all whom it may concern:

Be it known that we, MOMME ANDRESEN and ERNST LEUPOLD, of Berlin, in the Kingdom of Prussia, German Empire, have invented new and useful Improvements in Intensifying Photographic Silver Prints; and we do hereby declare that the following is a full, clear, and exact description of the invention, which will enable others skilled in the art to which it appertains to make and use the same.

For intensifying photographic silver prints, (negatives or positives,) especially in the negative process, with gelatine silver bromid two methods have heretofore principally been used. The first method consists in using mercuric chlorid as intensifier, by the action of which the black silver print is first bleached, assuming a greater transparency. After washing thoroughly the print is again densified and darkened by treatment with ammonia or sodium sulfite, whereupon it is washed once more. The second method consists in using as intensifiers uranium salts. This process only requires one operation. However, the intensive red-brown color produced in the print by the action of the uranium salts is not at all stable, and besides the degree of the intensification attained cannot be safely calculated. Moreover, the uranium intensifier does not keep, but is decomposed in a short time. We have now found that the double salts of mercuric sulfocyanid yield solutions which keep well and which intensify the photographic silver print with black color in a single operation. Of the double salts of mercuric sulfocyanid, especially those formed with sulfocyanids or with chlorids of the alkalies, alkaline earths or ammonia or mixtures of the same can be practically used.

The proportions in which we dissolve the above constituents in order to produce the new intensifiers are not exactly those calculated for the formation of the double salts from equimolecular quantities of mercuric sulfocyanid with the sulfocyanids or chlorids of the before-mentioned alkalies, since an excess of the alkali salts has been found suitable, as the mixtures so obtained are easier soluble in water and more stable in aqueous solution than are the pure double salts.

The invention is illustrated by the following examples:

First. Ten parts of mercuric sulfocyanid and eight parts of potassium sulfocyanid are dissolved in one hundred parts of distilled water. This stock solution, which can be kept without decomposing, is diluted with ten parts of water for use as intensifier. The negative or positive which needs intensifying is placed into the diluted solution and left therein, while preferably keeping the liquid in motion until the desired degree of intensification is reached. The intensified negative or positive is then washed and dried.

Second. Ten parts of mercuric sulfocyanid and ten parts of sodium chlorid are dissolved in fifty parts of water. For use as intensifier this stock solution is diluted with ten parts of water.

Third. Ten parts of the double salt of mercuric sulfocyanid with potassium sulfocyanid and six parts of sodium chlorid are dissolved in fifty parts of water. For use as intensifier this stock solution is diluted with ten parts of water.

Having now described our invention and in what manner the same can be performed, what we claim as new is—

The process herein described of intensifying photographic silver prints, which consists in subjecting the prints to the action of the herein-described solutions containing double salts of mercuric sulfocyanid.

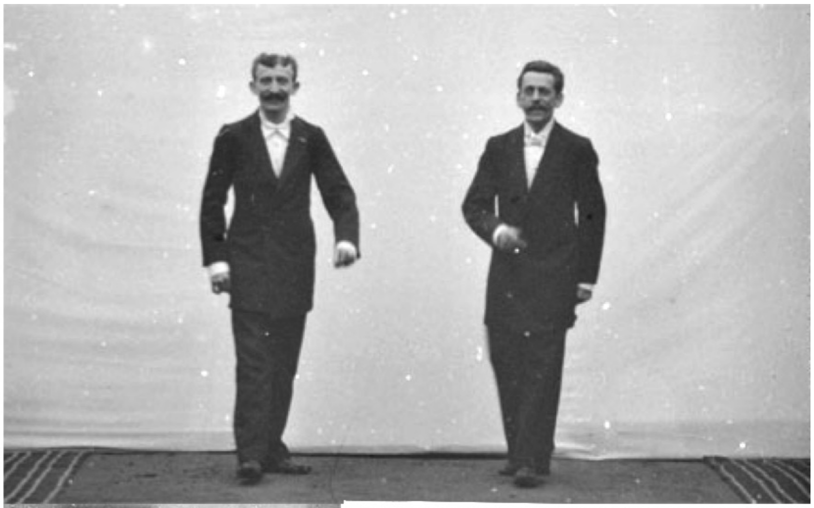
In witness whereof we have hereunto signed our names, this 5th day of July, 1899, in the presence of two subscribing witnesses.

MOMME ANDRESEN.
ERNST LEUPOLD.

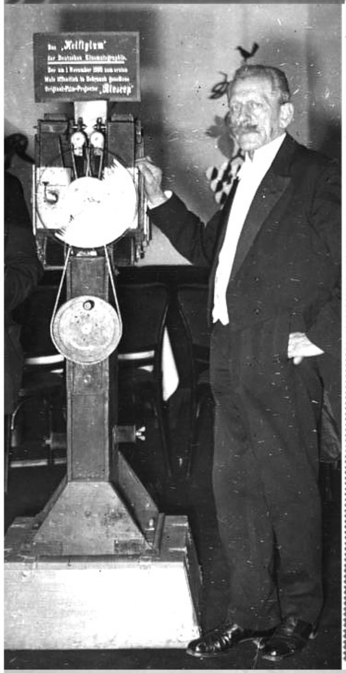
Witnesses:
HENRY HASPER,
WOLDEMAR HAUPT.

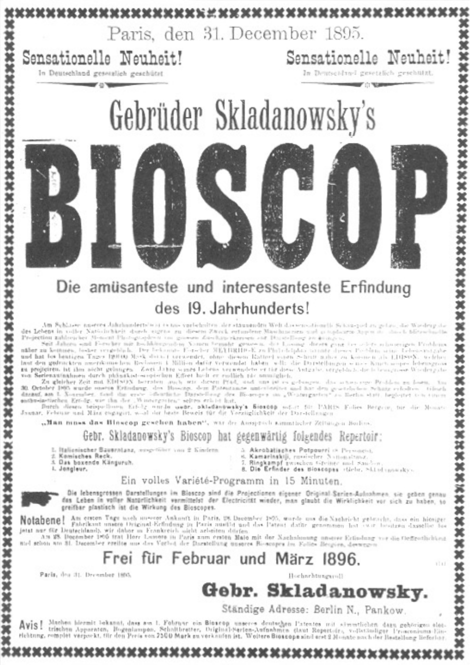
Figure 3.135: Momme Andresen invented new and improved chemical developers and fixers for photography from the 1880s onward. He helped to build what became known as the Agfa photography company and employed other chemists such as Ernst Leupold.

Max Skladanowsky (1863–1939) and Emil Skladanowsky (1866–1945) created the Bioscop motion picture camera and projector (1892) and presented the first public films (1895)



Max Skladanowsky with a Bioscop projector





Paris, den 31. December 1895.

Sensationelle Neuheit! In Deutschland gesetzlich geschützt

Sensationelle Neuheit! In Deutschland gesetzlich geschützt.

Gebrüder Skladanowsky's

BIOSCOP

Die amüsanteste und interessanteste Erfindung des 19. Jahrhunderts!

„Man muss das Bioscop gesehen haben", war der Ausspruch sämmtlicher Zeitungen Berlins.

Gebr. Skladanowsky's Bioscop hat gegenwärtig folgendes Repertoir:

1. Italienischer Bauerntanz, ausgeführt von 2 Kindern
2. Komisches Reck.
3. Das boxende Känguruh.
4. Jongleur.
5. Akrobatisches Potpourri (8 Personen).
6. Kamarinskaja, russischer Nationaltanz.
7. Ringkampf zwischen Greiner und Sandow.
8. Die Erfinder des Bioscopes (Gebr. Skladanowsky).

Ein volles Variété-Programm in 15 Minuten.

Die lebensgrossen Darstellungen im Bioscop sind die Projectionen eigener Original-Serien-Aufnahmen, sie geben genau das Leben in voller Natürlichkeit vermittelst der Electricität wieder, man glaubt die Wirklichkeit vor sich zu haben, so greifbar plastisch ist die Wirkung des Bioscopes.

Frei für Februar und März 1896.

Paris, den 31. December 1895.

Hochachtungsvoll

Gebr. Skladanowsky.

Ständige Adresse: Berlin N., Pankow.

Avis! Machen hiermit bekannt, dass am 1. Februar ein Bioscop unseres deutschen Patentes mit sämmtlichen dazu gehörigen electrischen Apparaten, Bogenlampen, Schaltbrettern, Original-Serien-Aufnahmen (laut Repertoir), vollständiger Prosceniums-Einrichtung, complet verpackt, für den Preis von 2500 Mark zu verkaufen ist. Weitere Bioscope sind erst 2 Monate nach der Bestellung lieferbar.

A frame from one of the 1895 Bioscop films

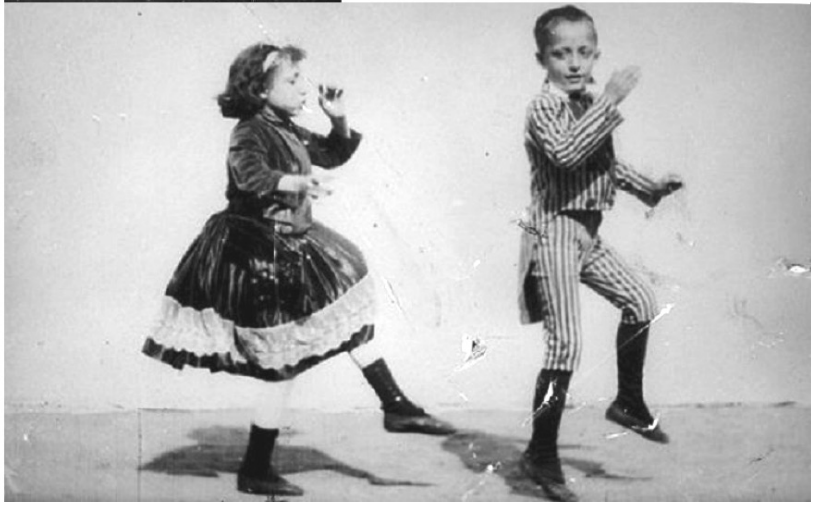


Figure 3.136: The brothers Max and Emil Skladanowsky created the Bioscop motion picture camera and projector in 1892 and presented the first public films in 1895.

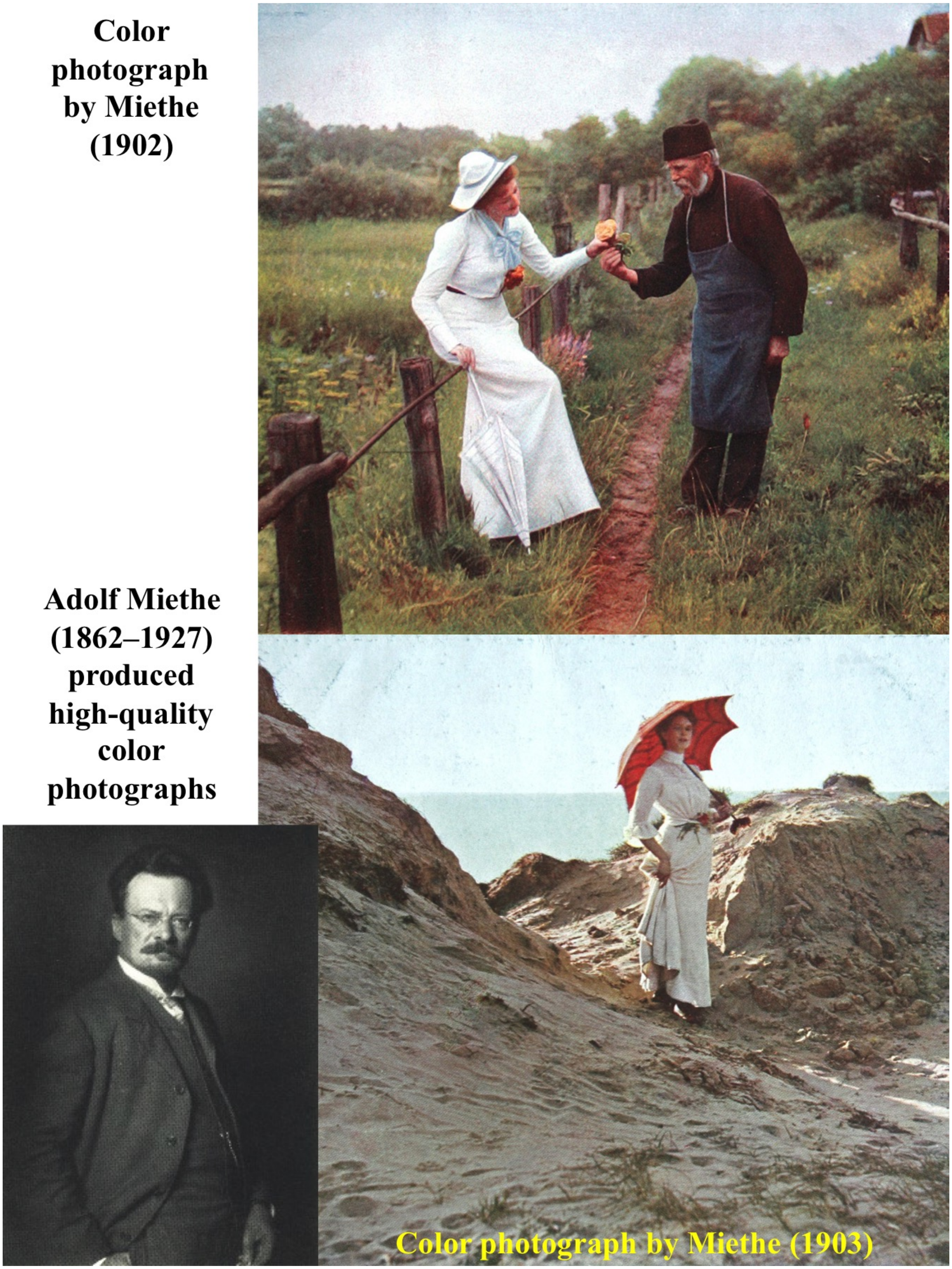
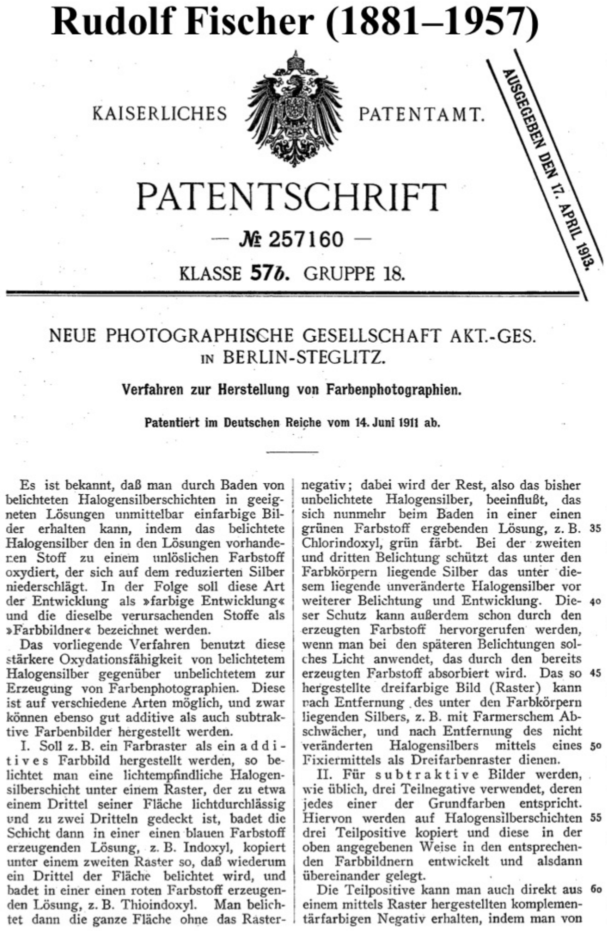

Color photograph by Miethe (1902)
Adolf Miethe (1862–1927) produced high-quality color photographs
Color photograph by Miethe (1903)

Figure 3.137: Adolf Miethe produced high-quality color photographs using a three-color process beginning in 1901. He also invented the first practical flash powder.


Rudolf Fischer (1881–1957)

KAISERLICHES PATENTAMT.

AUSGEGEBEN DEN 17. APRIL 1913.

PATENTSCHRIFT

— № 257160 —

KLASSE 57*b*. GRUPPE 18.

NEUE PHOTOGRAPHISCHE GESELLSCHAFT AKT.-GES.
IN BERLIN-STEGLITZ.

Verfahren zur Herstellung von Farbenphotographien.

Patentiert im Deutschen Reiche vom 14. Juni 1911 ab.

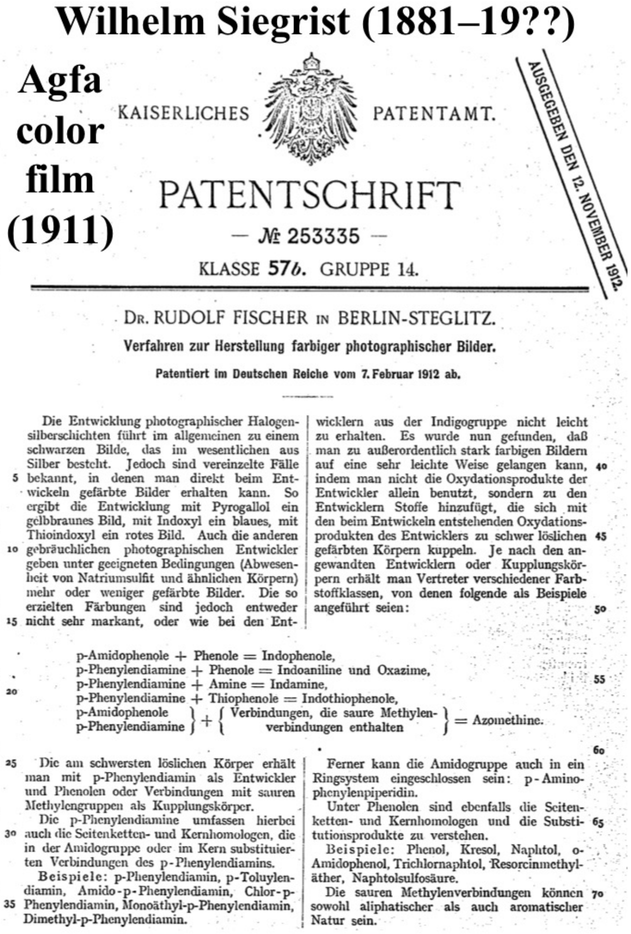
Es ist bekannt, daß man durch Baden von belichteten Halogensilberschichten in geeigneten Lösungen unmittelbar einfarbige Bilder erhalten kann, indem das belichtete Halogensilber den in den Lösungen vorhandenen Stoff zu einem unlöslichen Farbstoff oxydiert, der sich auf dem reduzierten Silber niederschlägt. In der Folge soll diese Art der Entwicklung als »farbige Entwicklung« und die dieselbe verursachenden Stoffe als »Farbbildner« bezeichnet werden.

Das vorliegende Verfahren benutzt diese stärkere Oxydationsfähigkeit von belichtetem Halogensilber gegenüber unbelichtetem zur Erzeugung von Farbenphotographien. Diese ist auf verschiedene Arten möglich, und zwar können ebenso gut additive als auch subtraktive Farbenbilder hergestellt werden.

I. Soll z. B. ein Farbraster als ein additives Farbbild hergestellt werden, so belichtet man eine lichtempfindliche Halogensilberschicht unter einem Raster, der zu etwa einem Drittel seiner Fläche lichtdurchlässig und zu zwei Dritteln gedeckt ist, badet die Schicht dann in einer einen blauen Farbstoff erzeugenden Lösung, z. B. Indoxyl, kopiert unter einem zweiten Raster so, daß wiederum ein Drittel der Fläche belichtet wird, und badet in einer einen roten Farbstoff erzeugenden Lösung, z. B. Thioindoxyl. Man belichtet dann die ganze Fläche ohne das Rasternegativ; dabei wird der Rest, also das bisher unbelichtete Halogensilber, beeinflußt, das sich nunmehr beim Baden in einer einen grünen Farbstoff ergebenden Lösung, z. B. Chlorindoxyl, grün färbt. Bei der zweiten und dritten Belichtung schützt das unter den Farbkörpern liegende Silber das unter diesem liegende unveränderte Halogensilber vor weiterer Belichtung und Entwicklung. Dieser Schutz kann außerdem schon durch den erzeugten Farbstoff hervorgerufen werden, wenn man bei den späteren Belichtungen solches Licht anwendet, das durch den bereits erzeugten Farbstoff absorbiert wird. Das so hergestellte dreifarbige Bild (Raster) kann nach Entfernung des unter den Farbkörpern liegenden Silbers, z. B. mit Farmerschem Abschwächer, und nach Entfernung des nicht veränderten Halogensilbers mittels eines Fixiermittels als Dreifarbenraster dienen.

II. Für subtraktive Bilder werden, wie üblich, drei Teilnegative verwendet, deren jedes einer der Grundfarben entspricht. Hiervon werden auf Halogensilberschichten drei Teilpositive kopiert und diese in der oben angegebenen Weise in den entsprechenden Farbbildnern entwickelt und alsdann übereinander gelegt.

Die Teilpositive kann man auch direkt aus einem mittels Raster hergestellten komplementärfarbigen Negativ erhalten, indem man von


Wilhelm Siegrist (1881–19??)
Agfa color film (1911)

KAISERLICHES PATENTAMT.

AUSGEGEBEN DEN 12. NOVEMBER 1912.

PATENTSCHRIFT

— № 253335 —

KLASSE 57*b*. GRUPPE 14.

DR. RUDOLF FISCHER IN BERLIN-STEGLITZ.

Verfahren zur Herstellung farbiger photographischer Bilder.

Patentiert im Deutschen Reiche vom 7. Februar 1912 ab.

Die Entwicklung photographischer Halogensilberschichten führt im allgemeinen zu einem schwarzen Bilde, das im wesentlichen aus Silber besteht. Jedoch sind vereinzelte Fälle bekannt, in denen man direkt beim Entwickeln gefärbte Bilder erhalten kann. So ergibt die Entwicklung mit Pyrogallol ein gelbbraunes Bild, mit Indoxyl ein blaues, mit Thioindoxyl ein rotes Bild. Auch die anderen gebräuchlichen photographischen Entwickler geben unter geeigneten Bedingungen (Abwesenheit von Natriumsulfit und ähnlichen Körpern) mehr oder weniger gefärbte Bilder. Die so erzielten Färbungen sind jedoch entweder nicht sehr markant, oder wie bei den Entwicklern aus der Indigogruppe nicht leicht zu erhalten. Es wurde nun gefunden, daß man zu außerordentlich stark farbigen Bildern auf eine sehr leichte Weise gelangen kann, indem man nicht die Oxydationsprodukte der Entwickler allein benutzt, sondern zu den Entwicklern Stoffe hinzufügt, die sich mit den beim Entwickeln entstehenden Oxydationsprodukten des Entwicklers zu schwer löslichen gefärbten Körpern kuppeln. Je nach den angewandten Entwicklern oder Kupplungskörpern erhält man Vertreter verschiedener Farbstoffklassen, von denen folgende als Beispiele angeführt seien:

p-Amidophenole + Phenole = Indophenole,
p-Phenylendiamine + Phenole = Indoaniline und Oxazime,
p-Phenylendiamine + Amine = Indamine,
p-Phenylendiamine + Thiophenole = Indothiophenole,

$$\left.\begin{array}{l}\text{p-Amidophenole}\\ \text{p-Phenylendiamine}\end{array}\right\} + \left\{\begin{array}{c}\text{Verbindungen, die saure Methylen-}\\ \text{verbindungen enthalten}\end{array}\right\} = \text{Azomethine.}$$

Die am schwersten löslichen Körper erhält man mit p-Phenylendiamin als Entwickler und Phenolen oder Verbindungen mit sauren Methylengruppen als Kupplungskörper.

Die p-Phenylendiamine umfassen hierbei auch die Seitenketten- und Kernhomologen, die in der Amidogruppe oder im Kern substituierten Verbindungen des p-Phenylendiamins.

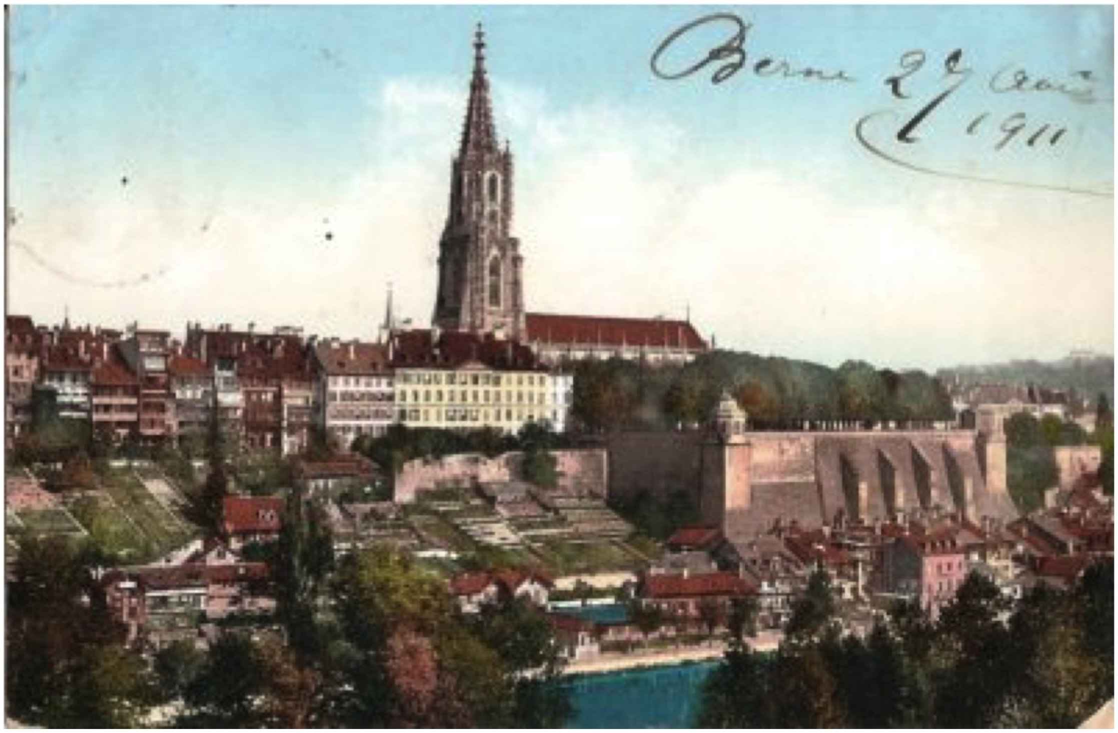
Beispiele: p-Phenylendiamin, p-Toluylendiamin, Amido-p-Phenylendiamin, Chlor-p-Phenylendiamin, Monoäthyl-p-Phenylendiamin, Dimethyl-p-Phenylendiamin.

Ferner kann die Amidogruppe auch in ein Ringsystem eingeschlossen sein: p-Aminophenylenpiperidin.

Unter Phenolen sind ebenfalls die Seitenketten- und Kernhomologen und die Substitutionsprodukte zu verstehen.

Beispiele: Phenol, Kresol, Naphtol, o-Amidophenol, Trichlornaphtol, Resorcinmethyläther, Naphtolsulfosäure.

Die sauren Methylenverbindungen können sowohl aliphatischer als auch aromatischer Natur sein.



Berne 27 août
1911

Figure 3.138: Rudolf Fischer invented Agfa color film in 1911. He worked closely with Wilhelm Siegrist for part of that period.

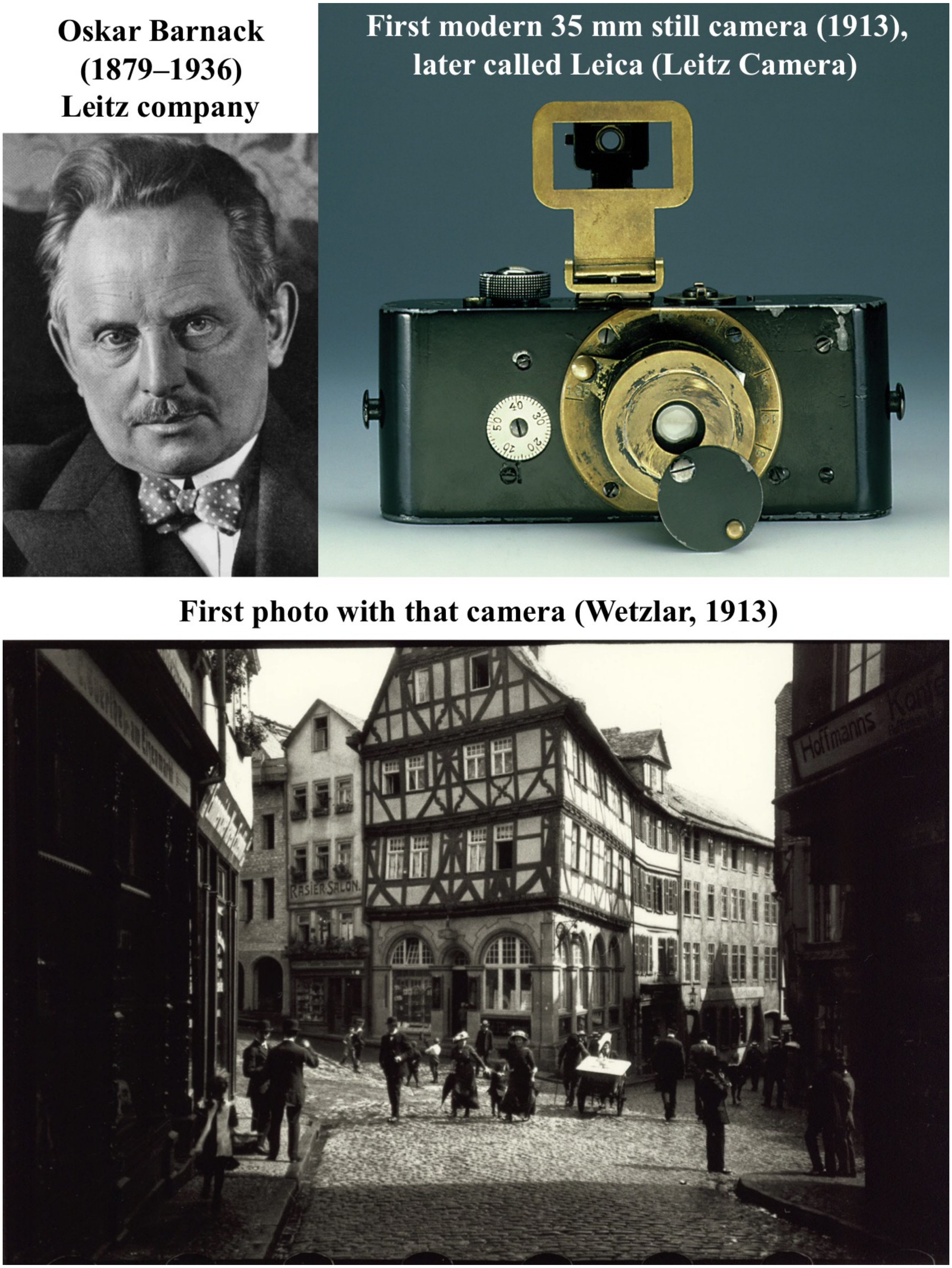
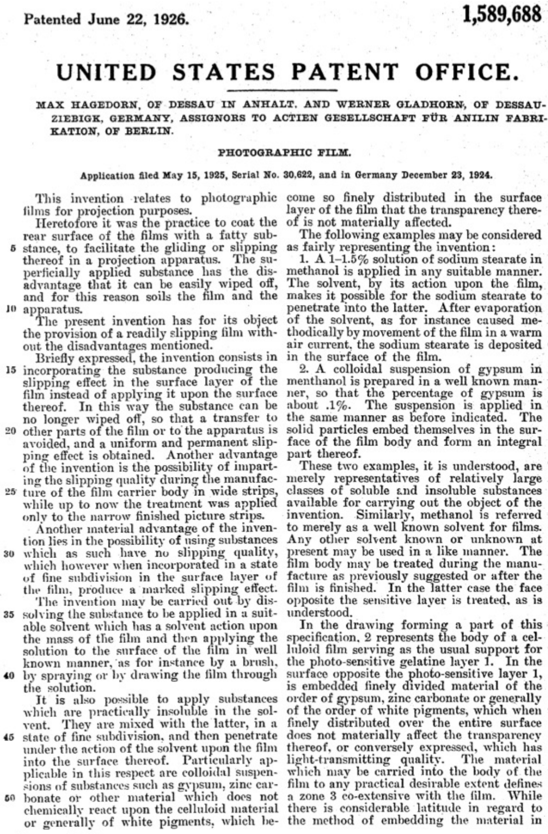

Oskar Barnack
(1879–1936)
Leitz company
First modern 35 mm still camera (1913),
later called Leica (Leitz Camera)
50
40
30
20
15
First photo with that camera (Wetzlar, 1913)
RASIER SALON.
Hoffmanns

Figure 3.139: In 1913, Oskar Barnack invented the first modern 35 mm still camera, which later was dubbed Leica (Leitz Camera).



Patented June 22, 1926. **1,589,688**

UNITED STATES PATENT OFFICE.

MAX HAGEDORN, OF DESSAU IN ANHALT, AND WERNER GLADHORN, OF DESSAU-ZIEBIGK, GERMANY, ASSIGNORS TO ACTIEN GESELLSCHAFT FÜR ANILIN FABRIKATION, OF BERLIN.

PHOTOGRAPHIC FILM.

Application filed May 15, 1925, Serial No. 30,622, and in Germany December 23, 1924.

This invention relates to photographic films for projection purposes.

Heretofore it was the practice to coat the rear surface of the films with a fatty substance, to facilitate the gliding or slipping thereof in a projection apparatus. The superficially applied substance has the disadvantage that it can be easily wiped off, and for this reason soils the film and the apparatus.

The present invention has for its object the provision of a readily slipping film without the disadvantages mentioned.

Briefly expressed, the invention consists in incorporating the substance producing the slipping effect in the surface layer of the film instead of applying it upon the surface thereof. In this way the substance can be no longer wiped off, so that a transfer to other parts of the film or to the apparatus is avoided, and a uniform and permanent slipping effect is obtained. Another advantage of the invention is the possibility of imparting the slipping quality during the manufacture of the film carrier body in wide strips, while up to now the treatment was applied only to the narrow finished picture strips.

Another material advantage of the invention lies in the possibility of using substances which as such have no slipping quality, which however when incorporated in a state of fine subdivision in the surface layer of the film, produce a marked slipping effect.

The invention may be carried out by dissolving the substance to be applied in a suitable solvent which has a solvent action upon the mass of the film and then applying the solution to the surface of the film in well known manner, as for instance by a brush, by spraying or by drawing the film through the solution.

It is also possible to apply substances which are practically insoluble in the solvent. They are mixed with the latter, in a state of fine subdivision, and then penetrate under the action of the solvent upon the film into the surface thereof. Particularly applicable in this respect are colloidal suspensions of substances such as gypsum, zinc carbonate or other material which does not chemically react upon the celluloid material or generally of white pigments, which become so finely distributed in the surface layer of the film that the transparency thereof is not materially affected.

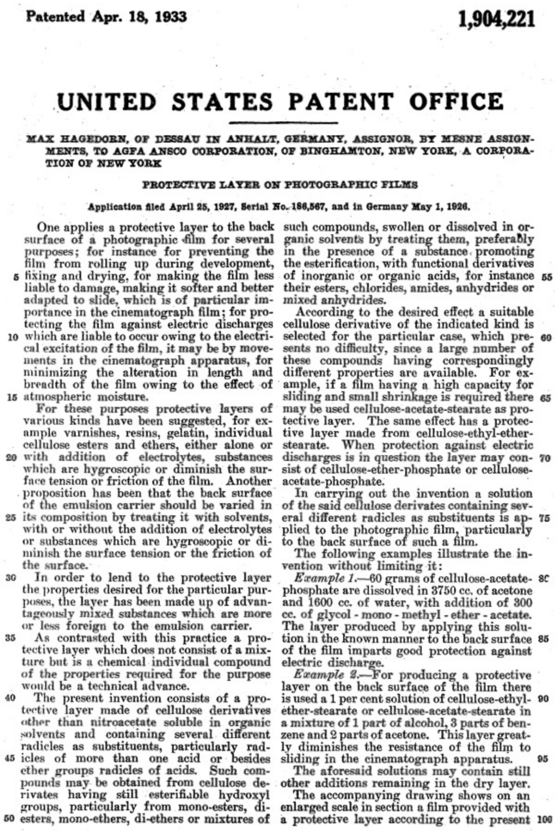
The following examples may be considered as fairly representing the invention:

1. A 1–1.5% solution of sodium stearate in methanol is applied in any suitable manner. The solvent, by its action upon the film, makes it possible for the sodium stearate to penetrate into the latter. After evaporation of the solvent, as for instance caused methodically by movement of the film in a warm air current, the sodium stearate is deposited in the surface of the film.

2. A colloidal suspension of gypsum in menthanol is prepared in a well known manner, so that the percentage of gypsum is about .1%. The suspension is applied in the same manner as before indicated. The solid particles embed themselves in the surface of the film body and form an integral part thereof.

These two examples, it is understood, are merely representatives of relatively large classes of soluble and insoluble substances available for carrying out the object of the invention. Similarly, methanol is referred to merely as a well known solvent for films. Any other solvent known or unknown at present may be used in a like manner. The film body may be treated during the manufacture as previously suggested or after the film is finished. In the latter case the face opposite the sensitive layer is treated, as is understood.

In the drawing forming a part of this specification, 2 represents the body of a celluloid film serving as the usual support for the photo-sensitive gelatine layer 1. In the surface opposite the photo-sensitive layer 1, is embedded finely divided material of the order of gypsum, zinc carbonate or generally of the order of white pigments, which when finely distributed over the entire surface does not materially affect the transparency thereof, or conversely expressed, which has light-transmitting quality. The material which may be carried into the body of the film to any practical desirable extent defines a zone 3 co-extensive with the film. While there is considerable latitude in regard to the method of embedding the material in



Patented Apr. 18, 1933 **1,904,221**

UNITED STATES PATENT OFFICE

MAX HAGEDORN, OF DESSAU IN ANHALT, GERMANY, ASSIGNOR, BY MESNE ASSIGNMENTS, TO AGFA ANSCO CORPORATION, OF BINGHAMTON, NEW YORK, A CORPORATION OF NEW YORK

PROTECTIVE LAYER ON PHOTOGRAPHIC FILMS

Application filed April 25, 1927, Serial No. 186,567, and in Germany May 1, 1926.

One applies a protective layer to the back surface of a photographic film for several purposes; for instance for preventing the film from rolling up during development, fixing and drying, for making the film less liable to damage, making it softer and better adapted to slide, which is of particular importance in the cinematograph film; for protecting the film against electric discharges which are liable to occur owing to the electrical excitation of the film, it may be by movements in the cinematograph apparatus, for minimizing the alteration in length and breadth of the film owing to the effect of atmospheric moisture.

For these purposes protective layers of various kinds have been suggested, for example varnishes, resins, gelatin, individual cellulose esters and ethers, either alone or with addition of electrolytes, substances which are hygroscopic or diminish the surface tension or friction of the film. Another proposition has been that the back surface of the emulsion carrier should be varied in its composition by treating it with solvents, with or without the addition of electrolytes or substances which are hygroscopic or diminish the surface tension or the friction of the surface.

In order to lend to the protective layer the properties desired for the particular purposes, the layer has been made up of advantageously mixed substances which are more or less foreign to the emulsion carrier.

As contrasted with this practice a protective layer which does not consist of a mixture but is a chemical individual compound of the properties required for the purpose would be a technical advance.

The present invention consists of a protective layer made of cellulose derivatives other than nitroacetate soluble in organic solvents and containing several different radicles as substituents, particularly radicles of more than one acid or besides ether groups radicles of acids. Such compounds may be obtained from cellulose derivates having still esterifiable hydroxyl groups, particularly from mono-esters, di-esters, mono-ethers, di-ethers or mixtures of such compounds, swollen or dissolved in organic solvents by treating them, preferably in the presence of a substance promoting the esterification, with functional derivatives of inorganic or organic acids, for instance their esters, chlorides, amides, anhydrides or mixed anhydrides.

According to the desired effect a suitable cellulose derivative of the indicated kind is selected for the particular case, which presents no difficulty, since a large number of these compounds having correspondingly different properties are available. For example, if a film having a high capacity for sliding and small shrinkage is required there may be used cellulose-acetate-stearate as protective layer. The same effect has a protective layer made from cellulose-ethyl-ether-stearate. When protection against electric discharges is in question the layer may consist of cellulose-ether-phosphate or cellulose-acetate-phosphate.

In carrying out the invention a solution of the said cellulose derivates containing several different radicles as substituents is applied to the photographic film, particularly to the back surface of such a film.

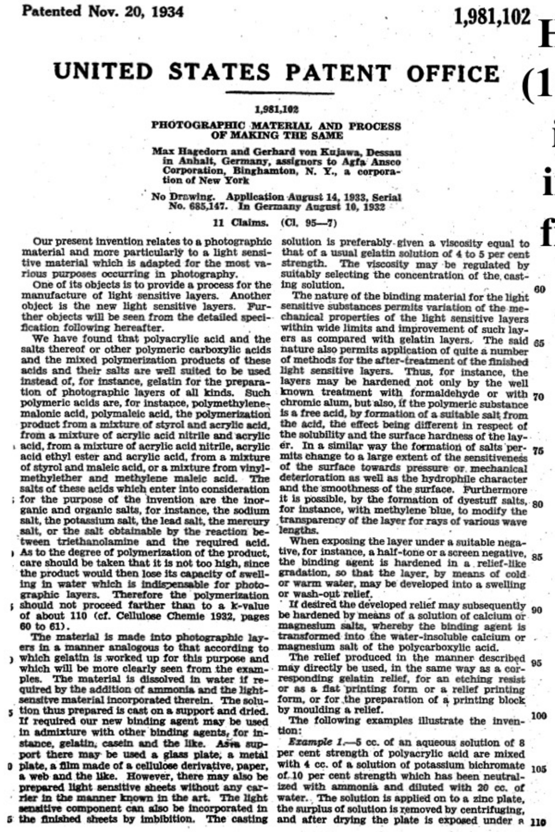
The following examples illustrate the invention without limiting it:

Example 1.—60 grams of cellulose-acetate-phosphate are dissolved in 3750 cc. of acetone and 1600 cc. of water, with addition of 300 cc. of glycol - mono - methyl - ether - acetate. The layer produced by applying this solution in the known manner to the back surface of the film imparts good protection against electric discharge.

Example 2.—For producing a protective layer on the back surface of the film there is used a 1 per cent solution of cellulose-ethyl-ether-stearate or cellulose-acetate-stearate in a mixture of 1 part of alcohol, 3 parts of benzene and 2 parts of acetone. This layer greatly diminishes the resistance of the film to sliding in the cinematograph apparatus.

The aforesaid solutions may contain still other additions remaining in the dry layer.

The accompanying drawing shows on an enlarged scale in section a film provided with a protective layer according to the present



Patented Nov. 20, 1934 **1,981,102**

UNITED STATES PATENT OFFICE

1,981,102

PHOTOGRAPHIC MATERIAL AND PROCESS OF MAKING THE SAME

Max Hagedorn and Gerhard von Kujawa, Dessau in Anhalt, Germany, assignors to Agfa Ansco Corporation, Binghamton, N. Y., a corporation of New York

No Drawing. Application August 14, 1933, Serial No. 685,147. In Germany August 10, 1932

11 Claims. (Cl. 95—7)

Our present invention relates to a photographic material and more particularly to a light sensitive material which is adapted for the most various purposes occurring in photography.

One of its objects is to provide a process for the manufacture of light sensitive layers. Another object is the new light sensitive layers. Further objects will be seen from the detailed specification following hereafter.

We have found that polyacrylic acid and the salts thereof or other polymeric carboxylic acids and the mixed polymerization products of these acids and their salts are well suited to be used instead of, for instance, gelatin for the preparation of photographic layers of all kinds. Such polymeric acids are, for instance, polymethylene-malonic acid, polymaleic acid, the polymerization product from a mixture of styrol and acrylic acid, from a mixture of acrylic acid nitrile and acrylic acid, from a mixture of acrylic acid nitrile, acrylic acid ethyl ester and acrylic acid, from a mixture of styrol and maleic acid, or a mixture from vinylmethylether and methylene maleic acid. The salts of these acids which enter into consideration for the purpose of the invention are the inorganic and organic salts, for instance, the sodium salt, the potassium salt, the lead salt, the mercury salt, or the salt obtainable by the reaction between triethanolamine and the required acid. As to the degree of polymerization of the product, care should be taken that it is not too high, since the product would then lose its capacity of swelling in water which is indispensable for photographic layers. Therefore the polymerization should not proceed farther than to a k-value of about 110 (cf. Cellulose Chemie 1932, pages 60 to 61).

The material is made into photographic layers in a manner analogous to that according to which gelatin is worked up for this purpose and which will be more clearly seen from the examples. The material is dissolved in water if required by the addition of ammonia and the light-sensitve material incorporated therein. The solution thus prepared is cast on a support and dried. If required our new binding agent may be used in admixture with other binding agents, for instance, gelatin, casein and the like. Asra support there may be used a glass plate, a metal plate, a film made of a cellulose derivative, paper, a web and the like. However, there may also be prepared light sensitive sheets without any carrier in the manner known in the art. The light sensitive component can also be incorporated in the finished sheets by imbibition. The casting solution is preferably given a viscosity equal to that of a usual gelatin solution of 4 to 5 per cent strength. The viscosity may be regulated by suitably selecting the concentration of the casting solution.

The nature of the binding material for the light sensitive substances permits variation of the mechanical properties of the light sensitive layers within wide limits and improvement of such layers as compared with gelatin layers. The said nature also permits application of quite a number of methods for the after-treatment of the finished light sensitive layers. Thus, for instance, the layers may be hardened not only by the well known treatment with formaldehyde or with chromic alum, but also, if the polymeric substance is a free acid, by formation of a suitable salt from the acid, the effect being different in respect of the solubility and the surface hardness of the layér. In a similar way the formation of salts permits change to a large extent of the sensitiveness of the surface towards pressure or mechanical deterioration as well as the hydrophile character and the smoothness of the surface. Furthermore it is possible, by the formation of dyestuff salts, for instance, with methylene blue, to modify the transparency of the layer for rays of various wave lengths.

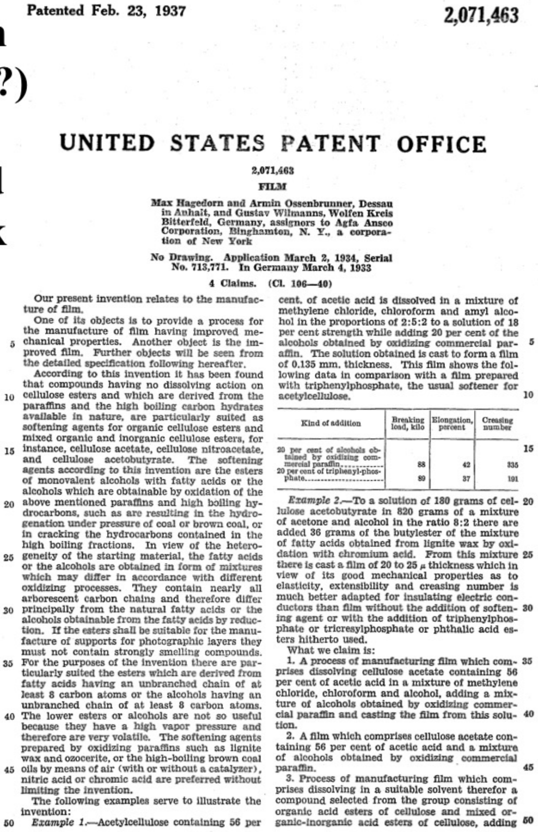
When exposing the layer under a suitable negative, for instance, a half-tone or a screen negative, the binding agent is hardened in a relief-like gradation, so that the layer, by means of cold or warm water, may be developed into a swelling or wash-out relief.

If desired the developed relief may subsequently be hardened by means of a solution of calcium or magnesium salts, whereby the binding agent is transformed into the water-insoluble calcium or magnesium salt of the polycarboxylic acid.

The relief produced in the manner described may directly be used, in the same way as a corresponding gelatin relief, for an etching resist or as a flat printing form or a relief printing form, or for the preparation of a printing block by moulding a relief.

The following examples illustrate the invention:

Example 1.—5 cc. of an aqueous solution of 8 per cent strength of polyacrylic acid are mixed with 4 cc. of a solution of potassium bichromate of 10 per cent strength which has been neutralized with ammonia and diluted with 20 cc. of water. The solution is applied on to a zinc plate, the surplus of solution is removed by centrifuging, and after drying the plate is exposed under a



Patented Feb. 23, 1937 **2,071,463**

UNITED STATES PATENT OFFICE

2,071,463

FILM

Max Hagedorn and Armin Ossenbrunner, Dessau in Anhalt, and Gustav Wilmanns, Wolfen Kreis Bitterfeld, Germany, assignors to Agfa Ansco Corporation, Binghamton, N. Y., a corporation of New York

No Drawing. Application March 2, 1934, Serial No. 713,771. In Germany March 4, 1933

4 Claims. (Cl. 106—40)

Our present invention relates to the manufacture of film.

One of its objects is to provide a process for the manufacture of film having improved mechanical properties. Another object is the improved film. Further objects will be seen from the detailed specification following hereafter.

According to this invention it has been found that compounds having no dissolving action on cellulose esters and which are derived from the paraffins and the high boiling carbon hydrates available in nature, are particularly suited as softening agents for organic cellulose esters and mixed organic and inorganic cellulose esters, for instance, cellulose acetate, cellulose nitroacetate, and cellulose acetobutyrate. The softening agents according to this invention are the esters of monovalent alcohols with fatty acids or the alcohols which are obtainable by oxidation of the above mentioned paraffins and high boiling hydrocarbons, such as are resulting in the hydrogenation under pressure of coal or brown coal, or in cracking the hydrocarbons contained in the high boiling fractions. In view of the heterogeneity of the starting material, the fatty acids or the alcohols are obtained in form of mixtures which may differ in accordance with different oxidizing processes. They contain nearly all arborescent carbon chains and therefore differ principally from the natural fatty acids or the alcohols obtainable from the fatty acids by reduction. If the esters shall be suitable for the manufacture of supports for photographic layers they must not contain strongly smelling compounds. For the purposes of the invention there are particularly suited the esters which are derived from fatty acids having an unbranched chain of at least 8 carbon atoms or the alcohols having an unbranched chain of at least 8 carbon atoms. The lower esters or alcohols are not so useful because they have a high vapor pressure and therefore are very volatile. The softening agents prepared by oxidizing paraffins such as lignite wax and ozocerite, or the high-boiling brown coal oils by means of air (with or without a catalyzer), nitric acid or chromic acid are preferred without limiting the invention.

The following examples serve to illustrate the invention:

Example 1.—Acetylcellulose containing 56 per cent. of acetic acid is dissolved in a mixture of methylene chloride, chloroform and amyl alcohol in the proportions of 2:5:2 to a solution of 18 per cent strength while adding 20 per cent of the alcohols obtained by oxidizing commercial paraffin. The solution obtained is cast to form a film of 0.135 mm. thickness. This film shows the following data in comparison with a film prepared with triphenylphosphate, the usual softener for acetylcellulose.

Kind of addition	Breaking load, kilo	Elongation, percent	Creasing number
20 per cent of alcohols obtained by oxidizing commercial paraffin	88	42	335
20 per cent of triphenyl-phosphate	89	37	191

Example 2.—To a solution of 180 grams of cellulose acetobutyrate in 820 grams of a mixture of acetone and alcohol in the ratio 8:2 there are added 36 grams of the butylester of the mixture of fatty acids obtained from lignite wax by oxidation with chromium acid. From this mixture there is cast a film of 20 to 25 μ thickness which in view of its good mechanical properties as to elasticity, extensibility and creasing number is much better adapted for insulating electric conductors than film without the addition of softening agent or with the addition of triphenylphosphate or tricresylphosphate or phthalic acid esters hitherto used.

What we claim is:

1. A process of manufacturing film which comprises dissolving cellulose acetate containing 56 per cent of acetic acid in a mixture of methylene chloride, chloroform and alcohol, adding a mixture of alcohols obtained by oxidizing commercial paraffin and casting the film from this solution.

2. A film which comprises cellulose acetate containing 56 per cent of acetic acid and a mixture of alcohols obtained by oxidizing commercial paraffin.

3. Process of manufacturing film which comprises dissolving in a suitable solvent therefor a compound selected from the group consisting of organic acid esters of cellulose and mixed organic-inorganic acid esters of cellulose, adding

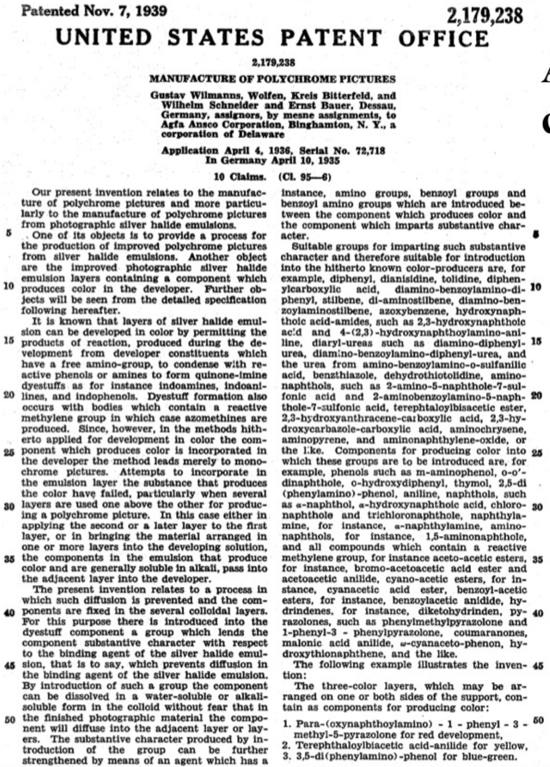
Max Hagedorn (18??–19??) invented improved film stock (1924–)

Figure 3.140: Max Hagedorn created improved film stock from 1924 onward.

Ernst Bauer
(18??–19??)

Wilhelm Schneider
(18??–19??)

Gustav Wilmanns
(18??–19??)



Patented Nov. 7, 1939 2,179,238

UNITED STATES PATENT OFFICE

2,179,238

MANUFACTURE OF POLYCHROME PICTURES

Gustav Wilmanns, Wolfen, Kreis Bitterfeld, and Wilhelm Schneider and Ernst Bauer, Dessau, Germany, assignors, by mesne assignments, to Agfa Ansco Corporation, Binghamton, N. Y., a corporation of Delaware

Application April 4, 1936, Serial No. 72,718
In Germany April 10, 1935

10 Claims. (Cl. 95—6)

Our present invention relates to the manufacture of polychrome pictures and more particularly to the manufacture of polychrome pictures from photographic silver halide emulsions.

One of its objects is to provide a process for the production of improved polychrome pictures from silver halide emulsions. Another object are the improved photographic silver halide emulsion layers containing a component which produces color in the developer. Further objects will be seen from the detailed specification following hereafter.

It is known that layers of silver halide emulsion can be developed in color by permitting the products of reaction, produced during the development from developer constituents which have a free amino-group, to condense with reactive phenols or amines to form quinone-imine dyestuffs as for instance indoamines, indoanilines, and indophenols. Dyestuff formation also occurs with bodies which contain a reactive methylene group in which case azomethines are produced. Since, however, in the methods hitherto applied for development in color the component which produces color is incorporated in the developer the method leads merely to monochrome pictures. Attempts to incorporate in the emulsion layer the substance that produces the color have failed, particularly when several layers are used one above the other for producing a polychrome picture. In this case either in applying the second or a later layer to the first layer, or in bringing the material arranged in one or more layers into the developing solution, the components in the emulsion that produce color and are generally soluble in alkali, pass into the adjacent layer into the developer.

The present invention relates to a process in which such diffusion is prevented and the components are fixed in the several colloidal layers. For this purpose there is introduced into the dyestuff component a group which lends the component substantive character with respect to the binding agent of the silver halide emulsion, that is to say, which prevents diffusion in the binding agent of the silver halide emulsion. By introduction of such a group the component can be dissolved in a water-soluble or alkali-soluble form in the colloid without fear that in the finished photographic material the component will diffuse into the adjacent layer or layers. The substantive character produced by introduction of the group can be further strengthened by means of an agent which has a precipitating action on or by means of a group which increases the molecular dimensions of the component. Agents which have a precipitating action are, for instance, diphenylguanidide and diphenylbiguanidide. Groups which increase the molecular dimensions of the component are, for instance, amino groups, benzoyl groups and benzoyl amino groups which are introduced between the component which produces color and the component which imparts substantive character.

Suitable groups for imparting such substantive character and therefore suitable for introduction into the hitherto known color-producers are, for example, diphenyl, dianisidine, tolidine, diphenylcarboxylic acid, diamino-benzoylamino-diphenyl, stilbene, di-aminostilbene, diamino-benzoylaminostilbene, azoxybenzene, hydroxynaphthoic acid-amides, such as 2,3-hydroxynaphthoic acid and 4-(2,3)-hydroxynaphthoylamino-aniline, diaryl-ureas such as diamino-diphenylurea, diamino-benzoylamino-diphenyl-urea, and the urea from amino-benzoylamino-o-sulfanilic acid, benzthiazole, dehydrothiotolidine, aminonaphthols, such as 2-amino-5-naphthole-7-sulfonic acid and 2-aminobenzoylamino-5-naphthole-7-sulfonic acid, terephtaloylbisacetic ester, 2,3-hydroxyanthracene-carboxylic acid, 2,3-hydroxycarbazole-carboxylic acid, aminochrysene, aminopyrene, and aminonaphthylene-oxide, or the like. Components for producing color into which these groups are to be introduced are, for example, phenols such as m-aminophenol, o-o′-dinaphthole, o-hydroxydiphenyl, thymol, 2,5-di (phenylamino)-phenol, aniline, naphthols, such as α-naphthol, α-hydroxynaphthoic acid, chloronaphthole and trichloronaphthole, naphthylamine, for instance, α-naphthylamine, aminonaphthols, for instance, 1,5-aminonaphthole, and all compounds which contain a reactive methylene group, for instance aceto-acetic esters, for instance, bromo-acetoacetic acid ester and acetoacetic anilide, cyano-acetic esters, for instance, cyanacetic acid ester, benzoyl-acetic esters, for instance, benzoylacetic anidide, hydrindenes, for instance, diketohydrinden, pyrazolones, such as phenylmethylpyrazolone and 1-phenyl-3 - phenylpyrazolone, coumaranones, malonic acid anilide, ω-cyanaceto-phenon, hydroxythionaphthene, and the like.

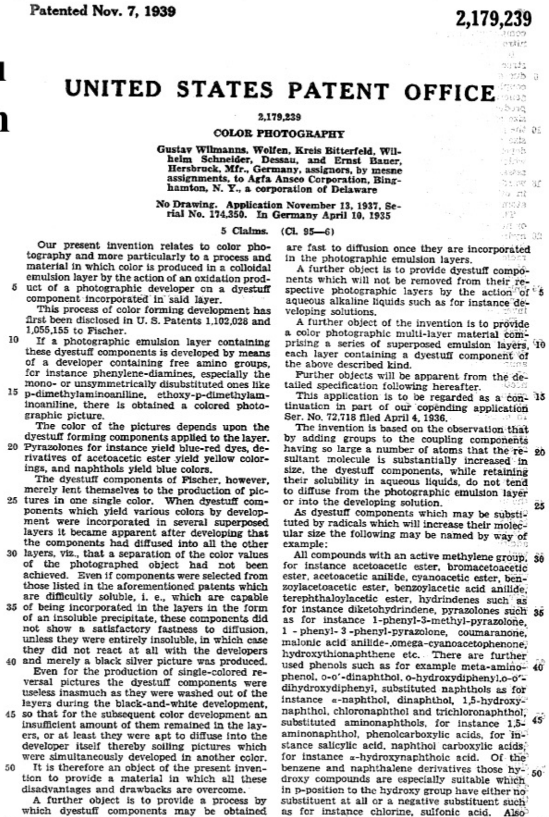
The following example illustrates the invention:

The three-color layers, which may be arranged on one or both sides of the support, contain as components for producing color:

1. Para-(oxynaphthoylamino) - 1 - phenyl - 3 - methyl-5-pyrazolone for red development,
2. Terephthaloylbiacetic acid-anilide for yellow,
3. 3,5-di(phenylamino)-phenol for blue-green.

The alkali salts of these bodies, dissolved in methanol, are stirred into a gelatin solution of 10 per cent strength in the proportion of 1 gram to 50 cc. of the gelatin solution, and the solution is then mixed with 100 cc. of silver halide emulsion. A suitable developer is one consisting of

Agfa Neu
color film
(1935)



Patented Nov. 7, 1939 2,179,239

UNITED STATES PATENT OFFICE

2,179,239

COLOR PHOTOGRAPHY

Gustav Wilmanns, Wolfen, Kreis Bitterfeld, Wilhelm Schneider, Dessau, and Ernst Bauer, Hersbruck, Mfr., Germany, assignors, by mesne assignments, to Agfa Ansco Corporation, Binghamton, N. Y., a corporation of Delaware

No Drawing. Application November 13, 1937, Serial No. 174,350. In Germany April 10, 1935

5 Claims. (Cl. 95—6)

Our present invention relates to color photography and more particularly to a process and material in which color is produced in a colloidal emulsion layer by the action of an oxidation product of a photographic developer on a dyestuff component incorporated in said layer.

This process of color forming development has first been disclosed in U. S. Patents 1,102,028 and 1,055,155 to Fischer.

If a photographic emulsion layer containing these dyestuff components is developed by means of a developer containing free amino groups, for instance phenylene-diamines, especially the mono- or unsymmetrically disubstituted ones like p-dimethylaminoaniline, ethoxy-p-dimethylaminoaniline, there is obtained a colored photographic picture.

The color of the pictures depends upon the dyestuff forming components applied to the layer. Pyrazolones for instance yield blue-red dyes, derivatives of acetoacetic ester yield yellow colorings, and naphthols yield blue colors.

The dyestuff components of Fischer, however, merely lent themselves to the production of pictures in one single color. When dyestuff components which yield various colors by development were incorporated in several superposed layers it became apparent after developing that the components had diffused into all the other layers, viz., that a separation of the color values of the photographed object had not been achieved. Even if components were selected from those listed in the aforementioned patents which are difficultly soluble, i. e., which are capable of being incorporated in the layers in the form of an insoluble precipitate, these components did not show a satisfactory fastness to diffusion, unless they were entirely insoluble, in which case they did not react at all with the developers and merely a black silver picture was produced.

Even for the production of single-colored reversal pictures the dyestuff components were useless inasmuch as they were washed out of the layers during the black-and-white development, so that for the subsequent color development an insufficient amount of them remained in the layers, or at least they were apt to diffuse into the developer itself thereby soiling pictures which were simultaneously developed in another color.

It is therefore an object of the present invention to provide a material in which all these disadvantages and drawbacks are overcome.

A further object is to provide a process by which dyestuff components may be obtained which are soluble in aqueous liquids and which are fast to diffusion once they are incorporated in the photographic emulsion layers.

A further object is to provide dyestuff components which will not be removed from their respective photographic layers by the action of aqueous alkaline liquids such as for instance developing solutions.

A further object of the invention is to provide a color photographic multi-layer material comprising a series of superposed emulsion layers, each layer containing a dyestuff component of the above described kind.

Further objects will be apparent from the detailed specification following hereafter.

This application is to be regarded as a continuation in part of our copending application Ser. No. 72,718 filed April 4, 1936.

The invention is based on the observation that by adding groups to the coupling components having so large a number of atoms that the resultant molecule is substantially increased in size, the dyestuff components, while retaining their solubility in aqueous liquids, do not tend to diffuse from the photographic emulsion layer or into the developing solution.

As dyestuff components which may be substituted by radicals which will increase their molecular size the following may be named by way of example:

All compounds with an active methylene group, for instance acetoacetic ester, bromacetoacetic ester, acetoacetic anilide, cyanoacetic ester, benzoylacetoacetic ester, benzoylacetic acid anilide, terephthaloylacetic ester, hydrindenes such as for instance diketohydrindene, pyrazolones such as for instance 1-phenyl-3-methyl-pyrazolone, 1 - phenyl- 3 -phenyl-pyrazolone, coumaranone, malonic acid anilide-,omega-cyanoacetophenone, hydroxythionaphthene etc. There are further used phenols such as for example meta-aminophenol, o-o′-dinaphthol, o-hydroxydiphenyl,o-o′-dihydroxydiphenyl, substituted naphthols as for instance α-naphthol, dinaphthol, 1,5-hydroxynaphthol, chloronaphthol and trichloronaphthol, substituted aminonaphthols, for instance 1,5-aminonaphthol, phenolcarboxylic acids, for instance salicylic acid, naphthol carboxylic acids, for instance α-hydroxynaphthoic acid. Of the benzene and naphthalene derivatives those hydroxy compounds are especially suitable which in p-position to the hydroxy group have either no substituent at all or a negative substituent such as for instance chlorine, sulfonic acid. Also other substitution products of the above named

Frauen sind doch bessere Diplomaten
(filmed 1939–1940)

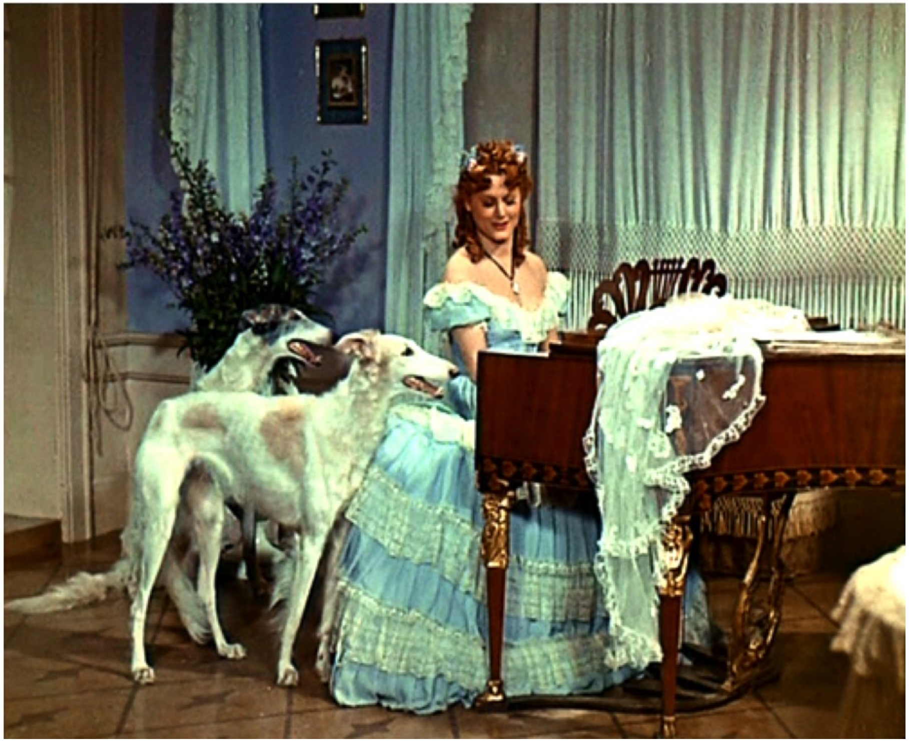
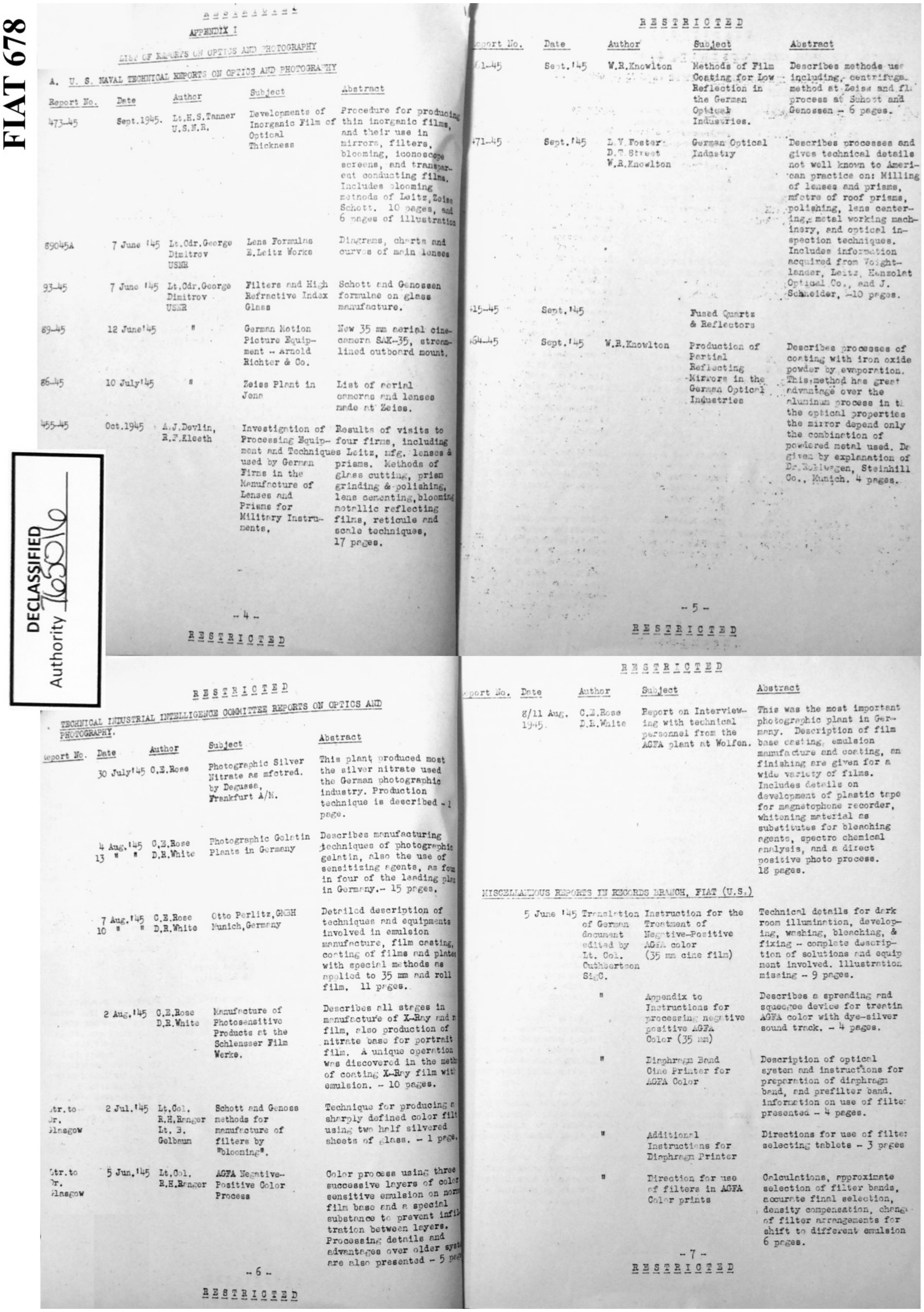


Figure 3.141: Ernst Bauer, Wilhelm Schneider, and Gustav Wilmanns invented Agfa Neu improved color film in 1935. Their technology was showcased in films such as *Frauen sind doch bessere Diplomaten* and became the basis for most color film around the world after World War II.



FIAT 678

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Authority 765016

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APPENDIX I

LIST OF REPORTS ON OPTICS AND PHOTOGRAPHY

A. U. S. NAVAL TECHNICAL REPORTS ON OPTICS AND PHOTOGRAPHY

Report No.	Date	Author	Subject	Abstract
473-45	Sept.1945.	Lt.H.S.Tanner U.S.N.R.	Developments of Inorganic Film of Optical Thickness	Procedure for producing thin inorganic films, and their use in mirrors, filters, blooming, iconoscope screens, and transparent conducting films. Includes blooming methods of Leitz, Zeiss Schott. 10 pages, and 6 pages of illustratio
89045A	7 June '45	Lt.Cdr.George Dimitrov USNR	Lens Formulas E.Leitz Works	Diagrams, charts and curves of main lenses
93-45	7 June '45	Lt.Cdr.George Dimitrov USNR	Filters and High Refractive Index Glass	Schott and Genossen formulae on glass manufacture.
89-45	12 June'45	"	German Motion Picture Equipment -- Arnold Richter & Co.	New 35 mm aerial cine-camera SAK-35, streamlined outboard mount.
86-45	10 July'45	"	Zeiss Plant in Jena	List of aerial cameras and lenses made at Zeiss.
455-45	Oct.1945	A.J.Devlin, R.F.Kleeth	Investigation of Processing Equipment and Techniques used by German Firms in the Manufacture of Lenses and Prisms for Military Instruments.	Results of visits to four firms, including Leitz, mfg. lenses & prisms. Methods of glass cutting, prism grinding & polishing, lens cementing, blooming metallic reflecting films, reticule and scale techniques, 17 pages.

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Report No.	Date	Author	Subject	Abstract
61-45	Sept.'45	W.R.Knowlton	Methods of Film Coating for Low Reflection in the German Optical Industries.	Describes methods use including, centrifuga method at Zeiss and fl process at Schott and Genossen - 6 pages.
71-45	Sept.'45	L.V.Foster D.T.Street W.R.Knowlton	German Optical Industry	Describes processes and gives technical details not well known to American practice on: Milling of lenses and prisms, mfctre of roof prisms, polishing, lens centering, metal working machinery, and optical inspection techniques. Includes information acquired from Voightlander, Leitz, Henzolat Optical Co., and J. Schneider, -10 pages.
15-45	Sept.'45		Fused Quartz & Reflectors	
64-45	Sept.'45	W.R.Knowlton	Production of Partial Reflecting Mirrors in the German Optical Industries	Describes processes of coating with iron oxide powder by evaporation. This method has great advantage over the aluminum process in th the optical properties the mirror depend only the combination of powdered metal used. De given by explanation of Dr.Schliwagen, Steinhill Co., Munich. 4 pages.

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TECHNICAL INDUSTRIAL INTELLIGENCE COMMITTEE REPORTS ON OPTICS AND PHOTOGRAPHY.

Report No.	Date	Author	Subject	Abstract
	30 July'45	C.E.Rose	Photographic Silver Nitrate as mfctred. by Degussa, Frankfurt A/M.	This plant produced most the silver nitrate used the German photographic industry. Production technique is described - 1 page.
	4 Aug.'45 13 " "	C.E.Rose D.R.White	Photographic Gelatin Plants in Germany	Describes manufacturing techniques of photographic gelatin, also the use of sensitizing agents, as fou in four of the leading pla in Germany.- 15 pages.
	7 Aug.'45 10 " "	C.E.Rose D.R.White	Otto Perlitz, GMBH Munich, Germany	Detailed description of techniques and equipments involved in emulsion manufacture, film casting, coating of films and plates with special methods as applied to 35 mm and roll film. 11 pages.
	2 Aug.'45	C.E.Rose D.R.White	Manufacture of Photosensitive Products at the Schlensser Film Werke.	Describes all stages in manufacture of X-Ray and n film, also production of nitrate base for portrait film. A unique operation was discovered in the meth of coating X-Ray film with emulsion. - 10 pages.
tr. to Dr. Glasgow	2 Jul.'45	Lt.Col. R.H.Ranger Lt. B. Gelbaum	Schott and Genoss methods for manufacture of filters by "blooming".	Technique for producing a sharply defined color filt using two half silvered sheets of glass. - 1 page.
Ltr. to Dr. Glasgow	5 Jun.'45	Lt.Col. R.H.Ranger	AGFA Negative-Positive Color Process	Color process using three successive layers of color sensitive emulsion on norm film base and a special substance to prevent infiltration between layers. Processing details and advantages over older syst are also presented - 5 pa

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Report No.	Date	Author	Subject	Abstract
	8/11 Aug. 1945.	C.E.Rose D.R.White	Report on Interviewing with technical personnel from the AGFA plant at Wolfen.	This was the most important photographic plant in Germany. Description of film base casting, emulsion manufacture and coating, an finishing are given for a wide variety of films. Includes details on development of plastic tape for magnetophone recorder, whitening material as substitutes for bleaching agents, spectro chemical analysis, and a direct positive photo process. 18 pages.

MISCELLANEOUS REPORTS IN RECORDS BRANCH, FIAT (U.S.)

Report No.	Date	Author	Subject	Abstract
	5 June '45	Translation of German document edited by Lt. Col. Cuthbertson SigC.	Instruction for the Treatment of Negative-Positive AGFA color (35 mm cine film)	Technical details for dark room illumination, developing, washing, bleaching, & fixing - complete description of solutions and equipment involved. Illustration missing - 9 pages.
		"	Appendix to Instructions for processing negative positive AGFA Color (35 mm)	Describes a spreading and squeegee device for treatin AGFA color with dye-silver sound track. - 4 pages.
		"	Diaphragm Band Cine Printer for AGFA Color	Description of optical system and instructions for preparation of diaphragm band, and prefilter band. information on use of filte presented - 4 pages.
		"	Additional Instructions for Diaphragm Printer	Directions for use of filte selecting tablets - 3 pages
		"	Direction for use of filters in AGFA Color prints	Calculations, approximate selection of filter bands, accurate final selection, density compensation, change of filter arrangements for shift to different emulsion 6 pages.

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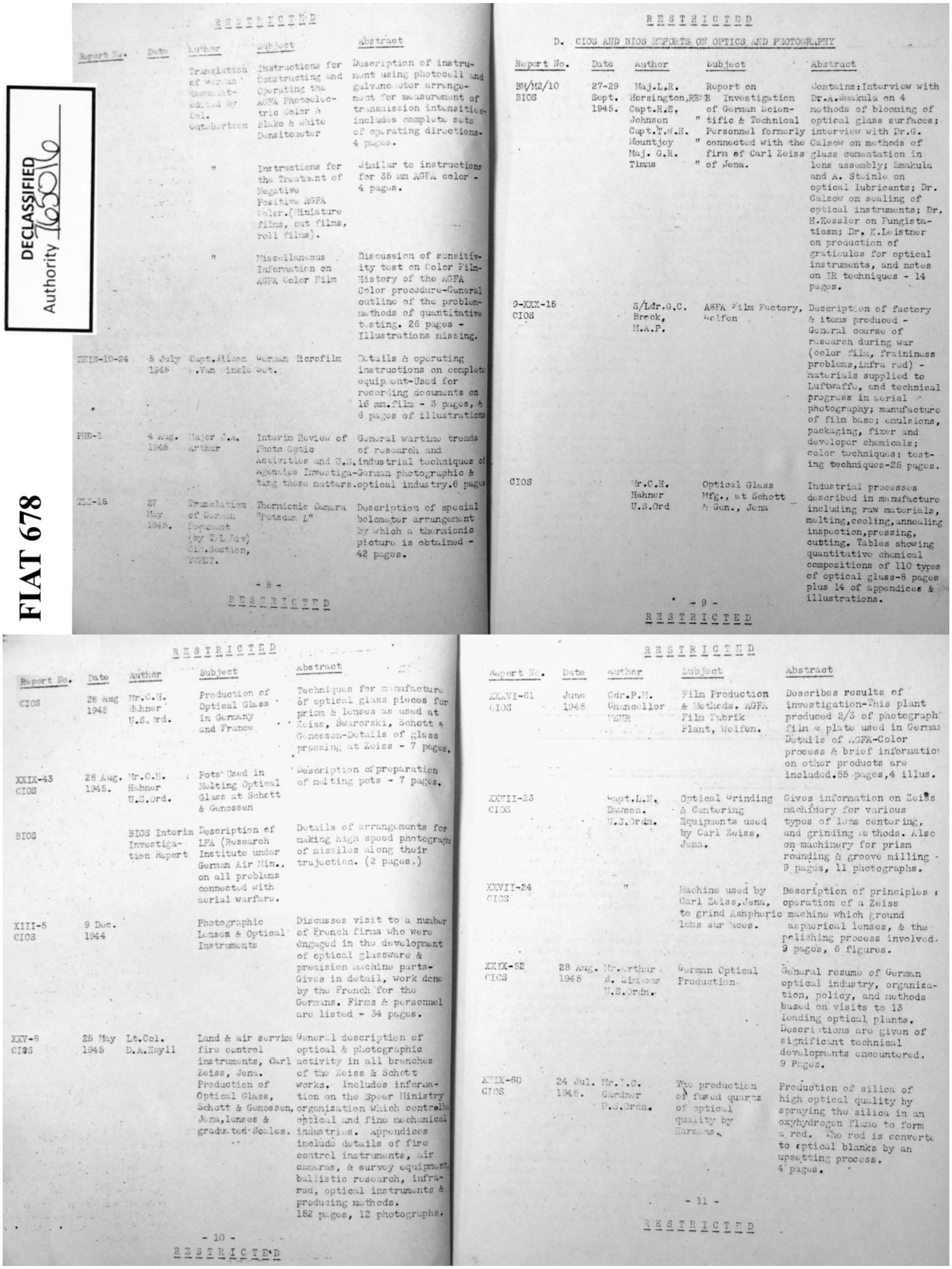
Figure 3.142: A wide variety of advanced technologies, components, and methods for photography were developed in the German-speaking world and transferred to other countries after World War II [FIAT 678].



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Authority 765016

FIAT 678

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Report No.	Date	Author	Subject	Abstract
		Translation of German Document-edited by Col. Cuthbertson	Instructions for Constructing and Operating the AGFA Photoelectric Color & Black & White Densitometer	Description of instrument using photocell and galvanometer arrangement for measurement of transmission intensities-includes complete sets of operating directions-4 pages.
		"	Instructions for the Treatment of Negative Positive AGFA Color.(Miniature films, cut films, roll films).	Similar to instructions for 35 mm AGFA color - 4 pages.
		"	Miscellaneous Information on AGFA Color Film	Discussion of sensitivity test on Color Film-History of the AGFA Color procedure-General outline of the problem-methods of quantitative testing. 26 pages - Illustrations missing.
EEIS-10-24	5 July 1945	Capt.Wilson .Van Winkle	German Microfilm Set.	Details & operating instructions on complete equipment-Used for recording documents on 16 mm.film - 3 pages, & 6 pages of illustrations
PHD-1	4 Aug. 1945	Major J.A. Arthur	Interim Review of Photo Optic Activities and U.S. Agencies Investigating these matters.	General wartime trends of research and industrial techniques of German photographic & optical industry.6 pages
TLI-15	27 May 1945.	Translation of German Document (by T/L Nav) CIR.Section, TMET.	Thermionic Camera "Potsdam L"	Description of special bolometer arrangement by which a thermionic picture is obtained - 42 pages.

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D. CIOS AND BIOS REPORTS ON OPTICS AND PHOTOGRAPHY

Report No.	Date	Author	Subject	Abstract
BM/M2/10 BIOS	27-29 Sept. 1945.	Maj.L.R. Horsington,REME Capt.R.S. Johnson " Capt.T.W.H. Mountjoy " Maj. G.R. Timms "	Report on Investigation of German Scientific & Technical Personnel formerly connected with the firm of Carl Zeiss of Jena.	Contains:Interview with Dr.A.Smakula on 4 methods of blooming of optical glass surfaces; interview with Dr.G. Calsow on methods of glass cementation in lens assembly; Smakula and A. Steinle on optical lubricants; Dr. Calsow on sealing of optical instruments; Dr. H.Kessler on Fungistaticsm; Dr. K.Leistner on production of graticules for optical instruments, and notes on IR techniques - 14 pages.
9-XXX-15 CIOS		S/Ldr.G.C. Breck, M.A.P.	AGFA Film Factory, Wolfen	Description of factory & items produced - General course of research during war (color film, fraininess problems,infra red) - materials supplied to Luftwaffe, and technical progress in aerial photography; manufacture of film base; emulsions, packaging, fixer and developer chemicals; color techniques; testing techniques-25 pages.
CIOS		Mr.C.H. Hahner U.S.Ord	Optical Glass Mfg., at Schott & Gen., Jena	Industrial processes described in manufacture including raw materials, melting,cooling,annealing inspection,pressing, cutting. Tables showing quantitative chemical compositions of 110 types of optical glass-8 pages plus 14 of appendices & illustrations.

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Report No.	Date	Author	Subject	Abstract
CIOS	28 Aug 1945	Mr.C.H. Hahner U.S. Ord.	Production of Optical Glass in Germany and France	Techniques for manufacture of optical glass pieces for prism & lenses as used at Zeiss, Śwarorski, Schott & Genossen-Details of glass pressing at Zeiss - 7 pages.
XXIX-43 CIOS	28 Aug. 1945.	Mr.C.H. Hahner U.S.Ord.	Pots Used in Melting Optical Glass at Schott & Genossen	Description of preparation of melting pots - 7 pages.
BIOS		BIOS Interim Investigation Report	Description of LFA (Research Institute under German Air Min., on all problems connected with aerial warfare.	Details of arrangements for making high speed photographs of missiles along their trajection. (2 pages.)
XIII-5 CIOS	9 Dec. 1944		Photographic Lenses & Optical Instruments	Discusses visit to a number of French firms who were engaged in the development of optical glassware & precision machine parts-Gives in detail, work done by the French for the Germans. Firms & personnel are listed - 34 pages.
XXV-8 CIOS	25 May 1945	Lt.Col. D.A.Kayll	Land & air service fire control instruments, Carl Zeiss, Jena. Production of Optical Glass, Schott & Genossen, Jena,lenses & graduated Scales.	General description of optical & photographic activity in all branches of the Zeiss & Schott works. Includes information on the Speer Ministry organization which controlls optical and fine mechanical industries. Appendices include details of fire control instruments, air cameras, & survey equipment, ballistic research, infra-red, optical instruments & producing methods. 152 pages, 12 photographs.

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Report No.	Date	Author	Subject	Abstract
XXXVI-61 CIOS	June 1945	Cdr.P.M. Chancellor USNR	Film Production & Methods. AGFA Film Fabrik Plant, Wolfen.	Describes results of investigation-This plant produced 2/3 of photographic film & plate used in Germany. Details of AGFA-Color process & brief information on other products are included.55 pages,4 illus.
XXVII-23 CIOS		Capt.L.N. Dawson. U.S.Ordn.	Optical Grinding & Centering Equipments used by Carl Zeiss, Jena.	Gives information on Zeiss machinery for various types of lens centering, and grinding methods. Also on machinery for prism rounding & groove milling - 9 pages, 11 photographs.
XXVII-24 CIOS		"	Machine used by Carl Zeiss,Jena, to grind Ashpheric lens surfaces.	Description of principles of operation of a Zeiss machine which ground aspherical lenses, & the polishing process involved. 9 pages, 6 figures.
XXIX-52 CIOS	28 Aug. 1945	Mr.Arthur B. Simmons U.S.Ordn.	German Optical Production	General resume of German optical industry, organization, policy, and methods based on visits to 13 leading optical plants. Descriptions are given of significant technical developments encountered. 9 Pages.
XXIX-60 CIOS	24 Jul. 1945.	Mr.T.C. Gardner U.S.Ordn.	The production of fused quartz of optical quality by Heraeus.	Production of silica of high optical quality by spraying the silica in an oxyhydrogen flame to form a rod. The rod is converted to optical blanks by an upsetting process. 4 pages.

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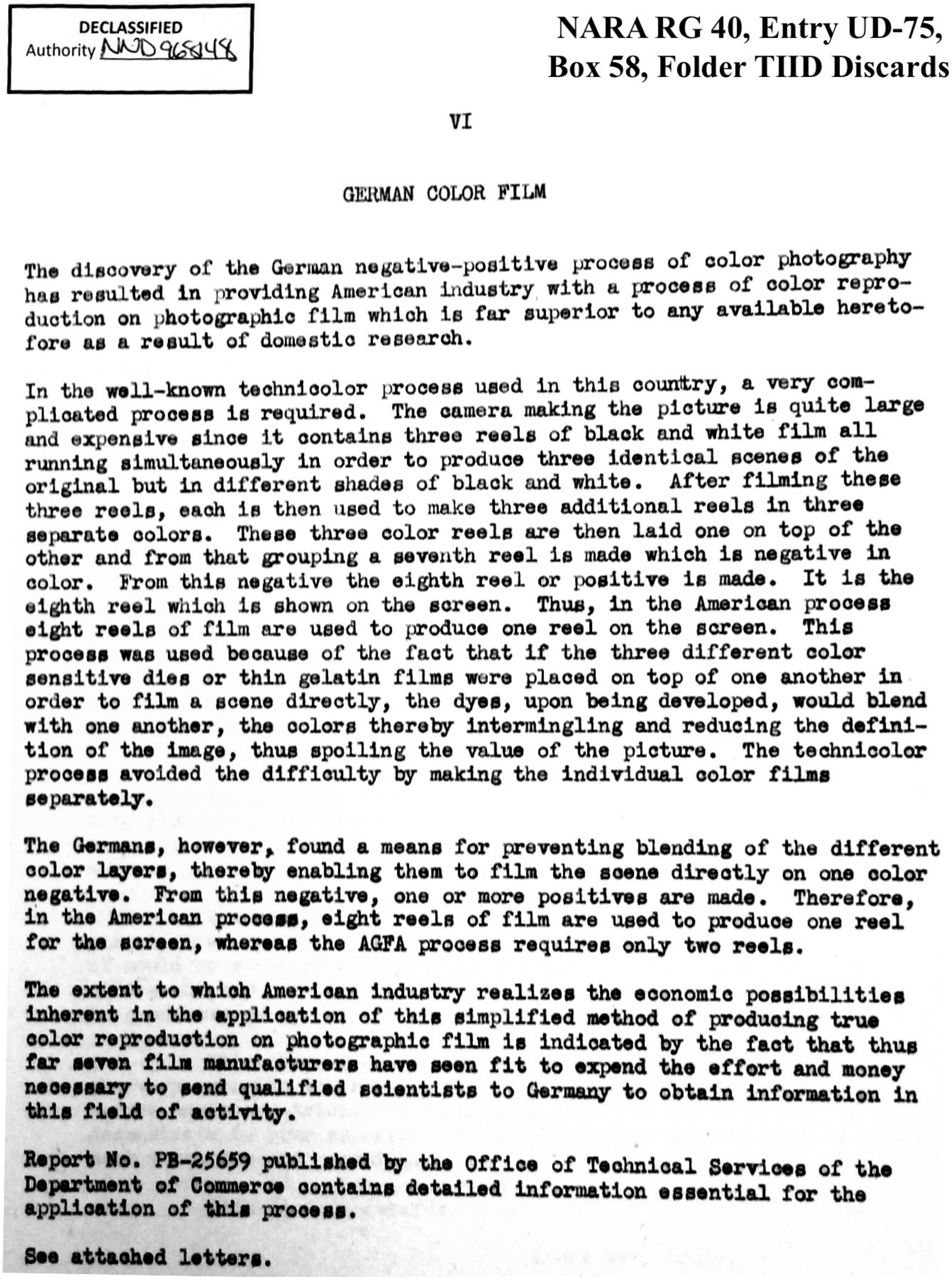
Figure 3.143: A wide variety of advanced technologies, components, and methods for photography were developed in the German-speaking world and transferred to other countries after World War II [FIAT 678].



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NARA RG 40, Entry UD-75,
Box 58, Folder TIID Discards

VI

GERMAN COLOR FILM

The discovery of the German negative-positive process of color photography has resulted in providing American industry with a process of color reproduction on photographic film which is far superior to any available heretofore as a result of domestic research.

In the well-known technicolor process used in this country, a very complicated process is required. The camera making the picture is quite large and expensive since it contains three reels of black and white film all running simultaneously in order to produce three identical scenes of the original but in different shades of black and white. After filming these three reels, each is then used to make three additional reels in three separate colors. These three color reels are then laid one on top of the other and from that grouping a seventh reel is made which is negative in color. From this negative the eighth reel or positive is made. It is the eighth reel which is shown on the screen. Thus, in the American process eight reels of film are used to produce one reel on the screen. This process was used because of the fact that if the three different color sensitive dies or thin gelatin films were placed on top of one another in order to film a scene directly, the dyes, upon being developed, would blend with one another, the colors thereby intermingling and reducing the definition of the image, thus spoiling the value of the picture. The technicolor process avoided the difficulty by making the individual color films separately.

The Germans, however, found a means for preventing blending of the different color layers, thereby enabling them to film the scene directly on one color negative. From this negative, one or more positives are made. Therefore, in the American process, eight reels of film are used to produce one reel for the screen, whereas the AGFA process requires only two reels.

The extent to which American industry realizes the economic possibilities inherent in the application of this simplified method of producing true color reproduction on photographic film is indicated by the fact that thus far seven film manufacturers have seen fit to expend the effort and money necessary to send qualified scientists to Germany to obtain information in this field of activity.

Report No. PB-25659 published by the Office of Technical Services of the Department of Commerce contains detailed information essential for the application of this process.

See attached letters.

Figure 3.144: Advanced technology to produce and process color film was developed in the German-speaking world and transferred to other countries after World War II [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

3.8 Materials Science

Materials science covers the creation of solid chemical compounds that make useful materials for various applications and products. For simplicity, this field can be divided into several areas, and German-speaking scientists played major roles in all of them:

3.8.1. Polymers

3.8.2. Ceramics and crystallography

3.8.3. Glass

3.8.4. Metals

3.8.1 Polymers

Creators from the German-speaking world led most of the development of polymers, including plastics and synthetic rubbers, which are now ubiquitous in consumer products.[15]

As shown in Fig. 3.145, polystyrene was first created in 1839 by Johann Eduard Simon (German states, 1789–1856), and developed further in 1845 by August Wilhelm von Hofmann (1818–1892) and John Blyth (Scottish but studied in Germany, 1814–1871). In 1929, Hermann Mark (Austrian, 1895–1992) and Carl Wulff (German?, 18??–19??) greatly improved the process of producing polystyrene. In the 1940s, Fritz Stastny (Austrian, 1908–1985) created expanded or porous polystyrene (Styrofoam). Polystyrene is used to make a wide variety of consumer products, and Styrofoam is used to make thermally insulated containers and protective packaging (Fig. 3.146).

Cellulose acetate was first created in 1865 by Paul Schützenberger (Franco-German, 1829–1897), and produced in larger quantities in 1903 by Arthur Eichengrün (German, 1867–1949) and Theodore Becker (German?, 18??–19??). The brothers Camille Dreyfus (Swiss, 1878–1956) and Henri Dreyfus (Swiss, 1882–1944) developed cellulose acetate yarn in 1913. Cellulose acetate has been used for photographic film, eyeglass frames, yarn, clothing, and other products, as illustrated in Fig. 3.147.

Eugen Baumann (German, 1846–1896) discovered photopolymerization and created polyvinyl chloride in 1872 (Fig. 3.148). Friedrich (Fritz) Klatte (German, 1880–1934) developed an improved method of producing polyvinyl chloride in 1913. Polyvinyl chloride is widely used for making water drain pipes and pipe fittings.

Phenol formaldehyde (phenolic) resin was first created in 1891 by Adolf von Baeyer (German, 1835–1917) and Werner Kleeberg (German, 18??–19??), and developed further in 1902 by Adolf Luft (German?, 18??–19??). Adolf von Baeyer won the Nobel Prize in Chemistry in 1905 (p. 459). In 1907, Leo Baekeland (Belgian but studied under August Kekulé, 1863–1944) began producing and commercializing phenolic resin under the trade name of Bakelite; phenolic resin was also sold under other trade names. Phenolic resin was used to make early plastic products such as telephone cases. See Fig. 3.149.

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[15] Dietrich Braun 2017; Feichtinger 2017; Kline 1946; Herman Mark 1993; Morris 2005; Schwedt 2013; Seymour 2013; Strom and Rasmussen 2012; Tuttle 1981; so many BIOS, CIOS, and FIAT reports that they cannot all be listed here.

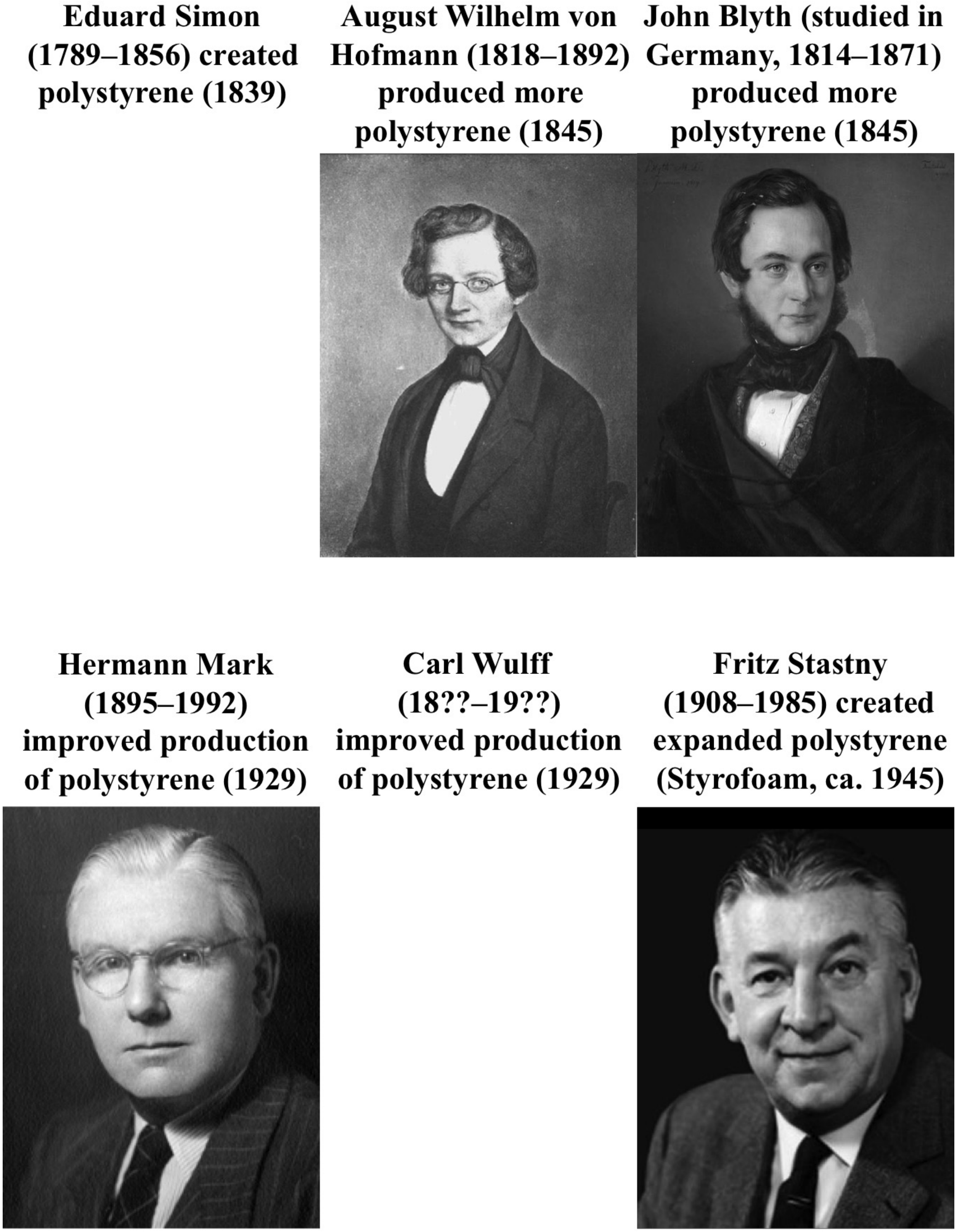

Eduard Simon (1789–1856) created polystyrene (1839)
August Wilhelm von Hofmann (1818–1892) produced more polystyrene (1845)
John Blyth (studied in Germany, 1814–1871) produced more polystyrene (1845)
Hermann Mark (1895–1992) improved production of polystyrene (1929)
Carl Wulff (18??–19??) improved production of polystyrene (1929)
Fritz Stastny (1908–1985) created expanded polystyrene (Styrofoam, ca. 1945)

Figure 3.145: Polystyrene was first created in 1839 by Eduard Simon, and developed further by August Wilhelm von Hofmann, John Blyth, Hermann Mark, Carl Wulff, and Fritz Stastny.

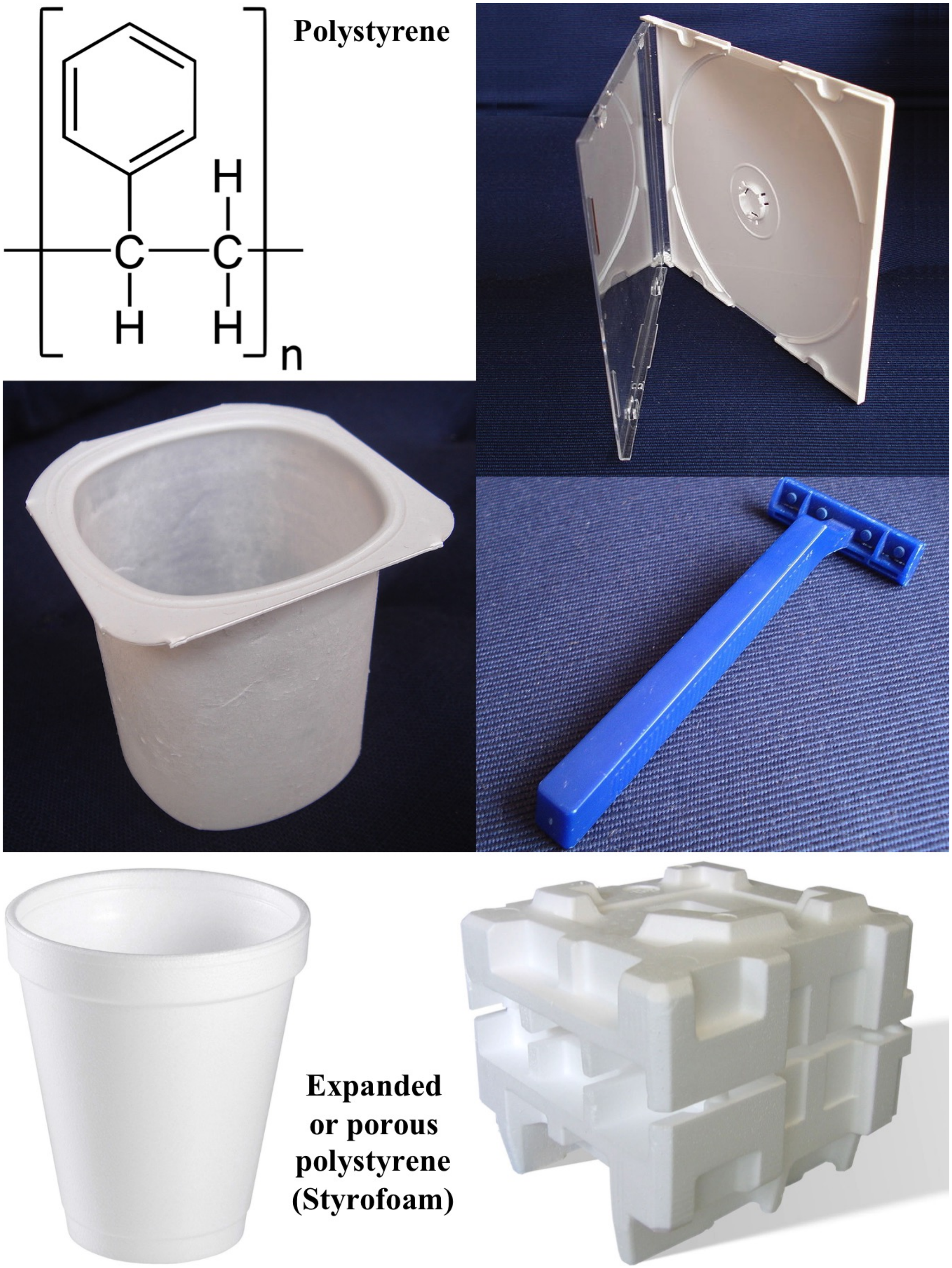

Polystyrene
Expanded or porous polystyrene (Styrofoam)

Figure 3.146: Polystyrene is used to make a wide variety of consumer products. Expanded or porous polystyrene (Styrofoam) is used to make thermally insulated containers and protective packaging.

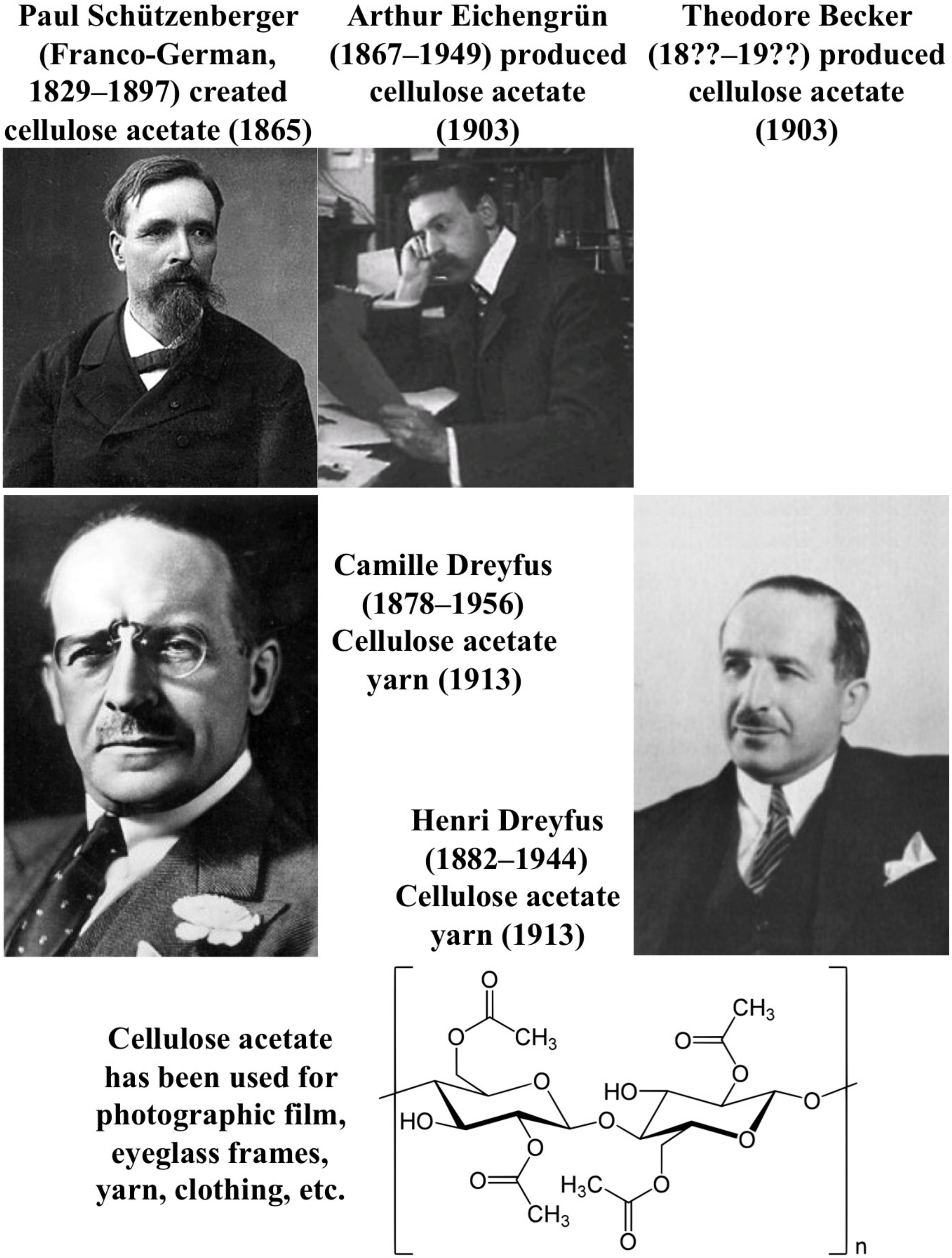

Paul Schützenberger (Franco-German, 1829–1897) created cellulose acetate (1865)
Arthur Eichengrün (1867–1949) produced cellulose acetate (1903)
Theodore Becker (18??–19??) produced cellulose acetate (1903)
Camille Dreyfus (1878–1956) Cellulose acetate yarn (1913)
Henri Dreyfus (1882–1944) Cellulose acetate yarn (1913)
Cellulose acetate has been used for photographic film, eyeglass frames, yarn, clothing, etc.
O
CH3
O
HO
O
HO
O
O
O
O
CH3
O
O
H3C
O
O
CH3
O
n

Figure 3.147: Cellulose acetate was first created in 1865 by Paul Schützenberger, and developed further by Arthur Eichengrün, Theodore Becker, Camille Dreyfus, and Henri Dreyfus. Cellulose acetate has been used for photographic film, eyeglass frames, yarn, clothing, and other products.

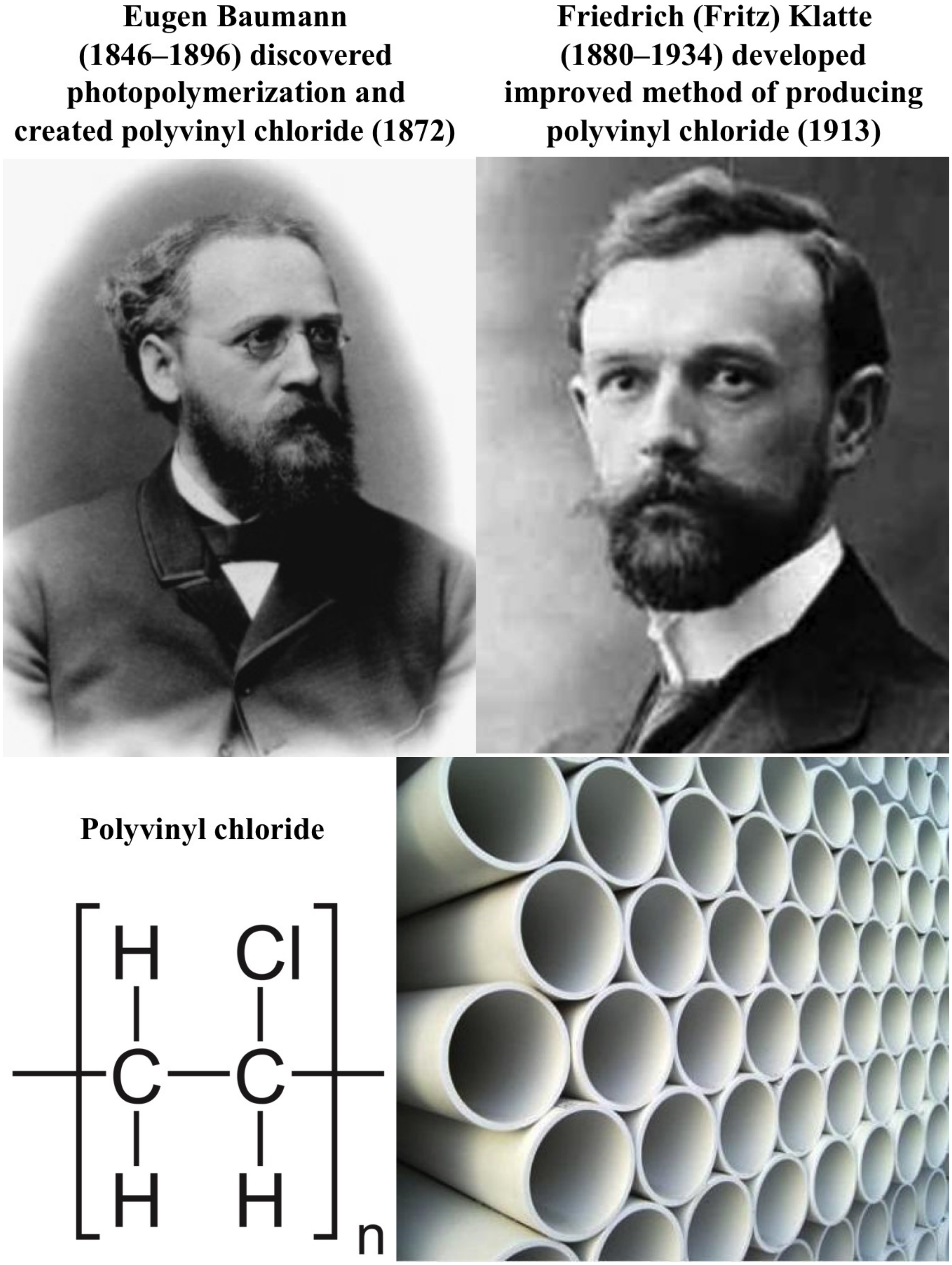

Eugen Baumann (1846–1896) discovered photopolymerization and created polyvinyl chloride (1872)
Friedrich (Fritz) Klatte (1880–1934) developed improved method of producing polyvinyl chloride (1913)
Polyvinyl chloride
H
Cl
C
C
H
H
n

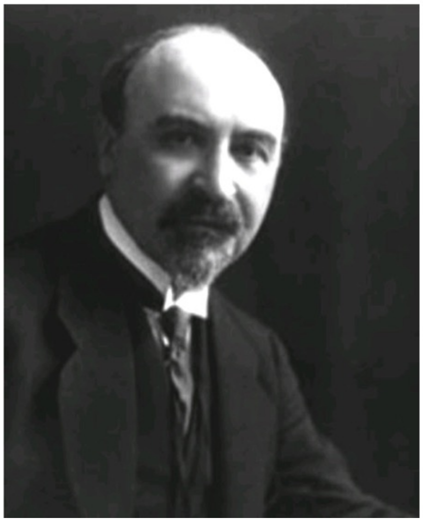
Figure 3.148: Eugen Baumann discovered photopolymerization and created polyvinyl chloride in 1872. Friedrich (Fritz) Klatte developed an improved method of producing polyvinyl chloride in 1913. Polyvinyl chloride is widely used for making water drain pipes and pipe fittings.

Adolf von Baeyer (1835–1917) created phenolic resin (1891); Nobel Prize in Chemistry 1905

Werner Kleeberg (18??–19??) created phenolic resin (1891)

Adolf Luft (18??–19??) produced phenolic resin (1902)

Leo Baekeland (studied under August Kekulé, 1863–1944) produced phenolic resin (1907)



Phenol formaldehyde resin (Bakelite, etc.)

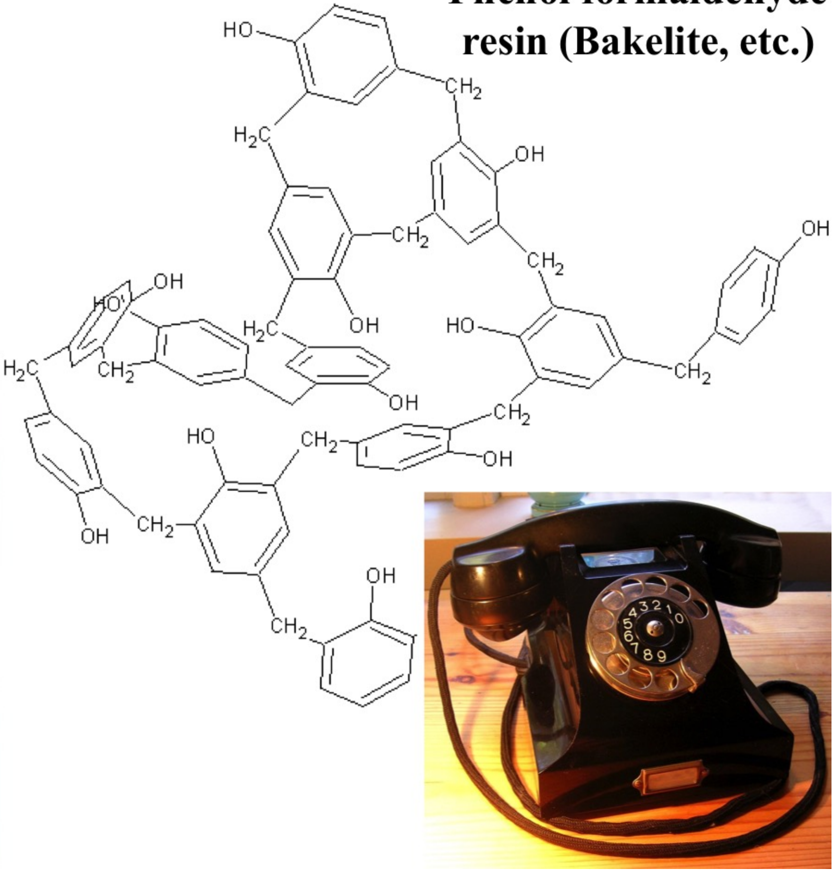

HO
CH2
H2C
OH
CH2
CH2
OH
HO
OH
H2C
OH
HO
H2C
CH2
OH
CH2
HO
CH2
OH
CH2
OH
CH2
OH
CH2
4 3 2 1 0
5 6 7 8 9

Figure 3.149: Phenol formaldehyde (phenolic) resin was first created in 1891 by Adolf von Baeyer and Werner Kleeberg, and developed further by Adolf Luft and Leo Baekeland. Phenolic resin was commercialized as Bakelite and other trade names and used to make early plastic products such as telephone cases.

In 1897, Wilhelm Krische (German, 1859–19??) and Friedrich Adolph Spitteler (German, 1846–1940) created a natural plastic (later dubbed Galalith) by purifying and crosslinking casein milk protein, as shown in Fig. 3.150. Galalith was also used to make a number of early plastic products.

Polyethylene was first created in 1898 by Hans von Pechmann (German, 1850–1902). In 1900, Eugen Bamberger (German, 1857–1932) and Friedrich Tschirner (German?, 18??–19??) determined the chemical structure of polyethylene. Karl Ziegler (German, 1898–1973) developed an improved method of producing polyethylene in 1952, and won the Nobel Prize in Chemistry in 1963 (p. 498). Polyethylene has been widely used to make plastic bags (Fig. 3.151), due to its flexibility and the low cost of Ziegler's production process.

Polycarbonate was first created in 1898 by Alfred Einhorn (German, 1856–1917). In 1953, Hermann Schnell (German, 1916–1999) developed an improved method of producing polycarbonate. Because polycarbonate is very rugged, it is used to make products such as compact discs, water bottles, cell phone cases, and safety glasses. See Fig. 3.152.

Friedrich (Fritz) Klatte (German, 1880–1934), shown in Fig. 3.153, created polyvinyl acetate in 1912. It has been used worldwide as white glue ever since.

Otto Röhm (German, 1876–1939) and Walter Hermann Bauer (German, 1893–1968) created polymethylacrylic (plexiglass) in 1928. Plexiglass pieces from a circa 1942 German aircraft windshield are shown in Fig. 3.154.

Some German-speaking scientists who made important contributions to rubber included (Fig. 3.155):

- Carl Harries (German, 1866–1923) studied the polymer structure of rubber.
- Fritz Hofmann (German, 1866–1956) produced synthetic rubbers.
- Kurt Gottlob (Austrian, 1881–1925) developed emulsion polymerization and improved vulcanization.
- Kurt Meyer (German, 1883–1952) studied the structure of cellulose and the effect of entropy on rubber elasticity.
- Herman(n) Mark (Austrian, 1895–1992) studied the structure of cellulose.
- Eugen(e) Guth (Hungarian, 1905–1990) developed a mathematical model using entropy to calculate the elasticity of rubber.

As shown in Fig. 3.156, Eduard Tschunkur (German, 1874–1946) and Walter Bock (German, 1895–1948) created styrene-butadiene synthetic rubber (Buna S) in 1929. It is now used to make most tires.

Similarly, Eduard Tschunkur, Helmut Kleiner (German, 1902–1987), and Erich Konrad (German, 1894–1975) created acrylonitrile butadiene synthetic rubber (Buna N) in 1930. It is now used for products such as latex-free nitrile rubber gloves (Fig. 3.157).

Wilhelm Krische (1859–19??) **Adolph Spitteler (1846–1940)**

Created a natural plastic from casein milk protein (Galalith, 1897)

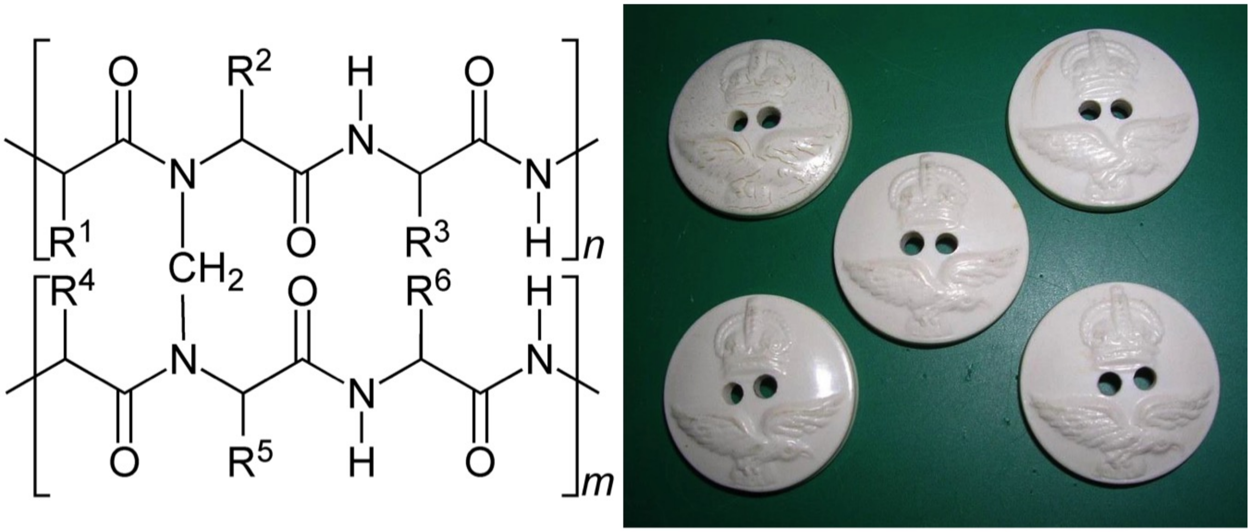

O
R2
H
O
N
N
N
O
R1
O
R3
H
n
CH2
R4
O
R6
H
N
N
N
O
R5
H
O
m

Figure 3.150: Wilhelm Krische and Adolph Spitteler created a natural plastic (later dubbed Galalith) from casein milk protein in 1897.

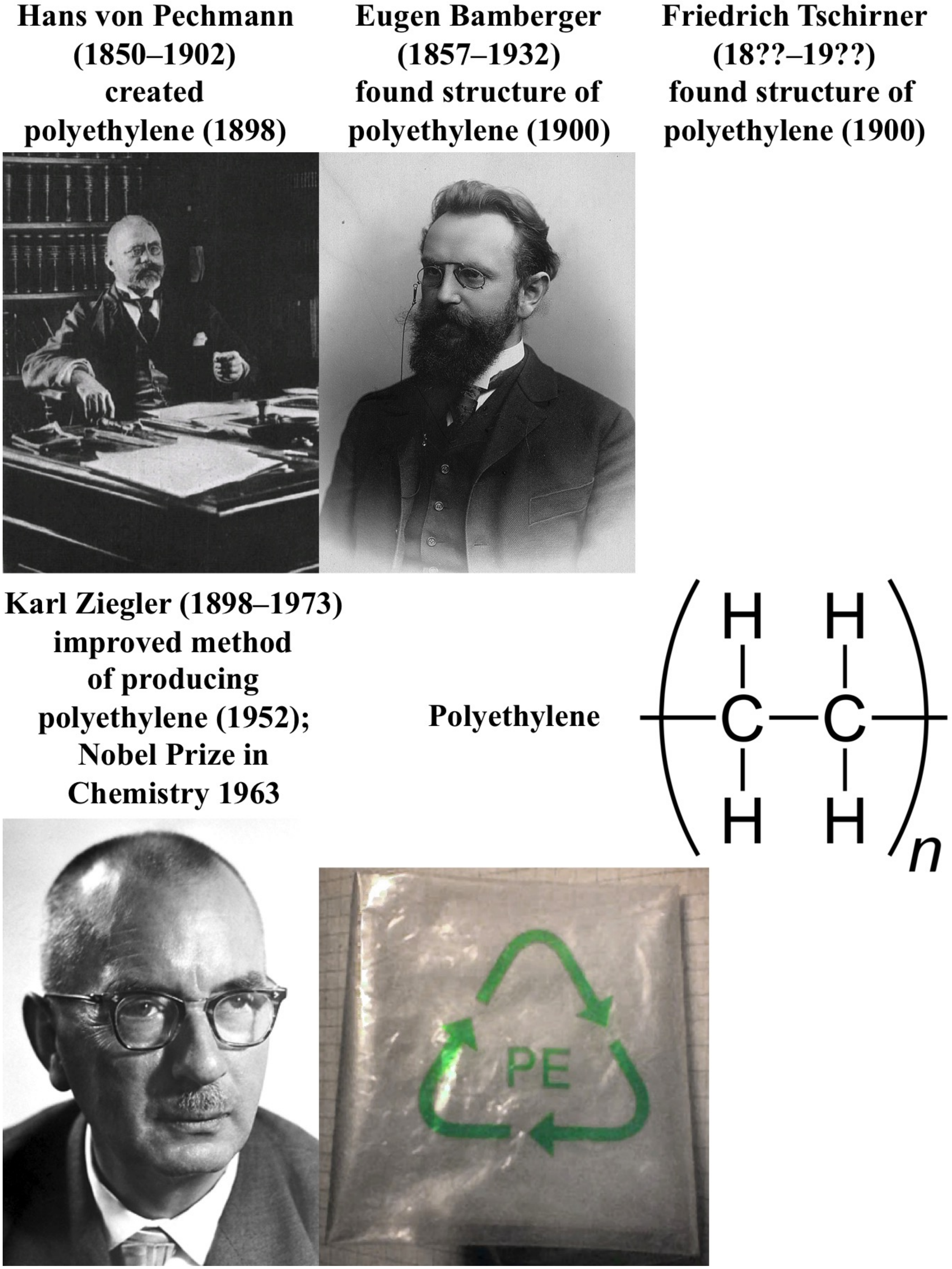

Hans von Pechmann (1850–1902) created polyethylene (1898)
Eugen Bamberger (1857–1932) found structure of polyethylene (1900)
Friedrich Tschirner (18??–19??) found structure of polyethylene (1900)
Karl Ziegler (1898–1973) improved method of producing polyethylene (1952); Nobel Prize in Chemistry 1963
Polyethylene
H
H
C
C
H
H
n
PE

Figure 3.151: Polyethylene was first created in 1898 by Hans von Pechmann, and developed further by Eugen Bamberger, Friedrich Tschirner, and Karl Ziegler. Polyethylene has been widely used to make plastic bags.

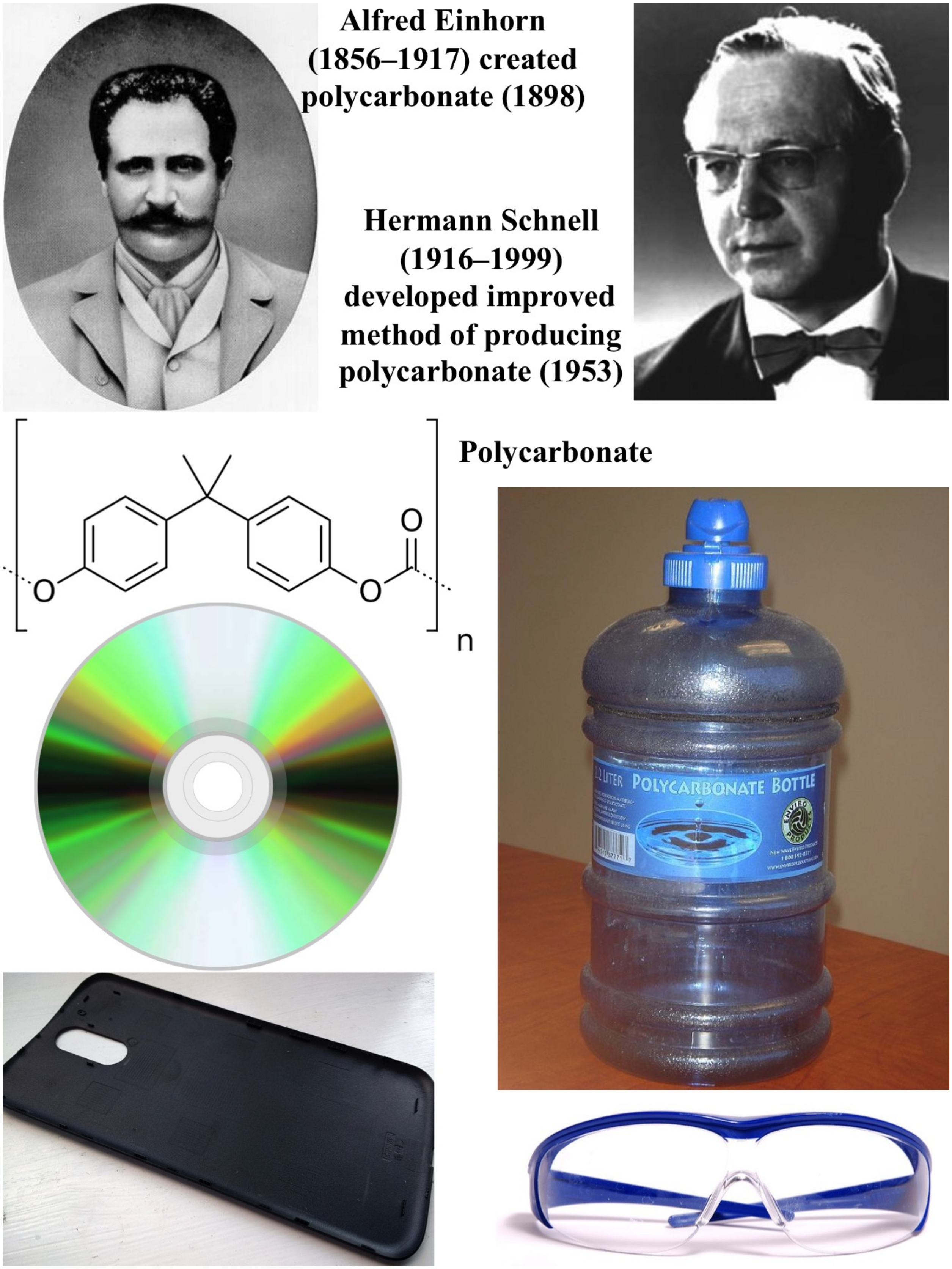

Alfred Einhorn (1856–1917) created polycarbonate (1898)
Hermann Schnell (1916–1999) developed improved method of producing polycarbonate (1953)
Polycarbonate
O
O
O
n
2.2 LITER
POLYCARBONATE BOTTLE

Figure 3.152: Polycarbonate was first created in 1898 by Alfred Einhorn, and developed further by Hermann Schnell. Because polycarbonate is very rugged, it is used to make products such as compact discs, water bottles, cell phone cases, and safety glasses.

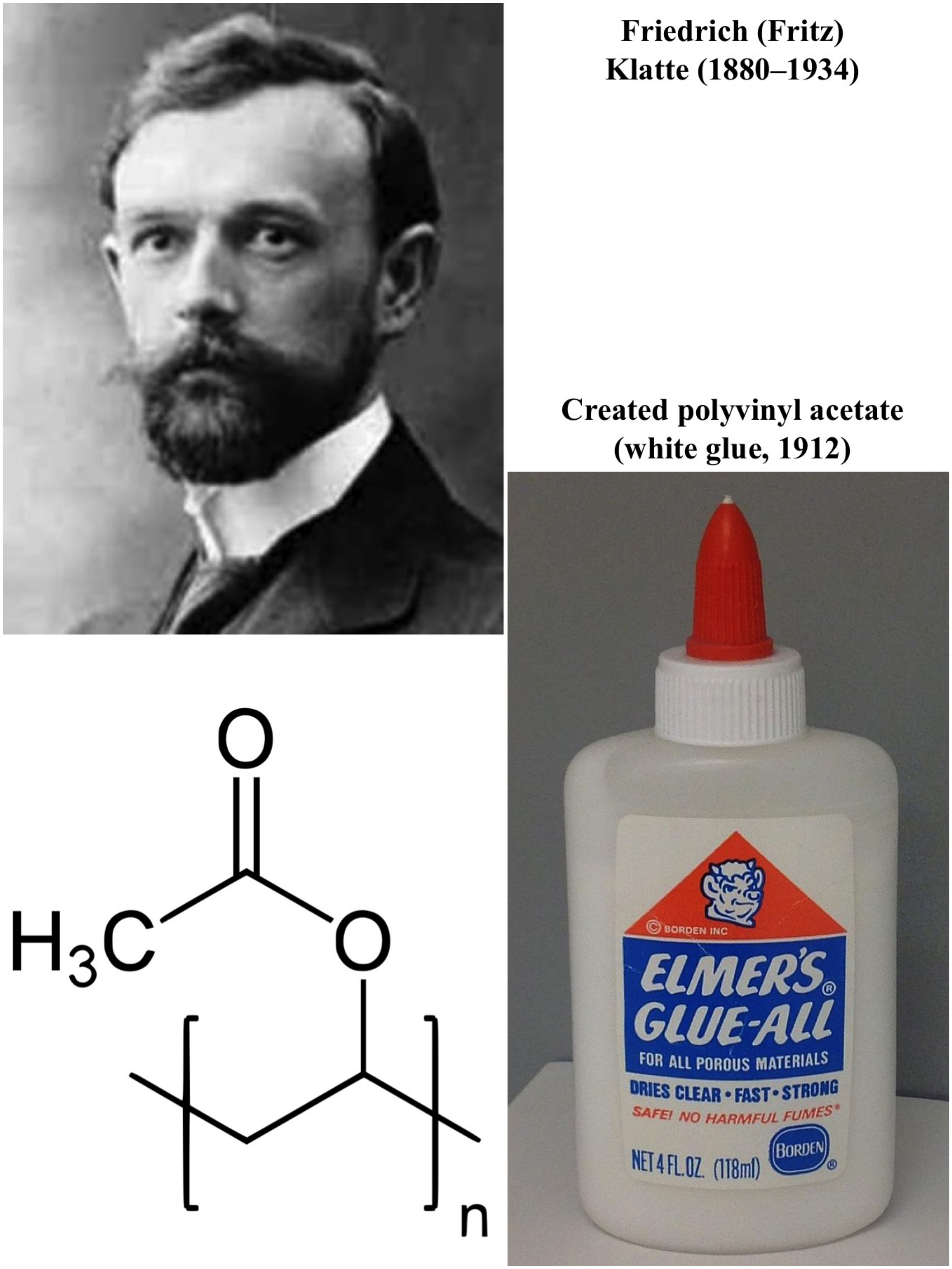

Friedrich (Fritz) Klatte (1880–1934)
Created polyvinyl acetate (white glue, 1912)
O
H3C
O
n
© BORDEN INC
ELMER'S®
GLUE-ALL
FOR ALL POROUS MATERIALS
DRIES CLEAR • FAST • STRONG
SAFE! NO HARMFUL FUMES*
NET 4 FL. OZ. (118ml)
BORDEN®

Figure 3.153: Friedrich (Fritz) Klatte created polyvinyl acetate (white glue) in 1912.

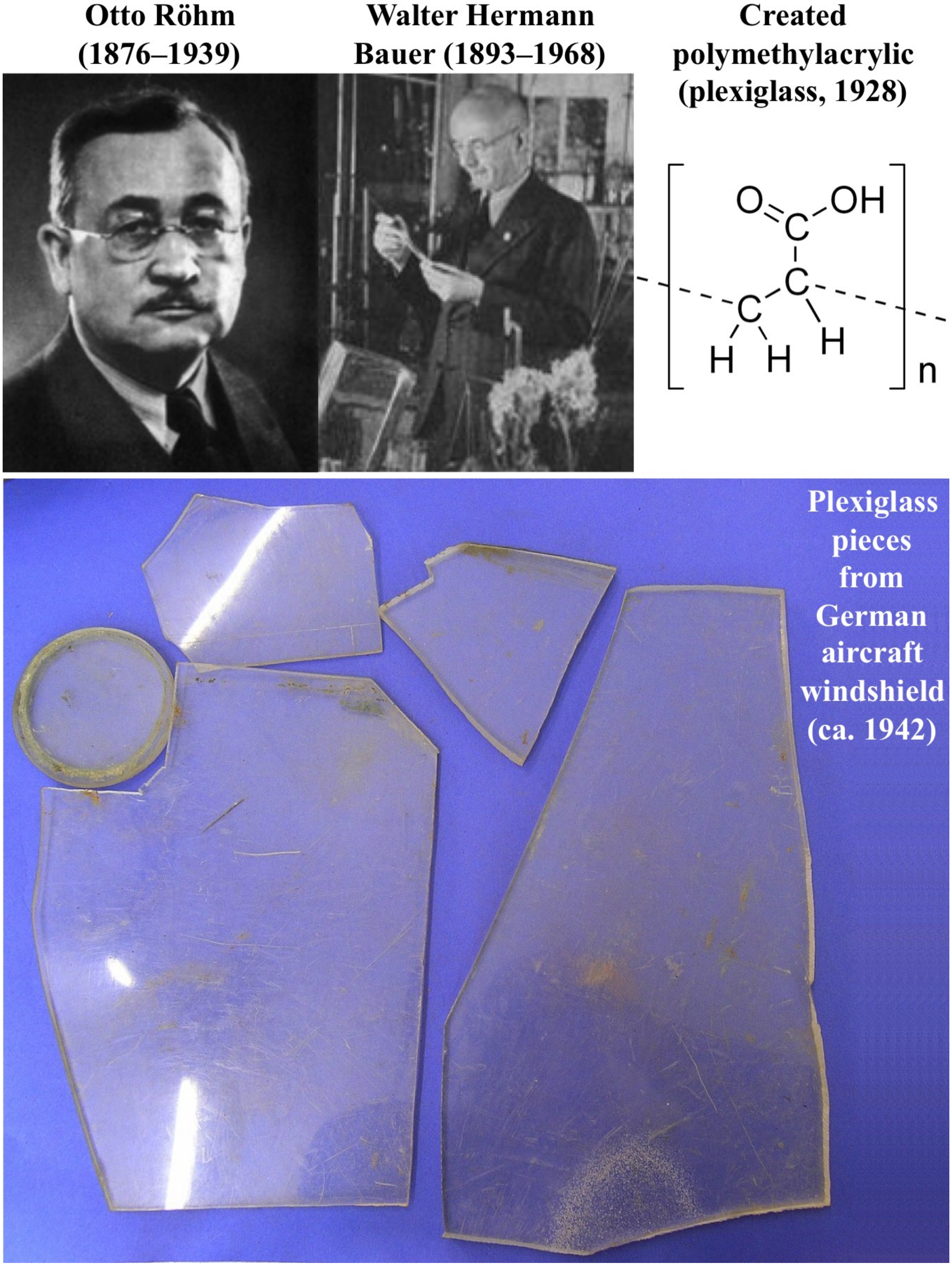

Otto Röhm
(1876–1939)
Walter Hermann
Bauer (1893–1968)
Created
polymethylacrylic
(plexiglass, 1928)
O
C
OH
C
C
H
H
H
n
Plexiglass
pieces
from
German
aircraft
windshield
(ca. 1942)

Figure 3.154: Otto Röhm and Walter Hermann Bauer created polymethylacrylic (plexiglass) in 1928. Plexiglass pieces from German aircraft windshield (ca. 1942).

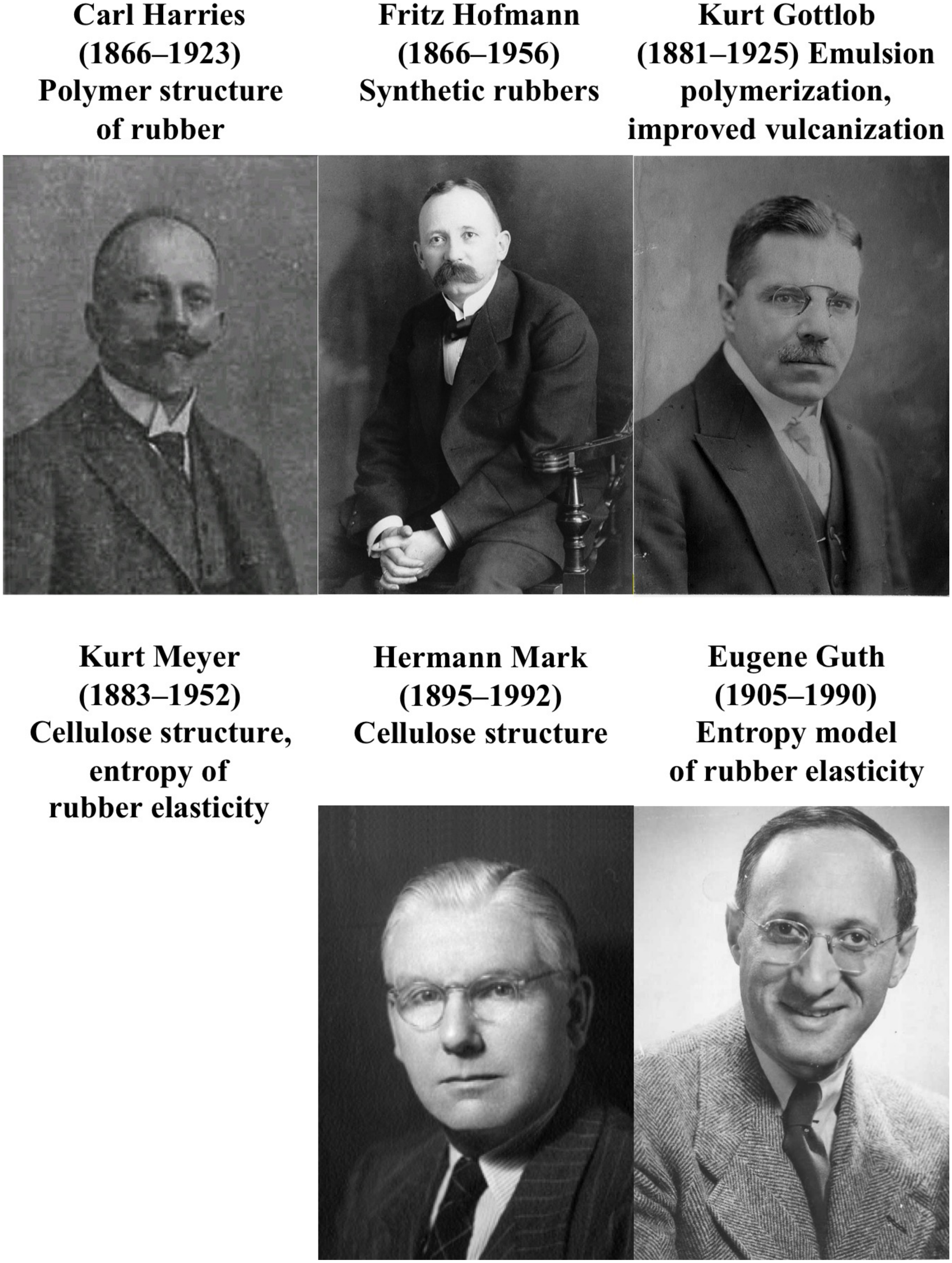

Carl Harries
(1866–1923)
Polymer structure
of rubber
Fritz Hofmann
(1866–1956)
Synthetic rubbers
Kurt Gottlob
(1881–1925) Emulsion
polymerization,
improved vulcanization
Kurt Meyer
(1883–1952)
Cellulose structure,
entropy of
rubber elasticity
Hermann Mark
(1895–1992)
Cellulose structure
Eugene Guth
(1905–1990)
Entropy model
of rubber elasticity

Figure 3.155: Some German-speaking scientists who made important contributions to rubber included Carl Harries, Fritz Hofmann, Kurt Gottlob, Kurt Meyer, Herman(n) Mark, and Eugen(e) Guth.

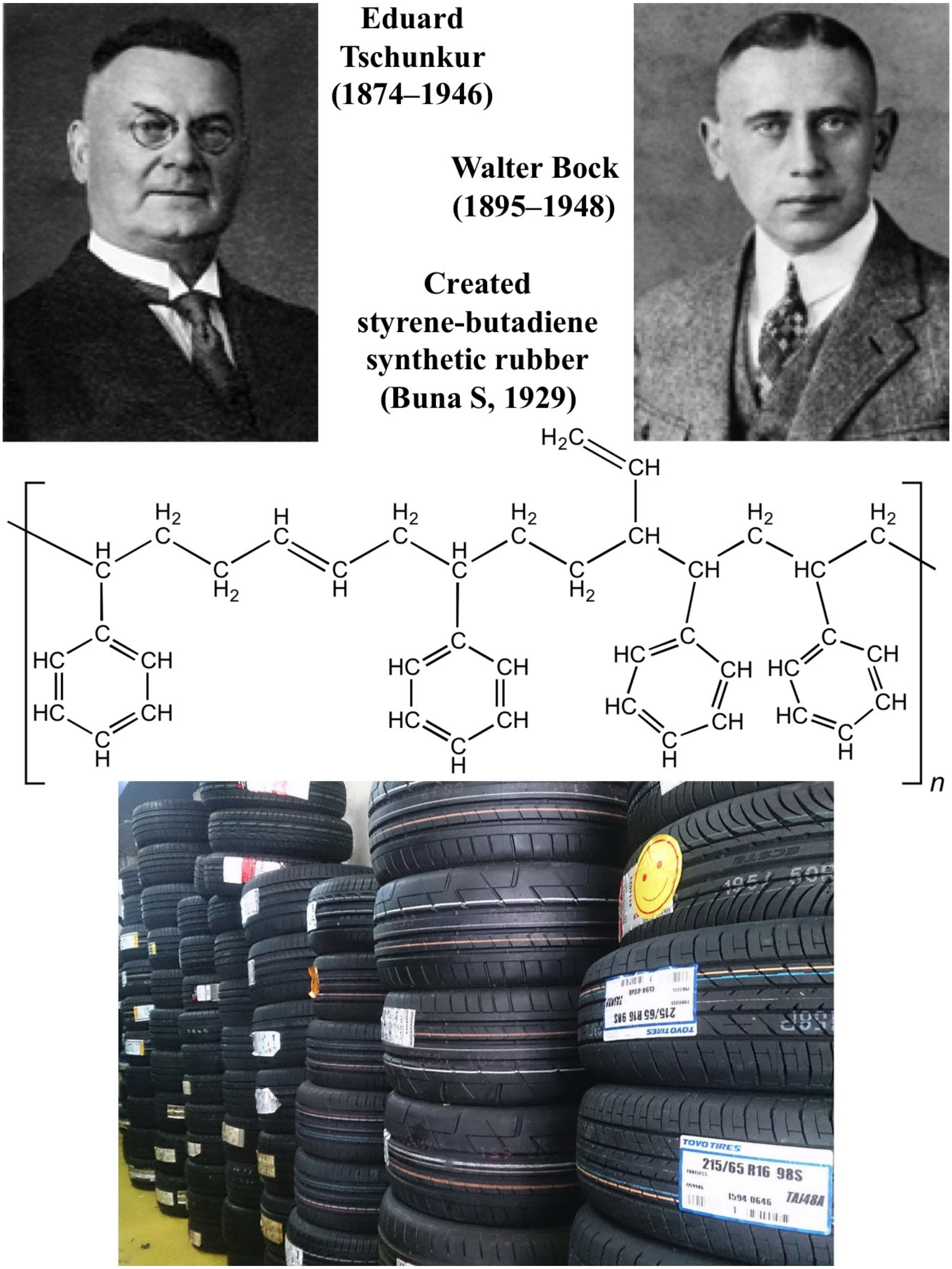
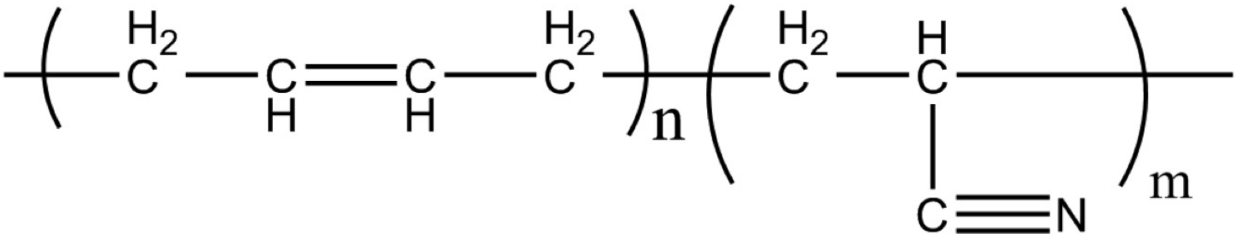

Eduard Tschunkur (1874–1946)
Walter Bock (1895–1948)
Created styrene-butadiene synthetic rubber (Buna S, 1929)
n

Figure 3.156: Eduard Tschunkur and Walter Bock created styrene-butadiene synthetic rubber (Buna S) in 1929; it is now used to make most tires.

Eduard Tschunkur (1874–1946) **Helmut Kleiner (1902–1987)** **Erich Konrad (1894–1975)**

Created acrylonitrile butadiene synthetic rubber (Buna N, 1930)



$-(CH_2-CH=CH-CH_2)_n-(CH_2-CH(C\equiv N))_m-$

Buna N production at Bayer Leverkusen (19??)

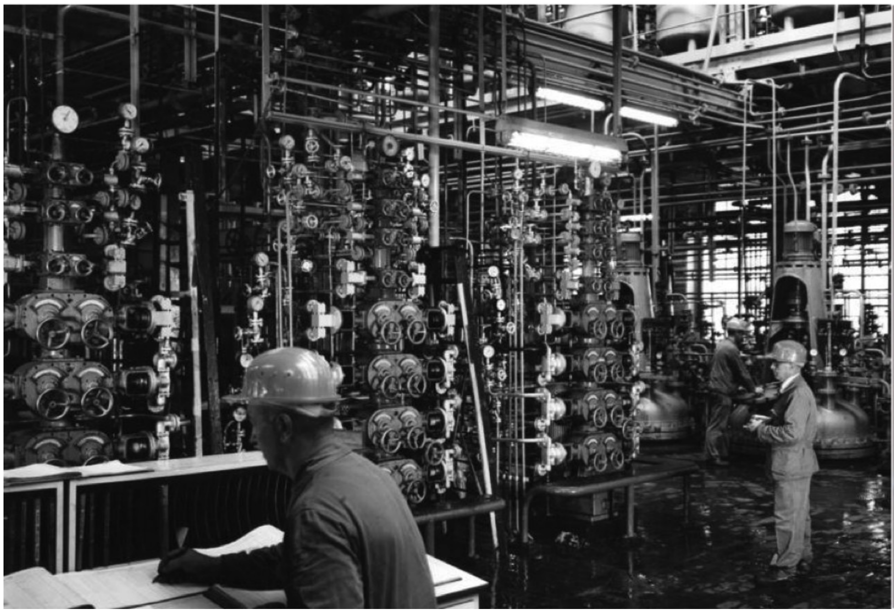


Figure 3.157: Eduard Tschunkur, Helmut Kleiner, and Erich Konrad created acrylonitrile butadiene synthetic rubber (Buna N) in 1930; it is now used for products such as latex-free nitrile rubber gloves.

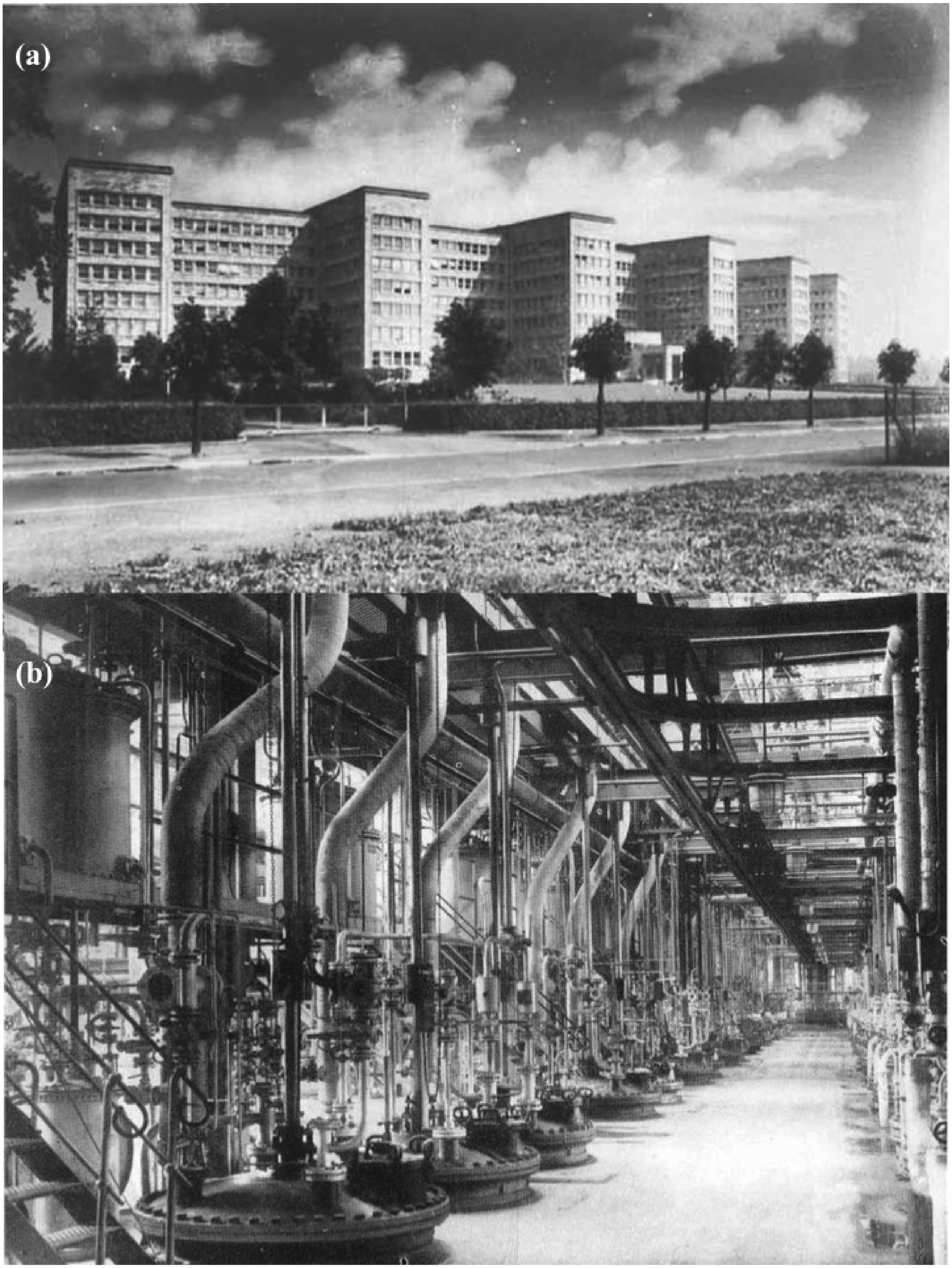


Figure 3.158: I.G. Farben headquarters in Frankfurt am Main (1930–1945) and production of butadiene or buna synthetic rubber.

Polyacrylonitrile (Orlon) was first created in 1930 by Hans Fikentscher (German, 1896–1983) and Claus Heuck (German?, 18??–19??). Beginning in 1938, it was produced in the form of fibers by Herbert Rein (German, 1899–1955). See Fig. 3.159.

As illustrated in Fig. 3.160, Otto Bayer (German, 1902–1982) created polyurethane in 1937. Polyurethane is now used for sprayable thermal insulation, surface coatings [BIOS 629], memory foam, Spandex, and other products.

Paul Schlack (German, 1897–1987) created polyamide (better known as Nylon or Perlon) in the 1930s. Wallace Carothers (American, 1896–1937) independently produced Nylon around the same time in the United States but became much better known than Schlack. Nylon/Perlon is widely used now to make thread, rope, and solid objects (Fig. 3.161).

Karl Rehn (German, 19??–19??) and Karl Ziegler (German, 1898–1973), shown in Fig. 3.162, produced polypropylene in 1951. Ziegler won the Nobel Prize in Chemistry in 1963 (p. 498). Polypropylene is widely used for products that must not crack even after repeated bending and stress, such as plastic hinges and centrifuge tubes.

Some other creators who made important contributions to polymers included (Fig. 3.163):

- Wilhelm Rudolph Fittig (German, 1835–1910) studied the chemistry of polymers.
- Bernhard Tollens (German, 1841–1918) developed urea-formaldehyde resin polymers.
- Oscar Troplowitz (German, 1863–1918) created adhesive bandages and adhesive tape in 1901.
- Hermann Staudinger (German, 1881–1965) studied polymer structures. He won the Nobel Prize in Chemistry in 1953 (p. 474).
- Werner Kuhn (Swiss, 1899–1963) was especially noted for his work on the physical chemistry of polymers. He applied the laws of statistical physics to polymer molecules to explain the temperature dependence of viscosity and elasticity in rubber and other polymers.
- Victor Garten (German, 19??–19??) conducted advanced research on polymers in Germany during World War II, then moved to Australia after the war to continue his research. In Australia, he produced revolutionary electrically conducting polymers that were quite likely based on wartime German work. The 2000 Nobel Prize in Chemistry was awarded to Alan Heeger, Alan MacDiarmid, and Hedeki Shiakawa for rediscovering electrically conducting polymers much later.

Polymer production also makes extensive use of the Diels-Alder reaction, which was developed by Otto Diels (German, 1876–1954) and Kurt Alder (German, 1902–1958). They both won the Nobel Prize in Chemistry in 1950 for that discovery. See pp. 468 and 483.

As shown in Fig. 3.164, George de Mestral (Swiss, 1907–1990) invented Velcro hook-and-loop fasteners in 1941. They were subsequently used in everything from the space program to sportswear.

After World War II, vast amounts of information on polymers were transferred from the German-speaking world to Allied countries: large numbers of scientists, reports on interrogations of scientists, patents, BIOS/CIOS/FIAT reports, samples, hardware, and even complete factories. See for example Fig. 3.165. Thus it was the innovations of German-speaking creators that dominated the field of polymers from the first inventions of polymers in the nineteenth century to the boom in commercial polymer production and applications in the latter half of the twentieth century.

Hans Fikentscher (1896–1983) created polyacrylonitrile (1930)

Claus Heuck (18??–19??) created polyacrylonitrile (1930)

Herbert Rein (1899–1955) produced polyacrylonitrile fibers (1938)

Polyacrylonitrile (Orlon)

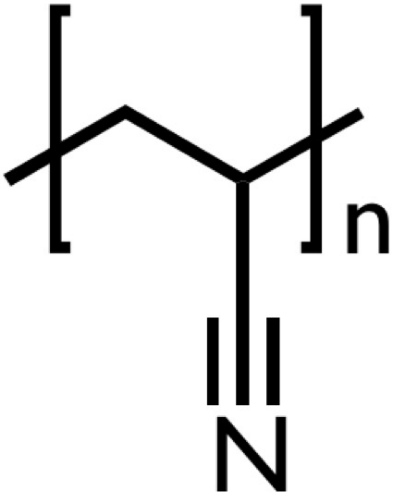


Figure 3.159: Polyacrylonitrile (Orlon) was first created in 1930 by Hans Fikentscher and Claus Heuck, and produced as fibers by Herbert Rein in 1938.

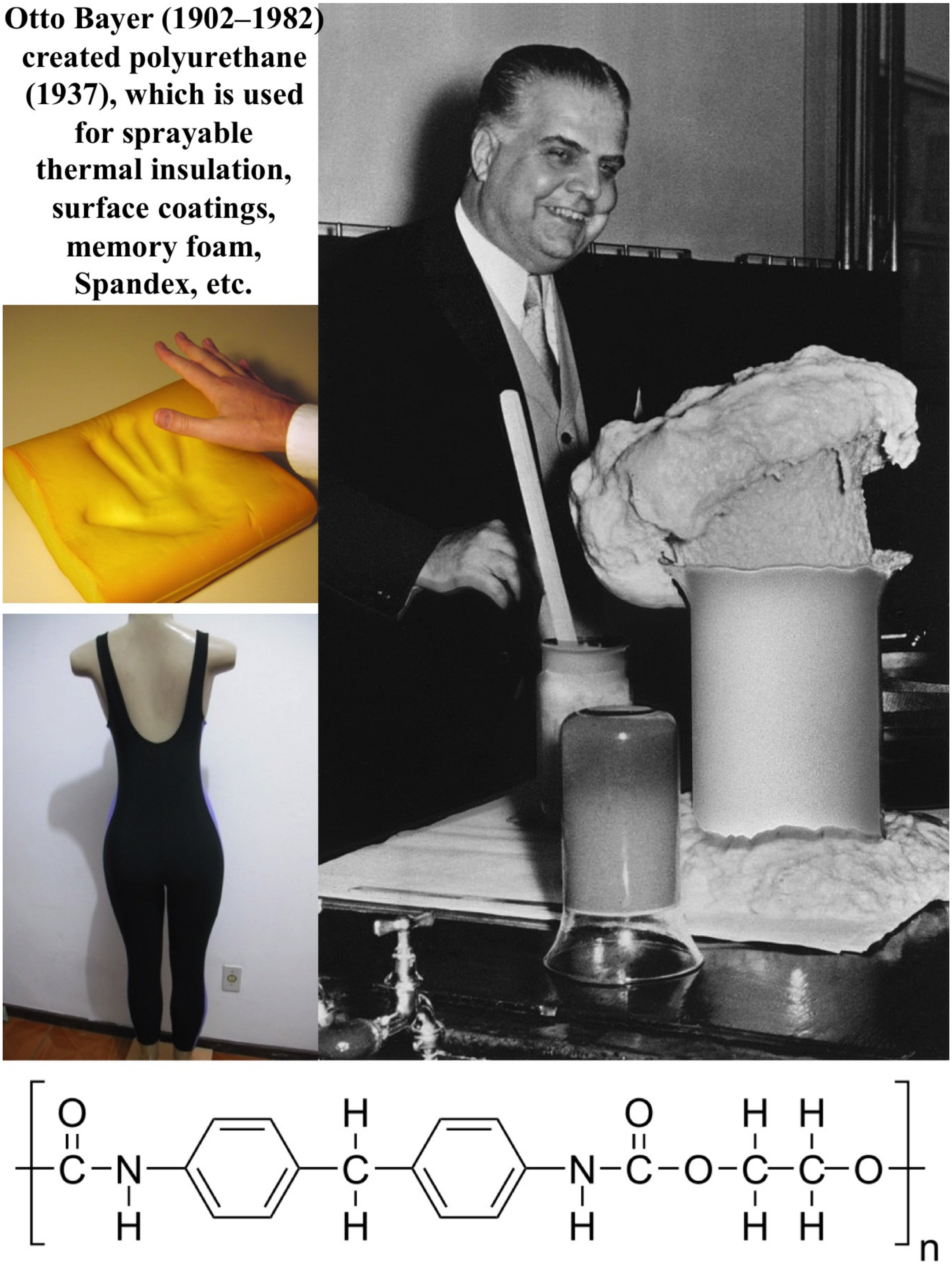
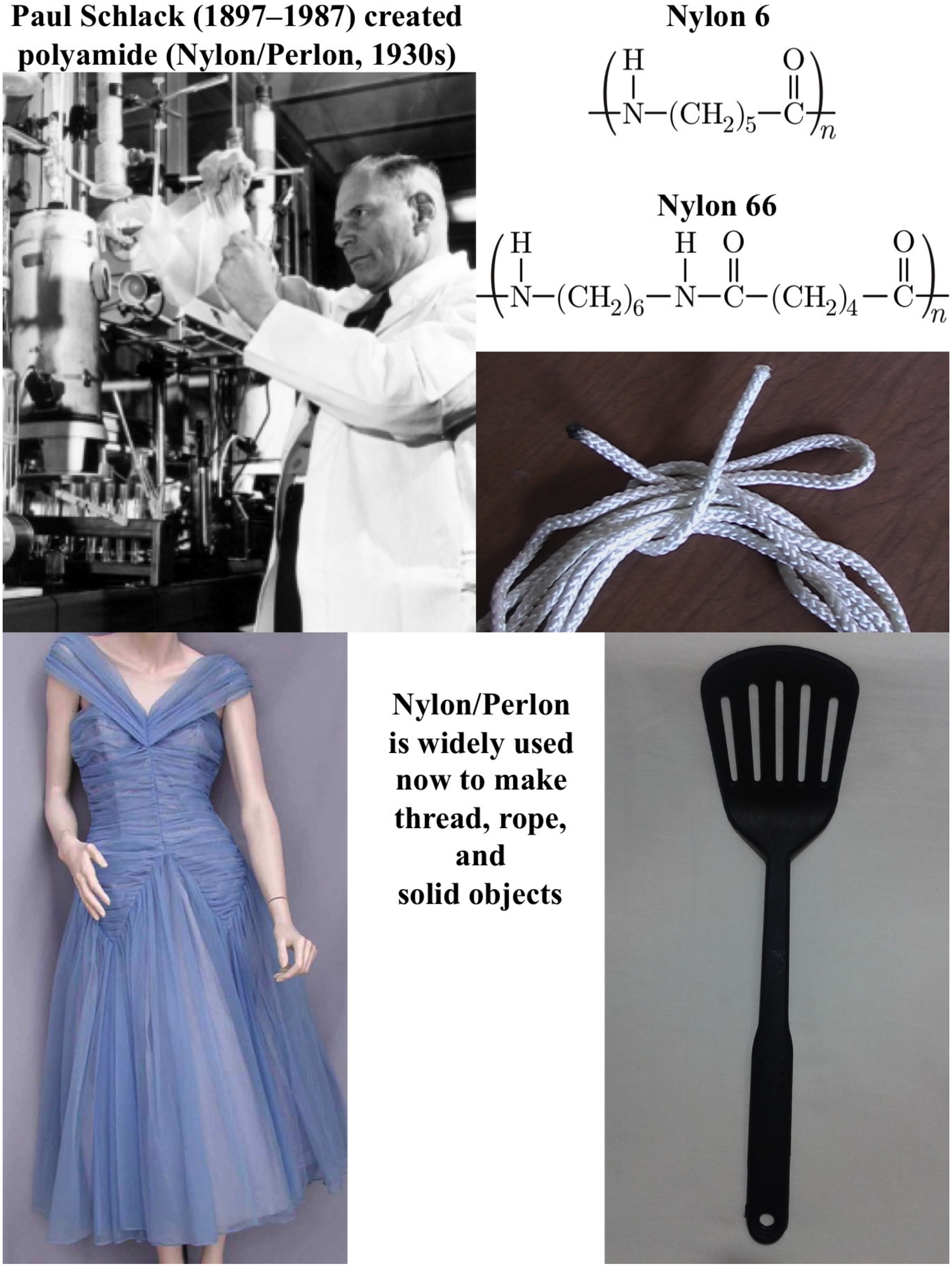

Otto Bayer (1902–1982)
created polyurethane
(1937), which is used
for sprayable
thermal insulation,
surface coatings,
memory foam,
Spandex, etc.
O
C
N
H
H
C
H
N
H
O
C
O
H
C
H
H
C
H
O
n

Figure 3.160: Otto Bayer created polyurethane in 1937. Polyurethane is now used for sprayable thermal insulation, surface coatings, memory foam, Spandex, and other products.


Paul Schlack (1897–1987) created polyamide (Nylon/Perlon, 1930s)
Nylon 6
Nylon 66
Nylon/Perlon is widely used now to make thread, rope, and solid objects

$$\left(\overset{\displaystyle H}{\overset{|}{N}}-(CH_2)_5-\overset{\displaystyle O}{\overset{\|}{C}}\right)_n$$

$$\left(\overset{\displaystyle H}{\overset{|}{N}}-(CH_2)_6-\overset{\displaystyle H}{\overset{|}{N}}-\overset{\displaystyle O}{\overset{\|}{C}}-(CH_2)_4-\overset{\displaystyle O}{\overset{\|}{C}}\right)_n$$

Figure 3.161: Paul Schlack created polyamide (Nylon/Perlon) in the 1930s. Nylon/Perlon is widely used now to make thread, rope, and solid objects.

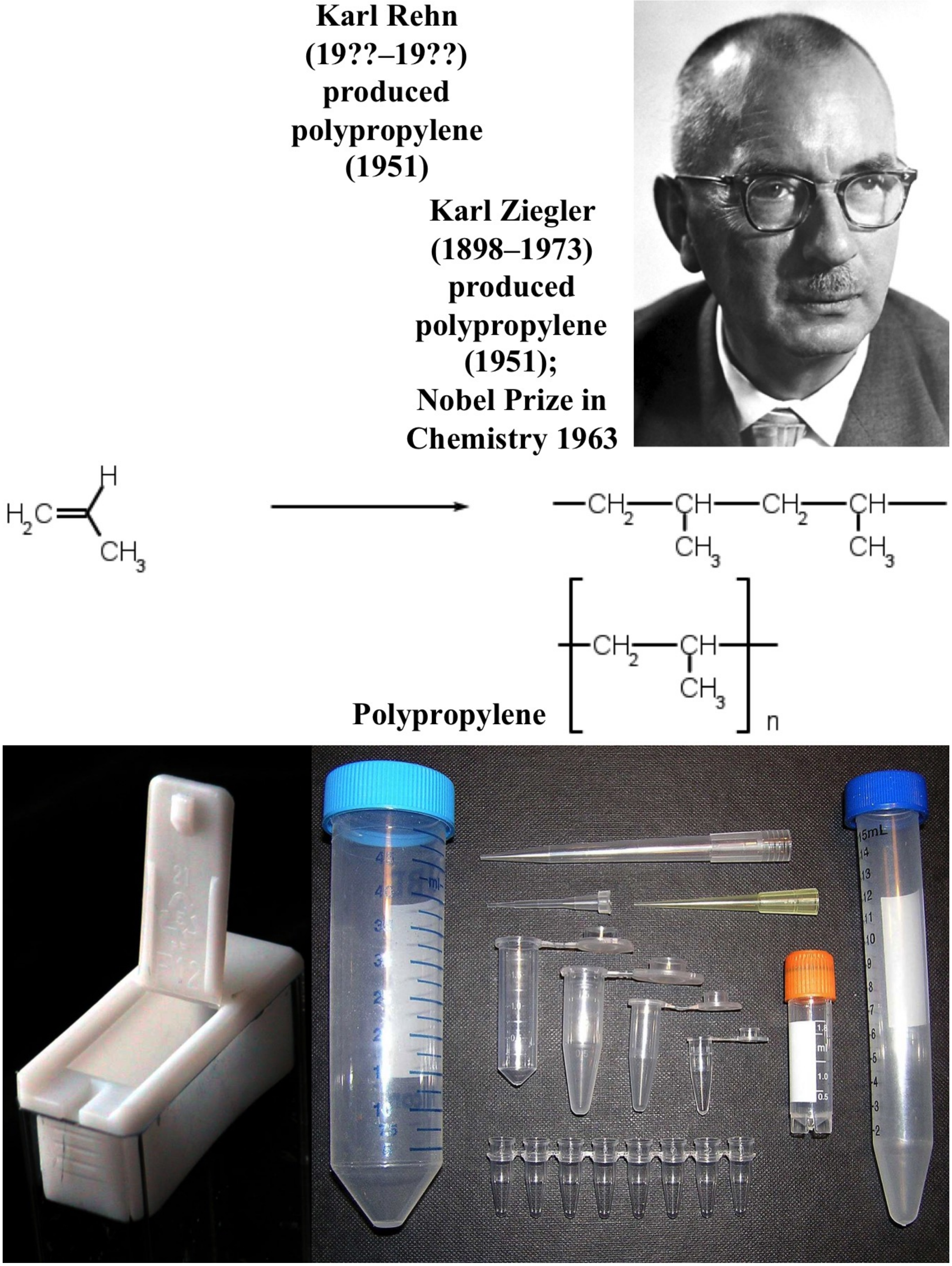
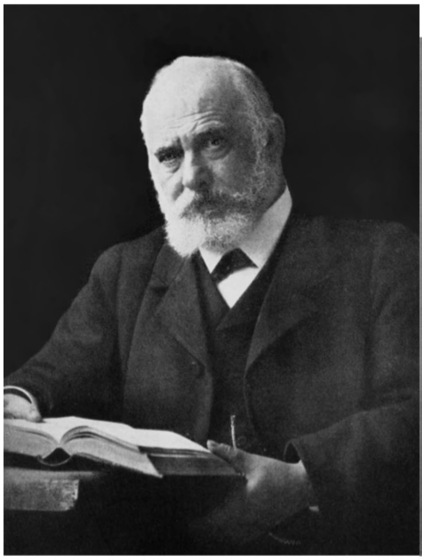
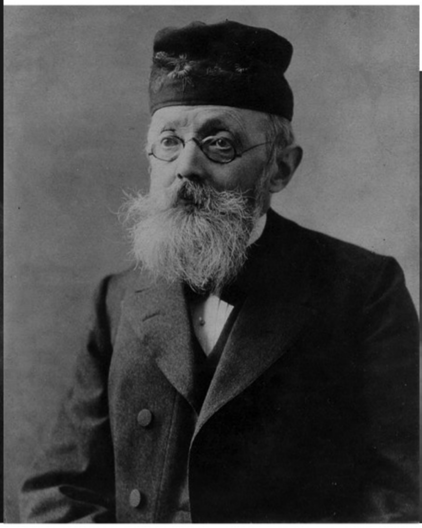

Karl Rehn
(19??–19??)
produced
polypropylene
(1951)
Karl Ziegler
(1898–1973)
produced
polypropylene
(1951);
Nobel Prize in
Chemistry 1963
H2C=CH–CH3
—CH2—CH(CH3)—CH2—CH(CH3)—
[—CH2—CH(CH3)—]n
Polypropylene

Figure 3.162: Karl Rehn and Karl Ziegler produced polypropylene in 1951. Ziegler won the Nobel Prize in Chemistry 1963. Polypropylene is widely used for products that must not crack even after repeated bending and stress, such as plastic hinges and centrifuge tubes.

**Wilhelm Rudolph
Fittig (1835–1910)
Polymers**

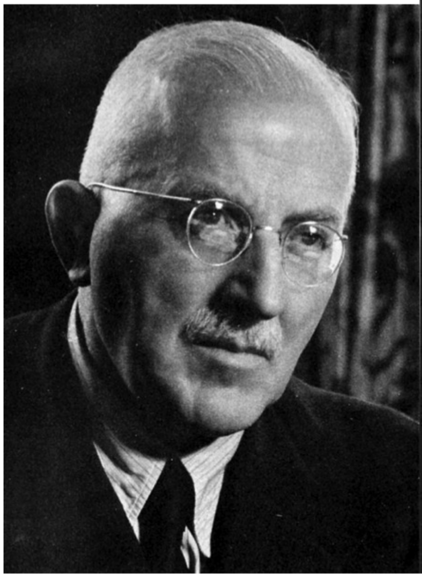


**Bernhard Tollens
(1841–1918)
Urea-formaldehyde
resin polymers**



**Oscar Troplowitz
(1863–1918)
Adhesive bandages
and tape (1901)**

**Hermann Staudinger
(1881–1965)
Polymer structures;
Nobel Prize in
Chemistry 1953**



**Werner Kuhn
(1899–1963)
Physical chemistry
of polymers**

**Victor Garten
(18??–19??)
Electrically conducting
polymers in Australia
after the war (2000
Nobel Prize in
Chemistry awarded
to others for
rediscovering
that much later)**

Figure 3.163: Other German-speaking scientists who made important contributions to polymers included Wilhelm Rudolph Fittig, Bernhard Tollens, Oscar Troplowitz, Hermann Staudinger, Werner Kuhn, and Victor Garten.

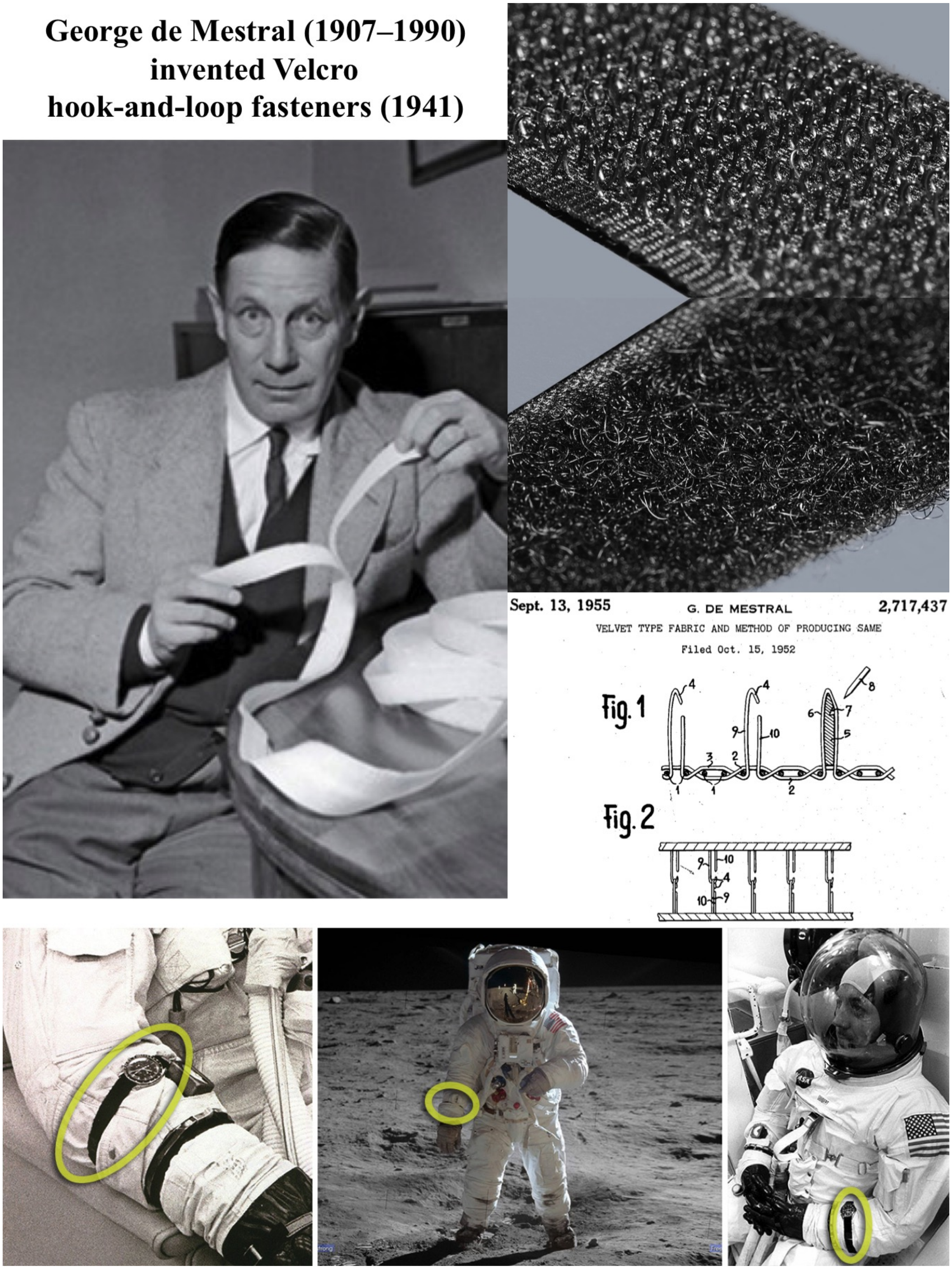
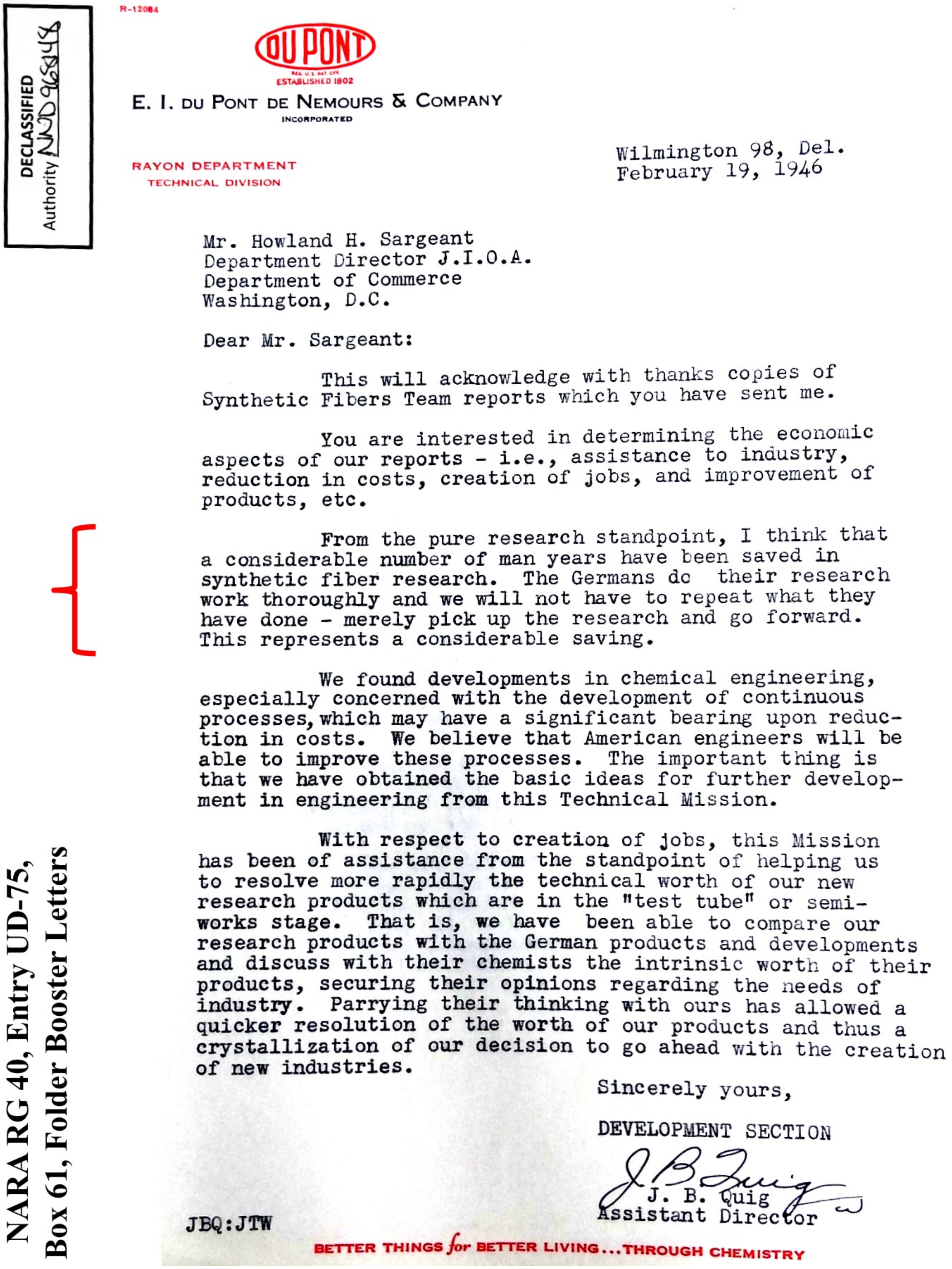

George de Mestral (1907–1990)
invented Velcro
hook-and-loop fasteners (1941)
Sept. 13, 1955
G. DE MESTRAL
2,717,437
VELVET TYPE FABRIC AND METHOD OF PRODUCING SAME
Filed Oct. 15, 1952
Fig. 1
Fig. 2

Figure 3.164: George de Mestral invented Velcro hook-and-loop fasteners in 1941. They were subsequently used in everything from the space program to sportswear.



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R-12084

DU PONT
REG. U.S. PAT. OFF.
ESTABLISHED 1802

E. I. DU PONT DE NEMOURS & COMPANY
INCORPORATED

RAYON DEPARTMENT
TECHNICAL DIVISION

Wilmington 98, Del.
February 19, 1946

Mr. Howland H. Sargeant
Department Director J.I.O.A.
Department of Commerce
Washington, D.C.

Dear Mr. Sargeant:

This will acknowledge with thanks copies of Synthetic Fibers Team reports which you have sent me.

You are interested in determining the economic aspects of our reports - i.e., assistance to industry, reduction in costs, creation of jobs, and improvement of products, etc.

From the pure research standpoint, I think that a considerable number of man years have been saved in synthetic fiber research. The Germans do their research work thoroughly and we will not have to repeat what they have done - merely pick up the research and go forward. This represents a considerable saving.

We found developments in chemical engineering, especially concerned with the development of continuous processes, which may have a significant bearing upon reduction in costs. We believe that American engineers will be able to improve these processes. The important thing is that we have obtained the basic ideas for further development in engineering from this Technical Mission.

With respect to creation of jobs, this Mission has been of assistance from the standpoint of helping us to resolve more rapidly the technical worth of our new research products which are in the "test tube" or semi-works stage. That is, we have been able to compare our research products with the German products and developments and discuss with their chemists the intrinsic worth of their products, securing their opinions regarding the needs of industry. Parrying their thinking with ours has allowed a quicker resolution of the worth of our products and thus a crystallization of our decision to go ahead with the creation of new industries.

Sincerely yours,

DEVELOPMENT SECTION

J. B. Quig
J. B. Quig
Assistant Director

JBQ:JTW

BETTER THINGS for BETTER LIVING...THROUGH CHEMISTRY

NARA RG 40, Entry UD-75,
Box 61, Folder Booster Letters

Figure 3.165: The Assistant Director of the Development Section at the U.S. Du Pont company wrote that because of all of the information on polymers that his company acquired from Germany and Austria after the war, "a considerable number of man years have been saved in synthetic fiber research" at his company [NARA RG 40, Entry UD-75, Box 61, Folder Booster Letters].

3.8.2 Ceramics and Crystallography

Large numbers of German-speaking scientists played major roles in ceramics and crystallography. [16] Some examples are shown in Figs. 3.166–3.171 and briefly discussed below.

In the 1930s and 1940s, Eberhard Both (German, 1910–19??) conducted and led research at Vacuum Schmelze AG in Hanau on the development of new ceramic materials and metal alloys with improved high-temperature and/or magnetic properties. After the war, he moved to the U.S. Army's laboratory in Fort Monmouth, New Jersey, where he initiated and ran similar research programs. ?? Kolmar (German, 19??–19??) was also involved in the Vacuum Schmelze work at Hanau and may have moved to the United States after the war.

At Siemens at Neuhaus near Sonnenberg during World War II, Wilhelm Buessem (German, 1903–1992), ?? Koenig (German, 19??–19??), Hans Joachim Reusch (German, 19??–19??), and Berthold Weber (German, 19??–19??) developed alumina-based ceramics for electronic components and for turbojet engine blades. They also created new titanium-oxide-based dielectrics for capacitors. After the war, Buessem moved to the U.S. Army's Fort Monmouth laboratory, and Weber went to the Air Force's laboratory at Wright Field, Ohio.

Adolf Hugo Dietzel (German, 1902–1993) studied silicates and other ceramic materials at the Kaiser Wilhelm (later Max Planck) Institute for Silicate Research during the period 1930–1969.

Wilhelm Eitel (German, 1891–1979) was director of the Kaiser Wilhelm Institute for Silicate Research 1926–1945, and continued his work on silicates and other materials in the United States after the war.

Johann Hessel (German, 1796–1872) was one of the pioneers of classifying crystal shapes and describing them mathematically. He also studied the composition of feldspar and other minerals.

At Degussa's research facility at Stierstadt during World War II, Gustav Jaeger (German, 19??–19??) and Eugen Ryschkewitz (German, 19??–19??) developed ceramic materials based on alumina, other metal oxides, and silicon carbide for a variety of applications, including electronic components, turbojet engine blades, cutting tools. After the war, Ryschkewitz moved to Wright Field, Ohio to continue this work.

At the wartime Hescho facility at Hermsdorf near Jena, ?? Kaase (German, 19??–19??), Fritz Obenaus (German, 1904–1980), ?? Rath (German, 19??–19??), and ?? Scheid (German, 19??–19??) developed high-temperature ceramics for turbojet engine blades. They created and tested several different ceramic materials, including soapstone-based Calit, silicon-carbide-based Sicalit, and kaolin-based Ardostan. They also developed titanium-oxide-based dielectrics for capacitors.

---

[16] Brock 1993; Bugge 1955; Engels et al. 1989; Farber 1961; Ihde 1984; Johnson 1990; Kahlert 2002; Maier 2015; Neufeldt 2003; Partington 1935, 1957, 1964; Thurnauer 1946; Warde 1946; Werner 2017; BIOS 23; BIOS 30; BIOS 143; BIOS 465; BIOS 470; BIOS 785; BIOS 788; BIOS 1111; BIOS 1446; BIOS 1448; BIOS 1459; BIOS 1705; BIOS 1762; BIOS Overall 28; CIOS XXII-11; CIOS XXV-9; CIOS XXV-10; CIOS XXVI-27; CIOS XXVI-28; CIOS XXVI-29; CIOS XXVI-30; CIOS XXVII-20; CIOS XXIX-48; CIOS XXX-66; FIAT 78; FIAT 278; FIAT 617; FIAT 740; FIAT 746; FIAT 747; FIAT 748; FIAT 749; FIAT 794; FIAT 892; FIAT 924; FIAT 927; FIAT 1050; FIAT 1150; JIOA 78; NavTecMisEu 166-45; NavTecMisEu 275-45; NavTecMisEu 465-45.

Ralph Kronig (German, 1904–1995) developed detailed theoretical models of the behavior of X-rays and electrons in crystal lattices, thus helping to better understand the structures and properties of crystalline materials, including ceramics, metals, and semiconductors.

Max von Laue (German, 1879–1960) pioneered the use of X-rays to analyze the atomic arrangements in crystals and ceramic materials. He focused primarily on theoretical methods of analyzing the results, and the experiments were implemented by Walter Friedrich (German, 1883–1968) and Paul Knipping (German, 1883–1935). Max von Laue won the Nobel Prize in Physics in 1914 for this work. Professor G. Granqvist, Chairman of the Nobel Committee for Physics, explained the importance of the methods and discoveries of von Laue's group [https://www.nobelprize.org/prizes/physics/1914/press-release/]:

> This was the situation when von Laue placed a research medium of the highest import at the disposal of science by virtue of his epoch-making discovery of the interference of X-rays and, at the same time, proved that X-rays, as is the case with light rays, consist of progressive transversal waves.
>
> Previous research had indicated, as is mentioned in the foregoing, that it was highly probable that, if X-rays are wave motions of the same type as light rays, then their wavelengths would have to be of an order of 10^{-9} cm. In order to obtain clear interference phenomena of the same type as those which are caused when light rays pass a grating it was necessary for the distance between the grating slits to be of an order of 10^{-8} cm. But this is approximately the distance between the molecules of a solid body and it was in this manner that von Laue arrived at the idea of employing, as a diffraction grating, a solid body with regularly-arranged molecules, e.g. a crystal. As early as 1850 Bravais had introduced into crystallography the assumption that the atoms composing the various crystals are arranged in regular groups, so-called three-dimensional lattices or space-lattices, whose constants could be calculated with the aid of crystallographic data.
>
> However, the theoretical basis of a space-lattice was unknown and thus it was first necessary for von Laue to develop this theory if else the investigation were to have a value. This he did mainly according to the same approximations as those conventional to the science of optics as applied to normal one-dimensional lattices.
>
> Von Laue left the execution of the experimental work in the hands of W. Friedrich and P. Knipping. The apparatus which they employed consisted of a lead box into which they admitted a thin bundle of X-rays which they directed so as to fall upon a precisely oriented crystal. Sensitized film was positioned both behind and at the sides of the crystal. Already the preparatory tests showed that the intensity maxima which had been anticipated by von Laue became evident in the form of blackened spots on the film positioned behind the crystal. [...]
>
> As a result of von Laue's discovery of the diffraction of X-rays in crystals proof was thus established that these light waves are of very small wavelengths. However, this discovery also resulted in the most important discoveries in the field of crystallography. It is now possible to determine the position of atoms in crystals and much important knowledge has been gained in this connection. We can anticipate further discoveries of equal note

> in the future. It is thus rendered likely that experimental research into the influence of temperature upon diffraction will provide the solution to the question of a zero-point energy, or will at least be of some assistance in arriving at a solution to this problem, as the temperature factor assumes a different value according to whether a zero-point energy exists or not. However, the direct results of this discovery of diffraction are of no less importance: it is now possible to subject the X-ray spectra to direct examination, their line spectra can even be photographed, and science has thus been enriched by a method of research whose full implications can not yet be fully appreciated.

At Lutz & Co. at Lauf an der Pegnitz during World War II, Nikolaus Lutz (German, 19??–19??) and Franz Rother (German, 19??–19??) developed new ceramic materials for specialized electronic applications. Their ceramics included titanium-oxide-based dielectrics, iron-oxide-based magnetic ceramics, magnesium oxide-based ceramics, and other materials with semiconducting and/or magnetic properties.

Herman(n) Mark (Austrian, 1895–1992) primarily focused on polymer research, yet he carried out some important work with X-ray crystallography as well.

Friedrich Mayer (German, 19??–19??) developed metal-oxide coatings and other ceramic coatings to harden metal tool surfaces.

Eilhard Mitscherlich (German states, 1794–1863) made several important contributions to crystallography. He is especially remembered for his discovery of crystallographic isomorphism, or the ability of the same chemical composition to form crystals of somewhat different shapes depending on the alignment of the component atoms.

Friedrich Mohs (German states, 1773–1839) studied many aspects of crystallography. He is particularly famous for introducing his mineral hardness scale in 1812. The Mohs scale ranks minerals from softer (starting with 1 for talc) to harder (ending with 10 for diamond) based on which mineral receives scratches when two dissimilar minerals are rubbed together. It is still widely used today.

Paul Niggli (Swiss, 1888–1953) was another important pioneer of X-ray crystallography, and further developed the mathematical methods of describing crystal structures.

Hans Pulfrich (German, 19??–19??) developed ceramics for electrical applications at AEG and Telefunken from the 1920s to the 1960s.

Working at the Aerodynamische Versuchsanstalt (AVA) at Göttingen during World War II, L. Ritz (German, 19??–19??) designed and demonstrated high-temperature ceramic heat exchangers for turbojet engines and other applications.

At the Luftfahrtforschungsanstalt (LFA) in Brunswick during World War II, Ernst Schmidt (German, 19??–19??) and H. Söhngren (German, 19??–19??) developed high-temperature ceramics for turbojet engine blades.

Arthur Schoenflies (German, 1853–1928) applied advanced mathematical methods such as group theory to the analysis of crystal structures. “Schoenflies notation” is still widely utilized in crystallography and solid state physics.

Working at various German companies from the 1930s to the 1950s, Carl Schusterius (German, 19??–19??) developed and patented novel ceramics for a wide variety of electrical components, as well as for other applications such as dental prostheses.

At the Machinenfabrik Augsburg-Nürnberg A.G., D. Emil Sorensen (German, 19??–19??) developed high-temperature ceramics for turbojet engine blades during World War II.

Gustav Tschermak von Seysenegg (Austrian, 1836–1927) studied the crystallographic structures and chemical compositions of a wide variety of minerals and even meteorites.

Christian Samuel Weiss (German states, 1780–1856) was one of the pioneers of classifying crystal shapes and describing them mathematically.

F. Werther (German, 19??–19??) developed titanium-oxide-based ceramics for various applications.

For German-speaking creators and creations in the closely related fields of solid state physics, semiconductor devices, superconductivity, and piezoelectricity, see Section 6.5.

Large amounts of information, materials, and scientists involved in work on advanced ceramics were transferred to other countries after World War II (Fig. 3.172). See for example:

> Warde, John M. 1946. Status Report on the German Ceramic, Glass, and Refractories Industries in the U.S. Zone of Occupation. *American Ceramic Society Bulletin* (15 September 1946) 25:321-32.
>
> Thurnauer, Hans. 1946. Electrical Insulators. *Ceramic Industry* (June 1946) 46:55-56.
>
> BIOS 23. *High Temperature Ceramics in South Germany.*
>
> BIOS 30. *Telefunken Metal/Ceramic Radio Valves.*
>
> BIOS 143. *German Porous Ceramic Industry.*
>
> BIOS 465. *High Temperature Refractories and Ceramics.*
>
> BIOS 470. *Specialized Ceramic Materials with Particular Reference to Ceramic Gas Turbine Blades.* [High-temp ceramics]
>
> BIOS 788. *The German Vitreous Enamel Industry.* With Appendix.
>
> BIOS 1111. *Industrial Ceramics. Interrogation of Dr. Ungewiss of Steatit-Magnesia A.G. Berlin at Beltane Schools, Wimbledon, S.W.19.* [titanium oxide and other ceramics for dielectrics]
>
> BIOS 1446. *Some Targets of Ceramic Interest in the Berlin Area.* [Silicate research]
>
> BIOS 1448. *The German Industrial Diamond Industry.*
>
> BIOS 1705. *The German Ceramic Industry.*

BIOS 1762. *German Electro-Technical Ceramics.*

BIOS Overall 28. *Fine Ceramics.*

CIOS XXV-9. *Development of Ceramic Materials for Use in Gas Turbine Engines.*

CIOS XXV-10. *Research and Development on Gas Turbines Hermann Goering Institute Volkenrode.*

CIOS XXVI-27. *Research and Development of Engines at Hermann Goering Institute, Volkenrode.*

CIOS XXVI-28. *Research and Development on Gas Turbines at Hermann Goering Institute, Volkenrode.*

CIOS XXVI-29. *Research and Development on Gas Turbines at Junkers Motoren Werke, Dessau.*

CIOS XXVI-30. *Gas Turbine Development by B. M. W.*

CIOS XXVII-20. *Prof. Dr. Ing. Emil Sorensen, Maschinenfabrik Augsberg-Nurnberg AG, Augsberg.* [Ceramic gas turbine blades]

CIOS XXIX-48. *Ceramic Developments of Dr. Rother, Lutz and Co., Lauf/Pegnitz.*

CIOS XXX-66. *Information on Ceramic and Water-Cooled Turbine Blading for Gas Turbines.*

FIAT 78. *High Frequency Technical Ceramic Materials of Germany.*

FIAT 278. *Specialized Ceramic Products, Their Use in German Communication Equipment.* [Selenium rectifiers]

FIAT 617. *The Electrical and Technical Ceramic Industry of Germany.* [High temp zirconium ceramics]

FIAT 740. *Report on High Frequency Technical Ceramic Materials of Germany.*

FIAT 794. *The Porcelain Enamel and Ceramic Color Industry in Germany.* With two supplements. [Rare earths (Dr. Egon Ihwe)]

FIAT 892. *Ceramic Dielectrics for Condensers.*

FIAT 924. *Investigation of Pure Oxide Ceramic Materials Intended for High Temperature and High Stress Applications.* [Silicon carbide]

FIAT 927. *Production of High Alumina Slags in Blast Furnaces and Allied Processes for Recovering Alumina.*

FIAT 1150. *Further Advances of the German Ceramic Industry.*

JIOA 78. *High Frequency Technical Ceramic Materials of Germany.*

NavTecMisEu 166-45. *Turbine Ceramic Bucket and Wheel Development Project at M.A.N. Plant, Augsburg, Germany.*

NavTecMisEu 275-45. *Information on Ceramic and Water-Cooled Turbine Blading for Gas Turbines Obtained from Dr. E. Schmidt (LFA).*

NavTecMisEu 465-45. *Ceramic Fuses.*

While the postwar technology transfer involved a broad range of advanced ceramic materials, one especially important area was synthetic mica for electronics applications. Due to a shortage of real mica in wartime Germany, scientists invented synthetic mica-like ceramics that proved to be superior to the original material. After the war, large amounts of information, materials, and scientists involved in work on synthetic mica were transferred to other countries, as documented in reports such as:

BIOS 785. *The German Mica Industry.*

BIOS 1459. *German Radio Ceramics.*

CIOS XXII-11. *Synthetic Mica Process, Ostheim.*

FIAT 746. *Synthetic Mica Research.*

FIAT 747. *The Synthesis of Fluorine-Mica of the Phlogopite Group.*

FIAT 748. *Crystallochemical and Microscopic Investigations of Synthetic Phlogopites.*

FIAT 749. *Regular Intergrowth of Synthetic Phlogopite with Hydrous Mica.*

FIAT 1050. *Crucibles for Synthetic Mica Development.*

Ceramics and crystallography

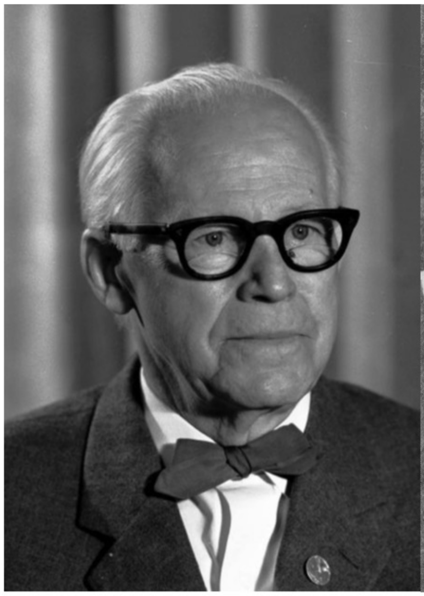
Eberhard Both
(1910–19??)

Wilhelm Buessem
(1903–1992)

Adolf Hugo Dietzel
(1902–1993)

Wilhelm Eitel
(1891–1979)

Walter Friedrich
(1883–1968)



Johann Hessel
(1796–1872)

Figure 3.166: Some creators who made important contributions to ceramics and crystallography included Eberhard Both, Wilhelm Buessem, Adolf Dietzel, Wilhelm Eitel, Walter Friedrich, and Johann Hessel.

Ceramics and crystallography

Gustav Jaeger
(19??–19??)

?? Kaase
(19??–19??)

Paul Knipping
(1883–1935)

?? Koenig
(19??–19??)

?? Kolmar
(19??–19??)

Ralph Kronig
(1904–1995)

Figure 3.167: Other creators who made important contributions to ceramics and crystallography included Gustav Jaeger, ?? Kaase, Paul Knipping, ?? Koenig, ?? Kolmar, and Ralph Kronig.

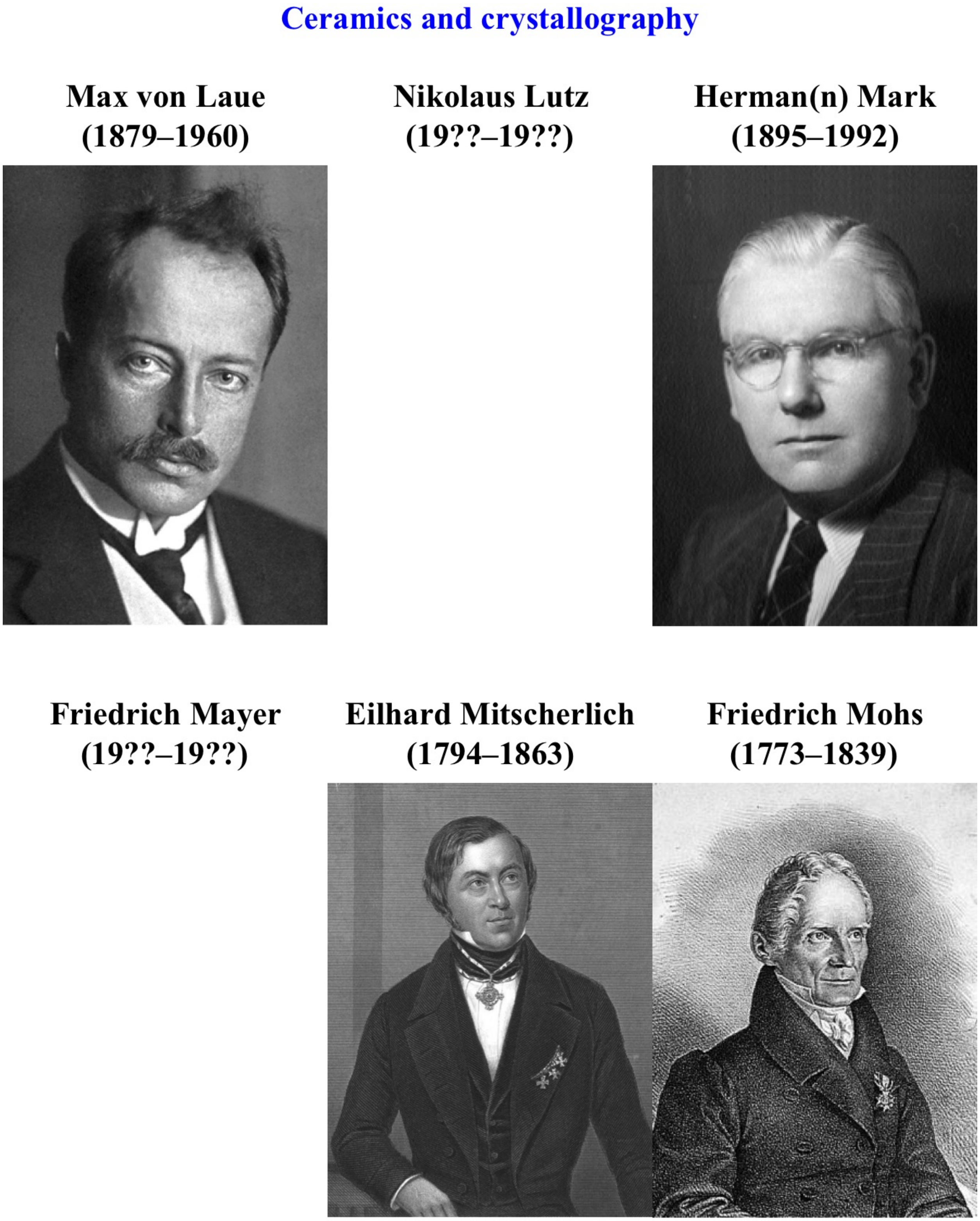
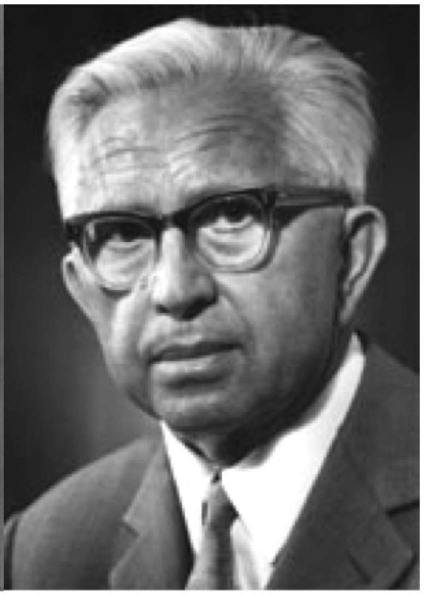

Ceramics and crystallography
Max von Laue
(1879–1960)
Nikolaus Lutz
(19??–19??)
Herman(n) Mark
(1895–1992)
Friedrich Mayer
(19??–19??)
Eilhard Mitscherlich
(1794–1863)
Friedrich Mohs
(1773–1839)

Figure 3.168: Other creators who made important contributions to ceramics and crystallography included Max von Laue, Nikolaus Lutz, Herman(n) Mark, Friedrich Mayer, Eilhard Mitscherlich, and Friedrich Mohs.

Ceramics and crystallography

Paul Niggli
(1888–1953)

Fritz Obenaus
(1904–1980)



Hans Pulfrich
(19??–19??)

?? Rath
(19??–19??)

Hans Reusch
(19??–19??)

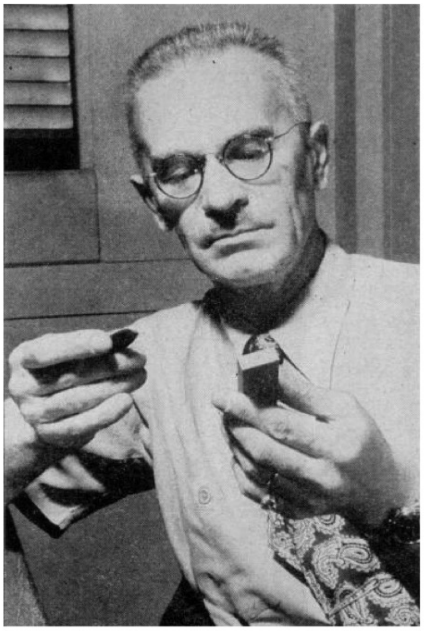
L. Ritz
(19??–19??)

Figure 3.169: Other creators who made important contributions to ceramics and crystallography included Paul Niggli, Fritz Obenaus, Hans Pulfrich, ?? Rath, Hans Reusch, and L. Ritz.

Ceramics and crystallography

Franz Rother (19??–19??)

Eugen Ryschkewitz (19??–19??)



?? Scheid (19??–19??)

Ernst Schmidt (19??–19??)

Arthur Schoenflies (1853–1928)

Carl Schusterius (19??–19??)

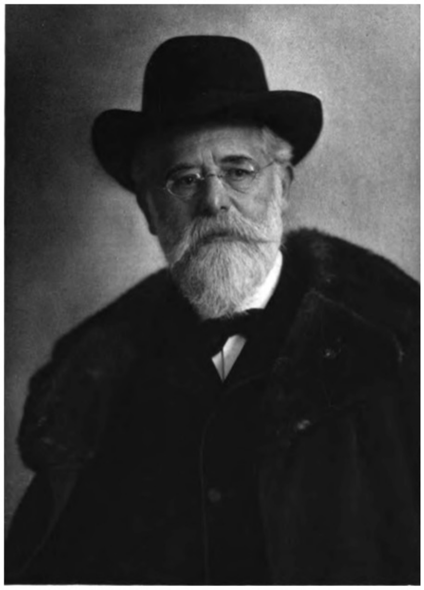
Figure 3.170: Other creators who made important contributions to ceramics and crystallography included Franz Rother, Eugen Ryschkewitz, ?? Scheid, Ernst Schmidt, Arthur Schoenflies, and Carl Schusterius.

Ceramics and crystallography

H. Söhngren
(19??–19??)

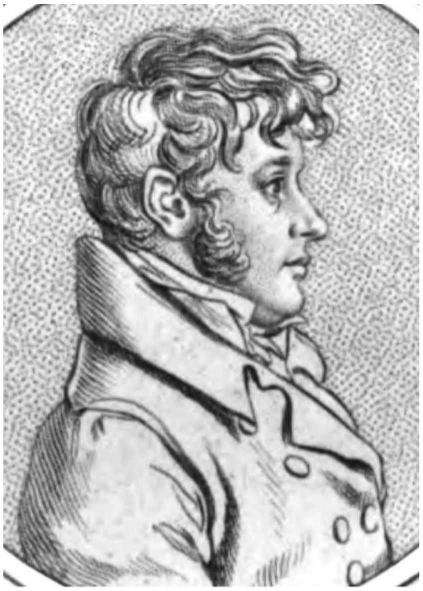
D. Emil Sorensen
(19??–19??)

Gustav Tschermak von Seysenegg
(1836–1927)



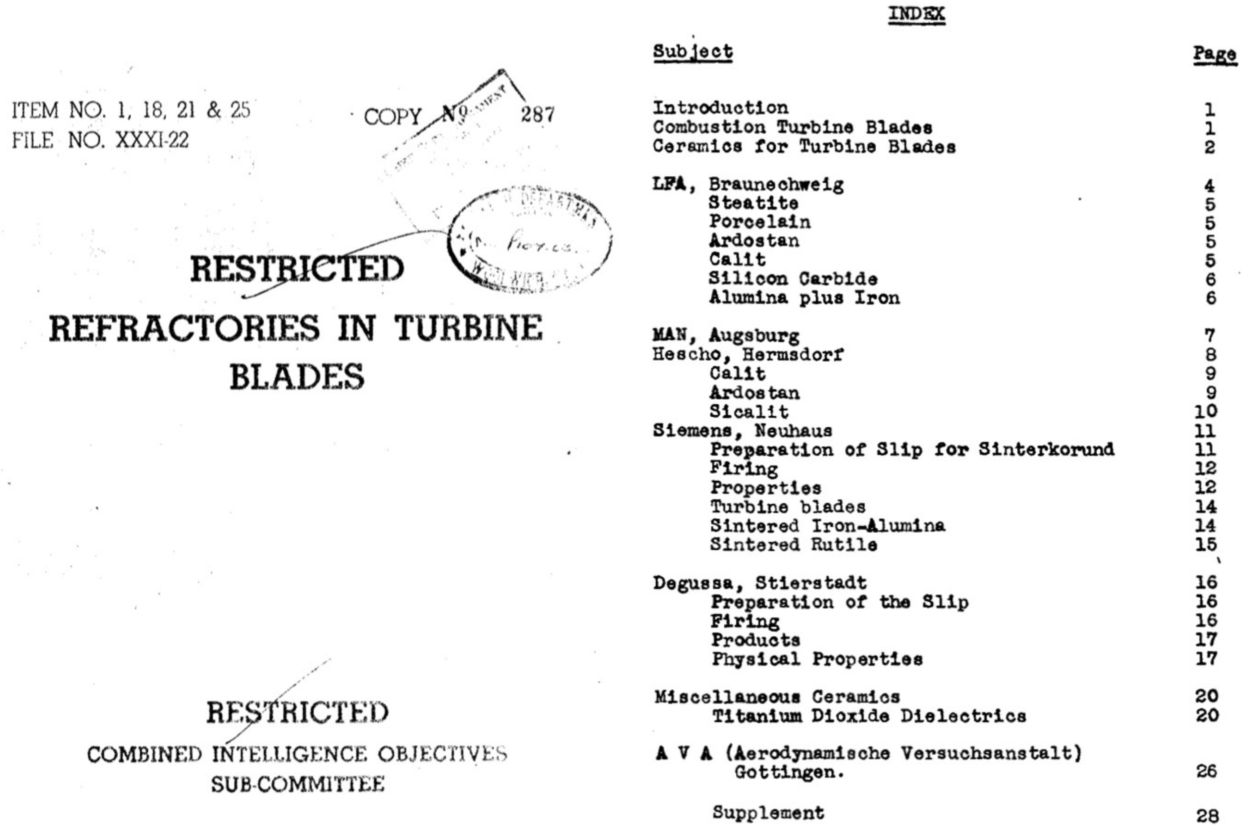
Berthold Weber
(19??–19??)

Christian Samuel Weiss
(1780–1856)



F. Werther
(19??–19)

Figure 3.171: Other creators who made important contributions to ceramics and crystallography included H. Söhngren, D. Emil Sorensen, Gustav Tschermak von Seysenegg, Berthold Weber, Christian Samuel Weiss, and F. Werther.



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REFRACTORIES IN TURBINE BLADES

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COMBINED INTELLIGENCE OBJECTIVES
SUB-COMMITTEE

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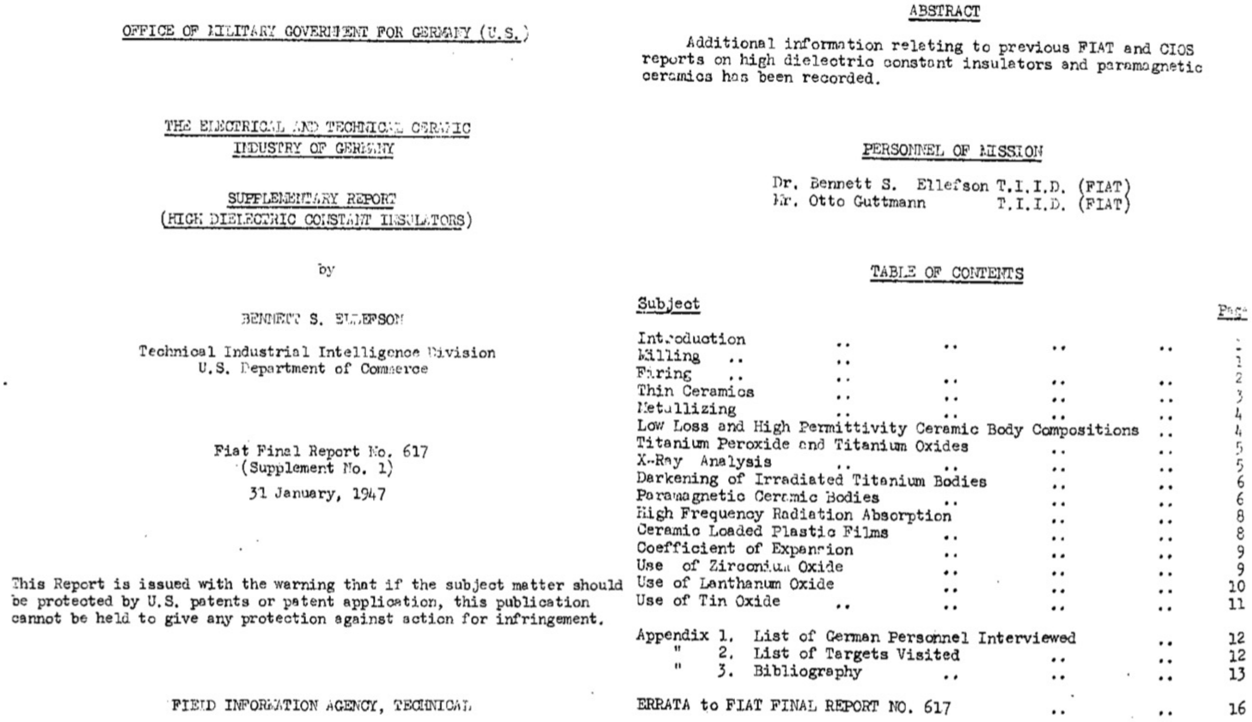

OFFICE OF MILITARY GOVERNMENT FOR GERMANY (U.S.)

THE ELECTRICAL AND TECHNICAL CERAMIC
INDUSTRY OF GERMANY

SUPPLEMENTARY REPORT
(HIGH DIELECTRIC CONSTANT INSULATORS)

by

BENNETT S. ELLEFSON

Technical Industrial Intelligence Division
U.S. Department of Commerce

Fiat Final Report No. 617
(Supplement No. 1)
31 January, 1947

This Report is issued with the warning that if the subject matter should be protected by U.S. patents or patent application, this publication cannot be held to give any protection against action for infringement.

FIELD INFORMATION AGENCY, TECHNICAL

ABSTRACT

Additional information relating to previous FIAT and CIOS reports on high dielectric constant insulators and paramagnetic ceramics has been recorded.

PERSONNEL OF MISSION

Dr. Bennett S. Ellefson T.I.I.D. (FIAT)
Mr. Otto Guttmann T.I.I.D. (FIAT)

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Figure 3.172: Large amounts of information, materials, and scientists involved in work on advanced ceramics were transferred to other countries after World War II [CIOS XXXI-22, FIAT 617].

3.8.3 Glass

Glass production has a history going back to ancient times, and has been practiced worldwide. The glassmaking industry was especially prominent and advanced in the German-speaking world, dating back many centuries in Thuringia, Bohemia, and other regions. As scientific research gained greater prominence in the German-speaking world around 1800, it was combined with the older traditions of glassmaking craftsmanship, resulting in a number of major technological advances in methods of producing and utilizing glass.

Joseph von Fraunhofer (German states, 1787–1826) made a number of early improvements in glass manufacturing processes for optics and other applications. He then used his glass elements to create new optical instruments such as spectroscopes (pp. 961 and 1260).

Other especially important early glassmakers who produced and used improved optical elements and optical instruments included:

- Simon Plössl (Austrian, 1794–1868, Fig. 6.228), who was particularly noted for producing achromatic (non-color-distorting) lenses for microscopes and telescopes.
- Georg Johann Oberhäuser (German states, 1798–1868) and Edmund Hartnack (German, 1826–1891), who also produced early microscopes. Hartnack invented liquid-immersion lenses to achieve higher resolution. See p. 1269.
- Carl Zeiss (German, 1816–1888) and Ernst Abbe (German, 1840–1905), who revolutionized the production of high-quality microscopes at the Zeiss optical company (p. 1270).
- Carl Kellner (German states, 1826–1855) and Ernst Leitz I (German, 1843–1920) at the Leitz optical company (p. 1275), another producer of high-quality microscopes and other optical instruments.

Arguably the most important glass scientist in the German optical industry, though, was Otto Schott (German, 1851–1935), who is shown in Fig. 3.173. In partnership with the Zeiss company, he founded the Schott glassworks in Jena and created a variety of special-purpose types of glass, including optical glass (1873, for Zeiss microscopes to achieve the maximum diffraction-limited resolution), lithium glass (1879), and borosilicate glass (1887). Borosilicate glass is resistant to thermal stress (when exposed to temperature changes, it expands and contracts less than normal glass, and therefore is much less likely to shatter when heated or cooled), so it is still widely used to make glassware containers for cooking and laboratory work.

One area of traditional German glassmaking craftsmanship, dating back before 1800, was producing long, flexible fibers of glass. The glass fibers were used for decoration and other applications.

Apparently drawing upon those German glass fiber methods, Hermann Hammesfahr (German, 1845–1914) moved to the United States and began producing and patenting fiberglass threads, cloth, and insulation. See Fig. 3.174. After a slow start, his work eventually prompted broader American industrial interest in fiberglass in the twentieth century.

Even as Hammesfahr took fiberglass technology to the United States, fiberglass production and applications continued to advance in the German-speaking world. For example, Ulrich Hütter (Austrian, 1910–1990, Fig. 3.175) produced glass-fiber-reinforced polymers in Germany during and after World War II for applications ranging from aircraft structures to wind turbine blades.

Similarly, Alfred Schmid (Swiss, 1899–1968) demonstrated how to make very strong yet very light composite materials by reinforcing processed wood and/or polymers with fiberglass. After the war, Schmid transferred that technology to Allied countries (Fig. 3.175). For example, BIOS 563, *The German Radio Component Industry*, p. 18, reported:

> A synthetic material composed of fibreglass coated with an artificial resin had been developed, and was used to coat articles made of a low-density homogeneous wood with a coating 0.02 mm thick. This resulted in an article of light weight but having great strength. It was claimed that both tensioned and compressional forces could be dealt with. Dr. Schmid envisaged the aircraft of the future as being made from glass coated homogeneous wood for light weight combined with great strength. He also claimed that repairs to the skin, if damaged, could be done simply by the application of more of the fibre-glass material.

As shown in Fig. 3.176, an 11 May 1945 document from the U.S. Army Air Forces stated [AFHRA A5729 electronic pp. 1650–1651]:

> Glass types which are not available in this country and which might be of considerable value to American manufacturers are known to have existed in Germany before the war and it is recommended that a survey be made[...]

Indeed, numerous BIOS, CIOS, and FIAT reports documented widespread production and use of advanced glass and fiberglass products in the German-speaking world, as well as the transfer of those technologies to Allied countries after World War II (Fig. 3.177). See for example:

> BIOS 403. [Glass fibers]
>
> BIOS 404. *German Asbestos Industry.*
>
> BIOS 563. *The German Radio Component Industry.* [fiberglass composite materials]
>
> BIOS 627. *The Worsted Spinning Industry in the British and U.S. Zones of Germany.* [glass fibers]
>
> BIOS 894. *Mineral Wool Plant, Gelsenkirchener Eisenwerk.*
>
> BIOS 1066. *German Glass Manufacturing Equipment.*
>
> BIOS 1118. *Final Report on the Investigation of the Use of Industrial Glassware for Chemical Plants in Germany.*
>
> BIOS 1183. *Anti-Reflection Surfaces on Glass, Optical Cements & Etching Resist for Fine Lines.*

BIOS 1340. *Report on Glass Fibre Industry in Germany.*

BIOS 1451. *Glass Jets. Interrogation of Bernhard Wempe at Coventry.*

BIOS 1664. *German Fibrous and Scientific Glass Industry.*

BIOS 1780. *Some Aspects of the German Glass Industry in 1946.*

BIOS Overall 4. *Glass and Industry.*

CIOS XXV-8. *Land and Air Service Fire Control Instruments, Carl Zeiss, Jena—Production of Optical Glass Schott and Genossen Lenses and Graduated Scales, Zeiss and Others.*

CIOS XXVII-43. *Manufacture of Glass Fabric Impregnated Fibre Used as a Substitute for Mica Insulation Between Commutator Segments in Motors and Generators.*

CIOS XXIX-41. *Production of Optical Glass in Germany and France. CIOS Target Nos. 9/1, 9/36 & 9/80. Physical and Optical Instruments and Devices.*

CIOS XXIX-42. *The Production of Binoculars by Zeiss. CIOS Target No. 9/1. Physical and Optical Instruments and Devices.*

CIOS XXIX-43. *Pots Used in Melting Optical Glass at Schott and Genossen.*

CIOS XXXII-22. *Optical Glass Manufacturing at Schott & Gen, Jena.*

CIOS XXXIII-23. *Investigation of German Plastics Plants, Part 2.* [Glass-like wire with cellulose acetate—fiber optics?]

CIOS XXXIII-50. [Synthetic fibers comprehensive survey]

CIOS XXXIII-69. *Schott and Genossen of Jena.* [Schott glass, mirrors]

FIAT 9. *Investigation of Scientific and Laboratory Glassware Area of Thuringia, Germany.*

FIAT 454. *Records of Wartime Improvements in Fiber Manufacture and in Fiber Processing. I.G. Farben (Badische Plant) Ludwigshafen.* [Synthetic fibers and fabric treatments]

FIAT 460. *The Asbestos Textile Industry in Germany.*

FIAT 461. *The Fibrous Glass Textile Industry in Germany.*

FIAT 552. *Fiberglass-Weaving by Rheydt Glass-Weaving Company, Walter Klevers, Rheydt Near München-Gladbach.*

FIAT 824. *The Miscellaneous Glass Industry of Central Europe.* [Neodymium glasses and other exotic glasses]

FIAT 981. *The Dyeing of Glass Fiber Textiles.*

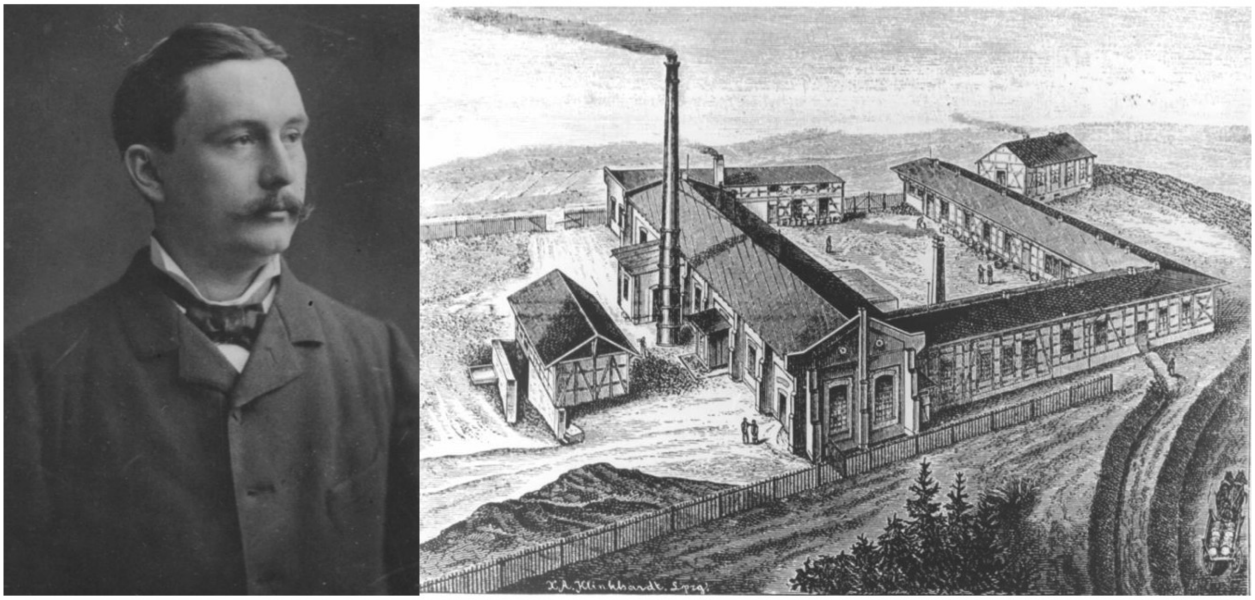
NavTecMisEu 519-45. *The Properties of Klieforth Infrared Transparent Glasses.*

During World War II, the Zeiss infrared Lichtsprechgerät was used for optical transmission of voice communications over distances up to several kilometers (pp. 1131, 1142). That device also would have been quite suitable for use with optical fibers instead of free-space transmission. Fiber optics would have given the signals far more privacy, which would have been an obvious advantage during wartime. More historical research is needed to determine if optical fibers (made of either glass or polymers) were indeed used in conjunction with optical data transmissions in wartime Germany.

In fact, further archival research on all aspects of the history, accomplishments, and global influence of the German-speaking world on glassmaking technologies and applications could be quite enlightening.

Otto Schott (1851–1935) created optical glass (1873), lithium glass (1879), borosilicate glass (1887)

Schott Glassworks Jena (1884)


L.A. Klinkhardt. Lpzg.

Borosilicate glass is resistant to thermal stress and widely used for glassware containers for cooking and laboratory work

PYREX
1.0 LITER
750ml
500ml
250ml
METRIC
1000 ml
KIMAX
80 ml
50ml

Figure 3.173: Otto Schott created optical glass, lithium glass, borosilicate glass. Borosilicate glass is resistant to thermal stress and widely used for glassware containers for cooking and laboratory work.

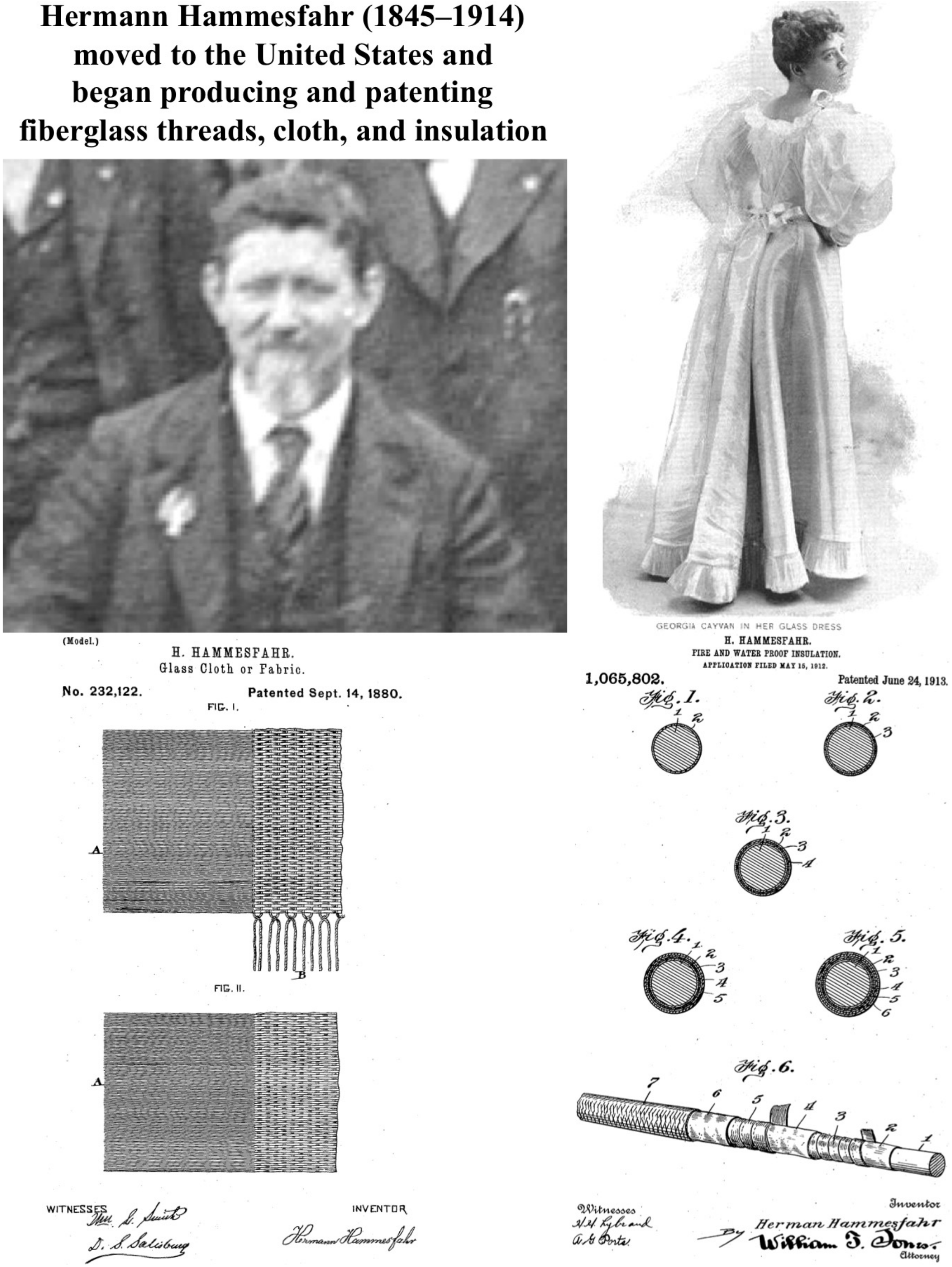
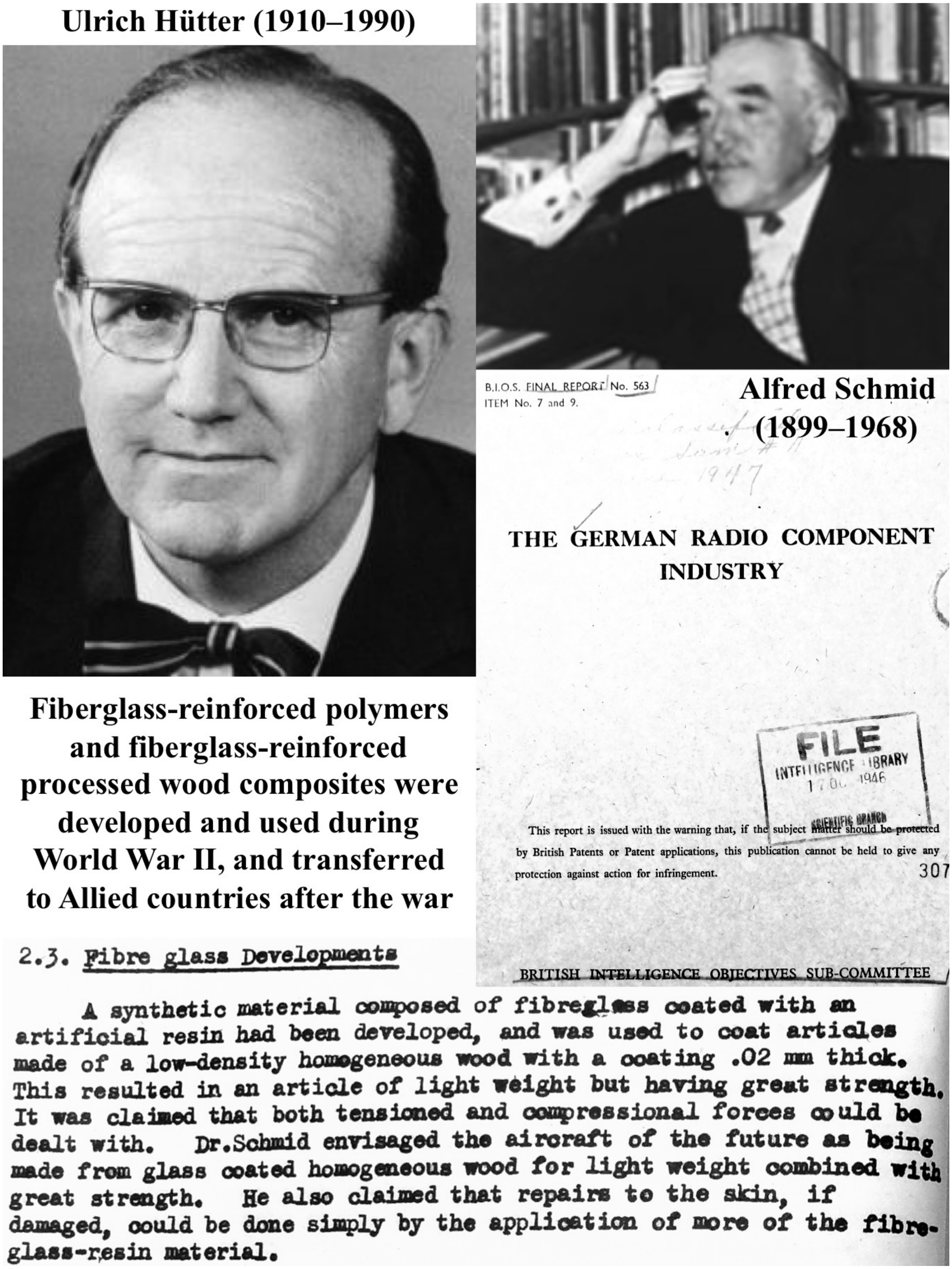

Hermann Hammesfahr (1845–1914)
moved to the United States and
began producing and patenting
fiberglass threads, cloth, and insulation
GEORGIA CAYVAN IN HER GLASS DRESS
(Model.)
H. HAMMESFAHR.
Glass Cloth or Fabric.
No. 232,122.
Patented Sept. 14, 1880.
FIG. I.
A
B
FIG. II.
A
WITNESSES
INVENTOR
Hermann Hammesfahr
H. HAMMESFAHR.
FIRE AND WATER PROOF INSULATION.
APPLICATION FILED MAY 15, 1912.
1,065,802.
Patented June 24, 1913.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
1
2
3
4
5
6
7
Witnesses
Inventor
Herman Hammesfahr
By William J. Jones
Attorney

Figure 3.174: Hermann Hammesfahr moved to the United States and began producing and patenting fiberglass threads, cloth, and insulation.


Ulrich Hütter (1910–1990)
Alfred Schmid
(1899–1968)
Fiberglass-reinforced polymers and fiberglass-reinforced processed wood composites were developed and used during World War II, and transferred to Allied countries after the war

B.I.O.S. FINAL REPORT No. 563
ITEM No. 7 and 9.

1947

THE GERMAN RADIO COMPONENT INDUSTRY

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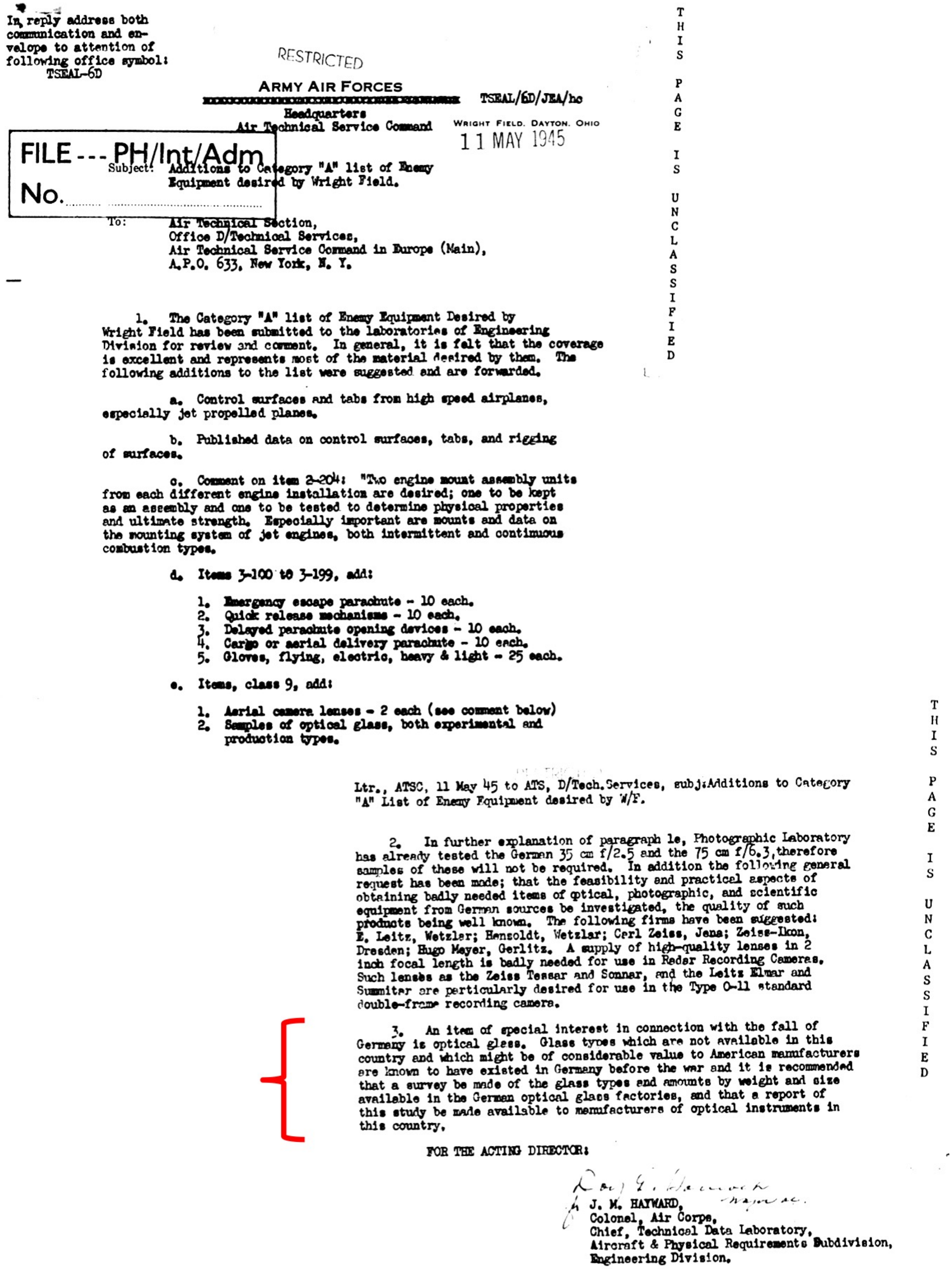
307

BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE

2.3. Fibre glass Developments

A synthetic material composed of fibreglass coated with an artificial resin had been developed, and was used to coat articles made of a low-density homogeneous wood with a coating .02 mm thick. This resulted in an article of light weight but having great strength. It was claimed that both tensioned and compressional forces could be dealt with. Dr.Schmid envisaged the aircraft of the future as being made from glass coated homogeneous wood for light weight combined with great strength. He also claimed that repairs to the skin, if damaged, could be done simply by the application of more of the fibreglass-resin material.

Figure 3.175: Ulrich Hütter and Alfred Schmid separately demonstrated fiberglass-reinforced polymers and fiberglass-reinforced processed wood composite materials during World War II, then transferred that technology to Allied countries after the war [BIOS 563].



In reply address both communication and envelope to attention of following office symbol:
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ARMY AIR FORCES
TSEAL/6D/JEA/hc
Headquarters
Air Technical Service Command
WRIGHT FIELD, DAYTON, OHIO
11 MAY 1945

FILE --- PH/Int/Adm
No.

Subject: Additions to Category "A" list of Enemy Equipment desired by Wright Field.

To: Air Technical Section,
Office D/Technical Services,
Air Technical Service Command in Europe (Main),
A.P.O. 633, New York, N. Y.

1. The Category "A" list of Enemy Equipment Desired by Wright Field has been submitted to the laboratories of Engineering Division for review and comment. In general, it is felt that the coverage is excellent and represents most of the material desired by them. The following additions to the list were suggested and are forwarded.

a. Control surfaces and tabs from high speed airplanes, especially jet propelled planes.

b. Published data on control surfaces, tabs, and rigging of surfaces.

c. Comment on item 2-204: "Two engine mount assembly units from each different engine installation are desired; one to be kept as an assembly and one to be tested to determine physical properties and ultimate strength. Especially important are mounts and data on the mounting system of jet engines, both intermittent and continuous combustion types.

d. Items 3-100 to 3-199, add:

1. Emergency escape parachute - 10 each.
2. Quick release mechanisms - 10 each.
3. Delayed parachute opening devices - 10 each.
4. Cargo or aerial delivery parachute - 10 each.
5. Gloves, flying, electric, heavy & light - 25 each.

e. Items, class 9, add:

1. Aerial camera lenses - 2 each (see comment below)
2. Samples of optical glass, both experimental and production types.

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Ltr., ATSC, 11 May 45 to ATS, D/Tech.Services, subj:Additions to Category "A" List of Enemy Equipment desired by W/F.

2. In further explanation of paragraph 1e, Photographic Laboratory has already tested the German 35 cm f/2.5 and the 75 cm f/6.3, therefore samples of these will not be required. In addition the following general request has been made; that the feasibility and practical aspects of obtaining badly needed items of optical, photographic, and scientific equipment from German sources be investigated, the quality of such products being well known. The following firms have been suggested: E. Leitz, Wetzlar; Hensoldt, Wetzlar; Carl Zeiss, Jena; Zeiss-Ikon, Dresden; Hugo Meyer, Gerlitz. A supply of high-quality lenses in 2 inch focal length is badly needed for use in Radar Recording Cameras. Such lenses as the Zeiss Tessar and Sonnar, and the Leitz Elmar and Summitar are particularly desired for use in the Type O-11 standard double-frame recording camera.

3. An item of special interest in connection with the fall of Germany is optical glass. Glass types which are not available in this country and which might be of considerable value to American manufacturers are known to have existed in Germany before the war and it is recommended that a survey be made of the glass types and amounts by weight and size available in the German optical glass factories, and that a report of this study be made available to manufacturers of optical instruments in this country.

FOR THE ACTING DIRECTOR:

J. M. HAYWARD,
Colonel, Air Corps,
Chief, Technical Data Laboratory,
Aircraft & Physical Requirements Subdivision,
Engineering Division.

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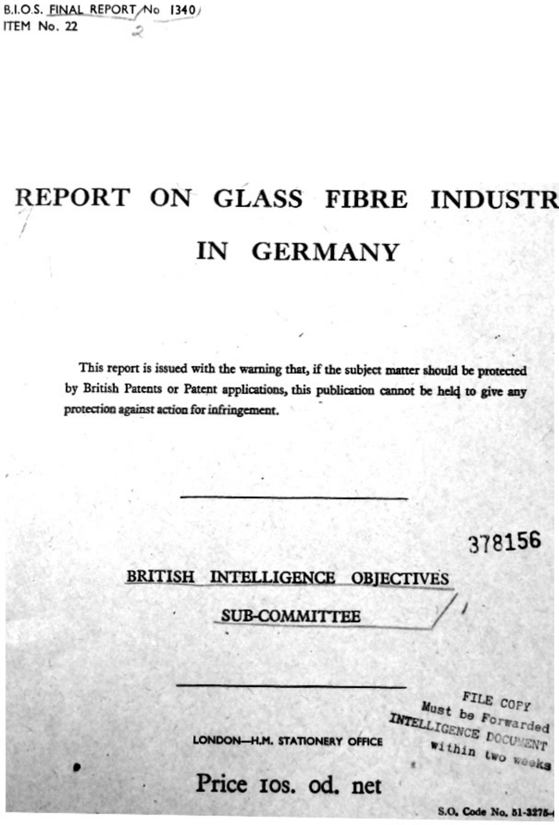
Figure 3.176: An 11 May 1945 document from the U.S. Army Air Forces stated: "Glass types which are not available in this country and which might be of considerable value to American manufacturers are known to have existed in Germany before the war and it is recommended that a survey be made..." [AFHRA A5729 electronic pp. 1650–1651].

Numerous BIOS, CIOS, and FIAT reports documented widespread production and use of glass fiber products in the German-speaking world, as well as the transfer of those technologies to Allied countries after World War II



B.I.O.S. FINAL REPORT No 1340
ITEM No. 22

REPORT ON GLASS FIBRE INDUSTRY
IN GERMANY

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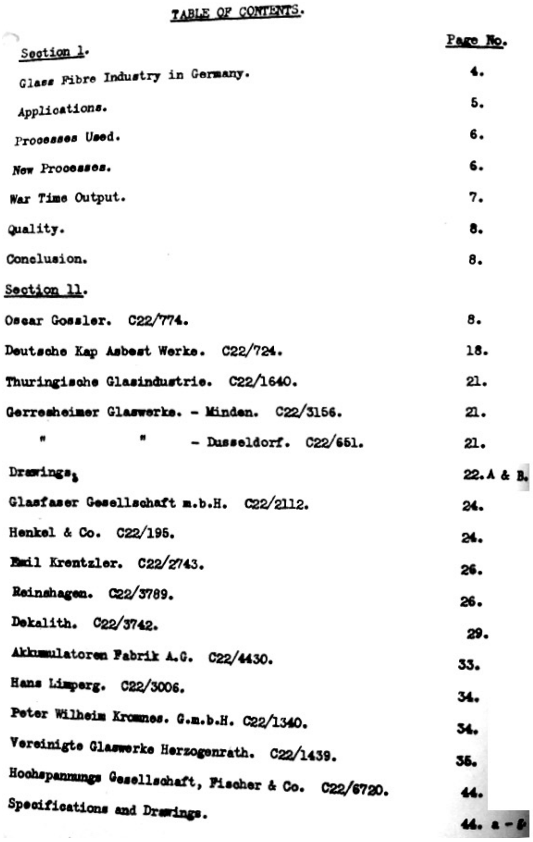

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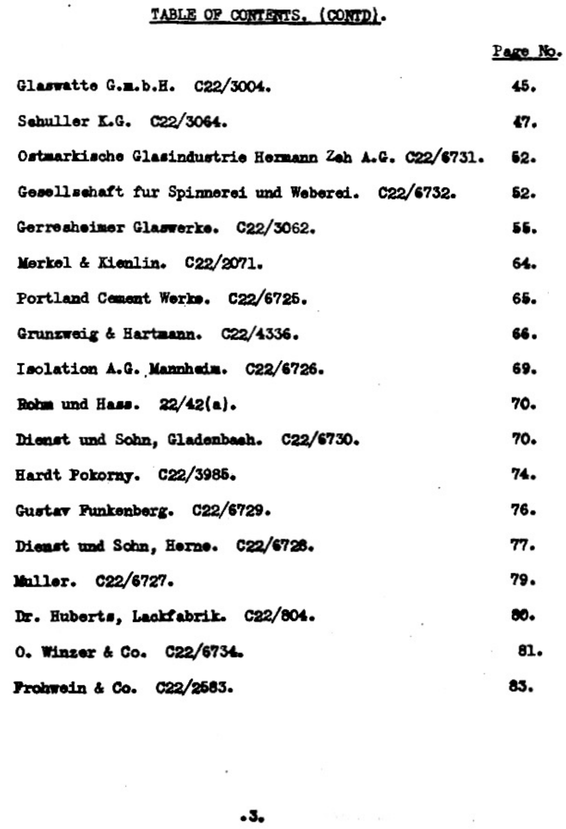

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Figure 3.177: Numerous BIOS, CIOS, and FIAT reports documented widespread production and use of advanced glass and fiberglass products in the German-speaking world, as well as the transfer of those technologies to Allied countries after World War II [BIOS 1340].

3.8.4 Metals

A common view is that by 1945, metallurgy was less advanced in the German-speaking world than elsewhere, due to the scarcity of some types of metal ores in German-speaking areas and the international blockade of metal imports during the wars. In fact, a huge number of German-speaking scientists made major contributions to metallurgy from the nineteenth century through WWII, and then many of these creators and their creations were transferred to the United States and other countries [Maier 2007]. Just a few illustrative examples are shown in Figs. 3.178–3.186 and discussed below in alphabetical order.

Heinrich Adenstedt (German, 1910–1991) was an expert on titanium and other metal alloys who came to the United States after the war [Figs. 3.178–3.179]. Both in Germany during the war and in the United States after the war, he worked very closely with jet/helicopter/tank engine designer Anselm Franz (pp. 1381 and 1739–1740). In a 1948 article [Adenstedt 1948], Adenstedt listed several advanced iron-based (steel) alloys that were developed and used in Germany before and during WWII, including Tinidur (Titanium Nickel Durable alloy), Cromadur (Chromium Manganese Durable alloy), FKDM 10 (V, Cr, W, Mo), FKM 10 (V, Cr, Mo), and MC 120 (Mo, Cr). Some of the related alloys that were also developed and used then included Vanidur (Vanadium Nickel Durable alloy) and Sinidur (Silver Nickel Durable alloy). Most of those advanced alloys were produced by Krupp and were intended for jet engine components, due to their heat resistance and good structural properties. They are still used for that purpose even today.

Georgius Agricola, or Georg Bauer (German states, 1494–1555, Fig. 3.10), discovered bismuth around 1540 and conducted extensive work on metallurgy.

Kurt Anderko (German, 19??–19??) was another expert on titanium and advanced metal alloys in Germany during World War II. After the war, he came to the United States as part of the Paperclip program.

Carl Josef Bayer (Austrian, 1847–1904) developed a practical industrial process for extracting aluminum metal from the mineral bauxite.

A. Beerwald (German, 19??–19??) developed very lightweight magnesium alloys for aerospace vehicles in Germany during World War II.

?? Berblinger (German, 19??–19??) was a metallurgy expert in Germany during World War II, and was employed or at least sought by the U.S. Army's Fort Monmouth, New Jersey laboratory after the war.

Carl Berg (German, 1851–1906) developed and supplied aluminum alloys for the first rigid airships that were made by David Schwarz and Ferdinand von Zeppelin (pp. 1644–1645).

Franz Bollenrath (German, 1898–1981) was an expert on metallic materials and structures who worked at the Technische Hochschule Berlin before World War II, Sonthofen on secret military work during the war, and the Technische Hochschule Aachen after the war.

August Borsig (German states, 1804–1854) was a metal manufacturer and industrialist who founded the Borsig company, which later became Rheinmetall-Borsig.

Hermann Bottenhorn (German, 19??–19??) was an expert on aircraft metallurgy in Germany during World War II, and continued his work at Wright Field, Ohio, after the war.

?? Bruche (German, 19??–19??) conducted work on metallurgy during World War II. After the war, he either worked for or at least was actively sought by the U.S. Army's Fort Monmouth laboratory.

Robert Bunsen (German, 1811–1899, p. 433) discovered that pure aluminum could be produced using electrolysis.

Otto Dahl (German, 19??–19??) developed metal alloys at Siemens & Halske during World War II.

Walter Dawihl (German, 1904–19??), the head of Osram's research department, developed novel hard metal alloys and hard coatings for metal tools during World War II. After the war, he was extensively interrogated by Allied investigators, and he wrote a widely used handbook on hard metal alloys and coatings.

Ulrich Dehlinger (German, 1901–1981) developed the theory of dislocations in metals at the University of Stuttgart, where he worked from the 1920s to the end of his career.

Bernard Dirksen (German, 19??–19??) conducted research on metallic materials and structures in Germany during World War II and at Wright Field, Ohio, after the war.

Hans Fischer (German, 19??–19??) was an expert on the cold processing of steel in Germany during World War II. After the war, he continued his work at the Aberdeen Proving Ground in Maryland, along with Heinrich Kopp and Ludwig Schuster.

Richard Glocker (German, 19??–19??) was a metallurgist in Stuttgart during World War II and worked at the U.S. Army's Fort Monmouth laboratory after the war.

Max Hansen (German, 1901–1978) was another expert on titanium and other metal alloys who came to the United States after the war, before eventually returning to (West) Germany. In her history of titanium research, Kathleen Housley wrote [Housley 2007]:

> The research at Armour [Research Foundation in Chicago] was led by Max Hansen, a German metallurgist and world-renowned expert on phase diagrams whose doctoral work had been paid for by Kroll, who considered Hansen's intelligence to be worth the gift of tuition. Hansen had taken the position of professor of metallurgy at Illinois Institute of Technology after the war. Harold Kessler, who worked with Hansen at Armour, recalled the circumstances of his appointment. "As the war was coming to an end, the British were aware of Max, for he had published many important papers on aluminum alloy development as well as his pioneering work on binary alloy phase diagrams. They smuggled him out of Germany to England just as the Russians were coming to get him with the intention of smuggling him to the U.S.S.R. Then the position at Armour opened up and he came to the States." Like his mentor Kroll, Hansen was a gentle, soft-spoken man venerated by his co-workers who included besides Kessler, Donald McPherson, William Rostocker, Frank Crossley, Raymond van Thyne, and C. Robert Lillie. "He set a personal example of professional excellence and integrity," remembered Kessler. "He taught, counseled, and cajoled his students and colleagues toward better, more productive careers, and inspired an esprit de corps in all those with whom he

> worked." According to Margolin, the esteem in which Hansen was held bordered on awe. "On phase diagrams, Hansen was the authority. With a phase diagram, you do it, but a lot of times, there are things wrong because you don't fully understand what you are doing, and you have to guess. It is a very time-consuming process. I remember that Hansen did the titanium-aluminum diagram in three months. I was absolutely amazed." [...] Armour had several contracts with industry and branches of the Armed Forces, particularly with Wright-Patterson Air Force Base where metallurgical research was under the direction of Dr. H. K. Adenstedt. A close friend of Hansen's, Adenstedt had worked with him in the German aluminum industry and had come to the United States as part of the round-up of German scientists.

F. Heimes (German, 19??–19??) conducted metallurgy research at Neckersulm during World War II. After the war, he either worked for or was sought by the U.S. Army's Fort Monmouth lab.

Wilhelm Carl Heraeus (German, 1827–1904), who came from a generations-long family pharmacy, developed a high-temperature smelting process to produce pure platinum in 1856. To make use of that process, he founded and managed the Heraeus metallurgy company in Hanau. The company was subsequently run, and its metallurgical processes improved, by this founder's son Wilhelm Heraeus (German, 1860–1948) and then grandson Wilhelm Heinrich Heraeus (German, 1900–1985), both of whom were Ph.D. scientists.[17]

Albrecht Herzog (German, 19??–19??) worked on metallic materials and structures in Germany during World War II and at Wright Field, Ohio, after the war.

Albert Kochendörfer (German, 19??–19??) and Werner Köster (German, 1896–1989) conducted metallurgy research at Stuttgart during World War II. After the war, they either worked for or were sought by the U.S. Army's Fort Monmouth lab.

Heinrich Anton Karl Kopp (German, 19??–19??) was another expert on the cold processing of steel in Germany during World War II. After the war, he continued his work at the Aberdeen Proving Ground in Maryland, along with Hans Fischer and Ludwig Schuster.

?? Kornetzke (German, 19??–19??) conducted metallurgy research at Heidenheim during World War II. After the war, he either worked for or was sought by the U.S. Army's Fort Monmouth lab.

A. Krisch (German, 19??–19??) developed new processes for manufacturing and fabricating steel stock and components during World War II. He appears to have worked for the United States after the war.

William Kroll (1889–1973) was born in Luxembourg but was educated and worked in Germany. Like Anderko, Adenstedt, and Hansen, he developed titanium and other advanced metal alloys in Germany during World War II and in the United States after the war.

Friedrich Krupp (German states, 1787–1826) founded the Krupp steel company and developed new casting techniques. Alfred Krupp (German, 1812–1887) inherited and expanded the Krupp steel company. He and others at the company developed greatly improved methods of fabricating steel components ranging from train wheels to cannon barrels.

---

[17] https://www.heraeus.com/en/group/about_heraeus/corporate_history/corporate_history.html

Richard Küch (German, 1860–1915) was the head scientist at Heraeus in the years around 1900. Küch developed alloys and processes for producing them, as well as a high-temperature process to produce quartz of exceptionally high purity and quality.

Ernest Kugel (German, 19??–19??) was an expert on aircraft metallurgy in Germany during World War II, and continued his work at Wright Field, Ohio, after the war.

Reinhard Mannesmann (German, 1856–1922) inherited and expanded the Reinhard Mannesmann steel company along with his brothers. He developed a number of new methods of fabricating steel stock and steel components.

Günther Möhling (German, 19??–19??) obtained his Ph.D. in Germany in 1928 with a thesis "Über Optisch Aktive Arsenverbindungen" ("On Optically Active Arsenic Compounds"). He appears to have moved to the United States in the 1930s. He ended up in charge of metallurgical development at the Allegheny Ludlum Steel Corporation, where he introduced German metallurgical methods and alloys and began receiving U.S. government funding.[18] He also appears to have reaped a windfall of additional metallurgical information from Germany when World War II ended. At Allegheny Ludlum, Möhling copied Tinidur (renamed A-286), Cromadur (renamed AF-71), and other German alloys, as well as German metallurgical methods such as vacuum melting. Metallurgist Art Kracke briefly alluded to the early history of these technologies in Germany and their transfer to the United States during and after World War II [Kracke 2010]:

> Breakthrough Events in Superalloy Processing
>
> - 1905: W. von Bolton consumable electrode arc melted tantalum in a cooled copper crucible under a low pressure of argon. [See p. 967.]
> - 1917: W. Rohn first melted nickel alloy in a vacuum resistance heated furnace.
> - 1923: Heraeus Vacuumschmelze A.G. founded to operate vacuum furnaces.
> - 1926: Two VIM furnaces in operation melting 80 Ni 20 Cr and 65 Ni 15Fe 20 Cr for thermocouples and denture alloys.
> - 1950: Dr. Möhling melts first large heat, ten tons, vacuum induction melt of aluminum and titanium containing strengthened superalloy at Allegheny Ludlum Steel laboratory in Watervliet, NY.
> - 1952: Special Metals Co., New Hartford, N.Y. produces the first production heat of Waspaloy in a 6-lb furnace for Pratt & Whitney J48 turbine engine blades
> - 1953: First production vacuum arc remelting of superalloys by Allegheny Ludlum Steel in their Watervliet, NY laboratory.
>
> [...] Vacuum melting was first performed in 1916 in Hanau, Germany by Dr. Wilhelm Rohn and W. C. Heraeus in a vacuum induction furnace of their design. Their work,

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[18] *Automotive News*, 30 April 1945, p. 57, cols. 3–4. https://chroniclingamerica.loc.gov/lccn/77618337/1945-04-30/ed-1/seq-57/

> focused on steels, led to the development of clean steels that enabled aircraft engine technology including the development of turbine engines for military aircraft used in WWII.
>
> In 1945 a small vacuum furnace was built at NACA to melt high temperature alloy samples for evaluation. [...]
>
> The following comment made by Rudolph Thielemann in 1967 in a presentation to the European Investment Casters Federation is a testimonial to the role vacuum melting played in the success of superalloys and their role in gas turbines. “Since the early work on the exhaust gas driven turbosuperchargers, a great deal of progress has been made in developing high temperature alloys for critical gas turbine applications. In this effort, the development of new processes and techniques for melting, consolidating and casting the alloys has been very important. The introduction of the (vacuum) melting furnace has furthered the metallurgical progress in the alloy development more than any other single factor.”

Hermann Nehlsen (German, 19??–19??) was an expert on aircraft metallurgy in Germany during World War II, and continued his work at Wright Field, Ohio, after the war.

Wilhelm Rohn (German, 1887–1943) was the head scientist at Heraeus after Richard Küch. In 1913 he invented vacuum melting, a technique that enabled the production of advanced, high-temperature alloys. Rohn and Heraeus developed and used the technique for commercial applications from then through World War II.[19]

Franz Sauerwald (German, 1894–1979) developed very lightweight magnesium alloys for aerospace vehicles in Breslau during World War II.

Ludwig Schuster (German, 19??–19??) was another expert on the cold processing of steel in Germany during World War II. After the war, he continued his work at the Aberdeen Proving Ground in Maryland, along with Hans Fischer and Heinrich Kopp.

Hugo Stinnes (German, 1870–1924) ran the Stinnes steel company, which developed new metal alloys and custom metal components for new technological applications.

Fritz Thyssen (German, 1873–1951) was a metallurgist who inherited, expanded, and ran the Thyssen steel company, which developed a variety of new alloys in the early twentieth century.

Carl Auer von Welsbach (Austrian, 1858–1929, pp. 435 and 966) discovered praseodymium (1885), neodymium (1885), ytterbium (1905), and lutetium (1905). He also invented the gaslight mantle (1885), osmium wire (1890), metal filament incandescent lamps (1898), and the flint metal lighter (1903). In order to commercialize his discoveries and inventions, he founded the companies of Auergesellschaft, Treibacher Industrie, and Osram.

In 1906, Alfred Wilm (German, 1869–1937) invented the Duralumin aluminum alloy (aluminum with small amounts of copper, magnesium, manganese), which has been widely used in the aerospace industry ever since. He also discovered age hardening for aluminum alloys and other metals in 1901.

---

[19] https://vacuumschmelze.de/unternehmen/firmenhistorie

Friedrich Wöhler (German, 1800–1882, p. 432) discovered and purified aluminum.

Despite the wartime shortages, by 1945 metallurgy was so advanced in the German-speaking world that Allied countries seized large quantities of information and scientists, and even complete factories, to improve the state of metallurgy in their own countries (Figs. 3.187–3.188).

For example, in September 1945, R. P. Linstead and T. J. Betts, the British and American chairs of the Combined Intelligence Objectives Subcommittee (CIOS), listed a number of important German innovations in metallurgy [AFHRA A5186 electronic version pp. 904–1026, Ch. 4, pp. 52–53]:

> In the field of ferrous and nonferrous metallurgy the following discoveries are worth recording:
>
> 1. A new flux for welding magnesium.
>
> 2. A hard magnesium coating obtained by anodizing aluminum oxide which had many industrial and armament applications.
>
> 3. Refinements in the process of continuous casting. This casting was done into a tank of water rather than an open pit. The method employed a small mould which resulted in many economies of production.
>
> 4. The use of chemicals in the grain refining process in heating magnesium for casting. This process, used in the production of high quality magnesium, permitted achievement of equal quality by using a temperature 100^oC below that employed in the conventional process.
>
> 5. The electric smelting furnace developed by Siemens and Halske. This resulted in the production of pig iron with little coke, a process with distinct advantages when coke supplies are limited and cheap hydro-electric power abundant. A further advantage is the reduction of the sulphur content in pig iron.
>
> 6. Improved hard cemented carbide for use in cutting tools.
>
> 7. German development and use of drawn steel cartridge cases. Steel cartridge cases were designed for a wide range of calibers ranging from small arms to large artillery pieces. Steel cartridge cases have the obvious advantages of saving critical materials.

As a more focused example, BIOS 925, *Tungsten Carbide Research in Germany*, p. 3, discussed German innovations in metal hardening that Allied countries wanted to copy (see also BIOS 1076):

> This report contains the results of a detailed interrogation of Dr. [Walter] Dawihl who was head of Osram's Research Department. By agreement with Krupps this Laboratory carried out all hard metal research on behalf of the Widia organisation and as such was the most important Hard Metal Research Laboratory in Germany.
>
> The report gives a general survey of the Research Programme of the Laboratory during the war years and traverses the latest theories on the fundamental metallurgy of hard metal as developed by Dr. Dawihl.

> It describes his experiments to relate the practical performance of hard metal with metallurgy and discusses the effect of crystal formation and shape on the physical properties.
>
> A technique of coating steel with a thin hard metal skin is described and the composition of the metal is given.
>
> Descriptions of the processes of making boron carbide and titanium boride are given and a very brief resume of the work done on sintered iron and steel.
>
> Part III deals with the practical application of Laboratory Research to commercial practice and gives brief descriptions of methods of manufacture, specifications and a detailed costing of each operation.
>
> Appendix I is probably the most valuable portion of the report as it contains a list of Reports issued by the laboratory, copies of which are in our hands. They are listed by H.E.C. numbers, title and number of pages and diagrams.
>
> Appendix II is a description of making tungsten carbide in an electric arc furnace of novel design by D.E.W., Krefeld.
>
> Appendix III is a drawing of a continuous rotary tube furnace for carburising.

For further examples of how advanced German and Austrian metallurgy technologies were transferred to Allied countries after the war, see pp. 4090– 4152. See also the large number of metallurgy-related BIOS ER, BIOS, BIOS Misc., BIOS Overall, CIOS ER, CIOS, FIAT, *FIAT Review*, JIOA, NavTecMisEu LR, and NavTecMisEu reports in the Bibliography.

American metallurgists Charles R. Simcoe and Frances Richards provided a glimpse of how German-speaking scientists and methods were utilized to create advanced metal alloys in the postwar United States [Simcoe and Richards 2018 pp. 145, 147–148]:

> Titanium was on its way to becoming the aerospace metal that its promoters had hoped it would be. Then an earthquake shook both the aerospace industry and titanium. The Secretary of Defense, Charles Wilson, formerly of General Motors Corporation, announced a decision to base the defense of the country on missiles rather than on manned aircraft. The accompanying reductions and cancellations of contracts rocked the industry. [...] The reduction in aircraft and engine production caused a near-total collapse of the titanium market. This most promising of metals for the postwar era, which had received an estimated $200 million in government support, was in serious danger of extinction by the very DOD that had brought it into being. [...]
>
> The changes in the titanium industry had changed the career paths of many of the individuals selected as founders. William Kroll returned to Europe to enjoy his retirement years in Brussels. Max Hansen left ARF to accept a high-level post in the metals industry in Germany. In 1958, Hansen and Kurt Anderko, another German who worked with Hansen at ARF and who had returned to Germany with him, published a monumental second edition of the "Constitution of Binary Alloys." [...]

> By the late 1950s and early 1960s, the major research and development support for titanium by the government had ceased. The founders, as well as the younger researchers, were forced to find other areas of research or move on to other employment. [...]
>
> One significant development in the 1960s was the building of the SR-71 Blackbird military reconnaissance plane with a speed capability of Mach 3. The SR-71 was an all-titanium aircraft manufactured with Ti-6Al-4V and a new alloy, Ti-13V-11Cr-3Al. Another early 1960s attraction was the interest in a supersonic transport plane. It would have been an all-titanium aircraft that was planned to compete with the European-made Concorde. It was planned to fly at nearly Mach 3 and would have used large amounts of titanium per plane for a planned 200-plane fleet. The program was cancelled by Congress in 1971.

Thus German-speaking scientists were apparently responsible for the heat-resistant, strong, lightweight titanium alloys that made the SR-71 Blackbird spy plane and the XB-70 Valkyrie bomber (pp. 1750, 1754–1755) possible, and that would have made possible a fleet of Mach-3 passenger aircraft. Unfortunately the United States lost interest in such technologies, and those German-speaking scientists retired or found employment in other areas.

Much more archival research should be conducted to clarify the direct (via invention and development) and indirect (via technology transfer) contributions of German-speaking scientists to the methods and applications of metallurgy.

Heinrich Adenstedt (1910–1991)

FEATURE

Governmental, scientific and industrial agencies as well as engineering societies and individuals are invited to submit papers believed to be of general interest to the readers of the TECHNICAL DATA DIGEST, for publication in this section. Manuscripts should be prepared in the conventional manner and addressed to CG, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio — Attn: Air Documents Division, MCIDXS5.

GERMAN METHODS IN DEVELOPING TURBINE-WHEEL BLADES FOR THE JUMO-004

HEINRICH K. O. ADENSTEDT

Analysis Division, Intelligence Department, Air Materiel Command

Designs

The turbine wheel of the Jumo-004 measures approximately 700 mm (27.49 in.) in total diameter, and contains 61 blades, each approximately 110 mm (4.33 in.) in length. The blades were mounted on the wheel and fixed by two riveted pins, while the wheel was flanged to the shaft and bolted with stud bolts. Figure 1 shows a section of the turbine wheel.

For the blade attachment two designs were used: (1) the so-called Junkers attachment as shown in Fig. 2, and (2) the so-called Lamelle base, developed by the Allgemeine Elektricitaets Gesellschaft (General Electric Co.), Berlin, as shown in Fig. 3.

Materials

The construction of the first jet engines was accomplished without considering the scarcity of materials, because the initial work required operational safety. For this reason the entire wheel was made from Krupp's top-grade, heat-resistant steel, P 193 (later called "Tinidur"). The composition of Tinidur can be seen in Table I. The original steel used had a carbon content of 0.4%, but this was immediately replaced by a steel with 0.15% carbon. Cobalt steels, although better in creep-resistance properties, could not be used because of a shortage of this material in Germany.

At first the blades were machined from steel rod, 45 mm by 45 mm (1.77 in. by 1.77 in.) and later from die-forged material. The wheels were machined from rough blanks. Prior to 1944 blades were made of Tinidur, which was later replaced by Cromadur (Table I).

The disk material was then changed over to a heat-treatable composition, after it was established that the temperatures were lower than 600°C (1112°F) in the turbine wheel. At first the principal steels used were MC 120 from DEW (Krefeld and FKDM 10 from Krupp at Essen (Table I). Later, when more accurate temperature measurements with thermocolor paints were made, the alloy content (Mo and Cr) of the disk material was further reduced, and Flw 1310 steel was used. This material was employed in a special heat-treated condition, 1310.9 (Table I), which was developed particularly for this purpose. Heat-treatment consisted of heating to about 1000°C (1832°F) and quenching in a warm-oil bath or salts. The temperature of the salt bath was about 350°C (662°F). The purpose of this heat treatment was to produce bainite (at least in the rim) to assure the best high-temperature properties. In the meantime other steels which had physical properties falling between Flw 1310.9 and FKDM 10 (e.g., FKM 10, Flw 1456.9 and Flw 1620.9) were tried.

TABLE I
COMPOSITION OF THE STEELS USED IN THE JUMO-004

JUNKERS-NORM	ALLOY NO. (Flieg No.)	STEELMAKER AND TRADEMARK	CONTENT IN PERCENT										
			C	Si	Mn	Cr	Ni	Mo	W	V	Ti	N_2	Fe
Jumo N-12139		Krupp (Tinidur), Schoeller u. Bleckmann (IGT), Poldi.	<0.15	0.8	0.7	15	30				2.0		Bal
Jumo N-12142	1585	Krupp (Cromadur) other Steel mills	<0.12	0.5	18	12				0.65		0.2	Bal
Jumo N-12140		Krupp (FKDM 10) other Steel mills	0.20	0.3	0.40	2.8		0.45	0.4	0.7			Bal
Jumo N-12141		Krupp (FKM 10)	0.20	0.3	0.40	2.8		0.45		0.7			Bal
		DEW (MC 120)	0.25	0.35	0.40	1.5		1.0					Bal
	1456	All mfrs. of aircraft-quality steel	0.30	<0.4	0.6	2.5		0.20		0.20			Bal
	1620	,,	0.30	<0.4	0.6	2.4				0.20			Bal
	1310	,,	0.40	<0.4	1.75					0.15			Bal
	1267	,,	0.35	<0.4	1.75								Bal

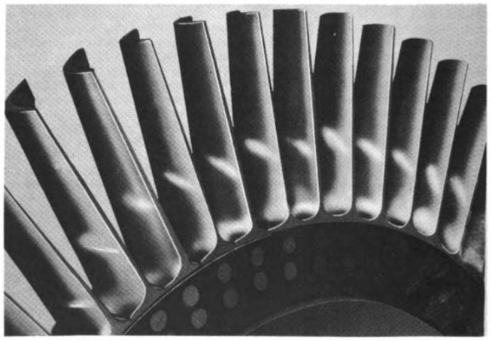


Fig. 1—Section of the Jumo-004 Turbine Wheel.

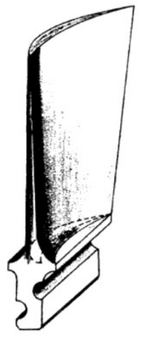


Fig. 2—Junkers Attachment.

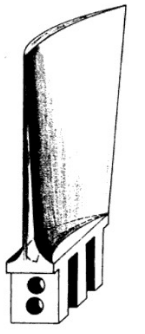


Fig. 3—Lamelle Base.

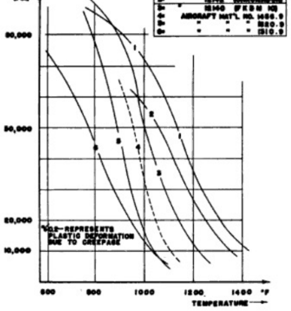


Fig. 4—Creep Resistance of Various Steels.

The pin material was changed from Tinidur to FKDM 10, FKM 10 or Flw 1456.9. A molybdenum-free steel, e.g., 1310.9, could not be used for the pins. This will be explained later. The creep resistance of the most important of these steels will be found in Fig. 4.

Difficulties with Turbine Disks

In the case of the first austenitic disks made of Tinidur steel, surface tears were experienced, which indicated the difficult forgeability of this titanium-bearing steel. Some of these tears were so deep that it became necessary to discard the disks; the remaining disks were used satisfactorily. During operation no difficulty occurred with them as there were only about ten disks that were made from this material.

From the disks made of heat-treated steel two acute failures occurred. On one disk of MC 120, which still had the old Junkers attachment, several attaching pivots broke on the grooves of the pins without elongation. An investigation revealed that on the same jet, cooling for the disks did not prove effective, and the disks had become overheated. Therefore, the stress of 28 kg/mm^2 (39,800 psi), effective at this place, caused a creep break.

A wheel of material Jumo N 12141 exploded completely. Investigation proved that a quenching crack had occurred, which had not been discovered by the inspectors.

Final Acceptance for the Wheels

The disks were inspected and tested in the steel mill in the usual way by the inspector representative of the Reichsverband Deutscher Luftfahrt Industrie (RDLI). There was no special acceptance specification. Each of the first few disks was forged with a prolongation, which was used as a test coupon. Determinations were made of ultimate strength, yield strength, elongation, impact resistivity and creep rates. In mass production, all of these tests could not be carried out, which limited inspection to magnaflux and hardness tests. On the basis of magnaflux tests, a small percentage of the disks was always scrapped because of tears.

Figure 3.178: Heinrich Adenstedt developed and used advanced metal alloys in Germany during the war and in the United States after the war [Adenstedt 1948]. Throughout his career, he worked very closely with jet/helicopter/tank engine designer Anselm Franz (pp. 1381, 1739–1740).

Temperature Measurements of the Disks

At first, temperature measurements were made with thermocouples. In using these measurements, the wheel was made stationary and the blades were heated to the correct temperature by means of a ring burner, while the other testing apparatus cooled the disk to a ratio as if it were in operation. These tests could give only approximate results, and were later replaced by thermocolor paints which determined the temperature of the wheel during operation. This test was made as follows: Several small strips along different radius vectors of the disk were sand blasted and then sprayed with aluminum by the Schoop procedure. Onto the white rough aluminum surface a suitable thermocolor paint was applied by brush. On this prepared surface a strip of asbestos and a sheet-metal strip of 18-8 steel were screwed tightly against the disk. This arrangement, which proved satisfactory, can be seen in Fig. 5. The asbestos covering prevented the thermocolor paint from being affected by external heat conditions caused by surrounding air. This insured accurate wheel temperature determinations by the thermocolor paints. On the white aluminum surface the change of color was easily visible and the few isolated strips affected very little the cooling of the disk through the surface. (Only 10% of the disk surface was covered by the strips). These investigations proved an operational temperature of 400°C (752°F) at the lower end of the blade base and 220°C (428°F) in the center of the disk. These values gave the basis for the material change to Flw 1310.9. Later the temperature measurements were repeated on hollow-blade wheels in a somewhat different manner. The thermocolor paints were placed inside of hollow drilled screws of 18-8 steel; the hole was then closed with a piece of sheet metal. The screw prepared in this way was driven into the disk at the desired place for temperature measurement. After the test the screw was opened, the paint was sifted on paper and spread out with a knife; the color change was easily visible.

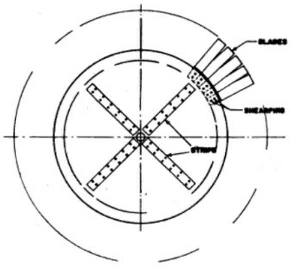


Fig. 5—Location of Strips for Temperature Measurement on the Wheel.

Difficulties with Shear Pins

During mass production, no pin failures were caused by shear. Two test wheels were constructed with pins of steel Flw 1267.9 (Table I). In the case of one wheel, after 92-hr operation the pins sheared off, and one blade flew off. Because of this failure, the pins were then made of a molybdenum steel (Flw 1456.9, Jumo N 12140 or 12141). Flw 1310.9, which has a higher creep resistance than 1267.9 by about 30°C, was not used for the pins, because the 30°C advantage was considered insufficient. Special final acceptance was not prescribed for the pins.

Difficulties with the Blades

The observed blade breaks can be placed into two categories: (1) fatigue breaks and (2) creep breaks. These are discussed specifically below.

1. Fatigue Breaks

This type of break was observed almost exclusively at the beginning of turbine-blade development, with fractures occurring at different points in the lower part of the blades. Using the old Junkers attachment (Fig. 2), the weak place proved to be the upper shear-pin hole. Fatigue fractures were experienced in a number of blades at this particular place. This condition was improved by employing a different method of fastening. The diameter of the upper pin was decreased, and the outer radius (R) on the wheel base and on the pivots was decreased as shown in Fig. 2. Also on the lamelle base (Fig. 3) several fatigue breaks were recognized - in the lamelles themselves and in the base plate. This necessitated a heavier base plate. The fatigue breaks in the blades themselves occurred mostly at the lower part of the blade length.

The temperature and velocity distribution behind the nozzle diaphragm were found to be not uniform, which led to excitations of the blades, causing the fatigue breaks. At full power there are 145 rps x 6 (combustion chambers) = 870 stress cps. This figure corresponded to nearly fundamental natural frequency of the blades during operation. When cold, the latter was 900 - 950 cps, but this value is increased during the operation by centrifugal force, and decreased by modification of the material (change of modulus of elasticity). In all, a decrease of 8% was calculated.

The breaks appeared partially after operation of 50 hours or more, which corresponds to over 10^8 c of load, and therefore means a very long working time. After the lapse of such a long time, no breaks should be expected if we consider a Woehler curve. The explanation is the very sharp natural frequency of the blades, effected by a small degree of damping. Therefore a small rpm fluctuation gives a great reduction of the stresses in the critical blades. All these cycles with reduced stresses do not count in our consideration of the Woehler curve.

As a remedy, the natural frequency was increased about 100 cps by more acutely conical forming of the blades, and by a 1-mm reduction of the length. Further, a 100% frequency test was prescribed, whereby the natural frequency was required to be over 1000 cps. Blades with too low natural frequencies were saved by reworking (material machining of the inner side of the blade in the upper quarter of the length).

The frequency test of the finished wheel was carried out by an acoustical method. The 61 blades were agitated at the head end with a violin bow, and the arising tone was compared with a normal known tone. The normal tone was created by a set of tuning forks consisting of prongs with a natural frequency (with an interval of 25) of between 950 and 1150 cps. The forks were agitated by means of an eccentric, and the tone was reproduced by means of a coil, an amplifier, and a loud speaker. All forks could be simultaneously agitated, and the desired tone could be heard by pressing the proper button. Figure 6 shows the arrangement schematically. In this way it was possible to test a wheel in a few minutes, and the natural frequencies of the different blades could be determined within limits of less than 25 cps.

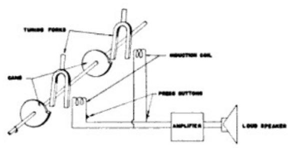


Fig. 6—Schematic Diagram of Frequency Generator.

After the increase of the blade frequencies and after the introduction of the preceding acceptance test, practically no fatigue breaks occurred.

2. Creep Breaks

Creep breaks occurred particularly in the upper part of the blades. These were mostly intergranular and without deformation. As such breaks practically marked the life limit of the wheel, great effort was made to avert them as long as possible. This was done in collaboration with the factory of Krupp, the AEG turbine factory, and the branches of the Junkers concern.

From the breaks which occurred and from the creep-rupture tests, it was concluded that Tinidur is not very ductile at elevated temperatures when subjected to creep conditions; that when creep progresses to about 1.5%, a brittle fracture will occur, and that the ultimate elongation caused by creep is further reduced by: (1) large grains, (2) notches (grinding marks, too sharp edges, etc.), (3) inclusions which cause notch effects (oxides, segregations, etc.), and (4) melting influences, which could not be explained in detail (gas content, melting procedure, etc.).

If these irregularities occur, premature failures are to be expected, especially if, by the tilting of the blade (caused by manufacturing inaccuracy) or by thermal shock, a stress raiser occurs locally. The stress raiser, caused by tilting of the blade, is dependent upon the direction of the inclination of the blade outwards of its gravity line. This stress increase can be very important. Numerical values can be given only when exact drawings of the blades are available. A thermal shock (caused by sudden heating or cooling of the blades during starting or stopping) may overstress the extreme edges of the blades. It was found that the number of cycles of starting and stopping is very important for the life of the blades. In particular, coarse-grain blades were very sensitive to thermal shock. In the Jumo-004 a more elastic type of controller system minimized excessive thermal shock.

Control of the Blades

The specifications prescribed for the control of the blades were:

1. Control of the Melt - The chemical composition had to be as prescribed in the standard Jumo N 12139; especially the titanium content had to be precise. Difficulties in the chemical-analysis procedure which existed at first in the titanium determination were removed. In the steel mill, the basic suitability of the melt was proved (RDLI Control, quality test, precipitated hardening).

2. Forging Procedure - The forging was inspected at each place in order to facilitate the procedure. Between the various steps of forging, macro-etchings were made. Rod sections with center segregation were rejected; half-finished rough forgings with surface tears were ground out or rejected. Figure 7 depicts in both views A and B two characteristic troubles of Tinidur. View A shows a surface crack caused by titanium oxide aggregation, and View B a preforged sample with opened head due to central segregations. The forging furnaces were temperature-controlled and the various forging dies were adapted in such a way that the end deformation was greater than 15%. By this procedure at 1080°C (1976°F) end forging temperature, good rough forgings with suitably small grains were obtained. The rough forgings were random tested for grain size by surface grinding the head of the blade (Krupp Company's system).

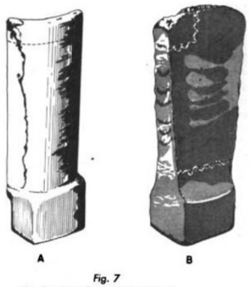


Fig. 7
A—Forging with a Surface Crack.
B—Preforged Sample with a Center Crack.

3. Testing the Finished Blades - The finished blades were all macro-etched before the end polishing, and then, by means of a magnifying glass, inspected by experienced workers for surface tears, large grains, segregations, and aggregation of titanium oxides. Acceptance specifications were determined by reference to photos and standard parts. By means of a special marking procedure which made it possible to recognize the particular steel mill, the melt number, and the forging manufacturer of the respective blade, it was possible to publish a monthly reject report from Dessau. This report was important for the steel mills and for the forges, because especially bad melts and bad forgings could immediately be traced. Ultimately 80 percent of the blades were found to be good.

4. Length Polishing - The surface of the blades was length ground and length polished in order to erase all transverse grinding marks.

5. Control of Tilting - After the blades were mounted, a special measuring procedure was provided for keeping the blades erect and for preventing tilting.

6. Frequency Control - Finally, the frequency test was made as described above.

7. Operating Life - The wheels were permitted to run 25 hours; then the blades were tested at random for hardness on the small phase, which is on the exhaust side of the blades. If the hardness of the entire length of the blade was higher than 200 Brinell, the blades were again length ground, and eventually notches were removed. The wheel was then operated for another 25 hours. The total time of operation was inscribed on the wheel by means of number stamps. It was the intention to continue this service to 100-hr total operation time, and then to replace the blades.

Up until the end of the war, only a few solid-blade wheels had reached this total operation time. Since 1944, the hollow blade has replaced the solid blade.

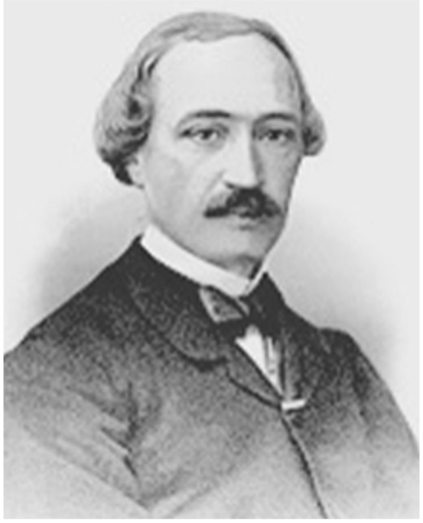
Figure 3.179: Heinrich Adenstedt developed and used advanced metal alloys in Germany during the war and in the United States after the war [Adenstedt 1948]. Throughout his career, he worked very closely with jet/helicopter/tank engine designer Anselm Franz (pp. 1381, 1739–1740).

Metallurgy

Kurt Anderko
(19??–19??)

Carl Josef Bayer
(1847–1904)

A. Beerwald
(19??–19??)



?? Berblinger
(19??–19??)

Carl Berg
(1851–1906)

Franz Bollenrath
(1898–1981)

Figure 3.180: Some creators who made important contributions to metallurgy included Kurt Anderko, Carl Josef Bayer, A. Beerwald, ?? Berblinger, Carl Berg, and Franz Bollenrath.

Metallurgy

August Borsig
(1804–1854)

Hermann Bottenhorn
(19??–19??)

?? Bruche
(19??–19??)

Otto Dahl
(19??–19??)

Walter Dawihl
(1904–19??)

Ulrich Dehlinger
(1901–1981)

Figure 3.181: Other creators who made important contributions to metallurgy included August Borsig, Hermann Bottenhorn, ?? Bruche, Otto Dahl, Walter Dawihl, and Ulrich Dehlinger.

Metallurgy

Bernard Dirksen
(19??–19??)

Hans Fischer
(19??–19??)

Richard Glocker
(19??–19??)

Max Hansen
(1901–1978)

F. Heimes
(19??–19??)

Wilhelm Carl Heraeus
(1827–1904)

Figure 3.182: Other creators who made important contributions to metallurgy included Bernard Dirksen, Hans Fischer, Richard Glocker, Max Hansen, F. Heimes, and Wilhelm Carl Heraeus.

Metallurgy

Wilhelm Heraeus (1860–1948)

Wilhelm Heinrich Heraeus (1900–1985)

Albrecht Herzog (19??–19??)

Albert Kochendörfer (19??–19??)

Heinrich Anton Karl Kopp (19??–19??)

?? Kornetzke (19??–19??)

Figure 3.183: Other creators who made important contributions to metallurgy included Wilhelm Heraeus, Wilhelm Heinrich Heraeus, Albrecht Herzog, Albert Kochendörfer, Heinrich Anton Karl Kopp, and ?? Kornetzke.

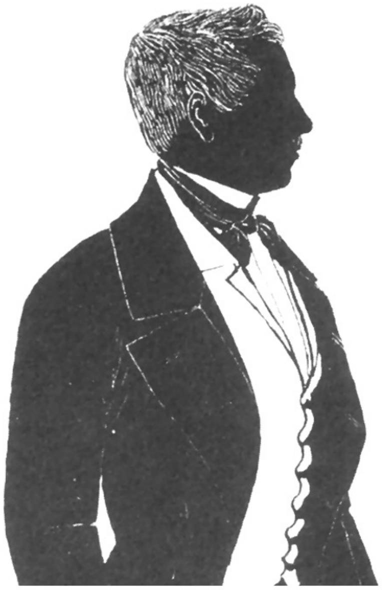
Metallurgy

Werner Köster
(1896–1989)

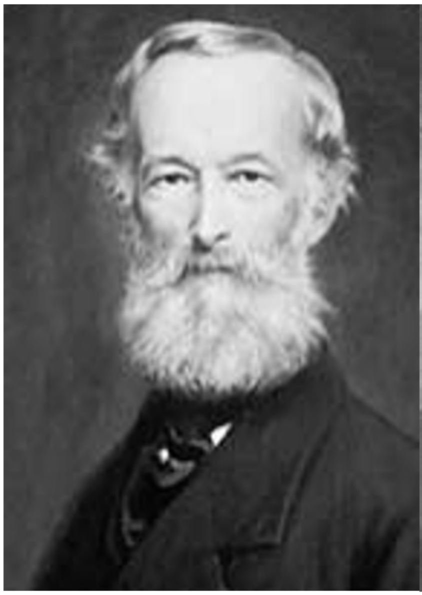
A. Krisch
(19??–19??)

William Kroll
(1889–1973)

Friedrich Krupp
(1787–1826)



Alfred Krupp
(1812–1887)



Richard Küch
(1860–1915)

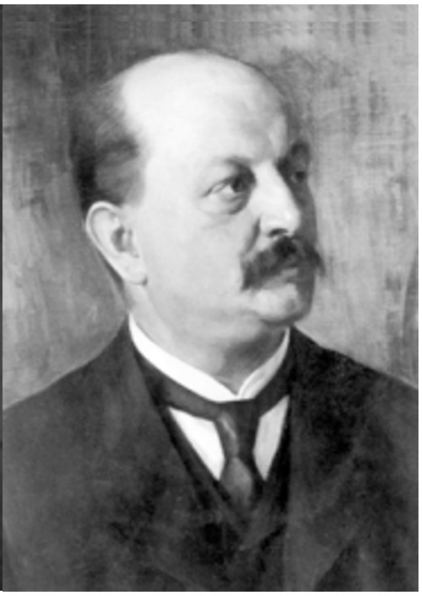


Figure 3.184: Other creators who made important contributions to metallurgy included Werner Köster, A. Krisch, William Kroll, Friedrich Krupp, Alfred Krupp, and Richard Küch.

Metallurgy

Ernest Kugel
(19??–19??)

Reinhard Mannesmann
(1856–1922)

Günther Möhling
(19??–19??)

Hermann Nehlsen
(19??–19??)

Wilhelm Rohn
(1887–1943)

Franz Sauerwald
(1894–1979)

Figure 3.185: Other creators who made important contributions to metallurgy included Ernest Kugel, Reinhard Mannesmann, Günther Möhling, Hermann Nehlsen, Wilhelm Rohn, and Franz Sauerwald.

Metallurgy

Ludwig Schuster
(19??–19??)

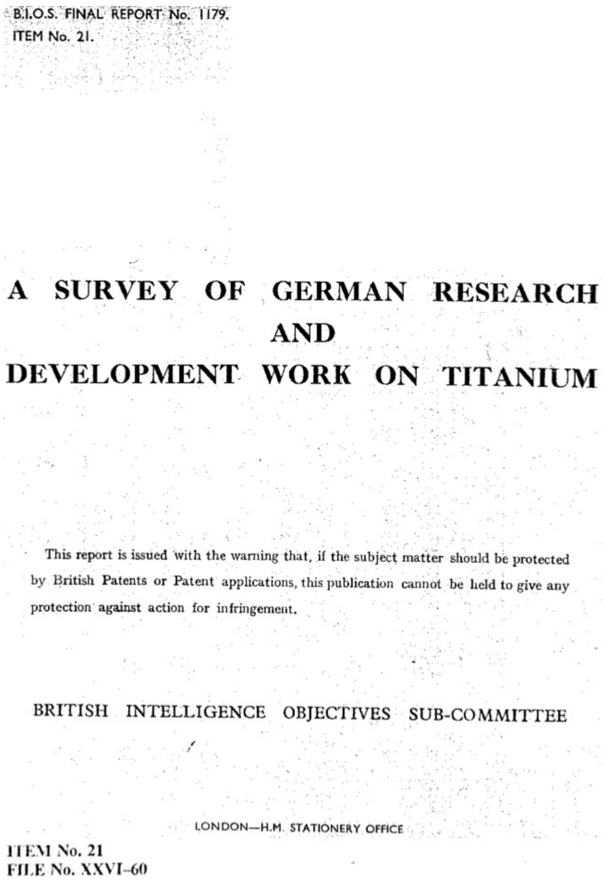
Hugo Stinnes
(1870–1924)

Fritz Thyssen
(1873–1951)

Carl Auer von Welsbach
(1858–1929)

Alfred Wilm
(1869–1937)

Figure 3.186: Other creators who made important contributions to metallurgy included Ludwig Schuster, Hugo Stinnes, Fritz Thyssen, Carl Auer von Welsbach, and Alfred Wilm.



B.I.O.S. FINAL REPORT No. 1179.
ITEM No. 21.

A SURVEY OF GERMAN RESEARCH
AND
DEVELOPMENT WORK ON TITANIUM

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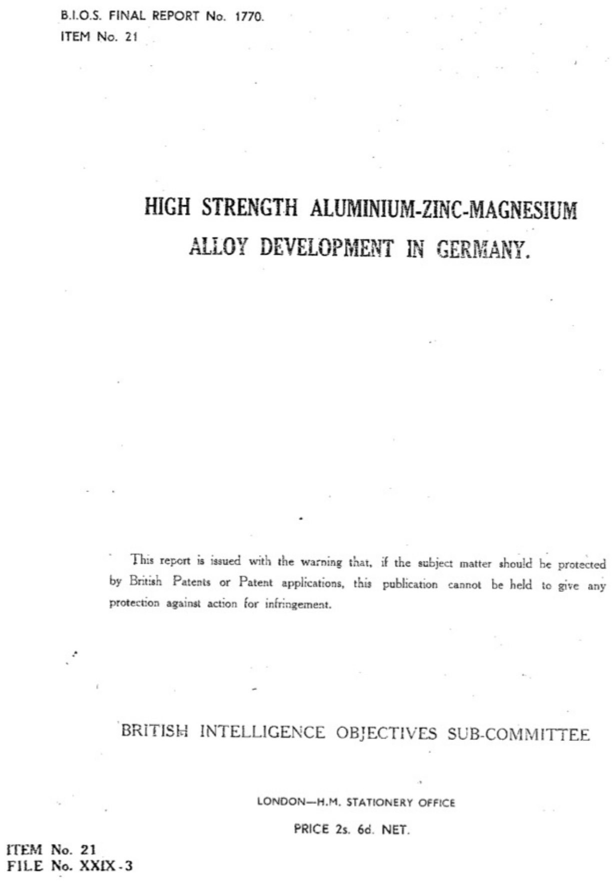

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ITEM No. 21

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ALLOY DEVELOPMENT IN GERMANY.

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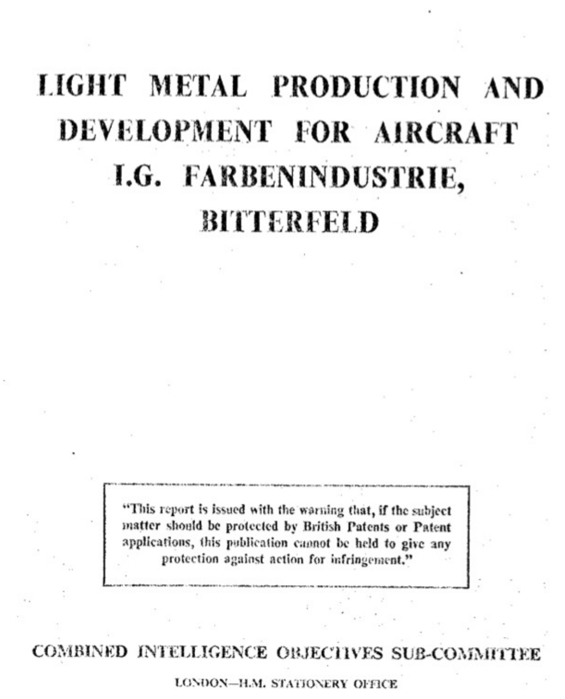

LIGHT METAL PRODUCTION AND
DEVELOPMENT FOR AIRCRAFT
I.G. FARBENINDUSTRIE,
BITTERFELD

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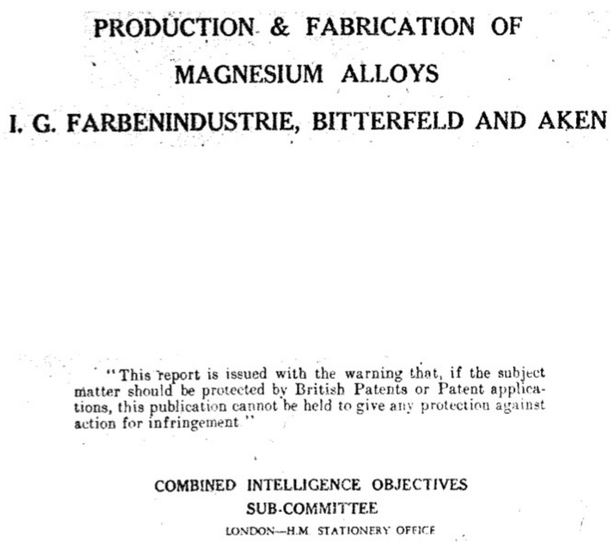

PRODUCTION & FABRICATION OF
MAGNESIUM ALLOYS
I. G. FARBENINDUSTRIE, BITTERFELD AND AKEN

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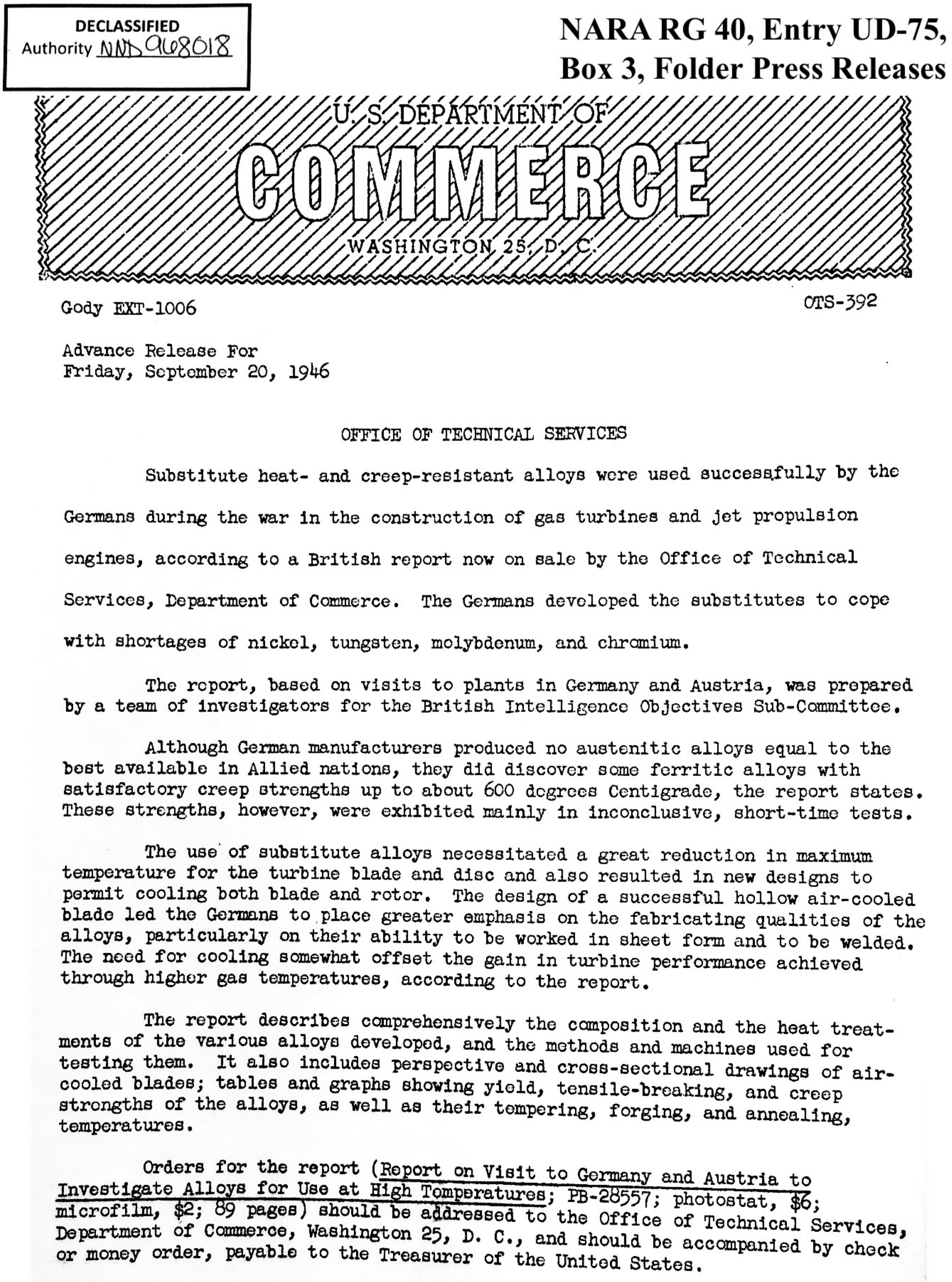
Figure 3.187: Large amounts of information, materials, and scientists involved in work on advanced metallurgy were transferred to other countries after World War II [BIOS 1179; BIOS 1770; CIOS XXVI-60; CIOS XXIX-3].



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NARA RG 40, Entry UD-75, Box 3, Folder Press Releases

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OTS-392

Advance Release For
Friday, September 20, 1946

OFFICE OF TECHNICAL SERVICES

Substitute heat- and creep-resistant alloys were used successfully by the Germans during the war in the construction of gas turbines and jet propulsion engines, according to a British report now on sale by the Office of Technical Services, Department of Commerce. The Germans developed the substitutes to cope with shortages of nickel, tungsten, molybdenum, and chromium.

The report, based on visits to plants in Germany and Austria, was prepared by a team of investigators for the British Intelligence Objectives Sub-Committee.

Although German manufacturers produced no austenitic alloys equal to the best available in Allied nations, they did discover some ferritic alloys with satisfactory creep strengths up to about 600 degrees Centigrade, the report states. These strengths, however, were exhibited mainly in inconclusive, short-time tests.

The use of substitute alloys necessitated a great reduction in maximum temperature for the turbine blade and disc and also resulted in new designs to permit cooling both blade and rotor. The design of a successful hollow air-cooled blade led the Germans to place greater emphasis on the fabricating qualities of the alloys, particularly on their ability to be worked in sheet form and to be welded. The need for cooling somewhat offset the gain in turbine performance achieved through higher gas temperatures, according to the report.

The report describes comprehensively the composition and the heat treatments of the various alloys developed, and the methods and machines used for testing them. It also includes perspective and cross-sectional drawings of air-cooled blades; tables and graphs showing yield, tensile-breaking, and creep strengths of the alloys, as well as their tempering, forging, and annealing, temperatures.

Orders for the report (Report on Visit to Germany and Austria to Investigate Alloys for Use at High Temperatures; PB-28557; photostat, $6; microfilm, $2; 89 pages) should be addressed to the Office of Technical Services, Department of Commerce, Washington 25, D. C., and should be accompanied by check or money order, payable to the Treasurer of the United States.

Figure 3.188: Large amounts of information, materials, and scientists involved in work on advanced metallurgy were transferred to other countries after World War II [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases].

3.9 Other Creations in Chemistry

German-speaking scientists made many other important discoveries and inventions in chemistry. This section covers just a few examples, including:

3.9.1. Chromatography

3.9.2. Colloids

3.9.3. Synthetic lubricating oils

3.9.4. Synthetic detergents and paper recycling

3.9.5. Chemical treatments to make fabrics resistant to fire, water, stains, and wrinkling

3.9.6. Firefighting chemicals

3.9.7. "Superglue"

3.9.1 Chromatography

Chromatography is a technique for separating molecules of different sizes that are initially mixed together, based on the fact that they will diffuse at different rates through wet paper, capillary tubes, or other solid, liquid, or gaseous materials. German-speaking scientists developed the general approach of chromatography as well as most of its specific implementations [Ettre 2001; Goppelsröder 1861, 1901; Runge 1850; Schönbein 1861].

Friedlieb Ferdinand Runge (German, 1795–1867) developed chemical spot tests on filter paper in the 1840s and first published his results in 1850, as shown in Fig. 3.189 [Runge 1850]. Runge's tests were essentially two-dimensional chromatography for separating a pool of molecules placed in the central spot into concentric rings of different types of molecules. (In 1820, Runge was also the first scientist to extract and identify caffeine.)

By exploring and harnessing that initial technique, Christian Schönbein (German states, 1799–1868) and his student Friedrich Goppelsröder (Swiss, 1837–1919) demonstrated one-dimensional chromatography methods both in filter paper and in capillary tubes in 1861 [Schönbein 1861; Goppelsröder 1861]. See Fig. 3.190.

Goppelsröder continued working to improve and to apply capillary-based chromatography for several decades, including using it to separate and analyze the colored pigments from plant leaves [Goppelsröder 1901]. See Figs. 3.191–3.193.

Raphael Eduard Liesegang (German, 1869–1947, Fig. 3.194) also developed and used improved methods of capillary and paper chromatography [Ettre 2001].

Building on the earlier work of Goppelsröder with the chromatography of plant pigments, Richard Willstätter (German, 1872–1942) developed improved methods for chromatography and used those to identify in detail the molecular structures of different types of chlorophyll and other plant pigment molecules (Fig. 3.194). For that work, he won the Nobel Prize in Chemistry in 1915 (p. 407).

Gustav Hertz (German, 1887–1975) invented gaseous diffusion enrichment and gas chromatography; he filed detailed patent applications on his methods in 1923 (Fig. 3.195). He continued to work on gas chromatography (as well as other projects) in Germany until 1945, and in the Soviet Union during the period 1945–1955. It seems likely that his work for those two countries involved using gaseous diffusion methods to separate uranium isotopes for nuclear weapons programs, although currently very little documentation from that work is publicly available.

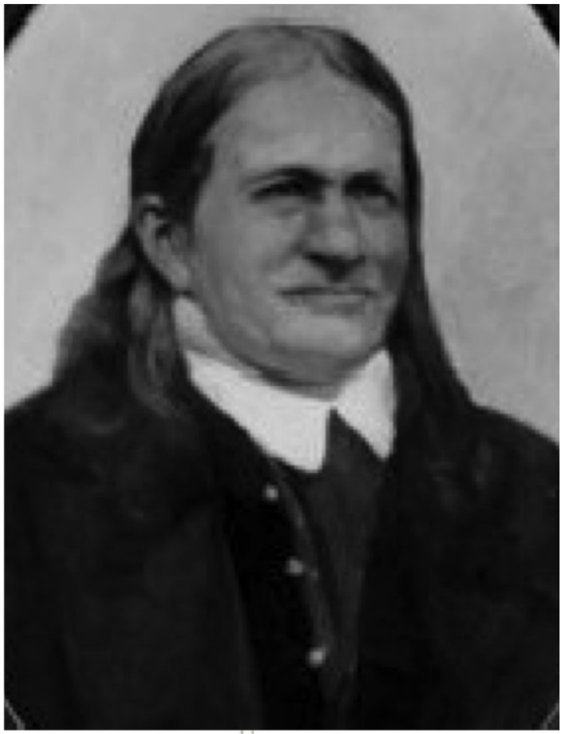
Inspired by the pioneering work by Hertz, Erika Cremer (German, 1900–1996) began developing improved methods of gaseous diffusion and gas chromatography in the late 1930s and continued throughout World War II (Fig. 3.195). As with Hertz, it seems likely that her work involved using gaseous diffusion methods to separate uranium isotopes for the German nuclear program, though little documentation is currently available. Cremer continued to work on gas chromatography after the war, and is best known for her postwar demonstrations and publications on gas chromatography, including those with her student Fritz Prior (Austrian, 1921–1996) [Bobleter 1997].

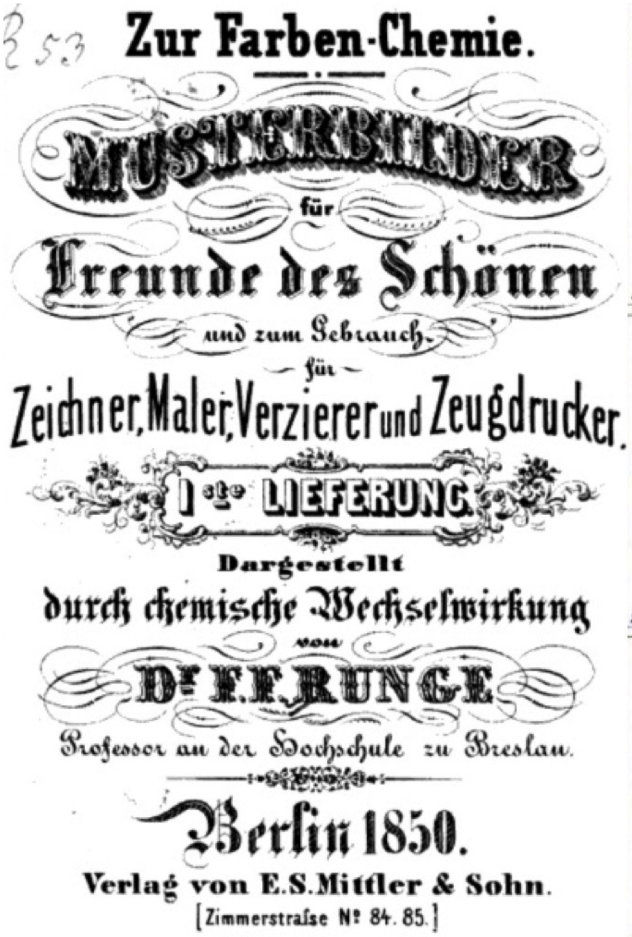
See also pp. 3494–3640 for other work related to gaseous separation and gas chromatography.

Two-dimensional paper chromatography

Friedlieb Ferdinand Runge (1795–1867)

Chemical spot tests on filter paper (1850)





B 53

Zur Farben-Chemie.

MUSTERBILDER

für

Freunde des Schönen

und zum Gebrauch

für

Zeichner, Maler, Verzierer und Zeugdrucker.

1ste LIEFERUNG.

Dargeſtellt

durch chemiſche Wechſelwirkung

von

Dr. F. F. RUNGE

Profeſſor an der Hochſchule zu Breslau.

Berlin 1850.

Verlag von E. S. Mittler & Sohn.

[Zimmerstraſse No. 84. 85.]

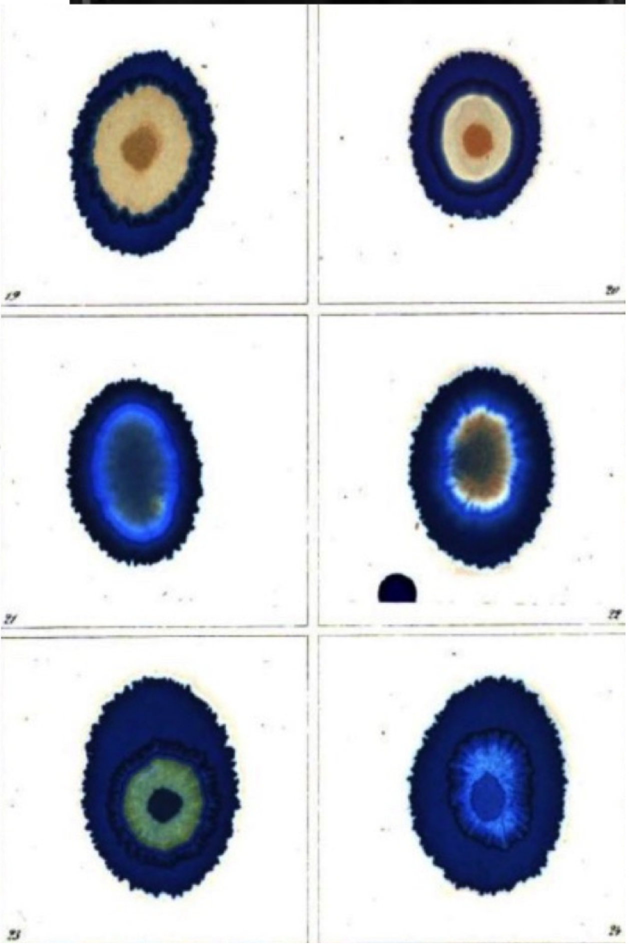
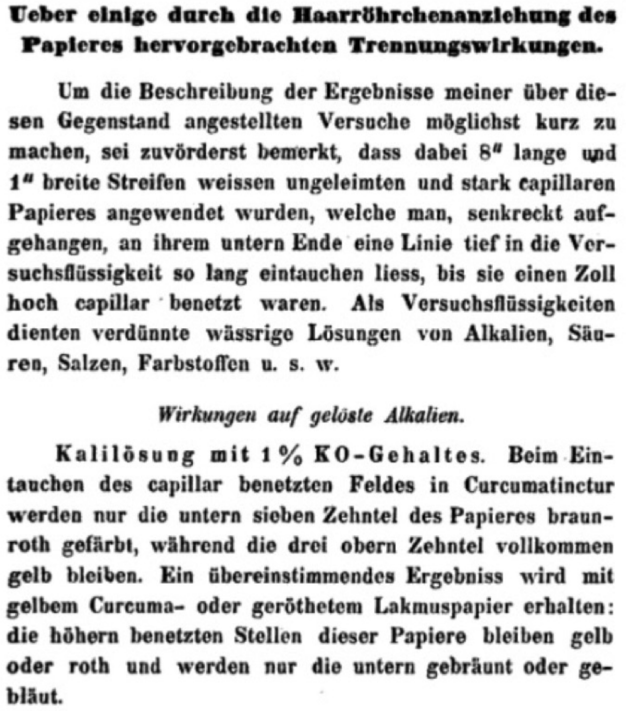


Figure 3.189: Friedlieb Ferdinand Runge developed chemical spot tests or two-dimensional chromatography on filter paper in 1850 [Runge 1850].

Chromatography in filter paper and in capillary tubes (1861)

Christian Friedrich Schönbein (1799–1868)



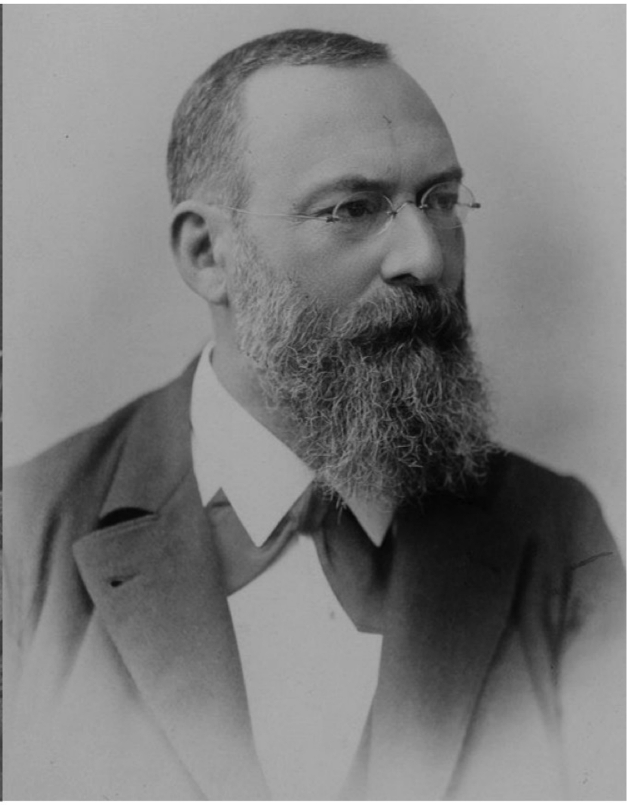
Ueber einige durch die Haarröhrchenanziehung des Papieres hervorgebrachten Trennungswirkungen.

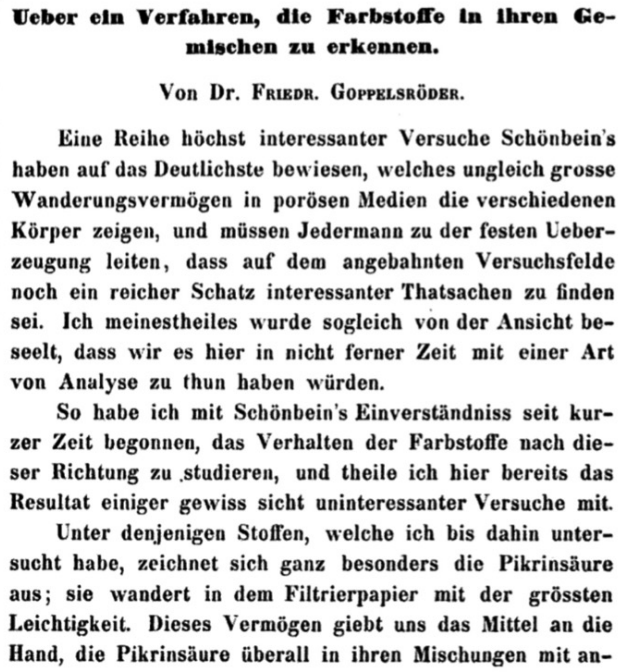
Um die Beschreibung der Ergebnisse meiner über diesen Gegenstand angestellten Versuche möglichst kurz zu machen, sei zuvörderst bemerkt, dass dabei 8″ lange und 1″ breite Streifen weissen ungeleimten und stark capillaren Papieres angewendet wurden, welche man, senkrecht aufgehangen, an ihrem untern Ende eine Linie tief in die Versuchsflüssigkeit so lang eintauchen liess, bis sie einen Zoll hoch capillar benetzt waren. Als Versuchsflüssigkeiten dienten verdünnte wässrige Lösungen von Alkalien, Säuren, Salzen, Farbstoffen u. s. w.

Wirkungen auf gelöste Alkalien.

Kalilösung mit 1% KO-Gehaltes. Beim Eintauchen des capillar benetzten Feldes in Curcumatinctur werden nur die untern sieben Zehntel des Papieres braunroth gefärbt, während die drei obern Zehntel vollkommen gelb bleiben. Ein übereinstimmendes Ergebniss wird mit gelbem Curcuma- oder geröthetem Lakmuspapier erhalten: die höhern benetzten Stellen dieser Papiere bleiben gelb oder roth und werden nur die untern gebräunt oder gebläut.

Friedrich Goppelsröder (1837–1919)





Ueber ein Verfahren, die Farbstoffe in ihren Gemischen zu erkennen.

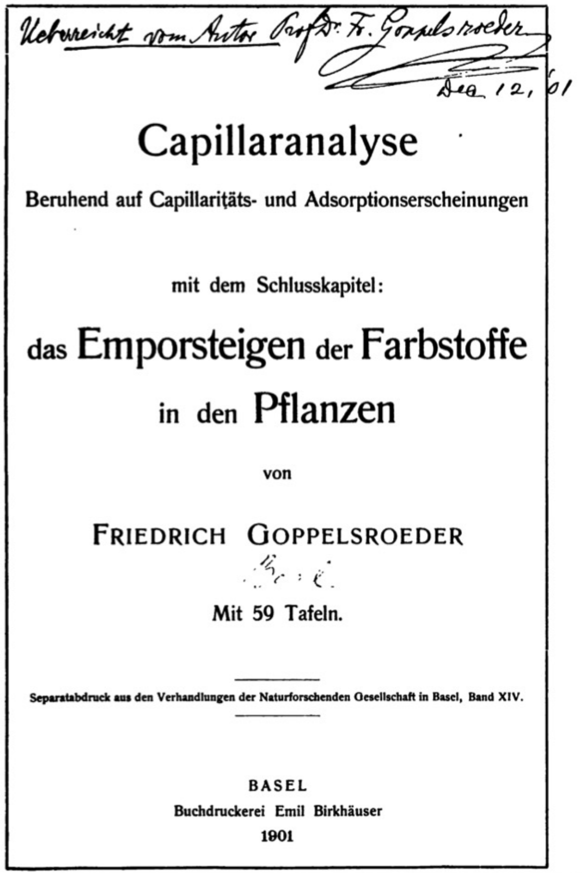
Von Dr. Friedr. Goppelsröder.

Eine Reihe höchst interessanter Versuche Schönbein's haben auf das Deutlichste bewiesen, welches ungleich grosse Wanderungsvermögen in porösen Medien die verschiedenen Körper zeigen, und müssen Jedermann zu der festen Ueberzeugung leiten, dass auf dem angebahnten Versuchsfelde noch ein reicher Schatz interessanter Thatsachen zu finden sei. Ich meinestheiles wurde sogleich von der Ansicht beseelt, dass wir es hier in nicht ferner Zeit mit einer Art von Analyse zu thun haben würden.

So habe ich mit Schönbein's Einverständniss seit kurzer Zeit begonnen, das Verhalten der Farbstoffe nach dieser Richtung zu studieren, und theile ich hier bereits das Resultat einiger gewiss sicht uninteressanter Versuche mit.

Unter denjenigen Stoffen, welche ich bis dahin untersucht habe, zeichnet sich ganz besonders die Pikrinsäure aus; sie wandert in dem Filtrierpapier mit der grössten Leichtigkeit. Dieses Vermögen giebt uns das Mittel an die Hand, die Pikrinsäure überall in ihren Mischungen mit an-

Figure 3.190: Christian Schönbein and Friedrich Goppelsröder developed one-dimensional chromatography in filter paper and in capillary tubes in 1861 [Schönbein 1861; Goppelsröder 1861].



Ueberreicht vom Autor Prof Dr. F. Goppelsroeder
Dec 12, '01

Capillaranalyse

Beruhend auf Capillaritäts- und Adsorptionserscheinungen

mit dem Schlusskapitel:

das Emporsteigen der Farbstoffe in den Pflanzen

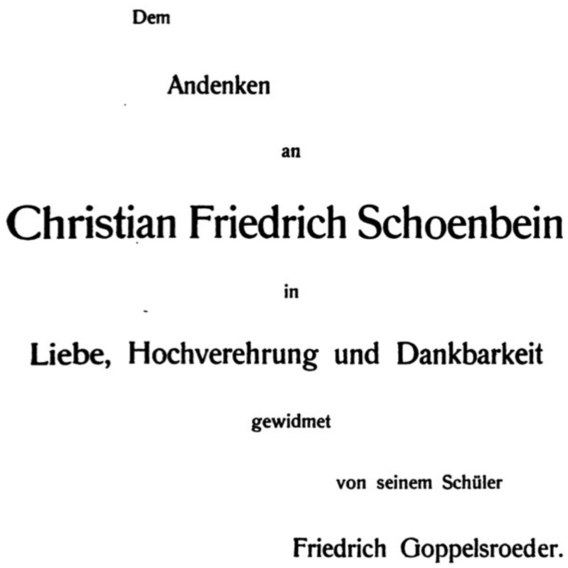
von

FRIEDRICH GOPPELSROEDER

Mit 59 Tafeln.

Separatabdruck aus den Verhandlungen der Naturforschenden Gesellschaft in Basel, Band XIV.

BASEL
Buchdruckerei Emil Birkhäuser
1901



Dem
Andenken
an
Christian Friedrich Schoenbein
in
Liebe, Hochverehrung und Dankbarkeit
gewidmet
von seinem Schüler
Friedrich Goppelsroeder.

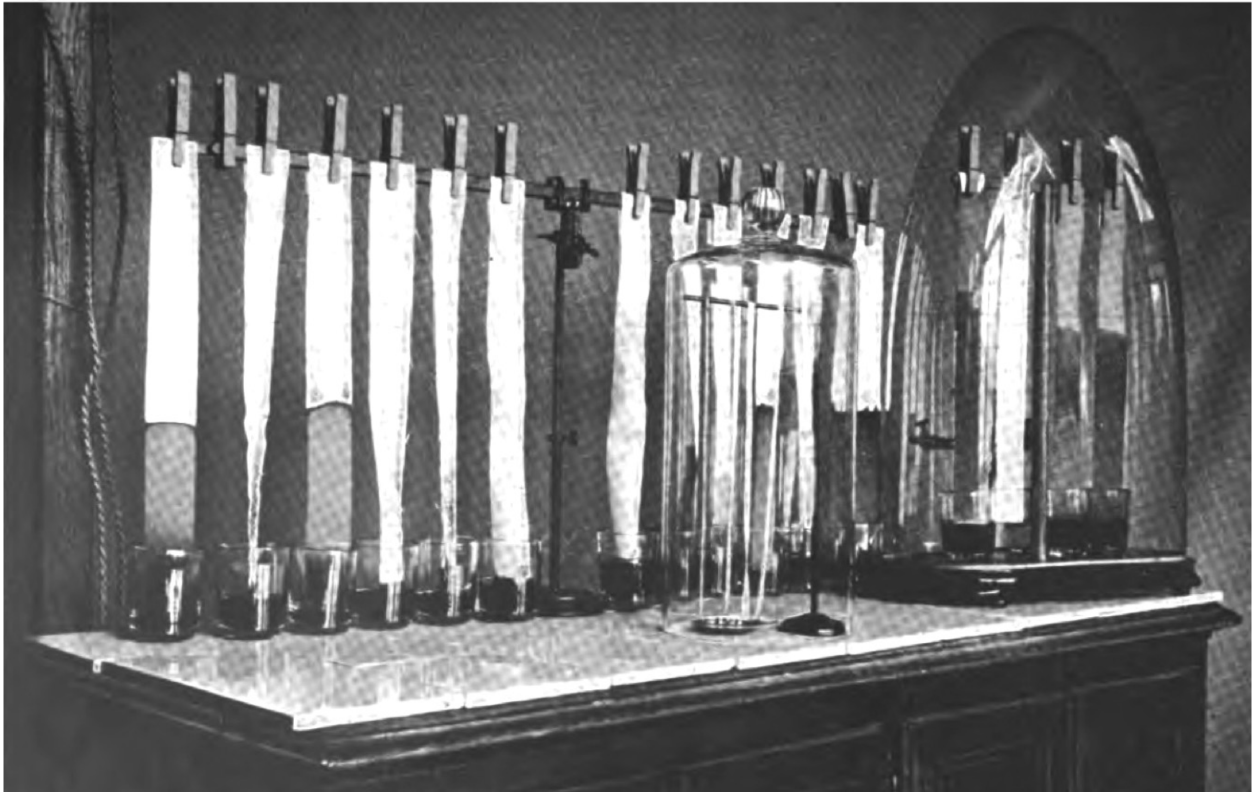


Figure 3.191: Friedrich Goppelsröder continued working to improve and to apply capillary-based chromatography for several decades, including using it to separate and analyze the colored pigments from plant leaves [Goppelsröder 1901].

Chromatography

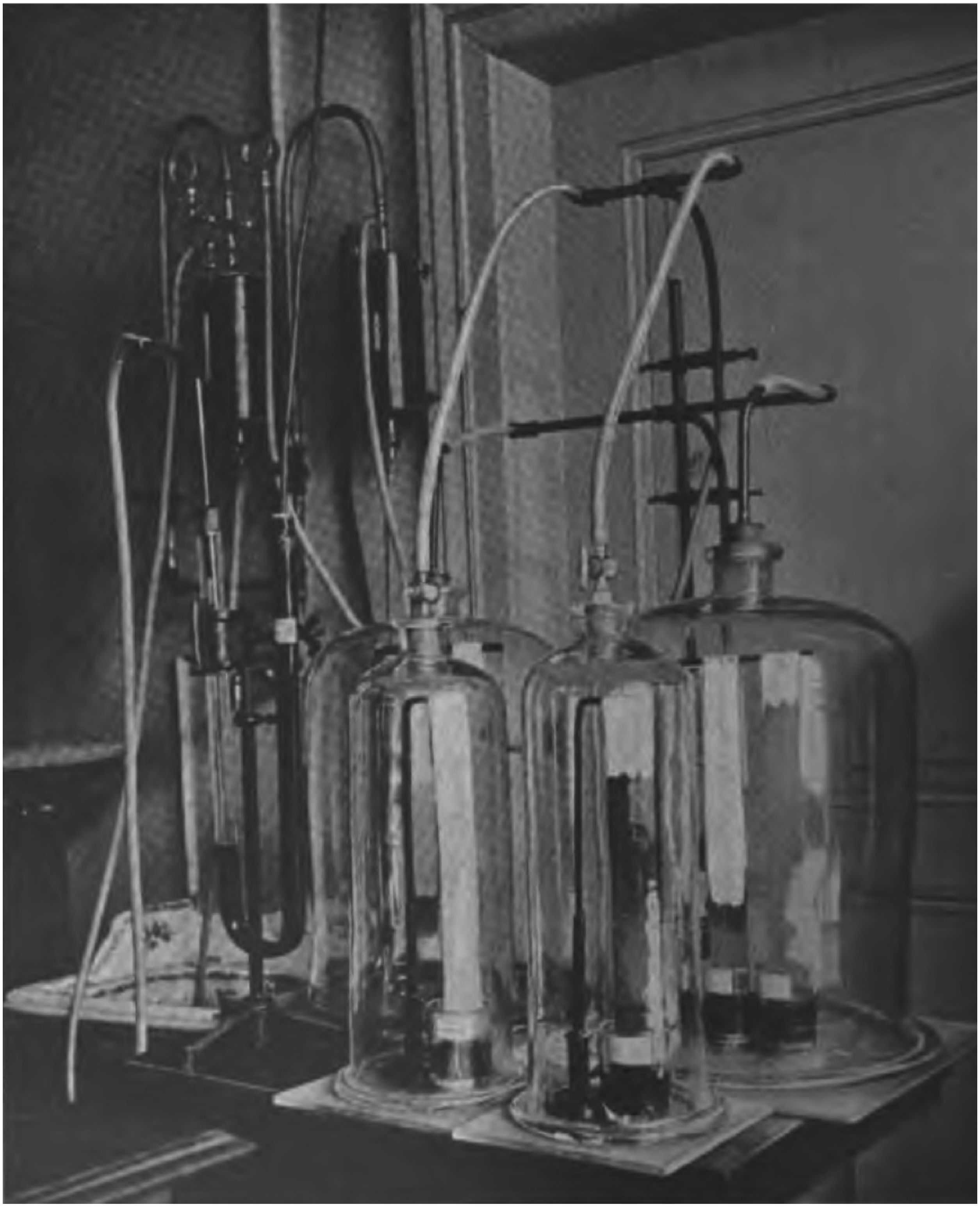


Figure 3.192: Friedrich Goppelsröder continued working to improve and to apply capillary-based chromatography for several decades, including using it to separate and analyze the colored pigments from plant leaves [Goppelsröder 1901].

Chromatography

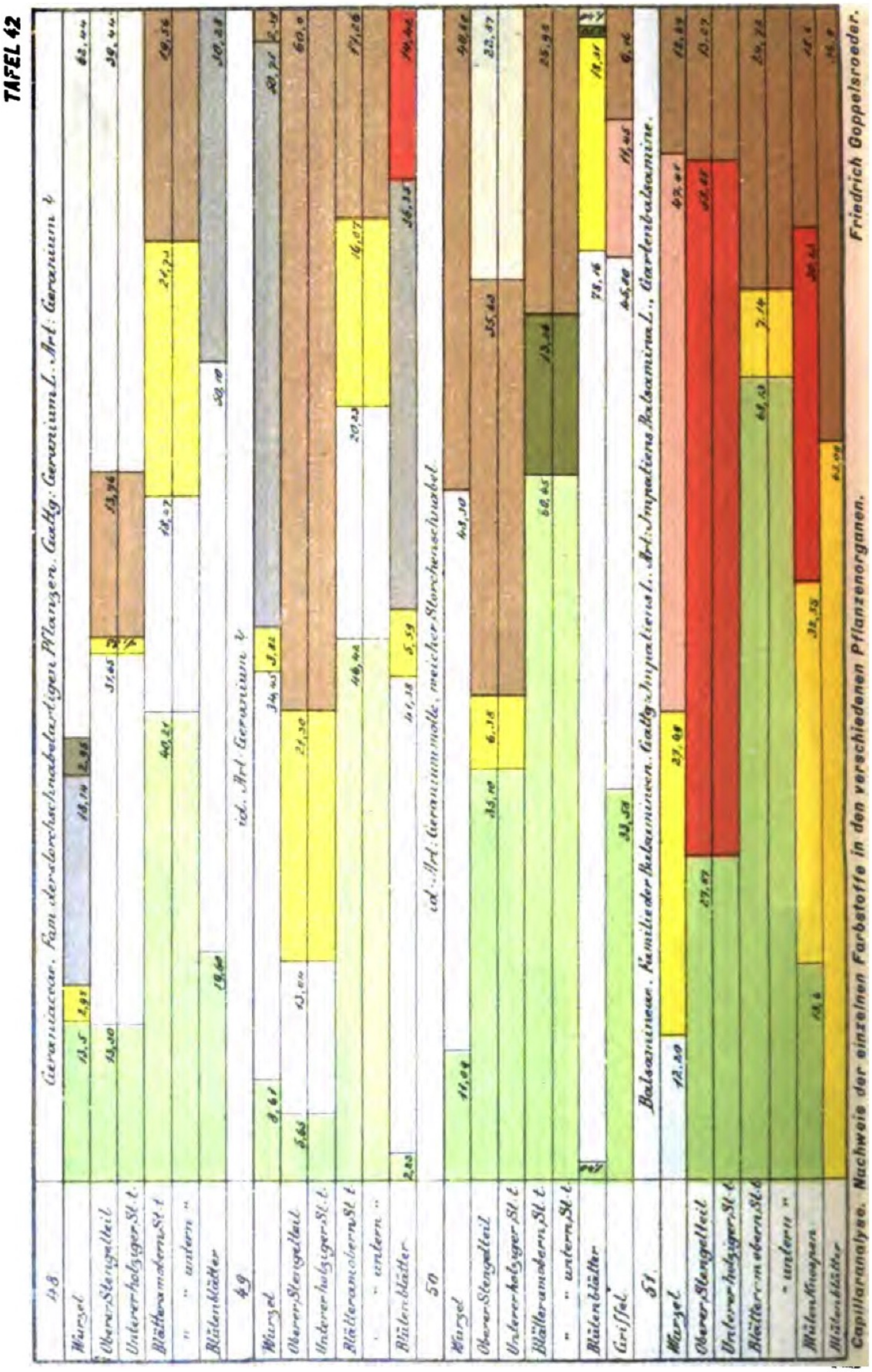


Figure 3.193: Friedrich Goppelsröder continued working to improve and to apply capillary-based chromatography for several decades, including using it to separate and analyze the colored pigments from plant leaves [Goppelsröder 1901].

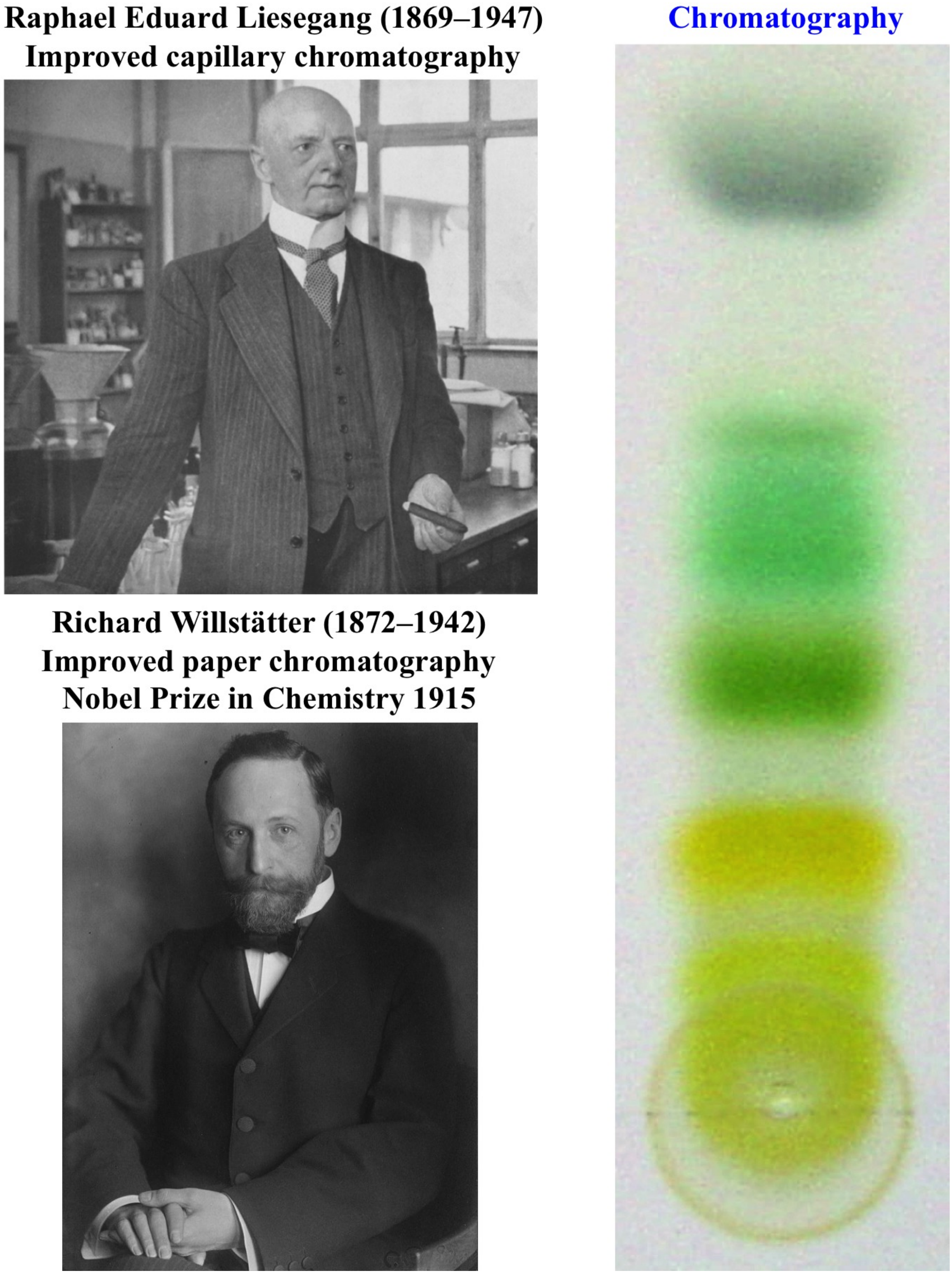
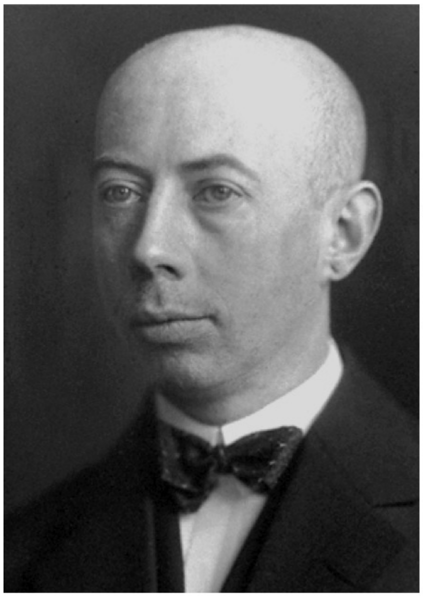
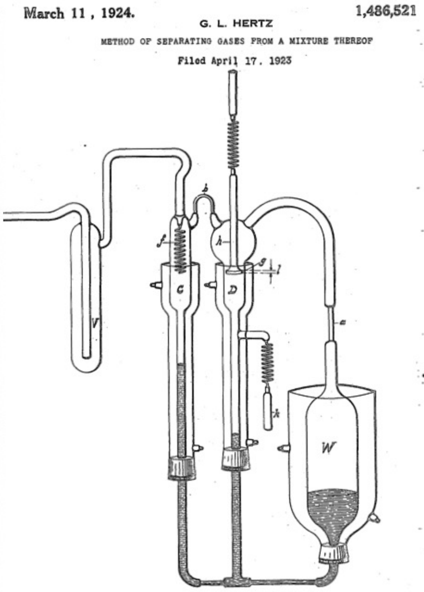

Raphael Eduard Liesegang (1869–1947)
Improved capillary chromatography
Chromatography
Richard Willstätter (1872–1942)
Improved paper chromatography
Nobel Prize in Chemistry 1915

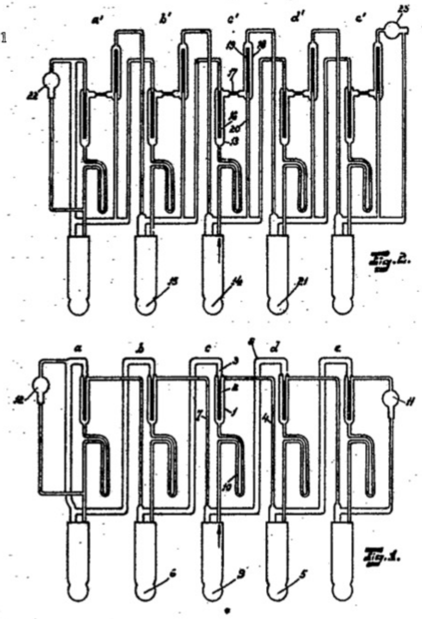
Figure 3.194: Raphael Eduard Liesegang and Richard Willstätter developed and applied improved methods for capillary and paper chromatography.

Gaseous diffusion separation and gas chromatography

Gustav Hertz
(1887–1975)




March 11, 1924.
G. L. HERTZ
1,486,521
METHOD OF SEPARATING GASES FROM A MIXTURE THEREOF
Filed April 17, 1923
W


a'
b'
c'
d'
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a
b
c
d
e
Fig. 2.
Fig. 1.

Erika Cremer (1900–1996)

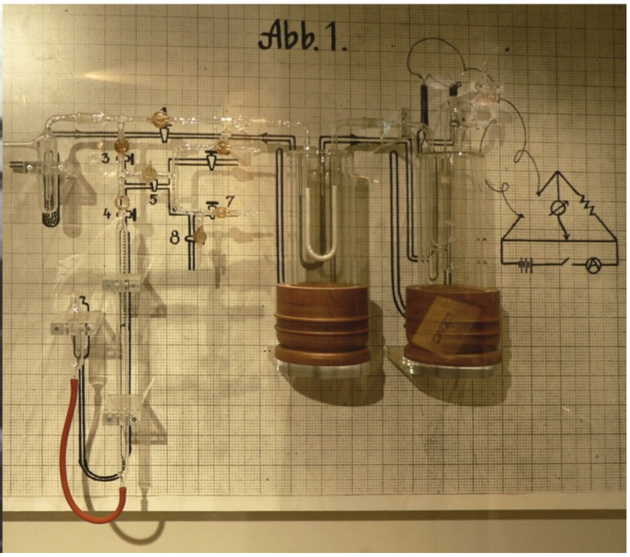


Figure 3.195: Gustav Hertz and Erika Cremer invented the methods of gaseous diffusion separation and gas chromatography.

3.9.2 Colloids

Figure 3.196 illustrates what a colloid is. As opposed to solutions of tiny particles that remain dissolved permanently (such as salt in water), or suspensions of large particles that eventually settle out (such as sand in water), colloids have medium-sized particles that can remain suspended indefinitely within a material (such as fat particles suspended in water as in milk). Some German-speaking scientists who made important contributions to the understanding and application of colloids are shown in Figs. 3.196–3.197.

Georg Bredig (German, 1868–1944) developed colloidal solutions of metals as catalysts.

Herbert Freundlich (German, 1880–1941) studied colloidal stability and coagulation.

Franz Kolb (German, 18??–19??) worked with colloids and invented plasticine modeling clay in 1890.

Robert Havemann (German, 1910–1982) conducted research on colloids. In 1936, he also invented the spectrophotometer, which is now a widely used instrument in biology and chemistry laboratories (p. 2307).

Carl Wilhelm Wolfgang Ostwald (German, 1883–1943) also did important work on colloids.

Hermann Staudinger (German, 1881–1965) studied colloids, macromolecules, and polymers. He found that many substances that had been regarded as colloidal clumps of small molecules were actually composed of macromolecules or polymers. For his discoveries, he won the Nobel Prize in Chemistry in 1953 (p. 474).

Richard Zsigmondy (Austrian, 1865–1929) made a number of important discoveries regarding colloids, and also developed synthetic food products. He won the Nobel Prize in Chemistry 1925 for his work on colloids. Professor H.G. Söderbaum, Secretary of the Royal Swedish Academy of Sciences, stated [https://www.nobelprize.org/prizes/chemistry/1925/ceremony-speech/]:

> Zsigmondy's work has quite simply been pioneering as regards the explanation of the mechanism of the coagulation phenomenon and also as regards the study of the structure of gels. [...]
>
> The brief review given here of some of the most important work of Zsigmondy is necessarily highly incomplete, if not to say fragmentary, but should surely suffice to show how it pioneered the way and opened up new regions in a field of research which had so far been difficult of access, a field which must be recognized as having the very greatest importance for human knowledge. Let us only remember in this connection that all manifestations of organic life are finally bound to the colloidal media of the protoplasm.
>
> This by way of motivation for the decision of the Academy of Sciences to award the Chemistry Nobel Prize for 1925 to Dr. Richard Zsigmondy, Professor of Chemistry at the University of Göttingen, for proving the heterogeneous nature of colloidal solutions and for the methods used which have laid the foundation of modern colloid chemistry.

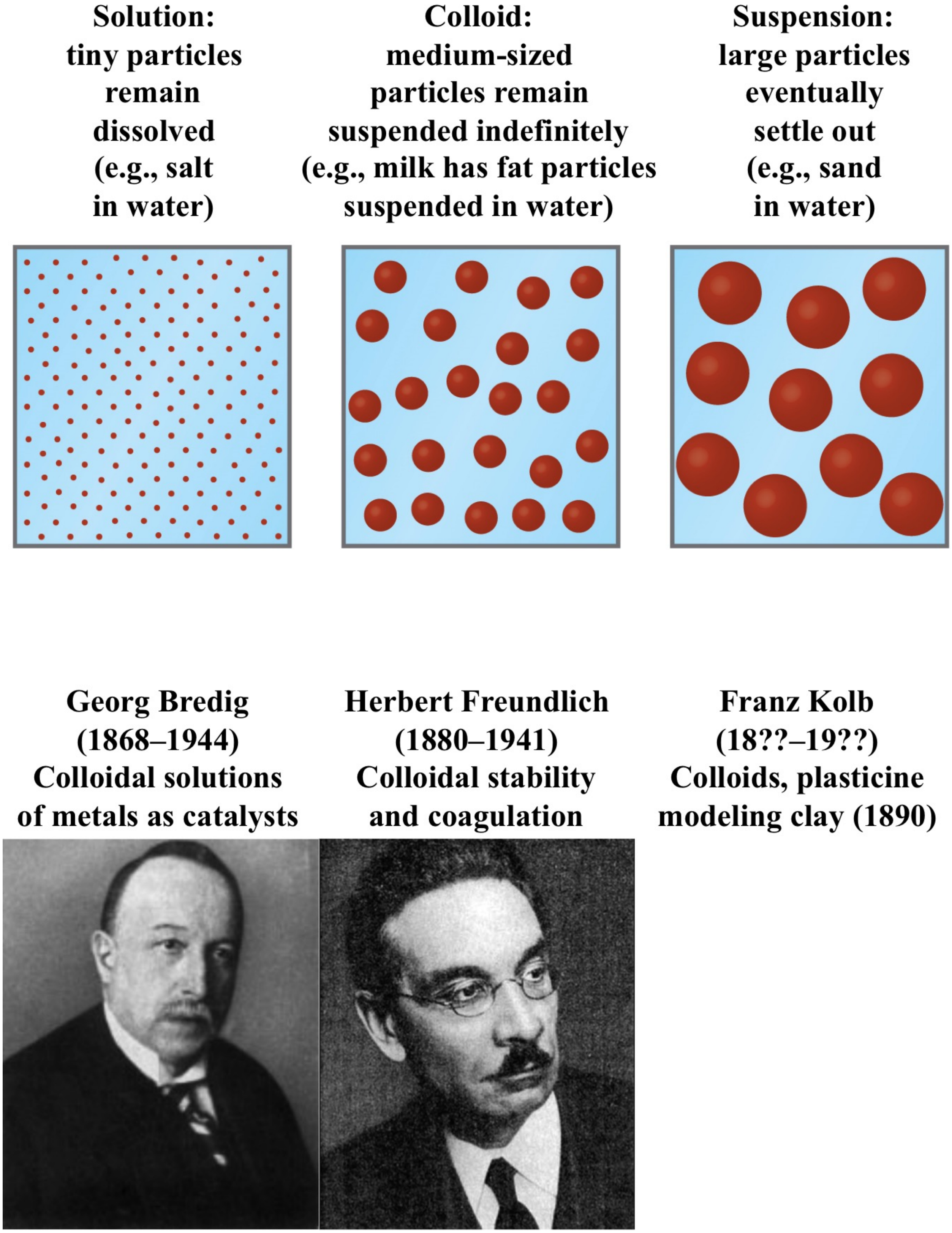
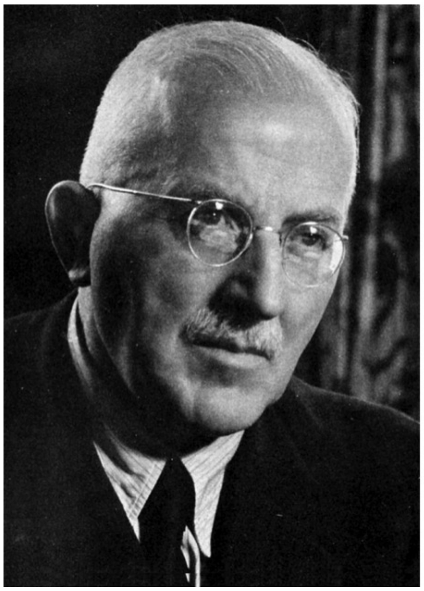

Solution: tiny particles remain dissolved (e.g., salt in water)
Colloid: medium-sized particles remain suspended indefinitely (e.g., milk has fat particles suspended in water)
Suspension: large particles eventually settle out (e.g., sand in water)
Georg Bredig (1868–1944) Colloidal solutions of metals as catalysts
Herbert Freundlich (1880–1941) Colloidal stability and coagulation
Franz Kolb (18??–19??) Colloids, plasticine modeling clay (1890)

Figure 3.196: Colloids have medium-sized particles that can remain suspended indefinitely in a medium, such as the fat particles in milk. Some German-speaking scientists who made important contributions to the understanding and application of colloids included Georg Bredig, Herbert Freundlich, and Franz Kolb.

Robert Havemann (1910–1982) Colloids, spectrophotometer (1936)

Carl Wolfgang Ostwald (1883–1943) Colloids

Hermann Staudinger (1881–1965) Colloids and macromolecules Nobel Prize in Chemistry 1953



Richard Zsigmondy (1865–1929) Colloids, synthetic food products, Nobel Prize in Chemistry 1925

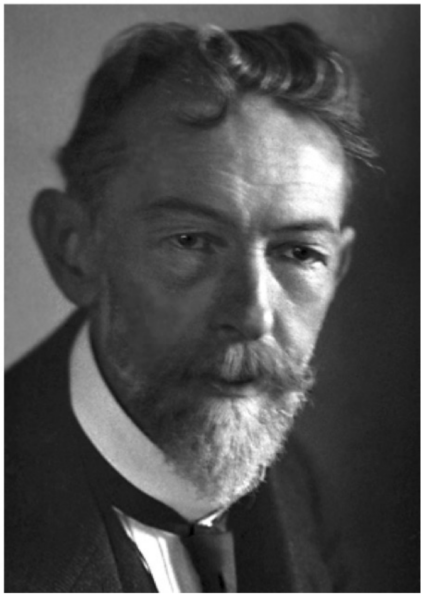


Figure 3.197: Other German-speaking scientists who made important contributions to the understanding and application of colloids included Robert Havemann, Carl Wolfgang Ostwald, Hermann Staudinger, and Richard Zsigmondy.

3.9.3 Synthetic Lubricating Oils

During the period 1927–1945, Hermann Zorn (German, 1896–1983) led a large group at I.G. Farben Ludwigshafen that invented and mass-produced synthetic lubricating oils and additives [Jantzen 1996a, 1996b]. As a result of their work, Zorn and his coworkers filed a large number of patents worldwide; see Figs. 3.198–3.199 for some examples. Some of their patents were approved and issued in the 1930s, but many were not finally approved and issued until after World War II.

In addition to Zorn's group, several other groups of German-speaking scientists developed various types of synthetic lubricating oils during the same time period, as documented in BIOS 1611, *Major Developments in Synthetic Lubricants and Additives in Germany*, pp. 92–93 and 99–100:

> In the investigation of the German oil industry and interrogation of the leading personnel, certain facts have come to light which show that Germany had a well-developed synthetic lubricating oil industry already in being, and undergoing rapid expansion. Although from a quantity basis the products obtained from natural petroleum resources predominated, it would appear that from the quality standpoint the synthetic production was of most importance. [...]
>
> As would be expected, the outstanding developments were made under the auspices of the I.G. Farbenindustrie. It would appear that as early as 1927 a department under Dr. Zorn at Ludwigshafen commenced research on the polymerisation of olefines for the production of lubricants, this work being coupled with an investigation of the possible constituents of lubricating oils by synthesis of likely hydrocarbons; this work was similar to but apparently much wider in scope than that of Mikeska.
>
> By 1936 the process based on the polymerisation of ethylene was developed and production started in 1937 at Leuna, and later at Schkopau. By Government order this development was kept secret. Similar processes but based on the production of olefines by wax cracking were developed and operated by the I.G. and Vakuum at Pölitz and Rhenania Ossag (Shell) at Harburg. [...]
>
> Besides the above developments, Ruhrchemie produced about 1500 tons/month of a synthetic automotive engine oil (based on Fischer-Tropsch products) of a rather unsaturated, easily oxidisable character, which was used by the Army[...] [...] Rheinpreussen A.G., Homberg produced spindle oil, machine oil and steam cylinder oil, each of which found application in the various Services, particularly the Navy, where the aromatic character of the products was found beneficial in diesel engine lubricants. Other low pour steam cylinder oils were produced at Pölitz and Ludwigshafen, the latter by the Paraflow synthesis. [...]
>
> Reviewing the above topics as a whole it is apparent that in the synthetic field particularly, the Germans were ahead of the Allied developments, especially in their widespread application of the adipic ester type of lubricant. [...] Certainly some of the uses already explored experimentally open up very interesting fields for development, particularly in the lubrication of internal combustion engines.

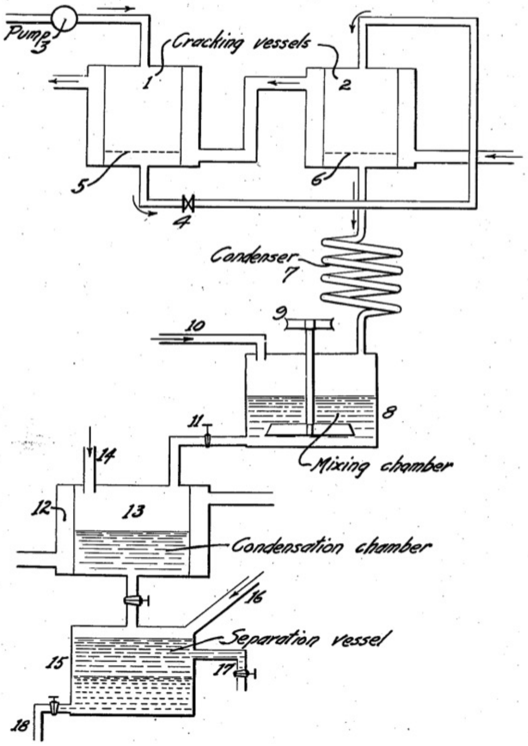
The synthetic lubricating oils and additives that were invented by Zorn and other German-speaking scientists were extensively studied by Allied countries [e.g., BIOS 373; BIOS 1611; CIOS XXXII-68; CIOS XXXII-94; CIOS XXXII-107.] Now they are widely used around the world.

Hermann Zorn
(1896–1983)
led a group at
I.G. Farben
Ludwigshafen
that invented and
mass-produced
synthetic
lubricating oils
and additives
(1927–1945)

Dec. 5, 1933. W. PUNGS ET AL **1,938,088**

PRODUCTION OF HIGH QUALITY LUBRICATING OILS

Filed Jan. 30, 1931


Pump 3
Cracking vessels
1
2
5
6
4
Condenser 7
9
10
8
11
Mixing chamber
14
12
13
Condensation chamber
16
Separation vessel
15
17
18

July 10, 1934. H. ZORN ET AL **1,965,952**

PRODUCTION OF HIGH QUALITY LUBRICATING OILS

Filed Feb. 28, 1931

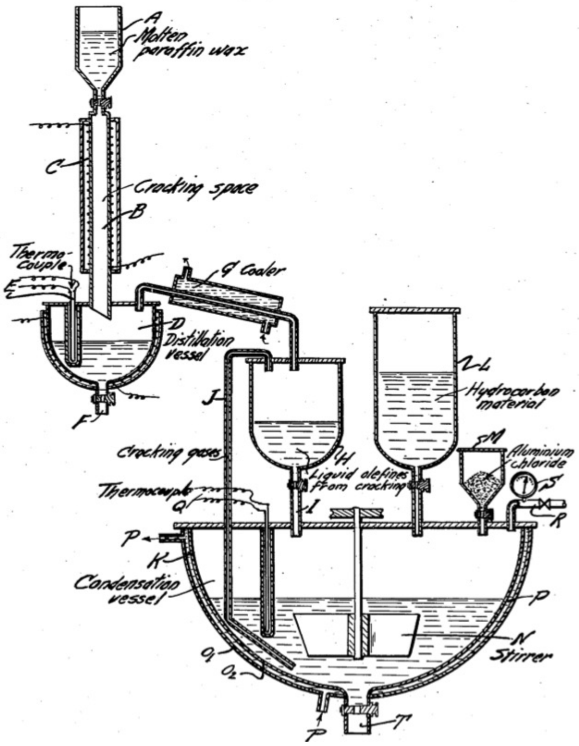
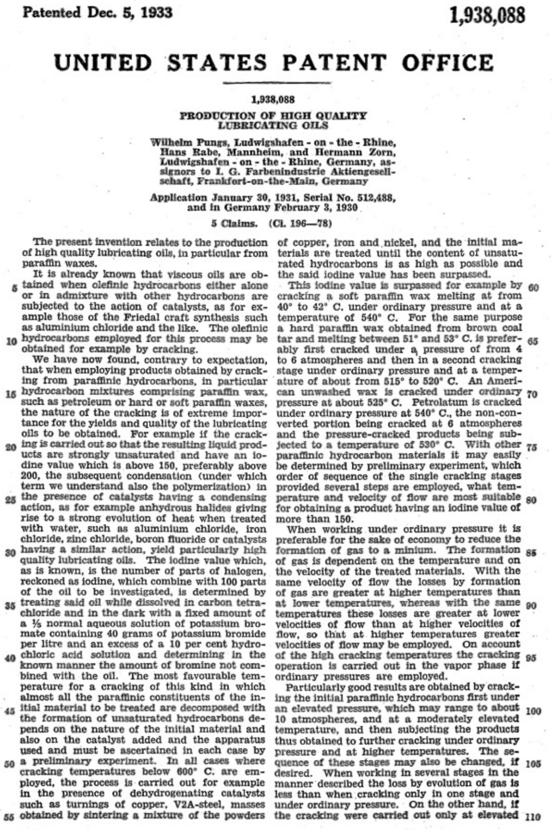

A
Molten paraffin wax
C
Cracking space
B
Thermo-couple
E
G Cooler
D
Distillation vessel
F
J
L
Hydrocarbon material
M
Aluminium chloride
S
R
Cracking gases
H
Liquid olefines from cracking
Thermocouple
Q
I
P
K
Condensation vessel
P
N
Stirrer
O_1
O_2
P
T

Figure 3.198: Hermann Zorn led a group at I.G. Farben Ludwigshafen that invented and mass-produced synthetic lubricating oils and additives during the period 1927–1945.



Patented Dec. 5, 1933 **1,938,088**

UNITED STATES PATENT OFFICE

1,938,088

PRODUCTION OF HIGH QUALITY LUBRICATING OILS

Wilhelm Pungs, Ludwigshafen - on - the - Rhine, Hans Rabe, Mannheim, and Hermann Zorn, Ludwigshafen - on - the - Rhine, Germany, assignors to I. G. Farbenindustrie Aktiengesellschaft, Frankfort-on-the-Main, Germany

Application January 30, 1931, Serial No. 512,488, and in Germany February 3, 1930

5 Claims. (Cl. 196—78)

The present invention relates to the production of high quality lubricating oils, in particular from paraffin waxes.

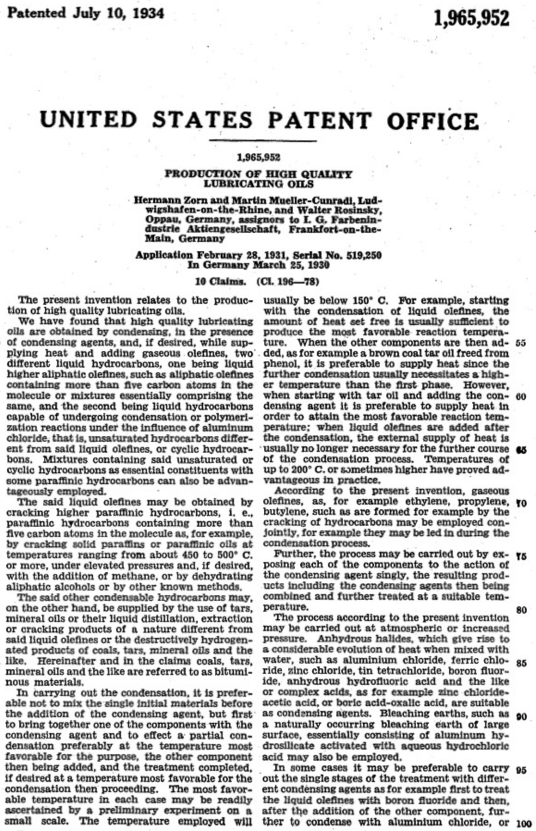
It is already known that viscous oils are obtained when olefinic hydrocarbons either alone or in admixture with other hydrocarbons are subjected to the action of catalysts, as for example those of the Friedal craft synthesis such as aluminium chloride and the like. The olefinic hydrocarbons employed for this process may be obtained for example by cracking.

We have now found, contrary to expectation, that when employing products obtained by cracking from paraffinic hydrocarbons, in particular hydrocarbon mixtures comprising paraffin wax, such as petroleum or hard or soft paraffin waxes, the nature of the cracking is of extreme importance for the yields and quality of the lubricating oils to be obtained. For example if the cracking is carried out so that the resulting liquid products are strongly unsaturated and have an iodine value which is above 150, preferably above 200, the subsequent condensation (under which term we understand also the polymerization) in the presence of catalysts having a condensing action, as for example anhydrous halides giving rise to a strong evolution of heat when treated with water, such as aluminium chloride, iron chloride, zinc chloride, boron fluoride or catalysts having a similar action, yield particularly high quality lubricating oils. The iodine value which, as is known, is the number of parts of halogen, reckoned as iodine, which combine with 100 parts of the oil to be investigated, is determined by treating said oil while dissolved in carbon tetrachloride and in the dark with a fixed amount of a ⅕ normal aqueous solution of potassium bromate containing 40 grams of potassium bromide per litre and an excess of a 10 per cent hydrochloric acid solution and determining in the known manner the amount of bromine not combined with the oil. The most favourable temperature for a cracking of this kind in which almost all the paraffinic constituents of the initial material to be treated are decomposed with the formation of unsaturated hydrocarbons depends on the nature of the initial material and also on the catalyst added and the apparatus used and must be ascertained in each case by a preliminary experiment. In all cases where cracking temperatures below 600° C. are employed, the process is carried out for example in the presence of dehydrogenating catalysts such as turnings of copper, V2A-steel, masses obtained by sintering a mixture of the powders of copper, iron and nickel, and the initial materials are treated until the content of unsaturated hydrocarbons is as high as possible and the said iodine value has been surpassed.

This iodine value is surpassed for example by cracking a soft paraffin wax melting at from 40° to 42° C. under ordinary pressure and at a temperature of 540° C. For the same purpose a hard paraffin wax obtained from brown coal tar and melting between 51° and 53° C. is preferably first cracked under a pressure of from 4 to 6 atmospheres and then in a second cracking stage under ordinary pressure and at a temperature of about from 515° to 520° C. An American unwashed wax is cracked under ordinary pressure at about 525° C. Petrolatum is cracked under ordinary pressure at 540° C., the non-converted portion being cracked at 6 atmospheres and the pressure-cracked products being subjected to a temperature of 530° C. With other paraffinic hydrocarbon materials it may easily be determined by preliminary experiment, which order of sequence of the single cracking stages provided several steps are employed, what temperature and velocity of flow are most suitable for obtaining a product having an iodine value of more than 150.

When working under ordinary pressure it is preferable for the sake of economy to reduce the formation of gas to a minium. The formation of gas is dependent on the temperature and on the velocity of the treated materials. With the same velocity of flow the losses by formation of gas are greater at higher temperatures than at lower temperatures, whereas with the same temperatures these losses are greater at lower velocities of flow than at higher velocities of flow, so that at higher temperatures greater velocities of flow may be employed. On account of the high cracking temperatures the cracking operation is carried out in the vapor phase if ordinary pressures are employed.

Particularly good results are obtained by cracking the initial paraffinic hydrocarbons first under an elevated pressure, which may range to about 10 atmospheres, and at a moderately elevated temperature, and then subjecting the products thus obtained to further cracking under ordinary pressure and at higher temperatures. The sequence of these stages may also be changed, if desired. When working in several stages in the manner described the loss by evolution of gas is less than when cracking only in one stage and under ordinary pressure. On the other hand, if the cracking were carried out only at elevated



Patented July 10, 1934 **1,965,952**

UNITED STATES PATENT OFFICE

1,965,952

PRODUCTION OF HIGH QUALITY LUBRICATING OILS

Hermann Zorn and Martin Mueller-Cunradi, Ludwigshafen-on-the-Rhine, and Walter Rosinsky, Oppau, Germany, assignors to I. G. Farbenindustrie Aktiengesellschaft, Frankfort-on-the-Main, Germany

Application February 28, 1931, Serial No. 519,250 In Germany March 25, 1930

10 Claims. (Cl. 196—78)

The present invention relates to the production of high quality lubricating oils.

We have found that high quality lubricating oils are obtained by condensing, in the presence of condensing agents, and, if desired, while supplying heat and adding gaseous olefines, two different liquid hydrocarbons, one being liquid higher aliphatic olefines, such as aliphatic olefines containing more than five carbon atoms in the molecule or mixtures essentially comprising the same, and the second being liquid hydrocarbons capable of undergoing condensation or polymerization reactions under the influence of aluminum chloride, that is, unsaturated hydrocarbons different from said liquid olefines, or cyclic hydrocarbons. Mixtures containing said unsaturated or cyclic hydrocarbons as essential constituents with some paraffinic hydrocarbons can also be advantageously employed.

The said liquid olefines may be obtained by cracking higher paraffinic hydrocarbons, i. e., paraffinic hydrocarbons containing more than five carbon atoms in the molecule as, for example, by cracking solid paraffins or paraffinic oils at temperatures ranging from about 450 to 500° C. or more, under elevated pressures and, if desired, with the addition of methane, or by dehydrating aliphatic alcohols or by other known methods.

The said other condensable hydrocarbons may, on the other hand, be supplied by the use of tars, mineral oils or their liquid distillation, extraction or cracking products of a nature different from said liquid olefines or the destructively hydrogenated products of coals, tars, mineral oils and the like. Hereinafter and in the claims coals, tars, mineral oils and the like are referred to as bituminous materials.

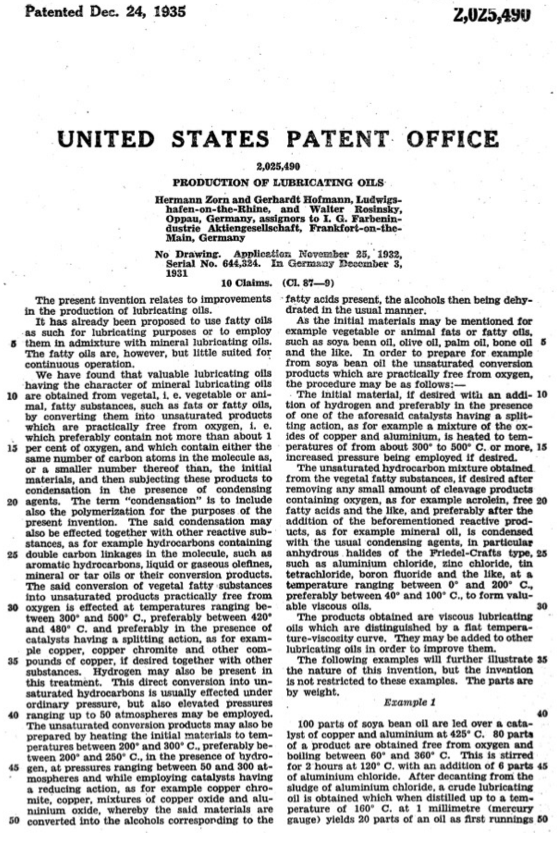
In carrying out the condensation, it is preferable not to mix the single initial materials before the addition of the condensing agent, but first to bring together one of the components with the condensing agent and to effect a partial condensation preferably at the temperature most favorable for the purpose, the other component then being added, and the treatment completed, if desired at a temperature most favorable for the condensation then proceeding. The most favorable temperature in each case may be readily ascertained by a preliminary experiment on a small scale. The temperature employed will usually be below 150° C. For example, starting with the condensation of liquid olefines, the amount of heat set free is usually sufficient to produce the most favorable reaction temperature. When the other components are then added, as for example a brown coal tar oil freed from phenol, it is preferable to supply heat since the further condensation usually necessitates a higher temperature than the first phase. However, when starting with tar oil and adding the condensing agent it is preferable to supply heat in order to attain the most favorable reaction temperature; when liquid olefines are added after the condensation, the external supply of heat is usually no longer necessary for the further course of the condensation process. Temperatures of up to 200° C. or sometimes higher have proved advantageous in practice.

According to the present invention, gaseous olefines, as, for example ethylene, propylene, butylene, such as are formed for example by the cracking of hydrocarbons may be employed conjointly, for example they may be led in during the condensation process.

Further, the process may be carried out by exposing each of the components to the action of the condensing agent singly, the resulting products including the condensing agents then being combined and further treated at a suitable temperature.

The process according to the present invention may be carried out at atmospheric or increased pressure. Anhydrous halides, which give rise to a considerable evolution of heat when mixed with water, such as aluminium chloride, ferric chloride, zinc chloride, tin tetrachloride, boron fluoride, anhydrous hydrofluoric acid and the like or complex acids, as for example zinc chloride-acetic acid, or boric acid-oxalic acid, are suitable as condensing agents. Bleaching earths, such as a naturally occurring bleaching earth of large surface, essentially consisting of aluminum hydrosilicate activated with aqueous hydrochloric acid may also be employed.

In some cases it may be preferable to carry out the single stages of the treatment with different condensing agents as for example first to treat the liquid olefines with boron fluoride and then, after the addition of the other component, further to condense with aluminium chloride, or



Patented Dec. 24, 1935 **2,025,490**

UNITED STATES PATENT OFFICE

2,025,490

PRODUCTION OF LUBRICATING OILS

Hermann Zorn and Gerhardt Hofmann, Ludwigshafen-on-the-Rhine, and Walter Rosinsky, Oppau, Germany, assignors to I. G. Farbenindustrie Aktiengesellschaft, Frankfort-on-the-Main, Germany

No Drawing. Application November 25, 1932, Serial No. 644,324. In Germany December 3, 1931

10 Claims. (Cl. 87—9)

The present invention relates to improvements in the production of lubricating oils.

It has already been proposed to use fatty oils as such for lubricating purposes or to employ them in admixture with mineral lubricating oils. The fatty oils are, however, but little suited for continuous operation.

We have found that valuable lubricating oils having the character of mineral lubricating oils are obtained from vegetal, i. e. vegetable or animal, fatty substances, such as fats or fatty oils, by converting them into unsaturated products which are practically free from oxygen, i. e. which preferably contain not more than about 1 per cent of oxygen, and which contain either the same number of carbon atoms in the molecule as, or a smaller number thereof than, the initial materials, and then subjecting these products to condensation in the presence of condensing agents. The term "condensation" is to include also the polymerization for the purposes of the present invention. The said condensation may also be effected together with other reactive substances, as for example hydrocarbons containing double carbon linkages in the molecule, such as aromatic hydrocarbons, liquid or gaseous olefines, mineral or tar oils or their conversion products. The said conversion of vegetal fatty substances into unsaturated products practically free from oxygen is effected at temperatures ranging between 300° and 500° C., preferably between 420° and 480° C. and preferably in the presence of catalysts having a splitting action, as for example copper, copper chromite and other compounds of copper, if desired together with other substances. Hydrogen may also be present in this treatment. This direct conversion into unsaturated hydrocarbons is usually effected under ordinary pressure, but also elevated pressures ranging up to 50 atmospheres may be employed. The unsaturated conversion products may also be prepared by heating the initial materials to temperatures between 200° and 300° C., preferably between 200° and 250° C., in the presence of hydrogen, at pressures ranging between 50 and 300 atmospheres and while employing catalysts having a reducing action, as for example copper chromite, copper, mixtures of copper oxide and aluminium oxide, whereby the said materials are converted into the alcohols corresponding to the fatty acids present, the alcohols then being dehydrated in the usual manner.

As the initial materials may be mentioned for example vegetable or animal fats or fatty oils, such as soya bean oil, olive oil, palm oil, bone oil and the like. In order to prepare for example from soya bean oil the unsaturated conversion products which are practically free from oxygen, the procedure may be as follows:—

The initial material, if desired with an addition of hydrogen and preferably in the presence of one of the aforesaid catalysts having a splitting action, as for example a mixture of the oxides of copper and aluminium, is heated to temperatures of from about 300° to 500° C. or more, increased pressure being employed if desired.

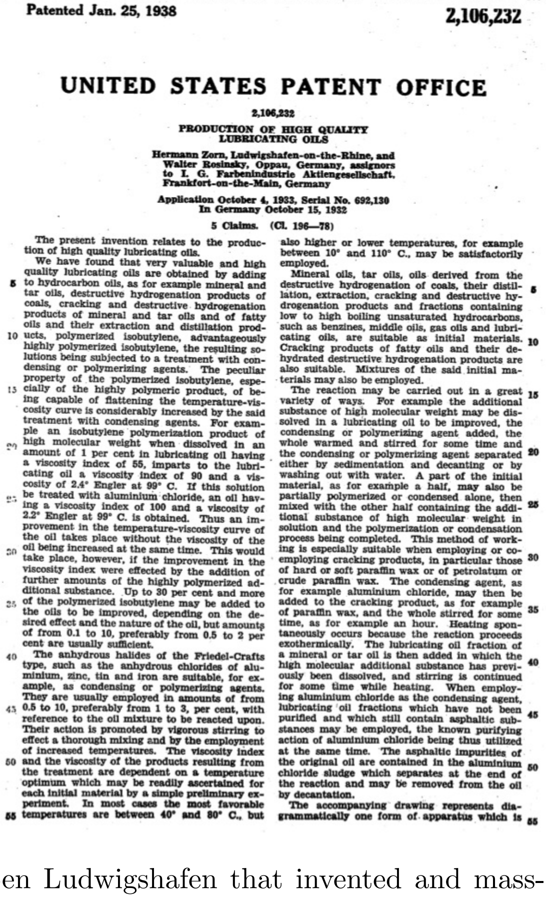
The unsaturated hydrocarbon mixture obtained from the vegetal fatty substances, if desired after removing any small amount of cleavage products containing oxygen, as for example acrolein, free fatty acids and the like, and preferably after the addition of the beforementioned reactive products, as for example mineral oil, is condensed with the usual condensing agents, in particular anhydrous halides of the Friedel-Crafts type, such as aluminium chloride, zinc chloride, tin tetrachloride, boron fluoride and the like, at a temperature ranging between 0° and 200° C., preferably between 40° and 100° C., to form valuable viscous oils.

The products obtained are viscous lubricating oils which are distinguished by a flat temperature-viscosity curve. They may be added to other lubricating oils in order to improve them.

The following examples will further illustrate the nature of this invention, but the invention is not restricted to these examples. The parts are by weight.

Example 1

100 parts of soya bean oil are led over a catalyst of copper and aluminium at 425° C. 80 parts of a product are obtained free from oxygen and boiling between 60° and 360° C. This is stirred for 2 hours at 120° C. with an addition of 6 parts of aluminium chloride. After decanting from the sludge of aluminium chloride, a crude lubricating oil is obtained which when distilled up to a temperature of 160° C. at 1 millimetre (mercury gauge) yields 20 parts of an oil as first runnings



Patented Jan. 25, 1938 **2,106,232**

UNITED STATES PATENT OFFICE

2,106,232

PRODUCTION OF HIGH QUALITY LUBRICATING OILS

Hermann Zorn, Ludwigshafen-on-the-Rhine, and Walter Rosinsky, Oppau, Germany, assignors to I. G. Farbenindustrie Aktiengesellschaft, Frankfort-on-the-Main, Germany

Application October 4, 1933, Serial No. 692,130 In Germany October 15, 1932

5 Claims. (Cl. 196—78)

The present invention relates to the production of high quality lubricating oils.

We have found that very valuable and high quality lubricating oils are obtained by adding to hydrocarbon oils, as for example mineral and tar oils, destructive hydrogenation products of coals, cracking and destructive hydrogenation products of mineral and tar oils and of fatty oils and their extraction and distillation products, polymerized isobutylene, advantageously highly polymerized isobutylene, the resulting solutions being subjected to a treatment with condensing or polymerizing agents. The peculiar property of the polymerized isobutylene, especially of the highly polymeric product, of being capable of flattening the temperature-viscosity curve is considerably increased by the said treatment with condensing agents. For example an isobutylene polymerization product of high molecular weight when dissolved in an amount of 1 per cent in lubricating oil having a viscosity index of 55, imparts to the lubricating oil a viscosity index of 90 and a viscosity of 2.4° Engler at 99° C. If this solution be treated with aluminium chloride, an oil having a viscosity index of 100 and a viscosity of 2.2° Engler at 99° C. is obtained. Thus an improvement in the temperature-viscosity curve of the oil takes place without the viscosity of the oil being increased at the same time. This would take place, however, if the improvement in the viscosity index were effected by the addition of further amounts of the highly polymerized additional substance. Up to 30 per cent and more of the polymerized isobutylene may be added to the oils to be improved, depending on the desired effect and the nature of the oil, but amounts of from 0.1 to 10, preferably from 0.5 to 2 per cent are usually sufficient.

The anhydrous halides of the Friedel-Crafts type, such as the anhydrous chlorides of aluminium, zinc, tin and iron are suitable, for example, as condensing or polymerizing agents. They are usually employed in amounts of from 0.5 to 10, preferably from 1 to 3, per cent, with reference to the oil mixture to be reacted upon. Their action is promoted by vigorous stirring to effect a thorough mixing and by the employment of increased temperatures. The viscosity index and the viscosity of the products resulting from the treatment are dependent on a temperature optimum which may be readily ascertained for each initial material by a simple preliminary experiment. In most cases the most favorable temperatures are between 40° and 80° C., but also higher or lower temperatures, for example between 10° and 110° C., may be satisfactorily employed.

Mineral oils, tar oils, oils derived from the destructive hydrogenation of coals, their distillation, extraction, cracking and destructive hydrogenation products and fractions containing low to high boiling unsaturated hydrocarbons, such as benzines, middle oils, gas oils and lubricating oils, are suitable as initial materials. Cracking products of fatty oils and their dehydrated destructive hydrogenation products are also suitable. Mixtures of the said initial materials may also be employed.

The reaction may be carried out in a great variety of ways. For example the additional substance of high molecular weight may be dissolved in a lubricating oil to be improved, the condensing or polymerizing agent added, the whole warmed and stirred for some time and the condensing or polymerizing agent separated either by sedimentation and decanting or by washing out with water. A part of the initial material, as for example a half, may also be partially polymerized or condensed alone, then mixed with the other half containing the additional substance of high molecular weight in solution and the polymerization or condensation process being completed. This method of working is especially suitable when employing or co-employing cracking products, in particular those of hard or soft paraffin wax or of petrolatum or crude paraffin wax. The condensing agent, as for example aluminium chloride, may then be added to the cracking product, as for example of paraffin wax, and the whole stirred for some time, as for example an hour. Heating spontaneously occurs because the reaction proceeds exothermically. The lubricating oil fraction of a mineral or tar oil is then added in which the high molecular additional substance has previously been dissolved, and stirring is continued for some time while heating. When employing aluminium chloride as the condensing agent, lubricating oil fractions which have not been purified and which still contain asphaltic substances may be employed, the known purifying action of aluminium chloride being thus utilized at the same time. The asphaltic impurities of the original oil are contained in the aluminium chloride sludge which separates at the end of the reaction and may be removed from the oil by decantation.

The accompanying drawing represents diagrammatically one form of apparatus which is

Figure 3.199: Hermann Zorn led a group at I.G. Farben Ludwigshafen that invented and mass-produced synthetic lubricating oils and additives during the period 1927–1945.

3.9.4 Synthetic Detergents and Paper Recycling

Traditional soap-making requires animal fat. Even during peacetime and certainly during wartime, most animal fat in the German-speaking world was needed for cooking purposes. Therefore it was in short supply for soap, and there was a strong incentive to find synthetic chemical alternatives. German-speaking chemists developed both inorganic and organic detergents using methods of direct chemical synthesis.[20] Such synthetic detergents are now used worldwide, since they proved to have superior properties and lower production costs compared to traditional soaps.

In 1876, Friedrich (Fritz) Henkel (German, 1848–1930) founded the Henkel & Cie. soap company and began producing the first synthetic inorganic detergent powder, a mixture of sodium carbonate for bleaching and sodium silicate for abrasive cleaning. See Fig. 3.200. Later Henkel's sons joined the company; in particular, his third son, Hugo Henkel (German, 1881–1952), obtained a Ph.D. in chemistry and became the head chemist for the Henkel company. In 1907, Hugo Henkel invented and began selling an improved inorganic detergent powder, using sodium perborate for bleaching and sodium silicate for abrasive cleaning, that was dubbed Persil for those two components. Hugo Henkel and Otto Gessler (German, 18??–19??) also invented the first successful methods of recycling printed paper by using similar bleaching and cleaning compounds. Along the way, the Henkels and several other chemists in their company developed a variety of other chemical products, including new adhesives (and later the first glue stick, Pritt).

In contrast to inorganic detergents, organic detergents such as those made from animal fat contain long hydrocarbon molecules that are better able to interact with and remove hydrocarbon stains such as grease. Thus there was a strong need to develop synthetic organic detergents.

Perhaps the most important chemist in the development of synthetic organic detergents was Fritz Günther (German, 1877–1957), who led a large research group devoted to that topic at BASF in Ludwigshafen (which became I.G. Farben Ludwigshafen). Günther and his group began working on the problem during World War I and produced their first commercial synthetic organic detergent, called Nekal, in 1916.

Günther and his group developed a wide range of other synthetic organic detergents over the following decades: Nekalin, alkylbenzene sulfonates (ABS) such as sodium dodecyl benzene sulfonate, and others. See Fig. 3.201. Günther retired in 1938 due to failing eyesight (possibly caused by prolonged chemical exposure), yet his group at Ludwigshafen remained highly active until at least 1945.

At I.G. Farben Höchst, Hermann Ludwig Orthner (German, 1897–1971) ran another important group that developed and mass-produced synthetic organic detergents such as Igepon/Hostapon and Mersol until at least 1945 (Fig. 3.202). For example, BIOS 1222, *Mersol and Hostapon Processes, I.G. Farbenindustrie, Höchst*, p. 1, reported:

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[20] Baird 1955; Gritz 2013, 2014; BIOS 518; BIOS 1222; FIAT 913.

> During the war the I.G. Farbenindustrie manufactured large quantities of Mersol type products from a hydrogenated Fischer Tropsch cut, Mepasin. Large scale manufacture of this product was carried out at Leuna and Wolfen, but the development work was done at Höchst under Professor Orthner. Höchst laboratories also developed two further processes for detergents (Hostapon) of the same type from Mepasin.

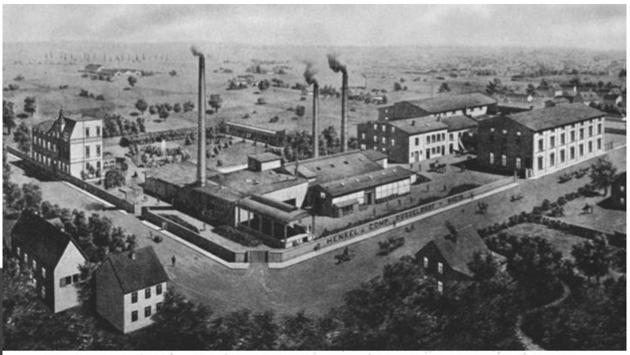
German-speaking scientists also invented methods of mass-producing and purifying enzymes (such as proteases that degrade proteins and lipases that degrade fats) and adding them to commercial detergents to improve their cleaning power (see for example p. 2353).

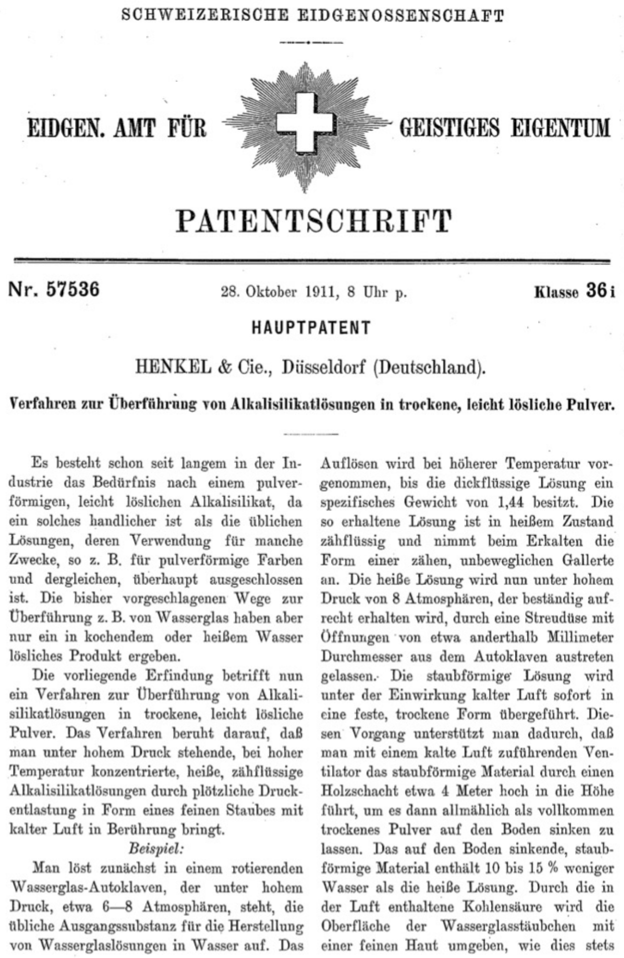
Many of these German developments were patented and known through those patents to other countries from the early 1900s onward. Others were not adopted by other countries until Allied investigators interrogated German scientists and visited plants after World War II. Synthetic detergents and detergents incorporating cleaning enzymes are now commonly used worldwide. Recycling of printed paper, as first developed by Hugo Henkel and Otto Gessler, is also used worldwide.

Persil synthetic detergents and paper recycling

Friedrich Henkel (1848–1930)

Hugo Henkel (1881–1952)





SCHWEIZERISCHE EIDGENOSSENSCHAFT

EIDGEN. AMT FÜR GEISTIGES EIGENTUM

PATENTSCHRIFT

Nr. 57536 28. Oktober 1911, 8 Uhr p. **Klasse 36 i**

HAUPTPATENT

HENKEL & Cie., Düsseldorf (Deutschland).

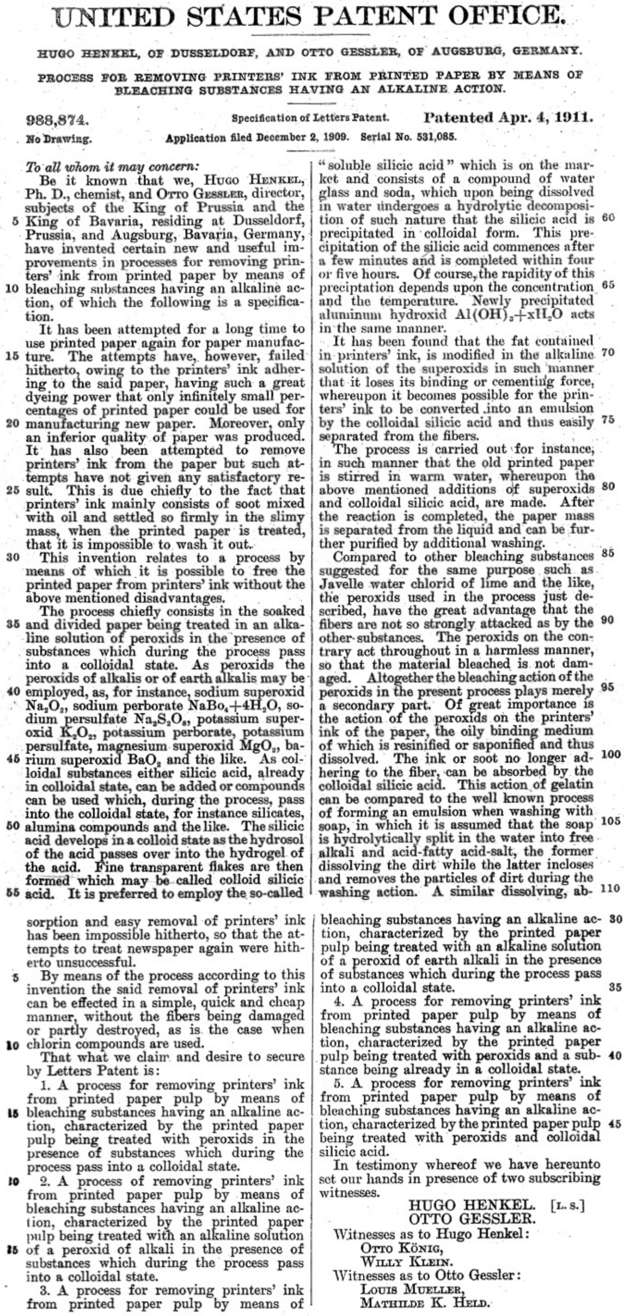
Verfahren zur Überführung von Alkalisilikatlösungen in trockene, leicht lösliche Pulver.

Es besteht schon seit langem in der Industrie das Bedürfnis nach einem pulverförmigen, leicht löslichen Alkalisilikat, da ein solches handlicher ist als die üblichen Lösungen, deren Verwendung für manche Zwecke, so z. B. für pulverförmige Farben und dergleichen, überhaupt ausgeschlossen ist. Die bisher vorgeschlagenen Wege zur Überführung z. B. von Wasserglas haben aber nur ein in kochendem oder heißem Wasser lösliches Produkt ergeben.

Die vorliegende Erfindung betrifft nun ein Verfahren zur Überführung von Alkalisilikatlösungen in trockene, leicht lösliche Pulver. Das Verfahren beruht darauf, daß man unter hohem Druck stehende, bei hoher Temperatur konzentrierte, heiße, zähflüssige Alkalisilikatlösungen durch plötzliche Druckentlastung in Form eines feinen Staubes mit kalter Luft in Berührung bringt.

Beispiel:

Man löst zunächst in einem rotierenden Wasserglas-Autoklaven, der unter hohem Druck, etwa 6—8 Atmosphären, steht, die übliche Ausgangssubstanz für die Herstellung von Wasserglaslösungen in Wasser auf. Das Auflösen wird bei höherer Temperatur vorgenommen, bis die dickflüssige Lösung ein spezifisches Gewicht von 1,44 besitzt. Die so erhaltene Lösung ist in heißem Zustand zähflüssig und nimmt beim Erkalten die Form einer zähen, unbeweglichen Gallerte an. Die heiße Lösung wird nun unter hohem Druck von 8 Atmosphären, der beständig aufrecht erhalten wird, durch eine Streudüse mit Öffnungen von etwa anderthalb Millimeter Durchmesser aus dem Autoklaven austreten gelassen. Die staubförmige Lösung wird unter der Einwirkung kalter Luft sofort in eine feste, trockene Form übergeführt. Diesen Vorgang unterstützt man dadurch, daß man mit einem kalte Luft zuführenden Ventilator das staubförmige Material durch einen Holzschacht etwa 4 Meter hoch in die Höhe führt, um es dann allmählich als vollkommen trockenes Pulver auf den Boden sinken zu lassen. Das auf den Boden sinkende, staubförmige Material enthält 10 bis 15 % weniger Wasser als die heiße Lösung. Durch die in der Luft enthaltene Kohlensäure wird die Oberfläche der Wasserglasstäubchen mit einer feinen Haut umgeben, wie dies stets



UNITED STATES PATENT OFFICE.

HUGO HENKEL, OF DUSSELDORF, AND OTTO GESSLER, OF AUGSBURG, GERMANY.

PROCESS FOR REMOVING PRINTERS' INK FROM PRINTED PAPER BY MEANS OF BLEACHING SUBSTANCES HAVING AN ALKALINE ACTION.

988,874. Specification of Letters Patent. **Patented Apr. 4, 1911.**

No Drawing. **Application filed December 2, 1909. Serial No. 531,085.**

To all whom it may concern:

Be it known that we, Hugo Henkel, Ph. D., chemist, and Otto Gessler, director, subjects of the King of Prussia and the King of Bavaria, residing at Dusseldorf, Prussia, and Augsburg, Bavaria, Germany, have invented certain new and useful improvements in processes for removing printers' ink from printed paper by means of bleaching substances having an alkaline action, of which the following is a specification.

It has been attempted for a long time to use printed paper again for paper manufacture. The attempts have, however, failed hitherto, owing to the printers' ink adhering to the said paper, having such a great dyeing power that only infinitely small percentages of printed paper could be used for manufacturing new paper. Moreover, only an inferior quality of paper was produced. It has also been attempted to remove printers' ink from the paper but such attempts have not given any satisfactory result. This is due chiefly to the fact that printers' ink mainly consists of soot mixed with oil and settled so firmly in the slimy mass, when the printed paper is treated, that it is impossible to wash it out.

This invention relates to a process by means of which it is possible to free the printed paper from printers' ink without the above mentioned disadvantages.

The process chiefly consists in the soaked and divided paper being treated in an alkaline solution of peroxids in the presence of substances which during the process pass into a colloidal state. As peroxids the peroxids of alkalis or of earth alkalis may be employed, as, for instance, sodium superoxid Na_2O_2, sodium perborate $NaBo_4+4H_2O$, sodium persulfate $Na_2S_2O_8$, potassium superoxid K_2O_2, potassium perborate, potassium persulfate, magnesium superoxid MgO_2, barium superoxid BaO_2 and the like. As colloidal substances either silicic acid, already in colloidal state, can be added or compounds can be used which, during the process, pass into the colloidal state, for instance silicates, alumina compounds and the like. The silicic acid develops in a colloid state as the hydrosol of the acid passes over into the hydrogel of the acid. Fine transparent flakes are then formed which may be called colloid silicic acid. It is preferred to employ the so-called "soluble silicic acid" which is on the market and consists of a compound of water glass and soda, which upon being dissolved in water undergoes a hydrolytic decomposition of such nature that the silicic acid is precipitated in colloidal form. This precipitation of the silicic acid commences after a few minutes and is completed within four or five hours. Of course, the rapidity of this preciptation depends upon the concentration and the temperature. Newly precipitated aluminum hydroxid $Al(OH)_3+xH_2O$ acts in the same manner.

It has been found that the fat contained in printers' ink, is modified in the alkaline solution of the superoxids in such manner that it loses its binding or cementing force, whereupon it becomes possible for the printers' ink to be converted into an emulsion by the colloidal silicic acid and thus easily separated from the fibers.

The process is carried out for instance, in such manner that the old printed paper is stirred in warm water, whereupon the above mentioned additions of superoxids and colloidal silicic acid, are made. After the reaction is completed, the paper mass is separated from the liquid and can be further purified by additional washing.

Compared to other bleaching substances suggested for the same purpose such as Javelle water chlorid of lime and the like, the peroxids used in the process just described, have the great advantage that the fibers are not so strongly attacked as by the other substances. The peroxids on the contrary act throughout in a harmless manner, so that the material bleached is not damaged. Altogether the bleaching action of the peroxids in the present process plays merely a secondary part. Of great importance is the action of the peroxids on the printers' ink of the paper, the oily binding medium of which is resinified or saponified and thus dissolved. The ink or soot no longer adhering to the fiber, can be absorbed by the colloidal silicic acid. This action of gelatin can be compared to the well known process of forming an emulsion when washing with soap, in which it is assumed that the soap is hydrolytically split in the water into free alkali and acid-fatty acid-salt, the former dissolving the dirt while the latter incloses and removes the particles of dirt during the washing action. A similar dissolving, ab-

sorption and easy removal of printers' ink has been impossible hitherto, so that the attempts to treat newspaper again were hitherto unsuccessful.

By means of the process according to this invention the said removal of printers' ink can be effected in a simple, quick and cheap manner, without the fibers being damaged or partly destroyed, as is the case when chlorin compounds are used.

That what we claim and desire to secure by Letters Patent is:

1. A process for removing printers' ink from printed paper pulp by means of bleaching substances having an alkaline action, characterized by the printed paper pulp being treated with peroxids in the presence of substances which during the process pass into a colloidal state.

2. A process of removing printers' ink from printed paper pulp by means of bleaching substances having an alkaline action, characterized by the printed paper pulp being treated with an alkaline solution of a peroxid of alkali in the presence of substances which during the process pass into a colloidal state.

3. A process for removing printers' ink from printed paper pulp by means of bleaching substances having an alkaline action, characterized by the printed paper pulp being treated with an alkaline solution of a peroxid of earth alkali in the presence of substances which during the process pass into a colloidal state.

4. A process for removing printers' ink from printed paper pulp by means of bleaching substances having an alkaline action, characterized by the printed paper pulp being treated with peroxids and a substance being already in a colloidal state.

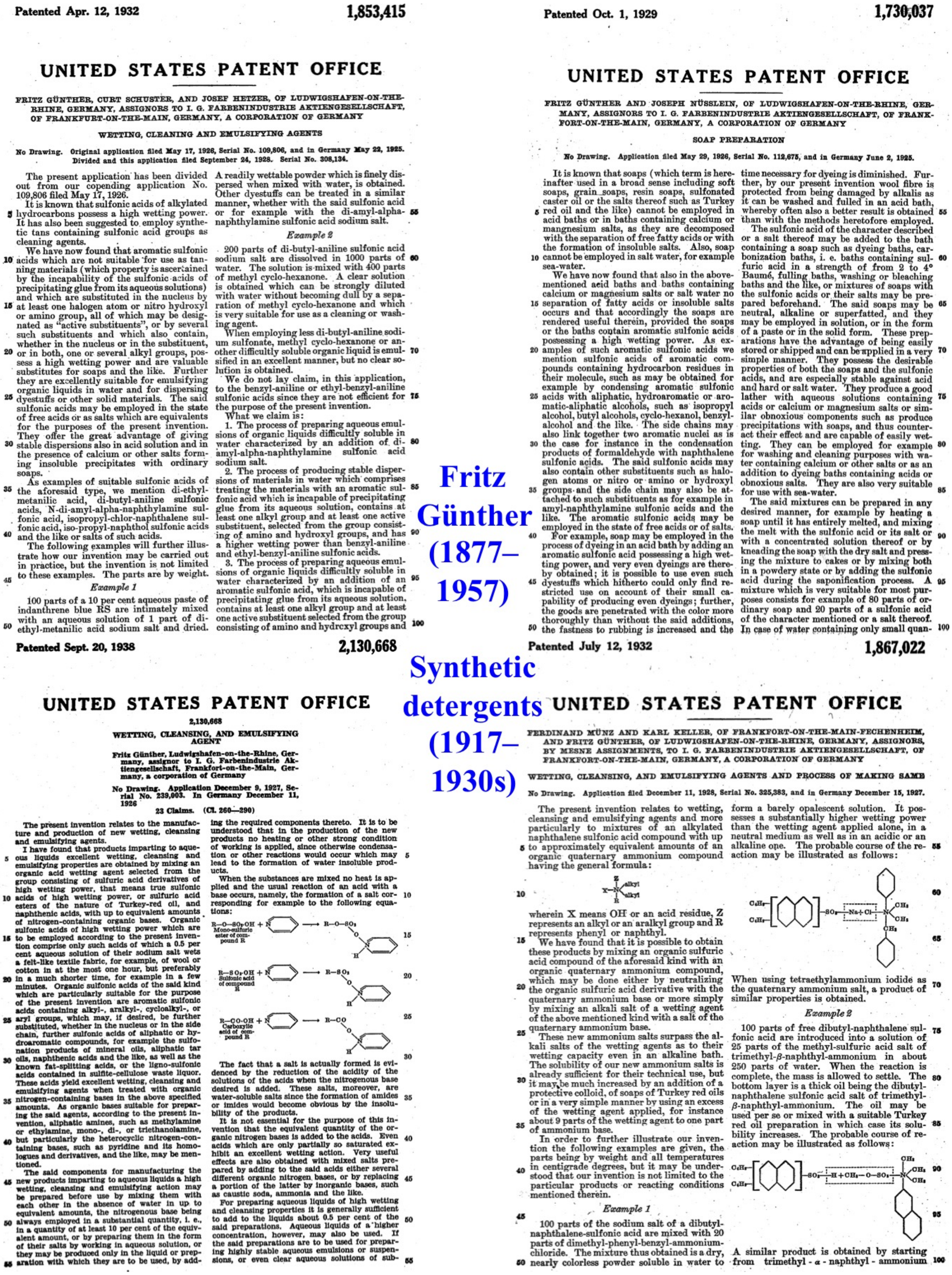
5. A process for removing printers' ink from printed paper pulp by means of bleaching substances having an alkaline action, characterized by the printed paper pulp being treated with peroxids and colloidal silicic acid.

In testimony whereof we have hereunto set our hands in presence of two subscribing witnesses.

HUGO HENKEL. [L. S.]
OTTO GESSLER.

Witnesses as to Hugo Henkel:
Otto König,
Willy Klein.
Witnesses as to Otto Gessler:
Louis Mueller,
Mathilde K. Held.

Figure 3.200: Friedrich (Fritz) Henkel and his sons, especially Hugo Henkel, as well as other chemists at their company, developed synthetic inorganic detergents such as Persil, as well as the first successful methods of recycling printed paper.



Patented Apr. 12, 1932 **1,853,415**

UNITED STATES PATENT OFFICE

FRITZ GÜNTHER, CURT SCHUSTER, AND JOSEF HETZER, OF LUDWIGSHAFEN-ON-THE-RHINE, GERMANY, ASSIGNORS TO I. G. FARBENINDUSTRIE AKTIENGESELLSCHAFT, OF FRANKFURT-ON-THE-MAIN, GERMANY, A CORPORATION OF GERMANY

WETTING, CLEANING AND EMULSIFYING AGENTS

No Drawing. Original application filed May 17, 1926, Serial No. 109,806, and in Germany May 22, 1925. Divided and this application filed September 24, 1928. Serial No. 308,134.

The present application has been divided out from our copending application No. 109,806 filed May 17, 1926.

It is known that sulfonic acids of alkylated hydrocarbons possess a high wetting power. It has also been suggested to employ synthetic tans containing sulfonic acid groups as cleaning agents.

We have now found that aromatic sulfonic acids which are not suitable for use as tanning materials (which property is ascertained by the incapability of the sulfonic acids of precipitating glue from its aqueous solutions) and which are substituted in the nucleus by at least one halogen atom or nitro hydroxyl or amino group, all of which may be designated as "active substituents", or by several such substituents and which also contain, whether in the nucleus or in the substituent, or in both, one or several alkyl groups, possess a high wetting power and are valuable substitutes for soaps and the like. Further they are excellently suitable for emulsifying organic liquids in water and for dispersing dyestuffs or other solid materials. The said sulfonic acids may be employed in the state of free acids or as salts which are equivalents for the purposes of the present invention. They offer the great advantage of giving stable dispersions also in acid solution and in the presence of calcium or other salts forming insoluble precipitates with ordinary soaps.

As examples of suitable sulfonic acids of the aforesaid type, we mention di-ethyl-metanilic acid, di-butyl-aniline sulfonic acids, N-di-amyl-alpha-naphthylamine sulfonic acid, isopropyl-chlor-naphthalene sulfonic acid, iso-propyl-naphthol sulfonic acids and the like or salts of such acids.

The following examples will further illustrate how our invention may be carried out in practice, but the invention is not limited to these examples. The parts are by weight.

Example 1

100 parts of a 10 per cent aqueous paste of indanthrene blue RS are intimately mixed with an aqueous solution of 1 part of di-ethyl-metanilic acid sodium salt and dried. A readily wettable powder which is finely dispersed when mixed with water, is obtained. Other dyestuffs can be treated in a similar manner, whether with the said sulfonic acid or for example with the di-amyl-alpha-naphthylamine sulfonic acid sodium salt.

Example 2

200 parts of di-butyl-aniline sulfonic acid sodium salt are dissolved in 1000 parts of water. The solution is mixed with 400 parts of methyl cyclo-hexanone. A clear solution is obtained which can be strongly diluted with water without becoming dull by a separation of methyl cyclo-hexanone and which is very suitable for use as a cleaning or washing agent.

When employing less di-butyl-aniline sodium sulfonate, methyl cyclo-hexanone or another difficultly soluble organic liquid is emulsified in an excellent manner, but no clear solution is obtained.

We do not lay claim, in this application, to the benzyl-aniline or ethyl-benzyl-aniline sulfonic acids since they are not efficient for the purpose of the present invention.

What we claim is:

1. The process of preparing aqueous emulsions of organic liquids difficultly soluble in water characterized by an addition of di-amyl-alpha-naphthylamine sulfonic acid sodium salt.

2. The process of producing stable dispersions of materials in water which comprises treating the materials with an aromatic sulfonic acid which is incapable of precipitating glue from its aqueous solution, contains at least one alkyl group and at least one active substituent, selected from the group consisting of amino and hydroxyl groups, and has a higher wetting power than benzyl-aniline and ethyl-benzyl-aniline sulfonic acids.

3. The process of preparing aqueous emulsions of organic liquids difficultly soluble in water characterized by an addition of an aromatic sulfonic acid, which is incapable of precipitating glue from its aqueous solution, contains at least one alkyl group and at least one active substituent selected from the group consisting of amino and hydrcxyl groups and

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Patented Oct. 1, 1929 **1,730,037**

UNITED STATES PATENT OFFICE

FRITZ GÜNTHER AND JOSEPH NÜSSLEIN, OF LUDWIGSHAFEN-ON-THE-RHINE, GERMANY, ASSIGNORS TO I. G. FARBENINDUSTRIE AKTIENGESELLSCHAFT, OF FRANKFORT-ON-THE-MAIN, GERMANY, A CORPORATION OF GERMANY

SOAP PREPARATION

No Drawing. Application filed May 29, 1926, Serial No. 112,675, and in Germany June 2, 1925.

It is known that soaps (which term is hereinafter used in a broad sense including soft soaps, grain soaps, resin soaps, sulfonated caster oil or the salts thereof such as Turkey red oil and the like) cannot be employed in acid baths or in baths containing calcium or mangnesium salts, as they are decomposed with the separation of free fatty acids or with the formation of insoluble salts. Also, soap cannot be employed in salt water, for example sea-water.

We have now found that also in the above-mentioned acid baths and baths containing calcium or magnesium salts or salt water no separation of fatty acids or insoluble salts occurs and that accordingly the soaps are rendered useful therein, provided the soaps or the baths contain aromatic sulfonic acids possessing a high wetting power. As examples of such aromatic sulfonic acids we mention sulfonic acids of aromatic compounds containing hydrocarbon residues in their molecule, such as may be obtained for example by condensing aromatic sulfonic acids with aliphatic, hydroaromatic or aromatic-aliphatic alcohols, such as isopropyl alcohol, butyl alcohols, cyclo-hexanol, benzyl-alcohol and the like. The side chains may also link together two aromatic nuclei as is the case for instance in the condensation products of formaldehyde with naphthalene sulfonic acids. The said sulfonic acids may also contain other substituents such as halogen atoms or nitro or amino or hydroxyl groups and the side chain may also be attached to such substituents as for example in amyl-naphthylamine sulfonic acids and the like. The aromatic sulfonic acids may be employed in the state of free acids or of salts.

For example, soap may be employed in the process of dyeing in an acid bath by adding an aromatic sulfonic acid possessing a high wetting power, and very even dyeings are thereby obtained; it is possible to use even such dyestuffs which hitherto could only find restricted use on account of their small capability of producing even dyeings; further, the goods are penetrated with the color more thoroughly than without the said additions, the fastness to rubbing is increased and the time necessary for dyeing is diminished. Further, by our present invention wool fibre is protected from being damaged by alkalis as it can be washed and fulled in an acid bath, whereby often also a better result is obtained than with the methods heretofore employed.

The sulfonic acid of the character described or a salt thereof may be added to the bath containing a soap such as dyeing baths, carbonization baths, i. e. baths containing sulfuric acid in a strength of from 2 to 4° Baumé, fulling baths, washing or bleaching baths and the like, or mixtures of soaps with the sulfonic acids or their salts may be prepared beforehand. The said soaps may be neutral, alkaline or superfatted, and they may be employed in solution, or in the form of a paste or in the solid form. These preparations have the advantage of being easily stored or shipped and can be applied in a very simple manner. They possess the desirable properties of both the soaps and the sulfonic acids, and are especially stable against acid and hard or salt water. They produce a good lather with aqueous solutions containing acids or calcium or magnesium salts or similar obnoxious components such as produce precipitations with soaps, and thus counteract their effect and are capable of easily wetting. They can be employed for example for washing and cleaning purposes with water containing calcium or other salts or as an addition to dyeing baths containing acids or obnoxious salts. They are also very suitable for use with sea-water.

The said mixtures can be prepared in any desired manner, for example by heating a soap until it has entirely melted, and mixing the melt with the sulfonic acid or its salt or with a concentrated solution thereof or by kneading the soap with the dry salt and pressing the mixture to cakes or by mixing both in a powdery state or by adding the sulfonic acid during the saponification process. A mixture which is very suitable for most purposes consists for example of 80 parts of ordinary soap and 20 parts of a sulfonic acid of the character mentioned or a salt thereof. In case of water containing only small quan-

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Patented Sept. 20, 1938 **2,130,668**

UNITED STATES PATENT OFFICE

2,130,668

WETTING, CLEANSING, AND EMULSIFYING AGENT

Fritz Günther, Ludwigshafen-on-the-Rhine, Germany, assignor to I. G. Farbenindustrie Aktiengesellschaft, Frankfort-on-the-Main, Germany, a corporation of Germany

No Drawing. Application December 9, 1927, Serial No. 239,003. In Germany December 11, 1926

23 Claims. (Cl. 260—290)

The present invention relates to the manufacture and production of new wetting, cleansing and emulsifying agents.

I have found that products imparting to aqueous liquids excellent wetting, cleansing and emulsifying properties are obtained by mixing an organic acid wetting agent selected from the group consisting of sulfuric acid derivatives of high wetting power, that means true sulfonic acids of high wetting power, or sulfuric acid esters of the nature of Turkey-red oil, and naphthenic acids, with up to equivalent amounts of nitrogen-containing organic bases. Organic sulfonic acids of high wetting power which are to be employed according to the present invention comprise only such acids of which a 0.5 per cent aqueous solution of their sodium salt wets a felt-like textile fabric, for example, of wool or cotton in at the most one hour, but preferably in a much shorter time, for example in a few minutes. Organic sulfonic acids of the said kind which are particularly suitable for the purpose of the present invention are aromatic sulfonic acids containing alkyl-, aralkyl-, cycloalkyl-, or aryl groups, which may, if desired, be further substituted, whether in the nucleus or in the side chain, further sulfonic acids of aliphatic or hydroaromatic compounds, for example the sulfonation products of mineral oils, aliphatic tar oils, naphthenic acids and the like, as well as the known fat-splitting acids, or the ligno-sulfonic acids contained in sulfite-cellulose waste liquor. These acids yield excellent wetting, cleansing and emulsifying agents when treated with organic nitrogen-containing bases in the above specified amounts. As organic bases suitable for preparing the said agents, according to the present invention, aliphatic amines, such as methylamine or ethylamine, mono-, di-, or triethanolamine, but particularly the heterocyclic nitrogen-containing bases, such as pyridine and its homologues and derivatives, and the like, may be mentioned.

The said components for manufacturing the new products imparting to aqueous liquids a high wetting, cleansing and emulsifying action may be prepared before use by mixing them with each other in the absence of water in up to equivalent amounts, the nitrogenous base being always employed in a substantial quantity, i. e., in a quantity of at least 10 per cent of the equivalent amount, or by preparing them in the form of their salts by working in aqueous solution, or they may be produced only in the liquid or preparation with which they are to be used, by adding the required components thereto. It is to be understood that in the production of the new products no heating or other strong condition of working is applied, since otherwise condensation or other reactions would occur which may lead to the formation of water insoluble products.

When the substances are mixed no heat is applied and the usual reaction of an acid with a base occurs, namely, the formation of a salt corresponding for example to the following equations:

$R{-}O{-}SO_2{\cdot}OH$ + N ⟶ $R{-}O{-}SO_2$
Mono-sulfuric ester of compound R

$R{-}SO_2{\cdot}OH$ + N ⟶ $R{-}SO_2$
Sulfonic acid of compound R

$R{-}CO{\cdot}OH$ + N ⟶ $R{-}CO$
Carboxylic acid of compound R

The fact that a salt is actually formed is evidenced by the reduction of the acidity of the solutions of the acids when the nitrogenous base desired is added. These salts, moreover, are water-soluble salts since the formation of amides or imides would become obvious by the insolubility of the products.

It is not essential for the purpose of this invention that the equivalent quantity of the organic nitrogen bases is added to the acids. Even acids which are only partially so saturated exhibit an excellent wetting action. Very useful effects are also obtained with mixed salts prepared by adding to the said acids either several different organic nitrogen bases, or by replacing a portion of the latter by inorganic bases, such as caustic soda, ammonia and the like.

For preparing aqueous liquids of high wetting and cleansing properties it is generally sufficient to add to the liquids about 0.5 per cent of the said preparations. Aqueous liquids of a higher concentration, however, may also be used. If the said preparations are to be used for preparing highly stable aqueous emulsions or suspensions, or even clear aqueous solutions of sub-

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Patented July 12, 1932 **1,867,022**

UNITED STATES PATENT OFFICE

FERDINAND MÜNZ AND KARL KELLER, OF FRANKFORT-ON-THE-MAIN-FECHENHEIM, AND FRITZ GÜNTHER, OF LUDWIGSHAFEN-ON-THE-RHINE, GERMANY, ASSIGNORS, BY MESNE ASSIGNMENTS, TO I. G. FARBENINDUSTRIE AKTIENGESELLSCHAFT, OF FRANKFORT-ON-THE-MAIN, GERMANY, A CORPORATION OF GERMANY

WETTING, CLEANSING, AND EMULSIFYING AGENTS AND PROCESS OF MAKING SAME

No Drawing. Application filed December 11, 1928, Serial No. 325,383, and in Germany December 15, 1927.

The present invention relates to wetting, cleansing and emulsifying agents and more particularly to mixtures of an alkylated naphthalene sulfonic acid compound with up to approximately equivalent amounts of an organic quaternary ammonium compound having the general formula:

$$X{-}\overset{Z}{\underset{R}{N}}{<}^{\text{alkyl}}_{\text{alkyl}}$$

wherein X means OH or an acid residue, Z represents an alkyl or an aralkyl group and R represents phenyl or naphthyl.

We have found that it is possible to obtain these products by mixing an organic sulfuric acid compound of the aforesaid kind with an organic quaternary ammonium compound, which may be done either by neutralizing the organic sulfuric acid derivative with the quaternary ammonium base or more simply by mixing an alkali salt of a wetting agent of the above mentioned kind with a salt of the quaternary ammonium base.

These new ammonium salts surpass the alkali salts of the wetting agents as to their wetting capacity even in an alkaline bath. The solubility of our new ammonium salts is already sufficient for their technical use, but it may be much increased by an addition of a protective colloid, of soaps of Turkey red oils or in a very simple manner by using an excess of the wetting agent applied, for instance about 9 parts of the wetting agent to one part of ammonium base.

In order to further illustrate our invention the following examples are given, the parts being by weight and all temperatures in centigrade degrees, but it may be understood that our invention is not limited to the particular products or reacting conditions mentioned therein.

Example 1

100 parts of the sodium salt of a dibutyl-naphthalene-sulfonic acid are mixed with 20 parts of dimethyl-phenyl-benzyl-ammonium-chloride. The mixture thus obtained is a dry, nearly colorless powder soluble in water to form a barely opalescent solution. It possesses a substantially higher wetting power than the wetting agent applied alone, in a neutral medium as well as in an acidic or an alkaline one. The probable course of the reaction may be illustrated as follows:

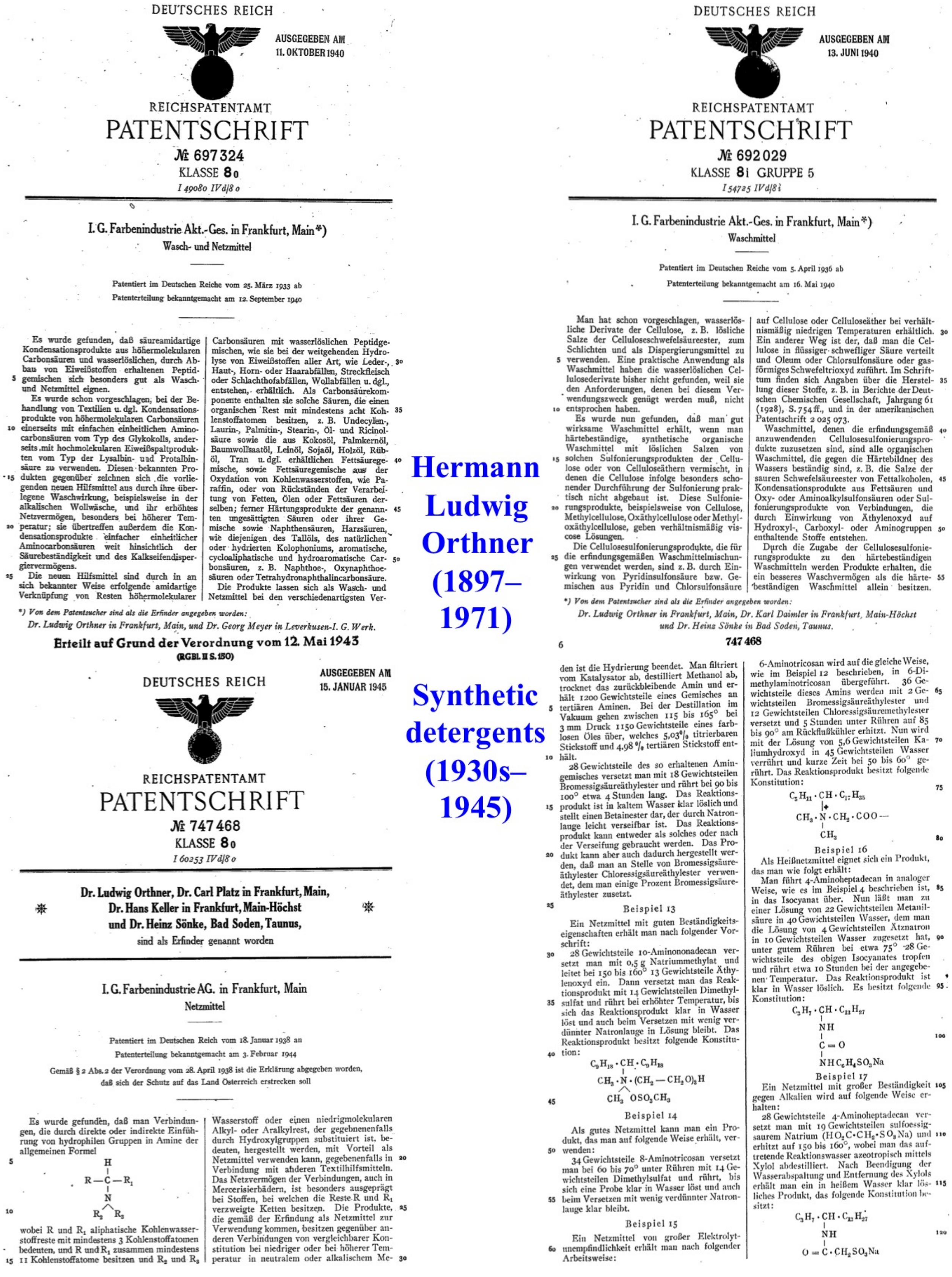
When using tetraethylammonium iodide as the quaternary ammonium salt, a product of similar properties is obtained.

Example 2

100 parts of free dibutyl-naphthalene sulfonic acid are introduced into a solution of 25 parts of the methyl-sulfuric acid salt of trimethyl-β-naphthyl-ammonium in about 250 parts of water. When the reaction is complete, the mass is allowed to settle. The bottom layer is a thick oil being the dibutyl-naphthalene sulfonic acid salt of trimethyl-β-naphthyl-ammonium. The oil may be used per se or mixed with a suitable Turkey red oil preparation in which case its solubility increases. The probable course of reaction may be illustrated as follows:

A similar product is obtained by starting from trimethyl-α-naphthyl-ammonium

Figure 3.201: Fritz Günther developed synthetic organic detergents from 1916 to the 1930s.


Hermann Ludwig Orthner (1897–1971)
Synthetic detergents (1930s–1945)

DEUTSCHES REICH

AUSGEGEBEN AM
11. OKTOBER 1940

REICHSPATENTAMT

PATENTSCHRIFT

№ 697 324

KLASSE 8o

I 49080 IVd/8 o

I. G. Farbenindustrie Akt.-Ges. in Frankfurt, Main*)

Wasch- und Netzmittel

Patentiert im Deutschen Reiche vom 25. März 1933 ab
Patenterteilung bekanntgemacht am 12. September 1940

Es wurde gefunden, daß säureamidartige Kondensationsprodukte aus höhermolekularen Carbonsäuren und wasserlöslichen, durch Abbau von Eiweißstoffen erhaltenen Peptidgemischen sich besonders gut als Wasch- und Netzmittel eignen.

Es wurde schon vorgeschlagen, bei der Behandlung von Textilien u. dgl. Kondensationsprodukte von höhermolekularen Carbonsäuren einerseits mit einfachen einheitlichen Aminocarbonsäuren vom Typ des Glykokolls, anderseits mit hochmolekularen Eiweißspaltprodukten vom Typ der Lysalbin- und Protalbinsäure zu verwenden. Diesen bekannten Produkten gegenüber zeichnen sich die vorliegenden neuen Hilfsmittel aus durch ihre überlegene Waschwirkung, beispielsweise in der alkalischen Wollwäsche, und ihr erhöhtes Netzvermögen, besonders bei höherer Temperatur; sie übertreffen außerdem die Kondensationsprodukte einfacher einheitlicher Aminocarbonsäuren weit hinsichtlich der Säurebeständigkeit und des Kalkseifendispergiervermögens.

Die neuen Hilfsmittel sind durch in an sich bekannter Weise erfolgende amidartige Verknüpfung von Resten höhermolekularer Carbonsäuren mit wasserlöslichen Peptidgemischen, wie sie bei der weitgehenden Hydrolyse von Eiweißstoffen aller Art, wie Leder-, Haut-, Horn- oder Haarabfällen, Streckfleisch oder Schlachthofabfällen, Wollabfällen u. dgl., entstehen, erhältlich. Als Carbonsäurekomponente enthalten sie solche Säuren, die einen organischen Rest mit mindestens acht Kohlenstoffatomen besitzen, z. B. Undecylen-, Laurin-, Palmitin-, Stearin-, Öl- und Ricinolsäure sowie die aus Kokosöl, Palmkernöl, Baumwollsaatöl, Leinöl, Sojaöl, Holzöl, Rüböl, Tran u. dgl. erhältlichen Fettsäuregemische, sowie Fettsäuregemische aus der Oxydation von Kohlenwasserstoffen, wie Paraffin, oder von Rückständen der Verarbeitung von Fetten, Ölen oder Fettsäuren derselben; ferner Härtungsprodukte der genannten ungesättigten Säuren oder ihrer Gemische sowie Naphthensäuren, Harzsäuren, wie diejenigen des Tallöls, des natürlichen oder hydrierten Kolophoniums, aromatische, cycloaliphatische und hydroaromatische Carbonsäuren, z. B. Naphthoe-, Oxynaphthoesäuren oder Tetrahydronaphthalincarbonsäure.

Die Produkte lassen sich als Wasch- und Netzmittel bei den verschiedenartigsten Ver-

*) *Von dem Patentsucher sind als die Erfinder angegeben worden:*
Dr. Ludwig Orthner in Frankfurt, Main, und Dr. Georg Meyer in Leverkusen-I. G. Werk.

Erteilt auf Grund der Verordnung vom 12. Mai 1943
(RGBl. II S. 150)

DEUTSCHES REICH

AUSGEGEBEN AM
15. JANUAR 1945

REICHSPATENTAMT

PATENTSCHRIFT

№ 747 468

KLASSE 8o

I 60253 IVd/8 o

Dr. Ludwig Orthner, Dr. Carl Platz in Frankfurt, Main,
Dr. Hans Keller in Frankfurt, Main-Höchst
und Dr. Heinz Sönke, Bad Soden, Taunus,
sind als Erfinder genannt worden

I. G. Farbenindustrie AG. in Frankfurt, Main

Netzmittel

Patentiert im Deutschen Reich vom 18. Januar 1938 an
Patenterteilung bekanntgemacht am 3. Februar 1944

Gemäß § 2 Abs. 2 der Verordnung vom 28. April 1938 ist die Erklärung abgegeben worden, daß sich der Schutz auf das Land Österreich erstrecken soll

Es wurde gefunden, daß man Verbindungen, die durch direkte oder indirekte Einführung von hydrophilen Gruppen in Amine der allgemeinen Formel

$$\begin{array}{c} \mathrm{H} \\ | \\ \mathrm{R}-\mathrm{C}-\mathrm{R}_1 \\ | \\ \mathrm{N} \\ \diagup\ \diagdown \\ \mathrm{R}_2 \quad \mathrm{R}_3 \end{array}$$

wobei R und R_1 aliphatische Kohlenwasserstoffreste mit mindestens 3 Kohlenstoffatomen bedeuten, und R und R_1 zusammen mindestens 11 Kohlenstoffatome besitzen und R_2 und R_3 Wasserstoff oder einen niedrigmolekularen Alkyl- oder Aralkylrest, der gegebnenenfalls durch Hydroxylgruppen substituiert ist, bedeuten, hergestellt werden, mit Vorteil als Netzmittel verwenden kann, gegebenenfalls in Verbindung mit anderen Textilhilfsmitteln. Das Netzvermögen der Verbindungen, auch in Mercerisierbädern, ist besonders ausgeprägt bei Stoffen, bei welchen die Reste R und R_1 verzweigte Ketten besitzen. Die Produkte, die gemäß der Erfindung als Netzmittel zur Verwendung kommen, besitzen gegenüber anderen Verbindungen von vergleichbarer Konstitution bei niedriger oder bei höherer Temperatur in neutralem oder alkalischem Me-

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DEUTSCHES REICH

AUSGEGEBEN AM
13. JUNI 1940

REICHSPATENTAMT

PATENTSCHRIFT

№ 692 029

KLASSE 8i GRUPPE 5

I 54725 IVd/8 i

I. G. Farbenindustrie Akt.-Ges. in Frankfurt, Main*)

Waschmittel

Patentiert im Deutschen Reiche vom 5. April 1936 ab
Patenterteilung bekanntgemacht am 16. Mai 1940

Man hat schon vorgeschlagen, wasserlösliche Derivate der Cellulose, z. B. lösliche Salze der Celluloseschwefelsäureester, zum Schlichten und als Dispergierungsmittel zu verwenden. Eine praktische Anwendung als Waschmittel haben die wasserlöslichen Cellulosederivate bisher nicht gefunden, weil sie den Anforderungen, denen bei diesem Verwendungszweck genügt werden muß, nicht entsprochen haben.

Es wurde nun gefunden, daß man gut wirksame Waschmittel erhält, wenn man härtebeständige, synthetische organische Waschmittel mit löslichen Salzen von solchen Sulfonierungsprodukten der Cellulose oder von Celluloseäthern vermischt, in denen die Cellulose infolge besonders schonender Durchführung der Sulfonierung praktisch nicht abgebaut ist. Diese Sulfonierungsprodukte, beispielsweise von Cellulose, Methylcellulose, Oxäthylcellulose oder Methyloxäthylcellulose, geben verhältnismäßig viscose Lösungen.

Die Cellulosesulfonierungsprodukte, die für die erfindungsgemäßen Waschmittelmischungen verwendet werden, sind z. B. durch Einwirkung von Pyridinsulfonsäure bzw. Gemischen aus Pyridin und Chlorsulfonsäure auf Cellulose oder Celluloseäther bei verhältnismäßig niedrigen Temperaturen erhältlich. Ein anderer Weg ist der, daß man die Cellulose in flüssiger schwefliger Säure verteilt und Oleum oder Chlorsulfonsäure oder gasförmiges Schwefeltrioxyd zuführt. Im Schrifttum finden sich Angaben über die Herstellung dieser Stoffe, z. B. in Berichte der Deutschen Chemischen Gesellschaft, Jahrgang 61 (1928), S. 754 ff., und in der amerikanischen Patentschrift 2 025 073.

Waschmittel, denen die erfindungsgemäß anzuwendenden Cellulosesulfonierungsprodukte zuzusetzen sind, sind alle organischen Waschmittel, die gegen die Härtebildner des Wassers beständig sind, z. B. die Salze der sauren Schwefelsäureester von Fettalkoholen, Kondensationsprodukte aus Fettsäuren und Oxy- oder Aminoalkylsulfonsäuren oder Sulfonierungsprodukte von Verbindungen, die durch Einwirkung von Äthylenoxyd auf Hydroxyl-, Carboxyl- oder Aminogruppen enthaltende Stoffe entstehen.

Durch die Zugabe der Cellulosesulfonierungsprodukte zu den härtebeständigen Waschmitteln werden Produkte erhalten, die ein besseres Waschvermögen als die härtebeständigen Waschmittel allein besitzen.

*) *Von dem Patentsucher sind als die Erfinder angegeben worden:*
Dr. Ludwig Orthner in Frankfurt, Main, Dr. Karl Daimler in Frankfurt, Main-Höchst und Dr. Heinz Sönke in Bad Soden, Taunus.

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6 **747 468**

den ist die Hydrierung beendet. Man filtriert vom Katalysator ab, destilliert Methanol ab, trocknet das zurückbleibende Amin und erhält 1200 Gewichtsteile eines Gemisches an tertiären Aminen. Bei der Destillation im Vakuum gehen zwischen 115 bis 165° bei 3 mm Druck 1150 Gewichtsteile eines farblosen Öles über, welches 5,03% titrierbaren Stickstoff und 4,98% tertiären Stickstoff enthält.

28 Gewichtsteile des so erhaltenen Amingemisches versetzt man mit 18 Gewichtsteilen Bromessigsäureäthylester und rührt bei 90 bis 100° etwa 4 Stunden lang. Das Reaktionsprodukt ist in kaltem Wasser klar löslich und stellt einen Betainester dar, der durch Natronlauge leicht verseifbar ist. Das Reaktionsprodukt kann entweder als solches oder nach der Verseifung gebraucht werden. Das Produkt kann aber auch dadurch hergestellt werden, daß man an Stelle von Bromessigsäureäthylester Chloressigsäureäthylester verwendet, dem man einige Prozent Bromessigsäureäthylester zusetzt.

Beispiel 13

Ein Netzmittel mit guten Beständigkeitseigenschaften erhält man nach folgender Vorschrift:

28 Gewichtsteile 10-Aminononadecan versetzt man mit 0,5 g Natriummethylat und leitet bei 150 bis 160° 13 Gewichtsteile Äthylenoxyd ein. Dann versetzt man das Reaktionsprodukt mit 14 Gewichtsteilen Dimethylsulfat und rührt bei erhöhter Temperatur, bis sich das Reaktionsprodukt klar in Wasser löst und auch beim Versetzen mit wenig verdünnter Natronlauge in Lösung bleibt. Das Reaktionsprodukt besitzt folgende Konstitution:

$$\begin{array}{c} \mathrm{C_9H_{18}\cdot CH\cdot C_9H_{18}} \\ | \\ \mathrm{CH_3\cdot N\cdot(CH_2-CH_2O)_3H} \\ \diagup\ \diagdown \\ \mathrm{CH_3 \quad OSO_3CH_3} \end{array}$$

Beispiel 14

Als gutes Netzmittel kann man ein Produkt, das man auf folgende Weise erhält, verwenden:

34 Gewichtsteile 8-Aminotricosan versetzt man bei 60 bis 70° unter Rühren mit 14 Gewichtsteilen Dimethylsulfat und rührt, bis sich eine Probe klar in Wasser löst und auch beim Versetzen mit wenig verdünnter Natronlauge klar bleibt.

Beispiel 15

Ein Netzmittel von großer Elektrolytunempfindlichkeit erhält man nach folgender Arbeitsweise:

6-Aminotricosan wird auf die gleiche Weise, wie im Beispiel 12 beschrieben, in 6-Dimethylaminotricosan übergeführt. 36 Gewichtsteile dieses Amins werden mit 2 Gewichtsteilen Bromessigsäureäthylester und 12 Gewichtsteilen Chloressigsäuremethylester versetzt und 5 Stunden unter Rühren auf 85 bis 90° am Rückflußkühler erhitzt. Nun wird mit der Lösung von 5,6 Gewichtsteilen Kaliumhydroxyd in 45 Gewichtsteilen Wasser verrührt und kurze Zeit bei 50 bis 60° gerührt. Das Reaktionsprodukt besitzt folgende Konstitution:

$$\begin{array}{c} \mathrm{C_5H_{11}\cdot CH\cdot C_{17}H_{35}} \\ |+ \\ \mathrm{CH_3\cdot N\cdot CH_2\cdot COO-} \\ | \\ \mathrm{CH_3} \end{array}$$

Beispiel 16

Als Heißnetzmittel eignet sich ein Produkt, das man wie folgt erhält:

Man führt 4-Aminoheptadecan in analoger Weise, wie es im Beispiel 4 beschrieben ist, in das Isocyanat über. Nun läßt man zu einer Lösung von 22 Gewichtsteilen Metanilsäure in 40 Gewichtsteilen Wasser, dem man die Lösung von 4 Gewichtsteilen Ätznatron in 10 Gewichtsteilen Wasser zugesetzt hat, unter gutem Rühren bei etwa 75° 28 Gewichtsteile des obigen Isocyanates tropfen und rührt etwa 10 Stunden bei der angegebenen Temperatur. Das Reaktionsprodukt ist klar in Wasser löslich. Es besitzt folgende Konstitution:

$$\begin{array}{c} \mathrm{C_3H_7\cdot CH\cdot C_{13}H_{27}} \\ | \\ \mathrm{NH} \\ | \\ \mathrm{C=O} \\ | \\ \mathrm{NHC_6H_4SO_3Na} \end{array}$$

Beispiel 17

Ein Netzmittel mit großer Beständigkeit gegen Alkalien wird auf folgende Weise erhalten:

28 Gewichtsteile 4-Aminoheptadecan versetzt man mit 19 Gewichtsteilen sulfoessigsaurem Natrium ($HO_2C\cdot CH_2\cdot SO_3Na$) und erhitzt auf 150 bis 160°, wobei man das auftretende Reaktionswasser azeotropisch mittels Xylol abdestilliert. Nach Beendigung der Wasserabspaltung und Entfernung des Xylols erhält man ein in heißem Wasser klar lösliches Produkt, das folgende Konstitution besitzt:

$$\begin{array}{c} \mathrm{C_3H_7\cdot CH\cdot C_{13}H_{27}} \\ | \\ \mathrm{NH} \\ | \\ \mathrm{O=C\cdot CH_2SO_3Na} \end{array}$$

Figure 3.202: Hermann Ludwig Orthner developed synthetic organic detergents from the 1930s to 1945.

3.9.5 Chemical Fabric Treatments

Scientists at I.G. Farben developed a wide variety of chemical treatments to make clothing and other fabrics resistant to fire, water, stains, wrinkling, etc. By the early 1940s, those chemical fabric treatments were in widespread production and use in the German-speaking world. Especially important in this area were Gustav Schwen's (German, 18??–19??) group of chemists at I.G. Farben Ludwigshafen and August Gutmann's (German, 18??–19??) group at I.G. Farben Höchst.

After the war, those chemical fabric treatments were closely inspected and eagerly adopted by Allied countries. Figures 3.203–3.205 show examples from one postwar Allied report, BIOS 518, *Textile Auxiliary Products of I.G. Farbenindustrie: Application, Testing and Miscellaneous Information.*

Another report, BIOS 698, *Survey of the German Heavy Textile Proofing Industry*, explained the great importance and innovation of the chemical treatments, for example for making fabrics simultaneously fire-retardant and water-resistant (especially useful for protective clothing for firefighters):

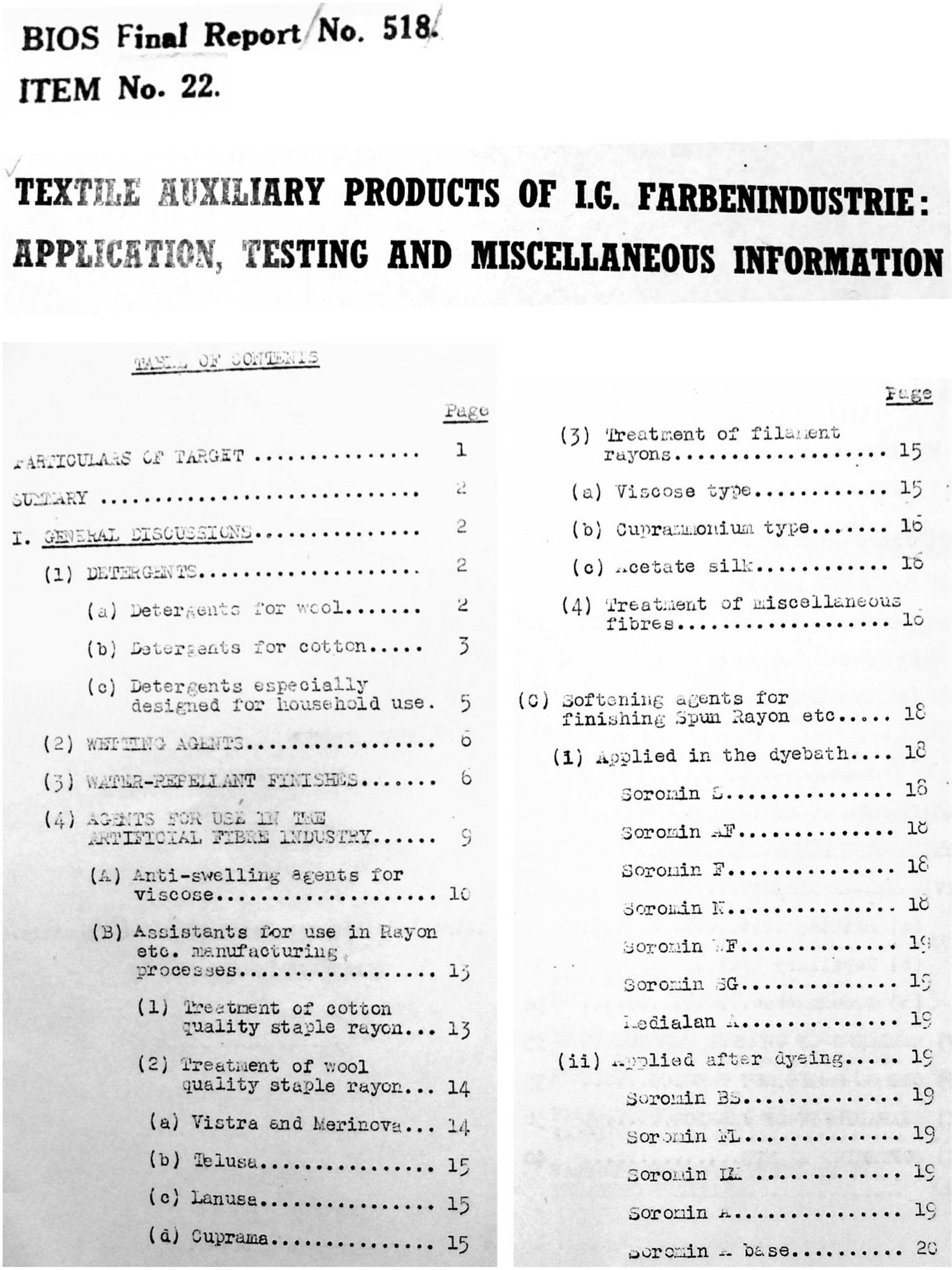
> FIREPROOFING
>
> Several of the firms visited had experience of this type of proofing mainly using the I.G. Akaustan products. The latter are mainly water soluble ammonium salts but Akaustan S is of particular interest in that it gives a water-insoluble fireproofing effect. It can be applied simultaneously with Persistol to give combined fireproofness and water repellency and there is reason to believe that this is probably the only known method of obtaining the combined proofing effects which does not interfere with the ventility of the cloth.

[See also FIAT 170.]

3.9.6 Firefighting Chemicals

In addition to creating fire-retardant fabrics, German-speaking scientists also made major improvements to chemical methods of fighting and extinguishing fires, and those were later adopted by Allied countries. For example, BIOS 704, *Mechanical Foam Liquid and Equipment*, reported:

> 6. Conclusions and Recommendations.
>
> (a) Substantial war time improvements were made in German foam fire fighting equipment.
>
> (b) Some German foam liquids are reported to be a blend of protein and synthetic materials. Protein foams were recognized as possessing the best fire extinguishing properties. Blending was necessary because of a shortage of protein materials.
>
> (c) The new standard German foam nozzle should be studied and tested.
>
> (d) The foam proportioner shown in Figure 2, has a very practical use in fire fighting. Development of a similar device for shipboard use is recommended.
>
> (e) Where adequate fire main pressure is not available to operate standard Navy foam fire fighting equipment, compressed air or carbon dioxide gas can be used to boost the pressure of water obtained from bilge pumps. Study and investigation of this principle for use on small Naval Craft is recommended.



BIOS Final Report No. 518.
ITEM No. 22.

TEXTILE AUXILIARY PRODUCTS OF I.G. FARBENINDUSTRIE: APPLICATION, TESTING AND MISCELLANEOUS INFORMATION

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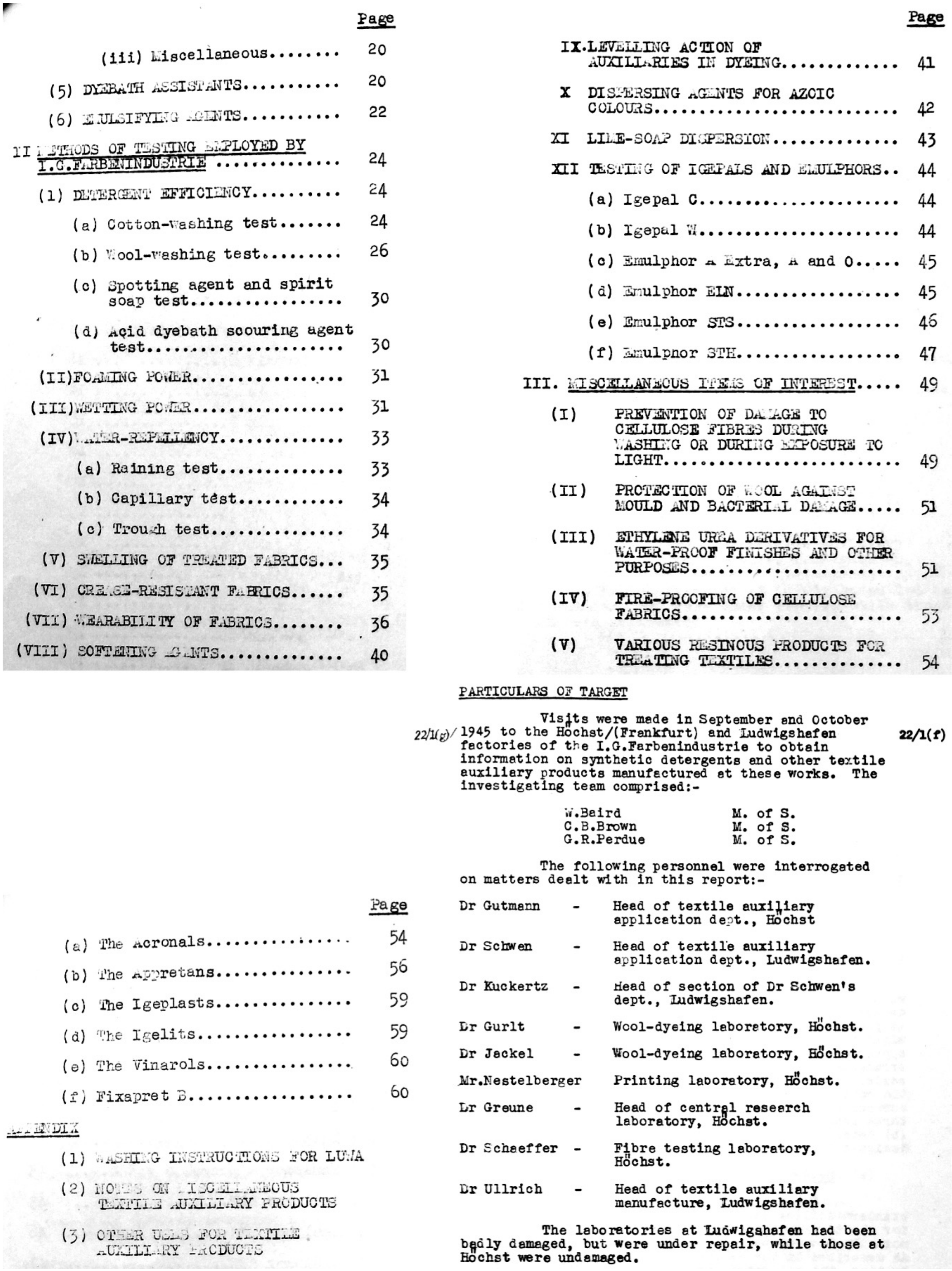
Figure 3.203: Scientists at I.G. Farben developed a wide variety of chemical treatments to make fabrics resistant to fire, water, stains, wrinkles, etc. Those chemical fabric treatments were adopted by Allied countries [BIOS 518].



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PARTICULARS OF TARGET

22/1(g)/ Visits were made in September and October 1945 to the Höchst/(Frankfurt) and Ludwigshafen factories of the I.G.Farbenindustrie to obtain information on synthetic detergents and other textile auxiliary products manufactured at these works. The investigating team comprised:- 22/1(f)

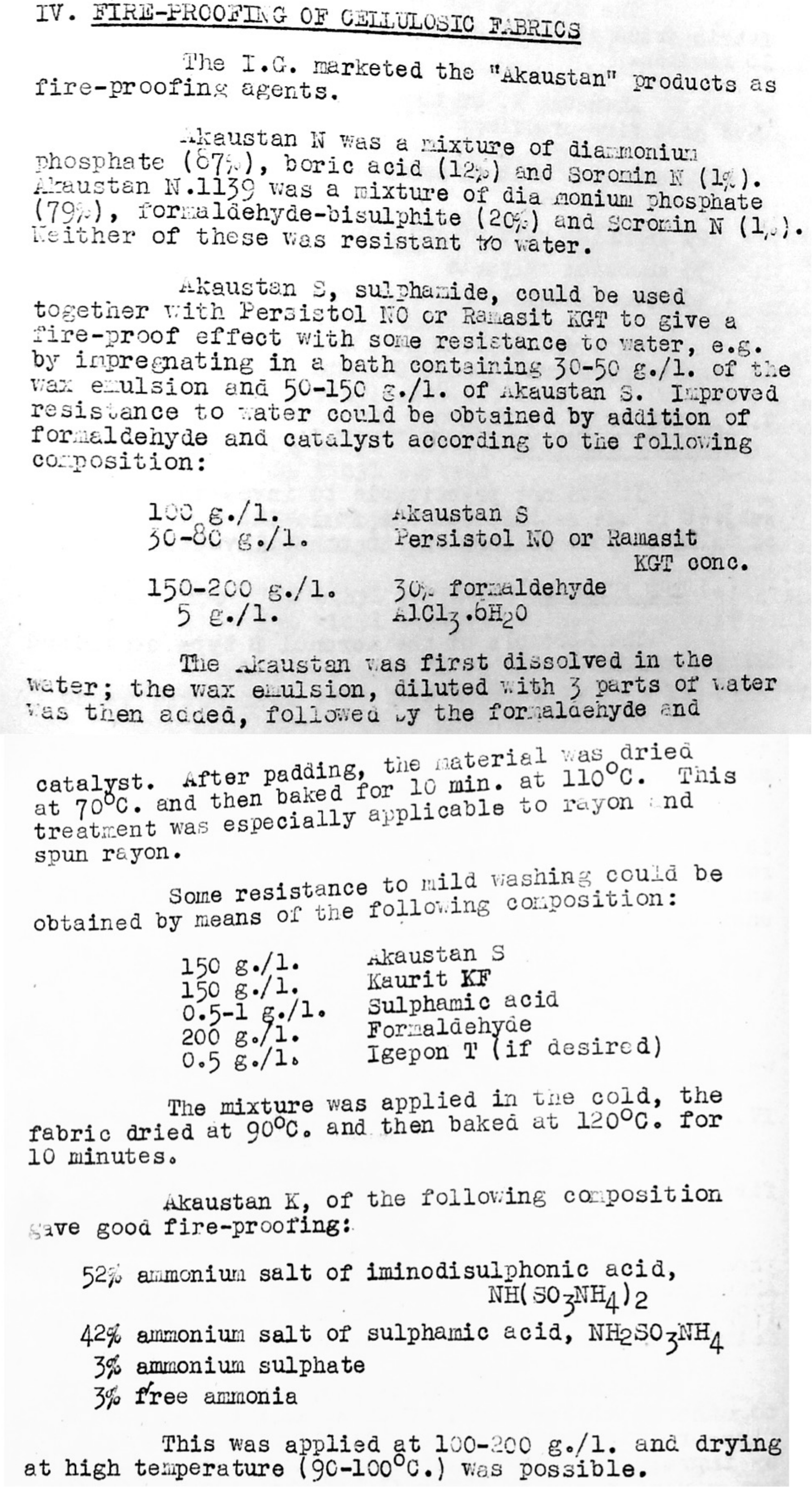
W.Baird	M. of S.
C.B.Brown	M. of S.
G.R.Perdue	M. of S.

The following personnel were interrogated on matters dealt with in this report:-

Dr Gutmann - Head of textile auxiliary application dept., Höchst
Dr Schwen - Head of textile auxiliary application dept., Ludwigshafen.
Dr Kuckertz - Head of section of Dr Schwen's dept., Ludwigshafen.
Dr Gurlt - Wool-dyeing laboratory, Höchst.
Dr Jackel - Wool-dyeing laboratory, Höchst.
Mr.Nestelberger Printing laboratory, Höchst.
Dr Greune - Head of central research laboratory, Höchst.
Dr Scheeffer - Fibre testing laboratory, Höchst.
Dr Ullrich - Head of textile auxiliary manufacture, Ludwigshafen.

The laboratories at Ludwigshafen had been badly damaged, but were under repair, while those at Höchst were undamaged.

Figure 3.204: Scientists at I.G. Farben developed a wide variety of chemical treatments to make fabrics resistant to fire, water, stains, wrinkles, etc. Those chemical fabric treatments were adopted by Allied countries [BIOS 518].



IV. FIRE-PROOFING OF CELLULOSIC FABRICS

The I.G. marketed the "Akaustan" products as fire-proofing agents.

Akaustan N was a mixture of diammonium phosphate (87%), boric acid (12%) and Soromin N (1%). Akaustan N.1139 was a mixture of diammonium phosphate (79%), formaldehyde-bisulphite (20%) and Soromin N (1%). Neither of these was resistant to water.

Akaustan S, sulphamide, could be used together with Persistol NO or Ramasit KGT to give a fire-proof effect with some resistance to water, e.g. by impregnating in a bath containing 30-50 g./l. of the wax emulsion and 50-150 g./l. of Akaustan S. Improved resistance to water could be obtained by addition of formaldehyde and catalyst according to the following composition:

100 g./l.	Akaustan S
30-80 g./l.	Persistol NO or Ramasit KGT conc.
150-200 g./l.	30% formaldehyde
5 g./l.	$AlCl_3.6H_2O$

The Akaustan was first dissolved in the water; the wax emulsion, diluted with 3 parts of water was then added, followed by the formaldehyde and catalyst. After padding, the material was dried at 70°C. and then baked for 10 min. at 110°C. This treatment was especially applicable to rayon and spun rayon.

Some resistance to mild washing could be obtained by means of the following composition:

150 g./l.	Akaustan S
150 g./l.	Kaurit KF
0.5-1 g./l.	Sulphamic acid
200 g./l.	Formaldehyde
0.5 g./l.	Igepon T (if desired)

The mixture was applied in the cold, the fabric dried at 90°C. and then baked at 120°C. for 10 minutes.

Akaustan K, of the following composition gave good fire-proofing:

52%	ammonium salt of iminodisulphonic acid, $NH(SO_3NH_4)_2$
42%	ammonium salt of sulphamic acid, $NH_2SO_3NH_4$
3%	ammonium sulphate
3%	free ammonia

This was applied at 100-200 g./l. and drying at high temperature (90-100°C.) was possible.

Figure 3.205: Scientists at I.G. Farben developed a wide variety of chemical treatments to make fabrics resistant to fire, water, stains, wrinkles, etc. Those chemical fabric treatments were adopted by Allied countries [BIOS 518].

3.9.7 “Superglue”

The family of isocyanate “superglue” products was developed in the 1930s by a large research group led by Otto Bayer (German, 1902–1982) at I.G. Farben Leverkusen. (The same group also developed polyurethane and other related products—see Fig. 3.160.)

BIOS 719, *Interview with Professor Otto Bayer, Formerly Member of the Directorate and Head of the Scientific Laboratories of the I.G. Farbenindustrie, Leverkusen*, provided information on that program:

> This interview was to obtain information on the chemistry of isocyanates and particularly the new polyisocyanates and their derivatives which have been intensively studied in Germany for some years.
>
> Professor Bayer confirmed that he had pioneered and developed this new isocyanate chemistry and stated that at Leverkusen he had had about 50–60 chemists and 200 other workers engaged on these problems.
>
> Professor Bayer was obviously an expert in his subject and had considerable knowledge of the synthesis, analysis, chemical properties, and industrial uses of the polyisocyanates and their derivatives. [...]
>
> Professor Bayer said that about 50 polyisocyanates have been prepared and examined in the laboratory. The more important of these are the following: [...]
>
> (c) Desmodur R. Triphenylmethane triisocyanate.
>
> This material was of importance for bonding rubber and Buna to various other surfaces, e.g. metals and textiles. [...]
>
> It is suggested by Professor Bayer that the adhesion obtained by the use of polyisocyanates in bonding rubber to metal is due to a film of oxide and moisture on the metal surface, the water producing ureide bridges between two isocyanate groups and such bridges then forming complexes with metal oxide films.
>
> On the rubber interface, adhesion is thought to be due to solubility of isocyanates in the rubber and to secondary valence forces. With cellulose, bonding results from the unavoidable water present in the cellulose reacting preferentially with the isocyanate.
>
> Leather can be bonded by means of isocyanates by reaction between the amino groups of the leather and the isocyanate.

These German-developed adhesives were intensively studied by Allied countries [e.g., BIOS 629; BIOS 719; BIOS 1691; BIOS 1699] and came to be used around the world after the war.

Chapter 4

Creators and Creations in Earth and Space Science

Daher ist die Aufgabe nicht sowohl zu sehen was noch keiner gesehen hat, als bei Dem was Jeder sieht, zu denken was noch Keiner gedacht hat.	Therefore the problem is not so much, to see what no one has yet seen, but rather to think concerning that which everyone sees, what no one has yet thought.

Arthur Schopenhauer. 1851.
Parerga und Paralipomena: Kleine Philosophische Schriften.
Vol. 2, Section 76, p. 93. Berlin: A. W. Hayn.

This chapter gives an overview of some earth and space science innovations that have played major roles in the modern world and that were discovered or developed by scientists and engineers who were trained in the predominantly German-speaking central European research world in the nineteenth and early twentieth centuries.[1]

---

[1] In addition to specific references that are cited in different areas throughout this chapter, this chapter makes use of general biographical and project information from: ACLS 2000; Albrecht et al. 1992; Ash and Söllner 1996; Bar-Zohar 1967; Bower 1987; Bunch and Hellemans 2004; Challoner 2009; Cornwell 2003; Crim 2018; EB 1911, 2010; Gillispie 1970–1990; Gimbel 1990a; Glatt 1994; Hall 2019a; István Hargittai 2006, 2011; Linda Hunt 1991; Impey et al. 2008; Jacobsen 2014; Koertge 2007; Kurowski 1982; Lasby 1971; Lusar 1956, 1971; Medawar and Pyke 2000; Mick 2000; Murray 2003; Nachmansohn 1979; NDB 1953–2020; Neufeld 2012; Nouzille and Huwart 1999; O'Reagan 2014, 2019; Porter 1994; Charles Walker 1946; Peter Watson 2010; Weitensfelder 2009.

For coverage of major portions of the history of earth and space science in the German-speaking world, see: von Boguslawski and Krümmel 1884–1887; Bowler 1993; Brückner and Penck 1909; Chambers 2002; Chladni 1794; Galle and Wattenberg 1963; Geiger 1950; Greene 2015; von Hann 1887; von Hann and Süring 1926; Haurwitz 1941; Hesse 1924, 1937; Hoskin 2011; Javanović-Kruspel 2015; Köppen 1955; Lemonick 2008; Lüdecke 2015; Mohs 1825; North 1995; Nothdurft and Smith 2002; Probst 2015; Schön 2004; Schwarzschild 1958; Spiess 1985; Wegener 1966; Wellnhofer 2008; Wulf 2015.

Creators from the German-speaking world made major contributions to geophysical and space science fields, including:

4.1. Geological science

4.2. Paleontology

4.3. Ocean and hydrological science

4.4. Atmospheric science

4.5. Planetary science

4.6. Astrophysics

4.1 Geological Science

German-speaking scientists made a long string of discoveries in geological science and related fields, including:

4.1.1. Stratigraphy and continental drift

4.1.2. Geophysics

4.1.3. The Universal Transverse Mercator (UTM) for map coordinates

Outside observers were impressed and even envious of how seriously the whole German-speaking world took the field of geology. For example, in BIOS 948, *German Academic Geology*, visiting British scientists wrote after World War II:

> Geology was a subject formerly taught in German schools but was removed from the curriculum under the Hitler regime. It is, we understand, to be replaced and it is clear that teachers should receive sound geological training up to the necessary level at their Universities. [...]
>
> Strong representations have been made for a number of years that Geology should be a part of the normal science curriculum in British schools. In this respect, the team regard the proposed German curriculum as on a considerably wider basis than the existing British practice. [...]
>
> In prewar times, German geologists found employment in considerable numbers outside Germany[...]
>
> We were impressed with the high status of German mining and miners. There is a deep-routed tradition derived from the thousand years of their honourable history that has given the German miners a sense of self-esteem and a realisation of their high place in the community.

I have deliberately left a blank space where images of some creators or creations should go. Those are people or projects that I felt were important enough that they should definitely be shown in this book, yet I have not yet been able to locate a suitable image that I have permission to use, despite my searches in Europe and in the United States. If readers have any relevant images and could send them to me, I would be very grateful and will include them in future editions of this book. Even where a suitable photo cannot be located, I believe that leaving a blank space pays tribute both to the scientific importance of that creator or creation and to how that historical fact has been very nearly forgotten.

4.1.1 Stratigraphy and Continental Drift

Abraham Gottlob Werner (German states, 1749–1817, Fig. 4.1) developed stratigraphy, the scientific analysis of rock layers of increasing age with increasing depth. He also taught a large number of students, many of whom became highly influential geologists. *Encyclopaedia Britannica* called him the "father of German geology" [EB 1911].

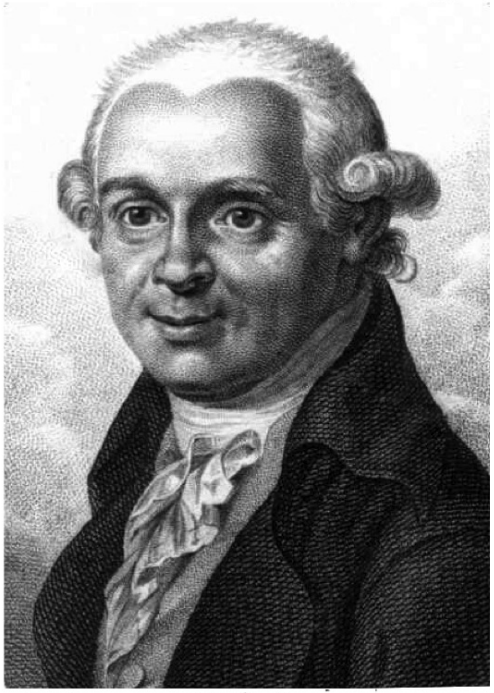
Eduard Suess (Austrian, 1831–1914) discovered and correctly interpreted evidence for the Paleozoic southern supercontinent Gondwana and the adjacent Tethys Ocean (1861); see Fig. 4.2. Suess also proposed methods of measuring changes in ancient sea levels vs. time and was one of the first scientists to discuss the ecology of biospheres. Oxford University's *Biographical Dictionary of Scientists* summarized some of Suess's research accomplishments [Porter 1994, p. 651]:

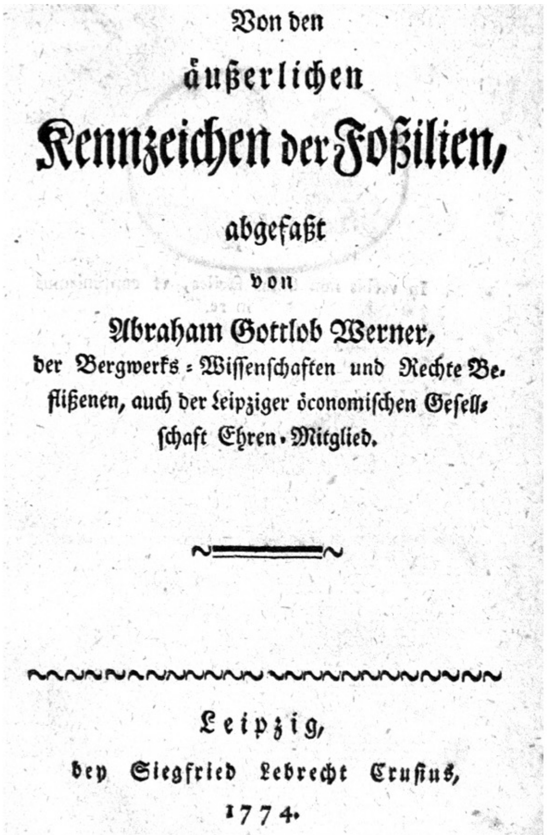
> The outcome of these interests was *The Face of the Earth* 1885–1909, a massive work devoted to analysing the physical agencies contributing to the Earth's geographical evolution. Suess offered an encyclopedic view of crustal movement, of the structure and grouping of mountain chains, of sunken continents, and of the history of the oceans. He also made significant contributions to rewriting the structural geology of each continent.
>
> In many respects, Suess cleared the path for the new views associated with the theory of continental drift in the twentieth century. In view of geological similarities between parts of the southern continents, Suess suggested that there had once been a great supercontinent, made up of the present southern continents; this he named Gondwanaland, after a region of India. Wegener's work was later to establish the soundness and penetration of such speculations.

Alfred Wegener (German, 1880–1930) marshalled detailed evidence for his theory of continental drift (1912–1930) and also made major contributions to the understanding of polar air circulation. Wegener, shown in Fig. 4.3, was the son-in-law of Wladimir Köppen (p. 782). Wegener died while on an expedition to Greenland to gather more evidence for his theories. His ideas regarding continental drift became widely accepted and celebrated after his death [Greene 2015; Wegener 1966]. The *Encyclopedia Britannica* described Wegener's research [EB 2010]:

> German meteorologist and geophysicist who formulated the first complete statement of the continental drift hypothesis. [...]
>
> In about 1910 he began toying with the idea that in the Late Paleozoic era (about 250 million years ago) all the present-day continents had formed a single large mass, or supercontinent, which had subsequently broken apart. Wegener called this ancient continent Pangaea. [...]
>
> Wegener first presented his theory in lectures in 1912 and published it in full in 1915 in his most important work, *Die Entstehung der Kontinente und Ozeane* (*The Origin of Continents and Oceans*). He searched the scientific literature for geological and paleontological evidence that would buttress his theory, and he was able to point to many closely related fossil organisms and similar rock strata that occurred on widely separated continents, particularly those found in both the Americas and in Africa.

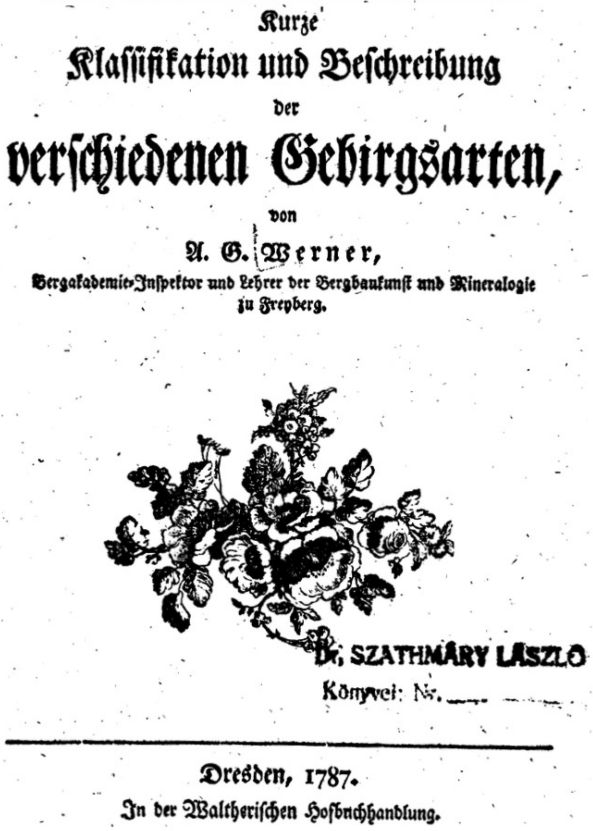
Abraham Gottlob Werner
(1749–1817) stratigraphy,
“father of German geology”





Von den
äußerlichen
Kennzeichen der Foßilien,
abgefaßt
von
Abraham Gottlob Werner,
der Bergwerks-Wiſſenſchaften und Rechte Beflißenen, auch der leipziger öconomiſchen Geſellſchaft Ehren-Mitglied.

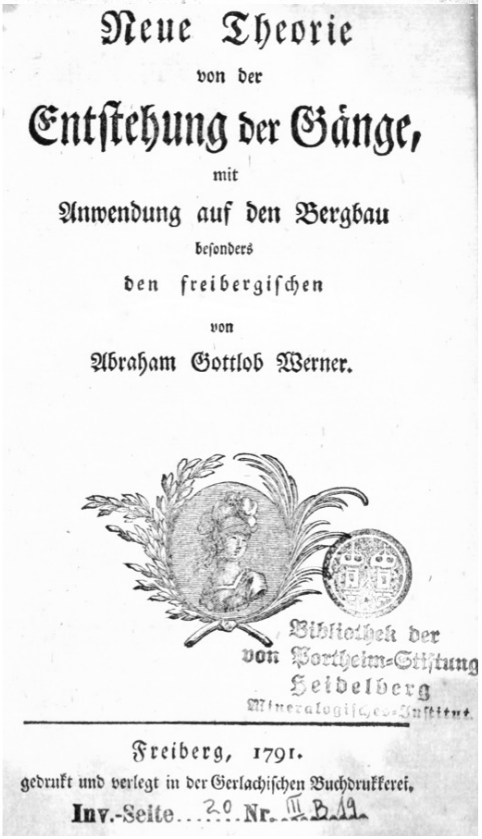
Leipzig,
bey Siegfried Lebrecht Cruſius,
1774.



Kurze
Klaſſifikation und Beſchreibung
der
verſchiedenen Gebirgsarten,
von
A. G. Werner,
Bergakademie-Inſpektor und Lehrer der Bergbaukunſt und Mineralogie
zu Freyberg.

Dr. SZATHMÁRY LÁSZLÓ
Könyvei: Nr.

Dresden, 1787.
In der Waltheriſchen Hofbuchhandlung.



Neue Theorie
von der
Entſtehung der Gänge,
mit
Anwendung auf den Bergbau
beſonders
den freibergiſchen
von
Abraham Gottlob Werner.

Bibliothek der
von Portheim-Stiftung
Heidelberg
Mineralogiſches Inſtitut

Freiberg, 1791.
gedrukt und verlegt in der Gerlachiſchen Buchdrukkerei.

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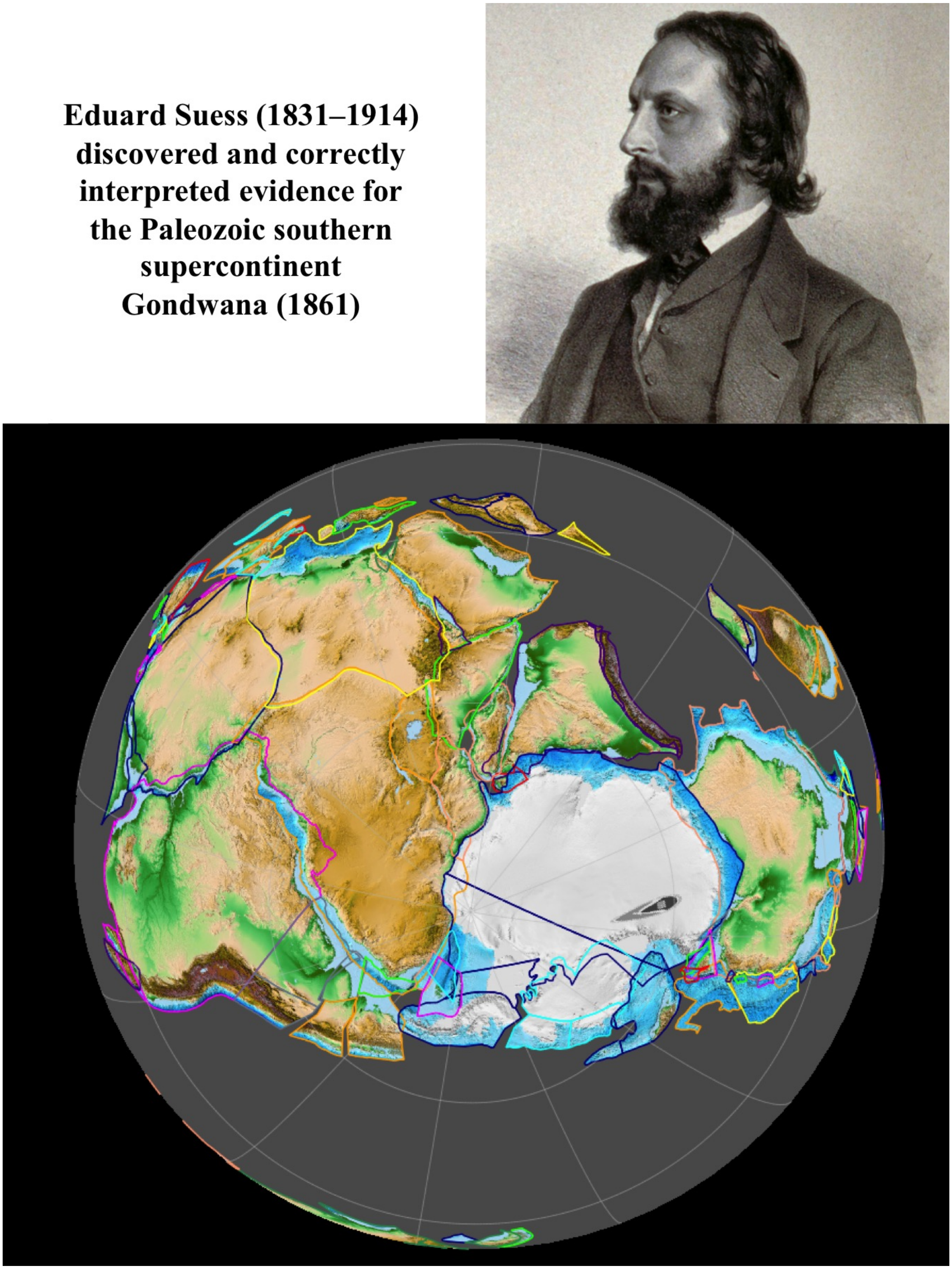
Figure 4.1: Abraham Gottlob Werner developed stratigraphy, the scientific analysis of rock layers of increasing age with increasing depth, and is regarded as the “father of German geology.”



**Eduard Suess (1831–1914)
discovered and correctly
interpreted evidence for
the Paleozoic southern
supercontinent
Gondwana (1861)**

Figure 4.2: Eduard Suess discovered and correctly interpreted evidence for the Paleozoic southern supercontinent Gondwana (1861).

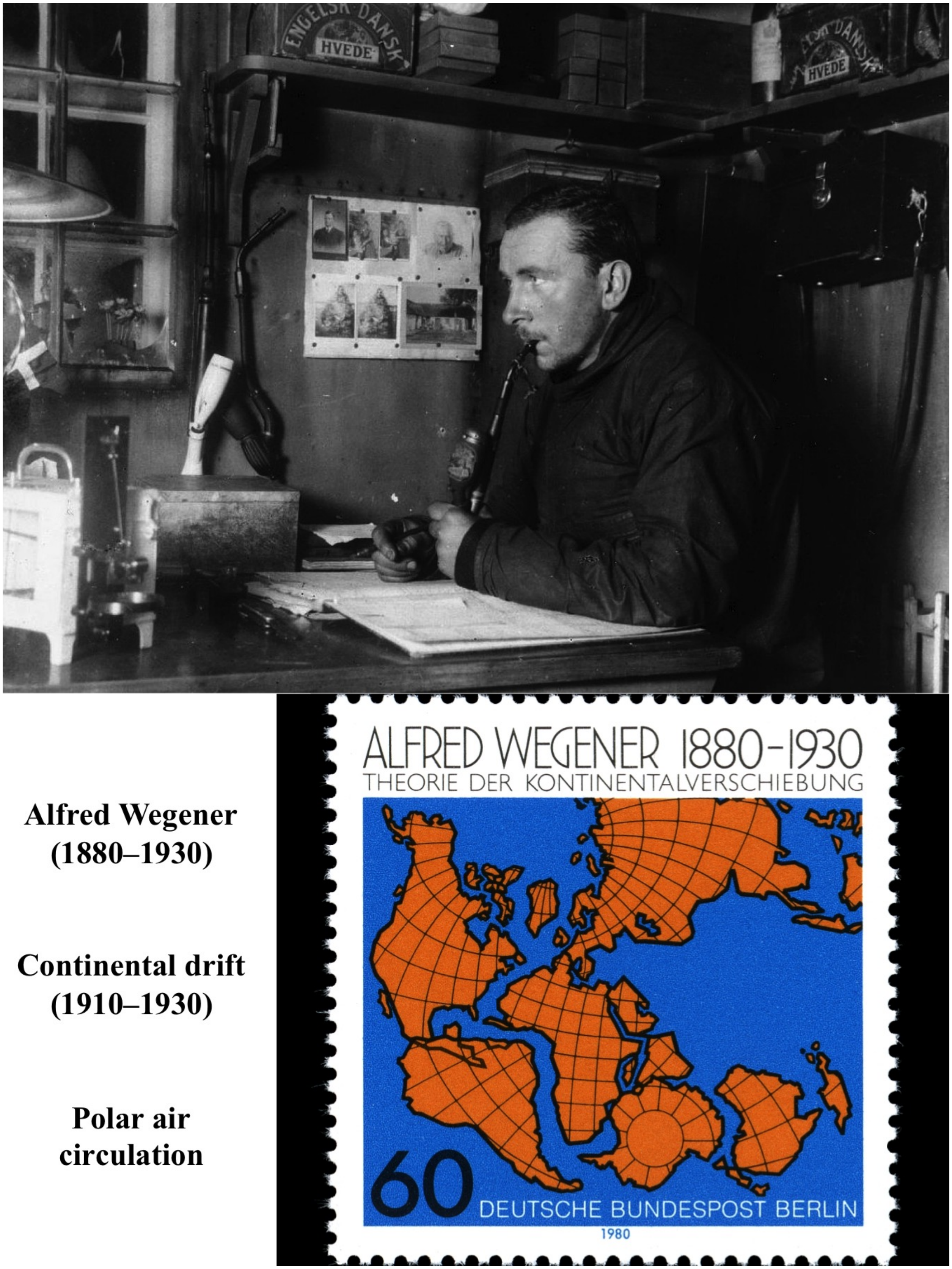

ENGELSK·DANSK
HVEDE
Alfred Wegener
(1880–1930)
Continental drift
(1910–1930)
Polar air
circulation
ALFRED WEGENER 1880-1930
THEORIE DER KONTINENTALVERSCHIEBUNG
60
DEUTSCHE BUNDESPOST BERLIN
1980

Figure 4.3: Alfred Wegener marshalled detailed evidence for his theory of continental drift (1910–1930) and also made major contributions to the understanding of polar air circulation.

4.1.2 Geophysics

Emil Wiechert (German, 1861–1928) established the detailed study of the structure of the Earth and the behavior of different types of seismic waves passing through parts of the Earth; see Fig. 4.4. Specifically, he invented an improved seismograph, calculated how seismic waves propagate through the Earth, demonstrated evidence for layers within the Earth, and proposed that the Earth's core was made of iron. Wiechert was also one of several German-speaking scientists who discovered and analyzed the electron before the more famous work of J. J. Thomson (p. 863).

Wiechert was the first professor of geophysics in Germany and founded the world's first Institute of Geophysics at Göttingen University in 1898. In 1922, he also initiated the foundation of the German Geophysical Society (initially called the Deutsche Seismologische Gesellschaft). Wiechert attracted, taught, and collaborated with many younger scientists who made fundamental discoveries in geophysics, such as:

- Gustav Angenheister (German, 1878–1945, Fig. 4.5) studied surface waves from earthquakes, was the director of an observatory in Samoa for several years, and in 1928 became the successor of Wiechert as head of the Institute of Geophysics at Göttingen University.

- Ludwig Carl Geiger (Swiss, 1882–1966, Fig. 4.5) made many contributions to seismology, most notably by developing a method to determine the epicenter of an earthquake.

- Beno Gutenberg (German, 1889–1960) was one of Wiechert's greatest students at the Göttingen Institute of Geophysics, and he continued to conduct geophysics research after he obtained his doctorate in 1911. Gutenberg built upon all of the Institute's work up to that time by developing a system of quantifying earthquake energy, and also by making major contributions to the knowledge of the Earth's interior structure and convective circulation in the Earth's mantle (Fig. 4.6). Due to rising antisemitism in Germany, in 1930 Gutenberg moved to the California Institute of Technology and founded the Seismological Laboratory there. In the United States, the name of one of Gutenberg's American students, Charles Richter, became associated with the earthquake energy scale that had been developed by Gutenberg and that was based on decades of German seismological work at Göttingen. As a result, Richter's name has been immortalized with the "Richter scale," and the work of Gutenberg and all of his predecessors back to Emil Wiechert has been largely forgotten by the general public.

- Gustav Herglotz (German, 1881–1953, Fig. 4.5) worked with Emil Wiechert to develop equations for the velocities and travel times of seismic waves in the Earth (the Wiechert-Herglotz method). He also made many important contributions to applied mathematics and relativistic physics.

- Ludger Mintrop (German, 1880–1956, Fig. 4.5) invented seismic methods of exploring for oil and minerals, using his own specially designed vibrometers and seismographs. His work revolutionized oil drilling and minerals mining industries worldwide. During World War I, he developed seismic methods to locate the position of enemy artillery guns.

- Wilhelm Schlüter (German?, 1875–1902, Fig. 4.5) invented the clinograph for measuring changes in the angle of inclination of a slope. He used his new instrument to demonstrate that long waves from earthquakes are not linear oscillations that vibrate in one direction, but rather elliptical oscillations that vibrate around an elliptical pattern in two dimensions.

- Karl Bernhard Zoeppritz (German, 1881–1908, Fig. 4.5) developed the Zoeppritz equations for calculating the propagation and reflection of S and P seismic waves. He probably would have gone on to make many more important discoveries in geophysics, but unfortunately he died from an infection when he was only 26 years old.

Loránd Eötvös (Hungarian, 1848–1919) and Felix Vening Meinesz (Dutch, 1887–1966) developed increasingly sensitive gravitational gradiometers for mapping the mass distribution of underlying geological structures; see Fig. 4.7.

Alexander von Humboldt (Prussian, 1769–1859, Fig. 4.8) pioneered geomagnetic mapping, making and recording measurements of the Earth's magnetic field in his travels around the world [Wulf 2015]. He discovered that the strength of the magnetic field increases as one travels from the equator toward the poles. He also coined the term "physical geography," which later became known as geophysics.

Carl Friedrich Gauss (German states, 1777–1855) and Wilhelm Weber (German, 1804–1891), shown in Fig. 4.8, greatly improved geomagnetic mapping. They invented more accurate instruments for measuring the strength and direction of the magnetic field, established a society to make magnetic measurements around the world, and developed mathematical methods (potential theory) for analyzing the results to locate magnetic sources and to distinguish magnetic sources inside the Earth from those outside the Earth [Dunnington 1955]. (See also pp. 793, 828, 858, and 972.)

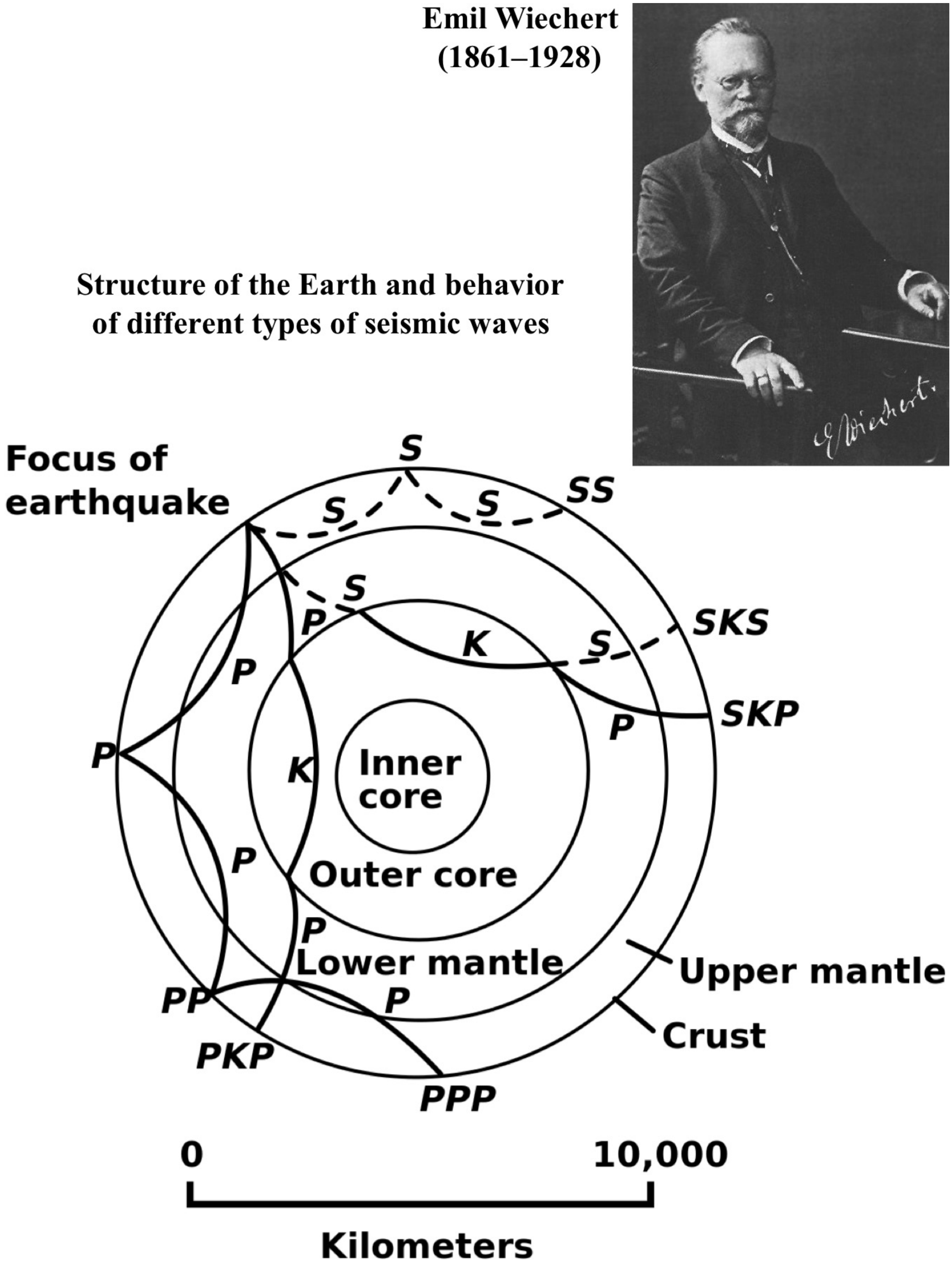
Julius Bartels (German, 1899–1964) and Gerhard Fanselau (German, 1904–1982) also made detailed studies of the Earth's magnetic field (Fig. 4.9).

Educated at Göttingen University and building upon all of that earlier German work on geomagnetism and geophysics, Walter Elsasser (German, 1904–1991) developed the dynamo model that explains how the Earth's magnetic field is generated by the Earth's core (Fig. 4.9). Though sadly little remembered now, Elsasser made strikingly innovative contributions to multiple scientific fields, including methods of calculating the "magic numbers" of protons and neutrons required to fill different energy levels of the atomic nucleus (p. 1535) [Rubin 1995]. The *Encyclopedia Britannica* praised his many revolutionary insights [EB 2010]:

> Elsasser received the Ph.D. from the University of Göttingen in 1927[...]
>
> While Elsasser was a graduate student he correctly predicted that a beam of electrons would be diffracted by a crystalline material; after the neutron was discovered, he predicted the same behaviour for neutrons. Independently of Nobel Prize winner Hans Bethe, Elsasser carried out important work on the likelihood of certain interactions between neutrons and atomic nuclei.
>
> Elsasser formulated what is called the dynamo model of the Earth's structure to account for the origin and properties of its magnetic field. He suggested that convection within the core, driven by the energy of radioactive decay, generates electric currents that

> intereract with concentric spherical shells of the Earth's mantle, which are rotating at different speeds, and that the Coriolis effect produces eddies at the boundaries of these shells.
>
> He also investigated the applicability of contemporary theoretical concepts of physics, especially quantum mechanics, to the biological sciences, presenting his views in *The Physical Foundation of Biology* (1958), *Atom and Organism* (1966), and *The Chief Abstractions of Biology* (1975).

As illustrated in Fig. 4.10, Victor Goldschmidt (Swiss, 1888–1947) founded the field of geochemistry, and Walter Hermann Bucher (German, 1888–1965) made major contributions to structural geology and paleontology.



Emil Wiechert
(1861–1928)

Structure of the Earth and behavior of different types of seismic waves

Focus of earthquake
S
S
S
SS
S
P
K
S
SKS
P
SKP
P
P
K
Inner core
P
Outer core
P
Lower mantle
Upper mantle
PP
P
Crust
PKP
PPP
0
10,000
Kilometers

Figure 4.4: Emil Wiechert established the detailed study of the structure of the Earth and the behavior of different types of seismic waves passing through parts of the Earth.

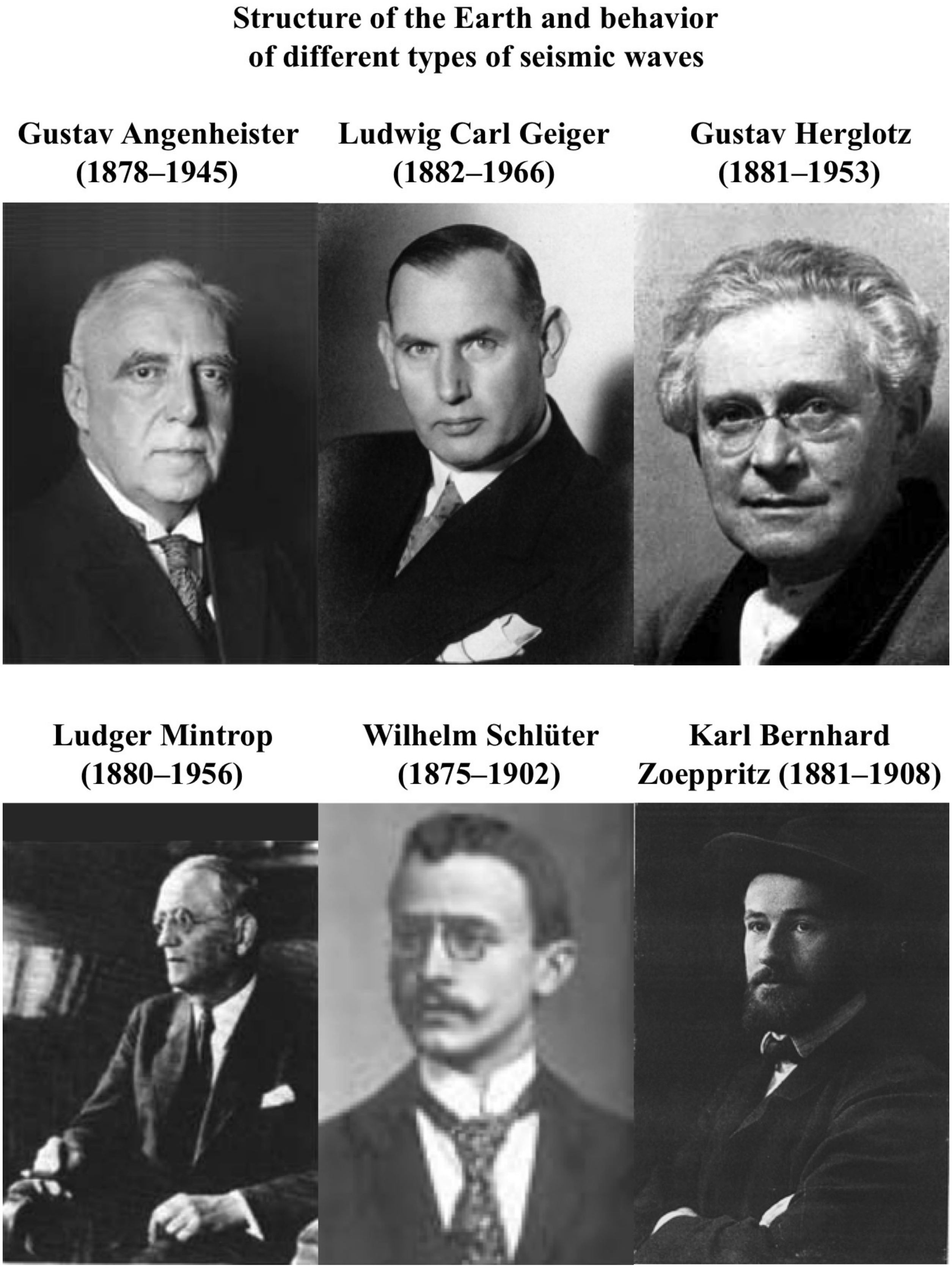

Structure of the Earth and behavior of different types of seismic waves
Gustav Angenheister (1878–1945)
Ludwig Carl Geiger (1882–1966)
Gustav Herglotz (1881–1953)
Ludger Mintrop (1880–1956)
Wilhelm Schlüter (1875–1902)
Karl Bernhard Zoeppritz (1881–1908)

Figure 4.5: Some other creators who made major contributions to knowledge of the structure of the Earth and the behavior of different types of seismic waves included Gustav Angenheister, Ludwig Carl Geiger, Gustav Herglotz, Ludger Mintrop, Wilhelm Schlüter, and Karl Bernhard Zoeppritz.

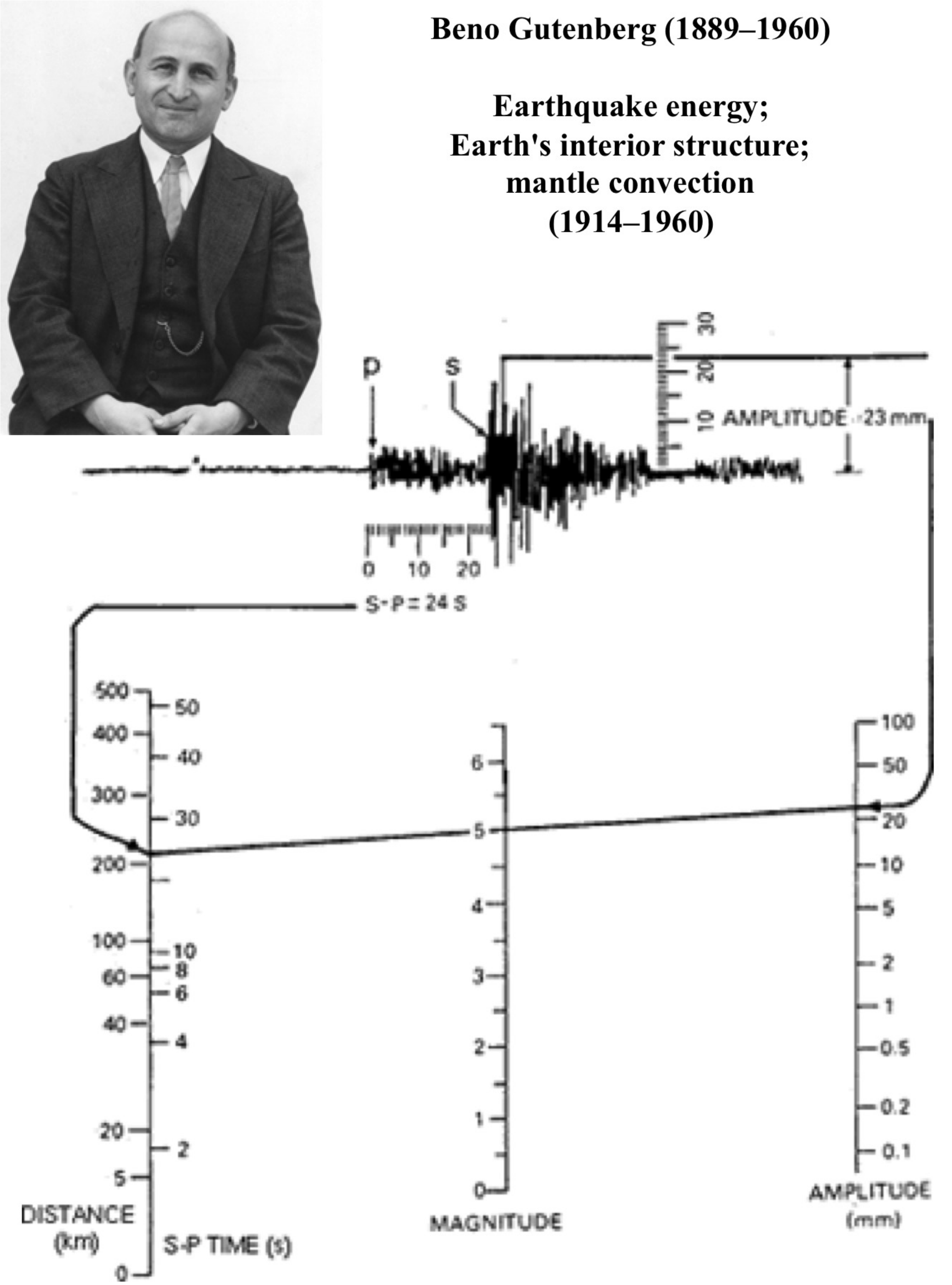
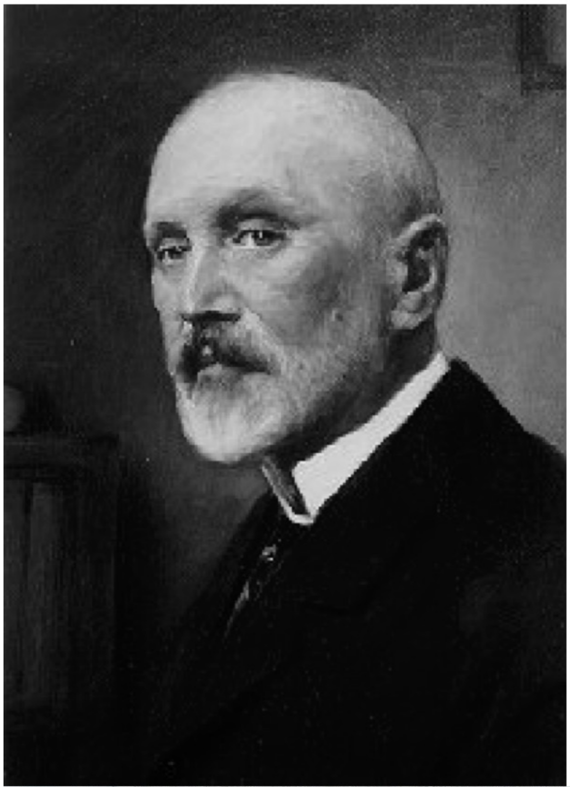
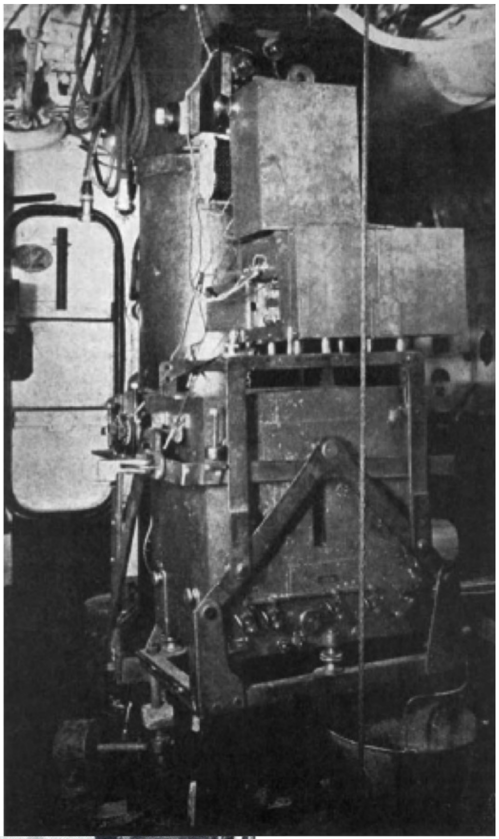

Beno Gutenberg (1889–1960)
Earthquake energy;
Earth's interior structure;
mantle convection
(1914–1960)
P
S
10
20
30
AMPLITUDE = 23 mm
0
10
20
S-P = 24 S
500
400
300
200
100
60
40
20
5
0
50
40
30
10
8
6
4
2
DISTANCE (km)
S-P TIME (s)
6
5
4
3
2
1
0
MAGNITUDE
100
50
20
10
5
2
1
0.5
0.2
0.1
AMPLITUDE (mm)

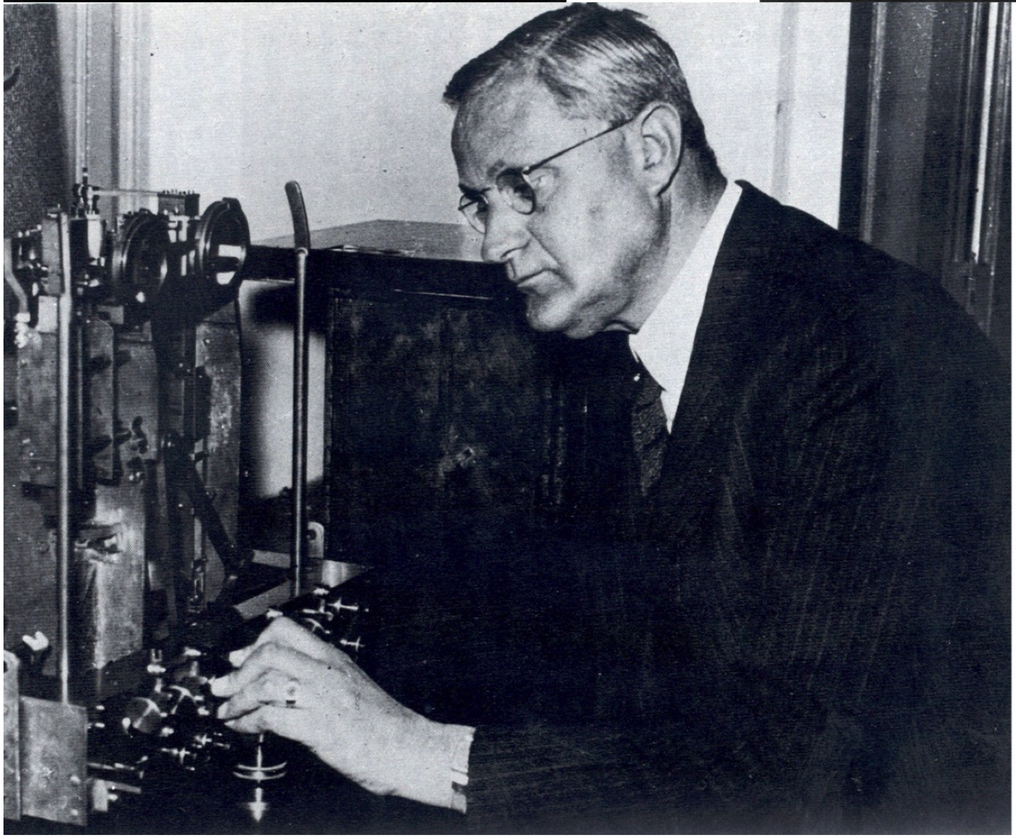
Figure 4.6: Beno Gutenberg developed a system of quantifying earthquake energy. He also made major contributions to knowledge regarding the Earth's interior structure and convective circulation in the Earth's mantle (1914–1960).

Loránd Eötvös (1848–1919)





Meinesz gravitational gradiometer for submarines



Felix Vening Meinesz (1887–1966)

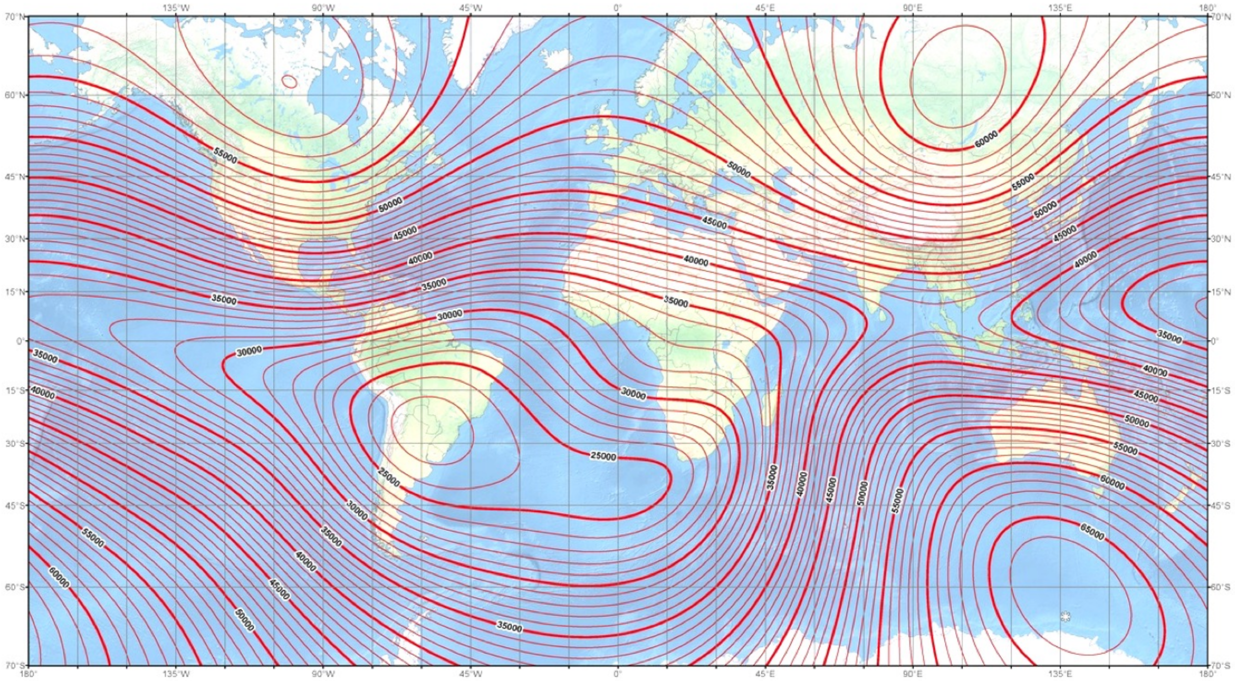
Figure 4.7: Loránd Eötvös and Felix Vening Meinesz developed increasingly sensitive gravitational gradiometers for measuring the mass of underlying geological structures.

Alexander von Humboldt (1769–1859)

Carl Friedrich Gauss (1777–1855)

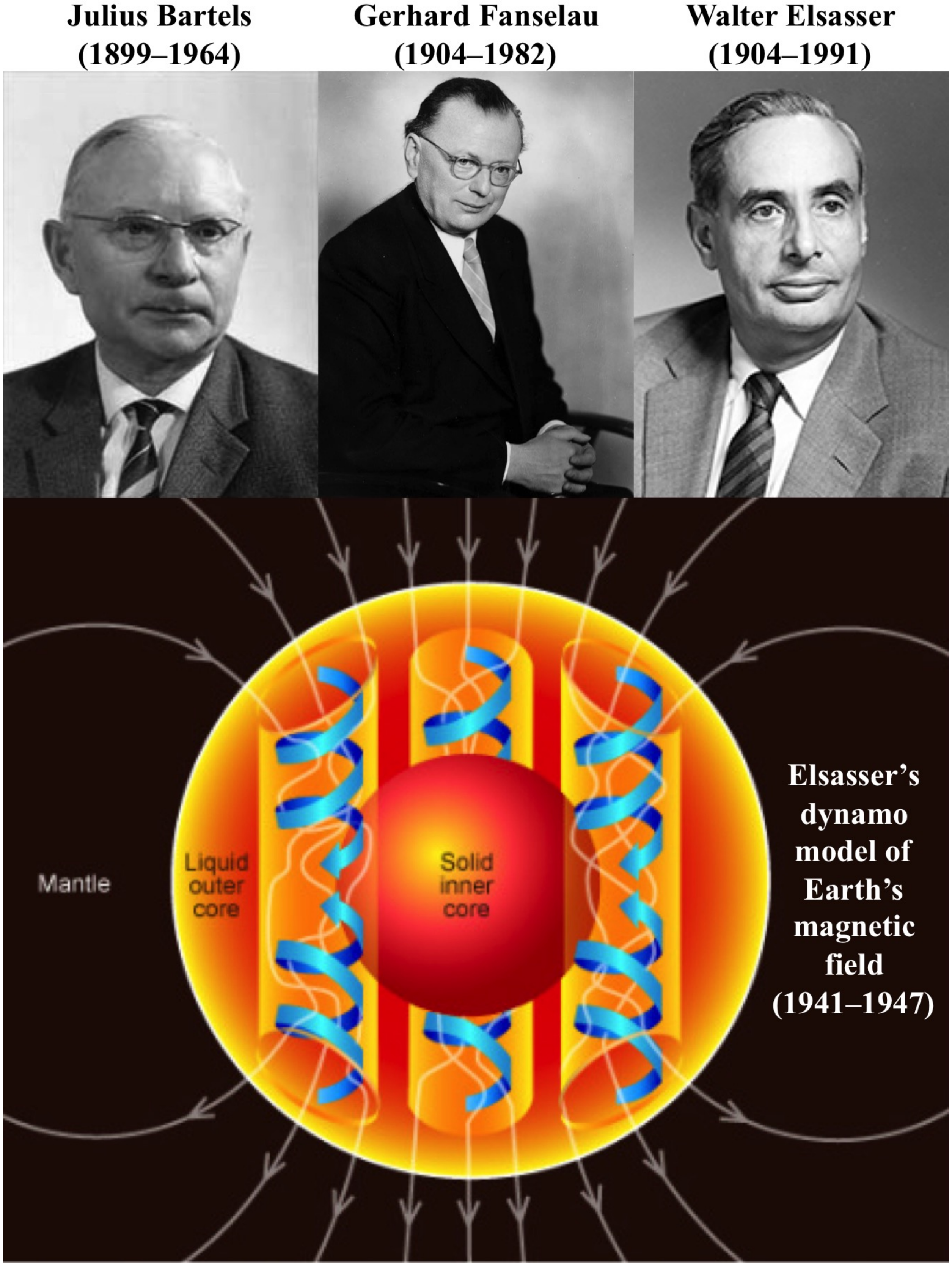
Wilhelm Weber (1804–1891)

Geomagnetic mapping



135°W
90°W
45°W
0°
45°E
90°E
135°E
180°
70°N
60°N
45°N
30°N
15°N
0°
15°S
30°S
45°S
60°S
70°S
25000
30000
35000
40000
45000
50000
55000
60000
65000

Figure 4.8: Alexander von Humboldt, Carl Friedrich Gauss, and Wilhelm Weber developed geomagnetic mapping.



Julius Bartels (1899–1964)

Gerhard Fanselau (1904–1982)

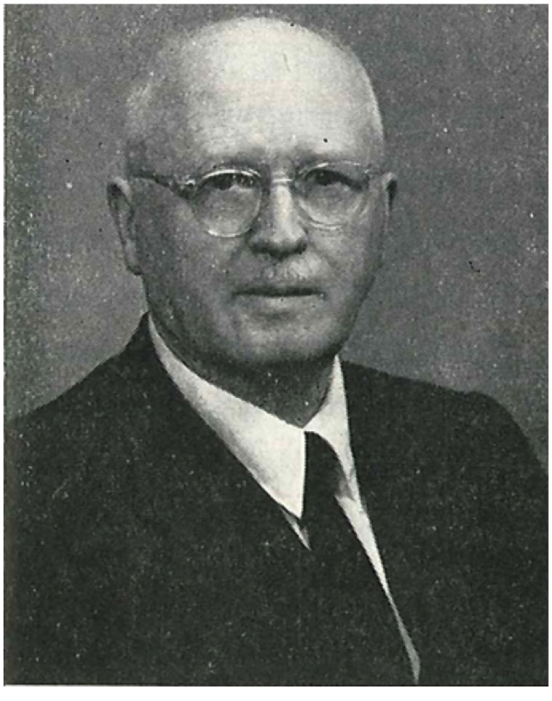
Walter Elsasser (1904–1991)

Elsasser's dynamo model of Earth's magnetic field (1941–1947)

Mantle
Liquid outer core
Solid inner core

Figure 4.9: Julius Bartels and Gerhard Fanselau made detailed studies of the Earth's magnetic field, and Walter Elsasser developed the dynamo model that explains how the Earth's magnetic field is generated (1941–1947).

Victor Goldschmidt
(1888–1947, right)
founder of geochemistry



Walter Hermann Bucher
(1888–1965)
structural geology,
paleontology

Figure 4.10: Victor Goldschmidt founded the field of geochemistry, and Walter Hermann Bucher made major contributions to structural geology and paleontology.

4.1.3 Universal Transverse Mercator (UTM) for Map Coordinates

German-speaking creators also developed the Universal Transverse Mercator (UTM) projection system for map coordinates, which is now used worldwide for the Global Positioning System (GPS) [Buchroithner and Pfahlbusch 2016]. Official histories have claimed that the UTM system was developed by the United States after World War II, but cartographers Manfred Buchroithner and René Pfahlbusch discovered evidence that the UTM system was developed in Germany before and during World War II, and seized by the United States at the end of the war:

> Recent discoveries of Wehrmacht Maps in the Military Archive of the Federal Archive of Germany in Freiburg im Breisgau raised the motivation for further investigations into the history of the internationally employed Universal Transverse Mercator (UTM) projection which actually represents a prerequisite for the global use of Global Positioning System (GPS)—and thus of any type of navigation—instruments. In contrast to the frequently stated opinion that this map projection was first operationally used by U.S. Americans it turned out that presumably the first operational maps with indication of the orthogonal UTM grid were produced by German Wehrmacht officers prior to the post World War (WW) II triumph of this projection. Based on the authors' recent discoveries this article reveals some hitherto hardly known facts concerning the history of cartography of the 1940s. [...]
>
> With the complete military occupation of Germany through the Allied Forces in spring 1945 the largest part of the German geodetic documents and records stored in the Thuringian temporary evasion quarters of the "Reichsamt für Landesaufnahme" (RfL, Reich Office for Surveying) and the "Kriegskartenhauptamt" (Main Office for Military Maps) fell into the hands of the American troops. The U.S. Army Map Service (AMS) immediately examined these "German Materials, as they came to be called" (Cloud 2002, 264, cum lit.) and recognized its value. Since Thuringia was by negotiation provided as part of the Soviet Occupation Zone, all the material and the expert staff was evacuated to Bamberg in the American Occupation Zone. Directly after the war (Bamberg Conference in June 1945), with cooperation of staff members of the former RfL, a new geodetic "armaments program" for Europe began. Leading members of the mapping activities of the Deutsches Reich, last not least of the Reconnaissance Unit "Dora" and the "Forschungsstaffel zur besonderen Verwendung" (Research Squadron for Special Deployment) were, during the first months and years after the war, interrogated by the Americans.
>
> In his memoirs, Wolfgang Pillewizer (1911–1999), first member of the Reconnaissance Unit "Dora" and then of the "Forschungsstaffel zur besonderen Verwendung" (cf. Stams 2012) and as chair holder of cartography predecessor of the first author of this article, describes in considerable detail the interrogations of himself and also other members of the Reconnaissance Unit "Dora" and the "Research Squadron for Special Deployment" by OSS, the Office of Strategic Services, the then military secret service (Pillewizer 1986). In his book and later during oral communications with the prime author in the 1990s, he also mentioned that one task of the "Forschungsstaffel" was the mapping of possible "extension areas" of the Deutsches Reich, and that immediately after the war OSS chased him and subsequently kept him detained in Kransberg Castle, Germany,

over 16 months for interrogations about his cartographic activities in Eastern Europe and outside Europe (cf. also Häusler 2007b; Buchroithner, Koch, and Stams 2012). There, not only thematic but also geometric questions of the cartographic work were subject of the questioning. [...]

Early German research and development results were adopted by the Soviet Union in the 1930s and later by the USA and gained worldwide recognition—last not least through the introduction of the UTM system by the NATO member states in 1951. The end of the Cold War and the release of the military satellite navigation system of NATO for civilian purposes led to its final breakthrough. This implies that today almost all industrialized countries use for their authoritative map series a geodetic coordinate system which has its origin, for the most essential part, in Germany. In the twenty-first century, in a world of ubiquitous application of GPS at a global scale, UTM Projection became simply a *conditio sine qua non* for everyday life.

4.2 Paleontology

Scientists from the German-speaking world made many valuable contributions to areas of paleontology including:[2]

4.2.1. Animal and plant fossils

4.2.2. Hominid fossils

4.2.3. Biogeography

4.2.1 Animal and Plant Fossils

Friedrich von Alberti (German, 1795–1878), shown in Fig. 4.11, identified and characterized Triassic rock strata and their fossils, as well as the preceding large Permian-Triassic extinction event, and the following Triassic-Jurassic extinction event. He published the results of those studies in 1834. He also greatly improved salt mining and salt processing by introducing a process of steam heating.

Christian Leopold von Buch (German states, 1774–1853, Fig. 4.12) similarly characterized Jurassic rock strata and their fossils, and also explained igneous rock formation. He created the first geological map of Germany in 1826.

As shown in Fig. 4.13, Karl Häberlein (German?, 18??–19??), Hermann von Meyer (German states, 1801–1869), and Wilhelm Dames (German, 1843–1898) discovered and analyzed *Archaeopteryx* specimens, which are important transitional fossils for bird evolution (1861–1884) [Chambers 2002; Wellnhofer 2008]. Hermann von Meyer also discovered *Plateosaurus*, an important step in the evolution of sauropod dinosaurs, and Wilhelm Dames also studied whale evolution.

The American Council of Learned Societies described von Meyer's importance in the field of paleontology [ACLS 2000, p. 602]:

> His main scientific area of interest was the fossil vertebrates, and his chief work was *Fauna der Vorwelt* (4 vols., 1845). He considered all types of vertebrates and was one of the most distinguished scientists in the field; his descriptions were characterized by great accuracy and clarity of expression.

Ernst Stromer (German, 1871–1952, Fig. 4.14) led an important expedition to Egypt to excavate Cretaceous deposits, and he spent much of the rest of his career analyzing his finds in Germany. Through this material, Stromer discovered *Spinosaurus* and several other Cretaceous dinosaurs along with many non-dinosaur species. Unfortunately almost all of his fossil collection was destroyed when the Munich museum housing it was bombed by the Allies in 1944 [Nothdurft and Smith 2002; Probst 2015].

---

[2] Bowler 1993; Chambers 2002; Colbert 1984; Hesse 1924, 1937; Javanović-Kruspel 2015; Nothdurft and Smith 2002; Probst 2015; Wellnhofer 2008; Wulf 2015.

Louis Agassiz (Swiss, 1807–1873, Fig. 4.15) studied in Germany and worked in Switzerland before eventually moving to the United States, where he helped to build up the field of paleontology from his post at Harvard. He found and analyzed a wide variety of fossils over the course of his career.

Heinrich Ernst Beyrich (German, 1815–1896, Fig. 4.15) discovered many Cenozoic fossils and named the Oligocene epoch of the Cenozoic era.

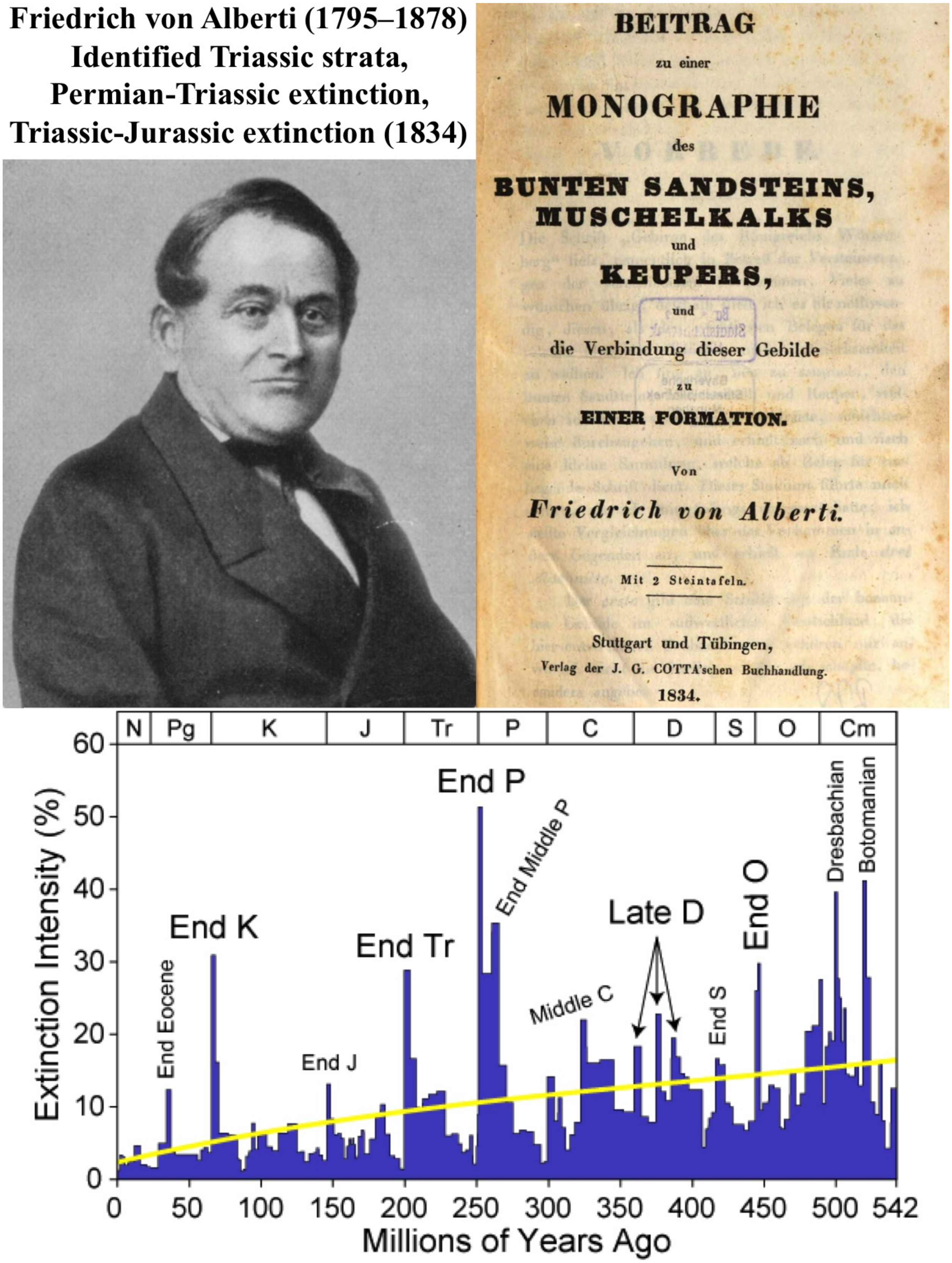
Johanna "Tilly" Edinger (German, 1897–1967, Fig. 4.15) founded the field of paleoneurology, the study of brain structure and brain evolution from endocasts preserved inside some fossil skulls. Oxford University's *Biographical Dictionary of Scientists* emphasized the importance of Edinger's research [Porter 1994, p. 201]:

> Edinger was a leading figure in the field of twentieth-century vertebrate palaeontology and laid the foundations for the study of palaeoneurology. In her two great works *Die fossilen Gehirne* (Fossil Brains) (1929) and *The Evolution of the Horse Brain* (1948) she demonstrated that the evolution of the brain could be studied directly from fossil cranial casts.

Hanns Bruno Geinitz (German, 1814–1900, Fig. 4.15) collected and analyzed fossils from Europe, Asia, and North America, and discovered a wide variety of Paleozoic and Mesozoic species.

Friedrich von Hüne (German, 1875–1969, Fig. 4.15) discovered fossils of many new species of dinosaurs, other reptiles, and amphibians, and worked to reclassify previously discovered fossil species in a much more systematic fashion. Edwin Colbert, a curator of paleontology at the American Museum of Natural History, praised von Hüne's accomplishments [Colbert 1984, pp. 108–109]:

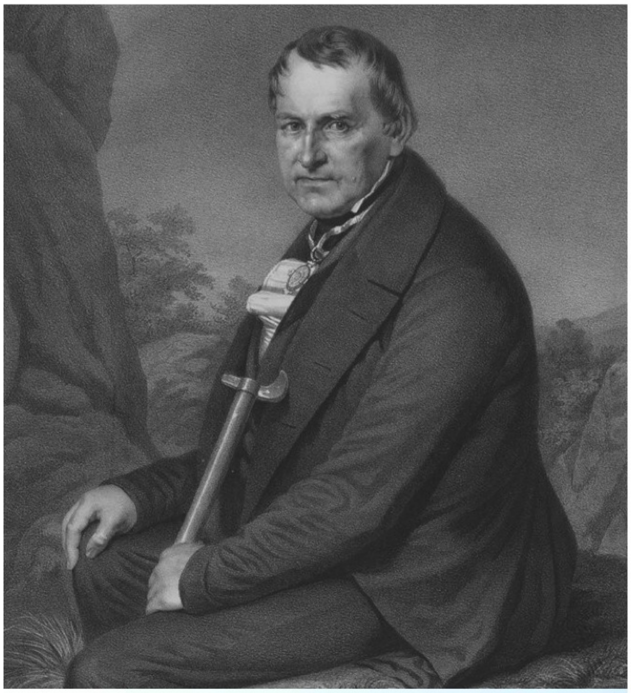
> Von Huene was wholeheartedly interested in the dinosaurs; during his lifetime he became one of the great authorities on these reptiles. [...]
>
> He has spent many decades in the study of fossil reptiles, with a singleness of purpose and a degree of industry that are truly amazing. The volume of his publications through the years is prodigious, and his contributions to our knowledge of fossil reptiles are numerous and significant. They include papers on reptilian relationships and classification, descriptions of dinosaurs from all over the world, investigations of various Mesozoic marine reptiles, especially ichthyosaurs, and other technical studies too numerous to mention. [...]
>
> He has been noted for his activity in the field, traveling all over the world to study and collect fossil reptiles—not only in his native Germany but also in other parts of Europe, in North America, in Brazil, in Argentina, in Africa, and in Asia.

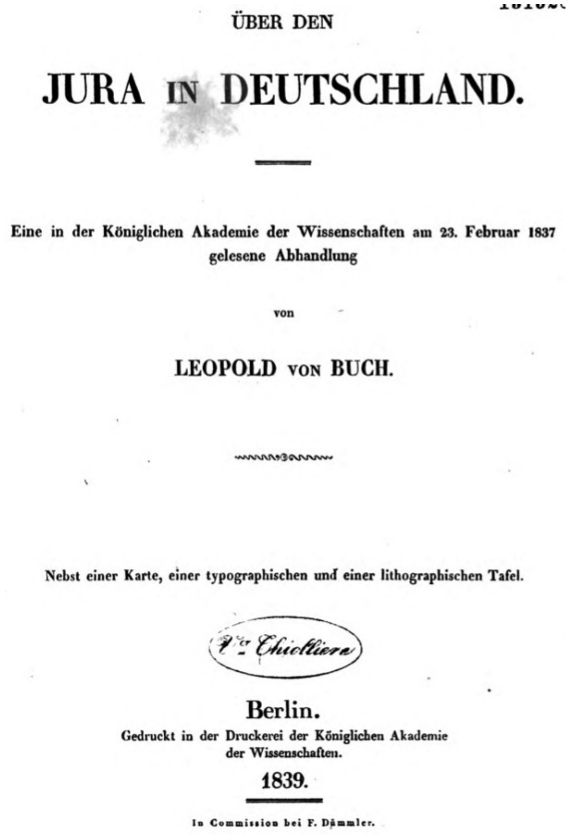


BEITRAG
zu einer
MONOGRAPHIE
des
BUNTEN SANDSTEINS,
MUSCHELKALKS
und
KEUPERS,
und
die Verbindung dieser Gebilde
zu
EINER FORMATION.
Von
Friedrich von Alberti.
Mit 2 Steintafeln.
Stuttgart und Tübingen,
Verlag der J. G. COTTA'schen Buchhandlung.
1834.

Figure 4.11: Friedrich von Alberti identified and characterized Triassic rock strata and their fossils, the preceding Permian-Triassic extinction, and the following Triassic-Jurassic extinction (1834).

Christian Leopold von Buch (1774–1853) Jurassic period, igneous rock formation





ÜBER DEN

JURA IN DEUTSCHLAND.

Eine in der Königlichen Akademie der Wissenschaften am 23. Februar 1837
gelesene Abhandlung

von

LEOPOLD VON BUCH.

Nebst einer Karte, einer typographischen und einer lithographischen Tafel.

V.e Chicliere

Berlin.
Gedruckt in der Druckerei der Königlichen Akademie
der Wissenschaften.
1839.

In Commission bei F. Dümmler.

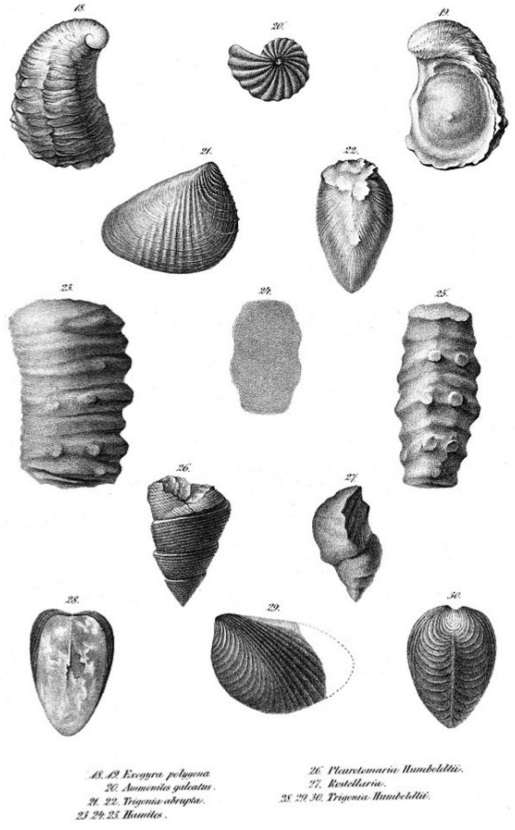

18.
20.
19.
21.
22.
23.
24.
25.
26.
27.
28.
29.
30.
18. 19. Exogyra polygona
20. Ammonites galeatus.
21. 22. Trigonia abrupta.
23. 24. 25. Hamites.
26. Pleurotomaria Humboldtii.
27. Rostellaria.
28. 29. 30. Trigonia Humboldtii.

Figure 4.12: Christian Leopold von Buch characterized Jurassic rock strata and their fossils, and also explained igneous rock formation.

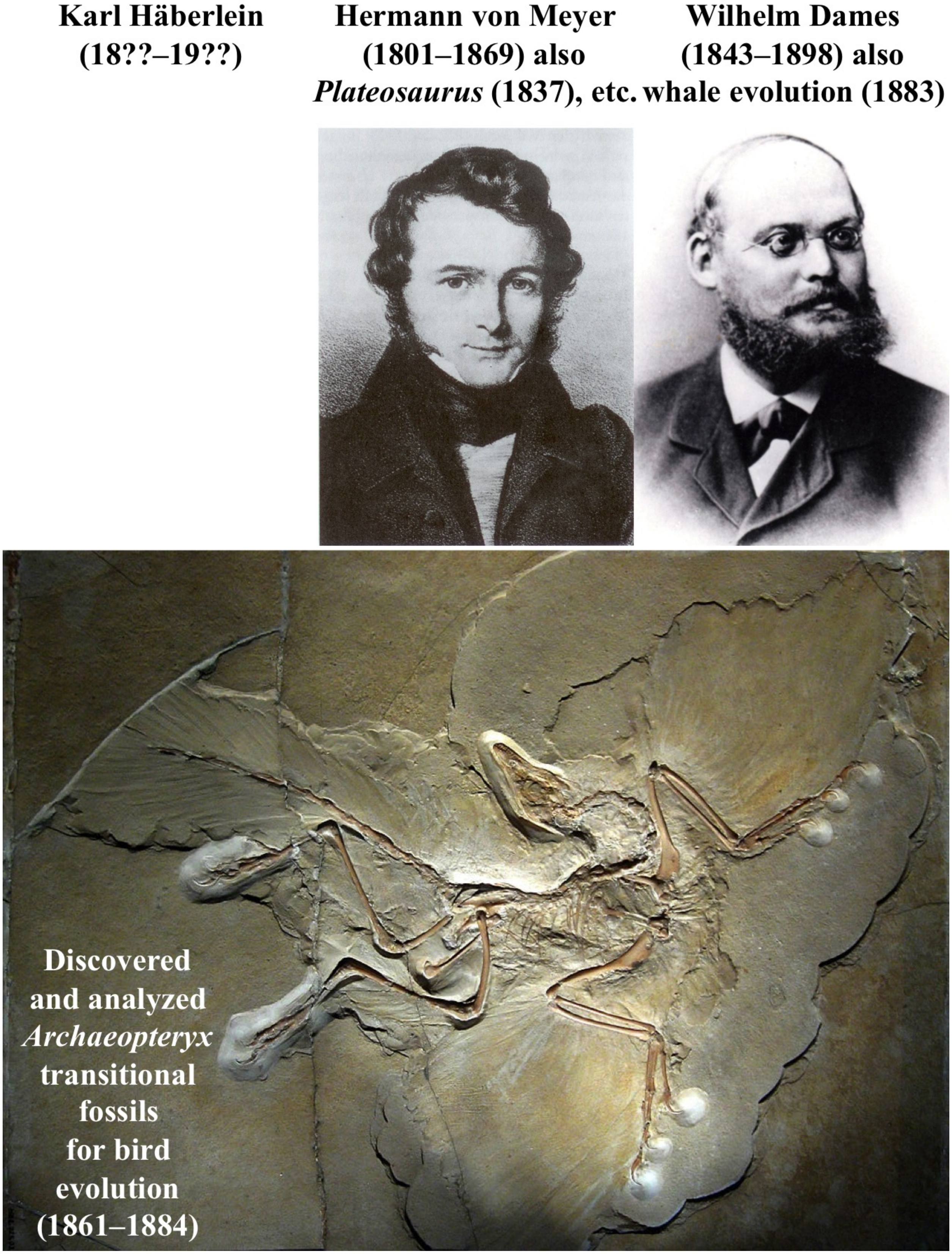
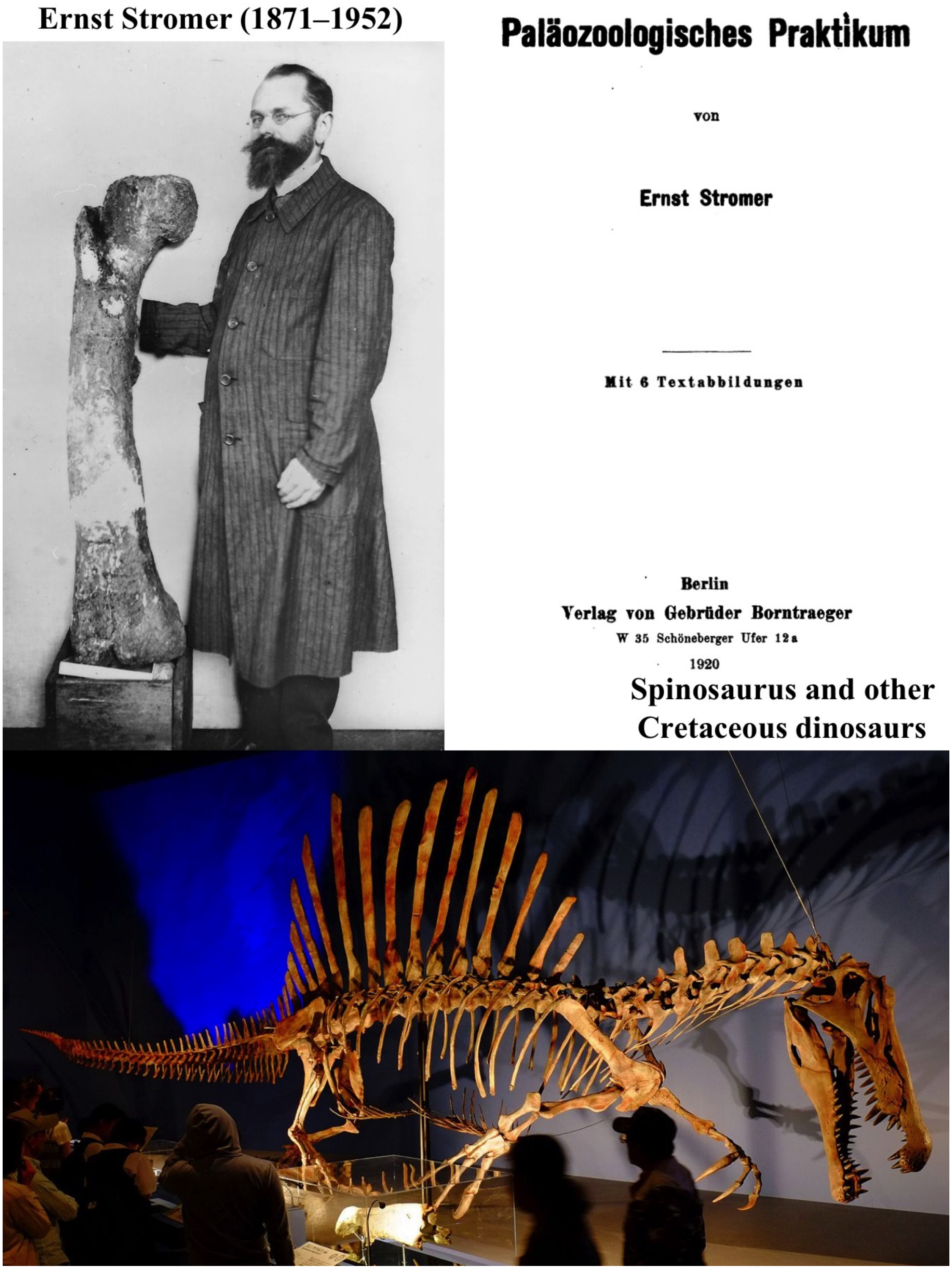

Karl Häberlein
(18??–19??)
Hermann von Meyer
(1801–1869) also
Plateosaurus (1837), etc.
Wilhelm Dames
(1843–1898) also
whale evolution (1883)
Discovered
and analyzed
Archaeopteryx
transitional
fossils
for bird
evolution
(1861–1884)

Figure 4.13: Karl Häberlein, Hermann von Meyer, and Wilhelm Dames discovered and analyzed *Archaeopteryx* specimens, which are important transitional fossils for bird evolution, during the period 1861–1884.



Ernst Stromer (1871–1952)
Spinosaurus and other Cretaceous dinosaurs

Paläozoologisches Praktikum

von

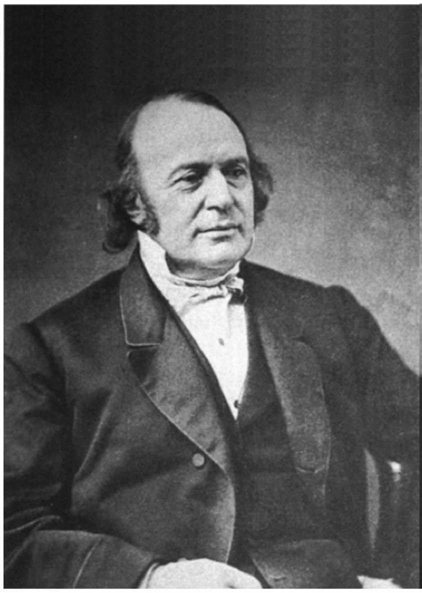
Ernst Stromer

Mit 6 Textabbildungen

Berlin
Verlag von Gebrüder Borntraeger
W 35 Schöneberger Ufer 12a
1920

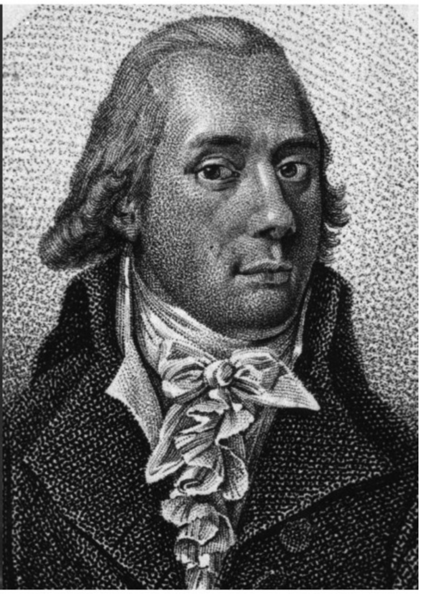
Figure 4.14: Ernst Stromer discovered Spinosaurus and other Cretaceous dinosaurs.

Louis Agassiz (1807–1873) found and analyzed a wide variety of fossils



Heinrich Ernst Beyrich (1815–1896) discovered many Cenozoic fossils

Johann Blumenbach (1752–1840) developed the foundations of anthropology



Johanna “Tilly” Edinger (1897–1967) founded paleoneurology

Hanns Bruno Geinitz (1814–1900) discovered a wide variety of Paleozoic and Mesozoic fossils

Friedrich von Hüne (1875–1969) discovered many dinosaurs, other reptiles, and amphibians

Figure 4.15: Other creators who made important discoveries in paleontology included Louis Agassiz, Heinrich Ernst Beyrich, Johann Blumenbach, Johanna “Tilly” Edinger, Hanns Bruno Geinitz, and Friedrich von Hüne.

4.2.2 Hominid Fossils

Many important discoveries in human evolution were made by scientists from the greater German-speaking world.

Johann Blumenbach (German states, 1752–1840, Fig. 4.15) developed the foundations of the field of anthropology, studying the skeletal remains and evidence of the lifestyles of prehistoric humans worldwide.

Marie Eugène Dubois (Dutch, 1858–1940) discovered the first fossils of *Homo erectus* (dubbed "Java Man") in 1891; see Fig. 4.16. *Homo erectus* was a widespread and tremendously important ancestor of modern *Homo sapiens*. Franz Weidenreich (German, 1873–1948) and Ralph von Königswald (German, 1902–1982) discovered and analyzed additional *Homo erectus* fossils.

As shown in Fig. 4.17, in 1907 Otto Schoetensack (German, 1850–1912) and Daniel Hartmann (German?, 18??–19??) discovered the first fossils of *Homo heidelbergensis*, which was either a direct ancestor or a close cousin of modern humans.

Johann Fuhlrott (German, 1803–1877) and Hermann Schaaffhausen (German, 1816–1893) discovered the first fossils of *Homo neanderthalensis* in 1856 (Fig. 4.18). *Homo neanderthalensis* or Neanderthals were a sophisticated species of humans that existed in parallel with *Homo sapiens* for thousands of years, then disappeared for reasons that are still unclear.

Hugo Obermaier (German, 1877–1946) made important discoveries regarding the migrations, tools, and cave paintings of humans during the Ice Ages, as illustrated in Fig. 4.19.

4.2.3 Biogeography

As shown in Fig. 4.20, several creators made major contributions to the field of biogeography, or the worldwide distributions of modern species.

Alexander von Humboldt (Prussian, 1769–1859) collected and compared plant samples from around the world, as illustrated in Fig. 4.20. He published many books on his discoveries and thereby helped to establish the field of biogeography. He also made important measurements of geomagnetism in his travels around the world [Wulf 2015].

Christian Ehrenberg (German, 1795–1876) collected zoological, botanical, and microbiological specimens, and studied the comparative anatomy of samples from Europe, the Middle East, and around the world.

Richard Hesse (German, 1868–1944) published *Tiergeographie auf Ökologischer Grundlage* in 1924. Together with its 1937 revised English edition, *Ecological Animal Geography*, that book had an enormous impact in advancing the field of biogeography [Hesse 1924, 1937].

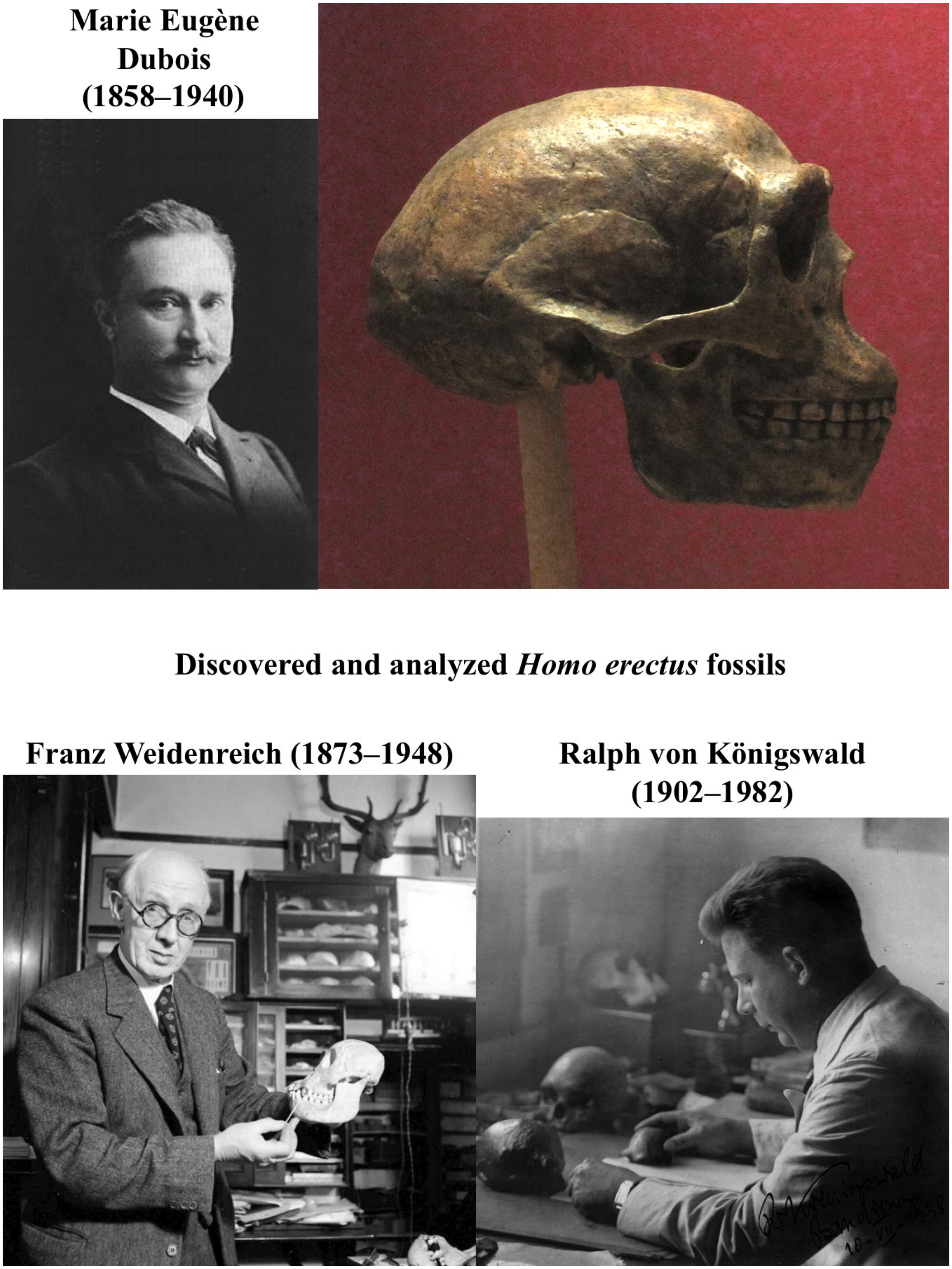
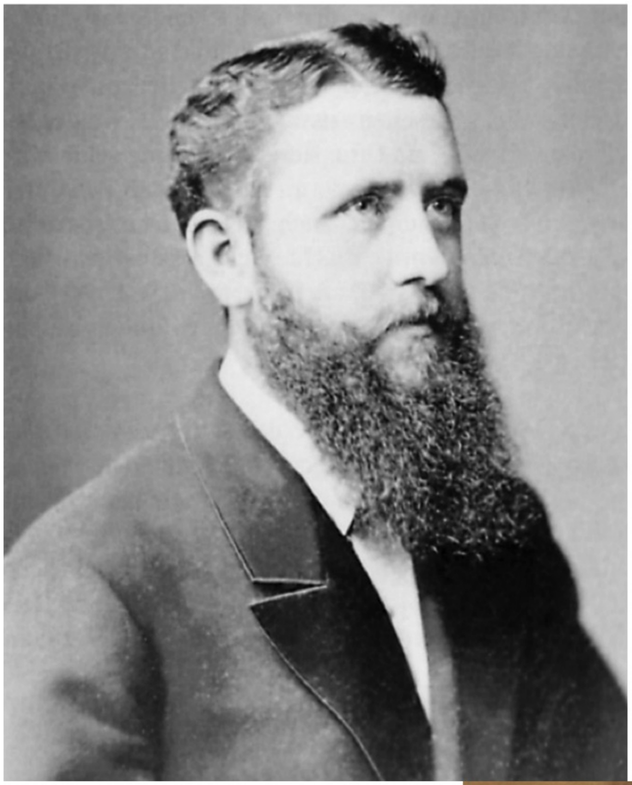

Marie Eugène Dubois (1858–1940)
Discovered and analyzed *Homo erectus* fossils
Franz Weidenreich (1873–1948)
Ralph von Königswald (1902–1982)

Figure 4.16: Marie Eugène Dubois, Franz Weidenreich, and Ralph von Königswald discovered and analyzed *Homo erectus* fossils.

Otto Schoetensack (1850–1912) **Daniel Hartmann (18??–19??)**



Discovered
Homo
heidelbergensis
(1907)

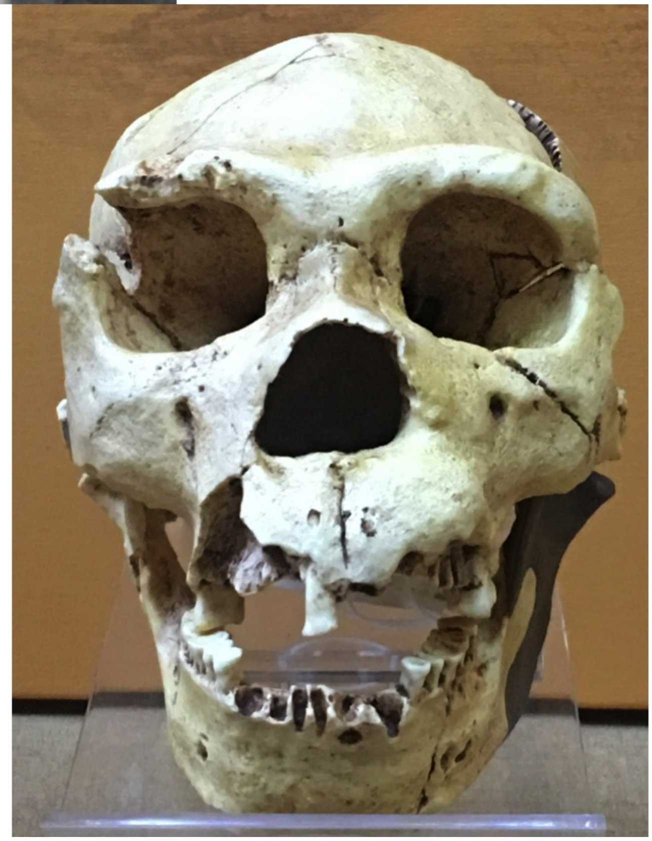


Figure 4.17: Otto Schoetensack and Daniel Hartmann discovered *Homo heidelbergensis* in 1907.

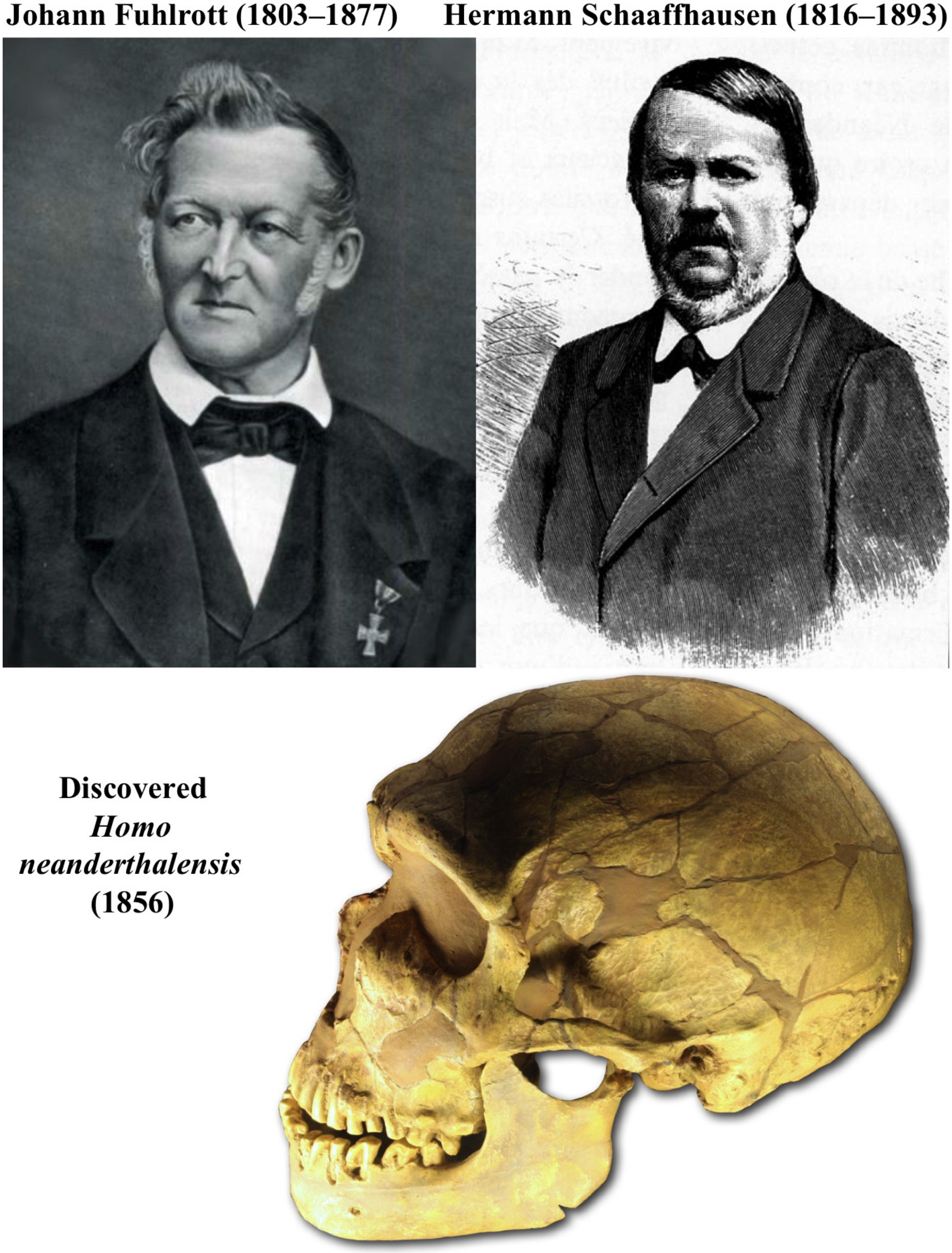

Johann Fuhlrott (1803–1877)
Hermann Schaaffhausen (1816–1893)
Discovered
Homo
neanderthalensis
(1856)

Figure 4.18: Johann Fuhlrott and Hermann Schaaffhausen discovered *Homo neanderthalensis* in 1856.

Hugo Obermaier
(1877–1946)
Migrations and tools of
humans during the Ice Ages

Figure 4.19: Hugo Obermaier made important discoveries regarding the migrations and the tools of humans during the Ice Ages.

Alexander von Humboldt (1769–1859, also geomagnetism)

Christian Ehrenberg (1795–1876)

Richard Hesse (1868–1944)

Biogeography

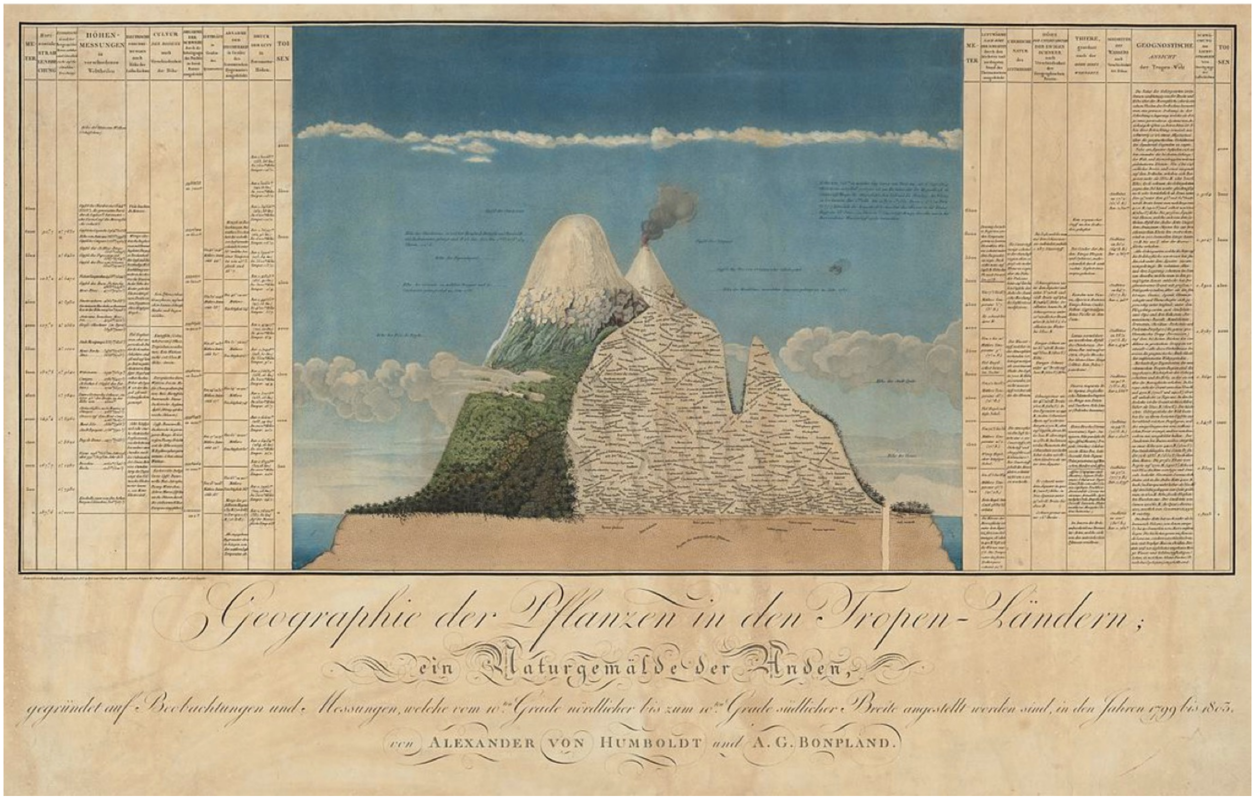

Geographie der Pflanzen in den Tropen-Ländern;
ein Naturgemälde der Anden,
gegründet auf Beobachtungen und Messungen, welche vom 10ten Grade nördlicher bis zum 10ten Grade südlicher Breite angestellt worden sind, in den Jahren 1799 bis 1803.
von Alexander von Humboldt und A. G. Bonpland.

Figure 4.20: Creators who made major contributions to the field of biogeography, or the worldwide distributions of modern species, included Alexander von Humboldt, Christian Ehrenberg, and Richard Hesse.

4.3 Ocean and Hydrological Science

German-speaking scientists made major contributions to ocean and hydrological sciences and related areas, including:[3]

4.3.1. Oceanography

4.3.2. The discovery and exploration of Antarctica

4.3.3. Evidence for the Ice Ages

4.3.1 Oceanography

Heinrich Georg von Boguslawski (German, 1827–1884, Fig. 4.21) coauthored the *Handbuch der Ozeanographie* [*Handbook of Oceanography*] with Otto Krümmel. It appeared in 1884–1887 in two large volumes covering all major aspects of ocean spatial distribution, physical properties, chemistry, circulation, etc., and became the standard reference work on the subject for many decades, including later updates.

Carl Chun (German, 1852–1914, Fig. 4.21) led expeditions in the *Valdivia* research ship (Fig. 4.23) and made important discoveries regarding deep sea life, marine invertebrates, and subarctic seas.

Carl Wilhelm Correns (German, 1893–1980, Fig. 4.21) was the world's leading expert in marine sediments [BIOS 1368]. He collected sediments on marine expeditions in the 1920s, and used new methods such as X-ray diffraction to analyze them in his laboratory in the 1930s. He was the son of the biologist Karl Correns (p. 107). The American Council of Learned Societies described some of his accomplishments [ACLS 2000, pp. 209–210]:

> A pioneer in modern sedimentary petrology, he found that clays are not amorphous substances but mixtures of well-defined crystalline minerals such as kaolinite, halloysite, montmorillonite, and mica materials. With samples from the bottom of the South Atlantic, he developed methods for dividing sediments into grain size classes that could be investigated by optical microscopy, X-ray diffraction, and chemical analysis.

Albert Defant (Austrian, 1884–1974, Fig. 4.21) founded the field of physical oceanography and was an expert on the physics of the ocean, the atmosphere, and the interactions between the two. He was one of the main scientists on the *Meteor* oceanographic research ship.

Günter Dietrich (German, 1911–1972, Fig. 4.21) helped to refine the comprehensive understanding of ocean tides, currents, and circulation.

---

[3] von Boguslawski and Krümmel 1884–1887; Bowler 1993; Spiess 1985.

Felix Anton Dohrn (German, 1840–1909, Fig. 4.21) established the model of marine biological research stations, especially with a station on the Gulf of Naples (Stazione Zoologica, initiated in 1871). The American Council of Learned Societies described the importance of his work [ACLS 2000, p. 256–257]:

> Primary contribution was the establishment of the Zoological Station in Naples: not only the first laboratory set up specifically for marine studies, but also the first institute formally organized for the sole pursuit of research. The station was conceived by Dohrn in 1870, and the doors opened in February 1874. [...M]any important pioneering experimental investigations were carried out. Especially significant were studies in comparative physiology and experimental embryology, which became the foundations of whole new sciences.

Ernst Ehrenbaum (German, 1861–1942, Fig. 4.22) made major contributions to systematic ichthyology as well as the study of marine invertebrates.

Vagn Walfrid Ekman (1874–1954, Fig. 4.22) was Swedish but worked very closely with German expeditions, providing oceanographic measuring instruments and conducting theoretical calculations to compare with the measured data. Many oceanographic properties are named after him: the Ekman layer, Ekman number, Ekman pumping, Ekman spiral, Ekman transport, etc.

Otto Krümmel (German, 1854–1912, Fig. 4.22) coauthored the *Handbuch der Ozeanographie* [*Handbook of Oceanography*] with Heinrich Georg von Boguslawski, completing the first edition after von Boguslawski's death and then updating it later. Some of Krümmel's greatest contributions involved the study of ocean currents and circulation patterns (Fig. 4.24).

Alfred Merz (Austrian, 1880–1925, Fig. 4.22) was a pioneer of oceanography and was the first chief scientist for the *Meteor* research ship (Fig. 4.23).

Friedrich (Fritz) Spiess (German, 1881–1959, Fig. 4.22) championed the funding and execution of oceanographic research, and he planned and commanded the expeditions of the *Meteor* research ship.

Georg Wüst (German, 1890–1977, Fig. 4.22) studied ocean circulation and was one of the main scientists on the *Meteor* research ship.

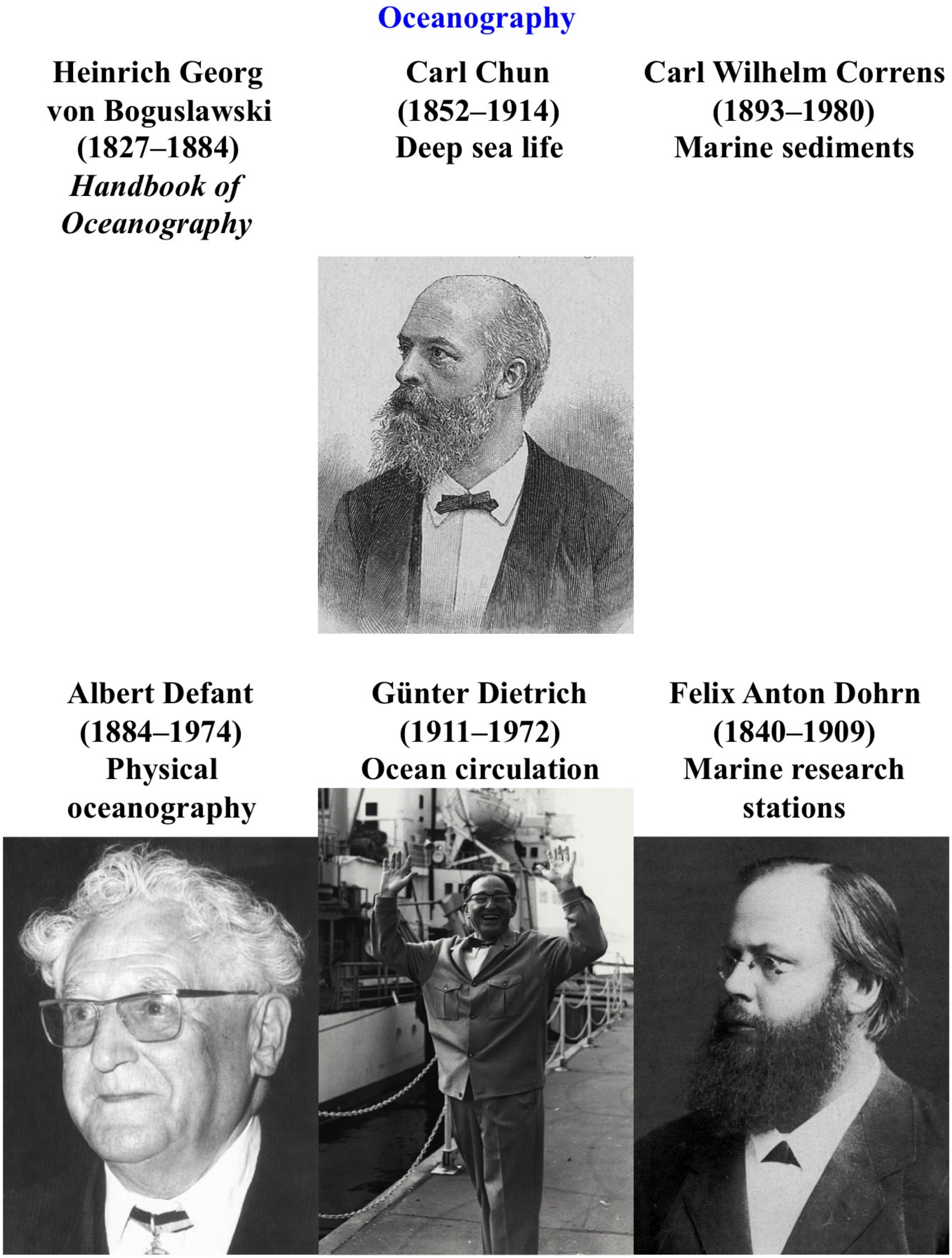

Oceanography
Heinrich Georg von Boguslawski (1827–1884) Handbook of Oceanography
Carl Chun (1852–1914) Deep sea life
Carl Wilhelm Correns (1893–1980) Marine sediments
Albert Defant (1884–1974) Physical oceanography
Günter Dietrich (1911–1972) Ocean circulation
Felix Anton Dohrn (1840–1909) Marine research stations

Figure 4.21: Some important creators in oceanography included Heinrich Georg von Boguslawski, Carl Chun, Carl Wilhelm Correns, Albert Defant, Günter Dietrich, and Felix Anton Dohrn.

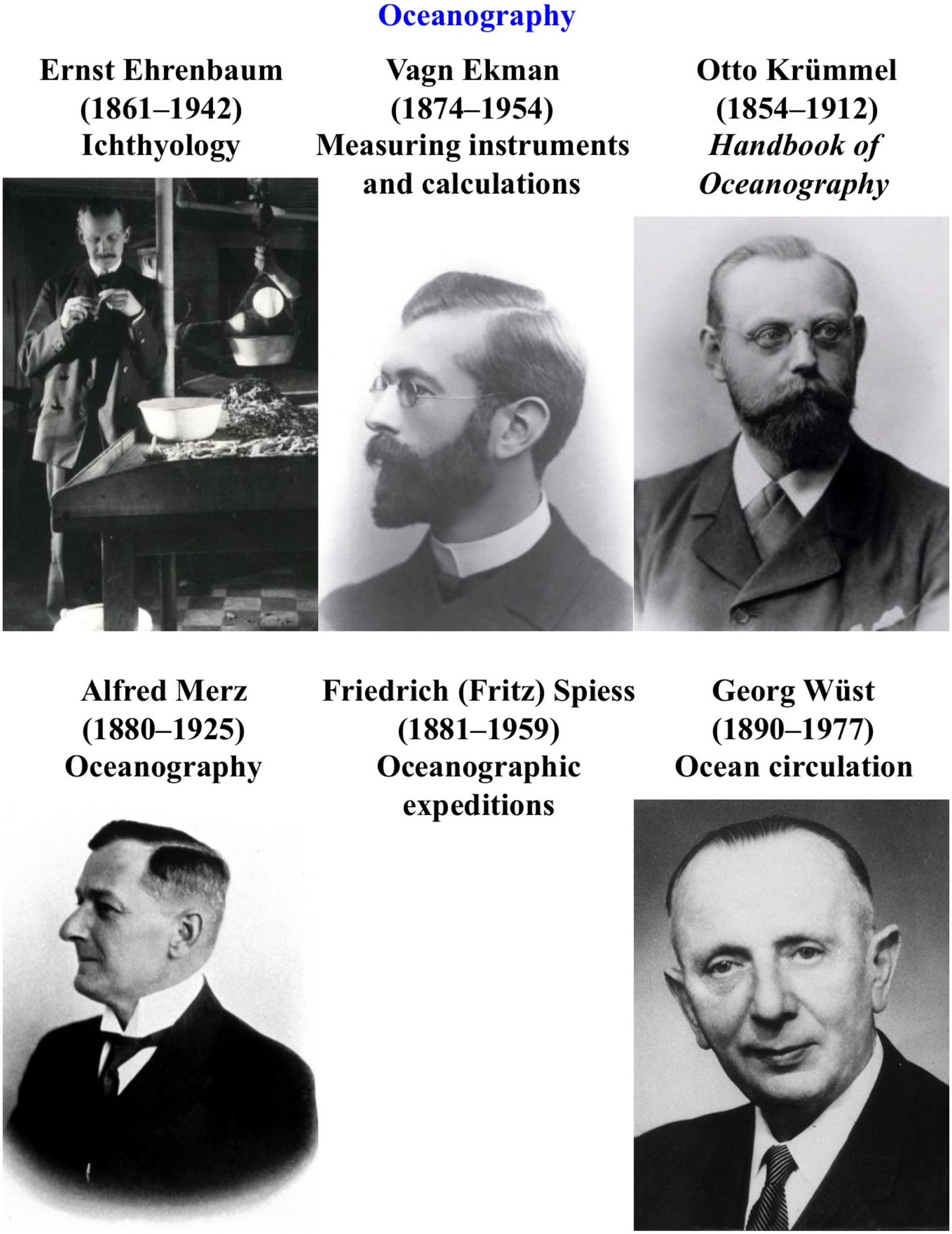

Oceanography
Ernst Ehrenbaum
(1861–1942)
Ichthyology
Vagn Ekman
(1874–1954)
Measuring instruments and calculations
Otto Krümmel
(1854–1912)
Handbook of Oceanography
Alfred Merz
(1880–1925)
Oceanography
Friedrich (Fritz) Spiess
(1881–1959)
Oceanographic expeditions
Georg Wüst
(1890–1977)
Ocean circulation

Figure 4.22: Other important creators in oceanography included Ernst Ehrenbaum, Vagn Ekman, Otto Krümmel, Alfred Merz, Friedrich (Fritz) Spiess, and Georg Wüst.

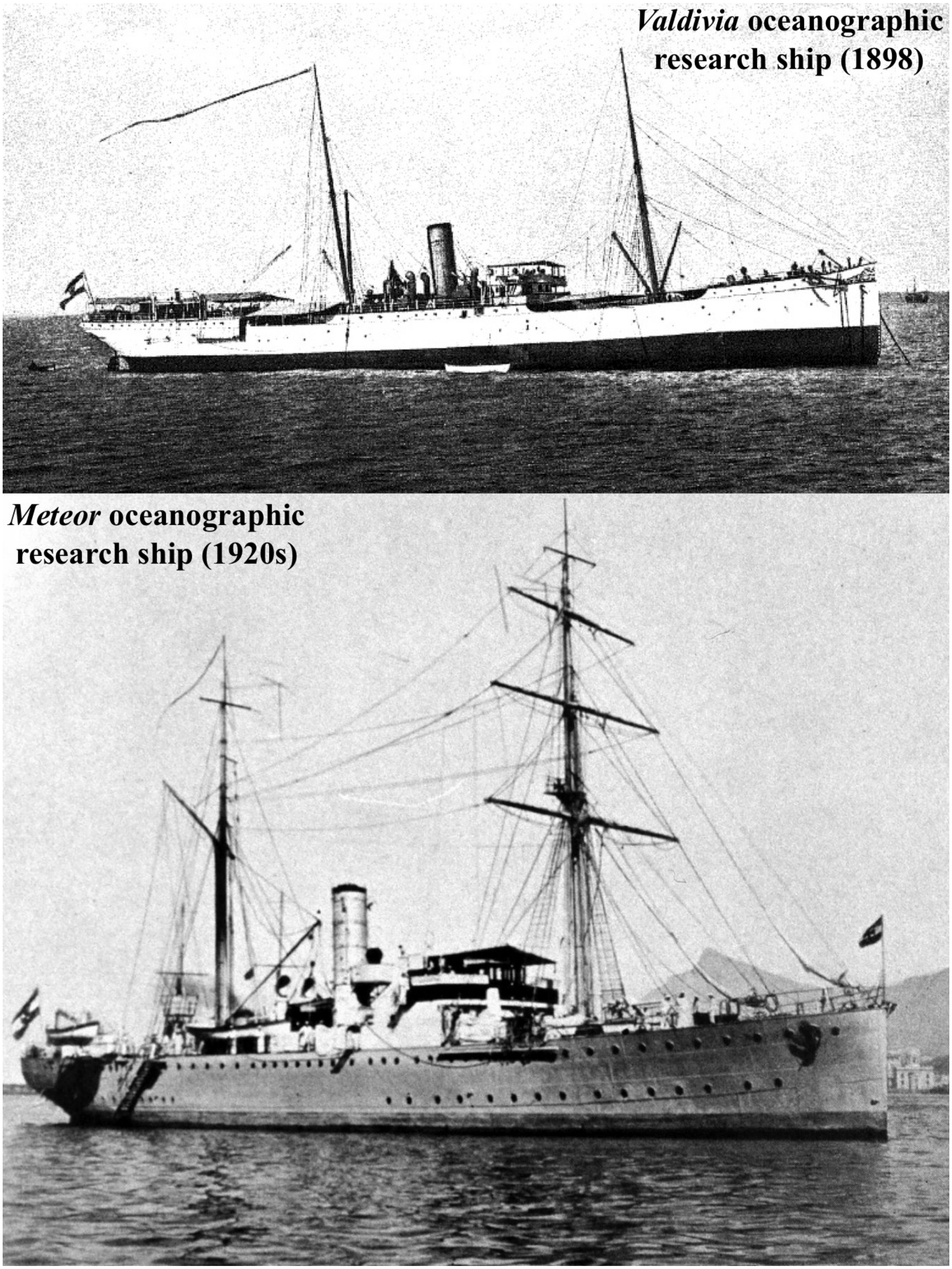

Valdivia oceanographic research ship (1898)
Meteor oceanographic research ship (1920s)

Figure 4.23: Examples of important German oceanographic research ships included the *Valdivia* and the *Meteor*.

Map of Atlantic ocean currents by Otto Krümmel (1883)

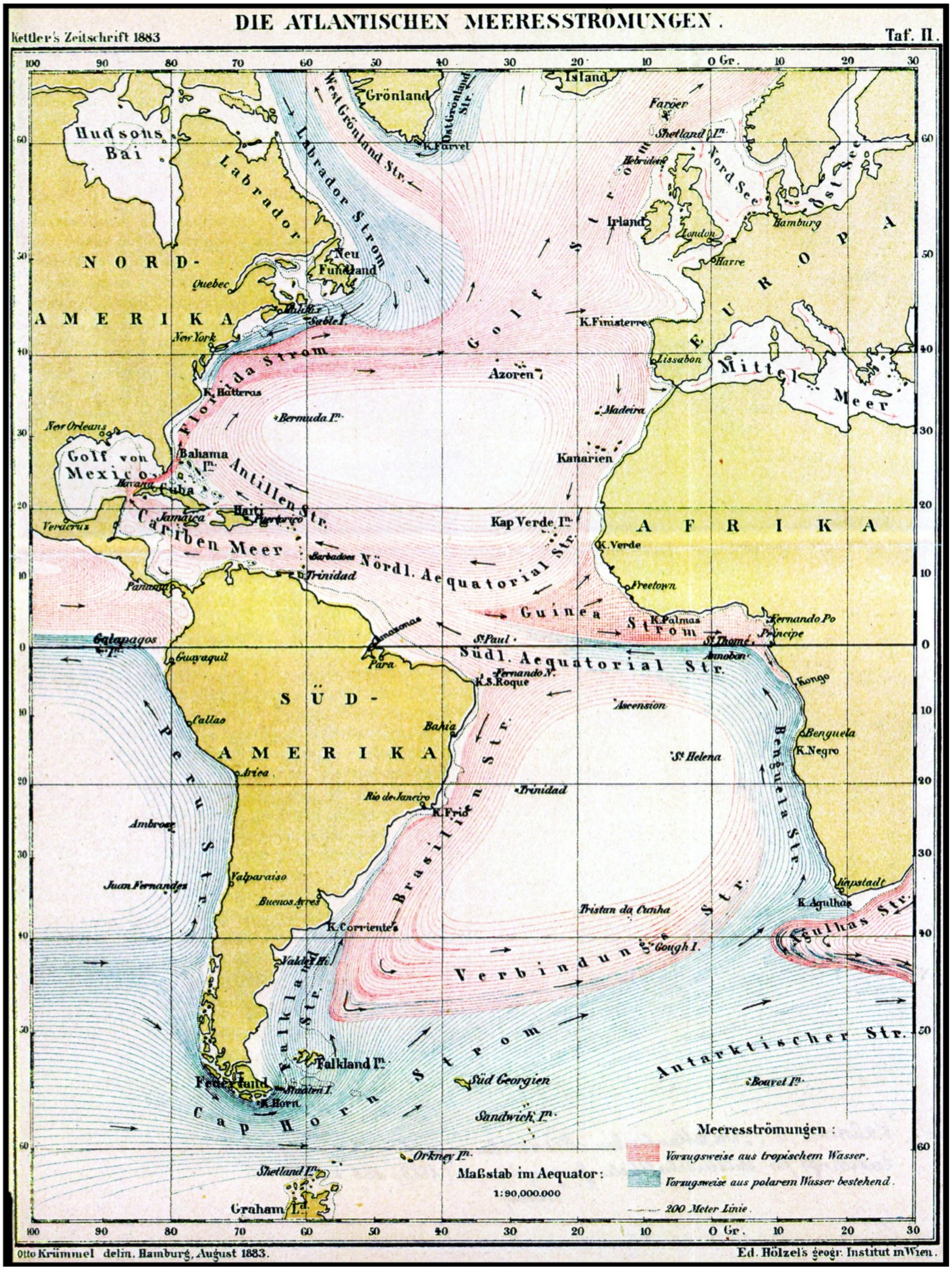

DIE ATLANTISCHEN MEERESSTROMUNGEN.
Kettler's Zeitschrift 1883
Taf. II.
Grönland
Island
Ost-Grönland Str.
West-Grönland Str.
K. Farvel
Hudsons Bai
Labrador
Labrador Strom
Neu Fundland
Quebec
Halifax
Sable I.
New York
NORD-AMERIKA
K. Hatteras
Florida Strom
Golf Strom
Bermuda In.
Azoren
Färöer
Shetland In.
Hebriden
Nord See
Ost See
Irland
London
Hamburg
Havre
EUROPA
K. Finisterre
Lissabon
Mittel Meer
Madeira
Kanarien
New Orleans
Golf von Mexico
Bahama In.
Havana
Cuba
Antillen Str.
Haiti
Jamaica
Portorico
Veracruz
Cariben Meer
Barbados
Trinidad
Panama
Kap Verde In.
K. Verde
Nördl. Aequatorial Str.
AFRIKA
Freetown
Guinea Strom
K. Palmas
Fernando Po
Principe
St. Thomé
Annobon
Galapagos In.
Guayaquil
Amazonas
Para
St. Paul
Südl. Aequatorial Str.
Fernando N.
K. S. Roque
Ascension
Kongo
SÜD-AMERIKA
Callao
Bahia
Arica
Peru Str.
St. Helena
Benguela
K. Negro
Benguela Str.
Trinidad
Rio de Janeiro
K. Frio
Brasilien Str.
Ambrose
Juan Fernandez
Valparaiso
Buenos Ayres
Tristan da Cunha
Kapstadt
K. Agulhas
Agulhas Str.
K. Corrientes
Valdez Hi.
Falkland Str.
Verbindungs Str.
Gough I.
Falkland In.
Feuerland
Staaten I.
K. Horn
Cap Horn Strom
Süd Georgien
Sandwich In.
Antarktischer Str.
Bouvet In.
Orkney In.
Shetland In.
Graham Ld.
Maßstab im Aequator: 1:90,000,000
Meeresströmungen:
Vorzugsweise aus tropischem Wasser.
Vorzugsweise aus polarem Wasser bestehend.
200 Meter Linie.
100
90
80
70
60
50
40
30
20
10
0 Gr.
10
20
30
Otto Krümmel delin. Hamburg, August 1883.
Ed. Hölzel's geogr. Institut in Wien.

Figure 4.24: Map of Atlantic ocean currents by Otto Krümmel from 1883.

4.3.2 Antarctica

German-speaking scientists discovered Antarctica and played a major role in its exploration [Lüdecke 2015; Schön 2004].

Fabian Gottlieb von Bellingshausen (Baltic German, 1778–1852) led an expedition that discovered Antarctica in 1820. He proceeded to circumnavigate Antarctica and to make contact with its coastline at several points along the way; Fig. 4.25 illustrates the route of his expedition. Bellingshausen Island and Bellingshausen Sea near Antarctica are named after him.

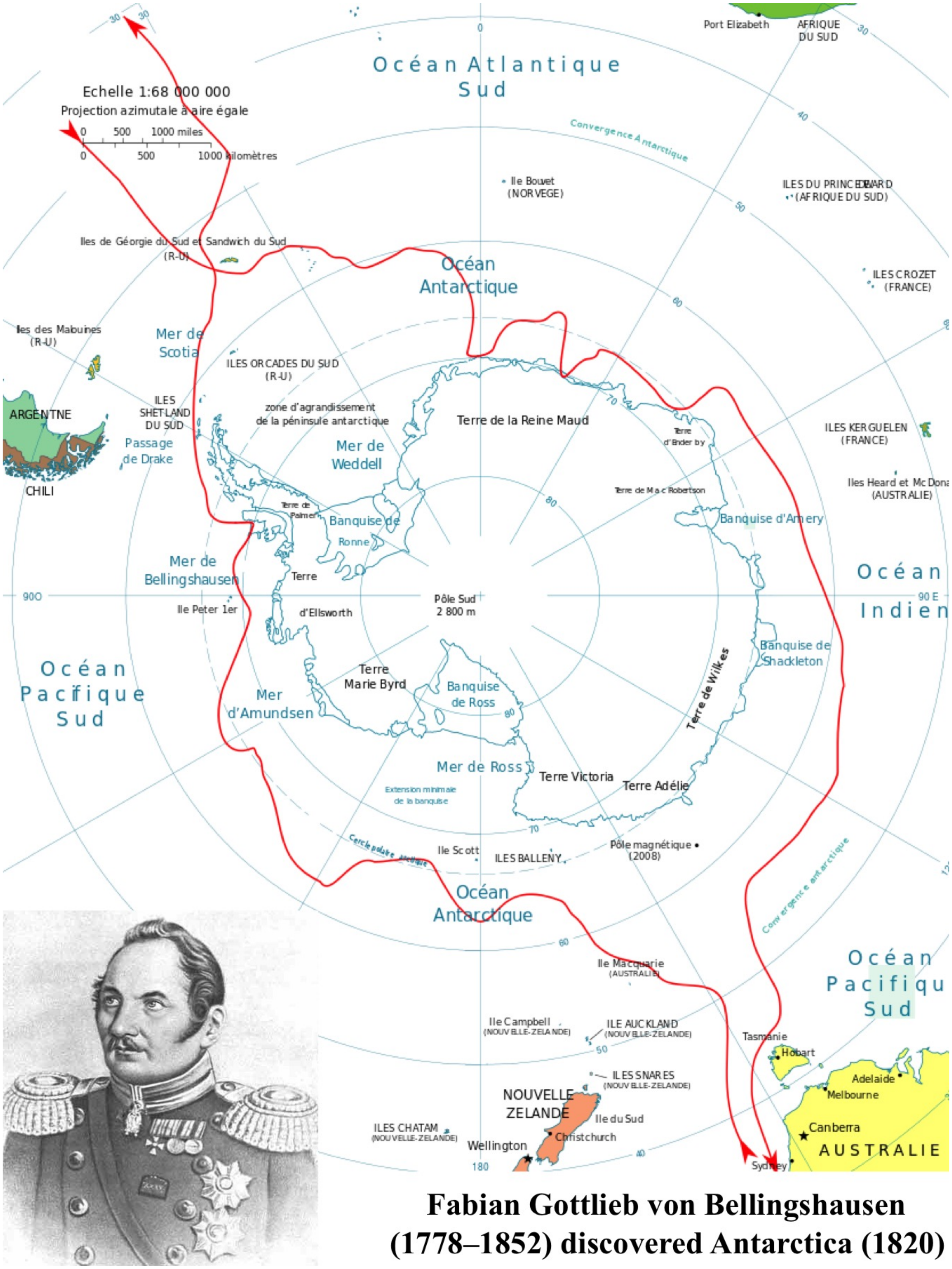
Erich von Drygalski (German, 1865–1949, Fig. 4.26) led groups that explored Greenland during 1891–1893 and Antarctica during 1901–1903. In Antarctica, his expedition discovered and named Kaiser Wilhelm II Land and the Gaussberg volcano, and was the first to use a balloon for Antarctic exploration and photography. Drygalski Island in Antarctica is named after him.

Wilhelm Filchner (German, 1877–1957, Fig. 4.26) headed an Antarctic expedition during 1911–1912 that discovered the Luitpold Coast and mapped part of Antarctica. The Filchner-Ronne Ice Shelf in the Antarctic is named for him (and the much later U.S. Ronne expedition from 1947–1948).

Alfred Ritscher (German, 1879–1963, Fig. 4.26) led a major Antarctic expedition during 1938–1939 that mapped a large part of Queen Maud Land. Ritscher Peak and Ritscher Upland in Antarctica are named after him.

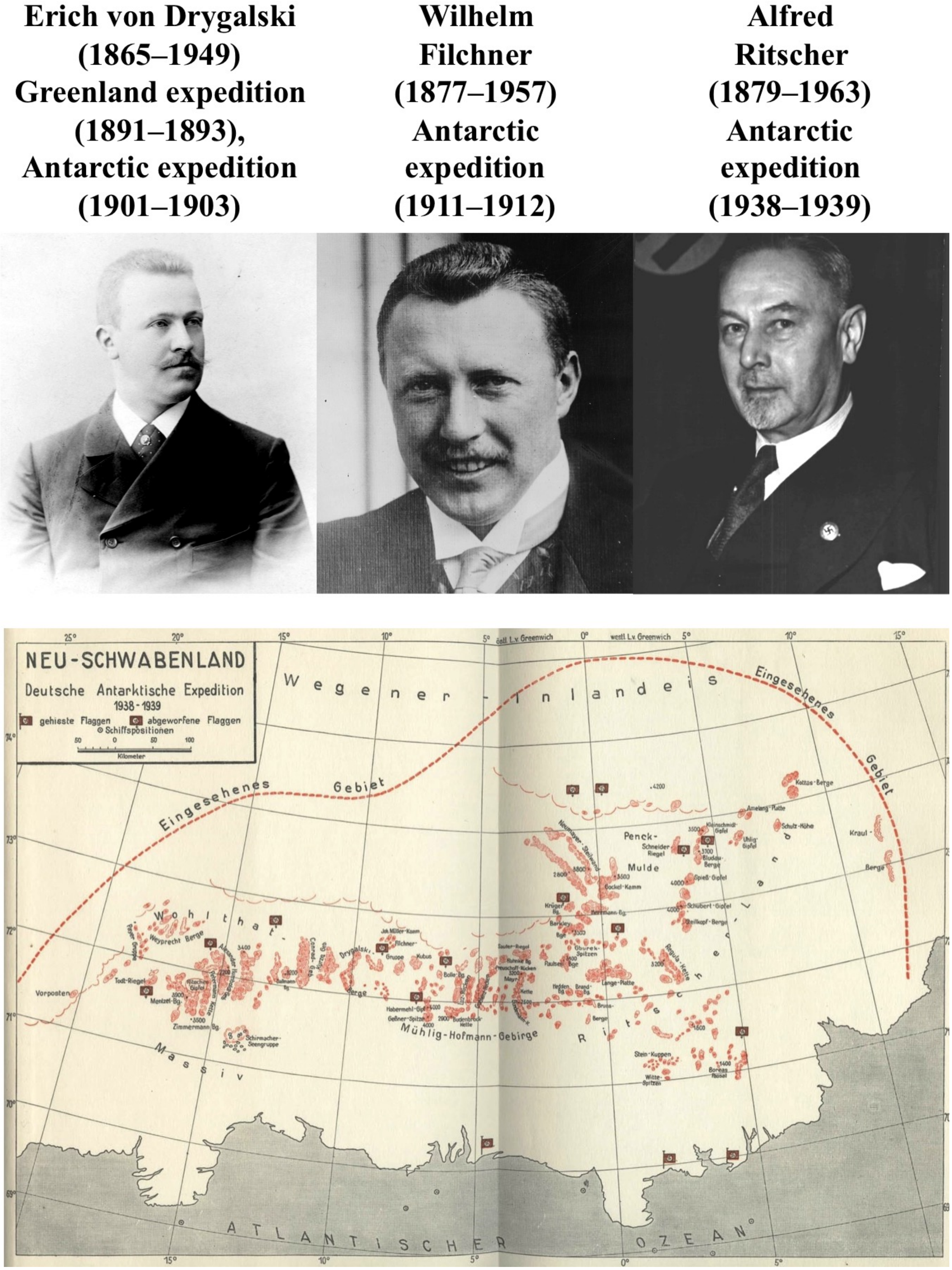
4.3.3 Ice Ages

As illustrated in Fig. 4.27, Eduard Brückner (German, 1862–1927) and Albrecht Penck (German, 1858–1945) amassed and correctly interpreted a huge amount of evidence for the Ice Ages, especially from the Alps, from 1901 onward. In 1909, they published their results as the landmark three-volume work, *Die Alpen im Eiszeitalter* [*The Alps in the Ice Age*].


Océan Atlantique Sud
Echelle 1:68 000 000
Projection azimutale à aire égale
0 500 1000 miles
0 500 1000 kilomètres
Port Elizabeth
AFRIQUE DU SUD
Convergence Antarctique
Ile Bouvet (NORVEGE)
ILES DU PRINCE EDWARD (AFRIQUE DU SUD)
Iles de Géorgie du Sud et Sandwich du Sud (R-U)
Océan Antarctique
ILES CROZET (FRANCE)
Iles des Malouines (R-U)
Mer de Scotia
ILES ORCADES DU SUD (R-U)
ARGENTINE
ILES SHETLAND DU SUD
zone d'agrandissement de la péninsule antarctique
Terre de la Reine Maud
Terre d'Enderby
ILES KERGUELEN (FRANCE)
Passage de Drake
Mer de Weddell
CHILI
Terre de Mac Robertson
Iles Heard et McDonald (AUSTRALIE)
Terre de Palmer
Banquise de Ronne
Banquise d'Amery
Mer de Bellingshausen
Terre d'Ellsworth
Océan Indien
Ile Peter 1er
Pôle Sud 2 800 m
Océan Pacifique Sud
Terre Marie Byrd
Banquise de Ross
Banquise de Shackleton
Mer d'Amundsen
Terre de Wilkes
Mer de Ross
Terre Victoria
Terre Adélie
Extension minimale de la banquise
Cercle polaire antarctique
Ile Scott
ILES BALLENY
Pôle magnétique (2008)
Océan Antarctique
Ile Macquarie (AUSTRALIE)
Océan Pacifique Sud
Ile Campbell (NOUVELLE-ZELANDE)
ILE AUCKLAND (NOUVELLE-ZELANDE)
Tasmanie
Hobart
ILES SNARES (NOUVELLE-ZELANDE)
Adelaide
Melbourne
NOUVELLE ZELANDE
Ile du Sud
Canberra
ILES CHATAM (NOUVELLE-ZELANDE)
Christchurch
Wellington
AUSTRALIE
Sydney
0
30
40
50
60
70
80
90 O
90 E
180

Fabian Gottlieb von Bellingshausen (1778–1852) discovered Antarctica (1820)

Figure 4.25: Fabian Gottlieb von Bellingshausen discovered Antarctica in 1820.



Erich von Drygalski (1865–1949) Greenland expedition (1891–1893), Antarctic expedition (1901–1903)

Wilhelm Filchner (1877–1957) Antarctic expedition (1911–1912)

Alfred Ritscher (1879–1963) Antarctic expedition (1938–1939)

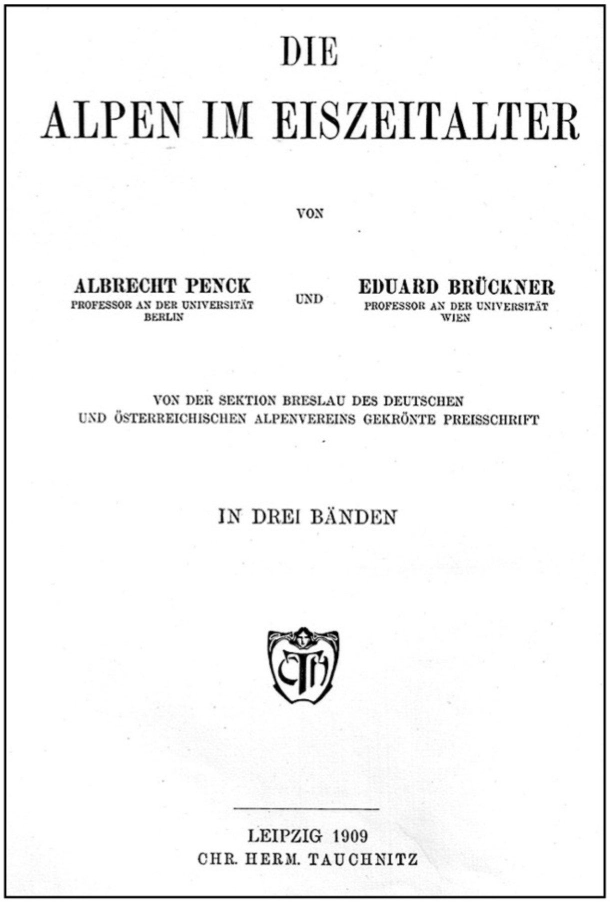
NEU-SCHWABENLAND
Deutsche Antarktische Expedition
1938-1939
gehisste Flaggen
abgeworfene Flaggen
⊙ Schiffspositionen
50 0 50 100
Kilometer
25° 20° 15° 10° 5° östl. L.v. Greenwich 0° westl. L.v. Greenwich 5° 10° 15°
74° 73° 72° 71° 70° 69°
Wegener-Inlandeis
Eingesehenes Gebiet
Eingesehenes Gebiet
Wohlthat-Massiv
Weyprecht Berge
Payer Gruppe
Alexander Humboldt Geb.
Petermann Kette
Todt-Riegel
Vorposten
Ritscher Gipfel
Mentzel-Bg.
3900
3400
2200
•3500
Zimmermann Bg.
Schirmacher-Seengruppe
Conrad-Geb.
Kurze Geb.
3200
Ballmann Bg.
Drygalski-Berge
Joh. Müller-Kamm
Filchner-Gruppe
Kubus
Bolle Bg.
Habermehl-Gipf.
4000
Geßner-Spitze
4000
2900
Budenbrock-Kette
Mühlig-Hofmann-Gebirge
Sauter-Riegel
Ruhnke Bg.
Preuschoff-Rücken
3200
Mayr-Kette
2500
•4200
Neumayer-Steilwand
2800
3800
3500
Penck-Mulde
Schneider-Riegel
Zockel-Kamm
Krüger Bg.
Herrmann-Bg.
Barkley Bge
3500
Gburek-Spitzen
3100
Paulsen Bge
Hedden Bg.
Brand-Bg.
Lange-Platte
Bruns-Berge
3500
Kleinschmidt-Gipfel
3700
Bludau-Berge
Uhlig-Gipfel
Spieß-Gipfel
4000
Schubert-Gipfel
4000
Zeilkopf-Berge
Amelang-Platte
Schulz-Höhe
Kottas-Berge
Kraul-Berge
Regula-Kette
3200
Ritscher Hochland
1600
Stein-Kuppen
Witte-Spitzen
1400
Boreas-Rüssel
ATLANTISCHER OZEAN
15° 10° 5° 0° 5°

Figure 4.26: Erich von Drygalski led important scientific expeditions to both Greenland and Antarctica. Wilhelm Filchner and Alfred Ritscher led major expeditions to Antarctica.

Eduard Brückner (1862–1927)

Albrecht Penck (1858–1945)

Identified Ice Ages (1901–1909)



DIE

ALPEN IM EISZEITALTER

VON

ALBRECHT PENCK
PROFESSOR AN DER UNIVERSITÄT
BERLIN

UND

EDUARD BRÜCKNER
PROFESSOR AN DER UNIVERSITÄT
WIEN

VON DER SEKTION BRESLAU DES DEUTSCHEN
UND ÖSTERREICHISCHEN ALPENVEREINS GEKRÖNTE PREISSCHRIFT

IN DREI BÄNDEN

LEIPZIG 1909
CHR. HERM. TAUCHNITZ

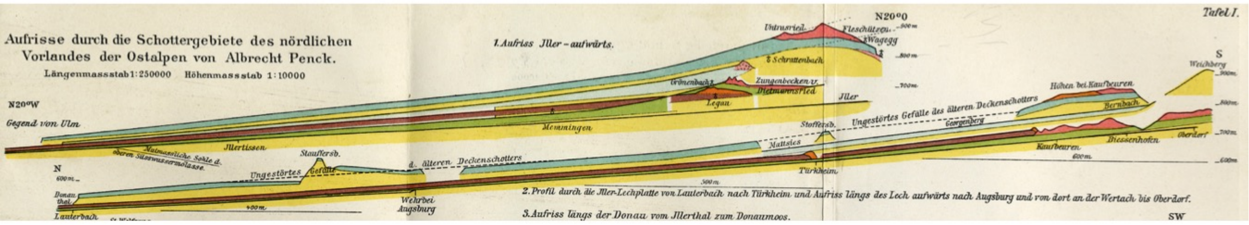

Aufrisse durch die Schottergebiete des nördlichen Vorlandes der Ostalpen von Albrecht Penck.
Längenmassstab 1:250000 Höhenmassstab 1:10000
Tafel I.
1. Aufriss Jller-aufwärts.
N20°W
Gegend von Ulm
Jllertissen
Memmingen
Malmassliche Sohle d. oberen Süsswassermolasse.
Grönenbach
Legau
Zungenbecken v. Dietmannsried
Schrattenbach
Unterusried
Fleschützen
Wagegg
N20°O
900m
800m
700m
Jller
N
600m
Stauffersb.
Ungestörtes Gefälle d. älteren Deckenschotters
Donau thal
Lauterbach
400m
Wehr bei Augsburg
Mattsies
Stoffersb.
Türkheim
500m
Ungestörtes Gefälle des älteren Deckenschotters
Georgenberg
Höhen bei Kaufbeuren
Bernbach
Kaufbeuren
Biessenhofen
Oberdorf
S
Weichberg
600m
SW
2. Profil durch die Jller-Lechplatte von Lauterbach nach Türkheim und Aufriss längs des Lech aufwärts nach Augsburg und von dort an der Wertach bis Oberdorf.
3. Aufriss längs der Donau vom Jllerthal zum Donaumoos.

Figure 4.27: Eduard Brückner and Albrecht Penck collected and correctly interpreted evidence for the Ice Ages (1901–1909).

4.4 Atmospheric Science

As shown by the examples in Figs. 4.28–4.34, many creators from the German-speaking world made major discoveries in atmospheric science.[4]

Richard Assmann (German, 1845–1918, Fig. 4.28) published the first weather map for Germany in 1880, invented the Assmann aspiration psychrometer around 1890, and discovered the stratosphere in 1902. He was a strong and effective advocate for meteorology research and education.

Arthur Berson (German, 1859–1942, Fig. 4.28) made measurements of atmospheric conditions and human physiology at high altitudes, and led expeditions to study weather conditions in the Arctic, South America, Africa, and other regions.

Wilhelm von Bezold (German, 1837–1907, Fig. 4.28) made important discoveries regarding atmospheric thermodynamics and thunderstorms, as well as optical illusions (the Bezold effect and the Bezold–Brücke shift).

C. H. D. Buys Ballot (Dutch, 1817–1890, Fig. 4.28) studied the direction of air flow in weather systems (now known as the Buys Ballot law) and the effect of the annual cycle on Earth's atmospheric temperatures (now known as the Buys Ballot table). Even the American Council of Learned Societies deemed his work especially noteworthy, over a century after his death [ACLS 2000, p. 158]:

> [H]is chief accomplishment was to help shape the new field of meteorology by emphasizing and himself collecting data from the widest possible network of simultaneous observations.

Paul Crutzen (Dutch, worked in Germany, 1933–, Fig. 4.28) was instrumental in analyzing and predicting damage to the ozone layer by pollution, climate change effects caused by burning fossil fuels, and the possibility of a nuclear winter created by dust from numerous explosions. He won the Nobel Prize in Chemistry in 1995 for his work on the ozone layer. Professor Ingmar Grenthe of the Royal Swedish Academy of Sciences noted [https://www.nobelprize.org/prizes/chemistry/1995/ceremony-speech/]:

> In 1970 Paul Crutzen demonstrated that nitrogen oxides, formed during combustion processes, could affect the rate of ozone depletion in the stratosphere. He suggested that dinitrogen monoxide, popularly known as "laughing gas" and formed through microbiological processes in the ground, could have the same effect. He has also studied the formation of ozone in the lower atmosphere. Ozone is one ingredient of "smog," which is formed by the influence of solar radiation on air pollutants, especially exhaust gases from motor vehicles and other combustion systems. Whereas stratospheric ozone is a prerequisite for life, tropospheric ozone is strongly toxic and harmful to most organisms, even in small quantities.

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[4] Bowler 1993; von Hann 1887; von Hann and Süring 1926; Haurwitz 1941.

Julius von Hann (Austrian, 1839–1921, Fig. 4.28) was arguably the founder of systemic global meteorology. Figures 4.32–4.32 show a few pages from his *Atlas der Meteorologie* (1887) giving average isotherms, isobars, winds, and rainfall worldwide. Julius von Hann and Reinhard Süring wrote the *Lehrbuch der Meteorologie*, which became the standard textbook for generations of meteorology students. The American Council of Learned Societies noted [ACLS 2000, p. 394]:

> Hann was one of the most prominent meteorologists of his day. His importance rested less on the creation of new theoretical concepts than on his efforts to coordinate empirical and theoretical results into a coherent structure. [...] He was a driving force in the establishment of mountain observatories, where he studied upper-air data from many different aspects. He produced the first comprehensive climatologies of both the tropics and the polar regions.

Bernhard Haurwitz (German, 1905–1986, Fig. 4.29) received his Ph.D. in meteorology and geophysics from the University of Leipzig in 1927, worked there after graduating, and then moved to the United States in late 1932 due to rising antisemitism in Germany. He helped to bring German methods of meteorology to the United States. Haurwitz taught at MIT and New York University and wrote *Dynamic Meteorology*, which became the standard reference on the subject.

Hugo Hergesell (German, 1859–1938, Fig. 4.29) organized the regular collection of temperature, humidity, and pressure data by balloons at different altitudes in order to improve weather forecasts.

Karl Jelinek (Austrian, 1822–1876, Fig. 4.29) studied both meteorology and geomagnetism, combining measurements with new types of instruments and sophisticated mathematical analysis to obtain important new results.

Joseph Kölzer (German, 1883–1970, Fig. 4.29) established the field of military meteorology before World War I and continued to develop that area until after World War II. He also studied the propagation of sound waves in different layers of the atmosphere.

As shown in Fig. 4.33, Wladimir Köppen (German, 1846–1940) developed a detailed system of climate classification (how wet/dry and how hot/cold a region tends to be) that is still in use, with subsequent improvements by Rudolf Geiger (German, 1894–1981) [Geiger 1950; Köppen 1955]. Wladimir Köppen was the father-in-law of Alfred Wegener (p. 738), and Rudolf Geiger was the brother of Hans Geiger (p. 1520). The *Encyclopedia Britannica* described the importance of Köppen and his work [EB 2010]:

> German meteorologist and climatologist best known for his delineation and mapping of the climatic regions of the world. He played a major role in the advancement of climatology and meteorology for more than 70 years. His achievements, practical and theoretical, profoundly influenced the development of atmospheric science. [...]
>
> A climax in geographical climatology was reached in 1900 when Köppen introduced his mathematical system of climatic classification. Each of five major climate types was assigned a mathematical value according to temperature and rainfall. Since then, many of the systems introduced by other scholars have been based on Köppen's work. [...]

> In 1927 he undertook, with Rudolph Geiger, the editorship of a five-volume *Handbuch der Klimatologie* ("Handbook of Climatology"), which was nearly completed when he died. [...]
>
> Köppen was one of the last scholars of an era when an erudite man could attain competence in, and make significant contributions to, many branches of natural science.

As illustrated in Fig. 4.34, Auguste Piccard (Swiss, 1884–1962) and Paul Kipfer (Swiss, 1905–1980) studied the upper atmosphere and cosmic rays using their own specially designed high-altitude balloon with a pressurized crew compartment.

Reinhard Süring (German, 1866–1950, Fig. 4.29) made important discoveries regarding clouds, atmospheric radiation, the upper atmosphere, and high-altitude physiology. He and Julius von Hann wrote the *Lehrbuch der Meteorologie*, which became the standard textbook for generations of meteorology students.

See also related work in the German-speaking world on:

- Aerospace medicine (p. 390)
- Cosmic rays (p. 804)
- Lighter-than-air craft (p. 1640)

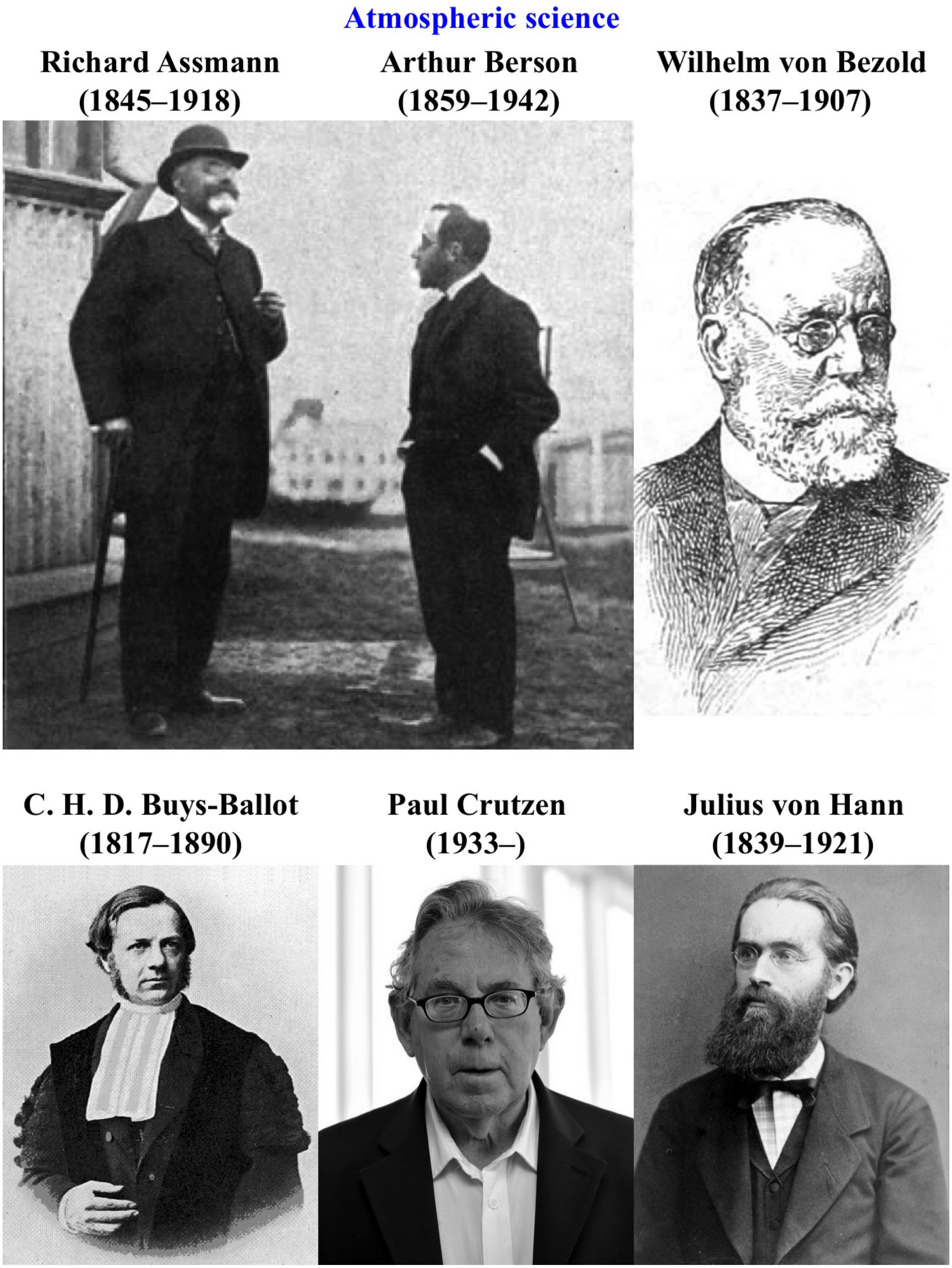

Atmospheric science
Richard Assmann
(1845–1918)
Arthur Berson
(1859–1942)
Wilhelm von Bezold
(1837–1907)
C. H. D. Buys-Ballot
(1817–1890)
Paul Crutzen
(1933–)
Julius von Hann
(1839–1921)

Figure 4.28: Some creators who made major discoveries in atmospheric science included Richard Assmann, Arthur Berson, Wilhelm von Bezold, C. H. D. Buys-Ballot, Paul Crutzen, and Julius von Hann.

Atmospheric science

Bernhard Haurwitz
(1905–1986)

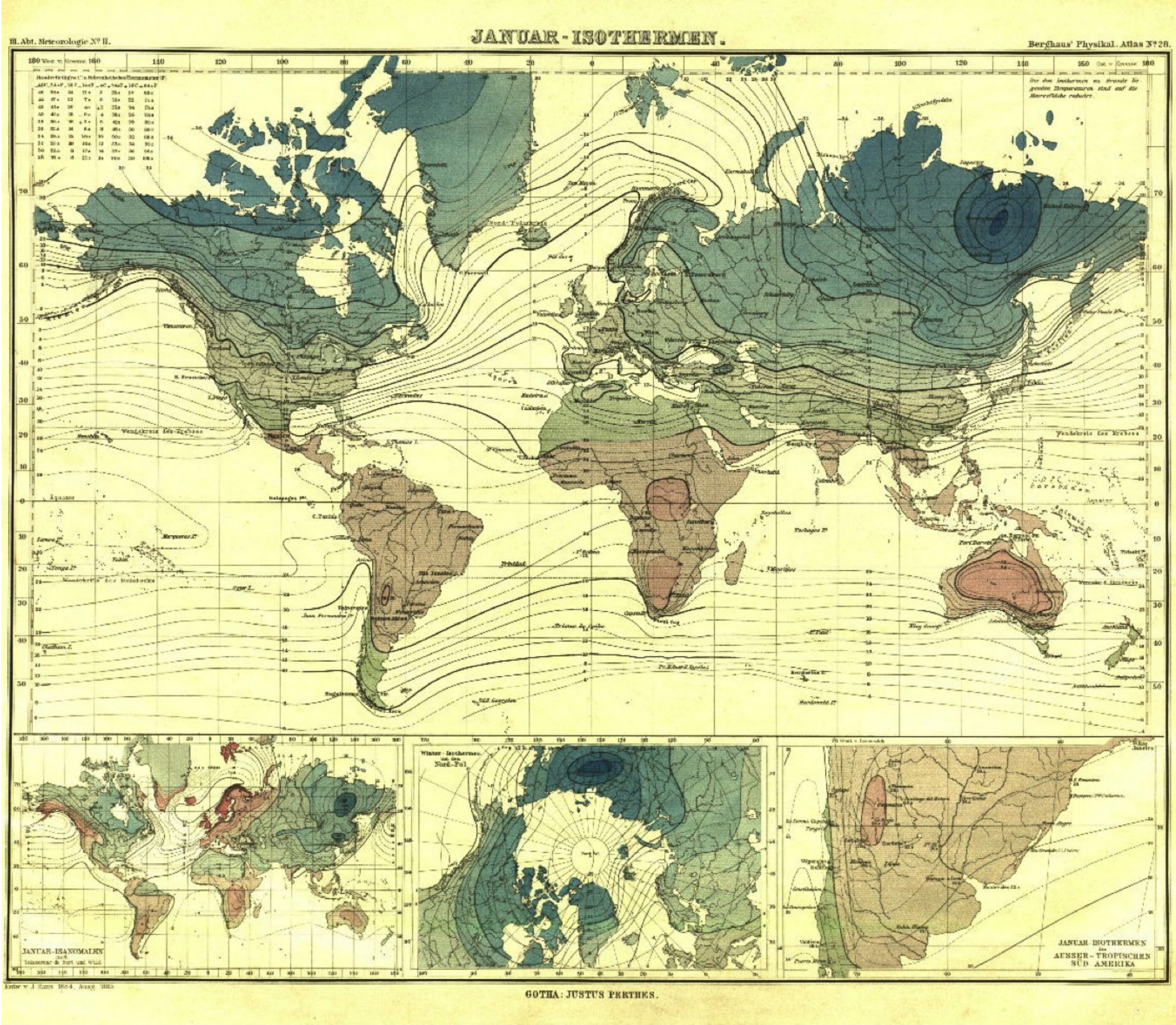
Hugo Hergesell
(1859–1938)

Karl Jelinek
(1822–1876)

Joseph Kölzer
(1883–1970)

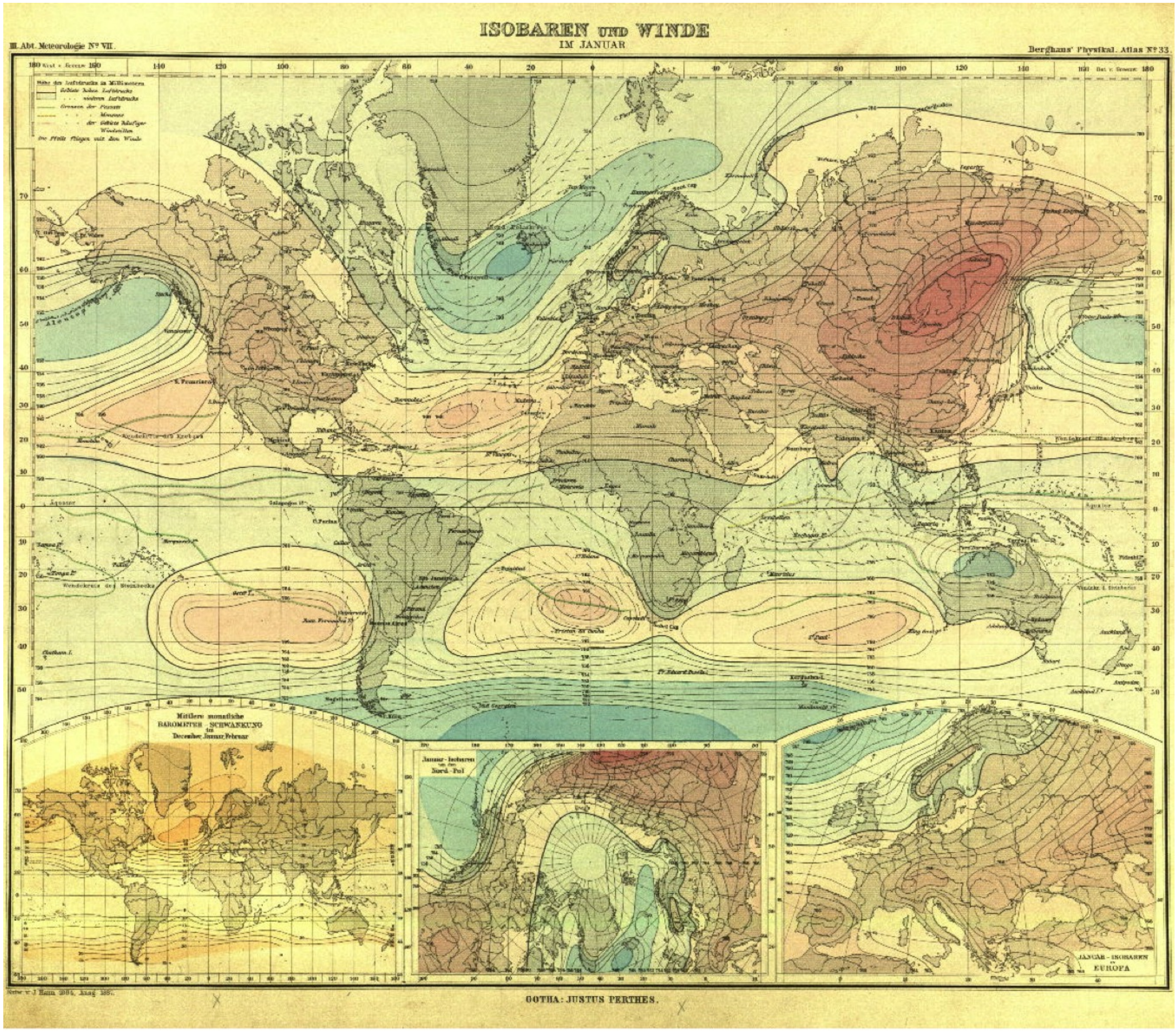
Reinhard Süring
(1866–1950)

Figure 4.29: Other creators who made major discoveries in atmospheric science included Bernhard Haurwitz, Hugo Hergesell, Karl Jelinek, Joseph Kölzer, and Reinhard Süring.


III. Abt. Meteorologie No II.
JANUAR-ISOTHERMEN.
Berghaus' Physikal. Atlas No 28.
JANUAR-ISANOMALEN
Winter-Isothermen um den Nord-Pol
JANUAR-ISOTHERMEN des AUSSER-TROPISCHEN SÜD AMERIKA
GOTHA: JUSTUS PERTHES.

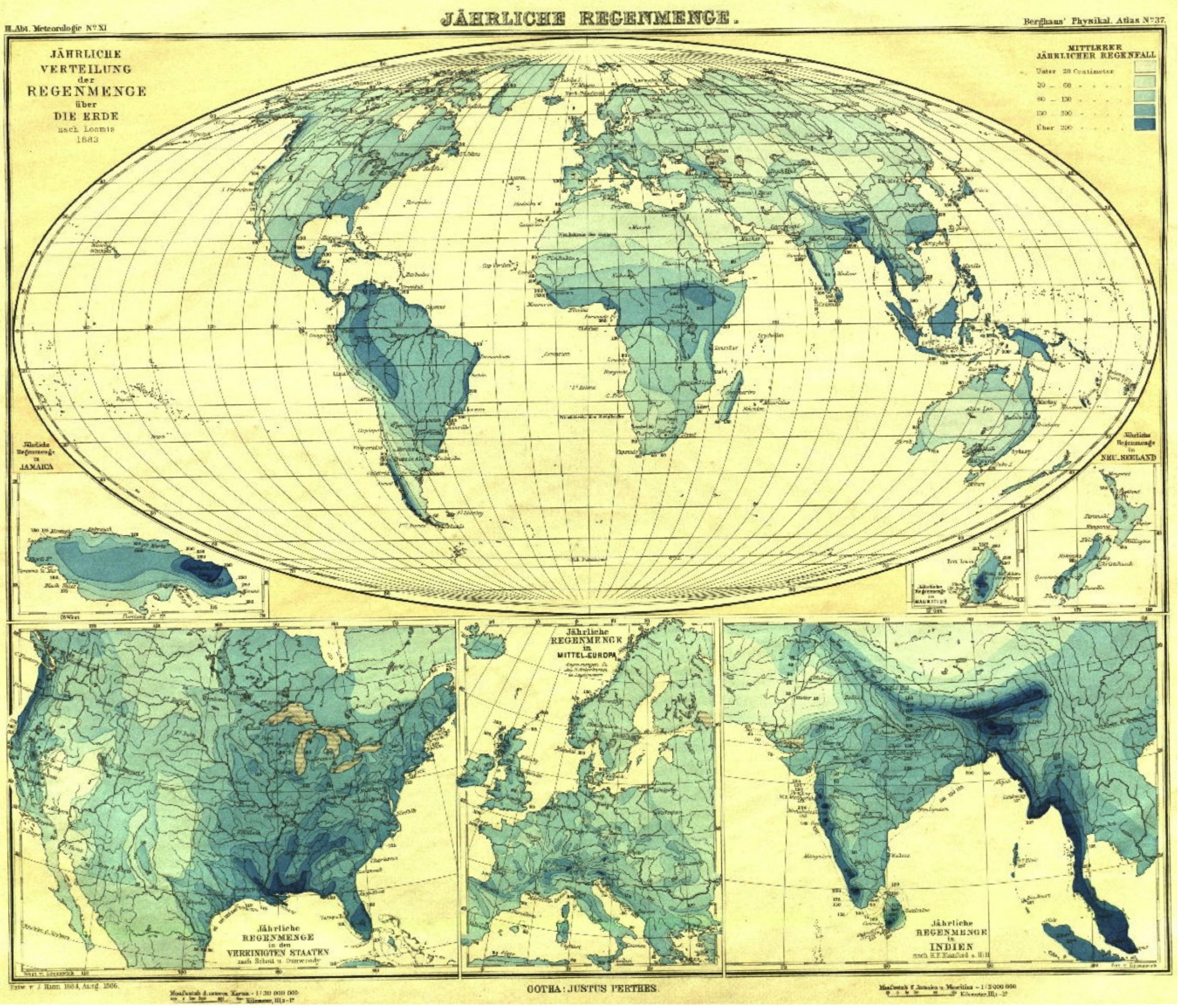
Page from Julius von Hann's *Atlas der Meteorologie* (1887)

Figure 4.30: A page from Julius von Hann's *Atlas der Meteorologie* (1887) showing average isotherms worldwide in January.


ISOBAREN UND WINDE
IM JANUAR
III. Abt. Meteorologie No VII.
Berghaus' Physikal. Atlas No 33.
Mittlere monatliche BAROMETER SCHWANKUNG
December, Januar, Februar
Januar-Isobaren um den Nord-Pol
JANUAR-ISOBAREN EUROPA
GOTHA: JUSTUS PERTHES.

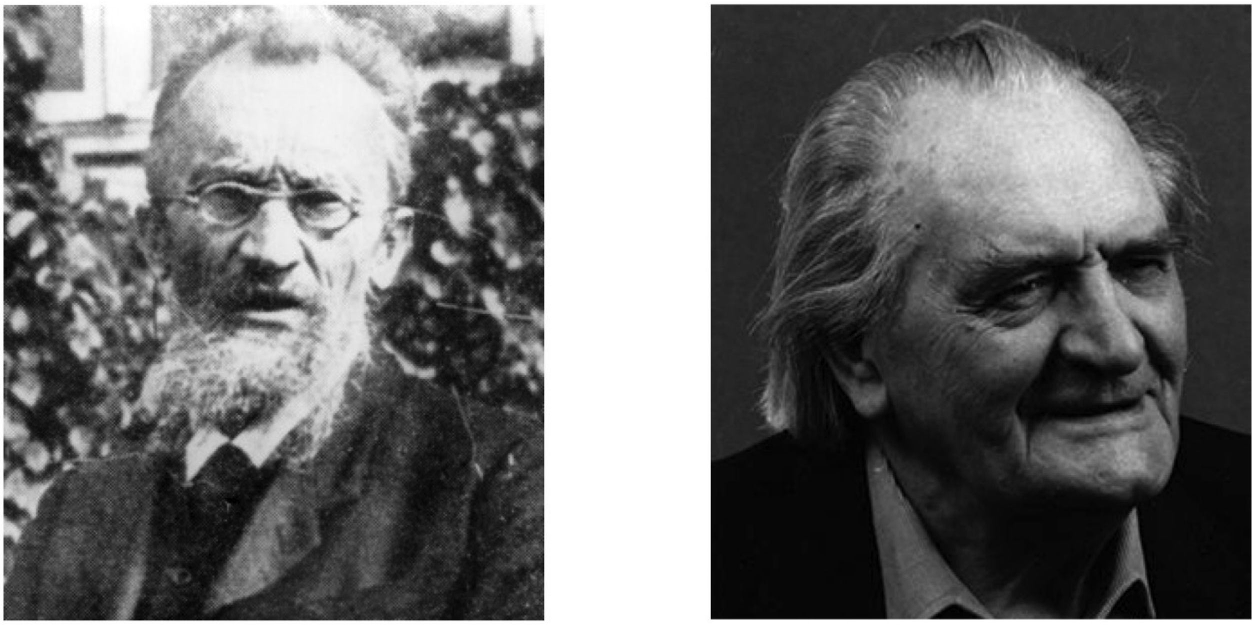
Page from Julius von Hann's *Atlas der Meteorologie* (1887)

Figure 4.31: A page from Julius von Hann's *Atlas der Meteorologie* (1887) showing average isobars and winds worldwide in January.


II. Abt. Meteorologie Nº XI
JÄHRLICHE REGENMENGE.
Berghaus' Physikal. Atlas Nº 37.
JÄHRLICHE VERTEILUNG der REGENMENGE über DIE ERDE nach Loomis 1883
MITTLERER JÄHRLICHER REGENFALL
Unter 20 Centimeter
20 – 60
60 – 130
130 – 200
Über 200
Jährliche Regenmenge in JAMAICA
Jährliche Regenmenge in NEU-SEELAND
Jährliche REGENMENGE in MITTEL-EUROPA
Jährliche REGENMENGE in den VEREINIGTEN STAATEN nach Schott u. Gannett
Jährliche REGENMENGE in INDIEN nach H.F. Blanford u. Hill
GOTHA: JUSTUS PERTHES.

Page from Julius von Hann's *Atlas der Meteorologie* (1887)

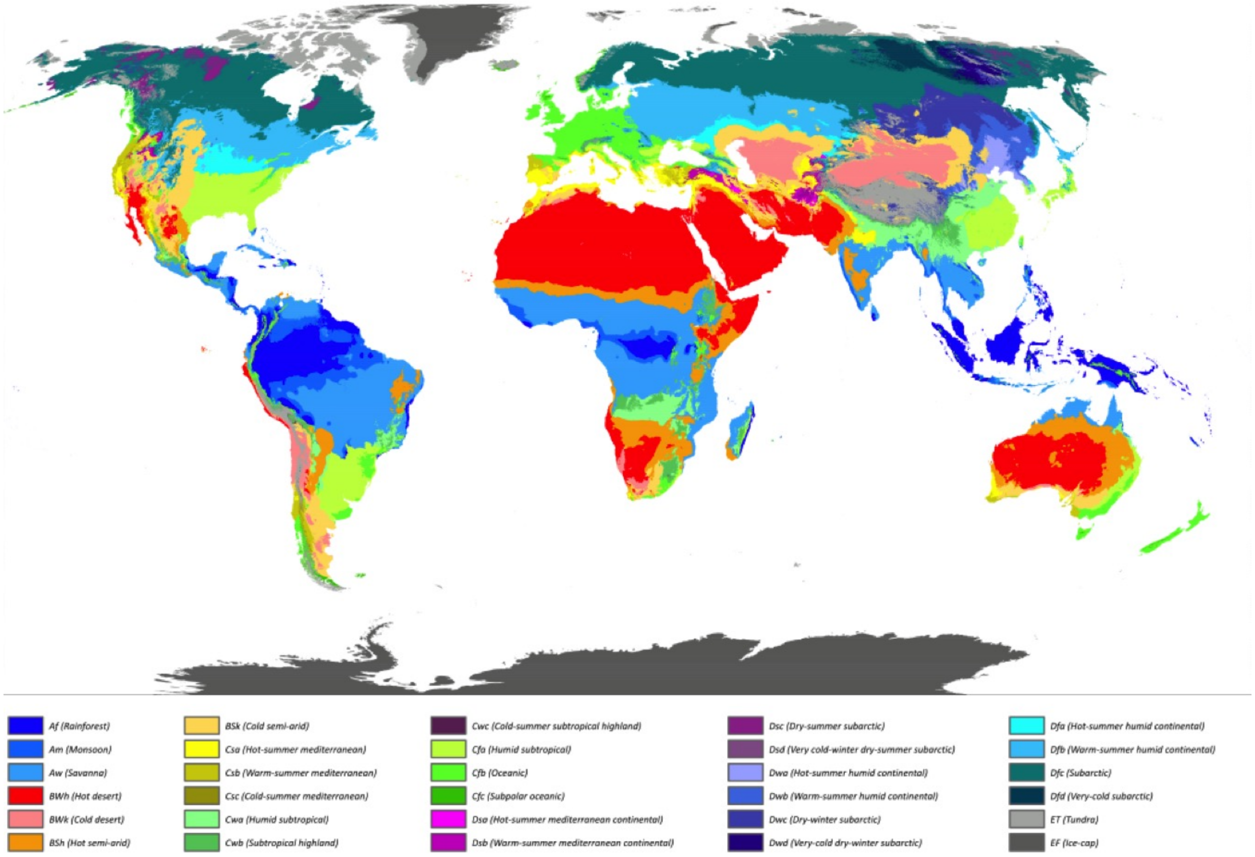
Figure 4.32: A page from Julius von Hann's *Atlas der Meteorologie* (1887) showing average annual rainfall worldwide.



Wladimir Köppen (1846–1940)

Rudolf Geiger (1894–1981)

Climate classification


Af (Rainforest)
Am (Monsoon)
Aw (Savanna)
BWh (Hot desert)
BWk (Cold desert)
BSh (Hot semi-arid)
BSk (Cold semi-arid)
Csa (Hot-summer mediterranean)
Csb (Warm-summer mediterranean)
Csc (Cold-summer mediterranean)
Cwa (Humid subtropical)
Cwb (Subtropical highland)
Cwc (Cold-summer subtropical highland)
Cfa (Humid subtropical)
Cfb (Oceanic)
Cfc (Subpolar oceanic)
Dsa (Hot-summer mediterranean continental)
Dsb (Warm-summer mediterranean continental)
Dsc (Dry-summer subarctic)
Dsd (Very cold-winter dry-summer subarctic)
Dwa (Hot-summer humid continental)
Dwb (Warm-summer humid continental)
Dwc (Dry-winter subarctic)
Dwd (Very-cold dry-winter subarctic)
Dfa (Hot-summer humid continental)
Dfb (Warm-summer humid continental)
Dfc (Subarctic)
Dfd (Very-cold subarctic)
ET (Tundra)
EF (Ice-cap)

*Isotherm used to distinguish temperate (C) and continental (D) climates is -3°C
Climate types calculated from data from WorldClim.org (1970-2000 normals)

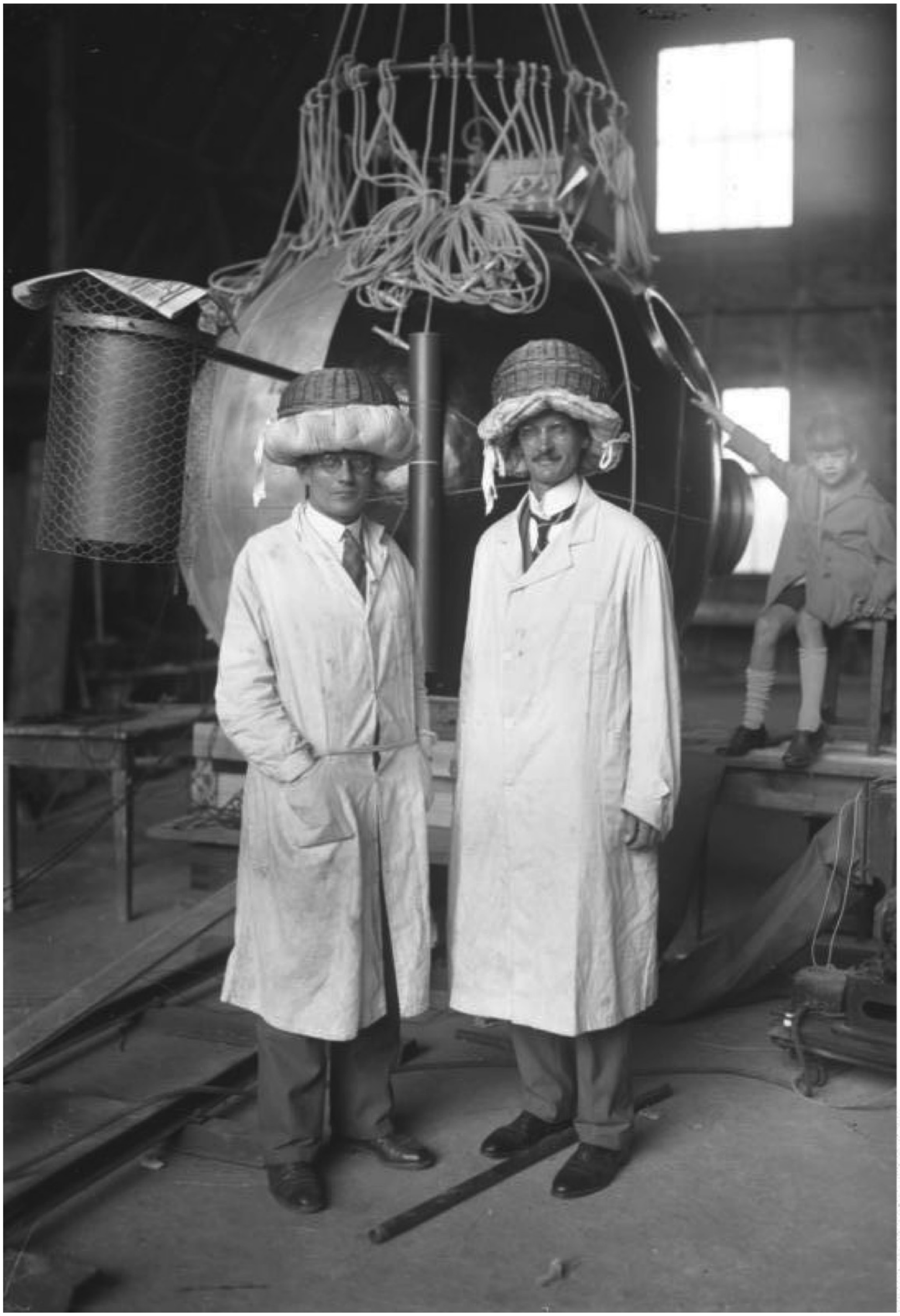
Coordinate system: Robinson
Map created by Adam Peterson on 20 February, 2019
This work is licensed under CC BY-SA 4.0

Figure 4.33: Wladimir Köppen and Rudolf Geiger developed a detailed system of climate classification that is still in use.

Paul Kipfer
(18??–19??)

Balloons; cosmic rays;
upper atmosphere

Auguste Piccard
(1884–1962)



Bundesarchiv, Bild 102-11505
Foto: o.Ang. | April 1931

Figure 4.34: Auguste Piccard and Paul Kipfer also used balloons to study the upper atmosphere and cosmic rays.

4.5 Planetary Science

German-speaking scientists made a large number of important discoveries in planetary science [North 1995], including:

4.5.1. The heliocentric nature and orbits of the solar system

4.5.2. Moon and Mars maps

4.5.3. Asteroids

4.5.4. The outer solar system

For related contributions by German-speaking scientists to space travel and exploration, see Sections 9.7–9.10.

4.5.1 Heliocentric Solar System and Planetary Orbits

Although the German-speaking research world became more established after 1800 or so, one cannot cover planetary science without mentioning three very important creators from before that time:

Nicolaus Copernicus (Prussian, 1473–1543, Fig. 4.35) proposed that the planets orbit around the sun and conducted other work on astronomy and the design of scientific instruments. The scientific historian John North explained [North 1995, pp. 280–281]:

> Copernicus' greatest work, *De revolutionibus orbium caelestium* (On the Revolutions of the Celestial Spheres), was his definitive statement. It was completed at the very end of his life (1543) and differed in several technical respects from the brief sketch, which was probably written around 1510 (and certainly not later than 1514). The sketch contains a statement that the calculations in it are reduced to the meridian of Cracow, which he took to be the same as that of Frombork. In arguing that the Earth revolves around the Sun like any other planet, he introduced the names of authorities that he knew would carry weight in his own time, namely the Pythagoreans.

Tycho Brahe (Danish but educated and worked in the German-speaking world, 1546–1601, Fig. 4.36) made detailed astronomical observations that were used by Johannes Kepler to calculate planetary orbits.

Johannes Kepler (Weil der Stadt, 1571–1630, Fig. 4.37) worked out the physics of planetary orbits, which are slightly elliptical and not perfectly circular as Copernicus had previously assumed. Kepler also conducted other scientific research, including publishing a star catalog/astronomy handbook (*Rudolphine Tables*), describing the hexagonal close-packed symmetry of some crystals, and studying optics. Oxford University's *Biographical Dictionary of Scientists* praised Kepler's approach and accomplishments [Porter 1994, pp. 385, 387]:

> Kepler [...] was a German astronomer who combined great mathematical skills with patience and an almost mystical sense of universal harmony. He is particularly remembered for what are now known as Kepler's laws of motion. These had a profound influence on Newton and hence on all modern science. Kepler was also absorbed with the forces that govern the whole universe and he was one of the first and most powerful advocates of Copernican heliocentric (Sun-centred) cosmology.
>
> [...H]e finally completed the Rudolphine Tables. They appeared in 1627 and brought Kepler much popular acclaim. These were the first modern astronomical tables, a vast improvement on previous attempts of this kind, and they enabled astronomers to calculate the positions of the planets at any time in the past, present or future. The publication also included other vital information, such as a map of the world, a catalogue of stars, and the latest aid to computation, logarithms.
>
> Kepler wrote the first science-fiction story, *Solemnium*, which described a man who travelled to the Moon. It was published in 1631, a year after his death, although it had been written 20 years earlier. Kepler was a remarkable man and a brilliant scientist. He kept a steady eye on what he saw as his true vocation as a 'speculative physicist and cosmologist' and, despite living in times of political unrest and religious turmoil, was never swayed by religious bigotry or political pressures. His new astronomy provided the basis on which Newton and others were to build, and to this day his three laws of motion are considered to be the basis of our understanding of the Solar System.

As shown in Fig. 4.38, Milutin Milanković (or Milankovitch, Serbian but educated and worked in Austria, 1879–1958) worked out how periodic changes in the Earth's orbit and axis affect its climate (Milanković or Milankovitch cycles). He also studied similar effects for Mercury, Venus, the Moon, and Mars.

4.5.2 Moon and Mars Maps

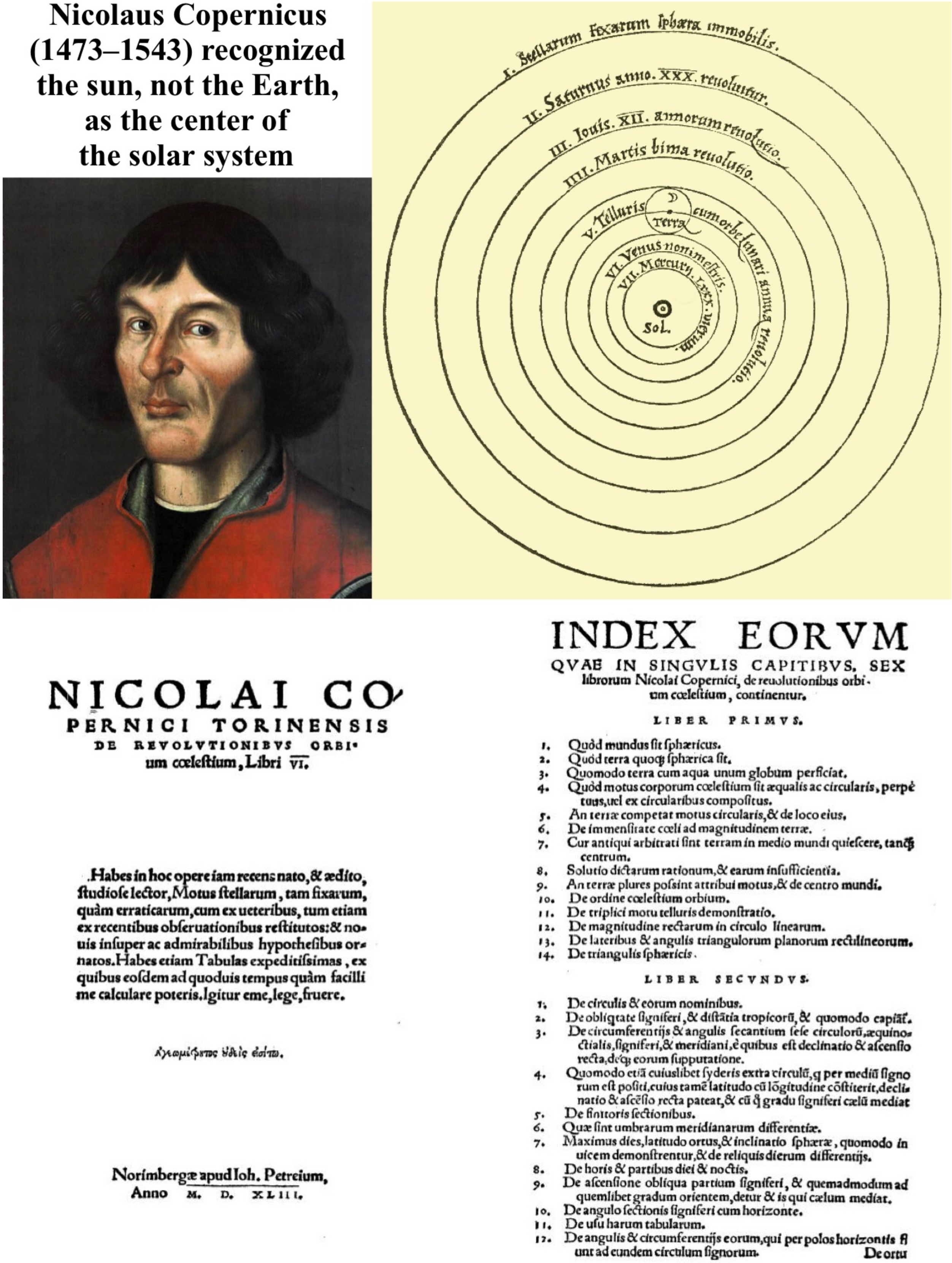
Creators who made important early detailed maps of the Moon and Mars included (Fig. 4.39):

Johann Hieronymus Schröter (German states, 1745–1816) created a Moon map in 1791 and a Mars map in 1800. The American Council of Learned Societies noted [ACLS 2000, p. 789]:

> The observatory he built and equipped at Lilienthal was a center of astronomical research for thirty years, becoming world-famous for the excellence of its instruments. First to observe the surface of the moon and the planets systematically over a long period; discovered and named the lunar rills. He had important influence on Harding, Bessel, and J. F. J. Schmidt.

Wilhelm Beer (Prussian, 1797–1850) and Johann Heinrich von Mädler (German, 1794–1874) produced a highly detailed Moon map during the period 1834–1837 (Fig. 4.40) and the best Mars map then available during the period 1830–1840 (Fig. 4.41).

Johann Friedrich Julius Schmidt (German, 1825–1884) created a Moon map even more detailed than that of Beer and Mädler during the period 1858–1874.


Nicolaus Copernicus
(1473–1543) recognized
the sun, not the Earth,
as the center of
the solar system
I. Stellarum fixarum ſphæra immobilis.
II. Saturnus anno. XXX. reuoluitur.
III. Iouis. XII. annorum reuolutio.
IIII. Martis bima reuolutio.
V. Telluris cum orbe lunari annua reuolutio.
terra
VI. Venus nonimestris.
VII. Mercury. LXXX. dierum.
Sol.

NICOLAI CO-
PERNICI TORINENSIS
DE REVOLVTIONIBVS ORBI-
um cœleſtium, Libri VI.

Habes in hoc opere iam recens nato, & ædito,
ſtudioſe lector, Motus ſtellarum, tam fixarum,
quàm erraticarum, cum ex ueteribus, tum etiam
ex recentibus obſeruationibus reſtitutos: & no-
uis inſuper ac admirabilibus hypotheſibus or-
natos. Habes etiam Tabulas expeditiſsimas, ex
quibus eoſdem ad quoduis tempus quàm facilli
me calculare poteris. Igitur eme, lege, fruere.

Ἀγεωμέτρητος οὐδεὶς εἰσίτω.

Norimbergæ apud Ioh. Petreium,
Anno M. D. XLIII.

INDEX EORVM
QVAE IN SINGVLIS CAPITIBVS, SEX
librorum Nicolai Copernici, de reuolutionibus orbi-
um cœleſtium, continentur.

LIBER PRIMVS.

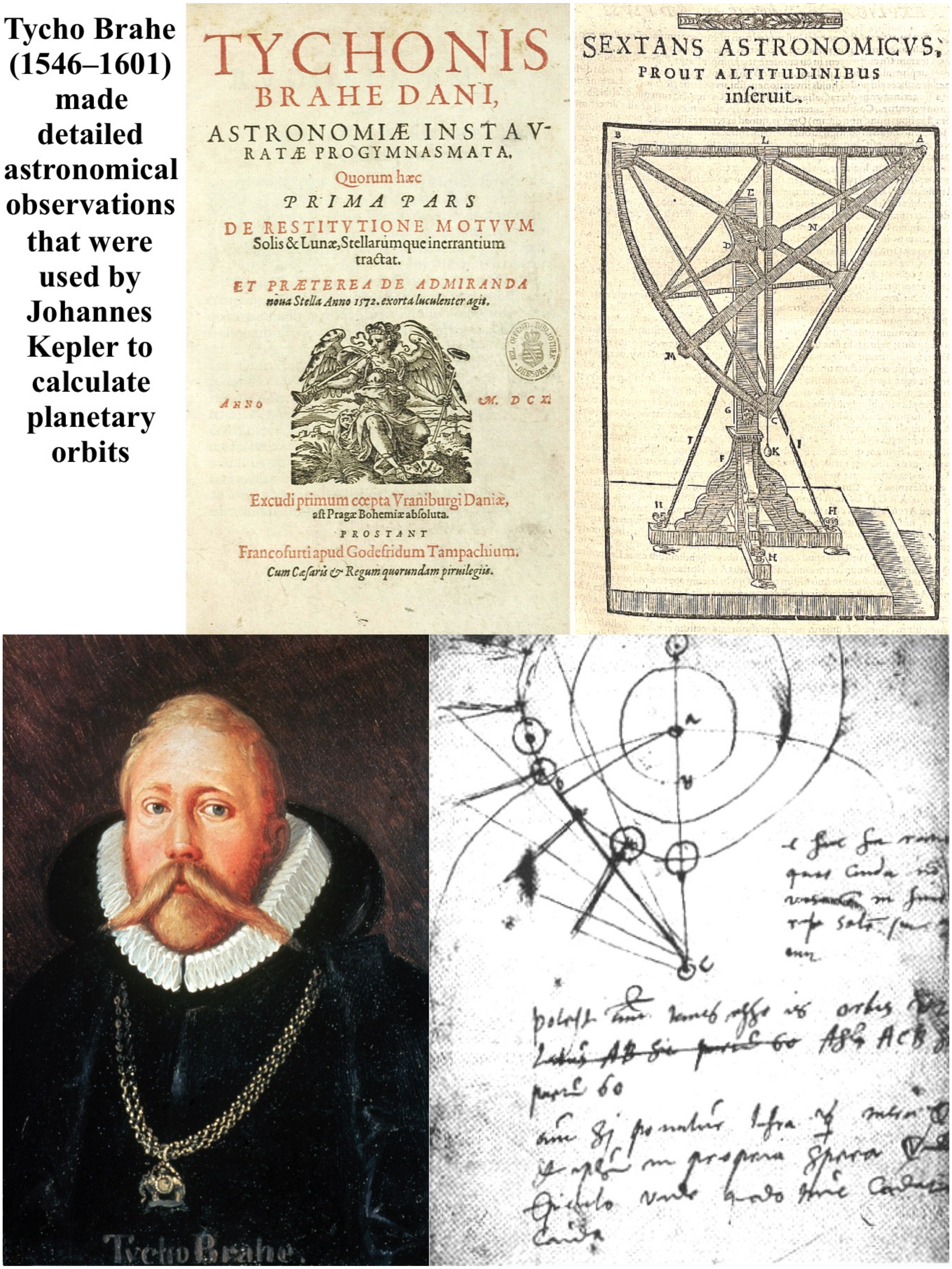
1. Quòd mundus ſit ſphæricus.
2. Quòd terra quoq; ſphærica ſit.
3. Quomodo terra cum aqua unum globum perficiat.
4. Quòd motus corporum cœleſtium ſit æqualis ac circularis, perpetuus, uel ex circularibus compoſitus.
5. An terræ competat motus circularis, & de loco eius.
6. De immenſitate cœli ad magnitudinem terræ.
7. Cur antiqui arbitrati ſint terram in medio mundi quieſcere, tanq̃ centrum.
8. Solutio dictarum rationum, & earum inſufficientia.
9. An terræ plures poſsint attribui motus, & de centro mundi.
10. De ordine cœleſtium orbium.
11. De triplici motu telluris demonſtratio.
12. De magnitudine rectarum in circulo linearum.
13. De lateribus & angulis triangulorum planorum rectilineorum.
14. De triangulis ſphæricis.

LIBER SECVNDVS.

1. De circulis & eorum nominibus.
2. De obliqtate ſigniferi, & diſtãtia tropicorũ, & quomodo capiãt.
3. De circumferentijs & angulis ſecantium ſeſe circulorũ, æquinoctialis, ſigniferi, & meridiani, è quibus eſt declinatio & aſcenſio recta, deq; eorum ſupputatione.
4. Quomodo etiã cuiuslibet ſyderis extra circulũ, q per mediũ ſignorum eſt poſiti, cuius tamẽ latitudo cũ lõgitudine cõſtiterit, declinatio & aſcẽſio recta pateat, & cũ q̃ gradu ſigniferi cælũ mediat
5. De finitoris ſectionibus.
6. Quæ ſint umbrarum meridianarum differentiæ.
7. Maximus dies, latitudo ortus, & inclinatio ſphæræ, quomodo inuicem demonſtrentur, & de reliquis dierum differentijs.
8. De horis & partibus diei & noctis.
9. De aſcenſione obliqua partium ſigniferi, & quemadmodum ad quemlibet gradum orientem, detur & is qui cælum mediat.
10. De angulo ſectionis ſigniferi cum horizonte.
11. De uſu harum tabularum.
12. De angulis & circumferentijs eorum, qui per polos horizontis ſiunt ad eundem circulum ſignorum.

De ortu

Figure 4.35: Nicolaus Copernicus recognized the sun, not the Earth, as the center of the solar system.



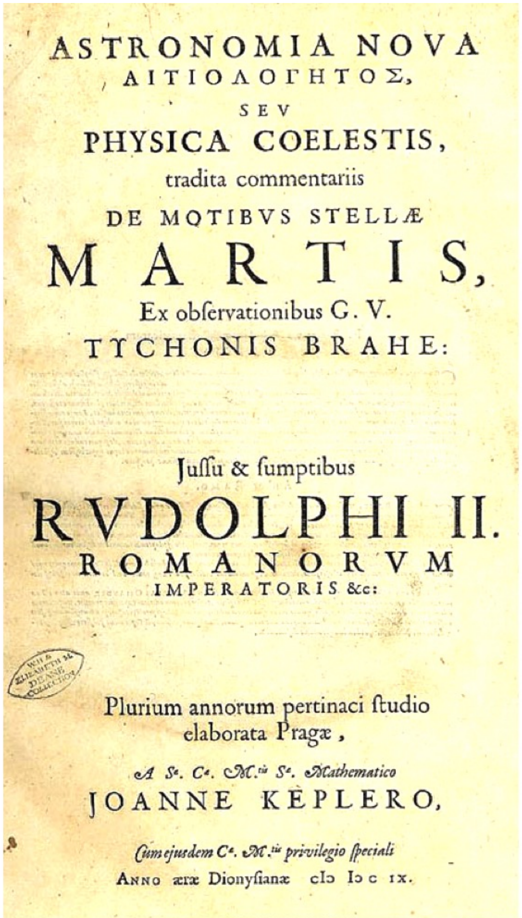
Tycho Brahe (1546–1601) made detailed astronomical observations that were used by Johannes Kepler to calculate planetary orbits

TYCHONIS
BRAHE DANI,
ASTRONOMIÆ INSTAVRATÆ PROGYMNASMATA.
Quorum hæc
PRIMA PARS
DE RESTITVTIONE MOTVVM
Solis & Lunæ, Stellarumque inerrantium
tractat.
ET PRÆTEREA DE ADMIRANDA
noua Stella Anno 1572. exorta luculenter agit.
ANNO M. DCX.
Excudi primum cœpta Vraniburgi Daniæ,
aſt Pragæ Bohemiæ abſoluta.
PROSTANT
Francofurti apud Godefridum Tampachium.
Cum Cæſaris & Regum quorundam pirulegiis.

SEXTANS ASTRONOMICVS,
PROUT ALTITUDINIBUS
inſeruit.
B
L
A
E
N
D
M
G
C
K
I
F
H
H
H
Tycho Brahe.
a
b
c
Latus AB sit partis 60
partis 60

Figure 4.36: Tycho Brahe made detailed astronomical observations that were used by Johannes Kepler to calculate planetary orbits.

Johannes Kepler (1571–1630) calculated the elliptical orbits of planets in the solar system



ASTRONOMIA NOVA
ΑΙΤΙΟΛΟΓΗΤΟΣ,
SEV
PHYSICA COELESTIS,
tradita commentariis
DE MOTIBVS STELLÆ
MARTIS,
Ex obſervationibus G. V.
TYCHONIS BRAHE:

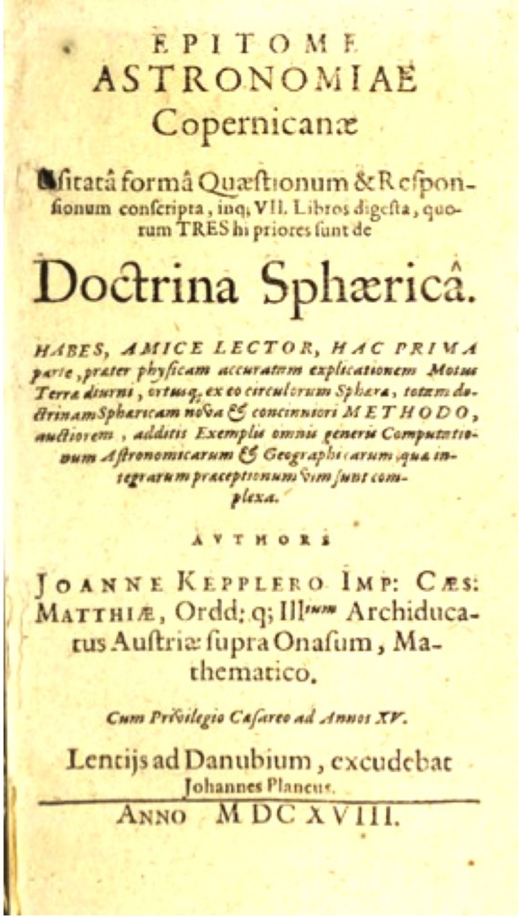
Juſſu & ſumptibus
RVDOLPHI II.
ROMANORVM
IMPERATORIS &c:

WH & ELIZABETH M DEANE COLLECTION

Plurium annorum pertinaci ſtudio
elaborata Pragæ,

A S^e. C^a. M.^tis S^e. Mathematico
JOANNE KEPLERO,

Cum ejusdem C^a. M.^tis privilegio ſpeciali
ANNO æræ Dionyſianæ clɔ Iɔc ix.



EPITOME
ASTRONOMIAE
Copernicanæ

Vſitatâ formâ Quæſtionum & Reſponſionum
conſcripta, inq; VII. Libros digeſta, quorum
TRES hi priores ſunt de

Doctrina Sphæricâ.

HABES, AMICE LECTOR, HAC PRIMA
parte, præter phyſicam accuratam explicationem Motus
Terræ diurni, ortusq; ex eo circulorum Sphæræ, totam doctrinam
Sphæricam nova & concinniori METHODO,
auctiorem, additis Exemplis omnis generis Computationum
Aſtronomicarum & Geographicarum, quæ integrarum
præceptionum vim ſunt complexa.

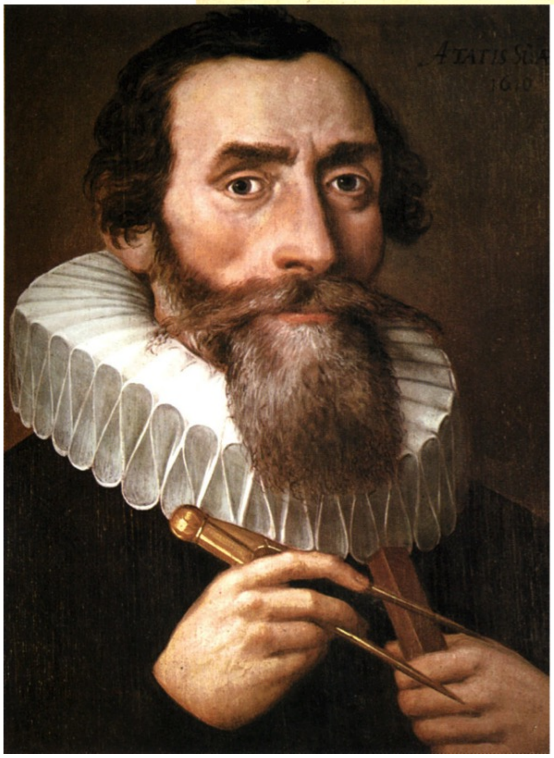
AVTHORE

JOANNE KEPPLERO IMP: CÆS:
MATTHIÆ, Ordd: q; Ill^mum Archiducatus
Auſtriæ ſupra Onaſum, Mathematico.

Cum Privilegio Cæſareo ad Annos XV.

Lentijs ad Danubium, excudebat
Johannes Plancus.

ANNO MDCXVIII.



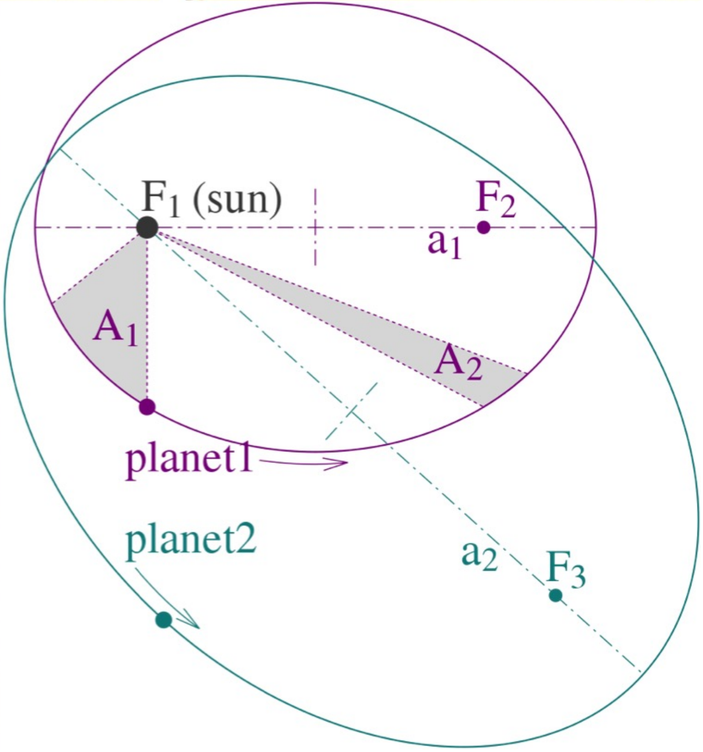
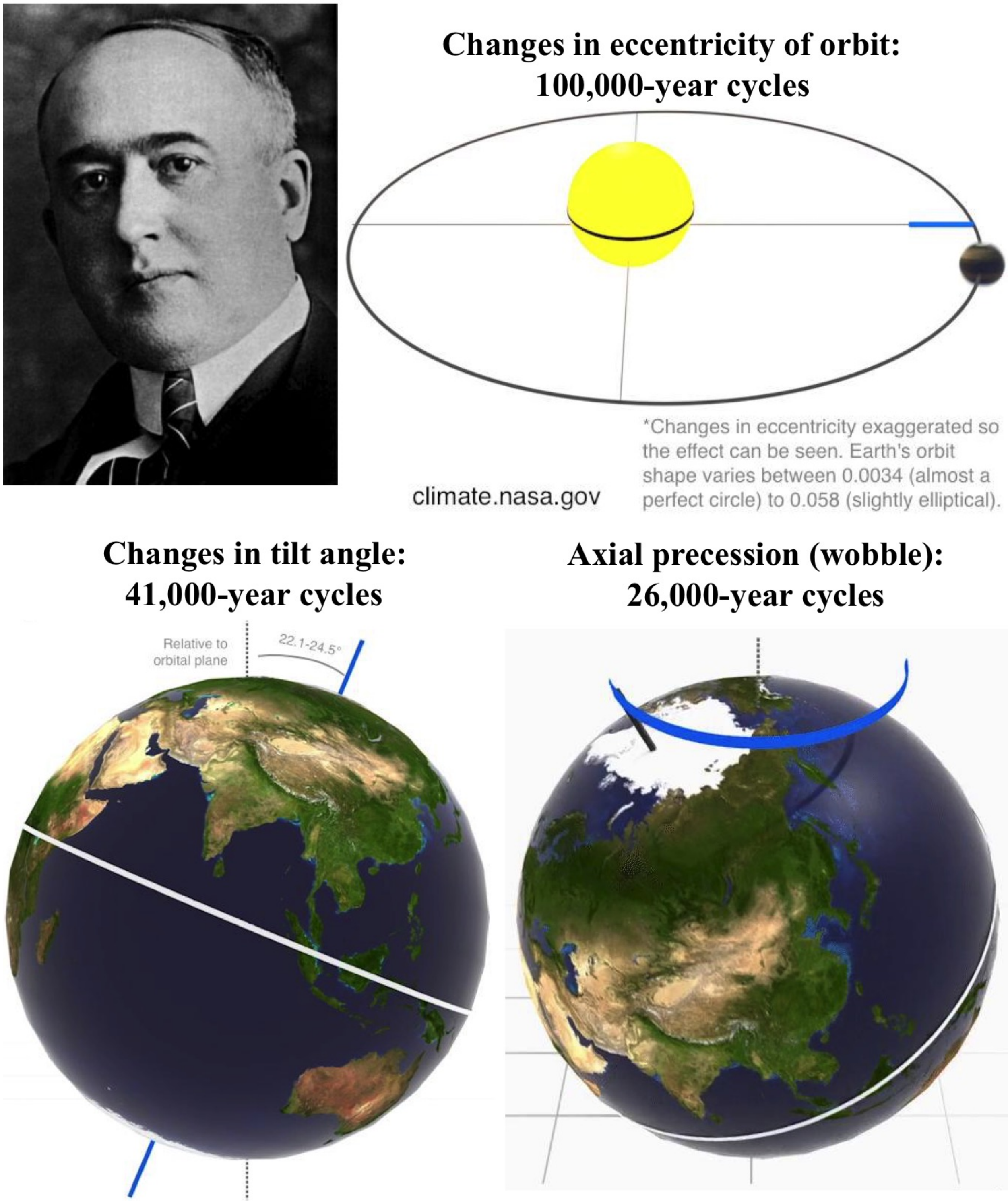


Figure 4.37: Johannes Kepler calculated the elliptical orbits of planets in the solar system.

Milutin Milanković (1879–1958) worked out how periodic changes in the Earth's orbit and axis affect its climate (Milanković cycles). He studied similar effects for Mercury, Venus, the Moon, and Mars.



Changes in eccentricity of orbit: 100,000-year cycles

*Changes in eccentricity exaggerated so the effect can be seen. Earth's orbit shape varies between 0.0034 (almost a perfect circle) to 0.058 (slightly elliptical).

climate.nasa.gov

Changes in tilt angle: 41,000-year cycles

Axial precession (wobble): 26,000-year cycles

Figure 4.38: Milutin Milanković (or Milankovitch) worked out how periodic changes in the Earth's orbit and axis affect its climate (Milanković or Milankovitch cycles). He also studied similar effects for Mercury, Venus, the Moon, and Mars.

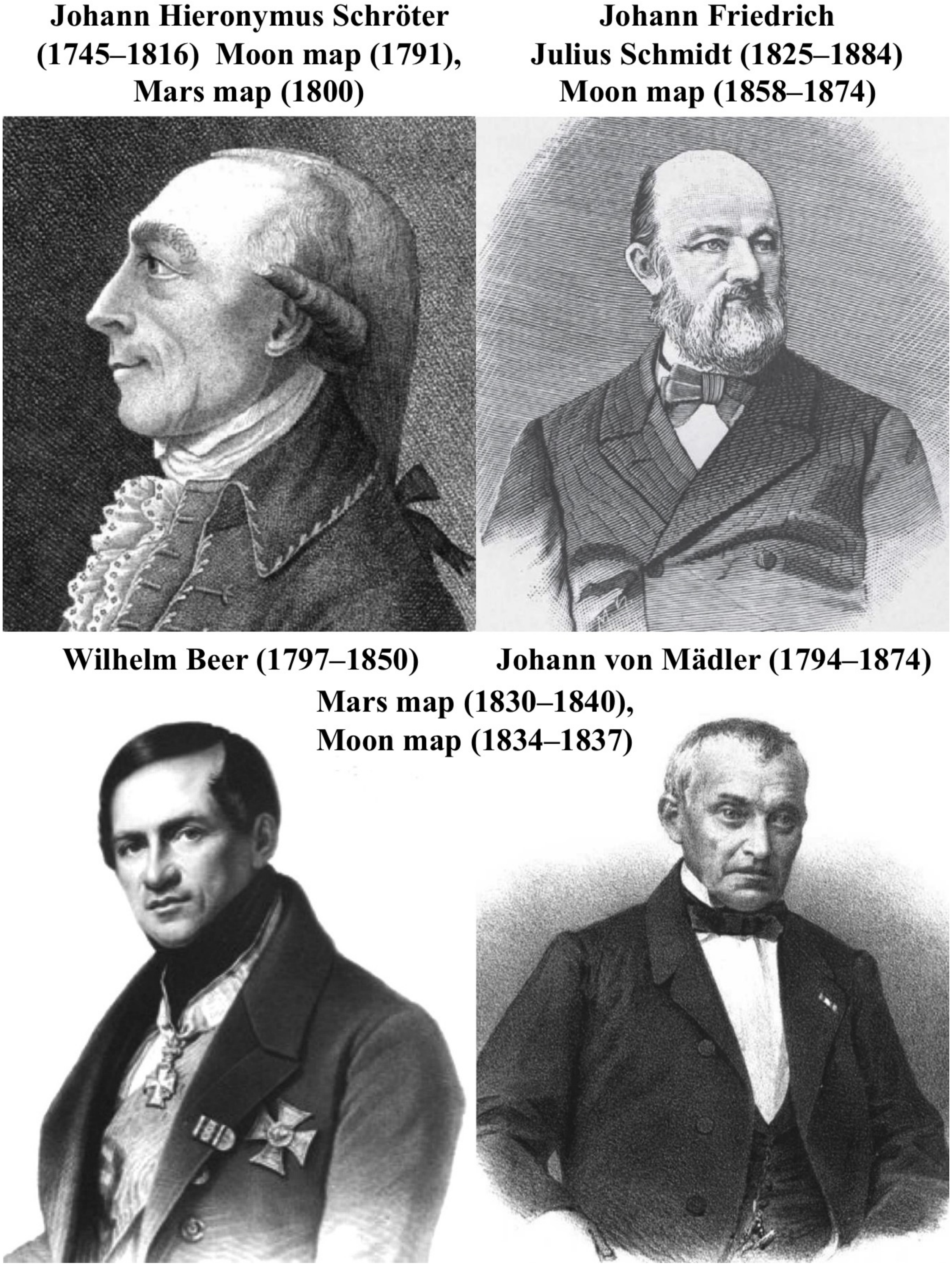

Johann Hieronymus Schröter (1745–1816) Moon map (1791), Mars map (1800)
Johann Friedrich Julius Schmidt (1825–1884) Moon map (1858–1874)
Wilhelm Beer (1797–1850)
Johann von Mädler (1794–1874)
Mars map (1830–1840), Moon map (1834–1837)

Figure 4.39: Creators who made important early detailed maps of the Moon and Mars included Johann Hieronymus Schröter, Wilhelm Beer and Johann von Mädler, and Johann Friedrich Julius Schmidt.

Moon map (1834–1837) by Wilhelm Beer and Johann von Mädler

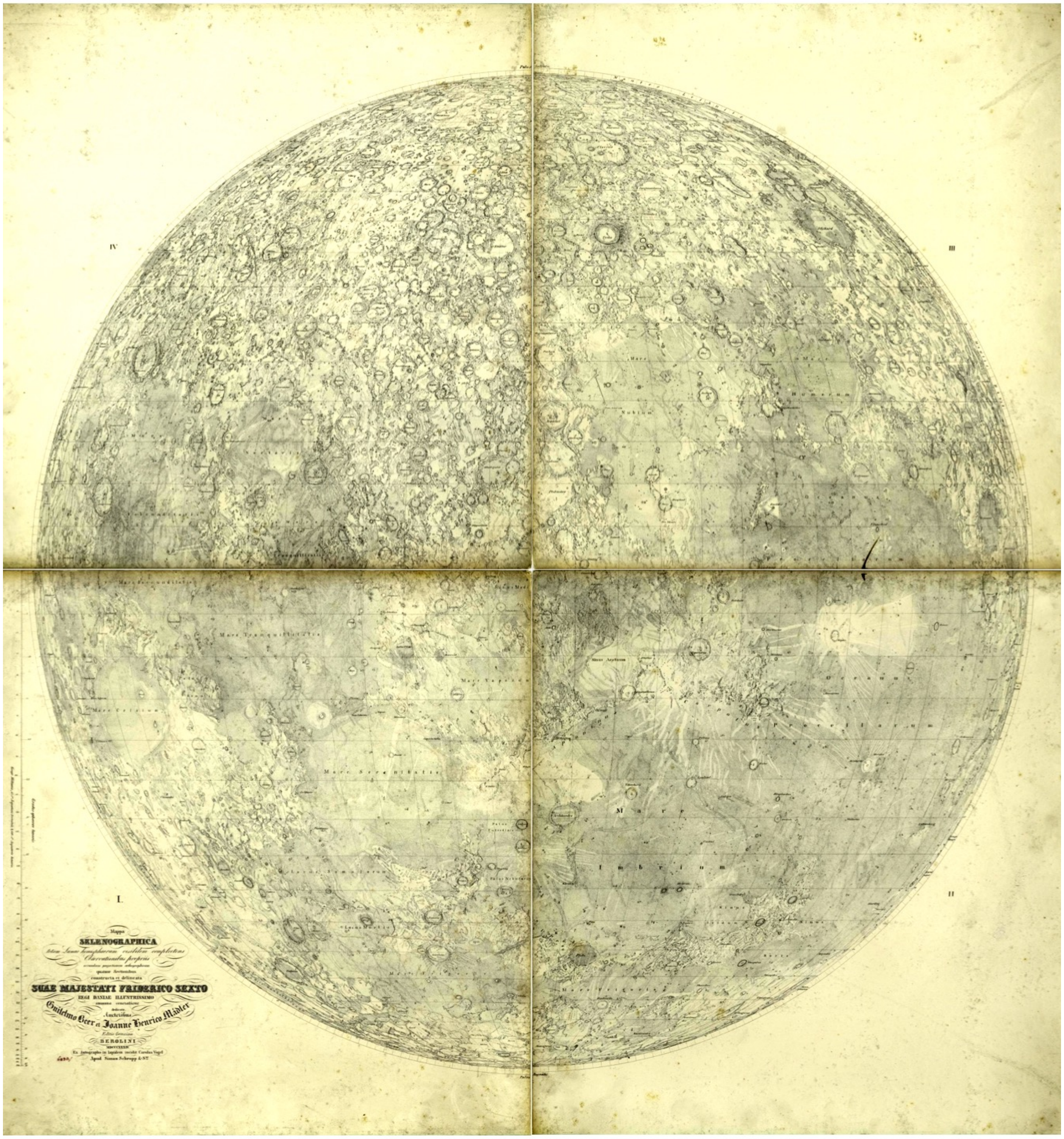
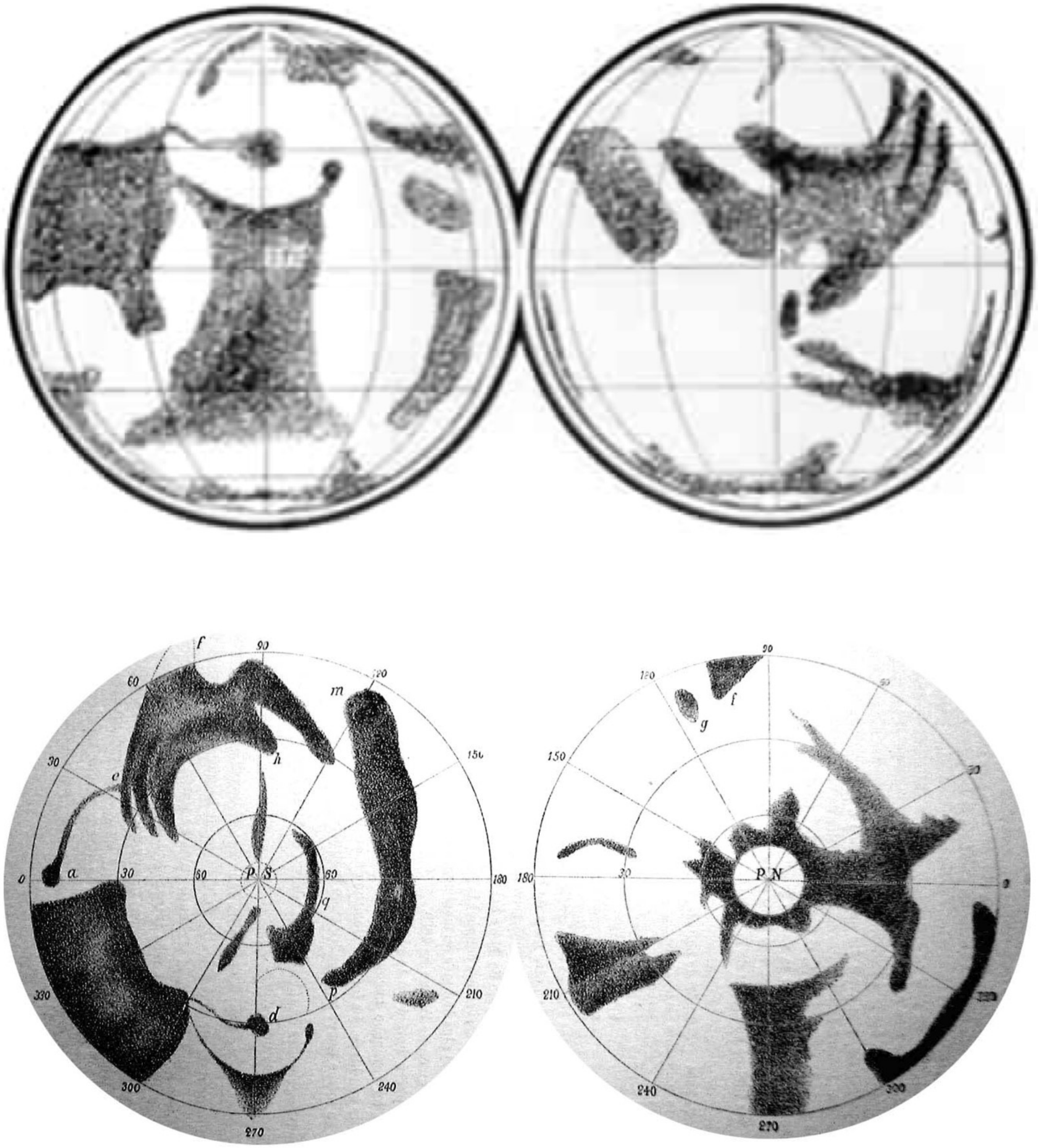

IV
III
I.
II
Mare Tranquillitatis
Mare Serenitatis
Mare Imbrium
Mappa
SELENOGRAPHICA
constructa et delineata
SUAE MAJESTATI FRIDERICO SEXTO
REGI DANIAE ILLUSTRISSIMO
Guilelmo Beer et Joanne Henrico Mädler
BEROLINI
Apud Simon Schropp & S°

Figure 4.40: The Moon map (1834–1837) produced by Wilhelm Beer and Johann von Mädler.

Mars map (1830–1840) by Wilhelm Beer and Johann von Mädler



90
120
150
180
210
240
270
300
330
0
30
60
f
m
h
c
a
P S
q
p
d
90
120
150
180
210
240
270
300
0
30
60
f
g
P N

Figure 4.41: The Mars map (1830–1840) produced by Wilhelm Beer and Johann von Mädler.

4.5.3 Asteroids

As shown in Fig. 4.42, Ernst Chladni (German states, 1756–1827) discovered and published (in 1794) detailed evidence that meteorites come from space [Chladni 1794]. He also spent much of his career investigating the physics of vibrations, sound waves, and musical instruments.

German-speaking creators discovered many major asteroids, including the largest asteroids in the main asteroid belt between Mars and Jupiter (Figs. 4.43–4.46).

Franz Xaver von Zach (Hungarian, 1754–1832) organized astronomical searches for asteroids and was one of the astronomers (along with Heinrich Olbers, Carl Friedrich Gauss, and Giuseppe Piazzi) to spot the largest asteroid, Ceres, in 1801.

Heinrich Olbers (German states, 1758–1840) was one of the astronomers who spotted Ceres in 1801. He also discovered the very large asteroids Pallas in 1802 and Vesta in 1807. He discovered Olbers' comet in 1815, and proposed Olbers' paradox (Why is the night sky dark if there are an infinite number of stars in every direction, if you look far enough?) in 1823. Olbers also aided the career of the young Friedrich Bessel. For much of his life, Olbers was actually a practicing ophthalmologist in Bremen; he was also an early proponent of smallpox vaccination.

Carl Friedrich Gauss (German states, 1777–1855) developed revolutionary new methods for calculating orbits that led to the discovery and tracking of Ceres in 1801. He also calculated other asteroid orbits and developed methods of accounting for the perturbations of asteroid orbits by planets [Dunnington 1955]. (See also pp. 740, 828, 858, and 972.)

At the University of Göttingen, Karl Ludwig Harding (German states, 1765–1834) discovered the very large asteroid Juno in 1804. He also discovered several comets, created an important star catalog, and studied the behavior of variable stars.

Hermann Goldschmidt (German states, 1802–1866) found 14 asteroids and also made other astronomical discoveries regarding variable stars and atmospheric distortions during solar eclipses. In addition, he had a long and successful career as a painter.

Karl Robert Luther (German, 1822–1900) spent several decades working at an observatory in Düsseldorf; he discovered 24 asteroids.

Johann Palisa (Austrian, 1848–1925) was director of the Austrian Pula and Vienna observatories. He discovered 122 asteroids as well as some comets, and later collaborated with Maximilian Wolf on a photographic star atlas.

Friedrich Schwassmann (German, 1870–1964) worked at observatories in Potsdam and Hamburg, where he discovered 22 asteroids and 4 comets.

Maximilian Wolf (German, 1863–1932) was an important pioneer of astrophotography, and used that technique to discover hundreds of asteroids, including the first of the large population of 'Trojan asteroids' in orbit near Jupiter. He also discovered several nebulae, studied sunspots, carried out observations of Halley's comet, and invented the stereo-comparator tool for astronomical observations. Oxford University's *Biographical Dictionary of Scientists* explained the importance of Wolf's innovations [Porter 1994, p. 732]:

> One of his most successful innovations was a technique for discovering large numbers of asteroids. Until this time, asteroids had always been discovered visually[...] Wolf arranged for time-lapse photographs to be taken, using a camera mounted on a telescope whose clock mechanism followed as exactly as possible the proper motion of the 'fixed stars'. On the developed plate, the stars would appear as discrete spots—the size being a function of the star's magnitude—whereas any asteroids present would appear as short streaks in the foreground.
>
> The first asteroid Wolf discovered using this technique was number 323, afterwards named Brucia. He subsequently discovered more than 200 other asteroids using the same method. In September 1903, he discovered a special asteroid, number 588, later named Achilles. Its particular significance was that it was the first of the so-called 'Trojan satellites' whose orbits are in precise synchrony with that of Jupiter's; they form a gravitationally stable configuration between Jupiter and the Sun.

Many of Wolf's students at the University of Heidelberg made their own discoveries and had very productive careers in astronomy, including for example:

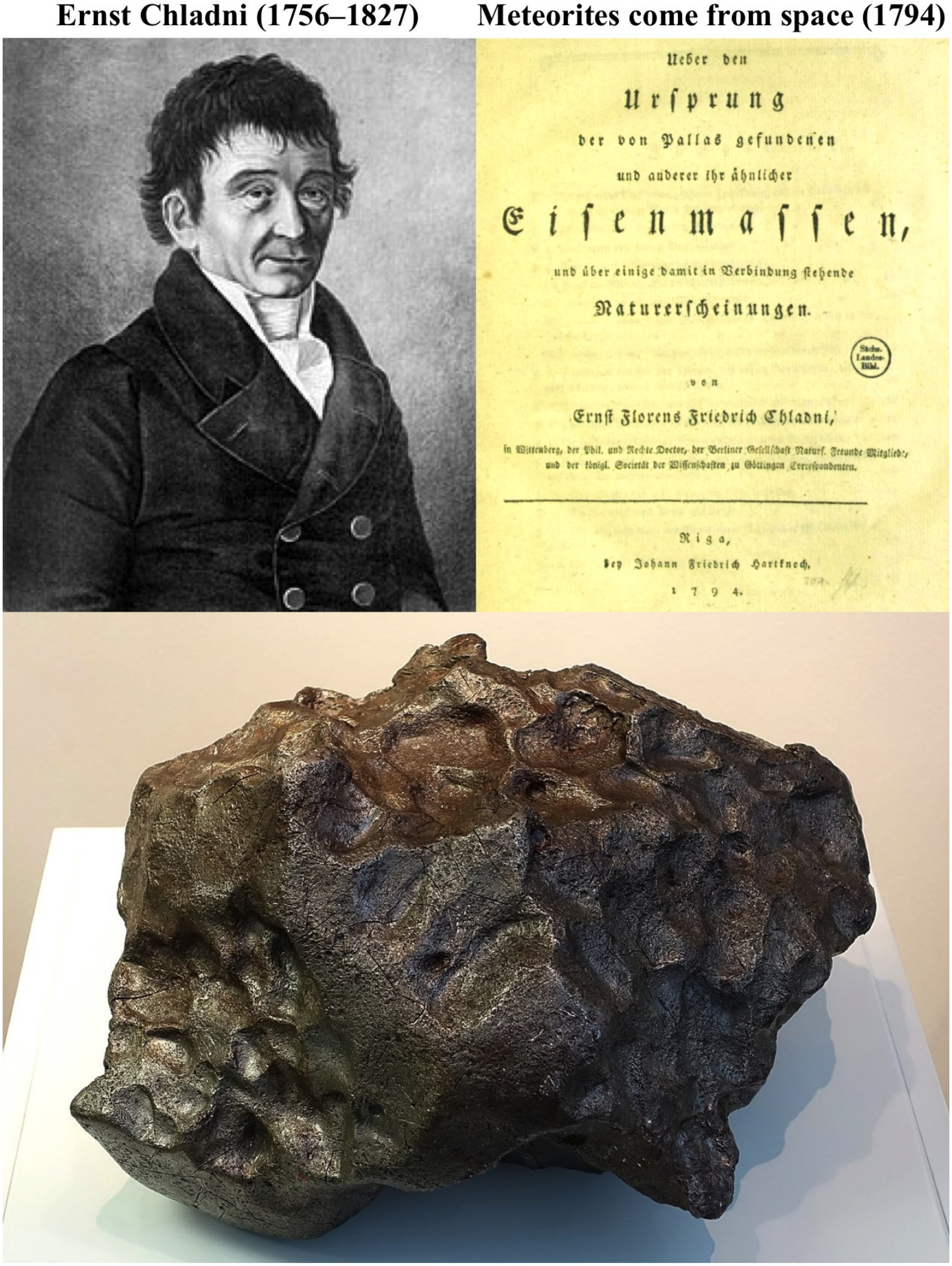
- Alfred Bohrmann (German, 1904–2000) discovered 9 asteroids and made extensive observations of many others.
- Paul Götz (German, 1883–1962) identified 20 asteroids.
- Joseph Helffrich (German, 1890–1971) found 13 asteroids.
- Franz Kaiser (German, 1891–1962) discovered 21 asteroids.
- August Kopff (German, 1882–1960) identified 68 asteroids and several comets.
- Karl Wilhelm Reinmuth (German, 1892–1979) found 395 asteroids plus some comets.

Antonín Mrkos (Czech/Austrian, 1918–1996) was one of the leading astronomers in Czechoslovakia; he discovered 274 asteroids and 13 comets.

Paul Wild (Swiss, 1925–2014) worked at the University of Bern and also with Fritz Zwicky at Caltech (p. 813). He found 94 asteroids, plus 41 supernovae and at least 7 comets.

Johann M. Baur (German, 1930–2007) founded a private observatory in northern Italy and discovered 15 asteroids.

Working at the Karl Schwarzschild Observatory in Tautenburg, Freimut Börngen (German, 1930–2021) discovered 538 asteroids and also made extensive studies of galaxies.



Ueber den

Urſprung

der von Pallas gefundenen

und anderer ihr ähnlicher

Eiſenmaſſen,

und über einige damit in Verbindung ſtehende

Naturerſcheinungen.

von

Ernſt Florens Friedrich Chladni,

in Wittenberg, der Phil. und Rechte Doctor, der Berliner Geſellſchaft Naturf. Freunde Mitglied:, und der königl. Societät der Wiſſenſchaften zu Göttingen Correſpondenten.

Riga,

bey Johann Friedrich Hartknoch.

1794.

Figure 4.42: Ernst Chladni discovered and published detailed evidence that meteorites come from space (1794).

Johann M. Baur
(1930–2007)
15 asteroids

Alfred Bohrmann
(1904–2000)
9 asteroids + observations of many others

Freimut Börngen
(1930–2021)
538 asteroids

Carl Friedrich Gauss
(1777–1855)
Ceres (1801), asteroid orbits and perturbations by planets

Hermann Goldschmidt
(1802–1866)
14 asteroids + other astronomical discoveries

Paul Götz
(1883–1962)
20 asteroids

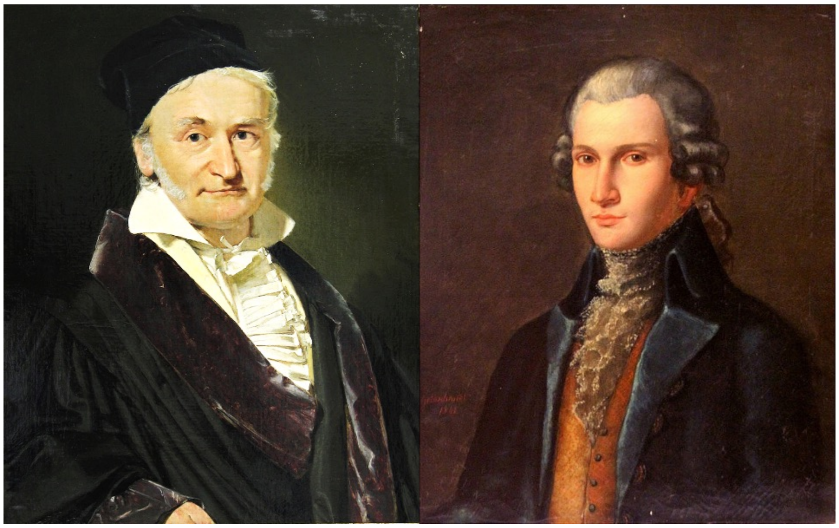


Figure 4.43: Some creators who discovered many major asteroids included Johann M. Baur, Alfred Bohrmann, Freimut Börngen, Carl Friedrich Gauss, Hermann Goldschmidt, and Paul Götz.

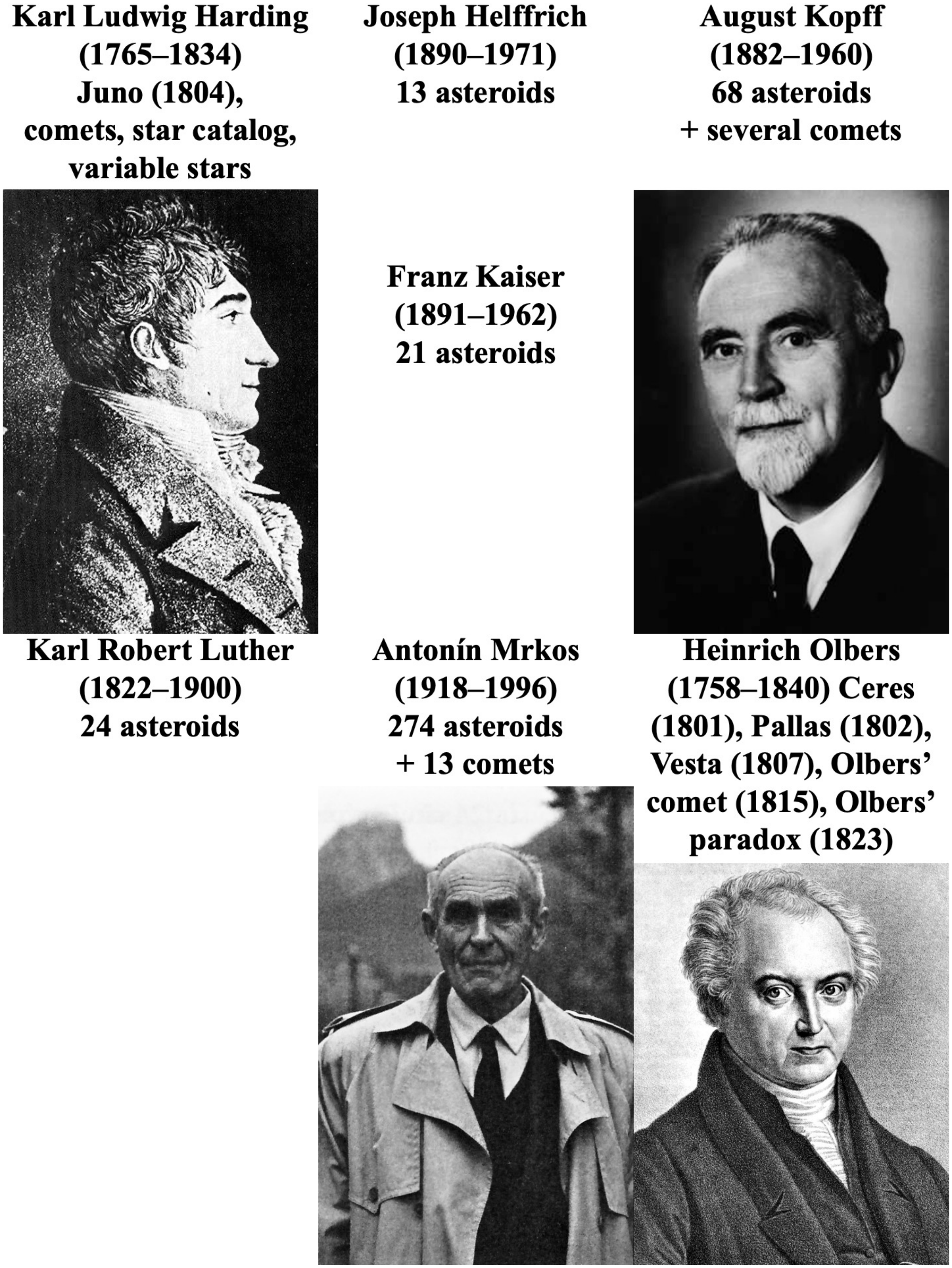

Karl Ludwig Harding
(1765–1834)
Juno (1804),
comets, star catalog,
variable stars
Joseph Helffrich
(1890–1971)
13 asteroids
August Kopff
(1882–1960)
68 asteroids
+ several comets
Franz Kaiser
(1891–1962)
21 asteroids
Karl Robert Luther
(1822–1900)
24 asteroids
Antonín Mrkos
(1918–1996)
274 asteroids
+ 13 comets
Heinrich Olbers
(1758–1840) Ceres
(1801), Pallas (1802),
Vesta (1807), Olbers'
comet (1815), Olbers'
paradox (1823)

Figure 4.44: Other creators who discovered many major asteroids included Karl Ludwig Harding, Joseph Helffrich, Franz Kaiser, August Kopff, Karl Robert Luther, Antonín Mrkos, and Heinrich Olbers.

Johann Palisa
(1848–1925)
122 asteroids
+ some comets

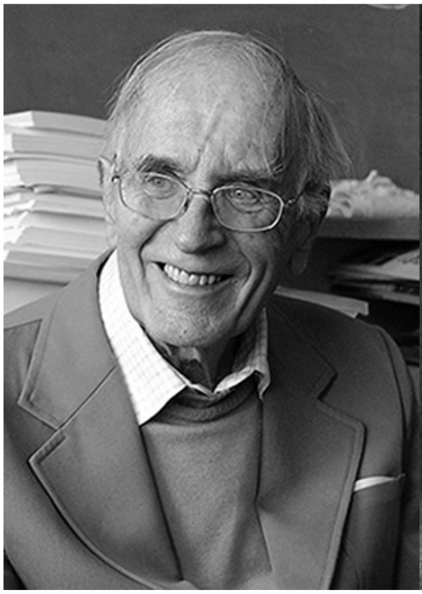
Karl Wilhelm
Reinmuth (1892–1979)
395 asteroids
+ some comets

Friedrich Schwassmann
(1870–1964)
22 asteroids
+ 4 comets

Paul Wild
(1925–2014)
94 asteroids +
other astronomical
discoveries

Maximilian Wolf
(1863–1932)
Astrophotography,
hundreds
of asteroids

Franz Xaver von Zach
(1754–1832)
Ceres (1801),
astronomical
searches for
asteroids



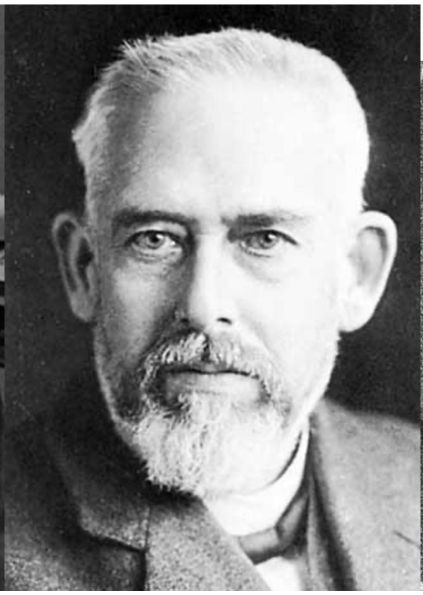


Figure 4.45: Other creators who discovered many major asteroids included Johann Palisa, Karl Wilhelm Reinmuth, Friedrich Schwassmann, Paul Wild, Maximilian Wolf, and Franz Xaver von Zach.

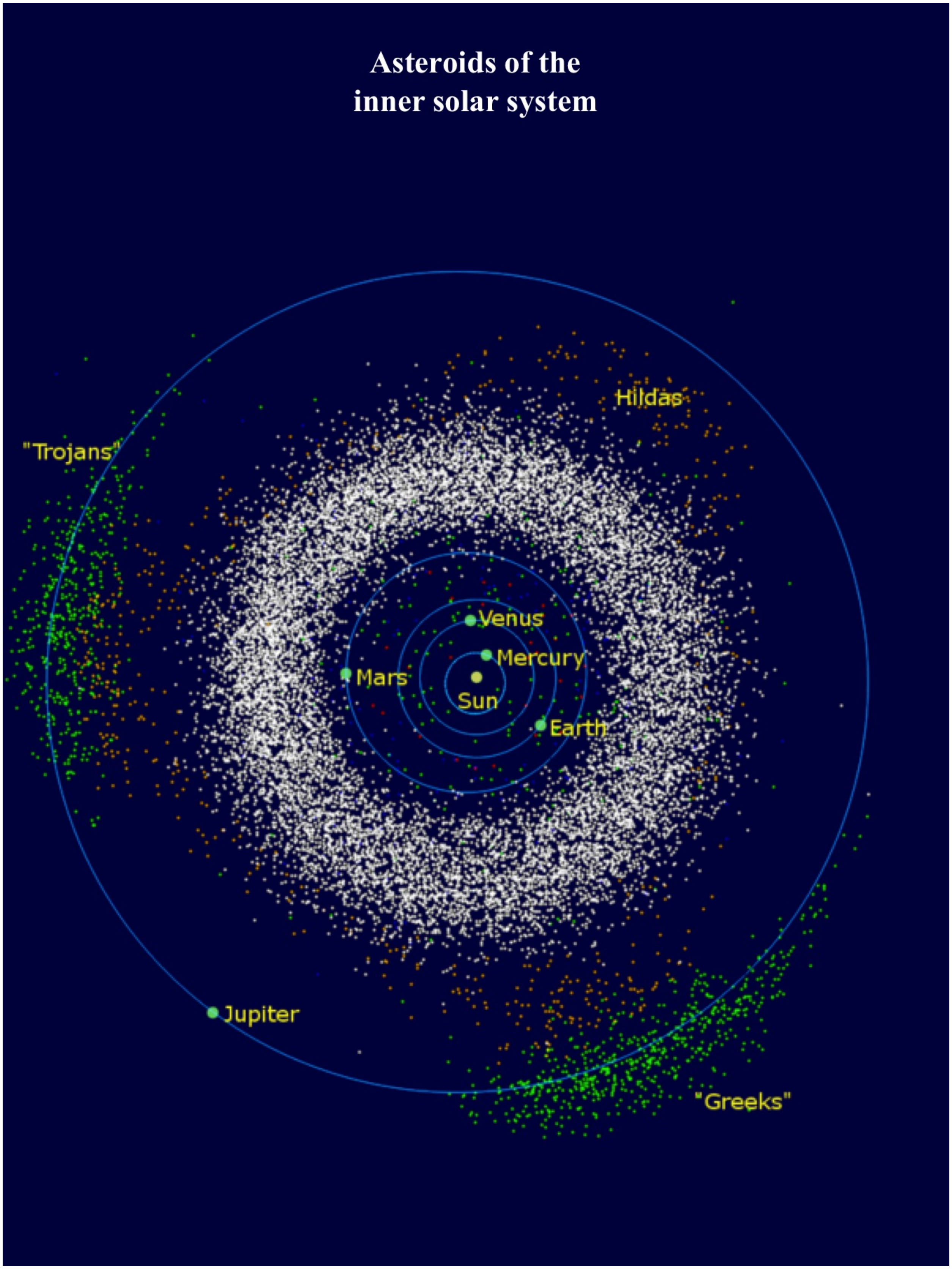

Asteroids of the inner solar system
Hildas
"Trojans"
Venus
Mercury
Mars
Sun
Earth
Jupiter
"Greeks"

Figure 4.46: Asteroids of the inner solar system.

4.5.4 Outer Solar System

Creators from the greater German-speaking world made many major discoveries regarding the planets, moons, and comets of the outer solar system.

Johann Encke (German states, 1791–1865) and Theodor von Oppolzer (Austrian, 1841–1886) each carefully worked out the detailed orbits of many planets, asteroids, and comets (Fig. 4.47).

Friedrich Wilhelm Herschel (Hanover, 1738–1822, Fig. 4.48) discovered the planet Uranus in 1781, as well as two of its moons: Oberon (1787) and Titania (1787). He also discovered two additional moons of Saturn (Enceladus and Mimas, both in 1789) and studied the behavior of sunspots.

Friedrich Wilhelm Herschel's sister, Caroline Herschel (Hanover, 1750–1848), worked with him in those endeavors and also composed a very important early star catalog [Hoskin 2011; Lemonick 2008].

Friedrich Wilhelm Herschel's son, John Herschel (1792–1871), later discovered several other moons of Saturn and Uranus and conducted important research in other scientific fields.

In 1782, Johann Bode (German states, 1747–1826, Fig. 4.49) named and worked out the orbit of the planet Uranus following Friedrich Wilhelm Herschel's discovery.

Johann Galle (German, 1812–1910, Fig. 4.49) discovered the planet Neptune in 1846 [Galle and Wattenberg 1963].

Gerard Kuiper (Dutch, 1905–1973, Fig. 4.49) discovered the methane atmosphere of Saturn's moon Titan (1944), carbon dioxide in the atmosphere of Mars (1947), Uranus's moon Miranda (1948), Neptune's moon Nereid (1949), and evidence for the Kuiper belt of comets orbiting beyond Neptune (1951). The astronomer Carl Sagan eulogized him [Sagan 1980, p. 143]:

> Gerard Peter Kuiper, who in the 1940's and 1950's was the world's only full-time planetary astrophysicist. The subject was then considered by most professional astronomers to be at least slightly disreputable[...] I am grateful to have been Kuiper's student.

Jan Oort (Dutch, 1900–1992, Fig. 4.60) proposed the existence of the Oort cloud of comets in the outer reaches of our solar system.

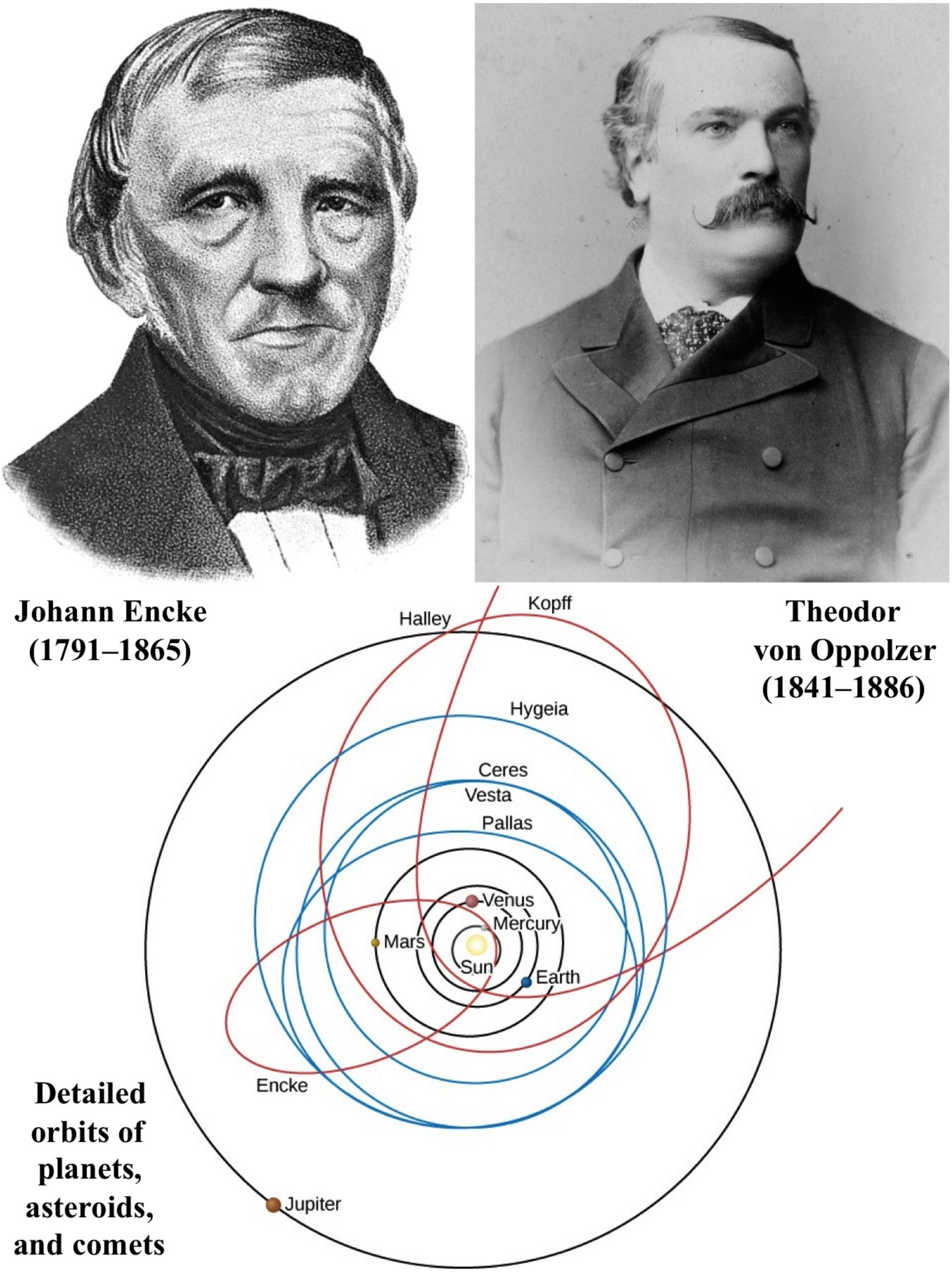
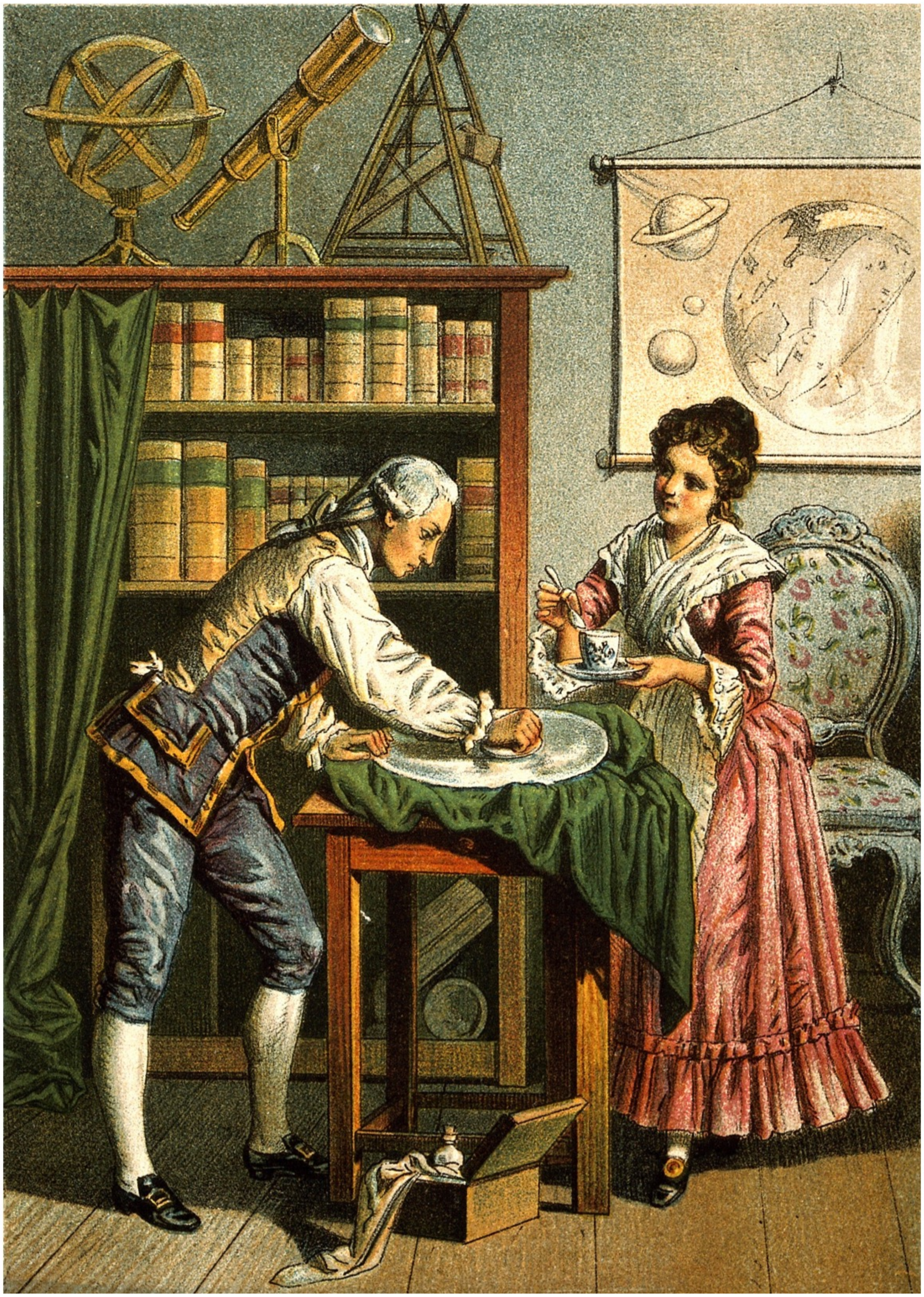

Johann Encke
(1791–1865)
Theodor
von Oppolzer
(1841–1886)
Halley
Kopff
Hygeia
Ceres
Vesta
Pallas
Venus
Mercury
Mars
Sun
Earth
Encke
Jupiter
Detailed
orbits of
planets,
asteroids,
and comets

Figure 4.47: Johann Encke and Theodor von Oppolzer each carefully worked out the detailed orbits of many planets, asteroids, and comets.



Friedrich Wilhelm Herschel (1738–1822)
Uranus (1781), Oberon (1787), Titania (1787)
Enceladus (1789), Mimas (1789), sunspots

Caroline Herschel
(1750–1848)
Star catalog

Figure 4.48: Friedrich Wilhelm Herschel discovered the planet Uranus, two of its moons, and two additional moons of Saturn. His sister Caroline Herschel worked with him in those endeavors and also composed a very important early star catalog.

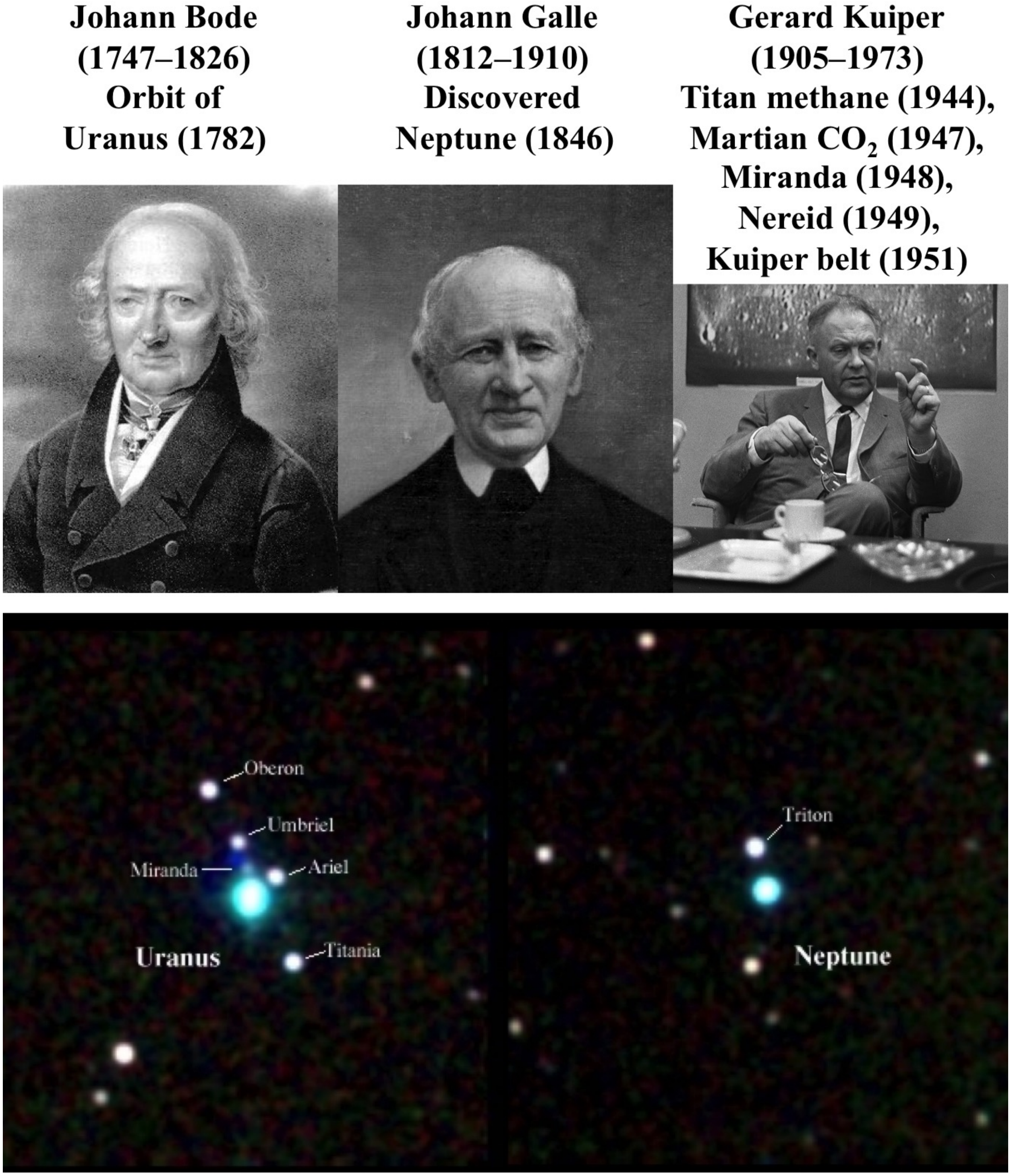

Johann Bode
(1747–1826)
Orbit of
Uranus (1782)
Johann Galle
(1812–1910)
Discovered
Neptune (1846)
Gerard Kuiper
(1905–1973)
Titan methane (1944),
Martian CO_2 (1947),
Miranda (1948),
Nereid (1949),
Kuiper belt (1951)
Oberon
Umbriel
Miranda
Ariel
Uranus
Titania
Triton
Neptune

Figure 4.49: Some other creators who made major discoveries about Uranus, Neptune, and the outer solar system included Johann Bode, Johann Galle, and Gerard Kuiper.

4.6 Astrophysics

Scientists from the German-speaking world played a dominant role in the development of astrophysics, including:

4.6.1. Cosmic rays

4.6.2. Stellar physics

4.6.3. Maps of stars and galaxies

4.6.4. Cosmology

4.6.1 Cosmic Rays

Cosmic rays are high-energy radiation that is emitted by the sun or other objects further out in space and that strikes the Earth's atmosphere, which mostly shields the Earth's surface from the rays [L'Annunziata 2016; North 1995].

German-speaking creators made most of the major discoveries regarding cosmic rays (Figs. 4.50–4.51).

Theodor Wulf (German, 1868–1946) created electroscopes for measuring radiation (Fig. 4.51) and demonstrated in 1910 that they detected more radiation from high on the Eiffel Tower than on the ground, suggesting that radiation was coming from space.

Victor Franz Hess (Austrian, 1883–1964) carried some of Theodor Wulf's electroscopes up in his 1912 balloon flight to measure cosmic rays, and showed that the measured cosmic ray radiation increased with altitude (Fig. 4.51). Hess won the Nobel Prize in Physics in 1936 for this work. Professor H. Pleijel, Chairman of the Nobel Committee for Physics of the Royal Swedish Academy of Sciences, praised Hess's discovery [https://www.nobelprize.org/prizes/physics/1936/ceremony-speech/]:

> Professor Hess. By virtue of your purposeful researches into the effects of radioactive radiation carried out with exceptional experimental skill you discovered the surprising presence of radiation coming from the depths of space, i.e. cosmic radiation. As you have proved, this new radiation possesses a penetrating power and an intensity of previously unknown magnitude; it has become a powerful tool of research in physics, and has already given us important new results with respect to matter and its composition. The presence of this cosmic radiation has offered us new, important problems on the formation and destruction of matter, problems which open up new fields for research. We congratulate you on your fine achievements.

Werner Kolhörster (German, 1887–1946) conducted more thorough balloon experiments in 1913–1914 and obtained more accurate data on cosmic ray radiation vs. altitude (Fig. 4.51).

Erich Regener (German, 1881–1955) developed improved radiation detectors and related instruments and launched them first in balloons and later in rockets.

Eduard Gottfried Steinke (German, 1899–1963) measured cosmic rays of different energies.

Georg Pfotzer (German, 1909–1981) was a student of Erich Regener and collaborated with him in his experiments.

Auguste Piccard (Swiss, 1884–1962) and Paul Kipfer (Swiss, 1905–1980) measured cosmic ray intensities up to the highest altitudes then possible in a balloon (Fig. 4.34).

For more information on the development of radiation detection methods in the German-speaking world, see Sections 8.1–8.2.

Cosmic rays

Theodor Wulf
(1868–1946)

Victor Hess
(1883–1964)

Werner Kolhörster
(1887–1946)

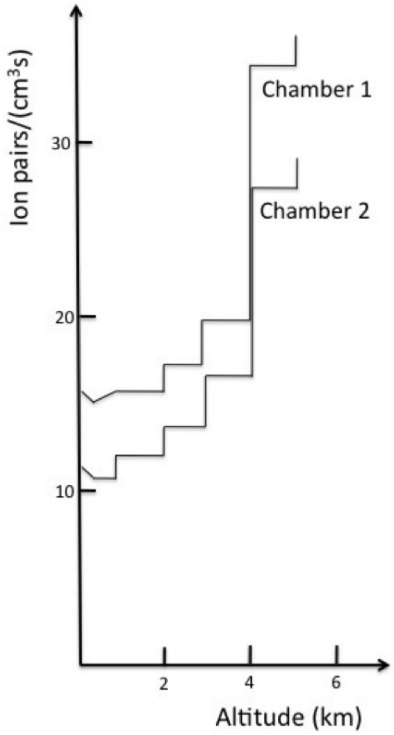
Erich Regener
(1881–1955)

Eduard Steinke
(1899–1963)

Georg Pfotzer
(1909–1981)

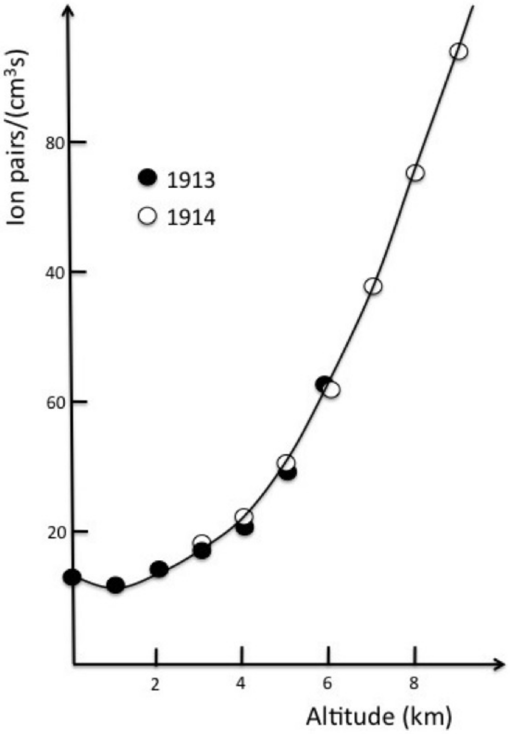
Figure 4.50: Some creators who discovered and studied cosmic rays included Theodor Wulf, Victor Hess, Werner Kolhörster, Erich Regener, Eduard Steinke, and Georg Pfotzer.

Electroscope by Theodor Wulf for measuring radiation



Victor Hess's data on radiation vs. altitude (1912)

Victor Hess's balloon flight to measure cosmic rays (1912)



Werner Kolhörster's data on radiation vs. altitude (1913–1914)

Figure 4.51: Theodor Wulf created electroscopes for measuring radiation, and Victor Hess carried them up in his 1912 balloon flight to measure cosmic rays. The graphs show Victor Hess's 1912 data on the measured cosmic ray radiation vs. altitude, and Werner Kolhörster's more accurate 1913–1914 data.

4.6.2 Stellar Physics

As illustrated in Fig. 4.52, stars such as the sun create such intense heat and pressure in the central core that they convert hydrogen into helium plus lots of energy. There are two parallel processes for that conversion, proton-proton fusion reactions and carbon-catalyzed fusion reactions.

Figures 4.53–4.54 show some of the creators who made major discoveries in stellar physics.[5]

Walter Baade (German, 1893–1960) identified and studied different types of stars.

Hans Bethe (German, 1906–2005) worked out the major fusion reactions in stars, for which he won the Nobel Prize in Physics in 1967 (p. 1542).

Ludwig Biermann (German, 1907–1986) studied the solar wind of charged particles streaming outward from the sun.

Robert Emden (Swiss, 1862–1940) developed the Emden equation describing the spatial variation of pressure inside a star.

Joseph von Fraunhofer (German states, 1787–1826) performed spectral analyses of the sun.

Fritz Houtermans (German, 1903–1966) first worked out some of the fusion reactions and reaction rates in stars.

Rudolph Minkowski (German, 1895–1976) used astrophotography to study supernovae.

J. Robert Oppenheimer (1904–1967) calculated the conditions involved in stellar collapse at the end of a star's life. Oppenheimer was born in the United States but had a German father and second-generation German-American mother, was raised speaking German, repeatedly visited family in Germany during his childhood, and received his Ph.D. in Germany under Max Born at Göttingen.

Samuel Heinrich Schwabe (German, 1789–1875) studied sunspots.

Martin Schwarzschild (German, 1912–1997) made major contributions to our understanding of stellar structure and evolution.

Hermann Carl (or Karl) Vogel (German, 1841–1907) performed spectral analyses of stars. Among other findings, he discovered spectroscopic binary stars—pairs of mutually orbiting stars that are so close together that they appear as one point of light when viewed from Earth, yet that can be distinguished from each other by the spectra of light that they emit.

Carl Friedrich von Weizsäcker (German, 1912–2007) worked out the major fusion reactions in stars.

For more information on fusion reactions, see Section 8.6.

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[5] Bethe 1991, 1997; Bird and Sherwin 2005; Brown and Lee 2006; Davis 1968; L'Annunziata 2016; North 1995; Schwarzschild 1958; Schweber 2012.

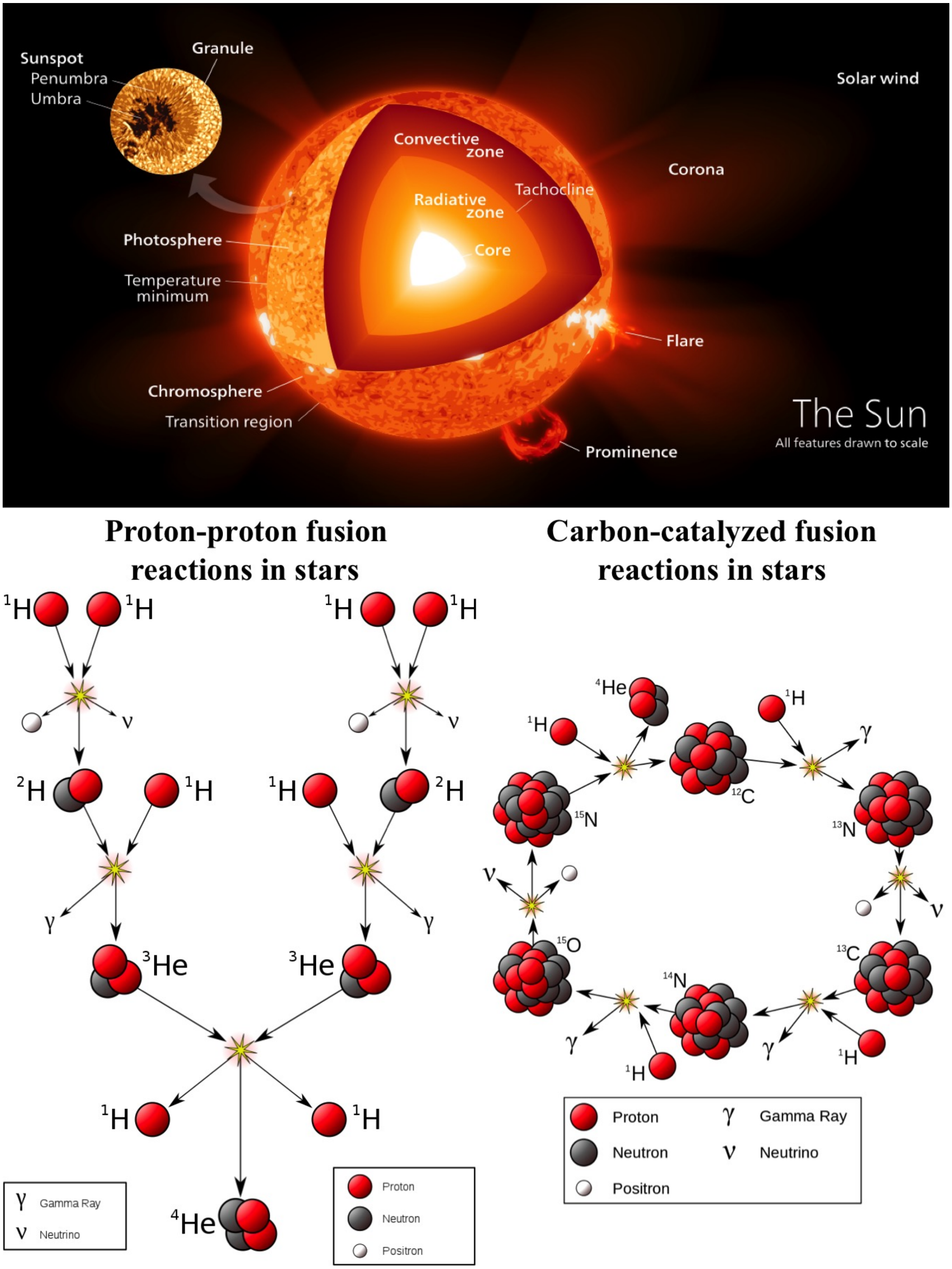

Sunspot
Penumbra
Umbra
Granule
Solar wind
Convective zone
Corona
Tachocline
Radiative zone
Photosphere
Core
Temperature minimum
Flare
Chromosphere
Transition region
The Sun
All features drawn to scale
Prominence
Proton-proton fusion reactions in stars
Carbon-catalyzed fusion reactions in stars
¹H
²H
³He
⁴He
γ
ν
¹²C
¹³N
¹³C
¹⁴N
¹⁵O
¹⁵N
γ Gamma Ray
ν Neutrino
Proton
Neutron
Positron

Figure 4.52: Stars such as the sun create such intense heat and pressure in the central core that they convert hydrogen into helium plus lots of energy, via both proton-proton fusion reactions and carbon-catalyzed fusion reactions.

Stellar physics

Walter Baade
(1893–1960)
Different types of stars

Hans Bethe
(1906–2005)
Fusion reactions in stars

Ludwig Biermann
(1907–1986)
Solar wind

Robert Emden
(1862–1940)
Emden equation for pressure inside a star

Joseph von Fraunhofer
(1787–1826)
Spectral analysis of the sun

Fritz Houtermans
(1903–1966)
Fusion reactions in stars

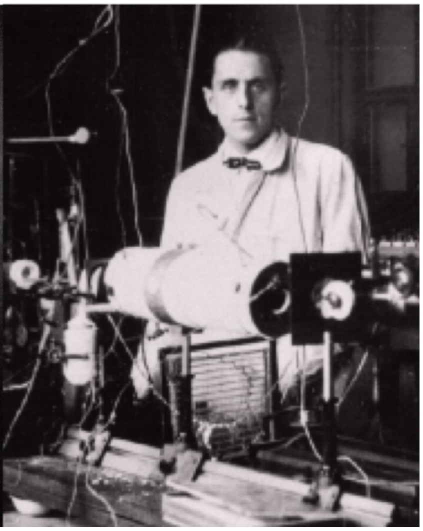


Figure 4.53: Some creators who made major discoveries in stellar physics included Walter Baade, Hans Bethe, Ludwig Biermann, Robert Emden, Joseph von Fraunhofer, and Fritz Houtermans.

Stellar physics

Rudolph Minkowski
(1895–1976)
Supernovae and astrophotography

J. Robert Oppenheimer
(1904–1967)
Stellar collapse

Samuel Heinrich Schwabe
(1789–1875)
Sunspots

Martin Schwarzschild
(1912–1997)
Stellar structure and evolution

Hermann Carl Vogel
(1841–1907)
Spectral analysis of stars

Carl Friedrich von Weizsäcker
(1912–2007)
Fusion reactions in stars

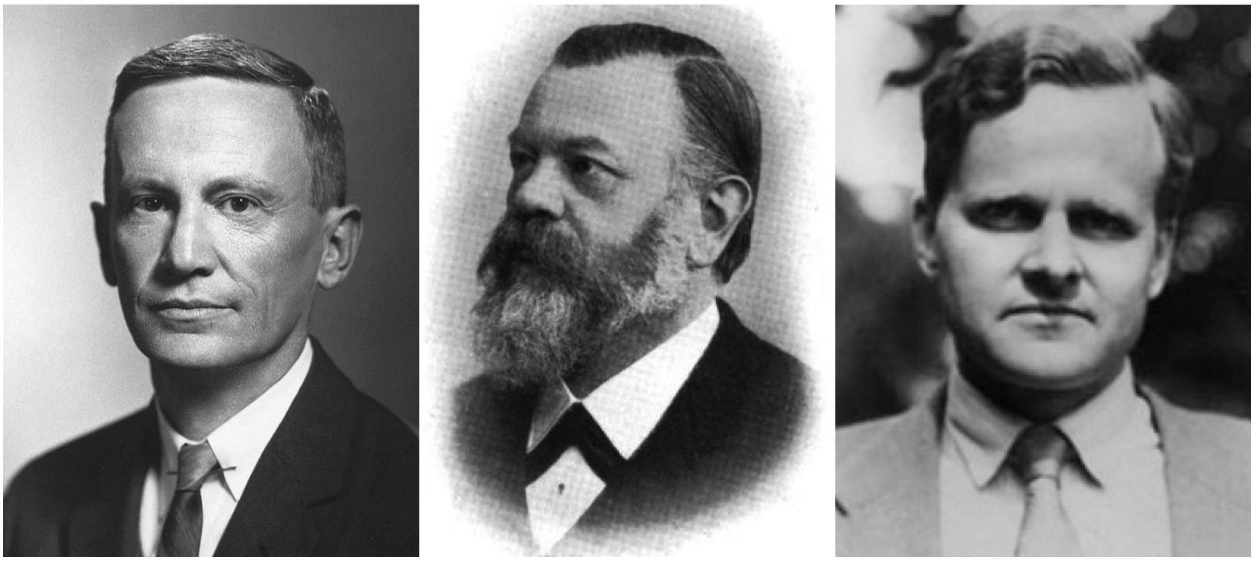


Figure 4.54: Other creators who made major discoveries in stellar physics included Rudolph Minkowski, J. Robert Oppenheimer, Samuel Heinrich Schwabe, Martin Schwarzschild, Hermann Carl Vogel, and Carl Friedrich von Weizsäcker.

4.6.3 Maps of Stars and Galaxies

Friedrich Bessel (German states, 1784–1846) developed the parallax method of measuring distances to stars (see Fig. 4.55), as well as Bessel mathematical functions. Based on geodetic observations, he approximated the figure of the Earth, and in 1841 he established the Bessel ellipsoid, which was used as an important geodetic reference system for over a century. His theory of observational errors was also highly influential in the physical sciences. The *Encyclopedia Britannica* explained the impact of Bessel's work [EB 2010]:

> Bessel was a scientist whose works laid the foundations for a better determination than any previous method had allowed of the scale of the universe and the sizes of stars, galaxies, and clusters of galaxies. In addition, he made fundamental contributions to accurate positional astronomy, the exact measurement of the positions of celestial bodies; to celestial mechanics, dealing with their movements; and to geodesy, the study of the Earth's size and shape. Further, he enlarged the resources of pure mathematics by his introduction and investigation of what are now known as Bessel functions, which he used first in 1817 to investigate the very difficult problem of determining the motion of three bodies moving under mutual gravitation. Seven years later he developed Bessel functions more fully for the treatment of planetary perturbations. Much credit for the final establishment of a scale for the universe in terms of solar system and terrestrial distances, which depends vitally on accurate measurement of the distances of the nearest starts from the Earth, must go to Bessel.

The multigenerational Baltic German Struve family of astronomers included (Fig. 4.56):

- Friedrich Georg Wilhelm von Struve (1793–1864), the son of German math teacher Jacob Struve (1755–1841), measured the distances to many stars using Bessel's parallax method, and also produced a catalog of binary stars (pairs of stars orbiting each other).

- Otto Wilhelm von Struve (1819–1905), the son of Friedrich Georg Wilhelm von Struve, made many important astronomical observations, including precession measurements for the solar system.

- Karl Hermann von Struve (1854–1920), a son of Otto Wilhelm von Struve, made detailed measurements of the positions of many moons and stars, and also devised the mathematical Struve function in 1882.

- Gustav Wilhelm Ludwig von Struve (1858–1920), another son of Otto Wilhelm von Struve, measured accurate positions of stars and the rotation rate of our Milky Way galaxy.

- Georg Otto Hermann Struve (1886–1933), the son of Karl Hermann von Struve, carefully measured the orbits of several moons of Saturn and Uranus. He also made important observations of stars and asteroids.

- Otto Struve (1897–1963), the son of Gustav Wilhelm Ludwig von Struve, studied interstellar matter and stellar physics.

Creators such as Friedrich Argelander (German, 1799–1875), Eduard Schönfeld (German, 1828–1891), Adalbert Krüger (German, 1832–1896), and Robert Trümpler (Swiss, 1886–1956) composed important catalogs of stars that are visible from Earth; see Fig. 4.57. Figure 4.58 shows examples of star catalogs by Argelander from 1843, and by Argelander, Schönfeld, and Krüger from 1859.

Bart Bok (Dutch, 1906–1983, Fig. 4.59) pioneered the study of interstellar matter and the structure of our Milky Way galaxy.

4.6.4 Cosmology

Several creators discovered and analyzed dark matter, a mysterious, invisible substance that only interacts with other things via gravity and that surrounds normal matter such as galaxies (Fig. 4.60):

- Jacobus Kapteyn (Dutch, 1851–1922) developed astrophotography, measured galactic rotation rates, and used that data to deduce the existence of dark matter.
- Fritz Zwicky (Swiss, 1898–1974) conducted experimental observations and theoretical analyses of dark matter and stellar physics, and also helped to develop jets and rockets in the United States [John Johnson, Jr., 2019; Stöckli and Müller 2008].
- Jan Oort (Dutch, 1900–1992) studied dark matter and the structure of the Milky Way galaxy, and also proposed the existence of the Oort cloud of comets in the outer reaches of our solar system.

Albert Einstein (German, 1879–1955) predicted the possible existence of dark energy (which he called the cosmological constant) in 1917 [Pais 1982]. As shown in Fig. 4.61, dark energy currently appears to make up approximately 68% of the universe and acts as an antigravitational force to push the universe apart. Approximately 27% of the universe seems to be dark matter, and only about 5% of the universe is atoms or other ordinary matter.

In 1917, Einstein and Willem de Sitter (Dutch, 1872–1934) showed that Einstein's equations of general relativity predicted that the universe should be expanding (or possibly contracting).

In a series of 1918–1924 publications (p. 882), Carl Wilhelm Wirtz (German, 1876–1939) measured the distances and velocities (based on the red-shifting of light) of other galaxies. He demonstrated that the universe was indeed expanding, and that more distant galaxies were moving away from us faster than galaxies closer to us, in agreement with Einstein's and de Sitter's predictions [Wirtz 1918, 1922a, 1922b, 1924, 1936].

For more information on relativity and cosmology, see Section 5.3.

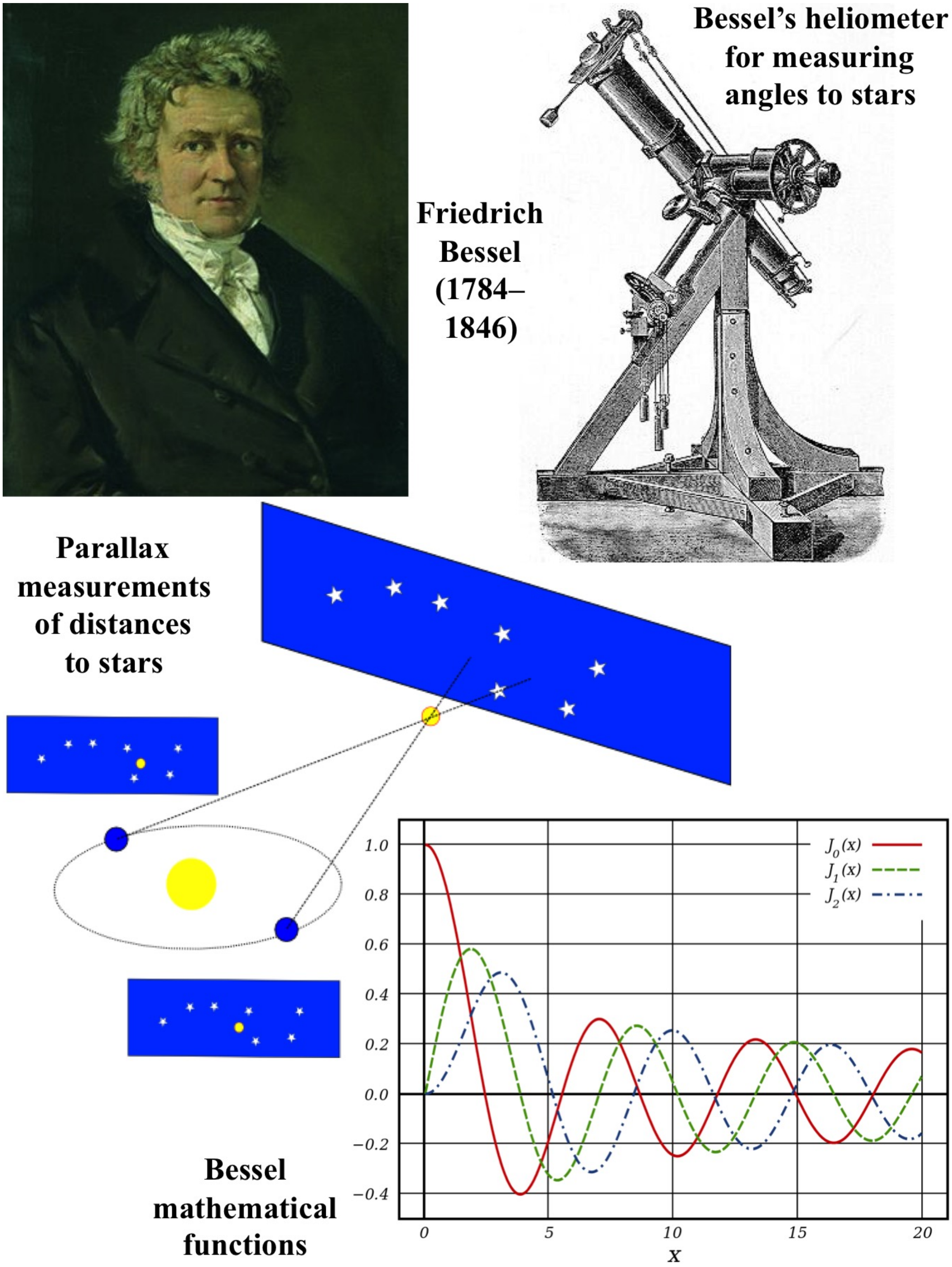

Bessel's heliometer for measuring angles to stars
Friedrich Bessel (1784–1846)
Parallax measurements of distances to stars
Bessel mathematical functions
$J_0(x)$
$J_1(x)$
$J_2(x)$
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
0
5
10
15
20
x

Figure 4.55: Friedrich Bessel developed the parallax method of measuring distances to stars, as well as Bessel mathematical functions.

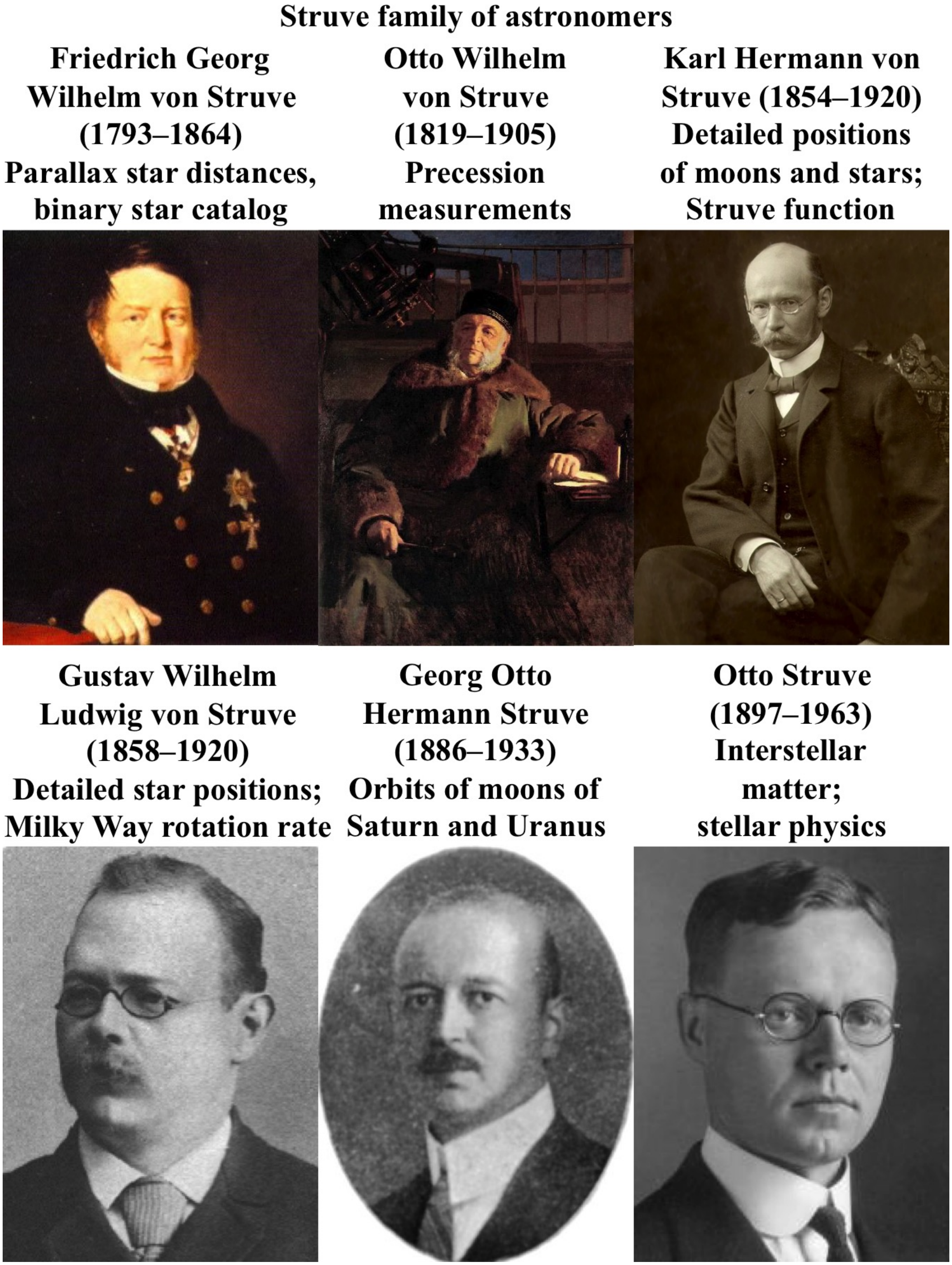

Struve family of astronomers
Friedrich Georg Wilhelm von Struve (1793–1864) Parallax star distances, binary star catalog
Otto Wilhelm von Struve (1819–1905) Precession measurements
Karl Hermann von Struve (1854–1920) Detailed positions of moons and stars; Struve function
Gustav Wilhelm Ludwig von Struve (1858–1920) Detailed star positions; Milky Way rotation rate
Georg Otto Hermann Struve (1886–1933) Orbits of moons of Saturn and Uranus
Otto Struve (1897–1963) Interstellar matter; stellar physics

Figure 4.56: The multigenerational Struve family of astronomers included Friedrich Georg Wilhelm von Struve, Otto Wilhelm von Struve, Karl Hermann von Struve, Gustav Wilhelm Ludwig von Struve, Georg Otto Hermann Struve, and Otto Struve.

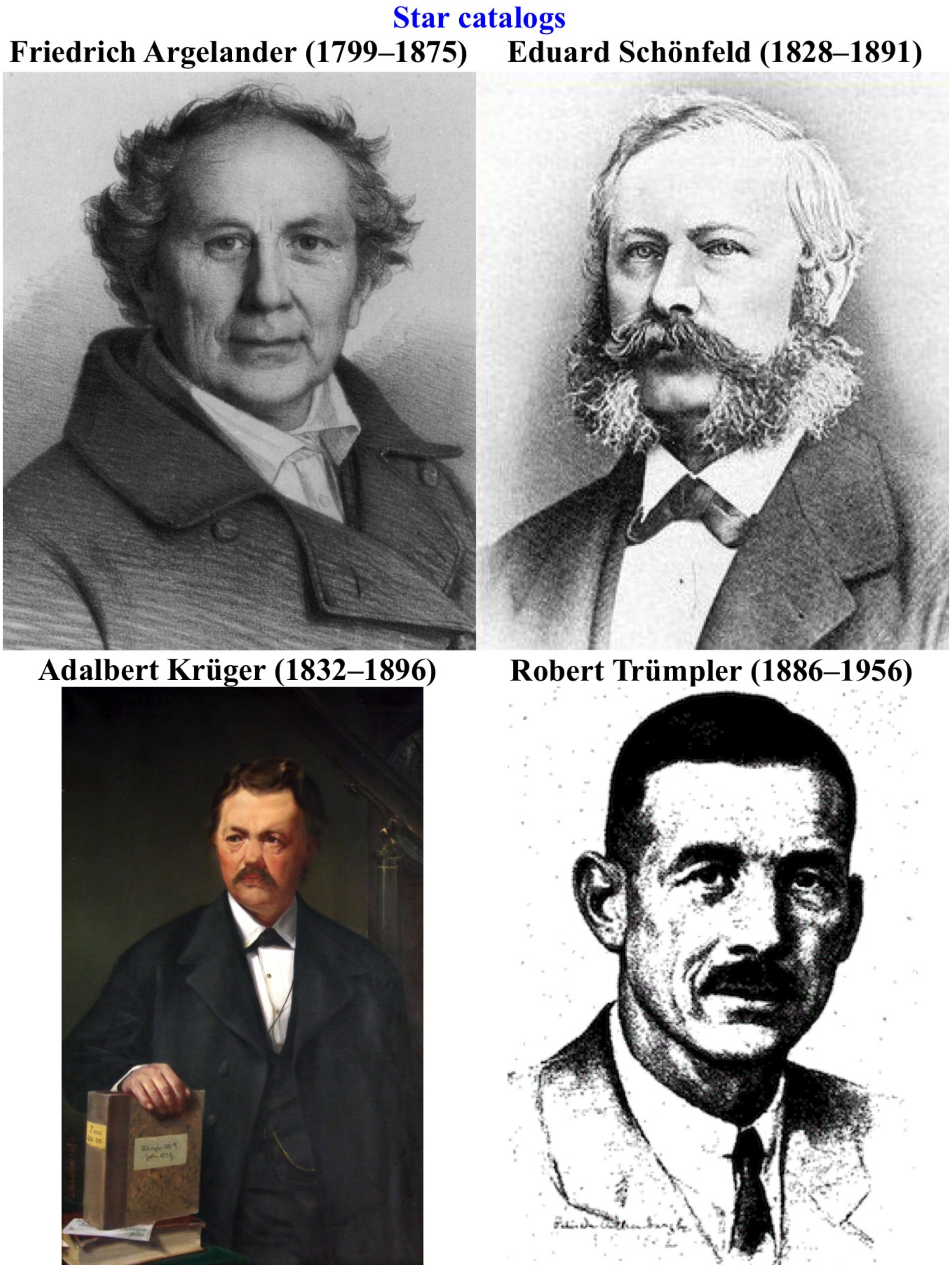
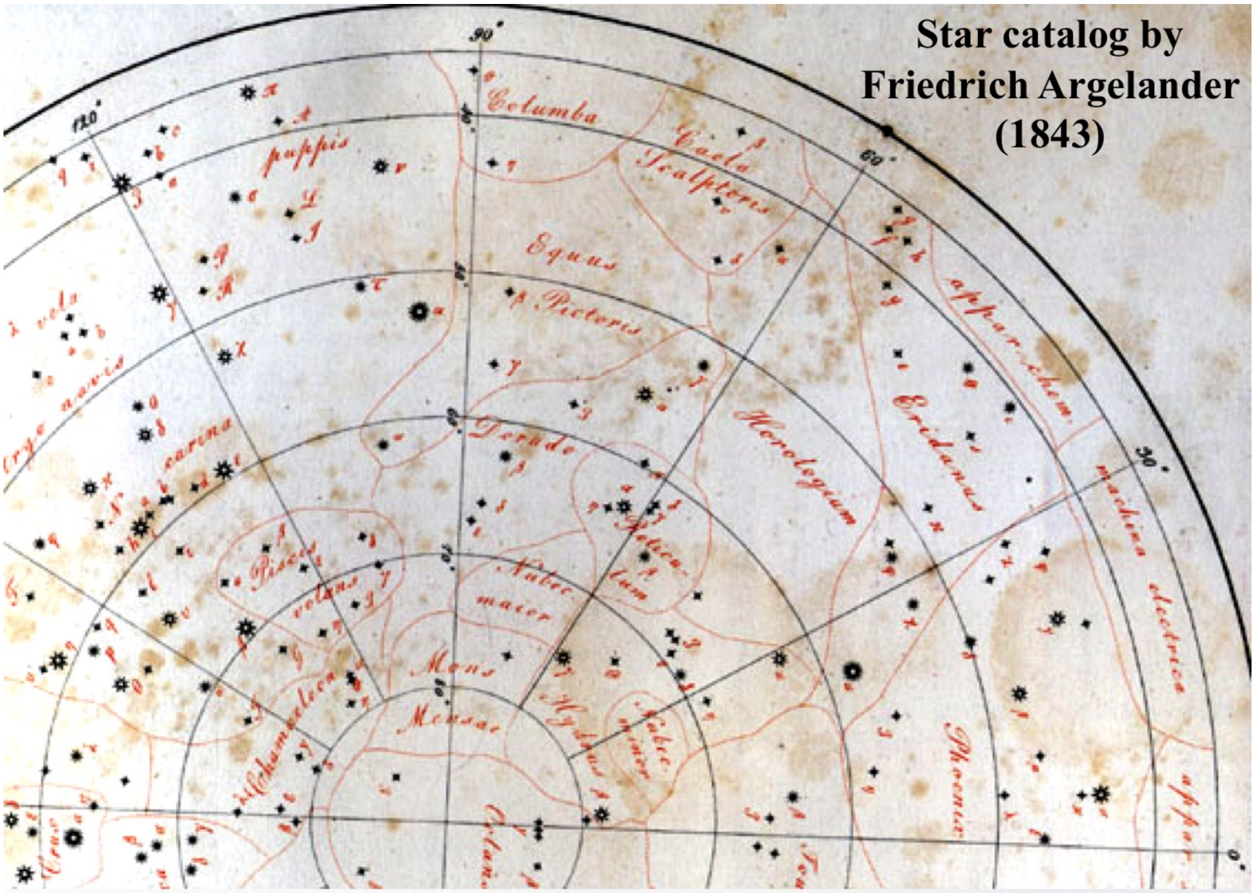

Star catalogs
Friedrich Argelander (1799–1875)
Eduard Schönfeld (1828–1891)
Adalbert Krüger (1832–1896)
Robert Trümpler (1886–1956)

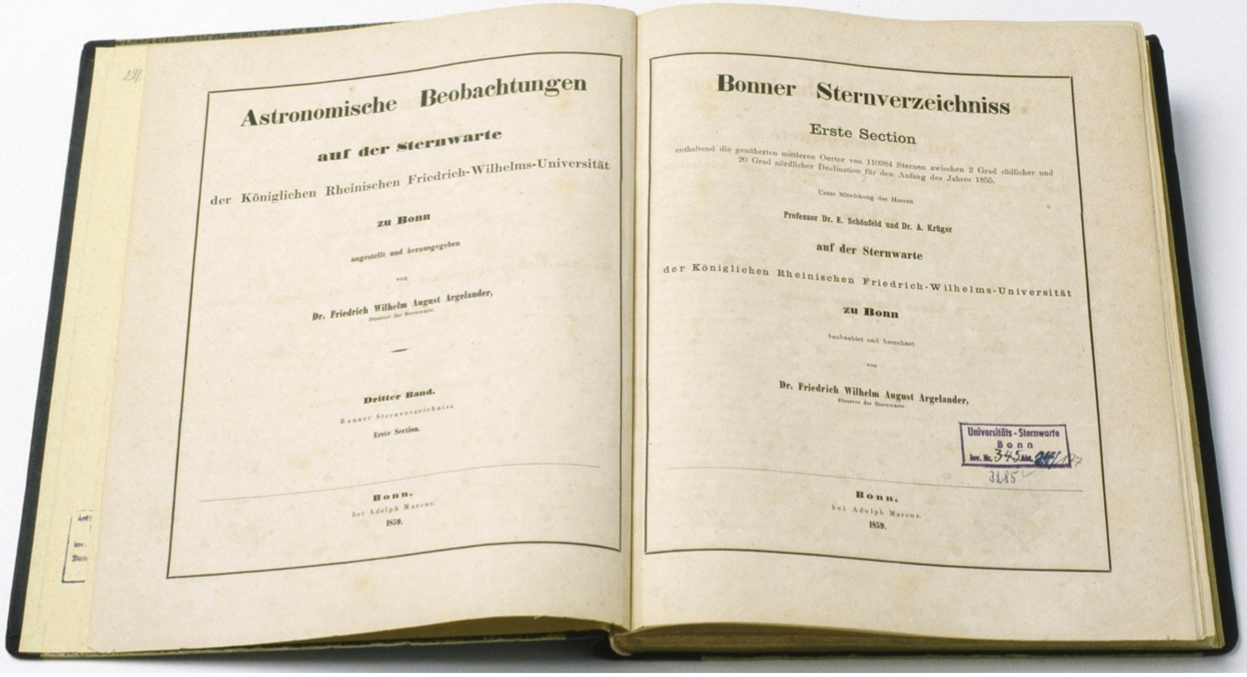
Figure 4.57: Creators such as Friedrich Argelander, Eduard Schönfeld, Adalbert Krüger, and Robert Trümpler composed important catalogues of stars that are visible from Earth.



Star catalog by Friedrich Argelander (1843)

90°
120°
60°
30°
0°
Columba
Caela Scalptoris
puppis
Equus Pictoris
Dorado
Horologium
Eridanus
apparat. chem.
machina electrica
Reticulum
Nubec. major
Mons Mensae
Piscis volans
Chamaeleon
carina
vela
Hydrus
Phoenix

Star catalog by Friedrich Argelander, Eduard Schönfeld, and Adalbert Krüger (1859)



Astronomische Beobachtungen
auf der Sternwarte
der Königlichen Rheinischen Friedrich-Wilhelms-Universität
zu Bonn
angestellt und herausgegeben
von
Dr. Friedrich Wilhelm August Argelander,
Director der Sternwarte.

Dritter Band.
Bonner Sternverzeichniss.
Erste Section.

Bonn,
bei Adolph Marcus.
1859.

Bonner Sternverzeichniss
Erste Section
enthaltend die genäherten mittleren Oerter von 110984 Sternen zwischen 2 Grad südlicher und 20 Grad nördlicher Declination für den Anfang des Jahres 1855.
Unter Mitwirkung der Herren
Professor Dr. E. Schönfeld und Dr. A. Krüger
auf der Sternwarte
der Königlichen Rheinischen Friedrich-Wilhelms-Universität
zu Bonn
beobachtet und berechnet
von
Dr. Friedrich Wilhelm August Argelander,
Director der Sternwarte.

Universitäts - Sternwarte
Bonn
Inv. Nr. 345

Bonn,
bei Adolph Marcus.
1859.

Figure 4.58: Star catalogs by Friedrich Argelander (1843), and by Argelander, Eduard Schönfeld, and Adalbert Krüger (1859).

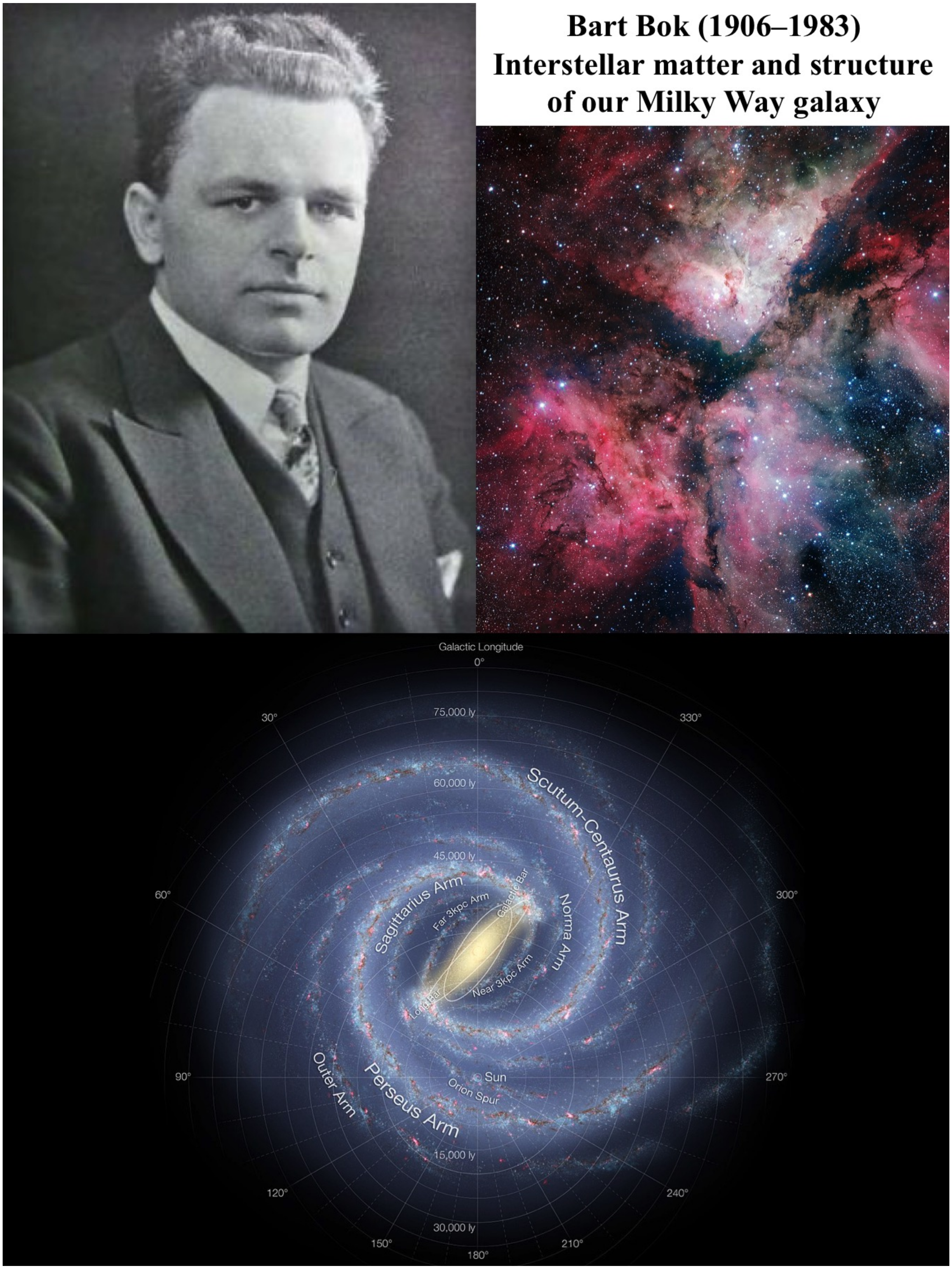

Bart Bok (1906–1983)
Interstellar matter and structure
of our Milky Way galaxy
Galactic Longitude
0°
30°
330°
75,000 ly
60,000 ly
Scutum-Centaurus Arm
45,000 ly
60°
300°
Sagittarius Arm
Far 3kpc Arm
Galactic Bar
Norma Arm
Long Bar
Near 3kpc Arm
90°
270°
Sun
Orion Spur
Outer Arm
Perseus Arm
15,000 ly
120°
240°
30,000 ly
150°
180°
210°

Figure 4.59: Bart Bok pioneered the study of interstellar matter and the structure of our Milky Way galaxy.

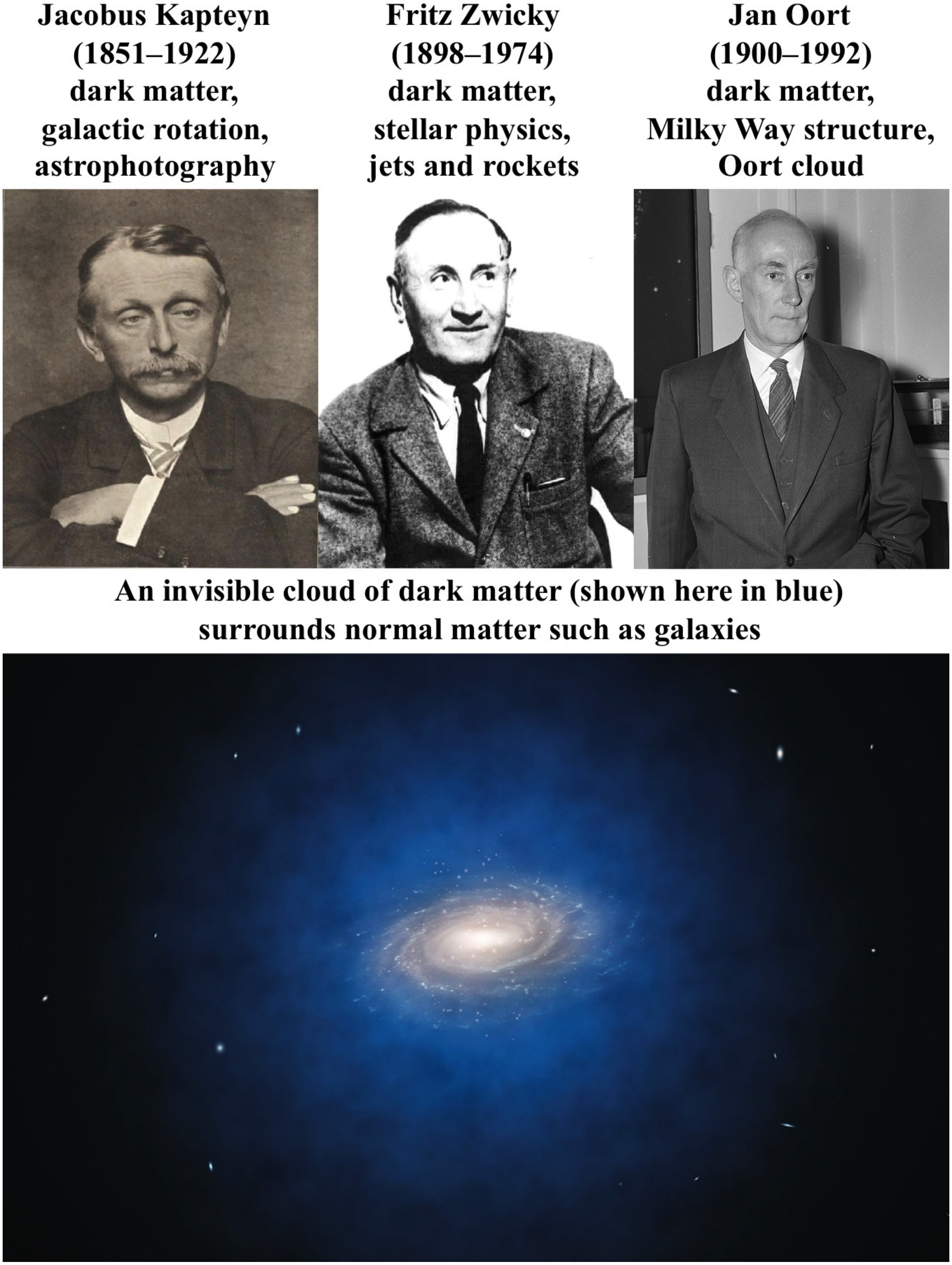

Jacobus Kapteyn
(1851–1922)
dark matter,
galactic rotation,
astrophotography
Fritz Zwicky
(1898–1974)
dark matter,
stellar physics,
jets and rockets
Jan Oort
(1900–1992)
dark matter,
Milky Way structure,
Oort cloud
An invisible cloud of dark matter (shown here in blue)
surrounds normal matter such as galaxies

Figure 4.60: Jacobus Kapteyn, Fritz Zwicky, and Jan Oort discovered and analyzed dark matter, a mysterious, invisible substance that only interacts with other things via gravity and surrounds normal matter such as galaxies.

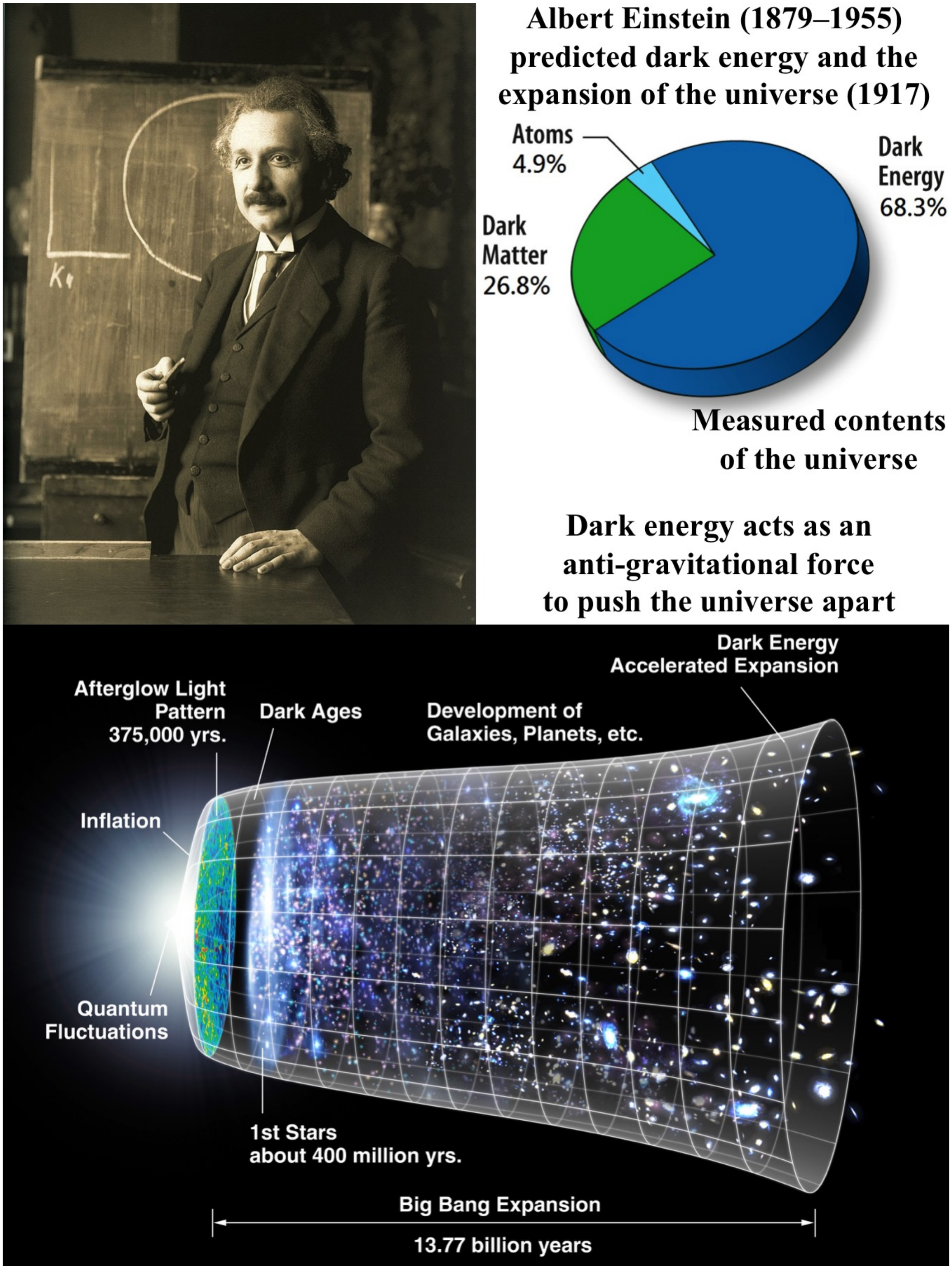

Albert Einstein (1879–1955)
predicted dark energy and the
expansion of the universe (1917)
Atoms
4.9%
Dark
Energy
68.3%
Dark
Matter
26.8%
Measured contents
of the universe
Dark energy acts as an
anti-gravitational force
to push the universe apart
Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
375,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.77 billion years

Figure 4.61: Albert Einstein predicted dark energy and the expansion of the universe in 1917. Dark energy currently appears to make up approximately 68% of the universe and acts as an antigravitational force to push the universe apart.

Chapter 5

Creators and Creations in Physics and Mathematics

Nicht die Wahrheit, in deren Besitz irgendein Mensch ist oder zu sein vermeinet, sondern die aufrichtige Mühe, die er angewandt hat, hinter die Wahrheit zu kommen, macht den Wert des Menschen. Denn nicht durch den Besitz, sondern durch die Nachforschung der Wahrheit erweitern sich seine Kräfte, worin allein seine immer wachsende Vollkommenheit bestehet.

The true value of a man is not determined by his possession, supposed or real, of Truth, but rather by his sincere exertion to get to the Truth. It is not possession of the Truth, but rather the pursuit of Truth by which he extends his powers and in which his ever-growing perfectibility is to be found.

Gotthold Lessing. 1777. Über die Wahrheit [About the Truth].

This chapter gives an overview of some physics and applied mathematics innovations that have played major roles in the modern world and that were invented or discovered by scientists and engineers who were trained in the predominantly German-speaking central European research world in the nineteenth and early twentieth centuries.

By the mid- to late-nineteenth century, intellectual leadership in applied mathematics and physics research had passed from primarily French and British scientists to German-speaking scientists:[1]

- Prior to that time, many giants of mathematical physics came out of the French intellectual tradition: Pierre-Simon Laplace (1749–1827), Joseph Fourier (1768–1830), André-Marie Ampère (1775–1836), Claude-Louis Navier (1785–1836), Sadi Carnot (1796–1832), and others. However, their numbers declined after that time, perhaps due to the nearly a century of continual political upheaval that followed the French Revolution.
- Several scientists from the United Kingdom made major physics contributions both before this point in time [e.g., Michael Faraday (1791–1867), James Clerk Maxwell (1831–1879), etc.] and after it [e.g., William Henry Bragg (1862–1942), William Lawrence Bragg (1890–1971), Ernest Rutherford (1871–1937), Paul Dirac (1902–1984), etc.]. Nonetheless, their relatively small numbers were soon dwarfed by the large numbers of talented German-speaking physicists.

As covered in this chapter, creators from the German-speaking world made major contributions to:

5.1. Applied mathematics and classical mechanics

5.2. Electromagnetism

5.3. Special and general relativity

5.4. Non-relativistic quantum physics

5.5. Statistical and thermal physics

5.6. Relativistic quantum physics

Scientists from the German-speaking world also made numerous contributions to other physics-related areas listed in Chapters 6 (applied electromagnetic technologies), 8 (nuclear physics), and 9 (applied physics in aerodynamics and spaceflight).

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[1] In addition to specific references that are cited in different areas throughout this chapter, this chapter makes use of general biographical and project information from: ACLS 2000; Albrecht et al. 1992; Ash and Söllner 1996; Bar-Zohar 1967; Bower 1987; Bunch and Hellemans 2004; Challoner 2009; Cornwell 2003; Crim 2018; EB 1911, 2010; Gillispie 1970–1990; Gimbel 1990a; Glatt 1994; Hall 2019a; István Hargittai 2006, 2011; Linda Hunt 1991; Impey et al. 2008; Jacobsen 2014; Koertge 2007; Kurowski 1982; Lasby 1971; Lusar 1956, 1971; Medawar and Pyke 2000; Mick 2000; Murray 2003; Nachmansohn 1979; NDB 1953–2020; Neufeld 2012; Nouzille and Huwart 1999; O'Reagan 2014, 2019; Porter 1994; Charles Walker 1946; Peter Watson 2010; Weitensfelder 2009.

For general overviews of large portions of the history of physics in the German-speaking world, see: Laurie Brown et al. 1995; István Hargittai 2002, 2006, 2011; Jungnickel and McCormmach 1986, 2017; Kragh 2002; von Meÿenn 1997; Teichmann 2008; Weber 1988.

I have deliberately left a blank space where images of some creators or creations should go. Those are people or projects that I felt were important enough that they should definitely be shown in this book, yet I have not yet been able to locate a suitable image that I have permission to use, despite my searches in Europe and in the United States. If readers have any relevant images and could send them to me, I would be very grateful and will include them in future editions of this book. Even where a suitable photo cannot be located, I believe that leaving a blank space pays tribute both to the scientific importance of that creator or creation and to how that historical fact has been very nearly forgotten.

5.1 Applied Mathematics and Classical Mechanics

Beginning in the nineteenth century, applied mathematics and classical mechanics were dominated by a long list of creators from the German speaking world, as shown by the examples in this section. Today, mathematicians, physicists, and engineers still use Bessel functions, Christoffel symbols, Jacobians, Kronecker delta functions, Noether's theorem, Riemannian geometry, and other contributions made by those scientists and mathematicians. Even children learn about Möbius strips and Klein bottles, and university students still learn from the two-volume mathematical textbook of Courant and Hilbert.

5.1.1 Creators and Creations Before 1800

Although the German-speaking mathematics and physics research world became more established after 1800, there were some very important earlier creators in applied math and physics that must be mentioned.

Nicolaus Copernicus (Prussian, 1473–1543, p. 786) proposed that the planets orbit around the sun and conducted other research in physics and math.

Tycho Brahe (Danish but educated and worked in the German-speaking world, 1546–1601, p. 787) made detailed astronomical observations that were used by Johannes Kepler to calculate planetary orbits.

Johannes Kepler (Weil der Stadt, 1571–1630, p. 788) worked out the physics of planetary orbits and also did other work in physics and math.

Otto von Guericke (also spelled von Gericke; German states, 1602–1686, p. 1488) established the physics of water and air pressure, and also studied the electrostatic force and other forces. He used those discoveries to create several ingenuous inventions [Harsch 2007b].

Christiaan Huygens (Dutch, 1629–1695, Fig. 5.1) derived mathematical formulas describing centripetal force, pendulums, optics, and other important aspects of mathematics and classical mechanics [Andriesse 2005].

Gottfried Leibniz (Saxony, 1646–1716, Fig. 5.1) developed differential and integral calculus and made numerous other contributions to mathematics and classical mechanics (including the conservation of energy and the idea that time and space could be relative instead of absolute). Leibniz also developed binary mathematics and built calculating machines (p. 1160). He designed other hardware from mining equipment to prototype submarines and proposed very prescient theories regarding everything from biological evolution to the interior structure of the Earth [Antognazza 2009].

Daniel Bernoulli (Swiss, 1700–1782, p. 1659) derived the Bernoulli equation for incompressible, inviscid fluid flow, and published it in 1738. He also made important contributions to the theory of flexible beams, probability, statistics, and economic theory.

Leonhard Euler (Swiss, 1707–1783, Fig. 5.1) made extensive contributions to calculus, complex number theory, topology and graph theory, mechanical stress and strain calculations, astronomy, optics, fluid mechanics, logic, and other topics [Calinger 2015; Richeson 2008].

Applied mathematics and classical mechanics
Christiaan Huygens (1629–1695)
Gottfried Leibniz (1646–1716)
Leonhard Euler (1707–1783)
TAB·II ad Nova Acta Erud. A. 1744 Mens. Junii P. I p.
Fig. I
Fig. II
Fig. III
Fig. IV
Fig. V

Figure 5.1: Early creators who made significant contributions to applied mathematics and classical mechanics included Christiaan Huygens, Gottfried Leibniz, and Leonhard Euler.

5.1.2 Creators and Creations After 1800

From around 1800 onward, the number and importance of people in the greater German-speaking world who made major contributions to mathematics and classical mechanics steadily increased until they dominated these fields.[2] In fact, the number of contributors was so great that this section will only briefly list some of the more notable ones (shown in Figs. 5.2–5.17) and their accomplishments in alphabetical order.

Emil Artin (Austrian, 1898–1962) made major contributions in algebraic number theory, class field theory, and other areas of mathematics, and is also remembered for his Artin's conjectures on certain mathematical problems.

Stefan Banach (Polish, 1892–1945) developed the general theory of functional analysis and introduced many mathematical concepts that still bear his name, such as Banach algebras, the Banach fixed-point theorem, Banach measures, Banach space, the Banach-Alaoglu theorem, the Banach-Mazur game, the Banach-Steinhaus theorem, the Banach-Tarski paradox, the Hahn-Banach theorem, etc.

Paul Bernays (Swiss, 1888–1977) made important discoveries in axiomatic set theory, mathematical logic, and complex analysis. He worked closely with David Hilbert, for example on what is now known as the Hilbert-Bernays paradox.

In addition to fundamental discoveries in astronomy, Friedrich Bessel (Minden, 1784–1846) made major contributions to applied mathematics, which he used to analyze his astronomical data. In particular, he developed what are now called Bessel functions, which are especially useful for describing waves (such as electromagnetic waves, sound waves, or quantum waves) in cylindrical geometries like pipes and waveguides.

János Bolyai (Hungarian, 1802–1860) helped to develop non-Euclidean geometry, or mathematics describing dimensions that are warped, such as Albert Einstein later used in analyzing how gravity warps the dimensions of space and time. He was the son of Wolfgang Farkas Bolyai.

Wolfgang Farkas Bolyai (Hungarian, 1775–1856) did important work on new methods of analysis in geometry and on iterative and convergent solutions to mathematical problems. He was the father of János Bolyai.

Bernardus Bolzano (Bohemian, 1781–1848) contributed in the areas of math analysis, analytic proofs, and mathematical limits, and his name is remembered in theorems such as Bolzano's theorem and the Bolzano-Weierstrass theorem.

Alexander von Brill (German, 1842–1935) worked in the area of algebraic geometry and functions, and is perhaps best remembered for Brill-Noether theory. One of his students was Max Planck, who went on to help found the field of quantum physics (p. 890).

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[2] For good overviews of this area, see especially: Grattan-Guinness 1998; Jungnickel and McCormmach 1986, 2017; Kragh 2002. On the end of this era, see Segal 2003. For a much more extensive list, with excellent details about each mathematician, see: https://mathshistory.st-andrews.ac.uk/Countries/.

Luitzen Brouwer (Dutch, 1881–1966) did important work in complex analysis, measure theory, set theory, and topology. His name is still attached to concepts such as the Brouwer fixed-point theorem and the Phragmen-Brouwer theorem.

Karl Hermann Brunn (German, 1862–1939) conducted research in convex geometry and knot theory. He is known for Brunnian links and the Brunn-Minkowski inequality.

Heinrich Burkhardt (German, 1861–1914) worked on Fourier analysis, real-variable analysis, and group theory.

Georg Cantor (born in Russia but educated and worked in Germany, 1845–1918) developed the theory of mathematical sets and applied it to a wide range of cases, greatly influencing later mathematicians such as John von Neumann. He also made major contributions to Fourier analysis and the foundations of real analysis.

Constantin Carathéodory (German, 1873–1950) made important findings regarding the calculus of variations, conformal representations, measure theory, and real analysis.

Elwin Christoffel (German, 1829–1900) worked in complex variable analysis, differential geometry, number analysis, and Abelian functions and integrals. He is best remembered for creating certain tensors or matrices that are now called Christoffel symbols, which describe warped dimensions and were later incorporated into the theory of general relativity by Albert Einstein.

Rudolf Alfred Clebsch (German, 1833–1872) made useful discoveries in algebraic geometry and invariant theory. His name is still remembered in Clebsch surfaces, Clebsch representations and Clebsch potentials, and (with Paul Gordan) the Clebsch-Gordon coefficients that physicists later found useful for describing the quantum behavior of electron clouds in atoms.

Lothar Collatz (German, 1910–1990) specialized in developing novel numerical methods for finding approximate solutions to difficult equations. Among other creations, he is remembered for the Collatz conjecture and the Collatz-Wielandt formula.

Richard Courant (German, 1888–1972) made a wide range of contributions to mathematics during his long career. In modern times, he is especially remembered for developing finite element methods to produce approximate numerical solutions of differential equations to any desired accuracy, which became especially useful once computers were available. In collaboration with David Hilbert, he wrote a two-volume textbook, *Methods of Mathematical Physics*, that is still widely used in university courses today.

Richard Dedekind (German, 1831–1916) did important work in abstract algebra, algebraic number theory, the axiomatic foundation for the natural numbers, real numbers, and other areas of mathematics. He was the last doctoral student of Carl Friedrich Gauss.

Max Dehn (German, 1878–1952) made useful innovations in geometry, group theory, and topology, and his name is attached to concepts such as Dehn's algorithm, Dehn functions, and the Dehn-Nielsen theorem.

Peter Gustav Lejeune Dirichlet (Prussian, 1805–1859) made so many vital contributions to mathematics, especially in the areas of number theory, Fourier series, and mathematical analysis, that his name remains attached to well over two dozen different mathematical concepts that are still in use. Those mathematical innovations named after him include: Dirichlet's approximation theorem, the Dirichlet beta function, Dirichlet boundary conditions, Dirichlet's box principle, Dirichlet characters, Dirichlet conditions, Dirichlet convolution, the Dirichlet density, Dirichlet distributions of several types, the Dirichlet divisor problem, the Dirichlet eigenvalue, Dirichlet's ellipsoidal function, Dirichlet's energy, the Dirichlet form, the Dirichlet function, Dirichlet integrals, Dirichlet kernels, the Dirichlet L-function, the Dirichlet principle, the Dirichlet problem, Dirichlet processes of different types, the Dirichlet ring, Dirichlet series, Dirichlet space, the Dirichlet stability criterion, Dirichlet tessellation or cells, Dirichlet's test, Dirichlet's theorem on arithmetic progressions, and Dirichlet's unit theorem.

Paul du Bois Reymond (German, 1831–1889) worked in the areas of differential equations, Fourier analysis, and real-variable analysis.

Walther von Dyck (German, 1856–1934) made many contributions to group theory and Riemann surfaces. His name remains attached to Dyck graphs, Dyck groups, Dyck language, Dyck paths, Dyck's surface, Dyck tessellations, and Dyck's theorem.

Samuel Eilenberg (Polish, 1913–1998) worked in algebraic topology and automata theory, developed category theory, and is remembered for mathematical constructs such as the Eilenberg swindle and the Eilenberg-Steenrod axioms.

Andreas von Ettingshausen (Austrian, 1796–1878) made important contributions to combinatorial analysis that are widely used in probability and physics, and also conducted extensive research in electromagnetism and optics.

Alfred Enneper (German, 1830–1885) worked in several areas of mathematics and is especially remembered for Enneper's minimal surfaces and Enneper-Weierstrass parameterization.

Erwin Fehlberg (German, 1911–1990) developed improved numerical methods for finding approximate solutions to differential equations, most notably the Runge-Kutta-Fehlberg method. Fehlberg moved to the United States after World War II and was ultimately awarded NASA's Exceptional Scientific Achievement Medal for his work calculating trajectories for the Apollo missions to the moon.

William Feller (Austro-Hungarian Croatian, 1906–1970) did most of his work in probability and statistics, but also contributed to mathematical analysis, geometry, and other areas. His name is attached to Feller's explosion test, Feller-Brown movement, Feller processes, and the Lindeberg-Feller theorem.

Abraham Fränkel (German, 1891–1965) worked in axiomatic set theory; his name is still remembered in the Zermelo-Fränkel axioms.

Friedrich Gottlob Frege (German, 1848–1925) focused on the field of mathematical logic; his name is tied to the Frege-Church ontology, the Frege-Geach problem, Frege's puzzles, the Frege-Russell view, and Frege's theorem.

Robert Fricke (German, 1861–1930) worked in the areas of automorphic functions and elliptic functions. He is perhaps best remembered for Fricke involution and for his collaborative writings with Felix Klein.

Georg Frobenius (German, 1849–1917) made many contributions to differential equations, elliptic functions, group theory, and number theory. His name is attached to concepts such as Frobenius manifolds, the Frobenius matrix, the Frobenius method, and the Frobenius-Stickelberger formulae.

Lazarus Immanuel Fuchs (German, 1833–1902) made important innovations in complex variable analysis and Abelian functions and integrals. He focused especially on methods of solving differential equations, and is remembered for Fuchs's conditions, Fuchsian groups, Fuchs's theorem, and the Picard-Fuchs equation. He was the father of Maximilian Fuchs.

Maximilian Ernst Richard Fuchs (German, 1873–1944), the son of Lazarus Fuchs, continued and significantly extended his father's work on differential equations.

Karl Rudolf Fueter (Swiss, 1880–1950) worked on algebraic number theory and quaternions, and is known for the Fueter-Pólya theorem.

Carl Friedrich Gauss (German states, 1777–1855) made discoveries in mathematics, science, and engineering that were staggering in both their number and importance [Dunnington 1955]. Among other mathematical accomplishments, he proved several important theorems in algebra, was the first to consider non-Euclidean geometries, and discovered four-dimensional complex numbers (quaternions) in 1819. (See also pp. 740, 793, 858, and 972.)

Kurt Gödel (Austrian, 1906–1978) made revolutionary contributions to mathematical logic and set theory. His name is immortalized with Gödel's incompleteness and completeness theorems, the Gödel metric, Gödel numbering, the Gödel ontological proof, and Gödel-Dummett logic.

Paul Gordan (German, 1837–1912) made many contributions to invariant theory as well as Abelian functions and integrals, developed the Clebsch-Gordan coefficients with Rudolf Clebsch, and is also known for Gordan's lemma. He was the doctoral advisor of Emmy Noether.

Hermann Grassmann (German, 1809–1877) developed a whole field that is now known as Grassmann algebra; it combines algebra, geometry, and group theory in an approach that is useful for solving a wide variety of problems.

Hermann Hankel (German, 1839–1873) worked in complex analysis and other areas of mathematics. He is especially remembered for the Hankel contour, Hankel functions, the Hankel matrix, and the Hankel transform.

Carl Gustav Axel Harnack (Baltic German, 1851–1888) made contributions in the areas of real-variable analysis and also algebraic geometry and functions. He is still remembered for Harnack's inequality, Harnack's principle, and Harnack's theorem.

Friedrich Hartogs (German, 1874–1943) developed many important concepts in set theory and complex analysis, such as the Hartogs domain, Hartogs's extension theorem, Hartogs's function, Hartogs's lemma, the Hartogs number, Hartogs's theorem, the Hartogs-Laurent expansion, and the Hartogs-Rosenthal theorem.

Felix Hausdorff (German, 1868–1942) made major contributions in topology, set theory, measure theory, and functional analysis. He is known for the Hausdorff dimension, Hausdorff distance, the Hausdorff maximal principle, the Hausdorff measure, the Hausdorff moment problem, the Hausdorff paradox, Hausdorff space, and the Hausdorff-Young inequality.

Heinrich Eduard Heine (German, 1821–1881, not to be confused with the earlier German poet Heinrich Heine) worked in real analysis and introduced important innovations regarding spherical harmonics, Legendre functions, hypergeometric series, and other mathematical approaches. His name remains known via the Heine-Borel theorem, the Heine-Cantor theorem, Heine-Stieltjes polynomials, the Heine definition of continuity, Heine functions, Heine's identity, and the Mehler-Heine formula.

David Hilbert (German, 1862–1943) made huge contributions to many areas of mathematics, including algebraic number theory, the calculus of variations, commutative algebra, Euclidean and non-Euclidean geometry, and invariant theory. His name remains associated with Hilbert's axioms, Hilbert's basis theorem, Hilbert's problems, Hilbert's program, and Hilbert space. In collaboration with Richard Courant, he wrote a two-volume textbook, *Methods of Mathematical Physics*, that is still widely used.

Heinz Hopf (German, 1894–1971) worked in topology and geometry, and is known for many concepts, such as Hopf algebra, the Hopf conjecture, Hopf fibration, the Hopf invariant, the Hopf link, the Hopf manifold, the Hopf map, Hopf surfaces, the Hopf theorem, and the Killing-Hopf theorem.

Adolf Hurwitz (German, 1859–1919) contributed to complex variable analysis, elliptic functions, real-variable analysis, and Riemann surfaces. He is remembered for Hurwitz's automorphisms theorem, Hurwitz quaternions, the Riemann-Hurwitz formula, and the Routh-Hurwitz stability criterion.

Carl Gustav Jacobi (Prussian, 1804–1851) introduced important innovations in the classical mechanics of orbits, differential equations, elliptic functions, and number theory. His name is widely recognized from concepts such as the Jacobian, the Jacobi ellipsoid, Jacobi's elliptic functions, the Jacobi identity, the Jacobi method, Jacobi operators, Jacobi polynomials, Jacobi symbols, the Jacobi transform, and the Hamilton-Jacobi equation.

Theodor Kaluza (German, 1885–1954) produced very creative ideas regarding non-Euclidean geometries and extra dimensions that proved useful in some versions of relativity and unified field theories. His son Theodor Kaluza Jr. (German, 1910–1994) was also a mathematician.

Wilhelm Killing (German, 1847–1923) made numerous important contributions to group theory. His name is attached to many concepts, such as the Killing equation, the Killing form, the Killing-Hopf theorem, the Killing horizon, the Killing spinor, the Killing tensor, and the Killing vector field.

Christian Felix Klein (German, 1849–1925) made a large number of discoveries in algebraic geometry and functions, automorphic functions, elliptic functions, and Riemann surfaces. His mathematical innovations found many later applications in theoretical physics. He also created the structure now known as a Klein bottle, somewhat like a three-dimensional Möbius strip.

Sofia Kovalevskaya (Russian but educated in Germany, 1850–1891) did important work in differential equations, as well as Abelian functions and integrals. She is still known from the Cauchy-Kowalevski theorem.

Leopold Kronecker (German, 1823–1891) made research advances in algebra, mathematical logic, and number theory. Today is he remembered from the Kronecker delta function, Kronecker's lemma, the Kronecker product, the Kronecker symbol, Kronecker's theorem, and the Kronecker-Weber theorem.

Ernst Kummer (German, 1810–1893) worked on Bessel functions, class field theory, hypergeometric series, and other topics. His name remains linked to Kummer extensions of fields, the Kummer surface, and Kummer theory.

Martin Wilhelm Kutta (German, 1867–1944) developed practical methods of extracting useful answers from very complicated physics and engineering equations, especially in aerodynamics. He collaborated with Carl Runge to create the Runge-Kutta methods of producing approximate but sufficiently accurate numerical solutions to differential equations. He also developed complex analysis transformations for solving the equations for airflow around wings and other objects.

Daniel Christian Ludolph Lehmus (German, 1780–1863) worked in geometry and is especially remembered for the Steiner-Lehmus theorem.

Sophus Lie (Norwegian but studied and worked in Germany, 1842–1899) made huge contributions to differential equations and group theory that are now widely used in theoretical physics. His name is immortalized in concepts such as Lie algebra, Lie groups, Lie symmetries, and Lie theorems.

Carl Ferdinand von Lindemann (German, 1852–1939) worked in algebraic geometry and functions, and became famous for proving that π is a transcendental number. He was also the doctoral advisor for prominent mathematicians and physicists such as David Hilbert, Martin Kutta, Alfred Loewy, Hermann Minkowski, Oskar Perron, Arthur Rosenthal, and Arnold Sommerfeld.

Rudolf Lipschitz (German, 1832–1903) made important contributions to differential equations, real-variable analysis, and Fourier analysis. Perhaps most importantly, he independently discovered "Clifford algebras" at approximately the same time or earlier than William Clifford (English, 1845–1879), but with far less fame. He is remembered with the Lipschitz continuity condition, the Lipschitz integral condition, and the Lipschitz quaternion.

Alfred Loewy (German, 1873–1935) focused on representation theory and introduced innovations now known as Loewy decomposition, the Loewy length, Loewy rings, and Loewy series.

Gustav Ferdinand Mehler (German, 1835–1895) worked in several areas of mathematics, and is noted for Mehler's formula, Mehler functions, the Mehler kernel, the Mehler-Fock transform, and the Mehler-Heine formula.

Friedrich Wilhelm Franz Meyer (German, 1856–1934) spent his career investigating algebraic geometry and functions.

Hermann Minkowski (German, 1864–1909) did important work in geometry and number theory, and also contributed to the development of the theory of relativity. His name is still attached to concepts such as Minkowski addition, Minkowski content, Minkowski diagrams, Minkowski's question mark function, Minkowski space, the Minkowski functional, the Minkowski inequality, the Minkowski problem, Minkowski's bound, Minkowski's theorem in geometry of numbers, and the Brunn-Minkowski inequality.

Richard von Mises (Austro-Hungarian, 1883–1953) developed mathematical methods of solving equations in aerodynamics and the mechanics of materials, working with differential equations, complex analysis, probability, and statistics.

August Möbius (Saxony, 1790–1868) worked in topology and geometry as well as astronomy. He is particularly famous for the Möbius strip (a figure-8 formed from a strip of paper, which effectively only has one side), but he is also known for the Möbius function, the Möbius inversion formula, Möbius transformations, the Möbius-Kantor configuration, and the Möbius-Kantor graph.

Carl Neumann (German, 1832–1925), the son of physicist Franz Ernst Neumann, developed mathematical methods for analyzing physics problems. He is especially remembered for the Neumann boundary condition and Neumann series.

John von Neumann (Hungarian, 1903–1957) contributed a vast number of innovations to mathematics, physics, engineering, computer science, and economics [Macrae 1992]. Among many other contributions, he is known for von Neumann algebra, von Neumann architecture, the von Neumann bicommutant theorem, the von Neumann cardinal assignment, the von Neumann cellular automaton, the von Neumann conjecture, the von Neumann entropy, the von Neumann equation, the von Neumann ergodic theorem, the von Neumann extractor, von Neumann's inequality, von Neumann interpretation, the von Neumann measurement scheme, the von Neumann neighborhood, von Neumann ordinals, the von Neumann paradox, the von Neumann regular ring, the von Neumann spectral theorem, von Neumann stability analysis, the von Neumann universal constructor, the von Neumann universe, and von Neumann-Bernays-Gödel set theory.

Rolf Nevanlinna (Finnish but an active part of the German research world, 1895–1980) worked in complex analysis and developed what are now known as Nevanlinna theory and Nevanlinna class functions.

Emmy Noether (German, 1882–1935), the daughter of Max Noether, made revolutionary discoveries in both mathematics and theoretical physics. In mathematics, she worked on algebraic invariants, number fields, abstract algebra, noncommutative algebras, hypercomplex numbers, group theory, and topology. In physics, she is most famous for discovering Noether's theorem, which explains the relationship between conservation laws (such as the conservation of energy or the conservation of momentum) and symmetries (ways that variables such as time and space can be shifted without altering the fundamental laws of physics). Noether's theorem has been employed in many areas of physics since she first articulated it.

Max Noether (German, 1844–1921) conducted research on algebraic functions, algebraic geometry, and Riemann surfaces. His full name (to distinguish him from his even more famous daughter) is attached to Max Noether's inequality, Max Noether's residual intersection theorem, Max Noether's theorem on canonical curves, Max Noether's theorem on the Cremona group, Max Noether's theorem on curves on algebraic surfaces, and Max Noether's theorem on rationality for surfaces.

Moritz Pasch (German, 1843–1930) focused on algebraic geometry and functions and the foundations of geometry. He is most noted for Pasch's axiom.

Oskar Perron (German, 1880–1975) worked on differential equations and continued fractions, and is known for the Perron method for solving elliptic differential equations and for Perron's paradox.

Ernst Peschl (German, 1906–1986) made important contributions to complex analysis, the solution of partial differential equations, and differential geometry.

Michel Plancherel (Swiss, 1885–1967) worked in mathematical analysis and algebra, and is remembered for the Plancherel measure, the Plancherel theorem for harmonic analysis, and the Plancherel theorem for spherical functions.

Julius Plücker (German states, 1801–1868) contributed to geometry and also physics. In mathematics, he is known for Plücker's conoid, Plücker coordinates, Plücker embedding, the Plücker formula, the Plücker matrix, the Plücker relations, and the Plücker surface.

George Pólya (Hungarian, 1887–1985) worked in many areas of mathematics, including algebra, combinatorics, geometry, mathematical analysis, number theory, probability, and series. He is associated with numerous concepts such as the Pólya-Aeppli distribution, the Pólya conjecture, the Pólya distribution, the Pólya enumeration theorem, the Pólya inequality, the Pólya urn model, the Fueter-Pólya theorem, and the Hilbert-Pólya conjecture.

Alfred Pringsheim (German, 1850–1941) contributed to real-variable analysis, the foundations of real analysis, and Fourier analysis.

Bernhard Riemann (Kingdom of Hanover, 1826–1866) made enormous contributions to differential geometry, mathematical analysis, number theory, and other fields of mathematics. In particular, his methods of using tensors in differential geometry later proved especially useful to describe how gravity warps space and time, as Albert Einstein found. Riemann's name is attached to dozens of concepts, including Riemann bilinear relations, Riemann conditions, Riemann's differential equation, Riemann's existence theorem, Riemann's explicit formula, the Riemann form, the Riemann function, Riemannian geometry, the Riemann-Hurwitz formula, the Riemann hypothesis, the Riemann integral, the Riemann invariant, the Riemann matrix, Riemann's minimal surface, the Riemann operator, the Riemann series theorem, the Riemann singularity theorem, the Riemann sum, the Riemann surface, Riemann's theorem on removable singularities, the Riemann theta function, the Riemann Xi function, and the Riemann zeta function.

Arthur Rosenthal (German, 1887–1959) worked in geometry, mathematical analysis, and dynamical systems analysis. He is perhaps best known for the Hartogs-Rosenthal theorem.

Carl Runge (German, 1856–1927) made important contributions to numerical analysis and spectroscopy. He collaborated with Martin Wilhelm Kutta to develop the Runge-Kutta methods of numerically solving differential equations. He is also known for Runge's phenomenon, the behavior of certain errors that occur when finding approximate answers for functions. Carl Runge's son, Wilhelm Runge, was one of the developers of radar (p. 1220).

Ludwig Schlesinger (German, 1864–1933) conducted research in the areas of automorphic functions and differential equations. His name remain attached to the Schlesinger equations and Schlesinger transformations.

Arthur Schönflies (German, 1853–1928) made major contributions to group theory, set theory, and topology. His name is still widely known from Schönflies notation, Schönflies displacement, and Schönflies problems.

Friedrich Schottky (German, 1851–1935) worked on Abelian functions and integrals, complex variable analysis, and elliptic functions. He is remembered for the Schottky form, the Schottky-Klein prime form, Schottky groups, the Schottky problem, and Schottky's theorem. He was the father of Walter Schottky, one of the pioneers of semiconductor microelectronics (p. 1050).

Issai Schur (Russian but studied and worked in Germany, 1875–1941) performed innovative research in group theory, number theory, and combinatorics. He is best remembered for Schur decomposition and Schur's lemma.

Karl Hermann Amandus Schwarz (German, 1843–1921) made many contributions to complex variable analysis and differential equations. His name remains well known from concepts such as the additive Schwarz method, the Schwarz alternating method, the Schwarzian derivative, the Schwarz lantern, the Schwarz lemma, Schwarz's list, the Schwarz minimal surface, the Schwarz theorem, the Schwarz integral formula, Schwarz-Christoffel mapping, the Schwarz reflection principle, the Schwarz triangle, and the Cauchy-Schwarz inequality.

Jakob Steiner (Swiss, 1796–1863) carried out work in geometry and other areas of mathematics. He is remembered in names such as the Steinerian, the Steiner chain, Steiner's conic problem, the Steiner inellipse, the Steiner point, Steiner's problem, the Steiner surface, the Steiner system, the Steiner tree, the Steiner-Lehmus theorem, and the Poncelet-Steiner theorem.

Ludwig Stickelberger (Swiss, 1850–1936) made important contributions to linear algebra and number theory, such as the Stickelberger relation and the Frobenius-Stickelberger theorem.

Thomas Joannes Stieltjes (Dutch, 1856–1894) worked in mathematical analysis, continued fractions, and number theory. His name is attached to the Riemann-Stieltjes integral.

Otto Stolz (Austrian, 1842–1905) did innovative research in complex variable analysis and the foundations of real analysis.

Oswald Teichmüller (German, 1913–1943) made important contributions in complex analysis and is best known for Teichmüller space and Teichmüller theory.

B. L. van der Waerden (Dutch, 1903–1996) contributed to abstract algebra and algebraic geometry. He is remembered for concepts such as van der Waerden's conjecture, van der Waerden notation, the van der Waerden number, the van der Waerden test, and van der Waerden's theorem.

Heinrich Martin Weber (German, 1842–1913) did work in algebra, mathematical analysis, and number theory. His name is associated with Weber functions, Weber's theorem, and the Kronecker-Weber theorem.

Karl Weierstrass (German, 1815–1897) made major advances in a wide range of areas, including Abelian functions and integrals, complex variable analysis, elliptic functions, the foundations of real analysis, and real-variable analysis. He is known for concepts such as the Weierstrass approximation theorem, Weierstrass coordinates, Weierstrass's elliptic functions, the Weierstrass equation, the Weierstrass factorization theorem, the Weierstrass function, the Weierstrass M-test, the Weierstrass point, the Weierstrass preparation theorem, the Weierstrass product inequality, the Weierstrass ring, and the Weierstrass transform.

Hermann Weyl (German, 1885–1955) introduced important innovations in group theory, number theory, and non-Euclidean geometry, as well as general relativity. His name remains attached to countless concepts such as Weyl algebra, the Weyl basis of the gamma matrices, the Weyl chamber, the Weyl character formula, the Weyl equation, Weyl fermions, the Weyl gauge, Weyl gravity, Weyl notation, Weyl quantization, Weyl spinors, Weyl sums, Weyl symmetry, Weyl tensors, Weyl transformations, the Weyl-Schouten theorem, Weyl's criterion, and Weyl's lemmas.

Hans Zassenhaus (German, 1912–1991) worked in abstract algebra and group theory, and helped to develop computer algebra and number theory.

Ernst Zermelo (German, 1871–1953) made many contributions to set theory and mathematical logic, such as Zermelo-Fränkel set theory, Zermelo's navigation problem, the Zermelo ordinal, and Zermelo's theorem.

Applied mathematics and classical mechanics

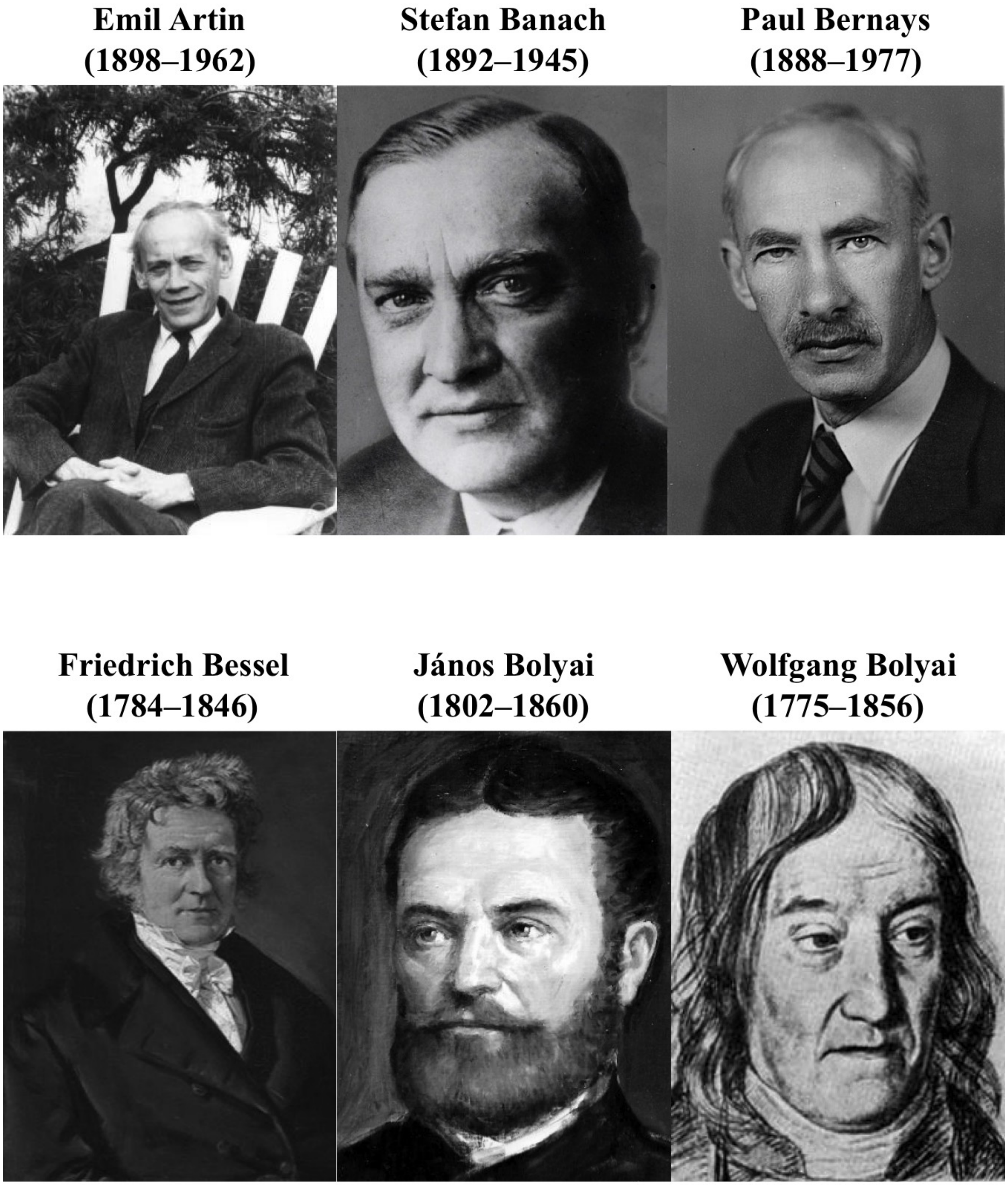
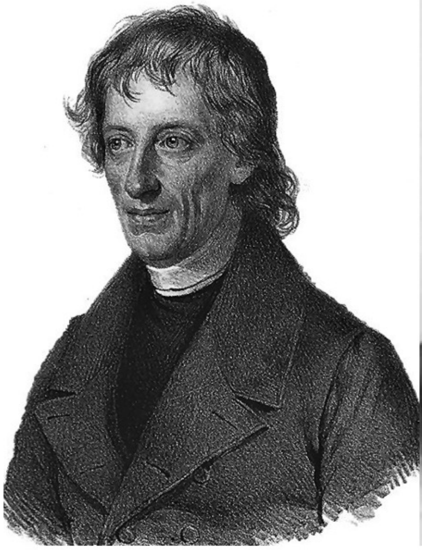

Emil Artin
(1898–1962)
Stefan Banach
(1892–1945)
Paul Bernays
(1888–1977)
Friedrich Bessel
(1784–1846)
János Bolyai
(1802–1860)
Wolfgang Bolyai
(1775–1856)

Figure 5.2: Some creators who made significant contributions to applied mathematics and classical mechanics included Emil Artin, Stefan Banach, Paul Bernays, Friedrich Bessel, János Bolyai, and Wolfgang Bolyai.

Applied mathematics and classical mechanics

Bernardus Bolzano
(1781–1848)



Alexander von Brill
(1842–1935)

Luitzen Brouwer
(1881–1966)

Karl Hermann
Brunn
(1862–1939)

Heinrich Burkhardt
(1861–1914)

Georg Cantor
(1845–1918)

Figure 5.3: Other creators who made significant contributions to applied mathematics and classical mechanics included Bernardus Bolzano, Alexander von Brill, Luitzen Brouwer, Karl Hermann Brunn, Heinrich Burkhardt, and Georg Cantor.

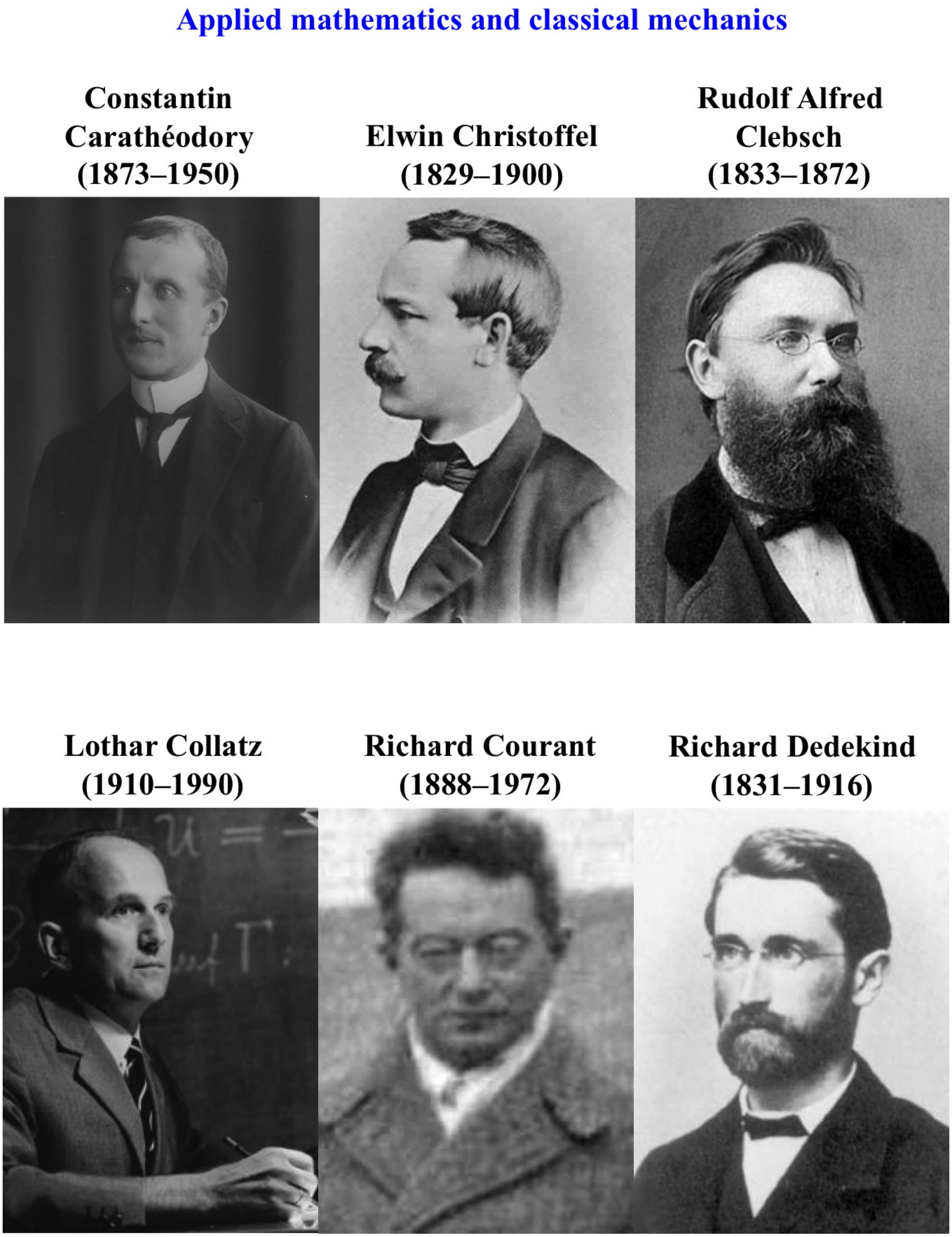

Applied mathematics and classical mechanics
Constantin Carathéodory (1873–1950)
Elwin Christoffel (1829–1900)
Rudolf Alfred Clebsch (1833–1872)
Lothar Collatz (1910–1990)
Richard Courant (1888–1972)
Richard Dedekind (1831–1916)

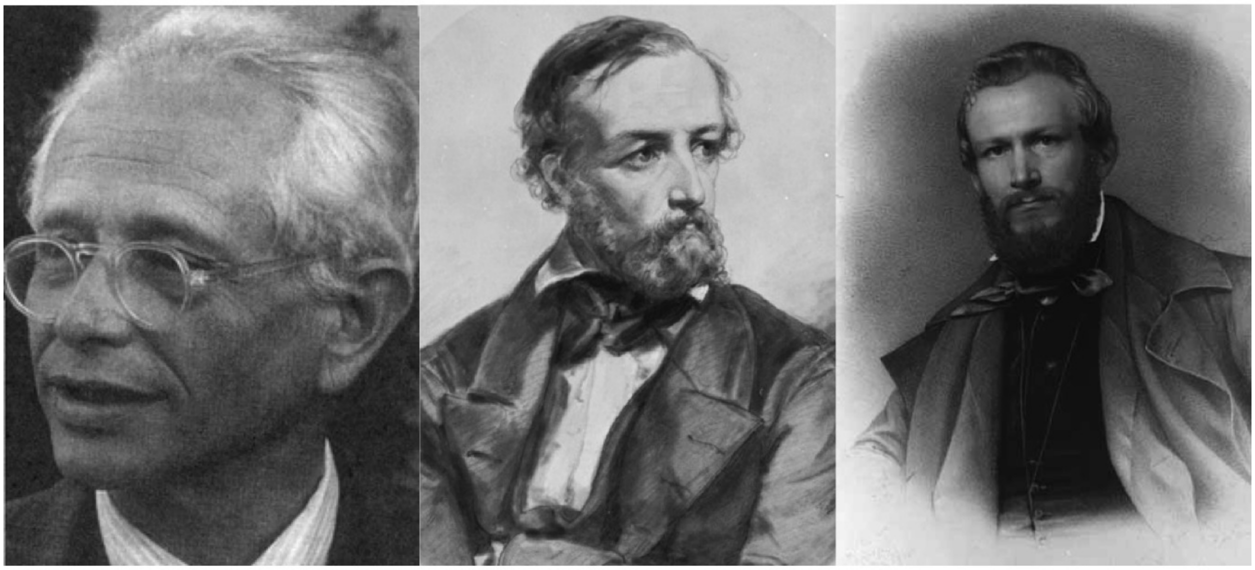
Figure 5.4: Other creators who made significant contributions to applied mathematics and classical mechanics included Constantin Carathéodory, Elwin Christoffel, Rudolf Alfred Clebsch, Lothar Collatz, Richard Courant, and Richard Dedekind.

Applied mathematics and classical mechanics

Max Dehn
(1878–1952)

Peter Gustav
Lejeune Dirichlet
(1805–1859)

Paul du Bois
Reymond
(1831–1889)



Walther von Dyck
(1856–1934)

Samuel Eilenberg
(1913–1998)

Alfred Enneper
(1830–1885)

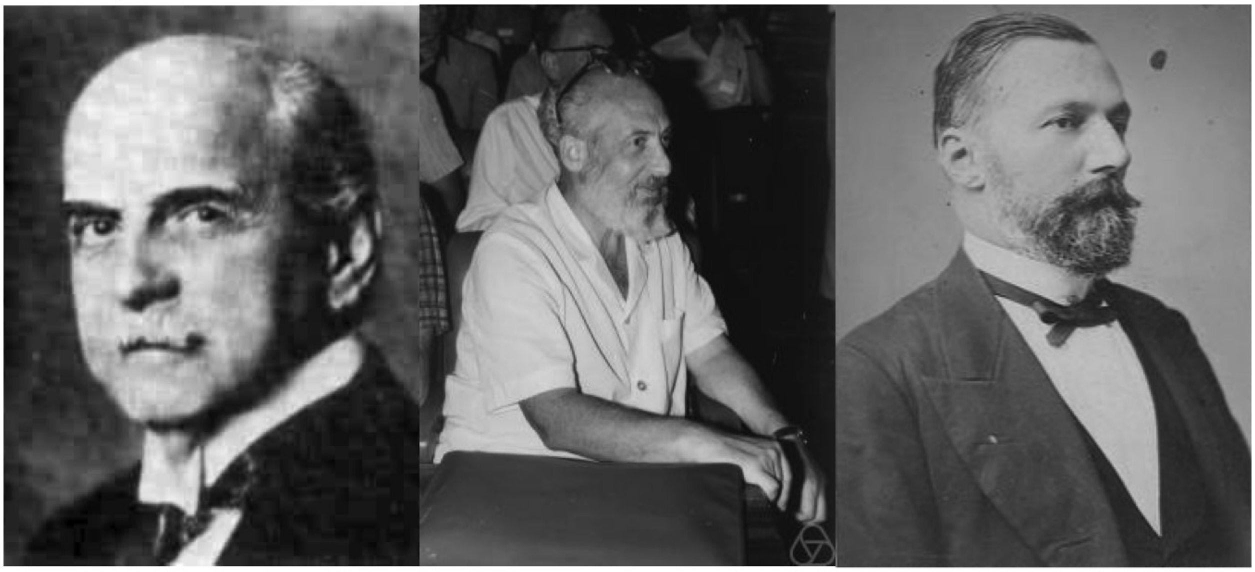
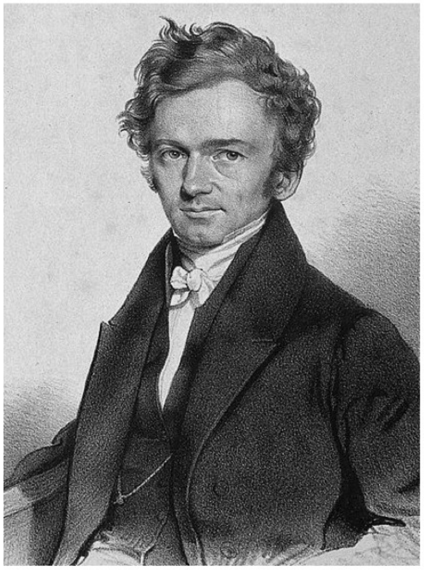


Figure 5.5: Other creators who made significant contributions to applied mathematics and classical mechanics included Max Dehn, Peter Dirichlet, Paul du Bois Reymond, Walther von Dyck, Samuel Eilenberg, and Alfred Enneper.

Applied mathematics and classical mechanics

Andreas von Ettingshausen (1796–1878)



Erwin Fehlberg (1911–1990)

William Feller (1906–1970)

Abraham Fränkel (1891–1965)

Friedrich Gottlob Frege (1848–1925)

Robert Fricke (1861–1930)

Figure 5.6: Other creators who made significant contributions to applied mathematics and classical mechanics included Andreas von Ettingshausen, Erwin Fehlberg, William Feller, Abraham Fränkel, Friedrich Gottlob Frege, and Robert Fricke.

Applied mathematics and classical mechanics

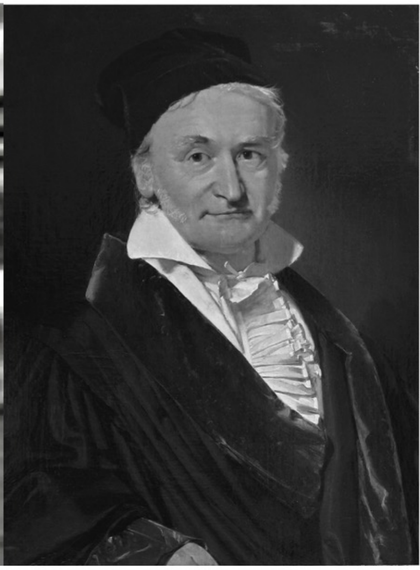
Georg Frobenius (1849–1917)

Lazarus Immanuel Fuchs (1833–1902)

Maximilian Richard Fuchs (1873–1944)

Karl Rudolf Fueter (1880–1950)

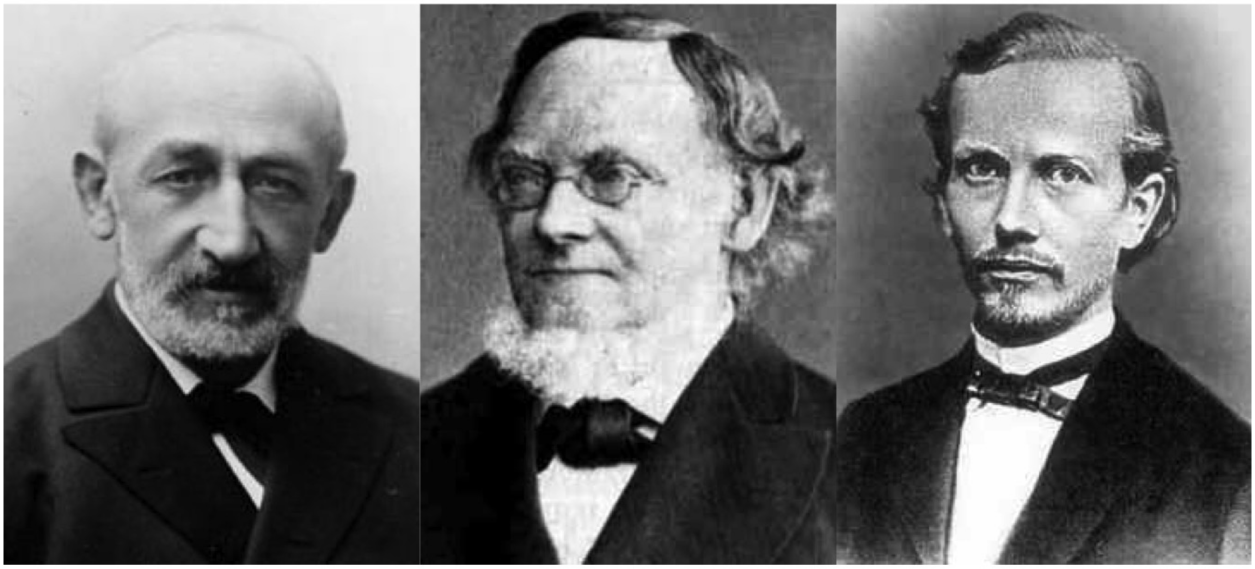
Carl Friedrich Gauss (1777–1855)



Kurt Gödel (1906–1978)

Figure 5.7: Other creators who made significant contributions to applied mathematics and classical mechanics included Georg Frobenius, Lazarus Immanuel Fuchs, Maximilian Richard Fuchs, Karl Rudolf Fueter, Carl Friedrich Gauss, and Kurt Gödel.

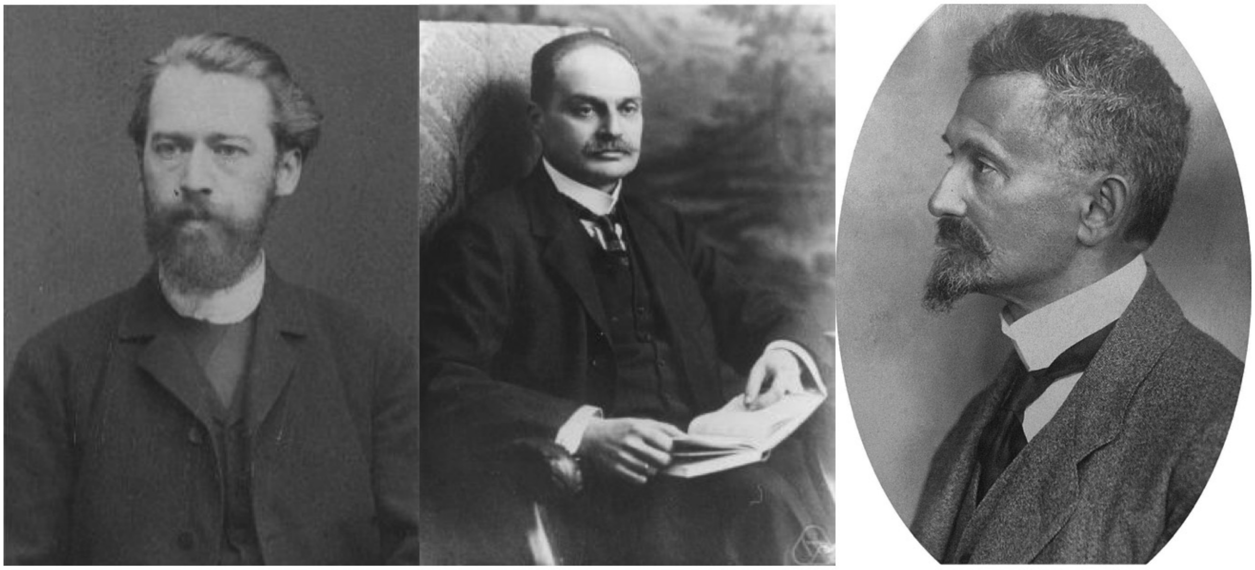
Applied mathematics and classical mechanics



Paul Gordan
(1837–1912)

Hermann Grassmann
(1809–1877)

Hermann Hankel
(1839–1873)



Carl Gustav
Axel Harnack
(1851–1888)

Friedrich Hartogs
(1874–1943)

Felix Hausdorff
(1868–1942)

Figure 5.8: Other creators who made significant contributions to applied mathematics and classical mechanics included Paul Gordan, Hermann Grassmann, Hermann Hankel, Carl Gustav Axel Harnack, Friedrich Hartogs, and Felix Hausdorff.

Applied mathematics and classical mechanics

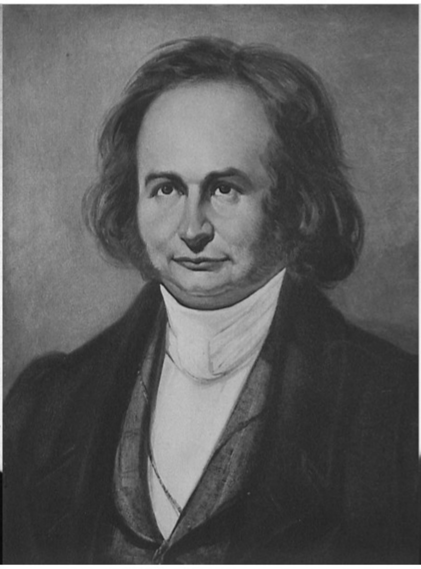
Heinrich Eduard Heine (1821–1881)

David Hilbert (1862–1943)

Heinz Hopf (1894–1971)

Adolf Hurwitz (1859–1919)

Carl Gustav Jacobi (1804–1851)



Theodor Kaluza (1885–1954)

Figure 5.9: Other creators who made significant contributions to applied mathematics and classical mechanics included Heinrich Eduard Heine, David Hilbert, Heinz Hopf, Adolf Hurwitz, Carl Gustav Jacobi, and Theodor Kaluza.

Applied mathematics and classical mechanics

Theodor Kaluza, Jr.
(1910–1994)

Wilhelm Killing
(1847–1923)

Christian Felix Klein
(1849–1925)

Sofia Kovalevskaya
(1850–1891)

Leopold Kronecker
(1823–1891)

Ernst Kummer
(1810–1893)

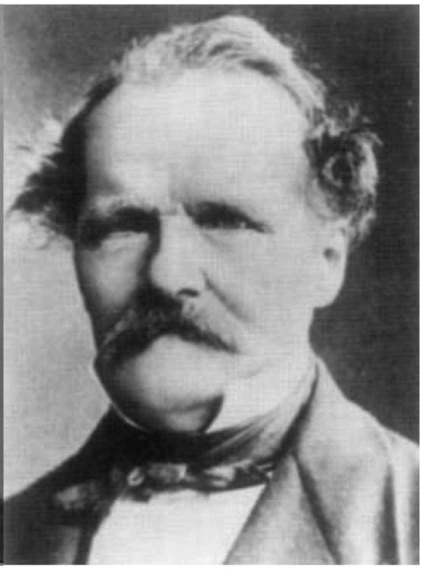


Figure 5.10: Other creators who made significant contributions to applied mathematics and classical mechanics included Theodor Kaluza, Jr., Wilhelm Killing, Christian Felix Klein, Sofia Kovalevskaya, Leopold Kronecker, and Ernst Kummer.

Applied mathematics and classical mechanics

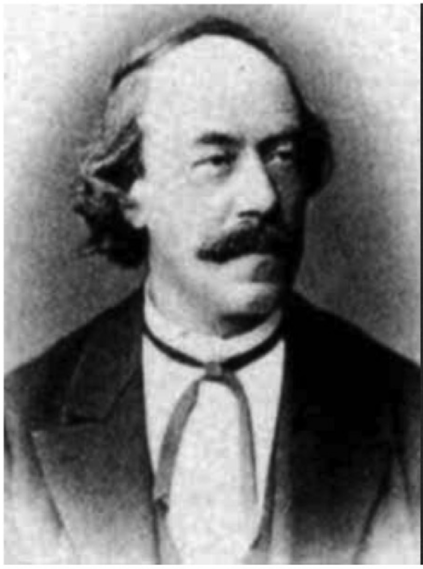
Martin Wilhelm Kutta
(1867–1944)

Daniel Christian
Ludolph Lehmus
(1780–1863)

Sophus Lie
(1842–1899)

Carl Ferdinand
von Lindemann
(1852–1939)

Rudolf Lipschitz
(1832–1903)



Alfred Loewy
(1873–1935)

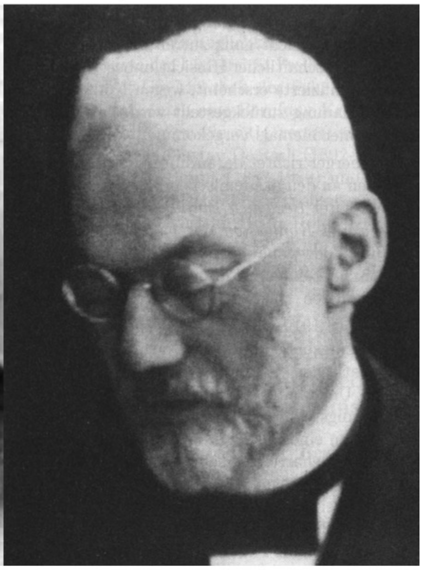


Figure 5.11: Other creators who made significant contributions to applied mathematics and classical mechanics included Martin Wilhelm Kutta, Daniel Christian Ludolph Lehmus, Sophus Lie, Carl Ferdinand von Lindemann, Rudolf Lipschitz, and Alfred Loewy.

Applied mathematics and classical mechanics

Gustav Ferdinand Mehler (1835–1895)

Friedrich Wilhelm Franz Meyer (1856–1934)

Hermann Minkowski (1864–1909)

Richard von Mises (1883–1953)

August Möbius (1790–1868)

Carl Neumann (1832–1925)

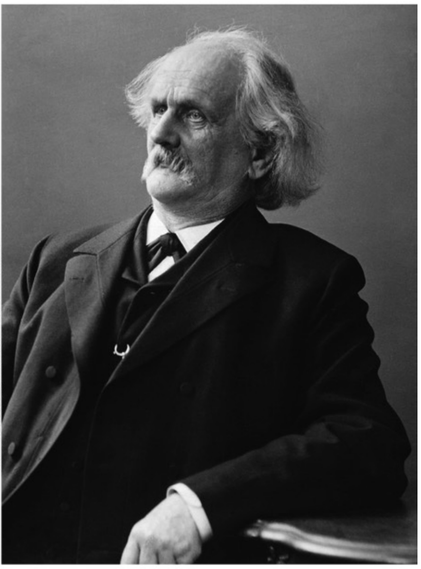


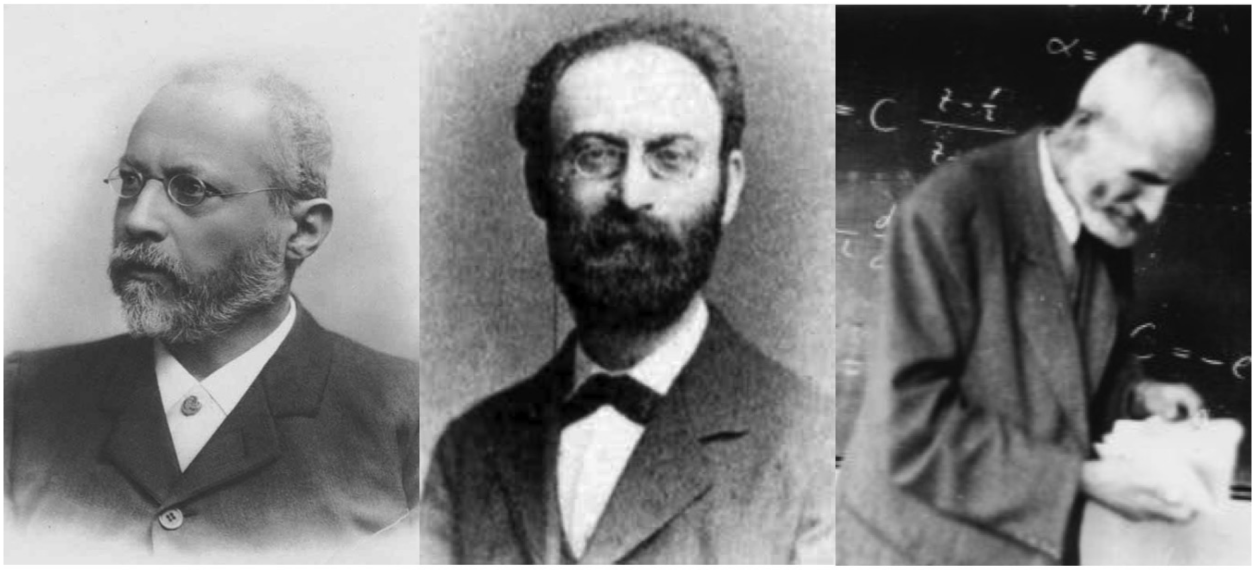
Figure 5.12: Other creators who made significant contributions to applied mathematics and classical mechanics included Gustav Ferdinand Mehler, Friedrich Meyer, Hermann Minkowski, Richard von Mises, August Möbius, and Carl Neumann.

Applied mathematics and classical mechanics

John von Neumann (1903–1957)

Rolf Nevanlinna (1895–1980)

Emmy Noether (1882–1935)



Max Noether (1844–1921)

Moritz Pasch (1843–1930)

Oskar Perron (1880–1975)

Figure 5.13: Other creators who made significant contributions to applied mathematics and classical mechanics included John von Neumann, Rolf Nevanlinna, Emmy Noether, Max Noether, Moritz Pasch, and Oskar Perron.

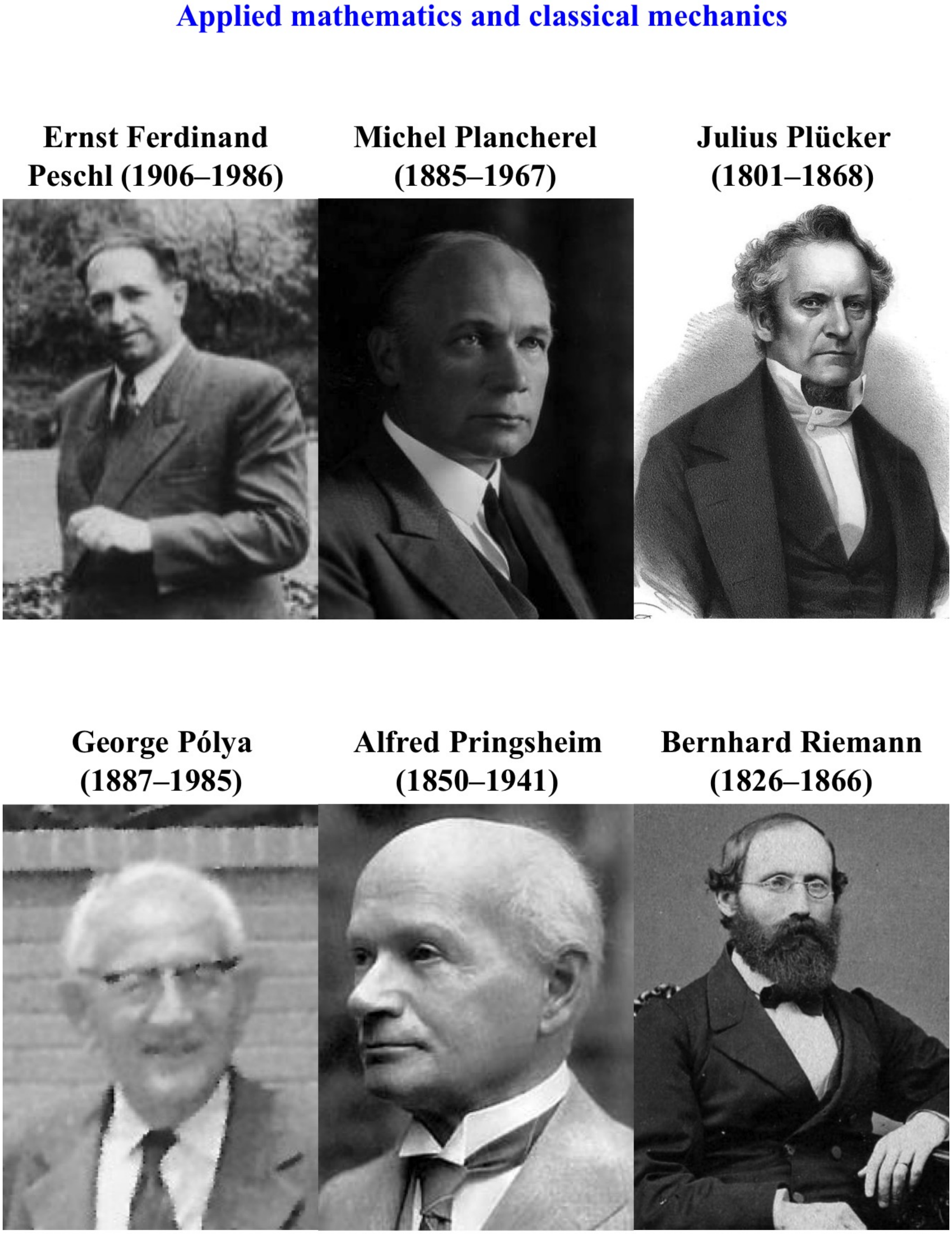

Applied mathematics and classical mechanics
Ernst Ferdinand Peschl (1906–1986)
Michel Plancherel (1885–1967)
Julius Plücker (1801–1868)
George Pólya (1887–1985)
Alfred Pringsheim (1850–1941)
Bernhard Riemann (1826–1866)

Figure 5.14: Other creators who made significant contributions to applied mathematics and classical mechanics included Ernst Ferdinand Peschl, Michel Plancherel, Julius Plücker, George Pólya, Alfred Pringsheim, and Bernhard Riemann.

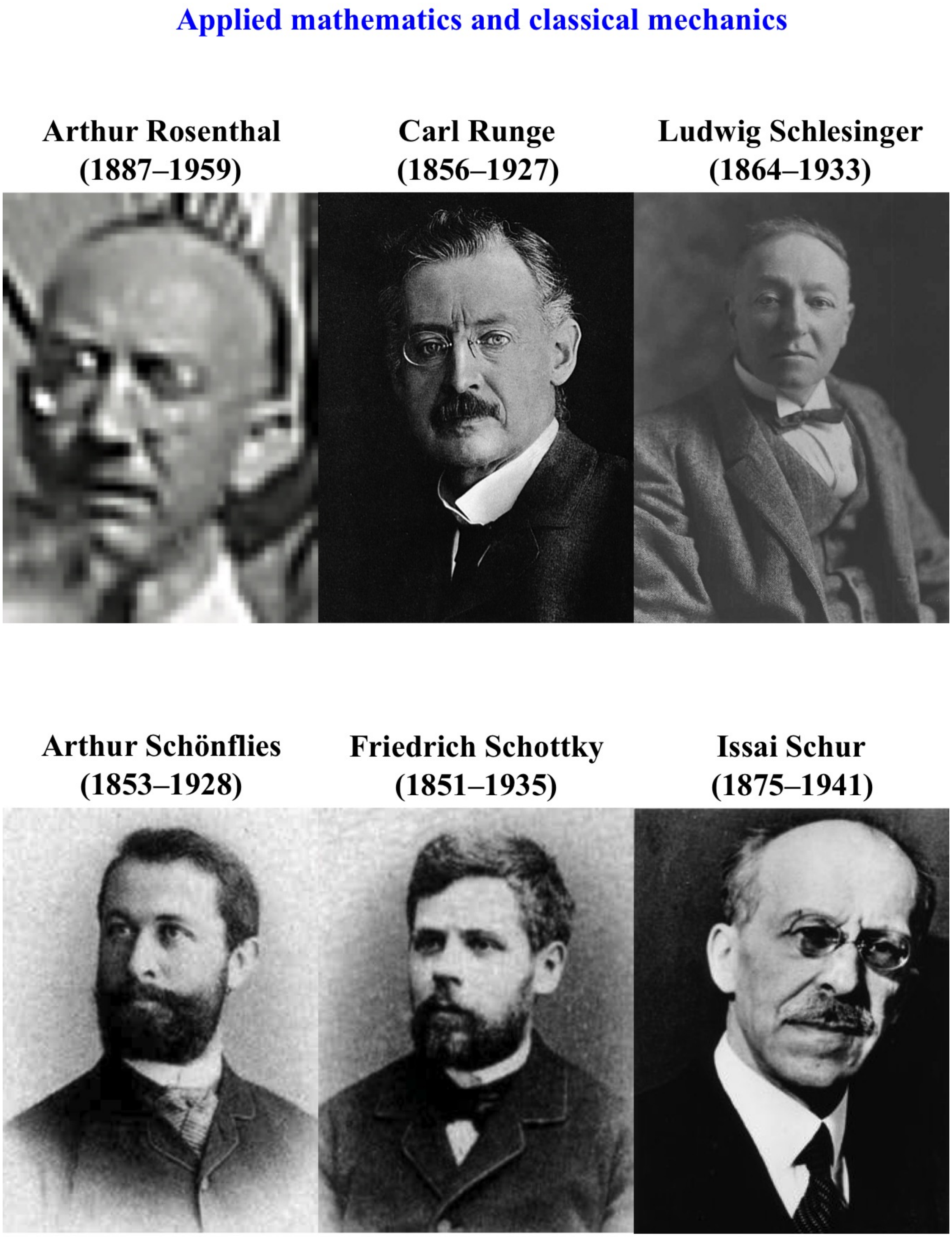

Applied mathematics and classical mechanics
Arthur Rosenthal (1887–1959)
Carl Runge (1856–1927)
Ludwig Schlesinger (1864–1933)
Arthur Schönflies (1853–1928)
Friedrich Schottky (1851–1935)
Issai Schur (1875–1941)

Figure 5.15: Other creators who made significant contributions to applied mathematics and classical mechanics included Arthur Rosenthal, Carl Runge, Ludwig Schlesinger, Arthur Schönflies, Friedrich Schottky, and Issai Schur.

Applied mathematics and classical mechanics

Karl Hermann Amandus Schwarz (1843–1921)
Jakob Steiner (1796–1863)
Ludwig Stickelberger (1850–1936)
Thomas Stieltjes (1856–1894)
Otto Stolz (1842–1905)
Oswald Teichmüller (1913–1943)

Figure 5.16: Other creators who made significant contributions to applied mathematics and classical mechanics included Karl Hermann Amandus Schwarz, Jakob Steiner, Ludwig Stickelberger, Thomas Stieltjes, Otto Stolz, and Oswald Teichmüller.

Applied mathematics and classical mechanics

B. L. van der Waerden (1903–1996)

Heinrich Martin Weber (1842–1913)

Karl Weierstrass (1815–1897)

Hermann Weyl (1885–1955)

Hans Zassenhaus (1912–1991)

Ernst Zermelo (1871–1953)

Figure 5.17: Other creators who made significant contributions to applied mathematics and classical mechanics included B. L. van der Waerden, Heinrich Martin Weber, Karl Weierstrass, Hermann Weyl, Hans Zassenhaus, and Ernst Zermelo.

5.2 Electromagnetism

Electromagnetic theory describes the behavior of electric fields, electric currents, magnetic fields, and electromagnetic waves (such as light and radio waves). The German-speaking scientific world slowly ramped up during the nineteenth century, and before then scientists had already begun working out the laws of electromagnetism. Therefore, most of the major early electromagnetic discoveries came from scientists outside the German-speaking world, including:

- Italian scientists (e.g., Luigi Galvani and Alessandro Volta).
- British scientists (e.g., Michael Faraday and James Clerk Maxwell).
- French scientists (e.g., André-Marie Ampère and Charles-Augustin de Coulomb).
- Hans Christian Ørsted in Denmark.
- Benjamin Franklin in the United States.

As the German-speaking scientific world became larger and more advanced over the course of the nineteenth century, German-speaking scientists came to increasingly dominate new discoveries in electromagnetism; see Figs. 5.18–5.23 for some examples.[3] That dominance is reflected in the modern physics terminology of Doppler shifts, Gauss's law, Helmholtz coils, Kirchhoff's laws, Lenz's law, Lorentz force, Ohm's law, and various physics quantities measured in Gauss, Hertz, Ohms, Siemens, Teslas, and Webers.

For convenience, the creators and creations in this section are divided into the following broad (and somewhat overlapping) categories:

5.2.1. Electric currents and magnetic fields

5.2.2. Electromagnetic waves

5.2.3. Electron beams and proton beams

The fundamental physics discoveries in electromagnetism led to a vast range of applications, which is the field of electrical and electromagnetic engineering; see Chapter 6 for more information.

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[3] For good overviews of this area, see especially: Jungnickel and McCormmach 1986, 2017; Kragh 2002; von Meÿenn 1997; Sarkar et al. 2006; Teichmann 2008; https://www.crtsite.com.

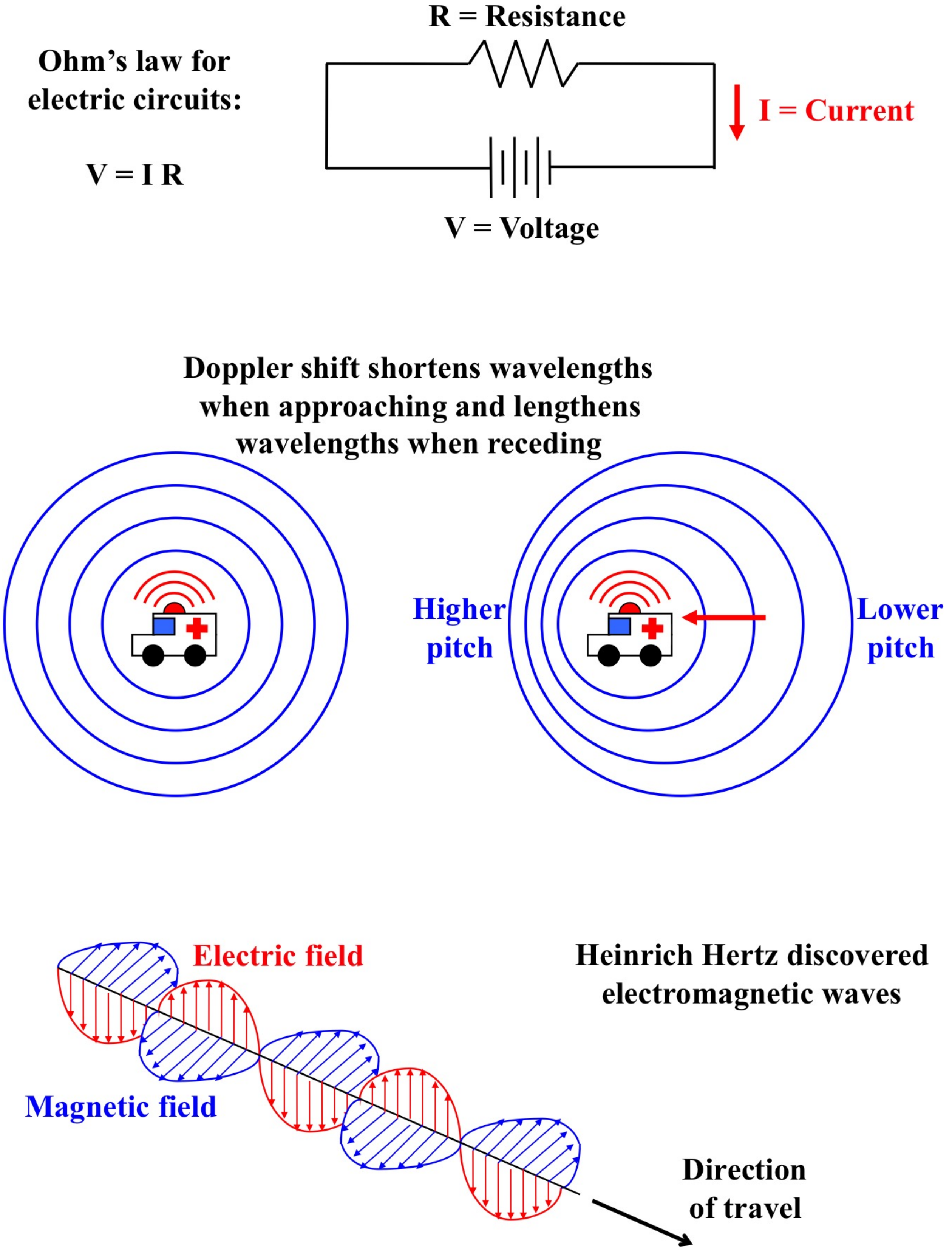

Ohm's law for electric circuits:
V = I R
R = Resistance
I = Current
V = Voltage
Doppler shift shortens wavelengths when approaching and lengthens wavelengths when receding
Higher pitch
Lower pitch
Electric field
Magnetic field
Heinrich Hertz discovered electromagnetic waves
Direction of travel

Figure 5.18: Examples of major German-speaking contributions to electromagnetism include Ohm's law for the relationship among voltage, current, and resistance in an electrical circuit; Christian Doppler's explanation for why the frequency and wavelength of waves change when their source is moving; and Heinrich Hertz's demonstration of electromagnetic waves.

Electromagnetism

Christian Doppler (1803–1853) **Paul Drude (1863–1906)** **Andreas von Ettingshausen (1796–1878)**

Joseph von Fraunhofer (1787–1826) **Carl Friedrich Gauss (1777–1855)** **Heinrich Geissler (1814–1879)**

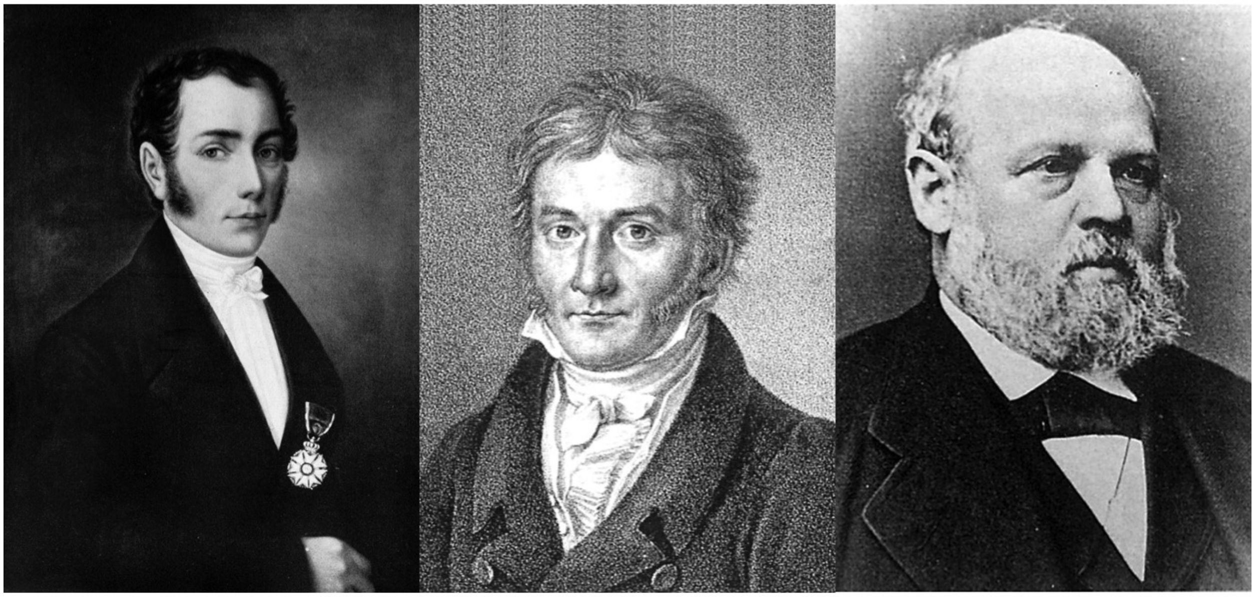


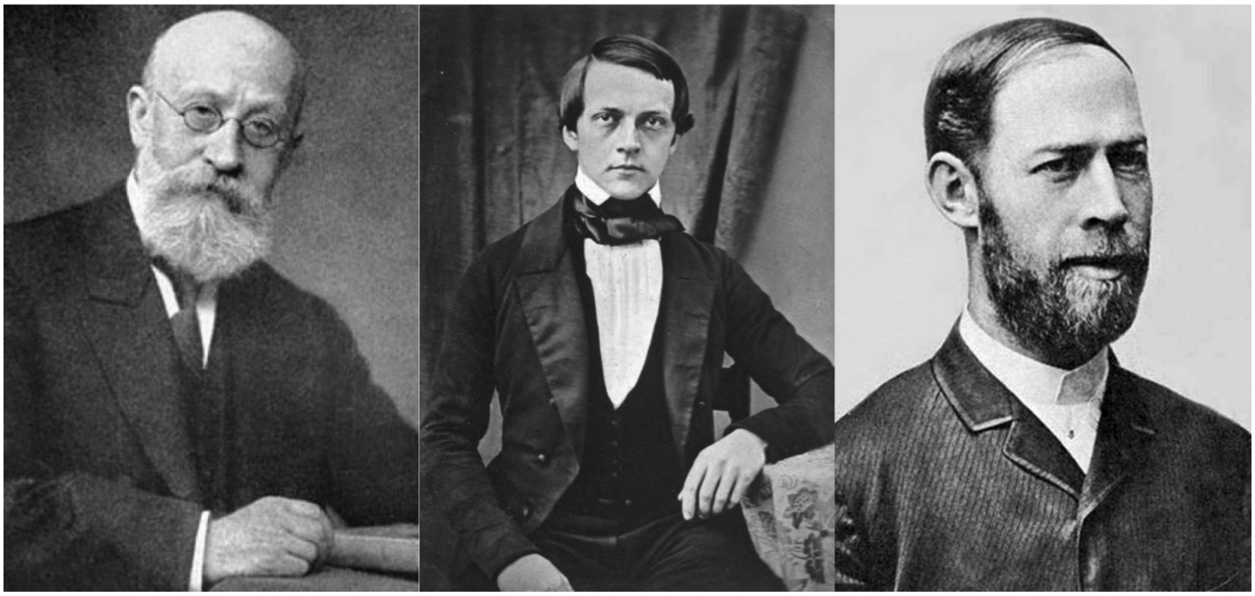
Figure 5.19: Some creators who made significant contributions to electromagnetism included Christian Doppler, Paul Drude, Andreas von Ettingshausen, Joseph von Fraunhofer, Carl Friedrich Gauss, and Heinrich Geissler.

Electromagnetism

Eugen Goldstein (1850–1930)

Hermann von Helmholtz (1821–1894)

Heinrich Hertz (1857–1894)



Johann Wilhelm Hittorf (1824–1914)

Wilhelm Holtz (1836–1913)

Gustav Kirchhoff (1824–1887)

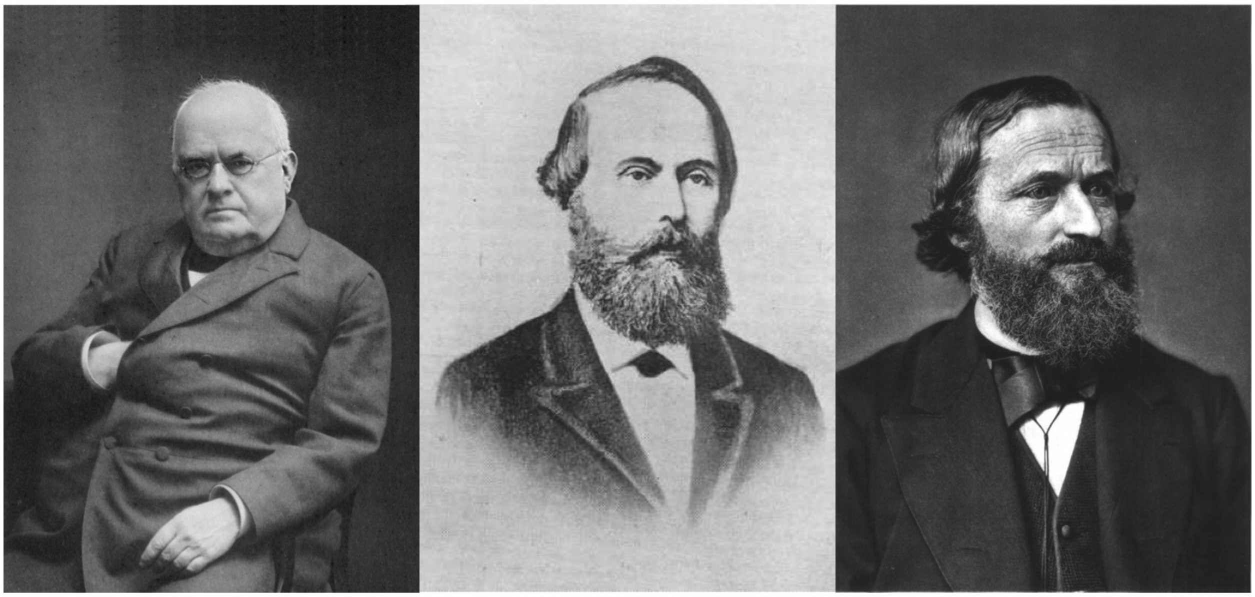


Figure 5.20: Other creators who made significant contributions to electromagnetism included Eugen Goldstein, Hermann von Helmholtz, Heinrich Hertz, Johann Wilhelm Hittorf, Wilhelm Holtz, and Gustav Kirchhoff.

Electromagnetism

Rudolf Kohlrausch
(1809–1858)

Ernst Lecher
(1856–1926)

Philipp Lenard
(1862–1947)

Heinrich Lenz
(1804–1865)

Hendrik Lorentz
(1853–1928)

Albert Michelson
(1852–1931)

Figure 5.21: Other creators who made significant contributions to electromagnetism included Rudolf Kohlrausch, Ernst Lecher, Philipp Lenard, Heinrich Lenz, Hendrik Lorentz, and Albert Michelson.

Electromagnetism

Gustav Mie (1868–1957)

Franz Ernst Neumann (1798–1895)

Georg Ohm (1789–1854)

Julius Plücker (1801–1868)

Johann Christian Poggendorff (1796–1877)

Heinrich Rühmkorff (1803–1877)

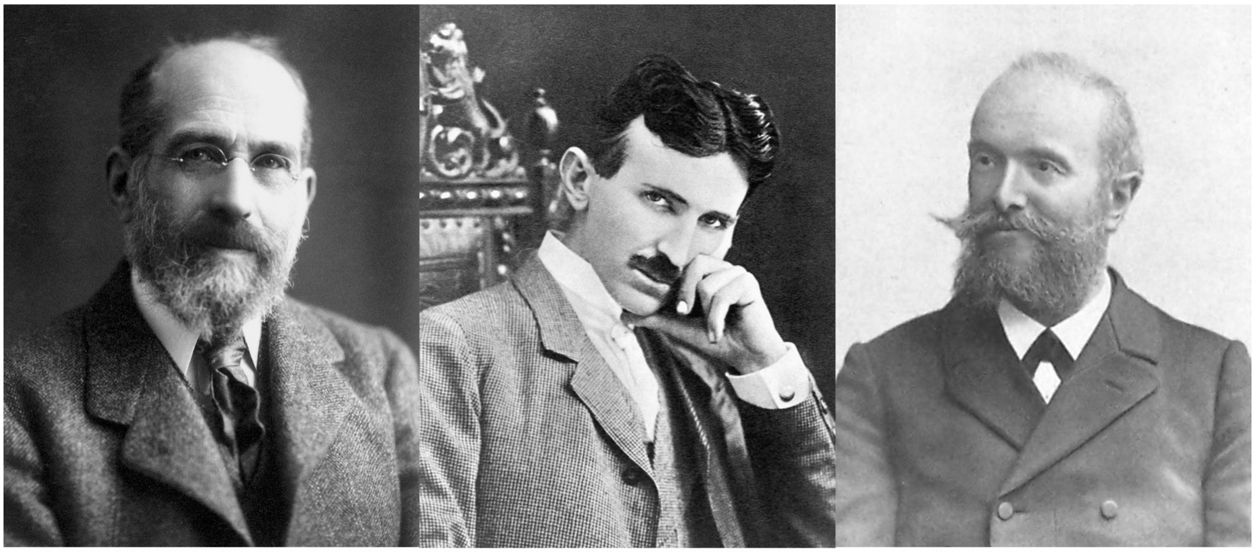
Figure 5.22: Other creators who made significant contributions to electromagnetism included Gustav Mie, Franz Ernst Neumann, Georg Ohm, Julius Plücker, Johann Christian Poggendorff, and Heinrich Rühmkorff.

Electromagnetism

Arthur Schuster
(1851–1934)

Nikola Tesla
(1856–1943)

August Toepler
(1836–1912)



Wilhelm Weber
(1804–1891)

Emil Wiechert
(1861–1928)

Wilhelm Wien
(1864–1928)

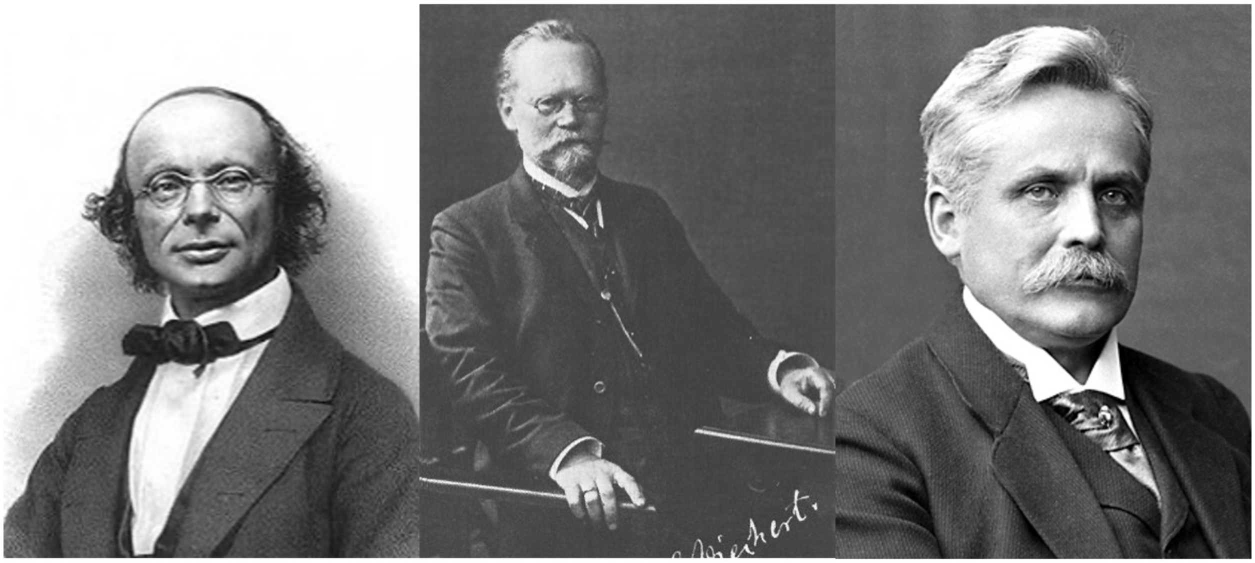


Figure 5.23: Other creators who made significant contributions to electromagnetism included Arthur Schuster, Werner von Siemens (p. 950), Nikola Tesla, August Toepler, Wilhelm Weber, Emil Wiechert, and Wilhelm Wien.

5.2.1 Electric Currents and Magnetic Fields

Carl Friedrich Gauss (German states, 1777–1855) and Wilhelm Weber (German, 1804–1891) conducted magnetic research together, building the first electromagnetic telegraph in 1833 (p. 974) and creating maps based on geomagnetic measurements. Along the way, Gauss discovered what is now known as Gauss's law, which determines how magnetic fields are created and spread out [Dunnington 1955]. (See also pp. 740, 793, 828, and 972.) The cgs (centimeter-gram-second) unit of magnetic field strength is named in Gauss's honor, and the metric SI (Système International) unit of magnetic flux is named after Weber.

Georg Ohm (German states, 1789–1854) studied the electrical properties of circuits and demonstrated that the voltage difference V across an electrical component depends on the current I through the component and the electrical resistance R of the component, in accordance with the equation $V = IR$, which is now known as Ohm's law. (See Fig. 5.18 top.) The unit of electrical resistance is named in his honor.

Andreas von Ettingshausen (Austrian, 1796–1878) designed the first machine to use electromagnetic induction to generate power, and also did research in optics.

Franz Ernst Neumann (German, 1798–1895) worked out laws for the induction of currents by magnetic fields, as well as the optical behavior of crystals.

Heinrich Lenz (Baltic German, 1804–1865) formulated what is now known as Lenz's law, which describes how a changing magnetic field induces electric currents in nearby conductors that create new magnetic fields opposing the changing field. He also discovered that the power P consumed by an electric circuit depends on the current I flowing through the circuit and the electrical resistance R of the circuit, $P = I^2R$.

Heinrich Rühmkorff (German, 1803–1877) developed improved magnetic induction coils, now called Rühmkorff coils, and used them in a variety of applications such as high-voltage generators (p. 949). He also investigated the rotation of the plane of polarized light in magnetic media, thermoelectric effects, and other aspects of electromagnetism.

Werner von Siemens (German, 1816–1892) began his career by creating more sophisticated telegraphs that could point to individual letters, and went on to produce a wide range of additional electrical innovations such as generators and transformers (pp. 950 and 975). The unit of electrical conductivity (the inverse of electrical resistance) is named in his honor [Bähr 2016; von Siemens 1895].

Gustav Kirchhoff (German, 1824–1887) discovered a number of physical laws that now have his name attached to them. Kirchhoff's various laws describe the current and voltage in electric circuits (p. 951), the emission and absorption spectra of materials as measured by spectroscopy (p. 433), and the emission and absorption of thermal radiation (p. 915).

Hendrik Lorentz (Dutch, 1853–1928) made many contributions to electromagnetism and other areas of physics, including formulating what is now called the Lorentz force, the force that electric and magnetic fields exert on a particle with a given electric charge and velocity. He won the Nobel Prize in Physics in 1902 (p. 891).

Johann Christian Poggendorff (German, 1796–1877), Wilhelm Holtz (German, 1836–1913), and August Toepler (German, 1836–1912) each built very early high-voltage generators and used those to study electrostatics. Other physicists used such high-voltage generators to power some of the earliest cathode ray tubes for producing electron beams.

5.2.2 Electromagnetic Waves

Joseph von Fraunhofer (German states, 1787–1826) made a number of important discoveries and inventions in optics. He improved prisms, invented diffraction grating, and studied the diffraction of light of different wavelengths. He used a diffraction slit and prism to develop a spectroscope, which he and others then applied to make important measurements in physics and chemistry (p. 961). He also created achromatic telescope lenses and other specialized lenses. Through all of these developments, von Fraunhofer learned and applied a great deal of knowledge about the behavior of light waves.

Christian Doppler (Austrian, 1803–1853) discovered and explained how the wavelength and frequency of waves changes depending on the velocity of the object emitting the waves, which is now commonly known as the Doppler effect. (See Fig. 5.18 middle.)

In 1856, Wilhelm Weber collaborated with Rudolf Kohlrausch (German states, 1809–1858) to combine the laws governing electric fields with those governing magnetic fields, and to use those to show that light is an electromagnetic wave with its speed c (as Weber and Kohlrausch labelled it) given by those equations. [Rudolf Kohlrausch was the father of Friedrich Kohlrausch (p. 599).] At approximately the same time, Gustav Kirchhoff independently arrived at a mathematical derivation of the speed of electromagnetic waves. Several years later, in the 1860s and 1870s, James Clerk Maxwell (Scottish, 1831–1879) also derived and published the equations for electromagnetic waves and the speed of light. In his published papers, Maxwell specifically gave credit to Weber's earlier work. It could be interesting for historians to more closely scrutinize the connections, similarities, and differences between Maxwell's work and the earlier work by Weber, Kohlrausch, and Kirchhoff.

Hermann von Helmholtz (German, 1821–1894) made a wide variety of major discoveries in biology (pp. 239, 282, 297, 311), chemistry (p. 597), and physics (p. 912) [Cahan 2018]. In electromagnetic theory, he is best remembered for the Helmholtz equation for electromagnetic waves, and also for Helmholtz electromagnetic coils for producing a very uniform magnetic field within a small volume.

Heinrich Hertz (German, 1857–1894), a student of Gustav Kirchhoff and Hermann von Helmholtz, produced, detected, and measured electromagnetic waves, specifically radio waves, making him also the true original inventor of radio transmitters and receivers. (See Fig. 5.18 bottom.) Unfortunately Hertz died very young; otherwise he would likely have played even more of a role (and been recognized far more) in the early development of radio technology. The unit of frequency (1 Hertz = 1 Hz = 1 wave/second) is named in his honor. Because Hertz died before Nobel Prizes were awarded, he was not eligible to be considered for one. However, Professor Hj. Théel, President of the Royal Swedish Academy of Sciences, paid tribute to Hertz's groundbreaking contributions in his speech for the 1902 Nobel Prize in Physics [https://www.nobelprize.org/prizes/physics/1902/ceremony-speech/]:

> This so-called electromagnetic theory of light of Maxwell's at first aroused compara-

> tively little interest. Twenty years after its first appearance however it led to a scientific discovery which demonstrated its great significance in no uncertain manner. The German physicist Heinrich Hertz then succeeded in demonstrating that the electrical vibrations—which are generated under certain conditions when an electrically charged body is discharged—are propagated through the surrounding space in the form of a wave motion, and that the wave motion spreads at the speed of light and also possesses its properties. This gave a firm experimental basis for the electromagnetic theory of light.

Building on the earlier work of Weber, Kohlrausch, Helmholtz, and Hertz on electromagnetic waves, Ernst Lecher (Austrian, 1856–1926) developed a device that used parallel wires (now called Lecher lines) to measure the wavelength of radio waves.

Nikola Tesla (Serbo-Croatian, educated in Austria, 1856–1943) showed that Hertz's radio waves could be used to transmit signals and even power (using what are now known as Tesla coils) over considerable distances. Tesla also made countless other contributions to electromagnetism and electrical engineering, especially in AC (alternating current) electricity generation, distribution, and usage (p. 954) [Cheney 1981; Cheney and Uth 1999; Tesla 1893, 1904, 1919, 1940]. The SI unit of magnetic field strength is named in his honor.

Although Albert Michelson (1852–1931) was a U.S. citizen, he was born in Prussia, was raised by German-speaking parents, and studied in Berlin and Heidelberg. He developed methods to measure the speed of light very accurately, and then used those methods to demonstrate that the speed of light was the same in all directions. That result showed that light is simply electromagnetic waves in empty space and not waves in some invisible vibrating "ether" material that fills the universe and moves in a particular direction with some velocity relative to the earth. For these experiments, Michelson won the Nobel Prize in Physics in 1907. Professor the Count K. A. H. Mörner, President of the Royal Swedish Academy of Sciences, announced the award [https://www.nobelprize.org/prizes/physics/1907/ceremony-speech/]:

> Professor Michelson. The Swedish Academy of Sciences has awarded you this year the Nobel Prize in Physics in recognition of the methods which you have discovered for insuring exactness in measurements, and also of the investigations in spectrology which you have carried out in connection therewith.
>
> Your interferometer has rendered it possible to obtain a non-material standard of length, possessed of a degree of accuracy never hitherto attained. By its means we are enabled to ensure that the prototype of the metre has remained unaltered in length, and to restore it with absolute infallibility, supposing it were to get lost.
>
> Your contributions to spectrology embrace methods for the determination of the length of waves in a more exact manner than those hitherto known.
>
> Furthermore, you have discovered the important fact that the lines in the spectra, which had been regarded as perfectly distinct, are really in most cases groups of lines. You have also afforded us the means of closely investigating this phenomenon, both in its spontaneous occurrence and when it is produced by magnetic influence, as in Zeeman's interesting experiments.

> Astronomy has also derived great advantage, and will do so yet more in the future, from your method of measurements.

Paul Drude (German, 1863–1906) used the latest ideas about electromagnetic waves and electrons to create some of the first mathematical models for the electrical and optical properties of solids.

Gustav Mie (German, 1868–1957) derived equations for the scattering of electromagnetic waves by spherical particles, which is now called Mie scattering. Mie scattering has proven useful for everything from studying the propagation of light though the atmosphere to designing modern metamaterials. He also analyzed the electrostatic forces between molecules, now called the Mie potential, and made other contributions to electromagnetic theory.

Creators from the German-speaking world also developed a wide range of practical applications of electromagnetic waves, such as:

- Lighting technology (p. 957).
- Radio communications (p. 978).
- Television communications (p. 996).
- Lasers and holography (p. 1023).
- Infrared vision and targeting (p. 1131).
- Radio-controlled robotic vehicles (p. 1198).
- Radar (p. 1217).
- Optical technologies (p. 1260).

5.2.3 Electron, Proton, and Neutron Beams

German-speaking scientists discovered, analyzed, and harnessed electron beams (cathode rays), proton beams (anode rays or canal rays), and neutron beams, thus identifying all three building blocks of the atom.

Heinrich Geissler (German, 1814–1879) invented the first high-voltage, low-pressure gas-filled glass electrical discharge tubes, which other German-speaking creators later adapted for a wide variety of applications ranging from fluorescent lights to television screens.

In the late 1850s and 1860s, Julius Plücker (German states, 1801–1868) and Johann Wilhelm Hittorf (German, 1824–1914) modified Geissler's tubes to produce cathode rays, which were later found to be electron beams, and to measure their properties.

Philipp Lenard (Austrian/German, 1862–1947) conducted a variety of novel experiments with cathode rays beginning in 1888. He demonstrated that the electrons were particles, and he experimentally measured many of their properties. For this work, he won the Nobel Prize in Physics in 1905. Professor A. Lindstedt, President of the Royal Swedish Academy of Sciences, described Lenard's experiments [https://www.nobelprize.org/prizes/physics/1905/ceremony-speech/]:

> The discovery of the cathode rays forms the first link in the chain of brilliant discoveries with which the names of Röntgen, Becquerel and Curie are connected. The discovery itself was made by Hittorf as long ago as 1869 and therefore falls in a period before that which the Nobel Foundation is able to take into account. However, the recognition which Lenard has earned himself by the further development of Hittorf's discovery (which is becoming of increasing importance) shows that he too deserves the same reward as has already come to several of his successors for work of a similar nature. [...]
>
> These were the circumstances prevailing when Lenard began his work on cathode rays in 1893. He started from a fact which had been observed by his great and prematurely deceased teacher Heinrich Hertz: that these rays were able to pass through thin metal plates which had been introduced into the discharge tube. At Hertz's suggestion he utilized this fact in an attempt to lead the rays out of the tube. He used for this a tube which was not wholly made of glass but terminated at one place in a very thin aluminium plate. As the cathode rays reached Lenard's "aluminium window", it was found that they passed through it and continued their course in the air outside the tube. This constituted a discovery which was to have the most far-reaching consequences, above all for the study of the radiation phenomena themselves. It became possible to study cathode rays under much simpler and more convenient experimental conditions than before, and also to separate observations on conditions needed for the production of the rays in the tube from questions concerning their propagation and other characteristics.
>
> Lenard found first of all that the rays coming through the aluminium window possessed the same characteristics as those previously noted in rays inside the tube, i.e. that they cause fluorescence, can be deflected by a magnet and so on. He further proved that cathode rays have certain chemical effects such as causing impressions on photographic plates, ozonizing air, making gases conducting through so-called ionisation, etc. It was also discovered that these rays pass unimpeded through empty space but that in gases

> they are subject to diffusion which increases with the density of the gas; and, moreover, that bodies in general differ in permeability, as their absorptive power bears a direct relationship to their density. Cathode rays proved to be carriers of negative electricity even in empty space and they could be deflected from their path by both magnetic and electrical fields. Finally, Lenard showed that there are various types of cathode rays, differentiated amongst other things by the fact that they are deflected by magnets, to a greater or lesser extent. He also found that the formation of one or other type of ray is determined by the degree of gas rarification in the discharge tube. [...]
>
> The research by Lenard, only a very brief report of which is given here, has been followed by a series of valuable studies by other scientists as well. Development of the theoretical basis for the theory of electrons has gone hand in hand with the experimental work. The study of electrons, their characteristics and their behaviour in relation to matter has been given a sounder basis through these researches on cathode rays and has been gradually developed into one of the foremost theories of modern physics by Lenard himself and by other workers. This theory is in fact not only important for the explanation of cathode rays and other closely related phenomena—the electron theory with its concepts on the constitution of matter has become of the most fundamental importance for the sciences of electricity and of light and for both the physicist and the chemist.

In 1890, Arthur Schuster (German, 1851–1934) measured the charge-to-mass ratio of electrons and showed that it was remarkably large, so electrons were particles with a very small mass compared to atoms. Schuster was also the first physicist to propose the existence of antimatter particles that would annihilate and produce energy if combined with particles of ordinary matter.

The geophysicist Emil Wiechert (German, 1861–1928) also demonstrated that cathode rays were particles and measured their charge-to-mass ratio.

One could make a very strong case that the fact that electrons are particles was discovered by the qualitative demonstrations of Julius Plücker and Johann Hittorf during the 1850s–1860s, or by the quantitative measurements of Lenard, Schuster, and Wiechert in the late 1880s and early 1890s. Yet traditionally, the credit for the discovery of the electron has been given to J. J. Thomson (British, 1856–1940), who conducted very similar but much more widely publicized experiments significantly later, in 1897. For that work, Thomson received the Nobel Prize in Physics in 1906.

Eugen Goldstein (German, 1850–1930) used similar tubes not only to produce and study cathode rays or electrons, but also to produce and analyze anode rays (also called canal rays), which turned out to be positively charged ions, or atomic nuclei. More specifically, Goldstein's anode rays were protons if he used hydrogen gas in his tubes. Goldstein showed that the anode rays were particles with a positive charge and a mass much larger than that of the electron.

Wilhelm Wien (German, 1864–1928) measured the mass of the anode rays produced from hydrogen gas in 1898 and specifically showed that they had the same mass as a hydrogen atom. For some of his other work (thermal radiation), Wien won the Nobel Prize in Physics in 1911 (p. 916).

Thus one could make a convincing case that the proton was discovered in 1886 by Goldstein, or at the latest was more fully demonstrated in 1898 by Wien. Yet traditionally the credit for the discovery of the proton has been given to Ernest Rutherford (New Zealand/British, 1871–1937) for a series of experiments he conducted decades later, during the period 1917–1919.

The neutron was the last of the three building blocks of the atom to be discovered, and it too was discovered by German-speaking scientists. Carl Auer von Welsbach (Austrian, 1858–1929, p. 966) produced free neutrons and observed their effects on various nuclei no later than 1910 [Auer von Welsbach 1910; Steinhauser et al. 2013]. Walther Bothe (German, 1891–1957, p. 1026) and Herbert Becker (German?, 18??–19??) rediscovered the neutron no later than 1930, when they bombarded beryllium with alpha particles from polonium and showed that in response the beryllium emitted a new type of particles that did not match the characteristics of alpha, beta, or gamma radiation [Bothe and Becker 1930]. James Chadwick repeated the Bothe-Becker experiment in 1932 and was trumpeted in the English-speaking world as the “discoverer” of the neutron while the earlier experimental discoveries of Carl Auer von Welsbach, Walther Bothe, and Herbert Becker were forgotten.

Other creators from the German-speaking world devised a wide range of practical applications of high-voltage gas discharge tubes, such as:

- Fluorescent lights (p. 957).
- Vacuum tubes (p. 978).
- Television picture tubes (p. 996).
- Photomultiplier tubes (p. 1131).
- Electron microscopes (p. 1286).
- X-ray tubes (p. 1505).
- Geiger counters (p. 1518).
- Particle beam sources (p. 1524).
- Electric rocket propulsion (p. 1954).
- Fusion reactions and neutron sources (Section D.9).

5.3 Special and General Relativity

The theory of relativity is thus named because it deals with objects that are moving differently relative to each other, as there is no absolute frame of reference to authoritatively declare what is moving and what is not. Relativistic physics was almost entirely a product of German-speaking creators.

Special relativity (Section 5.3.1) only considers the special case in which the objects move at constant velocities.

General relativity (Section 5.3.2) covers the general case in which the objects' velocities can change, or the objects can accelerate and decelerate.

5.3.1 Special Relativity

Special relativity is valid for the special case in which the objects' relative velocities remain constant, with no acceleration or deceleration. Following that initial assumption to its logical if surprising conclusions, special relativity describes the weird things that happen when something travels nearly as fast as the speed of light (relative to some other observer), including time slowing down, lengths contracting, and not being able to travel faster than light speed no matter how hard something is pushed (Fig. 5.24). These strange effects have all been confirmed in countless experiments. At the fundamental level, these effects are manifestations of the facts that space and time are interrelated, and mass and energy are interrelated.

Relativity is quite possibly unique in how much of the field came from a single person, Albert Einstein (German, 1879–1955, Fig. 5.25).[4] Indeed, Einstein and relativity are probably the most famous creator and creation from the entire German-speaking world. In addition to developing special relativity (1905) and general relativity (1915–1916), Einstein also made major contributions to statistical and thermal physics, non-relativistic quantum physics, and relativistic quantum physics, as covered in the next sections.

Shockingly, the Nobel Committee for Physics was unwilling to give Einstein an award for relativity even years later, since they considered it so counterintuitive and controversial. They did give him a Nobel Prize in 1921, but only for his work on the quantum physics of the photoelectric effect (p. 890).

Although Einstein is justifiably lauded for special relativity, at least six other scientists also made significant contributions to special relativity: Hendrik Lorentz, Woldemar Voigt, Ernst Mach, Hermann Minkowski, Walter Kaufmann, and Alfred Bucherer. Many other scientists from the German-speaking world also made contributions to general relativity. See Figs. 5.26–5.30.

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[4] For good overviews of this area, see especially: Laurie Brown et al. 1995; Isaacson 2007; Jungnickel and McCormmach 1986, 2017; Kragh 2002; Levenson 2003; Pais 1982; Thorne 1994.

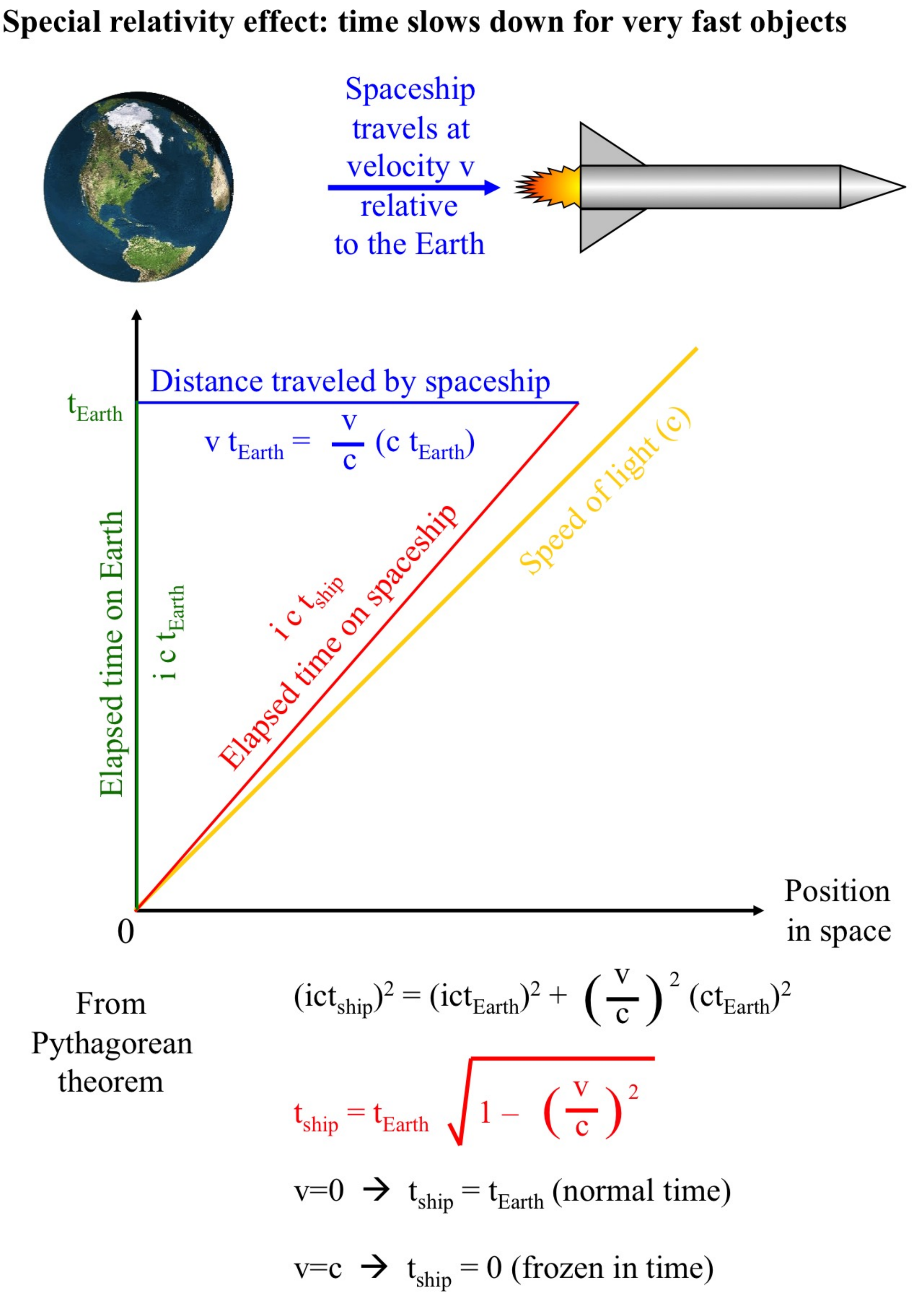
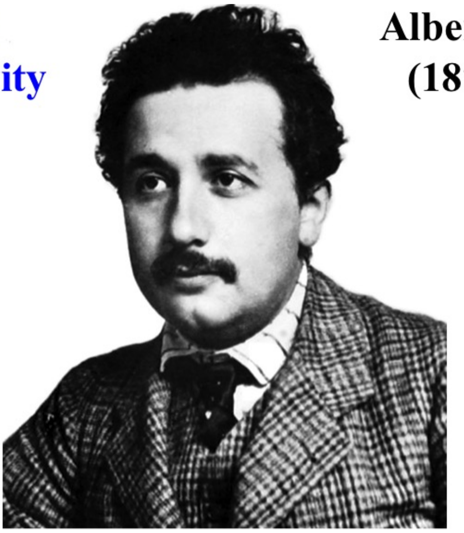
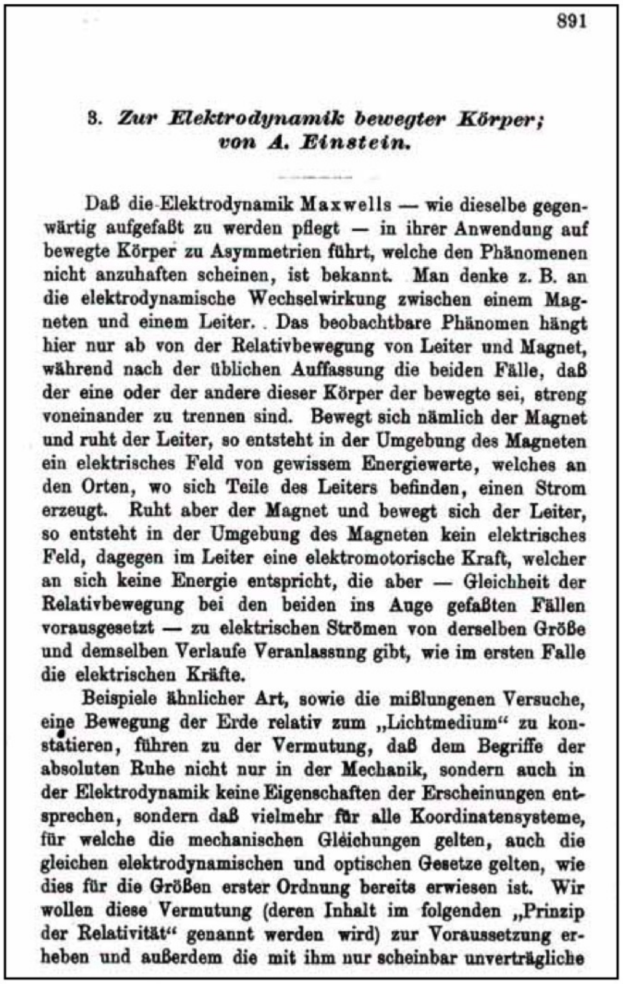

Special relativity effect: time slows down for very fast objects
Spaceship travels at velocity v relative to the Earth
Distance traveled by spaceship
t_{Earth}
$v\,t_{Earth} = \frac{v}{c}(c\,t_{Earth})$
Elapsed time on Earth
$i\,c\,t_{Earth}$
$i\,c\,t_{ship}$
Elapsed time on spaceship
Speed of light (c)
0
Position in space
From Pythagorean theorem
$(ict_{ship})^2 = (ict_{Earth})^2 + \left(\frac{v}{c}\right)^2 (ct_{Earth})^2$
$t_{ship} = t_{Earth}\sqrt{1 - \left(\frac{v}{c}\right)^2}$
$v=0 \rightarrow t_{ship} = t_{Earth}$ (normal time)
$v=c \rightarrow t_{ship} = 0$ (frozen in time)

Figure 5.24: Special relativity correctly predicts that time slows down for objects moving very quickly (approaching the speed of light).



Einstein's first 1905 paper on special relativity in *Annalen der Physik*



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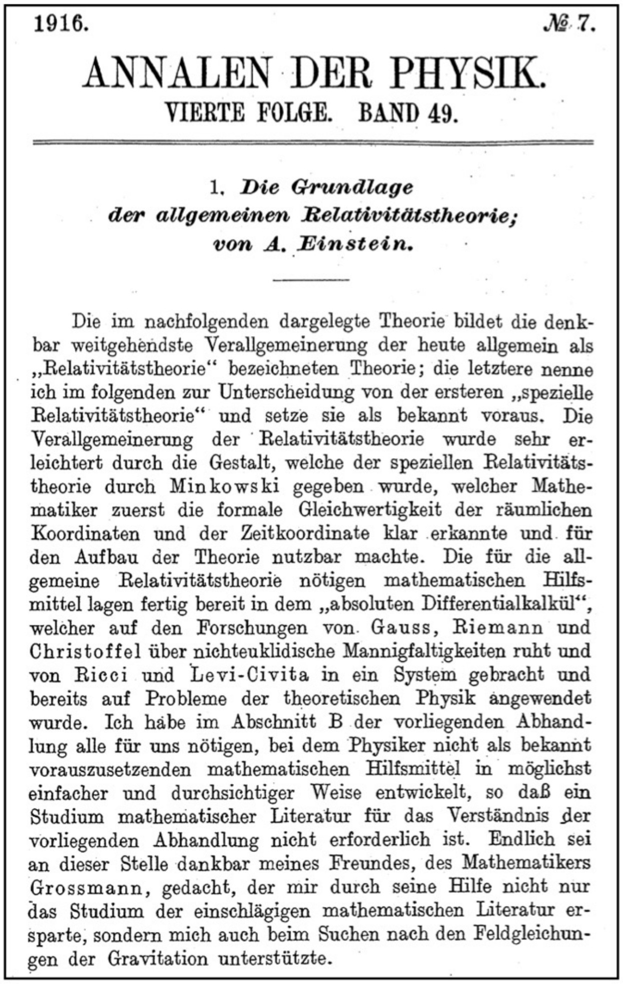
3. *Zur Elektrodynamik bewegter Körper;*
von A. Einstein.

Daß die Elektrodynamik Maxwells — wie dieselbe gegenwärtig aufgefaßt zu werden pflegt — in ihrer Anwendung auf bewegte Körper zu Asymmetrien führt, welche den Phänomenen nicht anzuhaften scheinen, ist bekannt. Man denke z. B. an die elektrodynamische Wechselwirkung zwischen einem Magneten und einem Leiter. Das beobachtbare Phänomen hängt hier nur ab von der Relativbewegung von Leiter und Magnet, während nach der üblichen Auffassung die beiden Fälle, daß der eine oder der andere dieser Körper der bewegte sei, streng voneinander zu trennen sind. Bewegt sich nämlich der Magnet und ruht der Leiter, so entsteht in der Umgebung des Magneten ein elektrisches Feld von gewissem Energiewerte, welches an den Orten, wo sich Teile des Leiters befinden, einen Strom erzeugt. Ruht aber der Magnet und bewegt sich der Leiter, so entsteht in der Umgebung des Magneten kein elektrisches Feld, dagegen im Leiter eine elektromotorische Kraft, welcher an sich keine Energie entspricht, die aber — Gleichheit der Relativbewegung bei den beiden ins Auge gefaßten Fällen vorausgesetzt — zu elektrischen Strömen von derselben Größe und demselben Verlaufe Veranlassung gibt, wie im ersten Falle die elektrischen Kräfte.

Beispiele ähnlicher Art, sowie die mißlungenen Versuche, eine Bewegung der Erde relativ zum „Lichtmedium" zu konstatieren, führen zu der Vermutung, daß dem Begriffe der absoluten Ruhe nicht nur in der Mechanik, sondern auch in der Elektrodynamik keine Eigenschaften der Erscheinungen entsprechen, sondern daß vielmehr für alle Koordinatensysteme, für welche die mechanischen Gleichungen gelten, auch die gleichen elektrodynamischen und optischen Gesetze gelten, wie dies für die Größen erster Ordnung bereits erwiesen ist. Wir wollen diese Vermutung (deren Inhalt im folgenden „Prinzip der Relativität" genannt werden wird) zur Voraussetzung erheben und außerdem die mit ihm nur scheinbar unverträgliche

Einstein's first 1916 paper on general relativity in *Annalen der Physik*



1916. № 7.

ANNALEN DER PHYSIK.
VIERTE FOLGE. BAND 49.

1. *Die Grundlage der allgemeinen Relativitätstheorie;*
von A. Einstein.

Die im nachfolgenden dargelegte Theorie bildet die denkbar weitgehendste Verallgemeinerung der heute allgemein als „Relativitätstheorie" bezeichneten Theorie; die letztere nenne ich im folgenden zur Unterscheidung von der ersteren „spezielle Relativitätstheorie" und setze sie als bekannt voraus. Die Verallgemeinerung der Relativitätstheorie wurde sehr erleichtert durch die Gestalt, welche der speziellen Relativitätstheorie durch Minkowski gegeben wurde, welcher Mathematiker zuerst die formale Gleichwertigkeit der räumlichen Koordinaten und der Zeitkoordinate klar erkannte und für den Aufbau der Theorie nutzbar machte. Die für die allgemeine Relativitätstheorie nötigen mathematischen Hilfsmittel lagen fertig bereit in dem „absoluten Differentialkalkül", welcher auf den Forschungen von Gauss, Riemann und Christoffel über nichteuklidische Mannigfaltigkeiten ruht und von Ricci und Levi-Civita in ein System gebracht und bereits auf Probleme der theoretischen Physik angewendet wurde. Ich habe im Abschnitt B der vorliegenden Abhandlung alle für uns nötigen, bei dem Physiker nicht als bekannt vorauszusetzenden mathematischen Hilfsmittel in möglichst einfacher und durchsichtiger Weise entwickelt, so daß ein Studium mathematischer Literatur für das Verständnis der vorliegenden Abhandlung nicht erforderlich ist. Endlich sei an dieser Stelle dankbar meines Freundes, des Mathematikers Grossmann, gedacht, der mir durch seine Hilfe nicht nur das Studium der einschlägigen mathematischen Literatur ersparte, sondern mich auch beim Suchen nach den Feldgleichungen der Gravitation unterstützte.

Figure 5.25: Albert Einstein proposed special relativity in papers he published in 1905, and general relativity in a series of papers published in 1915–1916.

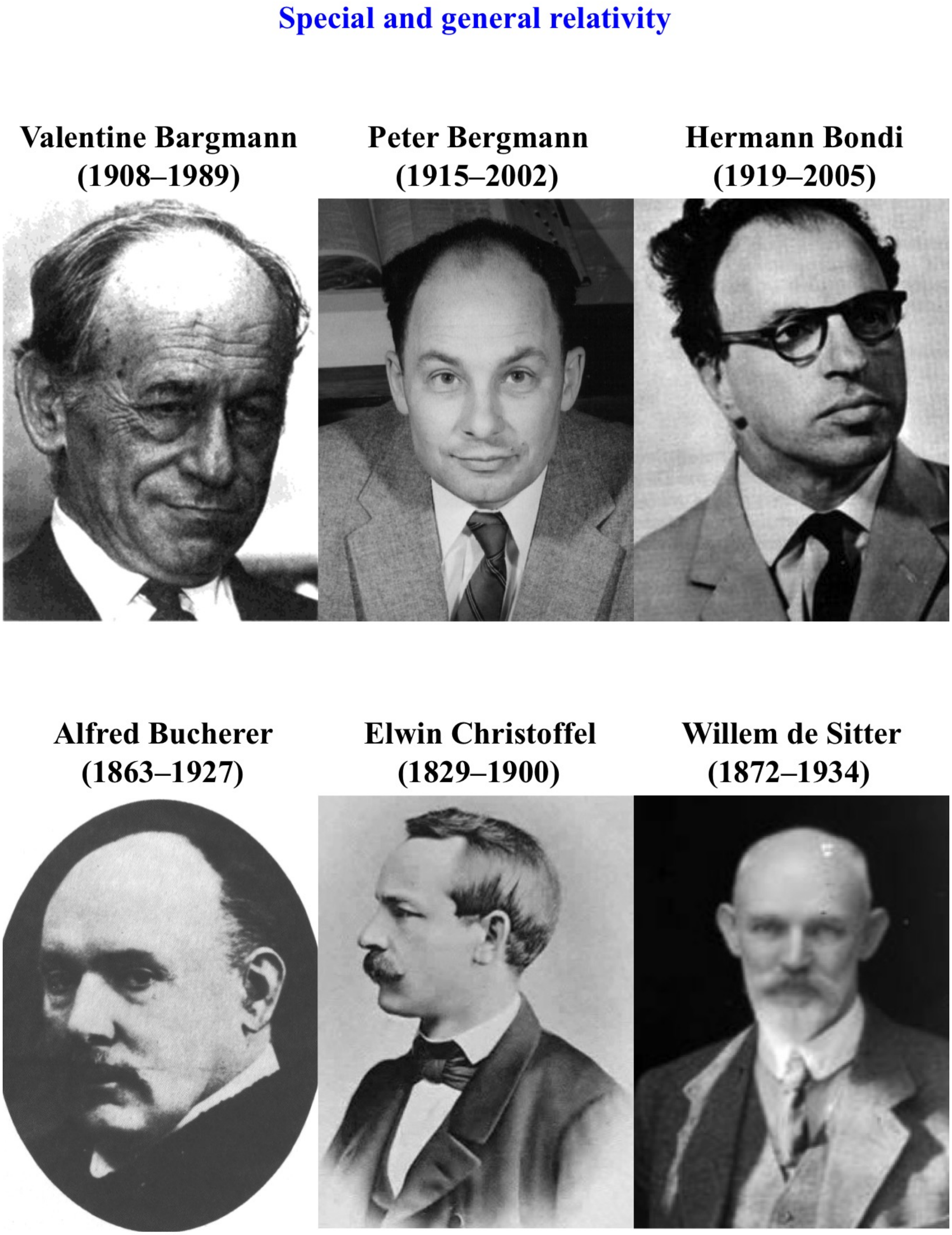

Special and general relativity
Valentine Bargmann (1908–1989)
Peter Bergmann (1915–2002)
Hermann Bondi (1919–2005)
Alfred Bucherer (1863–1927)
Elwin Christoffel (1829–1900)
Willem de Sitter (1872–1934)

Figure 5.26: Other creators who made significant contributions to special and general relativity included Valentine Bargmann, Peter Bergmann, Hermann Bondi, Alfred Bucherer, Elwin Christoffel, and Willem de Sitter.

Special and general relativity

Loránd Eötvös (1848–1919)

Ludwig Flamm (1885–1964)

Erwin Finlay-Freundlich (1885–1964)

George Gamow (1904–1968)

Thomas Gold (1920–2004)

Gustav Herglotz (1881–1953)

Figure 5.27: Other creators who made significant contributions to special and general relativity included Loránd Eötvös, Erwin Finlay-Freundlich, Ludwig Flamm, George Gamow, Thomas Gold, and Gustav Herglotz.

Special and general relativity

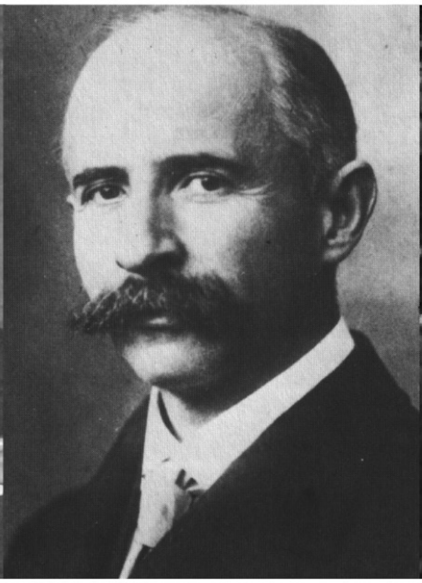
David Hilbert
(1862–1943)

Leopold Infeld
(1898–1968)

Theodor Kaluza
(1885–1954)

Jacobus Kapteyn
(1851–1922)

Walter Kaufmann
(1871–1947)



Oskar Klein
(1894–1977)

Figure 5.28: Other creators who made significant contributions to special and general relativity included David Hilbert, Leopold Infeld, Theodor Kaluza, Jacobus Kapteyn, Walter Kaufmann, and Oskar Klein.

Special and general relativity

Cornelius Lanczos (1893–1974) **Josef Lense (1890–1985)** **Hendrik Lorentz (1853–1928)**

Ernst Mach (1838–1916) **Hermann Minkowski (1864–1909)** **Gunnar Nordström (1881–1923)**

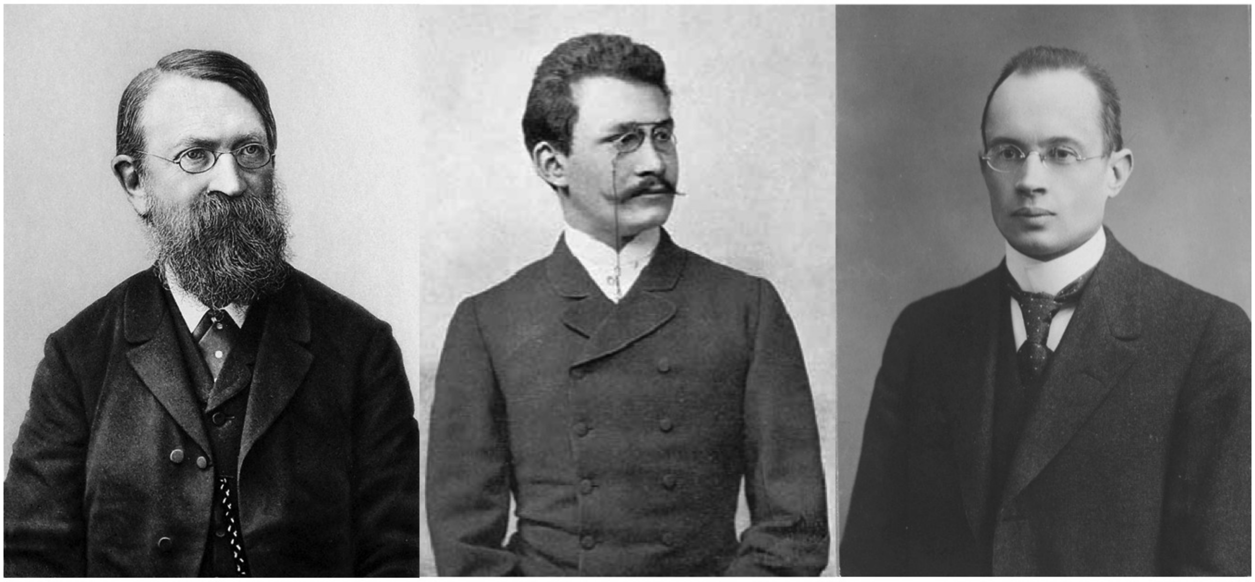


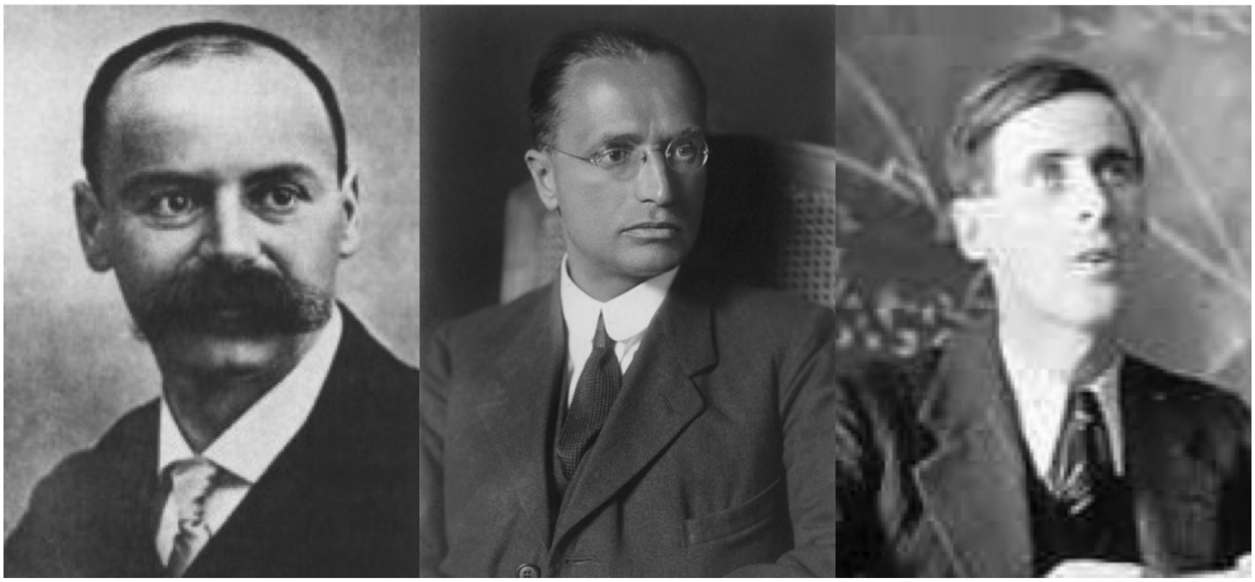
Figure 5.29: Other creators who made significant contributions to special and general relativity included Cornelius Lanczos, Josef Lense, Hendrik Lorentz, Ernst Mach, Hermann Minkowski, and Gunnar Nordström.

Special and general relativity

Jan Oort (1900–1992)

Hans Reissner (1874–1967)

Bernhard Riemann (1826–1866)



Karl Schwarzschild (1873–1916)

Hans Thirring (1888–1976)

Willem Jacob van Stockum (1910–1944)

Figure 5.30: Other creators who made significant contributions to special and general relativity included Jan Oort, Hans Reissner, Bernhard Riemann, Karl Schwarzschild, Hans Thirring, and Willem Jacob van Stockum.

Special and general relativity

Woldemar Voigt
(1850–1919)

Hermann Weyl
(1885–1955)

Carl Wilhelm Wirtz
(1876–1939)

Fritz Zwicky
(1898–1974)

Figure 5.31: Other creators who made significant contributions to special and general relativity included Woldemar Voigt, Hermann Weyl, Carl Wilhelm Wirtz, and Fritz Zwicky.

Over the period 1892–1905, Hendrik Lorentz (Dutch, 1853–1928, 1902 Nobel Prize in Physics—p. 891) developed mathematical formulas for apparent distortions of time and space for objects moving at nearly the speed of light. Those formulas for the distortions are now know as the Lorentz transformations, and they correctly describe special relativistic effects, as Einstein showed. Physicist Robert Weber described Lorentz's contributions to relativity [Weber 1988, pp. 12–13]:

> In 1892 Lorentz put forward the theory of electrons which profoundly influenced the development of theoretical physics. In 1895 he published his mathematical investigation of the effect on the shape of a body produced by its moving with speed v through the ether. [...] Ten years later this result was shown to follow from the theory of relativity.
>
> One deduction from Lorentz's electron theory of matter was that the mass of an electron increased with its velocity. Later experiments with beta rays from radioactive elements confirmed quantitatively his prediction, and once again Lorentz anticipated a finding of the theory of relativity. [...]
>
> In 1904 Lorentz made his greatest contribution to theoretical physics when he showed that James Clerk Maxwell's electromagnetic equations were not invariant with respect to velocity when transformed from one reference frame to another by the hitherto universally accepted Newtonian transformation formulae. These related the time and position coordinates of an event in one reference frame to those assigned to the same event viewed in another frame. Lorentz devised alternative transformation formulae which made Maxwell's equations invariant. Einstein, refusing to believe that there could be one set of such formulae (Newton's) for mechanical relationships and another (Lorentz's) for electrical, accepted Lorentz's transformation formulae as universally applicable. The special or restricted theory of relativity followed from that acceptance.

Actually, Woldemar Voigt (German, 1850–1919) correctly calculated the Lorentz transformations of space and time even earlier, in 1887, although he apparently did not fully consider their physical meaning or effects as in special relativity. Historians of science Christa Jungnickel and Russell McCormmach included a brief mention of Voigt's achievement in their history of early German physics [Jungnickel and McCormmach 1986, Vol. 2, p. 273]:

> In 1915, in honor of the tenth anniversary of the theory of relativity, the editors of the *Physikalische Zeitschrift* reprinted a paper of Voigt's from 1887 on the Doppler principle. This "very early precursor" of relativity theory contained what became known as the Lorentz transformations, which Voigt had derived from a study of the elastic light-ether. Physicists liked to recall this independent discovery, a curiosity that pointed up Voigt's remove from the developments that "modern" physics came to be identified with.
>
> Voigt had reservations about Einstein's relativity principle as a natural law[...]

Ernst Mach (Austrian, 1838–1916) intensively studied the physics of objects approaching or moving faster than the speed of sound waves. (Hence the Mach number of an object is the ratio of its speed to the speed of sound.) However, many of his results carry over to consideration of what would happen if objects approached or moved faster than the speed of light waves. Mach's philosophical approach to space and time also influenced Einstein's development of relativity, as described by historian Volker Berghahn [Berghahn 2005, p. 161]:

> Among the first to do so was Ernst Mach in Vienna who, in light of recent developments, proposed a total separation of metaphysics from the sciences. In his book *Die Mechanik in ihrer Entwicklung* (1883) he even went so far as to portray time and space as metaphysical concepts that should be thrown overboard. Nature, he wrote, did not know such confines. The body's temporal and spatial position was determined only in relation to other objects. Influenced by Mach, Einstein took the final step on this journey[...]

After Einstein worked out the physics and effects of special relativity, in 1907 Hermann Minkowski (German, 1864–1909) showed that those effects could be interpreted as the geometric behavior of four dimensions in which the three spatial dimensions are real numbers and the fourth or time dimension is an imaginary number (or equivalently, spatial dimensions are imaginary numbers and time is a real number). Physicist Abraham Pais summarized Minkowski's contributions [Pais 1982, pp. 151–152]:

> In 1902, Minkowski, at one time Einstein's teacher in Zürich, had moved to the University of Goettingen. There, on November 5, 1907, he gave a colloquium about relativity in which he identified Lorentz transformations with pseudorotations for which
>
> $$x_1^2 + x_2^2 + x_3^2 + x_4^2 \text{ is invariant,} \qquad x_4 = ict$$
>
> where x_1, x_2, x_3 denote the spatial variables. [...] Soon thereafter Minkowski published a detailed paper in which for the first time the Maxwell-Lorentz equations are presented in their modern tensor form, the equations of point mechanics are given a similar treatment, and the inadequacy of the Newtonian gravitation theory from the relativistic point of view is discussed. Terms such as *spacelike vector*, *timelike vector*, *light cone*, and *world line* stem from this paper.
>
> Thus began the enormous formal simplification of special relativity. Initially, Einstein was not impressed and regarded the transcriptions of his theory into tensor form as 'überflüssige Gelehrsamkeit,' (superfluous learnedness). However, in 1912 he adopted tensor methods and in 1916 acknowledged his indebtedness to Minkowski for having greatly facilitated the transition from special to general relativity.

Walter Kaufmann (German, 1871–1947) experimentally demonstrated that the mass of electrons increases with their velocity, as predicted by special relativity. He actually made his first measurements in 1901, before Einstein's first paper on relativity. Immediately after Einstein published his theory, Kaufmann made more accurate measurements of the electron mass increase in 1905. Alfred Bucherer (German, 1863–1927) made even more precise measurements in 1908, helping to distinguish between Einstein's version of special relativity and competing theories of electron mass increases.

To sum up the history of special relativity, Einstein justifiably earned the greatest credit for special relativity, through his discoveries about the physical origins and physical implications of space and time changing with velocity and his 1905 publications that elegantly tied all of that together. Yet if Einstein had never existed, these ideas were percolating within the German-speaking physics community, and it seems likely that Lorentz, Voigt, Minkowski, or others from that community would have arrived at the complete theory of special relativity within a few years after 1905.

5.3.2 General Relativity

General relativity covers the general case in which objects may be accelerating or decelerating. The forces inside an accelerating object are indistinguishable from the forces inside a gravitational field, so general relativity describes the weird things that happen when something gets close to very strong gravitational fields, such as time and space being warped (Fig. 5.32). Important effects that are correctly predicted by general relativity include the gravitational fields of stars, black holes, and wormholes; gravitational red-shifting of light; gravitational bending of light; precession of Mercury's perihelion as it orbits the sun; gravitational waves; and the overall structure and history of the universe.

While Einstein was the dominant figure in special relativity, it is even more evident that he was the primary discoverer of general relativity. Kip Thorne, a Nobel-Prize-winning expert on general relativity, pointed out how extraordinarily farsighted and exceptional Einstein's work was [Thorne 1994, p. 119]:

> In fact, without Einstein the general relativistic laws of gravity might not have been discovered until several decades later.

While's Einstein's theory of relativity was never recognized by the Nobel Committee for Physics, the reaction from other scientists and from the public was overwhelming, as summarized by historians of science Jean Medawar and David Pyke [Medawar and Pyke 2000, p. 33]:

> Einstein was already famous, for his special theory of relativity produced in 1905 and his general theory published in 1917. However, they were still theories and not everyone was convinced. Then in 1919 an expedition, under the British physicist Sir Arthur Eddington, went to tropical Africa to photograph a total eclipse of the sun. This confirmed Einstein's prediction, made in 1917, by showing that light was bent by gravity. Almost universal acceptance followed and Einstein was hailed as a genius.
>
> In London, the discovery was announced by J. J. Thomson, President of the Royal Society, as 'one of the greatest achievements in the history of human thought'. Introducing the findings based on the expedition's photographs, Thomson continued: 'It is not the discovery of an outlying island but of a whole continent of new ideas. It is the greatest discovery in connection with gravity since Newton enunciated his principles.'
>
> Einstein became world-famous not only among scientists but also to the public. He was modest and of a tentative demeanour but that did not dampen the interest in everything he said and did. [...] He was honoured and fêted everywhere as the embodiment of science and the cleverest man in the world. No scientist had then, nor has since, been so admired or so famous.

Despite Einstein's critical role in the development of general relativity, a number of other German-speaking physicists and mathematicians also made important contributions to the theory, before, during, and after Einstein's work.

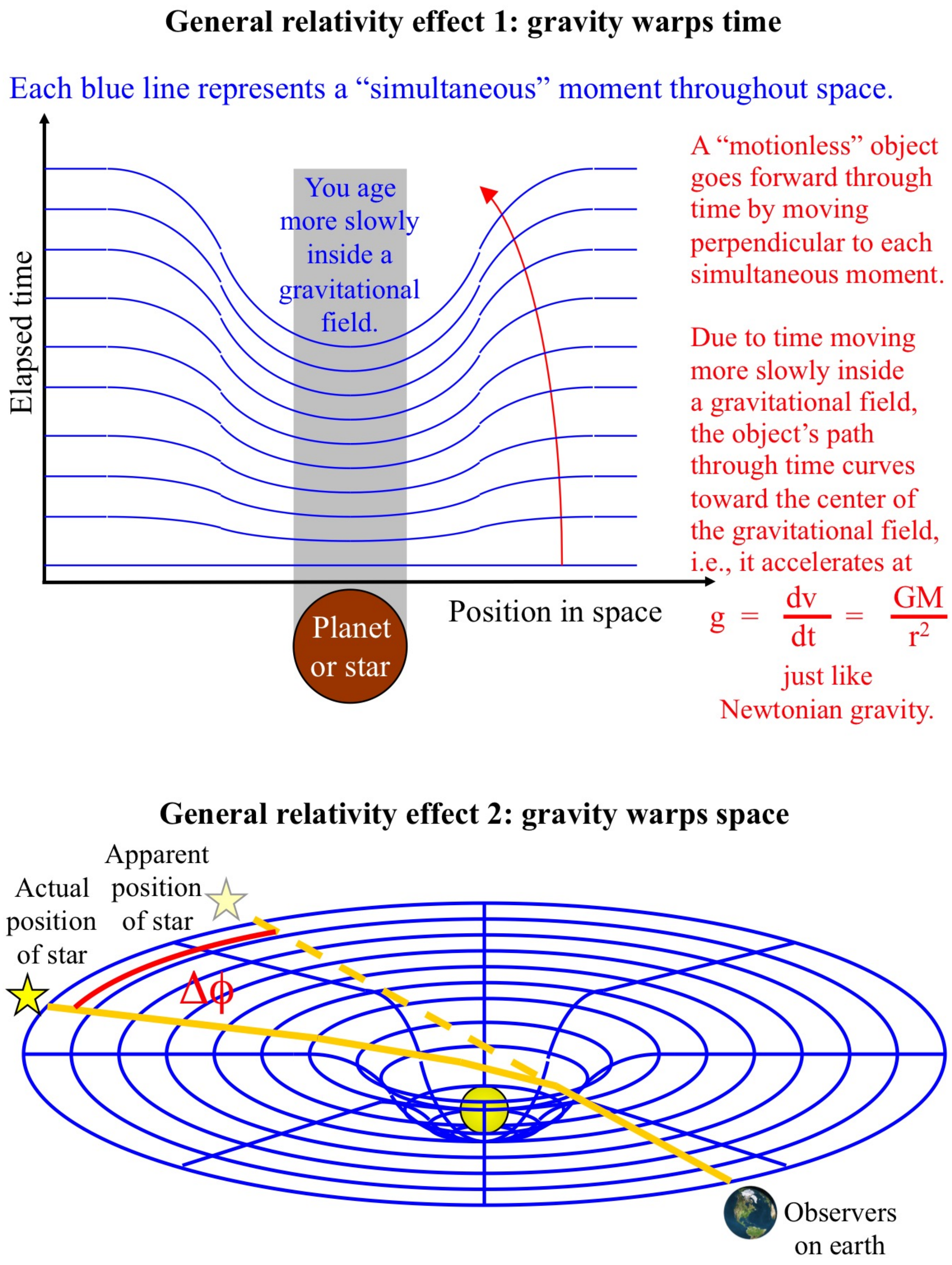

General relativity effect 1: gravity warps time
Each blue line represents a "simultaneous" moment throughout space.
Elapsed time
You age more slowly inside a gravitational field.
Planet or star
Position in space
A "motionless" object goes forward through time by moving perpendicular to each simultaneous moment.
Due to time moving more slowly inside a gravitational field, the object's path through time curves toward the center of the gravitational field, i.e., it accelerates at
$g = \frac{dv}{dt} = \frac{GM}{r^2}$
just like Newtonian gravity.
General relativity effect 2: gravity warps space
Actual position of star
Apparent position of star
$\Delta\phi$
Observers on earth

Figure 5.32: General relativity correctly predicts that gravitational fields warp both time and space, creating several measurable effects.

Just as Ernst Mach's ideas about space and time influenced Einstein's development of special relativity, Mach's ideas about inertia and acceleration also influenced Einstein's development of general relativity.

Likewise, Einstein incorporated Hermann Minkowski's ideas about the geometry of spatial and temporal dimensions, and his tensors for describing those mathematically, into the theory of general relativity.

Bernhard Riemann (German, 1826–1866) was the mathematician who originally developed most of the tensors and other mathematical methods of describing warped dimensions in general that Einstein later applied to describe warped space and time in particular.

Shortly after Riemann's death, Elwin Christoffel (German, 1829–1900) extended Riemann's work by adding some new tensors, now known as Christoffel symbols, to describe additional details of warped dimensions. Einstein ultimately incorporated the Christoffel symbols into general relativity, along with Riemann's tensors.

After Einstein's first papers on general relativity, the mathematician David Hilbert (German, 1862–1943) immersed himself in the new theory and independently published papers on the tensor mathematics of general relativity in parallel with Einstein's further papers on the topic. Gustav Herglotz (Austrian/German, 1881–1953) also published some independent and very early analyses of the tensor methods Einstein was using for general relativity.

As soon as Einstein's first equations for general relativity were available, Einstein, as well as Josef Lense (Austrian, 1890–1985) and Hans Thirring (Austrian, 1888–1976), found that in addition to the distortions of space and time caused by a massive object, if that object is rotating, it will also introduce "twisting" distortions into space and time. The twisting of space and time around massive rotating objects is called the Lense-Thirring effect or sometimes the Einstein-Lense-Thirring effect. Cornelius Lanczos (Hungarian, 1893–1974) and Willem Jacob van Stockum (Dutch, 1910–1944) later found that the spacetime twisting around massive rotating objects could be so extreme under certain circumstances that it might allow travel backward in time for someone circling in the right direction.

Loránd Eötvös (Austro-Hungarian, 1848–1919) conducted early experiments demonstrating the equivalence between gravity and acceleration, or the equivalence between gravitational mass and inertial mass. He also developed extremely sensitive methods of measuring gravitational gradients or variations along the earth's surface. The cgs unit for gravitational gradients is named in his honor, and Einstein cited Loránd Eötvös's experimental results when he published his theory of general relativity.

Immediately after Einstein published his first papers on general relativity in 1915, Karl Schwarzschild (German, 1873–1916) used those to solve the equations of general relativity for the gravitational field of a spherical, non-rotating mass. Einstein was impressed by his solution, and it is still widely used to describe the gravitational field of objects ranging from planets to black holes. The Schwarzschild radius, which appears in Schwarzschild's general mathematical solution, is the size to which a given mass must be compressed to form a black hole. Equivalently, the Schwarzschild radius is the distance from the center of the black hole to the point of no return (also called the event horizon) for objects near the black hole, where the gravitational field becomes so strong that not even light can escape from falling toward the center. If Schwarzschild had not died almost immediately after publishing his result, he might have gone on to make many more contributions to general relativity. Physicist Abraham Pais summarized Schwarzschild's contributions [Pais 1982, p. 255]:

> [O]n January 16, 1916, Einstein read a paper before the Prussian Academy on behalf of Karl Schwarzschild, who was in the German army at the Russian front at that time. The paper contained the exact solution of the static isotropic gravitational field of a mass point, the first instance of a rigorous solution of Einstein's full gravitational field equations. On February 24, 1916, Einstein read another paper by Schwarzschild, this one giving the solution for a mass point in the gravitational field of an incompressible fluid sphere. It is there that the Schwarzschild radius is introduced for the first time. On June 29, 1916, Einstein addressed the Prussian Academy to commemorate Schwarzschild, who had died on May 11 after a short illness contracted at the Russian front. He spoke of Schwarzschild's great talents and contributions both as an experimentalist and a theorist. He also spoke of Schwarzschild's achievements as director (since 1909) of the astrophysical observatory in Potsdam. He concluded by expressing his conviction that Schwarzschild's contributions would continue to play a stimulating role in science.

The same year (1916) that Schwarzschild published his solution for uncharged nonrotating black holes, Hans Reissner (German, 1874–1967) published the solution for charged nonrotating black holes. Gunnar Nordström (Finnish but very closely coupled to the German physics community, 1881–1923) and Hermann Weyl (German, 1885–1955) did further work on this solution.

Likewise, Ludwig Flamm (Austrian, 1885–1964) also responded to Einstein's first papers on general relativity by considering gravitational field solutions for specific cases in 1916. In particular, Flamm considered possible solutions for what would now be regarded as wormholes, or tunnels of warped space and time connecting two different parts of the universe. Hermann Weyl, Einstein, and Nathan Rosen (one of Einstein's close collaborators) later did further mathematical analysis of these wormhole solutions (which were ultimately dubbed Einstein-Rosen bridges).

The astronomer Erwin Finlay-Freundlich (German, 1885–1964) planned some of the first experimental tests of general relativity, including red-shifting of light from the sun and bending of starlight around the sun. Other scientists later carried out those tests and ultimately proved that general relativity was correct.

Gunnar Nordström, Theodor Kaluza (German, 1885–1954), and Oskar Klein (Swedish but very closely coupled to the German physics community, 1894–1977) considered how to extend Einstein's theory of general relativity to include extra dimensions and other forces such as electromagnetism.

Willem de Sitter (Dutch, 1872–1934) collaborated with Einstein to apply general relativity to describe various possible scenarios for the structure and history of the universe, and they both agreed that the equations of general relativity appeared to predict an expanding (or possibly contracting) universe. Historian Thomas Levenson wrote about the first interactions of de Sitter and Einstein regarding the theoretical discovery that the universe could be expanding [Levenson 2003, p. 135]:

> In February 1917 Willem De Sitter, professor of astronomy at the University of Leyden in the Netherlands, responded to Einstein's theory almost as soon as it appeared by

> proposing a model of an expanding universe. Einstein looked for some flaw in De Sitter's work that could rule out so unsettling a notion, but he soon gave up and admitted that there was nothing formally wrong with the idea.

In a series of 1918–1924 publications (Fig. 5.33), Carl Wilhelm Wirtz (German, 1876–1939) measured the distances and the red-shifting of light from other galaxies. The amount of red shift or Doppler shift indicated the galaxies' velocities relative to the Earth. With that data, he experimentally demonstrated that the universe was indeed expanding, and that more distant galaxies were moving away from us faster than galaxies closer to us, in agreement with de Sitter's and Einstein's predictions [Wirtz 1918, 1922a, 1922b, 1924, 1936]. Wirtz's first results in this area occurred more than a decade before Edwin Hubble's (American, 1889–1953) first 1929 paper that also showed evidence of the expanding universe. For example, in October 1921 Wirtz wrote [Wirtz 1922a]:

> Alle diese statistischen Erscheinungen lagern sich über den auffälligsten und Hauptvorgang, der sich als ein Auseinandertreiben des Systems den Spiralnebel relativ zu unserm Standpunkt beschreiben läßt. Dann bedeutet z.B. die Abhängigkeit von der galaktischen Breite, daß die Nebel bei den Polen sich rascher von uns entfernen als die Nebel der niedrigeren Breiten, und die Abhängigkeit von der Größenklasse zeigt an, daß die uns nächsten oder auch die massenstarken Spiralnebel eine geringere Auswärtsbewegung besitzen als die fernen oder etwa die massenschwachen Nebel. Daß der Zielpunkt aus den Radialbewegungen der Spiralnebel nichts zu tun hat mit dem Sonnenapex, ist bekannt.

> All of these statistical data result from the most remarkable and main process, which can be described as a driving apart of the system of the spiral galaxies relative to our point of view. Then for example the dependence on the galactic latitude means that the galaxies at the poles move away from us faster than the galaxies of the lower latitudes, and the dependence on the distance indicates that the spiral galaxies closest to us or perhaps the more massive galaxies have a smaller outward movement than the distant or the less massive galaxies. It is known that the target point from the radial movements of the spiral galaxies has nothing to do with the solar apex.

Several years after Wirtz's discovery and publications, Edwin Hubble aggressively promoted himself in public as the discoverer of the expanding universe, and Wirtz's accomplishments have unfortunately been nearly forgotten by history [Kragh and Smith 2003; Seitter and Duerbeck 1999; van den Bergh 2011]. Astronomer Sidney van den Bergh described the situation [van den Bergh 2011]:

> In his 1922 paper Wirtz concludes that either the nearest or the most massive galaxies have the lowest redshifts. From the more extensive observational material available in 1924 Wirtz found that the radial velocities of spiral nebulae grow quite significantly with increasing distance. He was aware of the fact that the General Theory of Relativity predicted that redshifts should increase with increasing distance. Wirtz published his results in the Astronomische Nachrichten, the leading German astronomy journal. (Hubble received an A in his high-school German course [...] and he also read German text books on corporate law [...] so he would have had no trouble reading Wirtz's papers.) [...]
>
> The myth that Hubble discovered the velocity-distance relation seems to have originated with Humason (1931) (who was at that time acting as Hubble's observing assistant).

Thus not only did Hubble's first papers on the expanding universe come more than a decade after Wirtz's first papers on that topic, but there are good reasons to believe that Hubble read the *Astronomische Nachrichten* journal containing Wirtz's papers, repeated Wirtz's astronomical observations, and tried to claim the discovery as his own while not mentioning Wirtz. If that is what happened, then Hubble was actually guilty of gross scientific misconduct. Books of scientific history should be rewritten to give proper credit to Wirtz, not Hubble.

George Gamow (Russian but educated and worked in Germany, lived 1904–1968) built on the earlier work of Einstein, de Sitter, Wirtz, and others regarding the history of the universe. Gamow considered the implications that the universe has been expanding outward ever since a "Big Bang" billions of years ago. Gamow made specific predictions about what evidence such a Big Bang would have produced (such as the production of certain amounts of nuclei and of electromagnetic "echoes" or background radiation) that were later discovered in experiments to be correct.

Following Einstein, de Sitter, and Wirtz, other theoretical physicists also took up the idea of an expanding universe: Alexander Friedman (Russian but published in German, 1888–1925) in 1924, Georges Lemaître (Belgian, 1894–1966) beginning in 1927, and Howard Robertson (American but trained in Germany, 1903–1961) and Arthur Walker (British, 1909–2001) in the 1930s.

In addition to his other predictions, in 1917 Einstein also predicted the properties and physical implications of what he called a "cosmological constant," but what is now called "dark energy," a diffuse field throughout the universe that acts to oppose the attraction of gravity [Pais 1982]. The first experimental evidence of dark energy was detected over 80 years later, in 1998, and much more evidence has been discovered since then (Fig. 4.61).

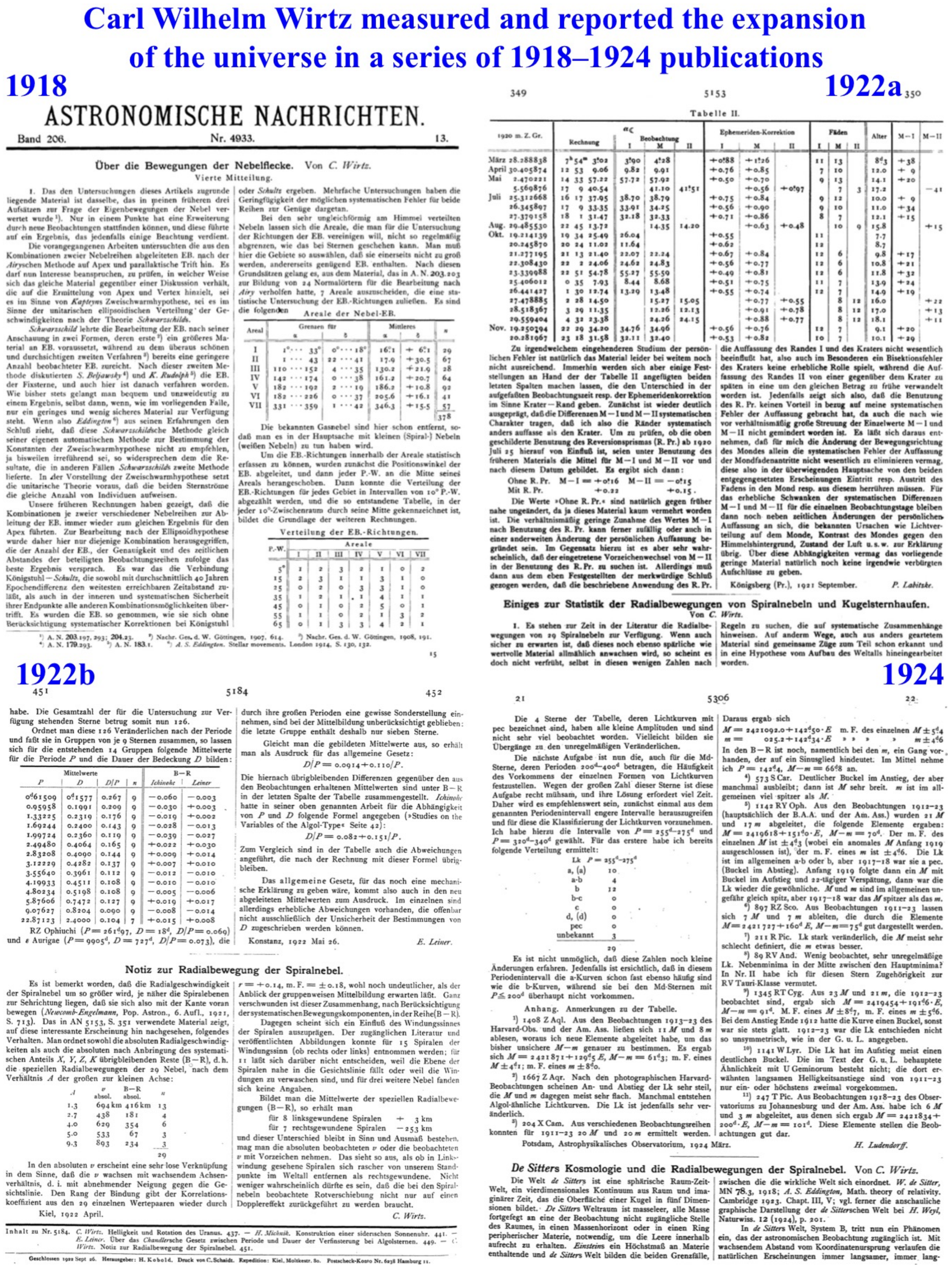
Jacobus Kapteyn (Dutch, 1851–1922), Fritz Zwicky (Swiss, 1898–1974), and Jan Oort (Dutch, 1900–1992) predicted dark matter, mysterious material that adds to the gravitational attraction of the universe but does not appear to be made out of known types of particles, decades before its existence was proven experimentally [John Johnson, Jr., 2019; Stöckli and Müller 2008]. Large amounts of evidence for the existence of dark matter were finally found in the 1970s and 1980s (Fig. 4.60).

Both dark energy and dark matter have had a decisive effect on the history and current state of our entire universe.

Hermann Bondi (Austrian, 1919–2005) and Thomas Gold (Austrian, 1920–2004) used general relativity to analyze a wide range of scenarios such as gravity waves, black holes, and the structure and history of the universe.

In the final decades of Einstein's life, Valentine Bargmann (German, 1908–1989) and Peter Bergmann (German, 1915–2002) collaborated with him on a number of possible extensions and applications of general relativity. Leopold Infeld (Austrian, 1898–1968) also collaborated with Einstein on how to calculate the motions of a large number of objects interacting with each other due to gravity.

For additional information on German-speaking contributions to astrophysics, see Section 4.6.



Carl Wilhelm Wirtz measured and reported the expansion of the universe in a series of 1918–1924 publications

1918

ASTRONOMISCHE NACHRICHTEN.

Band 206. Nr. 4933. 13.

Über die Bewegungen der Nebelflecke. Von *C. Wirtz.*

Vierte Mitteilung.

1. Das den Untersuchungen dieses Artikels zugrunde liegende Material ist dasselbe, das in meinen früheren drei Aufsätzen zur Frage der Eigenbewegungen der Nebel verwertet wurde[1]). Nur in einem Punkte hat eine Erweiterung durch neue Beobachtungen stattfinden können, und diese führte auf ein Ergebnis, das jedenfalls einige Beachtung verdient.

Die vorangegangenen Arbeiten untersuchten die aus den Kombinationen zweier Nebelreihen abgeleiteten EB. nach der *Airy*schen Methode auf Apex und parallaktische Trift hin. Es darf nun Interesse beanspruchen, zu prüfen, in welcher Weise sich das gleiche Material gegenüber einer Diskussion verhält, die auf die Ermittelung von Apex und Vertex hinzielt, sei es im Sinne von *Kapteyns* Zweischwarmhypothese, sei es im Sinne der unitarischen ellipsoidischen Verteilung der Geschwindigkeiten nach der Theorie *Schwarzschilds*.

Schwarzschild lehrte die Bearbeitung der EB. nach seiner Anschauung in zwei Formen, deren erste[2]) ein größeres Material an EB. voraussetzt, während zu dem überaus schönen und durchsichtigen zweiten Verfahren[3]) bereits eine geringere Anzahl beobachteter EB. zureicht. Nach dieser zweiten Methode diskutierten *S. Beljawsky*[4]) und *K. Rudolph*[5]) die EB. der Fixsterne, und auch hier ist danach verfahren worden. Wie bisher stets gelangt man bequem und unzweideutig zu einem Ergebnis, selbst dann, wenn, wie im vorliegenden Falle, nur ein geringes und wenig sicheres Material zur Verfügung steht. Wenn also *Eddington*[6]) aus seinen Erfahrungen den Schluß zieht, daß diese *Schwarzschild*sche Methode gleich seiner eigenen automatischen Methode zur Bestimmung der Konstanten der Zweischwarmhypothese nicht zu empfehlen, ja bisweilen irreführend sei, so widersprechen dem die Resultate, die in anderen Fällen *Schwarzschilds* zweite Methode lieferte. In der Vorstellung der Zweischwarmhypothese setzt die unitarische Theorie voraus, daß die beiden Sternströme die gleiche Anzahl von Individuen aufweisen.

Unsere früheren Rechnungen haben gezeigt, daß die Kombinationen je zweier verschiedener Nebelreihen zur Ableitung der EB. immer wieder zum gleichen Ergebnis für den Apex führten. Zur Bearbeitung nach der Ellipsoidhypothese wurde daher hier nur diejenige Kombination herausgegriffen, die der Anzahl der EB., der Genauigkeit und des zeitlichen Abstandes der beteiligten Beobachtungsreihen zufolge das beste Ergebnis versprach. Es war das die Verbindung Königstuhl—*Schultz*, die sowohl mit durchschnittlich 40 Jahren Epochendifferenz den weitesten erreichbaren Zeitabstand zuläßt, als auch in der inneren und systematischen Sicherheit ihrer Endpunkte alle anderen Kombinationsmöglichkeiten übertrifft. Es wurden die EB. so genommen, wie sie sich ohne Berücksichtigung systematischer Korrektionen bei Königstuhl oder *Schultz* ergeben. Mehrfache Untersuchungen haben die Geringfügigkeit der möglichen systematischen Fehler für beide Reihen zur Genüge dargetan.

Bei den sehr ungleichförmig am Himmel verteilten Nebeln lassen sich die Areale, die man für die Untersuchung der Richtungen der EB. vereinigen will, nicht so regelmäßig abgrenzen, wie das bei Sternen geschehen kann. Man muß hier die Gebiete so auswählen, daß sie einerseits nicht zu groß werden, andererseits genügend EB. enthalten. Nach diesen Grundsätzen gelang es, aus dem Material, das in A. N. **203**.203 zur Bildung von 24 Normalörtern für die Bearbeitung nach *Airy* verholfen hatte, 7 Areale auszuscheiden, die eine statistische Untersuchung der EB.-Richtungen zuließen. Es sind die folgenden

Areale der Nebel-EB.

Areal	Grenzen für α	Grenzen für δ	Mittleres α	Mittleres δ	n
I	1°···33°	0°···18°	16°.1	+6°.1	29
II	1···43	22···41	17.9	+30.5	67
III	110···152	4···35	130.2	+21.9	28
IV	142···174	0···38	161.2	+20.7	64
V	182···192	2···19	186.2	+10.8	92
VI	182···226	0···37	205.6	+16.1	41
VII	331···359	1···42	346.3	+15.5	57
					378

Die bekannten Gasnebel sind hier schon entfernt, sodaß man es in der Hauptsache mit kleinen (Spiral-) Nebeln (weißen Nebeln) zu tun haben wird.

Um die EB.-Richtungen innerhalb der Areale statistisch erfassen zu können, wurden zunächst die Positionswinkel der EB. abgeleitet, und dann jeder P.-W. an die Mitte seines Areals herangeschoben. Dann konnte die Verteilung der EB.-Richtungen für jedes Gebiet in Intervallen von 10° P.-W. abgezählt werden, und die so entstandene Tabelle, in der jeder 10°-Zwischenraum durch seine Mitte gekennzeichnet ist, bildet die Grundlage der weiteren Rechnungen.

Verteilung der EB.-Richtungen.

P.-W.	Areale I	II	III	IV	V	VI	VII
5°	1	2	3	2	1	0	2
15	2	3	1	1	3	1	0
25	0	2	0	3	3	1	0
35	1	2	1	1	4	1	1
45	0	1	0	2	5	0	1
55	1	1	0	2	1	3	2
65	0	1	3	3	4	2	1

---

[1]) A. N. **203**.197, 293; **204**.23. [2]) Nachr. Ges. d. W. Göttingen, 1907, 614. [3]) Nachr. Ges. d. W. Göttingen, 1908, 191. [4]) A. N. **179**.293. [5]) A. N. **183**.1. [6]) *A. S. Eddington.* Stellar movements. London 1914. S. 130, 132.

15

1922a

349 5153 350

Tabelle II.

1920 m. Z. Gr.	$\alpha_☾$ Rechnung	Beobachtung I	Beobachtung M	Beobachtung II	Ephemeriden-Korrektion I	Ephemeriden-Korrektion M	Ephemeriden-Korrektion II	Fäden I	Fäden M	Fäden II	Alter	M−I	M−II
März 28.288838	$7^h54^m3^s02$	3^s90	4^s28		$+0^s88$	$+1^s26$		11	13		8^d3	+38	
April 30.405874	12 53 9.06	9.82	9.91		+0.76	+0.85		7	10		12.0	+ 9	
Mai 2.470221	14 33 57.22	57.72	57.92		+0.50	+0.70		9	13		14.1	+20	
5.569876	17 9 40.54		41.10	41^s51		+0.56	$+0^s97$		7	3	17.2		−41
Juli 25.312668	16 17 37.95	38.70	38.79		+0.75	+0.84		9	12		10.0	+ 9	
26.345897	17 9 33.35	33.91	34.25		+0.56	+0.90		9	10		11.0	+34	
27.379158	18 1 31.47	32.18	32.33		+0.71	+0.86		8	7		12.1	+15	
Aug. 29.485530	22 45 13.72		14.35	14.20		+0.63	+0.48		10	9	15.8		+15
Okt. 19.214139	19 34 25.49	26.04			+0.55			11			7.7		
20.245870	20 24 11.02	11.64			+0.62			12			8.7		
21.277195	21 13 21.40	22.07	22.24		+0.67	+0.84		12	6		9.8	+17	
22.308430	22 2 24.06	24.62	24.83		+0.56	+0.77		12	6		10.8	+21	
23.339988	22 51 54.78	55.27	55.59		+0.49	+0.81		12	6		11.8	+32	
25.406012	0 35 7.93	8.44	8.68		+0.51	+0.75		11	7		13.9	+24	
26.441427	1 30 12.74	13.29	13.48		+0.55	+0.74		12	7		14.9	+19	
27.478885	2 28 14.50		15.27	15.05		+0.77	+0.55		8	12	16.0		+22
28.518367	3 29 11.35		12.26	12.13		+0.91	+0.78		8	12	17.0		+13
29.559404	4 32 23.38		24.26	24.15		+0.88	+0.77		8	12	18.1		+11
Nov. 19.250794	22 29 34.20	34.76	34.96		+0.56	+0.76		12	7		9.1	+20	
20.281967	23 18 31.58	32.11	32.40		+0.53	+0.82		10	7		10.1	+29	

Zu irgendwelchem eingehenderen Studium der persönlichen Fehler ist natürlich das Material leider bei weitem noch nicht ausreichend. Immerhin werden sich aber einige Feststellungen an Hand der der Tabelle II angefügten beiden letzten Spalten machen lassen, die den Unterschied in der aufgefaßten Beobachtungszeit resp. der Ephemeridenkorrektion im Sinne Krater—Rand geben. Zunächst ist wieder deutlich ausgeprägt, daß die Differenzen M—I und M—II systematischen Charakter tragen, daß ich also die Ränder systematisch anders auffasse als den Krater. Um zu prüfen, ob die oben geschilderte Benutzung des Reversionsprismas (R. Pr.) ab 1920 Juli 25 hierauf von Einfluß ist, seien unter Benutzung des früheren Materials die Mittel für M—I und M—II vor und nach diesem Datum gebildet. Es ergibt sich dann:

Ohne R. Pr. M—I = $+0^s16$ M—II = -0^s15
Mit R. Pr. +0.22 +0.15.

Die Werte »Ohne R. Pr.« sind natürlich gegen früher nahe ungeändert, da ja dieses Material kaum vermehrt worden ist. Die verhältnismäßig geringe Zunahme des Wertes M—I nach Benutzung des R. Pr. kann ferner zufällig oder auch in einer anderweiten Änderung der persönlichen Auffassung begründet sein. Im Gegensatz hierzu ist es aber sehr wahrscheinlich, daß der eingetretene Vorzeichenwechsel von M—II in der Benutzung des R. Pr. zu suchen ist. Allerdings muß dann aus dem eben Festgestellten der merkwürdige Schluß gezogen werden, daß die beschriebene Anwendung des R. Pr. die Auffassung des Randes I und des Kraters nicht wesentlich beeinflußt hat, also auch im Besonderen ein Bisektionsfehler des Kraters keine erhebliche Rolle spielt, während die Auffassung des Randes II von einer gegenüber dem Krater zu späten in eine um den gleichen Betrag zu frühe verwandelt worden ist. Jedenfalls zeigt sich also, daß die Benutzung des R. Pr. keinen Vorteil in bezug auf meine systematischen Fehler der Auffassung gebracht hat, da auch die nach wie vor verhältnismäßig große Streuung der Einzelwerte M—I und M—II nicht gemindert worden ist. Es läßt sich daraus entnehmen, daß für mich die Änderung der Bewegungsrichtung des Mondes allein die systematischen Fehler der Auffassung der Mondfadenantritte nicht wesentlich zu eliminieren vermag, diese also in der überwiegenden Hauptsache von den beiden entgegengesetzten Erscheinungen Eintritt resp. Austritt des Fadens in den Mond resp. aus diesem herrühren müssen. Für das erhebliche Schwanken der systematischen Differenzen M—I und M—II für die einzelnen Beobachtungstage bleiben dann noch neben zeitlichen Änderungen der persönlichen Auffassung an sich, die bekannten Ursachen wie Lichtverteilung auf dem Monde, Kontrast des Mondes gegen den Himmelshintergrund, Zustand der Luft u. s. w. zur Erklärung übrig. Über diese Abhängigkeiten vermag das vorliegende geringe Material natürlich noch keine irgendwie verbürgten Aufschlüsse zu geben.

Königsberg (Pr.), 1921 September. *P. Labitzke.*

Einiges zur Statistik der Radialbewegungen von Spiralnebeln und Kugelsternhaufen.

Von *C. Wirtz.*

1. Es stehen zur Zeit in der Literatur die Radialbewegungen von 29 Spiralnebeln zur Verfügung. Wenn auch sicher zu erwarten ist, daß dieses noch ebenso spärliche wie wertvolle Material allmählich anwachsen wird, so scheint es doch nicht verfrüht, selbst in diesen wenigen Zahlen nach Regeln zu suchen, die auf systematische Zusammenhänge hinweisen. Auf anderm Wege, auch aus anders geartetem Material sind gemeinsame Züge zum Teil schon erkannt und in eine Hypothese vom Aufbau des Weltalls hineingearbeitet worden.

1922b

451 5184 452

habe. Die Gesamtzahl der für die Untersuchung zur Verfügung stehenden Sterne betrug somit nun 126.

Ordnet man diese 126 Veränderlichen nach der Periode und faßt sie in Gruppen von je 9 Sternen zusammen, so lassen sich für die entstehenden 14 Gruppen folgende Mittelwerte für die Periode *P* und die Dauer der Bedeckung *D* bilden:

Mittelwerte *P*	*D*	*D/P*	*n*	B−R *Ichinohe*	B−R *Leiner*
0^d61509	0^d1577	0.267	9	−0.060	−0.003
0.95958	0.1991	0.209	9	−0.030	+0.003
1.33225	0.2319	0.176	9	−0.019	+0.002
1.69244	0.2400	0.143	9	−0.028	−0.013
1.99724	0.2360	0.119	9	−0.039	−0.027
2.49480	0.4064	0.165	9	+0.022	+0.030
2.83208	0.4090	0.144	9	+0.009	+0.014
3.12229	0.4282	0.137	9	+0.007	+0.010
3.55640	0.3961	0.112	9	−0.012	−0.010
4.19933	0.4511	0.108	9	−0.010	−0.010
4.80234	0.5198	0.108	9	−0.005	−0.006
5.87606	0.7472	0.127	9	+0.019	+0.017
9.07627	0.8204	0.090	9	−0.008	−0.014
22.87123	2.4000	0.104	7	+0.015	+0.008

RZ Ophiuchi ($P = 261^d97$, $D = 18^d$, $D/P = 0.069$) und ε Aurigae ($P = 9905^d$, $D = 727^d$, $D/P = 0.073$), die durch ihre großen Perioden eine gewisse Sonderstellung einnehmen, sind bei der Mittelbildung unberücksichtigt geblieben: die letzte Gruppe enthält deshalb nur sieben Sterne.

Gleicht man die gebildeten Mittelwerte aus, so erhält man als Ausdruck für das allgemeine Gesetz:

$$D/P = 0.0914 + 0.110/P.$$

Die hiernach übrigbleibenden Differenzen gegenüber den aus den Beobachtungen erhaltenen Mittelwerten sind unter B—R in der letzten Spalte der Tabelle zusammengestellt. *Ichinohe* hatte in seiner oben genannten Arbeit für die Abhängigkeit von *P* und *D* folgende Formel angegeben (»Studies on the Variables of the Algol-Type« Seite 42):

$$D/P = 0.082 + 0.151/P.$$

Zum Vergleich sind in der Tabelle auch die Abweichungen angeführt, die nach der Rechnung mit dieser Formel übrigbleiben.

Das allgemeine Gesetz, für das noch eine mechanische Erklärung zu geben wäre, kommt also auch in den neu abgeleiteten Mittelwerten zum Ausdruck. Im einzelnen sind allerdings erhebliche Abweichungen vorhanden, die offenbar nicht ausschließlich der Unsicherheit der Bestimmungen von *D* zugeschrieben werden können.

Konstanz, 1922 Mai 26. *E. Leiner.*

Notiz zur Radialbewegung der Spiralnebel.

Es ist bemerkt worden, daß die Radialgeschwindigkeit der Spiralnebel um so größer wird, je näher die Spiralebenen zur Sehrichtung liegen, daß sie sich also mit der Kante voran bewegen (*Newcomb-Engelmann*, Pop. Astron., 6. Aufl., 1921, S. 713). Das in AN 5153, S. 351 verwendete Material zeigt, auf diese interessante Erscheinung hin nachgesehen, folgendes Verhalten. Man ordnet sowohl die absoluten Radialgeschwindigkeiten als auch die absoluten nach Anbringung des systematischen Anteils *X*, *Y*, *Z*, *K* übrigbleibenden Reste (B—R), d. h. die speziellen Radialbewegungen der 29 Nebel, nach dem Verhältnis *A* der großen zur kleinen Achse:

A	*v* absol.	B−R absol.	*n*
1.3	694 km	416 km	13
2.7	438	181	4
4.0	629	354	6
5.0	533	67	3
9.3	893	234	3
			29

In den absoluten *v* erscheint eine sehr lose Verknüpfung in dem Sinne, daß die *v* wachsen mit wachsendem Achsenverhältnis, d. i. mit abnehmender Neigung gegen die Gesichtslinie. Den Rang der Bindung gibt der Korrelationskoeffizient aus den 29 einzelnen Wertepaaren wieder durch $r = +0.14$, m. F. $= \pm 0.18$, wohl noch undeutlicher, als der Anblick der gruppenweisen Mittelbildung erwarten läßt. Ganz verschwunden ist dieser Zusammenhang, nach Berücksichtigung der systematischen Bewegungskomponenten, in der Reihe (B—R).

Dagegen scheint sich ein Einfluß des Windungssinnes der Spiralen auszuprägen. Der zugänglichen Literatur und veröffentlichten Abbildungen konnte für 15 Spiralen der Windungssinn (ob rechts oder links) entnommen werden; für 11 läßt sich darüber nicht entscheiden, weil die Ebene der Spiralen nahe in die Gesichtslinie fällt oder weil die Windungen zu verwaschen sind, und für drei weitere Nebel fanden sich keine Angaben.

Bildet man die Mittelwerte der speziellen Radialbewegungen (B—R), so erhält man

für 8 linksgewundene Spiralen + 3 km
für 7 rechtsgewundene Spiralen −253 km

und dieser Unterschied bleibt in Sinn und Ausmaß bestehen, mag man die absoluten beobachteten *v* oder die beobachteten *v* mit Vorzeichen nehmen. Das sieht so aus, als ob in Linkswindung gesehene Spiralen sich rascher von unserem Standpunkte im Weltall entfernen als rechtsgewundene. Nicht weniger wahrscheinlich dürfte es sein, daß die bei den Spiralnebeln beobachtete Rotverschiebung nicht nur auf einen Dopplereffekt zurückgeführt zu werden braucht.

Kiel, 1922 April. *C. Wirtz.*

Inhalt zu Nr. 5184. *C. Wirtz.* Helligkeit und Rotation des Uranus. 437. — *H. Michnik.* Konstruktion einer siderischen Sonnenuhr. 441. — *E. Leiner.* Über das *Chandler*sche Gesetz zwischen Periode und Dauer der Verfinsterung bei Algolsternen. 449. — *C. Wirtz.* Notiz zur Radialbewegung der Spiralnebel. 451.

Geschlossen 1922 Sept 26. Herausgeber: H. Kobold. Druck von C. Schaidt. Expedition: Kiel, Moltkestr. 80. Postscheck-Konto Nr. 6238 Hamburg 11.

1924

21 5306 22

Die 4 Sterne der Tabelle, deren Lichtkurven mit pec bezeichnet sind, haben alle kleine Amplituden und sind nicht sehr viel beobachtet worden. Vielleicht bilden sie Übergänge zu den unregelmäßigen Veränderlichen.

Die nächste Aufgabe ist nun die, auch für die Md-Sterne, deren Perioden 200^d–400^d betragen, die Häufigkeit des Vorkommens der einzelnen Formen von Lichtkurven festzustellen. Wegen der großen Zahl dieser Sterne ist diese Aufgabe recht mühsam, und ihre Lösung erfordert viel Zeit. Daher wird es empfehlenswert sein, zunächst einmal aus dem genannten Periodenintervall engere Intervalle herauszugreifen und für diese die Klassifizierung der Lichtkurven vorzunehmen. Ich habe hierzu die Intervalle von $P = 255^d$–275^d und $P = 320^d$–340^d gewählt. Für das erstere habe ich bereits folgende Verteilung ermittelt:

Lk	$P = 255^d$–275^d
a, (a)	10
a-b	4
b	12
b-c	0
c	0
d, (d)	0
pec	0
unbekannt	3
	29

Es ist nicht unmöglich, daß diese Zahlen noch kleine Änderungen erfahren. Jedenfalls ist ersichtlich, daß in diesem Periodenintervall die a-Kurven schon fast ebenso häufig sind wie die b-Kurven, während sie bei den Md-Sternen mit $P \leq 200^d$ überhaupt nicht vorkommen.

Anhang. Anmerkungen zu der Tabelle.

[1]) 1408 Z Aql. Aus den Beobachtungen 1913–23 des Harvard-Obs. und der Am. Ass. ließen sich 11 *M* und 8 *m* ablesen, woraus ich neue Elemente abgeleitet habe, um das bisher unsichere *M*—*m* genauer zu bestimmen. Es ergab sich $M = 2421871 + 129^d5\,E$, $M - m = 61^d3$; m. F. eines $M \pm 4^d1$; m. F. eines $m \pm 8^d0$.

[2]) 1667 Z Aqr. Nach den photographischen Harvard-Beobachtungen scheinen An- und Abstieg der Lk sehr steil, die *M* und *m* dagegen meist sehr flach. Manchmal entstehen Algol-ähnliche Lichtkurven. Die Lk ist jedenfalls sehr veränderlich.

[3]) 204 X Cam. Aus verschiedenen Beobachtungsreihen konnten für 1911–23 20 *M* und 20 *m* ermittelt werden. Daraus ergab sich

$M = 2421092.0 + 142^d50 \cdot E$ m. F. des einzelnen $M \pm 5^d4$
$m = 025.2 + 142^d34 \cdot E$ » » » » $m \pm 4^d6$

In den B—R ist noch, namentlich bei den *m*, ein Gang vorhanden, der auf ein Sinusglied hindeutet. Im Mittel nehme ich $P = 142^d4$, $M - m = 66^d8$ an.

[4]) 573 S Car. Deutlicher Buckel im Anstieg, der aber manchmal ausbleibt; dann ist *M* sehr breit. *m* ist im allgemeinen viel spitzer als *M*.

[5]) 1142 RY Oph. Aus den Beobachtungen 1912–23 (hauptsächlich der B.A.A. und der Am. Ass.) wurden 21 *M* und 17 *m* abgeleitet, die folgende Elemente ergaben: $M = 2419618 + 151^d0 \cdot E$, $M - m = 70^d$. Der m. F. des einzelnen *M* ist $\pm 4^d3$ (wobei ein anomales *M* Anfang 1919 ausgeschlossen ist), der m. F. eines *m* ist $\pm 4^d6$. Die Lk ist im allgemeinen a-b oder b, aber 1917–18 war sie a pec. (Buckel im Abstieg). Anfang 1919 folgte dann ein *M* mit Buckel im Aufstieg und 22-tägiger Verspätung, dann war die Lk wieder die gewöhnliche. *M* und *m* sind im allgemeinen ungefähr gleich spitz, aber 1917–18 war das *M* spitzer als das *m*.

[6]) 897 RZ Sco. Aus Beobachtungen 1911–23 lassen sich 7 *M* und 7 *m* ableiten, die durch die Elemente $M = 2421727 + 160^d\,E$, $M - m = 75^d$ gut dargestellt werden.

[7]) 211 R Pic. Lk stark veränderlich, die *M* meist sehr schlecht definiert, die *m* etwas besser.

[8]) 89 RV And. Wenig beobachtet, sehr unregelmäßige Lk. Nebenminima in der Mitte zwischen den Hauptminima? In Nr. II habe ich für diesen Stern Zugehörigkeit zur RV Tauri-Klasse vermutet.

[9]) 1345 RT Cyg. Aus 23 *M* und 21 *m*, die 1912–23 beobachtet sind, ergab sich $M = 2419454 + 191^d6 \cdot E$, $M - m = 91^d$. M. F. eines $M \pm 8^d7$, m. F. eines $m \pm 5^d6$. Bei dem Anstieg Ende 1912 hatte die Kurve einen Buckel, sonst war sie stets glatt. 1912–23 war die Lk entschieden nicht so unsymmetrisch, wie in der G. u. L. angegeben.

[10]) 1141 W Lyr. Die Lk hat im Aufstieg meist einen deutlichen Buckel. Die im Text der G. u. L. behauptete Ähnlichkeit mit U Geminorum besteht nicht; die dort erwähnten langsamen Helligkeitsanstiege sind von 1911–23 nur ein- oder höchstens zweimal vorgekommen.

[11]) 247 T Pic. Aus Beobachtungen 1918–23 des Observatoriums zu Johannesburg und der Am. Ass. habe ich 6 *M* und 3 *m* abgeleitet, aus denen sich ergab $M = 2421834 + 200^d \cdot E$, $M - m = 101^d$. Diese Elemente stellen die Beobachtungen gut dar.

Potsdam, Astrophysikalisches Observatorium, 1924 März. *H. Ludendorff.*

De Sitters Kosmologie und die Radialbewegungen der Spiralnebel. Von *C. Wirtz.*

Die Welt *de Sitters* ist eine sphärische Raum-Zeit-Welt, ein vierdimensionales Kontinuum aus Raum und imaginärer Zeit, das die Oberfläche einer Kugel in fünf Dimensionen bildet. *De Sitters* Weltraum ist masseleer, alle Masse fortgefegt an eine der Beobachtung nicht zugängliche Stelle des Raumes, in einen Massenhorizont oder in einen Ring peripherischer Materie, notwendig, um die Leere innerhalb aufrecht zu erhalten. *Einsteins* ein Höchstmaß an Materie enthaltende und *de Sitters* Welt bilden die beiden Grenzfälle, zwischen die die wirkliche Welt sich einordnet. *W. de Sitter*, MN **78**.3, 1918; *A. S. Eddington*, Math. theory of relativity. Cambridge 1923. Chapt. III, V; vgl. ferner die anschauliche graphische Darstellung der *de Sitter*schen Welt bei *H. Weyl*, Naturwiss. 12 (1924), p. 201.

In *de Sitters* Welt, System B, tritt nun ein Phänomen ein, das der astronomischen Beobachtung zugänglich ist. Mit wachsendem Abstand vom Koordinatenursprung verlaufen die natürlichen Erscheinungen immer langsamer, immer lang-

Figure 5.33: Carl Wilhelm Wirtz measured and reported the expansion of the universe in a series of 1918–1924 publications [Wirtz 1918, 1922a, 1922b, 1924].

5.4 Non-Relativistic Quantum Physics

Like an Impressionist painting, matter looks clearly delineated and well behaved when seen macroscopically from a distance, but blurry and confusing when viewed microscopically at the level of individual atoms. (Non-relativistic) quantum physics describes the strange behavior of very small things. (Section 5.6 discusses relativistic quantum physics, the even stranger behavior when relativity and quantum physics are combined.)

As shown in Fig. 5.34, there are two fundamental ideas in quantum physics:

- What we normally think of as waves can act like particles; for example, electromagnetic waves can act like discrete particles called photons.
- Conversely, at the microscopic scale, particles of matter can act like blurry waves instead of discrete chunks of solid stuff.

Weird quantum effects of particles acting like waves (and vice versa) generally only happen with things the size of atoms or smaller, because the interrelationship between wave and particle behavior involves a very small physical constant (Planck's constant $h \approx 6.626 \times 10^{-34}$ Joule-seconds). Nevertheless, those quantum phenomena can have profound effects on the behavior of subatomic particles, atoms, and molecules, and therefore on any reactions (chemical or nuclear) in which they are involved, or devices (transistors, lasers, etc.) of which they are a part.

Like relativity, quantum physics was almost entirely a product of the German-speaking world (Figs. 5.35–5.39).[5] Perhaps the most significant contributions to quantum physics from outside the German-speaking world were those of the French physicist Louis de Broglie (1892–1987), who proposed the mathematical relationship between particle momentum and quantum wavelength, and the Danish physicist Niels Bohr (1885–1962), who proposed a simple quantum model of the atom and was closely connected with the German-speaking scientific world throughout his career. In fact, historians are generally in such agreement that quantum physics was primarily a product of the German-speaking world that they have spent decades debating what factors may have promoted that development [Carson et al. 2011].

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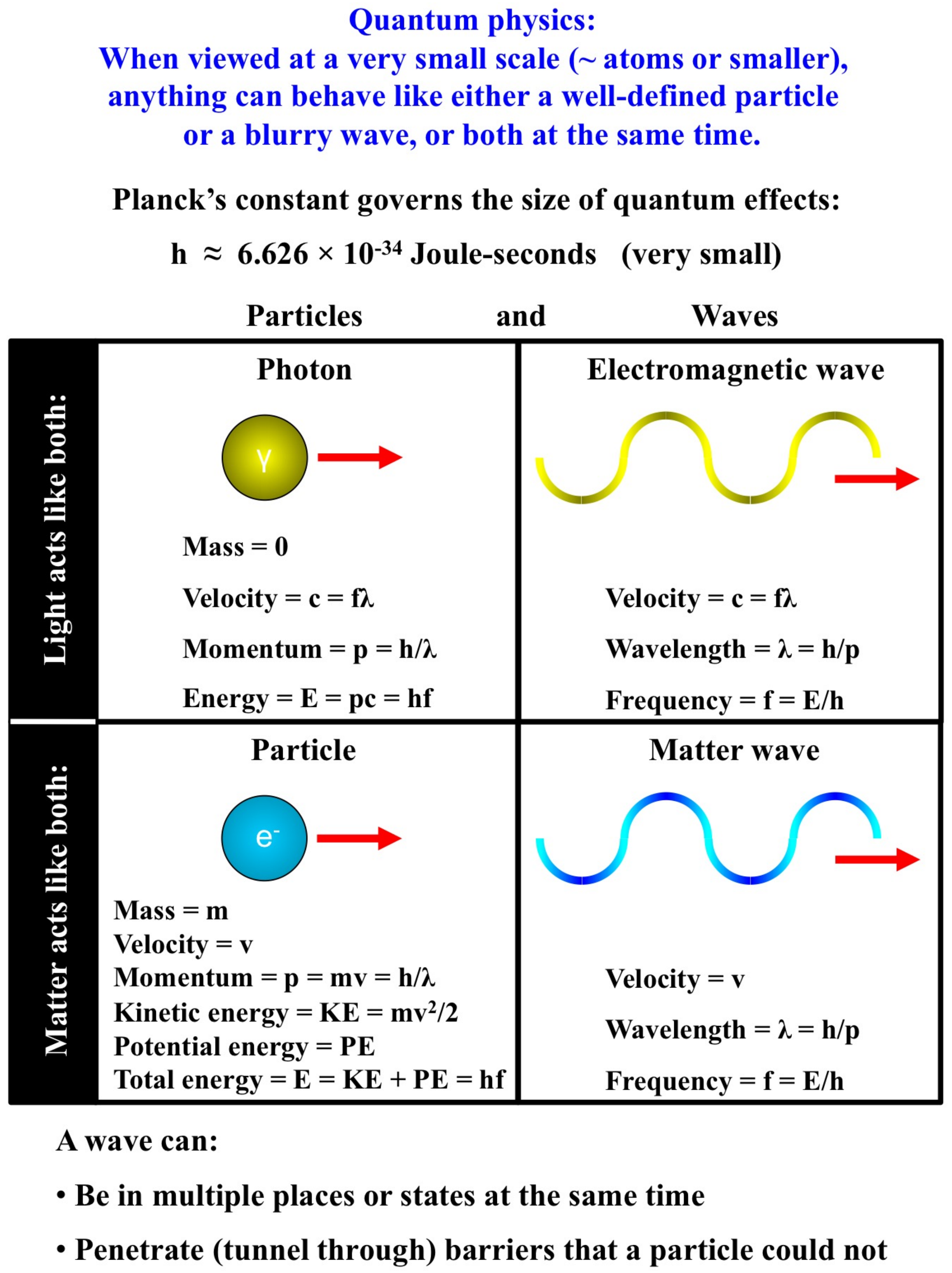
[5] For good overviews of this area, see especially: Laurie Brown et al. 1995; Gamow 1966; Jones 2008; Jungnickel and McCormmach 1986, 2017; Kragh 2002; L'Annunziata 2016; von Meÿenn 1997; Weber 1988.



Quantum physics:
When viewed at a very small scale (~ atoms or smaller), anything can behave like either a well-defined particle or a blurry wave, or both at the same time.

Planck's constant governs the size of quantum effects:

h ≈ 6.626×10^{-34} Joule-seconds (very small)

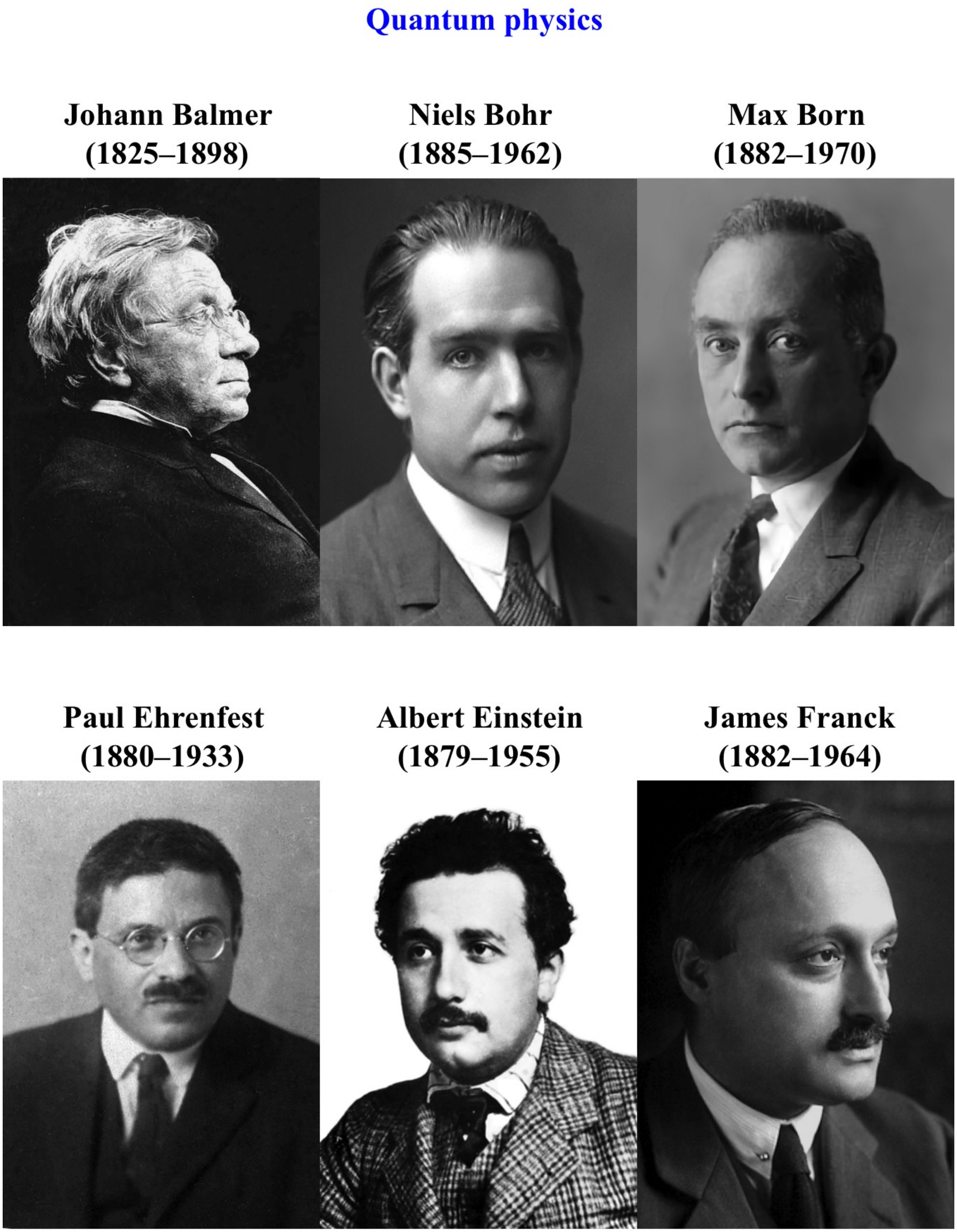
Particles and Waves

	Particles	Waves
Light acts like both:	**Photon** Mass = 0 Velocity = c = fλ Momentum = p = h/λ Energy = E = pc = hf	**Electromagnetic wave** Velocity = c = fλ Wavelength = λ = h/p Frequency = f = E/h
Matter acts like both:	**Particle** Mass = m Velocity = v Momentum = p = mv = h/λ Kinetic energy = KE = $mv^2/2$ Potential energy = PE Total energy = E = KE + PE = hf	**Matter wave** Velocity = v Wavelength = λ = h/p Frequency = f = E/h

A wave can:

- **Be in multiple places or states at the same time**
- **Penetrate (tunnel through) barriers that a particle could not**

Figure 5.34: The central concept of quantum physics is that when the world is viewed at a very small scale (typically at the size of atoms or smaller), anything can behave like either a well-defined particle or a blurry wave, or both at the same time.



Quantum physics

Johann Balmer (1825–1898)

Niels Bohr (1885–1962)

Max Born (1882–1970)

Paul Ehrenfest (1880–1933)

Albert Einstein (1879–1955)

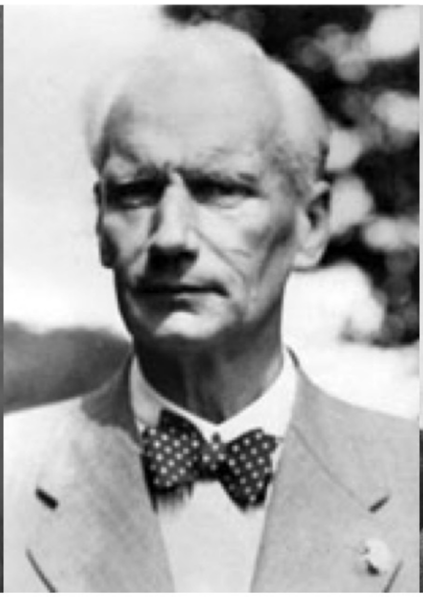
James Franck (1882–1964)

Figure 5.35: Some creators who made significant contributions to quantum physics included Johann Balmer, Niels Bohr (Danish but closely tied to the German scientific community), Max Born, Paul Ehrenfest, Albert Einstein, and James Franck.

Quantum physics

George Gamow
(1904–1968)

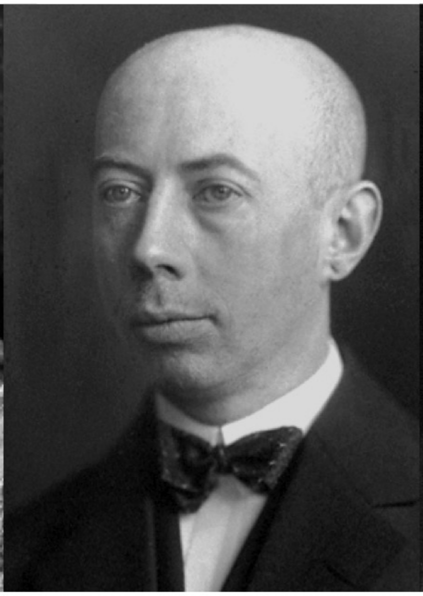
Walther Gerlach
(1889–1979)



Werner Heisenberg
(1901–1976)

Grete Hermann
(1901–1984)

Gustav Hertz
(1887–1975)



Friedrich Hund
(1896–1997)

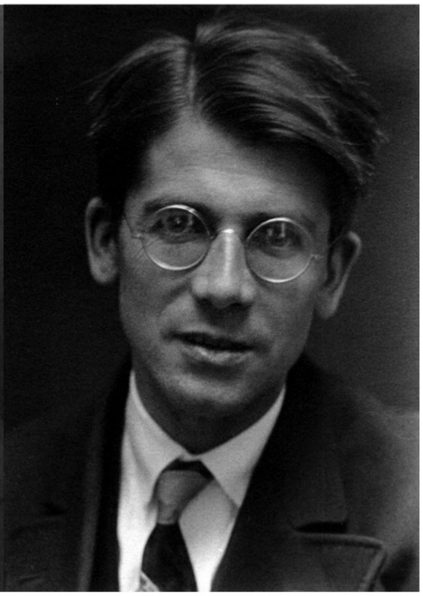


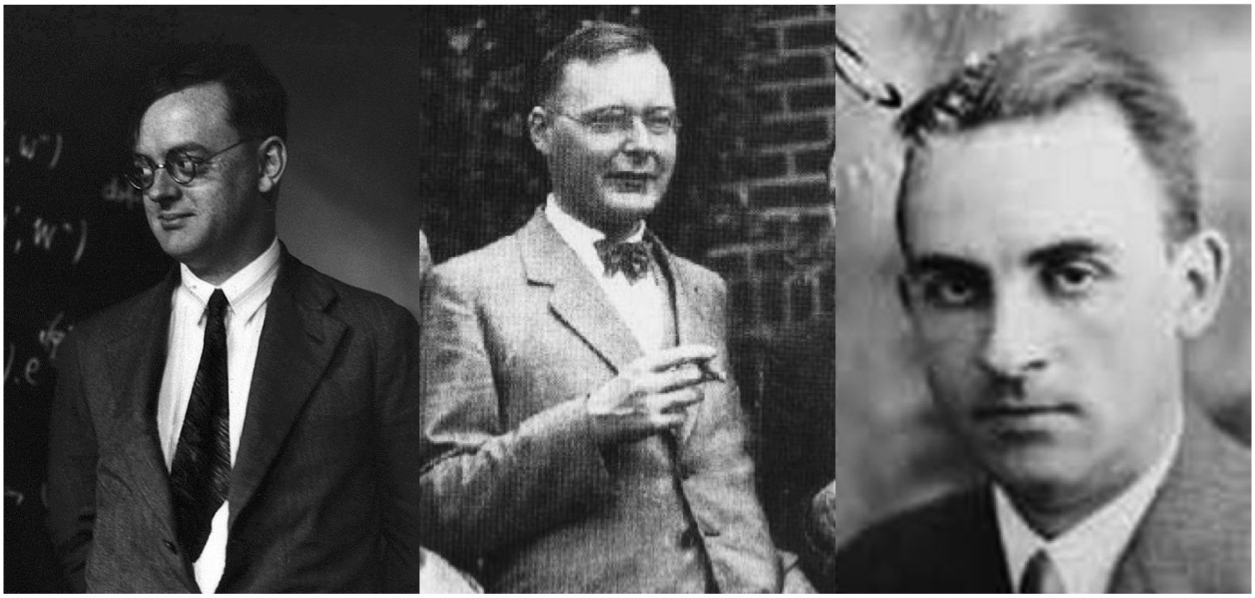
Figure 5.36: Other creators who made significant contributions to quantum physics included George Gamow, Walther Gerlach, Werner Heisenberg, Grete Hermann, Gustav Hertz, and Friedrich Hund.

Quantum physics

Pascual Jordan (1902–1980)

Hendrik Kramers (1894–1952)

Ralph Kronig (1904–1995)



Werner Kuhn (1899–1963)

Alfred Landé (1888–1976)

Hendrik Lorentz (1853–1928)

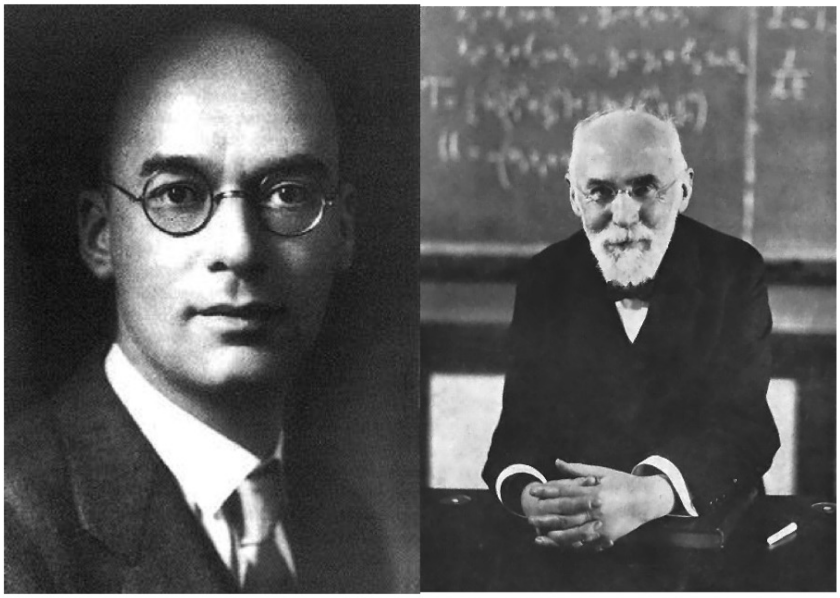
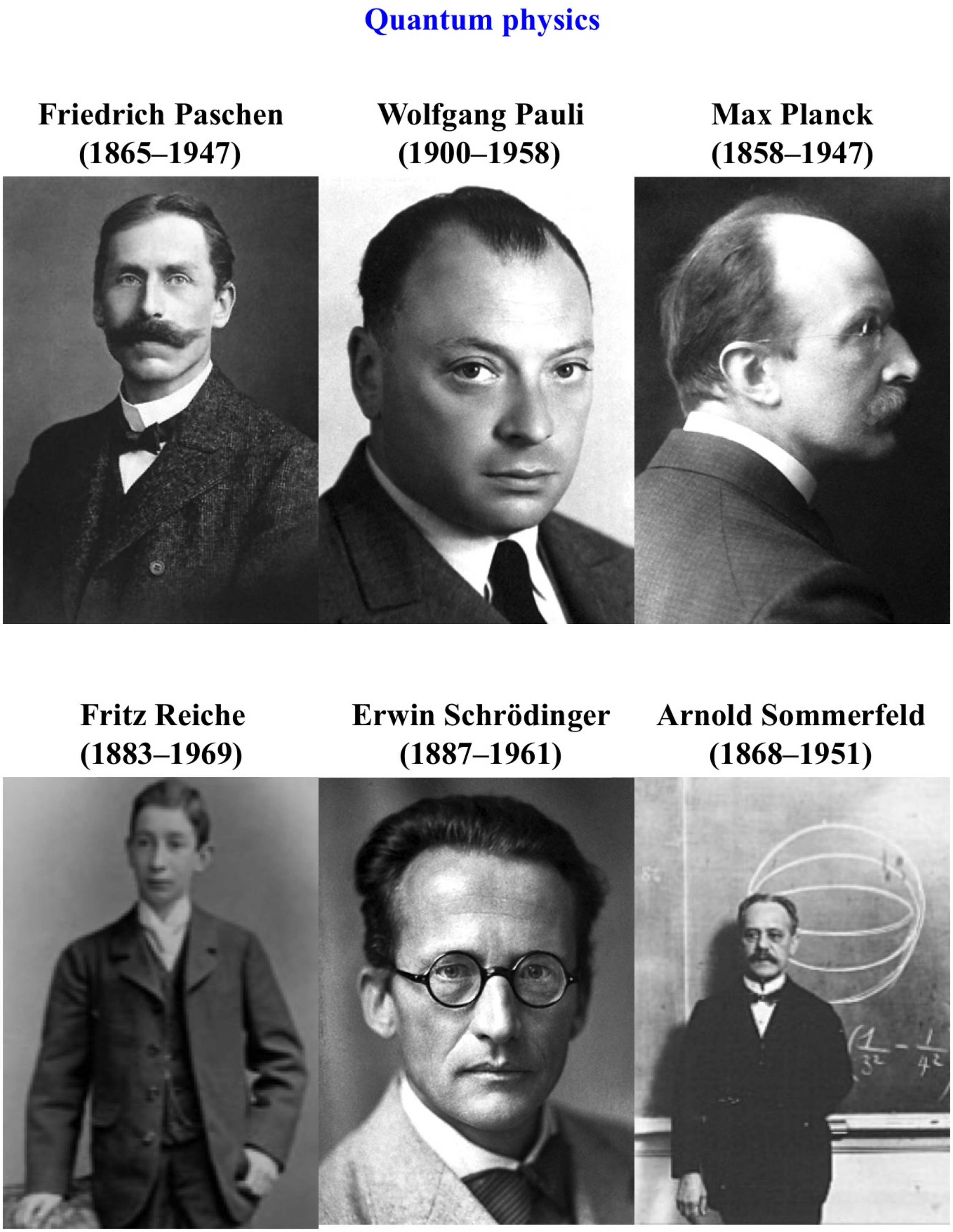


Figure 5.37: Other creators who made significant contributions to quantum physics included Pascual Jordan, Hendrik Kramers, Ralph Kronig, Werner Kuhn, Alfred Landé, and Hendrik Lorentz.



Quantum physics

Friedrich Paschen (1865–1947)

Wolfgang Pauli (1900–1958)

Max Planck (1858–1947)

Fritz Reiche (1883–1969)

Erwin Schrödinger (1887–1961)

Arnold Sommerfeld (1868–1951)

Figure 5.38: Other creators who made significant contributions to quantum physics included Friedrich Paschen, Wolfgang Pauli, Max Planck, Fritz Reiche, Erwin Schrödinger, and Arnold Sommerfeld.

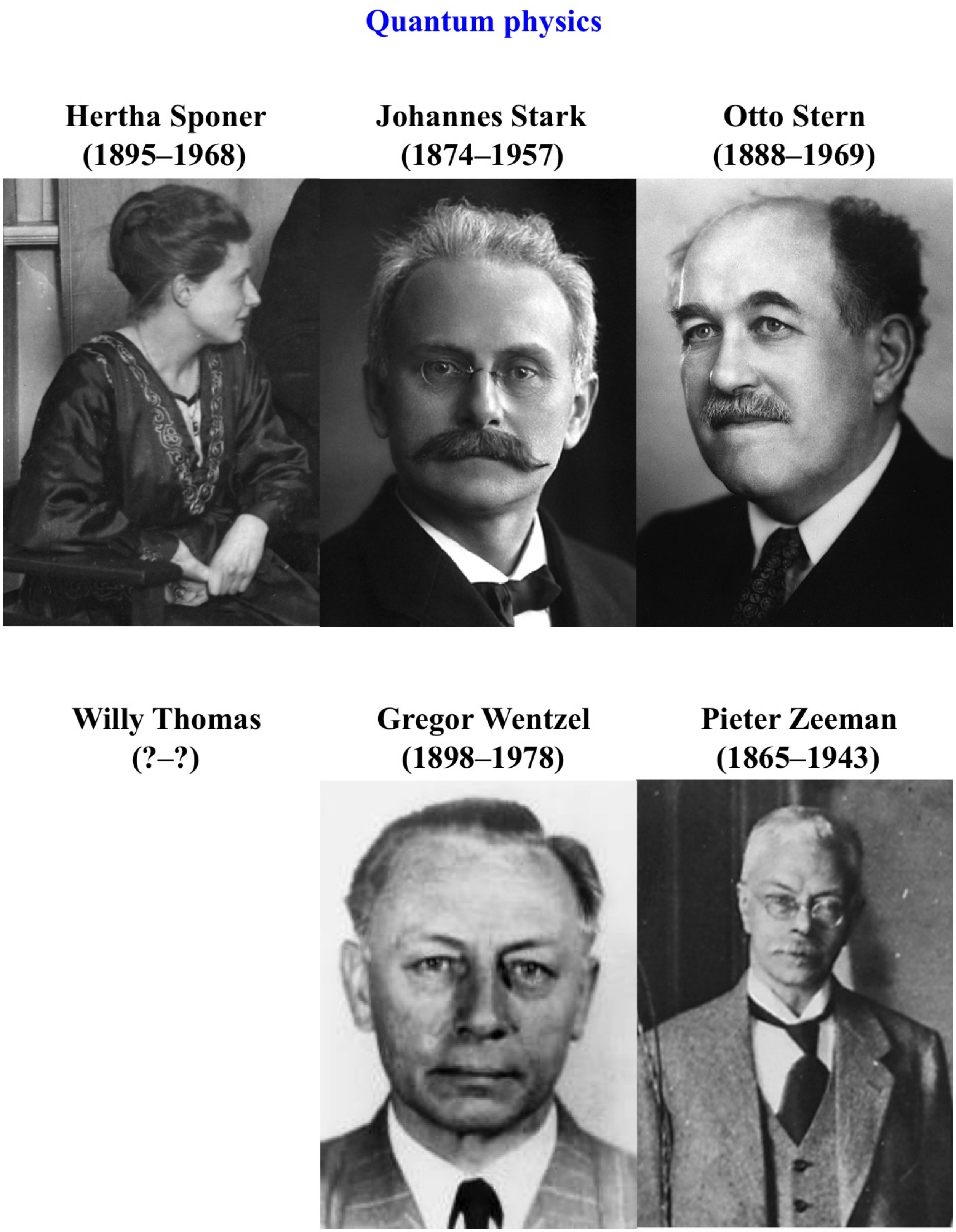

Quantum physics
Hertha Sponer
(1895–1968)
Johannes Stark
(1874–1957)
Otto Stern
(1888–1969)
Willy Thomas
(?–?)
Gregor Wentzel
(1898–1978)
Pieter Zeeman
(1865–1943)

Figure 5.39: Other creators who made significant contributions to quantum physics included Hertha Sponer, Johannes Stark, Otto Stern, Willy Thomas, Gregor Wentzel, and Pieter Zeeman.

5.4.1 Early Steps Toward Quantum Theory

Arguably the first significant work on quantum theory was by Johann Balmer (Swiss, 1825–1898). In 1885, he developed a mathematical formula that correctly described the spacing between different wavelengths of light that could be emitted or absorbed by hydrogen atoms. Many years later, other scientists would show that the spacings Balmer described occurred because quantum physics only allowed certain electron orbits and energy levels in atoms, and therefore certain energies or wavelengths of light that could be emitted or absorbed by electrons transitioning between those atomic energy levels. In 1908, Friedrich Paschen (German, 1865–1947) also demonstrated that the spectral lines continue beyond visible wavelengths well into the infrared spectrum [Jungnickel and McCormmach 1986].

In 1900, Max Planck (German, 1858–1947) made a seminal discovery in quantum physics [Brandon Brown 2015; Planck 1950]. He showed that the spectrum of light and other electromagnetic radiation emitted by a hot object (a "black body" that glows because of its heat) could be explained if the electromagnetic radiation was acting not just as waves, but also as particles (later dubbed "photons"). Planck found that the energy E of the particles was proportional to the frequency f of the waves, where the two quantities were related by a new constant $h \approx 6.626 \times 10^{-34}$ Joule-seconds that came to be known as Planck's constant ($E = hf$). Later scientists would realize that Planck's constant governed a wide variety of quantum effects. Planck won the Nobel Prize in Physics in 1918 for his pioneering work. Dr. Å. G. Ekstrand, President of the Royal Swedish Academy of Sciences, announced the award [https://www.nobelprize.org/prizes/physics/1918/ceremony-speech/]:

> Professor Planck. The Swedish Academy of Sciences has awarded you the Nobel Prize for 1918 in recognition of your epoch-making investigations into the quantum theory. This theory, which was originally connected with black-body radiation, has now demonstrated its validity for other fields and relationships of Nature, and the constant number, named after you, is a proportionality factor which describes a common, but until now unknown, property of matter.

Albert Einstein (German, 1879–1955) expanded on Planck's work regarding how light behaves like quantum particles, or photons [Isaacson 2007; Pais 1982]. Specifically, Einstein showed that the particle nature of light could explain the photoelectric effect, in which there is a clear difference between particles of light that do or do not have enough energy to knock electrons loose in a substance. For helping to further establish and expand the growing field of quantum physics (but not for his contributions to statistical physics or his development of special and general relativity!), Einstein received the Nobel Prize in Physics in 1921. Professor S. Arrhenius, Chairman of the Nobel Committee for Physics, explained [https://www.nobelprize.org/prizes/physics/1921/ceremony-speech/]:

> There is probably no physicist living today whose name has become so widely known as that of Albert Einstein. Most discussion centres on his theory of relativity. This pertains essentially to epistemology and has therefore been the subject of lively debate in philosophical circles. It will be no secret that the famous philosopher Bergson in Paris has challenged this theory, while other philosophers have acclaimed it wholeheartedly. The theory in question also has astrophysical implications which are being rigorously examined at the present time.
>
> Throughout the first decade of this century the so-called Brownian movement stimulated the keenest interest. In 1905 Einstein founded a kinetic theory to account for this

> movement by means of which he derived the chief properties of suspensions, i.e. liquids with solid particles suspended in them. This theory, based on classical mechanics, helps to explain the behaviour of what are known as colloidal solutions, a behaviour which has been studied by Svedberg, Perrin, Zsigmondy and countless other scientists within the context of what has grown into a large branch of science, colloid chemistry.
>
> A third group of studies, for which in particular Einstein has received the Nobel Prize, falls within the domain of the quantum theory founded by Planck in 1900. This theory asserts that radiant energy consists of individual particles, termed "quanta", approximately in the same way as matter is made up of particles, i.e. atoms. This remarkable theory, for which Planck received the Nobel Prize for Physics in 1918, suffered from a variety of drawbacks and about the middle of the first decade of this century it reached a kind of impasse. Then Einstein came forward with his work on specific heat and the photoelectric effect. This latter had been discovered by the famous physicist Hertz in 1887. He found that an electrical spark passing between two spheres does so more readily if its path is illuminated with the light from another electrical discharge. A more exhaustive study of this interesting phenomenon was carried out by Hallwachs who showed that under certain conditions a negatively charged body, e.g. a metal plate, illuminated with light of a particular colour—ultraviolet has the strongest effect—loses its negative charge and ultimately assumes a positive charge. In 1899 Lenard demonstrated the cause to be the emission of electrons at a certain velocity from the negatively charged body. The most extraordinary aspect of this effect was that the electron emission velocity is independent of the intensity of the illuminating light, which is proportional only to the number of electrons, whereas the velocity increases with the frequency of the light. Lenard stressed that this phenomenon was not in good agreement with the then prevailing concepts. [...]
>
> Einstein's law of the photo-electrical effect has been extremely rigorously tested by the American Millikan and his pupils and passed the test brilliantly. Owing to these studies by Einstein the quantum theory has been perfected to a high degree and an extensive literature grew up in this field whereby the extraordinary value of this theory was proved. Einstein's law has become the basis of quantitative photo-chemistry in the same way as Faraday's law is the basis of electro-chemistry.

While some physicists were exploring various aspects of the wave/particle duality of light, other physicists were investigating aspects of what ultimately proved to be the wave/particle duality of electrons, as revealed by how the electrons orbiting in atoms emitted and absorbed light. Building on the earlier work by Johann Balmer about the behavior of normal atoms, they studied how atoms responded to strong magnetic or electric fields.

Pieter Zeeman (Dutch, 1865–1943) demonstrated and Hendrik Lorentz (Dutch, 1853–1928) explained how applied magnetic fields shift the energy levels of electrons orbiting in atoms, and therefore the wavelengths of light that they absorb and emit [Jungnickel and McCormmach 1986]. For this work, they both won the Nobel Prize in Physics in 1902. Professor Hj. Théel, President of the Royal Swedish Academy of Sciences, remarked upon the importance of their discovery [https://www.nobelprize.org/prizes/physics/1902/ceremony-speech/]:

> The greatest credit for the further development of the electromagnetic theory of light

> is due to Professor Lorentz, whose theoretical work on this subject has borne the richest fruit. While Maxwell's theory is free from any assumptions of an atomistic nature, Lorentz starts from the hypothesis that in matter extremely small particles, called electrons, are the carriers of certain specific charges. These electrons move freely in so-called conductors and thus produce an electrical current, whereas in non-conductors their movement is apparent through electrical resistance. Starting from this simple hypothesis, Lorentz has been able not only to explain everything that the older theory explained but, in addition, to overcome some of its greatest shortcomings.
>
> [...] Guided by the electromagnetic theory of light, Zeeman took up Faraday's last experiment, and, after many unsuccessful attempts, finally succeeded in demonstrating that the radiation from a source of light changes its nature under the influence of magnetic forces in such a way that the different spectral lines of which it consisted were resolved into several components. The consequences of this discovery give a magnificent example of the importance of theory to experimental research. Not only was Professor Lorentz, with the aid of his electron theory, able to explain satisfactorily the phenomena discovered by Professor Zeeman, but certain details which had hitherto escaped Professor Zeeman's attention could also be foreseen, and were afterwards confirmed by him. He showed, in fact, that the spectral lines which were split under the influence of magnetism consisted of polarized light, or in other words that the light vibrations are orientated in one particular way under the influence of the magnetic force, and in a way which varies according to the direction of the beam of light in relation to this force.
>
> For the physicist this discovery—the Zeeman effect—represents one of the most important experimental advances that recent decades have to show. For, through the demonstration that light is affected by magnetism in accordance with the same laws as vibrating electrically charged particles, clearly not only has the strongest support been given to the electromagnetic theory of light, but the consequences of Zeeman's discovery promise to yield the most interesting contributions to our knowledge of the constitution of spectra and of the molecular structure of matter. For these reasons the Swedish Royal Academy of Sciences has come to the conclusion that the discovery outlined here is of such great importance for the understanding of the connection between the forces of Nature and for the development of physical science that its recognition by the award of the Nobel Prize for Physics is justified. The Academy also bore in mind the great part which Professor Lorentz has played in the following up of this discovery through his masterly theory of electrons, which is moreover of the greatest significance as a guiding principle in various other realms.

Alfred Landé (German, 1888–1976) later showed that the Zeeman effect was influenced by both the spin and orbital angular momentum of electrons in atoms. A factor in the relevant equations is still known as the Landé g-factor.

Likewise, Johannes Stark (German, 1874–1957) discovered how applied electric fields shift the energy levels of electrons orbiting in atoms, and hence the wavelengths of light that they absorb and emit [Jungnickel and McCormmach 1986]. The specific effects were somewhat different than those induced by magnetic fields, so they provided important new information about the quantum behavior of electrons in atoms. For these experiments, Stark won the Nobel Prize in Physics in 1919. Dr. Å.G. Ekstrand, President of the Royal Swedish Academy of Sciences, announced the award [https://www.nobelprize.org/prizes/physics/1919/ceremony-speech/]:

> Professor Stark. Our Academy of Sciences has awarded you the Nobel Prize in Physics for 1919 in recognition of your epoch-making research into the so-called Doppler effect in canal rays, which has given us an insight into the reality of the internal structure of atoms and molecules. The Nobel Prize relates also to your discovery of the splitting of spectral lines in electric fields—a discovery which is of the greatest scientific importance.

In 1914, James Franck (German, 1882–1964) and Gustav Hertz (German, 1887–1975) carried out an important experiment that became known as the Franck-Hertz experiment [L'Annunziata 2016; Weber 1988]. By colliding electrons of various energies with atoms, they demonstrated that electron orbits in atoms only have certain allowed energy levels, as had already been independently suggested by optical experiments. Both Franck and Hertz went on to make many other important contributions to physics, especially later in nuclear weapons programs (Franck in the United States, Hertz first in Germany and then in the Soviet Union—see Chapter 8). For their famous experiment together, though, they won the Nobel Prize in Physics in 1925. Professor C.W. Oseen, a member of the Nobel Committee for Physics, praised their work [https://www.nobelprize.org/prizes/physics/1925/ceremony-speech/]:

> Franck and Hertz have opened up a new chapter in physics, viz., the theory of collisions of electrons on the one hand, and of atoms, ions, molecules or groups of molecules on the other. This should not be interpreted as meaning that Franck and Hertz were the first to ask what happens when an electron collides with an atom or a molecule, or that they were the originators of the general method which paved the way for their discoveries and which consists of the study of the passage of a stream of electrons through a gas. The pioneer in this field is Lenard. But Franck and Hertz have developed and refined Lenard's method so that it has become a tool for studying the structure of atoms, ions, molecules and groups of molecules. By means of this method and not least through the work of Franck and Hertz themselves, a great deal of material has been obtained concerning collisions between electrons and matter of different types. Although this material is important, even more important at the present time is the general finding that Bohr's hypotheses concerning the different states of the atom and the connexion between these states and radiation, have been shown to agree completely with reality.

As already noted, the Danish physicist Niels Bohr used some of these results to propose one of the first quantum models of how electrons orbit in the atom, and how they can emit or absorb photons of electromagnetic energy by changing from one orbit to another. For that work, he won the Nobel Prize in Physics in 1922 [https://www.nobelprize.org/prizes/physics/1922/ceremony-speech/]. Bohr interacted very closely with the greater German-speaking scientific community throughout his long career, hosting visiting German-speaking scientists in Denmark and visiting German-speaking scientists in their home countries and in the U.S. nuclear laboratories that later employed many of them [Jungnickel and McCormmach 1986; Rhodes 1986].

Bohr's atomic models were expanded and extended by Arnold Sommerfeld (German, 1868–1951) [Eckert 2013]. Sommerfeld patiently worked out the theoretical foundations for much of quantum physics, applying it to everything from individual atoms to metallic solids. As a result, his name is still attached to many key formulas and theories, such as the Sommerfeld model of electrons in metals, the Sommerfeld fine structure constant, the Sommerfeld identity, the Sommerfeld approximation, and many others. He was also famed as a teacher and mentor, authoring physics books that were used worldwide and training a vast number of students in his own lab, many of whom went on to make major discoveries themselves. Historian Michael Eckert summed up Sommerfeld's enormous impact [Eckert 2013, p. XI]:

> Who was Arnold Sommerfeld? Along with Max Planck (1858–1947), Albert Einstein (1879–1955), and Niels Bohr (1885–1962), he belongs among the founders of theoretical physics, which developed into an independent discipline during his lifetime (1868–1951). Among his best known achievements is the elaboration of the Bohr atomic theory established a century ago. Even among physicists of the twenty-first century, the "Bohr-Sommerfeld Atom" and the "Sommerfeld fine-structure constant" remain current concepts. Older physicists associate Sommerfeld's name with the first "school" of modern theoretical physics, and with the work known as the "Bible of atomic physics," *Atomic Structure and Spectral Lines.* This legendary textbook was spread throughout the world in many editions and translations, and initiated generations of physics students into the field of nuclear physics. Additionally, Sommerfeld's *Lectures on Theoretical Physics*, published in six volumes, and reissued long after his death in ever new editions, conveys a sense of the charismatic teacher's personality. At the University of Munich, where he taught and pursued research from 1906 for over three decades, the tradition of the Sommerfeld school continues at the "Arnold Sommerfeld Center for Theoretical Physics." [...] A hundred years ago, the Munich "nursery of theoretical physics" (as Sommerfeld liked to describe his institute) was a haven for the new quantum physics. Sommerfeld's students included Nobel Prize winners Peter Debye (1884–1966), Max von Laue (1879–1960), Wolfgang Pauli (1900–1958), Werner Heisenberg (1901–1976), Linus Pauling (1901–1994) and Hans Bethe (1906–2005). With his 81 nominations, Sommerfeld himself holds the sad record of having been proposed for the Nobel Prize more often than any other physicists . . . without ever receiving the coveted distinction.

5.4.2 Final Development of Quantum Theory

Building on the work of Sommerfeld and other early physicists, much of the overarching framework of what became the final version of quantum theory was provided (at least in large part) by Erwin Schrödinger (Austrian, 1887–1961) [Moore 1989] and Werner Heisenberg (German, 1901–1976) [Cassidy 1992, 2009]. The names of these two physicists remain recognized even by the modern general public:

- "Schrödinger's cat" is a thought experiment involving a cat that is both alive and dead at the same time as the result of an unobserved quantum experiment, in order to emphasize the strangeness of the concept that smeared-out quantum waves can be in two different places or in two different states at the same time.

- The "Heisenberg uncertainty principle" describes how trying to make one aspect of a quantum wave (such as its position) less blurry and more accurately measured inevitably causes other aspects of the wave (such as its momentum) to become even more blurry and less accurately measured.

In the mid-1920s, Schrödinger and Heisenberg independently derived two theories of quantum physics that were fully equivalent to each other, yet expressed in very different mathematical terms.

Schrödinger used wave equations to calculate the smoothly varying back-and-forth wiggling motion of matter waves in space and time. Heisenberg preferred to calculate with matrices of numbers, where each number essentially represented how many humps a matter wave had. Ultimately both mathematical approaches gave the same answer, although Schrödinger's approach made it somewhat easier to solve some problems, and Heisenberg's approach made it somewhat easier to solve other problems.

Since the Nobel Committee for Physics had not awarded a prize in 1932, in 1933 it chose to simultaneously award Heisenberg with the 1932 Nobel Prize and Schrödinger with the 1933 Nobel Prize in Physics. Professor H. Pleijel, Chairman of the Nobel Committee for Physics, described how their discoveries fit together [https://www.nobelprize.org/prizes/physics/1933/ceremony-speech/]:

> Since the electrons were the seat of outgoing waves, Schrödinger thought that it should be possible to find a wave equation for the motions executed by the electrons which would define these waves in the same way as the wave equation which determined the propagation of light. From the solution of this wave equation one should be able to select those oscillations which were feasible for the motions within the atoms. He was successful, too, in determining the wave equation for a series of different motions of the electron, and it turned out that these equations gave finite solutions only when the energy of the system had specific discrete values, determined by Planck's constant. In Bohr's theory these discrete energy values of the electron paths were only hypothetical, but in Schrödinger's, on the contrary, they appeared as completely determined by the form of the wave equation. Schrödinger himself, and others after him, have applied his wave theory to various optical problems including the interpretation of the phenomena accompanying the impact between light rays and electrons, investigations into the behaviour of atoms in electric and magnetic fields, the diffraction of light rays, etc. In every direction, values and formulae have been obtained using Schrödinger's theory, which have been in closer agreement with experience than the older theories were. Schrödinger's wave equation has provided a convenient and simple method for handling problems to do with light spectra, and has become an indispensible tool for the present-day physicist.
>
> Somewhat before the appearance of Schrödinger's theory Heisenberg brought out his famous quantum mechanics. Heisenberg started off from quite different standpoints and viewed his problem, from the very beginning, from so broad an angle that it took care of systems of electrons, atoms, and molecules. According to Heisenberg one must start from such physical quantities as permit of direct observation, and the task consists of finding the laws which link these quantities together. The quantities first of all to be considered are the frequencies and intensities of the lines in the spectra of atoms and molecules. Heisenberg now considered the combination of all the oscillations of such a spectrum as one system, for the mathematical handling of which, he set out certain symbolical rules of calculation. It had formerly been determined already that certain kinds of motions within the atom must be viewed as independent from one another to a certain degree, in the same way that a specific difference is made in classical mechanics between parallel motion and rotational motion. It should be mentioned in this connection that in order to explain the properties of a spectrum it had been necessary to assume self-rotation of the positive nuclei and the electrons. These different kinds of motion for atoms and molecules produce different systems in Heisenberg's quantum mechanics. As

> the fundamental factor of Heisenberg's theory can be put forward the rule set out by him with reference to the relationship between the position coordinate and the velocity of an electron, by which rule Planck's constant is introduced into the quantum-mechanics calculations as a determining factor.
>
> Although Heisenberg's and Schrödinger's theories had different starting points and were developed by the use of different processes of thought, they produced the same results for problems treated by both theories.

What is often overlooked is that Heisenberg did not develop the matrix version of quantum physics alone, but rather with other physicists. One of those was Max Born (German, 1882–1970), Heisenberg's mentor at Göttingen [Greenspan 2005]. Born also made a hugely important contribution to Schrödinger's wave version of quantum physics, by showing that the waves represent the probability of where the corresponding particle could be found. Born made numerous other important contributions to theoretical physics, many of which now bear his name (Born approximation, Born equation, Born series, Born-Haber cycle, Born-Infeld theory, Born-Landé equation, Born-Oppenheimer approximation, Born-von Kármán boundary condition, etc.). Over the course of Born's career, he mentored many students and young scientists. In addition to Heisenberg, they included Max Delbrück, Walter Elsasser, Enrico Fermi, Siegfried Flügge, Maria Goeppert-Mayer, Friedrich Hund, Pascual Jordan, Lothar Nordheim, J. Robert Oppenheimer, and Victor Weisskopf. For his contributions to quantum physics, Max Born won the Nobel Prize in Physics in 1954. Professor I. Waller, a member of the Nobel Committee for Physics, explained the importance of Born's innovations [https://www.nobelprize.org/prizes/physics/1954/ceremony-speech/]:

> Research into the laws valid for the movement of the electrons around the nucleus in the centre of the atom has been a central problem for physics during this century. Niels Bohr made a start on the solution to the problem in 1913. But his theory was of a provisional nature. Professor Max Born took an active part in striving to improve it, as did the many followers who gathered round him in Göttingen. During the twenties of this century, Göttingen, together with Copenhagen and Munich, was a place of pilgrimage for researchers in the field of atomic theory. When the young Heisenberg, formerly a pupil of Sommerfeld in Munich and of Bohr in Copenhagen, published his epoch-making preliminary work on the exact laws for atomic phenomena in 1925, he was Born's assistant in Göttingen. His work was immediately continued by Born, who gave logical mathematical form to the Heisenberg theory. Owing to this progress, Born, in collaboration with his pupil Jordan and later with Heisenberg also, was able to expand the latter's original results into a comprehensive theory for atomic phenomena. This theory was called quantum mechanics.
>
> The following year Born got a new result of fundamental significance. Schrödinger had just then found a new formulation for quantum mechanics. Schrödinger's work expanded the earlier ideas of De Broglie which imply that atomic phenomena are connected with a wave undulation. However, Schrödinger had not solved the problem of how it is possible to make statements about the positions and velocities of particles if one knows the wave corresponding to the particle.
>
> Born provided the solution to the problem. He found that the waves determine the probability of the measuring results. For this reason, according to Born, quantum mechanics

> gives only a statistical description. This can be illustrated by a simple example. When you shoot at a target it is possible in principle—according to the older conception—to aim the shot from the start so that it is certain to hit the target in the middle. Quantum mechanics teaches us to the contrary—that in principle we cannot predict where a single shot will hit the target. But we can achieve this much, that from a large number of shots the average point of impact will lie in the middle of the target. In contradiction to the deterministic predictions of the older mechanics, quantum mechanics accordingly poses laws which are of a statistical character, and as regards single phenomena will only determine the probabilities that one or another of various possibilities will occur. For material bodies of ordinary dimensions the uncertainty of the predictions of quantum mechanics is practically of no significance. But in atomic phenomena, on the other hand, it is fundamental. Such a radical break with older ideas could not of course prevail without opposition. But Born's conception is now generally accepted by physicists, with a few exceptions.
>
> In addition to these achievements, which have been rewarded with the Nobel Prize, Born has made fundamental contributions to many fields of physics. In the first place he dedicated his interest to the theory of crystals and has been one of the great pioneers in that field.

Pascual Jordan (German, 1902–1980) played a major role in the development of both nonrelativistic quantum physics and relativistic quantum physics (Section 5.6) [Jones 2008]. Working directly with Heisenberg and Born, he helped to develop the matrix version of quantum theory. He then went on to publish a string of important papers on quantum theory, both alone and in collaboration with various other physicists. The modern *Encyclopedia Britannica* still includes a brief note testifying to his importance [EB 2010, Jordan, Pascual]:

> German physicist who in the late 1920s founded (with Max Born and Werner Heisenberg) quantum mechanics and (with Wolfgang Pauli and Eugene Wigner) quantum electrodynamics.

Nevertheless, other than a few similarly brief mentions or footnotes in modern books, Jordan's important contributions to the development of quantum physics have been largely forgotten by history, perhaps because of his associations with the German government during World War II. Modern historians should examine Jordan's many scientific accomplishments in much more detail than they generally have.

Paul Ehrenfest (Austrian, 1880–1933) made several important contributions to quantum theory [Jones 2008]. His most famous discovery became known as the Ehrenfest theorem. It described mathematically how, even though quantum waves are very blurry, averages of the waves have the same values as classical mechanics would predict for well-defined particles.

Otto Stern (German, 1888–1969) and Walther Gerlach (German, 1889–1979) demonstrated that the angular momentum of atoms was quantized, or could only have certain values, due to quantum effects [L'Annunziata 2016; Weber 1988]. Their experiment was one of the earliest insights into how quantum physics constrains the behavior of rotating things (angular momentum or spin). For this work, which has since become known as the Stern-Gerlach experiment, Stern won the Nobel Prize in Physics in 1943. Professor E. Hulthén, a member of the Nobel Committee for Physics, described the experiment [https://www.nobelprize.org/prizes/physics/1943/ceremony-speech/]:

> The experiment was carried out in Frankfurt in 1920 by Otto Stern and Walter Gerlach, and was arranged as follows: In a small electrically heated furnace, was bored a tiny hole, through which the vapour flowed into a high vacuum so as to form thereby an extremely thin beam of vapour. The molecules in this so-called atomic or molecular beam all fly forwards in the same direction without any appreciable collisions with one another, and they were registered by means of a detector, the design of which there is unfortunately no time to describe here. On its way between the furnace and the detector the beam is affected by a non-homogeneous magnetic field, so that the atoms—if they really are magnetic—become unlinked in one direction or another, according to the position which their magnetic axles may assume in relation to the field. The classical conception was that the thin and clear-cut beam would consequently expand into a diffuse beam, but in actual fact the opposite proved to be the case. The two experimenters found that the beam divided up into a number of relatively still sharply defined beams, each corresponding to one of the just mentioned discrete positional directions of the atoms in relation to the field. This confirmed the space-quantization hypothesis. Moreover, the experiment rendered it possible to estimate the magnetic factors of the electron, which proved to be in close accord with the universal magnetic unit, the so-called "Bohr's magneton".
>
> When Stern had, so to speak, become his own master, having been appointed Head of the Physical Laboratory at Hamburg in 1923, he was able to devote all his energies to perfecting the molecular beam method. Among many other problems investigated there was a particular one which excited considerable interest.
>
> It had already been realized when studying the fine structure of the spectral lines that the actual nucleus of the atom, like the electron, possesses a rotation of its own, a so-called "spin". Owing to the minute size of the nuclear magnet, estimated to be a couple of thousand times smaller than that of the electron, the spectroscopists could only determine its size by devious ways—and that too only very approximately. The immense interest attaching in this connection to a determination of the magnetic factors of the hydrogen nucleus, the so-called proton, was due to the fact that the proton, together with the recently discovered neutron, forms the basic constituent of all the elements of matter; and if these two kinds of particles were to be regarded, like the electron, as true elementary particles, indivisible and uncompounded, then as far as the proton is concerned, its magnetic factor would be as many times smaller than the electron's as its mass is greater than the electron's, implying that the magnetic factor of the proton must be, in round figures, 1,850 times smaller than the electron's. Naturally then, it aroused great interest when, in 1933, Stern and his colleagues made this determination according to the molecular beam method, it being found that the proton factor was about 2½ times greater than had theoretically been anticipated.

Wolfgang Pauli (Austrian, 1900–1958) explained mathematically how angular momentum or spin works in quantum systems, constructing what are now known as Pauli spin matrices [L'Annunziata 2016; Weber 1988]. Moreover, he proved that identical particles with half-integer spin values that are in the same atom or other quantum system do not want to do the exact same thing as each other, which became known as the Pauli exclusion principle. For example, in an atom, each electron finds a way to orbit or spin somewhat differently than every other electron. The same is also true among the protons in the atomic nucleus, and likewise among the neutrons in the nucleus. Pauli won the

Nobel Prize in Physics in 1945. Professor I. Waller, a member of the Nobel Committee for Physics, praised Pauli's discoveries [https://www.nobelprize.org/prizes/physics/1945/ceremony-speech/]/:

> At this stage of the development of atomic theory, Wolfgang Pauli made a decisive contribution through his discovery in 1925 of a new law of Nature, the exclusion principle or Pauli principle. [...]
>
> The principle, first discovered for electrons, has proved to be valid for the nuclei of hydrogen, called protons, and also for the neutrons which are formed in many nuclear reactions. The neutrons are particles which have no charge but have approximately the same masses as the protons. According to present views any atomic nucleus consists of protons and neutrons. The Pauli principle is therefore essential for the description of the properties of atomic nuclei.
>
> Pauli occupies a leading position in present theoretical physics. He has made many other important contributions to different branches of his science, among them several to nuclear physics.

Friedrich Hund (German, 1896–1997) worked out specifically how the electrons in an atom are arranged in accordance with the Pauli exclusion principle [Laurie Brown et al. 1995]. The patterns he found, now called Hund's rules, are still widely used in atomic physics and chemistry.

Other aspects of quantum theory were named after their originators [Laurie Brown et al. 1995]. Gregor Wentzel (German, 1898–1978), Hendrik Kramers (Dutch, 1894–1952), and Léon Brillouin (French, 1889–1969) independently and roughly simultaneously in 1926 proposed what is now known as the Wentzel-Kramers-Brillouin (WKB) approximation for estimating the size of a quantum matter wave under conditions that are too complicated to find exact mathematical solutions. George Gamow (1904–1968) was Russian but studied and worked in Germany before moving to the United States. In Göttingen in 1928, Gamow used the WKB approximation to calculate the rate at which alpha particles can quantum-mechanically tunnel out of the nucleus, introducing a factor still known as the Gamow factor.

Similarly, Willy Thomas (German?, ??–??), Fritz Reiche (German, 1883–1969), and Werner Kuhn (Swiss, 1899–1963) developed the Thomas-Reiche-Kuhn (TRK) sum rule for calculating transitions rates between different energy levels in atoms or other quantum systems [Laurie Brown et al. 1995]. The WKB and TRK methods of calculating quantum effects remain widely used to this day.

Ralph Kronig (German, 1904–1995) made a number of contributions to quantum theory, including early ideas about electron spin, the Kronig-Penney model of electron behavior in crystals, the Kramers-Kronig relations for optical and electronic properties, and other effects [Laurie Brown et al. 1995].

At least two German-speaking women made important contributions to quantum physics that have been largely overlooked by conventional histories, and there are significant parallels in their careers. Hertha Sponer (German, 1895–1968) received her Ph.D. in physics from the University of Göttingen in 1920 and spent her career doing experimental research on quantum effects (including molecular physics and spectroscopy), first in Germany and then in the United States. In 1946 she married James Franck [https://www.deutsche-biographie.de/sfz123855.html]. Grete Hermann (German, 1901–1984) received her Ph.D. in physics from the University of Göttingen in 1926 and spent her career exploring some of the theoretical and philosophical implications of quantum physics, including whether or not the apparent wave-like nature of matter could be explained away as classical particles simply obeying undiscovered "hidden variables" [https://arxiv.org/abs/0812.3986]. Both Sponer and Hermann left Germany during the Third Reich; Sponor did not return to live in Germany until late in life, whereas Hermann returned soon after the war. Sponer and Hermann, and any other women who played important roles in the development of quantum physics, deserve much more attention than they have received.

Within the German-speaking world, the development of non-relativistic quantum physics had a great impact on many other fields, such as:

Cellular respiration (p. 145).

Vision (p. 281).

Photosynthesis (p. 405).

Inorganic chemistry (p. 427).

Organic chemistry (p. 456).

Physical chemistry (p. 594).

Film Photography (p. 624).

Astrophysics (p. 804).

Statistical/thermal physics (p. 901).

Relativistic quantum physics (p. 923).

Lighting technology (p. 957).

Lasers and holography (p. 1023).

Solid state physics/microelectronics (p. 1034).

Infrared vision (p. 1131).

Electron microscopes (p. 1286).

Nuclear diagnostics/therapeutics (p. 1505).

Radiation detectors (p. 1518).

Models of the atomic nucleus (p. 1530).

Nuclear fission reactions (p. 1537).

Nuclear fusion reactions (p. 1542).

5.5 Statistical and Thermal Physics

Statistical and thermal physics deals with the collective behavior of enormous numbers of particles, such as those that make up solids, liquids, gases, plasmas, and even light or other electromagnetic radiation. Heat or thermal energy is a random jittering of those particles; the higher the temperature, the more the particles dance around. Even though one cannot predict the random motions of any individual particle, the laws of statistical and thermal physics can accurately predict the average behavior of a whole population of particles.

Because statistical and thermal physics deals with collections of microscopic particles, it overlaps with quantum physics, which governs the behavior of particles at the microscopic scale (Section 5.4). Many of the same scientists and discoveries were important for both areas. Yet whereas simple quantum physics only calculates the behavior of one or a few particles, statistical physics employs additional mathematical methods to extend those calculations to huge numbers of particles.

Statistical and thermal physics also describes how such a collection of particles will respond to and carry heat energy in a system such as a refrigerator, an engine, an ice crystal, or a blast furnace. Thus this topic has large degrees of overlap with physical chemistry (Section 3.6), solid state physics (Section 6.5), engineering thermodynamics (Section 7.3), aerodynamics (Section 9.2), and other areas.

According to quantum physics, particles can behave like spinning tops, and the allowed angular momentum of their spin comes in units of $\hbar = h/(2\pi)$, where h is Planck's constant (p. 883). Moreover, some particles have a spin value that is an integer multiple of $\hbar$ (e.g. photons that carry the electromagnetic force and particles that carry the nuclear force have "spin 1," or $1\hbar$), and other particles have a spin value that is a half-integer multiple of $\hbar$ (e.g. electrons, protons, and neutrons have "spin 1/2," or $\hbar/2$). According to statistical and thermal physics, these two categories of particles behave very differently when they are around other particles of the exact same type:

- Integer-spin particles (such as photons) are called "bosons" because they obey Bose-Einstein statistics, which basically means that they are conformists and love to be doing the same thing as each other, unless they have so much thermal energy that they randomly move in many different ways. Since light and other electromagnetic radiation can be viewed as either waves or particles (photons), the boson nature of light is especially important for "black-body radiation," or radiation emitted by something that is so hot that it glows. See Fig. 5.40 for information on how the energy density and spectral distribution of black-body radiation change with the temperature.

- Half-integer-spin particles (such as electrons) are called "fermions" because they obey Fermi-Dirac statistics, which essentially means that they are individualists, with each particle in a system insisting on doing at least one thing differently than any other identical particle in that system (the Pauli exclusion principle). That difference might be having a different energy, different spin direction (e.g., up vs. down), or different magnitude or direction for the angular momentum of the particle's orbit. If a population of fermions has very little thermal energy, they fill up all the lowest available energy states, like sports fans arriving in a stadium with open seating. If a population of fermions has significant thermal energy, some of them randomly jump up to higher energy states, leaving their formerly occupied lower energy states empty (like sports fans who are so excited that they run up and down the levels of the stadium). Figure 5.41 illustrates the characteristics of fermions such as electrons.

As some of the names in the introduction of this section suggest, there were some important contributions to statistical and thermal physics from outside the German-speaking world. The most notable outside contributions came from Satyendra Bose (Indian, 1894–1974), Sadi Carnot (French, 1796–1832), Subrahmanyan Chandrasekhar (Indian, 1910–1995), Paul Dirac (English, 1902–1984), Enrico Fermi (Italian, 1901–1954), James Joule (English, 1818–1889), Lord Kelvin (Scottish, 1824–1907), and James Clerk Maxwell (Scottish, 1831–1879). With the exception of Bose, Chandrasekhar, Dirac, and Fermi, those outside contributions occurred before the German-speaking scientific world had really ramped up by the late nineteenth century.

After that time, a large number of German-speaking physicists dominated the field, as shown in Figs. 5.42–5.47.[6]

For simplicity, the German-speaking creators in this section are divided into the following categories of research:

5.5.1. Thermodynamic properties

5.5.2. Bosons

5.5.3. Fermions

5.5.4. Cryogenics

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[6] For coverage of different aspects of this area, see especially: Laurie Brown et al. 1995; Gamow 1966; Jones 2008; Jungnickel and McCormmach 1986, 2017; Kragh 2002; L'Annunziata 2016; von Meÿenn 1997; Ingo Müller 2007; Teichmann et al. 2008; Weber 1988.

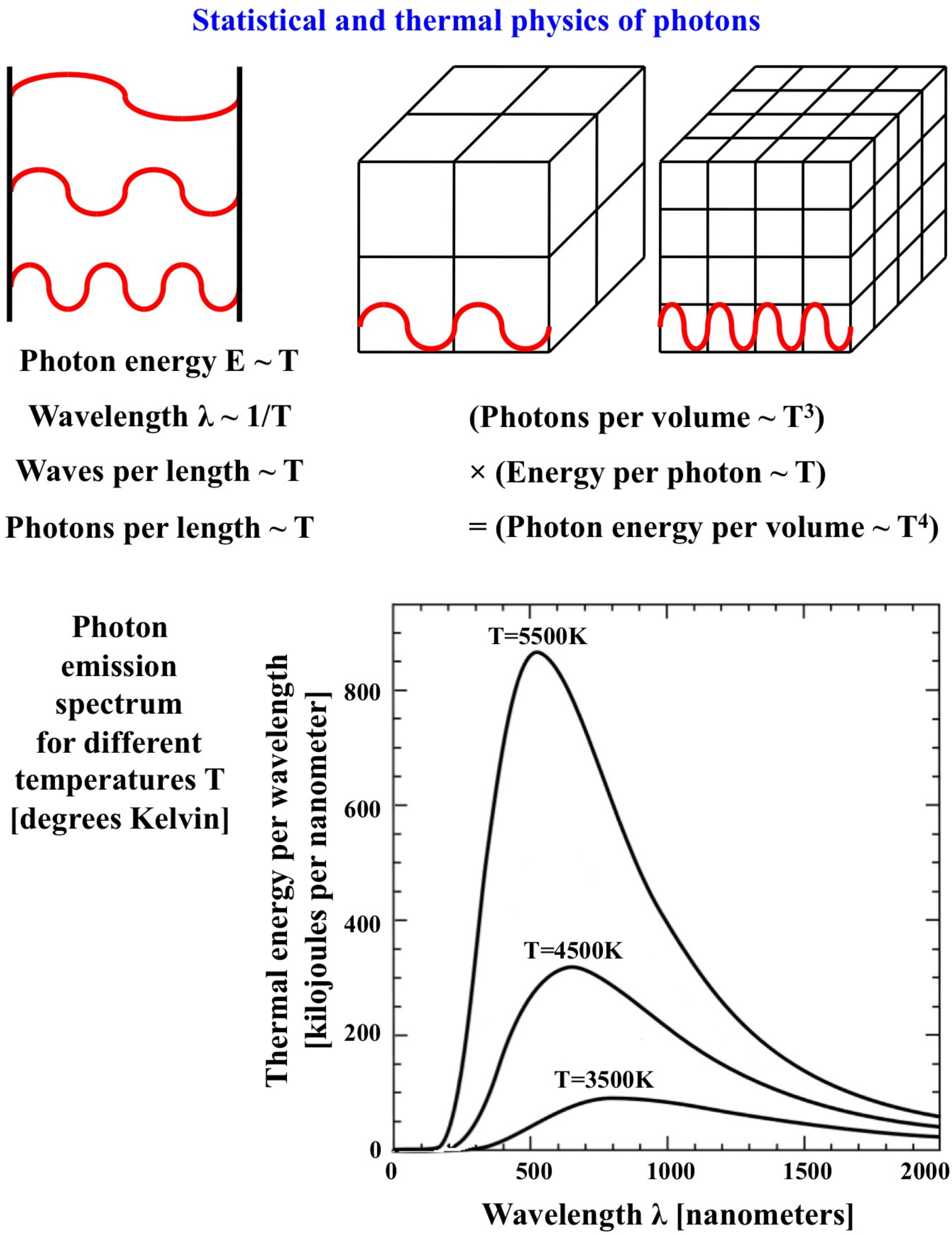


Figure 5.40: Some important discoveries in statistical and thermal physics are that the energy density of photons (electromagnetic radiation such as light) rapidly increases with temperature T (as T^4), and that a hot object emits a spectrum of photons with a predominant wavelength that becomes shorter as the temperature increases.

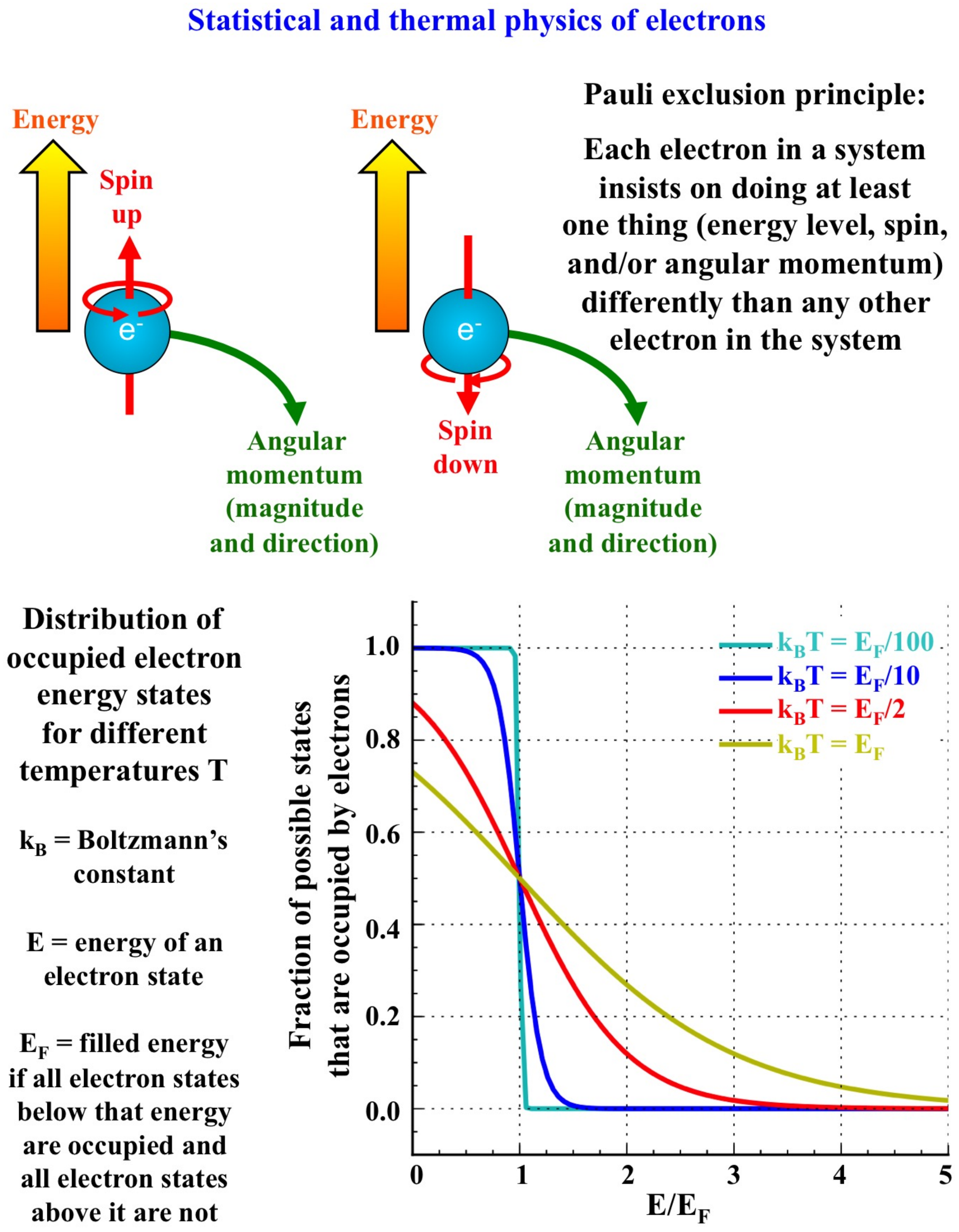
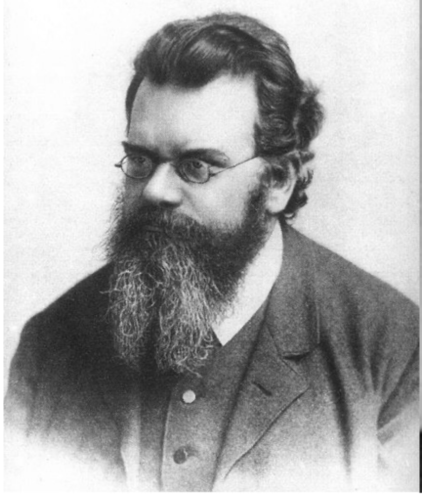

Statistical and thermal physics of electrons
Energy
Spin up
e-
Angular momentum (magnitude and direction)
Energy
e-
Spin down
Angular momentum (magnitude and direction)
Pauli exclusion principle:
Each electron in a system insists on doing at least one thing (energy level, spin, and/or angular momentum) differently than any other electron in the system
Distribution of occupied electron energy states for different temperatures T
k_B = Boltzmann's constant
E = energy of an electron state
E_F = filled energy if all electron states below that energy are occupied and all electron states above it are not
Fraction of possible states that are occupied by electrons
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
E/E_F
$k_BT = E_F/100$
$k_BT = E_F/10$
$k_BT = E_F/2$
$k_BT = E_F$

Figure 5.41: Other important discoveries in statistical and thermal physics are that each electron in a system does not want to do exactly the same thing as any other electron in the system. Thus like sports fans filling a stadium with open seating, the first electrons occupy the states with the lowest energy levels, and succeeding electrons occupy additional states with higher and higher energies.

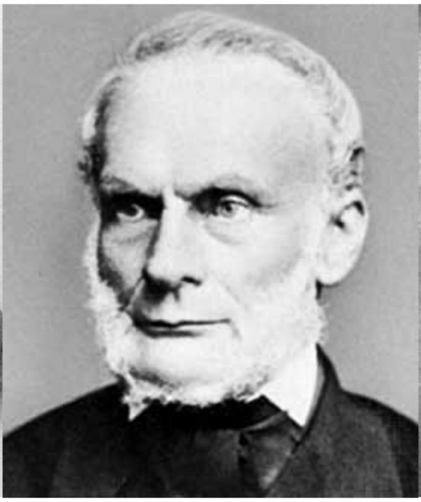
Statistical and thermal physics

**Richard Becker
(1887–1955)**

**Ludwig Boltzmann
(1844–1906)**



**Rudolf Clausius
(1822–1888)**



**Peter Debye
(1884–1966)**

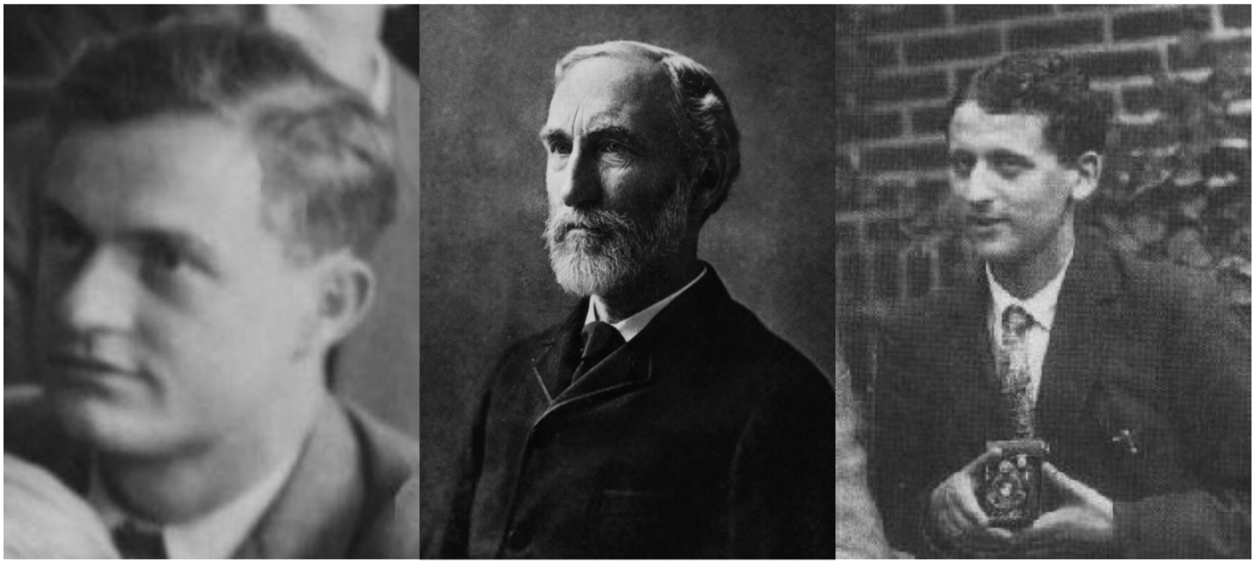
**Paul Ehrenfest
(1880–1933)**

**Tatjana Ehrenfest-
Afanassjewa (1876–1964)**

**Albert Einstein
(1879–1955)**

Figure 5.42: Some creators who made significant contributions to statistical and thermal physics included Richard Becker, Ludwig Boltzmann, Rudolf Clausius, Peter Debye, Paul Ehrenfest, Tatjana Ehrenfest-Afanassjewa, and Albert Einstein.

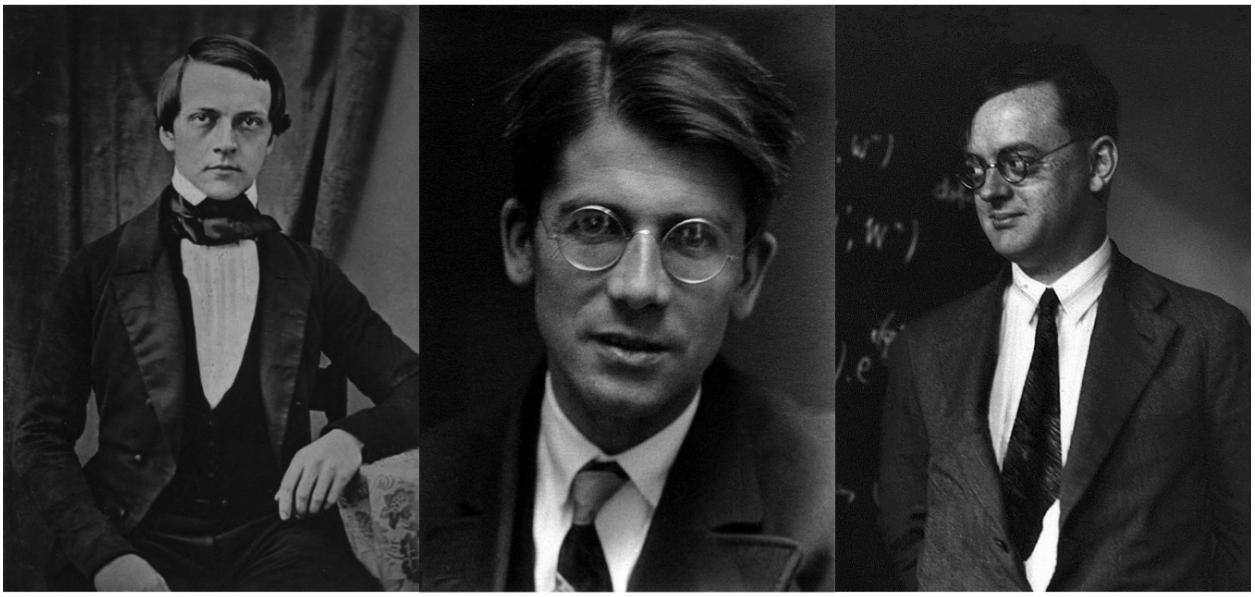
Statistical and thermal physics



Markus Fierz (1912–2006)

Josiah Gibbs (1839–1903)

Samuel Goudsmit (1902–1978)



Hermann von Helmholtz (1821–1894)

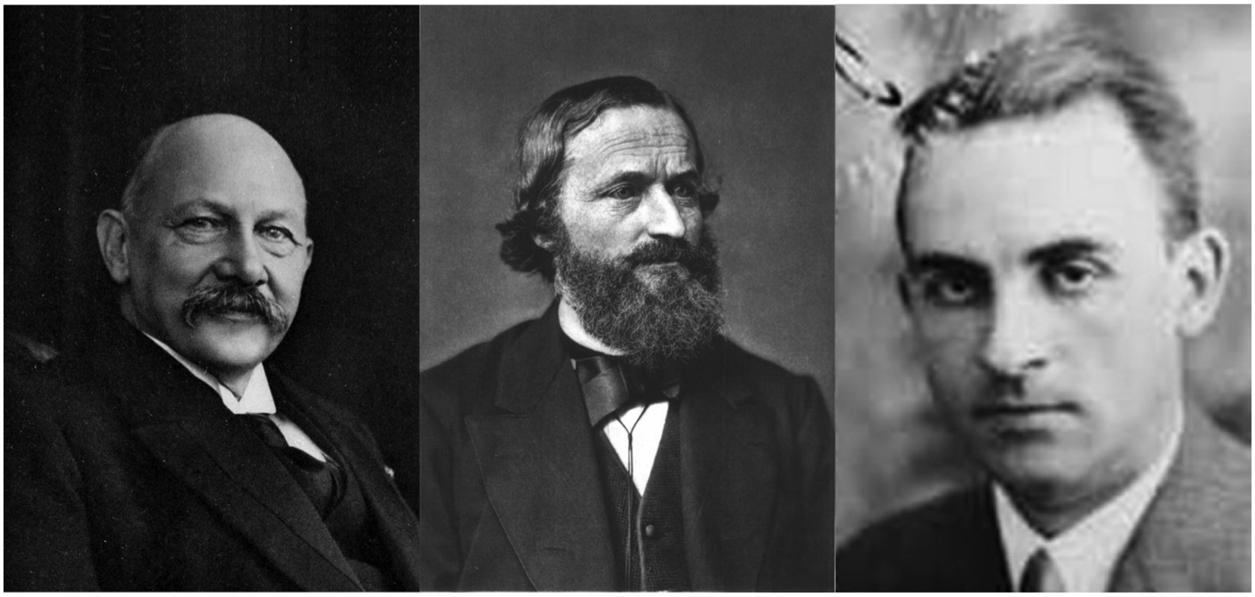
Friedrich Hund (1896–1997)

Pascual Jordan (1902–1980)

Figure 5.43: Other creators who made significant contributions to statistical and thermal physics included Markus Fierz, Josiah Gibbs, Samuel Goudsmit, Hermann von Helmholtz, Friedrich Hund, and Pascual Jordan.

Statistical and thermal physics

Heike Kammerlingh Onnes (1853–1926) **Gustav Kirchhoff (1824–1887)** **Ralph Kronig (1904–1995)**



Ferdinand Kurlbaum (1857–1927) **Nicholas Kurti (1908–1998)** **Max von Laue (1879–1960)**

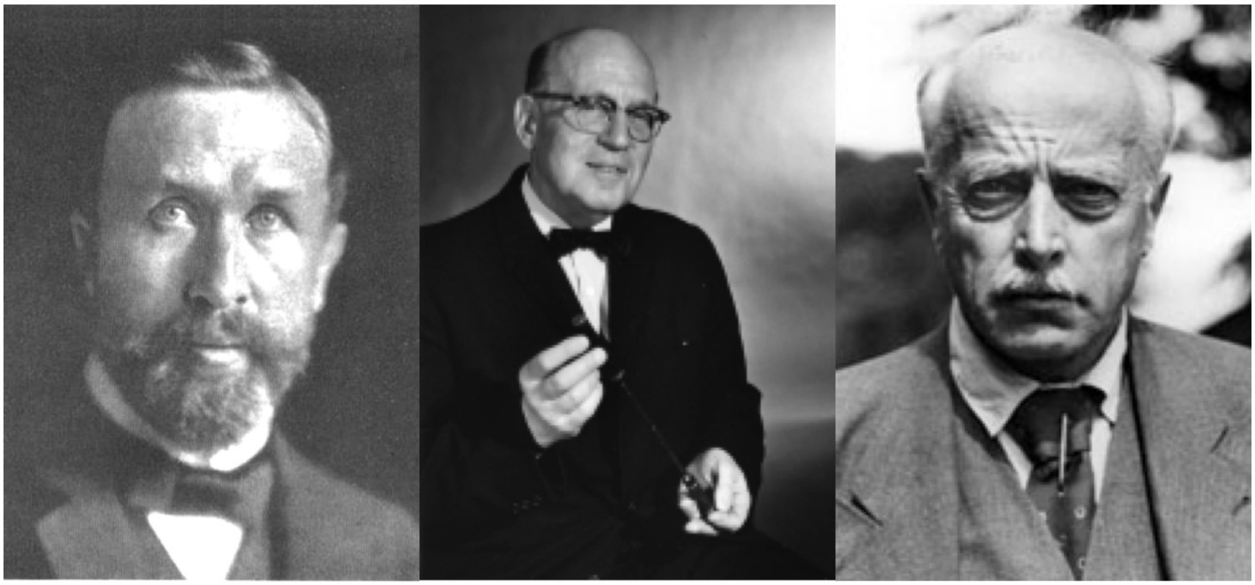
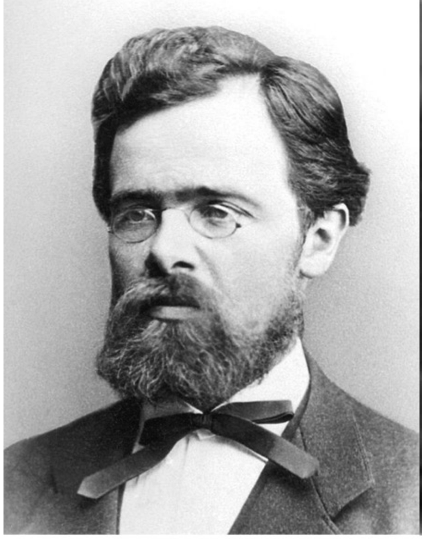


Figure 5.44: Other creators who made significant contributions to statistical and thermal physics included Heike Kammerlingh Onnes, Gustav Kirchhoff, Ralph Kronig, Ferdinand Kurlbaum, Nicholas Kurti, and Max von Laue.

Statistical and thermal physics

Carl von Linde
(1842–1934)



Fritz London
(1900–1954)

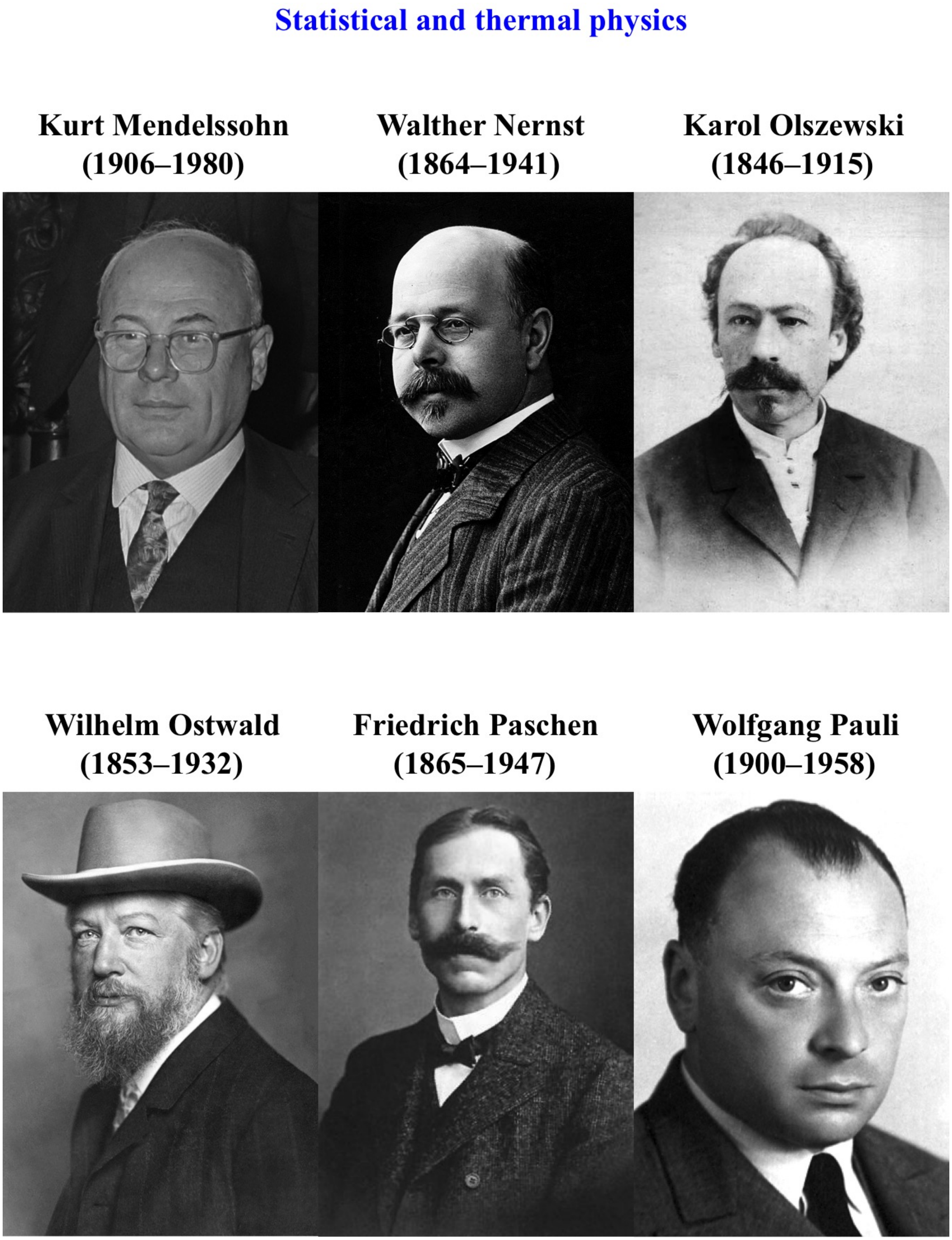
Heinz London
(1907–1970)

Otto Lummer
(1860–1925)

Julius von Mayer
(1814–1878)

Fritz Walther Meissner
(1882–1974)

Figure 5.45: Other creators who made significant contributions to statistical and thermal physics included Carl von Linde, Fritz London, Heinz London, Otto Lummer, Julius von Mayer, and Fritz Walther Meissner.



Statistical and thermal physics
Kurt Mendelssohn (1906–1980)
Walther Nernst (1864–1941)
Karol Olszewski (1846–1915)
Wilhelm Ostwald (1853–1932)
Friedrich Paschen (1865–1947)
Wolfgang Pauli (1900–1958)

Figure 5.46: Other creators who made significant contributions to statistical and thermal physics included Kurt Mendelssohn, Walther Nernst, Karol Olszewski, Wilhelm Ostwald, Friedrich Paschen, and Wolfgang Pauli.

Statistical and thermal physics

Raoul Pictet (1846–1929)
Max Planck (1858–1947)
Ernst Pringsheim (1859–1917)

Heinrich Rubens (1865–1922)
Franz Simon (1893–1956)
Arnold Sommerfeld (1868–1951)

Figure 5.47: Other creators who made significant contributions to statistical and thermal physics included Raoul Pictet, Max Planck, Ernst Pringsheim, Heinrich Rubens, Franz Simon, and Arnold Sommerfeld.

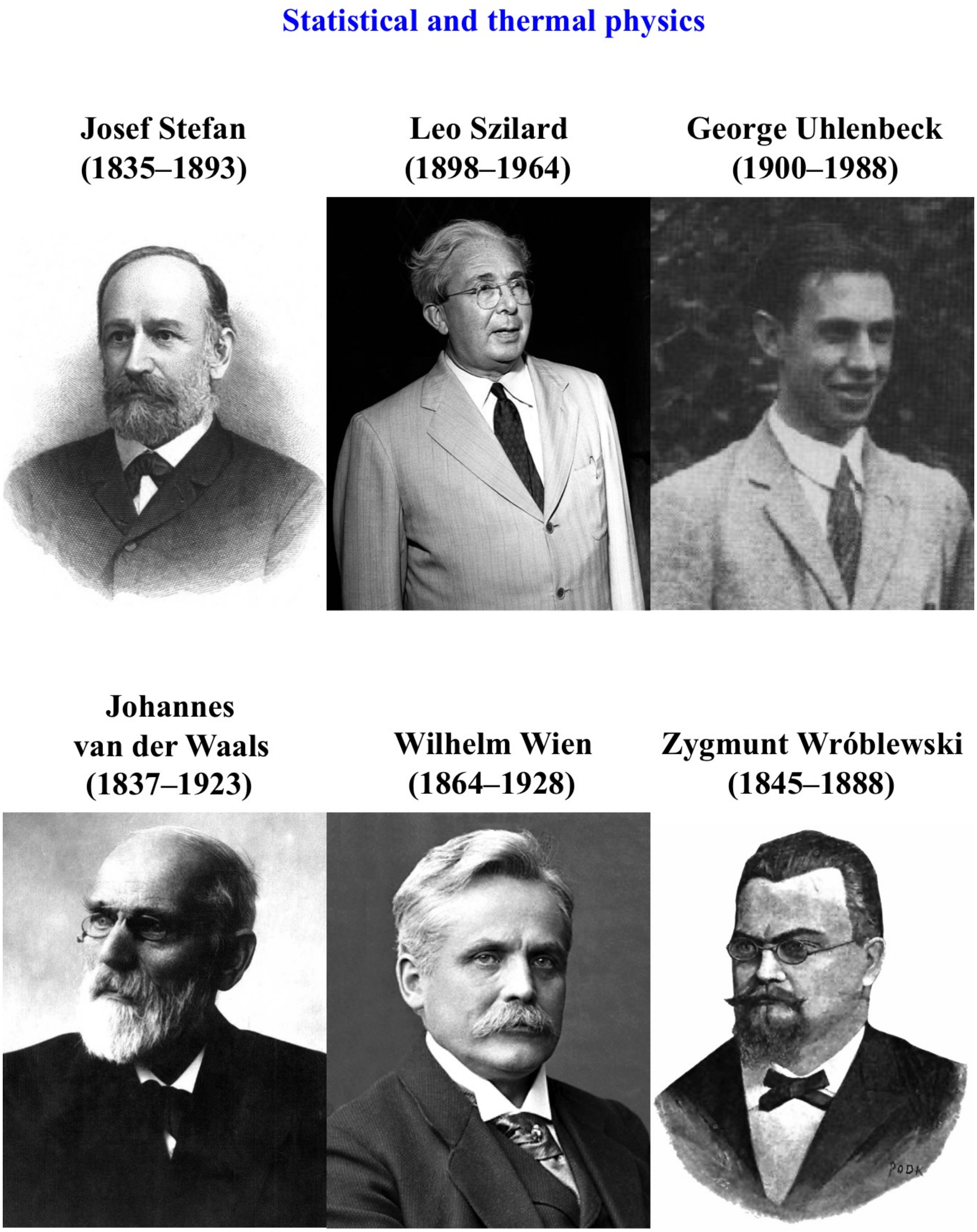

Statistical and thermal physics
Josef Stefan
(1835–1893)
Leo Szilard
(1898–1964)
George Uhlenbeck
(1900–1988)
Johannes
van der Waals
(1837–1923)
Wilhelm Wien
(1864–1928)
Zygmunt Wróblewski
(1845–1888)
PODK

Figure 5.48: Other creators who made significant contributions to statistical and thermal physics included Josef Stefan, Leo Szilard, George Uhlenbeck, Johannes van der Waals, Wilhelm Wien, and Zygmunt Wróblewski.

5.5.1 Thermodynamic Properties

Julius von Mayer (German, 1814–1878) expressed the first law of thermodynamics, the law of conservation of energy (including heat energy and work), in 1841. (James Joule independently rediscovered that law, published it in 1843, and historically has received most of the publicity for it.) He was also the first to find equations for the specific heat of an ideal gas, or the relationship between the amount of heat energy absorbed by a substance and the corresponding temperature rise for that substance.

Hermann von Helmholtz (German, 1821–1894) made a wide variety of major discoveries in biology (pp. 239, 282, 297, 311), chemistry (p. 597), and physics (p. 859) [Cahan 2018]. In 1847, he published a more detailed treatment of the first law of thermodynamics, *Über die Erhaltung der Kraft* (*On the Conservation of Energy*), and also studied the thermodynamics of fluids.

In 1850, Rudolf Clausius (German, 1822–1888) was the first to clearly articulate the second law of thermodynamics, that entropy cannot decrease, or equivalently that heat flows from regions of higher temperature to regions of lower temperature.

Johannes van der Waals (Dutch, 1837–1923) developed detailed thermodynamic equations relating the pressure, density, and temperature of gases and liquids. He won the Nobel Prize in Physics in 1910. Professor O. Montelius, President of the Royal Swedish Academy of Sciences, described his accomplishments [https://www.nobelprize.org/prizes/physics/1910/ceremony-speech/]:

> On the basis of this law of what are known as "corresponding states" for various gases and liquids Van der Waals was able to provide a complete description of the physical state of gases and, more important, of liquids under varying external conditions. He showed how certain regularities can be explained which had earlier been found by empirical means, and he devised a number of new, previously unknown laws for the behaviour of liquids.
>
> It appeared, however, that not all liquids conformed precisely to the simple laws formulated by Van der Waals. A protracted controversy arose around these discrepancies which were ultimately found to be attributable to the molecules in these liquids not all being of the same character; the older Van der Waals laws apply only to liquids of uniform composition. Van der Waals then extended his studies to mixtures of two or more types of molecules and here too he managed to find the laws and these, of course, are more complex than those which apply to substances composed of molecules of a single type. Van der Waals is still occupied with working out the details of this great investigation. [...]
>
> Yet Van der Waals' studies have been of the greatest importance not only for pure research. Modern refrigeration engineering, which is nowadays such a potent factor in our economy and industry, bases its vital methods mainly on Van der Waals' theoretical studies.

Josiah Gibbs (American but educated in Germany, 1839–1903) derived equations for the thermodynamic properties of chemical mixtures, and also showed how to calculate the behavior of substances as collections of large numbers of particles.

Ludwig Boltzmann (Austrian, 1844–1906) developed an extensive framework of statistical physics equations for describing the thermodynamic behavior of large numbers of particles in solids, liquids, or gases [Boltzmann 1964]. As part of that work, he gave a precise mathematical definition of entropy for the second law of thermodynamics.

Wilhelm Ostwald (German, 1853–1932) also developed statistical physics methods that were applicable to thermodynamic processes in both chemistry and physics. Ostwald's work won the Nobel Prize in Chemistry in 1909. Dr. H. Hildebrand, President of the Royal Academy of Sciences, praised Ostwald's discoveries [https://www.nobelprize.org/prizes/chemistry/1909/ceremony-speech/]:

> The Royal Academy of Sciences has resolved to award the former professor at Leipzig University and Geheimrat, Wilhelm Ostwald, the Nobel Prize for Chemistry 1909 in recognition of his work on catalysis and associated fundamental studies on chemical equilibria and rates of reaction. [...]
>
> The significance of this new idea is best revealed by the immensely important role—first pointed out by Ostwald—of catalytic processes in all sectors of chemistry. Catalytic processes are a commonplace occurrence, especially in organic synthesis. Key sections of industry such as e.g. sulphuric acid manufacture, the basis of practically the whole chemical industry, and the manufacture of indigo which has flourished so during the last ten years, are based on the action of catalysts. A factor of perhaps even greater weight, however, is the growing realization that the enzymes, so-called, which are extremely important for the chemical processes within living organisms, act as catalysts and hence the theory of plant and animal metabolism falls essentially in the field of catalyst chemistry. [...]
>
> Although the Nobel Prize for Chemistry is now being awarded to Professor Ostwald in recognition of his work on catalysis, he is a man to whom the chemical world is indebted also in other ways. By the spoken and the written word he, perhaps more than any other, has carried modern theories to a rapid victory and for several decennia he played a leading part in the field of general chemistry. In other ways too he has furthered chemistry by his versatile activity with numerous discoveries and refinements in both the experimental and the theoretical spheres.

Similar to Ostwald, Walther Nernst (German, 1864–1941) made important discoveries regarding the statistical physics underlying thermodynamics, physical chemistry, electrochemistry, and the physics of solids. He won the Nobel Prize in Chemistry in 1920. Professor Gerard de Geer, President of the Royal Swedish Academy of Sciences, announced the award [https://www.nobelprize.org/prizes/chemistry/1920/ceremony-speech/]:

> Herr Geheimrat Nernst. The discovery of fire, which during the classic age was still attributed to a titan, Prometheus, is both the oldest and certainly the most important of all discoveries.
>
> For long years chemists eagerly sought the suspected connection between the evolution

> of heat and the chemical affinity during the combustion of coal and in other chemical reactions.
>
> Your work has now brought this connection to light.
>
> You have used brilliant acuteness during your masterly experimental researches on specific heat and chemical equilibria.
>
> Using the heat theorem discovered by you it has now become possible on the one hand to calculate from the heat evolution during chemical reactions and the specific heats, the chemical affinity and the maximum possible output of energy during chemical reactions, and on the other hand to calculate the equilibrium in reactions not yet studied.
>
> The Academy of Sciences has decided to hand you the Nobel Prize for Chemistry as recognition of the exceptional merit of your work on Thermochemistry.

Peter Debye (Dutch, 1884–1966) studied and worked in Germany and Switzerland for many years. He developed statistical models of the behavior of molecules, chemical solutions, and crystalline solids. For his work, he was honored with the Nobel Prize in Chemistry in 1936. Professor A. Westgren, Secretary of the Nobel Committee for Chemistry, congratulated him [https://www.nobelprize.org/prizes/chemistry/1936/ceremony-speech/]:

> Professor Debye. Your rich scientific activity has been aimed in particular to research into the structure of matter. Your wealth of ideas, your penetration and your secure mastery of mathematical methods have yielded great success to your endeavours, and your results have enriched chemistry to an extraordinary degree in all kinds of ways. By your investigations on dipole moments and also on X-ray and electron interferences in gases you have widened and deepened our knowledge of molecular structure to such an extent that the Royal Academy of Sciences has awarded you the Nobel Prize for Chemistry.

Leo Szilard (Hungarian, 1898–1964) introduced several thermodynamic innovations including the Szilard engine, new ideas about Maxwell's demon, and the Einstein refrigerator.

5.5.2 Bosons

As mentioned in Section 5.4, experimental and theoretical investigations of black-body radiation led directly to the development of quantum physics. Those investigations were also a critical part of statistical and thermal physics, since black-body radiation is an example of the behavior of large numbers of bosons (photons).

Beginning in the 1850s, Gustav Kirchhoff (German, 1824–1887) conducted the first experimental and theoretical investigations of black-body radiation, and was also responsible for giving it that name. Historian of science Ingo Müller described Kirchhoff's foundational role in this area [Müller 2007, p. 199]:

> Kirchhoff conceived of a *black body*, a hypothetical body that sends out radiation of all frequencies and that should therefore—by Kirchhoff's law—also absorb all radiation, and reflect none, so that it appears black. Such black bodies came to play an important role in radiation research, although in the early days no real good black body existed to serve as a reliable object of study. Therefore Kirchhoff suggested an ingenious surrogate in the form of a cavity with blackened, e.g. soot-covered interior walls, which could be heated. Any radiation that enters the cavity by a small hole is absorbed or reflected when it hits a wall. If reflected, the light will most likely travel to another spot of the wall, being absorbed or reflected there, etc. In this way virtually no reflected light comes out through the hole so that the hole itself absorbs radiation *as if it were* a black body. The radiation emitted through the hole is called cavity radiation and it can be studied at leisure for any temperature of the walls.

In 1879, Josef Stefan (Austrian, 1835–1893) experimentally demonstrated that the power of emitted black-body radiation varies as the fourth power of the temperature, as shown at the top of Fig. 5.40. Stefan was also the doctoral advisor for Ludwig Boltzmann, who found a theoretical derivation for that relationship in 1884, so the relationship between power and temperature for thermal radiation is now known as the Stefan-Boltzmann law.

In the late nineteenth century, increasingly accurate experimental measurements of the spectrum of black-body radiation were conducted by Ferdinand Kurlbaum (German, 1857–1927), Otto Lummer (German, 1860–1925), Ernst Pringsheim (German, 1859–1917), Heinrich Rubens (German, 1865–1922), and Wilhelm Wien (German, 1864–1928). Those experiments essentially yielded the curves shown at the bottom of Fig. 5.40 for how the spectrum of black-body radiation varies with changes in the temperature of the object emitting the radiation.

Several scientists worked to develop equations to describe the measured black-body radiation spectrum, as well as physical explanations for the origins of those equations. Wilhelm Wien derived an approximate equation for that spectrum in 1896, and showed that it agreed quite well with his experiments except at very long wavelengths. Friedrich Paschen (German, 1865–1947) independently arrived at the same equation at the same time, although primarily based on experimental data and not theoretical reasons. In 1900, Max Planck (German, 1858–1947) found the exact equation for the black-body radiation spectrum at all wavelengths, and showed that it resulted from light behaving like a collection of particles, or photons.

For their discoveries regarding black-body radiation, Wien won the Nobel Prize in Physics in 1911 and Max Planck won it in 1918 [https://www.nobelprize.org/prizes/physics/1918/ceremony-speech/].

In awarding the 1911 Nobel Prize to Wien, Dr. E. W. Dahlgren, President of the Royal Swedish Academy of Sciences, emphasized the long line of German-speaking scientists who had pioneered the study of black-body radiation [https://www.nobelprize.org/prizes/physics/1911/ceremony-speech/]:

> Ever since the beginning of the last century and, in particular, since spectrum analysis reached an advanced stage of development as a result of the fundamental work by Bunsen and Kirchhoff, the problem of the laws of heat radiation has occupied the attention of physicists to an exceptionally high degree. [...]
>
> The difficulty in investigating the laws of radiation of black bodies was, firstly, that no completely black body exists in nature. In accordance with Kirchhoff's definition, such a body would reflect no light at all, nor allow light to pass. Even substances such as soot, platinum black etc. reflect part of the incident light.
>
> This difficulty was only removed in 1895, when Wien and Lummer stated the principles according to which a completely black body could be constructed, and showed that the radiation which issues from a small hole in a hollow body whose walls have the same temperature behaves in the same manner as the radiation emitted by a completely black body. The principle of this arrangement is based on the views of Kirchhoff and Boltzmann and had already been applied in part by Christiansen in 1884.
>
> With the assistance of this apparatus it now became possible to investigate black body radiation. In this manner, Lummer, together with Pringsheim and Kurlbaum, succeeded in substantiating the so-called Stefan-Boltzmann law which indicates the relationship between the quantity of heat radiated by a black body and its temperature. [...]
>
> In 1893 Wien published a theoretical paper which was destined to acquire the utmost importance in the development of radiation theory. In this paper he presented his so-called displacement law which provides a very simple relationship between the wavelength having the greatest radiation energy and the temperature of the radiating black body.
>
> The importance of Wien's displacement law extends in various directions. As we shall see, it provides one of the conditions which are required for the determination of the relationships between energy radiation, wavelength and temperature for black bodies, and thus represents one of the most important laws in the theory of heat radiation. Wien's displacement law has however acquired the greatest possible importance in other contexts as well. Lummer and Pringsheim have shown that the radiation of bodies other than black bodies obeys the displacement law, with the sole difference that the constant which forms part of the formula has a different value. [...]
>
> It was only natural that Wien who had contributed so much to the advancement of radiation theory should make an attempt to find an answer to the last remaining question also, i.e. that of the distribution of energy in radiation. In 1894 he indeed deduced a black body radiation law. This law has the virtue that, at short wavelengths, it agrees with the above-mentioned experimental investigations by Lummer and Pringsheim. [...]
>
> The problem now became to bridge the gap between these two laws each of which had been shown to be valid in a specific context. It was Planck who solved this problem; as far as we are aware, his formula provides the long sought-after connecting link between radiation energy, wavelength and black body temperature.

Physicist Robert Weber described the scientific contributions of Wien and Planck in more detail [Weber 1988, pp. 43, 58–59]:

> Wien's major work dealt with the distribution of radiant energy in the spectrum and the effect of a change in temperature on this distribution. Wien and Otto Lummer devised the first practical black-body or cavity radiator to provide the 'full radiation' needed for their experiments. [...]
>
> Wien next investigated the problem of the distribution of energy among the wavelengths in black-body radiation. Thermodynamical reasoning was not sufficient. Wien made some arbitrary assumptions (within the framework of classical physics) about the role of molecules in the emission of radiation, and arrived at the formula
>
> $$E_\lambda = \frac{c_1}{\lambda^{-5}\exp(-c_2/\lambda T)} ,$$
>
> where E_λ is the energy at wavelength λ over a unit range of wavelength, and c_1 and c_2 are constants, which he determined by curve-fitting. Wien's formula predicts intensities a little lower than experimental values for large values of λT. The search for a better formula led Max Planck to formulate the quantum theory of radiation. Satisfyingly, Planck's theory gives c_1 and c_2 in terms of fundamental physical constants, but oddly, Planck's equation differs from Wien's in form only by the addition of a (-1) in the denominator. In temperature measurements with an optical pyrometer, Wien's equation is still often used; the calculations are simpler and sufficiently accurate. [...]
>
> Beginning in about 1896 Planck became interested in finding the correct theoretical expression for the radiation from a black body. He applied Boltzmann's equation from the theory of gases (relating entropy and probability) to a set of resonators, the energy of which, he hypothesized, occurred only in *discrete multiples of* ε. From Wien's displacement law he reasoned that the entropy was a function of E/ν (energy/frequency). He was then led (1900) to the famous relation between a quantum of energy and the frequency, and to the introduction of the constant h named after him: $E = h\nu$.
>
> The resulting Planck radiation law, unlike Wien's, fitted all the experimental data [...] Einstein spotlighted attention on Planck's work when he used the concept of quanta in his explanation of the photoelectric effect, in 1905. Next the quantum concept was exploited in the Rutherford-Bohr model of the atom. The fact that it took 25 years of experimental and theoretical work to build the quantum theory is one measure of the quality of Planck's contribution.

In 1905, Albert Einstein (German, 1879–1955) provided detailed theoretical calculations to show that light was also behaving like particles or photons in the photoelectric effect. For that work, he won the Nobel Prize in Physics in 1921 (p. 890). In several papers published over the span of a couple of decades, Einstein extended his initial treatment of photons to cover a population of any identical particles of integer spin. In 1924, Einstein also helped Satyendra Bose to publish a paper that gave an alternative derivation of Planck's earlier equation. As a result, populations of integer-spin particles became known as Bose-Einstein particles, or bosons for short.[7] Historian Walter Isaacson evaluated Einstein's contributions [Isaacson 2007, pp. 98, 328–329]:

> Einstein explored this hypothesis [in 1905] by determining whether a volume of blackbody radiation, which he was now assuming consisted of discrete quanta, might in fact behave like a volume of gas, which he knew consisted of discrete particles. First, he looked at the formulas that showed how the entropy of a gas changes when its volume changes. Then he compared this to how the entropy of blackbody radiation changes as its volume changes. He found that the entropy of the radiation "varies with volume according to the same law as the entropy of an ideal gas."
>
> He did a calculation using Boltzmann's statistical formulas for entropy. The statistical mechanics that described a dilute gas of particles was mathematically the same as that for blackbody radiation. This led Einstein to declare that the radiation "behaves thermodynamically as if it consisted of mutually independent energy quanta." It also provided a way to calculate the energy of a "particle" of light at a particular frequency, which turned out to be in accord with what Planck had found. [...]
>
> Bose's [1924] paper dealt with photons, which have no mass. Einstein extended the idea by treating quantum particles *with mass* as being indistinguishable from one another for statistical purposes in certain cases. "The quanta or molecules are not treated as structures statistically independent of one another," he wrote. [...]
>
> When he applied this approach to a gas of quantum particles, Einstein discovered an amazing property: unlike a gas of classical particles, which will remain a gas unless the particles attract one another, a gas of quantum particles can condense into some kind of liquid even without a force of attraction between them.
>
> This phenomenon, now called Bose-Einstein condensation, was a brilliant and important discovery in quantum mechanics, and Einstein deserves most of the credit for it. [...]
>
> In 1995, Bose-Einstein condensation was finally achieved experimentally by Eric A. Cornell, Wolfgang Ketterle, and Carl E. Wieman, who were awarded the 2001 Nobel Prize for this work.

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[7] In retrospect, it seems odd that of all the scientists who worked on this topic, it was Bose who was immortalized when this category of particles was named. His 1924 paper arrived at the same result that Max Planck had nearly a quarter century earlier, it was only published with Einstein's input and assistance, and his other papers before and after that time were undistinguished (especially when compared with those of other Indian physicists and mathematicians such as Homi Bhabha, Subrahmanyan Chandrasekhar, C. V. Raman, and Srinivasa Ramanujan). The mathematical theory describing populations of photons or similar types of particles was progressively developed by Wien, Planck, and Einstein, based on experimental data and earlier work by the other German-speaking scientists going back to Kirchhoff. Perhaps in the aftermath of World War I, when English was the predominant language worldwide and German speakers were isolated and viewed with hostility because of the war, it was easier for the English-speaking world to give name credit to Bose, who was an English-speaking member of the British Empire, than to the series of German-speaking scientists who spent nearly three-quarters of a century developing this part of physics from beginning to end.

5.5.3 Fermions

The greater German-speaking world also dominated in discovering the behavior of fermions such as electrons. The largest and most important parts of this work were conducted by Wolfgang Pauli (Austrian, 1900–1958). In 1924, he realized that each electron in a system such as an atom refused to be in exactly the same state as any other electron in that system, a rule that became known as the Pauli exclusion principle. In 1925, Pauli further realized that data from atomic measurements showed that each state could actually have up to two electrons; he therefore proposed that there was some previously unknown, binary quantum property that was different between those two electrons, so that they would still satisfy the Pauli exclusion principle.

Pauli's new binary-valued property of electrons turned out to be their spin angular momentum, which could be pointed in two distinct directions (e.g., up or down). Ralph Kronig (German, 1904–1995) first proposed the concept of electron spin to Pauli in January 1925. Later in 1925, Paul Ehrenfest (Austrian, 1880–1933) and his students George Uhlenbeck (Dutch, 1900–1988) and Samuel Goudsmit (Dutch, 1902–1978) rediscovered the concept of spin. Ehrenfest also collaborated on statistical physics research with his wife, Tatjana Ehrenfest-Afanassjewa (1876–1964), who was Ukrainian but was educated in Germany and worked in Germany and the Netherlands.

Pauli went on to prove that particles with half-integer spins (such as electrons, protons, and neutrons) behaved as fermions and followed the Pauli exclusion principle with regard to other identical particles in the same system. Moreover, he proved that particles with integer spins (such as photons and mesons) behaved as bosons and actually liked being in the same state as each other when their energies were low enough. In 1927, Pauli also developed what are now known as the Pauli spin matrices, which mathematically describe how the spin states of particles can change (for example, how an electron might change its spin from up to down). For his decisive contributions to this topic, Pauli won the Nobel Prize in Physics in 1945. Physicist Robert Weber [Weber 1988, pp. 125–126] summarized Pauli's discoveries:

> In 1924 Pauli enunciated his 'exclusion principle' with which much of the then existing knowledge of atomic structure fell into order: no two electrons in an atom can be in the same quantum state. In 1925 Pauli wrote that a new quantum theory property of the electron, which he called a 'two-valuedness not describable classically,' was indispensable to an understanding of the anomalous Zeeman effect. Goudsmit and Uhlenbeck identified this fourth quantum number with an angular momentum (spin) of the electron. The exclusion principle could then be stated: no two electrons in an atom can have the same set of four quantum numbers. In this form, Pauli's principle led to an understanding of the formation of electron shells in an atom and the periodicity of chemical properties observed when the elements are arranged in order of increasing atomic number. [...]
>
> Other research papers by Pauli dealt with the relation of quantum spin and the appropriate distribution statistics for elementary particles, paramagnetic properties of gases and of metals (leading to the quantum mechanical theory of electrons in metals), extension of wave mechanics from one to a large number of particles, explanation of the meson, and the nuclear binding force. To explain the beta-decay of radioactive nuclei, Pauli in 1931 postulated the existence of a new subatomic particle; it was named the *neutrino* by Fermi in 1932, and was detected in 1956.

As soon as Pauli published his 1924–1925 papers on the exclusion principle for electrons, Pascual Jordan (German, 1902–1980) realized that that principle could be extended to describe the behavior of very large numbers of electrons (or other particles that behaved in a similar fashion). In 1925, Jordan wrote an elegant paper that derived what is now known as the Fermi-Dirac distribution for such particles, as shown at the bottom of Fig. 5.41. He submitted the paper to Max Born for prompt publication in the widely read physics journal that Born edited, *Zeitschrift für Physik*. Then something unfortunate happened, as recounted by historian Nancy Thorndike Greenspan [Greenspan 2005, p. 135]:

> Born had one disconcerting moment after returning [in 1926]—his discovery of a paper by Pascual Jordan at the bottom of his suitcase. Just before Born's departure [in 1925], Jordan had given it to him for possible publication in the journal *Zeitschrift für Physik*, of which Born was an editor. Born had packed it, intending to read it on the trip. When he pulled it out and finally read it, he saw that Jordan had discovered the important statistical laws that Enrico Fermi had just published in the *Zeitschrift für Physik*. Shortly, Paul Dirac made the same discovery of what became known as the *Fermi-Dirac statistics*. These laws describe the statistical distribution of identical particles of spin ½ (now called *fermions*). They follow Pauli's exclusion principle: that only one such particle can occupy an energy state at a time. These laws, as applied to electrons, aided in the development of the field of electronics. Amid the serious problems that rocked his future relationship with Jordan, Born always felt guilty, even "ashamed," that he had robbed Jordan of his due.

Sadly, it does not appear that journal editor Born made any attempt to rectify or publicly clarify the situation even after the fact. Thus the sequence of events is: Pauli worked out the behavior of small numbers of fermions in 1924–1925. Jordan extended Pauli's results to cover large numbers of fermions in 1925 and submitted his discovery for publication. After perusing Pauli's publications, Enrico Fermi (Italian, 1901–1954) independently rediscovered the same results as Jordan in 1926, and Paul Dirac (English, 1902–1984) rediscovered those same results again in 1927. Yet Jordan has been nearly forgotten by history, and the names of Fermi and Dirac will be forever linked to this topic.[8]

In 1927, Friedrich Hund (German, 1896–1997) used the Pauli exclusion principle to work out the detailed order in which electrons fill progressively higher energy states in atoms that have many electrons. His rules are still widely used today in chemistry and physics.

Also in 1927, Arnold Sommerfeld (German, 1868–1951) used the Pauli exclusion principle to describe the behavior of electrons in metals. Sommerfeld's theory successfully explained the contributions of electrons to the electrical and thermal conductivities of metals, and it is now known as the Sommerfeld or Drude-Sommerfeld model of free electrons. (For Paul Drude's earlier work, see p. 861).

Some other German-speaking scientists who made important contributions to the physics of fermions included Richard Becker (German, 1887–1955) and Markus Fierz (Swiss, 1912–2006).

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[8] Jordan's virtual omission from this part of history is certainly not the fault of Fermi and Dirac. If Jordan had not existed, Fermi and Dirac would indeed have been the first discoverers of this statistical distribution of particles. Both Fermi and Dirac made a long string of revolutionary discoveries before and after that time. For unrelated work, Dirac won the Nobel Prize in Physics in 1933, and Fermi won it in 1938. Although Fermi came out of the Italian system and Dirac out of the British system, both were highly individualistic geniuses whose accomplishments appear to have been due to their self-created natures and specific circumstances far more than the particular systems in which they lived. Both Fermi and Dirac had extensive interactions with the German-speaking scientific world during their careers. Books have been written about both of them, but their lives should be scrutinized in even more detail for lessons that future scientists might learn.

5.5.4 Cryogenics

Cryogenics concerns methods of producing extremely cold temperatures, very close to absolute zero, and also covers testing the properties of materials at those low temperatures. Many scientists from the greater German-speaking world made tremendously important contributions to cryogenics.

Carl von Linde (German, 1842–1934) greatly improved earlier attempts at ammonia refrigeration to create a truly practical and efficient large refrigeration system. He used that to liquefy air and various gases on an industrial scale.

Zygmunt Wróblewski (Polish, educated in Germany, 1845–1888) and Karol Olszewski (Polish, 1846–1915) also conducted important early work on liquefying different gases and studying their properties.

Raoul Pictet (Swiss, 1846–1929) was the first to produce liquid nitrogen.

Heike Kamerlingh Onnes (Dutch, educated in Germany, 1853–1926) built upon and extended that earlier work, reaching colder and colder temperatures. Using those extremely cold temperatures, he was the first to liquefy helium, and he also discovered superconductivity. For his discoveries, he won the Nobel Prize in Physics in 1913. Th. Nordstrom, President of the Royal Swedish Academy of Sciences, explained the importance of his contributions [https://www.nobelprize.org/prizes/physics/1913/ceremony-speech/]:

> It was for this research that Kamerlingh Onnes set up his famous laboratory at the beginning of the 1880's, and in it he designed and improved, with unusual success, the physical apparatus needed for his experiments.
>
> It is impossible to report briefly here on the many important results of this work. They embrace the thermodynamic properties at low temperatures of a series of monatomic and diatomic gases and their mixtures, and have contributed to the development of modern thermodynamics and to an elucidation of those associated phenomena which are so difficult to explain. They have also made very important contributions to our knowledge of the structure of matter and of phenomena related to it. [...]
>
> I should have to cover too much ground if I were to report here on the experimental equipment with which Kamerlingh Onnes was at last successful in liquefying helium, and on the enormous experimental difficulties which had to be overcome. I would only mention here that the liquefaction of helium represented a continuation of the long series of investigations into the properties of gases and liquids at low temperatures which Kamerlingh Onnes has carried out in so praiseworthy a manner. These investigations finally led to the determination of the so-called isotherms of helium and the knowledge gained here was the first step towards the liquefaction of helium. Kamerlingh Onnes has constructed cold baths with liquid helium which permit research to be done into the properties of substances at temperatures which lie between 4.3^o and 1.15^o from absolute zero.
>
> The attainment of these low temperatures is of the greatest importance to physics research, for at these temperatures both the properties of the substances and also the

> course followed by physical phenomena, are generally quite different from those at our normal and higher temperatures, and a knowledge of these changes is of fundamental importance in answering many of the questions of modern physics. [...]
>
> Various principles borrowed from gas thermodynamics have been transferred to the so-called theory of electrons, which is the guiding principle in physics in explaining all electrical, magnetic, optical, and many heat phenomena.
>
> The laws which have been arrived at in this way also seem to be confirmed by measurements at our normal and higher temperatures. That the situation is at very low temperatures not the same, however, has, amongst other things, been shown by Kamerlingh Onnes' experiments on resistance to electrical conduction at helium temperatures and by the determinations which Nernst and his students have carried out in relation to specific heat at liquid temperatures.

Physicist Anthony J. Leggett indicated how advanced Onnes's achievements were [Laurie Brown et al. 1995, p. 913]:

> If the subject which we now know as low-temperature physics can be said to have a birthday, that day would be 10 July 1908—the date on which Heike Kamerlingh Onnes and his team at the University of Leiden first successfully cooled the element helium (^{4}He) below 4.2 K and thereby liquefied it. For the next 15 years, the only place in the world where liquid helium existed was the Leiden laboratory (now named after Onnes).

Franz Simon (German, 1893–1956) and Nicholas Kurti (Hungarian, 1908–1998) developed refrigerators capable of cooling down to one millionth of a degree Celsius above absolute zero.

Kurt Mendelssohn (German, 1906–1980) studied the properties of liquid helium, demonstrating superfluidity, or flow without any viscosity or friction. He also further investigated the properties of superconductors.

Some other German-speaking scientists who made especially important contributions to superconductivity included Fritz Walther Meissner (German, 1882–1974), Max von Laue (German, 1879–1960), and the brothers Fritz London (German, 1900–1954) and Heinz London (German, 1907–1970). For more information on superconductivity, see p. 1112.

Many of these creators personally transferred their knowledge of advanced cryogenics out of the German-speaking world, as described by Leggett [Laurie Brown et al. 1995, p. 920]:

> By this time political events in Europe had begun to affect the course of low-temperature physics. Following the accession to power of the Nazi government in Germany, the years 1933–34 saw the exodus of many Jewish physicists, including Kurt Mendelssohn, Franz Simon, Nicholas Kurti and the London brothers, all of whom were attracted to Oxford by F A Lindemann (later Lord Cherwell) at the Clarendon Laboratory, which thereby rapidly became a major centre in experimental low-temperature physics. At the same time superconductivity at the PTR suffered a severe blow when Meissner left for Munich and von Laue was fired by the new Nazi-appointed head.

5.6 Relativistic Quantum Physics or Particle Physics

Relativistic quantum field theory (often simply called field theory, for short) combines special relativity, which describes very fast things, and (non-relativistic) quantum physics, which describes very small things. The resulting theory correctly predicts the behavior of fundamental particles, which are small and often move at high speeds, or are in tightly bound states where they rattle around at high speeds. For that reason, the topic is also often called particle physics, as it describes the behavior of particles that are collided together and new particles that are produced in large particle accelerators. Moreover, for the same reason, relativistic quantum theory is the best way to describe the effects of the fundamental physical forces: electromagnetic force, the strong and weak nuclear forces, and gravitational force (as well as real or potential interactions among those forces).

Relativistic quantum field theories describing the fundamental forces other than gravity do not need to incorporate general relativity. They are covered in Section 5.6.1.

However, relativistic quantum field theories describing gravity (often called quantum gravity for short) do need to incorporate general relativity, and therefore they are significantly more complicated. They are briefly treated in Section 5.6.2.

5.6.1 Quantum Field Theories of Fundamental Forces Other Than Gravity

Relativistic quantum theory applied to the electromagnetic force is called quantum electrodynamics (QED). As shown in Fig. 5.49, one may use QED to picture electrically charged particles such as electrons interacting with photons, the particles that make up an electromagnetic field. One of the first predictions of QED is that normal particles have antimatter versions or antiparticles, which have the opposite charge from the normal particles, or alternately have the same charge but travel backward in time relative to the normal particles. For example, the antimatter version of the negatively charged electron is called a positron, since it has a positive electric charge. A particle-antiparticle pair can be created from electromagnetic energy, or a particle-antiparticle pair can annihilate with each other and produce electromagnetic energy. QED correctly predicts electrostatic repulsion and attraction, particle-antiparticle annihilation, and a number of more complicated effects.

Relativistic quantum theory applied to the weak nuclear force describes phenomena such as the decay of neutrons (beta decay) and muons. Relativistic quantum theory applied to the strong nuclear force is called quantum chromodynamics, and is relevant to the behavior of the quarks that compose particles like protons, neutrons, and pions, as well as the collective interactions among protons, neutrons, and pions that hold the atomic nucleus together.

Relativistic quantum physics and particle physics are generally viewed as subjects that were developed largely after World War II, and largely outside the German-speaking world. The best-known luminaries in the field were mostly Americans (e.g., Richard Feynman, Murray Gell-Mann, Sheldon Glashow, Willis Lamb, Julian Schwinger, and Steven Weinberg) plus a few British (e.g., Paul Dirac and Freeman Dyson) and Japanese physicists (e.g., Sin-Itiro Tomonaga and Hideki Yukawa). Most of the early giant particle accelerators used to experimentally confirm the predictions of relativistic quantum theory were in the United States.

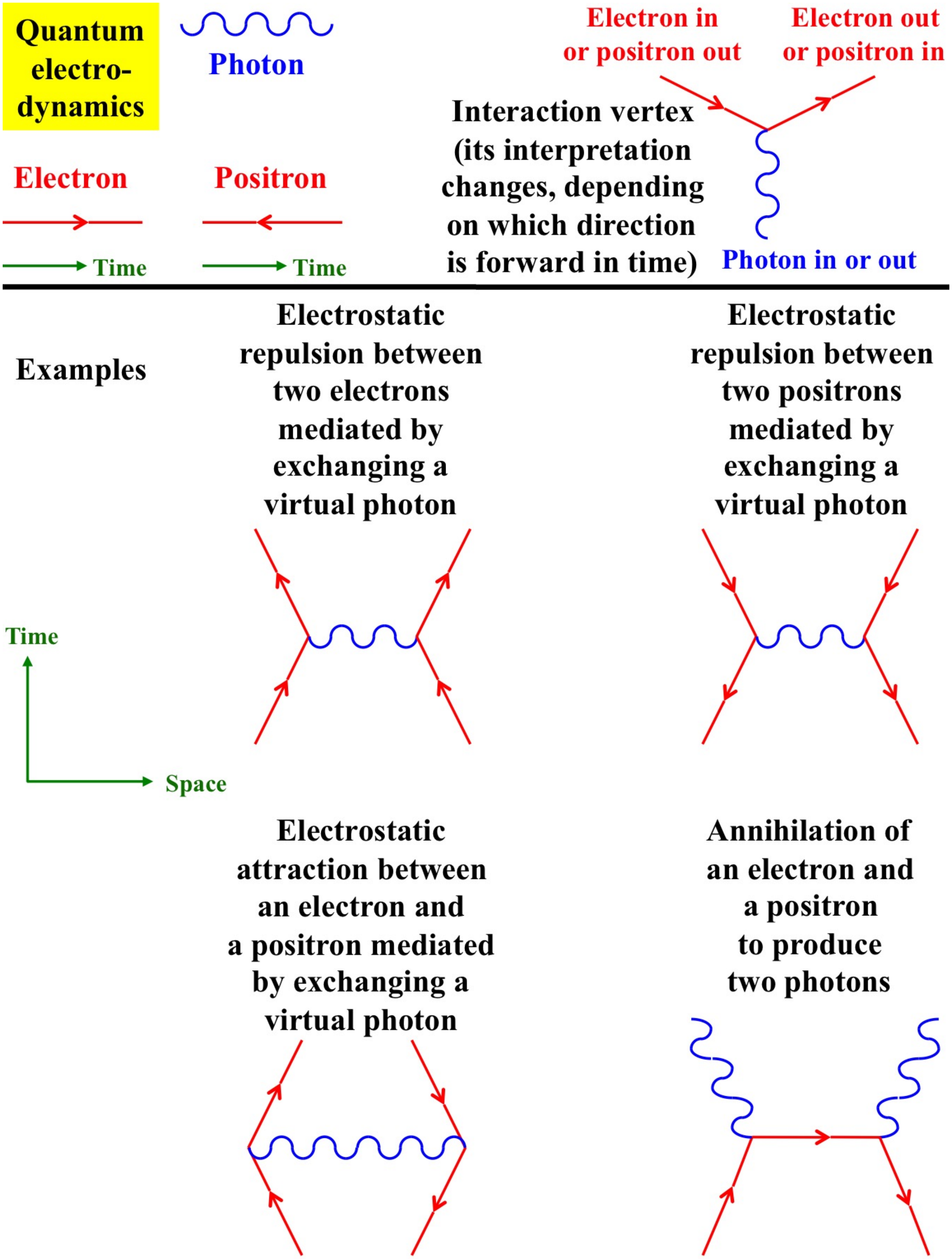
Quantum electro-dynamics
Photon
Electron in or positron out
Electron out or positron in
Interaction vertex (its interpretation changes, depending on which direction is forward in time)
Photon in or out
Electron
Positron
Time
Time
Examples
Electrostatic repulsion between two electrons mediated by exchanging a virtual photon
Electrostatic repulsion between two positrons mediated by exchanging a virtual photon
Time
Space
Electrostatic attraction between an electron and a positron mediated by exchanging a virtual photon
Annihilation of an electron and a positron to produce two photons

Figure 5.49: Combining special relativity, quantum physics, and electromagnetism yields quantum electrodynamics, which successfully predicted the existence of antimatter and numerous other effects.

In fact, there were a large number of German-speaking scientists who made major early contributions to relativistic quantum theory, as shown in Figs. 5.50–5.54.[9] Their research was foundational to later work outside the German-speaking world, and in some cases they made the same discoveries as non-German-speaking scientists, but earlier (and sadly with far less fame). There are several reasons why there was not even more German-speaking work on relativistic quantum theory, and why the work that was conducted is not as well known as it should be:

- The most detailed, successful work on combining relativity with non-relativistic quantum theory could not begin until non-relativistic quantum theory was fully developed, which did not occur until the end of the 1920s. Very soon thereafter, the rise of Nazism caused ~25% of scientists (including many of those working on relativistic quantum theory) to leave German-speaking Europe, disrupting their work and their interactions with other German-speaking scientists and/or spreading more of the development of relativistic quantum theory to other countries (especially the United States).

- Further development of relativistic quantum theory by scientists who remained in Germany and Austria during the Third Reich was hindered by the Nazi party's dislike for "Jewish physics" theories, the wartime focus on research with military applications, the difficulties of publishing scientific papers during the war and in the first several years after the war, and the scarcity of particle accelerators to confirm theoretical predictions. (The Third Reich appears to have possessed many particle accelerators by the end of the war, but they were devoted to military applications such as nuclear physics during the war, and most were confiscated by Allied countries after the war—see Section C.1 and pp. 3954–4022 and 4504–4510.)

- Likewise, immediate development of relativistic quantum theory by German-speaking scientists who fled to Allied countries was also retarded by the wartime focus on military research and the lack of particle accelerators not devoted to military purposes.

- Further work on relativistic quantum theory after the war in the German-speaking world was greatly impeded by the Allied procurement of most of the scientists, scientific documents, and scientific equipment from the German-speaking world at the end of the war. That chaotic dismantlement of the German-speaking scientific world also obscured many of the scientific results that it had achieved in the preceding years.

- Many of the Americans who contributed to relativistic quantum theory (Murray Gell-Mann, Julian Schwinger, Steven Weinberg, etc.) were the children of immigrants who had fled German-speaking areas of Europe due to the political turmoil of World War I, its aftermath, and the rise of Nazism.

- There are few books that cover the history of relativistic quantum physics, and most of those that do exist were generally written for American and British audiences, without devoting sufficient attention to German-speaking contributions in this field.

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[9] Most references that focus on relativistic quantum theory tend to provide far too little information on the German-speaking world, while references that do consider the German-speaking world in detail generally focus much more on non-relativistic than relativistic quantum theory. References with at least some information on this topic include: Laurie Brown et al. 1995; Laurie Brown and Hoddeson 1983; Cassidy 1992, 2009; Gamow 1966; Greiner and Reinhardt 1994; Jones 2008; Kragh 2002; L'Annunziata 2016; von Meÿenn 1997; Moore 1989; Schweber 1994; Weber 1988. Blum and Rickles 2018 is wonderful but focuses primarily on quantum gravity and not other parts of relativistic quantum theory in the German-speaking world. Historians of science should write more books in this area!

Relativistic quantum physics

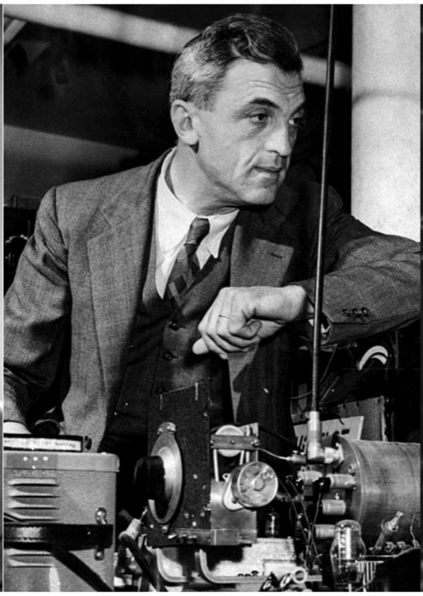
Valentine Bargmann
(1908–1989)

Richard Becker
(1887–1955)

Peter Bergmann
(1915–2002)

Hans Bethe
(1906–2005)

Felix Bloch
(1905–1983)



Fritz Bopp
(1909–1987)

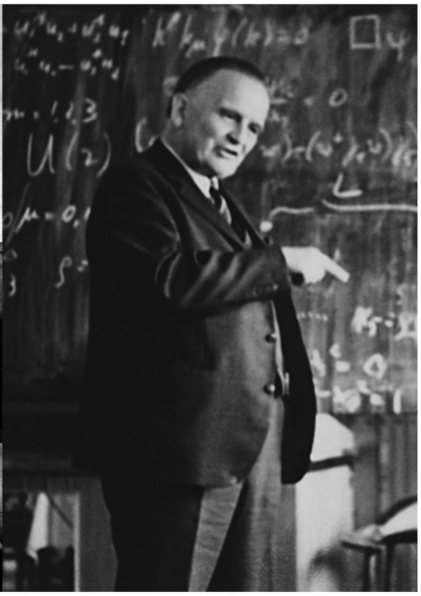


Figure 5.50: Some creators who made significant contributions to relativistic quantum physics included Valentine Bargmann, Richard Becker, Peter Bergmann, Hans Bethe, Felix Bloch, and Fritz Bopp.

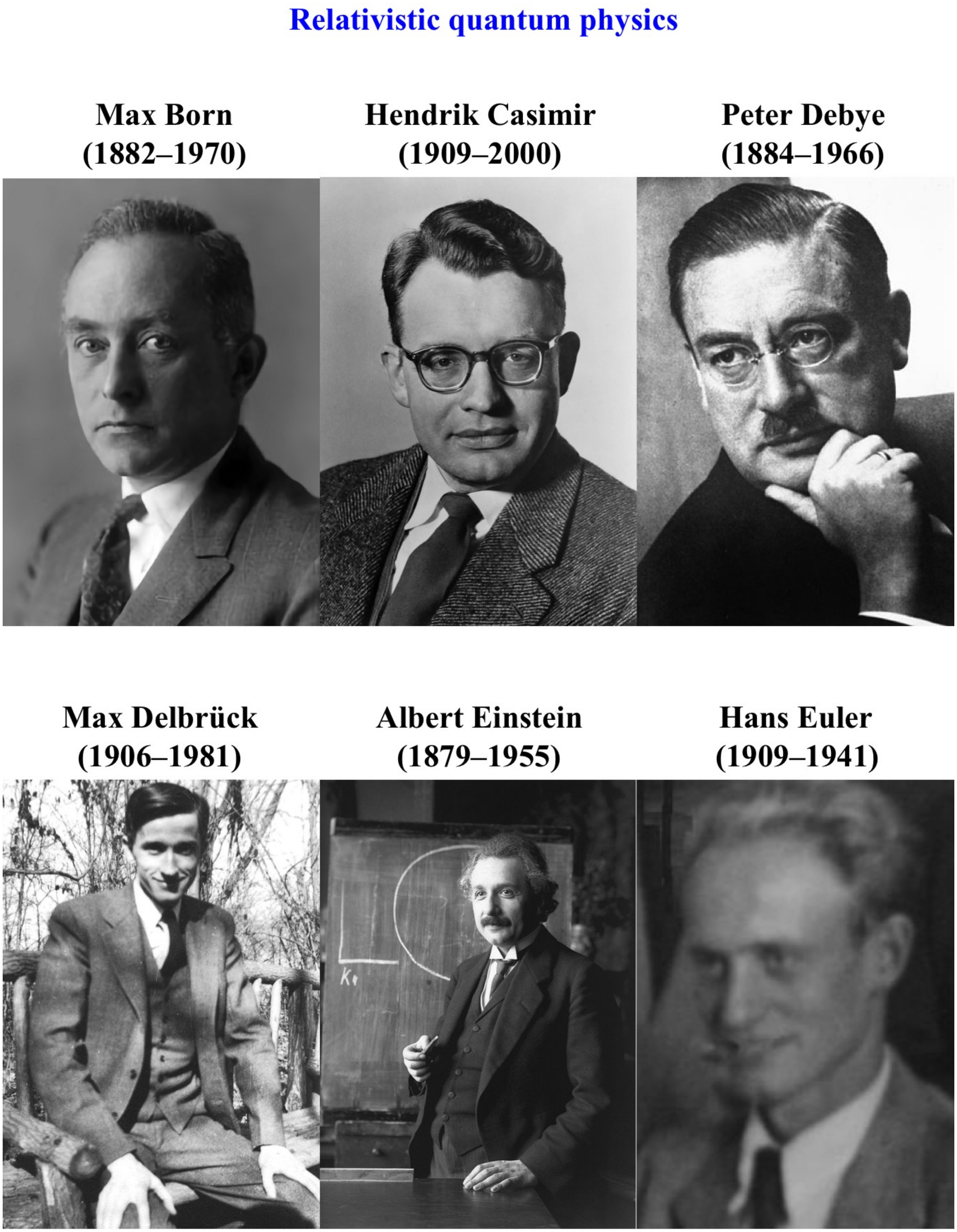

Relativistic quantum physics
Max Born
(1882–1970)
Hendrik Casimir
(1909–2000)
Peter Debye
(1884–1966)
Max Delbrück
(1906–1981)
Albert Einstein
(1879–1955)
Hans Euler
(1909–1941)

Figure 5.51: Other creators who made significant contributions to relativistic quantum physics included Max Born, Hendrik Casimir, Peter Debye, Max Delbrück, Albert Einstein, and Hans Euler.

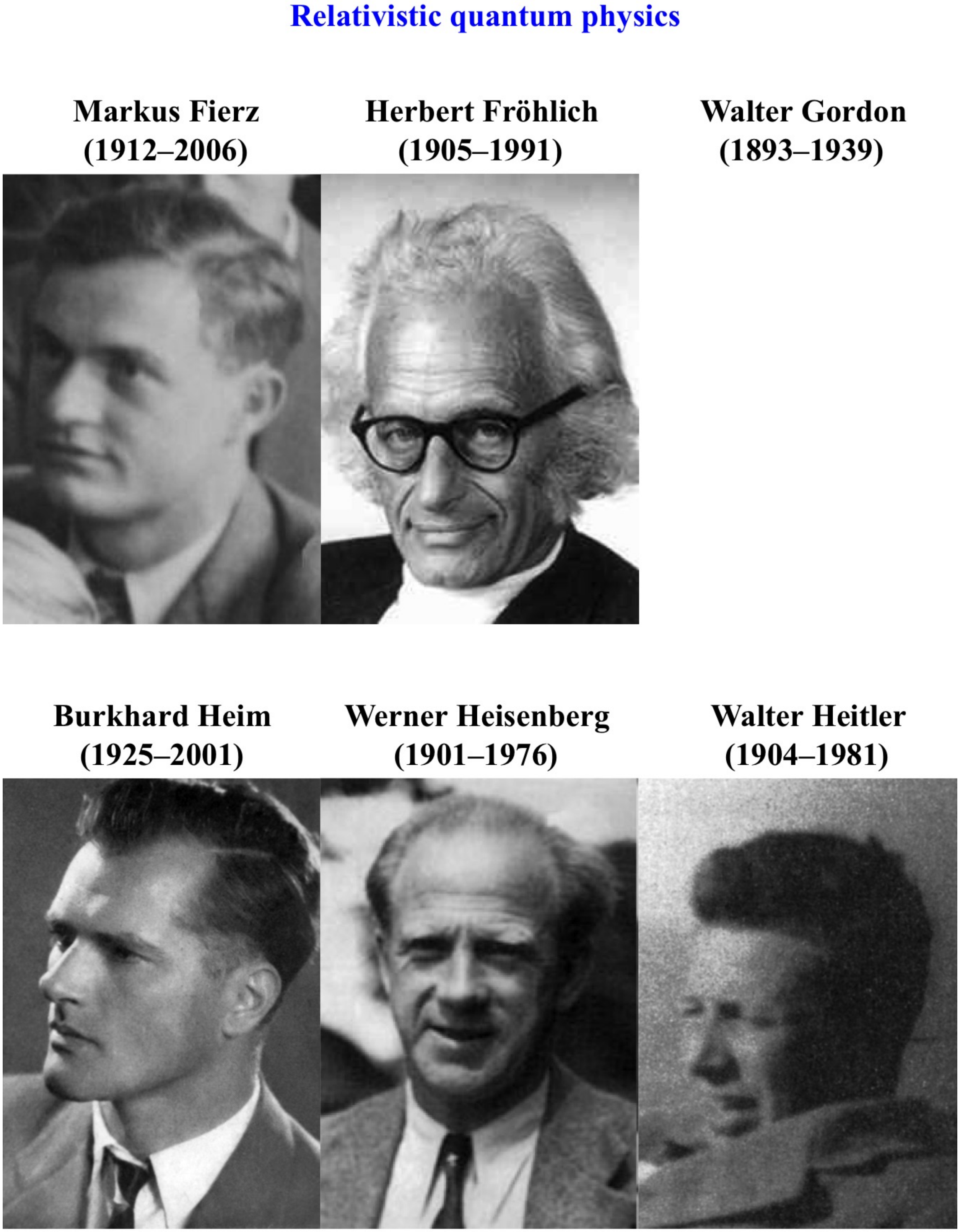
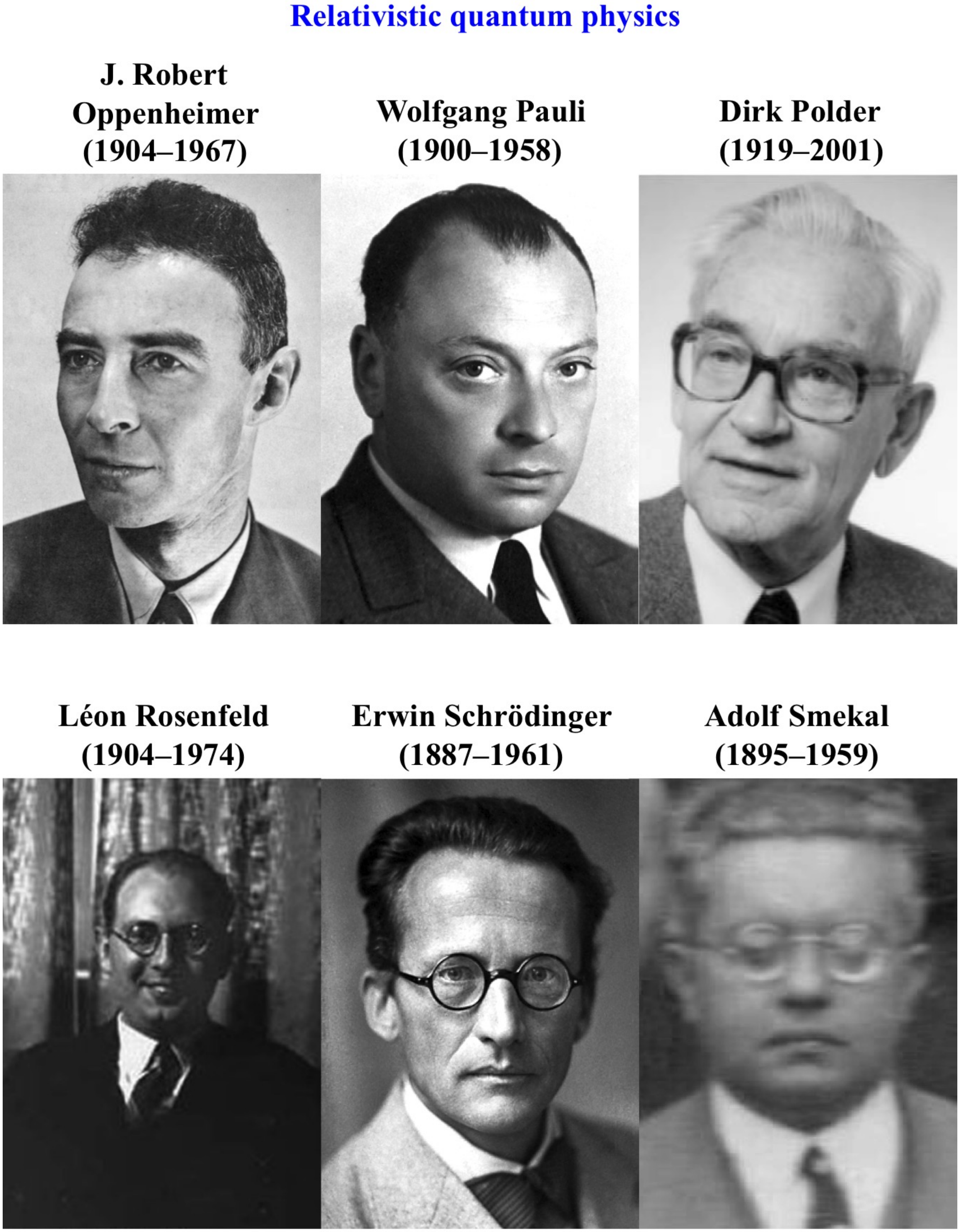

Relativistic quantum physics
Markus Fierz
(1912–2006)
Herbert Fröhlich
(1905–1991)
Walter Gordon
(1893–1939)
Burkhard Heim
(1925–2001)
Werner Heisenberg
(1901–1976)
Walter Heitler
(1904–1981)

Figure 5.52: Other creators who made significant contributions to relativistic quantum physics included Markus Fierz, Herbert Fröhlich, Walter Gordon, Burkhard Heim, Werner Heisenberg, and Walter Heitler.

Relativistic quantum physics
Leopold Infeld
(1898–1968)
Pascual Jordan
(1902–1980)
Theodor Kaluza
(1885–1954)
Nicholas Kemmer
(1911–1998)
Oskar Klein
(1894–1977)
Polykarp Kusch
(1911–1993)

Figure 5.53: Other creators who made significant contributions to relativistic quantum physics included Leopold Infeld, Pascual Jordan, Theodor Kaluza, Nicholas Kemmer, Oskar Klein, and Polykarp Kusch.



J. Robert Oppenheimer (1904–1967)
Wolfgang Pauli (1900–1958)
Dirk Polder (1919–2001)
Léon Rosenfeld (1904–1974)
Erwin Schrödinger (1887–1961)
Adolf Smekal (1895–1959)

Figure 5.54: Other creators who made significant contributions to relativistic quantum physics included J. Robert Oppenheimer, Wolfgang Pauli, Dirk Polder, Léon Rosenfeld, Erwin Schrödinger, and Adolf Smekal.

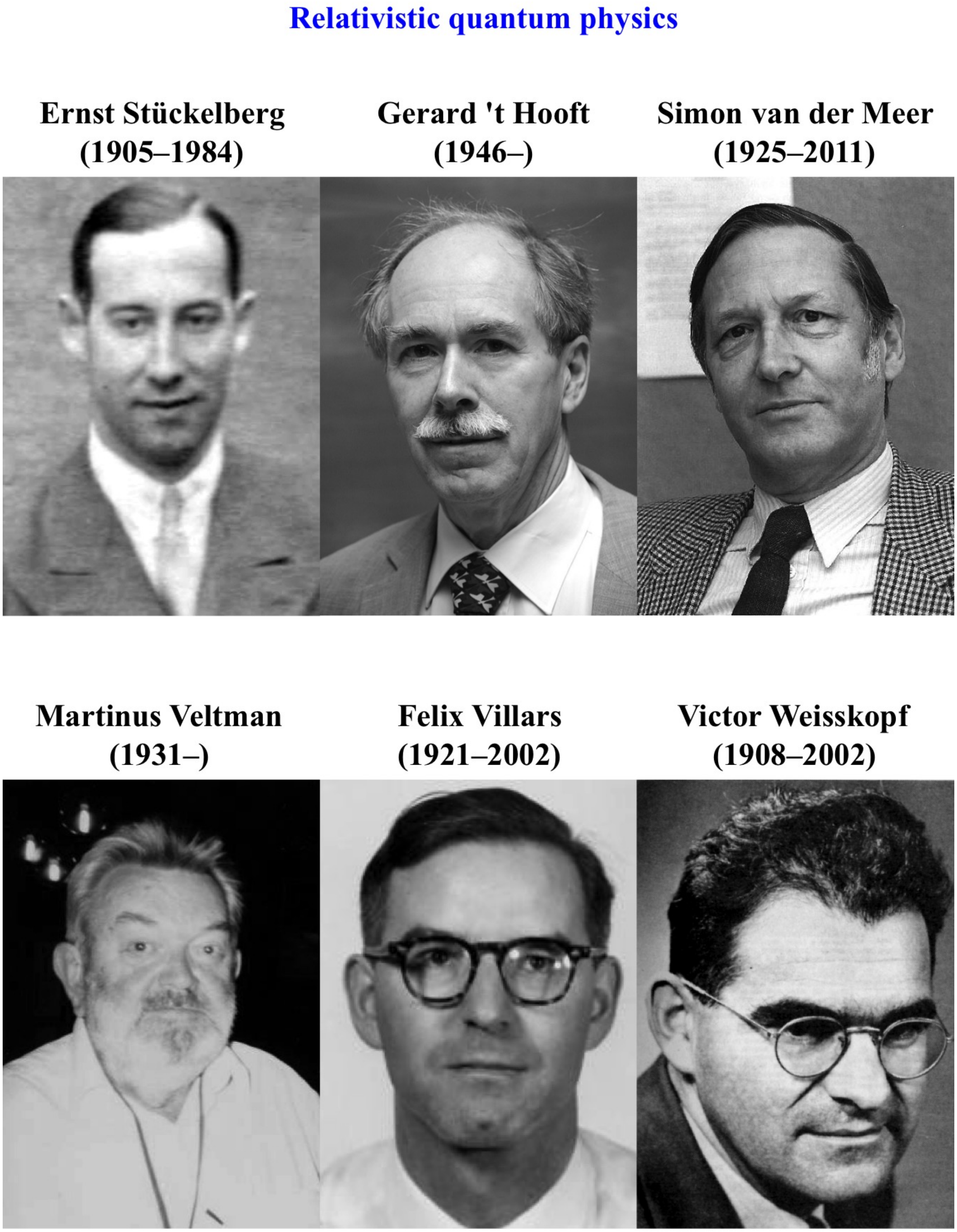
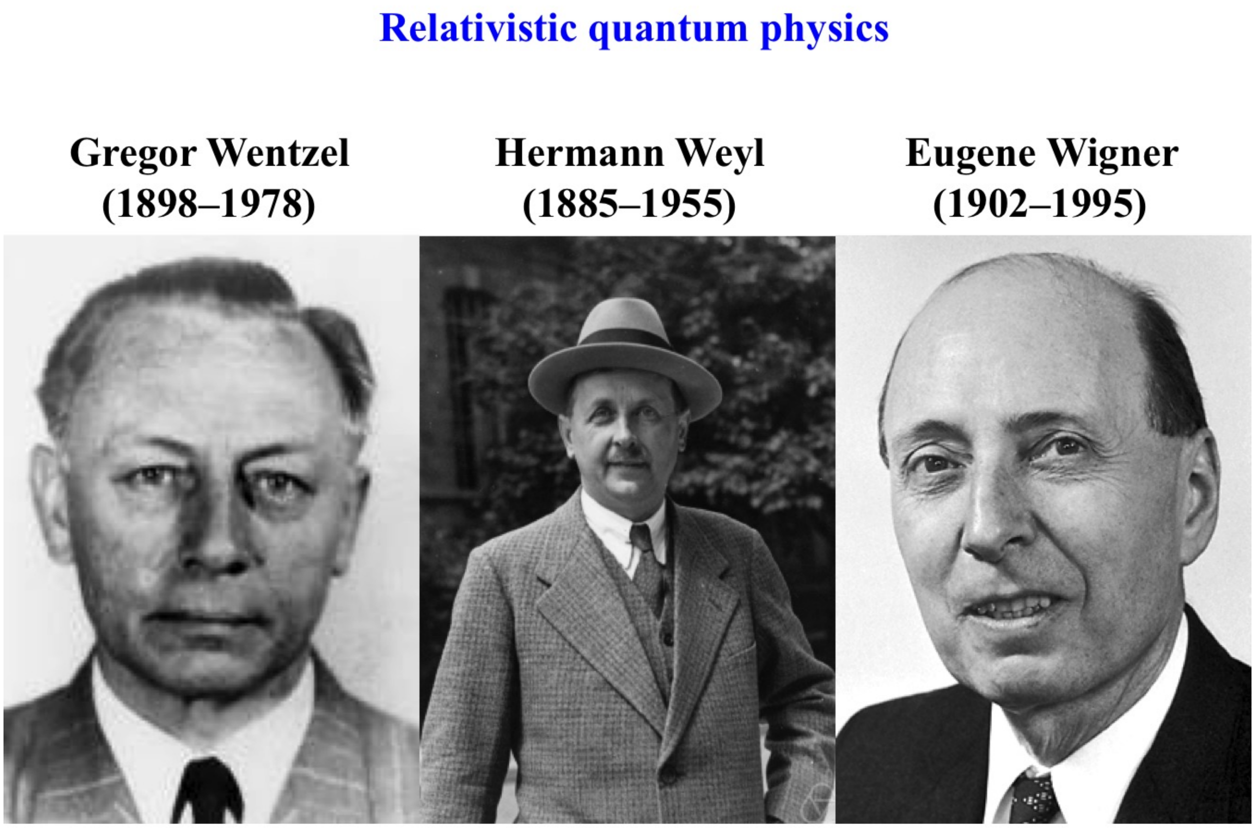

Relativistic quantum physics
Ernst Stückelberg (1905–1984)
Gerard 't Hooft (1946–)
Simon van der Meer (1925–2011)
Martinus Veltman (1931–)
Felix Villars (1921–2002)
Victor Weisskopf (1908–2002)

Figure 5.55: Other creators who made significant contributions to relativistic quantum physics included Ernst Stückelberg, Gerard 't Hooft, Simon van der Meer, Martinus Veltman, Felix Villars, and Victor Weisskopf.



Relativistic quantum physics

Gregor Wentzel (1898–1978)

Hermann Weyl (1885–1955)

Eugene Wigner (1902–1995)

Figure 5.56: Other creators who made significant contributions to relativistic quantum physics included Gregor Wentzel, Hermann Weyl, and Eugene Wigner.

Physicist and historian Alexander Blum made it clear that relativistic quantum theory came out of the same German-speaking world that had just produced non-relativistic quantum theory, and that it was founded by many of the same physicists, including Max Born, Werner Heisenberg, Pascual Jordan, Wolfgang Pauli, and Erwin Schrödinger [Blum and Rickles 2018, pp. 49, 255]:

> In the years 1925 to 1927, the old quantum theory was replaced by the newly developed theory of quantum mechanics, which grew out of the matrix mechanics of Heisenberg, Born, and Jordan and the wave mechanics of Schrödinger. Both of these theories were initially formulated entirely non-relativistically. But it was clear from the outset that contact would have to be made with the special theory of relativity for two important reasons: On the one hand, the mechanics would have to be complemented with a quantum electrodynamics (QED), in order to describe the emission and absorption of radiation, as well as the particulate properties of light itself, which by this time (in the wake of the discovery and interpretation of the Compton effect) was a generally accepted fact. On the other hand, the mechanics itself would have to be made relativistic, as it was known, already since the mid 1910s, that relativistic corrections to the kinematics of the electron would have a measurable effect in the fine structure of atomic spectra.
>
> It was Schrödinger's wave mechanics, rather than matrix mechanics, that provided the ideal starting point for a relativistic kinematics of matter: One needed to find a new, relativistic matter wave equation, but at first glance there were no immediate other conceptual difficulties, such as the problem of a non-commuting time variable in matrix mechanics. Schrödinger himself had initially attempted to find a relativistic wave equation, following de Broglie's program of matter waves, which had been formulated in a relativistic manner. But de Broglie had stopped short of addressing the dynamical equations. Schrödinger in fact arrived at the Klein Gordon equation, but he dismissed it, due to its empirical inadequacy (later understood as the absence of spin in the Klein Gordon equation). Others were not as scrupulous, and the Klein Gordon equation was rediscovered (and published) multiple times in the immediate aftermath of Schrödinger's first papers on wave mechanics. [...]
>
> In the years 1926–1928, immediately following the creation of matrix and wave mechanics, the protagonists of this development elaborated and expanded the techniques of the new quantum mechanics, so as to apply them to field theories. This work culminated in the theory of interacting quantum electrodynamics (QED), published in 1929 by Werner Heisenberg and Wolfgang Pauli.

As Blum noted, Schrödinger derived the Klein-Gordon relativistic quantum wave equation for spinless particles years before Klein and Gordon. Schrödinger also worked on quantum gravity, and made numerous other contributions to relativistic quantum field theory [Moore 1989; Weber 1988, pp. 99–100]. Walter Gordon (German, 1893–1939) and Oskar Klein (Swedish but closely coupled to the German-speaking scientific world, 1894–1977) were also part of the same German-speaking physics community.

Historian of science David Cassidy confirmed the foundational roles of German-speaking scientists such as Heisenberg, Jordan, and Pauli in relativistic quantum field theory [Cassidy 1992, p. 276]:

> Since electromagnetic radiation is a manifestation of electric and magnetic fields, the search began almost immediately for what is now called a relativistic quantum field the-

> ory. This extremely technical and mathematical branch of quantum physics, the foundations of which were laid by Heisenberg, Dirac, Pauli, Jordan, and their colleagues during the late 1920s and early 1930s, continues to this day with much the same program and approach. [...] The enormous high-energy accelerators, bubble chambers, and data analysis equipment that were built after World War II, employing vast teams of physicists, technicians, and students, are technological wonders in themselves. They were stimulated by the discovery of new types of nonelectromagnetic fields in the middle 1930s, the quantum behavior of which comes into play only when particles smash into each other at such extremely high energies that their internal workings become evident.
>
> Large-scale experimental research was paralleled by the continuing search for a unified field theory—a quantum field theory encompassing all four types of fields known today, rather than just the electromagnetic field. [...] Werner Heisenberg was again a leading member of the small band of abstract theorists who established the program and laid the foundations of relativistic quantum field theory as it has been pursued ever since.

Physicist Silvan Schweber further described Pauli's contributions to relativistic quantum physics [Schweber 1994, p. 583]:

> Quantum electrodynamics and quantum field theory became Pauli's main concern after 1927. [...] Pauli and Heisenberg formulated the canonical approach to the quantization of field systems in 1929. During the thirties many of the seminal papers in quantum field theory were either written by Pauli, had Pauli as one of its authors, or were written under the acknowledged guidance of Pauli. [...]
>
> Pauli spent the war years, from 1940 to 1946, at the Institute of Advanced Study in Princeton. Most of his efforts during that period were devoted to meson theory.

Felix Villars (Swiss, 1921–2002) collaborated with Pauli on what is now called Pauli-Villars regularization, a mathematical technique of getting physically sensible results (instead of mathematically infinite answers) from relativistic quantum calculations.

J. Robert Oppenheimer (1904–1967) was born in New York but had a German father and second-generation German-American mother, was raised speaking German, repeatedly visited family in Germany during his childhood, and received his Ph.D. under Max Born in Germany. He began working in relativistic quantum theory under Born and Pauli, and continued to work in that field in the United States.

Gregor Wentzel (German, 1898–1978) also began relativistic quantum research with Pauli and then continued in the United States.

Some physicists from the greater German-speaking world won Nobel Prizes related to relativistic quantum theory. Born, Heisenberg, Pauli, and Schrödinger won Nobel Prizes, although those were primarily for their earlier work on non-relativistic quantum physics. Peter Debye (Dutch, 1884–1966) won a Nobel Prize in Chemistry in 1936, yet he also made unrelated contributions to relativistic quantum theory (p. 914). Hans Bethe (German, 1906–2005) also made a number of important contributions to relativistic quantum theory, but his Nobel Prize was for unrelated work on nuclear fusion in stars (p. 1542). Similarly, Felix Bloch (Swiss, 1905–1983) won a Nobel Prize in Physics in 1952, but that was for his research on nuclear magnetic resonance, not his research on relativistic quantum theory (p. 1516). Eugene Wigner (Hungarian, 1902–1995) won a Nobel Prize in Physics in 1963 for his work on mathematical groups and symmetries in physics, which was highly applicable to both nuclear physics and relativistic quantum physics (p. 1535).

Polykarp Kusch (German, 1911–1993) won a Nobel Prize in Physics in 1955 for his contributions to quantum electrodynamics. Professor I. Wailer of the Nobel Committee for Physics explained Kusch's work [https://www.nobelprize.org/prizes/physics/1955/ceremony-speech/]:

> The discovery of Kusch refers directly to an important property of the electron, namely its magnetic moment. It had been known since long that the electron is a small magnet. The strength of this magnet is measured by its moment. The magnitude of the moment should be uniquely determined by the electron theory of Dirac, mentioned before. [...]
>
> Starting from this idea Kusch made a series of very careful investigations and found in 1947 that the magnetic moment of the electron is larger than the Bohr magneton by about one part in a thousand.

In 1936, Walter Heitler (German, 1904–1981) published the first complete textbook on quantum electrodynamics, *The Quantum Theory of Radiation*, which was so farsighted and useful that it is still in print.

Ernst Stückelberg (Swiss, 1905–1984) was one of the German-speaking scientists who made some of the most advanced and yet some of the most historically overlooked contributions to relativistic quantum field theory. He was the first to produce many of the major innovations and solutions in QED for which Richard Feynman later became famous, and he also made revolutionary suggestions regarding the nuclear strong force and other topics in relativistic quantum theory. Physicists Walter Greiner and Joachim Reinhardt gave a very short description of his work [Greiner and Reinhardt 1994, pp. 37–38]:

> Stückelberg [...] made pioneering contributions to quantum field theory. In 1942 he first conceived the idea that positrons can be interpreted as electrons running backward in time. The use of the causal propagator for calculating the scattering matrix was introduced in 1949 independently by R. Feynman and S. [Stückelberg] (with his student D. Rivier). Later S. (with A. Petermann) developed the idea of the renormalization group.

Markus Fierz (Swiss, 1912–2006) studied under and collaborated with Pauli, scrutinized the ideas of Stückelberg, and made a long and extremely fruitful research career of his own in quantum electrodynamics and other areas of relativistic quantum theory. Like Stückelberg, Fierz's many contributions have often been overlooked by those outside the German-speaking world.

Greiner and Reinhardt also mentioned some other German-speaking scientists who made important contributions to relativistic quantum theory. Those included: Max Delbrück (German, 1906–1981), who was much better known for his work on DNA and viruses (pp. 103 and 200); Hans Euler (German, 1909–1941), who obtained his Ph.D. in physics under Werner Heisenberg in 1935 and began a very promising career in quantum field theory that ended with his death during the war; and Victor Weisskopf (Austrian, 1908–2002), who worked in many areas of quantum field theory [Greiner and Reinhardt 1994, p. 381]:

> Delbrück [...] published a short addendum to an experimental paper on the coherent scattering of hard γ rays where he pointed out the possible interaction of photons with

> the vacuum polarization charge induced by a nucleus. The existence of this effect was demonstrated much later and called Delbrück scattering by H. Bethe. [...]
>
> Euler [...] The airplane in which he served as a meteorological observer was shot down in 1941. In his PhD thesis E. [Euler] calculated the QED process of scattering light by light. Subsequently he worked on the theory of high-energy cosmic ray collisions.
>
> Weisskopf [...] In 1934 W. [Weisskopf] formulated a relativistically covariant quantum field theory of bosons (with W. Pauli) and in 1936 introduced concepts which led to renormalization theory.

In 1923, Adolf Smekal (Austrian, 1895–1959) predicted one of the first QED effects, inelastic scattering of photons. That effect was demonstrated several years later by C. V. Raman, who won a Nobel Prize for it.

In 1947, Hendrik Casimir (Dutch, 1909–2000) and Dirk Polder (Dutch, 1919–2001) predicted the Casimir effect, a minute but real force exerted on electrically conductive objects by particles that quantum-mechanically appear out of nothingness and immediately disappear back into nothingness. This effect was actually demonstrated in the 1990s.

Some other physicists who made various early contributions to relativistic quantum theory in the German-speaking world included Richard Becker (German, 1887–1955), Fritz Bopp (German, 1909–1987), Herbert Fröhlich (German, 1905–1991), Nicholas Kemmer (Russian but educated and worked in Germany and Switzerland, lived 1911–1998), and Léon Rosenfeld (Belgian but worked in Germany and Switzerland, lived 1904–1974).

For completeness, some later contributions should also be mentioned. Martinus Veltman (Dutch, 1931–) and Gerard ’t Hooft (Dutch, 1946–) developed the electroweak theory that showed how the electromagnetic force and the weak nuclear force are two different aspects of the same theory. For that insight, they won the Nobel Prize in Physics in 1999. The Royal Swedish Academy of Sciences summarized their research [https://www.nobelprize.org/prizes/physics/1999/veltman/facts/]:

> According to modern physics, four fundamental forces exist in nature. Electromagnetic interaction is one of these. The weak interaction—responsible, for example, for the beta decay of nuclei—is another. In the 1960s, a unified theory was formulated for these two forces: the electroweak interaction. However, certain problems still remained to be solved. In the early 1970s, Martinus Veltman and Gerardus t’Hooft formulated and tested a mathematical theory that further explained the electroweak interaction.

In closely related work, Simon van der Meer (Dutch, 1925–2011) made improvements to particle accelerators that allowed electroweak theory to be confirmed experimentally. He won the Nobel Prize in Physics in 1984. The Royal Swedish Academy of Sciences noted [https://www.nobelprize.org/prizes/physics/1984/meer/facts/]:

> According to modern physics, there are four fundamental forces in nature. The weak interaction, responsible for e.g. the beta-decay of nuclei is one of them. According to the theory forces are mediated by particles: the weak interaction by the so called heavy bosons W, Z, about 100 times more massive than the proton. Simon van der Meer developed a method to accumulate a large number of energetic antiprotons in an accelerator ring. These were used in experiment where antiprotons and protons of high energy were brought to collide. In these experiments W and Z particles were discovered in 1983.

5.6.2 Quantum Gravity

Many of the physicists already mentioned in the previous section not only wrote papers on how to combine quantum theory with special relativity to describe quantum electrodynamics and other aspects of quantum field theory, but they also wrote papers with early ideas for how to combine quantum theory with general relativity in order to describe gravitational effects [Blum and Rickles 2018].

Relativistic quantum theory applied to the gravitational force is called quantum gravity, as illustrated in Fig. 5.57. Since it must incorporate general relativity as well as special relativity, it is far more complex than theories describing the other forces. One way to view the complexity of quantum gravity is to realize that gravitons (particles of the gravitational field) can be produced by anything with mass or energy, but gravitons themselves have energy and can therefore create unlimited numbers of additional gravitons. Another way to view the complexity of quantum gravity is to consider that calculations of particle interactions are made with reference to locations in space and time, yet gravitational interactions warp space and time themselves. For these reasons, even today physicists remain far from a satisfactory theory of quantum gravity (or at least experimental evidence that one of the many proposed approaches to quantum gravity is correct).

Other physicists bypassed mainstream quantum field theory and focused directly on quantum gravity or other approaches for combining gravity with other fundamental forces and theories [Blum and Rickles 2018; Pais 1982, pp. 325–354].

One of the earliest and most important physicists in this latter category was Theodor Kaluza (German, 1885–1954). In 1919, Kaluza combined Albert Einstein's equations of general relativity with the equations of electromagnetism by using an extra fifth dimension in addition to the usual three spatial dimensions and fourth time dimension. In 1926, Oskar Klein suggested ways to incorporate some aspects of quantum theory as well, so the resulting approach remains known as Kaluza-Klein theory.

Einstein himself was very impressed by Kaluza-Klein theory and spent the rest of his career (until his death in 1955) working on various versions and extensions of it. In that pursuit, Einstein was assisted at different points by Valentine Bargmann (German, 1908–1989) and Peter Bergmann (German, 1915–2002), who in turn each also contributed some of their own original ideas to the field.

Hermann Weyl (German, 1885–1955) and Leopold Infeld (Austrian, 1898–1968) also had some important early ideas about how to combine general relativity with other aspects of physics.

Burkhard Heim (German, 1925–2001) is an interesting case that deserves closer scrutiny. He was badly injured while doing research on novel explosives during the war, then spent the rest of his career pursuing his own ideas for how to combine quantum theory and general relativity [https://www.engon.de/protosimplex/index.htm]. Because his papers were published outside mainstream physics journals and employed Heim's own mathematical notation for his new approaches, his work has never been fully and properly evaluated. Some current or future German-speaking physicists with a detailed knowledge of quantum field theory and quantum gravity research should examine Heim's major papers to determine how sound his reasoning was and whether he had any physics insights that should be more widely known and utilized.

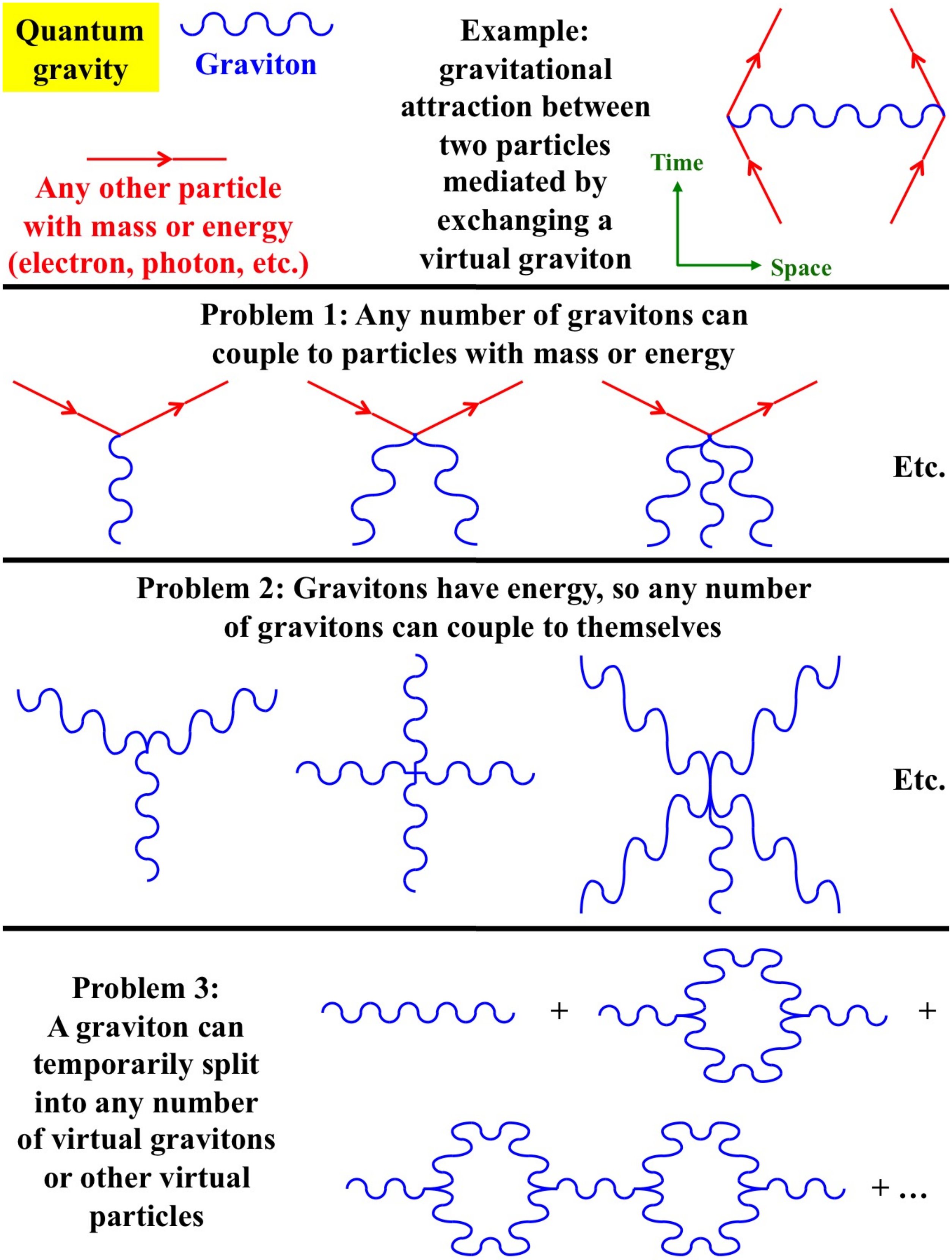

Quantum gravity
Graviton
Any other particle with mass or energy (electron, photon, etc.)
Example: gravitational attraction between two particles mediated by exchanging a virtual graviton
Time
Space
Problem 1: Any number of gravitons can couple to particles with mass or energy
Etc.
Problem 2: Gravitons have energy, so any number of gravitons can couple to themselves
Etc.
Problem 3: A graviton can temporarily split into any number of virtual gravitons or other virtual particles
+
+
+ …

Figure 5.57: Combining special and general relativity with quantum physics yields a theory of quantum gravity, which still suffers from several unresolved mathematical problems.

Chapter 6

Creators and Creations in Electrical and Electromagnetic Engineering

Nehmen Sie zum Beispiel dieses komische Rohr, das sie in Amsterdam verkaufen. Ich habe es genau untersucht. Eine Hülse aus grünem Leder und zwei Linsen, eine so—*er deutet eine konkave Linse an*—, eine so—*er deutet eine konvexe Linse an.* Ich höre, eine vergrößert und eine verkleinert. Jeder vernünftige Mensch würde denken, sie gleichen einander aus. Falsch. Man sieht alles fünfmal so groß durch das Ding. Das ist Ihre Wissenschaft.	You take for example that funny tube that they are selling in Amsterdam. I examined it closely. A casing of green leather and two lenses, one like that—*he indicates by gesture a concave lens*—, one like that—*he indicates a convex lens.* I hear that one enlarges and one reduces. Any sensible person would think that they would cancel each other out. Wrong. One sees everything five times as large through the thing. That is your science.

Bertolt Brecht. 1939. *Leben des Galilei* [*Life of Galileo*]. Scene 1. Ludovico.

This chapter gives an overview of some innovations in electrical and electromagnetic engineering that have played major roles in the modern world and that were invented or discovered by scientists and engineers who were trained in the predominantly German-speaking central European research world in the nineteenth and early twentieth centuries.

Creators from the German-speaking world made major contributions to:[1]

6.1. Electrical equipment and circuits

6.2. Lighting technology

6.3. Communications and recording technologies

6.4. Lasers and holography

6.5. Solid state physics and microelectronics

6.6. Infrared vision and targeting

6.7. Computers and robotics

6.8. Radar and sonar technologies and countermeasures

6.9. Optical microscopes, telescopes, and other optical instruments

6.10. Electron microscopes

---

[1] In addition to specific references that are cited in different areas throughout this chapter, this chapter makes use of general biographical and project information from: ACLS 2000; Albrecht et al. 1992; Ash and Söllner 1996; Bar-Zohar 1967; Bower 1987; Bunch and Hellemans 2004; Challoner 2009; Cornwell 2003; Crim 2018; EB 1911, 2010; Gillispie 1970–1990; Gimbel 1990a; Glatt 1994; Hall 2019a; István Hargittai 2006, 2011; Linda Hunt 1991; Impey et al. 2008; Jacobsen 2014; Koertge 2007; Kragh 2002; Kurowski 1982; Lasby 1971; Lusar 1956, 1971; Medawar and Pyke 2000; Mick 2000; Murray 2003; Nachmansohn 1979; NDB 1953–2020; Neufeld 2012; Nouzille and Huwart 1999; O'Reagan 2014, 2019; Porter 1994; Charles Walker 1946; Peter Watson 2010; Weitensfelder 2009.

For general overviews of large portions of the history of electrical and electromagnetic engineering in the German-speaking world, see: Buchheim and Sonnemann 1990; Bunch and Hellemans 2004 Cardwell 1995; Challoner 2009; Gerhart Göbel 1953; Gööck 2000; Heckl 2010, 2011; Heßler 2012; Hickethier 1998; Jankowsky 2000; König 2000, 2009; König and Schneider 2007; Ludwig 1974; Lundgreen and Grelon 1994; Radkau 1989, 2016; Technisches Museum Wien 2011; von Weiher 1983; Weitensfelder 2009, 2013; https://www.cdvandt.org; https://www.gfgf.org; https://www.radiomuseum.org.

I have deliberately left a blank space where images of some creators or creations should go. Those are people or projects that I felt were important enough that they should definitely be shown in this book, yet I have not yet been able to locate a suitable image that I have permission to use, despite my searches in Europe and in the United States. If readers have any relevant images and could send them to me, I would be very grateful and will include them in future editions of this book. Even where a suitable photo cannot be located, I believe that leaving a blank space pays tribute both to the scientific importance of that creator or creation and to how that historical fact has been very nearly forgotten.

To supplement this chapter, Appendix B provides examples of key documents on transistors, printed circuits and multi-pin connectors, integrated circuits, light emitting diodes (LEDs), etc. These documents demonstrate that German-speaking research groups invented, developed, and demonstrated those revolutionary microelectronics technologies many years before Bell Laboratories and other non-German firms claimed to have officially "invented" them. Moreover, the documents show numerous examples of how the relevant technical information was transferred from the German-speaking world to those firms.

Similarly, Appendix C provides considerable evidence for how directed energy technologies were developed within the German-speaking world and then transferred to other countries. Those directed energy technologies include not only lasers, but also particle beams and X-rays, electromagnetic pulse weapons, focused sound waves, and electromagnetic railguns.

Scientists from the German-speaking world also made numerous contributions to overlapping and related areas listed in other chapters, especially Chapter 5 (physics).

In September 1945, R. P. Linstead and T. J. Betts, the British and American chairs of the Combined Intelligence Objectives Subcommittee (CIOS), listed examples of several German innovations in electronics that would be copied by other countries [AFHRA A5186 electronic version pp. 904–1026, Ch. 4, pp. 38–40]:

> 1. The "Schornsteinfeger" project of radar camouflage is of definite interest. German scientists were discovered to have developed various types of anti-radar coverings which would prevent radar detection. These coverings were applied and used operationally in coating submarine "Schnorkels." Still further applications were contemplated by German experts engaged on this project.
>
> 2. Enemy development of Continuous Wave Transmission Navigational Aids was found to be well advanced. German equipment was capable of greater accuracy and greater range than any hitherto known. Fundamental research data was obtained concerning propagation conditions for use in CW Transmissions.
>
> 3. Infra-red development had received much attention by German experts, and their technique was in advance of that of the Allies. Infra-red was used for night vision to permit night driving of military vehicles, and night sighting and aiming of weapons under conditions of total black-out. Another application was in infra-red searchlights used for the protection of harbor entrances. An entire German combat element had been equipped with infra-red and trained in its use for employment on the Eastern front.
>
> 4. The design of polyrod aerials had been rejected as a development project by British and US authorities. It was discovered that the Germans had achieved successful use of this equipment in many applications. The polyrod aerial possesses important space saving advantages in centimetric radar work.
>
> 5. German scientists had conducted extensive ionospheric investigations. The bulk of their research data has been obtained by Allied scientists.
>
> 6. The enemy had achieved much in the development of materials with a wide range of

> electrical and magnetic properties, and of materials which become superconducting at relatively high temperatures.
>
> 7. Investigation revealed that German radio valve design was generally less advanced than our own. However, particular types of special valve designs have proven of interest.
>
> 8. German electron microscopes, capable of a magnification of 200,000 times, while not more advanced than our own, yield new information of interest.
>
> 9. Examination of anti-jamming circuits used by the Germans has provided new information.
>
> 10. Much valuable information on the use of electronic control and telemetering equipment in guided missiles of all kinds has been obtained.
>
> American experts discovered the Bosch machine and control equipment used for the manufacture of a new type of paper capacitors (condensers). Condensers produced by this process have important advantages over the types generally used in the US and United Kingdom. They are designed with a self-healing feature which will overcome repeated breakdowns resulting from over-voltage surges. One complete unit of this manufacturing equipment has been obtained for evacuation to the US.

In addition to large numbers of government reports, journalists also documented that many revolutionary electronic technologies were transferred out of the German-speaking world after World War II. For example, in October 1946, *Harper's Magazine* reported [Charles Walker 1946]:

> The head of the communications unit of Technical Industrial Intelligence Branch opened his desk drawer and took out the tiniest vacuum tube I had ever seen. It was about half thumb-size.
>
> *Notice it is heavy porcelain—not glass—and thus virtually indestructible. It is a thousand watt—one-tenth the size of similar American tubes. Today our manufacturers know the secret of making it. . . . And here's something. . . .*
>
> He pulled some brown, papery-looking ribbon off a spool. It was a quarter-inch wide, with a dull and a shiny side.
>
> "That's Magnetophone tape," he said. "It's plastic, metallized on one side with iron oxide. In Germany that supplanted phonograph recordings. A day's radio program can be magnetized on one reel. You can demagnetize it, wipe it off and put a new program on at any time. No needle; so absolutely no noise or record wear. An hour-long reel costs fifty cents." He showed me then what had been two of the most closely-guarded, technical secrets of the war: the infra-red device which the Germans invented for seeing at night, and the remarkable diminutive generator which operated it. German cars could drive at any speed in a total blackout, seeing objects clear as day two hundred meters ahead. Tanks with this device could spot targets two miles away. As a sniper scope it enabled German riflemen to pick off a man in total blackness.

There was a sighting tube, and a selenium screen out front. The screen caught the incoming infra-red light, which drove electrons from the selenium along the tube to another screen which was electrically charged and fluorescent. A visible image appeared on this screen. Its clearness and its accuracy for aiming purposes were phenomenal. Inside the tube, distortion of the stream of electrons by the earth's magnetism was even allowed for!

The diminutive generator—five inches across—stepped up current from an ordinary flashlight battery to 15,000 volts. It had a walnut-sized motor which spun a rotor at 10,000 rpm—so fast that originally it had destroyed all lubricants with the great amount of ozone it produced. The Germans had developed a new grease: chlorinated paraffin oil. The generator then ran 3,000 hours!

A canvas bag on the sniper's back housed the device. His rifle had two triggers. He pressed one for a few seconds to operate the generator and the scope. Then the other, to kill his man in the dark. "That captured secret," my guide declared, "we first used at Okinawa—to the bewilderment of the Japs."

We got, in addition, among these prize secrets, the technique and the machine for making the world's most remarkable electric condenser. Millions of condensers are essential to the radio and radar industry. Our condensers were always made of metal foil. This one is made of paper, coated with 1/250,000 of an inch of vaporized zinc. Forty per cent smaller, twenty per cent cheaper than our condensers, it is also self-healing. That is, if a breakdown occurs (like a fuse blowing out), the zinc film evaporates, the paper immediately insulates, and the condenser is right again. It keeps on working through multiple breakdowns—at fifty per cent higher voltage than our condensers! To most American radio experts this is magic, double-distilled.

6.1 Electrical Equipment and Circuits

German-speaking scientists led the discovery of electrical principles and the application of those principles to create essential types of electrical equipment and circuits.

In 1820, Johann Schweigger (German states, 1779–1857) developed the galvanometer for measuring electric current. See Fig. 6.1.

Using galvanometers and different electrical conductors, Georg Ohm (German states, 1789–1854, Fig. 6.1) studied the electrical properties of simple circuits. He demonstrated that the voltage difference V across an electrical component depends on the current I through the component and the electrical resistance R of the component, in accordance with the equation $V = IR$, which is now known as Ohm's law. Oxford University's *Biographical Dictionary of Scientists* explained how Ohm arrived at his conclusions [Porter 1994, p. 390]:

> Ohm began the work that led him to his law of electricity in 1825. He investigated the amount of electromagnetic force produced in a wire carrying a current[...] Ohm found that a longer wire produced a greater loss in electromagnetic force. [...]
>
> From this, Ohm reached the more general statement that the current is equal to the tension (emf or potential difference) divided by the overall resistance of the circuit, thus expressing the law in the form known as Ohm's law.
>
> Ohm went on to use an electroscope to measure how the tension varied at different points along a conductor to verify his law, and presented his arguments in mathematical form in his great work of 1827. He made a useful analogy with the flow of heat through a conductor, pointing out that an electric current flows through a conductor of varying resistance from one tension or potential to another to produce a potential difference, just as heat flows through a conductor of varying conductivity from one temperature to another to produce a temperature difference. [...]
>
> Ohm's derivation of a basic law of nature from experiment was a classic piece of scientific deduction.

Andreas von Ettingshausen (Austrian, 1796–1878, Fig. 6.1) designed the first machine to use electromagnetic induction to generate power.

Heinrich Lenz (Baltic German, 1804–1865, Fig. 6.1) formulated what is now known as Lenz's law, which describes how a changing magnetic field induces electric currents in nearby conductors that create new magnetic fields opposing the changing field. He also discovered that the power P consumed by an electric circuit depends on the current I flowing through the circuit and the electrical resistance R of the circuit, $P = I^2R$.

Heinrich Rühmkorff (German, 1803–1877) developed improved magnetic induction coils, now called Rühmkorff coils, and used them in a variety of applications such as AC transformers and high-voltage generators. See Fig. 6.2.

Werner von Siemens (German, 1816–1892, Figs. 6.3 and 6.22) began his career by creating more sophisticated telegraphs that could point to individual letters, and went on to invent and build a wide range of additional electrical innovations such as electric generators (dynamos), electric motors, transformers, electric elevators, and electric trains [Bähr 2016; von Siemens 1895]. The American Council of Learned Societies noted [ACLS 2000, p. 810]:

> First successful invention was an improved process for gold- and silverplating. After improving upon the indicator telegraph of Wheatstone, he developed an entire telegraph system; in 1847, together with Halske, he founded the Telegraphenbauanstalt von Siemens & Halske to manufacture and construct telegraph systems, eventually expanding to London, St. Petersburg, and Vienna. Helped design the first special cable-laying ship, the *Faraday*, and organized and constructed the Indo-European telegraph from London to Calcutta (1870). His most outstanding contribution was his discovery of the dynamo principle and its practical applications to streetcars and mine locomotives, in electrolysis, and in central generating stations.

Gustav Kirchhoff (German, 1824–1887) worked in many areas of physics, chemistry, and engineering (see also pp. 427, 599, 858, 915, and 957). He discovered a number of physical laws that now have his name attached to them, including laws illustrated in Fig. 6.4 that describe the current and voltage in electric circuits. Oxford University's *Biographical Dictionary of Scientists* summarized his contributions to electrical engineering and electromagnetism [Porter 1994, p. 390]:

> Kirchhoff made his first important contribution to physics while still a student. In 1845 and 1846 he extended Ohm's law to networks of conductors and derived the laws known as Kirchhoff's laws that determine the value of the current and potential at any point in a network. He went on to consider electrostatic charge and in 1849 showed that electrostatic potential is identical to tension, thus unifying static and current electricity. Kirchhoff made another fundamental discovery in electricity in 1857 by showing theoretically that an oscillating current is propagated in a conductor of zero resistance at the velocity of light. This was important in the development in the 1860s of the electromagnetic theory of light[...]

As shown in Fig. 6.5, Johann Sigmund Schuckert (German, 1846–1895) improved electric generators and motors, and also created some of the first lighting systems for streets and buildings in the 1870s. His company, Schuckert & Co., competed with the Siemens company to develop and sell new electrical products. After the deaths of their respective founders, the two companies merged.

František Křižík (Austrian/Czech, 1847–1941) created electric generators, electric motors, electric trains, electric cars, improved arc lamps, etc. (Fig. 6.6).[2] The company he founded, Krizik Works, continued to be an important high-tech industrial center during World War II and the postwar Soviet occupation of Czechoslovakia (e.g., pp. 3987–3998).

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[2] https://czech-presidency.consilium.europa.eu/en/news/frantisek-krizik-the-inventor-who-illuminated-the-world-and-bohemia-with-arc-lamps/

Nikola Tesla (Serbo-Croatian, educated in Austria, 1856–1943) invented a complete AC (alternating current) electric power generation, distribution, and usage system for the Westinghouse company in the United States. He also created a wide range of other revolutionary electrical innovations [Cheney 1981; Cheney and Uth 1999; Tesla 1893, 1904, 1919, 1940]. See Fig. 6.7. Tesla biographer Margaret Cheney summed up his impact [Cheney and Uth 1999, pp. vi–vii]:

> Tesla is indisputably the father of alternating current power generation and transmission. His AC technology, first introduced on a large scale at Niagara Falls in 1896, remains unchanged and unchallenged to this day. The same holds true for Tesla's "Apparatus for Transmission of Electrical Energy," patented in 1900, which is still the basis for transmitting and receiving all radio and television signals. These two technologies alone merit the recognition and gratitude of every inhabitant on this planet.
>
> Like other great inventors, Tesla was a true Renaissance man. He turned fresh loam across half-a-dozen fields of science. He patented hundreds of inventions, crafted his own tools, built his own machines, practiced and consulted as an electrical engineer, handled his own press relations with dexterity and *élan*, and was even known to write poetry. Not only did this 19th-century polymath perform such heavy roles under one hat, he was also an environmentalist, a health and nutrition advocate, a philosopher, and many would say a visionary genius.
>
> Tesla was a "heroic" inventor—something we need more of today. He looked at invention as a way to improve the lot of mankind, not just a means of enhancing wealth, or meeting the demands of the marketplace. [...]
>
> Though few inventors have contributed more to the development of the United States as a world power, the prestigious Smithsonian Institution has never substantially acknowledged Tesla's contribution. His alternating current generator, for example, is included in the museum's exhibit on Thomas Edison. The Institution has also been reluctant to credit Tesla's critical role in the invention of radio even though the U.S. Supreme Court affirmed his patent priority over Marconi in 1943. [...]
>
> As a result of this historical bias, Tesla's major inventions are usually attributed to others. [...]
>
> Every time we turn on a light, or a radio, or operate a remote control we continue his legacy. His name should be respected everywhere electricity flows.

As illustrated in Fig. 6.8, Charles (Karl) Steinmetz (German, 1865–1923) invented a complete AC electric power generation, distribution, and usage system for the rival General Electric company in the United States. The *Encyclopedia Britannica* listed some of his key insights [EB 2010]:

> Steinmetz' experiments on power losses in the magnetic materials used in electrical machinery led to his first important work, the law of hysteresis. This law deals with the power loss that occurs in all electrical devices when magnetic action is converted to unusable heat. Until that time the power losses in motors, generators, transformers, and other electrically powered machines could be known only after they were built. Once

> Steinmetz had found the law governing hysteresis loss, engineers could calculate and minimize losses of electric power due to magnetism in their designs.
>
> His second contribution was a practical method for making calculations concerning alternating current circuits. This method was another example of using mathematical aids for engineering the design of machinery and power lines, so that the performance of the electrical system could be predicted in advance. This accomplishment was largely responsible for the rapid progress made in the commercial introduction of alternating-current apparatus. [...]
>
> Steinmetz' third major achievement was in the theory of electrical transients—that is, changes in electrical circuits of very short duration. A prime example of this phenomenon is lightning, and Steinmetz' investigation of lightning phenomena resulted in his theory of traveling waves and opened the way for his development of devices to protect high-power transmission lines from lightning bolts.

Brothers Wilhelm Emil Fein (German, 1842–1898) and Carl Fein (German, 18??–19??) invented the electric hand drill in 1895. See Fig. 6.9.

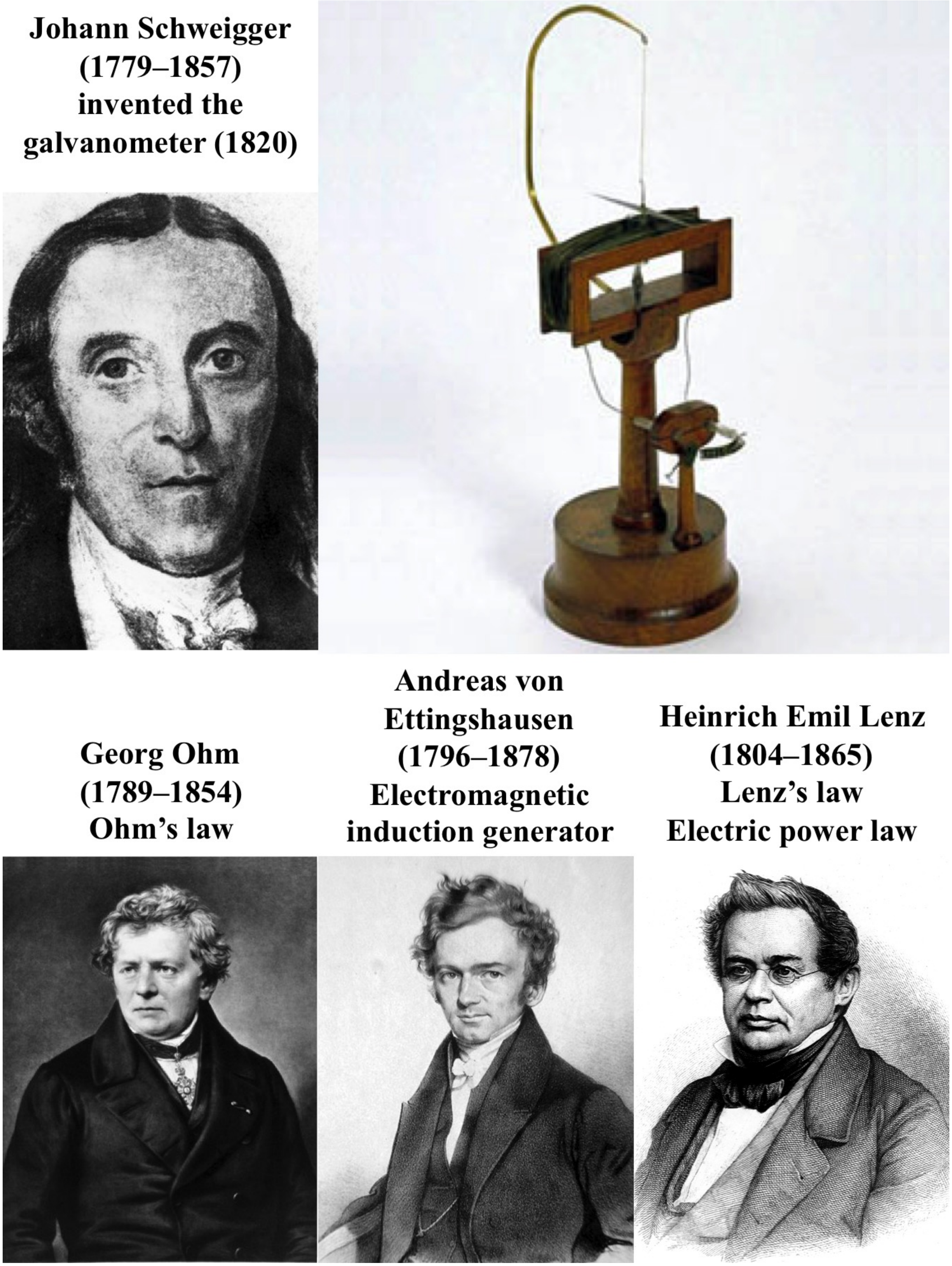

Johann Schweigger
(1779–1857)
invented the
galvanometer (1820)
Georg Ohm
(1789–1854)
Ohm's law
Andreas von
Ettingshausen
(1796–1878)
Electromagnetic
induction generator
Heinrich Emil Lenz
(1804–1865)
Lenz's law
Electric power law

Figure 6.1: Johann Schweigger invented the galvanometer, Georg Ohm discovered Ohm's law, Andreas von Ettingshausen developed the electromagnetic induction generator, and Heinrich Emil Lenz discovered Lenz's law and the electric power law.

Heinrich Rühmkorff (1803–1877)
created AC transformers and electric generators

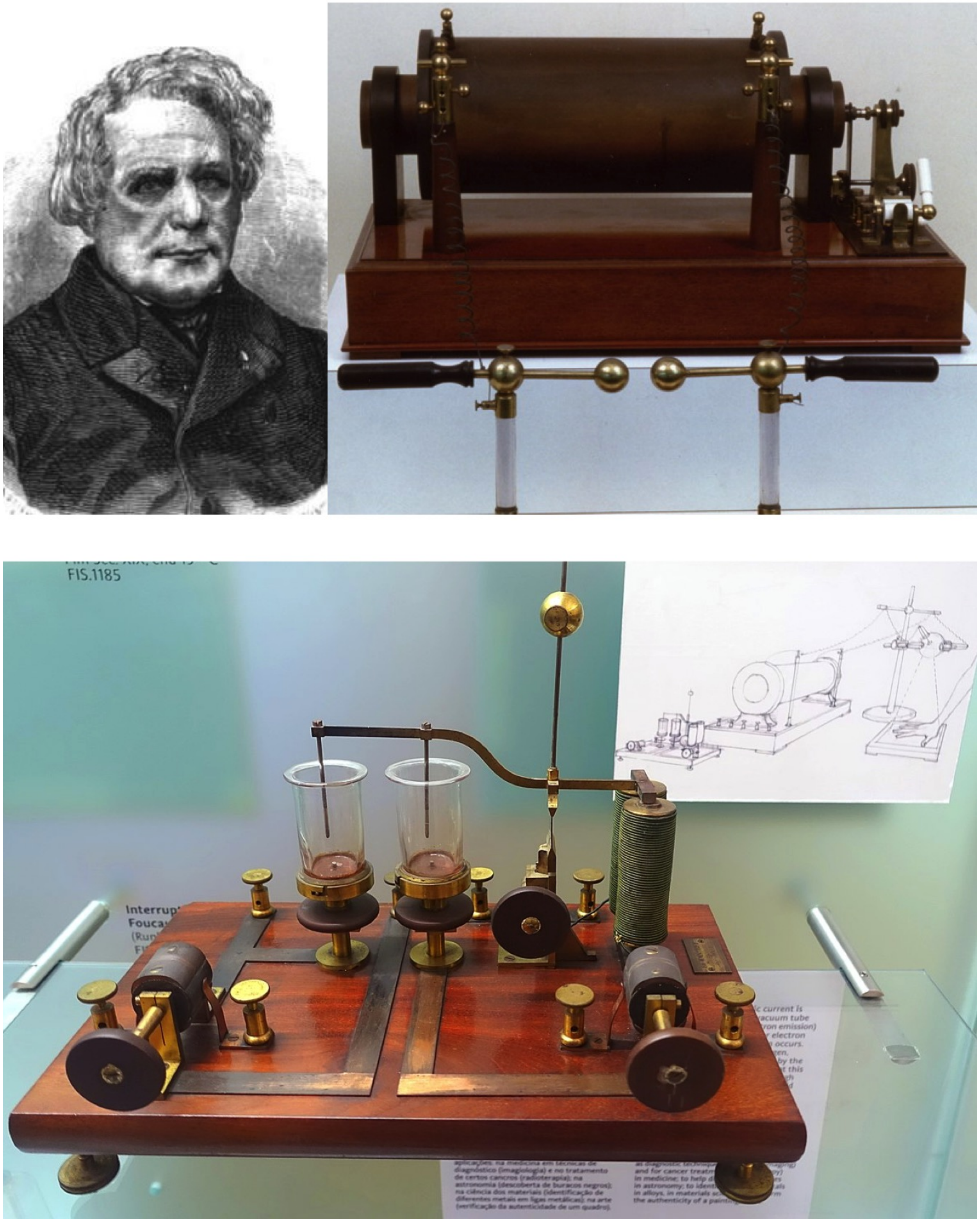


Figure 6.2: Heinrich Rühmkorff created AC transformers, electric generators, etc.

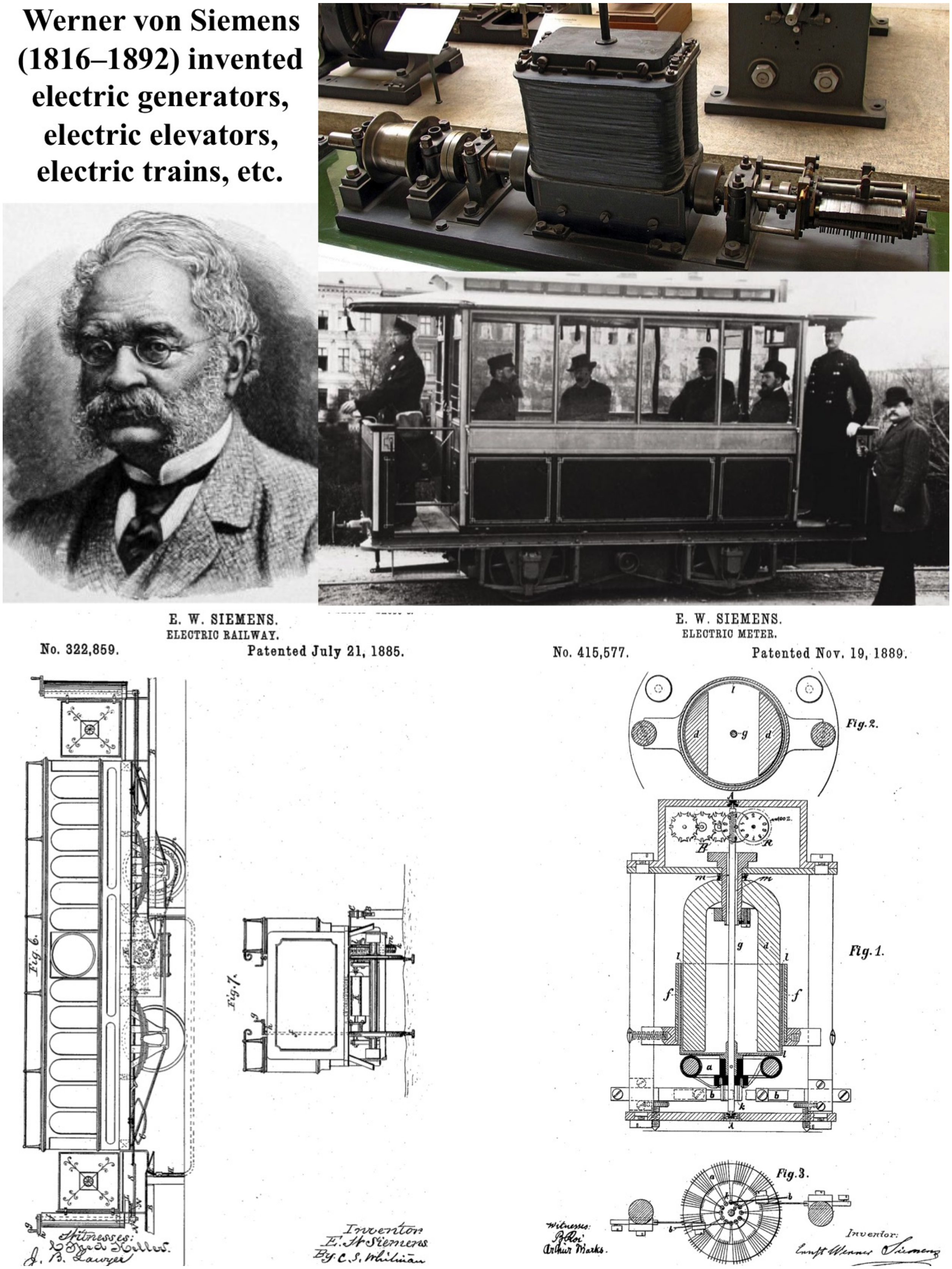

Werner von Siemens (1816–1892) invented electric generators, electric elevators, electric trains, etc.
E. W. SIEMENS.
ELECTRIC RAILWAY.
No. 322,859.
Patented July 21, 1885.
Fig. 6.
Fig. 7.
Witnesses:
J. B. Lawyer
Inventor
E. W. Siemens
By C. S. Whitman
E. W. SIEMENS.
ELECTRIC METER.
No. 415,577.
Patented Nov. 19, 1889.
Fig. 2.
Fig. 1.
Fig. 3.
Witnesses:
Arthur Marks.
Inventor:
Ernst Werner Siemens

Figure 6.3: Werner von Siemens invented electric generators, electric elevators, electric trains, etc.

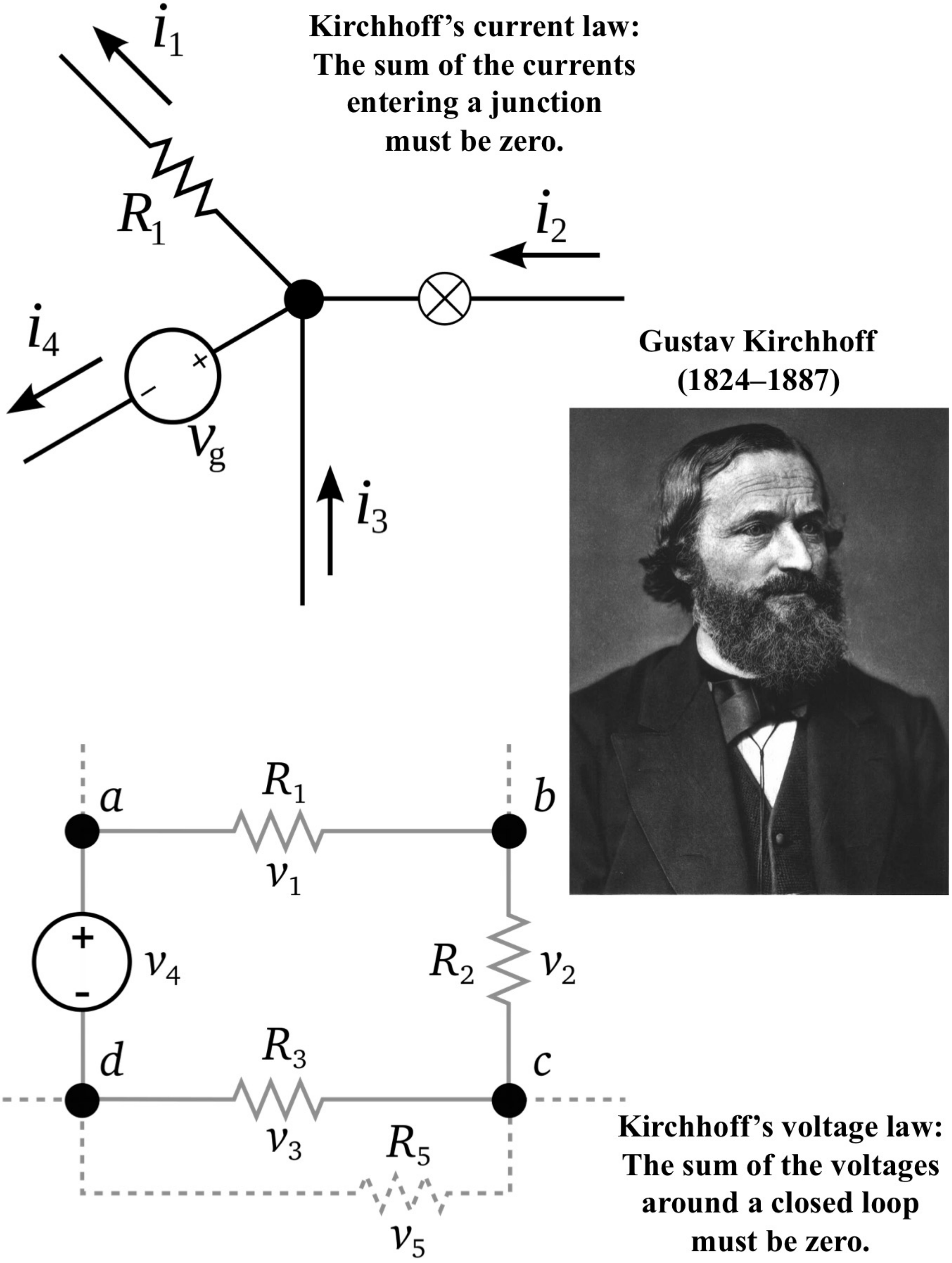

i_1
Kirchhoff's current law:
The sum of the currents
entering a junction
must be zero.
R_1
i_2
i_4
+
–
v_g
i_3
Gustav Kirchhoff
(1824–1887)
a
R_1
b
v_1
+
-
v_4
R_2
v_2
d
R_3
c
v_3
R_5
v_5
Kirchhoff's voltage law:
The sum of the voltages
around a closed loop
must be zero.

Figure 6.4: Gustav Kirchhoff discovered laws for currents and for voltages that are still widely used in analyzing electric circuits.

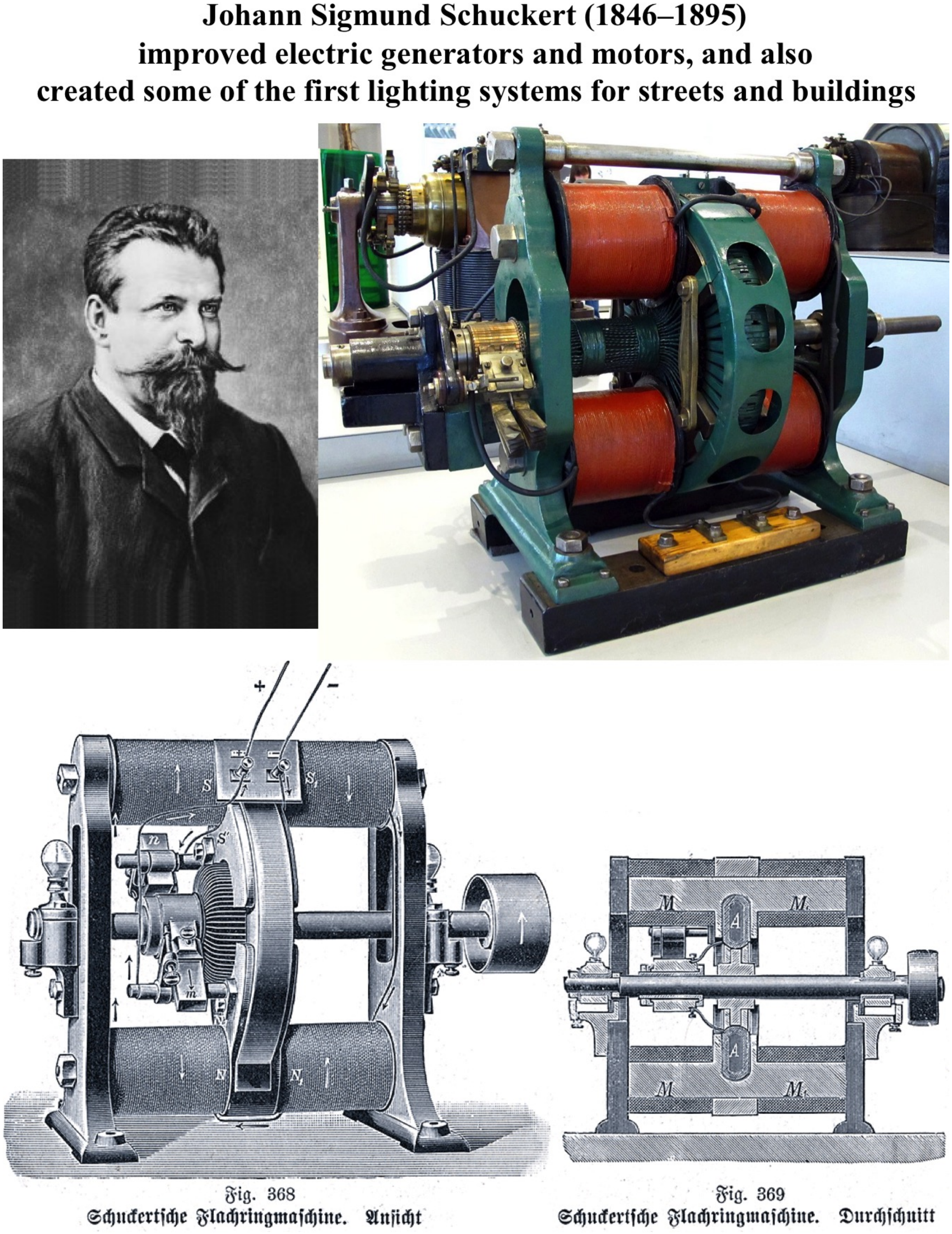

Johann Sigmund Schuckert (1846–1895)
improved electric generators and motors, and also
created some of the first lighting systems for streets and buildings
+
−
S
S
S'
n
m
N
N
M
M
A
A
M
M
Fig. 368
Schuckertſche Flachringmaſchine. Anſicht
Fig. 369
Schuckertſche Flachringmaſchine. Durchſchnitt

Figure 6.5: Johann Sigmund Schuckert improved electric generators and motors, and also created some of the first lighting systems for streets and buildings.

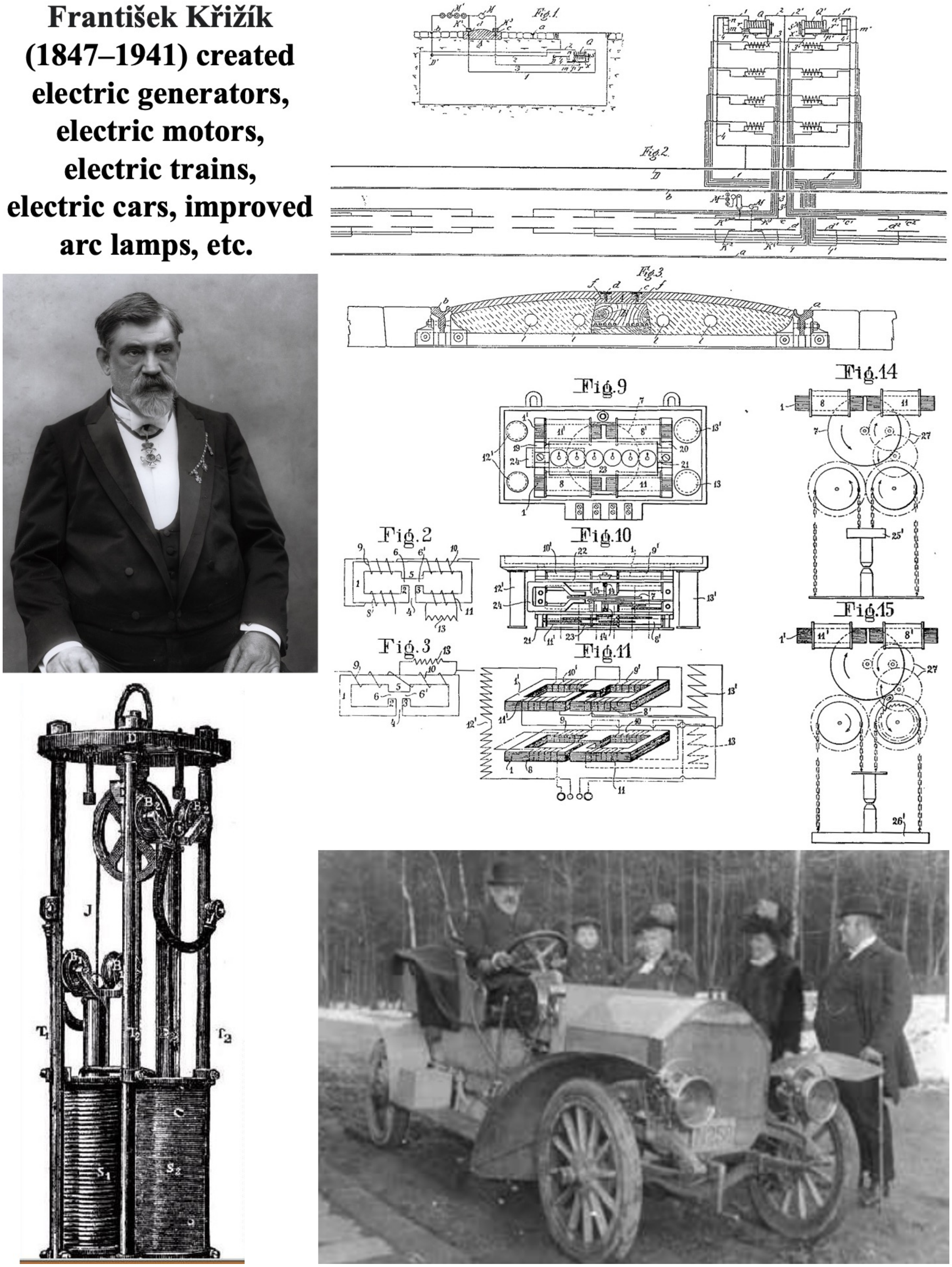

František Křižík
(1847–1941) created
electric generators,
electric motors,
electric trains,
electric cars, improved
arc lamps, etc.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 9
Fig. 14
Fig. 2
Fig. 10
Fig. 3
Fig. 11
Fig. 15
D
B2
J
T1
T2
S1
S2

Figure 6.6: František Křižík created electric generators, electric motors, electric trains, electric cars, improved arc lamps, etc.

Nikola Tesla (1856–1943) invented a complete AC electric power generation, distribution, and usage system for Westinghouse in U.S.

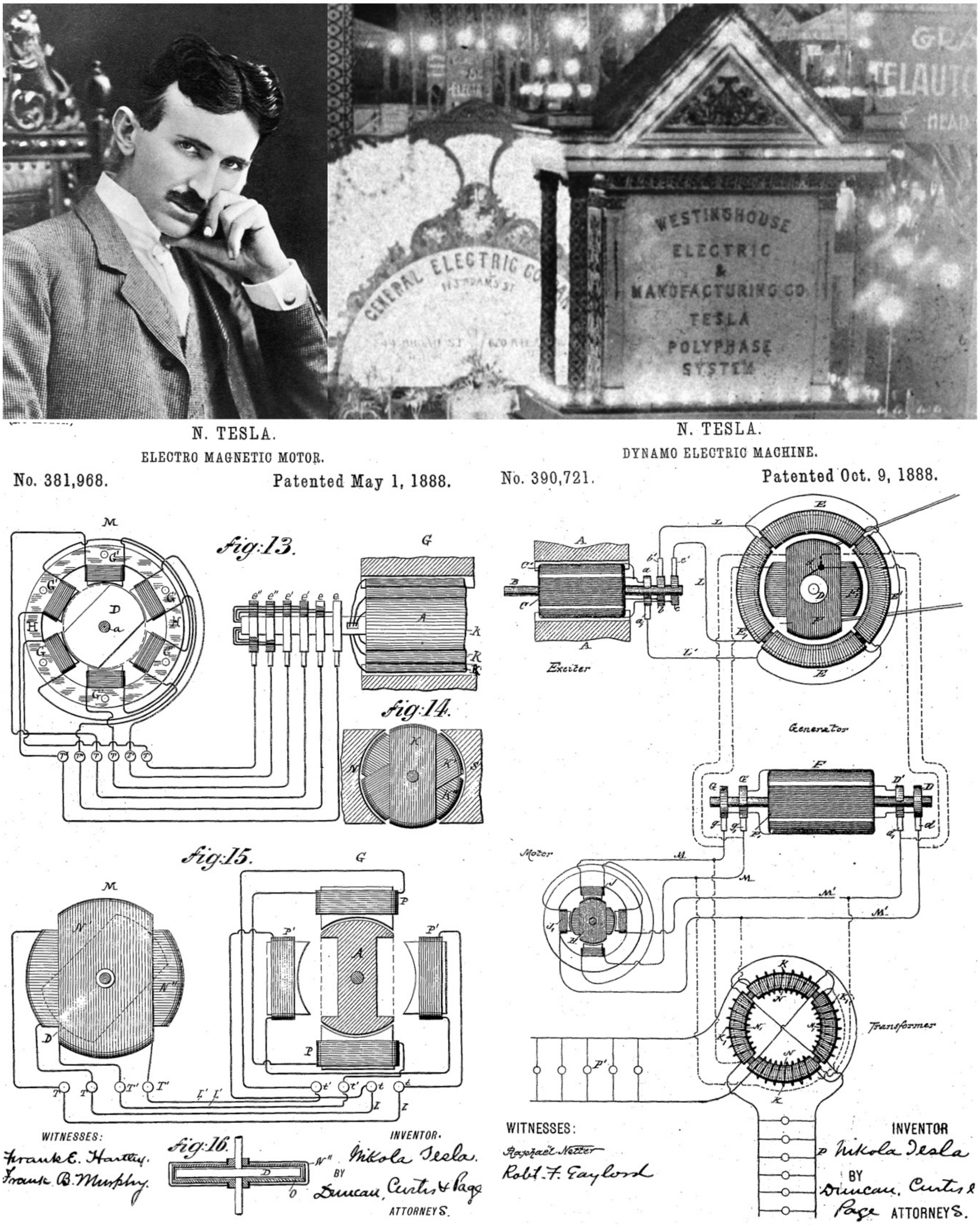

GENERAL ELECTRIC CO.
WESTINGHOUSE
ELECTRIC
&
MANUFACTURING CO.
TESLA
POLYPHASE
SYSTEM
N. TESLA.
ELECTRO MAGNETIC MOTOR.
No. 381,968.
Patented May 1, 1888.
Fig:13.
Fig:14.
Fig:15.
Fig:16.
WITNESSES:
Frank E. Hartley.
Frank B. Murphy.
INVENTOR.
Nikola Tesla.
BY
Duncan, Curtis & Page
ATTORNEYS.
N. TESLA.
DYNAMO ELECTRIC MACHINE.
No. 390,721.
Patented Oct. 9, 1888.
Exciter
Generator
Motor
Transformer
WITNESSES:
Raphaël Netter
Robt. F. Gaylord
INVENTOR
Nikola Tesla
BY
Duncan, Curtis & Page
ATTORNEYS.

Figure 6.7: Nikola Tesla invented a complete AC electric power generation, distribution, and usage system for the Westinghouse company in the United States.

Charles (Karl) Steinmetz (1865–1923) invented a complete AC electric power generation, distribution, and usage system for General Electric in U.S.

C. P. STEINMETZ.
SYSTEM OF DISTRIBUTION BY ALTERNATING CURRENTS.
No. 533,244. Patented Jan. 29, 1895.

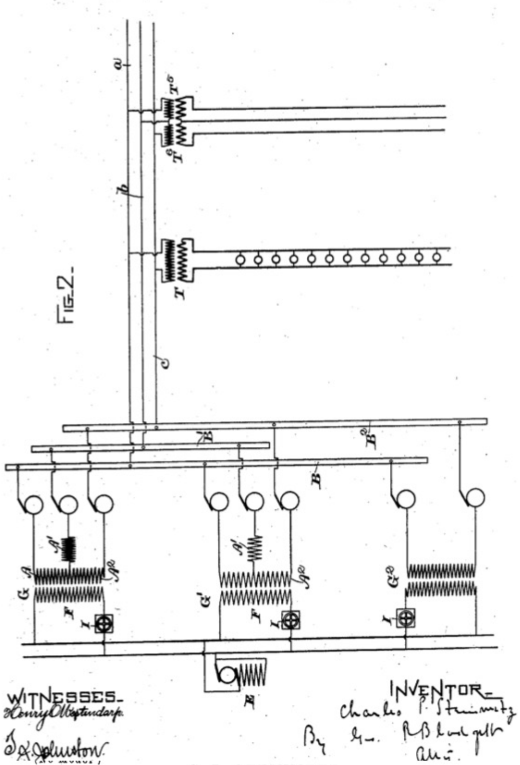


FIG. 2.
a
b
c
T
T'
T²
B
B'
B²
A
A'
G
G'
G²
F
I
WITNESSES.
Henry Oltegstandorp
INVENTOR.
Charles P. Steinmetz
By Geo. R. Blodgett Atty.

C. P. STEINMETZ.
INDUCTOR DYNAMO.
No. 559,419. Patented May 5, 1896.

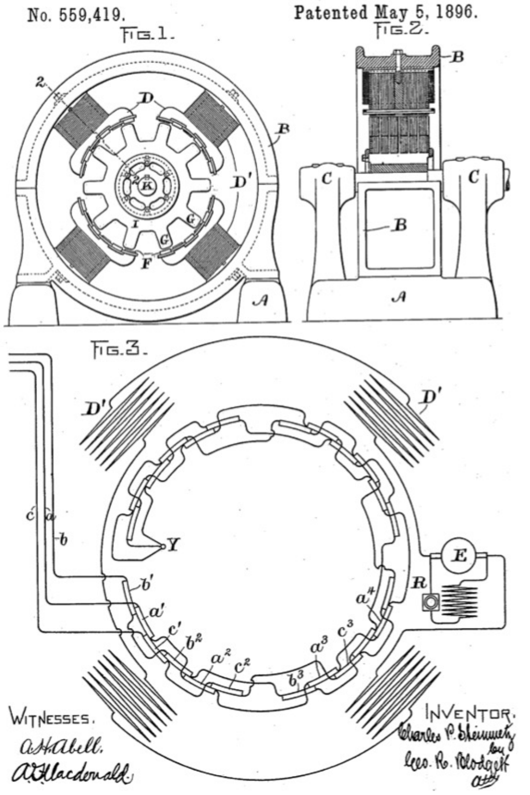


FIG. 1.
FIG. 2.
FIG. 3.
2
D
D'
B
C
K
F
G
A
Y
E
R
a
b
c
a'
b'
c'
a²
b²
c²
a³
b³
c³
a⁴
WITNESSES.
A. H. Abell.
A. G. Macdonald.
INVENTOR.
Charles P. Steinmetz
by Geo. R. Blodgett Atty.

C. P. STEINMETZ.
THREE PHASE INDUCTION METER.
No. 583,950. Patented June 8, 1897.

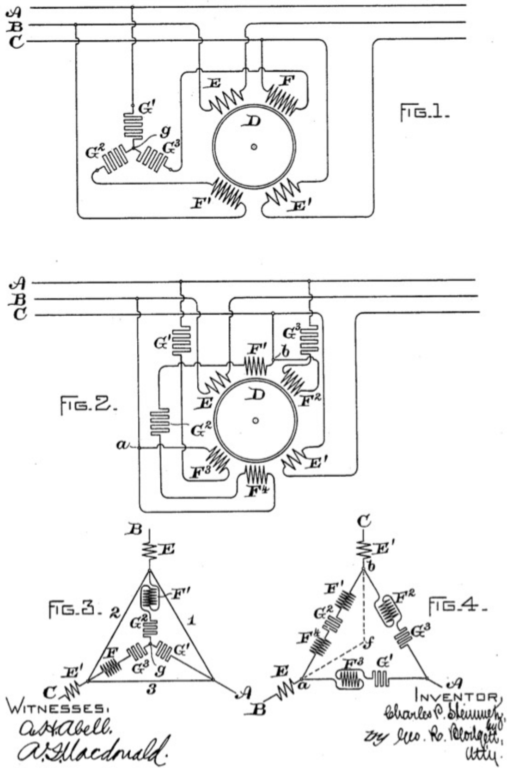
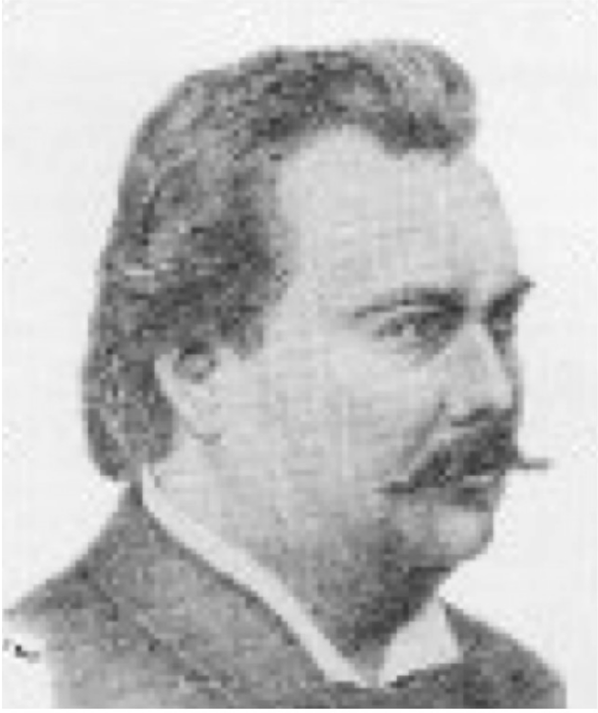


FIG. 1.
FIG. 2.
FIG. 3.
FIG. 4.
A
B
C
D
E
E'
F
F'
F²
F³
F⁴
G'
G²
G³
g
a
b
f
1
2
3
WITNESSES.
A. H. Abell.
A. G. Macdonald.
INVENTOR.
Charles P. Steinmetz
by Geo. R. Blodgett Atty.

Figure 6.8: Charles (Karl) Steinmetz invented a complete AC electric power generation, distribution, and usage system for the rival General Electric company in the United States.

Wilhelm Emil Fein (1842–1898)

Carl Fein (18??–19??)



Electric hand drill (1895)

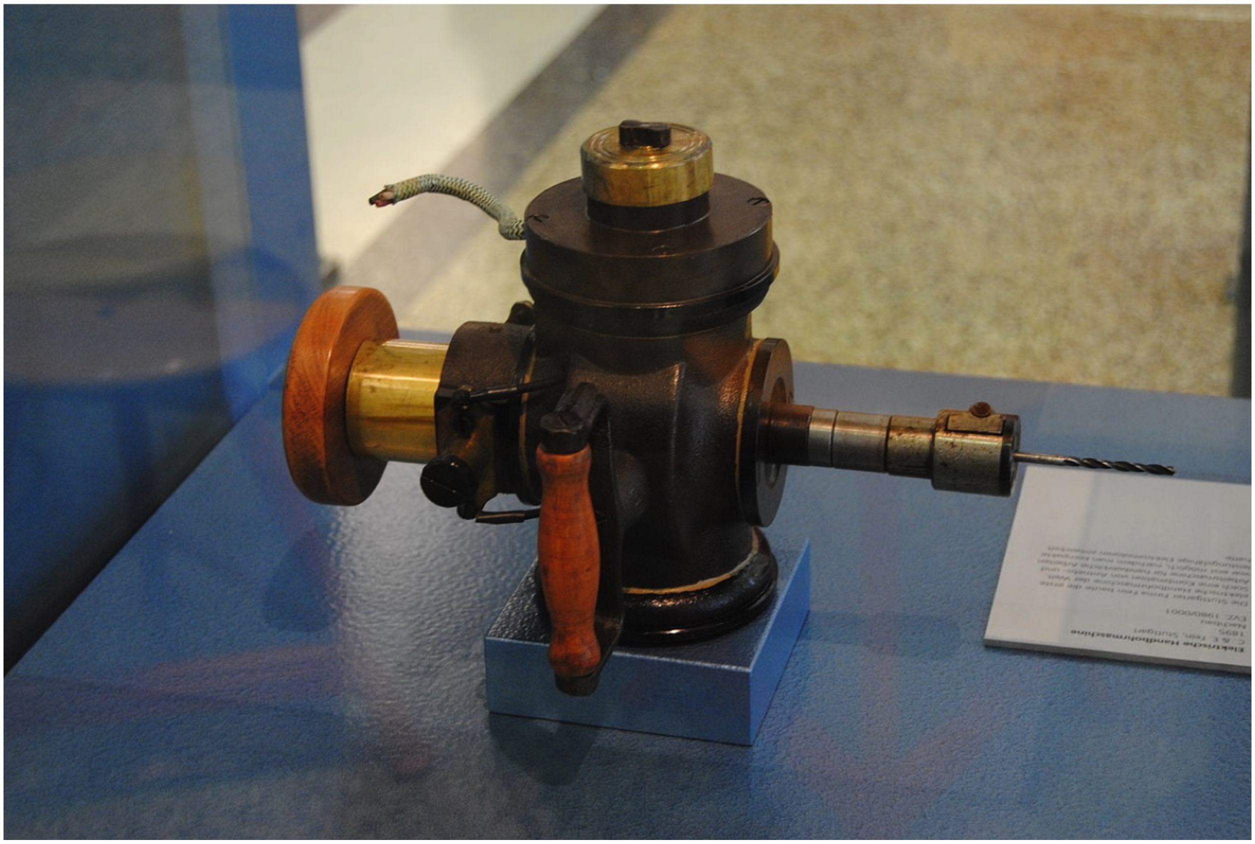


Figure 6.9: Brothers Wilhelm Emil Fein and Carl Fein invented the electric hand drill in 1895.

6.2 Lighting Technology

Creators from the German-speaking world pioneered all major categories of lighting science and technology. They developed spectroscopy to study visible light, and also discovered infrared and ultraviolet light (Section 6.2.1). They were directly responsible for inventing and developing all major types of artificial lighting—incandescent light bulbs (Section 6.2.2), fluorescent light tubes and their variations (Section 6.2.3), and light emitting diodes or LEDs (Section 6.2.4).

6.2.1 Tools for Analyzing the Visible Spectrum, Infrared, and Ultraviolet Light

Spectroscopy, the quantitative separation and measurement of different colors or wavelengths in light, was developed and demonstrated by Joseph von Fraunhofer (Bavarian, 1787–1826), Robert Bunsen (German, 1811–1899), and Gustav Kirchhoff (German, 1824–1887). See Figs. 3.4 and 6.10.

Using spectroscopy to search for energy beyond the colors of visible light, Friedrich Wilhelm (William) Herschel (Hanover, 1738–1822) discovered infrared light in 1800 [Herschel 1800]. See p. 1134. He also discovered the planet Uranus and made several other important astronomical discoveries (p. 802). For more information on infrared technologies, see Section 6.6.

Using spectroscopy in a very similar fashion to search beyond visible light, Johann Ritter (Prussian/Bavarian, 1776–1810) discovered ultraviolet light in 1801 (Fig. 6.10).

6.2.2 Incandescent Light Bulbs

There is significant evidence that Heinrich Göbel (German, 1818–1893) invented the first fully functional incandescent light bulb in 1854, 25 years before the much more famous light bulbs from Thomas Edison's laboratory.[3] See Fig. 6.11. Modern historians and archivists should examine Göbel's work more closely to clarify exactly what he did.

Even the light bulbs that Thomas Edison's laboratory produced in 1879 were heavily dependent upon German-speaking creators whom Edison employed. Those creators included:[4]

- Leonhard Sigmund Bergmann (German, 1851–1927, shown in Fig. 6.12) studied engineering in Thuringia. He was recruited by Edison in 1875, and he played an important role in the development of Edison's versions of the phonograph, telephone, and incandescent light bulb. After that, he worked relatively independently of Edison to produce a variety of electrical and mechanical devices in the United States. Around 1890, Bergmann returned to Germany, where he built up an industrial empire producing everything from electrical systems to steam turbines to automobiles.

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[3] https://data.tmw.at/object/281276; https://www.zobodat.at/pdf/VeroeffFerd_83_0165-0184.pdf; Paturi 1998, pp. 338–339. For a contrary opinion see Rohde 2007.

[4] Conot 1979; Josephson 1959; http://www.lamptech.co.uk; https://ethw.org/John_Kruesi

- Ludwig Karl Böhm (German, 1859–after 1907, Fig. 6.13) was a student and assistant of Heinrich Geissler, a German inventor of electric lighting (p. 958), during the period 1871–1878. During the crucial period 1879–1880, he worked in Edison's laboratory, where he drew upon his previous experience to create the vacuum pumps, glass envelopes, electrical assemblies, and other key details for the first incandescent lamps that were produced and patented there. He appears to have become quickly disillusioned with Edison and spent the rest of his life working for other companies or for himself. During his life, Böhm produced an astonishing variety of inventions, including multiple types of electric lights, improved vacuum pumps, refrigerated railroad cars, paper-making machines, acetylene gas generators, carbide furnaces, automated money-handling machines, etc.

- Johann Heinrich "John" Krüsi (Swiss, 1843–1899, Fig. 6.14) was a skilled machinist and machine maker who was educated and worked in Europe, then was recruited by Edison in 1872. He became the head machinist in Edison's lab, where he either invented or directly helped to invent the Edison phonograph. After that, he worked on the development of incandescent light bulbs, as well as other associated electrical and mechanical components and inventions.

Thomas Edison and his companies also made use of the innovations of a number of other creators from the German-speaking world, including Robert Bosch (p. 1349), Johann Sigmund Schuckert (p. 952), Charles Steinmetz (p. 955), and Nikola Tesla (p. 954). The accumulated mythology surrounding Edison should be carefully reexamined by modern historians to assign proper credit for the innovations to the appropriate people.[5]

Whereas the first incandescent light bulbs used short-lived, soot-forming carbon filaments, German-speaking creators developed greatly improved incandescent bulbs that used longer-lived, cleaner, and more efficient metal filaments:

- Walther Nernst (German, 1864–1941, Fig. 6.15) invented zirconium filaments in 1897.

- Carl Auer von Welsbach (Austrian, 1858–1929, Fig. 6.15) invented osmium filaments in 1898. (He also invented the gaslight mantle in 1885 and the flint metal lighter in 1903, and he founded Auergesellschaft, Treibacher Industrie, and Osram.)

- Werner von Bolton (German, 1868–1912) and Otto Feuerlein (Swiss, 1863–1930) invented tantalum filaments in 1902. See Fig. 6.16.

- Alexander Just (German, 1874–1937) and Franjo Hanaman (Austro-Hungarian/Croatian, 1878–1941) invented tungsten filaments in 1904, and they have been widely used ever since (Fig. 6.16).

6.2.3 Gas Discharge and Fluorescent Light Tubes

Heinrich Geissler (German, 1814–1879), Julius Plücker (German states, 1801–1868), and Johann Hittorf (German, 1824–1914) developed and tested early high-voltage gas discharge tubes that were ultimately diversified into vacuum tubes, X-ray tubes, cathode ray tubes, neon lighting tubes, and fluorescent lighting tubes. See Fig. 6.17.

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[5] There also appear to have been other inventors in the English-speaking world, such as William Sawyer (U.S., 1850–1883) and Joseph Swan (English, 1828–1914), whose accomplishments have been unfairly slighted by all of the hagiography focused on Edison.

As shown in Fig. 6.18, Leo Arons (German, 1860–1919) modified high-voltage gas discharge tubes to create the mercury vapor lamp in 1892.

Edmund Germer (German, 1901–1987), Friedrich Meyer (German?, 18??–19??), and Hans Spanner (German?, 18??–19??) further modified high-voltage gas discharge tubes to invent modern fluorescent lighting tubes in 1926. Specifically, they coated mercury vapor lamp tubes with fluorescent chemical pigments to absorb the ultraviolet light emitted by the mercury and reemit that energy as a range of visible light. See Fig. 6.19.

Nikolaus Riehl (German, 1901–1990, p. 1625), one of the leading scientists of Auergesellschaft, also made important contributions to chemical pigments for fluorescent lighting and to the optical spectroscopy of solid materials.

Both before and after World War II, these lighting technologies were transferred from the German-speaking world to other countries. BIOS 395, *German Fluorescent Lamp Industry and Phosphor Chemical Manufacture*, pp. 3 and 5, provides an example of the transfer of information on improved fluorescent light tubes to the United Kingdom and United States:

> REPORT 2—DISCUSSION WITH DR. ABRAHAMOZIK, FORMERLY RESEARCH CHEMIST OF THE WELT-POST INSTITUTE, HEIDELBERG. 14.11.1945.
>
> [...] With Dr. Lappe, a physicist, he had been engaged on the preparation of metallic sulphides, selenides and tellurides by new methods employing furnacing at ultrahigh-pressures circa 1,000 atmospheres. The object was to obtain improved efficiency of transformation of long wave U.V. into visible radiation and secondly to produce fluorescent powders responsive to infra-red radiation of long wavelength corresponding with 400^oC radiators.
>
> Ultra-Violet Phosphors:
>
> A large range of possible substances had been investigated of which the most effective was found to be zinc sulphide containing 5% zinc selenide activated with 0.0001% Cu, up to 1% Cu. This material was stated to be some 30% to 50% more efficient than a simple zinc sulphide produced by the same method.
>
> I.R. Phosphors:
>
> To produce powders responsive to long wavelength I.R. radiation—zinc, lead, mercury, cadmium sulphides, selenides and tellurides had been investigated. The zinc sulphide + 5% selenide was good and the telluride compound was probably better but less was known about the properties.
>
> These latter compounds were used in receiving circuits for detecting I.R. by employing the phosphor as the dielectric of a condenser fitted in a sensitive valve receiver. Reception

> of I.R. radiation was indicated by circuit changes resulting from changes in the dielectric constant of the phosphor.

Gilles Holst (Dutch, 1886–1968) and Willem Uyterhoeven (Dutch, 18??–19??) invented sodium vapor lamps in 1932, as shown in Fig. 6.20. Holst was the research director at the Philips Eindhoven laboratory [VanDelft 2014], which was closely tied to the rest of the predominantly German-speaking research world from the late nineteenth century through World War II, including work on electronics, communications, and directed energy beams.[6] Holst was also involved in research toward the development of transistors (pp. 1056–1057 and 2686–2689).

6.2.4 Light Emitting Diodes (LEDs)

Bernhard Gudden (German, 1892–1945), Robert Pohl (German, 1884–1976), Zoltan Bay (Hungarian, 1900–1992), György Szigeti (Hungarian, 1905–1978), and Kurt Lehovec (Bohemian/Austrian/Czech, 1918–2012) developed light emitting diodes (LEDs). See pp. 1106–1108 and Section B.4.

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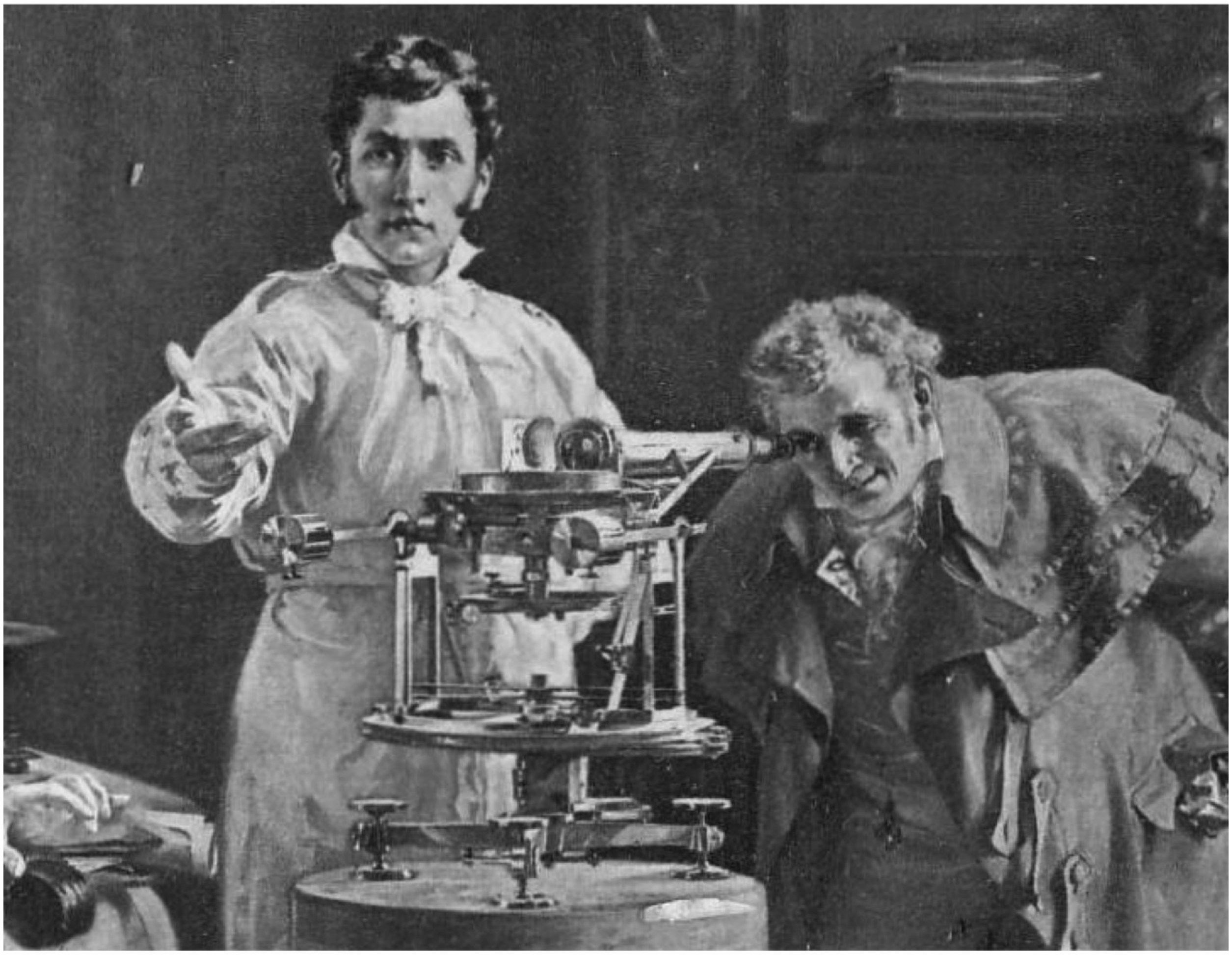
[6] See for example: CIOS III-1; CIOS VI-26, 27; CIOS X-13; CIOS XI-10; CIOS XII-22.

Joseph von Fraunhofer (standing, 1787–1826), Robert Bunsen (1811–1899), & Gustav Kirchhoff (1824–1887) developed spectroscopy



Johann Ritter (1776–1810) discovered ultraviolet light

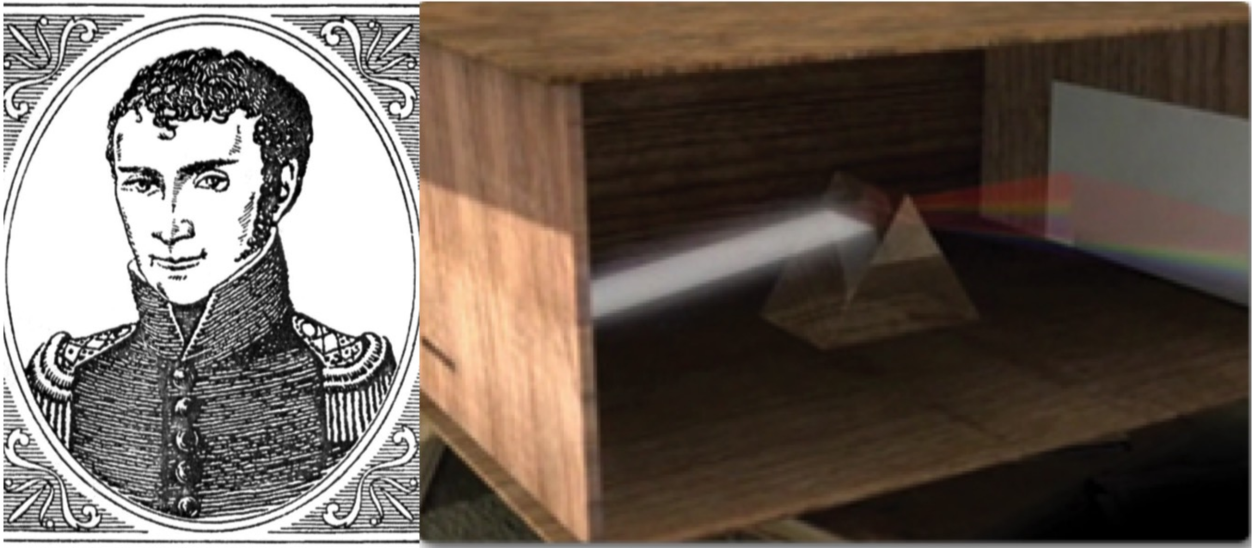


Figure 6.10: Joseph von Fraunhofer (standing), Robert Bunsen (Fig. 3.4), and Gustav Kirchhoff (Fig. 3.4) developed spectroscopy. Johann Ritter discovered ultraviolet light.

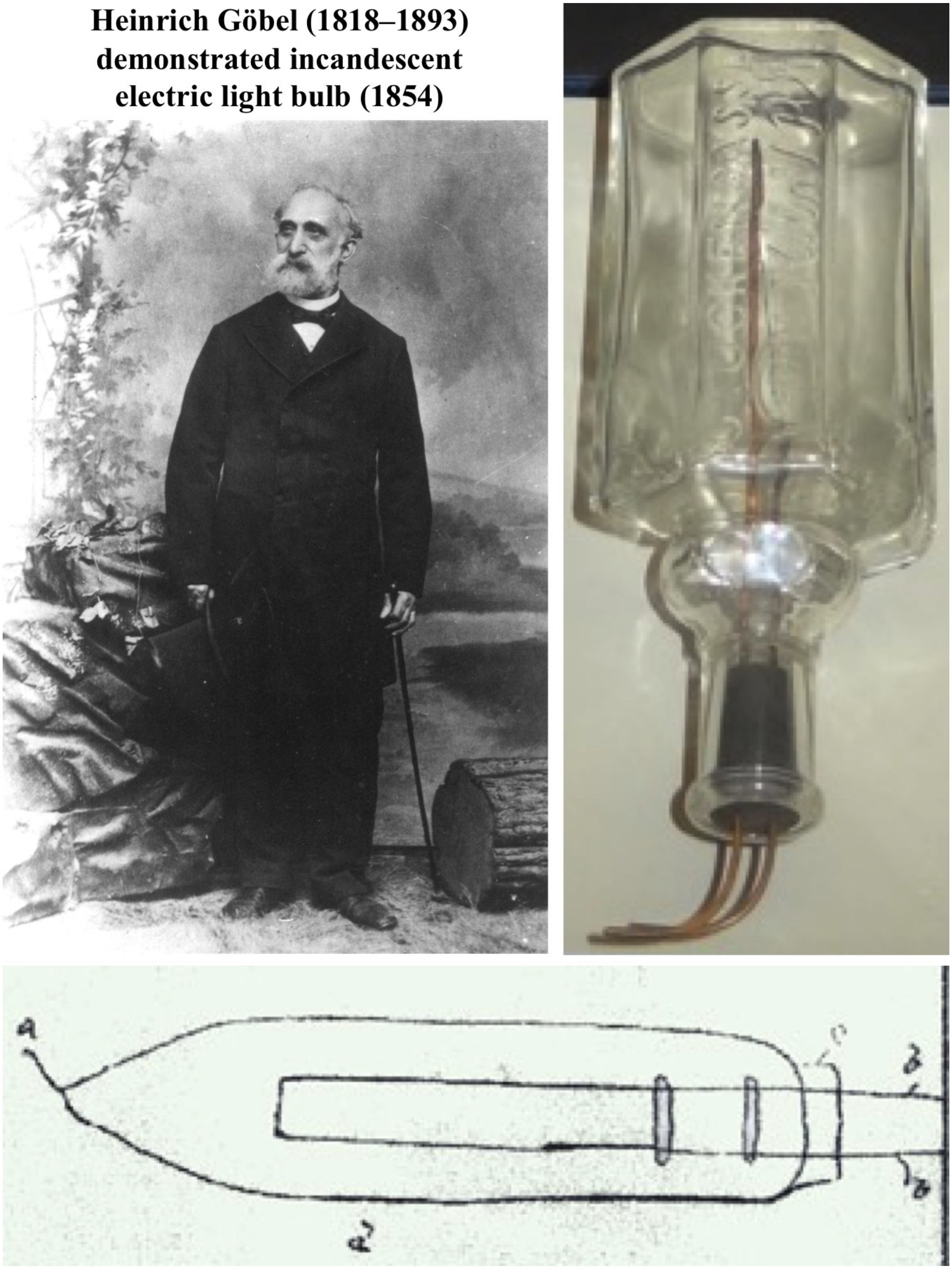

Heinrich Göbel (1818–1893)
demonstrated incandescent
electric light bulb (1854)
a
c
b
b
a

Figure 6.11: There is significant evidence that Heinrich Göbel (1818–1893) invented the first functional incandescent light bulb in 1854, 25 years before the much more famous light bulbs from Thomas Edison's laboratory.

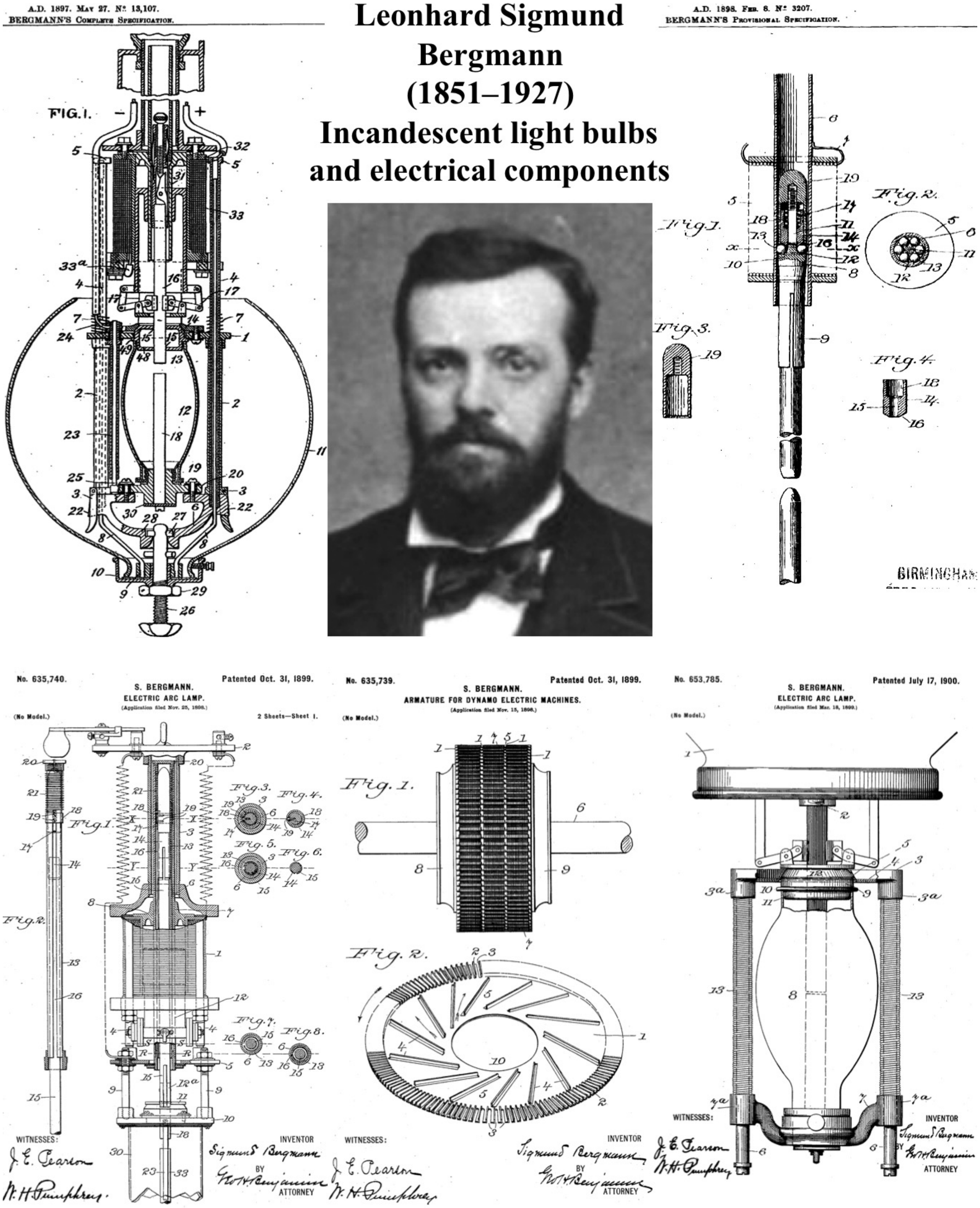

Leonhard Sigmund Bergmann
(1851–1927)
Incandescent light bulbs and electrical components
A.D. 1897. May 27. No 13,107.
BERGMANN'S COMPLETE SPECIFICATION.
FIG. I.
A.D. 1898. Feb. 8. No 3207.
BERGMANN'S PROVISIONAL SPECIFICATION.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
BIRMINGHAM
No. 635,740.
S. BERGMANN.
Patented Oct. 31, 1899.
ELECTRIC ARC LAMP.
(No Model.)
2 Sheets—Sheet 1.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
WITNESSES:
J. E. Pearson
W. H. Pumphrey
INVENTOR
Sigmund Bergmann
BY
Geo. H. Benjamin
ATTORNEY
No. 635,739.
S. BERGMANN.
Patented Oct. 31, 1899.
ARMATURE FOR DYNAMO ELECTRIC MACHINES.
(No Model.)
Fig. 1.
Fig. 2.
WITNESSES:
J. E. Pearson
W. H. Pumphrey
INVENTOR
Sigmund Bergmann
BY
Geo. H. Benjamin
ATTORNEY
No. 653,785.
S. BERGMANN.
Patented July 17, 1900.
ELECTRIC ARC LAMP.
(No Model.)
WITNESSES:
J. E. Pearson
W. H. Pumphrey
INVENTOR
Sigmund Bergmann
BY
Geo. H. Benjamin
ATTORNEY

Figure 6.12: Leonhard Sigmund Bergmann helped to develop the first incandescent light bulbs that Thomas Edison's laboratory made, then went into business for himself creating various electrical and mechanical devices.

Ludwig Karl Böhm (1859–after 1907)
Incandescent light bulbs and many other inventions

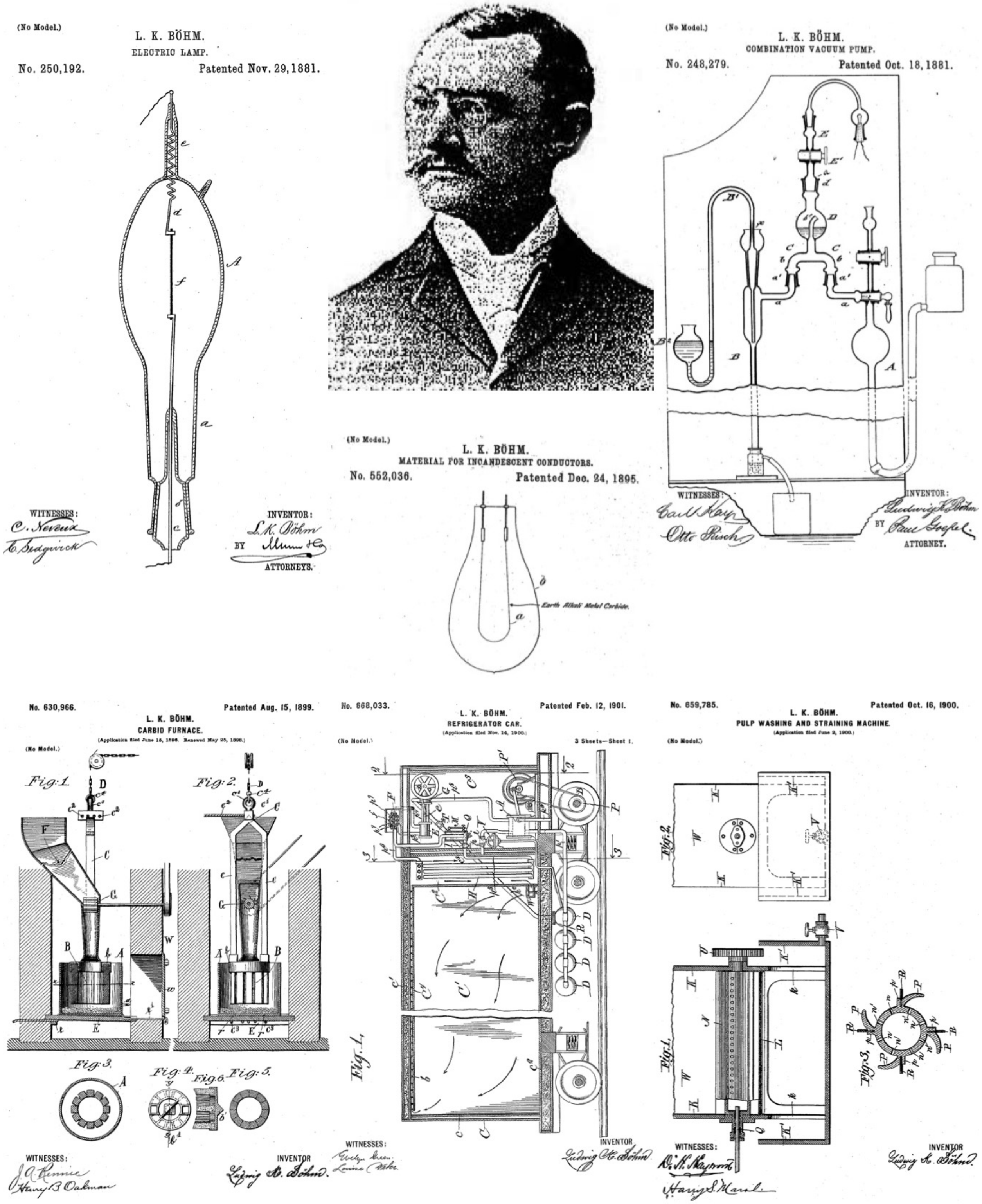

(No Model.)
L. K. BÖHM.
ELECTRIC LAMP.
No. 250,192.
Patented Nov. 29, 1881.
WITNESSES:
C. Neveux
C. Sedgwick
INVENTOR:
L.K. Böhm
BY Munn & Co
ATTORNEYS.
(No Model.)
L. K. BÖHM.
COMBINATION VACUUM PUMP.
No. 248,279.
Patented Oct. 18, 1881.
WITNESSES:
Carl Kay
Otto Risch
INVENTOR:
Ludwig K. Böhm
BY Paul Goepel
ATTORNEY.
(No Model.)
L. K. BÖHM.
MATERIAL FOR INCANDESCENT CONDUCTORS.
No. 552,036.
Patented Dec. 24, 1895.
Earth Alkali Metal Carbide.
No. 630,966.
Patented Aug. 15, 1899.
L. K. BÖHM.
CARBID FURNACE.
(Application filed June 15, 1896. Renewed May 25, 1898.)
(No Model.)
Fig:1.
Fig:2.
Fig:3.
Fig:4.
Fig:6.
Fig:5.
WITNESSES:
J. A. Rennie
Harry B. Oakman
INVENTOR
Ludwig K. Böhm.
No. 668,033.
L. K. BÖHM.
REFRIGERATOR CAR.
(Application filed Nov. 14, 1900.)
Patented Feb. 12, 1901.
(No Model.)
3 Sheets—Sheet 1.
Fig. 1.
WITNESSES:
INVENTOR
Ludwig K. Böhm
No. 659,785.
L. K. BÖHM.
PULP WASHING AND STRAINING MACHINE.
(Application filed June 2, 1900.)
Patented Oct. 16, 1900.
(No Model.)
Fig. 2.
Fig. 1.
Fig. 3.
WITNESSES:
INVENTOR
Ludwig K. Böhm.

Figure 6.13: Ludwig Karl Böhm helped to develop the first incandescent light bulbs that Thomas Edison's laboratory made, then worked for other companies. In addition to light bulbs, he created a wide variety of other inventions.

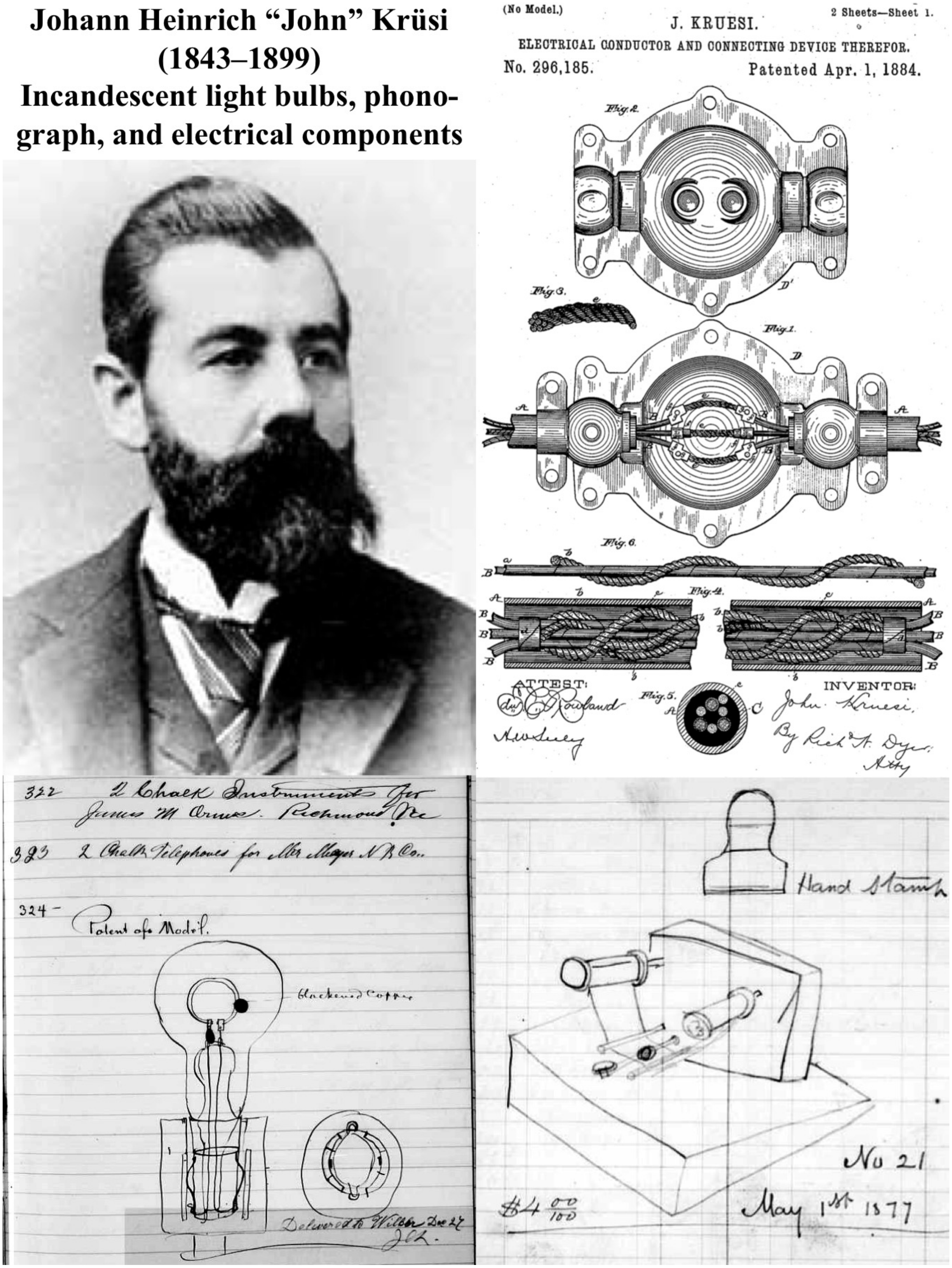

Johann Heinrich "John" Krüsi
(1843–1899)
Incandescent light bulbs, phonograph, and electrical components
(No Model.)
J. KRUESI.
2 Sheets—Sheet 1.
ELECTRICAL CONDUCTOR AND CONNECTING DEVICE THEREFOR.
No. 296,185.
Patented Apr. 1, 1884.
Fig. 2.
Fig. 3.
Fig. 1.
Fig. 6.
Fig. 4.
Fig. 5.
ATTEST:
INVENTOR:
John Kruesi,
By Rich^d N. Dyer, Atty
322 2 Chalk Instruments for James M Ormes. Richmond Va
323 2 Chalk Telephones for Mr Meyer N B Co.
324 – Patent of Model.
blackened Copper
Delivered to Wilber Dec 27
Hand Stamp
No 21
$4 00/100
May 1st 1877

Figure 6.14: Johann Heinrich "John" Krüsi helped to develop the first incandescent light bulbs that Thomas Edison's laboratory made. He also invented or helped to invent the Edison phonograph and other innovations that came out of that laboratory.

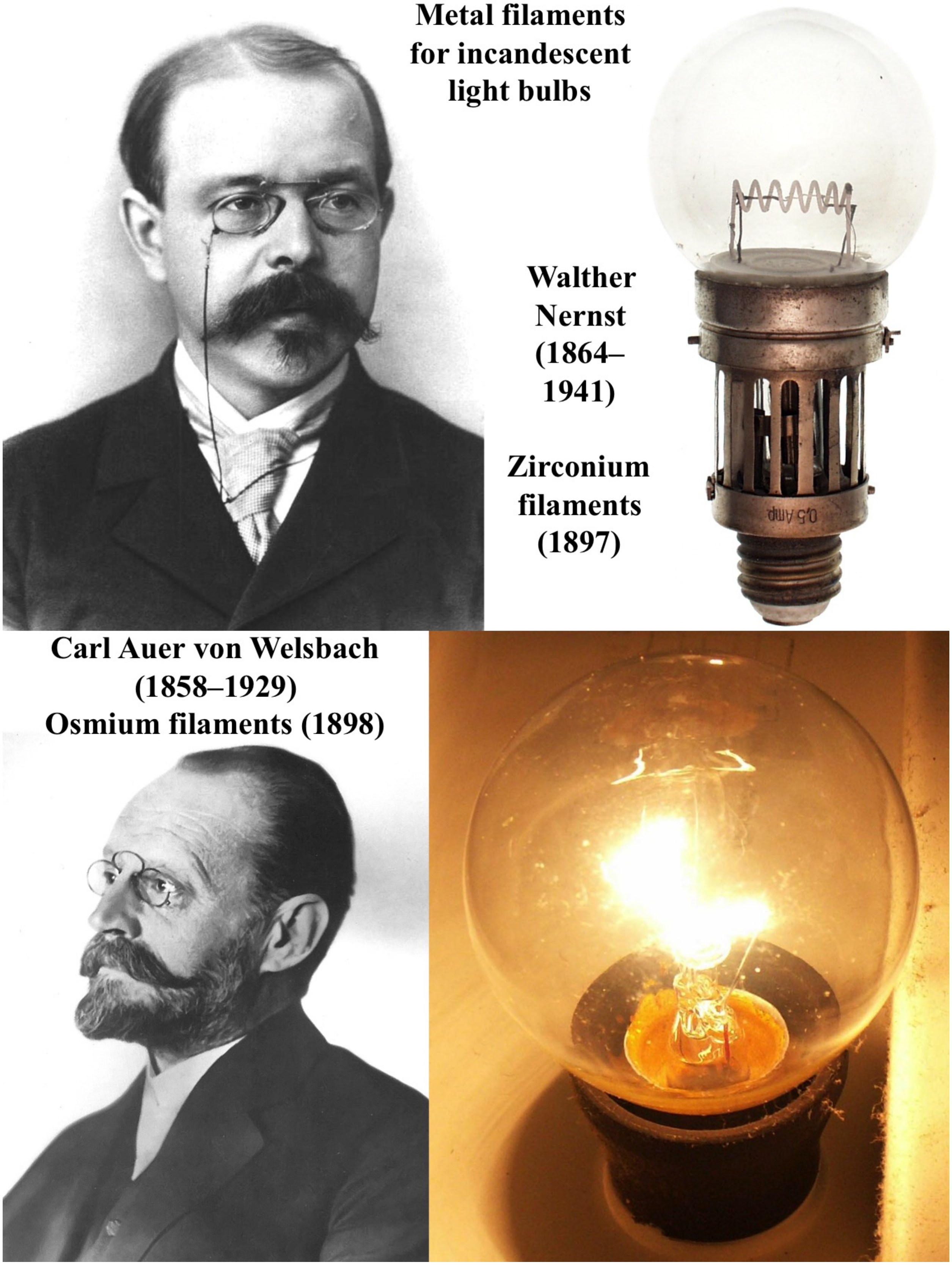

Metal filaments for incandescent light bulbs
Walther Nernst (1864–1941)
Zirconium filaments (1897)
Carl Auer von Welsbach (1858–1929)
Osmium filaments (1898)

Figure 6.15: Walther Nernst invented zirconium metal filaments for incandescent light bulbs in 1897. Carl Auer von Welsbach invented osmium filaments in 1898.

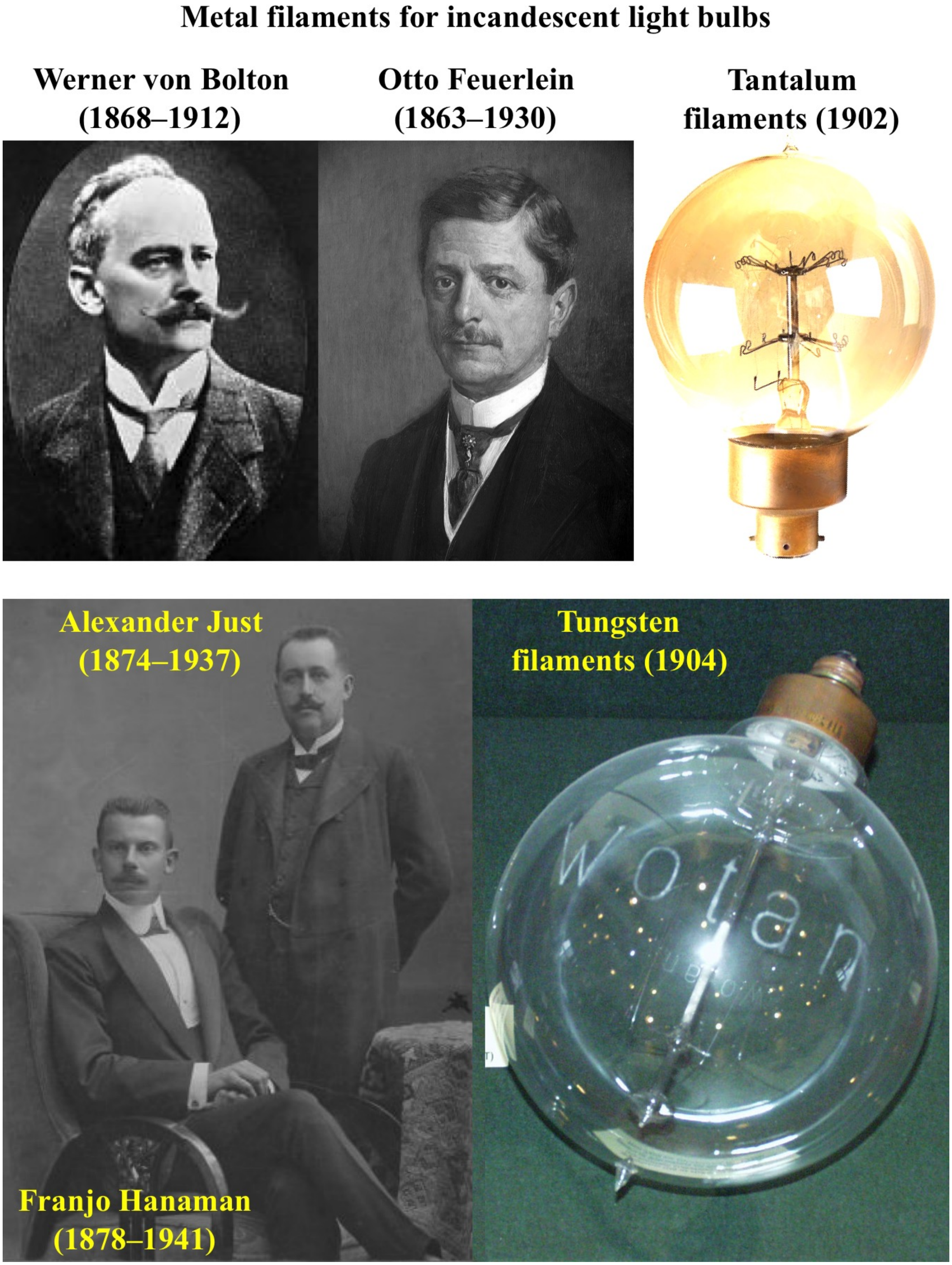

Metal filaments for incandescent light bulbs
Werner von Bolton (1868–1912)
Otto Feuerlein (1863–1930)
Tantalum filaments (1902)
Alexander Just (1874–1937)
Tungsten filaments (1904)
Franjo Hanaman (1878–1941)
wotan

Figure 6.16: Werner von Bolton and Otto Feuerlein invented tantalum metal filaments for incandescent light bulbs in 1902. Alexander Just and Franjo Hanaman invented tungsten filaments in 1904.

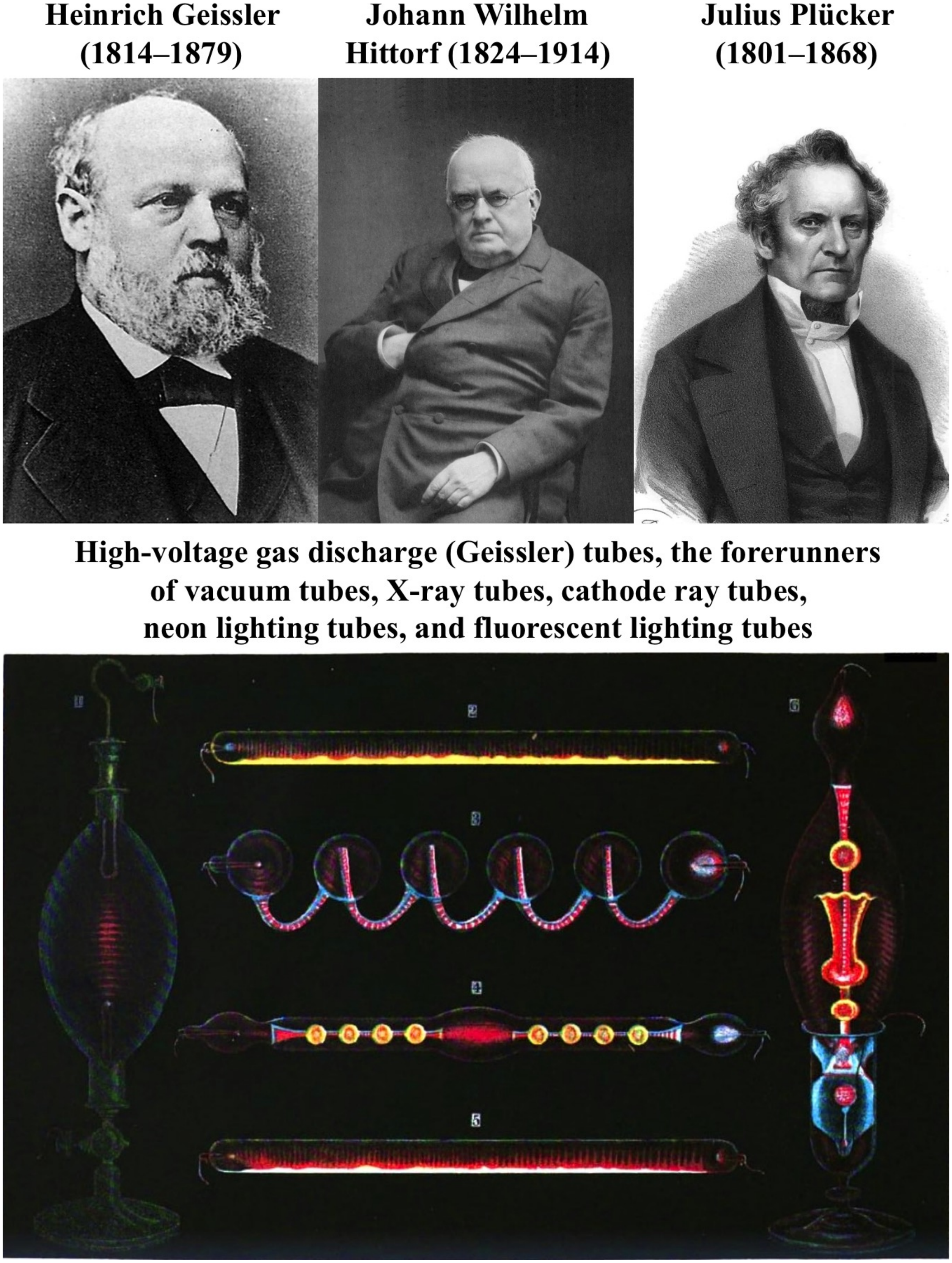

Heinrich Geissler (1814–1879)
Johann Wilhelm Hittorf (1824–1914)
Julius Plücker (1801–1868)
High-voltage gas discharge (Geissler) tubes, the forerunners of vacuum tubes, X-ray tubes, cathode ray tubes, neon lighting tubes, and fluorescent lighting tubes
1
2
3
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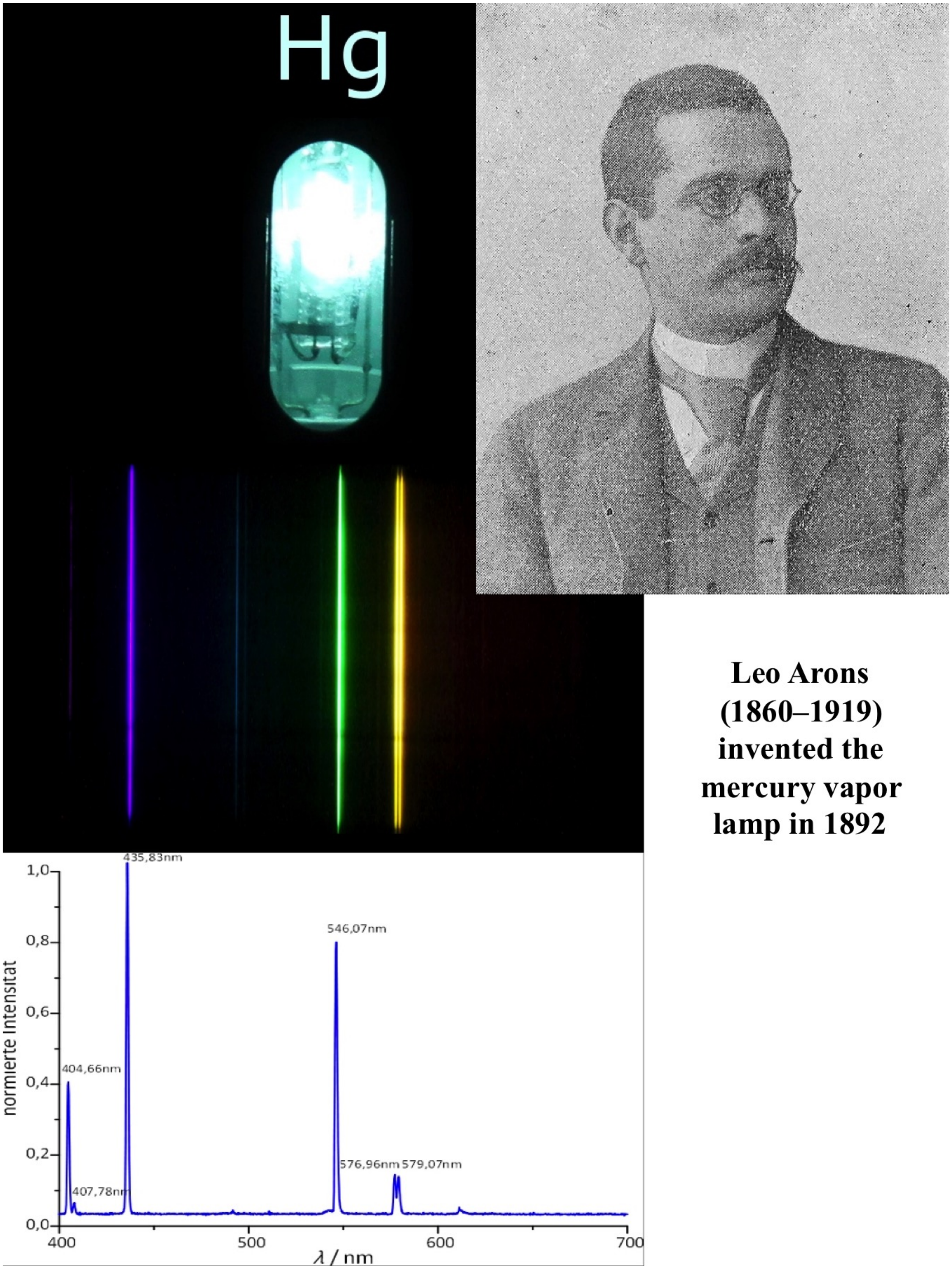
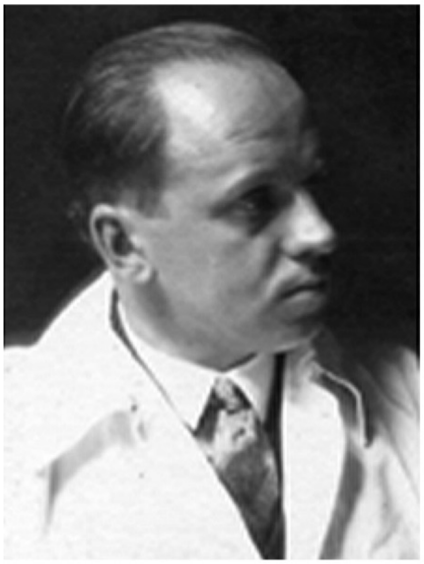
Figure 6.17: Heinrich Geissler, Johann Wilhelm Hittorf, and Julius Plücker created high-voltage gas discharge (Geissler) tubes, the forerunners of vacuum tubes, X-ray tubes, cathode ray tubes, neon lighting tubes, and fluorescent lighting tubes.

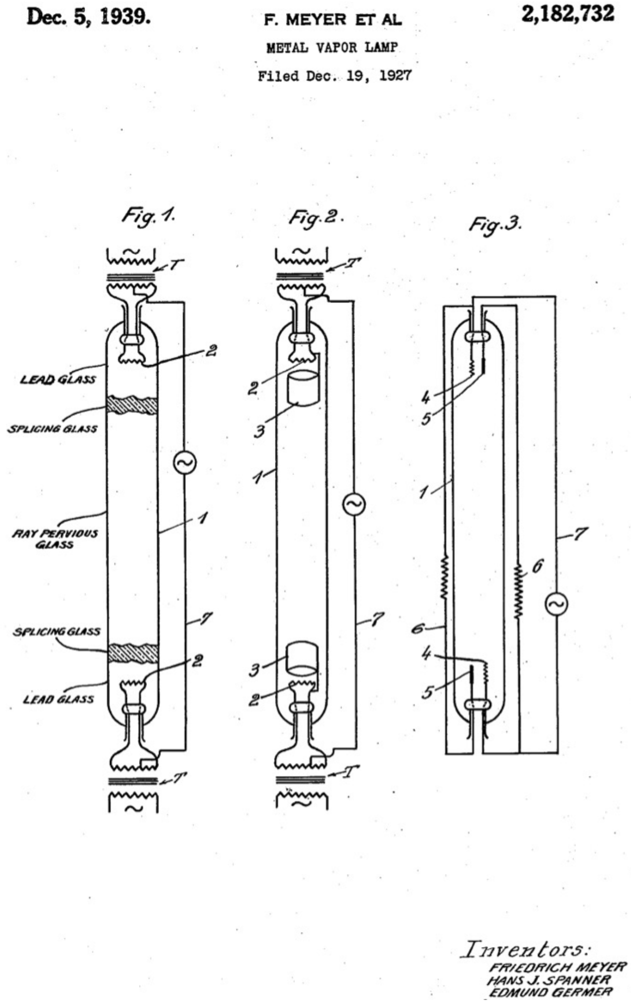


Leo Arons (1860–1919) invented the mercury vapor lamp in 1892

Figure 6.18: Leo Arons invented the mercury vapor lamp in 1892.

Edmund Germer (1901–1987) **Friedrich Meyer (18??–19??)** **Hans Spanner (18??–19??)**




Dec. 5, 1939.
F. MEYER ET AL
2,182,732
METAL VAPOR LAMP
Filed Dec. 19, 1927
Fig. 1.
Fig. 2.
Fig. 3.
T
LEAD GLASS
SPLICING GLASS
RAY PERVIOUS GLASS
SPLICING GLASS
LEAD GLASS
1
2
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Inventors:
FRIEDRICH MEYER
HANS J. SPANNER
EDMUND GERMER

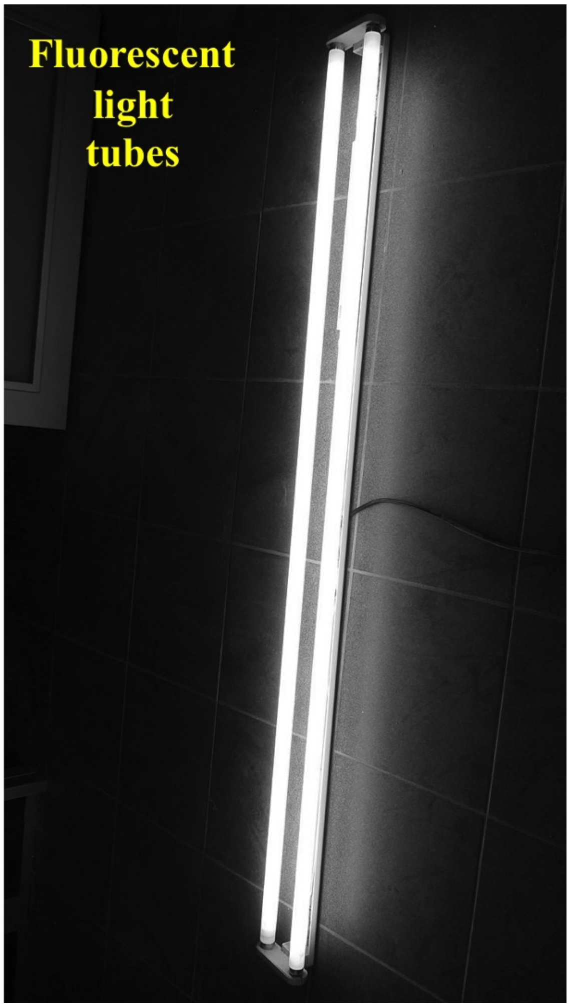
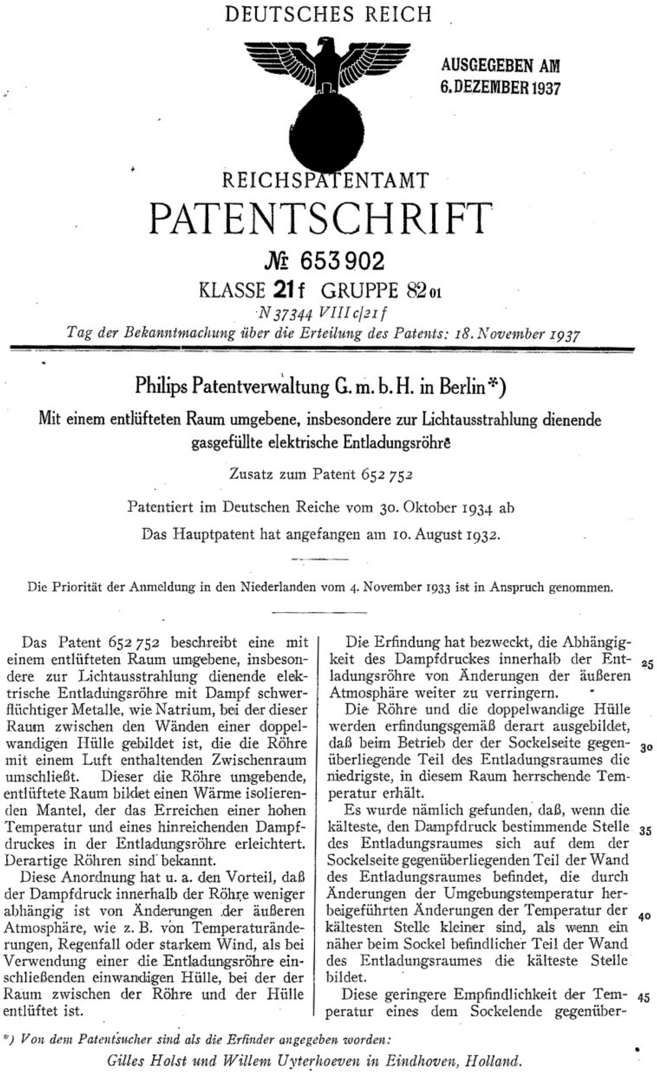

Fluorescent light tubes

Figure 6.19: Edmund Germer, Friedrich Meyer, and Hans Spanner modified mercury vapor tubes to invent modern fluorescent lighting tubes in 1926.

Sodium vapor lamp (1932)

Gilles Holst (1886–1968)

Willem Uyterhoeven (18??–19??)



DEUTSCHES REICH

AUSGEGEBEN AM
6. DEZEMBER 1937

REICHSPATENTAMT

PATENTSCHRIFT

№ 653 902

KLASSE 21f GRUPPE 82 01

N 37344 VIII c/21 f

Tag der Bekanntmachung über die Erteilung des Patents: 18. November 1937

Philips Patentverwaltung G. m. b. H. in Berlin*)

Mit einem entlüfteten Raum umgebene, insbesondere zur Lichtausstrahlung dienende gasgefüllte elektrische Entladungsröhre

Zusatz zum Patent 652 752

Patentiert im Deutschen Reiche vom 30. Oktober 1934 ab

Das Hauptpatent hat angefangen am 10. August 1932.

Die Priorität der Anmeldung in den Niederlanden vom 4. November 1933 ist in Anspruch genommen.

Das Patent 652 752 beschreibt eine mit einem entlüfteten Raum umgebene, insbesondere zur Lichtausstrahlung dienende elektrische Entladungsröhre mit Dampf schwerflüchtiger Metalle, wie Natrium, bei der dieser Raum zwischen den Wänden einer doppelwandigen Hülle gebildet ist, die die Röhre mit einem Luft enthaltenden Zwischenraum umschließt. Dieser die Röhre umgebende, entlüftete Raum bildet einen Wärme isolierenden Mantel, der das Erreichen einer hohen Temperatur und eines hinreichenden Dampfdruckes in der Entladungsröhre erleichtert. Derartige Röhren sind bekannt.

Diese Anordnung hat u. a. den Vorteil, daß der Dampfdruck innerhalb der Röhre weniger abhängig ist von Änderungen der äußeren Atmosphäre, wie z. B. von Temperaturänderungen, Regenfall oder starkem Wind, als bei Verwendung einer die Entladungsröhre einschließenden einwandigen Hülle, bei der der Raum zwischen der Röhre und der Hülle entlüftet ist.

Die Erfindung hat bezweckt, die Abhängigkeit des Dampfdruckes innerhalb der Entladungsröhre von Änderungen der äußeren Atmosphäre weiter zu verringern.

Die Röhre und die doppelwandige Hülle werden erfindungsgemäß derart ausgebildet, daß beim Betrieb der der Sockelseite gegenüberliegende Teil des Entladungsraumes die niedrigste, in diesem Raum herrschende Temperatur erhält.

Es wurde nämlich gefunden, daß, wenn die kälteste, den Dampfdruck bestimmende Stelle des Entladungsraumes sich auf dem der Sockelseite gegenüberliegenden Teil der Wand des Entladungsraumes befindet, die durch Änderungen der Umgebungstemperatur herbeigeführten Änderungen der Temperatur der kältesten Stelle kleiner sind, als wenn ein näher beim Sockel befindlicher Teil der Wand des Entladungsraumes die kälteste Stelle bildet.

Diese geringere Empfindlichkeit der Temperatur eines dem Sockelende gegenüber-

*) *Von dem Patentsucher sind als die Erfinder angegeben worden:*
Gilles Holst und Willem Uyterhoeven in Eindhoven, Holland.

Zu der Patentschrift 653 902
Kl. 21f Gr. 82 01

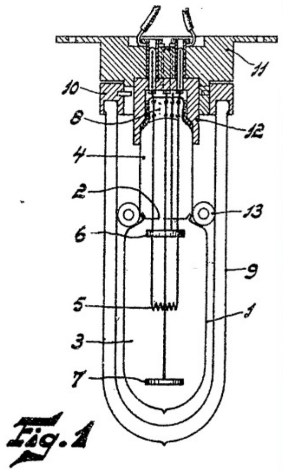


Fig. 1

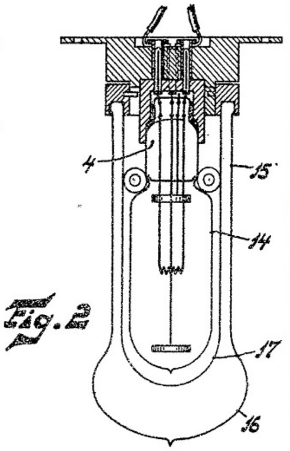


Fig. 2

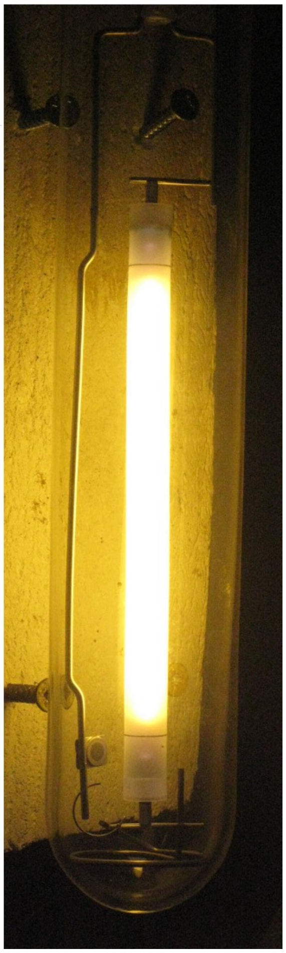


Figure 6.20: Gilles Holst and Willem Uyterhoeven invented sodium vapor lamps in 1932.

6.3 Communications and Recording Technologies

German-speaking creators invented and demonstrated communications and recording technologies that revolutionized the world:

6.3.1. Telegraphs

6.3.2. Telephones

6.3.3. Radio

6.3.4. Mobile telephone systems

6.3.5. Optical communications systems

6.3.6. Disc phonograph records and players

6.3.7. Magnetic tape recording

6.3.8. Motion picture cameras and projectors

6.3.9. Television

6.3.10. Video telephone system

6.3.11. Scanners, facsimile (fax) machines, and printers

6.3.12. Photocopiers

6.3.13. Optical discs and digital file formats

Unfortunately, the modern world often does not attribute these inventions to their actual creators.

6.3.1 Telegraphs

Carl Friedrich Gauss (German states, 1777–1855) and Wilhelm Weber (German, 1804–1891), shown in Fig. 6.21, worked out the laws of magnetism and electromagnetism. Using those, they invented and demonstrated the world's first electric (electromagnetic or electromechanical) telegraph in 1833, five years before Samuel Morse, whose work became much better known outside the German-speaking world [Dunnington 1955]. (See also pp. 740, 793, 828, and 858.)

In a 20 November 1833 letter from Carl Friedrich Gauss to Heinrich Olbers, Gauss described the design and successful operation of his telegraph [English translation by Guy Waldo Dunnington, in Dunnington 1955, p. 147]:

> I don't remember my having made any previous mention to you of an astonishing piece of mechanism that we have devised. It consists of a galvanic circuit conducted through wires stretched through the air over the houses up to the steeple of St. John's Church and down again, and connecting the observatory with the physics laboratory, which is under the direction of Weber. The entire length of wire may be computed at about eight thousand feet; both ends of the wire are connected with a multiplicator, the one at my end consisting of 170, that in Weber's laboratory of 50, coils of wire each wound around a one-pound magnet suspended according to a method which I have devised. By a simple contrivance—which I have named a commutator—I can reverse

> the current instantaneously. Carefully operating my voltaic pile, I can cause so violent a motion of the needle in the laboratory to take place that it strikes a bell, the sound of which is audible in the adjoining room. This serves merely as an amusement. Our aim is to display the movements with the utmost accuracy. We have already made use of this apparatus for telegraphic experiments, which have resulted successfully in the transmission of entire words and small phrases. This method of telegraphing has the advantage of being quite independent of either daytime or weather; the ones who receive it remain in their rooms, and if they desire it, with the shutters drawn. The employment of sufficiently stout wires, I feel convinced, would enable us to telegraph with but a single tap from Göttingen to Hanover, or from Hanover to Bremen.

Dunnington summarized further details about the history of the Gauss-Weber telegraph [Dunnington 1955, pp. 147–148, 150]:

> Gauss gave first public notice of the telegraph in the *Göttingische gelehrte Anzeigen*, issue of August 9, 1834. He gives detailed information about the "great galvanic circuit" between the physics laboratory and the observatory, to which the new magnetic observatory was connected, and emphasizes that this "unique setup" is due to Weber. The two had begun their electrical measurements on October 21, 1832. Gauss ordered magnetometers of varying size, from which he proceeded to larger magnets, and thus a number of galvanometers of varying size and construction came into being, although we do not know which ones were finally used in telegraphing. They were all to be used for this purpose, but the two scientists realized that the apparatus with the smallest magnets was best adapted for telegraphing on account of the magnets' small period of oscillation.
>
> It is reported that the first words sent on the telegraph were: *Michelmann kommt.* Michelmann was a servant who ran errands for Gauss and Weber. At first individual words were sent, and then complete sentences. The telegraph was operated once in the presence of the Duke of Cambridge, who seemed to take special interest in it.
>
> Weber's correspondence with the city council in April and May, 1833, gave exact information about the purpose and date of origin of the telegraph. At first Weber had used thin copper wire for the lines, which, however, did not stand up very well and had to be replaced by stronger wire. Even the latter did not resist weathering and was replaced by soft steel wire of one-millimeter strength. The lines existed until 1845, when they were destroyed by lightning on December 16. [...]
>
> The success of Gauss and Weber with their telegraph aroused great attention at that time, at least in Germany. Steps were under way to use it on the railroad. Gauss and Weber both wrote memoranda on the subject to the directorate of the Leipzig-Dresden railroad then under construction.

In 1846, Werner von Siemens (German, 1816–1892, Fig. 6.22) created more sophisticated telegraphs that could point to individual letters [Bähr 2016; von Siemens 1895]. Von Siemens also invented and sold a number of other important electrical components and systems (p. 944). Backed by a large industry and using more advanced designs, the von Siemens telegraphy systems overtook the demonstrations and proposals of Gauss and Weber. Werner von Siemens and Carl Wilhelm Siemens (German, 1823–1883), one of his younger brothers, designed and produced telegraph networks that were used in Europe and worldwide.

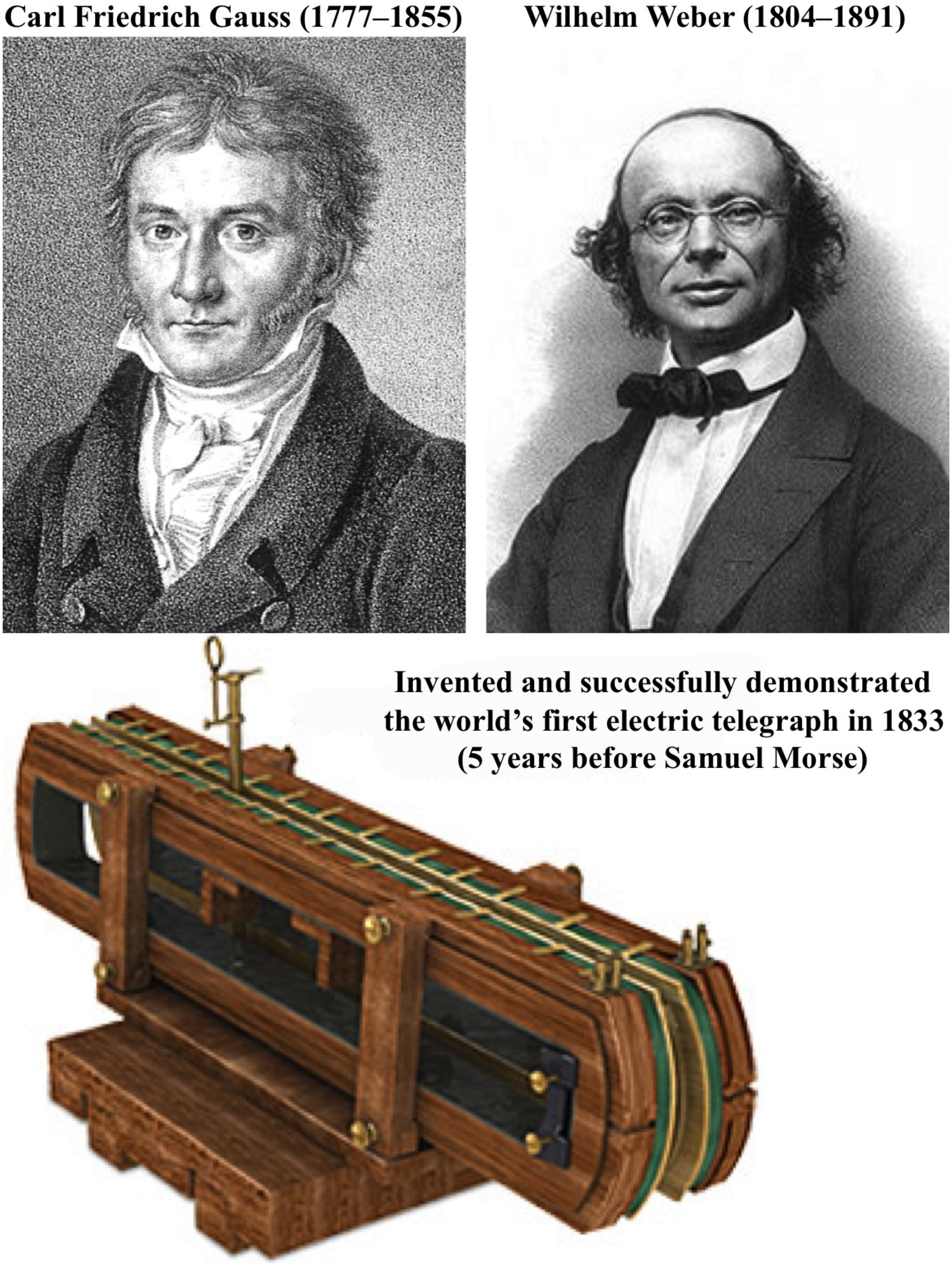

Carl Friedrich Gauss (1777–1855)
Wilhelm Weber (1804–1891)
Invented and successfully demonstrated the world’s first electric telegraph in 1833 (5 years before Samuel Morse)

Figure 6.21: Carl Friedrich Gauss and Wilhelm Weber invented and successfully demonstrated the world’s first electric telegraph in 1833 (five years before Samuel Morse).

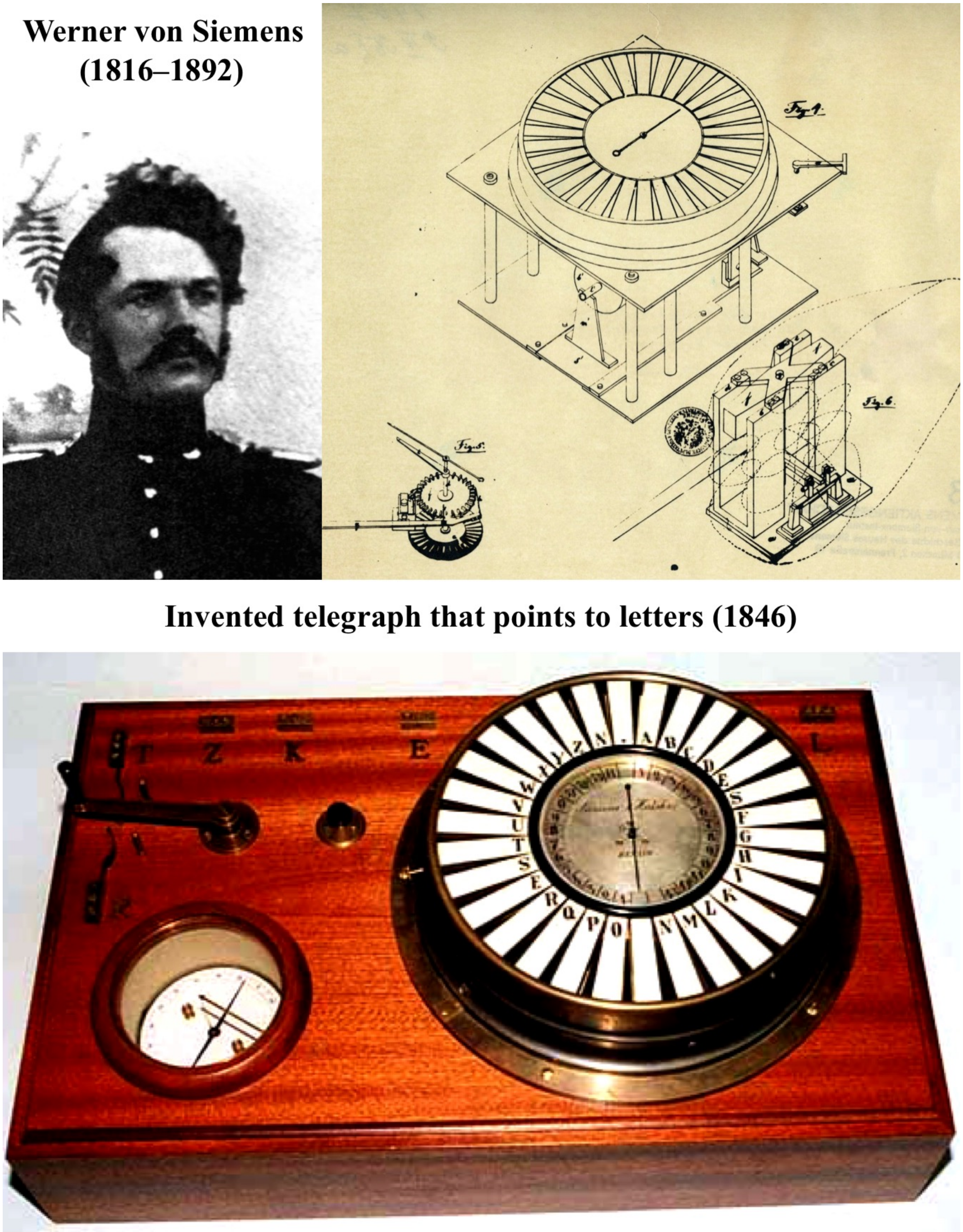

Werner von Siemens
(1816–1892)
Fig. 1.
Fig. 5.
Fig. 6.
Invented telegraph that points to letters (1846)
T
Z
K
E
L

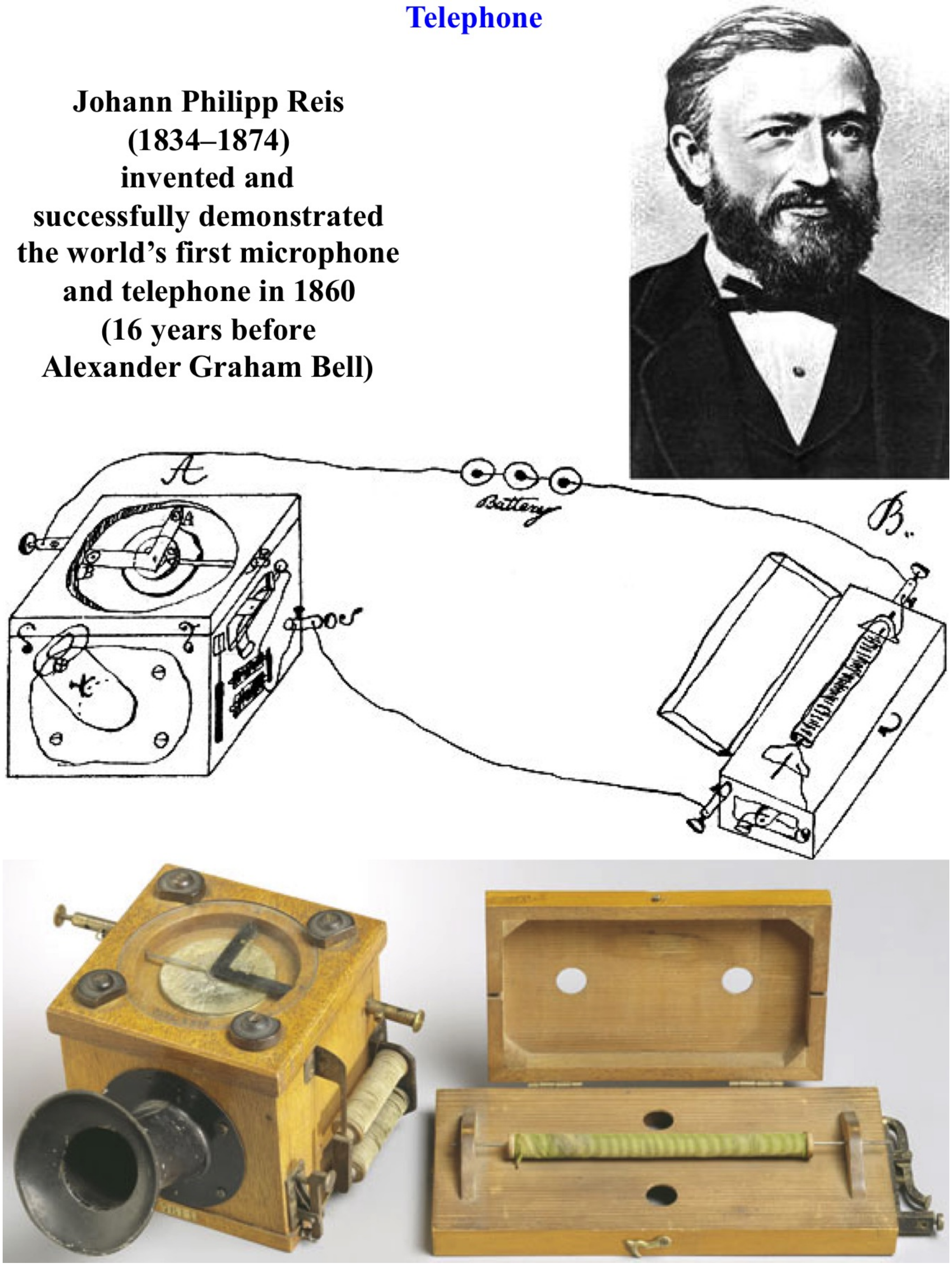
Figure 6.22: In 1846, Werner von Siemens created more sophisticated telegraphs that could point to individual letters.

6.3.2 Telephones

Johann Philipp Reis (German, 1834–1874) invented and successfully demonstrated the world's first microphone, speaker, and telephone in 1860 (Fig. 6.23). He then publicized and sought funding to improve his telephone. Reis demonstrated this working telephone system 16 years before Alexander Graham Bell's version in 1876, yet nowadays Reis is virtually unknown in the non-German-speaking world, and Bell is widely viewed as the inventor of the telephone. In 2003, BBC News confirmed that "Bell 'did not invent telephone'" [http://news.bbc.co.uk/2/hi/science/nature/3253174.stm]:

> Claims that a German scientist invented the telephone 15 years before Alexander Graham Bell are supported by evidence from newly surfaced archive papers.
>
> Successful tests on a German device manufactured in 1863 were covered up to maintain the Scot's reputation, the previously unseen files have revealed.
>
> They show the "Telephon", developed by German research scientist Philipp Reis, could transmit and receive speech.
>
> It is alleged UK businessman Sir Frank Gill was behind the cover-up.
>
> The evidence is contained in files from the archives of the Science Museum in London.
>
> The documents were rediscovered in October by the museum's curator of communications, John Liffen.
>
> Gill was chairman of Standard Telephones and Cables (STC), the company that conducted the tests on Reis's device.
>
> The company was at the time bidding for a contract from the American Telephone and Telegraph Company, which evolved from the Bell Company.
>
> Gill thought that if word got out of the test results, it would scupper STC's chances of winning the contract.
>
> Some researchers have argued for many years that Reis beat Bell to the invention of the telephone. The archived documents seem to support their claims.
>
> A memo, dated 18 March 1947, from Gerald Garratt, a predecessor of Mr Liffen's, show STC's reports on Reis's device were given to him under the strict condition that they would never be publicly referred to or published without permission.
>
> STC then became anxious to retrieve the documents. In a subsequent letter, Garratt wrote: "I am left with the thought that there is something so secret about [the documents] as to be a matter of first class historic interest.
>
> "You must know as well as I the old controversy: 'Did Bell invent the telephone?' and I have here an unpublished manuscript of over 400 pages which proves pretty conclusively that he didn't.
>
> "Does your anxiety to retrieve these reports rather suggest that you agree?"

Werner von Siemens (German, 1816–1892, Fig. 6.22) invented improved speakers.



Telephone

Johann Philipp Reis
(1834–1874)
invented and
successfully demonstrated
the world's first microphone
and telephone in 1860
(16 years before
Alexander Graham Bell)

Figure 6.23: Johann Philipp Reis invented and successfully demonstrated the world's first microphone and telephone in 1860 (16 years before Alexander Graham Bell).

6.3.3 Radio

In 1888, Heinrich Hertz (German, 1857–1894) produced, detected, and measured electromagnetic waves, specifically radio waves, making him also the true original inventor of radio transmitters and receivers (Fig. 6.24). Unfortunately Hertz died very young; otherwise he would likely have played even more of a role (and been recognized much more) in the early development of radio technology. Because Hertz died before the first Nobel Prizes were awarded in 1901, he was not eligible for the Nobel; nonetheless, the Nobel committee publicly praised his discoveries when they awarded other scientists (see below and p. 859).

Nikola Tesla (Serbo-Croatian, educated in Austria, 1856–1943) publicly demonstrated a radio transmitter and receiver in 1891, and a tunable transmitter and receiver in 1893 in St. Louis (Fig. 6.25). Tesla biographer Margaret Cheney listed some of the key technical features of Tesla's 1893 public demonstration [Cheney 1981, p. 69]:

> Although the St. Louis demonstration was no "message sent 'round the world" as Tesla would doubtless of course have preferred it to be, he had nevertheless demonstrated all the fundamental principles of modern radio: 1. an antenna or aerial wire; 2. a ground connection; 3. an aerial-ground circuit containing inductance and capacity; 4. adjustable inductance and capacity (for tuning); 5. sending and receiving sets tuned to resonance with each other; and 6. electronic tube detectors.

Tesla's 1893 lecture was published and translated around the world. Apparently it was the direct inspiration for Guglielmo Marconi (Italian, 1874–1937) to repeat part of Tesla's experiments a few years later, albeit in a much cruder and less effective fashion [Cheney 1981, p. 69]. A series of court cases over radio patents ultimately proved that Tesla's public disclosures, publications, and discoveries predated and directly informed Marconi's claims [Cheney 1981, p. 176–184; Cheney and Uth 1999, pp. 67–73]. Yet while Tesla continued working on his inventions, Marconi went on a lengthy public tour of self-promotion in Europe. As a result, Marconi was awarded a Nobel Prize for his "discovery," Tesla was not, and Marconi has been erroneously considered worldwide to be the inventor of radio.

Tesla further showed that radio waves transmit not only signals but large amounts of power over considerable distances [Cheney 1981; Cheney and Uth 1999; Tesla 1893, 1904, 1919, 1940]. Tesla also demonstrated a radio-controlled boat in 1898 (p. 1207) and invented many other electrical devices (p. 954).

Beginning in 1897, Karl Ferdinand Braun (German, 1850–1918) developed improved radio transmitters and receivers (Fig. 6.26), as well as phased array antennas. He also invented semiconductor diodes (p. 1045), cathode ray tubes, and oscilloscopes (p. 1000). For his work developing and improving radio technology, he won the Nobel Prize in Physics in 1909. H. Hildebrand, President of the Royal Swedish Academy of Sciences, praised both Braun's innovations and the earlier discoveries by Hertz [https://www.nobelprize.org/prizes/physics/1909/ceremony-speech/]:

> [I]t was Hertz who through his classical experiments showed that the new ideas as to the nature of electricity and light had a real basis in fact. To be sure, it was already well known before Hertz's time, that a capacitor charged with electricity can under certain

> circumstances discharge itself oscillatorily, that is to say, by electric currents passing to and fro. Hertz, however, was the first to demonstrate that the effects of these currents propagate themselves in space with the velocity of light, thereby producing a wave motion having all the distinguishing characteristics of light. This discovery—perhaps the greatest in the field of physics throughout the last half-century—was made in 1888. It forms the foundation, not only for modern science of electricity, but also for wireless telegraphy. But it was still a great step from laboratory trials in miniature where the electrical waves could be traced over but a small number of metres, to the transmission of signals over great distances. [...]
>
> The electrical oscillations sent out from the transmitting station were relatively weak and consisted of wave-series following each other, of which the amplitude rapidly fell-so-called "damped oscillations". A result of this was that the waves had a very weak effect at the receiving station, with the further result that waves from various other transmitting stations readily interfered, thus acting disturbing at the receiving station. It is due above all to the inspired work of Professor Ferdinand Braun that this unsatisfactory state of affairs was overcome. Braun made a modification in the layout of the circuit for the despatch of electrical waves so that it was possible to produce intense waves with very little damping. It was only through this that the so-called "long-distance telegraphy" became possible, where the oscillations from the transmitting station, as a result of resonance, could exert the maximum possible effect upon the receiving station. The further advantage was obtained that in the main only waves of the frequency used by the transmitting station were effective at the receiving station. It is only through the introduction of these improvements that the magnificent results in the use of wireless telegraphy have been attained in recent times.

Adolf Slaby (German, 1849–1913) and Georg von Arco (German, 1869–1940), shown in Fig. 6.27, developed radio systems from 1897 onward. They founded and ran radio research and development departments first at AEG and then at Telefunken.

By harnessing radio waves, Christian Hülsmeyer (German, 1881–1957) invented and demonstrated radar in 1903 (p. 1219). He also patented a radio remote control system in 1904.

Ernst Walter Ruhmer (German, 1878–1913) invented a number of electrical communications devices, collaborating with Salomon Kalischer (German, 1845–1924) and Adolf Pieper (German, 18??–19??) on some of them. In 1904, Ruhmer demonstrated a radiotelephone transmitter and receiver capable of sending the first intelligible voice signals (Fig. 6.28).

Vacuum tube technology evolved from the work of a series of German-speaking scientists, including Julius Plücker (German states, 1801–1868), Heinrich Geissler (German, 1814–1879), Johann Hittorf (German, 1824–1914), Eugen Goldstein (German, 1850–1930), Arthur Wehnelt (German, 1871–1944), and others. See Fig. 6.17.

In 1906, Robert von Lieben (Austrian, 1878–1913), Eugen Reisz (Austrian, 18??–19??), and Siegmund Strauss (Austrian, 18??–19??) invented and demonstrated the triode vacuum tube amplifier (Fig. 6.29). It greatly improved the performance of radio circuits.

No later than 1912, Alexander Meißner (Austrian, 1883–1958) invented, demonstrated, and patented the first modulated, amplified radio systems for high-quality transmission of voices and music. See Fig. 6.30.

Eugen Nesper (German, 1879–1961, Fig. 6.31) conducted experiments with radio transmitters and receivers from 1897 onward. Early in his career, he worked with Adolf Slaby and Georg von Arco. Among other accomplishments, he developed and demonstrated a radio receiver with a powerful seven-tube amplifier in 1923.

Hans Bredow (German, 1879–1959, Fig. 6.31) worked with electrical systems, especially radio, from 1900 onward. Throughout his long career, he was a strong proponent of public radio broadcasting systems in Germany.

6.3.4 Mobile Telephone Systems

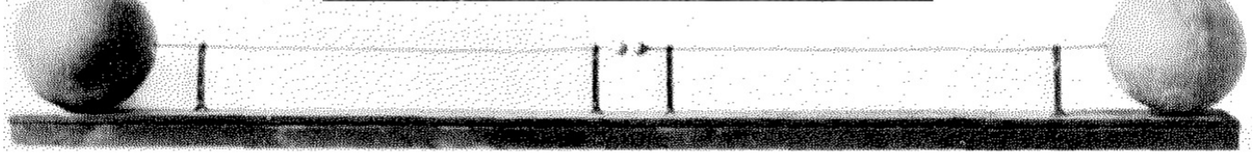
By combining telephone and radio technologies, German-speaking scientists invented and commercialized the world's first mobile telephone system. As shown in Fig. 6.32, such mobile phones consisted of telephones and compact radio transmitter boxes, and were installed in German passenger trains (the system was called Zugpostfunk or Zugtelefon). Transmitter/receiver towers near the track connected the train mobile phones to the normal wired telephone network, allowing passengers on trains to call (or receive calls from) people who either were not on trains or were on other trains. Development of the system began during World War I, and the service was commercialized and in service by January 1926. After World War II, the United States copied this mobile telephone system and installed it in U.S. trains. Ultimately mobile telephone technology was miniaturized using microelectronics components and methods that had also been invented in the German-speaking world (Section 6.5 and Appendix B).

6.3.5 Optical Communications Systems

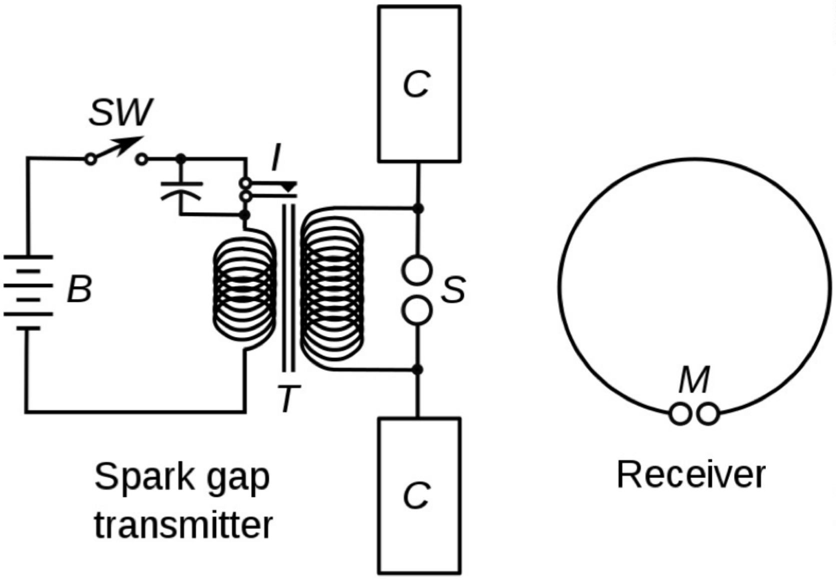
German-speaking scientists also developed systems for transmitting and receiving voices and data via light signals. See p. 1131.

Radio

Heinrich Hertz
(1857–1894)
transmitted
and detected
radio waves
(1888)



Hertz's spark gap radio transmitter


SW
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B
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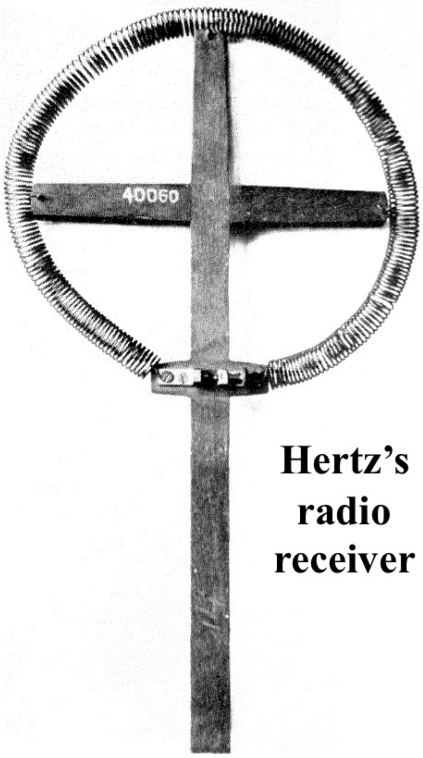
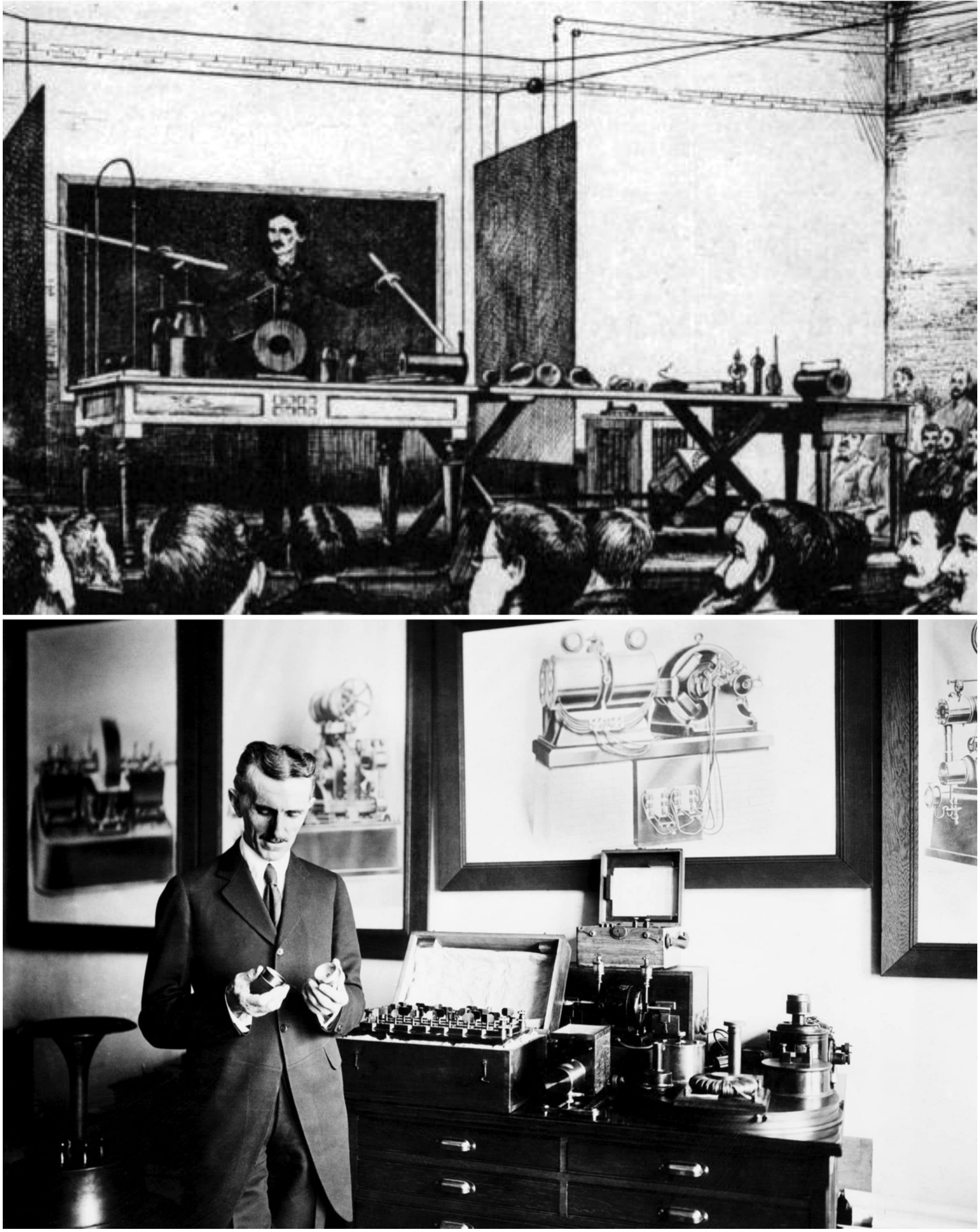
S
C
C
M
Spark gap transmitter
Receiver



Hertz's radio receiver

Figure 6.24: Heinrich Hertz transmitted and detected radio waves in 1888.



Nikola Tesla (1856–1943) publicly demonstrated a radio transmitter and receiver in 1891, and a tunable transmitter and receiver in 1893

Figure 6.25: Nikola Tesla publicly demonstrated a radio transmitter and receiver in 1891, and a tunable transmitter and receiver in 1893.

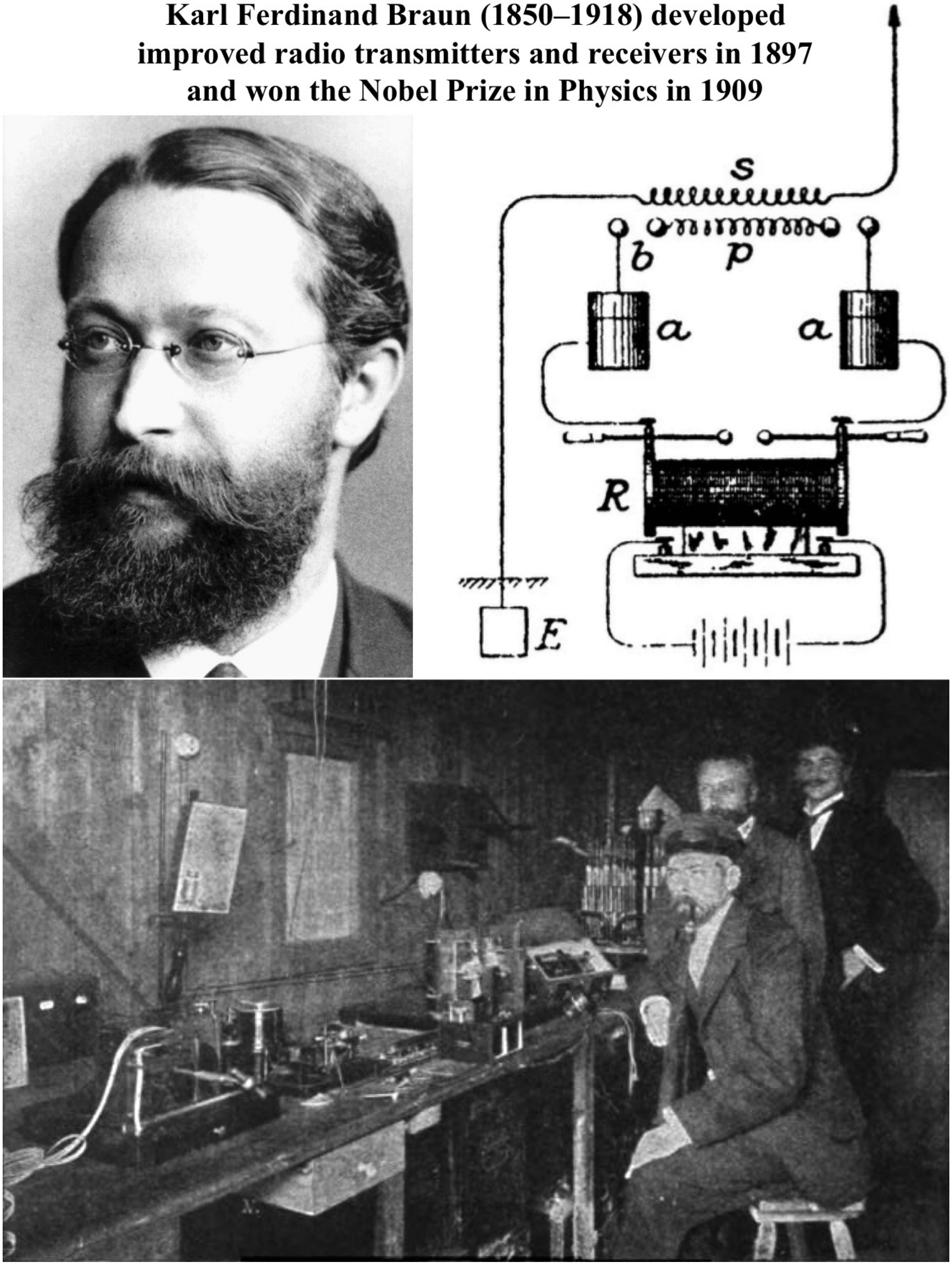
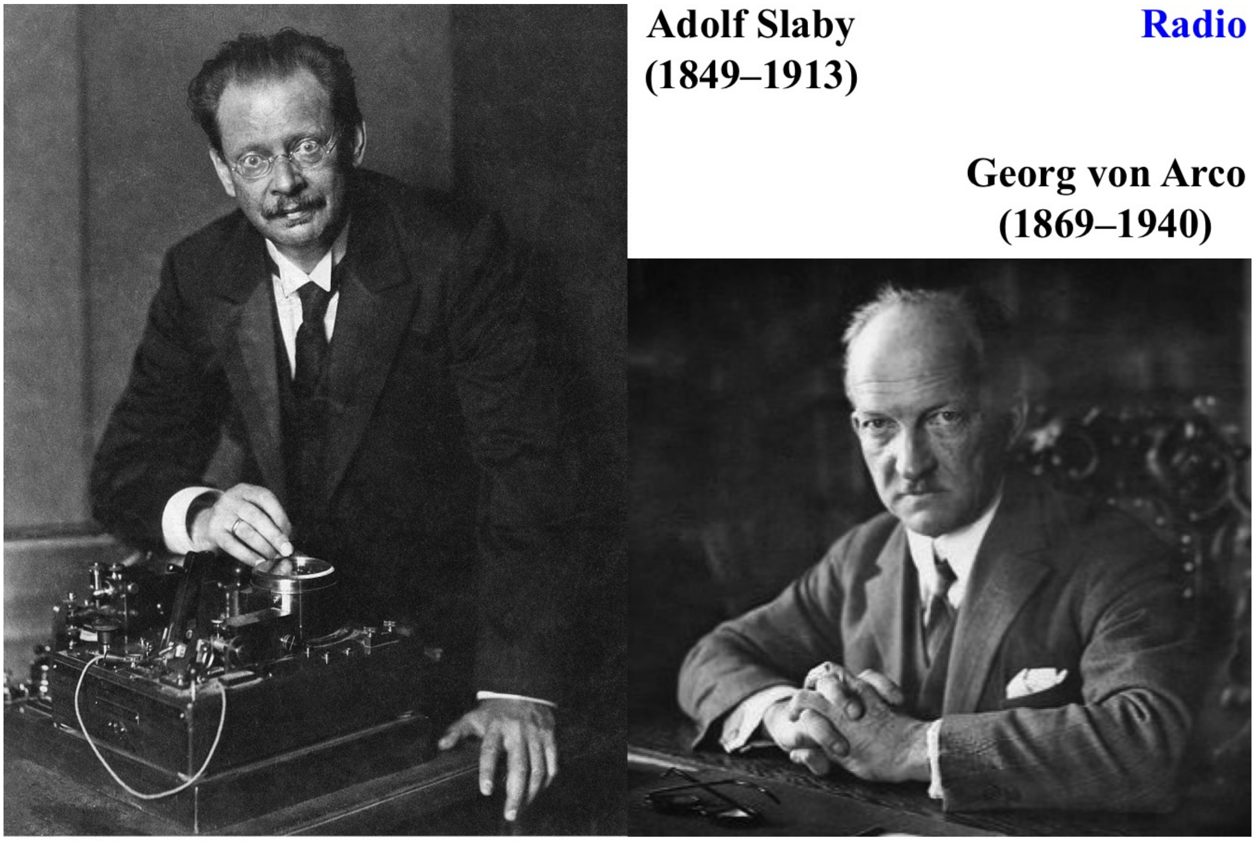

Karl Ferdinand Braun (1850–1918) developed improved radio transmitters and receivers in 1897 and won the Nobel Prize in Physics in 1909
s
b
p
a
a
R
E

Figure 6.26: Karl Ferdinand Braun developed improved radio transmitters and receivers in 1897 and won the Nobel Prize in Physics in 1909.

Adolf Slaby
(1849–1913)

Radio

Georg von Arco
(1869–1940)



Developed radio systems from 1897 onward. Founded and ran radio departments at AEG and Telefunken.

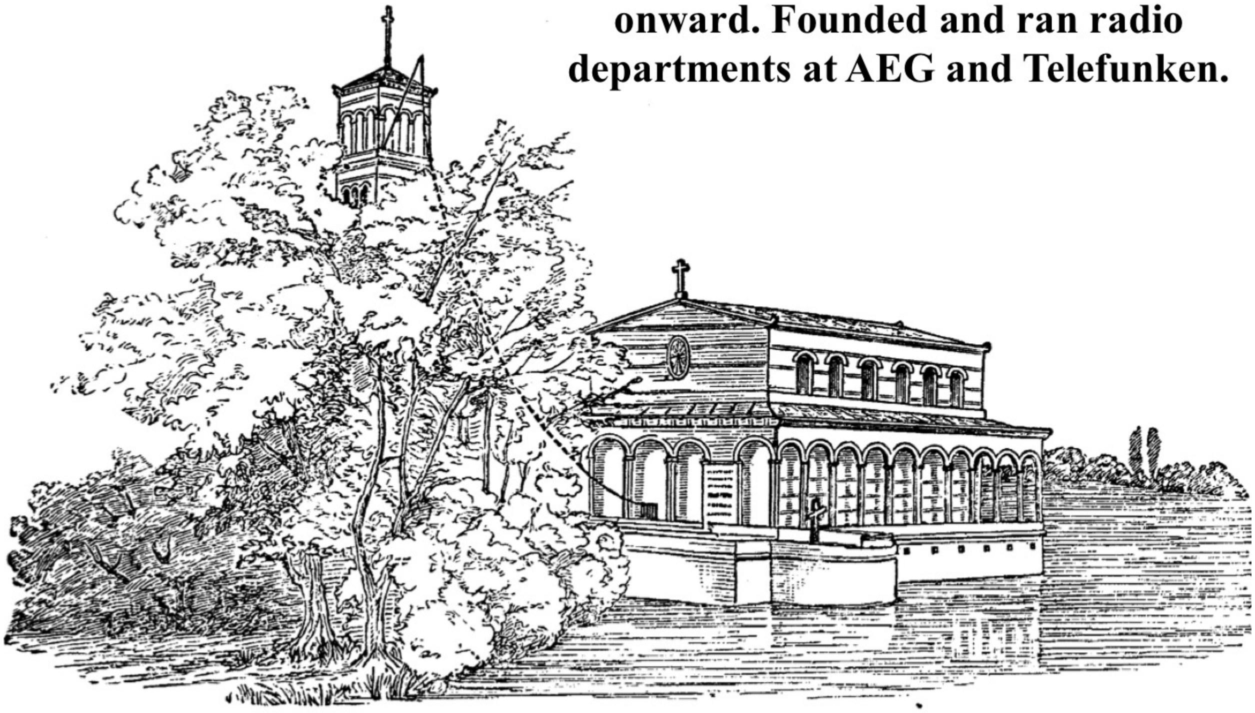


FIG. 7. FIRST TRANSMITTING-STATION, SACROW CHURCH, NEAR POTSDAM.

Figure 6.27: Adolf Slaby and Georg von Arco developed radio systems from 1897 onward. They founded and ran radio research and development departments at AEG and Telefunken.

Radio

Ernst Ruhmer (1878–1913) **Salomon Kalischer (1845–1924)** **Adolf Pieper (18??–19??)**

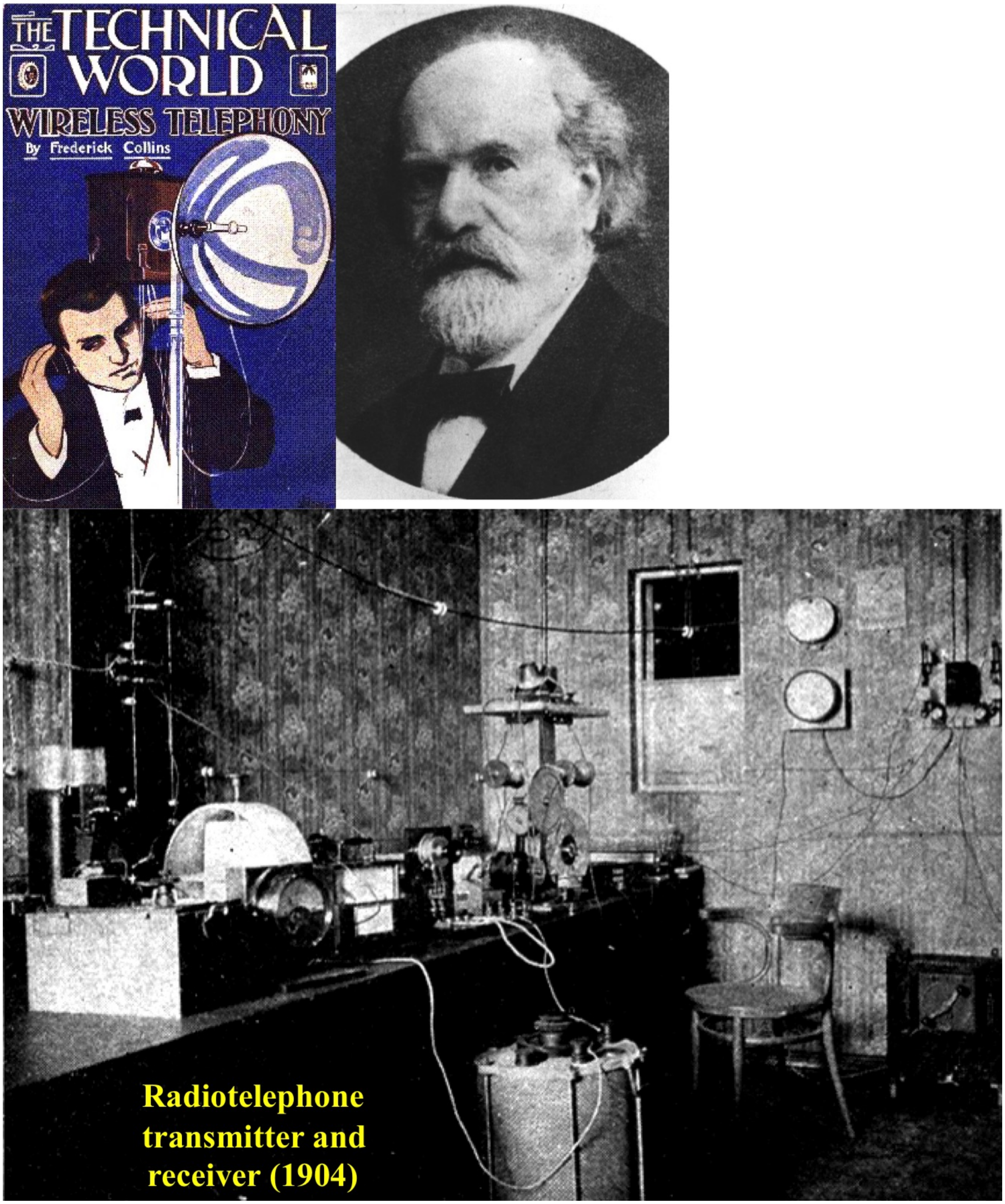
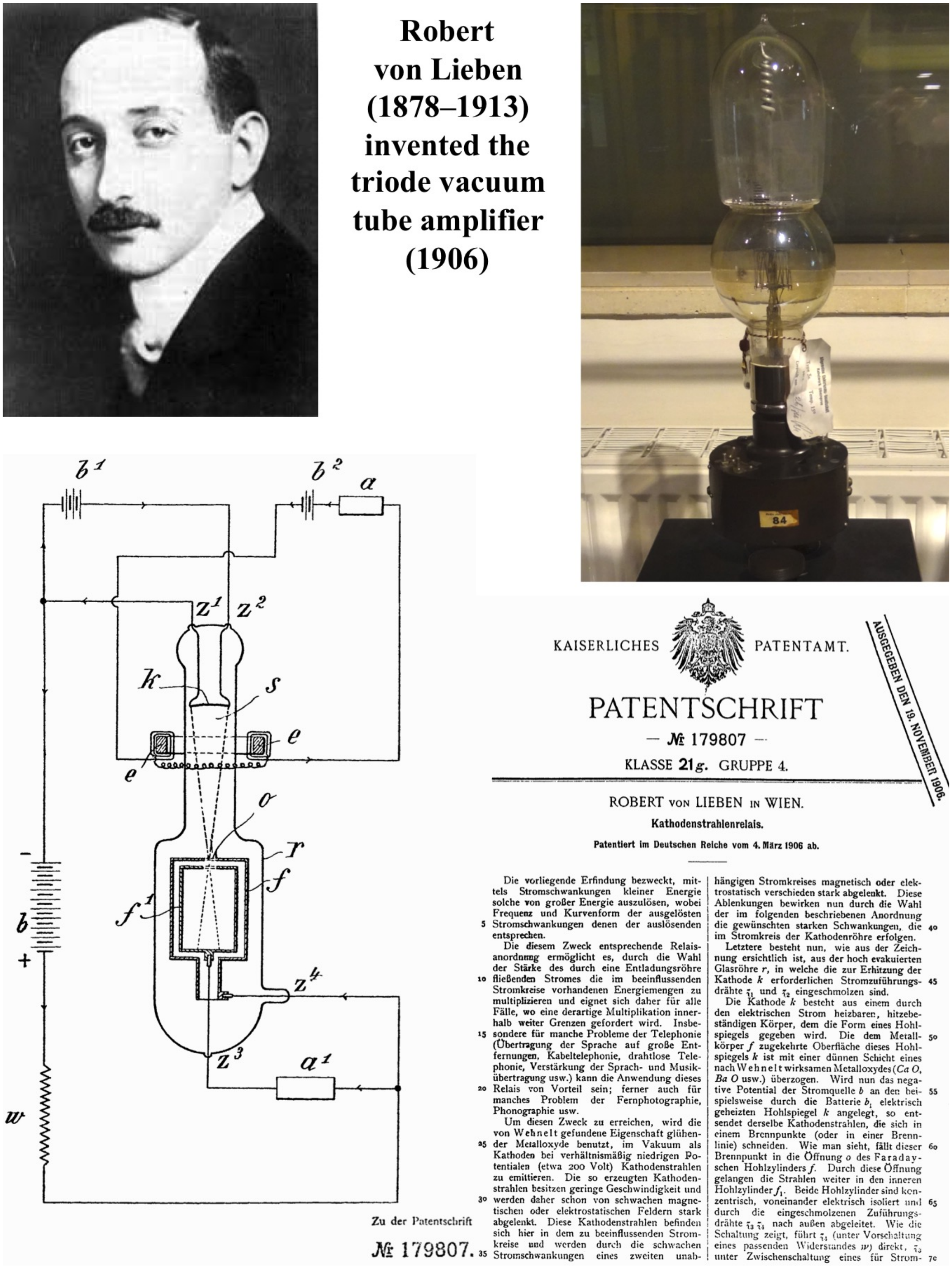

THE TECHNICAL WORLD
WIRELESS TELEPHONY
By Frederick Collins
Radiotelephone transmitter and receiver (1904)

Figure 6.28: Ernst Ruhmer invented a number of electrical communications devices, collaborating with Salomon Kalischer and Adolf Pieper on some of them. In 1904, Ruhmer demonstrated a radiotelephone transmitter and receiver capable of sending the first intelligible voice signals.



Robert von Lieben (1878–1913) invented the triode vacuum tube amplifier (1906)

Zu der Patentschrift

№ 179807.

KAISERLICHES PATENTAMT.

AUSGEGEBEN DEN 19. NOVEMBER 1906.

PATENTSCHRIFT

— № 179807 —

KLASSE 21*g*. GRUPPE 4.

ROBERT VON LIEBEN IN WIEN.

Kathodenstrahlenrelais.

Patentiert im Deutschen Reiche vom 4. März 1906 ab.

Die vorliegende Erfindung bezweckt, mittels Stromschwankungen kleiner Energie solche von großer Energie auszulösen, wobei Frequenz und Kurvenform der ausgelösten Stromschwankungen denen der auslösenden entsprechen.

Die diesem Zweck entsprechende Relaisanordnung ermöglicht es, durch die Wahl der Stärke des durch eine Entladungsröhre fließenden Stromes die im beeinflussenden Stromkreise vorhandenen Energiemengen zu multiplizieren und eignet sich daher für alle Fälle, wo eine derartige Multiplikation innerhalb weiter Grenzen gefordert wird. Insbesondere für manche Probleme der Telephonie (Übertragung der Sprache auf große Entfernungen, Kabeltelephonie, drahtlose Telephonie, Verstärkung der Sprach- und Musikübertragung usw.) kann die Anwendung dieses Relais von Vorteil sein; ferner auch für manches Problem der Fernphotographie, Phonographie usw.

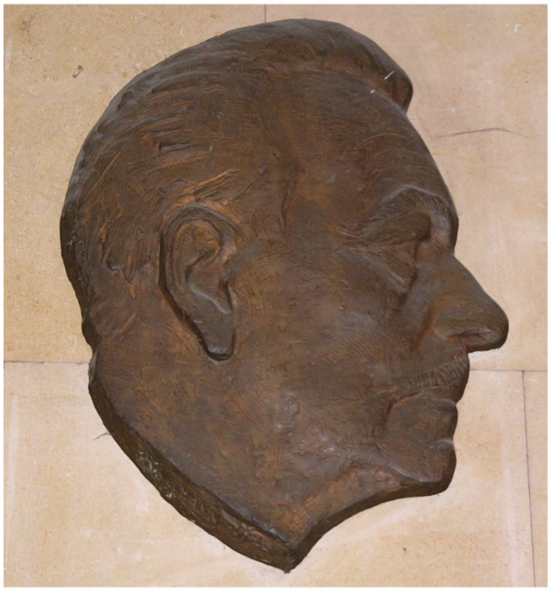
Um diesen Zweck zu erreichen, wird die von Wehnelt gefundene Eigenschaft glühender Metalloxyde benutzt, im Vakuum als Kathoden bei verhältnismäßig niedrigen Potentialen (etwa 200 Volt) Kathodenstrahlen zu emittieren. Die so erzeugten Kathodenstrahlen besitzen geringe Geschwindigkeit und werden daher schon von schwachen magnetischen oder elektrostatischen Feldern stark abgelenkt. Diese Kathodenstrahlen befinden sich hier in dem zu beeinflussenden Stromkreise und werden durch die schwachen Stromschwankungen eines zweiten unabhängigen Stromkreises magnetisch oder elektrostatisch verschieden stark abgelenkt. Diese Ablenkungen bewirken nun durch die Wahl der im folgenden beschriebenen Anordnung die gewünschten starken Schwankungen, die im Stromkreis der Kathodenröhre erfolgen.

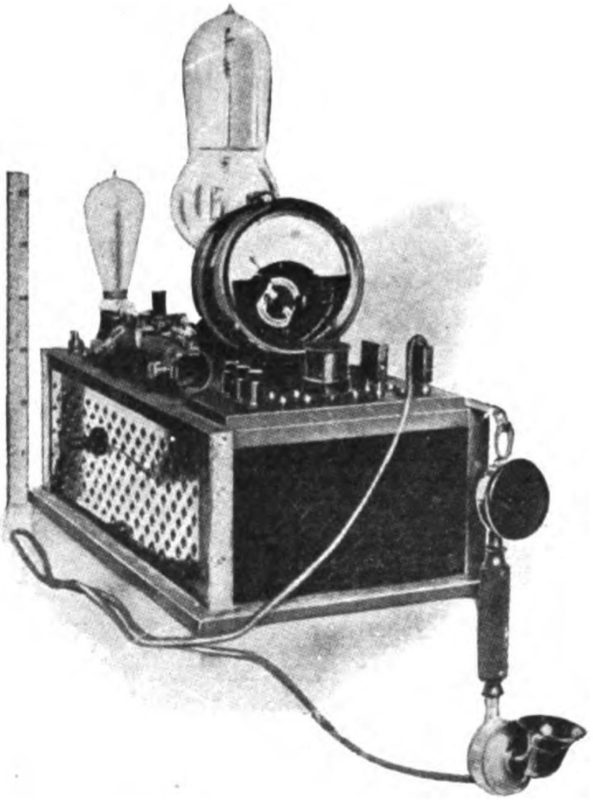
Letztere besteht nun, wie aus der Zeichnung ersichtlich ist, aus der hoch evakuierten Glasröhre *r*, in welche die zur Erhitzung der Kathode *k* erforderlichen Stromzuführungsdrähte $\mathfrak{z}_1$ und $\mathfrak{z}_2$ eingeschmolzen sind.

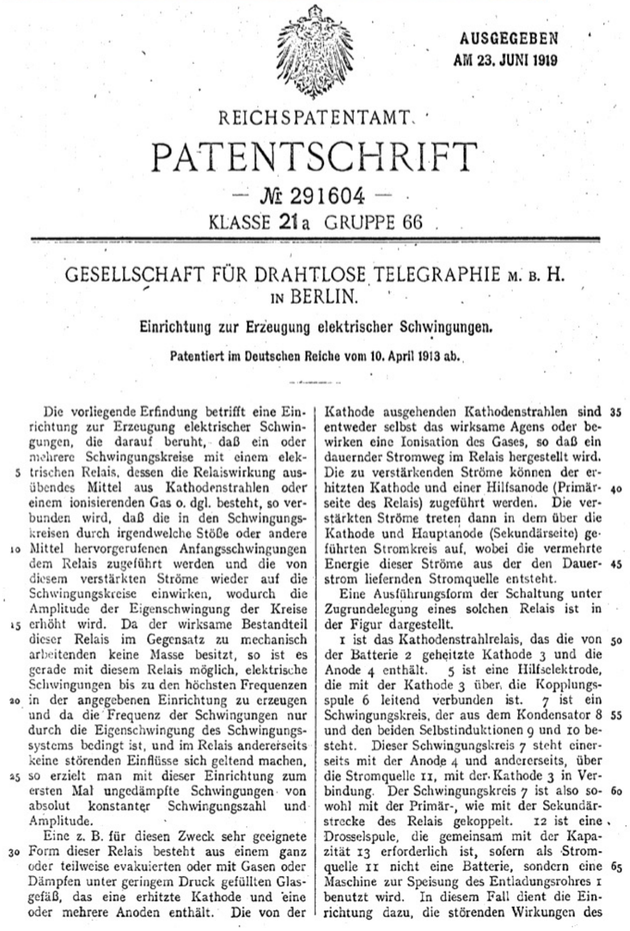
Die Kathode *k* besteht aus einem durch den elektrischen Strom heizbaren, hitzebeständigen Körper, dem die Form eines Hohlspiegels gegeben wird. Die dem Metallkörper *f* zugekehrte Oberfläche dieses Hohlspiegels *k* ist mit einer dünnen Schicht eines nach Wehnelt wirksamen Metalloxydes (*Ca O*, *Ba O* usw.) überzogen. Wird nun das negative Potential der Stromquelle *b* an den beispielsweise durch die Batterie b_1 elektrisch geheizten Hohlspiegel *k* angelegt, so entsendet derselbe Kathodenstrahlen, die sich in einem Brennpunkte (oder in einer Brennlinie) schneiden. Wie man sieht, fällt dieser Brennpunkt in die Öffnung *o* des Faradayschen Hohlzylinders *f*. Durch diese Öffnung gelangen die Strahlen weiter in den inneren Hohlzylinder f_1. Beide Hohlzylinder sind konzentrisch, voneinander elektrisch isoliert und durch die eingeschmolzenen Zuführungsdrähte $\mathfrak{z}_3$ $\mathfrak{z}_4$ nach außen abgeleitet. Wie die Schaltung zeigt, führt $\mathfrak{z}_4$ (unter Vorschaltung eines passenden Widerstandes *w*) direkt, $\mathfrak{z}_3$ unter Zwischenschaltung eines für Strom-

Figure 6.29: Robert von Lieben, Eugen Reisz, and Siegmund Strauss invented and demonstrated the triode vacuum tube amplifier in 1906. It greatly improved the performance of radio circuits.

Alexander Meißner (1883–1958) invented, demonstrated, and patented the first modulated, amplified radio systems for high-quality transmission of voices and music (1912)







AUSGEGEBEN
AM 23. JUNI 1919

REICHSPATENTAMT.

PATENTSCHRIFT

— № 291604 —

KLASSE 21a GRUPPE 66

GESELLSCHAFT FÜR DRAHTLOSE TELEGRAPHIE M. B. H. IN BERLIN.

Einrichtung zur Erzeugung elektrischer Schwingungen.

Patentiert im Deutschen Reiche vom 10. April 1913 ab.

Die vorliegende Erfindung betrifft eine Einrichtung zur Erzeugung elektrischer Schwingungen, die darauf beruht, daß ein oder mehrere Schwingungskreise mit einem elektrischen Relais, dessen die Relaiswirkung ausübendes Mittel aus Kathodenstrahlen oder einem ionisierenden Gas o. dgl. besteht, so verbunden wird, daß die in den Schwingungskreisen durch irgendwelche Stöße oder andere Mittel hervorgerufenen Anfangsschwingungen dem Relais zugeführt werden und die von diesem verstärkten Ströme wieder auf die Schwingungskreise einwirken, wodurch die Amplitude der Eigenschwingung der Kreise erhöht wird. Da der wirksame Bestandteil dieser Relais im Gegensatz zu mechanisch arbeitenden keine Masse besitzt, so ist es gerade mit diesem Relais möglich, elektrische Schwingungen bis zu den höchsten Frequenzen in der angegebenen Einrichtung zu erzeugen und da die Frequenz der Schwingungen nur durch die Eigenschwingung des Schwingungssystems bedingt ist, und im Relais andererseits keine störenden Einflüsse sich geltend machen, so erzielt man mit dieser Einrichtung zum ersten Mal ungedämpfte Schwingungen von absolut konstanter Schwingungszahl und Amplitude.

Eine z. B. für diesen Zweck sehr geeignete Form dieser Relais besteht aus einem ganz oder teilweise evakuierten oder mit Gasen oder Dämpfen unter geringem Druck gefüllten Glasgefäß, das eine erhitzte Kathode und eine oder mehrere Anoden enthält. Die von der Kathode ausgehenden Kathodenstrahlen sind entweder selbst das wirksame Agens oder bewirken eine Ionisation des Gases, so daß ein dauernder Stromweg im Relais hergestellt wird. Die zu verstärkenden Ströme können der erhitzten Kathode und einer Hilfsanode (Primärseite des Relais) zugeführt werden. Die verstärkten Ströme treten dann in dem über die Kathode und Hauptanode (Sekundärseite) geführten Stromkreis auf, wobei die vermehrte Energie dieser Ströme aus der den Dauerstrom liefernden Stromquelle entsteht.

Eine Ausführungsform der Schaltung unter Zugrundelegung eines solchen Relais ist in der Figur dargestellt.

1 ist das Kathodenstrahlrelais, das die von der Batterie 2 geheitzte Kathode 3 und die Anode 4 enthält. 5 ist eine Hilfselektrode, die mit der Kathode 3 über die Kopplungsspule 6 leitend verbunden ist. 7 ist ein Schwingungskreis, der aus dem Kondensator 8 und den beiden Selbstinduktionen 9 und 10 besteht. Dieser Schwingungskreis 7 steht einerseits mit der Anode 4 und andererseits, über die Stromquelle 11, mit der Kathode 3 in Verbindung. Der Schwingungskreis 7 ist also sowohl mit der Primär-, wie mit der Sekundärstrecke des Relais gekoppelt. 12 ist eine Drosselspule, die gemeinsam mit der Kapazität 13 erforderlich ist, sofern als Stromquelle 11 nicht eine Batterie, sondern eine Maschine zur Speisung des Entladungsrohres 1 benutzt wird. In diesem Fall dient die Einrichtung dazu, die störenden Wirkungen des

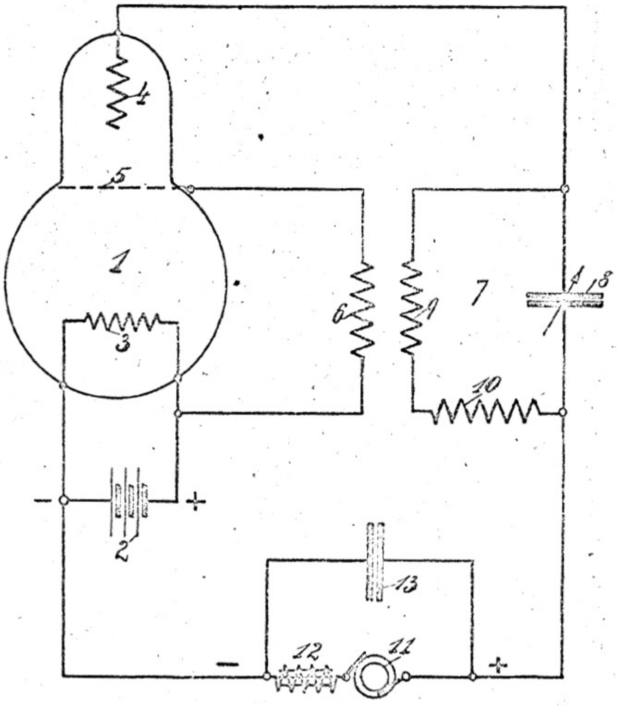


Figure 6.30: No later than 1912, Alexander Meißner invented, demonstrated, and patented the first modulated, amplified radio systems for high-quality transmission of voices and music.

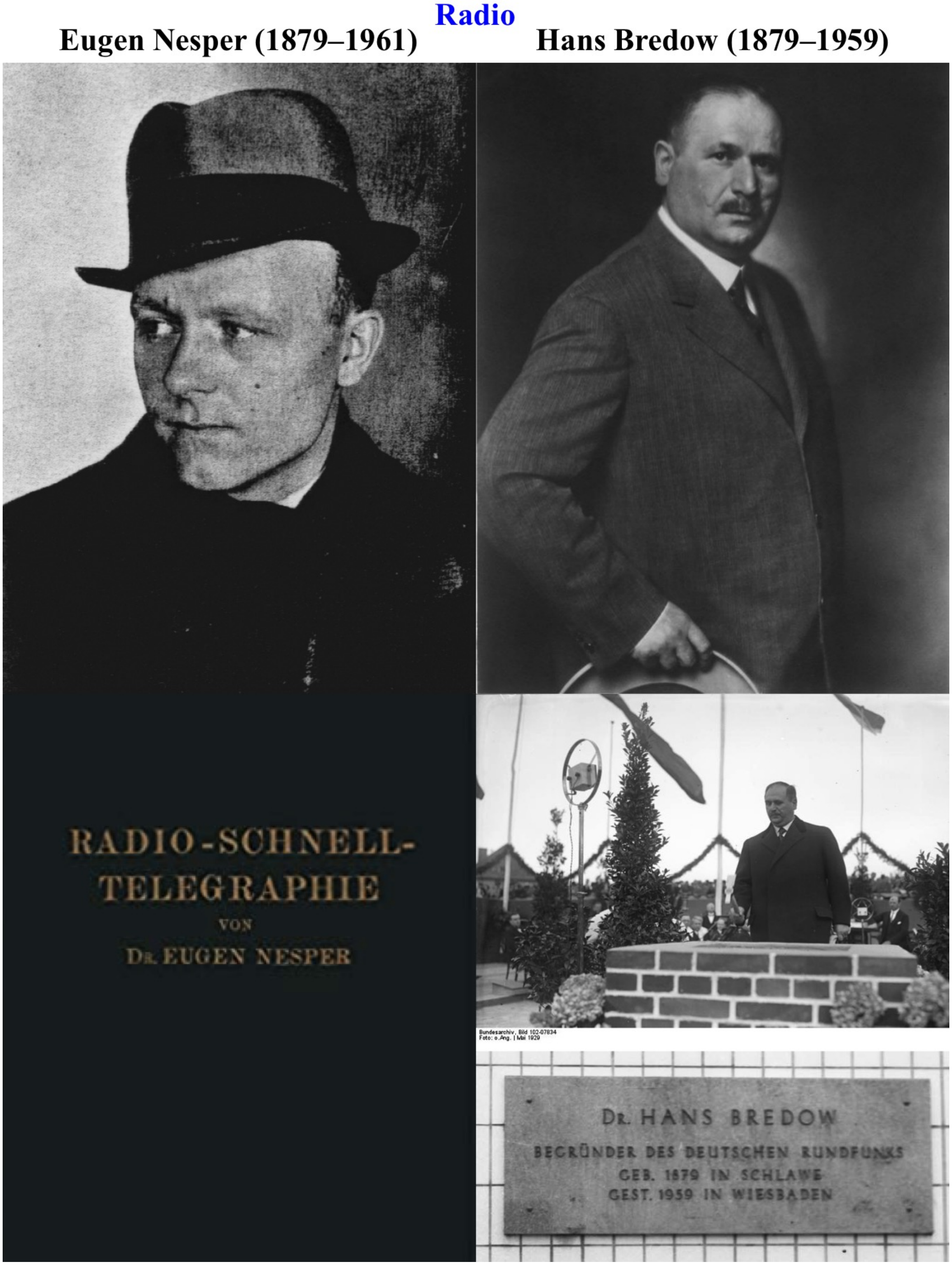
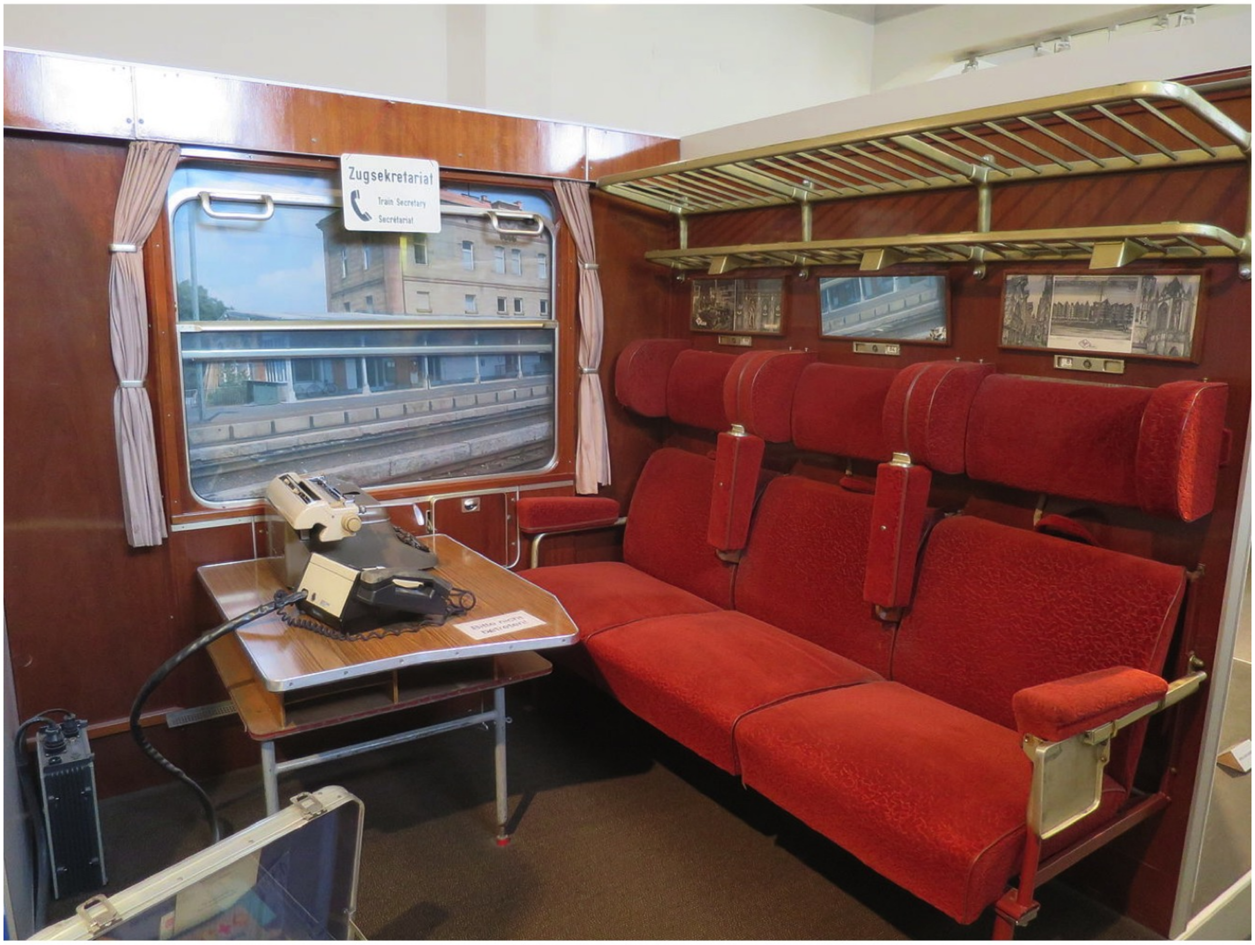

Radio
Eugen Nesper (1879–1961)
Hans Bredow (1879–1959)
RADIO-SCHNELL-TELEGRAPHIE
VON
DR. EUGEN NESPER
Bundesarchiv, Bild 102-07834
Foto: o.Ang. | Mai 1929
DR. HANS BREDOW
BEGRÜNDER DES DEUTSCHEN RUNDFUNKS
GEB. 1879 IN SCHLAWE
GEST. 1959 IN WIESBADEN

Figure 6.31: Some other important early radio pioneers included Eugen Nesper and Hans Bredow.



The world's first mobile telephone system began commercial operation on German trains in 1926

Zugsekretariat
Train Secretary
Secrétariat

Figure 6.32: The world's first mobile telephone system began commercial operation on German trains in 1926.

6.3.6 Disc Phonograph Records and Players

Emil(e) Berliner (German, 1851–1929) was educated in Germany and then moved to the United States. In 1886, he invented disc phonograph records and the corresponding player, which he called the Gramophone (Fig. 6.33). Earlier phonographs had used cylinders made of wax, which were quite cumbersome in shape and also very fragile and temperature sensitive. Berliner's flat discs made of hard rubber were durable recordings that could be easily stored, stacked, played, and flipped. Berliner also developed improved microphones, acoustic tile, and an improved loom for producing cloth, and he experimented with proto-helicopters and autogyros (p. 1804).

6.3.7 Magnetic Tape Recording

Fritz Pfleumer (Austrian, 1881–1945), Walter Weber (German, 1907–1944), and Hans-Joachim von Braunmühl (German, 1900–1980) developed magnetic plastic tape recorders, dubbed the Magnetophon, with the first demonstration in 1927 [Albert 2014]. See Fig. 6.34. Weber and von Braunmühl also invented improved designs for microphones.

German-speaking creators also developed a magnetic tape recorder that used steel tape instead of plastic tape. In 1930, Kurt Stille (German, 1873–1957) and Ludwig Blattner (German, 1881–1935) invented the Blattnerphone magnetic steel tape recorder, shown in Fig. 6.35. However, the advantages of the plastic tape soon won out.

Magnetic tape recording technology was transferred to other countries after World War II. For example, BIOS 951, *The Magnetophon Sound Recording and Reproducing System*, reported:

> This report describes a system for the recording and reproduction of sound, making use of the well-known magnetic principle, which has been developed in Germany both before and during the war. During the war an improvement in performance has been achieved and the quality of reproduction of speech and music now obtainable by means of this system is of a high order and, it is claimed, consistently better than that achieved with other systems.

There were a number of other postwar Allied reports on German magnetic tape recorders, such as BIOS 1379, *Plastics in German Sound Recording Systems*, and FIAT 705, *High Frequency Magnetophone Magnetic Sound Recorders*. In addition to the reports, many magnetic recorders and reels of tape were seized and later copied by Allied countries (Figs. 6.36–6.37). For example, a U.S. Army officer, John T. "Jack" Mullin, confiscated several German Magnetophon units, shipped them to a private address in the United States, and then presented their technology to potential customers and investors as his own invention. Mullin became much more famous and wealthy than the actual German and Austrian inventors, and he was part of a pattern, not an isolated case.

In 1963, small reels of magnetic audio tape were packaged and marketed as "compact cassette tapes" by Philips Eindhoven, and that format was dominant worldwide for over three decades. (For more information on Philips Eindhoven, see p. 1019.)

The Magnetophon is just one example of the revolutionary magnetic recording technologies for audio, video, and data that were invented and perfected in Germany, then transferred to Allied countries in 1945 and used worldwide for decades [Gimbel 1990]. Gunter Guttwein (German, 1906–1978) also developed magnetic recording and magnetic memory technologies in Germany, and brought those to the U.S. Army's Fort Monmouth electronics laboratory after World War II [Fort Monmouth Historical Office 2008].

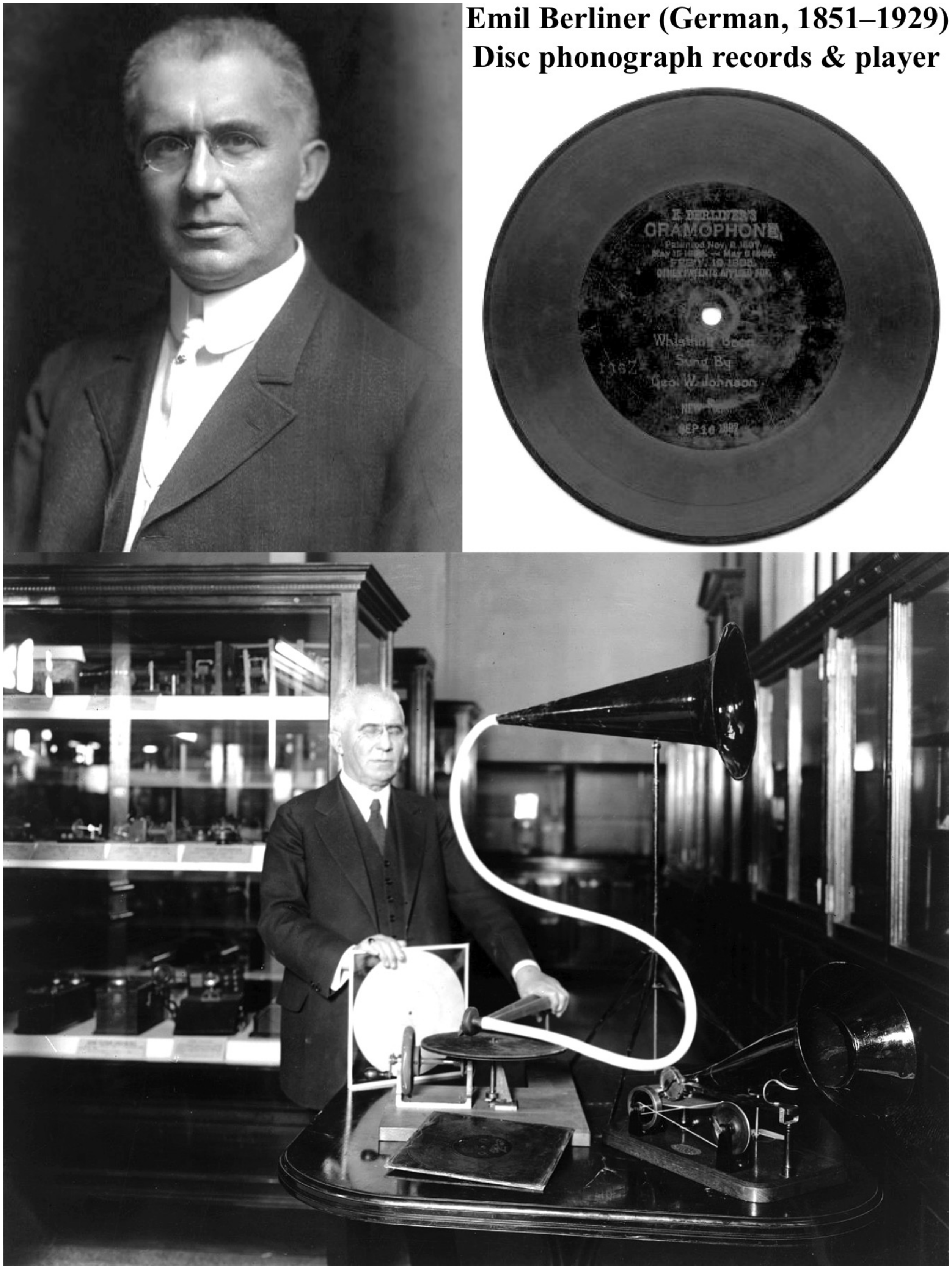

Emil Berliner (German, 1851–1929)
Disc phonograph records & player
E. BERLINER'S
GRAMOPHONE
Whistling Coon
Sung By
Geo. W. Johnson

Figure 6.33: Emil(e) Berliner invented the disc phonograph record and player in 1886.

Magnetic recording

Fritz Pfleumer
(1881–1945)

Walter Weber
(1907–1944)

Hans-Joachim
von Braunmühl
(1900–1980)

Magnetic plastic tape recorders (first demonstrated 1927)

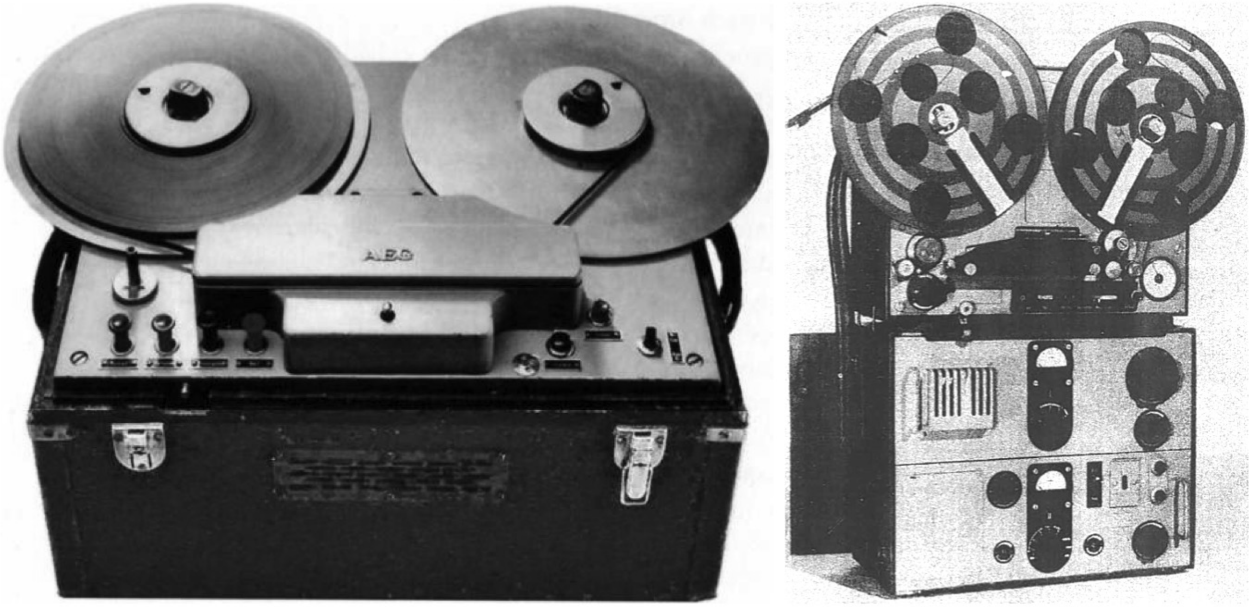


Figure 6.34: Fritz Pfleumer, Walter Weber, and Hans-Joachim von Braunmühl developed magnetic plastic tape recorders (first demonstrated in 1927).

Magnetic recording	Kurt Stille (1873–1957)	Ludwig Blattner (1881–1935)

Blattnerphone magnetic steel tape recorder (1930)

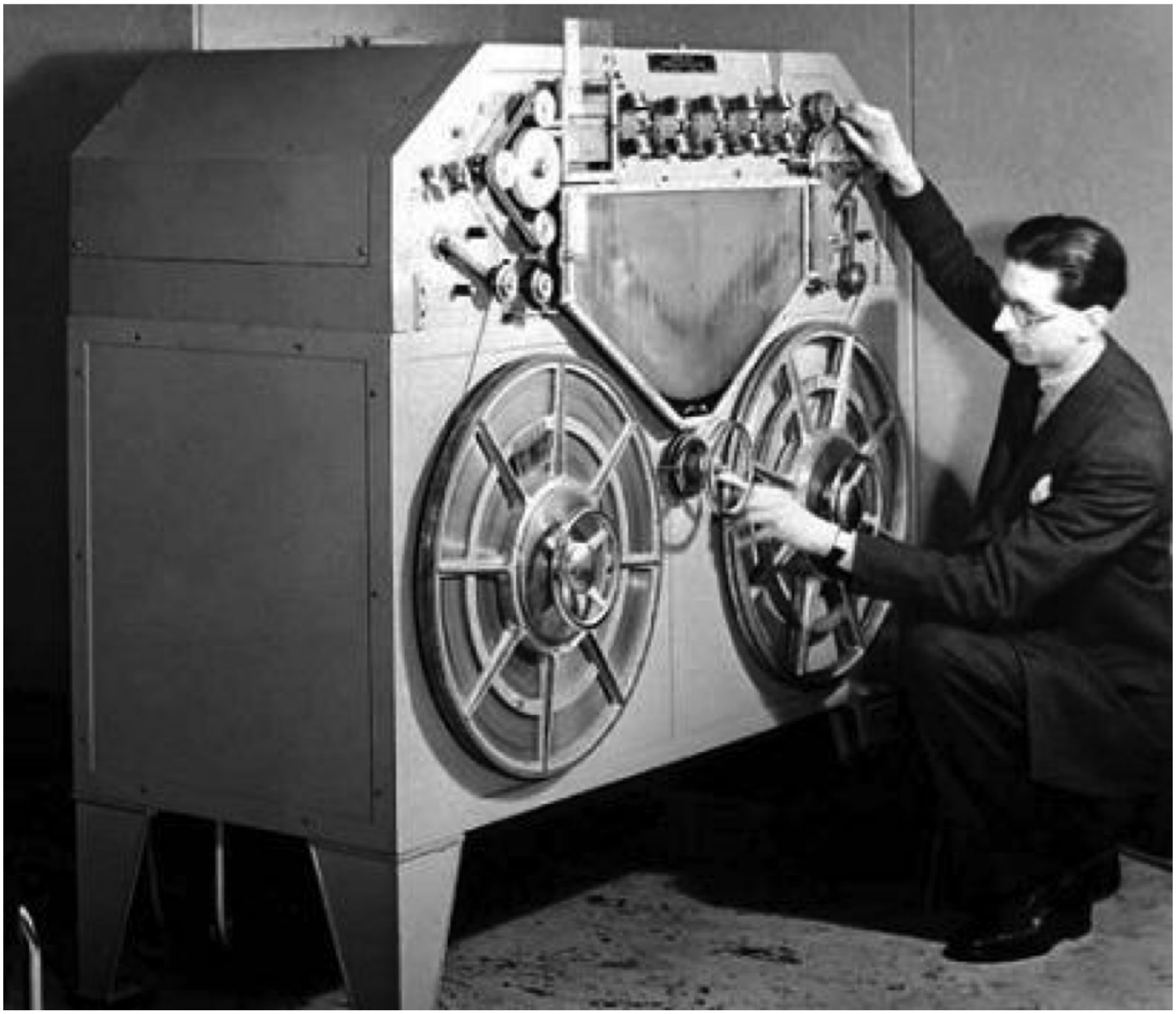


Figure 6.35: Kurt Stille and Ludwig Blattner developed the Blattnerphone magnetic steel tape recorder (1930).

DECLASSIFIED
Authority NND 968148

NARA RG 40, Entry UD-75, Box 58,
Folder Replies to Letters of April 29, 1947

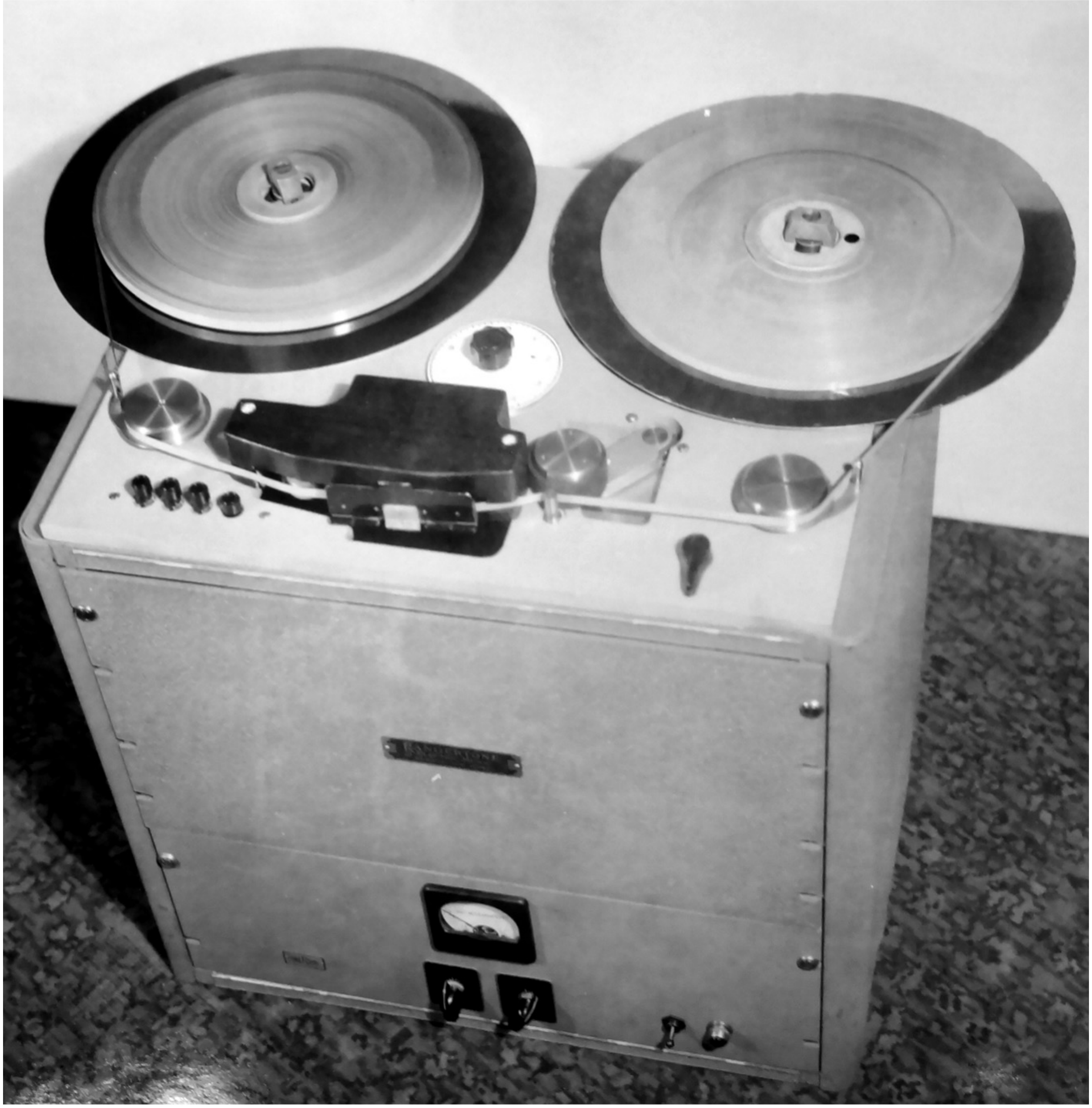
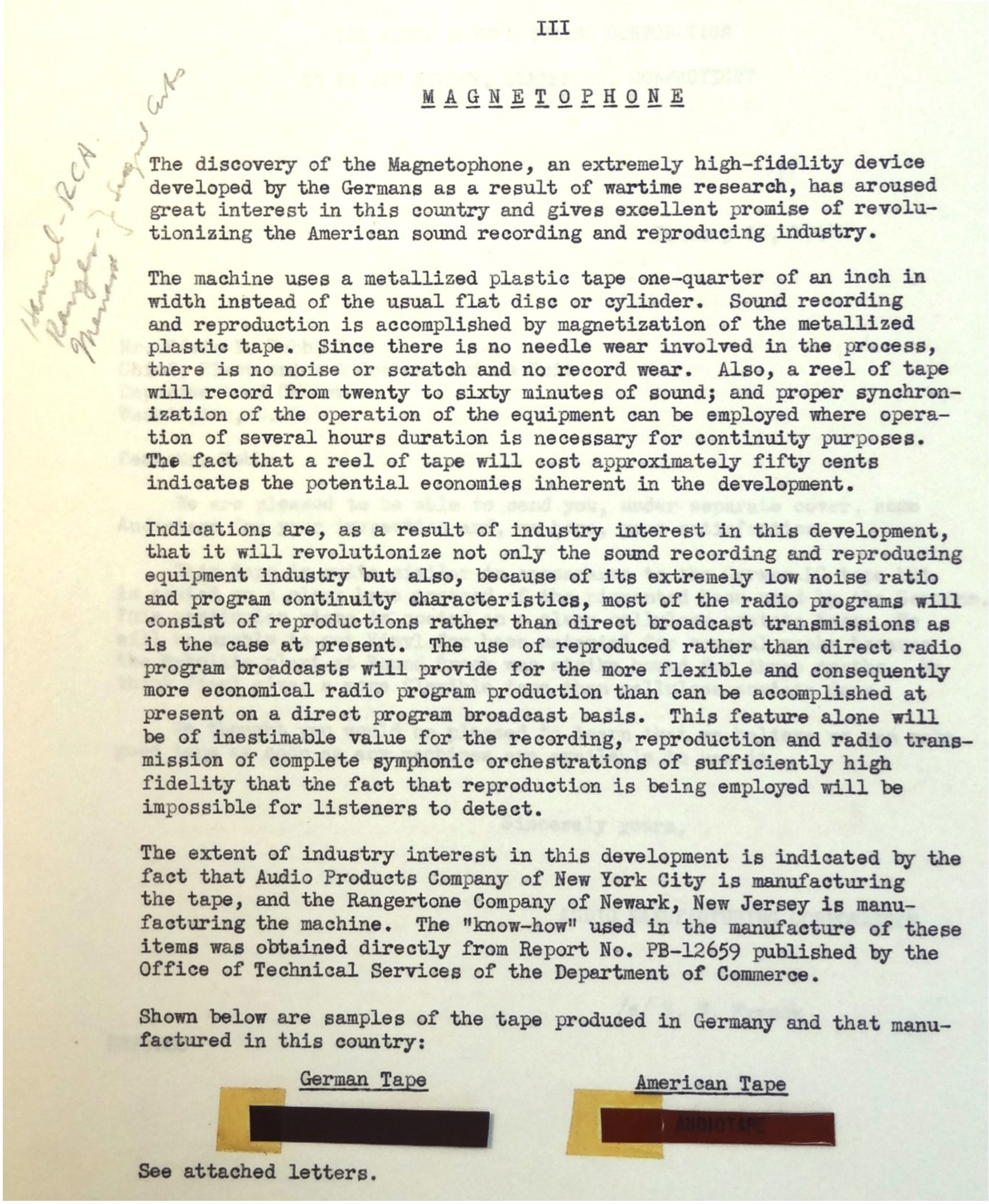


Figure 6.36: After World War II, German magnetic tape recorders, tape, and designs were taken by the United States and directly copied by U.S. companies [NARA RG 40, Entry UD-75, Box 58, Folder Replies to Letters of April 29, 1947].

DECLASSIFIED
Authority NND 968148

NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards



III

MAGNETOPHONE

Hamel-RCA.
Ranger-
Magnecord
} Signal Corps

The discovery of the Magnetophone, an extremely high-fidelity device developed by the Germans as a result of wartime research, has aroused great interest in this country and gives excellent promise of revolutionizing the American sound recording and reproducing industry.

The machine uses a metallized plastic tape one-quarter of an inch in width instead of the usual flat disc or cylinder. Sound recording and reproduction is accomplished by magnetization of the metallized plastic tape. Since there is no needle wear involved in the process, there is no noise or scratch and no record wear. Also, a reel of tape will record from twenty to sixty minutes of sound; and proper synchronization of the operation of the equipment can be employed where operation of several hours duration is necessary for continuity purposes. The fact that a reel of tape will cost approximately fifty cents indicates the potential economies inherent in the development.

Indications are, as a result of industry interest in this development, that it will revolutionize not only the sound recording and reproducing equipment industry but also, because of its extremely low noise ratio and program continuity characteristics, most of the radio programs will consist of reproductions rather than direct broadcast transmissions as is the case at present. The use of reproduced rather than direct radio program broadcasts will provide for the more flexible and consequently more economical radio program production than can be accomplished at present on a direct program broadcast basis. This feature alone will be of inestimable value for the recording, reproduction and radio transmission of complete symphonic orchestrations of sufficiently high fidelity that the fact that reproduction is being employed will be impossible for listeners to detect.

The extent of industry interest in this development is indicated by the fact that Audio Products Company of New York City is manufacturing the tape, and the Rangertone Company of Newark, New Jersey is manufacturing the machine. The "know-how" used in the manufacture of these items was obtained directly from Report No. PB-12659 published by the Office of Technical Services of the Department of Commerce.

Shown below are samples of the tape produced in Germany and that manufactured in this country:

German Tape   American Tape

See attached letters.

Figure 6.37: After World War II, German magnetic tape recorders, tape, and designs were taken by the United States and directly copied by U.S. companies [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

6.3.8 Motion Picture Cameras and Projectors

As shown on p. 634, the brothers Max Skladanowsky (German, 1863–1939) and Emil Skladanowsky (German, 1866–1945) created the Bioscop motion picture camera and projector in 1892 and presented the first public films in 1895.

Methods of recording audio tracks on visual film reels were developed by Josef Benedict Engl (German, 1893–1942), Joseph Massolle (German, 1889–1957), Hans von Ohain (German, 1911–1998), and Hans Vogt (German, 1890–1979).

6.3.9 Television

In the English-speaking world, television is generally regarded as an invention that originated with experiments before World War II by Philo Farnsworth (U.S., 1906–1971), Vladimir Zworykin (Russian but worked in the United States, 1888–1982), and John Logie Baird (Scottish, 1888–1946), and that led to the first major television systems and programs in the 1950s. While those scientists and events were indeed part of the history of television, scientists from the great German-speaking world were responsible for most of the key steps in the development of television, from the earliest experiments through the world's most advanced television systems in 1945 and beyond.

In the first important step toward television development, Julius Plücker (German states, 1801–1868) discovered magnetic deflection of electrons in a vacuum tube in 1857. See Fig. 6.38.

By harnessing Plücker's discovery, Karl Ferdinand Braun (German, 1850–1918) invented and demonstrated cathode ray tubes and oscilloscopes in 1897 (Fig. 6.38). Oscilloscopes are essentially television sets that visually display sine waves corresponding to electrical input signals; they have been used in various forms ever since as important diagnostic and readout instruments for electronic systems. In much of the world, cathode ray tube screens are still called Braun tubes. Braun also invented semiconductor diodes in 1874 (p. 1045) and won the Nobel Prize in Physics in 1909 for his radio-related research (p. 978).

Paul Nipkow (German, 1860–1940, Fig. 6.38) worked on an electromechanical television system that used a "Nipkow disk" to guide its scanning pattern. Nipkow's work greatly facilitated and inspired research by many other scientists after that.

In 1909, Ernst Ruhmer (German, 1878–1913) demonstrated a proof-of-concept 5x5 pixel CCD-like semiconductor television camera and a 5x5 pixel flat-panel television display (Fig. 6.39). He sought funding to build television cameras and displays with 100x100 pixels, but unfortunately he fell ill and died.

Some other early pioneers of television included August Karolus (German, 1893–1972), Kálmán Tihanyi (Hungarian, 1897–1947), Max Knoll (German, 1897–1969, one of the inventors of electron microscopes—see p. 1290), and Erhard Kietz (German, 1909–1982), as shown in Fig. 6.40.

Siegmund Loewe (German, 1885–1962) and Manfred von Ardenne (German, 1907–1997) developed a complete television transmitter and receiver system in 1931, and then an improved and larger television receiver in 1936 (Fig. 6.41). Figure 6.42 also shows a competing Telefunken commercial television receiver from 1933.

Emil Mechau (German, 1882–1945), Walter Heimann (German, 1908–1981), and Werner Flechsig (German, 1900–1981) developed the long-range zoom television cameras that were used to broadcast the 1936 Berlin Olympics (Fig. 6.43).

Fritz Schröter (German, 1886–1973) at Telefunken developed interlaced television scanning and rectangular picture tubes, such as the 1937 television receiver shown in Fig. 6.44; he also did seminal work on pulse code modulation and analog-to-digital converters [FIAT 865]. Fritz Fischer (Swiss, 1898–1947) and Edgar Gretener (Swiss 1902–1958, also important in cryptography) developed television projectors. Friedrich Gladenbeck (German, 1899–1987, also important in robotics, p. 1209) developed high-frequency radio, remote control, and television systems.

Figure 6.45 shows a Telefunken television camera and Einheitsempfänger E1 home receiver, both from 1939. Late 1930s German television broadcasts featured a wide variety of regular news and entertainment shows with 441 horizontal lines of resolution for the height of the picture and 50 interlaced frames per second (25 full frames per second), fully comparable in both quality and content to American television of two decades later [Kloft 2000].

German-speaking scientists miniaturized television systems for use in smart bombs and missiles, decades before that technology became popularized in the first U.S.-Iraq war (pp. 1842–1844, 5412–5417). The same technology was also employed in battlefield robotics (pp. 1209–1210). Figures 6.46–6.48 show a shoebox-sized Fernseh television receiver/picture tube and shoebox-sized Tonne television camera/transmitter that were first operational in 1942.

CIOS XXXII-125, *German Guided Missile Research*, pp. 139–143, described the miniaturized television systems and some of their applications (see pp. 5412–5417):

> 3. Television System for Guided Missiles.
>
> This consists of two units (camera and transmitter) in the missile, and a further two circuits (receiver and indicator) in the controlling aircraft.
>
> All units measure 7" x 7" x 14½". Only the camera and indicator were designed by Fernseh, the radio link being designed by another firm.
>
> In the early models a 441 line interlaced picture was used, the picture frequency being 25 per second (frame frequency 50 per second). [...]
>
> The picture quality obtained would appear to be excellent. Some photographs have been obtained of the picture given by the 441 line interlaced equipment. These pictures were

> taken using the whole equipment, including the radio link, but a large, good quality receiving tube was used. The photographs indicate that the definition was about as good as can be obtained with a 441 line system. [...]
>
> The D.F.S. have been concerned with the testing and installation of the Fernseh television in the Hs 293. [...]
>
> On one test a range of 263 kms. was obtained with the controlling aircraft at a height of 4,000 metres and the bomb at a height of 1,000 metres. [...]
>
> It is understood that the Fernseh television camera using the infra-red tube was also used in the robot tank. [...]
>
> An interesting television camera of very compact design is being developed for Wasserfall. [...]

In "Nazis Had Television Eye to Guide Missile's Path," the *New York Times* reported [NYT 1949-05-22]:

> DAYTON, Ohio, May 21—German scientists during World War II developed a television device similar to the human eye for controlling guided missiles or aircraft but never put it to use, the Air Materiel Command at Wright Field disclosed today.
>
> The device was built into missiles such as bombs and guided them toward a pre-set target without outside help, it was said. It used a movable mirror which reflected the target to a television tube. This tube transmitted electrical impulses to the missile's steering device, keeping the missile constantly pointed at the target.
>
> The pilot aligned his target in the television picture in his sighting mechanism, switched on the bomb's steering device and released the bomb. The missile then was on its own.
>
> The entire device was no bigger than eight inches in diameter and weighed only four pounds. Some were as small as five inches in diameter.

In addition to such military applications, handheld compact video cameras based on this technology were used for many decades after the war.

These wartime video cameras and television receivers could also achieve remarkable resolution. Some systems transmitted images up to 1029 horizontal lines in height at 25 frames per second [Faensen 2001, p. 90], comparable to modern high-definition television (HDTV, 1080 lines) and far greater than the 480-line standard resolution that was used for U.S. commercial television broadcasts until the early 2000s.

Walter Bruch (German, 1908–1990) operated television cameras at the 1936 Berlin Olympics and then developed the color PAL television system after the war. See Fig. 6.49.

Peter Carl Goldmark (Hungarian, 1906–1977) developed magnetic video recording (the Electronic Video Recording system, 1967), as well as LP records and a color television system in the United States (Fig. 6.49).

Robert Adler (Austrian, 1913–2007, Fig. 6.50), a physicist from Vienna, joined Zenith Electronics in the United States in 1941 and patented a huge number of television-related inventions, including remote controls (using ultrasonic or optical signals), subscription television channels (using scrambled and descrambled signals), and color television systems.

German-speaking scientists also invented both light-emitting diodes (LEDs, pp. 1104 and 2888) and liquid crystals (p. 506), which are the basis of modern video screens.

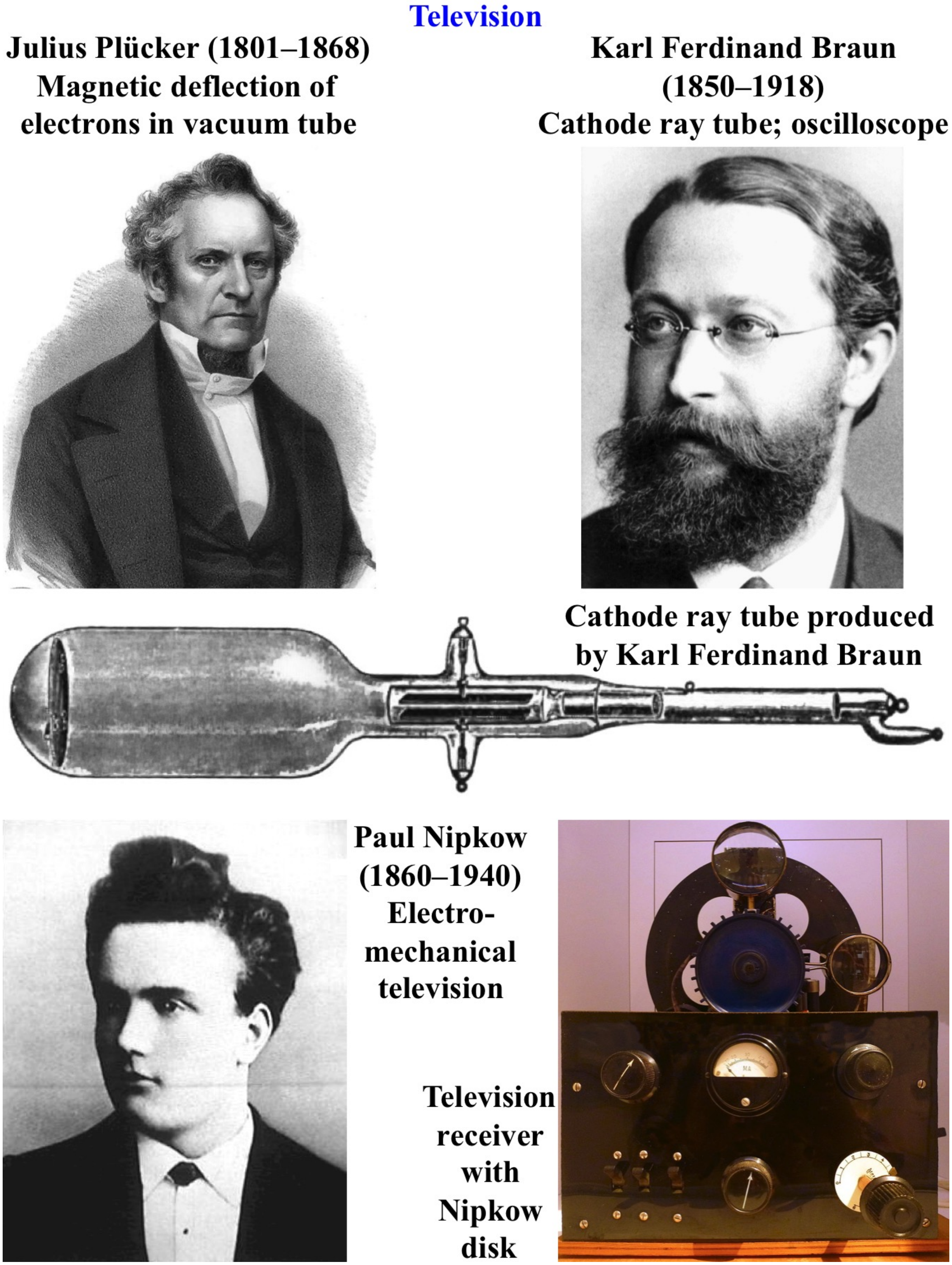

Television
Julius Plücker (1801–1868)
Magnetic deflection of electrons in vacuum tube
Karl Ferdinand Braun (1850–1918)
Cathode ray tube; oscilloscope
Cathode ray tube produced by Karl Ferdinand Braun
Paul Nipkow (1860–1940)
Electro-mechanical television
Television receiver with Nipkow disk

Figure 6.38: In the first steps toward television development, Julius Plücker discovered magnetic deflection of electrons in a vacuum tube, Karl Ferdinand Braun created cathode ray tubes and oscilloscopes, and Paul Nipkow worked on an electromechanical television system that used a "Nipkow disk" to guide its scanning pattern.

Television

Ernst Ruhmer (1878–1913) demonstrated a proof-of-concept 5x5 pixel CCD-like semiconductor television camera and a 5x5 pixel flat-panel television display (1909). He sought funding to build television cameras and displays with 100x100 pixels, but unfortunately he fell ill and died.

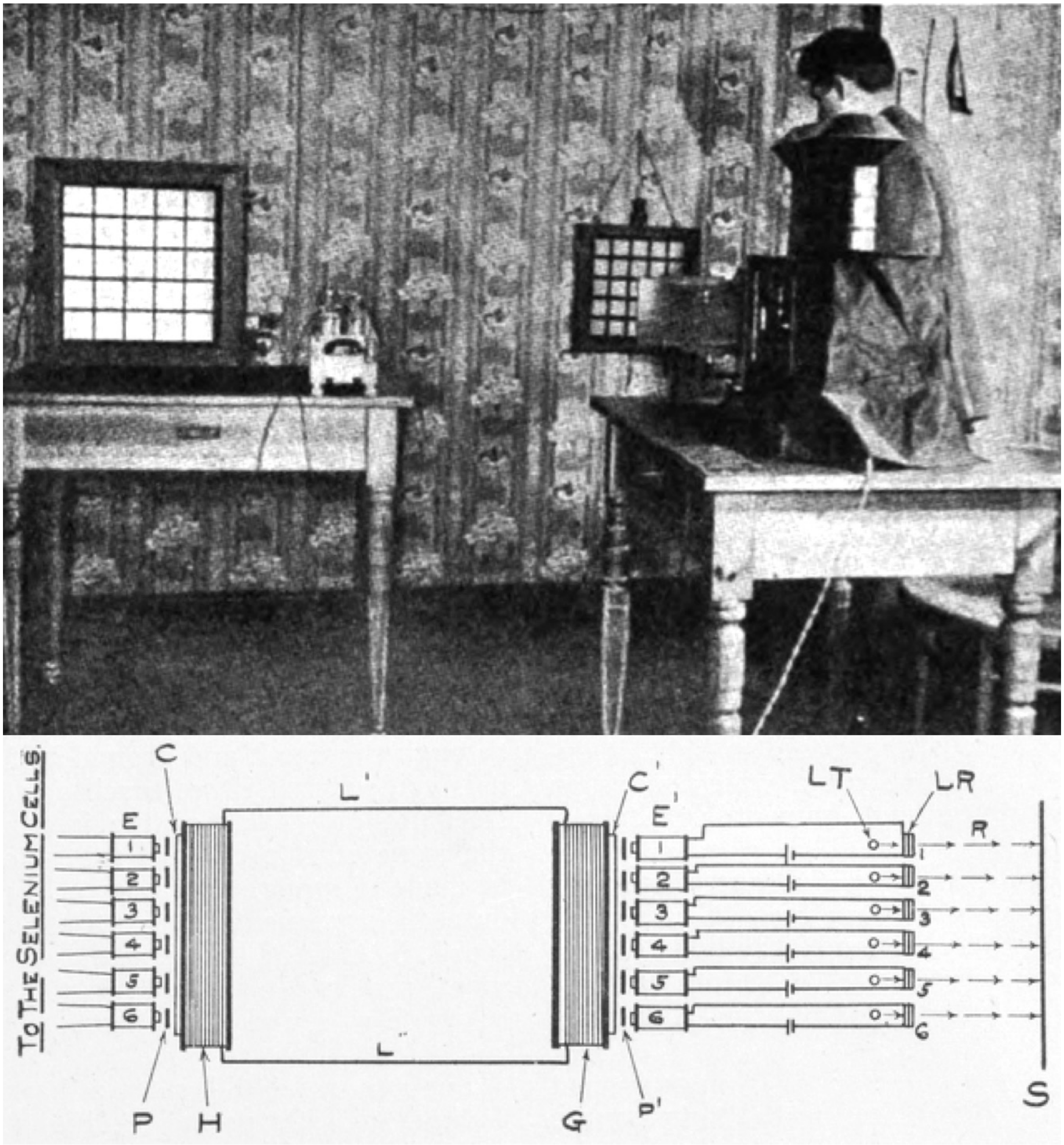


Figure 6.39: In 1909, Ernst Ruhmer demonstrated a proof-of-concept 5x5 pixel CCD-like semiconductor television camera and a 5x5 pixel flat-panel television display [Gernsback 1909]. He sought funding to build television cameras and displays with 100x100 pixels, but unfortunately he fell ill and died.

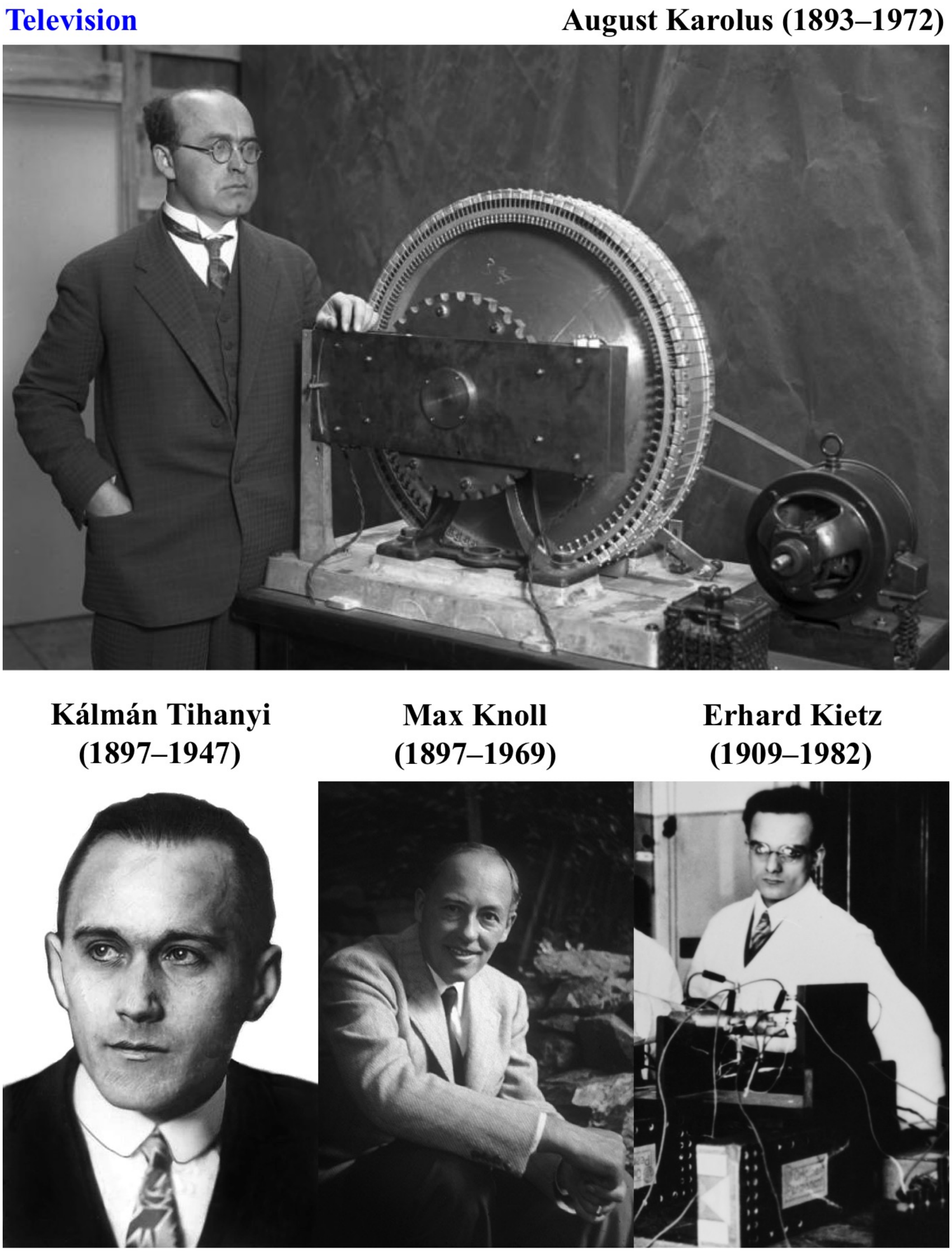

Television
August Karolus (1893–1972)
Kálmán Tihanyi (1897–1947)
Max Knoll (1897–1969)
Erhard Kietz (1909–1982)

Figure 6.40: Other pioneers of television included August Karolus, Kálmán Tihanyi, Max Knoll, and Erhard Kietz.

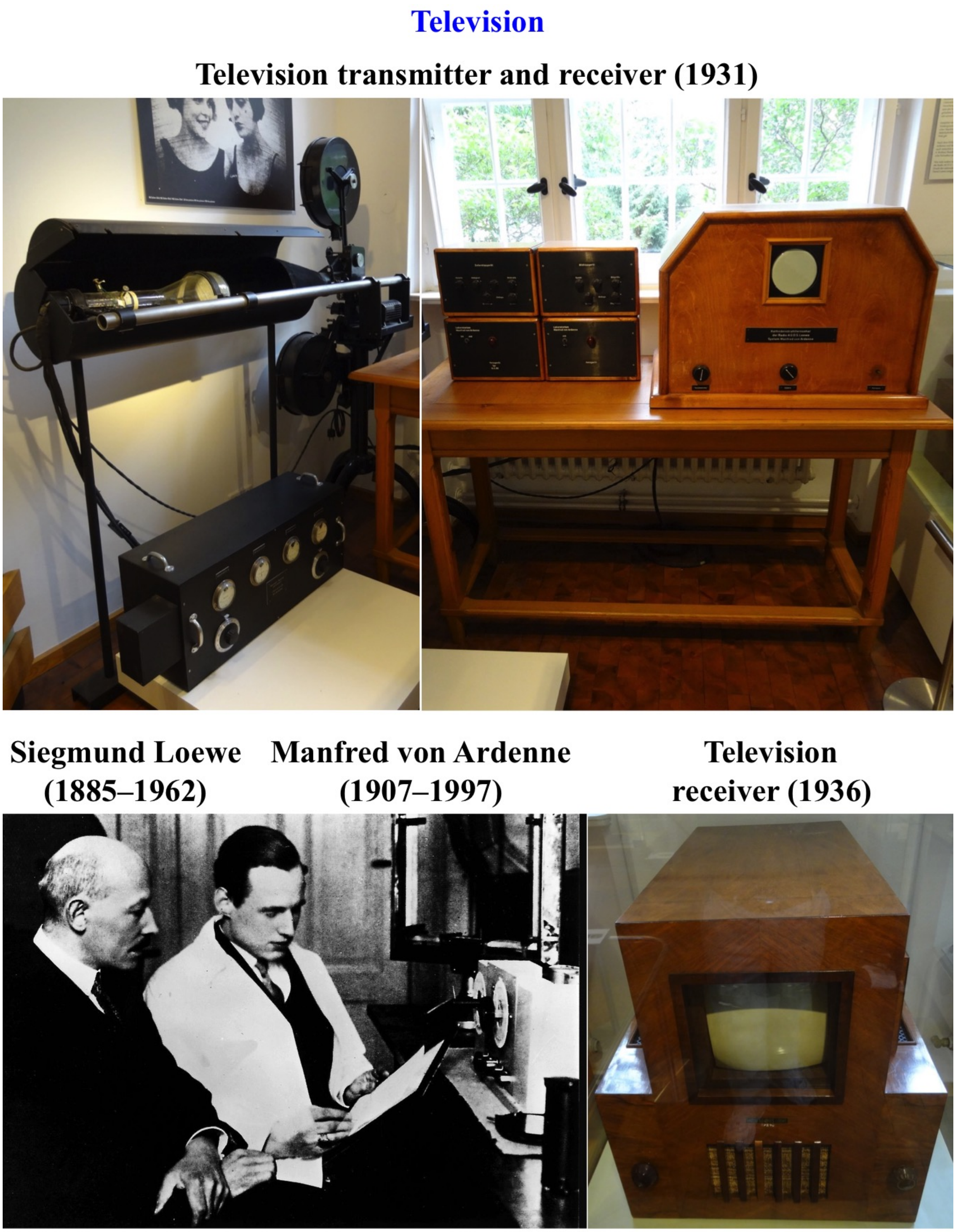

Television
Television transmitter and receiver (1931)
Siegmund Loewe (1885–1962)
Manfred von Ardenne (1907–1997)
Television receiver (1936)

Figure 6.41: Siegmund Loewe and Manfred von Ardenne developed a complete television transmitter and receiver system in 1931 and then an improved and larger television receiver in 1936.

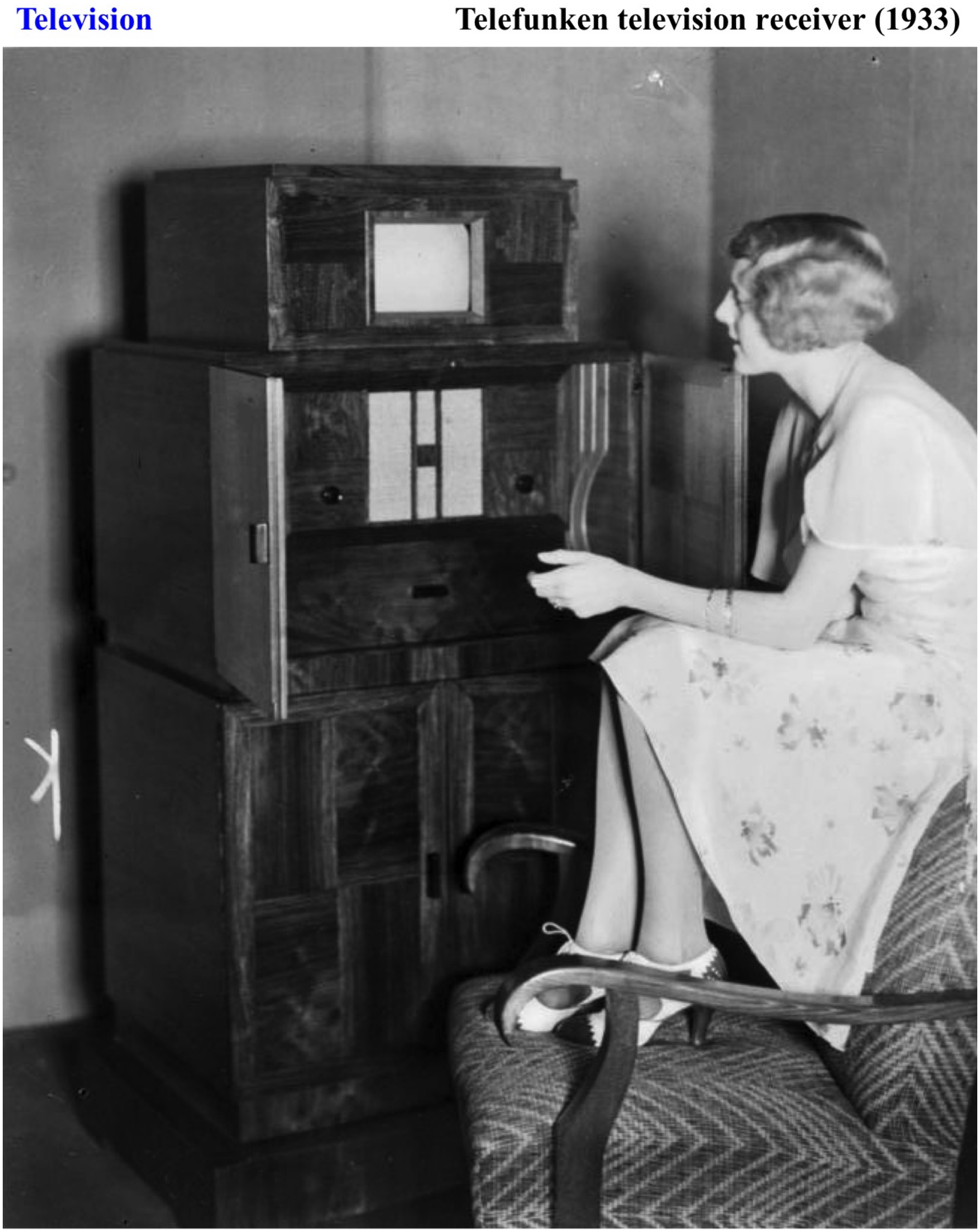
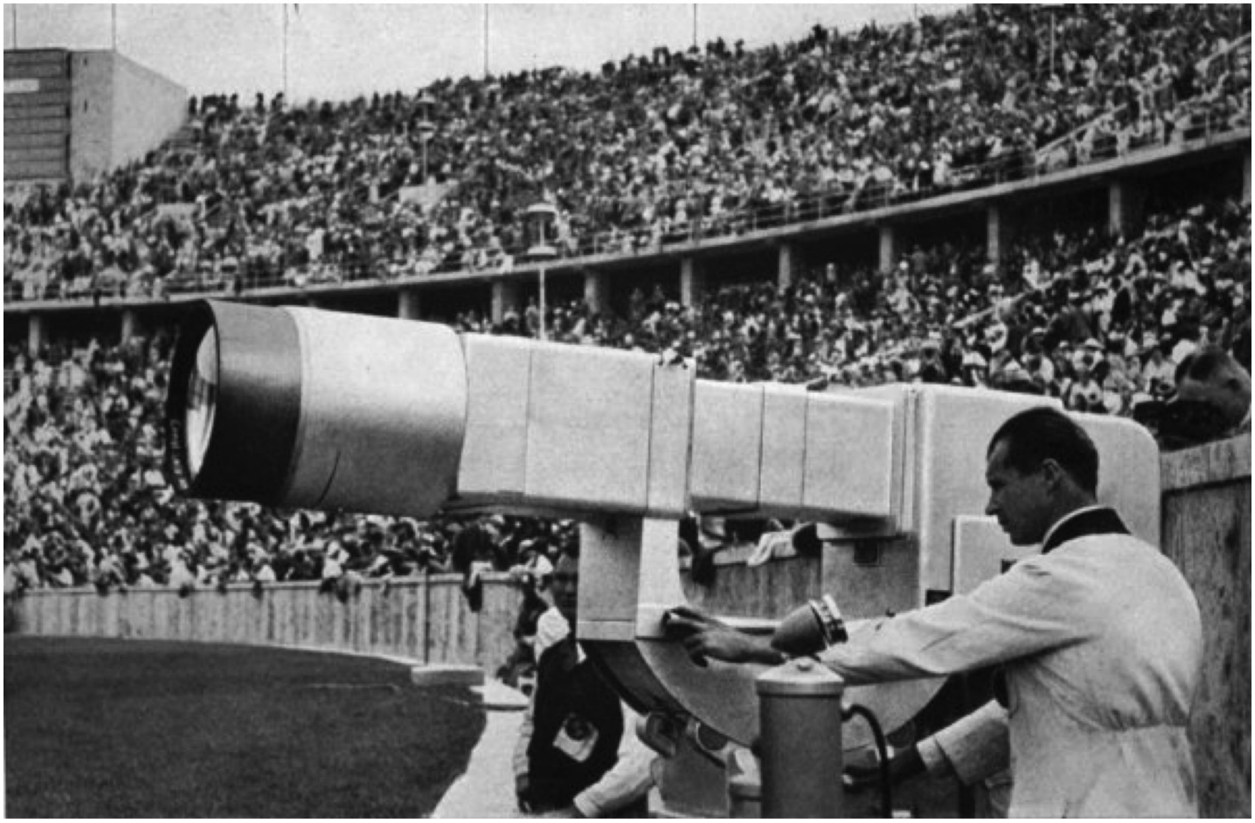

Television
Telefunken television receiver (1933)

Figure 6.42: Telefunken commercial television receiver in 1933.

Television **1936 Berlin Olympics TV camera with long-range zoom**



Emil Mechau (1882–1945) **Walter Heimann (1908–1981)** **Werner Flechsig (1900–1981)**

Figure 6.43: Emil Mechau, Walter Heimann, and Werner Flechsig developed the long-range zoom television cameras that were used to broadcast the 1936 Berlin Olympics.

Television

**Fritz Schröter (1886–1973)
Interlaced TV scanning;
rectangular tubes**

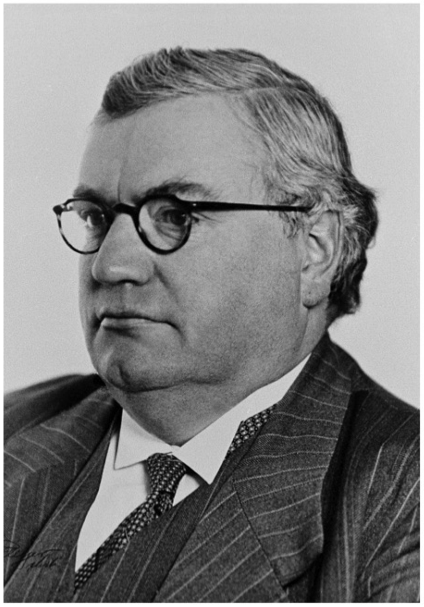
TELEFUNKEN

**Television
receiver
(1937)**

**Fritz Fischer
(1898–1947)
Television
projector**

**Edgar Gretener
(1902–1958)
Television projector;
cryptography**

**Friedrich Gladenbeck
(1899–1987)
High-frequency radio;
television**



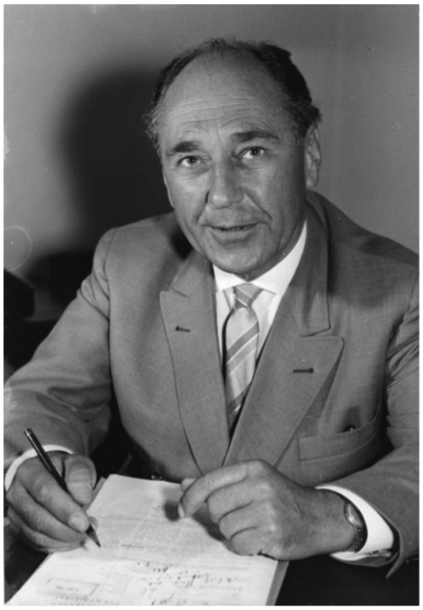
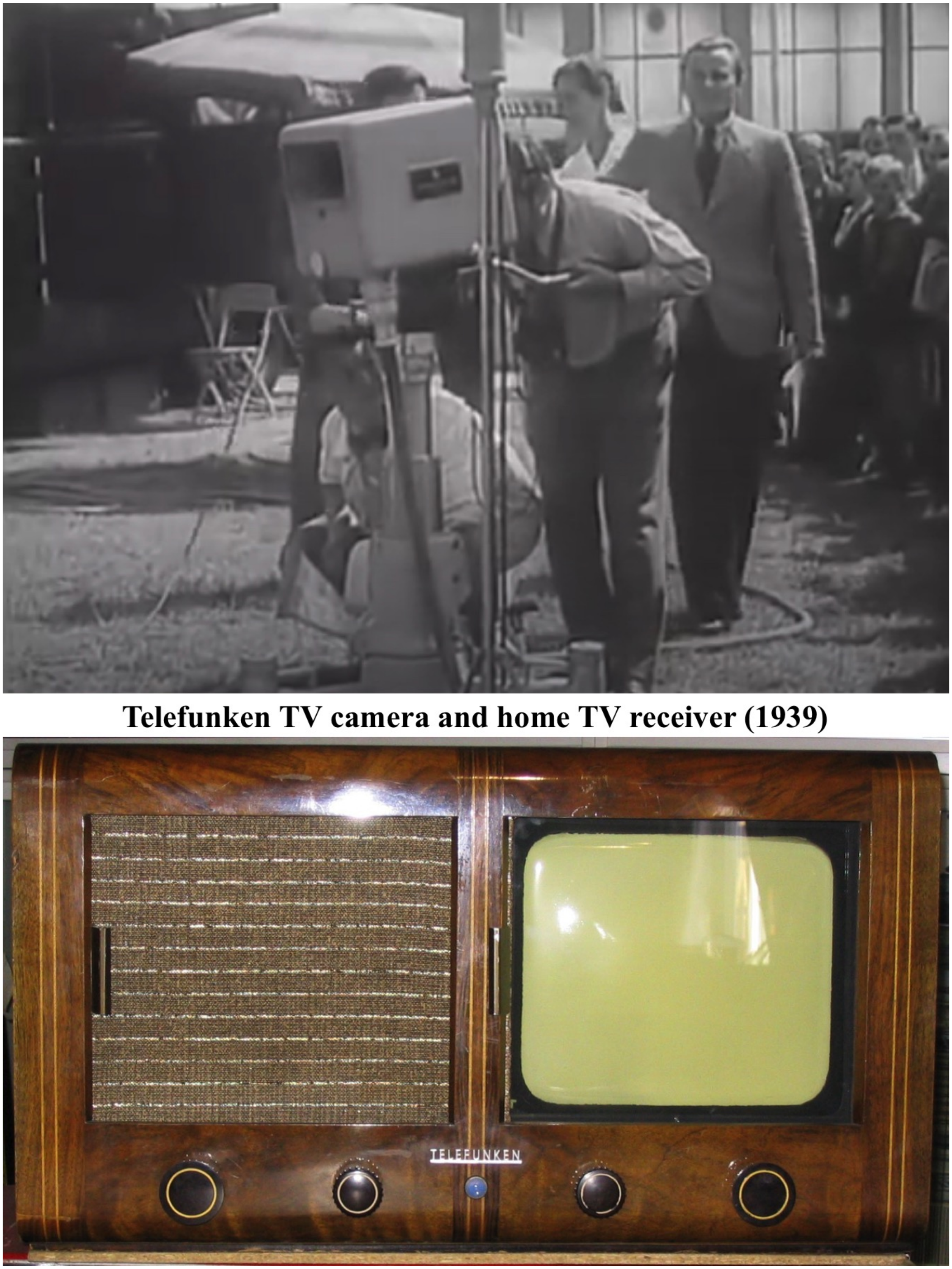


Figure 6.44: Fritz Schröter at Telefunken developed interlaced TV scanning and rectangular picture tubes, such as the 1937 television receiver shown here. Fritz Fischer and Edgar Gretener (also important in cryptography) developed television projectors. Friedrich Gladenbeck (also important in robotics, p. 1209) developed high-frequency radio, remote control, and television systems.



Telefunken TV camera and home TV receiver (1939)

Figure 6.45: Telefunken television camera and Einheitsempfänger E1 home receiver, both from 1939. Late 1930s German television broadcasts featured a wide variety of shows with 441 vertical lines of resolution and 50 interlaced frames per second, comparable in quality to American television of two decades later.

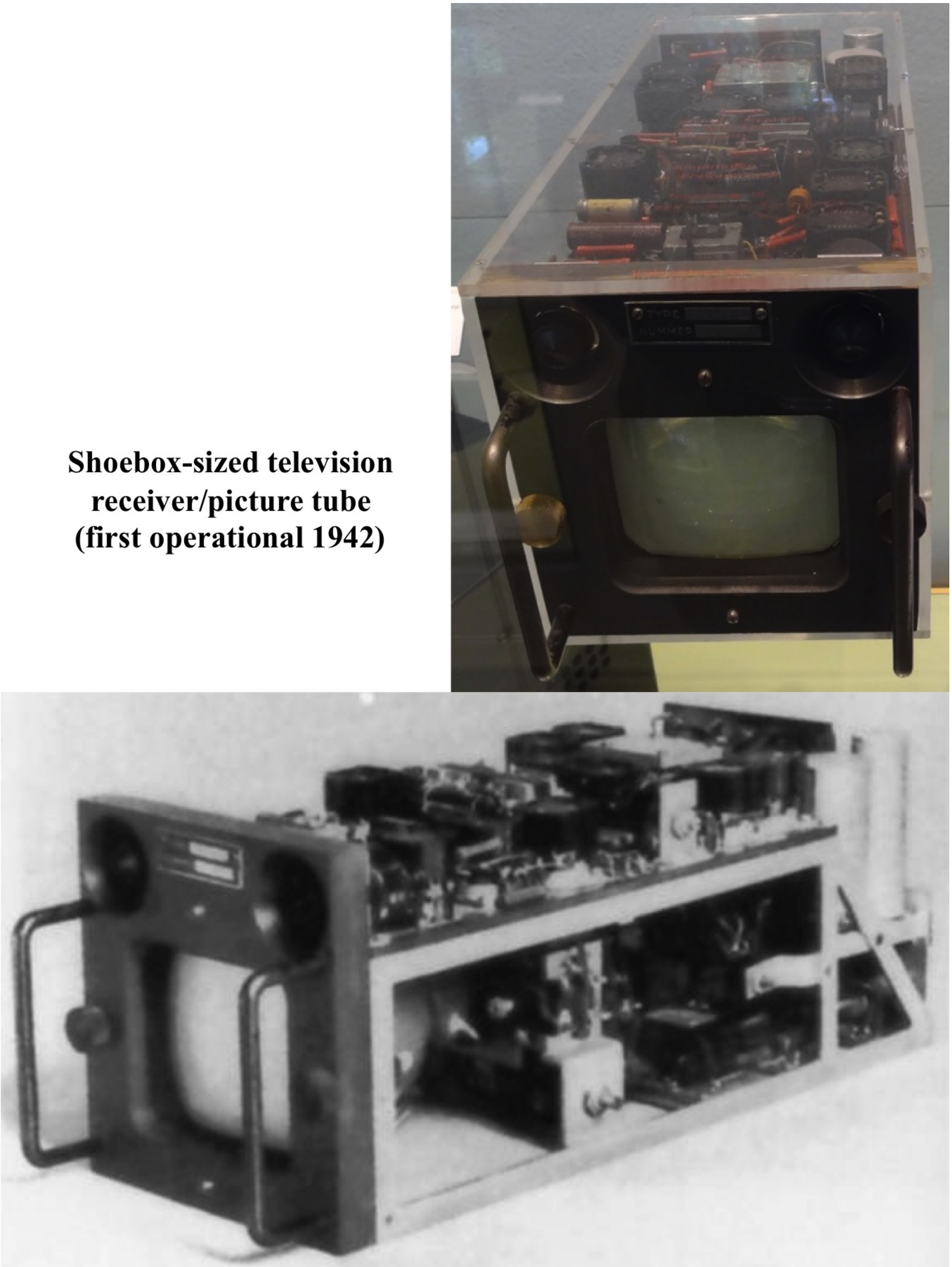

Shoebox-sized television
receiver/picture tube
(first operational 1942)
TYPE
NUMMER

Figure 6.46: German-speaking scientists miniaturized television systems for use in smart bombs and missiles (pp. 1842–1844), as exemplified by this shoebox-sized television receiver/picture tube, which was first operational in 1942. (See also pp. 5412–5417.)

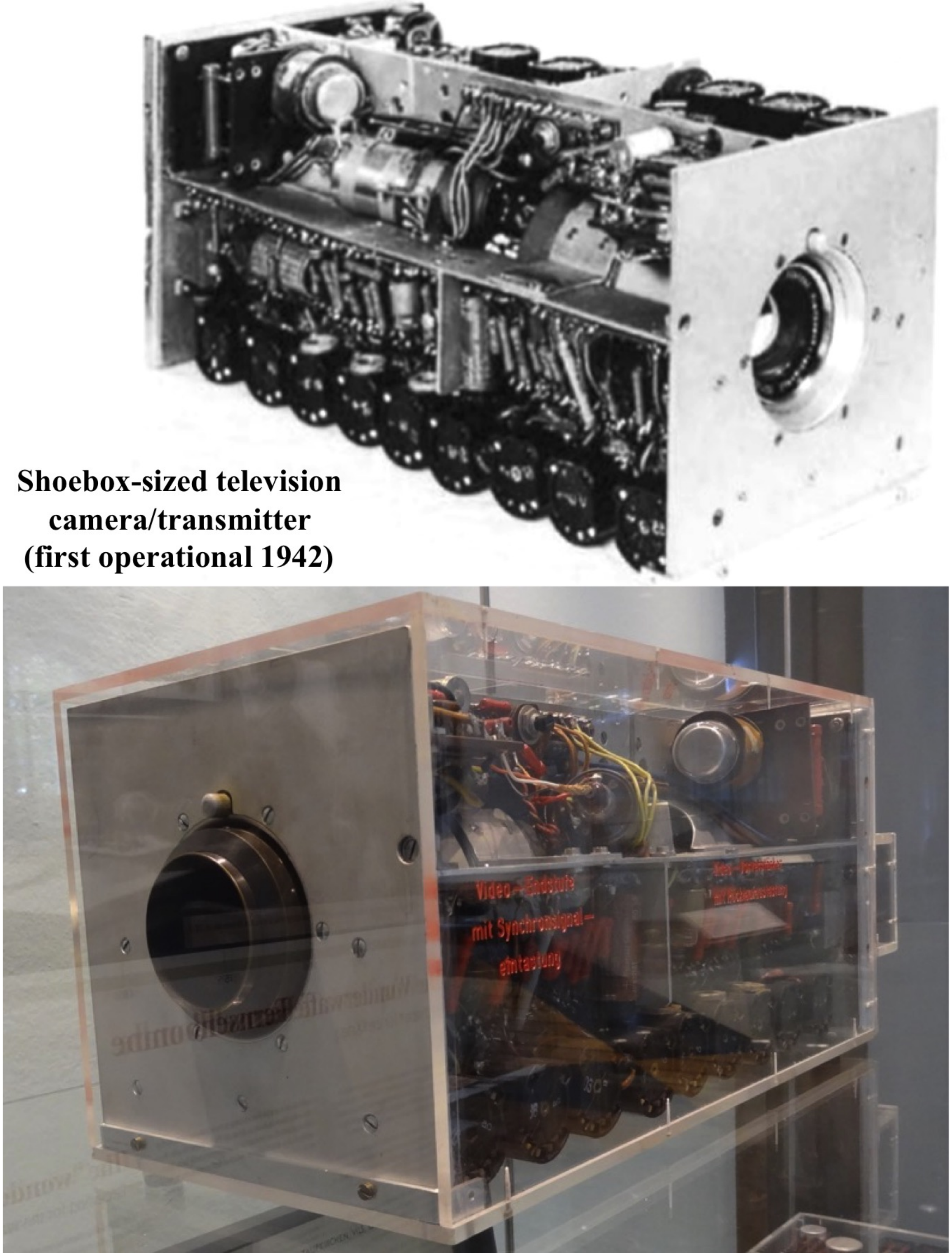
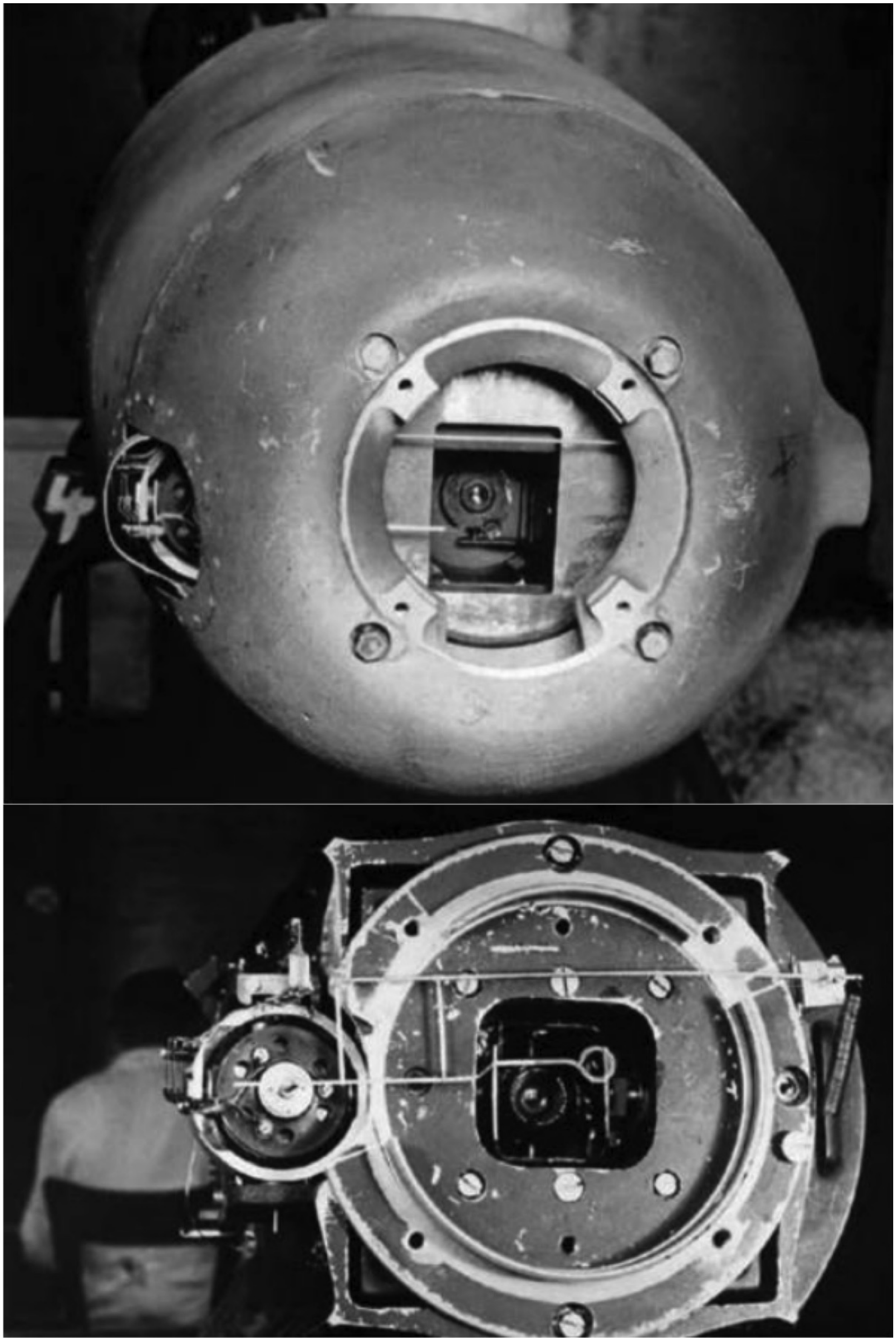

Shoebox-sized television
camera/transmitter
(first operational 1942)
Video – Endstufe
mit Synchronsignal –
eintastung

Figure 6.47: German-speaking scientists miniaturized television systems for use in smart bombs and missiles (pp. 1842–1844), as exemplified by this shoebox-sized Tonne television camera/transmitter, which was first operational in 1942. (See also pp. 5412–5417.)



Television camera/transmitter installed in guided missile (first operational 1942)

Figure 6.48: German-speaking scientists miniaturized television systems for use in smart bombs and missiles (pp. 1842–1844), as exemplified by this shoebox-sized Tonne television camera/transmitter, which was first operational in 1942. (See also pp. 5412–5417.)

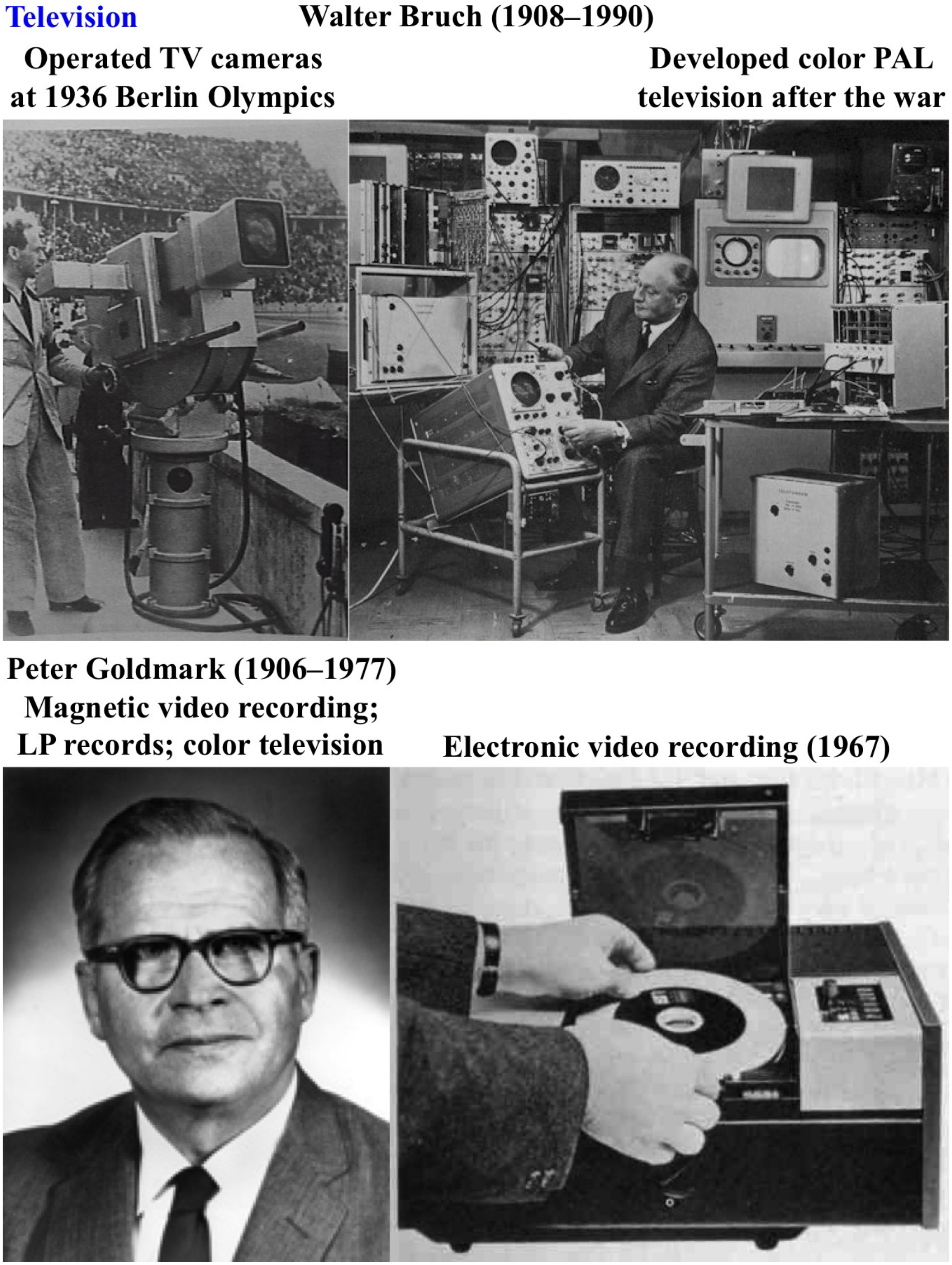
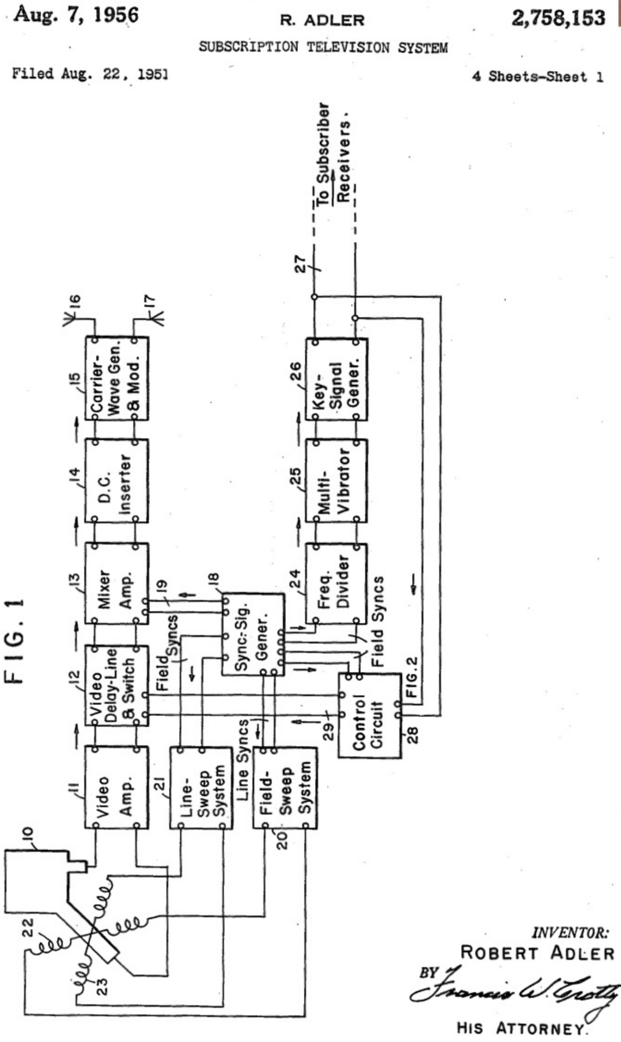

Television
Walter Bruch (1908–1990)
Operated TV cameras at 1936 Berlin Olympics
Developed color PAL television after the war
Peter Goldmark (1906–1977)
Magnetic video recording; LP records; color television
Electronic video recording (1967)

Figure 6.49: Walter Bruch operated TV cameras at the 1936 Berlin Olympics and then developed the color PAL television system after the war. Peter Goldmark developed magnetic video recording (the Electronic Video Recording system, 1967), as well as LP records and a color television system.

Robert Adler (1913–2007)
Many television-related inventions including remote controls and subscription television channels

ZENITH
CHANNEL VOLUME SOUND CHANNEL
LOWER ON-OFF MUTE HIGHER
RED HUE
MUTE
GREEN HUE
ADJUST HUE AFTER PUSHING MUTE
SPACE COMMANDER
Six hundred
COLOR TV



Aug. 7, 1956 R. ADLER 2,758,153
SUBSCRIPTION TELEVISION SYSTEM
Filed Aug. 22, 1951 4 Sheets-Sheet 1

FIG. 1
To Subscriber Receivers
Carrier-Wave Gen. & Mod.
D.C. Inserter
Mixer Amp.
Video Delay-Line & Switch
Video Amp.
Line-Sweep System
Field-Sweep System
Sync.-Sig. Gener.
Key-Signal Gener.
Multi-Vibrator
Freq. Divider
Control Circuit
Field Syncs
Line Syncs
FIG. 2
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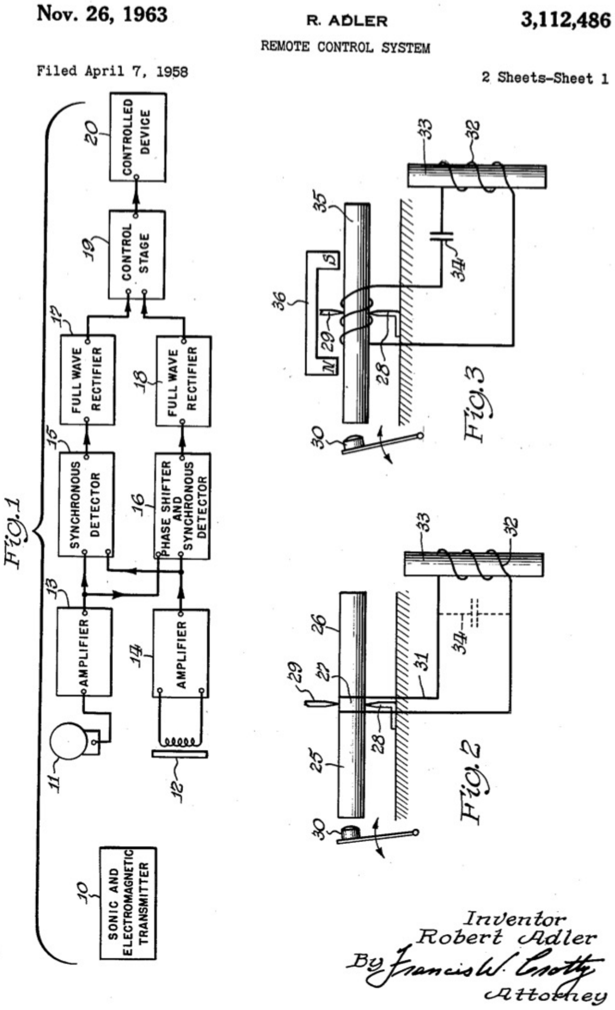
INVENTOR:
ROBERT ADLER
BY Francis W. Crotty
HIS ATTORNEY.



Nov. 26, 1963 R. ADLER 3,112,486
REMOTE CONTROL SYSTEM
Filed April 7, 1958 2 Sheets-Sheet 1

Fig. 1
Fig. 2
Fig. 3
CONTROLLED DEVICE
CONTROL STAGE
FULL WAVE RECTIFIER
FULL WAVE RECTIFIER
SYNCHRONOUS DETECTOR
PHASE SHIFTER AND SYNCHRONOUS DETECTOR
AMPLIFIER
AMPLIFIER
SONIC AND ELECTROMAGNETIC TRANSMITTER
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Inventor
Robert Adler
By Francis W. Crotty
Attorney

Figure 6.50: Robert Adler made many television-related inventions including remote controls and subscription television channels.

6.3.10 Video Telephone System

Georg Oskar Schubert (German, 1900–1955), working with other engineers at Fernseh and the Reichspost, combined the new television technologies with the already advanced German telephone system, and offered the first public video telephone system beginning in 1936 (Fig. 6.51). The system featured two-way video and audio, a broadband coaxial cable network, and service for customers in cities such as Berlin, Hamburg, Leipzig, Munich, Nuremberg, etc.[7]

During the war, this system was greatly expanded (for example, even including service to underground installations in remote parts of the Reich—see p. 4508) but used only for government business.

Although this system ceased operation in 1945, it was many decades ahead of its time, and the direct forerunner of now-common video teleconferencing calls.

Nearly three decades after the introduction of the German public video telephone system, and after a massive postwar transfer of technologies from Germany (Section B.5), AT&T Bell Laboratories announced it had just then "invented" the "first" public video telephone system [*Look*, 11 August 1964, p. 9]. See Fig. 6.52.

6.3.11 Scanners, Facsimile (Fax) Machines, and Printers

High-speed electronic scanners and facsimile or fax machines were developed in the German-speaking world and transferred to other countries after World War II [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards]. See Figs. 6.53–6.54. Many people were involved in their development, but special mention should go to Arthur Korn (German, 1870–1945) for doing some of the earliest work on this topic, and to Rudolf Hell (German, 1901–2002) for creating fully functional scanners, fax machines, and printers. See also FIAT 908, *The Siemens and Halske Teleprinter, T-Typ 68.*

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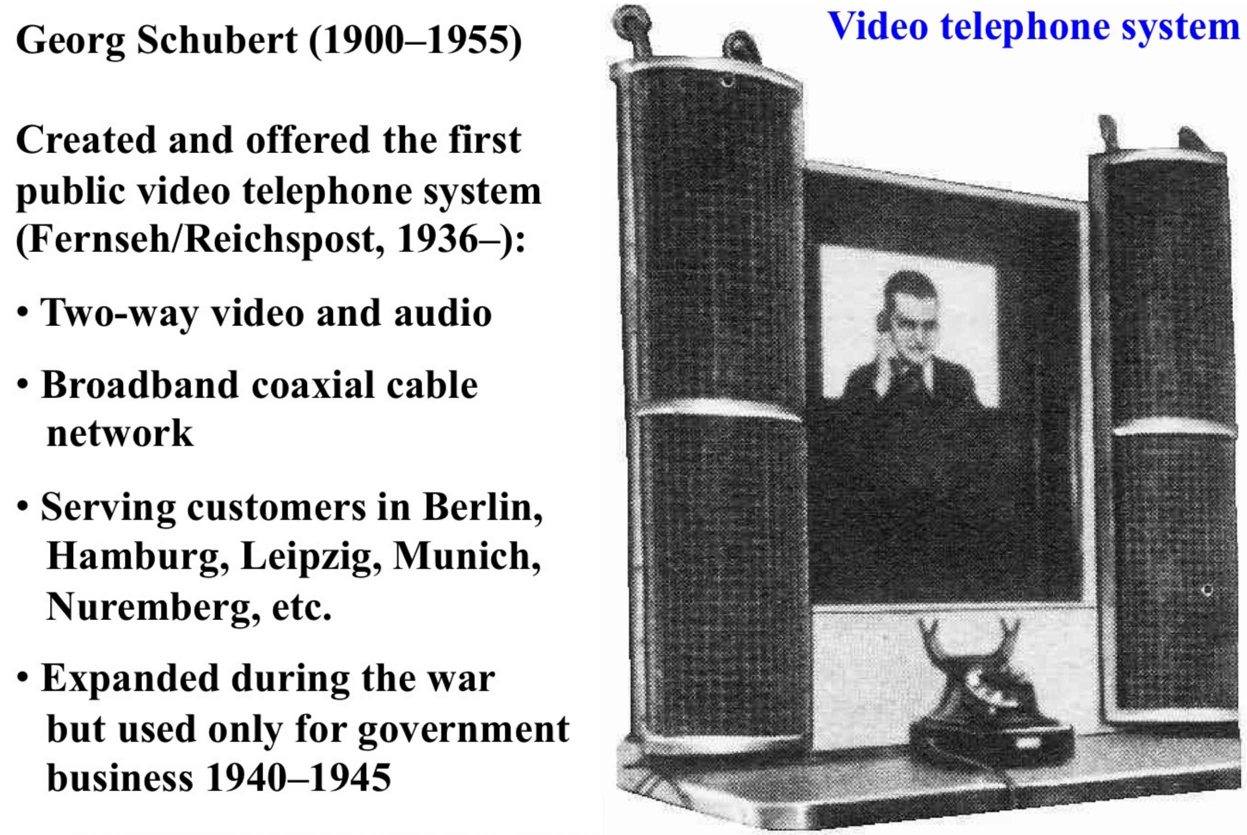
[7] Gehrts 1940; Gerhart Göbel 1953; Hickethier 1998; *Nature* 1936; von Weiher 1983;
https://www.economist.com/babbage/2010/10/12/telepresence-1936-style
https://vsee.com/blog/a-missing-link-in-the-history-of-the-videophone/
https://web.archive.org/web/20120603145806/http://w3.siemens.de/siemens-stadt/schubrt0.htm



Georg Schubert (1900–1955)

Created and offered the first public video telephone system (Fernseh/Reichspost, 1936–):

- **Two-way video and audio**
- **Broadband coaxial cable network**
- **Serving customers in Berlin, Hamburg, Leipzig, Munich, Nuremberg, etc.**
- **Expanded during the war but used only for government business 1940–1945**

Video telephone system

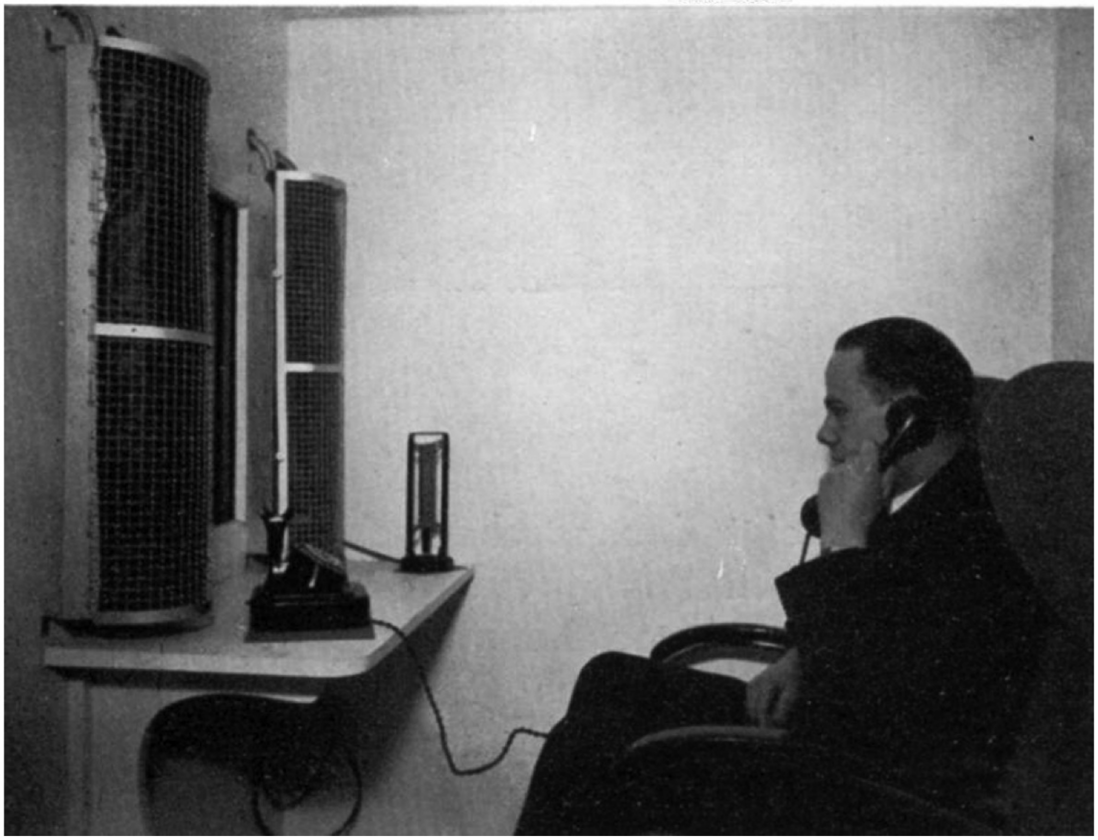
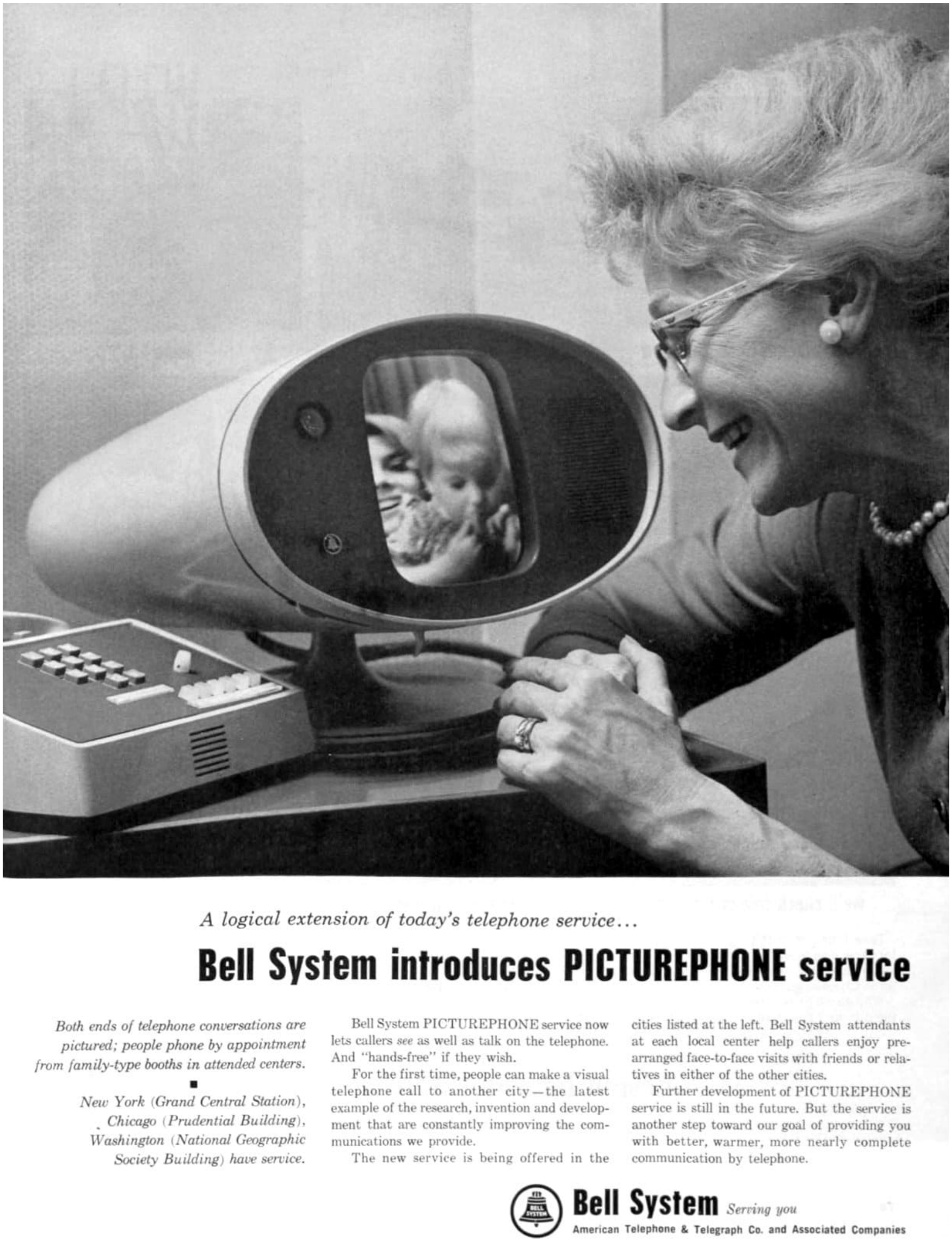


Figure 6.51: Georg Schubert, working with other engineers at Fernseh and the Reichspost, created and offered the first public video telephone system in 1936.



A logical extension of today's telephone service…

Bell System introduces PICTUREPHONE service

Both ends of telephone conversations are pictured; people phone by appointment from family-type booths in attended centers.

■

New York (Grand Central Station), Chicago (Prudential Building), Washington (National Geographic Society Building) have service.

Bell System PICTUREPHONE service now lets callers *see* as well as talk on the telephone. And "hands-free" if they wish.

For the first time, people can make a visual telephone call to another city—the latest example of the research, invention and development that are constantly improving the communications we provide.

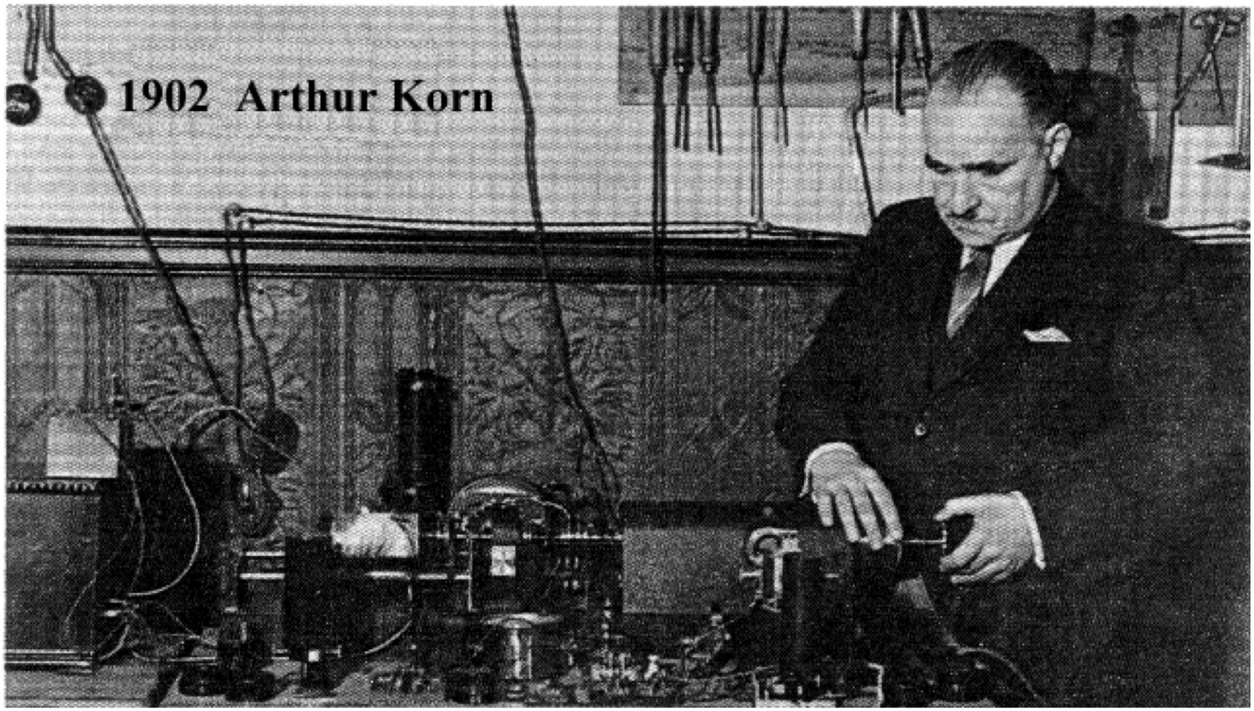
The new service is being offered in the cities listed at the left. Bell System attendants at each local center help callers enjoy prearranged face-to-face visits with friends or relatives in either of the other cities.

Further development of PICTUREPHONE service is still in the future. But the service is another step toward our goal of providing you with better, warmer, more nearly complete communication by telephone.

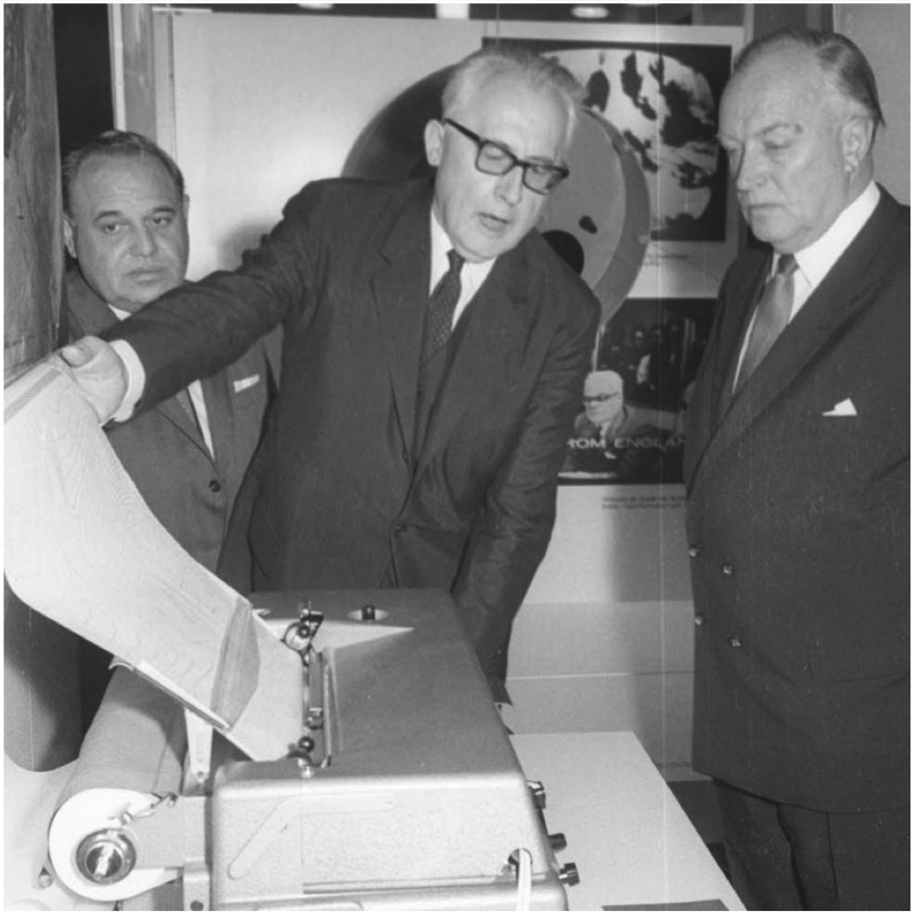
Bell System *Serving you*

American Telephone & Telegraph Co. and Associated Companies

Figure 6.52: Nearly three decades later, and after a massive postwar transfer of technologies from Germany (Section B.5), AT&T Bell Laboratories announced it had just then "invented" the "first" public video telephone system [*Look*, 11 August 1964, p. 9].



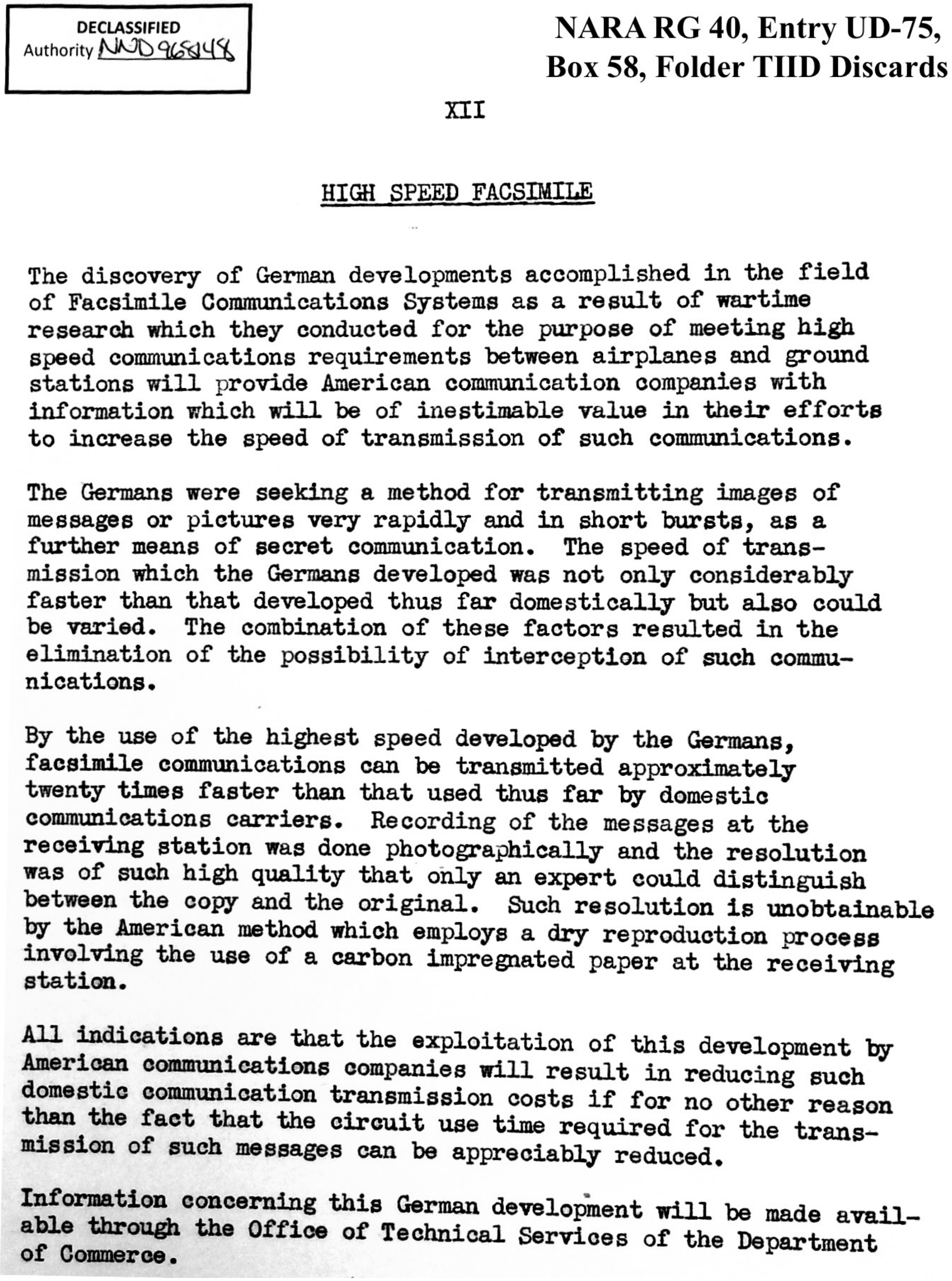
Arthur Korn (1870–1945) worked on early scanners and fax machines



Rudolf Hell (in center, 1901–2002)

Scanners, fax machines, and printers

Figure 6.53: High-speed electronic scanners and facsimile or fax machines were developed in the German-speaking world by a series of creators including Arthur Korn and Rudolf Hell (who also developed printers).



DECLASSIFIED
Authority NND 968148

NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards

XII

HIGH SPEED FACSIMILE

The discovery of German developments accomplished in the field of Facsimile Communications Systems as a result of wartime research which they conducted for the purpose of meeting high speed communications requirements between airplanes and ground stations will provide American communication companies with information which will be of inestimable value in their efforts to increase the speed of transmission of such communications.

The Germans were seeking a method for transmitting images of messages or pictures very rapidly and in short bursts, as a further means of secret communication. The speed of transmission which the Germans developed was not only considerably faster than that developed thus far domestically but also could be varied. The combination of these factors resulted in the elimination of the possibility of interception of such communications.

By the use of the highest speed developed by the Germans, facsimile communications can be transmitted approximately twenty times faster than that used thus far by domestic communications carriers. Recording of the messages at the receiving station was done photographically and the resolution was of such high quality that only an expert could distinguish between the copy and the original. Such resolution is unobtainable by the American method which employs a dry reproduction process involving the use of a carbon impregnated paper at the receiving station.

All indications are that the exploitation of this development by American communications companies will result in reducing such domestic communication transmission costs if for no other reason than the fact that the circuit use time required for the transmission of such messages can be appreciably reduced.

Information concerning this German development will be made available through the Office of Technical Services of the Department of Commerce.

Figure 6.54: High-speed electronic scanners and facsimile or fax machines were developed in the German-speaking world and transferred to other countries after World War II [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

6.3.12 Photocopiers

Photocopier technology was developed in the German-speaking world and then transferred to other countries during and after the Third Reich. Early forms of the technology used chemically coated, light-sensitive paper. There is some evidence that the modern form of photocopiers, using powdered ink electrostatically attracted to uncoated paper, may have also been developed in wartime Germany, although much more archival research is needed on this topic.

Allied investigators wrote many reports on German photocopier technology after the war. For example, BIOS 1255, *Research in the German Printing Industry*, p. 17, stated:

> The Suitability of Mercury Vapour Lamps for Exposing
> Pigment Paper for Photogravure: by J. Albrecht and O. Watter.
>
> Comparisons were made on the copying effect of carbon arcs, high-pressure mercury vapour lamps and fluorescent lamps.
>
> At even-distance carbon arcs are superior in using the least energy for equal copying effect but in practice the conditions are varied by the fact that the carbon arc does have a point source combined with high heat-output whereas fluorescent tubes distribute the light emission over a fairly large area with consequent lower heat generation per unit area and permit exposure at much closer distances at the time, giving better light-distribution.
>
> High-pressure mercury vapour lamps are not quite as suited as fluorescent tubes.
>
> Description of a practical arrangement of fluorescent tubes for exposing pigment papers is given.

Among other examples of Allied reports on German photocopier technology, see:

> BIOS 435. *Ozalid Light-Sensitive Materials, Kalle & Co., Wiesbaden—Biebrich (I.G. Farbenindustrie A.G.).* [Ozalid chemical-coated paper for dry photocopying]
>
> BIOS 1475. *Engineers' Sensitised Material and Allied Products.* [Light-sensitive papers for photocopying]
>
> FIAT 528. *German Patents and Patent Applications Concerning Light Sensitive Reproduction Materials and Summary of Patents Issued 1917 Through 1939.* With 62 supplements.
>
> FIAT 813. *Photo-Reproduction Research of Kalle & Co., A.G. Index of Microfilmed Reports.*

As an example that electrostatic rollers for carbon powder were known and used for various applications in wartime Germany, see BIOS 1035, *Metallgesellschaft A.G. and Lurgi Bau, Frankfurt am Main. Electrostatic Separation of Coal and Other Minerals.*

6.3.13 Optical Discs and Digital File Formats

In 1935, Edwin Welte (German, 1876–1958) created a system for recording and playing back music from optical discs, as shown in Fig. 6.55. He patented and produced the system, and continued to improve it through World War II. Much of Welte's work was destroyed in Allied bombing near the end of the war, yet his innovations appear to have exerted direct or indirect influence on postwar work.

The development of lasers (which also originated in the German-speaking world—see Sections 6.4 and C.3) made it much more practical to record and read data on high-density optical discs. The most important postwar laboratory for developing laser optical discs was the Philips Eindhoven research center, which had been closely tied to the rest of the predominantly German-speaking research world from the late nineteenth century through World War II, including work on electronics, communications, and directed energy beams.[8] Various types of laser optical discs (LaserDiscs, compact discs or CDs, digital video discs or DVDs, etc.) were produced from 1969 onward at Philips Eindhoven by Gijs Bouwhuis (Dutch, 19??–), Piet Kramer (Dutch, 19??–), Klaas Compaan (Dutch, 19??–), Kees Schouhamer Immink (Dutch, 1946–), Lou Ottens (Dutch, 1926–), and Joop Sinjou (Dutch, 19??–). See Fig. 6.56. Laser optical disc technology was rapidly adopted by Japan, the United States, and other countries.

Beginning in 1970, Dieter Seitzer (German, 1933–) at the University of Erlangen pioneered methods to compress digital files without a noticeable loss of signal detail. Based on those methods, the now-ubiquitous MP3 digital audio file format was developed and perfected at the Fraunhofer Society by Seitzer's students and associates, including Karlheinz Brandenburg (German, 1954–), Ernst Eberlein (German, 19??–), Heinz Gerhäuser (German, 1946–), Bernhard Grill (German, 1961–), Jürgen Herre (German, 19??–), and Harald Popp (German, 1956–). See Fig. 6.57.

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[8] See for example: CIOS III-1; CIOS VI-26, 27; CIOS X-13; CIOS XI-10; CIOS XII-22.

**Edwin Welte (1876–1958)
created a system for
recording and
playing back
music from
optical discs (1935)**

№ 712570
KLASSE 51f GRUPPE 1 03
W 97327 IX a/51 f

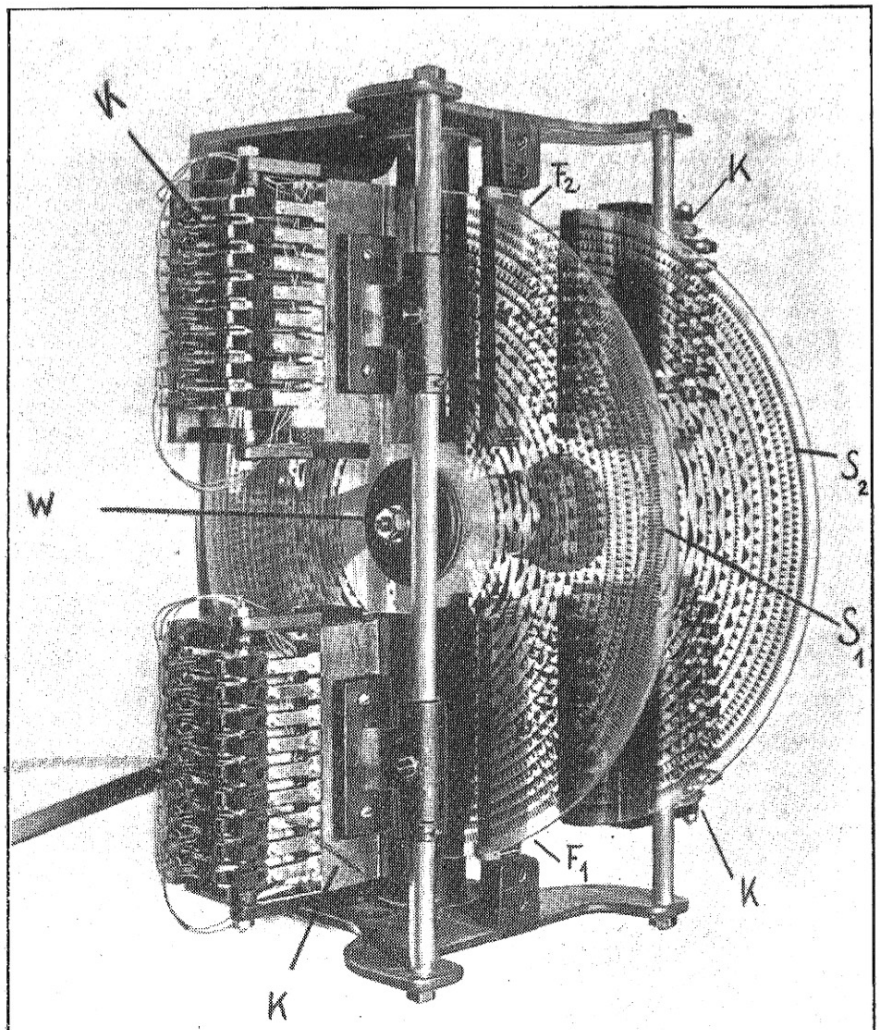
Edwin Welte in Leipzig
Verfahren zum Herstellen von gemischte Stimmen darstellenden Phonogrammen
auf Tonscheiben für Lichttonorgeln

Patentiert im Deutschen Reich vom 16. Oktober 1935 an

The main parts of the W.L.O. are electro-optic

TONE-UNITS

with two discs of plate-glass, carrying the sound tracks. They are in detail of construction alike and differ only in regard to the rotating speed of the discs.



W Tone-discs of glass

K Elektro-optic relays

F Photocells

S Oscillograms of the single tones

Figure 6.55: In 1935, Edwin Welte created a system for recording and playing back music from optical discs.

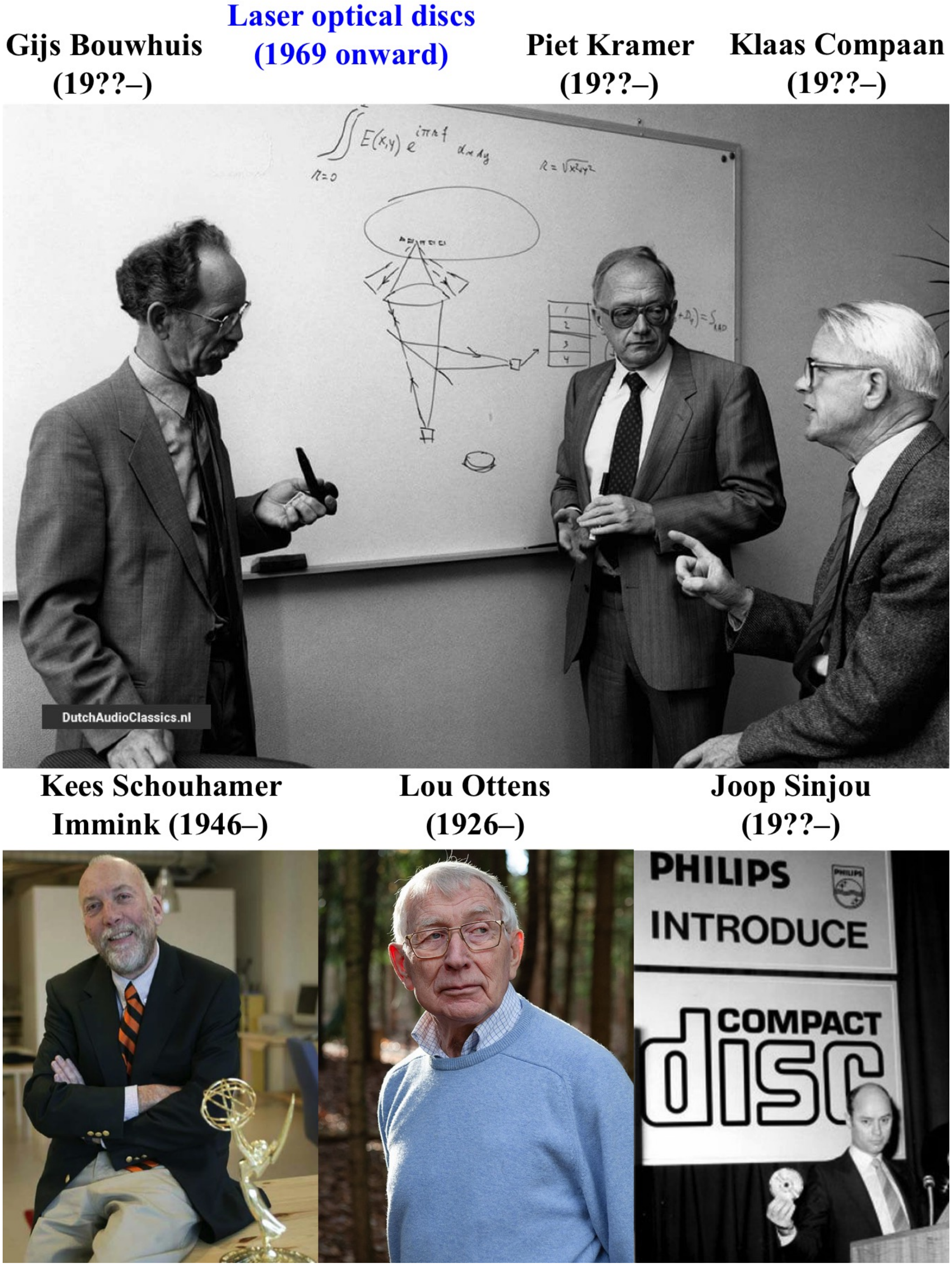
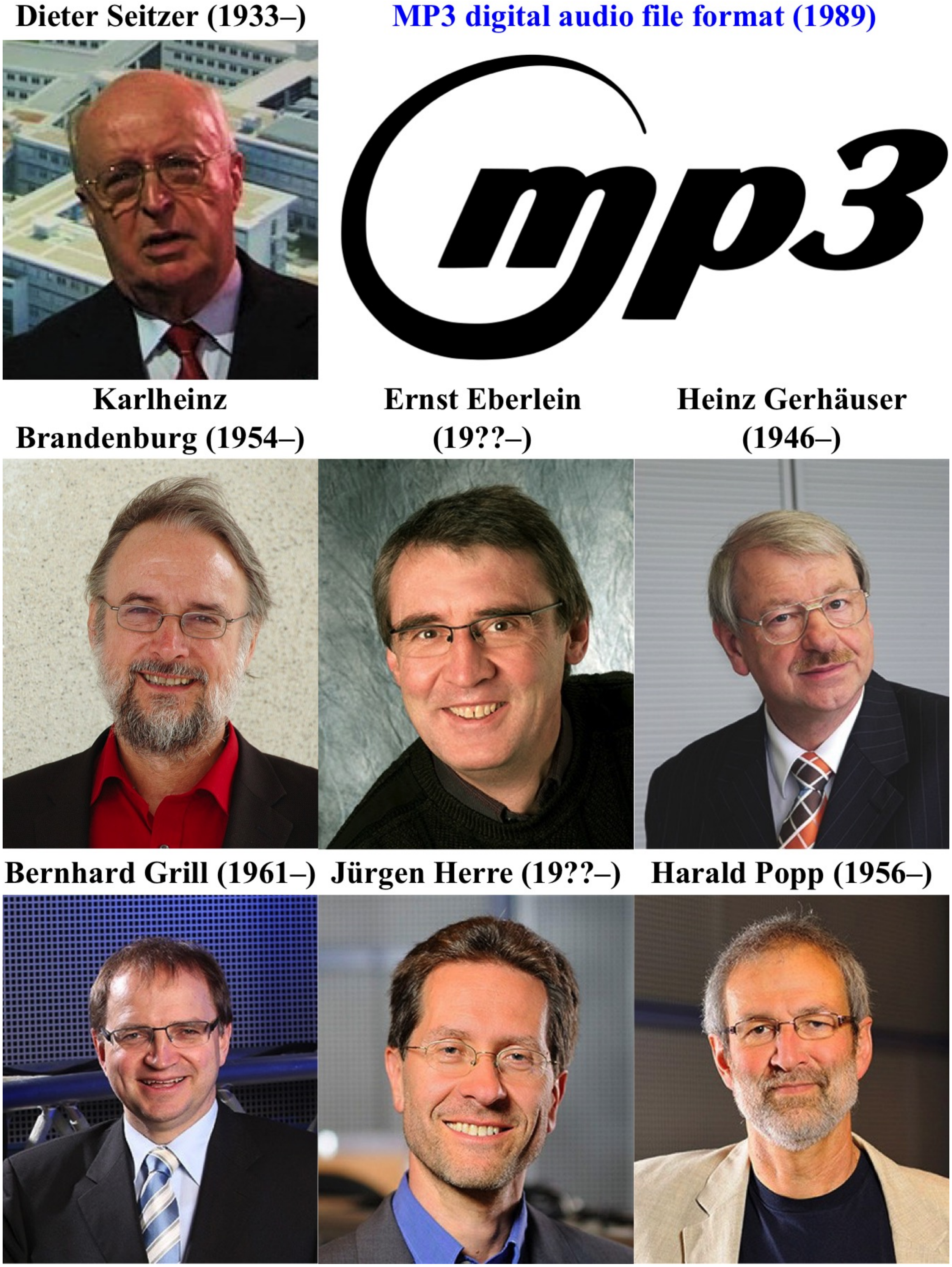

Gijs Bouwhuis (19??–)
Laser optical discs (1969 onward)
Piet Kramer (19??–)
Klaas Compaan (19??–)
DutchAudioClassics.nl
Kees Schouhamer Immink (1946–)
Lou Ottens (1926–)
Joop Sinjou (19??–)
PHILIPS
INTRODUCE
COMPACT disc

Figure 6.56: Laser optical discs (LaserDiscs, compact discs, digital video discs, etc.) were produced from 1969 onward by Gijs Bouwhuis, Piet Kramer, Klaas Compaan, Kees Schouhamer Immink, Lou Ottens, and Joop Sinjou.



Dieter Seitzer (1933–)

MP3 digital audio file format (1989)

Karlheinz Brandenburg (1954–)

Ernst Eberlein (19??–)

Heinz Gerhäuser (1946–)

Bernhard Grill (1961–)

Jürgen Herre (19??–)

Harald Popp (1956–)

Figure 6.57: The MP3 digital audio file format was developed by Dieter Seitzer, Karlheinz Brandenburg, Ernst Eberlein, Heinz Gerhäuser, Bernhard Grill, Jürgen Herre, and Harald Popp.

6.4 Lasers, Holography, and Laser Spectroscopy

Creators from the greater German-speaking world played key roles in the development of lasers (Section 6.4.1), holography (Section 6.4.2), and laser spectroscopy (Section 6.4.3).

6.4.1 Lasers

A laser (Light Amplification by Stimulated Emission of Radiation) produces light that all has the same wavelength and the same phase, which enables all of the optical power to be concentrated into just one wavelength or color instead of a broader spectrum, and also allows the beam to remain much more tightly focused than a normal beam of light can. (Because the laser light all has the same wavelength and phase unlike a normal light beam, constructive interference with itself keeps it on course, and destructive interference with itself prevents it from veering off course.) According to official histories, the idea of a laser was not proposed until the late 1950s by Charles Townes, Arthur Schawlow, and Gordon Gould, and the first laser was not built until 1960 by Theodore Maiman, all in the United States.[9]

In fact, most of the discoveries and innovations that led to lasers were made decades earlier by German-speaking scientists. Their discoveries prompted the far more publicly visible U.S. work in this field in the late 1950s and early 1960s.

As shown on pp. 1025 and 3102–3104, Albert Einstein (German, 1879–1955) first proposed the idea of stimulated light emission from atoms (amplification of the number of photons of light from atoms) in 1916.

During the period 1919–1926, Christian Füchtbauer (German, 1877–1959), James Franck (German, 1882–1964), Max Born (German, 1882–1970), Walther Bothe (German, 1891–1957), and Hendrik Kramers (Dutch, 1894–1952) separately wrote several journal articles further developing the theory of stimulated light emission from atoms. See pp. 1026 and 3105–3115.

Putting those theories into experimental practice, Rudolf Ladenburg (1882–1952), Hans Kopfermann (1895–1963), and other members of the Ladenburg group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie investigated and demonstrated stimulated photon emission from atoms of electrically excited gases during the period 1921–1931. See pp. 1027 and 3115–3127. Because Ladenburg was Jewish and faced rising antisemitism in Germany, he had to discontinue his experiments there and move to the United States. Unfortunately, the U.S. research system at the time had little interest in his work on stimulated photon emission, so his revolutionary progress toward lasers ended.

In 1934, Franz Weidert and Hans Löffler invented neodymium-doped glass with unusual spectral properties that made it suitable for a variety of optical applications, eventually including neodymium glass lasers. See pp. 3128–3132.

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[9] See for example: Bertolotti 2015; Bromberg 1991; Hecht 2010; Taylor 2000; Townes 1999.

Ladenburg's research was carried further by Wilhelm von Meyeren (German, 1905–1983). In a 20 February 1945 report to Walther Gerlach, von Meyeren described his 1944 experiments with laser-like monochromatic stimulated light emission from electron population inversions in argon, cesium, or rubidium gases (pp. 1028 and 3137–3156). Von Meyeren appeared to be on the verge of creating an argon laser or other gas laser (or perhaps he succeeded, if he conducted further experiments not mentioned in this one surviving document). However, after the war ended in 1945, von Meyeren's Prague laboratory was ransacked, and von Meyeren was imprisoned for a while and eventually sent empty-handed to West Germany. His hardware and files may well have contributed to the later development of lasers in the Soviet Union.

There is also evidence that there was other major work on lasers in the German-speaking world during the war, and possibly even demonstrations of fully functional prototype lasers (pp. 3157–3179).

For more information on this early developmental work toward lasers, see Section C.3. Much more archival research is needed to investigate the complete history, full accomplishments, and ultimate influence of work in this field by German-speaking scientists.[10]

Semiconductor lasers or laser diodes were also created by German-speaking scientists. Laser diodes were designed and developed by John von Neumann (Hungarian, 1903–1957), Walter Heywang (German, 1923–2010), and Herbert Kroemer (German, 1928–). See pp. 1109–1111 and Section B.4.

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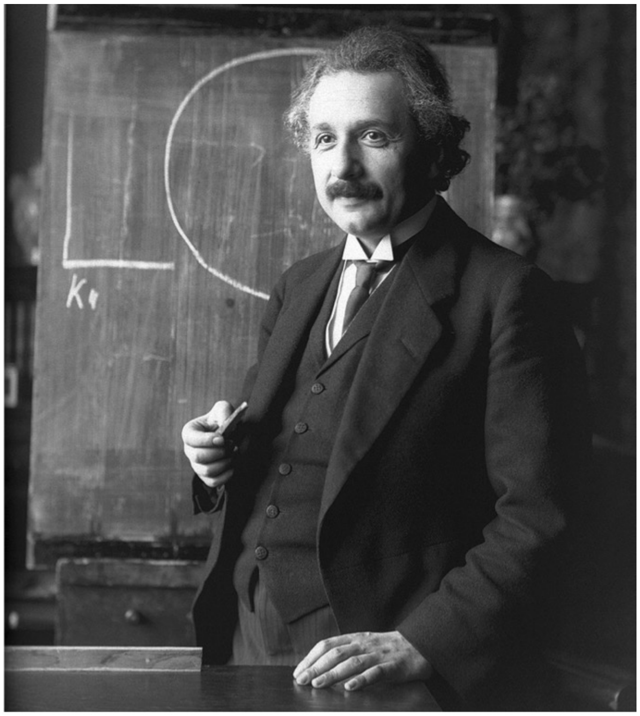
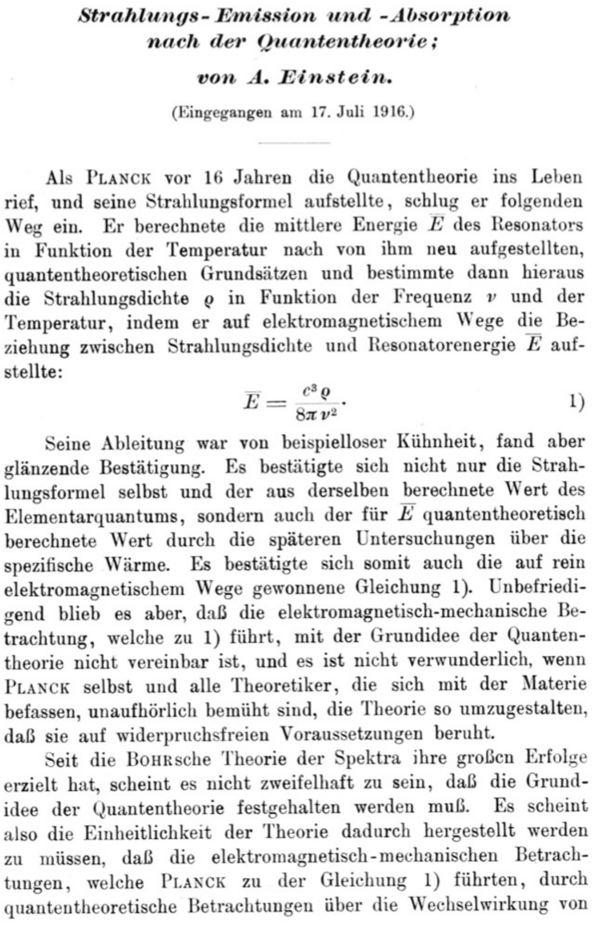
[10] Albrecht 2019; Bertolotti 2015; Lemmerich 1987.

Lasers (Light Amplification by Stimulated Emission of Radiation)

Albert Einstein (1879–1955)

Theory predicting stimulated emission of photons (1916)





Strahlungs-Emission und -Absorption nach der Quantentheorie;

von A. Einstein.

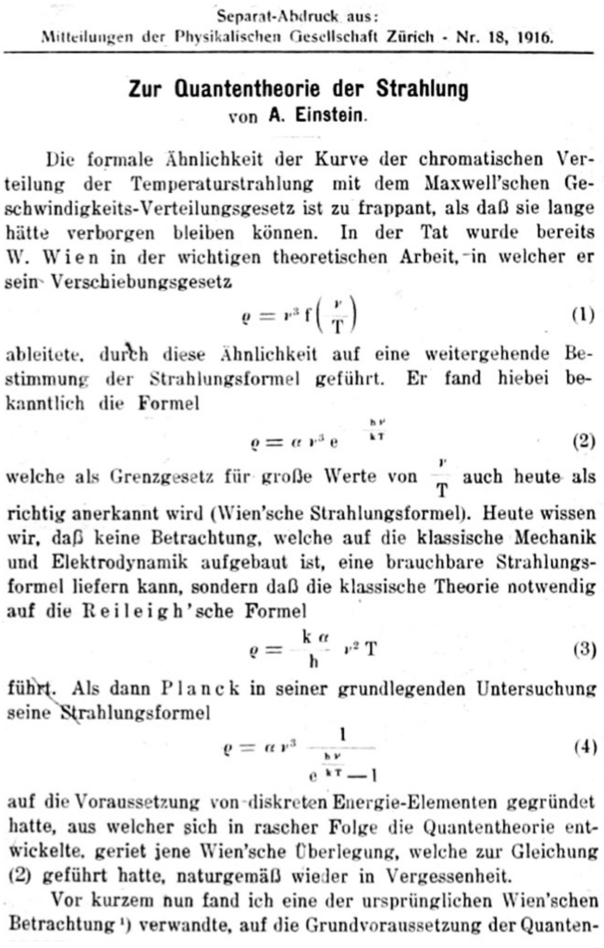
(Eingegangen am 17. Juli 1916.)

Als Planck vor 16 Jahren die Quantentheorie ins Leben rief, und seine Strahlungsformel aufstellte, schlug er folgenden Weg ein. Er berechnete die mittlere Energie $\overline{E}$ des Resonators in Funktion der Temperatur nach von ihm neu aufgestellten, quantentheoretischen Grundsätzen und bestimmte dann hieraus die Strahlungsdichte ϱ in Funktion der Frequenz ν und der Temperatur, indem er auf elektromagnetischem Wege die Beziehung zwischen Strahlungsdichte und Resonatorenergie $\overline{E}$ aufstellte:

$$\overline{E} = \frac{c^3 \varrho}{8\pi \nu^2}. \qquad 1)$$

Seine Ableitung war von beispielloser Kühnheit, fand aber glänzende Bestätigung. Es bestätigte sich nicht nur die Strahlungsformel selbst und der aus derselben berechnete Wert des Elementarquantums, sondern auch der für $\overline{E}$ quantentheoretisch berechnete Wert durch die späteren Untersuchungen über die spezifische Wärme. Es bestätigte sich somit auch die auf rein elektromagnetischem Wege gewonnene Gleichung 1). Unbefriedigend blieb es aber, daß die elektromagnetisch-mechanische Betrachtung, welche zu 1) führt, mit der Grundidee der Quantentheorie nicht vereinbar ist, und es ist nicht verwunderlich, wenn Planck selbst und alle Theoretiker, die sich mit der Materie befassen, unaufhörlich bemüht sind, die Theorie so umzugestalten, daß sie auf widerpruchsfreien Voraussetzungen beruht.

Seit die Bohrsche Theorie der Spektra ihre großen Erfolge erzielt hat, scheint es nicht zweifelhaft zu sein, daß die Grundidee der Quantentheorie festgehalten werden muß. Es scheint also die Einheitlichkeit der Theorie dadurch hergestellt werden zu müssen, daß die elektromagnetisch-mechanischen Betrachtungen, welche Planck zu der Gleichung 1) führten, durch quantentheoretische Betrachtungen über die Wechselwirkung von



Separat-Abdruck aus:
Mitteilungen der Physikalischen Gesellschaft Zürich - Nr. 18, 1916.

Zur Quantentheorie der Strahlung

von **A. Einstein.**

Die formale Ähnlichkeit der Kurve der chromatischen Verteilung der Temperaturstrahlung mit dem Maxwell'schen Geschwindigkeits-Verteilungsgesetz ist zu frappant, als daß sie lange hätte verborgen bleiben können. In der Tat wurde bereits W. Wien in der wichtigen theoretischen Arbeit, in welcher er sein Verschiebungsgesetz

$$\varrho = \nu^3 \, f\left(\frac{\nu}{T}\right) \qquad (1)$$

ableitete, durch diese Ähnlichkeit auf eine weitergehende Bestimmung der Strahlungsformel geführt. Er fand hiebei bekanntlich die Formel

$$\varrho = \alpha \nu^3 e^{-\frac{h\nu}{kT}} \qquad (2)$$

welche als Grenzgesetz für große Werte von $\frac{\nu}{T}$ auch heute als richtig anerkannt wird (Wien'sche Strahlungsformel). Heute wissen wir, daß keine Betrachtung, welche auf die klassische Mechanik und Elektrodynamik aufgebaut ist, eine brauchbare Strahlungsformel liefern kann, sondern daß die klassische Theorie notwendig auf die Reileigh'sche Formel

$$\varrho = \frac{k\alpha}{h} \nu^2 T \qquad (3)$$

führt. Als dann Planck in seiner grundlegenden Untersuchung seine Strahlungsformel

$$\varrho = \alpha \nu^3 \frac{1}{e^{\frac{h\nu}{kT}} - 1} \qquad (4)$$

auf die Voraussetzung von diskreten Energie-Elementen gegründet hatte, aus welcher sich in rascher Folge die Quantentheorie entwickelte, geriet jene Wien'sche Überlegung, welche zur Gleichung (2) geführt hatte, naturgemäß wieder in Vergessenheit.

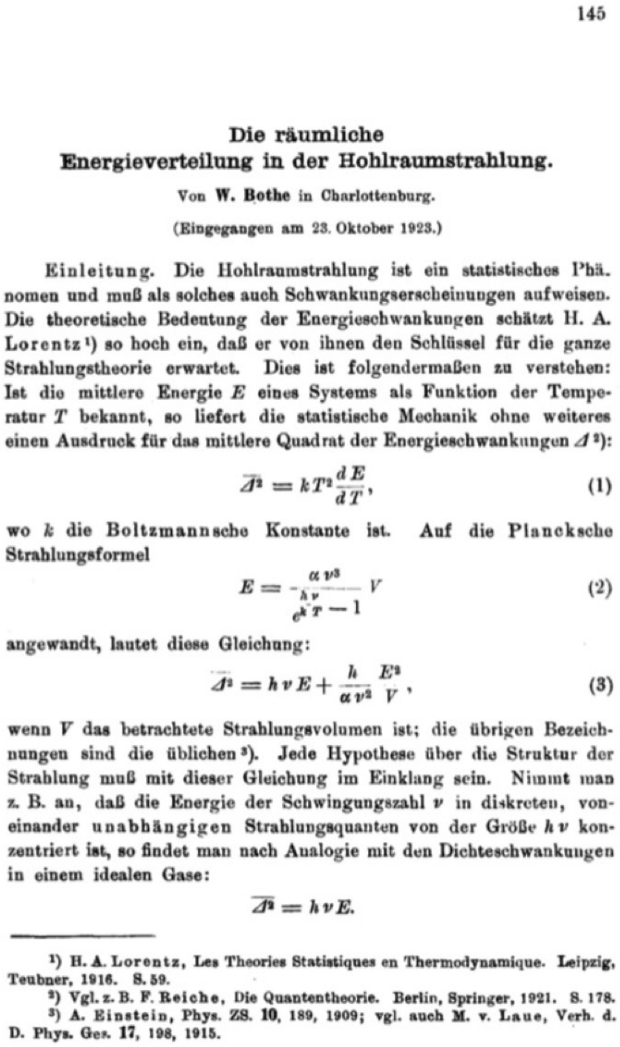
Vor kurzem nun fand ich eine der ursprünglichen Wien'schen Betrachtung [1]) verwandte, auf die Grundvoraussetzung der Quanten-

Figure 6.58: Albert Einstein first proposed the idea of stimulated light emission from atoms (amplification of the number of photons of light from atoms) in 1916.

Lasers

Theory predicting stimulated emission of photons (1919–1926)

Christian Füchtbauer (1877–1959)



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Die räumliche Energieverteilung in der Hohlraumstrahlung.

Von **W. Bothe** in Charlottenburg.

(Eingegangen am 23. Oktober 1923.)

Einleitung. Die Hohlraumstrahlung ist ein statistisches Phänomen und muß als solches auch Schwankungserscheinungen aufweisen. Die theoretische Bedeutung der Energieschwankungen schätzt H. A. Lorentz[1]) so hoch ein, daß er von ihnen den Schlüssel für die ganze Strahlungstheorie erwartet. Dies ist folgendermaßen zu verstehen: Ist die mittlere Energie E eines Systems als Funktion der Temperatur T bekannt, so liefert die statistische Mechanik ohne weiteres einen Ausdruck für das mittlere Quadrat der Energieschwankungen Δ^2[2]):

$$\overline{\Delta^2} = kT^2 \frac{dE}{dT}, \tag{1}$$

wo k die Boltzmannsche Konstante ist. Auf die Plancksche Strahlungsformel

$$E = \frac{\alpha \nu^3}{e^{\frac{h\nu}{kT}} - 1} V \tag{2}$$

angewandt, lautet diese Gleichung:

$$\overline{\Delta^2} = h\nu E + \frac{h}{\alpha \nu^2} \frac{E^2}{V}, \tag{3}$$

wenn V das betrachtete Strahlungsvolumen ist; die übrigen Bezeichnungen sind die üblichen[3]). Jede Hypothese über die Struktur der Strahlung muß mit dieser Gleichung im Einklang sein. Nimmt man z. B. an, daß die Energie der Schwingungszahl ν in diskreten, voneinander unabhängigen Strahlungsquanten von der Größe $h\nu$ konzentriert ist, so findet man nach Analogie mit den Dichteschwankungen in einem idealen Gase:

$$\overline{\Delta^2} = h\nu E.$$

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[1]) H. A. Lorentz, Les Theories Statistiques en Thermodynamique. Leipzig, Teubner, 1916. S. 59.

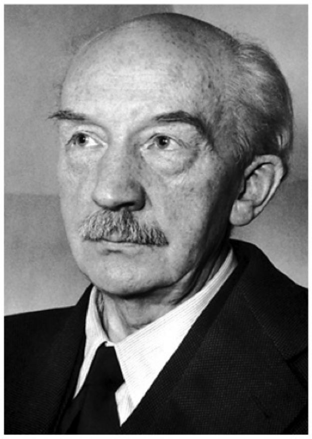
[2]) Vgl. z. B. F. Reiche, Die Quantentheorie. Berlin, Springer, 1921. S. 178.

[3]) A. Einstein, Phys. ZS. **10**, 189, 1909; vgl. auch M. v. Laue, Verh. d. D. Phys. Ges. **17**, 198, 1915.

James Franck (1882–1964)

Max Born (1882–1970)

Walther Bothe (1891–1957)



Hendrik Kramers (1894–1952)

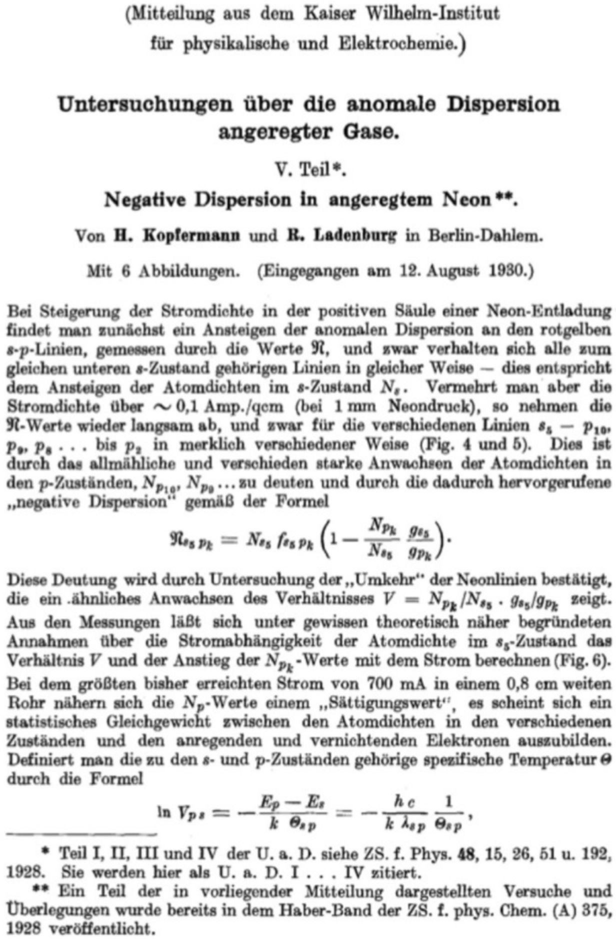
Figure 6.59: Christian Füchtbauer, James Franck, Max Born, Walther Bothe, and Hendrik Kramers further developed the theory of stimulated light emission from atoms (amplification of the number of photons of light from atoms) during the period 1919–1926.

Lasers

Experiments with stimulated emission of photons (1921–1931)

Rudolf Ladenburg (1882–1952)

Hans Kopfermann (1895–1963)



(Mitteilung aus dem Kaiser Wilhelm-Institut für physikalische und Elektrochemie.)

Untersuchungen über die anomale Dispersion angeregter Gase.

V. Teil*.

Negative Dispersion in angeregtem Neon**.

Von **H. Kopfermann** und **R. Ladenburg** in Berlin-Dahlem.

Mit 6 Abbildungen. (Eingegangen am 12. August 1930.)

Bei Steigerung der Stromdichte in der positiven Säule einer Neon-Entladung findet man zunächst ein Ansteigen der anomalen Dispersion an den rotgelben s-p-Linien, gemessen durch die Werte $\mathfrak{N}$, und zwar verhalten sich alle zum gleichen unteren s-Zustand gehörigen Linien in gleicher Weise — dies entspricht dem Ansteigen der Atomdichten im s-Zustand N_s. Vermehrt man aber die Stromdichte über $\sim 0{,}1$ Amp./qcm (bei 1 mm Neondruck), so nehmen die $\mathfrak{N}$-Werte wieder langsam ab, und zwar für die verschiedenen Linien $s_5 - p_{10}$, p_9, p_8 . . . bis p_2 in merklich verschiedener Weise (Fig. 4 und 5). Dies ist durch das allmähliche und verschieden starke Anwachsen der Atomdichten in den p-Zuständen, $N_{p_{10}}$, N_{p_9} ... zu deuten und durch die dadurch hervorgerufene „negative Dispersion" gemäß der Formel

$$\mathfrak{N}_{s_5 p_k} = N_{s_5} f_{s_5 p_k} \left(1 - \frac{N_{p_k}}{N_{s_5}} \frac{g_{s_5}}{g_{p_k}}\right).$$

Diese Deutung wird durch Untersuchung der „Umkehr" der Neonlinien bestätigt, die ein ähnliches Anwachsen des Verhältnisses $V = N_{p_k}/N_{s_5} \cdot g_{s_5}/g_{p_k}$ zeigt. Aus den Messungen läßt sich unter gewissen theoretisch näher begründeten Annahmen über die Stromabhängigkeit der Atomdichte im s_5-Zustand das Verhältnis V und der Anstieg der N_{p_k}-Werte mit dem Strom berechnen (Fig. 6). Bei dem größten bisher erreichten Strom von 700 mA in einem 0,8 cm weiten Rohr nähern sich die N_p-Werte einem „Sättigungswert", es scheint sich ein statistisches Gleichgewicht zwischen den Atomdichten in den verschiedenen Zuständen und den anregenden und vernichtenden Elektronen auszubilden. Definiert man die zu den s- und p-Zuständen gehörige spezifische Temperatur Θ durch die Formel

$$\ln V_{ps} = -\frac{E_p - E_s}{k\ \Theta_{sp}} = -\frac{h\,c}{k\ \lambda_{sp}} \frac{1}{\Theta_{sp}},$$

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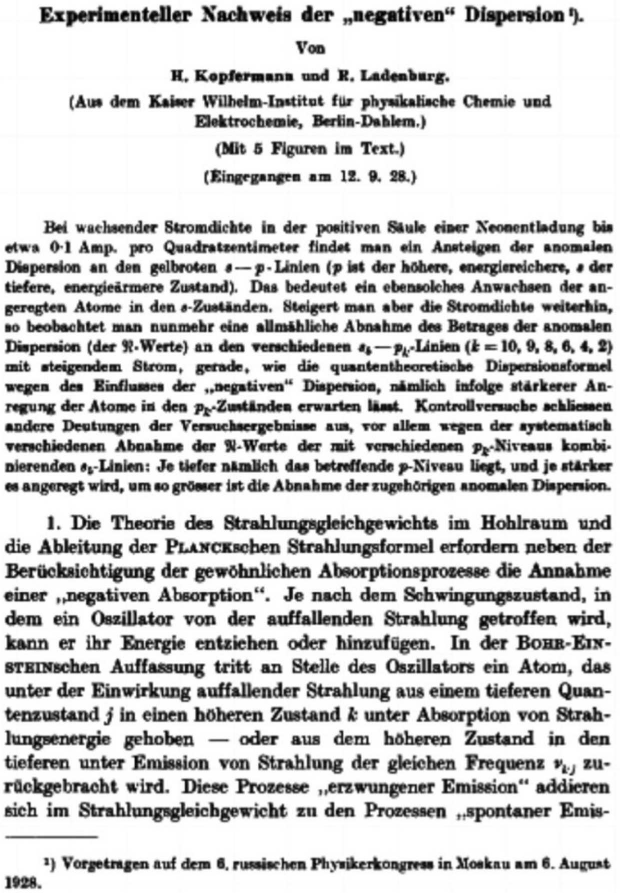
* Teil I, II, III und IV der U. a. D. siehe ZS. f. Phys. **48**, 15, 26, 51 u. 192, 1928. Sie werden hier als U. a. D. I . . . IV zitiert.

** Ein Teil der in vorliegender Mitteilung dargestellten Versuche und Überlegungen wurde bereits in dem Haber-Band der ZS. f. phys. Chem. (A) 375, 1928 veröffentlicht.



Experimenteller Nachweis der „negativen" Dispersion[1].

Von

H. Kopfermann und R. Ladenburg.

(Aus dem Kaiser Wilhelm-Institut für physikalische Chemie und Elektrochemie, Berlin-Dahlem.)

(Mit 5 Figuren im Text.)

(Eingegangen am 12. 9. 28.)

Bei wachsender Stromdichte in der positiven Säule einer Neonentladung bis etwa 0·1 Amp. pro Quadratzentimeter findet man ein Ansteigen der anomalen Dispersion an den gelbroten $s - p$-Linien (p ist der höhere, energiereichere, s der tiefere, energieärmere Zustand). Das bedeutet ein ebensolches Anwachsen der angeregten Atome in den s-Zuständen. Steigert man aber die Stromdichte weiterhin, so beobachtet man nunmehr eine allmähliche Abnahme des Betrages der anomalen Dispersion (der $\mathfrak{N}$-Werte) an den verschiedenen $s_5 - p_k$-Linien ($k = 10, 9, 8, 6, 4, 2$) mit steigendem Strom, gerade, wie die quantentheoretische Dispersionsformel wegen des Einflusses der „negativen" Dispersion, nämlich infolge stärkerer Anregung der Atome in den p_k-Zuständen erwarten lässt. Kontrollversuche schliessen andere Deutungen der Versuchsergebnisse aus, vor allem wegen der systematisch verschiedenen Abnahme der $\mathfrak{N}$-Werte der mit verschiedenen p_k-Niveaus kombinierenden s_5-Linien: Je tiefer nämlich das betreffende p-Niveau liegt, und je stärker es angeregt wird, um so grösser ist die Abnahme der zugehörigen anomalen Dispersion.

1. Die Theorie des Strahlungsgleichgewichts im Hohlraum und die Ableitung der PLANCKschen Strahlungsformel erfordern neben der Berücksichtigung der gewöhnlichen Absorptionsprozesse die Annahme einer „negativen Absorption". Je nach dem Schwingungszustand, in dem ein Oszillator von der auffallenden Strahlung getroffen wird, kann er ihr Energie entziehen oder hinzufügen. In der BOHR-EINSTEINschen Auffassung tritt an Stelle des Oszillators ein Atom, das unter der Einwirkung auffallender Strahlung aus einem tieferen Quantenzustand j in einen höheren Zustand k unter Absorption von Strahlungsenergie gehoben — oder aus dem höheren Zustand in den tieferen unter Emission von Strahlung der gleichen Frequenz ν_{kj} zurückgebracht wird. Diese Prozesse „erzwungener Emission" addieren sich im Strahlungsgleichgewicht zu den Prozessen „spontaner Emis-

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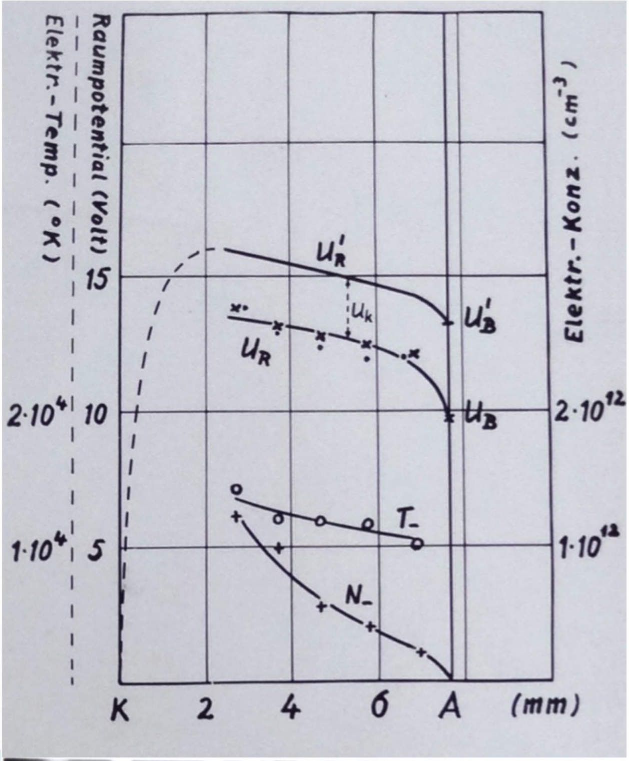
[1] Vorgetragen auf dem 6. russischen Physikerkongress in Moskau am 6. August 1928.

Figure 6.60: Rudolf Ladenburg, Hans Kopfermann, and other members of the Ladenburg group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie investigated and demonstrated stimulated light emission from atoms (amplification of the number of photons of light from atoms) during the period 1921–1931.

Lasers

Wilhelm von Meyeren
(1905–1983)



Experiments with stimulated emission of photons (1944)

NARA RG 319,
Entry NM3-82A,
Box 6, Folder G3

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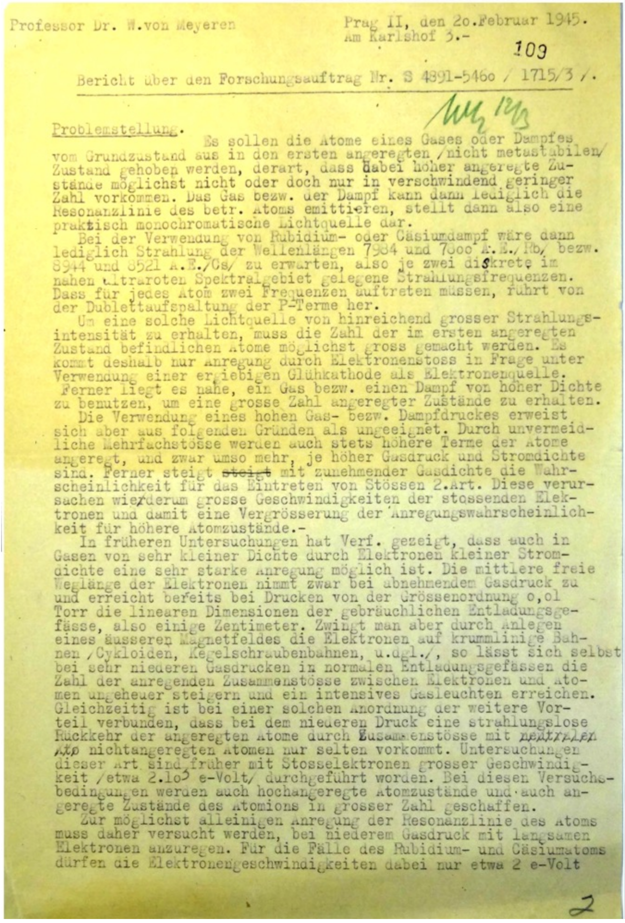
Authority NND755001



Professor Dr. W.von Meyeren

Prag II, den 2o.Februar 1945.
Am Karlshof 3.-

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Bericht über den Forschungsauftrag Nr. S 4891-546o / 1715/3 /.

12/3

Problemstellung. Es sollen die Atome eines Gases oder Dampfes vom Grundzustand aus in den ersten angeregten /nicht metastabilen/ Zustand gehoben werden, derart, dass dabei höher angeregte Zustände möglichst nicht oder doch nur in verschwindend geringer Zahl vorkommen. Das Gas bezw. der Dampf kann dann lediglich die Resonanzlinie des betr. Atoms emittieren, stellt dann also eine praktisch monochromatische Lichtquelle dar.

Bei der Verwendung von Rubidium- oder Cäsiumdampf wäre dann lediglich Strahlung der Wellenlängen 7984 und 78oo A.E./Rb/ bezw. 8944 und 8521 A.E./Cs/ zu erwarten, also je zwei diskrete im nahen ultraroten Spektralgebiet gelegene Strahlungsfrequenzen. Dass für jedes Atom zwei Frequenzen auftreten müssen, rührt von der Dublettaufspaltung der P-Terme her.

Um eine solche Lichtquelle von hinreichend grosser Strahlungsintensität zu erhalten, muss die Zahl der im ersten angeregten Zustand befindlichen Atome möglichst gross gemacht werden. Es kommt deshalb nur Anregung durch Elektronenstoss in Frage unter Verwendung einer ergiebigen Glühkathode als Elektronenquelle.

Ferner liegt es nahe, ein Gas bezw. einen Dampf von höher Dichte zu benutzen, um eine grosse Zahl angeregter Zustände zu erhalten.

Die Verwendung eines hohen Gas- bezw. Dampfdruckes erweist sich aber aus folgenden Gründen als ungeeignet. Durch unvermeidliche Mehrfachstösse werden auch stets höhere Terme der Atome angeregt, und zwar umso mehr, je höher Gasdruck und Stromdichte sind. Ferner steigt ~~steigt~~ mit zunehmender Gasdichte die Wahrscheinlichkeit für das Eintreten von Stössen 2.Art. Diese verursachen wiederum grosse Geschwindigkeiten der stossenden Elektronen und damit eine Vergrösserung der Anregungswahrscheinlichkeit für höhere Atomzustände.-

In früheren Untersuchungen hat Verf. gezeigt, dass auch in Gasen von sehr kleiner Dichte durch Elektronen kleiner Stromdichte eine sehr starke Anregung möglich ist. Die mittlere freie Weglänge der Elektronen nimmt zwar bei abnehmendem Gasdruck zu und erreicht bereits bei Drucken von der Grössenordnung o,ol Torr die linearen Dimensionen der gebräuchlichen Entladungsgefässe, also einige Zentimeter. Zwingt man aber durch Anlegen eines äusseren Magnetfeldes die Elektronen auf krummlinige Bahnen /Cykloiden, Kegelschraubenbahnen, u.dgl./, so lässt sich selbst bei sehr niederen Gasdrucken in normalen Entladungsgefässen die Zahl der anregenden Zusammenstösse zwischen Elektronen und Atomen ungeheuer steigern und ein intensives Gasleuchten erreichen. Gleichzeitig ist bei einer solchen Anordnung der weitere Vorteil verbunden, dass bei dem niederen Druck eine strahlungslose Rückkehr der angeregten Atome durch Zusammenstösse mit ~~neutralen~~ ~~Ato~~ nichtangeregten Atomen nur selten vorkommt. Untersuchungen dieser Art sind früher mit Stosselektronen grosser Geschwindigkeit /etwa 2.1o^5 e-Volt/ durchgeführt worden. Bei diesen Versuchsbedingungen werden auch hochangeregte Atomzustände und auch angeregte Zustände des Atomions in grosser Zahl geschaffen.

Zur möglichst alleinigen Anregung der Resonanzlinie des Atoms muss daher versucht werden, bei niederem Gasdruck mit langsamen Elektronen anzuregen. Für die Fälle des Rubidium- und Cäsiumatoms dürfen die Elektronengeschwindigkeiten dabei nur etwa 2 e-Volt

2

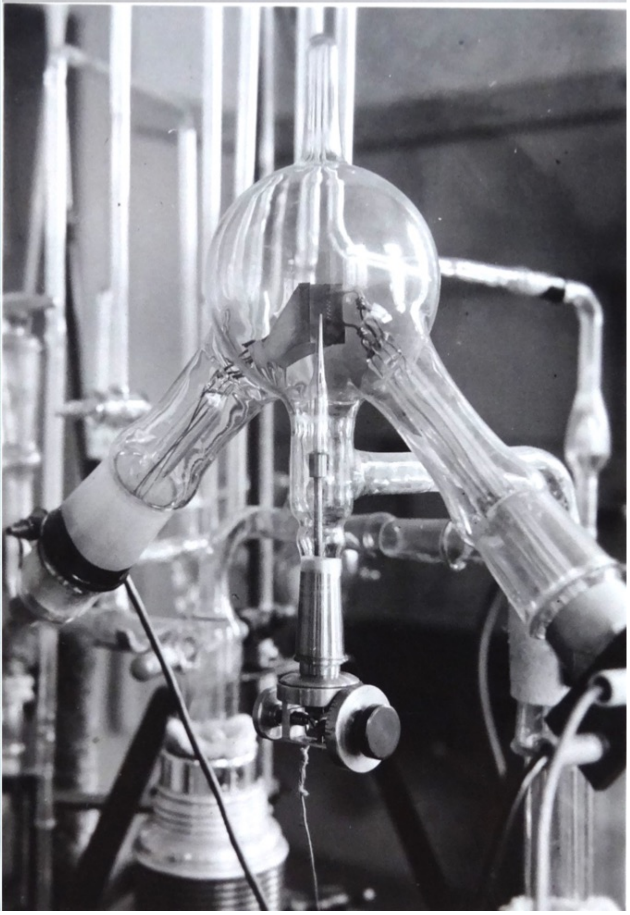


Figure 6.61: In a 20 February 1945 report to Walther Gerlach, Wilhelm von Meyeren described his 1944 experiments with laser-like monochromatic stimulated light emission from electron population inversions in argon, cesium, or rubidium gases.

6.4.2 Holography

Ludwig Mach (Austrian, 1868–1951) and Ludwig Zehnder (Swiss, 1854–1949) developed the Mach-Zehnder interferometer during the period 1891–1892. A Mach-Zehnder interferometer splits a collimated and preferably monochromatic beam of light into two beams, passes one beam through a transparent object (or reflected off a non-transparent object), then recombines the beams, which are projected onto a screen. Phase changes to the light waves caused by the object create constructive and destructive interference and thus visible patterns that can provide useful information about the object. See Fig. 6.62.

Ludwig Mach was the son of Ernst Mach (Austrian, 1838–1916). Ludwig and Ernst Mach used similar principles to visualize shock waves around bullets traveling faster than the speed of sound through air (p. 1657).

The Mach-Zehnder interferometric approach was later applied to microscopes, resulting in phase contrast microscopy (p. 1274).

In 1947, Dennis Gabor (Hungarian but educated and worked in Germany, 1900–1979) invented holography by applying Mach-Zehnder interferometry to photography (Fig. 6.63). Essentially, a holographic recording system is a Mach-Zehnder interferometer used as a camera, with photographic film placed at the final point to record the constructive and destructive interference produced when half of the light beam encounters an object and then the two halves of the beam are recombined. Such an image appears three-dimensional to human eyes, unlike regular photographs. (Though invented in 1947, holography later became a more powerful and more practical technique once lasers were readily available to be used as the light source.)

For introducing and developing holography, Gabor won the Nobel Prize in Physics in 1971. Professor Erik Ingelstam of the Royal Academy of Sciences discussed the far-reaching applications of Gabor's methods [https://www.nobelprize.org/prizes/physics/1971/ceremony-speech/]:

> [...I]mportant information about the object is missing in a photographic image. This is a problem which has been a key one for Dennis Gabor during his work on information theory. Because the image reproduces only the effect of the intensity of the incident wave-field, not its nature. The other characteristic quantity of the waves, phase, is lost and thereby the three dimensional geometry. The phase depends upon from which direction the wave is coming and how far it has travelled from the object to be imaged.
>
> Gabor found the solution to the problem of how one can retain a wave-field with its phase on a photographic plate. A part of the wave-field, upon which the object has not had an effect, namely a reference wave, is allowed to fall on the plate together with the wave-field from the object. These two fields are superimposed upon one another, they interfere, and give the strongest illumination where they have the same phase, the weakest where they extinguish each other by having the opposite phase. Gabor called this plate a hologram, from the Greek holos, which means whole or complete, since the plate contains the whole information. This information is stored in the plate in a coded form. When the hologram is irradiated only with the reference wave, this wave is deflected in the hologram structure, and the original object's field is reconstructed.

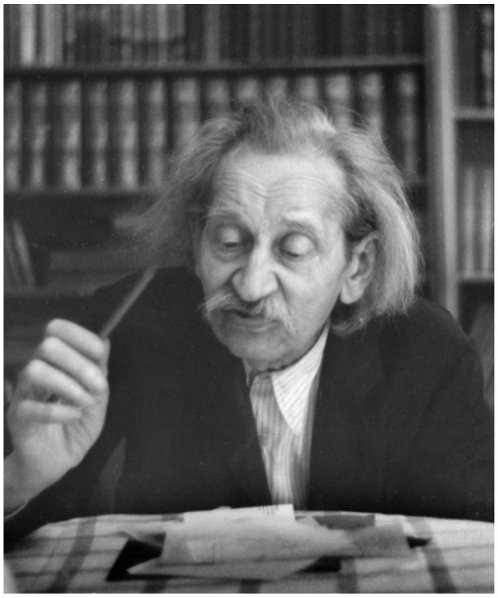
The result is a three dimensional image.

Gabor originally thought of using the principle to make an electron microscope image in two steps: first to register an object's field with electron rays in a hologram, and then to reconstruct this with visible light to make a three dimensional image with high resolution. But suitable electron sources for this were not available, and also for other technical reasons the idea could not be tested. However, through successful experiments with light Gabor could show that the principle was correct. In three papers from 1948 to 1951 he attained an exact analysis of the method, and his equations, even today, contain all the necessary information. [...]

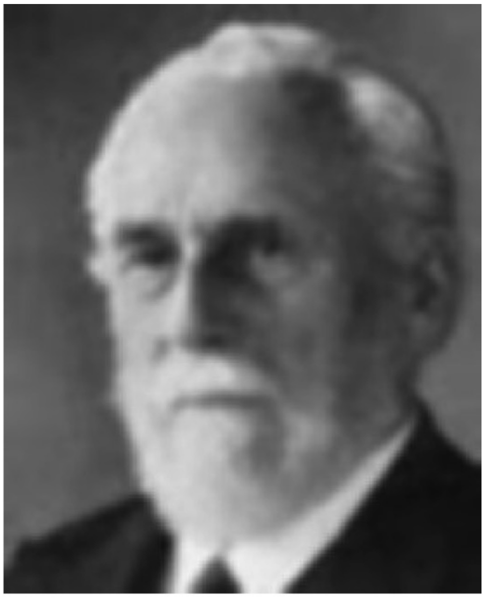
The fascinated observer's admiration when he experiences the three dimensional space effect in a holographic image is, however, an unsufficient acknowledgement for the inventor. More important are the scientific and technical uses to which his idea has led. The position of each object's point in space is determined to a fraction of a light wave-length, a few ten-thousandths of a millimetre, thanks to the phase in the wave-field. With this, the hologram has, in an unexpected way, enriched optical measurement techniques, and particularly interferometric measurements have been made possible on many objects. The shape of the object at different times can be stored in one and the same hologram, through illumination of it several times. When they are reconstructed simultaneously, the different wave-fields interfere with each other, and the image of the object is covered with interference lines, which directly, in light wavelengths, correspond to changes of shape between the exposures. These changes can also be, for example, vibrations in a membrane or a musical instrument.

Also, very rapid sequences of events, even in plasma physics, are amenable to analysis through hologram exposures at certain times with short light flashes from modern impulse lasers.

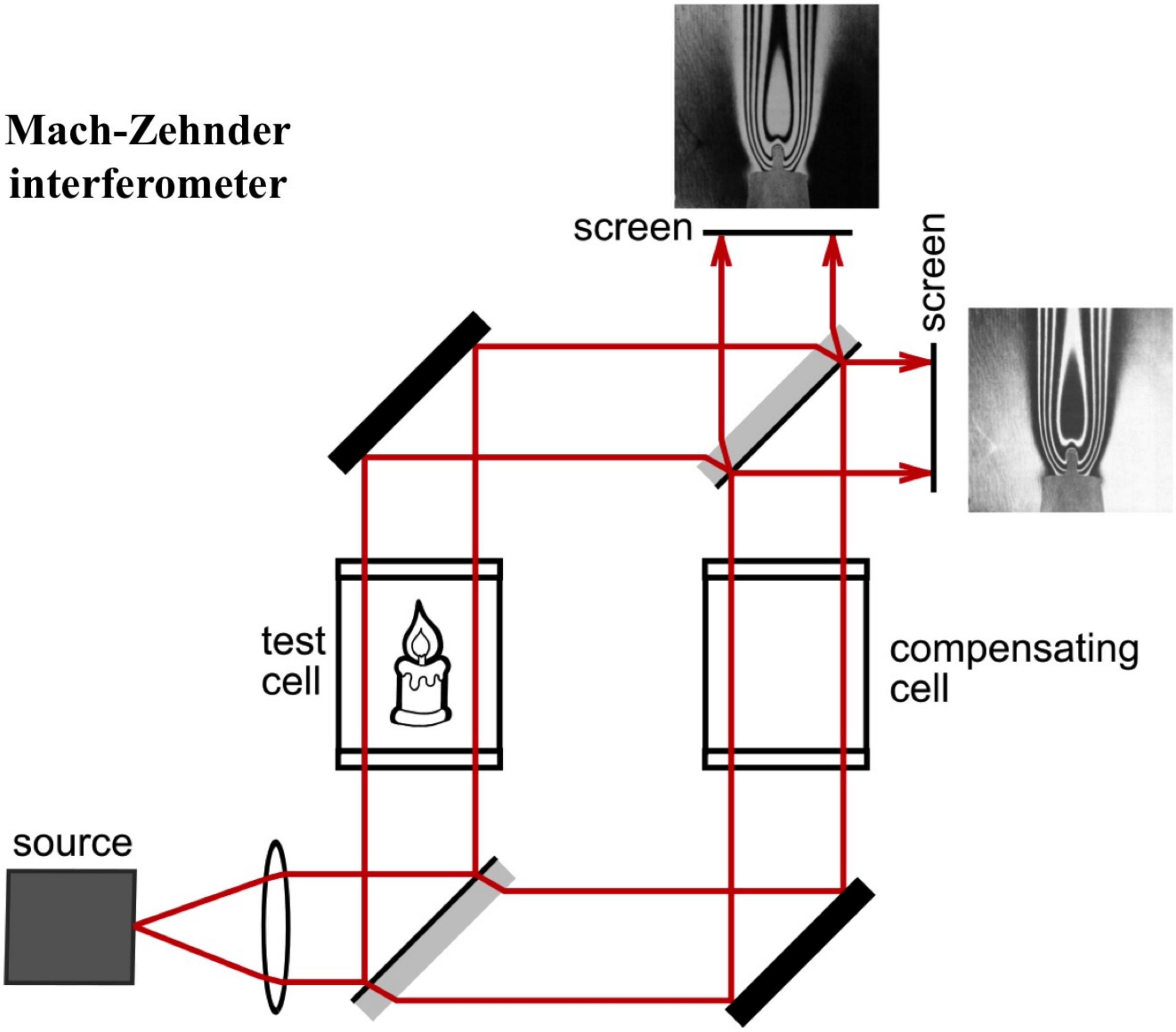
Gabor's original thought to use different waves for both steps within holography, has been taken up in many connections. It is especially attractive to use ultra sound waves for exposures, so that, in the second step, a sound field is reconstructed in the shape of an optical image. Despite significant difficulties there is work, with a certain amount of progress, being done in this area. Such a method should be of value for medical diagnosis, since the deflected sound field gives different information from that in X ray radiography.



Ludwig Mach (1868–1951)

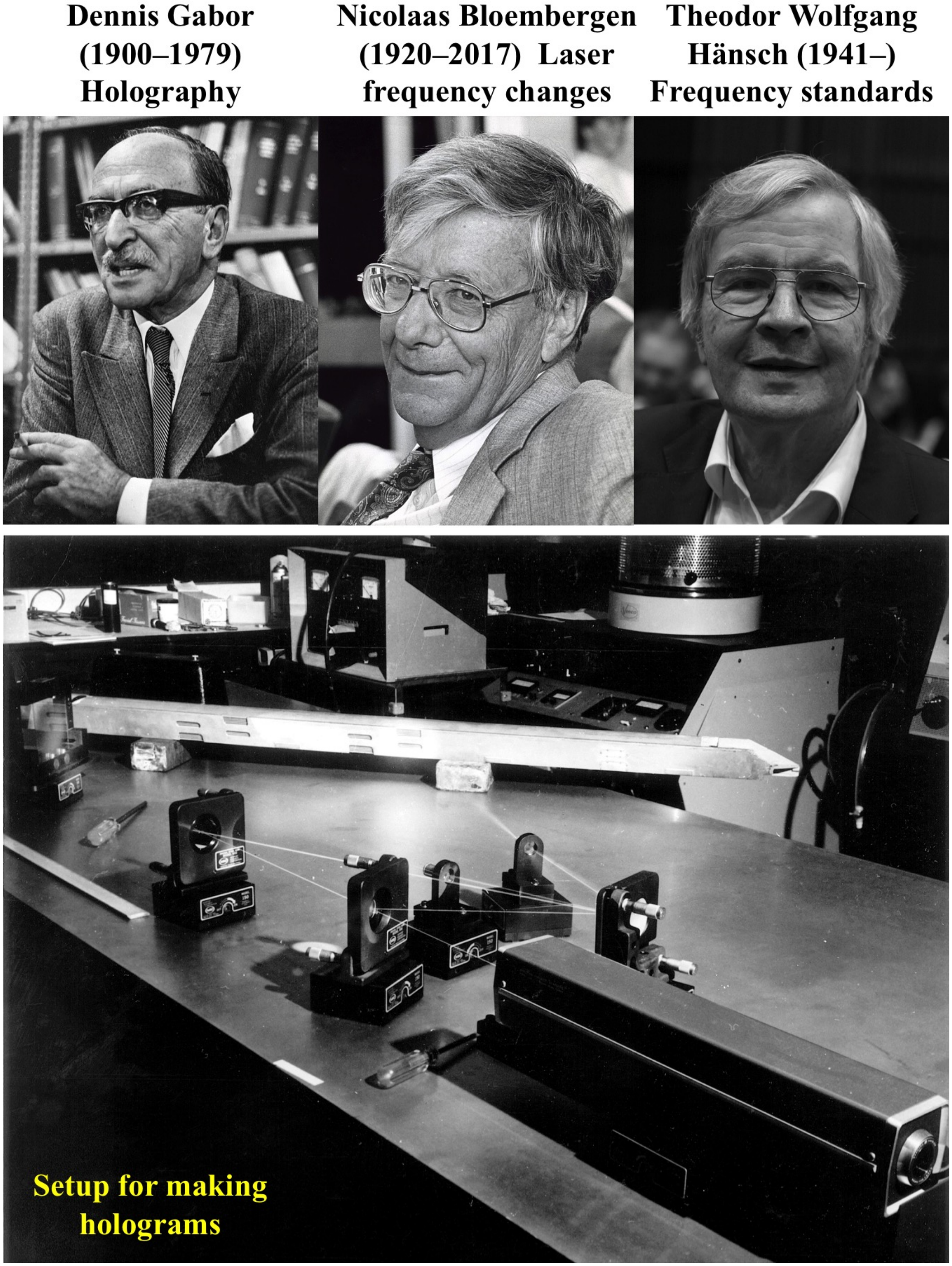


Ludwig Zehnder (1854–1949)



Mach-Zehnder interferometer
screen
screen
test cell
compensating cell
source

Figure 6.62: Ludwig Mach and Ludwig Zehnder developed the Mach-Zehnder interferometer during the period 1891–1892.



Dennis Gabor (1900–1979) Holography

Nicolaas Bloembergen (1920–2017) Laser frequency changes

Theodor Wolfgang Hänsch (1941–) Frequency standards

Figure 6.63: Dennis Gabor invented holography (essentially using a Mach-Zehnder interferometer as a camera), Nicolaas Bloembergen used nonlinear optics to increase or decrease laser frequencies by multiples, and Theodor Wolfgang Hänsch developed more precise laser frequency standards.

6.4.3 Laser Spectroscopy

Nicolaas Bloembergen (Dutch, 1920–2017, Fig. 6.63) developed early magnetic resonance imaging (MRI) machines and invented methods of using nonlinear optics to convert laser beams of one frequency or wavelength into beams of other frequencies or wavelengths (for example by halving or by doubling the frequency). He won the Nobel Prize in Physics in 1981 for his laser work. Professor Ingvar Lindgren of the Royal Swedish Academy of Sciences described that research and its applications [https://www.nobelprize.org/prizes/physics/1981/ceremony-speech/]:

> Nicolaas Bloembergen has contributed to the development of laser spectroscopy in a different way. Laser light is sometimes so intense that, when it is shone on to matter, the response of the system could not be described by existing theories. Bloembergen and his collaborators have formulated a more general theory to describe these effects and founded a new field of science we now call non-linear optics. Several laser spectroscopy methods are based upon this phenomenon, particularly such methods where two or more beams of laser light are mixed in order to produce laser light of a different wave length. Such methods can be applied in many fields, for instance, for studying combustion processes. Furthermore, it has been possible in this way to generate laser light of shorter as well as longer wave lengths, which has extended the field of application for laser spectroscopy quite appreciably.

Theodor Wolfgang Hänsch (German, 1941–, Fig. 6.63) developed more precise laser frequency standards, for which he won the Nobel Prize in Physics in 2005 (along with John Hall). Professor Stig Stenholm, a member of the Royal Swedish Academy of Sciences, explained the importance of the innovation [https://www.nobelprize.org/prizes/physics/2005/ceremony-speech/]:

> John Hall and Theodor Hänsch have worked on ever-improved standard references for frequency measurements. In order to compare an unknown period of light with the reference, they have developed the frequency comb technique. This gives a sequence of exactly separated frequencies and a method to set this measuring rod against an unknown frequency. Thus one obtains an extremely accurate number for the unknown period. This allows spectroscopic measurements with extremely high precision. Today this technique is as exact as the methods developed for this purpose during earlier decades, but it promises many times improved accuracy.
>
> The history of physics shows that, when the accuracy of measurements is improved, new physics may be discovered and explored. The work honored today facilitates tests of our basic theories in physics. The character of time and space may be clarified, and the limitations of the laws of physics may be established.

6.5 Solid State Physics and Microelectronics

German-speaking creators made many of the revolutionary advances in solid state physics and microelectronics that have made the modern world possible, yet to date, the full extent of their contributions has not been widely understood and recognized.[11]

This section gives an overview of the critical roles played by creators from the German-speaking world with regard to:

6.5.1. Solid state physics

6.5.2. Semiconductor materials and devices

6.5.3. Transistors

6.5.4. Postwar transfer of microelectronics technologies

6.5.5. Capacitors

6.5.6. Printed circuits

6.5.7. Integrated circuits

6.5.8. Light emitting diodes and laser diodes

6.5.9. Superconductivity

6.5.10. Piezoelectricity

For more extensive documentation in these areas, see Appendix B.

6.5.1 Solid State Physics

Solid state physics, the basic science underlying microelectronics, describes the motions of negatively charged electrons and positively charged ions in crystal lattices. Figure 6.64 gives a simple visual explanation of some of the major aspects of solid state physics.

There is a great need for someone to write a comprehensive and scientifically detailed history of German-speaking contributions to the combined area of solid state physics and microelectronics. Such a history should include all of the creators, creations, and evidence listed in this section and in Appendix B, and draw upon further archival research to solve many of the remaining mysteries.

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[11] For individual pieces of the history of this area, see the documents in Appendix B and also: Arns 1998; Bernstein 1984; Crawford 1991; Eckert and Schubert 1990; Eisler 1989; Gertner 2012; Gimbel 1990a; Handel 1999; Hicks 2012; Hilsch 1939; Hilsch and Pohl 1938; Hoddeson et al. 1992; Hoddeson and Daitch 2002; Medawar and Pyke 2000; Metzler 2020; Mertz 1946; Nagel 2006; Noll and Geselowitz 2011; Pierce 1975; Rhoads 2005; Riordan and Hoddeson 1997; Sarkar et al. 2006; Saxena 2009; Sullivan 1949; Sze 1991; Teichmann 1988; Warnow-Blewett and Teichmann 1992.

As shown in upper part of Fig. 6.64, electrons belong to different energy levels, or energy bands, depending on whether the electrons behave like waves with peaks between the ions (higher energy, conduction band) or like waves with peaks at the ions (lower energy, valence band). In the illustration, electrons moving through a simple one-dimensional lattice of positively charged ions behave as standing waves with a wave function $\Psi(x)$. The magnitude of the wave function squared, $|\Psi(x)|^2$, represents the probability that the electrons will be at a given location, so electrons will usually be found near the antinodes (maxima) of the standing waves. If the electron wave function has antinodes between the ion locations as in the upper graph, the negatively charged electrons will tend to be found far away from positively charged ions, so they will have higher energies. If the electron wave function has antinodes near the ion locations, the negatively charged electrons will tend to be found very close to the positively charged ions, so they will have lower energies. Thus there are different possible levels or bands of energies for the electrons, and they are separated by an energy band gap.

The lower part of Fig. 6.64 is a schematic illustration of the occupation of electron energy bands in metals, insulators, semiconductors, and semimetals:

- In metals, an energy band is 10–90% filled. That provides plenty of electrons in the band, but it leaves them lots of nearby vacant energy states they can move to in order to run around and conduct electricity.
- In electrical insulators, each band is either completely full or completely empty. Completely full bands do not provide their electrons with nearby vacant states they can move to in order to conduct electricity, and completely empty bands do not have any electrons to conduct electricity. The band gap between the highest filled band and the lowest empty band is large enough that essentially no electrons from the filled band can jump up to the empty band and conduct electricity.
- Semiconductors are very similar to insulators, except that the energy band gap between the highest filled band (the valence band) and the lowest empty band (the conduction band) is much smaller. Because the band gap is smaller, a small but significant number of electrons can jump up to the conduction band and conduct electricity. These electrons leave behind vacant states in the valence band; the vacant states are called “holes” and act like positive charge-carrying particles.
- Just like semiconductors, semimetals also have a small but significant number of electrons in one band and a corresponding collection of holes in another. However, in semimetals, this effect is due to a negative energy band gap between two bands; an essentially full band overlaps in energy with an essentially empty band, causing some electrons to leave the full energy band and occupy lower energy states in the nearly empty band.

While the ions cannot move as freely as the electrons in a solid, they can vibrate in place, and those vibrations can carry energy. By considering the motions of both the electrons and the ions, solid state physics is able to explain the electrical, magnetic, optical, and thermal properties of solid materials.

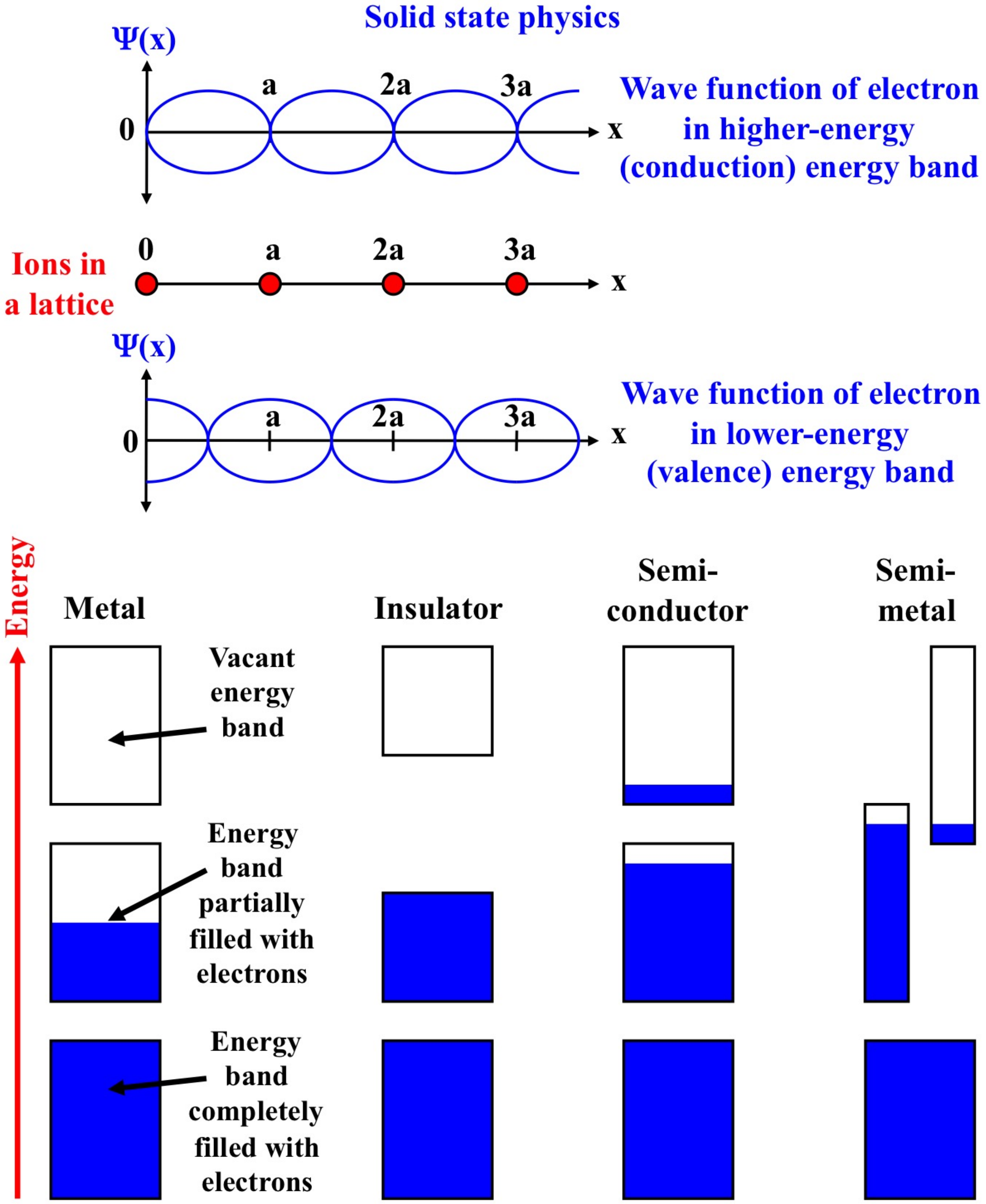

Solid state physics
Ψ(x)
0
a
2a
3a
x
Wave function of electron in higher-energy (conduction) energy band
Ions in a lattice
0
a
2a
3a
x
Ψ(x)
0
a
2a
3a
x
Wave function of electron in lower-energy (valence) energy band
Energy
Metal
Insulator
Semi-conductor
Semi-metal
Vacant energy band
Energy band partially filled with electrons
Energy band completely filled with electrons

Figure 6.64: Solid state physics, the basic science underlying microelectronics, describes the motions of negatively charged electrons and positively charged ions in crystal lattices. Electrons belong to different energy levels, or energy bands, depending on whether the electrons behave like waves with peaks between the ions (higher energy, conduction band) or with peaks at the ions (lower energy, valence band). Metals have a band partially full of electrons, with plenty of room for them to gain energy and run around. Electrical insulators have bands filled with electrons, and a large energy gap separating those from unfilled bands where they could run around. Semiconductors and semimetals have bands that can be more or less full, depending on the conditions.

In a crystalline solid, the ions are arranged in a three-dimensional periodic pattern or lattice, which has a large effect on the properties of the solid. For different solids with different crystal shapes, those three-dimensional lattice structures can be quite complex. Real crystals often have imperfections such as individual ions that have been knocked out of their correct locations within the lattice. Such lattice defects often absorb certain colors of visible light and are known even in the English-speaking physics community as “F centers” for the German word for color, Farbe.

Some creators who made major contributions to solid state physics are shown in Figs. 6.65–6.69.

Franz Ernst Neumann (German, 1798–1895) was one of the first scientists to make a detailed study of the optical behavior of crystals based on their composition and shapes.

Woldemar Voigt (German, 1850–1919) made contributions to several areas of physics and wrote the first textbook on solid state physics (*Lehrbuch der Kristallphysik*) in 1910.

Arthur Schoenflies (German, 1853–1928) applied advanced mathematical methods such as group theory to the analysis of crystal structures. “Schoenflies notation” is still widely utilized in crystallography and solid state physics.

Eugene Wigner (Hungarian, 1902–1995) greatly extended the group theory methods of Schoenflies with applications in solid state physics and particle physics. He won a Nobel Prize in Physics in 1963 for this work (p. 1535).

Hendrik Lorentz (Dutch, 1853–1928) used what were then the latest ideas about electromagnetic waves and electrons to create one of the first mathematical models for the electrical and optical properties of solids. He won the Nobel Prize in Physics in 1902 (p. 891).

Paul Drude (German, 1863–1906) also created a mathematical model for electrons in solids. Although the Drude model only considered classical mechanics and electromagnetism, it can be used to analyze and obtain the correct expressions for several important solid state phenomena.

Gustav Wiedemann (German, 1826–1899) and Rudolph Franz (German, 1826–1902) measured the thermal conductivity and the electrical conductivity of metals at different temperatures. They showed empirically that the ratio of the thermal and electrical conductivities increased in direct proportion to the temperature, which came to be called the Wiedemann-Franz law. While the Drude model could explain many properties of solids, it could not correctly explain the Wiedemann-Franz law.

Wolfgang Pauli (Austrian, 1900–1958) showed that electrons obey what is now called the Pauli exclusion rule; every electron in an atom, a solid, or other system is an individualist that refuses to do exactly the same thing as any other electron in that system. For this discovery, Pauli won the Nobel Prize in Physics in 1945 (p. 899).

Arnold Sommerfeld (German, 1868–1951) greatly improved the Drude model by using the Pauli exclusion principle to explain the behavior of electrons in metals. The resulting Sommerfeld or Drude-Sommerfeld model of free electrons yielded theoretical predictions that agreed with the experimental measurements of the Wiedemann-Franz law.

Max Born (German, 1882–1970) wrote an early textbook (*Dynamik der Kristallgitter*) on solid state physics in 1915, and contributed to the subject further as one of the pioneers of quantum physics in the 1920s. He won the Nobel Prize in Physics in 1954 (p. 896).

Felix Bloch (Swiss, 1905–1983) incorporated the wave-like behavior of electrons into models of solids, and the mathematical wave functions of electrons in solids became known as Bloch functions. Bloch won a Nobel Prize in Physics in 1952 (p. 1516).

Ralph Kronig (German, 1904–1995) extended Felix Bloch's calculations of the wave-like behavior of electrons in solids; the updated theory later became known as the Kronig-Penney model. Kronig was also one of the first physicists to propose electron spin. Kronig and Hendrik Kramers (Dutch, 1894–1952) independently developed the Kramers-Kronig relations for the optical and electronic properties of solids.

Gregory Wannier (Swiss, 1911–1983) further improved the calculations of the wave-like behavior of electrons in solids, resulting in the Wannier functions. With Hendrik Kramers, he also discovered the Kramers-Wannier duality for the magnetic properties of solids.

Wilhelm Lenz (German, 1888–1957) and Ernst Ising (German, 1900–1998) developed what became known as the Ising model to explain the magnetic properties of solids.

Walther Nernst (German, 1864–1941) made important contributions to the statistical physics and thermal properties of solids. He won the Nobel Prize in Chemistry in 1920 (p. 913).

Peter Debye (Dutch, 1884–1966) calculated the effects of vibrations of the ions in a crystal lattice on the thermal properties of the crystal. He won a Nobel Prize in Chemistry in 1936 (p. 914).

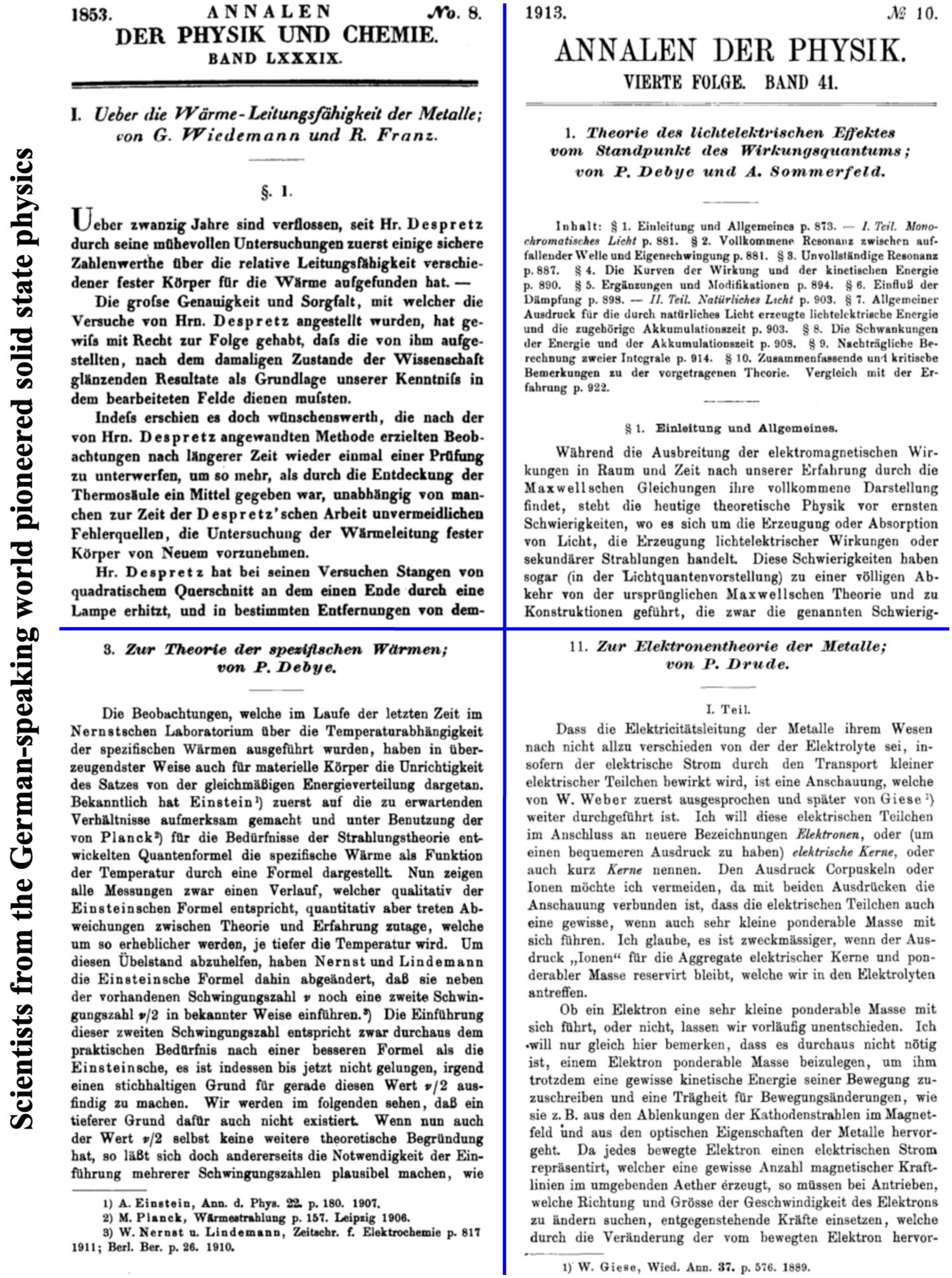
Erwin Madelung (German, 1881–1972) modeled the electrostatic effects of all the ions on an individual ion or on the electrons, resulting in what is now known as the Madelung constant.

Rudolf Peierls (German, 1907–1995) made many major discoveries in solid state physics, including the behavior of the positive "holes" left behind by negative electrons that have left atoms, the properties of phonons or vibrations of the ion lattice, and the shapes of repeating zones in momentum space corresponding to the shapes of repeated crystal shapes in regular space (a fundamentally important discovery that was incorrectly later attributed to Léon Brillouin).

Walther Kossel (German, 1888–1956) studied the structure, bonding, and growth of crystals. He was the son of Albrecht Kossel (p. 90).

Hans Bethe (German, 1906–2005) wrote his doctoral thesis on solid state physics and continued to make new discoveries in the field until after World War II. He won a Nobel Prize in Physics in 1967 (p. 1542).

Georg Joos (German, 1894–1959) gathered a wide variety of solid state physics theories and experiments and assimilated them into organized textbooks that taught several generations of physicists.



1853. ANNALEN №. 8.
DER PHYSIK UND CHEMIE.
BAND LXXXIX.

I. *Ueber die Wärme-Leitungsfähigkeit der Metalle; von G. Wiedemann und R. Franz.*

§. 1.

Ueber zwanzig Jahre sind verflossen, seit Hr. Despretz durch seine mühevollen Untersuchungen zuerst einige sichere Zahlenwerthe über die relative Leitungsfähigkeit verschiedener fester Körper für die Wärme aufgefunden hat. —

Die groſse Genauigkeit und Sorgfalt, mit welcher die Versuche von Hrn. Despretz angestellt wurden, hat gewiſs mit Recht zur Folge gehabt, daſs die von ihm aufgestellten, nach dem damaligen Zustande der Wissenschaft glänzenden Resultate als Grundlage unserer Kenntniſs in dem bearbeiteten Felde dienen muſsten.

Indeſs erschien es doch wünschenswerth, die nach der von Hrn. Despretz angewandten Methode erzielten Beobachtungen nach längerer Zeit wieder einmal einer Prüfung zu unterwerfen, um so mehr, als durch die Entdeckung der Thermosäule ein Mittel gegeben war, unabhängig von manchen zur Zeit der Despretz'schen Arbeit unvermeidlichen Fehlerquellen, die Untersuchung der Wärmeleitung fester Körper von Neuem vorzunehmen.

Hr. Despretz hat bei seinen Versuchen Stangen von quadratischem Querschnitt an dem einen Ende durch eine Lampe erhitzt, und in bestimmten Entfernungen von dem-

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1913. № 10.
ANNALEN DER PHYSIK.
VIERTE FOLGE. BAND 41.

1. *Theorie des lichtelektrischen Effektes vom Standpunkt des Wirkungsquantums; von P. Debye und A. Sommerfeld.*

Inhalt: § 1. Einleitung und Allgemeines p. 873. — *I. Teil. Monochromatisches Licht* p. 881. § 2. Vollkommene Resonanz zwischen auffallender Welle und Eigenschwingung p. 881. § 3. Unvollständige Resonanz p. 887. § 4. Die Kurven der Wirkung und der kinetischen Energie p. 890. § 5. Ergänzungen und Modifikationen p. 894. § 6. Einfluß der Dämpfung p. 898. — *II. Teil. Natürliches Licht* p. 903. § 7. Allgemeiner Ausdruck für die durch natürliches Licht erzeugte lichtelektrische Energie und die zugehörige Akkumulationszeit p. 903. § 8. Die Schwankungen der Energie und der Akkumulationszeit p. 908. § 9. Nachträgliche Berechnung zweier Integrale p. 914. § 10. Zusammenfassende und kritische Bemerkungen zu der vorgetragenen Theorie. Vergleich mit der Erfahrung p. 922.

§ 1. **Einleitung und Allgemeines.**

Während die Ausbreitung der elektromagnetischen Wirkungen in Raum und Zeit nach unserer Erfahrung durch die Maxwellschen Gleichungen ihre vollkommene Darstellung findet, steht die heutige theoretische Physik vor ernsten Schwierigkeiten, wo es sich um die Erzeugung oder Absorption von Licht, die Erzeugung lichtelektrischer Wirkungen oder sekundärer Strahlungen handelt. Diese Schwierigkeiten haben sogar (in der Lichtquantenvorstellung) zu einer völligen Abkehr von der ursprünglichen Maxwellschen Theorie und zu Konstruktionen geführt, die zwar die genannten Schwierig-

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3. *Zur Theorie der spezifischen Wärmen; von P. Debye.*

Die Beobachtungen, welche im Laufe der letzten Zeit im Nernstschen Laboratorium über die Temperaturabhängigkeit der spezifischen Wärmen ausgeführt wurden, haben in überzeugendster Weise auch für materielle Körper die Unrichtigkeit des Satzes von der gleichmäßigen Energieverteilung dargetan. Bekanntlich hat Einstein[1]) zuerst auf die zu erwartenden Verhältnisse aufmerksam gemacht und unter Benutzung der von Planck[2]) für die Bedürfnisse der Strahlungstheorie entwickelten Quantenformel die spezifische Wärme als Funktion der Temperatur durch eine Formel dargestellt. Nun zeigen alle Messungen zwar einen Verlauf, welcher qualitativ der Einsteinschen Formel entspricht, quantitativ aber treten Abweichungen zwischen Theorie und Erfahrung zutage, welche um so erheblicher werden, je tiefer die Temperatur wird. Um diesen Übelstand abzuhelfen, haben Nernst und Lindemann die Einsteinsche Formel dahin abgeändert, daß sie neben der vorhandenen Schwingungszahl ν noch eine zweite Schwingungszahl $\nu/2$ in bekannter Weise einführen.[3]) Die Einführung dieser zweiten Schwingungszahl entspricht zwar durchaus dem praktischen Bedürfnis nach einer besseren Formel als die Einsteinsche, es ist indessen bis jetzt nicht gelungen, irgend einen stichhaltigen Grund für gerade diesen Wert $\nu/2$ ausfindig zu machen. Wir werden im folgenden sehen, daß ein tieferer Grund dafür auch nicht existiert. Wenn nun auch der Wert $\nu/2$ selbst keine weitere theoretische Begründung hat, so läßt sich doch andererseits die Notwendigkeit der Einführung mehrerer Schwingungszahlen plausibel machen, wie

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1) A. Einstein, Ann. d. Phys. **22.** p. 180. 1907.
2) M. Planck, Wärmestrahlung p. 157. Leipzig 1906.
3) W. Nernst u. Lindemann, Zeitschr. f. Elektrochemie p. 817 1911; Berl. Ber. p. 26. 1910.

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11. *Zur Elektronentheorie der Metalle; von P. Drude.*

I. Teil.

Dass die Elektricitätsleitung der Metalle ihrem Wesen nach nicht allzu verschieden von der der Elektrolyte sei, insofern der elektrische Strom durch den Transport kleiner elektrischer Teilchen bewirkt wird, ist eine Anschauung, welche von W. Weber zuerst ausgesprochen und später von Giese[1]) weiter durchgeführt ist. Ich will diese elektrischen Teilchen im Anschluss an neuere Bezeichnungen *Elektronen*, oder (um einen bequemeren Ausdruck zu haben) *elektrische Kerne*, oder auch kurz *Kerne* nennen. Den Ausdruck Corpuskeln oder Ionen möchte ich vermeiden, da mit beiden Ausdrücken die Anschauung verbunden ist, dass die elektrischen Teilchen auch eine gewisse, wenn auch sehr kleine ponderable Masse mit sich führen. Ich glaube, es ist zweckmässiger, wenn der Ausdruck „Ionen“ für die Aggregate elektrischer Kerne und ponderabler Masse reservirt bleibt, welche wir in den Elektrolyten antreffen.

Ob ein Elektron eine sehr kleine ponderable Masse mit sich führt, oder nicht, lassen wir vorläufig unentschieden. Ich will nur gleich hier bemerken, dass es durchaus nicht nötig ist, einem Elektron ponderable Masse beizulegen, um ihm trotzdem eine gewisse kinetische Energie seiner Bewegung zuzuschreiben und eine Trägheit für Bewegungsänderungen, wie sie z. B. aus den Ablenkungen der Kathodenstrahlen im Magnetfeld und aus den optischen Eigenschaften der Metalle hervorgeht. Da jedes bewegte Elektron einen elektrischen Strom repräsentirt, welcher eine gewisse Anzahl magnetischer Kraftlinien im umgebenden Aether erzeugt, so müssen bei Antrieben, welche Richtung und Grösse der Geschwindigkeit des Elektrons zu ändern suchen, entgegenstehende Kräfte einsetzen, welche durch die Veränderung der vom bewegten Elektron hervor-

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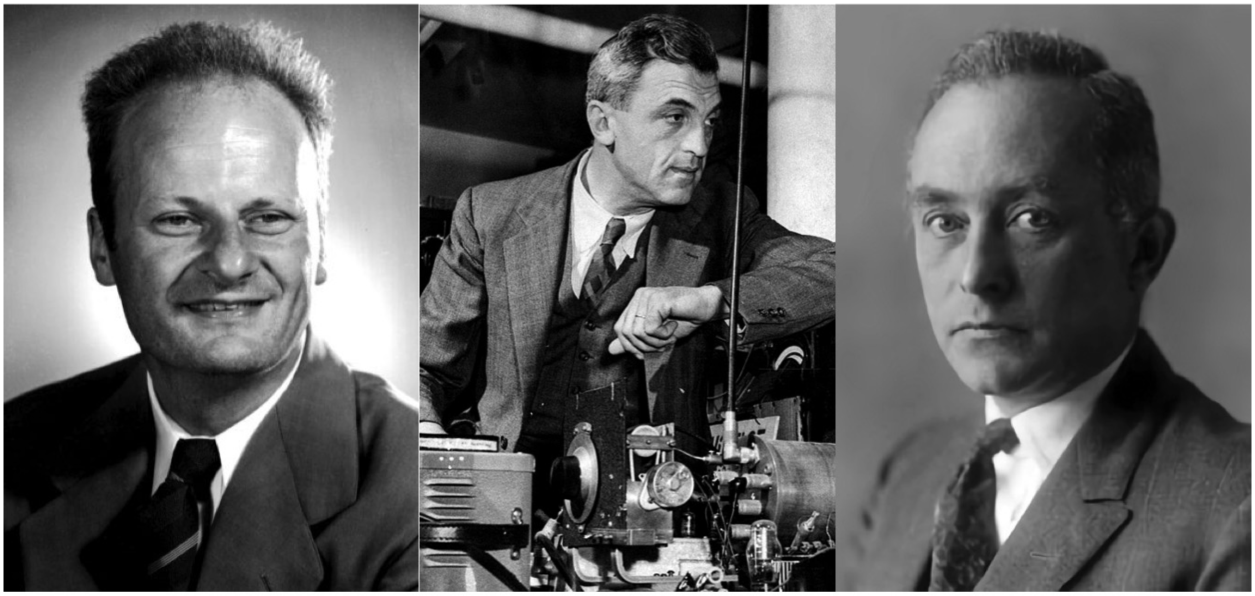
1) W. Giese, Wied. Ann. **37.** p. 576. 1889.

Figure 6.65: Scientists from the German-speaking world pioneered solid state physics, as illustrated by these examples of some of their original papers [Wiedemann and Franz 1853; Debye and Sommerfeld 1913; Debye 1912; Drude 1900].

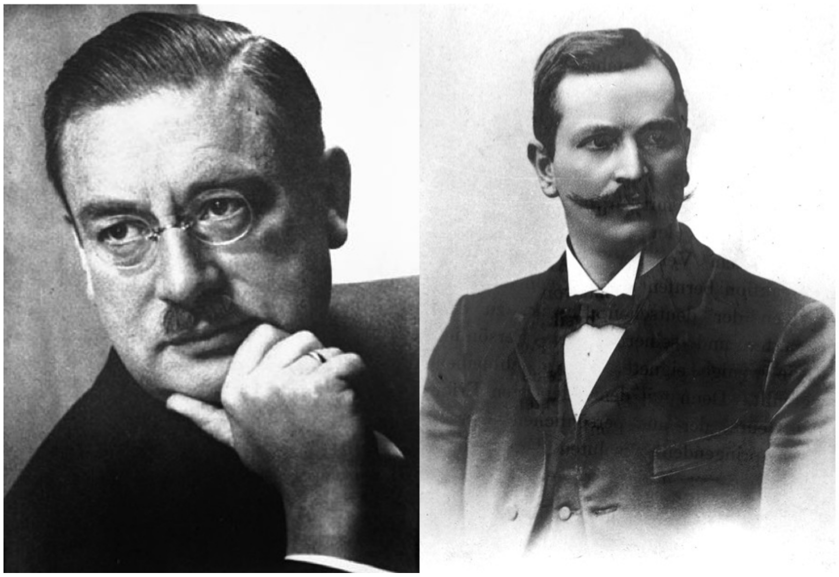
Solid state physics



Hans Bethe (1906–2005)

Felix Bloch (1905–1983)

Max Born (1882–1970)



Peter Debye (1884–1966)

Paul Drude (1863–1906)

Rudolph Franz (1826–1902)

Figure 6.66: Some creators who made major contributions to solid state physics include Hans Bethe, Felix Bloch, Max Born, Peter Debye, Paul Drude, and Rudolph Franz.

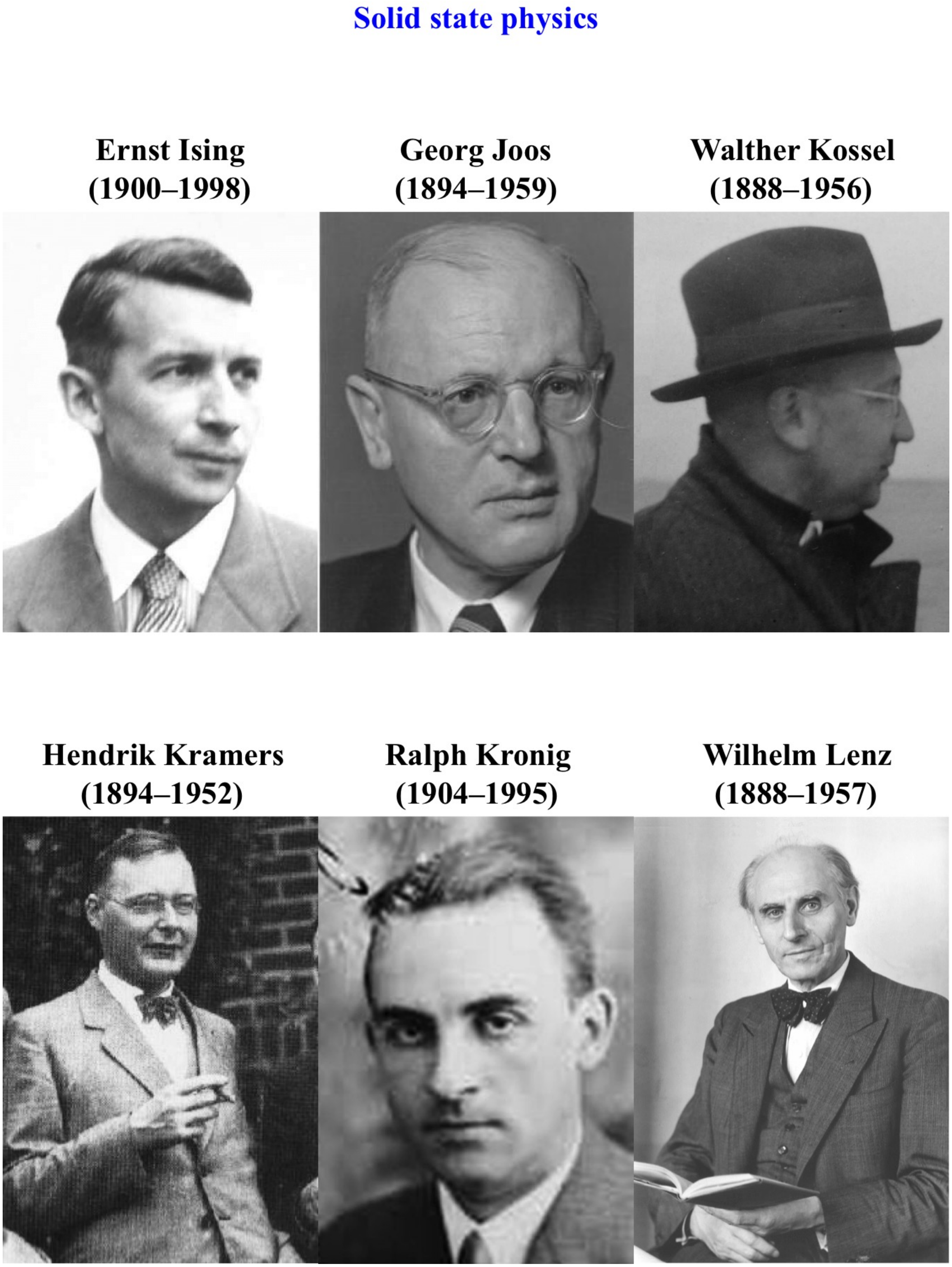

Solid state physics
Ernst Ising (1900–1998)
Georg Joos (1894–1959)
Walther Kossel (1888–1956)
Hendrik Kramers (1894–1952)
Ralph Kronig (1904–1995)
Wilhelm Lenz (1888–1957)

Figure 6.67: Other creators who made major contributions to solid state physics include Ernst Ising, Georg Joos, Walther Kossel, Hendrik Kramers, Ralph Kronig, and Wilhelm Lenz.

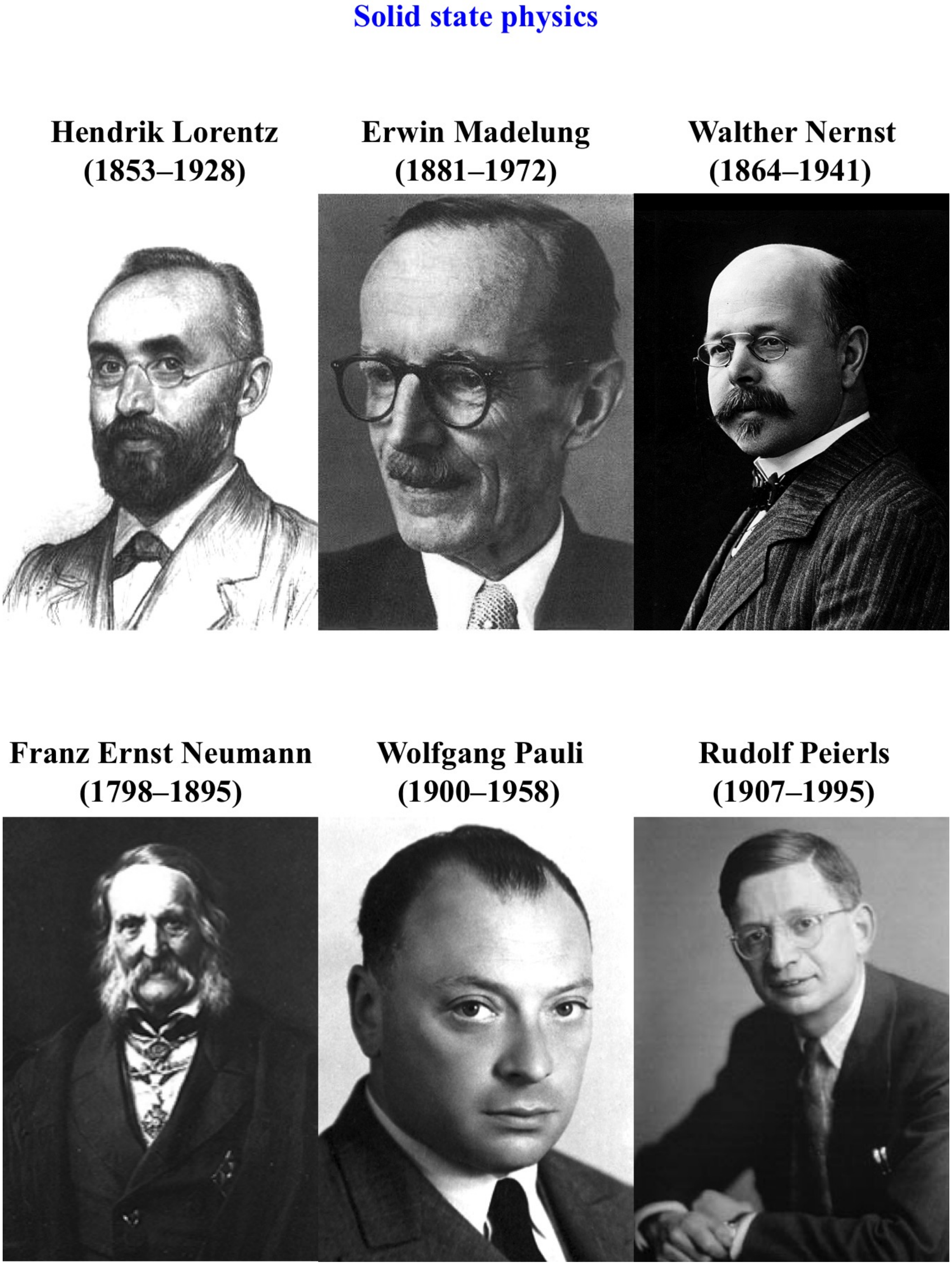

Solid state physics
Hendrik Lorentz (1853–1928)
Erwin Madelung (1881–1972)
Walther Nernst (1864–1941)
Franz Ernst Neumann (1798–1895)
Wolfgang Pauli (1900–1958)
Rudolf Peierls (1907–1995)

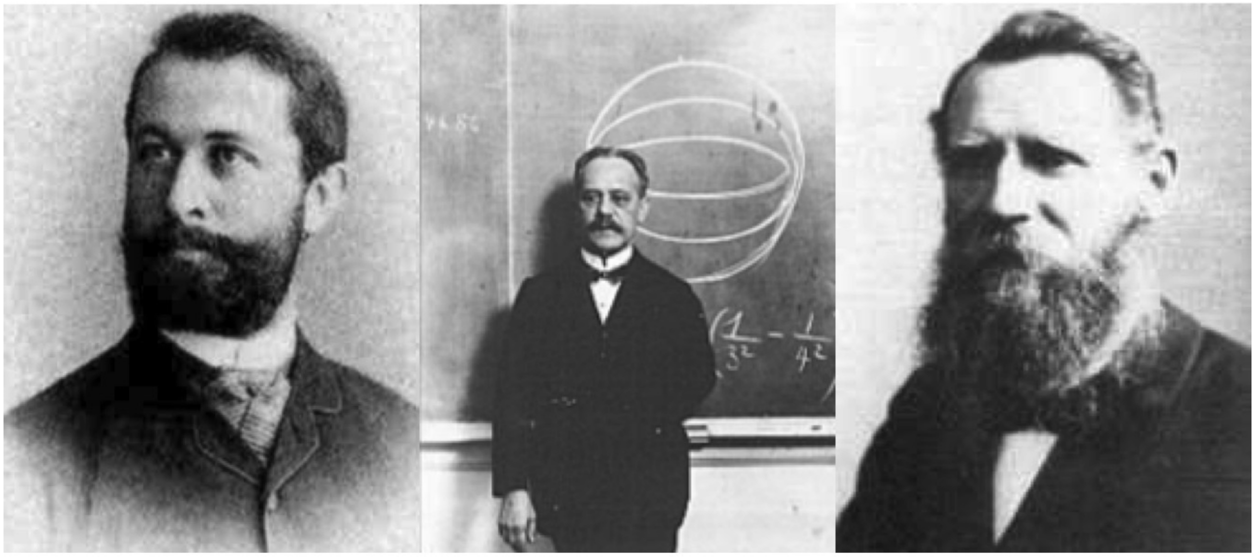
Figure 6.68: Other creators who made major contributions to solid state physics include Hendrik Lorentz, Erwin Madelung, Walther Nernst, Franz Ernst Neumann, Wolfgang Pauli, and Rudolf Peierls.

Solid state physics

Arthur Schoenflies
(1853–1928)

Arnold Sommerfeld
(1868–1951)

Woldemar Voigt
(1850–1919)



Gregory Wannier
(1911–1983)

Gustav Wiedemann
(1826–1899)

Eugene Wigner
(1902–1995)

Figure 6.69: Other creators who made major contributions to solid state physics include Arthur Schoenflies, Arnold Sommerfeld, Woldemar Voigt, Gregory Wannier, Gustav Wiedemann, and Eugene Wigner.

6.5.2 Semiconductor Materials and Devices

Harnessing solid state physics effects, especially those in semiconductors, led to the development of numerous microelectronic devices for various applications. Scientists from the greater German-speaking world took the lead in that area.

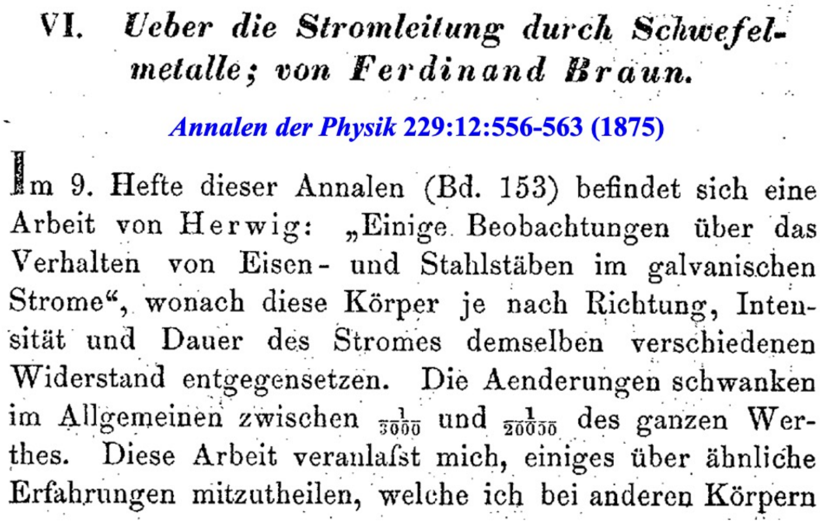
Karl Ferdinand Braun (German, 1850–1918) invented and demonstrated semiconductor diodes in 1874, using point contacts and crystals of metal sulfides for his first diodes (Fig. 6.70). Braun continued to experiment with and improve semiconductor diodes over the following years and ultimately harnessed them to develop radio systems. Braun also produced many other innovations in electronics, including oscilloscopes and phased array antennas. He won the Nobel Prize in Physics in 1909 for his radio-related research (p. 978).

In 1893, Julius Elster (German, 1854–1920) and Hans Geitel (German, 1855–1923) invented the semiconductor photoelectric cell, which could detect and measure the amount of light and produce a corresponding electrical output signal (Fig. 6.71). They continued to test photoelectric cells and devise applications for them for at least a decade, launching what became a large German industry. Elster and Geitel also made important discoveries on a wide variety of other topics in atmospheric physics, astronomy, nuclear physics, and other scientific areas.

In 1916, Jan Czochralski (Polish/German, 1885–1953) at the huge AEG electronics company developed a method for growing single, large, high-purity crystals of semiconductors or other materials (Fig. 6.72). The Czochralski method, as it became known, is now used worldwide to prepare semiconductor crystals, which are usually then sliced into wafers and chips.

Bernhard Gudden (German, 1892–1945) and Robert Pohl (German, 1884–1976) developed improved photoelectric cells and also electroluminescent semiconductor devices, the direct forerunners of light emitting diodes (LEDs), during the period 1919–1923 (pp. 1104, 1106). After that time, both Gudden and Pohl separately continued to conduct research on advanced semiconductor devices and microelectronics through World War II, including developing prototype transistors.

Karl Ferdinand Braun (1850–1918) invented semiconductor diodes (1874), improved radio transmitters and receivers (1897), cathode ray tubes and oscilloscopes (1897), phased array antennas (1905), etc.



VI. *Ueber die Stromleitung durch Schwefelmetalle; von Ferdinand Braun.*

***Annalen der Physik* 229:12:556-563 (1875)**

Im 9. Hefte dieser Annalen (Bd. 153) befindet sich eine Arbeit von Herwig: „Einige Beobachtungen über das Verhalten von Eisen- und Stahlstäben im galvanischen Strome“, wonach diese Körper je nach Richtung, Intensität und Dauer des Stromes demselben verschiedenen Widerstand entgegensetzen. Die Aenderungen schwanken im Allgemeinen zwischen $\frac{1}{3000}$ und $\frac{1}{20000}$ des ganzen Werthes. Diese Arbeit veranlaſst mich, einiges über ähnliche Erfahrungen mitzutheilen, welche ich bei anderen Körpern

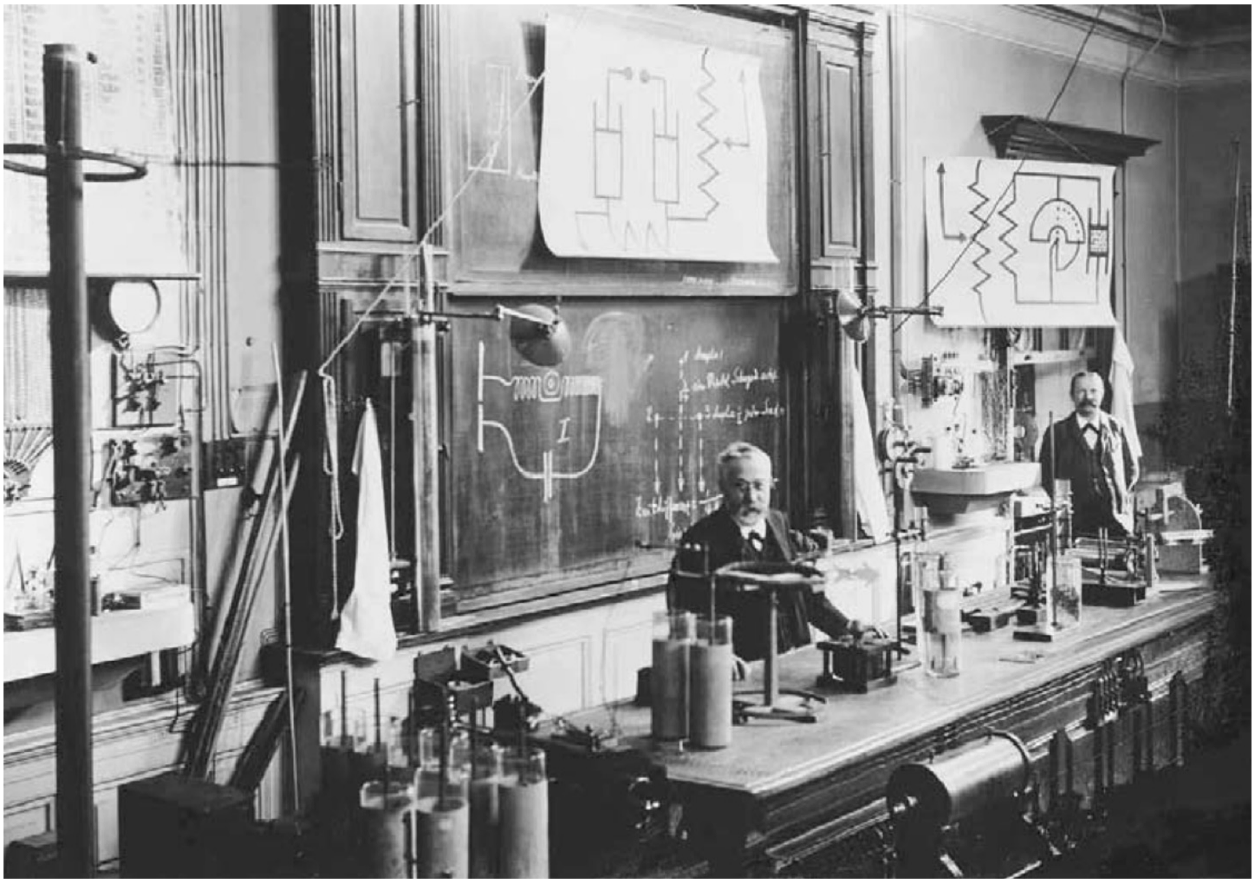
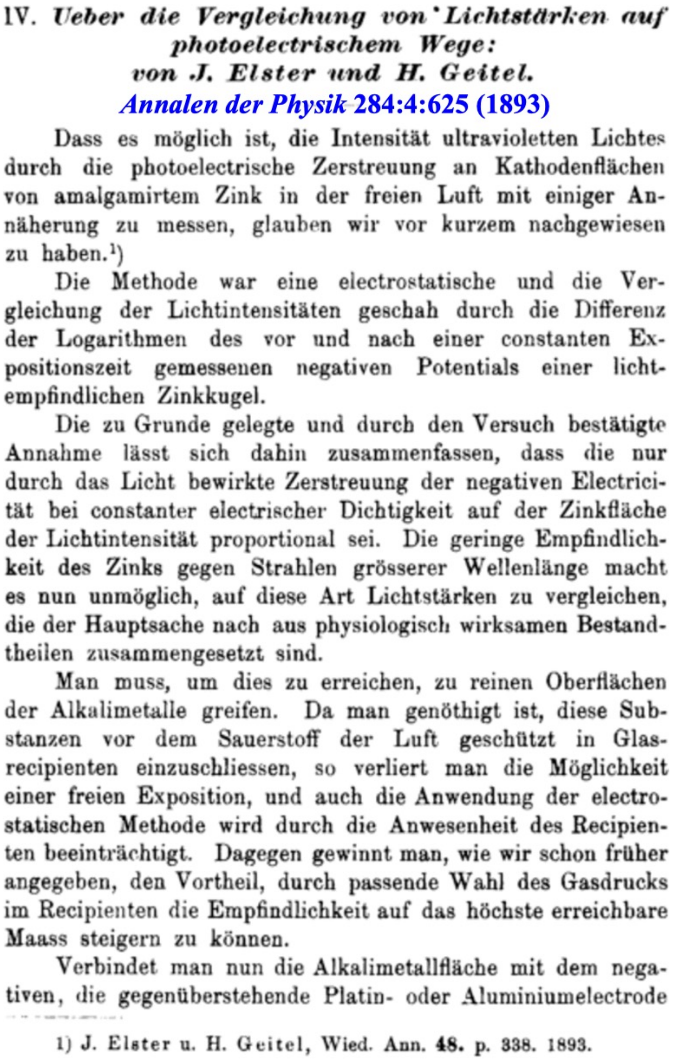


Figure 6.70: Karl Ferdinand Braun invented semiconductor diodes (1874), improved radio transmitters and receivers (1897), cathode ray tubes and oscilloscopes (1897), phased array antennas (1905), etc.

Julius Elster (left, 1854–1920) and Hans Geitel (right, 1855–1923) invented the photoelectric cell (1893)



IV. ***Ueber die Vergleichung von Lichtstärken auf photoelectrischem Wege;***
von J. Elster und H. Geitel.
Annalen der Physik 284:4:625 (1893)

Dass es möglich ist, die Intensität ultravioletten Lichtes durch die photoelectrische Zerstreuung an Kathodenflächen von amalgamirtem Zink in der freien Luft mit einiger Annäherung zu messen, glauben wir vor kurzem nachgewiesen zu haben.[1])

Die Methode war eine electrostatische und die Vergleichung der Lichtintensitäten geschah durch die Differenz der Logarithmen des vor und nach einer constanten Expositionszeit gemessenen negativen Potentials einer lichtempfindlichen Zinkkugel.

Die zu Grunde gelegte und durch den Versuch bestätigte Annahme lässt sich dahin zusammenfassen, dass die nur durch das Licht bewirkte Zerstreuung der negativen Electricität bei constanter electrischer Dichtigkeit auf der Zinkfläche der Lichtintensität proportional sei. Die geringe Empfindlichkeit des Zinks gegen Strahlen grösserer Wellenlänge macht es nun unmöglich, auf diese Art Lichtstärken zu vergleichen, die der Hauptsache nach aus physiologisch wirksamen Bestandtheilen zusammengesetzt sind.

Man muss, um dies zu erreichen, zu reinen Oberflächen der Alkalimetalle greifen. Da man genöthigt ist, diese Substanzen vor dem Sauerstoff der Luft geschützt in Glasrecipienten einzuschliessen, so verliert man die Möglichkeit einer freien Exposition, und auch die Anwendung der electrostatischen Methode wird durch die Anwesenheit des Recipienten beeinträchtigt. Dagegen gewinnt man, wie wir schon früher angegeben, den Vortheil, durch passende Wahl des Gasdrucks im Recipienten die Empfindlichkeit auf das höchste erreichbare Maass steigern zu können.

Verbindet man nun die Alkalimetallfläche mit dem negativen, die gegenüberstehende Platin- oder Aluminiumelectrode

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1) J. Elster u. H. Geitel, Wied. Ann. **48.** p. 338. 1893.

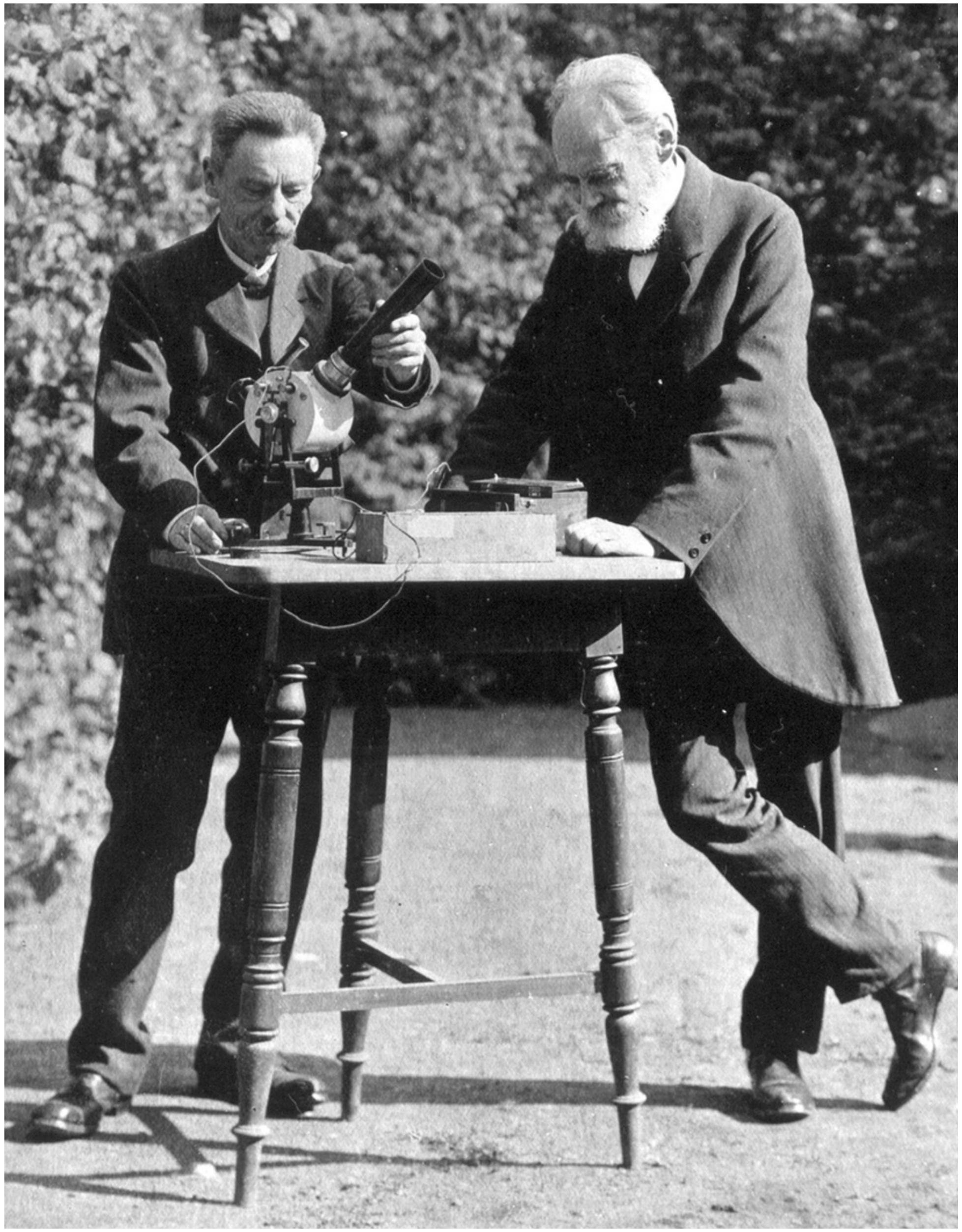
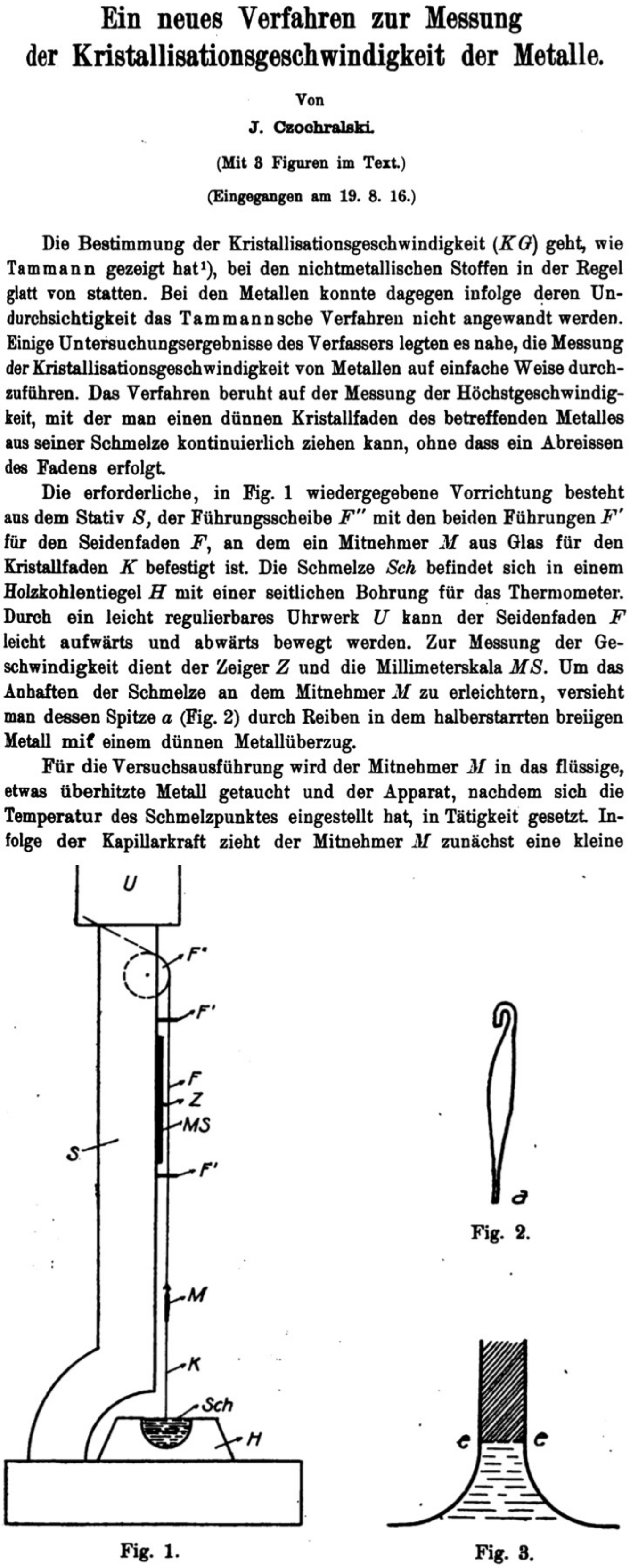


Figure 6.71: Julius Elster and Hans Geitel invented the photoelectric cell in 1893.

Jan Czochralski (1885–1953)
Method for growing semiconductor crystals/wafers (1916)



Ein neues Verfahren zur Messung der Kristallisationsgeschwindigkeit der Metalle.

Von

J. Czochralski.

(Mit 3 Figuren im Text.)

(Eingegangen am 19. 8. 16.)

Die Bestimmung der Kristallisationsgeschwindigkeit (*KG*) geht, wie Tammann gezeigt hat[1]), bei den nichtmetallischen Stoffen in der Regel glatt von statten. Bei den Metallen konnte dagegen infolge deren Undurchsichtigkeit das Tammannsche Verfahren nicht angewandt werden. Einige Untersuchungsergebnisse des Verfassers legten es nahe, die Messung der Kristallisationsgeschwindigkeit von Metallen auf einfache Weise durchzuführen. Das Verfahren beruht auf der Messung der Höchstgeschwindigkeit, mit der man einen dünnen Kristallfaden des betreffenden Metalles aus seiner Schmelze kontinuierlich ziehen kann, ohne dass ein Abreissen des Fadens erfolgt.

Die erforderliche, in Fig. 1 wiedergegebene Vorrichtung besteht aus dem Stativ *S*, der Führungsscheibe F'' mit den beiden Führungen F' für den Seidenfaden *F*, an dem ein Mitnehmer *M* aus Glas für den Kristallfaden *K* befestigt ist. Die Schmelze *Sch* befindet sich in einem Holzkohlentiegel *H* mit einer seitlichen Bohrung für das Thermometer. Durch ein leicht regulierbares Uhrwerk *U* kann der Seidenfaden *F* leicht aufwärts und abwärts bewegt werden. Zur Messung der Geschwindigkeit dient der Zeiger *Z* und die Millimeterskala *MS*. Um das Anhaften der Schmelze an dem Mitnehmer *M* zu erleichtern, versieht man dessen Spitze *a* (Fig. 2) durch Reiben in dem halberstarrten breiigen Metall mit einem dünnen Metallüberzug.

Für die Versuchsausführung wird der Mitnehmer *M* in das flüssige, etwas überhitzte Metall getaucht und der Apparat, nachdem sich die Temperatur des Schmelzpunktes eingestellt hat, in Tätigkeit gesetzt. Infolge der Kapillarkraft zieht der Mitnehmer *M* zunächst eine kleine

Fig. 1.

Fig. 2.

Fig. 3.

Figure 6.72: Jan Czochralski at AEG developed a method for growing semiconductor crystals and wafers in 1916.

6.5.3 Transistors

According to official histories, the first transistor was invented at Bell Laboratories in late 1947 and early 1948 by John Bardeen (American, 1908–1991), Walter Brattain (American, 1902–1987), and William Shockley (American, 1910–1989). However, there is significant evidence that at least 12 different groups of German-speaking scientists may have invented transistors earlier:

1. Julius Edgar Lilienfeld (Austrian, 1882–1963) invented an improved X-ray tube in 1912, the field effect transistor in 1925, and an improved electrolytic capacitor in 1931, as shown on pp. 1084–1052 and 2657–2677. Lilienfeld filed several patent applications on his field effect transistor during the period 1925–1928. The great level of detail in those applications regarding the production and performance of such transistors suggests that he built and tested them [Arns 1998; Crawford 1991], although exactly what results he achieved are not clear from currently available documents. Much later, Bell Laboratories secretly built functioning devices based directly on Lilienfeld's patents, lending further support to the view that the patents were based on Lilienfeld's own successful experimentation [Arns 1998; Shockley and Pearson 1948]. In the 1920s Lilienfeld moved to the United States, where he married an American woman. It appears that he was unsuccessful in finding sufficient support for his transistor idea in the United States. In the 1930s Lilienfeld and his wife moved to the island of Saint Thomas in the Caribbean, where they lived the rest of their lives.

2. Oskar Heil (German, 1908–1994) filed a detailed patent application on field effect transistors in 1934; see pp. 1054 and 2679–2681. Currently it is unclear just what experimental work Heil may have done on the concept either before or after filing the patent application, or whether other German-speaking scientists may have taken up the ideas proposed in the application.

3. Gilles Holst (Dutch, 1886–1968) and Willem Christiaan van Geel (Dutch, 1895–1967) filed a German patent application on transistors in 1935. See pp. 1056–1057 and 2686–2689. Holst was the research director at the Philips Eindhoven laboratory [Van Delft 2014], and van Geel was an expert there on metal and semiconductor materials. Both were nominated for the Nobel Prize in Physics but never won.[12] Holst was also one of the inventors of the sodium vapor lamp in 1932 (p. 971). Philips Eindhoven was closely tied to the rest of the predominantly German-speaking research world from the late nineteenth century through World War II, including work on electronics, communications, and directed energy beams.[13] More archival research is needed to determine how far the work of Holst and van Geel got by 1945, or how much it was influenced by or influenced transistor-related work by other research groups.

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[12] https://www.nobelprize.org/nomination/archive/show.php?id=4874

https://www.nobelprize.org/nomination/archive/show.php?id=4936

[13] See for example: CIOS III-1; CIOS VI-26, 27; CIOS X-13; CIOS XI-10; CIOS XII-22.

4. Rudolf Hilsch (German, 1903–1972) and Robert Pohl demonstrated a proof-of-concept point-contact transistor in 1938 [Hilsch and Pohl 1938]. As shown on pp. 1058 and 2691–2692, like a modern transistor, this solid-state semiconductor device had three electrodes, with the current flow into the middle electrode (the base, in modern terminology) controlling and greatly amplified by the much larger current flow between the other two electrodes. For the 1938 experiments, that signal amplification was approximately a factor of 20. These results were extremely impressive, but the reason they are best described as "proof of concept" is that they were obtained in a material (a potassium bromide crystal) that became a good semiconductor only at a very high temperature (490^{o}C) and voltages (100–150 Volts), which would not be practical for use in normal electronic circuits.

Hilsch recognized those limitations and promptly proposed that the results be replicated by modifying existing room-temperature semiconductor diodes to add a third electrode for the base [Hilsch 1939]:

> Durch diese Messung ist zum erstenmal gezeigt worden, daß man auch in festen Körpern Ströme steuern kann. Die Trägheit der Ströme in diesem "großen" Modell ist naturgemäß groß. Es ist jetzt nur eine Aufgabe der Technik, auch in den dünnen Sperrschichten der technischen Gleichrichter das Steuergitter unterzubringen. Wenn die Lösung dieser Aufgabe gelingt, kann der Dreielektroden-Kristall auch technisch neben dem Dreielektroden-Rohr seine Bedeutung erhalten.

> This measurement has shown for the first time that it is also possible to control currents in solid bodies. The inertia of the currents in this "large" model is naturally large. It is now only a technical task to add the control grid in the thin barrier layers of engineering rectifiers. If the solution to this problem is successful, the three-electrode crystal can also gain technical significance alongside the three-electrode tube.

From available documentation, it is unclear exactly what projects Hilsch worked on between 1939 and the post-war period. Given his determination to replicate the transistor amplifier results in a more practical semiconductor device, and given the extensive wartime work on new and improved semiconductor devices, it seems likely that he would have carried his transistor work further, or collaborated with other scientists to do so. In any event, the 1938 Hilsch and Pohl paper and the 1939 Hilsch paper were published in physics journals that were highly regarded and widely read in the German-speaking world, so they would have encouraged many other scientists (such as those listed below) to try to replicate and extend that work.

5. Erich Habann (German, 1892–1968) filed a very detailed patent application on point-contact transistors, their fabrication, and use in 1942 (pp. 1060 and 2695–2699). The level of detail suggests that Habann may well have already produced and demonstrated such transistors at his Hessenwinkel laboratory. Although documentation on his results is not currently available, it is known that Habann worked on a number of secretive research projects during the war and was well funded by the German military [Nagel 2006].

6. Walter Schottky (Swiss/German, 1886–1976) published detailed analyses of semiconductor properties necessary for transistors in 1942 [Handel 1999]. See pp. 1062 and 2701–2709. All of Schottky's papers were seized by the United States in 1945 and never returned to him or publicly disclosed.

7. Heinrich Welker (German, 1912–1981) and Herbert Mataré (German, 1912–2011) began developing a point-contact transistor in Germany during the war, filed a detailed patent application based on that wartime work on 6 April 1945, and publicly announced their transistor in 1948 in France.[14] See pp. 1064 and 2711–2720.

8. Erwin Weise (German?, 19??–19??) admitted to Allied investigators that he "had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes" to create "electronic amplifiers without vacuum" (pp. 1066 and 2722–2733).

9. Frank Rose (German?, 19??–19??), Eberhard Spenke (German, 1905–1992), and Erich Waldkötter (German?, 19??–19??) filed detailed patent applications on transistors in 1949, as shown on pp. 1068 and 2735–2744. Because of the extreme political and financial restrictions on conducting research in Germany after the war, it seems likely that their patent applications were based on wartime work [Handel 1999]. Indeed, large numbers of patent applications on wartime inventions were filed in 1949 when the West German patent office opened.

10. Karl Seiler (German, 1910–1991) and Paul Ludwig Günther (German, 1892–1969) developed methods for designing and fabricating silicon semiconductor devices throughout the war and into the postwar period (pp. 1070 and 2746–2754). Their work was applied to transistors after the war, and it may have been used for that purpose during the war [Handel 1999].

11. Helmar Frank (Moravian, 1919–2015) and Jan Tauc (Bohemian, 1922–2010) worked in very large, secret, German-run laboratories in Tannwald (now Tanvald, Czech Republic) during the war [Lojek 2007]. When Czechoslovakia salvaged what was left of those laboratories and restarted them after the war, one of the first actions that Frank and Tauc carried out was to produce and demonstrate transistors. Those postwar Czech transistors were based at least in part, and quite possibly entirely, on wartime German work (pp. 1072, 2756–2757, 3983, 5503, 5513, and 5549). Both Frank and Tauc continued to develop semiconductor and microelectronics technologies in Czechoslovakia for many years. Frank was interrogated by the United States in 1945 regarding his knowledge of advanced electronics technologies. Tauc eventually moved to the United States.

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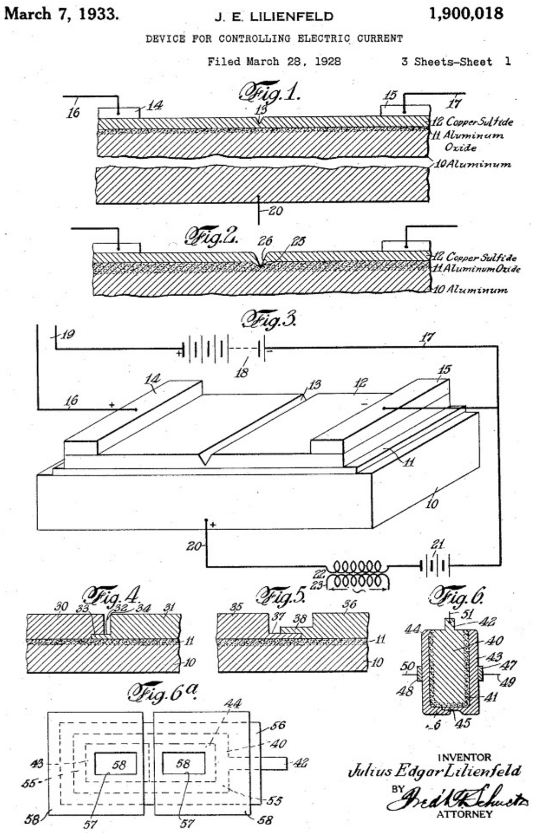
[14] Handel 1999; Ringer and Welker 1948; Riordan 2005; Van Dormael 2004, 2009, 2012.

12. During the war, Bernhard Gudden (German, 1892–1945) and Kurt Lehovec (Bohemian/Austrian/Czech, 1918–2012) ran a secretive and well-funded group that was developing advanced semiconductor devices at Charles University in Prague [Lojek 2007]. After the war, Gudden refused to assist Russian or Russian-backed forces and died in a Czech prison. Lehovec was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits. His first U.S. patent application on transistors covered a design that had several advantages over the transistors from Bell Laboratories, and that may well have been based on wartime work that he and Gudden had been conducting. See pp. 1074, 1097, 2757–2763, 2818–2832, and 2895–2910.

In addition to these 12 groups, were there any other German-speaking groups developing transistors, for example at laboratories run by AEG, Askania, Blaupunkt, Fernseh, Loewe Radio, C. Lorenz, Philips, the Reichspost, Siemens, the SS, Telefunken, various universities, or other laboratories in Germany, Austria, Czech territory, Polish territory, or elsewhere? Much more archival research is needed.

Transistors (1)
Julius Edgar Lilienfeld
(1882–1963) invented the
field effect transistor (1925)



March 7, 1933. J. E. LILIENFELD 1,900,018

DEVICE FOR CONTROLLING ELECTRIC CURRENT

Filed March 28, 1928 3 Sheets-Sheet 1

Fig.1.
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12 Copper Sulfide
11 Aluminum Oxide
10 Aluminum
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Fig.2.
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12 Copper Sulfide
11 Aluminum Oxide
10 Aluminum
Fig.3.
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Fig.4
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Fig.5
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Fig.6.
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Fig.6a.
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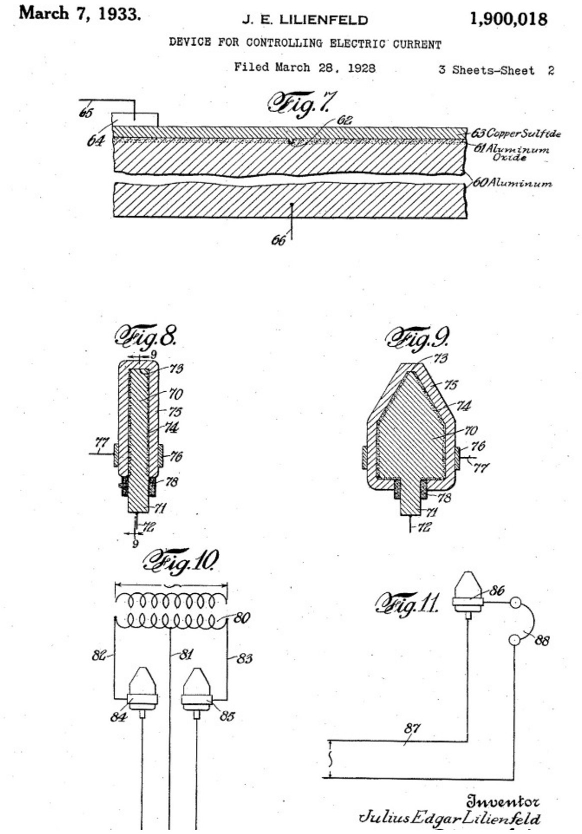
INVENTOR
Julius Edgar Lilienfeld
BY
ATTORNEY



March 7, 1933. J. E. LILIENFELD 1,900,018

DEVICE FOR CONTROLLING ELECTRIC CURRENT

Filed March 28, 1928 3 Sheets-Sheet 2

Fig.7.
65
62
64
63 Copper Sulfide
61 Aluminum Oxide
60 Aluminum
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Fig.8.
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Fig.9.
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Fig.10.
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Fig.11.
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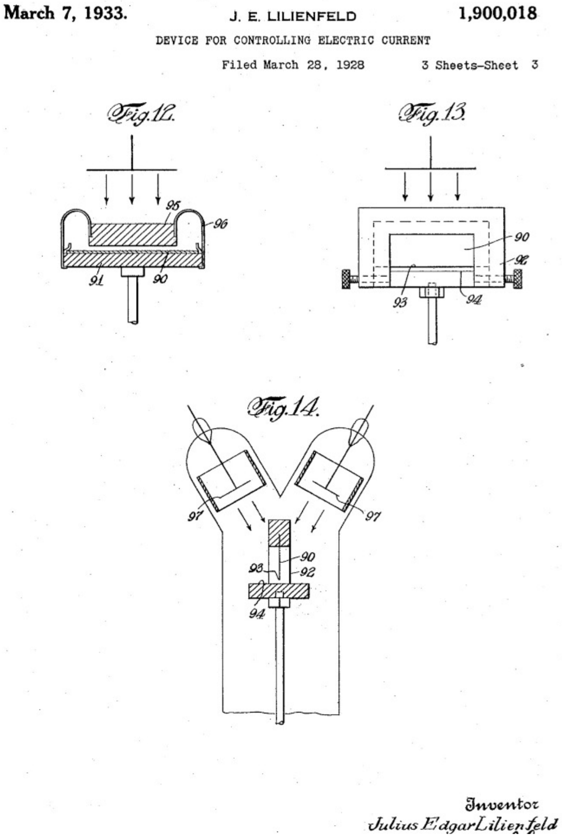
Inventor
Julius Edgar Lilienfeld



March 7, 1933. J. E. LILIENFELD 1,900,018

DEVICE FOR CONTROLLING ELECTRIC CURRENT

Filed March 28, 1928 3 Sheets-Sheet 3

Fig.12.
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Fig.13.
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Fig.14.
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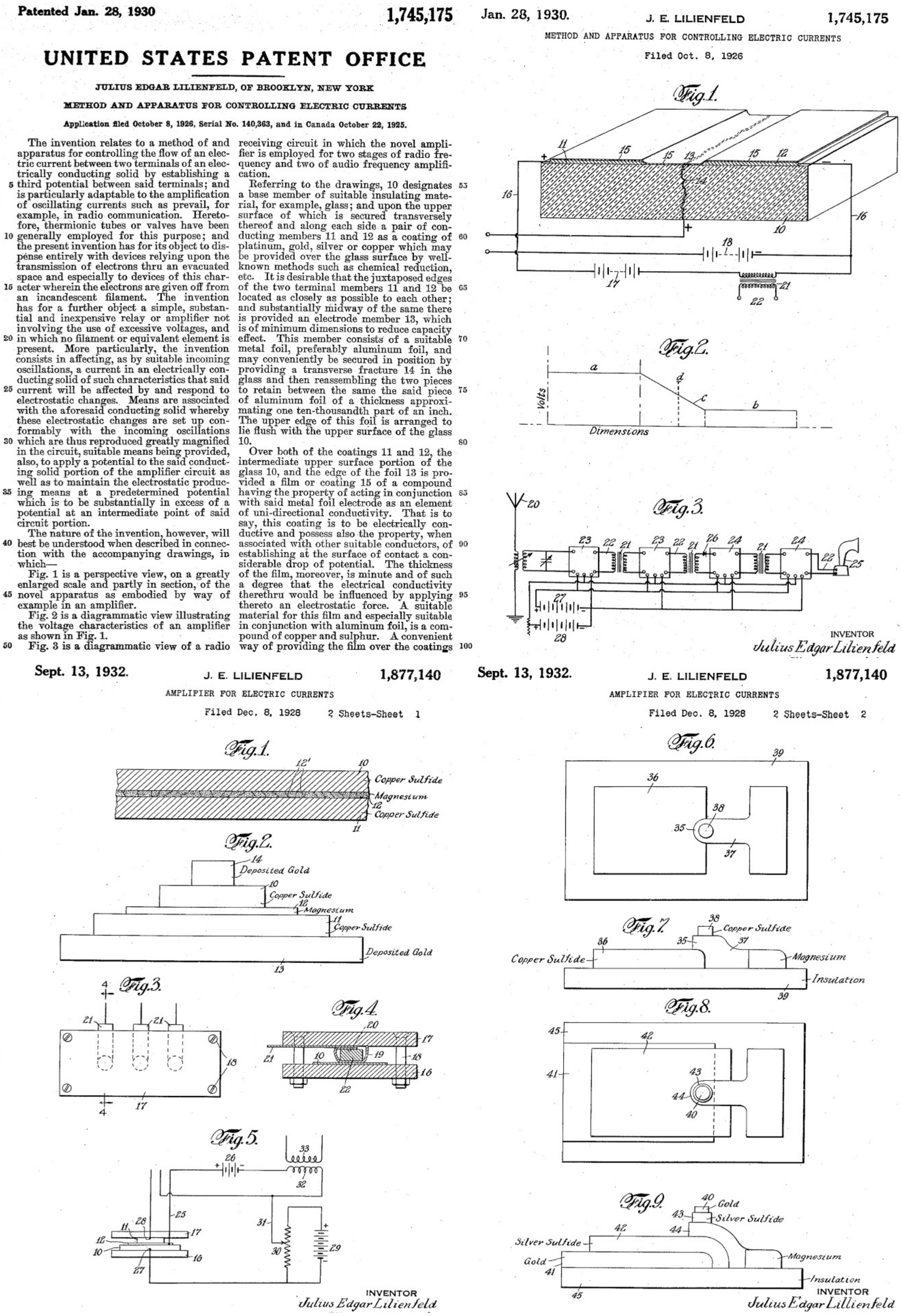
Inventor
Julius Edgar Lilienfeld

Figure 6.73: Julius Edgar Lilienfeld invented the field effect transistor in 1925 and filed a number of highly detailed patent applications on it.

Transistors (1)

Julius Edgar Lilienfeld (1882–1963) invented the field effect transistor (1925)



Patented Jan. 28, 1930 **1,745,175**

UNITED STATES PATENT OFFICE

JULIUS EDGAR LILIENFELD, OF BROOKLYN, NEW YORK

METHOD AND APPARATUS FOR CONTROLLING ELECTRIC CURRENTS

Application filed October 8, 1926, Serial No. 140,363, and in Canada October 22, 1925.

The invention relates to a method of and apparatus for controlling the flow of an electric current between two terminals of an electrically conducting solid by establishing a third potential between said terminals; and is particularly adaptable to the amplification of oscillating currents such as prevail, for example, in radio communication. Heretofore, thermionic tubes or valves have been generally employed for this purpose; and the present invention has for its object to dispense entirely with devices relying upon the transmission of electrons thru an evacuated space and especially to devices of this character wherein the electrons are given off from an incandescent filament. The invention has for a further object a simple, substantial and inexpensive relay or amplifier not involving the use of excessive voltages, and in which no filament or equivalent element is present. More particularly, the invention consists in affecting, as by suitable incoming oscillations, a current in an electrically conducting solid of such characteristics that said current will be affected by and respond to electrostatic changes. Means are associated with the aforesaid conducting solid whereby these electrostatic changes are set up conformably with the incoming oscillations which are thus reproduced greatly magnified in the circuit, suitable means being provided, also, to apply a potential to the said conducting solid portion of the amplifier circuit as well as to maintain the electrostatic producing means at a predetermined potential which is to be substantially in excess of a potential at an intermediate point of said circuit portion.

The nature of the invention, however, will best be understood when described in connection with the accompanying drawings, in which—

Fig. 1 is a perspective view, on a greatly enlarged scale and partly in section, of the novel apparatus as embodied by way of example in an amplifier.

Fig. 2 is a diagrammatic view illustrating the voltage characteristics of an amplifier as shown in Fig. 1.

Fig. 3 is a diagrammatic view of a radio receiving circuit in which the novel amplifier is employed for two stages of radio frequency and two of audio frequency amplification.

Referring to the drawings, 10 designates a base member of suitable insulating material, for example, glass; and upon the upper surface of which is secured transversely thereof and along each side a pair of conducting members 11 and 12 as a coating of platinum, gold, silver or copper which may be provided over the glass surface by well-known methods such as chemical reduction, etc. It is desirable that the juxtaposed edges of the two terminal members 11 and 12 be located as closely as possible to each other; and substantially midway of the same there is provided an electrode member 13, which is of minimum dimensions to reduce capacity effect. This member consists of a suitable metal foil, preferably aluminum foil, and may conveniently be secured in position by providing a transverse fracture 14 in the glass and then reassembling the two pieces to retain between the same the said piece of aluminum foil of a thickness approximating one ten-thousandth part of an inch. The upper edge of this foil is arranged to lie flush with the upper surface of the glass 10.

Over both of the coatings 11 and 12, the intermediate upper surface portion of the glass 10, and the edge of the foil 13 is provided a film or coating 15 of a compound having the property of acting in conjunction with said metal foil electrode as an element of uni-directional conductivity. That is to say, this coating is to be electrically conductive and possess also the property, when associated with other suitable conductors, of establishing at the surface of contact a considerable drop of potential. The thickness of the film, moreover, is minute and of such a degree that the electrical conductivity therethru would be influenced by applying thereto an electrostatic force. A suitable material for this film and especially suitable in conjunction with aluminum foil, is a compound of copper and sulphur. A convenient way of providing the film over the coatings

Jan. 28, 1930. J. E. LILIENFELD 1,745,175

METHOD AND APPARATUS FOR CONTROLLING ELECTRIC CURRENTS

Filed Oct. 8, 1926

INVENTOR
Julius Edgar Lilienfeld

Sept. 13, 1932. J. E. LILIENFELD 1,877,140

AMPLIFIER FOR ELECTRIC CURRENTS

Filed Dec. 8, 1928 2 Sheets-Sheet 1

INVENTOR
Julius Edgar Lilienfeld

Sept. 13, 1932. J. E. LILIENFELD 1,877,140

AMPLIFIER FOR ELECTRIC CURRENTS

Filed Dec. 8, 1928 2 Sheets-Sheet 2

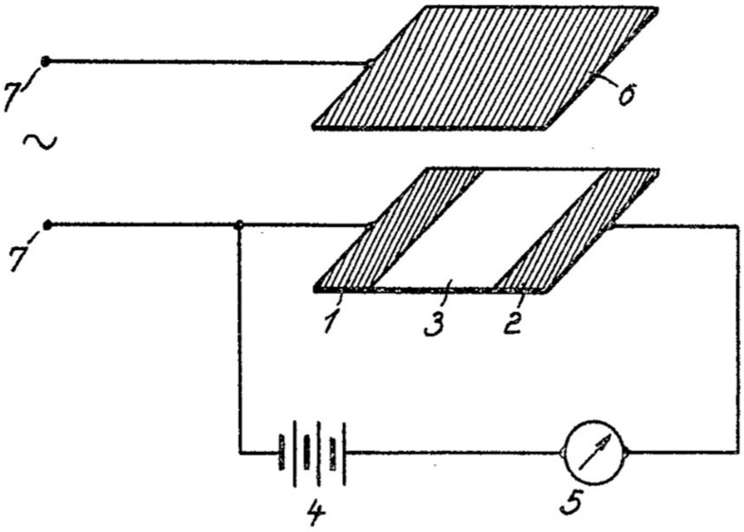
INVENTOR
Julius Edgar Lillienfeld

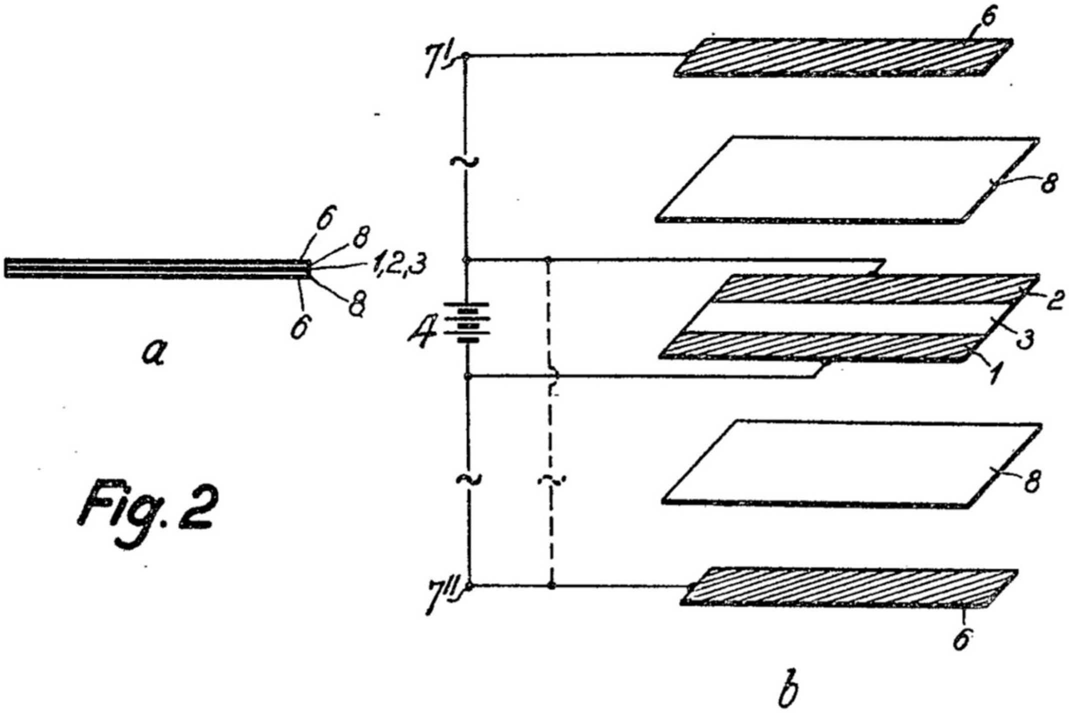
Figure 6.74: Julius Edgar Lilienfeld invented the field effect transistor in 1925 and filed a number of highly detailed patent applications on it.

Transistors (2)

Oskar Heil (1908–1994) filed a patent application on field effect transistors (1934)

Fig. 1

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4
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3
1
8
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7''
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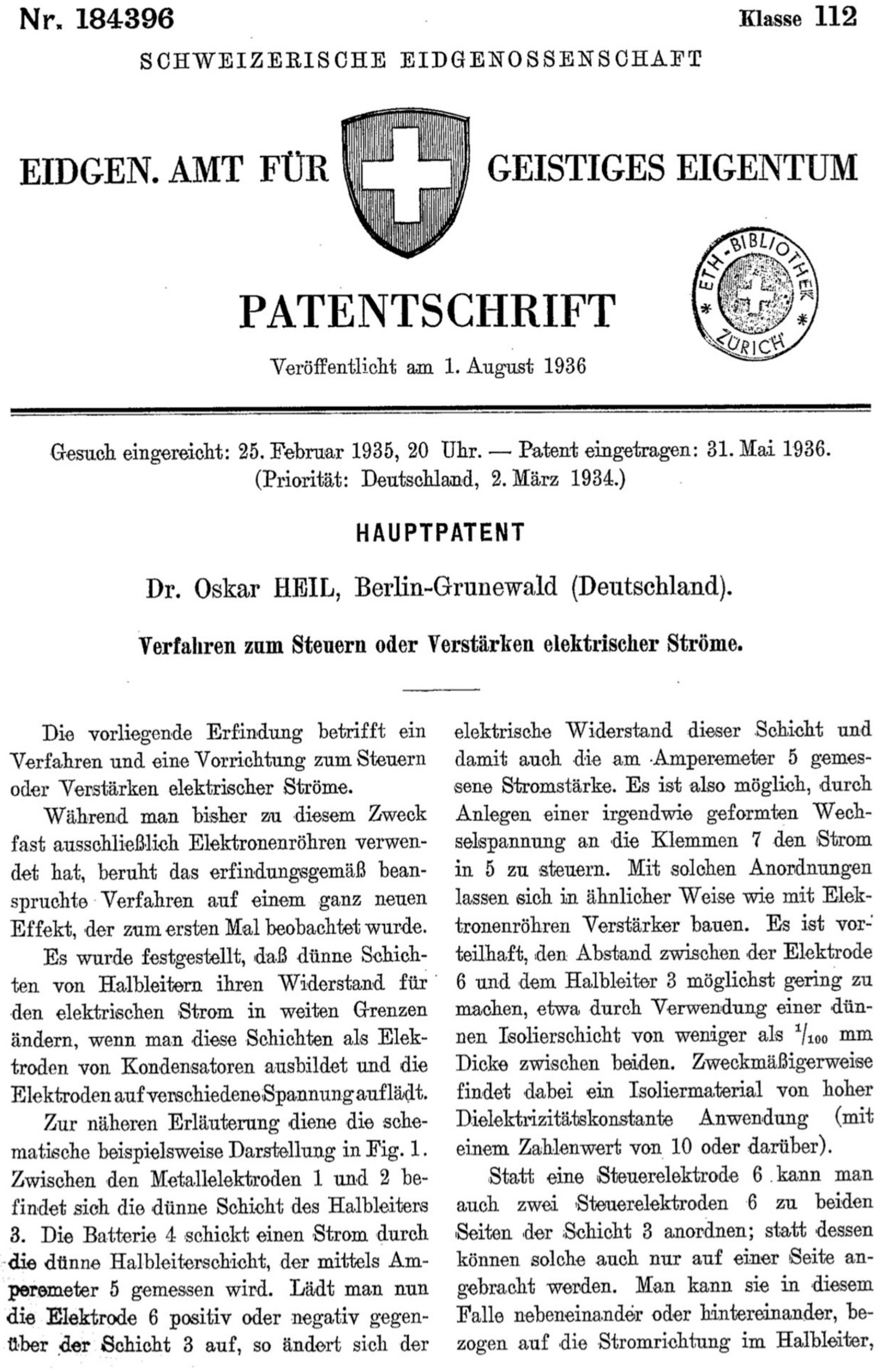
b

Fig. 2

Figure 6.75: Oskar Heil filed a detailed patent application on field effect transistors in 1934.

Transistors (2)

Oskar Heil (1908–1994) filed a patent application on field effect transistors (1934)



Nr. 184396 Klasse 112

SCHWEIZERISCHE EIDGENOSSENSCHAFT

EIDGEN. AMT FÜR GEISTIGES EIGENTUM

PATENTSCHRIFT

ETH-BIBLIOTHEK ZÜRICH

Veröffentlicht am 1. August 1936

Gesuch eingereicht: 25. Februar 1935, 20 Uhr. — Patent eingetragen: 31. Mai 1936.
(Priorität: Deutschland, 2. März 1934.)

HAUPTPATENT

Dr. Oskar HEIL, Berlin-Grunewald (Deutschland).

Verfahren zum Steuern oder Verstärken elektrischer Ströme.

Die vorliegende Erfindung betrifft ein Verfahren und eine Vorrichtung zum Steuern oder Verstärken elektrischer Ströme.

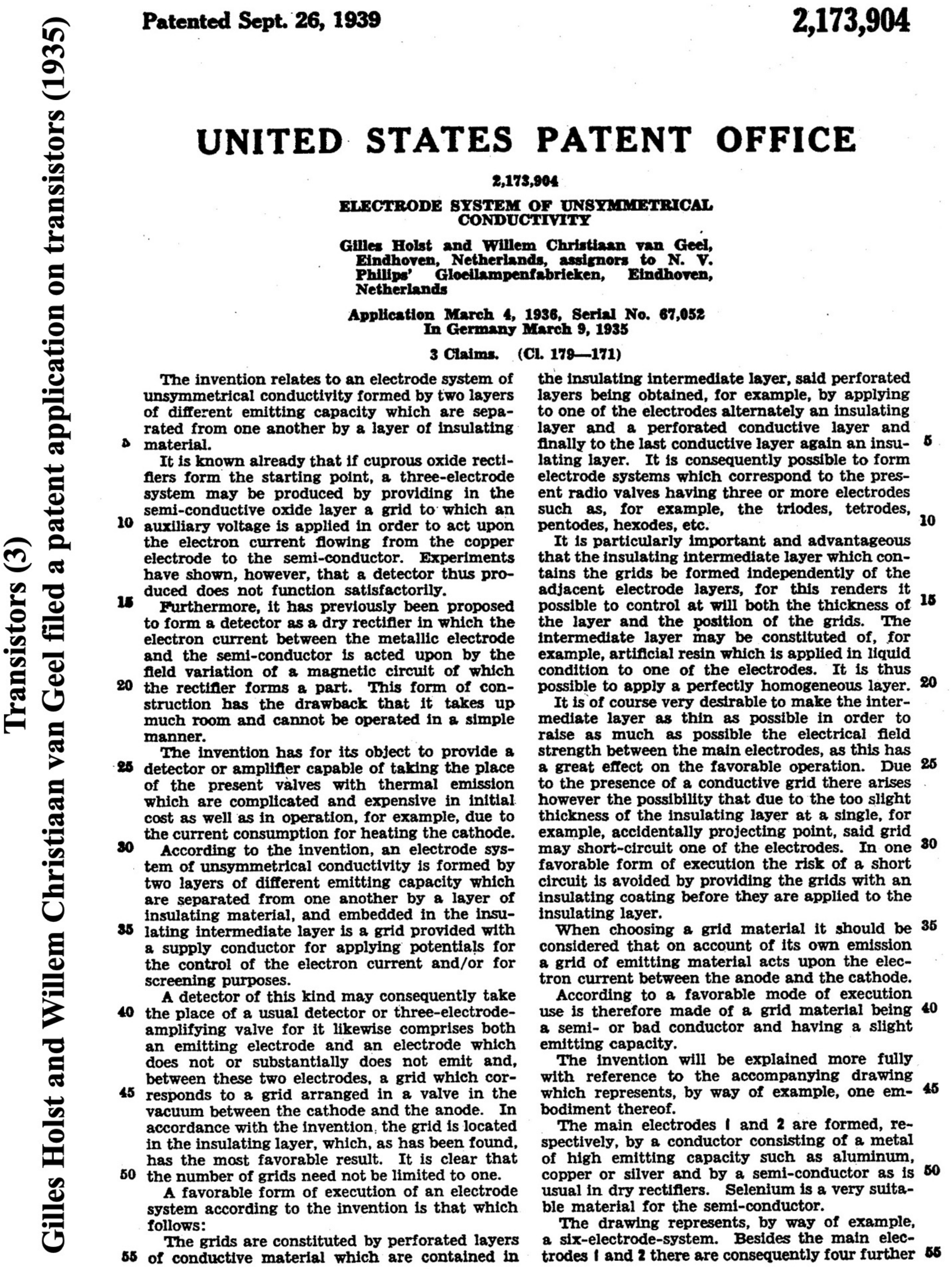
Während man bisher zu diesem Zweck fast ausschließlich Elektronenröhren verwendet hat, beruht das erfindungsgemäß beanspruchte Verfahren auf einem ganz neuen Effekt, der zum ersten Mal beobachtet wurde.

Es wurde festgestellt, daß dünne Schichten von Halbleitern ihren Widerstand für den elektrischen Strom in weiten Grenzen ändern, wenn man diese Schichten als Elektroden von Kondensatoren ausbildet und die Elektroden auf verschiedene Spannung auflädt.

Zur näheren Erläuterung diene die schematische beispielsweise Darstellung in Fig. 1. Zwischen den Metallelektroden 1 und 2 befindet sich die dünne Schicht des Halbleiters 3. Die Batterie 4 schickt einen Strom durch die dünne Halbleiterschicht, der mittels Amperemeter 5 gemessen wird. Lädt man nun die Elektrode 6 positiv oder negativ gegenüber der Schicht 3 auf, so ändert sich der elektrische Widerstand dieser Schicht und damit auch die am Amperemeter 5 gemessene Stromstärke. Es ist also möglich, durch Anlegen einer irgendwie geformten Wechselspannung an die Klemmen 7 den Strom in 5 zu steuern. Mit solchen Anordnungen lassen sich in ähnlicher Weise wie mit Elektronenröhren Verstärker bauen. Es ist vorteilhaft, den Abstand zwischen der Elektrode 6 und dem Halbleiter 3 möglichst gering zu machen, etwa durch Verwendung einer dünnen Isolierschicht von weniger als $^1/_{100}$ mm Dicke zwischen beiden. Zweckmäßigerweise findet dabei ein Isoliermaterial von hoher Dielektrizitätskonstante Anwendung (mit einem Zahlenwert von 10 oder darüber).

Statt eine Steuerelektrode 6 kann man auch zwei Steuerelektroden 6 zu beiden Seiten der Schicht 3 anordnen; statt dessen können solche auch nur auf einer Seite angebracht werden. Man kann sie in diesem Falle nebeneinander oder hintereinander, bezogen auf die Stromrichtung im Halbleiter, be-

Figure 6.76: Oskar Heil filed a detailed patent application on field effect transistors in 1934.



Transistors (3)

Gilles Holst and Willem Christiaan van Geel filed a patent application on transistors (1935)

Patented Sept. 26, 1939 **2,173,904**

UNITED STATES PATENT OFFICE

2,173,904

ELECTRODE SYSTEM OF UNSYMMETRICAL CONDUCTIVITY

Gilles Holst and Willem Christiaan van Geel, Eindhoven, Netherlands, assignors to N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands

Application March 4, 1936, Serial No. 67,052
In Germany March 9, 1935

3 Claims. (Cl. 179—171)

The invention relates to an electrode system of unsymmetrical conductivity formed by two layers of different emitting capacity which are separated from one another by a layer of insulating material.

It is known already that if cuprous oxide rectifiers form the starting point, a three-electrode system may be produced by providing in the semi-conductive oxide layer a grid to which an auxiliary voltage is applied in order to act upon the electron current flowing from the copper electrode to the semi-conductor. Experiments have shown, however, that a detector thus produced does not function satisfactorily.

Furthermore, it has previously been proposed to form a detector as a dry rectifier in which the electron current between the metallic electrode and the semi-conductor is acted upon by the field variation of a magnetic circuit of which the rectifier forms a part. This form of construction has the drawback that it takes up much room and cannot be operated in a simple manner.

The invention has for its object to provide a detector or amplifier capable of taking the place of the present valves with thermal emission which are complicated and expensive in initial cost as well as in operation, for example, due to the current consumption for heating the cathode.

According to the invention, an electrode system of unsymmetrical conductivity is formed by two layers of different emitting capacity which are separated from one another by a layer of insulating material, and embedded in the insulating intermediate layer is a grid provided with a supply conductor for applying potentials for the control of the electron current and/or for screening purposes.

A detector of this kind may consequently take the place of a usual detector or three-electrode-amplifying valve for it likewise comprises both an emitting electrode and an electrode which does not or substantially does not emit and, between these two electrodes, a grid which corresponds to a grid arranged in a valve in the vacuum between the cathode and the anode. In accordance with the invention, the grid is located in the insulating layer, which, as has been found, has the most favorable result. It is clear that the number of grids need not be limited to one.

A favorable form of execution of an electrode system according to the invention is that which follows:

The grids are constituted by perforated layers of conductive material which are contained in the insulating intermediate layer, said perforated layers being obtained, for example, by applying to one of the electrodes alternately an insulating layer and a perforated conductive layer and finally to the last conductive layer again an insulating layer. It is consequently possible to form electrode systems which correspond to the present radio valves having three or more electrodes such as, for example, the triodes, tetrodes, pentodes, hexodes, etc.

It is particularly important and advantageous that the insulating intermediate layer which contains the grids be formed independently of the adjacent electrode layers, for this renders it possible to control at will both the thickness of the layer and the position of the grids. The intermediate layer may be constituted of, for example, artificial resin which is applied in liquid condition to one of the electrodes. It is thus possible to apply a perfectly homogeneous layer.

It is of course very desirable to make the intermediate layer as thin as possible in order to raise as much as possible the electrical field strength between the main electrodes, as this has a great effect on the favorable operation. Due to the presence of a conductive grid there arises however the possibility that due to the too slight thickness of the insulating layer at a single, for example, accidentally projecting point, said grid may short-circuit one of the electrodes. In one favorable form of execution the risk of a short circuit is avoided by providing the grids with an insulating coating before they are applied to the insulating layer.

When choosing a grid material it should be considered that on account of its own emission a grid of emitting material acts upon the electron current between the anode and the cathode. According to a favorable mode of execution use is therefore made of a grid material being a semi- or bad conductor and having a slight emitting capacity.

The invention will be explained more fully with reference to the accompanying drawing which represents, by way of example, one embodiment thereof.

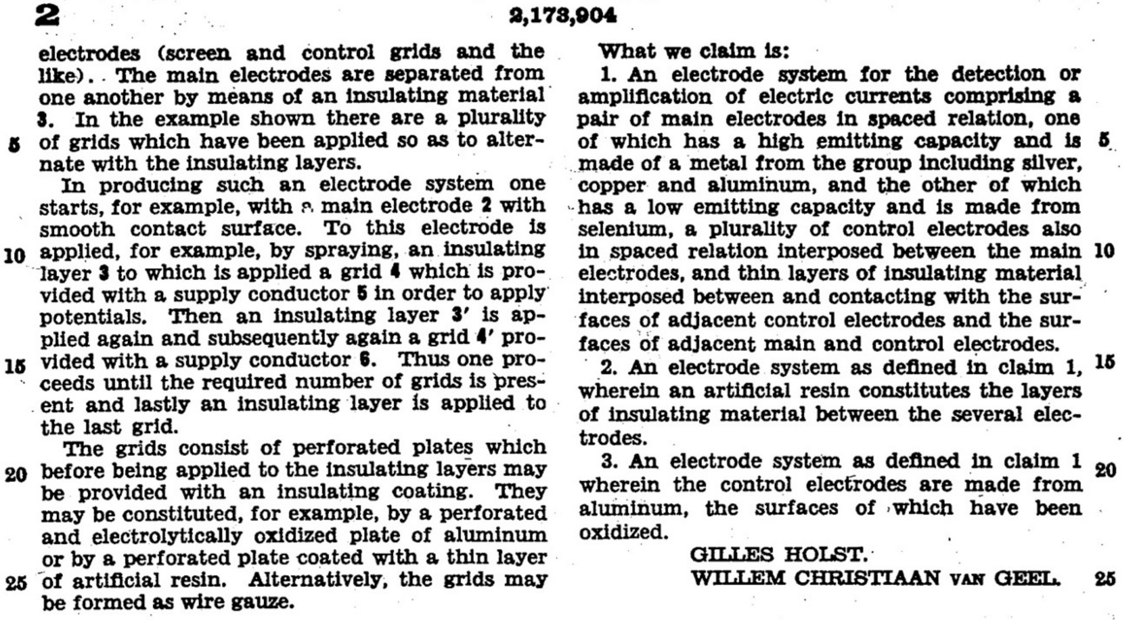
The main electrodes **1** and **2** are formed, respectively, by a conductor consisting of a metal of high emitting capacity such as aluminum, copper or silver and by a semi-conductor as is usual in dry rectifiers. Selenium is a very suitable material for the semi-conductor.

The drawing represents, by way of example, a six-electrode-system. Besides the main electrodes **1** and **2** there are consequently four further

Figure 6.77: Gilles Holst and Willem Christiaan van Geel filed a patent application on transistors in 1935.

Transistors (3)

Gilles Holst and Willem Christiaan van Geel filed a patent application on transistors (1935)



2 2,173,904

electrodes (screen and control grids and the like). The main electrodes are separated from one another by means of an insulating material 3. In the example shown there are a plurality of grids which have been applied so as to alternate with the insulating layers.

In producing such an electrode system one starts, for example, with a main electrode 2 with smooth contact surface. To this electrode is applied, for example, by spraying, an insulating layer 3 to which is applied a grid 4 which is provided with a supply conductor 5 in order to apply potentials. Then an insulating layer 3' is applied again and subsequently again a grid 4' provided with a supply conductor 6. Thus one proceeds until the required number of grids is present and lastly an insulating layer is applied to the last grid.

The grids consist of perforated plates which before being applied to the insulating layers may be provided with an insulating coating. They may be constituted, for example, by a perforated and electrolytically oxidized plate of aluminum or by a perforated plate coated with a thin layer of artificial resin. Alternatively, the grids may be formed as wire gauze.

What we claim is:

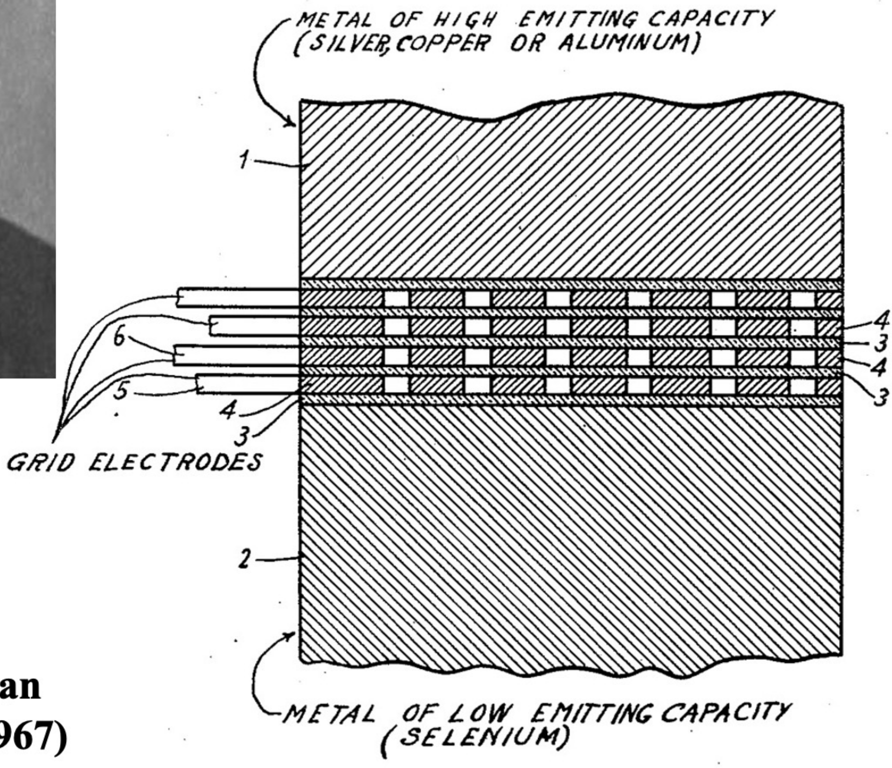
1. An electrode system for the detection or amplification of electric currents comprising a pair of main electrodes in spaced relation, one of which has a high emitting capacity and is made of a metal from the group including silver, copper and aluminum, and the other of which has a low emitting capacity and is made from selenium, a plurality of control electrodes also in spaced relation interposed between the main electrodes, and thin layers of insulating material interposed between and contacting with the surfaces of adjacent control electrodes and the surfaces of adjacent main and control electrodes.

2. An electrode system as defined in claim 1, wherein an artificial resin constitutes the layers of insulating material between the several electrodes.

3. An electrode system as defined in claim 1 wherein the control electrodes are made from aluminum, the surfaces of which have been oxidized.

GILLES HOLST.
WILLEM CHRISTIAAN VAN GEEL.

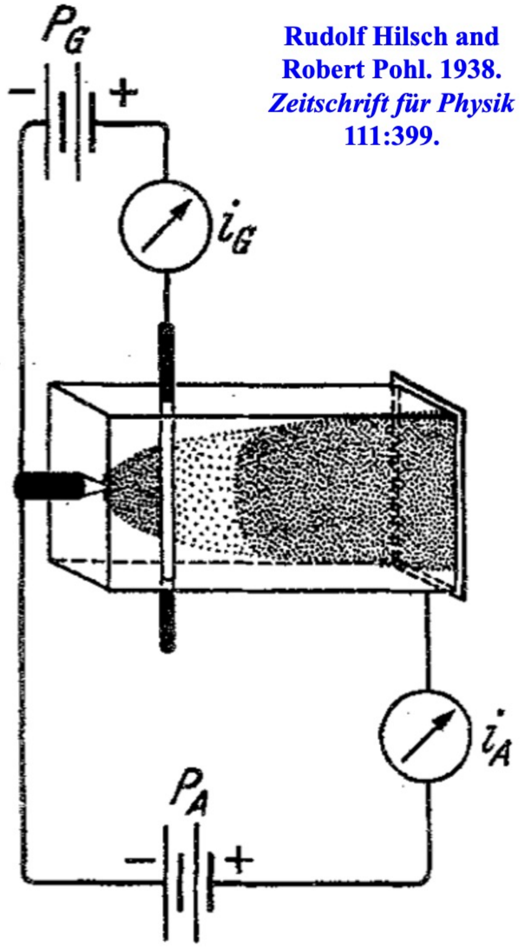
Gilles Holst (1886–1968)


METAL OF HIGH EMITTING CAPACITY (SILVER, COPPER OR ALUMINUM)
1
6
5
4
3
GRID ELECTRODES
4''
3''
4'
3'
2
METAL OF LOW EMITTING CAPACITY (SELENIUM)

Willem Christiaan van Geel (1895–1967)

Figure 6.78: Gilles Holst and Willem Christiaan van Geel filed a patent application on transistors in 1935.

Transistors (4)
Rudolf Hilsch and Robert Pohl demonstrated a proof-of-concept point-contact transistor with 20x signal amplification (1938)



Rudolf Hilsch and Robert Pohl. 1938.
Zeitschrift für Physik
111:399.

Fig. 6. Schema und Schaltung eines Dreielektrodenkristalles. Gezeichnet ist die durch Farbzentren sichtbar gemachte Elektronenverteilung während einer Abnahme des Anodenstromes. Die negative Aufladung des Gitters ist vergrößert worden, der Anodenstrom hat aber noch nicht seinen stationären Wert erreicht. (Kristallabmessungen $2 \times 5 \times 10$ mm).

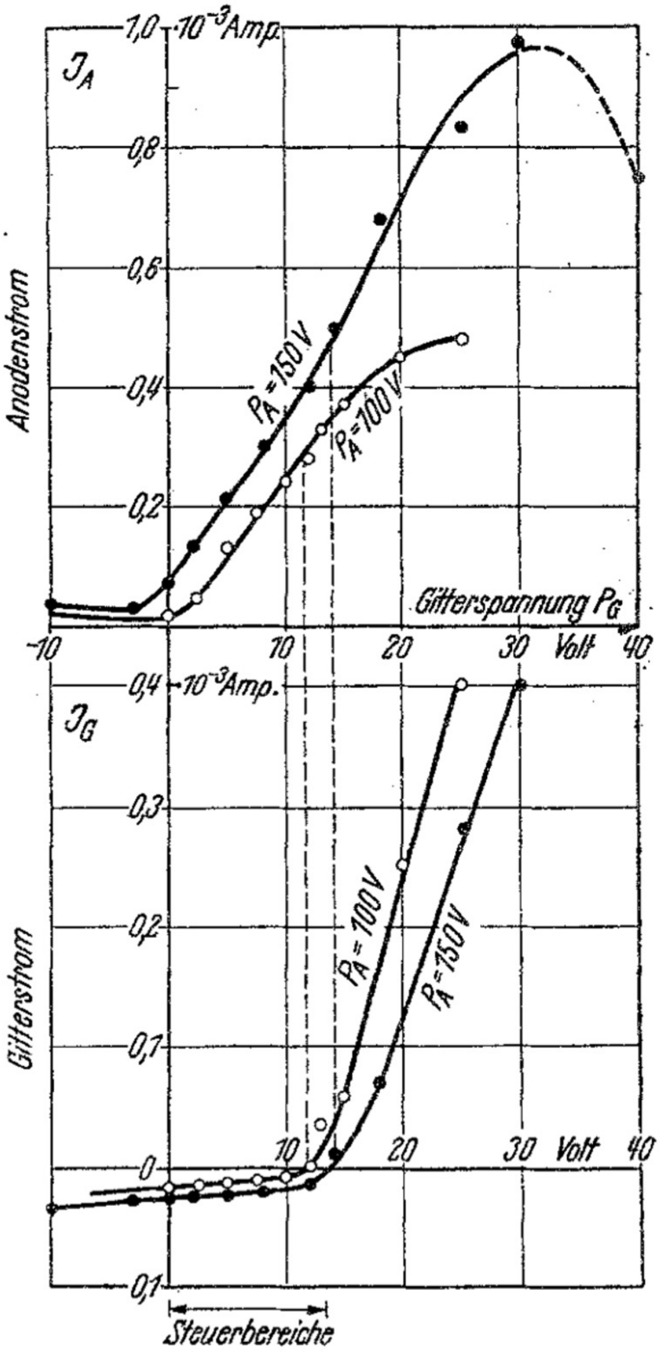


Fig. 7 und 8. Die beiden Kennlinien eines Dreielektrodenkristalles mit 20facher Verstärkung. $T = 490^0$ C.

Figure 6.79: Rudolf Hilsch and Robert Pohl demonstrated a prototype point-contact transistor in 1938 [Hilsch and Pohl 1938].

Transistors (4)

Robert Pohl (1884–1976)

Rudolf Hilsch (1903–1972)

Hilsch and Pohl demonstrated a proof-of-concept point-contact transistor with 20x signal amplification (1938).

KBr semiconductor crystal only worked at high temperature (490^{o}C) and voltages (100-150 Volts).

Hilsch proposed that the results be replicated by modifying existing room-temperature semiconductor diodes to add a third electrode for the base.

Rudolf Hilsch. 1939. Elektronenleitung in Kristallen. *Die Naturwissenschaften* 27:489-492:

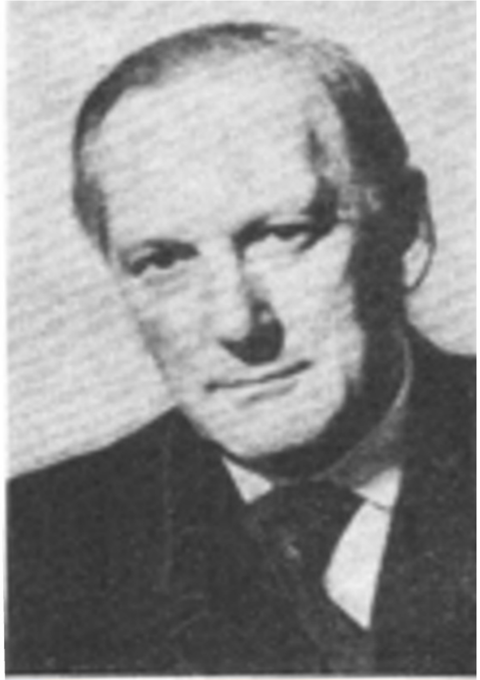
“This measurement has shown for the first time that it is also possible to control currents in solid bodies. The inertia of the currents in this ‘large’ model is naturally large. It is now only a technical task to add the control grid in the thin barrier layers of engineering rectifiers. If the solution to this problem is successful, the three-electrode crystal can also gain technical significance alongside the three-electrode tube.”

What did Hilsch and Pohl work on 1938–1945? At the very least, their 1938 paper inspired other German-speaking scientists.

Figure 6.80: Rudolf Hilsch and Robert Pohl demonstrated a prototype point-contact transistor in 1938 [Hilsch and Pohl 1938].

Transistors (5)

Erich Habann (1892–1968) filed a very detailed patent application on point-contact transistors, their fabrication, and use (1942)



Erich Habann's Hessenwinkel laboratory

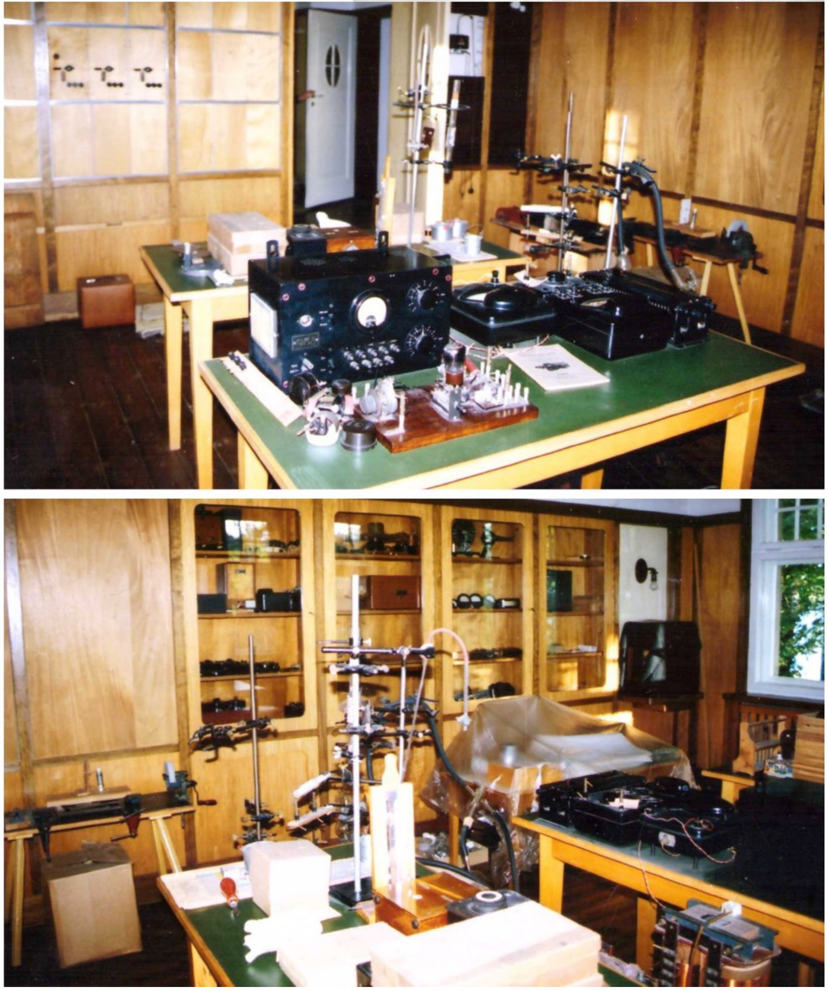
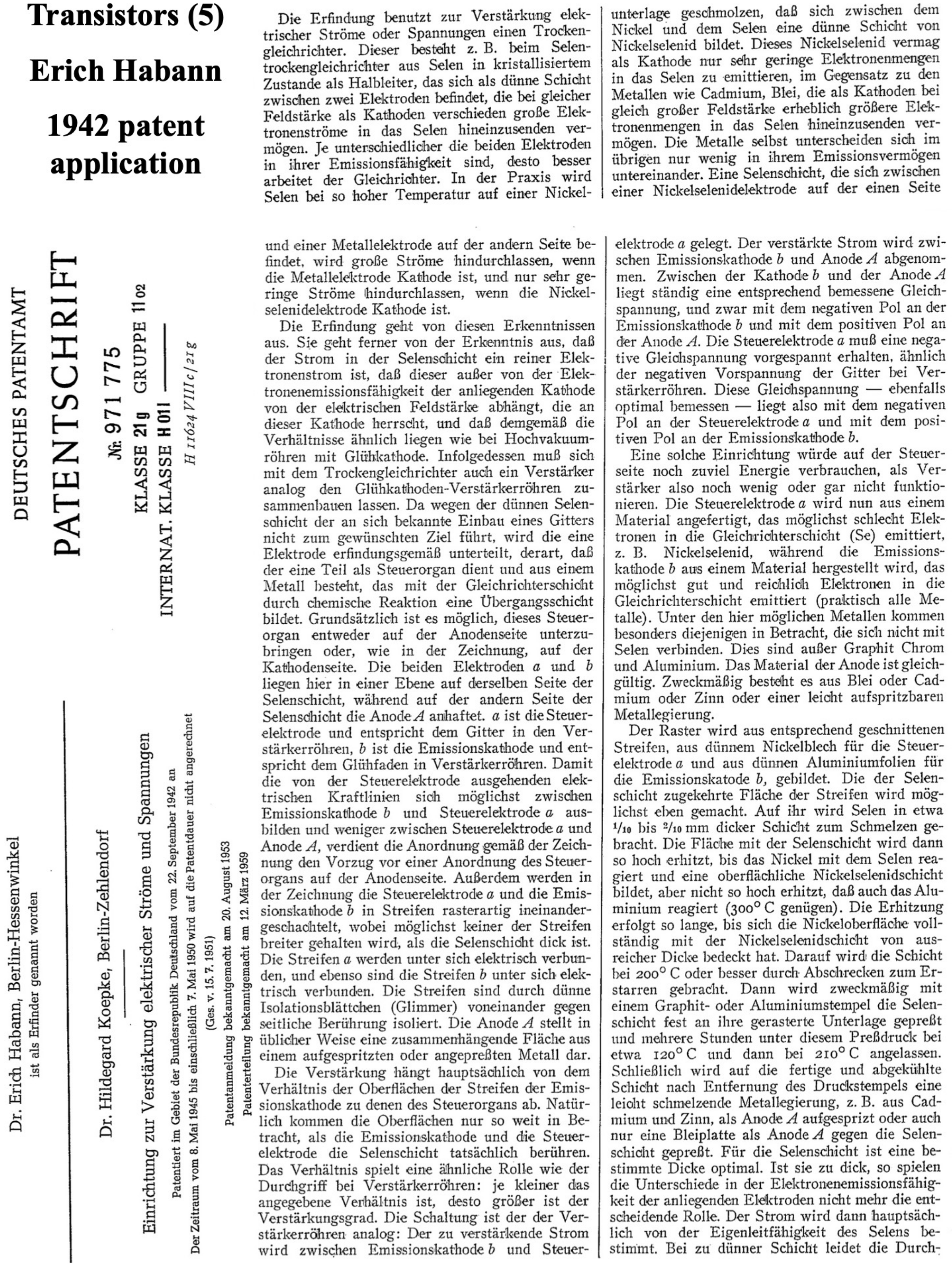


Figure 6.81: Erich Habann filed a very detailed patent application on point-contact transistors, their fabrication, and use in 1942, which suggests that he had already demonstrated them at his Hessenwinkel laboratory.

Transistors (5)

Erich Habann

1942 patent application



DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 971 775

KLASSE 21g GRUPPE 11 02

INTERNAT. KLASSE H 01l

H 11624 VIIIc/21g

Dr. Erich Habann, Berlin-Hessenwinkel
ist als Erfinder genannt worden

Dr. Hildegard Koepke, Berlin-Zehlendorf

Einrichtung zur Verstärkung elektrischer Ströme und Spannungen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 22. September 1942 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
(Ges. v. 15. 7. 1951)

Patentanmeldung bekanntgemacht am 20. August 1953
Patenterteilung bekanntgemacht am 12. März 1959

Die Erfindung benutzt zur Verstärkung elektrischer Ströme oder Spannungen einen Trockengleichrichter. Dieser besteht z. B. beim Selentrockengleichrichter aus Selen in kristallisiertem Zustande als Halbleiter, das sich als dünne Schicht zwischen zwei Elektroden befindet, die bei gleicher Feldstärke als Kathoden verschieden große Elektronenströme in das Selen hineinzusenden vermögen. Je unterschiedlicher die beiden Elektroden in ihrer Emissionsfähigkeit sind, desto besser arbeitet der Gleichrichter. In der Praxis wird Selen bei so hoher Temperatur auf einer Nickelunterlage geschmolzen, daß sich zwischen dem Nickel und dem Selen eine dünne Schicht von Nickelselenid bildet. Dieses Nickelselenid vermag als Kathode nur sehr geringe Elektronenmengen in das Selen zu emittieren, im Gegensatz zu den Metallen wie Cadmium, Blei, die als Kathoden bei gleich großer Feldstärke erheblich größere Elektronenmengen in das Selen hineinzusenden vermögen. Die Metalle selbst unterscheiden sich im übrigen nur wenig in ihrem Emissionsvermögen untereinander. Eine Selenschicht, die sich zwischen einer Nickelselenidelektrode auf der einen Seite und einer Metallelektrode auf der andern Seite befindet, wird große Ströme hindurchlassen, wenn die Metallelektrode Kathode ist, und nur sehr geringe Ströme hindurchlassen, wenn die Nickelselenidelektrode Kathode ist.

Die Erfindung geht von diesen Erkenntnissen aus. Sie geht ferner von der Erkenntnis aus, daß der Strom in der Selenschicht ein reiner Elektronenstrom ist, daß dieser außer von der Elektronenemissionsfähigkeit der anliegenden Kathode von der elektrischen Feldstärke abhängt, die an dieser Kathode herrscht, und daß demgemäß die Verhältnisse ähnlich liegen wie bei Hochvakuumröhren mit Glühkathode. Infolgedessen muß sich mit dem Trockengleichrichter auch ein Verstärker analog den Glühkathoden-Verstärkerröhren zusammenbauen lassen. Da wegen der dünnen Selenschicht der an sich bekannte Einbau eines Gitters nicht zum gewünschten Ziel führt, wird die eine Elektrode erfindungsgemäß unterteilt, derart, daß der eine Teil als Steuerorgan dient und aus einem Metall besteht, das mit der Gleichrichterschicht durch chemische Reaktion eine Übergangsschicht bildet. Grundsätzlich ist es möglich, dieses Steuerorgan entweder auf der Anodenseite unterzubringen oder, wie in der Zeichnung, auf der Kathodenseite. Die beiden Elektroden a und b liegen hier in einer Ebene auf derselben Seite der Selenschicht, während auf der andern Seite der Selenschicht die Anode A anhaftet. a ist die Steuerelektrode und entspricht dem Gitter in den Verstärkerröhren, b ist die Emissionskathode und entspricht dem Glühfaden in Verstärkerröhren. Damit die von der Steuerelektrode ausgehenden elektrischen Kraftlinien sich möglichst zwischen Emissionskathode b und Steuerelektrode a ausbilden und weniger zwischen Steuerelektrode a und Anode A, verdient die Anordnung gemäß der Zeichnung den Vorzug vor einer Anordnung des Steuerorgans auf der Anodenseite. Außerdem werden in der Zeichnung die Steuerelektrode a und die Emissionskathode b in Streifen rasterartig ineinandergeschachtelt, wobei möglichst keiner der Streifen breiter gehalten wird, als die Selenschicht dick ist. Die Streifen a werden unter sich elektrisch verbunden, und ebenso sind die Streifen b unter sich elektrisch verbunden. Die Streifen sind durch dünne Isolationsblättchen (Glimmer) voneinander gegen seitliche Berührung isoliert. Die Anode A stellt in üblicher Weise eine zusammenhängende Fläche aus einem aufgespritzten oder angepreßten Metall dar.

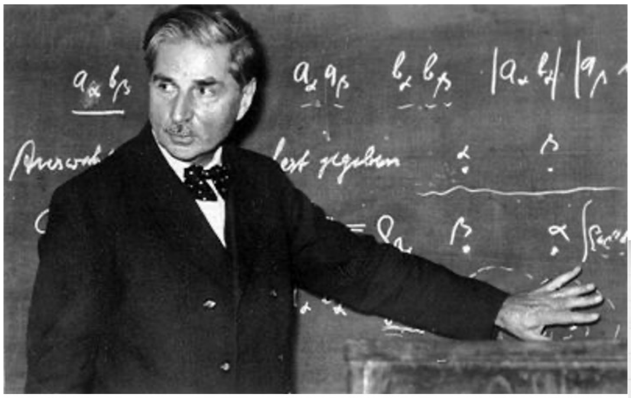
Die Verstärkung hängt hauptsächlich von dem Verhältnis der Oberflächen der Streifen der Emissionskathode zu denen des Steuerorgans ab. Natürlich kommen die Oberflächen nur so weit in Betracht, als die Emissionskathode und die Steuerelektrode die Selenschicht tatsächlich berühren. Das Verhältnis spielt eine ähnliche Rolle wie der Durchgriff bei Verstärkerröhren: je kleiner das angegebene Verhältnis ist, desto größer ist der Verstärkungsgrad. Die Schaltung ist der der Verstärkerröhren analog: Der zu verstärkende Strom wird zwischen Emissionskathode b und Steuerelektrode a gelegt. Der verstärkte Strom wird zwischen Emissionskathode b und Anode A abgenommen. Zwischen der Kathode b und der Anode A liegt ständig eine entsprechend bemessene Gleichspannung, und zwar mit dem negativen Pol an der Emissionskathode b und mit dem positiven Pol an der Anode A. Die Steuerelektrode a muß eine negative Gleichspannung vorgespannt erhalten, ähnlich der negativen Vorspannung der Gitter bei Verstärkerröhren. Diese Gleichspannung — ebenfalls optimal bemessen — liegt also mit dem negativen Pol an der Steuerelektrode a und mit dem positiven Pol an der Emissionskathode b.

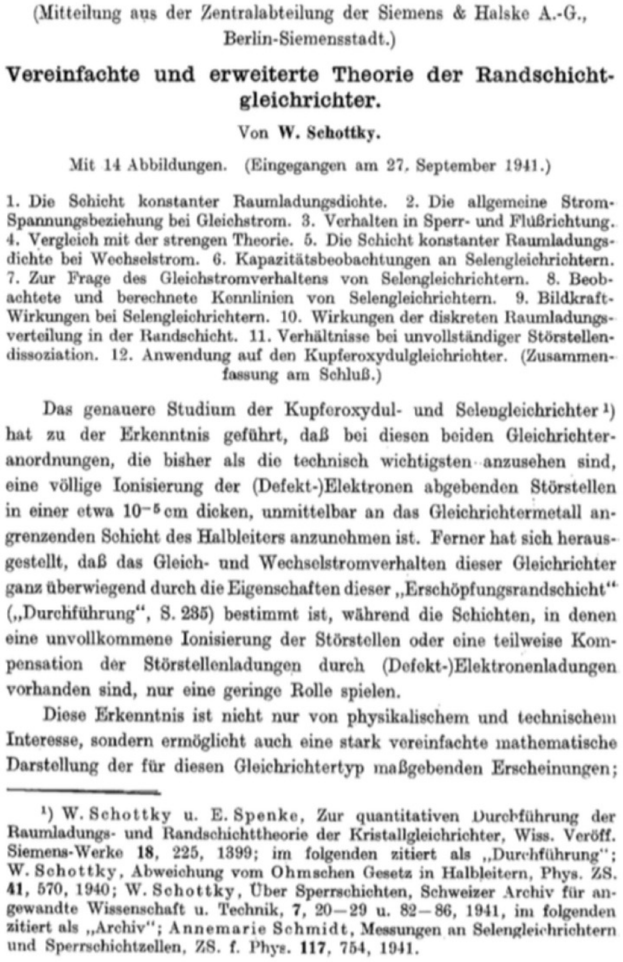
Eine solche Einrichtung würde auf der Steuerseite noch zuviel Energie verbrauchen, als Verstärker also noch wenig oder gar nicht funktionieren. Die Steuerelektrode a wird nun aus einem Material angefertigt, das möglichst schlecht Elektronen in die Gleichrichterschicht (Se) emittiert, z. B. Nickelselenid, während die Emissionskathode b aus einem Material hergestellt wird, das möglichst gut und reichlich Elektronen in die Gleichrichterschicht emittiert (praktisch alle Metalle). Unter den hier möglichen Metallen kommen besonders diejenigen in Betracht, die sich nicht mit Selen verbinden. Dies sind außer Graphit Chrom und Aluminium. Das Material der Anode ist gleichgültig. Zweckmäßig besteht es aus Blei oder Cadmium oder Zinn oder einer leicht aufspritzbaren Metallegierung.

Der Raster wird aus entsprechend geschnittenen Streifen, aus dünnem Nickelblech für die Steuerelektrode a und aus dünnen Aluminiumfolien für die Emissionskatode b, gebildet. Die der Selenschicht zugekehrte Fläche der Streifen wird möglichst eben gemacht. Auf ihr wird Selen in etwa 1/10 bis 2/10 mm dicker Schicht zum Schmelzen gebracht. Die Fläche mit der Selenschicht wird dann so hoch erhitzt, bis das Nickel mit dem Selen reagiert und eine oberflächliche Nickelselenidschicht bildet, aber nicht so hoch erhitzt, daß auch das Aluminium reagiert (300° C genügen). Die Erhitzung erfolgt so lange, bis sich die Nickeloberfläche vollständig mit der Nickelselenidschicht von ausreicher Dicke bedeckt hat. Darauf wird die Schicht bei 200° C oder besser durch Abschrecken zum Erstarren gebracht. Dann wird zweckmäßig mit einem Graphit- oder Aluminiumstempel die Selenschicht fest an ihre gerasterte Unterlage gepreßt und mehrere Stunden unter diesem Preßdruck bei etwa 120° C und dann bei 210° C angelassen. Schließlich wird auf die fertige und abgekühlte Schicht nach Entfernung des Druckstempels eine leicht schmelzende Metallegierung, z. B. aus Cadmium und Zinn, als Anode A aufgespritzt oder auch nur eine Bleiplatte als Anode A gegen die Selenschicht gepreßt. Für die Selenschicht ist eine bestimmte Dicke optimal. Ist sie zu dick, so spielen die Unterschiede in der Elektronenemissionsfähigkeit der anliegenden Elektroden nicht mehr die entscheidende Rolle. Der Strom wird dann hauptsächlich von der Eigenleitfähigkeit des Selens bestimmt. Bei zu dünner Schicht leidet die Durch-

Figure 6.82: Erich Habann filed a very detailed patent application on point-contact transistors, their fabrication, and use in 1942, which suggests that he had already demonstrated them at his Hessenwinkel laboratory.

Transistors (6)





(Mitteilung aus der Zentralabteilung der Siemens & Halske A.-G., Berlin-Siemensstadt.)

Vereinfachte und erweiterte Theorie der Randschichtgleichrichter.

Von **W. Schottky.**

Mit 14 Abbildungen. (Eingegangen am 27. September 1941.)

1. Die Schicht konstanter Raumladungsdichte. 2. Die allgemeine Strom-Spannungsbeziehung bei Gleichstrom. 3. Verhalten in Sperr- und Flußrichtung. 4. Vergleich mit der strengen Theorie. 5. Die Schicht konstanter Raumladungsdichte bei Wechselstrom. 6. Kapazitätsbeobachtungen an Selengleichrichtern. 7. Zur Frage des Gleichstromverhaltens von Selengleichrichtern. 8. Beobachtete und berechnete Kennlinien von Selengleichrichtern. 9. Bildkraft-Wirkungen bei Selengleichrichtern. 10. Wirkungen der diskreten Raumladungsverteilung in der Randschicht. 11. Verhältnisse bei unvollständiger Störstellendissoziation. 12. Anwendung auf den Kupferoxydulgleichrichter. (Zusammenfassung am Schluß.)

Das genauere Studium der Kupferoxydul- und Selengleichrichter [1]) hat zu der Erkenntnis geführt, daß bei diesen beiden Gleichrichteranordnungen, die bisher als die technisch wichtigsten anzusehen sind, eine völlige Ionisierung der (Defekt-)Elektronen abgebenden Störstellen in einer etwa 10^{-5} cm dicken, unmittelbar an das Gleichrichtermetall angrenzenden Schicht des Halbleiters anzunehmen ist. Ferner hat sich herausgestellt, daß das Gleich- und Wechselstromverhalten dieser Gleichrichter ganz überwiegend durch die Eigenschaften dieser „Erschöpfungsrandschicht" („Durchführung", S. 235) bestimmt ist, während die Schichten, in denen eine unvollkommene Ionisierung der Störstellen oder eine teilweise Kompensation der Störstellenladungen durch (Defekt-)Elektronenladungen vorhanden sind, nur eine geringe Rolle spielen.

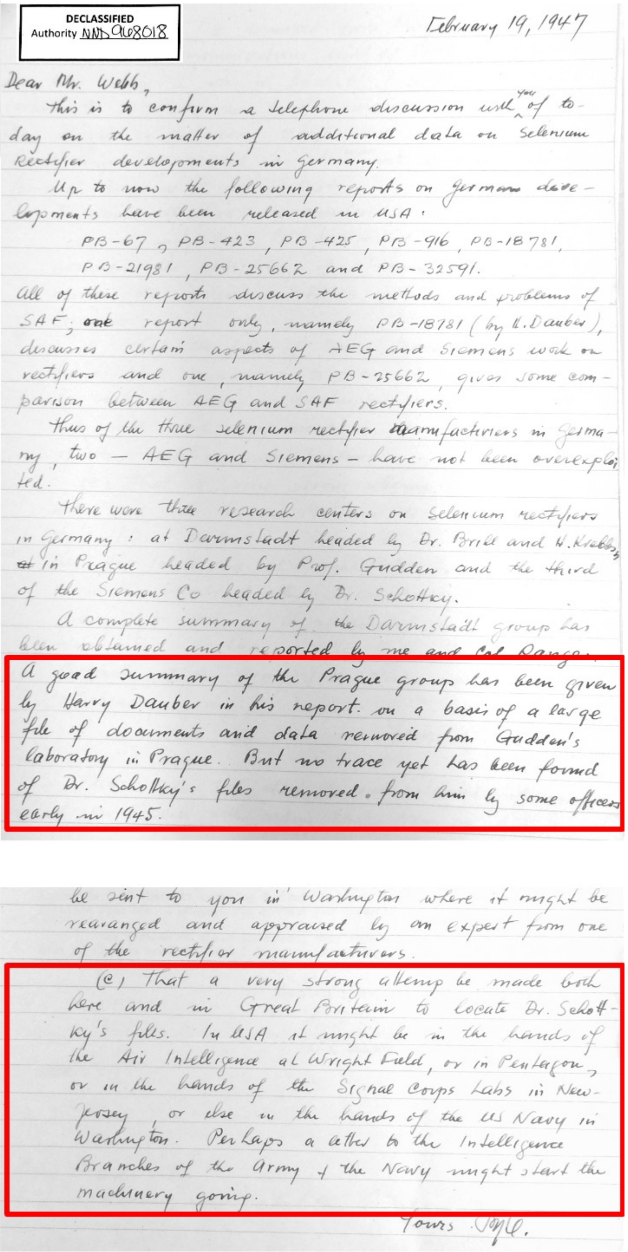
Diese Erkenntnis ist nicht nur von physikalischem und technischem Interesse, sondern ermöglicht auch eine stark vereinfachte mathematische Darstellung der für diesen Gleichrichtertyp maßgebenden Erscheinungen;

---

[1]) W. Schottky u. E. Spenke, Zur quantitativen Durchführung der Raumladungs- und Randschichttheorie der Kristallgleichrichter, Wiss. Veröff. Siemens-Werke **18**, 225, 1399; im folgenden zitiert als „Durchführung"; W. Schottky, Abweichung vom Ohmschen Gesetz in Halbleitern, Phys. ZS. **41**, 570, 1940; W. Schottky, Über Sperrschichten, Schweizer Archiv für angewandte Wissenschaft u. Technik, **7**, 20–29 u. 82–86, 1941, im folgenden zitiert als „Archiv"; Annemarie Schmidt, Messungen an Selengleichrichtern und Sperrschichtzellen, ZS. f. Phys. **117**, 754, 1941.

Zeitschrift für Physik
118:9–10:539–592 (1942)

Walter Schottky (1886–1976) published detailed analyses of semiconductor properties necessary for transistors. The U.S. seized all his papers in 1945 and never returned them.



DECLASSIFIED
Authority NND 968018

February 19, 1947

Dear Mr. Webb,

this is to confirm a telephone discussion with you of to-day on the matter of additional data on Selenium Rectifier developments in Germany.

Up to now the following reports on German developments have been released in USA:

PB-67, PB-423, PB-425, PB-916, PB-18781,
PB-21981, PB-25662 and PB-32591.

All of these reports discuss the methods and problems of SAF; ~~one~~ report only, namely PB-18781 (by H. Dauber), discusses certain aspects of AEG and Siemens work on rectifiers and one, namely PB-25662, gives some comparison between AEG and SAF rectifiers.

thus of the three selenium rectifier manufactories in Germany, two – AEG and Siemens – have not been overexploited.

there were three research centers on Selenium rectifiers in Germany: at Darmstadt headed by Dr. Brill and H. Krebbs, ~~at~~ in Prague headed by Prof. Gudden and the third of the Siemens Co headed by Dr. Schottky.

A complete summary of the Darmstadt group has been obtained and reported by me and Col. Range.

A good summary of the Prague group has been given by Harry Dauber in his report. on a basis of a large file of documents and data removed from Gudden's laboratory in Prague. But no trace yet has been found of Dr. Schottky's files removed. from him by some officers early in 1945.

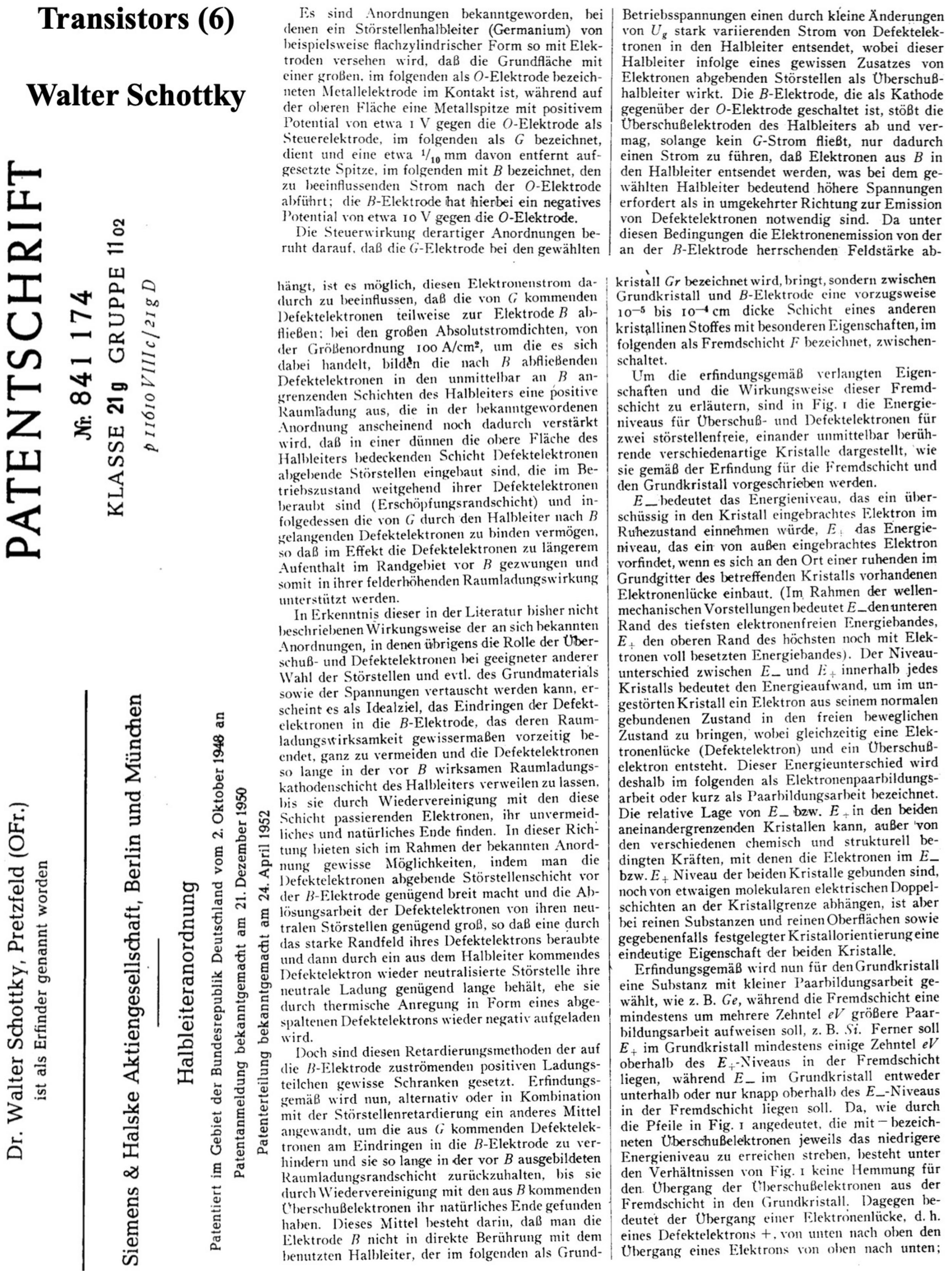
be sent to you in Washington where it might be rearanged and appraised by an expert from one of the rectifier manufacturers.

(c) That a very strong attemp be made both here and in Great Britain to locate Dr. Schottky's files. In USA it might be in the hands of the Air Intelligence at Wright Field, or in Pentagon, or in the hands of the Signal Corps Labs in New-Jersey, or else in the hands of the US Navy in Washington. Perhaps a letter to the Intelligence Branches of the Army + the Navy might start the machinery going.

Yours

NARA RG 40, Entry UD-75, Box 24, Folder Selenium Rectifier Machinery

Figure 6.83: Walter Schottky published detailed analyses of semiconductor properties necessary for transistors in 1942. All of his papers were seized by the United States in 1945 and never returned.



Transistors (6)

Walter Schottky

PATENTSCHRIFT

Nr. 841 174

KLASSE 21g GRUPPE 11 02

p 11610 VIIIc/21g D

Dr. Walter Schottky, Pretzfeld (OFr.)
ist als Erfinder genannt worden

Siemens & Halske Aktiengesellschaft, Berlin und München

Halbleiteranordnung

Patentiert im Gebiet der Bundesrepublik Deutschland vom 2. Oktober 1948 an
Patentanmeldung bekanntgemacht am 21. Dezember 1950
Patenterteilung bekanntgemacht am 24. April 1952

Es sind Anordnungen bekanntgeworden, bei denen ein Störstellenhalbleiter (Germanium) von beispielsweise flachzylindrischer Form so mit Elektroden versehen wird, daß die Grundfläche mit einer großen, im folgenden als *O*-Elektrode bezeichneten Metallelektrode im Kontakt ist, während auf der oberen Fläche eine Metallspitze mit positivem Potential von etwa 1 V gegen die *O*-Elektrode als Steuerelektrode, im folgenden als *G* bezeichnet, dient und eine etwa $^1/_{10}$ mm davon entfernt aufgesetzte Spitze, im folgenden mit *B* bezeichnet, den zu beeinflussenden Strom nach der *O*-Elektrode abführt; die *B*-Elektrode hat hierbei ein negatives Potential von etwa 10 V gegen die *O*-Elektrode.

Die Steuerwirkung derartiger Anordnungen beruht darauf, daß die *G*-Elektrode bei den gewählten Betriebsspannungen einen durch kleine Änderungen von U_g stark variierenden Strom von Defektelektronen in den Halbleiter entsendet, wobei dieser Halbleiter infolge eines gewissen Zusatzes von Elektronen abgebenden Störstellen als Überschußhalbleiter wirkt. Die *B*-Elektrode, die als Kathode gegenüber der *O*-Elektrode geschaltet ist, stößt die Überschußelektroden des Halbleiters ab und vermag, solange kein *G*-Strom fließt, nur dadurch einen Strom zu führen, daß Elektronen aus *B* in den Halbleiter entsendet werden, was bei dem gewählten Halbleiter bedeutend höhere Spannungen erfordert als in umgekehrter Richtung zur Emission von Defektelektronen notwendig sind. Da unter diesen Bedingungen die Elektronenemission von der an der *B*-Elektrode herrschenden Feldstärke abhängt, ist es möglich, diesen Elektronenstrom dadurch zu beeinflussen, daß die von *G* kommenden Defektelektronen teilweise zur Elektrode *B* abfließen; bei den großen Absolutstromdichten, von der Größenordnung 100 A/cm², um die es sich dabei handelt, bilden die nach *B* abfließenden Defektelektronen in den unmittelbar an *B* angrenzenden Schichten des Halbleiters eine positive Raumladung aus, die in der bekanntgewordenen Anordnung anscheinend noch dadurch verstärkt wird, daß in einer dünnen die obere Fläche des Halbleiters bedeckenden Schicht Defektelektronen abgebende Störstellen eingebaut sind, die im Betriebszustand weitgehend ihrer Defektelektronen beraubt sind (Erschöpfungsrandschicht) und infolgedessen die von *G* durch den Halbleiter nach *B* gelangenden Defektelektronen zu binden vermögen, so daß im Effekt die Defektelektronen zu längerem Aufenthalt im Randgebiet vor *B* gezwungen und somit in ihrer felderhöhenden Raumladungswirkung unterstützt werden.

In Erkenntnis dieser in der Literatur bisher nicht beschriebenen Wirkungsweise der an sich bekannten Anordnungen, in denen übrigens die Rolle der Überschuß- und Defektelektronen bei geeigneter anderer Wahl der Störstellen und evtl. des Grundmaterials sowie der Spannungen vertauscht werden kann, erscheint es als Idealziel, das Eindringen der Defektelektronen in die *B*-Elektrode, das deren Raumladungswirksamkeit gewissermaßen vorzeitig beendet, ganz zu vermeiden und die Defektelektronen so lange in der vor *B* wirksamen Raumladungskathodenschicht des Halbleiters verweilen zu lassen, bis sie durch Wiedervereinigung mit den diese Schicht passierenden Elektronen, ihr unvermeidliches und natürliches Ende finden. In dieser Richtung bieten sich im Rahmen der bekannten Anordnung gewisse Möglichkeiten, indem man die Defektelektronen abgebende Störstellenschicht vor der *B*-Elektrode genügend breit macht und die Ablösungsarbeit der Defektelektronen von ihren neutralen Störstellen genügend groß, so daß eine durch das starke Randfeld ihres Defektelektrons beraubte und dann durch ein aus dem Halbleiter kommendes Defektelektron wieder neutralisierte Störstelle ihre neutrale Ladung genügend lange behält, ehe sie durch thermische Anregung in Form eines abgespaltenen Defektelektrons wieder negativ aufgeladen wird.

Doch sind diesen Retardierungsmethoden der auf die *B*-Elektrode zuströmenden positiven Ladungsteilchen gewisse Schranken gesetzt. Erfindungsgemäß wird nun, alternativ oder in Kombination mit der Störstellenretardierung ein anderes Mittel angewandt, um die aus *G* kommenden Defektelektronen am Eindringen in die *B*-Elektrode zu verhindern und sie so lange in der vor *B* ausgebildeten Raumladungsrandschicht zurückzuhalten, bis sie durch Wiedervereinigung mit den aus *B* kommenden Überschußelektronen ihr natürliches Ende gefunden haben. Dieses Mittel besteht darin, daß man die Elektrode *B* nicht in direkte Berührung mit dem benutzten Halbleiter, der im folgenden als Grundkristall *Gr* bezeichnet wird, bringt, sondern zwischen Grundkristall und *B*-Elektrode eine vorzugsweise 10^{-5} bis 10^{-4} cm dicke Schicht eines anderen kristallinen Stoffes mit besonderen Eigenschaften, im folgenden als Fremdschicht *F* bezeichnet, zwischenschaltet.

Um die erfindungsgemäß verlangten Eigenschaften und die Wirkungsweise dieser Fremdschicht zu erläutern, sind in Fig. 1 die Energieniveaus für Überschuß- und Defektelektronen für zwei störstellenfreie, einander unmittelbar berührende verschiedenartige Kristalle dargestellt, wie sie gemäß der Erfindung für die Fremdschicht und den Grundkristall vorgeschrieben werden.

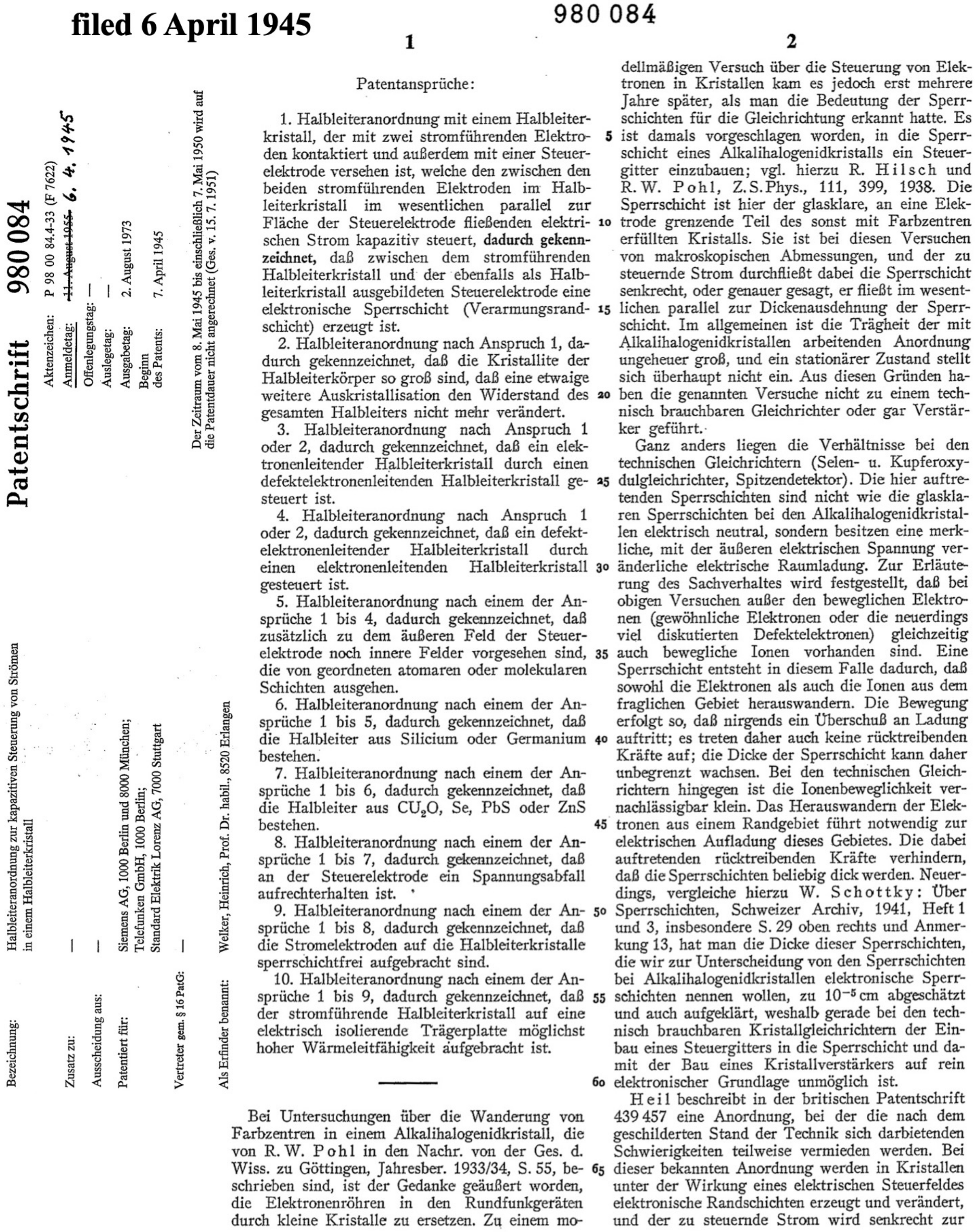
E_- bedeutet das Energieniveau, das ein überschüssig in den Kristall eingebrachtes Elektron im Ruhezustand einnehmen würde, E_+ das Energieniveau, das ein von außen eingebrachtes Elektron vorfindet, wenn es sich an den Ort einer ruhenden im Grundgitter des betreffenden Kristalls vorhandenen Elektronenlücke einbaut. (Im Rahmen der wellenmechanischen Vorstellungen bedeutet E_- den unteren Rand des tiefsten elektronenfreien Energiebandes, E_+ den oberen Rand des höchsten noch mit Elektronen voll besetzten Energiebandes). Der Niveauunterschied zwischen E_- und E_+ innerhalb jedes Kristalls bedeutet den Energieaufwand, um im ungestörten Kristall ein Elektron aus seinem normalen gebundenen Zustand in den freien beweglichen Zustand zu bringen, wobei gleichzeitig eine Elektronenlücke (Defektelektron) und ein Überschußelektron entsteht. Dieser Energieunterschied wird deshalb im folgenden als Elektronenpaarbildungsarbeit oder kurz als Paarbildungsarbeit bezeichnet. Die relative Lage von E_- bzw. E_+ in den beiden aneinandergrenzenden Kristallen kann, außer von den verschiedenen chemisch und strukturell bedingten Kräften, mit denen die Elektronen im E_- bzw. E_+ Niveau der beiden Kristalle gebunden sind, noch von etwaigen molekularen elektrischen Doppelschichten an der Kristallgrenze abhängen, ist aber bei reinen Substanzen und reinen Oberflächen sowie gegebenenfalls festgelegter Kristallorientierung eine eindeutige Eigenschaft der beiden Kristalle.

Erfindungsgemäß wird nun für den Grundkristall eine Substanz mit kleiner Paarbildungsarbeit gewählt, wie z. B. *Ge*, während die Fremdschicht eine mindestens um mehrere Zehntel *eV* größere Paarbildungsarbeit aufweisen soll, z. B. *Si*. Ferner soll E_+ im Grundkristall mindestens einige Zehntel *eV* oberhalb des E_+-Niveaus in der Fremdschicht liegen, während E_- im Grundkristall entweder unterhalb oder nur knapp oberhalb des E_--Niveaus in der Fremdschicht liegen soll. Da, wie durch die Pfeile in Fig. 1 angedeutet, die mit − bezeichneten Überschußelektronen jeweils das niedrigere Energieniveau zu erreichen streben, besteht unter den Verhältnissen von Fig. 1 keine Hemmung für den Übergang der Überschußelektronen aus der Fremdschicht in den Grundkristall. Dagegen bedeutet der Übergang einer Elektronenlücke, d. h. eines Defektelektrons +, von unten nach oben den Übergang eines Elektrons von oben nach unten;

Figure 6.84: Walter Schottky published detailed analyses of semiconductor properties necessary for transistors in 1942. All of his papers were seized by the United States in 1945 and never returned.

Detailed patent application based on wartime work filed 6 April 1945

Transistors (7)
Heinrich Welker & Herbert Mataré



980 084

Patentschrift 980 084

Aktenzeichen: P 98 00 84.4-33 (F 7622)
Anmeldetag: ~~11. August 1955~~ 6. 4. 1945
Offenlegungstag: —
Auslegetag: —
Ausgabetag: 2. August 1973
Beginn des Patents: 7. April 1945

Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet (Ges. v. 15. 7. 1951)

Bezeichnung: Halbleiteranordnung zur kapazitiven Steuerung von Strömen in einem Halbleiterkristall
Zusatz zu: —
Ausscheidung aus: —
Patentiert für: Siemens AG, 1000 Berlin und 8000 München; Telefunken GmbH, 1000 Berlin; Standard Elektrik Lorenz AG, 7000 Stuttgart
Vertreter gem. § 16 PatG: —
Als Erfinder benannt: Welker, Heinrich, Prof. Dr. habil., 8520 Erlangen

1

Patentansprüche:

1. Halbleiteranordnung mit einem Halbleiterkristall, der mit zwei stromführenden Elektroden kontaktiert und außerdem mit einer Steuerelektrode versehen ist, welche den zwischen den beiden stromführenden Elektroden im Halbleiterkristall im wesentlichen parallel zur Fläche der Steuerelektrode fließenden elektrischen Strom kapazitiv steuert, **dadurch gekennzeichnet,** daß zwischen dem stromführenden Halbleiterkristall und der ebenfalls als Halbleiterkristall ausgebildeten Steuerelektrode eine elektronische Sperrschicht (Verarmungsrandschicht) erzeugt ist.

2. Halbleiteranordnung nach Anspruch 1, dadurch gekennzeichnet, daß die Kristallite der Halbleiterkörper so groß sind, daß eine etwaige weitere Auskristallisation den Widerstand des gesamten Halbleiters nicht mehr verändert.

3. Halbleiteranordnung nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß ein elektronenleitender Halbleiterkristall durch einen defektelektronenleitenden Halbleiterkristall gesteuert ist.

4. Halbleiteranordnung nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß ein defektelektronenleitender Halbleiterkristall durch einen elektronenleitenden Halbleiterkristall gesteuert ist.

5. Halbleiteranordnung nach einem der Ansprüche 1 bis 4, dadurch gekennzeichnet, daß zusätzlich zu dem äußeren Feld der Steuerelektrode noch innere Felder vorgesehen sind, die von geordneten atomaren oder molekularen Schichten ausgehen.

6. Halbleiteranordnung nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß die Halbleiter aus Silicium oder Germanium bestehen.

7. Halbleiteranordnung nach einem der Ansprüche 1 bis 6, dadurch gekennzeichnet, daß die Halbleiter aus CU_2O, Se, PbS oder ZnS bestehen.

8. Halbleiteranordnung nach einem der Ansprüche 1 bis 7, dadurch gekennzeichnet, daß an der Steuerelektrode ein Spannungsabfall aufrechterhalten ist.

9. Halbleiteranordnung nach einem der Ansprüche 1 bis 8, dadurch gekennzeichnet, daß die Stromelektroden auf die Halbleiterkristalle sperrschichtfrei aufgebracht sind.

10. Halbleiteranordnung nach einem der Ansprüche 1 bis 9, dadurch gekennzeichnet, daß der stromführende Halbleiterkristall auf eine elektrisch isolierende Trägerplatte möglichst hoher Wärmeleitfähigkeit aufgebracht ist.

Bei Untersuchungen über die Wanderung von Farbzentren in einem Alkalihalogenidkristall, die von R. W. Pohl in den Nachr. von der Ges. d. Wiss. zu Göttingen, Jahresber. 1933/34, S. 55, beschrieben sind, ist der Gedanke geäußert worden, die Elektronenröhren in den Rundfunkgeräten durch kleine Kristalle zu ersetzen. Zu einem modellmäßigen Versuch über die Steuerung von Elektronen in Kristallen kam es jedoch erst mehrere Jahre später, als man die Bedeutung der Sperrschichten für die Gleichrichtung erkannt hatte. Es ist damals vorgeschlagen worden, in die Sperrschicht eines Alkalihalogenidkristalls ein Steuergitter einzubauen; vgl. hierzu R. Hilsch und R. W. Pohl, Z. S. Phys., 111, 399, 1938. Die Sperrschicht ist hier der glasklare, an eine Elektrode grenzende Teil des sonst mit Farbzentren erfüllten Kristalls. Sie ist bei diesen Versuchen von makroskopischen Abmessungen, und der zu steuernde Strom durchfließt dabei die Sperrschicht senkrecht, oder genauer gesagt, er fließt im wesentlichen parallel zur Dickenausdehnung der Sperrschicht. Im allgemeinen ist die Trägheit der mit Alkalihalogenidkristallen arbeitenden Anordnung ungeheuer groß, und ein stationärer Zustand stellt sich überhaupt nicht ein. Aus diesen Gründen haben die genannten Versuche nicht zu einem technisch brauchbaren Gleichrichter oder gar Verstärker geführt.

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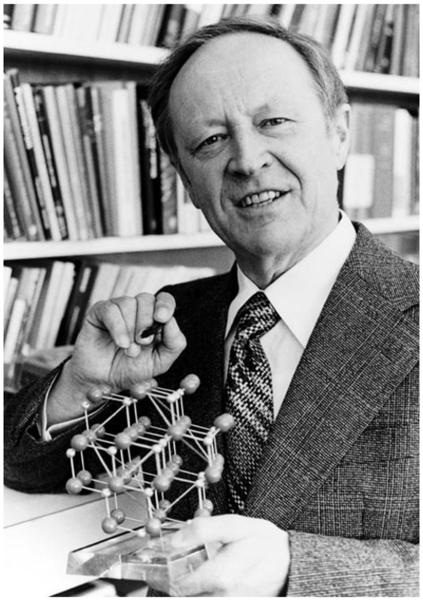
Ganz anders liegen die Verhältnisse bei den technischen Gleichrichtern (Selen- u. Kupferoxydulgleichrichter, Spitzendetektor). Die hier auftretenden Sperrschichten sind nicht wie die glasklaren Sperrschichten bei den Alkalihalogenidkristallen elektrisch neutral, sondern besitzen eine merkliche, mit der äußeren elektrischen Spannung veränderliche elektrische Raumladung. Zur Erläuterung des Sachverhaltes wird festgestellt, daß bei obigen Versuchen außer den beweglichen Elektronen (gewöhnliche Elektronen oder die neuerdings viel diskutierten Defektelektronen) gleichzeitig auch bewegliche Ionen vorhanden sind. Eine Sperrschicht entsteht in diesem Falle dadurch, daß sowohl die Elektronen als auch die Ionen aus dem fraglichen Gebiet herauswandern. Die Bewegung erfolgt so, daß nirgends ein Überschuß an Ladung auftritt; es treten daher auch keine rücktreibenden Kräfte auf; die Dicke der Sperrschicht kann daher unbegrenzt wachsen. Bei den technischen Gleichrichtern hingegen ist die Ionenbeweglichkeit vernachlässigbar klein. Das Herauswandern der Elektronen aus einem Randgebiet führt notwendig zur elektrischen Aufladung dieses Gebietes. Die dabei auftretenden rücktreibenden Kräfte verhindern, daß die Sperrschichten beliebig dick werden. Neuerdings, vergleiche hierzu W. Schottky: Über Sperrschichten, Schweizer Archiv, 1941, Heft 1 und 3, insbesondere S. 29 oben rechts und Anmerkung 13, hat man die Dicke dieser Sperrschichten, die wir zur Unterscheidung von den Sperrschichten bei Alkalihalogenidkristallen elektronische Sperrschichten nennen wollen, zu 10^{-5} cm abgeschätzt und auch aufgeklärt, weshalb gerade bei den technisch brauchbaren Kristallgleichrichtern der Einbau eines Steuergitters in die Sperrschicht und damit der Bau eines Kristallverstärkers auf rein elektronischer Grundlage unmöglich ist.

Heil beschreibt in der britischen Patentschrift 439 457 eine Anordnung, bei der die nach dem geschilderten Stand der Technik sich darbietenden Schwierigkeiten teilweise vermieden werden. Bei dieser bekannten Anordnung werden in Kristallen unter der Wirkung eines elektrischen Steuerfeldes elektronische Randschichten erzeugt und verändert, und der zu steuernde Strom wird senkrecht zur

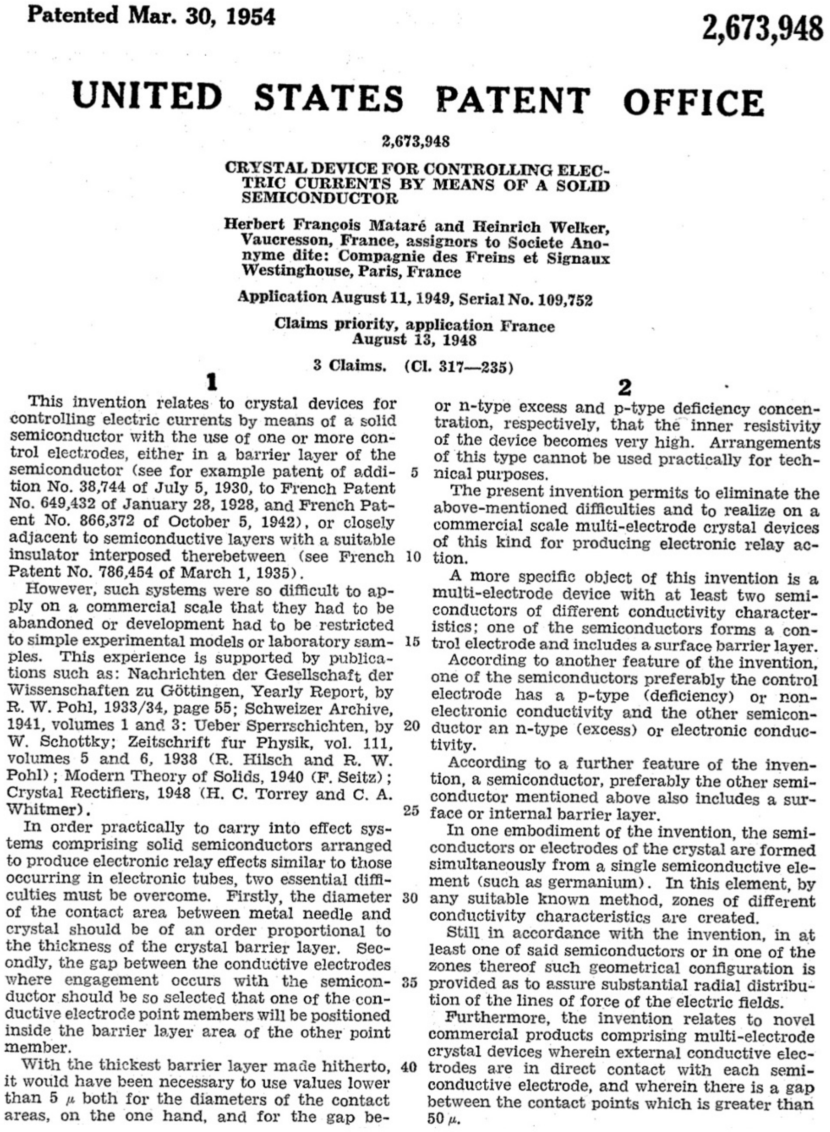
Figure 6.85: Heinrich Welker and Herbert Mataré began developing a point-contact transistor in Germany during the war, filed a detailed patent application based on that wartime work on 6 April 1945, and publicly announced their transistor in 1948 in France.

Transistors (7)

Heinrich Welker
(1912–1981)



Herbert Mataré
(1912–2011)



Patented Mar. 30, 1954 **2,673,948**

UNITED STATES PATENT OFFICE

2,673,948

CRYSTAL DEVICE FOR CONTROLLING ELECTRIC CURRENTS BY MEANS OF A SOLID SEMICONDUCTOR

Herbert François Mataré and Heinrich Welker, Vaucresson, France, assignors to Societe Anonyme dite: Compagnie des Freins et Signaux Westinghouse, Paris, France

Application August 11, 1949, Serial No. 109,752

Claims priority, application France
August 13, 1948

3 Claims. (Cl. 317—235)

1

This invention relates to crystal devices for controlling electric currents by means of a solid semiconductor with the use of one or more control electrodes, either in a barrier layer of the semiconductor (see for example patent of addition No. 38,744 of July 5, 1930, to French Patent No. 649,432 of January 28, 1928, and French Patent No. 866,372 of October 5, 1942), or closely adjacent to semiconductive layers with a suitable insulator interposed therebetween (see French Patent No. 786,454 of March 1, 1935).

However, such systems were so difficult to apply on a commercial scale that they had to be abandoned or development had to be restricted to simple experimental models or laboratory samples. This experience is supported by publications such as: Nachrichten der Gesellschaft der Wissenschaften zu Göttingen, Yearly Report, by R. W. Pohl, 1933/34, page 55; Schweizer Archive, 1941, volumes 1 and 3: Ueber Sperrschichten, by W. Schottky; Zeitschrift fur Physik, vol. 111, volumes 5 and 6, 1938 (R. Hilsch and R. W. Pohl); Modern Theory of Solids, 1940 (F. Seitz); Crystal Rectifiers, 1948 (H. C. Torrey and C. A. Whitmer).

In order practically to carry into effect systems comprising solid semiconductors arranged to produce electronic relay effects similar to those occurring in electronic tubes, two essential difficulties must be overcome. Firstly, the diameter of the contact area between metal needle and crystal should be of an order proportional to the thickness of the crystal barrier layer. Secondly, the gap between the conductive electrodes where engagement occurs with the semiconductor should be so selected that one of the conductive electrode point members will be positioned inside the barrier layer area of the other point member.

With the thickest barrier layer made hitherto, it would have been necessary to use values lower than 5 μ both for the diameters of the contact areas, on the one hand, and for the gap be-

2

or n-type excess and p-type deficiency concentration, respectively, that the inner resistivity of the device becomes very high. Arrangements of this type cannot be used practically for technical purposes.

The present invention permits to eliminate the above-mentioned difficulties and to realize on a commercial scale multi-electrode crystal devices of this kind for producing electronic relay action.

A more specific object of this invention is a multi-electrode device with at least two semiconductors of different conductivity characteristics; one of the semiconductors forms a control electrode and includes a surface barrier layer.

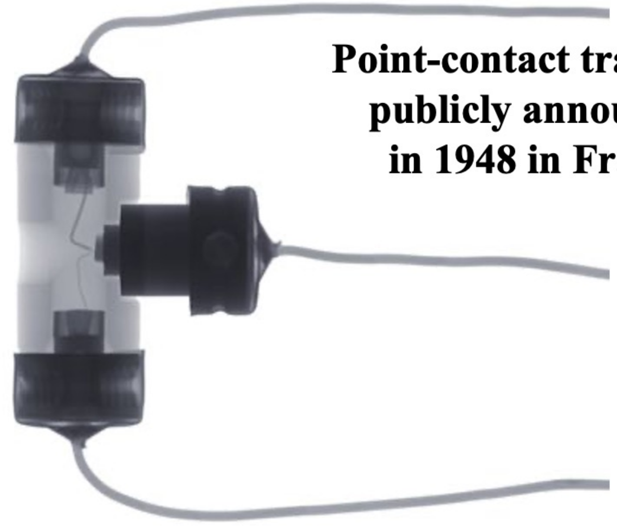
According to another feature of the invention, one of the semiconductors preferably the control electrode has a p-type (deficiency) or non-electronic conductivity and the other semiconductor an n-type (excess) or electronic conductivity.

According to a further feature of the invention, a semiconductor, preferably the other semiconductor mentioned above also includes a surface or internal barrier layer.

In one embodiment of the invention, the semiconductors or electrodes of the crystal are formed simultaneously from a single semiconductive element (such as germanium). In this element, by any suitable known method, zones of different conductivity characteristics are created.

Still in accordance with the invention, in at least one of said semiconductors or in one of the zones thereof such geometrical configuration is provided as to assure substantial radial distribution of the lines of force of the electric fields.

Furthermore, the invention relates to novel commercial products comprising multi-electrode crystal devices wherein external conductive electrodes are in direct contact with each semiconductive electrode, and wherein there is a gap between the contact points which is greater than 50 μ.



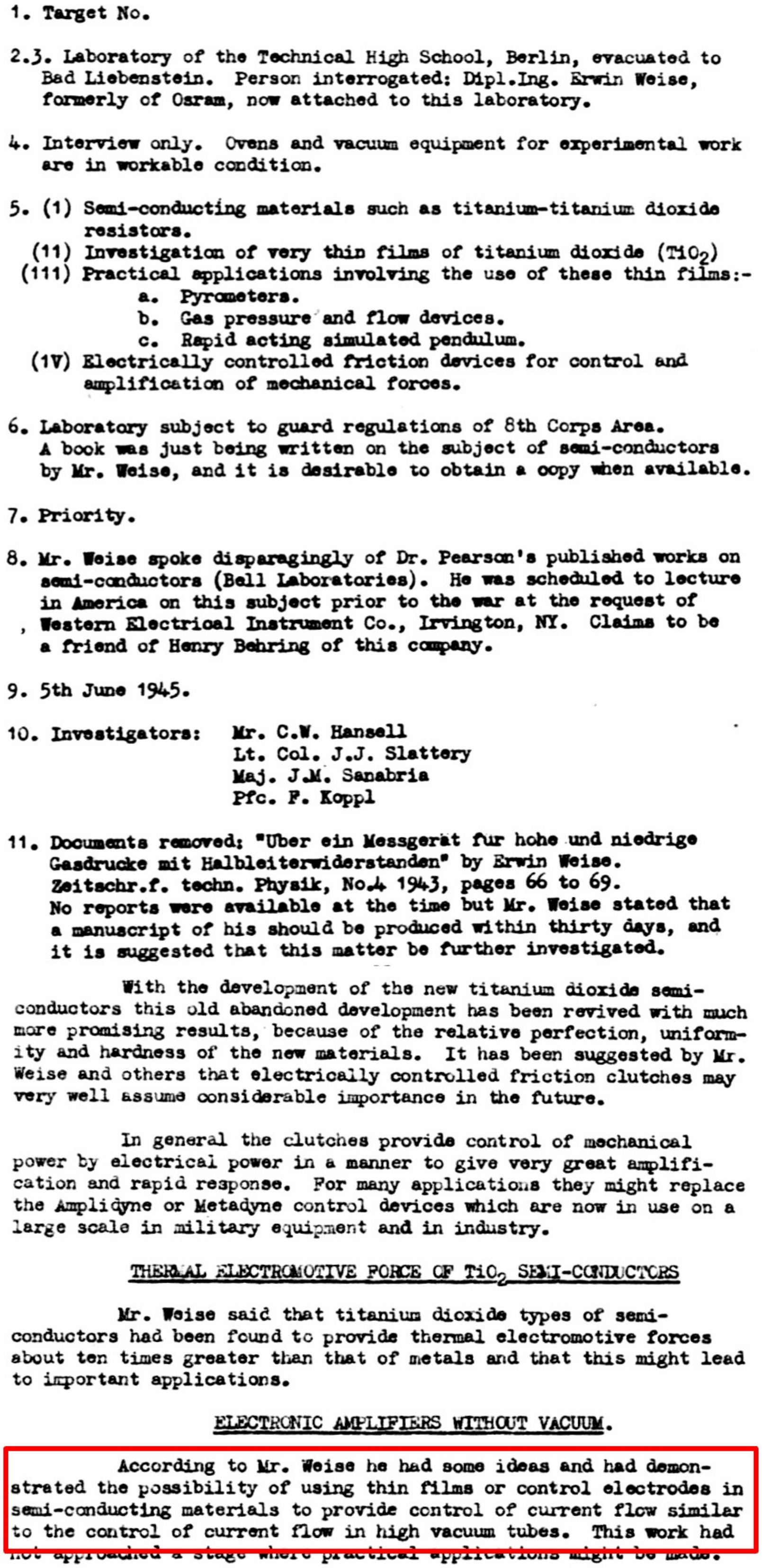
Point-contact transistor publicly announced in 1948 in France

Figure 6.86: Heinrich Welker and Herbert Mataré began developing a point-contact transistor in Germany during the war, filed a detailed patent application based on that wartime work on 6 April 1945, and publicly announced their transistor in 1948 in France.

Transistors (8)

Erwin Weise (19??–19??) described a transistor to Allied investigators

CIOS XXXI-2



1. Target No.

2.3. Laboratory of the Technical High School, Berlin, evacuated to Bad Liebenstein. Person interrogated: Dipl.Ing. Erwin Weise, formerly of Osram, now attached to this laboratory.

4. Interview only. Ovens and vacuum equipment for experimental work are in workable condition.

5. (1) Semi-conducting materials such as titanium-titanium dioxide resistors.
(11) Investigation of very thin films of titanium dioxide (TiO_2)
(111) Practical applications involving the use of these thin films:-
  a. Pyrometers.
  b. Gas pressure and flow devices.
  c. Rapid acting simulated pendulum.
(1V) Electrically controlled friction devices for control and amplification of mechanical forces.

6. Laboratory subject to guard regulations of 8th Corps Area. A book was just being written on the subject of semi-conductors by Mr. Weise, and it is desirable to obtain a copy when available.

7. Priority.

8. Mr. Weise spoke disparagingly of Dr. Pearson's published works on semi-conductors (Bell Laboratories). He was scheduled to lecture in America on this subject prior to the war at the request of Western Electrical Instrument Co., Irvington, NY. Claims to be a friend of Henry Behring of this company.

9. 5th June 1945.

10. Investigators: Mr. C.W. Hansell
Lt. Col. J.J. Slattery
Maj. J.M. Sanabria
Pfc. F. Koppl

11. Documents removed: "Uber ein Messgerat fur hohe und niedrige Gasdrucke mit Halbleiterwiderstanden" by Erwin Weise. Zeitschr.f. techn. Physik, No.4 1943, pages 66 to 69. No reports were available at the time but Mr. Weise stated that a manuscript of his should be produced within thirty days, and it is suggested that this matter be further investigated.

With the development of the new titanium dioxide semi-conductors this old abandoned development has been revived with much more promising results, because of the relative perfection, uniformity and hardness of the new materials. It has been suggested by Mr. Weise and others that electrically controlled friction clutches may very well assume considerable importance in the future.

In general the clutches provide control of mechanical power by electrical power in a manner to give very great amplification and rapid response. For many applications they might replace the Amplidyne or Metadyne control devices which are now in use on a large scale in military equipment and in industry.

THERMAL ELECTROMOTIVE FORCE OF TiO_2 SEMI-CONDUCTORS

Mr. Weise said that titanium dioxide types of semi-conductors had been found to provide thermal electromotive forces about ten times greater than that of metals and that this might lead to important applications.

ELECTRONIC AMPLIFIERS WITHOUT VACUUM.

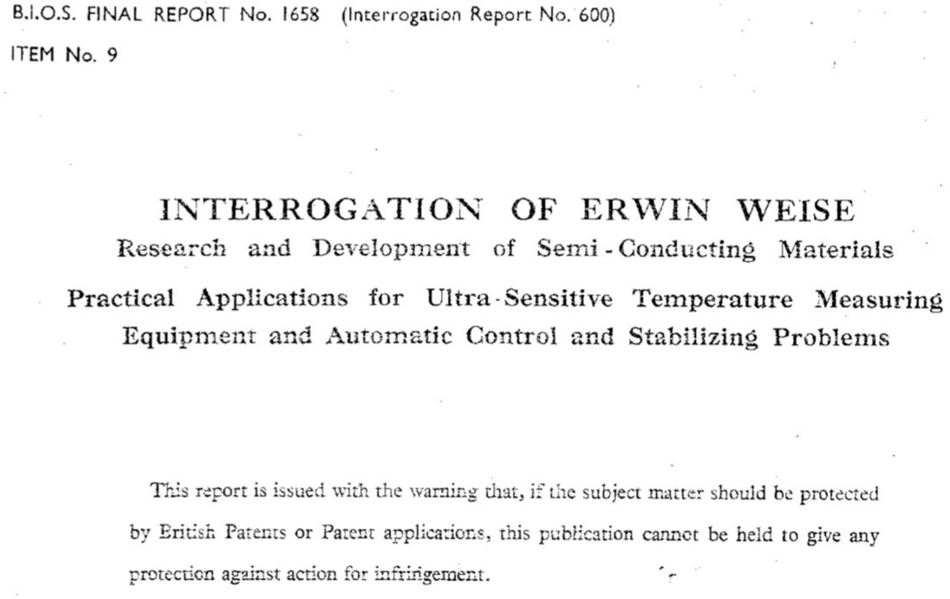
According to Mr. Weise he had some ideas and had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes. This work had not approached a stage where practical applications might be made.

Figure 6.87: Erwin Weise told Allied investigators that he "had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes" to create "electronic amplifiers without vacuum."

Transistors (8)

**Erwin Weise
(19??–19??)
described a
transistor
to Allied
investigators**

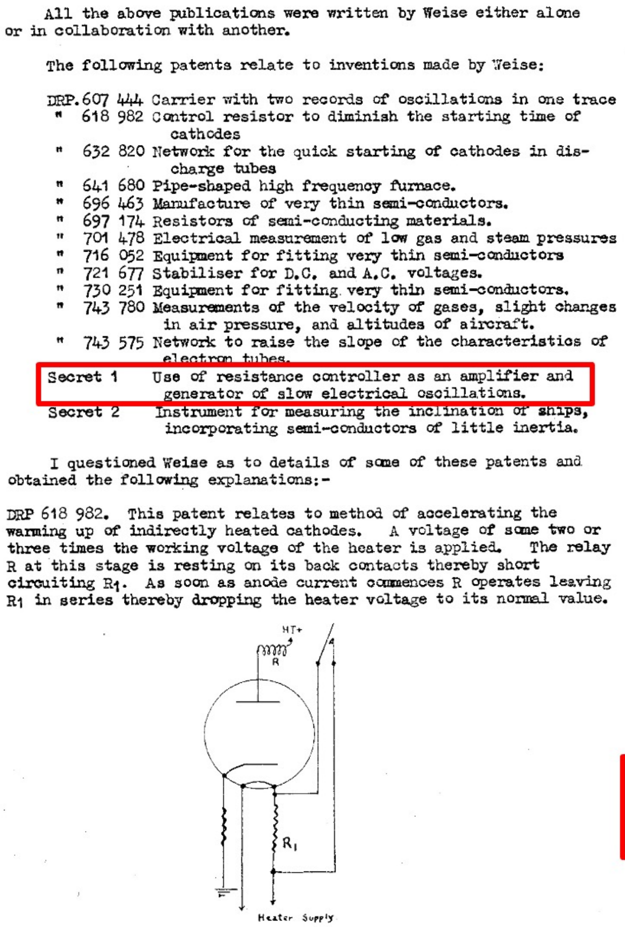
BIOS 1658



B.I.O.S. FINAL REPORT No. 1658 (Interrogation Report No. 600)
ITEM No. 9

INTERROGATION OF ERWIN WEISE
Research and Development of Semi-Conducting Materials
Practical Applications for Ultra-Sensitive Temperature Measuring
Equipment and Automatic Control and Stabilizing Problems

This report is issued with the warning that, if the subject matter should be protected by British Patents or Patent applications, this publication cannot be held to give any protection against action for infringement.



All the above publications were written by Weise either alone or in collaboration with another.

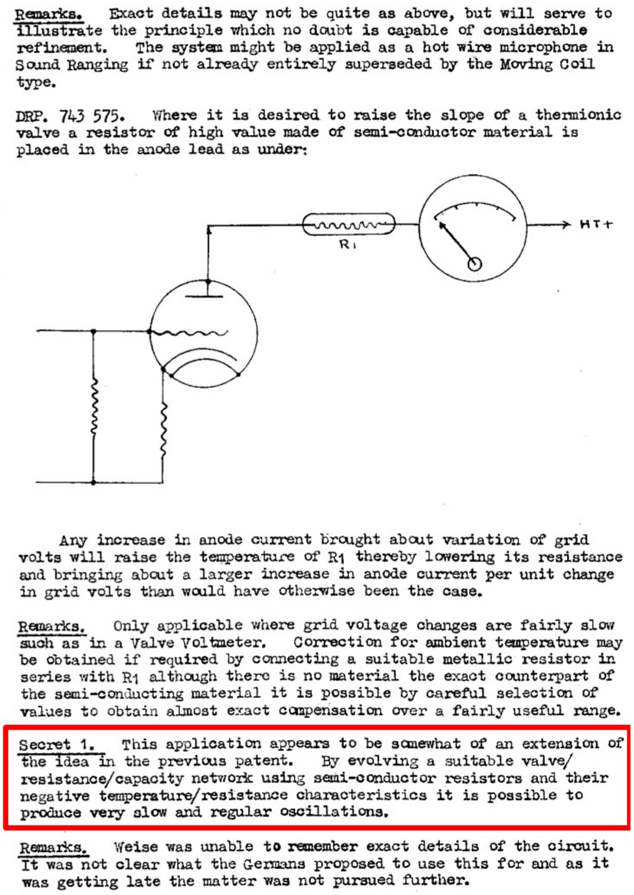
The following patents relate to inventions made by Weise:

DRP. 607 444 Carrier with two records of oscillations in one trace
" 618 982 Control resistor to diminish the starting time of cathodes
" 632 820 Network for the quick starting of cathodes in discharge tubes
" 641 680 Pipe-shaped high frequency furnace.
" 696 463 Manufacture of very thin semi-conductors.
" 697 174 Resistors of semi-conducting materials.
" 701 478 Electrical measurement of low gas and steam pressures
" 716 052 Equipment for fitting very thin semi-conductors
" 721 677 Stabiliser for D.C. and A.C. voltages.
" 730 251 Equipment for fitting very thin semi-conductors.
" 743 780 Measurements of the velocity of gases, slight changes in air pressure, and altitudes of aircraft.
" 743 575 Network to raise the slope of the characteristics of electron tubes.
Secret 1 Use of resistance controller as an amplifier and generator of slow electrical oscillations.
Secret 2 Instrument for measuring the inclination of ships, incorporating semi-conductors of little inertia.

I questioned Weise as to details of some of these patents and obtained the following explanations:-

DRP 618 982. This patent relates to method of accelerating the warming up of indirectly heated cathodes. A voltage of some two or three times the working voltage of the heater is applied. The relay R at this stage is resting on its back contacts thereby short circuiting R_1. As soon as anode current commences R operates leaving R_1 in series thereby dropping the heater voltage to its normal value.

HT+
R
R_1
Heater Supply



Remarks. Exact details may not be quite as above, but will serve to illustrate the principle which no doubt is capable of considerable refinement. The system might be applied as a hot wire microphone in Sound Ranging if not already entirely superseded by the Moving Coil type.

DRP. 743 575. Where it is desired to raise the slope of a thermionic valve a resistor of high value made of semi-conductor material is placed in the anode lead as under:

Any increase in anode current brought about variation of grid volts will raise the temperature of R_1 thereby lowering its resistance and bringing about a larger increase in anode current per unit change in grid volts than would have otherwise been the case.

Remarks. Only applicable where grid voltage changes are fairly slow such as in a Valve Voltmeter. Correction for ambient temperature may be obtained if required by connecting a suitable metallic resistor in series with R_1 although there is no material the exact counterpart of the semi-conducting material it is possible by careful selection of values to obtain almost exact compensation over a fairly useful range.

Secret 1. This application appears to be somewhat of an extension of the idea in the previous patent. By evolving a suitable valve/resistance/capacity network using semi-conductor resistors and their negative temperature/resistance characteristics it is possible to produce very slow and regular oscillations.

Remarks. Weise was unable to remember exact details of the circuit. It was not clear what the Germans proposed to use this for and as it was getting late the matter was not pursued further.

Figure 6.88: Erwin Weise told Allied investigators that he “had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes” to create “electronic amplifiers without vacuum.”

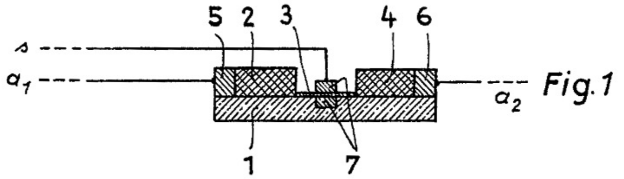
Transistors (9)

Frank Rose
(19??–19??)

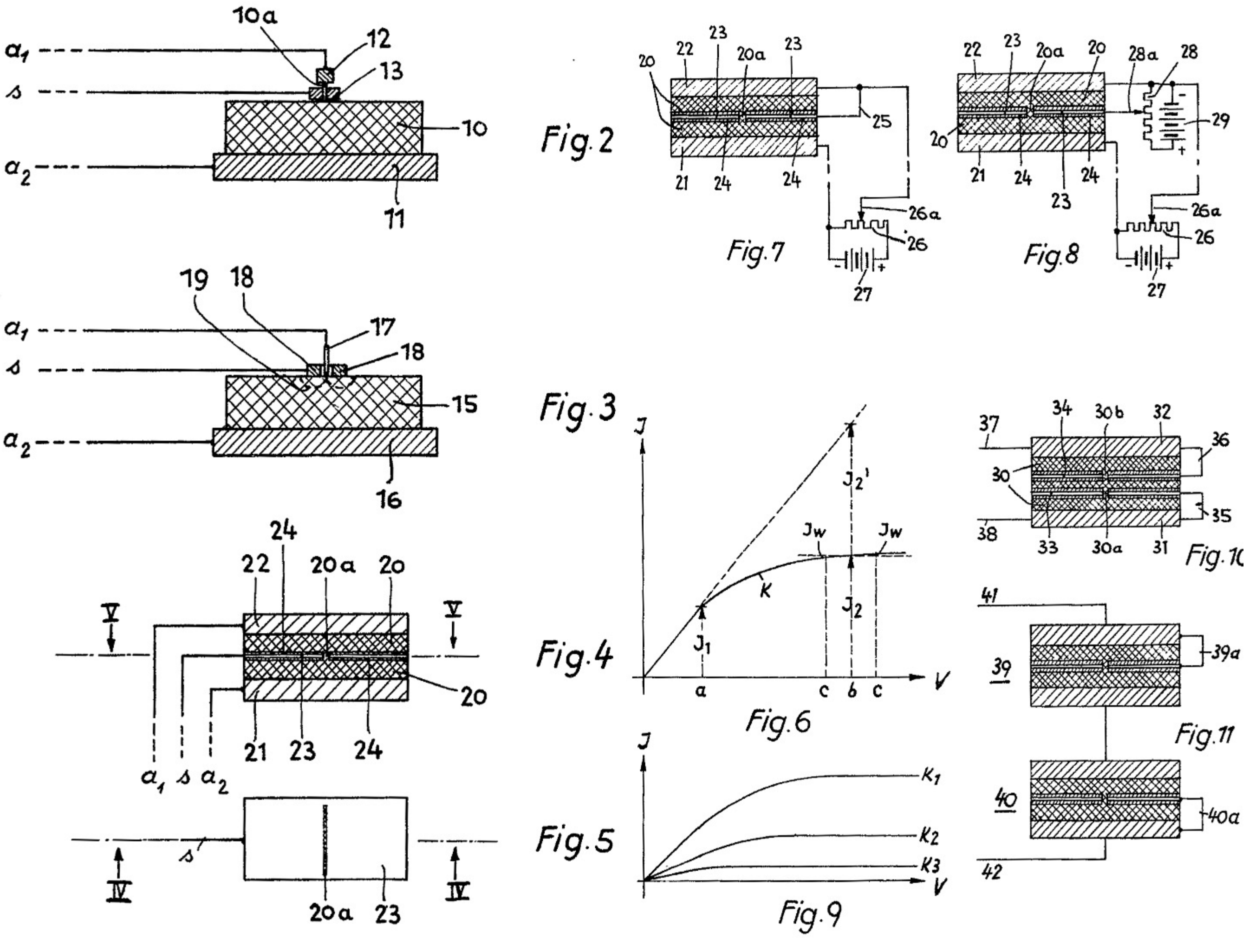
Erich Waldkötter
(19??–19??)

Eberhard Spenke
(1905–1992)

Filed detailed patent applications on transistors in 1949 (based on wartime work?)



5
2
3
4
6
s
a_1
a_2
Fig. 1
1
7

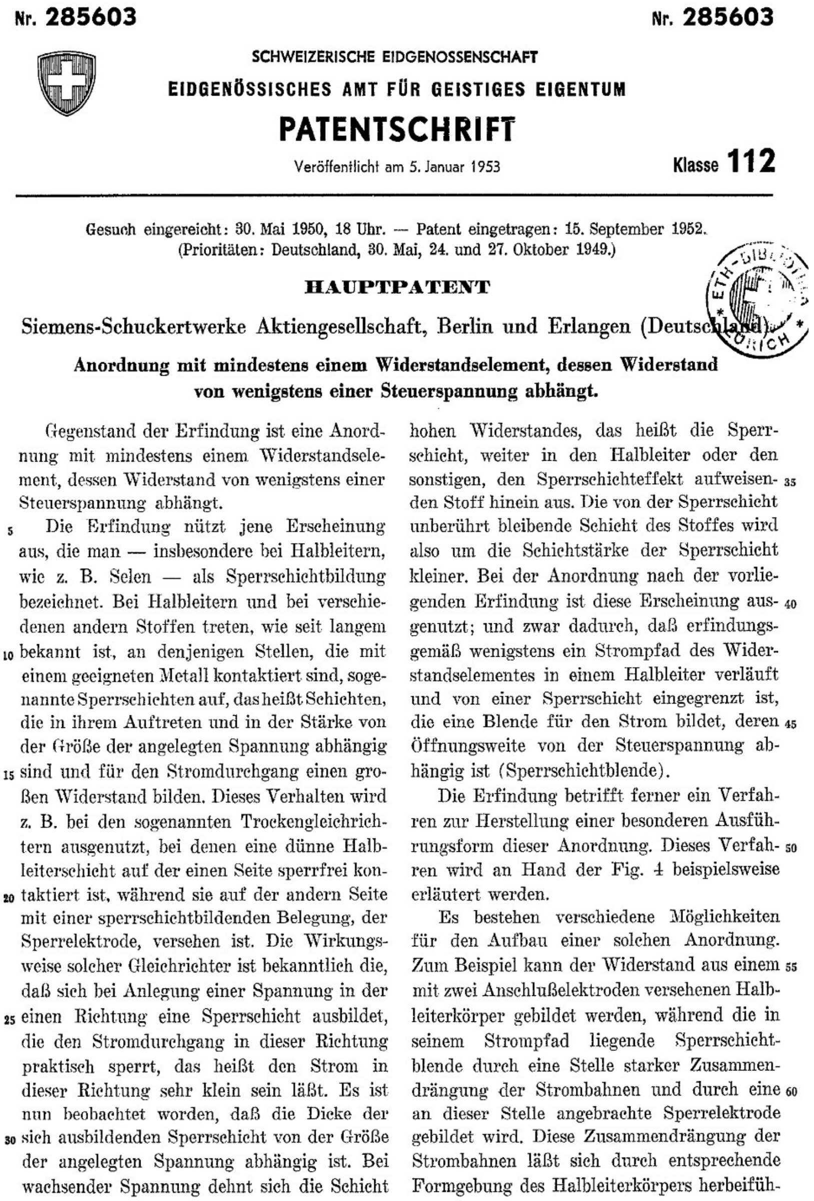


10a
12
13
a_1
s
a_2
10
11
Fig. 2
19
18
17
15
16
Fig. 3
24
22
20a
20
21
23
V
IV
a_1 s a_2
Fig. 4
s
Fig. 5
20
22
23
20a
21
24
25
26a
26
27
Fig. 7
28a
28
29
Fig. 8
J
J_2'
J_w
J_2
J_1
k
a
c
b
V
Fig. 6
k_1
k_2
k_3
Fig. 9
37
34
30b
32
36
30
35
38
33
30a
31
Fig. 1(
41
39
39a
Fig. 11
40
40a
42

Figure 6.89: Frank Rose, Eberhard Spenke, and Erich Waldkötter filed detailed patent applications on transistors in 1949, likely based on wartime work.

Transistors (9)

Eberhard Spenke, Frank Rose, and Erich Waldkötter filed detailed patent applications on transistors in 1949 (based on wartime work?)



Nr. 285603 **Nr. 285603**

SCHWEIZERISCHE EIDGENOSSENSCHAFT
EIDGENÖSSISCHES AMT FÜR GEISTIGES EIGENTUM

PATENTSCHRIFT

Veröffentlicht am 5. Januar 1953

Klasse **112**

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(Prioritäten: Deutschland, 30. Mai, 24. und 27. Oktober 1949.)

ETH-Bibliothek Zürich

HAUPTPATENT

Siemens-Schuckertwerke Aktiengesellschaft, Berlin und Erlangen (Deutschland).

Anordnung mit mindestens einem Widerstandselement, dessen Widerstand von wenigstens einer Steuerspannung abhängt.

Gegenstand der Erfindung ist eine Anordnung mit mindestens einem Widerstandselement, dessen Widerstand von wenigstens einer Steuerspannung abhängt.

Die Erfindung nützt jene Erscheinung aus, die man — insbesondere bei Halbleitern, wie z. B. Selen — als Sperrschichtbildung bezeichnet. Bei Halbleitern und bei verschiedenen andern Stoffen treten, wie seit langem bekannt ist, an denjenigen Stellen, die mit einem geeigneten Metall kontaktiert sind, sogenannte Sperrschichten auf, das heißt Schichten, die in ihrem Auftreten und in der Stärke von der Größe der angelegten Spannung abhängig sind und für den Stromdurchgang einen großen Widerstand bilden. Dieses Verhalten wird z. B. bei den sogenannten Trockengleichrichtern ausgenutzt, bei denen eine dünne Halbleiterschicht auf der einen Seite sperrfrei kontaktiert ist, während sie auf der andern Seite mit einer sperrschichtbildenden Belegung, der Sperrelektrode, versehen ist. Die Wirkungsweise solcher Gleichrichter ist bekanntlich die, daß sich bei Anlegung einer Spannung in der einen Richtung eine Sperrschicht ausbildet, die den Stromdurchgang in dieser Richtung praktisch sperrt, das heißt den Strom in dieser Richtung sehr klein sein läßt. Es ist nun beobachtet worden, daß die Dicke der sich ausbildenden Sperrschicht von der Größe der angelegten Spannung abhängig ist. Bei wachsender Spannung dehnt sich die Schicht hohen Widerstandes, das heißt die Sperrschicht, weiter in den Halbleiter oder den sonstigen, den Sperrschichteffekt aufweisenden Stoff hinein aus. Die von der Sperrschicht unberührt bleibende Schicht des Stoffes wird also um die Schichtstärke der Sperrschicht kleiner. Bei der Anordnung nach der vorliegenden Erfindung ist diese Erscheinung ausgenutzt; und zwar dadurch, daß erfindungsgemäß wenigstens ein Strompfad des Widerstandselementes in einem Halbleiter verläuft und von einer Sperrschicht eingegrenzt ist, die eine Blende für den Strom bildet, deren Öffnungsweite von der Steuerspannung abhängig ist (Sperrschichtblende).

Die Erfindung betrifft ferner ein Verfahren zur Herstellung einer besonderen Ausführungsform dieser Anordnung. Dieses Verfahren wird an Hand der Fig. 4 beispielsweise erläutert werden.

Es bestehen verschiedene Möglichkeiten für den Aufbau einer solchen Anordnung. Zum Beispiel kann der Widerstand aus einem mit zwei Anschlußelektroden versehenen Halbleiterkörper gebildet werden, während die in seinem Strompfad liegende Sperrschichtblende durch eine Stelle starker Zusammendrängung der Strombahnen und durch eine an dieser Stelle angebrachte Sperrelektrode gebildet wird. Diese Zusammendrängung der Strombahnen läßt sich durch entsprechende Formgebung des Halbleiterkörpers herbeifüh-

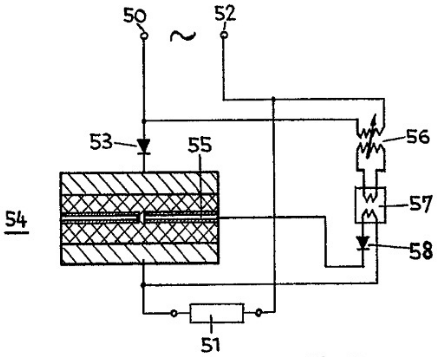


Fig. 12

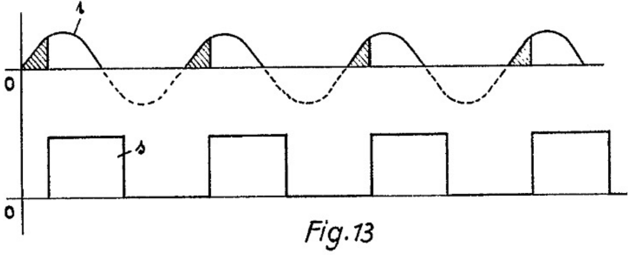


Fig. 13

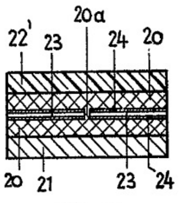


Fig. 14

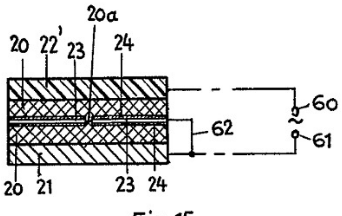
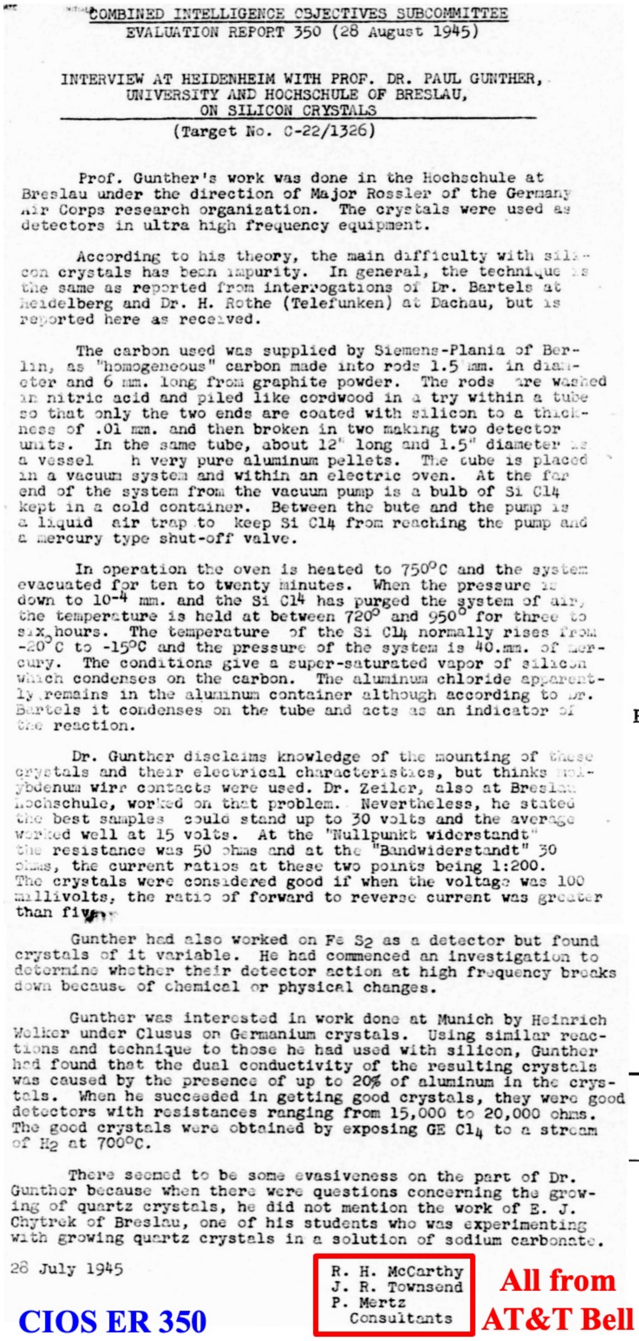


Fig. 15

Figure 6.90: Frank Rose, Eberhard Spenke, and Erich Waldkötter filed detailed patent applications on transistors in 1949, likely based on wartime work.

Transistors (10)

Design and fabrication of silicon semiconductor devices (wartime onward)



COMBINED INTELLIGENCE OBJECTIVES SUBCOMMITTEE
EVALUATION REPORT 350 (28 August 1945)

INTERVIEW AT HEIDENHEIM WITH PROF. DR. PAUL GUNTHER,
UNIVERSITY AND HOCHSCHULE OF BRESLAU,
ON SILICON CRYSTALS
(Target No. C-22/1326)

Prof. Gunther's work was done in the Hochschule at Breslau under the direction of Major Rossler of the Germany Air Corps research organization. The crystals were used as detectors in ultra high frequency equipment.

According to his theory, the main difficulty with silicon crystals has been impurity. In general, the technique is the same as reported from interrogations of Dr. Bartels at Heidelberg and Dr. H. Rothe (Telefunken) at Dachau, but is reported here as received.

The carbon used was supplied by Siemens-Plania of Berlin, as "homogeneous" carbon made into rods 1.5 mm. in diameter and 6 mm. long from graphite powder. The rods are washed in nitric acid and piled like cordwood in a try within a tube so that only the two ends are coated with silicon to a thickness of .01 mm. and then broken in two making two detector units. In the same tube, about 12" long and 1.5" diameter is a vessel h very pure aluminum pellets. The tube is placed in a vacuum system and within an electric oven. At the far end of the system from the vacuum pump is a bulb of Si Cl4 kept in a cold container. Between the bute and the pump is a liquid air trap to keep Si Cl4 from reaching the pump and a mercury type shut-off valve.

In operation the oven is heated to 750°C and the system evacuated for ten to twenty minutes. When the pressure is down to 10^{-4} mm. and the Si Cl^4 has purged the system of air, the temperature is held at between 720° and 950° for three to six hours. The temperature of the Si Cl4 normally rises from -20°C to -15°C and the pressure of the system is 40.mm. of mercury. The conditions give a super-saturated vapor of silicon which condenses on the carbon. The aluminum chloride apparently remains in the aluminum container although according to Dr. Bartels it condenses on the tube and acts as an indicator of the reaction.

Dr. Gunther disclaims knowledge of the mounting of these crystals and their electrical characteristics, but thinks molybdenum wirr contacts were used. Dr. Zeiler, also at Breslau Hochschule, worked on that problem. Nevertheless, he stated the best samples could stand up to 30 volts and the average worked well at 15 volts. At the "Nullpunkt widerstandt" the resistance was 50 ohms and at the "Bandwiderstandt" 30 ohms, the current ratios at these two points being 1:200. The crystals were considered good if when the voltage was 100 millivolts, the ratio of forward to reverse current was greater than five.

Gunther had also worked on Fe S_2 as a detector but found crystals of it variable. He had commenced an investigation to determine whether their detector action at high frequency breaks down because of chemical or physical changes.

Gunther was interested in work done at Munich by Heinrich Welker under Clusus on Germanium crystals. Using similar reactions and technique to those he had used with silicon, Gunther had found that the dual conductivity of the resulting crystals was caused by the presence of up to 20% of aluminum in the crystals. When he succeeded in getting good crystals, they were good detectors with resistances ranging from 15,000 to 20,000 ohms. The good crystals were obtained by exposing GE Cl_4 to a stream of H_2 at 700°C.

There seemed to be some evasiveness on the part of Dr. Gunther because when there were questions concerning the growing of quartz crystals, he did not mention the work of E. J. Chytrek of Breslau, one of his students who was experimenting with growing quartz crystals in a solution of sodium carbonate.

28 July 1945

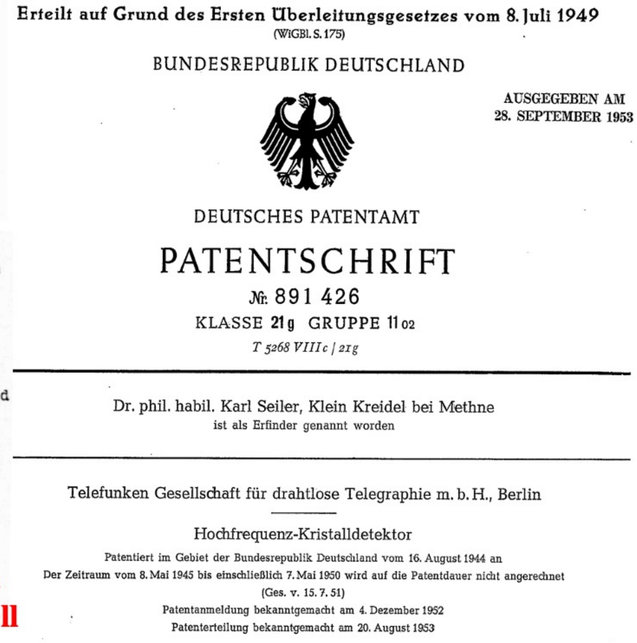
R. H. McCarthy
J. R. Townsend
P. Mertz
Consultants

All from AT&T Bell

CIOS ER 350

Paul Ludwig Günther (1892–1969)

Karl Seiler (1910–1991)



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
28. SEPTEMBER 1953

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 891 426

KLASSE 21g GRUPPE 11 02

T 5268 VIIIc / 21g

Dr. phil. habil. Karl Seiler, Klein Kreidel bei Methne
ist als Erfinder genannt worden

Telefunken Gesellschaft für drahtlose Telegraphie m. b. H., Berlin

Hochfrequenz-Kristalldetektor

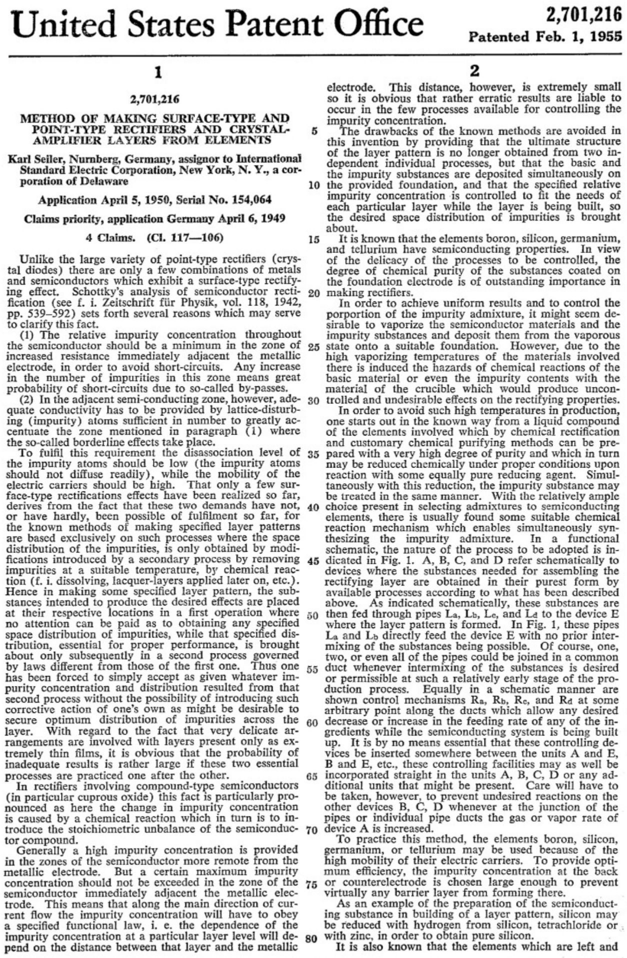
Patentiert im Gebiet der Bundesrepublik Deutschland vom 16. August 1944 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
(Ges. v. 15. 7. 51)
Patentanmeldung bekanntgemacht am 4. Dezember 1952
Patenterteilung bekanntgemacht am 20. August 1953

Figure 6.91: Karl Seiler and Paul Ludwig Günther developed methods for designing and fabricating silicon semiconductor devices throughout the war and into the postwar period.

Transistors (10)

Paul Ludwig Günther (1892–1969)

Karl Seiler (1910–1991)



United States Patent Office

2,701,216
Patented Feb. 1, 1955

1

2,701,216

METHOD OF MAKING SURFACE-TYPE AND POINT-TYPE RECTIFIERS AND CRYSTAL-AMPLIFIER LAYERS FROM ELEMENTS

Karl Seiler, Nurnberg, Germany, assignor to International Standard Electric Corporation, New York, N. Y., a corporation of Delaware

Application April 5, 1950, Serial No. 154,064

Claims priority, application Germany April 6, 1949

4 Claims. (Cl. 117—106)

Unlike the large variety of point-type rectifiers (crystal diodes) there are only a few combinations of metals and semiconductors which exhibit a surface-type rectifying effect. Schottky's analysis of semiconductor rectification (see f. i. Zeitschrift für Physik, vol. 118, 1942, pp. 539–592) sets forth several reasons which may serve to clarify this fact.

(1) The relative impurity concentration throughout the semiconductor should be a minimum in the zone of increased resistance immediately adjacent the metallic electrode, in order to avoid short-circuits. Any increase in the number of impurities in this zone means great probability of short-circuits due to so-called by-passes.

(2) In the adjacent semi-conducting zone, however, adequate conductivity has to be provided by lattice-disturbing (impurity) atoms sufficient in number to greatly accentuate the zone mentioned in paragraph (1) where the so-called borderline effects take place.

To fulfil this requirement the disassociation level of the impurity atoms should be low (the impurity atoms should not diffuse readily), while the mobility of the electric carriers should be high. That only a few surface-type rectifications effects have been realized so far, derives from the fact that these two demands have not, or have hardly, been possible of fulfilment so far, for the known methods of making specified layer patterns are based exclusively on such processes where the space distribution of the impurities, is only obtained by modifications introduced by a secondary process by removing impurities at a suitable temperature, by chemical reaction (f. i. dissolving, lacquer-layers applied later on, etc.). Hence in making some specified layer pattern, the substances intended to produce the desired effects are placed at their respective locations in a first operation where no attention can be paid as to obtaining any specified space distribution of impurities, while that specified distribution, essential for proper performance, is brought about only subsequently in a second process governed by laws different from those of the first one. Thus one has been forced to simply accept as given whatever impurity concentration and distribution resulted from that second process without the possibility of introducing such corrective action of one's own as might be desirable to secure optimum distribution of impurities across the layer. With regard to the fact that very delicate arrangements are involved with layers present only as extremely thin films, it is obvious that the probability of inadequate results is rather large if these two essential processes are practiced one after the other.

In rectifiers involving compound-type semiconductors (in particular cuprous oxide) this fact is particularly pronounced as here the change in impurity concentration is caused by a chemical reaction which in turn is to introduce the stoichiometric unbalance of the semiconductor compound.

Generally a high impurity concentration is provided in the zones of the semiconductor more remote from the metallic electrode. But a certain maximum impurity concentration should not be exceeded in the zone of the semiconductor immediately adjacent the metallic electrode. This means that along the main direction of current flow the impurity concentration will have to obey a specified functional law, i. e. the dependence of the impurity concentration at a particular layer level will depend on the distance between that layer and the metallic

2

electrode. This distance, however, is extremely small so it is obvious that rather erratic results are liable to occur in the few processes available for controlling the impurity concentration.

The drawbacks of the known methods are avoided in this invention by providing that the ultimate structure of the layer pattern is no longer obtained from two independent individual processes, but that the basic and the impurity substances are deposited simultaneously on the provided foundation, and that the specified relative impurity concentration is controlled to fit the needs of each particular layer while the layer is being built, so the desired space distribution of impurities is brought about.

It is known that the elements boron, silicon, germanium, and tellurium have semiconducting properties. In view of the delicacy of the processes to be controlled, the degree of chemical purity of the substances coated on the foundation electrode is of outstanding importance in making rectifiers.

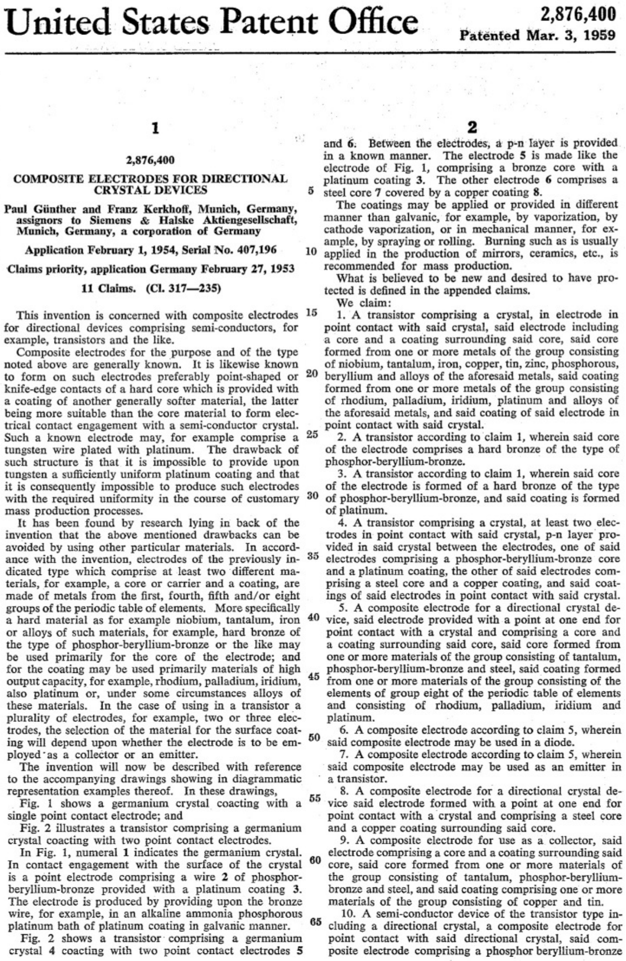
In order to achieve uniform results and to control the porportion of the impurity admixture, it might seem desirable to vaporize the semiconductor materials and the impurity substances and deposit them from the vaporous state onto a suitable foundation. However, due to the high vaporizing temperatures of the materials involved there is induced the hazards of chemical reactions of the basic material or even the impurity contents with the material of the crucible which would produce uncontrolled and undesirable effects on the rectifying properties.

In order to avoid such high temperatures in production, one starts out in the known way from a liquid compound of the elements involved which by chemical rectification and customary chemical purifying methods can be prepared with a very high degree of purity and which in turn may be reduced chemically under proper conditions upon reaction with some equally pure reducing agent. Simultaneously with this reduction, the impurity substance may be treated in the same manner. With the relatively ample choice present in selecting admixtures to semiconducting elements, there is usually found some suitable chemical reaction mechanism which enables simultaneously synthesizing the impurity admixture. In a functional schematic, the nature of the process to be adopted is indicated in Fig. 1. A, B, C, and D refer schematically to devices where the substances needed for assembling the rectifying layer are obtained in their purest form by available processes according to what has been described above. As indicated schematically, these substances are then fed through pipes L_a, L_b, L_c, and L_d to the device E where the layer pattern is formed. In Fig. 1, these pipes L_a and L_b directly feed the device E with no prior intermixing of the substances being possible. Of course, one, two, or even all of the pipes could be joined in a common duct whenever intermixing of the substances is desired or permissible at such a relatively early stage of the production process. Equally in a schematic manner are shown control mechanisms R_a, R_b, R_c, and R_d at some arbitrary point along the ducts which allow any desired decrease or increase in the feeding rate of any of the ingredients while the semiconducting system is being built up. It is by no means essential that these controlling devices be inserted somewhere between the units A and E, B and E, etc., these controlling facilities may as well be incorporated straight in the units A, B, C, D or any additional units that might be present. Care will have to be taken, however, to prevent undesired reactions on the other devices B, C, D whenever at the junction of the pipes or individual pipe ducts the gas or vapor rate of device A is increased.

To practice this method, the elements boron, silicon, germanium, or tellurium may be used because of the high mobility of their electric carriers. To provide optimum efficiency, the impurity concentration at the back or counterelectrode is chosen large enough to prevent virtually any barrier layer from forming there.

As an example of the preparation of the semiconducting substance in building of a layer pattern, silicon may be reduced with hydrogen from silicon, tetrachloride or with zinc, in order to obtain pure silicon.

It is also known that the elements which are left and



United States Patent Office

2,876,400
Patented Mar. 3, 1959

1

2,876,400

COMPOSITE ELECTRODES FOR DIRECTIONAL CRYSTAL DEVICES

Paul Günther and Franz Kerkhoff, Munich, Germany, assignors to Siemens & Halske Aktiengesellschaft, Munich, Germany, a corporation of Germany

Application February 1, 1954, Serial No. 407,196

Claims priority, application Germany February 27, 1953

11 Claims. (Cl. 317—235)

This invention is concerned with composite electrodes for directional devices comprising semi-conductors, for example, transistors and the like.

Composite electrodes for the purpose and of the type noted above are generally known. It is likewise known to form on such electrodes preferably point-shaped or knife-edge contacts of a hard core which is provided with a coating of another generally softer material, the latter being more suitable than the core material to form electrical contact engagement with a semi-conductor crystal. Such a known electrode may, for example comprise a tungsten wire plated with platinum. The drawback of such structure is that it is impossible to provide upon tungsten a sufficiently uniform platinum coating and that it is consequently impossible to produce such electrodes with the required uniformity in the course of customary mass production processes.

It has been found by research lying in back of the invention that the above mentioned drawbacks can be avoided by using other particular materials. In accordance with the invention, electrodes of the previously indicated type which comprise at least two different materials, for example, a core or carrier and a coating, are made of metals from the first, fourth, fifth and/or eight groups of the periodic table of elements. More specifically a hard material as for example niobium, tantalum, iron or alloys of such materials, for example, hard bronze of the type of phosphor-beryllium-bronze or the like may be used primarily for the core of the electrode; and for the coating may be used primarily materials of high output capacity, for example, rhodium, palladium, iridium, also platinum or, under some circumstances alloys of these materials. In the case of using in a transistor a plurality of electrodes, for example, two or three electrodes, the selection of the material for the surface coating will depend upon whether the electrode is to be employed as a collector or an emitter.

The invention will now be described with reference to the accompanying drawings showing in diagrammatic representation examples thereof. In these drawings,

Fig. 1 shows a germanium crystal coacting with a single point contact electrode; and

Fig. 2 illustrates a transistor comprising a germanium crystal coacting with two point contact electrodes.

In Fig. 1, numeral **1** indicates the germanium crystal. In contact engagement with the surface of the crystal is a point electrode comprising a wire **2** of phosphor-beryllium-bronze provided with a platinum coating **3**. The electrode is produced by providing upon the bronze wire, for example, in an alkaline ammonia phosphorous platinum bath of platinum coating in galvanic manner.

Fig. 2 shows a transistor comprising a germanium crystal **4** coacting with two point contact electrodes **5**

2

and **6**. Between the electrodes, a p-n layer is provided in a known manner. The electrode **5** is made like the electrode of Fig. 1, comprising a bronze core with a platinum coating **3**. The other electrode **6** comprises a steel core **7** covered by a copper coating **8**.

The coatings may be applied or provided in different manner than galvanic, for example, by vaporization, by cathode vaporization, or in mechanical manner, for example, by spraying or rolling. Burning such as is usually applied in the production of mirrors, ceramics, etc., is recommended for mass production.

What is believed to be new and desired to have protected is defined in the appended claims.

We claim:

1. A transistor comprising a crystal, in electrode in point contact with said crystal, said electrode including a core and a coating surrounding said core, said core formed from one or more metals of the group consisting of niobium, tantalum, iron, copper, tin, zinc, phosphorous, beryllium and alloys of the aforesaid metals, said coating formed from one or more metals of the group consisting of rhodium, palladium, iridium, platinum and alloys of the aforesaid metals, and said coating of said electrode in point contact with said crystal.

2. A transistor according to claim 1, wherein said core of the electrode comprises a hard bronze of the type of phosphor-beryllium-bronze.

3. A transistor according to claim 1, wherein said core of the electrode is formed of a hard bronze of the type of phosphor-beryllium-bronze, and said coating is formed of platinum.

4. A transistor comprising a crystal, at least two electrodes in point contact with said crystal, p-n layer provided in said crystal between the electrodes, one of said electrodes comprising a phosphor-beryllium-bronze core and a platinum coating, the other of said electrodes comprising a steel core and a copper coating, and said coatings of said electrodes in point contact with said crystal.

5. A composite electrode for a directional crystal device, said electrode provided with a point at one end for point contact with a crystal and comprising a core and a coating surrounding said core, said core formed from one or more materials of the group consisting of tantalum, phosphor-beryllium-bronze and steel, said coating formed from one or more materials of the group consisting of the elements of group eight of the periodic table of elements and consisting of rhodium, palladium, iridium and platinum.

6. A composite electrode according to claim 5, wherein said composite electrode may be used in a diode.

7. A composite electrode according to claim 5, wherein said composite electrode may be used as an emitter in a transistor.

8. A composite electrode for a directional crystal device said electrode formed with a point at one end for point contact with a crystal and comprising a steel core and a copper coating surrounding said core.

9. A composite electrode for use as a collector, said electrode comprising a core and a coating surrounding said core, said core formed from one or more materials of the group consisting of tantalum, phosphor-beryllium-bronze and steel, and said coating comprising one or more materials of the group consisting of copper and tin.

10. A semi-conductor device of the transistor type including a directional crystal, a composite electrode for point contact with said directional crystal, said composite electrode comprising a phosphor beryllium-bronze

Figure 6.92: Karl Seiler and Paul Ludwig Günther developed methods for designing and fabricating silicon semiconductor devices throughout the war and into the postwar period.

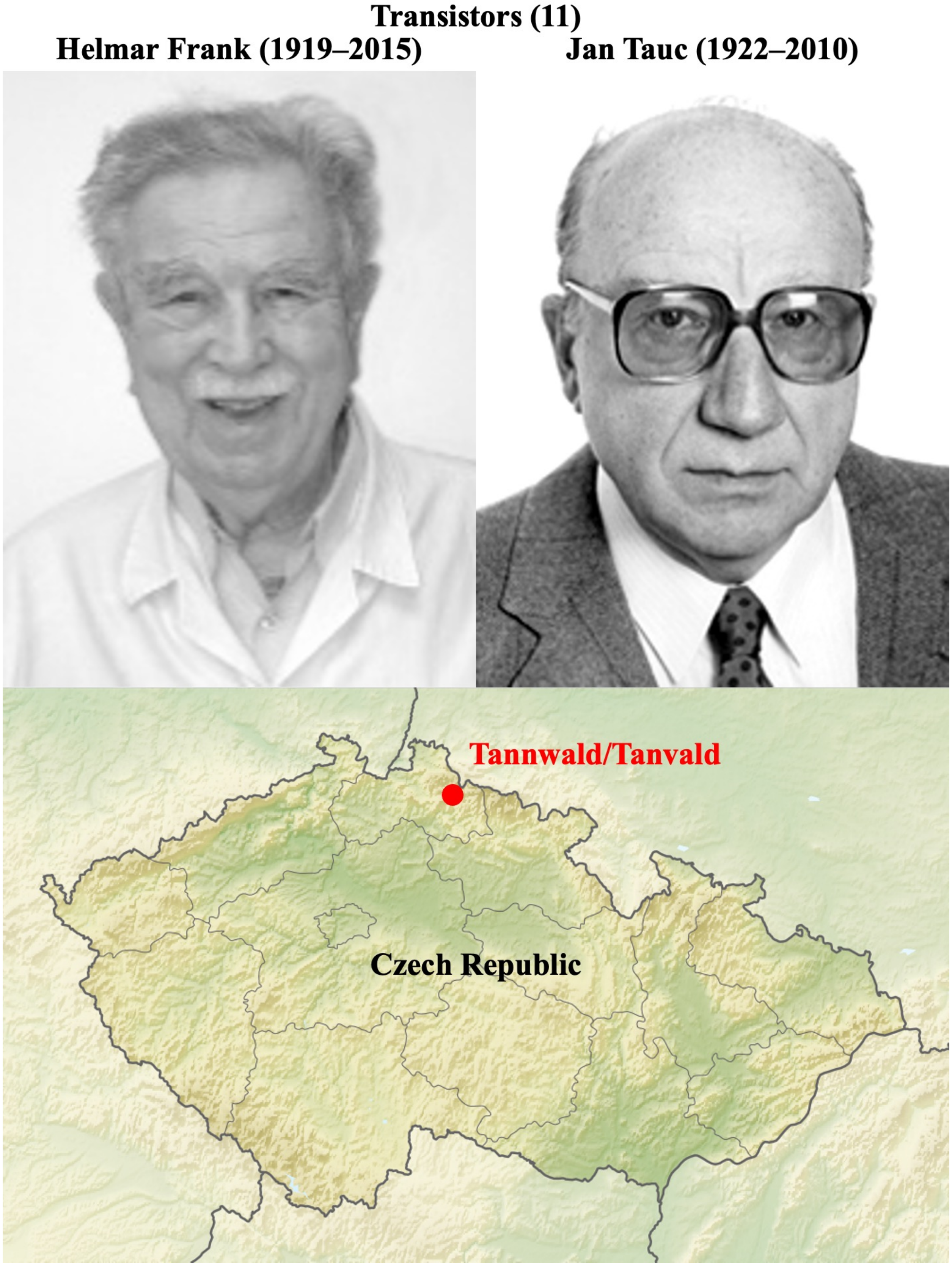
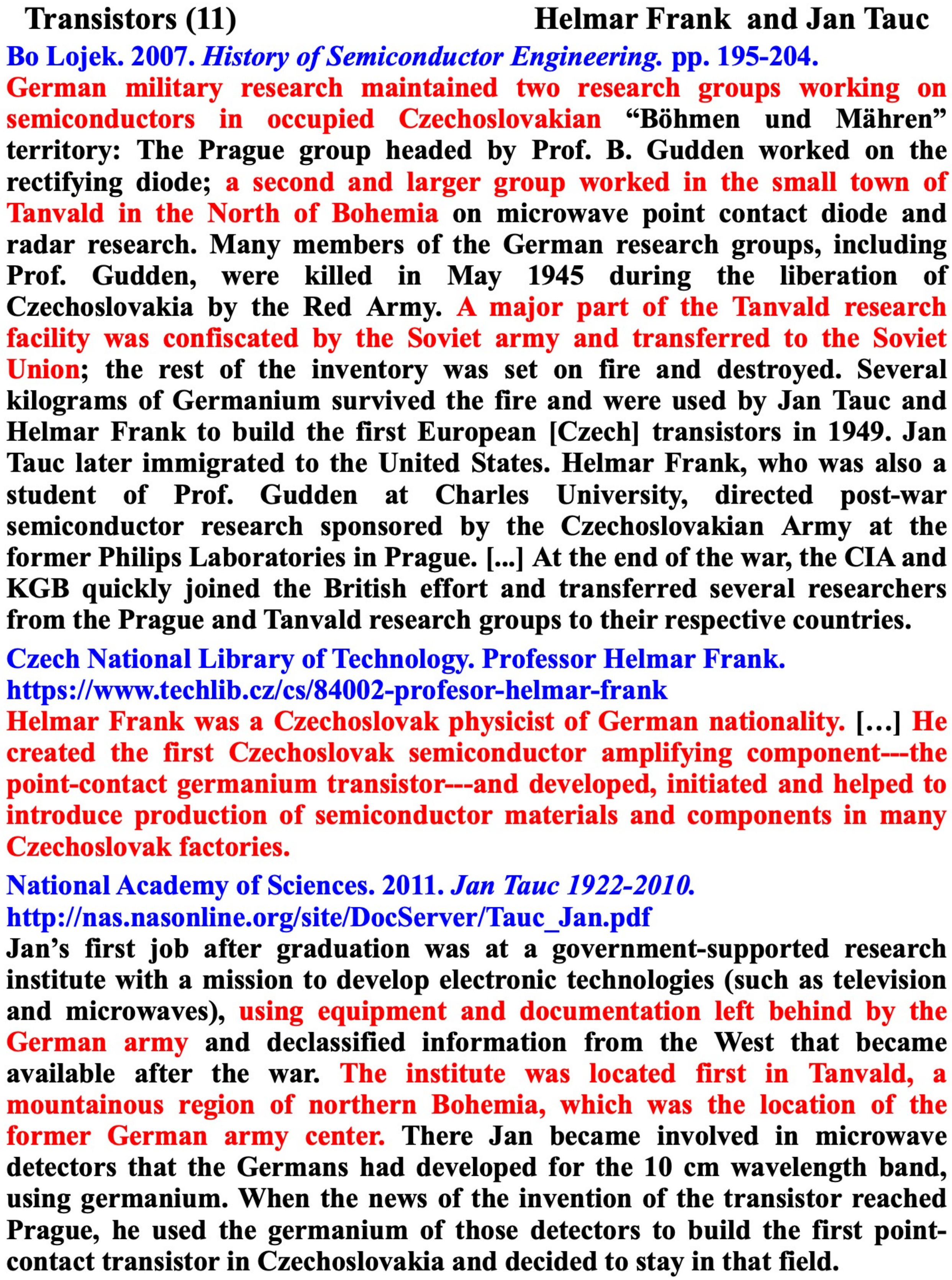

Transistors (11)
Helmar Frank (1919–2015)
Jan Tauc (1922–2010)
Tannwald/Tanvald
Czech Republic

Figure 6.93: Helmar Frank and Jan Tauc produced transistors at the former German electronics laboratory in Tannwald/Tanvald in Czechoslovakia in 1949, based at least in part (and perhaps entirely) on wartime German work there.



Transistors (11) Helmar Frank and Jan Tauc

Bo Lojek. 2007. *History of Semiconductor Engineering.* pp. 195-204.

German military research maintained two research groups working on semiconductors in occupied Czechoslovakian "Böhmen und Mähren" territory: The Prague group headed by Prof. B. Gudden worked on the rectifying diode; a second and larger group worked in the small town of Tanvald in the North of Bohemia on microwave point contact diode and radar research. Many members of the German research groups, including Prof. Gudden, were killed in May 1945 during the liberation of Czechoslovakia by the Red Army. A major part of the Tanvald research facility was confiscated by the Soviet army and transferred to the Soviet Union; the rest of the inventory was set on fire and destroyed. Several kilograms of Germanium survived the fire and were used by Jan Tauc and Helmar Frank to build the first European [Czech] transistors in 1949. Jan Tauc later immigrated to the United States. Helmar Frank, who was also a student of Prof. Gudden at Charles University, directed post-war semiconductor research sponsored by the Czechoslovakian Army at the former Philips Laboratories in Prague. [...] At the end of the war, the CIA and KGB quickly joined the British effort and transferred several researchers from the Prague and Tanvald research groups to their respective countries.

Czech National Library of Technology. Professor Helmar Frank.
https://www.techlib.cz/cs/84002-profesor-helmar-frank

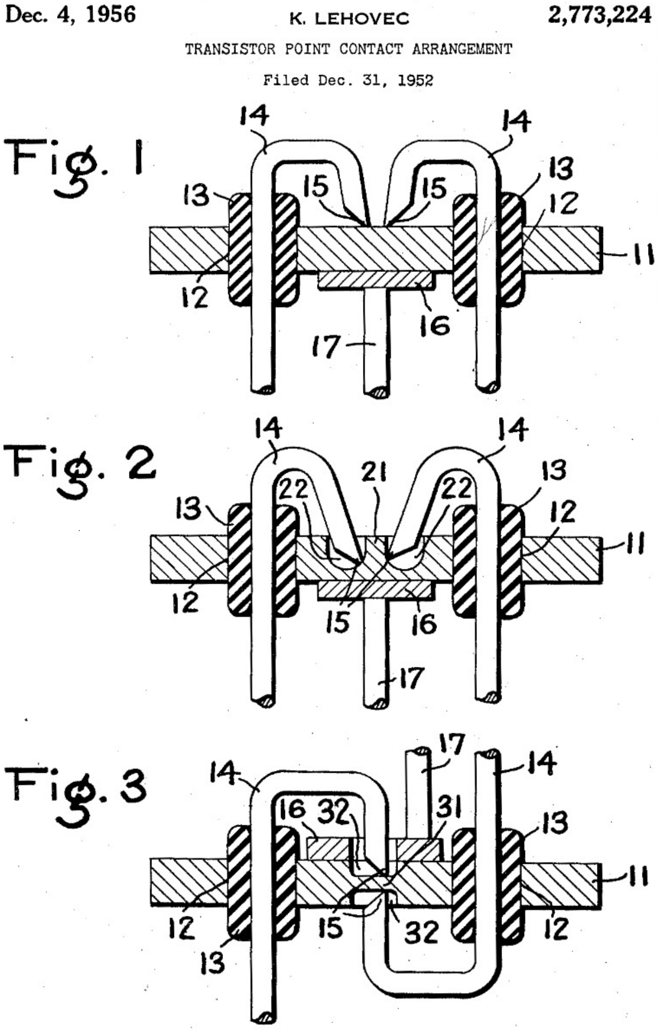
Helmar Frank was a Czechoslovak physicist of German nationality. […] He created the first Czechoslovak semiconductor amplifying component---the point-contact germanium transistor---and developed, initiated and helped to introduce production of semiconductor materials and components in many Czechoslovak factories.

National Academy of Sciences. 2011. *Jan Tauc 1922-2010.*
http://nas.nasonline.org/site/DocServer/Tauc_Jan.pdf

Jan's first job after graduation was at a government-supported research institute with a mission to develop electronic technologies (such as television and microwaves), using equipment and documentation left behind by the German army and declassified information from the West that became available after the war. The institute was located first in Tanvald, a mountainous region of northern Bohemia, which was the location of the former German army center. There Jan became involved in microwave detectors that the Germans had developed for the 10 cm wavelength band, using germanium. When the news of the invention of the transistor reached Prague, he used the germanium of those detectors to build the first point-contact transistor in Czechoslovakia and decided to stay in that field.

Figure 6.94: Helmar Frank and Jan Tauc produced transistors at the former German electronics laboratory in Tannwald/Tanvald in Czechoslovakia in 1949, based at least in part (and perhaps entirely) on wartime German work there.

Transistors (12)



Dec. 4, 1956 K. LEHOVEC 2,773,224

TRANSISTOR POINT CONTACT ARRANGEMENT

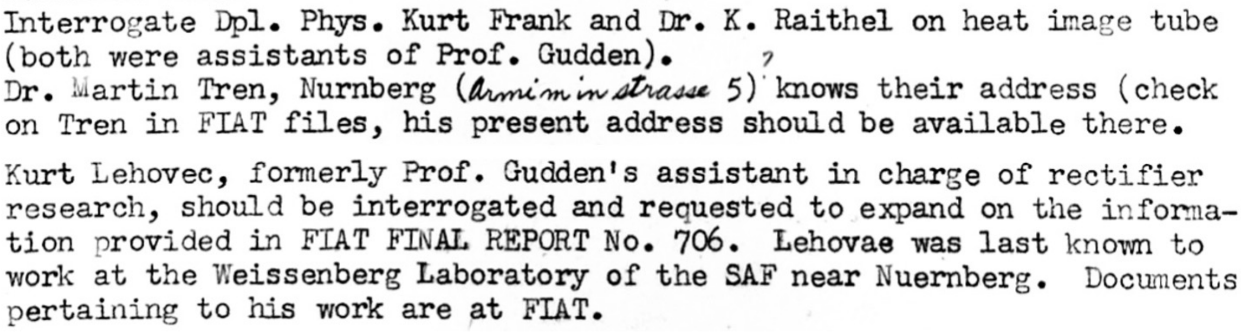
Filed Dec. 31, 1952

Charles University, Prague

Bernhard Gudden (1892–1945)

Kurt Lehovec (1918–2012)

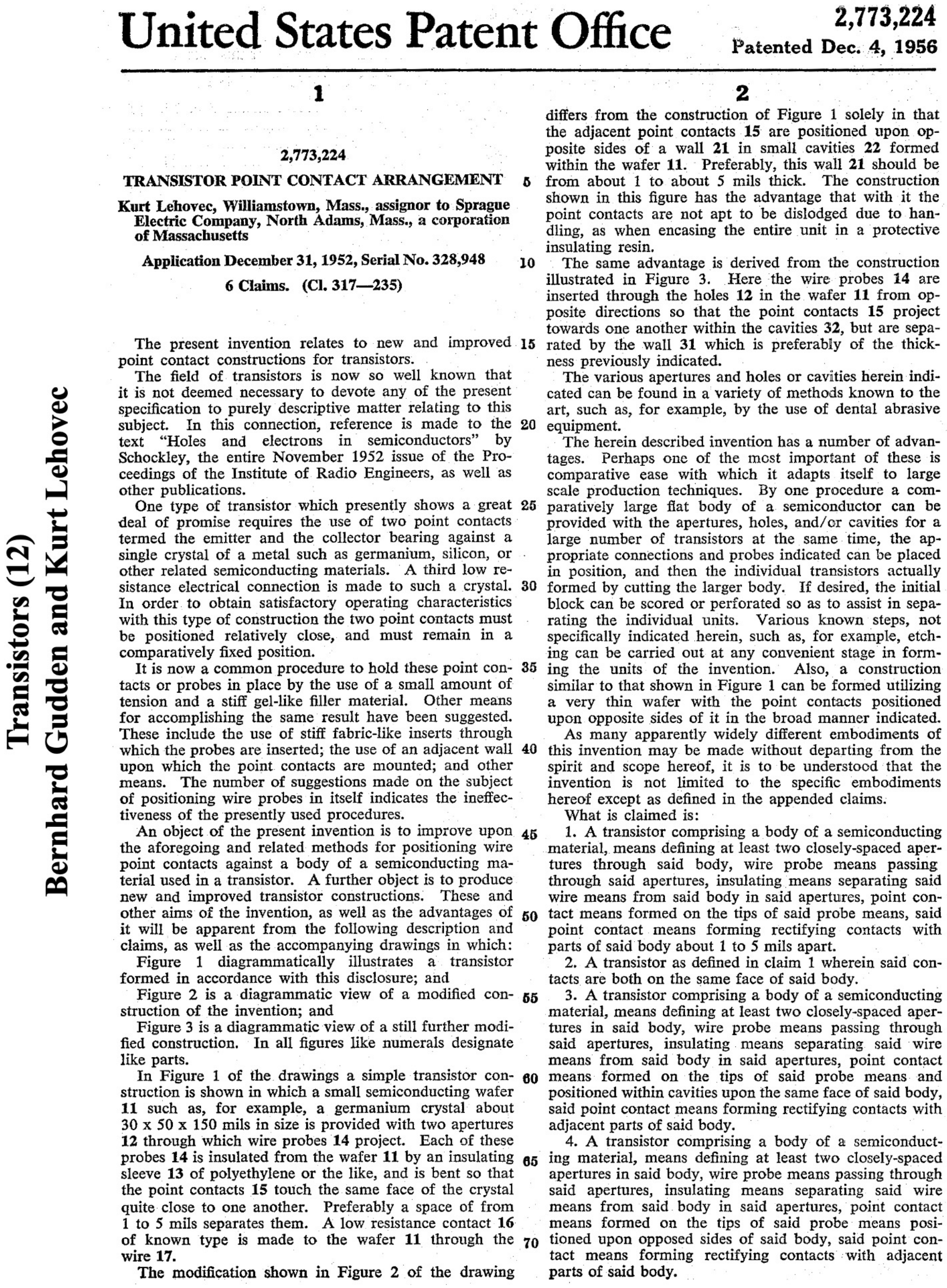
**NARA RG 40, Entry UD-75,
Box 28, Folder Edwin Y. Webb, Jr.
1945 memo from Harry Dauber.**



Interrogate Dpl. Phys. Kurt Frank and Dr. K. Raithel on heat image tube (both were assistants of Prof. Gudden).
Dr. Martin Tren, Nurnberg (Arminin strasse 5) knows their address (check on Tren in FIAT files, his present address should be available there.

Kurt Lehovec, formerly Prof. Gudden's assistant in charge of rectifier research, should be interrogated and requested to expand on the information provided in FIAT FINAL REPORT No. 706. Lehovae was last known to work at the Weissenberg Laboratory of the SAF near Nuernberg. Documents pertaining to his work are at FIAT.

Figure 6.95: During the war, Bernhard Gudden and Kurt Lehovec ran a very secretive and well-funded group that was developing advanced semiconductor devices at Charles University in Prague. After the war, Gudden died in a Czech prison and Lehovec moved to the United States, where he filed patent applications on transistor designs, possibly based on the wartime work.



Transistors (12)
Bernhard Gudden and Kurt Lehovec

United States Patent Office

2,773,224
Patented Dec. 4, 1956

1

2,773,224

TRANSISTOR POINT CONTACT ARRANGEMENT

Kurt Lehovec, Williamstown, Mass., assignor to Sprague Electric Company, North Adams, Mass., a corporation of Massachusetts

Application December 31, 1952, Serial No. 328,948

6 Claims. (Cl. 317—235)

The present invention relates to new and improved point contact constructions for transistors.

The field of transistors is now so well known that it is not deemed necessary to devote any of the present specification to purely descriptive matter relating to this subject. In this connection, reference is made to the text "Holes and electrons in semiconductors" by Schockley, the entire November 1952 issue of the Proceedings of the Institute of Radio Engineers, as well as other publications.

One type of transistor which presently shows a great deal of promise requires the use of two point contacts termed the emitter and the collector bearing against a single crystal of a metal such as germanium, silicon, or other related semiconducting materials. A third low resistance electrical connection is made to such a crystal. In order to obtain satisfactory operating characteristics with this type of construction the two point contacts must be positioned relatively close, and must remain in a comparatively fixed position.

It is now a common procedure to hold these point contacts or probes in place by the use of a small amount of tension and a stiff gel-like filler material. Other means for accomplishing the same result have been suggested. These include the use of stiff fabric-like inserts through which the probes are inserted; the use of an adjacent wall upon which the point contacts are mounted; and other means. The number of suggestions made on the subject of positioning wire probes in itself indicates the ineffectiveness of the presently used procedures.

An object of the present invention is to improve upon the aforegoing and related methods for positioning wire point contacts against a body of a semiconducting material used in a transistor. A further object is to produce new and improved transistor constructions. These and other aims of the invention, as well as the advantages of it will be apparent from the following description and claims, as well as the accompanying drawings in which:

Figure 1 diagrammatically illustrates a transistor formed in accordance with this disclosure; and

Figure 2 is a diagrammatic view of a modified construction of the invention; and

Figure 3 is a diagrammatic view of a still further modified construction. In all figures like numerals designate like parts.

In Figure 1 of the drawings a simple transistor construction is shown in which a small semiconducting wafer **11** such as, for example, a germanium crystal about 30 x 50 x 150 mils in size is provided with two apertures **12** through which wire probes **14** project. Each of these probes **14** is insulated from the wafer **11** by an insulating sleeve **13** of polyethylene or the like, and is bent so that the point contacts **15** touch the same face of the crystal quite close to one another. Preferably a space of from 1 to 5 mils separates them. A low resistance contact **16** of known type is made to the wafer **11** through the wire **17**.

The modification shown in Figure 2 of the drawing

2

differs from the construction of Figure 1 solely in that the adjacent point contacts **15** are positioned upon opposite sides of a wall **21** in small cavities **22** formed within the wafer **11**. Preferably, this wall **21** should be from about 1 to about 5 mils thick. The construction shown in this figure has the advantage that with it the point contacts are not apt to be dislodged due to handling, as when encasing the entire unit in a protective insulating resin.

The same advantage is derived from the construction illustrated in Figure 3. Here the wire probes **14** are inserted through the holes **12** in the wafer **11** from opposite directions so that the point contacts **15** project towards one another within the cavities **32**, but are separated by the wall **31** which is preferably of the thickness previously indicated.

The various apertures and holes or cavities herein indicated can be found in a variety of methods known to the art, such as, for example, by the use of dental abrasive equipment.

The herein described invention has a number of advantages. Perhaps one of the most important of these is comparative ease with which it adapts itself to large scale production techniques. By one procedure a comparatively large flat body of a semiconductor can be provided with the apertures, holes, and/or cavities for a large number of transistors at the same time, the appropriate connections and probes indicated can be placed in position, and then the individual transistors actually formed by cutting the larger body. If desired, the initial block can be scored or perforated so as to assist in separating the individual units. Various known steps, not specifically indicated herein, such as, for example, etching can be carried out at any convenient stage in forming the units of the invention. Also, a construction similar to that shown in Figure 1 can be formed utilizing a very thin wafer with the point contacts positioned upon opposite sides of it in the broad manner indicated.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope hereof, it is to be understood that the invention is not limited to the specific embodiments hereof except as defined in the appended claims.

What is claimed is:

1. A transistor comprising a body of a semiconducting material, means defining at least two closely-spaced apertures through said body, wire probe means passing through said apertures, insulating means separating said wire means from said body in said apertures, point contact means formed on the tips of said probe means, said point contact means forming rectifying contacts with parts of said body about 1 to 5 mils apart.

2. A transistor as defined in claim 1 wherein said contacts are both on the same face of said body.

3. A transistor comprising a body of a semiconducting material, means defining at least two closely-spaced apertures in said body, wire probe means passing through said apertures, insulating means separating said wire means from said body in said apertures, point contact means formed on the tips of said probe means and positioned within cavities upon the same face of said body, said point contact means forming rectifying contacts with adjacent parts of said body.

4. A transistor comprising a body of a semiconducting material, means defining at least two closely-spaced apertures in said body, wire probe means passing through said apertures, insulating means separating said wire means from said body in said apertures, point contact means formed on the tips of said probe means positioned upon opposed sides of said body, said point contact means forming rectifying contacts with adjacent parts of said body.

Figure 6.96: During the war, Bernhard Gudden and Kurt Lehovec ran a very secretive and well-funded group that was developing advanced semiconductor devices at Charles University in Prague. After the war, Gudden died in a Czech prison and Lehovec moved to the United States, where he filed patent applications on transistor designs, possibly based on the wartime work.

6.5.4 Postwar Transfer of Microelectronics Technologies

Appendix B presents evidence that suggests (but does not yet prove—much more investigation is required) that the German-speaking scientists' transistor developments not only preceded those of Bell Laboratories, but may have been directly used by Bell Laboratories as a guide to reproduce the earlier German-speaking work:

- The German-speaking transistor developments came from at least 12 different groups doing extensive work during a period of over two decades collectively.

- During World War II, the German military was keenly interested in funding the development of smaller, more rugged, and more sophisticated electronic guidance systems that could be used in rockets ranging from anti-aircraft missiles to intercontinental ballistic missiles. Transistors derived from the existing German patents and papers would have been an important part of those guidance systems.

- In spring 1945, hundreds of thousands of tons of German-language technical documents were seized by the United States, thousands of German-speaking scientists were interrogated by U.S. scientists and engineers, and countless prototypes, pieces of equipment, and whole laboratories were shipped to the United States.

- Personnel from Bell Laboratories played a prominent role in collecting that scientific information from Europe and processing it in the United States (for examples, see pp. 1078–1079 and Section B.5).

- In late 1945, Bell Laboratories put John Bardeen and Walter Brattain to work to try to produce a simple transistor, with some supervision by William Shockley. As noted by one source (p. 3015), "the semiconductor group at Bell Laboratories began its work with a survey of wartime developments in the field of semiconductors" [Eckert and Schubert 1990, p. 159].

- Bardeen and Shockley conducted detailed visits to numerous European laboratories from June through August 1947. During that time, Bardeen or Shockley could have easily encountered scientists, reports, or information from the earlier transistor development programs of the German-speaking world, or at least Allied investigators who had already studied those programs. Although any transistor-related information that Bardeen and Shockley learned during this time has never been publicly disclosed, Bardeen wrote at the end of the trip: "learned a lot during the trip, and have picked up some information that may be useful to the Lab" [Hoddeson and Daitch 2002, p. 130].

- Bardeen and Brattain did not begin serious experimentation with transistor-like devices until November 1947, two and a half years after the end of the war (and over two and a half years after the collection and study of German microelectronics information began in earnest). Within just a couple of months this very small team created what appears to be a crude replica of the earlier German work.

- Not only did Shockley not give any credit to the earlier German work, but he refused to give proper credit to Bardeen and Brattain, who actually performed the Bell Laboratories experiments.

- Due to their personal differences, the team of Bardeen, Brattain, and Shockley soon split up. Even in 1951, Western Electric (the manufacturing arm of AT&T/Bell Laboratories) was

> unable to produce reliable transistors. Most transistor development in the United States was carried out by other researchers, including several German-speaking scientists (Kurt Lehovec, Herbert Kroemer, Jean Hoerni, Eugene Kleiner, Karl Heinz Zaininger, etc.).

Much more archival research is needed to determine the true extent of microelectronics innovations in the German-speaking world, as well as how much that influenced postwar work in other countries.

Figures 6.99–6.100 show examples of how detailed technical information on the German semiconductor and microelectronics technologies was transferred to Allied countries after World War II. For instance, BIOS Final Report 725, *German Research on Rectifiers and Semi-Conductors*, described how German groups were making wafers of monocrystalline pure silicon, doping semiconductor materials with impurities to create the desired electrical properties, and producing semiconductor devices both from silicon and from germanium [BIOS 725]:

> Impurities in a semi-conductor produce additional energy-levels; perhaps a pure material could not be a semi-conductor. There must be some broadening of the energy levels into bands... Joos tried to produce large crystals of silicon for use in silicon-carbon detectors for cm. waves. The method was deposition from a solution of silicon in molten aluminum. The crystals so obtained were spectroscopically pure... They were aggregations of thin plates... Prof. Pohl confirmed that Dr. König had studied germanium and silicon rectifiers at Göttingen...

After the war, Hans K. Ziegler (German, 1911–1999) came to the United States in Operation Paperclip. He became the Chief Scientist of a U.S. Army laboratory in Fort Monmouth, New Jersey, that employed many other German-speaking scientists and harnessed many microelectronics technologies acquired from Germany, Austria, and Czech territory [Fort Monmouth Historical Office 2008]. See pp. 1153–1154, 2760, and 3013. Many other German-speaking scientists were hired by other U.S. laboratories or companies.

6.5.5 Capacitors

In addition to diodes and transistors, creators from the German-speaking world invented and perfected capacitors (sometimes called condensers), which temporarily store electric charge.

Ewald Georg von Kleist (German states, 1700–1748) invented and demonstrated the first capacitors in 1745; see Fig. 6.101. Pieter van Musschenbroek (Netherlands, 1692–1761) conducted further experiments with capacitors, and they became known as “Leiden jars.” Daniel Gralath (Danzig, 1708–1767) realized that multiple Leiden jars could be connected together to store more electric charge.

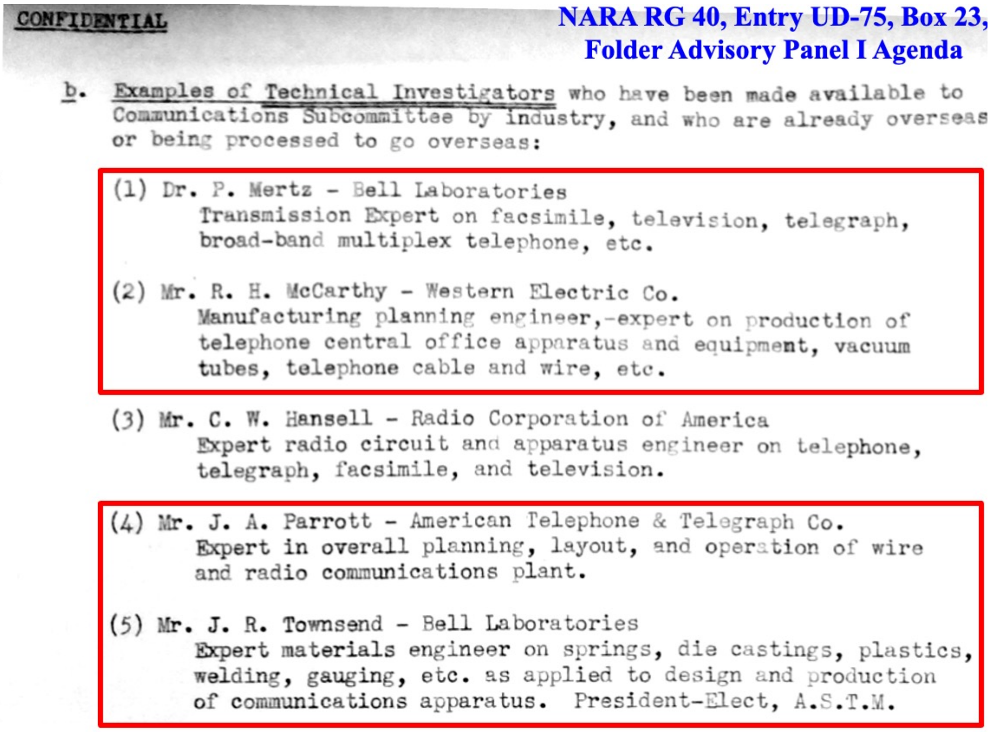
As shown in Fig. 6.102, Karol (Charles) Pollak (Polish, educated in Germany, worked in Germany and Austria, 1859–1928) invented the electrolytic capacitor in 1896. He also developed improved batteries and a variety of other electrical innovations.

Julius Edgar Lilienfeld invented and patented an improved design for electrolytic capacitors in 1931 (p. 1084).

In the 1930s, Eberhard Traub (German, 1906–20??) invented metallized paper capacitors, which worked well and could be manufactured very inexpensively. See Fig. 6.104.

The United States acquired Traub’s metallized paper capacitor technology in 1945, as illustrated in Figs. 6.105–6.106. Traub’s approach soon spread worldwide.

Examples of AT&T/Bell Labs/Western Electric active employees or longtime former employees involved in postwar technology transfer from Germany and Austria



NARA RG 40, Entry UD-75, Box 23, Folder Advisory Panel I Agenda

CONFIDENTIAL

b. Examples of Technical Investigators who have been made available to Communications Subcommittee by industry, and who are already overseas or being processed to go overseas:

(1) Dr. P. Mertz - Bell Laboratories
Transmission Expert on facsimile, television, telegraph, broad-band multiplex telephone, etc.

(2) Mr. R. H. McCarthy - Western Electric Co.
Manufacturing planning engineer,-expert on production of telephone central office apparatus and equipment, vacuum tubes, telephone cable and wire, etc.

(3) Mr. C. W. Hansell - Radio Corporation of America
Expert radio circuit and apparatus engineer on telephone, telegraph, facsimile, and television.

(4) Mr. J. A. Parrott - American Telephone & Telegraph Co.
Expert in overall planning, layout, and operation of wire and radio communications plant.

(5) Mr. J. R. Townsend - Bell Laboratories
Expert materials engineer on springs, die castings, plastics, welding, gauging, etc. as applied to design and production of communications apparatus. President-Elect, A.S.T.M.

DECLASSIFIED
Authority NND968018

Edwin Y. Webb Jr.	**AT&T 1928–1944. Chief for transferring electronics/communications technologies**
George Richert.	**Bell Telephone 1927–1942. Assistant Chief for transferring electronics/communications tech.**
Todos M. Odarenko	**Bell Telephone 1928–1943. Senior scientist for transferring electronics/communications tech.**
Julian Blanchard	**AT&T/Bell/Western Electric**
F. A. Cowan	**AT&T**
Lloyd Espenschied	**Bell Labs**
George W. Gilman	**Bell Labs**
Frederick Henderson	**Western Electric**
W. H. Martin	**Bell Labs**
Roland H. McCarthy	**Western Electric**
Pierre Mertz	**Bell Labs**
John A. Parrott	**AT&T**
R. E. Poole	**Bell Labs**
Victor Ronci	**Bell Labs**
R. E. Russell	**AT&T**
John N. Shive	**Bell Labs**
John R. Townsend	**Bell Labs**
John Bardeen*	**Bell Labs**
William Shockley*	**Bell Labs**

***See for example:**

Michael Eckert and Helmut Schubert. 1990. *Crystals, Electrons, Transistors.* pp. 158–163, 166.

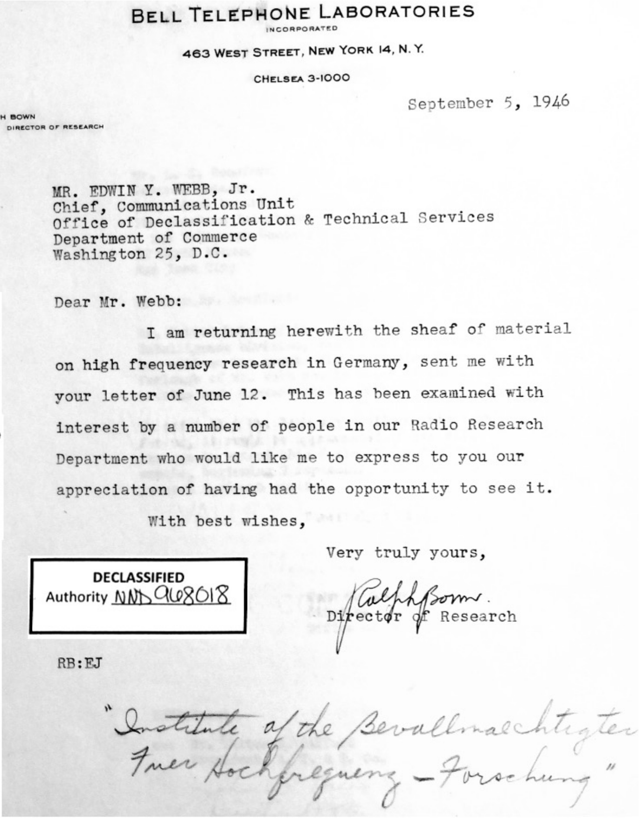
Jon Gertner. 2012. *The Idea Factory: Bell Labs and the Great Age of American Innovation.* pp. 90–92.

Lillian Hoddeson and Vicki Daitch. 2002. *True Genius: The Life and Science on John Bardeen.* pp. 128–131.

Figure 6.97: Examples of AT&T/Bell Labs/Western Electric active employees or longtime former employees involved in postwar technology transfer from Germany and Austria [NARA RG 40, Entry UD-75, Box 23, Folder Advisory Panel I Agenda].

Examples of technology transfer to AT&T Bell Laboratories

NARA RG 40, Entry UD-75, Box 24, Folder Bell System



BELL TELEPHONE LABORATORIES
INCORPORATED
463 WEST STREET, NEW YORK 14, N. Y.
CHELSEA 3-1000

RALPH BOWN
DIRECTOR OF RESEARCH

September 5, 1946

MR. EDWIN Y. WEBB, Jr.
Chief, Communications Unit
Office of Declassification & Technical Services
Department of Commerce
Washington 25, D.C.

Dear Mr. Webb:

I am returning herewith the sheaf of material on high frequency research in Germany, sent me with your letter of June 12. This has been examined with interest by a number of people in our Radio Research Department who would like me to express to you our appreciation of having had the opportunity to see it.

With best wishes,

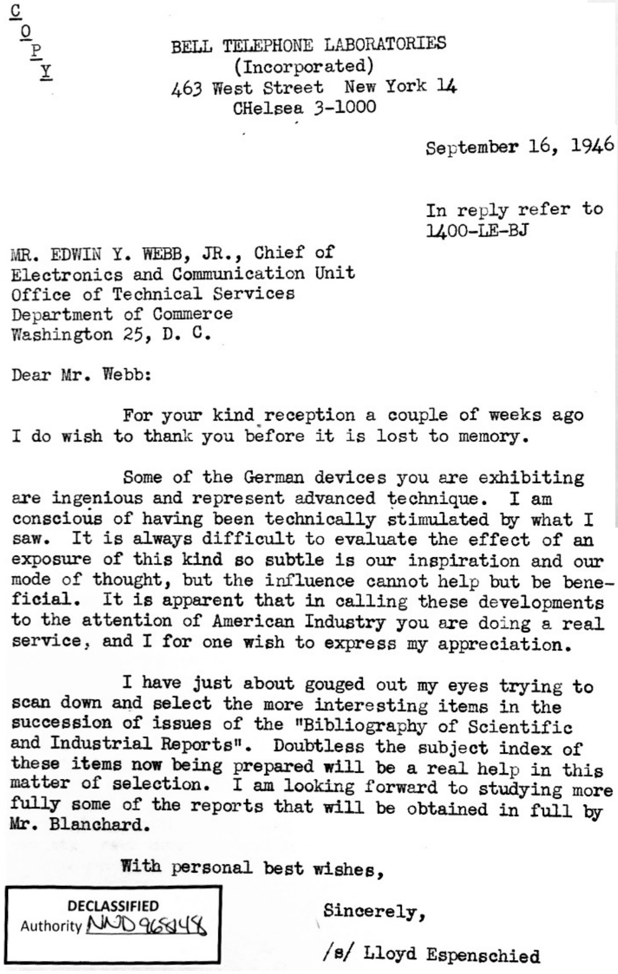
Very truly yours,

Ralph Bown.
Director of Research

DECLASSIFIED
Authority NND 968018

RB:EJ

"Institute of the Bevollmaechtigten
Fuer Hochfrequenz – Forschung"



C
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P
Y

BELL TELEPHONE LABORATORIES
(Incorporated)
463 West Street New York 14
CHelsea 3-1000

September 16, 1946

In reply refer to
1400-LE-BJ

MR. EDWIN Y. WEBB, JR., Chief of
Electronics and Communication Unit
Office of Technical Services
Department of Commerce
Washington 25, D. C.

Dear Mr. Webb:

For your kind reception a couple of weeks ago I do wish to thank you before it is lost to memory.

Some of the German devices you are exhibiting are ingenious and represent advanced technique. I am conscious of having been technically stimulated by what I saw. It is always difficult to evaluate the effect of an exposure of this kind so subtle is our inspiration and our mode of thought, but the influence cannot help but be beneficial. It is apparent that in calling these developments to the attention of American Industry you are doing a real service, and I for one wish to express my appreciation.

I have just about gouged out my eyes trying to scan down and select the more interesting items in the succession of issues of the "Bibliography of Scientific and Industrial Reports". Doubtless the subject index of these items now being prepared will be a real help in this matter of selection. I am looking forward to studying more fully some of the reports that will be obtained in full by Mr. Blanchard.

With personal best wishes,

Sincerely,

/s/ Lloyd Espenschied

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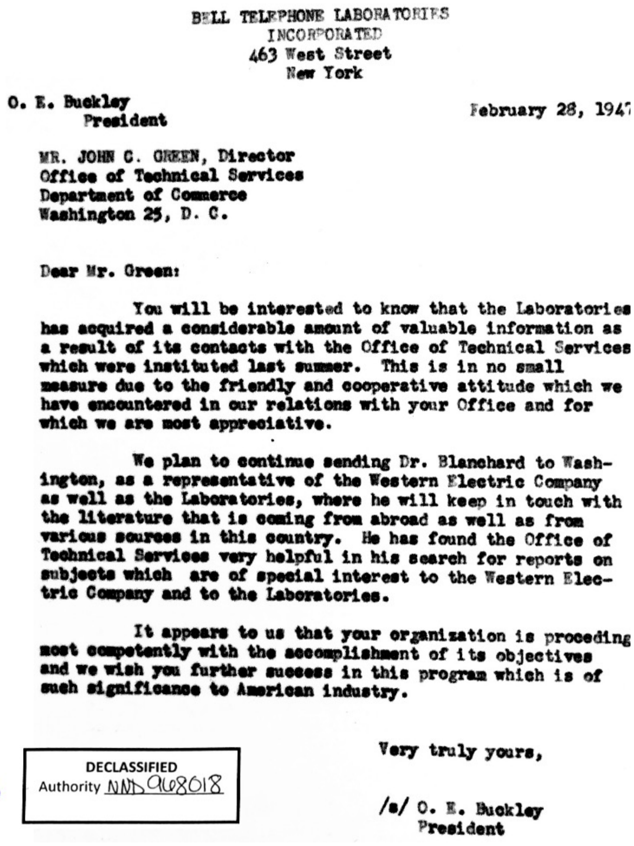
NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards



BELL TELEPHONE LABORATORIES
INCORPORATED
463 West Street
New York

O. E. Buckley
President

February 28, 1947

MR. JOHN C. GREEN, Director
Office of Technical Services
Department of Commerce
Washington 25, D. C.

Dear Mr. Green:

You will be interested to know that the Laboratories has acquired a considerable amount of valuable information as a result of its contacts with the Office of Technical Services which were instituted last summer. This is in no small measure due to the friendly and cooperative attitude which we have encountered in our relations with your Office and for which we are most appreciative.

We plan to continue sending Dr. Blanchard to Washington, as a representative of the Western Electric Company as well as the Laboratories, where he will keep in touch with the literature that is coming from abroad as well as from various sources in this country. He has found the Office of Technical Services very helpful in his search for reports on subjects which are of special interest to the Western Electric Company and to the Laboratories.

It appears to us that your organization is proceeding most competently with the accomplishment of its objectives and we wish you further success in this program which is of such significance to American industry.

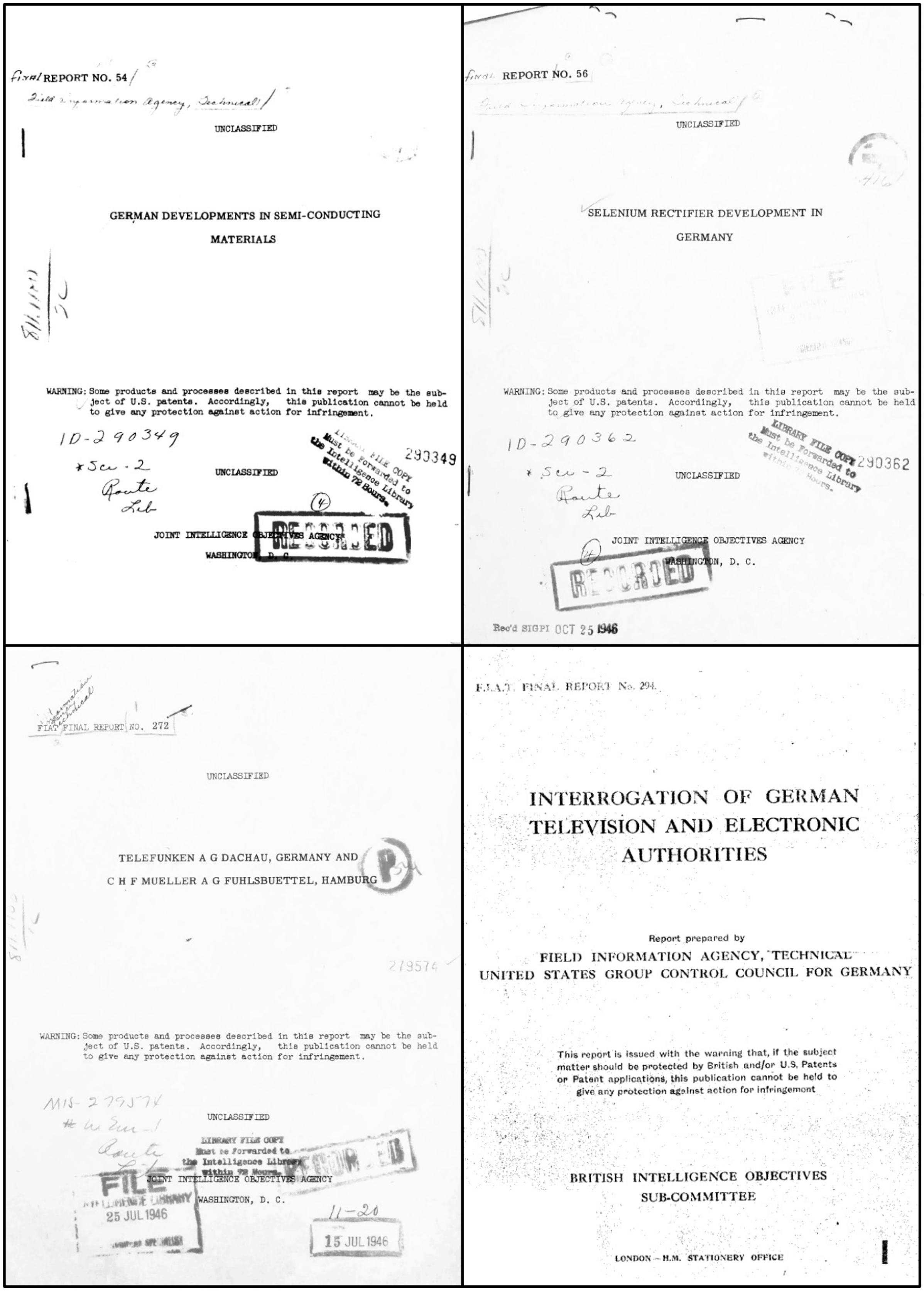
Very truly yours,

/s/ O. E. Buckley
President

DECLASSIFIED
Authority NND 968018

NARA RG 40, Entry UD-75, Box 24, Folder Bell System

Figure 6.98: Examples of technology transfer to AT&T Bell Laboratories [NARA RG 40, Entry UD-75, Boxes 24 and 58].



Final REPORT NO. 54

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F.I.A.T. FINAL REPORT No. 294.

INTERROGATION OF GERMAN TELEVISION AND ELECTRONIC AUTHORITIES

Report prepared by

FIELD INFORMATION AGENCY, TECHNICAL

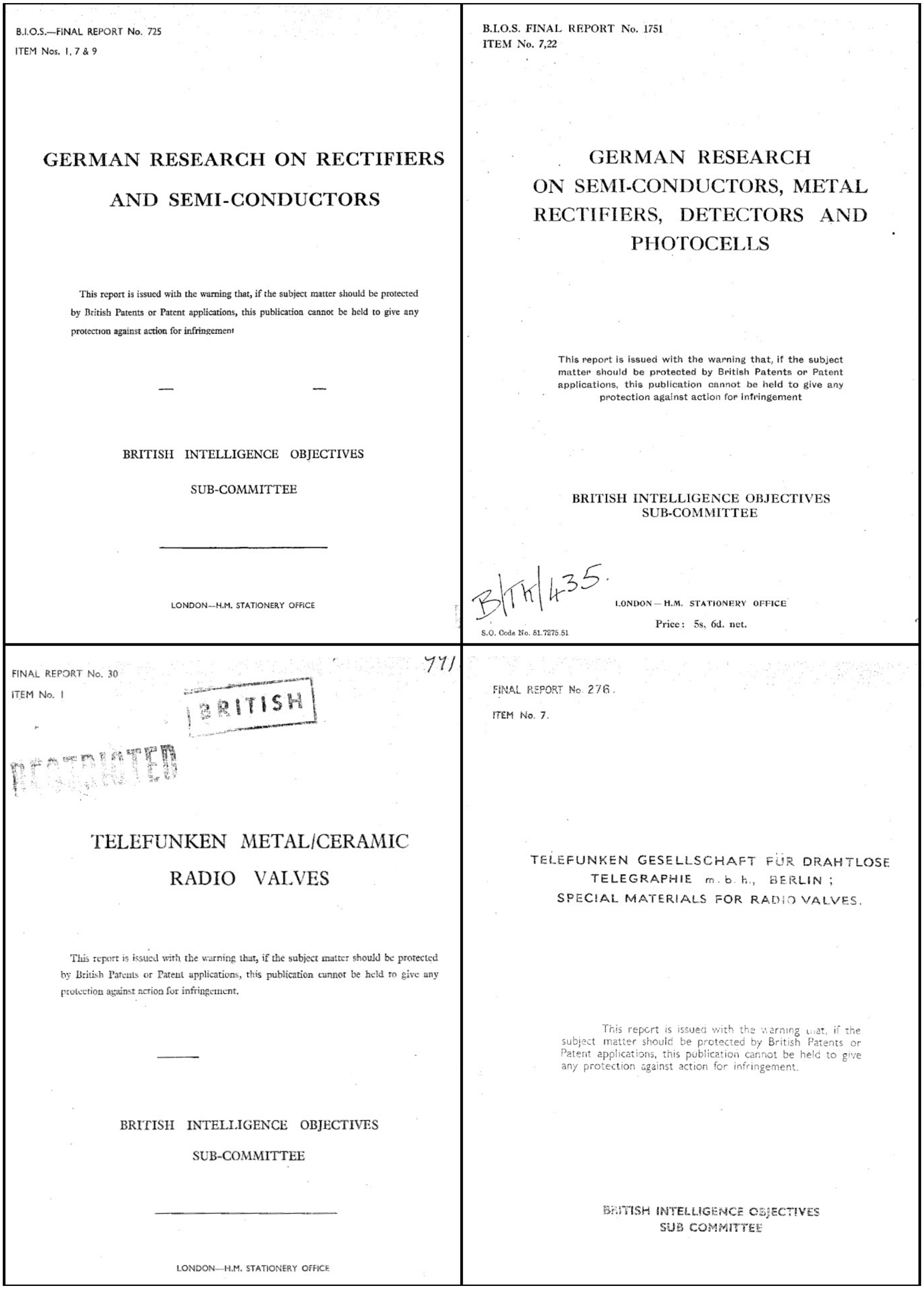
UNITED STATES GROUP CONTROL COUNCIL FOR GERMANY

This report is issued with the warning that, if the subject matter should be protected by British and/or U.S. Patents or Patent applications, this publication cannot be held to give any protection against action for infringement

BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE

LONDON – H.M. STATIONERY OFFICE

Figure 6.99: U.K. and U.S. officials investigated German microelectronics programs in detail in 1945 and wrote many reports about some of what they learned.



B.I.O.S.—FINAL REPORT No. 725
ITEM Nos. 1, 7 & 9

GERMAN RESEARCH ON RECTIFIERS AND SEMI-CONDUCTORS

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BRITISH INTELLIGENCE OBJECTIVES
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LONDON—H.M. STATIONERY OFFICE

B.I.O.S. FINAL REPORT No. 1751
ITEM No. 7,22

GERMAN RESEARCH ON SEMI-CONDUCTORS, METAL RECTIFIERS, DETECTORS AND PHOTOCELLS

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FINAL REPORT No. 30
ITEM No. 1

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TELEFUNKEN METAL/CERAMIC RADIO VALVES

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BRITISH INTELLIGENCE OBJECTIVES
SUB-COMMITTEE

LONDON—H.M. STATIONERY OFFICE

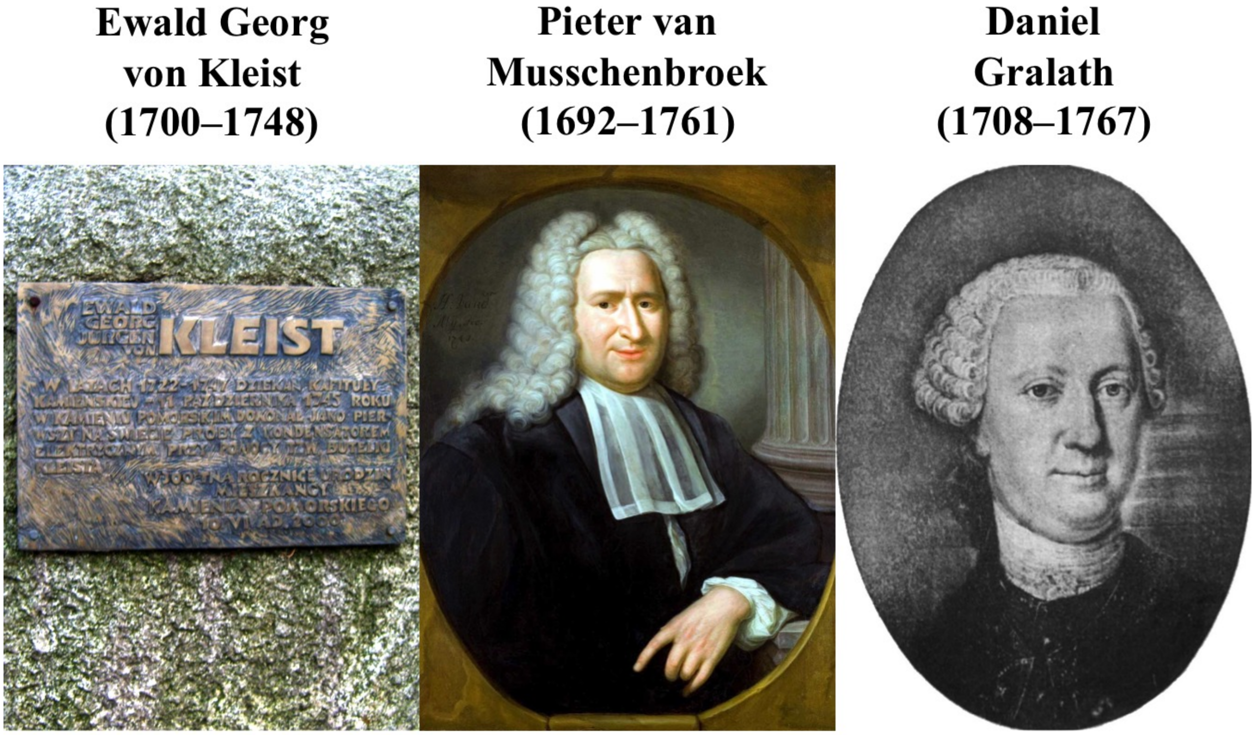
FINAL REPORT No. 276.
ITEM No. 7.

TELEFUNKEN GESELLSCHAFT FÜR DRAHTLOSE TELEGRAPHIE m. b. h., BERLIN ;
SPECIAL MATERIALS FOR RADIO VALVES.

This report is issued with the warning that, if the subject matter should be protected by British Patents or Patent applications, this publication cannot be held to give any protection against action for infringement.

BRITISH INTELLIGENCE OBJECTIVES
SUB COMMITTEE

Figure 6.100: U.K. and U.S. officials investigated German microelectronics programs in detail in 1945 and wrote many reports about some of what they learned.



Ewald Georg von Kleist (1700–1748)

Pieter van Musschenbroek (1692–1761)

Daniel Gralath (1708–1767)

EWALD GEORG JÜRGEN VON KLEIST
W LATACH 1722–1747 DZIEKAN KAPITUŁY KAMIEŃSKIEJ – 11 PAŹDZIERNIKA 1745 ROKU W KAMIENIU POMORSKIM DOKONAŁ JAKO PIERWSZY NA ŚWIECIE PRÓBY Z KONDENSATOREM ELEKTRYCZNYM PRZY POMOCY TZW. BUTELKI KLEISTA
W 300-TNA ROCZNICĘ URODZIN MIESZKAŃCY KAMIENIA POMORSKIEGO 10 VI A.D. 2000

Capacitor, or Leiden jar (1745)

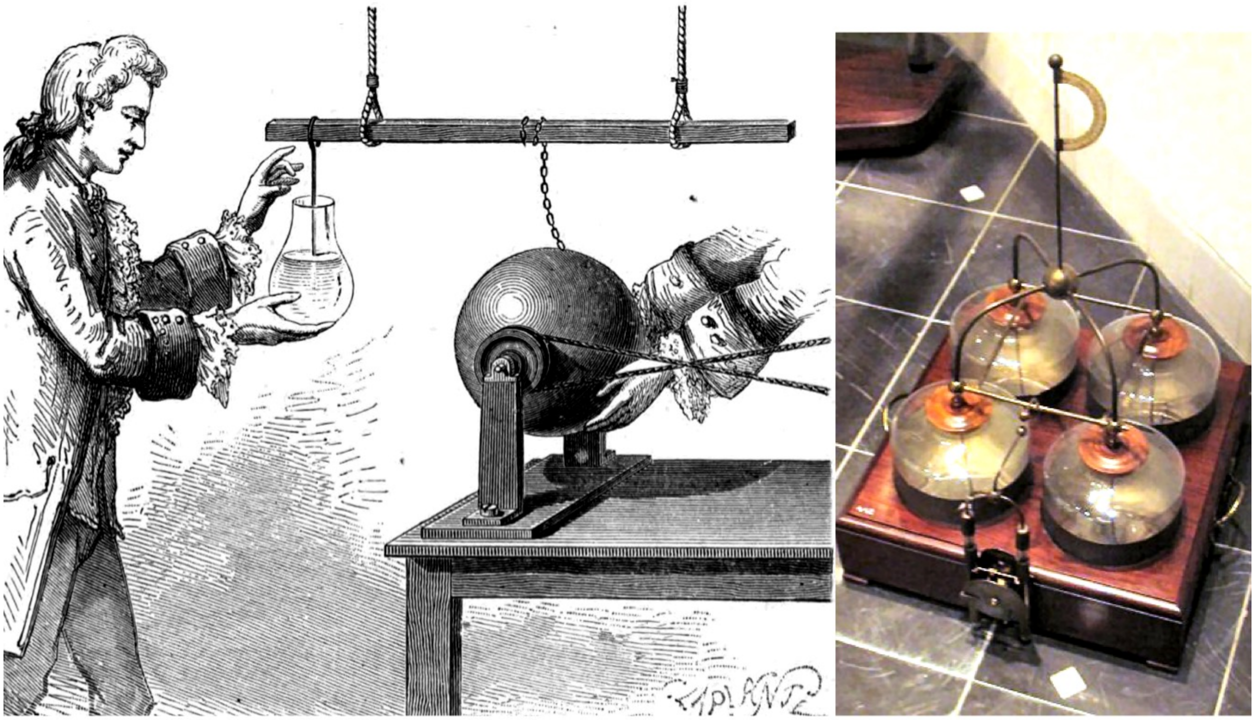
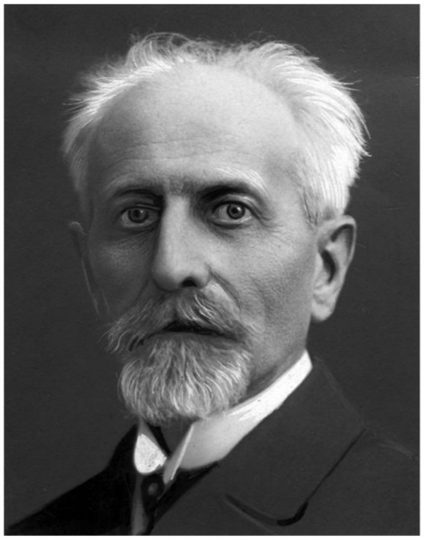
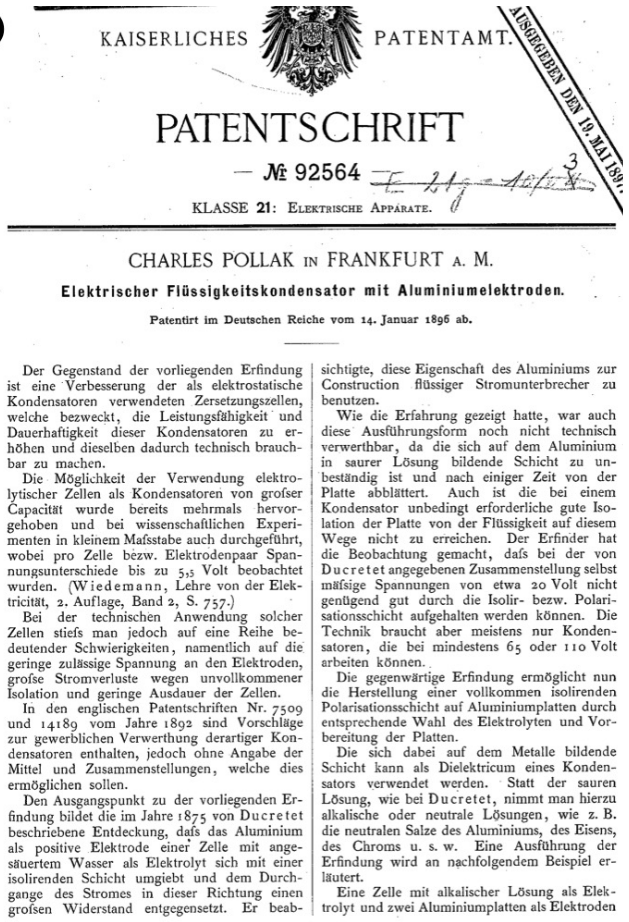


Figure 6.101: In 1745, Ewald Georg von Kleist invented the capacitor, which temporarily stores electric charge. Pieter van Musschenbroek conducted further experiments with capacitors, and they became known as "Leiden jars." Daniel Gralath realized that multiple Leiden jars could be connected together to store more electric charge.

Karol (Charles) Pollak (1859–1928) invented the electrolytic capacitor (1896) and improved batteries





KAISERLICHES PATENTAMT.

AUSGEGEBEN DEN 19. MAI 189

PATENTSCHRIFT

— № 92564 —

KLASSE 21: ELEKTRISCHE APPARATE.

CHARLES POLLAK IN FRANKFURT A. M.

Elektrischer Flüssigkeitskondensator mit Aluminiumelektroden.

Patentirt im Deutschen Reiche vom 14. Januar 1896 ab.

Der Gegenstand der vorliegenden Erfindung ist eine Verbesserung der als elektrostatische Kondensatoren verwendeten Zersetzungszellen, welche bezweckt, die Leistungsfähigkeit und Dauerhaftigkeit dieser Kondensatoren zu erhöhen und dieselben dadurch technisch brauchbar zu machen.

Die Möglichkeit der Verwendung elektrolytischer Zellen als Kondensatoren von groſser Capacität wurde bereits mehrmals hervorgehoben und bei wissenschaftlichen Experimenten in kleinem Maſsstabe auch durchgeführt, wobei pro Zelle bezw. Elektrodenpaar Spannungsunterschiede bis zu 5,5 Volt beobachtet wurden. (Wiedemann, Lehre von der Elektricität, 2. Auflage, Band 2, S. 757.)

Bei der technischen Anwendung solcher Zellen stieſs man jedoch auf eine Reihe bedeutender Schwierigkeiten, namentlich auf die geringe zulässige Spannung an den Elektroden, groſse Stromverluste wegen unvollkommener Isolation und geringe Ausdauer der Zellen.

In den englischen Patentschriften Nr. 7509 und 14189 vom Jahre 1892 sind Vorschläge zur gewerblichen Verwerthung derartiger Kondensatoren enthalten, jedoch ohne Angabe der Mittel und Zusammenstellungen, welche dies ermöglichen sollen.

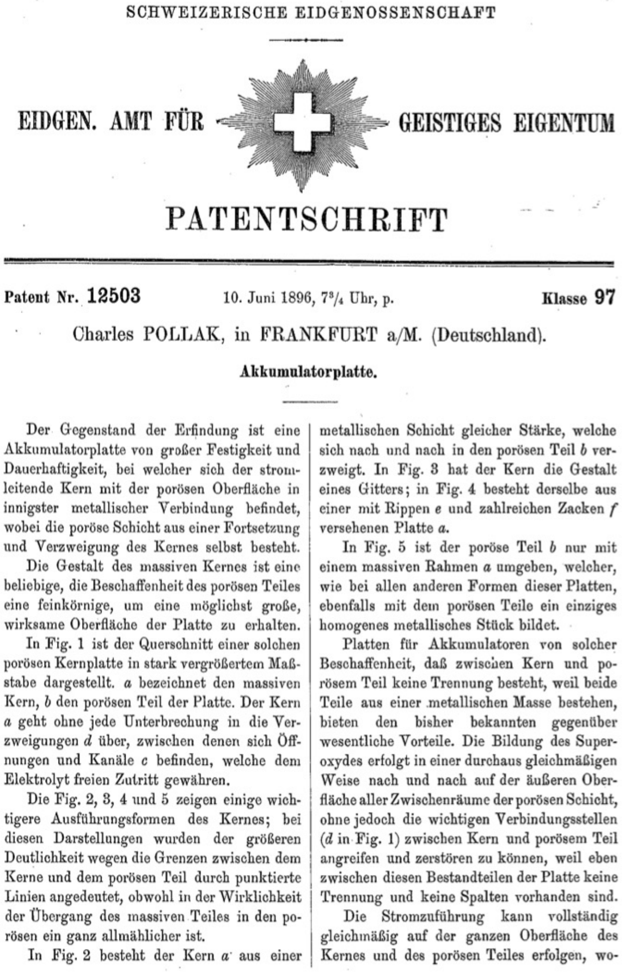
Den Ausgangspunkt zu der vorliegenden Erfindung bildet die im Jahre 1875 von Ducretet beschriebene Entdeckung, daſs das Aluminium als positive Elektrode einer Zelle mit angesäuertem Wasser als Elektrolyt sich mit einer isolirenden Schicht umgiebt und dem Durchgange des Stromes in dieser Richtung einen groſsen Widerstand entgegensetzt. Er beabsichtigte, diese Eigenschaft des Aluminiums zur Construction flüssiger Stromunterbrecher zu benutzen.

Wie die Erfahrung gezeigt hatte, war auch diese Ausführungsform noch nicht technisch verwerthbar, da die sich auf dem Aluminium in saurer Lösung bildende Schicht zu unbeständig ist und nach einiger Zeit von der Platte abblättert. Auch ist die bei einem Kondensator unbedingt erforderliche gute Isolation der Platte von der Flüssigkeit auf diesem Wege nicht zu erreichen. Der Erfinder hat die Beobachtung gemacht, daſs bei der von Ducretet angegebenen Zusammenstellung selbst mäſsige Spannungen von etwa 20 Volt nicht genügend gut durch die Isolir- bezw. Polarisationsschicht aufgehalten werden können. Die Technik braucht aber meistens nur Kondensatoren, die bei mindestens 65 oder 110 Volt arbeiten können.

Die gegenwärtige Erfindung ermöglicht nun die Herstellung einer vollkommen isolirenden Polarisationsschicht auf Aluminiumplatten durch entsprechende Wahl des Elektrolyten und Vorbereitung der Platten.

Die sich dabei auf dem Metalle bildende Schicht kann als Dielektricum eines Kondensators verwendet werden. Statt der sauren Lösung, wie bei Ducretet, nimmt man hierzu alkalische oder neutrale Lösungen, wie z. B. die neutralen Salze des Aluminiums, des Eisens, des Chroms u. s. w. Eine Ausführung der Erfindung wird an nachfolgendem Beispiel erläutert.

Eine Zelle mit alkalischer Lösung als Elektrolyt und zwei Aluminiumplatten als Elektroden



SCHWEIZERISCHE EIDGENOSSENSCHAFT

EIDGEN. AMT FÜR GEISTIGES EIGENTUM

PATENTSCHRIFT

Patent Nr. 12503 10. Juni 1896, 7³/₄ Uhr, p. **Klasse 97**

Charles POLLAK, in FRANKFURT a/M. (Deutschland).

Akkumulatorplatte.

Der Gegenstand der Erfindung ist eine Akkumulatorplatte von großer Festigkeit und Dauerhaftigkeit, bei welcher sich der stromleitende Kern mit der porösen Oberfläche in innigster metallischer Verbindung befindet, wobei die poröse Schicht aus einer Fortsetzung und Verzweigung des Kernes selbst besteht.

Die Gestalt des massiven Kernes ist eine beliebige, die Beschaffenheit des porösen Teiles eine feinkörnige, um eine möglichst große, wirksame Oberfläche der Platte zu erhalten.

In Fig. 1 ist der Querschnitt einer solchen porösen Kernplatte in stark vergrößertem Maßstabe dargestellt. *a* bezeichnet den massiven Kern, *b* den porösen Teil der Platte. Der Kern *a* geht ohne jede Unterbrechung in die Verzweigungen *d* über, zwischen denen sich Öffnungen und Kanäle *c* befinden, welche dem Elektrolyt freien Zutritt gewähren.

Die Fig. 2, 3, 4 und 5 zeigen einige wichtigere Ausführungsformen des Kernes; bei diesen Darstellungen wurden der größeren Deutlichkeit wegen die Grenzen zwischen dem Kerne und dem porösen Teil durch punktierte Linien angedeutet, obwohl in der Wirklichkeit der Übergang des massiven Teiles in den porösen ein ganz allmählicher ist.

In Fig. 2 besteht der Kern *a* aus einer metallischen Schicht gleicher Stärke, welche sich nach und nach in den porösen Teil *b* verzweigt. In Fig. 3 hat der Kern die Gestalt eines Gitters; in Fig. 4 besteht derselbe aus einer mit Rippen *e* und zahlreichen Zacken *f* versehenen Platte *a*.

In Fig. 5 ist der poröse Teil *b* nur mit einem massiven Rahmen *a* umgeben, welcher, wie bei allen anderen Formen dieser Platten, ebenfalls mit dem porösen Teile ein einziges homogenes metallisches Stück bildet.

Platten für Akkumulatoren von solcher Beschaffenheit, daß zwischen Kern und porösem Teil keine Trennung besteht, weil beide Teile aus einer metallischen Masse bestehen, bieten den bisher bekannten gegenüber wesentliche Vorteile. Die Bildung des Superoxydes erfolgt in einer durchaus gleichmäßigen Weise nach und nach auf der äußeren Oberfläche aller Zwischenräume der porösen Schicht, ohne jedoch die wichtigen Verbindungsstellen (*d* in Fig. 1) zwischen Kern und porösem Teil angreifen und zerstören zu können, weil eben zwischen diesen Bestandteilen der Platte keine Trennung und keine Spalten vorhanden sind.

Die Stromzuführung kann vollständig gleichmäßig auf der ganzen Oberfläche des Kernes und des porösen Teiles erfolgen, wo-

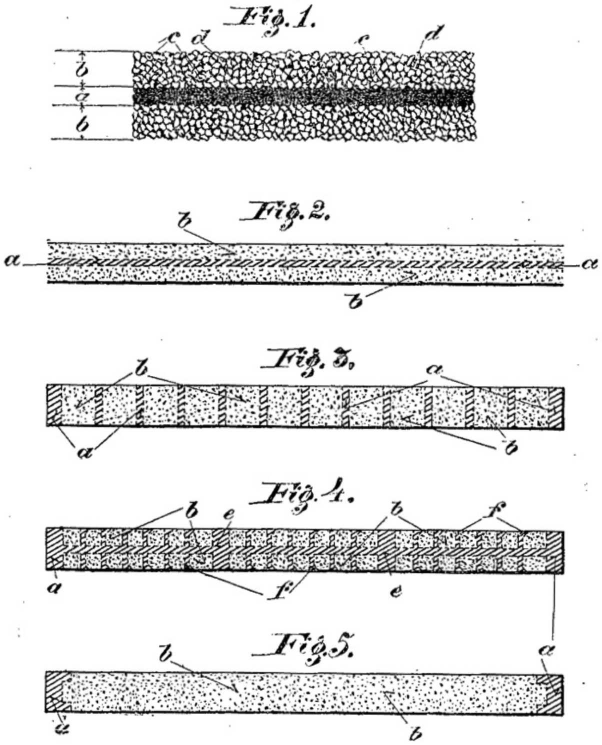
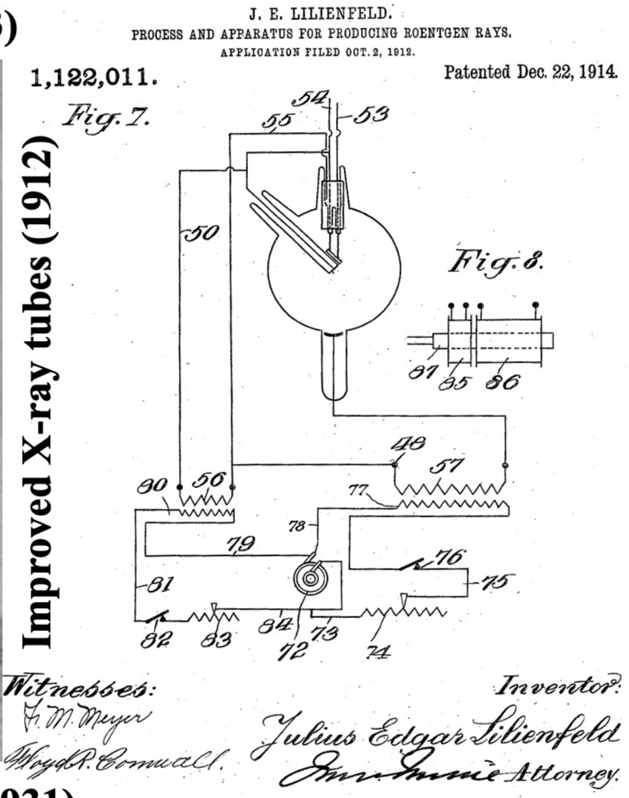
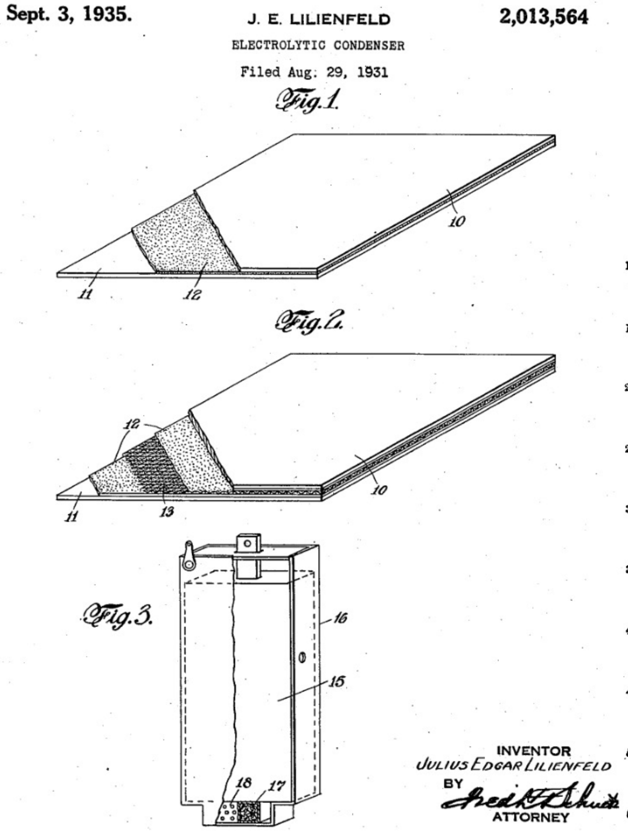
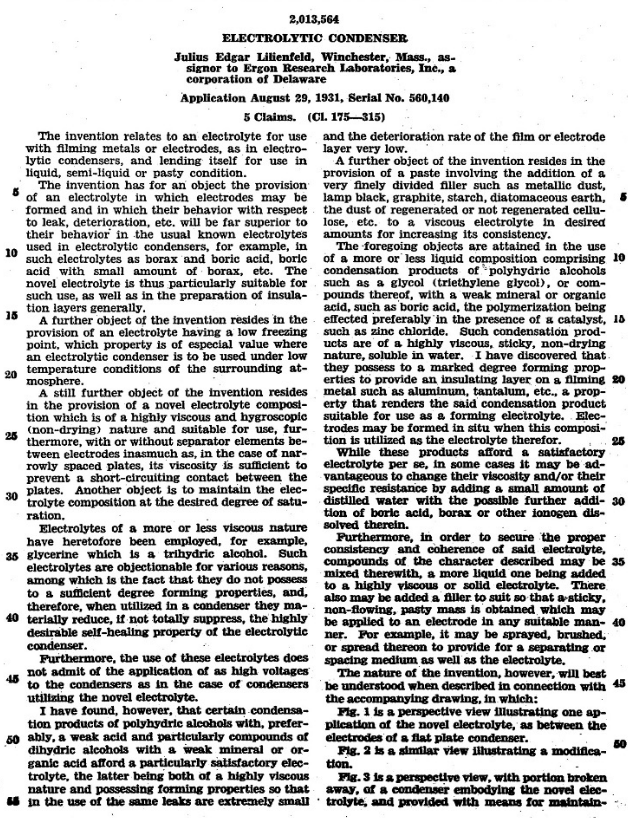


Figure 6.102: Karol (Charles) Pollak invented the electrolytic capacitor in 1896 and also developed improved batteries.

Julius Edgar Lilienfeld (1882–1963)







UNITED STATES PATENT OFFICE

2,013,564

ELECTROLYTIC CONDENSER

Julius Edgar Lilienfeld, Winchester, Mass., assignor to Ergon Research Laboratories, Inc., a corporation of Delaware

Application August 29, 1931, Serial No. 560,140

5 Claims. (Cl. 175—315)

The invention relates to an electrolyte for use with filming metals or electrodes, as in electrolytic condensers, and lending itself for use in liquid, semi-liquid or pasty condition.

The invention has for an object the provision of an electrolyte in which electrodes may be formed and in which their behavior with respect to leak, deterioration, etc. will be far superior to their behavior in the usual known electrolytes used in electrolytic condensers, for example, in such electrolytes as borax and boric acid, boric acid with small amount of borax, etc. The novel electrolyte is thus particularly suitable for such use, as well as in the preparation of insulation layers generally.

A further object of the invention resides in the provision of an electrolyte having a low freezing point, which property is of especial value where an electrolytic condenser is to be used under low temperature conditions of the surrounding atmosphere.

A still further object of the invention resides in the provision of a novel electrolyte composition which is of a highly viscous and hygroscopic (non-drying) nature and suitable for use, furthermore, with or without separator elements between electrodes inasmuch as, in the case of narrowly spaced plates, its viscosity is sufficient to prevent a short-circuiting contact between the plates. Another object is to maintain the electrolyte composition at the desired degree of saturation.

Electrolytes of a more or less viscous nature have heretofore been employed, for example, glycerine which is a trihydric alcohol. Such electrolytes are objectionable for various reasons, among which is the fact that they do not possess to a sufficient degree forming properties, and, therefore, when utilized in a condenser they materially reduce, if not totally suppress, the highly desirable self-healing property of the electrolytic condenser.

Furthermore, the use of these electrolytes does not admit of the application of as high voltages to the condensers as in the case of condensers utilizing the novel electrolyte.

I have found, however, that certain condensation products of polyhydric alcohols with, preferably, a weak acid and particularly compounds of dihydric alcohols with a weak mineral or organic acid afford a particularly satisfactory electrolyte, the latter being both of a highly viscous nature and possessing forming properties so that in the use of the same leaks are extremely small and the deterioration rate of the film or electrode layer very low.

A further object of the invention resides in the provision of a paste involving the addition of a very finely divided filler such as metallic dust, lamp black, graphite, starch, diatomaceous earth, the dust of regenerated or not regenerated cellulose, etc. to a viscous electrolyte in desired amounts for increasing its consistency.

The foregoing objects are attained in the use of a more or less liquid composition comprising condensation products of polyhydric alcohols such as a glycol (triethylene glycol), or compounds thereof, with a weak mineral or organic acid, such as boric acid, the polymerization being effected preferably in the presence of a catalyst, such as zinc chloride. Such condensation products are of a highly viscous, sticky, non-drying nature, soluble in water. I have discovered that they possess to a marked degree forming properties to provide an insulating layer on a filming metal such as aluminum, tantalum, etc., a property that renders the said condensation product suitable for use as a forming electrolyte. Electrodes may be formed in situ when this composition is utilized as the electrolyte therefor.

While these products afford a satisfactory electrolyte per se, in some cases it may be advantageous to change their viscosity and/or their specific resistance by adding a small amount of distilled water with the possible further addition of boric acid, borax or other ionogen dissolved therein.

Furthermore, in order to secure the proper consistency and coherence of said electrolyte, compounds of the character described may be mixed therewith, a more liquid one being added to a highly viscous or solid electrolyte. There also may be added a filler to suit so that a sticky, non-flowing, pasty mass is obtained which may be applied to an electrode in any suitable manner. For example, it may be sprayed, brushed, or spread thereon to provide for a separating or spacing medium as well as the electrolyte.

The nature of the invention, however, will best be understood when described in connection with the accompanying drawing, in which:

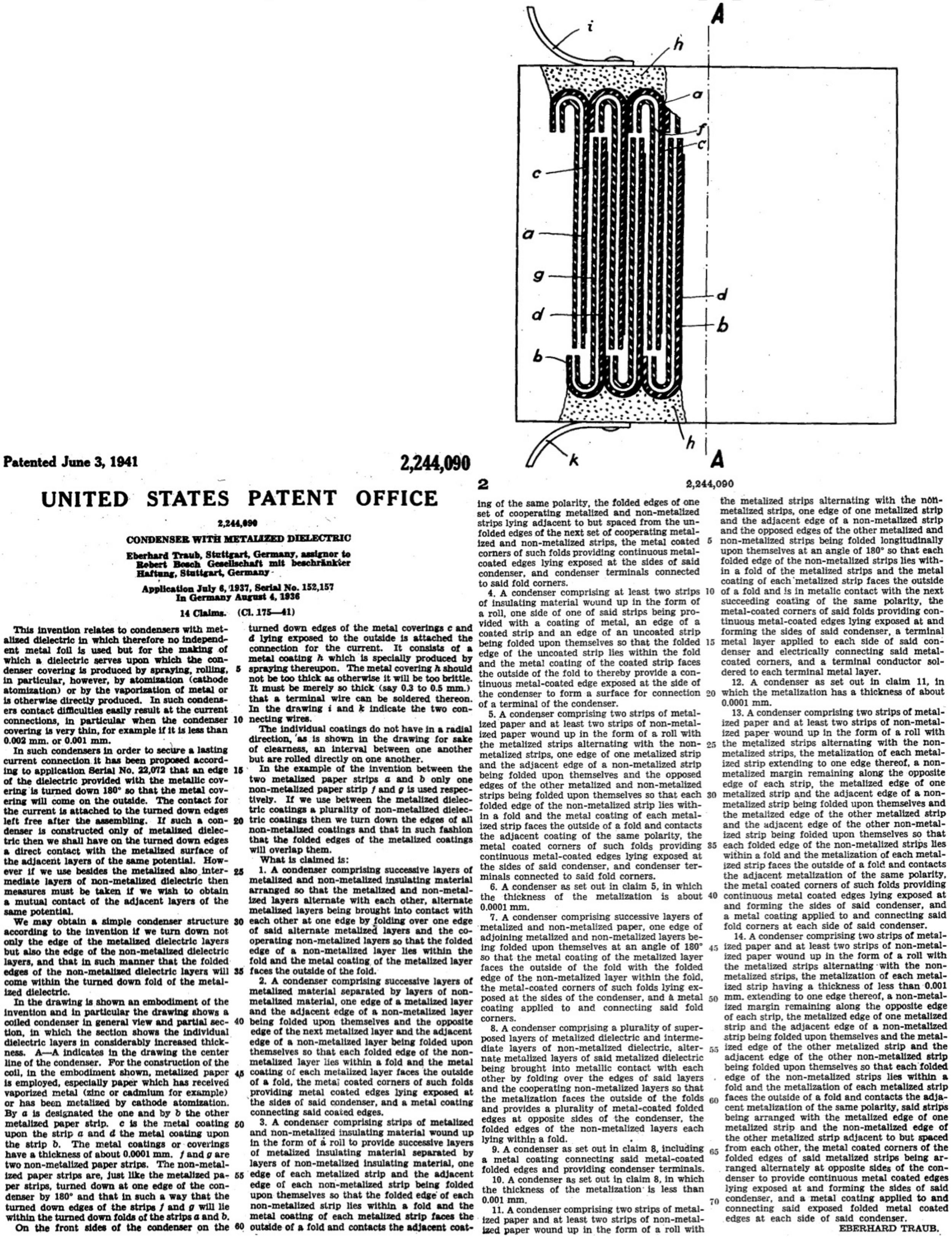
Fig. 1 is a perspective view illustrating one application of the novel electrolyte, as between the electrodes of a flat plate condenser.

Fig. 2 is a similar view illustrating a modification.

Fig. 3 is a perspective view, with portion broken away, of a condenser embodying the novel electrolyte, and provided with means for maintain-

Figure 6.103: Julius Edgar Lilienfeld invented an improved X-ray tube in 1912, the field effect transistor in 1925, and an improved electrolytic capacitor in 1931.

Eberhard Traub (1906–20??) invented metalized paper capacitors


i
h
A
a
f
c
c
a
g
d
d
b
b
h
k
A

Patented June 3, 1941 **2,244,090**

UNITED STATES PATENT OFFICE

2,244,090

CONDENSER WITH METALIZED DIELECTRIC

Eberhard Traub, Stuttgart, Germany, assignor to
Robert Bosch Gesellschaft mit beschränkter
Haftung, Stuttgart, Germany

Application July 6, 1937, Serial No. 152,157
In Germany August 4, 1936

14 Claims. (Cl. 175—41)

This invention relates to condensers with metalized dielectric in which therefore no independent metal foil is used but for the making of which a dielectric serves upon which the condenser covering is produced by spraying, rolling, in particular, however, by atomization (cathode atomization) or by the vaporization of metal or is otherwise directly produced. In such condensers contact difficulties easily result at the current connections, in particular when the condenser covering is very thin, for example if it is less than 0.002 mm. or 0.001 mm.

In such condensers in order to secure a lasting current connection it has been proposed according to application Serial No. 22,072 that an edge of the dielectric provided with the metallic covering is turned down 180° so that the metal covering will come on the outside. The contact for the current is attached to the turned down edges left free after the assembling. If such a condenser is constructed only of metalized dielectric then we shall have on the turned down edges a direct contact with the metalized surface of the adjacent layers of the same potential. However if we use besides the metalized also intermediate layers of non-metalized dielectric then measures must be taken if we wish to obtain a mutual contact of the adjacent layers of the same potential.

We may obtain a simple condenser structure according to the invention if we turn down not only the edge of the metalized dielectric layers but also the edge of the non-metalized dielectric layers, and that in such manner that the folded edges of the non-metalized dielectric layers will come within the turned down fold of the metalized dielectric.

In the drawing is shown an embodiment of the invention and in particular the drawing shows a coiled condenser in general view and partial section, in which the section shows the individual dielectric layers in considerably increased thickness. A—A indicates in the drawing the center line of the condenser. For the construction of the coil, in the embodiment shown, metalized paper is employed, especially paper which has received vaporized metal (zinc or cadmium for example) or has been metalized by cathode atomization. By *a* is designated the one and by *b* the other metalized paper strip. *c* is the metal coating upon the strip *a* and *d* the metal coating upon the strip *b*. The metal coatings or coverings have a thickness of about 0.0001 mm. *f* and *g* are two non-metalized paper strips. The non-metalized paper strips are, just like the metalized paper strips, turned down at one edge of the condenser by 180° and that in such a way that the turned down edges of the strips *f* and *g* will lie within the turned down folds of the strips *a* and *b*.

On the front sides of the condenser on the turned down edges of the metal coverings *c* and *d* lying exposed to the outside is attached the connection for the current. It consists of a metal coating *h* which is specially produced by spraying thereupon. The metal covering *h* should not be too thick as otherwise it will be too brittle. It must be merely so thick (say 0.3 to 0.5 mm.) that a terminal wire can be soldered thereon. In the drawing *i* and *k* indicate the two connecting wires.

The individual coatings do not have in a radial direction, as is shown in the drawing for sake of clearness, an interval between one another but are rolled directly on one another.

In the example of the invention between the two metalized paper strips *a* and *b* only one non-metalized paper strip *f* and *g* is used respectively. If we use between the metalized dielectric coatings a plurality of non-metalized dielectric coatings then we turn down the edges of all non-metalized coatings and that in such fashion that the folded edges of the metalized coatings will overlap them.

What is claimed is:

1. A condenser comprising successive layers of metalized and non-metalized insulating material arranged so that the metalized and non-metalized layers alternate with each other, alternate metalized layers being brought into contact with each other at one edge by folding over one edge of said alternate metalized layers and the cooperating non-metalized layers so that the folded edge of a non-metalized layer lies within the fold and the metal coating of the metalized layer faces the outside of the fold.

2. A condenser comprising successive layers of metalized material separated by layers of non-metalized material, one edge of a metalized layer and the adjacent edge of a non-metalized layer being folded upon themselves and the opposite edge of the next metalized layer and the adjacent edge of a non-metalized layer being folded upon themselves so that each folded edge of the non-metalized layer lies within a fold and the metal coating of each metalized layer faces the outside of a fold, the metal coated corners of such folds providing metal coated edges lying exposed at the sides of said condenser, and a metal coating connecting said coated edges.

3. A condenser comprising strips of metalized and non-metalized insulating material wound up in the form of a roll to provide successive layers of metalized insulating material separated by layers of non-metalized insulating material, one edge of each metalized strip and the adjacent edge of each non-metalized strip being folded upon themselves so that the folded edge of each non-metalized strip lies within a fold and the metal coating of each metalized strip faces the outside of a fold and contacts the adjacent coating of the same polarity, the folded edges of one set of cooperating metalized and non-metalized strips lying adjacent to but spaced from the unfolded edges of the next set of cooperating metalized and non-metalized strips, the metal coated corners of such folds providing continuous metal-coated edges lying exposed at the sides of said condenser, and condenser terminals connected to said fold corners.

2 **2,244,090**

4. A condenser comprising at least two strips of insulating material wound up in the form of a roll, one side of one of said strips being provided with a coating of metal, an edge of a coated strip and an edge of an uncoated strip being folded upon themselves so that the folded edge of the uncoated strip lies within the fold and the metal coating of the coated strip faces the outside of the fold to thereby provide a continuous metal-coated edge exposed at the side of the condenser to form a surface for connection of a terminal of the condenser.

5. A condenser comprising two strips of metalized paper and at least two strips of non-metalized paper wound up in the form of a roll with the metalized strips alternating with the non-metalized strips, one edge of one metalized strip and the adjacent edge of a non-metalized strip being folded upon themselves and the opposed edges of the other metalized and non-metalized strips being folded upon themselves so that each folded edge of the non-metalized strip lies within a fold and the metal coating of each metalized strip faces the outside of a fold and contacts the adjacent coating of the same polarity, the metal coated corners of such folds providing continuous metal-coated edges lying exposed at the sides of said condenser, and condenser terminals connected to said fold corners.

6. A condenser as set out in claim 5, in which the thickness of the metalization is about 0.0001 mm.

7. A condenser comprising successive layers of metalized and non-metalized paper, one edge of adjoining metalized and non-metalized layers being folded upon themselves at an angle of 180° so that the metal coating of the metalized layer faces the outside of the fold with the folded edge of the non-metalized layer within the fold, the metal-coated corners of such folds lying exposed at the sides of the condenser, and a metal coating applied to and connecting said fold corners.

8. A condenser comprising a plurality of superposed layers of metalized dielectric and intermediate layers of non-metalized dielectric, alternate metalized layers of said metalized dielectric being brought into metallic contact with each other by folding over the edges of said layers and the cooperating non-metalized layers so that the metalization faces the outside of the folds and provides a plurality of metal-coated folded edges at opposite sides of the condenser, the folded edges of the non-metalized layers each lying within a fold.

9. A condenser as set out in claim 8, including a metal coating connecting said metal-coated folded edges and providing condenser terminals.

10. A condenser as set out in claim 8, in which the thickness of the metalization is less than 0.001 mm.

11. A condenser comprising two strips of metalized paper and at least two strips of non-metalized paper wound up in the form of a roll with the metalized strips alternating with the non-metalized strips, one edge of one metalized strip and the adjacent edge of a non-metalized strip and the opposed edges of the other metalized and non-metalized strips being folded longitudinally upon themselves at an angle of 180° so that each folded edge of the non-metalized strips lies within a fold of the metalized strips and the metal coating of each metalized strip faces the outside of a fold and is in metalic contact with the next succeeding coating of the same polarity, the metal-coated corners of said folds providing continuous metal-coated edges lying exposed at and forming the sides of said condenser, a terminal metal layer applied to each side of said condenser and electrically connecting said metal-coated corners, and a terminal conductor soldered to each terminal metal layer.

12. A condenser as set out in claim 11, in which the metalization has a thickness of about 0.0001 mm.

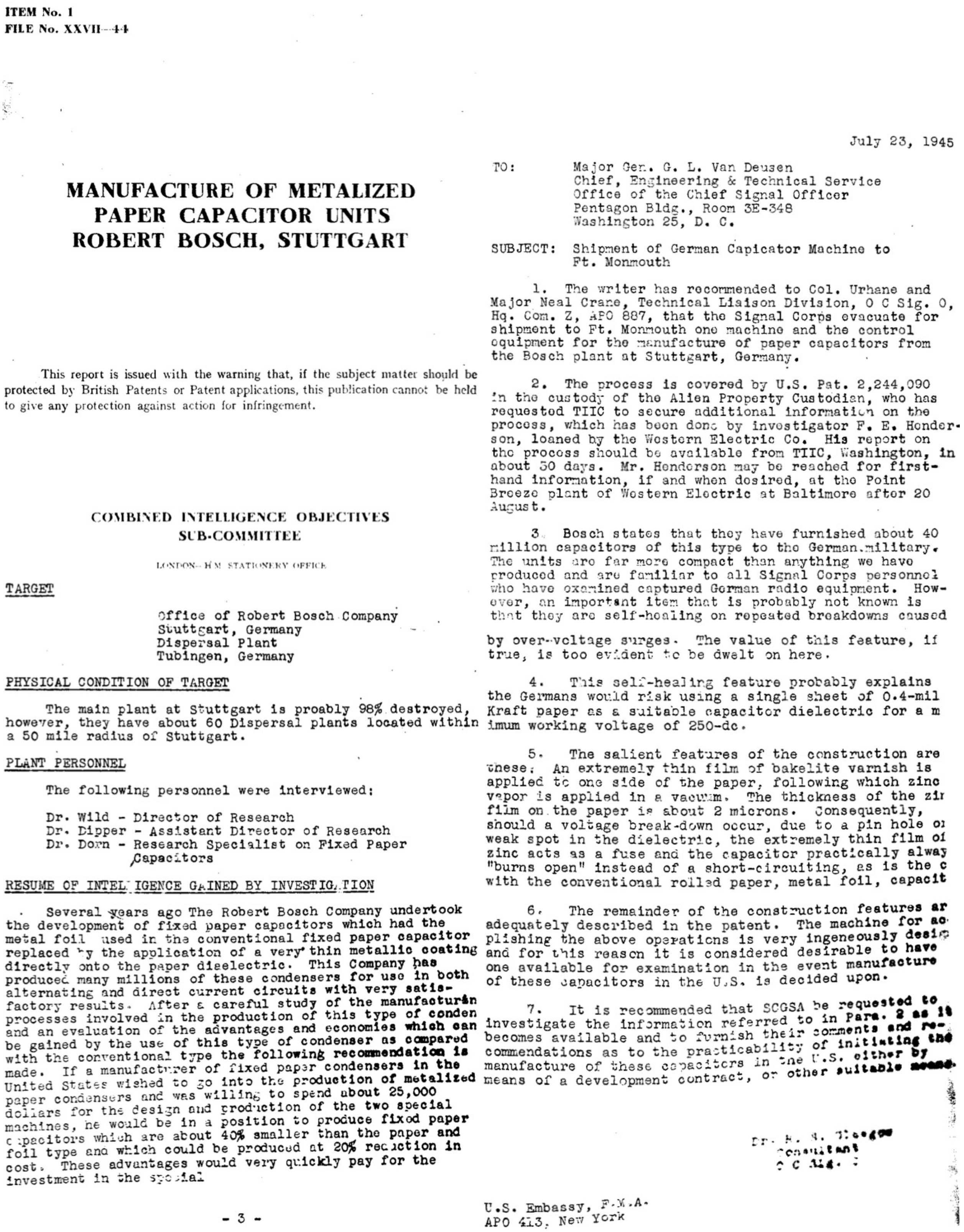
13. A condenser comprising two strips of metalized paper and at least two strips of non-metalized paper wound up in the form of a roll with the metalized strips alternating with the non-metalized strips, the metalization of each metalized strip extending to one edge thereof, a non-metalized margin remaining along the opposite edge of each strip, the metalized edge of one metalized strip and the adjacent edge of a non-metalized strip being folded upon themselves and the metalized edge of the other metalized strip and the adjacent edge of the other non-metalized strip being folded upon themselves so that each folded edge of the non-metalized strips lies within a fold and the metalization of each metalized strip faces the outside of a fold and contacts the adjacent metalization of the same polarity, the metal coated corners of such folds providing continuous metal coated edges lying exposed at and forming the sides of said condenser, and a metal coating applied to and connecting said fold corners at each side of said condenser.

14. A condenser comprising two strips of metalized paper and at least two strips of non-metalized paper wound up in the form of a roll with the metalized strips alternating with the non-metalized strips, the metalization of each metalized strip having a thickness of less than 0.001 mm. extending to one edge thereof, a non-metalized margin remaining along the opposite edge of each strip, the metalized edge of one metalized strip and the adjacent edge of a non-metalized strip being folded upon themselves and the metalized edge of the other metalized strip and the adjacent edge of the other non-metalized strip being folded upon themselves so that each folded edge of the non-metalized strips lies within a fold and the metalization of each metalized strip faces the outside of a fold and contacts the adjacent metalization of the same polarity, said strips being arranged with the metalized edge of one metalized strip and the non-metalized edge of the other metalized strip adjacent to but spaced from each other, the metal coated corners of the folded edges of said metalized strips being arranged alternately at opposite sides of the condenser to provide continuous metal coated edges lying exposed at and forming the sides of said condenser, and a metal coating applied to and connecting said exposed folded metal coated edges at each side of said condenser.

EBERHARD TRAUB.

Figure 6.104: Eberhard Traub invented metallized paper capacitors.

United States acquired Eberhard Traub's metalized paper capacitors



ITEM No. 1
FILE No. XXVII—44

MANUFACTURE OF METALIZED PAPER CAPACITOR UNITS ROBERT BOSCH, STUTTGART

This report is issued with the warning that, if the subject matter should be protected by British Patents or Patent applications, this publication cannot be held to give any protection against action for infringement.

COMBINED INTELLIGENCE OBJECTIVES
SUB-COMMITTEE

LONDON—H.M. STATIONERY OFFICE

TARGET

Office of Robert Bosch Company
Stuttgart, Germany
Dispersal Plant
Tubingen, Germany

PHYSICAL CONDITION OF TARGET

The main plant at Stuttgart is proably 98% destroyed, however, they have about 60 Dispersal plants located within a 50 mile radius of Stuttgart.

PLANT PERSONNEL

The following personnel were interviewed:

Dr. Wild - Director of Research
Dr. Dipper - Assistant Director of Research
Dr. Dorn - Research Specialist on Fixed Paper Capacitors

RESUME OF INTELLIGENCE GAINED BY INVESTIGATION

. Several years ago The Robert Bosch Company undertook the development of fixed paper capacitors which had the metal foil used in the conventional fixed paper capacitor replaced by the application of a very thin metallic coating directly onto the paper dieelectric. This Company has produced many millions of these condensers for use in both alternating and direct current circuits with very satisfactory results. After a careful study of the manufacturin processes involved in the production of this type of conden and an evaluation of the advantages and economies which can be gained by the use of this type of condenser as compared with the conventional type the following recommendation is made. If a manufacturer of fixed paper condensers in the United States wished to go into the production of metalized paper condensers and was willing to spend about 25,000 dollars for the design and production of the two special machines, he would be in a position to produce fixed paper capacitors which are about 40% smaller than the paper and foil type and which could be produced at 20% reduction in cost. These advantages would very quickly pay for the investment in the special

- 3 -

July 23, 1945

TO: Major Gen. G. L. Van Deusen
Chief, Engineering & Technical Service
Office of the Chief Signal Officer
Pentagon Bldg., Room 3E-348
Washington 25, D. C.

SUBJECT: Shipment of German Capicator Machine to Ft. Monmouth

1. The writer has recommended to Col. Urhane and Major Neal Crane, Technical Liaison Division, O C Sig. O, Hq. Com. Z, APO 887, that the Signal Corps evacuate for shipment to Ft. Monmouth one machine and the control equipment for the manufacture of paper capacitors from the Bosch plant at Stuttgart, Germany.

2. The process is covered by U.S. Pat. 2,244,090 in the custody of the Alien Property Custodian, who has requested TIIC to secure additional information on the process, which has been done by investigator F. E. Henderson, loaned by the Western Electric Co. His report on the process should be available from TIIC, Washington, in about 30 days. Mr. Henderson may be reached for first-hand information, if and when desired, at the Point Breeze plant of Western Electric at Baltimore after 20 August.

3. Bosch states that they have furnished about 40 million capacitors of this type to the German military. The units are far more compact than anything we have produced and are familiar to all Signal Corps personnel who have examined captured German radio equipment. However, an important item that is probably not known is that they are self-healing on repeated breakdowns caused by over-voltage surges. The value of this feature, if true, is too evident to be dwelt on here.

4. This self-healing feature probably explains the Germans would risk using a single sheet of 0.4-mil Kraft paper as a suitable capacitor dielectric for a m imum working voltage of 250-dc.

5. The salient features of the construction are these: An extremely thin film of bakelite varnish is applied to one side of the paper, following which zinc vapor is applied in a vacuum. The thickness of the zi film on the paper is about 2 microns. Consequently, should a voltage break-down occur, due to a pin hole o weak spot in the dielectric, the extremely thin film o zinc acts as a fuse and the capacitor practically alwa "burns open" instead of a short-circuiting, as is the c with the conventional rolled paper, metal foil, capacit

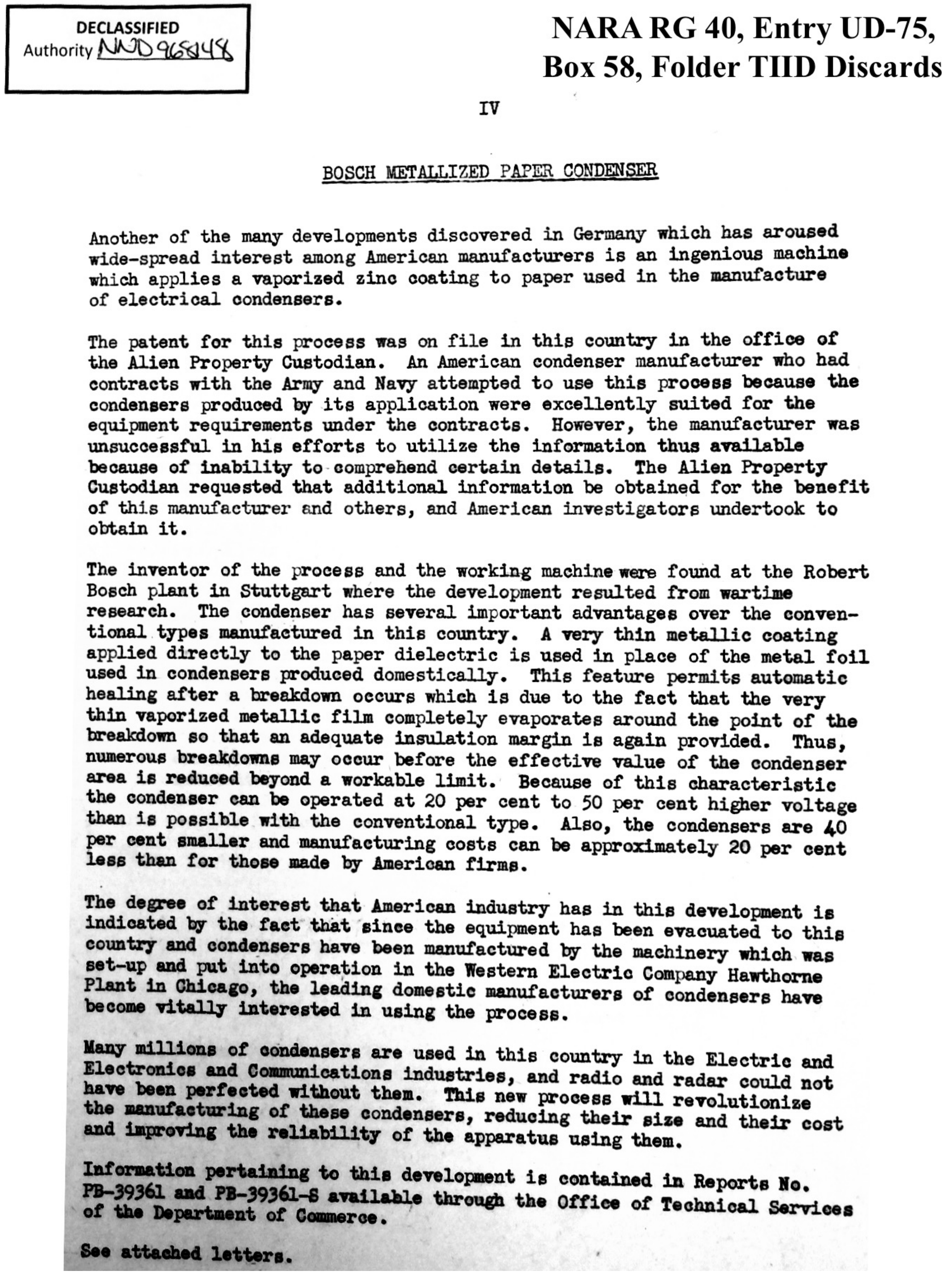
6. The remainder of the construction features a adequately described in the patent. The machine for ac plishing the above operations is very ingeneously desi and for this reason it is considered desirable to have one available for examination in the event manufacture of these capacitors in the U.S. is decided upon.

7. It is recommended that SCGSA be requested to investigate the information referred to in Para. 2 as it becomes available and to furnish their comments and recommendations as to the practicability of initiating the manufacture of these capacitors in the U.S. either by means of a development contract, or other suitable means.

Dr. H. S. [illegible]
Consultant
O C Sig. O

U.S. Embassy, F.M.A.
APO 413, New York

Figure 6.105: The United States acquired Eberhard Traub's metallized paper capacitor technology in 1945.



DECLASSIFIED
Authority NND965048

NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards

IV

BOSCH METALLIZED PAPER CONDENSER

Another of the many developments discovered in Germany which has aroused wide-spread interest among American manufacturers is an ingenious machine which applies a vaporized zinc coating to paper used in the manufacture of electrical condensers.

The patent for this process was on file in this country in the office of the Alien Property Custodian. An American condenser manufacturer who had contracts with the Army and Navy attempted to use this process because the condensers produced by its application were excellently suited for the equipment requirements under the contracts. However, the manufacturer was unsuccessful in his efforts to utilize the information thus available because of inability to comprehend certain details. The Alien Property Custodian requested that additional information be obtained for the benefit of this manufacturer and others, and American investigators undertook to obtain it.

The inventor of the process and the working machine were found at the Robert Bosch plant in Stuttgart where the development resulted from wartime research. The condenser has several important advantages over the conventional types manufactured in this country. A very thin metallic coating applied directly to the paper dielectric is used in place of the metal foil used in condensers produced domestically. This feature permits automatic healing after a breakdown occurs which is due to the fact that the very thin vaporized metallic film completely evaporates around the point of the breakdown so that an adequate insulation margin is again provided. Thus, numerous breakdowns may occur before the effective value of the condenser area is reduced beyond a workable limit. Because of this characteristic the condenser can be operated at 20 per cent to 50 per cent higher voltage than is possible with the conventional type. Also, the condensers are 40 per cent smaller and manufacturing costs can be approximately 20 per cent less than for those made by American firms.

The degree of interest that American industry has in this development is indicated by the fact that since the equipment has been evacuated to this country and condensers have been manufactured by the machinery which was set-up and put into operation in the Western Electric Company Hawthorne Plant in Chicago, the leading domestic manufacturers of condensers have become vitally interested in using the process.

Many millions of condensers are used in this country in the Electric and Electronics and Communications industries, and radio and radar could not have been perfected without them. This new process will revolutionize the manufacturing of these condensers, reducing their size and their cost and improving the reliability of the apparatus using them.

Information pertaining to this development is contained in Reports No. PB-39361 and PB-39361-S available through the Office of Technical Services of the Department of Commerce.

See attached letters.

Figure 6.106: The United States acquired Eberhard Traub's metalized paper capacitor technology in 1945 [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

6.5.6 Printed Circuits

While moving from large vacuum tubes to small transistors greatly helped to miniaturize and simplify electronics, the development of printed circuit boards was another major step in microelectronics. In printed circuits, electronic components are attached to an insulating board that is covered with etched metal lines for wires, avoiding the labor and bulkiness involved in connecting separate physical wires to each component. A closely related technological development was multi-pin connectors, which could be used without printed circuits but became even more advantageous when used together with printed circuits.

As shown on pp. 1090 and 2766–2777, Albert Hanson (German, 18??–19??) filed patent applications on printed circuits and multi-pin connectors in 1902 and 1903. From the available documentation, it is not clear how far he got in implementing his designs, although the highly detailed nature of the patents suggests that he may well have built and tested printed circuits and multi-pin connectors.

Mathias Nowottnick, an engineering professor at the University of Rostock, noted that printed circuit technology, apparently based on Hanson's patents, was being used by at least three German companies by 1927–1932 [Nowottnick 2014, p. 4]:

1927 Telefunken, Verdrahtung von Bauteilen mittels Messingstreifen.	1927 Telefunken, wiring of components using brass strips.
1930 Hescho-Werke in Hermsdorf Aufdrucken von Leiterzügen auf Keramiksubstrat mittels Siebdrucktechnik (stellt heute noch die Grundlage für die Dickschichttechnik dar!)—"Gedruckte Schaltung".	1930 Hescho Works in Hermsdorf Imprinting of conductors on ceramic substrate using screen printing technology (still the basis for thick-film technology today!)—"printed circuits."
1932 erste Leiterplatte mit genieteten Metallstreifen, Sachsenwerk Licht und Kraft AG [Fig. 6.108]	1932 first printed circuit board with riveted metal strips, Sachsenwerk Light and Power AG [Fig. 6.108]

Wolfgang Scheel, a longtime department head of the Fraunhofer Institute, named additional German companies that were among the first to use printed circuits [Manfred Frank 2003, p. 2]:

Lassen Sie mich zunächst feststellen, dass die Leiterplatte in diesem Jahr [2003] ihren 100. Geburtstag feiert. Der Berliner Hanson hat dafür das Patent 1903 angemeldet. Ferner möchte ich anmerken, dass als Pionierfirmen auf dem Gebiet der Leiterplatteentwicklung in Deutschland die Sachsenwerk Licht und Kraft AG Niedersedlitz, die Ruwelwerke Geldern, die Lackwerke Peters in Kempen und die Isola AG in Düren zu nennen sind.	Let me first note that the printed circuit board celebrates its 100th birthday this year [2003]. Hanson from Berlin filed the patent for it in 1903. I would also like to note that the pioneering companies in the field of printed circuit board development in Germany are Sachsenwerk Licht und Kraft AG Niedersedlitz, Ruwelwerke Geldern, Lackwerke Peters in Kempen and Isola AG in Düren.

Paul Eisler (Austrian, 1907–1992) studied engineering at the University of Vienna, graduated in 1930, and worked in electrical engineering, during which time he apparently became familiar with then-current German and Austrian printed circuit technologies that were based on Hanson's original patents. In 1936 Eisler fled to the United Kingdom, taking his knowledge of printed circuit technologies with him, and he immediately began building printed circuits upon his arrival there [Eisler 1989; Medawar and Pyke 2000]. He brought the technology to the attention of the British government during World War II and filed patent applications on it in 1944 (pp. 1092 and 2779–2795). Some U.S. officials discovered Eisler's work and incorporated simple printed circuits into proximity fuses for artillery shells that were used in late 1944 and 1945, but otherwise Allied countries do not seem to have harnessed the potential of printed circuits during the war.

In contrast, as shown on pp. 1093 and 2796–2799, printed circuits were in "wide use" in wartime Germany (presumably having grown far beyond just Telefunken, Hescho-Werke, and Sachsenwerk since ∼1930), and all of that printed circuit technology was transferred to the United States on a large scale after the war by people such as longtime Bell Telephone Laboratories engineer Todos Odarenko.

The final step in the development of printed circuits came when Rudolf Strauss (German, 1913–2001, Fig. 6.111) developed the wave soldering method for the fully automated manufacturing of printed circuits, or surface mount technology (SMT), from 1951 to 1955 [rondinax.wordpress.com/2014/01/31/rudolf-strauss-1913-2001-a-key-player-in-the-rondinax-and-rondix-story/]. See also pp. 2800–2806. (Was Strauss truly the original creator of wave soldering, or did he bring that method with him from the German-speaking world, just as Eisler apparently brought printed circuits?)

Historians of science Jean Medawar and David Pyke emphasized the importance of the development of printed circuits [Medawar and Pyke 2000, p. 93]:

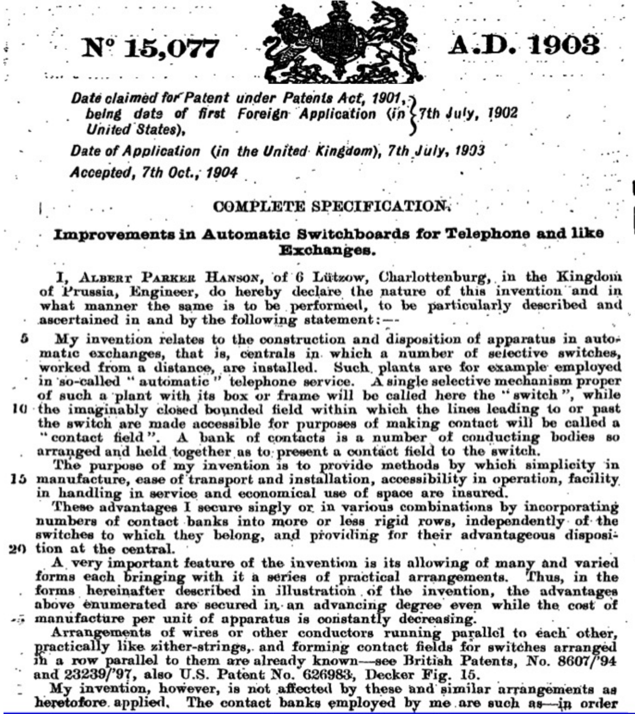
> Rudolf Strauss [...] met and became friends with Paul Eisler, a refugee from Austria, who had invented the printed electrical circuit board, which revolutionized the electronics industry. Strauss invented a technique for soldering thousands of electric connections in one operation. His 'wave soldering' machine, built in 1958, is still being made in a sophisticated form all over the industrial world. [...]
>
> Recognition of Eisler's work took years. In late 1957 Lord Hailsham told the Royal Society that he rated the printed electric circuit as important an invention as penicillin or atomic fission.

Note that Medawar and Pyke described Eisler as the inventor of printed circuits, as have many other modern historians. While Eisler played a critical role in transferring printed circuit technology out of the German-speaking world and producing the first printed circuits in Allied countries, it seems clear from the historical record that Albert Hanson was the original inventor in 1902, and that multiple companies in the German-speaking world were building and selling printed circuits several years before Eisler ever built his first printed circuit board.

Boris Chertok, who led some of the Soviet missions removing German technologies after World War II, mentioned the widespread German use of sophisticated multi-pin connectors. Those likely went along with printed circuits, since printed circuits were in wide use and both multi-pin connectors and printed circuits traced back to Albert Hanson's inventions. Chertok also described the transfer of many other advanced electronics technologies to the Soviet Union (pp. 2807–2812).

Much more archival research is needed to reconstruct the detailed history and extent of research and development of printed circuits in the German-speaking world, as well as how that work was transferred to other countries during and after the Third Reich.

Albert Hanson (18??–19??) filed detailed patent applications on printed circuits and multi-pin connectors 1902–1903



Nº 15,077 **A.D. 1903**

Date claimed for Patent under Patents Act, 1901, being date of first Foreign Application (in United States), } *7th July, 1902*

Date of Application (in the United Kingdom), 7th July, 1903

Accepted, 7th Oct., 1904

COMPLETE SPECIFICATION.

Improvements in Automatic Switchboards for Telephone and like Exchanges.

I, Albert Parker Hanson, of 6 Lützow, Charlottenburg, in the Kingdom of Prussia, Engineer, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

My invention relates to the construction and disposition of apparatus in automatic exchanges, that is, centrals in which a number of selective switches, worked from a distance, are installed. Such plants are for example employed in so-called "automatic" telephone service. A single selective mechanism proper of such a plant with its box or frame will be called here the "switch", while the imaginably closed bounded field within which the lines leading to or past the switch are made accessible for purposes of making contact will be called a "contact field". A bank of contacts is a number of conducting bodies so arranged and held together as to present a contact field to the switch.

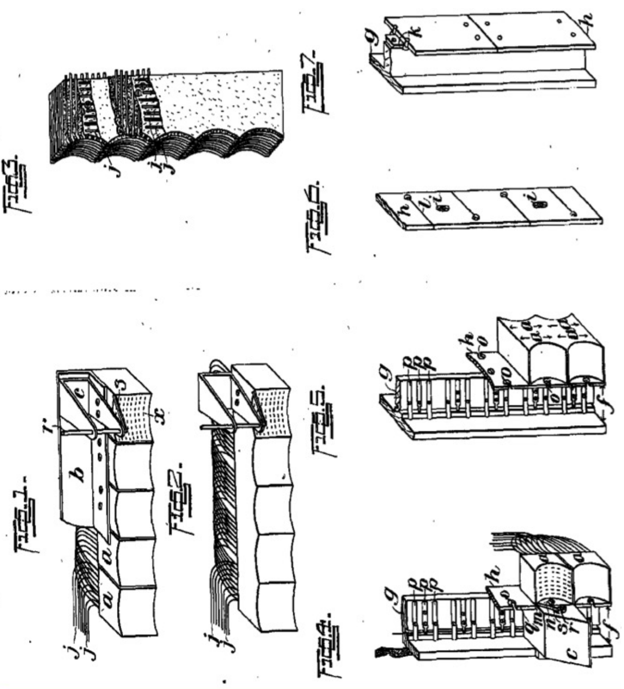
The purpose of my invention is to provide methods by which simplicity in manufacture, ease of transport and installation, accessibility in operation, facility in handling in service and economical use of space are insured.

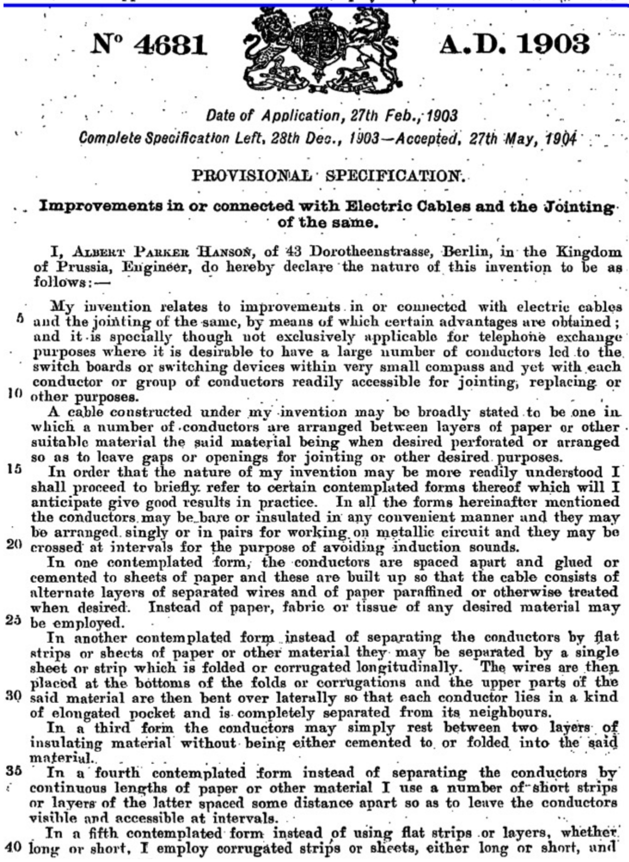
These advantages I secure singly or in various combinations by incorporating numbers of contact banks into more or less rigid rows, independently of the switches to which they belong, and providing for their advantageous disposition at the central.

A very important feature of the invention is its allowing of many and varied forms each bringing with it a series of practical arrangements. Thus, in the forms hereinafter described in illustration of the invention, the advantages above enumerated are secured in an advancing degree even while the cost of manufacture per unit of apparatus is constantly decreasing.

Arrangements of wires or other conductors running parallel to each other, practically like zither-strings, and forming contact fields for switches arranged in a row parallel to them are already known—see British Patents, No. 8607/'94 and 23239/'97, also U.S. Patent No. 626983, Decker Fig. 15.

My invention, however, is not affected by these and similar arrangements as heretofore applied. The contact banks employed by me are such as—in order





Nº 4681 **A.D. 1903**

Date of Application, 27th Feb., 1903

Complete Specification Left, 28th Dec., 1903—Accepted, 27th May, 1904

PROVISIONAL SPECIFICATION.

Improvements in or connected with Electric Cables and the Jointing of the same.

I, Albert Parker Hanson, of 43 Dorotheenstrasse, Berlin, in the Kingdom of Prussia, Engineer, do hereby declare the nature of this invention to be as follows:—

My invention relates to improvements in or connected with electric cables and the jointing of the same, by means of which certain advantages are obtained; and it is specially though not exclusively applicable for telephone exchange purposes where it is desirable to have a large number of conductors led to the switch boards or switching devices within very small compass and yet with each conductor or group of conductors readily accessible for jointing, replacing or other purposes.

A cable constructed under my invention may be broadly stated to be one in which a number of conductors are arranged between layers of paper or other suitable material the said material being when desired perforated or arranged so as to leave gaps or openings for jointing or other desired purposes.

In order that the nature of my invention may be more readily understood I shall proceed to briefly refer to certain contemplated forms thereof which will I anticipate give good results in practice. In all the forms hereinafter mentioned the conductors may be bare or insulated in any convenient manner and they may be arranged singly or in pairs for working on metallic circuit and they may be crossed at intervals for the purpose of avoiding induction sounds.

In one contemplated form, the conductors are spaced apart and glued or cemented to sheets of paper and these are built up so that the cable consists of alternate layers of separated wires and of paper paraffined or otherwise treated when desired. Instead of paper, fabric or tissue of any desired material may be employed.

In another contemplated form instead of separating the conductors by flat strips or sheets of paper or other material they may be separated by a single sheet or strip which is folded or corrugated longitudinally. The wires are then placed at the bottoms of the folds or corrugations and the upper parts of the said material are then bent over laterally so that each conductor lies in a kind of elongated pocket and is completely separated from its neighbours.

In a third form the conductors may simply rest between two layers of insulating material without being either cemented to or folded into the said material.

In a fourth contemplated form instead of separating the conductors by continuous lengths of paper or other material I use a number of short strips or layers of the latter spaced some distance apart so as to leave the conductors visible and accessible at intervals.

In a fifth contemplated form instead of using flat strips or layers, whether long or short, I employ corrugated strips or sheets, either long or short, and

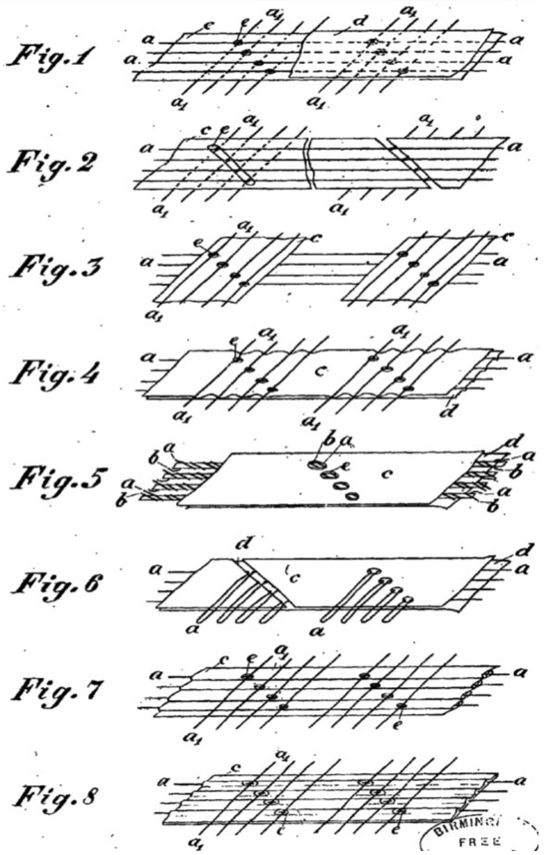
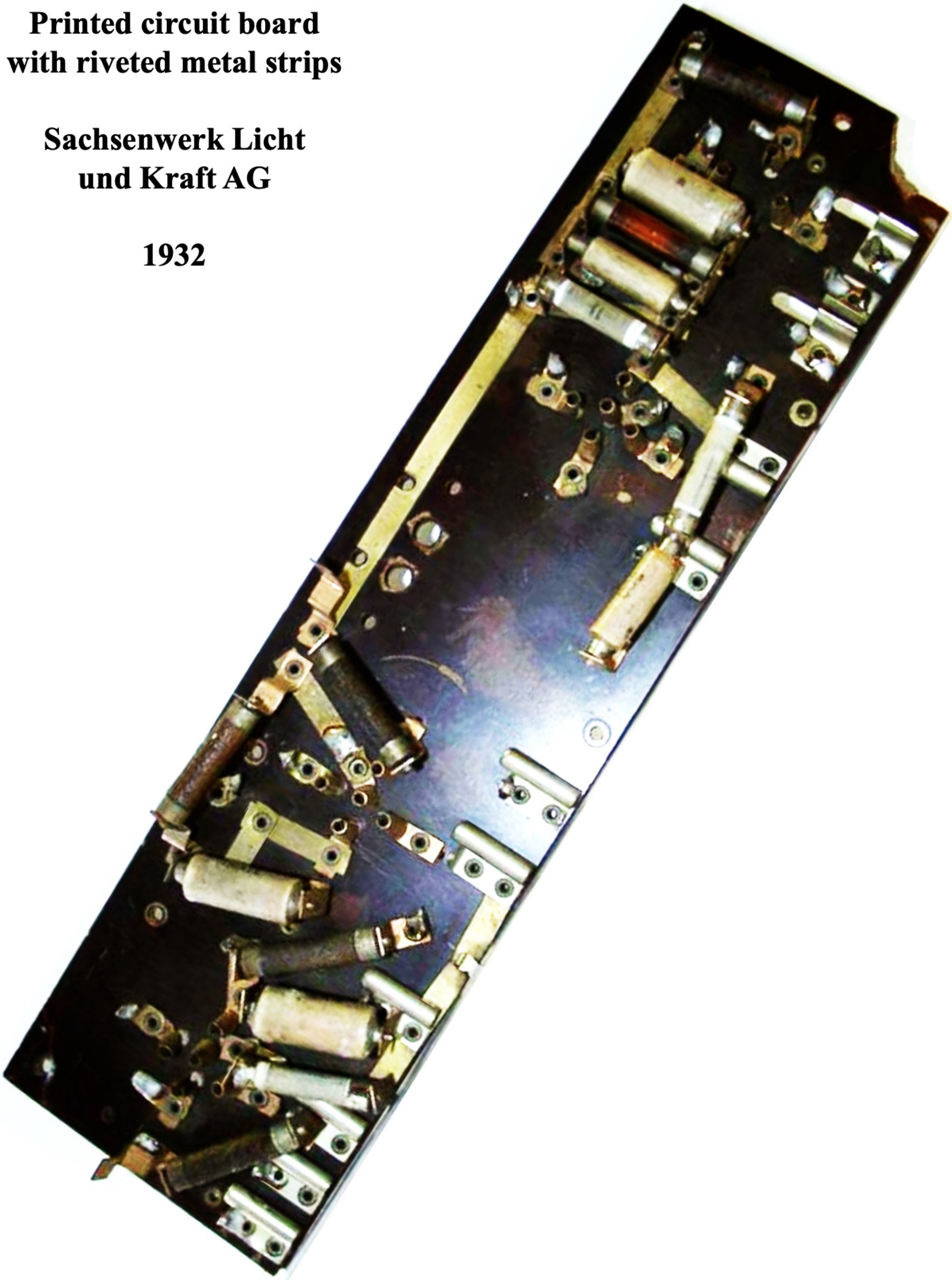


Figure 6.107: Albert Hanson filed detailed patent applications on printed circuits and multi-pin connectors in 1902 and 1903.



Printed circuit board
with riveted metal strips

Sachsenwerk Licht
und Kraft AG

1932

Figure 6.108: Printed circuit board with riveted metal strips, Sachsenwerk Licht und Kraft AG, 1932.

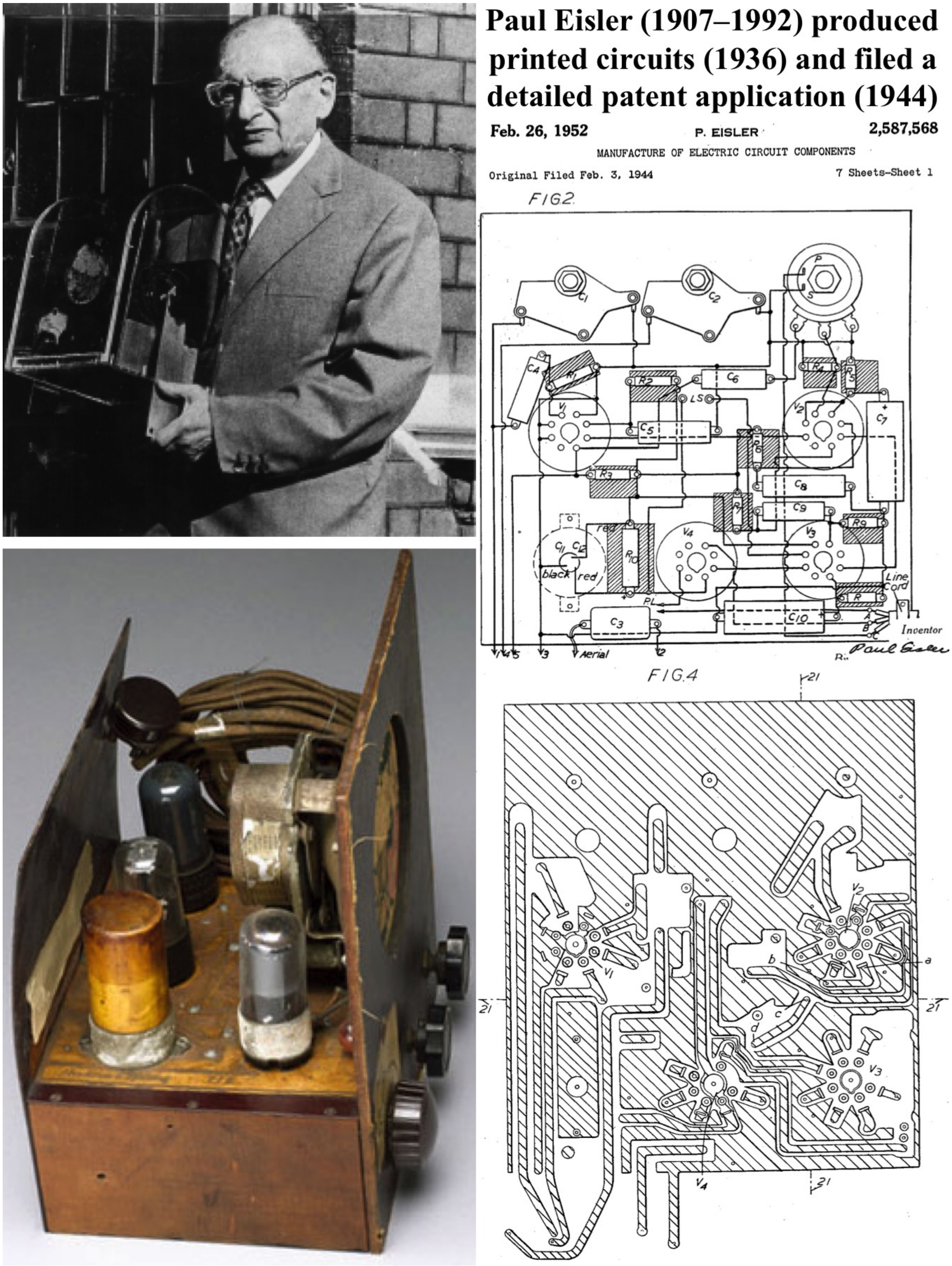
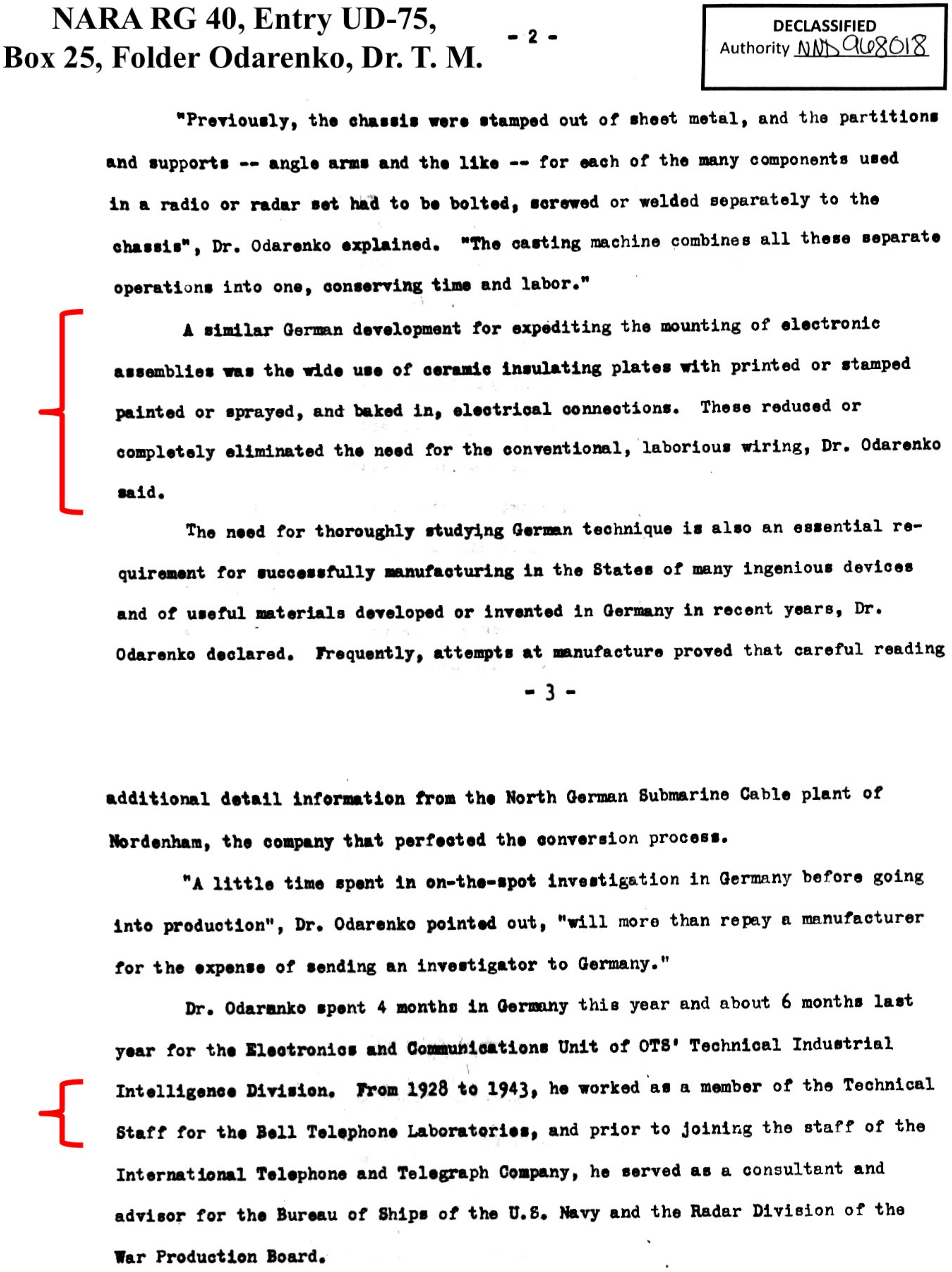

Paul Eisler (1907–1992) produced printed circuits (1936) and filed a detailed patent application (1944)
Feb. 26, 1952
P. EISLER
2,587,568
MANUFACTURE OF ELECTRIC CIRCUIT COMPONENTS
Original Filed Feb. 3, 1944
7 Sheets-Sheet 1
FIG.2
FIG.4
Inventor
Paul Eisler

Figure 6.109: Paul Eisler produced printed circuits in 1936 and filed a patent application on them in 1944. At least three German companies produced printed circuits several years before Eisler, and he was presumably familiar with their technology from his studies and work as an electrical engineer in the German-speaking world.



NARA RG 40, Entry UD-75, Box 25, Folder Odarenko, Dr. T. M.

- 2 -

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Authority NND968018

"Previously, the chassis were stamped out of sheet metal, and the partitions and supports -- angle arms and the like -- for each of the many components used in a radio or radar set had to be bolted, screwed or welded separately to the chassis", Dr. Odarenko explained. "The casting machine combines all these separate operations into one, conserving time and labor."

A similar German development for expediting the mounting of electronic assemblies was the wide use of ceramic insulating plates with printed or stamped painted or sprayed, and baked in, electrical connections. These reduced or completely eliminated the need for the conventional, laborious wiring, Dr. Odarenko said.

The need for thoroughly studying German technique is also an essential requirement for successfully manufacturing in the States of many ingenious devices and of useful materials developed or invented in Germany in recent years, Dr. Odarenko declared. Frequently, attempts at manufacture proved that careful reading

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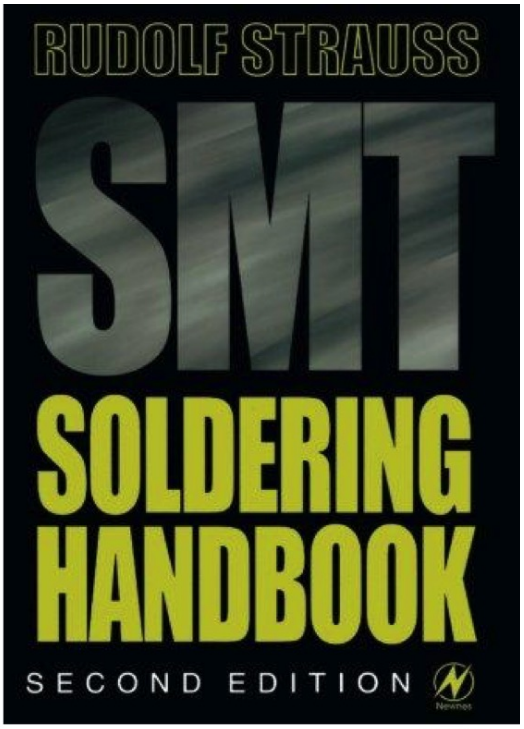
additional detail information from the North German Submarine Cable plant of Nordenham, the company that perfected the conversion process.

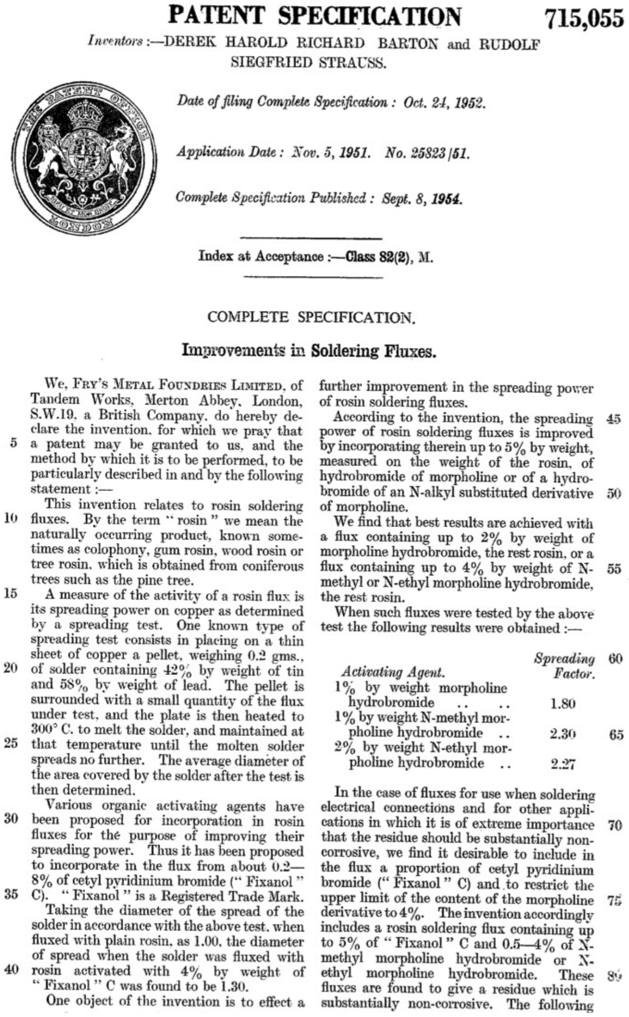
"A little time spent in on-the-spot investigation in Germany before going into production", Dr. Odarenko pointed out, "will more than repay a manufacturer for the expense of sending an investigator to Germany."

Dr. Odarenko spent 4 months in Germany this year and about 6 months last year for the Electronics and Communications Unit of OTS' Technical Industrial Intelligence Division. From 1928 to 1943, he worked as a member of the Technical Staff for the Bell Telephone Laboratories, and prior to joining the staff of the International Telephone and Telegraph Company, he served as a consultant and advisor for the Bureau of Ships of the U.S. Navy and the Radar Division of the War Production Board.

Figure 6.110: Printed circuits were in "wide use" in wartime Germany and the technology was transferred to the United States after the war by people such as longtime Bell Telephone Laboratories engineer Todos Odarenko [NARA RG 40, Entry UD-75, Box 25, Folder Odarenko, Dr. T. M., undated press release (probably late 1946)].

Rudolf Strauss (1913–2001) invented wave soldering for printed circuits, or surface mount technology (1951–1955)





PATENT SPECIFICATION 715,055

Inventors :—DEREK HAROLD RICHARD BARTON and RUDOLF SIEGFRIED STRAUSS.

Date of filing Complete Specification : Oct. 24, 1952.

Application Date : Nov. 5, 1951. No. 25823/51.

Complete Specification Published : Sept. 8, 1954.

Index at Acceptance :—Class 82(2), M.

COMPLETE SPECIFICATION.

Improvements in Soldering Fluxes.

We, FRY'S METAL FOUNDRIES LIMITED, of Tandem Works, Merton Abbey, London, S.W.19, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement :—

This invention relates to rosin soldering fluxes. By the term " rosin " we mean the naturally occurring product, known sometimes as colophony, gum rosin, wood rosin or tree rosin, which is obtained from coniferous trees such as the pine tree.

A measure of the activity of a rosin flux is its spreading power on copper as determined by a spreading test. One known type of spreading test consists in placing on a thin sheet of copper a pellet, weighing 0.2 gms., of solder containing 42% by weight of tin and 58% by weight of lead. The pellet is surrounded with a small quantity of the flux under test, and the plate is then heated to 300° C. to melt the solder, and maintained at that temperature until the molten solder spreads no further. The average diameter of the area covered by the solder after the test is then determined.

Various organic activating agents have been proposed for incorporation in rosin fluxes for the purpose of improving their spreading power. Thus it has been proposed to incorporate in the flux from about 0.2—8% of cetyl pyridinium bromide (" Fixanol " C). " Fixanol " is a Registered Trade Mark.

Taking the diameter of the spread of the solder in accordance with the above test, when fluxed with plain rosin, as 1.00, the diameter of spread when the solder was fluxed with rosin activated with 4% by weight of " Fixanol " C was found to be 1.30.

One object of the invention is to effect a further improvement in the spreading power of rosin soldering fluxes.

According to the invention, the spreading power of rosin soldering fluxes is improved by incorporating therein up to 5% by weight, measured on the weight of the rosin, of hydrobromide of morpholine or of a hydrobromide of an N-alkyl substituted derivative of morpholine.

We find that best results are achieved with a flux containing up to 2% by weight of morpholine hydrobromide, the rest rosin, or a flux containing up to 4% by weight of N-methyl or N-ethyl morpholine hydrobromide, the rest rosin.

When such fluxes were tested by the above test the following results were obtained :—

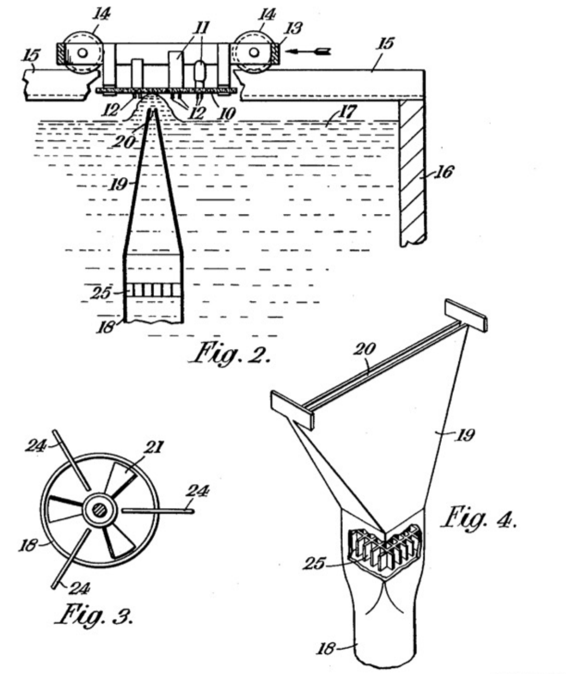
Activating Agent.	*Spreading Factor.*
1% by weight morpholine hydrobromide	1.80
1% by weight N-methyl morpholine hydrobromide ..	2.30
2% by weight N-ethyl morpholine hydrobromide ..	2.27

In the case of fluxes for use when soldering electrical connections and for other applications in which it is of extreme importance that the residue should be substantially non-corrosive, we find it desirable to include in the flux a proportion of cetyl pyridinium bromide (" Fixanol " C) and to restrict the upper limit of the content of the morpholine derivative to 4%. The invention accordingly includes a rosin soldering flux containing up to 5% of " Fixanol " C and 0.5—4% of N-methyl morpholine hydrobromide or N-ethyl morpholine hydrobromide. These fluxes are found to give a residue which is substantially non-corrosive. The following

Oct. 2, 1962 A. F. C. BARNES ETAL **3,056,370**

APPARATUS FOR SOLDERING

Filed Oct. 9, 1956 2 Sheets-Sheet 2



INVENTORS
ALLAN F.C. BARNES
VICTOR B. ELLIOTT
RUDOLF S. STRAUSS

Figure 6.111: Rudolf Strauss developed the wave soldering method for automated manufacturing of printed circuits, or surface mount technology (SMT), from 1951 to 1955.

6.5.7 Integrated Circuits

Even further miniaturization of electronics required moving from individual electronic components to integrated circuit chips that could contain large numbers of components on the same semiconductor substrate.

In 1949, Werner Jacobi (German, 1904–1985) filed a West German patent application on integrated circuits on behalf of Siemens & Halske. Since there were a large number of German inventors who filed patents on their wartime work when the (West) German patent office reopened in 1949, it is quite likely that Jacobi's patent application was based on experimental work that he had conducted at Siemens & Halske during the war (pp. 1096 and 2816–2817).

Kurt Lehovec (Bohemian/Austrian/Czech, 1918–2012) developed advanced semiconductor devices for Germany in Prague during the war. After the war he was extensively interrogated by the United States and then moved to the United States (as part of Operation Paperclip), where he filed patents on transistors, integrated circuits, and light emitting diodes. See pp. 1074, 1097, 2757–2763, 2818–2832, and 2895–2910. Lehovec's integrated circuit designs may well have been based on wartime work, but even if they were early postwar ideas, they preceded the claims of American engineers who later worked on integrated circuits.

Other German-speaking scientists developed transistor fabrication methods that made integrated circuits practical:

- Herbert Kroemer (German, 1928–) invented the drift transistor in 1953 or earlier, the double-hetero-structure laser diode in 1963, and III-V semiconductor heterostructures in 1966 or earlier. See pp. 1111, 2833–2845, and 2917–2922. He won the Nobel Prize in Physics in 2000 (p. 1104).

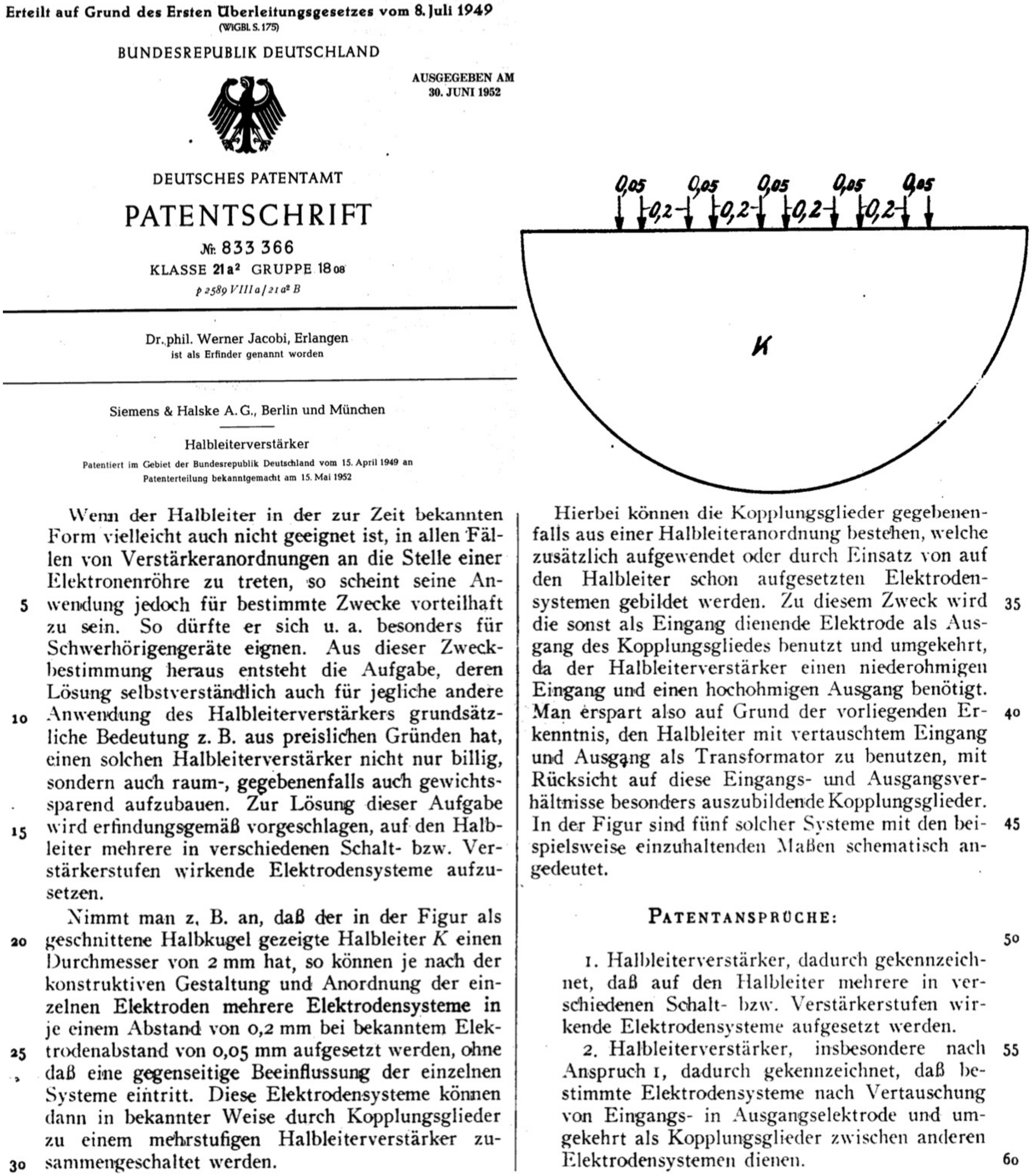
- Jean Hoerni (Swiss, 1924–1997) and Eugene Kleiner (Austrian, 1923–2003) devised methods of manufacturing silicon transistors at Fairchild Semiconductor; see pp. 1101 and 2846–2861. Through Fairchild and their later companies and investments, they also helped to develop Silicon Valley.

- Karl Heinz Zaininger (German, 1929–) developed modern methods for fabricating field effect transistors (pp. 1102 and 2862–2876).

As shown on pp. 1103 and 2877–2887, Helmut Gröttrup (German, 1916–1981) and Jürgen Dethloff (German, 1924–2002) invented the smart card, or chip card, in 1966. Earlier, Gröttrup developed avionics systems in Germany during the war and led the German-speaking contributions to the postwar Soviet ballistic missile program (pp. 1874–1881).

As with transistors and printed circuits, much more research should be conducted to determine how much work on integrated circuits was conducted in the German-speaking world during the war, and how much impact German-speaking scientists and knowledge had on the postwar development of integrated circuits in other countries.

Werner Jacobi (1904–1985) filed a patent application on integrated circuits in 1949 (based on wartime work?)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Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

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30. JUNI 1952

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 833 366
KLASSE $21a^2$ GRUPPE 18_{08}
p 2589 VIII a / 21 a^2 B

Dr. phil. Werner Jacobi, Erlangen
ist als Erfinder genannt worden

Siemens & Halske A. G., Berlin und München

Halbleiterverstärker

Patentiert im Gebiet der Bundesrepublik Deutschland vom 15. April 1949 an
Patenterteilung bekanntgemacht am 15. Mai 1952

Wenn der Halbleiter in der zur Zeit bekannten Form vielleicht auch nicht geeignet ist, in allen Fällen von Verstärkeranordnungen an die Stelle einer Elektronenröhre zu treten, so scheint seine Anwendung jedoch für bestimmte Zwecke vorteilhaft zu sein. So dürfte er sich u. a. besonders für Schwerhörigengeräte eignen. Aus dieser Zweckbestimmung heraus entsteht die Aufgabe, deren Lösung selbstverständlich auch für jegliche andere Anwendung des Halbleiterverstärkers grundsätzliche Bedeutung z. B. aus preislichen Gründen hat, einen solchen Halbleiterverstärker nicht nur billig, sondern auch raum-, gegebenenfalls auch gewichtssparend aufzubauen. Zur Lösung dieser Aufgabe wird erfindungsgemäß vorgeschlagen, auf den Halbleiter mehrere in verschiedenen Schalt- bzw. Verstärkerstufen wirkende Elektrodensysteme aufzusetzen.

Nimmt man z. B. an, daß der in der Figur als geschnittene Halbkugel gezeigte Halbleiter *K* einen Durchmesser von 2 mm hat, so können je nach der konstruktiven Gestaltung und Anordnung der einzelnen Elektroden mehrere Elektrodensysteme in je einem Abstand von 0,2 mm bei bekanntem Elektrodenabstand von 0,05 mm aufgesetzt werden, ohne daß eine gegenseitige Beeinflussung der einzelnen Systeme eintritt. Diese Elektrodensysteme können dann in bekannter Weise durch Kopplungsglieder zu einem mehrstufigen Halbleiterverstärker zusammengeschaltet werden.

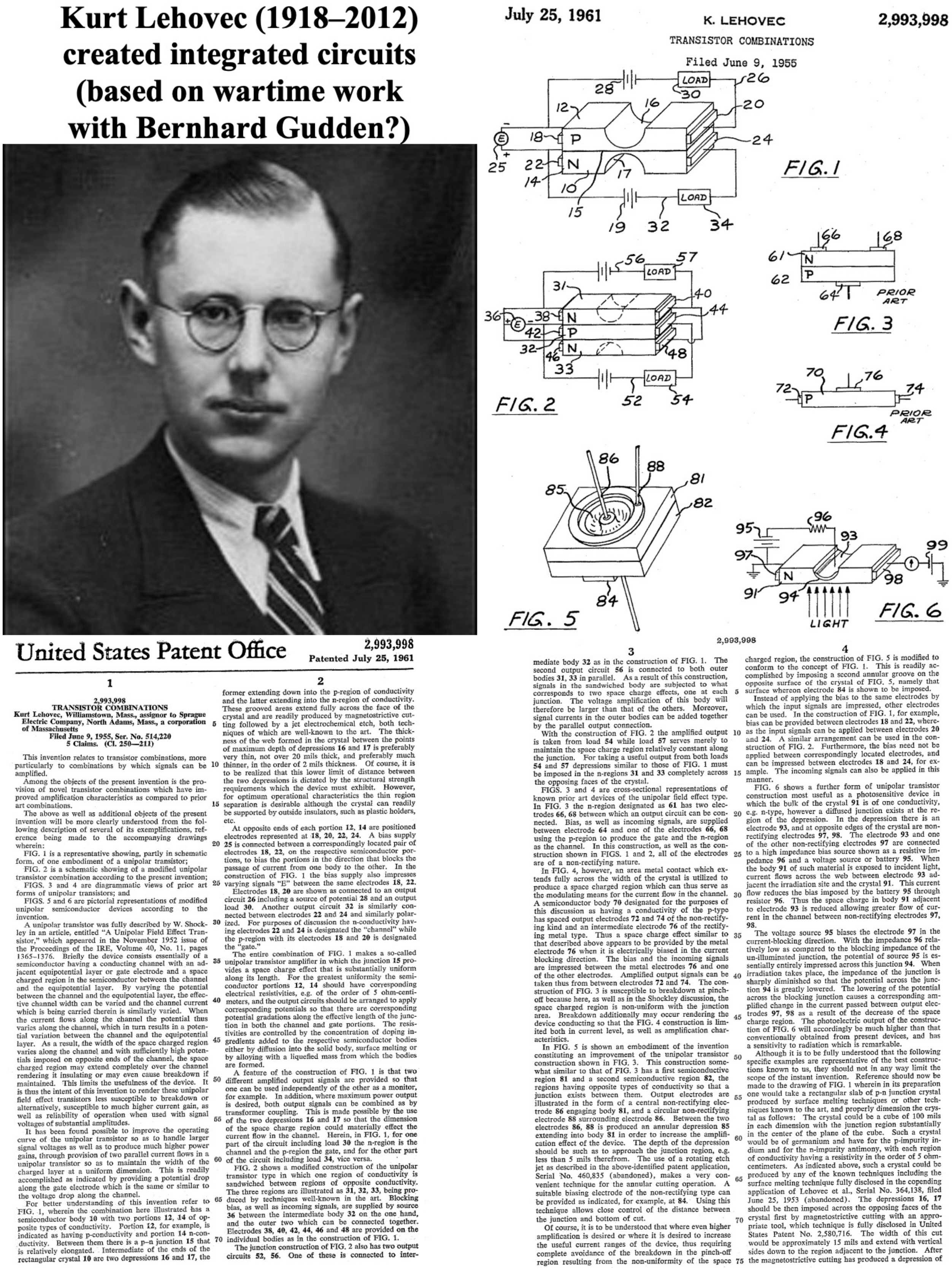
Hierbei können die Kopplungsglieder gegebenenfalls aus einer Halbleiteranordnung bestehen, welche zusätzlich aufgewendet oder durch Einsatz von auf den Halbleiter schon aufgesetzten Elektrodensystemen gebildet werden. Zu diesem Zweck wird die sonst als Eingang dienende Elektrode als Ausgang des Kopplungsgliedes benutzt und umgekehrt, da der Halbleiterverstärker einen niederohmigen Eingang und einen hochohmigen Ausgang benötigt. Man erspart also auf Grund der vorliegenden Erkenntnis, den Halbleiter mit vertauschtem Eingang und Ausgang als Transformator zu benutzen, mit Rücksicht auf diese Eingangs- und Ausgangsverhältnisse besonders auszubildende Kopplungsglieder. In der Figur sind fünf solcher Systeme mit den beispielsweise einzuhaltenden Maßen schematisch angedeutet.

PATENTANSPRÜCHE:

1. Halbleiterverstärker, dadurch gekennzeichnet, daß auf den Halbleiter mehrere in verschiedenen Schalt- bzw. Verstärkerstufen wirkende Elektrodensysteme aufgesetzt werden.

2. Halbleiterverstärker, insbesondere nach Anspruch 1, dadurch gekennzeichnet, daß bestimmte Elektrodensysteme nach Vertauschung von Eingangs- in Ausgangselektrode und umgekehrt als Kopplungsglieder zwischen anderen Elektrodensystemen dienen.

Figure 6.112: Werner Jacobi filed a patent on integrated circuits in 1949, likely based on wartime work.



Kurt Lehovec (1918–2012) created integrated circuits (based on wartime work with Bernhard Gudden?)

July 25, 1961 K. LEHOVEC 2,993,998
TRANSISTOR COMBINATIONS
Filed June 9, 1955

LOAD
28
30
26
12
16
20
E
18
P
24
25
22
N
14
10
17
FIG. 1
15
19
32
34
66
68
61
N
62
P
64
PRIOR ART
FIG. 3
56
57
31
40
44
36
38
N
42
P
32
N
46
48
33
52
54
FIG. 2
70
76
72
P
74
PRIOR ART
FIG. 4
86
88
81
85
82
84
FIG. 5
96
95
93
99
97
N
98
91
94
LIGHT
FIG. 6

United States Patent Office

2,993,998
Patented July 25, 1961

2,993,998
TRANSISTOR COMBINATIONS
Kurt Lehovec, Williamstown, Mass., assignor to Sprague Electric Company, North Adams, Mass., a corporation of Massachusetts
Filed June 9, 1955, Ser. No. 514,220
5 Claims. (Cl. 250—211)

This invention relates to transistor combinations, more particularly to combinations by which signals can be amplified.

Among the objects of the present invention is the provision of novel transistor combinations which have improved amplification characteristics as compared to prior art combinations.

The above as well as additional objects of the present invention will be more clearly understood from the following description of several of its exemplifications, reference being made to the accompanying drawings wherein:

FIG. 1 is a representative showing, partly in schematic form, of one embodiment of a unipolar transistor;

FIG. 2 is a schematic showing of a modified unipolar transistor combination according to the present invention;

FIGS. 3 and 4 are diagrammatic views of prior art forms of unipolar transistors; and

FIGS. 5 and 6 are pictorial representations of modified unipolar semiconductor devices according to the invention.

A unipolar transistor was fully described by W. Shockley in an article, entitled "A Unipolar Field Effect Transistor," which appeared in the November 1952 issue of the Proceedings of the IRE, Volume 40, No. 11, pages 1365–1376. Briefly the device consists essentially of a semiconductor having a conducting channel with an adjacent equipotential layer or gate electrode and a space charged region in the semiconductor between the channel and the equipotential layer. By varying the potential between the channel and the equipotential layer, the effective channel width can be varied and the channel current which is being carried therein is similarly varied. When the current flows along the channel the potential thus varies along the channel, which in turn results in a potential variation between the channel and the equipotential layer. As a result, the width of the space charged region varies along the channel and with sufficiently high potentials imposed on opposite ends of the channel, the space charged region may extend completely over the channel rendering it insulating or may even cause breakdown if maintained. This limits the usefulness of the device. It is thus the intent of this invention to render these unipolar field effect transistors less susceptible to breakdown or alternatively, susceptible to much higher current gain, as well as reliability of operation when used with signal voltages of substantial amplitudes.

It has been found possible to improve the operating curve of the unipolar transistor so as to handle larger signal voltages as well as to produce much higher power gains, through provision of two parallel current flows in a unipolar transistor so as to maintain the width of the charged layer at a uniform dimension. This is readily accomplished as indicated by providing a potential drop along the gate electrode which is the same or similar to the voltage drop along the channel.

For better understanding of this invention refer to FIG. 1, wherein the combination here illustrated has a semiconductor body **10** with two portions **12**, **14** of opposite types of conductivity. Portion **12**, for example, is indicated as having p-conductivity and portion **14** n-conductivity. Between them there is a p–n junction **15** that is relatively elongated. Intermediate of the ends of the rectangular crystal **10** are two depressions **16** and **17**, the former extending down into the p-region of conductivity and the latter extending into the n-region of conductivity. These grooved areas extend fully across the face of the crystal and are readily produced by magnetostrictive cutting followed by a jet electrochemical etch, both techniques of which are well-known to the art. The thickness of the web formed in the crystal between the points of maximum depth of depressions **16** and **17** is preferably very thin, not over 20 mils thick, and preferably much thinner, in the order of 2 mils thickness. Of course, it is to be realized that this lower limit of distance between the two depressions is dictated by the structural strength requirements which the device must exhibit. However, for optimum operational characteristics the thin region separation is desirable although the crystal can readily be supported by outside insulators, such as plastic holders, etc.

At opposite ends of each portion **12**, **14** are positioned electrodes represented at **18**, **20**, **22**, **24**. A bias supply **25** is connected between a correspondingly located pair of electrodes **18**, **22**, on the respective semiconductor portions, to bias the portions in the direction that blocks the passage of current from one body to the other. In the construction of FIG. 1 the bias supply also impresses varying signals "E" between the same electrodes **18**, **22**.

Electrodes **18**, **20** are shown as connected to an output circuit **26** including a source of potential **28** and an output load **30**. Another output circuit **32** is similarly connected between electrodes **22** and **24** and similarly polarized. For purposes of discussion the n-conductivity having electrodes **22** and **24** is designated the "channel" while the p-region with its electrodes **18** and **20** is designated the "gate."

The entire combination of FIG. 1 makes a so-called unipolar transistor amplifier in which the junction **15** provides a space charge effect that is substantially uniform along its length. For the greatest uniformity the semiconductor portions **12**, **14** should have corresponding electrical resistivities, e.g. of the order of 5 ohm-centimeters, and the output circuits should be arranged to apply corresponding potentials so that there are corresponding potential gradations along the effective length of the junction in both the channel and gate portions. The resistivities are controlled by the concentration of doping ingredients added to the respective semiconductor bodies either by diffusion into the solid body, surface melting or by alloying with a liquefied mass from which the bodies are formed.

A feature of the construction of FIG. 1 is that two different amplified output signals are provided so that one can be used independently of the other as a monitor, for example. In addition, where maximum power output is desired, both output signals can be combined as by transformer coupling. This is made possible by the use of the two depressions **16** and **17** so that the dimension of the space charge region could materially effect the current flow in the channel. Herein, in FIG. 1, for one part of the circuit including load **30** the n-region is the channel and the p-region the gate, and for the other part of the circuit including load **34**, vice versa.

FIG. 2 shows a modified construction of the unipolar transistor type in which one region of conductivity is sandwiched between regions of opposite conductivity. The three regions are illustrated as **31**, **32**, **33**, being produced by techniques well-known in the art. Blocking bias, as well as incoming signals, are supplied by source **36** between the intermediate body **32** on the one hand, and the outer two which can be connected together. Electrodes **38**, **40**, **42**, **44**, **46** and **48** are provided on the individual bodies as in the construction of FIG. 1.

The junction construction of FIG. 2 also has two output circuits **52**, **56**. One of these is connected to intermediate body **32** as in the construction of FIG. 1. The second output circuit **56** is connected to both outer bodies **31**, **33** in parallel. As a result of this construction, signals in the sandwiched body are subjected to what corresponds to two space charge effects, one at each junction. The voltage amplification of this body will therefore be larger than that of the others. Moreover, signal currents in the outer bodies can be added together by the parallel output connection.

With the construction of FIG. 2 the amplified output is taken from load **54** while load **57** serves merely to maintain the space charge region relatively constant along the junction. For taking a useful output from both loads **54** and **57** depressions similar to those of FIG. 1 must be imposed in the n-regions **31** and **33** completely across the opposing faces of the crystal.

FIGS. 3 and 4 are cross-sectional representations of known prior art devices of the unipolar field effect type. In FIG. 3 the n-region designated as **61** has two electrodes **66**, **68** between which an output circuit can be connected. Bias, as well as incoming signals, are supplied between electrode **64** and one of the electrodes **66**, **68** using the p-region to produce the gate and the n-region as the channel. In this construction, as well as the construction shown in FIGS. 1 and 2, all of the electrodes are of a non-rectifying nature.

In FIG. 4, however, an area metal contact which extends fully across the width of the crystal is utilized to produce a space charged region which can thus serve as the modulating means for the current flow in the channel. A semiconductor body **70** designated for the purposes of this discussion as having a conductivity of the p-type has spaced output electrodes **72** and **74** of the non-rectifying kind and an intermediate electrode **76** of the rectifying metal type. Thus a space charge effect similar to that described above appears to be provided by the metal electrode **76** when it is electrically biased in the current blocking direction. The bias and the incoming signals are impressed between the metal electrodes **76** and one of the other electrodes. Amplified output signals can be taken thus from between electrodes **72** and **74**. The construction of FIG. 3 is susceptible to breakdown at pinch-off because here, as well as in the Shockley discussion, the space charged region is non-uniform with the junction area. Breakdown additionally may occur rendering the device conducting so that the FIG. 4 construction is limited both in current level, as well as amplification characteristics.

In FIG. 5 is shown an embodiment of the invention constituting an improvement of the unipolar transistor construction shown in FIG. 3. This construction somewhat similar to that of FIG. 3 has a first semiconductive region **81** and a second semiconductive region **82**, the regions having opposite types of conductivity so that a junction exists between them. Output electrodes are illustrated in the form of a central non-rectifying electrode **86** engaging body **81**, and a circular non-rectifying electrode **88** surrounding electrode **86**. Between the two electrodes **86**, **88** is produced an annular depression **85** extending into body **81** in order to increase the amplification effect of the device. The depth of the depression should be such as to approach the junction region, e.g. less than 5 mils therefrom. The use of a rotating etch jet as described in the above-identified patent application, Serial No. 460,835 (abandoned), makes a very convenient technique for the annular cutting operation. A suitable biasing electrode of the non-rectifying type can be provided as indicated, for example, at **84**. Using this technique allows close control of the distance between the junction and bottom of cut.

Of course, it is to be understood that where even higher amplification is desired or where it is desired to increase the useful current ranges of the device, thus requiring complete avoidance of the breakdown in the pinch-off region resulting from the non-uniformity of the space charged region, the construction of FIG. 5 is modified to conform to the concept of FIG. 1. This is readily accomplished by imposing a second annular groove on the opposite surface of the crystal of FIG. 5, namely that surface whereon electrode **84** is shown to be imposed.

Instead of applying the bias to the same electrodes by which the input signals are impressed, other electrodes can be used. In the construction of FIG. 1, for example, bias can be provided between electrodes **18** and **22**, whereas the input signals can be applied between electrodes **20** and **24**. A similar arrangement can be used in the construction of FIG. 2. Furthermore, the bias need not be applied between correspondingly located electrodes, and can be impressed between electrodes **18** and **24**, for example. The incoming signals can also be applied in this manner.

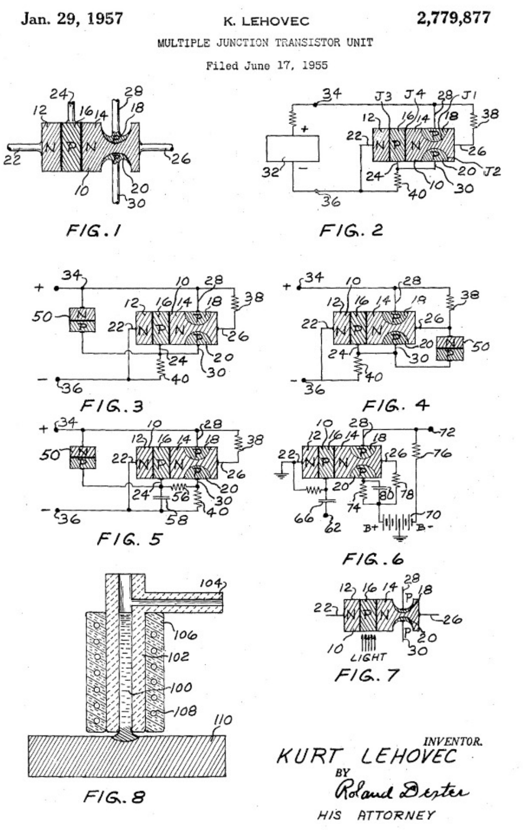
FIG. 6 shows a further form of unipolar transistor construction most useful as a photosensitive device in which the bulk of the crystal **91** is of one conductivity, e.g. n-type, however a diffused junction exists at the region of the depression. In the depression there is an electrode **93**, and at opposite edges of the crystal are non-rectifying electrodes **97**, **98**. The electrode **93** and one of the other non-rectifying electrodes **97** are connected to a high impedance bias source shown as a resistive impedance **96** and a voltage source or battery **95**. When the body **91** of such material is exposed to incident light, current flows across the web between electrode **93** adjacent the irradiation site and the crystal **91**. This current flow reduces the bias imposed by the battery **95** through resistor **96**. Thus the space charge in body **91** adjacent to electrode **93** is reduced allowing greater flow of current in the channel between non-rectifying electrodes **97**, **98**.

The voltage source **95** biases the electrode **97** in the current-blocking direction. With the impedance **96** relatively low as compared to the blocking impedance of the un-illuminated junction, the potential of source **95** is essentially entirely impressed across this junction **94**. When irradiation takes place, the impedance of the junction is sharply diminished so that the potential across the junction **94** is greatly lowered. The lowering of the potential across the blocking junction causes a corresponding amplified change in the current passed between output electrodes **97**, **98** as a result of the decrease of the space charge region. The photoelectric output of the construction of FIG. 6 will accordingly be much higher than that conventionally obtained from present devices, and has a sensitivity to radiation which is remarkable.

Although it is to be fully understood that the following specific examples are representative of the best constructions known to us, they should not in any way limit the scope of the instant invention. Reference should now be made to the drawing of FIG. 1 wherein in its preparation one would take a rectangular slab of p-n junction crystal produced by surface melting techniques or other techniques known to the art, and properly dimension the crystal as follows: The crystal could be a cube of 100 mils in each dimension with the junction region substantially in the center of the plane of the cube. Such a crystal would be of germanium and have for the p-impurity indium and for the n-impurity antimony, with each region of conductivity having a resistivity in the order of 5 ohm-centimeters. As indicated above, such a crystal could be produced by any of the known techniques including the surface melting technique fully disclosed in the copending application of Lehovec et al., Serial No. 364,138, filed June 25, 1953 (abandoned). The depressions **16**, **17** should be then imposed across the opposing faces of the crystal first by magnetostrictive cutting with an appropriate tool, which technique is fully disclosed in United States Patent No. 2,580,716. The width of this cut would be approximately 15 mils and extend with vertical sides down to the region adjacent to the junction. After the magnetostrictive cutting has produced a depression of

Figure 6.113: Kurt Lehovec created integrated circuits (based on wartime work with Bernhard Gudden?).

Kurt Lehovec created integrated circuits (based on wartime work with Bernhard Gudden?)



Jan. 29, 1957 K. LEHOVEC 2,779,877

MULTIPLE JUNCTION TRANSISTOR UNIT

Filed June 17, 1955

INVENTOR.
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BY Roland Dexter
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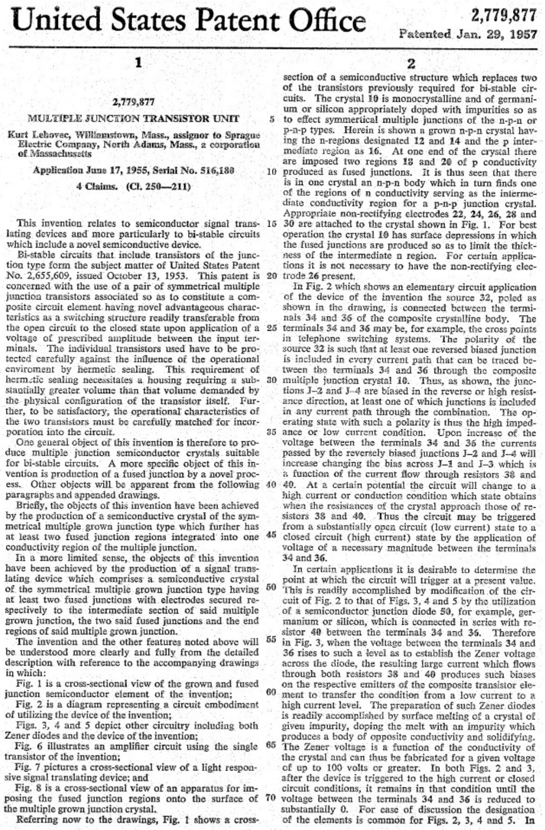

United States Patent Office

2,779,877
Patented Jan. 29, 1957

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2,779,877

MULTIPLE JUNCTION TRANSISTOR UNIT

Kurt Lehovec, Williamstown, Mass., assignor to Sprague Electric Company, North Adams, Mass., a corporation of Massachusetts

Application June 17, 1955, Serial No. 516,180

4 Claims. (Cl. 250—211)

This invention relates to semiconductor signal translating devices and more particularly to bi-stable circuits which include a novel semiconductive device.

Bi-stable circuits that include transistors of the junction type form the subject matter of United States Patent No. 2,655,609, issued October 13, 1953. This patent is concerned with the use of a pair of symmetrical multiple junction transistors associated so as to constitute a composite circuit element having novel advantageous characteristics as a switching structure readily transferable from the open circuit to the closed state upon application of a voltage of prescribed amplitude between the input terminals. The individual transistors used have to be protected carefully against the influence of the operational enviroment by hermetic sealing. This requirement of hermetic sealing necessitates a housing requiring a substantially greater volume than that volume demanded by the physical configuration of the transistor itself. Further, to be satisfactory, the operational characteristics of the two transistors must be carefully matched for incorporation into the circuit.

One general object of this invention is therefore to produce multiple junction semiconductor crystals suitable for bi-stable circuits. A more specific object of this invention is production of a fused junction by a novel process. Other objects will be apparent from the following paragraphs and appended drawings.

Briefly, the objects of this invention have been achieved by the production of a semiconductive crystal of the symmetrical multiple grown junction type which further has at least two fused junction regions integrated into one conductivity region of the multiple junction.

In a more limited sense, the objects of this invention have been achieved by the production of a signal translating device which comprises a semiconductive crystal of the symmetrical multiple grown junction type having at least two fused junctions with electrodes secured respectively to the intermediate section of said multiple grown junction, the two said fused junctions and the end regions of said multiple grown junction.

The invention and the other features noted above will be understood more clearly and fully from the detailed description with reference to the accompanying drawings in which:

Fig. 1 is a cross-sectional view of the grown and fused junction semiconductor element of the invention;

Fig. 2 is a diagram representing a circuit embodiment of utilizing the device of the invention;

Figs. 3, 4 and 5 depict other circuitry including both Zener diodes and the device of the invention;

Fig. 6 illustrates an amplifier circuit using the single transistor of the invention;

Fig. 7 pictures a cross-sectional view of a light responsive signal translating device; and

Fig. 8 is a cross-sectional view of an apparatus for imposing the fused junction regions onto the surface of the multiple grown junction crystal.

Referring now to the drawings, Fig. 1 shows a cross-

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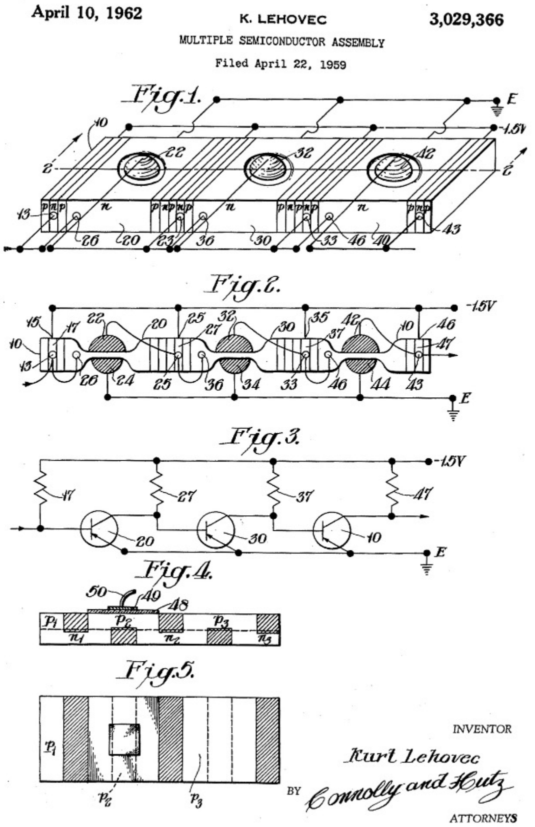
section of a semiconductive structure which replaces two of the transistors previously required for bi-stable circuits. The crystal 10 is monocrystalline and of germanium or silicon appropriately doped with impurities so as to effect symmertical multiple junctions of the n-p-n or p-n-p types. Herein is shown a grown n-p-n crystal having the n-regions designated 12 and 14 and the p intermediate region as 16. At one end of the crystal there are imposed two regions 18 and 20 of p conductivity produced as fused junctions. It is thus seen that there is in one crystal an n-p-n body which in turn finds one of the regions of n conductivity serving as the intermediate conductivity region for a p-n-p junction crystal. Appropriate non-rectifying electrodes 22, 24, 26, 28 and 30 are attached to the crystal shown in Fig. 1. For best operation the crystal 10 has surface depressions in which the fused junctions are produced so as to limit the thickness of the intermediate n region. For certain applications it is not necessary to have the non-rectifying electrode 26 present.

In Fig. 2 which shows an elementary circuit application of the device of the invention the source 32, poled as shown in the drawing, is connected between the terminals 34 and 36 of the composite crystalline body. The terminals 34 and 36 may be, for example, the cross points in telephone switching systems. The polarity of the source 32 is such that at least one reversed biased junction is included in every current path that can be traced between the terminals 34 and 36 through the composite multiple junction crystal 10. Thus, as shown, the junctions J–2 and J–4 are biased in the reverse or high resistance direction, at least one of which junctions is included in any current path through the combination. The operating state with such a polarity is thus the high impedance or low current condition. Upon increase of the voltage between the terminals 34 and 36 the currents passed by the reversely biased junctions J–2 and J–4 will increase changing the bias across J–1 and J–3 which is a function of the current flow through resistors 38 and 40. At a certain potential the circuit will change to a high current or conduction condition which state obtains when the resistances of the crystal approach those of resistors 38 and 40. Thus the circuit may be triggered from a substantially open circuit (low current) state to a closed circuit (high current) state by the application of voltage of a necessary magnitude between the terminals 34 and 36.

In certain applications it is desirable to determine the point at which the circuit will trigger at a present value. This is readily accomplished by modification of the circuit of Fig. 2 to that of Figs. 3, 4 and 5 by the utilization of a semiconductor junction diode 50, for example, germanium or silicon, which is connected in series with resistor 40 between the terminals 34 and 36. Therefore in Fig. 3, when the voltage between the terminals 34 and 36 rises to such a level as to establish the Zener voltage across the diode, the resulting large current which flows through both resistors 38 and 40 produces such biases on the respective emitters of the composite transistor element to transfer the condition from a low current to a high current level. The preparation of such Zener diodes is readily accomplished by surface melting of a crystal of given impurity, doping the melt with an impurity which produces a body of opposite conductivity and solidifying. The Zener voltage is a function of the conductivity of the crystal and can thus be fabricated for a given voltage of up to 100 volts or greater. In both Figs. 2 and 3, after the device is triggered to the high current or closed circuit conditions, it remains in that condition until the voltage between the terminals 34 and 36 is reduced to substantially 0. For ease of discussion the designation of the elements is common for Figs. 2, 3, 4 and 5. In



April 10, 1962 K. LEHOVEC 3,029,366

MULTIPLE SEMICONDUCTOR ASSEMBLY

Filed April 22, 1959

INVENTOR
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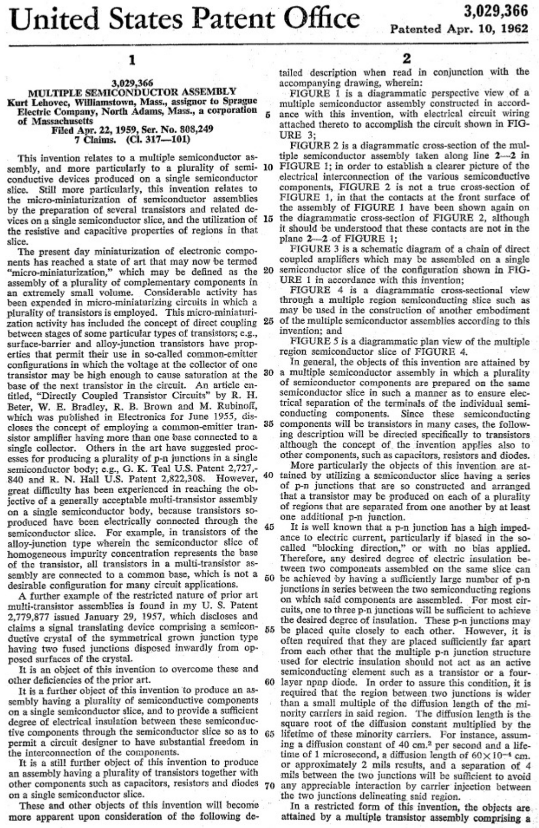
BY Connolly and Hutz
ATTORNEYS



United States Patent Office

3,029,366
Patented Apr. 10, 1962

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3,029,366
MULTIPLE SEMICONDUCTOR ASSEMBLY
Kurt Lehovec, Williamstown, Mass., assignor to Sprague Electric Company, North Adams, Mass., a corporation of Massachusetts
Filed Apr. 22, 1959, Ser. No. 808,249
7 Claims. (Cl. 317—101)

This invention relates to a multiple semiconductor assembly, and more particularly to a plurality of semiconductive devices produced on a single semiconductor slice. Still more particularly, this invention relates to the micro-miniaturization of semiconductor assemblies by the preparation of several transistors and related devices on a single semiconductor slice, and the utilization of the resistive and capacitive properties of regions in that slice.

The present day miniaturization of electronic components has reached a state of art that may now be termed "micro-miniaturization," which may be defined as the assembly of a plurality of complementary components in an extremely small volume. Considerable activity has been expended in micro-miniaturizing circuits in which a plurality of transistors is employed. This micro-miniaturization activity has included the concept of direct coupling between stages of some particular types of transistors; e.g., surface-barrier and alloy-junction transistors have properties that permit their use in so-called common-emitter configurations in which the voltage at the collector of one transistor may be high enough to cause saturation at the base of the next transistor in the circuit. An article entitled, "Directly Coupled Transistor Circuits" by R. H. Beter, W. E. Bradley, R. B. Brown and M. Rubinoff, which was published in Electronics for June 1955, discloses the concept of employing a common-emitter transistor amplifier having more than one base connected to a single collector. Others in the art have suggested processes for producing a plurality of p-n junctions in a single semiconductor body; e.g., G. K. Teal U.S. Patent 2,727,840 and R. N. Hall U.S. Patent 2,822,308. However, great difficulty has been experienced in reaching the objective of a generally acceptable multi-transistor assembly on a single semiconductor body, because transistors so-produced have been electrically connected through the semiconductor slice. For example, in transistors of the alloy-junction type wherein the semiconductor slice of homogeneous impurity concentration represents the base of the transistor, all transistors in a multi-transistor assembly are connected to a common base, which is not a desirable configuration for many circuit applications.

A further example of the restricted nature of prior art multi-transistor assemblies is found in my U. S. Patent 2,779,877 issued January 29, 1957, which discloses and claims a signal translating device comprising a semiconductive crystal of the symmetrical grown junction type having two fused junctions disposed inwardly from opposed surfaces of the crystal.

It is an object of this invention to overcome these and other deficiencies of the prior art.

It is a further object of this invention to produce an assembly having a plurality of semiconductive components on a single semiconductor slice, and to provide a sufficient degree of electrical insulation between these semiconductive components through the semiconductor slice so as to permit a circuit designer to have substantial freedom in the interconnection of the components.

It is a still further object of this invention to produce an assembly having a plurality of transistors together with other components such as capacitors, resistors and diodes on a single semiconductor slice.

These and other objects of this invention will become more apparent upon consideration of the following de-

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tailed description when read in conjunction with the accompanying drawing, wherein:

FIGURE 1 is a diagrammatic perspective view of a multiple semiconductor assembly constructed in accordance with this invention, with electrical circuit wiring attached thereto to accomplish the circuit shown in FIGURE 3;

FIGURE 2 is a diagrammatic cross-section of the multiple semiconductor assembly taken along line 2—2 in FIGURE 1; in order to establish a clearer picture of the electrical interconnection of the various semiconductive components, FIGURE 2 is not a true cross-section of FIGURE 1, in that the contacts at the front surface of the assembly of FIGURE 1 have been shown again on the diagrammatic cross-section of FIGURE 2, although it should be understood that these contacts are not in the plane 2—2 of FIGURE 1;

FIGURE 3 is a schematic diagram of a chain of direct coupled amplifiers which may be assembled on a single semiconductor slice of the configuration shown in FIGURE 1 in accordance with this invention;

FIGURE 4 is a diagrammatic cross-sectional view through a multiple region semiconducting slice such as may be used in the construction of another embodiment of the multiple semiconductor assemblies according to this invention; and

FIGURE 5 is a diagrammatic plan view of the multiple region semiconductor slice of FIGURE 4.

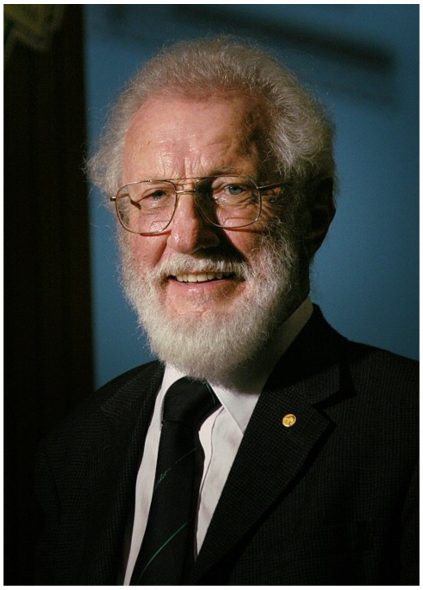
In general, the objects of this invention are attained by a multiple semiconductor assembly in which a plurality of semiconductor components are prepared on the same semiconductor slice in such a manner as to ensure electrical separation of the terminals of the individual semiconducting components. Since these semiconducting components will be transistors in many cases, the following description will be directed specifically to transistors although the concept of the invention applies also to other components, such as capacitors, resistors and diodes.

More particularly the objects of this invention are attained by utilizing a semiconductor slice having a series of p-n junctions that are so constructed and arranged that a transistor may be produced on each of a plurality of regions that are separated from one another by at least one additional p-n junction.

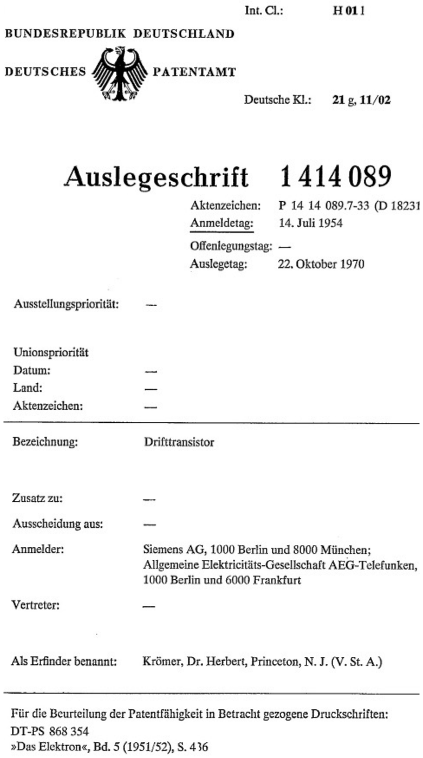
It is well known that a p-n junction has a high impedance to electric current, particularly if biased in the so-called "blocking direction," or with no bias applied. Therefore, any desired degree of electric insulation between two components assembled on the same slice can be achieved by having a sufficiently large number of p-n junctions in series between the two semiconducting regions on which said components are assembled. For most circuits, one to three p-n junctions will be sufficient to achieve the desired degree of insulation. These p-n junctions may be placed quite closely to each other. However, it is often required that they are placed sufficiently far apart from each other that the multiple p-n junction structure used for electric insulation should not act as an active semiconducting element such as a transistor or a four-layer npnp diode. In order to assure this condition, it is required that the region between two junctions is wider than a small multiple of the diffusion length of the minority carriers in said region. The diffusion length is the square root of the diffusion constant multiplied by the lifetime of these minority carriers. For instance, assuming a diffusion constant of 40 cm.^{2} per second and a lifetime of 1 microsecond, a diffusion length of 60×10^{-4} cm. or approximately 2 mils results, and a separation of 4 mils between the two junctions will be sufficient to avoid any appreciable interaction by carrier injection between the two junctions delineating said region.

In a restricted form of this invention, the objects are attained by a multiple transistor assembly comprising a

Figure 6.114: Kurt Lehovec created integrated circuits (based on wartime work with Bernhard Gudden?).



Herbert Kroemer (1928–) invented drift transistors (1953 or earlier)



Int. Cl.: **H 01** l

BUNDESREPUBLIK DEUTSCHLAND

DEUTSCHES PATENTAMT

Deutsche Kl.: **21** g, **11/02**

Auslegeschrift 1 414 089

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Anmeldetag: 14. Juli 1954
Offenlegungstag: —
Auslegetag: 22. Oktober 1970

Ausstellungspriorität: —

Unionspriorität
Datum: —
Land: —
Aktenzeichen: —

Bezeichnung: Drifttransistor

Zusatz zu: —

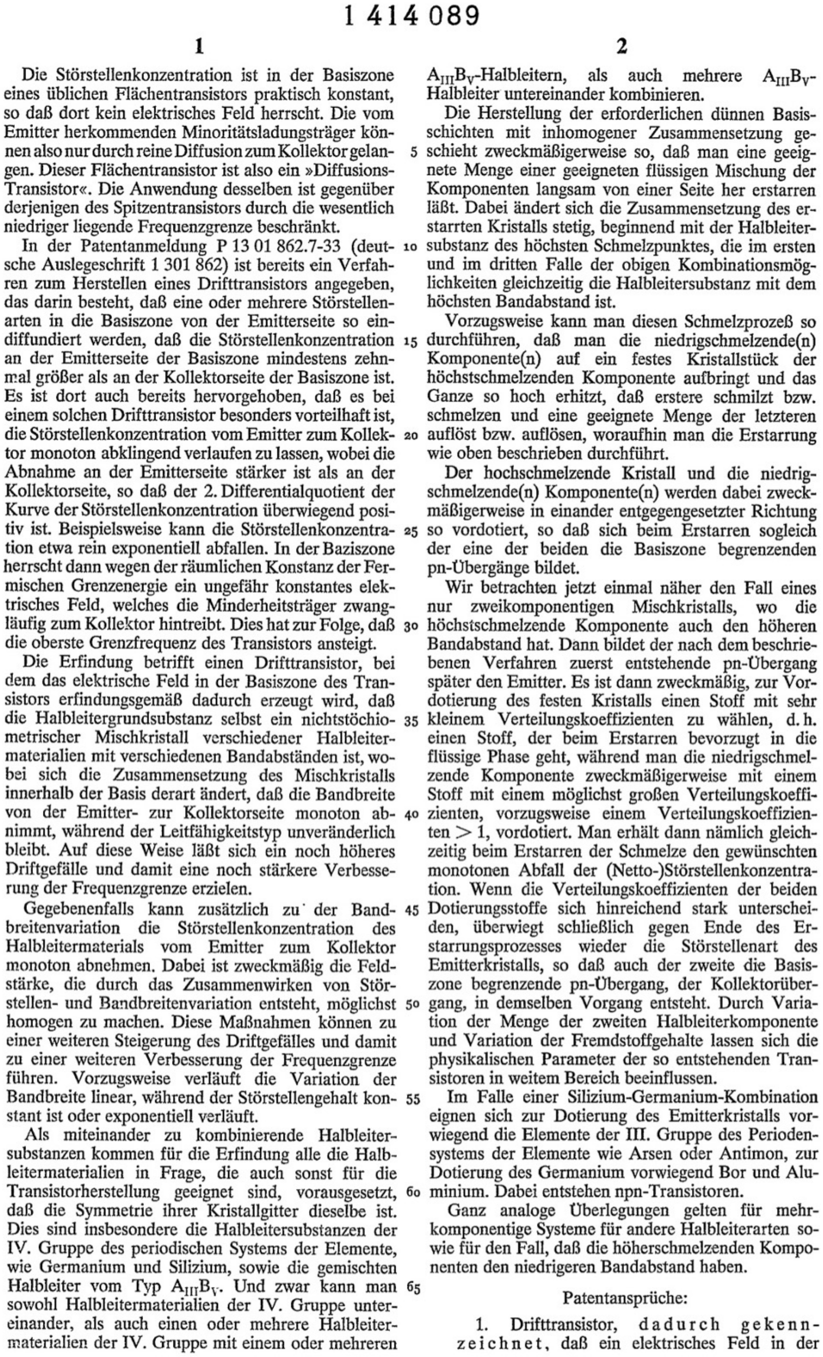
Ausscheidung aus: —

Anmelder: Siemens AG, 1000 Berlin und 8000 München; Allgemeine Elektricitäts-Gesellschaft AEG-Telefunken, 1000 Berlin und 6000 Frankfurt

Vertreter: —

Als Erfinder benannt: Krömer, Dr. Herbert, Princeton, N. J. (V. St. A.)

Für die Beurteilung der Patentfähigkeit in Betracht gezogene Druckschriften:
DT-PS 868 354
»Das Elektron«, Bd. 5 (1951/52), S. 436



1 414 089

1

Die Störstellenkonzentration ist in der Basiszone eines üblichen Flächentransistors praktisch konstant, so daß dort kein elektrisches Feld herrscht. Die vom Emitter herkommenden Minoritätsladungsträger können also nur durch reine Diffusion zum Kollektor gelangen. Dieser Flächentransistor ist also ein »Diffusions-Transistor«. Die Anwendung desselben ist gegenüber derjenigen des Spitzentransistors durch die wesentlich niedriger liegende Frequenzgrenze beschränkt.

In der Patentanmeldung P 13 01 862.7-33 (deutsche Auslegeschrift 1 301 862) ist bereits ein Verfahren zum Herstellen eines Drifttransistors angegeben, das darin besteht, daß eine oder mehrere Störstellenarten in die Basiszone von der Emitterseite so eindiffundiert werden, daß die Störstellenkonzentration an der Emitterseite der Basiszone mindestens zehnmal größer als an der Kollektorseite der Basiszone ist. Es ist dort auch bereits hervorgehoben, daß es bei einem solchen Drifttransistor besonders vorteilhaft ist, die Störstellenkonzentration vom Emitter zum Kollektor monoton abklingend verlaufen zu lassen, wobei die Abnahme an der Emitterseite stärker ist als an der Kollektorseite, so daß der 2. Differentialquotient der Kurve der Störstellenkonzentration überwiegend positiv ist. Beispielsweise kann die Störstellenkonzentration etwa rein exponentiell abfallen. In der Baziszone herrscht dann wegen der räumlichen Konstanz der Fermischen Grenzenergie ein ungefähr konstantes elektrisches Feld, welches die Minderheitsträger zwangläufig zum Kollektor hintreibt. Dies hat zur Folge, daß die oberste Grenzfrequenz des Transistors ansteigt.

Die Erfindung betrifft einen Drifttransistor, bei dem das elektrische Feld in der Basiszone des Transistors erfindungsgemäß dadurch erzeugt wird, daß die Halbleitergrundsubstanz selbst ein nichtstöchiometrischer Mischkristall verschiedener Halbleitermaterialien mit verschiedenen Bandabständen ist, wobei sich die Zusammensetzung des Mischkristalls innerhalb der Basis derart ändert, daß die Bandbreite von der Emitter- zur Kollektorseite monoton abnimmt, während der Leitfähigkeitstyp unveränderlich bleibt. Auf diese Weise läßt sich ein noch höheres Driftgefälle und damit eine noch stärkere Verbesserung der Frequenzgrenze erzielen.

Gegebenenfalls kann zusätzlich zu der Bandbreitenvariation die Störstellenkonzentration des Halbleitermaterials vom Emitter zum Kollektor monoton abnehmen. Dabei ist zweckmäßig die Feldstärke, die durch das Zusammenwirken von Störstellen- und Bandbreitenvariation entsteht, möglichst homogen zu machen. Diese Maßnahmen können zu einer weiteren Steigerung des Driftgefälles und damit zu einer weiteren Verbesserung der Frequenzgrenze führen. Vorzugsweise verläuft die Variation der Bandbreite linear, während der Störstellengehalt konstant ist oder exponentiell verläuft.

Als miteinander zu kombinierende Halbleitersubstanzen kommen für die Erfindung alle die Halbleitermaterialien in Frage, die auch sonst für die Transistorherstellung geeignet sind, vorausgesetzt, daß die Symmetrie ihrer Kristallgitter dieselbe ist. Dies sind insbesondere die Halbleitersubstanzen der IV. Gruppe des periodischen Systems der Elemente, wie Germanium und Silizium, sowie die gemischten Halbleiter vom Typ $A_{III}B_V$. Und zwar kann man sowohl Halbleitermaterialien der IV. Gruppe untereinander, als auch einen oder mehrere Halbleitermaterialien der IV. Gruppe mit einem oder mehreren $A_{III}B_V$-Halbleitern, als auch mehrere $A_{III}B_V$-Halbleiter untereinander kombinieren.

2

Die Herstellung der erforderlichen dünnen Basisschichten mit inhomogener Zusammensetzung geschieht zweckmäßigerweise so, daß man eine geeignete Menge einer geeigneten flüssigen Mischung der Komponenten langsam von einer Seite her erstarren läßt. Dabei ändert sich die Zusammensetzung des erstarrten Kristalls stetig, beginnend mit der Halbleitersubstanz des höchsten Schmelzpunktes, die im ersten und im dritten Falle der obigen Kombinationsmöglichkeiten gleichzeitig die Halbleitersubstanz mit dem höchsten Bandabstand ist.

Vorzugsweise kann man diesen Schmelzprozeß so durchführen, daß man die niedrigschmelzende(n) Komponente(n) auf ein festes Kristallstück der höchstschmelzenden Komponente aufbringt und das Ganze so hoch erhitzt, daß erstere schmilzt bzw. schmelzen und eine geeignete Menge der letzteren auflöst bzw. auflösen, woraufhin man die Erstarrung wie oben beschrieben durchführt.

Der hochschmelzende Kristall und die niedrigschmelzende(n) Komponente(n) werden dabei zweckmäßigerweise in einander entgegengesetzter Richtung so vordotiert, so daß sich beim Erstarren sogleich der eine der beiden die Basiszone begrenzenden pn-Übergänge bildet.

Wir betrachten jetzt einmal näher den Fall eines nur zweikomponentigen Mischkristalls, wo die höchstschmelzende Komponente auch den höheren Bandabstand hat. Dann bildet der nach dem beschriebenen Verfahren zuerst entstehende pn-Übergang später den Emitter. Es ist dann zweckmäßig, zur Vordotierung des festen Kristalls einen Stoff mit sehr kleinem Verteilungskoeffizienten zu wählen, d. h. einen Stoff, der beim Erstarren bevorzugt in die flüssige Phase geht, während man die niedrigschmelzende Komponente zweckmäßigerweise mit einem Stoff mit einem möglichst großen Verteilungskoeffizienten, vorzugsweise einem Verteilungskoeffizienten > 1, vordotiert. Man erhält dann nämlich gleichzeitig beim Erstarren der Schmelze den gewünschten monotonen Abfall der (Netto-)Störstellenkonzentration. Wenn die Verteilungskoeffizienten der beiden Dotierungsstoffe sich hinreichend stark unterscheiden, überwiegt schließlich gegen Ende des Erstarrungsprozesses wieder die Störstellenart des Emitterkristalls, so daß auch der zweite die Basiszone begrenzende pn-Übergang, der Kollektorübergang, in demselben Vorgang entsteht. Durch Variation der Menge der zweiten Halbleiterkomponente und Variation der Fremdstoffgehalte lassen sich die physikalischen Parameter der so entstehenden Transistoren in weitem Bereich beeinflussen.

Im Falle einer Silizium-Germanium-Kombination eignen sich zur Dotierung des Emitterkristalls vorwiegend die Elemente der III. Gruppe des Periodensystems der Elemente wie Arsen oder Antimon, zur Dotierung des Germanium vorwiegend Bor und Aluminium. Dabei entstehen npn-Transistoren.

Ganz analoge Überlegungen gelten für mehrkomponentige Systeme für andere Halbleiterarten sowie für den Fall, daß die höherschmelzenden Komponenten den niedrigeren Bandabstand haben.

Patentansprüche:

1. Drifttransistor, dadurch gekennzeichnet, daß ein elektrisches Feld in der

Figure 6.115: Herbert Kroemer invented the drift transistor in 1953 or earlier.

Herbert Kroemer invented III-V semiconductor heterostructures (1966 or earlier)

Sept. 16, 1969 H. KROEMER 3,467,896
HETEROJUNCTIONS AND DOMAIN CONTROL IN BULK
NEGATIVE CONDUCTIVITY SEMICONDUCTORS
Filed March 28, 1966 3 Sheets-Sheet 1

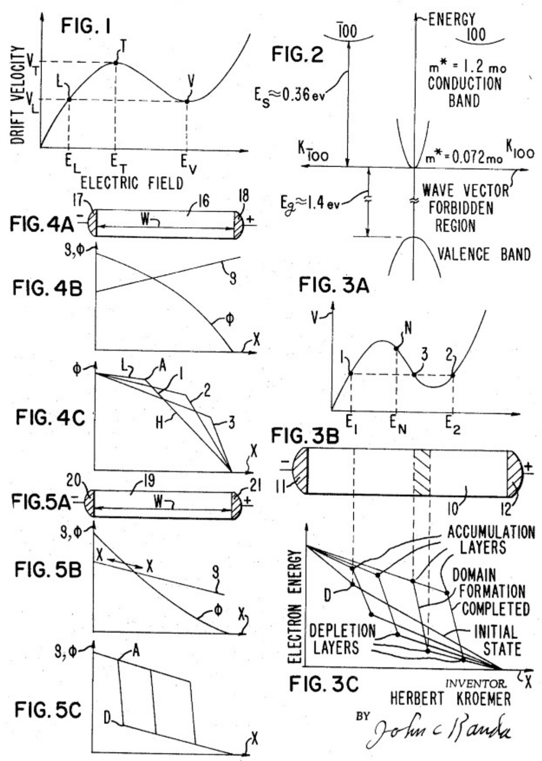


FIG. 1
DRIFT VELOCITY
ELECTRIC FIELD
FIG. 2
ENERGY
$E_S \approx 0.36$ ev
$m^* = 1.2\ m_o$
CONDUCTION BAND
$m^* = 0.072\ m_o$
$E_g \approx 1.4$ ev
WAVE VECTOR
FORBIDDEN REGION
VALENCE BAND
FIG. 4A
FIG. 4B
FIG. 4C
FIG. 3A
FIG. 3B
FIG. 5A
FIG. 5B
FIG. 5C
ACCUMULATION LAYERS
DOMAIN FORMATION COMPLETED
INITIAL STATE
DEPLETION LAYERS
ELECTRON ENERGY
FIG. 3C
INVENTOR.
HERBERT KROEMER
BY John C Banda

Sept. 16, 1969 H. KROEMER 3,467,896
HETEROJUNCTIONS AND DOMAIN CONTROL IN BULK
NEGATIVE CONDUCTIVITY SEMICONDUCTORS
Filed March 28, 1966 3 Sheets-Sheet 2

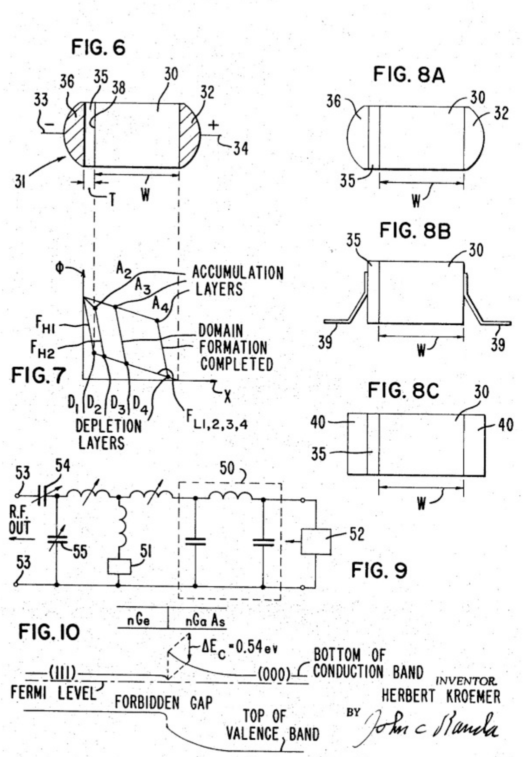


FIG. 6
FIG. 8A
FIG. 8B
FIG. 8C
ACCUMULATION LAYERS
DOMAIN FORMATION COMPLETED
FIG. 7
DEPLETION LAYERS
R.F. OUT
FIG. 9
FIG. 10
nGe
nGaAs
$\Delta E_C = 0.54$ ev
BOTTOM OF CONDUCTION BAND
FERMI LEVEL
FORBIDDEN GAP
TOP OF VALENCE BAND
INVENTOR.
HERBERT KROEMER
BY John C Banda

Sept. 16, 1969 H. KROEMER 3,467,896
HETEROJUNCTIONS AND DOMAIN CONTROL IN BULK
NEGATIVE CONDUCTIVITY SEMICONDUCTORS
Filed March 28, 1966 3 Sheets-Sheet 3

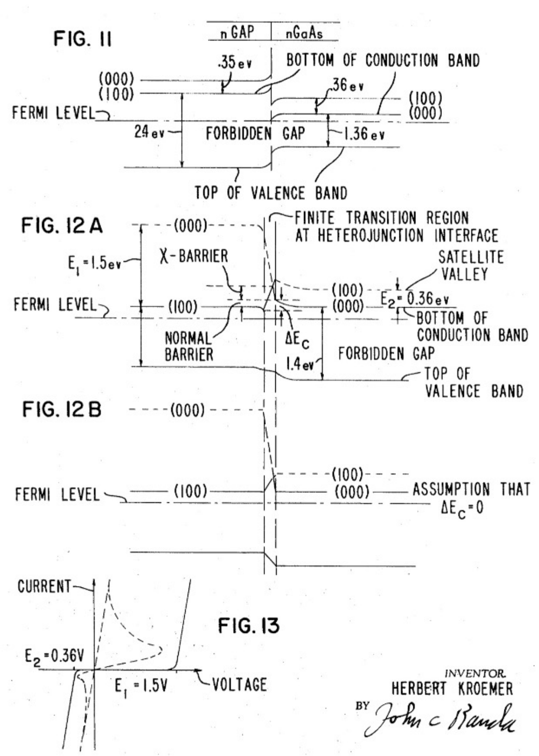
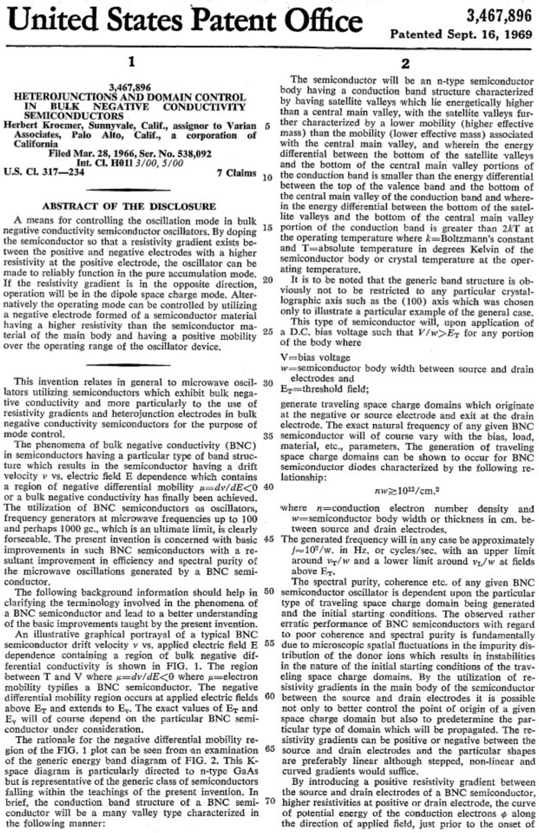


FIG. 11
n GAP
nGaAs
.35 ev
BOTTOM OF CONDUCTION BAND
.36 ev
FERMI LEVEL
2.24 ev
FORBIDDEN GAP
1.36 ev
TOP OF VALENCE BAND
FIG. 12A
FINITE TRANSITION REGION AT HETEROJUNCTION INTERFACE
$E_1 = 1.5$ ev
X-BARRIER
SATELLITE VALLEY
$E_2 = 0.36$ ev
NORMAL BARRIER
ΔE_C
1.4 ev
FORBIDDEN GAP
TOP OF VALENCE BAND
FIG. 12B
ASSUMPTION THAT $\Delta E_C = 0$
CURRENT
FIG. 13
$E_2 = 0.36$V
$E_1 = 1.5$V
VOLTAGE
INVENTOR.
HERBERT KROEMER
BY John C Banda



United States Patent Office 3,467,896
Patented Sept. 16, 1969

1

3,467,896
HETEROJUNCTIONS AND DOMAIN CONTROL IN BULK NEGATIVE CONDUCTIVITY SEMICONDUCTORS
Herbert Kroemer, Sunnyvale, Calif., assignor to Varian Associates, Palo Alto, Calif., a corporation of California
Filed Mar. 28, 1966, Ser. No. 538,092
Int. Cl. H01l *3/00, 5/00*
U.S. Cl. 317—234 7 Claims

ABSTRACT OF THE DISCLOSURE

A means for controlling the oscillation mode in bulk negative conductivity semiconductor oscillators. By doping the semiconductor so that a resistivity gradient exists between the positive and negative electrodes with a higher resistivity at the positive electrode, the oscillator can be made to reliably function in the pure accumulation mode. If the resistivity gradient is in the opposite direction, operation will be in the dipole space charge mode. Alternatively the operating mode can be controlled by utilizing a negative electrode formed of a semiconductor material having a higher resistivity than the semiconductor material of the main body and having a positive mobility over the operating range of the oscillator device.

This invention relates in general to microwave oscillators utilizing semiconductors which exhibit bulk negative conductivity and more particularly to the use of resistivity gradients and heterojunction electrodes in bulk negative conductivity semiconductors for the purpose of mode control.

The phenomena of bulk negative conductivity (BNC) in semiconductors having a particular type of band structure which results in the semiconductor having a drift velocity v vs. electric field E dependence which contains a region of negative differential mobility $\mu = dv/dE < 0$ or a bulk negative conductivity has finally been achieved. The utilization of BNC semiconductors as oscillators, frequency generators at microwave frequencies up to 100 and perhaps 1000 gc., which is an ultimate limit, is clearly forseeable. The present invention is concerned with basic improvements in such BNC semiconductors with a resultant improvement in efficiency and spectral purity of the microwave oscillations generated by a BNC semiconductor.

The following background information should help in clarifying the terminology involved in the phenomena of a BNC semiconductor and lead to a better understanding of the basic improvements taught by the present invention.

An illustrative graphical portrayal of a typical BNC semiconductor drift velocity v vs. applied electric field E dependence containing a region of bulk negative differential conductivity is shown in FIG. 1. The region between T and V where $\mu = dv/dE < 0$ where μ=electron mobility typifies a BNC semiconductor. The negative differential mobility region occurs at applied electric fields above E_T and extends to E_V. The exact values of E_T and E_V will of course depend on the particular BNC semiconductor under consideration.

The rationale for the negative differential mobility region of the FIG. 1 plot can be seen from an examination of the generic energy band diagram of FIG. 2. This K-space diagram is particularly directed to n-type GaAs but is representative of the generic class of semiconductors falling within the teachings of the present invention. In brief, the conduction band structure of a BNC semiconductor will be a many valley type characterized in the following manner:

2

The semiconductor will be an n-type semiconductor body having a conduction band structure characterized by having satellite valleys which lie energetically higher than a central main valley, with the satellite valleys further characterized by a lower mobility (higher effective mass) than the mobility (lower effective mass) associated with the central main valley, and wherein the energy differential between the bottom of the satellite valleys and the bottom of the central main valley portions of the conduction band is smaller than the energy differential between the top of the valence band and the bottom of the central main valley of the conduction band and wherein the energy differential between the bottom of the satellite valleys and the bottom of the central main valley portion of the conduction band is greater than $2kT$ at the operating temperature where k=Boltzmann's constant and T=absolute temperature in degrees Kelvin of the semiconductor body or crystal temperature at the operating temperature.

It is to be noted that the generic band structure is obviously not to be restricted to any particular crystallographic axis such as the (100) axis which was chosen only to illustrate a particular example of the general case.

This type of semiconductor will, upon application of a D.C. bias voltage such that $V/w > E_T$ for any portion of the body where

V=bias voltage
w=semiconductor body width between source and drain electrodes and
E_T=threshold field;

generate traveling space charge domains which originate at the negative or source electrode and exit at the drain electrode. The exact natural frequency of any given BNC semiconductor will of course vary with the bias, load, material, etc., parameters. The generation of traveling space charge domains can be shown to occur for BNC semiconductor diodes characterized by the following relationship:

$$nw \gtrsim 10^{12}/\text{cm.}^2$$

where n=conduction electron number density and w=semiconductor body width or thickness in cm. between source and drain electrodes.

The generated frequency will in any case be approximately $f \approx 10^7/w$. in Hz. or cycles/sec. with an upper limit around v_T/w and a lower limit around v_L/w at fields above E_T.

The spectral purity, coherence etc. of any given BNC semiconductor oscillator is dependent upon the particular type of traveling space charge domain being generated and the initial starting conditions. The observed rather erratic performance of BNC semiconductors with regard to poor coherence and spectral purity is fundamentally due to microscopic spatial fluctuations in the impurity distribution of the donor ions which results in instabilities in the nature of the initial starting conditions of the traveling space charge domains. By the utilization of resistivity gradients in the main body of the semiconductor between the source and drain electrodes it is possible not only to better control the point of origin of a given space charge domain but also to predetermine the particular type of domain which will be propagated. The resistivity gradients can be positive or negative between the source and drain electrodes and the particular shapes are preferably linear although stepped, non-linear and curved gradients would suffice.

By introducing a positive resistivity gradient between the source and drain electrodes of a BNC semiconductor, higher resistivities at positive or drain electrode, the curve of potential energy of the conduction electrons ϕ along the direction of applied field, just prior to the onset of

Figure 6.116: Herbert Kroemer invented III-V semiconductor heterostructures in 1966 or earlier.

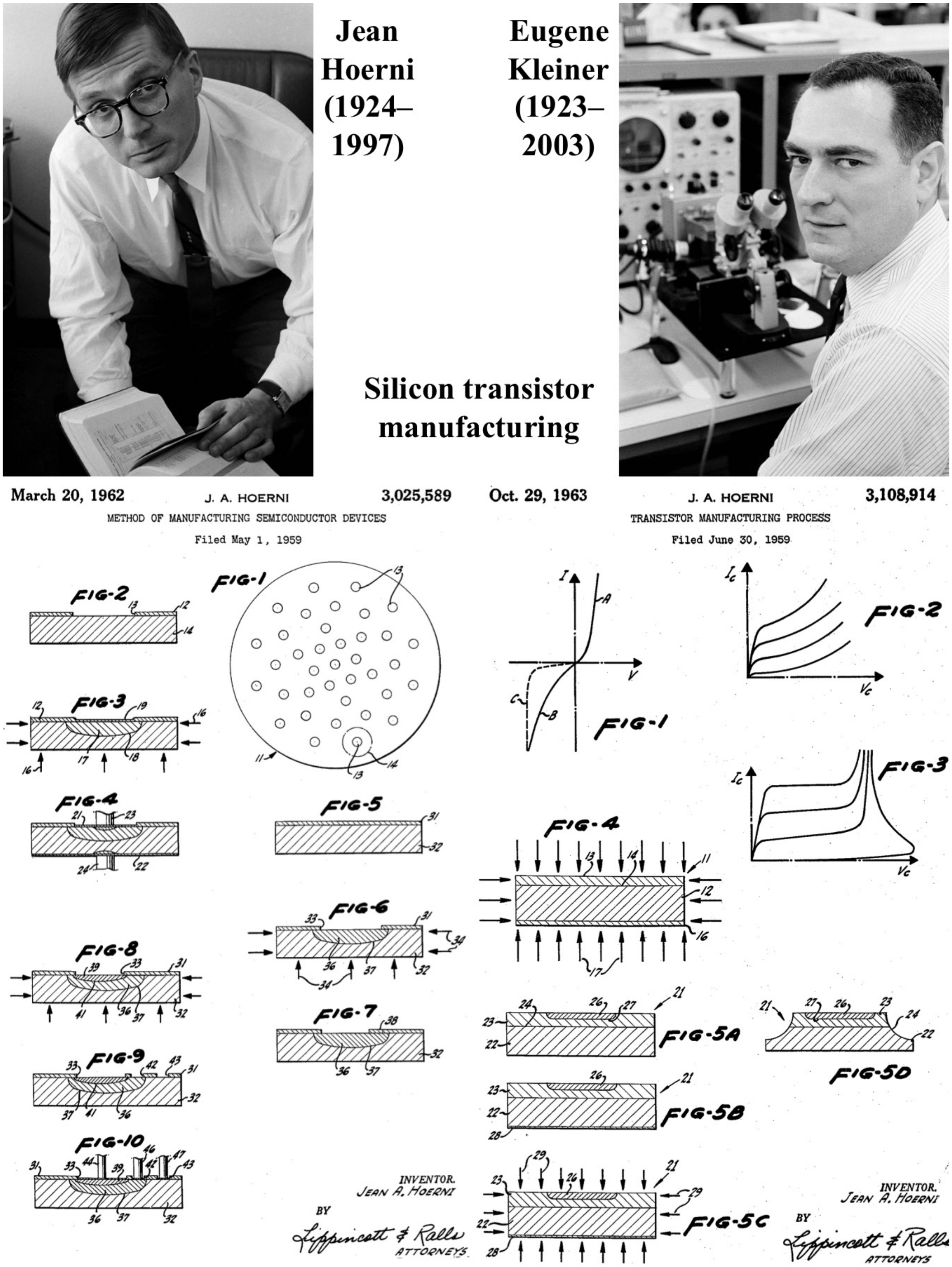

Jean Hoerni (1924–1997)
Eugene Kleiner (1923–2003)
Silicon transistor manufacturing
March 20, 1962
J. A. HOERNI
3,025,589
METHOD OF MANUFACTURING SEMICONDUCTOR DEVICES
Filed May 1, 1959
FIG-1
FIG-2
FIG-3
FIG-4
FIG-5
FIG-6
FIG-7
FIG-8
FIG-9
FIG-10
INVENTOR.
JEAN A. HOERNI
BY
Lippincott & Ralls
ATTORNEYS
Oct. 29, 1963
J. A. HOERNI
3,108,914
TRANSISTOR MANUFACTURING PROCESS
Filed June 30, 1959
I
V
A
B
C
FIG-1
I_c
V_c
FIG-2
FIG-3
FIG-4
FIG-5A
FIG-5B
FIG-5C
FIG-5D
INVENTOR.
JEAN A. HOERNI
BY
Lippincott & Ralls
ATTORNEYS

Figure 6.117: Jean Hoerni and Eugene Kleiner developed methods of manufacturing silicon transistors.

Karl Heinz Zaininger (1929–) Field effect transistor manufacturing

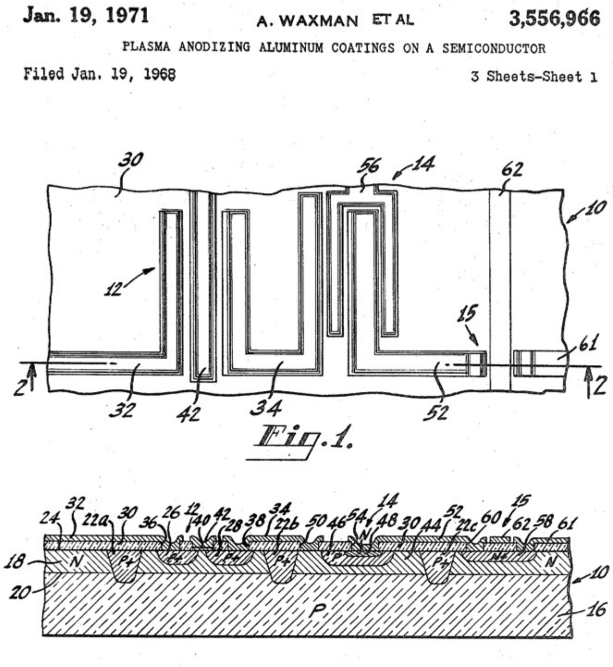
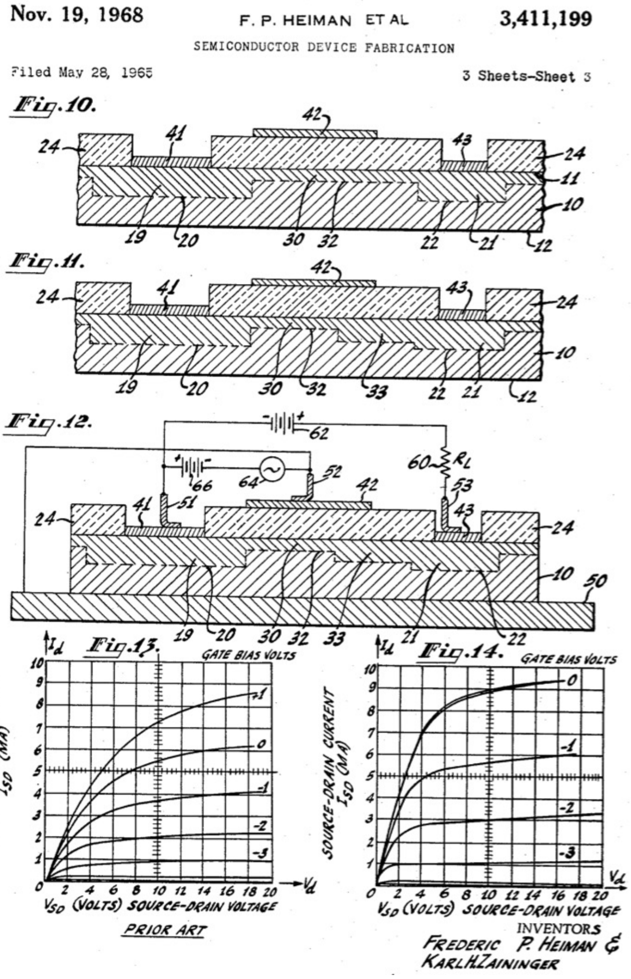

Jan. 19, 1971
A. WAXMAN ET AL
3,556,966
PLASMA ANODIZING ALUMINUM COATINGS ON A SEMICONDUCTOR
Filed Jan. 19, 1968
3 Sheets-Sheet 1
30
56
14
62
10
12
15
61
2
2
32
42
34
52
Fig. 1.
32 24 22a 30 36 26 12 40 42 28 38 34 22b 50 46 54 14 48 30 44 52 22c 60 15 62 58 61
18
N
P+
P+
P+
P+
P
P+
N+
N
10
20
P
16

Fig. 2.


Nov. 19, 1968
F. P. HEIMAN ET AL
3,411,199
SEMICONDUCTOR DEVICE FABRICATION
Filed May 28, 1965
3 Sheets-Sheet 3
Fig. 10.
42
24
41
43
24
11
10
19
20
30
32
22
21
12
Fig. 11.
42
24
41
43
24
10
19
20
30
32
33
22
21
12
Fig. 12.
62
66
64
52
42
60
RL
53
24
41
51
43
24
10
50
19
20
30
32
33
21
22
Id
Fig. 13.
GATE BIAS VOLTS
SOURCE-DRAIN CURRENT ISD (MA)
1
0
-1
-2
-3
0 2 4 6 8 10 12 14 16 18 20
Vd
VSD (VOLTS) SOURCE-DRAIN VOLTAGE
PRIOR ART
Id
Fig. 14.
GATE BIAS VOLTS
SOURCE-DRAIN CURRENT ISD (MA)
0
-1
-2
-3
0 2 4 6 8 10 12 14 16 18 20
Vd
VSD (VOLTS) SOURCE-DRAIN VOLTAGE
INVENTORS
FREDERIC P. HEIMAN &
KARL H. ZAININGER

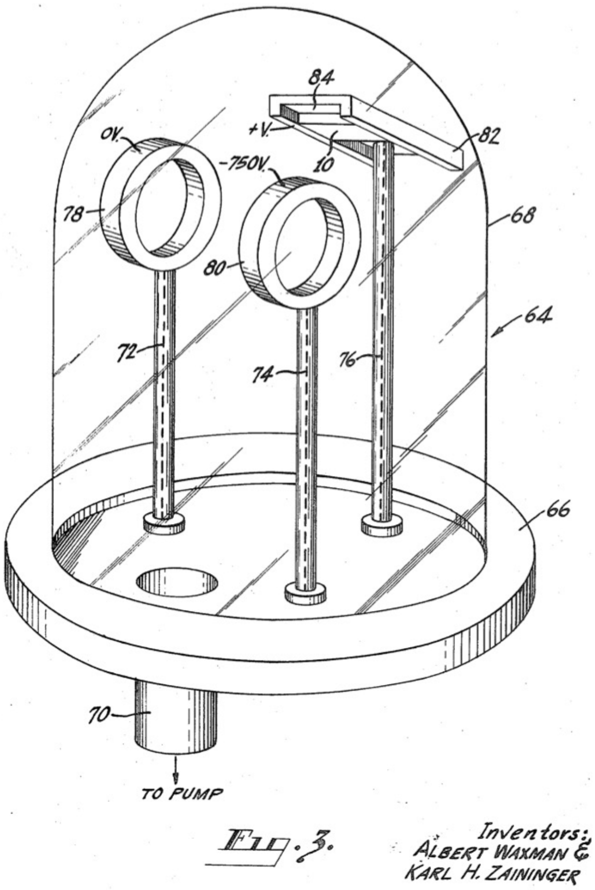
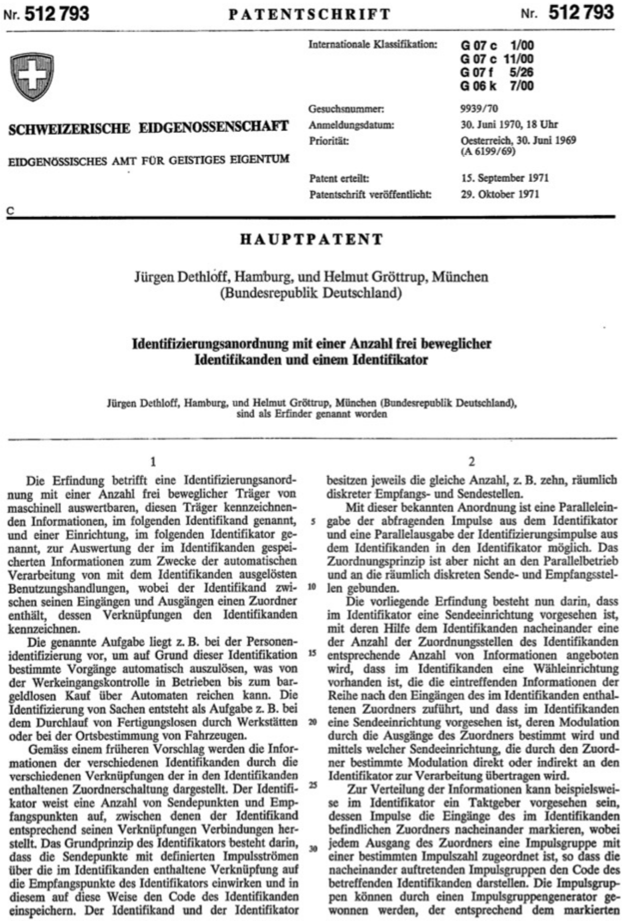

84
+V.
82
0V.
10
-750V.
78
68
80
64
72
74
76
66
70
TO PUMP
Fig. 3.
Inventors:
ALBERT WAXMAN &
KARL H. ZAININGER

Figure 6.118: Karl Heinz Zaininger developed modern methods for fabricating field effect transistors.

Helmut Gröttrup (1916–1981)

Jürgen Dethloff (1924–2002)

Invented smart card, or chip card (1966)



Nr. **512 793** **PATENTSCHRIFT** Nr. **512 793**

SCHWEIZERISCHE EIDGENOSSENSCHAFT

EIDGENÖSSISCHES AMT FÜR GEISTIGES EIGENTUM

Internationale Klassifikation:	G 07 c 1/00 G 07 c 11/00 G 07 f 5/26 G 06 k 7/00
Gesuchsnummer:	9939/70
Anmeldungsdatum:	30. Juni 1970, 18 Uhr
Priorität:	Oesterreich, 30. Juni 1969 (A 6199/69)
Patent erteilt:	15. September 1971
Patentschrift veröffentlicht:	29. Oktober 1971

C

HAUPTPATENT

Jürgen Dethloff, Hamburg, und Helmut Gröttrup, München
(Bundesrepublik Deutschland)

Identifizierungsanordnung mit einer Anzahl frei beweglicher Identifikanden und einem Identifikator

Jürgen Dethloff, Hamburg, und Helmut Gröttrup, München (Bundesrepublik Deutschland), sind als Erfinder genannt worden

1

Die Erfindung betrifft eine Identifizierungsanordnung mit einer Anzahl frei beweglicher Träger von maschinell auswertbaren, diesen Träger kennzeichnenden Informationen, im folgenden Identifikand genannt, und einer Einrichtung, im folgenden Identifikator genannt, zur Auswertung der im Identifikanden gespeicherten Informationen zum Zwecke der automatischen Verarbeitung von mit dem Identifikanden ausgelösten Benutzungshandlungen, wobei der Identifikand zwischen seinen Eingängen und Ausgängen einen Zuordner enthält, dessen Verknüpfungen den Identifikanden kennzeichnen.

Die genannte Aufgabe liegt z. B. bei der Personenidentifizierung vor, um auf Grund dieser Identifikation bestimmte Vorgänge automatisch auszulösen, was von der Werkeingangskontrolle in Betrieben bis zum bargeldlosen Kauf über Automaten reichen kann. Die Identifizierung von Sachen entsteht als Aufgabe z. B. bei dem Durchlauf von Fertigungslosen durch Werkstätten oder bei der Ortsbestimmung von Fahrzeugen.

Gemäss einem früheren Vorschlag werden die Informationen der verschiedenen Identifikanden durch die verschiedenen Verknüpfungen der in den Identifikanden enthaltenen Zuordnerschaltung dargestellt. Der Identifikator weist eine Anzahl von Sendepunkten und Empfangspunkten auf, zwischen denen der Identifikand entsprechend seinen Verknüpfungen Verbindungen herstellt. Das Grundprinzip des Identifikators besteht darin, dass die Sendepunkte mit definierten Impulsströmen über die im Identifikanden enthaltene Verknüpfung auf die Empfangspunkte des Identifikators einwirken und in diesem auf diese Weise den Code des Identifikanden einspeichern. Der Identifikand und der Identifikator

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besitzen jeweils die gleiche Anzahl, z. B. zehn, räumlich diskreter Empfangs- und Sendestellen.

Mit dieser bekannten Anordnung ist eine Paralleleingabe der abfragenden Impulse aus dem Identifikator und eine Parallelausgabe der Identifizierungsimpulse aus dem Identifikanden in den Identifikator möglich. Das Zuordnungsprinzip ist aber nicht an den Parallelbetrieb und an die räumlich diskreten Sende- und Empfangsstellen gebunden.

Die vorliegende Erfindung besteht nun darin, dass im Identifikator eine Sendeeinrichtung vorgesehen ist, mit deren Hilfe dem Identifikanden nacheinander eine der Anzahl der Zuordnungsstellen des Identifikanden entsprechende Anzahl von Informationen angeboten wird, dass im Identifikanden eine Wähleinrichtung vorhanden ist, die die eintreffenden Informationen der Reihe nach den Eingängen des im Identifikanden enthaltenen Zuordners zuführt, und dass im Identifikanden eine Sendeeinrichtung vorgesehen ist, deren Modulation durch die Ausgänge des Zuordners bestimmt wird und mittels welcher Sendeeinrichtung, die durch den Zuordner bestimmte Modulation direkt oder indirekt an den Identifikator zur Verarbeitung übertragen wird.

Zur Verteilung der Informationen kann beispielsweise im Identifikator ein Taktgeber vorgesehen sein, dessen Impulse die Eingänge des im Identifikanden befindlichen Zuordners nacheinander markieren, wobei jedem Ausgang des Zuordners eine Impulsgruppe mit einer bestimmten Impulszahl zugeordnet ist, so dass die nacheinander auftretenden Impulsgruppen den Code des betreffenden Identifikanden darstellen. Die Impulsgruppen können durch einen Impulsgruppengenerator gewonnen werden, der entsprechend dem markierten

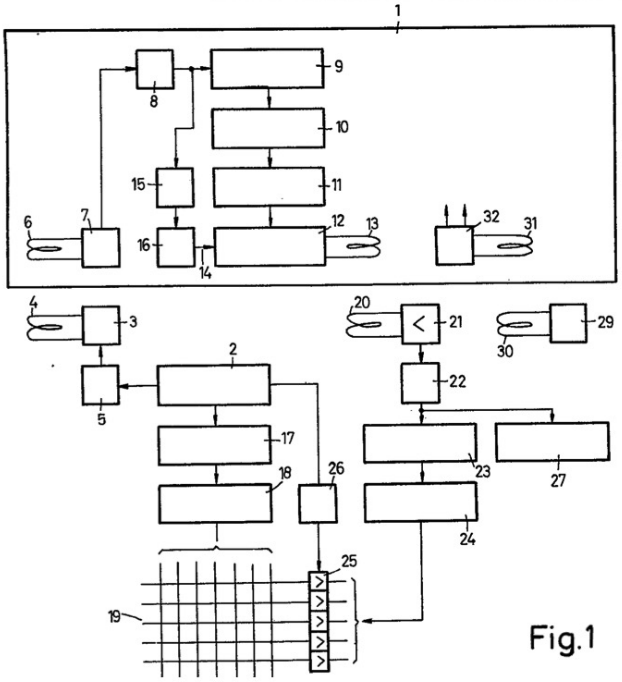


Fig.1

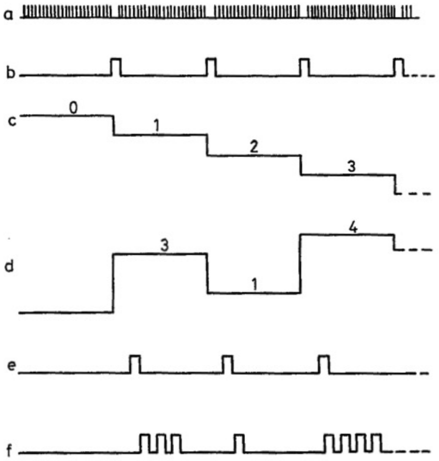


Fig.2

Figure 6.119: Helmut Gröttrup and Jürgen Dethloff invented the smart card, or chip card, in 1966.

6.5.8 Light Emitting Diodes (LEDs) and Laser Diodes

German-speaking scientists played leading roles in the development of light emitting diodes (LEDs) and laser diodes. LEDs are much more energy-efficient than incandescent and even fluorescent bulbs, so they are now widely used for everything from illuminated video screens to room lighting. Laser diodes are more compact, rugged, and efficient than most other types of lasers, so they are used for everything from optical disc drives to laser pointers. Both LEDs and laser diodes are utilized in different types of bar code scanners.

Bernhard Gudden (German, 1892–1945) and Robert Pohl (German, 1884–1976) developed and demonstrated the first electroluminescent semiconductor devices, the forerunners of LEDs, during the period 1919–1923. They also developed improved photoelectric cells. See pp. 1106 and 2889.

Zoltan Bay (Hungarian, 1900–1992) and György Szigeti (Hungarian, 1905–1978) extended the work of Gudden and Pohl and filed patent applications on true LEDs in 1939, as shown on pp. 1107 and 2890–2894.

Kurt Lehovec (Bohemian/Austrian/Czech, 1918–2012) worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs, quite possibly based on wartime work. See Fig. 6.122 and pp. 1097, 2757–2759, and 2895–2910.

John von Neumann (Hungarian, 1903–1957) made a detailed proposal for laser diodes in 1953, which was likely circulated via his many consulting roles in government and industry, and therefore had a broad and profound influence. See p. 1109.

Walter Heywang (German, 1923–2010) filed detailed patent applications on laser diodes in 1958 (pp. 1110 and 2912–2916)

Herbert Kroemer (German, 1928–) invented the drift transistor in 1953, the double-heterostructure laser diode in 1963, and III-V semiconductor heterostructures in 1966. (See pp. 1111 and 2917–2922.) He won the Nobel Prize in Physics in 2000 for his innovations in microelectronics. Professor Tord Claeson of the Royal Swedish Academy of Sciences described Kroemer's contributions [https://www.nobelprize.org/prizes/physics/2000/ceremony-speech/]:

> Early transistors were relatively slow. Semiconductor heterojunctions were proposed as a way of increasing amplification and achieving higher frequencies and power. Such a heterostructure consists of two semiconductors whose atomic structures fit one another well, but which have different electronic properties. A carefully worked out proposal was published in 1957 by Herbert Kroemer. Today, high-speed transistors are found in mobile (cellular) phones and in their base stations, in satellite dishes and links. There they are part of devices that amplify weak signals from outer space or from a faraway mobile telephone without drowning in the noise of the receiver itself.
>
> Semiconductor heterostructures have been at least equally important to the development of photonics—lasers, light emitting diodes, modulators and solar panels, to mention a few examples. The semiconductor laser is based upon the recombination of electrons

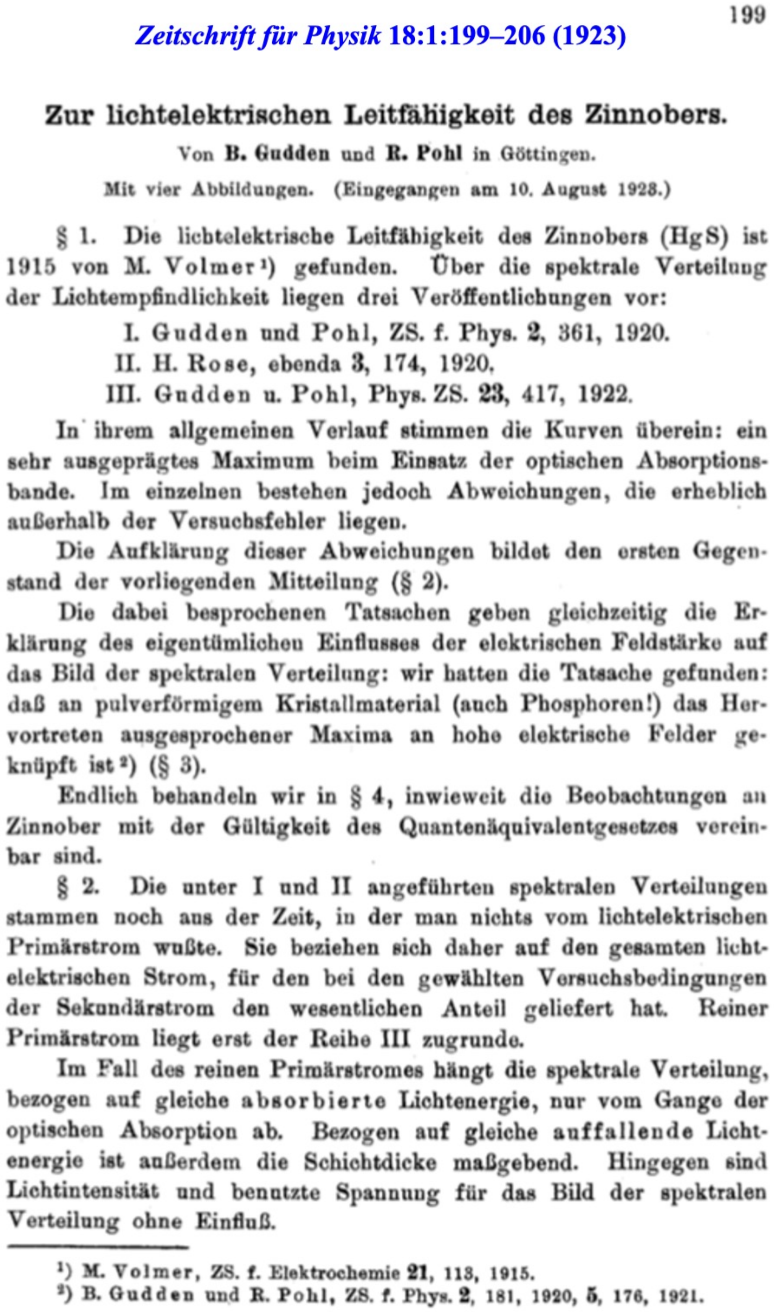
> and holes, emitting particles of light, photons. If the density of these photons becomes sufficiently high, they may begin to move in rhythm with each other and form a phase-coherent state, that is, laser light. The first semiconductor lasers had low efficiency and could only shine in short pulses.
>
> Herbert Kroemer and Zhores Alferov suggested in 1963 that the concentration of electrons, holes and photons would become much higher if they were confined to a thin semiconductor layer between two others—a double heterojunction. [...]
>
> Lasers and light emitting diodes (LEDs) have been further developed in many stages. Without the heterostructure laser, today we would not have had optical broadband links, CD players, laser printers, bar code readers, laser pointers and numerous scientific instruments. LEDs are used in displays of all kind, including traffic signals. Perhaps they will entirely replace light bulbs. In recent years, it has been possible to make LEDs and lasers that cover the full visible wavelength range, including blue light.
>
> I have emphasized the technical consequences of these discoveries, since these are easier to explain than the spectacular scientific breakthroughs that they have also led to. Challenging problems and matching resources have led to large-scale basic research. The advanced materials and tools of microelectronics are being used for studies in nanoscience and of quantum effects. Scientific experiments and computations are, of course, highly computerized.
>
> Semiconductor heterostructures can be regarded as laboratories of two-dimensional electron gases. The 1985 and 1998 Nobel Prizes in physics for quantum Hall effects were based on such confined geometries. They can be reduced further to form one-dimensional quantum channels and zero-dimensional quantum dots for future studies.

Other groups produced various types of laser diodes around the same time as Heywang and Kroemer. More archival research is needed to determine whether work in the other laser diode groups was seeded by Heywang's or Kroemer's ideas prior to their formal patent applications, by von Neumann's 1953 proposal, or by other German-speaking work going back to World War II.

Bernhard Gudden
(1892–1945)

Improved photoelectric cells and prototype light emitting diodes (LEDs)
(1919–1923)

Zeitschrift für Physik 18:1:199–206 (1923)



199

Zur lichtelektrischen Leitfähigkeit des Zinnobers.

Von **B. Gudden** und **R. Pohl** in Göttingen.

Mit vier Abbildungen. (Eingegangen am 10. August 1923.)

§ 1. Die lichtelektrische Leitfähigkeit des Zinnobers (HgS) ist 1915 von M. Volmer[1]) gefunden. Über die spektrale Verteilung der Lichtempfindlichkeit liegen drei Veröffentlichungen vor:

I. Gudden und Pohl, ZS. f. Phys. **2**, 361, 1920.
II. H. Rose, ebenda **3**, 174, 1920.
III. Gudden u. Pohl, Phys. ZS. **23**, 417, 1922.

In ihrem allgemeinen Verlauf stimmen die Kurven überein: ein sehr ausgeprägtes Maximum beim Einsatz der optischen Absorptionsbande. Im einzelnen bestehen jedoch Abweichungen, die erheblich außerhalb der Versuchsfehler liegen.

Die Aufklärung dieser Abweichungen bildet den ersten Gegenstand der vorliegenden Mitteilung (§ 2).

Die dabei besprochenen Tatsachen geben gleichzeitig die Erklärung des eigentümlichen Einflusses der elektrischen Feldstärke auf das Bild der spektralen Verteilung: wir hatten die Tatsache gefunden: daß an pulverförmigem Kristallmaterial (auch Phosphoren!) das Hervortreten ausgesprochener Maxima an hohe elektrische Felder geknüpft ist[2]) (§ 3).

Endlich behandeln wir in § 4, inwieweit die Beobachtungen an Zinnober mit der Gültigkeit des Quantenäquivalentgesetzes vereinbar sind.

§ 2. Die unter I und II angeführten spektralen Verteilungen stammen noch aus der Zeit, in der man nichts vom lichtelektrischen Primärstrom wußte. Sie beziehen sich daher auf den gesamten lichtelektrischen Strom, für den bei den gewählten Versuchsbedingungen der Sekundärstrom den wesentlichen Anteil geliefert hat. Reiner Primärstrom liegt erst der Reihe III zugrunde.

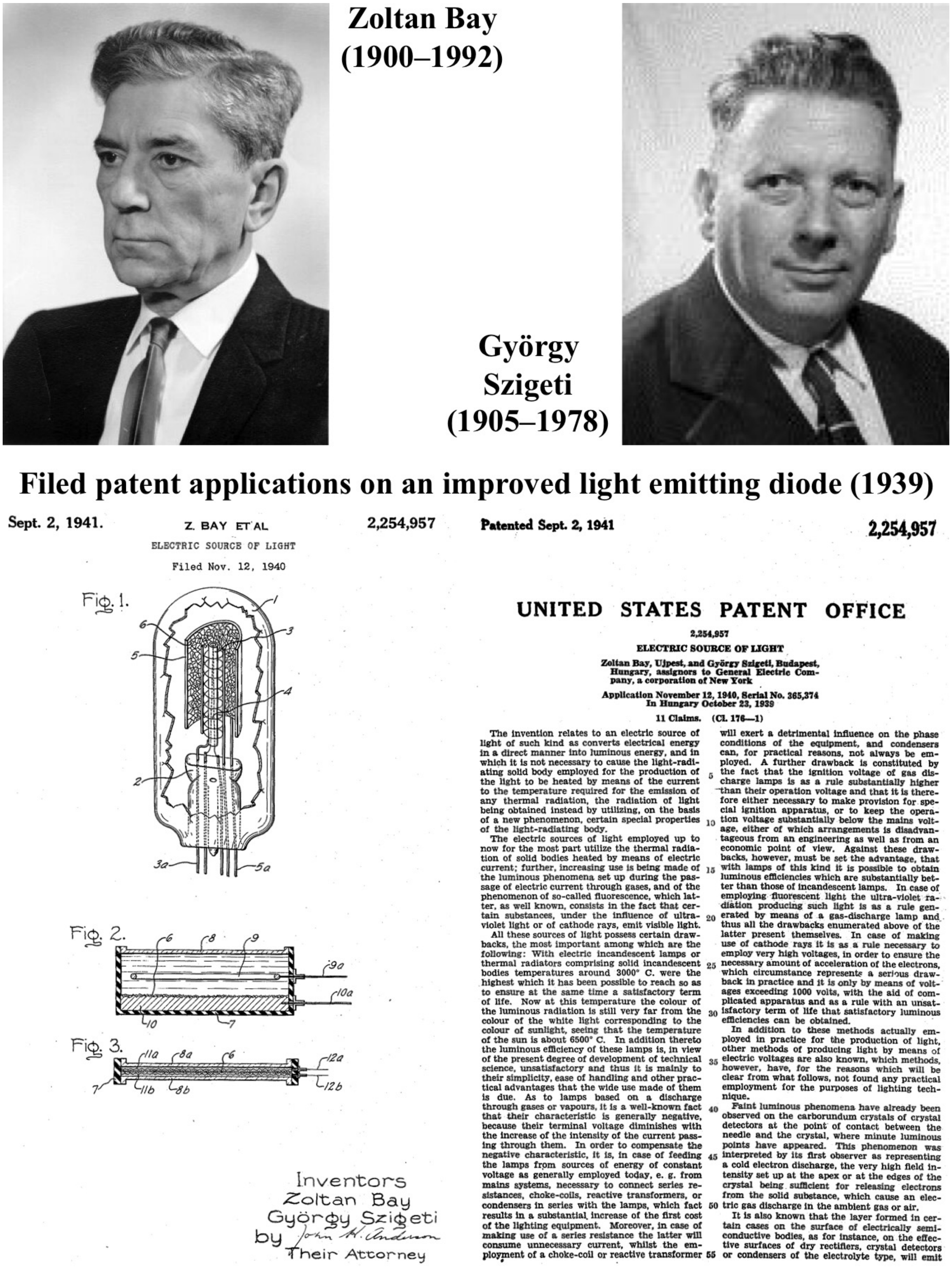
Im Fall des reinen Primärstromes hängt die spektrale Verteilung, bezogen auf gleiche absorbierte Lichtenergie, nur vom Gange der optischen Absorption ab. Bezogen auf gleiche auffallende Lichtenergie ist außerdem die Schichtdicke maßgebend. Hingegen sind Lichtintensität und benutzte Spannung für das Bild der spektralen Verteilung ohne Einfluß.

---

[1]) M. Volmer, ZS. f. Elektrochemie **21**, 113, 1915.
[2]) B. Gudden und R. Pohl, ZS. f. Phys. **2**, 181, 1920, **5**, 176, 1921.

Robert Pohl
(1884–1976)

Figure 6.120: Bernhard Gudden and Robert Pohl developed improved photoelectric cells and also electroluminescent semiconductor devices, the direct forerunners of light emitting diodes (LEDs), during the period 1919–1923 [*Zeitschrift für Physik* 18:1:199–206 (1923)].


Zoltan Bay
(1900–1992)
György
Szigeti
(1905–1978)
Filed patent applications on an improved light emitting diode (1939)
Fig. 1.
1
2
3
4
5
6
3a
5a
Fig. 2.
6
8
9
9a
10a
10
7
Fig. 3.
11a
8a
6
12a
12b
7
11b
8b

Sept. 2, 1941. Z. BAY ET AL 2,254,957

ELECTRIC SOURCE OF LIGHT

Filed Nov. 12, 1940

Inventors
Zoltan Bay
György Szigeti
by John H. Anderson
Their Attorney

Patented Sept. 2, 1941 2,254,957

UNITED STATES PATENT OFFICE

2,254,957

ELECTRIC SOURCE OF LIGHT

Zoltan Bay, Ujpest, and György Szigeti, Budapest, Hungary, assignors to General Electric Company, a corporation of New York

Application November 12, 1940, Serial No. 365,374
In Hungary October 23, 1939

11 Claims. (Cl. 176—1)

The invention relates to an electric source of light of such kind as converts electrical energy in a direct manner into luminous energy, and in which it is not necessary to cause the light-radiating solid body employed for the production of the light to be heated by means of the current to the temperature required for the emission of any thermal radiation, the radiation of light being obtained instead by utilizing, on the basis of a new phenomenon, certain special properties of the light-radiating body.

The electric sources of light employed up to now for the most part utilize the thermal radiation of solid bodies heated by means of electric current; further, increasing use is being made of the luminous phenomena set up during the passage of electric current through gases, and of the phenomenon of so-called fluorescence, which latter, as well known, consists in the fact that certain substances, under the influence of ultraviolet light or of cathode rays, emit visible light.

All these sources of light possess certain drawbacks, the most important among which are the following: With electric incandescent lamps or thermal radiators comprising solid incandescent bodies temperatures around 3000° C. were the highest which it has been possible to reach so as to ensure at the same time a satisfactory term of life. Now at this temperature the colour of the luminous radiation is still very far from the colour of the white light corresponding to the colour of sunlight, seeing that the temperature of the sun is about 6500° C. In addition thereto the luminous efficiency of these lamps is, in view of the present degree of development of technical science, unsatisfactory and thus it is mainly to their simplicity, ease of handling and other practical advantages that the wide use made of them is due. As to lamps based on a discharge through gases or vapours, it is a well-known fact that their characteristic is generally negative, because their terminal voltage diminishes with the increase of the intensity of the current passing through them. In order to compensate the negative characteristic, it is, in case of feeding the lamps from sources of energy of constant voltage as generally employed today, e. g. from mains systems, necessary to connect series resistances, choke-coils, reactive transformers, or condensers in series with the lamps, which fact results in a substantial increase of the first cost of the lighting equipment. Moreover, in case of making use of a series resistance the latter will consume unnecessary current, whilst the employment of a choke-coil or reactive transformer will exert a detrimental influence on the phase conditions of the equipment, and condensers can, for practical reasons, not always be employed. A further drawback is constituted by the fact that the ignition voltage of gas discharge lamps is as a rule substantially higher than their operation voltage and that it is therefore either necessary to make provision for special ignition apparatus, or to keep the operation voltage substantially below the mains voltage, either of which arrangements is disadvantageous from an engineering as well as from an economic point of view. Against these drawbacks, however, must be set the advantage, that with lamps of this kind it is possible to obtain luminous efficiencies which are substantially better than those of incandescent lamps. In case of employing fluorescent light the ultra-violet radiation producing such light is as a rule generated by means of a gas-discharge lamp and thus all the drawbacks enumerated above of the latter present themselves. In case of making use of cathode rays it is as a rule necessary to employ very high voltages, in order to ensure the necessary amount of acceleration of the electrons, which circumstance represents a serious drawback in practice and it is only by means of voltages exceeding 1000 volts, with the aid of complicated apparatus and as a rule with an unsatisfactory term of life that satisfactory luminous efficiencies can be obtained.

In addition to these methods actually employed in practice for the production of light, other methods of producing light by means of electric voltages are also known, which methods, however, have, for the reasons which will be clear from what follows, not found any practical employment for the purposes of lighting technique.

Faint luminous phenomena have already been observed on the carborundum crystals of crystal detectors at the point of contact between the needle and the crystal, where minute luminous points have appeared. This phenomenon was interpreted by its first observer as representing a cold electron discharge, the very high field intensity set up at the apex or at the edges of the crystal being sufficient for releasing electrons from the solid substance, which cause an electric gas discharge in the ambient gas or air.

It is also known that the layer formed in certain cases on the surface of electrically semiconductive bodies, as for instance, on the effective surfaces of dry rectifiers, crystal detectors or condensers of the electrolyte type, will emit

Figure 6.121: Zoltan Bay and György Szigeti filed patent applications on light emitting diodes (LEDs) in 1939.

Improved LEDs

Kurt Lehovec (1918–2012)

Was his postwar work in U.S. based on wartime work in Bernhard Gudden's lab?

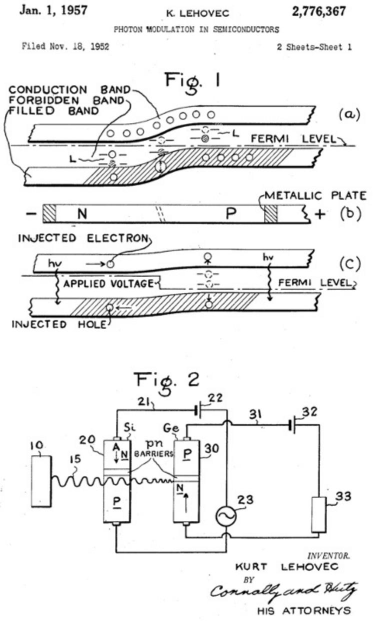

Jan. 1, 1957 K. LEHOVEC 2,776,367
PHOTON MODULATION IN SEMICONDUCTORS
Filed Nov. 18, 1952 2 Sheets-Sheet 1

Fig. 1
CONDUCTION BAND
FORBIDDEN BAND
FILLED BAND
L
FERMI LEVEL
(a)
N
P
METALLIC PLATE
(b)
INJECTED ELECTRON
hv
APPLIED VOLTAGE
FERMI LEVEL
(c)
INJECTED HOLE
Fig. 2
21
22
31
32
Si
Ge
10
20
15
pn BARRIERS
30
A
N
P
23
33
INVENTOR.
KURT LEHOVEC
BY
Connolly and Hutz
HIS ATTORNEYS

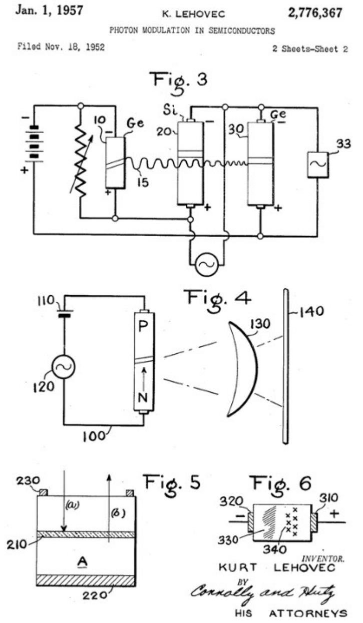

Jan. 1, 1957 K. LEHOVEC 2,776,367
PHOTON MODULATION IN SEMICONDUCTORS
Filed Nov. 18, 1952 2 Sheets-Sheet 2

Fig. 3
10
Ge
Si
20
30
Ge
33
15
Fig. 4
110
P
N
130
140
120
100
Fig. 5
230
(a)
(b)
210
A
220
Fig. 6
320
310
330
340
INVENTOR.
KURT LEHOVEC
BY
Connolly and Hutz
HIS ATTORNEYS

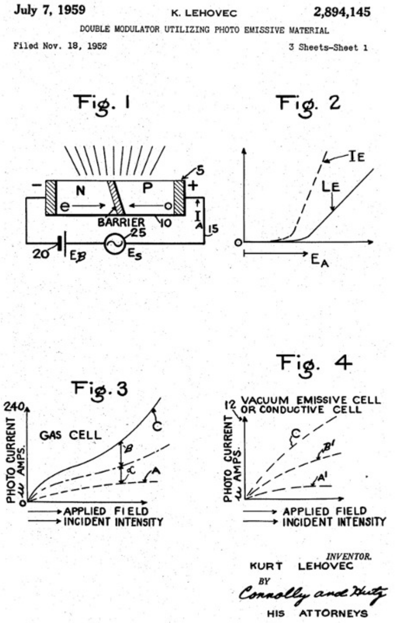

July 7, 1959 K. LEHOVEC 2,894,145
DOUBLE MODULATOR UTILIZING PHOTO EMISSIVE MATERIAL
Filed Nov. 18, 1952 3 Sheets-Sheet 1

Fig. 1
N
P
e
BARRIER
10
5
25
15
20
EB
ES
IA
Fig. 2
IE
LE
EA
Fig. 3
240
PHOTO CURRENT µµ AMPS.
GAS CELL
C
B
A
APPLIED FIELD
INCIDENT INTENSITY
Fig. 4
12
VACUUM EMISSIVE CELL OR CONDUCTIVE CELL
PHOTO CURRENT µµ AMPS.
C'
B'
A'
APPLIED FIELD
INCIDENT INTENSITY
INVENTOR.
KURT LEHOVEC
BY
Connolly and Hutz
HIS ATTORNEYS

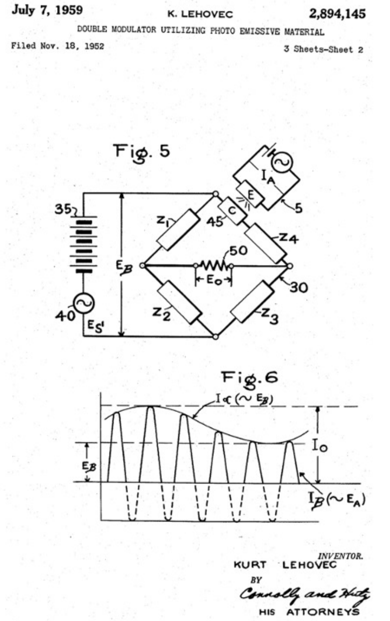

July 7, 1959 K. LEHOVEC 2,894,145
DOUBLE MODULATOR UTILIZING PHOTO EMISSIVE MATERIAL
Filed Nov. 18, 1952 3 Sheets-Sheet 2

Fig. 5
35
IA
5
C
E
45
Z1
Z4
50
EB
E0
30
Z2
Z3
40
ES'
Fig. 6
IE(~EB)
I0
EB
IB(~EA)
INVENTOR.
KURT LEHOVEC
BY
Connolly and Hutz
HIS ATTORNEYS

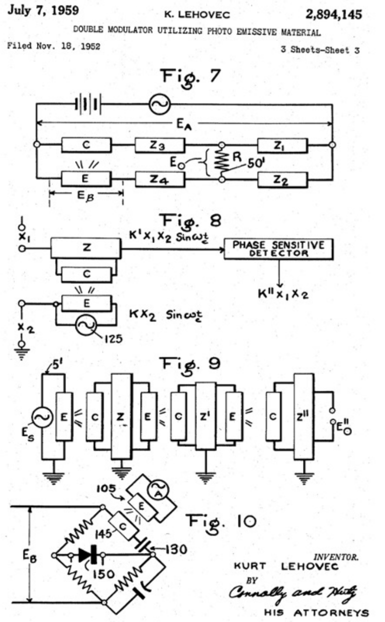
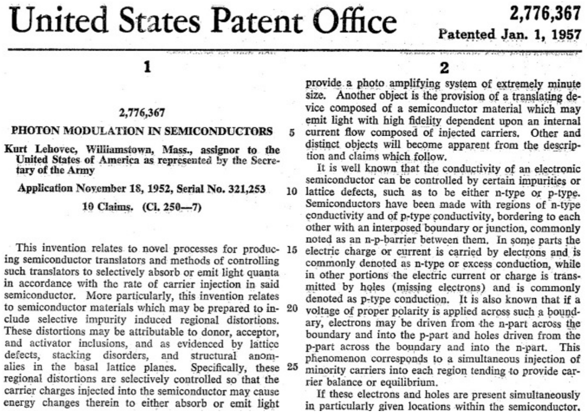

July 7, 1959 K. LEHOVEC 2,894,145
DOUBLE MODULATOR UTILIZING PHOTO EMISSIVE MATERIAL
Filed Nov. 18, 1952 3 Sheets-Sheet 3

Fig. 7
EA
C
Z3
Z1
E0
R
50'
E
Z4
Z2
EB
Fig. 8
X1
Z
K'X1X2 Sinωt
PHASE SENSITIVE DETECTOR
C
K''X1X2
E
KX2 Sinωt
X2
125
Fig. 9
5'
ES
E
C
Z
Z'
Z''
E0''
105
Fig. 10
EB
145
130
150
INVENTOR.
KURT LEHOVEC
BY
Connolly and Hutz
HIS ATTORNEYS


United States Patent Office

2,776,367
Patented Jan. 1, 1957

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2,776,367

PHOTON MODULATION IN SEMICONDUCTORS

Kurt Lehovec, Williamstown, Mass., assignor to the United States of America as represented by the Secretary of the Army

Application November 18, 1952, Serial No. 321,253

10 Claims. (Cl. 250—7)

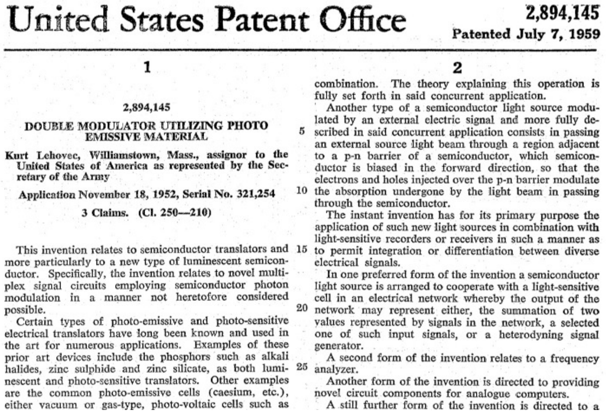
This invention relates to novel processes for producing semiconductor translators and methods of controlling such translators to selectively absorb or emit light quanta in accordance with the rate of carrier injection in said semiconductor. More particularly, this invention relates to semiconductor materials which may be prepared to include selective impurity induced regional distortions. These distortions may be attributable to donor, acceptor, and activator inclusions, and as evidenced by lattice defects, stacking disorders, and structural anomalies in the basal lattice planes. Specifically, these regional distortions are selectively controlled so that the carrier charges injected into the semiconductor may cause energy changes therein to either absorb or emit light

2

provide a photo amplifying system of extremely minute size. Another object is the provision of a translating device composed of a semiconductor material which may emit light with high fidelity dependent upon an internal current flow composed of injected carriers. Other and distinct objects will become apparent from the description and claims which follow.

It is well known that the conductivity of an electronic semiconductor can be controlled by certain impurities or lattice defects, such as to be either n-type or p-type. Semiconductors have been made with regions of n-type conductivity and of p-type conductivity, bordering to each other with an interposed boundary or junction, commonly noted as an n-p-barrier between them. In some parts the electric charge or current is carried by electrons and is commonly denoted as n-type or excess conduction, while in other portions the electric current or charge is transmitted by holes (missing electrons) and is commonly denoted as p-type conduction. It is also known that if a voltage of proper polarity is applied across such a boundary, electrons may be driven from the n-part across the boundary and into the p-part and holes driven from the p-part across the boundary and into the n-part. This phenomenon corresponds to a simultaneous injection of minority carriers into each region tending to provide carrier balance or equilibrium.

If these electrons and holes are present simultaneously in particularly given locations within the semiconductor.


United States Patent Office

2,894,145
Patented July 7, 1959

1

2,894,145

DOUBLE MODULATOR UTILIZING PHOTO EMISSIVE MATERIAL

Kurt Lehovec, Williamstown, Mass., assignor to the United States of America as represented by the Secretary of the Army

Application November 18, 1952, Serial No. 321,254

3 Claims. (Cl. 250—210)

This invention relates to semiconductor translators and more particularly to a new type of luminescent semiconductor. Specifically, the invention relates to novel multiplex signal circuits employing semiconductor photon modulation in a manner not heretofore considered possible.

Certain types of photo-emissive and photo-sensitive electrical translators have long been known and used in the art for numerous applications. Examples of these prior art devices include the phosphors such as alkali halides, zinc sulphide and zinc silicate, as both luminescent and photo-sensitive translators. Other examples are the common photo-emissive cells (caesium, etc.), either vacuum or gas-type, photo-voltaic cells such as

2

combination. The theory explaining this operation is fully set forth in said concurrent application.

Another type of a semiconductor light source modulated by an external electric signal and more fully described in said concurrent application consists in passing an external source light beam through a region adjacent to a p-n barrier of a semiconductor, which semiconductor is biased in the forward direction, so that the electrons and holes injected over the p-n barrier modulate the absorption undergone by the light beam in passing through the semiconductor.

The instant invention has for its primary purpose the application of such new light sources in combination with light-sensitive recorders or receivers in such a manner as to permit integration or differentiation between diverse electrical signals.

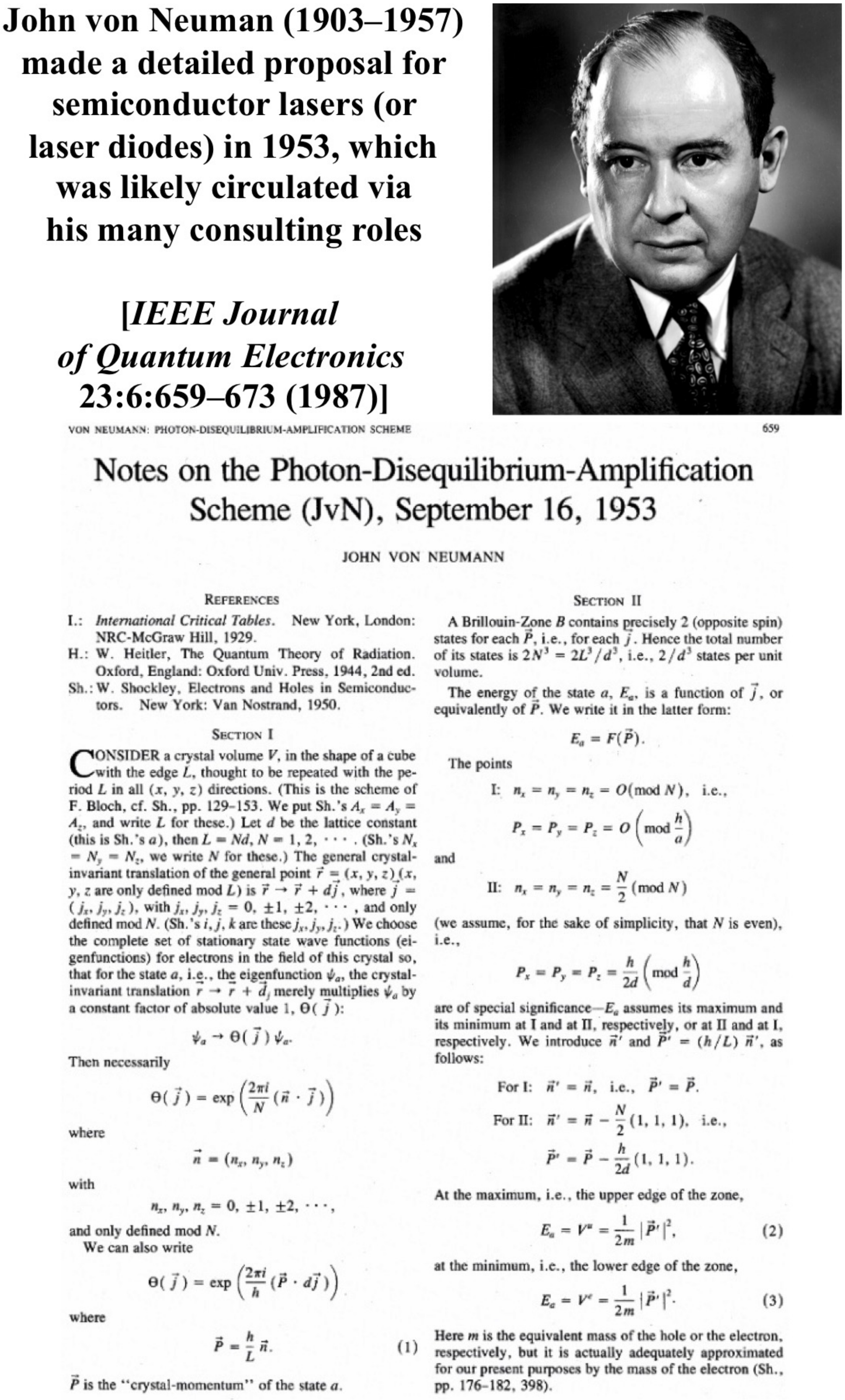
In one preferred form of the invention a semiconductor light source is arranged to cooperate with a light-sensitive cell in an electrical network whereby the output of the network may represent either, the summation of two values represented by signals in the network, a selected one of such input signals, or a heterodyning signal generator.

A second form of the invention relates to a frequency analyzer.

Another form of the invention is directed to providing novel circuit components for analogue computers.

A still further form of the invention is directed to a

Figure 6.122: Kurt Lehovec worked closely with Bernhard Gudden (p. 1106) on advanced semiconductor devices throughout WWII came to the U.S. after the war, and filed patents on improved light emitting diodes (LEDs). How much of Lehovec's postwar work was based on his wartime work with Gudden?



John von Neuman (1903–1957) made a detailed proposal for semiconductor lasers (or laser diodes) in 1953, which was likely circulated via his many consulting roles

[*IEEE Journal of Quantum Electronics* 23:6:659–673 (1987)]

VON NEUMANN: PHOTON-DISEQUILIBRIUM-AMPLIFICATION SCHEME 659

Notes on the Photon-Disequilibrium-Amplification Scheme (JvN), September 16, 1953

JOHN VON NEUMANN

REFERENCES

I.: *International Critical Tables.* New York, London: NRC-McGraw Hill, 1929.

H.: W. Heitler, The Quantum Theory of Radiation. Oxford, England: Oxford Univ. Press, 1944, 2nd ed.

Sh.: W. Shockley, Electrons and Holes in Semiconductors. New York: Van Nostrand, 1950.

SECTION I

CONSIDER a crystal volume V, in the shape of a cube with the edge L, thought to be repeated with the period L in all (x, y, z) directions. (This is the scheme of F. Bloch, cf. Sh., pp. 129–153. We put Sh.'s $A_x = A_y = A_z$, and write L for these.) Let d be the lattice constant (this is Sh.'s a), then $L = Nd$, $N = 1, 2, \cdots$. (Sh.'s $N_x = N_y = N_z$, we write N for these.) The general crystal-invariant translation of the general point $\vec{r} = (x, y, z)$ $(x, y, z$ are only defined mod $L)$ is $\vec{r} \rightarrow \vec{r} + d\vec{j}$, where $\vec{j} = (j_x, j_y, j_z)$, with $j_x, j_y, j_z = 0, \pm 1, \pm 2, \cdots$, and only defined mod N. (Sh.'s i, j, k are these j_x, j_y, j_z.) We choose the complete set of stationary state wave functions (eigenfunctions) for electrons in the field of this crystal so, that for the state a, i.e., the eigenfunction ψ_a, the crystal-invariant translation $\vec{r} \rightarrow \vec{r} + \vec{d}_j$ merely multiplies ψ_a by a constant factor of absolute value 1, $\Theta(\vec{j})$:

$$\psi_a \rightarrow \Theta(\vec{j})\,\psi_a.$$

Then necessarily

$$\Theta(\vec{j}) = \exp\left(\frac{2\pi i}{N}(\vec{n} \cdot \vec{j})\right)$$

where

$$\vec{n} = (n_x, n_y, n_z)$$

with

$$n_x, n_y, n_z = 0, \pm 1, \pm 2, \cdots,$$

and only defined mod N.

We can also write

$$\Theta(\vec{j}) = \exp\left(\frac{2\pi i}{h}(\vec{P} \cdot d\vec{j})\right)$$

where

$$\vec{P} = \frac{h}{L}\,\vec{n}. \tag{1}$$

$\vec{P}$ is the "crystal-momentum" of the state a.

SECTION II

A Brillouin-Zone B contains precisely 2 (opposite spin) states for each $\vec{P}$, i.e., for each $\vec{j}$. Hence the total number of its states is $2N^3 = 2L^3/d^3$, i.e., $2/d^3$ states per unit volume.

The energy of the state a, E_a, is a function of $\vec{j}$, or equivalently of $\vec{P}$. We write it in the latter form:

$$E_a = F(\vec{P}).$$

The points

$$\text{I:}\quad n_x = n_y = n_z = O(\text{mod } N), \quad \text{i.e.,}$$

$$P_x = P_y = P_z = O\left(\text{mod } \frac{h}{a}\right)$$

and

$$\text{II:}\quad n_x = n_y = n_z = \frac{N}{2}(\text{mod } N)$$

(we assume, for the sake of simplicity, that N is even), i.e.,

$$P_x = P_y = P_z = \frac{h}{2d}\left(\text{mod } \frac{h}{d}\right)$$

are of special significance—E_a assumes its maximum and its minimum at I and at II, respectively, or at II and at I, respectively. We introduce $\vec{n}'$ and $\vec{P}' = (h/L)\,\vec{n}'$, as follows:

$$\text{For I:}\quad \vec{n}' = \vec{n}, \quad \text{i.e.,} \quad \vec{P}' = \vec{P}.$$

$$\text{For II:}\quad \vec{n}' = \vec{n} - \frac{N}{2}(1, 1, 1), \quad \text{i.e.,}$$

$$\vec{P}' = \vec{P} - \frac{h}{2d}(1, 1, 1).$$

At the maximum, i.e., the upper edge of the zone,

$$E_a = V^u = \frac{1}{2m}|\vec{P}'|^2, \tag{2}$$

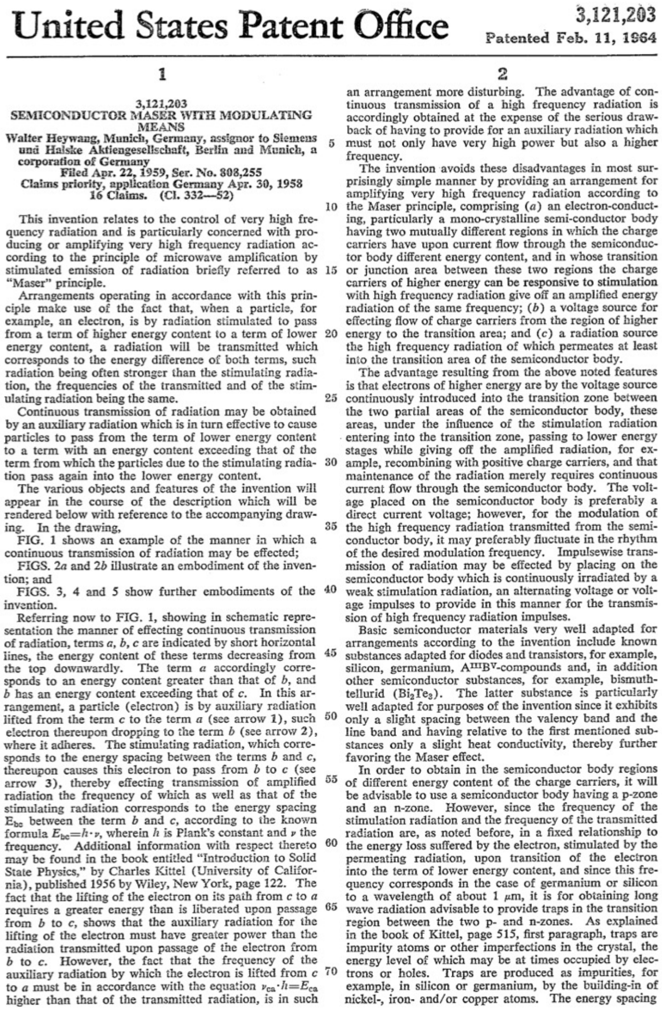
at the minimum, i.e., the lower edge of the zone,

$$E_a = V^e = \frac{1}{2m}|\vec{P}'|^2. \tag{3}$$

Here m is the equivalent mass of the hole or the electron, respectively, but it is actually adequately approximated for our present purposes by the mass of the electron (Sh., pp. 176–182, 398).

Figure 6.123: John von Neumann made a detailed proposal for laser diodes in 1953, which was likely circulated via his many consulting roles in government and industry [*IEEE Journal of Quantum Electronics* 23:6:659–673 (1987)].

**Walter Heywang (1923–2010)
filed patent applications
on semiconductor lasers,
or laser diodes (1958)**



United States Patent Office

3,121,203
Patented Feb. 11, 1964

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3,121,203
SEMICONDUCTOR MASER WITH MODULATING MEANS
Walter Heywang, Munich, Germany, assignor to Siemens und Halske Aktiengesellschaft, Berlin and Munich, a corporation of Germany
Filed Apr. 22, 1959, Ser. No. 808,255
Claims priority, application Germany Apr. 30, 1958
16 Claims. (Cl. 332—52)

This invention relates to the control of very high frequency radiation and is particularly concerned with producing or amplifying very high frequency radiation according to the principle of microwave amplification by stimulated emission of radiation briefly referred to as "Maser" principle.

Arrangements operating in accordance with this principle make use of the fact that, when a particle, for example, an electron, is by radiation stimulated to pass from a term of higher energy content to a term of lower energy content, a radiation will be transmitted which corresponds to the energy difference of both terms, such radiation being often stronger than the stimulating radiation, the frequencies of the transmitted and of the stimulating radiation being the same.

Continuous transmission of radiation may be obtained by an auxiliary radiation which is in turn effective to cause particles to pass from the term of lower energy content to a term with an energy content exceeding that of the term from which the particles due to the stimulating radiation pass again into the lower energy content.

The various objects and features of the invention will appear in the course of the description which will be rendered below with reference to the accompanying drawing. In the drawing,

FIG. 1 shows an example of the manner in which a continuous transmission of radiation may be effected;

FIGS. 2*a* and 2*b* illustrate an embodiment of the invention; and

FIGS. 3, 4 and 5 show further embodiments of the invention.

Referring now to FIG. 1, showing in schematic representation the manner of effecting continuous transmission of radiation, terms *a*, *b*, *c* are indicated by short horizontal lines, the energy content of these terms decreasing from the top downwardly. The term *a* accordingly corresponds to an energy content greater than that of *b*, and *b* has an energy content exceeding that of *c*. In this arrangement, a particle (electron) is by auxiliary radiation lifted from the term *c* to the term *a* (see arrow 1), such electron thereupon dropping to the term *b* (see arrow 2), where it adheres. The stimulating radiation, which corresponds to the energy spacing between the terms *b* and *c*, thereupon causes this electron to pass from *b* to *c* (see arrow 3), thereby effecting transmission of amplified radiation the frequency of which as well as that of the stimulating radiation corresponds to the energy spacing E_{bc} between the term *b* and *c*, according to the known formula $E_{bc}=h\cdot\nu$, wherein h is Plank's constant and ν the frequency. Additional information with respect thereto may be found in the book entitled "Introduction to Solid State Physics," by Charles Kittel (University of California), published 1956 by Wiley, New York, page 122. The fact that the lifting of the electron on its path from *c* to *a* requires a greater energy than is liberated upon passage from *b* to *c*, shows that the auxiliary radiation for the lifting of the electron must have greater power than the radiation transmitted upon passage of the electron from *b* to *c*. However, the fact that the frequency of the auxiliary radiation by which the electron is lifted from *c* to *a* must be in accordance with the equation $\nu_{ca}\cdot h=E_{ca}$ higher than that of the transmitted radiation, is in such an arrangement more disturbing. The advantage of continuous transmission of a high frequency radiation is accordingly obtained at the expense of the serious drawback of having to provide for an auxiliary radiation which must not only have very high power but also a higher frequency.

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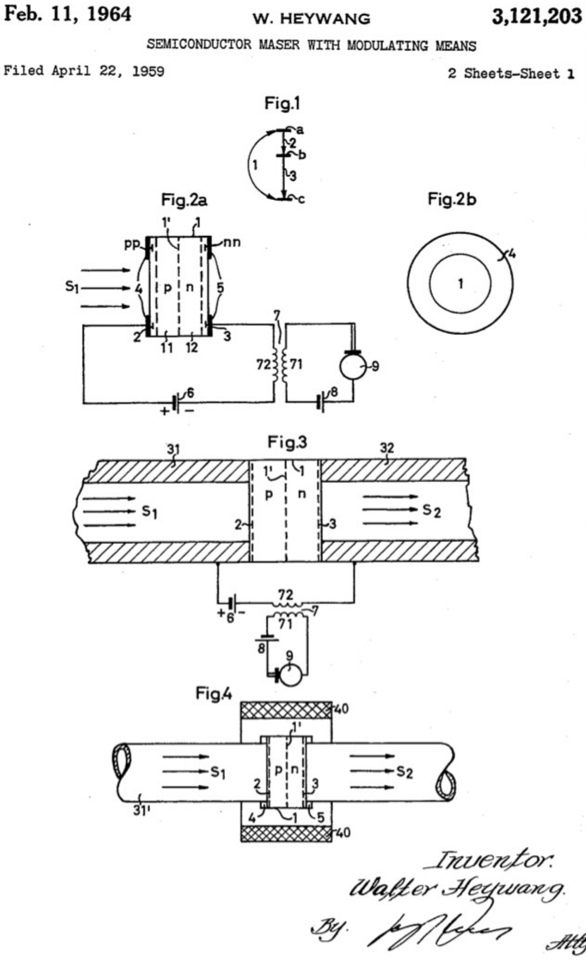
The invention avoids these disadvantages in most surprisingly simple manner by providing an arrangement for amplifying very high frequency radiation according to the Maser principle, comprising (*a*) an electron-conducting, particularly a mono-crystalline semi-conductor body having two mutually different regions in which the charge carriers have upon current flow through the semiconductor body different energy content, and in whose transition or junction area between these two regions the charge carriers of higher energy can be responsive to stimulation with high frequency radiation give off an amplified energy radiation of the same frequency; (*b*) a voltage source for effecting flow of charge carriers from the region of higher energy to the transition area; and (*c*) a radiation source the high frequency radiation of which permeates at least into the transition area of the semiconductor body.

The advantage resulting from the above noted features is that electrons of higher energy are by the voltage source continuously introduced into the transition zone between the two partial areas of the semiconductor body, these areas, under the influence of the stimulation radiation entering into the transition zone, passing to lower energy stages while giving off the amplified radiation, for example, recombining with positive charge carriers, and that maintenance of the radiation merely requires continuous current flow through the semiconductor body. The voltage placed on the semiconductor body is preferably a direct current voltage; however, for the modulation of the high frequency radiation transmitted from the semiconductor body, it may preferably fluctuate in the rhythm of the desired modulation frequency. Impulsewise transmission of radiation may be effected by placing on the semiconductor body which is continuously irradiated by a weak stimulation radiation, an alternating voltage or voltage impulses to provide in this manner for the transmission of high frequency radiation impulses.

Basic semiconductor materials very well adapted for arrangements according to the invention include known substances adapted for diodes and transistors, for example, silicon, germanium, $A^{III}B^{V}$-compounds and, in addition other semiconductor substances, for example, bismuthtellurid (Bi_2Te_3). The latter substance is particularly well adapted for purposes of the invention since it exhibits only a slight spacing between the valency band and the line band and having relative to the first mentioned substances only a slight heat conductivity, thereby further favoring the Maser effect.

In order to obtain in the semiconductor body regions of different energy content of the charge carriers, it will be advisable to use a semiconductor body having a p-zone and an n-zone. However, since the frequency of the stimulation radiation and the frequency of the transmitted radiation are, as noted before, in a fixed relationship to the energy loss suffered by the electron, stimulated by the permeating radiation, upon transition of the electron into the term of lower energy content, and since this frequency corresponds in the case of germanium or silicon to a wavelength of about 1 μm, it is for obtaining long wave radiation advisable to provide traps in the transition region between the two p- and n-zones. As explained in the book of Kittel, page 515, first paragraph, traps are impurity atoms or other imperfections in the crystal, the energy level of which may be at times occupied by electrons or holes. Traps are produced as impurities, for example, in silicon or germanium, by the building-in of nickel-, iron- and/or copper atoms. The energy spacing



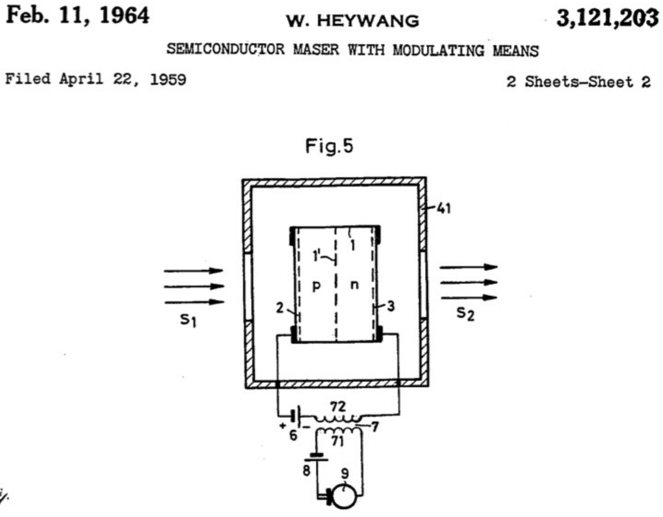
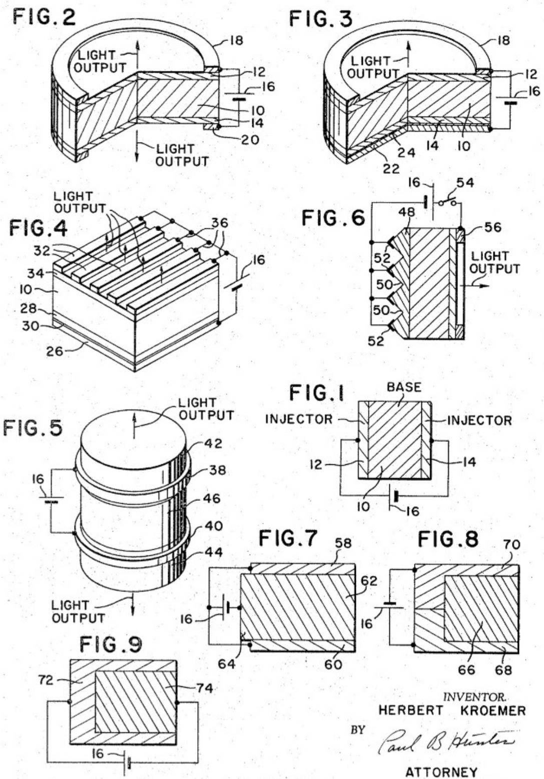


Figure 6.124: Walter Heywang filed detailed patent applications on laser diodes in 1958.

March 14, 1967 H. KROEMER **3,309,553**

SOLID STATE RADIATION EMITTERS

Filed Aug. 16, 1963



INVENTOR.
HERBERT KROEMER

BY Paul B Hunter

ATTORNEY

United States Patent Office

3,309,553
Patented Mar. 14, 1967

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3,309,553
SOLID STATE RADIATION EMITTERS
Herbert Kroemer, Sunnyvale, Calif., assignor to Varian Associates, Palo Alto, Calif., a corporation of California
Filed Aug. 16, 1963, Ser. No. 302,647
20 Claims. (Cl. 313—108)

This invention relates to solid state radiation emitters, and in particular to novel and improved semiconductor devices that afford enhanced radiating characteristics.

Although the semiconductor device of this invention may be useful for various applications, the description will be directed to the use of the inventive device as a laser, for the purpose of description and explanation. It should be understood that the inventive concept is not limited to laser applications only.

Radiation or lasing action by semiconductors may be achieved in one way by the recombination of injected excess charge carriers. By exciting or stimulating certain semiconductors by means of light energy or electric current, these semiconductors will emit visible light, infrared, or other radiation.

However, radiating or lasing structures utilizing solid state devices have been limited to the direct gap type semiconductors, such as gallium arsenide, indium arsenide and indium phosphide, and to the semiconductor alloys $GaAs_xP_{1-x}$ and $Ga_xIn_{1-x}As$. It has not been possible to effect highly radiative recombination with the common semiconductors of the indirect energy gap type, such as Ge, Si, GaP for example, because a very high carrier injection level is required. The indirect gap type semiconductor is characterized in that an electron from the lowest energy state in the conduction band is not able to recombine radiatively with a hole in the highest energy state in the valence band. In order for the higher electron states to contain any electrons, it is necessary that very high carrier densities be injected, whereby the indirect gap semiconductors will be capable of emitting light by means of recombination.

Also, the presently known semiconductor radiation emitters or lasers are of the homojunction type, that is, the two sides of the PN junction are formed from a single semiconductor material. A homojunction structure cannot inject a higher carrier density than the doping density on the more heavily doped side of the semiconductor junction, and therefore, it is not possible to realize carrier densities or injection levels that are high enough to overcome the degeneracy threshold of the semiconductor, nor the even higher carrier densities needed to cause lasing in indirect gap semiconductors.

The degeneracy threshold may be defined as the injection level above which injected electrons fill more than half of the available electron states at the lower edge of the conduction band, and above which more than half of the electron states at the upper edge of the valence is empty, or filled with holes. The value of the degeneracy threshold varies with the semiconductor material being used. At room temperature, this value may be approximately 10^{18} carriers per cubic centimeter, by way of example. However, the degeneracy threshold decreases with a decrease in temperature, being approximately proportional to $T^{+3/2}$, where T is the absolute temperature. To achieve optimum efficiency, it is preferable to utilize an injected carrier density that is close to the degeneracy threshold. Furthermore, to accomplish coherent light emission, it is necessary that the injected carrier density

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be greater than the degeneracy threshold. Since only limited injection levels are possible with conventional PN junctions, such as found in the presently known semiconductor lasers, the degeneracy threshold must be lowered by extreme cooling of the structure to provide a suitable injection level.

Thus it is obvious that if high injection densities were provided, there would be no need for the extreme cooling of semiconductor lasers down to cryogenic temperatures. Also, if high injection densities were provided, indirect gap type as well as direct gap type semiconductors could be made to radiate or lase coherently, and at ambient or room temperatures.

Furthermore, with presently known semiconductor lasers having homojunctions, the light is radiated from the end of the junction in a direction substantially perpendicular to the current flow. It would be desirable, as an alternative, to obtain coherent light that is emitted transversely relative to the junction surface of the lasing body and in the direction of current flow so that the light emission covers a substantially wide area.

An object of this invention is to provide novel and improved solid state radiation emitters.

Another object of this invention is to provide high density injection light-emitting structures characterized by increased operating efficiency.

Another object is to provide solid state light emitters and lasers that can operate at ambient temperatures.

A further object is to provide coherent laser devices that afford wide area emission.

According to this invention, a solid state radiation emitter device comprises a semiconductor base, and means for injecting charge carriers of high density into such base and for preventing the outflow of the injected carriers from the base, so that the charge carriers may be efficiently utilized in a radiative recombination process.

In one embodiment of the invention, a solid state radiation emitter includes a thin base or support formed from a first semiconductor material having a relatively low energy gap, and injector electrodes formed from another semiconductor material disposed on each side of such base to form heterojunctions. The injector electrode material is heavily doped and has a substantially wider energy gap than the base material. The pair of wider energy gap injector electrodes are preferably of opposite polarity, one being P-type and the other N-type. An external source of power such as direct electric current, is coupled to the injector electrodes for supplying a forward bias voltage to the emitter device. Thus, excess charge carriers may be injected with a high density so that the degeneracy threshold of the base material is overcome at ambient or room temperatures with resultant emission of radiation. In this manner, a highly efficient light-emitting action is obtained by recombination radiation with indirect gap type semiconductors as well as with direct gap semiconductors at ambient temperatures.

In another embodiment of the invention, the injector electrodes are doped to have the same polarity, and suitable biasing means are coupled to the injector electrodes and to the base to provide high density carrier injection to the base.

In specific embodiments of the invention, reflective or opaque conducting electrodes are disposed on the emitter device so that radiation is directed in predetermined configurations and directions.

It is recognized that various configurations are possible within the scope of the invention whereby injector elec-

Herbert Kroemer (1928–) invented double-heterostructure laser diodes (1963 or earlier)

3,309,553

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trodes formed from a semiconductor material with a higher energy gap are disposed adjacent to a semiconductor base with a relatively lower energy gap, and energizing means are provided for actuating injection of high density charge carriers into the base. The injector electrodes are so located relative to the base that carrier outflow from the base and surface recombination are prevented.

The invention will be described in greater detail with reference to the drawing in which:

FIGURE 1 is a representational schematic diagram of a semiconductor laser, in accordance with this invention;

FIGURES 2 and 3 are isometric views, partly broken away, of embodiments of this invention;

FIGURES 4 and 5 are isometric views of alternative embodiments of the inventive structure;

FIGURE 6 is a sectional view of another alternative embodiment; and

FIGURES 7–9 are representational schematic diagrams of other embodiments of the invention.

Similar numerals refer to similar parts throughout the drawing. It is to be noted that the figures of the drawing are merely illustrative, and that the parts are not represented in exact proportion.

In the schematic diagram of FIGURE 1, a semiconductor radiation emitter structure, according to this invention, comprises a weakly doped base **10** formed from a lower energy gap material; a higher energy gap P-type injector electrode **12** on one surface of the base; and a higher energy gap N-type injector electrode **14** disposed on the opposite surface of the base **10**. A direct current source **16** supplies a positive potential to the P-type injector electrode **12**, whereas a negative potential is supplied to the N-type injector electrode **14**.

In one embodiment of the invention, the lasing base **10** is formed from a single crystal germanium (Ge) wafer, and the injector electrodes **12** and **14** are made from gallium arsenide (GaAs) that has been suitably doped. The junctions formed between the dissimilar materials are referred to as heterojunctions, in contrast to homojunctions. When manufacturing the inventive laser utilizing these particular materials, a pair of layers of GaAs are grown on a germanium wafer or base having a thickness of about 100 microns or less.

The GaAs layers are formed by first preparing a melt consisting of gallium with a small percentage of arsenic. The arsenic content in the melt depends on the growing temperature, which may range from 350° to 750° C. by way of example. At a growing temperature of 500° C., a mixture comprising approximately 5 atomic percent of arsenic is used. The prepared melt is slowly heated to about 600° C. so that the arsenic reacts with the gallium to form GaAs. (Alternatively, an appropriate amount of GaAs may be dissolved in gallium to provide a suitable mixture.) In order to dissolve the residual arsenic that has not reacted, the melt is stirred repeatedly for the first ten minutes of the slow heating process. When the melt reaches about 600° C., the temperature is maintained for at least ten minutes to allow the excess arsenic to be evaporated, and to remove any condensation nuclei. The temperature of the melt is then reduced rapidly by about 100° C., within a period of less than ten minutes. When the temperature of the melt approaches approximately 500° C., the Ge wafer is quickly immersed into the supercooled melt.

The wafer acts as a seed so that the GaAs grows on the wafer support epitaxially. Before immersion, the Ge wafer is heated to a temperature higher than the melt, i.e. over 600° C., for example. The wafer is left in the melt for at least one minute and then withdrawn, providing a GaAs layer that is about 5–20 microns thick, for example. The above steps are performed in a reducing atmosphere, such as in pure hydrogen.

It is known that commercial arsenic contains impurities which produce only N-type GaAs injector electrodes. To

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increase the intensity of the N-type doping whereby higher injection levels are realized, an N-type dopant such as tin is added to the melt in a 1% proportion relative to the mixture.

However, in order to obtain a highly efficient semiconductor laser, one of the two GaAs layers is preferably made as a P-type injector electrode **12** by diffusing a P-type dopant such as zinc therein. To introduce the Zn into the GaAs layer, the base wafer and Zn doping material are heated within an evacuated quartz ampoule at about 800° C. for about one hour. The Zn dopant may comprise an alloy of 90% indium and 10% zinc, where the zinc is the primary diffusant and the indium acts as a buffer to prevent excess Zn vapor pressure. In order to retain the N-type doping of the other GaAs injector electrode, the N-type layer is masked with a film of evaporated or vapor-deposited SiO_2 prior to the introduction of the Zn dopant. The Zn diffuses rapidly in the exposed GaAs layer, but relatively slowly in the Ge wafer, and the diffusion virtually stops at the Ge-GaAs junction interface. After diffusion, the SiO_2 masking film is removed from the N-type layer with hydrochloric acid.

An alternative method of forming the semiconductor laser structure, with opposite polarity injector electrodes disposed on each side of a lasing base, employs a pair of Ge wafers that are placed back-to-back in a GaAs solution. N-type GaAs is grown on the exposed side of each wafer, while the surfaces that are positioned closely adjacent to each other are maintained unwetted. The edge surfaces also remain unwetted by coating the wafer edges with colloidal graphite. After growing suitable N-type injector electrodes, the wafers are then placed in a second GaAs solution that has been made P-type by adding one percent Zn, with the two coated N-type grown layers closely adjacent to each other in a back-to-back position. The P-type injector electrodes are then grown, and the graphite coating is subsequently removed from the edges of the two wafers. It is recognized that laser structure with injector electrodes may be produced by vapor epitaxy techniques.

After growing the injector electrode layers of opposite polarity, the structures are cut or cleaved to a desired shape or size, such as illustrated in FIGURES 2–6. Suitable conducting electrodes **18** and **20** are formed on the injector electrodes by evaporation, plating or other known means in any desired configuration, using screening or masking techniques. The electrodes may be formed by brushing or spraying silver paint or by evaporating thin conducting films, such as tin chloride or gold, in a well-known manner. The conducting electrodes may be made opaque or light-transmitting; or may be formed as a combination of opaque and transparent areas to allow selective areal transmission of light.

Various structures incorporating the inventive combination are shown in FIGURES 2–6. With reference to FIGURE 2, an embodiment of the invention includes a disk-like base structure **10** (shown in part) sandwiched between a P-type injector electrode **12** and N-type injector electrode **14**. Annular conducting electrodes **18** and **20**, which may be formed from silver paint, are disposed on the injector electrodes **12** and **14** respectively, and are connected to the terminals of a direct current supply **16**. Upon application of D.C. current, for example 1.0 volt, radiation or light is transmitted transversely to the plane of the base disk **10**. It is understood that the diameter of the base **10** may be of such length that the radiation is emitted radially from the base **10**.

FIGURE 3 illustrates a laser structure similar to that of FIGURE 2, but provides a continuous conducting electrode **22** covering the entire surface of the N-type injector electrode **14**. A reflecting layer **24**, formed from aluminum, for example, that has been positioned between the N-type injector layer **14** and the conductive electrode **22** serves to reflect the light radiation towards the P-type

Figure 6.125: Herbert Kroemer invented the double-heterostructure laser diode in 1963 or earlier.

6.5.9 Superconductivity

As illustrated in Figs. 6.126–6.131, creators from the German-speaking world also dominated research on superconductivity, the elimination of electrical resistance (and thus the elimination of power losses) when conductive materials are sufficiently cold.

Heike Kamerlingh Onnes (Dutch, educated in Germany, 1853–1926) produced the first liquid helium in 1908. By immersing metals in the liquid helium and measuring their electrical properties, he discovered superconductivity in 1911 (Fig. 6.126). He won the Nobel Prize in Physics in 1913 for all of his research on cryogenics—see p. 921 for more information.

Max von Laue (German, 1879–1960), Fritz Walther Meissner (German, 1882–1974), and Robert Ochsenfeld (German, 1901–1993) further studied the properties of superconductors (Fig. 6.127). Max von Laue won the Nobel Prize in Physics in 1914 for some of his other research (p. 668). In 1933, Meissner and Ochsenfeld discovered the now widely known Meissner (or Meissner-Ochsenfeld) effect, the levitation of a magnet above a superconductor; magnetic fields cannot penetrate a superconductor, so the compressed field between a magnet and a superconductor acts as a cushion.

From the late 1920s onward, Kurt Mendelssohn (German, 1906–1980) also extensively studied superconductivity, including the effects of lattice imperfections on superconductivity in various metal alloys. He studied superfluidity, the unusual behavior of fluids at cryogenic temperatures, as well, and he found direct analogies between the electrical behavior of superconductors and the mechanical behavior of superfluids.

In 1935, the brothers Fritz London (German, 1900–1954) and Heinz London (German, 1907–1970) developed the London equations, which provided a theoretical derivation and explanation for the Meissner effect and some other electromagnetic behaviors of superconductors.

Many of those experts on superconductivity fled Germany before World War II and spread their knowledge to other countries, but U.S. and U.K. reports also described impressive work on superconductivity that was carried out by other scientists in Germany and Austria during the war. For example, BIOS 1751, *German Research on Semi-Conductors, Metal Rectifiers, Detectors and Photocells*, gave some insight into one of Rudolf Hilsch's later projects [BIOS 1751]:

> Super-Conductivity[...] Hilsch [...] has investigated the critical temperature ("Sprungpunkt") of various pure metals, (i.e. that temperature at which super-conduction sets in), also the influence of a magnetic field (which has the effect of lowering the critical temperature) and the critical current ("Grenzstrom") which sets up a magnetic field of such magnitude as just to balance the external field. He also studied the very pronounced effects which some metals have on the critical temperature even if added in very small amounts only.

According to official histories, in 1956 the American Leon Cooper first proposed a detailed explanation of superconductivity, focusing on what came to be known as "Cooper pairs" of electrons that work together to avoid electrical resistance. Cooper won the Nobel Prize in Physics for that explanation. The document on pp. 1116–1118 proves that Josef Schintlmeister (Austrian, 1908–1971) and his coworkers had a detailed understanding of this physics no later than 1945, and were forced to give written reports on that to the United States. Scholars should investigate in much more detail the superconductivity research that Schintlmeister and his coworkers carried out, and how information on their discoveries may have influenced later researchers such as Cooper.

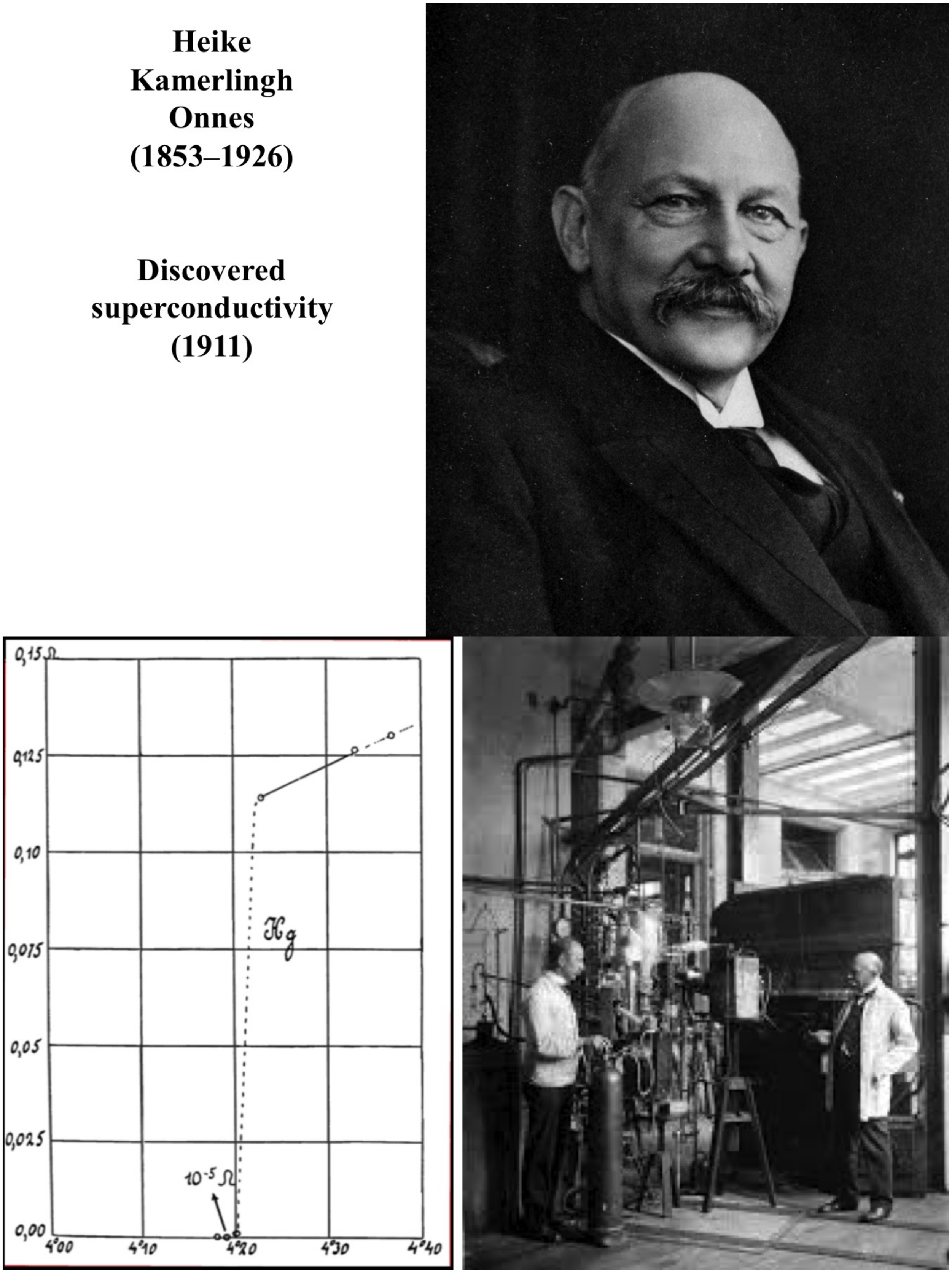
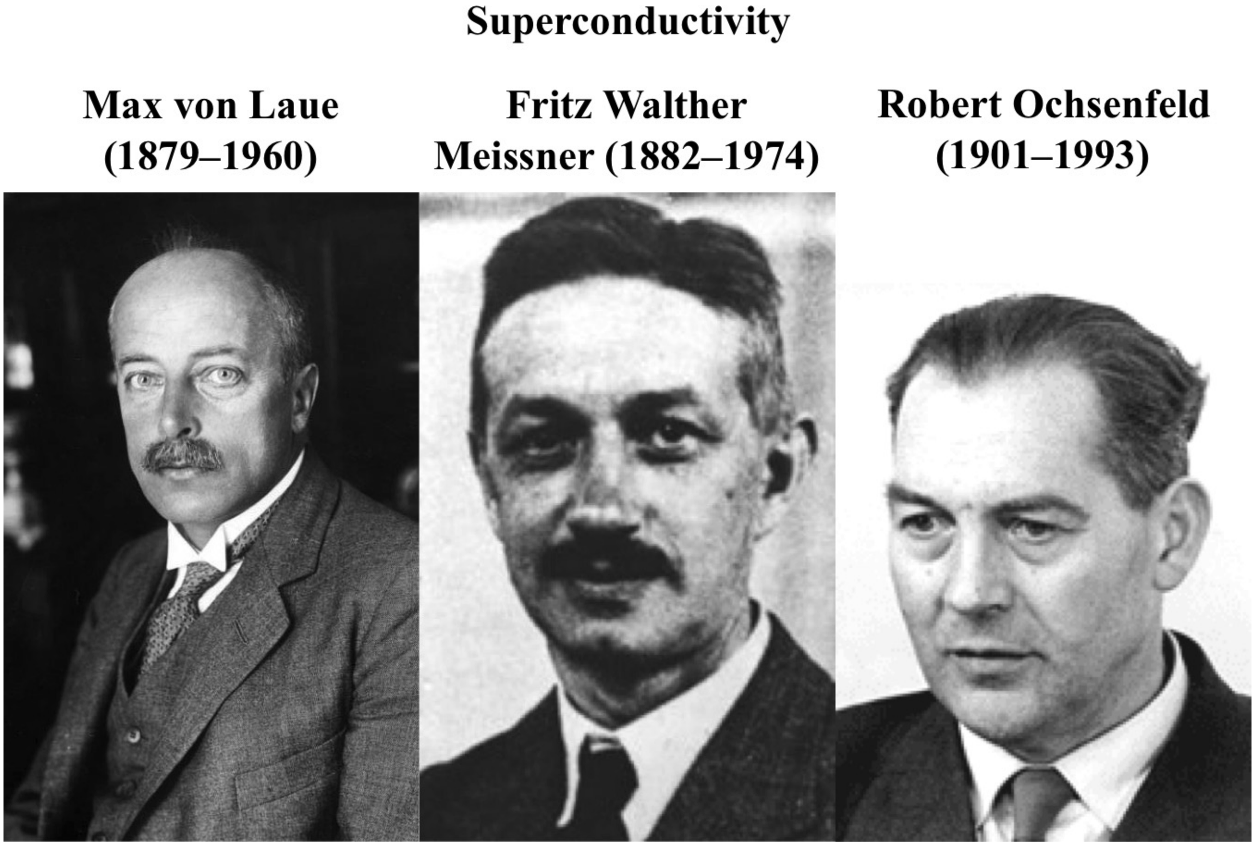

Heike
Kamerlingh
Onnes
(1853–1926)
Discovered
superconductivity
(1911)
0,15 Ω
0,125
0,10
0,075
0,05
0,025
0,00
4°00
4°10
4°20
4°30
4°40
Hg
10⁻⁵ Ω

Figure 6.126: Heike Kamerlingh Onnes discovered superconductivity in 1911.


Superconductivity
Max von Laue (1879–1960)
Fritz Walther Meissner (1882–1974)
Robert Ochsenfeld (1901–1993)

Meissner effect (magnetic levitation)

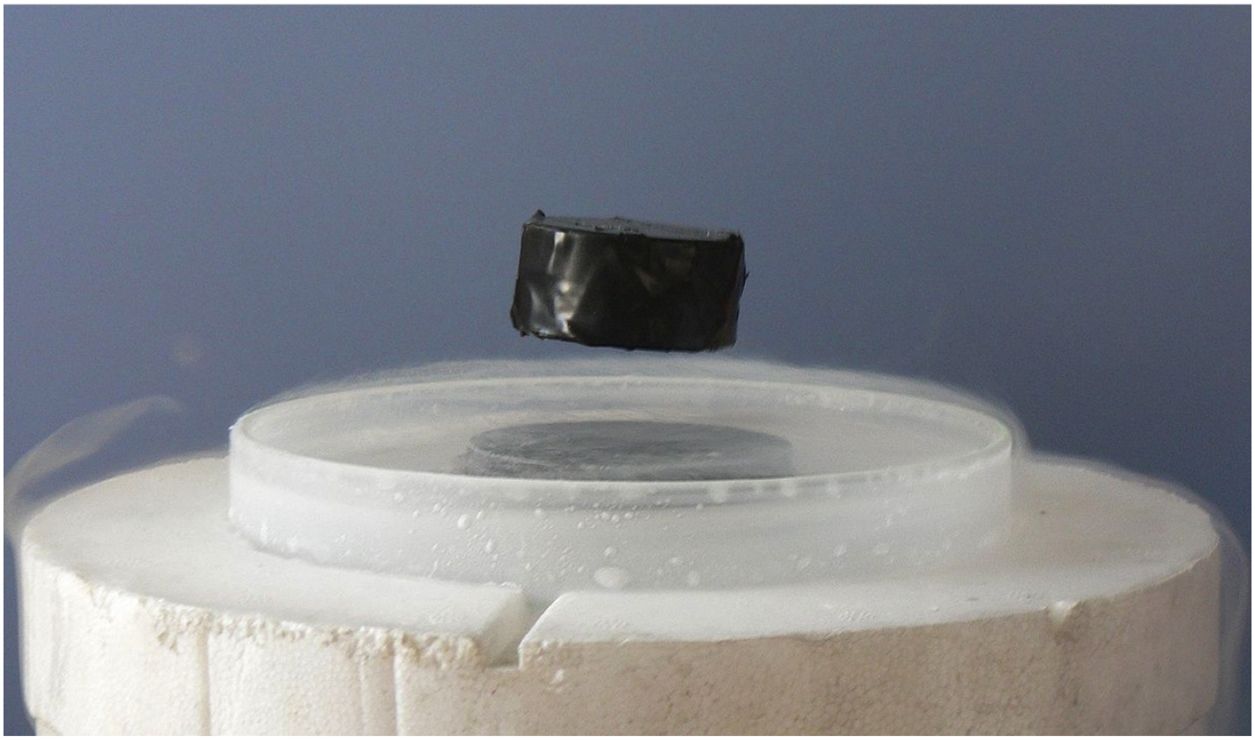


Figure 6.127: Max von Laue, Fritz Walther Meissner, and Robert Ochsenfeld further studied the properties of superconductors, including the "Meissner effect" or magnetic levitation.

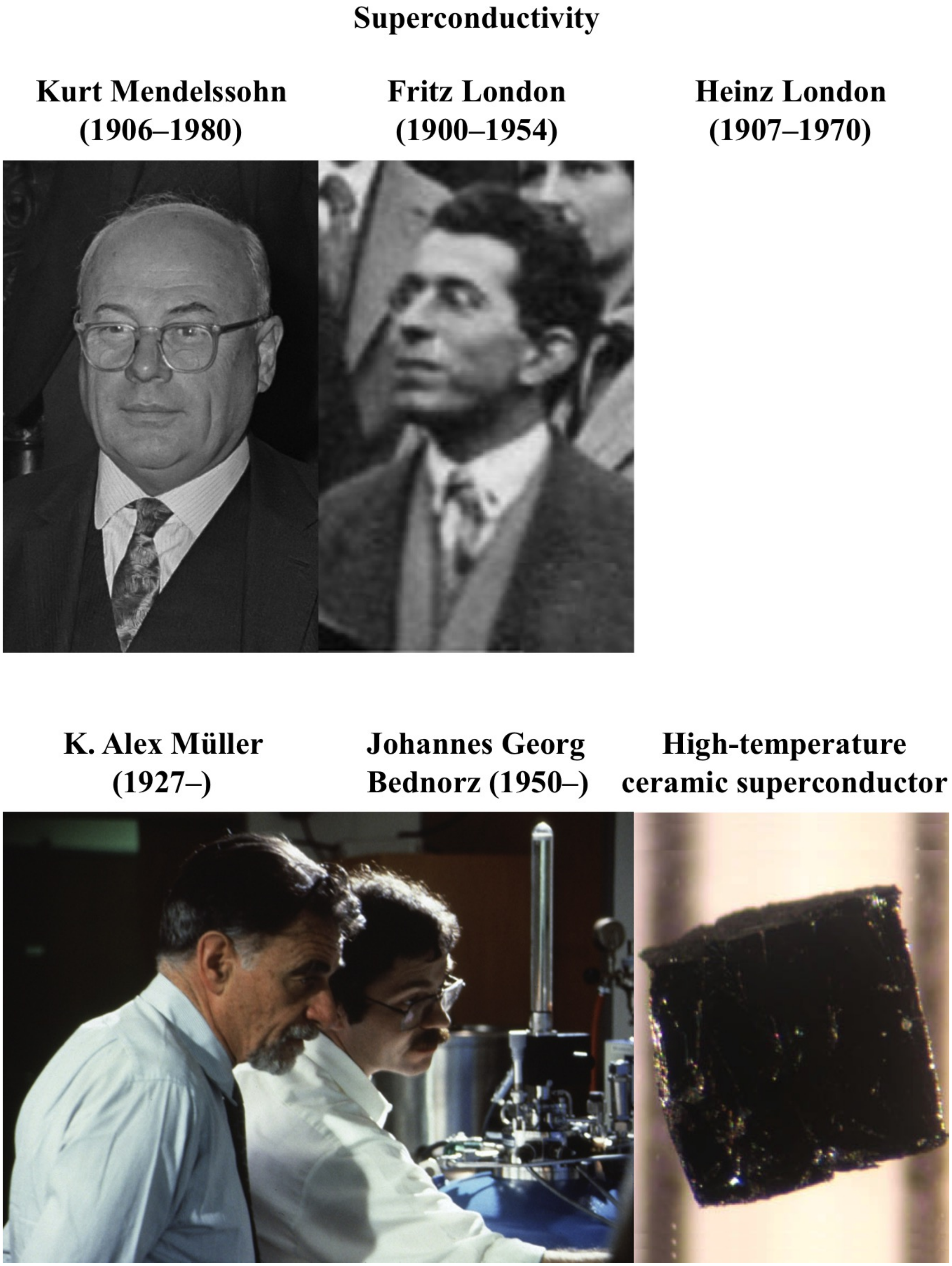
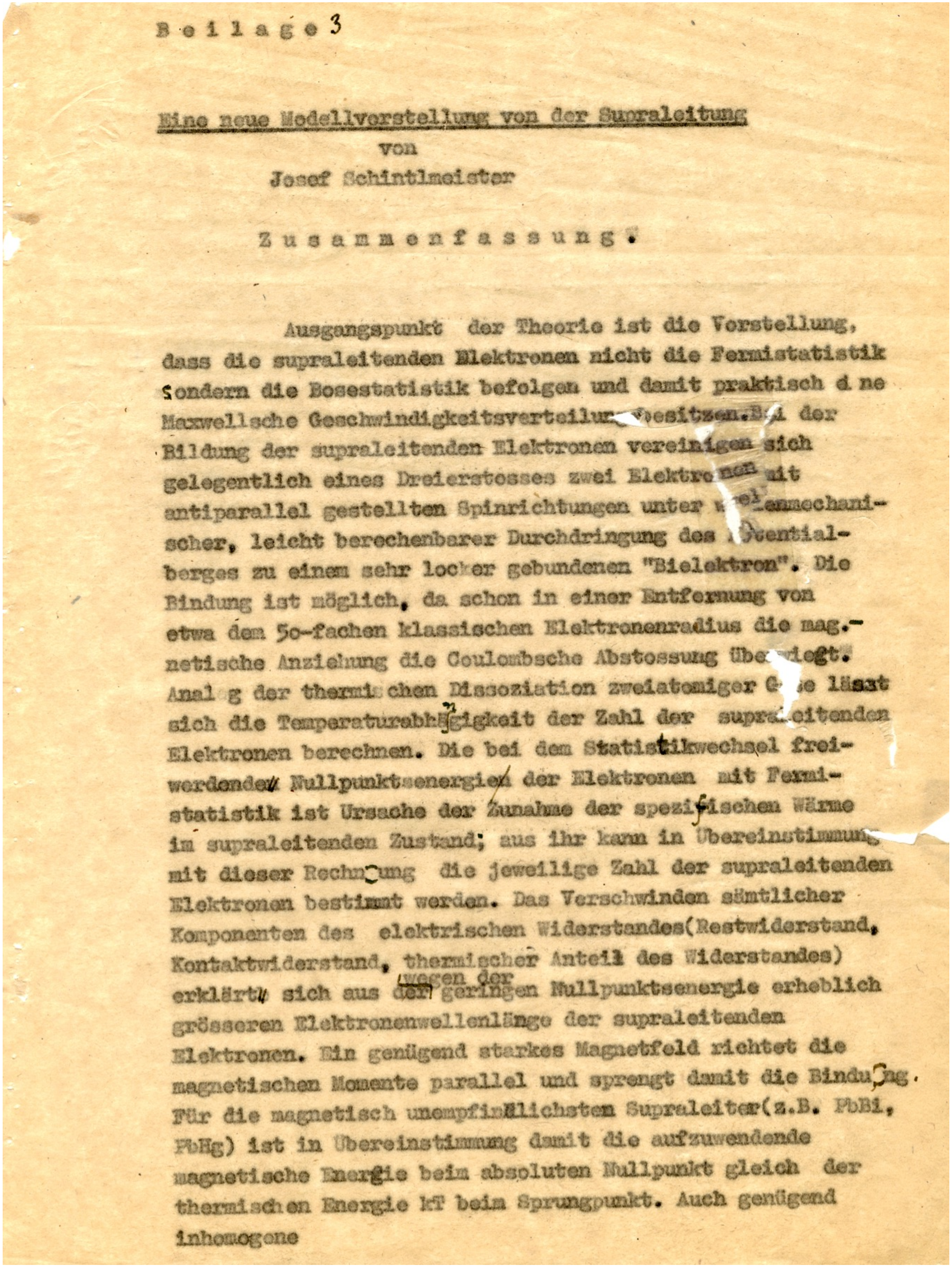

Superconductivity
Kurt Mendelssohn (1906–1980)
Fritz London (1900–1954)
Heinz London (1907–1970)
K. Alex Müller (1927–)
Johannes Georg Bednorz (1950–)
High-temperature ceramic superconductor

Figure 6.128: Other important pioneers of superconductivity included Kurt Mendelssohn, as well as the brothers Fritz London and Heinz London. K. Alex Müller and his student Johannes Georg Bednorz developed the first high-temperature ceramic superconductors.



Beilage 3

Eine neue Modellvorstellung von der Supraleitung

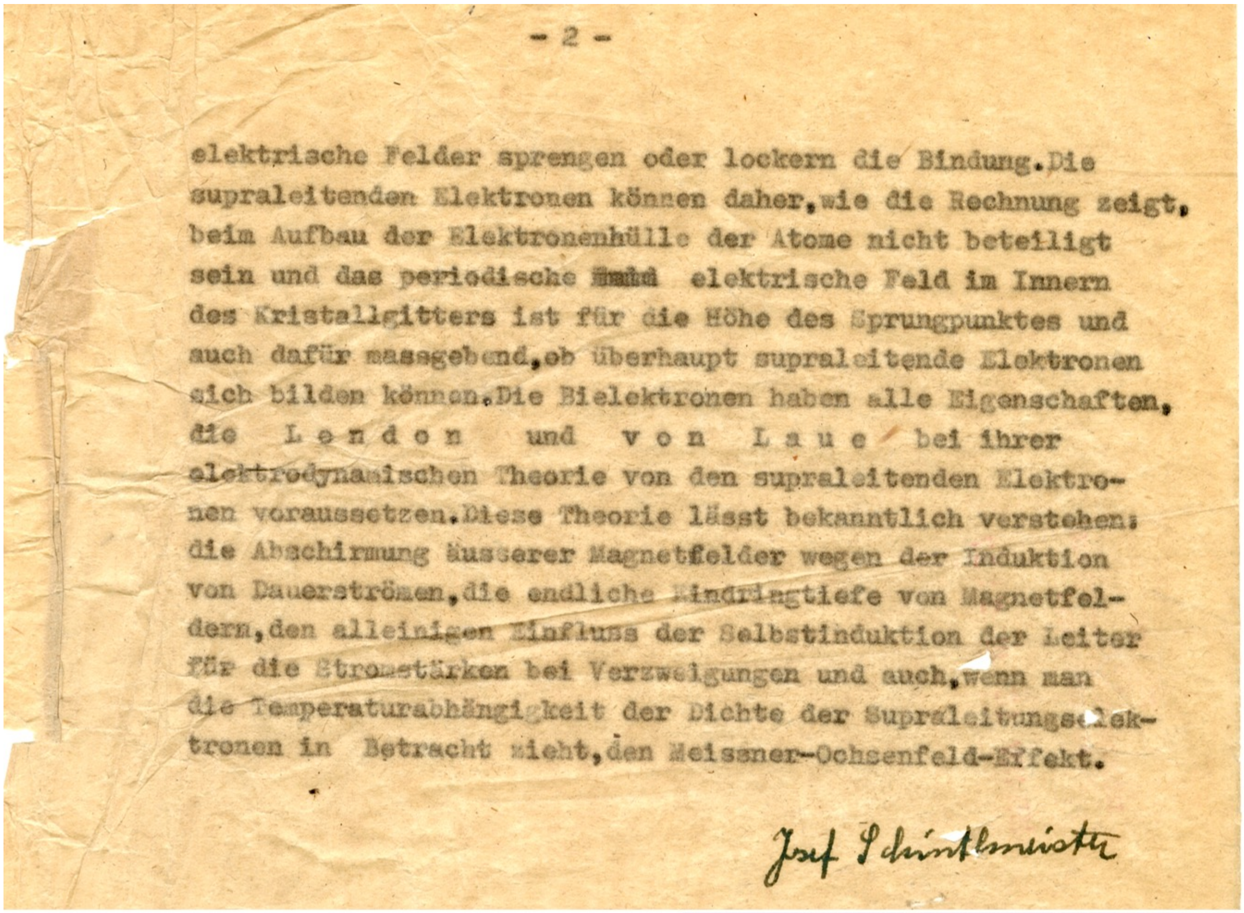
von

Josef Schintlmeister

Zusammenfassung.

Ausgangspunkt der Theorie ist die Vorstellung, dass die supraleitenden Elektronen nicht die Fermistatistik sondern die Bosestatistik befolgen und damit praktisch eine Maxwellsche Geschwindigkeitsverteilung besitzen. Bei der Bildung der supraleitenden Elektronen vereinigen sich gelegentlich eines Dreierstosses zwei Elektronen mit antiparallel gestellten Spinrichtungen unter wellenmechanischer, leicht berechenbarer Durchdringung des Potentialberges zu einem sehr locker gebundenen "Bielektron". Die Bindung ist möglich, da schon in einer Entfernung von etwa dem 5o-fachen klassischen Elektronenradius die magnetische Anziehung die Coulombsche Abstossung überwiegt. Analog der thermischen Dissoziation zweiatomiger Gase lässt sich die Temperaturabhängigkeit der Zahl der supraleitenden Elektronen berechnen. Die bei dem Statistikwechsel freiwerdende Nullpunktsenergie der Elektronen mit Fermistatistik ist Ursache der Zunahme der spezifischen Wärme im supraleitenden Zustand; aus ihr kann in Übereinstimmung mit dieser Rechnung die jeweilige Zahl der supraleitenden Elektronen bestimmt werden. Das Verschwinden sämtlicher Komponenten des elektrischen Widerstandes(Restwiderstand, Kontaktwiderstand, thermischer Anteil des Widerstandes) erklärt sich aus der wegen der geringen Nullpunktsenergie erheblich grösseren Elektronenwellenlänge der supraleitenden Elektronen. Ein genügend starkes Magnetfeld richtet die magnetischen Momente parallel und sprengt damit die Bindung. Für die magnetisch unempfindlichsten Supraleiter(z.B. PbBi, PbHg) ist in Übereinstimmung damit die aufzuwendende magnetische Energie beim absoluten Nullpunkt gleich der thermischen Energie kT beim Sprungpunkt. Auch genügend inhomogene

Figure 6.129: Josef Schintlmeister developed a correct theory of superconductivity, later known as Cooper pairs of electrons, no later than 1945 [G-345, Deutsches Museum FA 002/0712; English translation in FIAT 63].



- 2 -

elektrische Felder sprengen oder lockern die Bindung. Die supraleitenden Elektronen können daher, wie die Rechnung zeigt, beim Aufbau der Elektronenhülle der Atome nicht beteiligt sein und das periodische elektrische Feld im Innern des Kristallgitters ist für die Höhe des Sprungpunktes und auch dafür massgebend, ob überhaupt supraleitende Elektronen sich bilden können. Die Bielektronen haben alle Eigenschaften, die Lendon und von Laue bei ihrer elektrodynamischen Theorie von den supraleitenden Elektronen voraussetzen. Diese Theorie lässt bekanntlich verstehen: die Abschirmung äusserer Magnetfelder wegen der Induktion von Dauerströmen, die endliche Eindringtiefe von Magnetfeldern, den alleinigen Einfluss der Selbstinduktion der Leiter für die Stromstärken bei Verzweigungen und auch, wenn man die Temperaturabhängigkeit der Dichte der Supraleitungselektronen in Betracht zieht, den Meissner-Ochsenfeld-Effekt.

Josef Schintlmeister

Josef Schintlmeister
(1908–1971)

Detailed theory of superconductivity, much later called “Cooper” electron pairs

Figure 6.130: Josef Schintlmeister developed a correct theory of superconductivity, later known as Cooper pairs of electrons, no later than 1945 [G-345, Deutsches Museum FA 002/0712; English translation in FIAT 63].

T. M. Odarenko. FIAT 63. *Activities of the Second Institute of Physics of the University of Vienna.* p. 30 [the original German version of this report is G-345, pp. 1116–1117]:

Supplement 3.

Idea for a New Model for Super-Conductivity

by

Josef Schintlmeister

Point of departure of the theory is the idea that the super-conducting electrons do not follow the Fermi statistics but follow Bose statistics and thereby for practical purposes it possesses the Maxwell velocity distribution. Two electrons unite during the forming of the super-conducting electrons when activated by a force in all three directions with easily-computed quantum-mechanical penetration of the potential barrier to a very loosely bound "bielectron". The binding is possible, since the magnetic attraction surpasses the Coulomb repulsion as early as a distance of 50-fold, classical electron-radii. Similar to the thermic disassociation of two-atomic gases, the temperature dependence of the number of super-conducting electrons can be reckoned. The zero energy point of the electrons which become free at the change of statistics with Fermi statistics is the cause of the increase of the specific heat in the super-conducting state; from this the momentary number of the super-conducting electrons can be determined in agreement with this computation. The disappearance of all the components of the electrical resistance (residual resistance, contact resistance, thermic part of resistance) is explained by the considerably larger electron wave-length of the super-conducting electrons; the electron wave-lengths are considerably larger due to the low zero-energy point. A sufficiently strong magnetic field directs the magnetic moment and thus destroys the binding. For the magnetically insensitive superconductors (e.g., PbBl, PbHg), the magnetic energy to be used at the absolute zero-point is equal to the thermic energy kT at the elastic point. Sufficiently inhomogenous electrical fields destroy or loosen the binding. Thus the super-conducting electrons cannot take part in the construction of the electron orbit of the atoms and the periodic, electrical field in the interior of the crystal lattice is decisive for the height of the elastic point and also decisive for the contingency of whether super-conducting electrons can be formed or not. The bielectrons have all the properties which were pre-supposed in the electrodynamic theory of super-conducting electrons by London and von Laue. This theory makes very obvious: the screening of external magnetic penetration of magnetic fields due to the induction of the permanent current, the finite depth-penetration of magnetic fields, the individual influence of the self-induction of the conductors for the current strengths in the branchings and also, if one takes into consideration the temperature dependence of the density of the super-conductor electrons and the Meissner-Ochsenfeld Effect.

To complete the discussion of superconductivity, it should also be mentioned that K. Alex Müller (Swiss, 1927–) and his student Johannes Georg Bednorz (German, 1950–) developed the first high-temperature ceramic superconductors, for which they won the Nobel Prize in Physics in 1987. Professor Gösta Ekspong of the Royal Academy of Sciences explained the importance of their work [https://www.nobelprize.org/prizes/physics/1987/ceremony-speech/]:

> The Nobel Prize for Physics has been awarded to Dr. Georg Bednorz and Professor Dr. Alex Müller by the Royal Swedish Academy of Sciences "for their important breakthrough in the discovery of superconductivity in ceramic materials". This discovery is quite recent—less than two years old—but it has already stimulated research and development throughout the world to an unprecedented extent. The discovery made by this year's laureates concerns the transport of electricity without any resistance whatsoever and also the expulsion of magnetic flux from superconductors. [...]
>
> Dr. Bednorz and Professor Müller started some years ago a search for superconductivity in materials other than the usual alloys. Their new approach met with success early last year, when they found a sudden drop towards zero resistance in a ceramic material consisting of lanthanum-barium-copper oxide. Sensationally, the boundary temperature was 50 % higher than ever before, as measured from absolute zero. The expulsion of magnetic flux, which is a sure mark of superconductivity, was shown to occur in a following publication.

Also for completeness, two other postwar discoveries in cryogenic electrical properties should be mentioned.

Klaus von Klitzing (German, 1943–, Fig. 6.131) discovered the quantum Hall effect, in which the electrical conductivity at the surface of a cryogenic semiconductor in a strong magnetic field can only assume integer multiples of a certain value. He won the Nobel Prize in Physics in 1985. Professor Stig Lundqvist of the Royal Swedish Academy of Sciences praised von Klitzing's discovery [https://www.nobelprize.org/prizes/physics/1985/ceremony-speech/]:

> von Klitzing studied the Hall effect under quite extreme conditions. He used an extremely high magnetic field and cooled his samples to just a couple of degrees above the absolute zero point of temperature. Instead of the regular change one would expect, he found some very characteristic steps with plateaus in the conductivity. The values at these plateaus can with extremely high accuracy be expressed as an integer times a simple expression that just depends of two fundamental constants: the electric elementary charge and Planck's constant which appear everywhere in quantum physics.
>
> The result represents a quantization of the Hall effect—a completely unexpected effect. The accuracy in his results was about one part in ten million, which would correspond to measuring the distance between Stockholm and von Klitzing's home station Stuttgart with an accuracy of a few centimeters. The discovery of the quantized Hall effect is a beautiful example of the close interrelation between the highly advanced technology in the semiconductor industry and fundamental research in physics. The samples used by von Klitzing were relined versions of a kind of transistor we have in our radios. His samples, however, had to satisfy extremely high standards of perfection and could only be made by using a highly advanced technique and refined technology. [...]

> von Klitzing's discovery of the quantized Hall effect attracted immediately an enormous interest. Because of the extremely high accuracy the effect can be used to define an international standard for electric resistance. The metrological possibilities are of great importance and have been subject to detailed studies at many laboratories all over the world.
>
> The quantized Hall effect is one of the few examples, where quantum effects can be studied in ordinary macroscopic measurements. The underlying detailed physical mechanisms are not yet fully understood. Later experiments have revealed completely new and unexpected properties and the study of two-dimensional systems is now one of the most challenging areas of research in physics.

Horst Störmer (German, 1949–, Fig. 6.131) discovered the fractional quantum Hall effect, for which he won the Nobel Prize in Physics in 1998. The Royal Swedish Academy of Sciences summarized his work [https://www.nobelprize.org/prizes/physics/1998/stormer/facts/] :

> The Hall effect refers to the fact that if an electrical current flows lengthwise through a metal band and a magnetic field is placed against the surface of the band at a right angle, a charge arises diagonally in the band. In interfaces in certain materials a quantum Hall effect occurs. Klaus von Klitzing discovered that changes in the magnetic field result in changes in what is known as Hall conductance that vary in steps of whole-number multiples of a constant. Subsequently, Horst Störmer and Daniel Tsui discovered in 1982 that there also are steps that represent fractions of the constant.

Klaus von Klitzing (1943–)
1985 Nobel Prize in Physics
Quantum Hall effect

Horst Störmer (1949–)
1998 Nobel Prize in Physics
Fractional quantum Hall effect

In the quantum Hall effect, the electrical conductivity of a semiconductor surface increases in "stair steps" as the strength of an applied magnetic field (B) is changed.

The fractional quantum Hall effect is similar but with smaller stair steps.

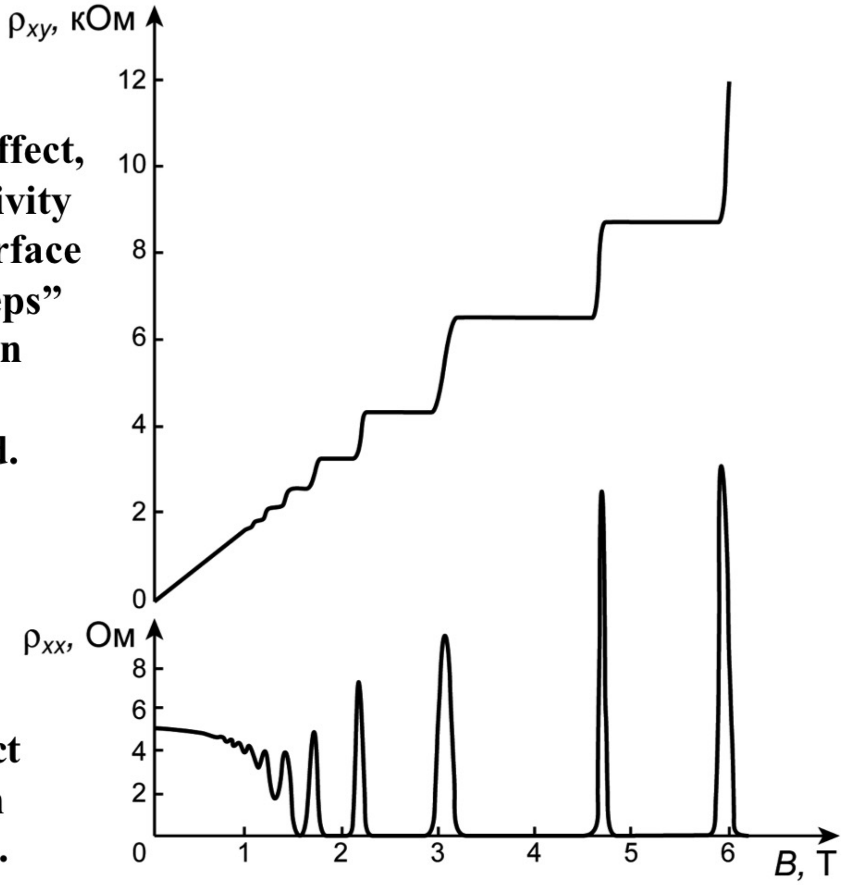


Figure 6.131: Klaus von Klitzing won the 1985 Nobel Prize in Physics for discovering the quantum Hall effect, and Horst Störmer won the 1998 Nobel Prize in Physics for the fractional quantum Hall effect.

6.5.10 Piezoelectricity

Piezoelectricity is an effect in quartz and certain other crystals in which small deformations of the crystal lattice (due to exerted pressure) shift the relative positions of charged ions and produce large electric fields and voltages. Thus piezoelectric crystals make ideal sensors for pressure or acceleration, convenient microphones to convert acoustic vibrations to electrical oscillations, and compact generators for producing high voltages for other components. The effect also operates in reverse—an applied voltage produces a small deformation of the crystal. Therefore, electrically stimulated piezoelectric crystals can be used as actuators to make small, controlled motions, for example by fine-tuning the focus of optical systems, oscillating to generate sound waves, or maintaining a constant vibration frequency to serve as a time standard in a clock or watch.

Piezoelectricity was initially discovered by the French brothers Pierre Curie (1859–1906) and Jacques Curie (1856–1941) in 1880. Their discovery prompted further studies of piezoelectricity over the following decades in France, the United Kingdom, the United States, and elsewhere.

Yet it was especially in the greater German-speaking world that piezoelectricity received an enormous amount of research attention, with large numbers of scientists exploring natural and synthetic piezoelectric materials, devising theoretical explanations of piezoelectricity, and developing a wide range of applications for piezoelectric elements.[15] Some of the more prominent scientists are discussed below, and a few of them are shown in Figs. 6.132–6.134.

Woldemar Voigt (German, 1850–1919) was one of the first major scientists to study piezoelectricity in detail after its initial discovery. He spent many years conducting experiments on the topic, and he also developed the first good theoretical explanation for piezoelectricity. He published most of his insights in his 1910 textbook, *Lehrbuch der Kristallphysik.* Voigt used sophisticated tensor analysis to calculate piezoelectric effects, and he described 20 different classes of natural crystals that exhibited piezoelectric effects.

Independently of Voigt but in parallel with him, Wilhelm Röntgen (German, 1845–1923) also spent many years investigating piezoelectricity. He finally published most of his results in 1914. Directly through their teaching and mentorship, and indirectly through their publications, Voigt and Röntgen inspired large numbers of younger scientists throughout the predominantly German-speaking scientific world to study and harness piezoelectricity.

Scientists at Jena University and the Zeiss optical company in Jena collaborated to study piezoelectric vibrations and the optical effects they could produce. Those scientists included (in alphabetical order): H.E.R. Becker (German, 18??–19??), Eduard Gerber (German, 1907–1986), Ernst Grossmann (German, 18??–19??), Norbert Günther (German, 18??–19??), ?? Hehlgans (German, 18??–19??), Harald Straubel (German, 1905–1991), and Max Wien (German, 1866–1938). (After the war, Gerber led research on piezoelectric devices at the U.S. Army's Fort Monmouth lab [Fort Monmouth Historical Office 2008; Gerber-Stroh 2012].)

At Göttingen University, Elisabeth Bormann (German, 18??–19??), Max Born (German, 1882–1970, p. 1040), ?? Gockel (German, 18??–19??), Gustav Heckmann (German, 1898–1996), and Max von Laue (German, 1879–1960) worked out detailed theoretical explanations of piezoelectricity.

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[15] Katzir 2006, 2018; BIOS 255; BIOS 552; BIOS 609; BIOS 724; BIOS 865; BIOS 1316; BIOS 1504; BIOS 1579; BIOS 1679; CIOS XXV-13; FIAT 575; FIAT 641; FIAT 642; FIAT 1098; NavTecMisEu 361-45.

Scientists at Breslau University developed piezoelectric devices for ultrasonic systems, acoustic levitation of small objects, and other applications. That research group included Hans Ludwig Bergmann (German, 1898–1959), Karl Bücks (German, 18??–19??), Erwin Fues (German, 1893–1970), ?? Kraefft (German, 18??–19??), ?? Lonn (German, 18??–19??), Hanfried Ludloff (German, 1899–1987), Hans Müller (German, 18??–19??), and Clemens Schaefer (German, 1878–1968).

At the Physikalisch-Technische Reichsanstalt (PTR), Udo Adelsberger (German, 1904–1992), Erich Blechschmidt (German, 18??–19??), Erich Giebe (German, 18??–19??), and Adolf Scheibe (German, 1895–1958) invented piezoelectric resonators that could be used as a very accurate frequency standard. Adelsberger later developed precise quartz clocks that were used to control timed reentry maneuvers by the U.S. Apollo spacecraft returning from the moon.

Working at Telefunken in Berlin, Rudolf Bechmann (German, 1902–1974), Kurt Heegner (German, 1893–1965), and Alexander Meissner (Austrian, 1883–1958) also created sophisticated piezoelectric resonators and conducted theoretical analyses of piezoelectricity. Bechmann continued his work in the United States after the war.

At Cologne University, H. R. Asbach (German, 19??–19??), Egon Hiedemann (German, 1900–1969), and K. H. Hoesch (German, 19??–19??) developed novel methods and applications involving the interactions of acoustic and optical waves in piezoelectric crystals.

Frankfurt University scientists such as Hermann Auer (German, 19??–19??), H. Doerffler (German, 19??–19??), and Richard Wachsmuth (German, 1868–1941) also carried out important work on piezoelectricity.

At Graz University, Berta Nussbaumer (Austrian?, 19??–19??) and Angelika Székely (Austrian?, 18??–19??) conducted experiments on piezoelectricity and its applications. Regrettably, historians of science seem to have paid little attention to these important female physicists.

Walter P. Kistler (Swiss, 1918–2015) developed sophisticated piezoelectric sensors before, during, and after World War II.

At Philips Eindhoven, B. van Dijl (Dutch, 19??–19??) and Balthasar van der Pol (Dutch, 1889–1959) studied and harnessed piezoelectricity.

There was a large research team working on piezoelectricity at Charles University and related institutions in Prague, carrying out X-ray studies and using piezoelectric vibrations. That team included ?? Dolejšek (Czech/Austrian, 19??–19??), ?? Jahoda (Czech/Austrian, 19??–19??), František Khol (Czech/Austrian, 19??–19??), Franz Krista (Austrian?, 19??–19??), Václav Petržílka (Czech/Austrian, 1905–1976), August Žáček (Czech/Austrian, 1886–1961), and L. Zachoval (Czech/Austrian, 19??–19??).

After World War II, large amounts of piezoelectric-related information, materials, and scientists were transferred from the German-speaking world to Allied countries (Fig. 6.135). See for example:

> BIOS 255. *Gas Turbine and Reciprocating Engine Activities.* [Piezoelectric sensors in engines]

BIOS 552. *Report on the Investigation on the Production of Synthetic Crystals in Germany and Copenhagen.*

BIOS 609. *Non-destructive Testing of Materials.*

BIOS 724. *Electronic Principles as Applied in Germany to the Testing of Materials.*

BIOS 865. *German Quartz Clocks and Frequency Standards.*

BIOS 1316. *German Quartz Clocks.*

BIOS 1504. *Industrial Applications of Ultrasonics.*

BIOS 1579. *Growing of Crystals.*

BIOS 1679. *Ultrasonic Material Testing and Other Applications.*

CIOS XXV-13. *Messrs. Steeg and Reuter Bad Homburg.* [Piezoelectrics and optical crystals]

FIAT 575. *Developments in Diesel Engineering.* [Piezoelectric sensors in engines]

FIAT 641. *The Interrogation of German Scientists Regarding Quartz Crystals and other Piezoelectric Materials.*

FIAT 642. *Measurement of Acceleration and Vibration.*

FIAT 1098. *Etch and Percussion Figures, and Twinning of Quartz.*

NavTecMisEu 361-45. *Piezo Pressure Measurements.*

Some of these documents also prove that German-speaking scientists developed piezoelectric sensors for aircraft engines and automobile engines before and during World War II, and that that technology was transferred to Allied countries after the war (Figs. 6.136–6.137). Piezoelectric sensors are now widely used in engines to optimize the operating conditions and report any problems.

See also the closely related research on sonar (p. 1241), ultrasound imaging (p. 1250), and other applications (p. 3181).

Please see Appendix B for much more information on some of the German-speaking creators and their creations in the field of microelectronics, as well as documents showing how those technologies were transferred to other countries.

Piezoelectricity

Rudolf Bechmann
(1902–1974)

Erwin Fues
(1893–1970)

Eduard Gerber
(1907–1986)

Gustav Heckmann
(1898–1996)

Kurt Heegner
(1893–1965)

Egon Hiedemann
(1900–1969)

Figure 6.132: Some creators who made important contributions to piezoelectricity included Rudolf Bechmann, Erwin Fues, Eduard Gerber, Gustav Heckmann, Kurt Heegner, and Egon Hiedemann.

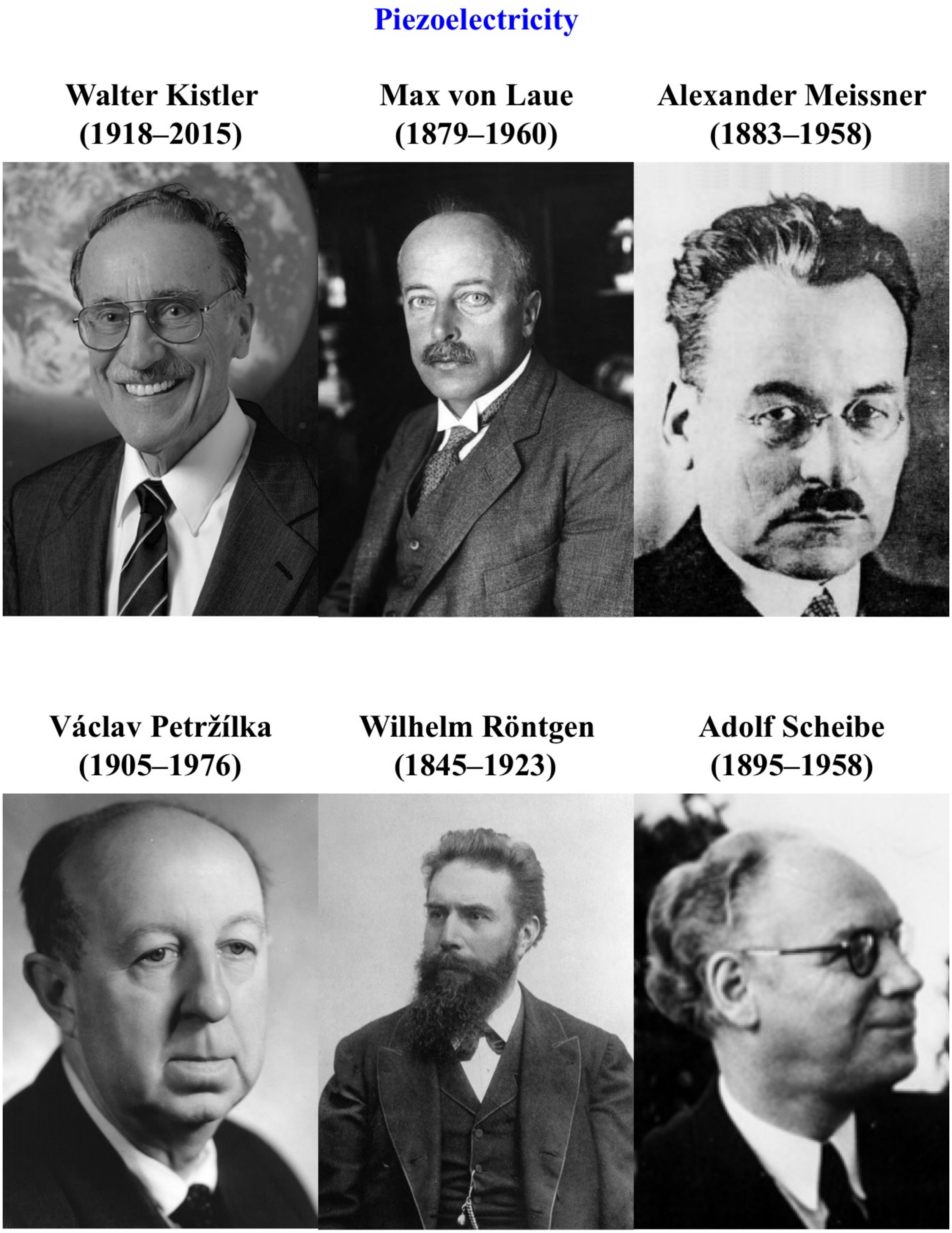

Piezoelectricity
Walter Kistler (1918–2015)
Max von Laue (1879–1960)
Alexander Meissner (1883–1958)
Václav Petržílka (1905–1976)
Wilhelm Röntgen (1845–1923)
Adolf Scheibe (1895–1958)

Figure 6.133: Other creators who made important contributions to piezoelectricity included Walter Kistler, Max von Laue, Alexander Meissner, Václav Petržílka, Wilhelm Röntgen, and Adolf Scheibe.

Piezoelectricity

Harald Straubel (1905–1991)

Angelika Székely (18??–19??)

Balthasar van der Pol (1889–1959)

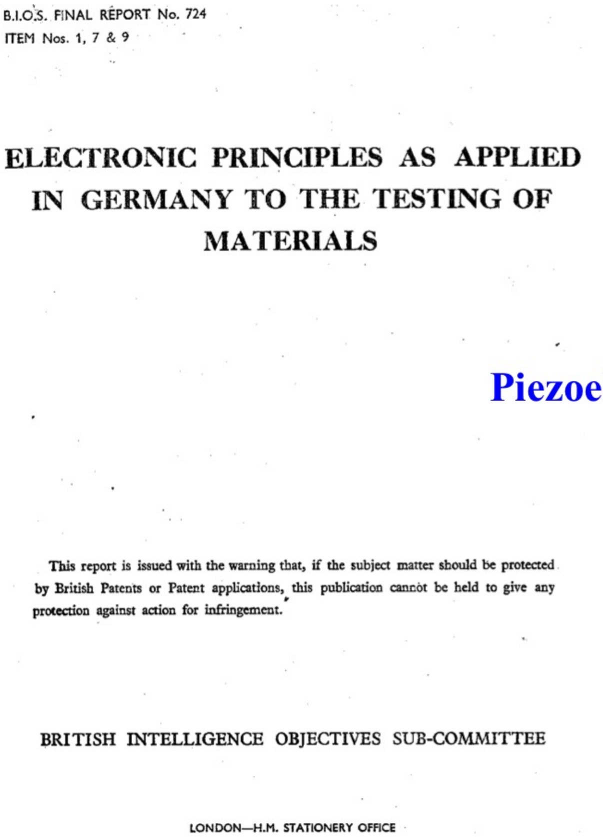
Woldemar Voigt (1850–1919)

Richard Wachsmuth (1868–1941)

August Žáček (1886–1961)

Figure 6.134: Other creators who made important contributions to piezoelectricity included Harald Straubel, Angelika Székely, Balthasar van der Pol, Woldemar Voigt, Richard Wachsmuth, and August Žáček.

Piezoelectricity



B.I.O.S. FINAL REPORT No. 724
ITEM Nos. 1, 7 & 9

ELECTRONIC PRINCIPLES AS APPLIED IN GERMANY TO THE TESTING OF MATERIALS

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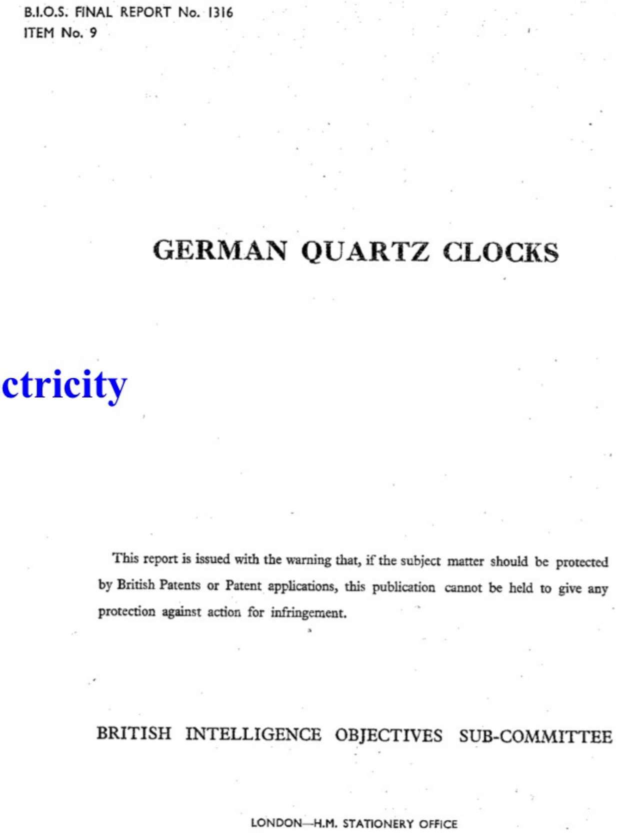

B.I.O.S. FINAL REPORT No. 1316
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GERMAN QUARTZ CLOCKS

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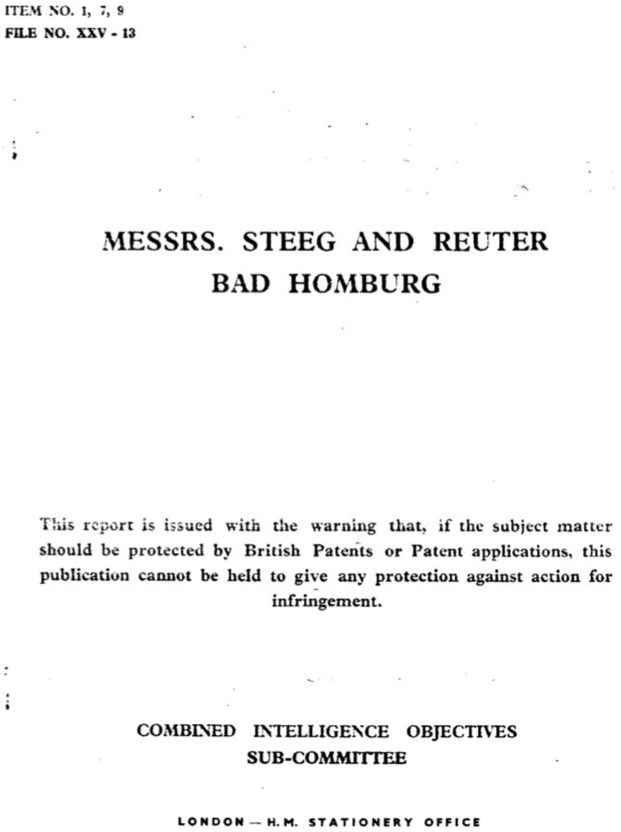

ITEM NO. 1, 7, 9
FILE NO. XXV - 13

MESSRS. STEEG AND REUTER BAD HOMBURG

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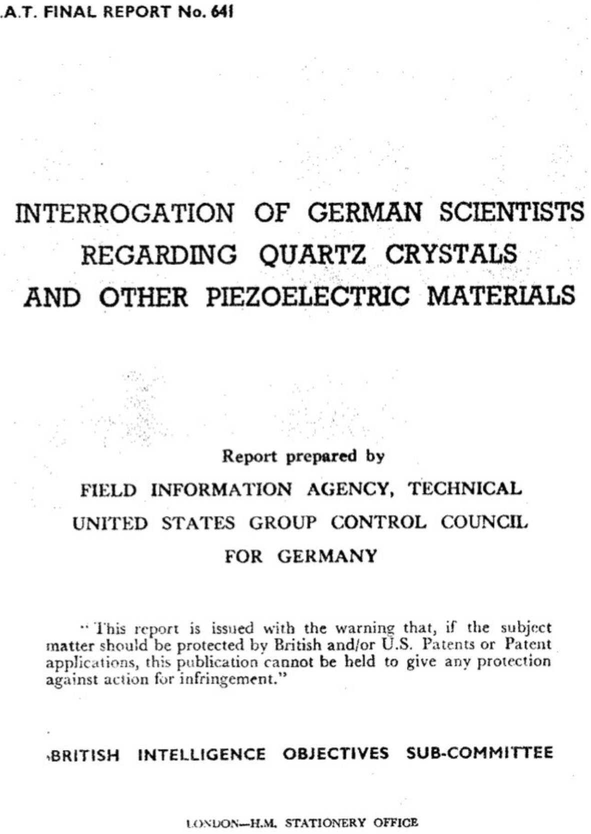

F.I.A.T. FINAL REPORT No. 641

INTERROGATION OF GERMAN SCIENTISTS REGARDING QUARTZ CRYSTALS AND OTHER PIEZOELECTRIC MATERIALS

Report prepared by
FIELD INFORMATION AGENCY, TECHNICAL
UNITED STATES GROUP CONTROL COUNCIL
FOR GERMANY

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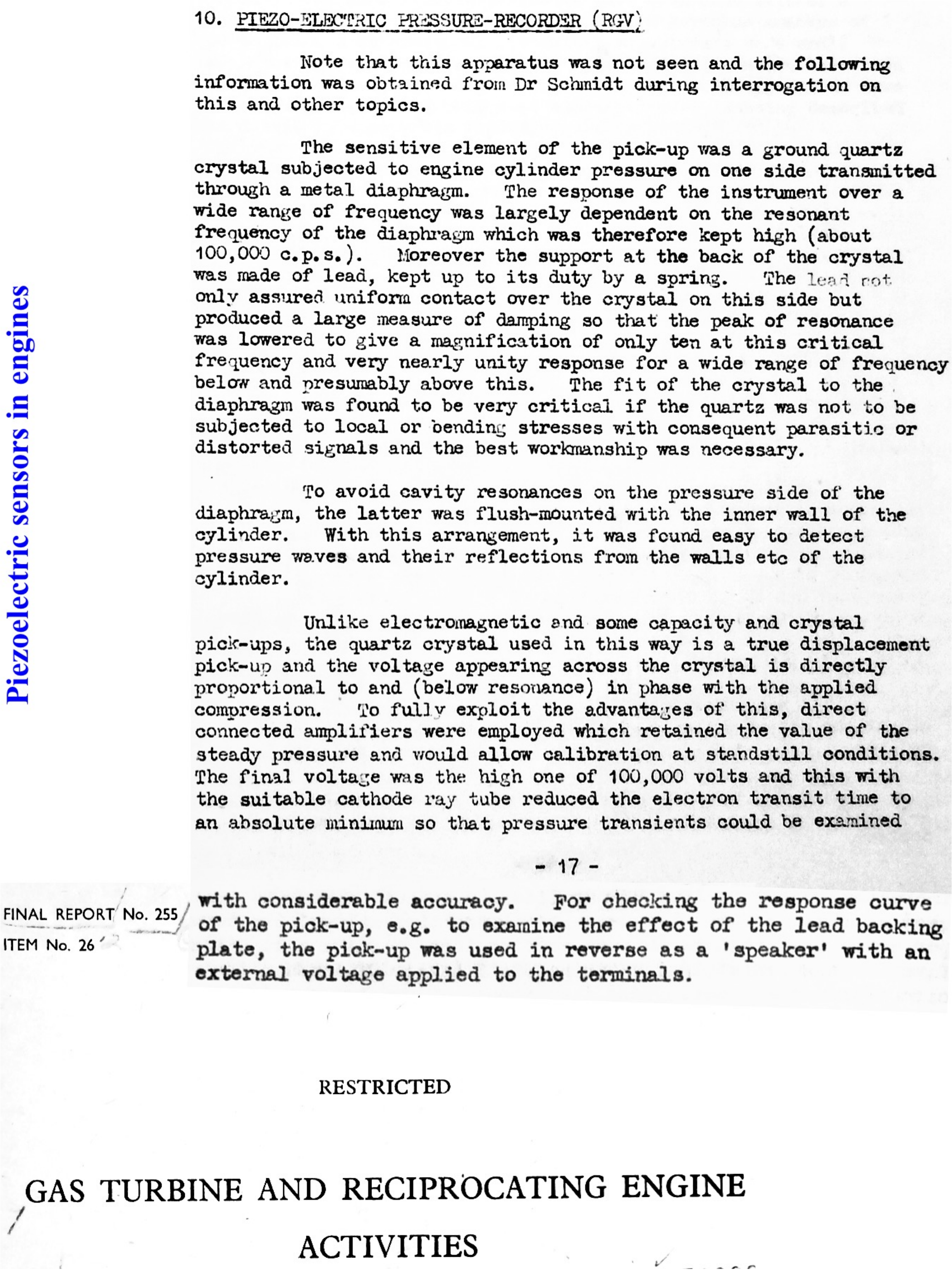
BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE

LONDON—H.M. STATIONERY OFFICE

Figure 6.135: Large amounts of information, materials, and scientists related to piezoelectric technologies were transferred out of the German-speaking world after World War II [BIOS 724; BIOS 1316; CIOS XXV-13; FIAT 641].

Piezoelectric sensors in engines



10. PIEZO-ELECTRIC PRESSURE-RECORDER (RGV)

Note that this apparatus was not seen and the following information was obtained from Dr Schmidt during interrogation on this and other topics.

The sensitive element of the pick-up was a ground quartz crystal subjected to engine cylinder pressure on one side transmitted through a metal diaphragm. The response of the instrument over a wide range of frequency was largely dependent on the resonant frequency of the diaphragm which was therefore kept high (about 100,000 c.p.s.). Moreover the support at the back of the crystal was made of lead, kept up to its duty by a spring. The lead not only assured uniform contact over the crystal on this side but produced a large measure of damping so that the peak of resonance was lowered to give a magnification of only ten at this critical frequency and very nearly unity response for a wide range of frequency below and presumably above this. The fit of the crystal to the diaphragm was found to be very critical if the quartz was not to be subjected to local or bending stresses with consequent parasitic or distorted signals and the best workmanship was necessary.

To avoid cavity resonances on the pressure side of the diaphragm, the latter was flush-mounted with the inner wall of the cylinder. With this arrangement, it was found easy to detect pressure waves and their reflections from the walls etc of the cylinder.

Unlike electromagnetic and some capacity and crystal pick-ups, the quartz crystal used in this way is a true displacement pick-up and the voltage appearing across the crystal is directly proportional to and (below resonance) in phase with the applied compression. To fully exploit the advantages of this, direct connected amplifiers were employed which retained the value of the steady pressure and would allow calibration at standstill conditions. The final voltage was the high one of 100,000 volts and this with the suitable cathode ray tube reduced the electron transit time to an absolute minimum so that pressure transients could be examined

- 17 -

with considerable accuracy. For checking the response curve of the pick-up, e.g. to examine the effect of the lead backing plate, the pick-up was used in reverse as a 'speaker' with an external voltage applied to the terminals.

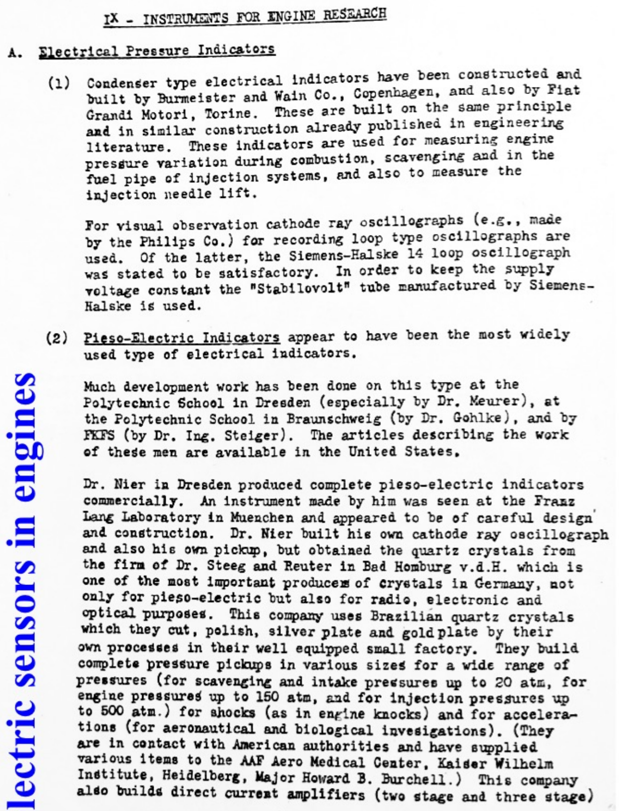
FINAL REPORT No. 255
ITEM No. 26

RESTRICTED

GAS TURBINE AND RECIPROCATING ENGINE ACTIVITIES

Figure 6.136: German-speaking scientists developed piezoelectric sensors for aircraft engines before and during World War II, and that technology was transferred to Allied countries after the war [BIOS 255].

Piezoelectric sensors in engines



IX - INSTRUMENTS FOR ENGINE RESEARCH

A. Electrical Pressure Indicators

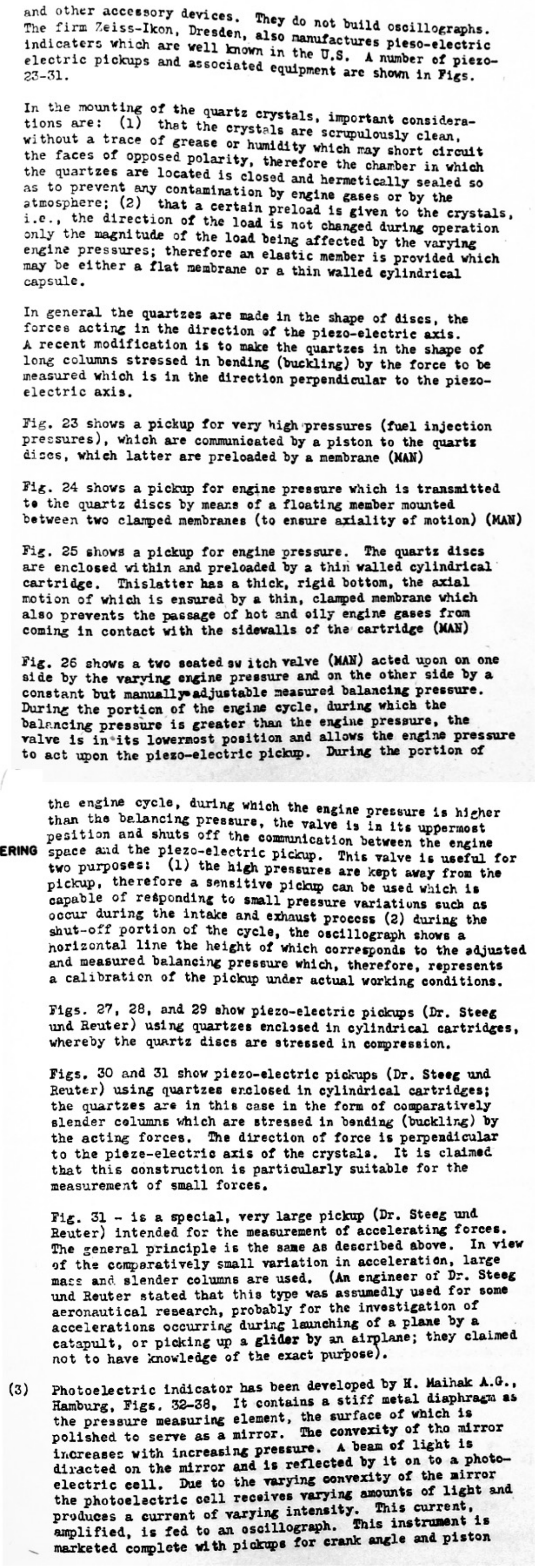
(1) Condenser type electrical indicators have been constructed and built by Burmeister and Wain Co., Copenhagen, and also by Fiat Grandi Motori, Torine. These are built on the same principle and in similar construction already published in engineering literature. These indicators are used for measuring engine pressure variation during combustion, scavenging and in the fuel pipe of injection systems, and also to measure the injection needle lift.

For visual observation cathode ray oscillographs (e.g., made by the Philips Co.) for recording loop type oscillographs are used. Of the latter, the Siemens-Halske 14 loop oscillograph was stated to be satisfactory. In order to keep the supply voltage constant the "Stabilovolt" tube manufactured by Siemens-Halske is used.

(2) Pieso-Electric Indicators appear to have been the most widely used type of electrical indicators.

Much development work has been done on this type at the Polytechnic School in Dresden (especially by Dr. Meurer), at the Polytechnic School in Braunschweig (by Dr. Gohlke), and by FKFS (by Dr. Ing. Steiger). The articles describing the work of these men are available in the United States.

Dr. Nier in Dresden produced complete pieso-electric indicators commercially. An instrument made by him was seen at the Franz Lang Laboratory in Muenchen and appeared to be of careful design and construction. Dr. Nier built his own cathode ray oscillograph and also his own pickup, but obtained the quartz crystals from the firm of Dr. Steeg and Reuter in Bad Homburg v.d.H. which is one of the most important producers of crystals in Germany, not only for pieso-electric but also for radio, electronic and optical purposes. This company uses Brazilian quartz crystals which they cut, polish, silver plate and gold plate by their own processes in their well equipped small factory. They build complete pressure pickups in various sizes for a wide range of pressures (for scavenging and intake pressures up to 20 atm, for engine pressures up to 150 atm, and for injection pressures up to 500 atm.) for shocks (as in engine knocks) and for accelerations (for aeronautical and biological invesigations). (They are in contact with American authorities and have supplied various items to the AAF Aero Medical Center, Kaiser Wilhelm Institute, Heidelberg, Major Howard B. Burchell.) This company also builds direct current amplifiers (two stage and three stage) and other accessory devices. They do not build oscillographs. The firm Zeiss-Ikon, Dresden, also manufactures pieso-electric indicaters which are well known in the U.S. A number of piezo-electric pickups and associated equipment are shown in Figs. 23-31.



In the mounting of the quartz crystals, important considerations are: (1) that the crystals are scrupulously clean, without a trace of grease or humidity which may short circuit the faces of opposed polarity, therefore the chamber in which the quartzes are located is closed and hermetically sealed so as to prevent any contamination by engine gases or by the atmosphere; (2) that a certain preload is given to the crystals, i.e., the direction of the load is not changed during operation only the magnitude of the load being affected by the varying engine pressures; therefore an elastic member is provided which may be either a flat membrane or a thin walled cylindrical capsule.

In general the quartzes are made in the shape of discs, the forces acting in the direction of the piezo-electric axis. A recent modification is to make the quartzes in the shape of long columns stressed in bending (buckling) by the force to be measured which is in the direction perpendicular to the piezo-electric axis.

Fig. 23 shows a pickup for very high pressures (fuel injection pressures), which are communicated by a piston to the quartz discs, which latter are preloaded by a membrane (MAN)

Fig. 24 shows a pickup for engine pressure which is transmitted to the quartz discs by means of a floating member mounted between two clamped membranes (to ensure axiality of motion) (MAN)

Fig. 25 shows a pickup for engine pressure. The quartz discs are enclosed within and preloaded by a thin walled cylindrical cartridge. Thislatter has a thick, rigid bottom, the axial motion of which is ensured by a thin, clamped membrane which also prevents the passage of hot and oily engine gases from coming in contact with the sidewalls of the cartridge (MAN)

Fig. 26 shows a two seated switch valve (MAN) acted upon on one side by the varying engine pressure and on the other side by a constant but manually-adjustable measured balancing pressure. During the portion of the engine cycle, during which the balancing pressure is greater than the engine pressure, the valve is in its lowermost position and allows the engine pressure to act upon the piezo-electric pickup. During the portion of the engine cycle, during which the engine pressure is higher than the balancing pressure, the valve is in its uppermost position and shuts off the communication between the engine space and the piezo-electric pickup. This valve is useful for two purposes: (1) the high pressures are kept away from the pickup, therefore a sensitive pickup can be used which is capable of responding to small pressure variations such as occur during the intake and exhaust process (2) during the shut-off portion of the cycle, the oscillograph shows a horizontal line the height of which corresponds to the adjusted and measured balancing pressure which, therefore, represents a calibration of the pickup under actual working conditions.

Figs. 27, 28, and 29 show piezo-electric pickups (Dr. Steeg und Reuter) using quartzes enclosed in cylindrical cartridges, whereby the quartz discs are stressed in compression.

Figs. 30 and 31 show piezo-electric pickups (Dr. Steeg und Reuter) using quartzes enclosed in cylindrical cartridges; the quartzes are in this case in the form of comparatively slender columns which are stressed in bending (buckling) by the acting forces. The direction of force is perpendicular to the pieze-electric axis of the crystals. It is claimed that this construction is particularly suitable for the measurement of small forces.

Fig. 31 - is a special, very large pickup (Dr. Steeg und Reuter) intended for the measurement of accelerating forces. The general principle is the same as described above. In view of the comparatively small variation in acceleration, large mass and slender columns are used. (An engineer of Dr. Steeg und Reuter stated that this type was assumedly used for some aeronautical research, probably for the investigation of accelerations occurring during launching of a plane by a catapult, or picking up a glider by an airplane; they claimed not to have knowledge of the exact purpose).

(3) Photoelectric indicator has been developed by H. Maihak A.G., Hamburg, Figs. 32-38. It contains a stiff metal diaphragm as the pressure measuring element, the surface of which is polished to serve as a mirror. The convexity of the mirror increases with increasing pressure. A beam of light is directed on the mirror and is reflected by it on to a photoelectric cell. Due to the varying convexity of the mirror the photoelectric cell receives varying amounts of light and produces a current of varying intensity. This current, amplified, is fed to an oscillograph. This instrument is marketed complete with pickups for crank angle and piston

FIAT FINAL REPORT 575

DEVELOPMENTS IN DIESEL ENGINEERING

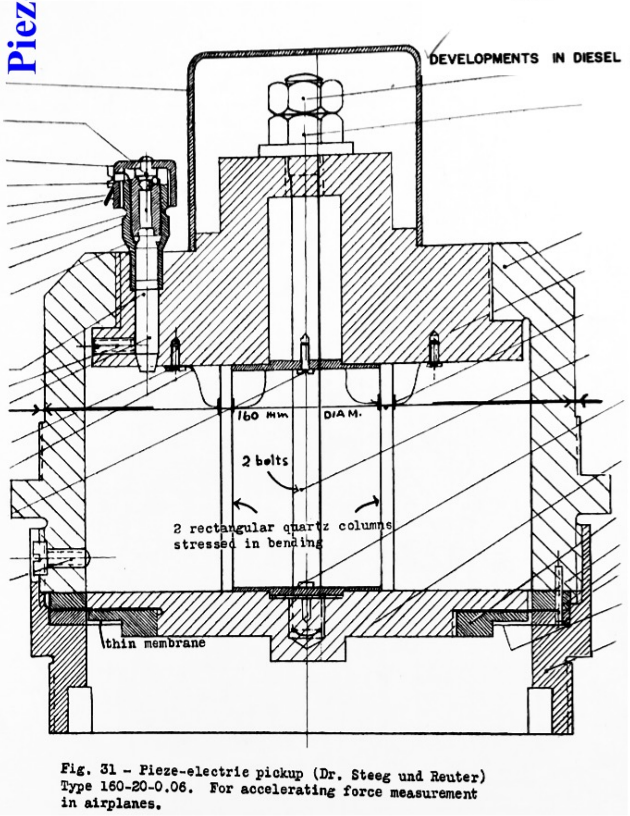


Fig. 31 - Pieze-electrie pickup (Dr. Steeg und Reuter) Type 160-20-0.06. For accelerating force measurement in airplanes.

Figure 6.137: German-speaking scientists developed piezoelectric sensors for automobile engines before and during World War II, and that technology was transferred to Allied countries after the war [FIAT 575].

6.6 Infrared Vision and Targeting

German-speaking creators played crucial roles in the development of infrared technologies, from the initial discovery of infrared light to the invention of infrared systems for night vision, optical communications, and heat-seeking missiles.[16] Those technologies were developed in Germany and Austria (Section 6.6.1) and then transferred to other countries after World War II (Section 6.6.2).

6.6.1 Development of Infrared Technologies

Using spectroscopy to search for energy beyond the colors of visible light, Friedrich Wilhelm (William) Herschel (Hanover, 1738–1822) discovered infrared light in 1800 [Herschel 1800]. See Fig. 6.138. He also discovered the planet Uranus and made several other important astronomical discoveries (p. 802).

Technologies such as photoelectric cells (p. 1046) and cathode ray tubes (p. 996) that had been invented by German-speaking scientists in the late nineteenth century and improved in the early twentieth century were later harnessed to detect infrared light for a wide variety of applications.

In 1941, Herbert C. J. Gaertner (German, 1906–19??) at the Zeiss optical company developed the Fahrgerät FG 1250 infrared vision system for nighttime driving. As shown in Fig. 6.139, the FG 1250 system combined a lamp that emitted only infrared light with a viewing scope that converted infrared to visible light. The FG 1250 system was also used for nighttime tank warfare (Fig. 6.140). Figure 6.141 shows an example of an armored vehicle with two FG 1250 infrared vision systems, one for a nighttime antiaircraft gun and another for nighttime driving.

The Uhu system was a closely related infrared vision system that was equipped with a larger nighttime infrared searchlight; see Fig. 6.142.

The Zielgerät 1229 Vampir (Vampire) infrared night-vision system for snipers was first operational in 1944. Figure 6.143 present photos of a ZG 1229 being demonstrated by a British soldier after the war. ZG 1229 and more advanced versions directly descended from it were rapidly adopted by Allied troops, and have been widely used ever since by everyone from soldiers to police to hunters.

Whereas the above systems all used relatively large viewing scopes, infrared viewing was also adapted to a compact binocular format, essentially producing the first infrared night-vision goggles. After the war, Allied investigators found prototypes of the infrared binoculars (Fig. 6.144) and used them as the basis for developing later versions of night-vision goggles.

Both infrared and visible light were employed for communications. In 1901, Ernst Ruhmer (German, 1878–1913) demonstrated a photophone that used visible light to transmit voice communications (Fig. 6.145). By World War II, the compact Zeiss infrared Lichtsprechgerät was used for efficient optical transmission of voice communications over distances up to several kilometers; see Fig. 6.146. The Lichtsprechgerät was also demonstrated with visible light. These systems were the direct forerunners of fiber optic communications that are now employed worldwide, except the light signals were transmitted through air instead of through transparent optical fibers. Optical glass fibers were also invented in the German-speaking world (p. 680). More archival research is needed to determine if optical fibers were ever used or considered for use in conjunction with optical data transmission in wartime Germany.

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[16] See for example: Benecke and Quick 1957; Herschel 1800; BIOS 2; BIOS 211; BIOS 1345; BIOS Misc 66; CIOS ER 160; CIOS XXIV-7; CIOS XXX-3; CIOS XXX-108; CIOS XXXI-14; CIOS XXXIII-9; FIAT 4; FIAT 708; FIAT 769; FIAT 1172; JIOA 5; NavTecMisEu LR 77-45; NavTecMisEu LR 228-45; NavTecMisEu 109-45; NavTecMisEu 127-45; NavTecMisEu 242-45; NavTecMisEu 273-45; NavTecMisEu 274-45; NavTecMisEu 488-45; NavTecMisEu 497-45; NavTecMisEu 518-45; NavTecMisEu 519-45; AFHRA B1975, frames 1325–1495; NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards.

Another important application of infrared was in heat-seeking missiles that could automatically home in on the heat emitted by the engines of their target. As shown in Fig. 6.147, Edgar Kutzscher (German, 1906–1997) developed and demonstrated infrared tracking systems for heat-seeking missiles during the war. In fact, at least half a dozen different types of heat-seeking missile guidance systems were developed and built during the war. Figures 6.148–6.150 show some of their designs and creators.

After the war, Edgar Kutzscher discussed the development of the infrared photocells that were used in these heat-seeking missile guidance systems [Benecke and Quick 1957, pp. 208–209]:

> Practically all infrared devices developed before and during the war in Germany, and especially the devices which were used for detection of or homing on aircraft, used as receiver elements these photoconductive cells which we had developed at the ELEKTROACUSTIC CO. in Kiel. Dr. GOTTFRIED SOMMER, Dr. PICK, and Mr. KURT JUNG were my main co-operators in this part of the development.
>
> The cells which were available during the war fulfilled sufficiently the requirements of such an infrared detector. Extensive research and development work was still going on at the end of the war. [...] The lead sulphide cell of the ELEKTROACUSTIC CO. was produced by using a chemical precipitation method. Cells with various sizes and shapes of the sensitive area have been made. A large scale production was under way. Similar cells were developed by Dr. GÖRLICH at the laboratories of ZEISS-IKON in Dresden. GÖRLICH refined and used an evaporation method which was developed by the late Prof. GUDDEN.
>
> Much time and effort was spent in continuously improving the paramount properties of both types of cells, especially by modifying the production parameters and introducing the right impurities in the optimum amount.
>
> The sensitivity of those cells could be increased by a factor of 10 to 20 by cooling them. Liquid air and later solid CO_2 were used as coolants.

Kutzscher also described some of the heat-seeking systems and their creators [Benecke and Quick 1957, pp. 215–216]:

> Homing systems based on the principles described were developed by the ELEKTROACUSTIC CO. in Kiel, under the name “HAMBURG”. [...]
>
> For cases where the homing device detected the target before launching the missile, the homing device signals should be displayed to the pilot. For other cases, additional

infrared search devices installed in the aeroplane were developed. My main co-operators in the field of system development were Dr. RÜCKLIN, Dr. OCHMANN, Dr. AHRENS, Dr. HEITMÜLLER, and Dipl.-Ing. ORLICH.

Other infrared homing devices which were under development used in general the same principles we have discussed. The main difference between these various devices was the scanning method in order to obtain the angular information.

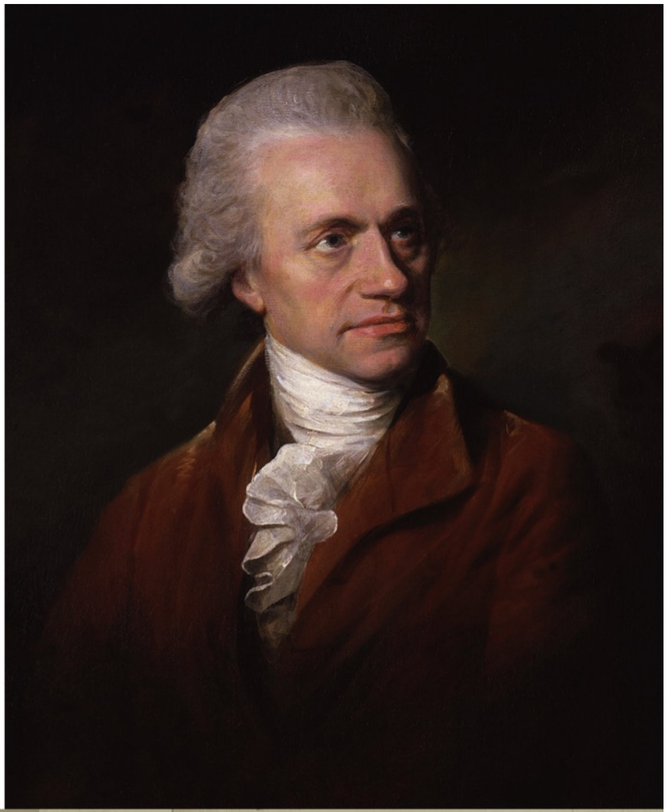
A device proposed by Dr. HILGERS of the AEG used a photocell with an area large enough to cover the total field of view in the focal plane. Two very narrow mechanical stops were moved perpendicular to each other across the cell. As soon as the image was covered by a stop a pulse was generated. [...] The firm KEPKA, in Vienna, used a similar principle by moving two narrow slits across the field. [...]

Mr. TRENKELFORD associated with RHEINMETALL-BORSIG developed a system for which the scanning was accomplished by two rotating discs, one of them having a spiral opening, the other one a slit. [...]

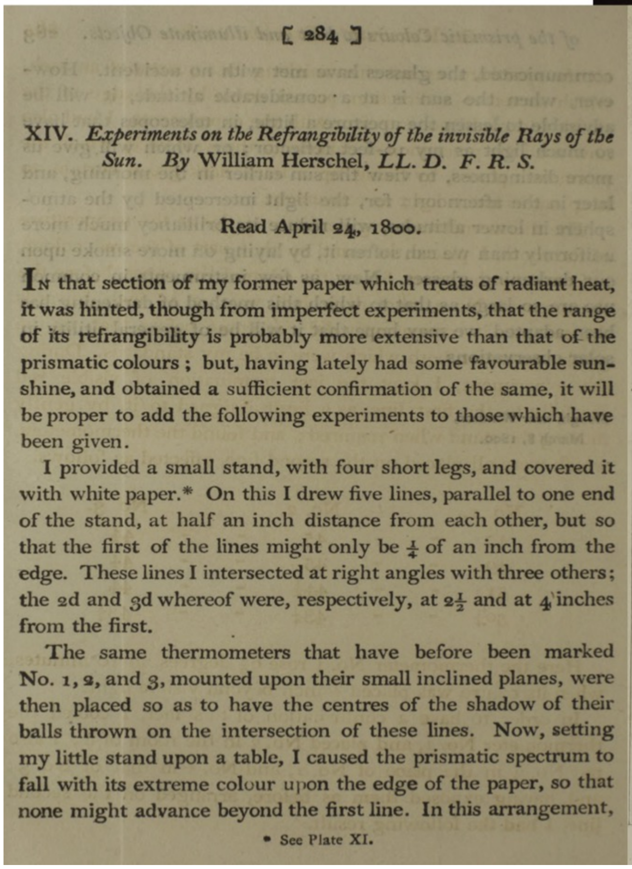
Dr. ORTHUBER of the AEG used a frequency modulation for scanning. The position of the target within the focal plane was given by a frequency, generated by two discs scanning the field of view. [...]

In conclusion, it should be noted that after considering the advantages and disadvantages of an infrared method and the results of the laboratory and field tests carried out on experimental devices, the people concerned were convinced in 1944 and 1945 that an infrared homing device constituted an excellent solution to certain guidance problems for missiles.

Friedrich Wilhelm (William) Herschel (1738–1822)



Discovered infrared light (1800)



[284]

XIV. *Experiments on the Refrangibility of the invisible Rays of the Sun. By* William Herschel, *LL. D. F. R. S.*

Read April 24, 1800.

In that section of my former paper which treats of radiant heat, it was hinted, though from imperfect experiments, that the range of its refrangibility is probably more extensive than that of the prismatic colours ; but, having lately had some favourable sunshine, and obtained a sufficient confirmation of the same, it will be proper to add the following experiments to those which have been given.

I provided a small stand, with four short legs, and covered it with white paper.* On this I drew five lines, parallel to one end of the stand, at half an inch distance from each other, but so that the first of the lines might only be $\frac{1}{4}$ of an inch from the edge. These lines I intersected at right angles with three others; the 2d and 3d whereof were, respectively, at $2\frac{1}{2}$ and at 4 inches from the first.

The same thermometers that have before been marked No. 1, 2, and 3, mounted upon their small inclined planes, were then placed so as to have the centres of the shadow of their balls thrown on the intersection of these lines. Now, setting my little stand upon a table, I caused the prismatic spectrum to fall with its extreme colour upon the edge of the paper, so that none might advance beyond the first line. In this arrangement,

* See Plate XI.

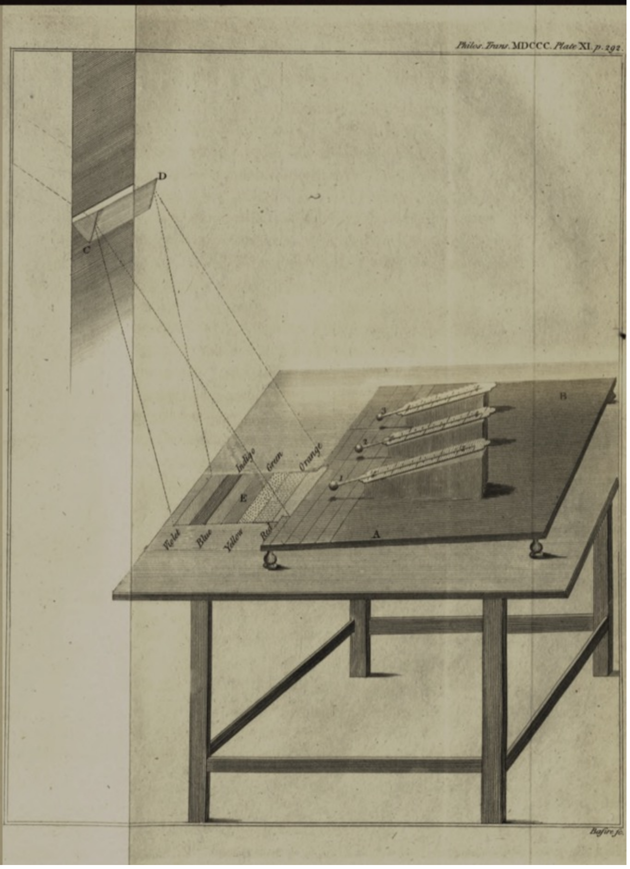


Figure 6.138: Friedrich Wilhelm (William) Herschel (1738–1822) discovered infrared light in 1800.

Herbert C. J. Gaertner
(1906–19??)

Fahrgerät FG 1250 infrared vision for nighttime driving

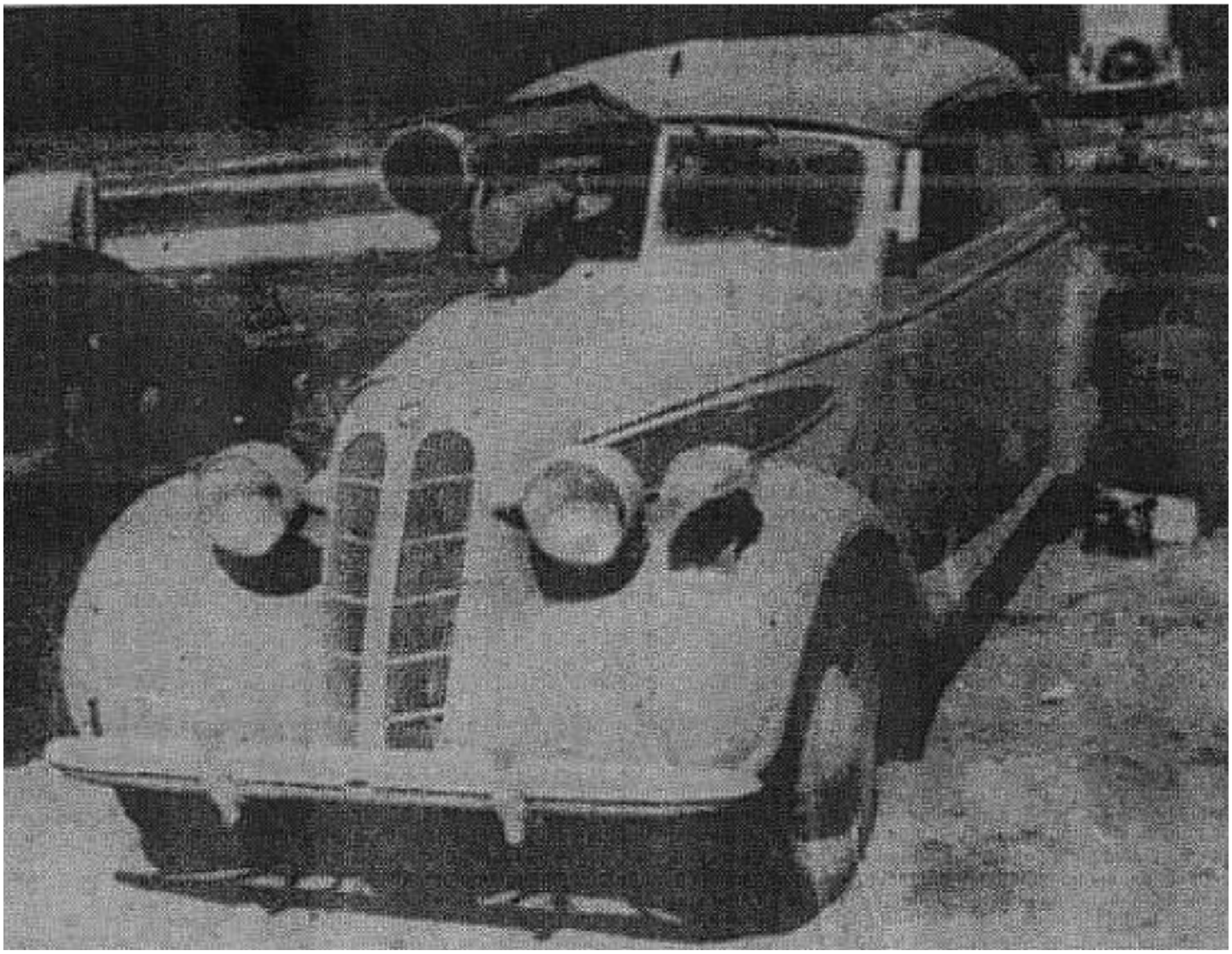


Figure 6.139: Herbert C. J. Gaertner developed the Fahrgerät FG 1250 infrared vision system for nighttime driving [BIOS Misc 66].

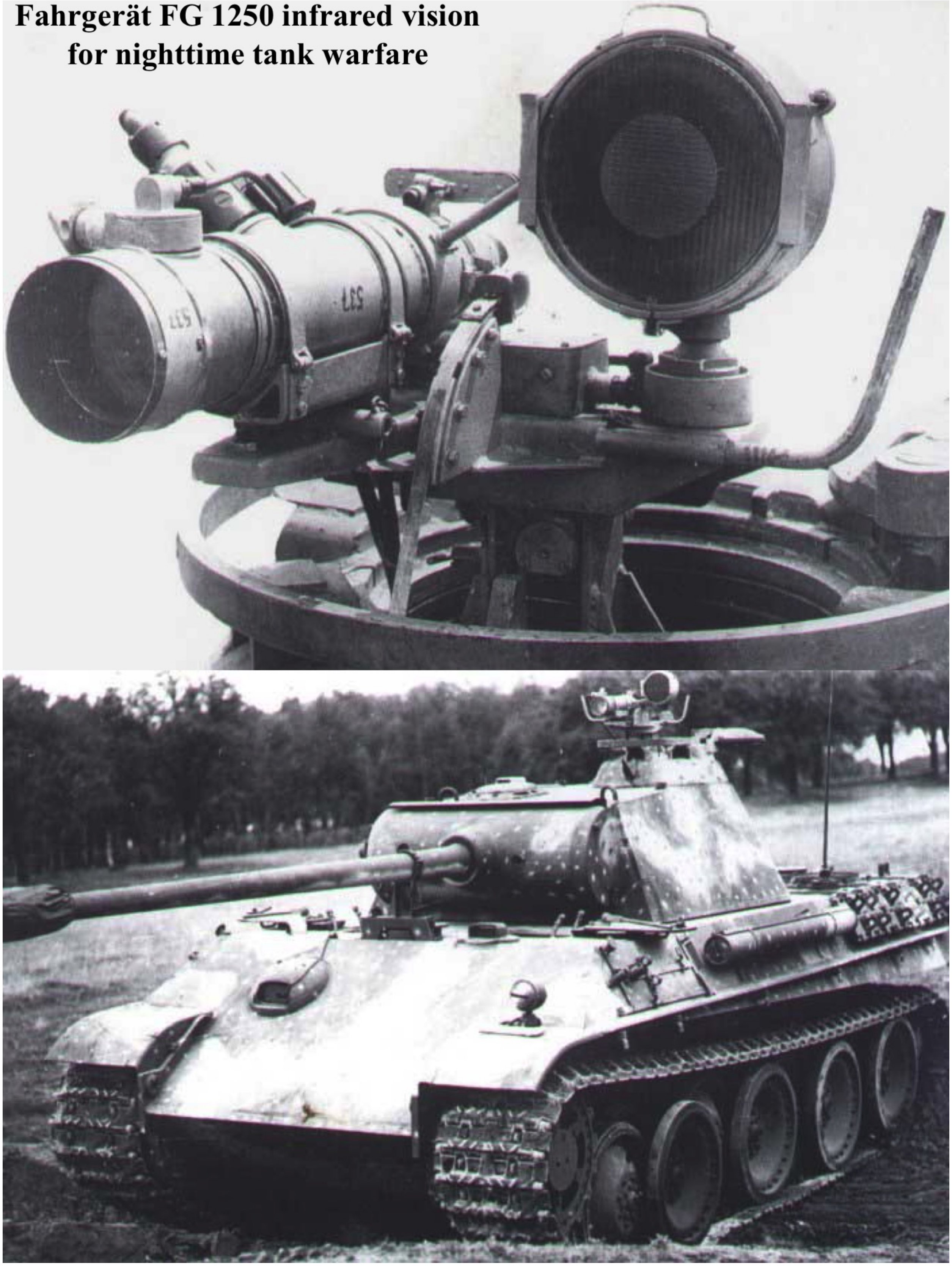

Fahrgerät FG 1250 infrared vision
for nighttime tank warfare

Figure 6.140: The Fahrgerät FG 1250 infrared vision system was also used for nighttime tank warfare.

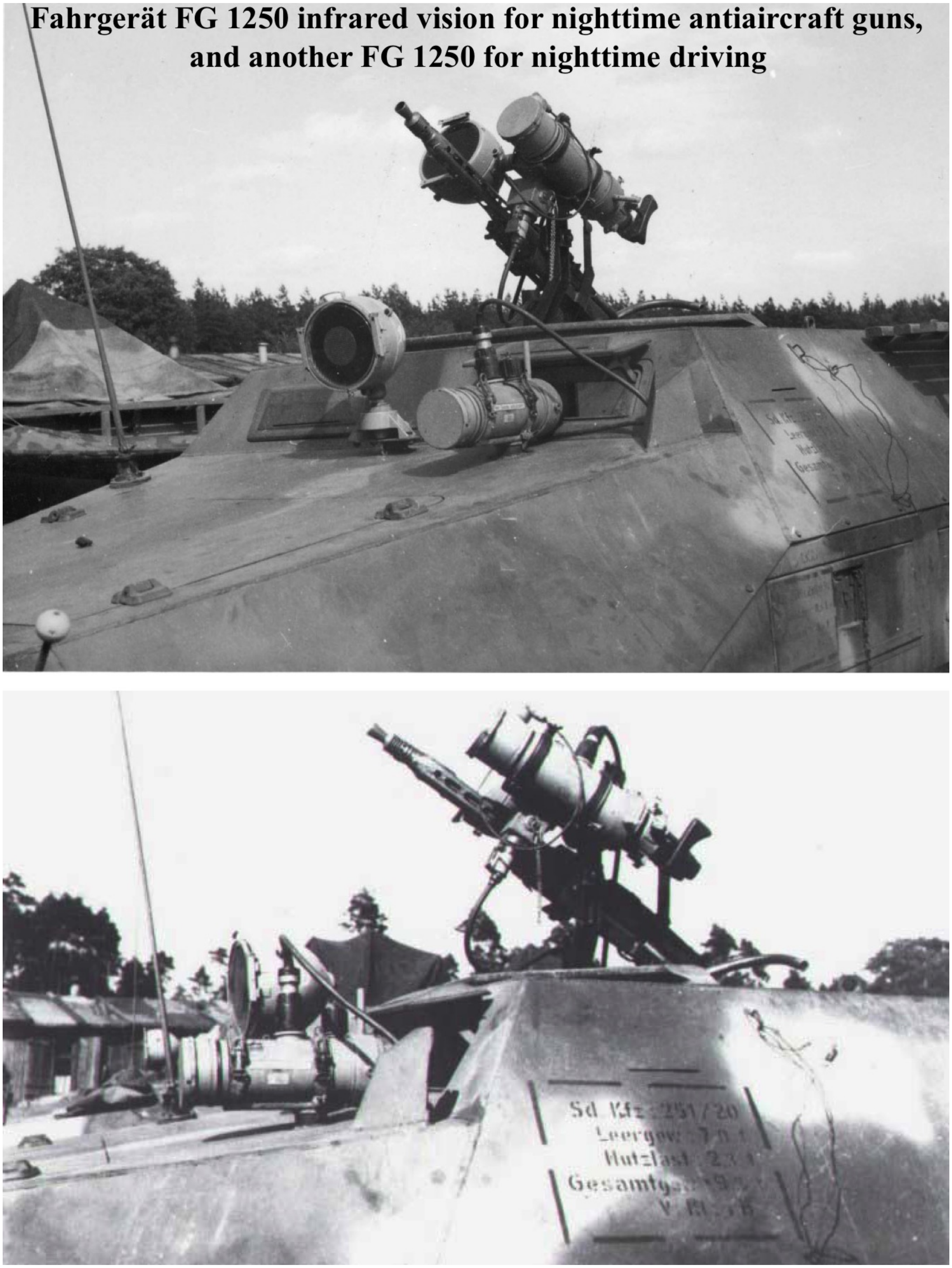

Fahrgerät FG 1250 infrared vision for nighttime antiaircraft guns,
and another FG 1250 for nighttime driving
Sd Kfz 251/20

Figure 6.141: Example of an armored vehicle with two Fahrgerät FG 1250 infrared vision systems, one for a nighttime antiaircraft gun and another for nighttime driving [BIOS Misc 66].

Uhu infrared vision for nighttime searchlights

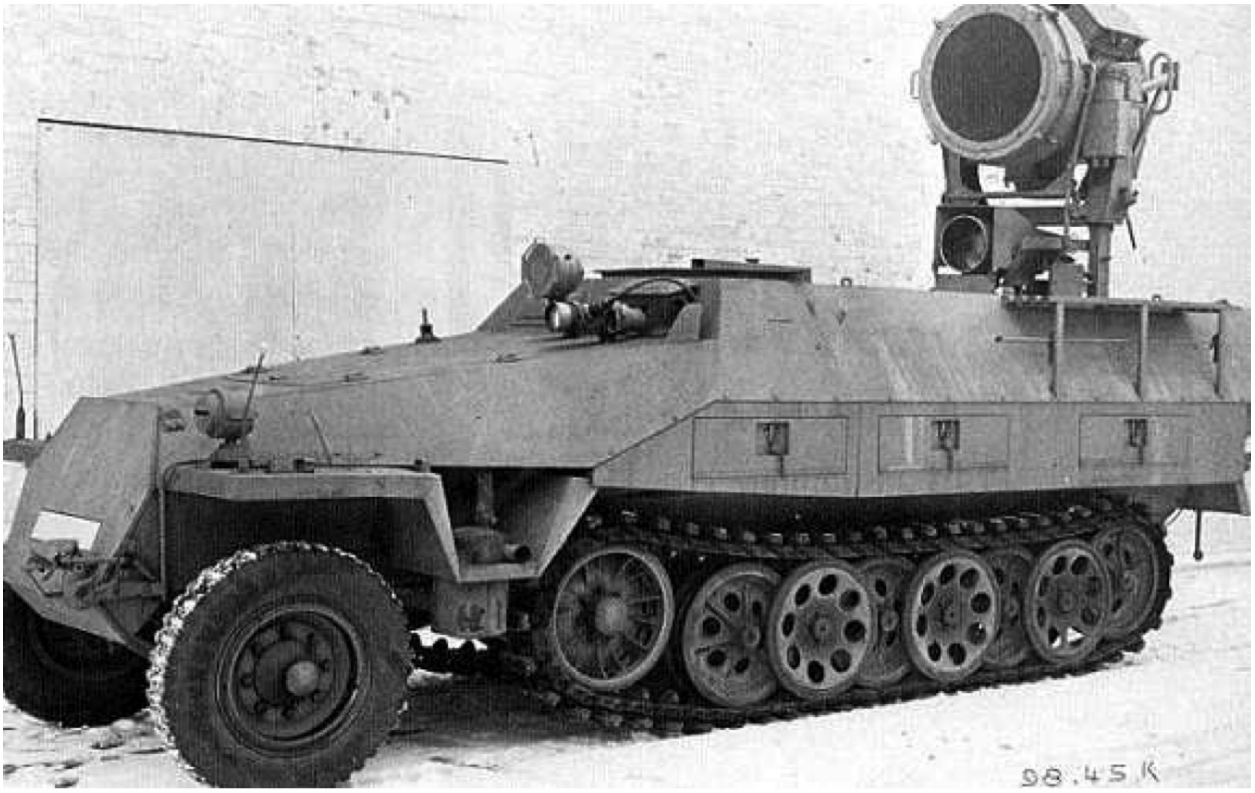


Figure 6.142: Uhu infrared vision system for nighttime searchlights.

Zielgerät 1229 Vampir infrared vision for nighttime snipers (1944)

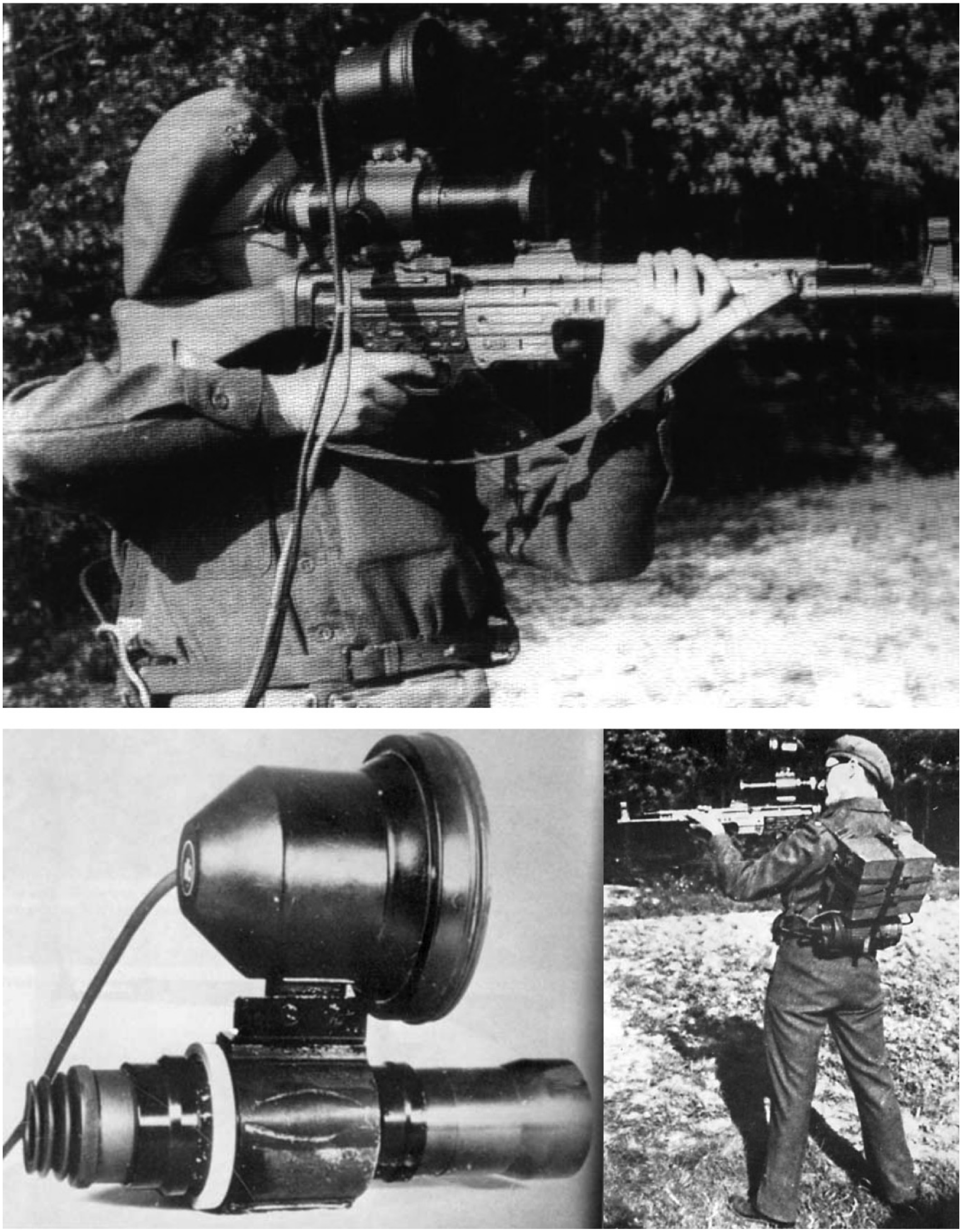
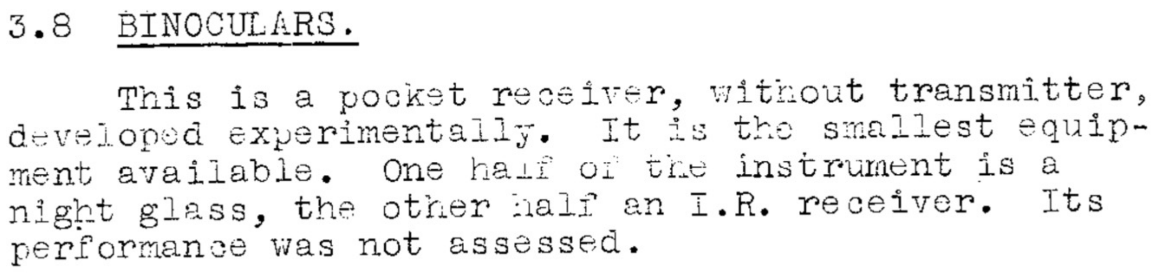


Figure 6.143: The Zielgerät 1229 Vampir (Vampire) infrared night-vision system for snipers, first operational in 1944 [BIOS Misc 66].

Infrared night-vision goggles



3.8 BINOCULARS.

This is a pocket receiver, without transmitter, developed experimentally. It is the smallest equipment available. One half of the instrument is a night glass, the other half an I.R. receiver. Its performance was not assessed.

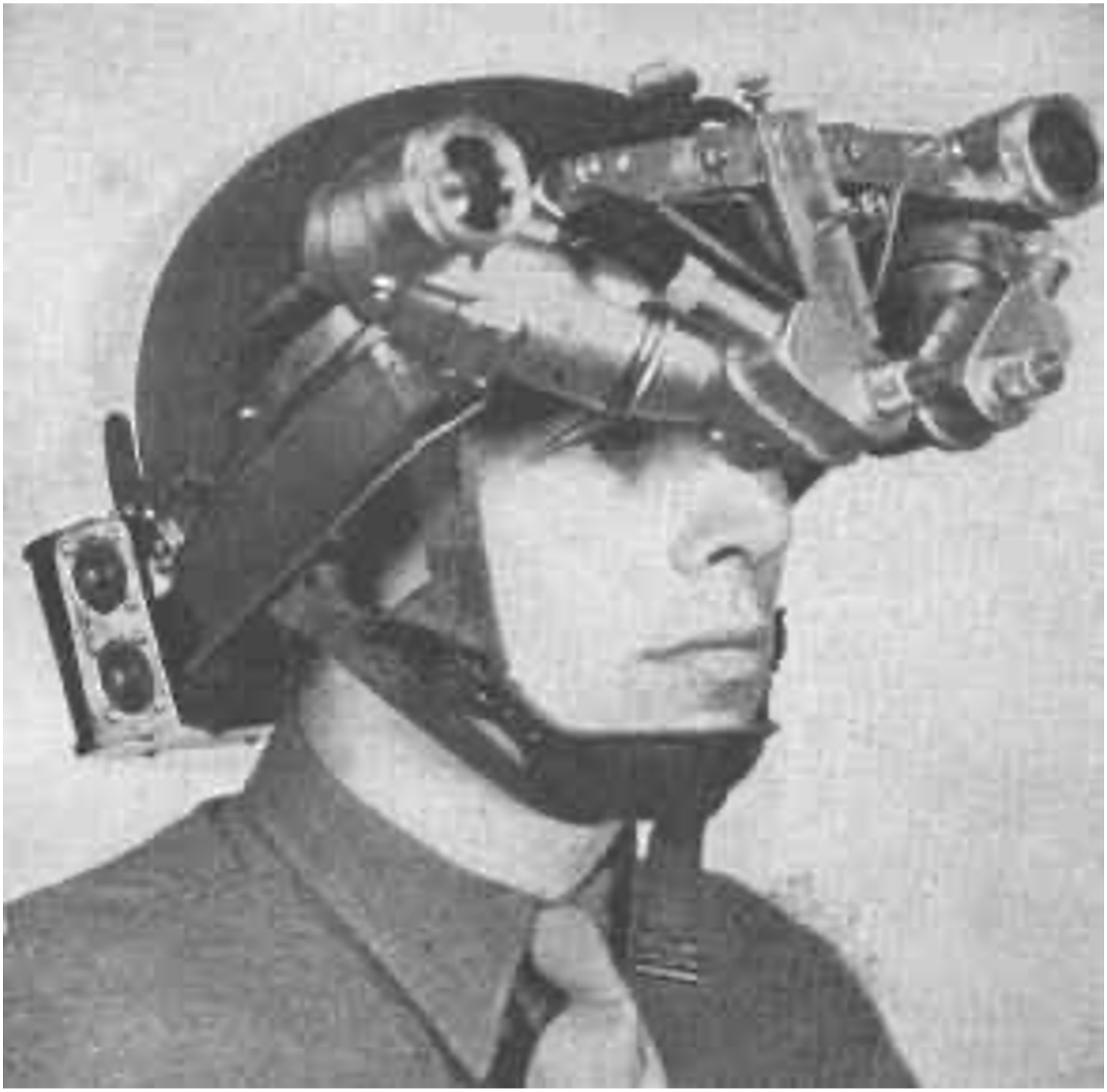
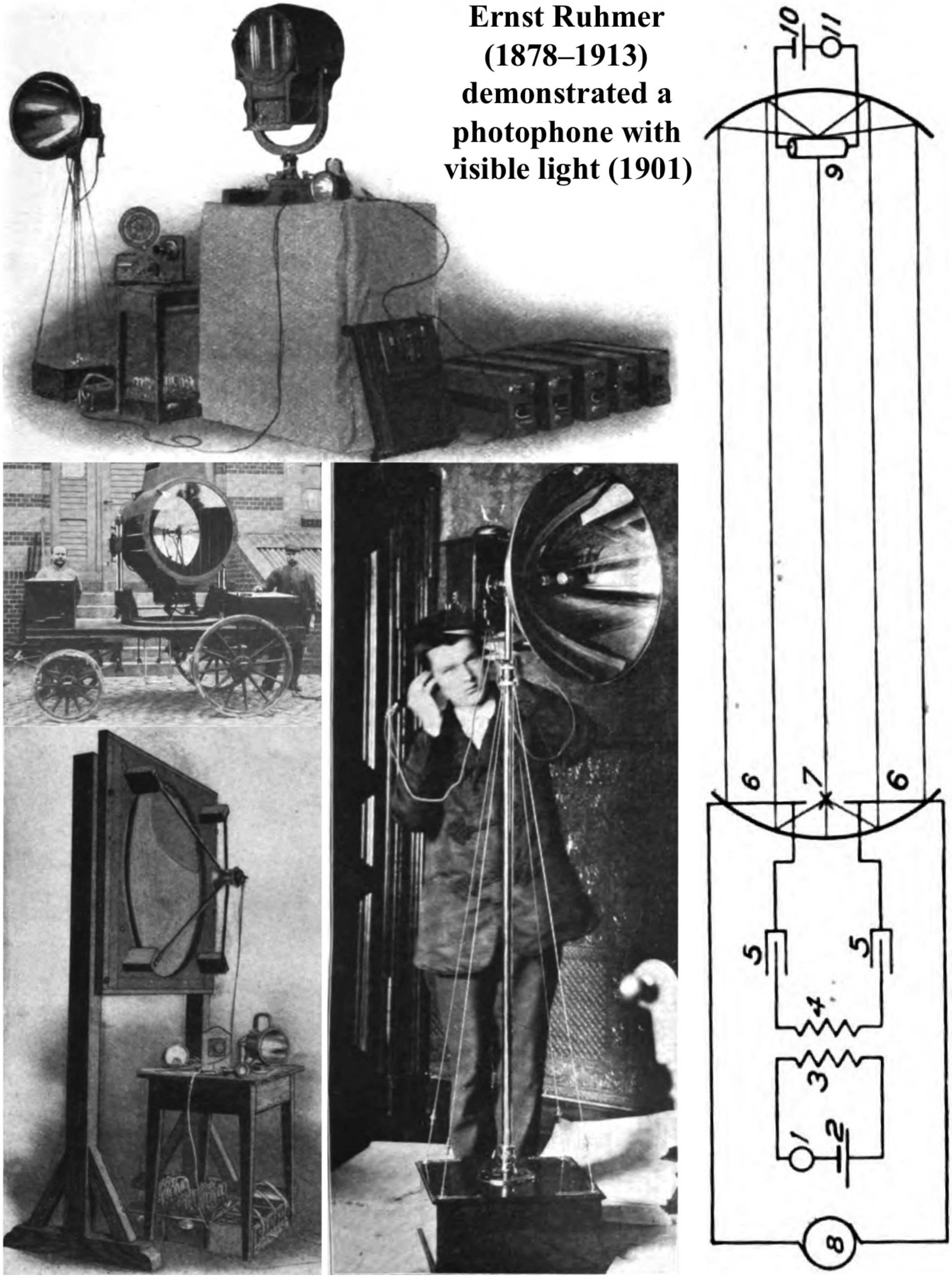


Figure 6.144: The first infrared night-vision goggles.



Ernst Ruhmer (1878–1913) demonstrated a photophone with visible light (1901)

Figure 6.145: In 1901, Ernst Ruhmer demonstrated a photophone that used visible light to transmit voice communications.

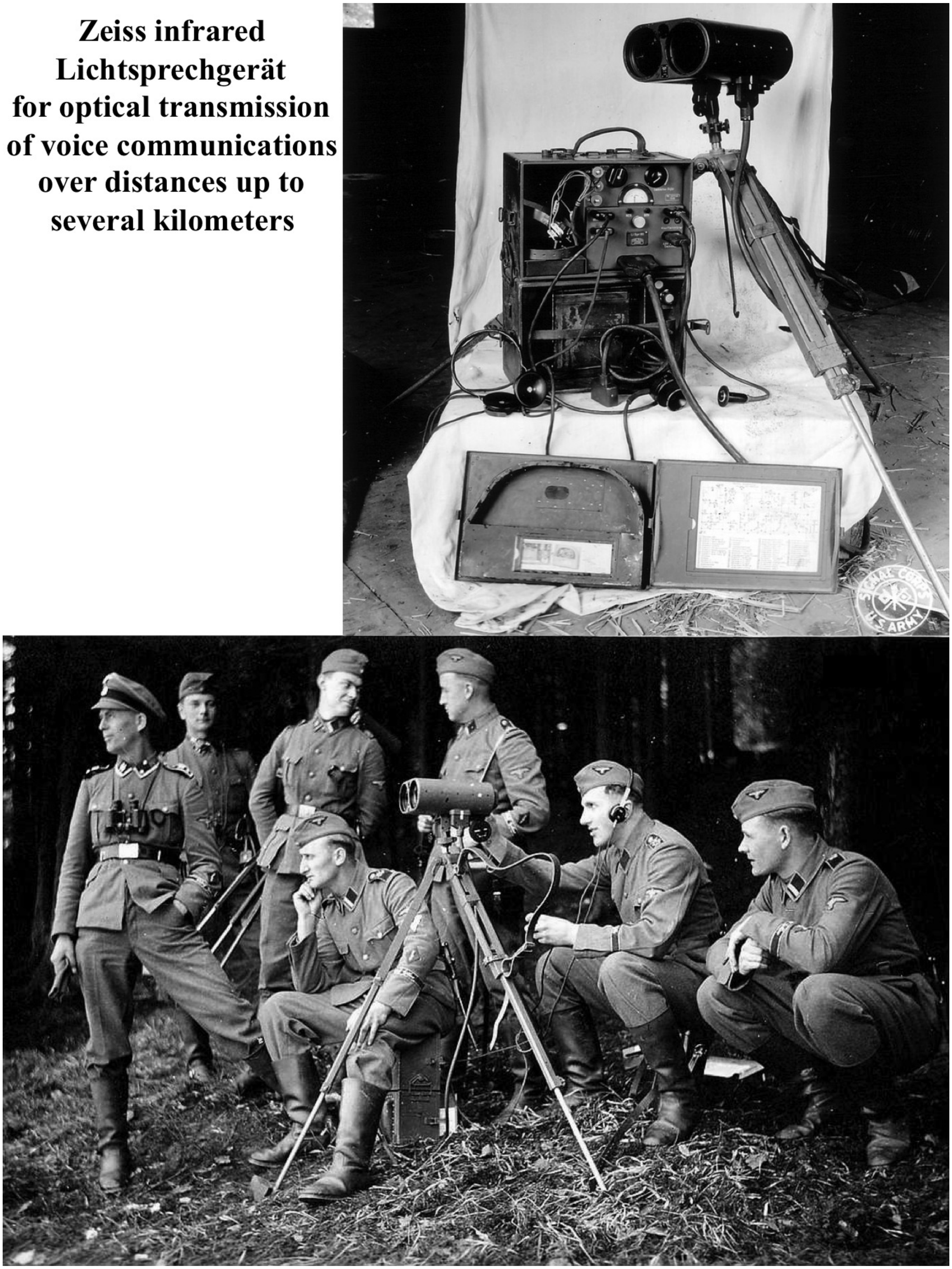
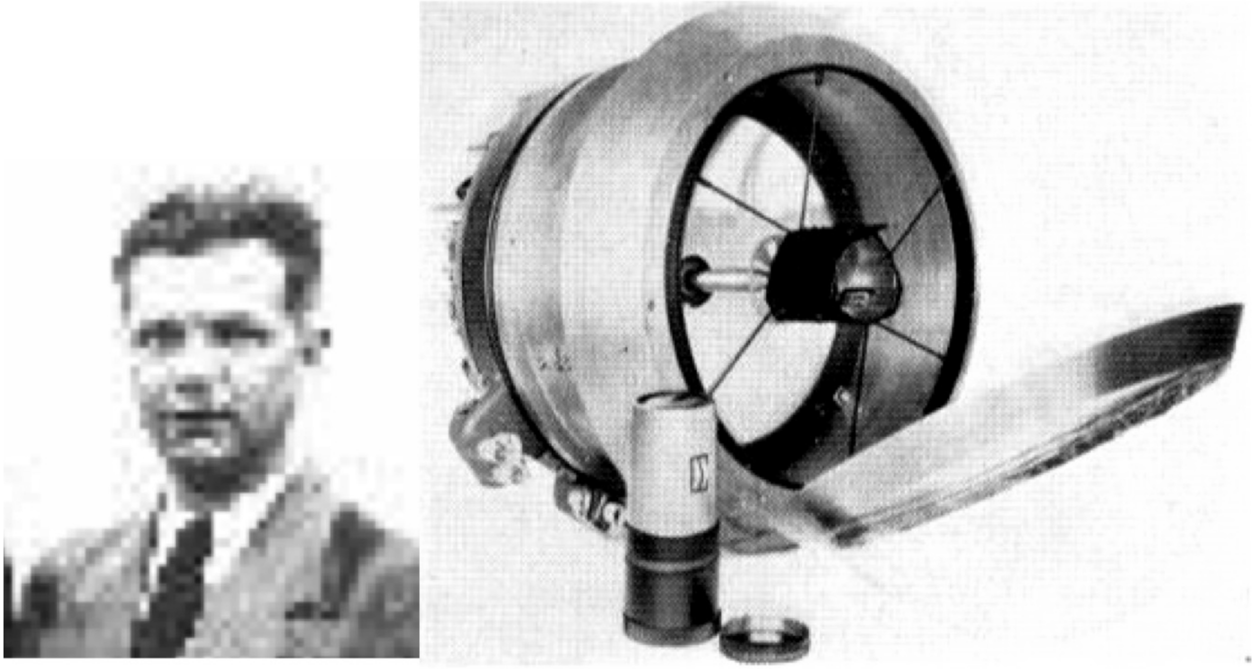

Zeiss infrared Lichtsprechgerät for optical transmission of voice communications over distances up to several kilometers
SIGNAL CORPS U.S. ARMY

Figure 6.146: The compact Zeiss infrared Lichtsprechgerät allowed the efficient optical transmission of high-quality voice communications over distances up to several kilometers.



Edgar Kutzscher
(1906–1997)

***Hamburg* heat-seeking system**
for Blohm & Voss BV 143 missile

Blohm & Voss BV 143 missile

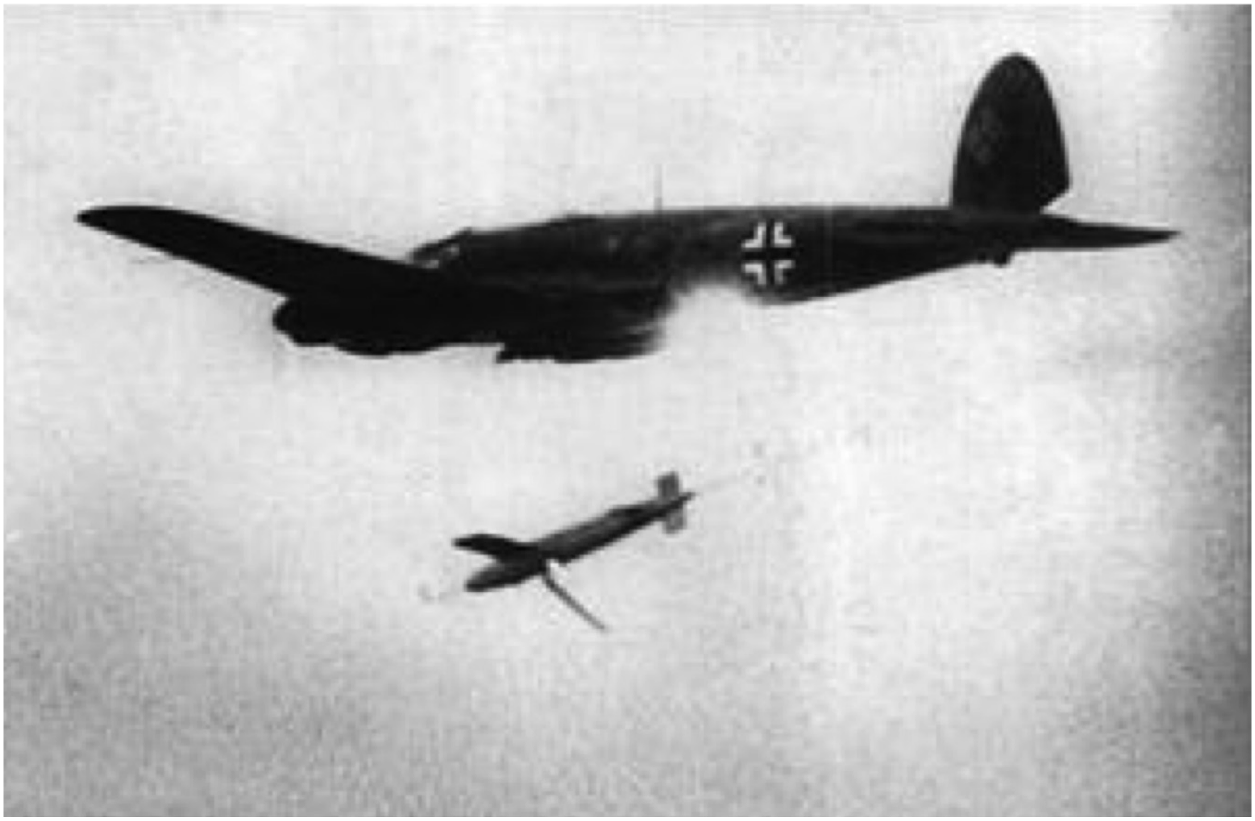
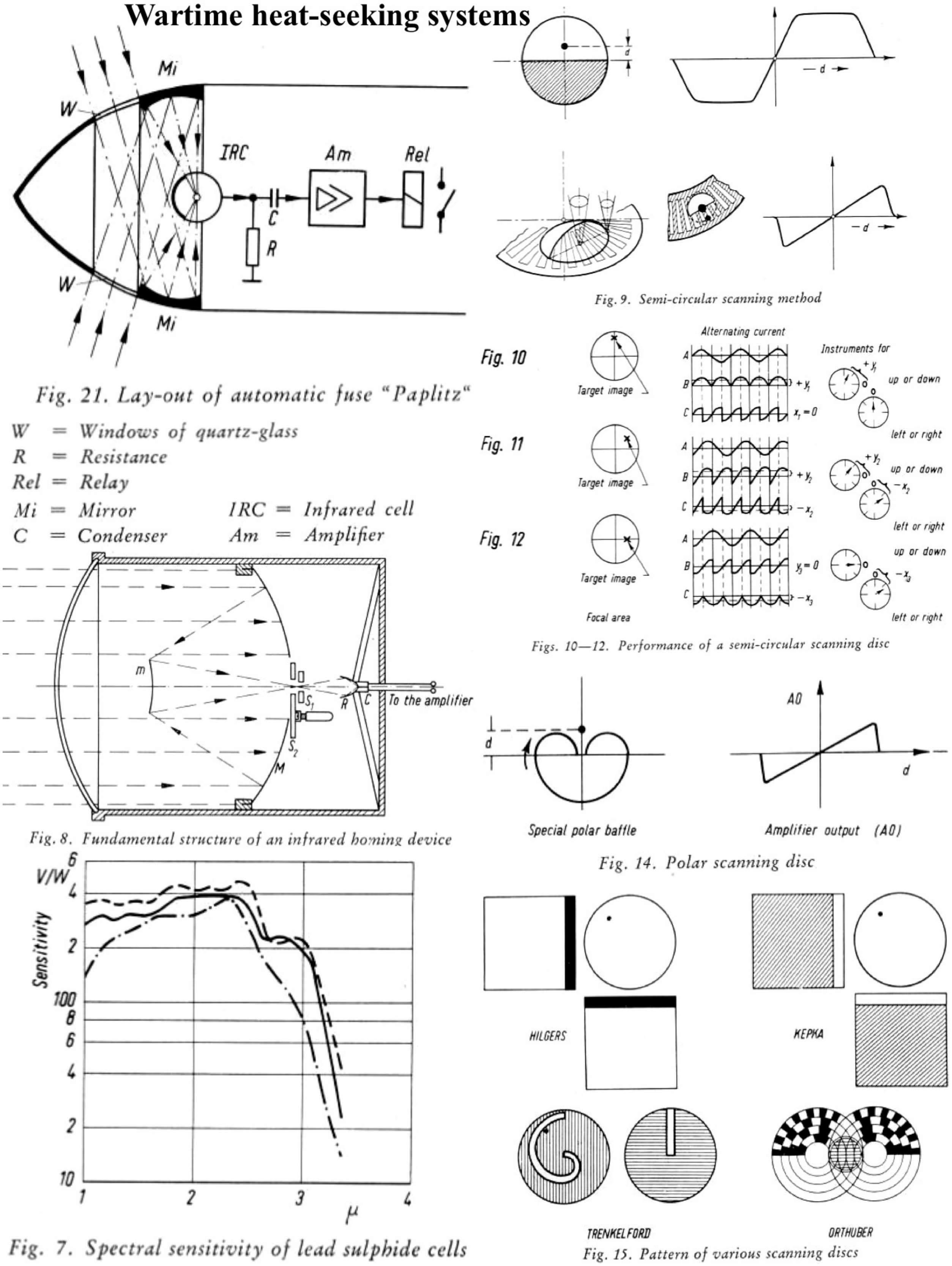


Figure 6.147: Edgar Kutzscher developed infrared tracking systems for heat-seeking missiles during the war.



Wartime heat-seeking systems

Fig. 21. Lay-out of automatic fuse "Paplitz"

W = Windows of quartz-glass
R = Resistance
Rel = Relay
Mi = Mirror
C = Condenser
IRC = Infrared cell
Am = Amplifier

Fig. 8. Fundamental structure of an infrared homing device

Fig. 7. Spectral sensitivity of lead sulphide cells

Fig. 9. Semi-circular scanning method

Figs. 10—12. Performance of a semi-circular scanning disc

Fig. 14. Polar scanning disc

Fig. 15. Pattern of various scanning discs

W
Mi
IRC
Am
Rel
C
R
m
M
S1
S2
R
C
To the amplifier
V/W
Sensitivity
6
4
2
100
8
6
4
2
10
1
2
3
4
μ
d
— d →
Fig. 10
Fig. 11
Fig. 12
Target image
Alternating current
A
B
C
+y1
x1 = 0
+y2
−x2
y3 = 0
−x3
Focal area
Instruments for
up or down
left or right
Special polar baffle
Amplifier output (AO)
AO
HILGERS
KEPKA
TRENKELFORD
ORTHUBER

Figure 6.148: Designs for several different heat-seeking missile guidance systems that were developed during the war [Benecke and Quick 1957].

Heat-seeking missile guidance systems

?? Ahrens
(19??–19??)
Heat seeking systems

Habil Görlich
(19??–19??)
IR PbS photocells

?? Heitmüller
(19??–19??)
Heat seeking systems

?? Hilgers
(19??–19??)
Heat seeking systems

Kurt Jung
(19??–19??)
IR PbS photocells

?? Ochmann
(19??–19??)
Heat seeking systems

Figure 6.149: Some other German-speaking creators of wartime and postwar heat-seeking missile guidance systems.

Heat-seeking missile guidance systems

?? Orlich
(19??–19??)
Heat seeking systems

?? Orthuber
(19??–19??)
Heat seeking systems

Heinz Pick
(1912–1983)
IR PbS photocells

?? Rücklin
(19??–19??)
Heat seeking systems

Gottfried Sommer
(19??–19??)
IR PbS photocells

?? Trenkelford
(19??–19??)
Heat seeking systems

Figure 6.150: Some other German-speaking creators of wartime and postwar heat-seeking missile guidance systems.

6.6.2 Transfer of Infrared Technologies

At the end of the war, Allied scientists, engineers, and military personnel pored over the German infrared technologies for use in their own countries and wrote numerous reports. See for example Fig. 6.152 and the following reports:

BIOS 2. *German Photoconducting Cells for the Detection of Infra-Red Radiation.*

BIOS 211. *Infra-red Research, Dr. A. Becker, 36 Blumenthal Strasse, Heidelberg.*

BIOS 1345. *Some Developments in Infra-Red and Raman Spectroscopy in Germany.*

BIOS Misc 66. *German Infra Red Driving and Fire Control Equipment.*

CIOS ER 160. *German Infra-Red and Ultra-Violet Developments.*

CIOS XXIV-7. *German Infra Red Driving and Fire Control Equipment at Falling Bostel.*

CIOS XXX-3. *German Infra-Red Equipment in the Kiel Area.*

CIOS XXX-108. *German Infra-Red Devices and Associated Investigations.*

CIOS XXXI-14. *Binoculars for Night Seeing.*

CIOS XXXIII-9. *German Infra-Red Devices and Associated Investigations Report No. 2.*

FIAT 4. *German Infrared Targets in South Germany and Austria.*

FIAT 708. *A Survey of the Use of Infra-Red Spectra in Chemical Analysis in Germany.*

FIAT 769. *Electron Microscopy, Infra Red and Other Branches of Applied Physics.*

FIAT 1172. *Measurements of Threshold Sensitivity of the Human Eye in the Near Infrared.*

JIOA 5. *Infrared Targets at Hillersleben, Jena and Wetzlar. 19 Apr–May 4, 1945.*

NavTecMisEu LR 77-45. *Lead Sulphide Semi-Conductor Infra-red Cells for Homing Rockets.*

NavTecMisEu LR 228-45. *Infra-red Homing Devices.*

NavTecMisEu 109-45. *German Infrared Equipment in the Kiel Area.*

NavTecMisEu 127-45. *German Infrared Devices and Associated Investigations.*

> NavTecMisEu 242-45. *"Paplitz" Infra-red Fuse Development of Elac.*
>
> NavTecMisEu 273-45. *German Infra-red Homing Device "Emden."*
>
> NavTecMisEu 274-45. *German Infra-red Homing Device "Karussell."*
>
> NavTecMisEu 488-45. *A Review of Infrared Developments by Gema, of Berlin.*
>
> NavTecMisEu 497-45. *A Review of the Infrared Work of the Electrical Testing an Experimental Office of the German Railways, "Elversa" (Elektro Technischos Versuchsamt Der Reichsbahn).*
>
> NavTecMisEu 518-45. *German Progress in the Development of Heat Iconoscopes (Infrared Image Tubes Sensitive To Wavelengths Longer than 2 Microns).*
>
> NavTecMisEu 519-45. *The Properties of Klieforth Infrared Transparent Glasses.*

After analyzing the German technologies, the U.S. Department of Commerce wrote an assessment (Fig. 6.151) praising how much more advanced they were than anything that the United States had possessed, and how much they would benefit the United States in the future [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards]:

> Information which has been secured concerning German developments accomplished in the field of infra-red light has proved to be of inestimable value to the military services of this country and will definitely effect an even greater contribution for our civilian purposes.
>
> Prior to the discovery of the German developments in this field, the United States had been unsuccessful in converting infra-red to visible light. Investigation has revealed that the Germans not only succeeded in converting infra-red light into visible light but also had been successful in its application for military purposes to a remarkable degree. They had applied this development in perfecting a spotlight which made possible the movement of army vehicles in total darkness without the use of visible illumination. By the use of another night-seeing device which the Germans used before the siege of Berlin, one of their tanks which was located in a woods, put sixty Russian tanks out of action by direct gunfire in total darkness as fast as the tanks came into view on a road which was a mile away from the German tank.
>
> The adaptation of similar device for use as a "sniperscope" enabled German snipers to fire effectively at Allied troops in total darkness at a range of 300 feet. Information obtained during interrogation of the first German prisoner who was captured with one of these units intact was immediately sent to this country where it was at first claimed that such a development was impossible. The device was then rushed to this country by air and production of it was started immediately. It was first used by American troops on Okinawa much to the bewilderment of the Japanese. Detailed information, including actual photographs of the captured German equipment is contained in Report No. PB-1587 made available by the Office of Technical Services of the Department of Commerce.

> The Germans also successfully applied infra-red light in the development of a device for voice transmission. This device permitted communication by means of an invisible light beam, without risk of interception, over short distances such as across rivers or valleys. A binocular attachment fitted with filters which made the infra-red beam visible, was used for focusing the wireless "telephone line". American industry is keenly interested in this device which has been evacuated to this country and is on loan to industry for test and research purposes. Information pertaining to this device is contained in Report No. PB-19746 published by the Office of Technical Services of the Department of Commerce.
>
> Some of the more obvious commercial applications of infra-red light developments thus revealed will be of inestimable value in the field of medicine, particularly in eye examination; and in the law enforcement field, where night-seeing can be employed in the detection of crime and the apprehension of criminals.

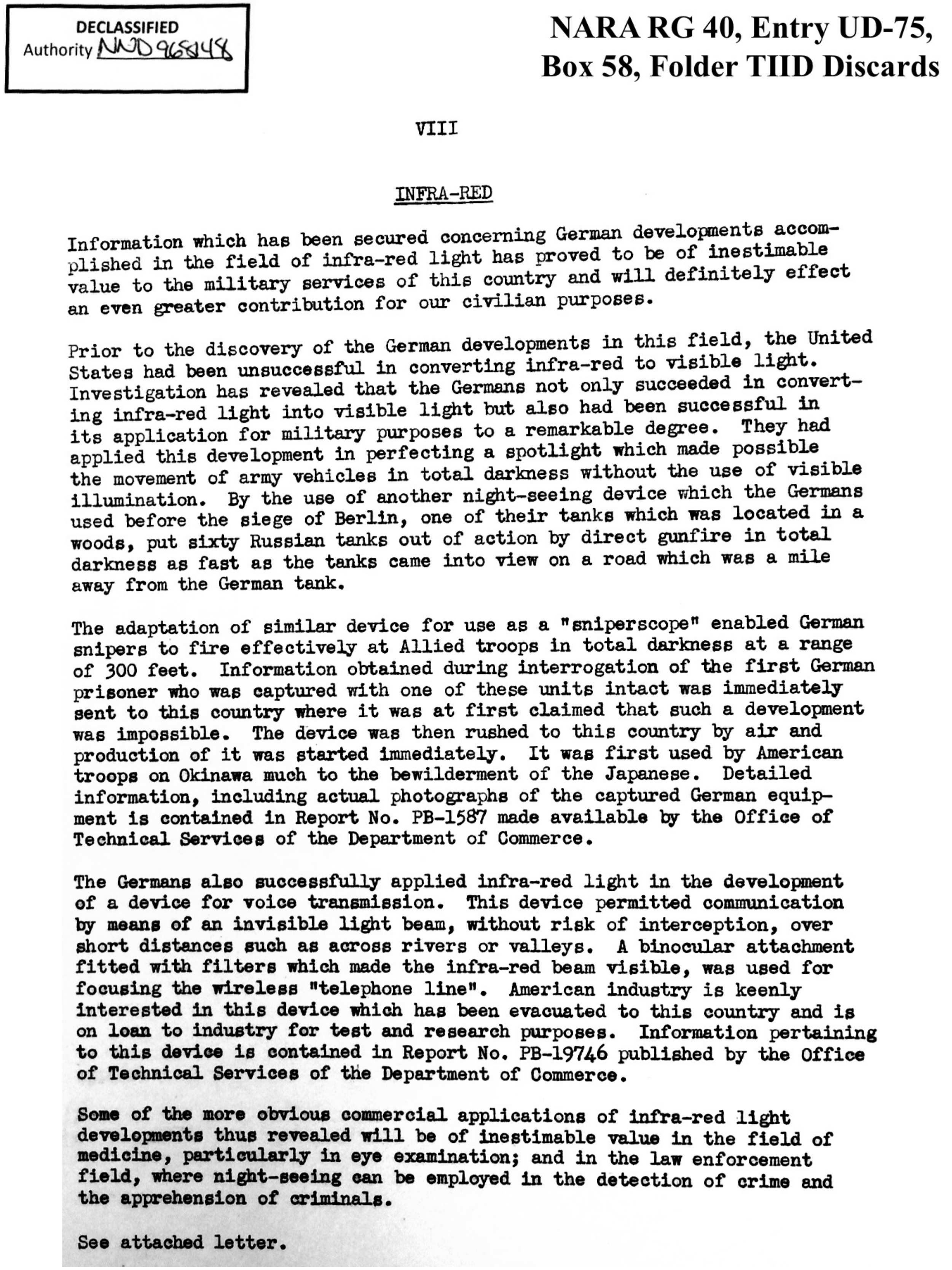
In addition to acquiring all of the infrared hardware, documentation, and information, the United States (and other countries) also hired many German-speaking experts to produce infrared systems after the war. Some examples include:

- Werner Karl Weihe (German, 19??–19??) developed infrared systems in Germany during the war, and at Wright Field, Ohio, after the war (Fig. 6.153).

- After the war, Hans K. Ziegler (German, 1911–1999) came to the United States in Operation Paperclip and became the Chief Scientist of a U.S. Army laboratory in Fort Monmouth, New Jersey, that employed many other German-speaking scientists and harnessed infrared and other technologies acquired from Germany and Austria [Fort Monmouth Historical Office 2008]. See Fig. 6.154–6.155.

- Edgar Kutzscher and other German-speaking creators used their wartime experience to develop postwar infrared heat-seeking missiles such as the U.S. Falcon and Sidewinder (Figs. 6.156–6.157).

- Heinz Schlicke (German, 1912–2006), an expert on infrared, electronics, and potentially nuclear-related technologies, arrived in the United States in May 1945 along with a whole German submarine filled with those technologies [AFHRA B1975, frames 1325–1495]. He spent the rest of his career in the United States. See pp. 4858–4892 for more information.



DECLASSIFIED
Authority NND 968148

**NARA RG 40, Entry UD-75,
Box 58, Folder TIID Discards**

VIII

INFRA-RED

Information which has been secured concerning German developments accomplished in the field of infra-red light has proved to be of inestimable value to the military services of this country and will definitely effect an even greater contribution for our civilian purposes.

Prior to the discovery of the German developments in this field, the United States had been unsuccessful in converting infra-red to visible light. Investigation has revealed that the Germans not only succeeded in converting infra-red light into visible light but also had been successful in its application for military purposes to a remarkable degree. They had applied this development in perfecting a spotlight which made possible the movement of army vehicles in total darkness without the use of visible illumination. By the use of another night-seeing device which the Germans used before the siege of Berlin, one of their tanks which was located in a woods, put sixty Russian tanks out of action by direct gunfire in total darkness as fast as the tanks came into view on a road which was a mile away from the German tank.

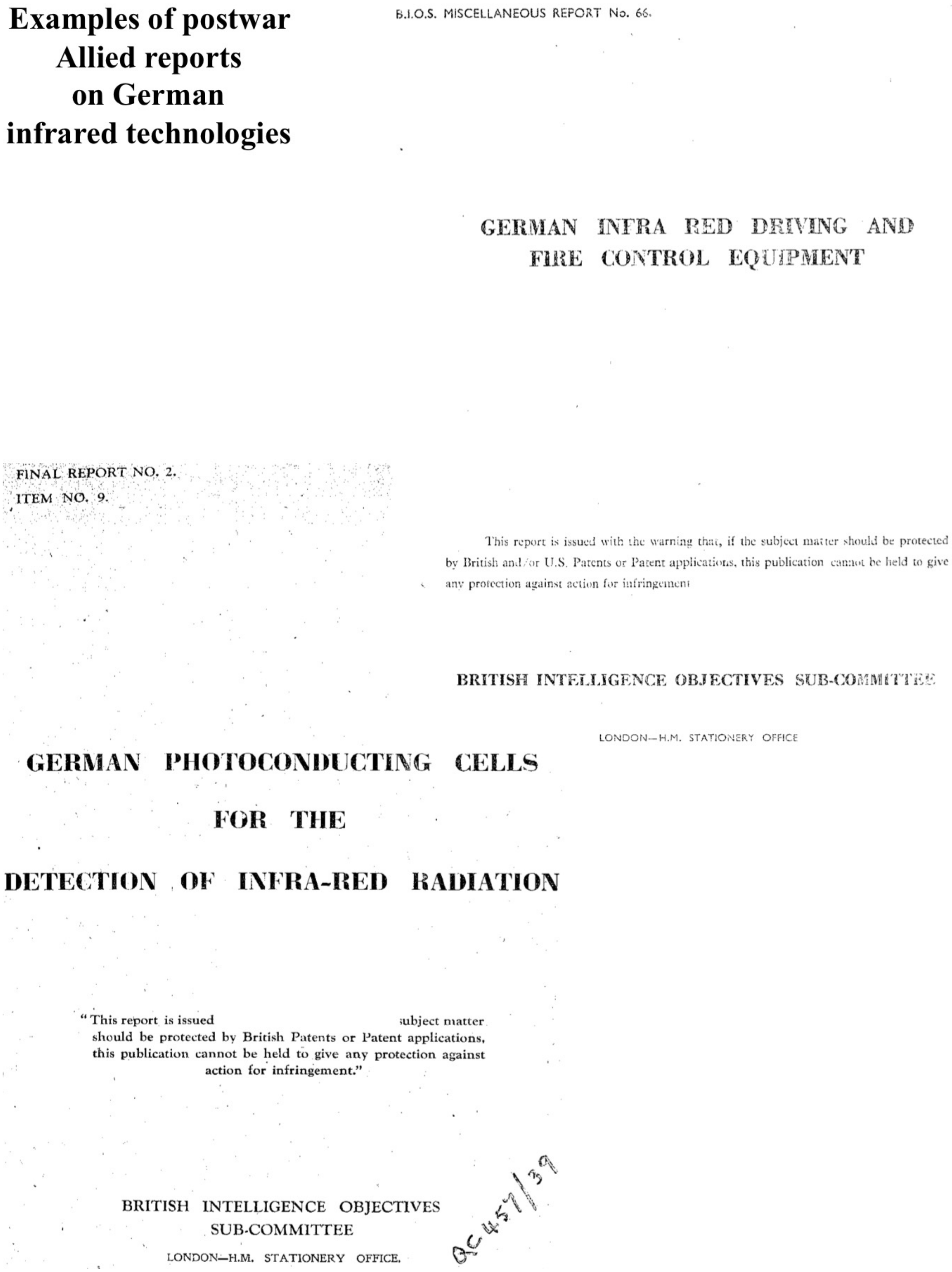
The adaptation of similar device for use as a "sniperscope" enabled German snipers to fire effectively at Allied troops in total darkness at a range of 300 feet. Information obtained during interrogation of the first German prisoner who was captured with one of these units intact was immediately sent to this country where it was at first claimed that such a development was impossible. The device was then rushed to this country by air and production of it was started immediately. It was first used by American troops on Okinawa much to the bewilderment of the Japanese. Detailed information, including actual photographs of the captured German equipment is contained in Report No. PB-1587 made available by the Office of Technical Services of the Department of Commerce.

The Germans also successfully applied infra-red light in the development of a device for voice transmission. This device permitted communication by means of an invisible light beam, without risk of interception, over short distances such as across rivers or valleys. A binocular attachment fitted with filters which made the infra-red beam visible, was used for focusing the wireless "telephone line". American industry is keenly interested in this device which has been evacuated to this country and is on loan to industry for test and research purposes. Information pertaining to this device is contained in Report No. PB-19746 published by the Office of Technical Services of the Department of Commerce.

Some of the more obvious commercial applications of infra-red light developments thus revealed will be of inestimable value in the field of medicine, particularly in eye examination; and in the law enforcement field, where night-seeing can be employed in the detection of crime and the apprehension of criminals.

See attached letter.

Figure 6.151: A wide variety of revolutionary infrared technologies were developed in the German-speaking world and transferred to other countries after World War II [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].



Examples of postwar Allied reports on German infrared technologies

B.I.O.S. MISCELLANEOUS REPORT No. 66.

GERMAN INFRA RED DRIVING AND FIRE CONTROL EQUIPMENT

This report is issued with the warning that, if the subject matter should be protected by British and/or U.S. Patents or Patent applications, this publication cannot be held to give any protection against action for infringement

BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE

LONDON—H.M. STATIONERY OFFICE

FINAL REPORT NO. 2.
ITEM NO. 9.

GERMAN PHOTOCONDUCTING CELLS FOR THE DETECTION OF INFRA-RED RADIATION

"This report is issued subject matter should be protected by British Patents or Patent applications, this publication cannot be held to give any protection against action for infringement."

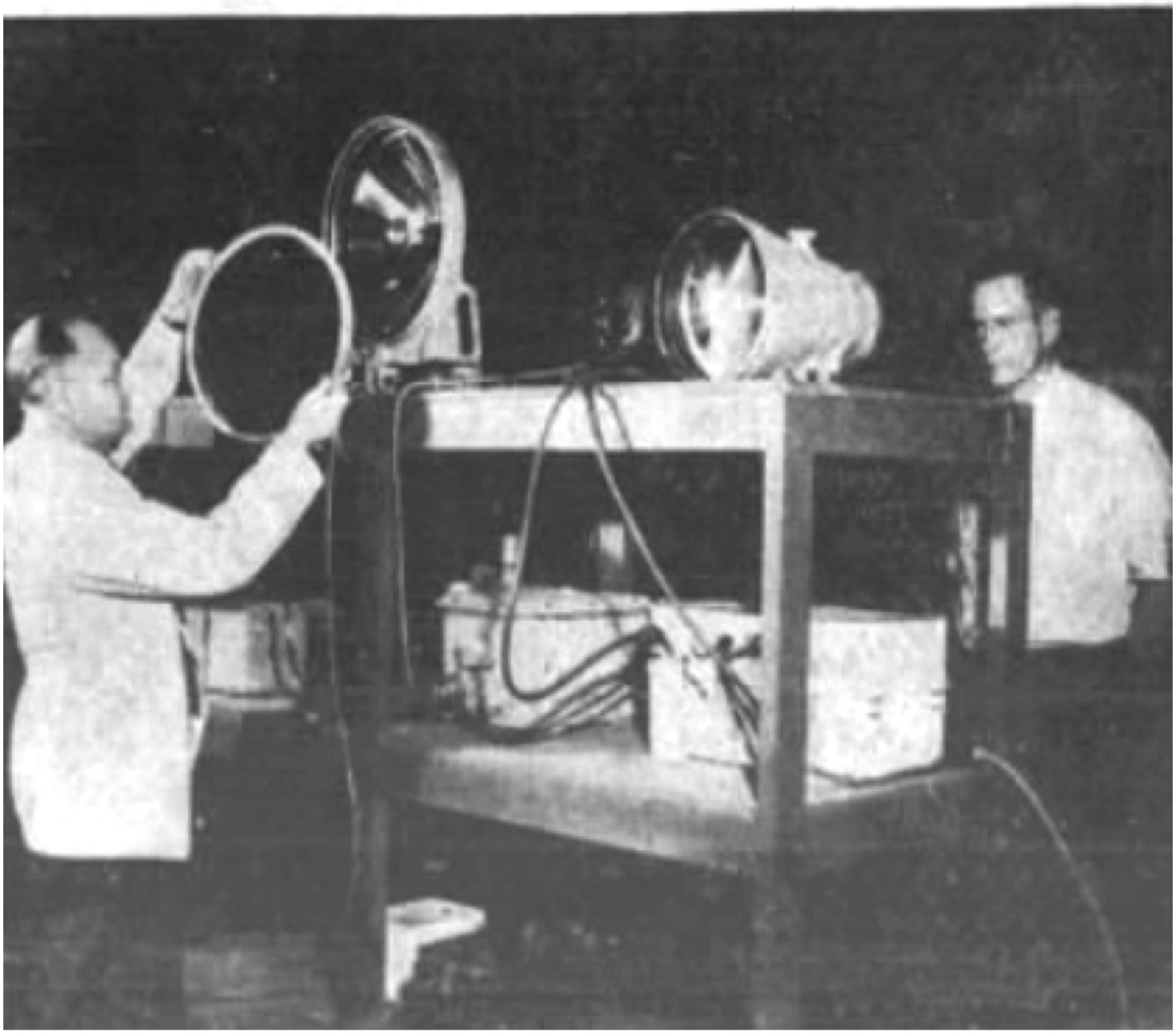
BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE

LONDON—H.M. STATIONERY OFFICE.

QC457/39

Figure 6.152: Examples of postwar Allied reports on German infrared technologies [BIOS 2; BIOS Misc 66].

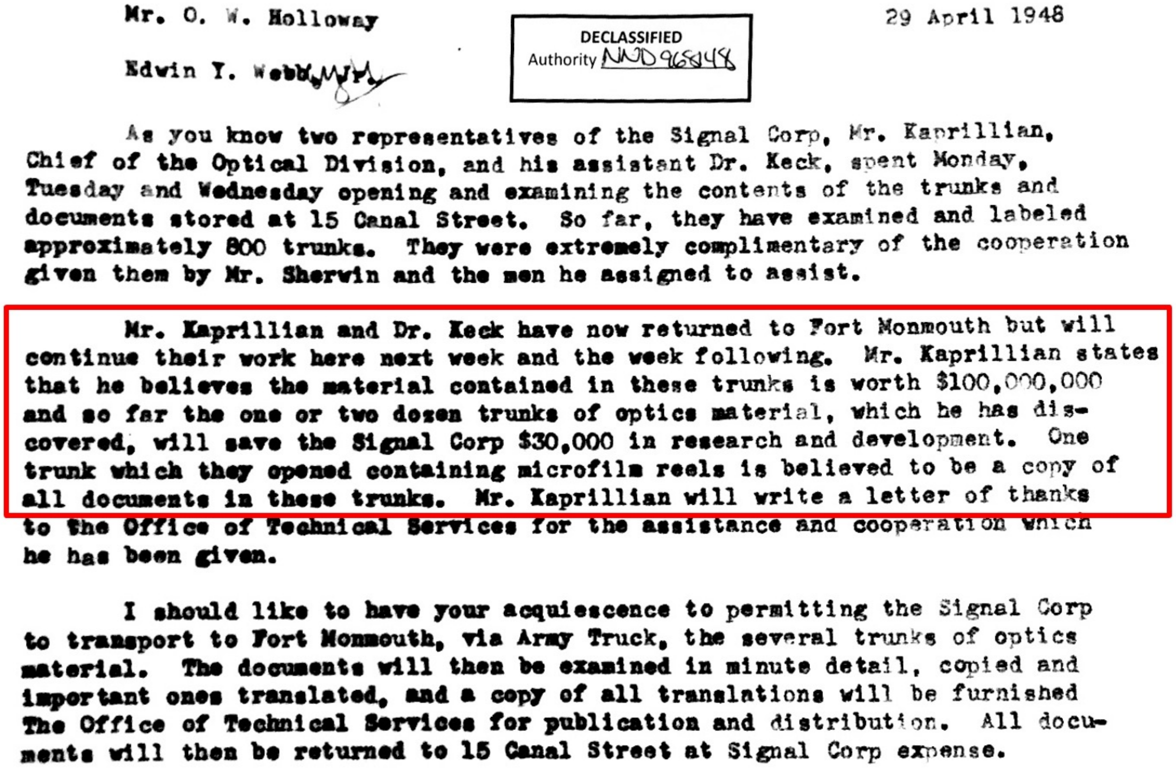
Germans led Allies in infra-red equipment. Here Dr. Weine, German specialist, left, inspects equipment with Dr. Overbo, U. S. expert.



Werner Karl Weihe
(19??–19??)
Infrared systems

Figure 6.153: Werner Karl Weihe developed infrared systems in Germany during the war, and at Wright Field, Ohio, after the war [*Dayton Daily News*, 8 December 1946, p. 55].

Fort Monmouth, NJ Army Lab
Lots of German scientists,
hardware, documents, etc.



NARA RG 40, Entry UD-75, Box 58, Folder Webb

Mr. O. W. Holloway 29 April 1948

Edwin Y. Webb

DECLASSIFIED
Authority NND 968148

As you know two representatives of the Signal Corp, Mr. Kaprillian, Chief of the Optical Division, and his assistant Dr. Keck, spent Monday, Tuesday and Wednesday opening and examining the contents of the trunks and documents stored at 15 Canal Street. So far, they have examined and labeled approximately 800 trunks. They were extremely complimentary of the cooperation given them by Mr. Sherwin and the men he assigned to assist.

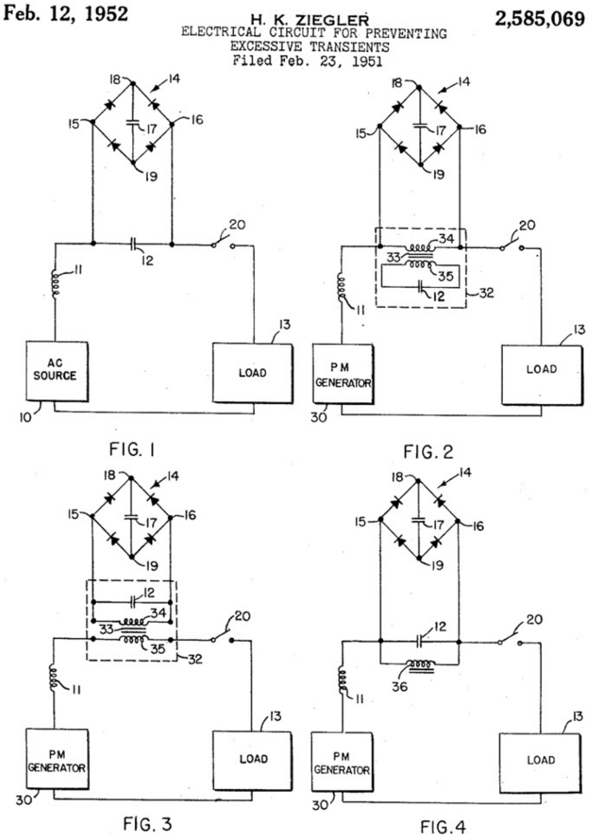
Mr. Kaprillian and Dr. Keck have now returned to Fort Monmouth but will continue their work here next week and the week following. Mr. Kaprillian states that he believes the material contained in these trunks is worth $100,000,000 and so far the one or two dozen trunks of optics material, which he has discovered, will save the Signal Corp $30,000 in research and development. One trunk which they opened containing microfilm reels is believed to be a copy of all documents in these trunks. Mr. Kaprillian will write a letter of thanks to the Office of Technical Services for the assistance and cooperation which he has been given.

I should like to have your acquiescence to permitting the Signal Corp to transport to Fort Monmouth, via Army Truck, the several trunks of optics material. The documents will then be examined in minute detail, copied and important ones translated, and a copy of all translations will be furnished The Office of Technical Services for publication and distribution. All documents will then be returned to 15 Canal Street at Signal Corp expense.

Figure 6.154: Hans K. Ziegler was the head of a largely German- and Austrian-derived research group at a U.S. Army laboratory in Fort Monmouth, New Jersey, that harnessed infrared and other technologies.

Fort Monmouth, NJ Army Lab
Lots of German scientists, hardware, documents, etc.

Hans K. Ziegler (1911–1999)
Head of German- and Austrian-derived research group


Feb. 12, 1952
H. K. ZIEGLER
ELECTRICAL CIRCUIT FOR PREVENTING EXCESSIVE TRANSIENTS
Filed Feb. 23, 1951
2,585,069
AC SOURCE
LOAD
PM GENERATOR
10
11
12
13
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15
16
17
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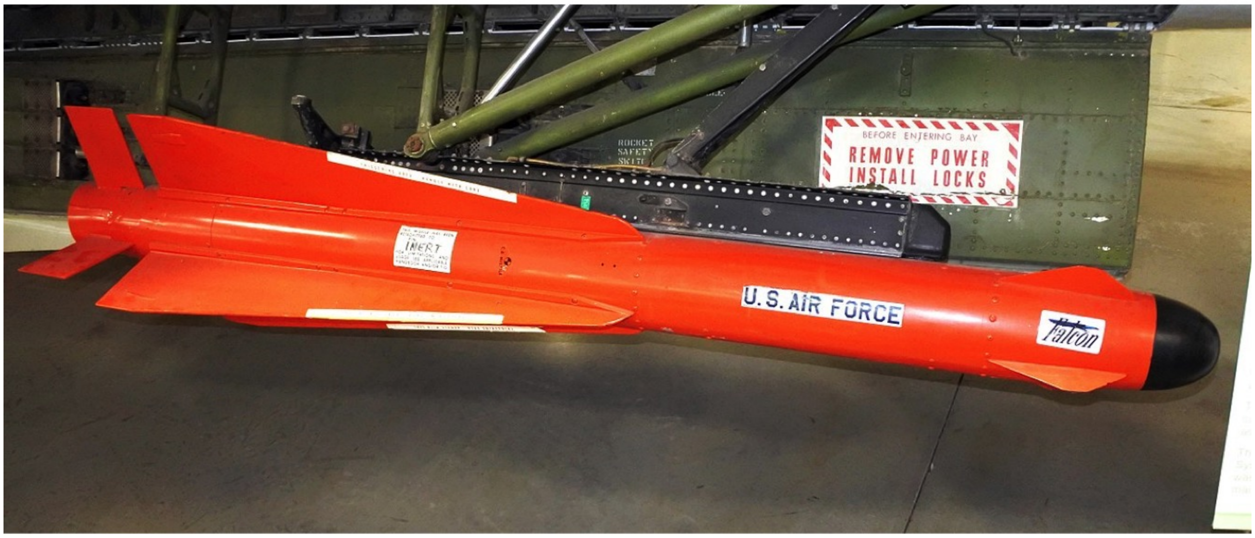
20
30
32
33
34
35
36
FIG. 1
FIG. 2
FIG. 3
FIG. 4

Ernst Baars	**Physical chemistry**
Eberhard Both	**Advanced ceramics/metals**
Rudolf Brill	**Semiconductor devices**
Wilhelm Buessem	**Advanced ceramics**
Eduard Gerber	**Piezoelectric devices**
Richard Glocker	**Metallurgy**
Georg Goubau	**Physics**
Richard Guenther	**Engineering**
Gunter Guttwein	**Magnetic data recording**
Georg Hass	**Optics**
Horst Kedesdy	**Physics**
Karl Kordesch	**Batteries and fuel cells**
Stanley Kronenberg	**Nuclear weapons**
Kurt Lehovec	**Semiconductor devices**
Gerhard Schwesinger	**Optics**
Helmut Weickmann	**Geophysics**
Etc.	

Figure 6.155: Hans K. Ziegler was the head of a largely German- and Austrian-derived research group at a U.S. Army laboratory in Fort Monmouth, New Jersey, that harnessed infrared and other technologies.

Falcon heat-seeking missile (1956)


BEFORE ENTERING BAY
REMOVE POWER
INSTALL LOCKS
INERT
U.S. AIR FORCE
Falcon

Sidewinder heat-seeking missile (1956)

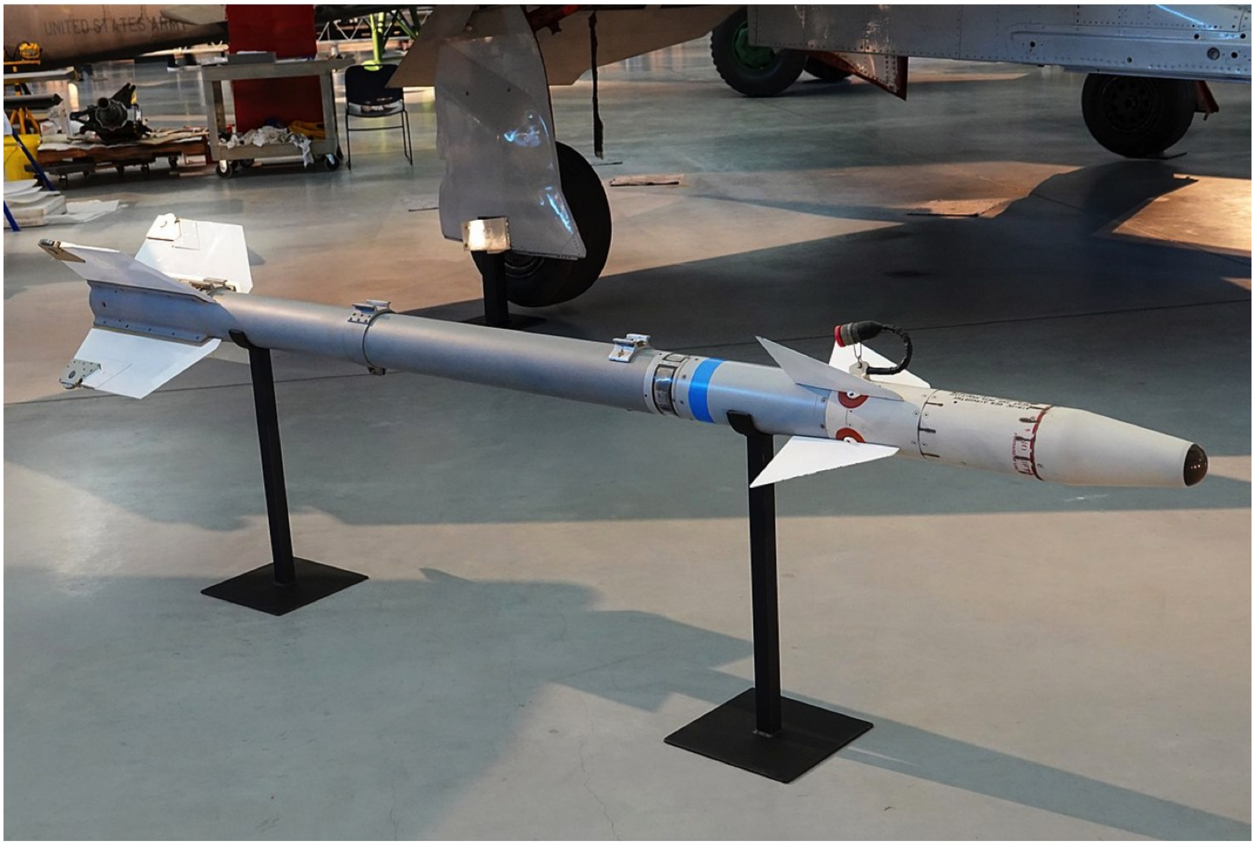
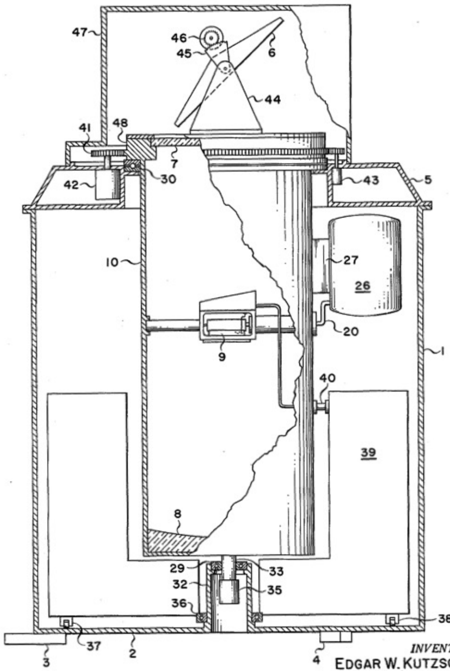

UNITED STATES ARMY

Figure 6.156: Edgar Kutzscher and other German-speaking creators helped to develop postwar infrared heat-seeking missiles such as the Falcon and Sidewinder.

Nov. 23, 1965 E. W. KUTZSCHER ETAL **3,219,822**

INFRARED SEARCH SYSTEM

Filed Sept. 1, 1961 4 Sheets-Sheet 1


47
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41
48
7
30
42
43
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10
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26
20
9
1
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39
8
29
32
36
33
35
38
37
2
3
4

FIG. 1

INVENTORS.
EDGAR W. KUTZSCHER
DOMINIC AMARA
BY George C. Sullivan
Agent

Nov. 23, 1965 E. W. KUTZSCHER ETAL **3,219,822**

INFRARED SEARCH SYSTEM

Filed Sept. 1, 1961 4 Sheets-Sheet 2

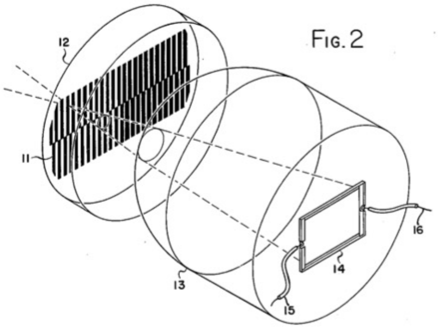

12
11
13
14
15
16

FIG. 2

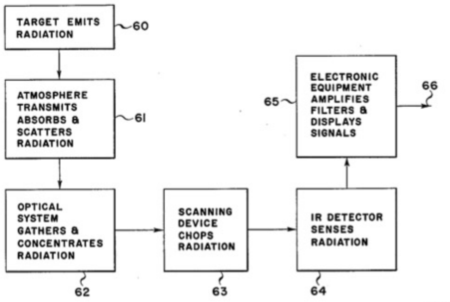

TARGET EMITS RADIATION
60
ATMOSPHERE TRANSMITS ABSORBS & SCATTERS RADIATION
61
OPTICAL SYSTEM GATHERS & CONCENTRATES RADIATION
62
SCANNING DEVICE CHOPS RADIATION
63
IR DETECTOR SENSES RADIATION
64
ELECTRONIC EQUIPMENT AMPLIFIES FILTERS & DISPLAYS SIGNALS
65
66

FIG. 6

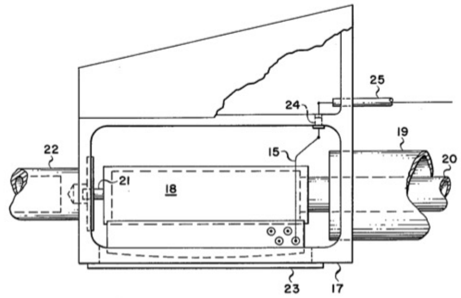
INVENTORS.
EDGAR W. KUTZSCHER
DOMINIC AMARA
BY George C. Sullivan
Agent

Nov. 23, 1965 E. W. KUTZSCHER ETAL **3,219,822**

INFRARED SEARCH SYSTEM

Filed Sept. 1, 1961 4 Sheets-Sheet 3

FIG. 3


25
24
15
19
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22
21
18
23
17

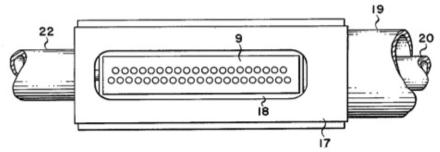
19
22
9
20
18
17

FIG. 4

INVENTORS.
EDGAR W. KUTZSCHER
DOMINIC AMARA
BY George C. Sullivan
Agent

Nov. 23, 1965 E. W. KUTZSCHER ETAL **3,219,822**

INFRARED SEARCH SYSTEM

Filed Sept. 1, 1961 4 Sheets-Sheet 4

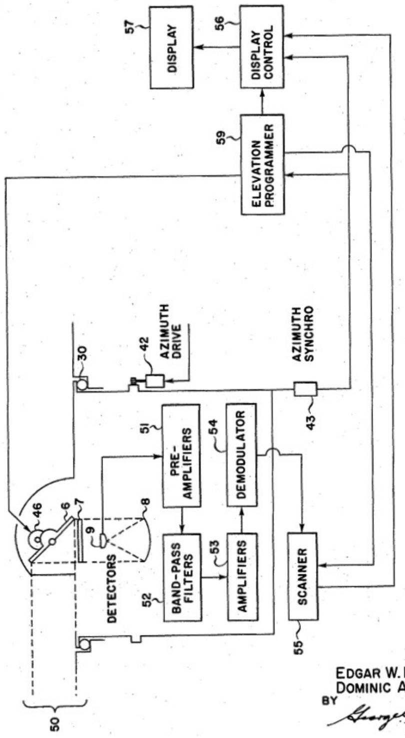
57
DISPLAY
56
DISPLAY CONTROL
59
ELEVATION PROGRAMMER
30
42
AZIMUTH DRIVE
AZIMUTH SYNCHRO
43
51
PRE-AMPLIFIERS
54
DEMODULATOR
46
6
7
8
9
DETECTORS
52
BAND-PASS FILTERS
53
AMPLIFIERS
SCANNER
55
50

FIG. 5

INVENTORS.
EDGAR W. KUTZSCHER
DOMINIC AMARA
BY George C. Sullivan
Agent

Figure 6.157: One of the postwar U.S. patents by Edgar Kutzscher on infrared targeting systems.

6.7 Computers and Robotics

While it is not widely known in the modern non-German-speaking world, German-speaking scientists and engineers made numerous incredibly prescient advances in:

6.7.1. Calculating machines

6.7.2. Computers

6.7.3. Cryptography

6.7.4. Robotics

6.7.1 Calculating Machines

As shown in Fig. 6.158, Wilhelm Schickard (Tübingen, 1592–1635) designed, built, and demonstrated the first calculating machines. Computer historian Herman Goldstine [Goldstine 1993, p. 6] explained how modern scholars rediscovered Schickard and his accomplishments:

> Our story really opens during the Thirty Years War with Wilhelm Schickard (1592–1635), who was a professor of astronomy, mathematics, and Hebrew in Tübingen. Some years ago (1957) Dr. Franz Hammer, then assistant curator of Kepler's papers, discovered some letters from Schickard to Kepler—both of whom were from Würtemberg—containing sketches and descriptions of a machine Schickard had designed and built in 1623 to do completely automatically the operations of addition and subtraction and, partially automatically, multiplication and division. The first letter was dated 20 September 1623, and a subsequent one 25 February 1624. In the first one, Schickard wrote of the machine that it "immediately computes the given numbers automatically, adds, subtracts, multiplies, and divides. Surely you will beam when you see how [it] accumulates left carries of tens and hundreds by itself or while subtracting takes something away from them. . . ."

Gottfried Leibniz (Saxony, 1646–1716) greatly extended Schickard's work (Fig. 6.159). He produced a machine that could add, subtract, multiply, and divide fully automatically. Leibniz also designed machines that could do algebra and calculus. He created binary mathematics, the base-2 system in which numbers are represented by strings of 0s and 1s, which forms the foundation for modern computers. Leibniz even developed mathematical logic functions (AND, OR, NOT, etc.) that are used by digital circuits and modern computers [Antognazza 2009]. Herman Goldstine [Goldstine 1993, pp. 7–9] praised all of Leibniz's contributions to computer science:

> [...] Gottfried Wilhelm Leibniz (1646–1716), another of the great universalists of his or indeed of all time, invented a device now known as the *Leibniz wheel* and still in use in some machines. The mechanism enabled him to build a machine which surpassed Pascal's in that it could do not only addition and subtraction fully automatically but also multiplication and division. [...]
>
> [...I]t was Leibniz who summed up the situation very well indeed when he wrote: "Also the astronomers surely will not have to continue to exercise the patience which is required for computation. It is this that deters them from computing or correcting tables, from the construction of Ephemerides, from working on hypotheses, and from discussions of observations with each other. For it is unworthy of excellent men to lose hours

> like slaves in the labor of calculation which could safely be relegated to anyone else if machines were used." [...]
>
> Leibniz's work did however stimulate a number of others to build improved machines, many of them ingenious variants of his. Today these machines are still with us and play a significant role for minor calculations. Indeed during World War II they were of greatest importance.
>
> It is also Leibniz, who in the grandeur of his genius realized, at least in principle, his Universal Mathematics. This was also to have greatest importance to our story—but much later. He wrote an essay in 1666 concerning Combinatorics, one of the great branches of mathematics, entitled *De Arte Combinatorica.* He described it as "a general method in which all truths of the reason could be reduced to a kind of calculation." [...] Thus Leibniz contributed very profoundly to computers. Not only by his machine but also by his studies of what is now known as symbolic logic. [...] In closing our few paragraphs on Leibniz, we feel it is worth emphasizing his four great accomplishments to the field of computing: his initiation of the field of formal logics; his construction of a digital machine; his understanding of the inhuman quality of calculation and the desirability as well as the capability of automating this task; and lastly, his very pregnant idea that the machine could be used for testing hypotheses.

Herman Hollerith (1860–1929) was born in the United States, but his parents were German immigrants, and his father, a professor, apparently played a major role in his education and training. Hollerith developed electromechanical punch card machines that were widely used (Fig. 6.160). The company he founded to produce them later became International Business Machines (IBM). Oxford University's *Biographical Dictionary of Scientists* described Hollerith's innovation process [Porter 1994, pp. 341–342]:

> He was probably the first to automate the large-scale processing of information, and as such was a pioneer of the electronic calculator, particularly its application to data handling in business and commerce.
>
> [...] Hollerith developed the idea of punching first a continuous roll of paper, and later individual cards the same size as a dollar bill, with holes to represent information. The quantities indicated by the holes were counted when the tape or cards passed through a device in which electrical contact was made through the holes. The passage of an electric current caused electromechanical counters to advance one place for each hole. The realization of these ideas in practical terms did not, however, come about in time for the processing of the 1880 [census] returns. [...]
>
> By 1889, he had developed not only his electrical machines for recording the information on punched cards, but also machines for punching the cards and for sorting them. [...]
>
> Hollerith soon realized that the age of large-scale data handling had begun, and in 1896 he formed the Tabulating Machine Company, to manufacture the machines and the cards they used. With the growth of business in this area, Hollerith's company was soon merged with two others into the Computing-Tabulating-Recording Company, which later became International Business Machines Corporation (IBM). [...]
>
> Hollerith stayed with IBM as a consultant engineer until his retirement in 1921.

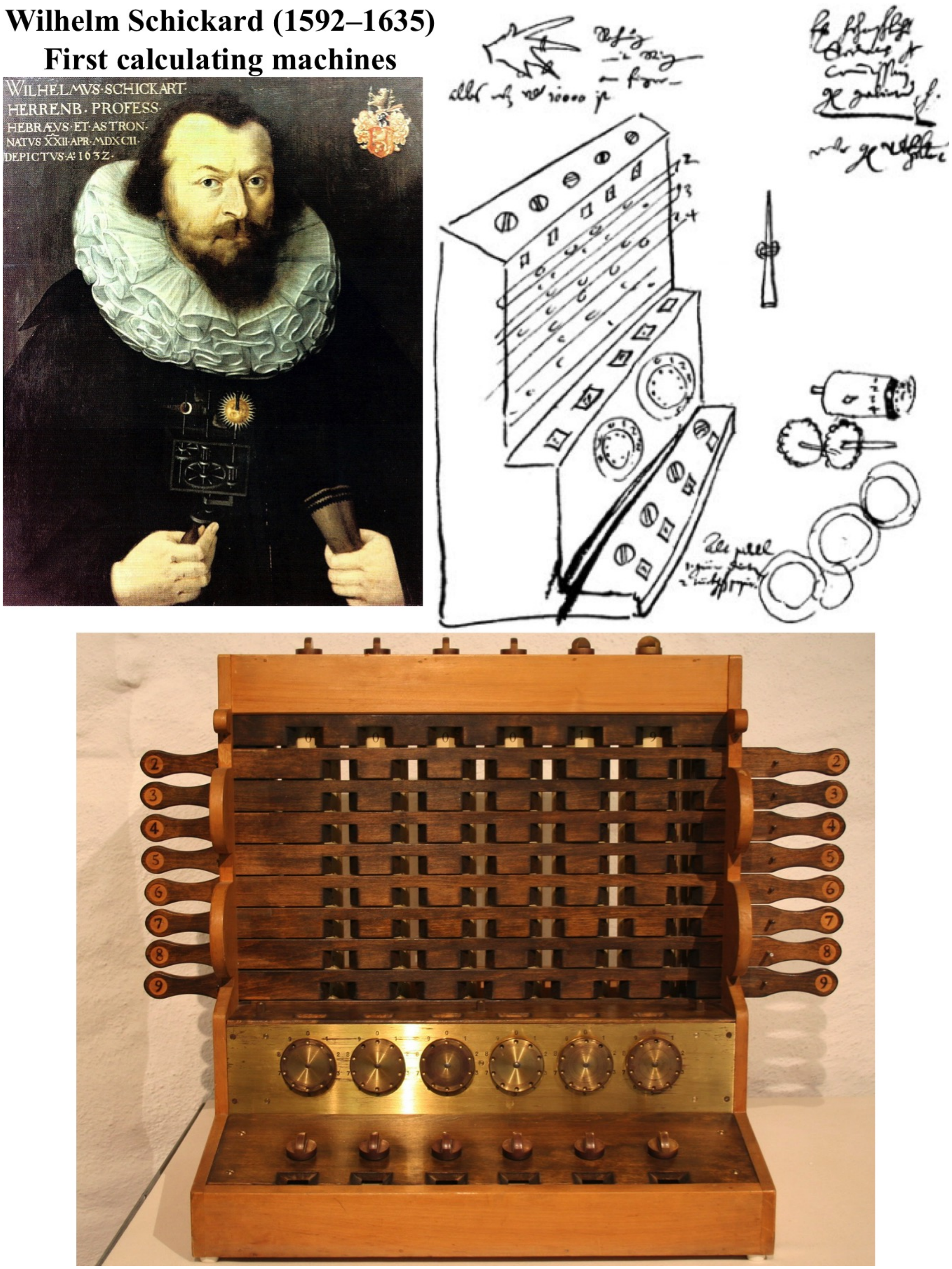
Wilhelm Schickard (1592–1635)
First calculating machines
WILHELMVS·SCHICKART·
HERRENB·PROFESS·
HEBRÆVS·ET·ASTRON·
NATVS XXII·APR·MDXCII·
DEPICTVS·A° 1632·
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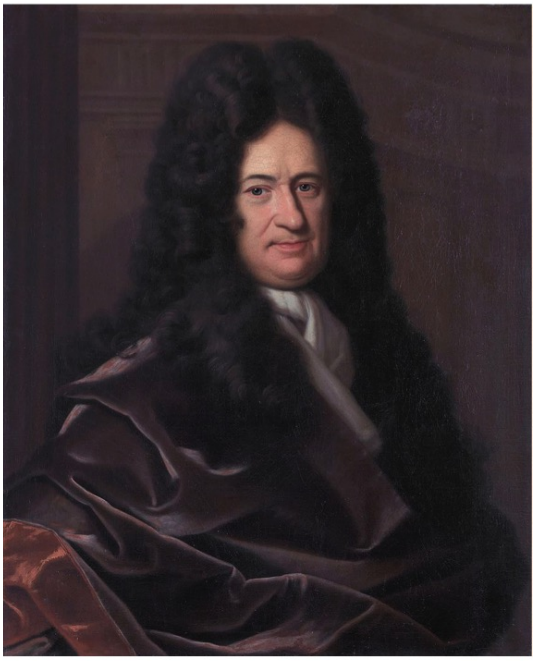
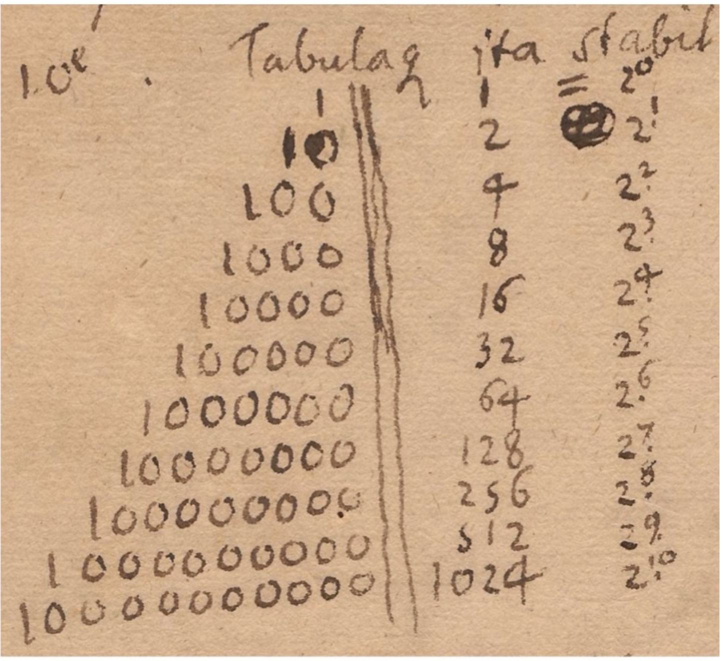
Figure 6.158: Wilhelm Schickard developed the first calculating machines.

Gottfried Leibniz (1646–1716) developed binary mathematics, produced a machine that could add, subtract, multiply, and divide, and designed machines that could do algebra and calculus





1.0e . Tabulae ita stabil

1	1	= 2^0
10	2	2^1
100	4	2^2
1000	8	2^3
10000	16	2^4
100000	32	2^5
1000000	64	2^6
10000000	128	2^7
100000000	256	2^8
1000000000	512	2^9
10000000000	1024	2^{10}
100000000000		

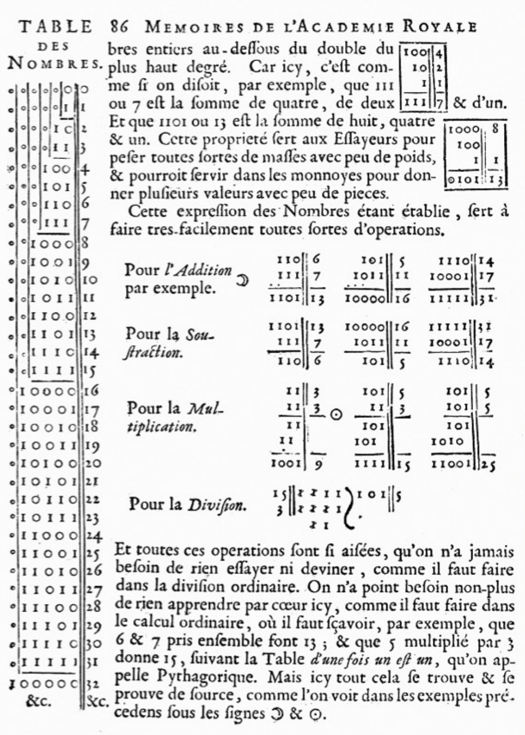


TABLE DES NOMBRES. 86 MEMOIRES DE L'ACADEMIE ROYALE

000000	0
000001	1
000010	2
000011	3
000100	4
000101	5
000110	6
000111	7
001000	8
001001	9
001010	10
001011	11
001100	12
001101	13
001110	14
001111	15
010000	16
010001	17
010010	18
010011	19
010100	20
010101	21
010110	22
010111	23
011000	24
011001	25
011010	26
011011	27
011100	28
011101	29
011110	30
011111	31
100000	32
&c.	&c.

bres entiers au-deſſous du double du plus haut degré. Car icy, c'eſt comme ſi on diſoit, par exemple, que 111 ou 7 eſt la ſomme de quatre, de deux & d'un. Et que 1101 ou 13 eſt la ſomme de huit, quatre & un. Cette proprieté ſert aux Eſſayeurs pour peſer toutes ſortes de maſſes avec peu de poids, & pourroit ſervir dans les monnoyes pour donner pluſieurs valeurs avec peu de pieces.

```
100 | 4
 10 | 2
  1 | 1
111 | 7

1000 | 8
 100 |
   1 | 1
0101 | 13
```

Cette expreſſion des Nombres étant établie, ſert à faire tres-facilement toutes ſortes d'operations.

Pour *l'Addition* par exemple. ☽

```
 110 | 6      101 | 5     1110 | 14
 111 | 7     1011 | 11   10001 | 17
1101 | 13   10000 | 16   11111 | 31
```

Pour la *Souſtraction.*

```
1101 | 13   10000 | 16   11111 | 31
 111 | 7     1011 | 11   10001 | 17
 110 | 6      101 | 5     1110 | 14
```

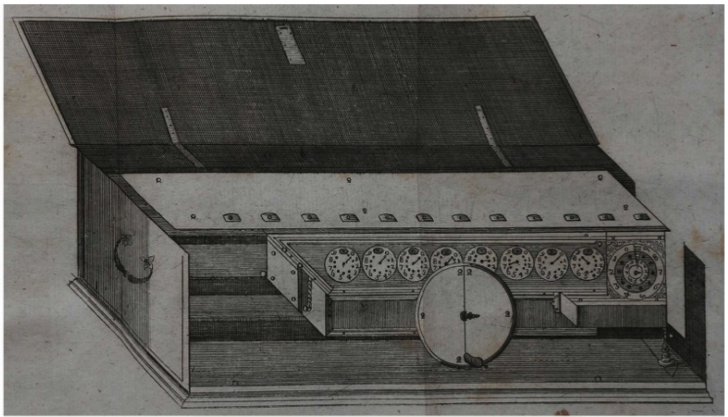
Pour la *Multiplication.*

```
  11 | 3  ⊙   101 | 5     101 | 5
  11 | 3        11 | 3     101 | 5
  11           101         101
 11           101         1010
1001 | 9      1111 | 15  11001 | 25
```

Pour la *Diviſion.*

```
15 | 1 1 1 1 } 101 | 5
 3 | 1 1 1 1 {
       1 1
```

Et toutes ces operations ſont ſi aiſées, qu'on n'a jamais beſoin de rien eſſayer ni deviner, comme il faut faire dans la diviſion ordinaire. On n'a point beſoin non-plus de rien apprendre par cœur icy, comme il faut faire dans le calcul ordinaire, où il faut ſçavoir, par exemple, que 6 & 7 pris enſemble font 13 ; & que 5 multiplié par 3 donne 15, ſuivant la Table *d'une fois un eſt un*, qu'on appelle Pythagorique. Mais icy tout cela ſe trouve & ſe prouve de ſource, comme l'on voit dans les exemples précedens ſous les ſignes ☽ & ⊙.



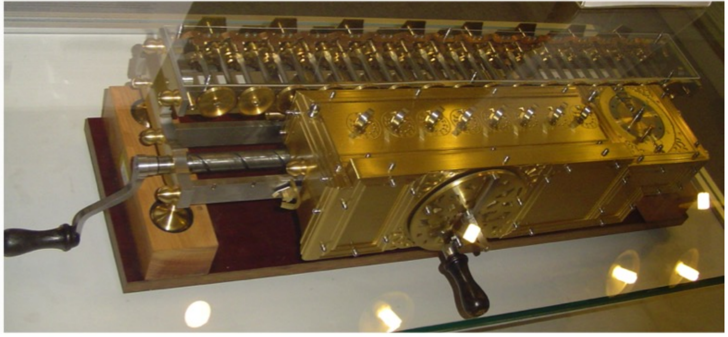


Figure 6.159: Gottfried Leibniz developed binary mathematics, produced a machine that could add, subtract, multiply, and divide, and designed machines that could do algebra and calculus.

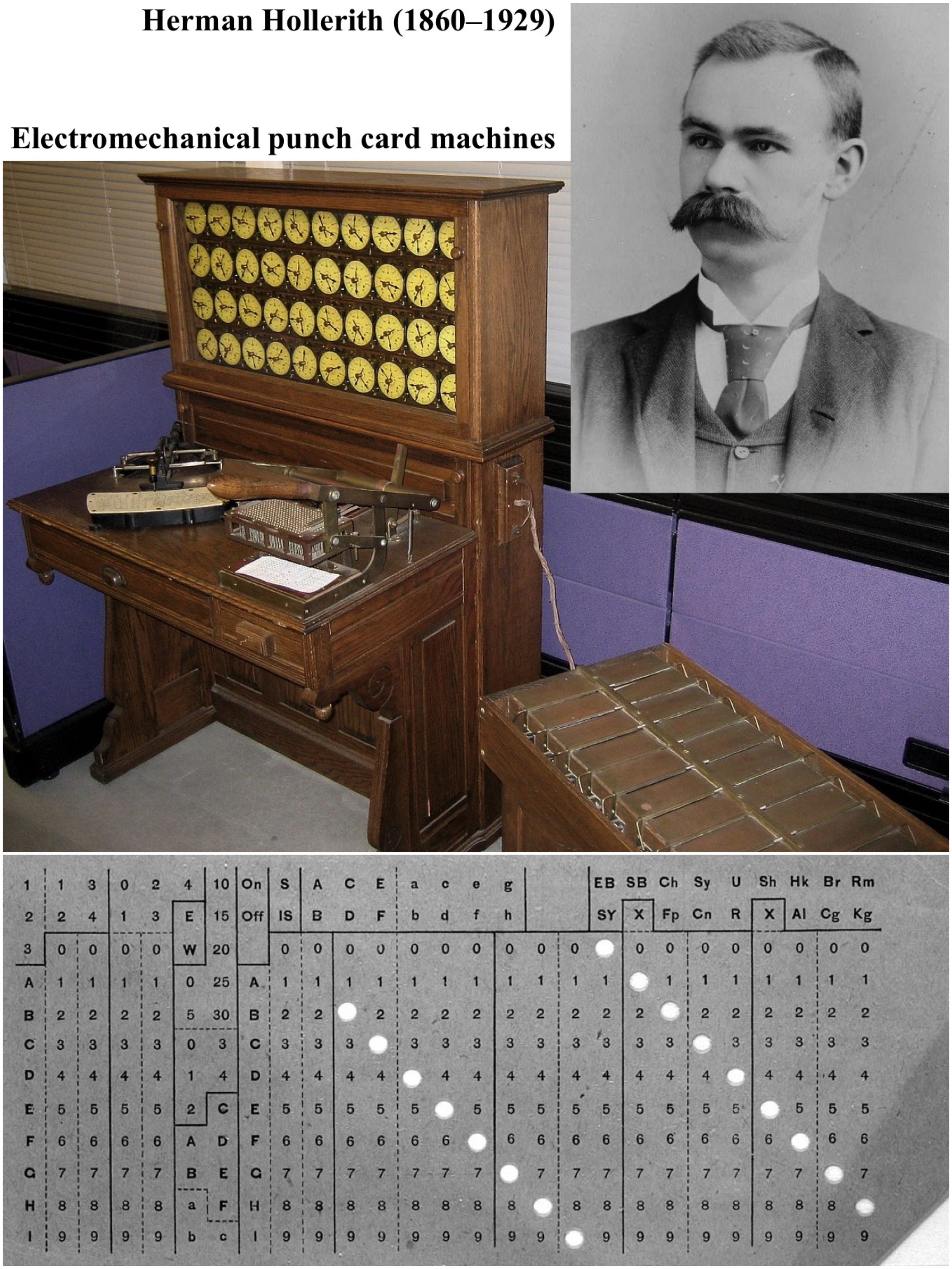

Herman Hollerith (1860–1929)
Electromechanical punch card machines

Figure 6.160: Herman Hollerith developed electromechanical punch card machines.

6.7.2 Computers

Gustav Tauschek (Austrian, 1899–1945) was an amazingly early, advanced, and prolific creator of computer technologies, as shown in Figs. 6.161–6.163 [Helfert et al. 2007]:

- From 1922 until his death in 1945, Tauschek designed, built, and patented a series of increasingly sophisticated programmable calculating machines that rivaled the computers that Zuse developed several years later, and surpassed any other computing machines in the world at that time.
- He invented the electric typewriter in 1927.
- Tauschek invented the world's first optical character recognition system in 1928.
- He also invented the world's first magnetic drum memories for computer data storage in 1929.
- IBM bought at least 169 of Tauschek's patents and used them as the basis of many of the machines that it built and marketed in the following decades.
- Along the way, Tauschek also invented lawnmowers, snowmobiles, the autopen or signing machine, and other devices.

Even though Tauschek's computer innovations were decades ahead of their time and exerted an enormous influence through his patents on IBM, and through IBM's products on the rest of the world, he has been virtually erased from history. Historians of computing worldwide should rediscover Tauschek and his work, and give him his proper place in the history books.

Konrad Zuse (German, 1910-1995), shown in Fig. 6.164, was another extremely early and important computer pioneer. He began designing and building prototype programmable digital computers in 1935. For his early Z1 and Z2 computers, he was assisted by people such as Helmut Schreyer (German, 1912–1984), who later developed his own computers. For his Z4 computer onward, he was assisted by people such as Heinz Rutishauser (Swiss, 1918–1970), who pioneered software and programming languages. Examples from Zuse's patents are provided in Fig. 6.165.

The first programmable digital computers built by Konrad Zuse included the:

- Z1 computer, which was first operational in 1938, was destroyed by Allied bombing during the war, and was rebuilt later as a museum piece (Fig. 6.166).
- Z2 computer, which was first operational in 1939, was destroyed during the war, and was never rebuilt (Fig. 6.166).
- Z3 computer, which was first operational in 1941, was destroyed in 1944, and was rebuilt after the war (Fig. 6.167).
- Z4 computer, which was first operational in 1944 and survived the war intact (Fig. 6.167).

- S1 special-purpose computer for measuring and calculating wing flutter, which was first operational in 1942, was destroyed in 1944, and was never rebuilt (Fig. 6.168).

- S2 special-purpose computer for measuring and calculating wing flutter, which was first operational in 1943 and was captured by Russian forces at the end of the war (Fig. 6.168).

In his autobiography, Zuse summarized the capabilities of the Z3 computer [Zuse 1993, pp. 62–63]:

> Z3 [...] was completed in 1941 and was the first fully operational machine to contain state-of-the-art versions of all the important elements of a program-controlled computing machine for scientific purposes[...] It had—in today's terminology—the following characteristics:
>
> – electromagnetic relay technology (600 relays in the arithmetic unit, 1400 relays in the memory unit)
>
> – binary number system
>
> – floating point
>
> – word length: 22 bits [...]
>
> – storage capacity: 64 words
>
> – control via an 8-track punched tape (i.e., a command is made up of 8 bits)
>
> – input entered via a special keyboard, through which the position of the points can be set relative to 4 decimal figures
>
> – output via display of results on a lamp strip, including the placement of the point
>
> – speed: approximately 3 seconds for multiplication, division or taking the square root
>
> [...] Yet the Z3 was relatively reliable. Unfortunately, I was the only one who could service it. [...]
>
> Aside from a few trial programs—programs to compute determinants or quadratic equations, for example—it was the program to compute a complex matrix that was of chief importance. This was an essential step in the computation of critical flutter frequencies of aircraft.

For the Z4 computer, Zuse increased the number of relays to approximately 2500 total, and the word length to 32 bits.

Zuse also developed the first high-level computer programming language, Plankalkül, in 1942 (Fig. 6.169). That was 14 years before IBM introduced the Fortran programming language, and may well have inspired and influenced the development of Fortran (through detailed postwar investigations of Zuse's work by Allied countries in general, and by IBM in particular).

In general, Zuse's first computers were years ahead of comparable technology that was later developed in the United States and other countries, and that was likely strongly influenced by Zuse's designs.[17] After the war, Zuse developed and sold a long series of commercial computers in Europe.

As illustrated in Fig. 6.170, Helmut Hölzer (German, 1912–1996) developed the world's first analog electronic computers beginning in 1939, including large mainframe computers and small onboard flight computers for rockets (p. 2814). Most of his work was conducted at and for the Peenemünde rocket research center [Tomayko 1985; https://www.cdvandt.org/v2__computer.htm]. After the war he went to the United States; in 1960 he became Director of Computers at the NASA Marshall Space Flight Center in Huntsville, Alabama.

Figure 6.171 presents some other early computer pioneers. Alwin Walther (German, 1898–1967) created and operated computers at Darmstadt for the Peenemünde rocket program during the war, and continued to develop computers after the war. Heinz Billing (German, 1914–2017) produced computers with magnetic drum and magnetic core memory, and later built the first laser-interferometer gravitational-wave detector; examples from his patents are shown in Fig. 6.172. Nikolaus Joachim Lehmann (German, 1921–1998) created computers in East Germany. As illustrated in Fig. 6.173, Walter Sprick (German, 1909–1989) developed computers ∼1939–1974; based on Sprick's designs, Heinz Nixdorf (German, 1925–1986) developed computers 1951–1986.

As shown in Figs. 6.175–6.178, creators who had been trained in the German-speaking research world also helped to develop computers in the United States. John von Neumann (Hungarian, 1903–1957) was involved in developing the first programmable digital computers in the United States, such as EDVAC (first operational in 1951). His wife, Klára Dán von Neumann (Hungarian, 1911–1963), was one of the first programmers on early computers such as MANIAC I (1952). Jan Rajchman (Polish, educated in Switzerland, 1911–1989) developed iron core computer memories and other computer technologies in the United States. Joseph Weizenbaum (German, 1923–2008) created the ELIZA software in 1965, a major step in the development of artificial intelligence.

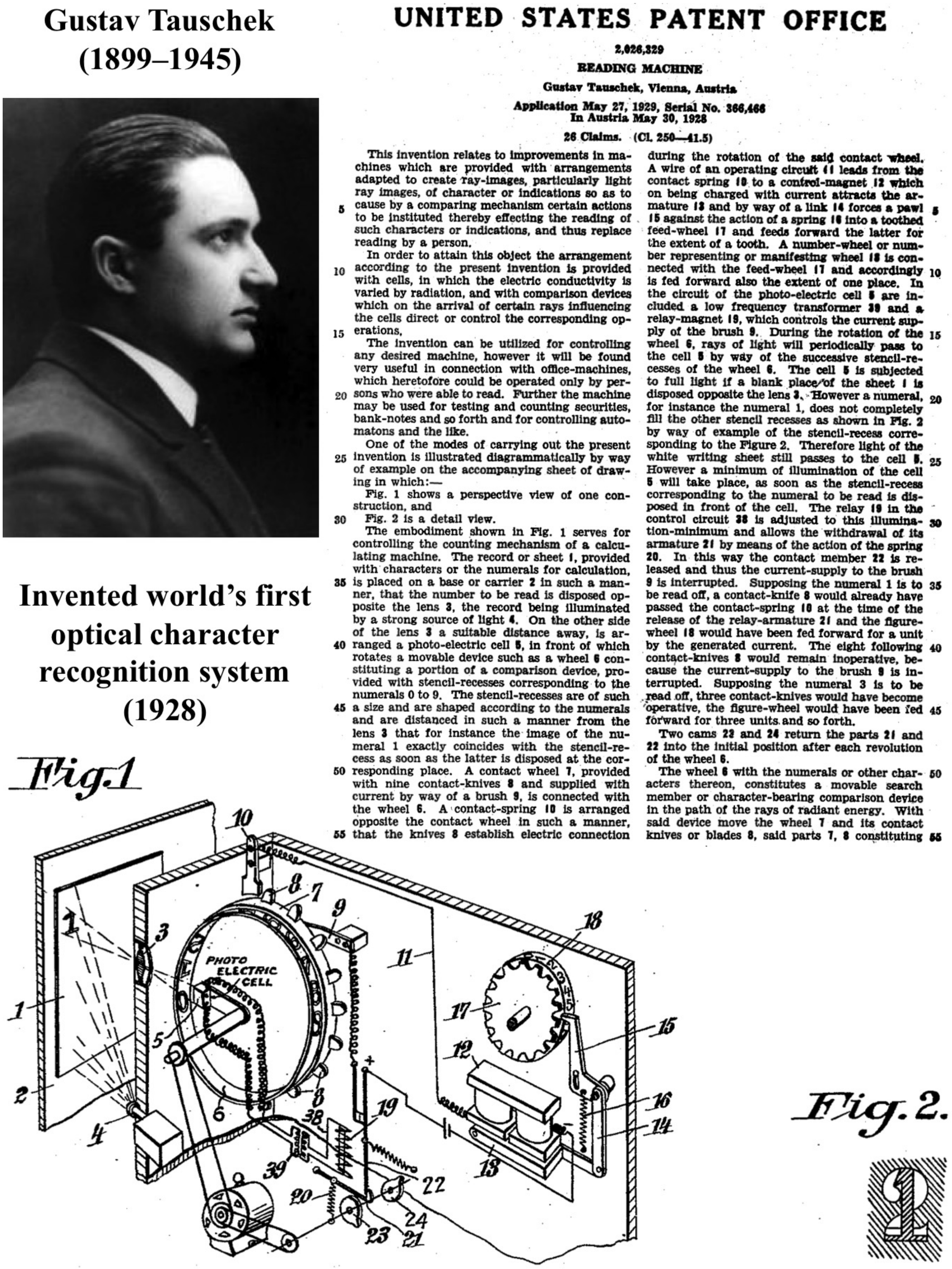
It was German-speaking scientists who took magnetic computer memory from its very beginnings (Tauschek) to its most advanced form. Peter Andreas Grünberg (German, 1939–2018) discovered giant magnetoresistance, which can be used for high-density magnetic hard drives. For that discovery, he won the Nobel Prize in Physics in 2007. The Royal Swedish Academy of Sciences summarized his work [https://www.nobelprize.org/prizes/physics/2007/grunberg/facts/]:

> When materials are reduced to just a few atomic layers—a few nanometers in thickness—their properties change. Independently of one another, Peter Grünberg and Albert Fert discovered the phenomenon Giant Magneto Resistance (GMR) in 1988. GMR involves small changes in magnetic fields creating major differences in electrical resistance. It has also had an impact on electronics, especially read heads, where information stored magnetically is converted to electric current. Thanks to GMR, hard drives have become much smaller.

German-speaking scientists also developed magnetic tape, which for decades was used to store computer data as well as audio and visual signals (pp. 990, 1011).

---

[17] Ceruzzi 1998; Füßl (ed.) 2010; Goldstine 1993; Lyndon 1947; Mons et al. 2005; Rojas 2023; Zuse 1993, esp. pp. 113–118; BIOS 142; CIOS XXXI-83; NARA RG 330, Entry A1-1B, Box 186, File Zuse, Konrad.



UNITED STATES PATENT OFFICE

2,026,329

READING MACHINE

Gustav Tauschek, Vienna, Austria

Application May 27, 1929, Serial No. 366,466
In Austria May 30, 1928

26 Claims. (Cl. 250—41.5)

This invention relates to improvements in machines which are provided with arrangements adapted to create ray-images, particularly light ray images, of character or indications so as to cause by a comparing mechanism certain actions to be instituted thereby effecting the reading of such characters or indications, and thus replace reading by a person.

In order to attain this object the arrangement according to the present invention is provided with cells, in which the electric conductivity is varied by radiation, and with comparison devices which on the arrival of certain rays influencing the cells direct or control the corresponding operations.

The invention can be utilized for controlling any desired machine, however it will be found very useful in connection with office-machines, which heretofore could be operated only by persons who were able to read. Further the machine may be used for testing and counting securities, bank-notes and so forth and for controlling automatons and the like.

One of the modes of carrying out the present invention is illustrated diagrammatically by way of example on the accompanying sheet of drawing in which:—

Fig. 1 shows a perspective view of one construction, and

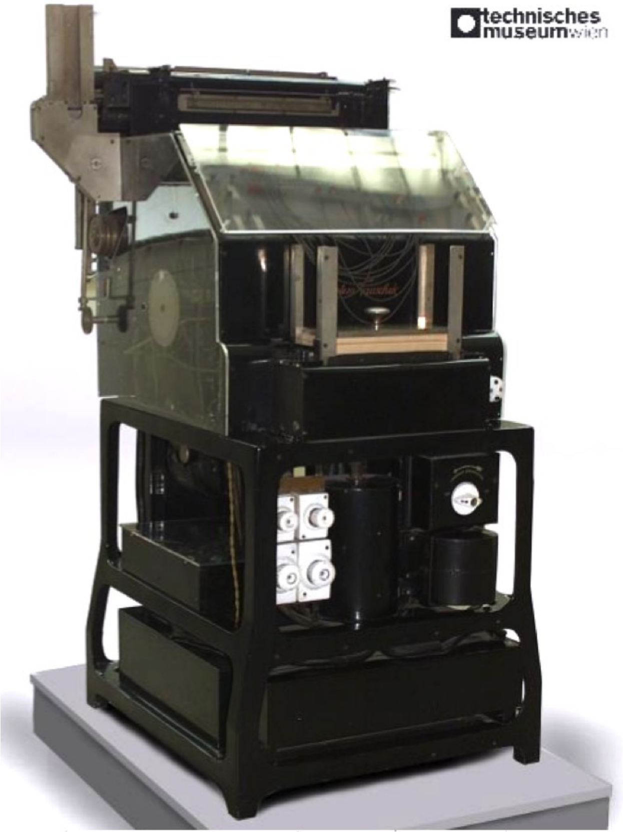
Fig. 2 is a detail view.

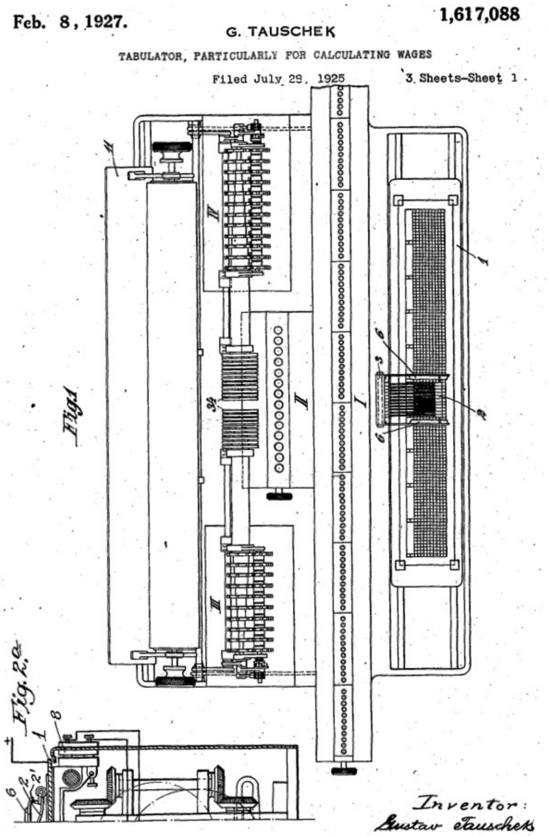
The embodiment shown in Fig. 1 serves for controlling the counting mechanism of a calculating machine. The record or sheet 1, provided with characters or the numerals for calculation, is placed on a base or carrier 2 in such a manner, that the number to be read is disposed opposite the lens 3, the record being illuminated by a strong source of light 4. On the other side of the lens 3 a suitable distance away, is arranged a photo-electric cell 5, in front of which rotates a movable device such as a wheel 6 constituting a portion of a comparison device, provided with stencil-recesses corresponding to the numerals 0 to 9. The stencil-recesses are of such a size and are shaped according to the numerals and are distanced in such a manner from the lens 3 that for instance the image of the numeral 1 exactly coincides with the stencil-recess as soon as the latter is disposed at the corresponding place. A contact wheel 7, provided with nine contact-knives 8 and supplied with current by way of a brush 9, is connected with the wheel 6. A contact-spring 10 is arranged opposite the contact wheel in such a manner, that the knives 8 establish electric connection during the rotation of the said contact wheel. A wire of an operating circuit 11 leads from the contact spring 10 to a control-magnet 12 which on being charged with current attracts the armature 13 and by way of a link 14 forces a pawl 15 against the action of a spring 16 into a toothed feed-wheel 17 and feeds forward the latter for the extent of a tooth. A number-wheel or number representing or manifesting wheel 18 is connected with the feed-wheel 17 and accordingly is fed forward also the extent of one place. In the circuit of the photo-electric cell 5 are included a low frequency transformer 39 and a relay-magnet 19, which controls the current supply of the brush 9. During the rotation of the wheel 6, rays of light will periodically pass to the cell 5 by way of the successive stencil-recesses of the wheel 6. The cell 5 is subjected to full light if a blank place of the sheet 1 is disposed opposite the lens 3. However a numeral, for instance the numeral 1, does not completely fill the other stencil recesses as shown in Fig. 2 by way of example of the stencil-recess corresponding to the Figure 2. Therefore light of the white writing sheet still passes to the cell 5. However a minimum of illumination of the cell 5 will take place, as soon as the stencil-recess corresponding to the numeral to be read is disposed in front of the cell. The relay 19 in the control circuit 38 is adjusted to this illumination-minimum and allows the withdrawal of its armature 21 by means of the action of the spring 20. In this way the contact member 22 is released and thus the current-supply to the brush 9 is interrupted. Supposing the numeral 1 is to be read off, a contact-knife 8 would already have passed the contact-spring 10 at the time of the release of the relay-armature 21 and the figure-wheel 18 would have been fed forward for a unit by the generated current. The eight following contact-knives 8 would remain inoperative, because the current-supply to the brush 9 is interrupted. Supposing the numeral 3 is to be read off, three contact-knives would have become operative, the figure-wheel would have been fed forward for three units and so forth.

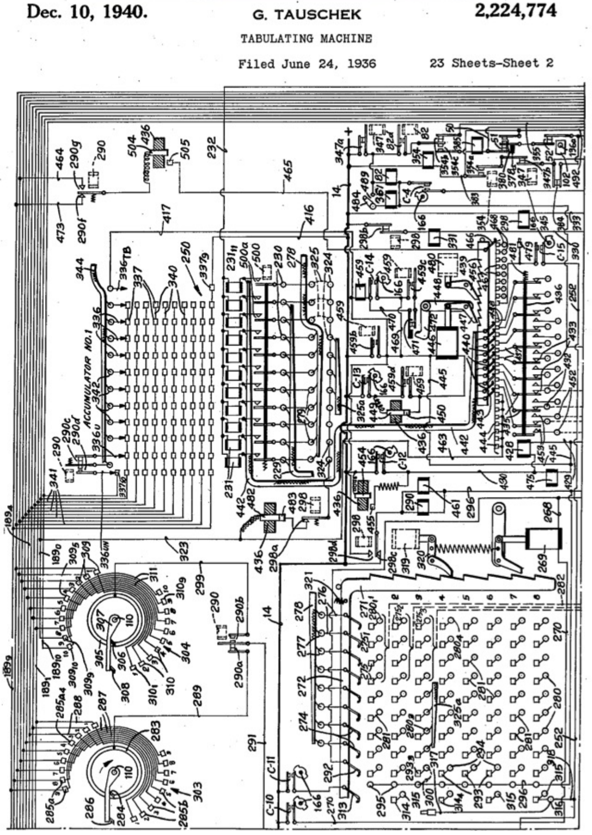
Two cams 23 and 24 return the parts 21 and 22 into the initial position after each revolution of the wheel 6.

The wheel 6 with the numerals or other characters thereon, constitutes a movable search member or character-bearing comparison device in the path of the rays of radiant energy. With said device move the wheel 7 and its contact knives or blades 8, said parts 7, 8 constituting

Figure 6.161: Gustav Tauschek pioneered numerous computer technologies, including the world's first optical character recognition system in 1928.


technisches museum wien


Feb. 8, 1927.
G. TAUSCHEK
1,617,088
TABULATOR, PARTICULARLY FOR CALCULATING WAGES
Filed July 29, 1925
3 Sheets-Sheet 1
Fig. 1
Fig. 2a
Inventor:
Gustav Tauschek


Dec. 10, 1940.
G. TAUSCHEK
2,224,774
TABULATING MACHINE
Filed June 24, 1936
23 Sheets-Sheet 2
ACCUMULATOR NO. 1

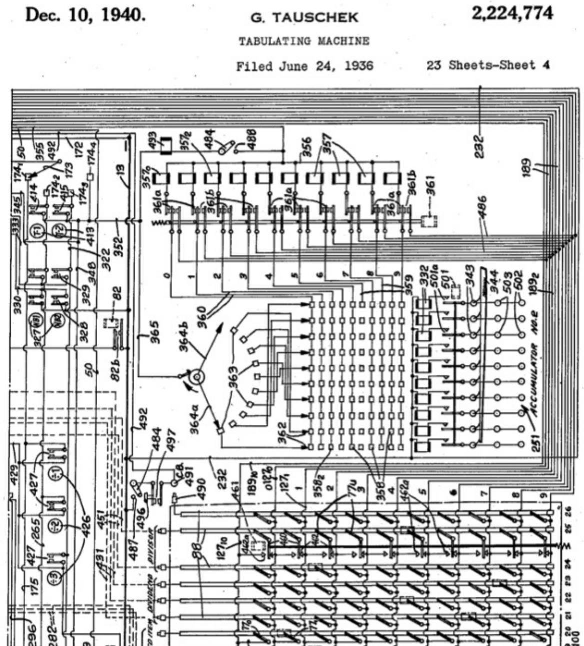
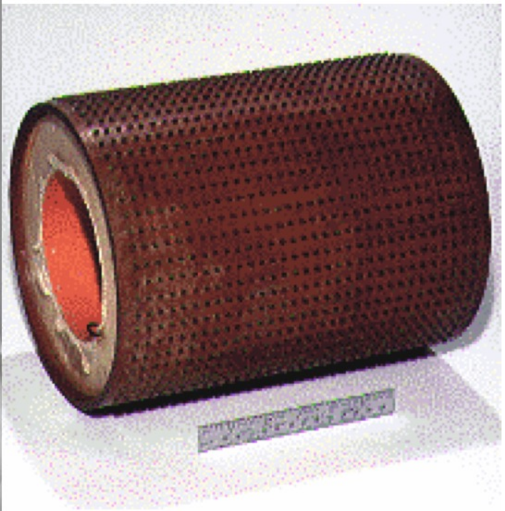
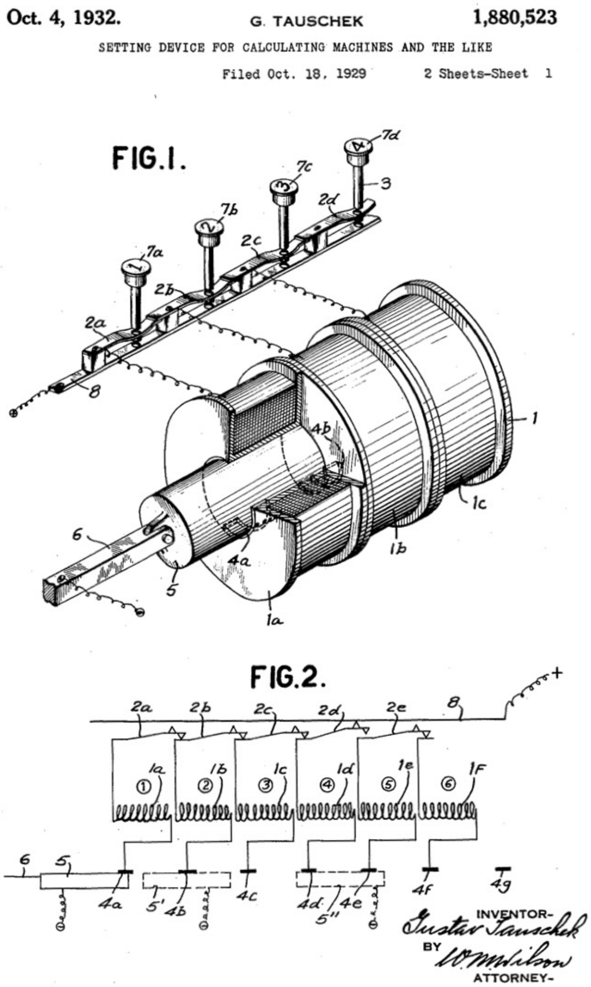

Dec. 10, 1940.
G. TAUSCHEK
2,224,774
TABULATING MACHINE
Filed June 24, 1936
23 Sheets-Sheet 4
ACCUMULATOR NO. 2

Figure 6.162: Gustav Tauschek designed, built, and patented a series of increasingly sophisticated programmable calculating machines between 1925 and 1945.

Gustav Tauschek with assistants

Invented magnetic drum data storage (1929)



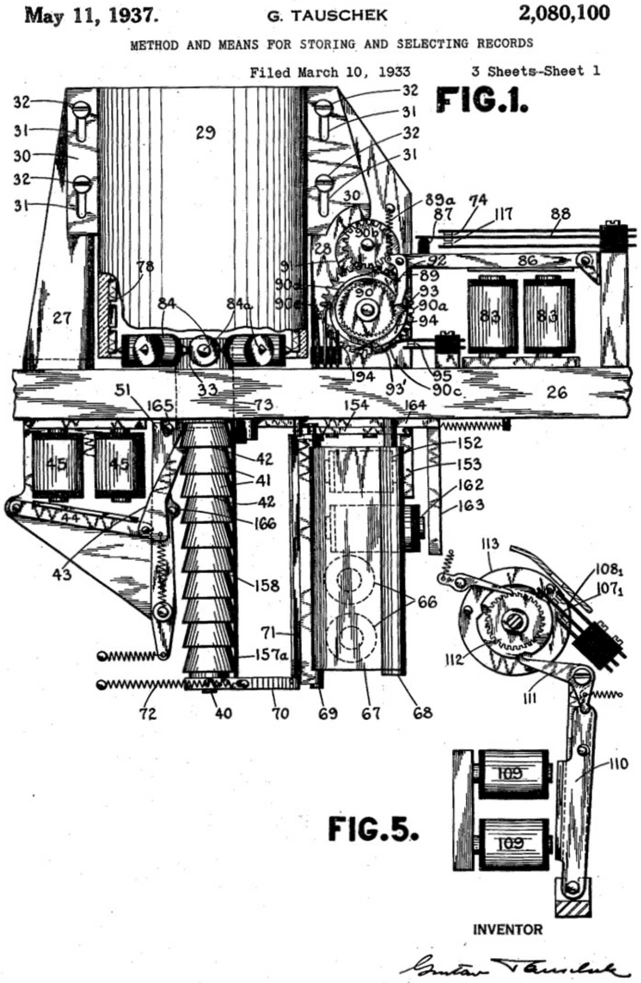


Oct. 4, 1932. G. TAUSCHEK 1,880,523

SETTING DEVICE FOR CALCULATING MACHINES AND THE LIKE

Filed Oct. 18, 1929 2 Sheets-Sheet 1

FIG.1.
7a
7b
7c
7d
2a
2b
2c
2d
3
8
1
1a
1b
1c
4a
4b
5
6
FIG.2.
2a
2b
2c
2d
2e
8
1a
1b
1c
1d
1e
1F
①
②
③
④
⑤
⑥
6
5
4a
5'
4b
4c
4d
5''
4e
4f
4g
INVENTOR-
Gustav Tauschek
BY
W.M. Wilson
ATTORNEY-



May 11, 1937. G. TAUSCHEK 2,080,100

METHOD AND MEANS FOR STORING AND SELECTING RECORDS

Filed March 10, 1933 3 Sheets-Sheet 1

FIG.1.
29
27
26
33
51
73
FIG.5.
109
110
INVENTOR
Gustav Tauschek

Figure 6.163: Gustav Tauschek also invented magnetic drum memories for computer data storage in 1929.

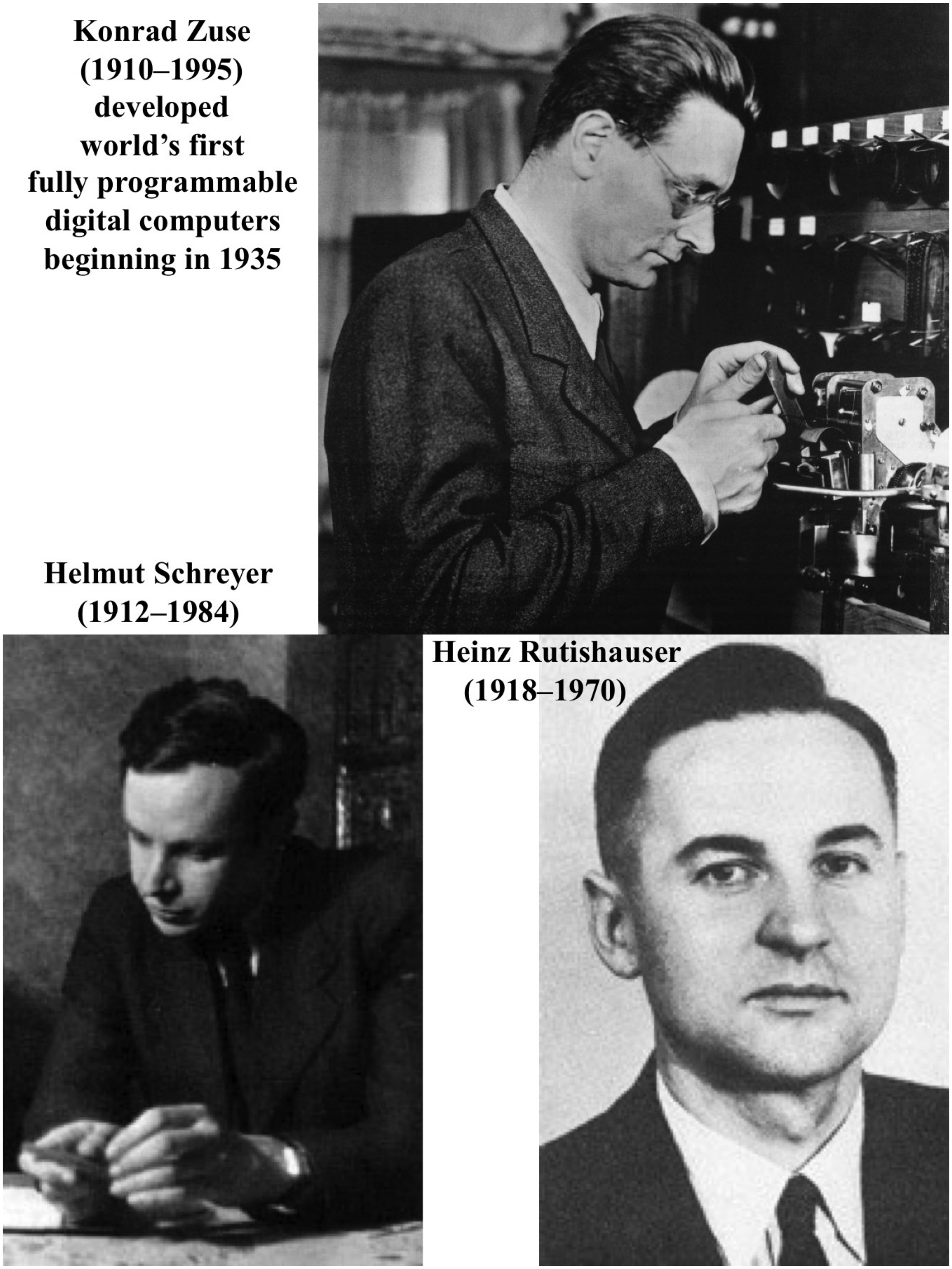
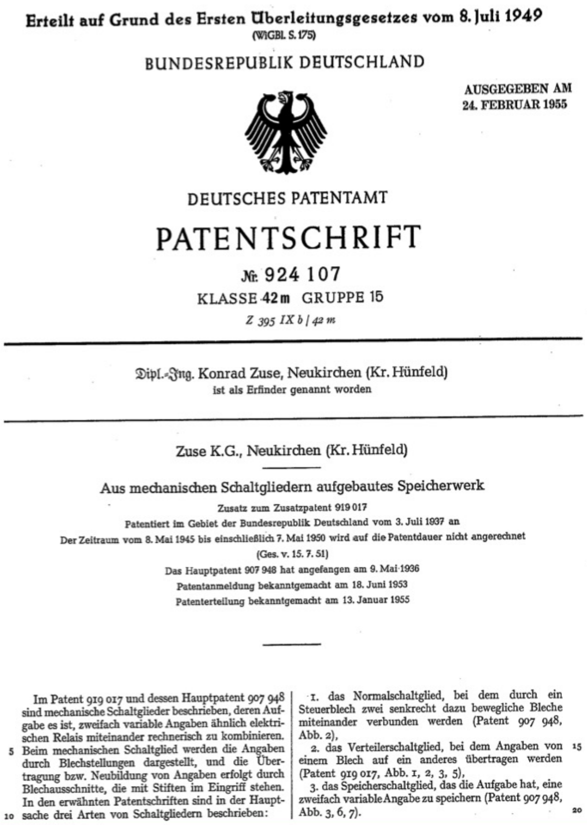

Konrad Zuse
(1910–1995)
developed
world's first
fully programmable
digital computers
beginning in 1935
Helmut Schreyer
(1912–1984)
Heinz Rutishauser
(1918–1970)

Figure 6.164: Konrad Zuse began designing and building prototype programmable digital computers in 1935. For his early Z1 and Z2 computers, he was assisted by people such as Helmut Schreyer, who later developed his own computers. For his Z4 computer onward, he was assisted by people such as Heinz Rutishauser, who pioneered software and programming languages.



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
24. FEBRUAR 1955

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 924 107

KLASSE **42m** GRUPPE 15

Z 395 IX b / 42 m

Dipl.-Ing. Konrad Zuse, Neukirchen (Kr. Hünfeld)
ist als Erfinder genannt worden

Zuse K.G., Neukirchen (Kr. Hünfeld)

Aus mechanischen Schaltgliedern aufgebautes Speicherwerk

Zusatz zum Zusatzpatent 919 017
Patentiert im Gebiet der Bundesrepublik Deutschland vom 3. Juli 1937 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
(Ges. v. 15. 7. 51)
Das Hauptpatent 907 948 hat angefangen am 9. Mai 1936
Patentanmeldung bekanntgemacht am 18. Juni 1953
Patenterteilung bekanntgemacht am 13. Januar 1955

Im Patent 919 017 und dessen Hauptpatent 907 948 sind mechanische Schaltglieder beschrieben, deren Aufgabe es ist, zweifach variable Angaben ähnlich elektrischen Relais miteinander rechnerisch zu kombinieren. Beim mechanischen Schaltglied werden die Angaben durch Blechstellungen dargestellt, und die Übertragung bzw. Neubildung von Angaben erfolgt durch Blechausschnitte, die mit Stiften im Eingriff stehen. In den erwähnten Patentschriften sind in der Hauptsache drei Arten von Schaltgliedern beschrieben:

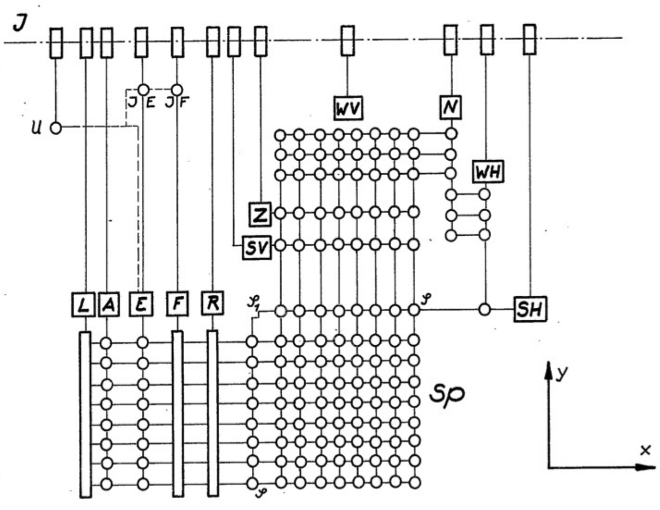
1. das Normalschaltglied, bei dem durch ein Steuerblech zwei senkrecht dazu bewegliche Bleche miteinander verbunden werden (Patent 907 948, Abb. 2),

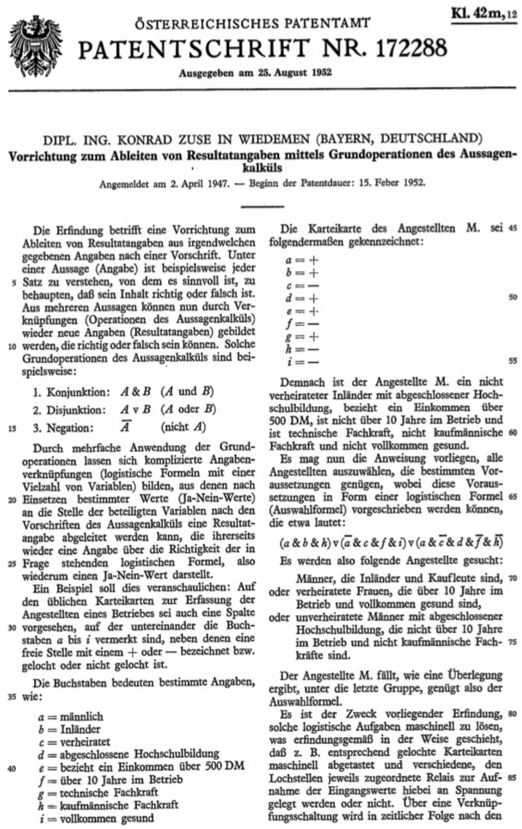
2. das Verteilerschaltglied, bei dem Angaben von einem Blech auf ein anderes übertragen werden (Patent 919 017, Abb. 1, 2, 3, 5),

3. das Speicherschaltglied, das die Aufgabe hat, eine zweifach variable Angabe zu speichern (Patent 907 948, Abb. 3, 6, 7).

Zu der Patentschrift 924 107
Kl. 42m Gr. 15

Abb.1





Kl. 42m, 12

ÖSTERREICHISCHES PATENTAMT

PATENTSCHRIFT NR. 172288

Ausgegeben am 25. August 1952

DIPL. ING. KONRAD ZUSE IN WIEDEMEN (BAYERN, DEUTSCHLAND)

Vorrichtung zum Ableiten von Resultatangaben mittels Grundoperationen des Aussagenkalküls

Angemeldet am 2. April 1947. — Beginn der Patentdauer: 15. Feber 1952.

Die Erfindung betrifft eine Vorrichtung zum Ableiten von Resultatangaben aus irgendwelchen gegebenen Angaben nach einer Vorschrift. Unter einer Aussage (Angabe) ist beispielsweise jeder Satz zu verstehen, von dem es sinnvoll ist, zu behaupten, daß sein Inhalt richtig oder falsch ist. Aus mehreren Aussagen können nun durch Verknüpfungen (Operationen des Aussagenkalküls) wieder neue Angaben (Resultatangaben) gebildet werden, die richtig oder falsch sein können. Solche Grundoperationen des Aussagenkalküls sind beispielsweise:

1. Konjunktion: $A \,\&\, B$ (A und B)
2. Disjunktion: $A \vee B$ (A oder B)
3. Negation: $\overline{A}$ (nicht A)

Durch mehrfache Anwendung der Grundoperationen lassen sich komplizierte Angabenverknüpfungen (logistische Formeln mit einer Vielzahl von Variablen) bilden, aus denen nach Einsetzen bestimmter Werte (Ja-Nein-Werte) an die Stelle der beteiligten Variablen nach den Vorschriften des Aussagenkalküls eine Resultatangabe abgeleitet werden kann, die ihrerseits wieder eine Angabe über die Richtigkeit der in Frage stehenden logistischen Formel, also wiederum einen Ja-Nein-Wert darstellt.

Ein Beispiel soll dies veranschaulichen: Auf den üblichen Karteikarten zur Erfassung der Angestellten eines Betriebes sei auch eine Spalte vorgesehen, auf der untereinander die Buchstaben a bis i vermerkt sind, neben denen eine freie Stelle mit einem + oder — bezeichnet bzw. gelocht oder nicht gelocht ist.

Die Buchstaben bedeuten bestimmte Angaben, wie:

a = männlich
b = Inländer
c = verheiratet
d = abgeschlossene Hochschulbildung
e = bezieht ein Einkommen über 500 DM
f = über 10 Jahre im Betrieb
g = technische Fachkraft
h = kaufmännische Fachkraft
i = vollkommen gesund

Die Karteikarte des Angestellten M. sei folgendermaßen gekennzeichnet:

$a = +$
$b = +$
$c = -$
$d = +$
$e = +$
$f = -$
$g = +$
$h = -$
$i = -$

Demnach ist der Angestellte M. ein nicht verheirateter Inländer mit abgeschlossener Hochschulbildung, bezieht ein Einkommen über 500 DM, ist nicht über 10 Jahre im Betrieb und ist technische Fachkraft, nicht kaufmännische Fachkraft und nicht vollkommen gesund.

Es mag nun die Anweisung vorliegen, alle Angestellten auszuwählen, die bestimmten Voraussetzungen genügen, wobei diese Voraussetzungen in Form einer logistischen Formel (Auswahlformel) vorgeschrieben werden können, die etwa lautet:

$$(a \,\&\, b \,\&\, h) \vee (\overline{a} \,\&\, c \,\&\, f \,\&\, i) \vee (a \,\&\, \overline{c} \,\&\, d \,\&\, \overline{f} \,\&\, \overline{h})$$

Es werden also folgende Angestellte gesucht:

Männer, die Inländer und Kaufleute sind,
oder verheiratete Frauen, die über 10 Jahre im Betrieb und vollkommen gesund sind,
oder unverheiratete Männer mit abgeschlossener Hochschulbildung, die nicht über 10 Jahre im Betrieb und nicht kaufmännische Fachkräfte sind.

Der Angestellte M. fällt, wie eine Überlegung ergibt, unter die letzte Gruppe, genügt also der Auswahlformel.

Es ist der Zweck vorliegender Erfindung, solche logistische Aufgaben maschinell zu lösen, was erfindungsgemäß in der Weise geschieht, daß z. B. entsprechend gelochte Karteikarten maschinell abgetastet und verschiedene, den Lochstellen jeweils zugeordnete Relais zur Aufnahme der Eingangswerte hiebei an Spannung gelegt werden oder nicht. Über eine Verknüpfungsschaltung wird in zeitlicher Folge nach den

Nr. 172288
Kl. 42 m, 12

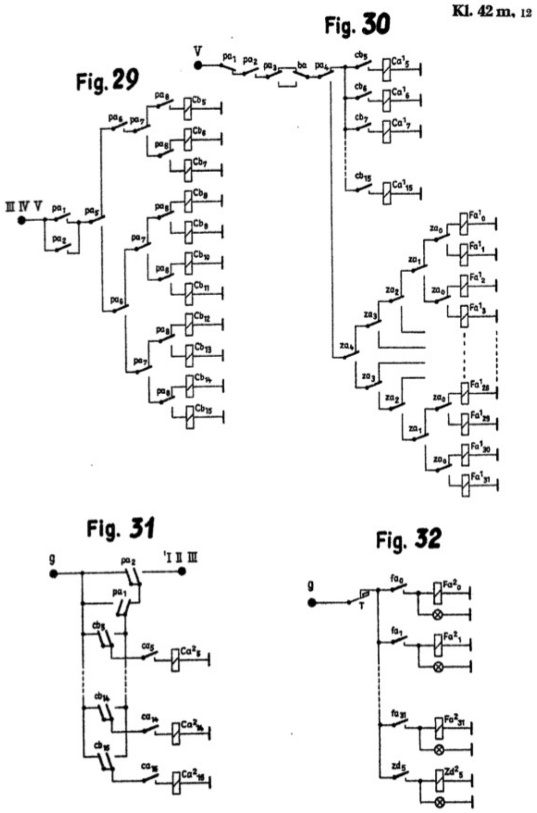
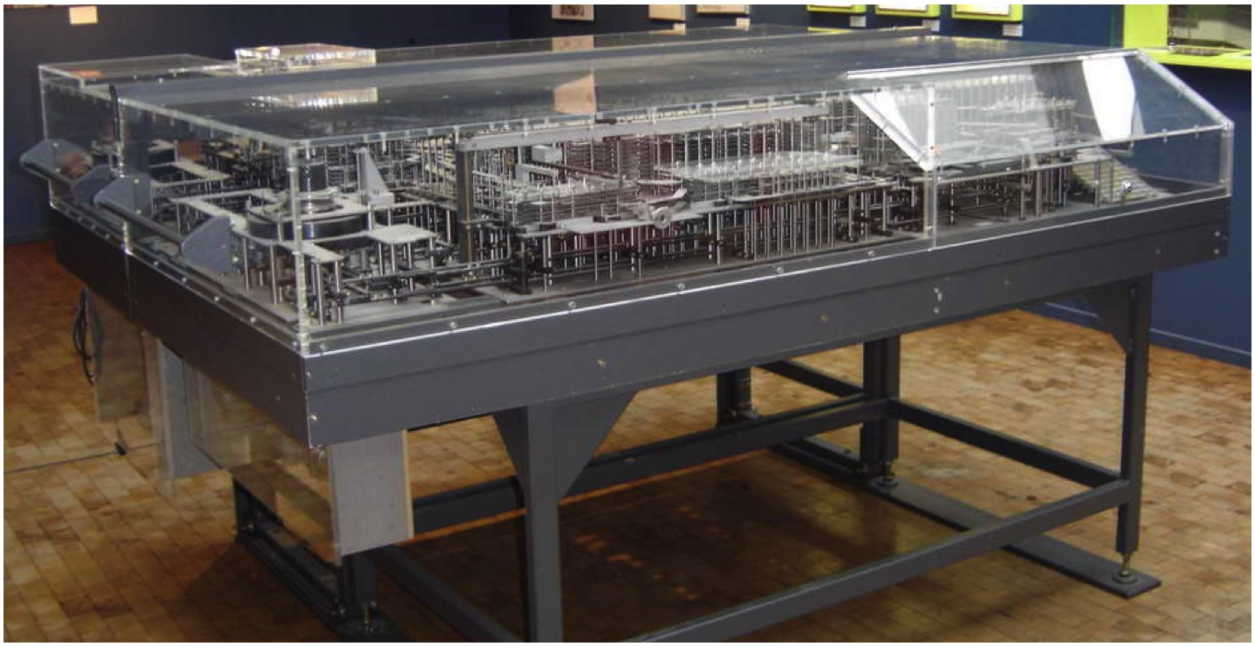


Figure 6.165: Examples from Konrad Zuse's patents on programmable digital computers.

Zuse Z1 programmable digital computer, first operational in 1938



Zuse Z2 programmable digital computer, first operational in 1939 (destroyed by Allied bombing)

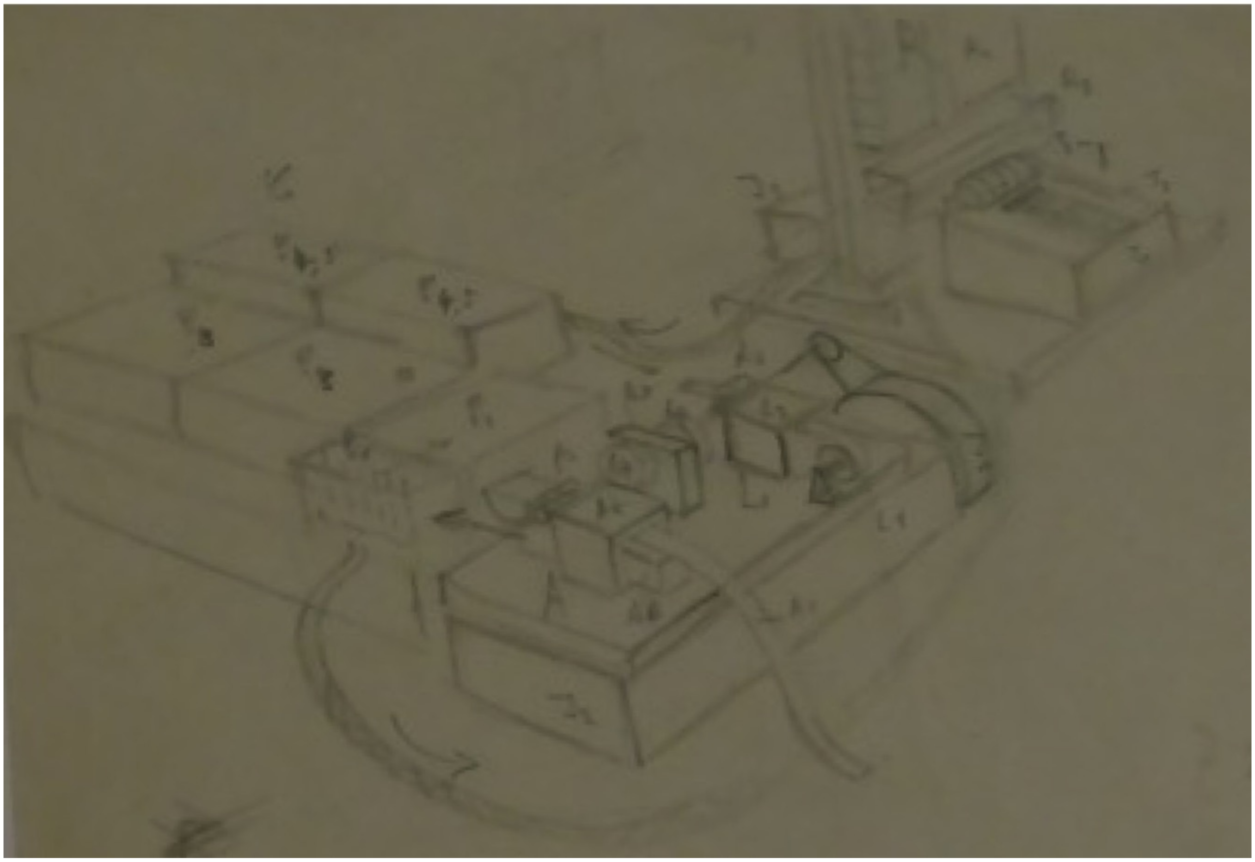
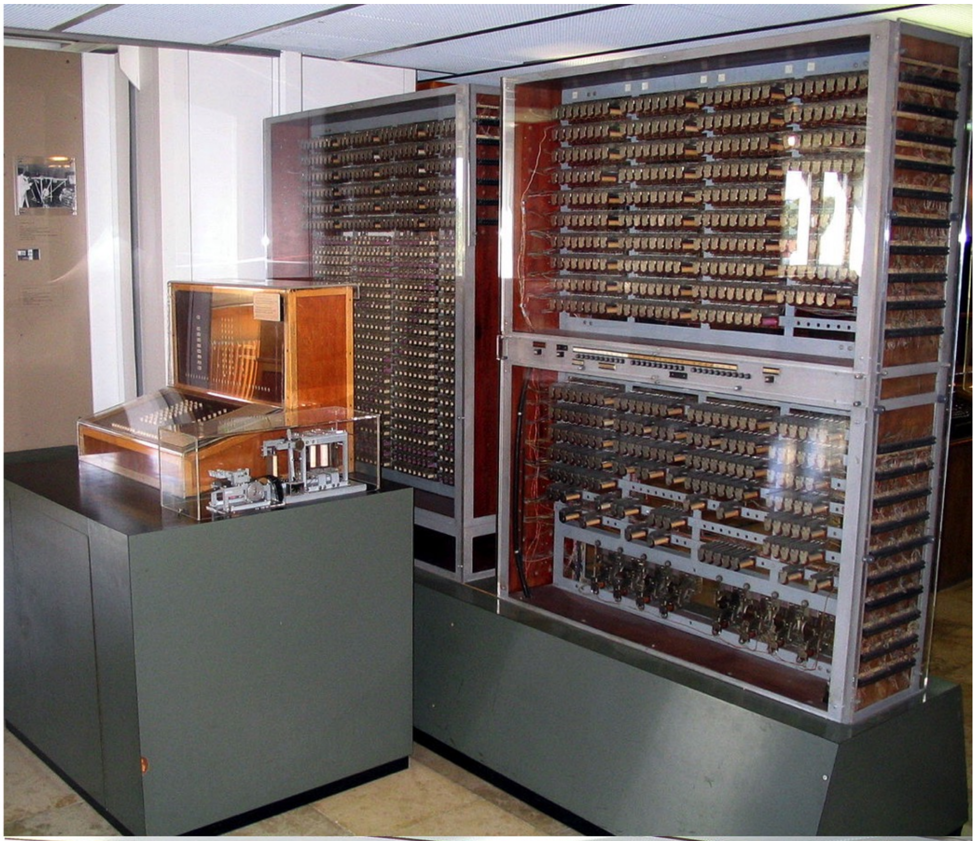


Figure 6.166: Programmable digital computers built by Konrad Zuse included the Z1 (first operational in 1938, destroyed during the war, and rebuilt later) and the Z2 (first operational in 1939, destroyed during the war, and not rebuilt).

Zuse Z3 programmable digital computer, first operational in 1941



Zuse Z4 programmable digital computer, first operational in 1944

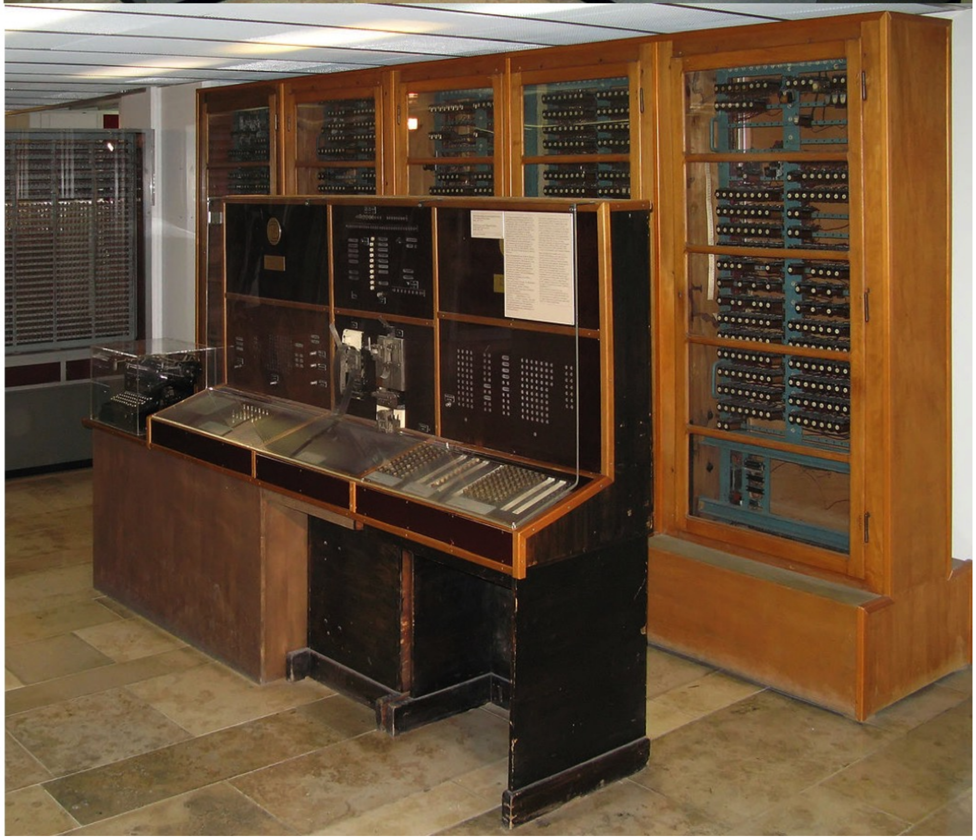
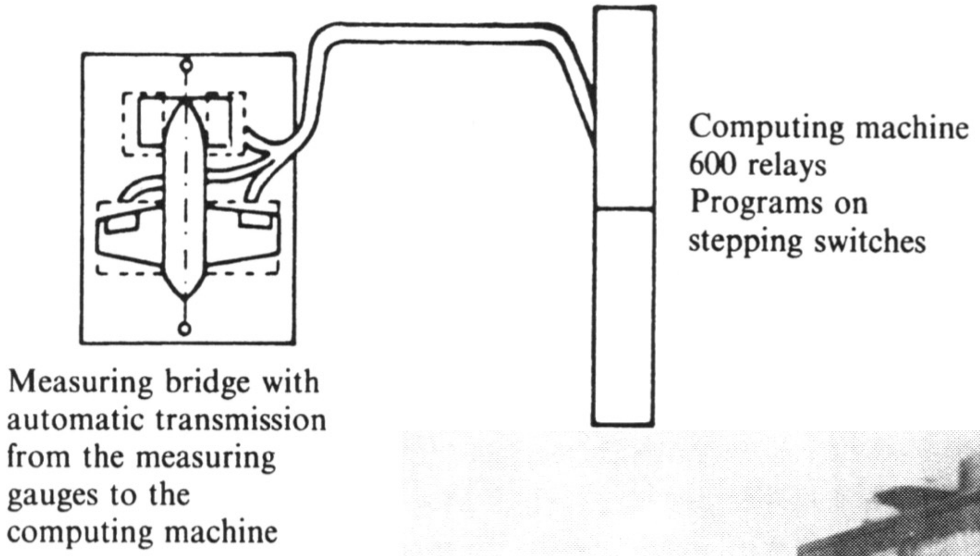
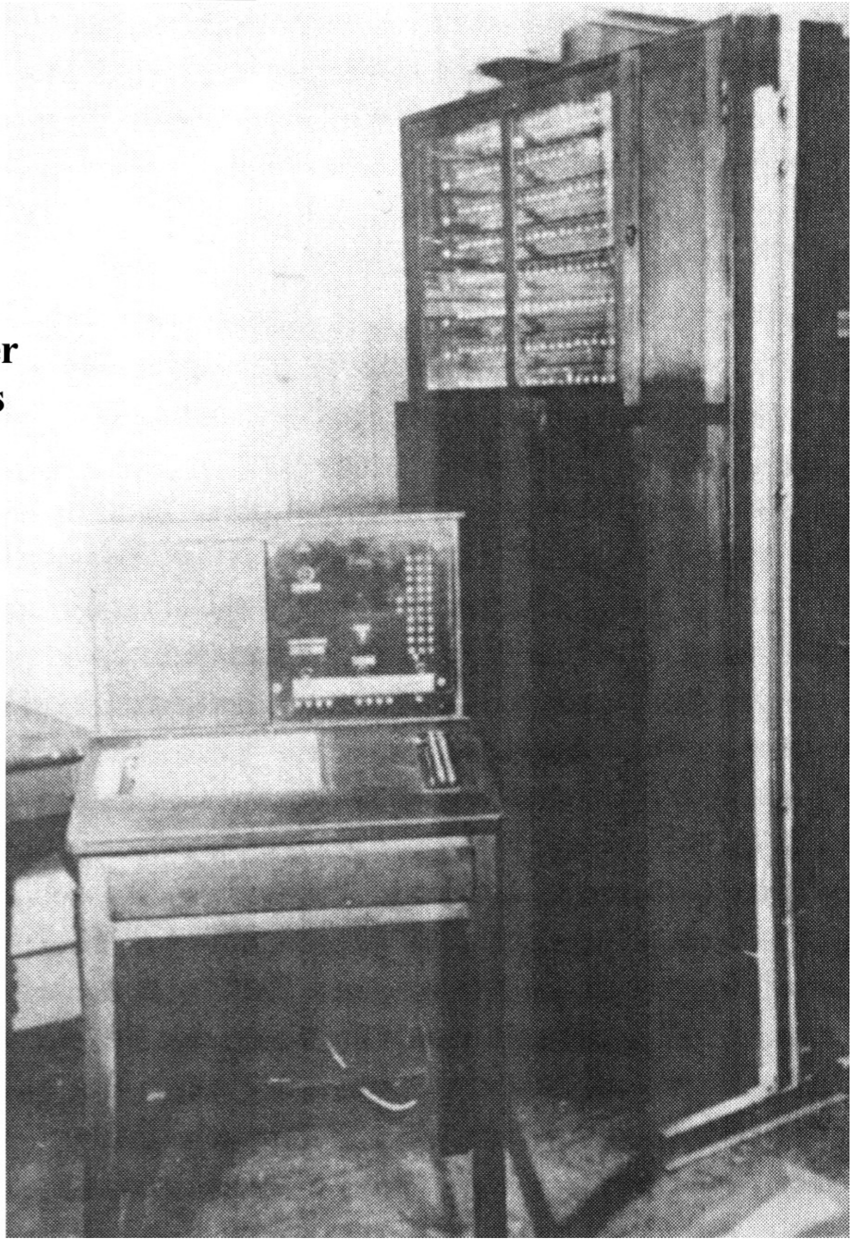


Figure 6.167: Other programmable digital computers built by Konrad Zuse included the Z3 (first operational in 1941, destroyed during the war, and rebuilt later) and the Z4 (first operational in 1944).


Computing machine
600 relays
Programs on
stepping switches
Measuring bridge with
automatic transmission
from the measuring
gauges to the
computing machine



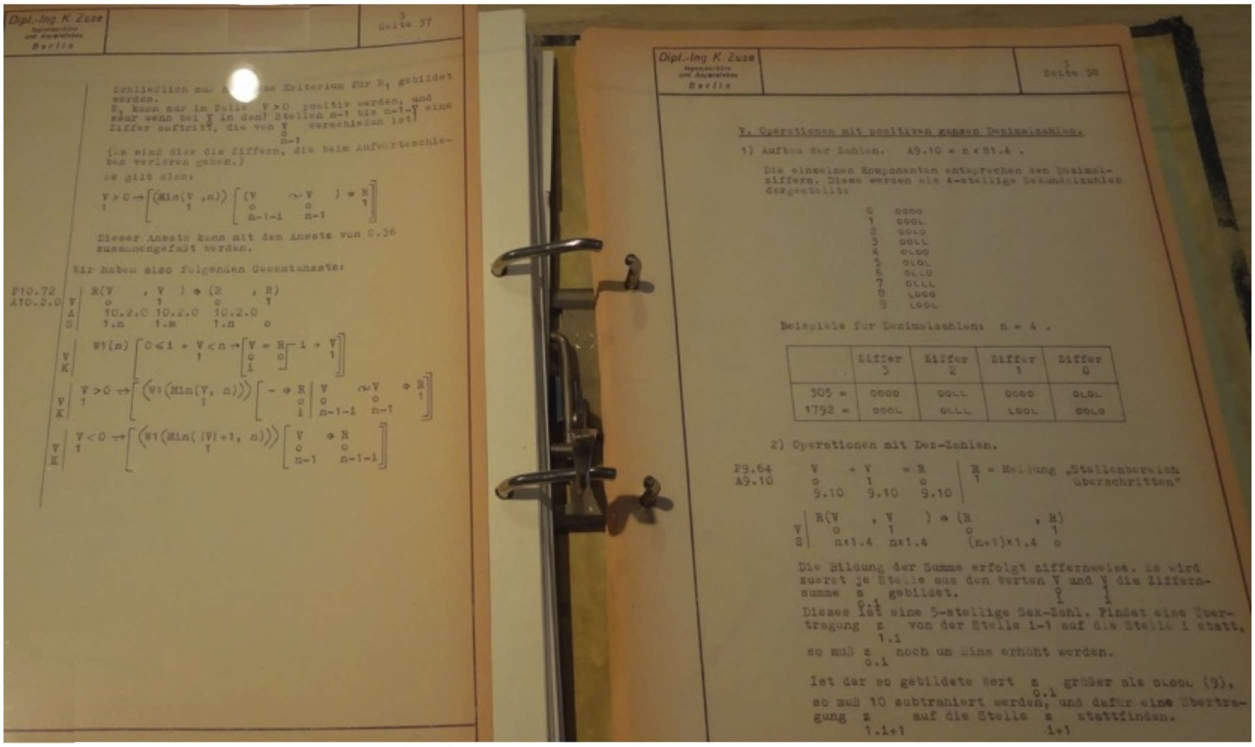
Zuse special-purpose digital computers for measuring and calculating wing flutter for Herbert Wagner's missiles at Henschel

Zuse S1 special-purpose digital computer, first operational in 1942

Very similar S2 computer was first operational in 1943

Figure 6.168: Konrad Zuse built special-purpose digital computers for measuring and calculating wing flutter for Herbert Wagner's missiles at Henschel: the S1 in 1942 and the S2 in 1943.

Konrad Zuse developed
the first high-level
computer programming language,
Plankalkül (1942)



Dipl.-Ing K. Zuse
Berlin

Seite 37

Schließlich muß n[illegible] Kriterium für R_1 gebildet werden.
R_1 kann nur im Falle V > 0 positiv werden, und zwar wenn bei V in den Stellen n-1 bis n-1-V eine Ziffer auftritt, die von V verschieden ist.
(Es sind dies die Ziffern, die beim Aufwärtsschieben verloren gehen.)
Es gilt also:

```
V > 0 →[(Min(V  ,n)) [(V       ~V    ) ⇒ R]]
1            1        o        o          1
                      n-1-i    n-1
```

Dieser Ansatz kann mit dem Ansatz von S.36 zusammengefaßt werden.

Wir haben also folgenden Gesamtansatz:

```
P10.72  |  R(V      , V     ) ⇒ (R      , R)
A10.2.0 V|    o        1           o        1
        A|    10.2.0   10.2.0      10.2.0
        S|    1.n      1.m         1.n      o

      V|  W1(n) [0≤i + V<n →[V = R┐ i + V]]
      K|                1    o   o      1
                             i

      V|  V >0 →[(W1(Min(V, n)))[- ⇒ R | V       ~V    ⇒ R]]
      K|  1                 1          o | o       o        1
                                       i | n-1-i   n-1

      V|  V<0 →[(W1(Min(|V|+1, n)))[V     ⇒ R    ]]
      K|  1                 1         o       o
                                      n-1     n-1-i
```

Dipl.-Ing K. Zuse
Berlin

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V. Operationen mit positiven ganzen Dezimalzahlen.

1) Aufbau der Zahlen. A9.10 = n × S1.4 .

Die einzelnen Komponenten entsprechen den Dezimalziffern. Diese werden als 4-stellige [illegible] dargestellt:

0 0000
1 000L
2 00L0
3 00LL
4 0L00
5 0L0L
6 0LL0
7 0LLL
8 L000
9 L00L

Beispiele für Dezimalzahlen: n = 4 .

	Ziffer 3	Ziffer 2	Ziffer 1	Ziffer 0
305 =	0000	00LL	0000	0L0L
1792 =	000L	0LLL	L00L	00L0

2) Operationen mit Dez-Zahlen.

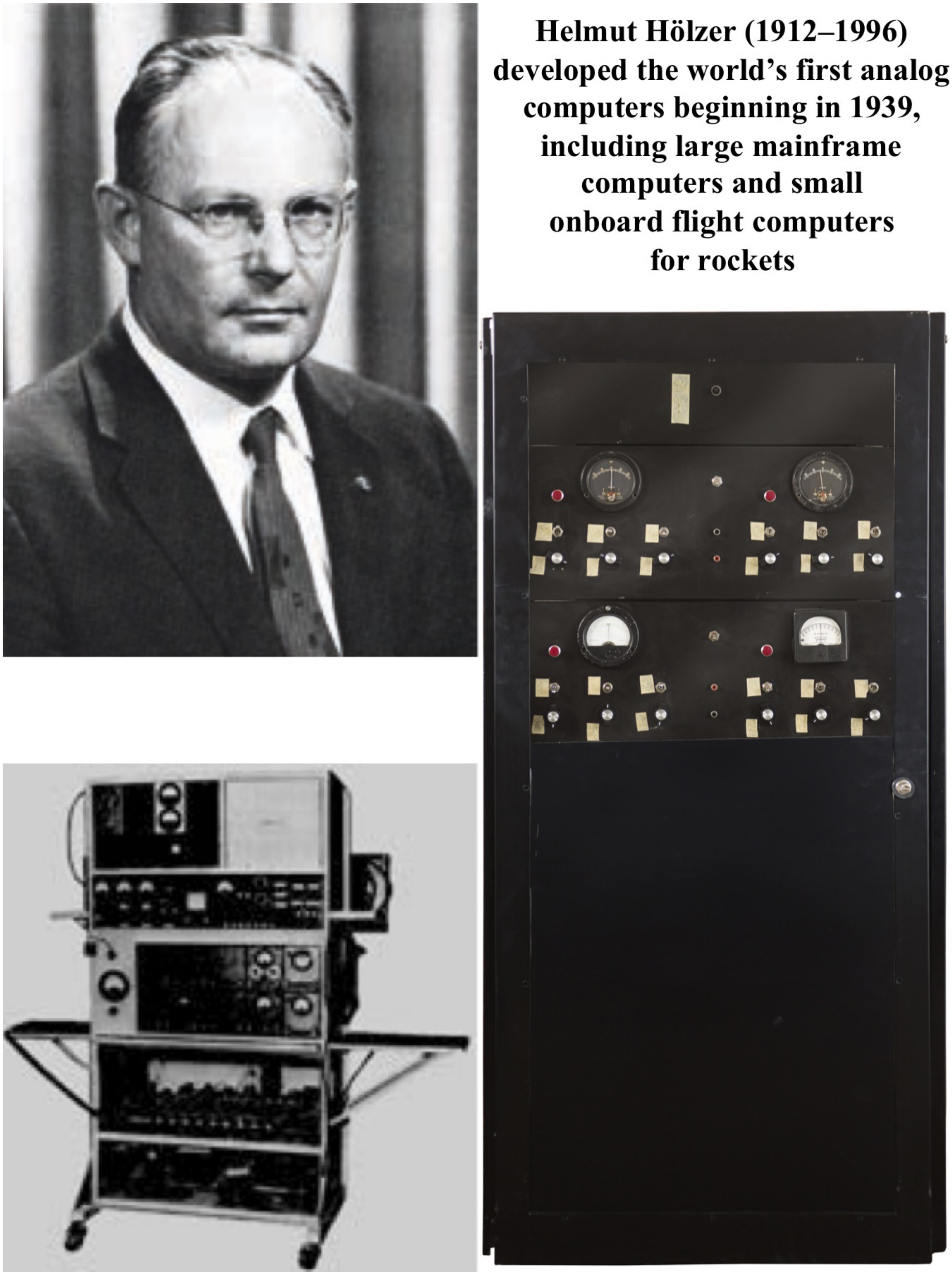
```
P9.64    V      + V      = R      | R = Meldung „Stellenbereich
A9.10    o        1        o      | 1             überschritten"
         9.10     9.10     9.10   |

    V| R(V      , V     ) ⇒ (R           , R)
    S|   o        1           o             1
         n×1.4    n×1.4       (n+1)×1.4     o
```

Die Bildung der Summe erfolgt ziffernweise. Es wird zuerst je Stelle aus den Werten V_0 und V_1 die Ziffernsumme $z_{0.i}$ gebildet.
Dieses ist eine 5-stellige Sek-Zahl. Findet eine Übertragung $z_{1.i}$ von der Stelle i-1 auf die Stelle i statt, so muß $z_{0.i}$ noch um Eins erhöht werden.

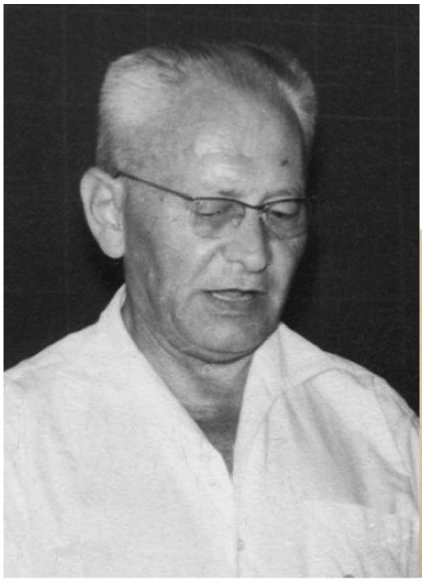
Ist der so gebildete Wert $z_{0.i}$ größer als 0L00L (9), so muß 10 subtrahiert werden, und dafür eine Übertragung $z_{1.i+1}$ auf die Stelle z_{i+1} stattfinden.

Figure 6.169: Konrad Zuse developed the first high-level computer programming language, Plankalkül (1942).

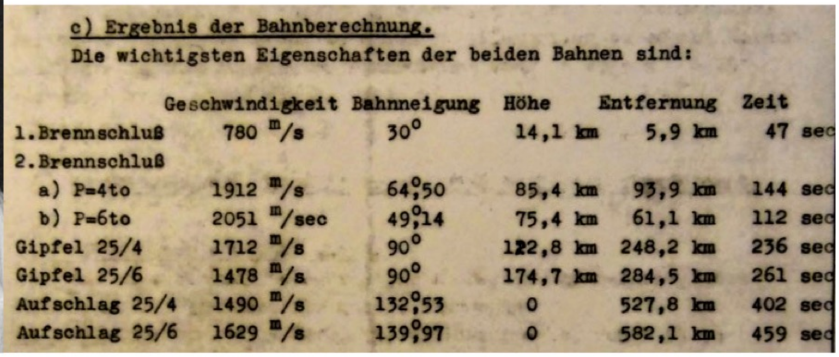


Helmut Hölzer (1912–1996) developed the world's first analog computers beginning in 1939, including large mainframe computers and small onboard flight computers for rockets

Figure 6.170: Helmut Hölzer developed the world's first analog computers beginning in 1939, including large mainframe computers and small onboard flight computers for rockets.



Alwin Walther (1898–1967) developed and operated computers at Darmstadt for the Peenemünde rocket program



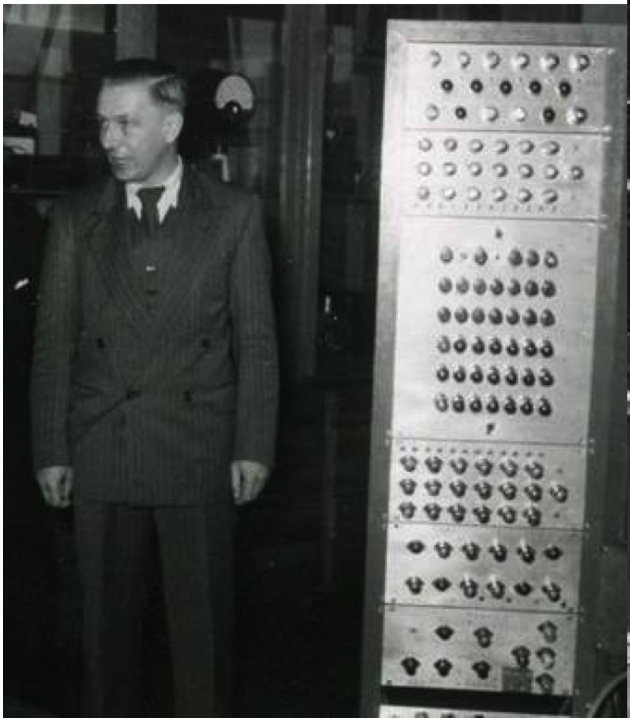
c) Ergebnis der Bahnberechnung.

Die wichtigsten Eigenschaften der beiden Bahnen sind:

	Geschwindigkeit	Bahnneigung	Höhe	Entfernung	Zeit
1.Brennschluß	780 m/s	30°	14,1 km	5,9 km	47 sec
2.Brennschluß					
a) P=4to	1912 m/s	64°,50	85,4 km	93,9 km	144 sec
b) P=6to	2051 m/sec	49°,14	75,4 km	61,1 km	112 sec
Gipfel 25/4	1712 m/s	90°	122,8 km	248,2 km	236 sec
Gipfel 25/6	1478 m/s	90°	174,7 km	284,5 km	261 sec
Aufschlag 25/4	1490 m/s	132°,53	0	527,8 km	402 sec
Aufschlag 25/6	1629 m/s	139°,97	0	582,1 km	459 sec

Heinz Billing (1914–2017) developed computers with magnetic drum and magnetic core memory, and later built the first laser-interferometer gravitational-wave detector

Nikolaus Joachim Lehmann (1921–1998) developed computers in East Germany



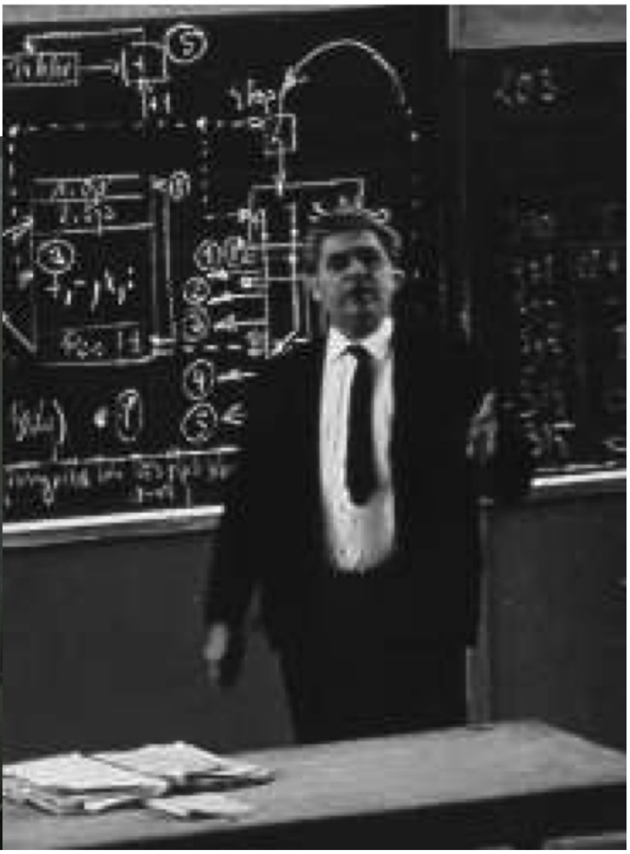
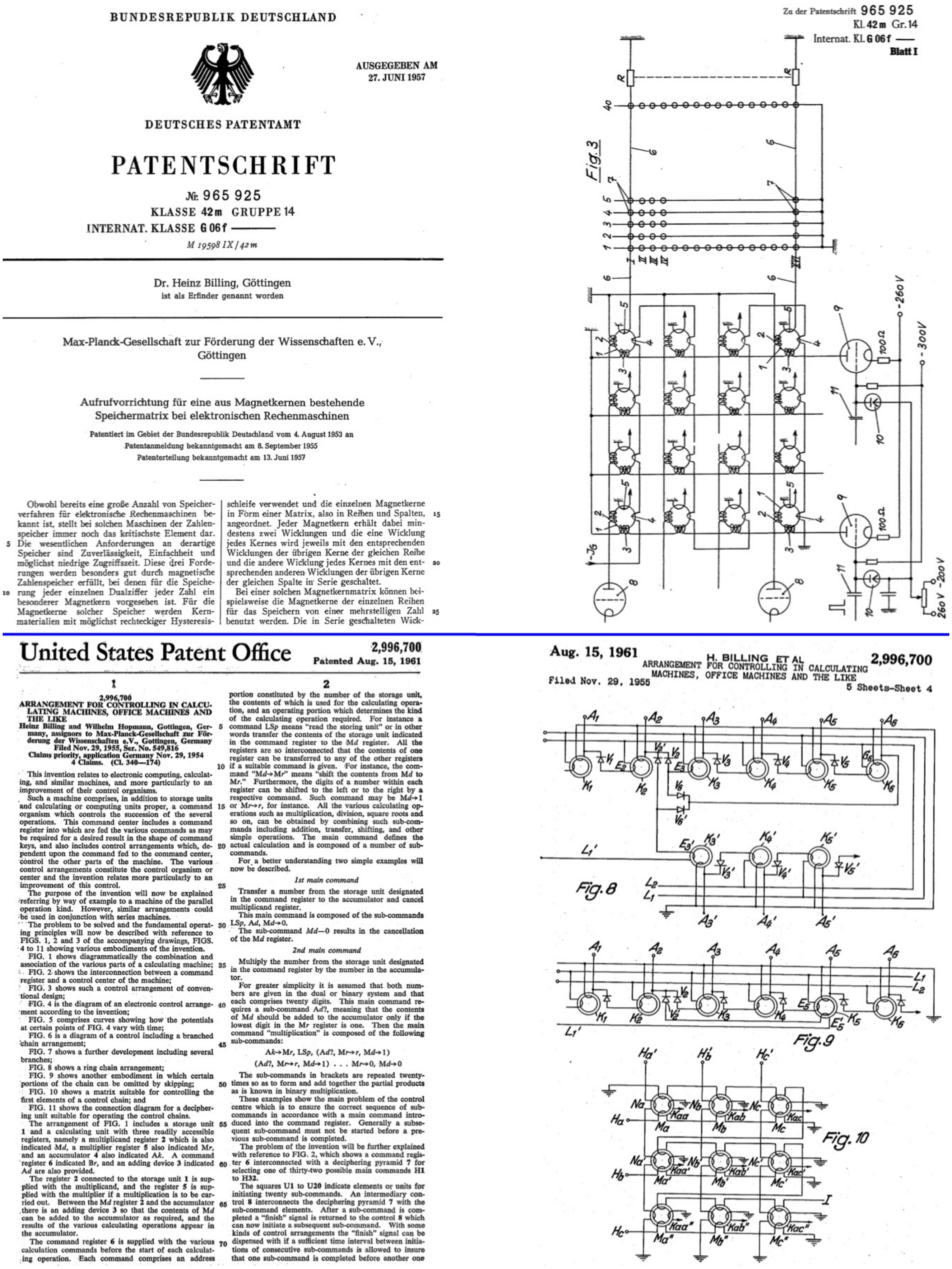


Figure 6.171: Some other early German computer pioneers included Heinz Billing, Alwin Walther, and Nikolaus Joachim Lehmann.



BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
27. JUNI 1957

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 965 925
KLASSE 42m GRUPPE 14
INTERNAT. KLASSE G 06 f ———
M 19598 IX / 42 m

Dr. Heinz Billing, Göttingen
ist als Erfinder genannt worden

Max-Planck-Gesellschaft zur Förderung der Wissenschaften e. V., Göttingen

Aufrufvorrichtung für eine aus Magnetkernen bestehende Speichermatrix bei elektronischen Rechenmaschinen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 4. August 1953 an
Patentanmeldung bekanntgemacht am 8. September 1955
Patenterteilung bekanntgemacht am 13. Juni 1957

Obwohl bereits eine große Anzahl von Speicherverfahren für elektronische Rechenmaschinen bekannt ist, stellt bei solchen Maschinen der Zahlenspeicher immer noch das kritischste Element dar. Die wesentlichen Anforderungen an derartige Speicher sind Zuverlässigkeit, Einfachheit und möglichst niedrige Zugriffszeit. Diese drei Forderungen werden besonders gut durch magnetische Zahlenspeicher erfüllt, bei denen für die Speicherung jeder einzelnen Dualziffer jeder Zahl ein besonderer Magnetkern vorgesehen ist. Für die Magnetkerne solcher Speicher werden Kernmaterialien mit möglichst rechteckiger Hysteresisschleife verwendet und die einzelnen Magnetkerne in Form einer Matrix, also in Reihen und Spalten, angeordnet. Jeder Magnetkern erhält dabei mindestens zwei Wicklungen und die eine Wicklung jedes Kernes wird jeweils mit den entsprechenden Wicklungen der übrigen Kerne der gleichen Reihe und die andere Wicklung jedes Kernes mit den entsprechenden anderen Wicklungen der übrigen Kerne der gleichen Spalte in Serie geschaltet.

Bei einer solchen Magnetkernmatrix können beispielsweise die Magnetkerne der einzelnen Reihen für das Speichern von einer mehrstelligen Zahl benutzt werden. Die in Serie geschalteten Wick-

Zu der Patentschrift 965 925
Kl. 42 m Gr. 14
Internat. Kl. G 06 f ———
Blatt I

United States Patent Office

2,996,700
Patented Aug. 15, 1961

1

2,996,700
ARRANGEMENT FOR CONTROLLING IN CALCULATING MACHINES, OFFICE MACHINES AND THE LIKE
Heinz Billing and Wilhelm Hopmann, Gottingen, Germany, assignors to Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V., Gottingen, Germany
Filed Nov. 29, 1955, Ser. No. 549,816
Claims priority, application Germany Nov. 29, 1954
4 Claims. (Cl. 340—174)

This invention relates to electronic computing, calculating, and similar machines, and more particularly to an improvement of their control organisms.

Such a machine comprises, in addition to storage units and calculating or computing units proper, a command organism which controls the succession of the several operations. This command center includes a command register into which are fed the various commands as may be required for a desired result in the shape of command keys, and also includes control arrangements which, dependent upon the command fed to the command center, control the other parts of the machine. The various control arrangements constitute the control organism or center and the invention relates more particularly to an improvement of this control.

The purpose of the invention will now be explained referring by way of example to a machine of the parallel operation kind. However, similar arrangements could be used in conjunction with series machines.

The problem to be solved and the fundamental operating principles will now be described with reference to FIGS. 1, 2 and 3 of the accompanying drawings, FIGS. 4 to 11 showing various embodiments of the invention.

FIG. 1 shows diagrammatically the combination and association of the various parts of a calculating machine;

FIG. 2 shows the interconnection between a command register and a control center of the machine;

FIG. 3 shows such a control arrangement of conventional design;

FIG. 4 is the diagram of an electronic control arrangement according to the invention;

FIG. 5 comprises curves showing how the potentials at certain points of FIG. 4 vary with time;

FIG. 6 is a diagram of a control including a branched chain arrangement;

FIG. 7 shows a further development including several branches;

FIG. 8 shows a ring chain arrangement;

FIG. 9 shows another embodiment in which certain portions of the chain can be omitted by skipping;

FIG. 10 shows a matrix suitable for controlling the first elements of a control chain; and

FIG. 11 shows the connection diagram for a deciphering unit suitable for operating the control chains.

The arrangement of FIG. 1 includes a storage unit **1** and a calculating unit with three readily accessible registers, namely a multiplicand register **2** which is also indicated $\mathrm{M}d$, a multiplier register **5** also indicated $\mathrm{M}r$, and an accumulator **4** also indicated $\mathrm{A}k$. A command register **6** indicated $\mathrm{B}r$, and an adding device **3** indicated $\mathrm{A}d$ are also provided.

The register **2** connected to the storage unit **1** is supplied with the multiplicand, and the register **5** is supplied with the multiplier if a multiplication is to be carried out. Between the $\mathrm{M}d$ register **2** and the accumulator there is an adding device **3** so that the contents of $\mathrm{M}d$ can be added to the accumulator as required, and the results of the various calculating operations appear in the accumulator.

The command register **6** is supplied with the various calculation commands before the start of each calculating operation. Each command comprises an address

2

portion constituted by the number of the storage unit, the contents of which is used for the calculating operation, and an operating portion which determines the kind of the calculating operation required. For instance a command $\mathrm{LS}p$ means "read the storing unit" or in other words transfer the contents of the storage unit indicated in the command register to the $\mathrm{M}d$ register. All the registers are so interconnected that the contents of one register can be transferred to any of the other registers if a suitable command is given. For instance, the command "$\mathrm{M}d \rightarrow \mathrm{M}r$" means "shift the contents from $\mathrm{M}d$ to $\mathrm{M}r$." Furthermore, the digits of a number within each register can be shifted to the left or to the right by a respective command. Such command may be $\mathrm{M}d \rightarrow 1$ or $\mathrm{M}r \rightarrow r$, for instance. All the various calculating operations such as multiplication, division, square roots and so on, can be obtained by combining such sub-commands including addition, transfer, shifting, and other simple operations. The main command defines the actual calculation and is composed of a number of sub-commands.

For a better understanding two simple examples will now be described.

1st main command

Transfer a number from the storage unit designated in the command register to the accumulator and cancel multiplicand register.

This main command is composed of the sub-commands $\mathrm{LS}p$, $\mathrm{A}d$, $\mathrm{M}d \rightarrow 0$.

The sub-command $Md—0$ results in the cancellation of the $\mathrm{M}d$ register.

2nd main command

Multiply the number from the storage unit designated in the command register by the number in the accumulator.

For greater simplicity it is assumed that both numbers are given in the dual or binary system and that each comprises twenty digits. This main command requires a sub-command $\mathrm{A}d?$, meaning that the contents of $\mathrm{M}d$ should be added to the accumulator only if the lowest digit in the $\mathrm{M}r$ register is one. Then the main command "multiplication" is composed of the following sub-commands:

$$\mathrm{A}k \rightarrow \mathrm{M}r,\ \mathrm{LS}p,\ (\mathrm{A}d?,\ \mathrm{M}r \rightarrow r,\ \mathrm{M}d \rightarrow 1)$$

$$(\mathrm{A}d?,\ \mathrm{M}r \rightarrow r,\ \mathrm{M}d \rightarrow 1)\ \ldots\ \mathrm{M}r \rightarrow 0,\ \mathrm{M}d \rightarrow 0$$

The sub-commands in brackets are repeated twenty-times so as to form and add together the partial products as is known in binary multiplication.

These examples show the main problem of the control centre which is to ensure the correct sequence of sub-commands in accordance with a main command introduced into the command register. Generally a subsequent sub-command must not be started before a previous sub-command is completed.

The problem of the invention will be further explained with reference to FIG. 2, which shows a command register **6** interconnected with a deciphering pyramid **7** for selecting one of thirty-two possible main commands **H1** to **H32**.

The squares **U1** to **U20** indicate elements or units for initiating twenty sub-commands. An intermediary control **8** interconnects the deciphering pyramid **7** with the sub-command elements. After a sub-command is completed a "finish" signal is returned to the control **8** which can now initiate a subsequent sub-command. With some kinds of control arrangements the "finish" signal can be dispensed with if a sufficient time interval between initiations of consecutive sub-commands is allowed to insure that one sub-command is completed before another one

Aug. 15, 1961
H. BILLING ET AL
ARRANGEMENT FOR CONTROLLING IN CALCULATING MACHINES, OFFICE MACHINES AND THE LIKE
2,996,700
Filed Nov. 29, 1955
5 Sheets-Sheet 4

Figure 6.172: Computer patents by Heinz Billing.

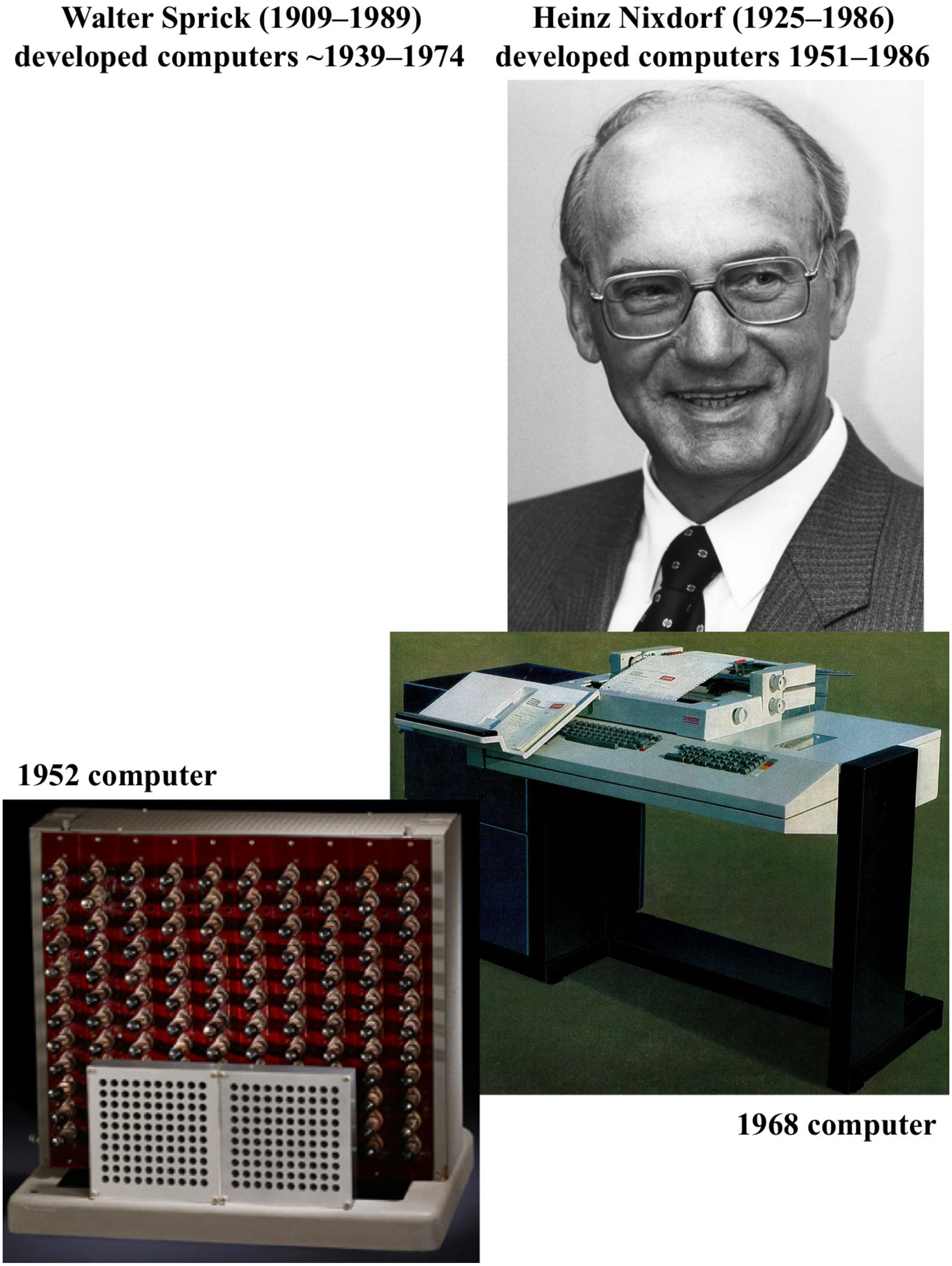
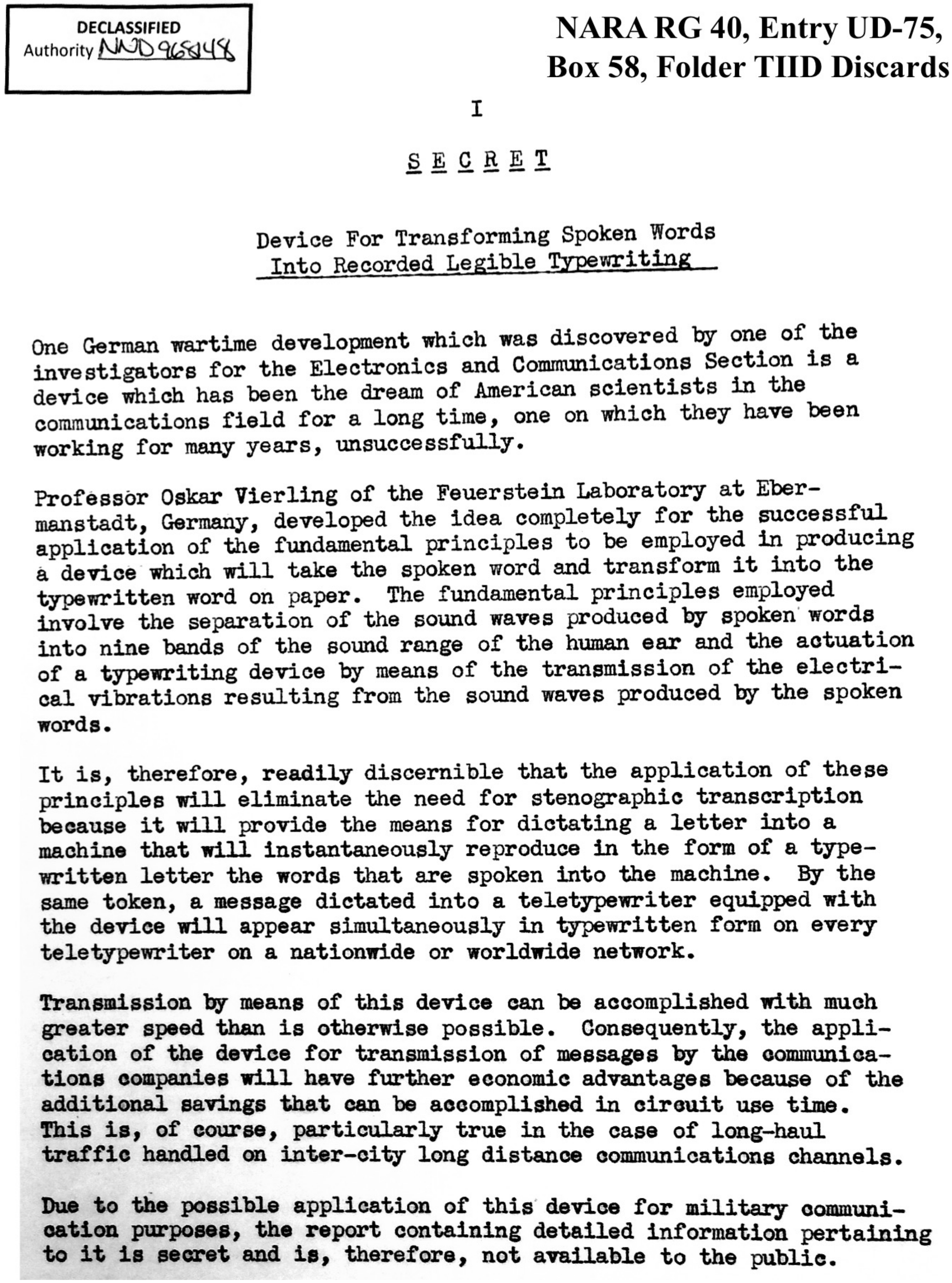

Walter Sprick (1909–1989)
developed computers ~1939–1974
Heinz Nixdorf (1925–1986)
developed computers 1951–1986
1952 computer
1968 computer

Figure 6.173: Walter Sprick developed computers ∼1939–1974. Based on Sprick's designs, Heinz Nixdorf developed computers 1951–1986.



DECLASSIFIED
Authority NND 968148

NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards

I

SECRET

Device For Transforming Spoken Words Into Recorded Legible Typewriting

One German wartime development which was discovered by one of the investigators for the Electronics and Communications Section is a device which has been the dream of American scientists in the communications field for a long time, one on which they have been working for many years, unsuccessfully.

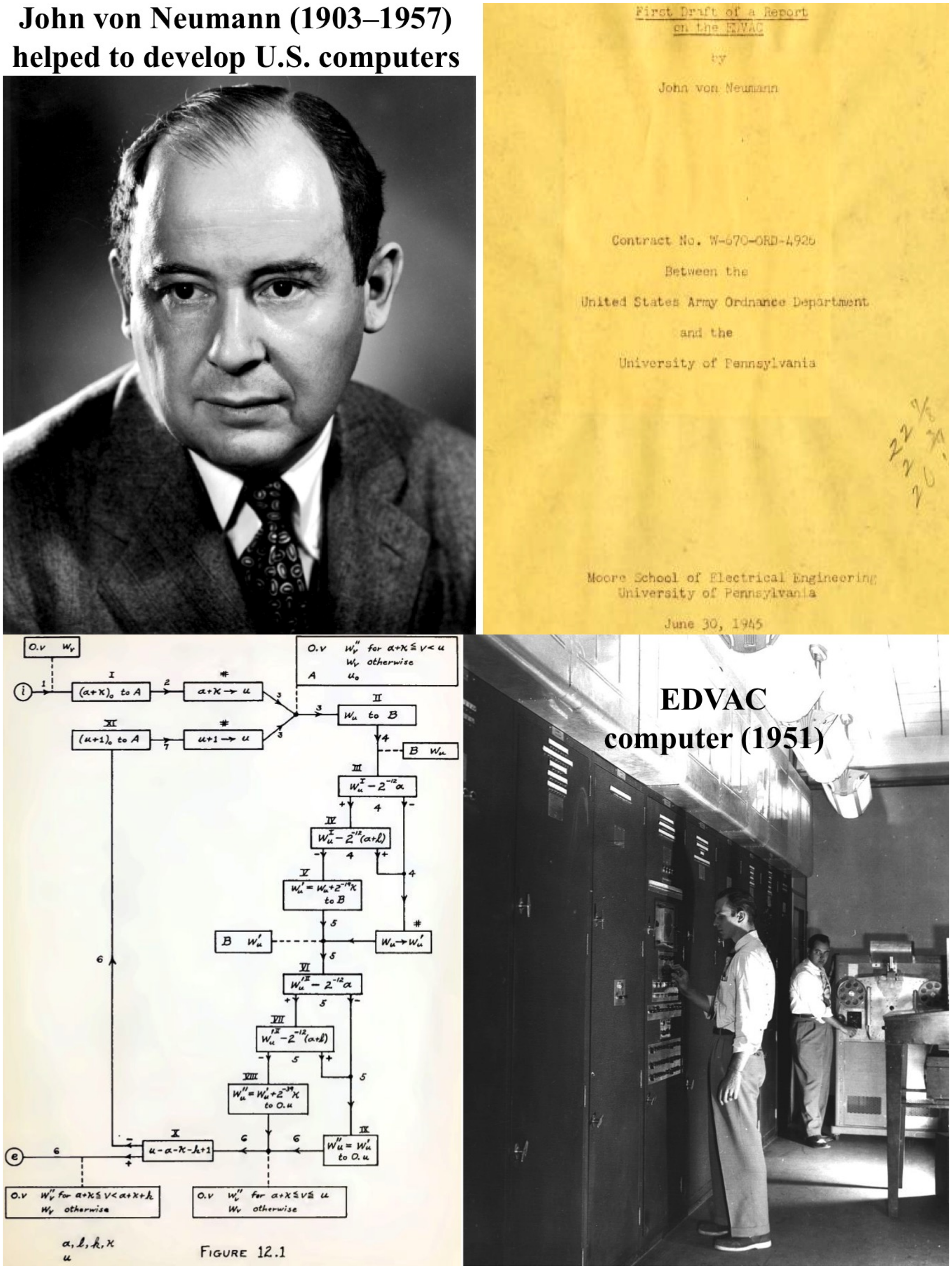
Professor Oskar Vierling of the Feuerstein Laboratory at Ebermanstadt, Germany, developed the idea completely for the successful application of the fundamental principles to be employed in producing a device which will take the spoken word and transform it into the typewritten word on paper. The fundamental principles employed involve the separation of the sound waves produced by spoken words into nine bands of the sound range of the human ear and the actuation of a typewriting device by means of the transmission of the electrical vibrations resulting from the sound waves produced by the spoken words.

It is, therefore, readily discernible that the application of these principles will eliminate the need for stenographic transcription because it will provide the means for dictating a letter into a machine that will instantaneously reproduce in the form of a typewritten letter the words that are spoken into the machine. By the same token, a message dictated into a teletypewriter equipped with the device will appear simultaneously in typewritten form on every teletypewriter on a nationwide or worldwide network.

Transmission by means of this device can be accomplished with much greater speed than is otherwise possible. Consequently, the application of the device for transmission of messages by the communications companies will have further economic advantages because of the additional savings that can be accomplished in circuit use time. This is, of course, particularly true in the case of long-haul traffic handled on inter-city long distance communications channels.

Due to the possible application of this device for military communication purposes, the report containing detailed information pertaining to it is secret and is, therefore, not available to the public.

Figure 6.174: The first methods of electronic speech recognition were developed in the German-speaking world and transferred to other countries after World War II [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].


John von Neumann (1903–1957)
helped to develop U.S. computers
EDVAC
computer (1951)
FIGURE 12.1

First Draft of a Report
on the EDVAC

by

John von Neumann

Contract No. W-670-ORD-4926
Between the
United States Army Ordnance Department
and the
University of Pennsylvania

Moore School of Electrical Engineering
University of Pennsylvania

June 30, 1945

Figure 6.175: John von Neumann helped to develop the first programmable digital computers in the United States, such as EDVAC (1951).

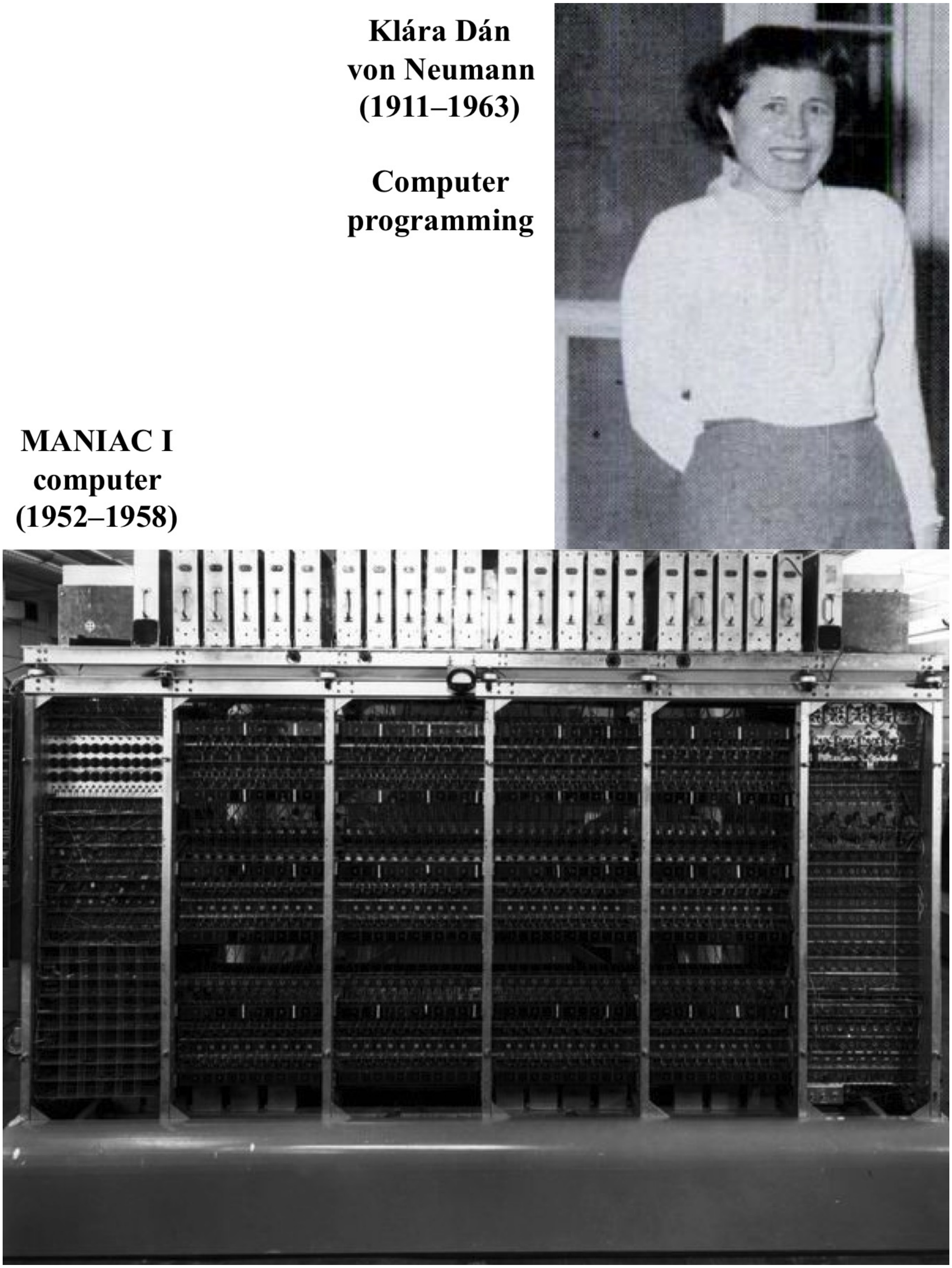

Klára Dán
von Neumann
(1911–1963)
Computer
programming
MANIAC I
computer
(1952–1958)

Figure 6.176: Klára Dán von Neumann was one of the first programmers on early computers such as MANIAC I (1952).

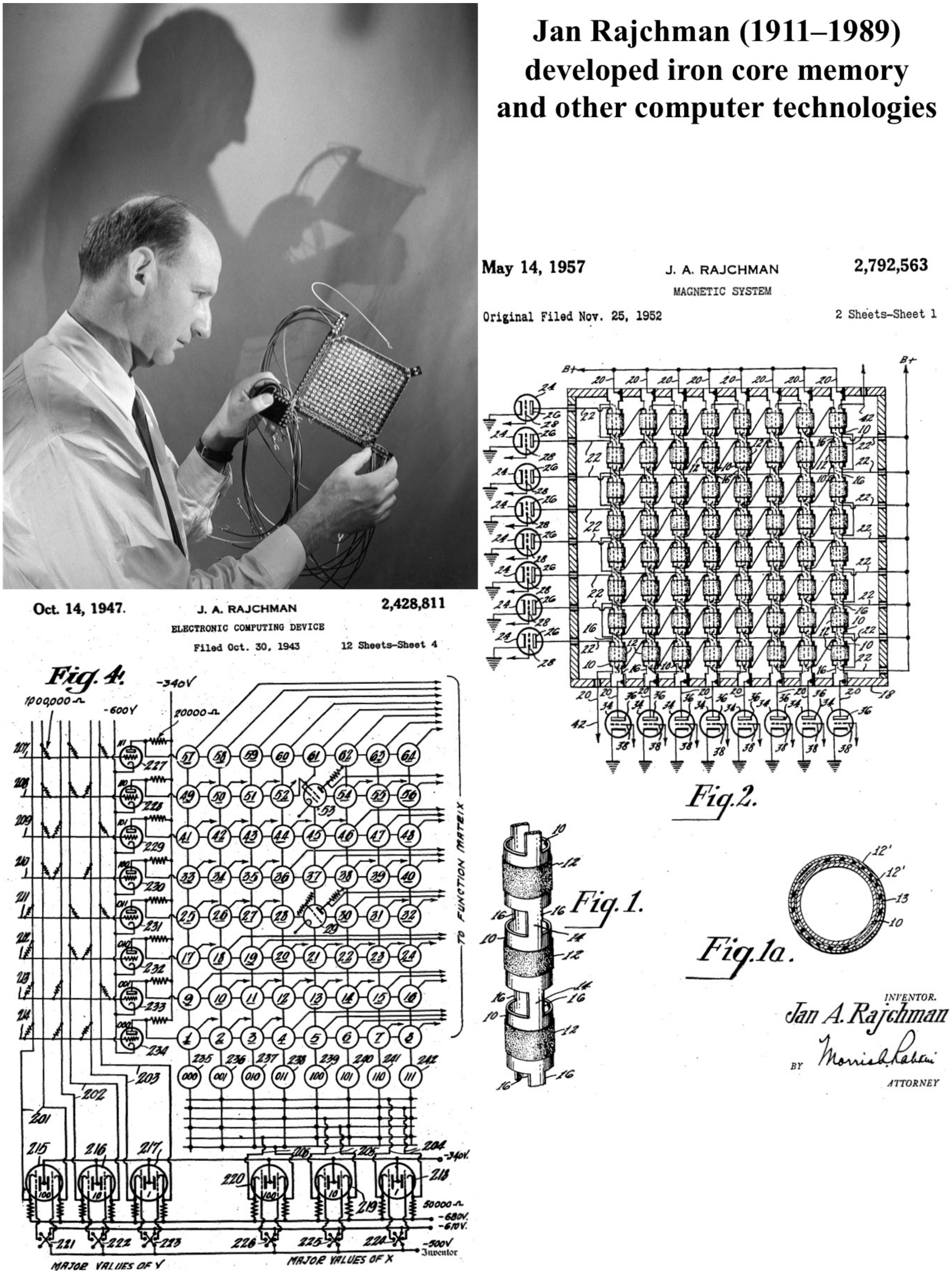
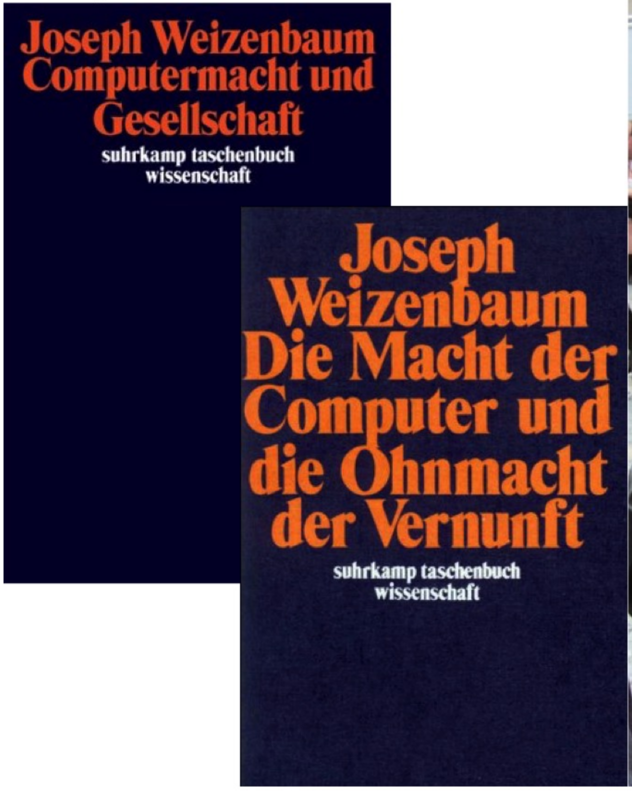
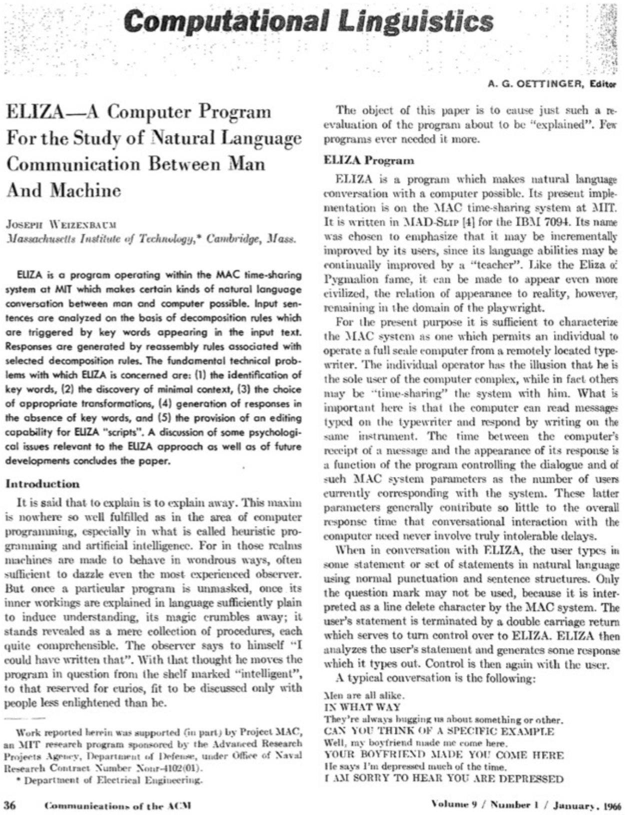

Jan Rajchman (1911–1989)
developed iron core memory
and other computer technologies
May 14, 1957
J. A. RAJCHMAN
2,792,563
MAGNETIC SYSTEM
Original Filed Nov. 25, 1952
2 Sheets–Sheet 1
B+
Fig.2.
Fig.1.
Fig.1a.
INVENTOR.
Jan A. Rajchman
BY
ATTORNEY
Oct. 14, 1947.
J. A. RAJCHMAN
2,428,811
ELECTRONIC COMPUTING DEVICE
Filed Oct. 30, 1943
12 Sheets–Sheet 4
Fig. 4.
1000,000 Ω
-600V
-340V
20000 Ω
TO FUNCTION MATRIX
-340V.
50000 Ω
-680V.
-610V.
-500V
Inventor
MAJOR VALUES OF Y
MAJOR VALUES OF X

Figure 6.177: Jan Rajchman developed iron core memory and other computer technologies.

Joseph Weizenbaum (1923–2008)


Joseph Weizenbaum
Computermacht und Gesellschaft
suhrkamp taschenbuch wissenschaft
Joseph Weizenbaum
Die Macht der Computer und die Ohnmacht der Vernunft
suhrkamp taschenbuch wissenschaft



Computational Linguistics

A. G. OETTINGER, Editor

ELIZA—A Computer Program For the Study of Natural Language Communication Between Man And Machine

Joseph Weizenbaum
Massachusetts Institute of Technology, Cambridge, Mass.*

ELIZA is a program operating within the MAC time-sharing system at MIT which makes certain kinds of natural language conversation between man and computer possible. Input sentences are analyzed on the basis of decomposition rules which are triggered by key words appearing in the input text. Responses are generated by reassembly rules associated with selected decomposition rules. The fundamental technical problems with which ELIZA is concerned are: (1) the identification of key words, (2) the discovery of minimal context, (3) the choice of appropriate transformations, (4) generation of responses in the absence of key words, and (5) the provision of an editing capability for ELIZA "scripts". A discussion of some psychological issues relevant to the ELIZA approach as well as of future developments concludes the paper.

Introduction

It is said that to explain is to explain away. This maxim is nowhere so well fulfilled as in the area of computer programming, especially in what is called heuristic programming and artificial intelligence. For in those realms machines are made to behave in wondrous ways, often sufficient to dazzle even the most experienced observer. But once a particular program is unmasked, once its inner workings are explained in language sufficiently plain to induce understanding, its magic crumbles away; it stands revealed as a mere collection of procedures, each quite comprehensible. The observer says to himself "I could have written that". With that thought he moves the program in question from the shelf marked "intelligent", to that reserved for curios, fit to be discussed only with people less enlightened than he.

The object of this paper is to cause just such a re-evaluation of the program about to be "explained". Few programs ever needed it more.

ELIZA Program

ELIZA is a program which makes natural language conversation with a computer possible. Its present implementation is on the MAC time-sharing system at MIT. It is written in MAD-Slip [4] for the IBM 7094. Its name was chosen to emphasize that it may be incrementally improved by its users, since its language abilities may be continually improved by a "teacher". Like the Eliza of Pygmalion fame, it can be made to appear even more civilized, the relation of appearance to reality, however, remaining in the domain of the playwright.

For the present purpose it is sufficient to characterize the MAC system as one which permits an individual to operate a full scale computer from a remotely located typewriter. The individual operator has the illusion that he is the sole user of the computer complex, while in fact others may be "time-sharing" the system with him. What is important here is that the computer can read messages typed on the typewriter and respond by writing on the same instrument. The time between the computer's receipt of a message and the appearance of its response is a function of the program controlling the dialogue and of such MAC system parameters as the number of users currently corresponding with the system. These latter parameters generally contribute so little to the overall response time that conversational interaction with the computer need never involve truly intolerable delays.

When in conversation with ELIZA, the user types in some statement or set of statements in natural language using normal punctuation and sentence structures. Only the question mark may not be used, because it is interpreted as a line delete character by the MAC system. The user's statement is terminated by a double carriage return which serves to turn control over to ELIZA. ELIZA then analyzes the user's statement and generates some response which it types out. Control is then again with the user.

A typical conversation is the following:

```
Men are all alike.
IN WHAT WAY
They're always bugging us about something or other.
CAN YOU THINK OF A SPECIFIC EXAMPLE
Well, my boyfriend made me come here.
YOUR BOYFRIEND MADE YOU COME HERE
He says I'm depressed much of the time.
I AM SORRY TO HEAR YOU ARE DEPRESSED
```

Work reported herein was supported (in part) by Project MAC, an MIT research program sponsored by the Advanced Research Projects Agency, Department of Defense, under Office of Naval Research Contract Number Nonr-4102(01).

* Department of Electrical Engineering.

36 Communications of the ACM Volume 9 / Number 1 / January, 1966

Development of artificial intelligence, including ELIZA software (1965)

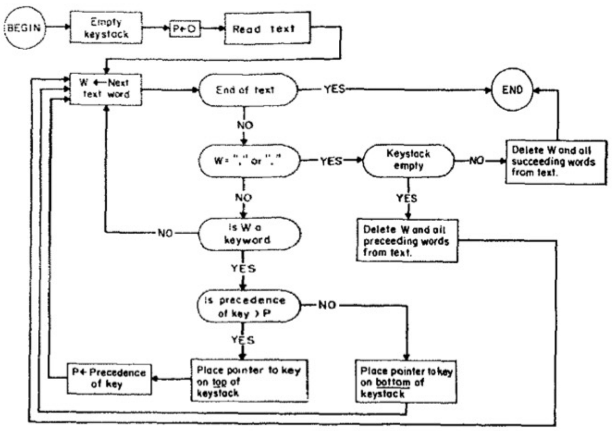


Fig. 2. Basic flow diagram of keyword detection

Figure 6.178: Joseph Weizenbaum created the ELIZA software in 1965, a major step in the development of artificial intelligence.

Peter Grünberg (1939–2018) discovered giant magnetoresistance, which can be used for high-density magnetic hard drives

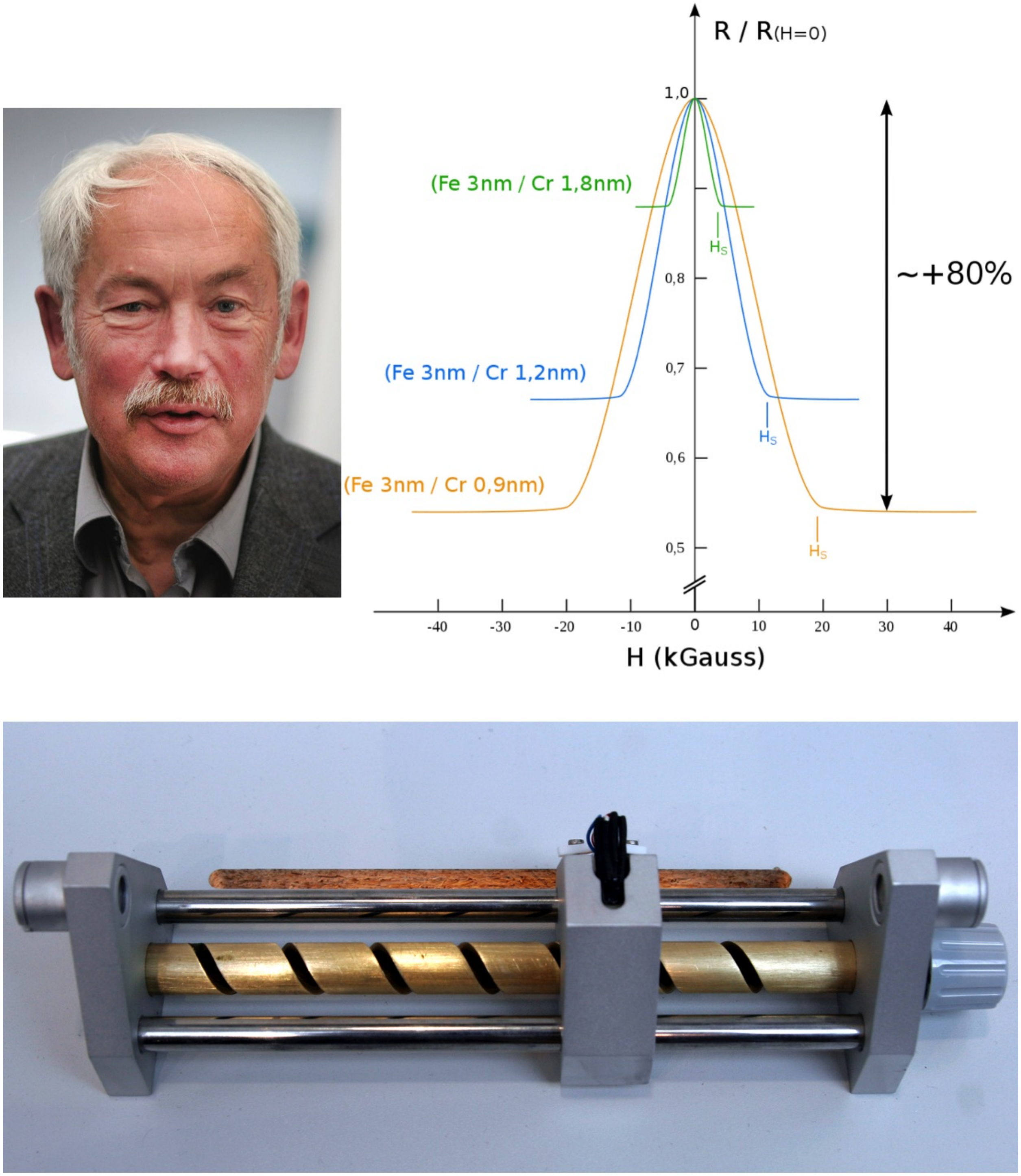


Figure 6.179: Peter Grünberg discovered giant magnetoresistance, which can be used for high-density magnetic hard drives.

6.7.3 Cryptography

German-speaking experts revolutionized cryptography from World War I through the Cold War.[18]

Arthur Scherbius (German, 1878–1929) developed and filed patents on Enigma cryptography machines beginning in 1918, as shown in Fig. 6.180. Despite being relatively small and inexpensive, the Enigma machines were so effective at encryption and decryption that it required two decades, millions of British pounds, hundreds of special-purpose calculating machines, and stolen Enigma machines and Enigma codes in order to reliably decipher the encrypted messages. The Enigma machines were a WW-I-era German technology that was so far ahead of its time that the machines remained useful into World War II.

In contrast to popular stories in the English-speaking world about codebreaking at Bletchley Park in the United Kingdom, even the key insights involved in breaking the Enigma code came from other creators from the greater predominantly German-speaking scientific world, especially Marian Rejewski (Polish, 1905–1980), Jerzy Różycki (Polish, 1909–1942), and Henryk Zygalski (Polish, 1908–1978) [Hinsley 1979, Vol. 3, Part 2, pp. 945–959]. See Figs. 6.181–6.182. Rejewski, Różycki, and Zygalski began breaking simple Enigma codes in 1932. As more and more complex Enigma codes were used by the German military, Rejewski, Różycki, and Zygalski's codebreaking methods grew more advanced. By 1938, they had designed and built a "Bomba" decoding machine that used electromechanical gears to run through possible combinations and decipher Enigma messages. Soon they were forced to flee to France and then the United Kingdom. Built with their assistance, the British "Bombe" (1940) scaled up the Rejewski/Różycki/Zygalski system with many identical subunits in parallel. Popular accounts depicting the British as having conceived and implemented the Enigma decryption methods on their own [such as Hodges 1983 and its 2014 film adaptation, *The Imitation Game*] deny proper credit to the real creators.

Another fact omitted from most popular English-language histories is that rather than stopping with Enigma, German-speaking experts went on to develop far more advanced cryptographic machines and methods before and during World War II. Their advanced encryption and decryption machines, and the German-speaking experts themselves, later became the foundation for Cold War cryptography in other countries in the following decades.

Some of the advanced German encryption machines included:

- The Siemens and Halske T-52 Geheimschreiber (Fig. 6.183).
- The Siemens Schlüssel-Fernschreibmaschine SFM T-43 Sägefisch (Swordfish, Fig. 6.184).
- The Lorenz Schlüssel-Zusatz SZ42 (Fig. 6.185).
- Other encryption systems that were developed and used by wartime Germany and then seized by Allied countries after the war (e.g., Fig. 6.186).

Those machines were captured by Allied countries at the end of World War II and formed the basis of Cold War encryption for many years thereafter.

---

[18] Bamford 2002; Faensen 2001; Hinsley 1979; Hodges 1983; Kahn 1998; Parrish 1985; Reuvers and Simons 2020; West 1999.

Along with the advanced encryption machines, German-speaking experts developed and used decryption computers to decipher coded transmissions from the United States, United Kingdom, Soviet Union, and other countries. Even highly secret coded messages between Washington and London were routinely intercepted and decrypted (Fig. 6.187). The German system for decrypting Soviet communications (sometimes called "Russian Fish") was especially advanced, and it accomplished a feat that the United States and United Kingdom had been unable to achieve (Fig. 6.188). That system was also captured by Allied countries and became the basis for much Cold War technology. Most of the details regarding the technology and its history remain secret even now.

In addition to the advanced encryption and decryption machines, Allied countries captured and utilized hundreds of highly skilled German and Austrian cryptographers. There were far too many of those cryptographers to list here, but some especially important ones who decrypted Allied coded communications during the war included Walter Fricke (German, 1915–1988), Erich Hüttenhain (German, 1905–1990), Kurt Vetterlein (German, 19??–19??), and Reinold Weber (German, 19??–19??), as shown in Fig. 6.188.

German-speaking creators such as Gustav Guanella (Swiss, 1909–1982) and Horst Feistel (German, 1915–1990) also made major contributions to cryptography after World War II. Fig. 6.190 presents examples from their patents on advanced cryptographic techniques.

Journalist James Bamford provided a rare glimpse into German cryptographic work that was discovered by the Allied TICOM (Target Intelligence Committee) team at the end of the war [Bamford 2002, pp. 8–18]:

> Colonel George A. Bicher, the director of the U.S. Signal Intelligence [Sigint] Division in Europe, conceived of TICOM in the summer of 1944. The organization was so secret that even today, more than half a century later, all details concerning its operations and activities remain classified higher than Top Secret by both the American and British governments. In 1992, the director of the National Security Agency extended the secrecy order until the year 2012, making TICOM probably the last great secret of the Second World War. [...]
>
> Although Bletchley Park had conquered the Enigma machine, the Germans had managed to go one better. They developed a new and even more secret cipher machine, the *Geheimschreiber*, or secret writer, which was reserved for the very-highest-level messages, including those to and from Hitler himself. German cryptographers called an early model Swordfish. The Americans and British simply called them the Fish. Unlike Enigma, the Fish were capable of automatically encrypting at one end and decrypting at the other. Also, rather than the standard 26-letter alphabet, the Fish used the 32-character Baudot code, which turned the machine into a high-speed teleprinter.
>
> TICOM's goal was to capture a working model intact and thus learn exactly how the Germans built such a complex, sophisticated encryption device. [...]
>
> With enough Fish and other equipment to keep the engineers busy for a long time at Bletchley, the team began a manhunt for key German codebreakers. On May 21, 1945, Lieutenant Commander Howard Campaigne and several other TICOM officers interviewed a small group of Siginit personnel being held in Rosenheim. They had all worked for a unit of the Signals Intelligence Agency of the German Abwehr High

Command, a major target of TICOM. What the prisoners told Campaigne would lead to one of the most important, and most secret, discoveries in the history of Cold War codebreaking. Their command, they said, had built a machine that broke the highest-level Russian cipher system. [...]

It was a massive haul of some 7½ tons.

Over the next several days the dark gray equipment was carefully lifted from its crates and set up in the basement of the building. Then, like magic, high-level encrypted Russian communications, pulled from the ether, began spewing forth in readable plaintext. [...]

The Russian system involved dividing the transmissions into nine separate parts and then transmitting them on nine different channels. The German machines were able to take the intercepted signals and stitch them back together again in the proper order. For Campaigne and the rest of the TICOM team, it was a once-in-a-lifetime discovery. Back in Washington, Campaigne would eventually go on to become chief of research at NSA. [...]

The discovery of the Russian codebreaking machine was a principal reason why both the U.S. and British governments still have an absolute ban on all details surrounding the TICOM operations.

All told, the TICOM teams salvaged approximately five tons of German Sigint documents. In addition, many cryptologic devices and machines were found and returned to Bletchley.

Equally important were the interrogations of the nearly 200 key German codebreakers, some of which were conducted at a secret location codenamed Dustbin. In addition to the discovery of the Russian Fish, another reason for the enormous secrecy surrounding TICOM may be the question of what happened to the hundreds of former Nazi codebreakers secretly brought to England. Were any of the war criminals given new identities and employed by the British or American governments to work on Russian codebreaking problems? Among those clandestinely brought into the United States was the top codebreaker Dr. Erich Huetterhain. “It is almost certain that no major cryptanalytic successes were achieved without his knowledge,” said one TICOM document.

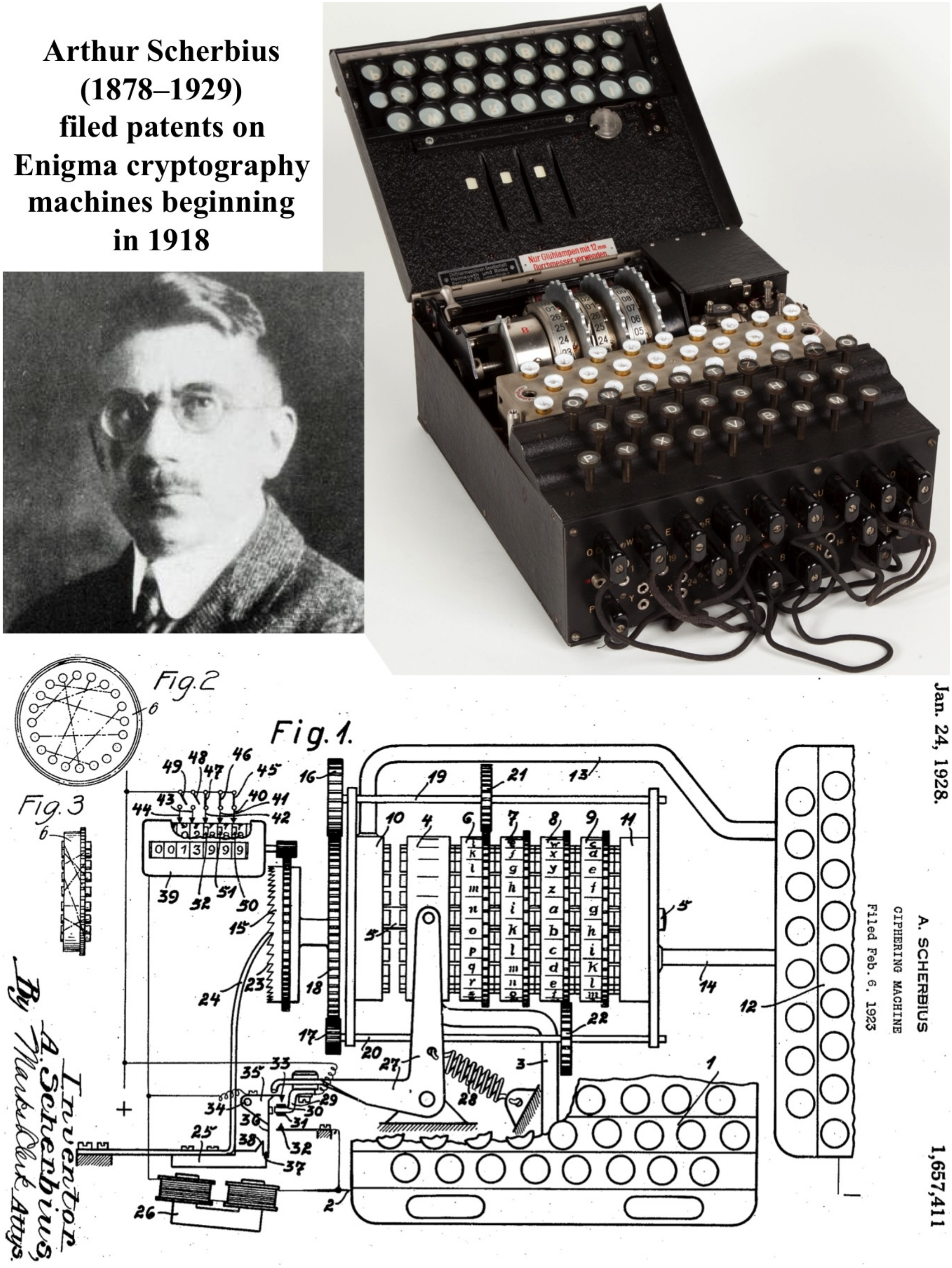
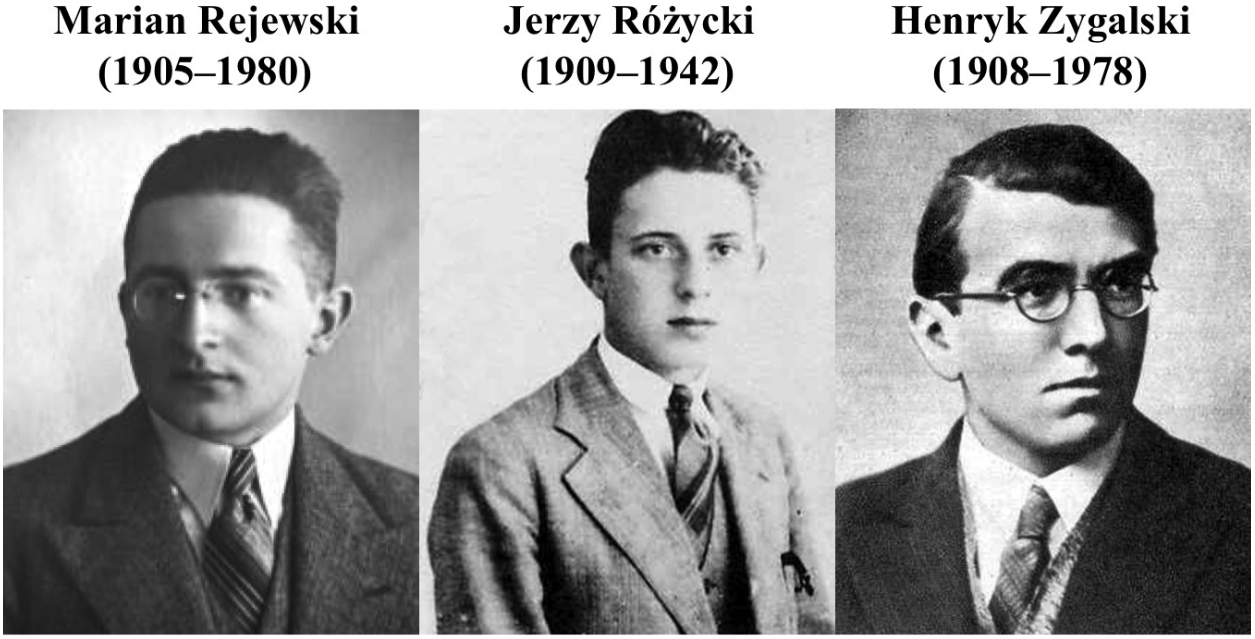

Arthur Scherbius
(1878–1929)
filed patents on
Enigma cryptography
machines beginning
in 1918
Nur Glühlampen mit 12 mm Durchmesser verwenden
Fig. 1.
Fig. 2
Fig. 3
Jan. 24, 1928.
A. SCHERBIUS
CIPHERING MACHINE
Filed Feb. 6, 1923
1,657,411
Inventor
A. Scherbius,
By Marks & Clerk Attys.

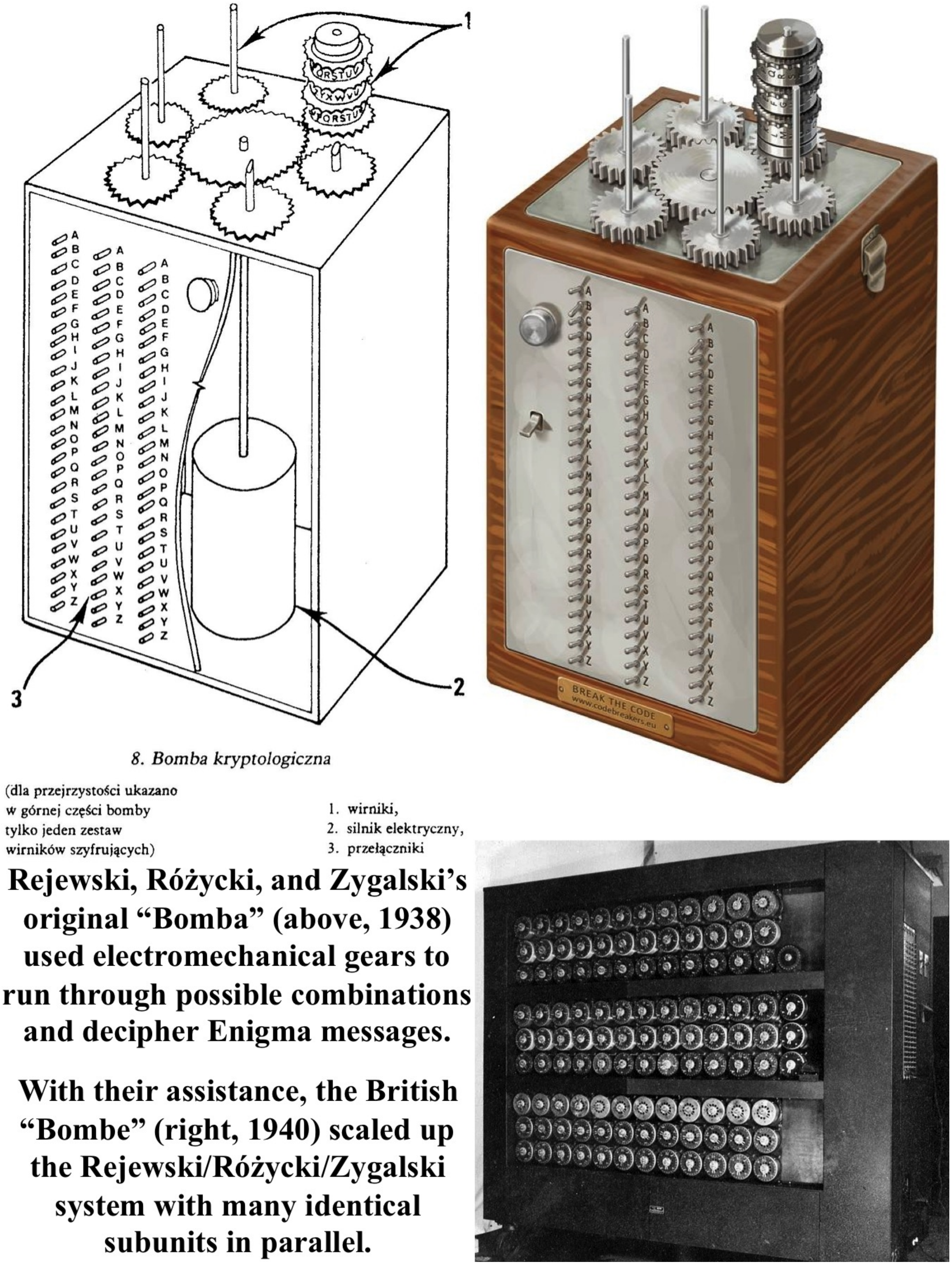
Figure 6.180: Arthur Scherbius filed patents on Enigma cryptography machines beginning in 1918.


Marian Rejewski (1905–1980)
Jerzy Różycki (1909–1942)
Henryk Zygalski (1908–1978)

Plaque at Bletchley Park, United Kingdom:
"This plaque commemorates the work of
Marian Rejewski, Jerzy Różycki, and Henryk Zygalski,
mathematicians of the Polish intelligence service,
in first breaking the Enigma code."

FOUNDED 2002

Figure 6.181: Marian Rejewski, Jerzy Różycki, and Henryk Zygalski were primarily responsible for breaking the Enigma code.



8. Bomba kryptologiczna

(dla przejrzystości ukazano
w górnej części bomby
tylko jeden zestaw
wirników szyfrujących)

1. wirniki,
2. silnik elektryczny,
3. przełączniki

Rejewski, Różycki, and Zygalski's original "Bomba" (above, 1938) used electromechanical gears to run through possible combinations and decipher Enigma messages.

With their assistance, the British "Bombe" (right, 1940) scaled up the Rejewski/Różycki/Zygalski system with many identical subunits in parallel.

Figure 6.182: Rejewski, Różycki, and Zygalski's original "Bomba" (1938) used electromechanical gears to run through possible combinations and decipher Enigma messages. With their assistance, the British "Bombe" (1940) scaled up the Rejewski/Różycki/Zygalski system with many identical subunits in parallel.

Siemens and Halske T-52 Geheimschreiber (1930 onward)

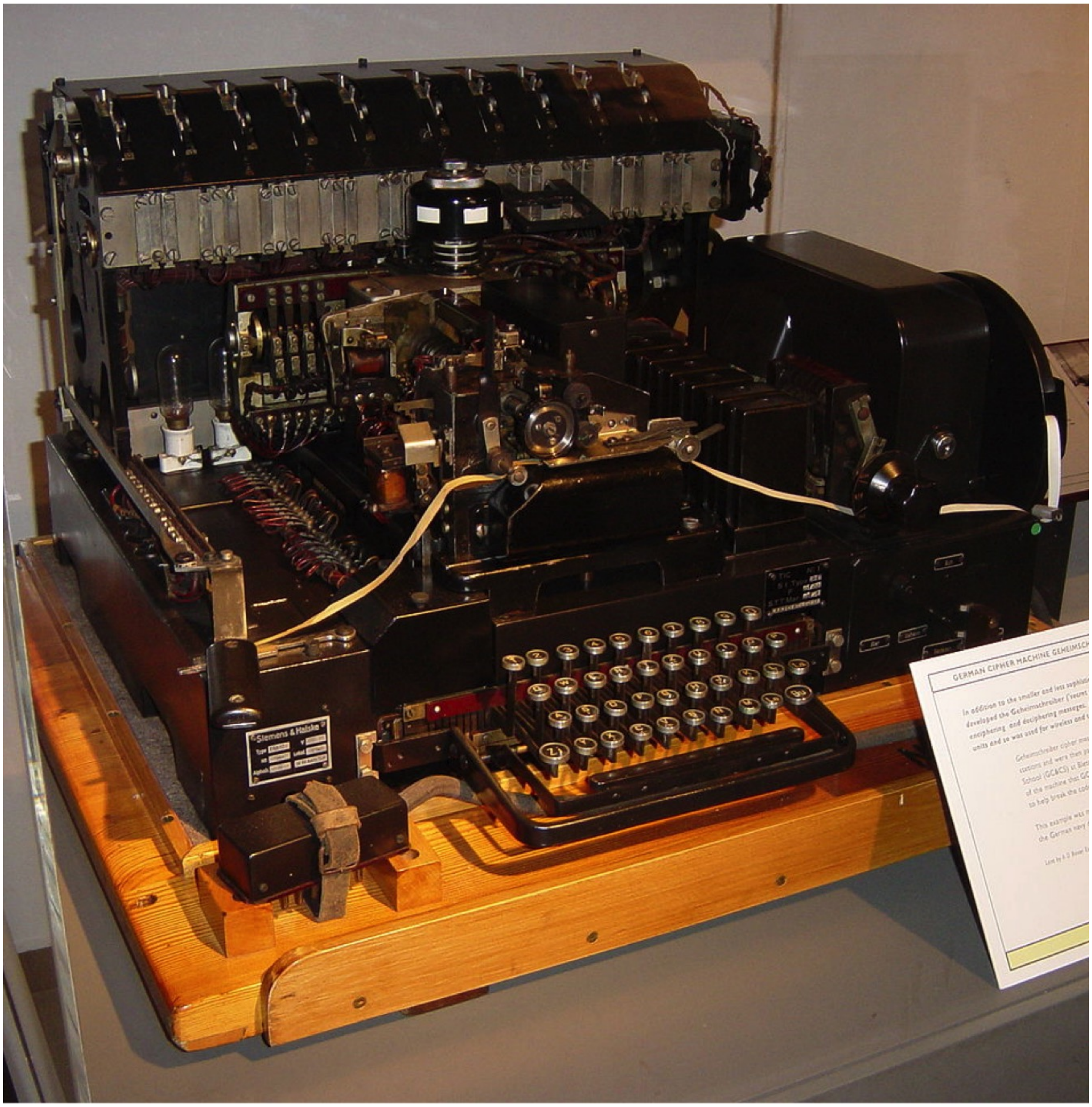


Figure 6.183: Siemens and Halske T-52 Geheimschreiber (used from 1930 onward).

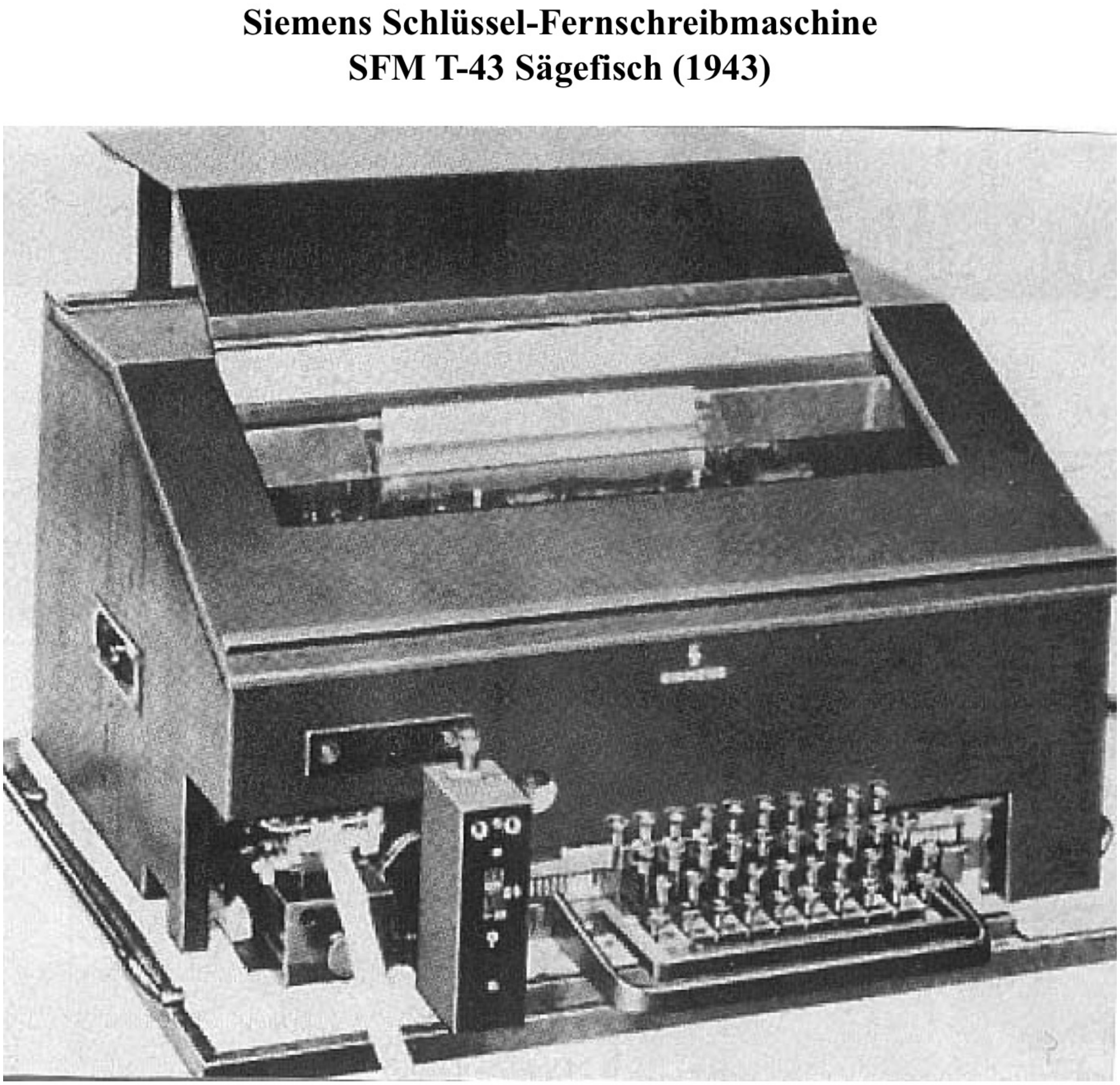
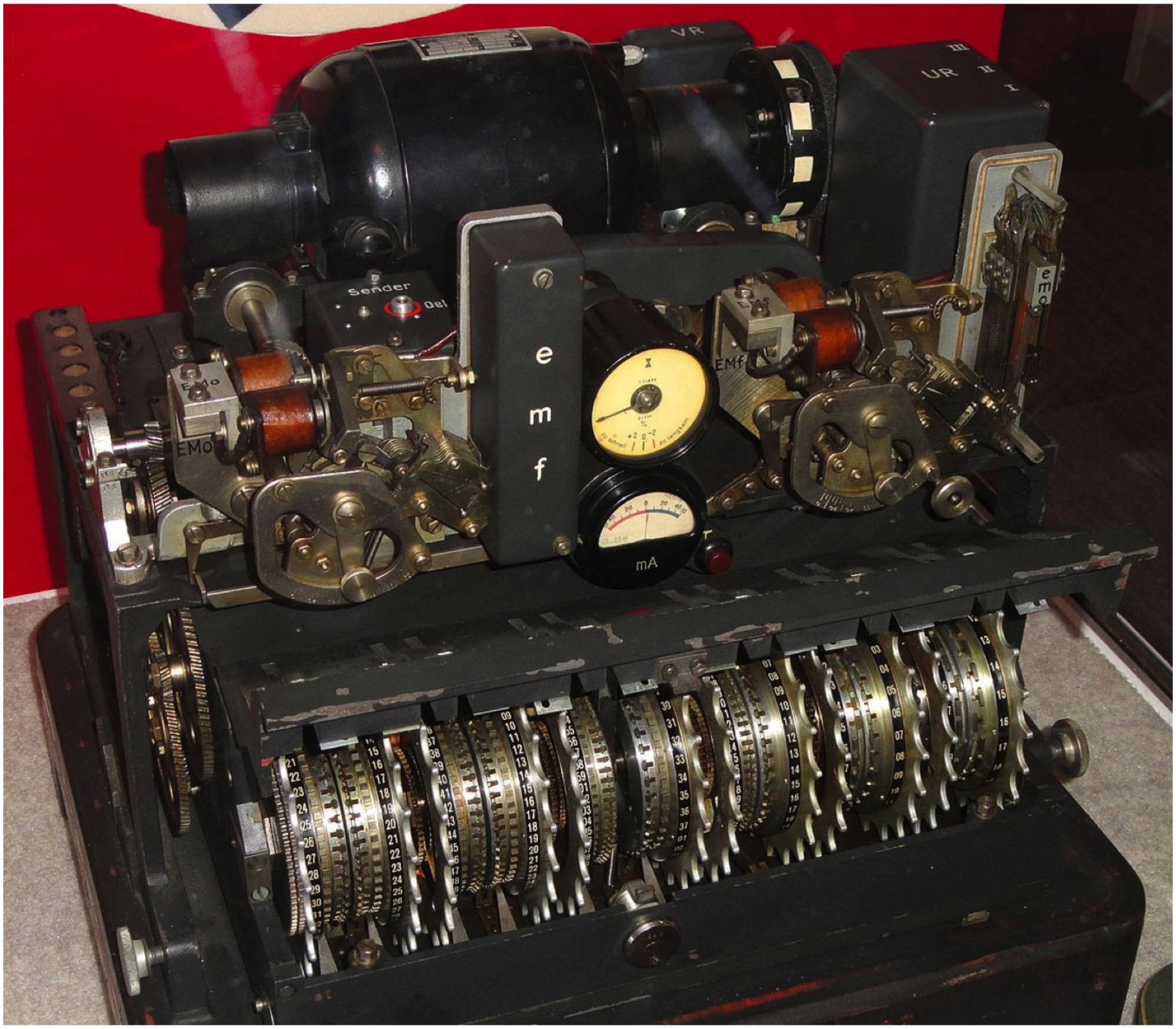

Siemens Schlüssel-Fernschreibmaschine
SFM T-43 Sägefisch (1943)

Figure 6.184: Siemens Schlüssel-Fernschreibmaschine SFM T-43 Sägefisch (Sawfish) encryption machine (1943).

Lorenz Schlüssel-Zusatz SZ42 (1942)


VR
UR
III
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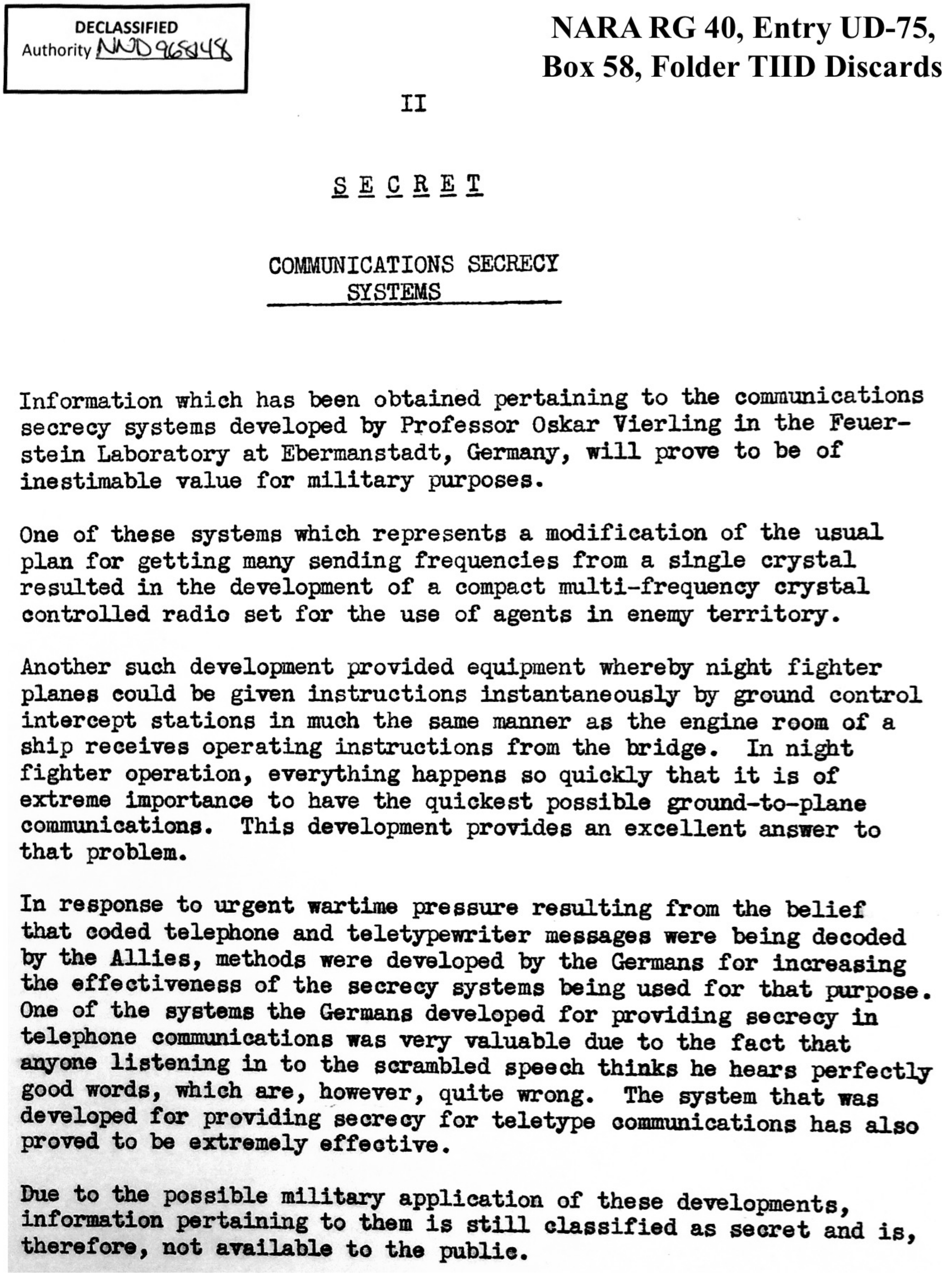
mA

Figure 6.185: Lorenz Schlüssel-Zusatz SZ42 encryption machine (1942).



DECLASSIFIED
Authority NND 968148

NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards

II

SECRET

COMMUNICATIONS SECRECY SYSTEMS

Information which has been obtained pertaining to the communications secrecy systems developed by Professor Oskar Vierling in the Feuerstein Laboratory at Ebermanstadt, Germany, will prove to be of inestimable value for military purposes.

One of these systems which represents a modification of the usual plan for getting many sending frequencies from a single crystal resulted in the development of a compact multi-frequency crystal controlled radio set for the use of agents in enemy territory.

Another such development provided equipment whereby night fighter planes could be given instructions instantaneously by ground control intercept stations in much the same manner as the engine room of a ship receives operating instructions from the bridge. In night fighter operation, everything happens so quickly that it is of extreme importance to have the quickest possible ground-to-plane communications. This development provides an excellent answer to that problem.

In response to urgent wartime pressure resulting from the belief that coded telephone and teletypewriter messages were being decoded by the Allies, methods were developed by the Germans for increasing the effectiveness of the secrecy systems being used for that purpose. One of the systems the Germans developed for providing secrecy in telephone communications was very valuable due to the fact that anyone listening in to the scrambled speech thinks he hears perfectly good words, which are, however, quite wrong. The system that was developed for providing secrecy for teletype communications has also proved to be extremely effective.

Due to the possible military application of these developments, information pertaining to them is still classified as secret and is, therefore, not available to the public.

Figure 6.186: Advanced technologies for encrypting communications signals were developed in the German-speaking world and transferred to other countries after World War II [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

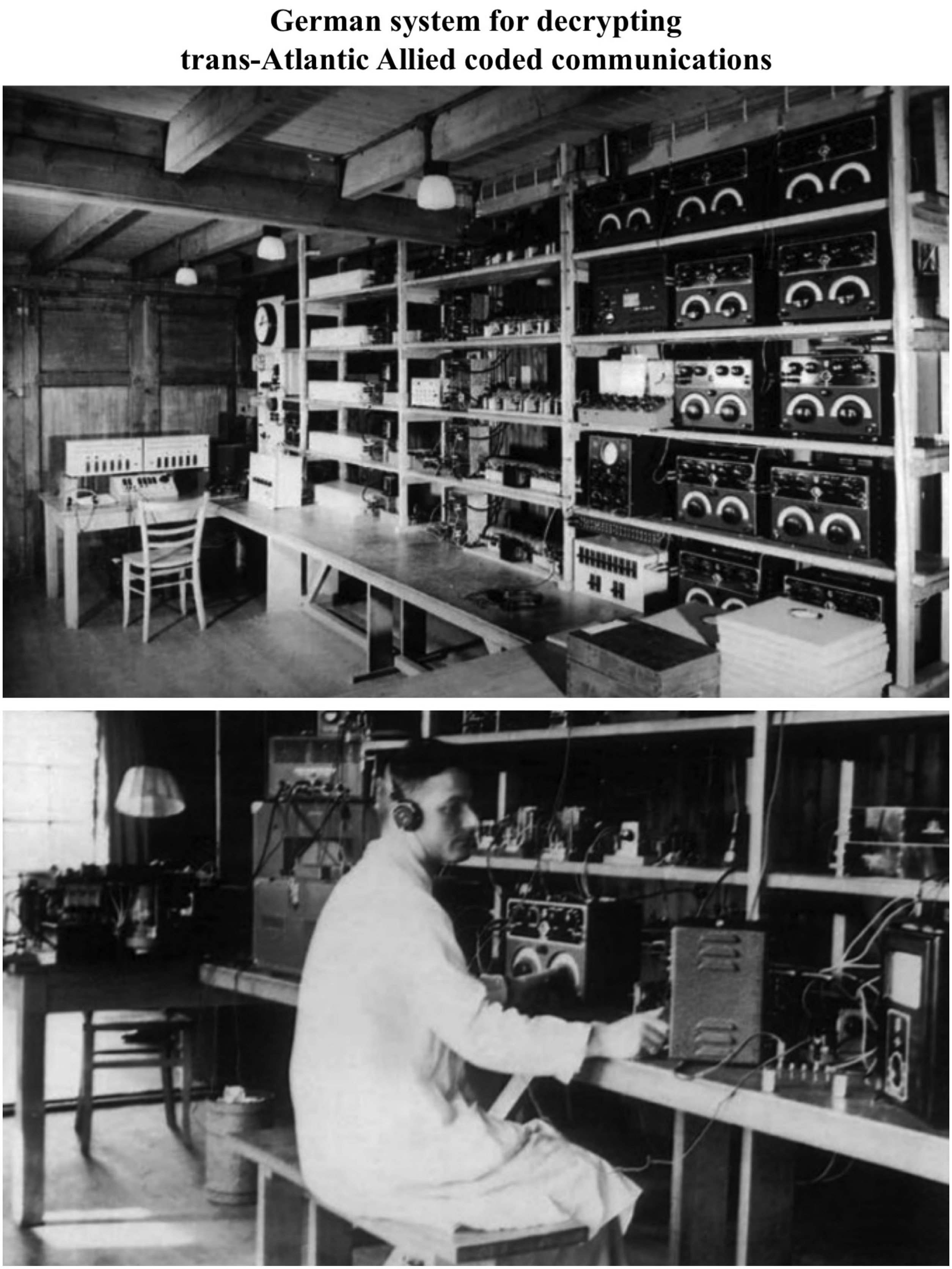


Figure 6.187: German system for decrypting trans-Atlantic Allied coded communications.

German system for decrypting Soviet coded communications

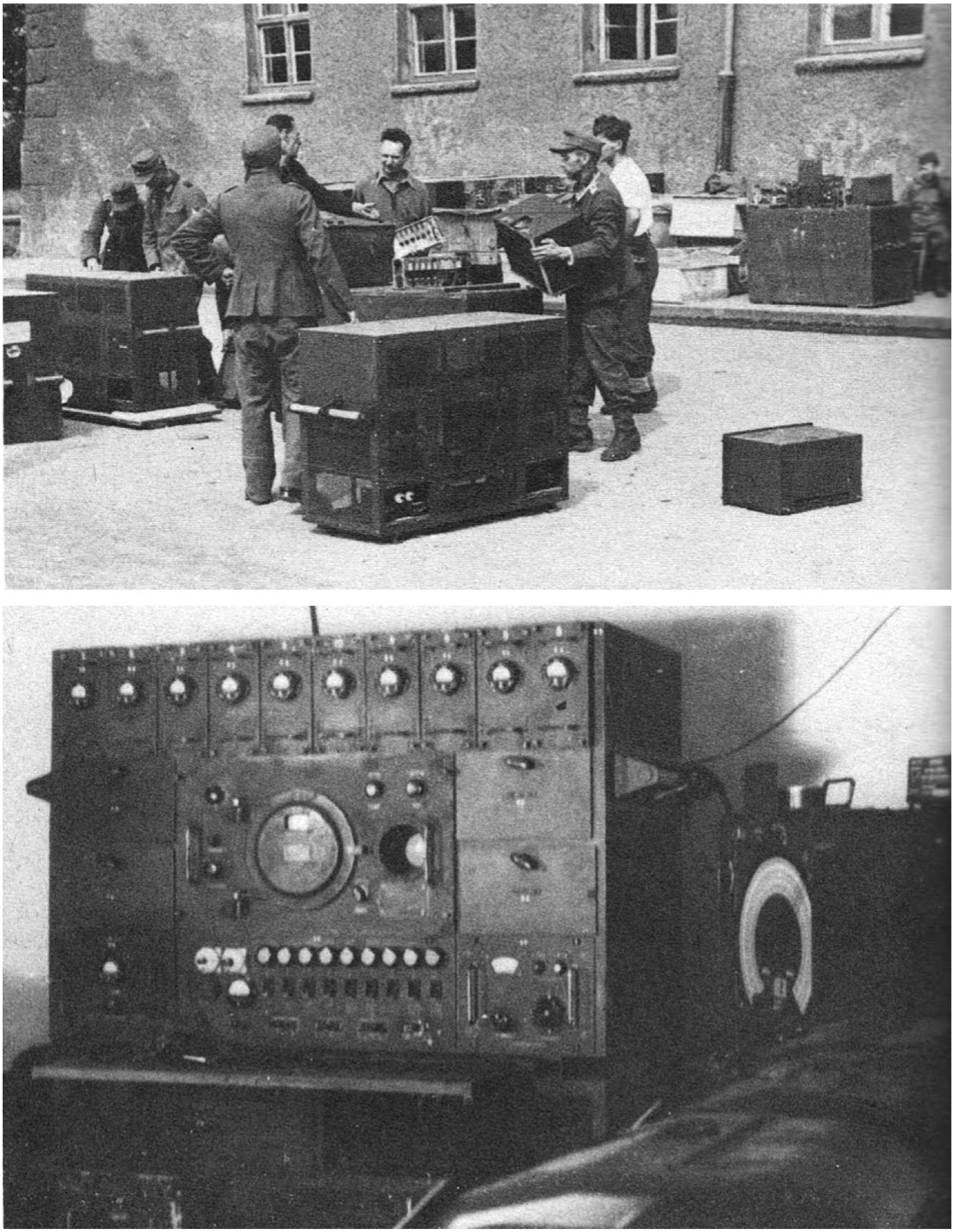


Figure 6.188: German system for decrypting Soviet coded communications (sometimes called “Russian Fish”).

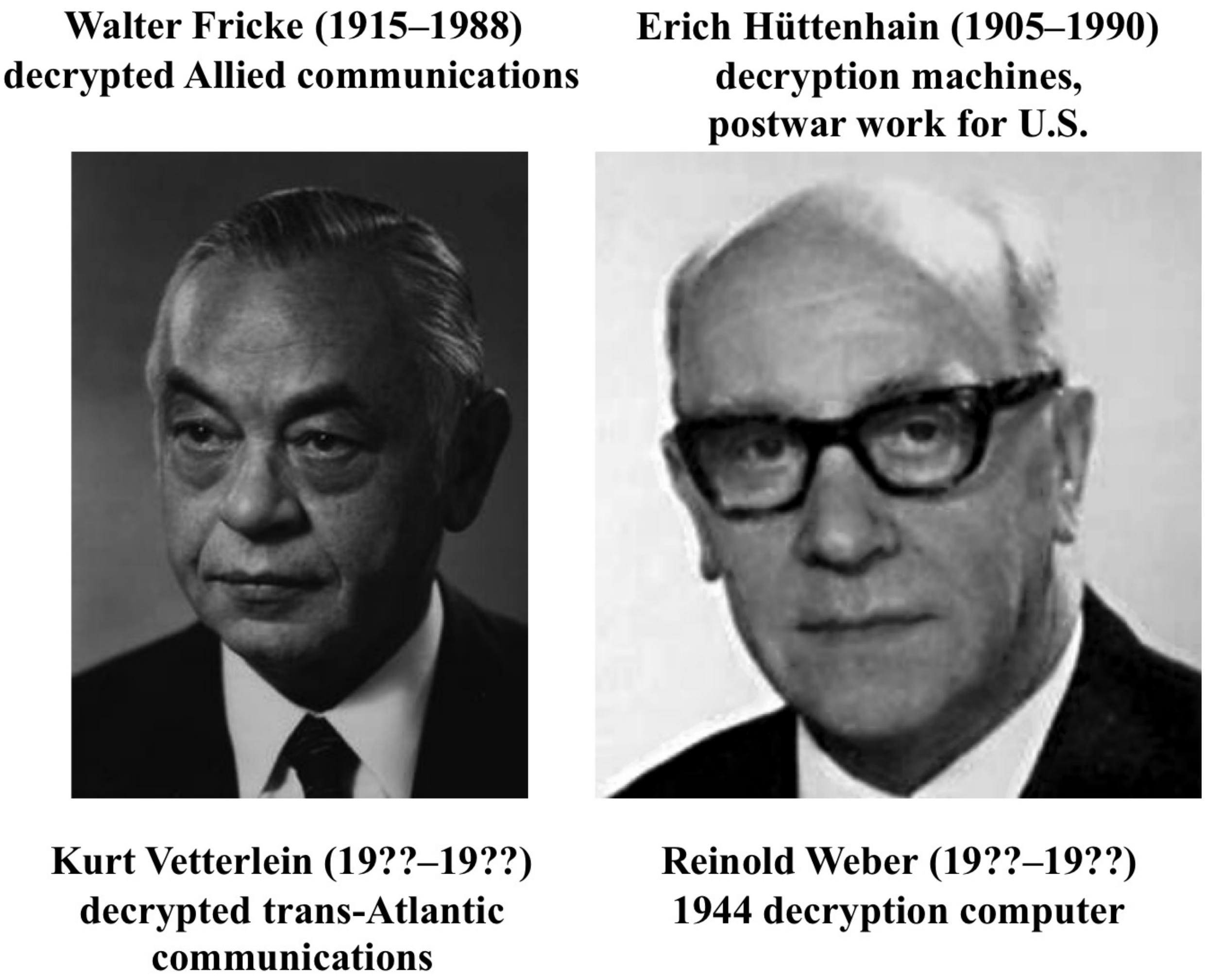
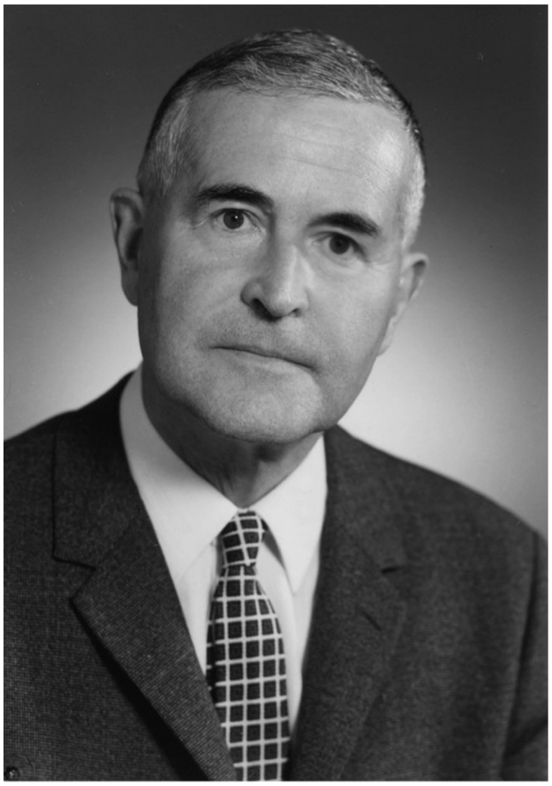
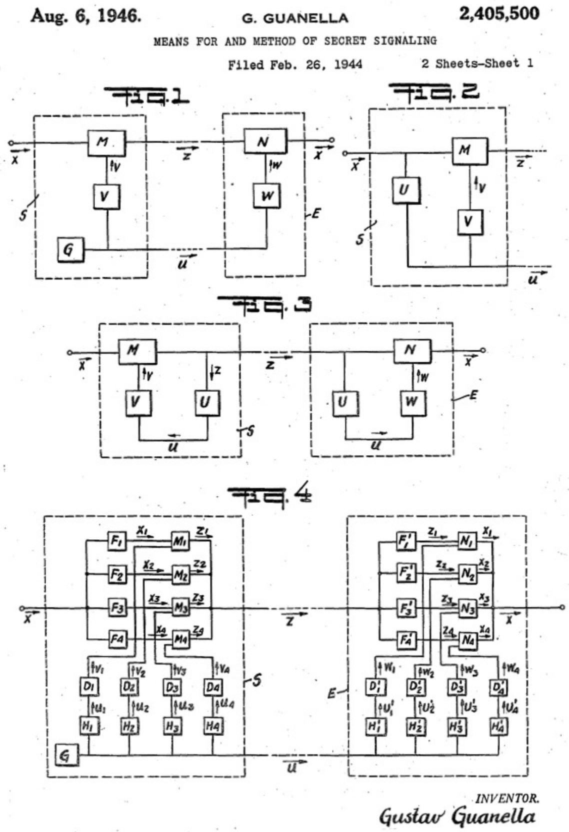

Walter Fricke (1915–1988)
decrypted Allied communications
Erich Hüttenhain (1905–1990)
decryption machines,
postwar work for U.S.
Kurt Vetterlein (19??–19??)
decrypted trans-Atlantic
communications
Reinold Weber (19??–19??)
1944 decryption computer

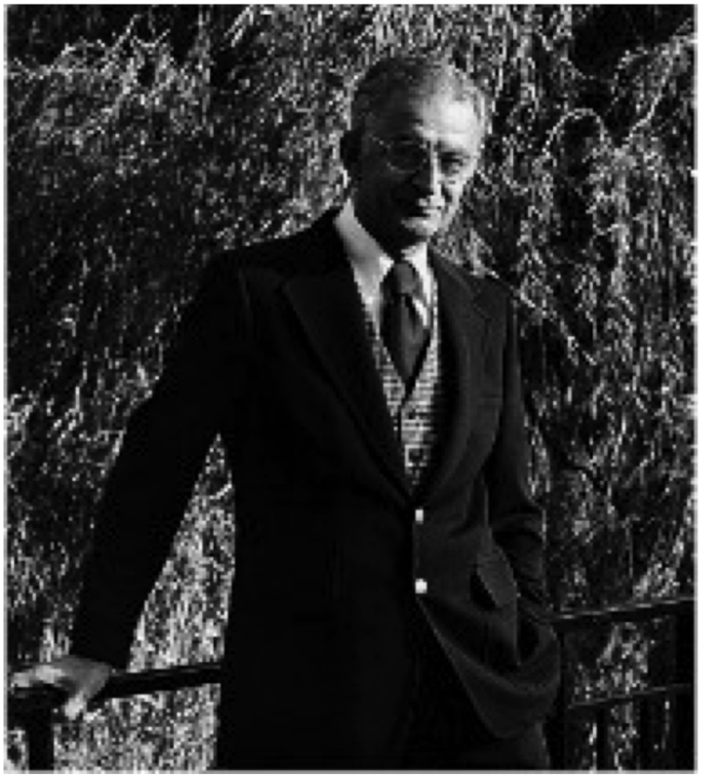
Figure 6.189: German-speaking experts who decrypted Allied coded communications included Walter Fricke, Erich Hüttenhain, Kurt Vetterlein, and Reinold Weber.

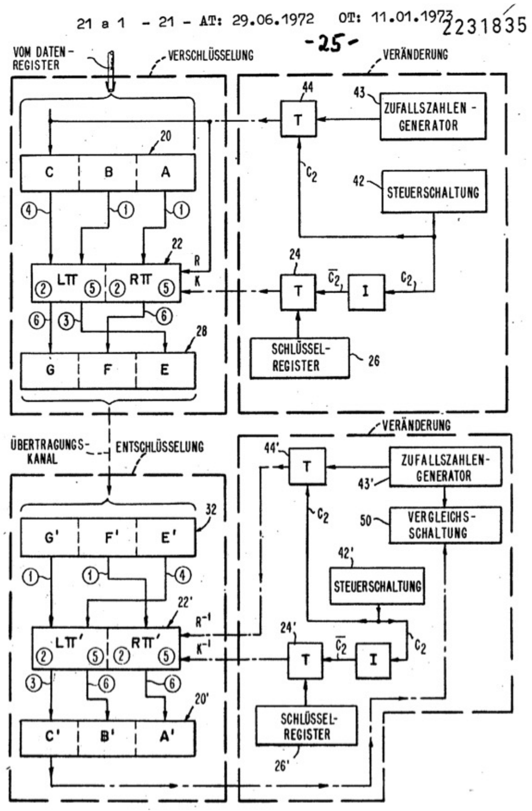
Gustav Guanella (1909–1982)




Aug. 6, 1946.
G. GUANELLA
2,405,500
MEANS FOR AND METHOD OF SECRET SIGNALING
Filed Feb. 26, 1944
2 Sheets-Sheet 1
FIG. 1
FIG. 2
FIG. 3
FIG. 4
M
N
V
W
G
U
x
z
u
v
w
S
E
F1 F2 F3 F4
M1 M2 M3 M4
N1 N2 N3 N4
D1 D2 D3 D4
H1 H2 H3 H4
INVENTOR.
Gustav Guanella

Horst Feistel (1915–1990)




21 a 1 - 21 - AT: 29.06.1972 OT: 11.01.1973
2231835
-25-
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VERSCHLÜSSELUNG
VERÄNDERUNG
ZUFALLSZAHLEN-GENERATOR
STEUERSCHALTUNG
SCHLÜSSEL-REGISTER
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G F E
R
K
c2
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26
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42
43
44
ÜBERTRAGUNGS-KANAL
ENTSCHLÜSSELUNG
VERÄNDERUNG
G' F' E'
LΠ' RΠ'
C' B' A'
R⁻¹
K⁻¹
VERGLEICHS-SCHALTUNG
20'
22'
24'
26'
32
42'
43'
44'
50

Figure 6.190: Other German-speaking pioneers of advanced cryptography included Gustav Guanella and Horst Feistel.

6.7.4 Robotics

The Jewish and greater German-speaking worlds had a centuries-long tradition of folklore regarding the creation of an artificial worker, or "Golem," out of inorganic materials (p. 2653). The concept of a Golem was especially prominent in the German-speaking world of the early twentieth century, featured in stories such as the 1913–1914 serialized novel *Der Golem* by Gustav Meyer/Meyrink (Austrian, 1868–1932) and in three films of the same name by Paul Wegener (German, 1874–1948) that were released in 1915, 1917, and 1920.

Apparently inspired by those stories, in 1920 Karel Čapek (Czech, 1890–1938) wrote the play *R.U.R. (Rossum's Universal Robots)*, in which he was the first to use the word "robot" to describe a factory-made artificial worker (Fig. 6.191) [Contrada 1995]. In Čapek's play, the manager of the factory producing the robots summarized the approach to creating them [Čapek 1923, Act I]:

> Young Rossum invented a worker with the minimum amount of requirements. He had to simplify him. He rejected everything that did not contribute directly to the progress of work. Everything that makes man more expensive. In fact he rejected man and made the Robot. My dear Miss Glory, the Robots are not people. Mechanically they are more perfect than we are; they have an enormously developed intelligence, but they have no soul. [...] Have you ever seen what a Robot looks like inside? [...] Very neat, very simple. Really a beautiful piece of work. Not much in it, but everything in flawless order. The product of an engineer is technically at a higher pitch of perfection than a product of Nature.

In the 1927 film *Metropolis*, Fritz Lang (Austrian, 1890–1976) and Thea von Harbou (German, 1888–1954) continued that theme by depicting the fictional creation of a robot (Maschinenmensch or machine-person) that was so lifelike that it could successfully impersonate a human woman (p. 1971).[19]

German-speaking scientists and engineers began making those general ideas a reality even before *R.U.R.* and *Metropolis* were released, and continued with even greater effort in the years afterward.[20]

In 1893, Nikola Tesla (Serbo-Croatian, educated in Austria, 1856–1943) began developing the world's first teleoperated robotic vehicles. By 1898, he patented and demonstrated a radio-controlled boat, and described how his approach could be extended to a wide variety of vehicles and much more elaborate control systems, and even to autonomously directed vehicles (Fig. 6.192). In his autobiography, Tesla summarized his work and his vision in the field of teleoperated vehicles and robotics [Tesla 1919, pp. 106–109]:

> The idea of constructing an automaton, to bear out my theory, presented itself to me early but I did not begin active work until 1893, when I started my wireless investigations. During the succeeding two or three years a number of automatic mechanisms, to be actuated from a distance, were constructed by me and exhibited to visitors in my laboratory. In 1896, however, I designed a complete machine capable of a multitude of operations, but the consummation of my labors was delayed until late in 1897. This machine was illustrated and described in my article in the Century Magazine of June, 1900,

---

[19] Bogdanovich 1967; Eisenschitz and Bertetto 1994; Eisner 1977; Jenkins 1981; McGilligan 1997.

[20] Cheney 1981; Cheney and Uth 1999; Everett 2015; Jaugitz 2001; Tesla 1919; Trenkle 1987.

and other periodicals of that time and, when first shown in the beginning of 1898, it created a sensation such as no other invention of mine has ever produced. In November, 1898, a basic patent on the novel art was granted to me, but only after the Examiner-in-Chief had come to New York and witnessed the performance, for what I claimed seemed unbelievable. I remember that when later I called on an official in Washington, with a view of offering the invention to the Government, he burst out in laughter upon my telling him what I had accomplished. Nobody thought then that there was the faintest prospect of perfecting such a device. It is unfortunate that in this patent, following the advice of my attorneys, I indicated the control as being effected thru the medium of a single circuit and a well-known form of detector, for the reason that I had not yet secured protection on my methods and apparatus for individualization. As a matter of fact, my boats were controlled thru the joint action of several circuits and interference of every kind was excluded. Most generally I employed receiving circuits in the form of loops, including condensers, because the discharges of my high-tension transmitter ionized the air in the hall so that even a very small aerial would draw electricity from the surrounding atmosphere for hours. Just to give an idea, I found, for instance, that a bulb 12" in diameter, highly exhausted, and with one single terminal to which a short wire was attached, would deliver well on to one thousand successive flashes before all charge of the air in the laboratory was neutralized. The loop form of receiver was not sensitive to such a disturbance and it is curious to note that it is becoming popular at this late date. In reality it collects much less energy than the aerials or a long grounded wire, but it so happens that it does away with a number of defects inherent to the present wireless devices. In demonstrating my invention before audiences, the visitors were requested to ask any questions, however involved, and the automaton would answer them by signs. This was considered magic at that time but was extremely simple, for it was myself who gave the replies by means of the device.

At the same period another larger telautomatic boat was constructed a photograph of which is shown in this number of the ELECTRICAL EXPERIMENTER. It was controlled by loops, having several turns placed in the hull, which was made entirely water-tight and capable of submergence. The apparatus was similar to that used in the first with the exception of certain special features I introduced as, for example, incandescent lamps which afforded a visible evidence of the proper functioning of the machine.

These automata, controlled within the range of vision of the operator, were, however, the first and rather crude steps in the evolution of the Art of Telautomatics as I had conceived it. The next logical improvement was its application to automatic mechanisms beyond the limits of vision and at great distance from the center of control, and I have ever since advocated their employment as instruments of warfare in preference to guns. The importance of this now seems to be recognized, if I am to judge from casual announcements thru the press of achievements which are said to be extraordinary but contain no merit of novelty, whatever. In an imperfect manner it is practicable, with the existing wireless plants, to launch an aeroplane, have it follow a certain approximate course, and perform some operation at a distance of many hundreds of miles. A machine of this kind can also be mechanically controlled in several ways and I have no doubt that it may prove of some usefulness in war. But there are, to my best knowledge, no instrumentalities in existence today with which such an object could be accomplished in

> a precise manner. I have devoted years of study to this matter and have evolved means, making such and greater wonders easily realizable.

As shown in Fig. 6.193, Anton Flettner (German, 1885-1961) filed patent applications on teleoperated robots beginning in 1906. He designed robots for various applications on land, in the water, and in the air. In 1915, he demonstrated a radio-controlled battlefield mini-tank with remote-controlled weapons (a blow torch in the demonstration model; the model is shown without its armored shell in Fig. 6.193). Flettner also invented rotor ships (p. 1484) and ultimately became most famous for creating helicopters (p. 1824). U.S. Navy robotics expert H. R. Everett presented information from several sources regarding the history of Flettner's work on teleoperated robots [Everett 2015, pp. 415–417]:

> In 1913, an up-and-coming German inventor named Anton Flettner [...] reportedly patented a radio-controlled "tank" in conjunction with the firm Felt-Guillaume-Lahnmeyer (Seydewitz and Doberer, 1937). Born into a family of ship owners on 1 November 1885 (Marine Review, 1926), Flettner grew up near Frankfurt on Main, where as a youth he became involved in the development and demonstration of radio control for riverboats (Hirschel et al., 2004, 299). As Flettner recounted in *Mein Weg zum Rotor*: "I was still a high school student in Hoechst on the Main when I made my first invention. I contrived to design a wireless distant control system whereby torpedoes, ships and other vehicles could be directed from a distance without any direct communication by wire or otherwise. My experiments were successful" (Flettner, 1926). [...]
>
> Following the outbreak of World War I, he was hired by the renowned Count Ferdinand von Zeppelin to investigate the feasibility of radio-controlled airships (Day and McNeil, 1996). [...]
>
> The gifted inventor's first brush with fame came the following year: "Flettner became known in his country and abroad in the summer of 1915, when a curious clumsy vehicle made its appearance in Berlin: a tank which could move in any direction without a crew. The whole program of the tank's maneuvers was being directed from an unknown spot in the distance" (Tokaty, 1994, 141). [...]
>
> In *Les rayons de la mort*, Seydewitz and Doberer (1937) indicate the tank was successfully controlled from a following car while crossing obstacles and breaching barbed wire. In addition to the basic mobility functions of *forward*, *reverse*, *left*, *right*, and *stop*, it also had an obstacle-clearing payload; Flettner (1926) described this feature in action: "In front of the wire entanglements constructed of angle iron the tank suddenly emitted the blinding hissing flames of an autogenous cutting device," and in a few minutes the obstacles were gone."

By the 1930s, Flettner had moved on to helicopters, but Werner Bergau (German, 1904–??), Robert Brüderlink (German, 1893–1978), Friedrich Gladenbeck (German, 1899–1987), and other German-speaking scientists and engineers took up Flettner's earlier work on robotic tanks (Fig. 6.194). They designed, built, optimized, and deployed rugged, teleoperated robotic systems to handle explosives and perform other complex tasks under actual battlefield conditions [Everett 2015; Jaugitz 2001; Trenkle 1987]:

- The small Leichter Ladungsträger Goliath was first deployed in 1942 (Fig. 6.194). It was primarily employed as a single-use vehicle to deliver demolition charges to bridges, enemy tanks, or other targets, although it was a versatile platform that could also be customized for other tasks. During the war, over 7500 Goliath units were produced and deployed to battlefields ranging from the Normandy beaches to the Eastern Front. It was the forerunner of, and remarkably similar to, modern teleoperated battlefield robots such as the U.S. Foster-Miller TALON (which was not deployed until six decades later, in 2000).

- The medium-sized Mittlerer Ladungsträger Springer was first deployed in 1944 (Fig. 6.195). Essentially it was a larger version of Goliath and was generally used operationally in very similar ways.

- The large Schwerer Ladungsträger Borgward B IV was first deployed in 1942 (Fig. 6.195). It served primarily as a reusable vehicle to remotely deliver demolition charges in vulnerable areas on the battlefield. Some models were also customized for other purposes, such as minesweeping and remote-controlled rocket-firing platforms.

While other countries were also experimenting with remote-controlled vehicles during World War II, the German systems were especially advanced, even including cameras (pp. 998, 5416) and remote-controlled weapons. They were used extensively during the war, and they were closely studied by other countries after the war, leading to modern robotic systems.

Some modern readers may object that these early German robots were teleoperated, but so are many modern robots such as battlefield units, bomb squad robots, aerial drones, and remote-controlled manipulator arms. Moreover, the German-speaking world simultaneously invented and demonstrated sophisticated computers (p. 1162) that could ultimately serve as “brains” to allow robots to function autonomously.

There were also numerous examples of both teleoperated and fully autonomous robotic vehicles among the variety of German torpedoes (pp. 1468–1473) and missiles (pp. 1144, 1254, and 1835) that were developed before and during World Wars I and II. Indeed, Allied press and intelligence reports of autonomously guided German missiles commonly referred to them as “robots” (e.g., pp. 5012, 4703, 5316, 5625, 5626).

Karl Saur (German, ca. 1901–1978, not to be confused with the Karl Saur who was a high-ranking government official under Albert Speer) and Rudolf Nebel (German, 1894–1978) invented, built, and used industrial robotics technology from the 1930s to 1945.[21] From 1937 onward, they designed and built customized industrial robots to perform tasks at a number of German companies. During 1944–1945, they built 20 industrial robots to assemble components at the underground Mittelwerk plant in Nordhausen. See Figs. 6.196–6.201.

---

[21] Nebel 1972 https://blog.hnf.de/vom-automatischen-arbeiter-zum-industrieroboter/

Tina Kubot and Frank Dittmann. Geschichte einer Vision. *Kulture & Technik* (Deutsches Museum) 3/2016, p. 16. https://www.deutsches-museum.de/assets/Verlag/Download/Kultur_und_Technik/2016/2016-3.pdf

Frank Dittmann. 2022. Automatische Arbeiter für die Raketenproduktion des Mittelwerks. https://www.buchenwald.de/47/date/2022/04/13/technik-im-nationalsozialismus/

https://www.mdr.de/nachrichten/thueringen/nord-thueringen/nordhausen/roboter-kz-mittelbau-dora-wunderwaffe-nazis-100.html

In his autobiography, Rudolf Nebel summarized the history of his work on industrial robots with Karl Saur [Nebel 1972, pp. 147–153]:

[1937] Bei Siemens in Berlin hatte ich Diplomingenieur Karl Saur kennengelernt. Er hatte eine Maschine konstruiert, die ein Uhrwerk automatisch zusammenbauen konnte. Die Idee der Automation packte mich sofort, und ich entschloß mich, den Siemens-Konzern zu verlassen und mich mit Saur selbständig zu machen. Wir eröffneten ein Ingenieurbüro in Berlin-Wilmersdorf und entwickelten einen “Automatischen Arbeiter”, der zahlreiche Arbeitsvorgänge bewältigen konnte. Saur und ich entwarfen einen Prospekt, der den werbewirksamen Titel hatte: “1 Million Arbeitskräfte automatisch.” In einer Zeit, wo die Handarbeit noch das Maß aller Dinge war, wirkte unsere Broschüre geradezu sensationell. Als Anwendungsmöglichkeiten unserer Erfindung schlugen wir unter anderen vor:	[1937] At Siemens in Berlin, I met engineer Karl Saur. He had constructed a machine that could automatically assemble a clockwork. The idea of automation immediately grabbed me, and I decided to leave the Siemens group and start my own business with Saur. We opened an engineering office in Berlin-Wilmersdorf and developed an “automatic worker” that could handle numerous operations. Saur and I designed a brochure that had the promotional title: “1 Million Workers Automatically.” At a time when manual labor was still the measure of all things, our brochure had an almost sensational effect. As possible applications for our invention, we suggested, among others:
1. Montage von Maschinenelementen aller Art.	1. Assembly of all kinds of machine elements.
2. Gefährliche Arbeiten, wie Pulver pressen, Munitionsherstellung, Arbeiten mit Sprengstoff.	2. Dangerous work, such as [explosive] powder pressing, ammunition production, work with explosives.
3. Montage elektrischer Teile.	3. Assembly of electrical parts.
4. Bedienung einer Fließstraße von halbautomatischen Maschinen, einschießlich Transport der Werkstücke. Eine ganze Anzahl solcher Maschinen kann durch eine Steuergruppe bedient werden, und zwar in der Reihenfolge, daß die Maschinen ununterbrochen Arbeit leisten.	4. Operation of an assembly line of semi-automatic machines, including transport of workpieces. A whole number of such machines can be operated by one control group, in order that the machines perform work continuously.

Wir verschickten rund 1000 dieser Broschüren an alle Firmen, die 1937 mit Rüstungsaufträgen beschäftigt waren. Natürlich gab es Proteste von den Arbeitsämtern, die zu dieser Zeit noch rund 400 000 Arbeitslose in ihren Karteien hatten. Ein Arbeitsamtsdirektor bekam bei einer Besprechung einen Wutanfall und schrie mich an: “Sind Sie wahnsinnig geworden? Kaum haben wir die furchtbare Arbeitslosenzeit hinter uns, da fangen Sie mit Robotern an, dieses Elend wieder heraufzubeschwören!” Doch in anderen Dienststellen hatte man nicht die Sorge, daß unsere Erfindung soziale Schwierigkeiten bringen würde. Sogar die NSDAP war auf unsere Automaten aufmerksam geworden und überlegte, wie man die neuartige Maschine im Rahmen des Vierjahresplanes für die Rüstung nützen könne. [...]

Bis Kriegsausbruch arbeitete ich nun mit Saur zusammen an der Entwicklung des “Automatischen Arbeiters”. Wir bekamen Aufträge verschiedener Privatfirmen und konnten sorgenfrei leben, obwohl ich bei der Partei in Ungnade gefallen war. [...]

Ich konnte während der nächsten Kriegsjahre weiter an meinen Erfindungen arbeiten. In einer kleinen Werkstatt in Berlin-Lichterfelde erstellte Saur mit fünf Mitarbeitern die Konstruktion für die Automaten, deren Anfertigung, Montage und Arbeiten ich bei unseren Kunden überwachte.

We sent out about 1,000 of these brochures to all the companies that were busy with armaments orders in 1937. Of course, there were protests from the labor offices, which at that time still had about 400,000 unemployed in their files. One labor office director threw a tantrum at a meeting and shouted at me: “Are you out of your mind? No sooner are we past the terrible unemployment period than you start conjuring up this misery again with robots!” But in other departments, there was no concern that our invention would bring social difficulties. Even the Party had become aware of our automation and was considering how the novel machines could be used for armaments within the framework of the Four-Year Plan. [...]

Until the outbreak of the war, I worked together with Saur on the development of the “automatic worker.” We received orders from various private companies and were able to live without worries, even though I had fallen out of favor with the Party. [...]

I was able to continue working on my inventions during the years of the war. In a small workshop in Berlin-Lichterfelde, Saur and five employees designed the automated machines, whose production, assembly, and operation I supervised for our customers.

Wir konnten unsere Arbeiten bis November 1943 fortsetzen. Am 23. November 1943 wurde das Berliner Konstruktionsbüro total ausgebombt, und Saur und ich verlegten unsere kleine Firma nach Bad Wilsnack an der Elbe. Wenige Tage vor dem Attentat auf Hitler am 20. Juli 1944—die Deutsche Propaganda stellte in dieser Woche die ersten Einsätze der V 1 groß heraus—rief mich Klaus Riedel im Büro an. Wir sprachen kurz über Kriegslage, und dann machte mir mein alter Mitarbeiter einer interessanten Vorschlag. Riedel sagte, er habe mit den beiden Chefs des geheimen "Mittelwerkes" gesprochen und sei auf großes Interesse gestoßen. Ich solle sofort mit meinem Raketenfilm und den Unterlagen über den "Automatischen Arbeiter" nach Berlin kommen. Direktor Sawatzki und Generaldirektor Rickhey seien gerade in den Borsigwerken, und es könne sein, daß sie mir einen Auftrag erteilen würden. [...]

We were able to continue our work until November 1943. On 23 November 1943, the Berlin design office was totally bombed out, and Saur and I moved our small company to Bad Wilsnack on the Elbe. A few days before the assassination attempt on Hitler on July 20, 1944—German propaganda that week gave great publicity to the first missions of the V-1—Klaus Riedel called me at the office. We talked briefly about the war situation, and then my old co-worker made me an interesting proposition. Riedel said he had talked to the two chiefs of the secret "Mittelwerk" and had met with great interest. I should come to Berlin immediately with my rocket film and the documents on the "Automatic Worker." Director Sawatzki and General Director Rickhey were at the Borsig Works at the moment, and they might be willing to place an order with me. [...]

Bei der Besprechung mit Rickhey und Sawatzki bekam ich den Auftrag, im "Mittelwerk" 20 "Automatische Arbeiter" zu bauen, für die Saur von Bad Wilsnack auch die Konstruktionszeichnungen zu liefern hatte. Meine Maschinen sollten bei der Fertigung der Rudermaschine für die "V 1" verwendet werden. Ich bezog ein Büro in Halle 40 der unterirdischen Rüstungsfabrik. Unter meiner Aufsicht arbeiten einige deutsche Techniker und 100 Häftlinge Tag und Nacht an der Montage der Automaten. Mit den Häftlingen hatte ich praktisch nie Kontakt, da ich ständig zwischen Bad Wilsnack und Nordhausen pendelte.

At the meeting with Rickhey and Sawatzki, I received the order to build 20 "automatic workers" in the "Mittelwerk," for which Saur from Bad Wilsnack also had to supply the design drawings. My machines were to be used in the production of the rudder machinery for the V-1. I moved into an office in Hall 40 of the underground armaments factory. Under my supervision, several German technicians and 100 prisoners worked day and night on assembling the automated machines. I practically never had any contact with the prisoners, since I was constantly commuting between Bad Wilsnack and Nordhausen.

Although Nebel (or his publisher) wrote “V 1” in the passage above in his 1972 autobiography, the industrial robots appear to have been intended to work on V-2 (A-4 rocket) parts. They may have been designed to fashion the graphite exhaust deflectors that required careful machining and shaping from several directions.

Future scholars should investigate whether these wartime German robotics projects directly or indirectly influenced postwar work on robotics by George Devol or others, in view of considerations such as these:

- U.S. forces seized control of Mittelwerk and the surrounding areas in April 1945 and shipped huge amounts of hardware and documentation back to the United States, which probably would have included the 20 “automatic workers” and any related information. (For other examples of the widespread removal of production machinery, see pp. 2075–2086.)

- The United States also confiscated all wartime German patents such as Saur’s patents on industrial automation (pp. 1215, 2108–2113).

- Saur, Nebel, and the other robotics engineers were likely interrogated by U.S. technical investigators after the war (e.g., pp. 2124–2136).

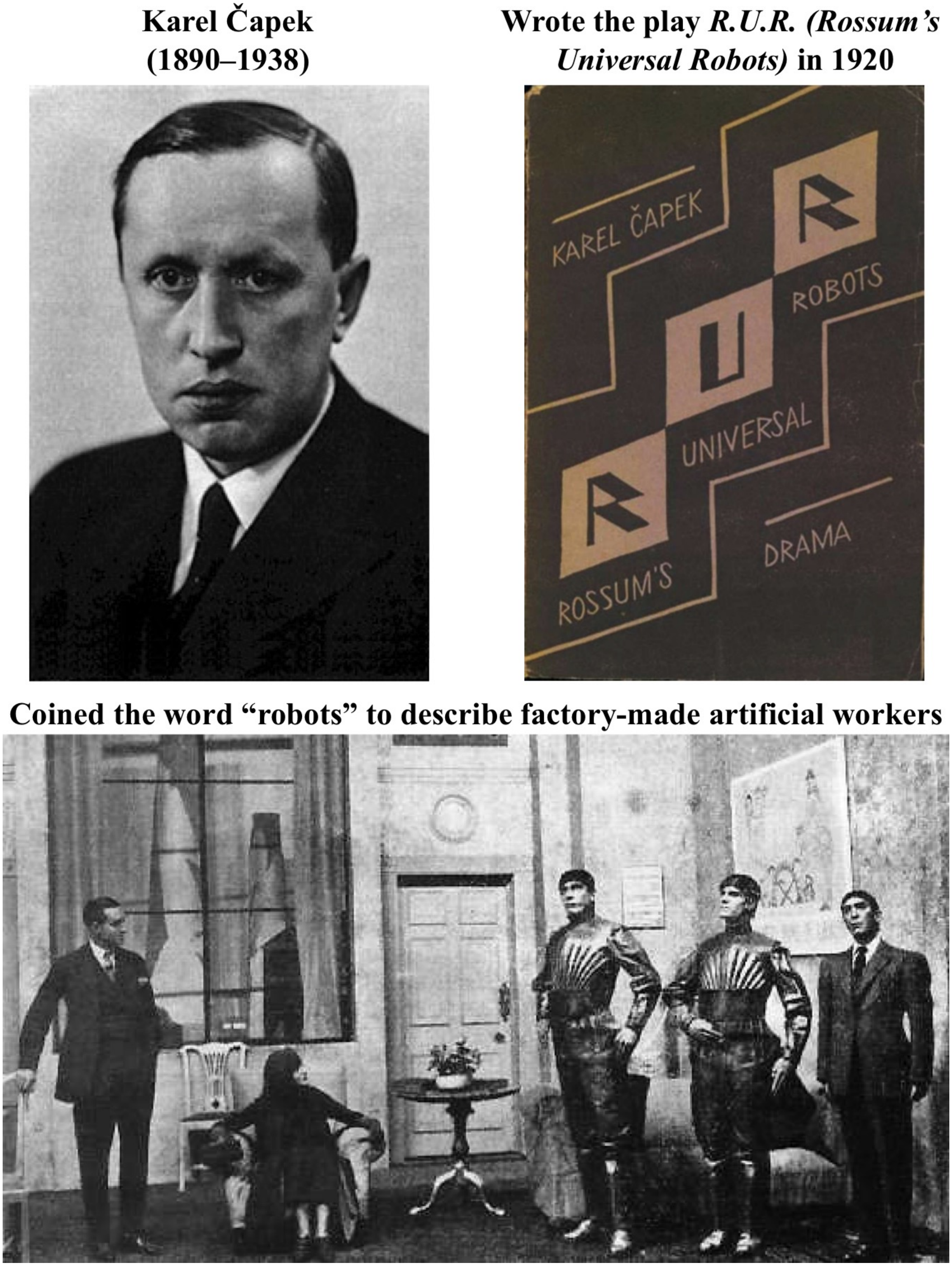
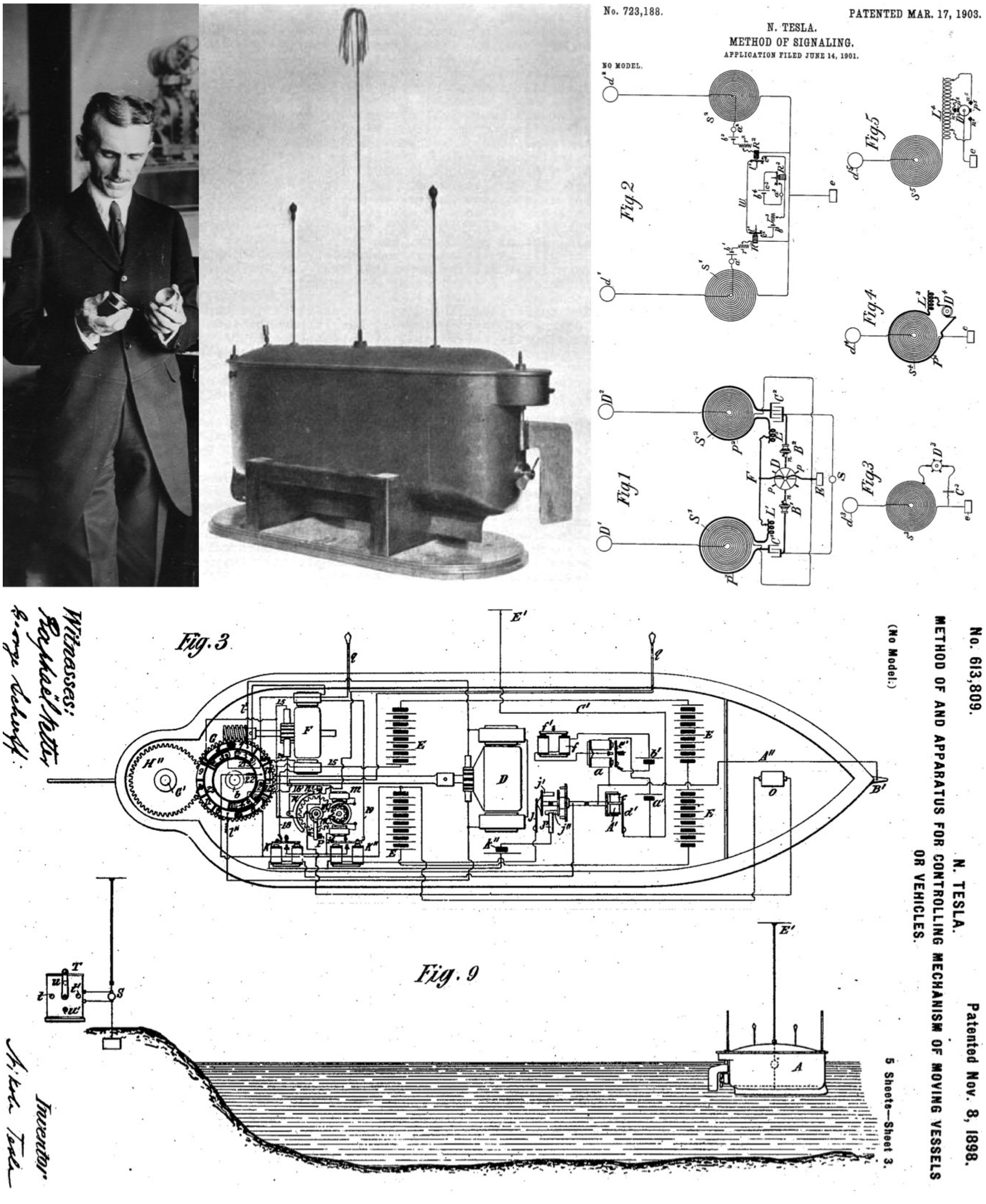

Karel Čapek
(1890–1938)
Wrote the play R.U.R. (Rossum's Universal Robots) in 1920
KAREL ČAPEK
R
U
R
ROBOTS
UNIVERSAL
ROSSUM'S
DRAMA
Coined the word "robots" to describe factory-made artificial workers

Figure 6.191: In 1920, Karel Čapek wrote the play *R.U.R. (Rossum's Universal Robots)*, in which he coined the word "robots" to describe factory-made artificial workers.

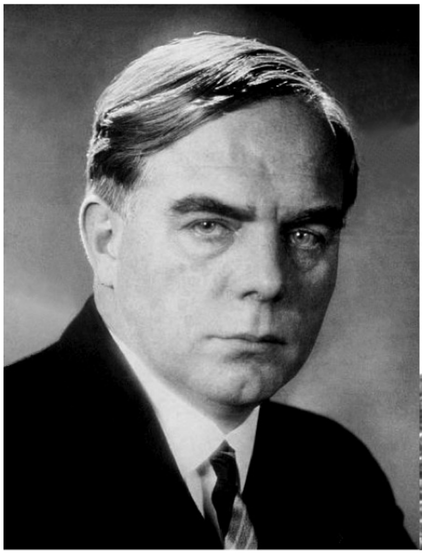


Nikola Tesla (1856–1943)
Patented and demonstrated radio-controlled boat (1898)

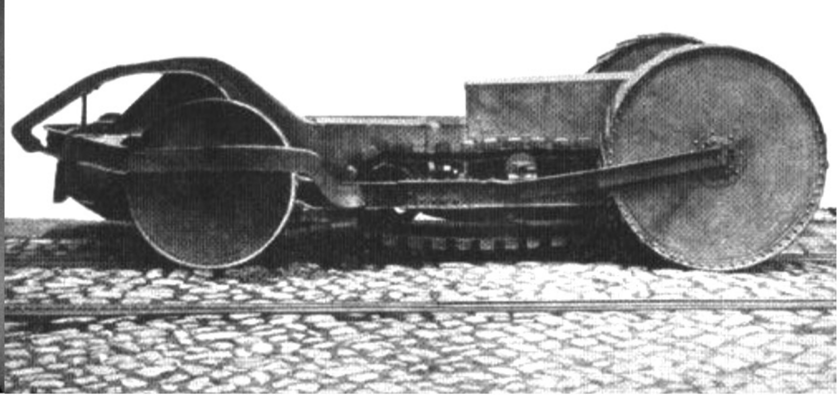
No. 723,188.
PATENTED MAR. 17, 1903.
N. TESLA.
METHOD OF SIGNALING.
APPLICATION FILED JUNE 14, 1901.
NO MODEL.
Fig.1
Fig.2
Fig.3
Fig.4
Fig.5
No. 613,809.
N. TESLA.
Patented Nov. 8, 1898.
METHOD OF AND APPARATUS FOR CONTROLLING MECHANISM OF MOVING VESSELS OR VEHICLES.
(No Model.)
5 Sheets—Sheet 3.
Fig. 3
Fig. 9
Witnesses:
Inventor
Nikola Tesla

Figure 6.192: Nikola Tesla patented and demonstrated a radio-controlled boat in 1898.

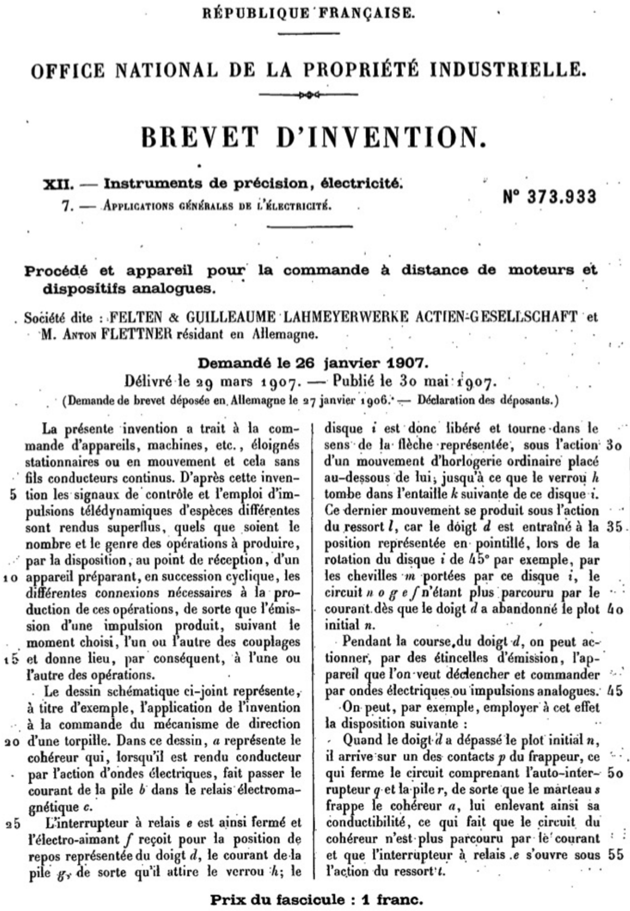
Anton Flettner (1885–1961)



Demonstrated radio-controlled battlefield mini-tank with remote-controlled weapons (1915)



Filed patent applications on teleoperated robots (1906)



RÉPUBLIQUE FRANÇAISE.

OFFICE NATIONAL DE LA PROPRIÉTÉ INDUSTRIELLE.

BREVET D'INVENTION.

XII. — Instruments de précision, électricité.
7. — Applications générales de l'électricité.

N° 373.933

Procédé et appareil pour la commande à distance de moteurs et dispositifs analogues.

Société dite : FELTEN & GUILLEAUME LAHMEYERWERKE ACTIEN-GESELLSCHAFT et M. Anton FLETTNER résidant en Allemagne.

Demandé le 26 janvier 1907.
Délivré le 29 mars 1907. — Publié le 30 mai 1907.
(Demande de brevet déposée en Allemagne le 27 janvier 1906. — Déclaration des déposants.)

La présente invention a trait à la commande d'appareils, machines, etc., éloignés stationnaires ou en mouvement et cela sans fils conducteurs continus. D'après cette invention les signaux de contrôle et l'emploi d'impulsions télédynamiques d'espèces différentes sont rendus superflus, quels que soient le nombre et le genre des opérations à produire, par la disposition, au point de réception, d'un appareil préparant, en succession cyclique, les différentes connexions nécessaires à la production de ces opérations, de sorte que l'émission d'une impulsion produit, suivant le moment choisi, l'un ou l'autre des couplages et donne lieu, par conséquent, à l'une ou l'autre des opérations.

Le dessin schématique ci-joint représente, à titre d'exemple, l'application de l'invention à la commande du mécanisme de direction d'une torpille. Dans ce dessin, *a* représente le cohéreur qui, lorsqu'il est rendu conducteur par l'action d'ondes électriques, fait passer le courant de la pile *b* dans le relais électromagnétique *c*.

L'interrupteur à relais *e* est ainsi fermé et l'électro-aimant *f* reçoit pour la position de repos représentée du doigt *d*, le courant de la pile *g*, de sorte qu'il attire le verrou *h*; le disque *i* est donc libéré et tourne dans le sens de la flèche représentée, sous l'action d'un mouvement d'horlogerie ordinaire placé au-dessous de lui, jusqu'à ce que le verrou *h* tombe dans l'entaille *k* suivante de ce disque *i*. Ce dernier mouvement se produit sous l'action du ressort *l*, car le doigt *d* est entraîné à la position représentée en pointillé, lors de la rotation du disque *i* de 45° par exemple, par les chevilles *m* portées par ce disque *i*, le circuit *n o g e f* n'étant plus parcouru par le courant dès que le doigt *d* a abandonné le plot initial *n*.

Pendant la course du doigt *d*, on peut actionner, par des étincelles d'émission, l'appareil que l'on veut déclencher et commander par ondes électriques ou impulsions analogues.

On peut, par exemple, employer à cet effet la disposition suivante :

Quand le doigt *d* a dépassé le plot initial *n*, il arrive sur un des contacts *p* du frappeur, ce qui ferme le circuit comprenant l'auto-interrupteur *q* et la pile *r*, de sorte que le marteau *s* frappe le cohéreur *a*, lui enlevant ainsi sa conductibilité, ce qui fait que le circuit du cohéreur n'est plus parcouru par le courant et que l'interrupteur à relais *e* s'ouvre sous l'action du ressort *t*.

Prix du fascicule : 1 franc.

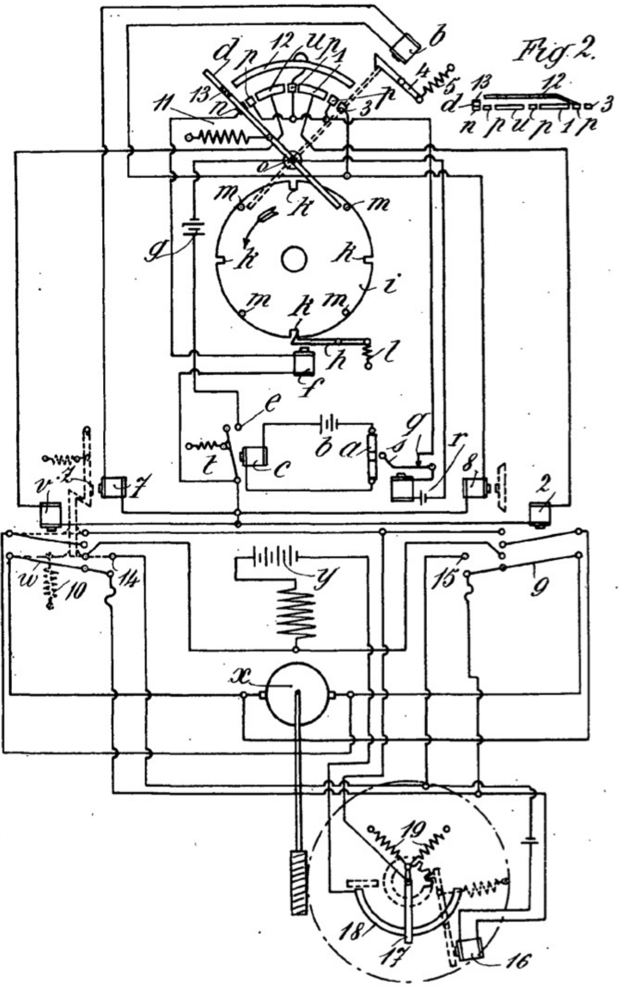


Figure 6.193: Anton Flettner filed patent applications on teleoperated robots beginning in 1906. He designed robots for various applications on land, in the water, and in the air. In 1915, he demonstrated a radio-controlled battlefield mini-tank with remote-controlled weapons (a blow torch in the demonstration model; the model is shown here without its armored shell).

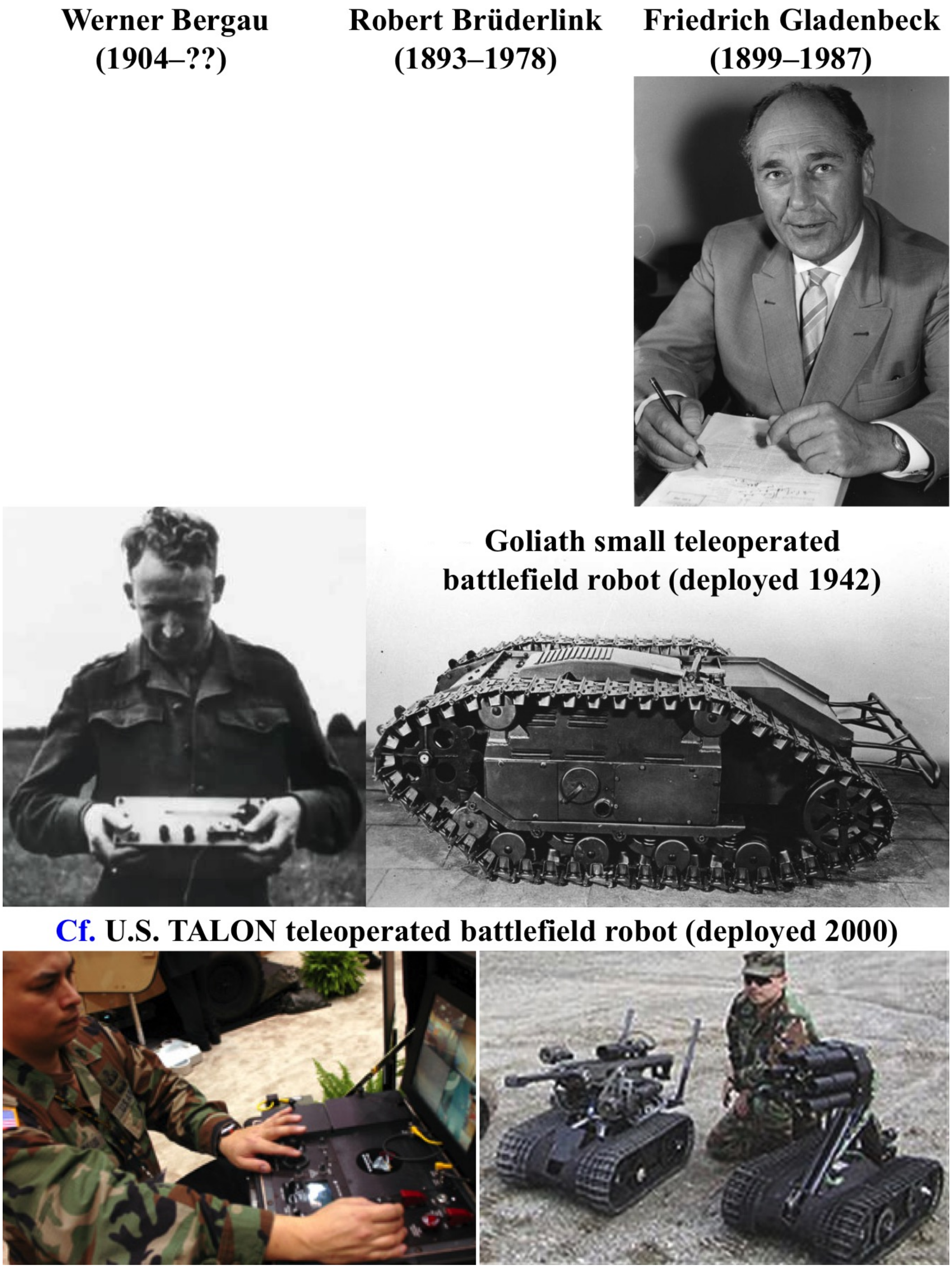
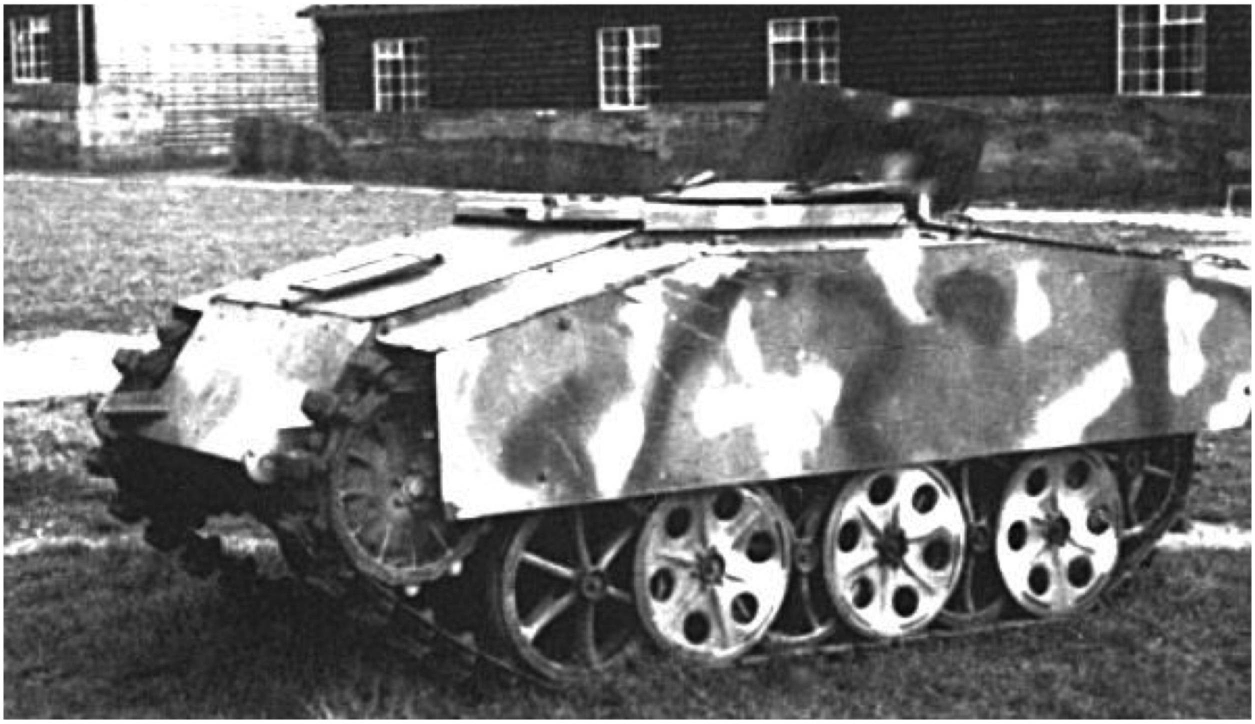

Werner Bergau
(1904–??)
Robert Brüderlink
(1893–1978)
Friedrich Gladenbeck
(1899–1987)
Goliath small teleoperated
battlefield robot (deployed 1942)
Cf. U.S. TALON teleoperated battlefield robot (deployed 2000)

Figure 6.194: Werner Bergau, Robert Brüderlink, and Friedrich Gladenbeck pioneered teleoperated battlefield robotics, such as the Leichter Ladungsträger Goliath, which was the forerunner of modern teleoperated battlefield robots such as the U.S. Foster-Miller TALON.

Springer medium-sized teleoperated battlefield robot (deployed 1944)



Borgward B IV large teleoperated battlefield robot (deployed 1942)

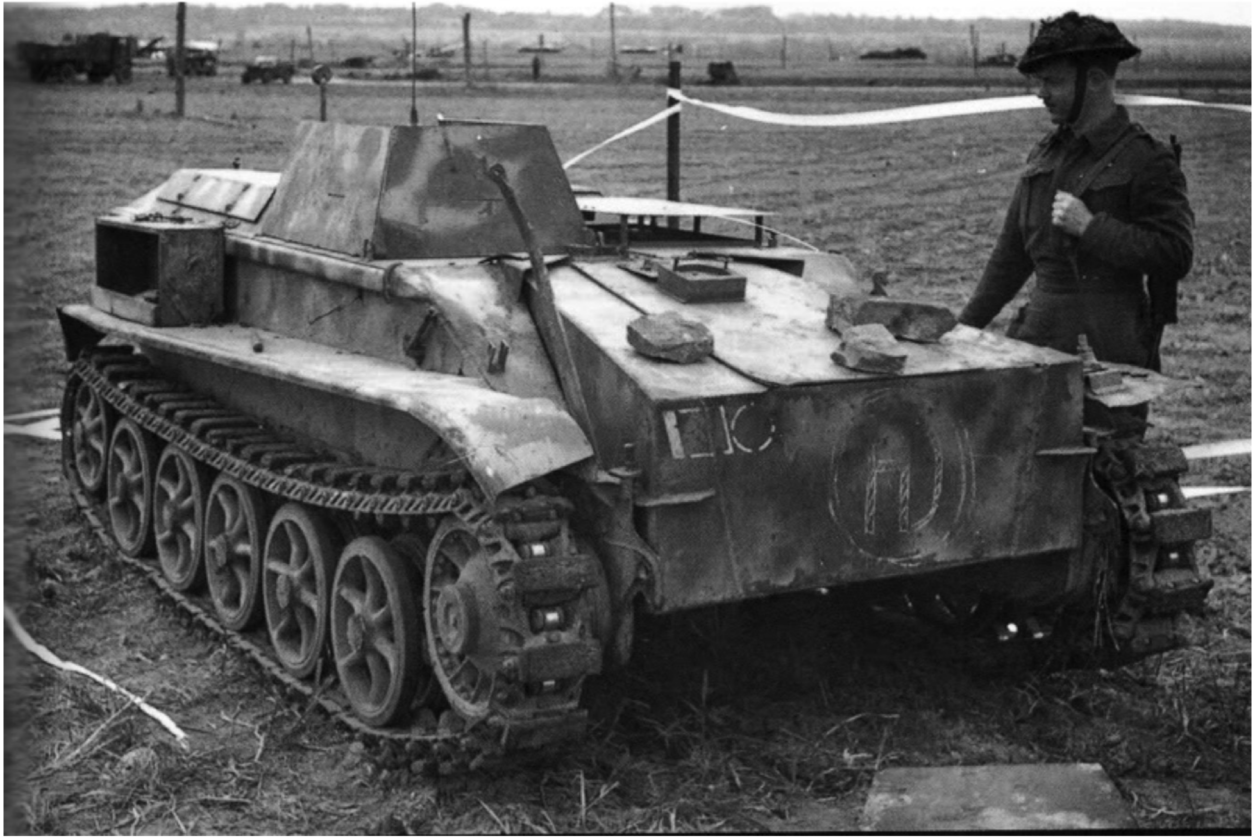
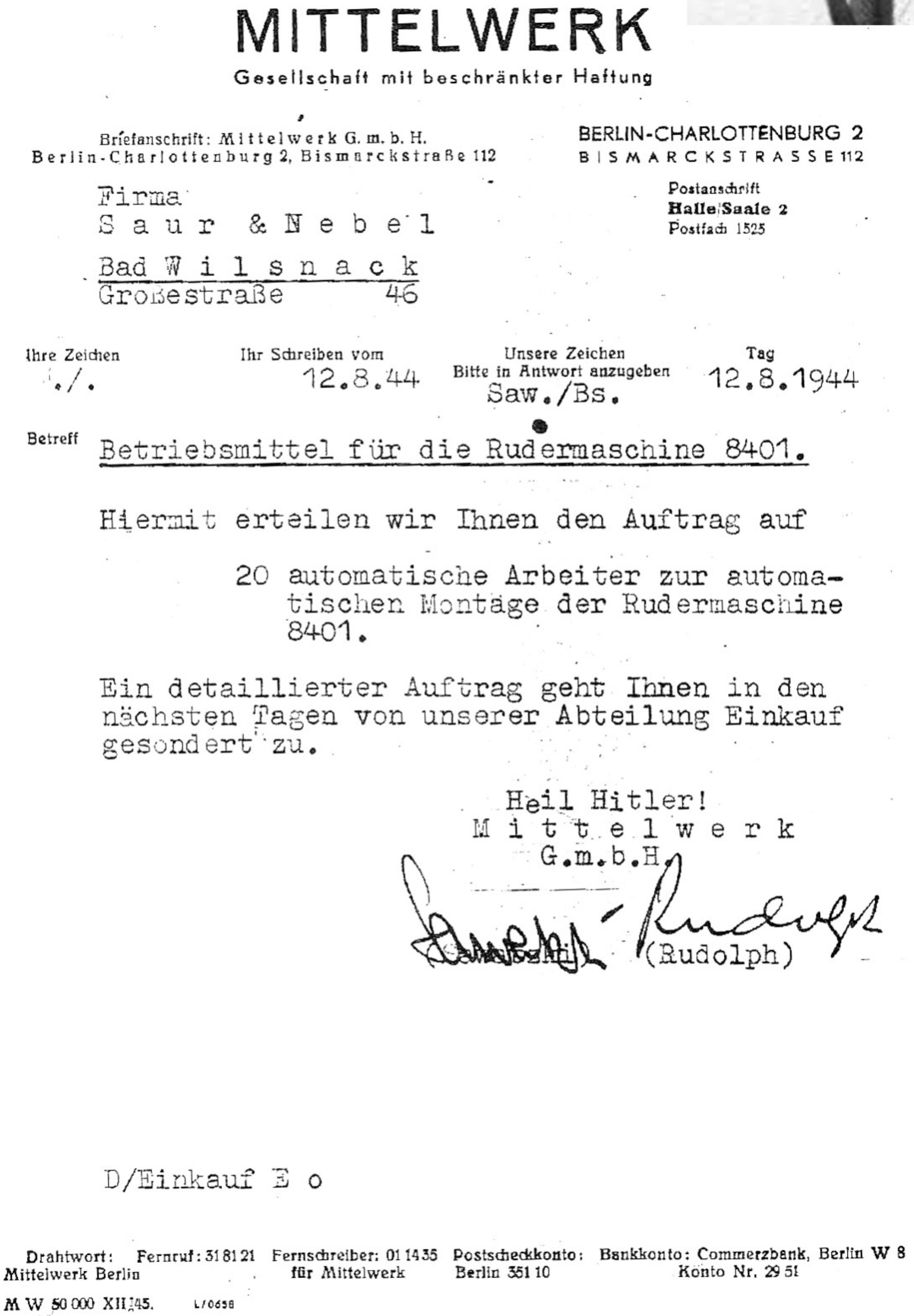


Figure 6.195: Larger teleoperated battlefield robots that were used in combat by Germany included the Mittlerer Ladungsträger Springer and the Schwerer Ladungsträger Borgward B IV.

Industrial robotics (1930s–1945)

Karl Saur
(ca. 1901–1978)

Rudolf Nebel
(1894–1978)



MITTELWERK
Gesellschaft mit beschränkter Haftung

Briefanschrift: Mittelwerk G. m. b. H.
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BERLIN-CHARLOTTENBURG 2
BISMARCKSTRASSE 112

Postanschrift
Halle/Saale 2
Postfach 1525

Firma
Saur & Nebel
Bad Wilsnack
Großestraße 46

Ihre Zeichen	Ihr Schreiben vom	Unsere Zeichen Bitte in Antwort anzugeben	Tag
./.	12.8.44	Saw./Bs.	12.8.1944

Betreff Betriebsmittel für die Rudermaschine 8401.

Hiermit erteilen wir Ihnen den Auftrag auf

20 automatische Arbeiter zur automatischen Montage der Rudermaschine 8401.

Ein detaillierter Auftrag geht Ihnen in den nächsten Tagen von unserer Abteilung Einkauf gesondert zu.

Heil Hitler!
Mittelwerk
G.m.b.H.

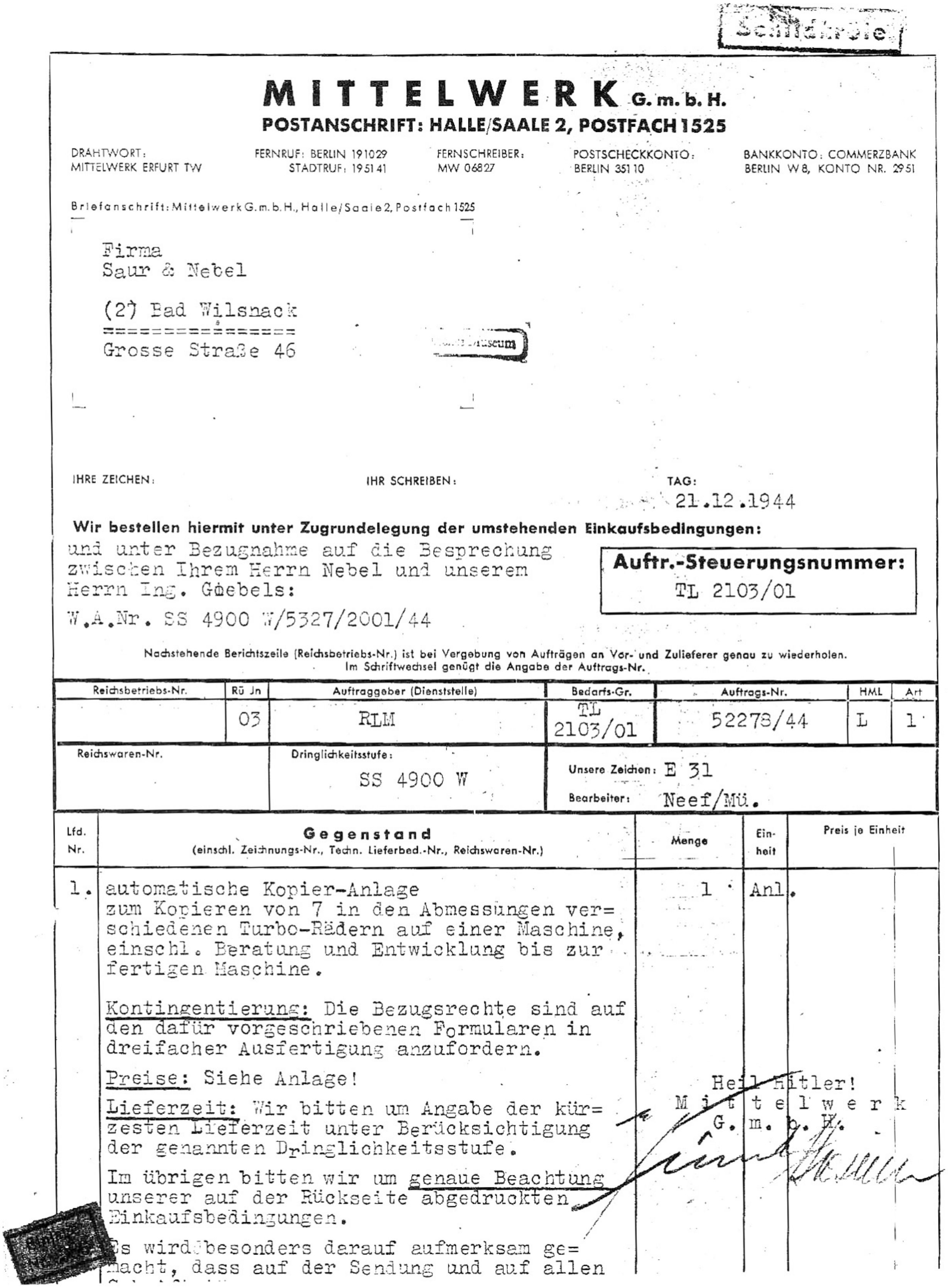
(Rudolph)

D/Einkauf E o

Drahtwort: Mittelwerk Berlin   Fernruf: 31 81 21   Fernschreiber: 01 14 35 für Mittelwerk   Postscheckkonto: Berlin 351 10   Bankkonto: Commerzbank, Berlin W 8 Konto Nr. 29 51

M W 50 000 XII.45.   L/0658

Figure 6.196: Karl Saur and Rudolf Nebel invented, built, and used industrial robotics technology from the 1930s to 1945. During 1944–1945, they built 20 industrial robots to assemble components at the underground Mittelwerk plant in Nordhausen.



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Briefanschrift: Mittelwerk G.m.b.H., Halle/Saale 2, Postfach 1525

Firma
Saur & Nebel

(2) Bad Wilsnack
===============
Grosse Straße 46

IHRE ZEICHEN:
IHR SCHREIBEN:
TAG: 21.12.1944

Wir bestellen hiermit unter Zugrundelegung der umstehenden Einkaufsbedingungen: und unter Bezugnahme auf die Besprechung zwischen Ihrem Herrn Nebel und unserem Herrn Ing. Goebels:

W.A.Nr. SS 4900 W/5327/2001/44

Auftr.-Steuerungsnummer: TL 2103/01

Nachstehende Berichtszeile (Reichsbetriebs-Nr.) ist bei Vergebung von Aufträgen an Vor- und Zulieferer genau zu wiederholen. Im Schriftwechsel genügt die Angabe der Auftrags-Nr.

Reichsbetriebs-Nr.	Rü Jn	Auftraggeber (Dienststelle)	Bedarfs-Gr.	Auftrags-Nr.	HML	Art
	03	RLM	TL 2103/01	52278/44	L	1

Reichswaren-Nr.	Dringlichkeitsstufe:	Unsere Zeichen: / Bearbeiter:
	SS 4900 W	Unsere Zeichen: E 31 Bearbeiter: Neef/Mü.

Lfd. Nr.	Gegenstand (einschl. Zeichnungs-Nr., Techn. Lieferbed.-Nr., Reichswaren-Nr.)	Menge	Einheit	Preis je Einheit
1.	automatische Kopier-Anlage zum Kopieren von 7 in den Abmessungen verschiedenen Turbo-Rädern auf einer Maschine, einschl. Beratung und Entwicklung bis zur fertigen Maschine.	1	Anl.	

Kontingentierung: Die Bezugsrechte sind auf den dafür vorgeschriebenen Formularen in dreifacher Ausfertigung anzufordern.

Preise: Siehe Anlage!

Lieferzeit: Wir bitten um Angabe der kürzesten Lieferzeit unter Berücksichtigung der genannten Dringlichkeitsstufe.

Im übrigen bitten wir um genaue Beachtung unserer auf der Rückseite abgedruckten Einkaufsbedingungen.

Es wird besonders darauf aufmerksam gemacht, dass auf der Sendung und auf allen

Heil Hitler!
Mittelwerk
G.m.b.H.

Figure 6.197: Karl Saur and Rudolf Nebel invented, built, and used industrial robotics technology from the 1930s to 1945. During 1944–1945, they built 20 industrial robots to assemble components at the underground Mittelwerk plant in Nordhausen.

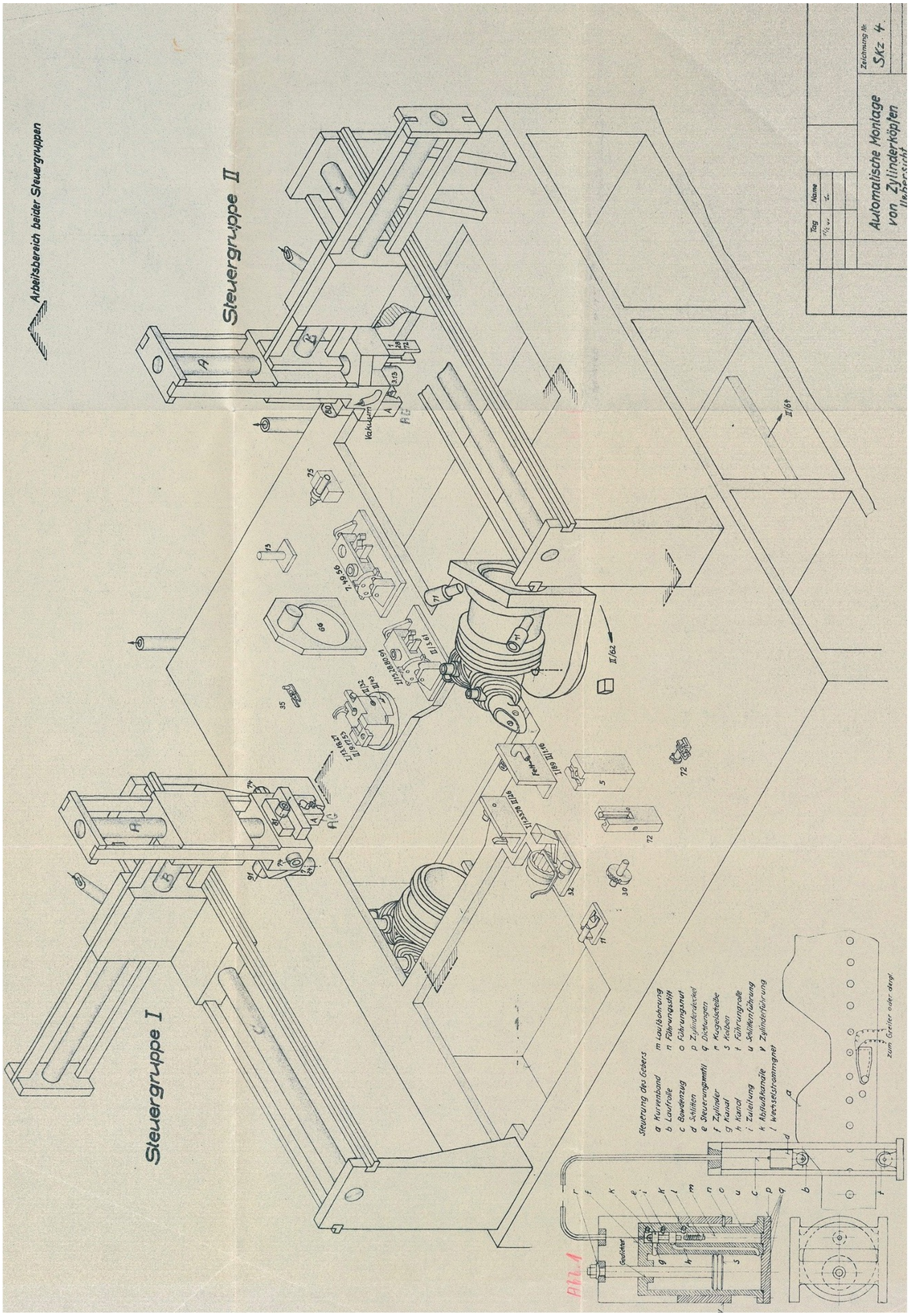

Arbeitsbereich beider Steuergruppen
Steuergruppe II
Steuergruppe I
Automatische Montage von Zylinderköpfen
Skz 4.
Vakuum
Steuerung des Gebers
a Kurvenband
b Laufrolle
c Bowdenzug
d Schlitten
e Steuerungsmittel
f Zylinder
g Kanal
h Kanal
i Zuleitung
k Abflußkanäle
l Wechselstrommagnet
m Laufbohrung
n Führungsstift
o Führungsnut
p Zylinderdeckel
q Dichtungen
r Kugelscheibe
s Kolben
t Führungsrolle
u Schlittenführung
v Zylinderführung
zum Greifer oder dergl.
Abb. 1

Figure 6.198: Part of the design drawings for one of the 20 industrial robots that Karl Saur and Rudolf Nebel built to assemble components at the underground Mittelwerk plant in Nordhausen.

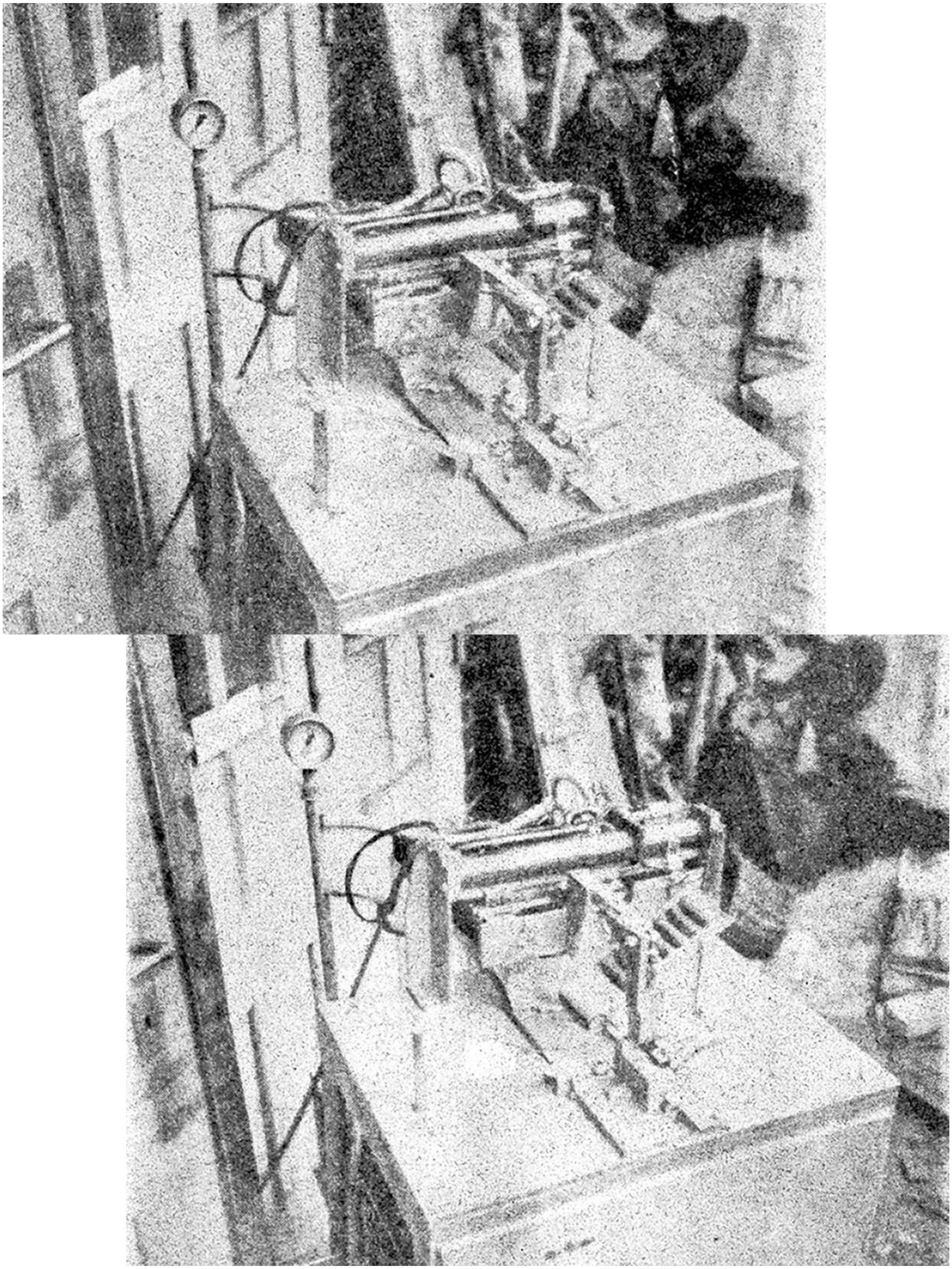
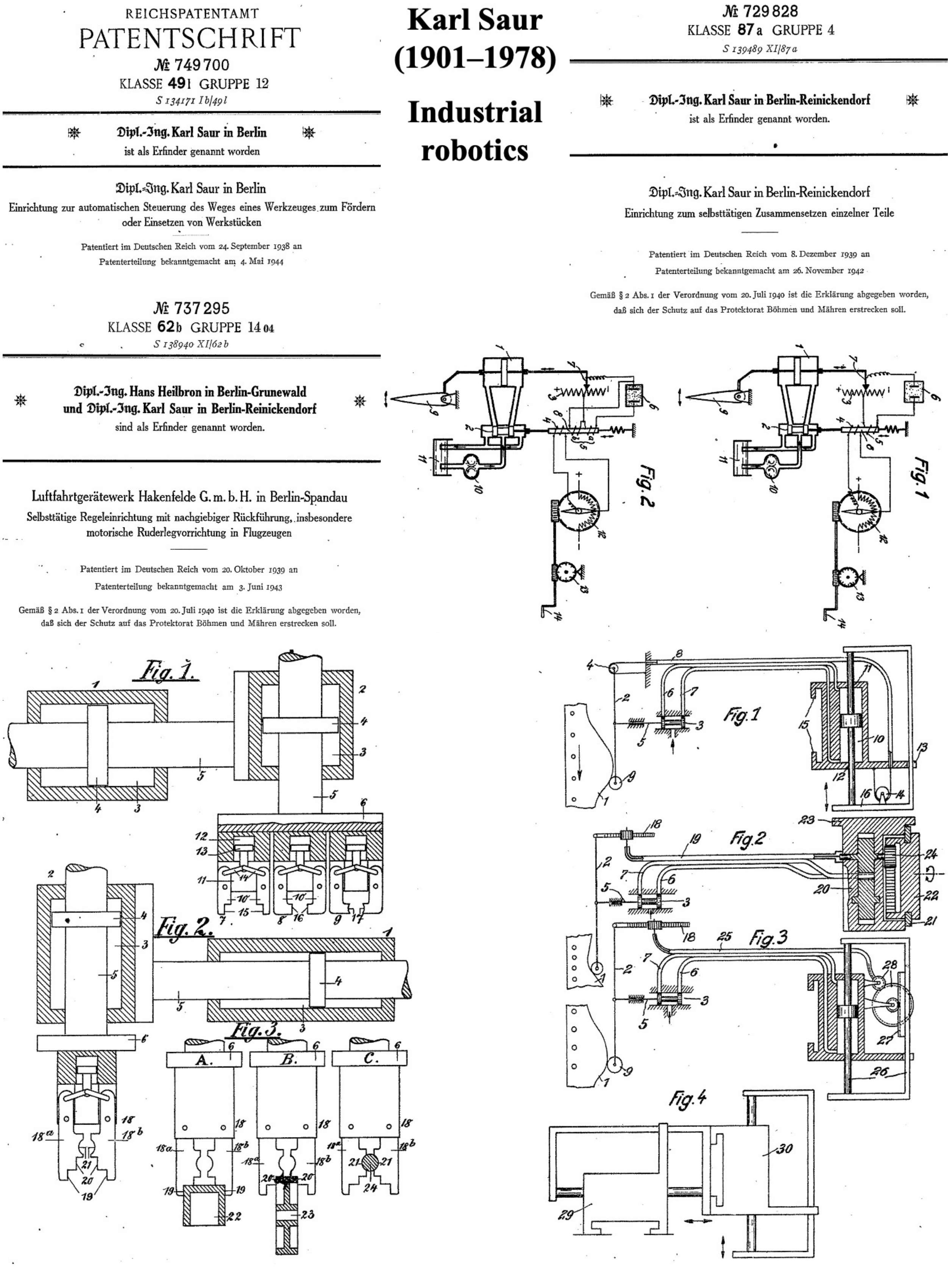


Figure 6.199: Photographs of one of the 20 industrial robots that Karl Saur and Rudolf Nebel built to assemble components at the underground Mittelwerk plant in Nordhausen.



REICHSPATENTAMT
PATENTSCHRIFT
№ 749 700
KLASSE 49l GRUPPE 12
S 134171 Ib/49l

Dipl.-Ing. Karl Saur in Berlin
ist als Erfinder genannt worden

Dipl.-Ing. Karl Saur in Berlin
Einrichtung zur automatischen Steuerung des Weges eines Werkzeuges zum Fördern oder Einsetzen von Werkstücken

Patentiert im Deutschen Reich vom 24. September 1938 an
Patenterteilung bekanntgemacht am 4. Mai 1944

№ 737 295
KLASSE 62b GRUPPE 14 04
S 138940 XI/62b

Dipl.-Ing. Hans Heilbron in Berlin-Grunewald
und Dipl.-Ing. Karl Saur in Berlin-Reinickendorf
sind als Erfinder genannt worden.

Luftfahrtgerätewerk Hakenfelde G. m. b. H. in Berlin-Spandau
Selbsttätige Regeleinrichtung mit nachgiebiger Rückführung, insbesondere motorische Ruderlegvorrichtung in Flugzeugen

Patentiert im Deutschen Reich vom 20. Oktober 1939 an
Patenterteilung bekanntgemacht am 3. Juni 1943

Gemäß § 2 Abs. 1 der Verordnung vom 20. Juli 1940 ist die Erklärung abgegeben worden, daß sich der Schutz auf das Protektorat Böhmen und Mähren erstrecken soll.

Karl Saur
(1901–1978)

Industrial robotics

№ 729 828
KLASSE 87a GRUPPE 4
S 139489 XI/87a

Dipl.-Ing. Karl Saur in Berlin-Reinickendorf
ist als Erfinder genannt worden.

Dipl.-Ing. Karl Saur in Berlin-Reinickendorf
Einrichtung zum selbsttätigen Zusammensetzen einzelner Teile

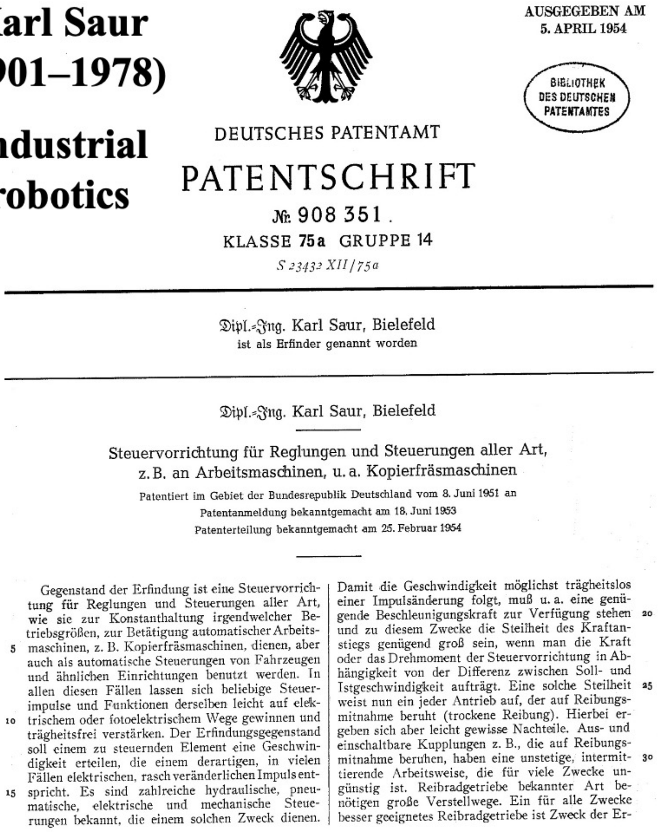
Patentiert im Deutschen Reich vom 8. Dezember 1939 an
Patenterteilung bekanntgemacht am 26. November 1942

Gemäß § 2 Abs. 1 der Verordnung vom 20. Juli 1940 ist die Erklärung abgegeben worden, daß sich der Schutz auf das Protektorat Böhmen und Mähren erstrecken soll.

Figure 6.200: Examples of Karl Saur's wartime patents on industrial robotics.

Karl Saur
(1901–1978)

Industrial robotics



AUSGEGEBEN AM
5. APRIL 1954

BIBLIOTHEK
DES DEUTSCHEN
PATENTAMTES

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 908 351.

KLASSE 75a GRUPPE 14

S 23432 XII/75a

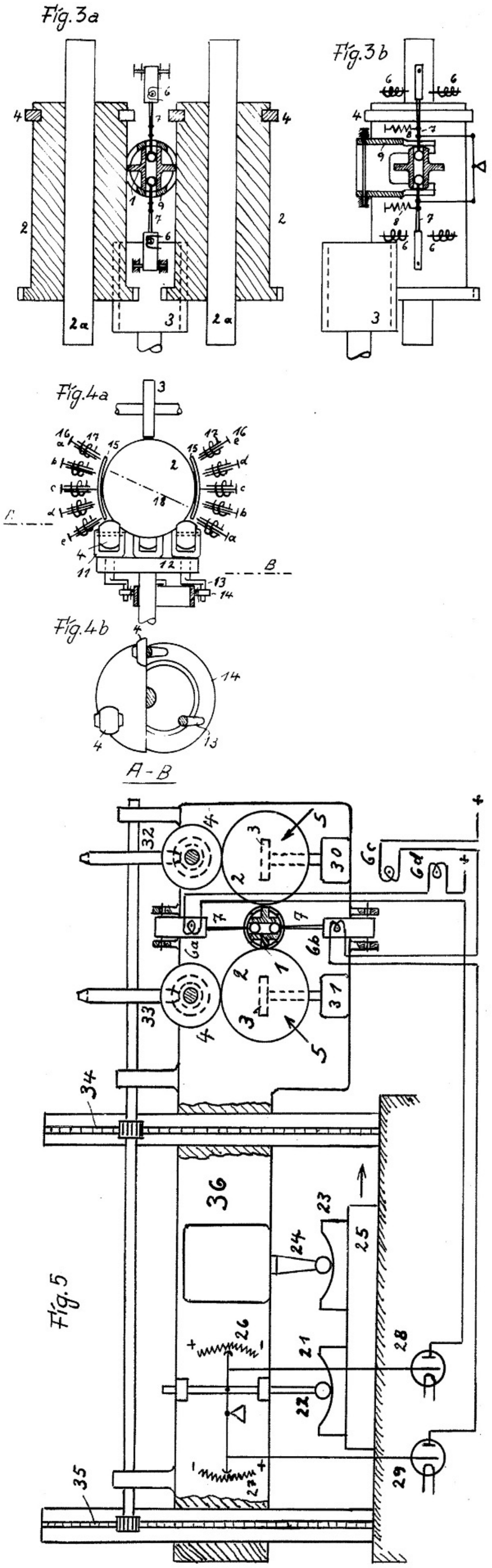
Dipl.-Ing. Karl Saur, Bielefeld
ist als Erfinder genannt worden

Dipl.-Ing. Karl Saur, Bielefeld

Steuervorrichtung für Reglungen und Steuerungen aller Art,
z. B. an Arbeitsmaschinen, u. a. Kopierfräsmaschinen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 8. Juni 1951 an
Patentanmeldung bekanntgemacht am 18. Juni 1953
Patenterteilung bekanntgemacht am 25. Februar 1954

Gegenstand der Erfindung ist eine Steuervorrichtung für Reglungen und Steuerungen aller Art, wie sie zur Konstanthaltung irgendwelcher Betriebsgrößen, zur Betätigung automatischer Arbeitsmaschinen, z. B. Kopierfräsmaschinen, dienen, aber auch als automatische Steuerungen von Fahrzeugen und ähnlichen Einrichtungen benutzt werden. In allen diesen Fällen lassen sich beliebige Steuerimpulse und Funktionen derselben leicht auf elektrischem oder fotoelektrischem Wege gewinnen und trägheitsfrei verstärken. Der Erfindungsgegenstand soll einem zu steuernden Element eine Geschwindigkeit erteilen, die einem derartigen, in vielen Fällen elektrischen, rasch veränderlichen Impuls entspricht. Es sind zahlreiche hydraulische, pneumatische, elektrische und mechanische Steuerungen bekannt, die einem solchen Zweck dienen. Damit die Geschwindigkeit möglichst trägheitslos einer Impulsänderung folgt, muß u. a. eine genügende Beschleunigungskraft zur Verfügung stehen und zu diesem Zwecke die Steilheit des Kraftanstiegs genügend groß sein, wenn man die Kraft oder das Drehmoment der Steuervorrichtung in Abhängigkeit von der Differenz zwischen Soll- und Istgeschwindigkeit aufträgt. Eine solche Steilheit weist nun ein jeder Antrieb auf, der auf Reibungsmitnahme beruht (trockene Reibung). Hierbei ergeben sich aber leicht gewisse Nachteile. Aus- und einschaltbare Kupplungen z. B., die auf Reibungsmitnahme beruhen, haben eine unstetige, intermittierende Arbeitsweise, die für viele Zwecke ungünstig ist. Reibradgetriebe bekannter Art benötigen große Verstellwege. Ein für alle Zwecke besser geeignetes Reibradgetriebe ist Zweck der Er-



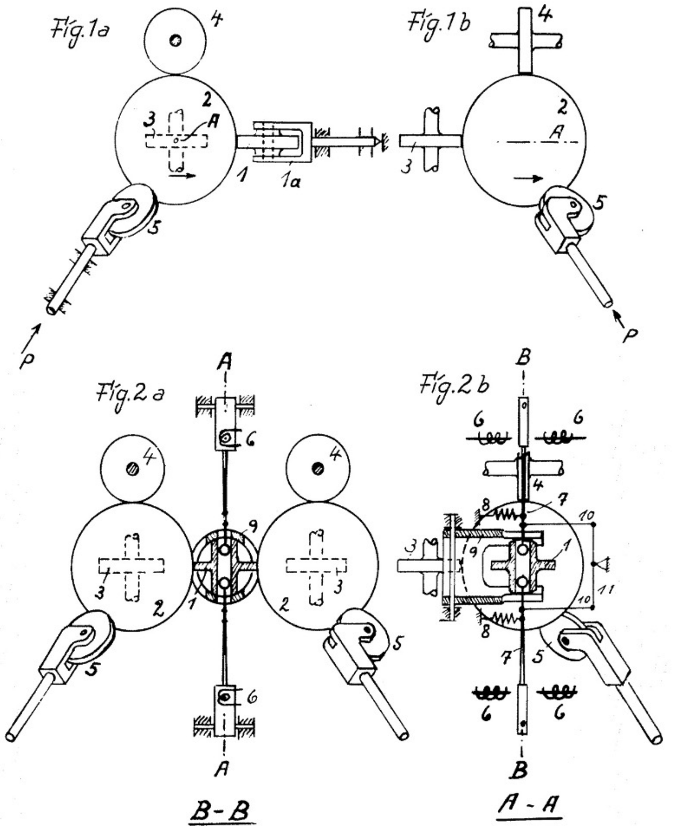


Figure 6.201: Karl Saur filed this patent on industrial robotics after the (West) German patent office reopened, but it appears to be directly based on his wartime work.

6.8 Radar and Sonar Technologies and Countermeasures

Creators from the German-speaking world invented, developed, and demonstrated:

6.8.1. Radar

6.8.2. Radar countermeasures

6.8.3. Microwave heating

6.8.4. Sonar

6.8.5. Sonar countermeasures

6.8.6. Ultrasound imaging

6.8.7. Acoustic weapons

6.8.8. Radio and acoustic proximity fuses and homing devices

6.8.1 Radar

German-speaking scientists invented radar at the beginning of the twentieth century and developed sophisticated radar systems for a variety of applications through World War II (and afterward in Allied countries).[22]

Nikola Tesla (Serbo-Croatian, educated in Austria, 1856–1943, p. 954) proposed radar in 1900, although as far as is presently known, he did not actually build a working system. Tesla biographer Margaret Cheney provided some details of Tesla's proposal [Cheney 1981, p. 208]:

> In the circumstances, it is not surprising that when Tesla first began to speculate about military applications of radar, it was with respect to locating ships and submarines rather than to detecting enemy bombers. Tesla had predicted the general concept of radar in his sweeping article for *Century* magazine of June 1900: "Stationary waves . . . mean something more than telegraphy without wires to any distance. . . . For instance, by their use we may produce at will, from a sending station, an electrical effect in any particular region of the globe; we may determine the relative position or course of a moving object, such as a vessel at sea, the distance traversed by the same, or its speed...."

---

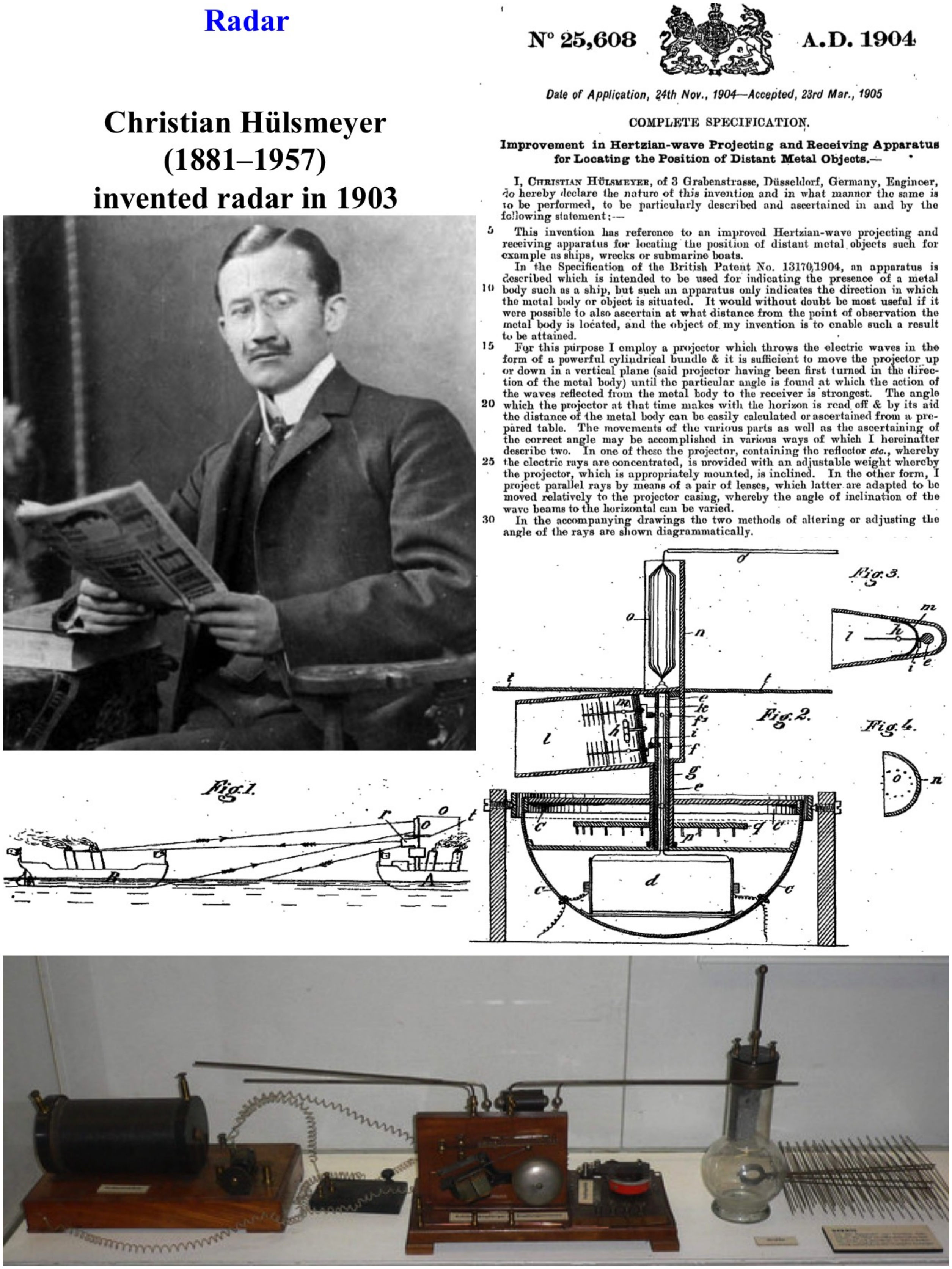
[22] Banneitz 1927; Bauer 2006; Blanchard et al. 2013; Louis Brown 2017; Bukowski 2007; Cheney 1981, Cheney and Uth 1999; Gregory Clark 2014; Gregory Goebel 2018; Goerth 2010; Guerlac 1987; Habann 1924, 1929; Hepcke 2012; Hollmann 2012; von Kroge 1998; Mergl 1998; Werner Müller 1998; Pritchard 1989; Sarkar et al. 2006; Swords 1986; Trenkle 1987; Raymond Watson 2009; Žáček 1924, 1936.

The world's first working radar system was created and demonstrated by Christian Hülsmeyer (German, 1881–1957) in 1903, decades before the widespread adoption of radar technology by other countries (Fig. 6.202). David Pritchard extensively researched Hülsmeyer's life and inventions [Pritchard 1989, pp. 16–17]:

> [...] Hülsmeyer was promptly invited to demonstrate his equipment to the representatives of shipping companies. The *Kölnischer Zeitung* of 18 May 1904 carried the report:
>
> > The Telemobiloscope, an invention of engineer Christian Hülsmeyer, was demonstrated to representatives of Norddeutscher Lloyd and the Argo Shipping Company of Bremen and other invited gentlemen at the Dom Hotel yesterday morning at 11 o'clock. The discovery is based on the principle of wireless telegraphy and is intended to locate ships and other metallic objects at sea. The difference between the already existing employment of wireless telegraphy and this discovery is based on an exclusive and constructional change, in that wireless telegraphy employs a transmitter and receiver on separate ships but with the Telemobiloscope the transmitter and receiver are arranged on one and the same vessel. The electrical waves radiated from the transmitter cannot directly reach the receiver, but must be reflected from metallic objects on the sea, logically ships, and thus return to the receiver. The great advantage which the discovery offers lies above all in the fact that ships which are fitted with this system of transmitter and receiver can locate any other ship that does not carry the apparatus. Indeed, the captain on the bridge can be informed of the approach of another vessel and find its bearing up to a range of 5 kilometres, so that should his lights and fog signals fail to work he still has sufficient time to steer his ship on the correct course and thus prevent severe disasters in good time. Research with smaller apparatus calculated for shorter ranges have been perfectly successful. A company for the manufacture of the discovery has been formed under the title of The Telemobiloscope Company, Hülsmeyer and Mannheim.
>
> [...O]n Thursday, 9 June 1904, assisted by students of Delft University, Hülsmeyer assembled his equipment in the tender *Columbus* and cruised up and down Rotterdam Harbour detecting vessels at up to 5 kilometres' range with unerring accuracy. The only problem was that as eight technical representatives of foreign shipping companies were with him to witness the demonstration he was obliged to take out a similar number of foreign patents, and this cost more money.
>
> The representatives were however enthusiastic about the demonstration and showered Hülsmeyer with praise, and after a lecture in which he explained that even longer ranges were quite possible he waited for orders.

While Hülsmeyer was unable to find commercial customers for his new radar system, his public demonstrations, worldwide research contacts, press coverage, and numerous patents directly seeded and guided the further development and application of radar by many other people and organizations.

Hans Dominik (German, 1872–1945), an engineer who was better known for his science fiction stories (p. 1970), worked together with Richard Scherl (German, 18??–19??) to build and demonstrate another prototype radar system in 1915–1916.



Radar

Christian Hülsmeyer
(1881–1957)
invented radar in 1903

N° 25,608 **A.D. 1904**

Date of Application, 24th Nov., 1904—Accepted, 23rd Mar., 1905

COMPLETE SPECIFICATION.

Improvement in Hertzian-wave Projecting and Receiving Apparatus for Locating the Position of Distant Metal Objects.—

I, CHRISTIAN HÜLSMEYER, of 3 Grabenstrasse, Düsseldorf, Germany, Engineer, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention has reference to an improved Hertzian-wave projecting and receiving apparatus for locating the position of distant metal objects such for example as ships, wrecks or submarine boats.

In the Specification of the British Patent No. 13170/1904, an apparatus is described which is intended to be used for indicating the presence of a metal body such as a ship, but such an apparatus only indicates the direction in which the metal body or object is situated. It would without doubt be most useful if it were possible to also ascertain at what distance from the point of observation the metal body is located, and the object of my invention is to enable such a result to be attained.

For this purpose I employ a projector which throws the electric waves in the form of a powerful cylindrical bundle & it is sufficient to move the projector up or down in a vertical plane (said projector having been first turned in the direction of the metal body) until the particular angle is found at which the action of the waves reflected from the metal body to the receiver is strongest. The angle which the projector at that time makes with the horizon is read off & by its aid the distance of the metal body can be easily calculated or ascertained from a prepared table. The movements of the various parts as well as the ascertaining of the correct angle may be accomplished in various ways of which I hereinafter describe two. In one of these the projector, containing the reflector *etc.*, whereby the electric rays are concentrated, is provided with an adjustable weight whereby the projector, which is appropriately mounted, is inclined. In the other form, I project parallel rays by means of a pair of lenses, which latter are adapted to be moved relatively to the projector casing, whereby the angle of inclination of the wave beams to the horizontal can be varied.

In the accompanying drawings the two methods of altering or adjusting the angle of the rays are shown diagrammatically.

Figure 6.202: Christian Hülsmeyer invented and demonstrated radar in 1903.

One obstacle to the first radar systems was the military focus during World War I on trench warfare, which was not particularly in need of a technology such as radar. However, by the end of World War I, it became clear that aircraft and submarines would play key roles in future wars, providing a strong military incentive to develop radar systems that could be used against or by such vehicles.

The first radar systems had relatively little power, which meant that their radio waves could not travel very far, reflect off an object, and return without being too weak to detect. A solution to that problem was developed in 1920 by Heinrich Barkhausen (German, 1881–1956) and Karl Kurz (German, 1881–1960). They invented the 300–400 MHz Barkhausen-Kurz oscillator, which enabled high-frequency, high-power radar systems (Fig. 6.203).

An alternative approach that enabled high-power radar systems was the magnetron. As shown in Fig. 6.204, Hans Gerdien (German, 1877–1951) invented and patented the first magnetron in 1910. By 1924, Erich Habann (German, 1892–1968; see also p. 1060) and August Žáček (Czech/Austrian, 1886–1961; see also Section 6.5.10), working independently, had improved the performance of magnetrons to enable them to produce frequencies up to 1 GHz. In 1935, Hans Erich Hollmann (German, 1899–1960) invented, demonstrated, and patented the cavity magnetron, which used multiple cavities within a metal block to achieve very high frequencies and power levels (Fig. 6.205).

With the move toward German rearmament, several German companies began developing sophisticated radar systems in the early 1930s (Figs. 6.206–6.207). In January 1934, Rudolf Kühnhold (German, 1903–1992) of the government Nachrichtenmittel-Versuchsanstalt (NVA, Navy Transmissions Laboratory) supported Paul-Günther Erbslöh (German, 1905–2002) and Hans-Karl von Willisen (German, 1906–1966) in founding GEMA (Gesellschaft für Elektroakustische und Mechanische Apparate) to produce radar and sonar systems. Kühnhold led the development at NVA and GEMA of the Freya long-range radar, which was first demonstrated in early 1937.

At the rival Telefunken company, Wilhelm Runge (German, 1895–1987, son of the mathematician Carl Runge, p. 833) led the development of the Würzburg-Riese short-range radar, which was also first demonstrated in 1937. Some radar experts such as Hans Erich Hollmann worked on both the GEMA and Telefunken radar programs [www.radarworld.org/germany.html]. (After World War II, Hollmann moved to the United States and improved radar systems there [www.radarworld.org/hollmann.html].)

In fact, the initially rival GEMA Freya and Telefunken Würzburg-Riese radar systems ended up working very well together, since Freya could track targets at long ranges and Würzburg-Riese could provide more accurate location information at short ranges. Thus Freya and Würzburg-Riese systems were often located together (Fig. 6.208), and they were widely and effectively used throughout World War II against Allied air raids.

Creators such as Johannes Plendl (German, 1900–1991) also developed a variety of airborne radar systems, of which X-Gerät was probably the best known.

The traveling wave tube (TWT) was an important invention for radar as well as other transmission systems. A TWT combines aspects of a vacuum tube amplifier, a cathode ray tube, and a cavity magnetron into one complex device. Its unique design allows it to amplify radio and microwave signals over a wide spectrum up to frequencies of tens of gigahertz (GHz) and with powers up to tens of kilowatts (kW). Because of this combination of properties, a TWT can simultaneously send a very large number of signals at different frequencies with enough power to be received over very long distances. As such, TWTs are useful for transmitting not only complex and powerful radar signals, but also microwave communications beams carrying many different simultaneous audio, visual, and/or data channels. TWTs are widely used even today, since it has been difficult to create reliable solid state devices with the necessary combination of extreme properties.[23]

According to officials histories, Rudolf Kompfner (Austrian, 1909–1977, Fig. 6.209) first conceived of TWTs while he was a refugee in the United Kingdom during World War II, and he built the first fully functional TWTs in the early 1950s after he had been transferred to AT&T Bell Laboratories. Kompfner went on to have a long and productive career at Bell Labs.[24]

There is evidence that another team of German-speaking creators designed and demonstrated TWTs and transferred that technology to Bell Labs, all earlier than Kompfner did (Figs. 6.207 and 6.210–6.211). From the currently available archival and published documents, Herbert Schnitger (German, 19??–19??), Dieter Weber (German, 19??–19??), and their associates appear to have invented and demonstrated TWTs in Germany during the war, especially for the purpose of sending multiplexed control signals back and forth between ground stations and long-range missiles. In July 1945, the U.S. Army evacuated Schnitger, Weber, some of their other team members, and their equipment and documents from Thuringia ahead of the Russian occupation. In September 1945, an investigator from the Western Electric division of American Telephone & Telegraph (AT&T) expressed great interest in Schnitger and requested that he, his equipment, and his information be transferred to the United States. Then in July 1946, AT&T suddenly announced that it had just "invented" a revolutionary new device—the traveling wave tube. Schnitger and Weber seem to have lapsed into obscurity while AT&T achieved great fame and fortune with their work. For more details, see pp. 2938–2962.

Historians should thoroughly investigate the details of the wartime Schnitger-Weber work, its postwar transfer, and whether and how the wartime/postwar Schnitger-Weber and Kompfner research programs were interrelated.

Reinhold Rüdenberg (German, 1883–1961), an innovator in many areas of electrical engineering, emigrated from Germany to the United States in the 1930s. In the 1940s, he developed phased-array radar systems, as shown in Fig. 6.212.

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[23] https://doi.org/10.1080/09205071.2020.1848643
https://www.analogictips.com/vacuum-tubes-traveling-wave-tube-part-1/
https://www.analogictips.com/vacuum-tubes-traveling-wave-tube-part-2/

[24] Gertner 2012; Kompfner 1964, 1976; Pierce 1983; 1991.

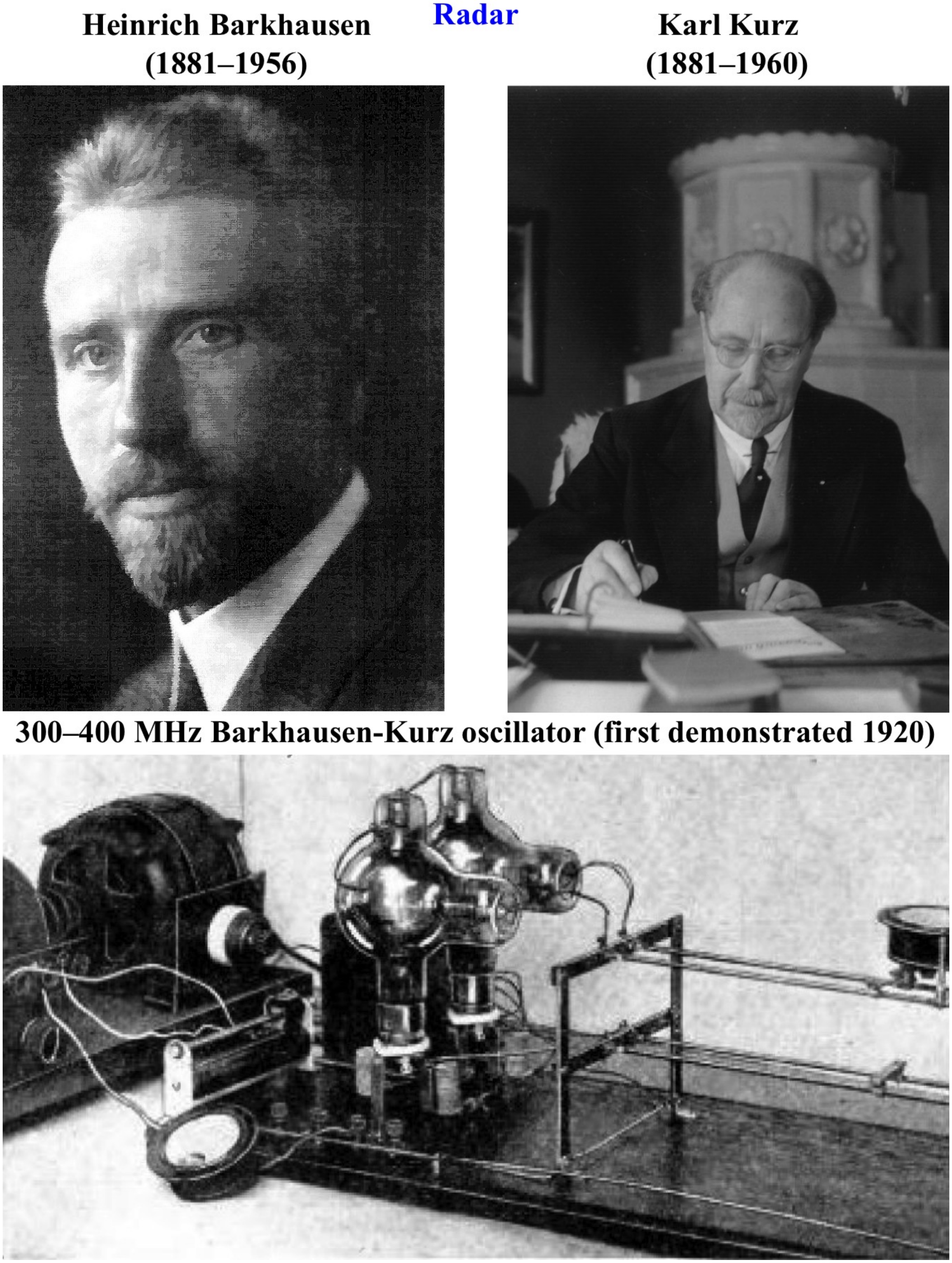
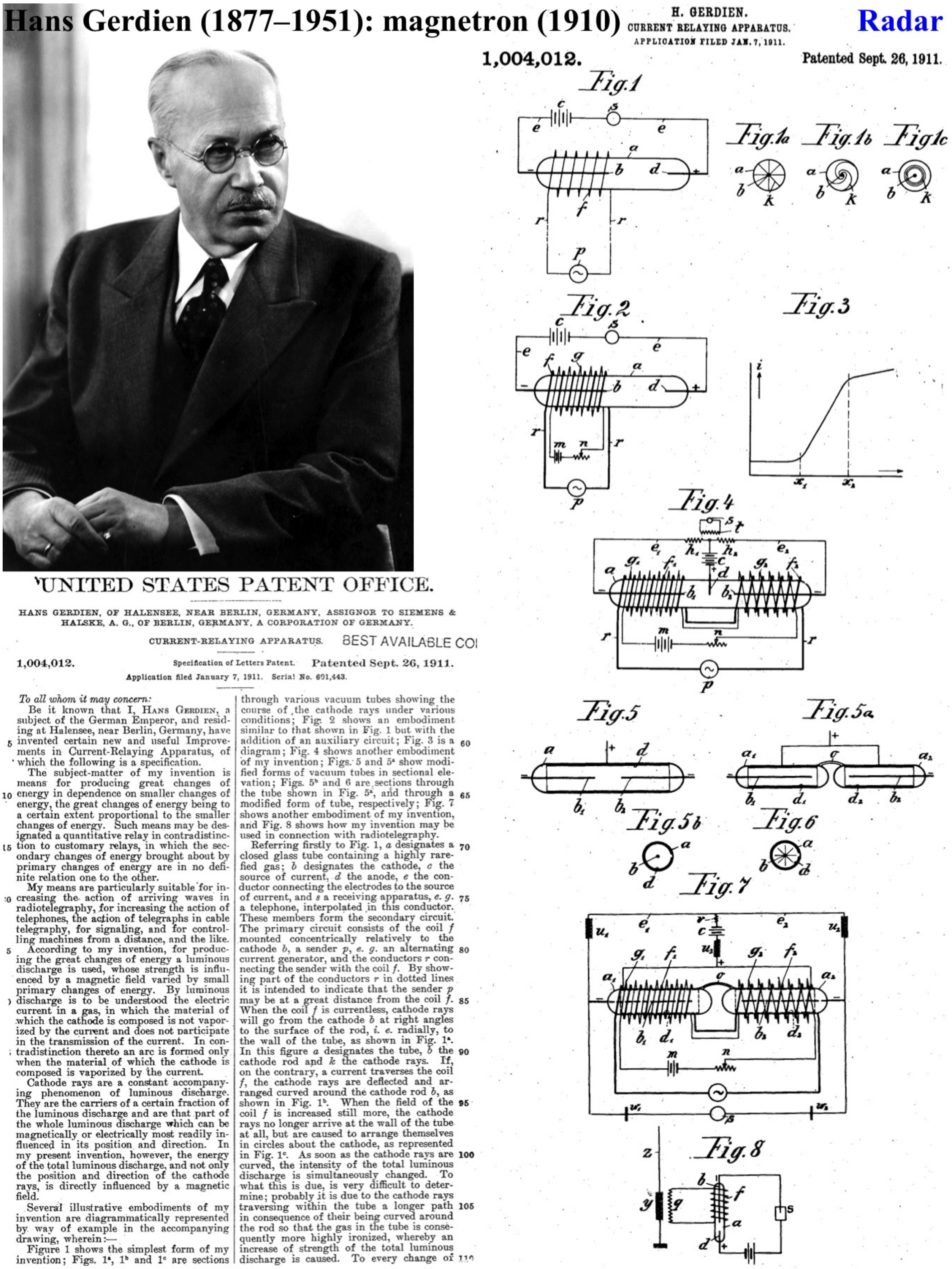

Radar
Heinrich Barkhausen
(1881–1956)
Karl Kurz
(1881–1960)
300–400 MHz Barkhausen-Kurz oscillator (first demonstrated 1920)

Figure 6.203: In 1920, Heinrich Barkhausen (1881–1956) and Karl Kurz (1881–1960) developed the 300–400 MHz Barkhausen-Kurz oscillator, which enabled high-frequency, high-power radar systems.



Hans Gerdien (1877–1951): magnetron (1910)

Radar

'UNITED STATES PATENT OFFICE.

HANS GERDIEN, OF HALENSEE, NEAR BERLIN, GERMANY, ASSIGNOR TO SIEMENS & HALSKE, A. G., OF BERLIN, GERMANY, A CORPORATION OF GERMANY.

CURRENT-RELAYING APPARATUS. BEST AVAILABLE CO

1,004,012. Specification of Letters Patent. Patented Sept. 26, 1911.

Application filed January 7, 1911. Seria! No. 601,443.

To all whom it may concern:

Be it known that I, Hans Gerdien, a subject of the German Emperor, and residing at Halensee, near Berlin, Germany, have invented certain new and useful Improvements in Current-Relaying Apparatus, of which the following is a specification.

The subject-matter of my invention is means for producing great changes of energy in dependence on smaller changes of energy, the great changes of energy being to a certain extent proportional to the smaller changes of energy. Such means may be designated a quantitative relay in contradistinction to customary relays, in which the secondary changes of energy brought about by primary changes of energy are in no definite relation one to the other.

My means are particularly suitable for increasing the action of arriving waves in radiotelegraphy, for increasing the action of telephones, the action of telegraphs in cable telegraphy, for signaling, and for controlling machines from a distance, and the like.

According to my invention, for producing the great changes of energy a luminous discharge is used, whose strength is influenced by a magnetic field varied by small primary changes of energy. By luminous discharge is to be understood the electric current in a gas, in which the material of which the cathode is composed is not vaporized by the current and does not participate in the transmission of the current. In contradistinction thereto an arc is formed only when the material of which the cathode is composed is vaporized by the current.

Cathode rays are a constant accompanying phenomenon of luminous discharge. They are the carriers of a certain fraction of the luminous discharge and are that part of the whole luminous discharge which can be magnetically or electrically most readily influenced in its position and direction. In my present invention, however, the energy of the total luminous discharge, and not only the position and direction of the cathode rays, is directly influenced by a magnetic field.

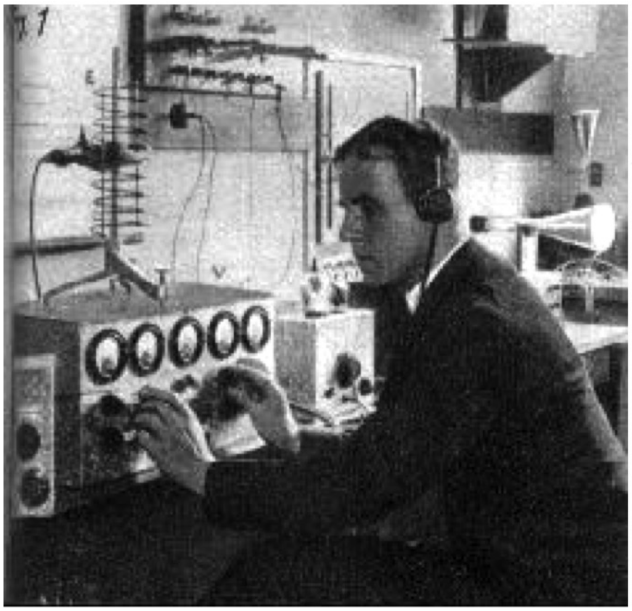
Several illustrative embodiments of my invention are diagrammatically represented by way of example in the accompanying drawing, wherein:—

Figure 1 shows the simplest form of my invention; Figs. 1^a, 1^b and 1^c are sections through various vacuum tubes showing the course of the cathode rays under various conditions; Fig. 2 shows an embodiment similar to that shown in Fig. 1 but with the addition of an auxiliary circuit; Fig. 3 is a diagram; Fig. 4 shows another embodiment of my invention; Figs. 5 and 5^a show modified forms of vacuum tubes in sectional elevation; Figs. 5^b and 6 are sections through the tube shown in Fig. 5^a, and through a modified form of tube, respectively; Fig. 7 shows another embodiment of my invention, and Fig. 8 shows how my invention may be used in connection with radiotelegraphy.

Referring firstly to Fig. 1, *a* designates a closed glass tube containing a highly rarefied gas; *b* designates the cathode, *c* the source of current, *d* the anode, *e* the conductor connecting the electrodes to the source of current, and *s* a receiving apparatus, *e. g.* a telephone, interpolated in this conductor. These members form the secondary circuit. The primary circuit consists of the coil *f* mounted concentrically relatively to the cathode *b*, a sender *p*, *e. g.* an alternating current generator, and the conductors *r* connecting the sender with the coil *f*. By showing part of the conductors *r* in dotted lines it is intended to indicate that the sender *p* may be at a great distance from the coil *f*. When the coil *f* is currentless, cathode rays will go from the cathode *b* at right angles to the surface of the rod, *i. e.* radially, to the wall of the tube, as shown in Fig. 1^a. In this figure *a* designates the tube, *b* the cathode rod and *k* the cathode rays. If, on the contrary, a current traverses the coil *f*, the cathode rays are deflected and arranged curved around the cathode rod *b*, as shown in Fig. 1^b. When the field of the coil *f* is increased still more, the cathode rays no longer arrive at the wall of the tube at all, but are caused to arrange themselves in circles about the cathode, as represented in Fig. 1^c. As soon as the cathode rays are curved, the intensity of the total luminous discharge is simultaneously changed. To what this is due, is very difficult to determine; probably it is due to the cathode rays traversing within the tube a longer path in consequence of their being curved around the rod so that the gas in the tube is consequently more highly ironized, whereby an increase of strength of the total luminous discharge is caused. To every change of

Figure 6.204: In 1910, Hans Gerdien invented and patented the magnetron.

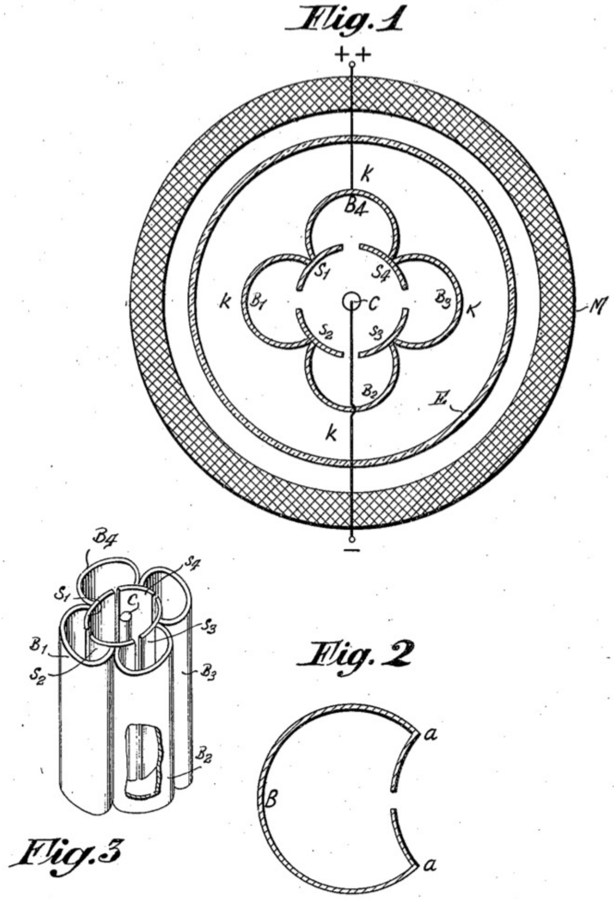
Radar Hans Erich Hollmann (1899–1960): cavity magnetron (1935)

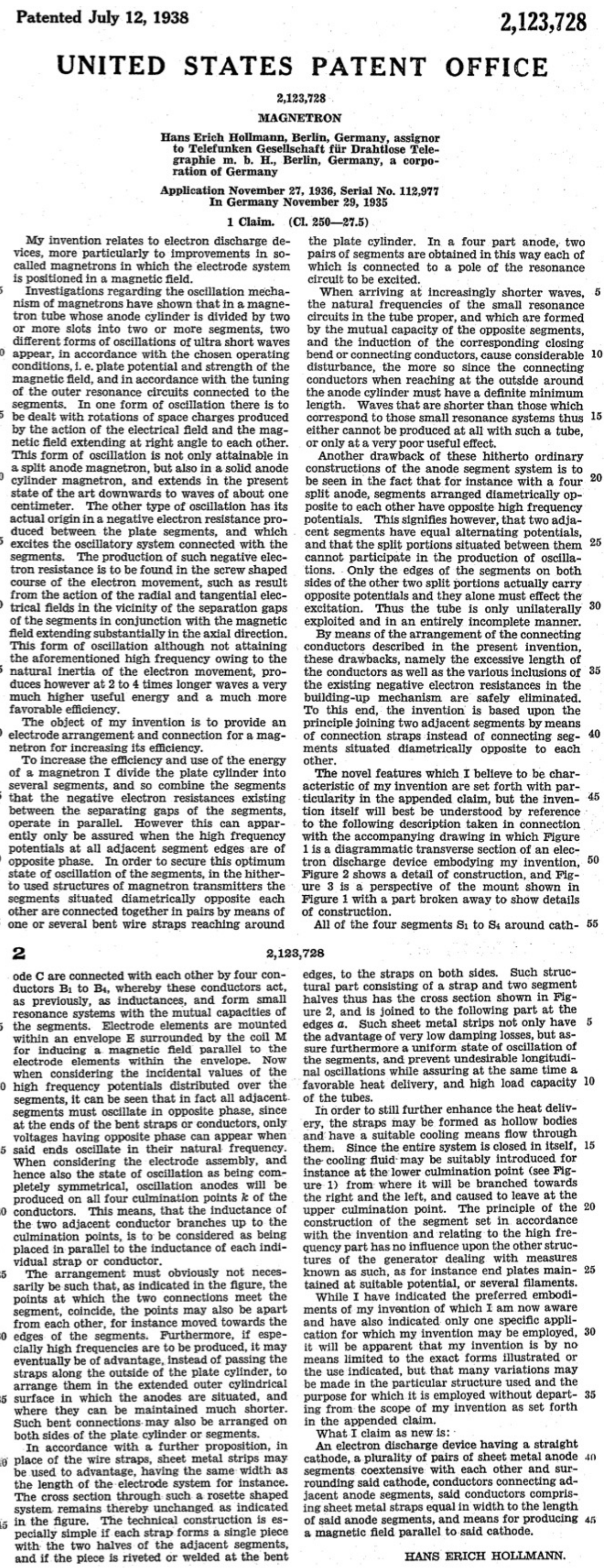


July 12, 1938. H. E. HOLLMANN 2,123,728

MAGNETRON

Filed Nov. 27, 1936





Patented July 12, 1938 2,123,728

UNITED STATES PATENT OFFICE

2,123,728

MAGNETRON

Hans Erich Hollmann, Berlin, Germany, assignor to Telefunken Gesellschaft für Drahtlose Telegraphie m. b. H., Berlin, Germany, a corporation of Germany

Application November 27, 1936, Serial No. 112,977
In Germany November 29, 1935

1 Claim. (Cl. 250—27.5)

My invention relates to electron discharge devices, more particularly to improvements in so-called magnetrons in which the electrode system is positioned in a magnetic field.

Investigations regarding the oscillation mechanism of magnetrons have shown that in a magnetron tube whose anode cylinder is divided by two or more slots into two or more segments, two different forms of oscillations of ultra short waves appear, in accordance with the chosen operating conditions, i. e. plate potential and strength of the magnetic field, and in accordance with the tuning of the outer resonance circuits connected to the segments. In one form of oscillation there is to be dealt with rotations of space charges produced by the action of the electrical field and the magnetic field extending at right angle to each other. This form of oscillation is not only attainable in a split anode magnetron, but also in a solid anode cylinder magnetron, and extends in the present state of the art downwards to waves of about one centimeter. The other type of oscillation has its actual origin in a negative electron resistance produced between the plate segments, and which excites the oscillatory system connected with the segments. The production of such negative electron resistance is to be found in the screw shaped course of the electron movement, such as result from the action of the radial and tangential electrical fields in the vicinity of the separation gaps of the segments in conjunction with the magnetic field extending substantially in the axial direction. This form of oscillation although not attaining the aforementioned high frequency owing to the natural inertia of the electron movement, produces however at 2 to 4 times longer waves a very much higher useful energy and a much more favorable efficiency.

The object of my invention is to provide an electrode arrangement and connection for a magnetron for increasing its efficiency.

To increase the efficiency and use of the energy of a magnetron I divide the plate cylinder into several segments, and so combine the segments that the negative electron resistances existing between the separating gaps of the segments, operate in parallel. However this can apparently only be assured when the high frequency potentials at all adjacent segment edges are of opposite phase. In order to secure this optimum state of oscillation of the segments, in the hitherto used structures of magnetron transmitters the segments situated diametrically opposite each other are connected together in pairs by means of one or several bent wire straps reaching around the plate cylinder. In a four part anode, two pairs of segments are obtained in this way each of which is connected to a pole of the resonance circuit to be excited.

When arriving at increasingly shorter waves, the natural frequencies of the small resonance circuits in the tube proper, and which are formed by the mutual capacity of the opposite segments, and the induction of the corresponding closing bend or connecting conductors, cause considerable disturbance, the more so since the connecting conductors when reaching at the outside around the anode cylinder must have a definite minimum length. Waves that are shorter than those which correspond to those small resonance systems thus either cannot be produced at all with such a tube, or only at a very poor useful effect.

Another drawback of these hitherto ordinary constructions of the anode segment system is to be seen in the fact that for instance with a four split anode, segments arranged diametrically opposite to each other have opposite high frequency potentials. This signifies however, that two adjacent segments have equal alternating potentials, and that the split portions situated between them cannot participate in the production of oscillations. Only the edges of the segments on both sides of the other two split portions actually carry opposite potentials and they alone must effect the excitation. Thus the tube is only unilaterally exploited and in an entirely incomplete manner.

By means of the arrangement of the connecting conductors described in the present invention, these drawbacks, namely the excessive length of the conductors as well as the various inclusions of the existing negative electron resistances in the building-up mechanism are safely eliminated. To this end, the invention is based upon the principle joining two adjacent segments by means of connection straps instead of connecting segments situated diametrically opposite to each other.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claim, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawing in which Figure 1 is a diagrammatic transverse section of an electron discharge device embodying my invention, Figure 2 shows a detail of construction, and Figure 3 is a perspective of the mount shown in Figure 1 with a part broken away to show details of construction.

All of the four segments S_1 to S_4 around cath-

2 2,123,728

ode C are connected with each other by four conductors B_1 to B_4, whereby these conductors act, as previously, as inductances, and form small resonance systems with the mutual capacities of the segments. Electrode elements are mounted within an envelope E surrounded by the coil M for inducing a magnetic field parallel to the electrode elements within the envelope. Now when considering the incidental values of the high frequency potentials distributed over the segments, it can be seen that in fact all adjacent segments must oscillate in opposite phase, since at the ends of the bent straps or conductors, only voltages having opposite phase can appear when said ends oscillate in their natural frequency. When considering the electrode assembly, and hence also the state of oscillation as being completely symmetrical, oscillation anodes will be produced on all four culmination points *k* of the conductors. This means, that the inductance of the two adjacent conductor branches up to the culmination points, is to be considered as being placed in parallel to the inductance of each individual strap or conductor.

The arrangement must obviously not necessarily be such that, as indicated in the figure, the points at which the two connections meet the segment, coincide, the points may also be apart from each other, for instance moved towards the edges of the segments. Furthermore, if especially high frequencies are to be produced, it may eventually be of advantage, instead of passing the straps along the outside of the plate cylinder, to arrange them in the extended outer cylindrical surface in which the anodes are situated, and where they can be maintained much shorter. Such bent connections may also be arranged on both sides of the plate cylinder or segments.

In accordance with a further proposition, in place of the wire straps, sheet metal strips may be used to advantage, having the same width as the length of the electrode system for instance. The cross section through such a rosette shaped system remains thereby unchanged as indicated in the figure. The technical construction is especially simple if each strap forms a single piece with the two halves of the adjacent segments, and if the piece is riveted or welded at the bent edges, to the straps on both sides. Such structural part consisting of a strap and two segment halves thus has the cross section shown in Figure 2, and is joined to the following part at the edges *a*. Such sheet metal strips not only have the advantage of very low damping losses, but assure furthermore a uniform state of oscillation of the segments, and prevent undesirable longitudinal oscillations while assuring at the same time a favorable heat delivery, and high load capacity of the tubes.

In order to still further enhance the heat delivery, the straps may be formed as hollow bodies and have a suitable cooling means flow through them. Since the entire system is closed in itself, the cooling fluid may be suitably introduced for instance at the lower culmination point (see Figure 1) from where it will be branched towards the right and the left, and caused to leave at the upper culmination point. The principle of the construction of the segment set in accordance with the invention and relating to the high frequency part has no influence upon the other structures of the generator dealing with measures known as such, as for instance end plates maintained at suitable potential, or several filaments.

While I have indicated the preferred embodiments of my invention of which I am now aware and have also indicated only one specific application for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claim.

What I claim as new is:

An electron discharge device having a straight cathode, a plurality of pairs of sheet metal anode segments coextensive with each other and surrounding said cathode, conductors connecting adjacent anode segments, said conductors comprising sheet metal straps equal in width to the length of said anode segments, and means for producing a magnetic field parallel to said cathode.

HANS ERICH HOLLMANN.

Figure 6.205: In 1935, Hans Erich Hollmann invented and patented the cavity magnetron.

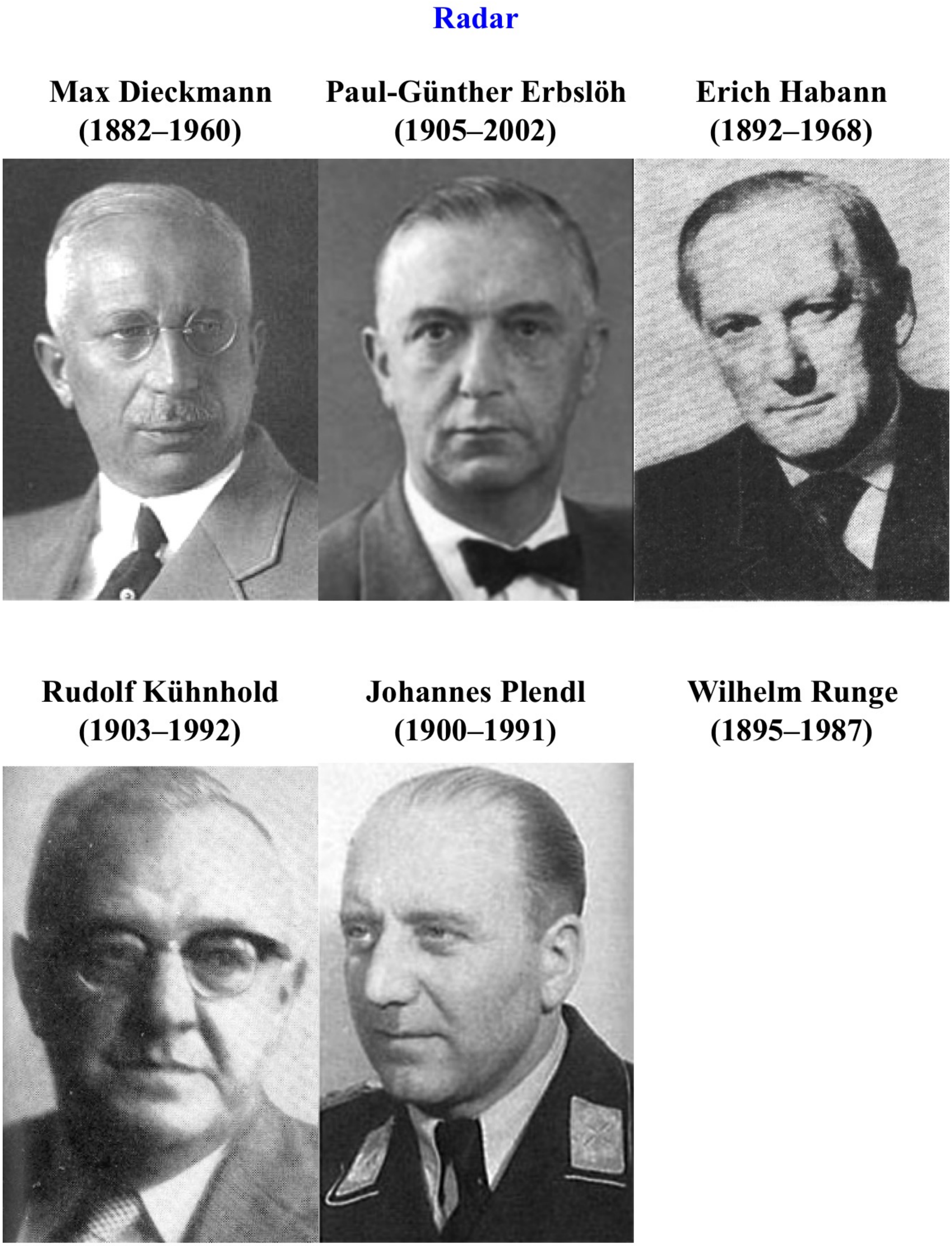

Radar
Max Dieckmann (1882–1960)
Paul-Günther Erbslöh (1905–2002)
Erich Habann (1892–1968)
Rudolf Kühnhold (1903–1992)
Johannes Plendl (1900–1991)
Wilhelm Runge (1895–1987)

Figure 6.206: Other creators who developed radar systems included Max Dieckmann, Paul-Günther Erbslöh, Erich Habann, Rudolf Kühnhold, Johannes Plendl, and Wilhelm Runge.

Radar

Herbert Schnitger (19??–19??)

Theodor Jakob Schultes (1901–1981)

Wilhelm Stepp (18??–19??)

Dieter Weber (19??–19??)

Hans-Karl von Willisen (1906–1966)

August Žáček (1886–1961)

Figure 6.207: Other creators who developed radar systems included Herbert Schnitger, Theodor Jakob Schultes, Wilhelm Stepp, Dieter Weber, Hans-Karl von Willisen, and August Žáček.

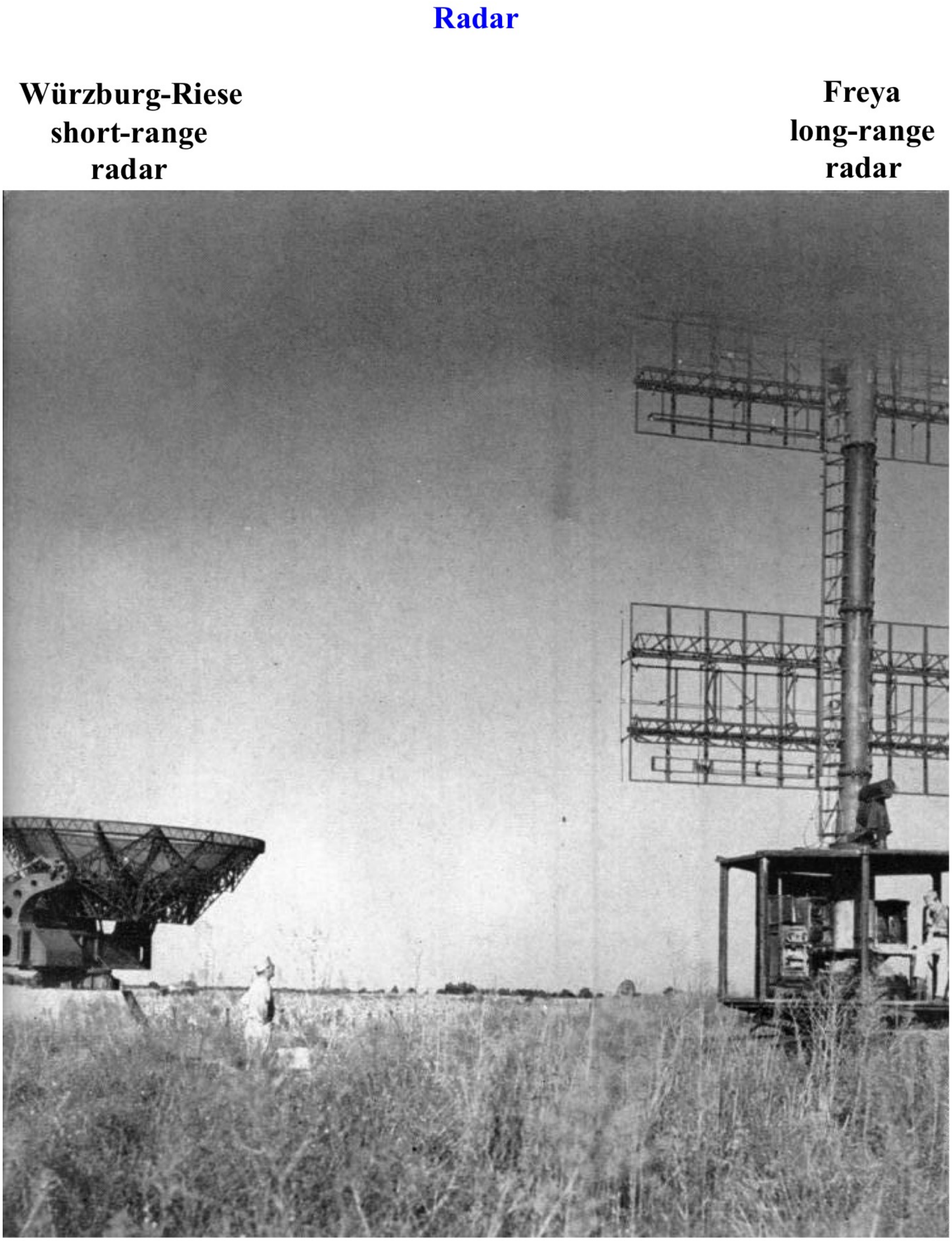
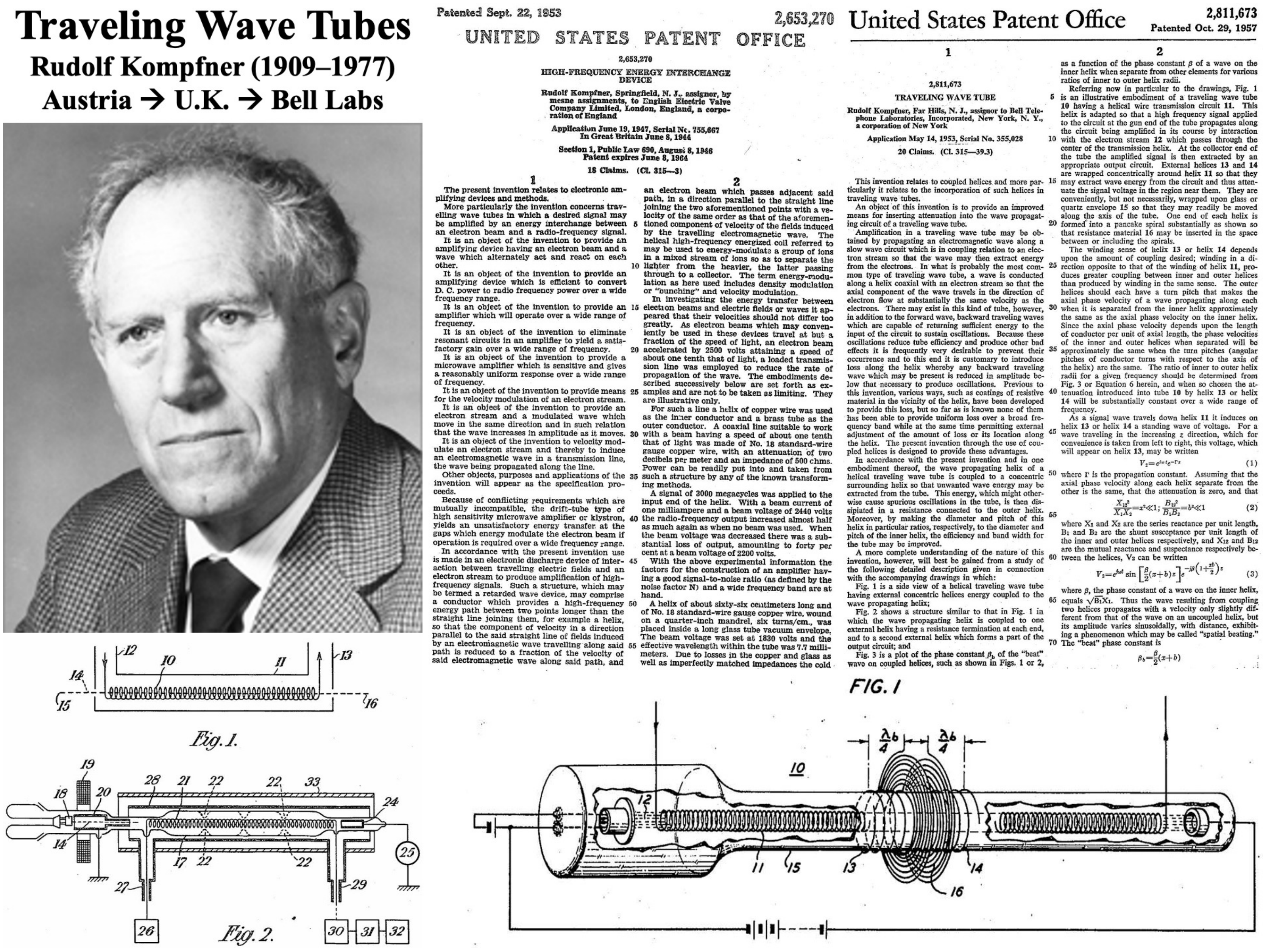

Radar
Würzburg-Riese short-range radar
Freya long-range radar

Figure 6.208: Examples of World War II German radar systems included the Würzburg-Riese short-range radar and the Freya long-range radar.


Traveling Wave Tubes
Rudolf Kompfner (1909–1977)
Austria → U.K. → Bell Labs
12
10
11
13
14
15
16
Fig. 1.
19
18
20
28
21
22
22
33
24
14
17
22
22
25
27
29
26
30
31
32
Fig. 2.
FIG. I
λb/4
λb/4
10
12
11
15
13
16
14

Patented Sept. 22, 1953 2,653,270

UNITED STATES PATENT OFFICE

2,653,270

HIGH-FREQUENCY ENERGY INTERCHANGE DEVICE

Rudolf Kompfner, Springfield, N. J., assignor, by mesne assignments, to English Electric Valve Company Limited, London, England, a corporation of England

Application June 19, 1947, Serial No. 755,667
In Great Britain June 8, 1944

Section 1, Public Law 690, August 8, 1946
Patent expires June 8, 1964

18 Claims. (Cl. 315—3)

1

The present invention relates to electronic amplifying devices and methods.

More particularly the invention concerns travelling wave tubes in which a desired signal may be amplified by an energy interchange between an electron beam and a radio-frequency signal.

It is an object of the invention to provide an amplifying device having an electron beam and a wave which alternately act and react on each other.

It is an object of the invention to provide an amplifying device which is efficient to convert D. C. power to radio frequency power over a wide frequency range.

It is an object of the invention to provide an amplifier which will operate over a wide range of frequency.

It is an object of the invention to eliminate resonant circuits in an amplifier to yield a satisfactory gain over a wide range of frequency.

It is an object of the invention to provide a microwave amplifier which is sensitive and gives a reasonably uniform response over a wide range of frequency.

It is an object of the invention to provide means for the velocity modulation of an electron stream.

It is an object of the invention to provide an electron stream and a modulated wave which move in the same direction and in such relation that the wave increases in amplitude as it moves.

It is an object of the invention to velocity modulate an electron stream and thereby to induce an electromagnetic wave in a transmission line, the wave being propagated along the line.

Other objects, purposes and applications of the invention will appear as the specification proceeds.

Because of conflicting requirements which are mutually incompatible, the drift-tube type of high sensitivity microwave amplifier or klystron, yields an unsatisfactory energy transfer at the gaps which energy modulate the electron beam if operation is required over a wide frequency range.

In accordance with the present invention use is made in an electronic discharge device of interaction between travelling electric fields and an electron stream to produce amplification of high-frequency signals. Such a structure, which may be termed a retarded wave device, may comprise a conductor which provides a high-frequency energy path between two points longer than the straight line joining them, for example a helix, so that the component of velocity in a direction parallel to the said straight line of fields induced by an electromagnetic wave travelling along said path is reduced to a fraction of the velocity of said electromagnetic wave along said path, and

2

an electron beam which passes adjacent said path, in a direction parallel to the straight line joining the two aforementioned points with a velocity of the same order as that of the aforementioned component of velocity of the fields induced by the travelling electromagnetic wave. The helical high-frequency energized coil referred to may be used to energy-modulate a group of ions in a mixed stream of ions so as to separate the lighter from the heavier, the latter passing through to a collector. The term energy-modulation as here used includes density modulation or "bunching" and velocity modulation.

In investigating the energy transfer between electron beams and electric fields or waves it appeared that their velocities should not differ too greatly. As electron beams which may conveniently be used in these devices travel at but a fraction of the speed of light, an electron beam accelerated by 2500 volts attaining a speed of about one tenth that of light, a loaded transmission line was employed to reduce the rate of propagation of the wave. The embodiments described successively below are set forth as examples and are not to be taken as limiting. They are illustrative only.

For such a line a helix of copper wire was used as the inner conductor and a brass tube as the outer conductor. A coaxial line suitable to work with a beam having a speed of about one tenth that of light was made of No. 18 standard-wire gauge copper wire, with an attenuation of two decibels per meter and an impedance of 500 ohms. Power can be readily put into and taken from such a structure by any of the known transforming methods.

A signal of 3000 megacycles was applied to the input end of the helix. With a beam current of one milliampere and a beam voltage of 2440 volts the radio-frequency output increased almost half as much again as when no beam was used. When the beam voltage was decreased there was a substantial loss of output, amounting to forty per cent at a beam voltage of 2200 volts.

With the above experimental information the factors for the construction of an amplifier having a good signal-to-noise ratio (as defined by the noise factor N) and a wide frequency band are at hand.

A helix of about sixty-six centimeters long and of No. 18 standard-wire gauge copper wire, wound on a quarter-inch mandrel, six turns/cm., was placed inside a long glass tube vacuum envelope. The beam voltage was set at 1830 volts and the effective wavelength within the tube was 7.7 millimeters. Due to losses in the copper and glass as well as imperfectly matched impedances the cold

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United States Patent Office 2,811,673
Patented Oct. 29, 1957

1

2,811,673

TRAVELING WAVE TUBE

Rudolf Kompfner, Far Hills, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application May 14, 1953, Serial No. 355,028

20 Claims. (Cl. 315—39.3)

This invention relates to coupled helices and more particularly it relates to the incorporation of such helices in traveling wave tubes.

An object of this invention is to provide an improved means for inserting attenuation into the wave propagating circuit of a traveling wave tube.

Amplification in a traveling wave tube may be obtained by propagating an electromagnetic wave along a slow wave circuit which is in coupling relation to an electron stream so that the wave may then extract energy from the electrons. In what is probably the most common type of traveling wave tube, a wave is conducted along a helix coaxial with an electron stream so that the axial component of the wave travels in the direction of electron flow at substantially the same velocity as the electrons. There may exist in this kind of tube, however, in addition to the forward wave, backward traveling waves which are capable of returning sufficient energy to the input of the circuit to sustain oscillations. Because these oscillations reduce tube efficiency and produce other bad effects it is frequently very desirable to prevent their occurrence and to this end it is customary to introduce loss along the helix whereby any backward traveling wave which may be present is reduced in amplitude below that necessary to produce oscillations. Previous to this invention, various ways, such as coatings of resistive material in the vicinity of the helix, have been developed to provide this loss, but so far as is known none of them has been able to provide uniform loss over a broad frequency band while at the same time permitting external adjustment of the amount of loss or its location along the helix. The present invention through the use of coupled helices is designed to provide these advantages.

In accordance with the present invention and in one embodiment thereof, the wave propagating helix of a helical traveling wave tube is coupled to a concentric surrounding helix so that unwanted wave energy may be extracted from the tube. This energy, which might otherwise cause spurious oscillations in the tube, is then dissipated in a resistance connected to the outer helix. Moreover, by making the diameter and pitch of this helix in particular ratios, respectively, to the diameter and pitch of the inner helix, the efficiency and band width for the tube may be improved.

A more complete understanding of the nature of this invention, however, will best be gained from a study of the following detailed description given in connection with the accompanying drawings in which:

Fig. 1 is a side view of a helical traveling wave tube having external concentric helices energy coupled to the wave propagating helix;

Fig. 2 shows a structure similar to that in Fig. 1 in which the wave propagating helix is coupled to one external helix having a resistance termination at each end, and to a second external helix which forms a part of the output circuit; and

Fig. 3 is a plot of the phase constant β_b of the "beat" wave on coupled helices, such as shown in Figs. 1 or 2,

2

as a function of the phase constant β of a wave on the inner helix when separate from other elements for various ratios of inner to outer helix radii.

Referring now in particular to the drawings, Fig. 1 is an illustrative embodiment of a traveling wave tube **10** having a helical wire transmission circuit **11**. This helix is adapted so that a high frequency signal applied to the circuit at the gun end of the tube propagates along the circuit being amplified in its course by interaction with the electron stream **12** which passes through the center of the transmission helix. At the collector end of the tube the amplified signal is then extracted by an appropriate output circuit. External helices **13** and **14** are wrapped concentrically around helix **11** so that they may extract wave energy from the circuit and thus attenuate the signal voltage in the region near them. They are conveniently, but not necessarily, wrapped upon glass or quartz envelope **15** so that they may readily be moved along the axis of the tube. One end of each helix is formed into a pancake spiral substantially as shown so that resistance material **16** may be inserted in the space between or including the spirals.

The winding sense of helix **13** or helix **14** depends upon the amount of coupling desired; winding in a direction opposite to that of the winding of helix **11**, produces greater coupling between inner and outer helices than produced by winding in the same sense. The outer helices should each have a turn pitch that makes the axial phase velocity of a wave propagating along each when it is separated from the inner helix approximately the same as the axial phase velocity on the inner helix. Since the axial phase velocity depends upon the length of conductor per unit of axial length, the phase velocities of the inner and outer helices when separated will be approximately the same when the turn pitches (angular pitches of conductor turns with respect to the axis of the helix) are the same. The ratio of inner to outer helix radii for a given frequency should be determined from Fig. 3 or Equation 6 herein, and when so chosen the attenuation introduced into tube **10** by helix **13** or helix **14** will be substantially constant over a wide range of frequency.

As a signal wave travels down helix **11** it induces on helix **13** or helix **14** a standing wave of voltage. For a wave traveling in the increasing z direction, which for convenience is taken from left to right, this voltage, which will appear on helix **13**, may be written

$$V_2=e^{j\omega t}e^{-\Gamma z} \qquad (1)$$

where Γ is the propagation constant. Assuming that the axial phase velocity along each helix separate from the other is the same, that the attenuation is zero, and that

$$\frac{X_{12}^2}{X_1X_2}=x^2\ll1;\ \frac{B_{12}^2}{B_1B_2}=b^2\ll1 \qquad (2)$$

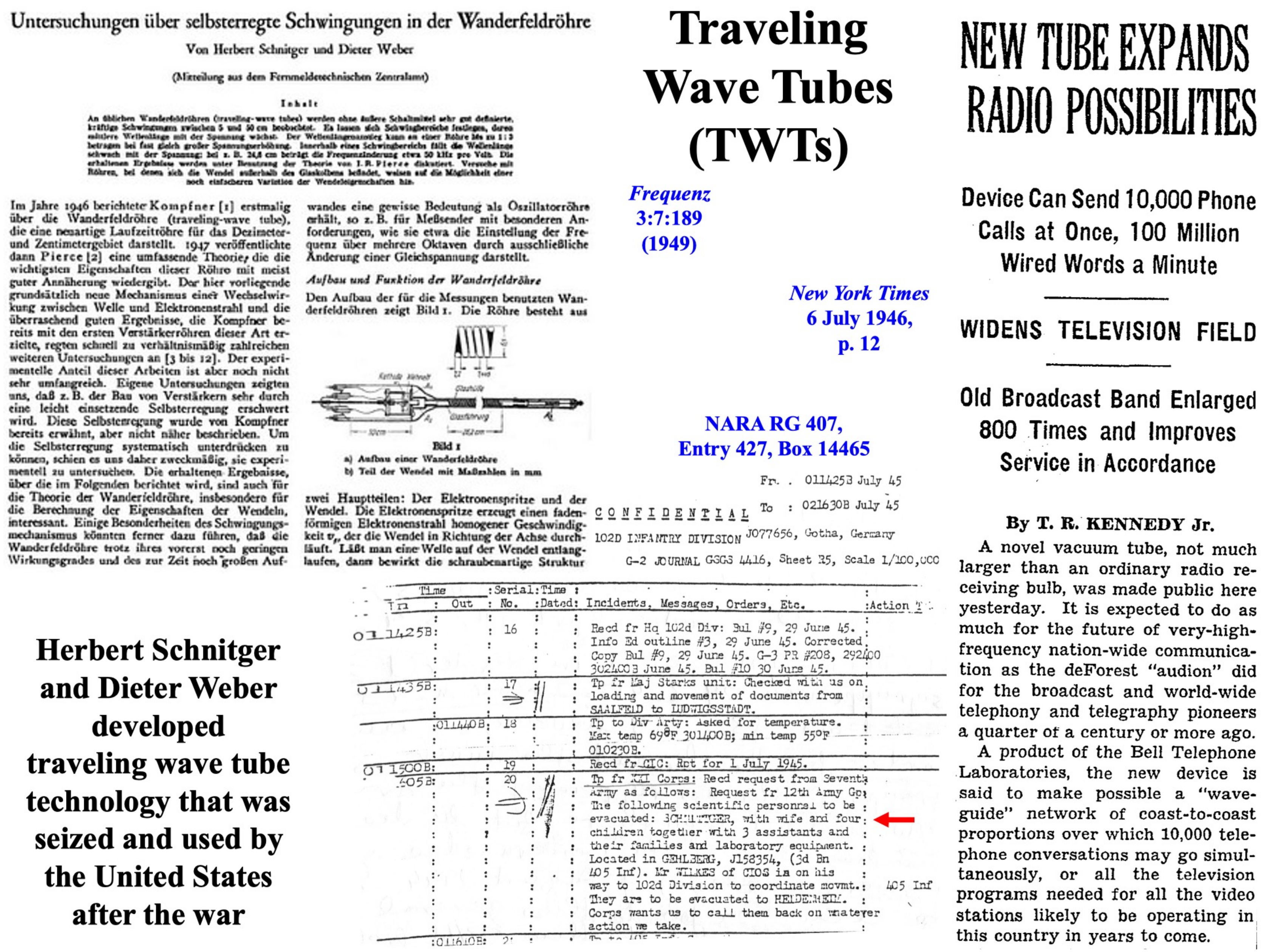
where X_1 and X_2 are the series reactance per unit length, B_1 and B_2 are the shunt susceptance per unit length of the inner and outer helices respectively, and X_{12} and B_{12} are the mutual reactance and suspectance respectively between the helices, V_2 can be written

$$V_2=e^{j\omega t}\sin\left[\frac{\beta}{2}(x+b)z\right]e^{-j\beta\left(1+\frac{xb}{2}\right)z} \qquad (3)$$

where β, the phase constant of a wave on the inner helix, equals $\sqrt{B_1X_1}$. Thus the wave resulting from coupling two helices propagates with a velocity only slightly different from that of the wave on an uncoupled helix, but its amplitude varies sinusoidally, with distance, exhibiting a phenomenon which may be called "spatial beating." The "beat" phase constant is

$$\beta_b=\frac{\beta}{2}(x+b)$$

Figure 6.209: Rudolf Kompfner developed traveling wave tube technology that was transferred to AT&T Bell Laboratories.


Kathode
Wehnelt
A_1
Glashülle
Glasführung
A_2
A_3
50cm
262 cm

Untersuchungen über selbsterregte Schwingungen in der Wanderfeldröhre

Von Herbert Schnitger und Dieter Weber

(Mitteilung aus dem Fernmeldetechnischen Zentralamt)

Inhalt

An üblichen Wanderfeldröhren (traveling-wave tubes) werden ohne äußere Schaltmittel sehr gut definierte, kräftige Schwingungen zwischen 5 und 50 cm beobachtet. Es lassen sich Schwingbereiche festlegen, deren mittlere Wellenlänge mit der Spannung wächst. Der Wellenlängenanstieg kann an einer Röhre bis zu 1:3 betragen bei fast gleich großer Spannungserhöhung. Innerhalb eines Schwingbereichs fällt die Wellenlänge schwach mit der Spannung: bei z. B. 24,8 cm beträgt die Frequenzänderung etwa 50 kHz pro Volt. Die erhaltenen Ergebnisse werden unter Benutzung der Theorie von J. R. Pierce diskutiert. Versuche mit Röhren, bei denen sich die Wendel außerhalb des Glaskolbens befindet, weisen auf die Möglichkeit einer noch einfacheren Variation der Wendeleigenschaften hin.

Im Jahre 1946 berichtete Kompfner [1] erstmalig über die Wanderfeldröhre (traveling-wave tube), die eine neuartige Laufzeitröhre für das Dezimeter- und Zentimetergebiet darstellt. 1947 veröffentlichte dann Pierce [2] eine umfassende Theorie, die die wichtigsten Eigenschaften dieser Röhre mit meist guter Annäherung wiedergibt. Der hier vorliegende grundsätzlich neue Mechanismus einer Wechselwirkung zwischen Welle und Elektronenstrahl und die überraschend guten Ergebnisse, die Kompfner bereits mit den ersten Verstärkerröhren dieser Art erzielte, regten schnell zu verhältnismäßig zahlreichen weiteren Untersuchungen an [3 bis 12]. Der experimentelle Anteil dieser Arbeiten ist aber noch nicht sehr umfangreich. Eigene Untersuchungen zeigten uns, daß z. B. der Bau von Verstärkern sehr durch eine leicht einsetzende Selbsterregung erschwert wird. Diese Selbsterregung wurde von Kompfner bereits erwähnt, aber nicht näher beschrieben. Um die Selbsterregung systematisch unterdrücken zu können, schien es uns daher zweckmäßig, sie experimentell zu untersuchen. Die erhaltenen Ergebnisse, über die im Folgenden berichtet wird, sind auch für die Theorie der Wanderfeldröhre, insbesondere für die Berechnung der Eigenschaften der Wendeln, interessant. Einige Besonderheiten des Schwingungsmechanismus könnten ferner dazu führen, daß die Wanderfeldröhre trotz ihres vorerst noch geringen Wirkungsgrades und des zur Zeit noch großen Aufwandes eine gewisse Bedeutung als Oszillatorröhre erhält, so z. B. für Meßsender mit besonderen Anforderungen, wie sie etwa die Einstellung der Frequenz über mehrere Oktaven durch ausschließliche Änderung einer Gleichspannung darstellt.

Aufbau und Funktion der Wanderfeldröhre

Den Aufbau der für die Messungen benutzten Wanderfeldröhren zeigt Bild 1. Die Röhre besteht aus zwei Hauptteilen: Der Elektronenspritze und der Wendel. Die Elektronenspritze erzeugt einen fadenförmigen Elektronenstrahl homogener Geschwindigkeit v_0, der die Wendel in Richtung der Achse durchläuft. Läßt man eine Welle auf der Wendel entlanglaufen, dann bewirkt die schraubenartige Struktur

Bild 1

a) Aufbau einer Wanderfeldröhre

b) Teil der Wendel mit Maßzahlen in mm

Herbert Schnitger and Dieter Weber developed traveling wave tube technology that was seized and used by the United States after the war

Traveling Wave Tubes (TWTs)

***Frequenz* 3:7:189 (1949)**

***New York Times* 6 July 1946, p. 12**

NARA RG 407, Entry 427, Box 14465

Fr. . 011425B July 45

C O N F I D E N T I A L To : 021630B July 45

102D INFANTRY DIVISION J077656, Gotha, Germany

G-2 JOURNAL GSGS 4416, Sheet R5, Scale 1/100,000

Time In	Time Out	Serial No.	Time Dated	Incidents, Messages, Orders, Etc.	Action T
011425B		16		Recd fr Hq 102d Div: Bul #9, 29 June 45. Info Ed outline #3, 29 June 45. Corrected Copy Bul #9, 29 June 45. G-3 PR #208, 292400 302400B June 45. Bul #10 30 June 45.	
011435B		17		Tp fr Maj Starks unit: Checked with us on loading and movement of documents from SAALFELD to LUDWIGSSTADT.	
	011440B	18		Tp to Div Arty: Asked for temperature. Max temp 69°F 301400B; min temp 55°F 010230B.	
011500B		19		Recd fr CIC: Rpt for 1 July 1945.	
605B		20		Tp fr XXI Corps: Recd request from Seventh Army as follows: Request fr 12th Army Gp: The following scientific personnel to be evacuated: SCHNITGER, with wife and four children together with 3 assistants and their families and laboratory equipment. Located in GEHLBERG, J158354, (3d Bn 405 Inf). Mr WILKES of CIOS is on his way to 102d Division to coordinate movmt. They are to be evacuated to HEIDENHEIM. Corps wants us to call them back on whatever action we take.	405 Inf
	011610B	21			

NEW TUBE EXPANDS RADIO POSSIBILITIES

Device Can Send 10,000 Phone Calls at Once, 100 Million Wired Words a Minute

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WIDENS TELEVISION FIELD

Old Broadcast Band Enlarged 800 Times and Improves Service in Accordance

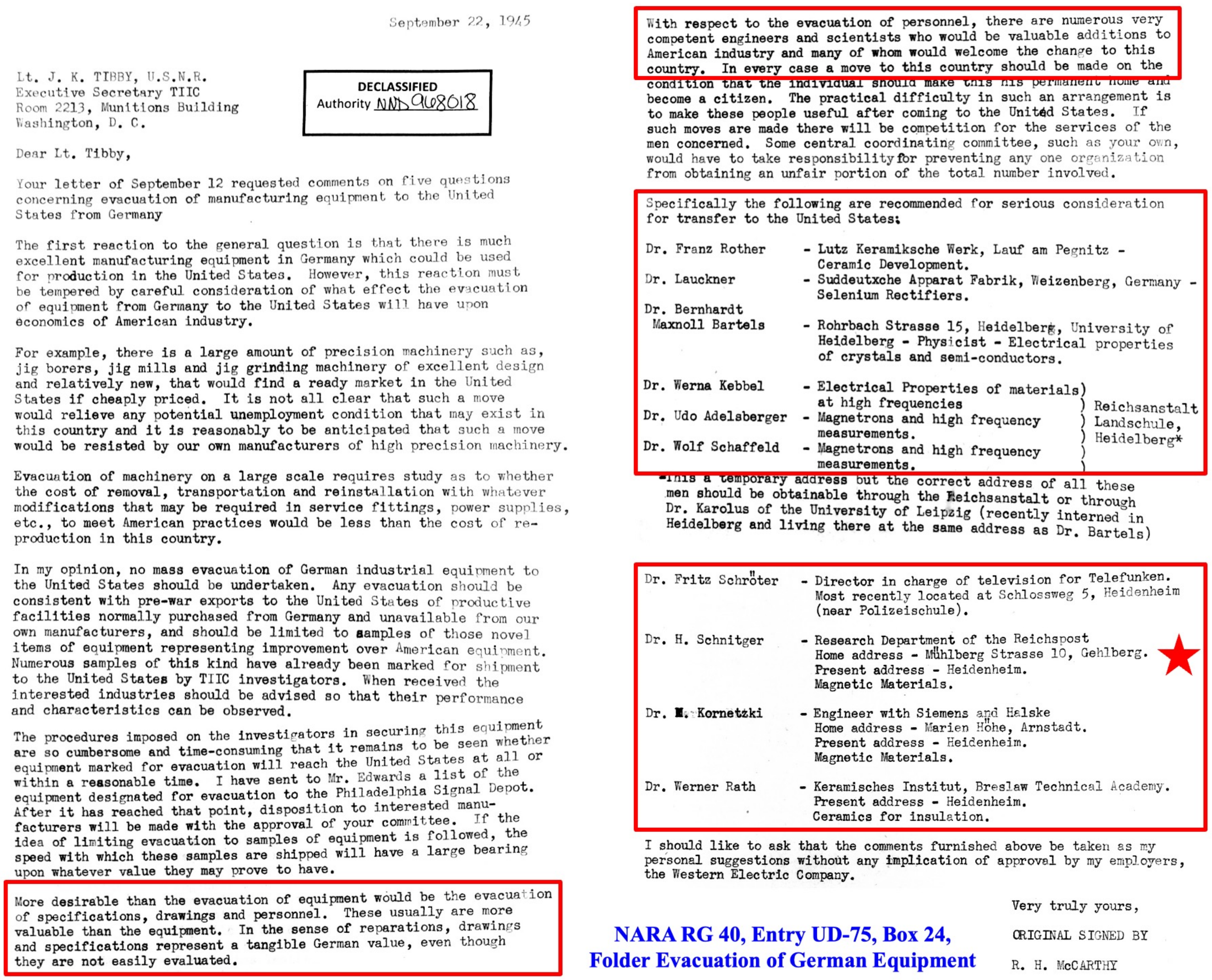
By T. R. KENNEDY Jr.

A novel vacuum tube, not much larger than an ordinary radio receiving bulb, was made public here yesterday. It is expected to do as much for the future of very-high-frequency nation-wide communication as the deForest "audion" did for the broadcast and world-wide telephony and telegraphy pioneers a quarter of a century or more ago.

A product of the Bell Telephone Laboratories, the new device is said to make possible a "wave-guide" network of coast-to-coast proportions over which 10,000 telephone conversations may go simultaneously, or all the television programs needed for all the video stations likely to be operating in this country in years to come.

Figure 6.210: Herbert Schnitger and Dieter Weber in Germany developed traveling wave tube technology that was transferred to AT&T Bell Laboratories after the war [courtesy of Norberto Lahuerta].

Technology Transfer to AT&T Bell Laboratories



September 22, 1945

DECLASSIFIED
Authority NND968018

Lt. J. K. TIBBY, U.S.N.R.
Executive Secretary TIIC
Room 2213, Munitions Building
Washington, D. C.

Dear Lt. Tibby,

Your letter of September 12 requested comments on five questions concerning evacuation of manufacturing equipment to the United States from Germany

The first reaction to the general question is that there is much excellent manufacturing equipment in Germany which could be used for production in the United States. However, this reaction must be tempered by careful consideration of what effect the evacuation of equipment from Germany to the United States will have upon economics of American industry.

For example, there is a large amount of precision machinery such as, jig borers, jig mills and jig grinding machinery of excellent design and relatively new, that would find a ready market in the United States if cheaply priced. It is not all clear that such a move would relieve any potential unemployment condition that may exist in this country and it is reasonably to be anticipated that such a move would be resisted by our own manufacturers of high precision machinery.

Evacuation of machinery on a large scale requires study as to whether the cost of removal, transportation and reinstallation with whatever modifications that may be required in service fittings, power supplies, etc., to meet American practices would be less than the cost of reproduction in this country.

In my opinion, no mass evacuation of German industrial equipment to the United States should be undertaken. Any evacuation should be consistent with pre-war exports to the United States of productive facilities normally purchased from Germany and unavailable from our own manufacturers, and should be limited to samples of those novel items of equipment representing improvement over American equipment. Numerous samples of this kind have already been marked for shipment to the United States by TIIC investigators. When received the interested industries should be advised so that their performance and characteristics can be observed.

The procedures imposed on the investigators in securing this equipment are so cumbersome and time-consuming that it remains to be seen whether equipment marked for evacuation will reach the United States at all or within a reasonable time. I have sent to Mr. Edwards a list of the equipment designated for evacuation to the Philadelphia Signal Depot. After it has reached that point, disposition to interested manufacturers will be made with the approval of your committee. If the idea of limiting evacuation to samples of equipment is followed, the speed with which these samples are shipped will have a large bearing upon whatever value they may prove to have.

More desirable than the evacuation of equipment would be the evacuation of specifications, drawings and personnel. These usually are more valuable than the equipment. In the sense of reparations, drawings and specifications represent a tangible German value, even though they are not easily evaluated.

With respect to the evacuation of personnel, there are numerous very competent engineers and scientists who would be valuable additions to American industry and many of whom would welcome the change to this country. In every case a move to this country should be made on the condition that the individual should make this his permanent home and become a citizen. The practical difficulty in such an arrangement is to make these people useful after coming to the United States. If such moves are made there will be competition for the services of the men concerned. Some central coordinating committee, such as your own, would have to take responsibility for preventing any one organization from obtaining an unfair portion of the total number involved.

Specifically the following are recommended for serious consideration for transfer to the United States:

Dr. Franz Rother	- Lutz Keramiksche Werk, Lauf am Pegnitz - Ceramic Development.
Dr. Lauckner	- Suddeutxche Apparat Fabrik, Weizenberg, Germany - Selenium Rectifiers.
Dr. Bernhardt Maxnoll Bartels	- Rohrbach Strasse 15, Heidelberg, University of Heidelberg - Physicist - Electrical properties of crystals and semi-conductors.
Dr. Werna Kebbel	- Electrical Properties of materials at high frequencies) Reichsanstalt Landschule, Heidelberg*
Dr. Udo Adelsberger	- Magnetrons and high frequency measurements.) Reichsanstalt Landschule, Heidelberg*
Dr. Wolf Schaffeld	- Magnetrons and high frequency measurements.) Reichsanstalt Landschule, Heidelberg*

*This a temporary address but the correct address of all these men should be obtainable through the Reichsanstalt or through Dr. Karolus of the University of Leipzig (recently interned in Heidelberg and living there at the same address as Dr. Bartels)

Dr. Fritz Schröter	- Director in charge of television for Telefunken. Most recently located at Schlossweg 5, Heidenheim (near Polizeischule).
Dr. H. Schnitger	- Research Department of the Reichspost Home address - Mühlberg Strasse 10, Gehlberg. ★ Present address - Heidenheim. Magnetic Materials.
Dr. M. Kornetzki	- Engineer with Siemens and Halske Home address - Marien Höhe, Arnstadt. Present address - Heidenheim. Magnetic Materials.
Dr. Werner Rath	- Keramisches Institut, Breslaw Technical Academy. Present address - Heidenheim. Ceramics for insulation.

I should like to ask that the comments furnished above be taken as my personal suggestions without any implication of approval by my employers, the Western Electric Company.

Very truly yours,

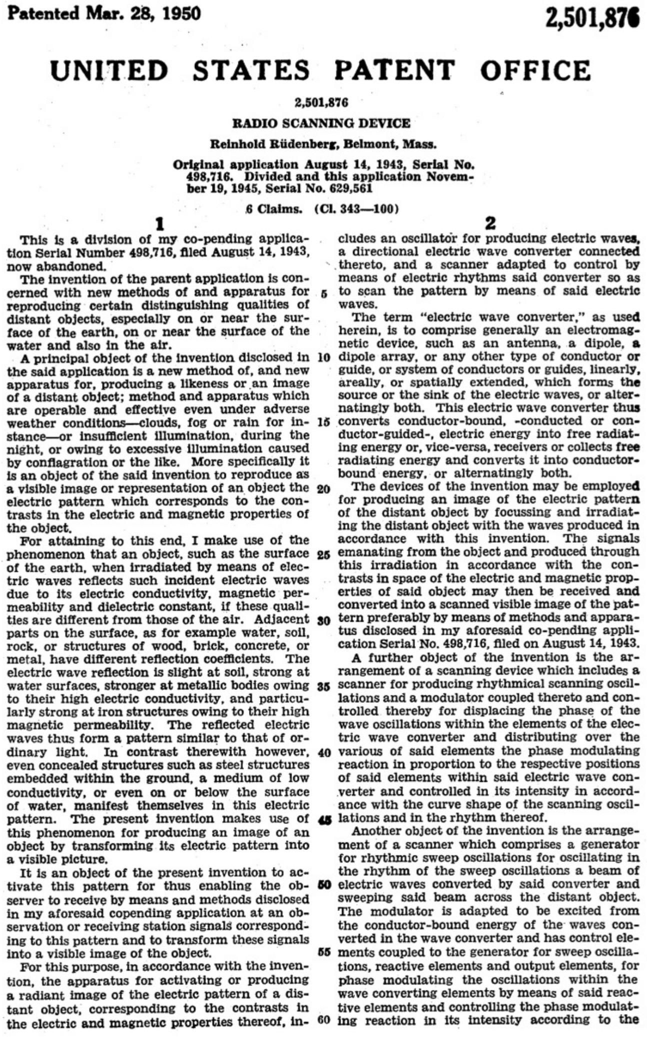
ORIGINAL SIGNED BY

R. H. McCARTHY

NARA RG 40, Entry UD-75, Box 24, Folder Evacuation of German Equipment

Figure 6.211: Herbert Schnitger and Dieter Weber in Germany developed traveling wave tube technology that was transferred to AT&T Bell Laboratories after the war [NARA RG 40, Entry UD-75, Box 24, Folder Evacuation of German Equipment].

Reinhold Rüdenberg (1883–1961)
Phased-array radar systems



Patented Mar. 28, 1950 **2,501,876**

UNITED STATES PATENT OFFICE

2,501,876

RADIO SCANNING DEVICE

Reinhold Rüdenberg, Belmont, Mass.

Original application August 14, 1943, Serial No. 498,716. Divided and this application November 19, 1945, Serial No. 629,561

6 Claims. (Cl. 343—100)

1

This is a division of my co-pending application Serial Number 498,716, filed August 14, 1943, now abandoned.

The invention of the parent application is concerned with new methods of and apparatus for reproducing certain distinguishing qualities of distant objects, especially on or near the surface of the earth, on or near the surface of the water and also in the air.

A principal object of the invention disclosed in the said application is a new method of, and new apparatus for, producing a likeness or an image of a distant object; method and apparatus which are operable and effective even under adverse weather conditions—clouds, fog or rain for instance—or insufficient illumination, during the night, or owing to excessive illumination caused by conflagration or the like. More specifically it is an object of the said invention to reproduce as a visible image or representation of an object the electric pattern which corresponds to the contrasts in the electric and magnetic properties of the object.

For attaining to this end, I make use of the phenomenon that an object, such as the surface of the earth, when irradiated by means of electric waves reflects such incident electric waves due to its electric conductivity, magnetic permeability and dielectric constant, if these qualities are different from those of the air. Adjacent parts on the surface, as for example water, soil, rock, or structures of wood, brick, concrete, or metal, have different reflection coefficients. The electric wave reflection is slight at soil, strong at water surfaces, stronger at metallic bodies owing to their high electric conductivity, and particularly strong at iron structures owing to their high magnetic permeability. The reflected electric waves thus form a pattern similar to that of ordinary light. In contrast therewith however, even concealed structures such as steel structures embedded within the ground, a medium of low conductivity, or even on or below the surface of water, manifest themselves in this electric pattern. The present invention makes use of this phenomenon for producing an image of an object by transforming its electric pattern into a visible picture.

It is an object of the present invention to activate this pattern for thus enabling the observer to receive by means and methods disclosed in my aforesaid copending application at an observation or receiving station signals corresponding to this pattern and to transform these signals into a visible image of the object.

For this purpose, in accordance with the invention, the apparatus for activating or producing a radiant image of the electric pattern of a distant object, corresponding to the contrasts in the electric and magnetic properties thereof, includes an oscillator for producing electric waves, a directional electric wave converter connected thereto, and a scanner adapted to control by means of electric rhythms said converter so as to scan the pattern by means of said electric waves.

2

The term "electric wave converter," as used herein, is to comprise generally an electromagnetic device, such as an antenna, a dipole, a dipole array, or any other type of conductor or guide, or system of conductors or guides, linearly, areally, or spatially extended, which forms the source or the sink of the electric waves, or alternatingly both. This electric wave converter thus converts conductor-bound, -conducted or conductor-guided-, electric energy into free radiating energy or, vice-versa, receivers or collects free radiating energy and converts it into conductor-bound energy, or alternatingly both.

The devices of the invention may be employed for producing an image of the electric pattern of the distant object by focussing and irradiating the distant object with the waves produced in accordance with this invention. The signals emanating from the object and produced through this irradiation in accordance with the contrasts in space of the electric and magnetic properties of said object may then be received and converted into a scanned visible image of the pattern preferably by means of methods and apparatus disclosed in my aforesaid co-pending application Serial No. 498,716, filed on August 14, 1943.

A further object of the invention is the arrangement of a scanning device which includes a scanner for producing rhythmical scanning oscillations and a modulator coupled thereto and controlled thereby for displacing the phase of the wave oscillations within the elements of the electric wave converter and distributing over the various of said elements the phase modulating reaction in proportion to the respective positions of said elements within said electric wave converter and controlled in its intensity in accordance with the curve shape of the scanning oscillations and in the rhythm thereof.

Another object of the invention is the arrangement of a scanner which comprises a generator for rhythmic sweep oscillations for oscillating in the rhythm of the sweep oscillations a beam of electric waves converted by said converter and sweeping said beam across the distant object. The modulator is adapted to be excited from the conductor-bound energy of the waves converted in the wave converter and has control elements coupled to the generator for sweep oscillations, reactive elements and output elements, for phase modulating the oscillations within the wave converting elements by means of said reactive elements and controlling the phase modulating reaction in its intensity according to the

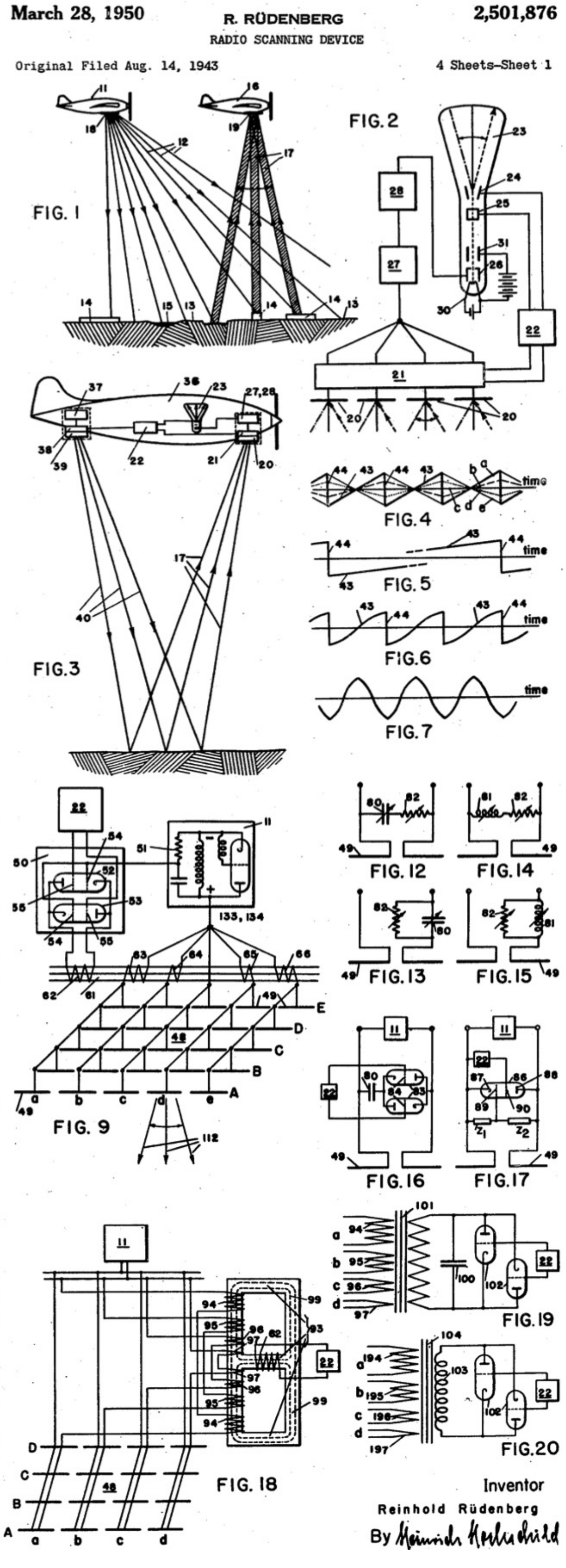


Figure 6.212: Reinhold Rüdenberg (1883–1961) developed phased-array radar systems.

In 1935, information on German radar development and testing reached the United Kingdom. In response, Robert Watson-Watt (Scottish, 1892–1973) began developing a British radar system. That program resulted in the Chain Home radar system. Chain Home was much more primitive than the German radar systems that had inspired it. Whereas the German radars had dishes that could be pointed in any direction or easily moved to other locations, Chain Home was just a series of simple vertical radio towers built at fixed locations on the U.K. coast; it could not be rotated or relocated, and it only detected aircraft over the sea, not over land.

Moreover, Chain Home used a wavelength of around 12 meters (frequency of 25 MHz), while Freya used a much shorter wavelength of around 2.4 meters (frequency of 125 MHz), and Würzburg-Riese had an even shorter wavelength of 0.54 meter (frequency of 560 MHz). That difference in wavelengths meant that the Chain Home antennas had to be 5–22 times larger than the German radar antennas, and Chain Home could only detect objects that were ∼6 meters or larger, whereas Würzburg-Riese could detect objects as small as ∼0.27 meter.

Despite its simplicity, Chain Home was used effectively in defending the United Kingdom from German air raids. In conventional histories written by English-speaking historians after the war, Watson-Watt was erroneously proclaimed to be the "inventor" of radar, and the supposed British lead in radar over Germany was cited as one of the reasons for the Allied victory in the war.

Moreover, in 1940, John Randall (English, 1905–1984) and Harry Boot (English, 1917–1983) began building simple cavity magnetrons for improved British radar systems. Their work was almost certainly based directly on the cavity magnetrons that had been invented, built, and patented internationally five years earlier by Hans Erich Hollmann (which in turn were based on the even earlier work by Gerdien, Habann, and Žáček). Famously, the British cavity magnetron designs were transferred to the United States by Henry Tizard's British Technical and Scientific Mission in September 1940. Most historians in the English-speaking world laud the work of Randall and Boot and the subsequent U.S. work that it inspired, while unfortunately ignoring the documented history of how that radar technology was actually invented years earlier in the German-speaking world and disseminated via international patents and publications.

Even Reginald V. Jones (English, 1911–1997), one of the top physicists in U.K. military science programs during World War II, tried later in life to correct the myths that had accumulated about the alleged British origins and alleged British superiority for radar technologies. In his foreword to David Prichard's *The Radar War*, Jones wrote [Pritchard 1989, pp. 7–8]:

> We in Britain are inclined to think that radar originated in Britain in 1935, stimulated by the threat from the Luftwaffe that was to materialize so dramatically in 1940. It may therefore come as a surprise to find not only that the basic idea of detecting objects by reflected radio waves had been conceived before the First World War, but also that it has been experimentally demonstrated as early as 1904 by a German engineer, Christian Hülsmeyer.
>
> In this book David Pritchard gives much the fullest account of Hülsmeyer's work that is available in the English language, and he then goes on to tell how radar was taken up by the German Armed Services in the years leading up to, and during, World War II. [...]
>
> As the story unfolds, with its many manifestations of German competence in the radio field, we in Britain can be increasingly thankful that the intensity of the Luftwaffe threat

> in the years leading up to 1939 brought our serving officers and scientists together at all levels into a close working relationship: it was this, more than any other factor, which resulted in our lead in the operational use of radar even though in some respects the German equipment was technically better.

The radar historian Pritchard described in detail how WWII British radar experts learned that German radar systems were much more advanced than British systems [Pritchard 1989, pp. 97–99]:

> It is no exaggeration to say that after examining the *Würzburg* [captured in the 28 February 1942 Bruneval raid] the British received quite a surprise.
>
> Even on the way home in the boat D. H. Priest, a radar specialist from TRE [Telecommunications Research Establishment] who had gone on the mission, had had time to examine it, and during an exchange of opinions with Cox came to the conclusion that the Germans had been making it for a long time, possibly even ten years.
>
> Cox, who had been in radio all his life, thought the *Würzburg* was a 'beautiful job', and was particularly impressed by the way it made use of unit construction for easy fault-finding and quick replacement, a view also shared by Jones. [...]
>
> The equipment had therefore to be made so well, and so easily replaceable if any part broke down, that the system could be operated by relatively unskilled personnel.
>
> The superiority of the engineering standard was indeed much higher than the British systems, and to ensure that no lack of morale appeared in engineering and (later) public circles, a story was disseminated (and still believed by some today) that German radar was much inferior to the British. That this was wildly inaccurate is however attested by those who at the time were in possession of the facts, as Jones points out:
>
> > ...the stability of every German radar station was better than that of the best instruments we had available to check them. In fact, Martin Ryle, afterwards to win a Nobel Prize for Radioastronomy, was one of our observers, and he told me that ever afterwards if he wanted to know whether a radar transmission was British or German, all he had to do was to check its stability.
>
> To achieve and maintain these standards, and even to improve upon them in the face of political and military dissension, and in spite of severe disruption of the production lines from Allied bombing, to say nothing of the strain of a war economy, must remain for all time a tribute to the skill and determination of all those involved in the German radar programme.

Because the wartime German radar systems had such advanced capabilities compared to British and American radar systems of the time, after the war they were transferred to other countries to be used and copied. Jones gave several examples [Jones 1978, p. 230]:

> If the German night interception procedure seemed unduly elaborate, the precision of the Giant Würzburg was not entirely wasted on the war: in 1945 specimens were brought to Britain and America and converted to radio telescopes for radioastronomy. Another specimen that remained on site in Holland was used by Dr. van de Hulst to discover the radiation coming in from the hydrogen atoms in the spiral arms of our galaxy on a wavelength of about 21 centimetres.

6.8.2 Radar Countermeasures

Scientists in wartime Germany pioneered radar countermeasures or stealth technologies. They created and tested a variety of radar-absorbing coatings, and gave the best ones names such as Eisenspane and Moltopren.[25] Germany successfully used those radar countermeasures on submarines, and it was developing and testing stealth aircraft as well; see pp. 1768, 1773–1774.[26]

Documentation, materials, and scientists from those wartime programs on radar countermeasures were acquired by Allied countries after the war and became the basis for modern stealth technologies. Some examples are below, but much more historical research on this topic should be conducted and published in the future.

Former Bell Laboratories scientist T. M. Odarenko gave an overview of some of the German programs in FIAT 61, *Radar Camouflage Radiation Absorption Materials*, pp. 1, 12–13:

> The problem of radar camouflage and radiation absorbers is not new to the radar workers in the U.S. The Radiation Laboratories and the War Committee on Dielectrics, among others, were concerned with it. [...] Because of the urgency of other problems, the work in U.S.A., however, did not progress very far. The Germans, on the other side, who placed high hopes in their submarine warfare, and whose submarines suffered severely from high losses due to the radar detection methods of the Allies, invested a great deal of efforts, and of scientific and of technological talents, into the anti-radar methods and devices. The results of their work prove to be of considerable interest to the allied intelligence organizations. [...]
>
> By the end of the European war, the Germans investigated the theoretical approach to the radiation camouflage quite exhaustively. Much practical data was accumulated by the Germans on the tuned and wide-band lossy “impedance-matching” absorbers. In addition, materials were produced successfully with permeability equal to dielectric constant and with reasonably high losses. As the side results of their work on the semiconductors, means were established of introducing high electrical losses into materials.
>
> As the result of the fundamental study of dielectric materials and various ferrites and oxides, new materials were obtained, the electromagnetic constants of which could be controlled by such factors as temperature, magnetic field, etc.
>
> The problem of an ideal radiation absorption material has not been solved in Germany. The Germans, however, went far enough to indicate that further researches on such materials are well worth while. Their failures with certain materials, and their successes with others, might assist this further work considerably if their results with complete reports and data are made promptly available to the proper research organizations in this country and in Great Britain.

---

[25] BIOS 132; BIOS 727; BIOS 869; BIOS 871; CIOS ER 4; CIOS XXVI-24; FIAT 61; NavTecMisEu LR 10-45; NavTecMisEu 90-45.

[26] Horten and Selliger 2012; Jorgensen 2009; Myhra 1998b; Shepelev and Ottens 2015.

> The importance of this work lies in the fact that the materials thus developed would be of interest not only in the strictly military field, where radars have proven of such value, but in the variety of other applications, such as selective shielding, static dissipators, tuned networks, etc.

BIOS 871, *Work of Professor Hüttig on Ferromagnetic Substances for Use in Radar Camouflage*, pp. 4–5, also described some of the wartime programs:

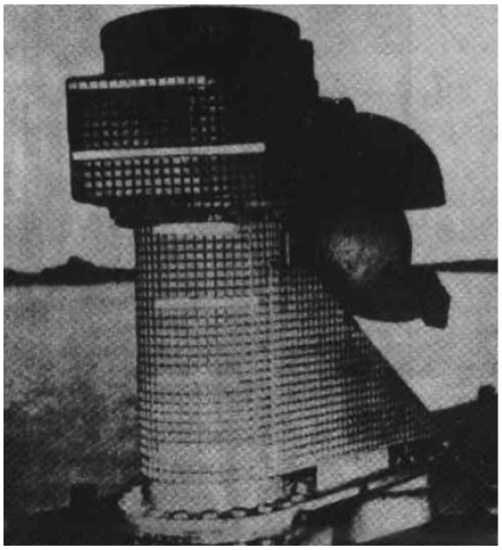
> Hüttig, who is essentially a physical chemist, and specialises in the properties of the solid state, worked on Schornsteinfeger in collaboration with a team including Professor Kafla, physicist, and Professor Flegler, who made the electro-magnetic absorption measurements. Their objective, as has already been noted, was the production of a ferromagnetic material with permeability and dielectric constant equal and high, and if possible lossy. The material first studied and developed to the production state, was gamma iron oxide, and this can be produced on a manufacturing scale with μ equal to *epsilon* equal to 6, with no loss. This material, known as W.61, was manufactured at the DEGUSSA works in Raudnitz-on-Elbe, and was rolled into Buna at Uhrineves, near Prague, giving a product containing 10% Buna and 90% W.61.
>
> Owing to the instability of gamma iron oxide and to the fact that the material is not lossy, attention was then turned to the development of ferrites. [...] A large number was prepared[...]
>
> Hüttig said that the most promising material was probably manganese ferrite from the point of view of giving the properties required, although for consistency in production, magnesium ferrite would be preferable. The best samples of manganese ferrites that his team had prepared had a permeability of 12 and a dielectric constant of 18 with magnetic and dielectric losses both equal to 0.35, the measurements being made at a wave length of 173 cm. [...]
>
> Hüttig was of the opinion that the system ferrous oxide–vanadium oxide was worth study, as the material had a very high ferromagnetism and formed solid solutions with metallic iron.

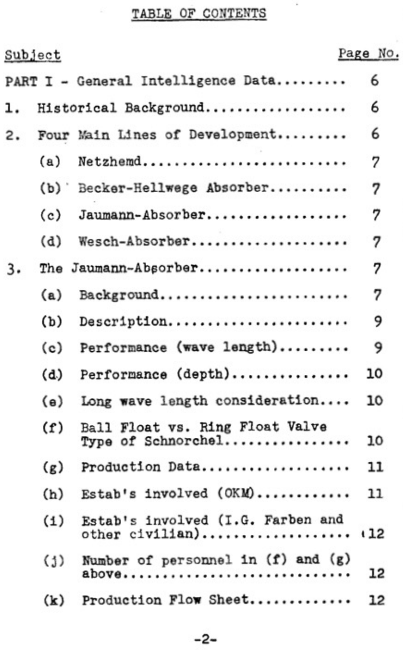
British Aerospace/BAE engineer Ronald Evans explicitly stated how dependent postwar Allied programs to develop stealth aircraft were on wartime German creations [Evans 2015, p. xv]:

> From 1978 until 2005, I was employed by British Aerospace and, after the merger with Marconi, by BAE Systems at their military aircraft site at Warton Aerodrome in Lancashire[...]
>
> I began work at Warton as a senior aerodynamicist in the Performance & Propulsion Group. [...] In 1980 I was tasked with running a radar stealth research programme. Capitalising on German development of radar-absorbing materials (RAM) during the Second World War, the UK became a world leader in reducing the radar signatures of its military aircraft during the 1950s and 1960s. [...] In 1962 there was a large exchange of information on the subject of radar stealth between the UK and US governments.

Radar countermeasures

CIOS XXVI-24





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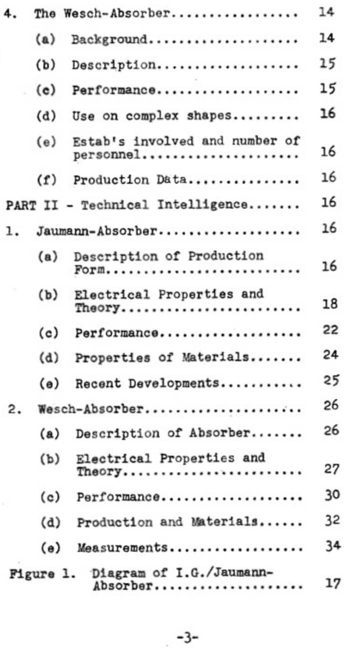

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Udo Adelsberger
(19??–19??)

?? Friedrich
(19??–19??)

?? Helmholz
(19??–19??)

Figure 6.213: Many German-speaking scientists developed a range of radar countermeasures (stealth) technologies during World War II.

Radar countermeasures

Gustav Franz Hüttig
(19??–19??)

?? Patat
(19??–19??)

?? Schaffeld
(19??–19??)

Heinz Schlicke
(1912–2006)

Ludwig Wesch
(19??–19??)

Karl Wolf
(19??–19??)

Figure 6.214: Many German-speaking scientists developed a range of radar countermeasures (stealth) technologies during World War II.

6.8.3 Microwave Heating

According to conventional histories, in October 1945, Percy Spencer (1894–1970), an American with only a high school education working as a business manager at Raytheon, suddenly invented, built, demonstrated, and perfected microwave ovens.

In fact, it was large numbers of highly educated German-speaking scientists at Siemens, Telefunken, and other German companies who worked diligently over the course of a decade to:

1. Invent microwave heating in the 1930s.
2. Perfect and apply it to a wide variety of applications (food preparation, delousing of clothing, glue drying, etc.) during the war.
3. Transfer the technology under duress after the war to Allied countries, which then publicly claimed it as their own postwar invention.

BIOS 866, *High Frequency Heating*, is a key piece of evidence documenting that history (Fig. 6.215):

> [p. 1:] This report contains a survey of the activities in the field of high frequency heating of the German industry and it has been compiled from information gained at 18 targets in the British, U.S. and French zones. It deals chiefly with work at Radio Frequencies and is not concerned with the use of rotating machines.
>
> Most of the activity has been confined to the large electrical firms particularly SIEMENS SCHUKERT, A.E.G. and TELEFUNKEN, and mainly in the Berlin sections of these companies.
>
> It would appear that in 1939 the Germans were fully aware of the industrial possibilities of high frequency heating and were reasonably far advanced in the techniques involved. During the war practically all the effort was devoted to essential war work and development appears to have been impeded to a considerable extent by government restrictions on the use of valves.
>
> Practically no equipment was seen. It was reputed to have been destroyed by bombing or removed by the Russians. Sets up to 20 kW or thereabouts had been made in some quantities for surface hardening and larger sets up to 200 kW for this field had been planned.
>
> Dielectric heating had been experimented with in many fields such as wood gluing; drying of timber, cigarettes etc; plastics heating; lice-killing and food processing. Only wood gluing for aircraft and lice killing in soldiers' uniforms had been applied on any scale.
>
> [p. 16:] (ix) SIEMENS-SCHUKERT WERKE BERLIN-SIEMENSSTADT [...]
>
> Induction Heating had been applied to surface hardening of gears and other articles at frequency of 100-200 kc/s using powers up to 200 kW.
>
> Dielectric Heating had been tried with wood drying, wood gluing, rubber vulcanisation, tobacco drying, plastics heating, milk sterilisation, wheat drying, meat cooking and

> drying, and killing of lice. Only wood gluing and lice killing had been put into practical application.
>
> Personnel Interviewed.
>
> > Mr. BENKERT, director and works manager.
> > Dr. MAIER, assistant to Mr. BENKERT.
> > Mr. ASCHMANN, in charge of industrial applications.
> > Dr. SCHNECKE, in charge of equipment design.
> > Dr. TSCHERMAK, in charge of dielectric heating.
> > Mr. KEUTNER, dielectric heating.
>
> [p. 18:] (a) Wood gluing: This was done chiefly for the aircraft industry and when the war ended 12 sets at 6 Mc and 20 kW had been installed for making plywood and general gluing of aircraft parts. [...]
>
> [p. 19:] (b) Killing lice in garments: The sets operated at 25 Mc/s with a power of 30–40 kW and 3 stationary and 1 mobile equipments had been supplied to the WEHRMACHT for treating uniforms. The uniforms were sprayed with water then carried through a condenser field on a leather conveyor at the rate of 400 Kg of clothing per hour. It was claimed that lice, eggs and typhoid bacteria were all killed.
>
> [pp. 22–23:] (xii) TELEFUNKEN.
> BERLIN-SCHÖNEBERG, MAXSTRASSE 10. [...]
>
> Dr. FRANZ stated that the limited resources available for H.F. Heating were being devoted in the first place to heating of foods with a view to making the most of the supplies available. After food heating work would be done on plastics.
>
> In conjunction with SAROTTI, a subsidiary of NESTLES experiments were being done on pre heating grain or flour. It was found that Rye flour heated in this way to a temperature of 150^{o}C had improved quality and it could be used in place of wheat flour for making soups. Cereals treated similarly by H.F. heating could be kept easily and were in a pre-cooked state requiring little cooking when they were to be used.
>
> The experiments were being done on a small scale with a 1 kW oscillator on a frequency between 15 and 30 Mc/s. About 0.5W per gm were required.
>
> Dr. FRANZ considered that there was quite a future for this activity.
>
> Demonstration experiments on cooking potatoes were mentioned. It had been found with H.F. heating that the water need not boil as long as in ordinary potato cooking. Thermocouple measurements had shown that with the H.F. heating the potato temperature was in advance of the water temperature.
>
> These food experiments were being done in co-operation with the "Food Institute".

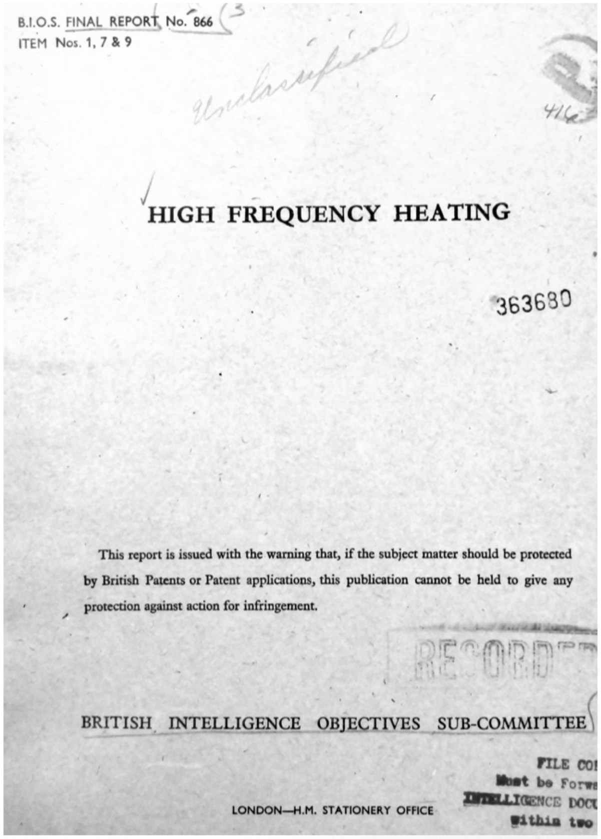
As the above document mentioned, German-speaking scientists also invented and perfected induction heating, which is now used in the most modern type of stovetops.

Microwave ovens were developed by 1939 by scientists at:

- **AEG**
- **Siemens Schuckert**
- **Telefunken**
- **Etc.**

Demonstrated applications:

- **Food preparation**
- **Wood glue drying**
- **Drying of timber**
- **Killing lice in clothing**
- **Etc.**



B.I.O.S. FINAL REPORT No. 866 (3
ITEM Nos. 1, 7 & 9

Unclassified

416

HIGH FREQUENCY HEATING

363680

This report is issued with the warning that, if the subject matter should be protected by British Patents or Patent applications, this publication cannot be held to give any protection against action for infringement.

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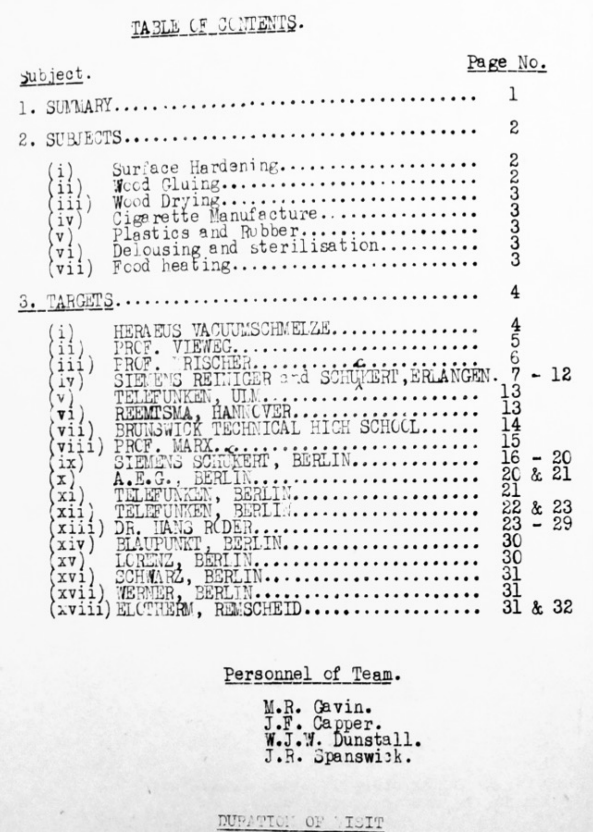

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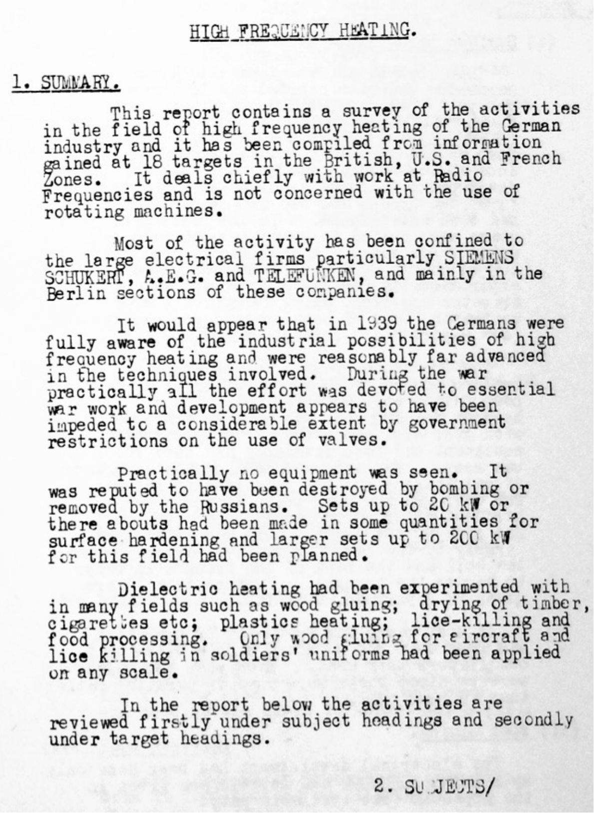
Personnel of Team.

M.R. Gavin.
J.F. Capper.
W.J.W. Dunstall.
J.R. Spanswick.

DURATION OF VISIT



HIGH FREQUENCY HEATING.

1. SUMMARY.

This report contains a survey of the activities in the field of high frequency heating of the German industry and it has been compiled from information gained at 18 targets in the British, U.S. and French Zones. It deals chiefly with work at Radio Frequencies and is not concerned with the use of rotating machines.

Most of the activity has been confined to the large electrical firms particularly SIEMENS SCHUKERT, A.E.G. and TELEFUNKEN, and mainly in the Berlin sections of these companies.

It would appear that in 1939 the Germans were fully aware of the industrial possibilities of high frequency heating and were reasonably far advanced in the techniques involved. During the war practically all the effort was devoted to essential war work and development appears to have been impeded to a considerable extent by government restrictions on the use of valves.

Practically no equipment was seen. It was reputed to have been destroyed by bombing or removed by the Russians. Sets up to 20 kW or there abouts had been made in some quantities for surface hardening and larger sets up to 200 kW for this field had been planned.

Dielectric heating had been experimented with in many fields such as wood gluing; drying of timber, cigarettes etc; plastics heating; lice-killing and food processing. Only wood gluing for aircraft and lice killing in soldiers' uniforms had been applied on any scale.

In the report below the activities are reviewed firstly under subject headings and secondly under target headings.

2. SUBJECTS/

Figure 6.215: Microwave ovens were developed no later than 1939 by scientists at AEG, Siemens Schuckert, Telefunken, and other laboratories. They were demonstrated to be effective for applications including food preparation, wood glue drying, drying of timber, killing lice in clothing, etc. The technology was transferred to Allied countries after the war [BIOS 866].

6.8.4 Sonar

German-speaking scientists invented underwater acoustic ranging and imaging technology in the early twentieth century and developed highly sophisticated and specialized systems by the 1930s and early 1940s.[27] This technology is now best known by the WWII-era American name sonar (originally an acronym derived from SOund NAvigation Ranging). In many early Allied documents, this technology was also called ASDIC (after the Anti-Submarine Division).

Alexander Behm (German, 1880–1952) invented and demonstrated sonar in 1912. Leo Löwenstein (German, 1879–1956) was another early German sonar pioneer. Independent work on sonar began in other countries within that same decade, especially in response to Germany's use of submarine warfare in World War I.

German-speaking scientists steadily improved sonar technology from World War I through World War II. By World War II, at least four companies had large programs developing and manufacturing sonar systems:

1. Atlas Werke based in Bremen.
2. Electroacustic Kommanditgesellschaft (ELAC) based in Kiel.
3. GEMA (Gesellschaft für Elektroakustische und Mechanische Apparate) based in Berlin.
4. AEG (Allgemeine Elektrizitäts-Gesellschaft) based in Berlin.

Improvements to German sonar technologies continued until the end of World War II, at which point they were transferred to Allied countries. For example, NavTecMisEu 530-45, *Sonar in the German Navy*, p. 2, stated:

> The GHG is the German counterpart of the multi-spot equipments which were abandoned in the U.S. before the war. The Germans, however, carried the principle to a much higher degree of development and appear to have attained excellent results. The GHG ordinarily permits detection at much longer range than supersonic [ultrasonic] listening or echo ranging gear.
>
> The other important class of German equipment is the S Anlage for echo ranging and supersonic listening. This apparatus was well designed, with emphasis on simplicity and reliability.

German companies also applied sonar methods to the air to create sonic altimeters for aircraft.[28]

After the war, many German sonar experts continued their work in Allied countries.

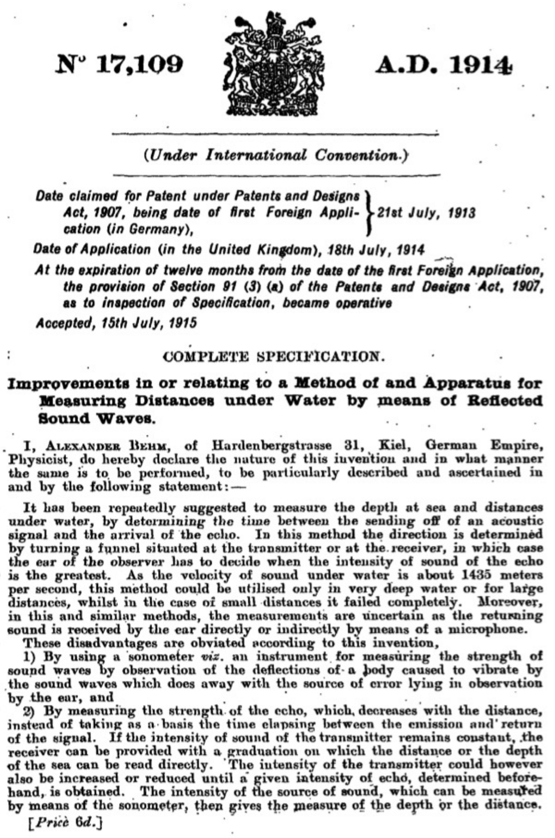
Robert Adler (Austrian, 1913–2007) invented ultrasonic remote control systems; see p. 1012.

---

[27] E.g., CIOS XXVIII-52, *German Submarine and Anti-Submarine Methods and Equipment*; NavTecMisEu 530-45, *Sonar in the German Navy.*

[28] CIOS XXXII-76, *A Sonic Altimeter for Aircraft*; NavTecMisEu 196-45, *A Sonic Altimeter for Aircraft (Landehoehenmesser).*

Alexander Behm (1880–1952)
invented sonar (1912)



Nº 17,109 **A.D. 1914**

(Under International Convention.)

Date claimed for Patent under Patents and Designs Act, 1907, being date of first Foreign Application (in Germany), } *21st July, 1913*

Date of Application (in the United Kingdom), 18th July, 1914

At the expiration of twelve months from the date of the first Foreign Application, the provision of Section 91 (3) (a) of the Patents and Designs Act, 1907, as to inspection of Specification, became operative

Accepted, 15th July, 1915

COMPLETE SPECIFICATION.

Improvements in or relating to a Method of and Apparatus for Measuring Distances under Water by means of Reflected Sound Waves.

I, ALEXANDER BEHM, of Hardenbergstrasse 31, Kiel, German Empire, Physicist, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

It has been repeatedly suggested to measure the depth at sea and distances under water, by determining the time between the sending off of an acoustic signal and the arrival of the echo. In this method the direction is determined by turning a funnel situated at the transmitter or at the receiver, in which case the ear of the observer has to decide when the intensity of sound of the echo is the greatest. As the velocity of sound under water is about 1435 meters per second, this method could be utilised only in very deep water or for large distances, whilst in the case of small distances it failed completely. Moreover, in this and similar methods, the measurements are uncertain as the returning sound is received by the ear directly or indirectly by means of a microphone.

These disadvantages are obviated according to this invention,

1) By using a sonometer *viz.* an instrument for measuring the strength of sound waves by observation of the deflections of a body caused to vibrate by the sound waves which does away with the source of error lying in observation by the ear, and

2) By measuring the strength of the echo, which decreases with the distance, instead of taking as a basis the time elapsing between the emission and return of the signal. If the intensity of sound of the transmitter remains constant, the receiver can be provided with a graduation on which the distance or the depth of the sea can be read directly. The intensity of the transmitter could however also be increased or reduced until a given intensity of echo, determined beforehand, is obtained. The intensity of the source of sound, which can be measured by means of the sonometer, then gives the measure of the depth or the distance.

[*Price 6d.*]

Fig. 1.

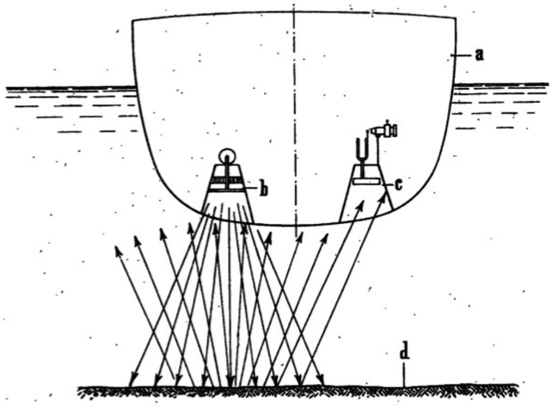


Fig. 2.

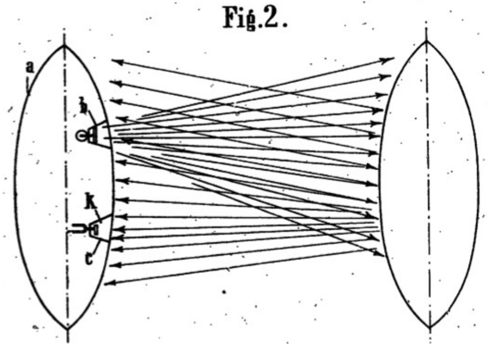


Fig. 3.

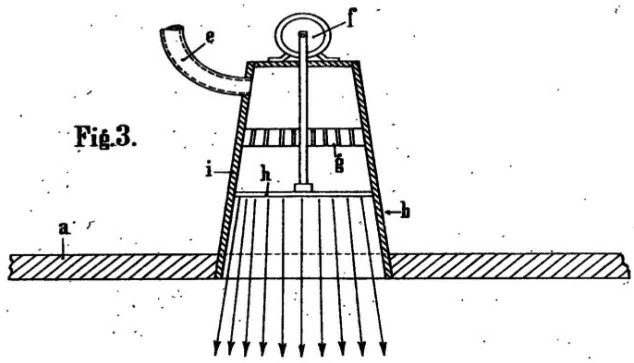


Fig. 4.

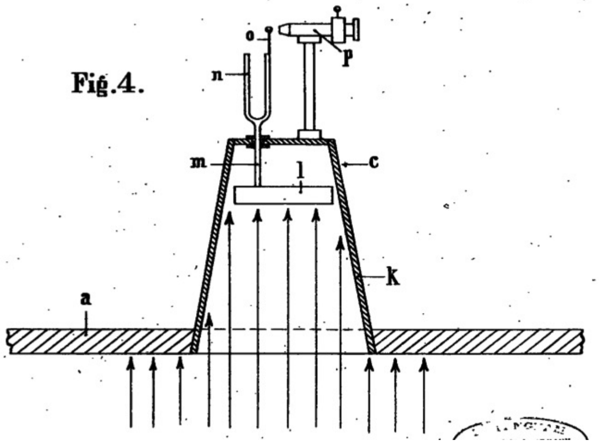
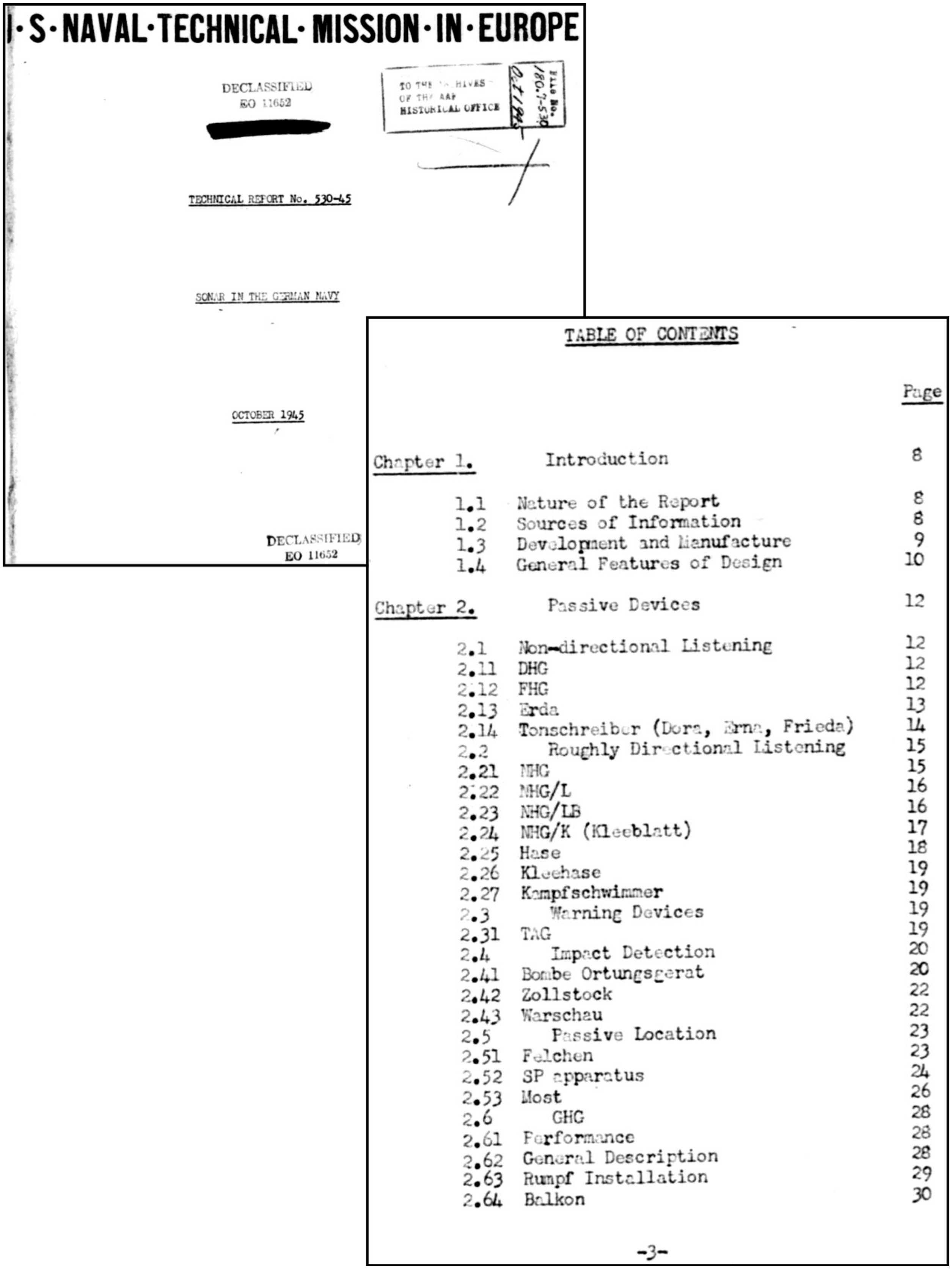


Figure 6.216: Alexander Behm invented and demonstrated sonar in 1912, and filed patents on it in 1913.



·S·NAVAL·TECHNICAL·MISSION·IN·EUROPE

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EO 11652
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TO THE ARCHIVES
OF THE AAF
HISTORICAL OFFICE
File No.
180.7-530
Oct 1945

TECHNICAL REPORT No. 530-45

SONAR IN THE GERMAN NAVY

OCTOBER 1945

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Figure 6.217: Atlas Werke, ELAC, GEMA, and AEG developed highly sophisticated and specialized sonar systems [NavTecMisEu 530-45].

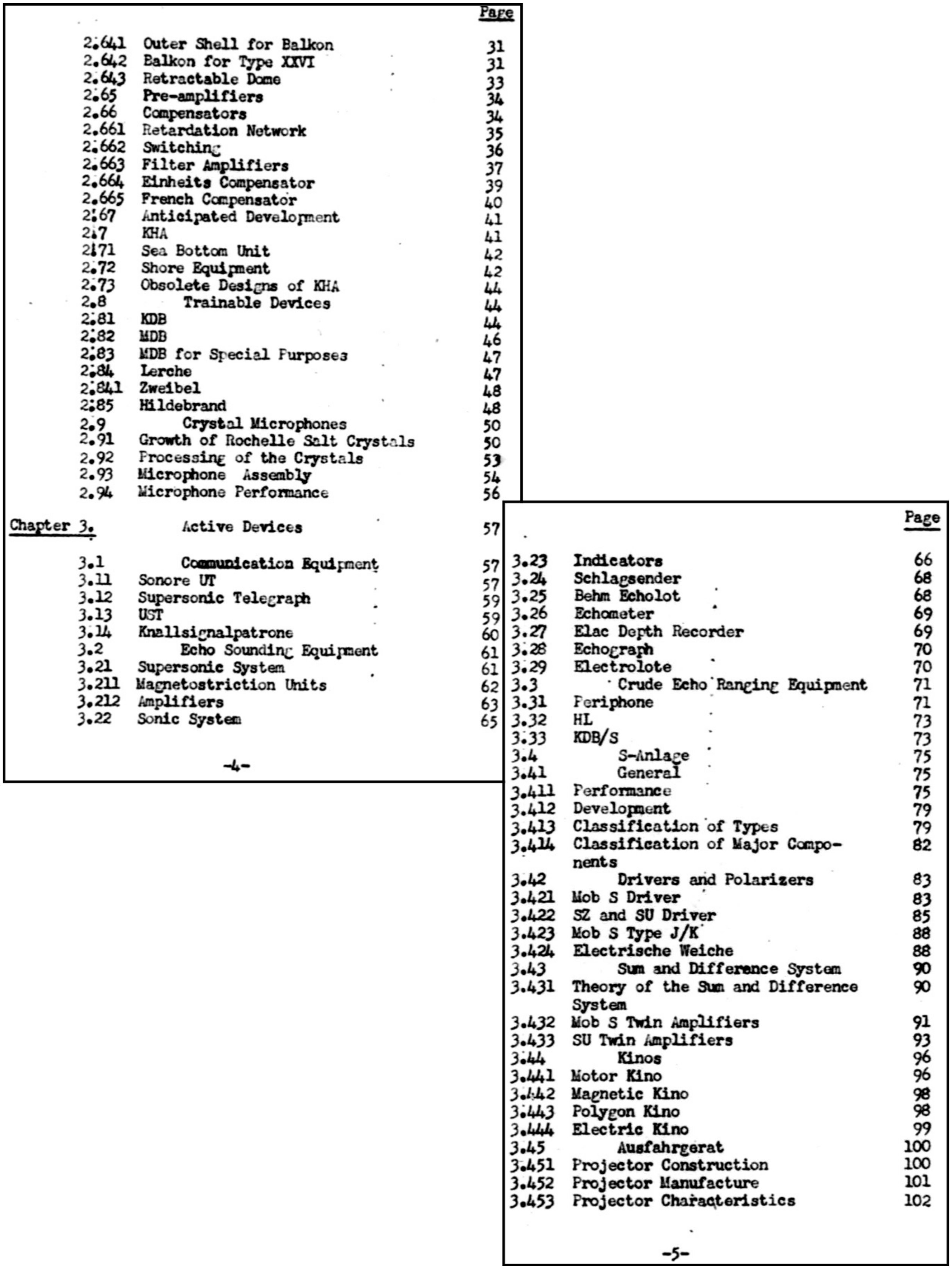

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Figure 6.218: Atlas Werke, ELAC, GEMA, and AEG developed highly sophisticated and specialized sonar systems [NavTecMisEu 530-45].

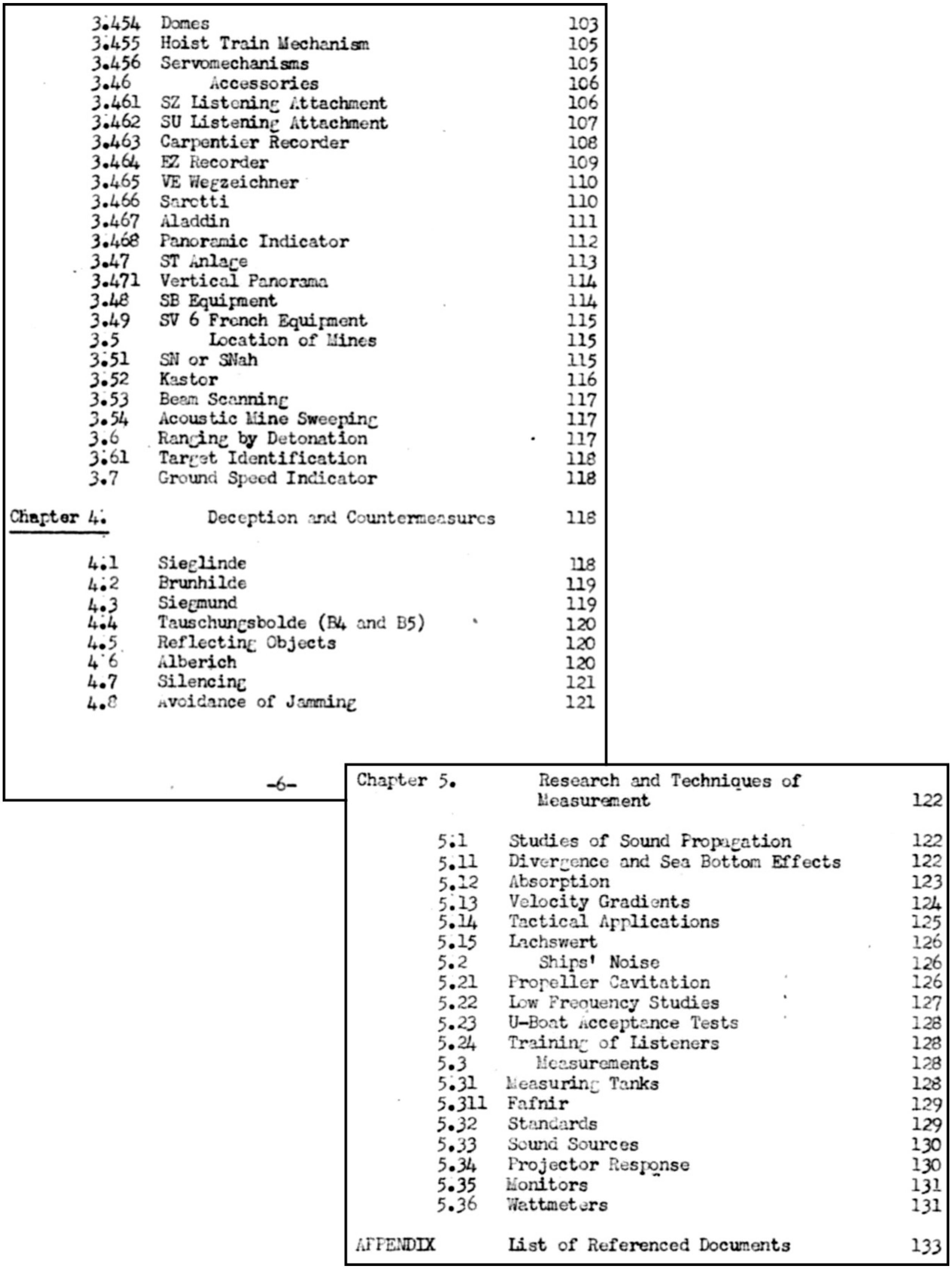

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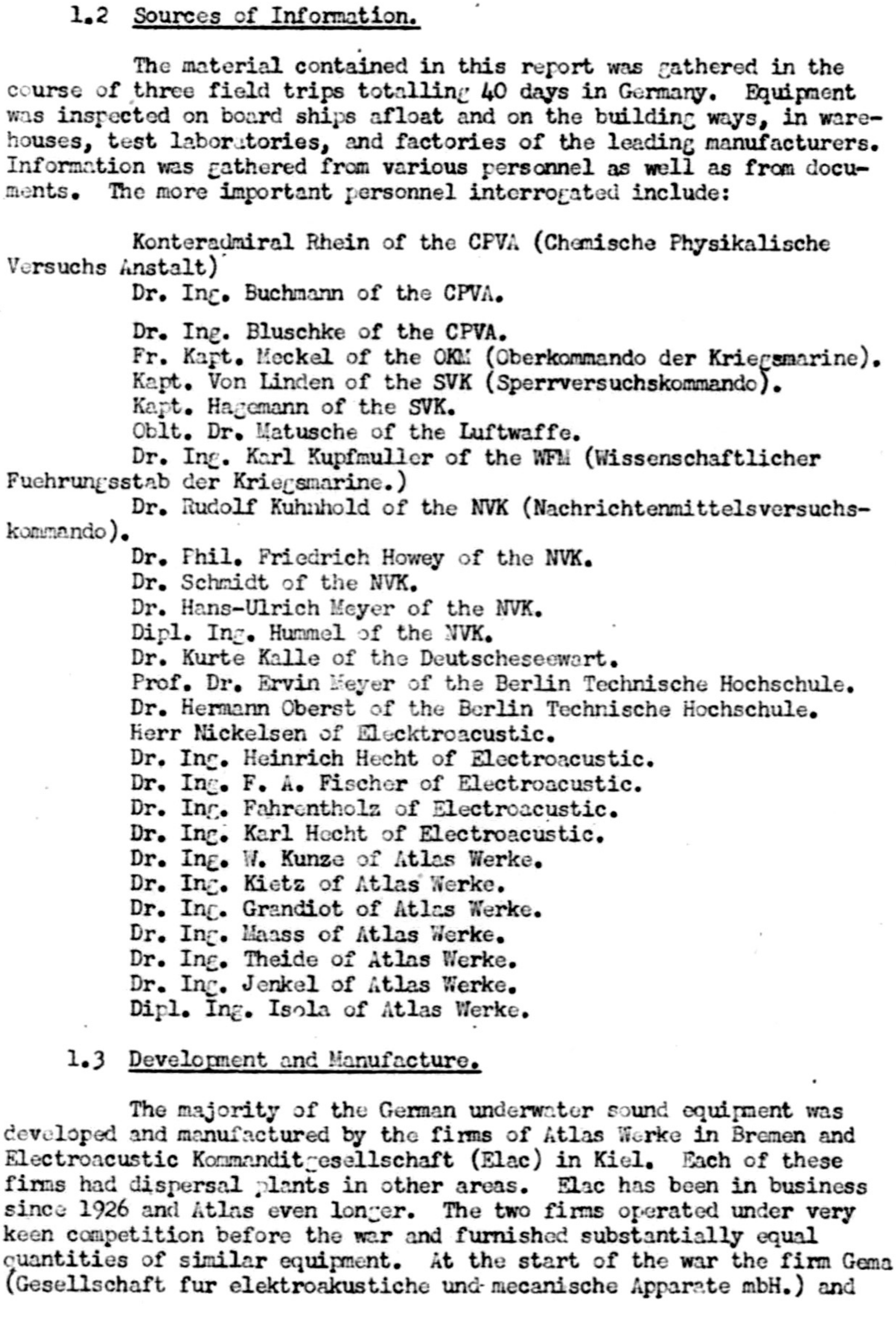
Figure 6.219: Atlas Werke, ELAC, GEMA, and AEG developed highly sophisticated and specialized sonar systems [NavTecMisEu 530-45].



1.2 Sources of Information.

The material contained in this report was gathered in the course of three field trips totalling 40 days in Germany. Equipment was inspected on board ships afloat and on the building ways, in warehouses, test laboratories, and factories of the leading manufacturers. Information was gathered from various personnel as well as from documents. The more important personnel interrogated include:

Konteradmiral Rhein of the CPVA (Chemische Physikalische Versuchs Anstalt)
Dr. Ing. Buchmann of the CPVA.

Dr. Ing. Bluschke of the CPVA.
Fr. Kapt. Meckel of the OKM (Oberkommando der Kriegsmarine).
Kapt. Von Linden of the SVK (Sperrversuchskommando).
Kapt. Hagemann of the SVK.
Oblt. Dr. Matusche of the Luftwaffe.
Dr. Ing. Karl Kupfmuller of the WFM (Wissenschaftlicher Fuehrungsstab der Kriegsmarine.)
Dr. Rudolf Kuhnhold of the NVK (Nachrichtenmittelsversuchskommando).
Dr. Phil. Friedrich Howey of the NVK.
Dr. Schmidt of the NVK.
Dr. Hans-Ulrich Meyer of the NVK.
Dipl. Ing. Hummel of the NVK.
Dr. Kurte Kalle of the Deutscheseewart.
Prof. Dr. Ervin Meyer of the Berlin Technische Hochschule.
Dr. Hermann Oberst of the Berlin Technische Hochschule.
Herr Nickelsen of Elecktroacustic.
Dr. Ing. Heinrich Hecht of Electroacustic.
Dr. Ing. F. A. Fischer of Electroacustic.
Dr. Ing. Fahrentholz of Electroacustic.
Dr. Ing. Karl Hecht of Electroacustic.
Dr. Ing. W. Kunze of Atlas Werke.
Dr. Ing. Kietz of Atlas Werke.
Dr. Ing. Grandiot of Atlas Werke.
Dr. Ing. Maass of Atlas Werke.
Dr. Ing. Theide of Atlas Werke.
Dr. Ing. Jenkel of Atlas Werke.
Dipl. Ing. Isola of Atlas Werke.

1.3 Development and Manufacture.

The majority of the German underwater sound equipment was developed and manufactured by the firms of Atlas Werke in Bremen and Electroacustic Kommanditgesellschaft (Elac) in Kiel. Each of these firms had dispersal plants in other areas. Elac has been in business since 1926 and Atlas even longer. The two firms operated under very keen competition before the war and furnished substantially equal quantities of similar equipment. At the start of the war the firm Gema (Gesellschaft fur elektroakustiche und mecanische Apparate mbH.) and

Figure 6.220: Atlas Werke, ELAC, GEMA, and AEG developed highly sophisticated and specialized sonar systems [NavTecMisEu 530-45].

6.8.5 Sonar Countermeasures

German-speaking scientists led by Erwin Meyer (German, 1899–1972) invented, perfected, and installed highly effective sonar-absorbing rubber coatings (code-named Alberich) on submarines such as U-480.[29]

BIOS 526, *Development and Manufacture of Alberich*, pp. 3–4, summarized the history of that program:

> 2. Organisation:
>
> Dr. Kieskalt was head of the section at I.G. Farben concerned with the development of anti-asdic coverings for submarines. The section was directly under the control of N.V.K. with Professor Erwin Meyer of the Technische Hochschule, Berlin, as Scientific Advisor. Professor Meyer was also in touch with the section through Dr. Oberst, a member of his team at the Hochschule.
>
> The scientific and development work was carried out at I.G. Farben at first by Dr. Brennschede, a physical chemist, and later by Drs. Patat and Mehnert. Patat, a physical chemist, was more concerned with the chemistry of the material, while Mehnert, a physicist under the guidance of Meyer was responsible for the designing and testing of the punched material. Dr. Ing. Laüer, who was employed at one time by Meyer, assisted Mehnert with the measurements which were made at Höchst and at Pelzerhaken.
>
> Engineering and workshop requirements were controlled by Ob. Ing. Geiger with Ing. Möller, Rechert, and Wieswar assisting. Geiger was a reserve U-boat Captain who was brought back at Kieskalt's request in April 1940. Rechert dealt with the firm of Sorst & Co., Hanover, who was responsible for the punching of the sheets. Wieswar was at Offenbach supervising the cementing of the sheets and Möller was responsible for the actual covering of the boats in the yards.
>
> The cements were manufactured at Höchst and were developed by Dr. Schaich, assisted by Dr. Koren.
>
> The buna sheet forming the basis of the material was manufactured by three or four specialist firms and sent to I.G. Farben at Offenbach, to be ground to the requisite thickness. Part of the material was then forwarded to Hanover to be punched by Ernst Sorst & Co., who returned it to Frankfurt where at I.G. Farben, Offenbach, the finished two-ply covering was produced and wrapped ready for shipment to the yards. Testing of samples was carried out at I.G. Farben, Höchst.
>
> Shortly before the end of the war plans were being made for the centralisation of the manufacturing processes in a new factory at Einbek, Hanover, to be under the direction of Sörst. A programme involving the covering of 80 boats was planned to take effect from April, 1945. Up to the cessation of hostilities with Germany only 10 boats had been covered, including two experimental models.

---

[29] Ruthven and Bardehle 2009; BIOS 210; BIOS 526; CIOS XXIV-8; NavTecMisEu 352-45.

3. Early attempts by I.G. Farben to solve the problem:

Kieskalt stated that early in 1940 he developed a sound absorbent surface for anti-asdic work which comprised a number of rubber cones filled with a plastic material, such as "Mowilith". Designed for a frequency range of 7–15 kc/s, said to be that of our asdics, the cones were about 100 mm. in height and spaced 50 mm. apart. Trials in the Baltic were carried out in the spring of 1941 with a submarine U-9 coated with the material but it was apparent that this solution was not a practical one.

4. Development of Alberich:

In 1941 Professor Erwin Meyer, in the search for a solution which could be used under operational conditions, introduced the idea of a resonant absorber composed of a two-ply rubber sheet, one ply of which is perforated. The theory underlying the operation of this material has already been discussed with Meyer (v. SRE/I/206) and Kieskalt had nothing further to add to this aspect of the problem.

5. Choice of raw material:

Preliminary experiments on this resonant type of absorber using existing rubber mixes, such as those prepared for the manufacture of linings for chemical engineering plant, enabled more precise requirements to be formulated. Important features, distinct from the dynamical properties of the material, were:-

(a) resistance to oil and sea-water.

(b) non-ageing.

(c) capable of being cemented to self and to the hull of a submarine.

(d) resistance to mechanical wear and abrasion.

6. Manufacture of sheet and cement:

[...]

After the war, scientists, materials, and information related to sonar countermeasures were transferred to Allied countries, guiding further work in this area.

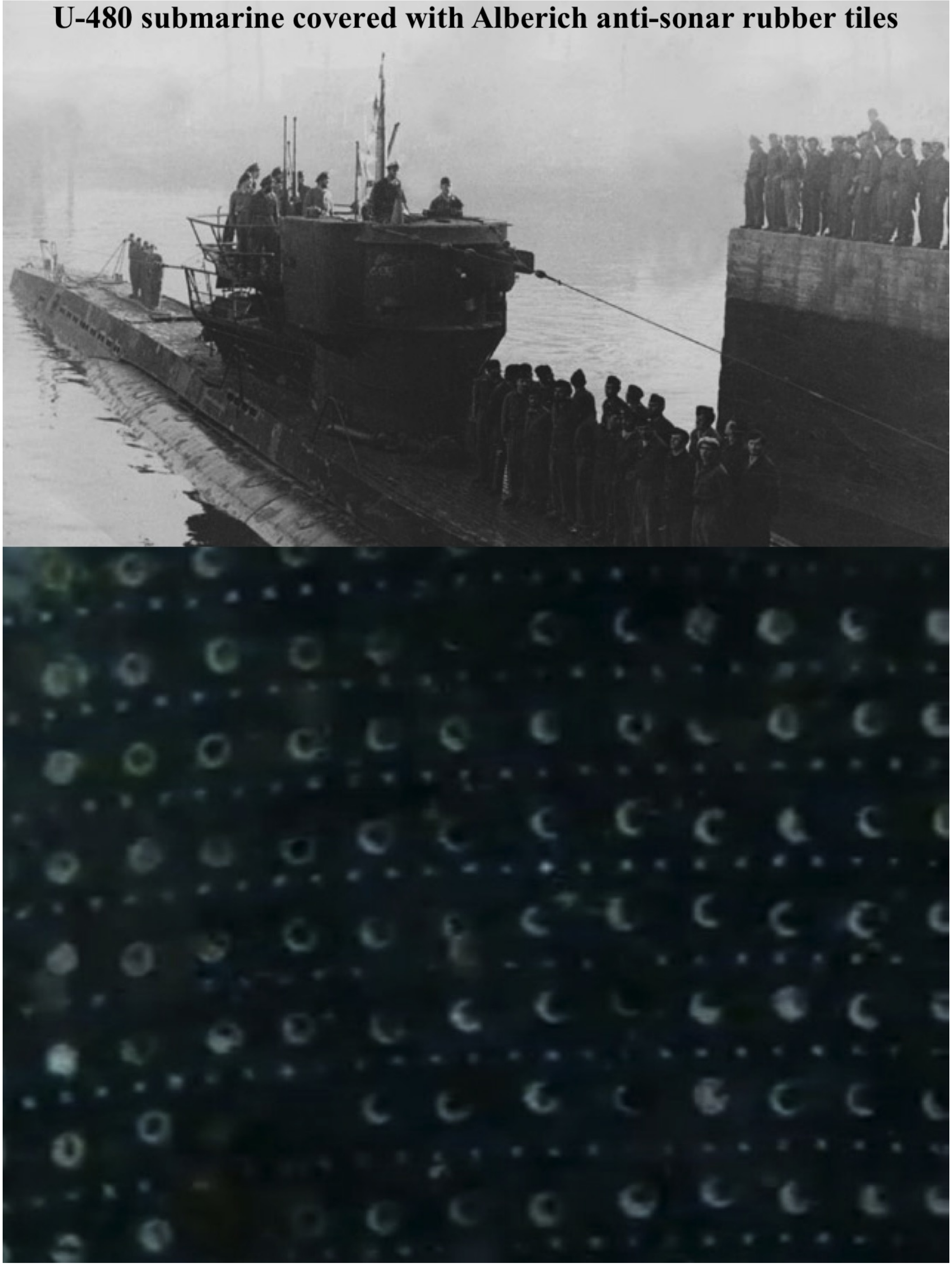


Figure 6.221: U-480 submarine covered with Alberich anti-sonar rubber tiles.

6.8.6 Ultrasound Imaging

During World War II, German-speaking scientists developed and demonstrated ultrasound imaging systems for both industrial and medical applications [Woo 2006; BIOS 609; BIOS 1679]. After the war, those technologies and in many cases the scientists themselves were transferred to Allied countries to optimize and commercialize ultrasound imaging in those countries.

Some of the major creators who developed ultrasound imaging systems included (Fig. 6.222):

- Karl Theodore Dussik (Austrian, 1908–1968) pioneered the use of ultrasound imaging for medical applications, beginning with his first research proposals in 1941, first hardware in 1942, and first experiments with medical imaging around 1945.
- Carl Hellmuth Hertz (German, 1920–1990), the son of Gustav Hertz (p. 893) and great nephew of Heinrich Hertz (p. 854), developed echocardiography, which uses ultrasonic waves and acoustic signal recording and imaging methods to analyze heart function. He obtained the first echocardiogram in 1953 (p. 336). He also developed inkjet printing.
- Theodor Hueter (German, 19??–19??) developed ultrasound imaging systems at Siemens during the war, and at MIT and Raytheon in the United States after the war.
- Paul Kretz (Austrian, 19??–19??) founded Kretztechnik after the war and produced ultrasound imaging systems for both industrial and medical applications.
- Carl Kretz (Austrian, 1932–20??), the nephew of Paul Kretz, joined Kretztechnik and took over the development of improved ultrasound imaging systems.
- Heinrich Netheler (German, 1909–1999) began developing ultrasound imaging systems for medical applications in 1943. After the war, he founded the company that ultimately became known as Eppendorf to continue developing that and other biomedical technologies.
- Reimar Pohlman (German, 1907–1978) at Siemens developed and demonstrated ultrasound imaging systems for industrial applications by 1943. See Fig. 6.223.

During World War II, German-speaking scientists also invented and successfully demonstrated acoustic systems for sonication of materials and for other applications. Those technologies were also transferred to Allied countries after the war.

For more information, see Section C.4.

6.8.7 Acoustic Weapons

Richard Wallauschek (Austrian/Czech, 1912–1962), a physicist from Telefunken, was funded by Albert Speer during the war to create acoustic weapons at a dedicated laboratory in Lofer, Austria. By 1945, he had developed and demonstrated an incapacitating weapon that could create a focused beam of sound waves with 134 dB (1 millibar) of intensity at a distance of 60 meters (Fig. 6.224). His technology was transferred to Allied countries [CIOS XXXII-77] and led to modern systems such as the Long-Range Acoustic Device (LRAD).

For more information, see Section C.4.

Ultrasound imaging
Karl Theodore Dussik (1908–1968)
Carl Hellmuth Hertz (1920–1990)
Theodor Hueter (19??–19??)
Carl Kretz (1932–20??)
Paul Kretz (19??–19??)
Heinrich Netheler (1909–1999)
Reimar Pohlman (1907–1978)

Figure 6.222: Creators who developed ultrasound imaging systems included Karl Theodore Dussik, Carl Hellmuth Hertz, Theodor Hueter, Carl Kretz, Paul Kretz, Heinrich Netheler, and Reimar Pohlman.

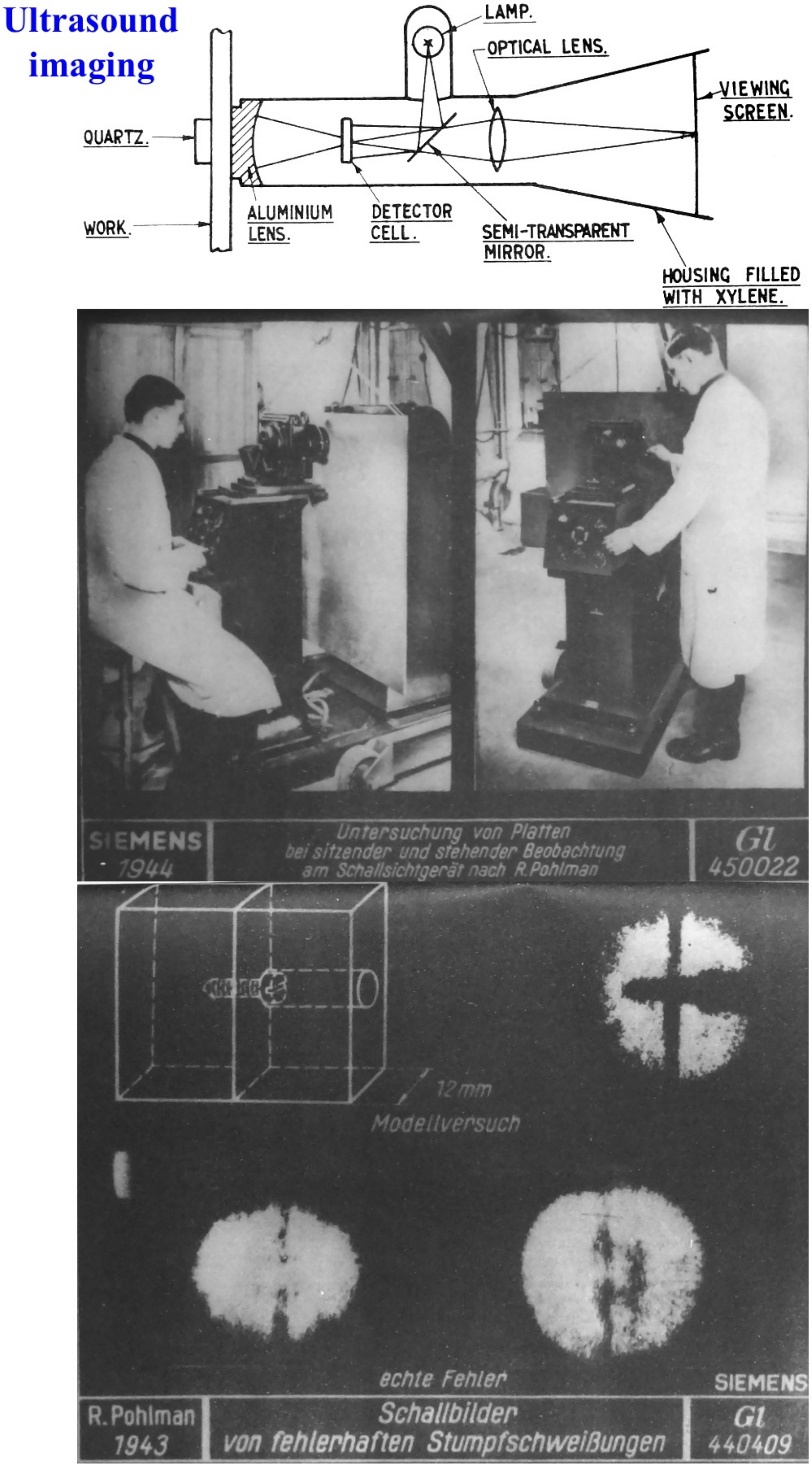
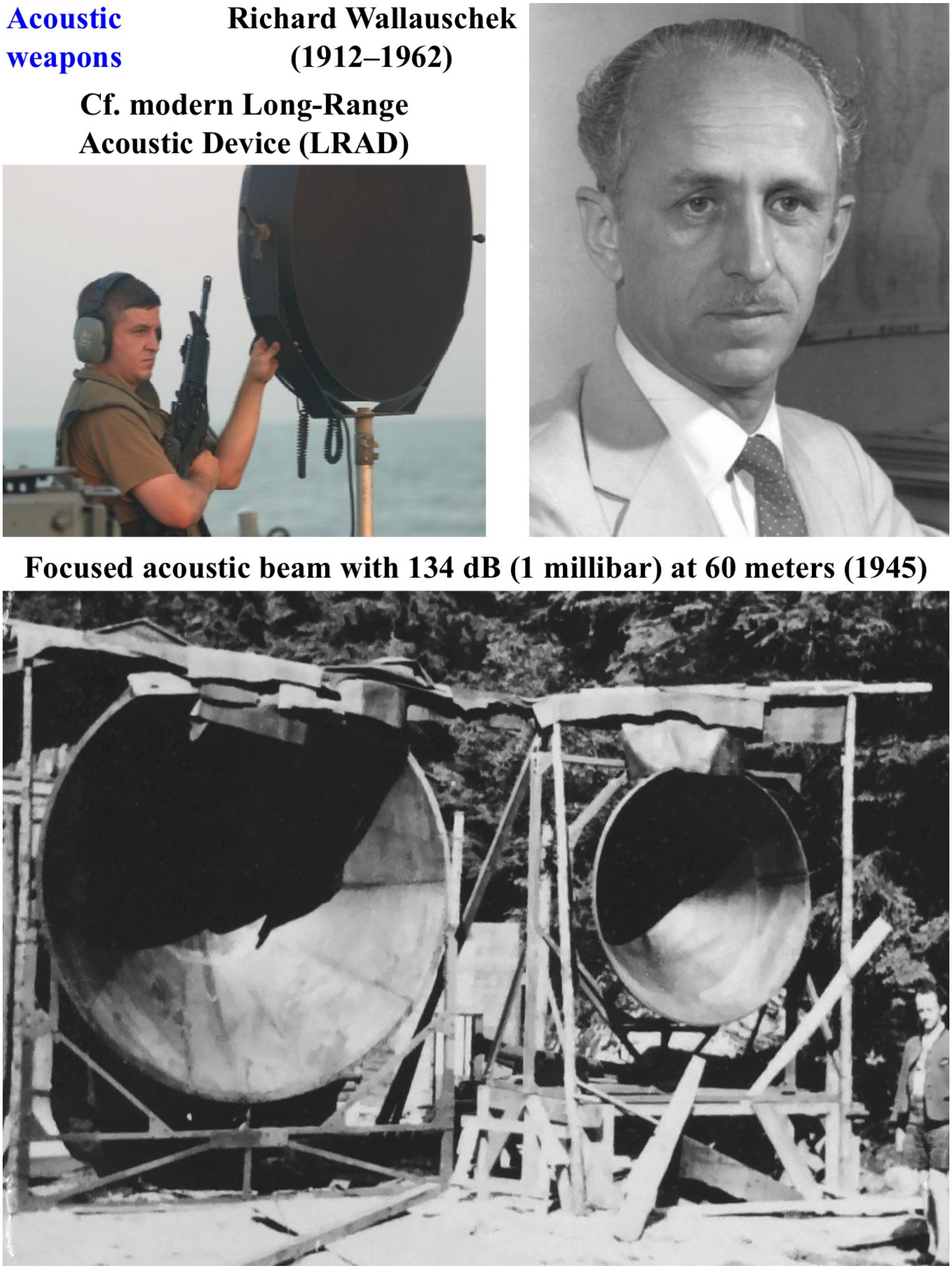

Ultrasound imaging
LAMP.
OPTICAL LENS.
VIEWING SCREEN.
QUARTZ.
WORK.
ALUMINIUM LENS.
DETECTOR CELL.
SEMI-TRANSPARENT MIRROR.
HOUSING FILLED WITH XYLENE.
SIEMENS 1944
Untersuchung von Platten bei sitzender und stehender Beobachtung am Schallsichtgerät nach R.Pohlman
Gl 450022
12 mm
Modellversuch
echte Fehler
SIEMENS
R.Pohlman 1943
Schallbilder von fehlerhaften Stumpfschweißungen
Gl 440409

Figure 6.223: By 1943, Reimar Pohlman and other scientists had developed and demonstrated ultrasound imaging systems [BIOS 609; BIOS 1679].



Acoustic weapons

Richard Wallauschek (1912–1962)

Cf. modern Long-Range Acoustic Device (LRAD)

Focused acoustic beam with 134 dB (1 millibar) at 60 meters (1945)

Figure 6.224: By 1945, Richard Wallauschek had developed and demonstrated an acoustic weapon that could create a focused beam of sound waves with 134 dB (1 millibar) of intensity at a distance of 60 meters [CIOS XXXII-77]. His technology was transferred to Allied countries and led to modern systems such as the Long-Range Acoustic Device (LRAD).

6.8.8 Radio and Acoustic Proximity Fuses and Homing Devices

As already covered, one postwar myth of Allied scientific superiority is that the United Kingdom invented radar and Germany lagged behind, even though there is abundant documentation that the opposite was true. A similar example of postwar historical revisionism by English-speaking historians is that Germany failed to develop a proximity fuse whereas the Allies did. (The Allied "VT" or Variable Time radar proximity fuse was deployed in 1944.)

In fact, scientists in Germany and Austria began work on proximity fuses and homing devices in the 1930s. From the 1930s to 1945, they invented a vast assortment of proximity fuses and homing devices. They created sensors based on active acoustic, passive acoustic, active radar, passive radar, electrostatic, infrared, remote television, and other approaches. They created sensors for guided missiles, smart bombs, artillery shells, and torpedoes. Those systems were documented in numerous postwar Allied reports such as:

> Theodore Benecke and A. W. Quick, eds. 1957. *History of German Guided Missiles Development*
>
> BIOS 249, *Rockets and Guided Missiles*
>
> BIOS 530, *Photosurfaces, a Report on German Developments of Photocells, Electron Multipliers, Television Pick-Up Tubes* [guided missiles]
>
> CIOS ER 259, *Private Investigators Working on Radar Control of a Guided Missile at Obersdorf bei Bad Aussee*
>
> CIOS ER 316, *Preliminary Report on Proximity Fuze Investigation at Rosenthal, Isolatoren, Selb, Bavaria*
>
> CIOS XXVI-1, *Proximity Fuze Development, Rheinmetall-Borsig AG, Mülhausen*
>
> CIOS XXVI-57, *German Development of Homing Devices*
>
> CIOS XXVI-65, *Findings on German Proximity Fuze Developments in 21 Army Group Area*
>
> CIOS XXVIII-41, *Institut für Physikalische Forschung, Neu Drossenfeld* [TV homing device]
>
> CIOS XXVIII-51, *Dipl. Ing. Hans Ludwig, Gross Quern* [missile homing device]
>
> CIOS XXXII-69, *Otto Acoustic Proximity Pistol for Torpedoes*
>
> CIOS XXXII-73. *The Development of German Optical Mine Firing Mechanisms.*

CIOS XXXII-78, *The Passive Acoustic Proximity Device "Kranich"*

CIOS XXXII-79, *Passive Acoustic Proximity Fuses for Use Against Bomber Formations*

CIOS XXXII-80, *Acoustic Steering Control for the X-4 Missile-Dogge*

CIOS XXXII-82, *German Acoustic Ground Proximity Fuse*

CIOS XXXII-88, *Stassfurter Rundfunk Stassfurt.* [Remote control for guiding bombs]

CIOS XXXII-123, *German Guided Missiles*

CIOS XXXII-125, *German Guided Missile Research*

NavTecMisEu LR 30-45, *German Air-to-Air Missile X-4*

NavTecMisEu LR 32-45, *Guided Missile, X4 Information Relative to*

NavTecMisEu LR 77-45, *Lead Sulphide Semi-Conductor Infra-red Cells for Homing Rockets*

NavTecMisEu LR 78-45, *German Pi-Berlin Acoustic Torpedo Pistol*

NavTecMisEu LR 79-45, *Development of Acoustic Torpedo Steering Control "Geier"*

NavTecMisEu LR 80-45, *Acoustic Torpedo Pistol "Otto"—Development of*

NavTecMisEu LR 81-45, *Guided Missiles—Report Interrogation of Personnel Concerned with*

NavTecMisEu LR 101-45. *"Influence Fuse" found at Unterluss.*

NavTecMisEu LR 228-45, *Infra-red Homing Devices*

NavTecMisEu 100-45, *German Development of Homing Devices*

NavTecMisEu 158-45, *Electronics as Applied to German Guided Missiles Volume II*

NavTecMisEu 161-45, *Otto Acoustic Proximity for Torpedoes*

NavTecMisEu 199-45, *Description of the Passive Acoustic Proximity Device-Kranich*

NavTecMisEu 200-45, *Passive Acoustic Proximity Fuses for use against Bomber Formations (Rheingold, Meise, Forelle, Kuckuck)*

> NavTecMisEu 201-45, *Acoustic Steering Control for the X-4 Missile—Dogge*
>
> NavTecMisEu 202-45, *General Survey of German Torpedoes*
>
> NavTecMisEu 203-45, *German Naval Torpedo Pistols and Warheads*
>
> NavTecMisEu 204-45, *German Naval Homing and Guided Torpedoes*
>
> NavTecMisEu 225-45, *German Acoustic Ground Proximity Fuse*
>
> NavTecMisEu 237-45, *Survey of Germany Activities in the Field of Guided Missiles.* See pp. 5429–5431 for some revealing quotes from this long report.
>
> NavTecMisEu 242-45, *"Paplitz" Infra-red Fuse Development of Elac*
>
> NavTecMisEu 273-45, *German Infra-red Homing Device "Emden"*
>
> NavTecMisEu 274-45, *German Infra-red Homing Device "Karussell"*
>
> NavTecMisEu 355-45, *Survey of the German Work on Proximity Fuses*
>
> NavTecMisEu 356-45, *German Aircraft Acoustic Homing Torpedo—"PFAU"*
>
> Alsos EOS 200 [NARA RG 38, Entry P-5, Box 8, Folder Alsos Mission Fuze Reports]
>
> Alsos EOS 225 [NARA RG 38, Entry P-5, Box 8, Folder Alsos Mission Fuze Reports]
>
> Alsos EOS 226 [NARA RG 38, Entry P-5, Box 8, Folder Alsos Mission Fuze Reports]
>
> Alsos EOS 240 [NARA RG 38, Entry P-5, Box 8, Folder Alsos Mission Fuze Reports]
>
> Alsos EOS 260 [NARA RG 38, Entry P-5, Box 8, Folder Alsos Mission Fuze Reports]
>
> Alsos EOS 270 [NARA RG 38, Entry P-5, Box 8, Folder Alsos Mission Fuze Reports]
>
> Alsos EOS 271 [NARA RG 38, Entry P-5, Box 8, Folder Alsos Mission Fuze Reports]
>
> Alsos EOS 274 [NARA RG 38, Entry P-5, Box 8, Folder Alsos Mission Fuze Reports]

For example, CIOS XXXII-125, *German Guided Missile Research*, reported (p. 5411):

> A.E.G. have developed an electronic proximity fuse which was said to be in mass production. It consisted of a unipole mounted on the nose of a missile, and tightly coupled to a small CW oscillator. A second oscillator was also incorporated which ran at a

> frequency of 800 c/s less than that of the first. The beat frequency was obtained in a mixer. In the proximity of an aircraft or other large conducting body the frequency of the first oscillator was pulled by the change of aerial impedance and the beat frequency increased. The latter signal was passed through a 1000 c/s filter the output of which operated the fuse.

U.S. Army Air Forces Colonel (later General) Donald Putt noted [Putt 1946b]:

> The Hs-117 [...] was a ground-to-air missile. It was named Schmetterling or butterfly, and was a rocket-propelled, radio-controlled missile to be launched from the ground against bomber formations. It accelerated to a speed of 560 mph, and was steadied in flight by a pendulum device. The take-off rocket burned out and were jettisoned; the main propulsion unit then drove the missile until it was detonated by a proximity fuse. Large-scale production began January, 1945, in an underground factory in Nordhausen. [...]
>
> The Rheintochter [...] was a ground-to-air missile. It was a rocket-propelled anti-aircraft weapon and was controlled in flight by radio. It traveled at a speed of 1100 mph and carried an explosive charge of 330 lb, equipped with a proximity fuse, to a ceiling of 48,000 ft. The starting rocket, attached to the base, was blown off after combustion was completed. Development did not go beyond the test firing stage, but experiments were still being conducted as late as February, 1945.

In November 1945, General Henry Arnold reported (p. 5456):

> At lower right is the X-4, a wire controlled, rocket-propelled gyro-stabilized missile, to be launched from parent plane against bombers. X-4 was almost ready for use. [...] Potency of X-4 (right) was tremendously increased by proximity fuse.

In June 1945, General Carl Spaatz requested the air lift evacuation of Rheintochter missiles with proximity fuses (p. 5664):

> FOR WING COMMANDER WHEELER. INFORMATION HERE THAT RHEINTOCHTER HAS SEVEN EACH NEW TYPE ROCKETS. ANTI AIRCRAFT ROCKETS SUPPOSED TO USE PROXIMITY FUZE. SIGNAL ALLSTONT [?] AND LOCATION FOR AIR LIFT BY OUR AIRCRAFT.

In 1946, the U.S. Army Ordnance Department reported [https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1059&context=dodmilintel]:

> In connection with the subject of proximity fuzes, the Germans had expended a vast amount of energy on the research and development of fuzes which would detonate ammunition without coming in physical contact with the target. We were far ahead of them on actually getting a proximity fuze into production and into active use during the war, they were very effective, particularly in antiaircraft use. However, at the time the war ended, the German research and development had progressed to such an extent

> that they had designs almost ready for production and had thoroughly investigated many of the possible types of proximity fuzes; e.g. acoustic, radio, photo-electric and electro-static types. [...]
>
> A number of rocket propelled missiles which could be guided from the ground and which would detonate by the use of a proximity fuze when coming within the danger area of one of our airplanes were developed to the production stage and one guided missile was actually in production at the end of the war. Our understanding of the way one was to have operated was by means of radar screen which could track both the target and the missile. The operator would have the necessary controls required to direct the missile and by watching the radar screen could take the necessary steps to bring the missile as close as possible to the airplane, at which time the proximity fuze would function and the airplane would disappear.

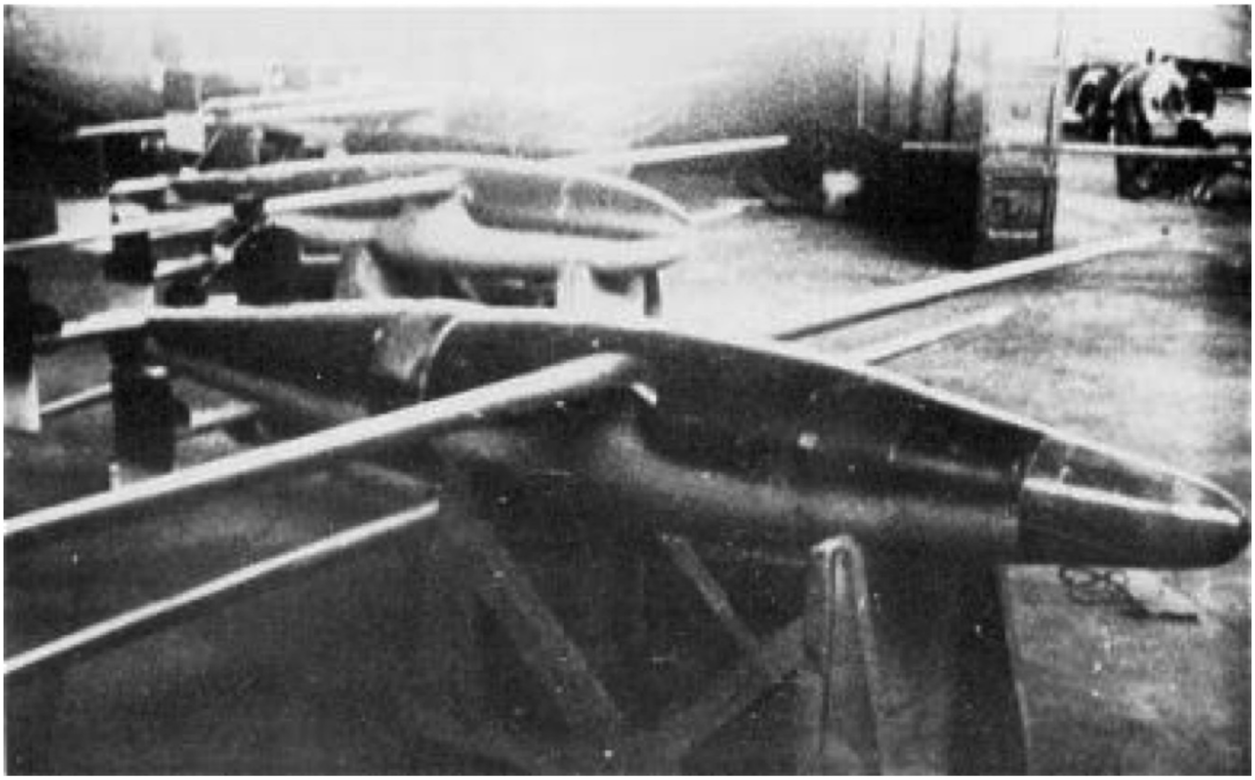
See also the statements of Hermann Goering (pp. 5200–5202).

The United States and United Kingdom developed a simple radar proximity fuse for artillery shells and employed it effectively for anti-aircraft fire. Germany developed an enormous quantity and variety of proximity fuses and homing devices, many of which were more advanced than the Allied proximity fuse. Few of the German proximity fuses and guidance systems appear to have been deployed during the war, but that was due to Allied bombing of the factories where those systems were being produced, as well as some of the decisions (or indecision) of German political and military leaders, not due to any failures of German and Austrian scientists.

As shown in Fig. 6.225, Germany also created the first High-speed Anti-Radiation Missile (HARM), designed to seek and destroy enemy radar systems. At least 1,000 units of the Blohm & Voss BV 246 Hagelkorn with a Radieschen guidance unit on the front were produced by the end of the war, though apparently none were used in combat. An anti-radar version of the Henschel Hs 293 was also developed (p. 5411). The BV 246 Radieschen and anti-radar Hs 293 were the foundation for postwar HARM weapons in other countries.

Because the proximity fuses and homing devices developed in wartime Germany were so advanced and so diverse, immediately after the war, Allied countries confiscated the documentation, hardware, and scientists from those programs, and used them to produce proximity fuses and homing devices in the United States, United Kingdom, France, Soviet Union, and other countries during the postwar period. (See also Sections 6.6 and 9.6.)

Blohm & Voss BV 246 Hagelkorn Radieschen (1945)
First High-speed Anti-Radiation Missile (HARM),
designed to seek and destroy enemy radar systems



Heinkel He 111 carrying 3 Blohm & Voss Hagelkorns

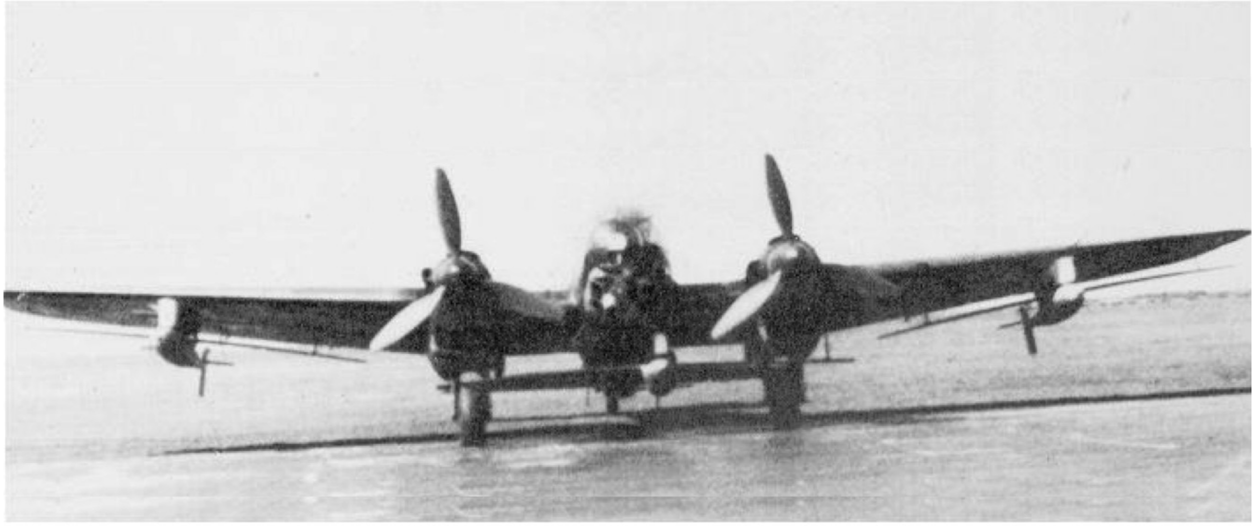


Figure 6.225: The Blohm & Voss BV 246 Hagelkorn with a Radieschen guidance unit on the front, mass-produced in 1945, was the first High-speed Anti-Radiation Missile (HARM), designed to seek and destroy enemy radar systems. It was also the foundation for postwar HARM weapons in other countries.

6.9 Microscopes, Telescopes, and Other Optical Instruments

Creators from the predominantly German-speaking scientific world dominated the development of optical microscopy methods, from inventing the first known microscope to obtaining the maximum theoretical resolution from a microscope to developing fluorescence and phase contrast microscope approaches that are now used worldwide. They also invented and developed telescopes as well as other methods and applications of optics.[30]

The first known telescopes were produced around 1608 by creators such as Hans Lipperhey (German states/Dutch, 1570–1619), Jacob Metius (Dutch, ca. 1571–1628), and Zacharias Janssen (Dutch, ca. 1585–<1632). See Fig. 6.226.

As shown in Fig. 6.227, Antonie van Leeuwenhoek (Dutch, 1632–1723) created the first known microscope and used it to observe numerous types of single-celled and multicellular organisms. The American Council of Learned Societies summarized his discoveries [ACLS 2000, pp. 528–529]:

> Built his first microscope (1671), a minute lens, ground by hand from a globule of glass, clamped between two metal plates, with specimen holder affixed; went on to grind about 550 lenses; the best that has survived has a magnifying power of 270 and a resolving power of 1.4μ. Believed inorganic and organic nature are similar and that all living creatures are similar in form and function. In 1674, recognized that microorganisms are alive; communicated observations on these "little animals" to the Royal Society (1676), causing a sensation. Subsequently described bacteria, protozoa, rotifers, and ciliate reproduction. From study of spermatozoa, postulated that these penetrate the egg[...] Investigated the transport of nutrients in plants and animals[...]

Joseph von Fraunhofer (German states, 1787–1826, p. 853) made a number of important discoveries and inventions in optics. He invented diffraction gratings, and he studied the diffraction of light of different wavelengths. He used a diffraction slit and prism to develop a spectroscope, which he and others then applied to make important measurements in physics and chemistry. He also created achromatic (non-color-distorting) lenses and other specialized lenses that greatly improved the image quality for both telescopes and microscopes. Oxford University's *Biographical Dictionary of Scientists* explained how he combined and advanced both experimental and theoretical optics [Porter 1994, pp. 251–252]:

> [H]is work laid the basis for subsequent German supremacy in the making of high-grade scientific and optical instruments. [...]
>
> Although he had little formal education, Fraunhofer sought to understand optical theory and apply it to the practical work of constructing lens combinations of minimum aberration. At that time there was little high-quality crown and flint glass, and methods of determining the optical constants of glass were crude, limiting the size and quality of lenses that could be produced and also confining instrument makers to trial-and-error methods of construction. Fraunhofer approached lens-making according to optical theory and set out to determine the dispersion powers and refractive indices of different

---

[30] Auerbach 1918, 1925; Daumas 1989; Dobell 1960; Gjudjenow and Meinl 2013; James Hansen 1974; Nigel Hawkes 1981; Korey 2007; Mills 1983; Petri 1896; Plaßmeyer2007; Stephenson et al. 2000; Turner 1981, 1989, 1998; Wimmer 2017.

> kinds of optical glass with greater accuracy. In collaboration with Guinand, he also sought to improve the quality of the glass used to make lenses.
>
> In 1814, Fraunhofer began to use two bright yellow lines in flame spectra as a source of monochromatic light to obtain more accurate optical values. Comparing the effect of the light from the flame with the light from the Sun, he found that the solar spectrum is crossed with many fine, dark lines. [...]
>
> In this way, Fraunhofer was able to make very accurate measurements of the dispersion and refractive properties of various kinds of glass, and in so doing he developed the spectroscope into an instrument for the scientific study of spectra.
>
> In 1821, Fraunhofer examined the patterns that result from light diffracted through a single slit, and related the width of the slit to the angles of dispersion of the light. Extending from a large number of slits, he constructed a grating of 260 parallel wires and made the first study of spectra produced by diffraction gratings. [...] By measuring the dispersion, he was able to determine the wavelengths of light of specific colours and the dark lines.
>
> Fraunhofer also constructed reflection gratings, enabling him to extend his studies to the effect of diffraction on oblique rays. By using the wave theory of light, he was able to derive a general form of the grating equation that is still in use today.

Simon Plössl (Austrian, 1794–1868) produced microscopes with achromatic objective lenses (Fig. 6.228). He also developed the now highly popular Plössl eyepiece design for telescopes, which offers an especially wide field of view.

Georg Johann Oberhäuser (German states, 1798–1868) and his successor Edmund Hartnack (German, 1826–1891) were other important early innovators in microscopy (Fig. 6.229). Edmund Hartnack produced the first water immersion lenses (putting a drop of liquid between the lens and the slide) to enable microscopes to see smaller details.

Carl Zeiss (German, 1816–1888, engineering and business), Ernst Abbe (German, 1840–1905, optical physics), and Otto Schott (German, 1851–1935, glass chemist) created and built up the Zeiss optical company, based in Jena, making it arguably the most advanced optical instrument company in the world. By the 1880s, they had perfected the diffraction-limited apochromatic microscope (Fig. 6.230), eliminating earlier flaws in lens design and glass composition in order to attain the maximum theoretical image resolution that can be achieved with visible light. That work remains the foundation of all modern optical microscope designs. They also developed a reputation for designing and manufacturing a wide range of other advanced optical instruments. The *Encyclopedia Britannica* explained some of the history [EB 2010]:

> Zeiss, Carl [...], German industrialist who gained a worldwide reputation as a manufacturer of fine optical instruments.
>
> In 1846 Zeiss opened a workshop in Jena for producing microscopes and other optical instruments. Realizing that improvements in optical instruments depended on advances in optical theory, he engaged as research worker Ernst Abbe, a physics and mathematics

lecturer (later professor) at the University of Jena, who in 1866 became Zeiss's partner. They engaged Otto Schott, a chemist, who developed about 100 new kinds of optical glass and numerous types of heat-resistant glass.

In the early 1900s, several scientists working at the Zeiss company made further significant advances in optical microscopy:

- In 1902, Richard Zsigmondy (Austrian, 1865–1929) and Henry Siedentopf (German, 1872-1940) invented the ultramicroscope for determining particle sizes in colloids; see Fig. 6.231.
- August Köhler (German, 1866–1948) and Moritz von Rohr (German, 1868–1940) invented the ultraviolet microscope in 1904, as shown in Fig. 6.232.
- August Köhler and Henry Siedentopf invented the fluorescence microscope in 1908 (Fig. 6.233). Fluorescence microscopes are now a widespread tool in biology laboratories because different cellular components can be labeled with different colors of fluorescent tags.

A Mach-Zehnder interferometer splits light into two beams, which travel different paths through transparent objects and then recombine, resulting in constructive and destructive interference patterns that can provide useful information about the objects (Fig. 6.62). Karl Bratuschek (German, 1865–1913) at the Zeiss company began trying to apply that same principle to microscopes but died before he could finish [Wimmer 2017]. Frits Zernike (Dutch, 1888–1966) continued that work and created the first phase contrast microscopes (1933), which were then mass-produced by Zeiss (pp. 1274, 2474–2484). Phase contrast microscopes make cells easily visible without having to add colored chemical stains. The chemical staining steps are not only cumbersome, but would usually kill the cells, so phase contrast microscopes are now a ubiquitous tool in biology laboratories worldwide to observe living cells. For the development of phase contrast microscopy, Frits Zernike won the Nobel Prize in Physics in 1953. Professor E. Hulthén of the Nobel Committee for Physics explained Zernike's work and noted how it built upon the earlier discoveries of Zeiss scientists such as Ernst Abbe [https://www.nobelprize.org/prizes/physics/1953/ceremony-speech/]:

> Probably no other instrument has been the object of so much technical and theoretical study as the microscope. The thorough theoretical foundation that we owe to the genius of Ernst Abbe of the famous Zeiss concern was followed at the end of the last century by a development of the microscope that brought its optical and illumination system very close to perfection.
>
> But even Abbe's theory had a gap, for it took into account only those conditions in which the microscopic objects appear against the background as a result of their contrasts in colour and intensity. Many microscopic objects, however, micro-organisms such as bacteria and cells, are colourless and transparent, and for this reason difficult to distinguish from their surroundings. Attempts have been made to overcome this difficulty with various methods of staining or with a special illumination system, the so-called darkfield illumination. The staining methods are not always suitable, as for example when we are dealing with living objects; and dark-field illumination easily leads to a misinterpretation of the finer details in the structural picture.
>
> It was this gap in Abbe's theory that in the 1930's led Zernike to re-investigate the refraction processes in the light that give rise to the image in a microscope. Even if

> the eye is not able to discern the change undergone by a beam of light when it passes through a transparent object, the change does nonetheless exist as a phase-difference of a quarter of a wavelength relative to the direct beam that does not pass through the object. The problem was thus to transform these otherwise imperceptible phase differences to visible contrasts in intensity. Zernike was able to show that this was possible, thanks to the fact that the two rays of light take different routes through the microscope before being reunited in the image. By interposing in the paths of the direct ray a so-called "phase-plate" which either further increases the phase-displacement to half a light-wavelength or smooths it out completely, Zernike attained the desired effect, so that the two rays either extinguish or reinforce each other. In this way the formerly invisible particle appears in dark or light contrast to the surroundings.
>
> I have deliberately dwelt upon the description of the phase-contrast microscope as the result of Zernike's method which is, so far, the most valuable. The phase-contrast method has, however, many other and increasingly important applications in optics. In addition to its capacity to render colourless and transparent objects visible in the microscope, it also enables one to detect slight flaws in mirrors, telescope lenses, and other instruments indispensable for research. In this connection, Zernike's phase-plate serves as an indicator which locates and measures small surface irregularities to a fraction of a light-wavelength. This sharpness of depth is so great that it penetrates to the point at which the atomic structure of the substance begins to become manifest.

Phase-contrast microscopy was adopted by Allied countries after they discovered some of the Zeiss phase-contrast microscopes at the end of World War II [FIAT 1059; pp. 2474–2484].

Carl Kellner (German states, 1826–1855), Ernst Leitz I (German, 1843–1920), and the son Ernst Leitz II (German, 1871–1956) created what came to be called the Leitz optical instrument company, which roughly paralleled the history and accomplishments of the Zeiss company. See Fig. 6.235.

- Ernst Arbeit (German, 18??–19??), Carl Metz (German, 18??–19??), and Felix Jentzsch (German, 18??–19??) developed microscopes at the Leitz company; see Fig. 6.236.

- In 1913, Oskar Barnack (German, 1879–1936) invented the first modern 35 mm still camera, which later was dubbed Leica (for Leitz Camera); see p. 637.

As shown in Fig. 6.237, John Jacob (Johann Jakob) Bausch (German, 1830–1926), Henry Lomb (German, 1828–1908), and Ernst Gundlach (German, 1834–1908) produced microscopes and other optical instruments at the Bausch & Lomb company in the United States.

In 1930, Bernhard Schmidt (German, 1879–1935) invented the Schmidt combination telescope and camera, which was adopted worldwide (Fig. 6.238). Oxford University's *Biographical Dictionary of Scientists* explained Schmidt's optical innovations [Porter 1994, p. 608]:

> After graduating in 1904 he stayed in Mittweida making lenses and mirrors for astronomers. One of his early accomplishments, in 1905, was a 40-cm/27-in mirror for the Potsdam Astrophysical Observatory. Schmidt worked independently, producing optical equipment of very high quality until 1926, when Schorr, the Director of the Hamburg Observatory, asked him to move into the Observatory and work there. Schmidt accepted the invitation. He worked on the mountings and drives of the telescopes, as well

> as on their optics. It was in Hamburg that he perfected his lens and built it into the Observatory telescope, specifically for use in photography. [...]
>
> It is usual for reflecting telescopes to have parabolic mirrors, rather than spherical ones; spherical ones are subject to an optical distortion known as spherical aberration. Parabolic mirrors too, however, suffer from their own optically distortive effect, 'coma'; but they provide an image that is at least centrally clear and focused. What Schmidt devised was a means of correcting the image formed by a spherical mirror—a disc-shaped lens thicker at the centre and edges than at half-radius. By replacing the parabolic mirror of a telescope with a spherical one plus his lens—his 'corrector plate', as he called it—he could produce an image that was sharply focused at every point (generally on a curved photographic plate, although on later models Schmidt used a second lens to compensate for the use of a flat photographic plate).

As illustrated in Fig. 6.239, Walther Bauersfeld (German, 1879–1959) developed the Zeiss planetarium projector Mark I (begun in 1912, delayed by World War I, and completed in 1923), Mark II (1930), and later models. Such planetarium projectors were adopted and used worldwide.

Wilhelm Schnittger (German, 19??–19??) invented advanced theodolites and cinetheodolites at Askania Werke in 1933 (Fig. 6.240). Askania instruments were used to monitor, measure, and guide test flights of A-4 (V-2) rockets and other aerospace vehicles during World War II. After the war, Askania theodolites were used for decades to track and film rockets and aircraft in the United States (Fig. 6.241). Askania instruments were also used by the Soviet Union and other countries after the war (e.g., pp. 2808, 3998, and 5535).

Alexander (or Olexander) Smakula (Austro-Hungarian, educated and worked in Germany, 1900–1983) invented antireflective coatings for lenses at Zeiss in 1935 (Fig. 6.242). His antireflective coatings were widely used in Germany during World War II. After the war, Allied investigators studied and copied Smakula's information on antireflective coatings, and he continued his work in the United States. Antireflective coatings have been used worldwide since then. For more information on the postwar transfer of this technology, see for example:

> BIOS 1183. *Anti-Reflection Surfaces on Glass, Optical Cements & Etching Resist for Fine Lines.*
>
> BIOS 1215. *German Methods of Rhodiumizing, Aluminizing, Anti-Reflection Surface Coating and Allied Subjects.*
>
> NavTecMisEu 461-45. *Methods of Film Coating for Low Reflection in the German Optical Industries.*

Marga Faulstich (German, 1915–1998) at the Schott glassworks developed improved optical lenses, incorporating not only Smakula's antireflective coatings but also new high-index-of-refraction materials such as Schwerflint 64 to make much thinner, lighter lenses for eyeglasses and other applications (Fig. 6.243).

After World War II, German high-quality plastic lenses and the technology to produce them were taken by the United States and directly copied by U.S. companies [NARA RG 40, Entry UD-75, Box 58, Folder Budget]. See Fig. 6.244.

Likewise, German optical and electron microscopes were seized by the United States and copied by U.S. companies [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards]. See Fig. 6.245.

German-speaking scientists even created gastroscopes or endoscopes that were appropriated by Allied countries after the war. For example, BIOS 874, *Computing and Testing Methods in the German Optical Industry*, p. 13, reported:

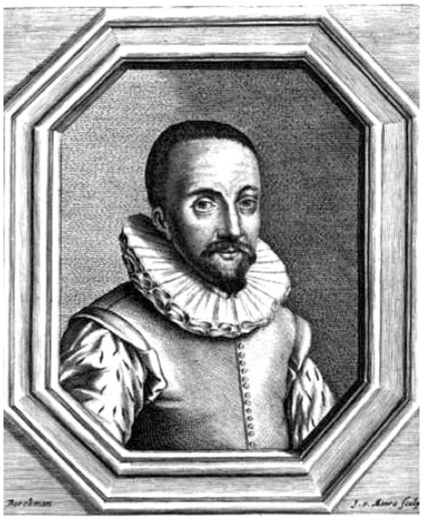
> [G. Wolf G.m.b.H. Berlin, a Zeiss subsidiary:] Probably the most interesting instrument is the Schindler flexible gastroscope, six to eight of which are being made monthly; thirty-eight glass elements are employed in the periscopic train, of which thirty-two are in the flexible portion, and a front negative lens is fitted to increase the visible field of view to 90^o. “Blooming” of the glass elements has not been tried.

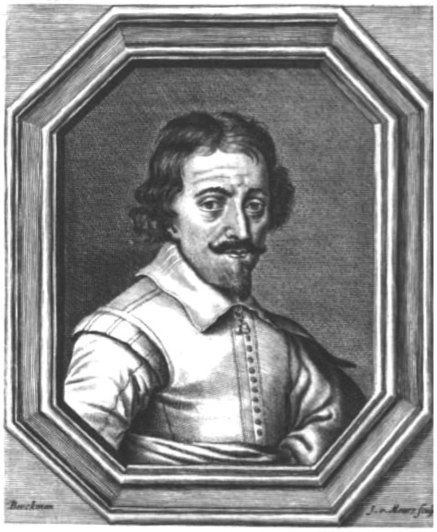
Telescopes (ca. 1608)

Hans Lipperhey
(1570–1619)

Jacob Metius
(ca. 1571–1628)

Zacharias Janssen
(ca. 1585–<1632)





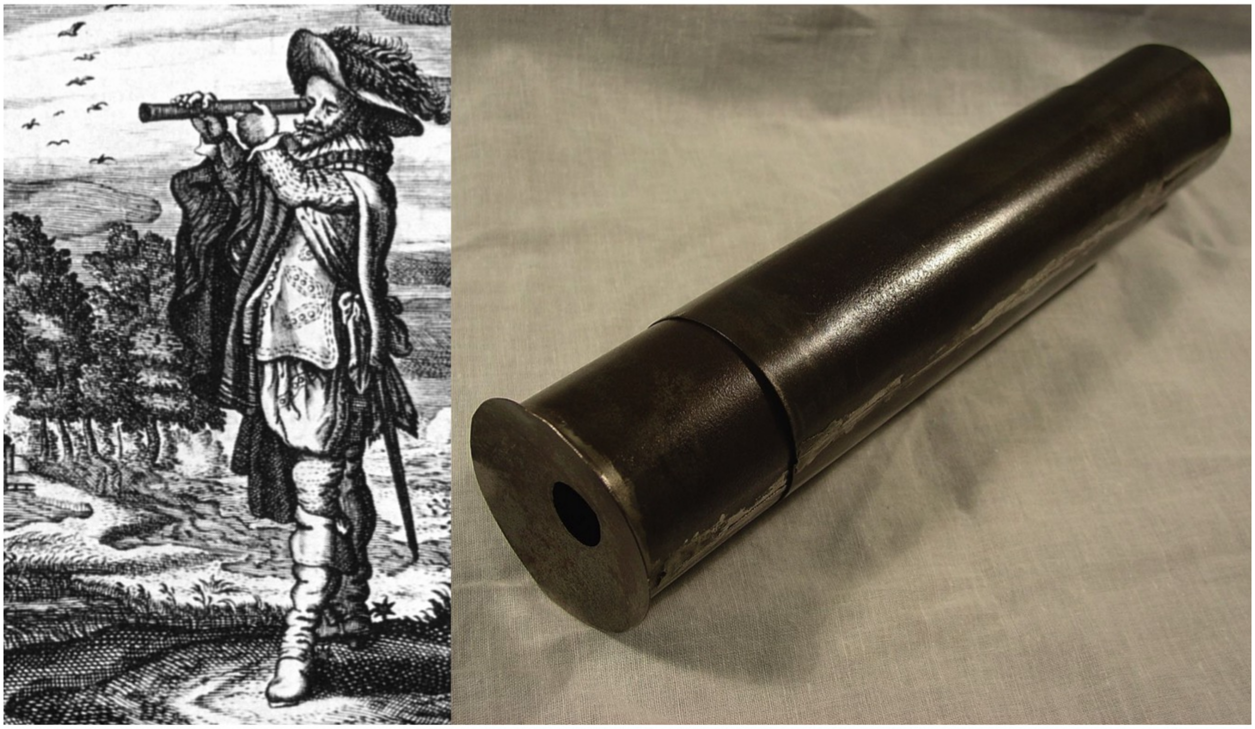


Figure 6.226: The first known telescopes were produced around 1608 by opticians such as Hans Lipperhey, Jacob Metius, and Zacharias Janssen.

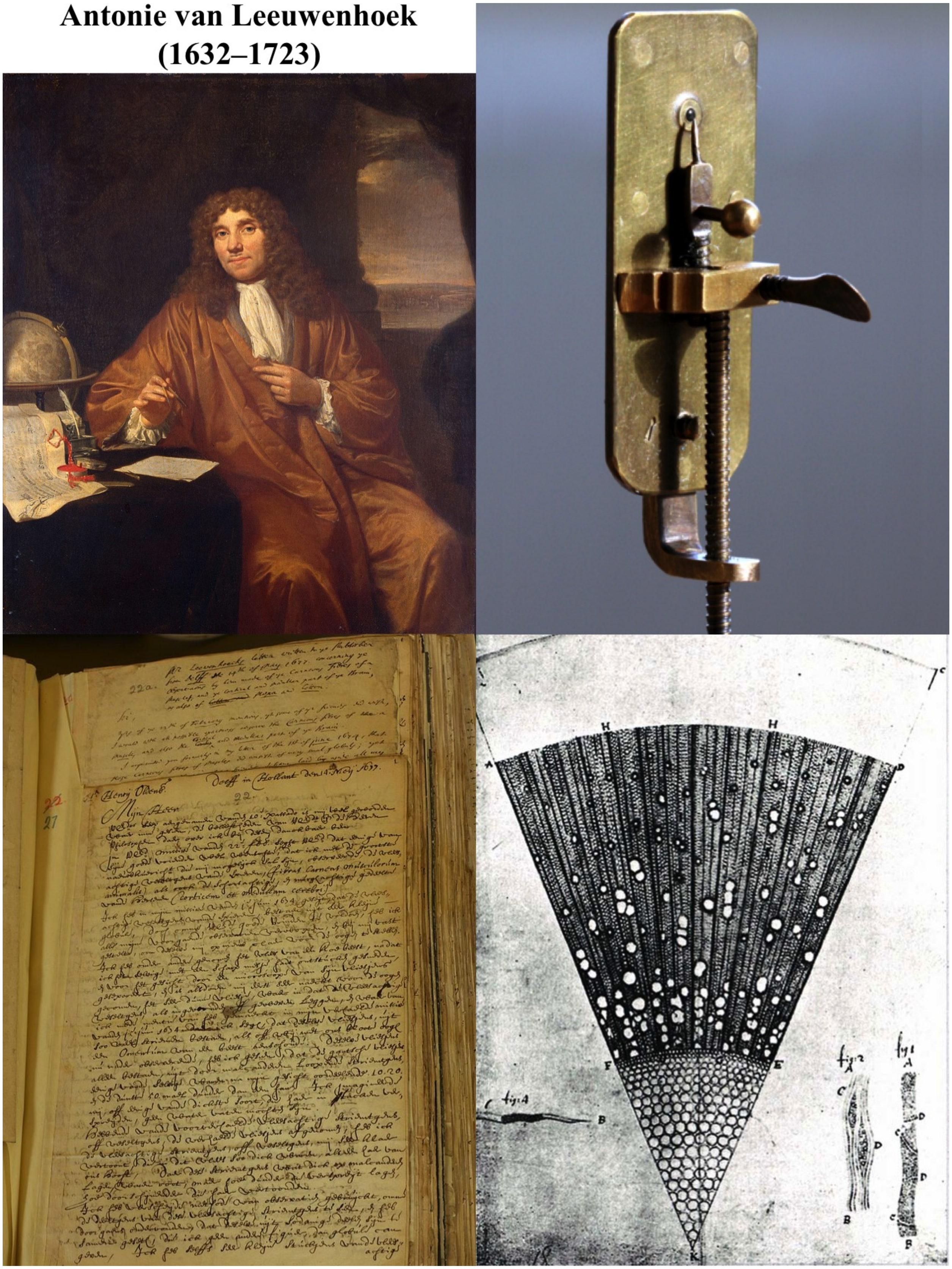
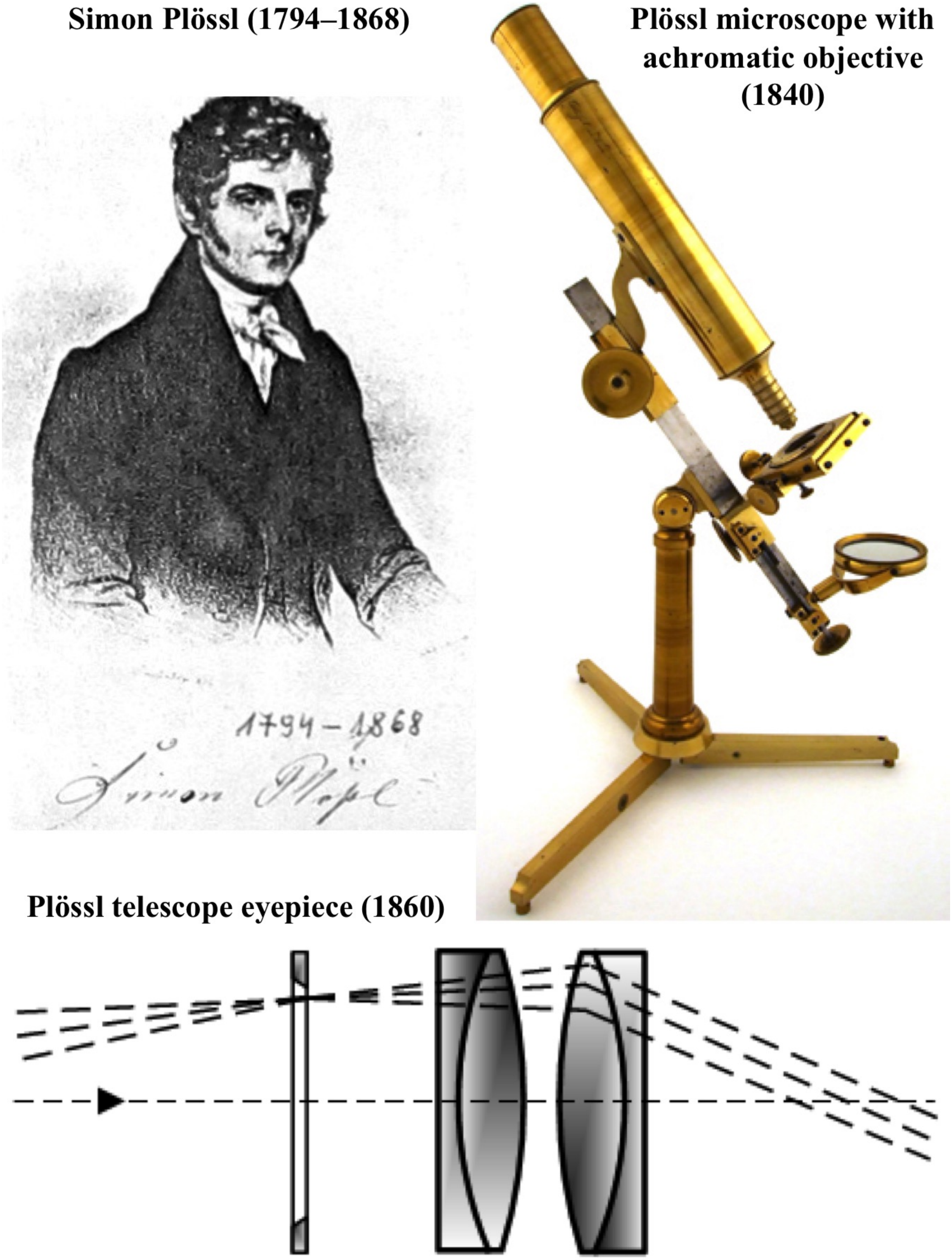

Antonie van Leeuwenhoek
(1632–1723)
A
B
C
D
E
F
H
K
fig. 1
fig. 2
fig. 4

Figure 6.227: Antonie van Leeuwenhoek created the first known microscope and used it to observe numerous types of single-celled and multicellular organisms.



Simon Plössl (1794–1868)

Plössl microscope with achromatic objective (1840)

Plössl telescope eyepiece (1860)

Figure 6.228: Simon Plössl produced microscopes with achromatic objective lenses, and also developed the now widely-used Plössl eyepiece design for telescopes.

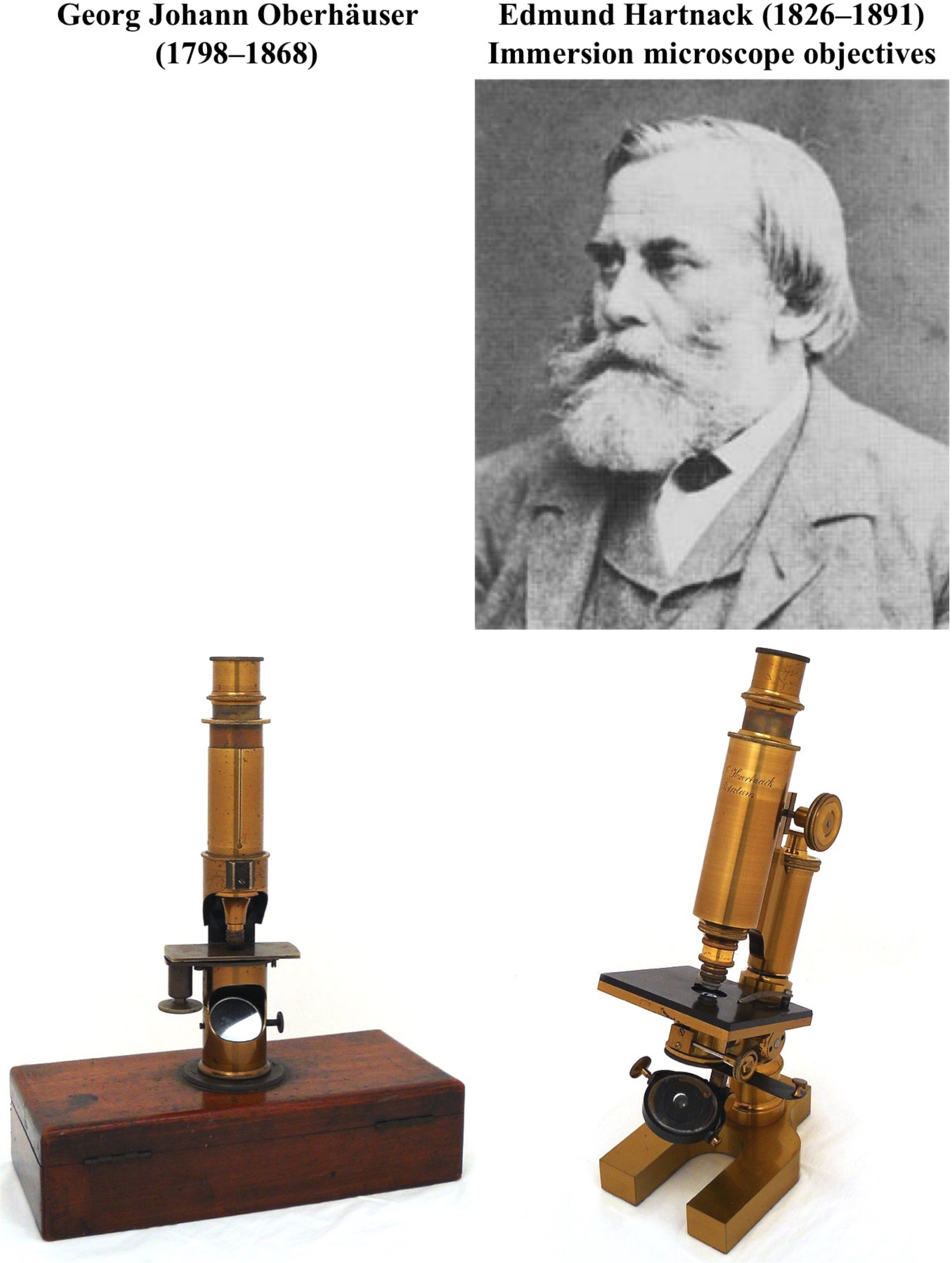

Georg Johann Oberhäuser
(1798–1868)
Edmund Hartnack (1826–1891)
Immersion microscope objectives

Figure 6.229: Georg Johann Oberhäuser and Edmund Hartnack developed improved microscopes. Hartnack produced the first water immersion lenses (putting a drop of liquid between the lens and the slide) to enable microscopes to see smaller details.

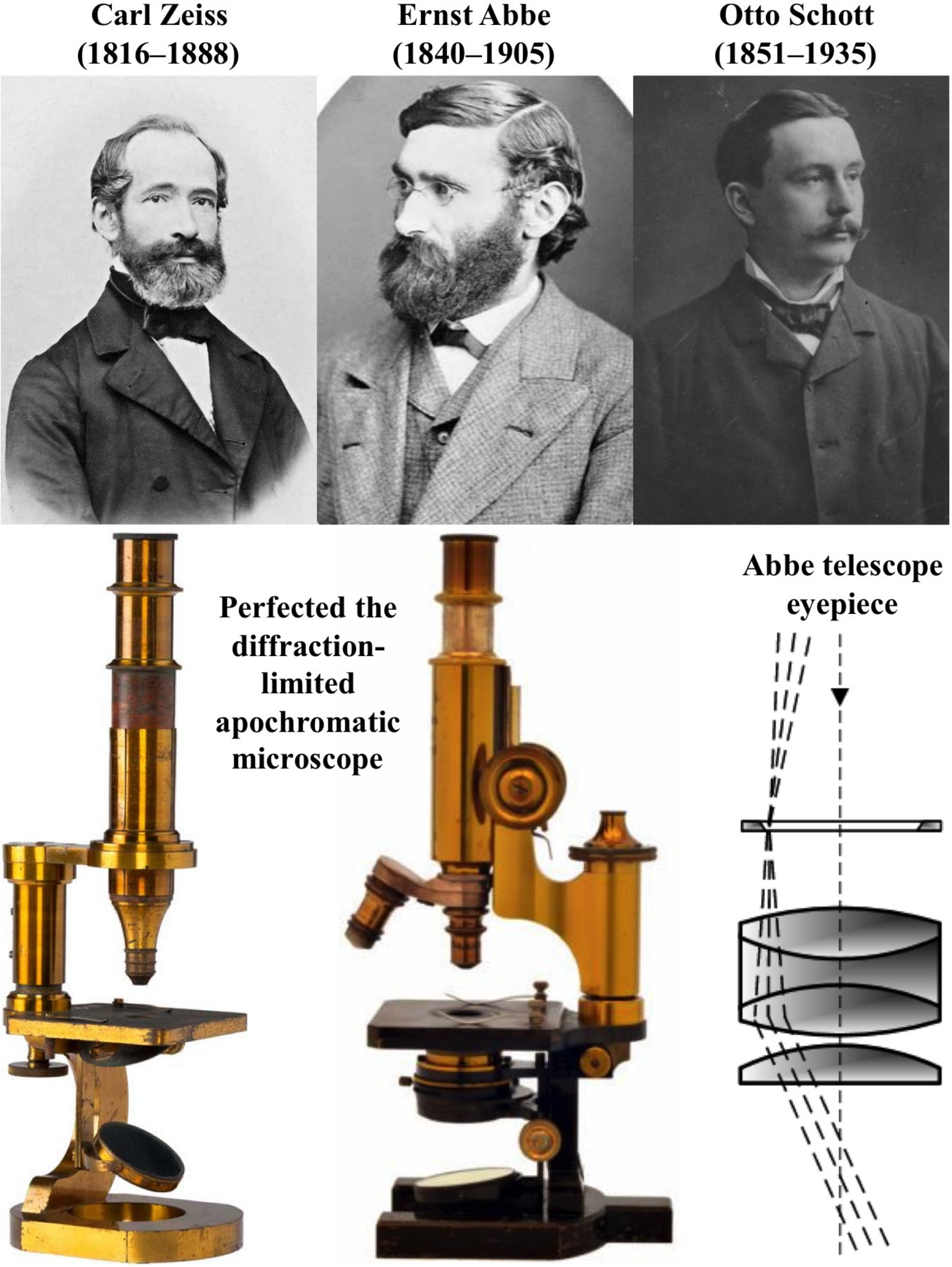

Carl Zeiss
(1816–1888)
Ernst Abbe
(1840–1905)
Otto Schott
(1851–1935)
Perfected the diffraction-limited apochromatic microscope
Abbe telescope eyepiece

Figure 6.230: Carl Zeiss (1816–1888), Ernst Abbe (1840–1905), and Otto Schott (1851–1935) built up the Zeiss optical company, perfected the diffraction-limited apochromatic microscope, and produced other optical instruments.

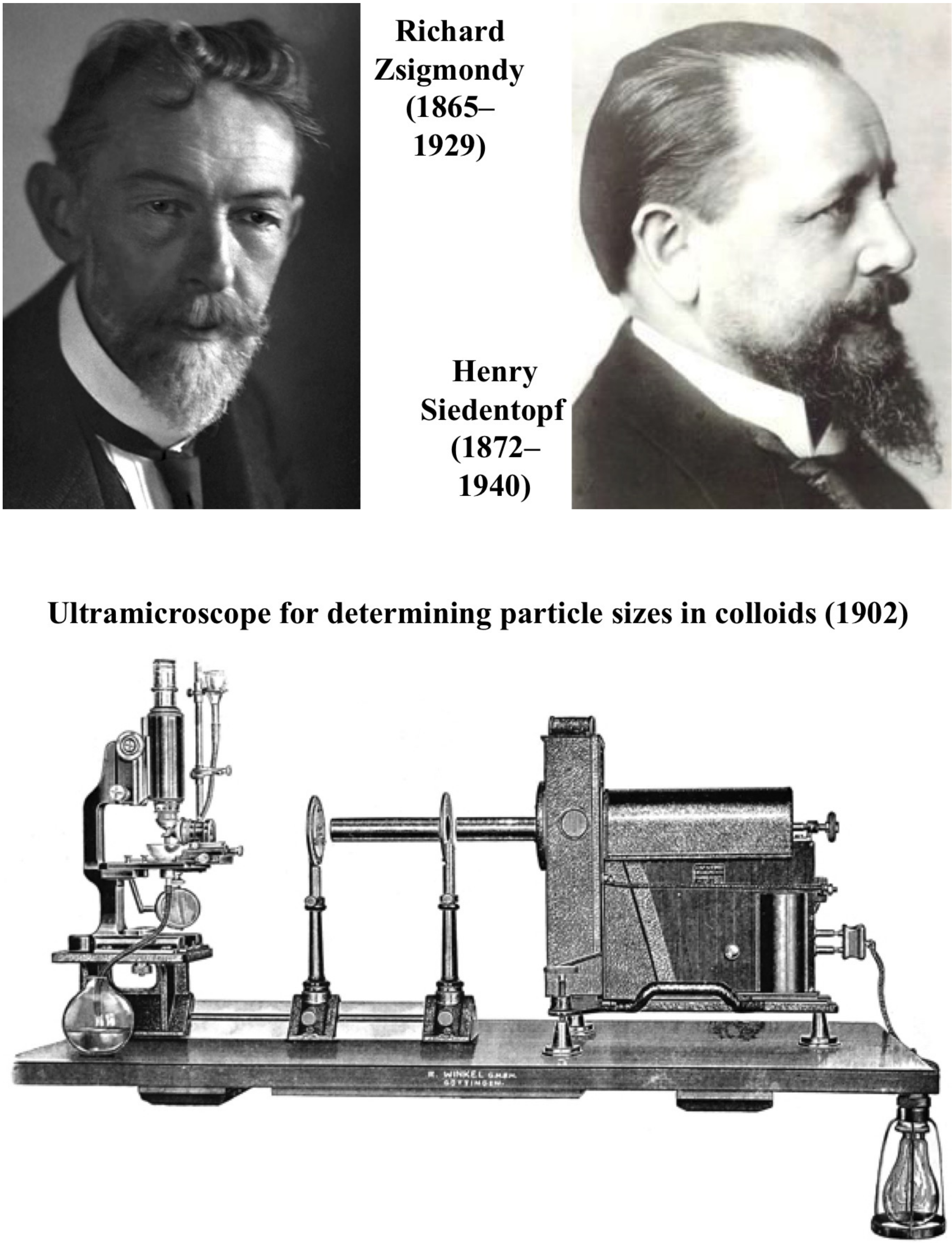

Richard Zsigmondy (1865–1929)
Henry Siedentopf (1872–1940)
Ultramicroscope for determining particle sizes in colloids (1902)
R. WINKEL G.M.B.H. GÖTTINGEN.

Figure 6.231: In 1902, Richard Zsigmondy and Henry Siedentopf invented the ultramicroscope for determining particle sizes in colloids.

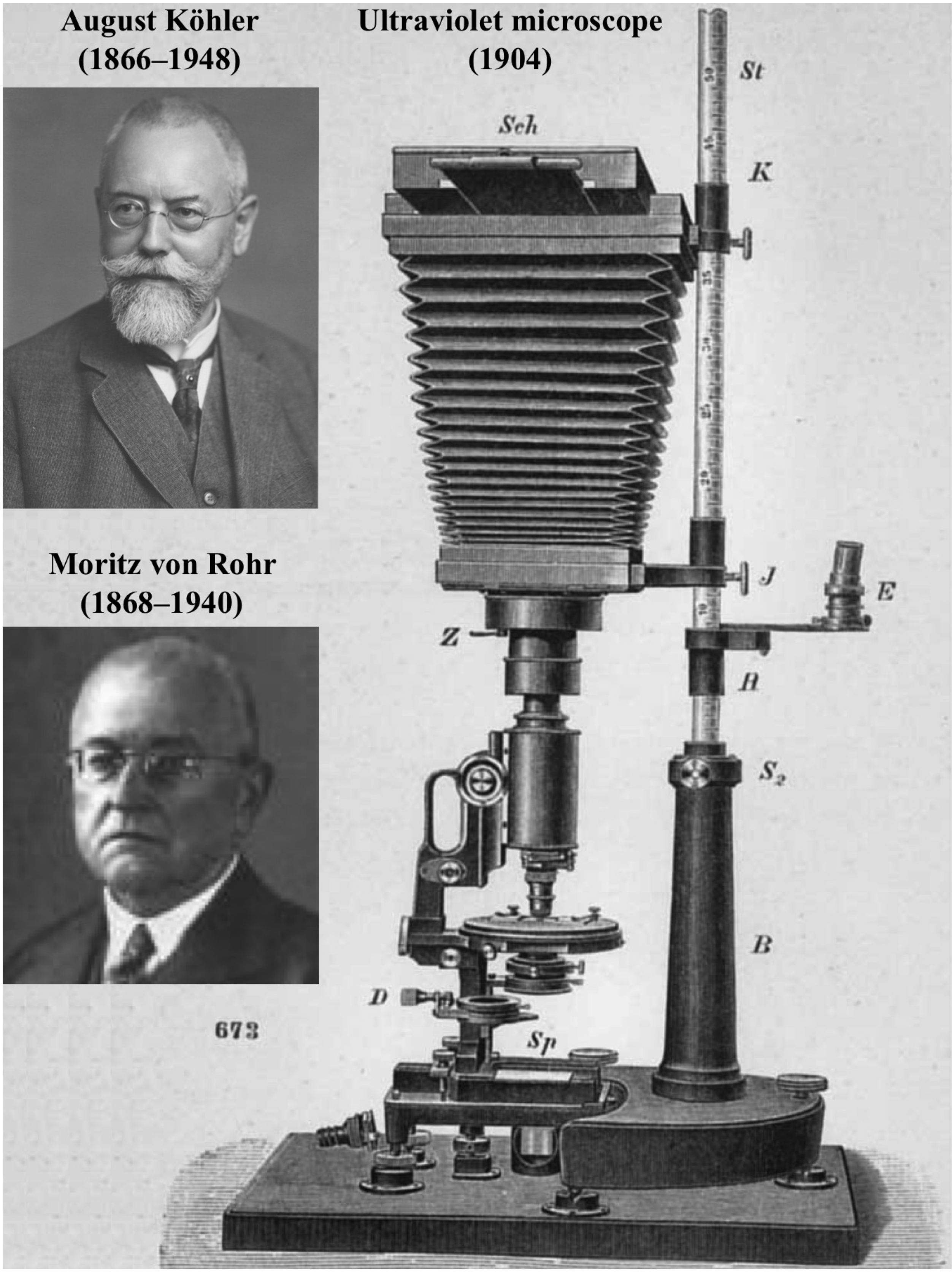

August Köhler
(1866–1948)
Ultraviolet microscope
(1904)
St
Sch
K
J
E
Z
H
S_2
Moritz von Rohr
(1868–1940)
B
D
673
Sp

Figure 6.232: August Köhler and Moritz von Rohr invented the ultraviolet microscope in 1904.

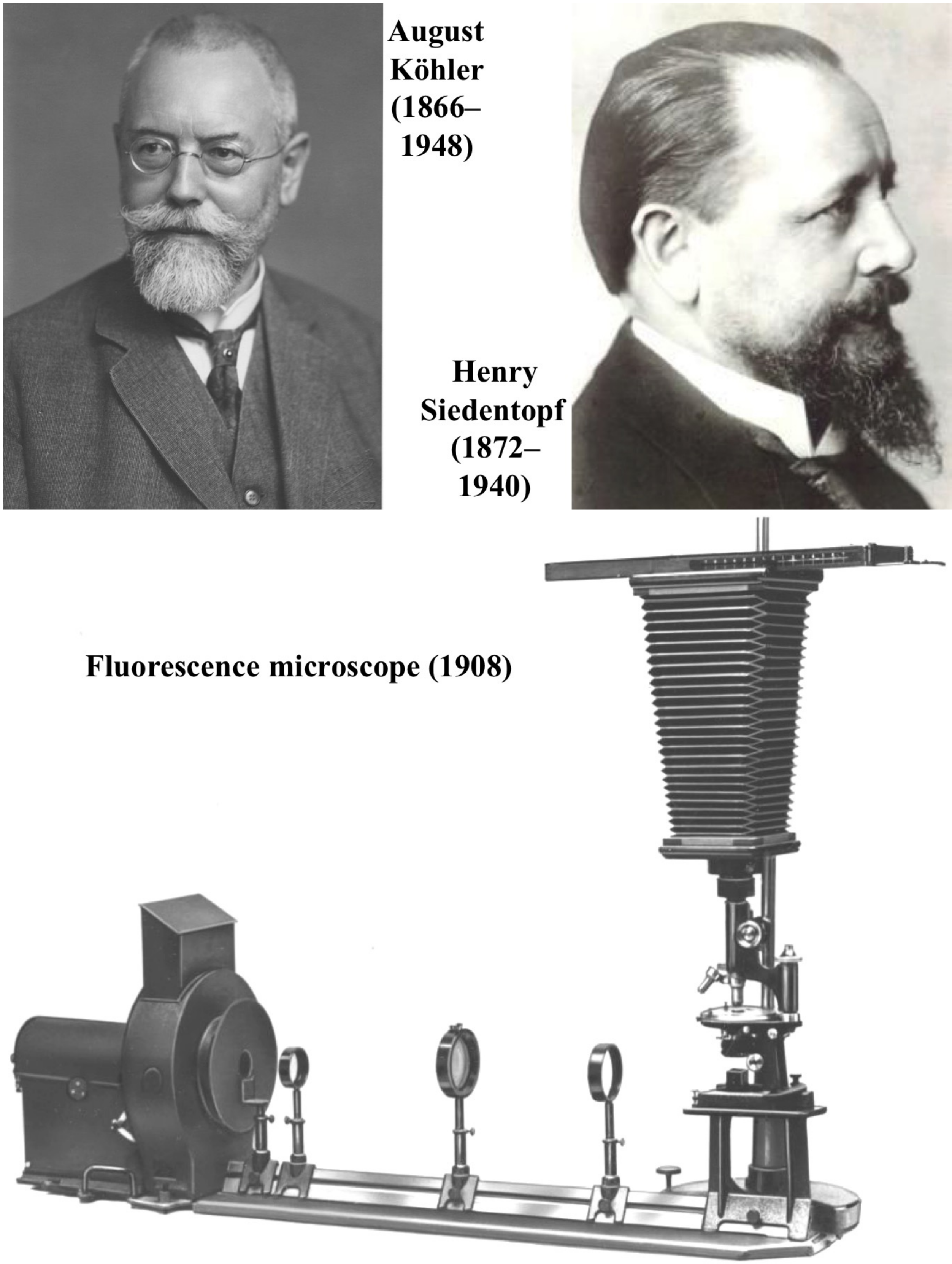
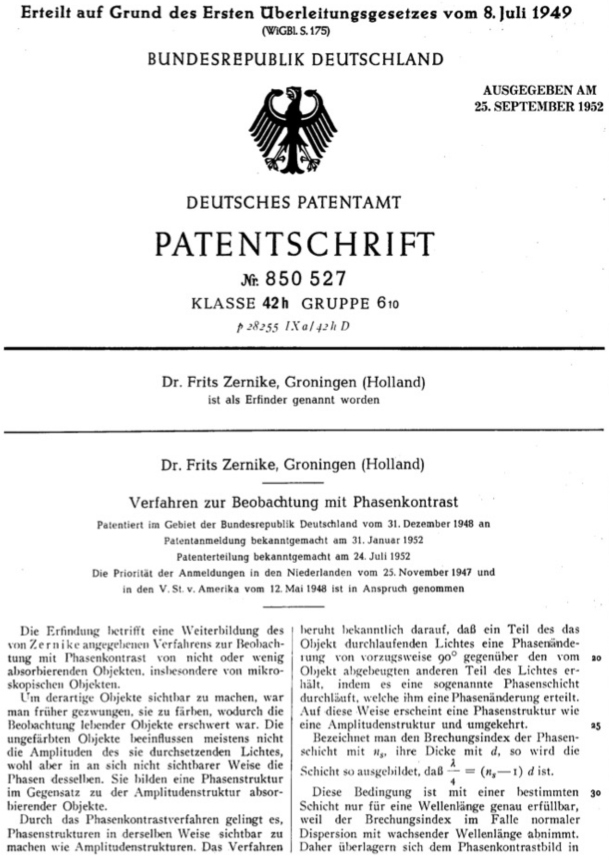

August Köhler (1866–1948)
Henry Siedentopf (1872–1940)
Fluorescence microscope (1908)

Figure 6.233: August Köhler and Henry Siedentopf invented the fluorescence microscope in 1908.

Frits Zernike (1888–1966) invented phase contrast microscopes (1933)



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
25. SEPTEMBER 1952

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 850 527

KLASSE 42h GRUPPE 6₁₀

p 28255 IXa/42h D

Dr. Frits Zernike, Groningen (Holland)
ist als Erfinder genannt worden

Dr. Frits Zernike, Groningen (Holland)

Verfahren zur Beobachtung mit Phasenkontrast

Patentiert im Gebiet der Bundesrepublik Deutschland vom 31. Dezember 1948 an
Patentanmeldung bekanntgemacht am 31. Januar 1952
Patenterteilung bekanntgemacht am 24. Juli 1952
Die Priorität der Anmeldungen in den Niederlanden vom 25. November 1947 und
in den V. St. v. Amerika vom 12. Mai 1948 ist in Anspruch genommen

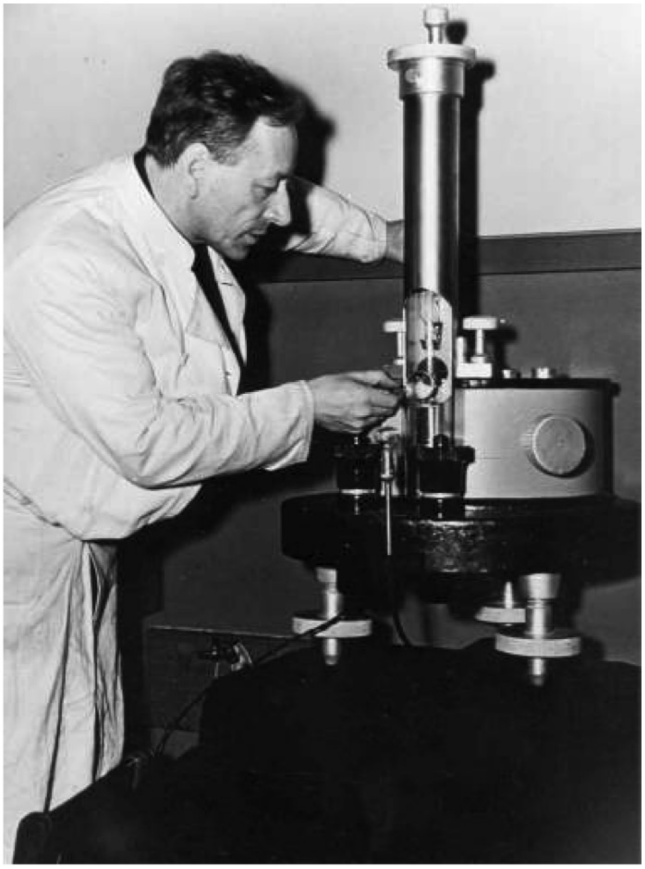
Die Erfindung betrifft eine Weiterbildung des von Zernike angegebenen Verfahrens zur Beobachtung mit Phasenkontrast von nicht oder wenig absorbierenden Objekten, insbesondere von mikroskopischen Objekten.

Um derartige Objekte sichtbar zu machen, war man früher gezwungen, sie zu färben, wodurch die Beobachtung lebender Objekte erschwert war. Die ungefärbten Objekte beeinflussen meistens nicht die Amplituden des sie durchsetzenden Lichtes, wohl aber in an sich nicht sichtbarer Weise die Phasen desselben. Sie bilden eine Phasenstruktur im Gegensatz zu der Amplitudenstruktur absorbierender Objekte.

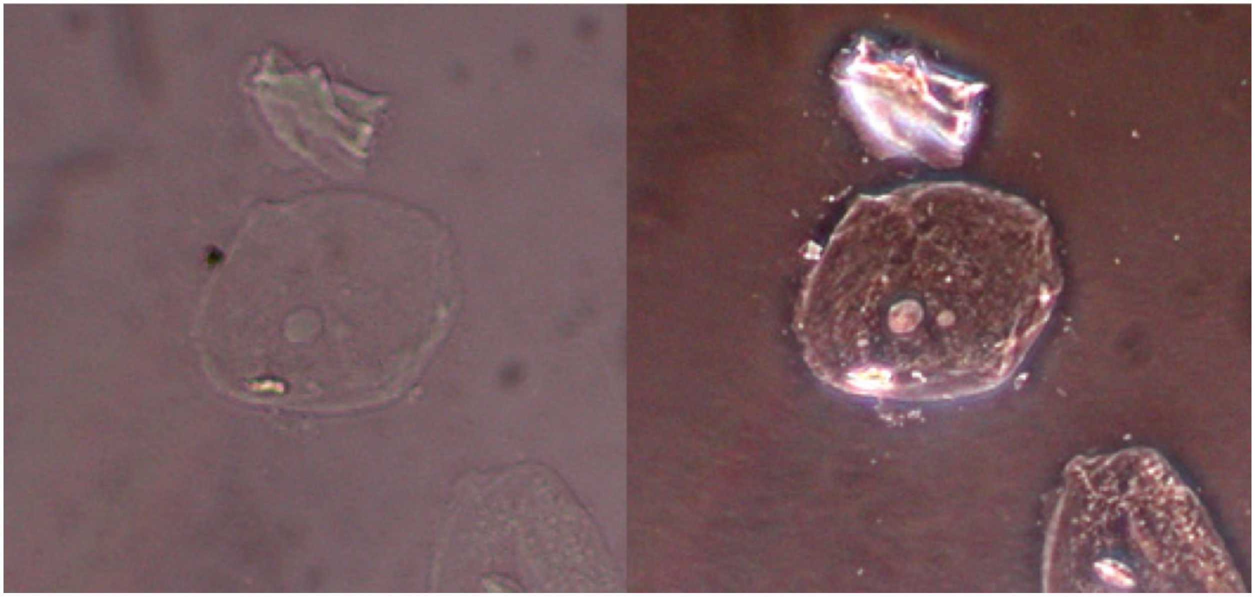
Durch das Phasenkontrastverfahren gelingt es, Phasenstrukturen in derselben Weise sichtbar zu machen wie Amplitudenstrukturen. Das Verfahren beruht bekanntlich darauf, daß ein Teil des das Objekt durchlaufenden Lichtes eine Phasenänderung von vorzugsweise 90° gegenüber den vom Objekt abgebeugten anderen Teil des Lichtes erhält, indem es eine sogenannte Phasenschicht durchläuft, welche ihm eine Phasenänderung erteilt. Auf diese Weise erscheint eine Phasenstruktur wie eine Amplitudenstruktur und umgekehrt.

Bezeichnet man den Brechungsindex der Phasenschicht mit n_s, ihre Dicke mit d, so wird die Schicht so ausgebildet, daß $\frac{\lambda}{4} = (n_s - 1)\, d$ ist.

Diese Bedingung ist mit einer bestimmten Schicht nur für eine Wellenlänge genau erfüllbar, weil der Brechungsindex im Falle normaler Dispersion mit wachsender Wellenlänge abnimmt. Daher überlagern sich dem Phasenkontrastbild in



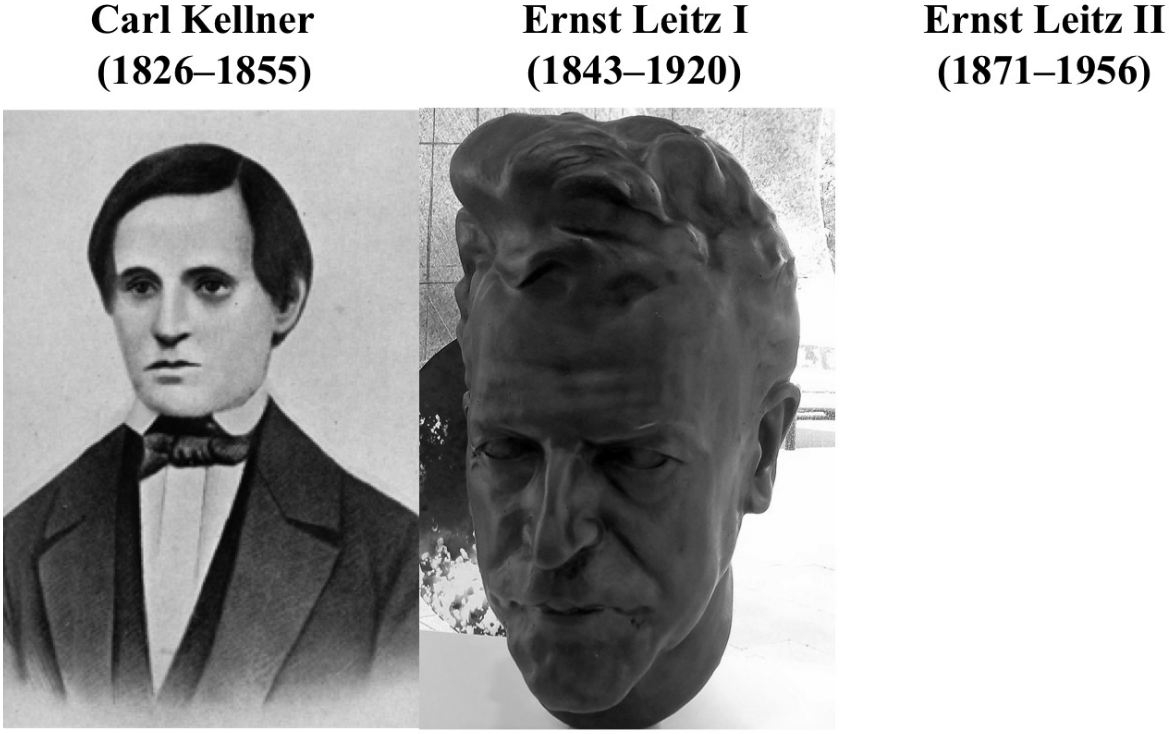
Phase contrast microscopes make cells easily visible without having to add colored chemical stains

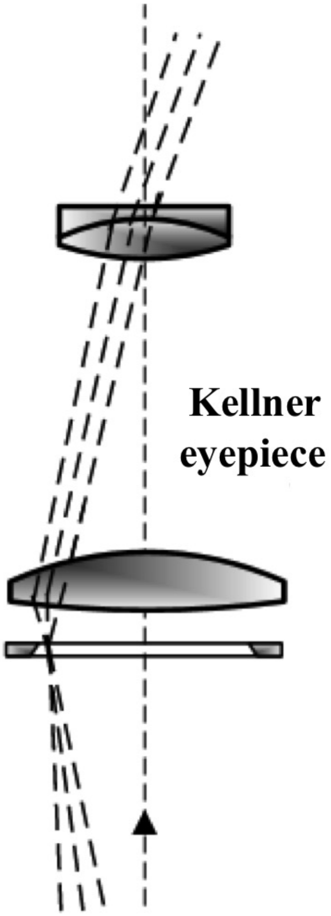


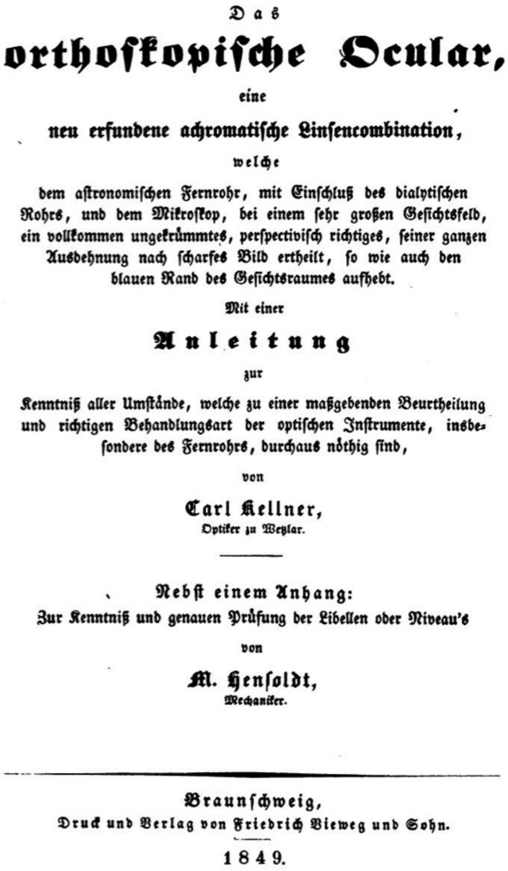
Without phase contrast

With phase contrast

Figure 6.234: Frits Zernike (1888–1966) invented phase contrast microscopes in 1933, and they were mass produced by the Zeiss company. Phase contrast microscopes make cells easily visible without having to add colored chemical stains.






Das
orthoſkopiſche Ocular,
eine
neu erfundene achromatiſche Linſencombination,
welche
dem aſtronomiſchen Fernrohr, mit Einſchluß des dialytiſchen
Rohrs, und dem Mikroſkop, bei einem ſehr großen Geſichtsfeld,
ein vollkommen ungekrümmtes, perſpectiviſch richtiges, ſeiner ganzen
Ausdehnung nach ſcharfes Bild ertheilt, ſo wie auch den
blauen Rand des Geſichtsraumes aufhebt.
Mit einer
Anleitung
zur
Kenntniß aller Umſtände, welche zu einer maßgebenden Beurtheilung
und richtigen Behandlungsart der optiſchen Inſtrumente, insbeſondere
des Fernrohrs, durchaus nöthig ſind,
von
Carl Kellner,
Optiker zu Wetzlar.

Nebſt einem Anhang:
Zur Kenntniß und genauen Prüfung der Libellen oder Niveau's
von
M. Henſoldt,
Mechaniker.

Braunſchweig,
Druck und Verlag von Friedrich Vieweg und Sohn.
1849.

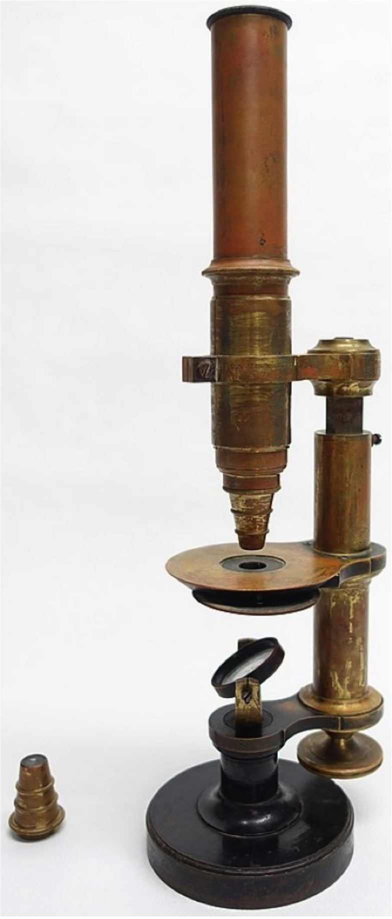


Figure 6.235: Carl Kellner, Ernst Leitz I, and the son Ernst Leitz II created what came to be called the Leitz optical instrument company.

Ernst Arbeit
(18??–19??)

Carl Metz
(18??–19??)

Felix Jentzsch
(18??–19??) modern
binocular microscope

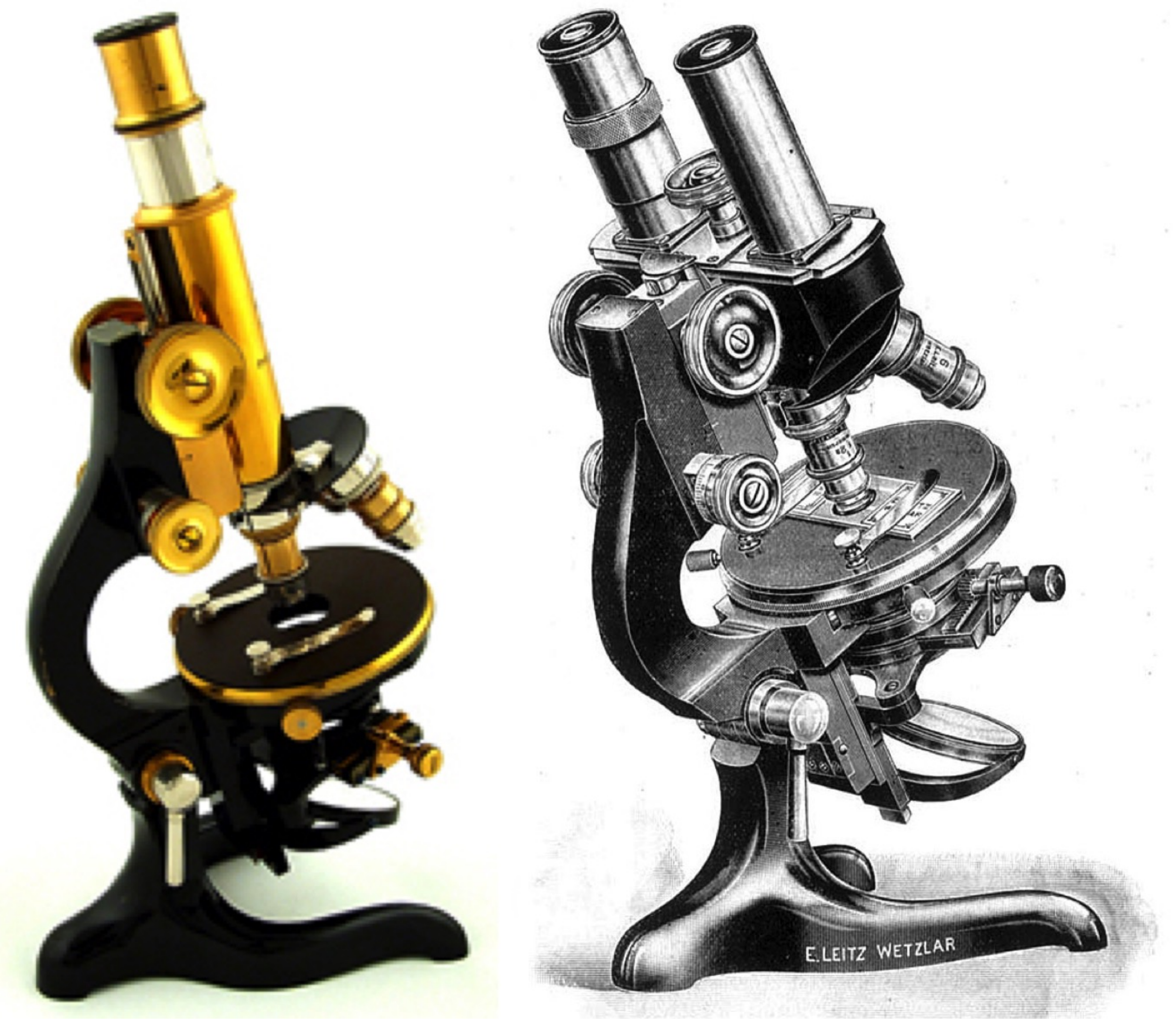


Figure 6.236: Ernst Arbeit, Carl Metz, and Felix Jentzsch developed microscopes at the Leitz company.

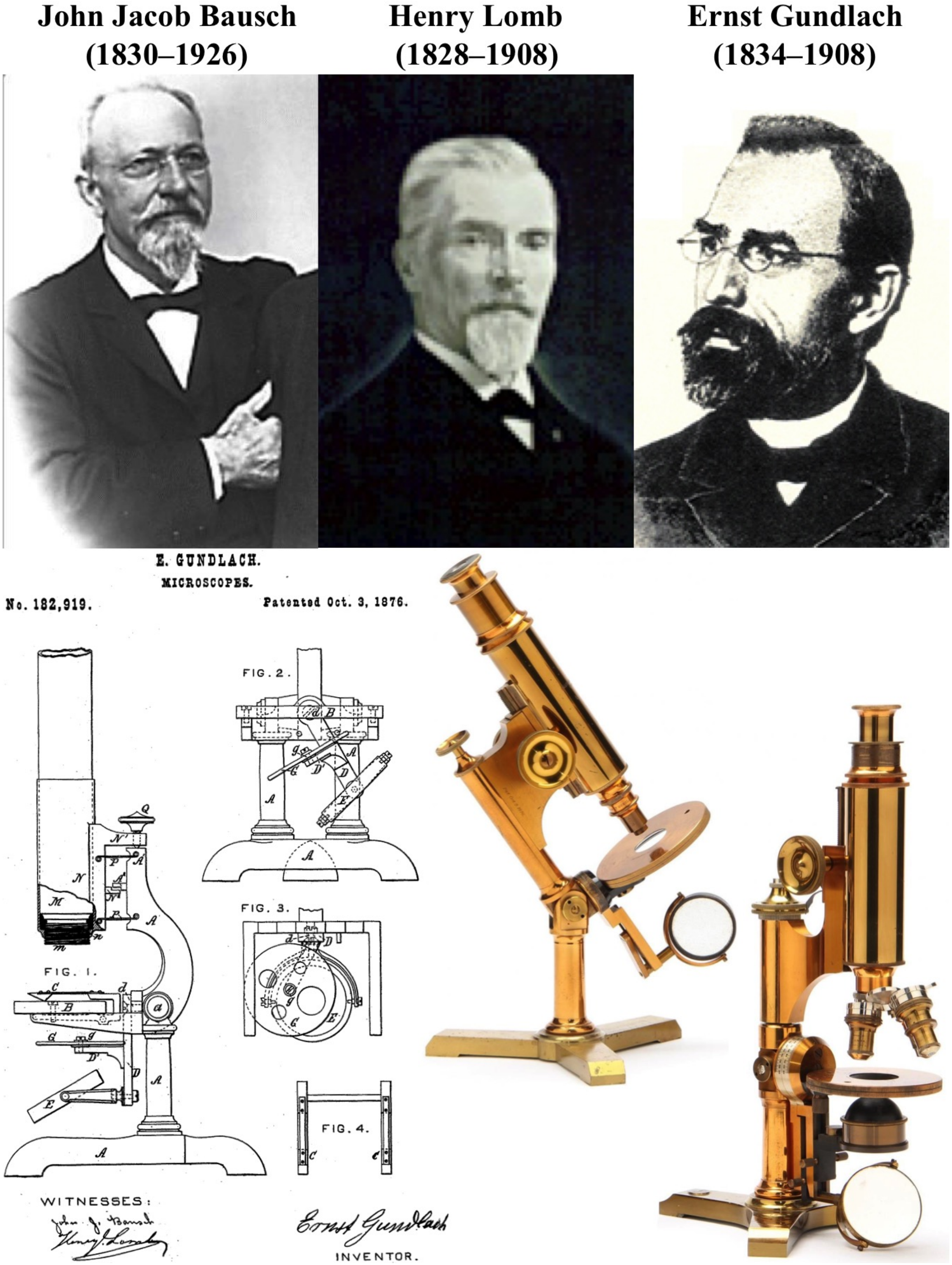
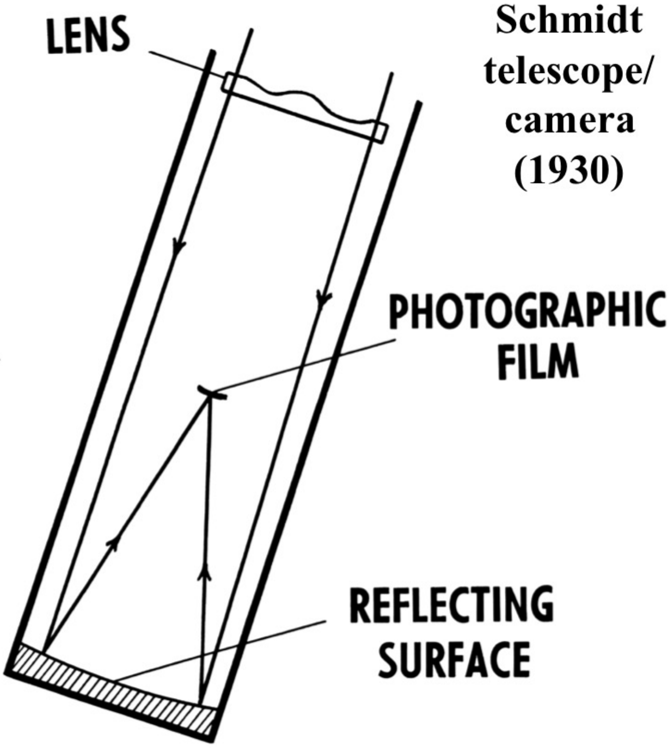

John Jacob Bausch
(1830–1926)
Henry Lomb
(1828–1908)
Ernst Gundlach
(1834–1908)
E. GUNDLACH.
MICROSCOPES.
No. 182,919.
Patented Oct. 3, 1876.
FIG. 1.
FIG. 2.
FIG. 3.
FIG. 4.
WITNESSES:
John J. Bausch
Henry Lomb
Ernst Gundlach
INVENTOR.

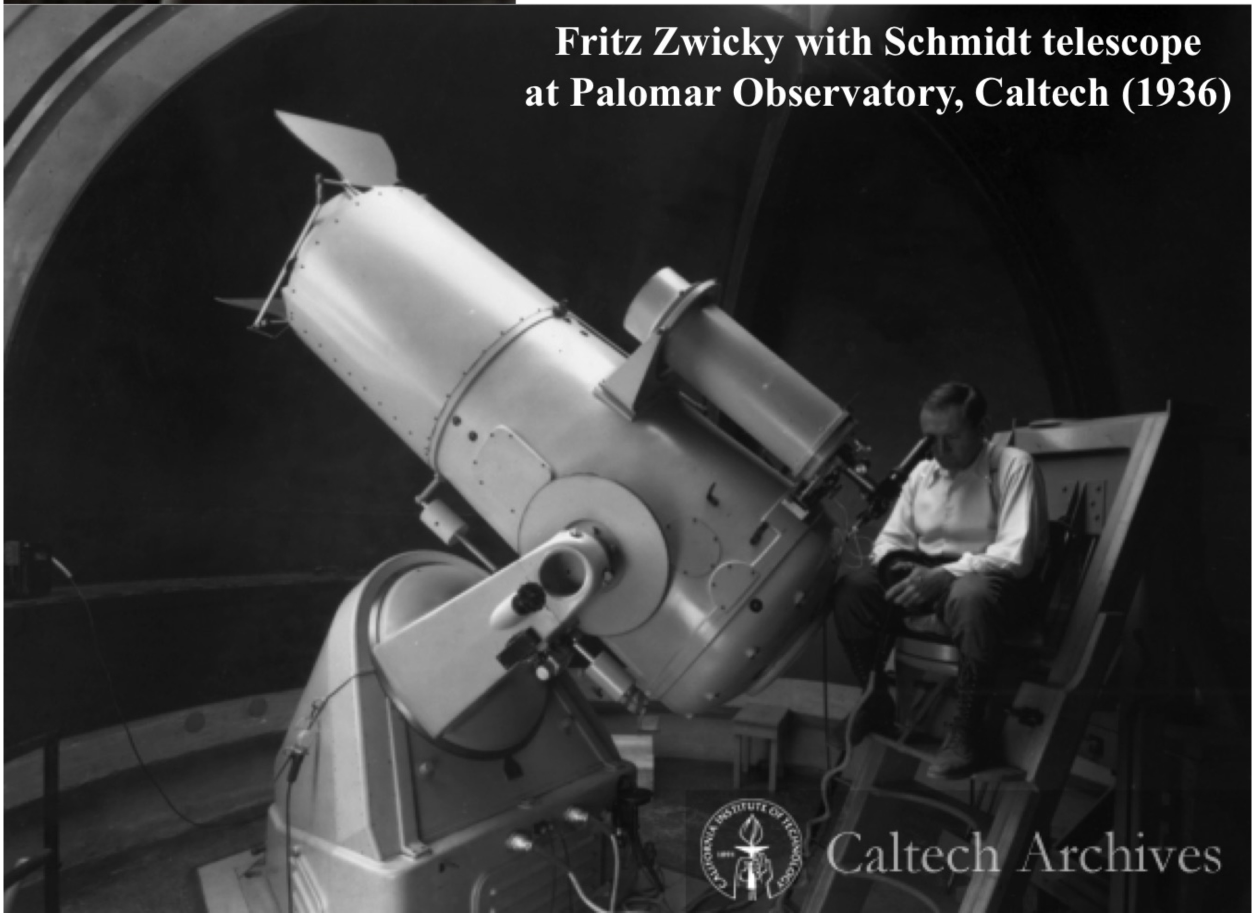
Figure 6.237: John Jacob Bausch, Henry Lomb, and Ernst Gundlach produced microscopes and other optical instruments at the Bausch & Lomb company in the United States.

Bernhard Schmidt (1879–1935)



Schmidt telescope/ camera (1930)

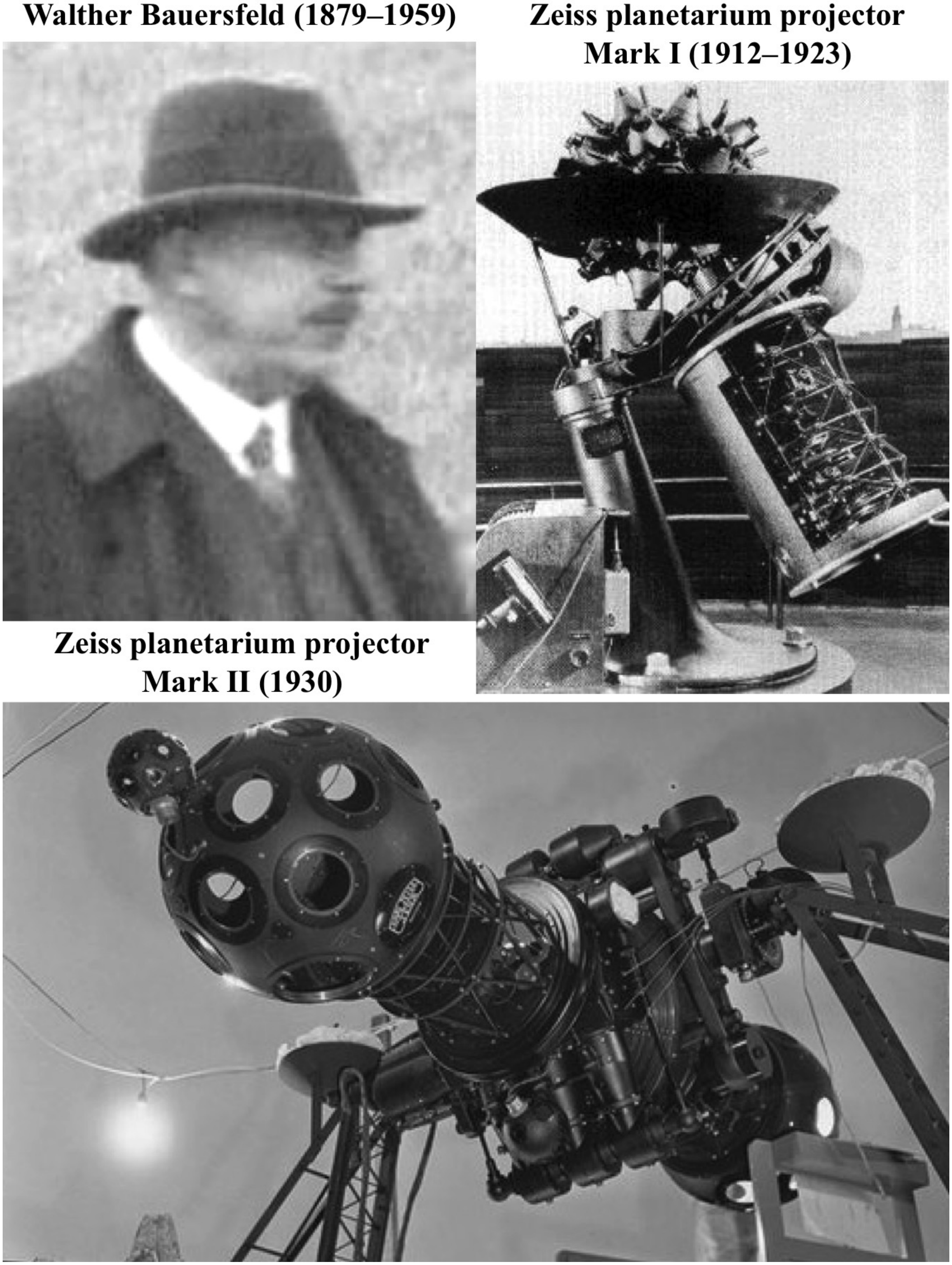
LENS
PHOTOGRAPHIC FILM
REFLECTING SURFACE



Fritz Zwicky with Schmidt telescope at Palomar Observatory, Caltech (1936)

Caltech Archives

Figure 6.238: Bernhard Schmidt (1879–1935) invented the Schmidt telescope/camera in 1930.



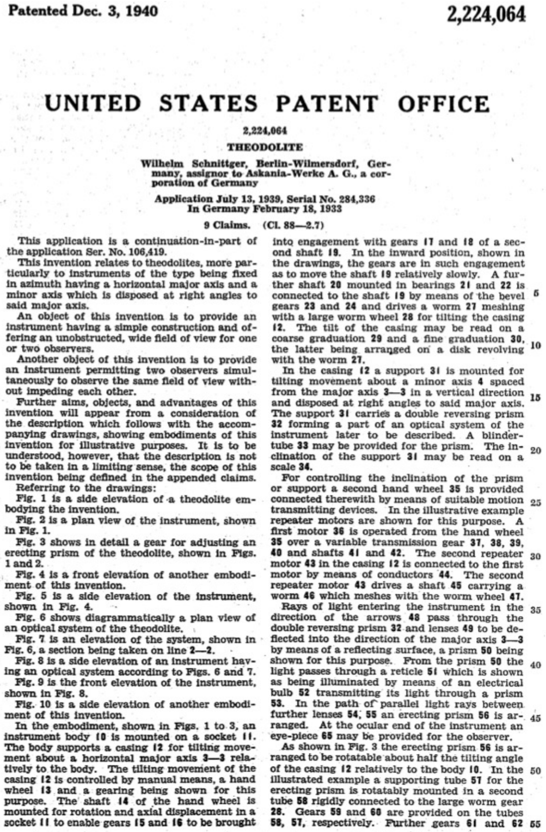
Walther Bauersfeld (1879–1959)

Zeiss planetarium projector Mark I (1912–1923)

Zeiss planetarium projector Mark II (1930)

Figure 6.239: Walther Bauersfeld (1879–1959) developed the Zeiss planetarium projector Mark I (1912–1923), Mark II (1930), and later models.

Wilhelm Schnittger (19??–19??) Advanced theodolites and cinetheodolites (1933, Askania)



Patented Dec. 3, 1940 **2,224,064**

UNITED STATES PATENT OFFICE

2,224,064

THEODOLITE

Wilhelm Schnittger, Berlin-Wilmersdorf, Germany, assignor to Askania-Werke A. G., a corporation of Germany

Application July 13, 1939, Serial No. 284,336
In Germany February 18, 1933

9 Claims. (Cl. 88—2.7)

This application is a continuation-in-part of the application Ser. No. 106,419.

This invention relates to theodolites, more particularly to instruments of the type being fixed in azimuth having a horizontal major axis and a minor axis which is disposed at right angles to said major axis.

An object of this invention is to provide an instrument having a simple construction and offering an unobstructed, wide field of view for one or two observers.

Another object of this invention is to provide an instrument permitting two observers simultaneously to observe the same field of view without impeding each other.

Further aims, objects, and advantages of this invention will appear from a consideration of the description which follows with the accompanying drawings, showing embodiments of this invention for illustrative purposes. It is to be understood, however, that the description is not to be taken in a limiting sense, the scope of this invention being defined in the appended claims.

Referring to the drawings:

Fig. 1 is a side elevation of a theodolite embodying the invention.

Fig. 2 is a plan view of the instrument, shown in Fig. 1.

Fig. 3 shows in detail a gear for adjusting an erecting prism of the theodolite, shown in Figs. 1 and 2.

Fig. 4 is a front elevation of another embodiment of this invention.

Fig. 5 is a side elevation of the instrument, shown in Fig. 4.

Fig. 6 shows diagrammatically a plan view of an optical system of the theodolite.

Fig. 7 is an elevation of the system, shown in Fig. 6, a section being taken on line 2—2.

Fig. 8 is a side elevation of an instrument having an optical system according to Figs. 6 and 7.

Fig. 9 is the front elevation of the instrument, shown in Fig. 8.

Fig. 10 is a side elevation of another embodiment of this invention.

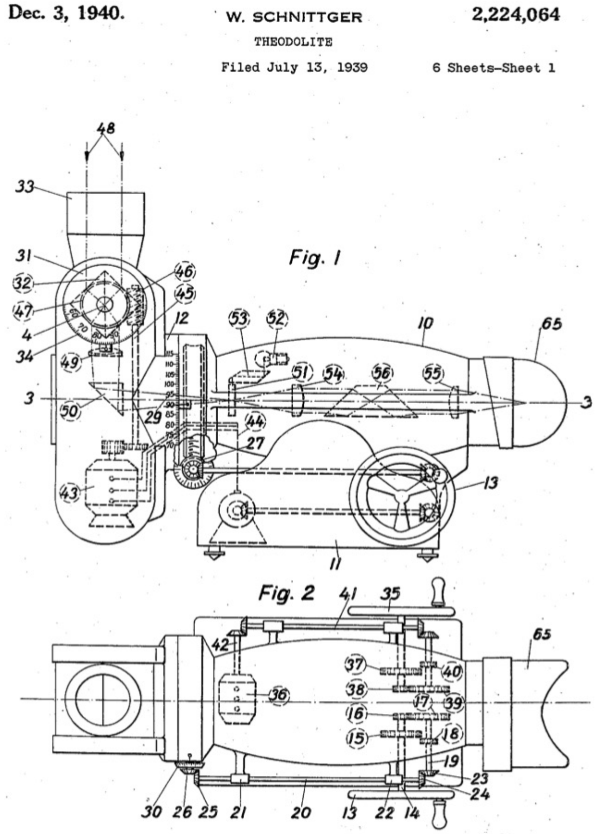
In the embodiment, shown in Figs. 1 to 3, an instrument body **10** is mounted on a socket **11**. The body supports a casing **12** for tilting movement about a horizontal major axis **3—3** relatively to the body. The tilting movement of the casing **12** is controlled by manual means, a hand wheel **13** and a gearing being shown for this purpose. The shaft **14** of the hand wheel is mounted for rotation and axial displacement in a socket **11** to enable gears **15** and **16** to be brought into engagement with gears **17** and **18** of a second shaft **19**. In the inward position, shown in the drawings, the gears are in such engagement as to move the shaft **19** relatively slowly. A further shaft **20** mounted in bearings **21** and **22** is connected to the shaft **19** by means of the bevel gears **23** and **24** and drives a worm **27** meshing with a large worm wheel **28** for tilting the casing **12**. The tilt of the casing may be read on a coarse graduation **29** and a fine graduation **30**, the latter being arranged on a disk revolving with the worm **27**.

In the casing **12** a support **31** is mounted for tilting movement about a minor axis **4** spaced from the major axis **3—3** in a vertical direction and disposed at right angles to said major axis. The support **31** carries a double reversing prism **32** forming a part of an optical system of the instrument later to be described. A blinder-tube **33** may be provided for the prism. The inclination of the support **31** may be read on a scale **34**.

For controlling the inclination of the prism or support a second hand wheel **35** is provided connected therewith by means of suitable motion transmitting devices. In the illustrative example repeater motors are shown for this purpose. A first motor **36** is operated from the hand wheel **35** over a variable transmission gear **37**, **38**, **39**, **40** and shafts **41** and **42**. The second repeater motor **43** in the casing **12** is connected to the first motor by means of conductors **44**. The second repeater motor **43** drives a shaft **45** carrying a worm **46** which meshes with the worm wheel **47**.

Rays of light entering the instrument in the direction of the arrows **48** pass through the double reversing prism **32** and lenses **49** to be deflected into the direction of the major axis **3—3** by means of a reflecting surface, a prism **50** being shown for this purpose. From the prism **50** the light passes through a reticle **51** which is shown as being illuminated by means of an electrical bulb **52** transmitting its light through a prism **53**. In the path of parallel light rays between further lenses **54**, **55** an erecting prism **56** is arranged. At the ocular end of the instrument an eye-piece **65** may be provided for the observer.

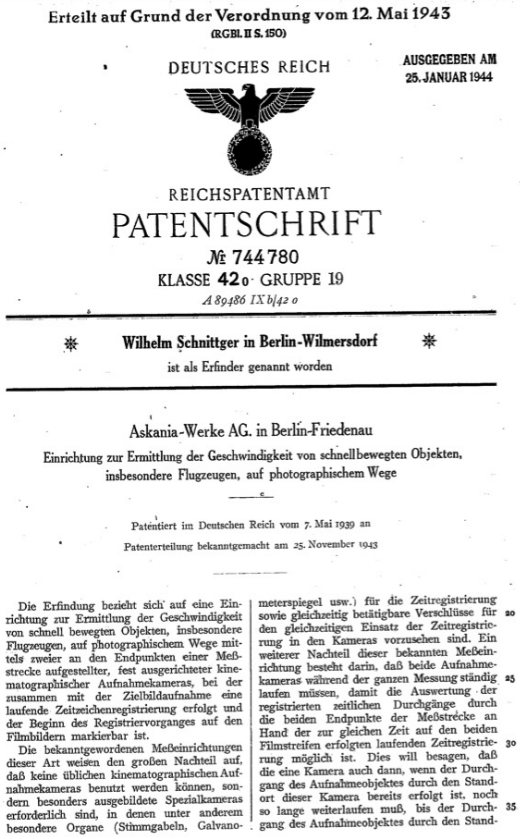
As shown in Fig. 3 the erecting prism **56** is arranged to be rotatable about half the tilting angle of the casing **12** relatively to the body **10**. In the illustrated example a supporting tube **57** for the erecting prism is rotatably mounted in a second tube **58** rigidly connected to the large worm gear **28**. Gears **59** and **60** are provided on the tubes **58**, **57**, respectively. Further gears **61** and **62**



Dec. 3, 1940. **W. SCHNITTGER** **2,224,064**

THEODOLITE

Filed July 13, 1939 6 Sheets—Sheet 1



Erteilt auf Grund der Verordnung vom 12. Mai 1943
(RGBl. II S. 150)

DEUTSCHES REICH

AUSGEGEBEN AM
25. JANUAR 1944

REICHSPATENTAMT

PATENTSCHRIFT

№ 744780

KLASSE 42o GRUPPE 19

A 89486 IX b/42 o

Wilhelm Schnittger in Berlin-Wilmersdorf

ist als Erfinder genannt worden

Askania-Werke AG. in Berlin-Friedenau

Einrichtung zur Ermittlung der Geschwindigkeit von schnellbewegten Objekten, insbesondere Flugzeugen, auf photographischem Wege

Patentiert im Deutschen Reich vom 7. Mai 1939 an

Patenterteilung bekanntgemacht am 25. November 1943

Die Erfindung bezieht sich auf eine Einrichtung zur Ermittlung der Geschwindigkeit von schnell bewegten Objekten, insbesondere Flugzeugen, auf photographischem Wege mittels zweier an den Endpunkten einer Meßstrecke aufgestellter, fest ausgerichteter kinematographischer Aufnahmekameras, bei der zusammen mit der Zielbildaufnahme eine laufende Zeitzeichenregistrierung erfolgt und der Beginn des Registriervorganges auf den Filmbildern markierbar ist.

Die bekanntgewordenen Meßeinrichtungen dieser Art weisen den großen Nachteil auf, daß keine üblichen kinematographischen Aufnahmekameras benutzt werden können, sondern besonders ausgebildete Spezialkameras erforderlich sind, in denen unter anderem besondere Organe (Stimmgabeln, Galvanometerspiegel usw.) für die Zeitregistrierung sowie gleichzeitig betätigbare Verschlüsse für den gleichzeitigen Einsatz der Zeitregistrierung in den Kameras vorzusehen sind. Ein weiterer Nachteil dieser bekannten Meßeinrichtung besteht darin, daß beide Aufnahmekameras während der ganzen Messung ständig laufen müssen, damit die Auswertung der registrierten zeitlichen Durchgänge durch die beiden Endpunkte der Meßstrecke an Hand der zur gleichen Zeit auf den beiden Filmstreifen erfolgten laufenden Zeitregistrierung möglich ist. Dies will besagen, daß die eine Kamera auch dann, wenn der Durchgang des Aufnahmeobjektes durch den Standort dieser Kamera bereits erfolgt ist, noch so lange weiterlaufen muß, bis der Durchgang des Aufnahmeobjektes durch den Stand-

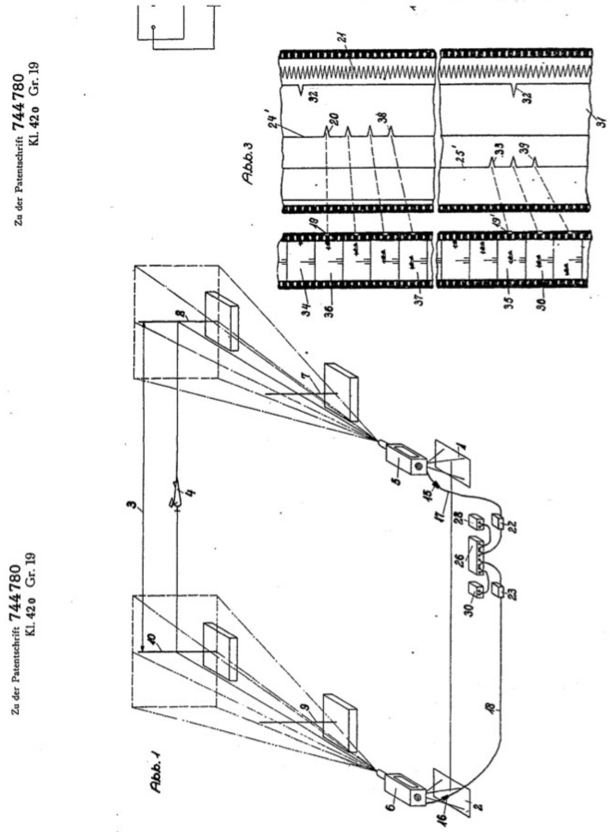


Figure 6.240: Wilhelm Schnittger invented advanced theodolites and cinetheodolites at Askania Werke in 1933.

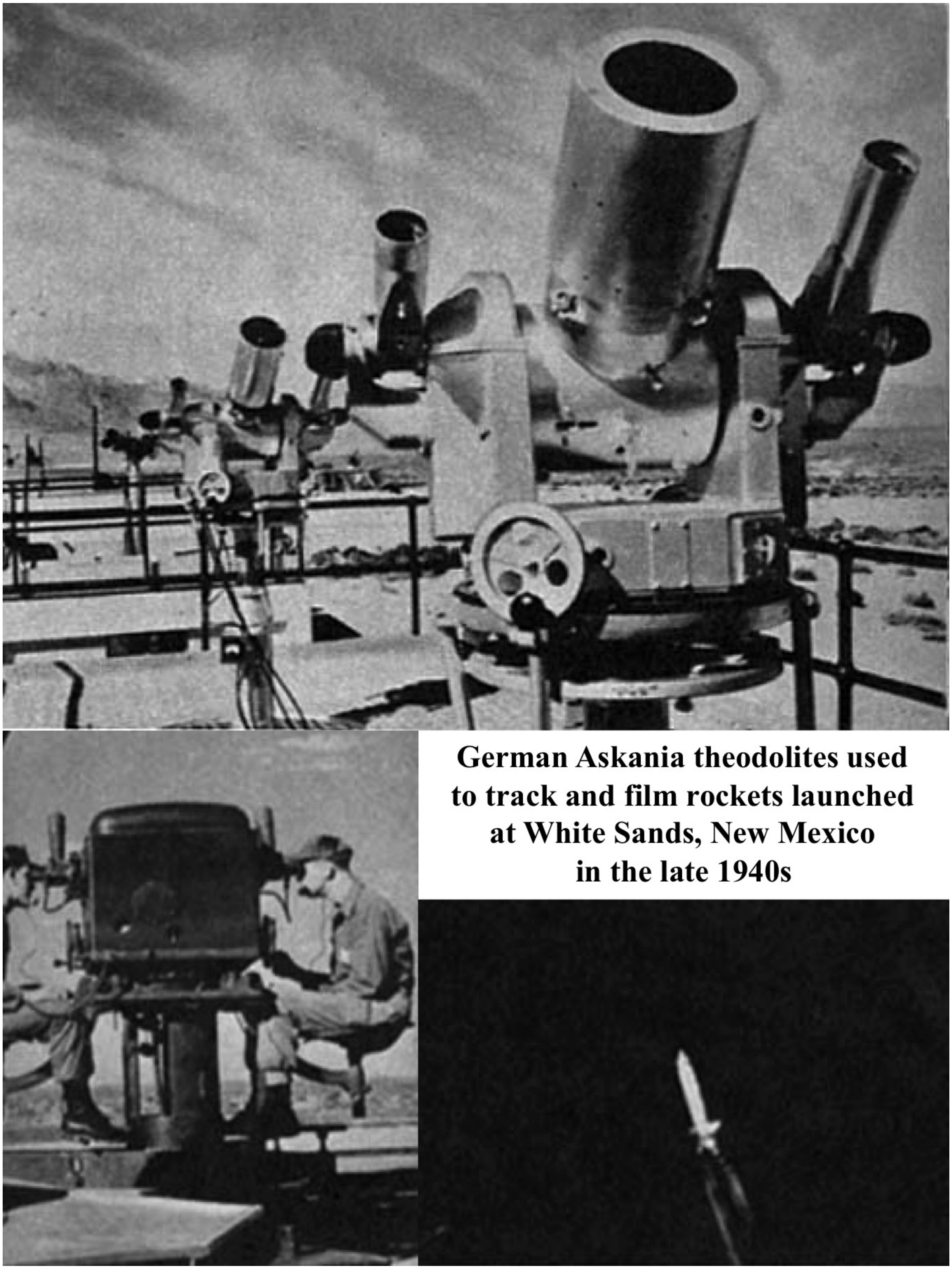
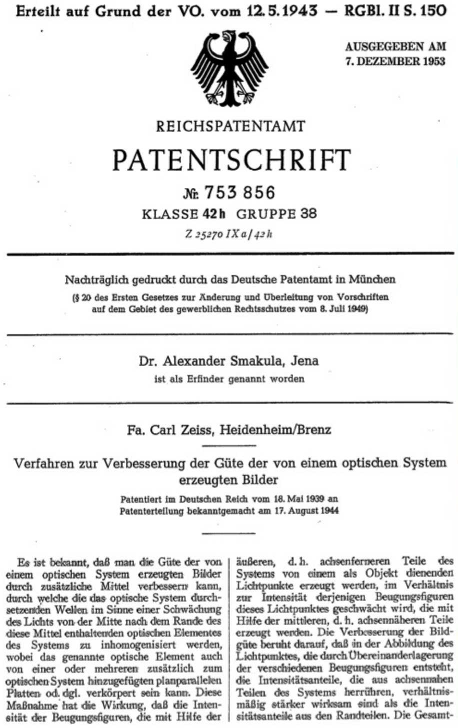

German Askania theodolites used
to track and film rockets launched
at White Sands, New Mexico
in the late 1940s

Figure 6.241: German Askania theodolites were used to track and film rockets launched at White Sands, New Mexico in the late 1940s, as well as many other U.S. aerospace vehicles in the decades following World War II.



Erteilt auf Grund der VO. vom 12.5.1943 — RGBl. II S. 150

AUSGEGEBEN AM
7. DEZEMBER 1953

REICHSPATENTAMT

PATENTSCHRIFT

№ 753 856
KLASSE 42h GRUPPE 38
Z 25270 IXa/42h

Nachträglich gedruckt durch das Deutsche Patentamt in München
(§ 20 des Ersten Gesetzes zur Änderung und Überleitung von Vorschriften auf dem Gebiet des gewerblichen Rechtsschutzes vom 8. Juli 1949)

Dr. Alexander Smakula, Jena
ist als Erfinder genannt worden

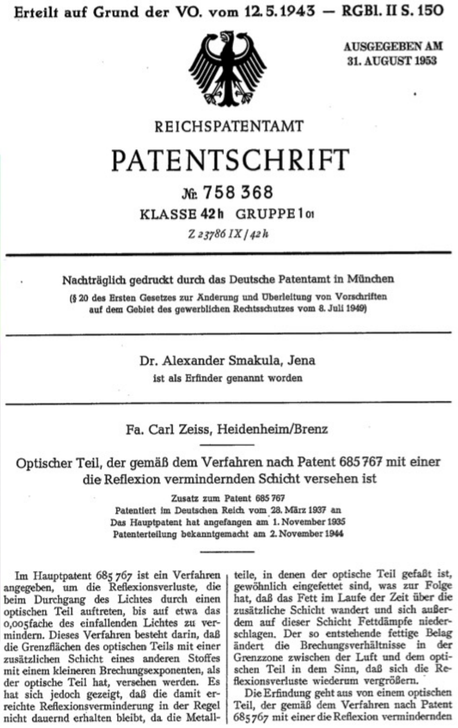
Fa. Carl Zeiss, Heidenheim/Brenz

Verfahren zur Verbesserung der Güte der von einem optischen System erzeugten Bilder

Patentiert im Deutschen Reich vom 18. Mai 1939 an
Patenterteilung bekanntgemacht am 17. August 1944

Es ist bekannt, daß man die Güte der von einem optischen System erzeugten Bilder durch zusätzliche Mittel verbessern kann, durch welche die das optische System durchsetzenden Wellen im Sinne einer Schwächung des Lichts von der Mitte nach dem Rande des diese Mittel enthaltenden optischen Elementes des Systems zu inhomogenisiert werden, wobei das genannte optische Element auch von einer oder mehreren zusätzlich zum optischen System hinzugefügten planparallelen Platten od. dgl. verkörpert sein kann. Diese Maßnahme hat die Wirkung, daß die Intensität der Beugungsfiguren, die mit Hilfe der äußeren, d. h. achsenferneren Teile des Systems von einem als Objekt dienenden Lichtpunkte erzeugt werden, im Verhältnis zur Intensität derjenigen Beugungsfiguren dieses Lichtpunktes geschwächt wird, die mit Hilfe der mittleren, d. h. achsennäheren Teile erzeugt werden. Die Verbesserung der Bildgüte beruht darauf, daß in der Abbildung des Lichtpunktes, die durch Übereinanderlagerung der verschiedenen Beugungsfiguren entsteht, die Intensitätsanteile, die aus achsennahen Teilen des Systems herrühren, verhältnismäßig stärker wirksam sind als die Intensitätsanteile aus den Randteilen. Die Gesamt-

Alexander Smakula (1900–1983)



Erteilt auf Grund der VO. vom 12.5.1943 — RGBl. II S. 150

AUSGEGEBEN AM
31. AUGUST 1953

REICHSPATENTAMT

PATENTSCHRIFT

№ 758 368
KLASSE 42h GRUPPE 1 01
Z 23786 IX/42h

Nachträglich gedruckt durch das Deutsche Patentamt in München
(§ 20 des Ersten Gesetzes zur Änderung und Überleitung von Vorschriften auf dem Gebiet des gewerblichen Rechtsschutzes vom 8. Juli 1949)

Dr. Alexander Smakula, Jena
ist als Erfinder genannt worden

Fa. Carl Zeiss, Heidenheim/Brenz

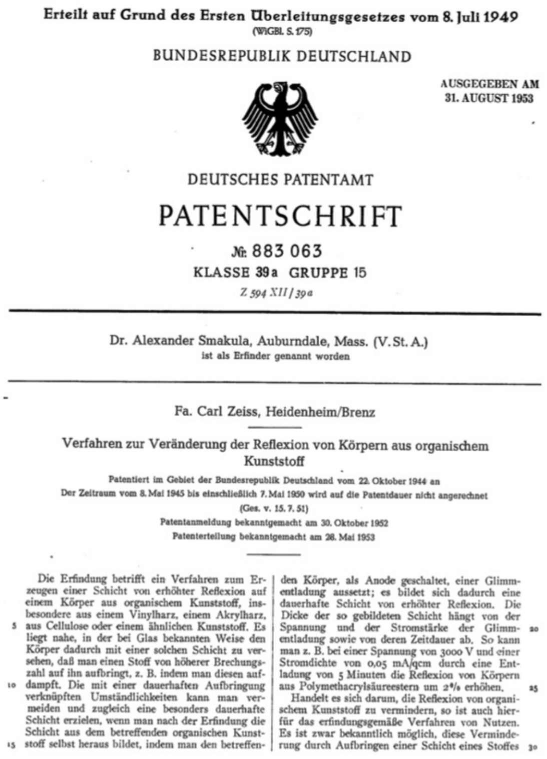
Optischer Teil, der gemäß dem Verfahren nach Patent 685 767 mit einer die Reflexion vermindernden Schicht versehen ist

Zusatz zum Patent 685 767
Patentiert im Deutschen Reich vom 28. März 1937 an
Das Hauptpatent hat angefangen am 1. November 1935
Patenterteilung bekanntgemacht am 2. November 1944

Im Hauptpatent 685 767 ist ein Verfahren angegeben, um die Reflexionsverluste, die beim Durchgang des Lichtes durch einen optischen Teil auftreten, bis auf etwa das 0,005fache des einfallenden Lichtes zu vermindern. Dieses Verfahren besteht darin, daß die Grenzflächen des optischen Teils mit einer zusätzlichen Schicht eines anderen Stoffes mit einem kleineren Brechungsexponenten, als der optische Teil hat, versehen werden. Es hat sich jedoch gezeigt, daß die damit erreichte Reflexionsverminderung in der Regel nicht dauernd erhalten bleibt, da die Metallteile, in denen der optische Teil gefaßt ist, gewöhnlich eingefettet sind, was zur Folge hat, daß das Fett im Laufe der Zeit über die zusätzliche Schicht wandert und sich außerdem auf dieser Schicht Fettdämpfe niederschlagen. Der so entstehende fettige Belag ändert die Brechungsverhältnisse in der Grenzzone zwischen der Luft und dem optischen Teil in dem Sinn, daß sich die Reflexionsverluste wiederum vergrößern.

Die Erfindung geht aus von einem optischen Teil, der gemäß dem Verfahren nach Patent 685767 mit einer die Reflexion vermindernden

Antireflective coatings for lenses (1935)



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
31. AUGUST 1953

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 883 063
KLASSE 39a GRUPPE 15
Z 594 XII/39a

Dr. Alexander Smakula, Auburndale, Mass. (V. St. A.)
ist als Erfinder genannt worden

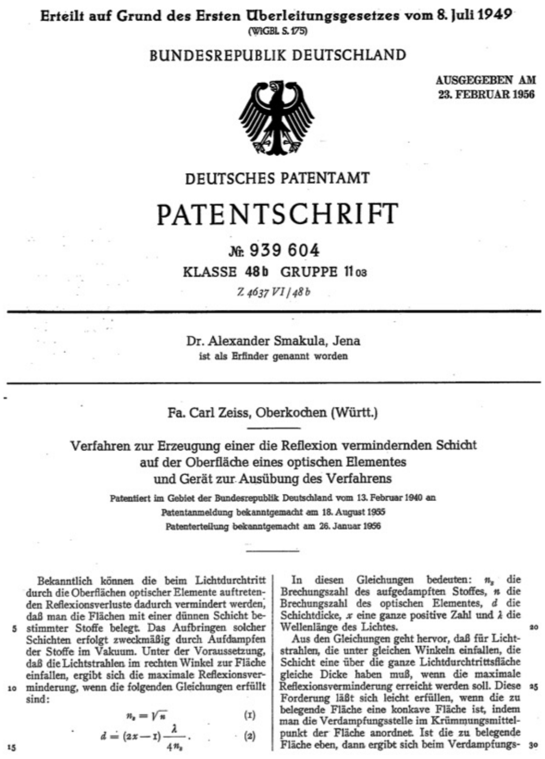
Fa. Carl Zeiss, Heidenheim/Brenz

Verfahren zur Veränderung der Reflexion von Körpern aus organischem Kunststoff

Patentiert im Gebiet der Bundesrepublik Deutschland vom 22. Oktober 1944 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
(Ges. v. 15. 7. 51)
Patentanmeldung bekanntgemacht am 30. Oktober 1952
Patenterteilung bekanntgemacht am 28. Mai 1953

Die Erfindung betrifft ein Verfahren zum Erzeugen einer Schicht von erhöhter Reflexion auf einem Körper aus organischem Kunststoff, insbesondere aus einem Vinylharz, einem Akrylharz, aus Cellulose oder einem ähnlichen Kunststoff. Es liegt nahe, in der bei Glas bekannten Weise den Körper dadurch mit einer solchen Schicht zu versehen, daß man einen Stoff von höherer Brechungszahl auf ihn aufbringt, z. B. indem man diesen aufdampft. Die mit einer dauerhaften Aufbringung verknüpften Umständlichkeiten kann man vermeiden und zugleich eine besonders dauerhafte Schicht erzielen, wenn man nach der Erfindung die Schicht aus dem betreffenden organischen Kunststoff selbst heraus bildet, indem man den betreffenden Körper, als Anode geschaltet, einer Glimmentladung aussetzt; es bildet sich dadurch eine dauerhafte Schicht von erhöhter Reflexion. Die Dicke der so gebildeten Schicht hängt von der Spannung und der Stromstärke der Glimmentladung sowie von deren Zeitdauer ab. So kann man z. B. bei einer Spannung von 3000 V und einer Stromdichte von 0,05 mA/qcm durch eine Entladung von 5 Minuten die Reflexion von Körpern aus Polymethacrylsäureestern um 2% erhöhen.

Handelt es sich darum, die Reflexion von organischem Kunststoff zu vermindern, so ist auch hierfür das erfindungsgemäße Verfahren von Nutzen. Es ist zwar bekanntlich möglich, diese Verminderung durch Aufbringen einer Schicht eines Stoffes



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
23. FEBRUAR 1956

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 939 604
KLASSE 48b GRUPPE 11 03
Z 4637 VI/48b

Dr. Alexander Smakula, Jena
ist als Erfinder genannt worden

Fa. Carl Zeiss, Oberkochen (Württ.)

Verfahren zur Erzeugung einer die Reflexion vermindernden Schicht auf der Oberfläche eines optischen Elementes und Gerät zur Ausübung des Verfahrens

Patentiert im Gebiet der Bundesrepublik Deutschland vom 13. Februar 1940 an
Patentanmeldung bekanntgemacht am 18. August 1955
Patenterteilung bekanntgemacht am 26. Januar 1956

Bekanntlich können die beim Lichtdurchtritt durch die Oberflächen optischer Elemente auftretenden Reflexionsverluste dadurch vermindert werden, daß man die Flächen mit einer dünnen Schicht bestimmter Stoffe belegt. Das Aufbringen solcher Schichten erfolgt zweckmäßig durch Aufdampfen der Stoffe im Vakuum. Unter der Voraussetzung, daß die Lichtstrahlen im rechten Winkel zur Fläche einfallen, ergibt sich die maximale Reflexionsverminderung, wenn die folgenden Gleichungen erfüllt sind:

$$n_s = \sqrt{n} \qquad (1)$$

$$d \doteq (2x-1)\frac{\lambda}{4n_s}. \qquad (2)$$

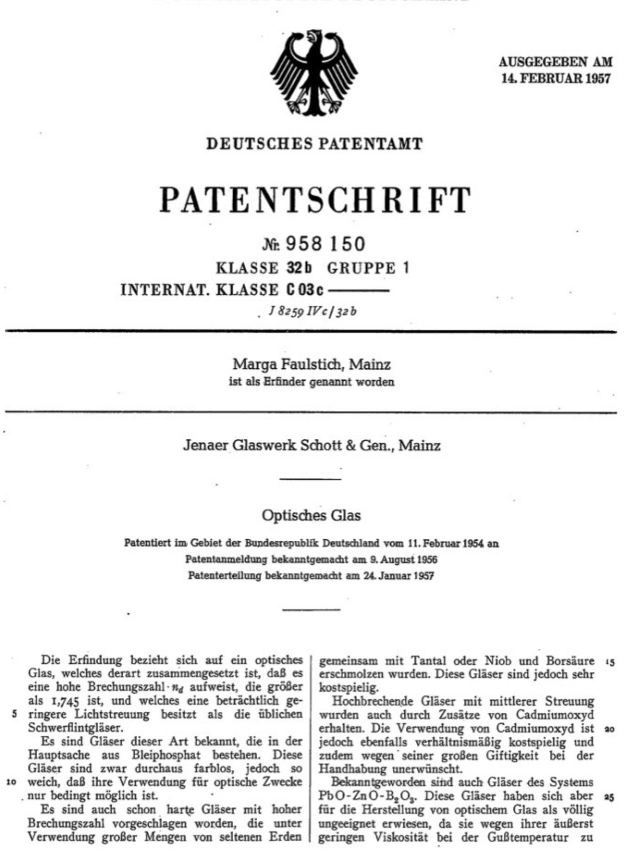
In diesen Gleichungen bedeuten: n_s die Brechungszahl des aufgedampften Stoffes, n die Brechungszahl des optischen Elementes, d die Schichtdicke, x eine ganze positive Zahl und λ die Wellenlänge des Lichtes.

Aus den Gleichungen geht hervor, daß für Lichtstrahlen, die unter gleichen Winkeln einfallen, die Schicht eine über die ganze Lichtdurchtrittsfläche gleiche Dicke haben muß, wenn die maximale Reflexionsverminderung erreicht werden soll. Diese Forderung läßt sich leicht erfüllen, wenn die zu belegende Fläche eine konkave Fläche ist, indem man die Verdampfungsstelle im Krümmungsmittelpunkt der Fläche anordnet. Ist die zu belegende Fläche eben, dann ergibt sich beim Verdampfungs-

Figure 6.242: Alexander Smakula invented antireflective coatings for lenses at Zeiss in 1935.

Marga Faulstich (1915–1998)

Improved optical lenses, including antireflective coatings and high-index-of-refraction materials (e.g., Schwerflint 64)



BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
14. FEBRUAR 1957

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 958 150
KLASSE 32b GRUPPE 1
INTERNAT. KLASSE C 03c
J 8259 IVc/32b

Marga Faulstich, Mainz
ist als Erfinder genannt worden

Jenaer Glaswerk Schott & Gen., Mainz

Optisches Glas

Patentiert im Gebiet der Bundesrepublik Deutschland vom 11. Februar 1954 an
Patentanmeldung bekanntgemacht am 9. August 1956
Patenterteilung bekanntgemacht am 24. Januar 1957

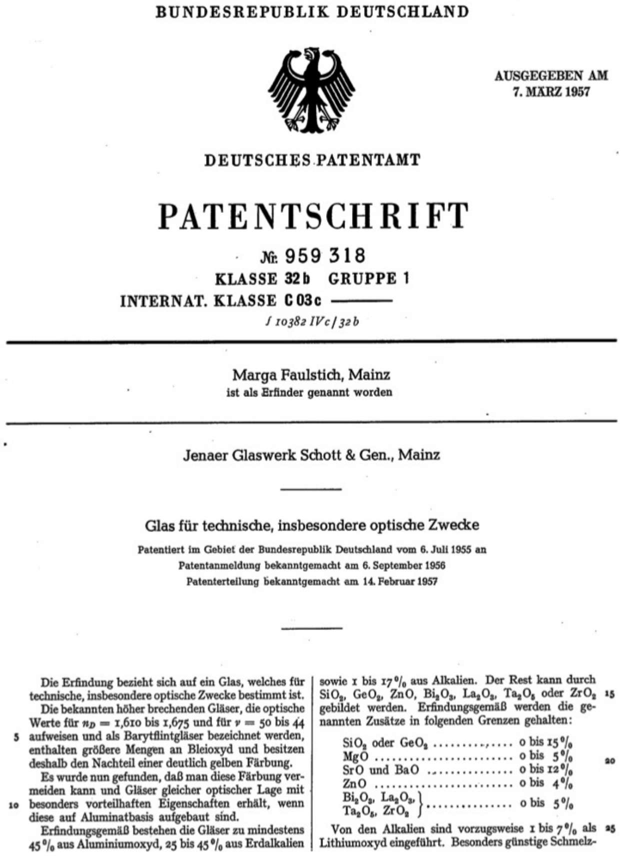
Die Erfindung bezieht sich auf ein optisches Glas, welches derart zusammengesetzt ist, daß es eine hohe Brechungszahl n_d aufweist, die größer als 1,745 ist, und welches eine beträchtlich geringere Lichtstreuung besitzt als die üblichen Schwerflintgläser.

Es sind Gläser dieser Art bekannt, die in der Hauptsache aus Bleiphosphat bestehen. Diese Gläser sind zwar durchaus farblos, jedoch so weich, daß ihre Verwendung für optische Zwecke nur bedingt möglich ist.

Es sind auch schon harte Gläser mit hoher Brechungszahl vorgeschlagen worden, die unter Verwendung großer Mengen von seltenen Erden gemeinsam mit Tantal oder Niob und Borsäure erschmolzen wurden. Diese Gläser sind jedoch sehr kostspielig.

Hochbrechende Gläser mit mittlerer Streuung wurden auch durch Zusätze von Cadmiumoxyd erhalten. Die Verwendung von Cadmiumoxyd ist jedoch ebenfalls verhältnismäßig kostspielig und zudem wegen seiner großen Giftigkeit bei der Handhabung unerwünscht.

Bekanntgeworden sind auch Gläser des Systems PbO-ZnO-B_2O_3. Diese Gläser haben sich aber für die Herstellung von optischem Glas als völlig ungeeignet erwiesen, da sie wegen ihrer äußerst geringen Viskosität bei der Gußtemperatur zu



BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
7. MÄRZ 1957

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 959 318
KLASSE 32b GRUPPE 1
INTERNAT. KLASSE C 03c
J 10382 IVc/32b

Marga Faulstich, Mainz
ist als Erfinder genannt worden

Jenaer Glaswerk Schott & Gen., Mainz

Glas für technische, insbesondere optische Zwecke

Patentiert im Gebiet der Bundesrepublik Deutschland vom 6. Juli 1955 an
Patentanmeldung bekanntgemacht am 6. September 1956
Patenterteilung bekanntgemacht am 14. Februar 1957

Die Erfindung bezieht sich auf ein Glas, welches für technische, insbesondere optische Zwecke bestimmt ist.

Die bekannten höher brechenden Gläser, die optische Werte für $n_D = 1{,}610$ bis $1{,}675$ und für $\nu = 50$ bis 44 aufweisen und als Barytflintgläser bezeichnet werden, enthalten größere Mengen an Bleioxyd und besitzen deshalb den Nachteil einer deutlich gelben Färbung.

Es wurde nun gefunden, daß man diese Färbung vermeiden kann und Gläser gleicher optischer Lage mit besonders vorteilhaften Eigenschaften erhält, wenn diese auf Aluminatbasis aufgebaut sind.

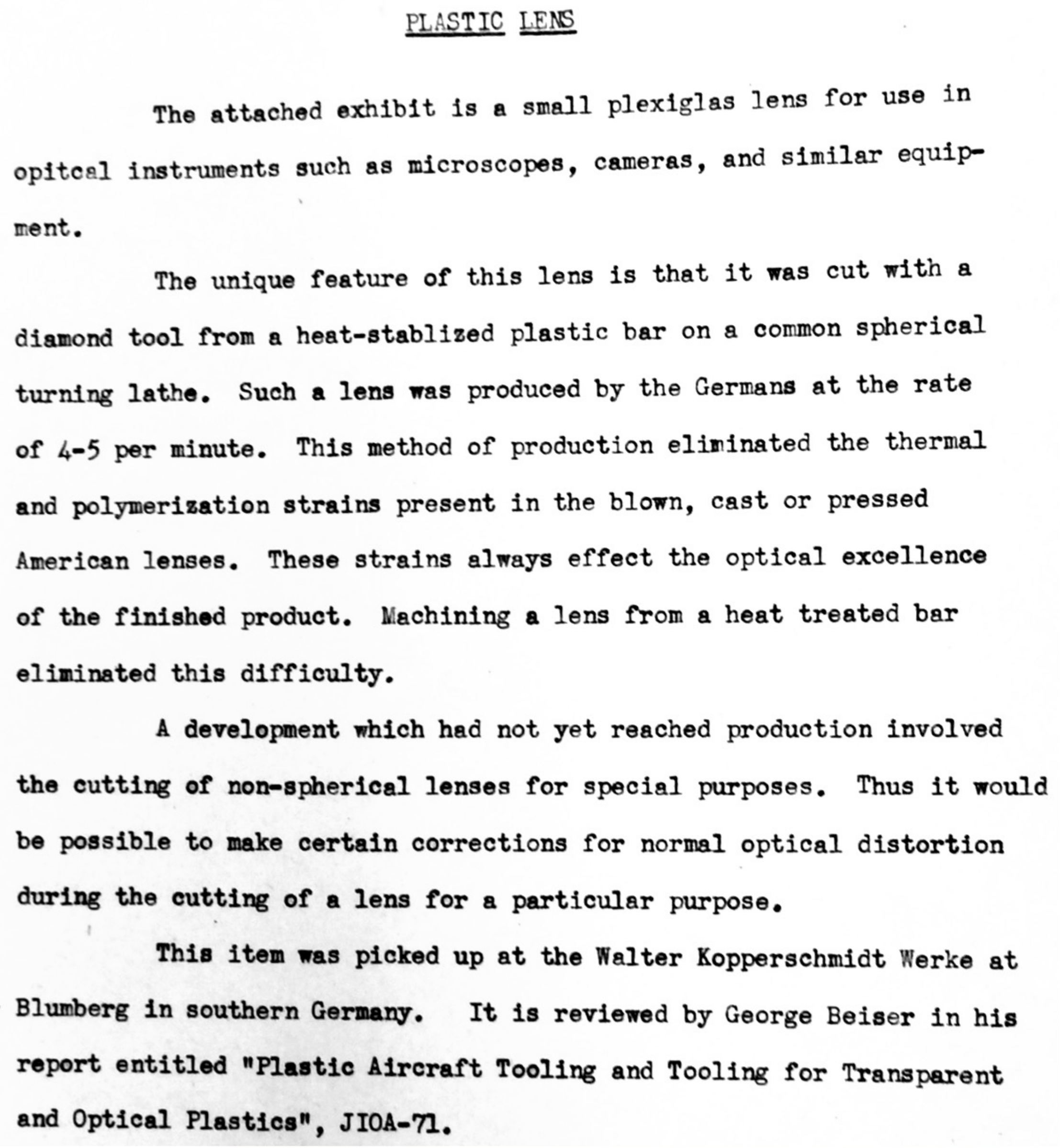
Erfindungsgemäß bestehen die Gläser zu mindestens 45 % aus Aluminiumoxyd, 25 bis 45 % aus Erdalkalien sowie 1 bis 17 % aus Alkalien. Der Rest kann durch SiO_2, GeO_2, ZnO, Bi_2O_3, La_2O_3, Ta_2O_5 oder ZrO_2 gebildet werden. Erfindungsgemäß werden die genannten Zusätze in folgenden Grenzen gehalten:

SiO_2 oder GeO_2	0 bis 15 %
MgO	0 bis 5 %
SrO und BaO	0 bis 12 %
ZnO	0 bis 4 %
Bi_2O_3, La_2O_3, Ta_2O_5, ZrO_2	0 bis 5 %

Von den Alkalien sind vorzugsweise 1 bis 7 % als Lithiumoxyd eingeführt. Besonders günstige Schmelz-

Figure 6.243: Marga Faulstich at Schott developed improved optical lenses, including antireflective coatings and high-index-of-refraction materials (such as Schwerflint 64).

NARA RG 40, Entry UD-75, Box 58, Folder Budget



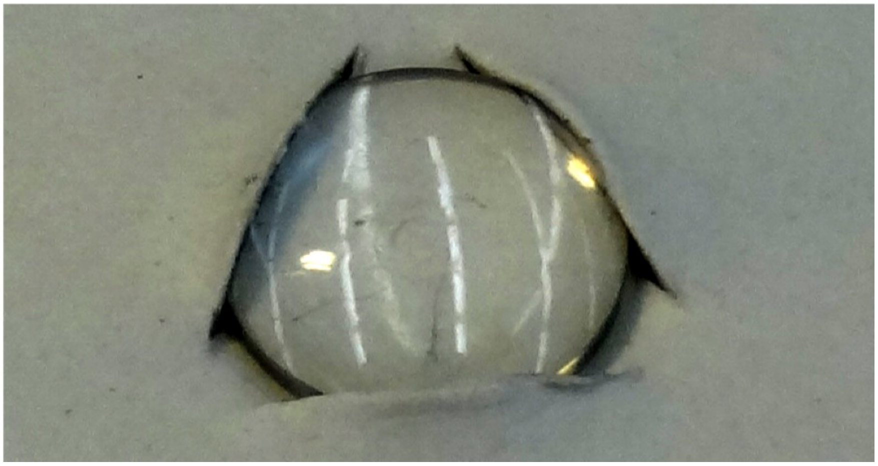
PLASTIC LENS

The attached exhibit is a small plexiglas lens for use in opitcal instruments such as microscopes, cameras, and similar equipment.

The unique feature of this lens is that it was cut with a diamond tool from a heat-stablized plastic bar on a common spherical turning lathe. Such a lens was produced by the Germans at the rate of 4-5 per minute. This method of production eliminated the thermal and polymerization strains present in the blown, cast or pressed American lenses. These strains always effect the optical excellence of the finished product. Machining a lens from a heat treated bar eliminated this difficulty.

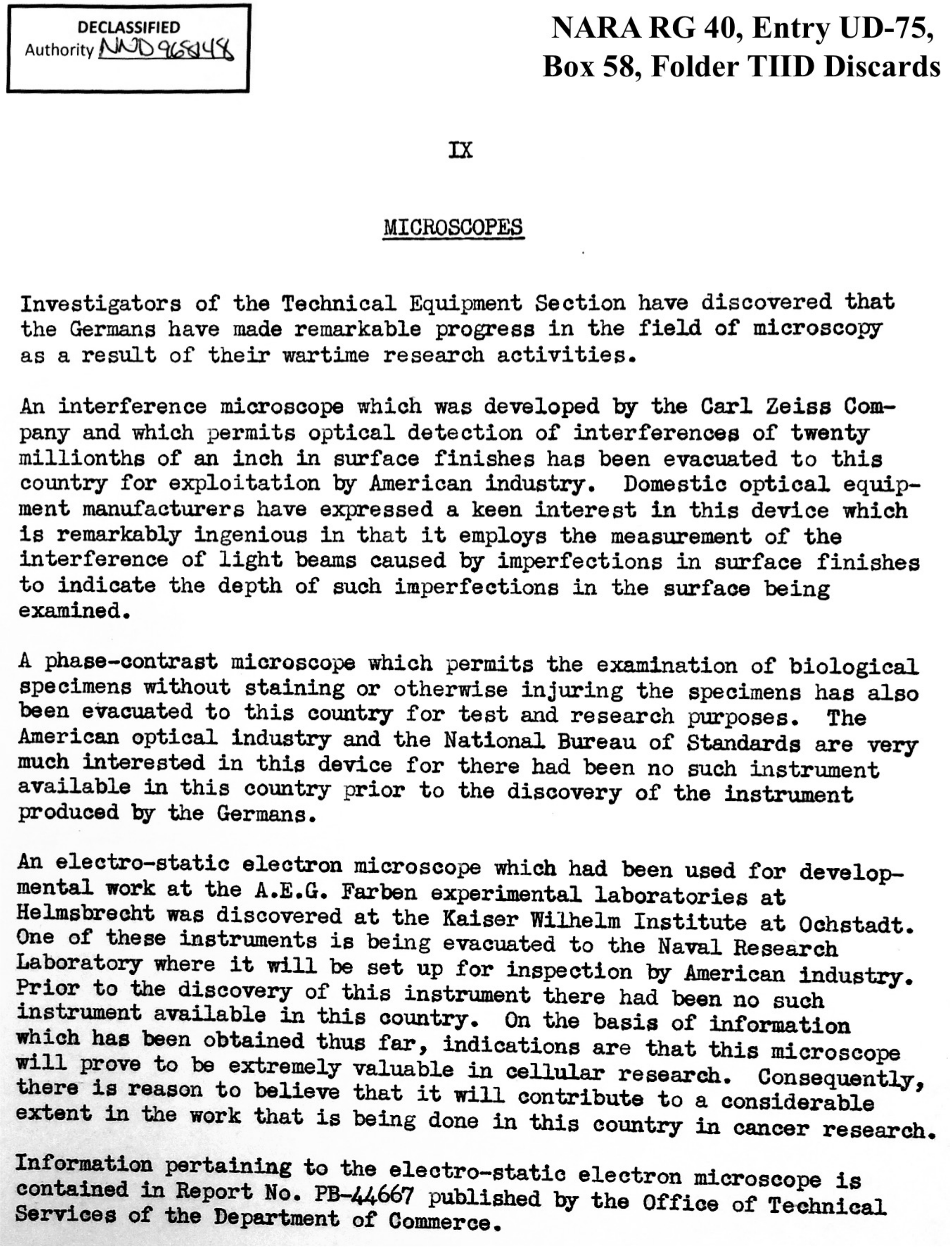
A development which had not yet reached production involved the cutting of non-spherical lenses for special purposes. Thus it would be possible to make certain corrections for normal optical distortion during the cutting of a lens for a particular purpose.

This item was picked up at the Walter Kopperschmidt Werke at Blumberg in southern Germany. It is reviewed by George Beiser in his report entitled "Plastic Aircraft Tooling and Tooling for Transparent and Optical Plastics", JIOA-71.



DECLASSIFIED
Authority NND 968148

Figure 6.244: After World War II, German high-quality plastic lenses and the technology to produce them were taken by the United States and directly copied by U.S. companies [NARA RG 40, Entry UD-75, Box 58, Folder Budget].



DECLASSIFIED
Authority NND 968148

**NARA RG 40, Entry UD-75,
Box 58, Folder TIID Discards**

IX

MICROSCOPES

Investigators of the Technical Equipment Section have discovered that the Germans have made remarkable progress in the field of microscopy as a result of their wartime research activities.

An interference microscope which was developed by the Carl Zeiss Company and which permits optical detection of interferences of twenty millionths of an inch in surface finishes has been evacuated to this country for exploitation by American industry. Domestic optical equipment manufacturers have expressed a keen interest in this device which is remarkably ingenious in that it employs the measurement of the interference of light beams caused by imperfections in surface finishes to indicate the depth of such imperfections in the surface being examined.

A phase-contrast microscope which permits the examination of biological specimens without staining or otherwise injuring the specimens has also been evacuated to this country for test and research purposes. The American optical industry and the National Bureau of Standards are very much interested in this device for there had been no such instrument available in this country prior to the discovery of the instrument produced by the Germans.

An electro-static electron microscope which had been used for developmental work at the A.E.G. Farben experimental laboratories at Helmsbrecht was discovered at the Kaiser Wilhelm Institute at Ochstadt. One of these instruments is being evacuated to the Naval Research Laboratory where it will be set up for inspection by American industry. Prior to the discovery of this instrument there had been no such instrument available in this country. On the basis of information which has been obtained thus far, indications are that this microscope will prove to be extremely valuable in cellular research. Consequently, there is reason to believe that it will contribute to a considerable extent in the work that is being done in this country in cancer research.

Information pertaining to the electro-static electron microscope is contained in Report No. PB-44667 published by the Office of Technical Services of the Department of Commerce.

Figure 6.245: After World War II, German optical and electron microscopes were taken by the United States and directly copied by U.S. companies [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

6.10 Electron Microscopes

Ordinary light microscopes use light waves to visualize objects. Visible light has wavelengths in the range of 400–700 nanometers, so it cannot image objects that are much smaller than those wavelengths. The minimum visible size is a little less than one hump of the wave, or a little less than half the wavelength, roughly 150 nanometers at the smallest. For comparison, most viruses are $\sim$ 20–150 nanometers wide, and individual atoms are $\sim$ 0.1–0.5 nanometers wide, so objects from atoms to viruses cannot be seen with light microscopes.

From quantum physics, small particles such as electrons can also behave like waves, and they can have wavelengths much smaller than those of light (p. 884). Moreover, one can build an electrostatic lens or a magnetic lens to focus a beam of electrons, just as a conventional optical lens can focus a beam of light (Fig. 6.246). Thus it is possible to build an electron microscope that uses electrostatic or magnetic lenses, fires a beam of electrons at tiny objects, collects the scattered electrons to detect the shape of the objects, and resolves objects far smaller than a light microscope could.

Just as most of the major developments in light microscopy and quantum physics came from the German-speaking world, most of the major innovations in electron microscopy also came from the German-speaking world, from the very first electron microscopes (Section 6.10.1) to electron microscopes powerful enough to see individual atoms (Section 6.10.2).[31] Electron microscopes have become indispensable for modern work in biology, materials science, microelectronics, and other fields.

6.10.1 Electron Microscopes and Scanning Electron Microscopes

As shown in Fig. 6.247, Hans Busch (German, 1884–1973) developed the first electrostatic and magnetic lenses for electrons in 1926. In 1928, Leo Szilard (Hungarian, 1898–1964) made the first known proposal to use such lenses to create an electron microscope.

Four different groups worked in parallel to build and demonstrate the world's first electron microscopes. All four groups were in the greater Berlin area:

1. A group at the Technische Hochschule Berlin produced electron microscopes from 1931 onward; see Fig. 6.248. The group included Max Knoll (German, 1897–1969), Bodo von Borries (German, 1905–1956), Ernst Ruska (German, 1906–1988), and Helmut Ruska (German, 1908–1973). Ernst Ruska played an especially large role in this group from the beginning, as well as later when this group closely collaborated with the Siemens & Halske group. Of all the earliest electron microscope builders, Ernst Ruska lived long enough to win the Nobel Prize in Physics in 1986. His brother Helmut took the first electron microscope

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[31] von Ardenne 1990, 1997; von Ardenne and Pyl 1940; Barkleit 2008; von Borries and Ruska 1940a, 1940b, 1940c, 1944; Gelderblom and Krüger 2014; Gentile and Gelderblom 2014; Peter Hawkes 2013; Knoll and Ruska 1932a, 1932b; Krüger 2000; Lanouette and Silard 1992, pp. 94, 101; Lickfeld 1979; Maas and Hooijmaijers 2009, Chapters 5, 8; Pfankuch and Ruska 1947; Qing 1995; Ernst Ruska 1930, 1933a, 1933b, 1940a, 1940b, 1952a, 1952b, 1952c, 1952d, 1954, 1979; Helmut Ruska 1939; Helmut Ruska and Poppe 1947; Simmons 2002, pp. 270–274; Weber 1988; BIOS 1671; FIAT 765; FIAT 769.

pictures of viruses (p. 200). Professor Sven Johansson of the Royal Academy of Sciences praised the surviving Ruska as well as the other original developers of electron microscopy [https://www.nobelprize.org/prizes/physics/1986/ceremony-speech/]:

> This new development was the electron microscope. The electron microscope is based on the principle that a short coil of a suitable construction, carrying an electric current, can deflect electrons in the same way that a lens deflects light. A coil can therefore give an enlarged image of an object that is irradiated with electrons. The image can be registered on a fluorescent screen or a photographic film. In the same way that lenses can be combined to form a microscope, it was found that an electron microscope could be constructed of coils. As the electrons used in an electron microscope have a much shorter wavelength than light, it is thus possible to reach down to much finer details. Several scientists, among them Hans Busch, Max Knoll, and Bodo von Borries, contributed to the development of the instrument, but Ernst Ruska deserves to be placed foremost. He built in 1933 the first electron microscope with a performance significantly better than that of an ordinary light microscope. Developments since then have led to better and better instruments. The importance, in many areas of research, of the invention of the electron microscope should, by now, be well known.

2. Siemens & Halske developed electron microscopes from 1931 onward, first independently and then in close collaboration with personnel from the Technische Hochschule Berlin group (Fig. 6.249). Siemens & Halske personnel included Reinhold Rüdenberg (German, 1883–1961), Ernst Lubcke (German, 1890–1971), Walter Glaser (Austrian, 1906–1960), and Heinz-Otto Müller (German, 1911–1945).

3. A group at Allgemeine Elektrizität Gesellschaft (AEG) developed electron microscopes from 1931 onward, as shown in Fig. 6.250. The group included Hans Boersch (German, 1909–1986), Ernst Brüche (German, 1900–1985), A. Jakob (German?, 19??–19??), E. Johannson (German?, 19??-19??), Hans Mahl (German, 1909–1988), Carl Ramsauer (German, 1879–1955), and Otto Scherzer (German, 1909–1982).

4. Manfred von Ardenne (German, 1907–1997) created the first scanning electron microscope in 1937, and continued to develop electron microscopes after that. See Fig. 6.251. At the end of World War II, von Ardenne moved to the Soviet Union; he was awarded a Stalin Prize for building electron microscopes there.

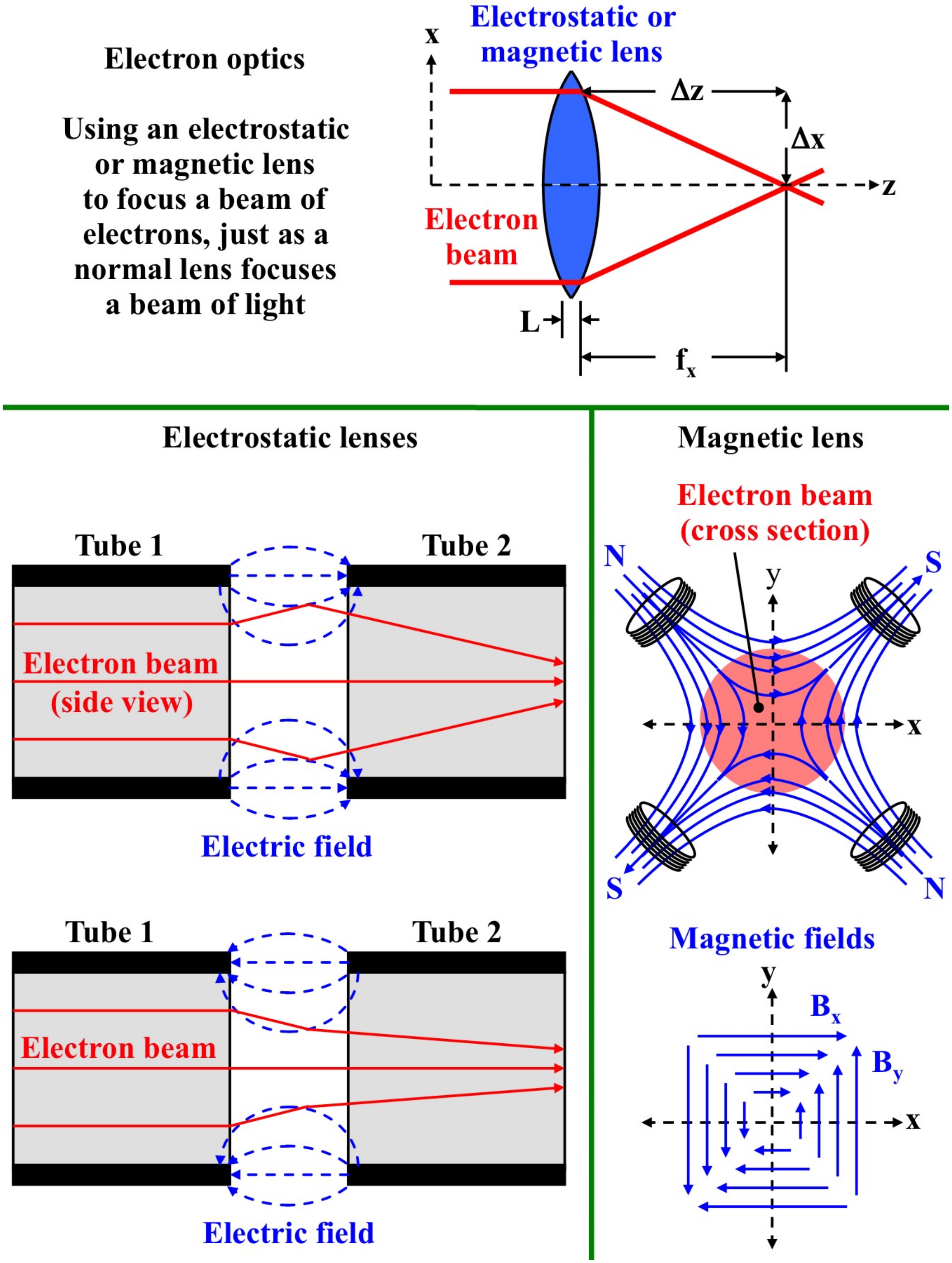

Electron optics
Using an electrostatic or magnetic lens to focus a beam of electrons, just as a normal lens focuses a beam of light
Electrostatic or magnetic lens
x
Δz
Δx
z
Electron beam
L
f_x
Electrostatic lenses
Tube 1
Tube 2
Electron beam (side view)
Electric field
Tube 1
Tube 2
Electron beam
Electric field
Magnetic lens
Electron beam (cross section)
N
S
y
x
S
N
Magnetic fields
y
B_x
B_y
x

Figure 6.246: Electron optics uses an electrostatic or a magnetic lens to focus a beam of electrons, just as conventional optics uses a normal lens to focus a beam of light.

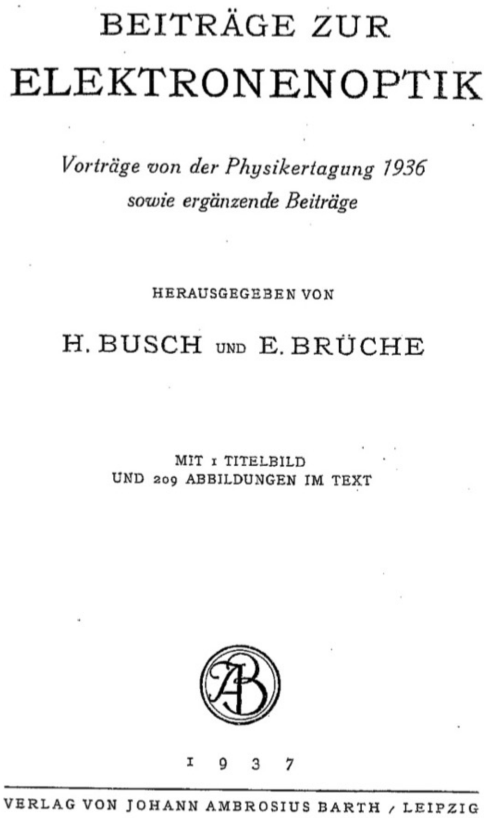
Hans Busch (1884–1973) created lenses for electrons (1926)

GEOMETRISCHE
ELEKTRONENOPTIK

VON

E. BRÜCHE UND O. SCHERZER

Leo Szilard (1898–1964) proposed electron microscope (1928)



BEITRÄGE ZUR
ELEKTRONENOPTIK

Vorträge von der Physikertagung 1936
sowie ergänzende Beiträge

HERAUSGEGEBEN VON

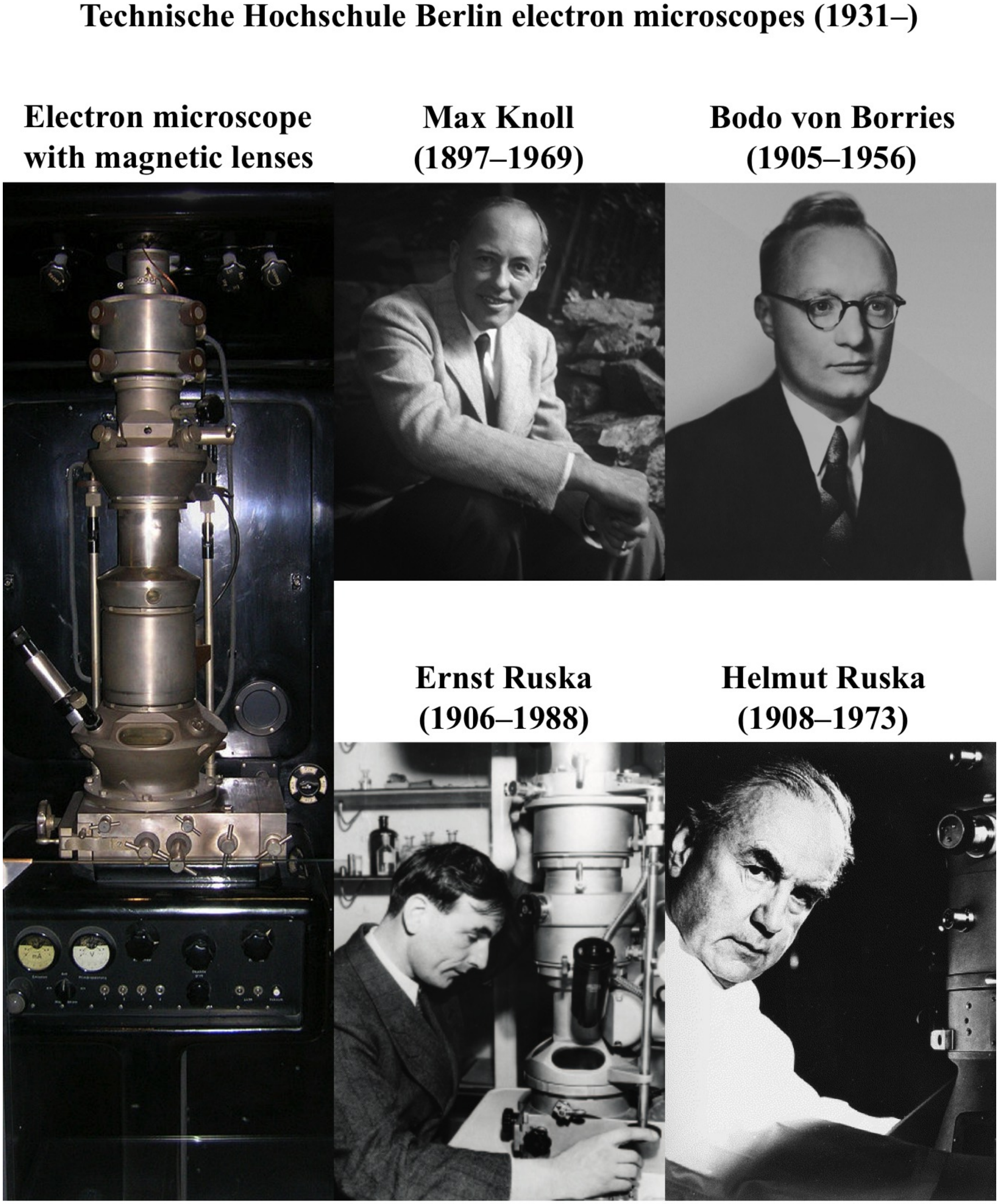
H. BUSCH UND E. BRÜCHE

MIT 1 TITELBILD
UND 209 ABBILDUNGEN IM TEXT

1937

VERLAG VON JOHANN AMBROSIUS BARTH / LEIPZIG

Figure 6.247: Hans Busch developed electrostatic and magnetic lenses for electrons in 1926. Leo Szilard proposed an electron microscope in 1928.



Technische Hochschule Berlin electron microscopes (1931–)

Electron microscope with magnetic lenses

Max Knoll (1897–1969)

Bodo von Borries (1905–1956)

Ernst Ruska (1906–1988)

Helmut Ruska (1908–1973)

Figure 6.248: A group at the Technische Hochschule Berlin produced electron microscopes from 1931 onward. The group included Max Knoll, Bodo von Borries, Ernst Ruska, and Helmut Ruska.

Siemens & Halske electron microscopes (1931–)

Reinhold Rüdenberg
(1883–1961)

Fig.5

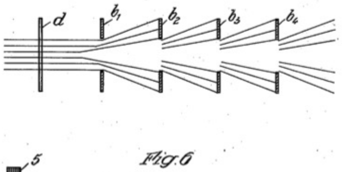


Fig.6

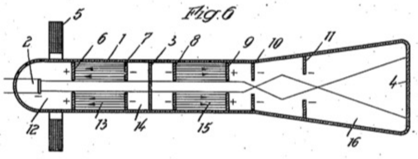
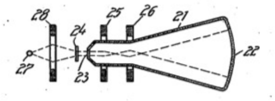
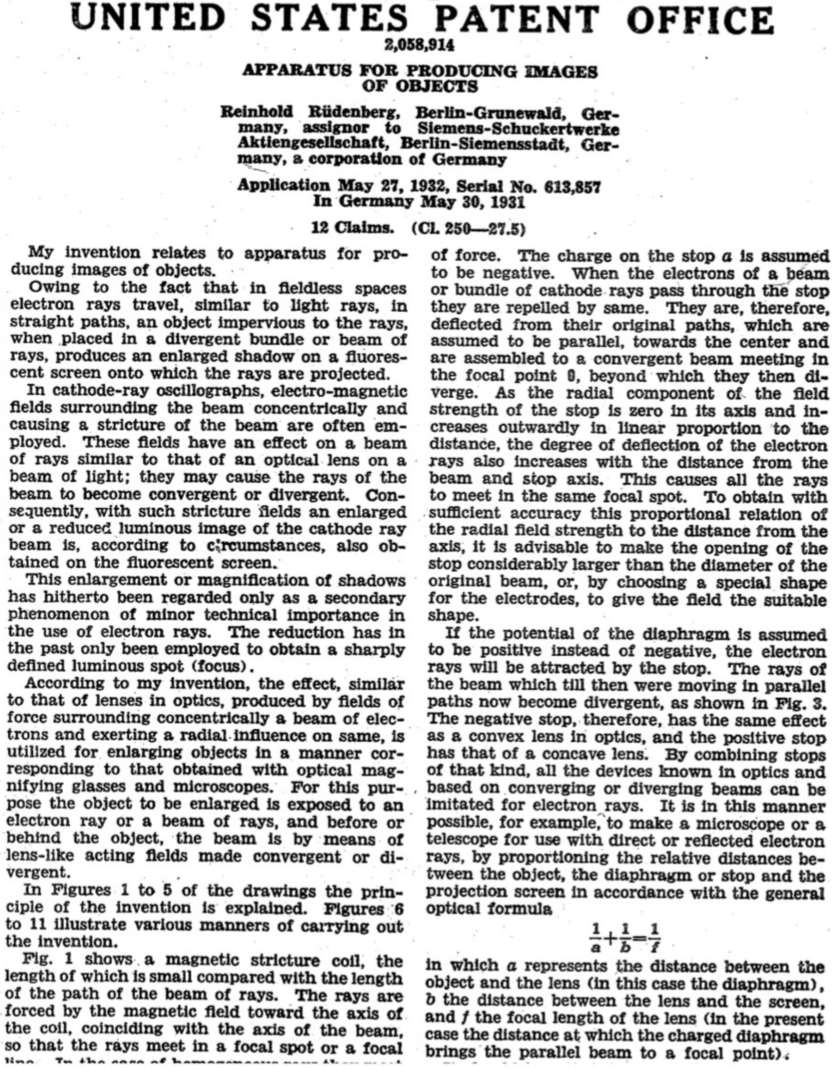


Fig.7





UNITED STATES PATENT OFFICE

2,058,914

APPARATUS FOR PRODUCING IMAGES
OF OBJECTS

Reinhold Rüdenberg, Berlin-Grunewald, Germany, assignor to Siemens-Schuckertwerke Aktiengesellschaft, Berlin-Siemensstadt, Germany, a corporation of Germany

Application May 27, 1932, Serial No. 613,857
In Germany May 30, 1931

12 Claims. (Cl. 250—27.5)

My invention relates to apparatus for producing images of objects.

Owing to the fact that in fieldless spaces electron rays travel, similar to light rays, in straight paths, an object impervious to the rays, when placed in a divergent bundle or beam of rays, produces an enlarged shadow on a fluorescent screen onto which the rays are projected.

In cathode-ray oscillographs, electro-magnetic fields surrounding the beam concentrically and causing a stricture of the beam are often employed. These fields have an effect on a beam of rays similar to that of an optical lens on a beam of light; they may cause the rays of the beam to become convergent or divergent. Consequently, with such stricture fields an enlarged or a reduced luminous image of the cathode ray beam is, according to circumstances, also obtained on the fluorescent screen.

This enlargement or magnification of shadows has hitherto been regarded only as a secondary phenomenon of minor technical importance in the use of electron rays. The reduction has in the past only been employed to obtain a sharply defined luminous spot (focus).

According to my invention, the effect, similar to that of lenses in optics, produced by fields of force surrounding concentrically a beam of electrons and exerting a radial influence on same, is utilized for enlarging objects in a manner corresponding to that obtained with optical magnifying glasses and microscopes. For this purpose the object to be enlarged is exposed to an electron ray or a beam of rays, and before or behind the object, the beam is by means of lens-like acting fields made convergent or divergent.

In Figures 1 to 5 of the drawings the principle of the invention is explained. Figures 6 to 11 illustrate various manners of carrying out the invention.

Fig. 1 shows a magnetic stricture coil, the length of which is small compared with the length of the path of the beam of rays. The rays are forced by the magnetic field toward the axis of the coil, coinciding with the axis of the beam, so that the rays meet in a focal spot or a focal

of force. The charge on the stop *a* is assumed to be negative. When the electrons of a beam or bundle of cathode rays pass through the stop they are repelled by same. They are, therefore, deflected from their original paths, which are assumed to be parallel, towards the center and are assembled to a convergent beam meeting in the focal point 0, beyond which they then diverge. As the radial component of the field strength of the stop is zero in its axis and increases outwardly in linear proportion to the distance, the degree of deflection of the electron rays also increases with the distance from the beam and stop axis. This causes all the rays to meet in the same focal spot. To obtain with sufficient accuracy this proportional relation of the radial field strength to the distance from the axis, it is advisable to make the opening of the stop considerably larger than the diameter of the original beam, or, by choosing a special shape for the electrodes, to give the field the suitable shape.

If the potential of the diaphragm is assumed to be positive instead of negative, the electron rays will be attracted by the stop. The rays of the beam which till then were moving in parallel paths now become divergent, as shown in Fig. 3. The negative stop, therefore, has the same effect as a convex lens in optics, and the positive stop has that of a concave lens. By combining stops of that kind, all the devices known in optics and based on converging or diverging beams can be imitated for electron rays. It is in this manner possible, for example, to make a microscope or a telescope for use with direct or reflected electron rays, by proportioning the relative distances between the object, the diaphragm or stop and the projection screen in accordance with the general optical formula

$$\frac{1}{a}+\frac{1}{b}=\frac{1}{f}$$

in which a represents the distance between the object and the lens (in this case the diaphragm), b the distance between the lens and the screen, and f the focal length of the lens (in the present case the distance at which the charged diaphragm brings the parallel beam to a focal point).

Ernst Lubcke
(1890–1971)

Walter Glaser
(1906–1960)

Heinz-Otto Müller
(1911–1945)

Figure 6.249: Siemens & Halske developed electron microscopes from 1931 onward, first independently and then in close collaboration with personnel from the Technische Hochschule Berlin group. Siemens & Halske personnel included Reinhold Rüdenberg, Ernst Lubcke, Walter Glaser, and Heinz-Otto Müller.

Allgemeine Elektrizität Gesellschaft (AEG)
electron microscopes (1931–)

Hans Boersch
(1909–1986)

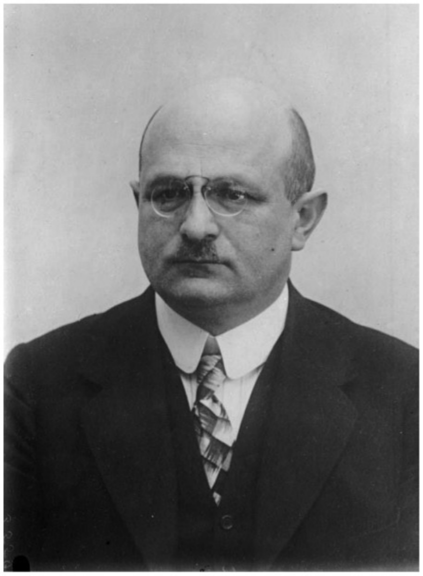
Ernst Brüche
(1900–1985)

A. Jakob
(19??–19??)

E. Johannson
(19??–19??)

Hans Mahl
(1909–1988)

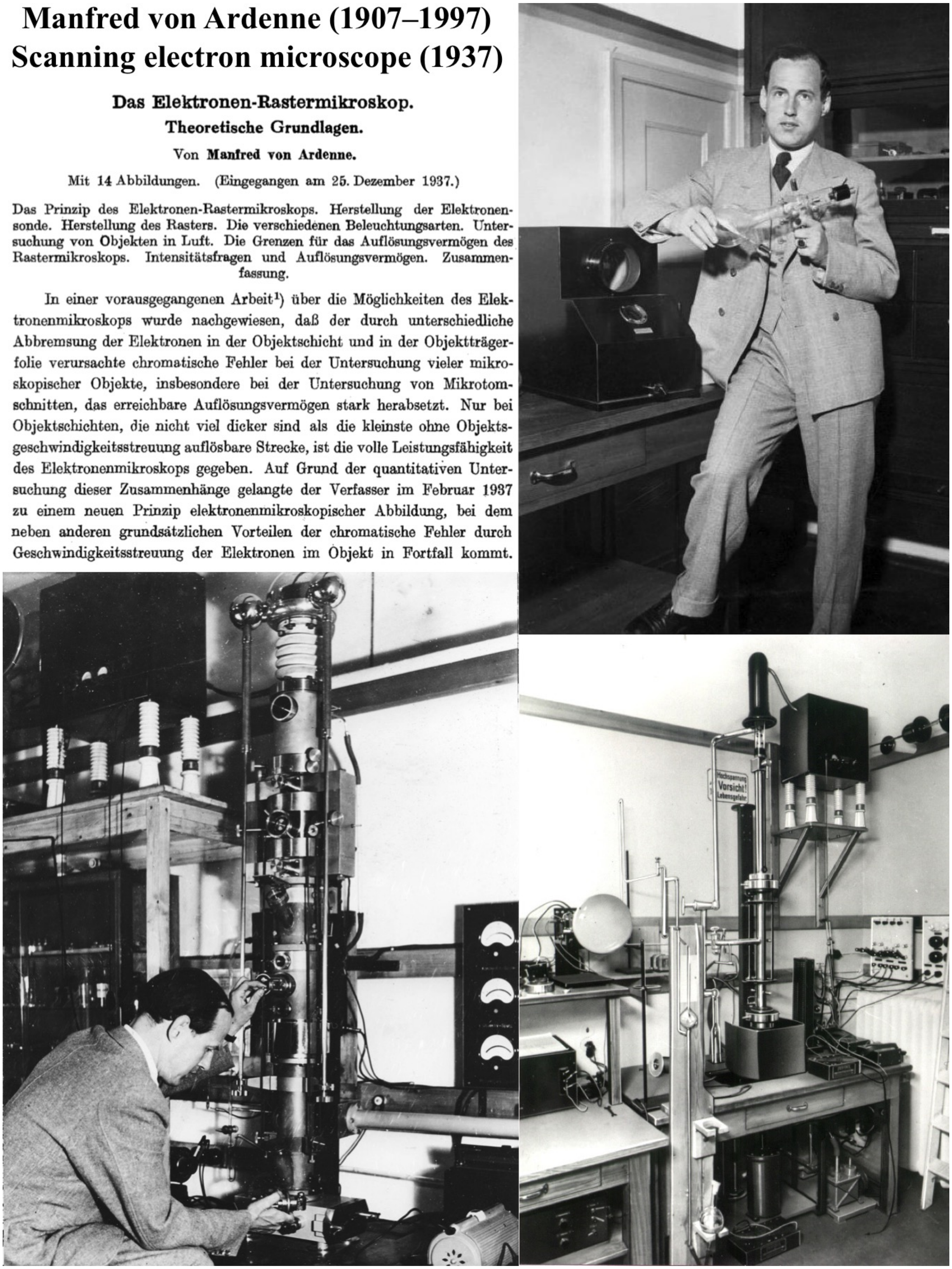
Carl Ramsauer
(1879–1955)



Otto Scherzer
(1909–1982)

AEG electron microscope

Figure 6.250: A group at Allgemeine Elektrizität Gesellschaft (AEG) developed electron microscopes from 1931 onward. The group included Hans Boersch, Ernst Brüche, A. Jakob, E. Johannson, Hans Mahl, Carl Ramsauer, and Otto Scherzer.



Manfred von Ardenne (1907–1997) Scanning electron microscope (1937)

Das Elektronen-Rastermikroskop.

Theoretische Grundlagen.

Von **Manfred von Ardenne.**

Mit 14 Abbildungen. (Eingegangen am 25. Dezember 1937.)

Das Prinzip des Elektronen-Rastermikroskops. Herstellung der Elektronensonde. Herstellung des Rasters. Die verschiedenen Beleuchtungsarten. Untersuchung von Objekten in Luft. Die Grenzen für das Auflösungsvermögen des Rastermikroskops. Intensitätsfragen und Auflösungsvermögen. Zusammenfassung.

In einer vorausgegangenen Arbeit[1]) über die Möglichkeiten des Elektronenmikroskops wurde nachgewiesen, daß der durch unterschiedliche Abbremsung der Elektronen in der Objektschicht und in der Objektträgerfolie verursachte chromatische Fehler bei der Untersuchung vieler mikroskopischer Objekte, insbesondere bei der Untersuchung von Mikrotomschnitten, das erreichbare Auflösungsvermögen stark herabsetzt. Nur bei Objektschichten, die nicht viel dicker sind als die kleinste ohne Objektsgeschwindigkeitsstreuung auflösbare Strecke, ist die volle Leistungsfähigkeit des Elektronenmikroskops gegeben. Auf Grund der quantitativen Untersuchung dieser Zusammenhänge gelangte der Verfasser im Februar 1937 zu einem neuen Prinzip elektronenmikroskopischer Abbildung, bei dem neben anderen grundsätzlichen Vorteilen der chromatische Fehler durch Geschwindigkeitsstreuung der Elektronen im Objekt in Fortfall kommt.

Figure 6.251: Manfred von Ardenne created the first scanning electron microscope in 1937, and continued to develop electron microscopes after that.

6.10.2 Scanning Tunneling Electron Microscopes and Atomic Force Microscopes

Although somewhat later than the time period that is the main focus of this book, in 1981, a group at IBM Zurich developed scanning tunneling electron microscopes powerful enough to see individual atoms (Fig. 6.252), as well as closely related atomic force microscopes. The group included Heinrich Rohrer (Swiss, 1933–2013), Gerd Binnig (German, 1947–), Christoph Gerber (Swiss, 1942–), and Edmund Weibel (Swiss?, 19??–). Rohrer and Binnig won the Nobel Prize in Physics in 1986, sharing the stage with Ernst Ruska. Professor Sven Johansson of the Royal Academy of Sciences explained the importance of their work [https://www.nobelprize.org/prizes/physics/1986/ceremony-speech/]:

> A crystal surface which appears completely flat in a microscope is seen with this instrument to be a plain on which atoms rise like hills in a regular pattern.
>
> Attempts by Russell Young and co-workers to realize these ideas revealed enormous experimental difficulties. The scientists who finally mastered these difficulties were Gerd Binnig and Heinrich Rohrer. Here it was a question of moving the needle over the surface of the sample and registering its vertical position, with great precision and without disturbing vibrations. The data obtained are then printed out, in the form of a topographic map of the surface, by a computer. The investigation may be concerned with a crystal surface, whose structure is of interest in microelectronic applications. Another example is the investigation of the adsorption of atoms on a surface. It has also been found to be possible to study organic structures, for example, DNA molecules and viruses. This is just the beginning of an extremely promising and fascinating development.

Heinrich Rohrer
(1933–2013)

Gerd Binnig
(1947–)

Christoph Gerber
(1942–)

Edmund Weibel
(19??–)

Scanning tunneling electron microscope (1981)

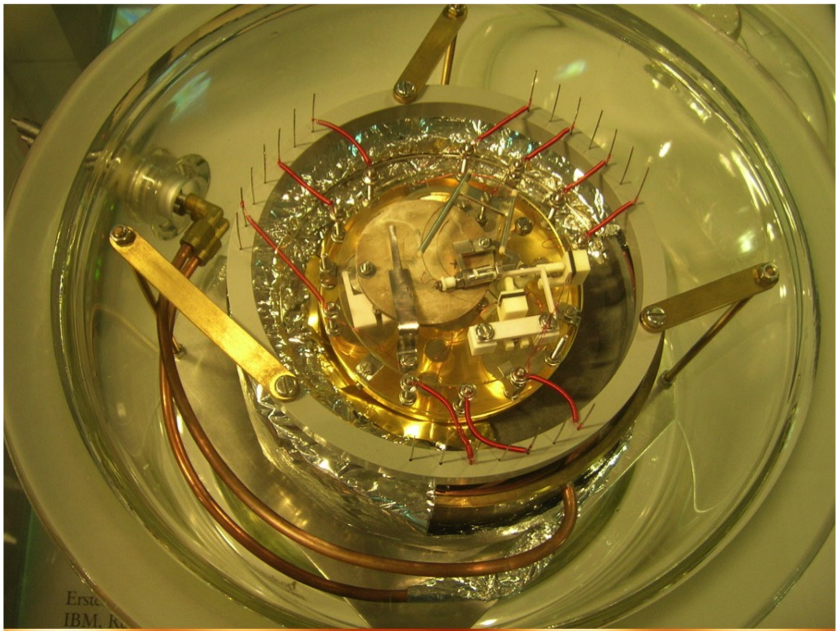


Image of individual atoms in a surface

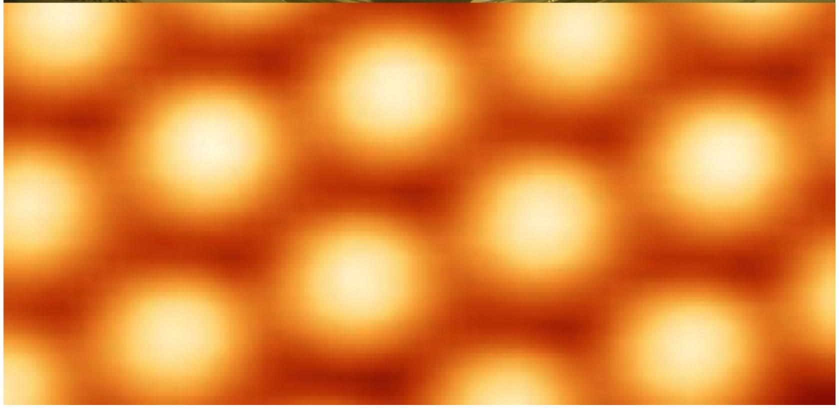


Figure 6.252: In 1981, a group at IBM Zurich developed scanning tunneling electron microscopes capable of imaging individual atoms. The group included Heinrich Rohrer, Gerd Binnig, Christoph Gerber, and Edmund Weibel.

Chapter 7

Creators and Creations in Mechanical Engineering

Fest gemauert in der Erden
Steht die Form, aus Lehm gebrannt.
Heute muß die Glocke werden.
Frisch Gesellen, seid zur Hand.
Von der Stirne heiß
Rinnen muß der Schweiß,
Soll das Werk den Meister loben,
Doch der Segen kommt von oben.

Zum Werke, das wir ernst bereiten,
Geziemt sich wohl ein ernstes Wort;
Wenn gute Reden sie begleiten,
Dann fließt die Arbeit munter fort.
So laßt uns jetzt mit Fleiß betrachten,
Was durch die schwache Kraft entspringt,
Den schlechten Mann muß man verachten,
Der nie bedacht, was er vollbringt.
Das ist's ja, was den Menschen zieret,
Und dazu ward ihm der Verstand,
Daß er im innern Herzen spüret,
Was er erschafft mit seiner Hand.

Nehmet Holz vom Fichtenstamme,
Doch recht trocken laßt es sein,
Daß die eingepreßte Flamme
Schlage zu dem Schwalch hinein.
Kocht des Kupfers Brei,
Schnell das Zinn herbei,
Daß die zähe Glockenspeise
Fließe nach der rechten Weise.

Walled up in the earth so steady
Burned from clay, the mould doth stand.
This day must the Bell be ready!
Fresh, O workmen, be at hand!
From the heated brow
Sweat must freely flow,
That the work may praise the Master,
Though the blessing comes from higher.

Our work in earnest preparation,
Befitteth well an earnest word;
When joined by goodly conversation,
Then flows the labor briskly forw'd.
So let us now with care consider,
What through a frail power springs forth:
The wicked man one must have scorn for,
Who ne'er reflects, what he brings forth.
This it is, what all mankind graceth,
And thereto his to understand,
That he in inner heart so traceth,
What he createth with his hand.

Take the wood from trunk of spruce tree,
Yet quite dry let it abide,
That the flame compressed so tightly
Strike the gullet deep inside!
Cook the copper brew,
Quick the tin in, too!
That the glutinous bell-metal
Flowing rightly then will settle!

Was in des Dammes tiefer Grube
Die Hand mit Feuers Hülfe baut,
Hoch auf des Turmes Glockenstube
Da wird es von uns zeugen laut.
Noch dauern wird's in späten Tagen
Und rühren vieler Menschen Ohr
Und wird mit dem Betrübten klagen
Und stimmen zu der Andacht Chor.
Was unten tief dem Erdensohne
Das wechselnde Verhängnis bringt,
Das schlägt an die metallne Krone,
Die es erbaulich weiterklingt.

What in the dam's dark cavern dour
The hand with fire's help did mould,
High in the belfry of the tower
There will our story loud be told.
Still will it last as years are tolling
And many ears will it inspire
And wail with mourners in consoling
And harmonize devotion's choir.
What here below to son terrestr'al
The ever-changing fate doth bring,
Doth strike the crown which made from metal,
Uplifting it doth sound its ring.

Friedrich Schiller. 1798. Das Lied von der Glocke [The Song of the Bell].
English verse translation by Marianna Wertz.

This chapter gives an overview of some innovations in mechanical engineering that have played major roles in the modern world and that were invented or discovered by scientists and engineers who were trained in the predominantly German-speaking central European research world in the nineteenth and early twentieth centuries.[1]

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[1] In addition to specific references that are cited in different areas throughout this chapter, this chapter makes use of general biographical and project information from: ACLS 2000; Albrecht et al. 1992; Ash and Söllner 1996; Bar-Zohar 1967; Bower 1987; Bunch and Hellemans 2004; Challoner 2009; Cornwell 2003; Crim 2018; EB 1911, 2010; Gillispie 1970–1990; Gimbel 1990a; Glatt 1994; Hall 2019a; István Hargittai 2006, 2011; Linda Hunt 1991; Impey et al. 2008; Jacobsen 2014; Koertge 2007; Kurowski 1982; Lasby 1971; Lusar 1956, 1971; Medawar and Pyke 2000; Mick 2000; Murray 2003; Nachmansohn 1979; NDB 1953–2020; Neufeld 2012; Nouzille and Huwart 1999; O'Reagan 2014, 2019; Porter 1994; Charles Walker 1946; Peter Watson 2010; Weitensfelder 2009.

For general overviews of large portions of the history of mechanical engineering in the German-speaking world, see: Buchheim and Sonnemann 1990; Bunch and Hellemans 2004; Cardwell 1995; Challoner 2009; Gööck 2000; Heckl 2010, 2011; Heßler 2012; Jankowsky 2000; König 2000, 2009; König and Schneider 2007; Ludwig 1974; Lundgreen and Grelon 1994; Radkau 1989, 2016; Technisches Museum Wien 2011; Weitensfelder 2009, 2013.

I have deliberately left a blank space where images of some creators or creations should go. Those are people or projects that I felt were important enough that they should definitely be shown in this book, yet I have not yet been able to locate a suitable image that I have permission to use, despite my searches in Europe and in the United States. If readers have any relevant images and could send them to me, I would be very grateful and will include them in future editions of this book. Even where a suitable photo cannot be located, I believe that leaving a blank space pays tribute both to the scientific importance of that creator or creation and to how that historical fact has been very nearly forgotten.

Creators from the German-speaking world made major contributions to:

- 7.1. Writing and printing technology
- 7.2. Musical instruments
- 7.3. Internal combustion engines and motor vehicles
- 7.4. Heat transfer
- 7.5. Civil engineering and architecture
- 7.6. Projectile weapons
- 7.7. Ocean engineering
- 7.8. Other aspects of mechanical engineering

Scientists and engineers from the German-speaking world also made numerous contributions to overlapping and related areas of engineering listed in Chapters 6 (electrical and electromagnetic engineering), 8 (nuclear engineering), and 9 (aerospace engineering).

7.1 Writing and Printing

German-speaking creators made many of the major innovations in technologies for writing and printing, including:[2]

- 7.1.1. The printing press
- 7.1.2. Typewriters
- 7.1.3. Stationery supplies
- 7.1.4. Improved printing processes

---

[2] For coverage of different aspects of this area, see especially: Ebeling 1985; Eisenstein 2005; Febvre and Martin 2010; Füssel 2004; Halkasch 1993; Hellbeck 2008; Kapr 1996; Kasischke 1999; Lassnig 1993; Lessing 2003, 2010; Michael Rauck 1983; Max Rößler 1982; Schlesinger 1989; Schmidt-Bachem 2011; Technisches Museum Wien 2005; Waize 2003; Wolf 1974.

7.1.1 Printing Press

Although this event preceded the time period that is the primary focus of this book, it would be impossible not to mention that Johannes Gutenberg (Mainz, ca. 1400–1468) invented the printing press around 1436 [Eisenstein 2005; Febvre and Martin 2010; Füssel 2004; Kapr 1996]. See Fig. 7.1. Donald Cardwell, a professor of the history of technology, described the enormous significance of Gutenberg's innovations [Cardwell 1995, p. 55]:

> Gutenberg's printing press revolutionized the publication of books. The first known printed book, produced at Mainz in 1455, was the Gutenberg Bible. It has been estimated that more books were published in the first fifty years following Gutenberg (up, that is, to the beginning of the sixteenth century) than had been produced in the previous thousand years. A twentyfold increase in productivity is highly impressive and it would not be unreasonable to regard Gutenberg as the first production engineer. Furthermore, it is easy to overlook Gutenberg's achievement of complete interchangeability in manufacture; each little unit of type could be used over and over again and fitted between any other little units[...] Finally, his invention brought about the first revolution in information technology. It was to be a long time—two hundred and fifty years—before another invention as dramatic and as important as Gutenberg's was to be made.

7.1.2 Typewriters

As shown in Fig. 7.2, Karl von Drais (German states, 1785–1851) created a paper music recorder in 1812 and then the first keyboard typewriter in 1821, [Ebeling 1985; Lessing 2003, 2010; Michael Rauck 1983]. He also invented the first bicycle (p. 1491).

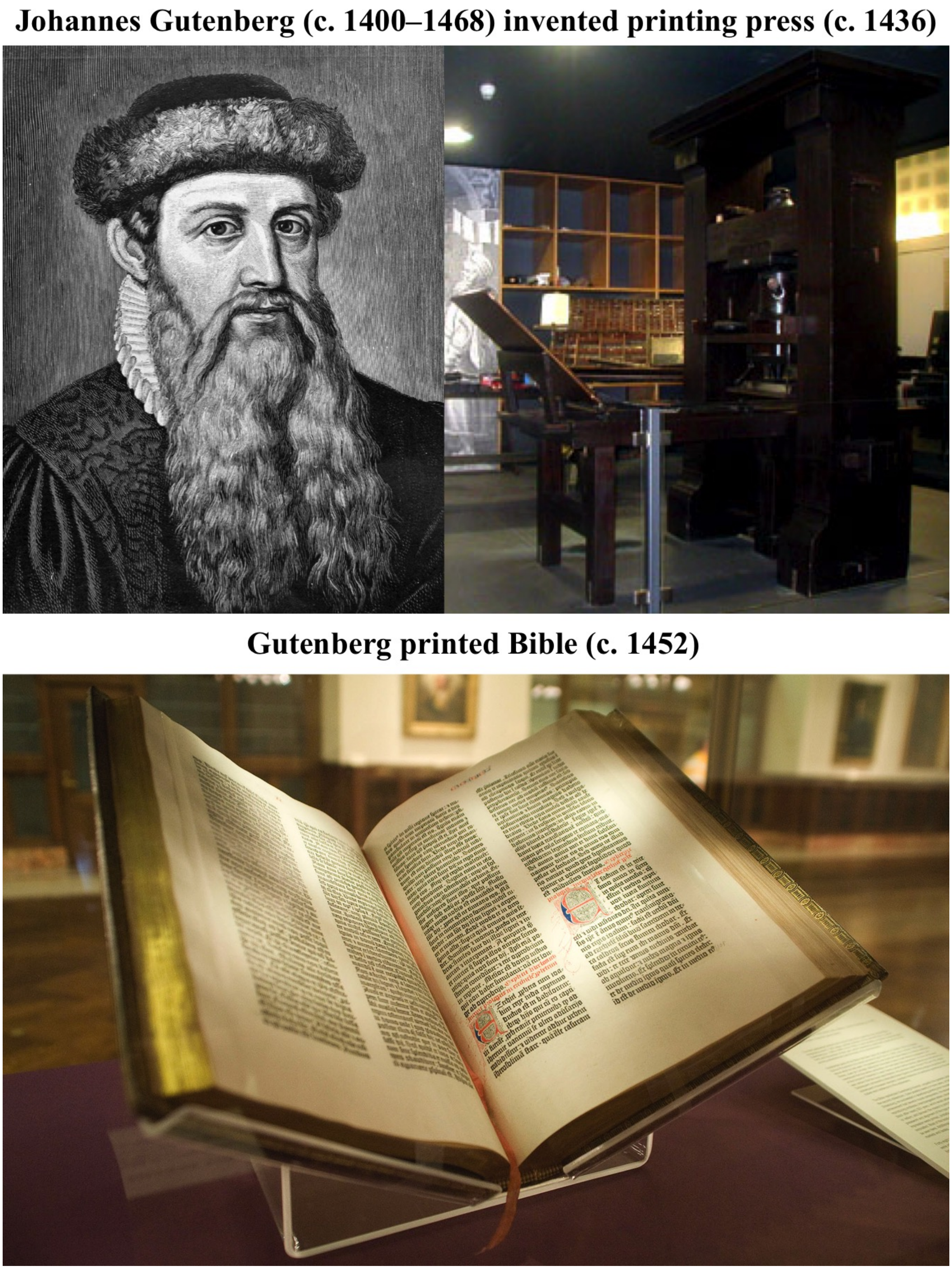
In the English-speaking world, credit for producing the first practical typewriters has traditionally been assigned primarily to Christopher Latham Sholes (U.S., 1819–1890), Carlos Glidden (U.S., 1834–1877), and James Densmore (U.S., 1820–1889), who marketed what became known as Remington typewriters beginning in the 1870s.

In fact, the first practical typewriters were invented and demonstrated a decade earlier by Peter Mitterhofer (Austrian, 1822–1893). Building upon the earlier work by Karl von Drais, Mitterhofer produced his first model in 1864. Mitterhofer created a series of improved models in rapid succession after that until around 1869 [Lassnig 1993; Technisches Museum Wien 2005; Waize 2003]. See Fig. 7.3. Lutz Rolf, an historian of science at the Berlin Technical University, explained how innovative Mitterhofer's work was [Technisches Museum Wien 2005, pp. 108–110]:

> The basic concept of Mitterhofer's models thus builds on the idea that all functions of the machine can be controlled by the keyboard. Even the cylindrical paper carrier mechanism used in the later models, which cleverly automated line spacing and the return of the platen, subscribes to this concept. [...]

> Mitterhofer's overall aim was to replace handwriting with a mechanised process derived from printing. As new technical solutions needed to be developed and combined for a vast range of different functional elements, a stepwise approach was adopted. Mitterhofer built several different models to experiment with, which he kept adding to and improving on in order to achieve his overall aim. [...]
>
> His design incorporates features that other typewriters were only to offer much later and was the most advanced typewriter of its time. Even from today's vantage point, some of the solutions Mitterhofer came up with for individual problems can still be regarded as the best possible.
>
> Mitterhofer's work was decisively influenced by the fact that, apart from creative talent, he also possessed remarkable technical skill and experience as well as a talent for improvisation. In addition, he also built his models himself. He was thus able to put his ideas into practice and test them directly. This may also be why, despite the sheer scope of detail solutions required and the host of construction problems he encountered, it only took him six years to create his machine, from the initial idea to the production of the prototype. The development of Sholes and Glidden's design, by comparison, which was embarked on much later, involved a great number of engineers and technicians who needed more than a decade to produce a machine comparable to Mitterhofer's creation.

As it turns out, even the Sholes/Remington typewriters that appeared a decade later in the United States were designed and built by German mechanics (Fig. 7.4). Sholes, Densmore, Remington, and their fellow financial backers wanted a typewriter that they could mass-produce and sell. However, for the actual design, development, and construction of suitable typewriters, they hired a machine shop owned and staffed by German-speaking and German-trained mechanics who had immigrated to the United States, and run by Carl Friedrich Kleinsteuber (German, 1822–1885). Kleinsteuber appointed a team led by Mathias Schwalbach (German, 1834–1920), who ultimately had a long career designing and building many clever machines, such as very sophisticated sewing machines, clocks, and watches [https://oztypewriter.blogspot.com/2011/09/on-this-day-in-typewriter-history-cxxii.html]. Schwalbach, Kleinsteuber, and others on the team used their own mechanical knowledge, and presumably also designs such as Mitterhofer's coming out of Europe, in order to design their typewriters. They produced a prototype in 1872 and then a series of improved versions after that, which Sholes and Remington began selling in the mid-1870s. The U.S.-born sponsors claimed most of the public credit for the line of typewriters, whereas the German-born creators were largely forgotten.



Johannes Gutenberg (c. 1400–1468) invented printing press (c. 1436)

Gutenberg printed Bible (c. 1452)

Figure 7.1: Johannes Gutenberg invented the printing press around 1436.

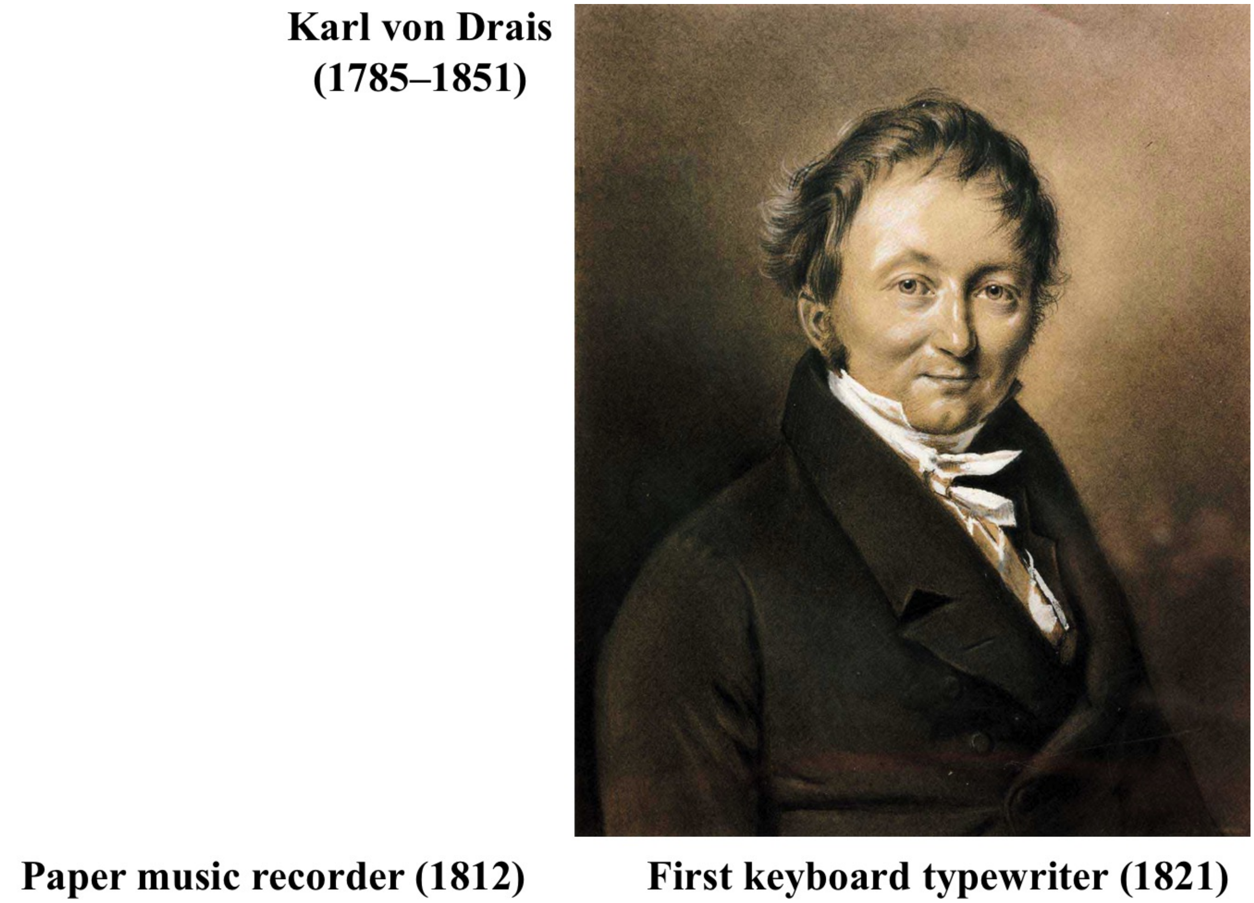

Karl von Drais
(1785–1851)
Paper music recorder (1812)
First keyboard typewriter (1821)

Figure 7.2: Karl von Drais created a paper music recorder in 1812 and the first keyboard typewriter in 1821.

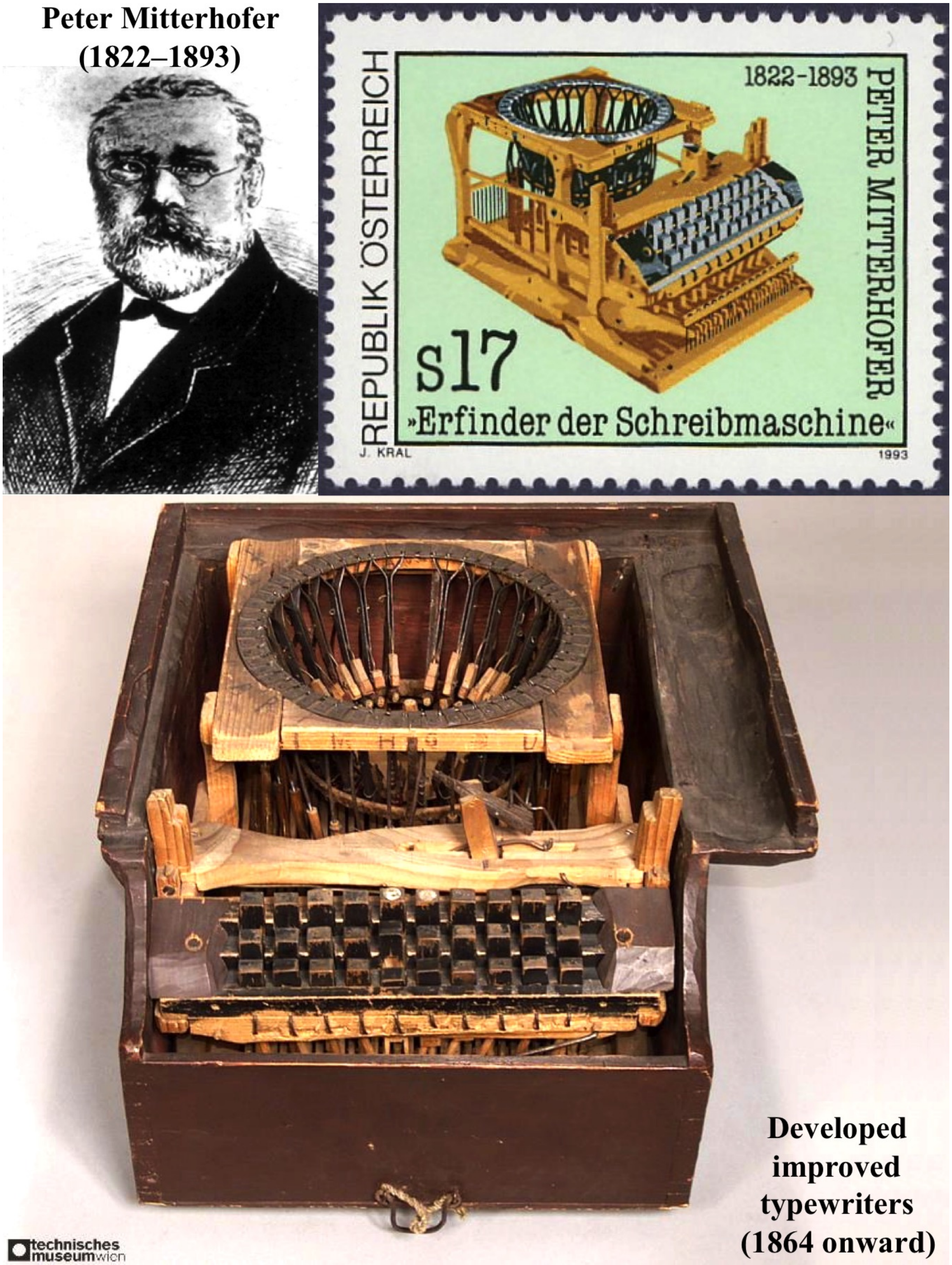

Peter Mitterhofer
(1822–1893)
REPUBLIK ÖSTERREICH
1822-1893
PETER MITTERHOFER
s17
»Erfinder der Schreibmaschine«
J. KRAL
1993
Developed improved typewriters (1864 onward)
technisches museum wien

Figure 7.3: Peter Mitterhofer produced a series of improved typewriters from 1864 onward.

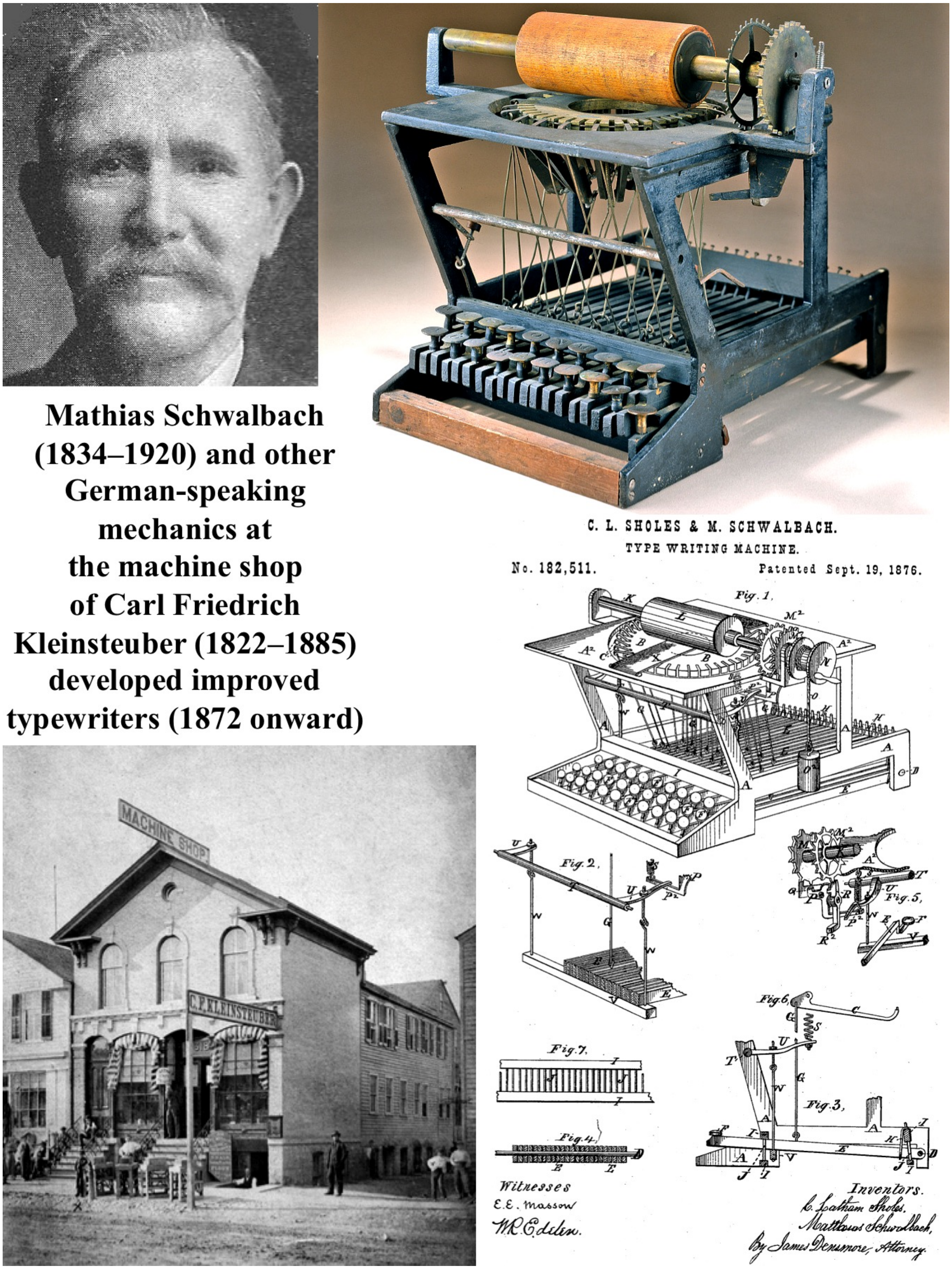

Mathias Schwalbach (1834–1920) and other German-speaking mechanics at the machine shop of Carl Friedrich Kleinsteuber (1822–1885) developed improved typewriters (1872 onward)
MACHINE SHOP
C.F.KLEINSTEUBER
C. L. SHOLES & M. SCHWALBACH.
TYPE WRITING MACHINE.
No. 182,511.
Patented Sept. 19, 1876.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Witnesses
E.E. Massow
W.R. Edelen.
Inventors.
C. Latham Sholes.
Matthias Schwalbach,
By James Densmore, Attorney.

Figure 7.4: Mathias Schwalbach developed an improved typewriter in 1872.

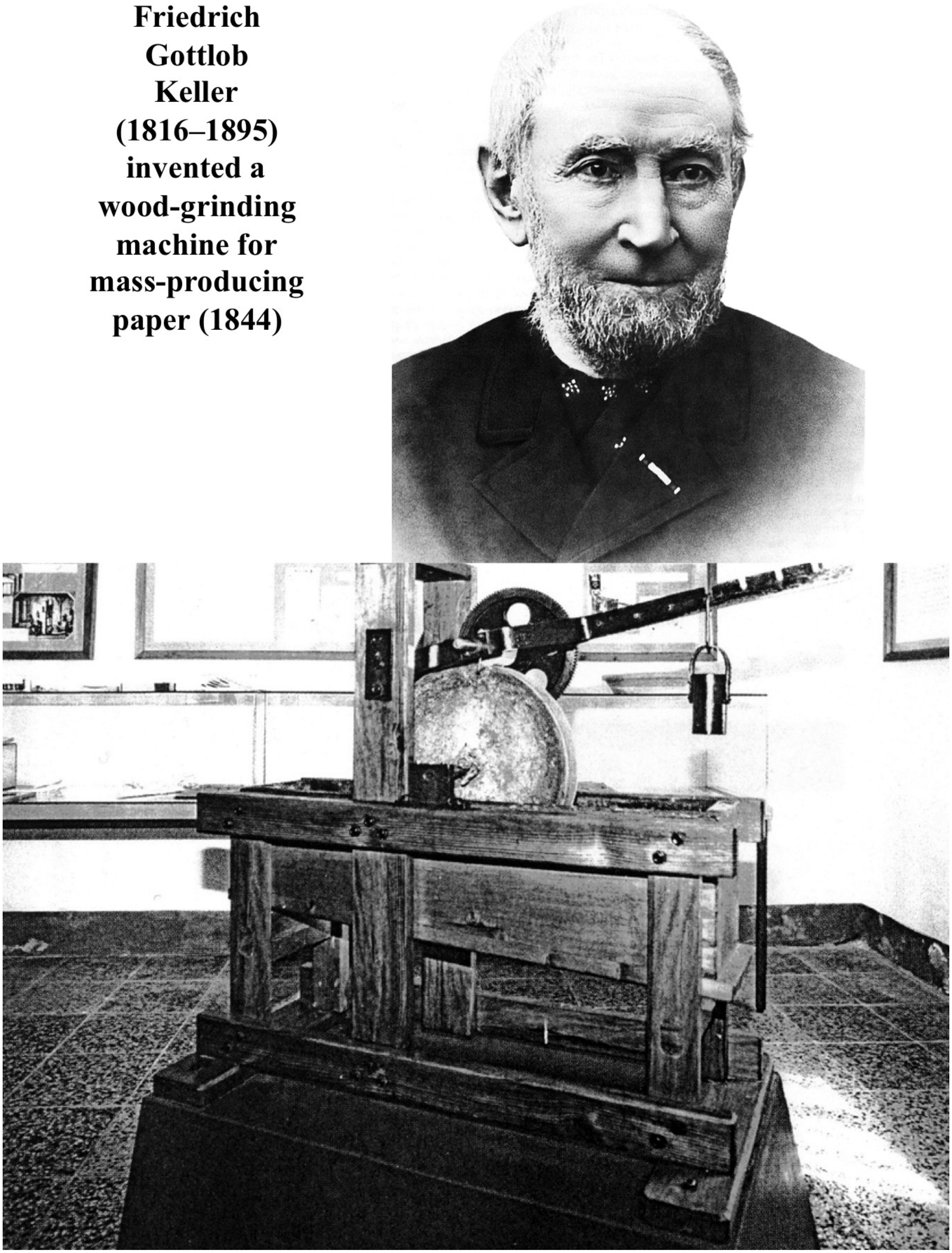
7.1.3 Stationery Supplies

In 1844, Friedrich Gottlob Keller (German, 1816–1895) invented a wood-grinding machine for mass-producing paper (Fig. 7.5). Prior to that time, paper had been made from cloth rags, which were in short supply and therefore greatly limited the maximum production rate and minimum cost of paper. Machines based on Keller's design revolutionized the production of paper and quickly became used worldwide.

As shown in Fig. 7.6, the Hungarian brothers László Bíró (1899–1985) and György Bíró (18??–19??) developed the ballpoint pen during the period 1931–1938. The science historian Felix Paturi described their invention [Paturi 1998, p. 529]:

“Kuli” revolutioniert das Schreiben	“Pen” revolutionizes writing
Die ungarischen Brüder Ladislao und Georg Biró erfinden den Kugelschreiber.	The Hungarian brothers László and György Bíró invent the ballpoint pen.
Das Grundprinzip des neuen Schreibgeräts ist einfach: Ein länglicher, im Griff eingearbeiteter Behälter (Mine) ist mit Tinte gefüllt. An ihrem vorderen Ende läuft die Mine konisch zu und wird durch eine kleine Kugel abgedichtet, die sich in einer Lagerpfanne drehen kann. Führt man den Stift mit der Kugel über Papier, befördert sie durch Rotation etwas Tinte aus der Mine auf die Schreibfläche. Die technischen Schwierigkeiten liegen zunächst in der Entwicklung einer geeigneten zählflüssigen und schnell trocknenden Tinte. Nachdem die Biró-Brüder eine solche Schreibflüssigkeit entwickelt haben, ist der weltweite Siegeszug des “Kulis” nur noch eine Frage der Zeit.	The basic principle of the new writing instrument is simple: an elongated container (refill) incorporated into the handle is filled with ink. At its front end, the refill tapers and is sealed by a small ball that can rotate in a bearing cup. When the ball and pen are placed over paper, the ball rotates and transports some ink from the refill to the writing surface. The technical difficulties initially lie in the development of a suitable viscous and quick-drying ink. Now that the Bíró brothers have developed such a writing fluid, the worldwide triumphal march of the “Kulis” is only a matter of time.

Friedrich Soennecken (German, 1848–1919) invented the paper hole punch and ring binders for hole-punched papers in 1886 [Hellbeck 2008]. See Fig. 7.7.



Friedrich Gottlob Keller (1816–1895) invented a wood-grinding machine for mass-producing paper (1844)

Figure 7.5: In 1844, Friedrich Gottlob Keller invented a wood-grinding machine for mass-producing paper.

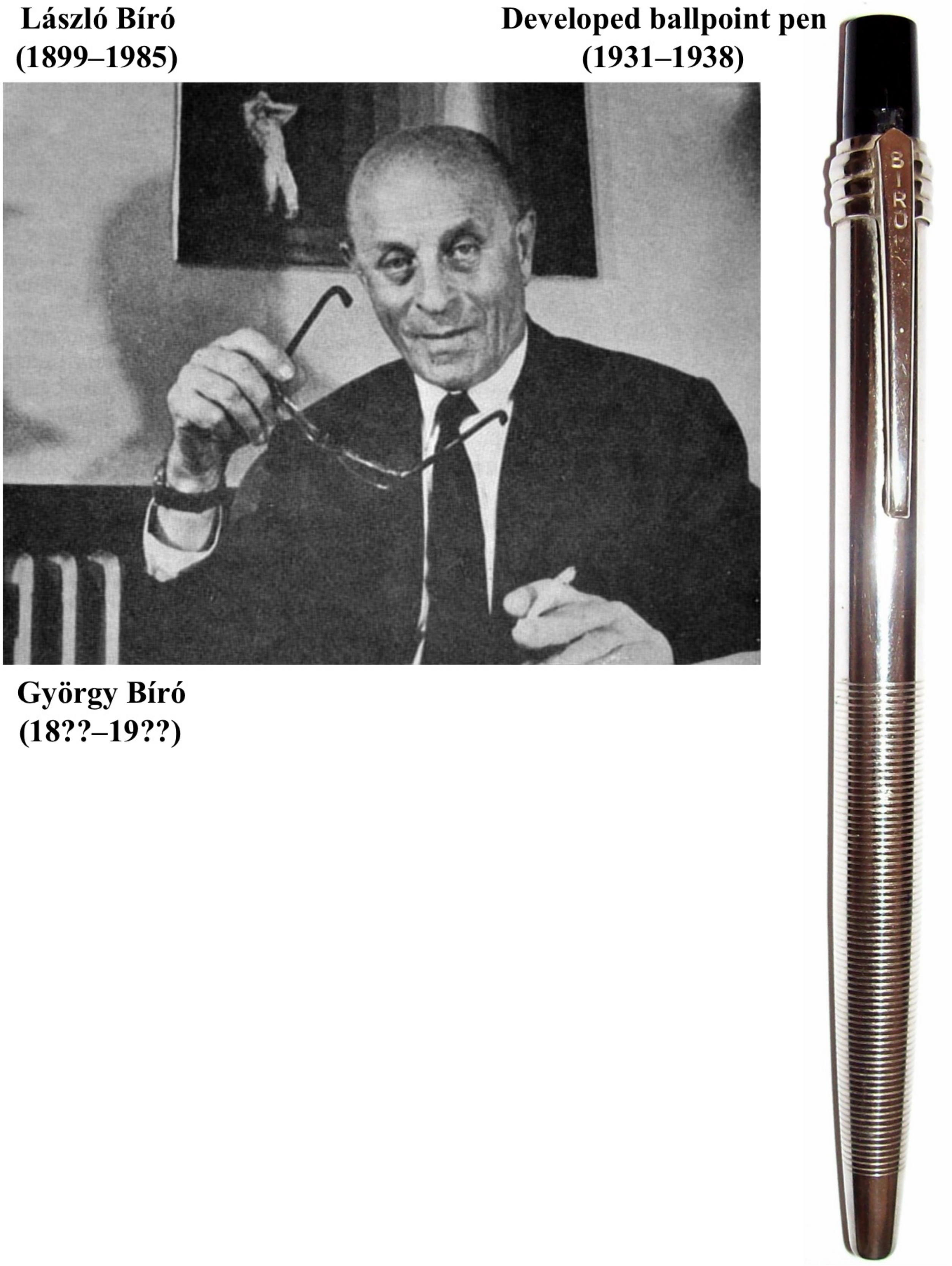

László Bíró
(1899–1985)
Developed ballpoint pen
(1931–1938)
György Bíró
(18??–19??)
BIRO

Figure 7.6: The brothers László and György Bíró developed the ballpoint pen 1931–1938.

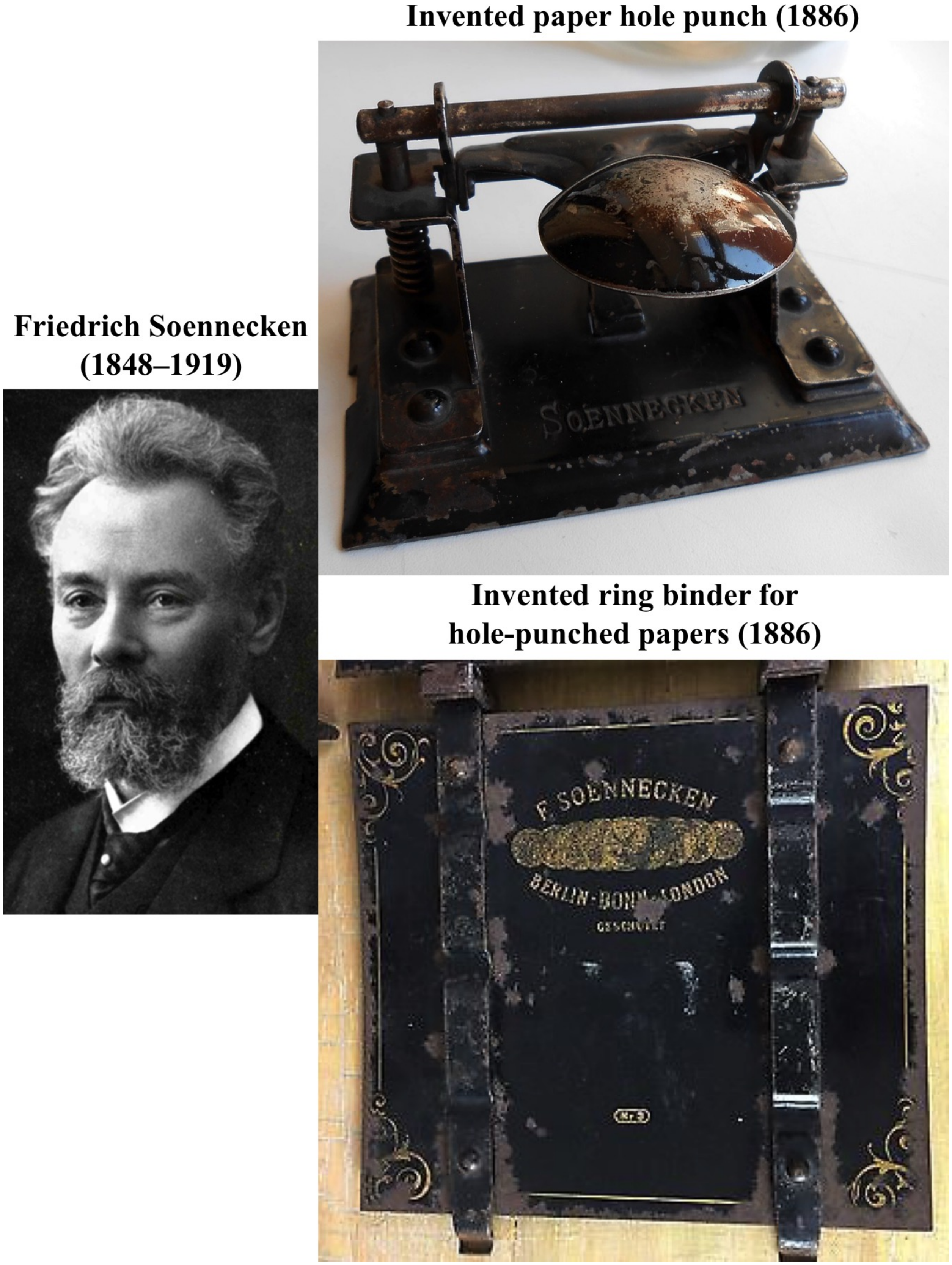

Invented paper hole punch (1886)
SOENNECKEN
Friedrich Soennecken
(1848–1919)
Invented ring binder for
hole-punched papers (1886)
F. SOENNECKEN
BERLIN-BONN-LONDON

Figure 7.7: Friedrich Soennecken invented the paper hole punch and ring binders for hole-punched papers in 1886.

7.1.4 Improved Printing Processes

Beginning in 1796, Alois Senefelder (Austrian/German states, 1771–1834) developed lithography for printing illustrations, as shown in Fig. 7.8. The *Encyclopedia Britannica* explained how Senefelder developed his invention [EB 2010]:

> German inventor of lithography. [...] Desiring to publish plays that he had written but unable to afford the expensive engraving of printing plates, Senefelder tried to engrave them himself. His work on copper plates was not proving very successful when an accident led to his discovery of the possibilities of stone (1796). Senefelder records that one day he jotted down a laundry list with grease pencil on a piece of Bavarian limestone. It occurred to him that if he etched away the rest of the surface, the markings would be left in relief. Two years of experimentation eventually led to the discovery of flat-surface printing (modern lithography).

After using single lithography plates to reproduce black-and-white illustrations in his early work, by 1818 Senefelder had developed methods to use multiple lithography plates with different colors of ink to make color illustrations [Bunch and Hellemans 2004, p. 306]. Very similar lithographic techniques of protecting and etching different parts of surfaces are now also widely used to make semiconductor devices (Section 6.5).

Friedrich König (German states, 1774–1833) and Andreas Bauer (German states, 1783–1860) developed the steam-powered printing press in 1814 [Halkasch 1993; Kasischke 1999; Max Rößler 1982; Wolf 1974]. See Fig. 7.9.

Paul Pretsch (German?, 18??–19??) and A. J. Berchtold (German?, 18??–19??) did early work and Georg Meisenbach (German, 1841–1912) perfected the halftone method for reproducing photographs with tiny printed dots [Dorothea Peters 2007]. Figure 7.10 shows the first image that Meisenbach produced with his final halftone method. This method is still widely used for newspapers, magazines, and computer printers.

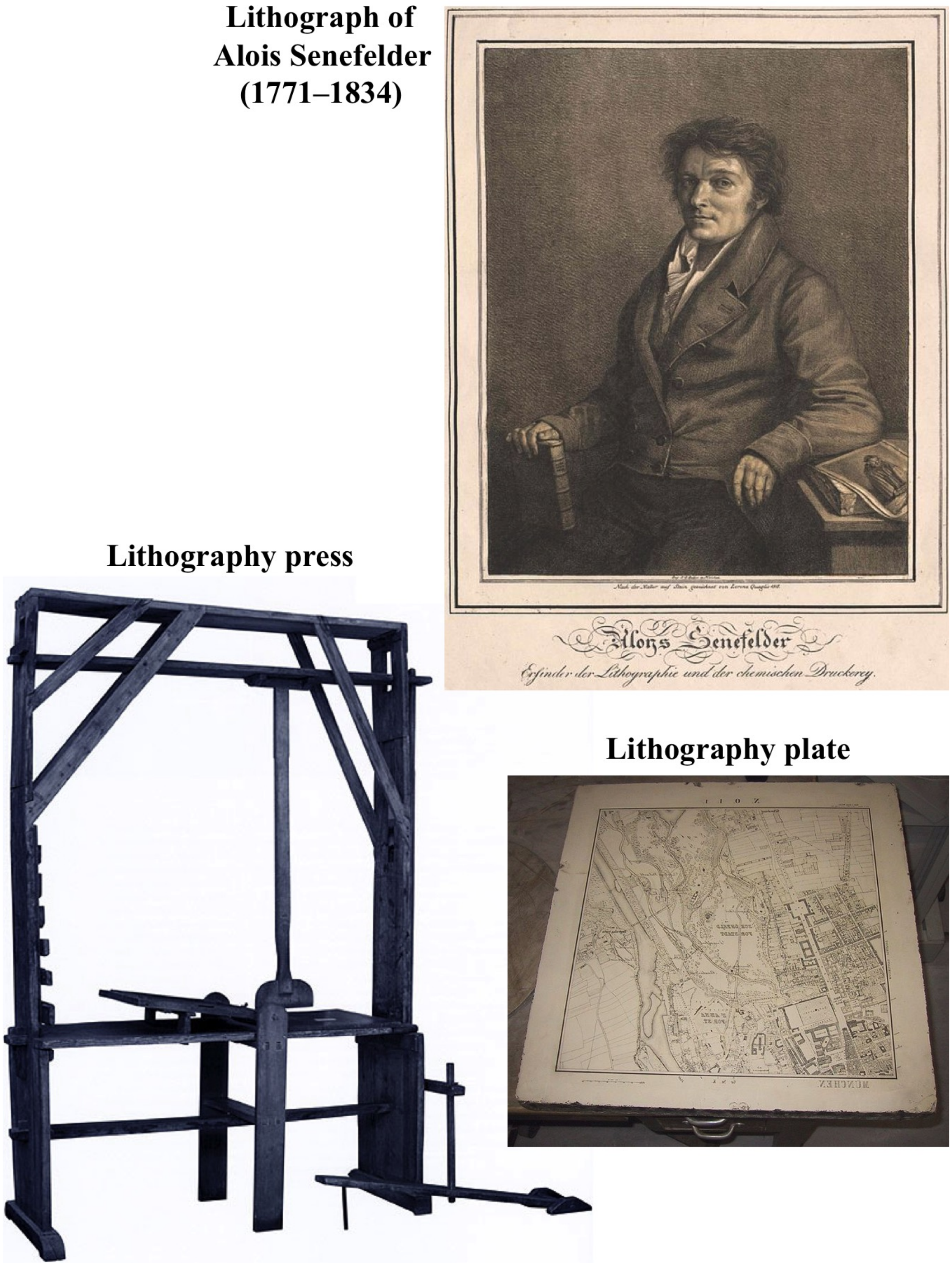
As shown in Fig. 7.11, Ottmar Mergenthaler (German, 1854–1899) was born and educated in Germany, then emigrated to the United States. During the period 1876–1899, he developed linotype machines for rapid typesetting for printing presses [Schlesinger 1989]. Oxford University's *Biographical Dictionary of Scientists* described the mechanism and importance of Mergenthaler's invention [Porter 1994, p. 478]:

> Before Linotype, printing was carried out by hand-setting, a long and laborious process. Mergenthaler's invention speeded this operation and made printed matter, from books to penny news sheets, cheaper to produce. The design of the machine enabled a line of type (hence the name) to be composed at one time and cast as a single piece of metal. The machine was rather like a large typewriter, about 2 m/6½ ft high, with a store of matrices (moulds) at the top. The operator selected the letters by means of rods controlled by the 'typewriter' keys, and these letters fell through tiny trapdoors to drop into position in a line setting. As each line was completed it was passed on to the 'metal pot' area where a cast was made to form a 'slug' with the letters in relief on one side.

> This then fitted into a page of type ready for printing, while the matrices were returned to the store at the top of the machine for reuse.
>
> A person operating one of Mergenthaler's keyboards could set type up to three or four times faster than by hand-setting, cutting the labour cost of production to a fraction of before. The machine heralded a new age for printing in which books became affordable, and newspapers could really claim to carry up-to-the-minute information, for the Linotype made it possible to change and reset copy to within minutes of going to press.

The German-speaking world developed advanced methods of printing that were transferred to other countries after World War II. See Fig. 7.12 for just one example among many [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases].

See also pp. 1013 and 1162 for German-speaking contributions to electronic technologies for document printing, document transfer, and document storage.


Lithograph of Alois Senefelder (1771–1834)

Lithography press

Lithography plate

Nach der Natur auf Stein gezeichnet von Lorenz Quaglio 1818.
Alois Senefelder
Erfinder der Lithographie und der chemischen Druckerey.

Figure 7.8: Alois Senefelder developed lithography for printing illustrations beginning in 1796.

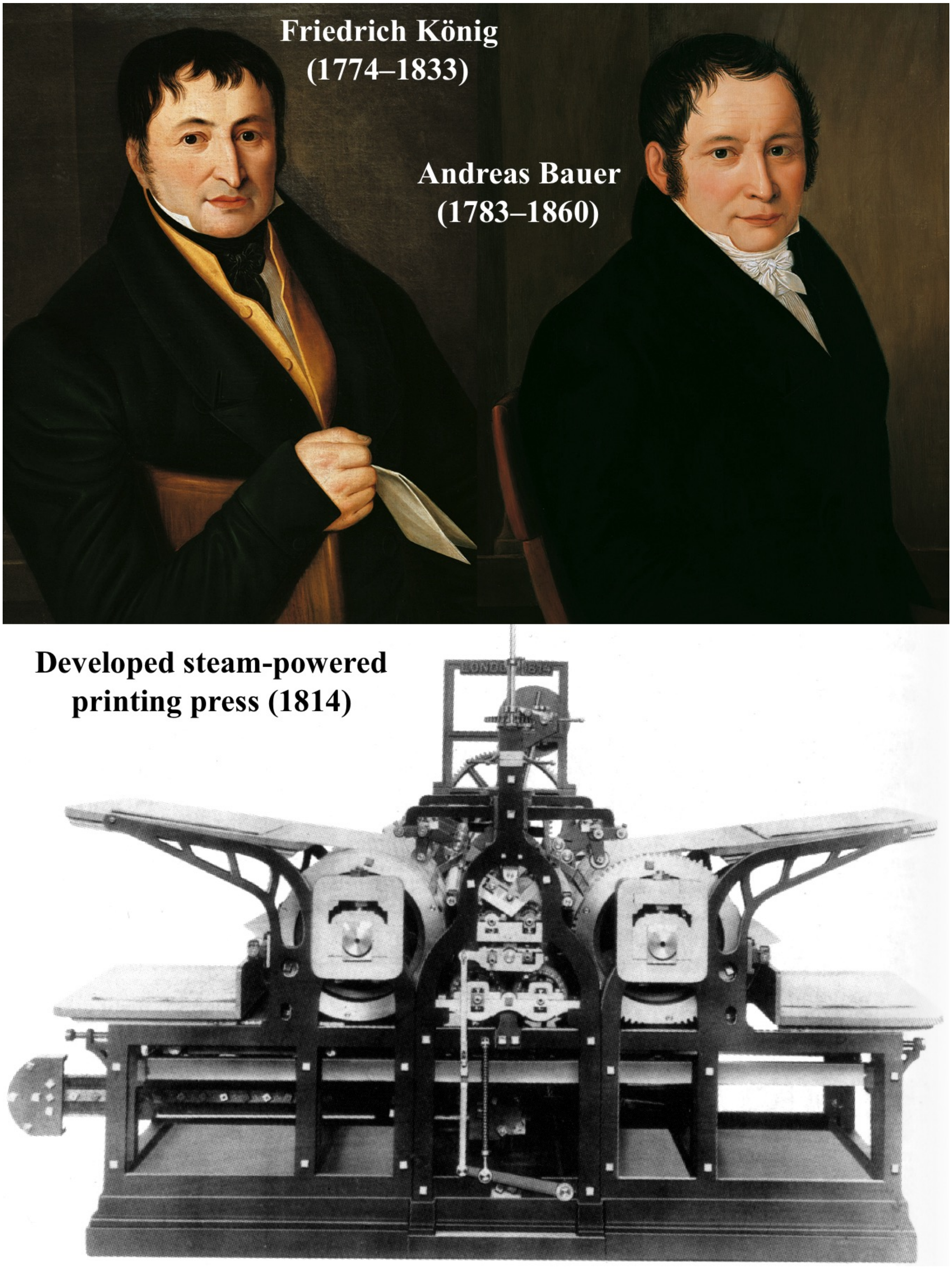

Friedrich König
(1774–1833)
Andreas Bauer
(1783–1860)
Developed steam-powered
printing press (1814)

Figure 7.9: Friedrich König and Andreas Bauer developed the steam-powered printing press in 1814.

Paul Pretsch
(18??–19??)
Halftone
experiments (1854)

A. J. Berchtold
(18??–19??)
Halftone
improvements (1855)

Georg Meisenbach
(1841–1912)
Reliable halftone
process (1882)

Halftone method for reproducing photographs with tiny printed dots

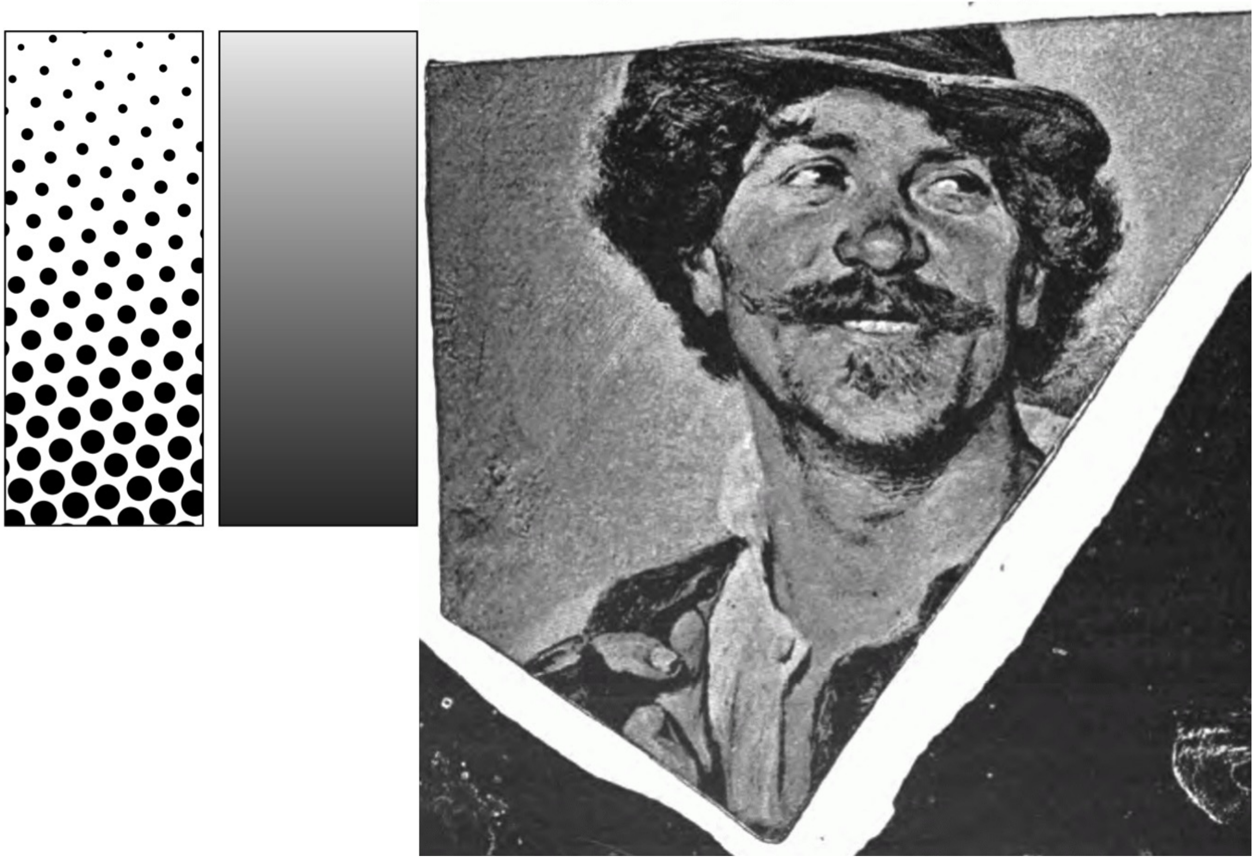


Figure 7.10: Paul Pretsch and A. J. Berchtold did early work and Georg Meisenbach perfected the halftone method for reproducing photographs with tiny printed dots.

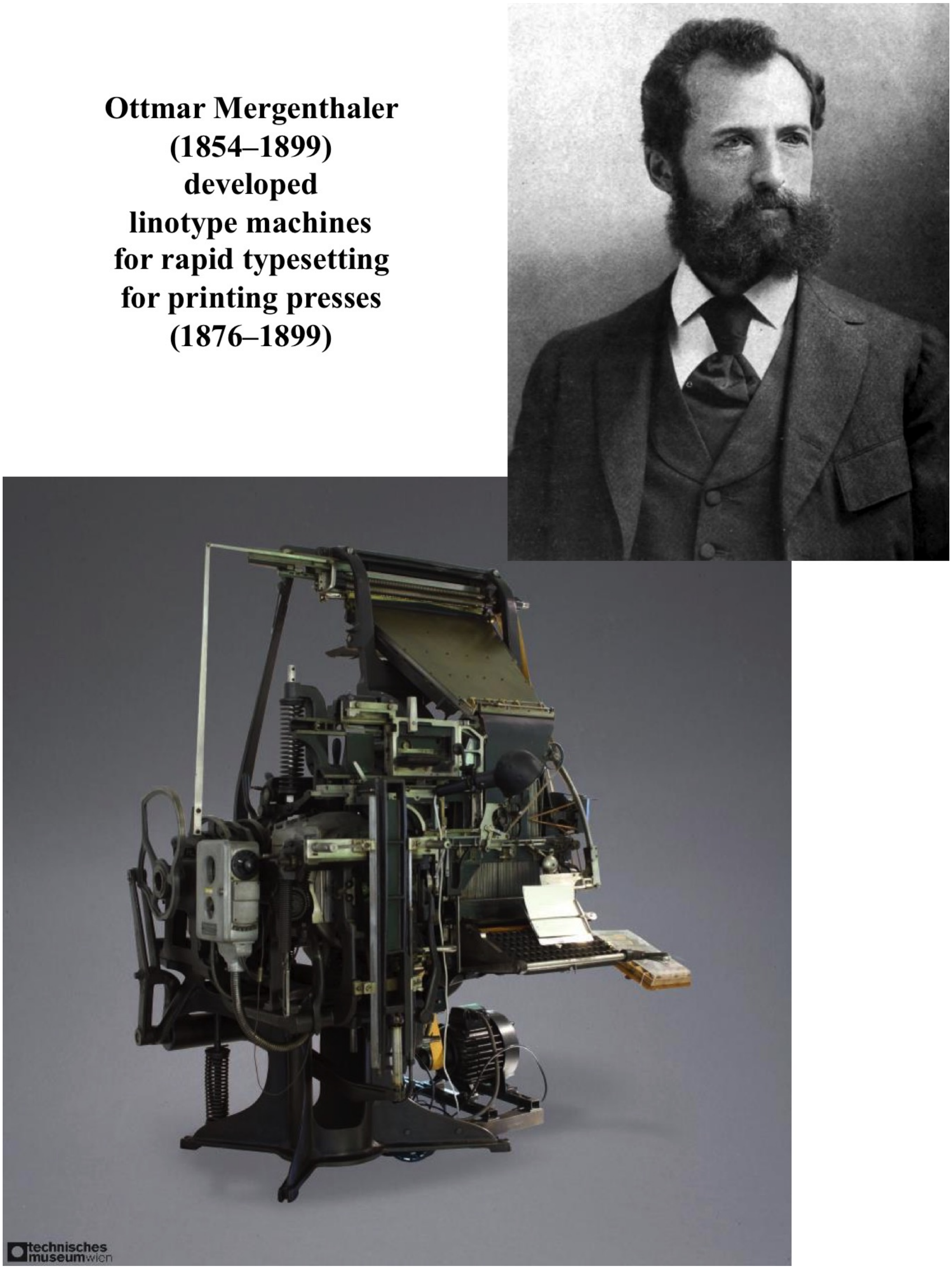

Ottmar Mergenthaler
(1854–1899)
developed
linotype machines
for rapid typesetting
for printing presses
(1876–1899)
technisches museum wien

Figure 7.11: Ottmar Mergenthaler developed linotype machines for rapid typesetting for printing presses (1876–1899).

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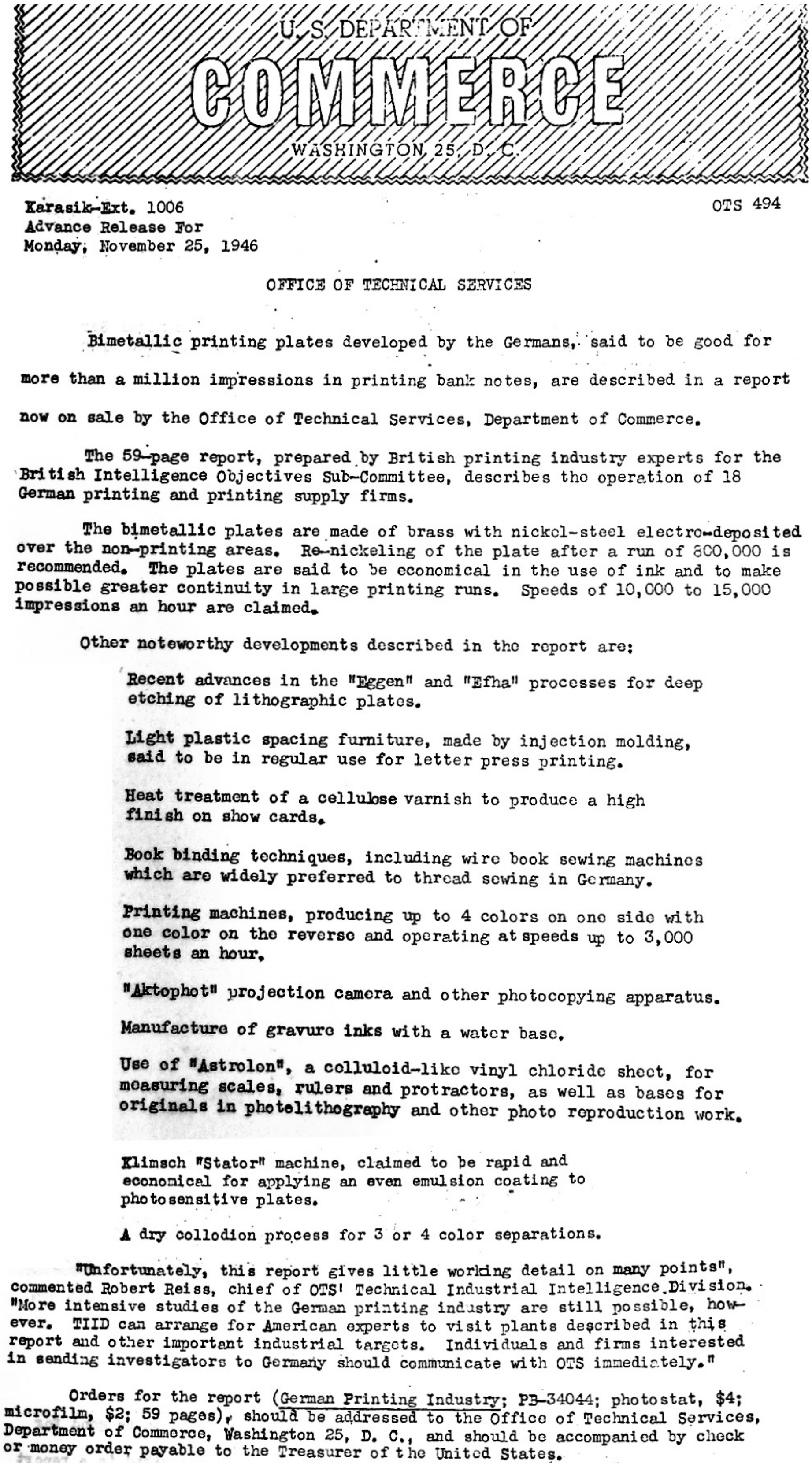
NARA RG 40, Entry UD-75, Box 3, Folder Press Releases



U. S. DEPARTMENT OF
COMMERCE
WASHINGTON 25, D. C.

Karasik-Ext. 1006
Advance Release For
Monday, November 25, 1946

OTS 494

OFFICE OF TECHNICAL SERVICES

Bimetallic printing plates developed by the Germans, said to be good for more than a million impressions in printing bank notes, are described in a report now on sale by the Office of Technical Services, Department of Commerce.

The 59-page report, prepared by British printing industry experts for the British Intelligence Objectives Sub-Committee, describes the operation of 18 German printing and printing supply firms.

The bimetallic plates are made of brass with nickel-steel electro-deposited over the non-printing areas. Re-nickeling of the plate after a run of 800,000 is recommended. The plates are said to be economical in the use of ink and to make possible greater continuity in large printing runs. Speeds of 10,000 to 15,000 impressions an hour are claimed.

Other noteworthy developments described in the report are:

Recent advances in the "Eggen" and "Efha" processes for deep etching of lithographic plates.

Light plastic spacing furniture, made by injection molding, said to be in regular use for letter press printing.

Heat treatment of a cellulose varnish to produce a high finish on show cards.

Book binding techniques, including wire book sewing machines which are widely preferred to thread sewing in Germany.

Printing machines, producing up to 4 colors on one side with one color on the reverse and operating at speeds up to 3,000 sheets an hour.

"Aktophot" projection camera and other photocopying apparatus.

Manufacture of gravure inks with a water base.

Use of "Astrolon", a celluloid-like vinyl chloride sheet, for measuring scales, rulers and protractors, as well as bases for originals in photelithography and other photo reproduction work.

Klimsch "Stator" machine, claimed to be rapid and economical for applying an even emulsion coating to photosensitive plates.

A dry collodion process for 3 or 4 color separations.

"Unfortunately, this report gives little working detail on many points", commented Robert Reiss, chief of OTS' Technical Industrial Intelligence Division. "More intensive studies of the German printing industry are still possible, however. TIID can arrange for American experts to visit plants described in this report and other important industrial targets. Individuals and firms interested in sending investigators to Germany should communicate with OTS immediately."

Orders for the report (German Printing Industry; PB-34044; photostat, $4; microfilm, $2; 59 pages), should be addressed to the Office of Technical Services, Department of Commerce, Washington 25, D. C., and should be accompanied by check or money order payable to the Treasurer of the United States.

Figure 7.12: The German-speaking world developed advanced methods of printing that were transferred to other countries after World War II [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases].

7.2 Musical Instruments

The quantity and quality of musical contributions by composers from the predominantly German-speaking central European world are well known. Composers such as those listed in Table 7.1 remain household names worldwide, even centuries later.

Name	**Nationality**	**Lived**
Johann Sebastian Bach	German states	1685–1750
Carl Philipp Emanuel Bach	German states	1714–1788
Johann Christian Bach	German states	1735–1782
Ludwig van Beethoven	German states	1770–1827
Alban Berg	Austrian	1885–1935
Johannes Brahms	German	1833–1897
Josef Anton Bruckner	Austrian	1824–1896
Fryderyk Chopin	Polish	1810–1849
Antonín Dvořák	Czech/Austrian	1841–1904
Christoph Willibald Gluck	German states/Austrian	1714–1787
Georg Friederich Handel	German states	1685–1759
Joseph Haydn	Austrian	1732–1809
Michael Haydn	Austrian	1737–1806
Paul Hindemith	German	1895–1963
Leoš Janáček	Czech/Austrian	1854–1928
Franz Liszt	Austro-Hungarian	1811–1886
Gustav Mahler	Austrian	1860–1911
Fanny Mendelssohn	German states	1805–1847
Felix Mendelssohn	German states	1809–1847
Leopold Mozart	Austrian	1719–1787
Wolfgang Amadeus Mozart	Austrian	1756–1791
Carl Orff	German	1895–1982
Johann Pachelbel	German states	1653–1706
Arnold Schoenberg	Austrian	1874–1951
Franz Schubert	Austrian	1797–1828
Robert Schumann	German states	1810–1856
Clara Schumann	German	1819–1896
Heinrich Schütz	German states	1585–1672
Bedřich Smetana	Czech/Austrian	1824–1884
Johann Strauss	Austrian	1825–1899
Richard Strauss	German	1864–1949
Georg Philipp Telemann	German states	1681–1767
Richard Wagner	German	1813–1883
Carl Maria von Weber	German states	1786–1826
Anton Webern	Austrian	1883–1945
Kurt Weill	German	1900–1950

Table 7.1: Examples of well-known musical composers from the predominantly German-speaking central European world.

While it is less well known to the general public, German-speaking creators also made enormous contributions to the development of modern musical instruments and equipment, including:[3]

7.2.1. Woodwind instruments

7.2.2. Brass instruments

7.2.3. Pianos

7.2.4. Metronomes

7.2.1 Woodwind Instruments

As shown in Fig. 7.13, Johann Christoph Denner (German states, 1655–1707) developed the clarinet around 1700. Iwan Müller (Baltic German, 1786–1854) later created airtight key pads for it and other woodwinds. Anthony Baines, an Oxford University musicologist and curator of musical instruments, praised Denner's creation [Baines 1991, p. 297]:

> The clarinet, Germany's great contribution to the woodwind, marks the first full exploitation in Western musical history—possibly in all history—of the upper register of a reed-sounded cylindrical tube. It was invented about the beginning of the eighteenth century by J. C. Denner of Nuremberg or his son. Doppelmeyr's 'Historical Report of Nuremberg Mathematicians and Craftsmen,' 1730, names the father.
>
> Denner was one of the leading German woodwind-makers of the end of the seventeenth century[...]

Although simple flutes had been used since antiquity, Theobald Böhm (German, 1794–1881, Fig. 7.14) developed the modern Western concert flute during the period 1831–1847. Anthony Baines explained some of the steps that Böhm went through to perfect his flute design [Baines 1991, pp. 320–322]:

> When Boehm returned to Munich, his keen, analytical mind faced up squarely to the question of the large holes, and he quickly decided to incorporate them on a systematic basis throughout the instrument. Moreover, he went yet a step further: he conceived the idea of securing *full venting* for the notes by changing all the existing closed keys into open keys—i.e. into keys standing normally open.
>
> This reversed key-system demanded some novel method of control, and for this Boehm embodied a mechanical device that had appeared already in rudimentary forms in the workshops of other experimental flute-makers: the now-familiar rings, through which a finger can operate a key in the same movement as closing its own hole. Thus he produced the *conical Boehm flute*, 1832, the greatest of all landmarks in the modern history of woodwind design. [...]
>
> Search for yet greater volume and freedom of sound led Boehm next to reason thus, assisted by experiments with numerous bits of brass tubing[...]

---

[3] Baines 1991, 1993; Ulrich Michels 2008; Sachs 1940; Wilkinson 2014.

> With this, Boehm had found his *cylindrical bore* (1847), the bore of the flute today. The holes, he discovered, should have at least three-quarters of the diameter of the bore, making covered action (finger-plates) necessary. Hole I was an exception to the rule: for the sake of the upper D's it had to be smaller than the other holes, and placed rather high up the flute. Boehm's first instruments were of silver, though late in life he himself changed to wood, or silver with wooden head.

The modern oboe (sometimes called the Wiener or Viennese oboe) was developed in stages by Johann Eichentopf (German states, 1678–1769), Jacob Denner (German states, 1681–1735), Stefan Koch (Austrian, 1772–1828), Karl Friedrich Golde (German, 1803–1873), Josef Hajek (Austrian, 1849–1926), and Hermann Zuleger (Austrian, 1885–1949). See Fig. 7.15.

The modern bassoon (sometimes called the Heckel bassoon) was developed by Gottfried Weber (German states, 1779–1839), improved by Carl Almenräder (German states, 1786–1846), and perfected by Johann Adam Heckel (German, 1812–1877), as illustrated in Fig. 7.16. Anthony Baines described the contributions of Almenräder and Heckel [Baines 1991, pp. 338–339]:

> The story of the Heckel bassoon begins about 1825, when Carl Almenraeder, a bandmaster and contemporary of the Savarys, set out to cure certain faults of the classical bassoon. [...]
>
> Thus far, Almenraeder was entirely successful, producing an instrument on which the notes came out as steadily and evenly as they do on the small woodwind. But the tone-quality suffered. [...] It has been the achievement of the firm of Heckel to undo the damage to the tone while yet preserving the technical benefits. The work included patient attention to the bore [...] and refinement of the manufacture by every possible means. During one period, Wagner himself was in and out of the workshop watching progress with keen interest.

The harmonica was created around 1821 in the German-speaking world and then copied so rapidly by several craftsmen there that it is unclear which one of them actually originated the instrument (Fig. 7.17). Proposed creators of the harmonica include Christian Friedrich Buschmann (German states, 1805–1864), Anton Häckl (Austrian, 17??–18??), Georg Anton Reinlein (Austrian, 1766–1834), and Joseph Richter (Austrian, 17??–18??).

In a very similar fashion, the accordion was developed around 1822 in the German-speaking world and immediately copied by craftsmen there. Proposed creators of the accordion include the same Christian Friedrich Buschmann, Cyrill Demian (Austrian, 1772–1849), and Carl Friedrich Uhlig (German, 1789–1874, inventor of the concertina). See Fig. 7.18. The *Encyclopedia Britannica* summarized some of what is known of the origins of the accordion [EB 2010]:

> The advent of the accordion is the subject of debate among researchers. Many credit C. Friedrich L. Buschmann, whose *Handäoline* was patented in Berlin in 1822, as the inventor of the accordion, while others give the distinction to Cyrill Demian of Vienna, who patented his *Accordion* in 1829, thus coining the name. A modification of the *Handäoline*, Demian's invention comprised a small manual bellows and five keys, although, as Demian noted in a description of the instrument, extra keys could be incorporated into the design. Numerous variations of the device soon followed.

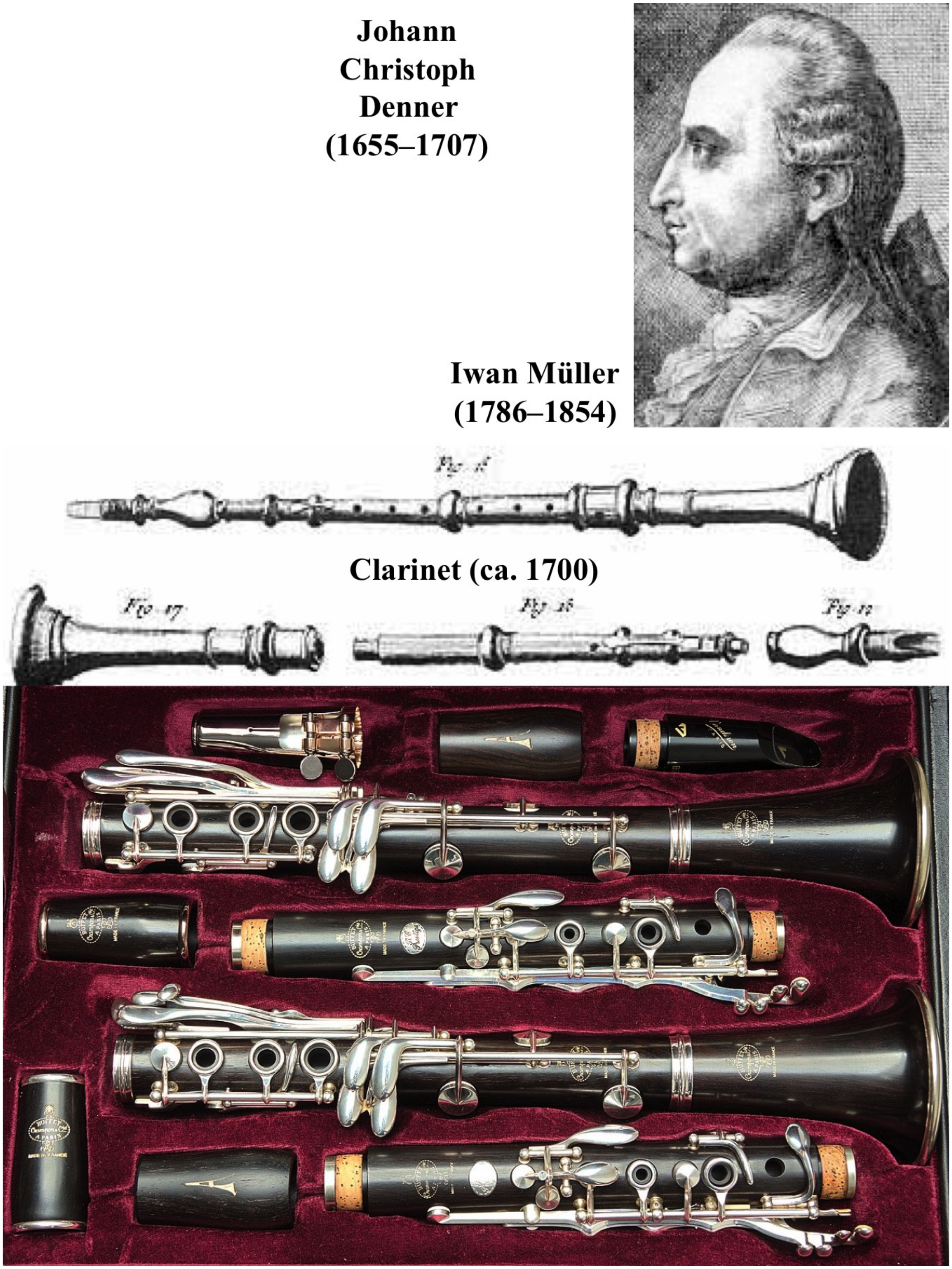

Johann Christoph Denner (1655–1707)
Iwan Müller (1786–1854)
Clarinet (ca. 1700)

Figure 7.13: Johann Christoph Denner developed the clarinet around 1700, and Iwan Müller created airtight key pads for it and other woodwinds.

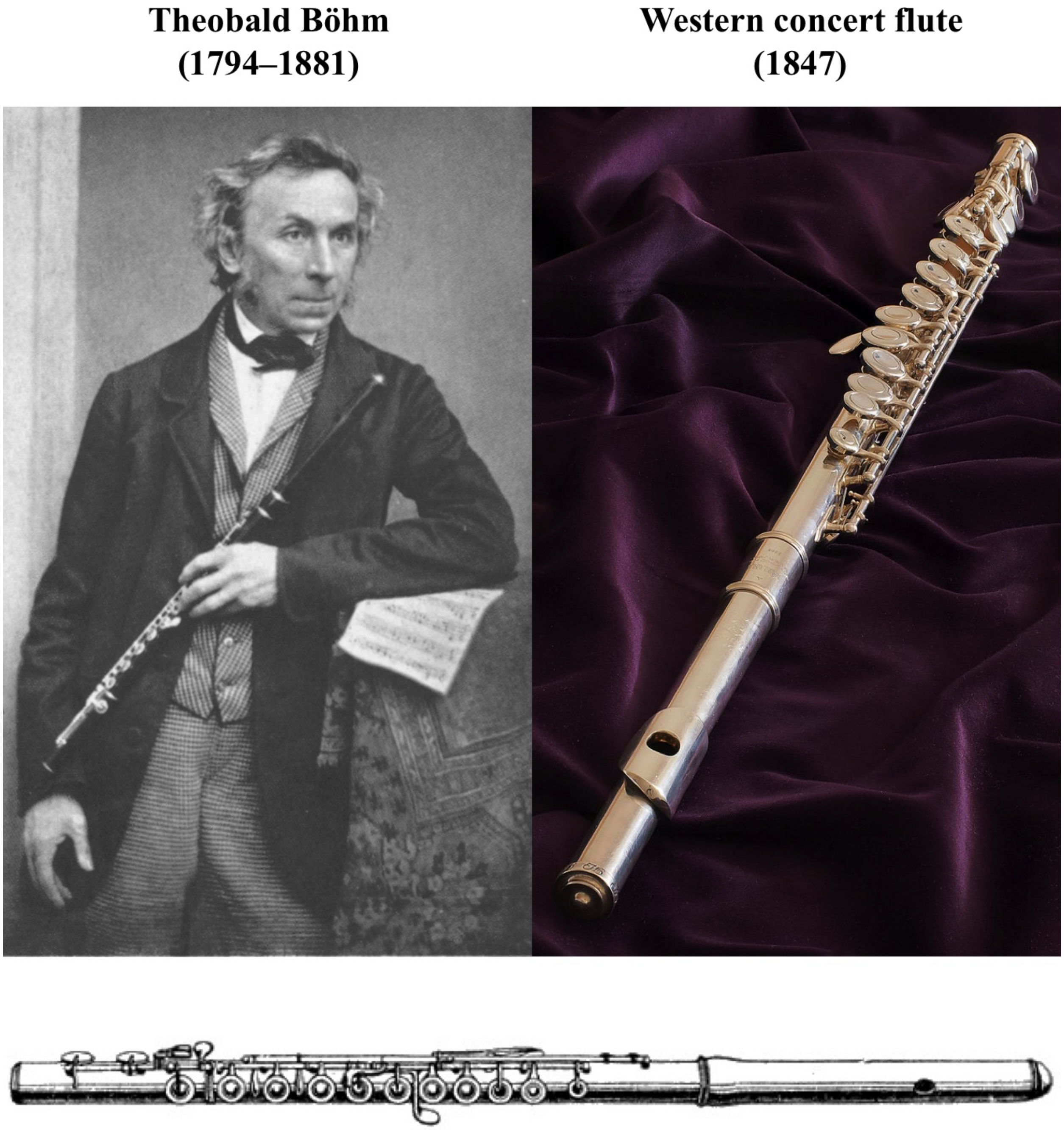

Theobald Böhm
(1794–1881)
Western concert flute
(1847)

Figure 7.14: Theobald Böhm developed the modern Western concert flute during the period 1831–1847.

Johann Eichentopf
(1678–1769)

Jacob Denner
(1681–1735)

Stefan Koch
(1772–1828)

Karl Friedrich Golde
(1803–1873)

Josef Hajek
(1849–1926)

Hermann Zuleger
(1885–1949)

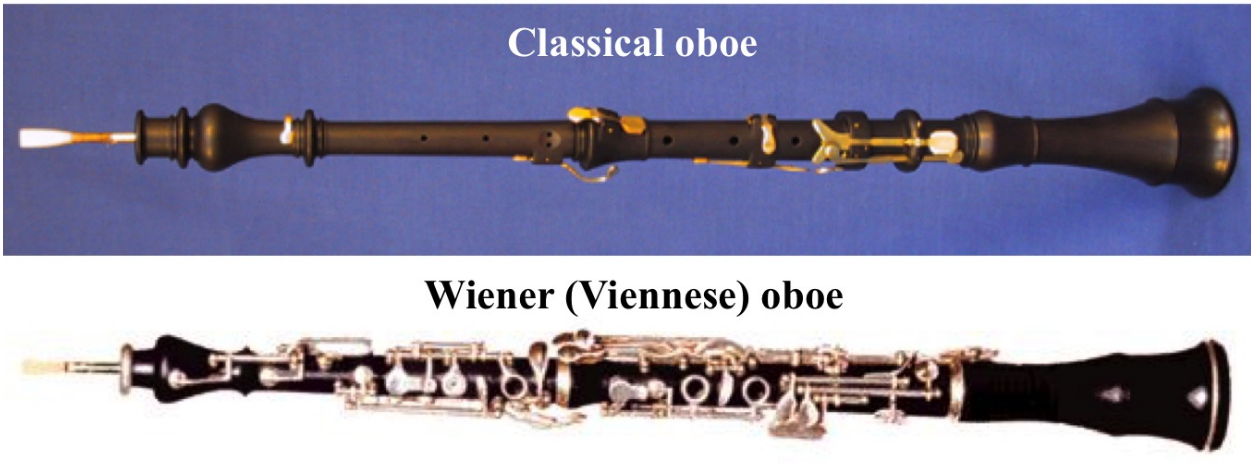


Figure 7.15: The modern oboe (sometimes called the Wiener or Viennese oboe) was developed in stages by Johann Eichentopf, Jacob Denner, Stefan Koch, Karl Friedrich Golde, Josef Hajek, and Hermann Zuleger.

Gottfried Weber
(1779–1839)

Carl Almenräder
(1786–1846)

Johann Adam Heckel
(1812–1877)

Heckel bassoon

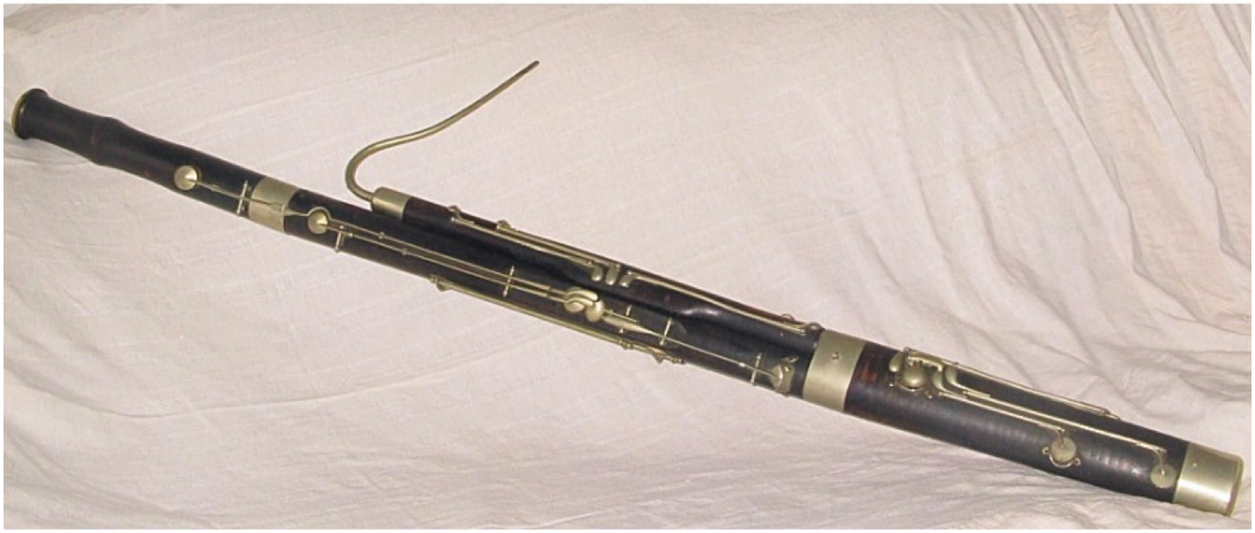


Figure 7.16: The modern bassoon (sometimes called the Heckel bassoon) was developed by Gottfried Weber, Carl Almenräder, and Johann Adam Heckel.

Christian Friedrich Buschmann
(1805–1864)

Anton Häckl
(17??–18??)

Georg Anton Reinlein
(1766–1834)

Joseph Richter
(17??–18??)

Harmonica (ca. 1821)

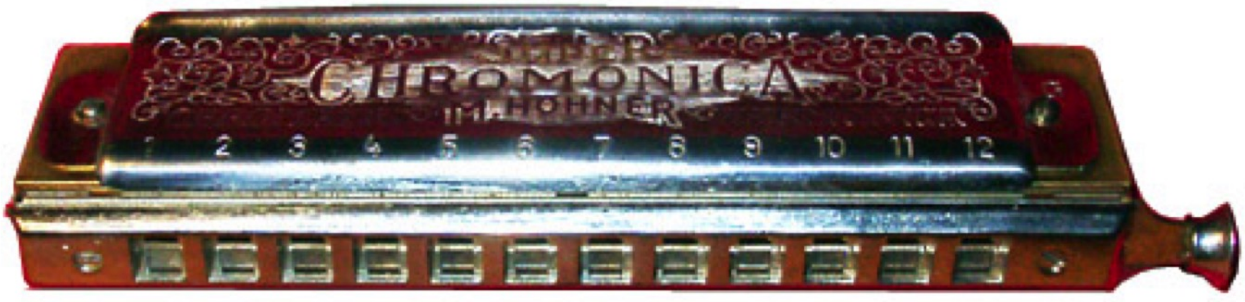


Figure 7.17: The harmonica was developed around 1821 in the German-speaking world and rapidly copied by several craftsmen there. Proposed creators of the harmonica include Christian Friedrich Buschmann, Anton Häckl, Georg Anton Reinlein, and Joseph Richter.

Christian Friedrich Buschmann (1805–1864) **Cyrill Demian (1772–1849)** **Carl Friedrich Uhlig (1789–1874)**

Accordion (ca. 1822)

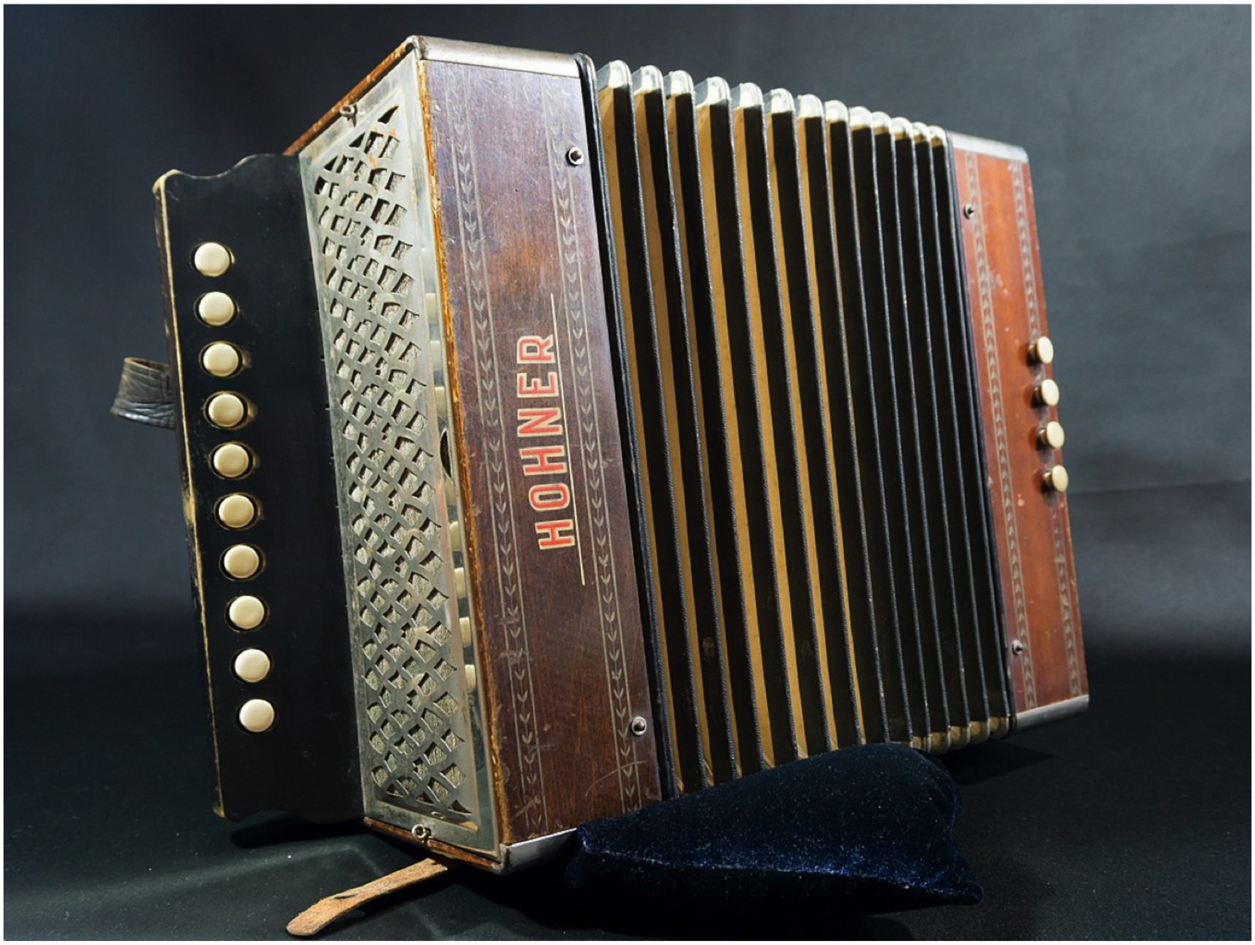


Figure 7.18: The accordion was developed around 1822 in the German-speaking world and rapidly copied by several craftsmen there. Proposed creators of the accordion include Christian Friedrich Buschmann, Cyrill Demian, and Carl Friedrich Uhlig.

7.2.2 Brass Instruments

Anton Joseph Hampel (Austrian/German states, 1710–1771) invented tuning slides for brass horns in 1753 or earlier. See Fig. 7.19.

Friedrich Blühmel (German states, 1777–1845) and/or Heinrich Stölzel (German states, 1777–1844) created valves for brass horns around 1813 (Fig. 7.19). Anthony Baines explained what is known of their history [Baines 1993, pp. 206–207]:

> In 1815 the *Allgemeine musikalische Zeitung* printed the historic communication from Breslau [...], signed by the director of the theatre there:
>
> NEW INVENTION
>
>> Kammermusikus Heinrich Stölzel of Pless in Upper Silesia has, for the perfection of the *Waldhorn*, devised a simple mechanism by which a chromatic scale of nearly three octaves, with all non-natural notes clear and strong, and similar in sound to the natural notes, is obtained by means of two levers for the right hand. [...]
>
> Heinrich Stoelzel (as he was sometimes more conveniently spelt) was then a thirty-eight year old horn-player in the orchestra of Prince von Pless. At once he began to advertise the new horn, performing on it at Leipzig in 1817[...] Next year he found himself a place in the royal orchestra at Berlin. He had, however, left out of the reckoning his younger collaborator, Friedrich Blühmel, a member of the miners' band (*Berg-Hoboist*) and for all we know a horn-player too. Blühmel chased to Berlin, to claim that the horn had been his and sold by him to Stoelzel. A ten-year Prussian patent was then issued in 1818 jointly to the two men ([...] both are described as coming from Waldenburg, today Walbrzych, southwest of Breslau, where Pless had a castle). [...] Stoelzel finally bought off Blühmel on the expiry of the patent. Both were evidently mechanics as well as musicians. But the only writer who knew them both personally, the great Berlin bandmaster Wilhelm Wieprecht, said that though the two men had worked together in Silesia for many years, their subsequent quarrels made it quite impossible to find out which of them had conceived the idea first.

Those two mechanical inventions—tuning slides and valves—revolutionized the entire family of brass musical instruments.

Wilhelm Friedrich Wieprecht (German, 1802–1872) and Johann Gottfried Moritz (German states, 1777–1840) invented the tuba in 1835. Moritz's son, Carl Wilhelm Moritz (German states, 1810–1855), created the tenor tuba in 1838. See Fig. 7.20. Anthony Baines wrote [Baines 1993, p. 250]:

> Still early in the period of these bombardons, Moritz and Wieprecht, in or just before 1835, produced their *Bass-tuba*. This very compact but rather heavy F bass has a valve bore of 15.5 mm. [...] Moritz's tuba won much admiration and must surely have been envisaged by Wagner in the opening of the *Faust* Overture, which no contemporary bombardon could have managed.

Edmund Gumpert (German, 18??–19??) and Friedrich Kruspe (German, 18??–19??) invented the modern double horn, sometimes called the "French" horn, in 1897, as illustrated in Fig. 7.21.

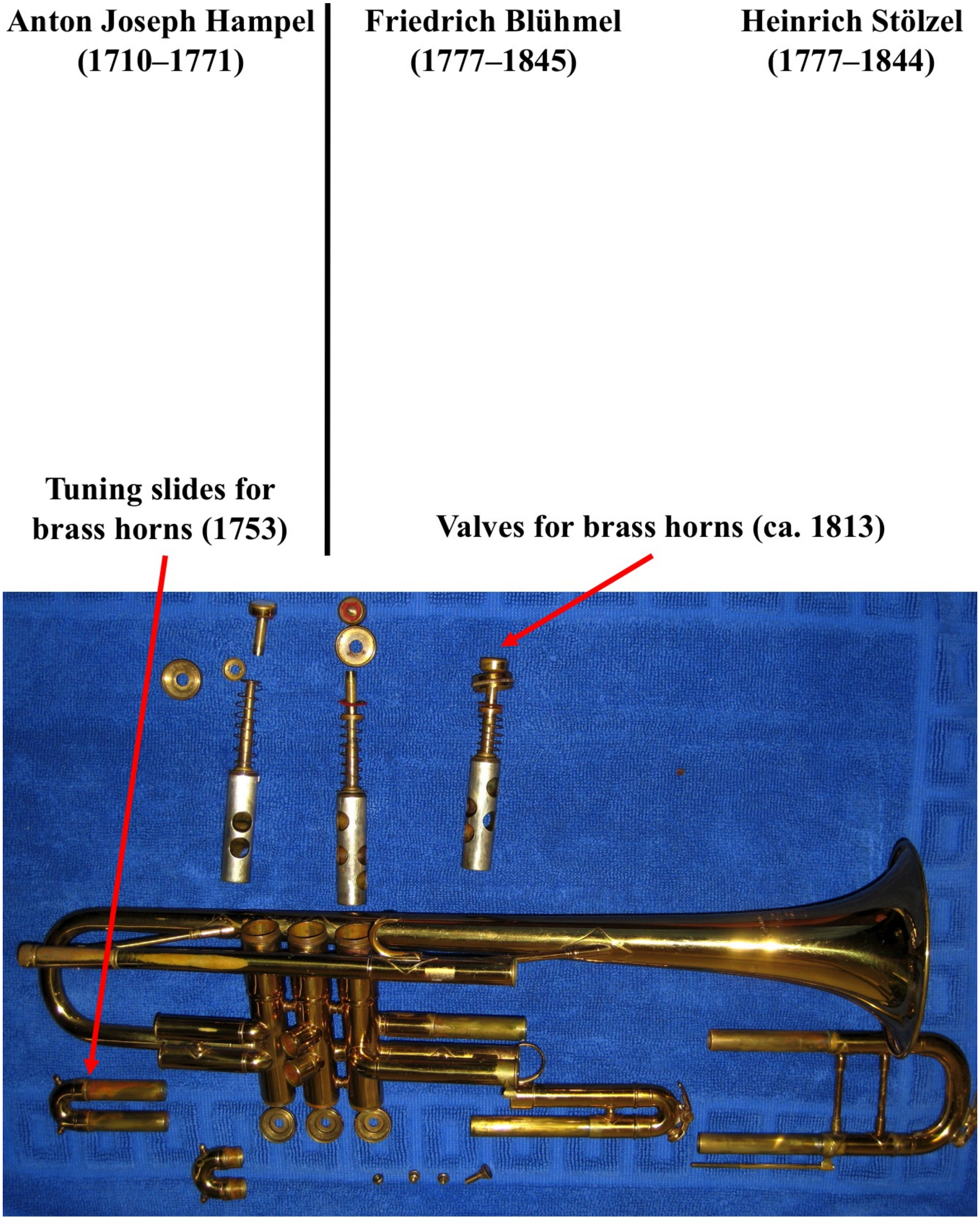
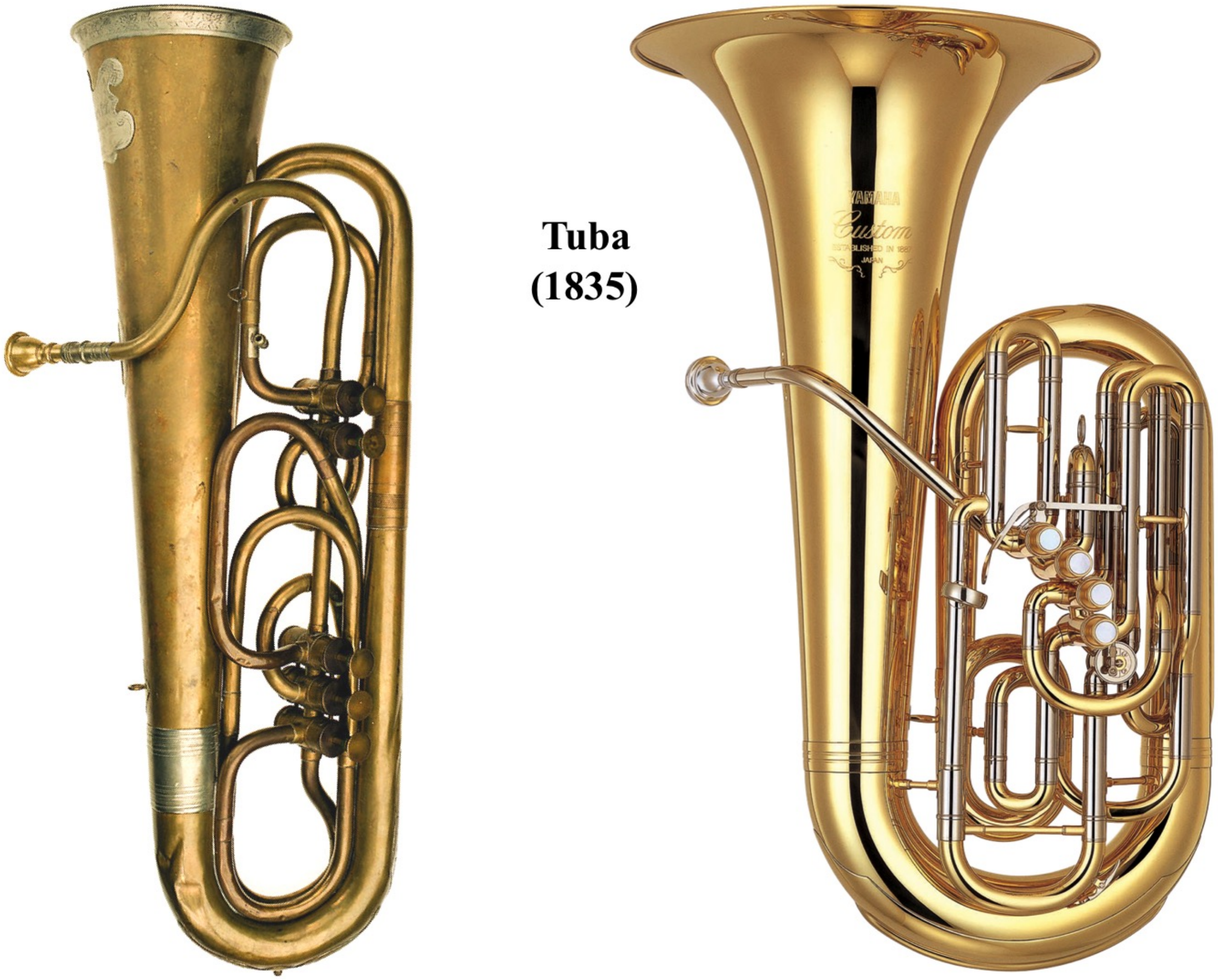

Anton Joseph Hampel
(1710–1771)
Friedrich Blühmel
(1777–1845)
Heinrich Stölzel
(1777–1844)
Tuning slides for brass horns (1753)
Valves for brass horns (ca. 1813)

Figure 7.19: Anton Joseph Hampel invented tuning slides for brass horns in 1753 or earlier. Friedrich Blühmel and/or Heinrich Stölzel created valves for brass horns around 1813.

Wilhelm Friedrich Wieprecht (1802–1872)

Johann Gottfried Moritz (1777–1840)

Carl Wilhelm Moritz (1810–1855)



Tuba (1835)

Figure 7.20: Wilhelm Friedrich Wieprecht and Johann Gottfried Moritz invented the tuba in 1835. Moritz's son, Carl Wilhelm Moritz, created the tenor tuba in 1838.

Edmund Gumpert
(18??–19??)

Friedrich Kruspe
(18??–19??)

Double horn or French horn (1897)

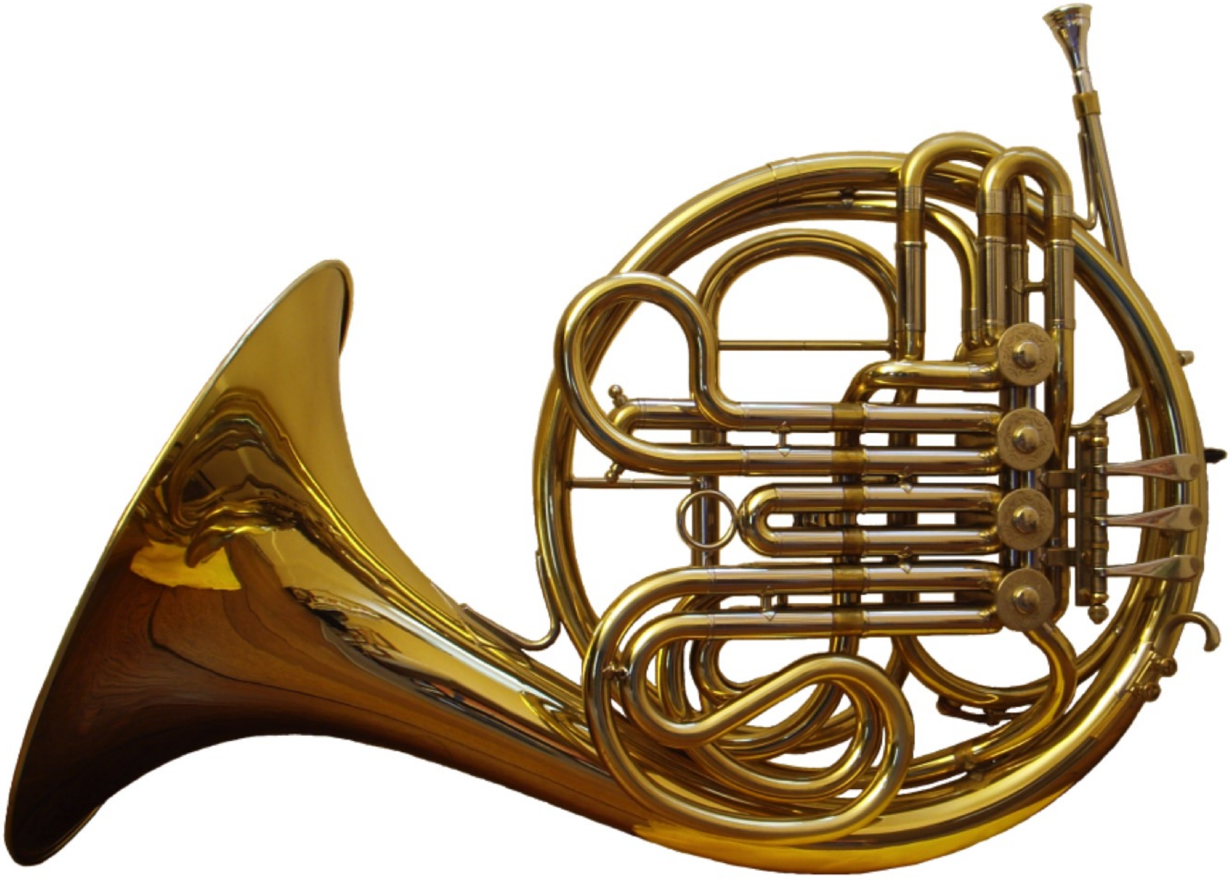


Figure 7.21: Edmund Gumpert and Friedrich Kruspe invented the modern double horn or French horn in 1897.

7.2.3 Pianos

Early pianos first evolved from harpsichords and clavichords, apparently in Italy, but then a series of German-speaking creators made numerous mechanical innovations to develop modern pianos (Fig. 7.22). Some of the major creators included Gottfried Silbermann (German states, 1683–1753), Christoph Gottlieb Schröter (German states, 1699–1782), Christian Ernst Friederici (German states, 1709–1780), Johann Christoph Zumpe (German states, 1726–1790), Johann Andreas Stein (German states, 1728–1792), and Johann Heinrich Pape (German states, 1789–1875). Musicologist Curt Sachs emphasized the dominance of German-speaking creators in the development of pianos [Sachs 1940, pp. 393–395]:

> Italy invented the piano, but then abandoned it. The Germans adopted the art and evolved and transformed the piano; for the following forty years pianos were made exclusively in Germany.
>
> The first and best early maker of grand pianos in Germany was the famous organ builder GOTTFRIED SILBERMANN, of Freiberg, Saxony. He was well acquainted with Johann Sebastian Bach, who criticized and advised him in his attempts, and Frederick the Great of Prussia bought three of the pianos which are now in Potsdam palaces. [...]
>
> This simple action was given an escapement about the year 1770, probably by JOHANN STEIN in Augsburg. In 1777, Wolfgang Amadeus Mozart wrote to his father that he had called on Stein's workshop. "His instruments distinguish themselves by an escapement; not one in a hundred makers troubles himself about that; but without an escapement a piano clatters and leaves a sound[...]" This action with an escaping hammer connected with the key was called first the *German action*, and later on, when the STEIN family had moved to Vienna, the *Viennese action*. [...]
>
> In 1760 a dozen Saxon piano makers, jobless on account of the Seven Years' War, came to settle in London. After this move Germany was no longer the exclusive piano-making country; England began to compete seriously and soon became the leading center. The most famous among the German makers in London were JACOB KIRCHMANN, who changed his name to KIRCKMAN, and JOHANN CHRISTIAN ZUMPE, a former pupil of Silbermann. [...] The first pianist, too, was a German on English soil—Johann Christian Bach, Johann Sebastian's youngest son, gave the world's first piano recital in 1768 in London.

7.2.4 Metronomes

Though technically not a musical instrument, metronomes are an extremely useful tool for musicians. In or before 1814, Dietrich Nikolaus Winkel (Lippstadt, 1777–1826) invented the metronome. Johann Mälzel (German states, 1772–1838) improved and mass-produced metronomes. See Fig. 7.23.

Gottfried Silbermann (1683–1753)

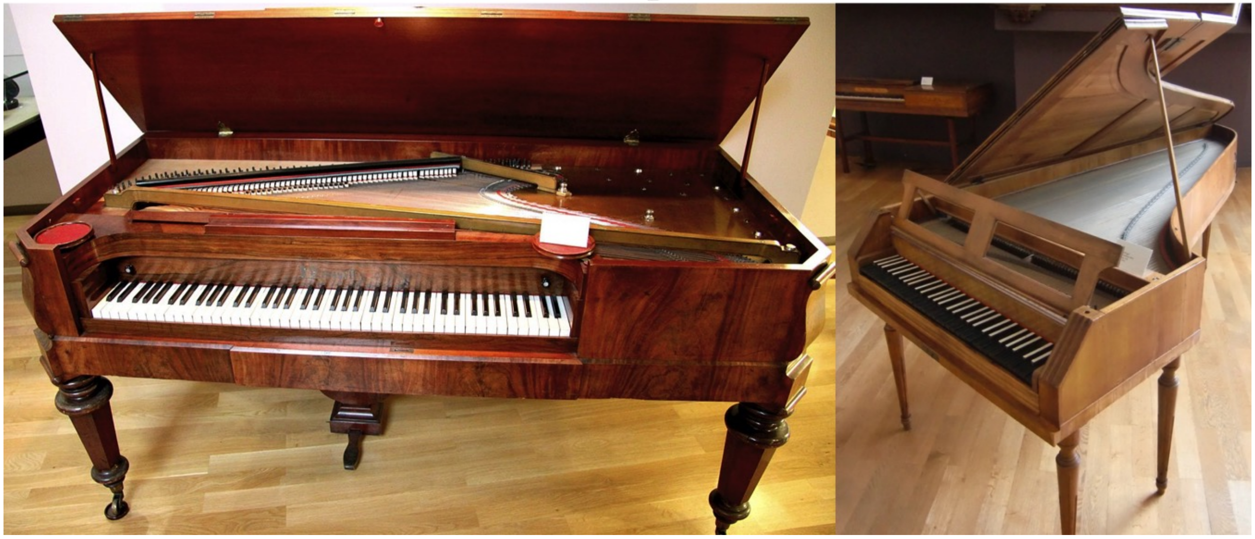
Christoph Gottlieb Schröter (1699–1782)

Christian Ernst Friederici (1709–1780)

Johann Christoph Zumpe (1726–1790)

Johann Andreas Stein (1728–1792)

Johann Heinrich Pape (1789–1875)



Modern pianos

Figure 7.22: Early pianos evolved from harpsichords and clavichords, but then a series of German-speaking creators made numerous mechanical innovations to develop modern pianos. Some of the major creators included Gottfried Silbermann, Christoph Gottlieb Schröter, Christian Ernst Friederici, Johann Christoph Zumpe, Johann Andreas Stein, and Johann Heinrich Pape.

Dietrich Nikolaus Winkel (1777–1826)

Johann Mälzel (1772–1838)

Metronome (1814)

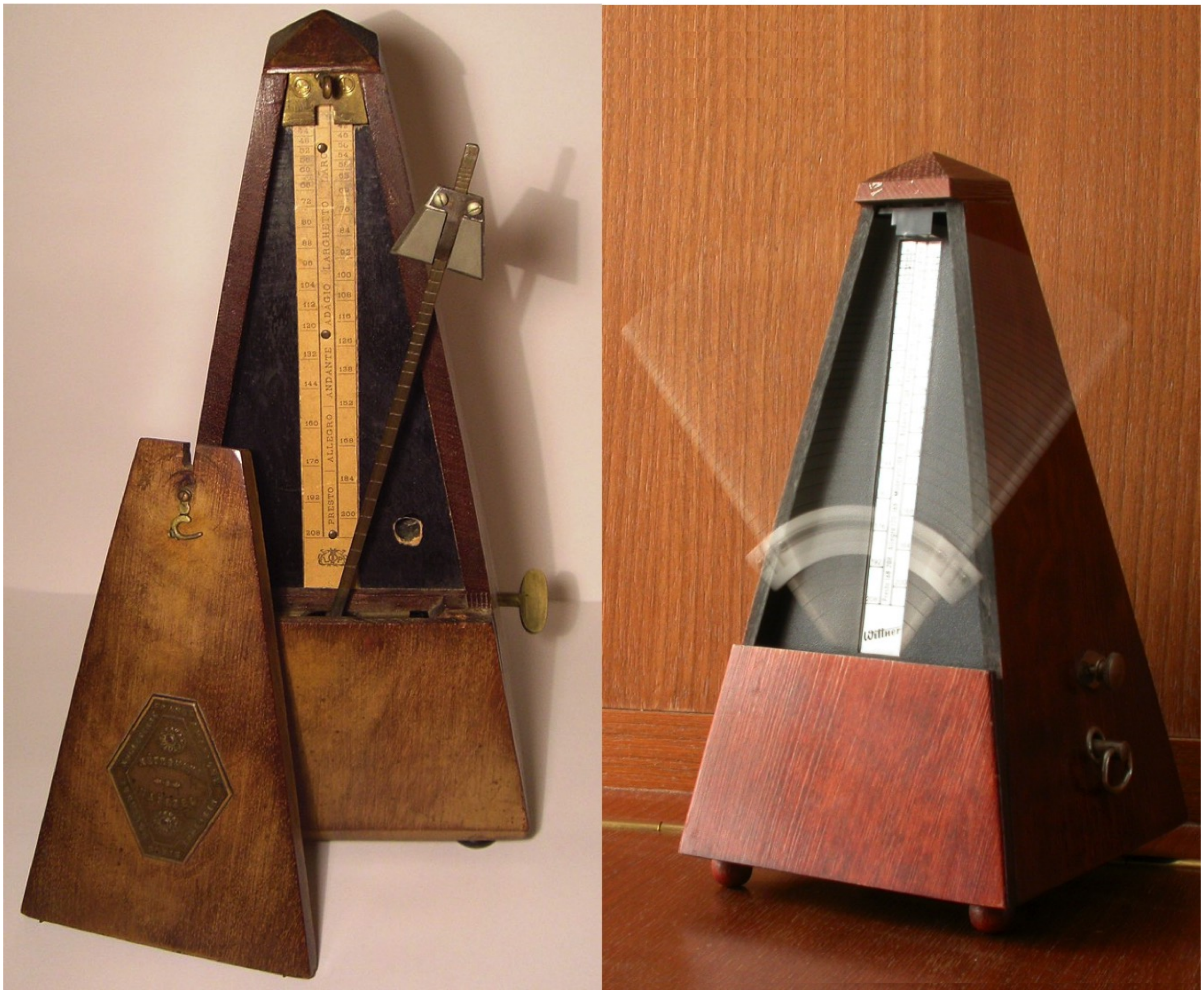


Figure 7.23: Dietrich Nikolaus Winkel invented and Johann Mälzel mass-produced the first metronomes in 1814.

7.3 Internal Combustion Engines and Motor Vehicles

In the eighteenth and early nineteenth centuries, most of the major innovations regarding steam engines and vehicles employing them occurred in the United Kingdom and France [Ingo Müller 2007]. Yet when it came time to supersede steam technology with improved engines in the late nineteenth century, it was the more recently developed German-speaking scientific world that rose to the challenge. Indeed, during the late nineteenth and earlier twentieth centuries, engineers from the German-speaking world were responsible for virtually all of the key innovations in the development of internal combustion engines as well as vehicles and tools powered by them, including:[4]

7.3.1. Motorcycles, motorboats, automobiles, and trucks

7.3.2. Chainsaws

7.3.3. Military tanks

7.3.4. Diesel train locomotives

Those German designs were rapidly copied in the United States and other countries, while the German-speaking world soon entered the decades-long period of World Wars I and II and their respective aftermaths, which greatly hindered German and Austrian industries from competing globally in the very technologies that they had pioneered. As a result, most people in the modern world do not realize how directly all of these creations can be traced to German-speaking creators.

7.3.1 Internal Combustion Engines, Motorcycles, Motorboats, Automobiles, Trucks

Figure 7.24 shows early steps away from steam engines. ?? Brackenburg (German?, 18??–18??) developed an automobile powered by a hydrogen/oxygen combustion engine in 1836. Julius Hock (Austrian, 18??–19??) developed an oil-burning internal combustion engine in 1873 [Cummins 2002].

With assistance from Eugen Langen (German, 1833–1895), Nikolaus Otto (German, 1832–1891) developed the four-stroke internal-combustion gasoline engine in 1876 [Cummins 2002]. See Fig. 7.25. Gasoline automobile engines still go through the steps known as the Otto cycle. *1001 Inventions That Changed the World* explained the importance of Otto's innovations, as well as his connections to later German engine designers [Challoner 2009, p. 400]:

> German engineer Nikolaus Otto (1832–1891) was responsible for one of the great developments in motorized vehicles with the invention of his four-stroke cycle internal combustion engine.

---

[4] For coverage of different aspects of this area, see especially: Cummins 2002; Graf and Metternich 1986; Ludvigsen 2015; Popplow 2011; Raidt 2014; Roth and Schmid 1987; Technisches Museum Wien 2006; Völker 2013.

> After developing an interest in technology, he began designs for a four-stroke engine based on Lenoir's earlier design for a two-stroke cycle. In 1864 he set up N. A. Otto and Cie alongside Eugen Langen, creating the world's first engine manufacturers. In 1872, he employed Gottlieb Daimler and Wilhelm Maybach as technical director and chief designer, respectively.
>
> In 1876 the first practical four-stroke engine was constructed. The four strokes are an intake stroke, where the piston moves down to allow a fuel-air mixture into the combustion chamber, a compression stroke, where the piston moves back up to compress the gases, a combustion or power stroke, where a spark ignites the fuel and the piston is forced down again, and a final exhaust stroke, where the piston moves up to expel spent fuel via the exhaust valve. [...]
>
> Initially combustion engines were stationary as they could not be adapted to run on liquid fuel and so required a pilot light. Otto solved this problem in 1884 with the invention of a magneto ignition system that created the spark needed for the power stroke. This increased the practicality of the four-stroke engine and allowed it to be used by Daimler and Maybach in the first motorcycles and automobiles.

As illustrated in Fig. 7.26, Wilhelm Wittig (German?, 18??–19??) and Wilhelm Hees (German?, 18??–19??) developed a two-stroke internal-combustion engine in 1878 [Cummins 2002].

Emile Capitaine (German, 1861–1907) developed an oil-burning internal combustion engine in 1879, a series of gasoline engines in the 1880s–1890s, and a motorcycle in 1896 [Cummins 2002]. See Fig. 7.27.

Rudolf Diesel (German, 1858–1913), shown in Fig. 7.28, created the first Diesel engines in the 1890s [Cummins 2002]. Diesel engines are also internal combustion engines but go through a series of steps somewhat different than the standard Otto cycle. *Encyclopedia Britannica* described the process by which Diesel developed his invention [EB 2010]:

> Diesel devoted much of his time to the self-imposed task of developing an internal combustion engine that would approach the theoretical efficiency of the Carnot cycle. For a time he experimented with an expansion engine using ammonia. About 1890, in which year he moved to a new post with the Linde firm in Berlin, he conceived the idea for the diesel engine. He obtained a German development patent in 1892 and the following year published a description of his engine under the title *Theorie und Konstruktion eines rationellen Wärmemotors* (*Theory and Construction of a Rational Heat Motor*). With support from the Maschinenfabrik Augsburg and the Krupp firms, he produced a series of increasingly successful models, culminating in his demonstration in 1897 of a 25-horsepower, four-stroke, single vertical cylinder compression engine. The high efficiency of Diesel's engine, together with its comparative simplicity of design, made it an immediate commercial success, and royalty fees brought great wealth to its inventor.

?? Brackenburg (18??–18??)

Automobile powered by a hydrogen/oxygen combustion engine (1836)

Julius Hock (18??–19??)

Oil engine (1873)

Figure 7.24: ?? Brackenburg developed an automobile powered by a hydrogen/oxygen combustion engine in 1836. Julius Hock developed an oil-burning internal combustion engine in 1873.

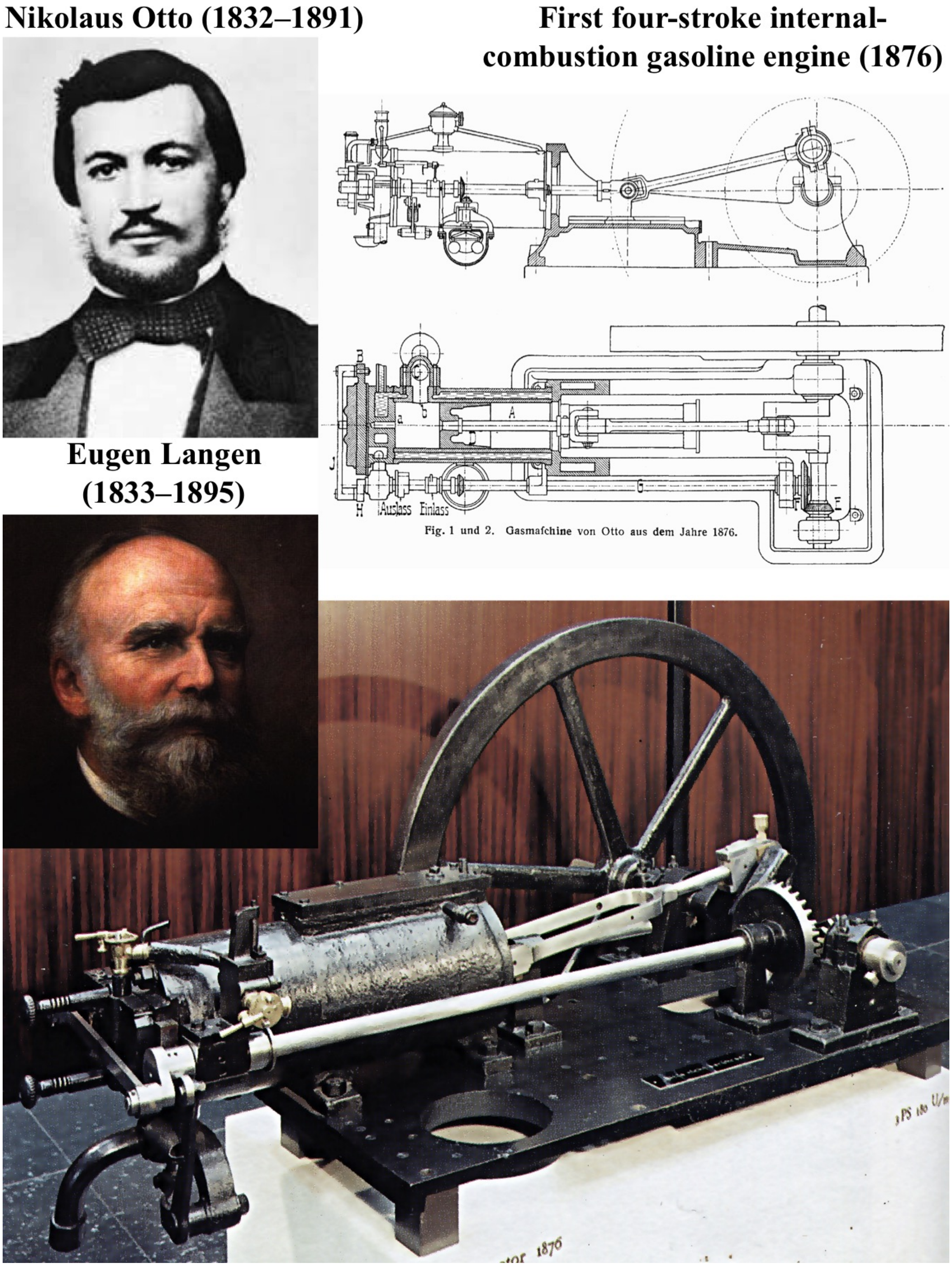

Nikolaus Otto (1832–1891)
First four-stroke internal-combustion gasoline engine (1876)
Eugen Langen (1833–1895)
B
a
b
A
J
G
H
Auslass
Einlass
F
E
Fig. 1 und 2. Gasmaſchine von Otto aus dem Jahre 1876.
3 PS 180 U/m
1876

Figure 7.25: With assistance from Eugen Langen, Nikolaus Otto developed the four-stroke internal-combustion gasoline engine in 1876.

Wilhelm Wittig (18??–19??) Wilhelm Hees (18??–19??)

Two-stroke engine (patent application filed 1878)

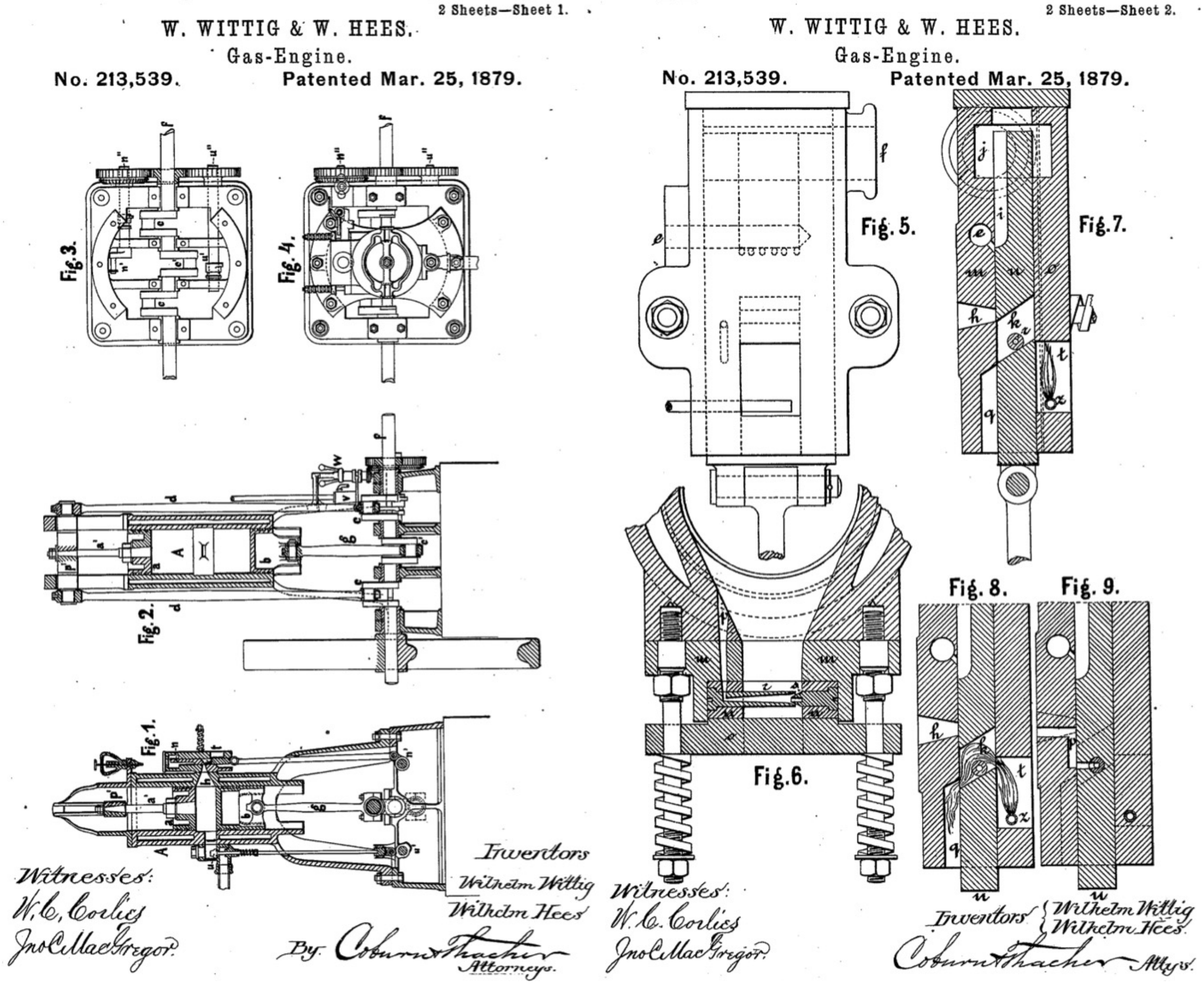
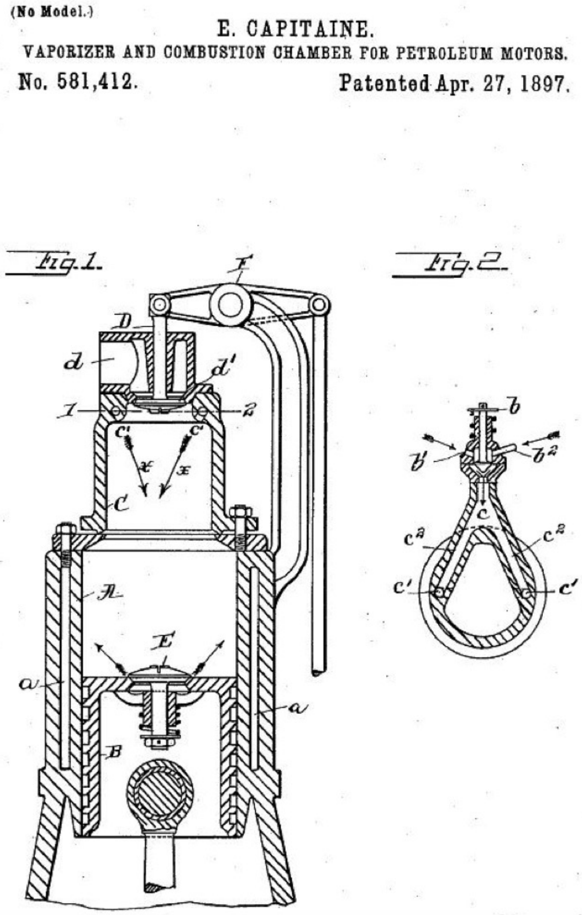
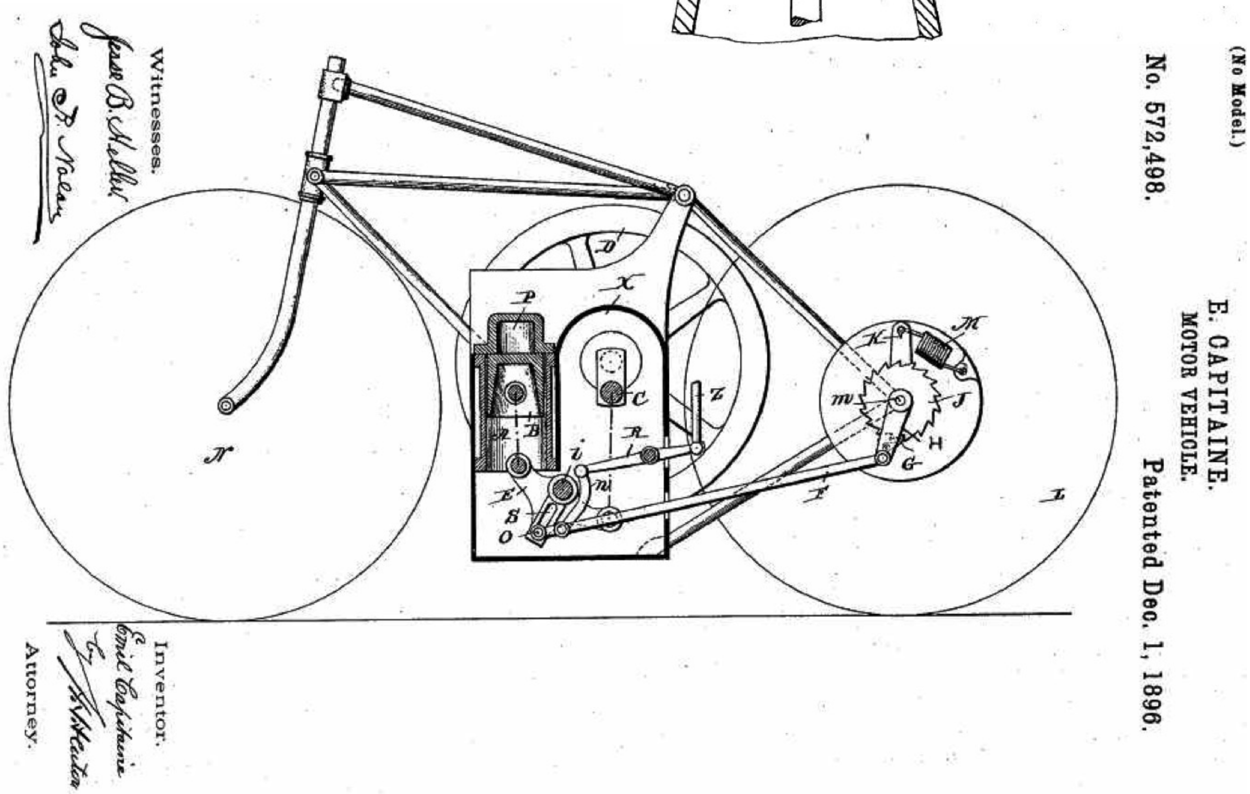

2 Sheets—Sheet 1.
W. WITTIG & W. HEES.
Gas-Engine.
No. 213,539.
Patented Mar. 25, 1879.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Witnesses:
W. C. Corliss
Jno C. MacGregor
Inventors
Wilhelm Wittig
Wilhelm Hees
By Coburn & Thacher
Attorneys.
2 Sheets—Sheet 2.
W. WITTIG & W. HEES.
Gas-Engine.
No. 213,539.
Patented Mar. 25, 1879.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Witnesses:
W. C. Corliss
Jno C. MacGregor
Inventors
Wilhelm Wittig
Wilhelm Hees
Coburn & Thacher Attys.

Figure 7.26: Wilhelm Wittig and Wilhelm Hees developed a two-stroke internal-combustion engine in 1878.

Emile Capitaine (1861–1907)


(No Model.)
E. CAPITAINE.
VAPORIZER AND COMBUSTION CHAMBER FOR PETROLEUM MOTORS.
No. 581,412.
Patented Apr. 27, 1897.
Fig. 1.
F
D
d
d'
1
2
c'
c'
x
x
C
A
E'
a
a
B
Fig. 2.
b
b'
b²
c
c²
c²
c'
c'

- **Oil engine (1879)**
- **Gasoline engines (1880s–1890s)**
- **Motorcycle (1896)**


(No Model.)
No. 572,498.
E. CAPITAINE.
MOTOR VEHICLE.
Patented Dec. 1, 1896.
Witnesses.
Inventor.
Emil Capitaine
by
Attorney.
N
D'
X
P
C
Z
B
A
i
R
E
m
S
O
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m
J
H
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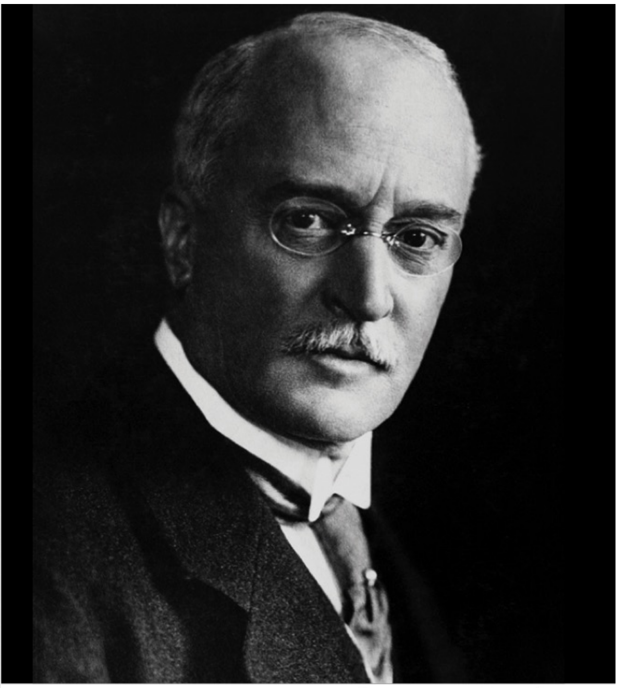
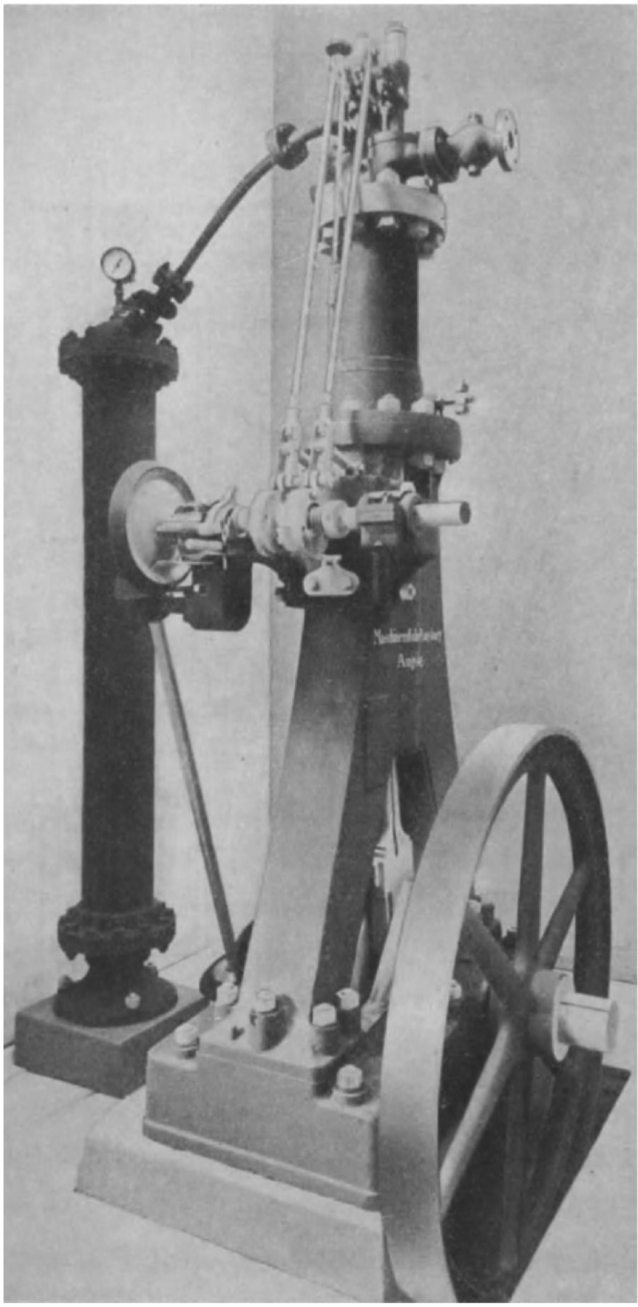
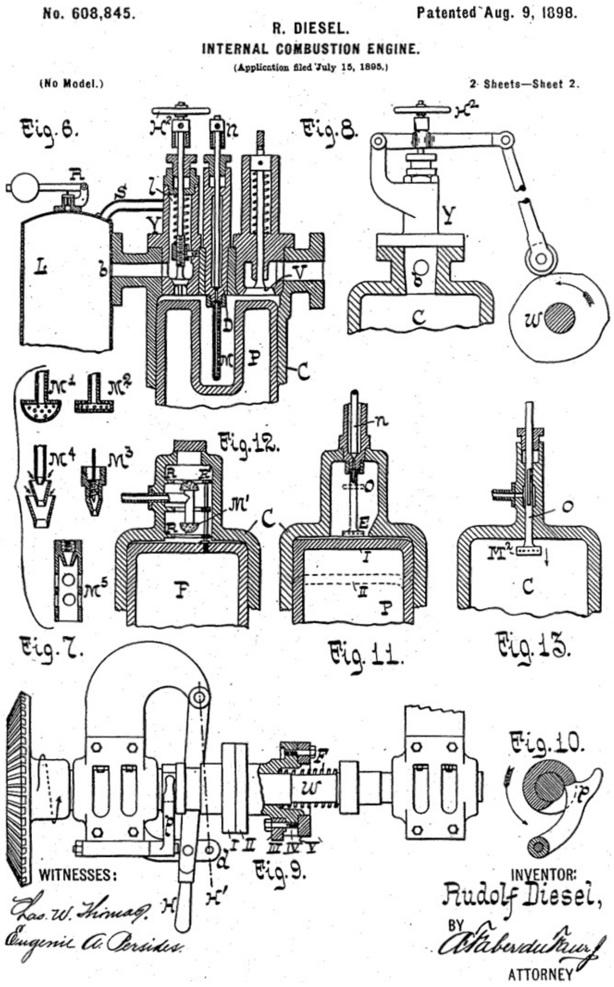
Figure 7.27: Emile Capitaine developed an oil-burning internal combustion engine in 1879, a series of gasoline engines in the 1880s–1890s, and a motorcycle in 1896.

Rudolf Diesel
(1858–1913)



Diesel engine (1893)





No. 608,845. Patented Aug. 9, 1898.

R. DIESEL.

INTERNAL COMBUSTION ENGINE.

(Application filed July 15, 1895.)

(No Model.) 2 Sheets—Sheet 2.

WITNESSES:

Chas. W. Thomas

Eugenie A. Persides

INVENTOR:

Rudolf Diesel,

BY

ATTORNEY

Fig. 6.
Fig. 8.
Fig. 12.
Fig. 7.
Fig. 11.
Fig. 13.
Fig. 10.
Fig. 9.
L
Y
V
C
P
W
F

Figure 7.28: Rudolf Diesel created the first Diesel engine in 1893.

Siegfried Marcus (German/Austrian, 1831–1898) developed an internal-combustion-engine-powered car in 1870, and then a greatly improved version in 1888 [Technisches Museum Wien 2006]. Figure 7.29 presents photos of Marcus and his two car versions.

As shown in Fig. 7.30, Karl Benz (German, 1844–1929) and his wife Bertha Benz (German, 1849–1944) developed and demonstrated an internal-combustion-engine-powered automobile in 1885 [Cummins 2002]. *1001 Inventions That Changed the World* explained how they publicized their first automobile [Challoner 2009, p. 446]:

> Benz recognized the great potential of petrol as a fuel. His three-wheeled car had a top speed of just ten miles (16 km) per hour with its four-stroke, one-cylinder engine. After receiving his patent in January 1886, he began selling the Benz [...], but the public doubted its reliability. Benz's wife Bertha had a brilliant idea to advertise the new car. In 1888 she took it on a 60-mile (100 km) trip from Mannheim to near Stuttgart.

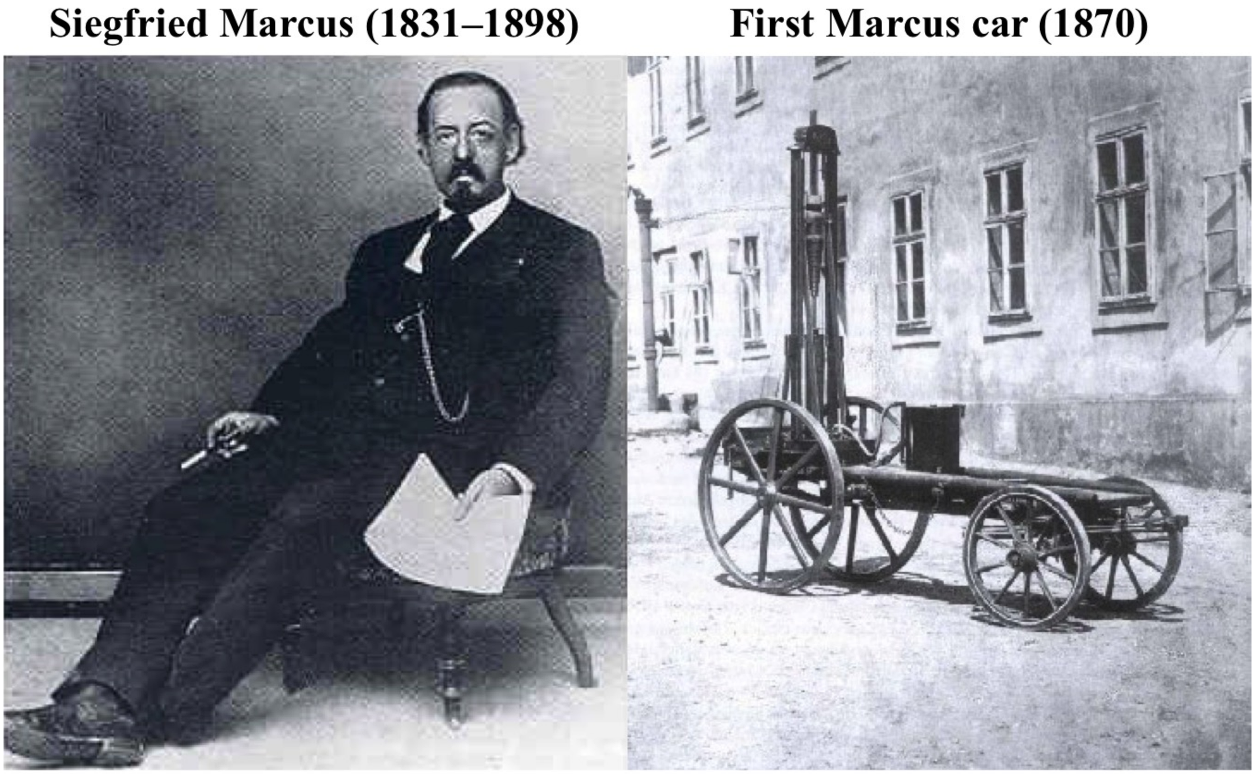
Benz developed other automobiles such as the first mass-produced automobile (Velo) in 1894, the first internal-combustion-engine-powered bus (Omnibus) in 1895, and a record-setting race car (Blitzen) in 1909 [Grünewald and Williamson 2013; Roth and Schmid 1987]. See Fig. 7.31.

Gottlieb Daimler (German, 1834–1900) and Wilhelm Maybach (German, 1846–1929), shown in Fig. 7.32, initially worked for Nikolaus Otto but then started their own company. They created the first internal-combustion-powered motorcycle (Reitwagen) in 1885 and their first internal-combustion-powered automobile (Motorcoach) in 1886 [Cummins 2002; Raidt 2014; Völker 2013]. Daimler and Maybach also created the first internal-combustion-powered boat in 1886 and the first internal-combustion-powered truck in 1896; see Fig. 7.33. Oxford University's *Biographical Dictionary of Scientists* described the key to their success [Porter 1994, p. 159]:

> The genius of Daimler and Maybach lay in the combining of four of the elements essential to the modern car engine: the four-stroke Otto cycle, the vaporization of the fuel with a device similar to a carburettor, low weight and high speeds. Lenoir had used electric ignition, but this proved unreliable; Daimler and Maybach used an igniter tube that was light, worked well and operated independently of engine speed.

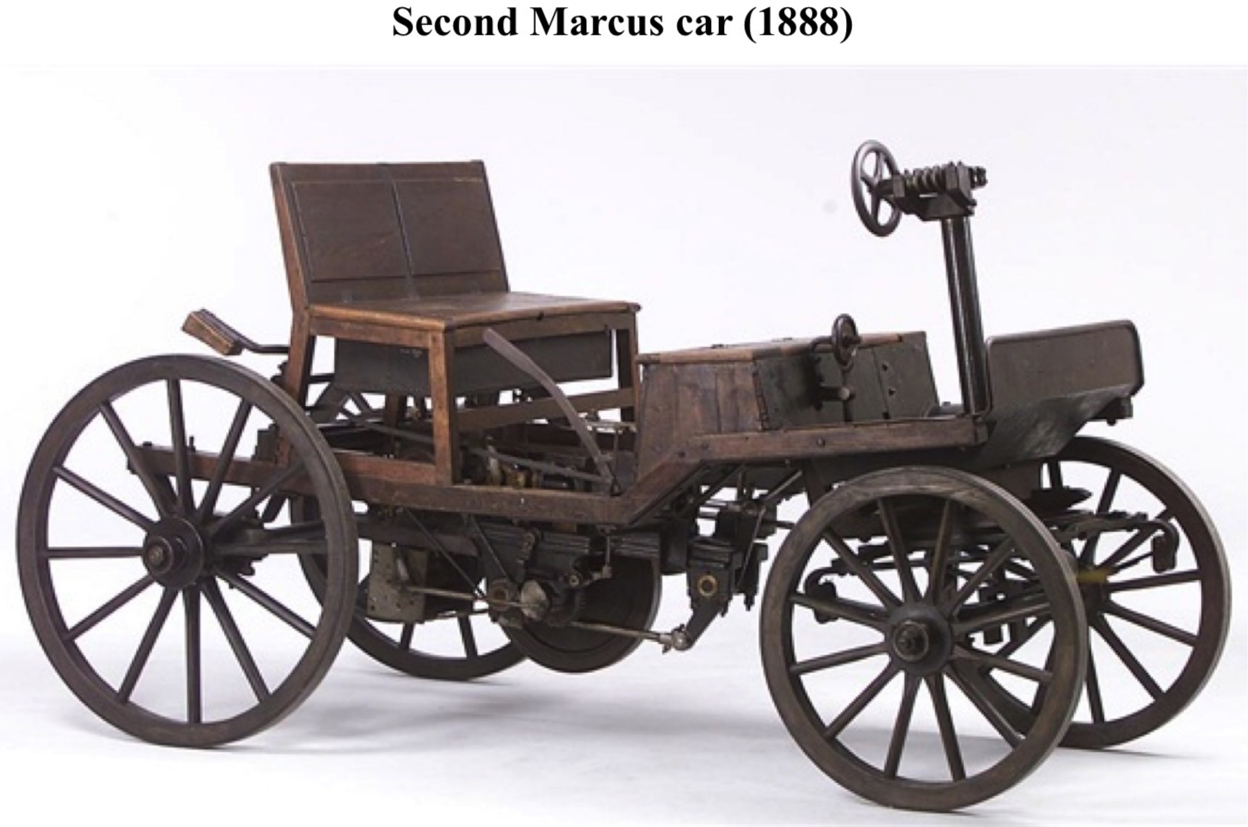
As illustrated in Figs. 7.34–7.36, in 1900, Wilhelm Maybach, Paul Daimler (German, 1869–1945), and Emil Jellinek (German/Austrian, 1853–1918) radically rethought the look of "horseless carriages" and developed the first automobile with a recognizably modern design, the Mercedes 35 hp. This was the first of a long line of automobiles that were named after Jellinek's daughter, Mercédès Jellinek (Austrian, 1889–1929) [Roth and Schmid 1987]. In the United States, Henry Ford's first Model T automobile, produced in 1909, was essentially a carbon copy of that 1900 German design. Soon thereafter, the German-speaking world was plunged into decades of war and the aftermath, giving great advantage to such foreign-made copies in the global market.

Robert Bosch (German, 1861–1942) created a magnetic engine ignition system and spark plugs in 1887 [Raidt 2014]. He was later joined by Gottlob Honold (German, 1876–1923), with whom he developed improved automobile engines, the car horn, and automotive headlights. See Fig. 7.37.



Siegfried Marcus (1831–1898)

First Marcus car (1870)

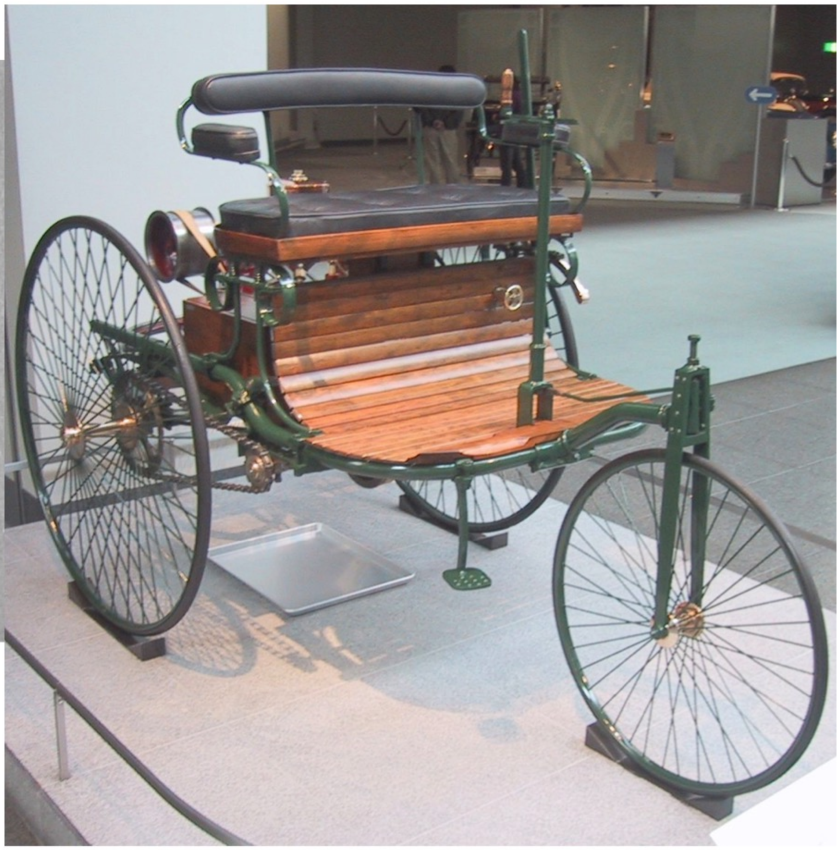


Second Marcus car (1888)

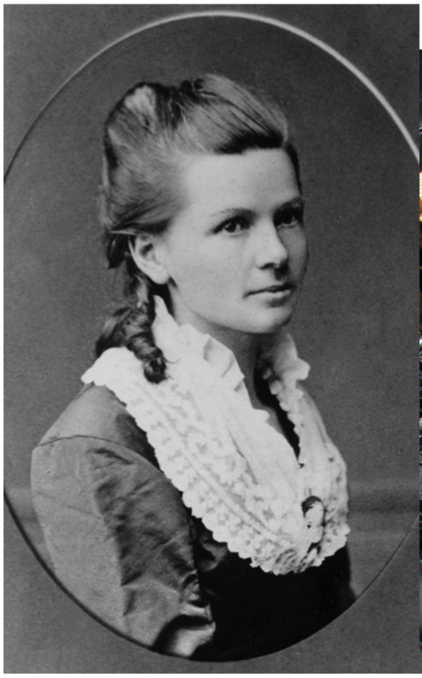
Figure 7.29: Siegfried Marcus developed an internal-combustion-engine-powered car in 1870, and a greatly improved version in 1888.

Karl Benz
(1844–1929)

Benz Patent Motorwagen (1885)



Bertha Benz
(1849–1944)



Benz Patent Motorwagen engine

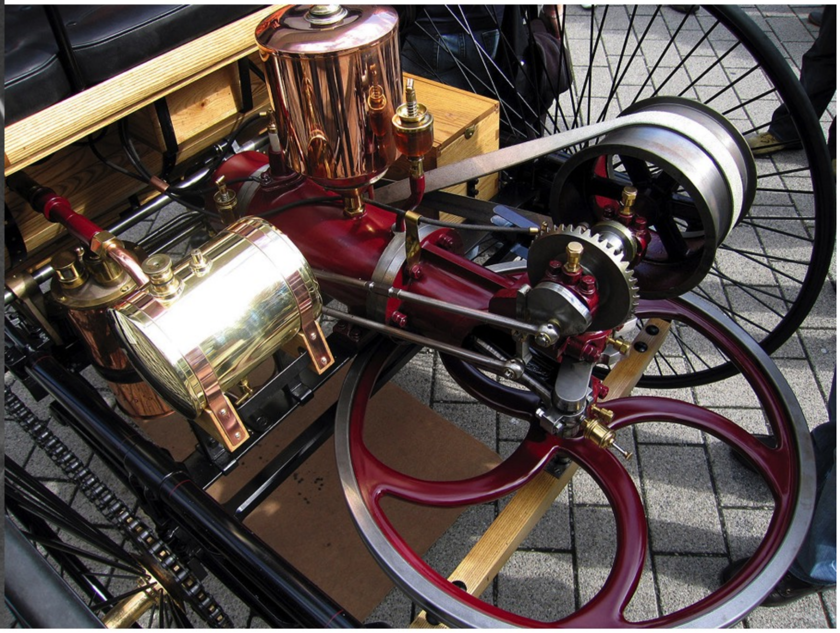


Figure 7.30: Karl Benz and his wife Bertha Benz developed and demonstrated an internal-combustion-engine-powered automobile in 1885.

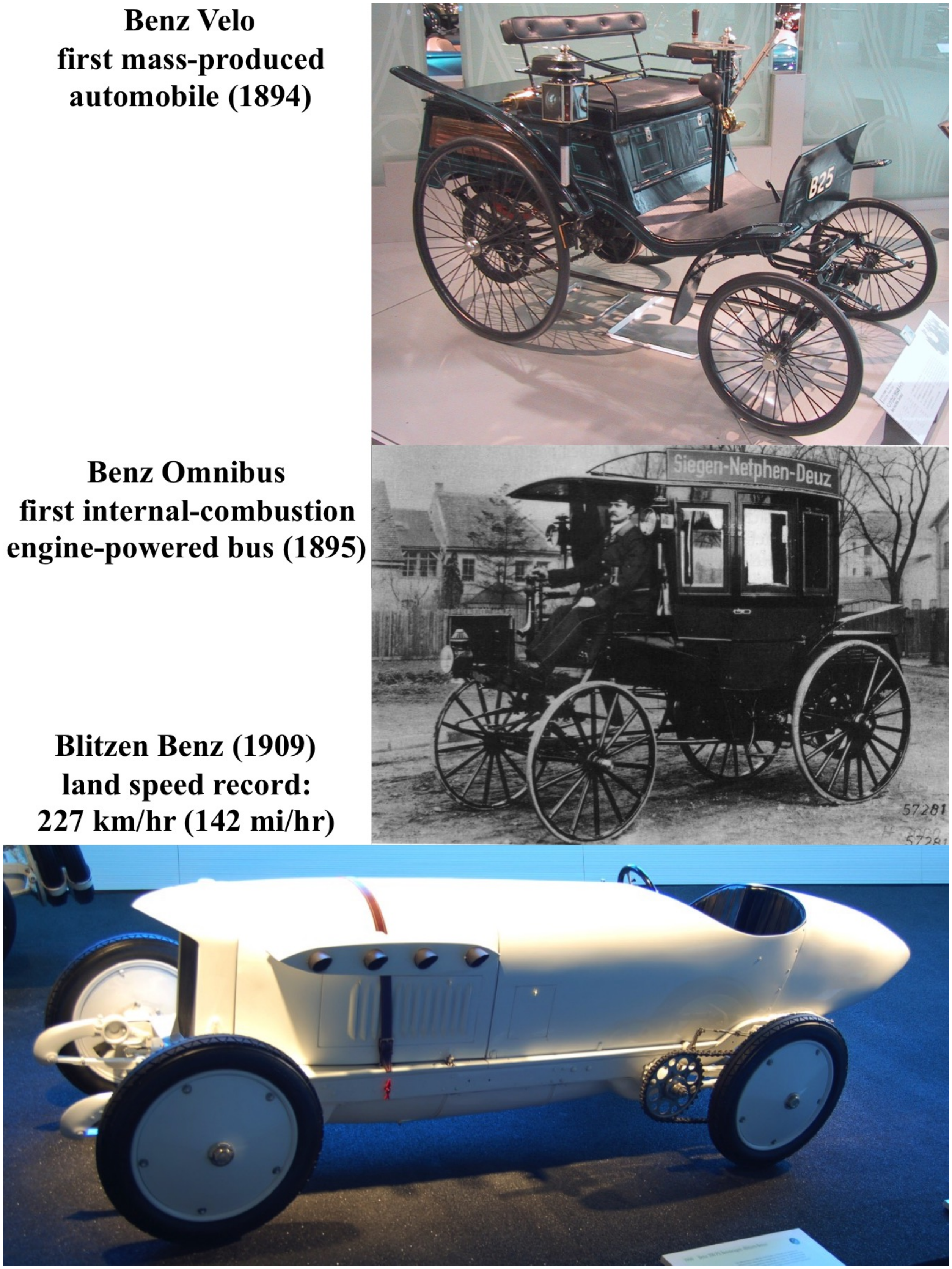
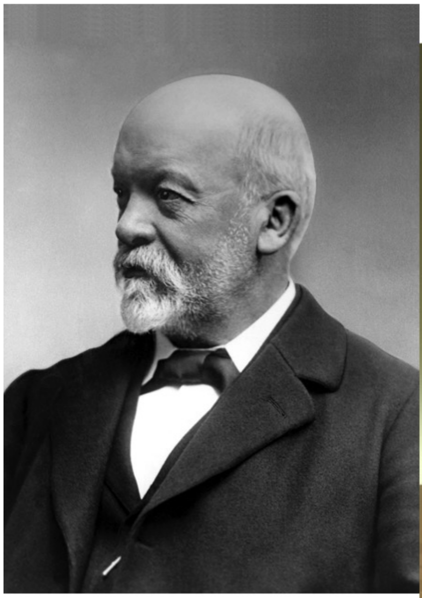
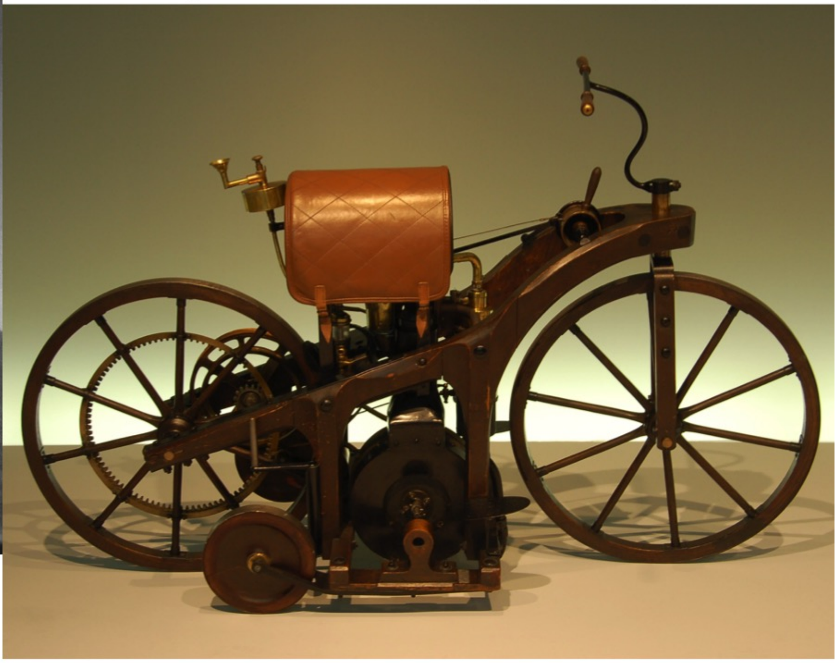

Benz Velo
first mass-produced
automobile (1894)
825
Benz Omnibus
first internal-combustion
engine-powered bus (1895)
Siegen-Netphen-Deuz
57281
Blitzen Benz (1909)
land speed record:
227 km/hr (142 mi/hr)

Figure 7.31: Benz developed other automobiles such as the first mass-produced automobile (Velo) in 1894, the first internal-combustion-engine-powered bus (Omnibus) in 1895, and a record-setting race car (Blitzen) in 1909.

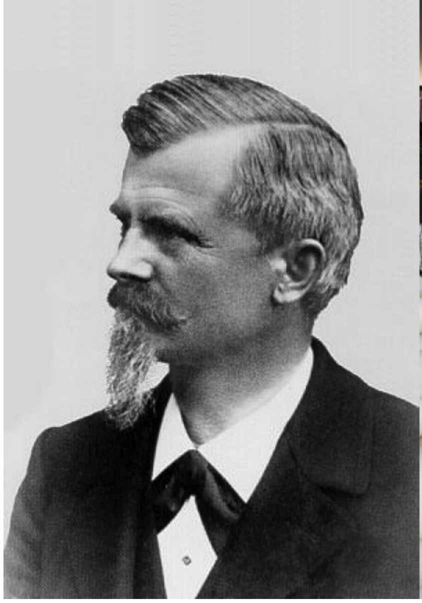
Gottlieb Daimler
(1834–1900)



Daimler-Maybach Reitwagen
first internal-combustion-powered motorcycle (1885)



Wilhelm Maybach
(1846–1929)



Daimler-Maybach Motorcoach
internal-combustion-powered automobile (1886)

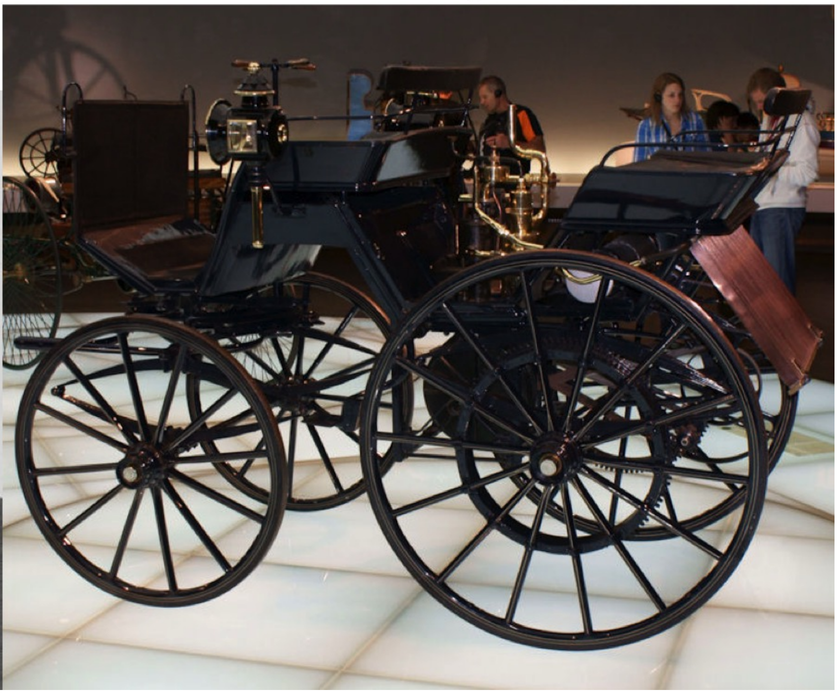


Figure 7.32: Gottlieb Daimler and Wilhelm Maybach created the first internal-combustion-powered motorcycle (Reitwagen) in 1885, and their first internal-combustion-powered automobile (Motorcoach) in 1886.

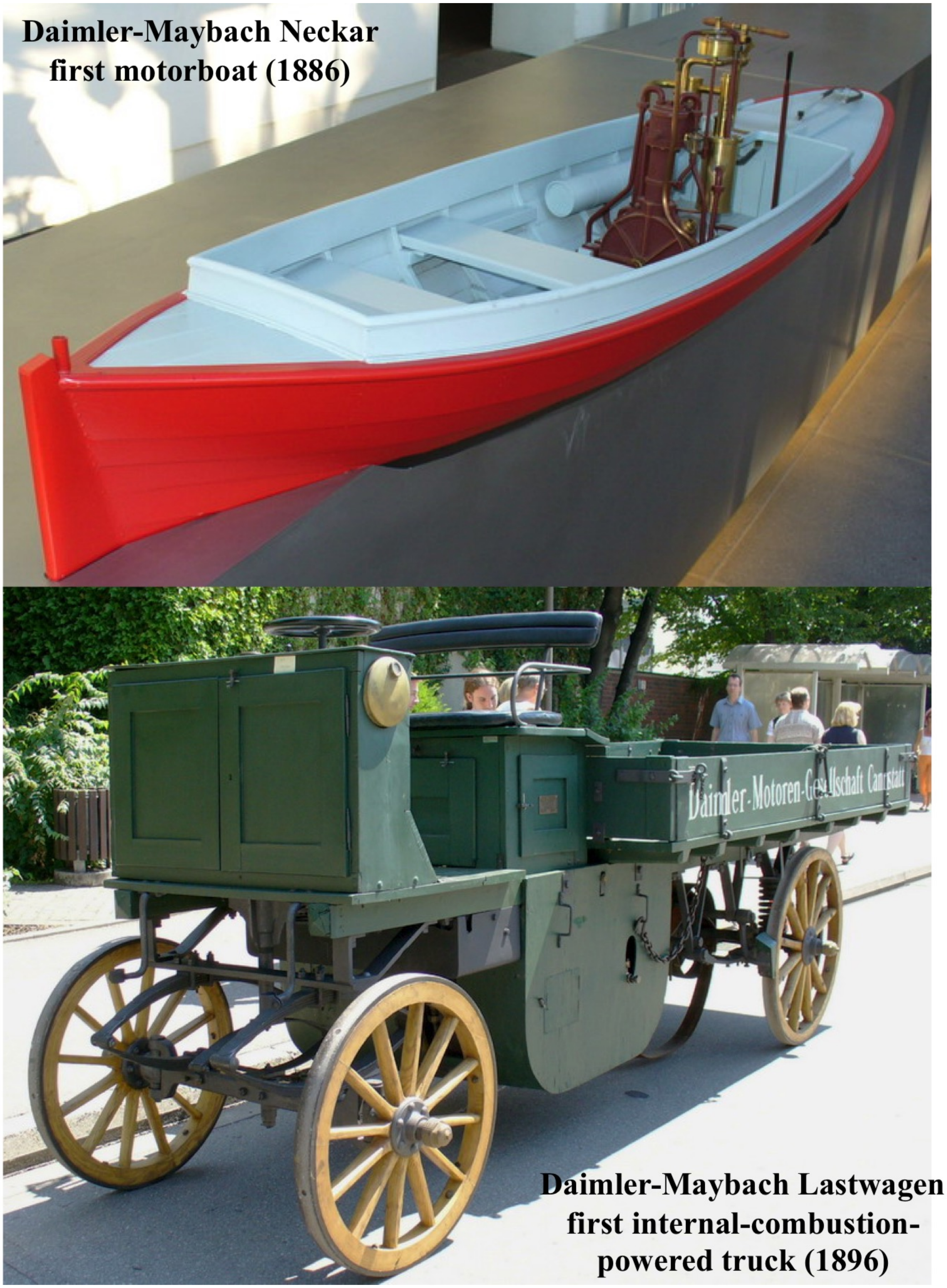
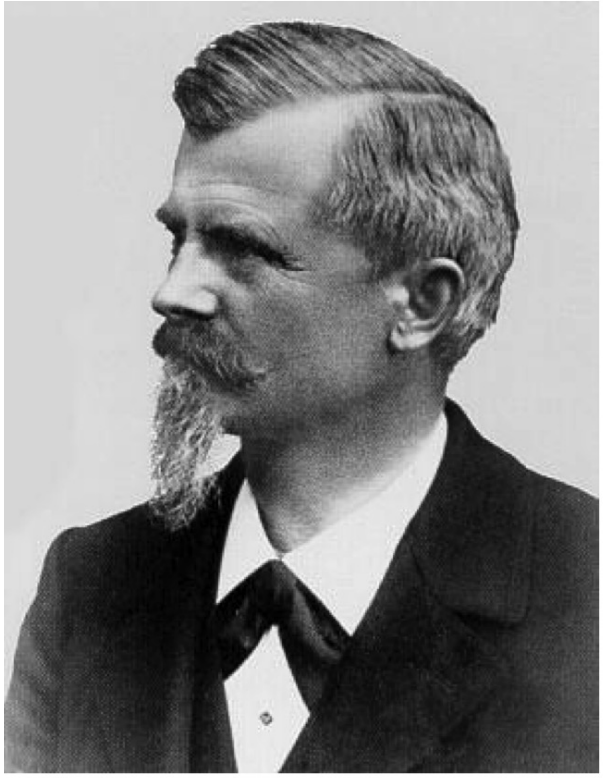
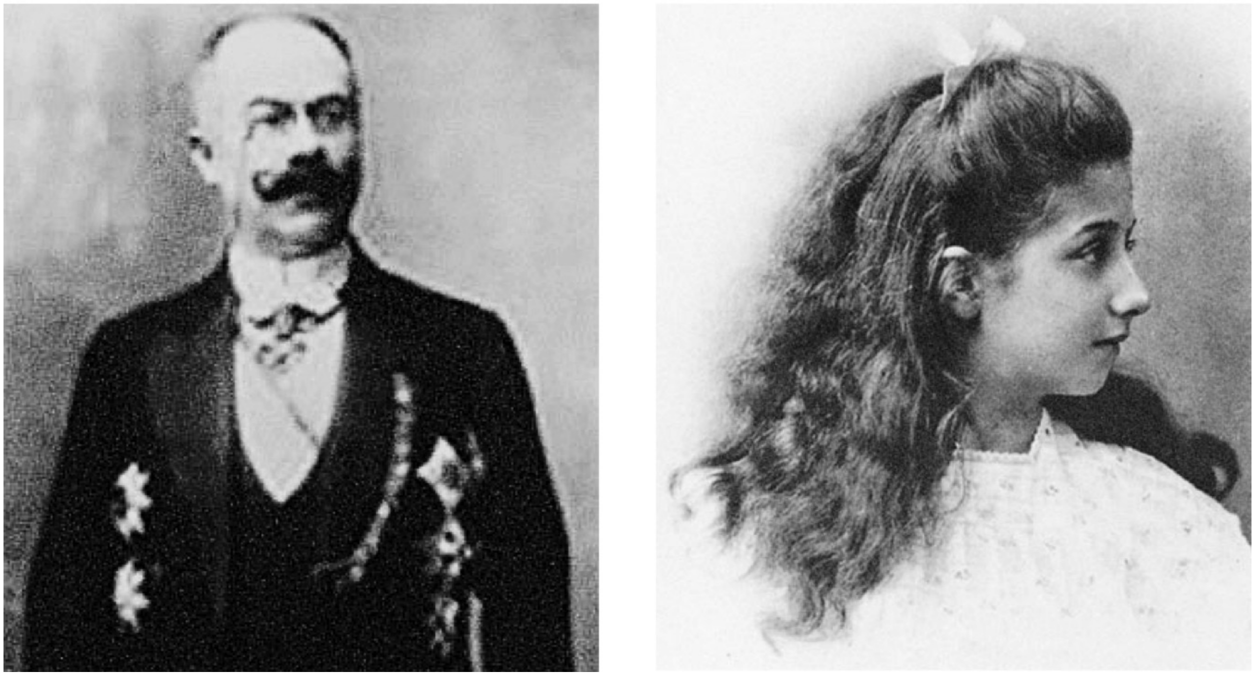

Daimler-Maybach Neckar
first motorboat (1886)
Daimler-Motoren-Gesellschaft Cannstatt
Daimler-Maybach Lastwagen
first internal-combustion-
powered truck (1896)

Figure 7.33: Gottlieb Daimler and Wilhelm Maybach created the first internal-combustion-powered boat in 1886 and truck in 1896.

Mercedes automobiles

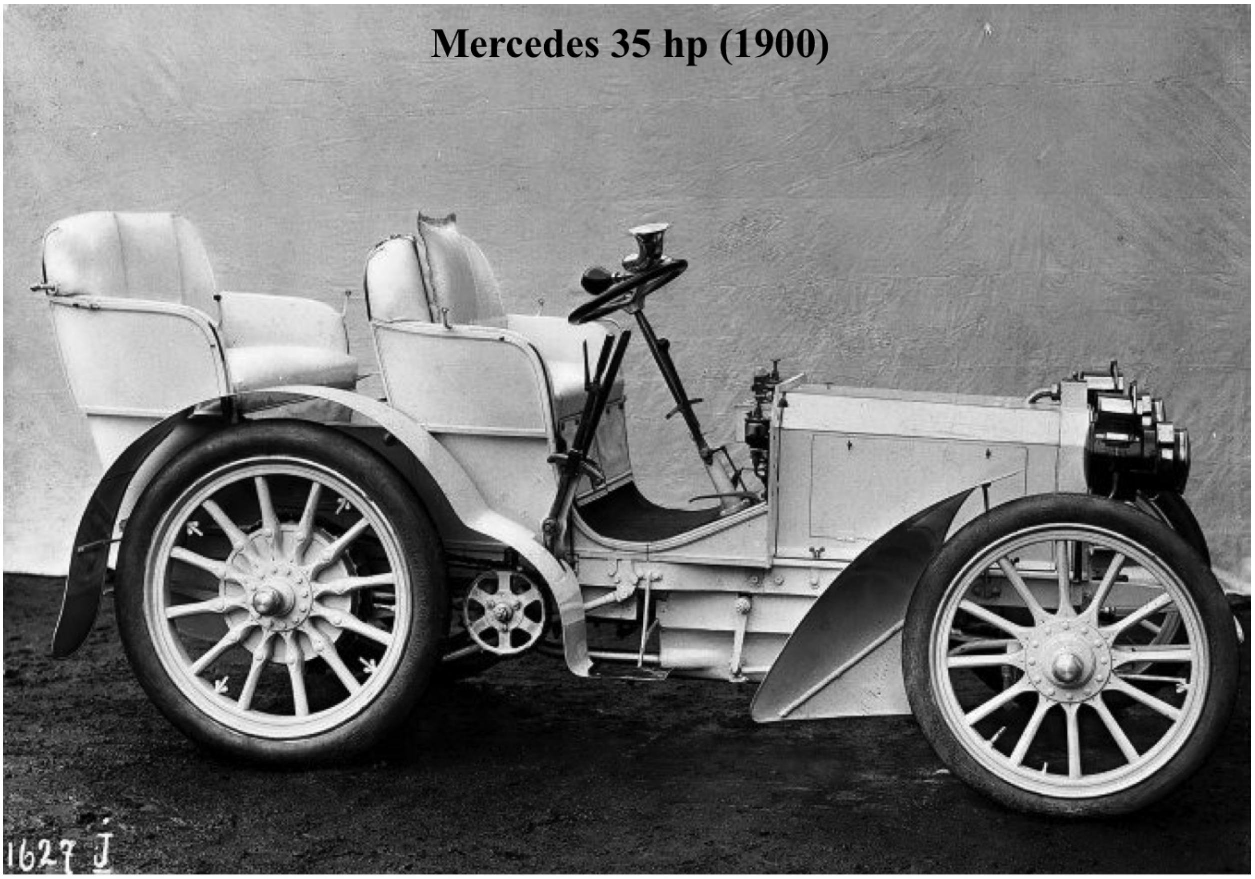
Wilhelm Maybach (1846–1929) **Paul Daimler (1869–1945)**





Emil Jellinek (1853–1918) **Mercédès Jellinek (1889–1929)**

Figure 7.34: In 1900, Wilhelm Maybach, Paul Daimler, and Emil Jellinek developed a radically redesigned automobile with a recognizably modern look, the Mercedes 35 hp. It was named after Emil Jellinek's daughter, Mercédès Jellinek, and was the first of a long line of Mercedes automobiles.



Henry Ford's first Model T automobile (United States, 1909)

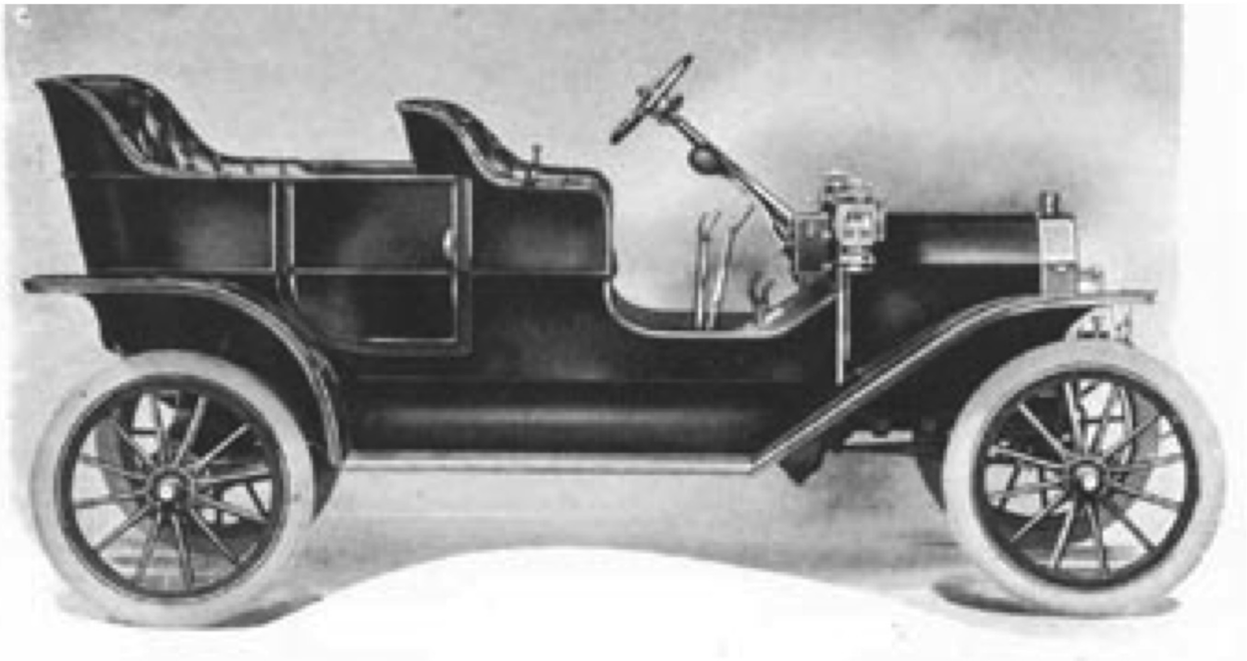


Figure 7.35: Wilhelm Maybach, Paul Daimler, and Emil Jellinek developed the first automobile with a recognizably modern design, the Mercedes 35 hp, in 1900. In the United States, Henry Ford's first Model T automobile, produced in 1909, was essentially a carbon copy of that earlier German design.

Mercedes 15/70/100 PS (1924)
(later named Mercedes-Benz Type 400)

Designed by Wilhelm Maybach and Ferdinand Porsche

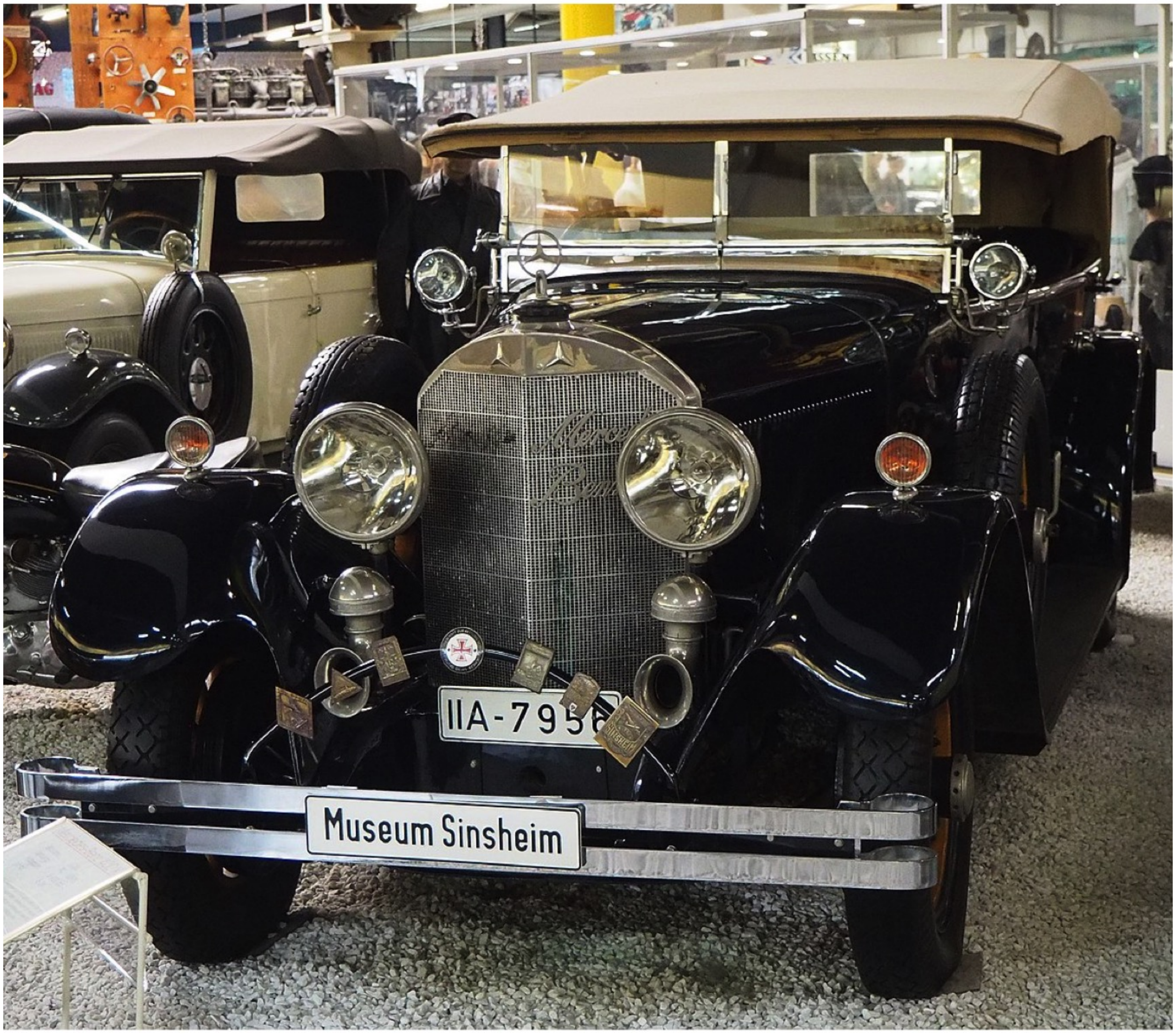


Figure 7.36: Wilhelm Maybach and Ferdinand Porsche designed the Mercedes 15/70/100 PS (1924, later named Mercedes-Benz Type 400).

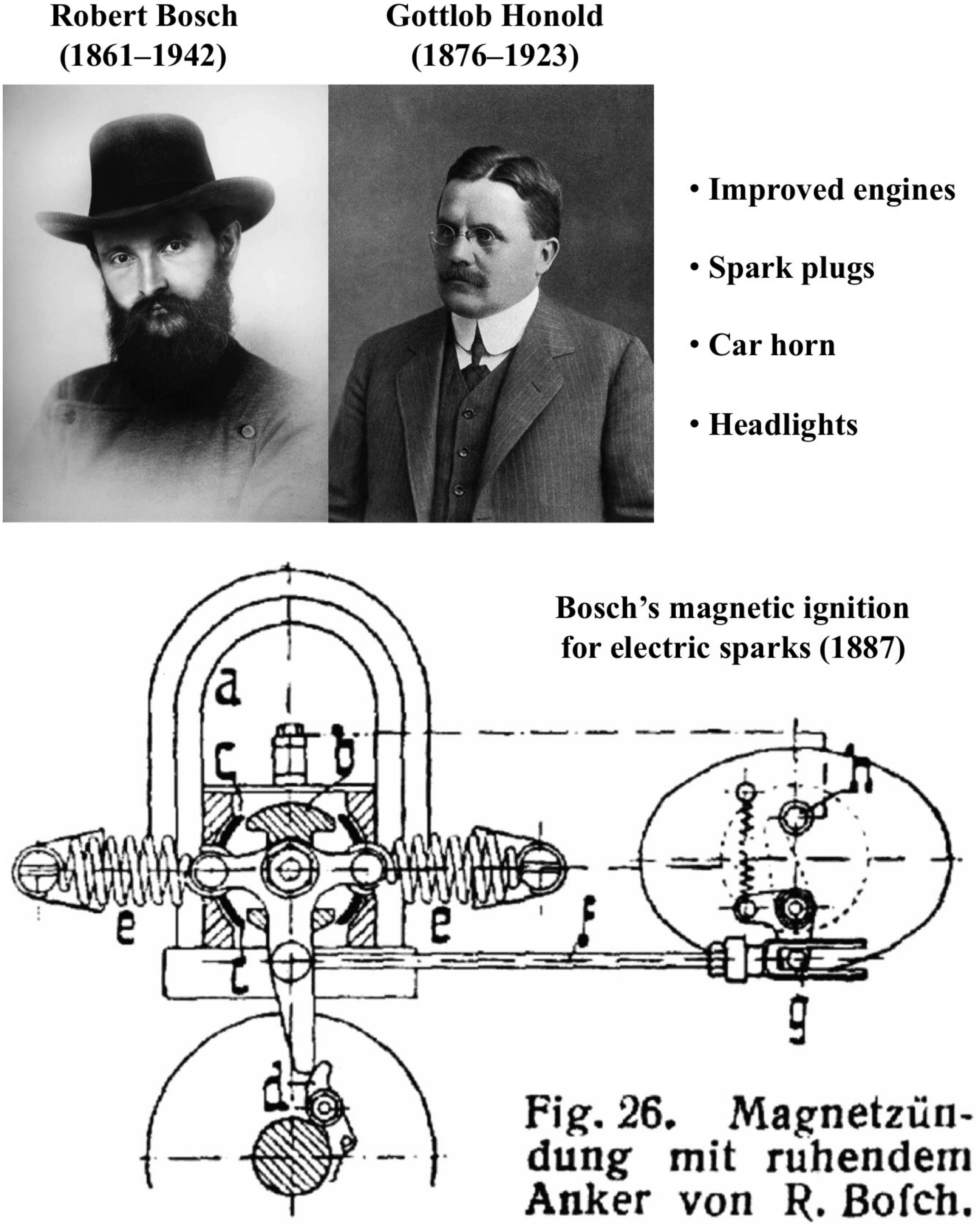

Robert Bosch
(1861–1942)
Gottlob Honold
(1876–1923)
• Improved engines
• Spark plugs
• Car horn
• Headlights
Bosch's magnetic ignition
for electric sparks (1887)
a
c
b
h
e
e
f
c
g
d
Fig. 26. Magnetzündung mit ruhendem Anker von R. Boſch.

Figure 7.37: Robert Bosch created a magnetic engine ignition system and spark plugs in 1887. He was later joined by Gottlob Honold, with whom he developed improved automobile engines, the car horn, and automotive headlights.

Figure 7.38 presents several other automotive creators:

- Paul Winand (German?, 18??–19??) also developed spark plugs in 1887 [Cummins 2002].
- Donát Bánki (Hungarian, 1859–1922) and János Csonka (Hungarian, 1852–1939) produced an improved carburetor.
- Hugo Mayer (German?, 18??-19??) created hydraulic auto brakes.
- Wilhelm von Opel (German, 1871–1948) introduced assembly line production of automobiles in Europe.
- Ludwig Elsbett (German, 1913–2003) developed improved diesel engines, as well as engines that run on vegetable oil as biofuel [www.elsbett-museum.de].

As shown in Fig. 7.39, Edmund Rumpler (Austrian, 1872–1940) not only was the first aircraft manufacturer in Germany, but also designed aerodynamic automobiles (such as the 1923 Rumpler-Benz Tropfenwagen), created a unified engine and gearbox, and developed swing-axle rear suspension [Graf and Metternich 1986].

Ferdinand Porsche (Austrian/German, 1875–1951) created the first gasoline-electric hybrid automobile (Lohner-Porsche) in 1900; see Fig. 7.40. In fact, development, production, and use of electric vehicles continued to be emphasized in the German-speaking world through 1945. For example, BIOS 384, *German Battery Electric Vehicles and the German Storage Battery Industry*, p. 28, reported:

> The GERMANS make very much more use of battery electric vehicles of all forms than is the custom in BRITAIN. They also employ batteries, both lead-acid and nickel-iron for a greater range of uses.

As shown in Fig. 7.36, Porsche also did early design work at Daimler, such as for the 1924 Mercedes 15/70/100 PS and its successors (later named the Mercedes-Benz Type 400).

For his later projects, Porsche was joined by Karl Rabe (Austrian, 1895–1968). Porsche, Rabe, and their team developed the prototype for what would become the Volkswagen Beetle (1931, Fig. 7.41), as well as a series of Auto Union racing cars in the 1930s [Christopher 2013, pp. 199–203; Ludvigsen 2015].

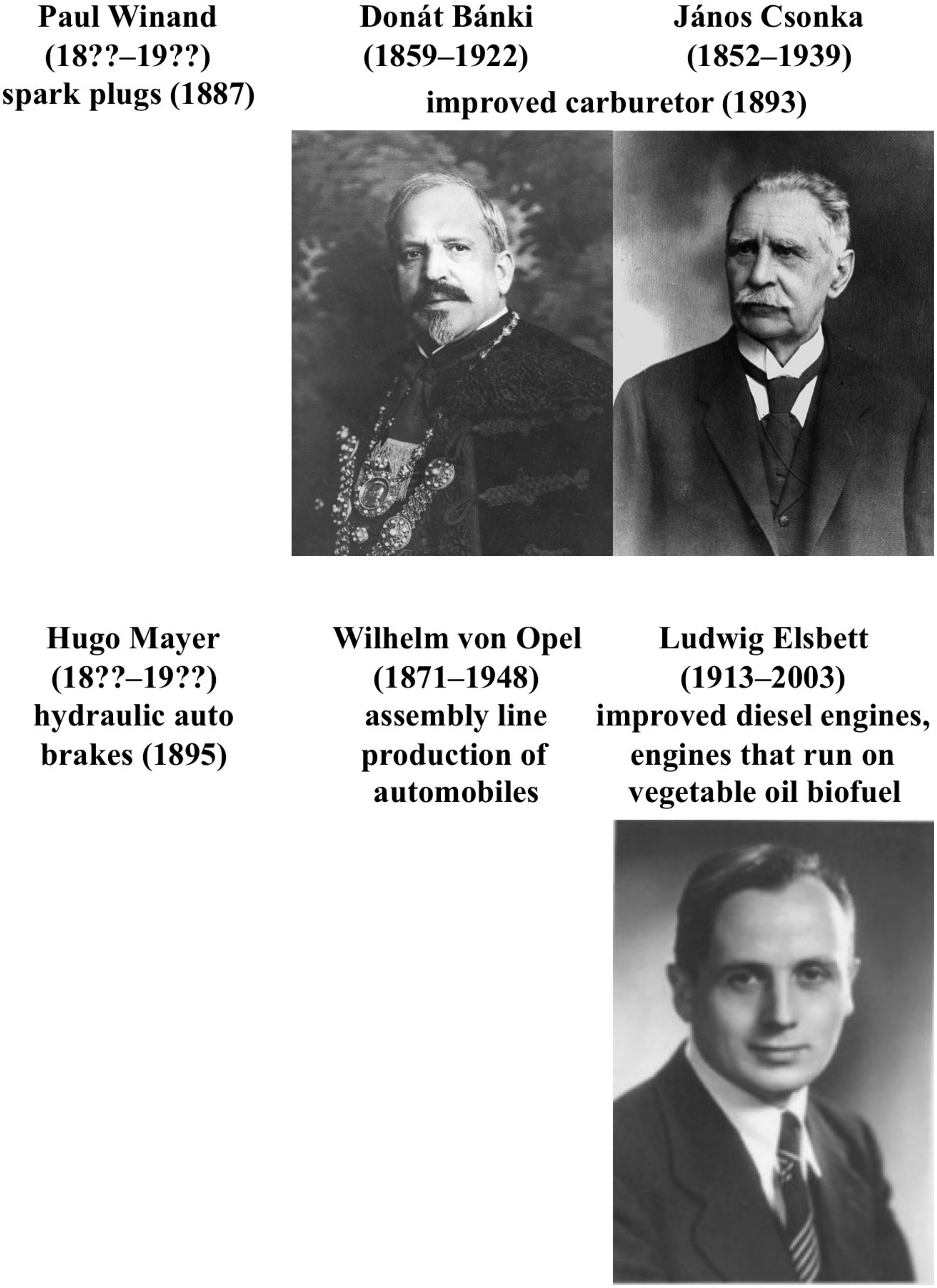
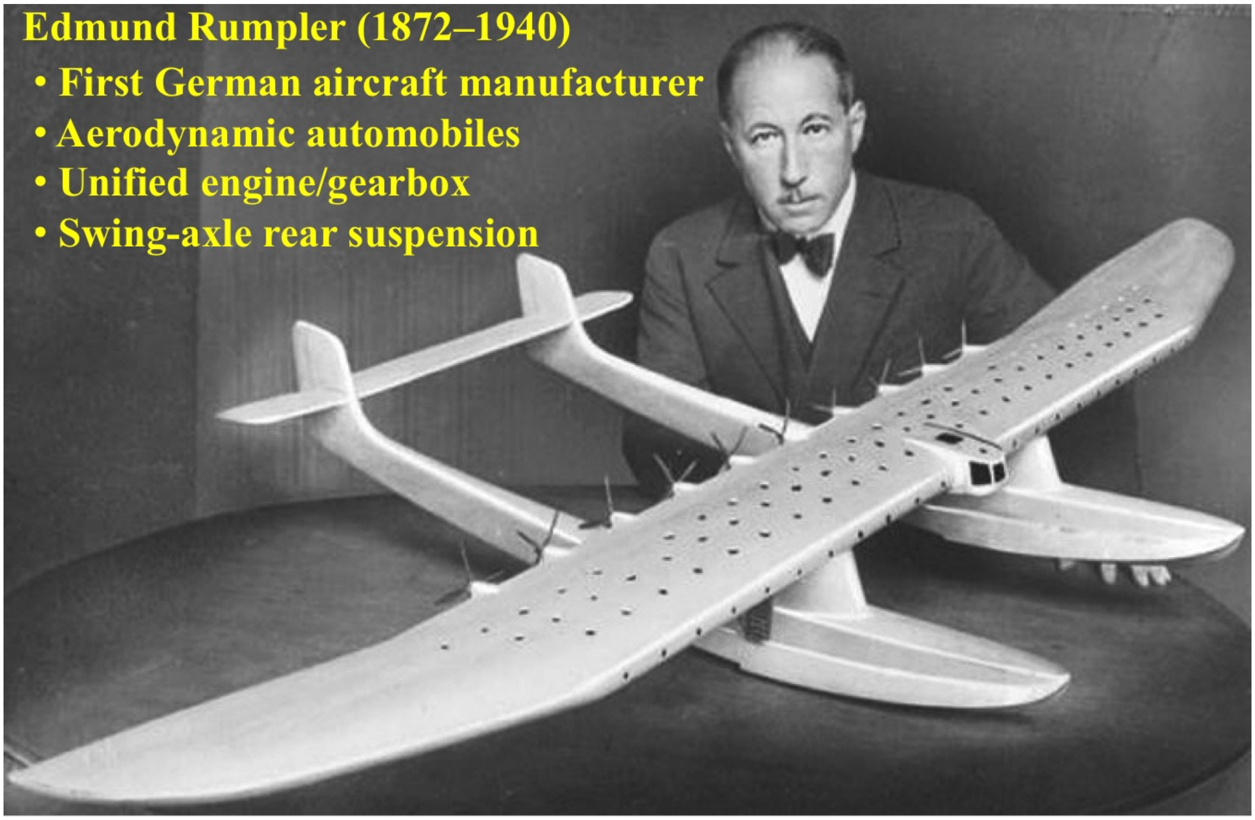

Paul Winand
(18??–19??)
spark plugs (1887)
Donát Bánki
(1859–1922)
János Csonka
(1852–1939)
improved carburetor (1893)
Hugo Mayer
(18??–19??)
hydraulic auto
brakes (1895)
Wilhelm von Opel
(1871–1948)
assembly line
production of
automobiles
Ludwig Elsbett
(1913–2003)
improved diesel engines,
engines that run on
vegetable oil biofuel

Figure 7.38: Paul Winand also developed spark plugs in 1887. Donát Bánki and János Csonka produced an improved carburetor, Hugo Mayer created hydraulic auto brakes, and Wilhelm von Opel introduced assembly line production of automobiles in Europe. Ludwig Elsbett developed improved diesel engines, as well as engines that run on vegetable oil as biofuel.


Edmund Rumpler (1872–1940)
• First German aircraft manufacturer
• Aerodynamic automobiles
• Unified engine/gearbox
• Swing-axle rear suspension

Rumpler-Benz Tropfenwagen (1923)

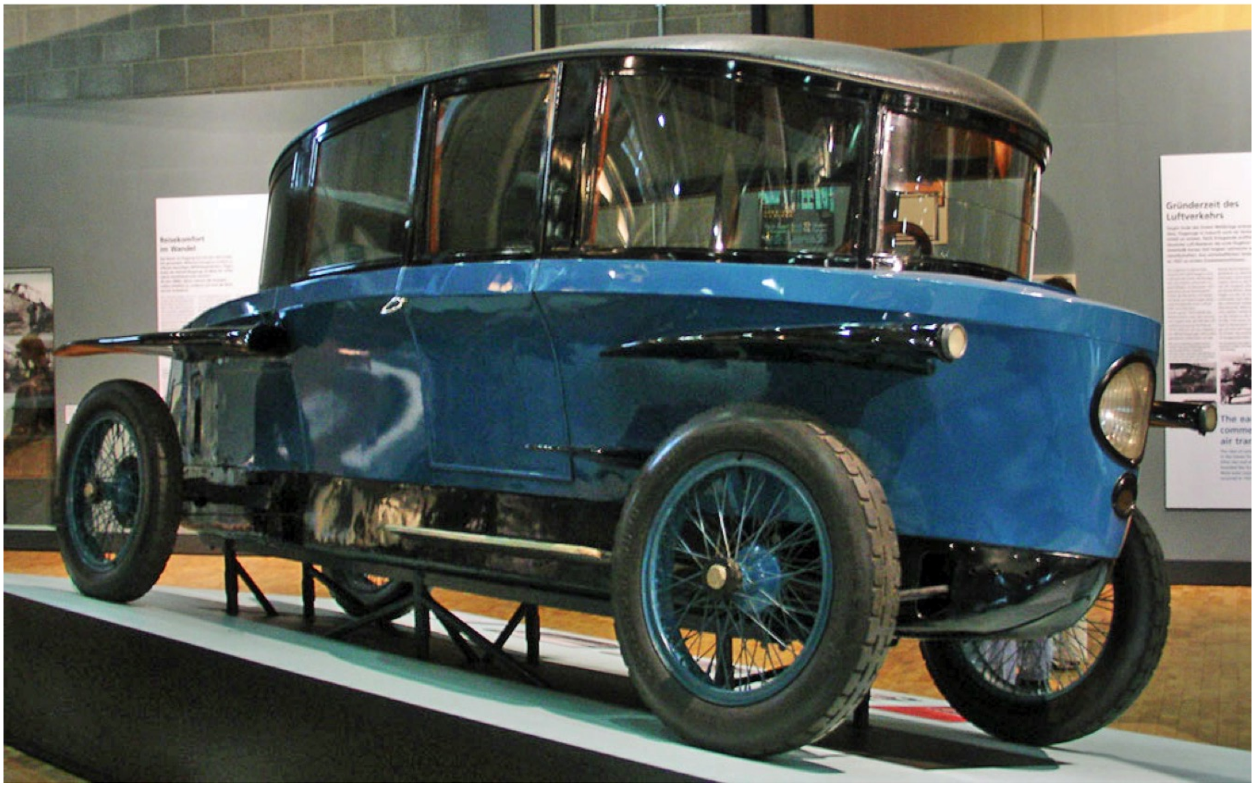


Figure 7.39: Edmund Rumpler was the first German aircraft manufacturer, designed aerodynamic automobiles (such as the 1923 Rumpler-Benz Tropfenwagen), created a unified engine and gearbox, and developed swing-axle rear suspension.

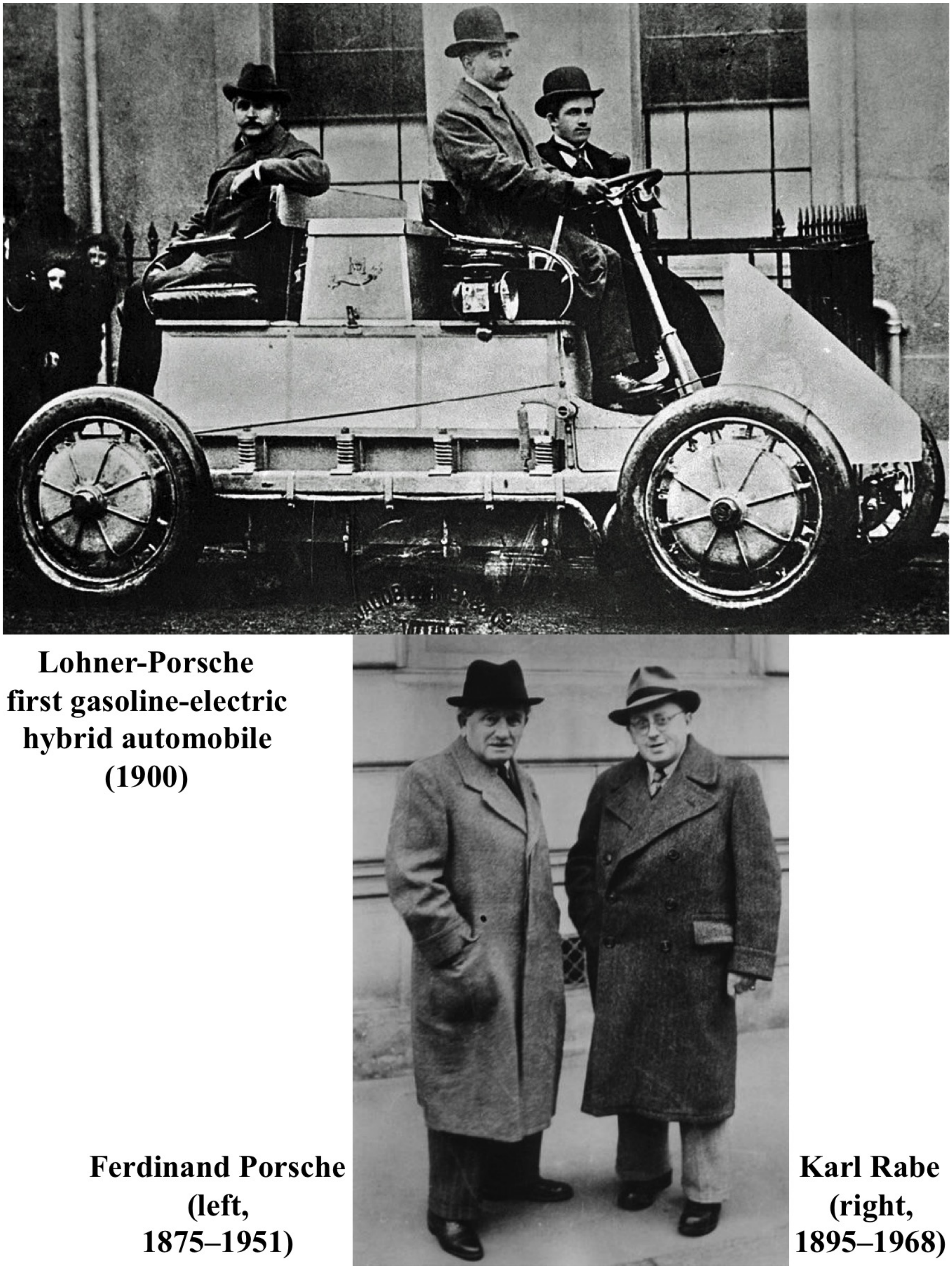
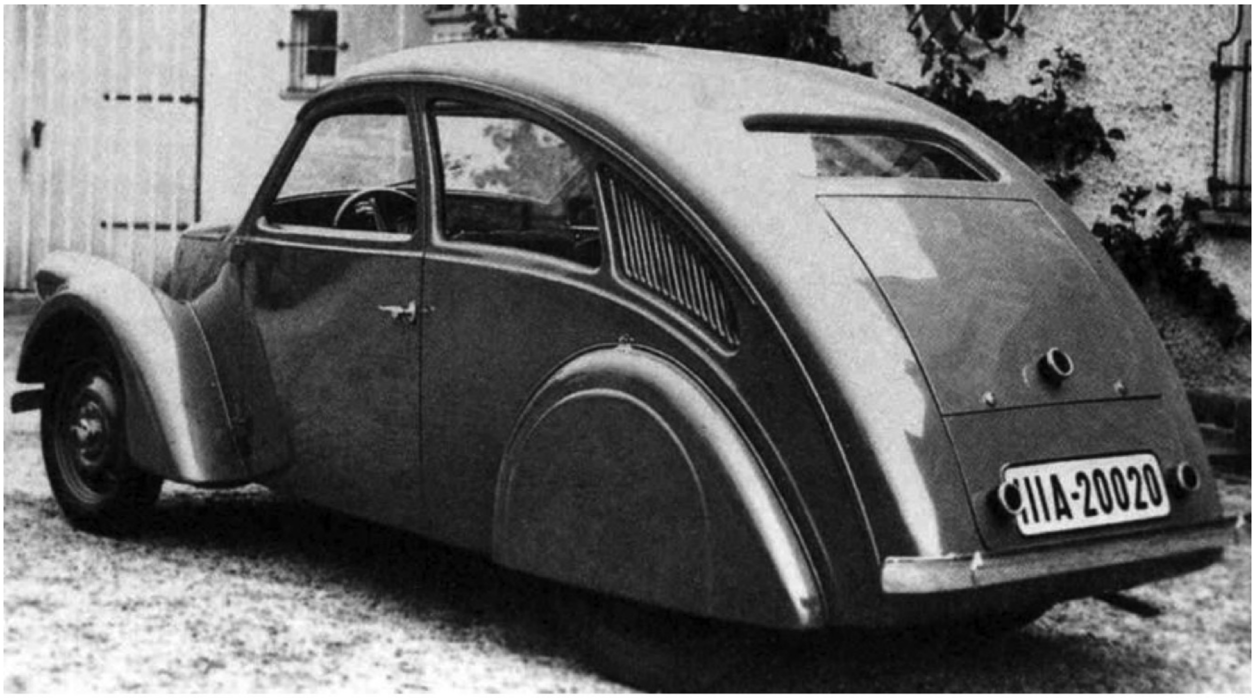
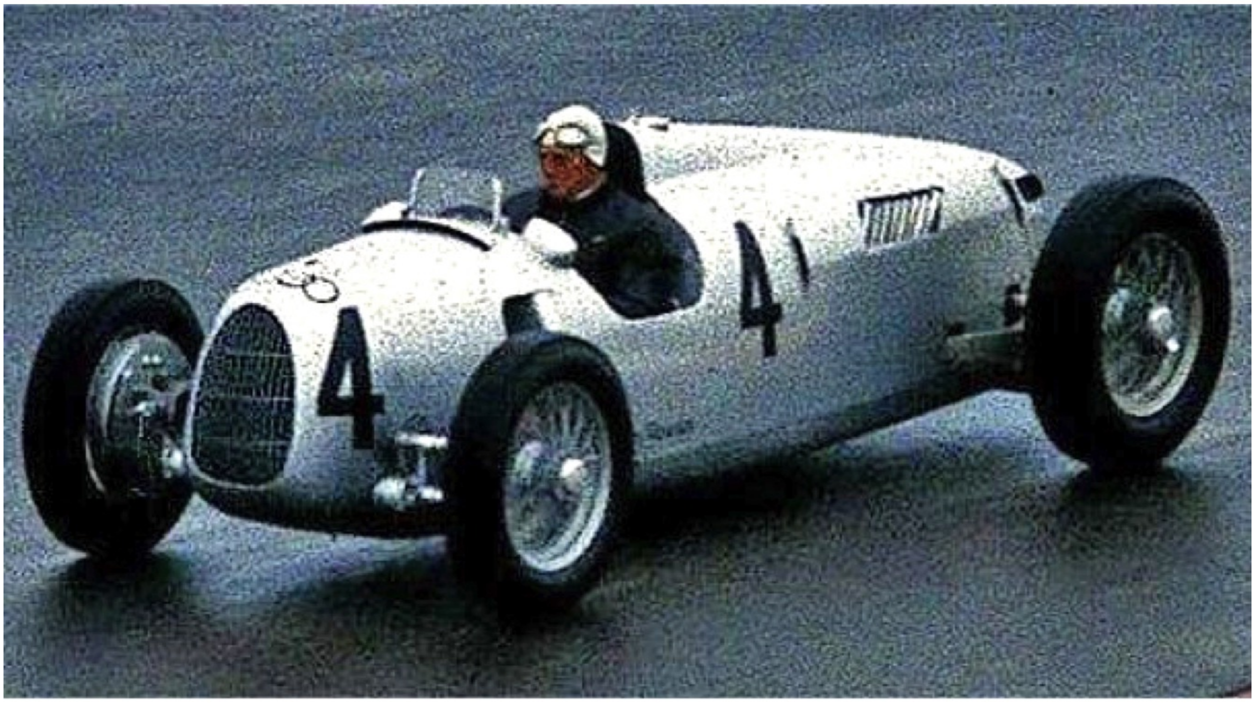

Lohner-Porsche
first gasoline-electric
hybrid automobile
(1900)
Ferdinand Porsche
(left,
1875–1951)
Karl Rabe
(right,
1895–1968)

Figure 7.40: Ferdinand Porsche created the first gasoline-electric hybrid automobile (Lohner-Porsche) in 1900. For his subsequent projects, Porsche was joined by Karl Rabe.



Porsche prototype for what would become the Volkswagen Beetle (1931)



Porsche Auto Union racing cars (1933–1939)

Figure 7.41: Ferdinand Porsche, Karl Rabe, and their team developed the prototype for what would become the Volkswagen Beetle (1931), as well as a series of Auto Union racing cars in the 1930s.

Oxford University's *Biographical Dictionary of Scientists* described some of Porsche's innovations [Porter 1994, pp. 560–561]:

> In 1936, he received a contract from the German government to develop the Volkswagen and plan the factory where it would be built. Just before this he conceived a racing car, without contract. The project was taken over by Auto Union and the car subsequently claimed victories on virtually every race track in Europe between 1934 and 1937, as well as many class records.
>
> The first VW prototypes were on the road by the end of 1935[...] Some other design jobs, however, had appeared alongside the major Volkswagen contract to cause Porsche to expand his company. [...H]e led the development of light tractors. Those tractors built to Porsche licence and under the firm's supervision after World War II can be traced to these designs. Concepts were also developed by him for aviation engines as well as plans and designs or wind-driven power plants—large wind-mills with automatic sail adjustment which delivered electric current via generators.
>
> The war cut short further development of the Volkswagen so Porsche designed the Leopard and Tiger tanks used by German Panzer regiments and helped to develop the V-1 flying bomb. [...]
>
> Porsche was a brilliant engineer whose genius reached into many disciplines. It has been said that the torsion-bar suspension alone would have sufficed to establish a monument to his name in the automotive industry. He can be considered one of the pioneers of aircooled engines in the industry.

Karl Schlör (German, 1911–1997), shown in Fig. 7.42, designed the Schlörwagen highly aerodynamic automobile in 1936 and demonstrated it in 1939 [Christopher 2013, pp. 199–201]. Even on today's roads, the Schlörwagen would look very forward-thinking.

German-speaking engineers not only took automobiles every step of the way from their first invention to high-speed aerodynamic models; they also carried motorcycles from their first creation (p. 1344) to sleek racing models. For example, when fitted with an aerodynamic shell, the BMW 500 Kompressor motorcycle model held the worldwide speed record for motorcycles from 1935 to 1951 (Fig. 7.43). It had a top speed of 279.5 km/hr in 1937.

As illustrated in Fig. 7.44, Felix Wankel (German, 1902–1988) developed Wankel rotary engines from 1924 onward. Hanns Paschke (German, 19??–??) later developed additional versions of Wankel engines [Popplow 2011]. Due to their very compact size, Wankel engines have been used in motorcycles, small cars, and small aircraft.

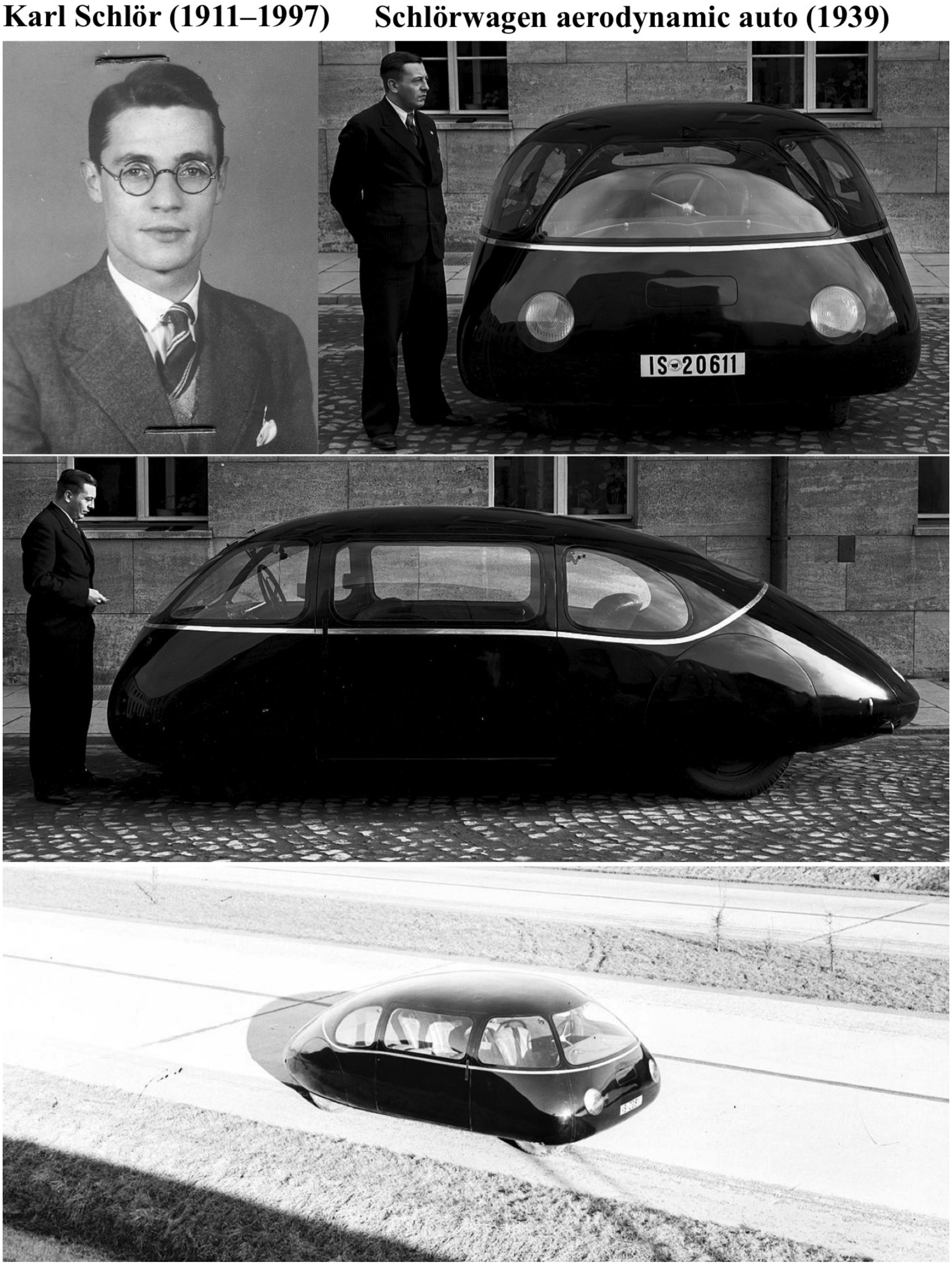

Karl Schlör (1911–1997)
Schlörwagen aerodynamic auto (1939)
IS-20611

Figure 7.42: Karl Schlör developed and demonstrated the Schlörwagen highly aerodynamic automobile in 1939.

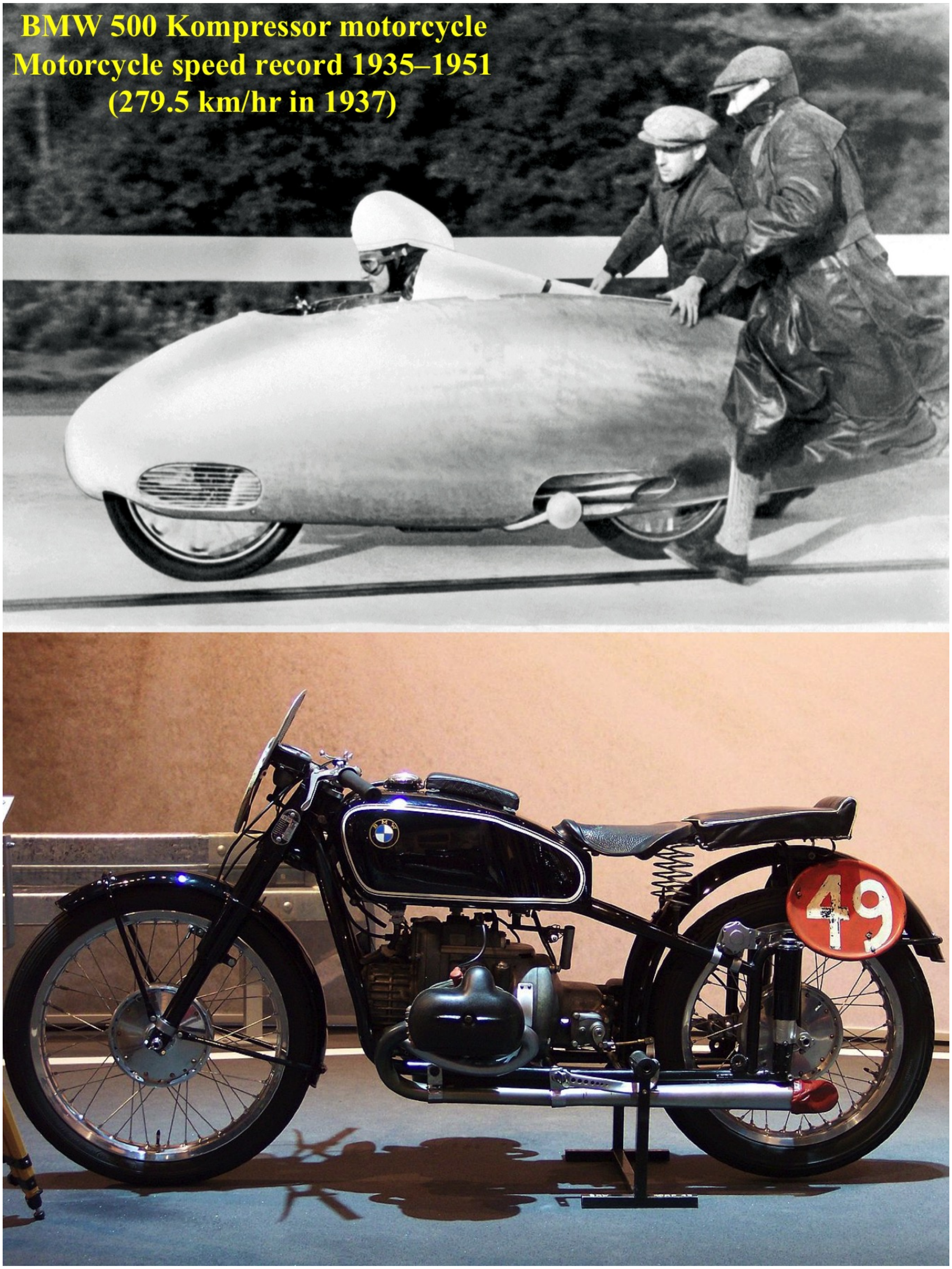

BMW 500 Kompressor motorcycle
Motorcycle speed record 1935–1951
(279.5 km/hr in 1937)
49

Figure 7.43: The BMW 500 Kompressor motorcycle model (enclosed in an aerodynamic shell above, and without the shell below) held the worldwide speed record for motorcycles from 1935 to 1951. It had a top speed of 279.5 km/hr in 1937.

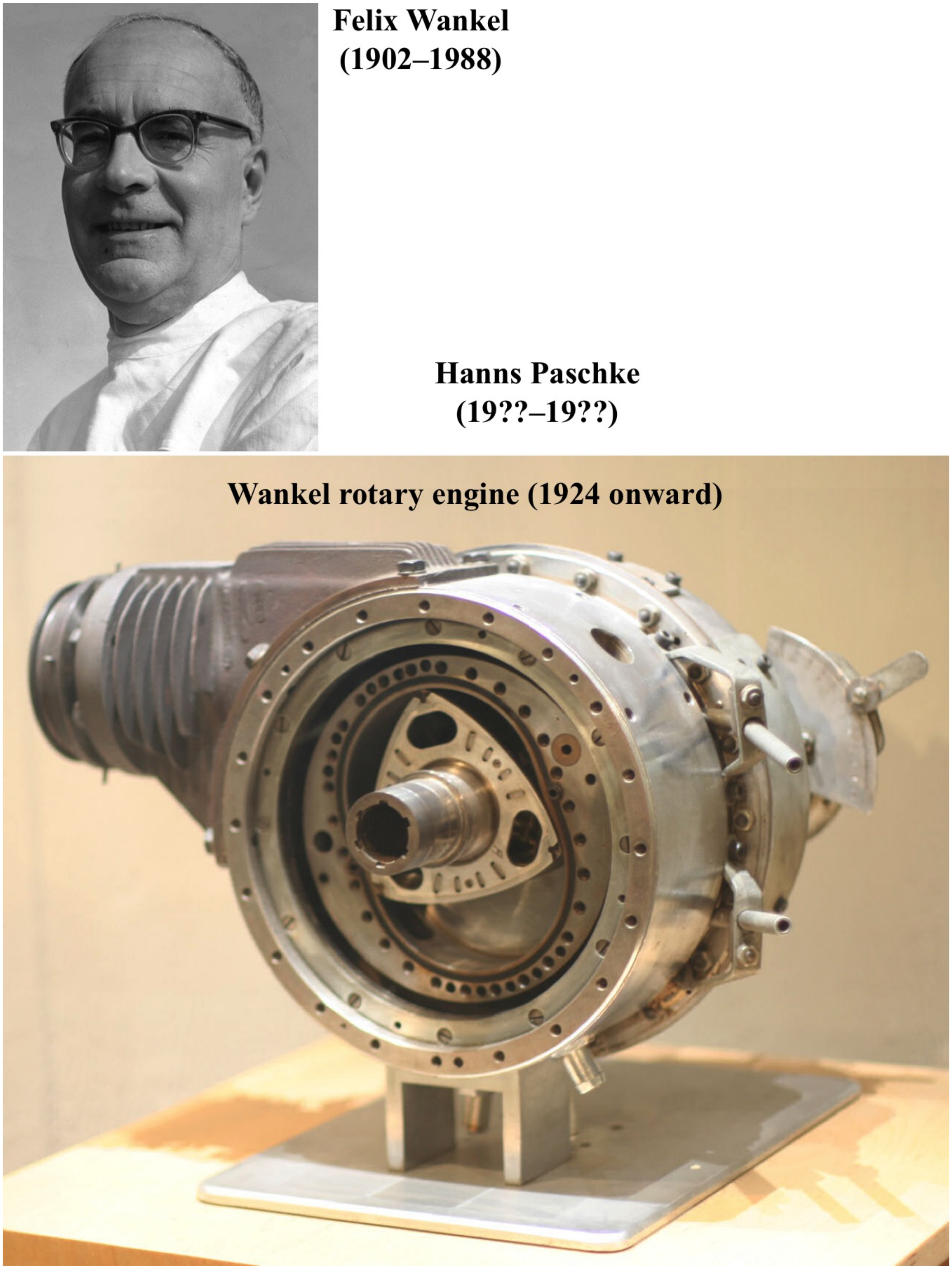

Felix Wankel
(1902–1988)
Hanns Paschke
(19??–19??)
Wankel rotary engine (1924 onward)

Figure 7.44: Felix Wankel developed Wankel rotary engines from 1924 onward, and Hanns Paschke later developed additional versions of Wankel engines.

In addition to the transfer of engine and automotive technologies out of the German-speaking world that occurred in the late nineteenth and early twentieth centuries, Allied countries removed an enormous amount of information on more advanced engine and automotive technologies at the end of World War II. The United States, United Kingdom, France, and Soviet Union removed engineers, prototypes, patents and other documents, and even whole factories. They also wrote detailed reports about the German and Austrian technologies that were transferred to Allied industries. For a few examples, see Figs. 7.45–7.47. There are a large number of additional examples among the BIOS ER, BIOS, BIOS Misc., BIOS Overall, CIOS ER, CIOS, FIAT, *FIAT Review*, JIOA, NavTecMisEu LR, and NavTecMisEu reports in the Bibliography.

Many other automotive-related technologies were also developed in the German-speaking world and then transferred to other countries. Examples include:

- Synthetic rubber for tires (p. 656).
- Synthetic oil for engine lubrication (p. 720).
- High-temperature metal alloys for engines with higher fuel efficiencies (p. 689).
- High-temperature ceramics for engine components (p. 667).
- Improved battery technologies (p. 615).
- Piezoelectric and photoelectric sensors inside engines to monitor engine performance in real time [e.g., pp. 1129–1130 and FIAT 575, *Developments in Diesel Engineering*].
- Fuel additives to prevent knocking in engines [e.g., BIOS 1612, *Fundamental Work on Combustion in Germany*].
- Nitrous oxide for short-term boosting of engines [e.g., BIOS 1612, *Fundamental Work on Combustion in Germany*].

As shown in Fig. 7.48, Walter Linderer (German, 19??–19??) filed the first patent on an automotive airbag in 1951. During World War II, a great deal of German research was focused on developing rapidly deployable vehicle safety devices such as ejection seats, parachutes, and chemically heated/inflatable clothing for water landings (Section 9.4). Moreover, many patent applications filed in the early years of the postwar West German patent office were based on wartime work. Therefore, it seems likely that Linderer's airbag patent was based on wartime projects. More archival research is needed to investigate the origins of Linderer's invention.

In order to make a truly practical airbag, it was necessary to develop a system that could fully inflate the airbag within less than 0.1 seconds during a collision. Working for Daimler-Benz, Helmut Patzelt (German?, 19??–??), Gerhard Schiesterl (German?, 19??–??), and Albert Seybold (German?, 19??–??) solved that problem. They developed an airbag deployed by a solid propellant gas generator in 1967, and they patented the system in 1971 (Fig. 7.49).

The solid propellant gas generator was essentially a miniature solid propellant rocket that used the exhaust gas to inflate the airbag. That aspect of the invention drew heavily upon the earlier development of solid explosives (Section 3.4) and solid propellant rockets (Section 9.8) in the German-speaking world.

German-designed airbag technology was rapidly copied and adopted by Japanese and American automobile manufacturers.

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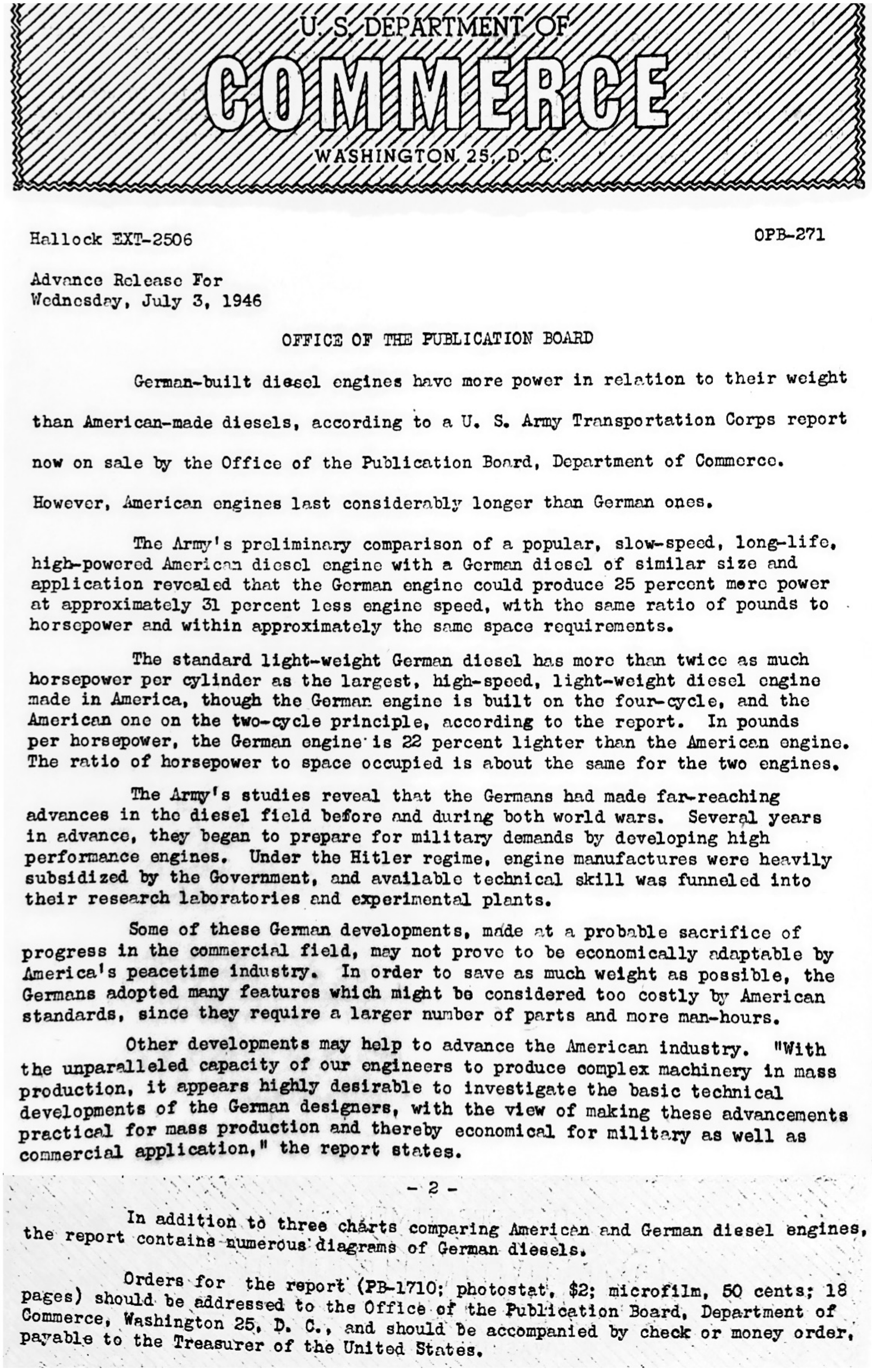

U. S. DEPARTMENT OF
COMMERCE
WASHINGTON 25, D. C.

Hallock EXT-2506 OPB-271

Advance Release For
Wednesday, July 3, 1946

OFFICE OF THE PUBLICATION BOARD

German-built diesel engines have more power in relation to their weight than American-made diesels, according to a U. S. Army Transportation Corps report now on sale by the Office of the Publication Board, Department of Commerce. However, American engines last considerably longer than German ones.

The Army's preliminary comparison of a popular, slow-speed, long-life, high-powered American diesel engine with a German diesel of similar size and application revealed that the German engine could produce 25 percent more power at approximately 31 percent less engine speed, with the same ratio of pounds to horsepower and within approximately the same space requirements.

The standard light-weight German diesel has more than twice as much horsepower per cylinder as the largest, high-speed, light-weight diesel engine made in America, though the German engine is built on the four-cycle, and the American one on the two-cycle principle, according to the report. In pounds per horsepower, the German engine is 22 percent lighter than the American engine. The ratio of horsepower to space occupied is about the same for the two engines.

The Army's studies reveal that the Germans had made far-reaching advances in the diesel field before and during both world wars. Several years in advance, they began to prepare for military demands by developing high performance engines. Under the Hitler regime, engine manufactures were heavily subsidized by the Government, and available technical skill was funneled into their research laboratories and experimental plants.

Some of these German developments, made at a probable sacrifice of progress in the commercial field, may not prove to be economically adaptable by America's peacetime industry. In order to save as much weight as possible, the Germans adopted many features which might be considered too costly by American standards, since they require a larger number of parts and more man-hours.

Other developments may help to advance the American industry. "With the unparalleled capacity of our engineers to produce complex machinery in mass production, it appears highly desirable to investigate the basic technical developments of the German designers, with the view of making these advancements practical for mass production and thereby economical for military as well as commercial application," the report states.

- 2 -

In addition to three charts comparing American and German diesel engines, the report contains numerous diagrams of German diesels.

Orders for the report (PB-1710; photostat, $2; microfilm, 50 cents; 18 pages) should be addressed to the Office of the Publication Board, Department of Commerce, Washington 25, D. C., and should be accompanied by check or money order, payable to the Treasurer of the United States.

NARA RG 40, Entry UD-75, Box 3, Folder Press Releases

Figure 7.45: This is an example from the large number of reports on German automotive technologies that were sent to other countries after World War II [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases].

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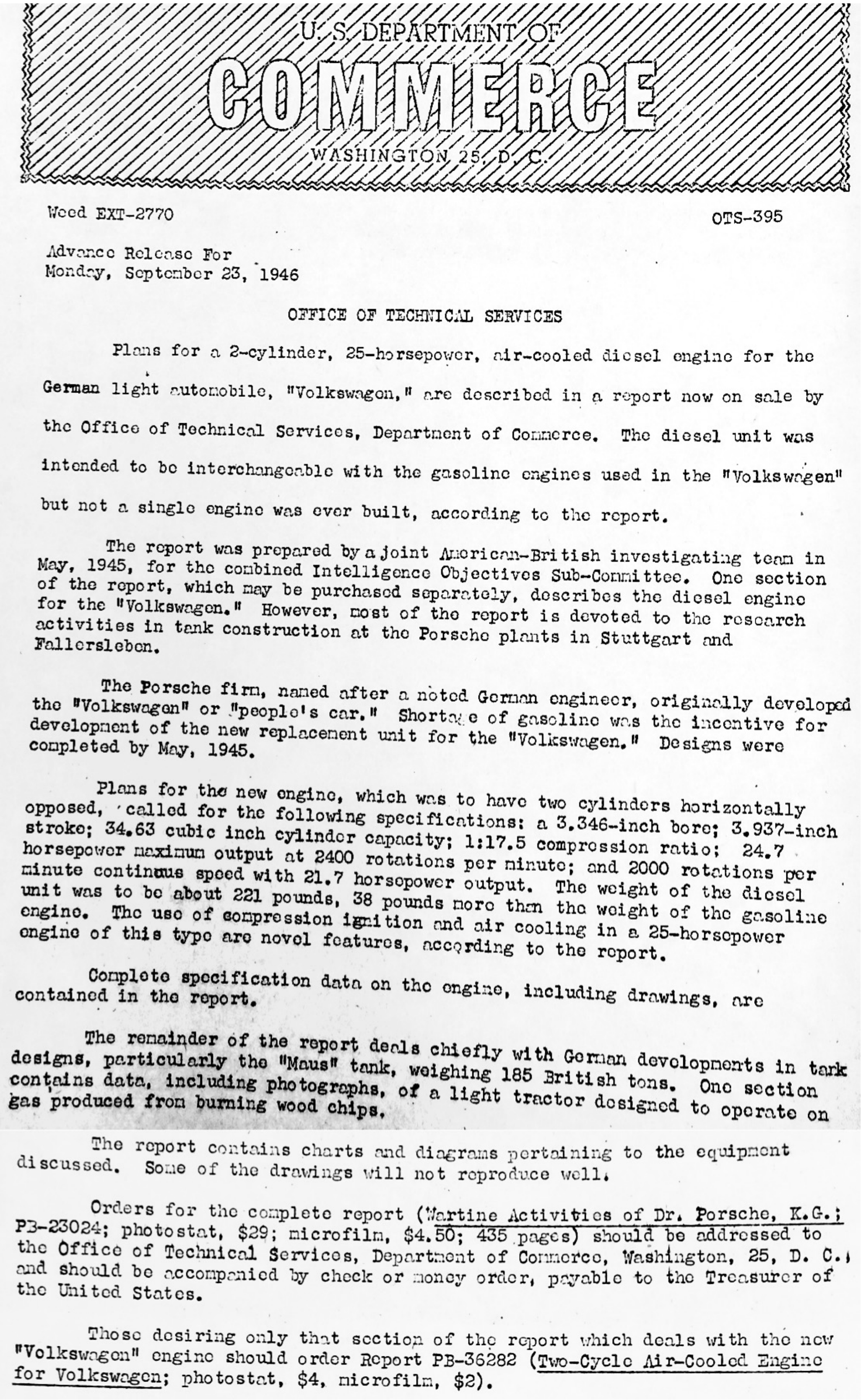
Authority NND 968018



U. S. DEPARTMENT OF
COMMERCE
WASHINGTON 25, D. C.

Wood EXT-2770 OTS-395

Advance Release For
Monday, September 23, 1946

OFFICE OF TECHNICAL SERVICES

Plans for a 2-cylinder, 25-horsepower, air-cooled diesel engine for the German light automobile, "Volkswagon," are described in a report now on sale by the Office of Technical Services, Department of Commerce. The diesel unit was intended to be interchangeable with the gasoline engines used in the "Volkswagen" but not a single engine was ever built, according to the report.

The report was prepared by a joint American-British investigating team in May, 1945, for the combined Intelligence Objectives Sub-Committee. One section of the report, which may be purchased separately, describes the diesel engine for the "Volkswagen." However, most of the report is devoted to the research activities in tank construction at the Porsche plants in Stuttgart and Fallersleben.

The Porsche firm, named after a noted German engineer, originally developed the "Volkswagen" or "people's car." Shortage of gasoline was the incentive for development of the new replacement unit for the "Volkswagen." Designs were completed by May, 1945.

Plans for the new engine, which was to have two cylinders horizontally opposed, called for the following specifications: a 3.346-inch bore; 3.937-inch stroke; 34.63 cubic inch cylinder capacity; 1:17.5 compression ratio; 24.7 horsepower maximum output at 2400 rotations per minute; and 2000 rotations per minute continuous speed with 21.7 horsepower output. The weight of the diesel unit was to be about 221 pounds, 38 pounds more than the weight of the gasoline engine. The use of compression ignition and air cooling in a 25-horsepower engine of this type are novel features, according to the report.

Complete specification data on the engine, including drawings, are contained in the report.

The remainder of the report deals chiefly with German developments in tank designs, particularly the "Maus" tank, weighing 185 British tons. One section contains data, including photographs, of a light tractor designed to operate on gas produced from burning wood chips.

The report contains charts and diagrams pertaining to the equipment discussed. Some of the drawings will not reproduce well.

Orders for the complete report (Wartime Activities of Dr. Porsche, K.G.; PB-23024; photostat, $29; microfilm, $4.50; 435 pages) should be addressed to the Office of Technical Services, Department of Commerce, Washington, 25, D. C., and should be accompanied by check or money order, payable to the Treasurer of the United States.

Those desiring only that section of the report which deals with the new "Volkswagon" engine should order Report PB-36282 (Two-Cycle Air-Cooled Engine for Volkswagen; photostat, $4, microfilm, $2).

NARA RG 40, Entry UD-75,
Box 3, Folder Press Releases

Figure 7.46: This is another example from the large number of reports on German automotive technologies that were sent to other countries after World War II [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases].

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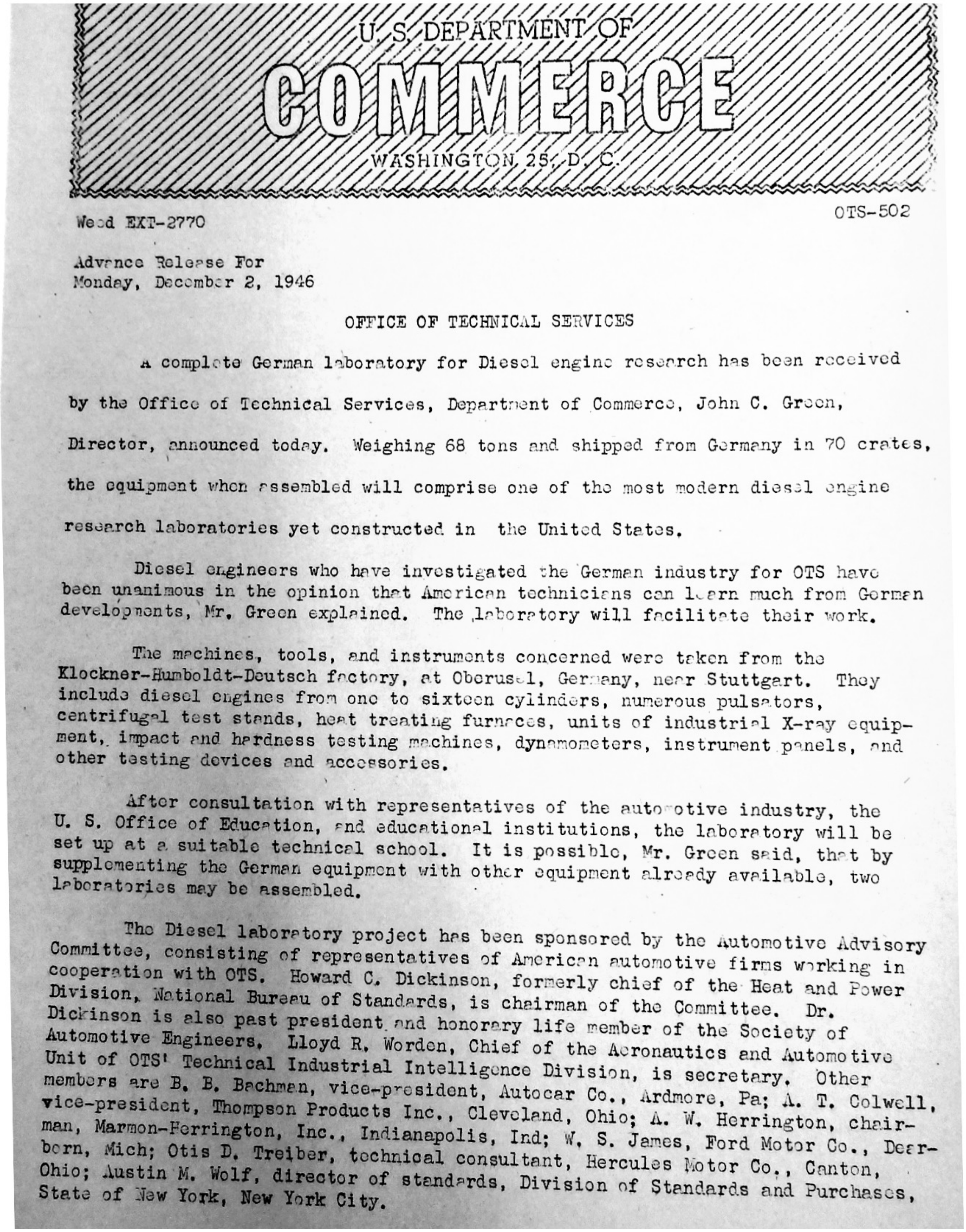
Authority NND968018

NARA RG 40, Entry UD-75,
Box 3, Folder Press Releases



U. S. DEPARTMENT OF
COMMERCE
WASHINGTON 25, D. C.

Weed EXT-2770

OTS-502

Advance Release For
Monday, December 2, 1946

OFFICE OF TECHNICAL SERVICES

A complete German laboratory for Diesel engine research has been received by the Office of Technical Services, Department of Commerce, John C. Green, Director, announced today. Weighing 68 tons and shipped from Germany in 70 crates, the equipment when assembled will comprise one of the most modern diesel engine research laboratories yet constructed in the United States.

Diesel engineers who have investigated the German industry for OTS have been unanimous in the opinion that American technicians can learn much from German developments, Mr. Green explained. The laboratory will facilitate their work.

The machines, tools, and instruments concerned were taken from the Klockner-Humboldt-Deutsch factory, at Oberusel, Germany, near Stuttgart. They include diesel engines from one to sixteen cylinders, numerous pulsators, centrifugal test stands, heat treating furnaces, units of industrial X-ray equipment, impact and hardness testing machines, dynamometers, instrument panels, and other testing devices and accessories.

After consultation with representatives of the automotive industry, the U. S. Office of Education, and educational institutions, the laboratory will be set up at a suitable technical school. It is possible, Mr. Green said, that by supplementing the German equipment with other equipment already available, two laboratories may be assembled.

The Diesel laboratory project has been sponsored by the Automotive Advisory Committee, consisting of representatives of American automotive firms working in cooperation with OTS. Howard C. Dickinson, formerly chief of the Heat and Power Division, National Bureau of Standards, is chairman of the Committee. Dr. Dickinson is also past president and honorary life member of the Society of Automotive Engineers. Lloyd R. Worden, Chief of the Aeronautics and Automotive Unit of OTS' Technical Industrial Intelligence Division, is secretary. Other members are B. B. Bachman, vice-president, Autocar Co., Ardmore, Pa; A. T. Colwell, vice-president, Thompson Products Inc., Cleveland, Ohio; A. W. Herrington, chairman, Marmon-Herrington, Inc., Indianapolis, Ind; W. S. James, Ford Motor Co., Dearborn, Mich; Otis D. Treiber, technical consultant, Hercules Motor Co., Canton, Ohio; Austin M. Wolf, director of standards, Division of Standards and Purchases, State of New York, New York City.

Figure 7.47: This is another example from the large number of reports on German automotive technologies that were sent to other countries after World War II [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases].

Walter Linderer (19??–19??)

Fig. 1

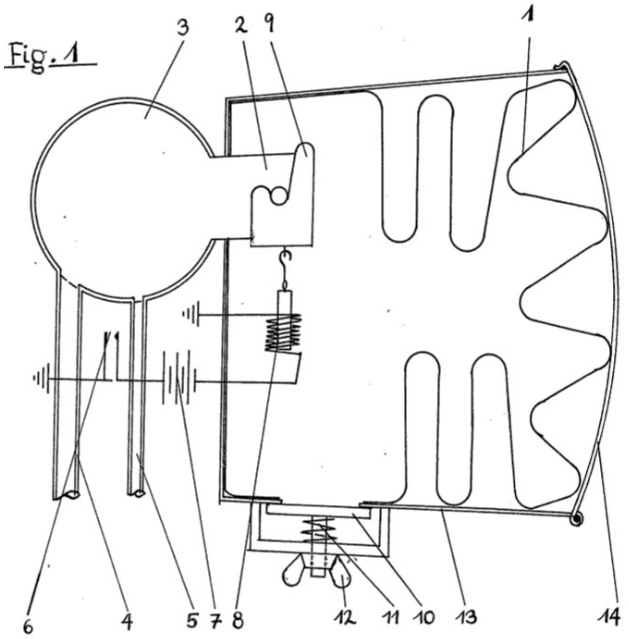
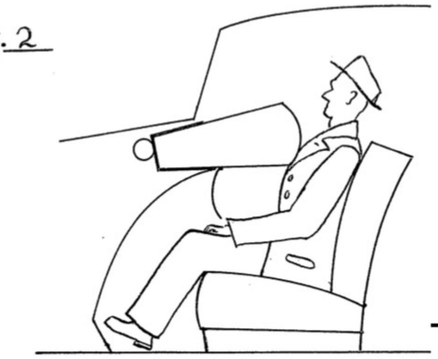
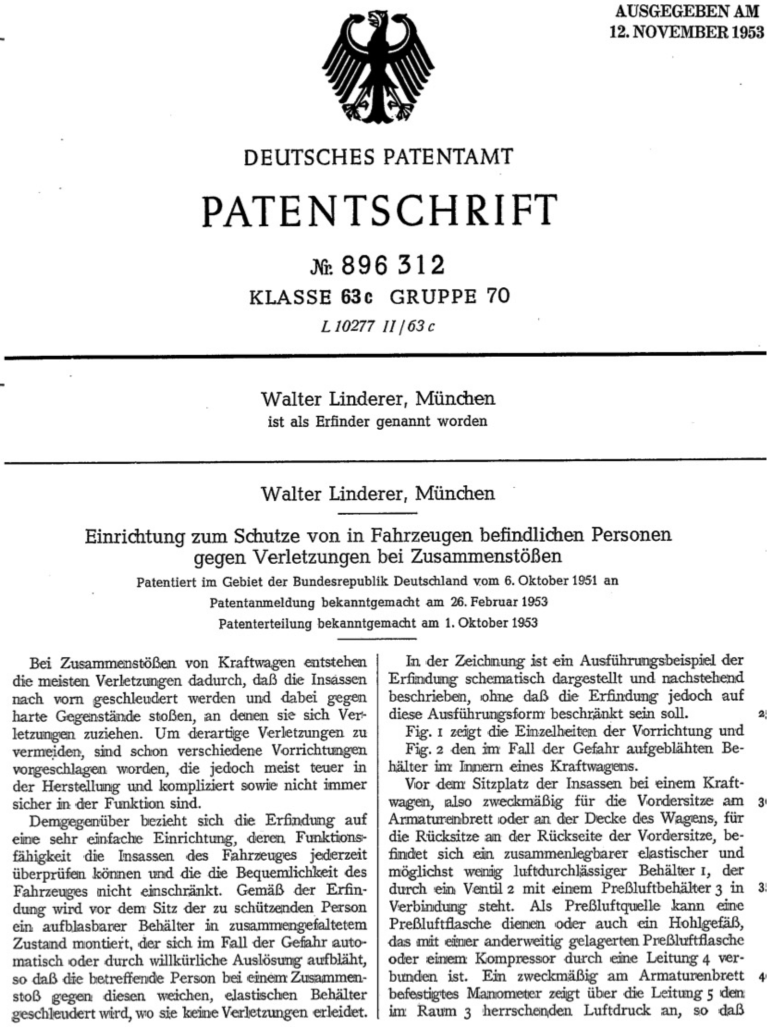


Fig. 2



Airbag (patented 1951, likely based on wartime work?)



AUSGEGEBEN AM
12. NOVEMBER 1953

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 896 312

KLASSE 63c GRUPPE 70

L 10277 II/63 c

Walter Linderer, München
ist als Erfinder genannt worden

Walter Linderer, München

Einrichtung zum Schutze von in Fahrzeugen befindlichen Personen gegen Verletzungen bei Zusammenstößen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 6. Oktober 1951 an
Patentanmeldung bekanntgemacht am 26. Februar 1953
Patenterteilung bekanntgemacht am 1. Oktober 1953

Bei Zusammenstößen von Kraftwagen entstehen die meisten Verletzungen dadurch, daß die Insassen nach vorn geschleudert werden und dabei gegen harte Gegenstände stoßen, an denen sie sich Verletzungen zuziehen. Um derartige Verletzungen zu vermeiden, sind schon verschiedene Vorrichtungen vorgeschlagen worden, die jedoch meist teuer in der Herstellung und kompliziert sowie nicht immer sicher in der Funktion sind.

Demgegenüber bezieht sich die Erfindung auf eine sehr einfache Einrichtung, deren Funktionsfähigkeit die Insassen des Fahrzeuges jederzeit überprüfen können und die die Bequemlichkeit des Fahrzeuges nicht einschränkt. Gemäß der Erfindung wird vor dem Sitz der zu schützenden Person ein aufblasbarer Behälter in zusammengefaltetem Zustand montiert, der sich im Fall der Gefahr automatisch oder durch willkürliche Auslösung aufbläht, so daß die betreffende Person bei einem Zusammenstoß gegen diesen weichen, elastischen Behälter geschleudert wird, wo sie keine Verletzungen erleidet.

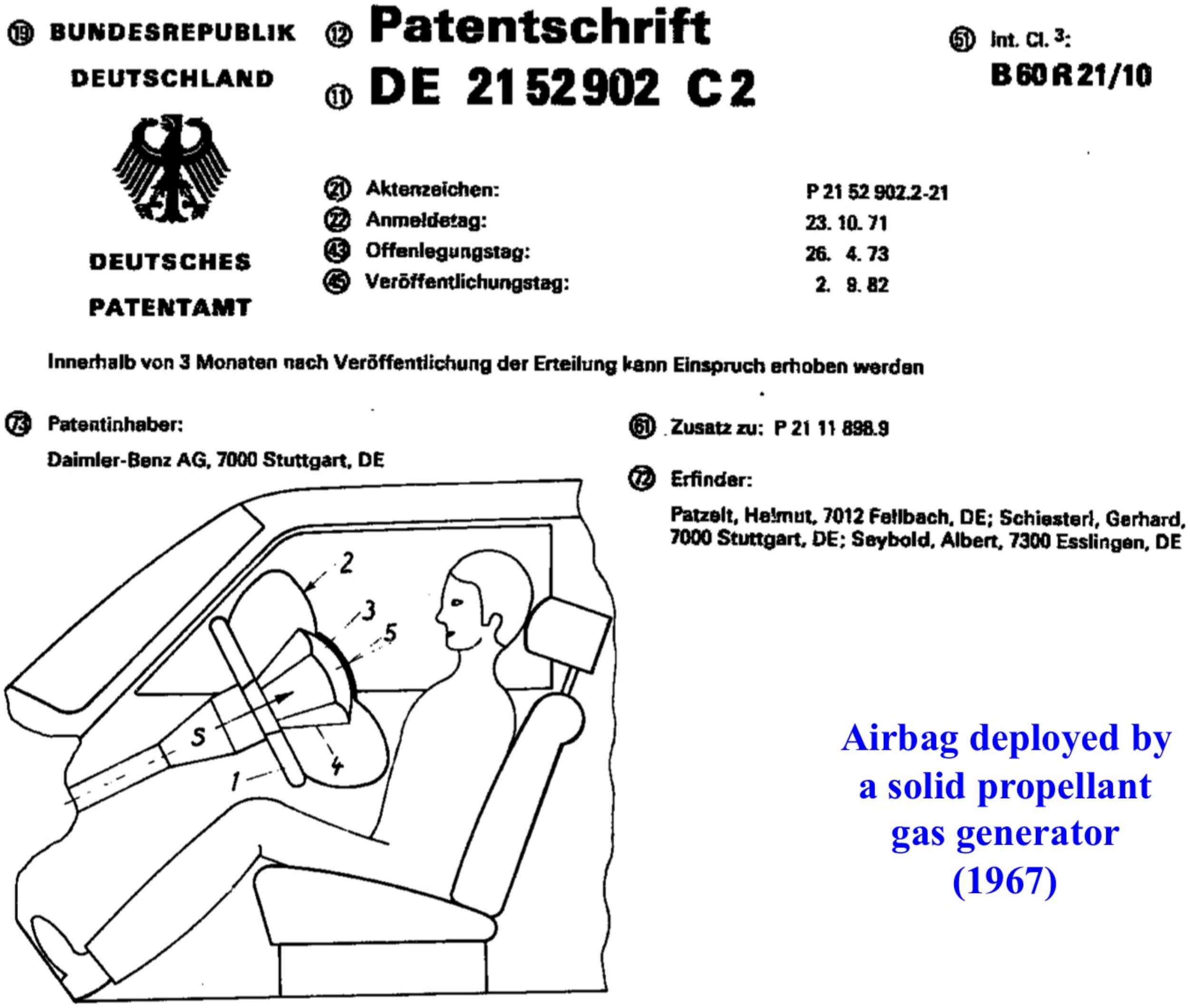
In der Zeichnung ist ein Ausführungsbeispiel der Erfindung schematisch dargestellt und nachstehend beschrieben, ohne daß die Erfindung jedoch auf diese Ausführungsform beschränkt sein soll.

Fig. 1 zeigt die Einzelheiten der Vorrichtung und
Fig. 2 den im Fall der Gefahr aufgeblähten Behälter im Innern eines Kraftwagens.

Vor dem Sitzplatz der Insassen bei einem Kraftwagen, also zweckmäßig für die Vordersitze am Armaturenbrett oder an der Decke des Wagens, für die Rücksitze an der Rückseite der Vordersitze, befindet sich ein zusammenlegbarer elastischer und möglichst wenig luftdurchlässiger Behälter 1, der durch ein Ventil 2 mit einem Preßluftbehälter 3 in Verbindung steht. Als Preßluftquelle kann eine Preßluftflasche dienen oder auch ein Hohlgefäß, das mit einer anderweitig gelagerten Preßluftflasche oder einem Kompressor durch eine Leitung 4 verbunden ist. Ein zweckmäßig am Armaturenbrett befestigtes Manometer zeigt über die Leitung 5 den im Raum 3 herrschenden Luftdruck an, so daß

Figure 7.48: Walter Linderer filed the first patent on an automotive airbag in 1951 (likely based on wartime work?).

Helmut Patzelt (19??–??) **Gerhard Schiesterl (19??–??)** **Albert Seybold (19??–??)**



⑲ BUNDESREPUBLIK DEUTSCHLAND

DEUTSCHES PATENTAMT

⑫ **Patentschrift**

⑪ **DE 2152902 C2**

(51) Int. Cl. 3: B 60 R 21/10

(21) Aktenzeichen: P 21 52 902.2-21
(22) Anmeldetag: 23. 10. 71
(43) Offenlegungstag: 26. 4. 73
(45) Veröffentlichungstag: 2. 9. 82

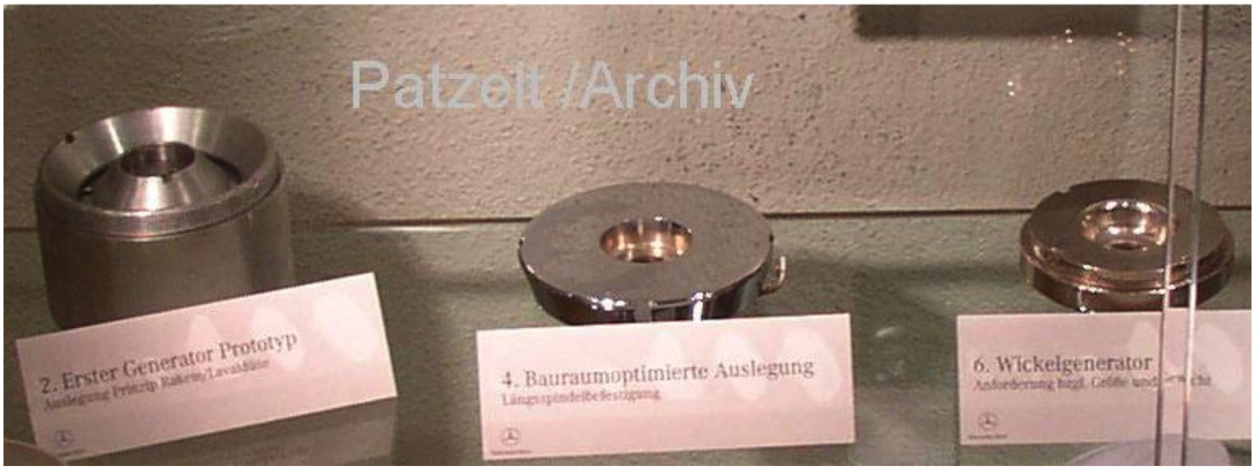
Innerhalb von 3 Monaten nach Veröffentlichung der Erteilung kann Einspruch erhoben werden

(73) Patentinhaber:
Daimler-Benz AG, 7000 Stuttgart, DE

(61) Zusatz zu: P 21 11 898.9

(72) Erfinder:
Patzelt, Helmut, 7012 Fellbach, DE; Schiesterl, Gerhard, 7000 Stuttgart, DE; Seybold, Albert, 7300 Esslingen, DE

Airbag deployed by a solid propellant gas generator (1967)



Patzelt /Archiv
2. Erster Generator Prototyp
Auslegung Prinzip Rakete/Lavaldüse
4. Bauraumoptimierte Auslegung
Längsspindelbefestigung
6. Wickelgenerator
Anforderung bzgl. Größe und Gewicht

Figure 7.49: Helmut Patzelt, Gerhard Schiesterl, and Albert Seybold developed an airbag deployed by a solid propellant gas generator in 1967, and they patented the system in 1971.

7.3.2 Chainsaws

German-speaking creators also invented chainsaws and adapted internal combustion engines to power them (Fig. 7.50).

Sometime before 1830, Bernhard Heine (German, 1800–1846) invented hand-powered chainsaws (osteotomes) for cutting bone during surgery, and then in 1830 he successfully promoted their use all over Europe. Heine was a surgeon who also made important discoveries about bone growth and bone repair. He likely would have made even more contributions during his career, but unfortunately he died from tuberculosis (probably acquired from his work).

In the late 1920s, Andreas Stihl (Swiss, educated and worked in Germany, 1896–1973), a mechanical engineer, developed both electric and gasoline-powered chainsaws. Based on his inventions, he founded the company that still bears his name.

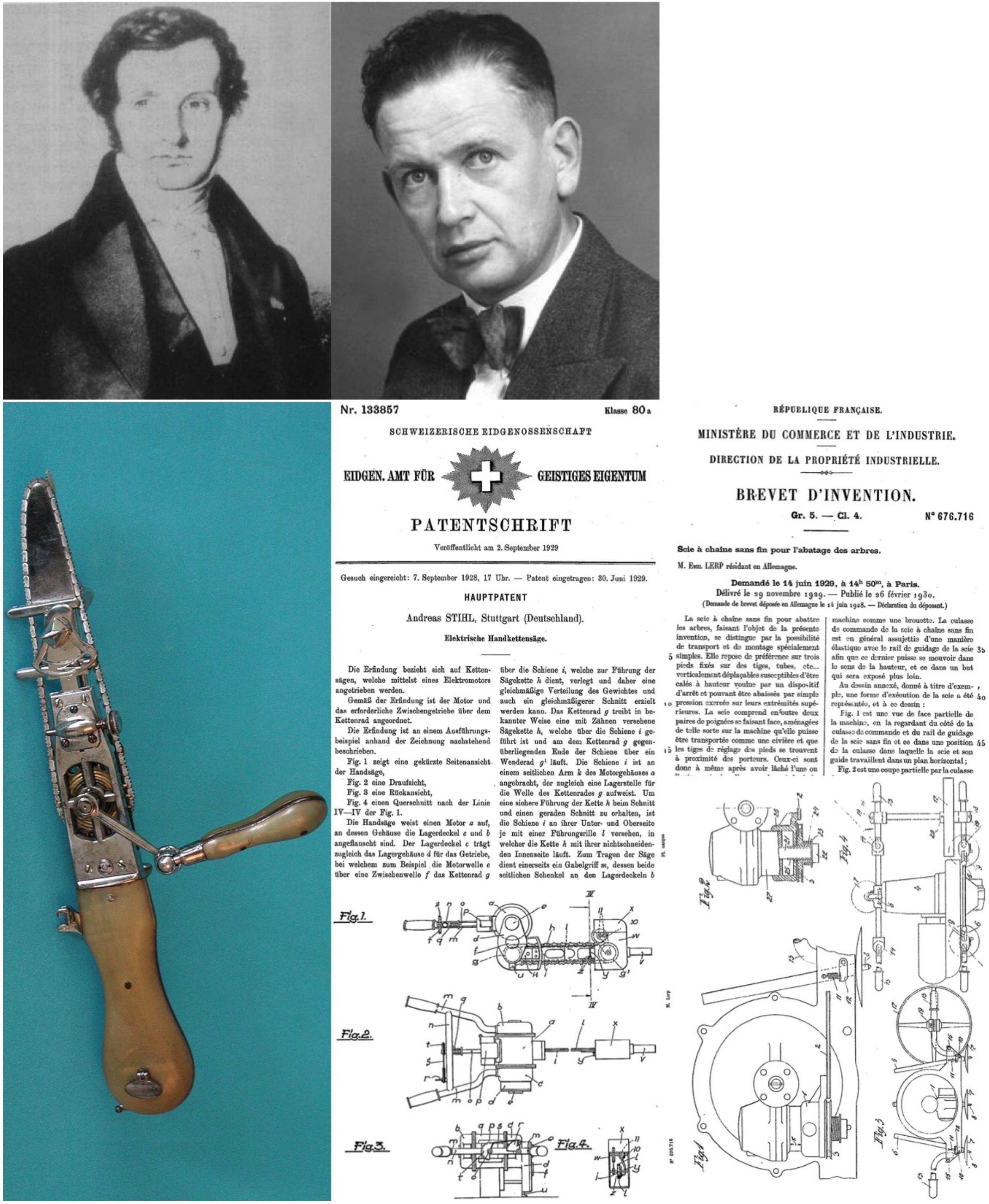
At the same time, Emil Lerp (German, 1886–1966) also developed gasoline-powered chainsaws and founded the Dolmar company to produce them. Early in their careers, Lerp and Stihl worked together for the Emil Ring saw company, so it is somewhat murky whether one of them borrowed the ideas of the other, or if they developed their chainsaws truly independently.

Chainsaw designs were spread worldwide both by the Stihl and Dolmar companies and by Allied investigators at the end of World War II [see for example FIAT 696, *Gasoline Powered Hand Tree Saws*].

Bernhard Heine
(1800–1846)
Manual chainsaw

Andreas Stihl
(1896–1973)
Electric & gas chainsaws

Emil Lerp
(1886–1966)
Gasoline chainsaw



Nr. 133857 Klasse 80 a

SCHWEIZERISCHE EIDGENOSSENSCHAFT

EIDGEN. AMT FÜR GEISTIGES EIGENTUM

PATENTSCHRIFT

Veröffentlicht am 2. September 1929

Gesuch eingereicht: 7. September 1928, 17 Uhr. — Patent eingetragen: 30. Juni 1929.

HAUPTPATENT

Andreas STIHL, Stuttgart (Deutschland).

Elektrische Handkettensäge.

Die Erfindung bezieht sich auf Kettensägen, welche mittelst eines Elektromotors angetrieben werden.

Gemäß der Erfindung ist der Motor und das erforderliche Zwischengetriebe über dem Kettenrad angeordnet.

Die Erfindung ist an einem Ausführungsbeispiel anhand der Zeichnung nachstehend beschrieben.

Fig. 1 zeigt eine gekürzte Seitenansicht der Handsäge,

Fig. 2 eine Draufsicht,

Fig. 3 eine Rückansicht,

Fig. 4 einen Querschnitt nach der Linie IV—IV der Fig. 1.

Die Handsäge weist einen Motor *a* auf, an dessen Gehäuse die Lagerdeckel *c* und *b* angeflanscht sind. Der Lagerdeckel *c* trägt zugleich das Lagergehäuse *d* für das Getriebe, bei welchem zum Beispiel die Motorwelle *e* über eine Zwischenwelle *f* das Kettenrad *g* über die Schiene *i*, welche zur Führung der Sägekette *h* dient, verlegt und daher eine gleichmäßige Verteilung des Gewichtes und auch ein gleichmäßigerer Schnitt erzielt werden kann. Das Kettenrad *g* treibt in bekannter Weise eine mit Zähnen versehene Sägekette *h*, welche über die Schiene *i* geführt ist und am dem Kettenrad *g* gegenüberliegenden Ende der Schiene über ein Wenderad g^1 läuft. Die Schiene *i* ist an einem seitlichen Arm *k* des Motorgehäuses *a* angebracht, der zugleich eine Lagerstelle für die Welle des Kettenrades *g* aufweist. Um eine sichere Führung der Kette *h* beim Schnitt und einen geraden Schnitt zu erhalten, ist die Schiene *i* an ihrer Unter- und Oberseite je mit einer Führungsrille *l* versehen, in welcher die Kette *h* mit ihrer nichtschneidenden Innenseite läuft. Zum Tragen der Säge dient einerseits ein Gabelgriff *m*, dessen beide seitlichen Schenkel an den Lagerdeckeln *b*

RÉPUBLIQUE FRANÇAISE.

MINISTÈRE DU COMMERCE ET DE L'INDUSTRIE.

DIRECTION DE LA PROPRIÉTÉ INDUSTRIELLE.

BREVET D'INVENTION.

Gr. 5. — Cl. 4. N° 676.716

Scie à chaîne sans fin pour l'abatage des arbres.

M. Emil LERP résidant en Allemagne.

Demandé le 14 juin 1929, à 14^h 50^m, à Paris.

Délivré le 29 novembre 1929. — Publié le 26 février 1930.

(Demande de brevet déposée en Allemagne le 14 juin 1928. — Déclaration du déposant.)

La scie à chaîne sans fin pour abattre les arbres, faisant l'objet de la présente invention, se distingue par la possibilité de transport et de montage spécialement simples. Elle repose de préférence sur trois pieds fixés sur des tiges, tubes, etc... verticalement déplaçables susceptibles d'être calés à hauteur voulue par un dispositif d'arrêt et pouvant être abaissés par simple pression exercée sur leurs extrémités supérieures. La scie comprend en outre deux paires de poignées se faisant face, aménagées de telle sorte sur la machine qu'elle puisse être transportée comme une civière et que les tiges de réglage des pieds se trouvent à proximité des porteurs. Ceux-ci sont donc à même après avoir lâché l'une ou

machine comme une brouette. La culasse de commande de la scie à chaîne sans fin est en général assujettie d'une manière élastique avec le rail de guidage de la scie afin que ce dernier puisse se mouvoir dans le sens de la hauteur, et ce dans un but qui sera exposé plus loin.

Au dessin annexé, donné à titre d'exemple, une forme d'exécution de la scie a été représentée, et à ce dessin :

Fig. 1 est une vue de face partielle de la machine, en la regardant du côté de la culasse de commande et du rail de guidage de la scie sans fin et ce dans une position de la culasse dans laquelle la scie et son guide travaillent dans un plan horizontal ;

Fig. 2 est une coupe partielle par la culasse

Figure 7.50: Bernhard Heine invented hand-powered chainsaws in 1830, Andreas Stihl developed electric and gasoline-powered chainsaws in the late 1920s, and Emil Lerp developed gasoline-powered chainsaws in the late 1920s.

7.3.3 Tanks

German-speaking creators were responsible for most of the major innovations in the development of military tanks powered by internal combustion engines or gas turbine engines.

As shown in Fig. 7.51, Frederick Simms (German, 1863–1944) developed the small armed Motor Scout in 1899, followed by the much larger Motor War Car in 1902. Then in 1904, Paul Daimler (German, 1869–1945) and his team developed the Panzerwagen armored car, pictured in Fig. 7.52.

In or before 1911, Günther Burstyn (Austrian, 1879–1945) invented the first combat tank to incorporate all of the major features of modern tanks (including treads, full armor, a large lower motor section, a smaller rotating turret with a long gun barrel of large caliber, and armored ports for smaller guns), as illustrated in Figs. 7.53–7.55. He tried unsuccessfully to interest many countries in funding him to mass-produce his combat tank, along the way publicizing his tank plans via presentations, patents (e.g., Fig. 7.54), and articles (e.g., Fig. 7.55). For example, he published a 1912 article that summarized the main features of his tank designs and included many accompanying diagrams [Burstyn 1912]:

> Die Bewegung im Gelände, besonders auf weichem Boden, erfolgt mit einem Paar über kleine breite Räder geführter endloser Bänder aus Drahtseilgeflecht. Diese Bänder fassen mit Rippen in den Boden ein und werden durch die äußeren, hochgestellten Räder, in welche sie zahnradartig eingreifen, angetrieben. Durch die Hochstellung dieser Räder sind die Bänder vorne und rückwärts schräg aufwärtsgeführt, so daß kleine Unebenheiten leicht überwunden werden können. Wendungen geschehen in der Weise, daß ein Band nach vorne, das andere nach rückwärts zum Antrieb gelangt. Im allgemeinen ist es das alte Prinzip der sich selbst Geleise legenden Lokomotive, das in letzter Zeit in ähnlicher Weise für Motorschlitten der antarktischen Expeditionen mit Erfolg angewendet wird.

> Movement in the terrain, especially on soft ground, is accomplished by a pair of endless belts made of braided wire rope guided over small wide wheels. These belts engage the ground with ribs and are driven by the outer raised wheels in which they mesh like cogwheels. Because of the raised position of these wheels, the belts are slanted upward at the front and back, so that small bumps can be easily overcome. Turns are executed in such a way that one belt is driven to move forward and the other backward. In general, it is the old principle of a locomotive laying tracks for itself, which has recently been successfully used in a similar way for snowmobiles on Antarctic expeditions.

> Zur Überschreitung von Hindernissen sind vorne und rückwärts an dem Fahrzeuge je zwei breite Gleitschienen, die an den äußeren Enden breite kleine Räder tragen, auslegerartig angebracht. Diese Gleitschienen sind um ihren Befestigungpunkt am Fahrzeuge im vertikalen Sinne schwenkbar und werden durch je eine Strebe gestützt. Die Schwenkung der Gleitschienen erfolgt durch die Streben, welche durch ein Getriebe, das vom Motor betätigt wird, entsprechend bewegt werden. Die Figuren 5–10 [Fig. 7.55] machen ersichtlich, wie das Motorgeschütz mit Hilfe der Gleitschienen eine Stufe überschreitet.

> In order to cross obstacles, two wide slide rails are attached to the front and two to the rear of the vehicle in the form of outriggers, which carry wide small wheels at the outer ends. These slide rails can be pivoted vertically about their point of attachment to the vehicle and are each supported by a strut. The pivoting of the slide rails is effected by the struts, which are moved accordingly by a gear operated by the motor. Figures 5–10 [Fig. 7.55] show how the motorized gun crosses a step with the aid of the slide rails.

Mit Hilfe der beschriebenen Fortbewegungsmittel erscheint die freie Bewegung des Motorgeschützes im Gelände gewährleistet. Hiebei sind zwei Geschwindigkeitsstufen erforderlich: eine normale (5–8 km pro Stunde) für das Fahren über freies Feld und eine langsame (zirka 3 km pro Stunde) für das Übersetzen von Hindernissen.

Zur raschen Bewegung auf Straßen, zu der die bisher beschriebene Art der Fortbewegung ungeeignet ist, sind zwei Paare von Rädern vorgesehen. Sie befinden sich unter dem Panzer und sind zum Heben, bzw. Senken eingerichtet. Die vorderen Räder beim Geschütz werden gelenkt, die rückwärtigen angetrieben. Die Geschwindigkeit, die auf Straßen erzielt werden soll, wird je nach der Motorstärke 20–30 km pro Stunde betragen.

Der Aufbau des Motorgeschützes ist so eingerichtet, daß sich vorne der Kampfraum, rückwärts der Motorraum befindet.

Der erstere wird oben durch eine drehbare Panzerhaube gebildet, die mit der Lafettierung des Geschützes in Verbindung steht. Auf dieses wird später näher eingegangen werden. Ferners befinden sich im Kampfraume für die zwei Mann Geschützbedienung Sitze, welche sich bei der Drehung der Haube mitbewegen.

Im Motorraum ist ein 40–60 H.P. Benzinmotor (Last wagentype) installiert. Ferners befindet sich dort der Sitz für den Motorwärter. Beiderseits von diesem sind geräumige Kästen zur Aufnahme von Benzin, Öl, Munition und Requisiten vorgesehen. Während des Feuergefechtes läßt sich der Motor- mit dem Kampfraum verbinden, so daß der Motorwärter die Zureichung der Munition besorgen kann.

With the help of the described means of locomotion, the free movement of the motor gun in terrain appears to be ensured. Two speed levels are required: a normal one (5–8 km per hour) for driving over open fields and a slow one (about 3 km per hour) for crossing obstacles.

For rapid movement on roads, for which the mode of locomotion described so far is unsuitable, two pairs of wheels are provided. They are located under the tank and are designed to be lifted or lowered. The front wheels on the gun are steered and the rear wheels are powered. The speed to be achieved on roads will be 20–30 km per hour, depending on the engine power.

The superstructure of the motorized gun is arranged so the fighting compartment is in the front and the engine compartment in the rear.

The former is formed at the top by a rotatable armored turret, which is connected to the mount of the gun. This will be discussed in more detail later. Furthermore, there are seats in the fighting compartment for the two-man gun crew, which move along with the rotation of the turret.

A 40–60 H.P. gasoline engine (truck type) is installed in the engine compartment. There is also a seat for the engine attendant. On either side of this are spacious boxes for storing gasoline, oil, ammunition, and props. During the firefight, the engine compartment can be connected to the fighting compartment, so that the engine attendant can resupply the ammunition.

Der Panzerschutz, welcher gleichzeitig den tragenden Rahmen für das Fahrzeug bildet, besteht aus Spezialstahl und ist vorne mit 8 mm, seit- und rückwärts mit 4 mm, an der Decke mit 3 mm Stärke angenommen. Die Panzerung nach unten gegen Geller wird wahrscheinlich auch notwendig werden.	The armor protection, which also forms the supporting frame for the vehicle, is made of special steel and is assumed to be 8 mm thick at the front, 4 mm thick at the sides and rear, and 3 mm thick on top. Underside armor against piercing will probably also be necessary.
Das Motorgeschütz, das infolge dieses Panzerschutzes gegen Infanteriefeuer fast unverwundbar erscheint, muß natürlich in der feind lichen Artillerie seinen stärksten Gegner erblicken und befähigt sein, den Kampf mit diesem zu bestehen.	The motorized gun, which as a result of this armor protection appears almost invulnerable to infantry fire, will of course find its strongest opponent to be enemy artillery and must be capable of holding its own against it.

Note that in addition to all of the now-common features of tanks, Burstyn's designs included two other novel options: retractable wheels underneath to allow faster travel on paved roads, and extendable wheeled beams on the front and back to aid in crossing over trenches.

Even though Burstyn was never able to find enough funding to fully develop his tanks himself, by widely publicizing his approach and designs through his international presentations, patents, and publications, it appears that he directly influenced engineers in several countries to implement his tank ideas for themselves during World War I.

Joseph Vollmer (German, 1871–1955) developed the first internal-combustion-engine-powered tractor-trailer truck in 1903; see Fig. 7.56. During World War I, he built upon the ideas of Günther Burstyn to create tanks such as the A7V.

As shown in Fig. 7.57, during World War II, Ferdinand Porsche, Karl Rabe, and their team developed advanced tanks such as the widely used Tiger I. They also created the huge 188-ton Panzerkampfwagen VIII Maus prototype [Ludvigsen 2015].

Another large tank prototype, the 140-ton Henschel Panzerkampfwagen E-100, was taken by British troops at the end of World War II. It is shown in Fig. 7.58 on top of a trailer, without the turret and treads.

Nicholas Straussler (Hungarian, 1891–1966), an automotive engineer, emigrated to the United Kingdom in the late 1920s due to rising intolerance in central Europe. From 1940 to 1944, he developed the duplex drive (DD) amphibious tanks that were used by Allied forces for the invasion of Normandy (Fig. 7.59).

German-speaking creators and their creations continued to influence tank design after World War II. In September 1945, R. P. Linstead and T. J. Betts, the British and American chairs of the Combined Intelligence Objectives Subcommittee (CIOS), listed a number of important German innovations for tanks that were of interest to Allied countries [AFHRA A5186 electronic version pp. 904–1026, Ch. 4, pp. 68–69]:

Investigation of the German automotive industry revealed that development was concentrated on armored fighting vehicles to the exclusion of ordinary motor transport. A new series of super heavy tanks, a group of self-propelled weapons knowns as "Waffentraeger", another series of tanks designated as the "E-Series" and the application of gas turbines as tank power plants were of particular interest.

The pilot model of the E-100 tank was located, and drawings of the important assemblies were evacuated by investigators. This tank weighed approximately 100 metric tons, mounted a 150 mm. gun and was provided with a sloping front armor plate 8 inches thick. It was discovered that an even heavier tank know as the "Maus" had been constructed and tested. The pilot model of this tank, which was reported to weigh 180 metric tons, was destroyed in the Russian area prior to occupation. [The Maus prototype was actually captured by the Russians—see Fig. 7.57.] However, complete engineering data on the "Maus" was obtained by CIOS investigators.

German authorities were planning mass production of self-propelled "Waffentraeger" guns. These gun mounts were lightly armored vehicles, which were to be equipped with normal field artillery weapons. It was initially conceived that provisions would be made for demounting the weapons for employment as conventional artillery pieces, but this feature was subsequently abandoned.

The "E-Series" of German tanks were the most interesting armored vehicles encountered. This series included the E-10, E-25, E-50 and E-100, all of which incorporated the most advanced thinking of the Heereswaffenamt. The series numbers represent the estimated weights of the basic chassis. It is significant to note that these vehicles represented a return of the German design trend to lighter and more maneuverable tanks.

The development of a gas turbine for tank motive power was not complete, nor had successful application been achieved. However, many US and British authorities believe that the gas turbine development is potentially the most important feature of German armored vehicle research. It was expected that a 30% increase in power would be obtained from substitution of a gas turbine for a conventional type power unit in a given size engine compartment. Considerable progress had been made on the development of a rotary ceramic heat exchanger capable of achieving fuel economy equal to that of the automotive type Diesel.

Tank armament projects included the rigidly mounted 75 and 88 mm. guns described previously. The design of gyroscopically stabilized sights led German experts to hope for an accuracy within a half-mile limit. The "Kugelblitz" anti-aircraft armored turret was discovered.

In respect to tank engines, designers had endeavored to produce an air-cooled Diesel power plant. The only successful new project encountered was the "Maybach HL-234" gasoline injection engine which had delivered 900 H.P. in preliminary tests.

The Germans had initiated many new projects of a more or less radical nature in the design of new tank transmissions. Electric drive had been tried but with little success. Turbo or torque converter-drive was considered the most promising of high horse-power applications.

BIOS 98, *Report on German Development of Gas Turbines for Armoured Fighting Vehicles*, pp. 3 and 13–14, gave more information on wartime development of gas turbine engines for tanks:

> During the investigation of the activities of Dr. Ing. Porsche, it was learned that he was associated with a project for the development of a gas turbine installation for the Tiger tank. The investigation was stated to be in the hands of Dipl. Ing. Otto Zadnik[...]
>
> The investigation of this target may be summed up briefly as follows:
>
> (a) Otto Zadnik was actually engaged upon the design of only one portion of the tank project, viz, the transmission. Although he had an over-riding responsibility for, and good general knowledge of the whole project, he was unable to provide details of the power unit.
>
> (b) Dr. Alfred Müller, who for some eighteen months, had been primarily responsible for turbine and turbo-blower development for aircraft (See his charter in Appendix 2) was made responsible for the design and development of the tank power unit. Dr. Müller has behind him a wide experience of gas turbines and blower development, but little or no development work appears to have been carried out on the tank motor itself. [...]
>
> (d) The torque characteristics (Scheme II), freedom from vibration, and the absence of any cooling system, make the gas turbine very attractive for tank use. [...]

During the war, Anselm Franz (Austrian, 1900–1994) developed gas turbine engines for jet fighters (Fig. 9.76). After the war, he came to the United States, where he brought the wartime dream of a gas turbine tank engine to reality. No later than 1951, he proposed the AGT1500 turboshaft engine to power U.S. tanks. After lengthy delays obtaining government funding, Franz finally demonstrated the AGT1500 engine in 1966. As shown in Fig. 7.60, the AGT1500 is still used in the M1A1 Abrams tank. Both in Germany during the war and in the United States after the war, Franz collaborated very closely with Heinrich Adenstedt (German, 1910–1991, pp. 697–698), an expert on high-temperature metal alloys.

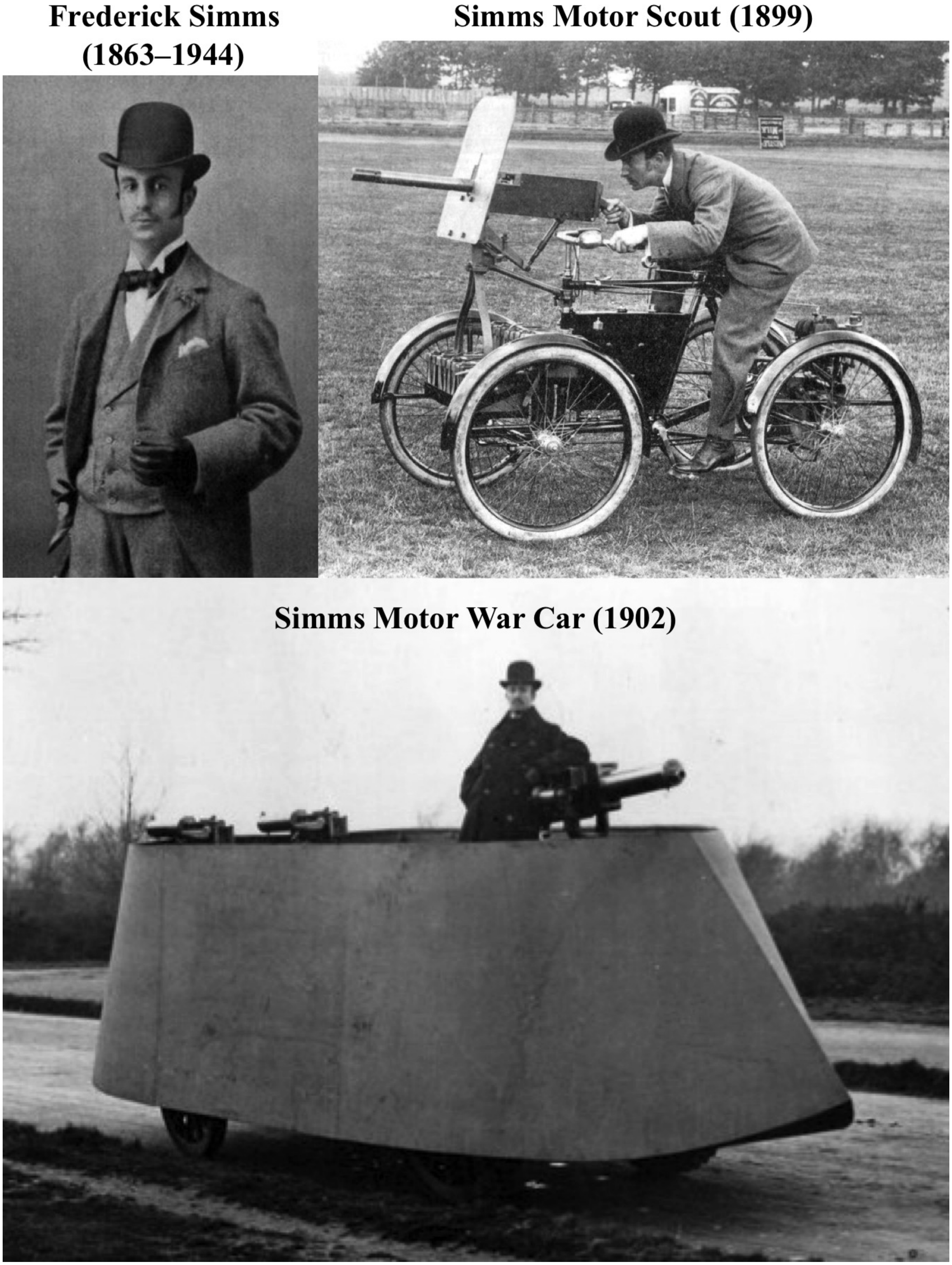

Frederick Simms (1863–1944)
Simms Motor Scout (1899)
Simms Motor War Car (1902)

Figure 7.51: Frederick Simms developed the small armed Motor Scout in 1899 and the much larger Motor War Car in 1902.

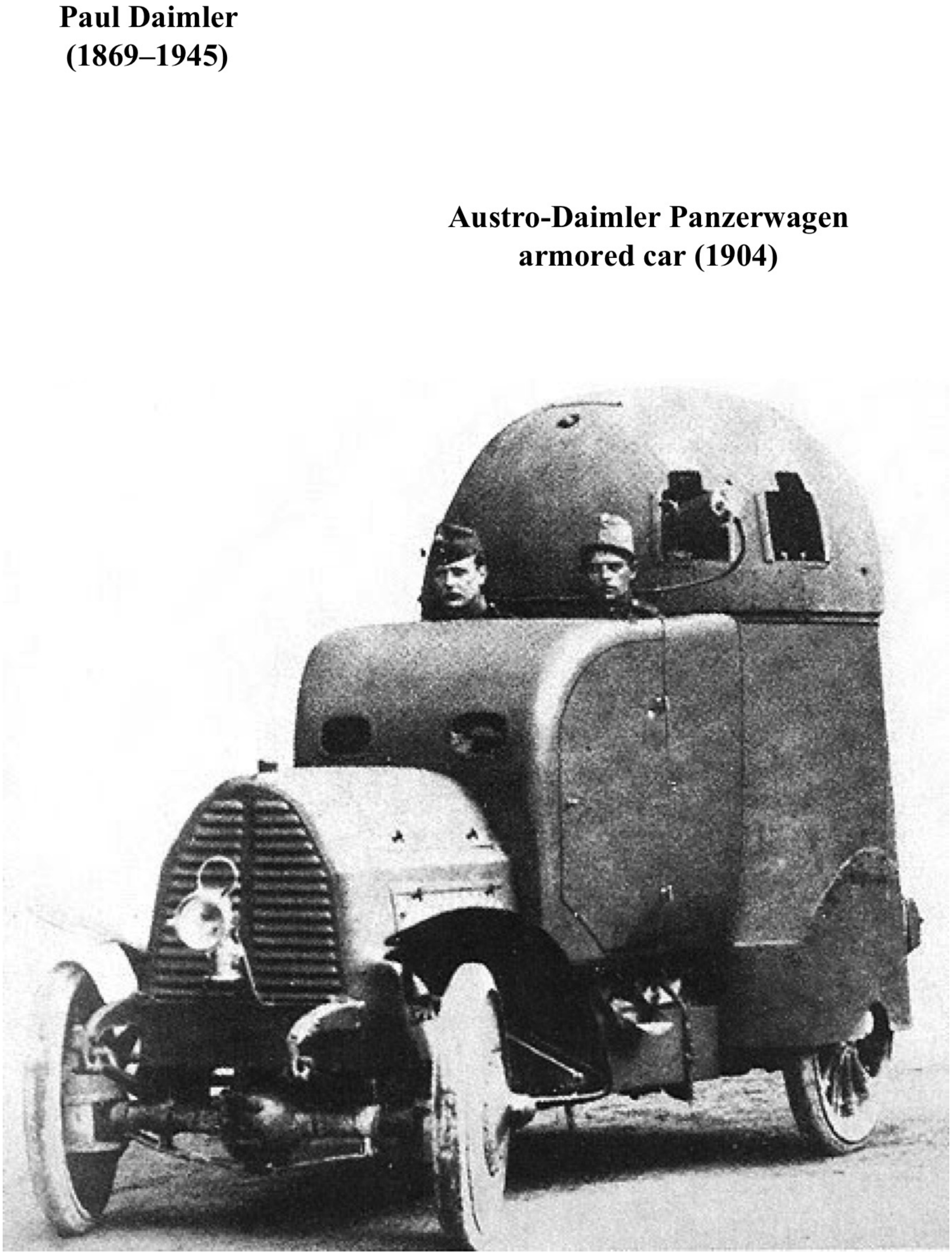

Paul Daimler
(1869–1945)
Austro-Daimler Panzerwagen
armored car (1904)

Figure 7.52: Paul Daimler and his team developed the Panzerwagen armored car in 1904.

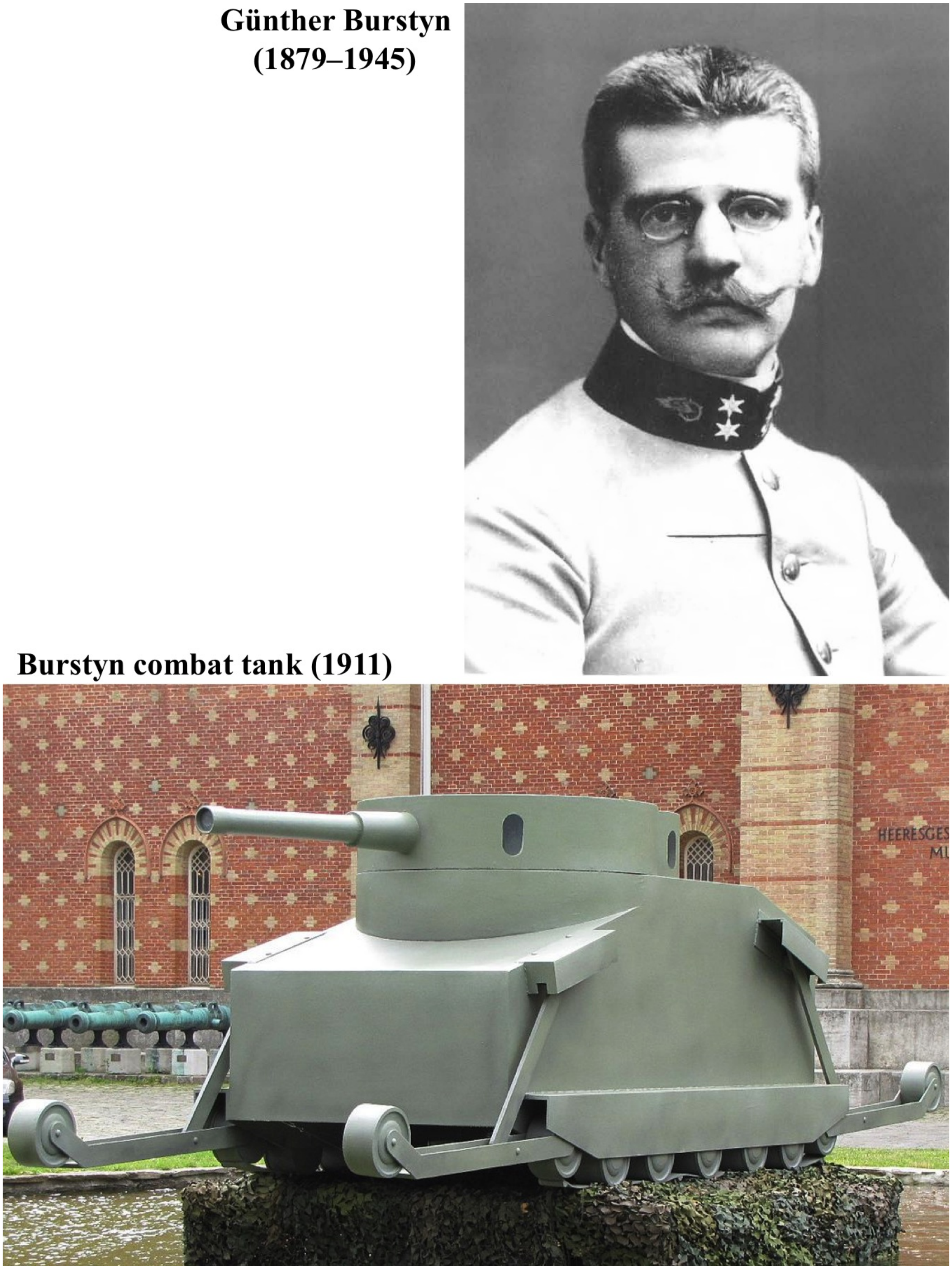
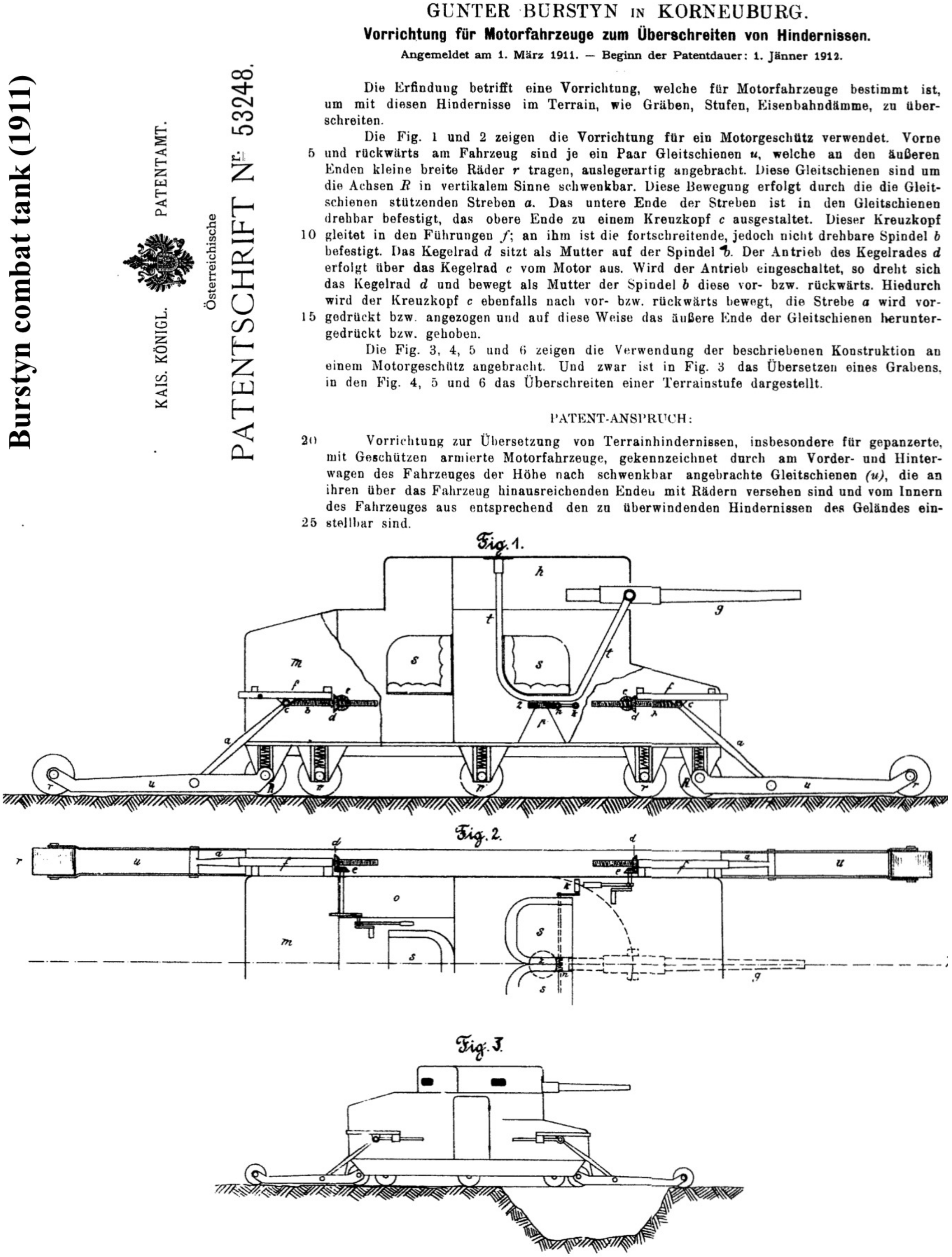

Günther Burstyn
(1879–1945)
Burstyn combat tank (1911)
HEERESGES
MU

Figure 7.53: In or before 1911, Günther Burstyn invented the first combat tank to incorporate all of the major features of modern tanks. It also had extendable wheeled beams on the front and back to aid in crossing over trenches.



Burstyn combat tank (1911)

KAIS. KÖNIGL. PATENTAMT.

Österreichische

PATENTSCHRIFT Nr 53248.

GUNTER BURSTYN in KORNEUBURG.

Vorrichtung für Motorfahrzeuge zum Überschreiten von Hindernissen.

Angemeldet am 1. März 1911. — Beginn der Patentdauer: 1. Jänner 1912.

Die Erfindung betrifft eine Vorrichtung, welche für Motorfahrzeuge bestimmt ist, um mit diesen Hindernisse im Terrain, wie Gräben, Stufen, Eisenbahndämme, zu überschreiten.

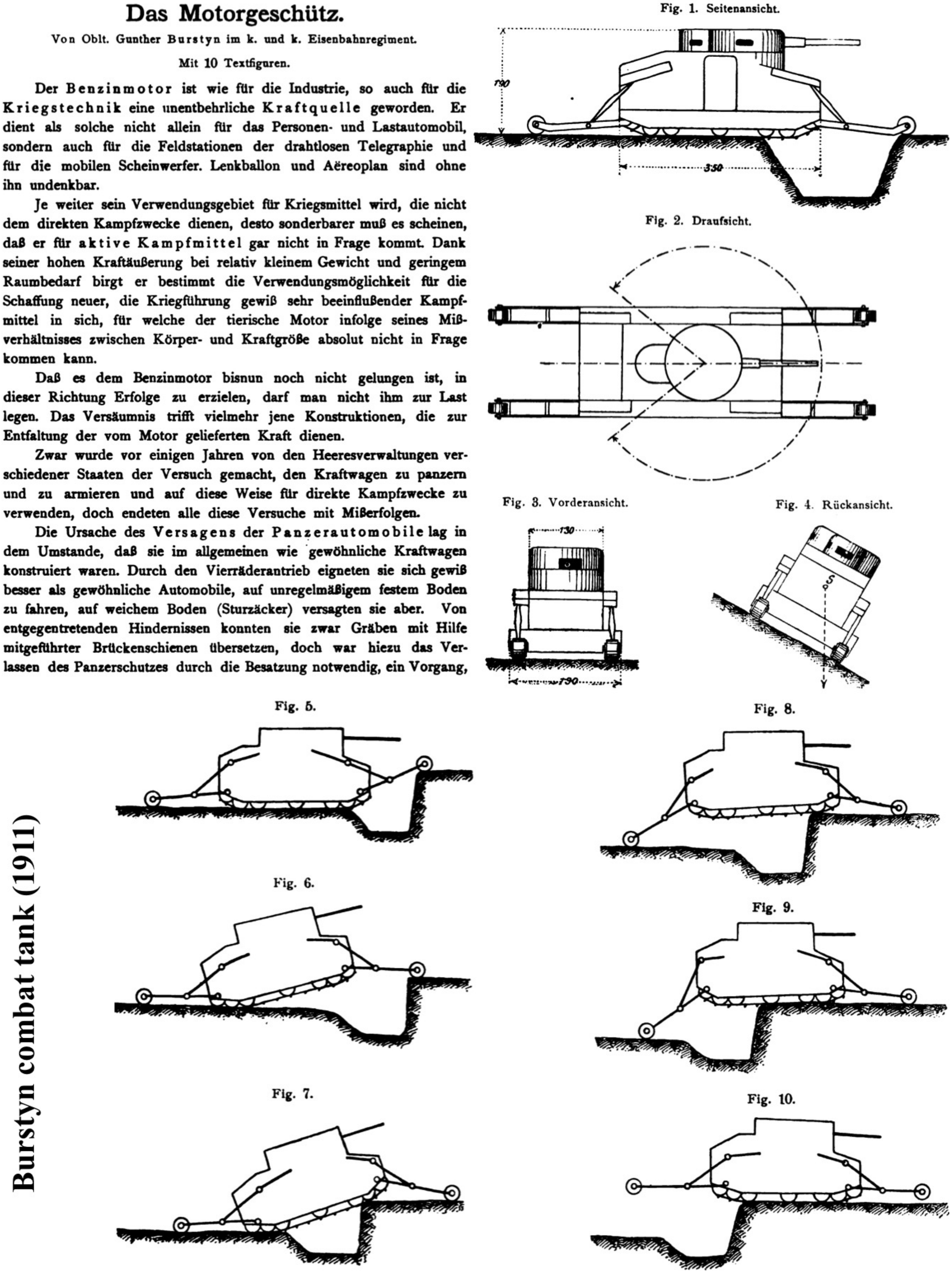
Die Fig. 1 und 2 zeigen die Vorrichtung für ein Motorgeschütz verwendet. Vorne und rückwärts am Fahrzeug sind je ein Paar Gleitschienen *u*, welche an den äußeren Enden kleine breite Räder *r* tragen, auslegerartig angebracht. Diese Gleitschienen sind um die Achsen *R* in vertikalem Sinne schwenkbar. Diese Bewegung erfolgt durch die die Gleitschienen stützenden Streben *a*. Das untere Ende der Streben ist in den Gleitschienen drehbar befestigt, das obere Ende zu einem Kreuzkopf *c* ausgestaltet. Dieser Kreuzkopf gleitet in den Führungen *f*; an ihm ist die fortschreitende, jedoch nicht drehbare Spindel *b* befestigt. Das Kegelrad *d* sitzt als Mutter auf der Spindel *b*. Der Antrieb des Kegelrades *d* erfolgt über das Kegelrad *e* vom Motor aus. Wird der Antrieb eingeschaltet, so dreht sich das Kegelrad *d* und bewegt als Mutter der Spindel *b* diese vor- bzw. rückwärts. Hiedurch wird der Kreuzkopf *c* ebenfalls nach vor- bzw. rückwärts bewegt, die Strebe *a* wird vorgedrückt bzw. angezogen und auf diese Weise das äußere Ende der Gleitschienen heruntergedrückt bzw. gehoben.

Die Fig. 3, 4, 5 und 6 zeigen die Verwendung der beschriebenen Konstruktion an einem Motorgeschütz angebracht. Und zwar ist in Fig. 3 das Übersetzen eines Grabens, in den Fig. 4, 5 und 6 das Überschreiten einer Terrainstufe dargestellt.

PATENT-ANSPRUCH:

Vorrichtung zur Übersetzung von Terrainhindernissen, insbesondere für gepanzerte, mit Geschützen armierte Motorfahrzeuge, gekennzeichnet durch am Vorder- und Hinterwagen des Fahrzeuges der Höhe nach schwenkbar angebrachte Gleitschienen *(u)*, die an ihren über das Fahrzeug hinausreichenden Enden mit Rädern versehen sind und vom Innern des Fahrzeuges aus entsprechend den zu überwindenden Hindernissen des Geländes einstellbar sind.

Figure 7.54: In or before 1911, Günther Burstyn invented the first combat tank to incorporate all of the major features of modern tanks. It also had extendable wheeled beams on the front and back to aid in crossing over trenches.



Das Motorgeschütz.

Von Oblt. Gunther Burstyn im k. und k. Eisenbahnregiment.

Mit 10 Textfiguren.

Der **Benzinmotor** ist wie für die Industrie, so auch für die **Kriegstechnik** eine unentbehrliche **Kraftquelle** geworden. Er dient als solche nicht allein für das Personen- und Lastautomobil, sondern auch für die Feldstationen der drahtlosen Telegraphie und für die mobilen Scheinwerfer. Lenkballon und Aëreoplan sind ohne ihn undenkbar.

Je weiter sein Verwendungsgebiet für Kriegsmittel wird, die nicht dem direkten Kampfzwecke dienen, desto sonderbarer muß es scheinen, daß er für **aktive Kampfmittel** gar nicht in Frage kommt. Dank seiner hohen Kraftäußerung bei relativ kleinem Gewicht und geringem Raumbedarf birgt er bestimmt die Verwendungsmöglichkeit für die Schaffung neuer, die Kriegführung gewiß sehr beeinflußender Kampfmittel in sich, für welche der tierische Motor infolge seines Mißverhältnisses zwischen Körper- und Kraftgröße absolut nicht in Frage kommen kann.

Daß es dem Benzinmotor bisnun noch nicht gelungen ist, in dieser Richtung Erfolge zu erzielen, darf man nicht ihm zur Last legen. Das Versäumnis trifft vielmehr jene Konstruktionen, die zur Entfaltung der vom Motor gelieferten Kraft dienen.

Zwar wurde vor einigen Jahren von den Heeresverwaltungen verschiedener Staaten der Versuch gemacht, den Kraftwagen zu panzern und zu armieren und auf diese Weise für direkte Kampfzwecke zu verwenden, doch endeten alle diese Versuche mit Mißerfolgen.

Die Ursache des **Versagens** der **Panzerautomobile** lag in dem Umstande, daß sie im allgemeinen wie gewöhnliche Kraftwagen konstruiert waren. Durch den Vierräderantrieb eigneten sie sich gewiß besser als gewöhnliche Automobile, auf unregelmäßigem festem Boden zu fahren, auf weichem Boden (Sturzäcker) versagten sie aber. Von entgegentretenden Hindernissen konnten sie zwar Gräben mit Hilfe mitgeführter Brückenschienen übersetzen, doch war hiezu das Verlassen des Panzerschutzes durch die Besatzung notwendig, ein Vorgang,

Figure 7.55: In or before 1911, Günther Burstyn invented the first combat tank to incorporate all of the major features of modern tanks. It also had extendable wheeled beams on the front and back to aid in crossing over trenches [Burstyn 1912].

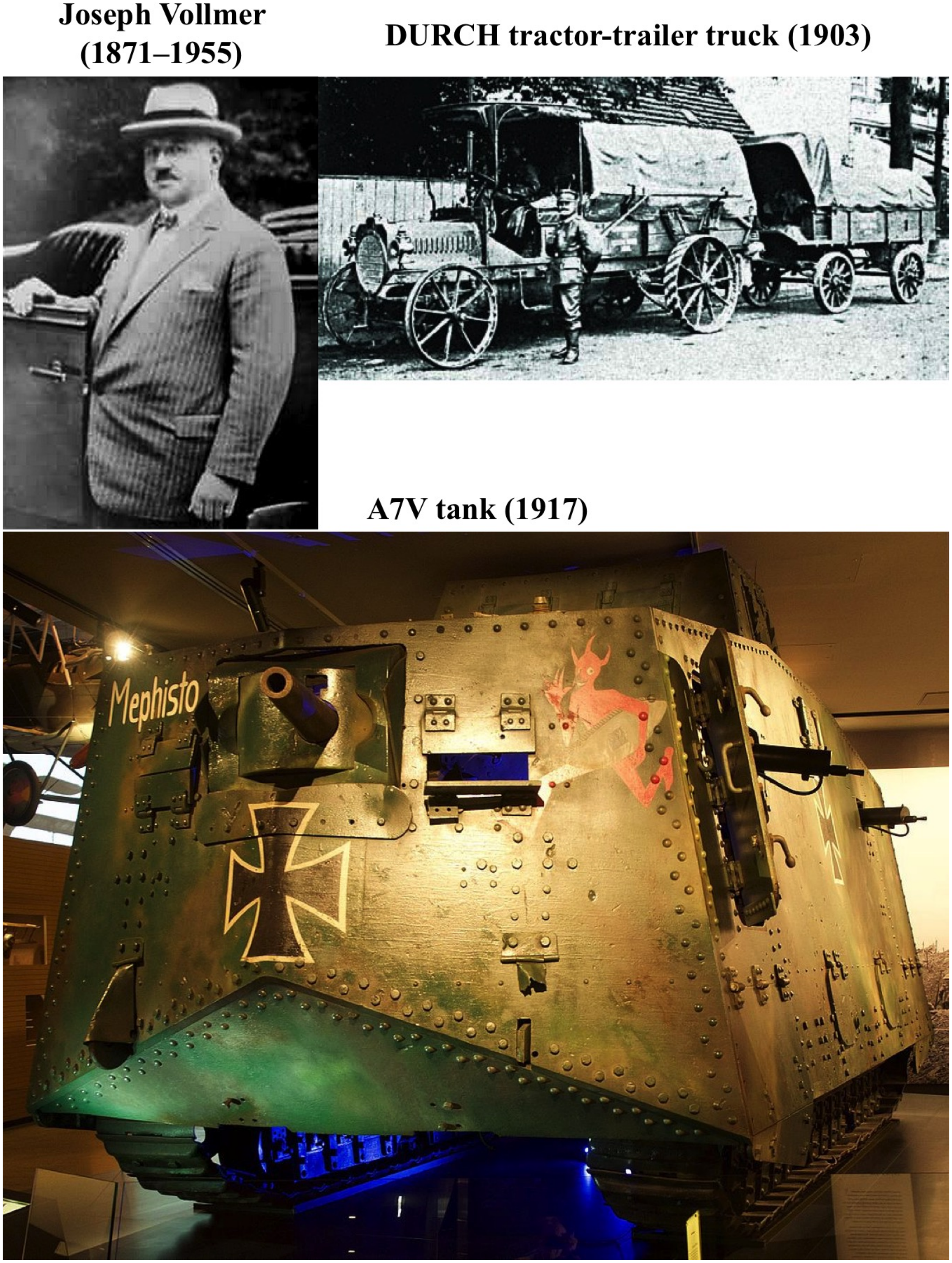

Joseph Vollmer
(1871–1955)
DURCH tractor-trailer truck (1903)
A7V tank (1917)
Mephisto

Figure 7.56: Joseph Vollmer developed the first internal-combustion-engine-powered tractor-trailer truck in 1903, then created tanks such as the A7V during World War I.

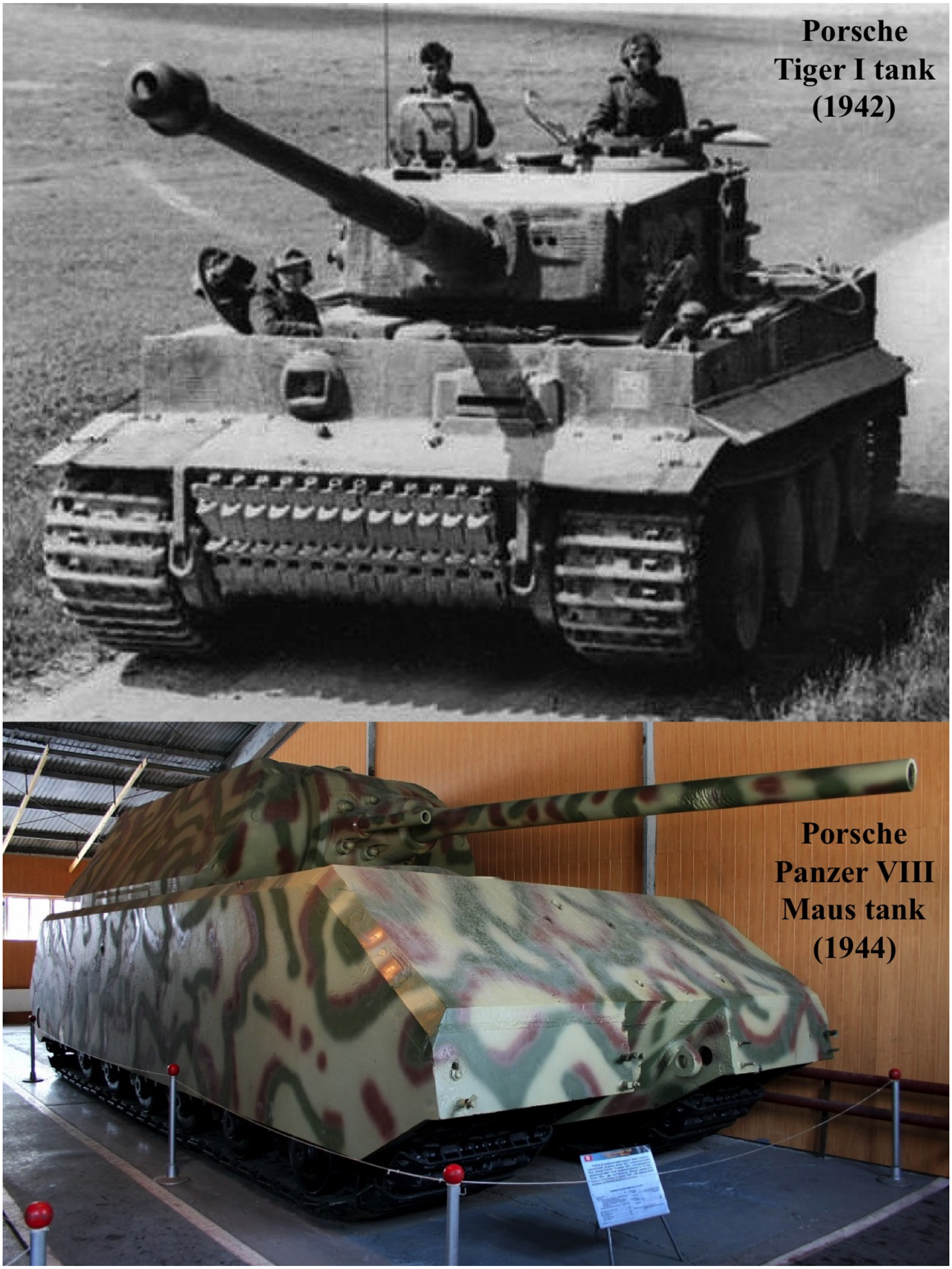
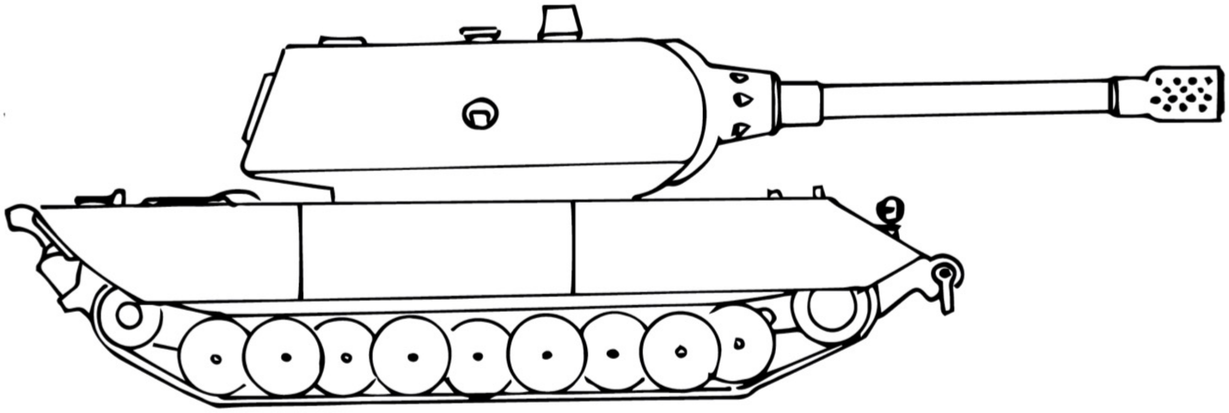

Porsche Tiger I tank (1942)
Porsche Panzer VIII Maus tank (1944)

Figure 7.57: Ferdinand Porsche, Karl Rabe, and their team developed advanced tanks such as the Tiger I 57-ton tank and the Panzerkampfwagen VIII Maus prototype 188-ton tank (now in the Kubinka Tank Museum) during World War II.



Henschel Panzerkampfwagen E-100 tank prototype (1945)

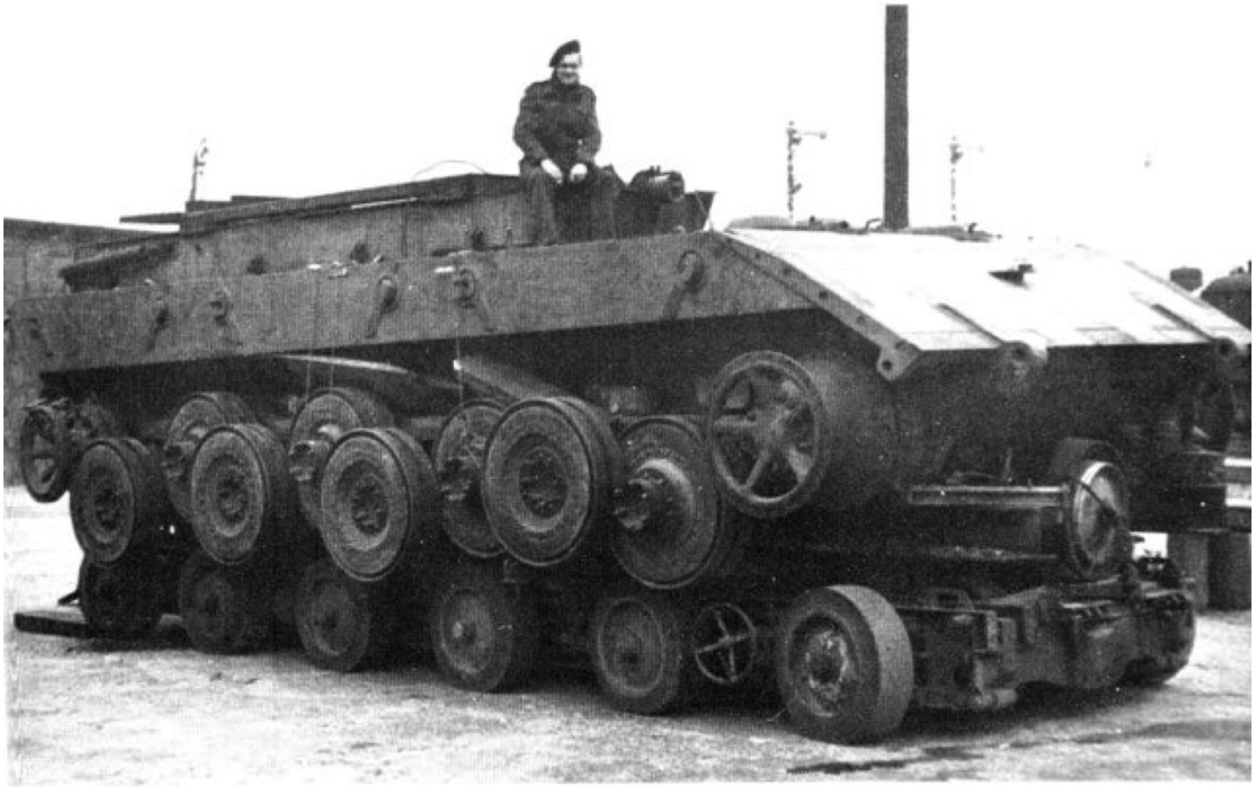
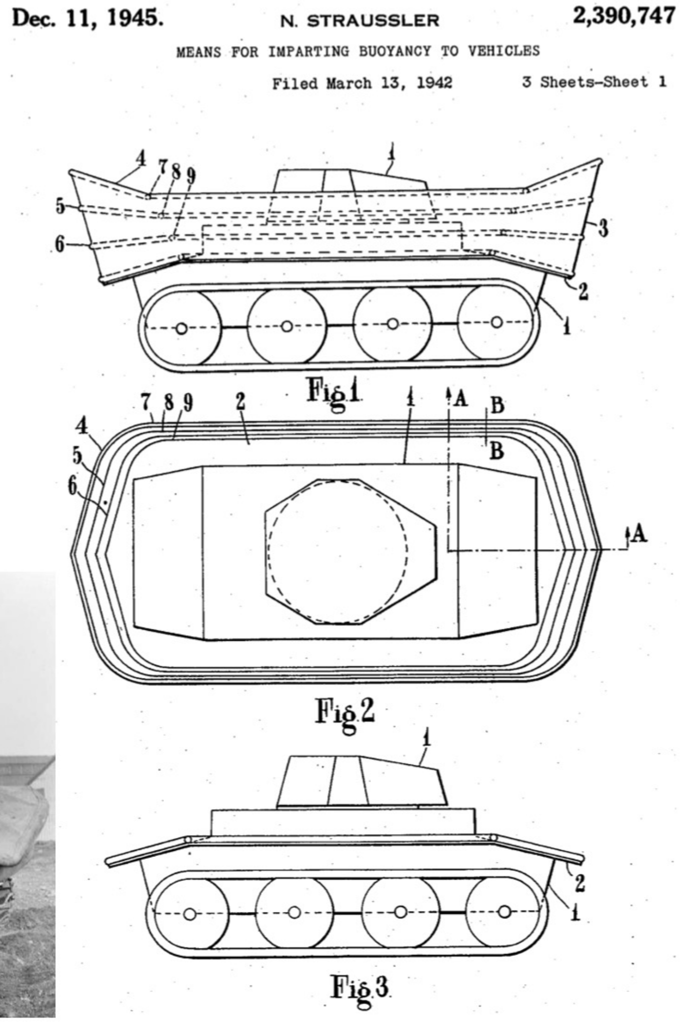


Figure 7.58: A Henschel Panzerkampfwagen E-100 140-ton tank prototype was taken by British troops at the end of World War II (shown on top of a trailer, without the turret and treads).

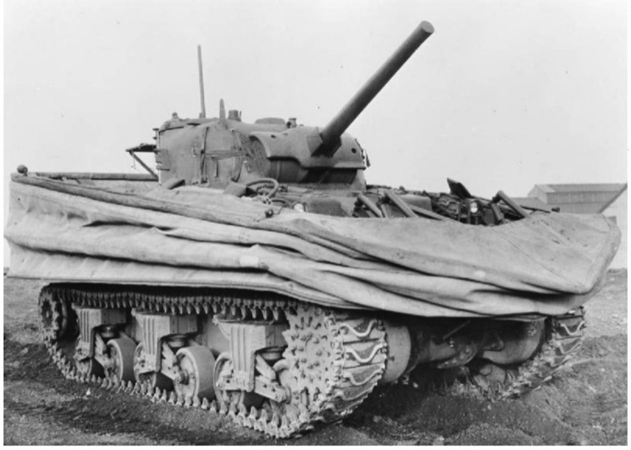
Nicholas Straussler (1891–1966)
Duplex drive (DD) amphibious tanks (1940–1944)



Dec. 11, 1945. N. STRAUSSLER 2,390,747

MEANS FOR IMPARTING BUOYANCY TO VEHICLES

Filed March 13, 1942 3 Sheets-Sheet 1



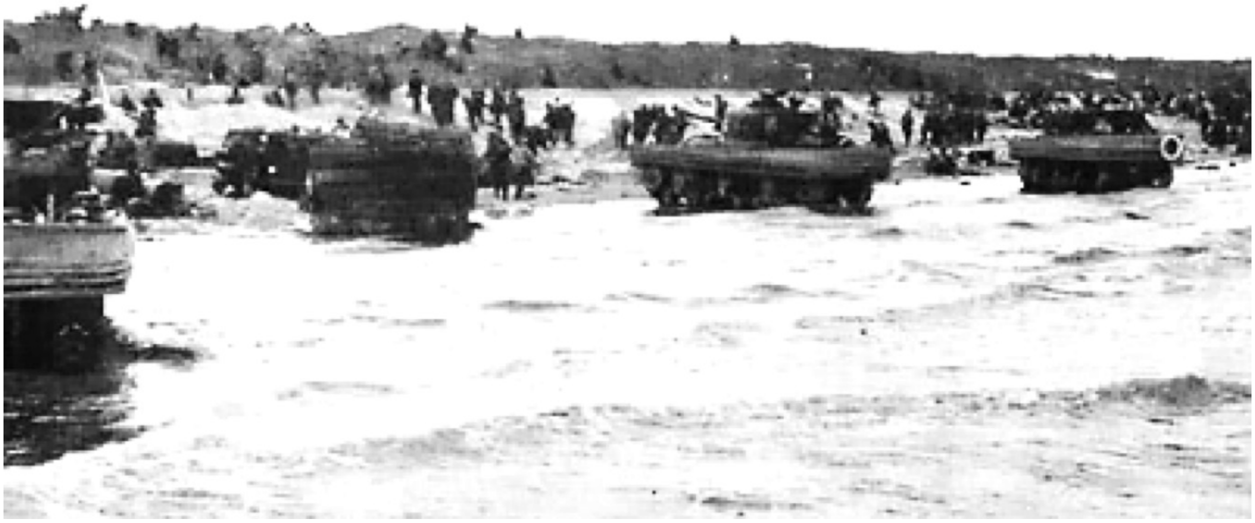


Figure 7.59: Nicholas Straussler emigrated to the United Kingdom and developed the duplex drive (DD) amphibious tanks that were used by Allied forces for the invasion of Normandy.

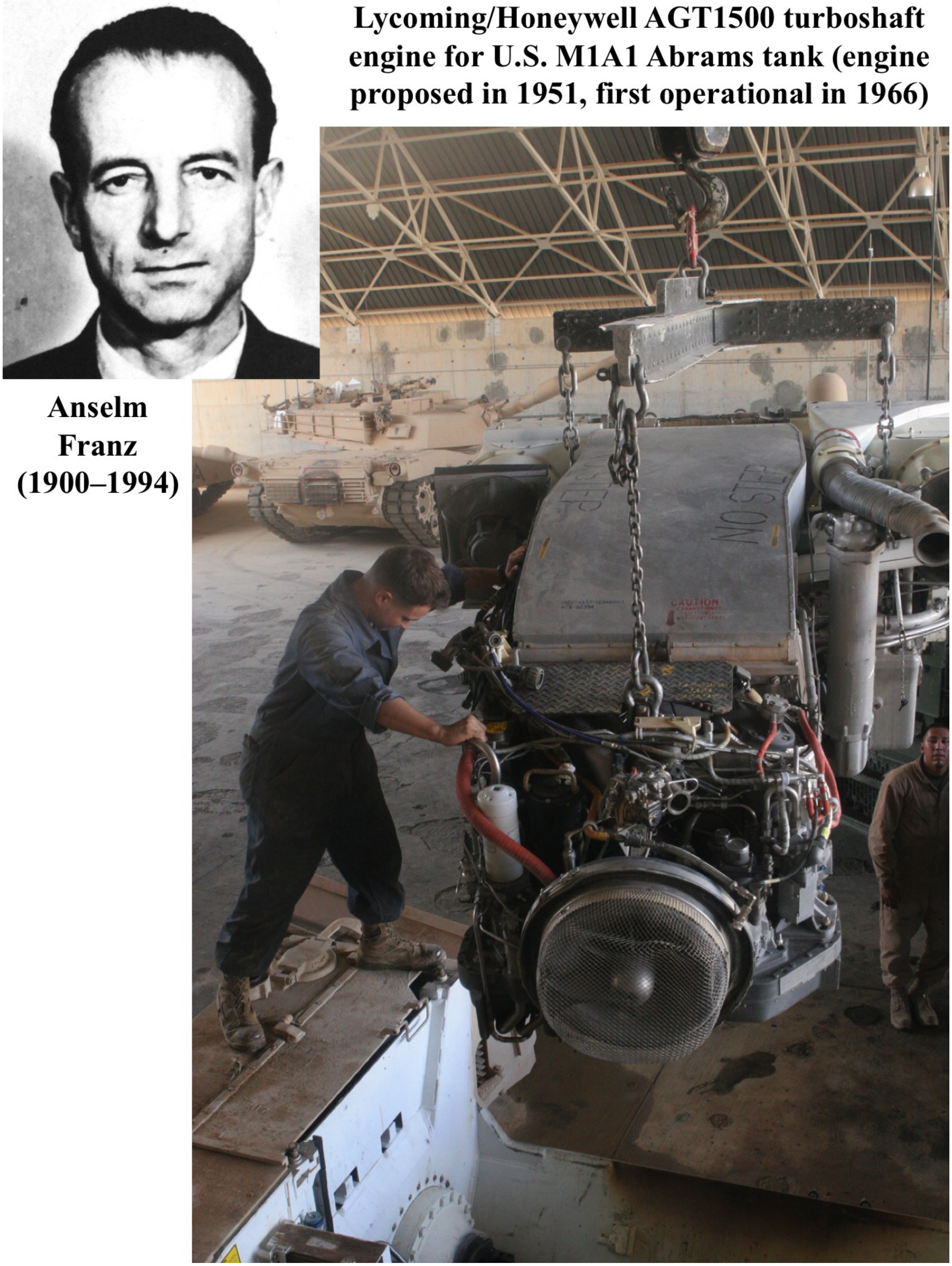

Lycoming/Honeywell AGT1500 turboshaft engine for U.S. M1A1 Abrams tank (engine proposed in 1951, first operational in 1966)
Anselm Franz (1900–1994)
NO STEP
NO STEP
CAUTION

Figure 7.60: Anselm Franz developed the AGT1500 turboshaft engine that is still used in the U.S. M1A1 Abrams tank.

7.3.4 Diesel Train Locomotives

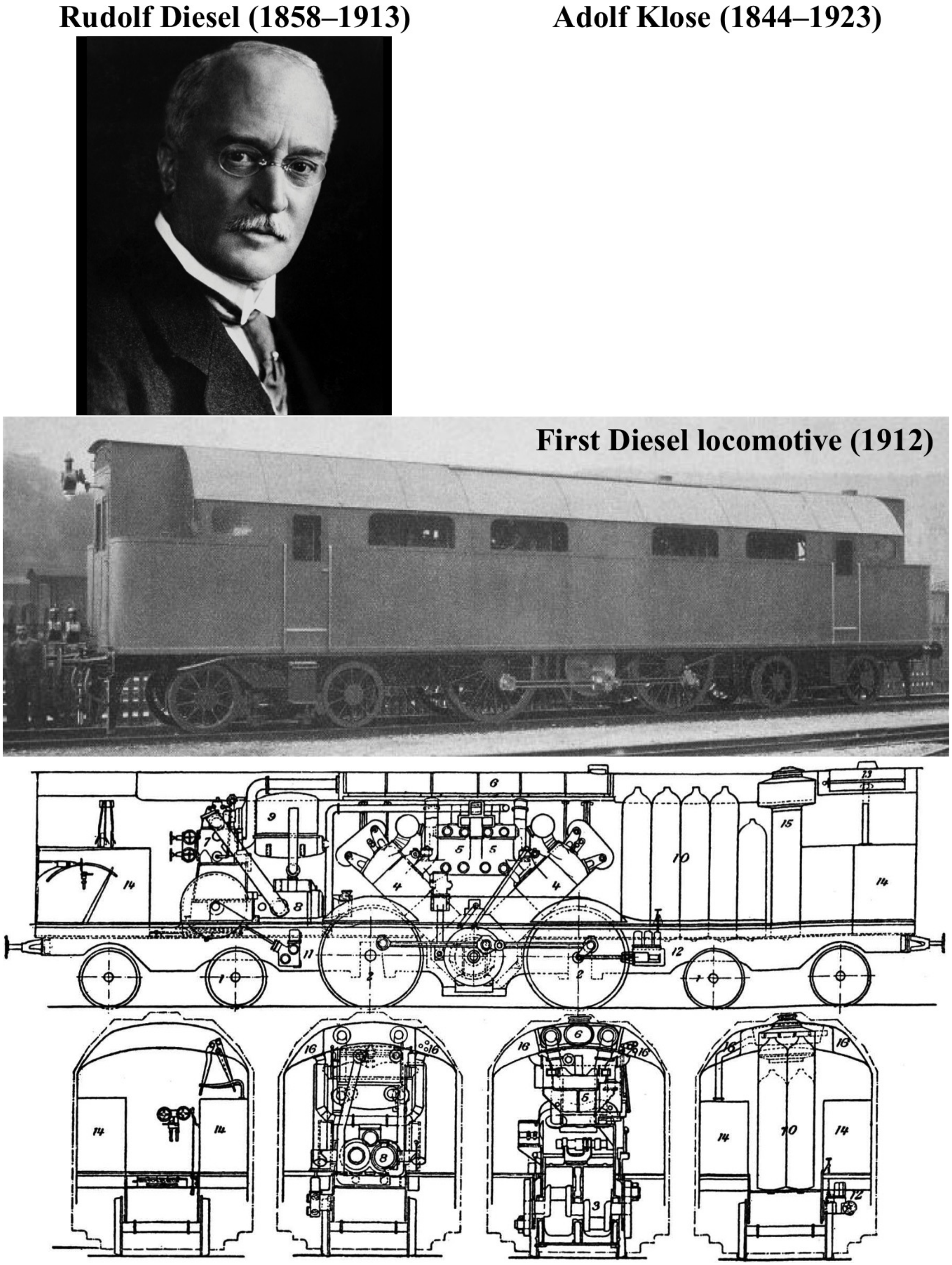
German-speaking creators were responsible for adapting Diesel internal combustion engines to locomotives, where they continue to be used worldwide.

In 1912, Rudolf Diesel (German, 1858–1913) and Adolf Klose (German, 1844–1923) developed the first Diesel locomotive, shown in Fig. 7.61. The shaft of a Diesel engine rotates at high speeds and produces relatively small amounts of torque or force, yet a locomotive's wheels must rotate at relatively low speeds and apply large amounts of torque. Therefore, Diesel and Klose had to build an elaborate gear system to convert the high-speed, low-torque rotation of the engine shaft to low-speed, high-torque rotation of the wheels.

As illustrated in Fig. 7.62, in 1914 Hermann Lemp (Swiss, 1862–1954) developed the Diesel-electric drive for trains. Lemp's design used the Diesel engine to power an electric generator, then used that electricity to run electric motors connected to the wheels. Lemp's approach eliminated the need for a complex gearing system, since the electric generator could receive high-speed, low-torque power from the Diesel engine and produce electricity to power low-speed, high-torque electric motors attached to the wheels. In other words, the electric generator essentially took the place of the earlier gearing system. From 1920 onward, Lemp designed a number of Diesel-electric locomotives for the General Electric company in the United States. Diesel-electric locomotives rapidly replaced pure Diesel locomotives and any remaining steam locomotives, and they continue to dominate train systems around the world.

Werner von Siemens (German, 1816–1892) built the first electric train in 1879 and filed a patent application on electric trains in 1884 [Bähr 2016; von Siemens 1895]. See Fig. 6.3. His company built electric trains and systems for cities in Europe and North America.

Alfred Zehden (German, 1876–19??) invented magnetic levitation (maglev) trains in 1902 (p. 3204). Hermann Kemper (German, 1892–1977) patented improved maglev train systems in 1934 (p. 3213). From currently available documentation, it is not clear how far Zehden and Kemper got with actually building and testing maglev train systems, but their designs and principles have guided that technology ever since.


Rudolf Diesel (1858–1913)
Adolf Klose (1844–1923)
First Diesel locomotive (1912)
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2
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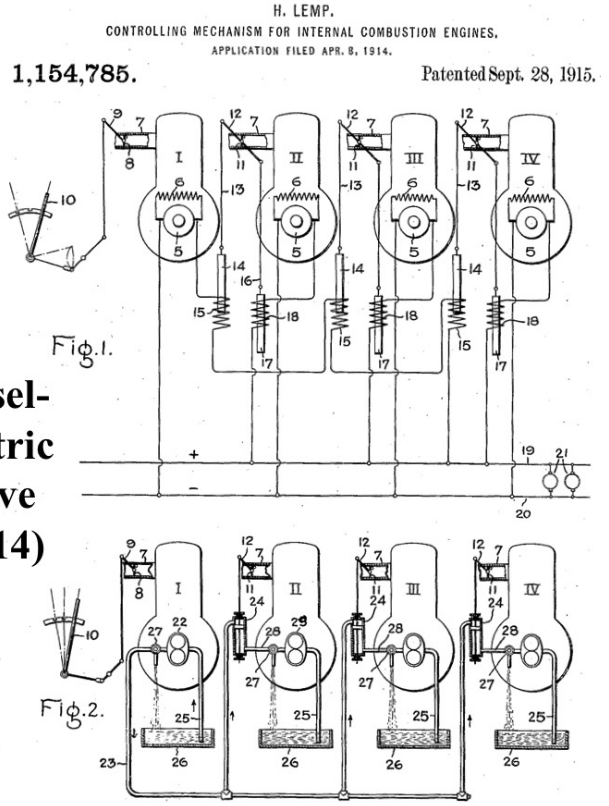
Figure 7.61: Rudolf Diesel and Adolf Klose developed the first Diesel locomotive in 1912.

Hermann Lemp (1862–1954)



H. LEMP.
CONTROLLING MECHANISM FOR INTERNAL COMBUSTION ENGINES.
APPLICATION FILED APR. 8, 1914.
1,154,785. Patented Sept. 28, 1915.

Fig.1.
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Fig.2.
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Diesel-electric drive (1914)

Lemp designed General Electric (GE) Diesel-electric locomotives (1920 onward)

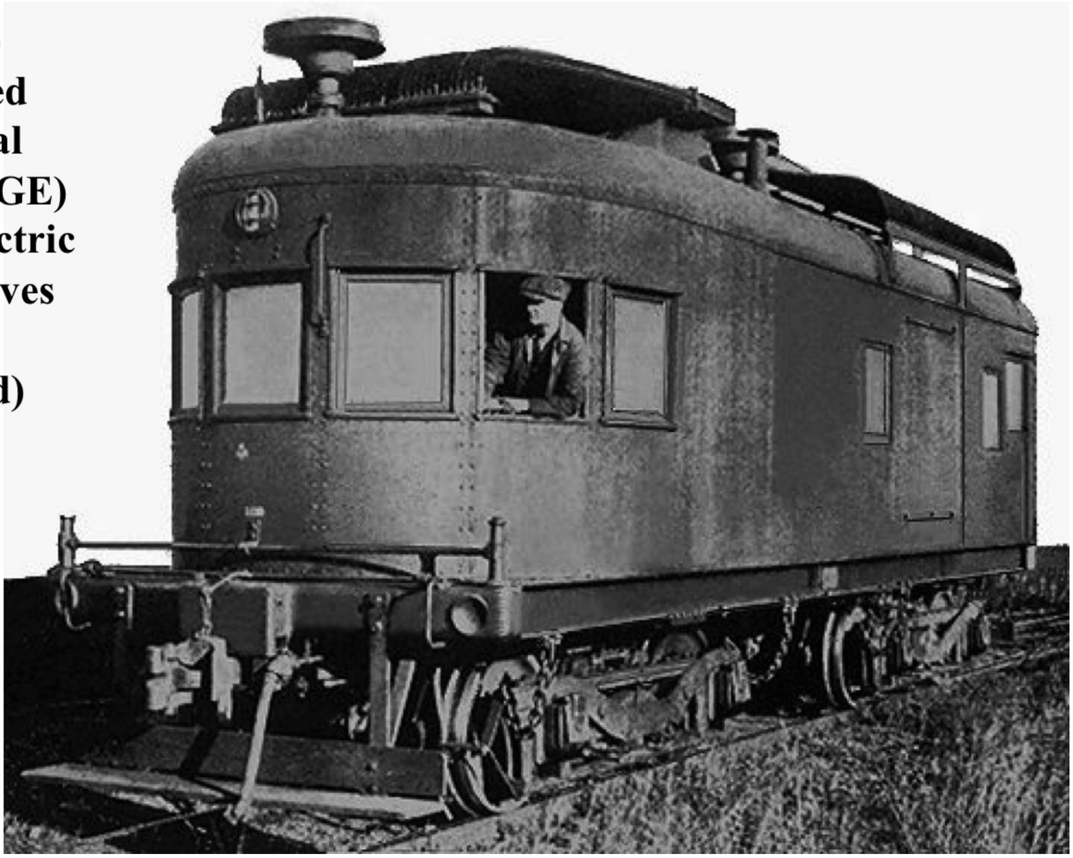


Figure 7.62: Hermann Lemp developed the Diesel-electric drive in 1914 and designed Diesel-electric locomotives for General Electric from 1920 onward.

7.4 Heat Transfer

Heat, or thermal energy, may be transferred from one place to another by several different mechanisms. As illustrated in Fig. 7.63, those mechanisms include:

(a) Conduction

(b) Forced convection

(c) Natural convection

(d) Condensation and evaporation

(e) Boiling

(f) Thermal radiation

For each type of heat transfer, the rate at which thermal energy is transferred depends in fairly complex ways on several different factors, such as the temperature difference, the composition of the materials involved, the surface area, and other variables. In general, heat transfer rates were first measured in a wide range of situations, and then the principles of physics were used to derive suitable equations to explain, extend, and generalize those empirical results. Those equations often involved "dimensionless numbers," or ratios of several parameters such that the measured dimensions cancel out, leaving only a number whose size governs the rate of heat transfer.

Once the heat transfer mechanisms were properly understood, they exploited to design cooling fins, heat exchangers, and other systems to control and utilize heat transfer. Heat transfer technology has enabled countless applications in the modern world, such as: thermal energy transport in heat engines and refrigerators; cooling of integrated circuit chips, nuclear reactors, and engines; and insulation of everything from thermos bottles to buildings.

Some of the earliest mathematical analyses of heat transfer were conducted by French scientists such as Jean Baptiste Biot (1774–1862) and Joseph Fourier (French, 1768–1830), although they had few successors, probably due to the long-term political turmoil in France. Some British scientists such as Osborne Reynolds (English, 1842–1912) and Thomas Edward Stanton (English, 1865–1931) also made relevant discoveries, yet their numbers were kept small by the relatively limited and focused British support for scientific research.

In contrast, the German-speaking world made a large number of contributions to heat transfer, due to its large-scale, long-term support for research in closely related fields such as internal combustion engines, aircraft engines, rocket engines, nuclear energy, aerodynamics, and other areas. Just a few illustrative examples of German-speaking scientists who carried out measurements and calculations of different modes of heat transfer are shown in Fig. 7.64 and discussed below.

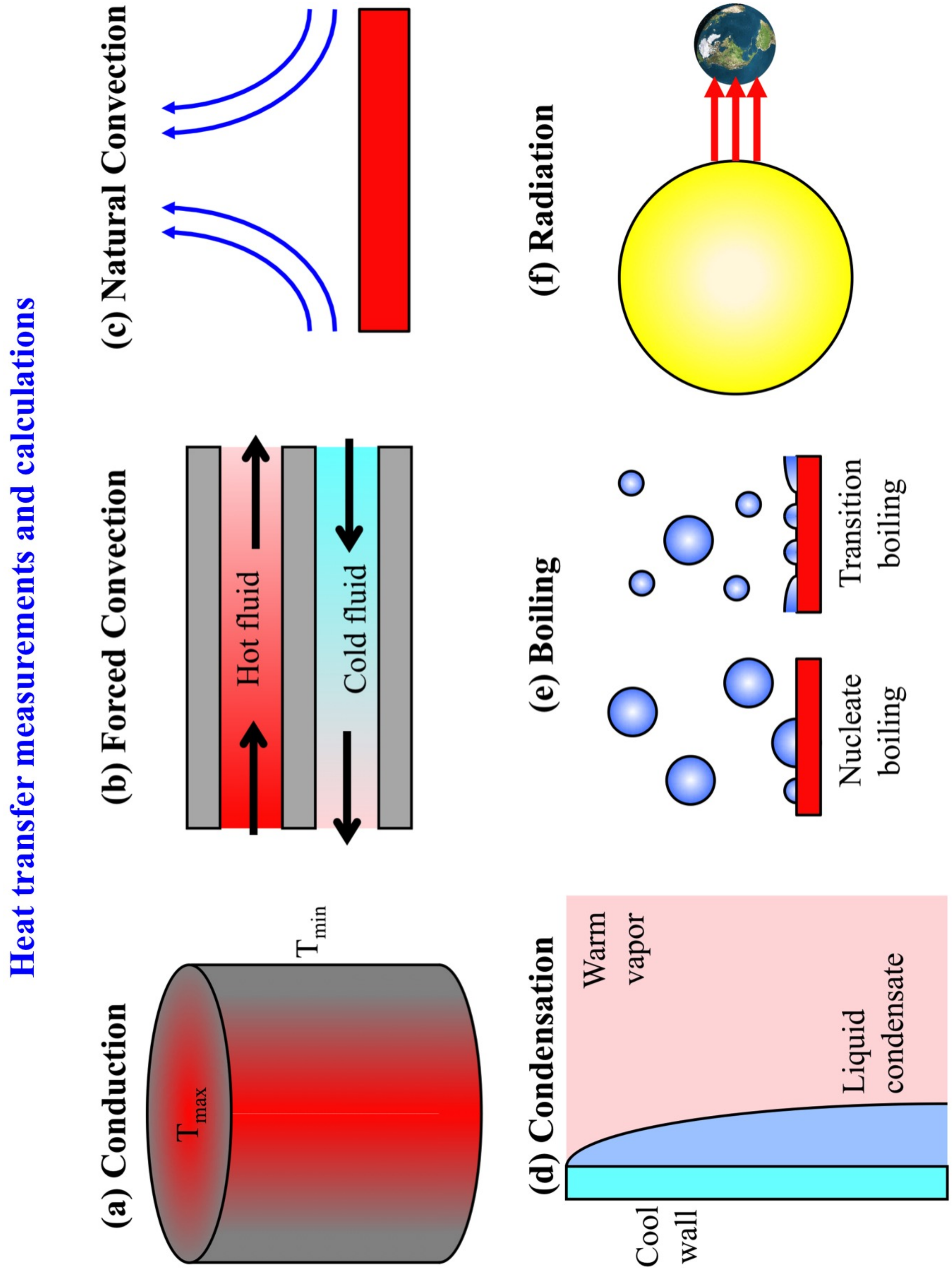

Heat transfer measurements and calculations
(a) Conduction
T_{max}
T_{min}
(b) Forced Convection
Hot fluid
Cold fluid
(c) Natural Convection
(d) Condensation
Warm vapor
Liquid condensate
Cool wall
(e) Boiling
Nucleate boiling
Transition boiling
(f) Radiation

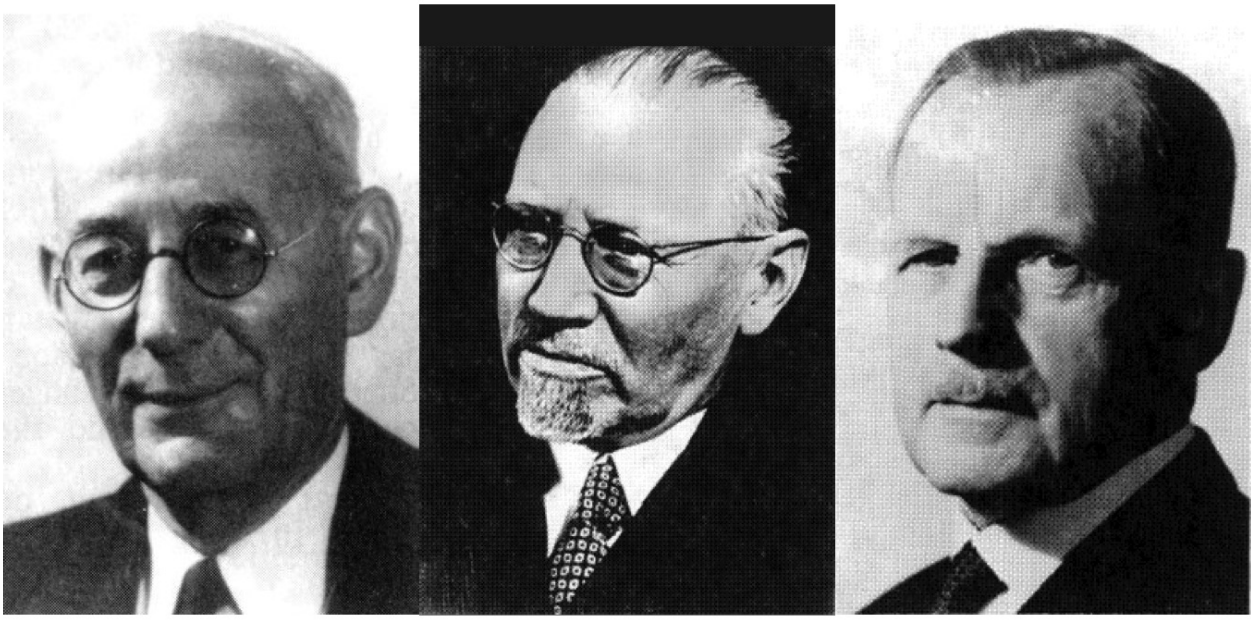
Figure 7.63: Heat, or thermal energy, may be transferred from one place to another by mechanisms such as (a) conduction, (b) forced convection, (c) natural convection, (d) condensation/evaporation, (e) boiling, and (f) thermal radiation.

Heat transfer measurements and calculations

Ernst Eckert (1904–2004)

Leo Graetz (1856–1941)

Franz Grashof (1826–1893)



Max Jakob (1879–1955)

Wilhelm Nusselt (1882–1957)

Ernst Schmidt (1892–1975)

Figure 7.64: Scientists such as Ernst Eckert, Leo Graetz, Franz Grashof, Max Jakob, Wilhelm Nusselt, and Ernst Schmidt carried out measurements and calculations of different modes of heat transfer.

Ernst Eckert (Austrian/German, 1904–2004) studied the fundamental principles of heat transfer and then applied those to jet engines during World War II. After the war, he came to the United States, where he continued his research on heat transfer and its applications. A dimensionless number, the Eckert number, is named in his honor and still widely used in calculating heat transfer dissipation during fluid flow. His obituary provided some details from his life [Jean 2004]:

> Ernst R.G. Eckert's 100th birthday party and symposium will continue as planned in September despite the July 8 death of the internationally renowned aeronautical research scientist and University of Minnesota professor emeritus.
>
> The West St. Paul resident was a specialist in heat transfer—the process in which heat moves from one medium to another—and was recognized for exploring new methods of cooling jet turbines so they wouldn't burn up in space.
>
> Eckert's seven decades of research and more than 550 published scientific papers and books significantly contributed to the development of thermodynamics. He developed the "Eckert Number"—a formula used to calculate high-speed heat transfers.
>
> "One of the things my father was proudest of was that he changed the field of thermodynamics," said Karin Winter, one of Eckert's daughters who was visiting from her home in Amherst, Mass. "My father was extremely modest, and he had a lot of grace, so people loved him. He was always forward-looking and positive."
>
> She recalled that when she was a German literature student at Stanford University, mechanical engineering students would ask her to autograph her father's textbooks. Eckert, a native of Prague, Czechoslovakia, (then part of the Austria-Hungary Dual Monarchy), graduated from the German Institute of Technology in Prague in 1927 and received his doctorate in 1931.
>
> "He used to joke with us kids that he changed citizenship several times without ever leaving home," Winter said.
>
> He was a World War II rocket and jet engine scientist at the Aeronautical Research Institute in Braunschweig, Germany, beginning in 1938 and professor at the German Institute of Technology.
>
> Eckert also held a place in history because he was one of more than 200 German scientists the U.S. government invited here after the war in 1945 under "Operation Paperclip." He joined the staff of Wright-Patterson Air Force Base in Dayton, Ohio, to continue his research on jet propulsion. He became a U.S. citizen in 1950.
>
> He joined the University of Minnesota in 1951 and became one of its first Regents' professors in the late 1960s. Later, Eckert became involved in researching how to turn solar energy into electric power.
>
> "He was an excellent teacher," said University of Minnesota Professor Emeritus Emil Pfender, who worked with Eckert for more than 30 years in the mechanical engineering

> department. “People really enjoyed his lectures because he really could explain things very well.”
>
> Eckert received several honorary doctorate degrees and awards, including the American Society of Mechanical Engineers’ first Max Jakob medal for outstanding engineering in 1961, and a Fulbright Award in 1962.

Leo Graetz (German, 1856–1941) conducted research in heat conduction, thermodynamics, radiation and radiative heat transfer, frictional heating, and many other areas of physics and engineering. His name remains associated with the Graetz number, a dimensionless number that is helpful in calculating heat transfer in heat exchanger pipes. The *Journal of Heat Transfer* described him as one of the pioneers of heat transfer [http://www.seas.ucla.edu/jht/pioneers/pioneers.html]:

> Leo Graetz was a German Physicist born at Breslau, Germany on September 26, 1856. He studied Mathematics and Physics at Breslau, Berlin and Strassburg. In 1881, he became the assistant to A. Kundt at Strassburg and in 1883 he went to the University of München where he became a Professor in 1908 and occupied the Second Chair for Physics parallel to Roentgen. His scientific work was first concerned with the fields of heat conduction, radiation, friction and elasticity. After 1890, his work focused upon problems of electromagnetic waves and cathode rays.

Franz Grashof (German, 1826–1893) made major discoveries across several fields in engineering, including heat transfer, fluid mechanics, the strength of materials, and other topics. He is memorialized with the Grashof number, a dimensionless number that is important in calculations of natural convection. The American Council of Learned Societies listed some of his important contributions [ACLS 2000, p. 369]:

> Studied and taught at the Gewerbe-Institut in Berlin; director of Office of Weights and Measures. Founding member (1856), editor, and long-time director of the Verein Deutscher Ingenieure (VDI). Later taught at the Polytechnikum in Karlsruhe. Authority on mechanical engineering in its broadest sense. Influenced a generation of engineers by bringing mathematical and scientific considerations to the burgeoning problems of the steam-engine age. Was first to present fundamental equations of theory of elasticity, in a text on strength of materials. Name perpetuated in the dimensionless Grashof number of heat transfer in free-convection flow systems for the transition from laminar to turbulent flow, and the Grashof criterion used in kinematics for establishing whether one link of a four-bar chain can rotate completely.

Max Jakob (German, 1879–1955) worked on many mechanisms and applications of heat transfer over his long career. In 1936, he fled Germany for the United States, where he continued his research for many more years. His name is tied to the Jakob number, a dimensionless number that is extremely useful for calculating heat transfer involving condensation or evaporation. The *Journal of Heat Transfer* explained Jakob’s importance for the field of heat transfer [http://www.seas.ucla.edu/jht/pioneers/pioneers.html]:

> Max Jakob was a German Physicist, born July 20, 1879, in Ludwigshafen, Germany. He studied Electrical Engineering at the Technical University of Munchen where he

> graduated in 1902. He was awarded a Diploma Ingenieur in Applied Physics in 1903, and the degree of Doctor Ingenieur in 1904. From 1903 until 1906, he was an assistant to O. Knoblauch at the Laboratory for Technical Physics and later joined the Physikalisch-Technische Reichsanstalt at Berlin-Charlottenburg in 1910, where he started his career in thermodynamics and heat transfer. He conducted a large amount of important work in these fields, covering such areas as steam and air at high pressure, devices for measuring thermal conductivity, the mechanisms of boiling and condensation, flow in pipes and nozzles and much more. During this time, he wrote over 200 technical papers and was a prolific source of critical reviews, articles and discussions. In 1936, he emigrated to the United States, and began a one-year lecture tour sponsored by ASME. He became a research professor at the Illinois Institute of Technology and a Consultant in Heat Transfer Research for the Armour Research Foundation. In 1942, he founded and became the first director of IIT's Heat Transfer Laboratory. His long years of research resulted in significant contributions to the literature of the profession; nearly 500 books, articles, reviews and discussions have been published bearing his name.

Wilhelm Nusselt (German, 1882–1957) made numerous important discoveries in heat transfer, including several different heat transfer mechanisms and applications. He is remembered with the Nusselt number, the ratio of convective vs. conductive heat transfer. The American Council of Learned Societies summarized his contributions [ACLS 2000, p. 654]:

> Studied mechanical engineering at Technischen Hochschulen of Munich and Charlottenburg (Berlin); received doctorate from Munich (1907). Held various teaching and industrial positions until 1925, when he was named to the chair in theoretical mechanics at the Technische Hochschule in Munich (retired 1952). Nusselt was the first significant contributor to the subject of analytical convective heat transfer. In "The Basic Law of Heat Transfer" (1915) he set up the dimensionless functional equations for both natural and forced convection, thus making it possible for experimentalists to generalize limited data; in "The Film Condensation of Steam" (1916) he provided a simple description of the film condensation of any liquid by linearizing the temperature profile and ignoring inertia in the liquid. He later provided an important description of the similarity between heat and mass transfer (1930), and published a book on technical thermodynamics (2 vols.; 1934, 1944).

Ernst Schmidt (German, 1892–1975) worked on conduction, convection, condensation, and radiative heat transfer, discovering important new information on each of those mechanisms. His name remains associated with the Schmidt number, a dimensionless number that makes an analogy between mass transfer and heat transfer. The *Journal of Heat Transfer* lauded his accomplishments [http://www.seas.ucla.edu/jht/pioneers/pioneers.html]:

> Ernst Schmidt was a German scientist and pioneer in the field of Engineering Thermodynamics, especially in Heat and Mass Transfer. He was born on February 11, 1892 at Vogelsen, near Luneburg, Germany. He studied Civil and Electrical Engineering at Dresden and Munchen and joined the Laboratory for Applied Physics at the Technical University, Munchen, in 1919 (which was then under the direction of Oscar Knoblauch). One of his early research efforts there was a careful measurement of the radiation properties of solids, which caused him to propose and develop the use of aluminum foil as

> an effective radiation shield. In 1925, he received a call to come serve as Professor and Director of the Engineering Laboratory at the Technical University in Danzig. Here he published papers on the now well known "Graphical Difference Method for Unsteady Heat Conduction" and on "The Schlieren and Shadow Method" to make thermal boundaries visible and to obtain local heat-transfer coefficients. He was the first to measure the velocity and temperature field in a free convection boundary layer and the large heat-transfer coefficients occurring in droplet condensation. A paper pointing out the analogy between heat and mass transfer caused the dimensionless quantity involved to be called the "Schmidt Number." In 1937, he became the Director of the Institute for Propulsion of the newly founded Aeronautical Research Establishment at Braunschweig and Professor at the University there. In 1952, Schmidt occupied the Chair for Thermodynamics at the Technical University of München which before him had been held by Nusselt. Being strongly involved in the development of the international steam tables, Schmidt continued his scientific activity after his retirement in 1961 and until his death in 1975. In recognition of his work, he received numerous honors and awards, including the Ludwig Prandtl Ring, the Max Jakob Award and the Grashof Commemorative Medal.

In the German-speaking world, there was an enormous amount of overlap between investigations of the fundamental mechanisms of heat transfer and research on many examples and applications of heat transfer, including:

- High-temperature and high-pressure chemistry (Section 3.2)
- Physical chemistry (Section 3.6)
- High-temperature ceramics (p. 667)
- High-temperature metal alloys (p. 689)
- Heat transfer within the Earth, ocean, atmosphere, and extraterrestrial bodies (Chapter 4)
- Thermal physics (Section 5.5)
- Internal combustion engines (Section 7.3)
- Nuclear engineering (Sections 8.7, 8.8, and 8.9)
- Aerodynamics (Section 9.2)
- Jet engines (Section 9.3)
- Rocket engines (Sections 9.6, 9.7, 9.8, 9.9, and 9.10)

7.5 Civil Engineering and Architecture

German-speaking creators made numerous important contributions in the areas of civil engineering and architecture.[5] Only a few illustrative examples are discussed in this section:

7.5.1. Stress, strain, and bridge design

7.5.2. Autobahn high-speed road system

7.5.3. Kitchen design

7.5.4. Other creations in civil engineering and architecture

7.5.1 Stress, Strain, and Bridge Design

Figure 7.65 shows examples of German-speaking scientists who made measurements and developed mathematical formulas for various types of stress and strain in materials:

- August Wöhler (1819–1914) analyzed the bending or deflection of beams under stress, and also produced curves showing the effects of fatigue or repeated stresses in metals.
- Franz Grashof (German, 1826–1893) wrote a textbook on the strength of materials, developed the fundamental equations of elasticity in materials, and also made important discoveries in heat transfer (pp. 1387, 1389).
- Christian Otto Mohr (German, 1835–1918) created the Mohr's circle method that is still used to analyze combinations of stresses.
- Heinrich Müller-Breslau (German, 1851–1925) greatly improved the theory of beams and frames, wrote textbooks on the strength of materials and structural mechanics, and designed airship frames and other structures (p. 1645).
- Wilhelm Flügge (German, 1904–1990) developed the theory of stresses and strains in hollow structures such as fuel tanks and aircraft fuselages.

German-speaking experts also applied their knowledge about stress and strain to design larger and better bridges and other structures:

- Wilhelm August Julius Albert (German states, 1787–1846, Fig. 7.66) studied metal fatigue in 1829. In 1834, he invented wire rope or cable and used it in the first construction projects.
- In 1872, Adolf Bleichert (German, 1845–1901, Fig. 7.66) used wire cable to invent the modern system of cable cars for carrying people and cargo. Bleichert and the company he founded went on to build cable car systems around the world.
- John Roebling (German states, 1806–1869, Fig. 7.67) designed many large-scale projects such as the Brooklyn Bridge (which was completed after his death by his oldest son and daughter-in-law).
- Albert Fink (German, 1827–1897, Fig. 7.68) was famous for developing truss bridges.
- Franz Dischinger (German, 1887–1953, Fig. 7.68) created both cable-stayed bridges and prestressed concrete.

---

[5] Buchheim and Sonnemann 1990; Bunch and Hellemans 2004; Cardwell 1995; Challoner 2009; Gööck 2000; Heckl 2010, 2011; Heßler 2012; Jankowsky 2000; König 2000, 2009; König and Schneider 2007; Ludwig 1974; Lundgreen and Grelon 1994; Radkau 1989, 2016; Technisches Museum Wien 2011; Weitensfelder 2009, 2013.

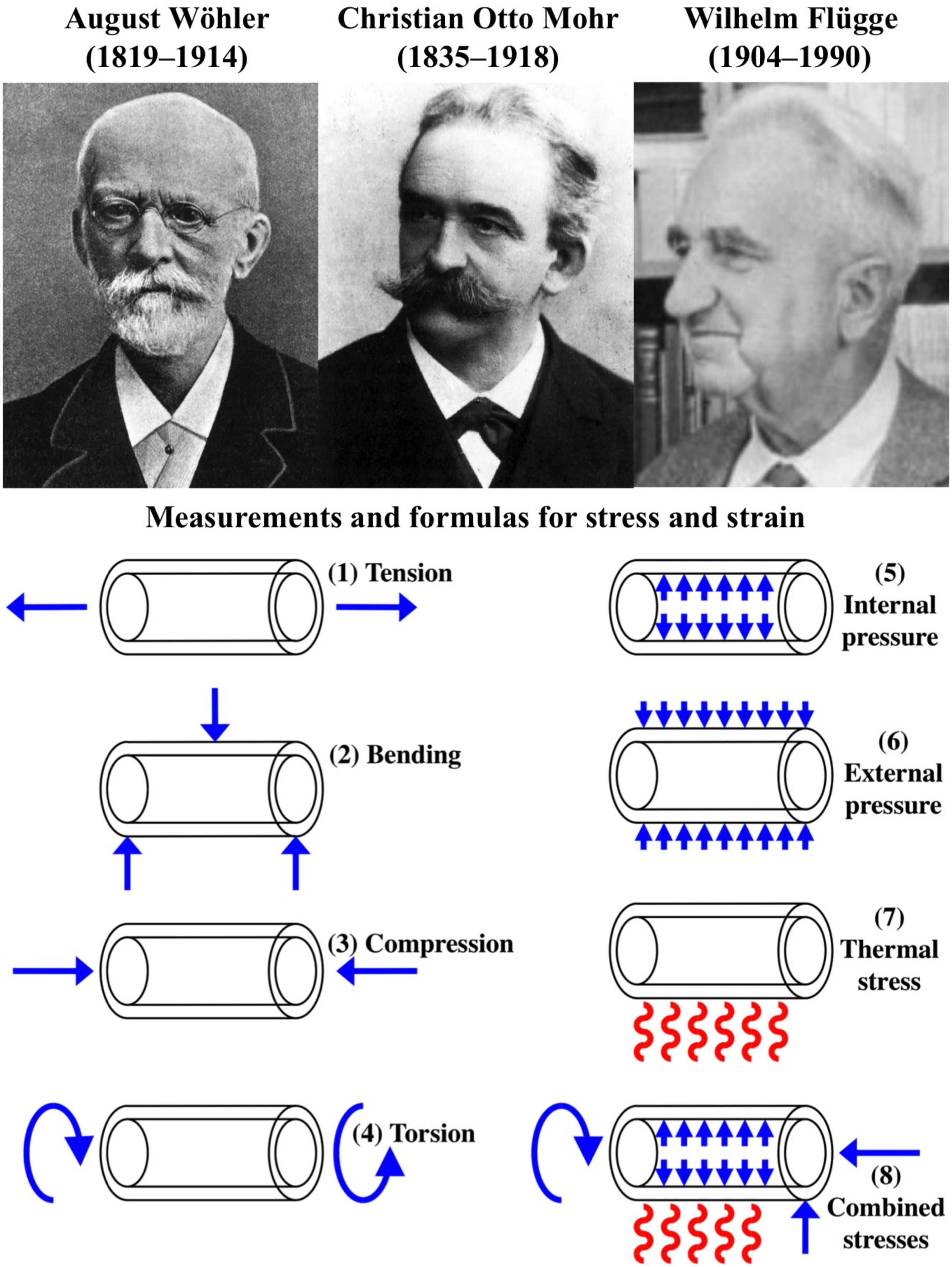
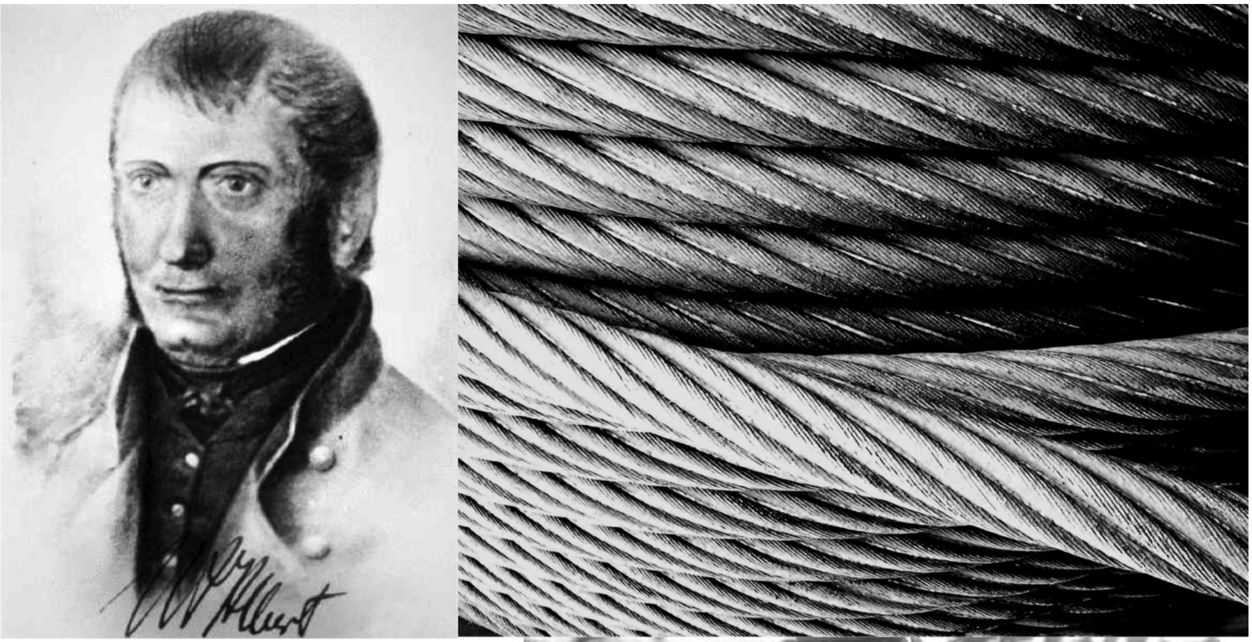

August Wöhler
(1819–1914)
Christian Otto Mohr
(1835–1918)
Wilhelm Flügge
(1904–1990)
Measurements and formulas for stress and strain
(1) Tension
(2) Bending
(3) Compression
(4) Torsion
(5) Internal pressure
(6) External pressure
(7) Thermal stress
(8) Combined stresses

Figure 7.65: August Wöhler, Christian Otto Mohr, and Wilhelm Flügge made measurements and developed mathematical formulas for various types of stress and strain in materials. Franz Grashof (pp. 1387, 1389) and Heinrich Müller-Breslau (p. 1645) also played major roles in this area.



Wilhelm August Julius Albert (1787–1846) studied metal fatigue (1829), invented wire rope (1834)

Bundesarchiv, Bild 102-13569
Foto: o.Ang. | Juni 1932

Adolf Bleichert (1845–1901) developed cable cars (1872)

Figure 7.66: Wilhelm August Julius Albert studied metal fatigue in 1829, and invented wire rope or cable in 1834. Using wire cable, Adolf Bleichert developed cable cars in 1872.

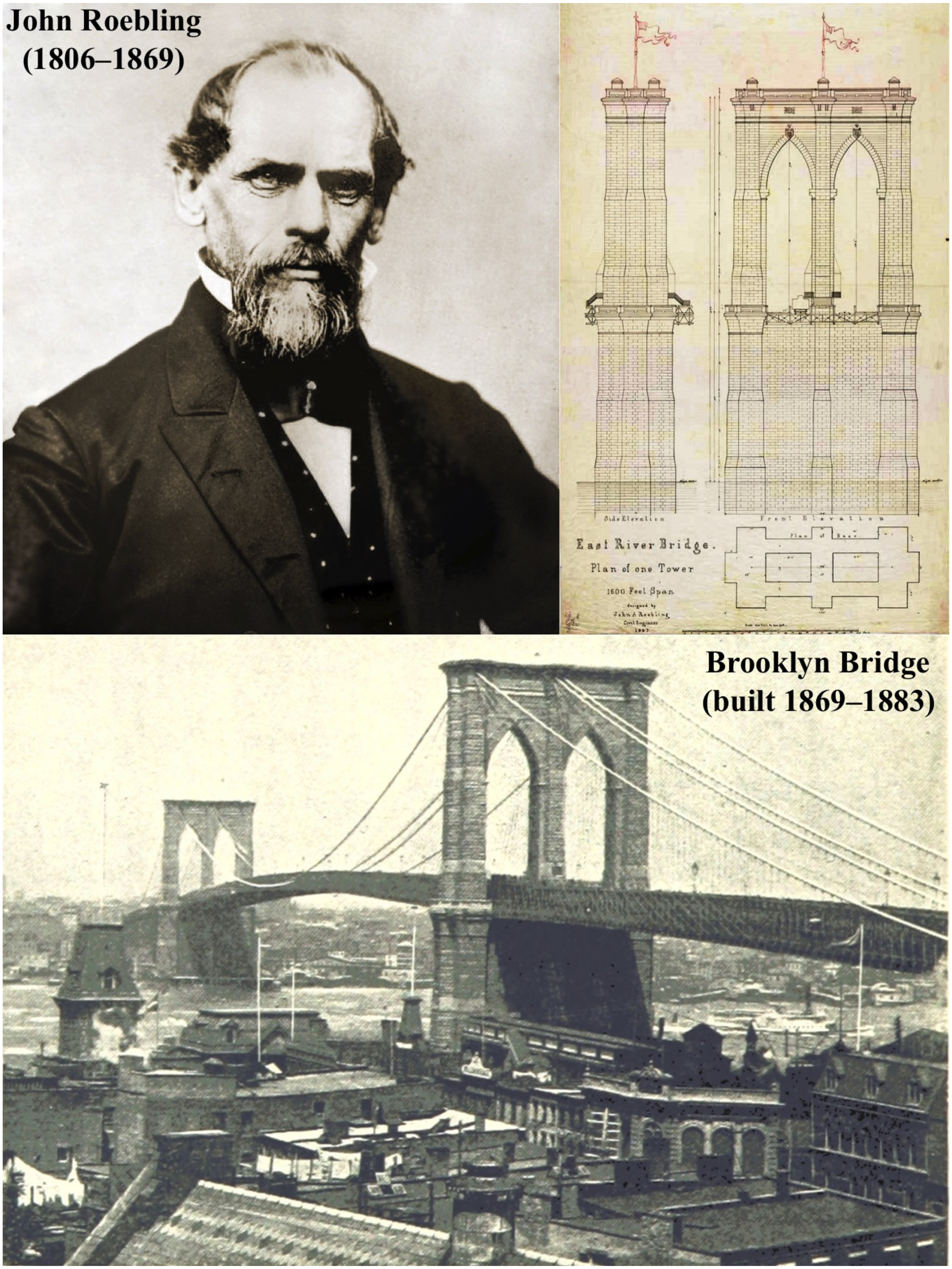
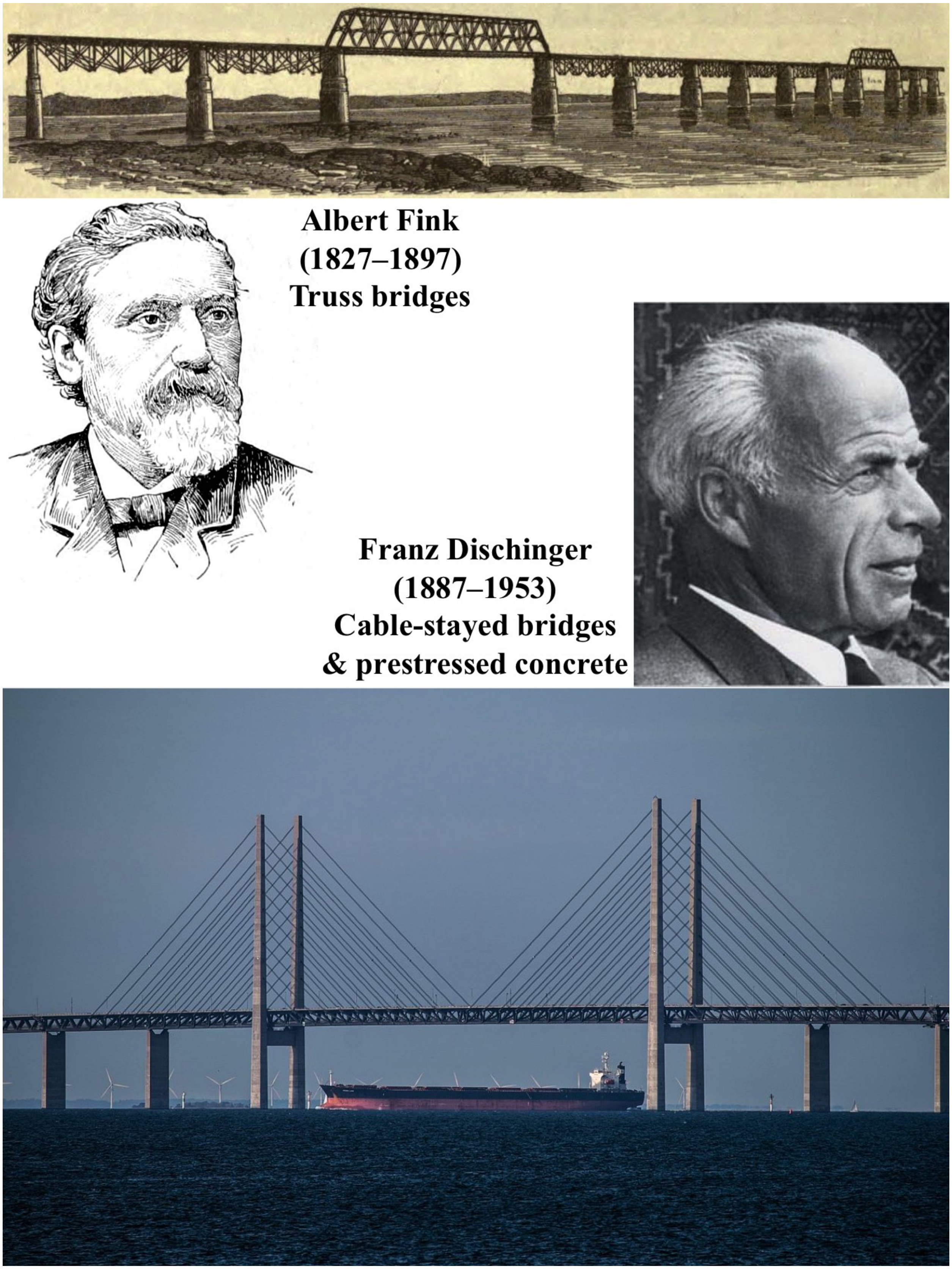

John Roebling
(1806–1869)
Side Elevation
Front Elevation
Plan of Base
East River Bridge.
Plan of one Tower
1600 Feet Span
designed by
John A. Roebling,
Civil Engineer
1867
Brooklyn Bridge
(built 1869–1883)

Figure 7.67: John Roebling designed many large-scale projects such as the Brooklyn Bridge, which was completed after his death.



Albert Fink
(1827–1897)
Truss bridges
Franz Dischinger
(1887–1953)
Cable-stayed bridges
& prestressed concrete

Figure 7.68: Albert Fink developed truss bridges, and Franz Dischinger developed both cable-stayed bridges and prestressed concrete.

7.5.2 Autobahn High-Speed Road System

Just as the German-speaking world invented internal combustion engines and vehicles to use them, it also created a revolutionary large-scale road system suitable for those vehicles. The German autobahn was designed in the 1920s and built in the 1930s. Figure 7.69 illustrates key aspects of the autobahn's design: one-way multilane roads traveling in each direction, separated by a median, and periodic off- and on-ramps for gas stations and exits. Figure 7.70 also shows examples of early German autobahn bridges, which were necessary both to pass over valleys and rivers and also to divert intersecting roads over or under the autobahn.

The autobahn served as the model for high-speed road networks that were built later in other countries around the world. For example, BIOS 1419, *German Autobahn Bridges* reported an Allied study of the autobahn after World War II:

> The Reichsautobahn is essentially a road system for the use of power driven vehicles at considerable speeds, and in order to achieve this end with safety, complete segregation of the traffic in either direction was adopted, and all road intersections on the same level avoided. Pedestrians, cyclists and horse drawn vehicles were forbidden to use these roads, so that no provision was necessary for footpaths, with a consequent reduction of the overall width required.
>
> On the other hand, complete grade separation at intersections made it necessary to build numerous bridges. [...]
>
> In the main, the construction of the autobahnen and their bridges was carried out during the six years, 1934 to 1939. Prior to this, preparatory work and designs had been prepared, while even after 1939, during the war years, a limited amount of work was done.

[For other examples of postwar Allied studies of the autobahn, see BIOS 575; BIOS 917; BIOS 918; FIAT 518].

Dwight Eisenhower was instrumental in copying the autobahn in the United States. In 1919, Eisenhower participated in a military training convoy across the United States and discovered how poorly suited U.S. roads were for automobiles at that time. During World War II, Eisenhower led U.S. forces into Germany and realized how useful the autobahn was. In the 1950s, Eisenhower became the U.S. president and successfully lobbied for the United States to begin construction of an autobahn-like system of interstate roads. U.S. highway historian Richard Weingroff explained [Weingroff 2003]:

> Although the 1919 convoy shaped Eisenhower's views, his perspective would be supplemented years later by his observations of the German autobahn network of freeways.
>
> Construction of the first segment of the autobahn began in 1929 and was dedicated on August 6, 1932. When Adolf Hitler assumed power as Chancellor of the Third Reich in 1933, he took over the program, claiming it for his own. The 23-kilometer (14-mile) expressway between Frankfurt and Darmstadt, which opened on May 19, 1935, was the

> first section completed under Hitler. By December 1941, when wartime needs brought construction to a halt, Germany had completed 3,864 kilometers (2,400 miles), with another 2,496 kilometers (1,550 miles) under construction.
>
> From the outset of World War II in Europe, the autobahn proved to be a key asset to Germany. The German blitzkrieg ("lightning war"), which involved massive coordinated air and ground attacks to stun opponents, was a key to the German defeat of Poland in 1939 and Belgium, Luxembourg, and the Netherlands in 1940; and the advance to within 480 kilometers (300 miles) of Moscow in 1941. The highway network also enhanced Germany's ability to fight on two fronts—Europe in the west, the Soviet Union in the east. [...]
>
> In the immediate aftermath of the war, Eisenhower was the military head of occupied Germany. Writer Phil Patton pointed out in Open Road that in this capacity, "Eisenhower oversaw the 'debriefing' of the Reich, the creation of a series of reports that include close study of the Autobahns."
>
> Like so many American highway engineers and government officials who had visited Germany during the 1930s, Eisenhower had been impressed by the autobahn. Years later, he would explain that "after seeing the autobahns of modern Germany and knowing the asset those highways were to the Germans, I decided, as President, to put an emphasis on this kind of road building. ... The old [1919] convoy had started me thinking about good, two-lane highways, but Germany had made me see the wisdom of broader ribbons across the land."

Fritz Todt (German, 1891–1942) established the Organisation Todt in 1933 and ran it until his death in a mysterious plane crash in 1942 (likely an assassination by his political rivals or by Allied agents). Organisation Todt designed and built massive government civil engineering projects, somewhat like the U.S. Army Corps of Engineers (Fig. 7.71).

After Fritz Todt's death, formal control of Organisation Todt was granted to Albert Speer. However, direct management of Organisation Todt was carried out by Todt's former deputy, Franz Xaver Dorsch (German, 1899–1986).

Fritz Todt, Franz Xaver Dorsch, and the rest of Organisation Todt built the autobahn in the 1930s. During World War II, they built the heavily fortified Atlantic Wall along the entire western coast of German-controlled territory, as well as the similarly fortified Siegfried Line or Westwall along the entire western border of Germany itself.

After the war, Dorsch continued to work on a wide range of projects in West Germany, and also consulted for the United States.

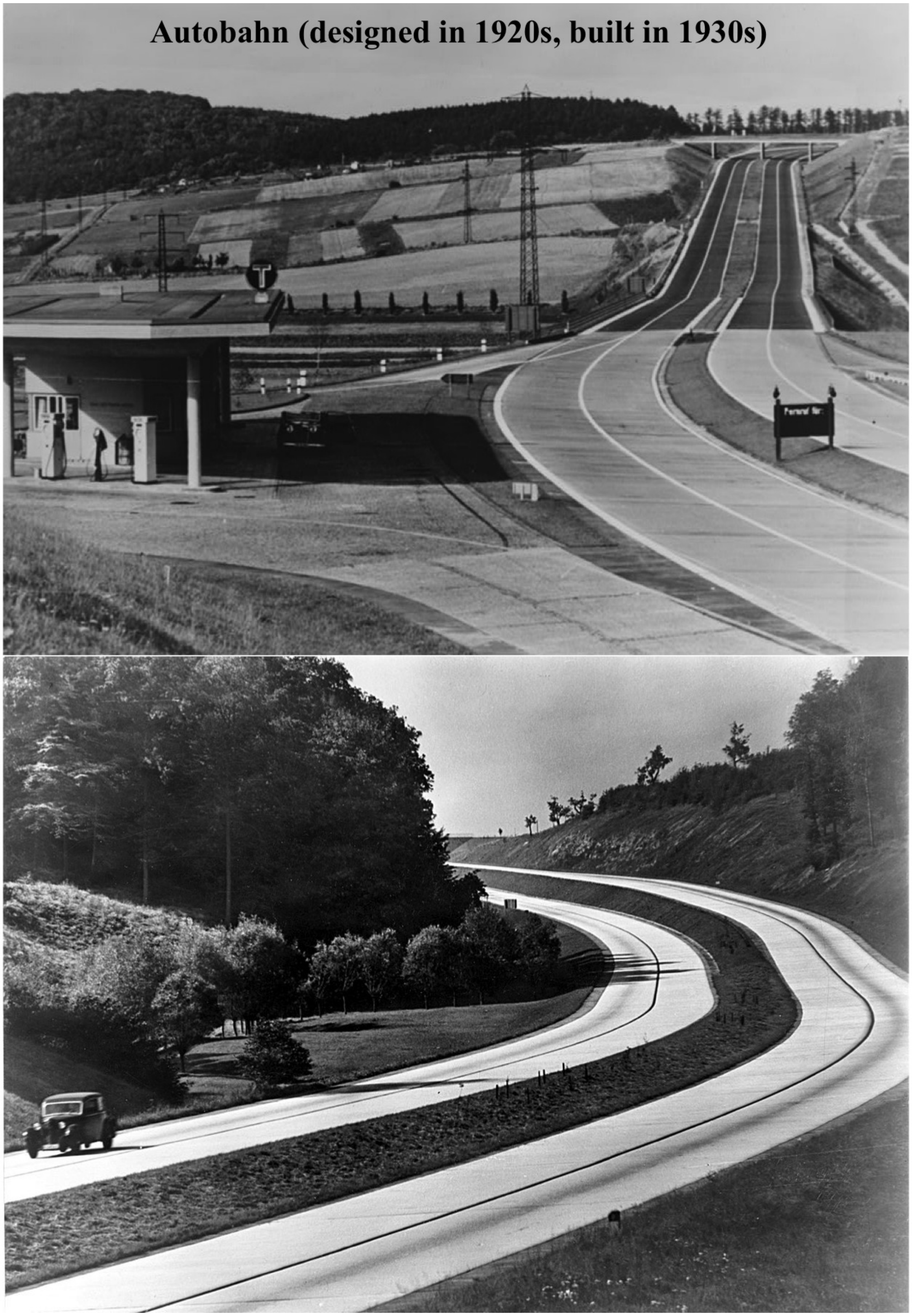

Autobahn (designed in 1920s, built in 1930s)
T

Figure 7.69: The German autobahn was designed in the 1920s and built in the 1930s.

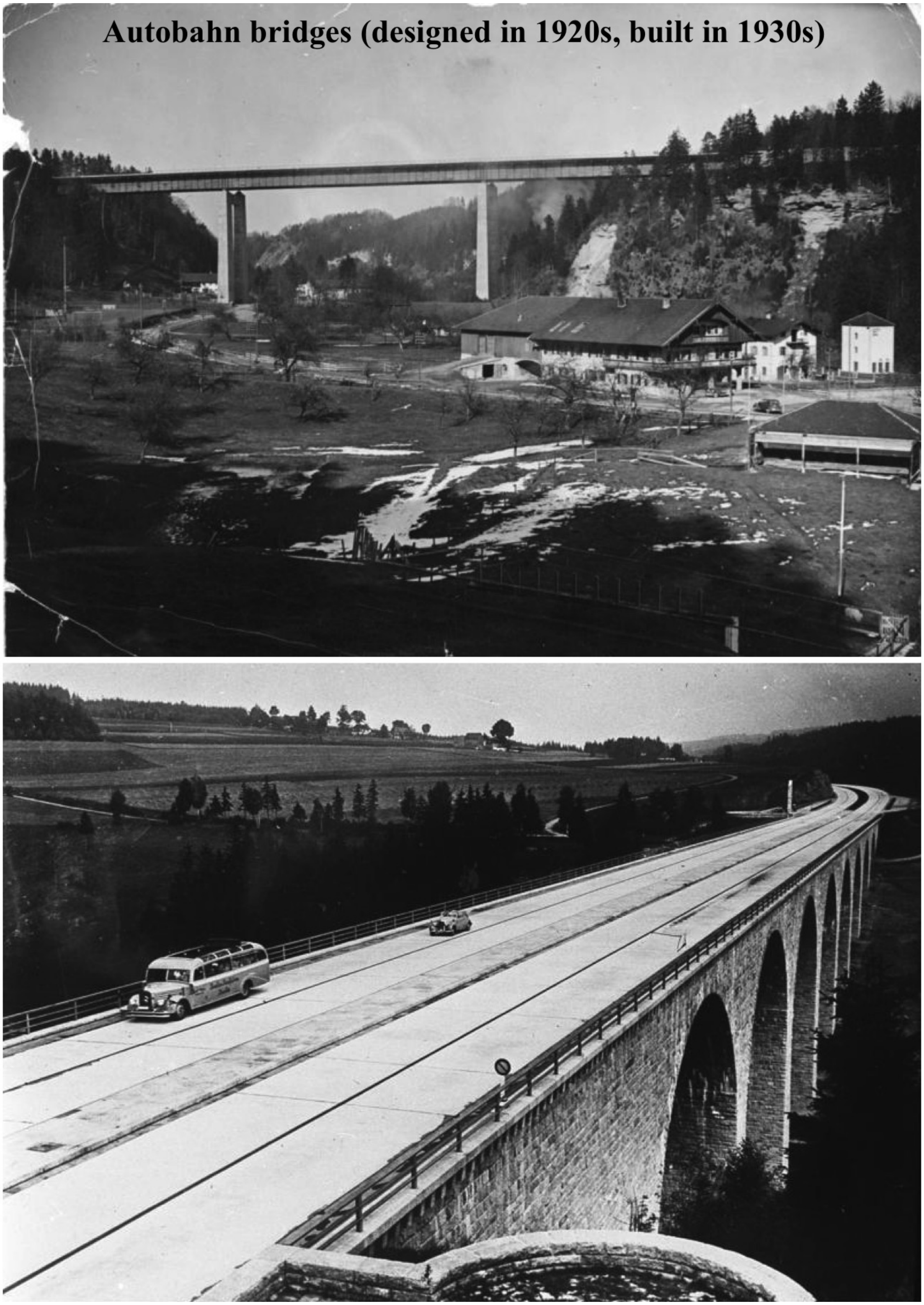

Autobahn bridges (designed in 1920s, built in 1930s)

Figure 7.70: Examples of early German autobahn bridges.

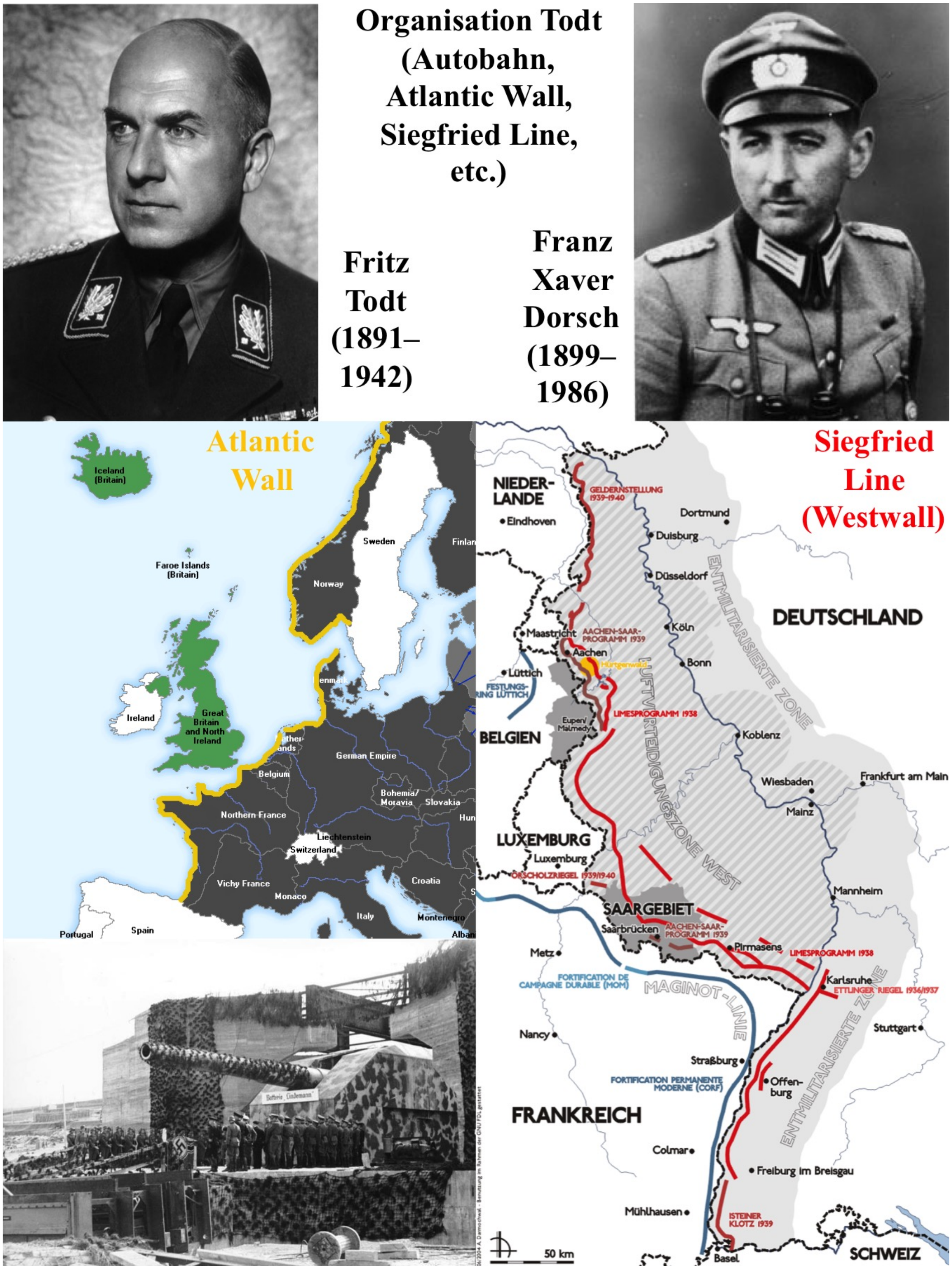

Organisation Todt (Autobahn, Atlantic Wall, Siegfried Line, etc.)
Fritz Todt (1891–1942)
Franz Xaver Dorsch (1899–1986)
Atlantic Wall
Iceland (Britain)
Faroe Islands (Britain)
Sweden
Finland
Norway
Denmark
Ireland
Great Britain and North Ireland
Netherlands
Belgium
German Empire
Bohemia/ Moravia
Slovakia
Northern France
Liechtenstein
Switzerland
Vichy France
Monaco
Croatia
Italy
Montenegro
Portugal
Spain
Batterie Lindemann
Siegfried Line (Westwall)
NIEDER-LANDE
Eindhoven
GELDERNSTELLUNG 1939-1940
Dortmund
Duisburg
Düsseldorf
ENTMILITARISIERTE ZONE
DEUTSCHLAND
Maastricht
AACHEN-SAAR-PROGRAMM 1939
Aachen
Köln
Hürtgenwald
Bonn
Lüttich
FESTUNGSRING LÜTTICH
LUFTVERTEIDIGUNGSZONE WEST
Eupen/ Malmedy
LIMESPROGRAMM 1938
BELGIEN
Koblenz
Wiesbaden
Frankfurt am Main
Mainz
LUXEMBURG
Luxemburg
ORSCHOLZRIEGEL 1939/1940
Mannheim
SAARGEBIET
Saarbrücken
AACHEN-SAAR-PROGRAMM 1939
Pirmasens
LIMESPROGRAMM 1938
Metz
FORTIFICATION DE CAMPAGNE DURABLE (MOM)
MAGINOT-LINIE
Karlsruhe
ETTLINGER RIEGEL 1936/1937
Nancy
Stuttgart
Straßburg
FORTIFICATION PERMANENTE MODERNE (CORF)
Offenburg
FRANKREICH
ENTMILITARISIERTE ZONE
Colmar
Freiburg im Breisgau
Mühlhausen
ISTEINER KLOTZ 1939
50 km
Basel
SCHWEIZ

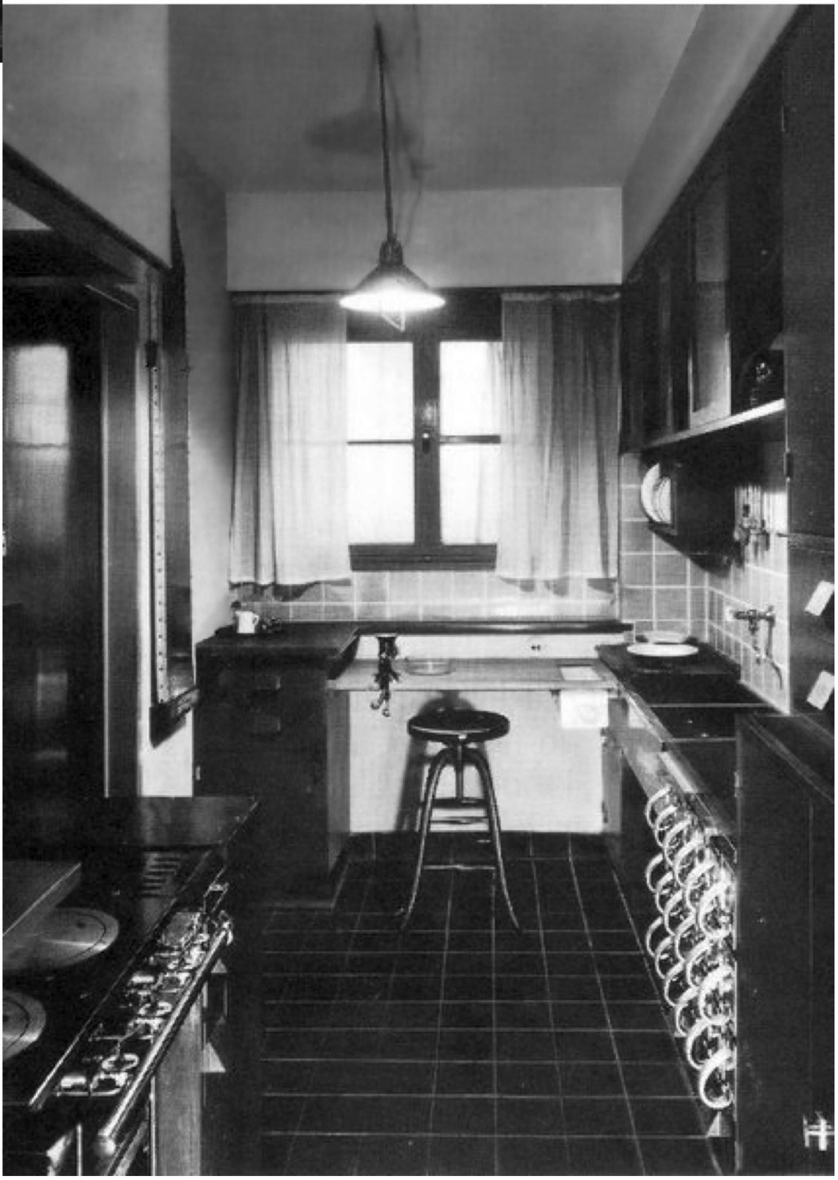
Figure 7.71: Fritz Todt and Franz Xaver Dorsch ran the Organisation Todt, which carried out massive government engineering projects 1933–1945, including the autobahn, Atlantic Wall, Siegfried Line (Westwall), etc. Dorsch continued to work in West Germany after the war.

7.5.3 Kitchen Design

Early kitchens had typically either been dedicated rooms staffed by servants in affluent households, or improvised tools gathered around a heating stove in more common households. Margarete Schütte-Lihotzky (Austrian, 1897–2000, Fig. 7.72) revolutionized the concept of the kitchen by designing a separate, standardized, small room that almost every household could use. By 1926, she created the "Frankfurt Kitchen," which ultimately became the standard kitchen design for apartments and small or medium houses worldwide. (The Frankfurt Kitchen was later adopted and heavily promoted by designers in Sweden, and thus was often incorrectly attributed as the "Swedish Kitchen.") Sarah Archer, an expert on the history of kitchens, described the importance of Schütte-Lihotzky's design [Archer 2019]:

> Margarete Schütte-Lihotzky (1897–2000) was the first Austrian woman ever to qualify as an architect. Following World War I, she was tasked with the design of standard kitchens for a new housing project by city planner and architect Ernst May. The Great War left rubble and a desperate housing shortage in its wake, but it also opened the way for new ideas and new designs. [...]
>
> Schütte-Lihotzky conceived of the Frankfurt Kitchen as a separate room in each apartment, which was a design choice that had previously applied only to the cavernous kitchens that served great houses. [...]
>
> The Frankfurt Kitchen featured an electric stove, a window over the sink, and lots of ingenious built-in storage including custom aluminum bins with a spout at one end. These bins could be used to store rice, sugar, or flour, then pulled out and used to pour the ingredients into a mixing bowl. The kitchen lacked a refrigerator, but in almost every other way, it was thoroughly modern. There was no clunky cast-iron stove, and no mismatched pieces of wooden furniture that had been drafted into kitchen duty. [...]
>
> Margarete Schütte-Lihotzky introduced design ideals that still hold sway over our living spaces. Recognition for her design spread slowly but steadily. [...]
>
> But in 1927, three different versions of the design were shown at a major Frankfurt exhibition. In the '30s, it was written up in the German, English, and French press, and attracted the attention of France's housing minister, who decided he wanted to commission 260,000 units inspired by its design. [...]
>
> While it transformed kitchen design in the 20th century, in certain ways the Frankfurt Kitchen lent more inspiration to new suburban homes than it did to their urban counterparts. This is partly because there was much more new construction in American suburbs following World War II, while large cities tended to be comprised mostly of renters who had to accept their kitchens as they were. The Frankfurt ideals of rational design, optimal work surfaces, color, and smart storage both took shape and grew in size once they took root in suburban ranch homes.

Margarete Schütte-Lihotzky (1897–2000)



“Frankfurt kitchen,” a separate, equipped room designed for apartments and houses (1926)

Figure 7.72: Margarete Schütte-Lihotzky created the standard “Frankfurt kitchen” design in 1926.

7.5.4 Other Creations in Civil Engineering and Architecture

Rudolf Virchow (German, 1821–1902, Fig. 2.4), Max Joseph von Pettenkofer (German, 1818–1901), James Hobrecht (German, 1825–1902), and Karl Imhoff (German, 1876–1965) designed sewage collection and treatment systems that revolutionized sanitation and health, and that were ultimately used worldwide. See Fig. 7.73.

Max Giese (German, 1879–1935) and Fritz Hell (German?, 18??–19??) invented the concrete pump in 1927; see Fig. 7.74. Jacob Kweimn (Dutch, 18??–19??) developed an improved concrete pump in 1932. The ability to pump liquid concrete completely transformed modern construction methods.

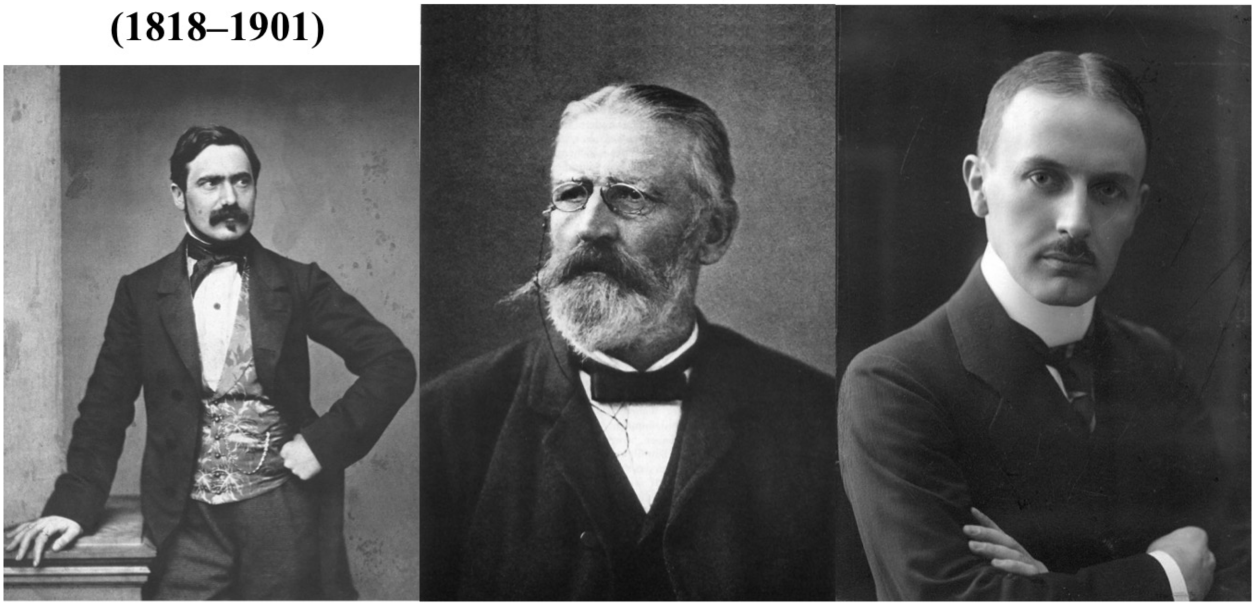
Philip Deidesheimer (German, 1832–1916) studied at the Freiberg University of Mining and moved to the United States in 1852. He invented (or possibly brought from Germany) the approach known as square-set timbering, which uses a sturdy wooden framework to support large three-dimensional cavities in mining (Fig. 7.75). No later than 1860, Deidesheimer was using square-set timbering in mines in the United States.

In 1887, Ernst Hubbard (Austrian?, 18??–19??) conducted the first experiments trying to develop useful particle board [Hubbard 1887]. In 1932, Max Himmelheber (German, 1904–2000) and Alfred Schmid (German, 1899–1968) perfected and patented particle board and machines to produce it [Sauer 2016]. The production and use of particle board spread throughout the German-speaking world during World War II and was transferred to other countries after the war. See Fig. 7.76.

Walter Gropius (German, 1883–1969) and Ludwig Mies, also known as Ludwig Mies van der Rohe (German, 1886–1969), created Bauhaus architecture and helped to create the International Style of architecture (Fig. 7.77).

Artur Fischer (German, 1919–2016, Fig. 7.77) invented split plastic wall plugs, Fischertechnik construction toys, and the synchronized photo flash.

Karl Fiebinger (Austrian, 1913–2014, Fig. 7.77) developed revolutionary methods that made it possible to create enormous, fully equipped, bomb-proof underground installations; he worked for Germany during World War II and for the United States after the war.



Max Joseph von Pettenkofer (1818–1901)

James Hobrecht (1825–1902)

Karl Imhoff (1876–1965)

Sewage collection and treatment systems

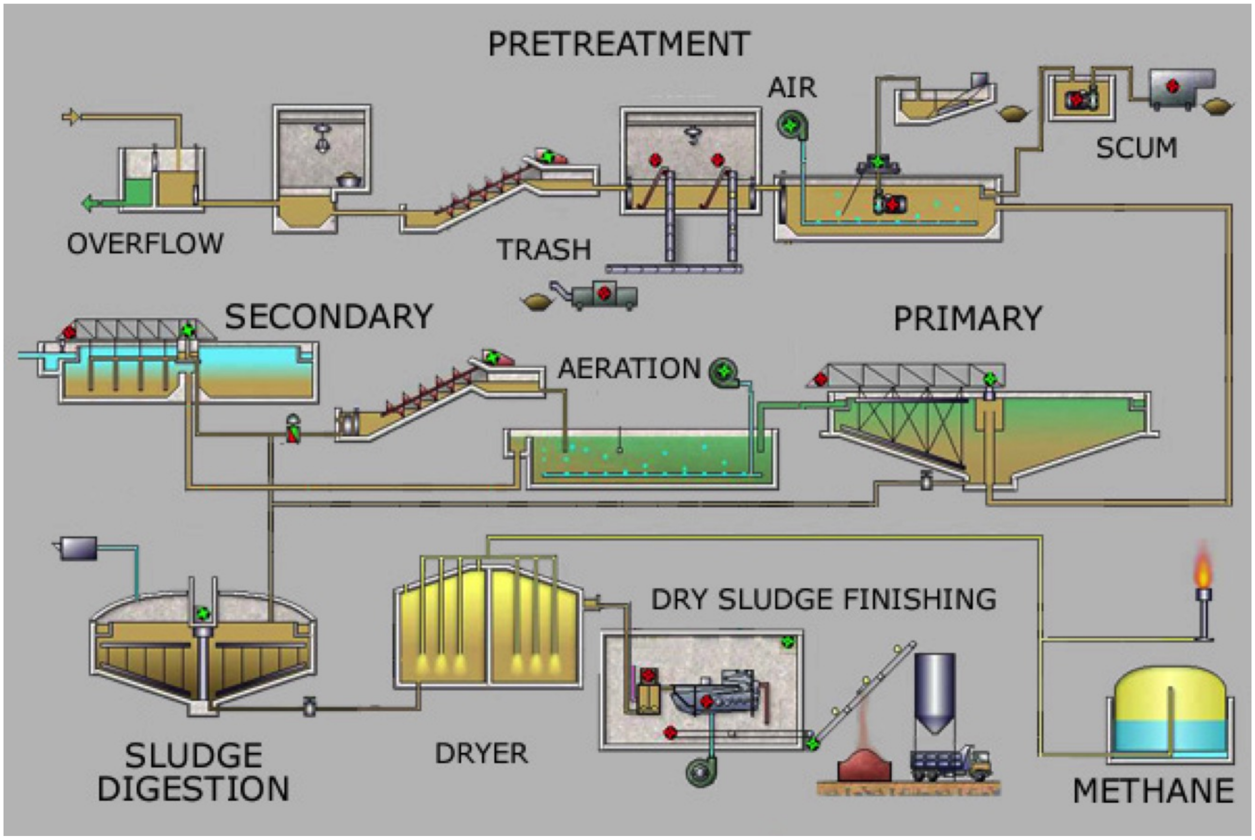

PRETREATMENT
AIR
SCUM
OVERFLOW
TRASH
SECONDARY
PRIMARY
AERATION
DRY SLUDGE FINISHING
SLUDGE DIGESTION
DRYER
METHANE

Figure 7.73: Rudolf Virchow (Fig. 2.4), Max Joseph von Pettenkofer, James Hobrecht, and Karl Imhoff designed sewage collection and treatment systems that were ultimately used worldwide.

Max Giese
(1879–1935)

Fritz Hell
(18??–19??)

Jacob Kweimn
(18??–19??)

Concrete pump (1927)

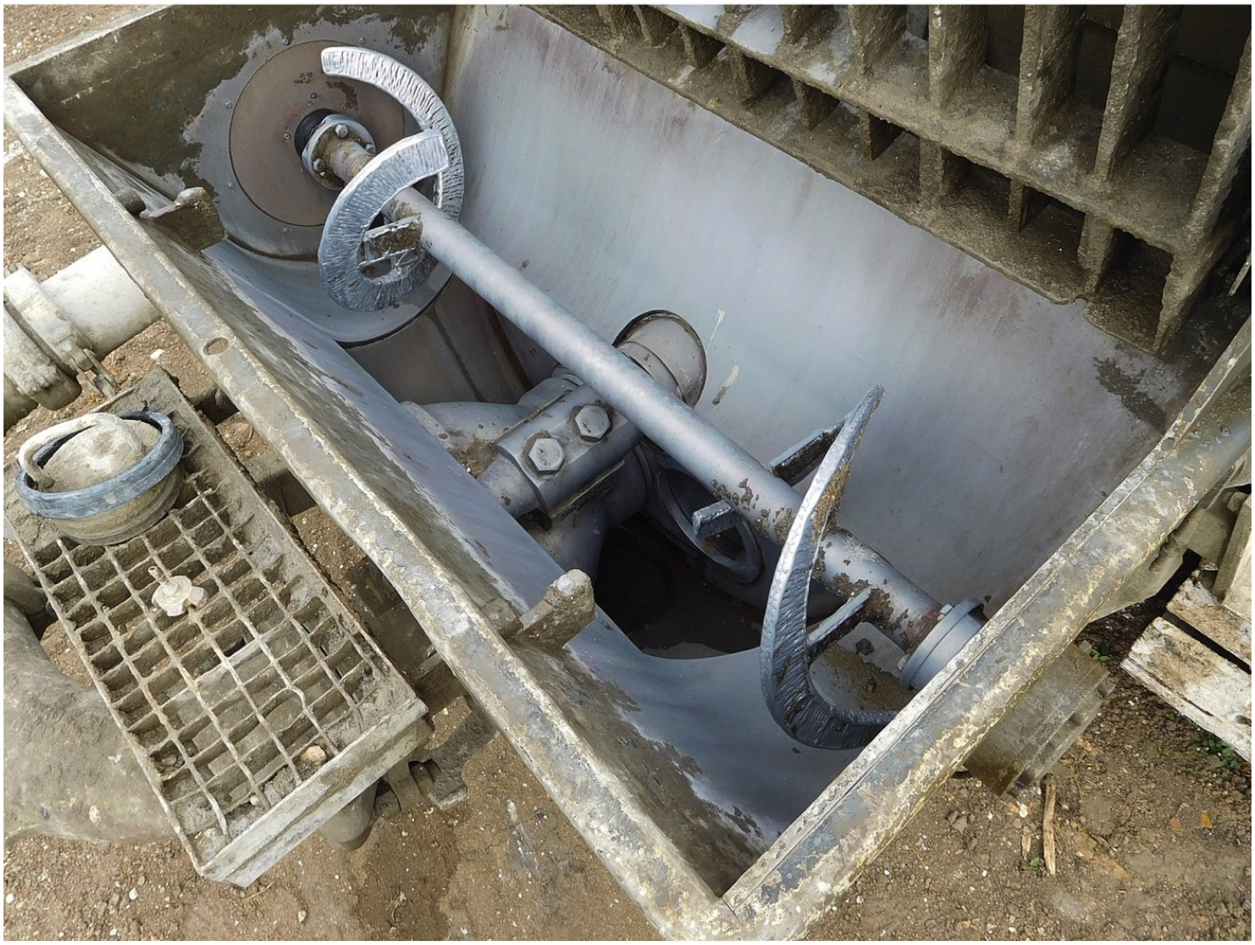
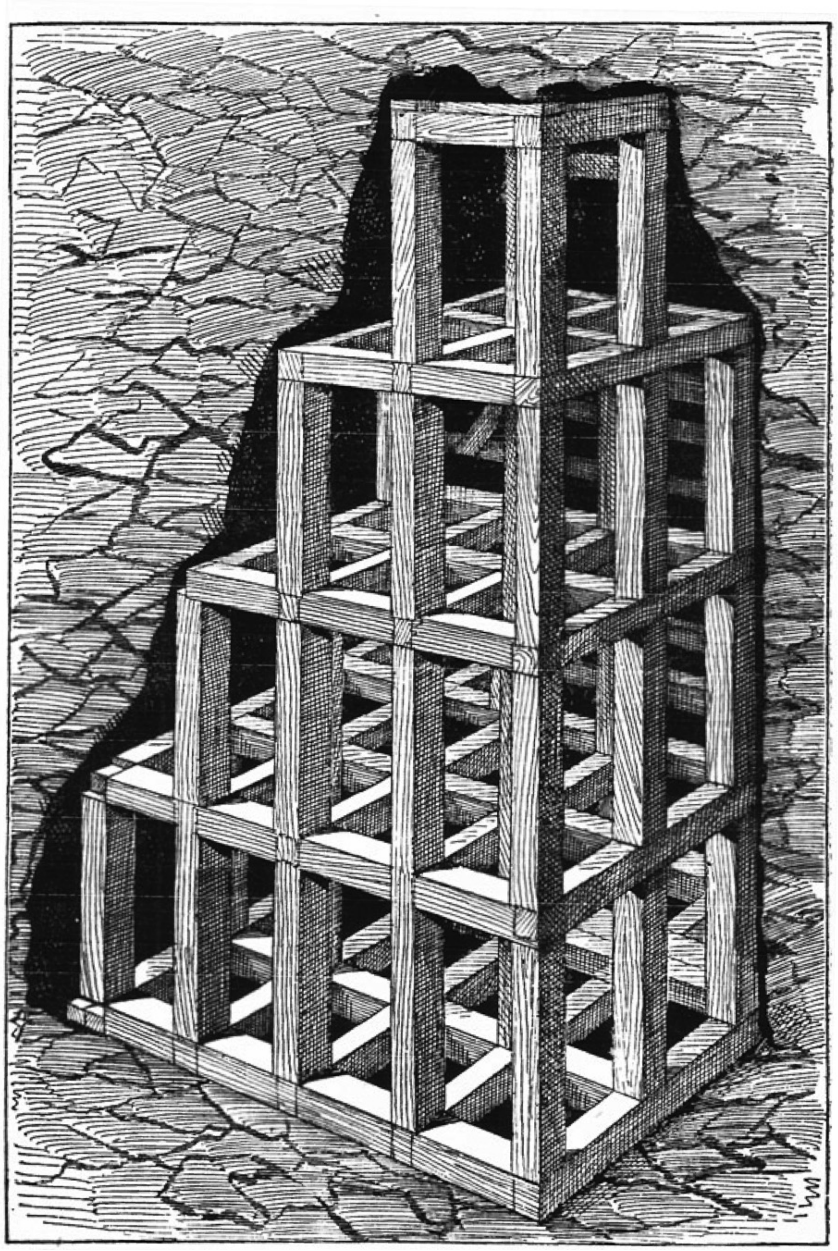


Figure 7.74: Max Giese, Fritz Hell, and Jacob Kweimn invented concrete pumps.

Philip Deidesheimer
(1832–1916)



Square set timbering for large three-dimensional cavities in mining (1860 or earlier)

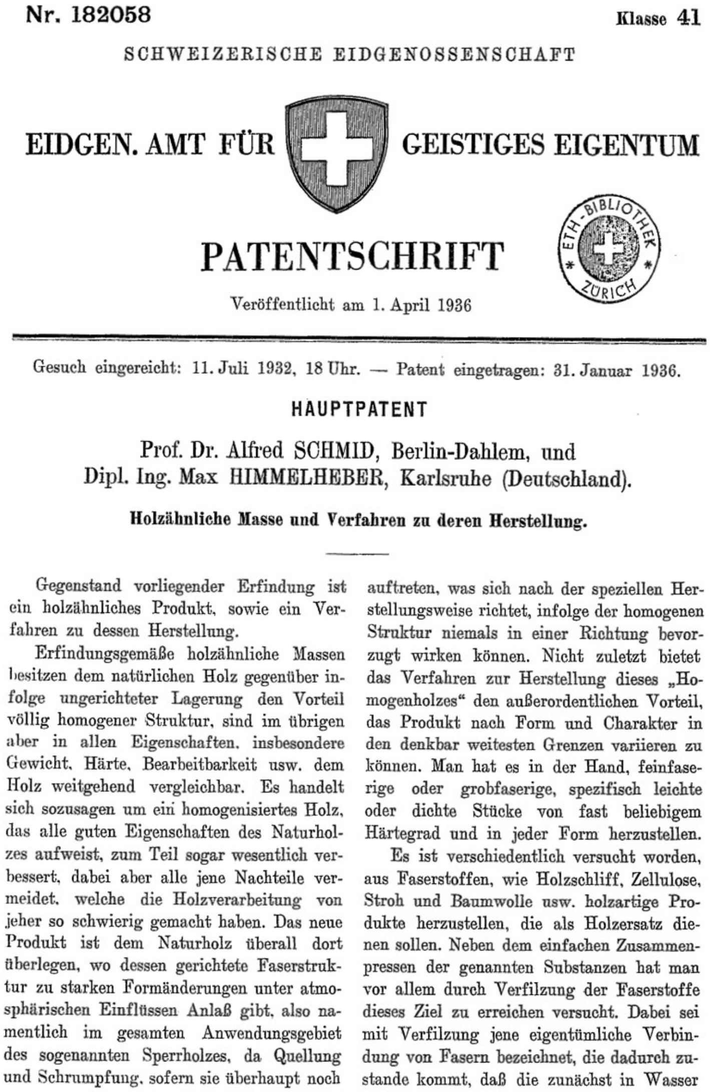
Figure 7.75: No later than 1860, Philip Deidesheimer created square set timbering to support large three-dimensional cavities in mining.

Ernst Hubbard
(18??–19??)
First experiments with
particle board (1887)

Alfred Schmid
(1899–1968)

Max Himmelheber
(1904–2000)

Himmelheber and Schmid perfected particle board (1932)



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EIDGEN. AMT FÜR GEISTIGES EIGENTUM

PATENTSCHRIFT

ETH-BIBLIOTHEK ZÜRICH

Veröffentlicht am 1. April 1936

Gesuch eingereicht: 11. Juli 1932, 18 Uhr. — Patent eingetragen: 31. Januar 1936.

HAUPTPATENT

Prof. Dr. Alfred SCHMID, Berlin-Dahlem, und
Dipl. Ing. Max HIMMELHEBER, Karlsruhe (Deutschland).

Holzähnliche Masse und Verfahren zu deren Herstellung.

Gegenstand vorliegender Erfindung ist ein holzähnliches Produkt, sowie ein Verfahren zu dessen Herstellung.

Erfindungsgemäße holzähnliche Massen besitzen dem natürlichen Holz gegenüber infolge ungerichteter Lagerung den Vorteil völlig homogener Struktur, sind im übrigen aber in allen Eigenschaften, insbesondere Gewicht, Härte, Bearbeitbarkeit usw. dem Holz weitgehend vergleichbar. Es handelt sich sozusagen um ein homogenisiertes Holz, das alle guten Eigenschaften des Naturholzes aufweist, zum Teil sogar wesentlich verbessert, dabei aber alle jene Nachteile vermeidet, welche die Holzverarbeitung von jeher so schwierig gemacht haben. Das neue Produkt ist dem Naturholz überall dort überlegen, wo dessen gerichtete Faserstruktur zu starken Formänderungen unter atmosphärischen Einflüssen Anlaß gibt, also namentlich im gesamten Anwendungsgebiet des sogenannten Sperrholzes, da Quellung und Schrumpfung, sofern sie überhaupt noch auftreten, was sich nach der speziellen Herstellungsweise richtet, infolge der homogenen Struktur niemals in einer Richtung bevorzugt wirken können. Nicht zuletzt bietet das Verfahren zur Herstellung dieses „Homogenholzes“ den außerordentlichen Vorteil, das Produkt nach Form und Charakter in den denkbar weitesten Grenzen variieren zu können. Man hat es in der Hand, feinfaserige oder grobfaserige, spezifisch leichte oder dichte Stücke von fast beliebigem Härtegrad und in jeder Form herzustellen.

Es ist verschiedentlich versucht worden, aus Faserstoffen, wie Holzschliff, Zellulose, Stroh und Baumwolle usw. holzartige Produkte herzustellen, die als Holzersatz dienen sollen. Neben dem einfachen Zusammenpressen der genannten Substanzen hat man vor allem durch Verfilzung der Faserstoffe dieses Ziel zu erreichen versucht. Dabei sei mit Verfilzung jene eigentümliche Verbindung von Fasern bezeichnet, die dadurch zustande kommt, daß die zunächst in Wasser

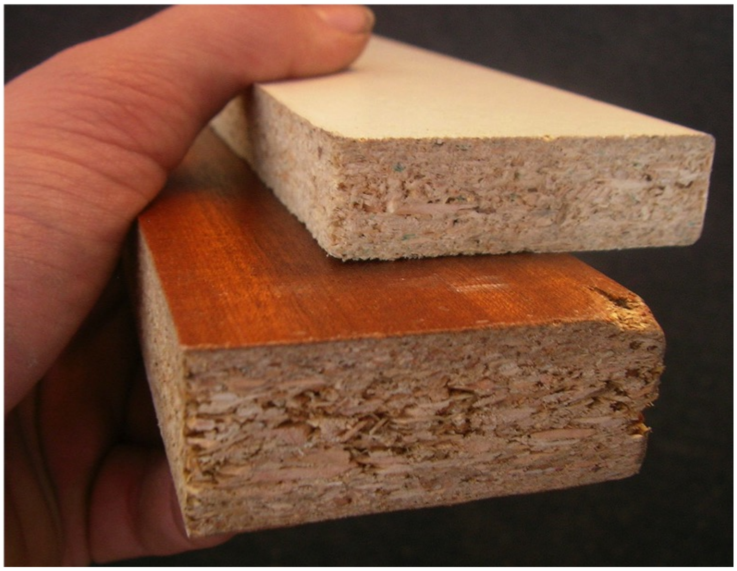

Figure 7.76: Ernst Hubbard conducted the first experiments with particle board in 1887. Max Himmelheber and Alfred Schmid perfected particle board in 1932.

Other civil engineering and architecture

Walter Gropius (1883–1969)
Bauhaus architecture

Ludwig Mies (1886–1969)
Bauhaus architecture

Artur Fischer (1919–2016)
Split plastic wall plug,
Fischertechnik
construction toys

Karl Fiebinger (1913–2014)
Underground installations

Figure 7.77: Walter Gropius and Ludwig Mies (also known as Ludwig Mies van der Rohe) created Bauhaus architecture and helped to create the International Style of architecture. Artur Fischer invented split plastic wall plugs and Fischertechnik construction toys. Karl Fiebinger designed huge, sophisticated underground installations in wartime Germany and the postwar United States.

7.6 Projectile Weapons

German-speaking creators made many important innovations regarding projectile weapons, including[6]:

7.6.1. Guns

7.6.2. Artillery

7.6.3. Shaped-charge anti-tank weapons

7.6.4. Electromagnetic railguns

7.6.5. Flamethrowers

7.6.1 Guns

Gaspard Kollner (Austrian, 14??–15??) and Augustus Kotter (Nuremberg, 14??–15??) are credited with inventing rifled gun barrels around 1498–1520. See Fig. 7.78.

Around 1580–1597, Hans Stopler (Nuremberg, 15??–16??) was the first or one of the first gunsmiths to use a revolving section for multiple bullets, shown in Fig. 7.79.

Johann Nikolaus von Dreyse (Thuringia, 1787–1867) invented the bolt-action rifle in 1824. His Dreyse Zündnadelgewehr bolt-action rifle was mass-produced from 1840 onward (Fig. 7.80).

Building upon von Dreyse's work, the brothers Peter Paul Mauser (German, 1838–1914) and Wilhelm Mauser (German, 1834–1882) created the Gewehr 71 bolt-action rifle in 1871. The Mauser company later developed improved versions, including the Gewehr 98 (1898) and Karabiner 98 kurz (1935), as well as the scaled-up Tankgewehr 18 (1918), which was the first anti-tank rifle. See Fig. 7.81.

As shown in Fig. 7.82, Hugo Borchardt (German, 1844–1924) developed the world's first self-loading, semi-automatic pistol, the Borchardt C93, in 1893. Georg Luger (Austrian, 1849–1923) improved upon that design to create the Luger semi-automatic pistol in 1900.

The German [?] brothers Fidel (18??–19??), Friedrich (18??–19??), and Josef Feederle (18??–19??) developed a different semi-automatic pistol design, the Mauser C96, in 1896; see Fig. 7.83.

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[6] For coverage of different aspects of this area, see especially: Bishop 2014; Bull 2004; DK 2014; Echle 1979; Engelmann and Scheibert 1974; Gander and Chamberlain 1979; Götz 1990; Hogg 1997, 1999, 2001; Jäger 2001; Klein 1977; Ortner 2007; Romanych and Rupp 2013; Senich 1982, 1987; Taube 1979, 1981; Wictor 2007; Wollert et al. 2008; Zaloga and Dennis 2016.

Based on the earlier Luger design, Fritz Walther (German, 18??–19??) created the more advanced Walther PP in 1929 and Walther P 38 in 1938. See Fig. 7.84. Many modern handguns still use the same designs and features as those guns.

As shown in Fig. 7.85, Theodor Bergmann (German, 1850–1931) and Louis Schmeisser (German, 1848–1917) developed the Maschinengewehr MG 15, an early machine gun, in 1915. Bergmann and one of Louis Schmeisser's sons, Hugo Schmeisser (German, 1884–1953), then developed the Maschinenpistole MP 18, the first practical submachine gun, in 1918. Louis Schmeisser's other son, Hans Schmeisser (German, 18??–19??), also continued to develop and produce various gun designs.

Modern machine gun designs evolved in the German-speaking world:

- Louis Stange (German, 1888–1971, Fig. 7.86) created the Maschinengewehr MG 30 machine gun in 1930.

- Heinrich Vollmer (German, 1885–1961, Fig. 7.87) developed Stange's design into the first general-purpose machine gun, the MG 34, in 1934.

- Based directly on the work of Stange and Vollmer, Werner Gruner (German, 1904–1995, Fig. 7.88) produced a further improved version, the MG 42, in 1942.

These German machine gun designs were widely copied and became the direct ancestors of later machine guns worldwide.

Similarly, modern assault rifles (multipurpose handheld weapons capable of acting as anything from single-shot rifles to fully automatic machine guns) were invented in the German-speaking world. Hugo Schmeisser created the Sturmgewehr StG 44 selective-fire assault rifle in 1944, as shown in Fig. 7.89. Based on Schmeisser's work, Wilhelm Stähle (German, 1901–1974) and Ludwig Vorgrimler (German, 1912–1983) developed an improved version, the Sturmgewehr StG 45, in 1945; see Fig. 7.90. These weapon designs were copied worldwide and gave rise to modern assault rifles such as the AK-47 and M16. In fact, Hugo Schmeisser, Werner Gruner, and other German gun manufacturers were taken to Russia to design guns after the war. Many German gun designers were also interrogated by or went to work for other Allied countries after the war.

As shown in Fig. 7.91, the Krummlauf (curved barrel) modified Sturmgewehr 44, produced in 1944, could shoot around corners. It was equipped with a periscope for seeing around corners as well. Krummlauf rifles were also installed in tank ports to defend the exterior of tanks from close attackers.

In the German-speaking world, innovations in gun design were greatly aided by parallel innovations in optics (see for example Section 6.9) for sighting scopes and by the development of revolutionary infrared imaging or night vision technologies (Section 6.6).

Gaspard Kollner (14??–15??) Augustus Kotter (14??–15??)

Rifled gun barrels (ca. 1498-1520)

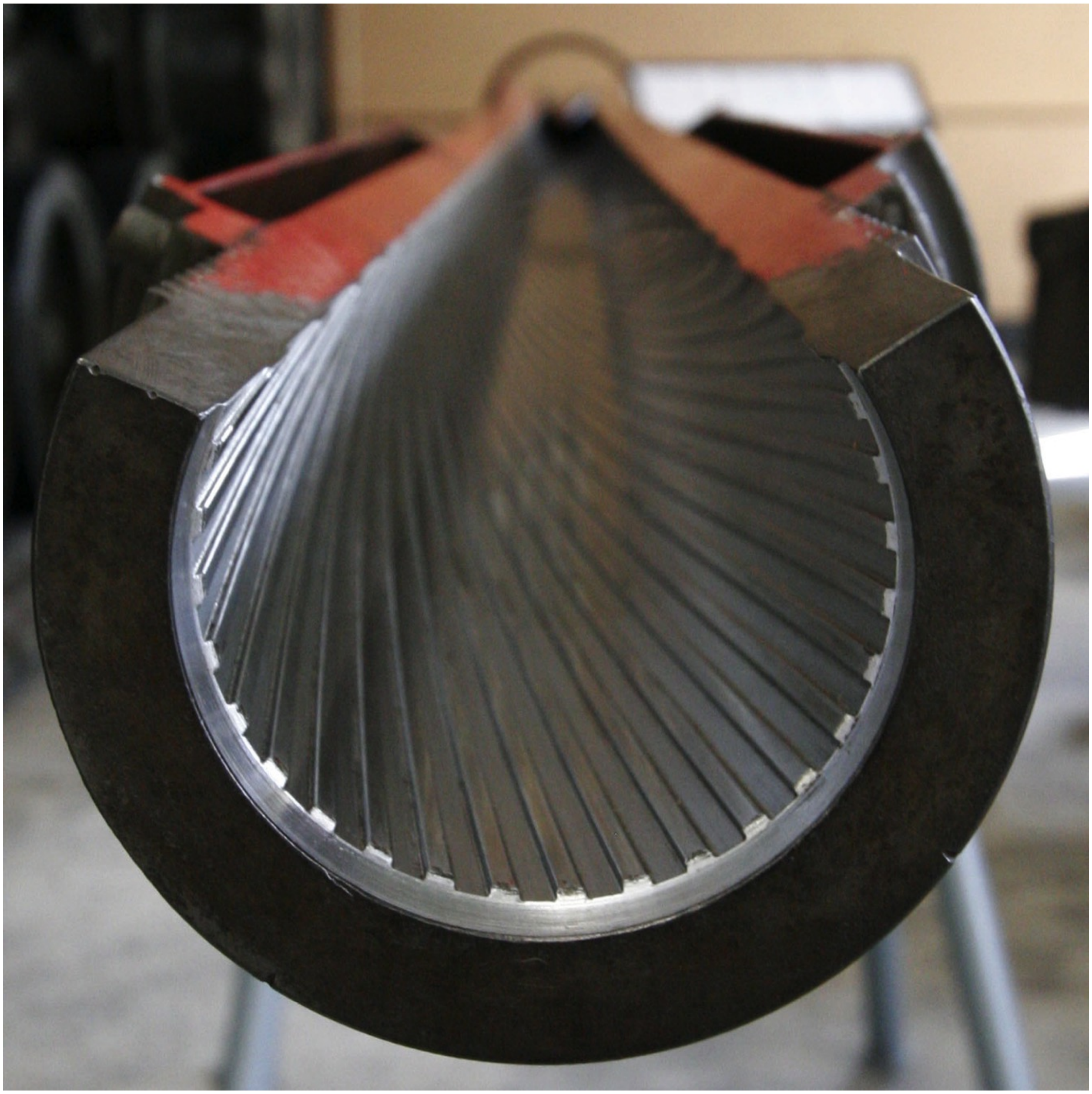
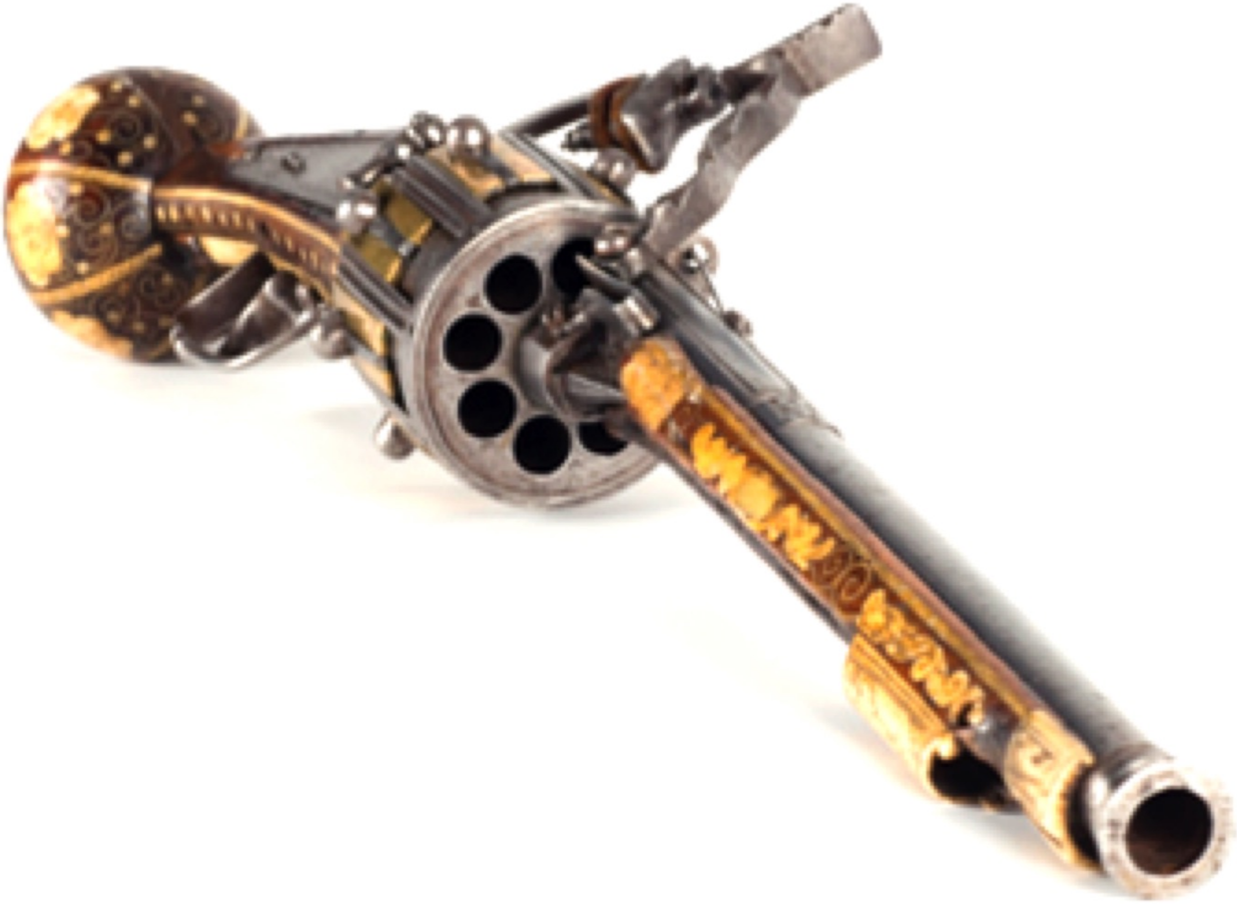


Figure 7.78: Gaspard Kollner and Augustus Kotter are credited with inventing rifled gun barrels around 1498–1520.

Hans Stopler (15??–16??) Revolvers (ca. 1580–1597)



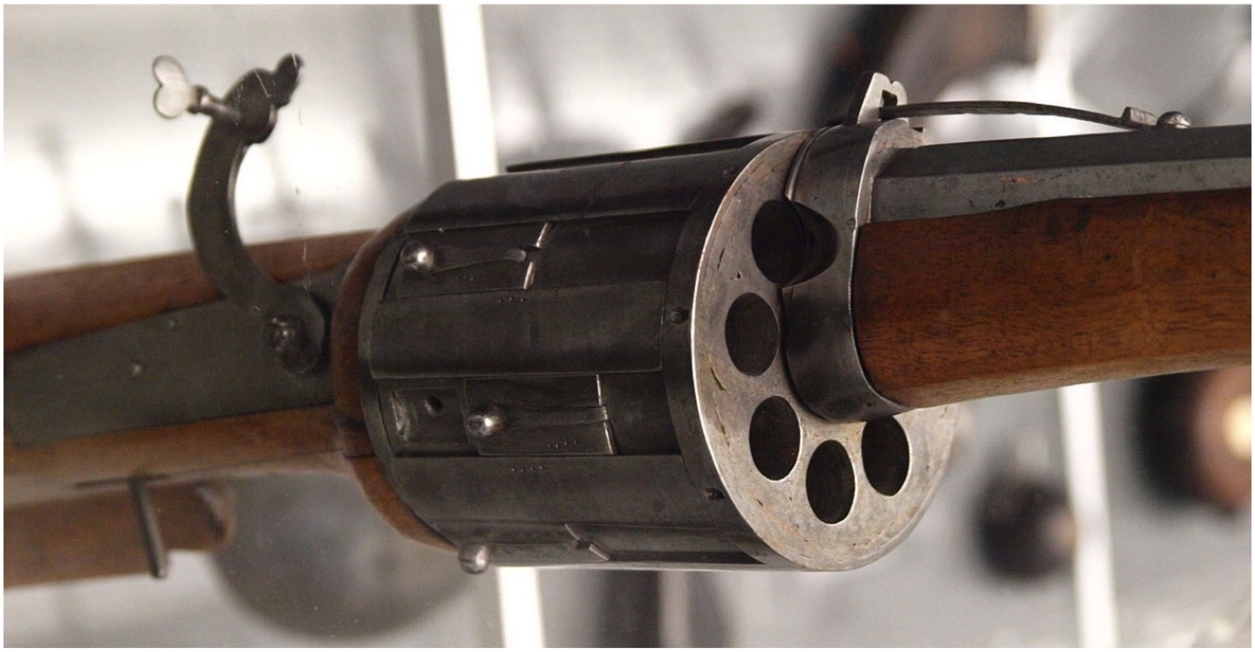


Figure 7.79: Hans Stopler was the first or one of the first gunsmiths to use a revolving section for multiple bullets, around 1580–1597.

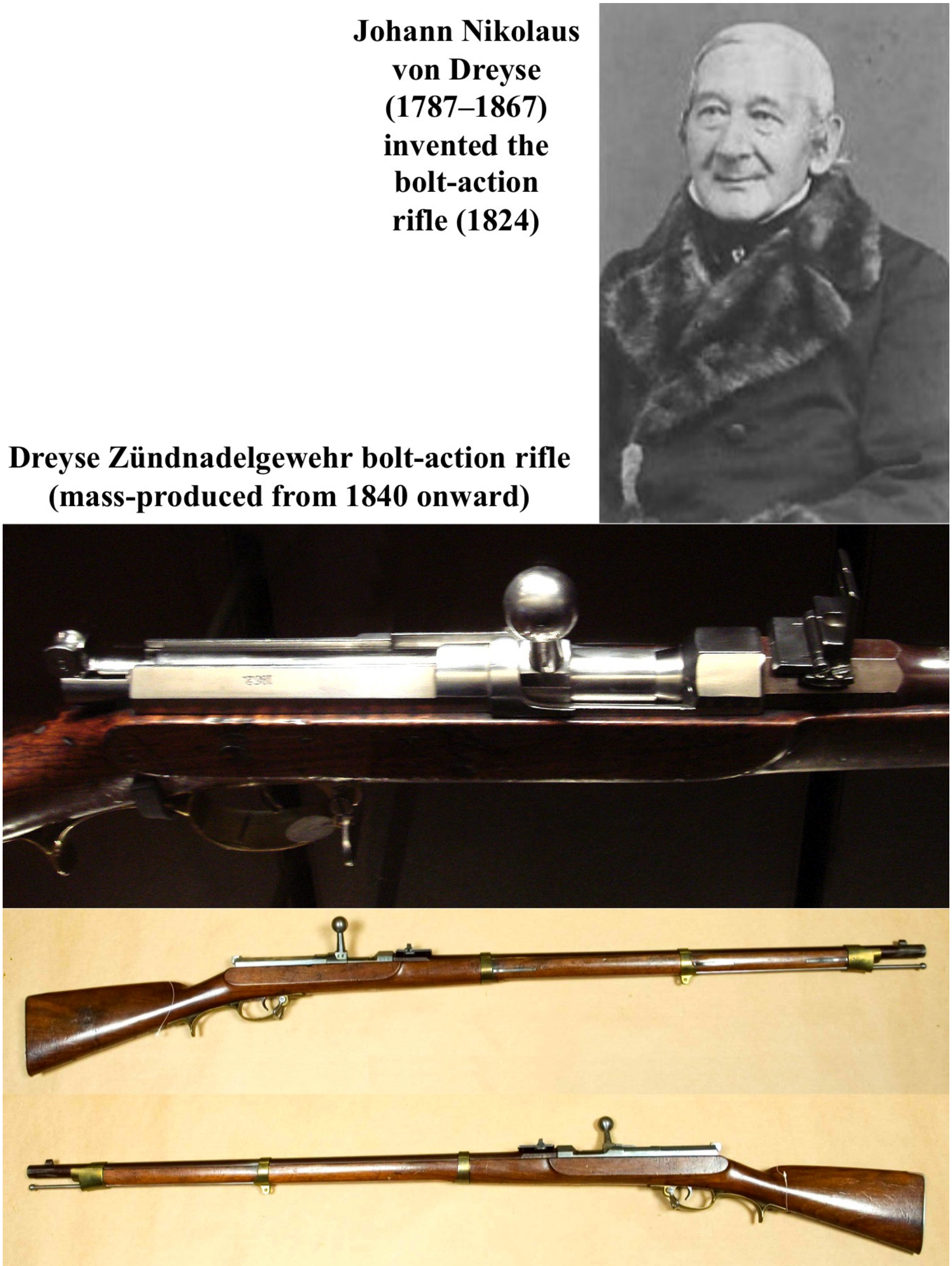

Johann Nikolaus von Dreyse (1787–1867) invented the bolt-action rifle (1824)
Dreyse Zündnadelgewehr bolt-action rifle (mass-produced from 1840 onward)

Figure 7.80: Johann Nikolaus von Dreyse invented the bolt-action rifle in 1824. His Dreyse Zündnadelgewehr bolt-action rifle was mass-produced from 1840 onward.

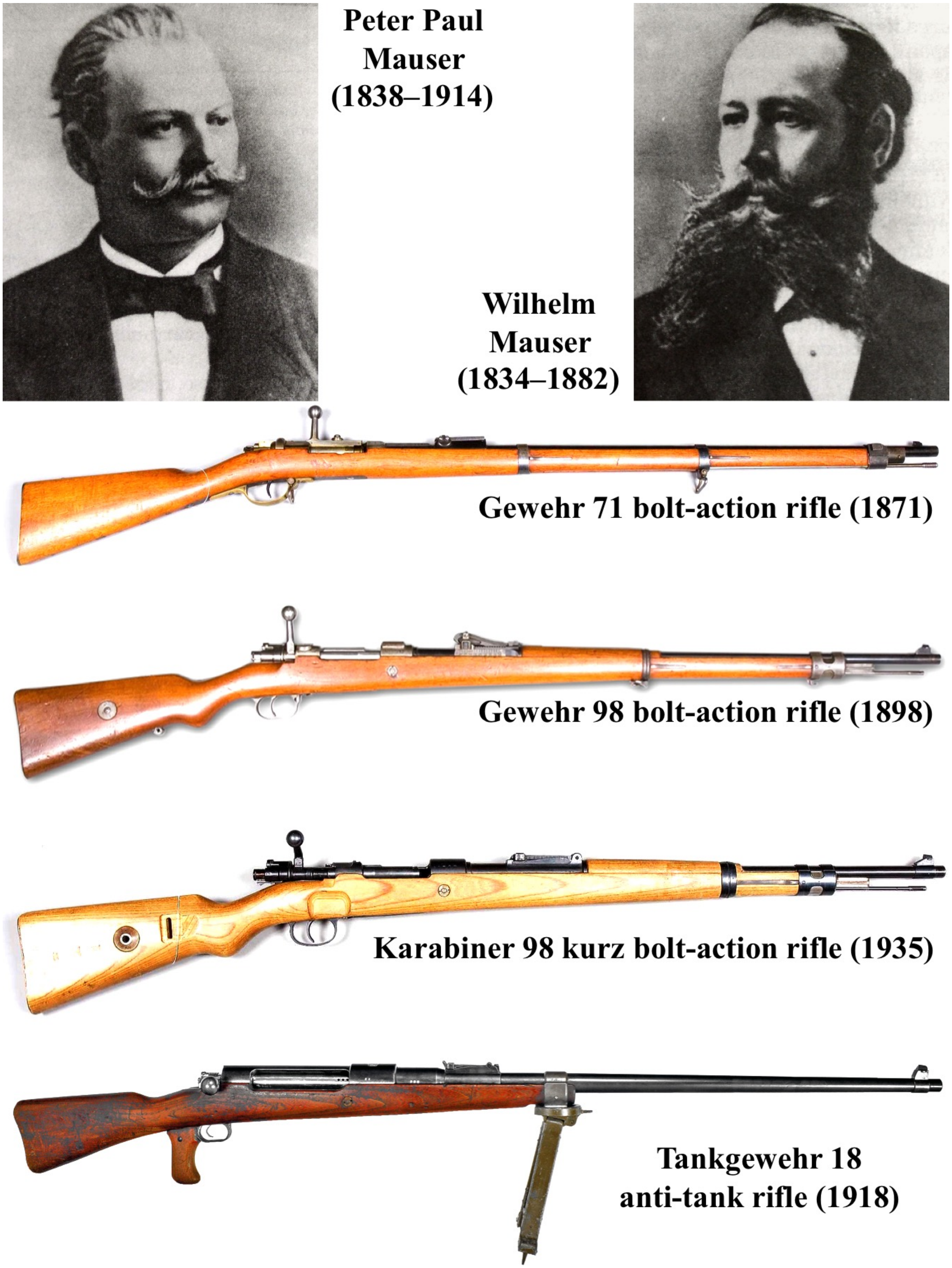

Peter Paul Mauser (1838–1914)
Wilhelm Mauser (1834–1882)
Gewehr 71 bolt-action rifle (1871)
Gewehr 98 bolt-action rifle (1898)
Karabiner 98 kurz bolt-action rifle (1935)
Tankgewehr 18 anti-tank rifle (1918)

Figure 7.81: The brothers Peter Paul Mauser and Wilhelm Mauser invented the Gewehr 71 bolt-action rifle in 1871. The Mauser company later developed improved versions, including the Gewehr 98 (1898) and Karabiner 98 kurz (1935), as well as the scaled-up Tankgewehr 18 anti-tank rifle (1918).

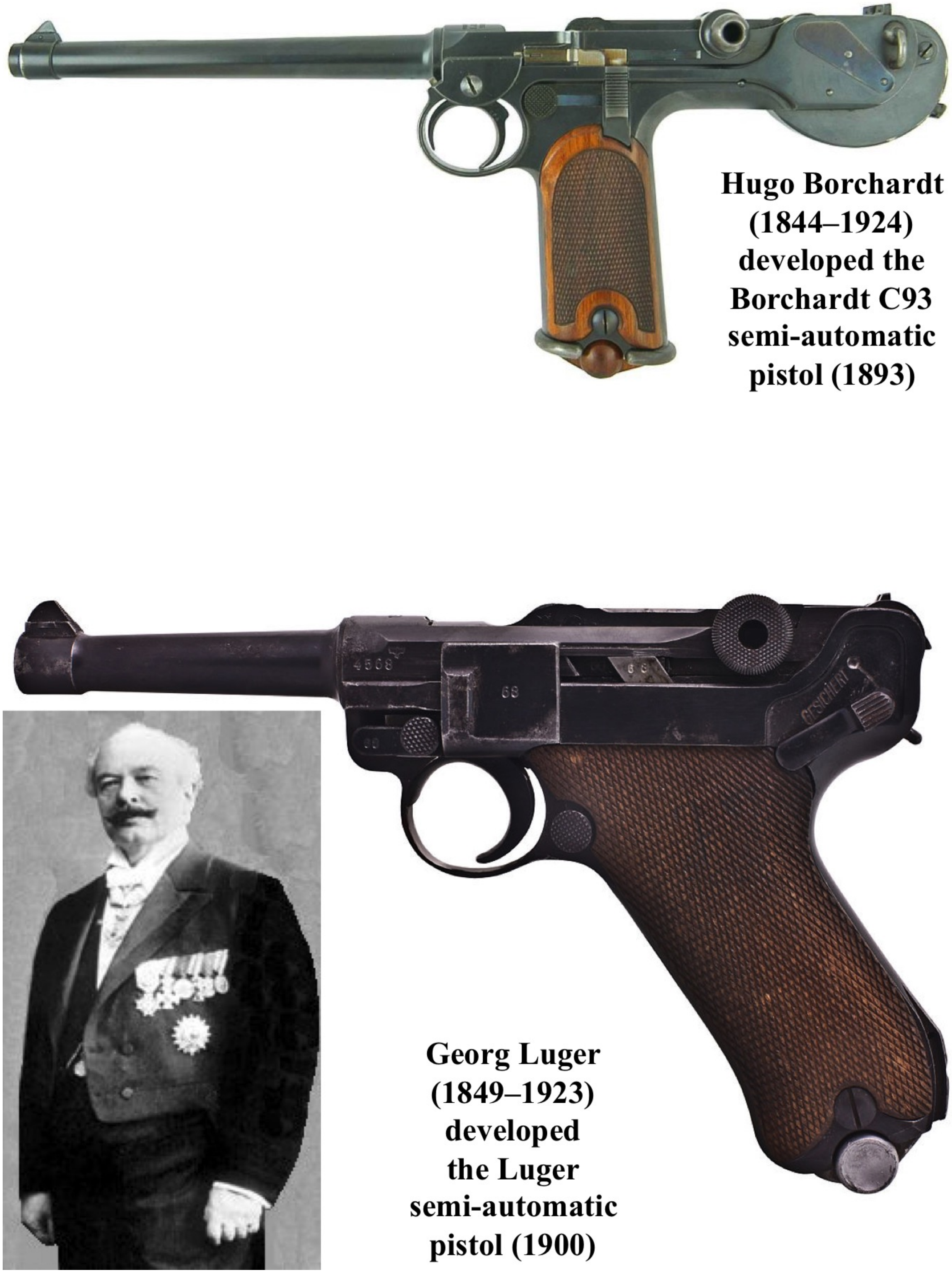

Hugo Borchardt
(1844–1924)
developed the
Borchardt C93
semi-automatic
pistol (1893)
Georg Luger
(1849–1923)
developed
the Luger
semi-automatic
pistol (1900)

Figure 7.82: Hugo Borchardt developed the first semi-automatic pistol, the Borchardt C93, in 1893. Georg Luger improved upon that design to create the Luger semi-automatic pistol in 1900.

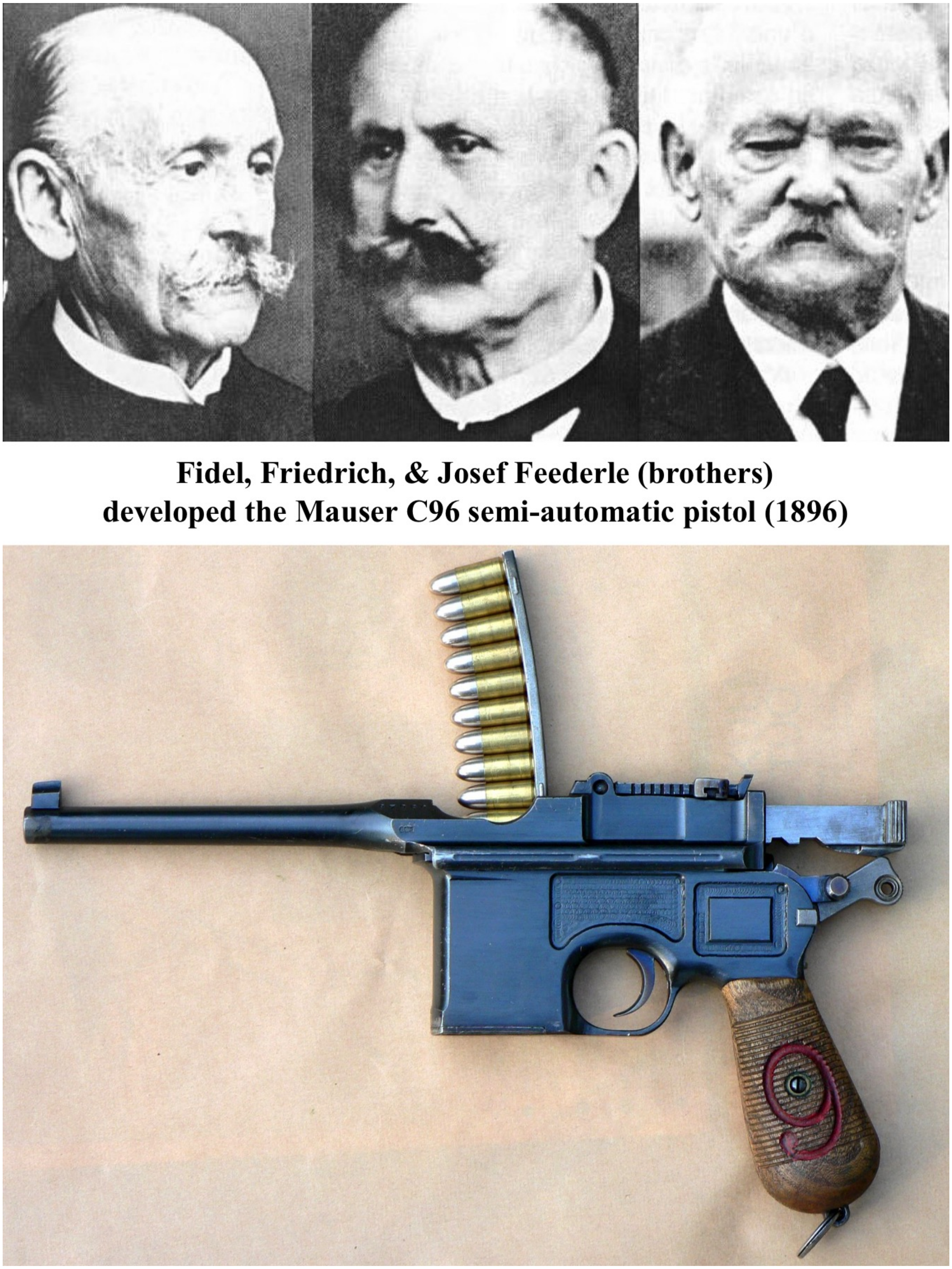

Fidel, Friedrich, & Josef Feederle (brothers)
developed the Mauser C96 semi-automatic pistol (1896)

Figure 7.83: The brothers Fidel, Friedrich, and Josef Feederle developed the Mauser C96 semi-automatic pistol in 1896.

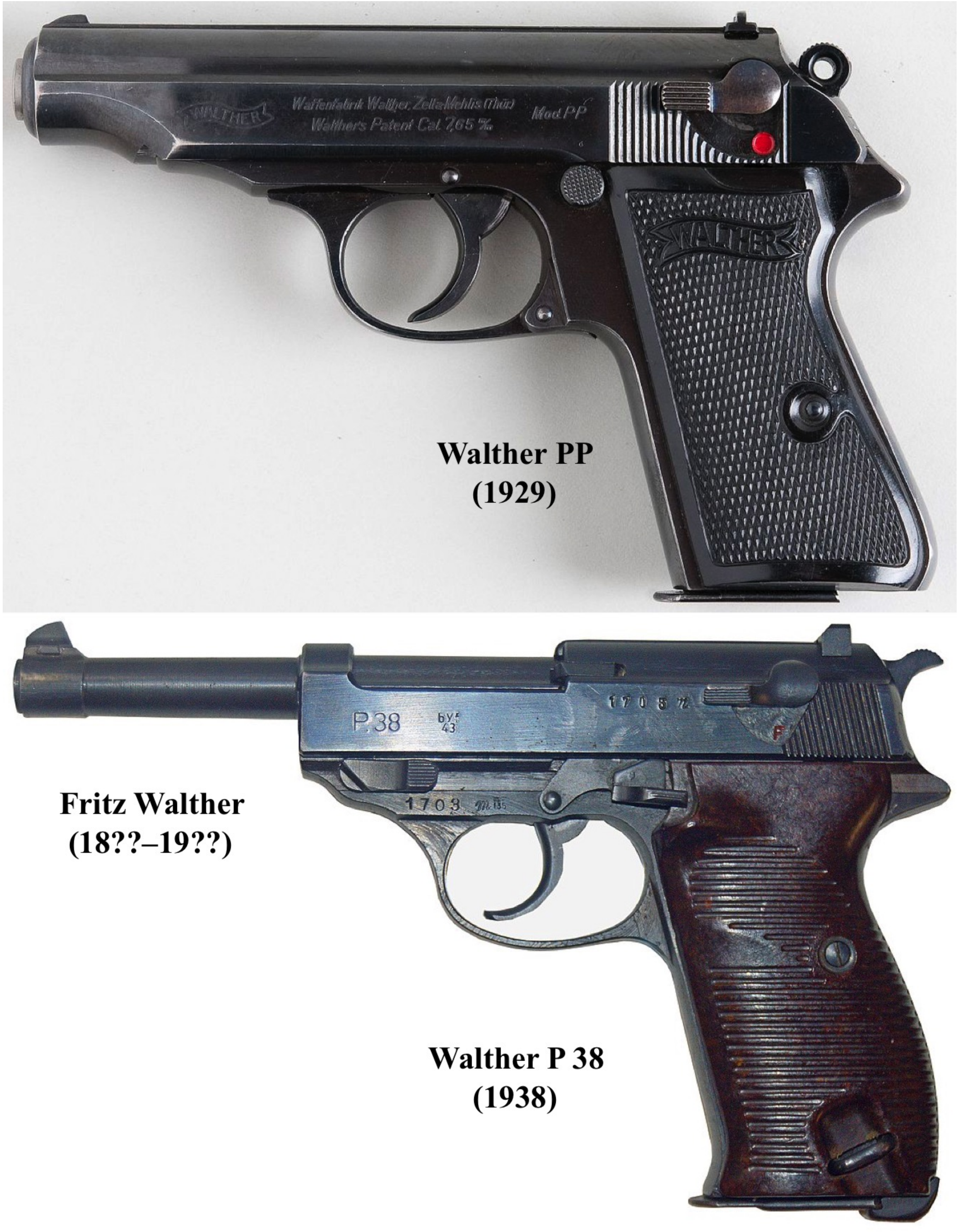

WALTHER
Waffenfabrik Walther, Zella-Mehlis (Thür)
Walthers Patent Cal. 7,65 %
Mod PP
WALTHER
Walther PP
(1929)
P.38
byf
43
Fritz Walther
(18??–19??)
Walther P 38
(1938)

Figure 7.84: Based on the earlier Luger design, Fritz Walther created the more advanced Walther PP in 1929 and Walther P 38 in 1938. Many modern handguns still use these same designs and features.

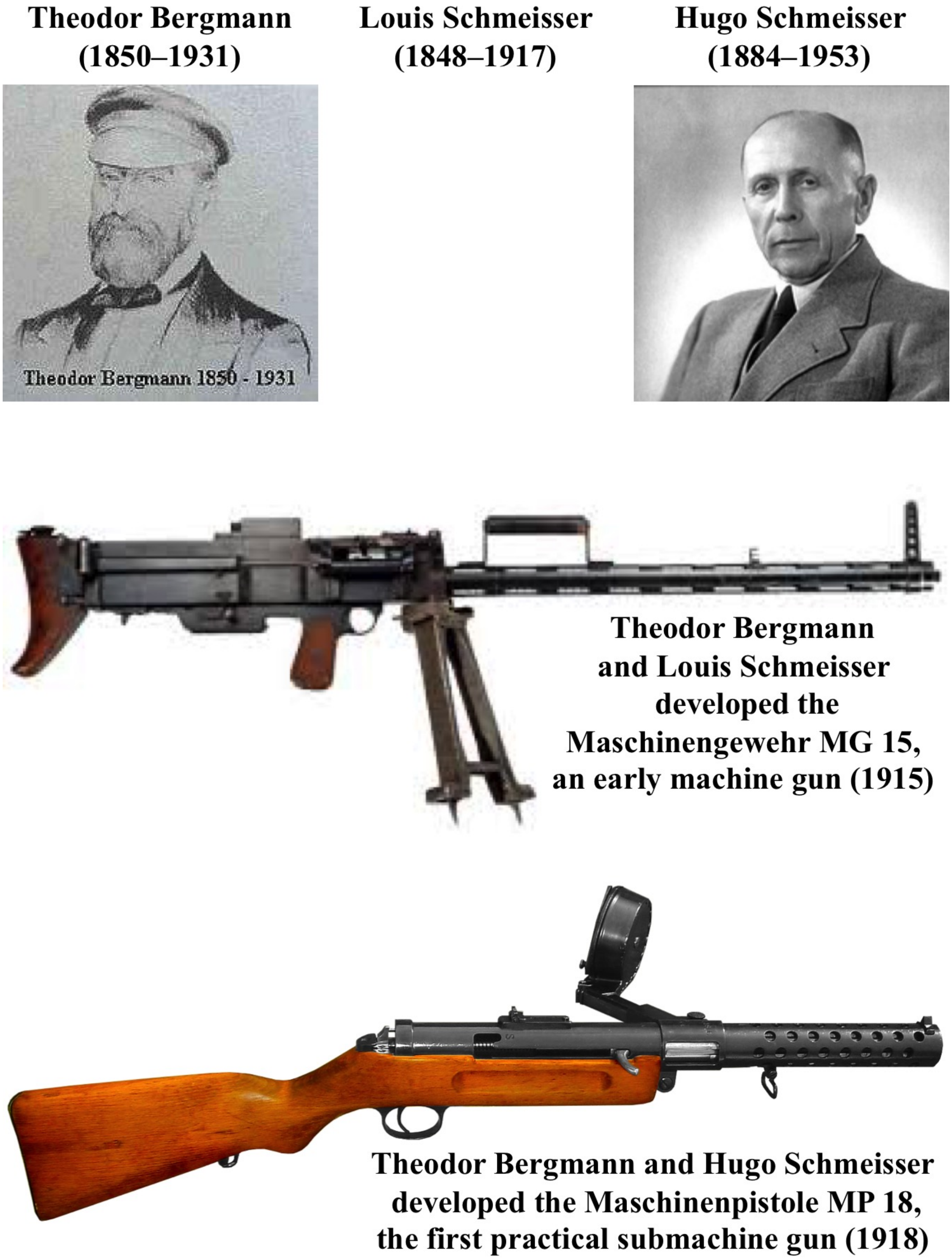

Theodor Bergmann (1850–1931)
Louis Schmeisser (1848–1917)
Hugo Schmeisser (1884–1953)
Theodor Bergmann 1850 - 1931
Theodor Bergmann and Louis Schmeisser developed the Maschinengewehr MG 15, an early machine gun (1915)
Theodor Bergmann and Hugo Schmeisser developed the Maschinenpistole MP 18, the first practical submachine gun (1918)

Figure 7.85: Theodor Bergmann and Louis Schmeisser developed the Maschinengewehr MG 15, an early machine gun, in 1915. Bergmann and one of Louis Schmeisser's sons, Hugo Schmeisser, developed the Maschinenpistole MP 18, the first practical submachine gun, in 1918.

Louis Stange
(1888–1971)
developed the
Maschinengewehr MG 30
machine gun (1930)

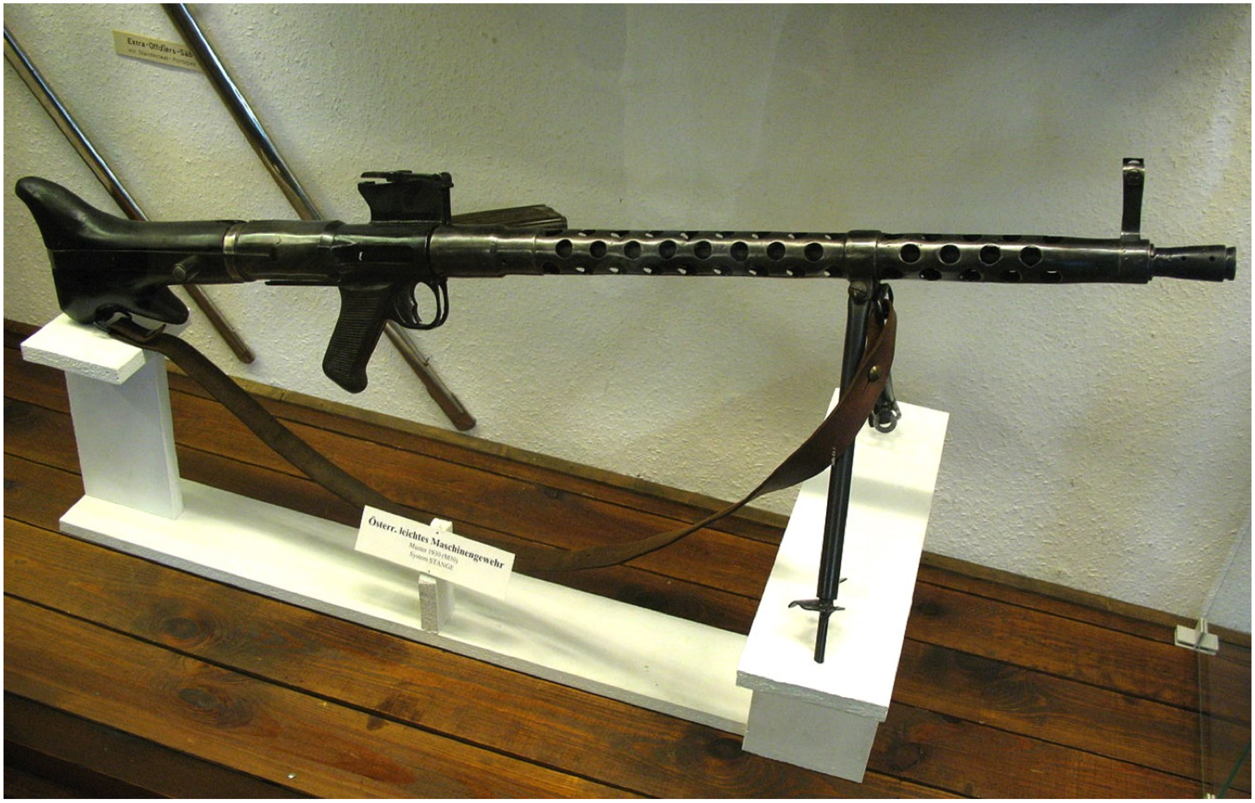

Österr. leichtes Maschinengewehr
Muster 1930 (M30)
System STANGE

Figure 7.86: Louis Stange created the Maschinengewehr MG 30 machine gun in 1930.

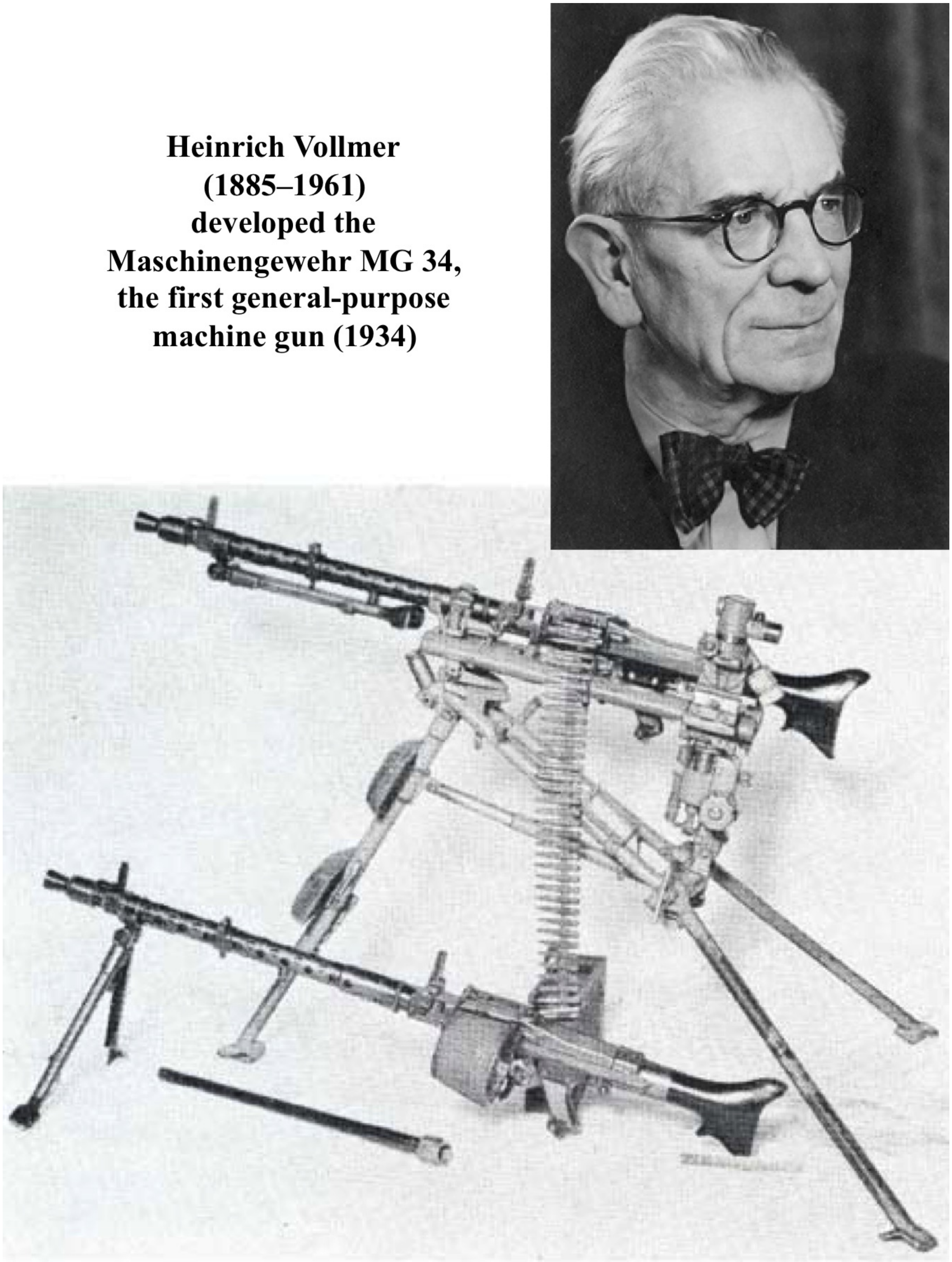

Heinrich Vollmer
(1885–1961)
developed the
Maschinengewehr MG 34,
the first general-purpose
machine gun (1934)

Figure 7.87: Heinrich Vollmer developed the first general-purpose machine gun, the MG 34, in 1934.

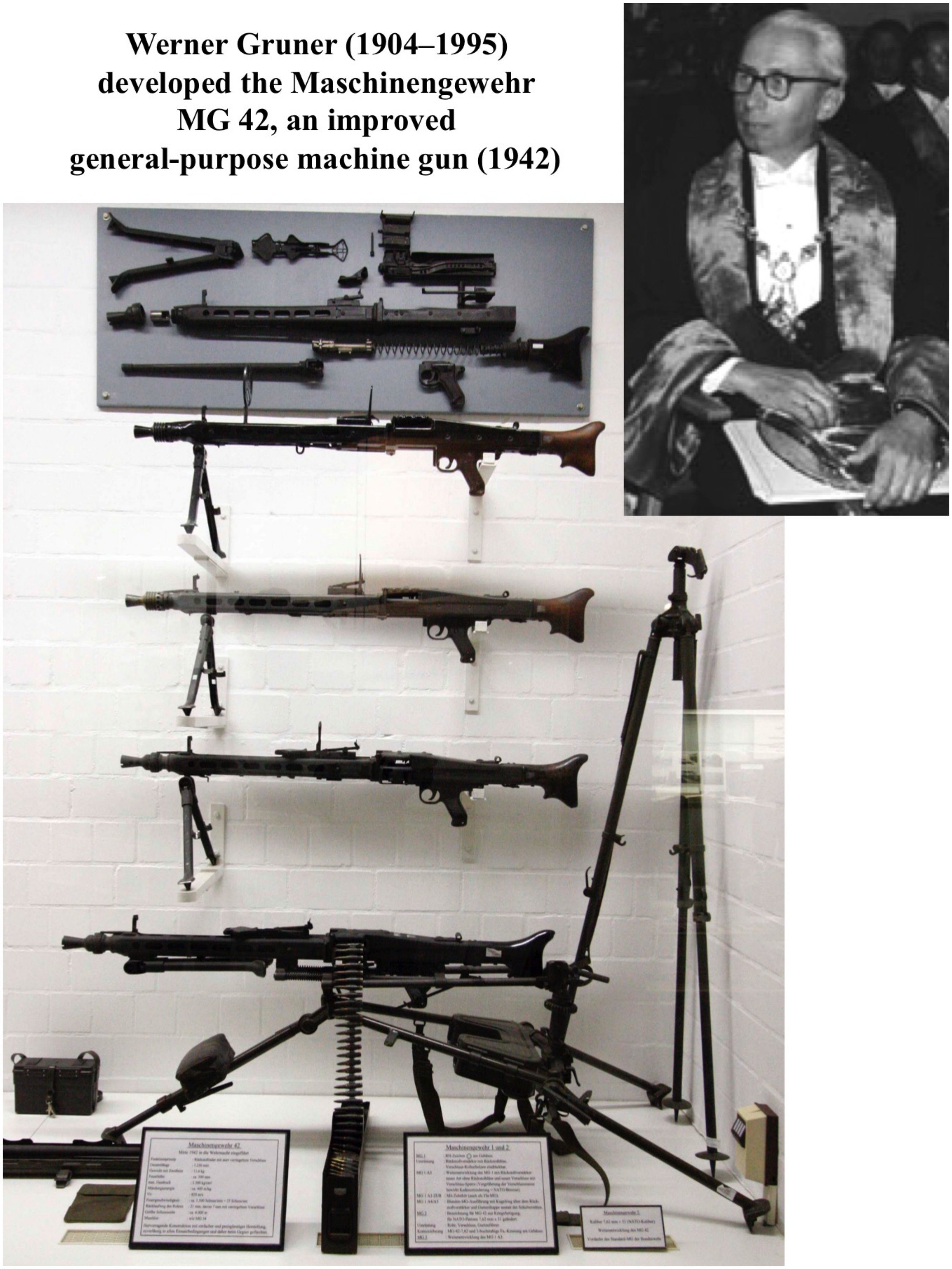

Werner Gruner (1904–1995)
developed the Maschinengewehr
MG 42, an improved
general-purpose machine gun (1942)

Figure 7.88: Werner Gruner produced an improved general-purpose machine gun, the MG 42, in 1942.

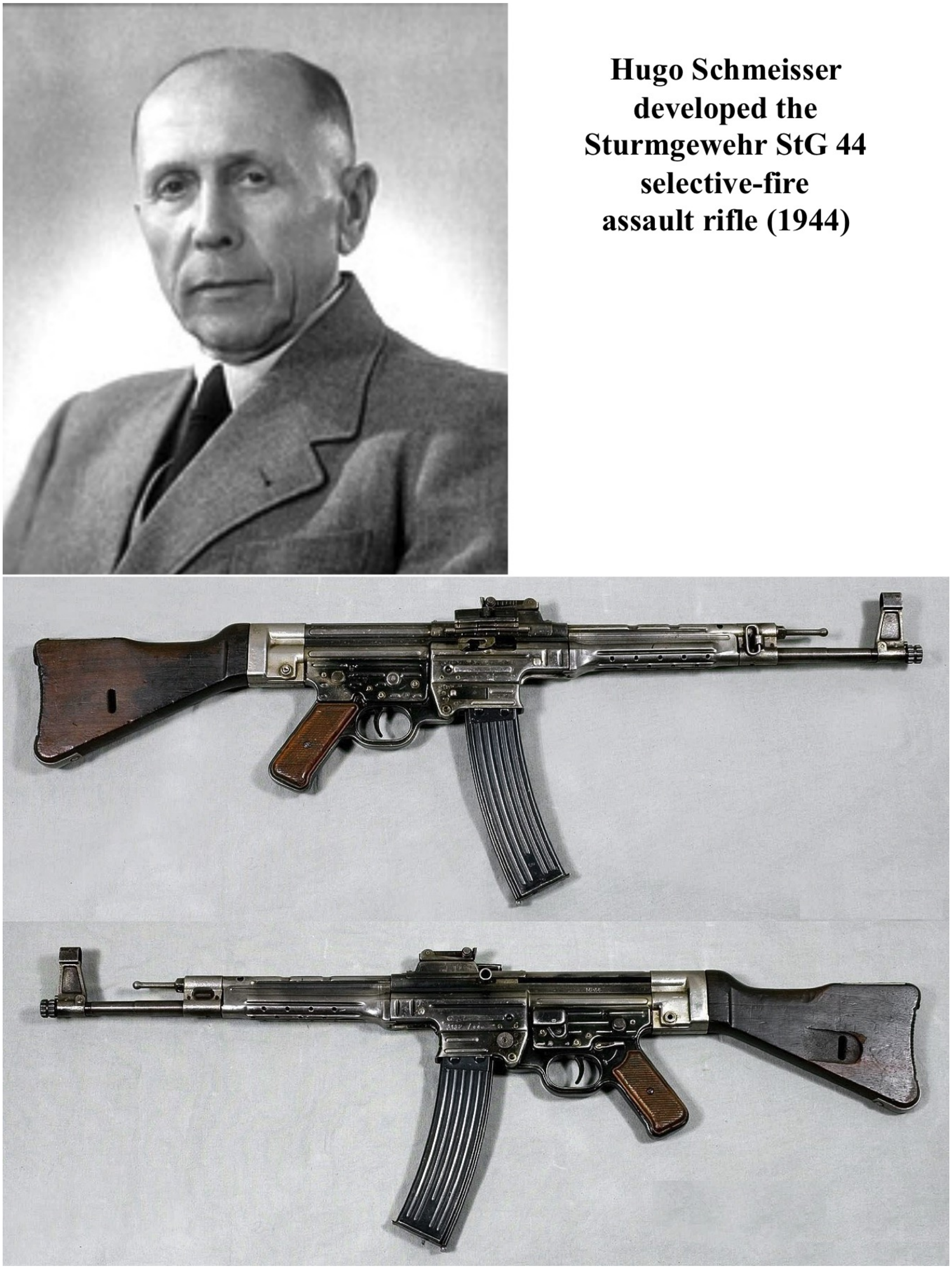
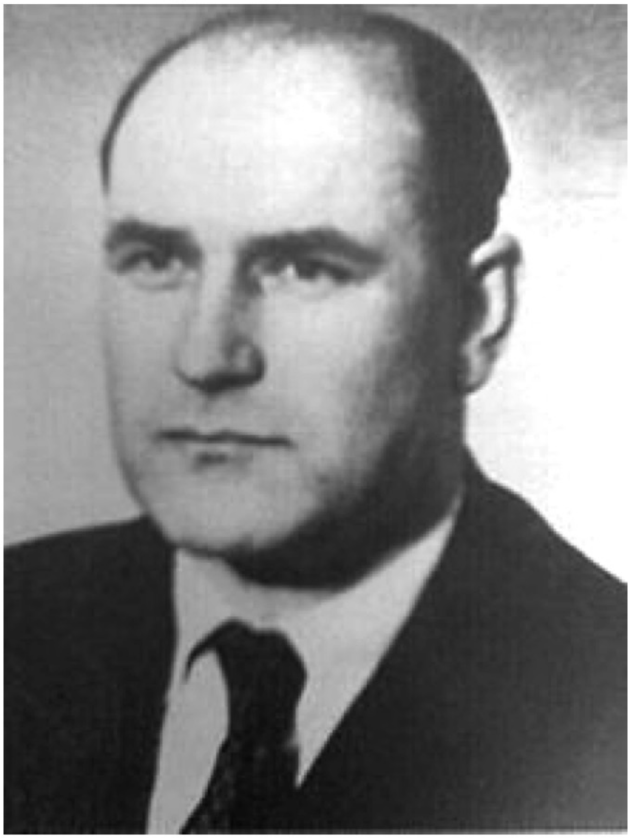

Hugo Schmeisser
developed the
Sturmgewehr StG 44
selective-fire
assault rifle (1944)

Figure 7.89: Hugo Schmeisser created the Sturmgewehr StG 44 selective-fire assault rifle, the direct ancestor of modern assault rifles, in 1944.

Wilhelm Stähle (1901–1974) and Ludwig Vorgrimler (1912–1983)



Developed the Sturmgewehr StG 45 improved assault rifle (1945)

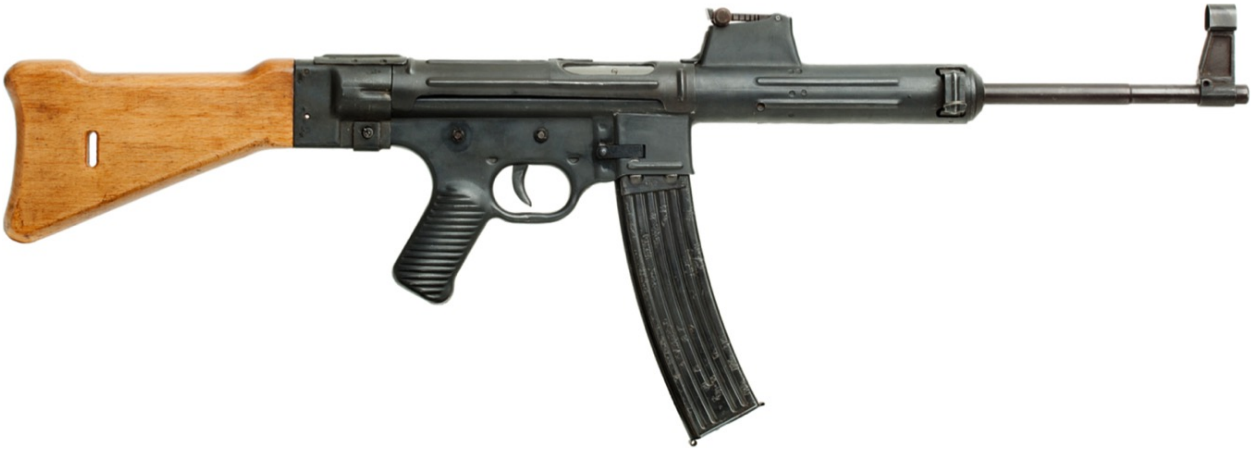


Figure 7.90: Wilhelm Stähle and Ludwig Vorgrimler developed an improved selective-fire assault rifle, the Sturmgewehr StG 45, in 1945.

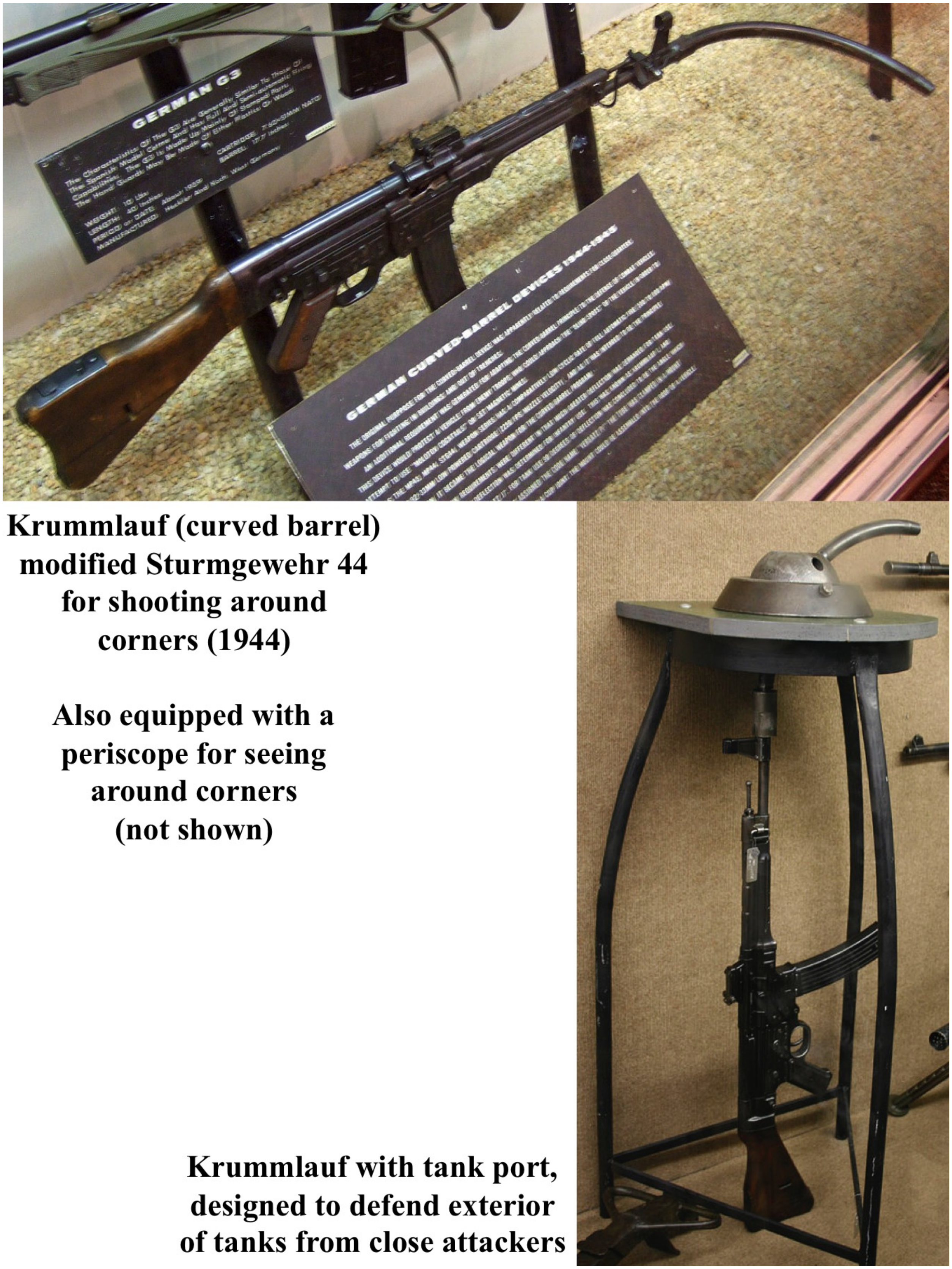

GERMAN G3
The Characteristics Of The G3 Are Generally Similar To Those Of
The Spanish Model Cetme And Has Full And Semi-automatic Firing
Capabilities. The G3 Is Made Up Mainly Of Stamped Parts.
The Hand Guards May Be Made Of Either Plastics Or Wood.
WEIGHT: 10 Lbs.
LENGTH: 40 Inches
PERIOD or DATE: About 1959
MANUFACTURED: Heckler And Koch, West Germany
CARTRIDGE: 7.62x51MM NATO
BARREL: 17.7 Inches
GERMAN CURVED-BARREL DEVICES 1944-1945
Krummlauf (curved barrel)
modified Sturmgewehr 44
for shooting around
corners (1944)
Also equipped with a
periscope for seeing
around corners
(not shown)
Krummlauf with tank port,
designed to defend exterior
of tanks from close attackers

Figure 7.91: The Krummlauf (curved barrel) modified Sturmgewehr 44 could shoot around corners, and was equipped with a periscope for seeing around corners (1944). Krummlauf rifles were also installed in tank ports to defend the exterior of tanks from close attackers.

7.6.2 Artillery

Engineers from the predominantly German-speaking world also made many important innovations in larger-caliber guns or artillery pieces.

In 1674, Menno van Coehoorn (Dutch, 1641–1704, Fig. 7.92) invented the Coehoorn or Coehorn style of mortar, which was widely used until the early twentieth century. He also made other innovations in methods of attacking or defending fortifications. *Encyclopedia Britannica* summarized some of his accomplishments [EB 2010]:

> Dutch soldier and military engineer [...] who made a number of innovations in weaponry and siege-warfare techniques.
>
> The son of an infantry officer, Coehoorn became a captain in 1667 and served in the Dutch War (1672–78) against Louis XIV of France. He attained prominence at the siege of Grave (1674), in which he introduced a highly effective bronze mortar, which subsequently was known as the Coehoorn mortar. His first book on siege techniques appeared in 1682 and was followed by his most important and most widely translated work, *Nieuwe vestingbouw* (1685; “New Fortress Construction”). He perfected a system of fortification suited to level terrain, such as that of the Netherlands, and he advocated a new strategy for citadel defense that involved the active deployment of troops instead of relying only on moats and ramparts.
>
> After greatly assisting in the capture of Bonn (1689) at the outset of the War of the Grand Alliance, Coehoorn fought in the Battle of Fleurus (1690). He improved the fortifications of Namur but lost the city to a French siege in 1692 and did not regain it until 1695. In 1695 he was promoted to master general of the artillery, and in that post he oversaw fortification of several Dutch cities.

In 1880, engineers at Krupp invented the first modern mortars (Mörser), which were rifled breechloaders designed for different calibers of ammunition: 7.5 cm, 15 cm, 21 cm, and other sizes (Fig. 7.93). They could be used either mounted on a wheeled carriage or unmounted on a flat base.

In 1909, engineers at Rheinmetall developed improved trench mortars (Minenwerfer), which were designed for three calibers of ammunition: 7.58 cm (leichte), 17 cm (mittlerer), and 25 cm (schwerer). Like the earlier Krupp mortars, all three sizes were used either mounted on a wheeled carriage or unmounted on a flat base. See Fig. 7.94. The innovative Krupp and Rheinmetall designs prompted other countries to copy and produce similar trench mortars.

Also in 1909, engineers at Skoda demonstrated the 30.5 cm M.11 Mörser siege howitzer, which could fire projectiles with a mass of 384 kg and a caliber of 30.5 cm up to a maximum range of 11.3 km. See Fig. 7.95. M.11 Mörser systems were used by Axis countries in World Wars I and II, and even by some Eastern Bloc countries during the Cold War.

Over the first several decades of the twentieth century, engineers at Krupp developed increasingly sophisticated giant artillery guns, such as:

- The Kurze Marine-Kanone 12 L/16 (also known as Big Bertha or Gamma-Gerät, 1909), which could fire projectiles with masses of 400–1160 kg and a caliber of 42 cm up to a maximum range of 14 km. See Fig. 7.96. Ten of these guns were used in World War I, and one in World War II.

- The Paris Gun (1918, so named because several were used to bombard Paris), which could fire projectiles with a mass of 106 kg and calibers of 22–24 cm up to a maximum range of 130 km. Its projectiles reached altitudes of 42 km, a record that was not broken until flights of the A-4 (V-2) rocket in 1942. See Fig. 7.98. Somewhat improved versions, the 21-cm K 12 (E) railway gun and the 28-cm K 5 (E) railway gun (sometimes called Anzio Annie by the Allies), were produced and used during World War II. (In the 1950s, the United States produced a copy of the 28-cm German gun, officially named the M65 and unofficially called Atomic Annie, since it could fire a specially designed W9 nuclear artillery shell. Was the W9 fission bomb also a copy of a German design?)

- The Schwerer Gustav gun (1941), which could fire projectiles with a mass of 7.1 tons and a caliber of 80 cm up to a maximum range of 47 km. It was the heaviest mobile artillery piece ever built, fired the heaviest artillery shells ever created, and had the largest caliber ever used in combat. See Fig. 7.99. During the war, the Schwerer Gustav gun was used to destroy targets on the Eastern Front, but the gun itself was (mostly) destroyed by Germany at the end of the war to prevent it from being captured intact by Allied troops.

- The Hochdruckpumpe or “V-3” gun (1944), which could fire projectiles with a mass of 140 kg and a caliber of 15 cm up to a maximum range of 165 km [Margry 2001]. See Fig. 7.100. The Hochdruckpumpe was just one of several unrelated projects competing for the title of “V-3,” the next large new weapon system to be publicly announced after the V-2 rocket. (A piloted V-1 cruise missile and multiple large rockets were also called “V-3” at times—see Appendix E.) The Hochdruckpumpe had a clever design in which propellant charges were planted in side chambers at regular intervals along the main barrel, and ignited sequentially as the projectile passed them. One such gun was successfully test fired on the Baltic coast of Pomerania in May 1944, and two guns were used to bombard Luxembourg during the period December 1944–February 1945. The guns were captured and studied by the U.S. Army at the end of the war.

Karl Puff (German, 18??–19??) patented a squeeze bore or tapered bore gun design in 1904. Just as reducing the opening of a garden hose with one’s thumb increases the flow velocity of water, steadily reducing the cross-sectional area of a gun barrel toward the end increases the muzzle velocity of a bullet. Hermann Gerlich (German, 18??–19??) filed more detailed patent applications on squeeze bore designs in 1929 and built such guns; see Fig. 7.101. The German military used squeeze bore guns such as the Pak 41 anti-tank gun (1941).

In September 1945, R. P. Linstead and T. J. Betts, the British and American chairs of the Combined Intelligence Objectives Subcommittee (CIOS), listed a number of important German innovations for large guns [AFHRA A5186 electronic version pp. 904–1026, Ch. 4, p. 41]:

> Guns ranging from 30 mm to 350 mm calibers were designed to operate without recoil. Certain of these weapons adopted the principle of a "blow-out" disc located at the rear of the powder chamber. This disc was designed to obdurate the powder pressure for a short interval while a given pressure build-up occurs in the chamber, it then releases this pressure to the rear of the weapon. In this manner equal components of momenta are achieved and recoil eliminated.
>
> The advantages of such a development are many. Construction is greatly simplified and elaborate recoil and counter recoil mechanisms are eliminated with savings in weight and material. Thus comparatively large caliber weapons can be adapted for aircraft mounting due to the elimination of recoil and accompanying trunnion stress.
>
> The Germans had made considerable progress with our rigidly mounted tank guns of comparatively large calibers. By the elimination of recoil mechanisms, a considerable saving of space for tank crews was achieved and tank turrets could be fitted with larger guns.
>
> The German design of smooth-bore, high velocity weapons, firing fin-stabilized projectiles was another development worth recording. These weapons resulted in extremely long ranges, excellent accuracy, and lessened gun wear.

7.6.3 Shaped-Charge Anti-Tank Weapons

German-speaking creators also invented shaped-charge anti-tank weapons. See pp. 558–563.

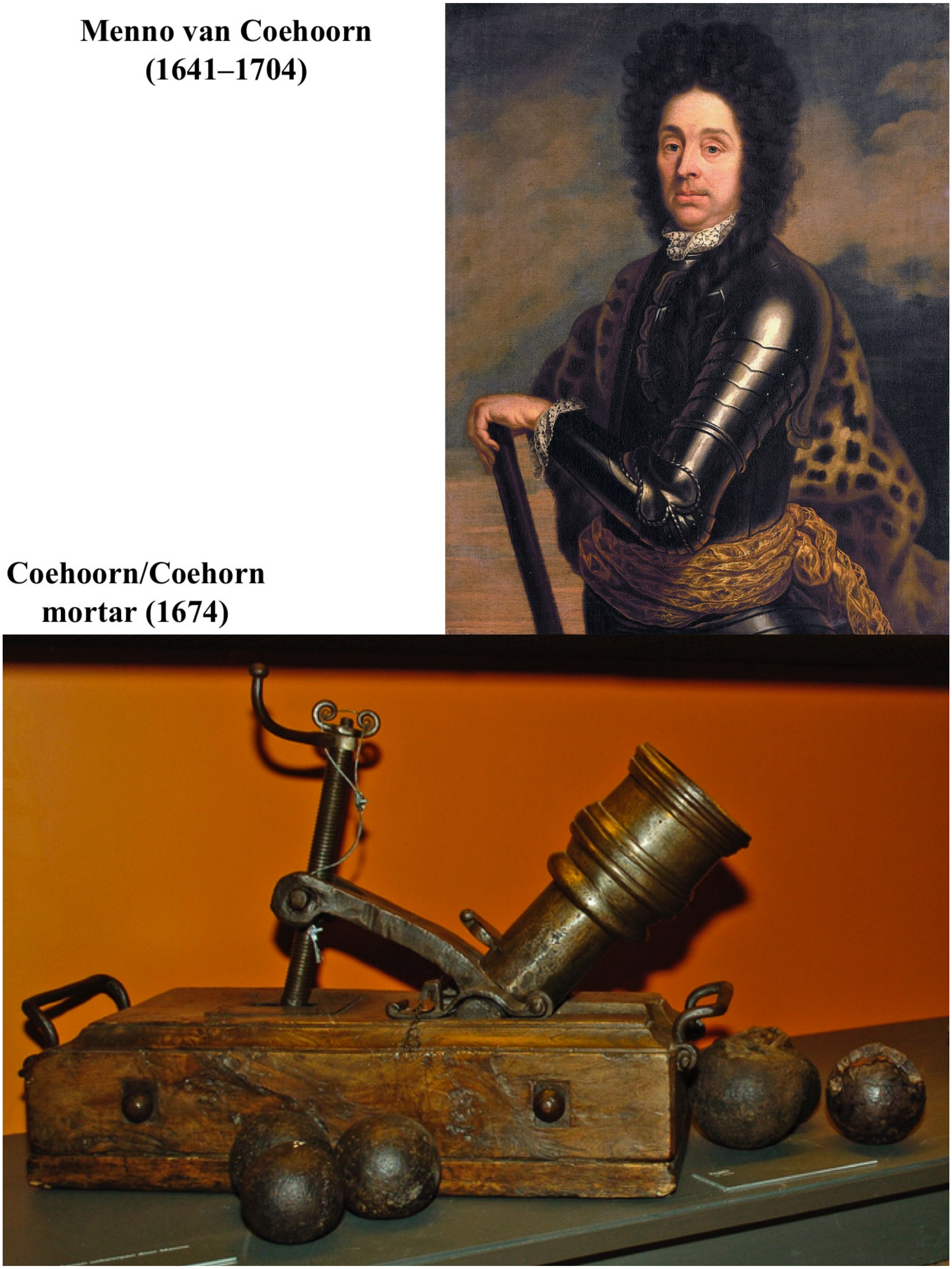
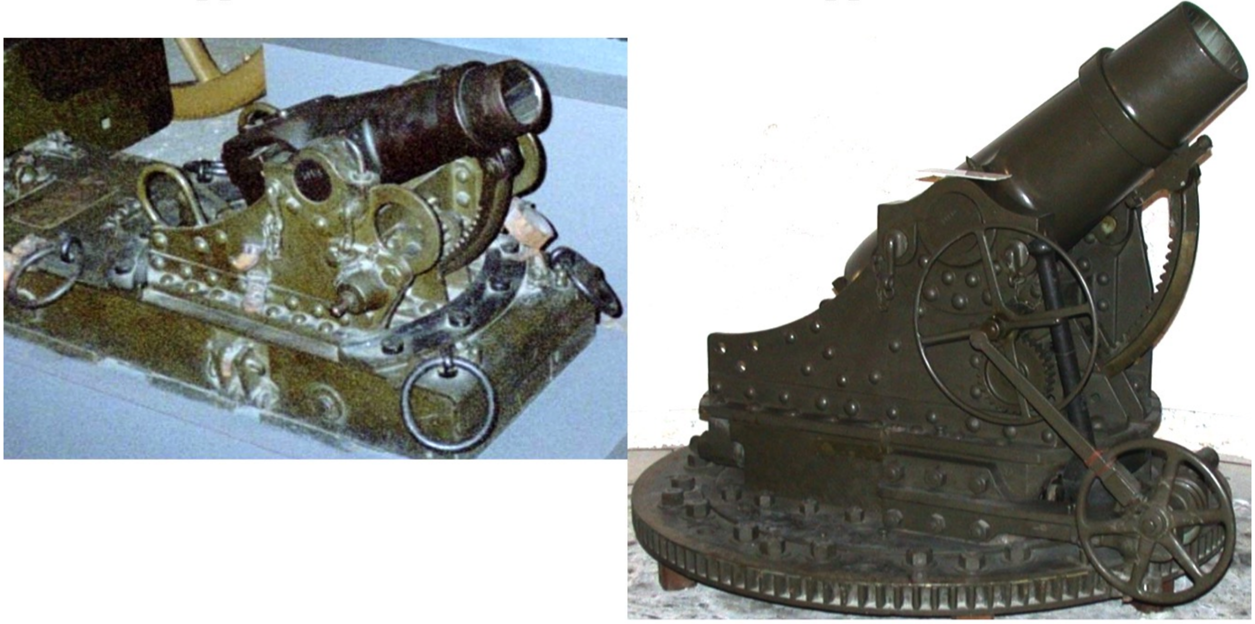

Menno van Coehoorn
(1641–1704)
Coehoorn/Coehorn
mortar (1674)

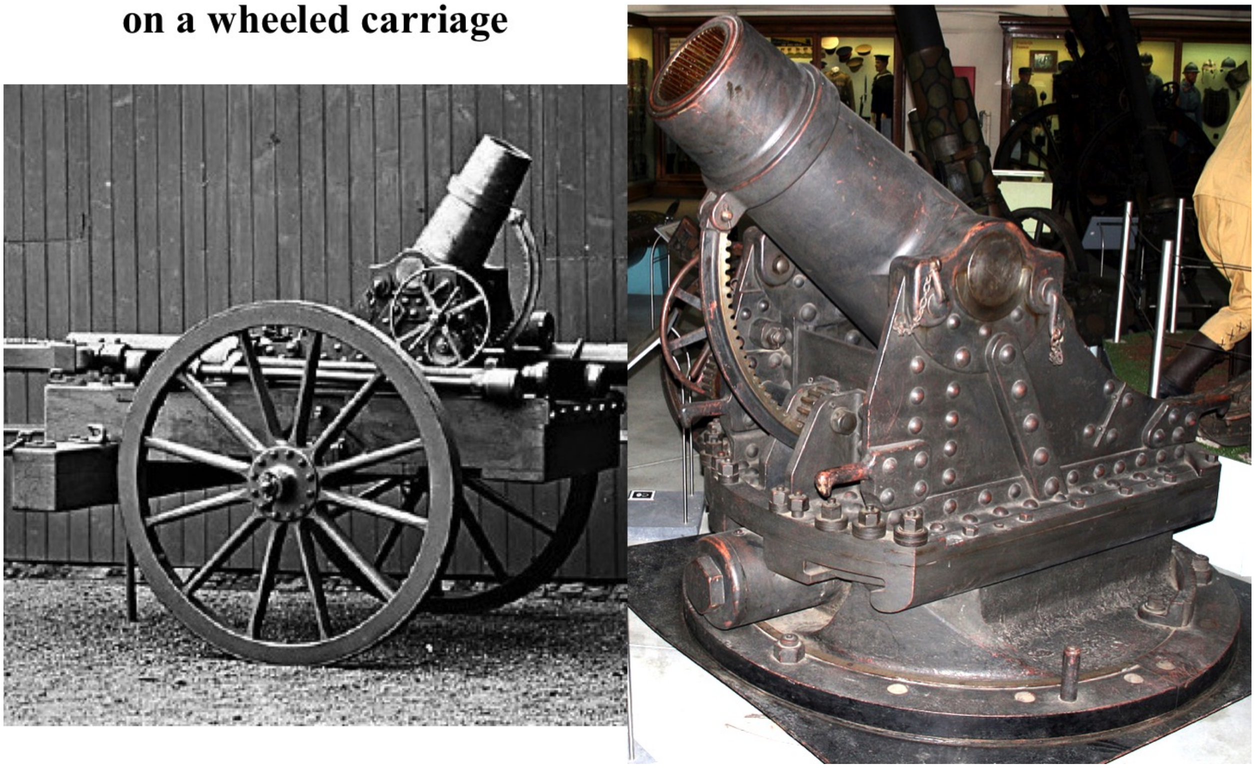
Figure 7.92: In 1674, Menno van Coehoorn invented the Coehoorn or Coehorn style of mortar, which was widely used until the early twentieth century. He also made other innovations in methods of attacking or defending fortifications.

Krupp Mörser rifled mortars (1880)



Krupp 7.5 cm Mörser

Krupp 15 cm Mörser



Krupp 15 cm Mörser on a wheeled carriage

Krupp 21 cm Mörser

Figure 7.93: In 1880, engineers at Krupp invented the first modern mortars (Mörser), which were rifled breech-loaders designed for different calibers of ammunition: 7.5 cm, 15 cm, 21 cm, and other sizes. They could be used either mounted on a wheeled carriage or unmounted on a flat base.

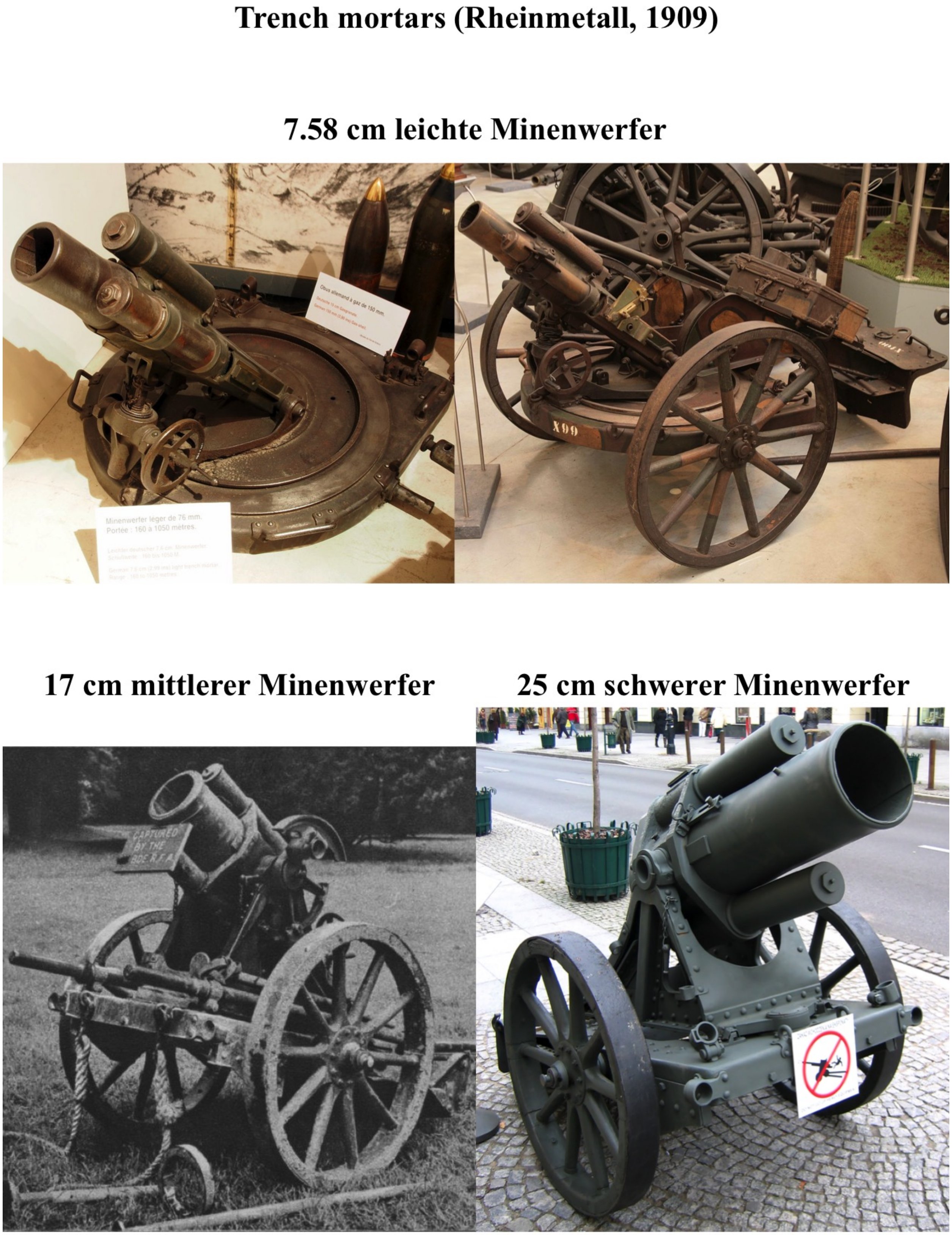

Trench mortars (Rheinmetall, 1909)
7.58 cm leichte Minenwerfer
Obus allemand à gaz de 150 mm.
Minenwerfer léger de 76 mm.
Portee : 160 à 1050 mètres.
X99
17 cm mittlerer Minenwerfer
CAPTURED BY THE BDE R.F.A.
25 cm schwerer Minenwerfer

Figure 7.94: In 1909, engineers at Rheinmetall developed improved trench mortars (Minenwerfer), which were designed for three calibers of ammunition: 7.58 cm (leichte), 17 cm (mittlerer), and 25 cm (schwerer). Like the earlier Krupp mortars, all three sizes were used either mounted on a wheeled carriage or unmounted on a flat base.

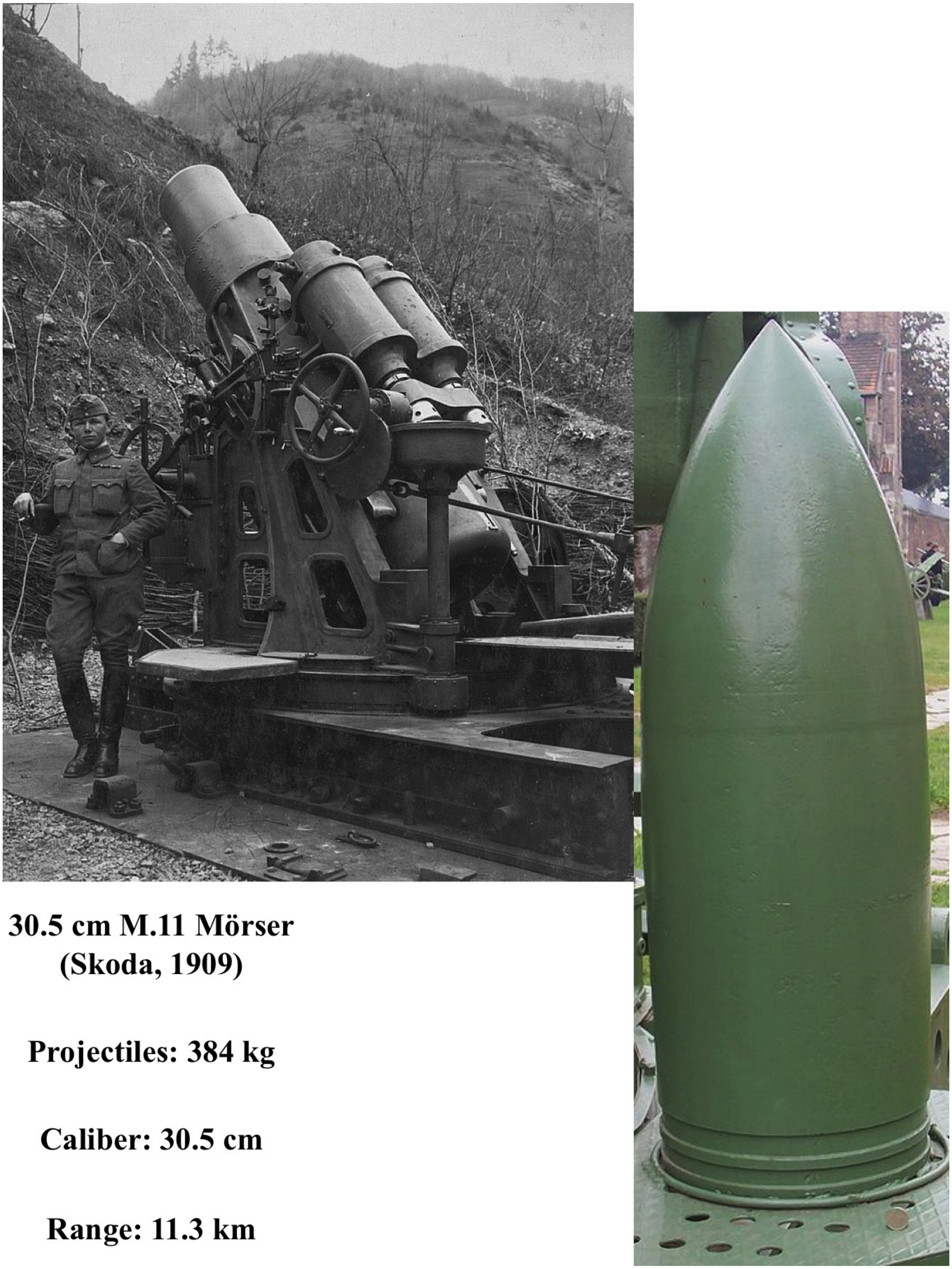

30.5 cm M.11 Mörser
(Skoda, 1909)
Projectiles: 384 kg
Caliber: 30.5 cm
Range: 11.3 km

Figure 7.95: In 1909, engineers at Skoda demonstrated the 30.5 cm M.11 Mörser, which could fire projectiles with a mass of 384 kg and a caliber of 30.5 cm up to a maximum range of 11.3 km.

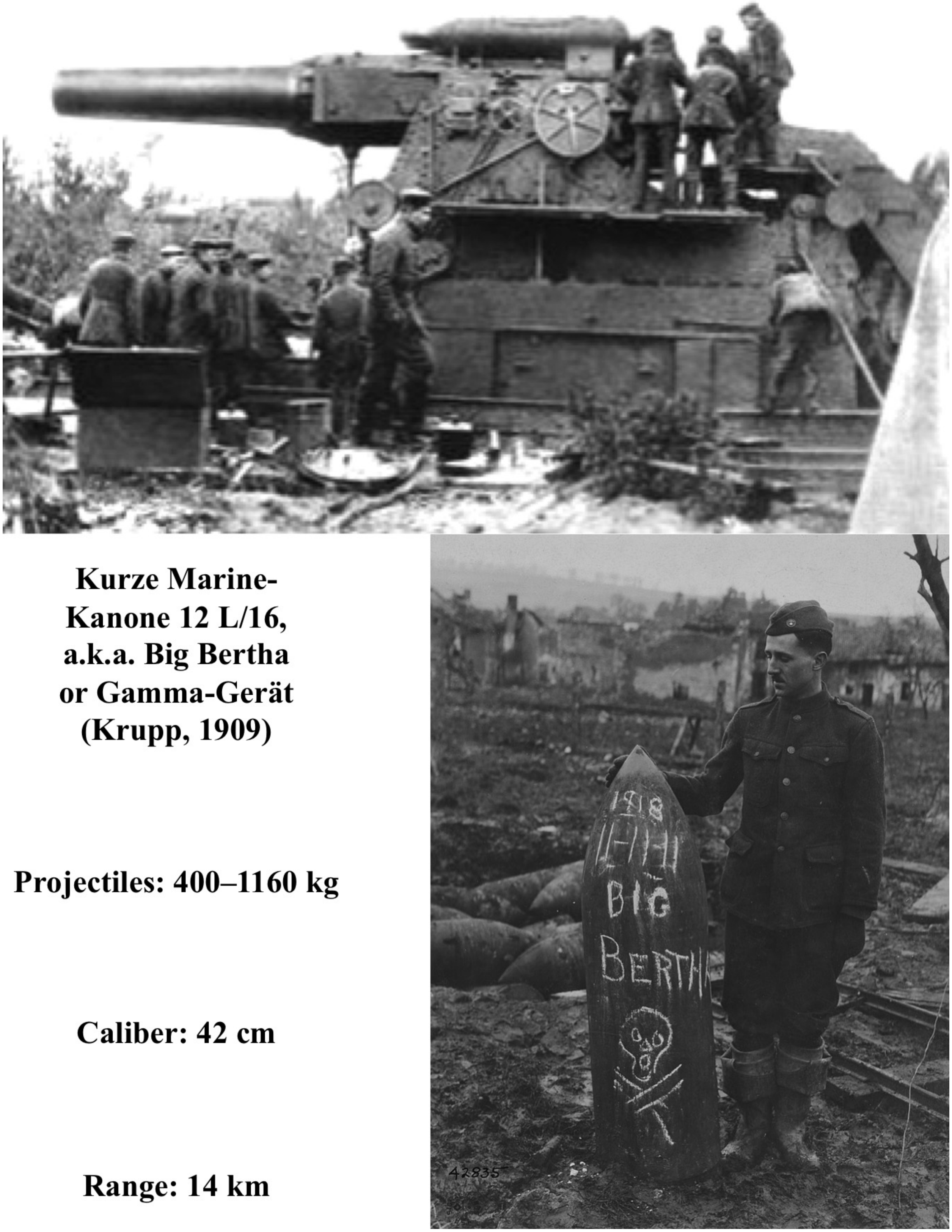

Kurze Marine-Kanone 12 L/16, a.k.a. Big Bertha or Gamma-Gerät (Krupp, 1909)
Projectiles: 400–1160 kg
Caliber: 42 cm
Range: 14 km
BIG BERTHA
42835

Figure 7.96: In 1909, engineers at Krupp demonstrated the Kurze Marine-Kanone 12 L/16 (also known as Big Bertha or Gamma-Gerät), which could fire projectiles with masses of 400–1160 kg and a caliber of 42 cm up to a maximum range of 14 km.

NARA Still Pictures, RG 111 SCA---Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941-1954. Captured German Equipment, German, Box 3344, Book 5, SC 205713, 205714.

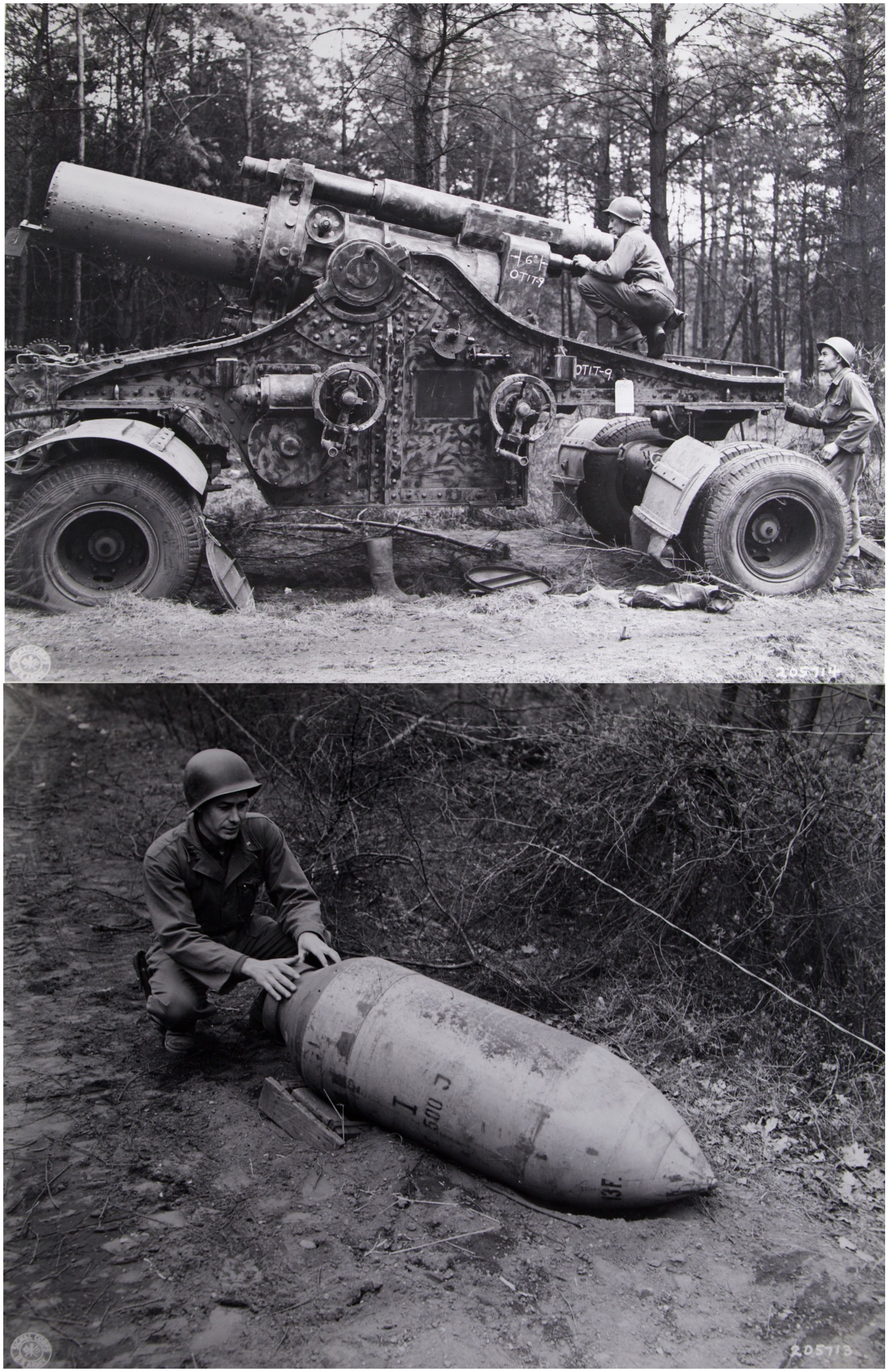


Figure 7.97: Original photo caption: “U.S. Army Ordnance men inspect howitzer-like gun captured by 30th Division units. The gun fires a rocket-type shell 15 inches in diameter, weighing about 1,500 pounds. 4/2/45” [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3344, Book 5, SC 205713, SC 205714.]

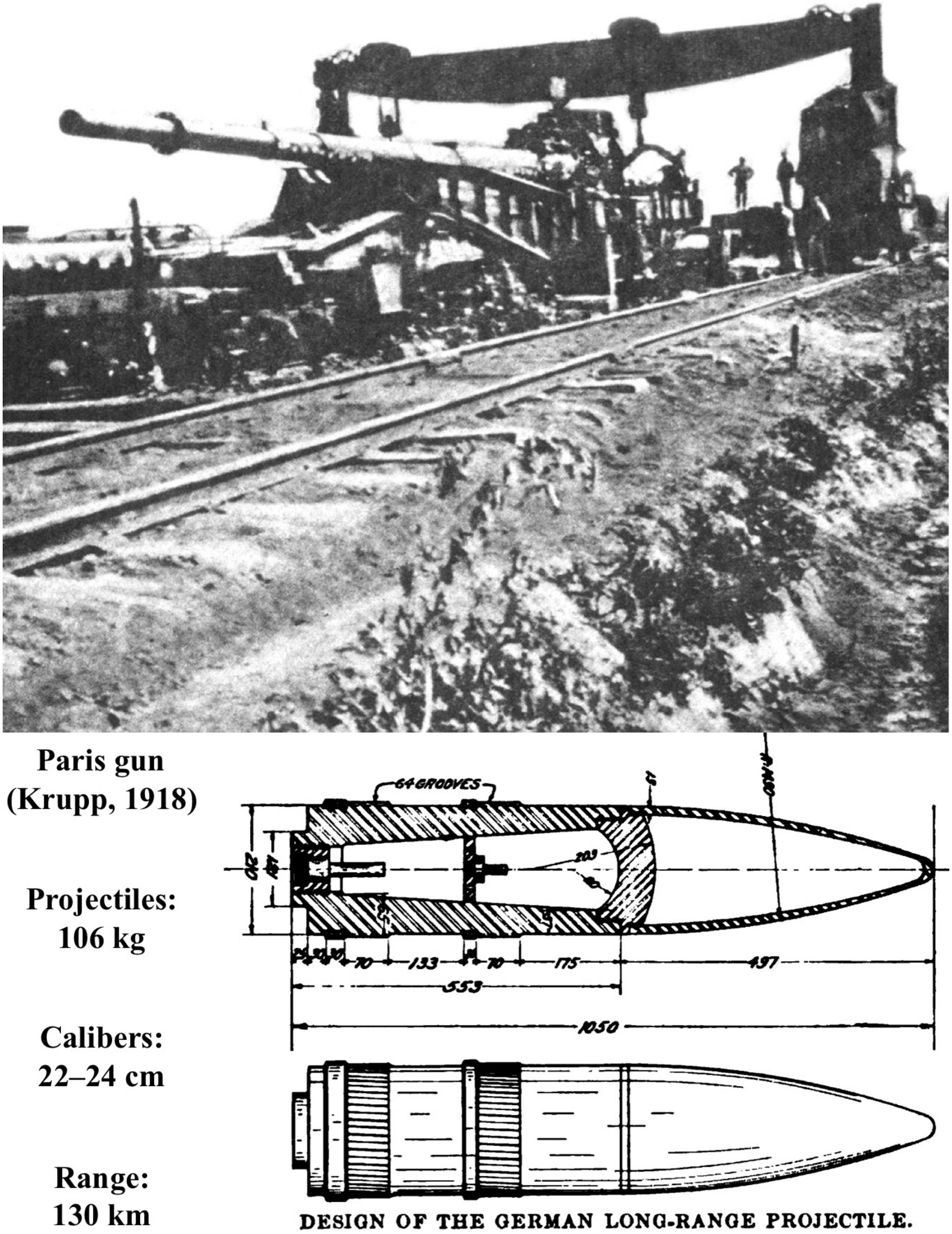

Paris gun
(Krupp, 1918)
Projectiles:
106 kg
Calibers:
22–24 cm
Range:
130 km
64 GROOVES
210
181
203
70
133
70
175
497
553
1050
DESIGN OF THE GERMAN LONG-RANGE PROJECTILE.

Figure 7.98: In 1918, engineers at Krupp demonstrated the Paris Gun, which could fire projectiles with a mass of 106 kg and calibers of 22–24 cm up to a maximum range of 130 km.

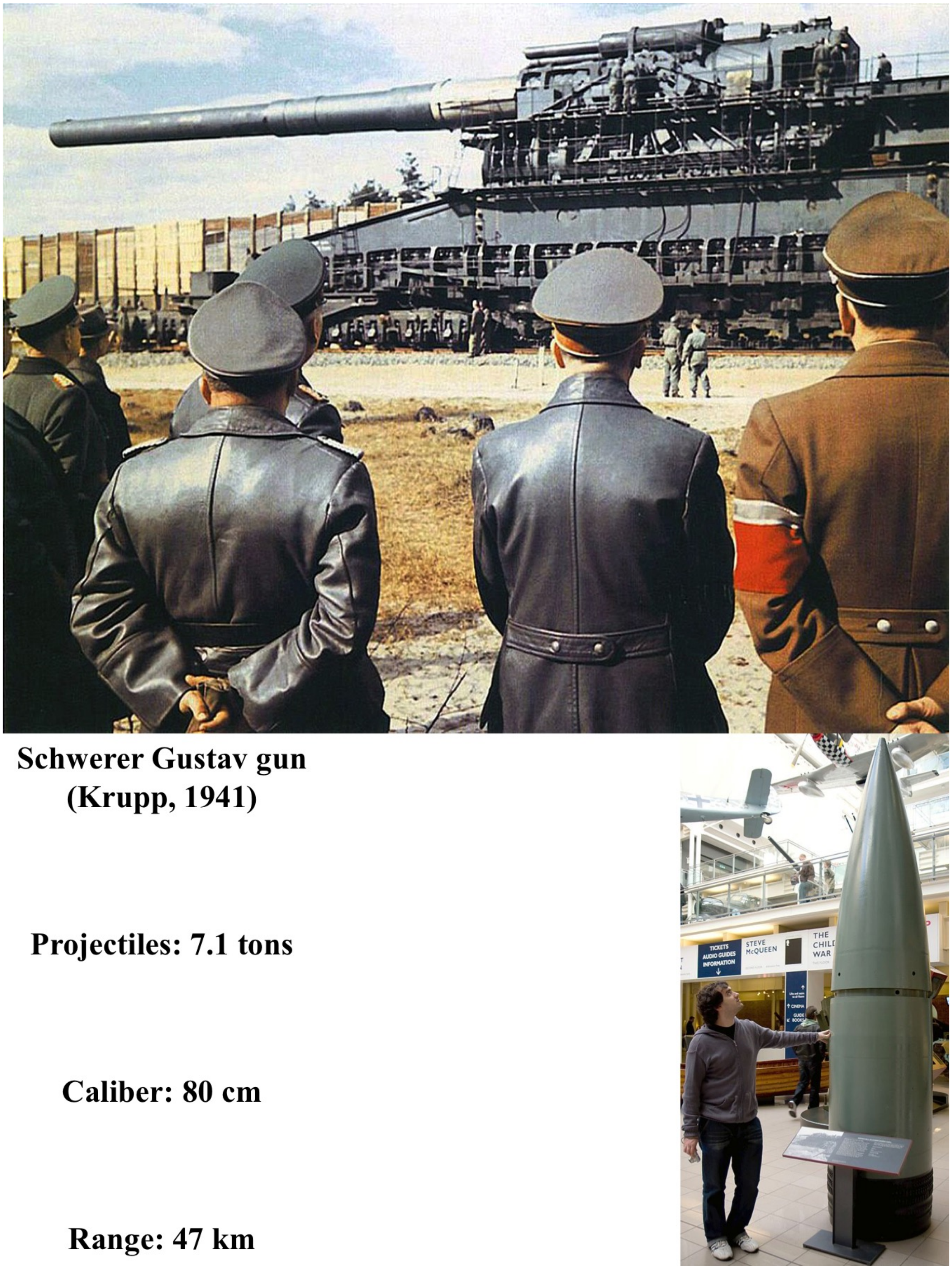

Schwerer Gustav gun
(Krupp, 1941)
Projectiles: 7.1 tons
Caliber: 80 cm
Range: 47 km

Figure 7.99: In 1941, engineers at Krupp demonstrated the Schwerer Gustav gun, which could fire projectiles with a mass of 7.1 tons and a caliber of 80 cm up to a maximum range of 47 km.

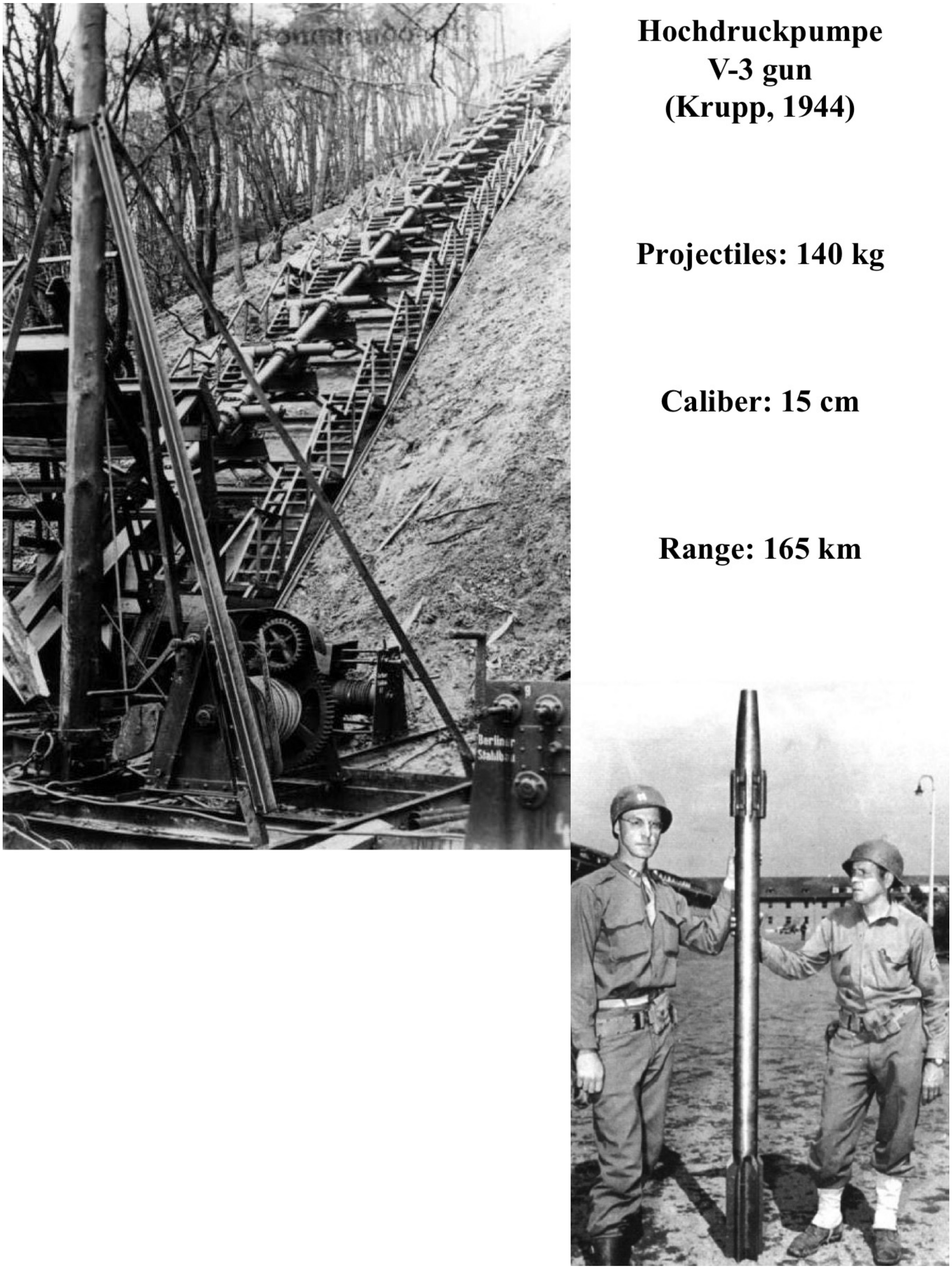
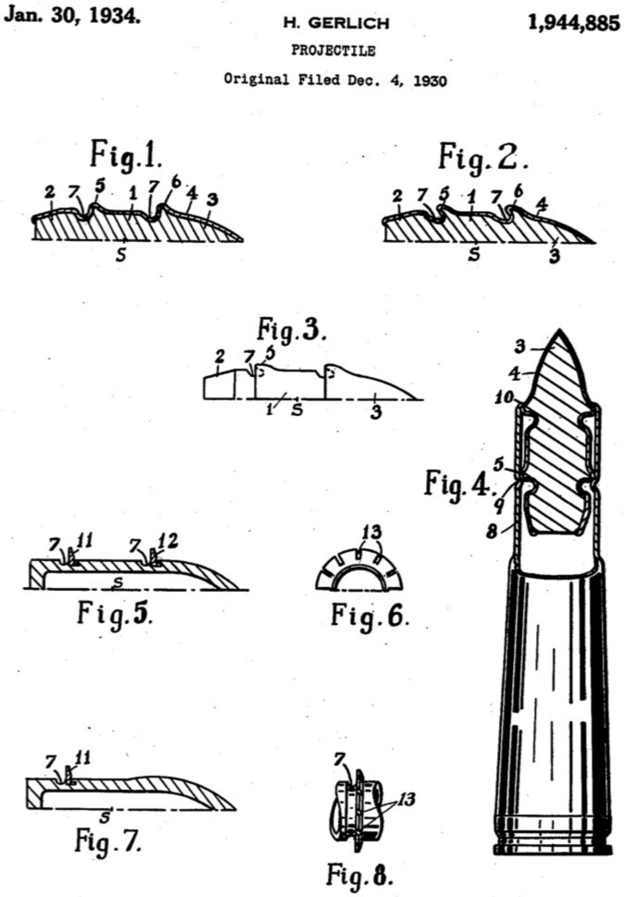
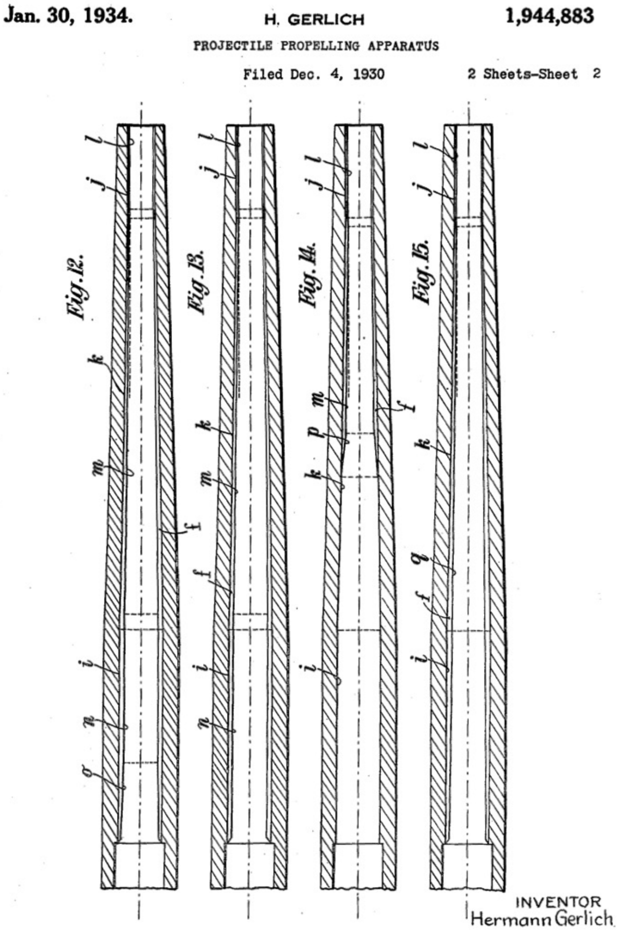

Hochdruckpumpe
V-3 gun
(Krupp, 1944)
Projectiles: 140 kg
Caliber: 15 cm
Range: 165 km

Figure 7.100: In 1944, engineers at Krupp demonstrated the Hochdruckpumpe or "V-3" gun, which could fire projectiles with a mass of 140 kg and a caliber of 15 cm up to a maximum range of 165 km.

Karl Puff (18??–19??) Hermann Gerlich (18??–19??)

Squeeze bore or tapered bore guns for increased muzzle velocities


Jan. 30, 1934.
H. GERLICH
1,944,885
PROJECTILE
Original Filed Dec. 4, 1930
Fig.1.
Fig.2.
Fig.3.
Fig.4.
Fig.5.
Fig.6.
Fig.7.
Fig.8.


Jan. 30, 1934.
H. GERLICH
1,944,883
PROJECTILE PROPELLING APPARATUS
Filed Dec. 4, 1930
2 Sheets-Sheet 2
Fig.12.
Fig.13.
Fig.14.
Fig.15.
INVENTOR
Hermann Gerlich

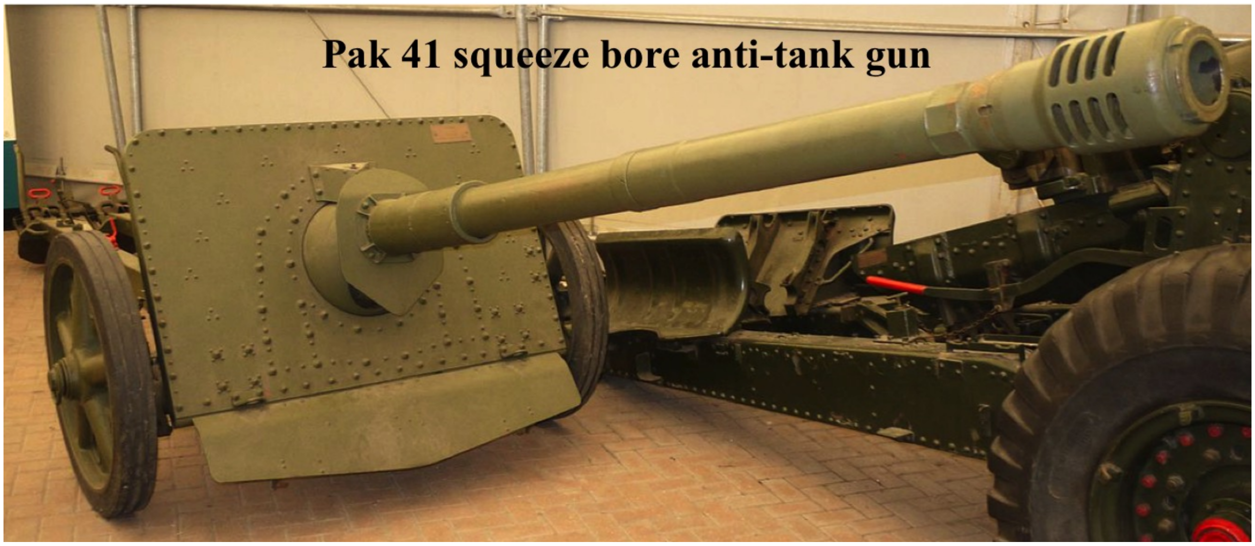

Pak 41 squeeze bore anti-tank gun

Figure 7.101: Karl Puff patented a squeeze bore or tapered bore gun design for increasing muzzle velocities in 1904. Hermann Gerlich filed more detailed patent applications in 1929 and built such guns. The German military used squeeze bore guns such as the Pak 41 anti-tank gun (1941).

7.6.4 Electromagnetic Railguns

Whereas conventional guns and artillery use the chemical energy of an explosion to propel a projectile and use a barrel to guide the projectile, electromagnetic railguns use the energy of electric and/or magnetic fields to propel a projectile and use rails to guide it. Multiple groups of German-speaking scientists developed and demonstrated electromagnetic railguns during World War II; see Fig. 7.102. The best-documented group was led by Joachim Hänsler (German, 19??–19??), but there were other groups as well.

Hänsler built and demonstrated electromagnetic railguns capable of launching projectiles at velocities up to 1200 meters/second, or over 3.5 times the speed of sound. By 1945, he was continuing to develop larger and faster railguns, planning to reach velocities over 2000 meters/second.[7]

Manfred von Ardenne (German, 1907–1997, p. 1293) led an even larger program to develop and produce electromagnetic railguns. Currently there are only a few known reports in archives that mention his program.[8] These reports demonstrate that during the war, electromagnetic railguns had moved beyond the stage of simple experiments. Very large railguns were being mass-produced in at least 13 factories, and specific launch sites for them were being built and equipped with up to 10 megawatts of dedicated electrical power per railgun.

Even nowadays, electromagnetic railguns are considered to be a high-tech "weapon of the future." The best modern railguns are essentially just larger versions of Joachim Hänsler's and Manfred von Ardenne's 1944–1945 devices, and can now fire projectiles at approximately twice the velocity of Hänsler's wartime railguns. Since Hänsler's (and perhaps von Ardenne's) detailed technical reports and even some of his equipment were brought back to the United States by the Alsos Mission, CIOS, and other teams of investigators in 1945, presumably such modern railguns are directly derived from the wartime German work.

For more information, see Section C.5. Much more archival research should be conducted to elucidate the history of electromagnetic railguns in the German-speaking world, as well as the impact of those innovators and innovations on postwar electromagnetic railguns in other countries.

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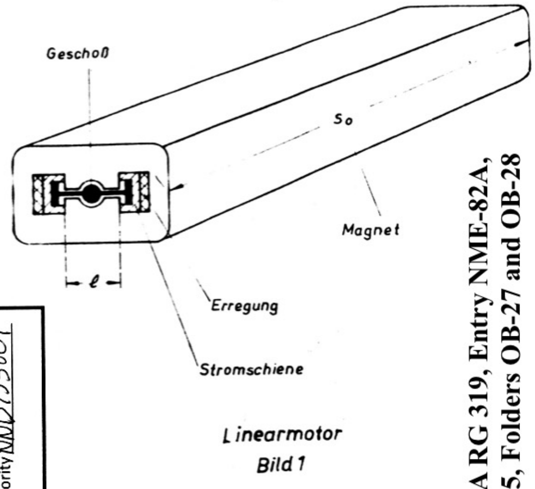
[7] CIOS XXXI-59; CIOS XXXI-84; NARA RG 319, Entry NM-82A, Box 15, Folders OB-27 and OB-28.

[8] AFHRA 25193 No. 2641 Posen; AFHRA 25216 electronic version p. 423; reports shown in Witkowski 2010, pp. 129–131, and Witkowski 2013, pp. 93–94.

Electromagnetic railguns

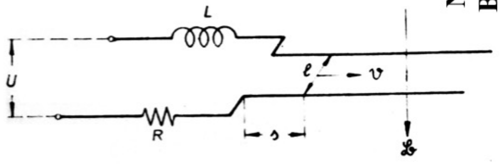
Cf. 2008 railgun test by U.S. Navy


Geschoß
So
Magnet
l
Erregung
Stromschiene

Linearmotor
Bild 1

DECLASSIFIED
Authority NND755001

NARA RG 319, Entry NME-82A,
Box 15, Folders OB-27 and OB-28



Stromkreis des Linearmotors
Bild 2

By 1945:

- **1200 m/sec velocity (Mach 3.6)**
- **Working toward >2000 m/sec**
- **Mass produced in 13 factories**
- **Launch sites built**
- **10 megawatts provided for launchers**

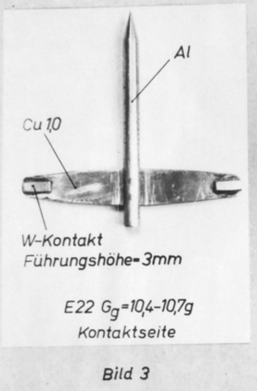

Al
Cu 1,0
W-Kontakt
Führungshöhe=3mm
E22 G_g=10,4-10,7g
Kontaktseite

Bild 3

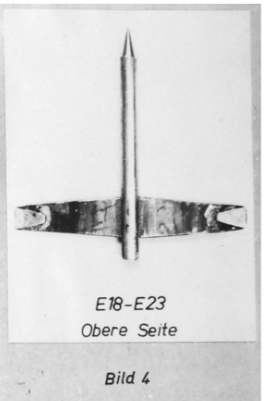

E18-E23
Obere Seite

Bild 4

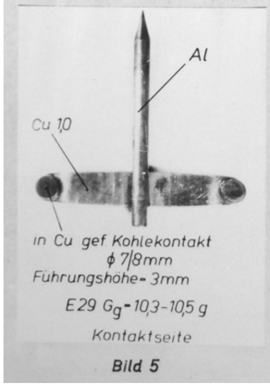

Al
Cu 1,0
in Cu gef Kohlekontakt
ϕ 7/8mm
Führungshöhe= 3mm
E29 G_g=10,3-10,5 g
Kontaktseite

Bild 5

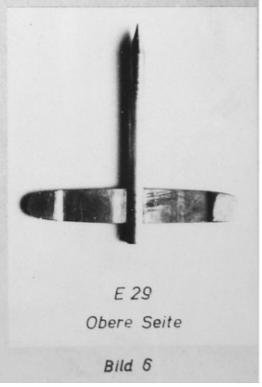

E 29
Obere Seite

Bild 6

Joachim Hänsler (19??–19??)

Manfred von Ardenne (1907–1997)

Many other engineers

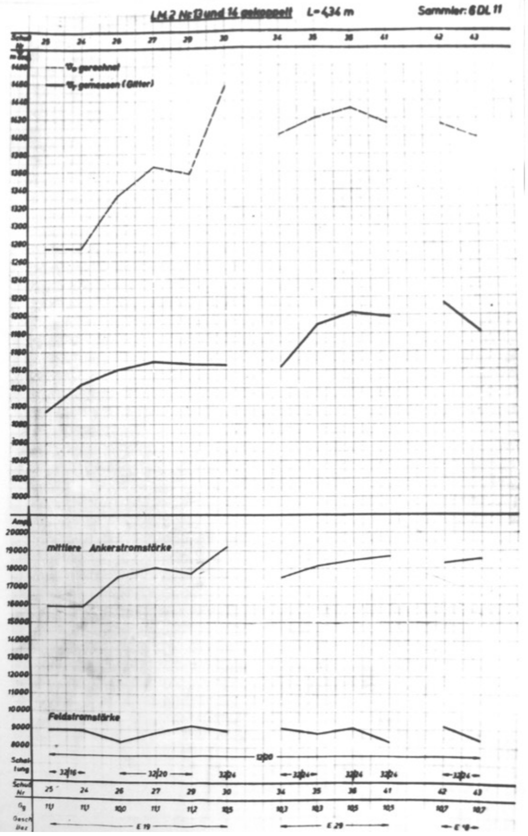


Figure 7.102: During World War II, Joachim Hänsler, Manfred von Ardenne, and other German-speaking scientists developed and demonstrated electromagnetic railguns capable of launching projectiles at velocities of at least 3.6 times the speed of sound. By the end of the war, railguns were being mass-produced for deployment on the battlefield.

7.6.5 Flamethrowers

As shown in Fig. 7.103, Richard Fiedler (German, 18??–19??) invented the modern flamethrower in 1901, and continued to develop improved versions until 1918.

Bernhard Reddemann (German, 1870–1938) and Gábor Szakáts (Austro-Hungarian, 1892–1937) began developing improved flamethrowers in 1904 and 1915, respectively.

Early flamethrowers included:

- The three-person Grossflammenwerfer (Grof, 1912, Fig. 7.103) with a large fuel tank that was not portable.
- The two-person portable Kleinflammenwerfer (Kleif, 1912, Fig. 7.104).
- The one-person portable Wechselapparat (Wex, 1916, Fig. 7.104).

One-person portable flamethrowers were further improved during the Third Reich, resulting in the Flammenwerfer 35 (1935, Fig. 7.105) and the lighter-weight Flammenwerfer 41 (1941, Fig. 7.106).

German-speaking scientists continued to make improvements in flamethrowers throughout World War II, and those improvements were transferred to other countries after the war. For example, BIOS 250, *German Research into Increasing Range and Performance of Flame Throwers*, p. 5, noted several wartime innovations that were identified for transfer to Allied countries in 1945:

> I should like to bring to the attention the following four points arising out of this visit to investigate German flame throwers. The interrogation and search for weapons was guided principally by the endeavor to find out what the Germans were about to develop and what theoretical ideas they had on the projection of fluids, and not so much on existing battle weapons.
>
> 1. B. Smits in Kassel has developed an original idea in the “creep spark plug”, the application of which to the ignition of flame throwers is fool-proof and 100 per cent efficient and was just being applied to their tank flame throwing units.
>
> 2. The Marine Research Station at Kiel (Danisch Nienhof) had developed a dual nozzle flame thrower, which had the advantage of improving the psychological effect of the thickened flame throwing fuel jet besides definitely improving its lethal and anti-personnel efficiency. This overcomes one of the chief criticisms of the thickened fuel flame jet in that in the effort to improve range you lost the anti-morale effect of the old type of flame thrower. The dual combination of Ingolin and heavy density oils is worth noting.
>
> 3. The results of Dr. Buch in Göppingen using the “sago” or dispersed swollen lumps in thickened fuel principle are very interesting in improving the range of the flame thrower into the 200 yards with a 32 mm. nozzle and 40–50 atmospheres pressure.

4. I would recommend the removal of Commander Jentsch and Dr. Eckhardt from the Marine Research Station at Danisch Nienhof to Langhurst or elsewhere in England, on the grounds that they are exceptional practical scientists, who could give us great assistance in the development of oil technology in this country.

I think if handled correctly they would be very willing and successful collaborators in technical developments much required here. Anyhow their stay in Danisch Nienhof is a complete waste of good human material.

Owing to the time factor, the visit could not be completed and the flame throwing research units in Munich and Vienna and an investigation of the Mauser works at Oberndorf should be undertaken. In particular, the Research Laboratory of Professor Ostwald in Munich was the first establishment (1926) to investigate the increase of viscosity of hydrocarbons by the dispersion of soaps in the oils.

Richard Fiedler
(18??–19??)
invented first modern
flamethrowers (1901)

Bernhard Reddemann
(1870–1938)
improved
flamethrowers (1904–)

Gábor Szakáts
(1892–1937)
improved
flamethrowers (1915–)

Grossflammenwerfer Grof with fixed (not portable) fuel tank (1912)

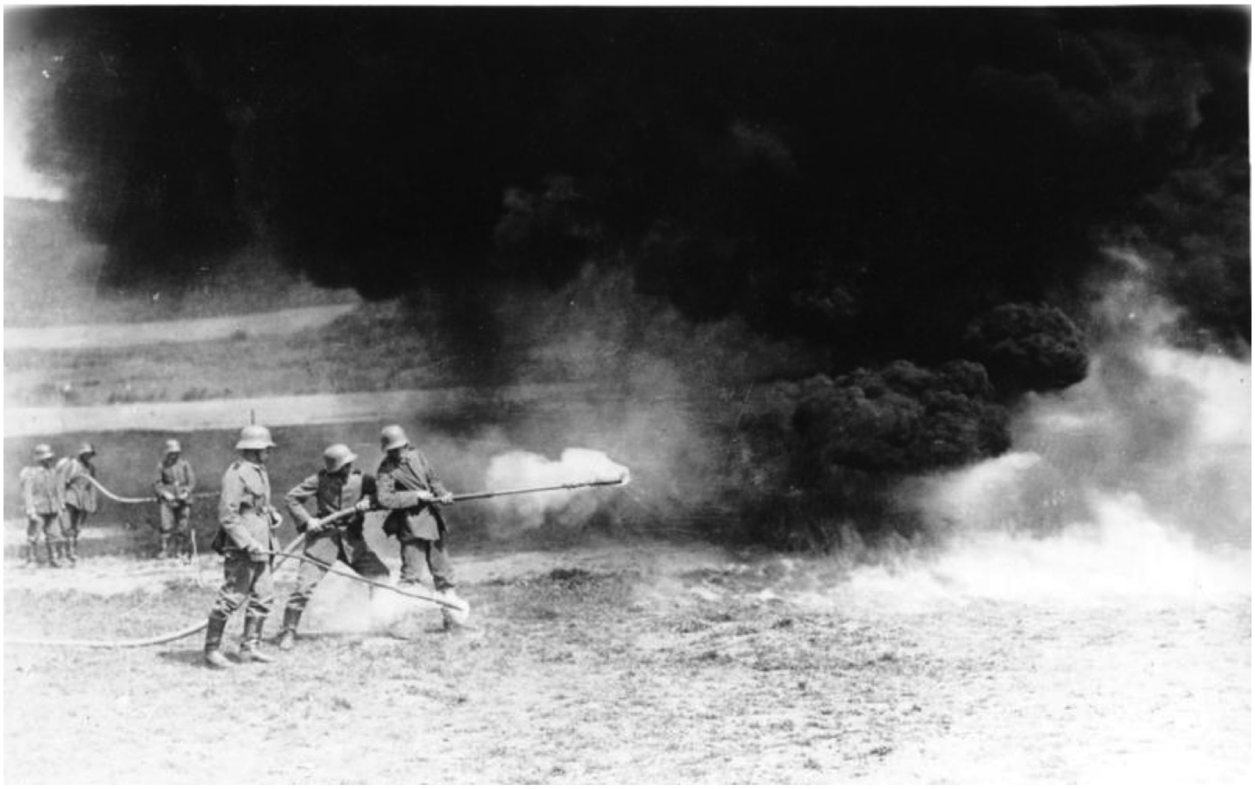


Figure 7.103: Richard Fiedler invented the modern flamethrower in 1901 and developed improved versions until 1918. Bernhard Reddemann and Gábor Szakáts began developing improved flamethrowers in 1904 and 1915, respectively. The Grossflammenwerfer (Grof, 1912) had a fixed (nonportable) fuel tank, required a crew of three operators, and had a range of 35 meters.

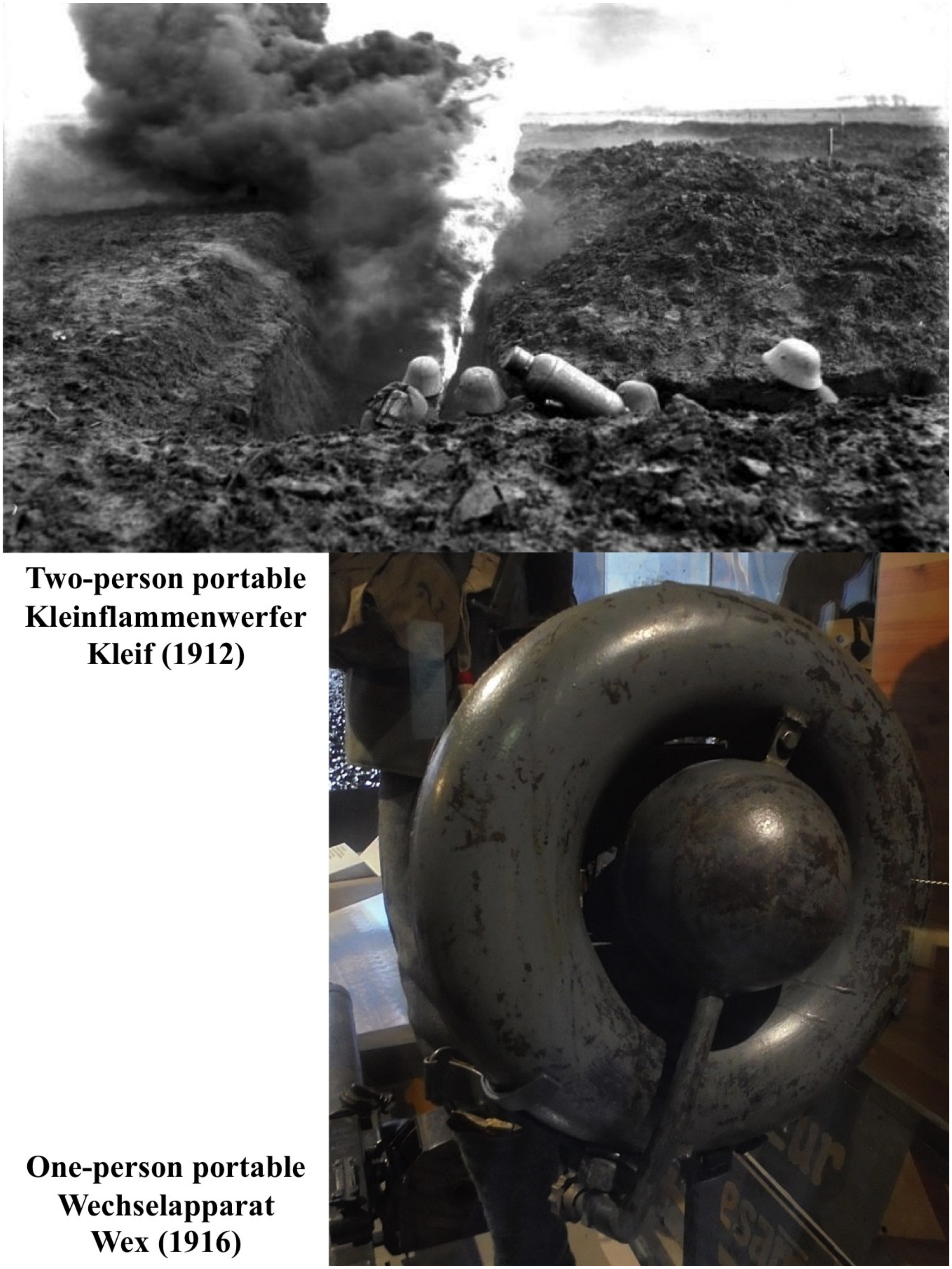

Two-person portable
Kleinflammenwerfer
Kleif (1912)
One-person portable
Wechselapparat
Wex (1916)

Figure 7.104: The two-person portable Kleinflammenwerfer (Kleif, 1912) weighed 32 kilograms and had a range of 20 meters. The one-person portable Wechselapparat (Wex, 1916) weighed ?? kilograms and had a range of 15 meters.

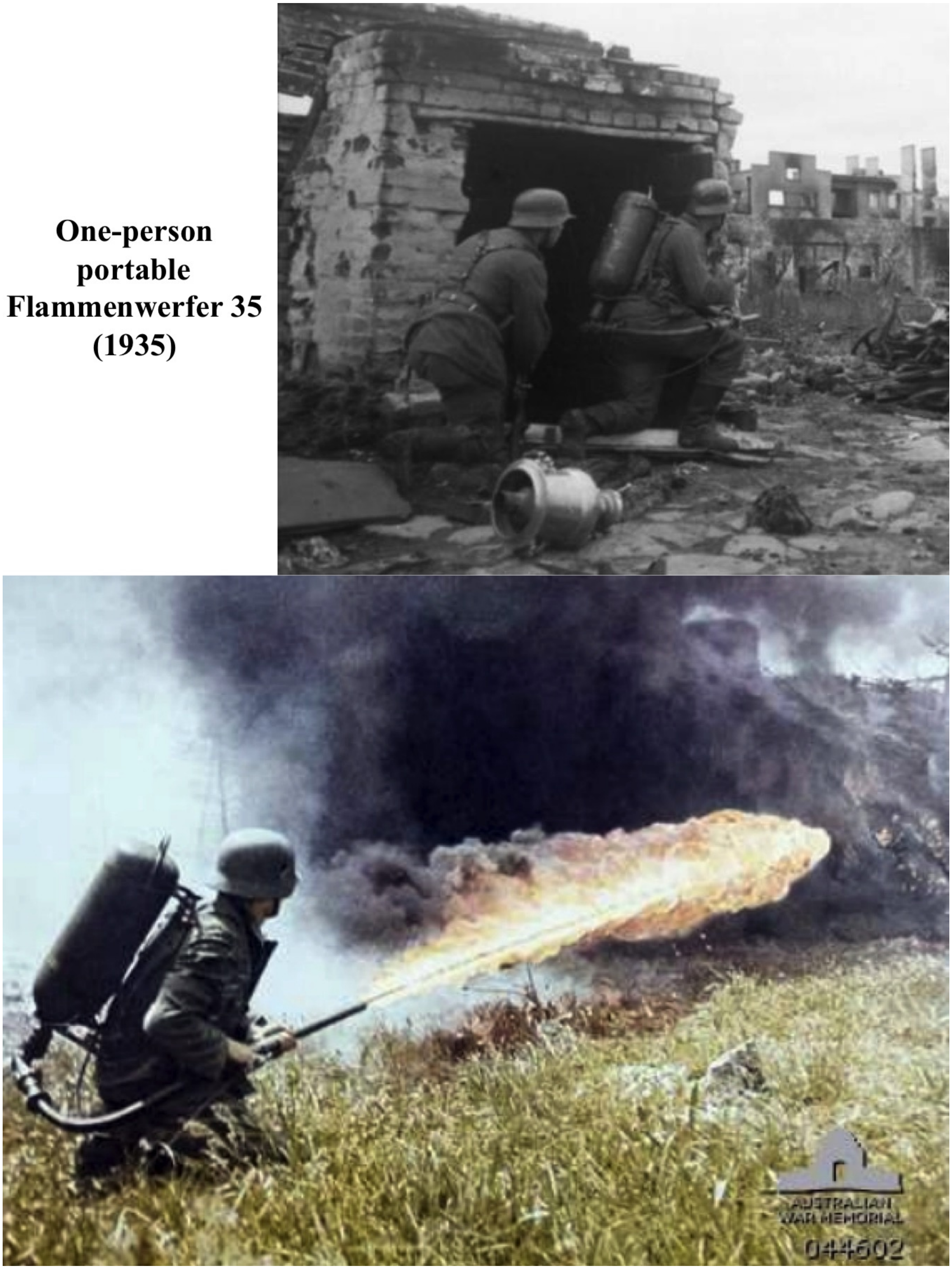

One-person portable Flammenwerfer 35 (1935)
AUSTRALIAN WAR MEMORIAL
044602

Figure 7.105: The one-person portable Flammenwerfer 35 (1935) weighed 36 kilograms and had a range of 25 meters.

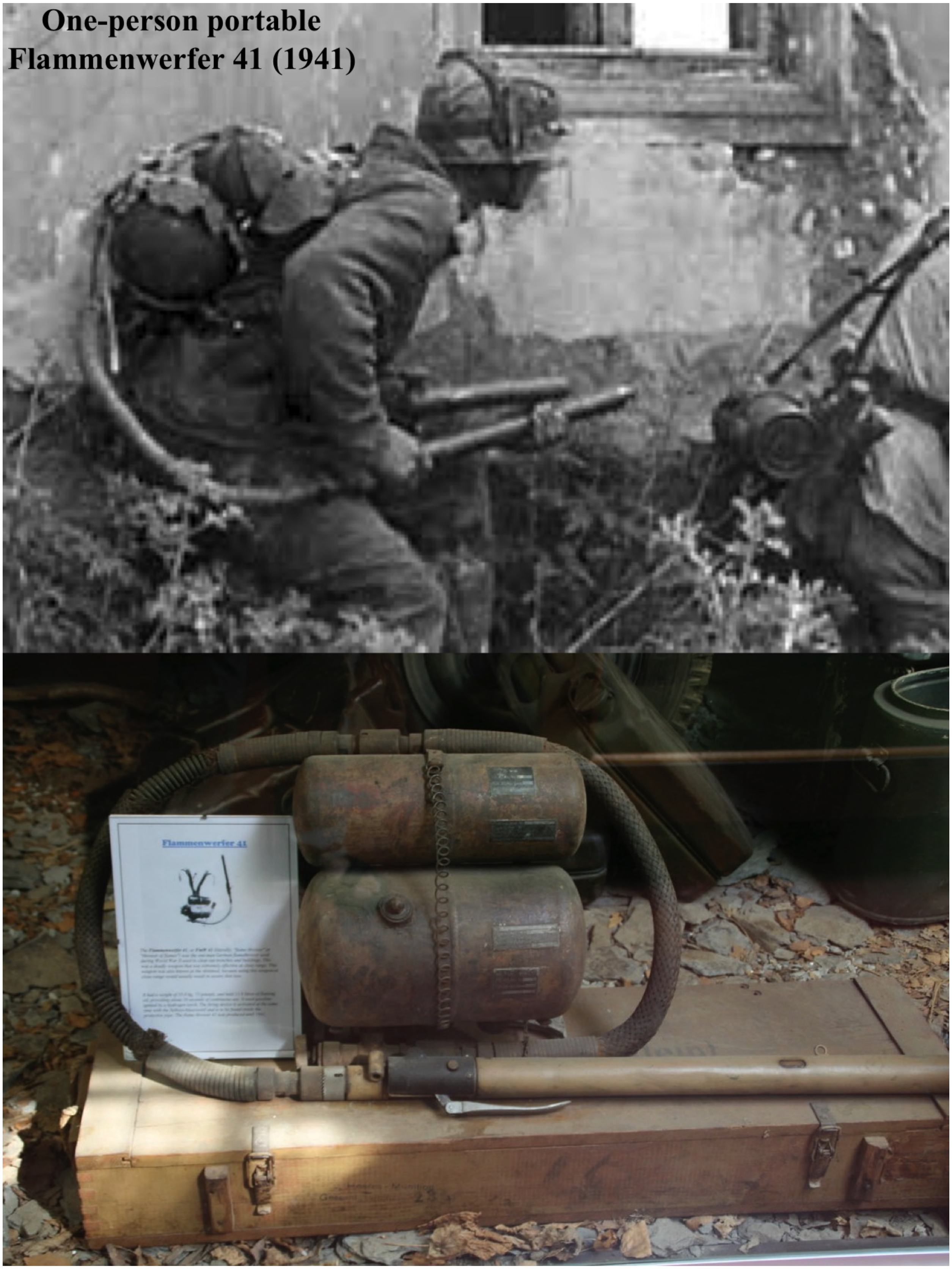

One-person portable
Flammenwerfer 41 (1941)
Flammenwerfer 41

Figure 7.106: The one-person portable Flammenwerfer 41 (1941) weighed 29 kilograms and had a range of 32 meters.

7.7 Ocean Engineering

Creators from the predominantly German-speaking scientific world masterminded the development of submarines and related technologies, producing not only undersea- or U-boats that revolutionized warfare during World Wars I and II, but also submarine technologies that were the foundation of postwar submarine designs by the United States, Soviet Union, and other countries.[9]

This section covers the contributions of German-speaking scientists and engineers to:

7.7.1. Early experimental submarines

7.7.2. Military submarines

7.7.3. Bathyscaphes

7.7.4. Rotor ships

7.7.1 Early Experimental Submarines

As shown in Fig. 7.107, Cornelius Drebbel (Dutch, 1572–1633) built a series of oar-propelled wooden submarines in the 1620s, culminating in a demonstration of the largest one in 1624 in the Thames for the British royal court. *Encyclopedia Britannica* explained [EB 2010]:

> Dutch inventor who built the first navigable submarine.
>
> An engraver and glassworker in Holland, Drebbel turned to applied science and in 1604 went to England, where King James I became his patron. He devised an ingenious "perpetual motion clock," actuated by changes in atmospheric pressure and temperature, which greatly enhanced his reputation. In 1620 he completed his "diving boat." Propelled by oars and sealed against the water by a covering of greased leather, the wooden vessel travelled the River Thames at a depth of 12 to 15 feet (about 4 metres) from Westminster to Greenwich. Air was supplied by two tubes with floats to maintain one end above water.
>
> Drebbel also discovered the use of tin compounds as mordants for cochineal, a scarlet dye, and suggested a method of making sulfuric acid by the oxidation of sulfur. Among many other inventions attributed to him are the compound microscope, an improved thermometer, and self-regulating ovens.

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[9] Bishop and Ross 2016; Breyer 1999; Broelmann 2012; Geoghegan 2013; Herzog 1996; Hutchinson 2001; Köberl 1990; Köhl 1988; Krzysztalowicz 2012; Möller 2000; Polmar and Moore 2004; Eberhard Rössler 1987, 1998, 2005, 2010, 2016; Sakaida 2006; Schulze-Wegener 1997; Wetzel 1999; Wise 2005; NYT 1945-11-22 p. 16a, 1947-02-12 p. 10.

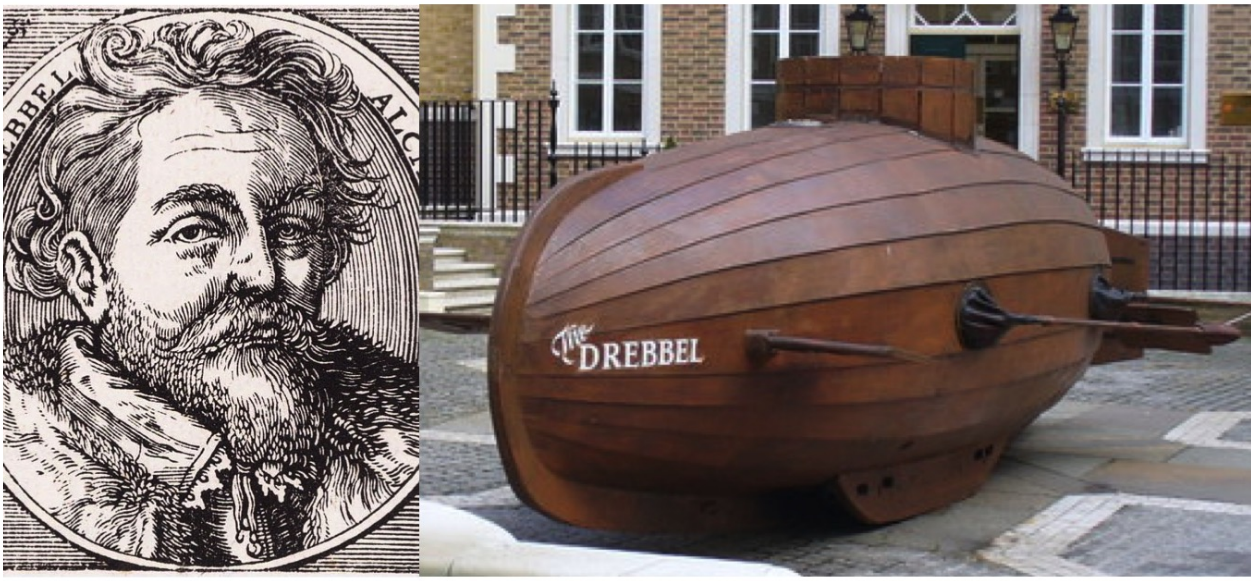
Wilhelm Bauer (Bavarian, 1822–1875) built and demonstrated the *Brandtaucher* prototype submarine in 1850, and the larger *Seeteufel* in 1855. He also raised a sunken ship using balloons. See Fig. 7.108. *Jane's Submarines* described his history of submarine development [Hutchinson 2001, pp. 10-11]:

> In 1850, the former artillery non-commissioned officer, Wilhelm Bauer (1822–1975) built the *Brandtaucher* ('Fire Diver') in Kiel, Germany: an unattractive 27-feet long craft with a short, stubby steel hull, a low conning tower right forward at the bows with two bulls-eye portholes, and a displacement of nearly 39 tons. It accommodated three men. Again, it relied on muscle power to drive the screws, via a large treadmill mounted amidships—after earlier tests with clockwork again failed to supply enough power. The aim was to develop a weapon that would disrupt a Danish naval blockade of northern German ports. It was tested to depths of just over 50 feet but was never deployed operationally after the first test, on February 1 1851, nearly became a disaster.
>
> The boat plunged to the sea bottom, 54 feet below the surface and after more than five terrifying hours, Bauer opened the flood valves to equalise the pressure within the hull to allow escape. When the seawater reached the chins of Bauer and his two fellow crewmen, a bubble of air blew the hatch open and all three shot to the surface—to survive. It was the first successful submarine escape.
>
> *Brandtaucher* was later raised from the bottom of Kiel Harbour in 1887 and renovated. This remains the oldest preserved submarine in the world and can be seen today in the Deutsches Armeemuseum, Neuer Garten, Potsdam, Germany.
>
> Four years later, Bauer built the *Seeteufel* ('Sea Devil') for the Russian Navy, a much larger and more ambitious design, with a steel hull, a 13 man crew, and a small engine for use on the surface. The flat, sausage-shaped hull, launched from the Leuchtemburg yard in St Petersburg, on November 2 1855, was 52-feet long and 12-feet wide. The problem of sub-surface propulsion remained intractable with the *Seeteufel* relying on his earlier, cumbersome system of a treadmill-cranked screw. Water ballast was controlled by a system of hand-pumps. The boat made 133 successful dives[...]

Julius Kröhl (Prussian, 1820–1867), shown in Fig. 7.108, built the Sub Marine Explorer prototype submarine during the period 1863–1867. Naval historian Jobst Broelmann provided some insight into Kröhl's otherwise rather mysterious submarine development program [Broelmann 2012, pp. 62–63]:

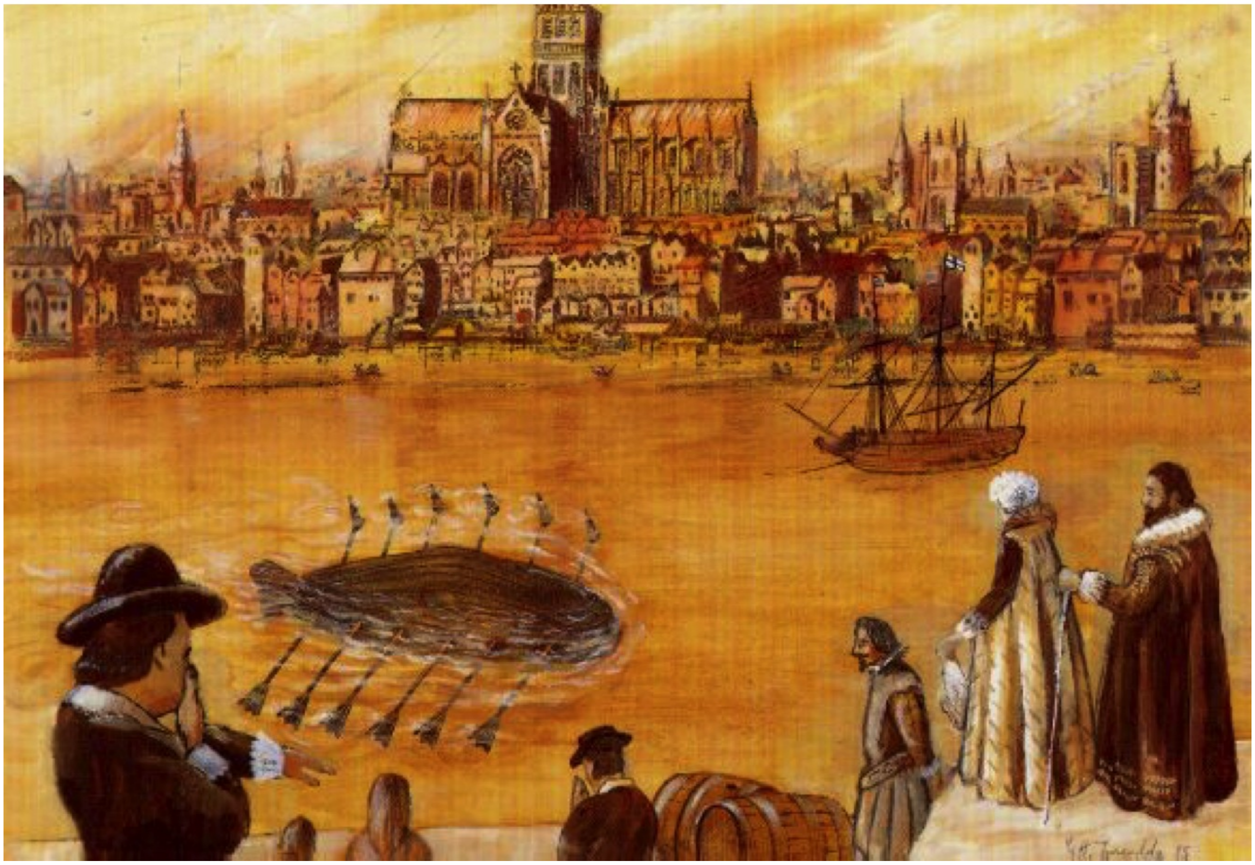
> Dies Argument soll den deutschen Ingenieur Julius H. Kröhl bewogen haben, ein Unterwasserförderschiff zu bauen, das die Prinzipien von Payerne aufgriff. Ein Angebot von William Henry Tiffany, dem Bruder des Gründers der Firma Tiffany, ermöglichte Kröhl den Bau. Tiffany war Hauptgesellschafter der Pacific Pearl Company, die Perlen im Pazifik ernten wollte und dazu einen geeigneten Tauchapparat brauchte. Das Boot wurde in einem Dock in Brooklyn gebaut und 1866 vorgestellt.
>
> Die längliche Form des Bootes entstand aus einer Reihe hintereinander angeordneter Räume, die wie Taucherglocken unten zu öffnen waren. Am Heck war ein manueller Propellerantrieb vorgesehen. Da bei diesen Apparaten Taucher das Boot durch Luken verlassen sollten, musste ihr Innendruck der Wassertiefe entsprechen oder eine Druckschleuse eingebaut sein. Im ersten Falle glichen sie also einer frei beweglichen Taucherglocke, die ohne Verbindung zur Oberfläche agieren konnte. Getaucht wurde durch einströmendes Wasser, aufgetaucht durch Einblasen von Druckluft.
>
> Das Explorationsschiff Kröhls wurde 1867 für kurze Zeit in Panama eingesetzt. Es wird vermutet, dass die Betreiber der Taucherkrankheit erlagen. Erst 2002 konnte ein Wrack in dieser Region als die ehemalige Konstruktion Kröhls identifiziert werden.

> This argument is said to have persuaded the German engineer Julius H. Kröhl to build an underwater production ship that took up Payerne's principles. An offer from William Henry Tiffany, the brother of the founder of the Tiffany company, enabled Kröhl to build it. Tiffany was the main shareholder of the Pacific Pearl Company, which wanted to harvest pearls in the Pacific and needed a suitable diving apparatus to do so. The boat was built in a dock in Brooklyn and presented in 1866.
>
> The elongated shape of the boat was created from a row of rooms arranged one behind the other, which opened like diving bells at the bottom. A manual propeller drive was provided at the stern. Since divers were supposed to leave the boat through hatches, their internal pressure had to correspond to the water depth or a pressure lock had to be installed. In the first case they resembled a freely movable diving bell, which could operate without connection to the surface. Diving was done by inflowing water, surfaced by blowing in compressed air.
>
> The exploration ship Kröhl's was used in Panama for a short time in 1867. It is assumed that the operators succumbed to the diving sickness. Only in 2002 a wreck in this region could be identified as the former construction of Kröhl.



Cornelis Drebbel (1572–1633)

Replica of Drebbel’s oar-propelled wooden submarine



Demonstration of Drebbel’s submarine in the Thames (1624)

Figure 7.107: Cornelius Drebbel built a series of oar-propelled wooden submarines, culminating in a demonstration of the largest one in 1624 in the Thames.

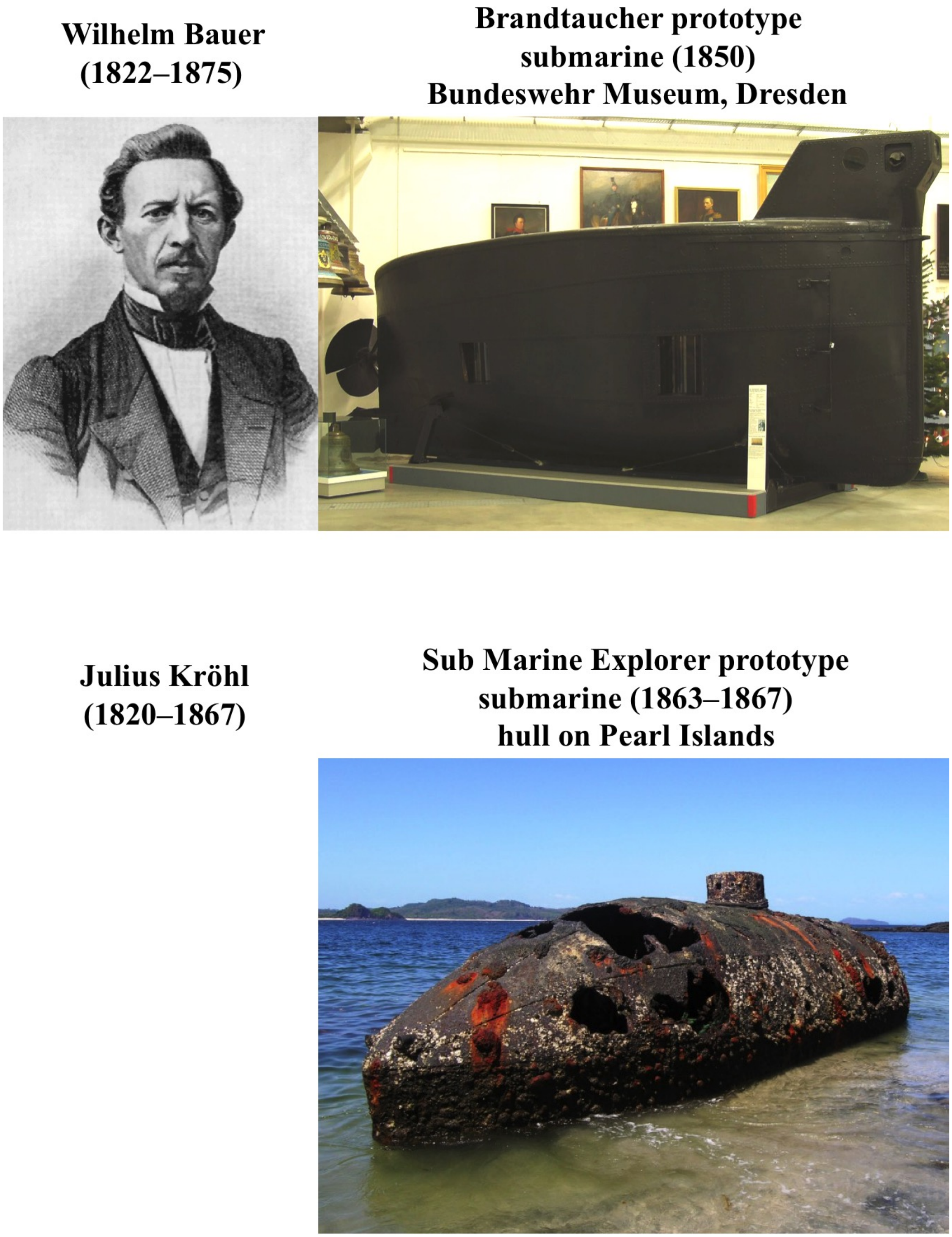

Wilhelm Bauer
(1822–1875)
Brandtaucher prototype
submarine (1850)
Bundeswehr Museum, Dresden
Julius Kröhl
(1820–1867)
Sub Marine Explorer prototype
submarine (1863–1867)
hull on Pearl Islands

Figure 7.108: Wilhelm Bauer built and demonstrated the Brandtaucher prototype submarine in 1850. Julius Kröhl developed the Sub Marine Explorer prototype submarine 1863–1867.

7.7.2 Military Submarines

Despite the early innovations by Cornelius Drebbel, Wilhelm Bauer, and Julius Kröhl, work on submarine prototypes shifted to France in the late nineteenth century, perhaps due to the fictional inspiration provided by Jules Verne's *Twenty Thousand Leagues Under the Sea* (1870). By the early twentieth century, though, German submarine designers had taken the lead, and continued to lead through World War II.

As illustrated in Fig. 7.109, some key submarine designers included:

- Christoph Aschmoneit (German, 1901–1984): World War II submarines
- Gustav Berling (German, 1869–1943): World War I submarines
- Fritz Bröking (German, 1877–1961): Type VII and Type XXI submarine propulsion
- Ulrich Gabler (German, 1913–1994): Type XXII, XVII A, and XXVI submarines
- Friedrich Schürer (German, 1881–1948): Type VII and Type XXI submarine propulsion
- Hellmuth Walter (German, 1900–1980): air-independent submarine propulsion; V 80 teardrop shape

Figure 7.110 presents plans for the Type UB III U-boat (built 1915–1918), as well as a photo of a Type UB III, the UB-86, shown abandoned and grounded after World War I.

Similarly, Fig. 7.111 shows plans for the Type VII U-boat (built 1935–1945) and a photo of a Type VII, the U-995, now on display at the Laboe Naval Museum. One can see that the Type VII was essentially an updated version of the older Type UB III design.

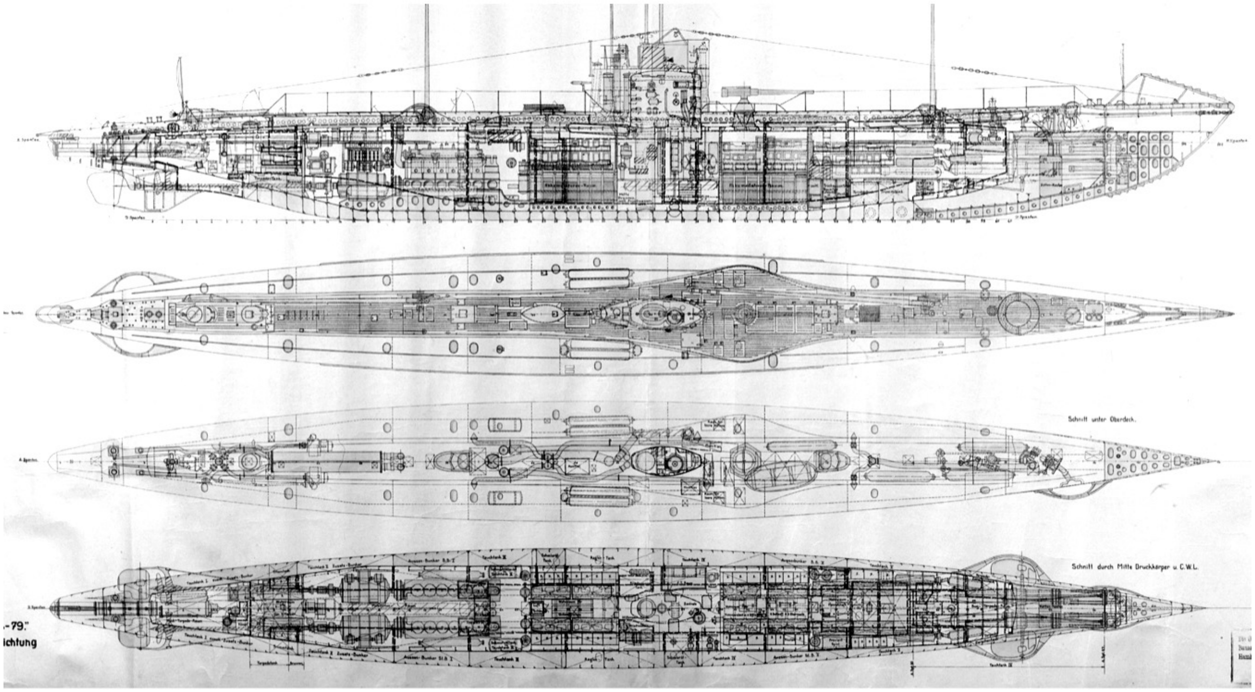
Figure 7.112 presents plans for the much more advanced Type XXI U-boat (built 1943–1945) and shows three Type XXI U-boats at the German naval base at Bergen, Norway. Figures 7.113–7.118 are photographs of a Type XXI, the U-2540 "Wilhelm Bauer," now on display at the German Maritime Museum in Bremerhaven. The Type XXI submarine design was so advanced for its time that the Allies considered it an extremely serious threat, even very late in the war. For example, the 12 January 1945 Top Secret Cable OUT 1005 from Office of Strategic Services Magruder to Bern Switzerland [NARA RG 226, Entry UD-90, Box 7, Folder BERN—IN OUT 1944–1945] stated:

> German program for new type submarines is perhaps most menacing aspect of German war capabilities due to exceptional defensive characteristics of new submersibles. At present only effective defense is to interfere with their production. I refer to types Roman number 21 and 23. Former of 1600 tons and latter of 200 tons plus. The 21 is particularly dangerous. Both are prefabricated in various places and shipped in parts to launching ports. Productive capacity and assembly speed high.
>
> Please give priority to information permitting air attack on places of manufacture of prefabricated hulls and routes to assembly ports. Also much desired is place of manufacture of new and highly efficient types of Diesel engines and batteries.

Some key submarine designers
Christoph Aschmoneit (1901–1984)
Gustav Berling (1869–1943)
Fritz Bröking (1877–1961)
Ulrich Gabler (1913–1994)
Friedrich Schürer (1881–1948)
Hellmuth Walter (1900–1980)

Figure 7.109: Some key submarine designers included Christoph Aschmoneit, Gustav Berling, Fritz Bröking, Ulrich Gabler, Friedrich Schürer, and Hellmuth Walter.

Type UB III U-Boat (1915–1918)


Schnitt unter Oberdeck
Schnitt durch Mitte Druckkörper u. C.W.L.
-79."
ichtung

UB-86 Type UB III submarine grounded after World War I

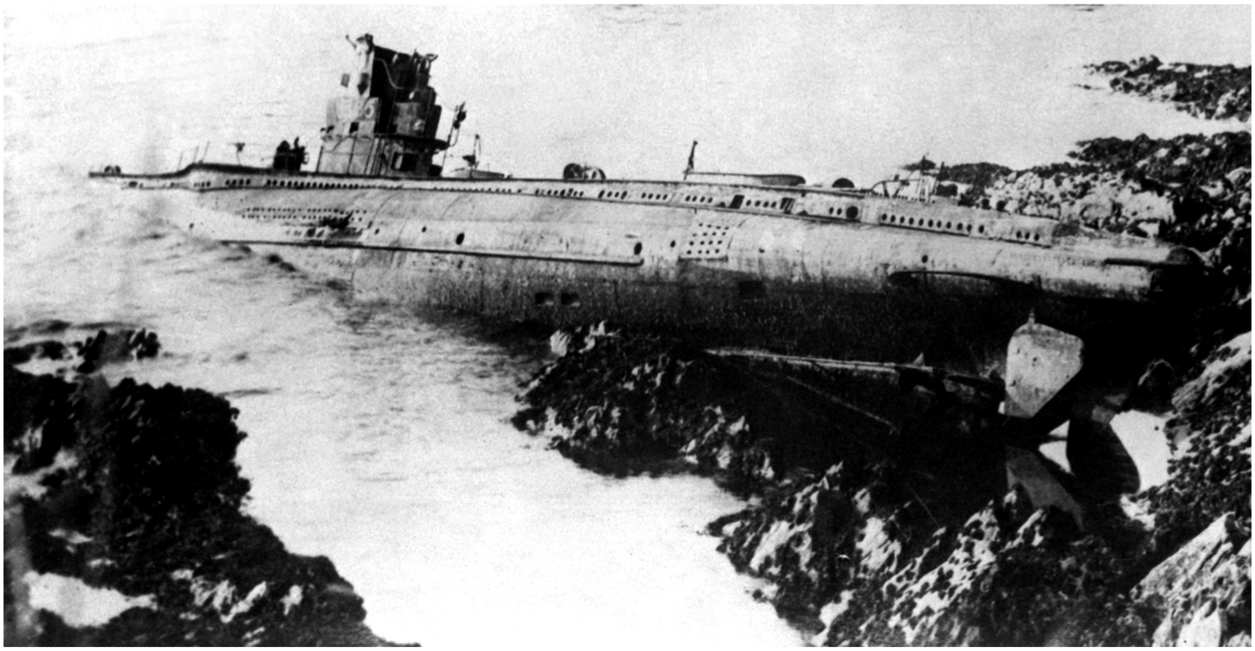
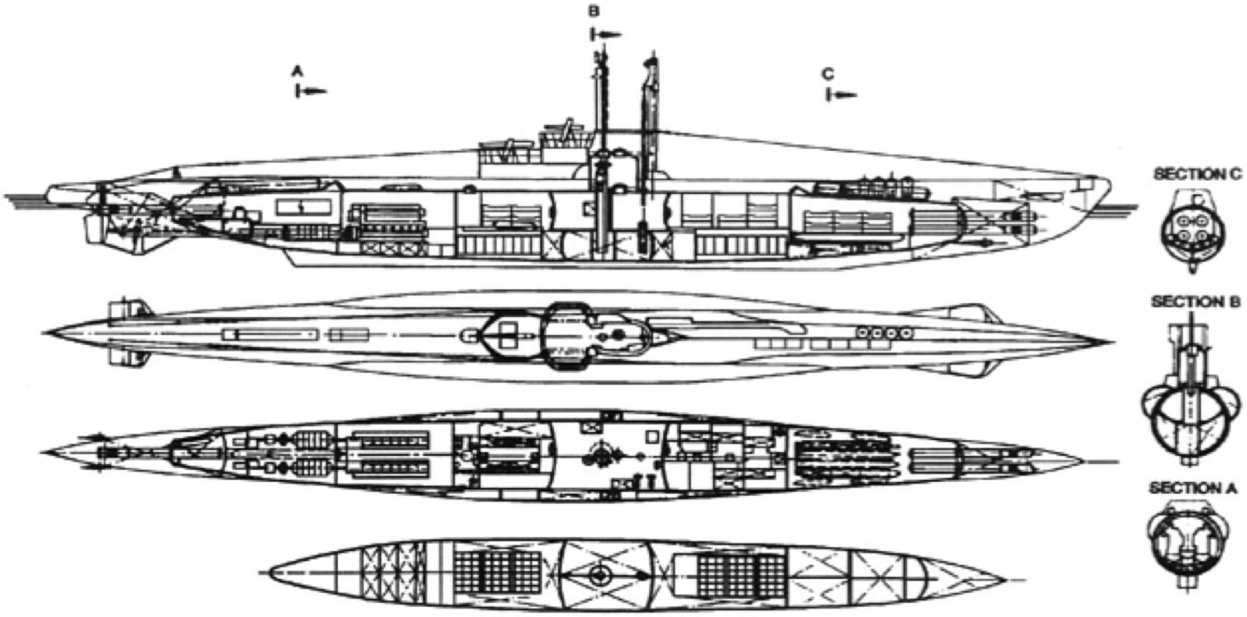


Figure 7.110: Plans for the Type UB III U-boat (built 1915–1918), and a Type UB III, the UB-86, abandoned and grounded after World War I.

Type VII U-boat (1935–1945)


B
A
C
SECTION C
SECTION B
SECTION A

U-995 Type VII, Laboe Naval Museum

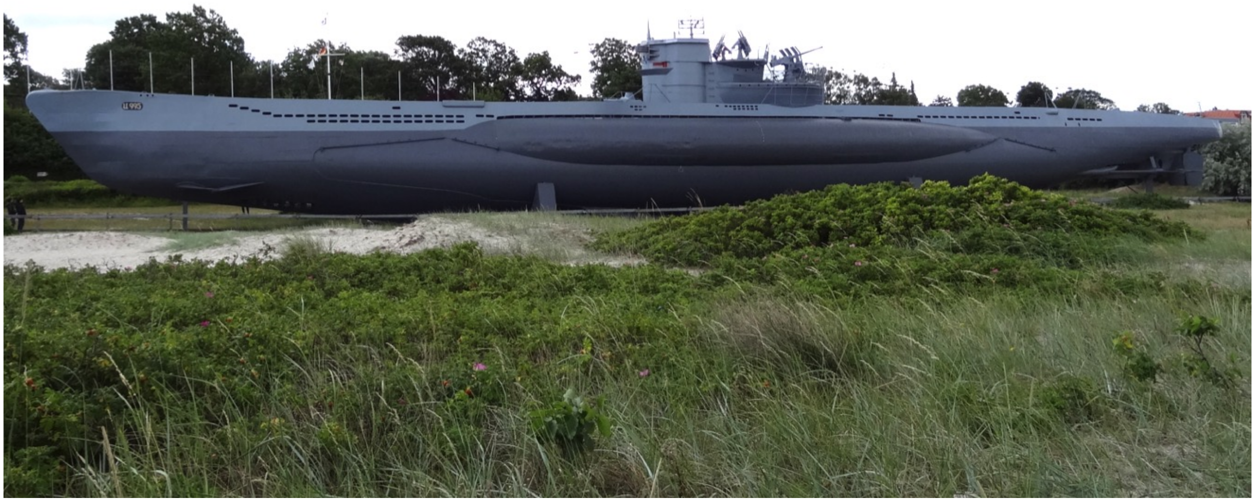
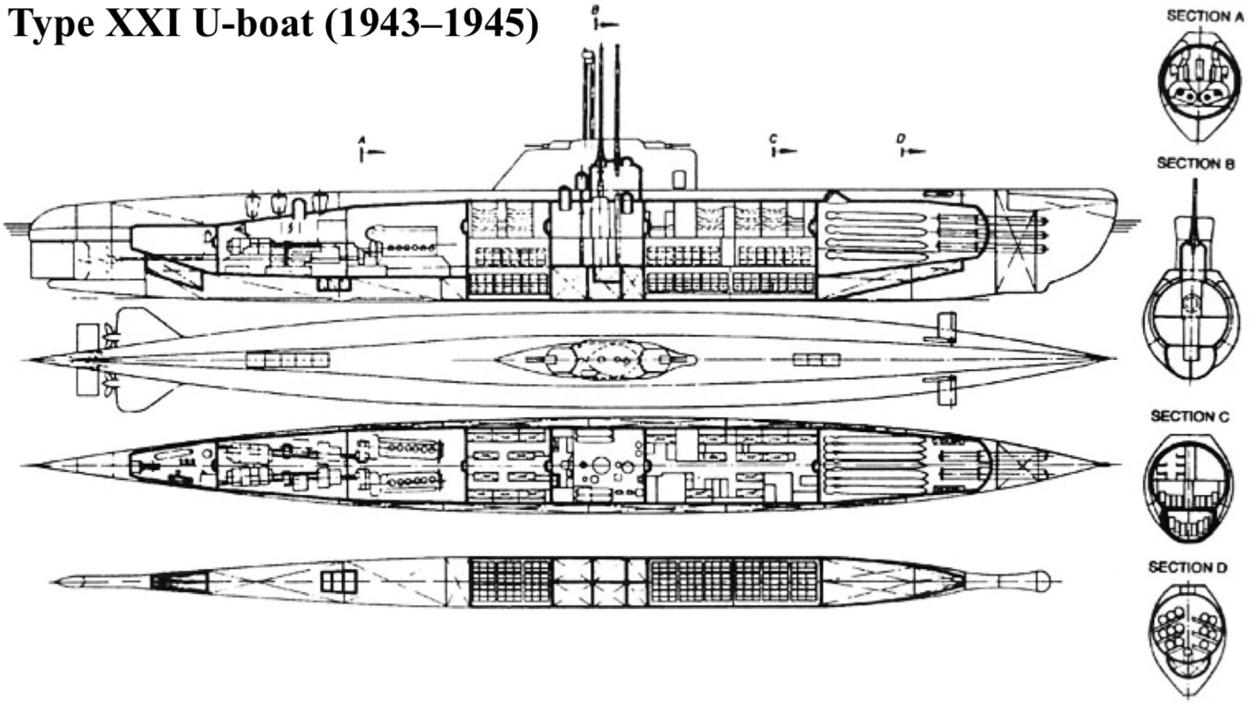


Figure 7.111: Plans for the Type VII U-boat (built 1935–1945), and a Type VII, the U-995, now on display at the Laboe Naval Museum.


Type XXI U-boat (1943–1945)
B
A
C
D
SECTION A
SECTION B
SECTION C
SECTION D

Three Type XXI U-boats and one Type VII U-boat (far left)
at Bergen, Norway (May 1945)

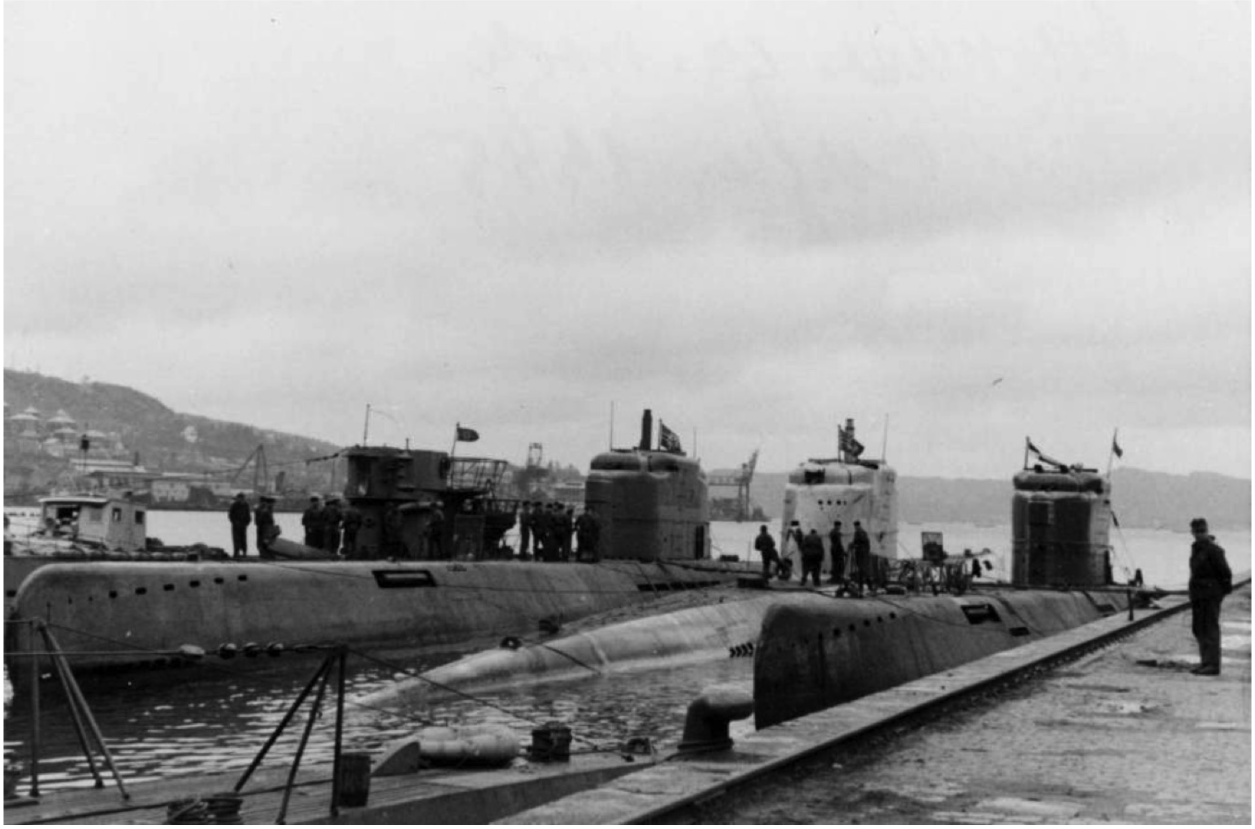


Figure 7.112: Plans for the Type XXI U-boat (1943–1945), and three Type XXI U-boats and one Type VII U-boat at Bergen, Norway (May 1945).

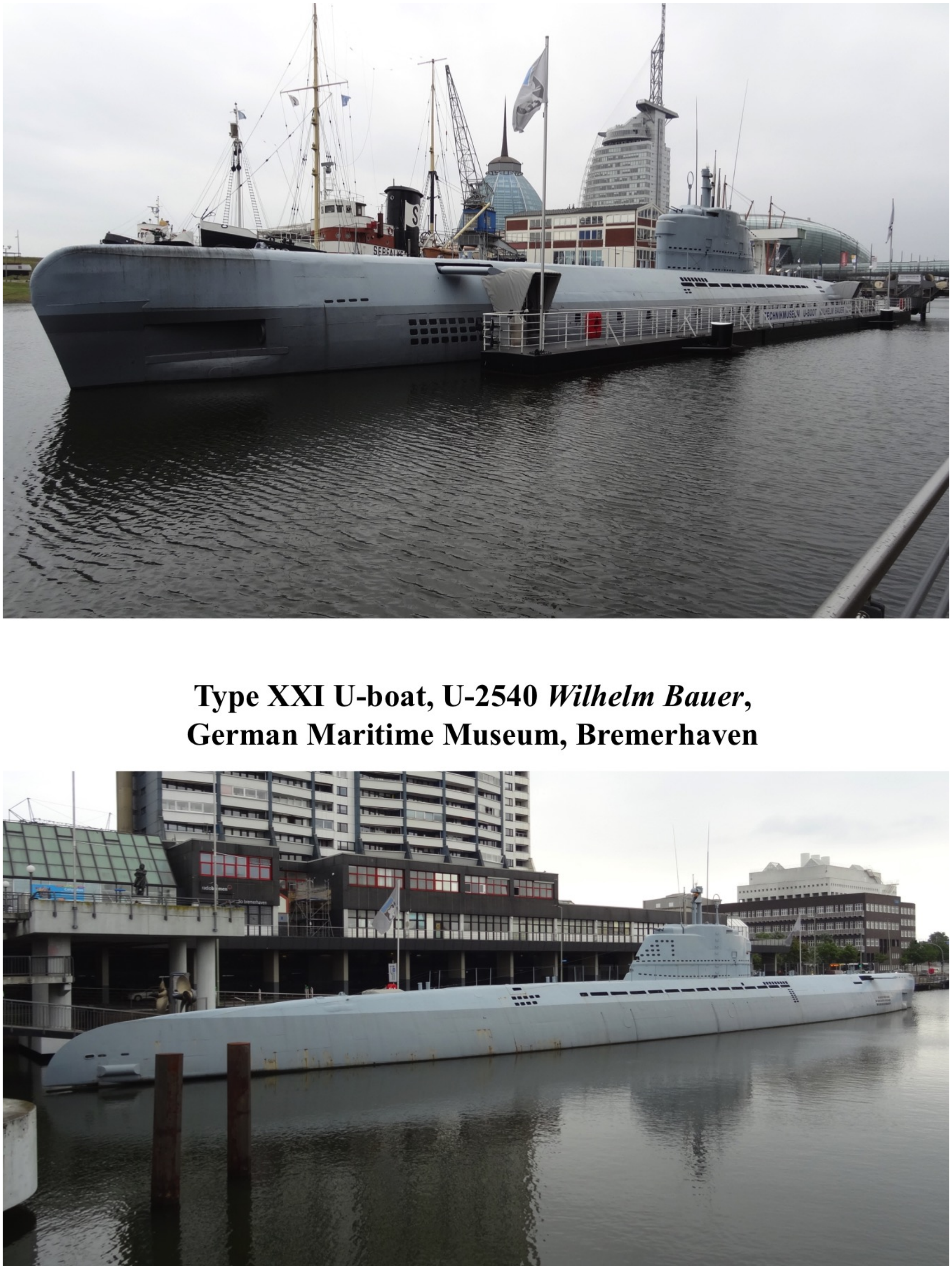

Type XXI U-boat, U-2540 *Wilhelm Bauer*,
German Maritime Museum, Bremerhaven

Figure 7.113: A Type XXI submarine, the U-2540 *Wilhelm Bauer*, now on display at the German Maritime Museum in Bremerhaven.

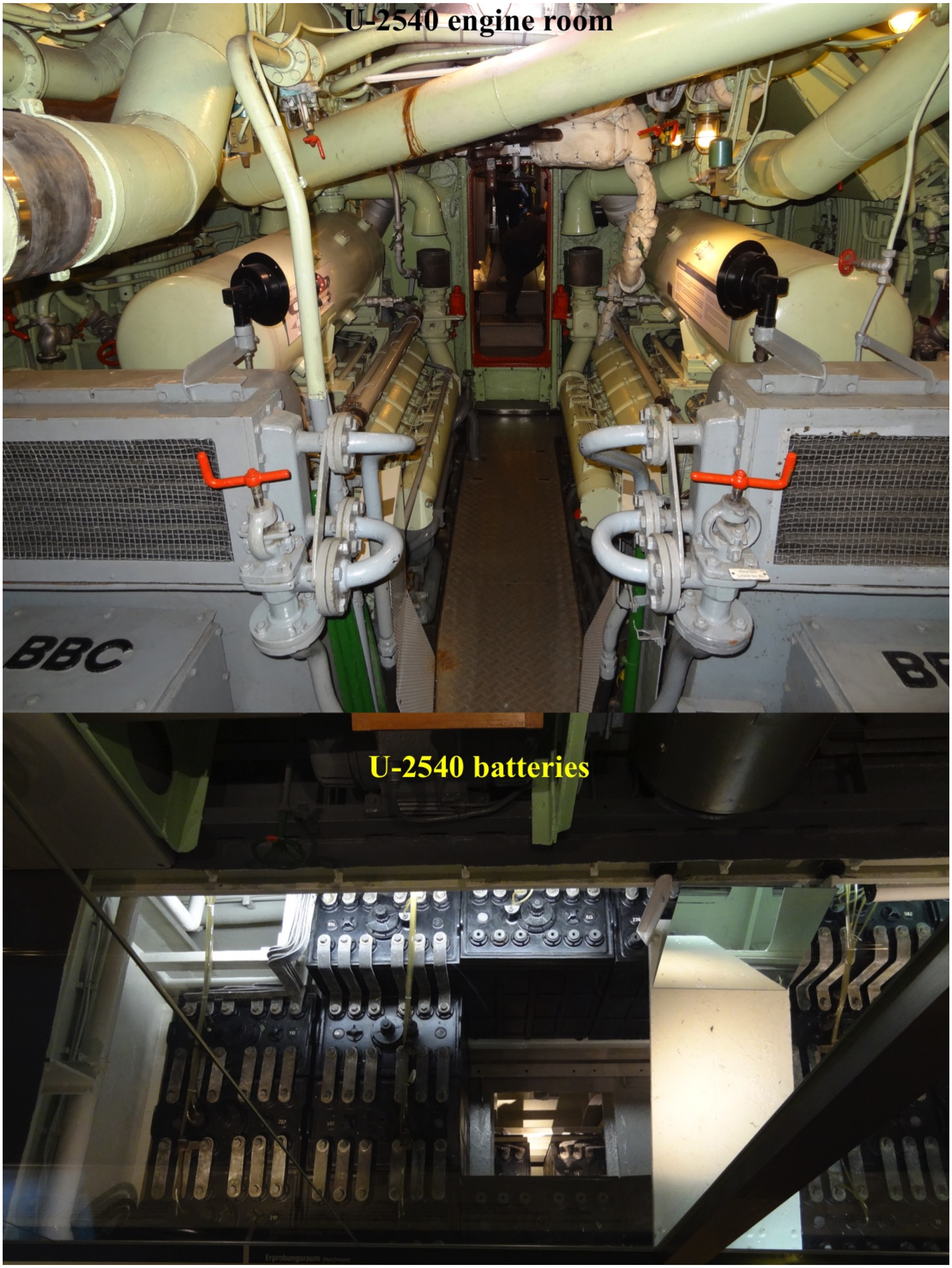

U-2540 engine room
BBC
BB
U-2540 batteries
Erprobungsraum

Figure 7.114: The engine room and the batteries of the U-2540 submarine.

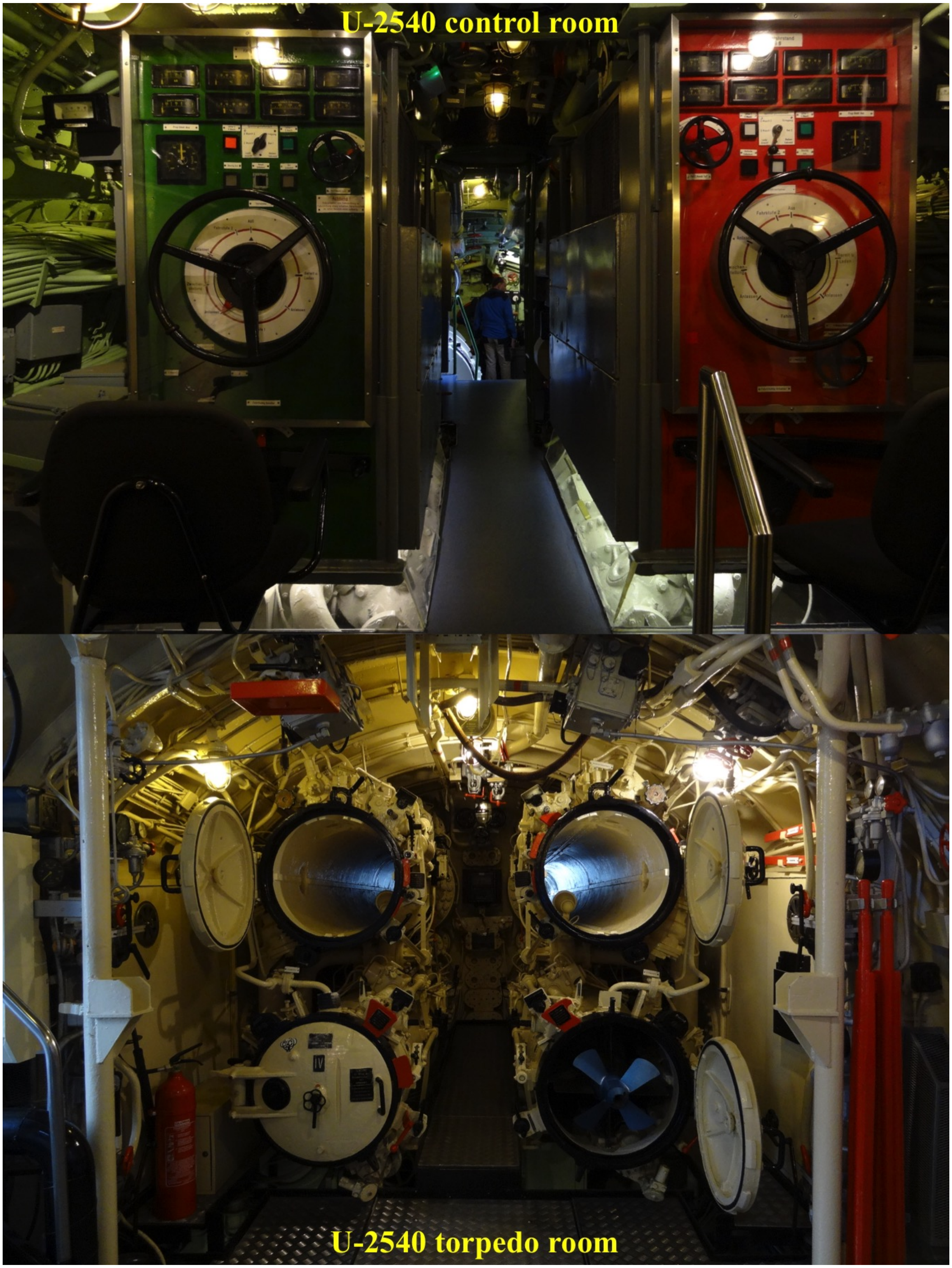

U-2540 control room
U-2540 torpedo room

Figure 7.115: The control room and the torpedo room of the U-2540 submarine.

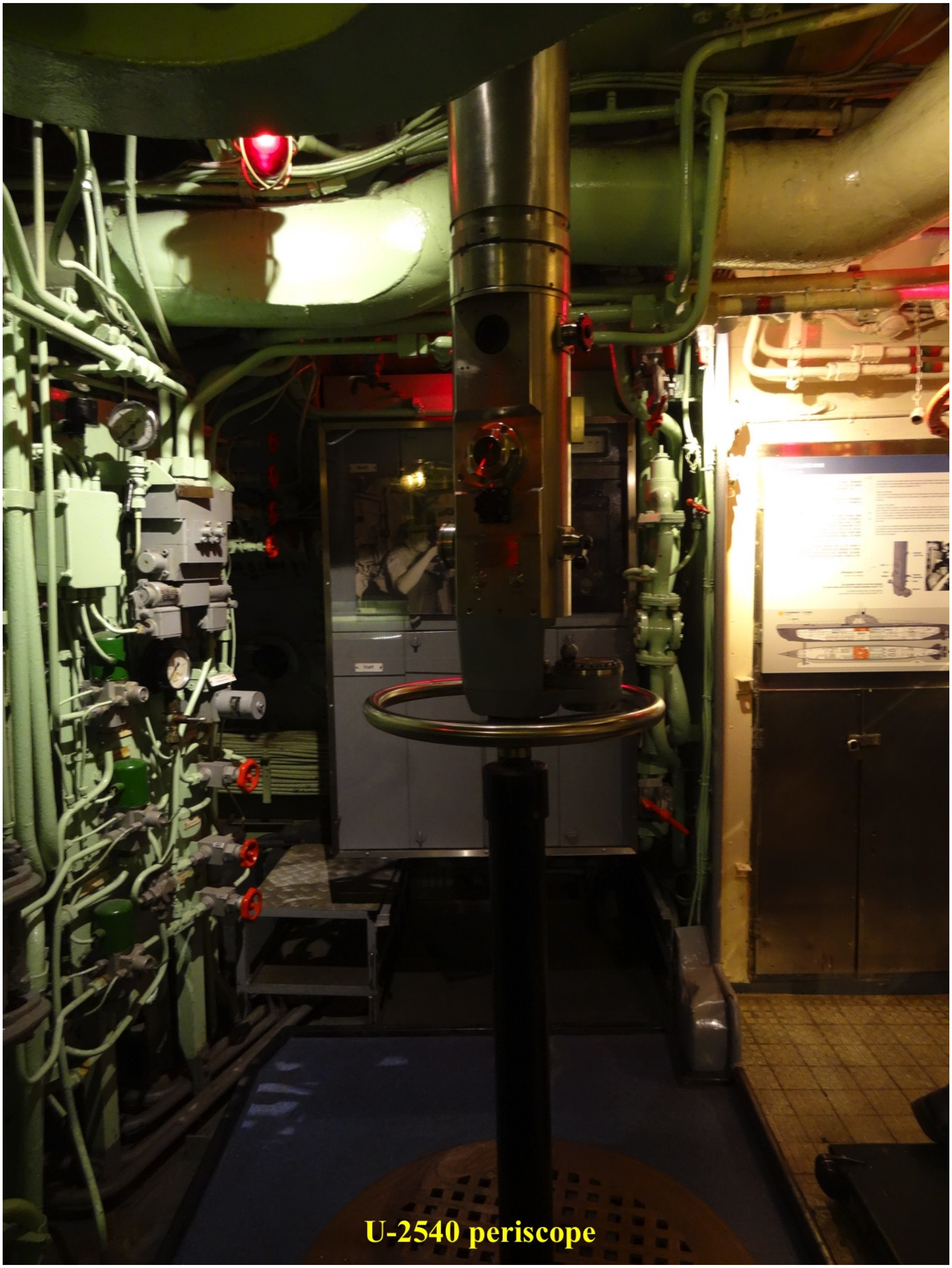

U-2540 periscope

Figure 7.116: The periscope of the U-2540 submarine.

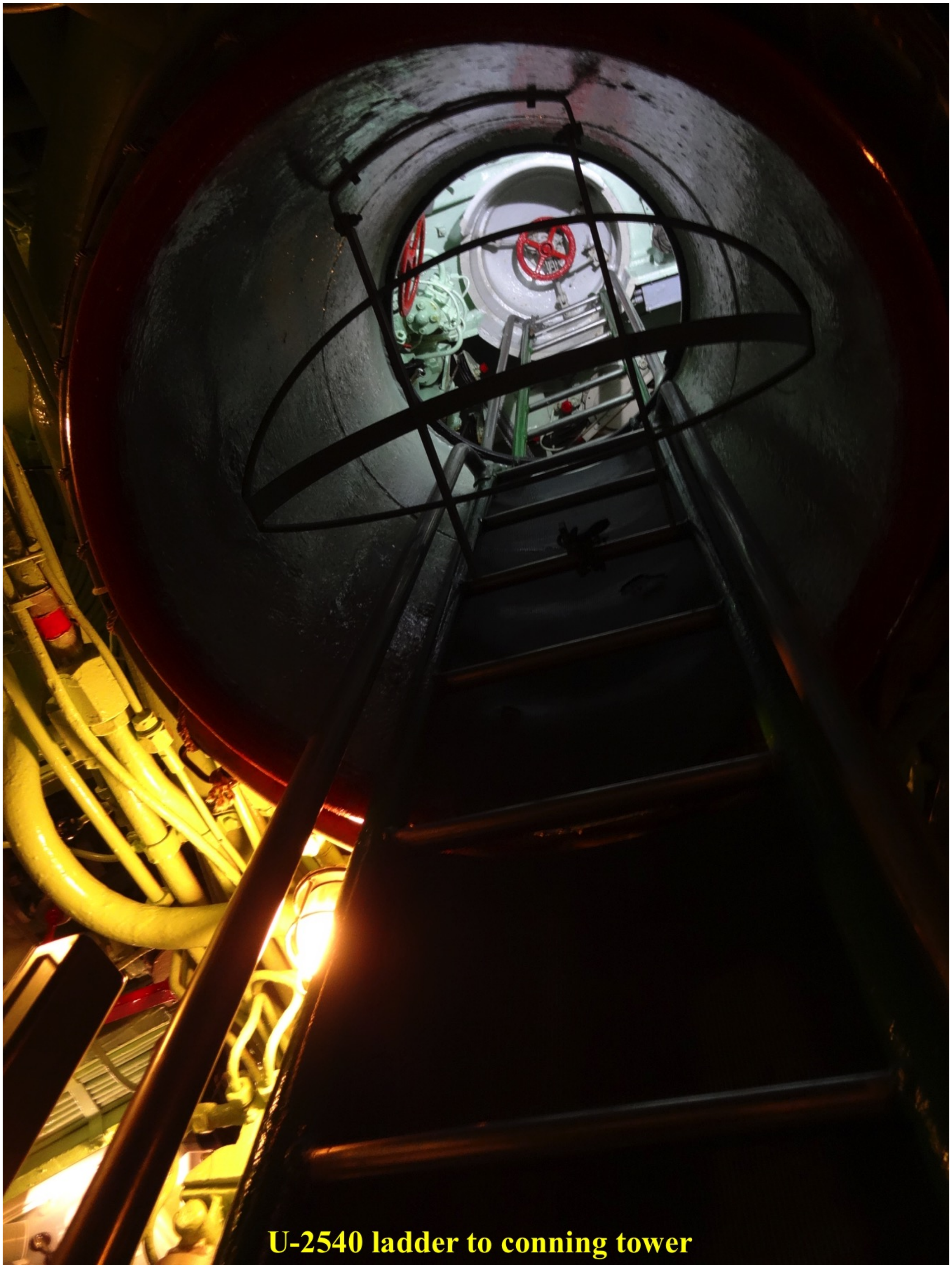

U-2540 ladder to conning tower

Figure 7.117: The ladder to the conning tower in the U-2540 submarine.

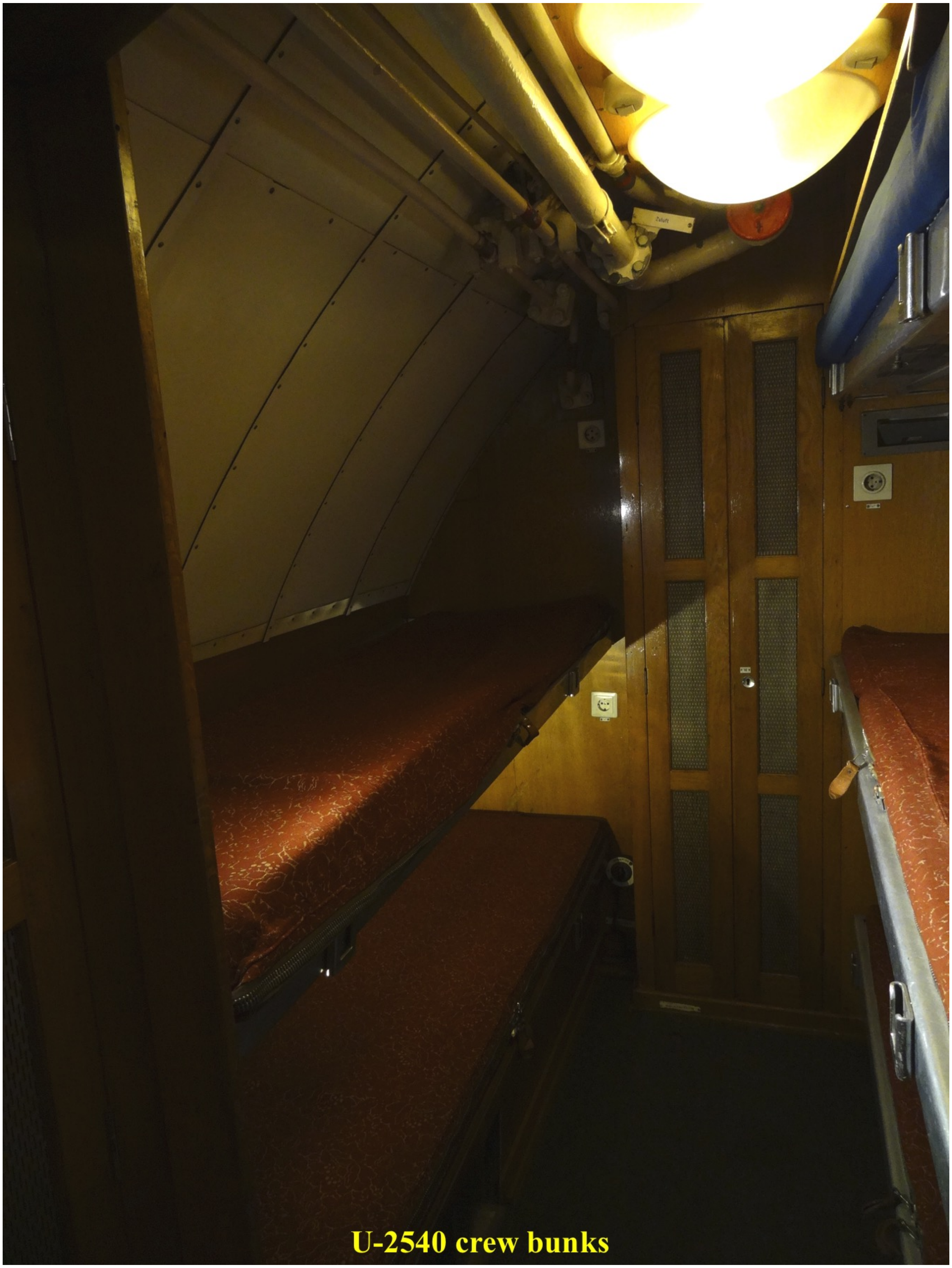

U-2540 crew bunks

Figure 7.118: One of the cabins with crew bunks in the U-2540 submarine.

Of the 123 Type XXI U-boats in service during the war, 23 were destroyed by Allied attacks and 88 were scuttled by Germany at the end of the war. After the war, the remaining 12 operational Type XXI submarines were divided among the U.S., U.K., France, and Soviet Union and studied very closely (Fig. 7.119) [Breyer 1999, p. 38; Wetzel 1999; NYT 1945-11-22 p. 16a, 1947-02-12 p. 10]. As just one example, on 12 February 1947, the *New York Times* reported:

> The House Armed Services Committee gave unanimous approval today to construction of two new experimental submarines embracing ideas gained from Allied war experiences and seized German U-boats. It approved, subject to House action next week, the Navy's request for authority to spend up to $30,000,000 in already appropriated funds to build the new vessels. The estimated cost of each submarine is from $11,000,000 to $15,000,000.

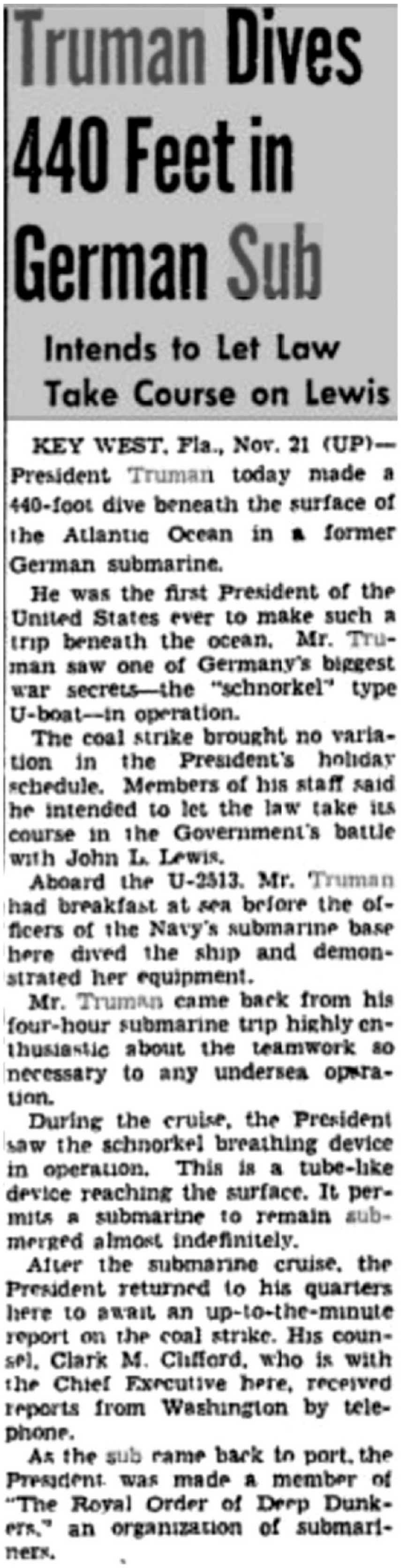
U.S. submarine experts Norman Polmar and Kenneth Moore confirmed that postwar submarines in the United States, Soviet Union, and other countries were based directly on the captured German submarine technology [Polmar and Moore 2004, p. xi]:

> Soviet and U.S. submarines of the Cold War era had the same origins: Their antecedents were German U-boat developments of 1943–1945, especially the Type XXI, the most advanced submarine to go to sea during World War II. The U.S. version of the Type XXI was the *Tang* (SS 563) class, with similar features being incorporated in the *K1*-class "killer" submarines and 52 conversions of war-built submarines in the so-called GUPPY program. The Soviets adopted Type XXI features in the Whiskey and Zulu designs and their successors. The U.S. and Soviet (as well as British) submarine communities also had major interest in German closed-cycle, or "single-drive," submarine propulsion systems, with these submarines being evaluated in the postwar period by Britain and the Soviet Union.

Wartime prototype submarines that utilized a teardrop hull design for high speeds included the V-80 (first demonstrated in 1940) and the *Delphin* (*Dolphin*, first demonstrated in 1944); see Fig. 7.120. Of course, the teardrop design was known much earlier from German airship designs (see Section 9.1). The teardrop hull is sometimes called the *Albacore* hull after the first U.S. submarine to use that shape, the USS *Albacore*, which was designed using captured German submarine designs and launched in 1953.

As illustrated in Fig. 7.121, the United States needed German machines (such as the Trebel balancing machine shown in the photo) in order to make propellers for its postwar submarines such as *Nautilus*, the first U.S. nuclear submarine [NYT 1958-10-09 p. 73].

As shown in Fig. 7.122, a recently declassified CIA report from 1950 (summarizing Soviet work from 1943 to 1948) reveals how dependent postwar Soviet submarines were on captured German-speaking scientists and submarines, torpedoes, missiles, and other technologies from wartime German programs [https://www.cia.gov/readingroom/document/cia-rdp80-00809a000600360061-4.].



Truman Dives 440 Feet in German Sub

Intends to Let Law Take Course on Lewis

KEY WEST, Fla., Nov. 21 (UP)—President Truman today made a 440-foot dive beneath the surface of the Atlantic Ocean in a former German submarine.

He was the first President of the United States ever to make such a trip beneath the ocean. Mr. Truman saw one of Germany's biggest war secrets—the "schnorkel" type U-boat—in operation.

The coal strike brought no variation in the President's holiday schedule. Members of his staff said he intended to let the law take its course in the Government's battle with John L. Lewis.

Aboard the U-2513, Mr. Truman had breakfast at sea before the officers of the Navy's submarine base here dived the ship and demonstrated her equipment.

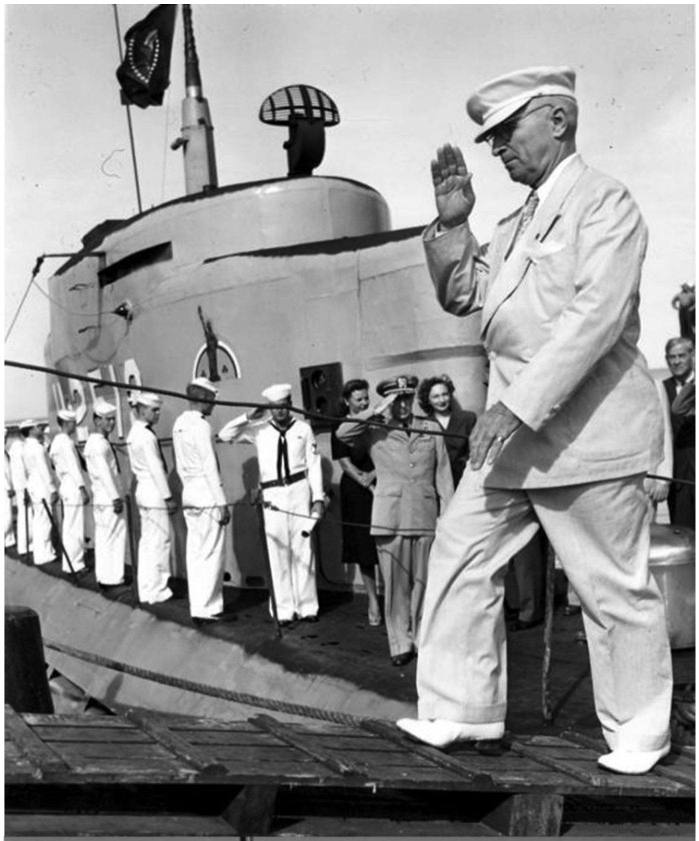
Mr. Truman came back from his four-hour submarine trip highly enthusiastic about the teamwork so necessary to any undersea operation.

During the cruise, the President saw the schnorkel breathing device in operation. This is a tube-like device reaching the surface. It permits a submarine to remain submerged almost indefinitely.

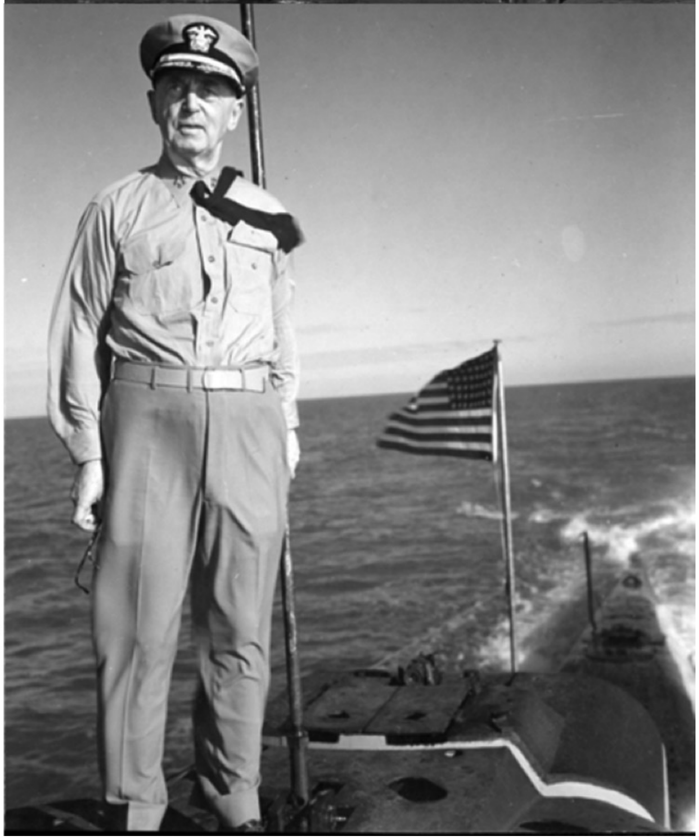
After the submarine cruise, the President returned to his quarters here to await an up-to-the-minute report on the coal strike. His counsel, Clark M. Clifford, who is with the Chief Executive here, received reports from Washington by telephone.

As the sub came back to port, the President was made a member of "The Royal Order of Deep Dunkers," an organization of submariners.

The Pittsburgh Press, 21 November 1946, p. 9



President Harry Truman visiting the U-2513 Type XXI submarine



Admiral William Leahy on the U-2513 Type XXI submarine

Figure 7.119: In 1946, President Harry Truman and Admiral William Leahy visited a captured Type XXI submarine, U-2513, that was being intensively studied by the U.S. Navy [*Pittsburgh Press*, 21 November 1946, p. 9; http://www.navsource.org/archives/08/08358.htm].

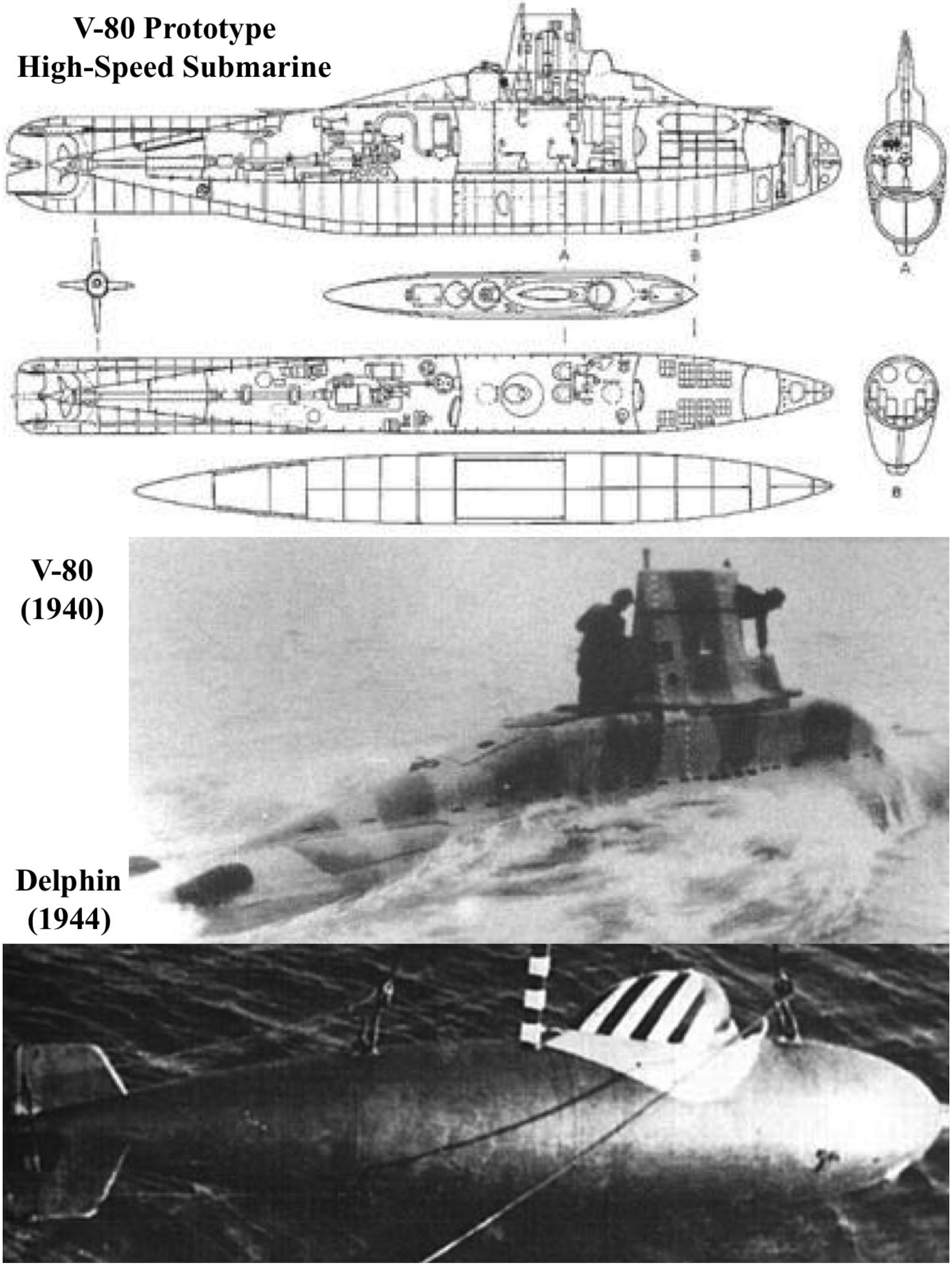
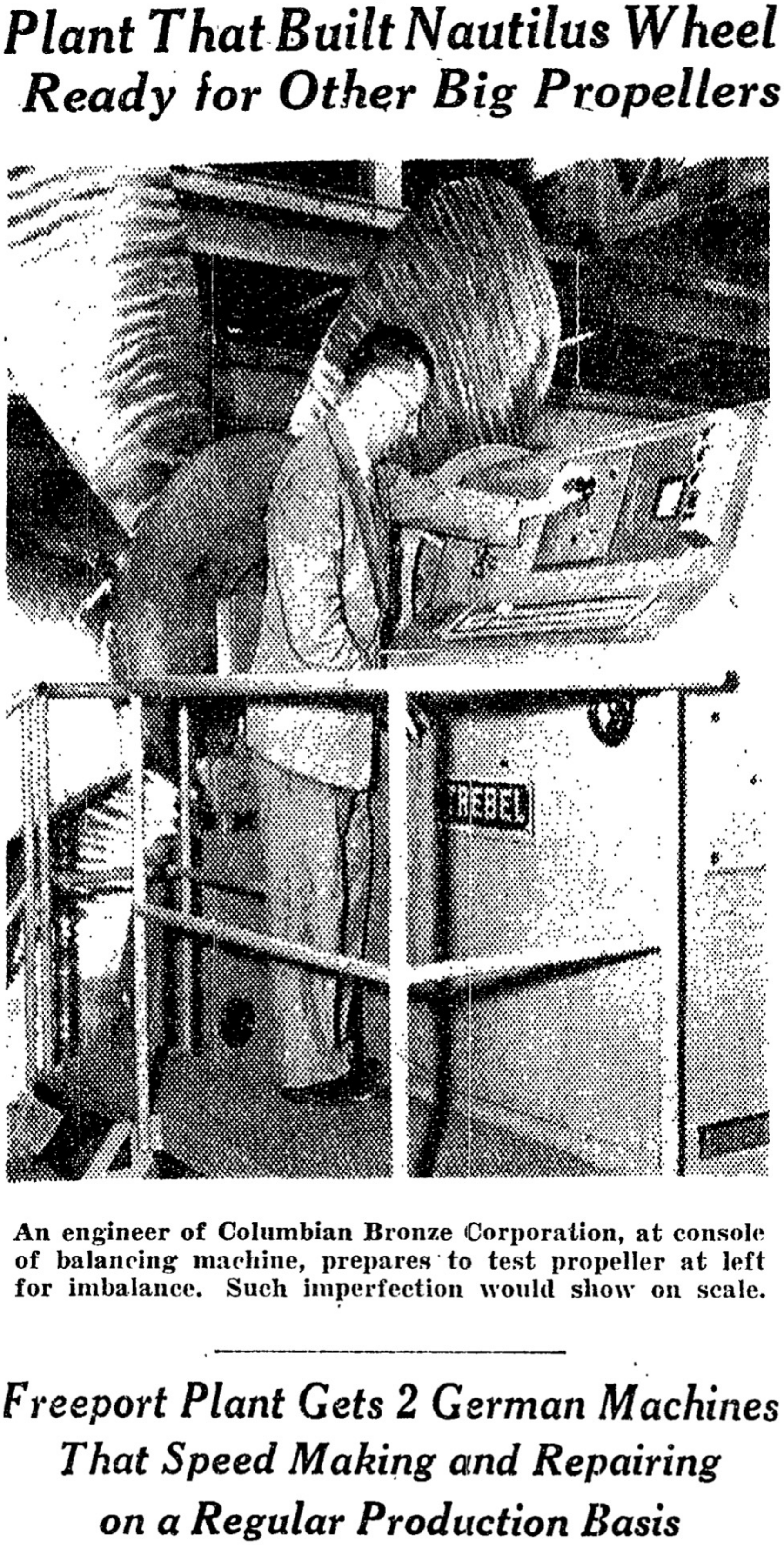

V-80 Prototype
High-Speed Submarine
A
B
A
B
V-80
(1940)
Delphin
(1944)

Figure 7.120: Prototype submarines that utilized a teardrop hull design for high speeds included the V-80 (first demonstrated in 1940) and the Delphin (Dolphin, first demonstrated in 1944).



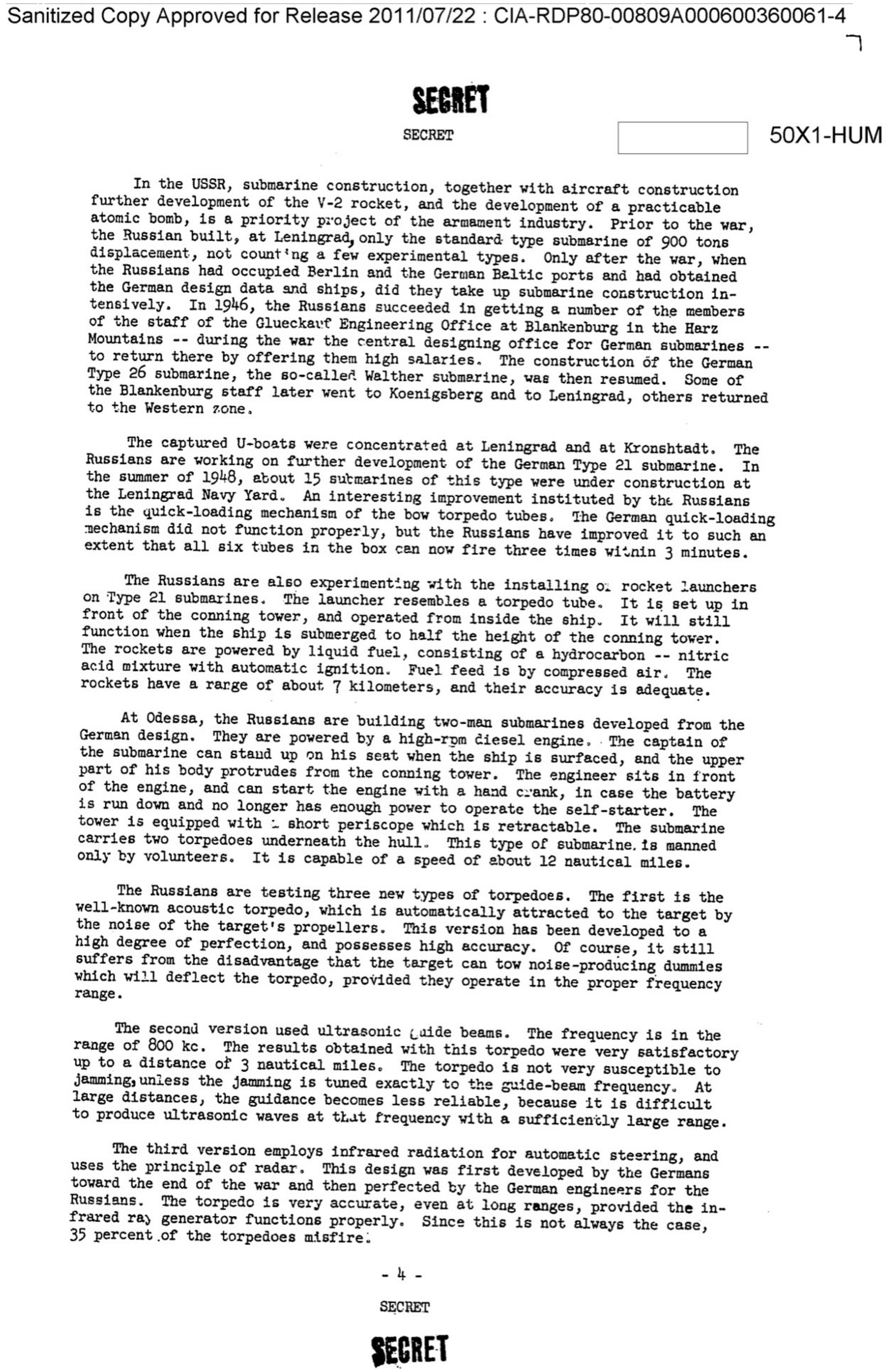
Plant That Built Nautilus Wheel Ready for Other Big Propellers

An engineer of Columbian Bronze Corporation, at console of balancing machine, prepares to test propeller at left for imbalance. Such imperfection would show on scale.

Freeport Plant Gets 2 German Machines That Speed Making and Repairing on a Regular Production Basis

***New York Times*, 9 October 1958, p. 73**

Figure 7.121: The United States needed German machines to make propellers for its postwar submarines such as *Nautilus*, the first U.S. nuclear submarine [NYT 1958-10-09 p. 73].



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In the USSR, submarine construction, together with aircraft construction further development of the V-2 rocket, and the development of a practicable atomic bomb, is a priority project of the armament industry. Prior to the war, the Russian built, at Leningrad, only the standard type submarine of 900 tons displacement, not counting a few experimental types. Only after the war, when the Russians had occupied Berlin and the German Baltic ports and had obtained the German design data and ships, did they take up submarine construction intensively. In 1946, the Russians succeeded in getting a number of the members of the staff of the Glueckauf Engineering Office at Blankenburg in the Harz Mountains -- during the war the central designing office for German submarines -- to return there by offering them high salaries. The construction of the German Type 26 submarine, the so-called Walther submarine, was then resumed. Some of the Blankenburg staff later went to Koenigsberg and to Leningrad, others returned to the Western zone.

The captured U-boats were concentrated at Leningrad and at Kronshtadt. The Russians are working on further development of the German Type 21 submarine. In the summer of 1948, about 15 submarines of this type were under construction at the Leningrad Navy Yard. An interesting improvement instituted by the Russians is the quick-loading mechanism of the bow torpedo tubes. The German quick-loading mechanism did not function properly, but the Russians have improved it to such an extent that all six tubes in the box can now fire three times within 3 minutes.

The Russians are also experimenting with the installing of rocket launchers on Type 21 submarines. The launcher resembles a torpedo tube. It is set up in front of the conning tower, and operated from inside the ship. It will still function when the ship is submerged to half the height of the conning tower. The rockets are powered by liquid fuel, consisting of a hydrocarbon -- nitric acid mixture with automatic ignition. Fuel feed is by compressed air. The rockets have a range of about 7 kilometers, and their accuracy is adequate.

At Odessa, the Russians are building two-man submarines developed from the German design. They are powered by a high-rpm diesel engine. The captain of the submarine can stand up on his seat when the ship is surfaced, and the upper part of his body protrudes from the conning tower. The engineer sits in front of the engine, and can start the engine with a hand crank, in case the battery is run down and no longer has enough power to operate the self-starter. The tower is equipped with a short periscope which is retractable. The submarine carries two torpedoes underneath the hull. This type of submarine is manned only by volunteers. It is capable of a speed of about 12 nautical miles.

The Russians are testing three new types of torpedoes. The first is the well-known acoustic torpedo, which is automatically attracted to the target by the noise of the target's propellers. This version has been developed to a high degree of perfection, and possesses high accuracy. Of course, it still suffers from the disadvantage that the target can tow noise-producing dummies which will deflect the torpedo, provided they operate in the proper frequency range.

The second version used ultrasonic guide beams. The frequency is in the range of 800 kc. The results obtained with this torpedo were very satisfactory up to a distance of 3 nautical miles. The torpedo is not very susceptible to jamming, unless the jamming is tuned exactly to the guide-beam frequency. At large distances, the guidance becomes less reliable, because it is difficult to produce ultrasonic waves at that frequency with a sufficiently large range.

The third version employs infrared radiation for automatic steering, and uses the principle of radar. This design was first developed by the Germans toward the end of the war and then perfected by the German engineers for the Russians. The torpedo is very accurate, even at long ranges, provided the infrared ray generator functions properly. Since this is not always the case, 35 percent of the torpedoes misfire.

- 4 -

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Figure 7.122: A recently declassified CIA report reveals how dependent postwar Soviet submarine technologies were on German-speaking innovators and innovations. New Soviet Weapons. 10 November 1950 [based on intelligence from 1943–1948]. https://www.cia.gov/readingroom/document/cia-rdp80-00809a000600360061-4.

The key features of modern naval mines and torpedoes were developed by creators from the German-speaking world.[10]

While the concept of naval mines had been around for centuries, the chief difficulty was making the mines detonate automatically and reliably, without direct human control or timers. That problem was solved by German inventors in the nineteenth century, as shown in Fig. 7.123. The first practical contact-activated naval mines were created by Moritz von Jacobi (German, 1801–1874) in 1853. His mines used electromechanical contact switches, and they were successfully employed during the Crimean War.

In 1868, Albert Hertz (German, 18??–19??) invented improved mines that used electrochemical contact switches, or "Hertz horns." Inside each metal horn was a fragile glass reservoir of liquid electrolyte; if the horn was bumped, the liquid electrolyte was released into the previously empty space between two electrodes, making a functional electrical battery that detonated the mine. That was a very simple and elegant solution that allowed a deployed naval mine to remain viable for many years. Even in the twenty-first century, many naval mines still use this method.

Self-propelled explosive torpedoes were developed in the 1850s–1860s by a currently unknown Austrian marine artillery officer, Giovanni Luppis von Rammer (Austro-Hungarian/Croatian, 1813–1875), Robert Whitehead (English but worked in Austria, 1823–1905), and Annibale Plöch (Austrian, 1826 or 1836–1906?). See Fig. 7.124. Using their designs, the world's first torpedo factory opened in 1872 in Fiume, Austro-Hungary (now Rijeka, Croatia; Fig. 7.125).

Nikola Tesla (Serbo-Croatian, educated in Austria, 1856–1943) made a revolutionary early advance when he patented and demonstrated a radio-controlled boat or torpedo in 1898 (p. 1207). Building on that invention, Siemens engineers developed the Fernlenkboot remote-controlled explosive motorboat/torpedo in 1911 (Fig. 7.126). Fernlenkboot models came in both radio-controlled and wire-guided versions, carried 700 kg of explosives, could travel up to 56 km/hour, had a range of up to 20 km, and were successfully employed during World War I.

German-speaking creators made numerous other improvements to torpedoes before, during, and after World War I. By World War II, German innovations in torpedo design included improved energy sources such as batteries (in G7e torpedoes) and concentrated hydrogen peroxide (H_2O_2, called Ingolene). Other innovations included improved guidance systems such as preprogrammed pattern running systems (Fat I/II and Lut I/II) and acoustic homing systems (Falke and Zaunkönig). Those innovations in torpedo design were adopted by other countries after the war.[11] See Fig. 7.127.

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[10] Cowie 1949; Hartmann and Truver 1991; Hussey 1946; Jolie 1978; Eberhard Rössler 2005.

[11] Eberhard Rössler 2005; CIOS XXXII-69; NavTecMisEu LR 78-45; NavTecMisEu LR 79-45; NavTecMisEu LR 80-45; NavTecMisEu 161-45; NavTecMisEu 202-45; NavTecMisEu 203-45; NavTecMisEu 204-45; NavTecMisEu 205-45; NavTecMisEu 206-45; NavTecMisEu 207-45; NavTecMisEu 208-45; NavTecMisEu 209-45; NavTecMisEu 211-45; NavTecMisEu 356-45.

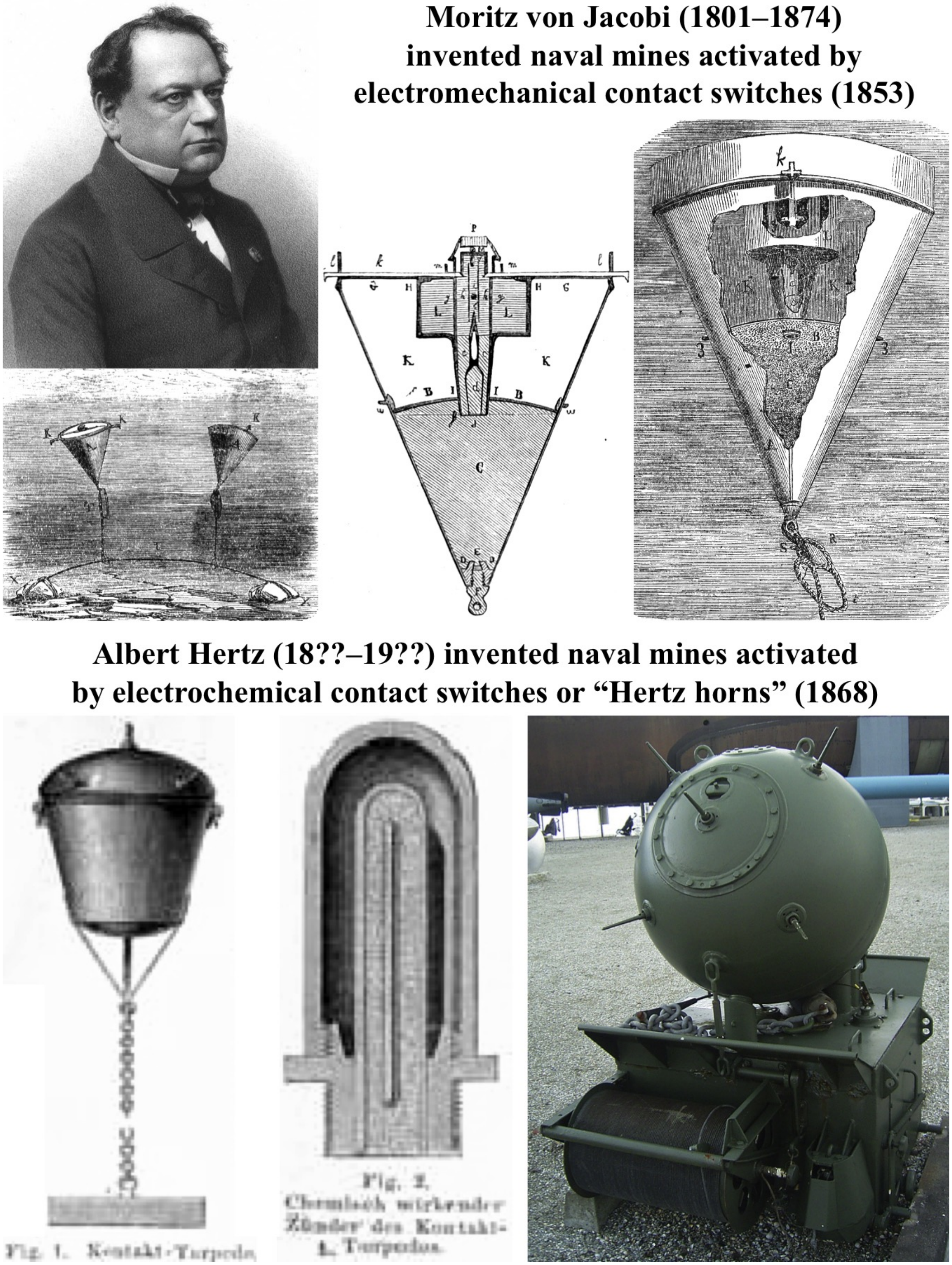

Moritz von Jacobi (1801–1874) invented naval mines activated by electromechanical contact switches (1853)
Albert Hertz (18??–19??) invented naval mines activated by electrochemical contact switches or “Hertz horns” (1868)
Fig. 1. Kontakt-Torpedo.
Fig. 2. Chemisch wirkender Zünder des Kontakt-Torpedos.

Figure 7.123: The first practical contact-activated naval mines were created by Moritz von Jacobi (1853, using electromechanical contact switches) and Albert Hertz (1868, using electrochemical contact switches).

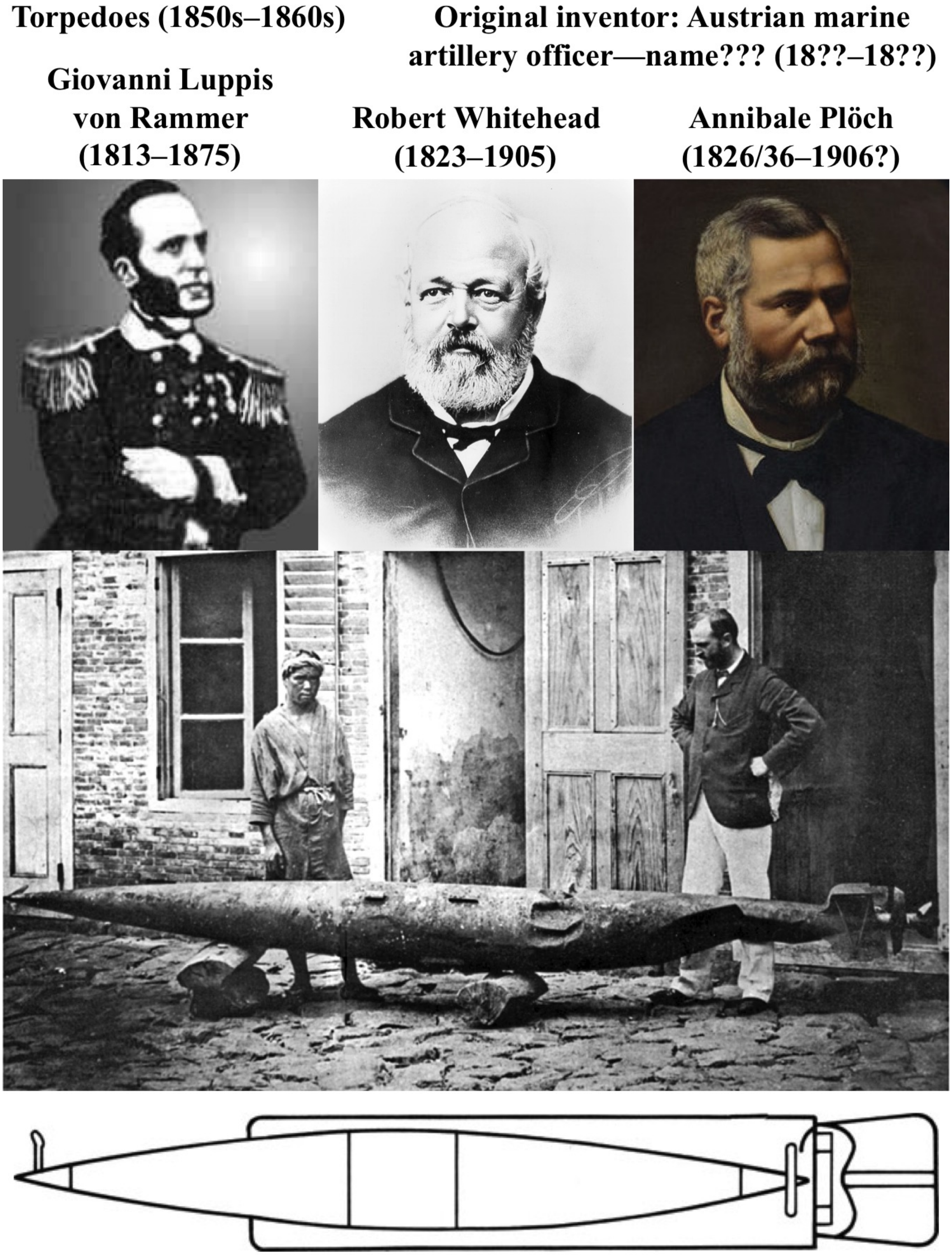
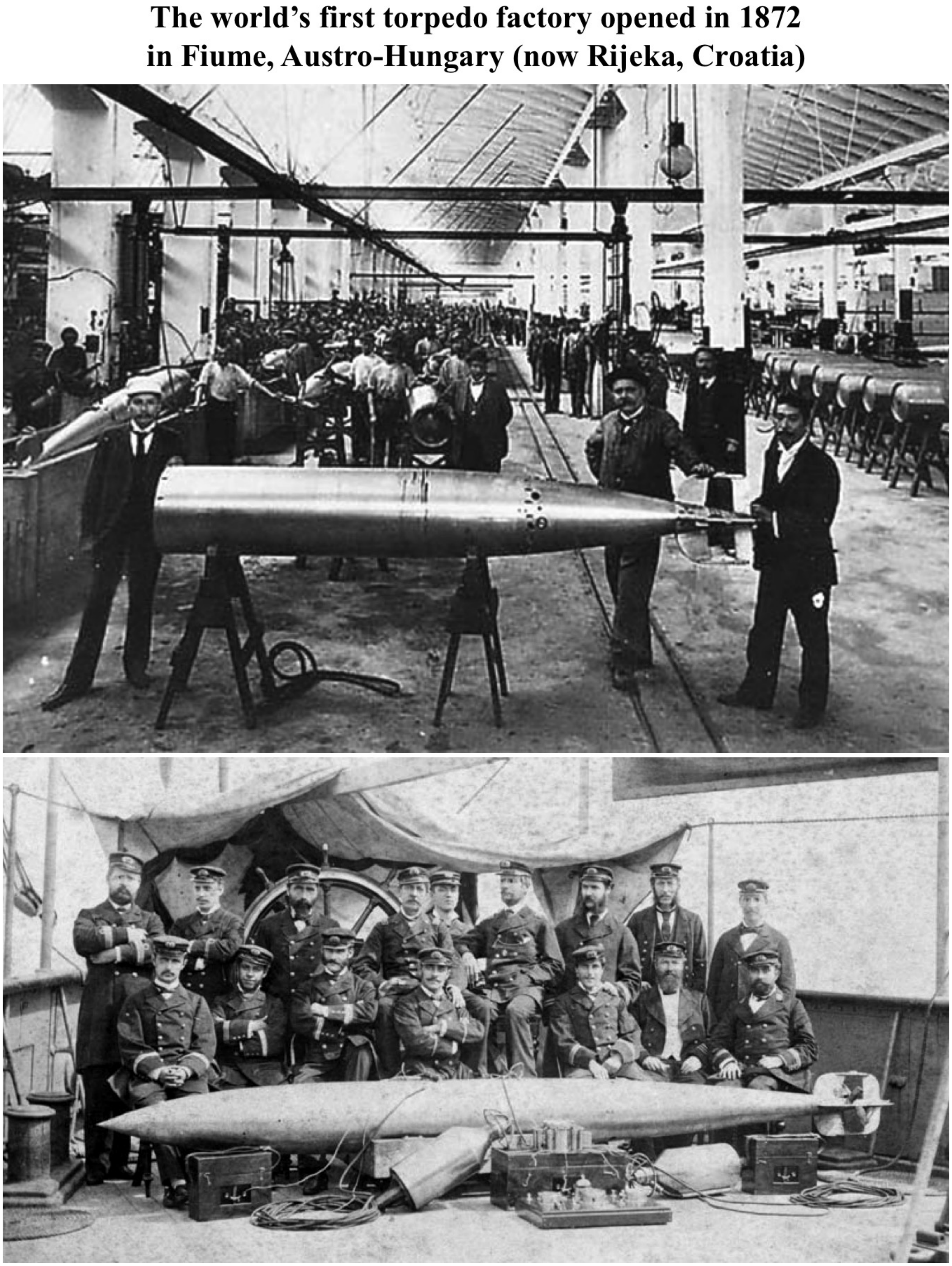

Torpedoes (1850s–1860s)
Original inventor: Austrian marine artillery officer—name??? (18??–18??)
Giovanni Luppis von Rammer (1813–1875)
Robert Whitehead (1823–1905)
Annibale Plöch (1826/36–1906?)

Figure 7.124: Torpedoes were developed in the 1850s–1860s by a currently unknown Austrian marine artillery officer, Giovanni Luppis von Rammer, Robert Whitehead (working in Austria), and Annibale Plöch.

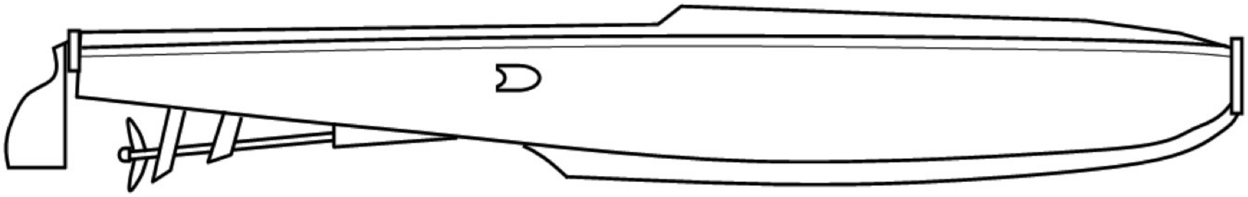


The world’s first torpedo factory opened in 1872
in Fiume, Austro-Hungary (now Rijeka, Croatia)

Figure 7.125: The world’s first torpedo factory opened in 1872 in Fiume, Austro-Hungary (now Rijeka, Croatia).

Siemens Fernlenkboot explosive motorboat/torpedo (1911)

Both radio-controlled and wire-guided versions were built and used



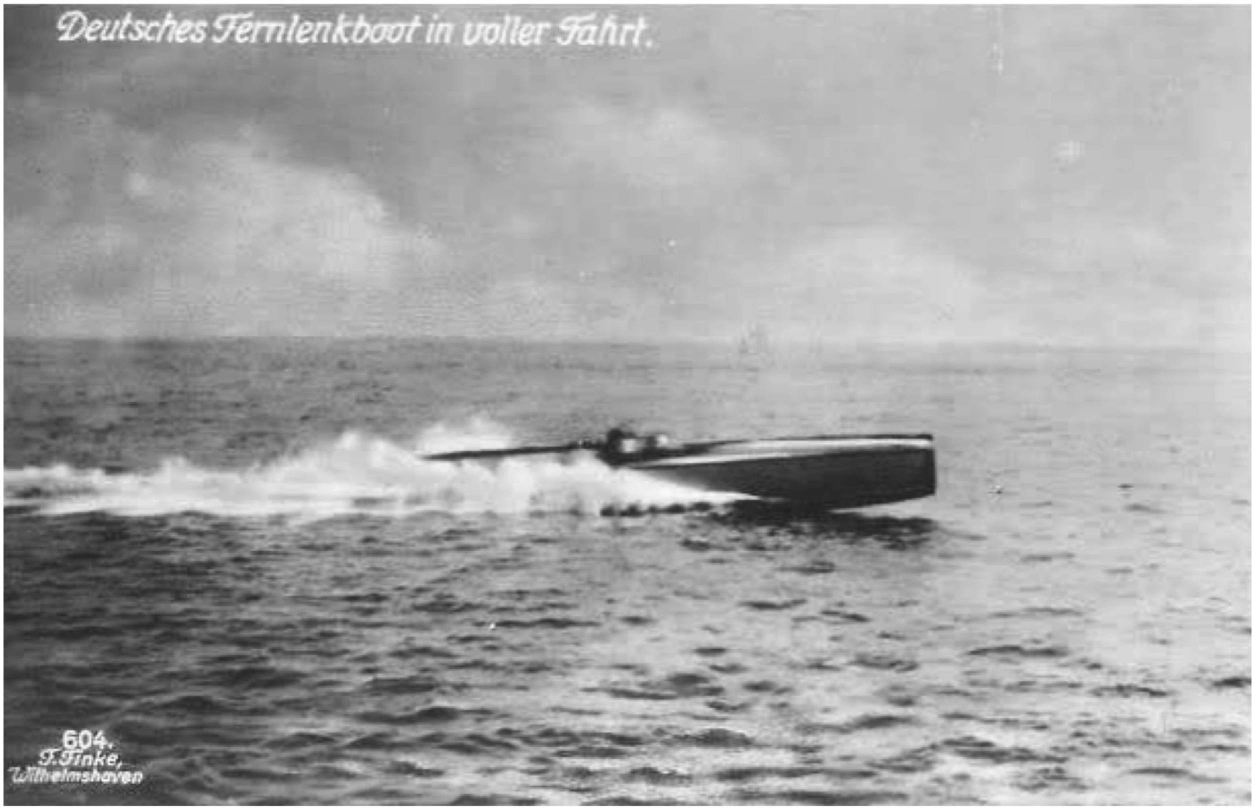
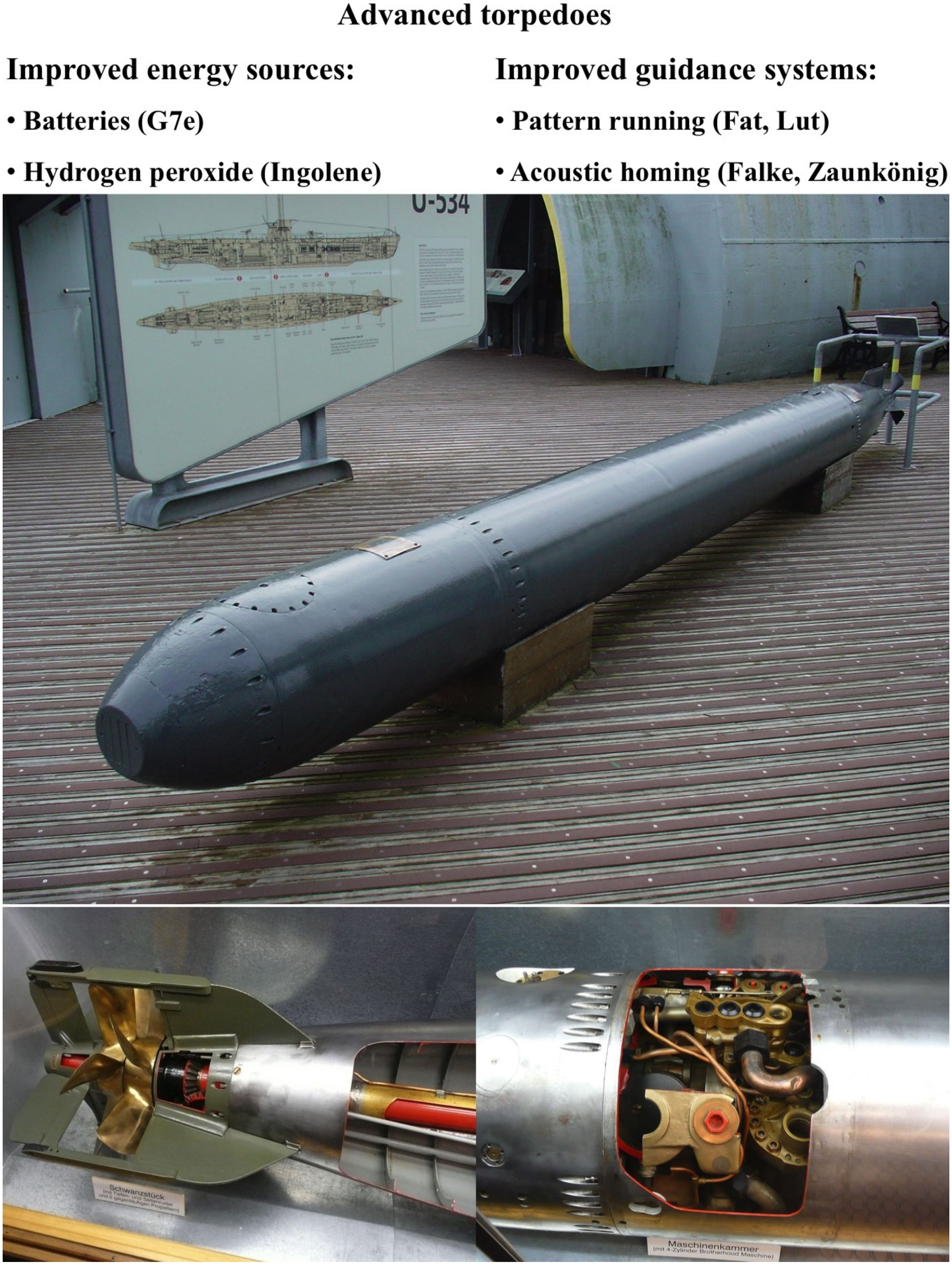

Deutsches Fernlenkboot in voller Fahrt.
604.
J. Finke,
Wilhelmshaven

Figure 7.126: In 1911, Siemens engineers developed the Fernlenkboot explosive motorboat/torpedo, available in both radio-controlled and wire-guided versions. It was successfully employed during World War I.



Advanced torpedoes

Improved energy sources:

- **Batteries (G7e)**
- **Hydrogen peroxide (Ingolene)**

Improved guidance systems:

- **Pattern running (Fat, Lut)**
- **Acoustic homing (Falke, Zaunkönig)**

U-534
Schwanzstück (mit Tiefen- und Seitenruder und 2 gegenläufigen Propellern)
Maschinenkammer (mit 4-Zylinder Brotherhood Maschine)

Figure 7.127: Some German innovations in torpedo design included improved energy sources such as batteries (in G7e torpedoes) and concentrated hydrogen peroxide (H_2O_2, called Ingolene). Other innovations included improved guidance systems such as preprogrammed pattern running systems (Fat I/II and Lut I/II) and acoustic homing systems (Falke and Zaunkönig).

German submarine bunkers were also quite sophisticated. For example, as shown in Fig. 7.128, the U-boat bunker Bruno in Bergen, Norway could hold and service up to nine submarines at a time, with six meters of overhead concrete reinforcement to protect them from Allied aerial bombing.

The Goliath low-frequency radio transmitter (Kalbe/Calbe an der Milde) could communicate with submerged submarines around the world. The transmitter was essentially a spiderweb of antennas that stretched 1600 m wide and 200 m high. Once it became operational in 1943, it radiated one million Watts of electromagnetic power [Bauer 1997; Klawitter 1998; AFHRA B1975, frames 1325–1495; https://www.kalbe-milde.de/gol.php]. See pp. 1476–1478. After the war, the Goliath transmitter was extensively studied by western Allied countries and completely removed by and reconstructed in the Soviet Union, inspiring postwar low-frequency radio transmitters for submarine communications in many countries. For example, the U.S. Navy's similar Clam Lake facility in Wisconsin became operational in 1985 (Fig. 7.132).

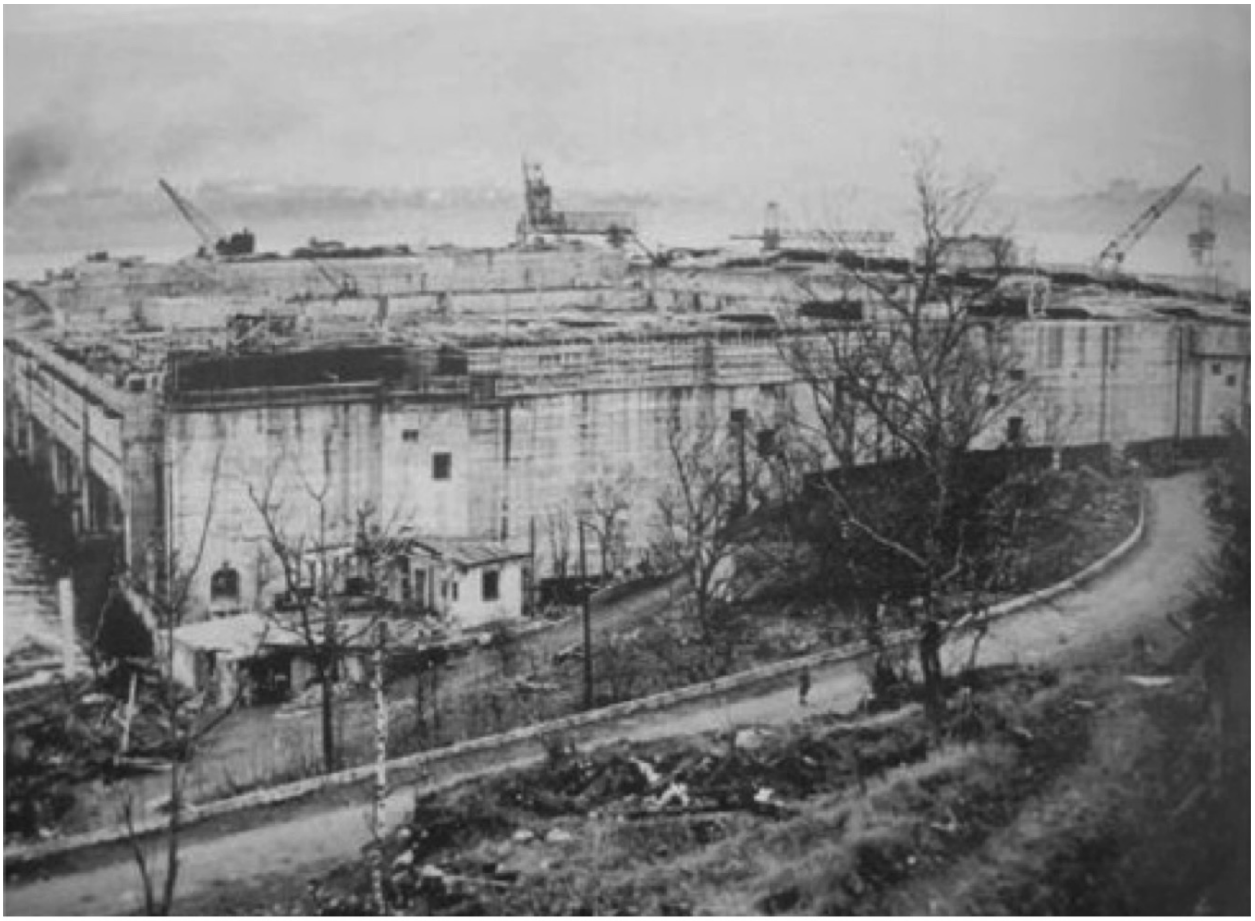
An especially mysterious and historically important topic is how far wartime Germany may have gotten in developing nuclear power for submarine propulsion, and how much that work influenced and aided postwar work on nuclear submarine propulsion in the United States and other countries. It seems very likely that there was such a wartime program, since Germany was very interested both in developing fission reactors (Appendix D) and also in improving the performance of its submarines (which were limited by needing air to power their diesel engines, except for short periods of fully submerged operation using batteries). Unfortunately there is very little available documentation at present. One intriguing comment long after the war came from Werner Grothmann, who had been Heinrich Himmler's chief adjutant [Krotzky 2002, p. 34; see pp. 3396–3397 regarding this source]:

> Deshalb kann ich auch nichts dazu sagen, was im einzelnen auf Bornholm war, außer daß auch die Kriegsmarine dort etwas machte. Vielleicht mit der Reichspost zusammen. An den Vorüberlegungen zum Atommotor für unsere U boote werden sie dort nicht gearbeitet haben, das lief ja in Berlin bei Rhein und der hatte sich dazu Physiker ausgeliehen, die auch mal beim Heereswaffenamt unter Vertrag standen, aber jedenfalls nicht bei der Reichspost.

> That is why I cannot say anything in detail about what was on Bornholm, except that the German Navy did something there as well. Maybe together with the Reichspost. They would not have worked there on the preliminary considerations for the atomic engine for our submarines; that ran in Berlin with [Admiral Wilhelm] Rhein and he had borrowed physicists, who were also under contract with the Army Ordnance Office, but in any case not with the Reichspost.

Admiral Wilhelm Rhein headed the Navy Weapons Office (Marinewaffenamt, MWA) in Berlin. He assembled a team of scientists (including Otto Haxel, Pascual Jordan, Helmut Hasse, Fritz Houtermans, and others) that worked on applications of nuclear technology for the German navy. Because so few documents from those programs survive (or have been declassified if they do survive), it is currently unclear just how far those programs progressed by the end of the war.

Nonetheless, it is quite intriguing that the zirconium (and possibly other materials, information, and/or expertise) for the first postwar U.S. nuclear submarine was left over from a mysterious wartime German program. See p. 4146–4147 for more information.



U-boat bunker Bruno in Bergen, Norway (circa 1944)

U-boat bunker Bruno in Bergen now (huge weathered concrete structure behind the black Rolls Royce building)

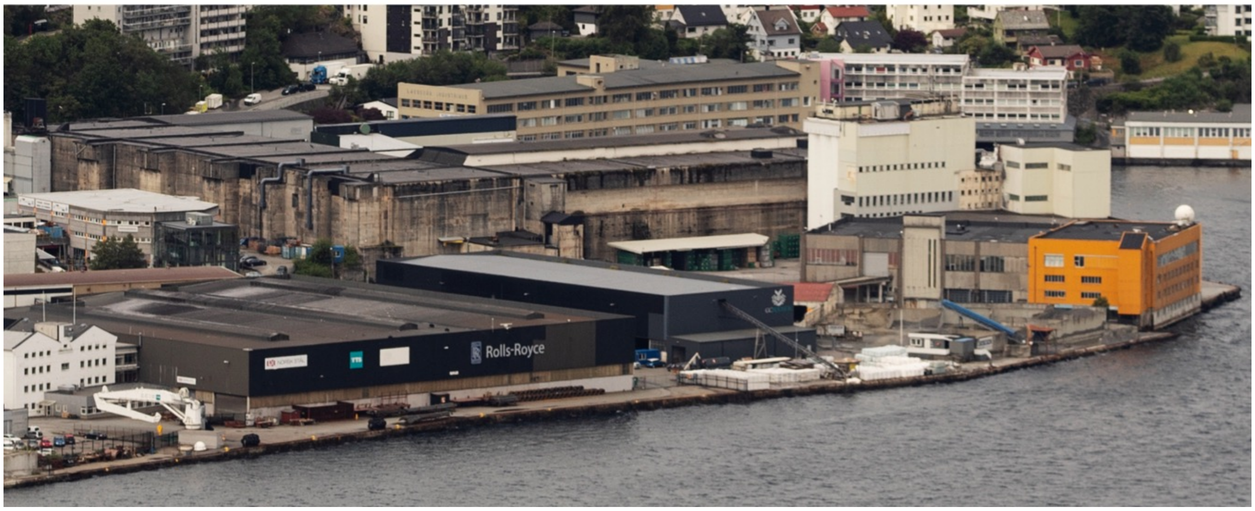


Figure 7.128: The U-boat bunker Bruno in Bergen, Norway could hold and service up to nine submarines at a time, with six meters of overhead concrete reinforcement to protect them from Allied aerial bombing.

Goliath low-frequency radio transmitter to communicate with submarines (Kalbe an der Milde, operational in 1943)

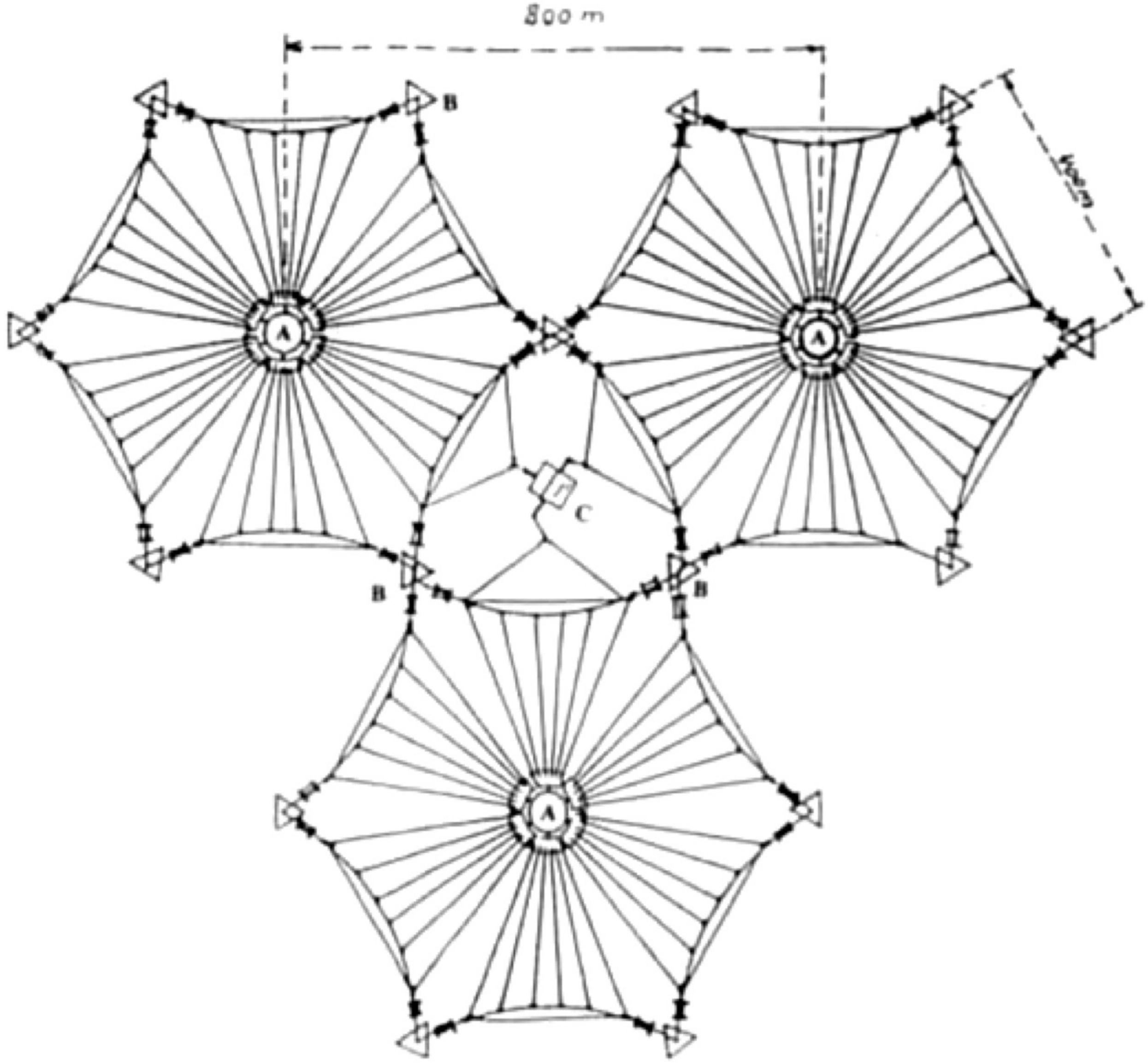


Figure 7.129: The Goliath low-frequency radio transmitter (Kalbe/Calbe an der Milde) could communicate with submerged submarines around the world. It was 1600 m wide and 200 m high, radiated one million Watts of electromagnetic power, and became operational in 1943.

Goliath low-frequency radio transmitter to communicate with submarines (Kalbe an der Milde, operational in 1943)

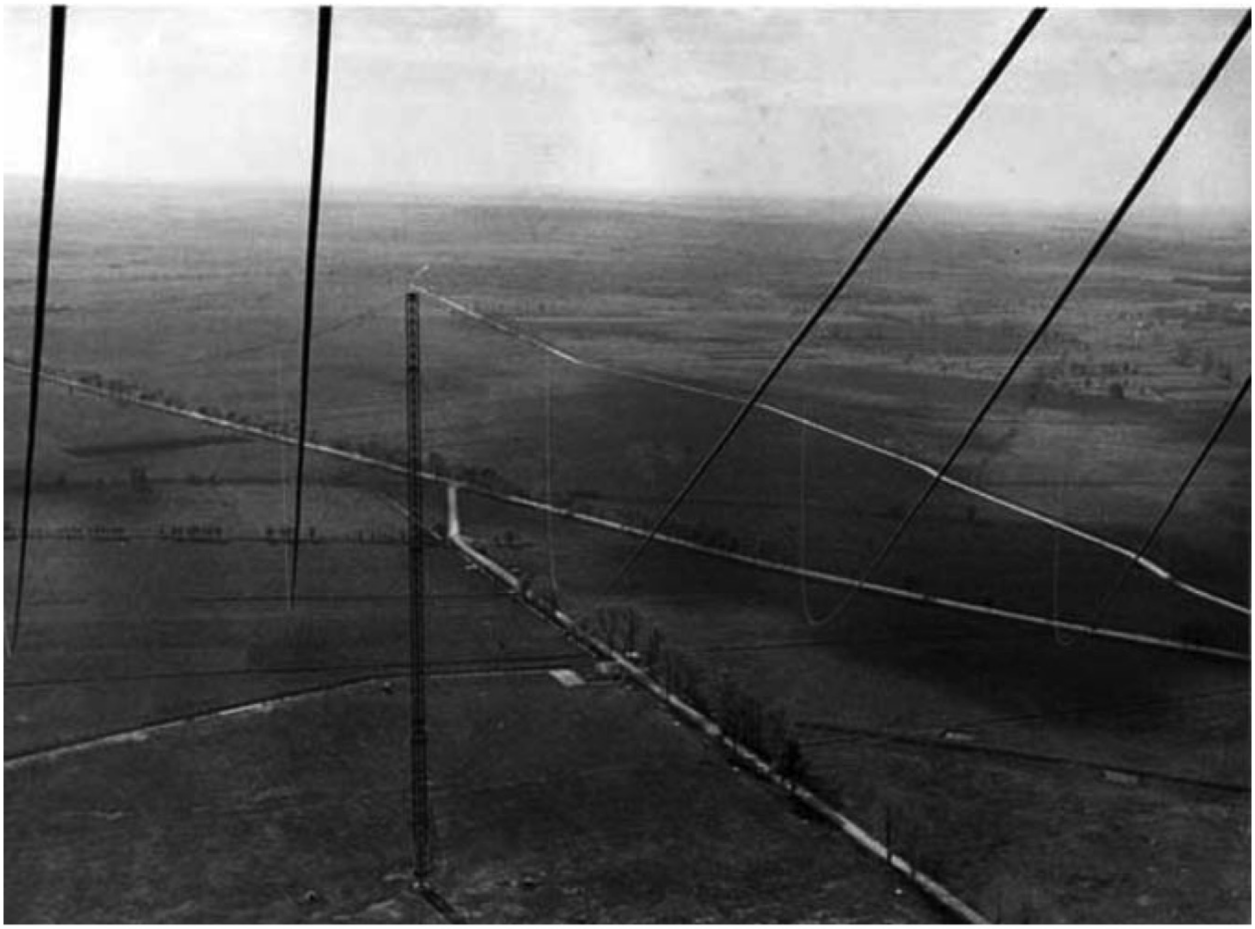


Figure 7.130: The Goliath low-frequency radio transmitter (Kalbe/Calbe an der Milde) could communicate with submerged submarines around the world. It was 1600 m wide and 200 m high, radiated one million Watts of electromagnetic power, and became operational in 1943.

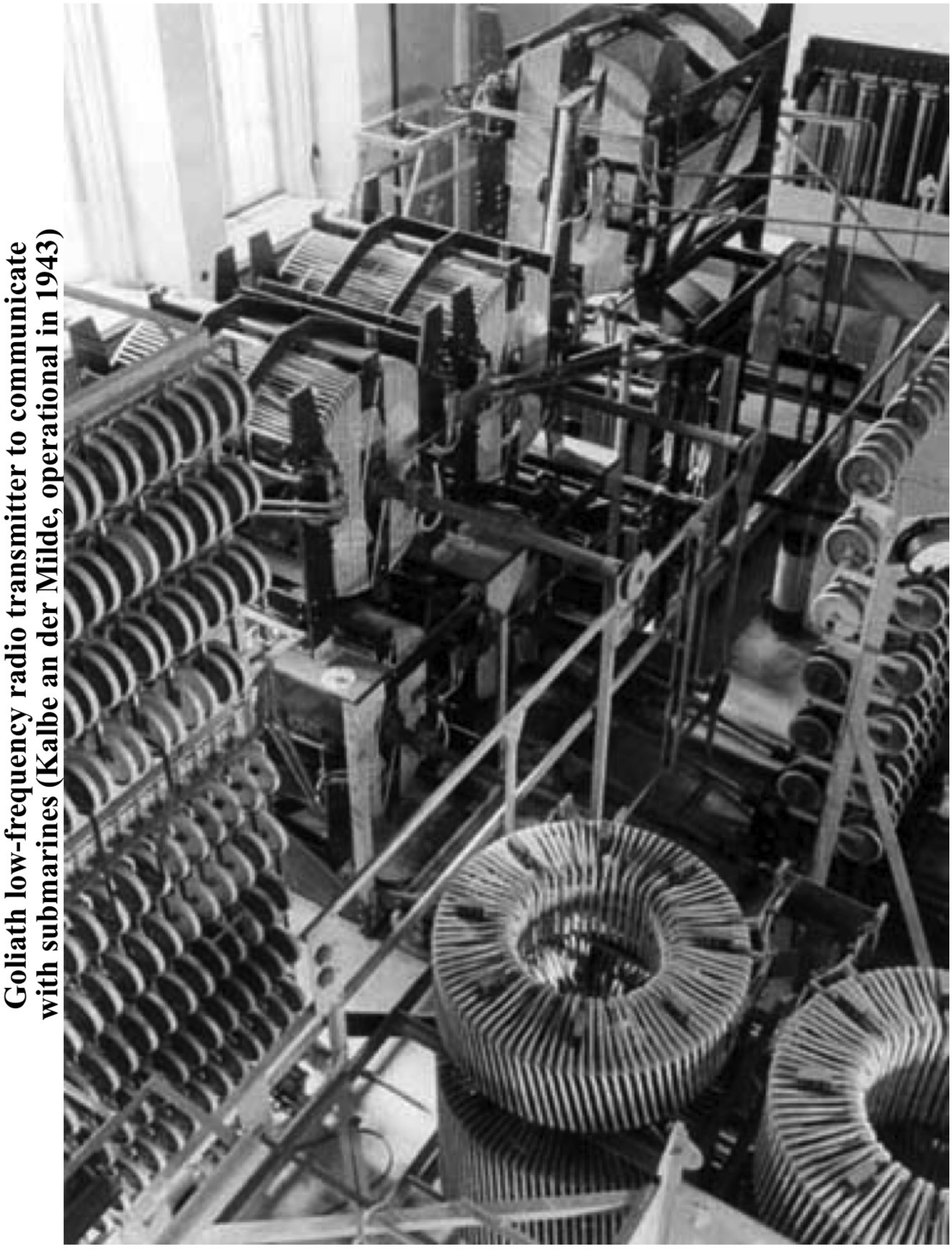
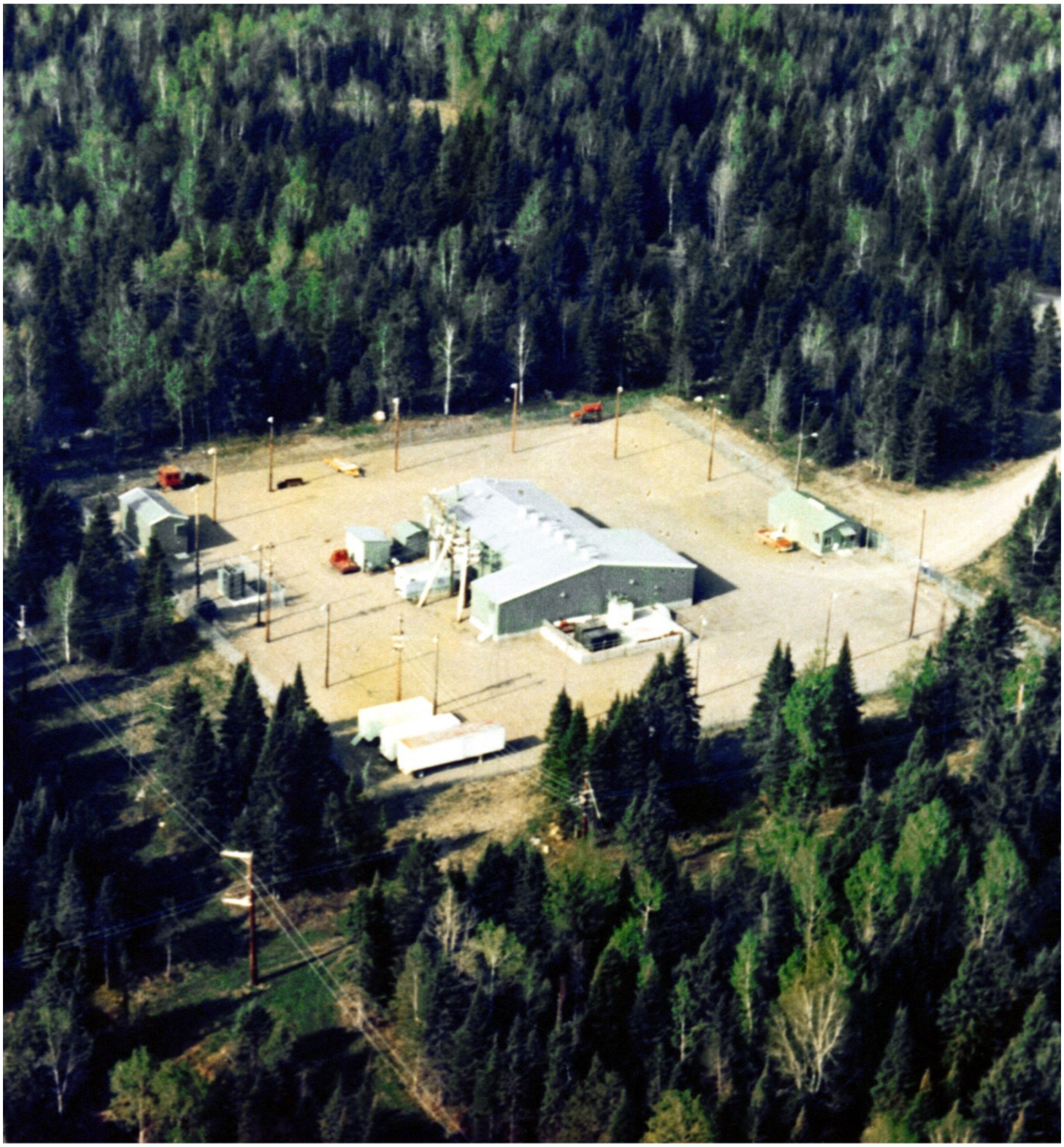

Goliath low-frequency radio transmitter to communicate
with submarines (Kalbe an der Milde, operational in 1943)

Figure 7.131: The Goliath low-frequency radio transmitter (Kalbe/Calbe an der Milde) could communicate with submerged submarines around the world. It was 1600 m wide and 200 m high, radiated one million Watts of electromagnetic power, and became operational in 1943.



U.S. low-frequency radio transmitter to communicate with submarines (U.S. Navy's Clam Lake facility, Wisconsin, operational in 1985)

Figure 7.132: Inspired by the wartime German Goliath transmitter, other countries later built similar massive low-frequency radio transmitters to communicate with submerged submarines around the world. For example, the U.S. Navy's Clam Lake facility in Wisconsin became operational in 1985. The Soviet Union used the Goliath transmitter itself, disassembled and reassembled by German experts in the Soviet Union.

At the very least, it is clear that wartime Germany adapted gas turbine engines for use in submarines, and that those engines and methods were found and utilized by other countries after the war. For example, BIOS 98, *Report on German Development of Gas Turbines for Armoured Fighting Vehicles*, p. 78, stated:

> Notes on the Interrogation of Dipl. Ing. Heinrich Holzapfel [...]
>
> At Messrs. Bruckner-Kanis he was engaged on the development of turbines operating on the hydrogen peroxide cycle, developed by the Walther Company of Hamburg. In addition he was responsible for the development of gas turbines for torpedo boats.

For another example, see FIAT 291, *Gas Turbine Project for a Schnell Boat Developed by Blohm & Voss, Hamburg.*

In September 1945, R. P. Linstead and T. J. Betts, the British and American chairs of the Combined Intelligence Objectives Subcommittee (CIOS), listed a number of important German innovations in ocean engineering that were transferred to Allied countries after the war [AFHRA A5186 electronic version pp. 904–1026, Ch. 4, pp. 70–71]:

> The Germans had developed submarines which were capable of underwater operation for sustained periods. It was discovered that one German submarine had operated for 40 days without surfacing. This was possible because of the “Schnorkel” which permitted the charging of batteries and the operation of engines while submerged. The “Schnorkel” is a tube-like device extending to the surface while the submarine hull is under water, thereby permitting air intake and exhaust discharge.
>
> Much research had been devoted to closed cycle engines. These engines were intended to supplant the conventional type of Diesel, and permit underwater operation without any air intake. The Germans employed extremely high concentrations of H_2O_2, liquid oxygen, and hydrazine-hydrate as fuels. Investigation revealed that high underwater speeds were achieved by use of these fuels in conjunction with new hull designs. U-boats actually constructed obtained submerged speeds in excess of 24 knots. Submarines fully equipped could sustain a 25 knot speed for 6 hours with an underwater operating radius of 150 miles.
>
> Intensive investigation was conducted regarding German torpedo developments. Torpedoes powered by liquid oxygen [sic: hydrogen peroxide] of 80 to 85% concentration, (Ingoline), were in large scale production. Torpedoes using this type of propulsion were capable of speeds in excess of 45 knots. It was discovered that the Germans had devised a method of employing salt water in torpedo propulsion motors, which obviated the necessity of providing fresh water tanks within the torpedo. The space and weight saving achieved enabled them to construct torpedoes capable of long ranges. Certain of these torpedoes had a range of 21,000 yards at 45 knots.
>
> American and British naval experts have conducted detailed investigations of new German torpedo pistols.
>
> The Germans were found to have used ultra-high boiler pressures and temperatures to attain maximum speed for surface ships, with a minimum of ship’s space devoted to power plants. [...]

Great quantities of highly classified German naval documents were obtained by US and British naval investigators. These documents included the following:

1. General specifications for the construction of ships for the German Navy; other specifications for machinery, and armament installations.

2. Complete plans for the Type 21 and Type 23 submarines and midget U-boats.

3. Plans and specifications for the latest type E-boats with the following characteristics:

   20 cylinder diesels, three 2500 HP motors capable of 42 knots speed, 35 meters long, 5.2 meters beam.

4. Detailed specifications for hull and machinery of the 10,000 ton Deutschland, the 6,000 ton Karlsruhe and Nuremberg, the 26,000 ton battleships Gneisenau and Scharnhorst, projected light cruisers “M” and projected battleship “O”.

5. Complete specifications for the hull, machinery and armament of the 21,000 ton aircraft carrier Graf Zeppelin.

7.7.3 Bathyscaphes

During the period 1937–1960, Auguste Piccard (Swiss, 1884–1962), later assisted by his son Jacques Piccard (Swiss, 1922–2008), developed a series of bathyscaphes in order to carry people to extreme ocean depths, where the pressure would crush a normal submarine. See Fig. 7.133. In 1960 their *Trieste* bathyscaphe reached the deepest known part of the ocean, the floor of the Challenger Deep in the Mariana Trench, which is approximately 11 kilometers below the surface and has a pressure approximately 1100 times greater than sea-level atmospheric pressure. *Encyclopedia Britannica* explained [EB 2010]:

> bathyscaphe, navigable diving vessel developed by the Swiss educator and scientist Auguste Piccard (with assistance in later years from his son Jacques), designed to reach great depths in the ocean.
>
> The first bathyscaphe, the *FNRS 2*, built in Belgium between 1946 and 1948, was damaged during 1948 trials in the Cape Verde Islands. Substantially rebuilt and greatly improved, the vessel was renamed *FNRS 3* and carried out a series of descents under excellent conditions, including one of 4,000 m (13,000 feet) into the Atlantic off Dakar, Senegal, on Feb. 15, 1954. A second improved bathyscaphe, the *Trieste*, was launched on Aug. 1, 1953, and dived to 3,150 m (10,300 feet) in the same year. In 1958 the *Trieste* was acquired by the United States Navy, taken to California, and equipped with a new cabin designed to enable it to reach the seabed of the great oceanic trenches. Several successive descents were made into the Pacific by Jacques Piccard, and on Jan. 23, 1960, Piccard, accompanied by Lieutenant Don Walsh of the U.S. Navy, dived to a record 10,916 m (35,810 feet) in the Pacific’s Mariana Trench.

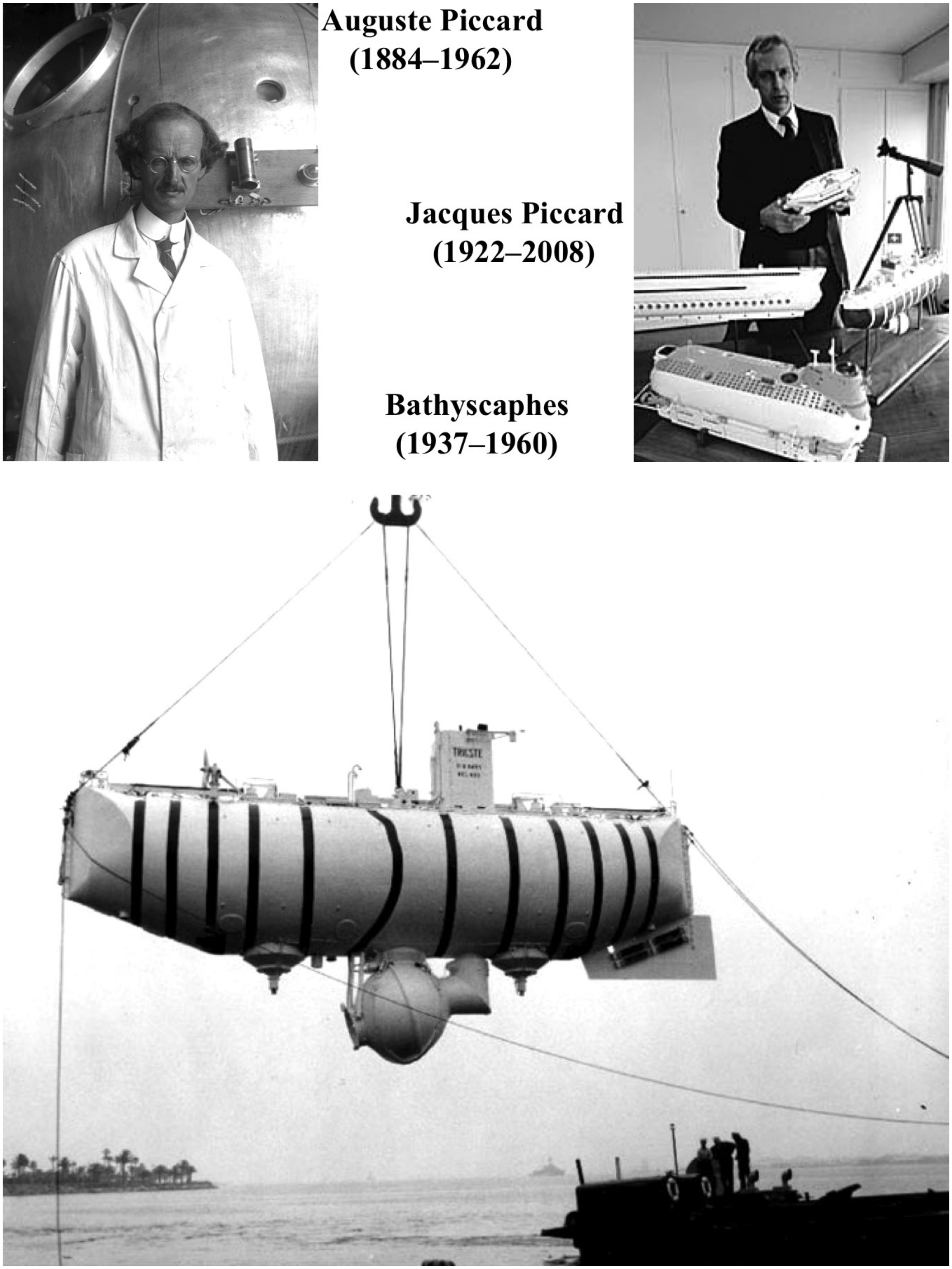

Auguste Piccard
(1884–1962)
Jacques Piccard
(1922–2008)
Bathyscaphes
(1937–1960)
TRIESTE

Figure 7.133: Auguste Piccard, later assisted by his son Jacques Piccard, developed a series of bathyscaphes during the period 1937–1960 in order to reach the deepest parts of the ocean.

7.7.4 Rotor Ships

In 1852, Heinrich Gustav Magnus (Prussian, 1802–1870, p. 1484) described and analyzed what is now known as the Magnus effect, in which a spinning cylinder or sphere deflects incoming airflow toward one side, pushing the cylinder or sphere toward the other side. By harnessing this Magnus effect, Anton Flettner (German, 1885-1961) developed rotor ships that use spinning cylinders or rotors like sails for steering or propulsion (Fig. 7.134). Jakob Ackeret (Swiss, 1898–1981, p. 1696), Albert Betz (German, 1885–1968, p. 1665), Martin Kutta (German, 1867–1944, p. 844), and Ludwig Prandtl (German, 1875–1953, p. 1696) also played roles in analyzing the airflow around the spinning cylindrical rotors. Flettner demonstrated the first rotor ship, *Buckau*, in 1924, and a larger one, *Barbara*, in 1926.

Engineering professor Kurt Knobling described Flettner's rotor ship innovation [Hirschel et al. 2004, p. 299]:

> He aroused worldwide attention with his proposal to replace the sails of ships with upright standing perpendicular rotating cylinders, which produce, in the presence of an airflow (wind), thrust by utilizing the Magnus effect (discovered by Gustav Magnus, 1852). The Flettner experimental boats did, however, not achieve the success hoped for. In 1925, he founded his own company aiming at the application of the Flettner-rotor as wing replacement on large wind turbines. Albert Einstein appreciated Anton Flettner's sense for utilizing physical knowledge in practical applications in his publication "My View of Life" ("Mein Weltbild"), of 1934: "*Flettner saw Ludwig Prandtl's experiments (remark: experiments on rotating cylinders in an incoming air flow) and thought that one could use this installation to replace sails. Who knows, whether anybody else would have thought of that?*"

As shown in Fig. 7.134, rotors are still used on ships to supplement other methods and increase energy efficiency.

Flettner also created battlefield robots (p. 1208) and helicopters (p. 1824).

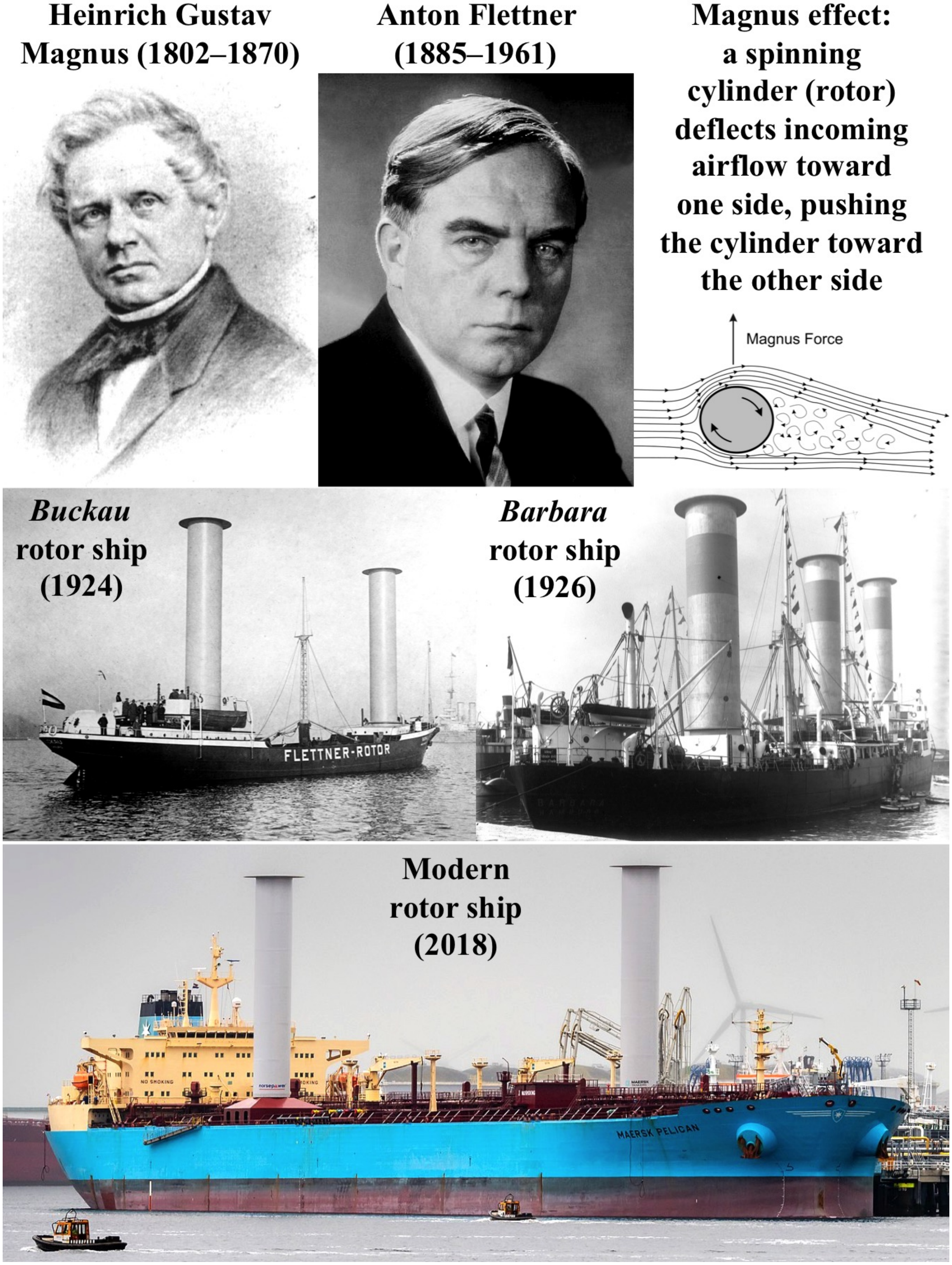

Heinrich Gustav Magnus (1802–1870)
Anton Flettner (1885–1961)
Magnus effect: a spinning cylinder (rotor) deflects incoming airflow toward one side, pushing the cylinder toward the other side
Magnus Force
Buckau rotor ship (1924)
FLETTNER-ROTOR
Barbara rotor ship (1926)
Modern rotor ship (2018)
MAERSK PELICAN

Figure 7.134: Based on the Magnus effect, Anton Flettner developed rotor ships that use spinning cylinders like sails for steering or propulsion. Flettner demonstrated the first rotor ship in 1924; rotors are still used on ships to supplement other methods and increase energy efficiency.

7.8 Other Creations in Mechanical Engineering

German-speaking creators also invented many other important devices in the field of mechanical engineering.[12] This section only includes a few illustrative examples:

7.8.1. Watches

7.8.2. Vacuum pumps and pressure valves

7.8.3. Bicycles

7.8.4. Polar planimeter

7.8.5. Liquid agitators and turbines

7.8.6. Gyroscopes and gyrocompasses

7.8.7. Sports shoes

7.8.1 Watches

Although stationary clocks had been around for centuries, Peter Henlein (German states, 1485–1542) invented the portable watch in 1505. Figure 7.135 shows the first Henlein watch from 1505 (upper right) and a very similar Henlein watch from 1530 (bottom). The science historian Felix Paturi described Henlein's innovations [Paturi 1998, p. 110]:

Bis über die Mitte des 15. Jh. hinaus mussten mechanische Uhren senkrecht stehen, da sie einen Schwerkraftantrieb durch Gewichte besaßen. Die Größe der Gewichte verbot zugleich den Bau kleiner mechanischer Uhren. Erst 1470 wurde der Federaufzug für mechanische Uhren bekannt.	Until beyond the middle of the 15th century, mechanical clocks had to stand vertically, as they had a gravity drive by weights. The size of the weights also prohibited the construction of small mechanical watches. It was not until 1470 that the spring winding mechanism for mechanical watches became known.
Der Nürnberger Mechaniker Peter Henlein (um 1485–1542) experimentiert als einer der Ersten mit kleinen Uhrfedern. Zugleich erkennt er, dass dieser Antrieb die Uhren lageunabhängig macht, weil die Schwerkraft keine Rolle mehr spielt. Bei seinen Versuchen gelingt es ihm, Uhren klein zu bauen, sodass sie in einförmige Dosen passen, die in der Tasche getragen werden können.	The Nuremberg mechanic Peter Henlein (around 1485–1542) was one of the first to experiment with small watch springs. At the same time, he realized that this drive made the watches independent of position, because gravity no longer played a role. In his experiments, he succeeded in making watches so small that they fit into standardized enclosures that could be carried in a pocket.

---

[12] Buchheim and Sonnemann 1990; Bunch and Hellemans 2004; Cardwell 1995; Challoner 2009; Gööck 2000; Heckl 2010, 2011; Heßler 2012; Jankowsky 2000; König 2000, 2009; König and Schneider 2007; Ludwig 1974; Lundgreen and Grelon 1994; Radkau 1989, 2016; Technisches Museum Wien 2011; Weitensfelder 2009, 2013.

Peter Henlein (1485–1542) invented the portable watch (1505)

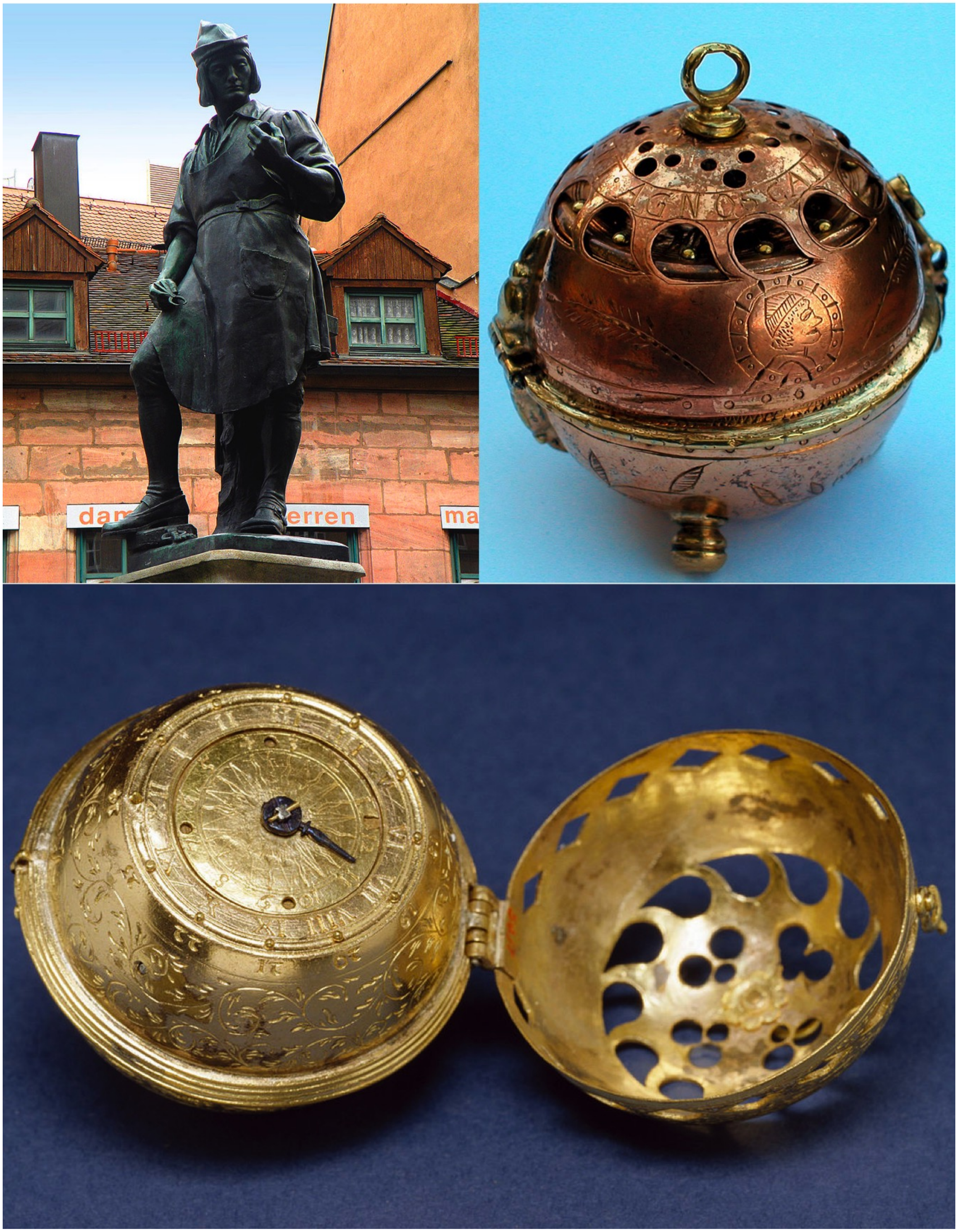


Figure 7.135: Peter Henlein invented the portable watch in 1505. Upper right: the first Henlein watch from 1505. Bottom: a very similar Henlein watch from 1530.

7.8.2 Vacuum Pumps and Pressure Valves

Otto von Guericke (German states, 1602–1686) invented the water barometer, manometer, and air pump. In 1650, he also created the "Magdeburg hemispheres" to demonstrate a vacuum; he pumped the air out of the space formed by two steel hemispheres, then demonstrated that two teams of horses could not pull the spheres apart (Fig. 7.136). *Encyclopedia Britannica* listed some of von Guericke's accomplishments [EB 2010]:

> Guericke was educated at the University of Leipzig and studied law at the University of Jena in 1621 and mathematics and mechanics at the University of Leyden in 1623. In 1631 he became an engineer in the army of Gustavus II Adolphus of Sweden, and from 1646 to 1681 he was *bürgermeister* (mayor) of Magdeburg and magistrate for Brandenburg.
>
> In 1650 Guericke invented the air pump, which he used to create a partial vacuum. His studies revealed that light travels through a vacuum but sound does not. In 1654, in a famous series of experiments that were performed before Emperor Ferdinand III at Regensburg, Guericke placed two copper bowls (Magdeburg hemispheres) together to form a hollow sphere about 35.5 (14 inches) in diameter. After he had removed the air from the sphere, horses were unable to pull the bowls apart, even though they were held together only by the air around them. Thus the tremendous force that air pressure exerts was first demonstrated.
>
> In 1663 he invented the first electric generator, which produced static electricity by applying friction against a revolving ball of sulfur. In 1672 he discovered that the electricity thus produced could cause the surface of the sulfur ball to glow; hence he became to first man to view electroluminescence. Guericke also studied astronomy and predicted that comets would return regularly from outer space.

Hermann Sprengel (German states, 1834–1906) invented the first pump for creating a high vacuum (<1/100,000,000 of normal atmospheric pressure), illustrated in Fig. 7.137.

As shown in Fig. 7.138, Hanns Hörbiger (Austrian, 1860–1931) invented the Hörbiger disc valve for high-pressure chemistry, compressors, blast furnaces, and other applications.[13]

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[13] https://www.fluid.de/faszination-fluid/erfinder-hanns-hoerbiger-und-das-stahlplattenventil-117.html

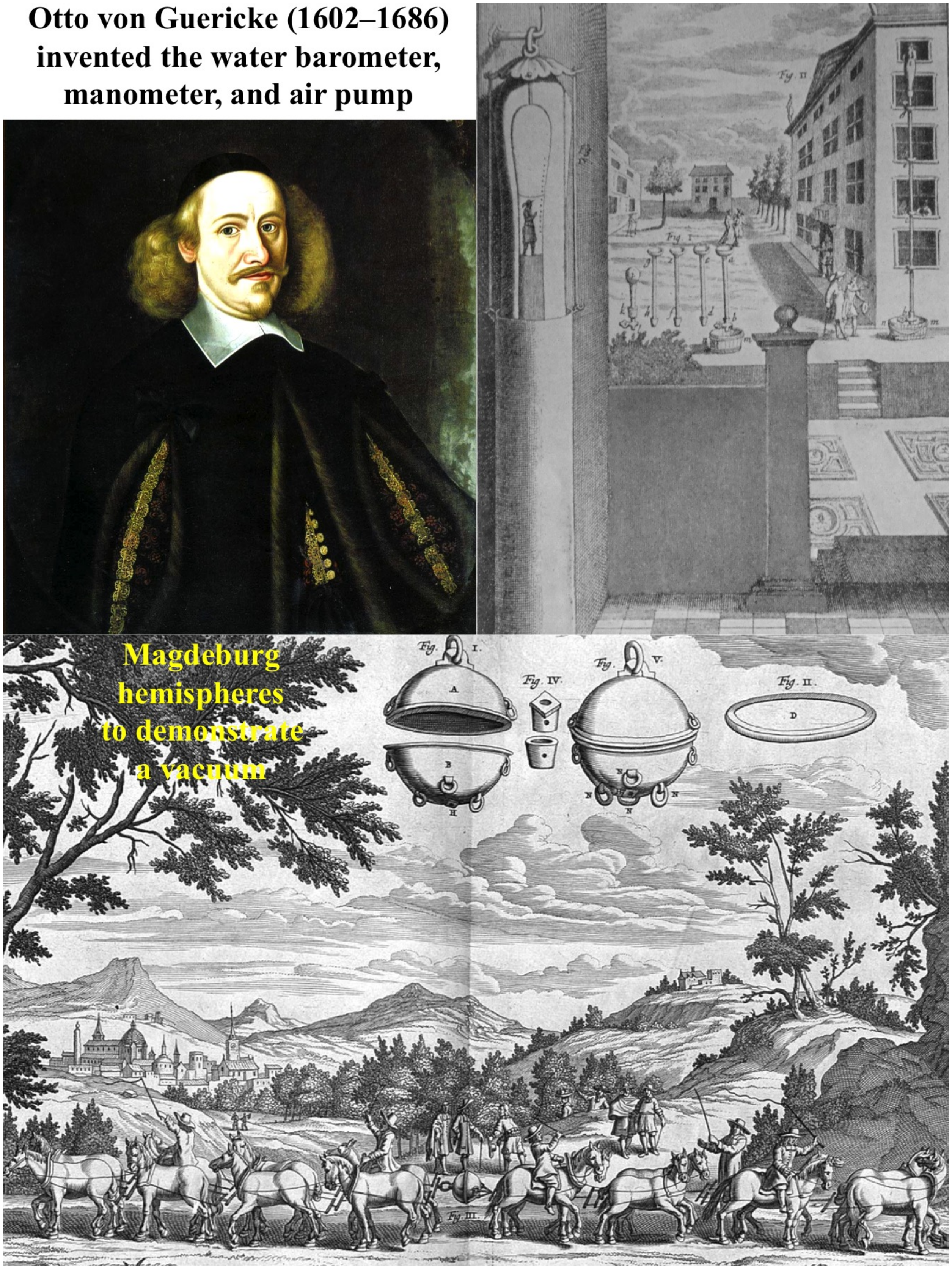
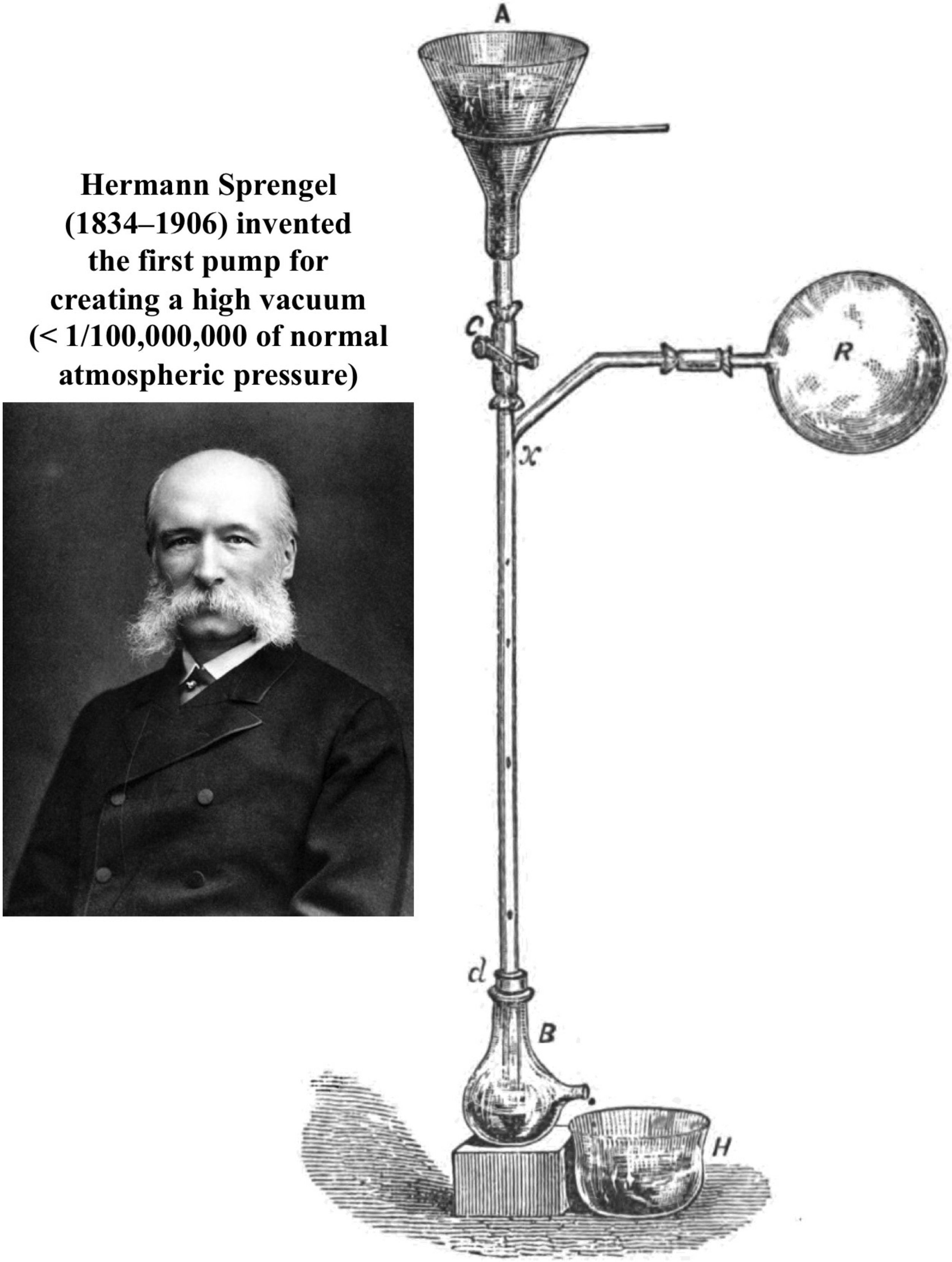

Otto von Guericke (1602–1686)
invented the water barometer,
manometer, and air pump
Fig. II
Fig. I
Magdeburg
hemispheres
to demonstrate
a vacuum
Fig. I.
A
B
H
Fig. IV.
Fig. V.
N
Fig. II.
D
Fig. III.

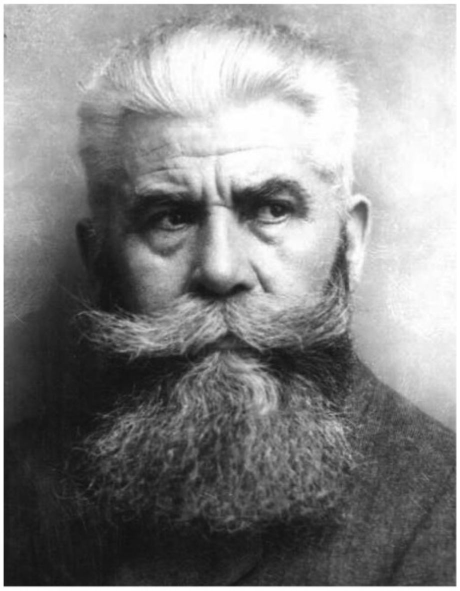
Figure 7.136: Otto von Guericke invented the water barometer, manometer, and air pump, and he also created the “Magdeburg hemispheres” to demonstrate a vacuum.

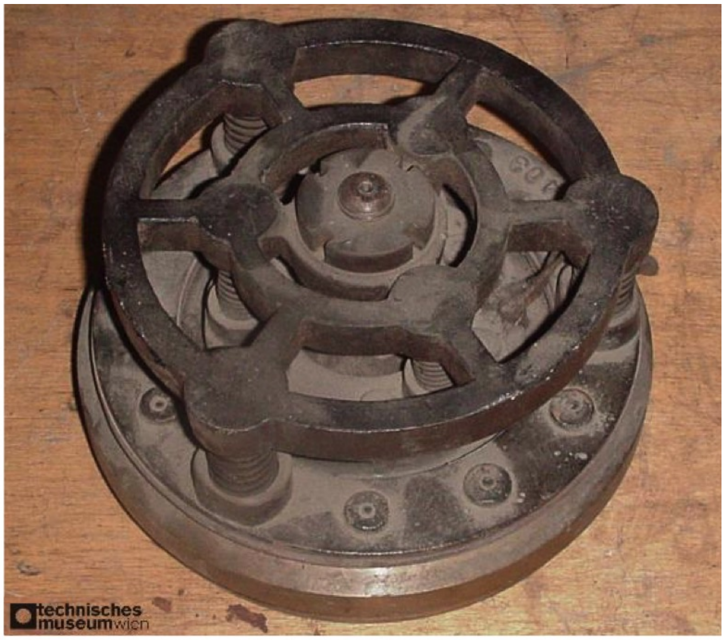


Hermann Sprengel (1834–1906) invented the first pump for creating a high vacuum (< 1/100,000,000 of normal atmospheric pressure)

Figure 7.137: Hermann Sprengel invented the first pump for creating a high vacuum.

Hanns Hörbiger (1860–1931)




technisches
museum wien

Hörbiger disc valve for high-pressure chemistry, compressors, etc. (1894)

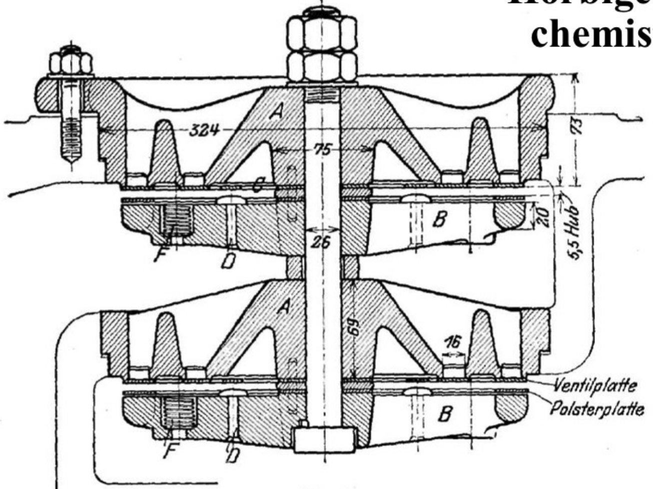

324
A
75
G
73
B
20
5,5 Hub
26
F
D
A
69
16
Ventilplatte
Polsterplatte
B
F
D

Fig. 1.

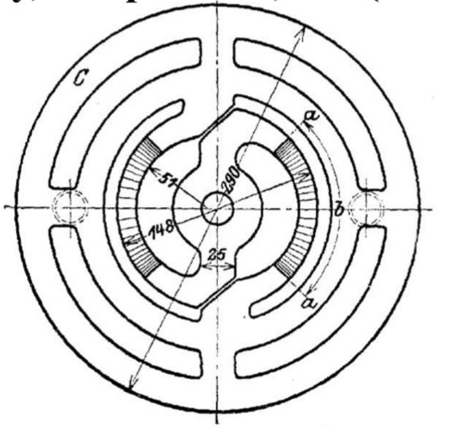

C
a
290
51
148
b
25
a

Fig. 2.

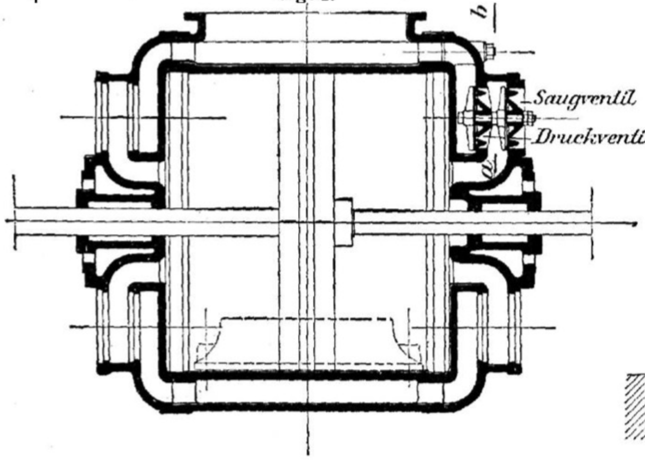

b
Saugventil
Druckventil
a

Fig. 3

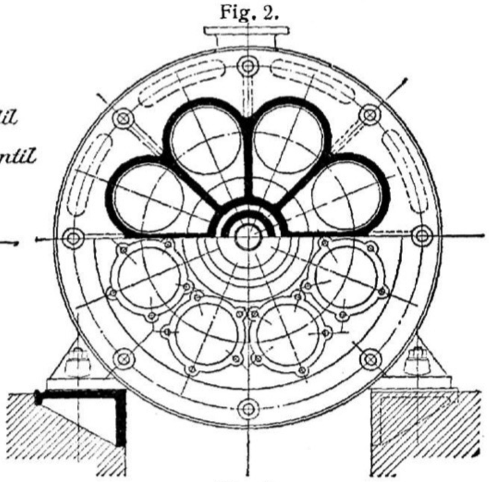


Fig. 4.

Figure 7.138: Hanns Hörbiger invented the Hörbiger disc valve for high-pressure chemistry, compressors, and other applications.

7.8.3 Bicycles

In the 1650s, Hans Hautsch (German states, 1595–1670) and Stephan Farfler or Farffler (German states, 1633–1689) invented and demonstrated tricycles and quadracycles powered by a hand-cranked gearbox for use as wheelchairs by paraplegics. Farfler himself was a paraplegic or amputee who made extensive use of such vehicles (Fig. 7.139).

Karl von Drais (German states, 1785–1851, Fig. 7.140) invented a quadracycle with foot pedals in 1813, and then the first bicycle (without pedals) in 1817. Von Drais also created a paper music recorder in 1812 and the first keyboard typewriter in 1821 (p. 1300).[14] *1001 Inventions That Changed the World* explained the motivation for von Drais's quadracycle and bicycle inventions [Challoner 2009, p. 268]:

> [...F]ollowing some bad weather in 1812, the price of oats was climbing, and the German inventor Karl Drais (1785–1851) was looking for something to replace hungry horses. He designed a four-wheeled vehicle, powered by a servant sitting in the back pedaling, while the master steered from the front with a tiller. It did not catch on and Drais decided to focus instead on surveying equipment.
>
> After the 1815 volcanic eruption, even worse weather caused oat prices to climb higher still. The need for horseless transport was even more pressing, and so Drais tried again. He switched from four wheels to two and got rid of the pedals completely. What he invented in 1817 was called the draisine or the *draisienne*, depending on where you lived.

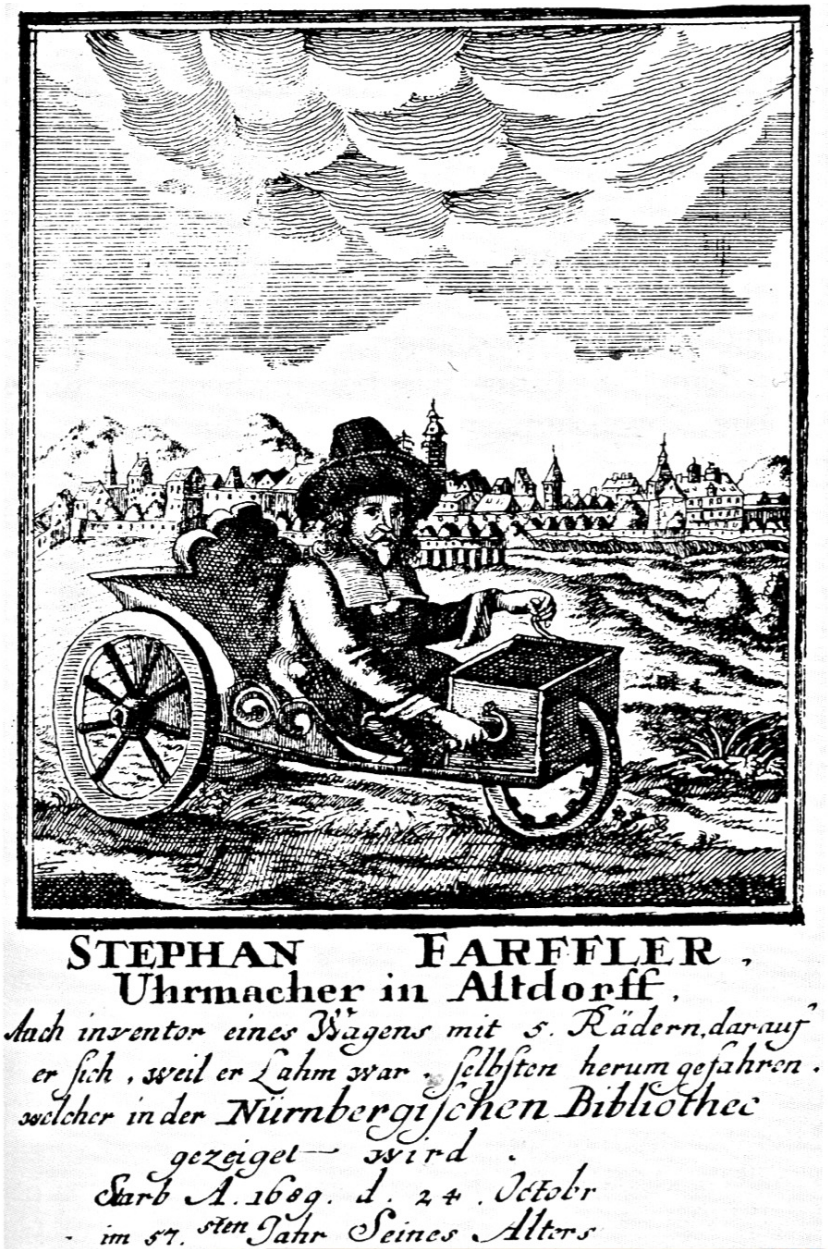
Philipp Moritz Fischer (German, 1812–1890) added pedals back to bicycles in 1853.[15] See Fig. 7.141.

---

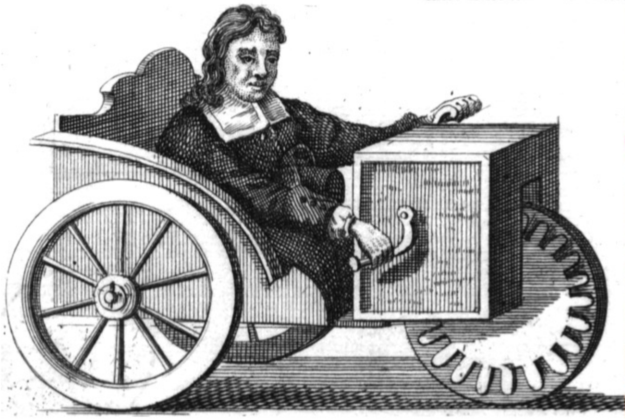
[14] Challoner 2009; Ebeling 1985; Lessing 2003, 2010; Michael Rauck 1983.

[15] Feldhaus 1914; Germanisches Nationalmuseum 1985; Max Rauck et al. 1979; von Salvisberg 1980; Wendlandt 1913.

Hans Hautsch (not shown, 1595–1670) and Stephan Farf(f)ler (shown, 1633–1689) created tricycles and quadracycles powered by a hand-cranked gearbox for use as wheelchairs by paraplegics (1650s)



STEPHAN FARFFLER,
Uhrmacher in Altdorff,
Auch inventor eines Wagens mit 5. Rädern, darauf
er ſich, weil er Lahm war, ſelbſten herum gefahren.
welcher in der Nürnbergiſchen Bibliothec
gezeiget wird.
Starb A. 1689. d. 24. Octobr
im 57. sten Jahr Seines Alters



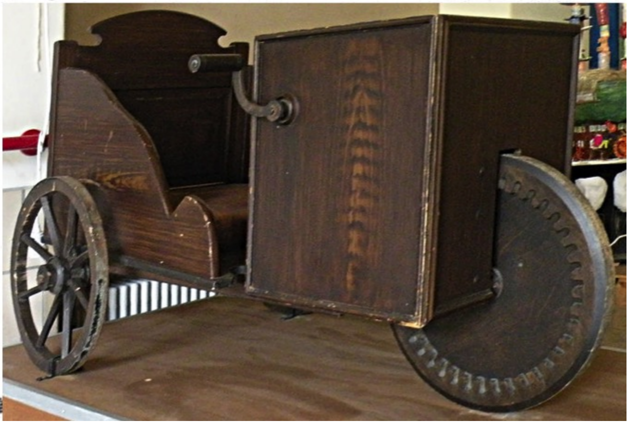


Figure 7.139: In the 1650s, Hans Hautsch and Stephan Farf(f)ler created tricycles and quadracycles powered by a hand-cranked gearbox for use as wheelchairs by paraplegics.

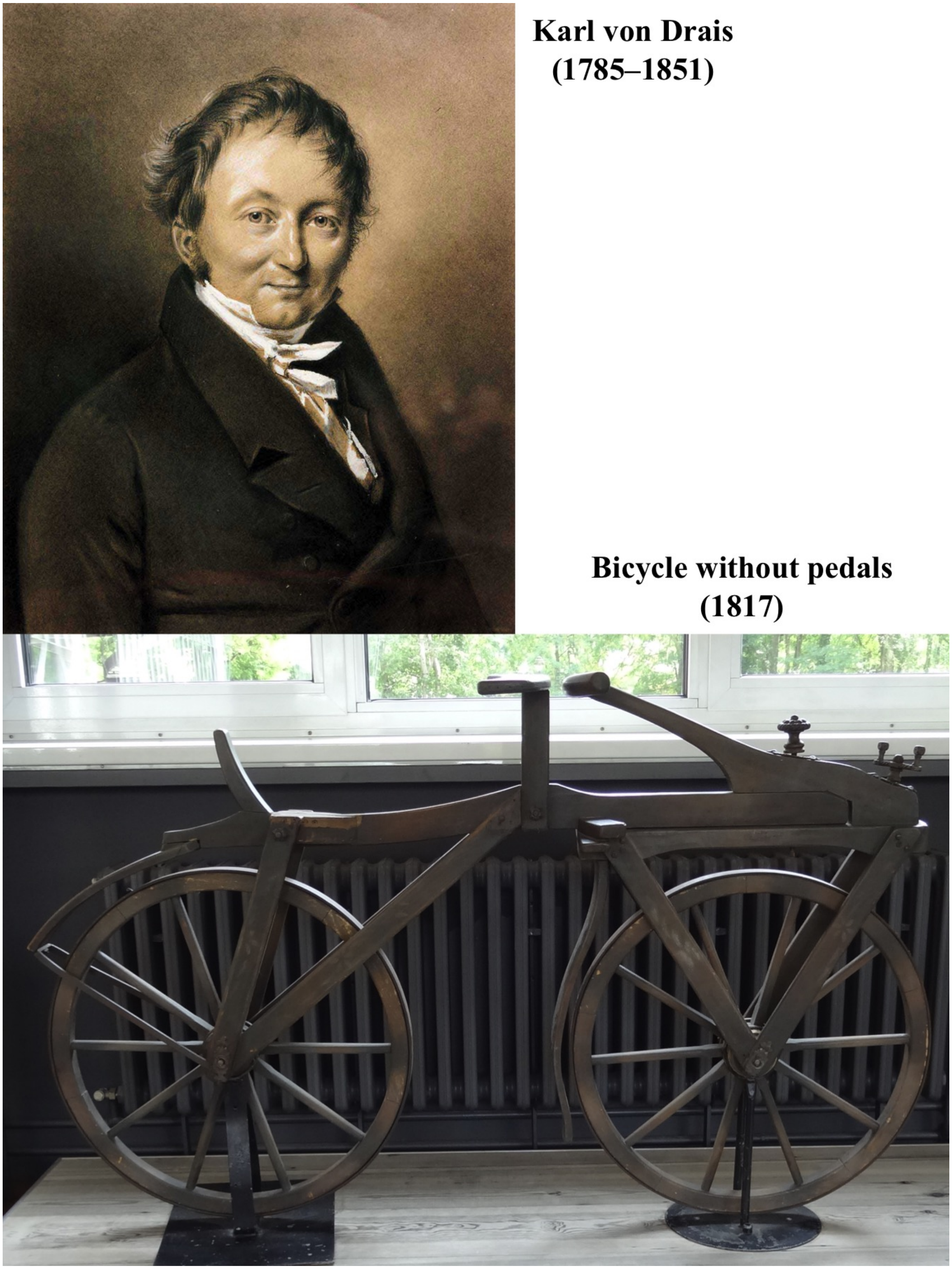

Karl von Drais
(1785–1851)
Bicycle without pedals
(1817)

Figure 7.140: Karl von Drais invented a quadracycle with pedals in 1813, followed in 1817 by the first bicycle without pedals, which proved to be far more popular.

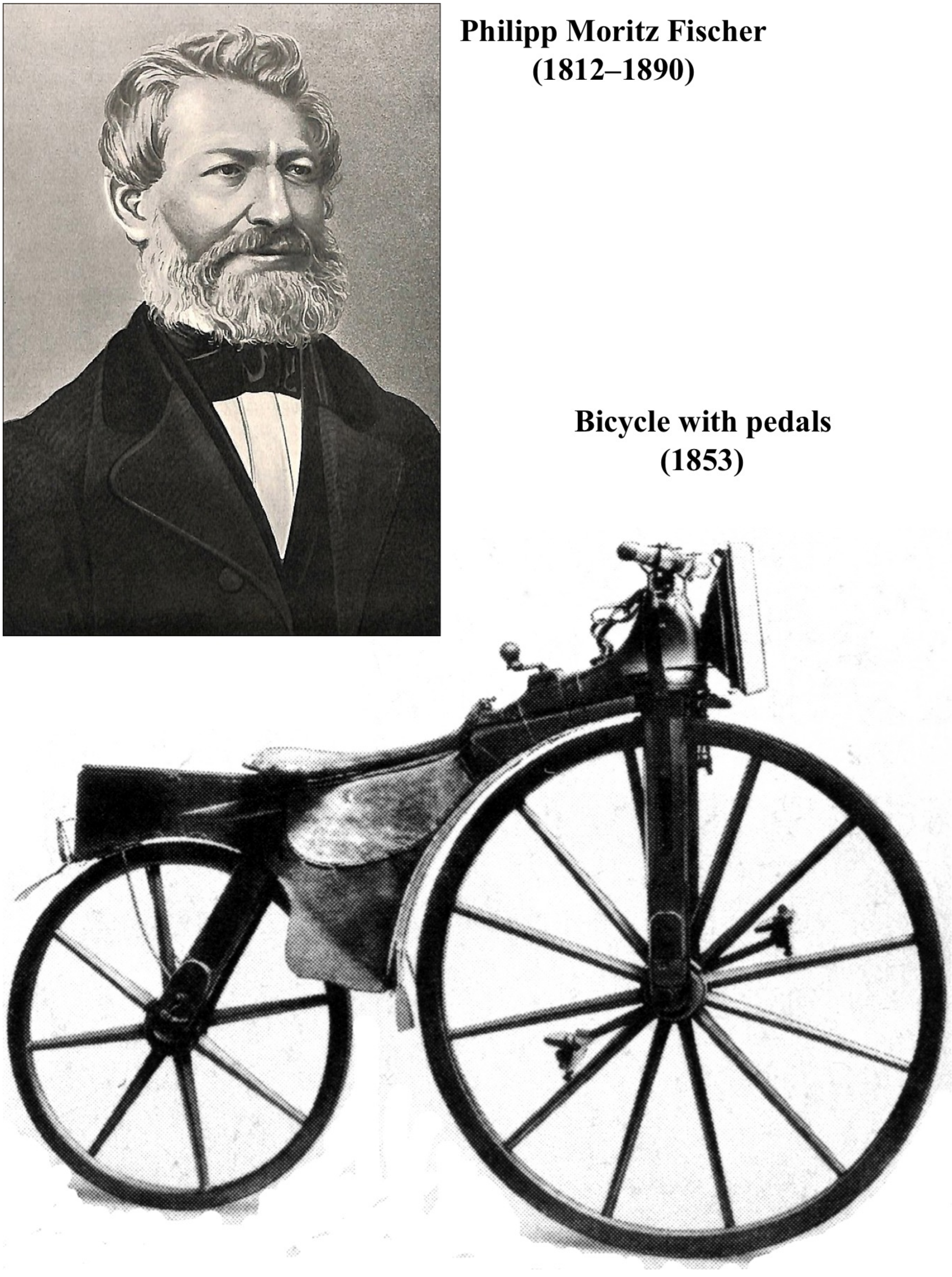

Philipp Moritz Fischer
(1812–1890)
Bicycle with pedals
(1853)

Figure 7.141: Philipp Moritz Fischer (1812–1890) created the first bicycle with pedals in 1853.

7.8.4 Polar Planimeter

In 1854, Jakob Amsler-Laffon (Swiss, 1823–1912) invented the polar planimeter (Fig. 7.142). The *Complete Dictionary of Scientific Biography* explained its importance [https://www.encyclopedia.com/science/dictionaries-thesauruses-pictures-and-press-releases/amsler-later-amsler-laffon-jakob]:

> Until 1854 Amsler's interests lay in the area of mathematical physics; he published articles on magnetic distribution, the theory of heat conduction, and the theory of attraction. One result of his work was a generalization of Ivory's theorem on the attraction of ellipsoids and of Poisson's extension of that theorem. In 1854 Amsler turned his attention to precision mathematical instruments, and his research resulted in his major contribution to mathematics: the polar planimeter, a device for measuring areas enclosed by plane curves. Previous such instruments, most notably that of Oppikofer (1827), had been based on the Cartesian coordinate system and had combined bulkiness with high cost. Amsler eliminated these drawbacks by basing his planimeter on a polar coordinate system referred to a null circle as curvilinear axis. The instrument, described in "Ueber das Polarplanimeter" (1856), adapted easily to the determination of static and inertial moments and of the coefficients of Fourier series; it proved especially useful to shipbuilders and railroad engineers.
>
> To capitalize on his inspiration, Amsler established his own precision tools workshop in 1854. From 1857 on he devoted full time to the venture. At his death, the shop had produced 50,000 polar planimeters and 700 momentum planimeters.

7.8.5 Liquid Agitators and Turbines

In the 1760s, Gotthard Friedrich Stender (Baltic German, 1714–1796) and Jacob Christian Schäffer (German states, 1718–1790) built clothes washing machines with agitator blades and mechanical drives for multiple machines. See Fig. 7.143.

Viktor Kaplan (Austrian, 1876–1934) invented highly efficient turbines with blades of adjustable tilt for hydroelectric power (pp. 1499, 3757). His designs are still in use today. Oxford University's *Biographical Dictionary of Scientists* described Kaplan's innovation [Porter 1994, p. 378]:

> Kaplan published his first paper on turbines in 1908, writing about the Francis turbine and basing it on work that he had done for his doctorate at the Technische Hochschule in Vienna. In connection with this paper, he set up a propeller turbine for the lowest possible fall of water. In 1913 the first prototype of the turbine was completed. The Kaplan turbine was patented in 1920 as a water turbine with adjustable rotor-blades; the runner blades can be varied to match the correct angle for a given flow of water. [...]
>
> The Kaplan turbine in its traditional form has a vertical shaft, although one power-generator design uses a horizontal shaft and an alternator mounted in a 'nacelle' (metal shell) in the water flow. This is particularly suitable for lower-output machines operating on very low heads of water, in which an almost straight water passage is possible.

7.8.6 Gyroscopes and Gyrocompasses

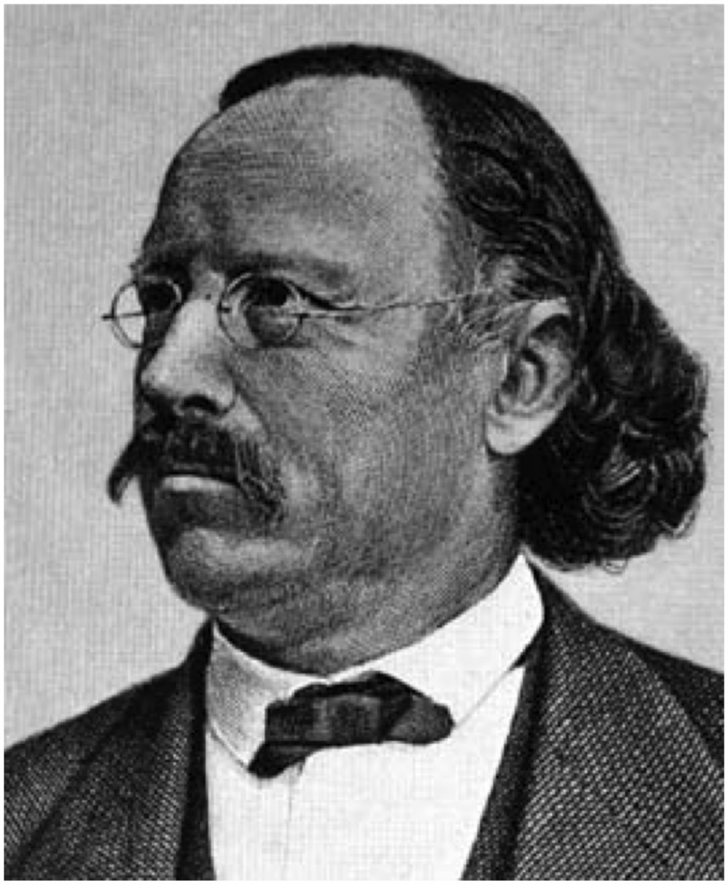
Johann Bohnenberger (German, 1765–1831) invented the gyroscope in 1817, as illustrated in Fig. 7.145. By harnessing the basic principles of gyroscopes to create guidance systems, Hermann Anschütz-Kaempfe (German, 1872–1931) and Max Schuler (German, 1882–1972) developed increasingly accurate gyrocompasses from 1904 onward. In 1923, Schuler developed the principle of Schuler tuning that helps to ensure that gyrocompasses remain accurate regardless of where they are carried around the earth. *1001 Inventions That Changed the World* explained the importance of the development of gyrocompasses [Challoner 2009, p. 547]:

> Gyrocompasses have two great advantages over magnetic needle compasses: They point to the spin pole of Earth as opposed to the magnetic pole; and they are completely unaffected by the ferrous metal of a ship's hull or the magnetic fields produced by electrical currents running through nearby wires. Their main component is a motorized, fast-spinning, damped, gimballed wheel. When this wheel is not spinning exactly in the plane containing Earth's spin axis, an interaction between the angular momentum of the wheel and the angular momentum of Earth produces a restoring torque that pushes the wheel back into the true north-south orientation.
>
> A ship's gyrocompass is mounted in a complex set of gimbals that isolate the instrument from the ever-present pitching, yawing, and rolling. Aircraft gyrocompasses are even more complicated due to the higher velocity of the plane and the speedy changes in altitude during takeoff and landing.
>
> German scientist Hermann Anschütz-Kaempfe (1872–1931) started working on the device because he needed a compass to guide a submarine on a planned expedition underneath the north polar ice. In partnership with his cousin, Max Schuler, Anschütz-Kaempfe sold a prototype to the German Navy in 1908. Schuler found that if the pendulous suspension of the gyroscope had a period of eighty-four minutes (the period of a pendulum of length equal to Earth's radius), disturbances due to the ship's acceleration were canceled out.

7.8.7 Sports Shoes

Adolf Dassler (German, 1900–1978) designed sports shoes (ultimately called Adidas) from 1918 onward. First working with him and then in competition with him, his brother Rudolf Dassler (German, 1898–1974) designed sports shoes (ultimately called Puma) from 1924 onward [Karlsch et al. 2019; Rolf-Herbert Peters 2007]. See Fig. 7.146.

Jakob Amsler-Laffon (1823–1912)



Polar planimeter (1854)

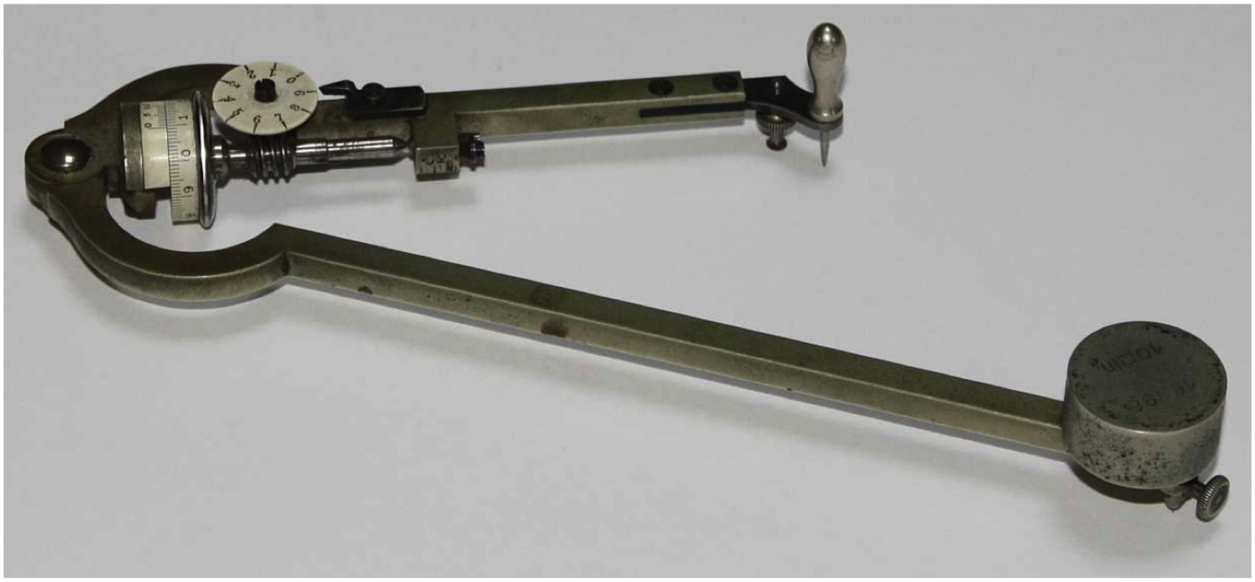


Figure 7.142: Jakob Amsler-Laffon invented the polar planimeter in 1854.

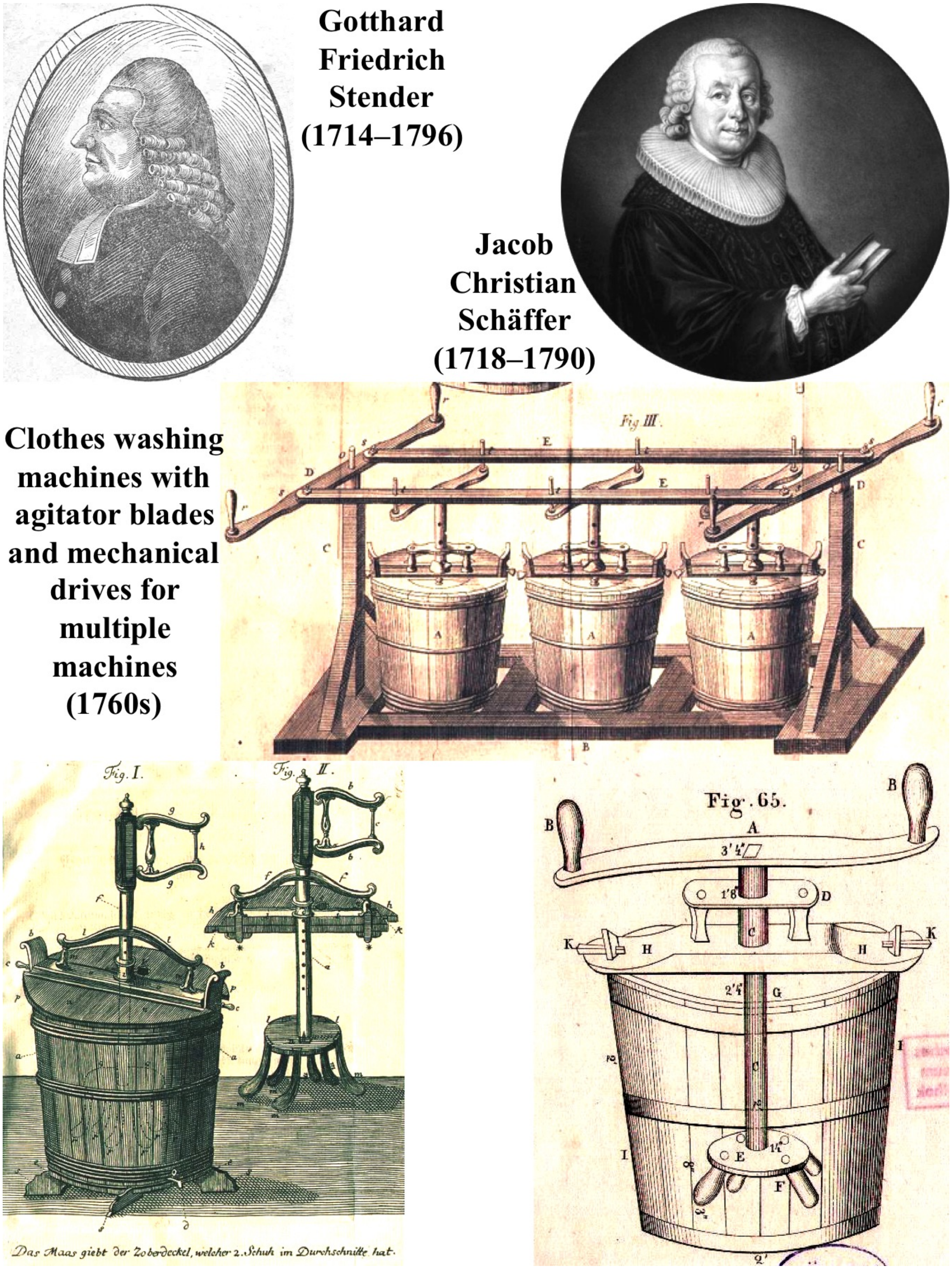

Gotthard Friedrich Stender (1714–1796)
Jacob Christian Schäffer (1718–1790)
Clothes washing machines with agitator blades and mechanical drives for multiple machines (1760s)
Fig III.
Fig. I.
Fig. II.
Das Maas giebt der Zoberdeckel, welcher 2. Schuh im Durchschnitte hat.
Fig. 65.
A
B
C
D
E
F
G
H
I
K

Figure 7.143: In the 1760s, Gotthard Friedrich Stender and Jacob Christian Schäffer built clothes washing machines with agitator blades and mechanical drives for multiple machines.

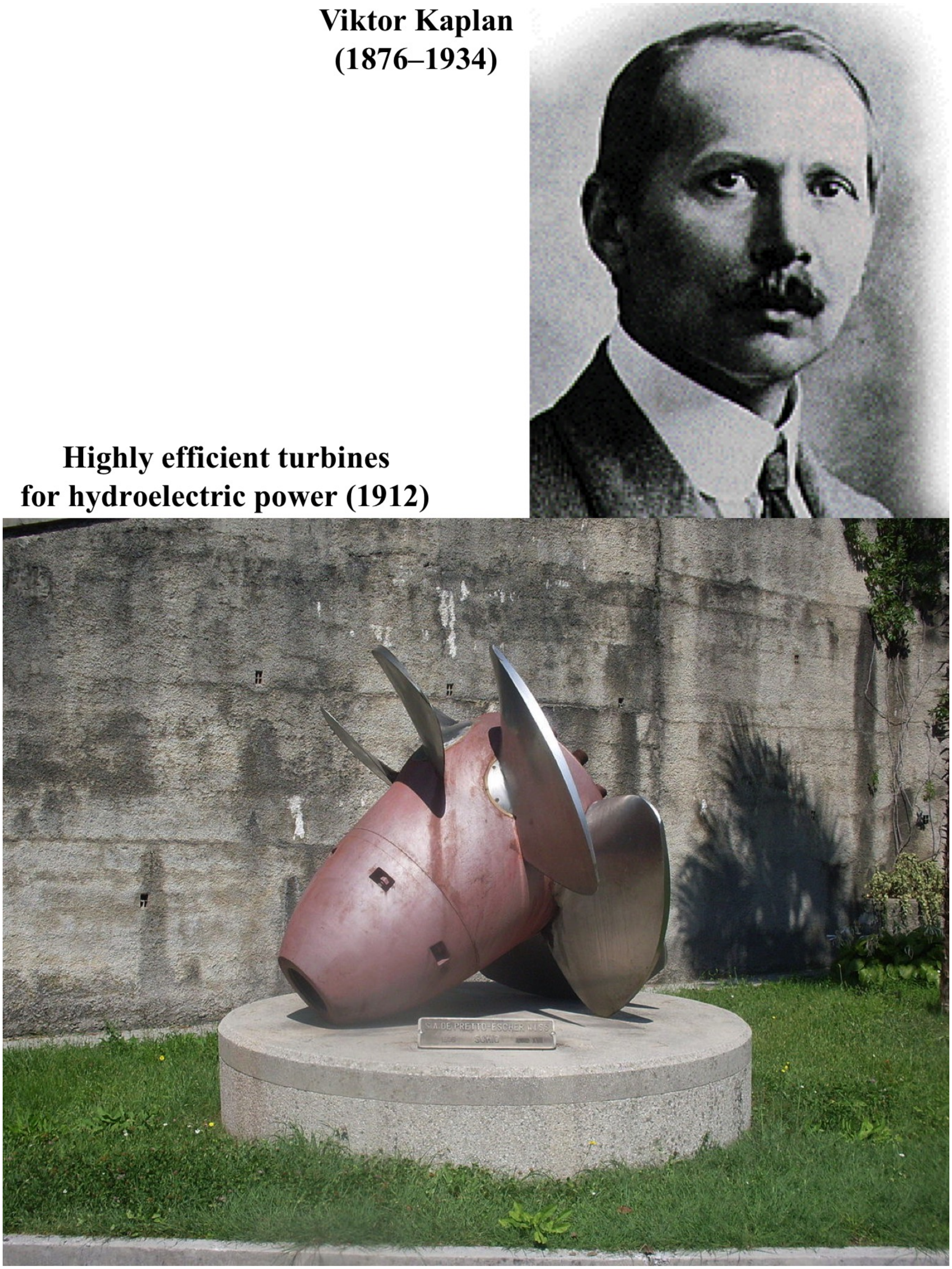

Viktor Kaplan
(1876–1934)
Highly efficient turbines
for hydroelectric power (1912)
S.A. DE PRETTO-ESCHER WYSS
SCHIO

Figure 7.144: Viktor Kaplan invented highly efficient turbines with blades of adjustable tilt for hydroelectric power. See also p. 3757.

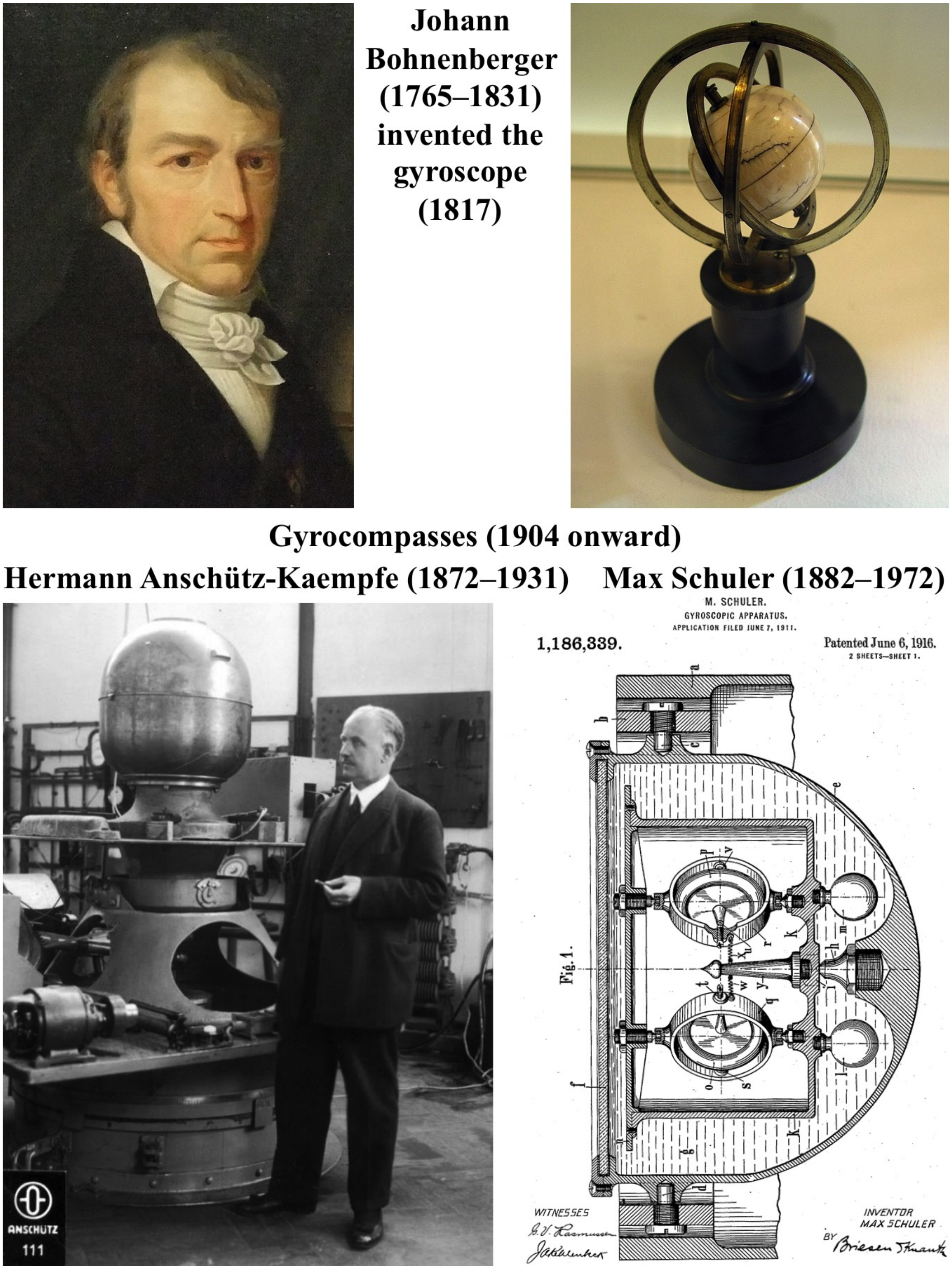

Johann Bohnenberger (1765–1831) invented the gyroscope (1817)
Gyrocompasses (1904 onward)
Hermann Anschütz-Kaempfe (1872–1931)
Max Schuler (1882–1972)
ANSCHUTZ
111
M. SCHULER.
GYROSCOPIC APPARATUS.
APPLICATION FILED JUNE 7, 1911.
1,186,339.
Patented June 6, 1916.
2 SHEETS—SHEET 1.
Fig. 1.
WITNESSES
INVENTOR
MAX SCHULER
BY

Figure 7.145: Johann Bohnenberger invented the gyroscope in 1817. Hermann Anschütz-Kaempfe and Max Schuler developed increasingly accurate gyrocompasses from 1904 onward.

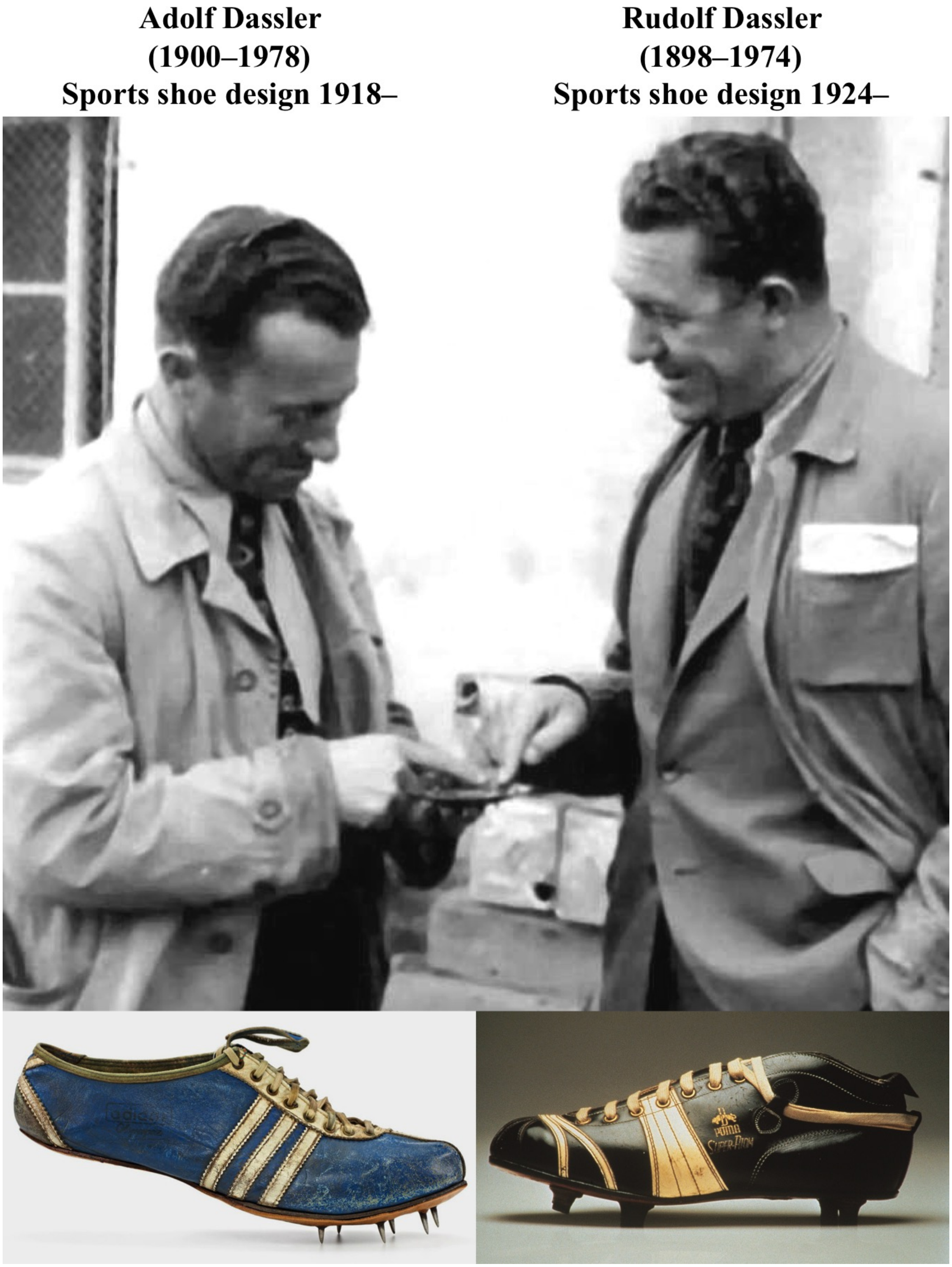

Adolf Dassler
(1900–1978)
Sports shoe design 1918–
Rudolf Dassler
(1898–1974)
Sports shoe design 1924–
PUMA

Figure 7.146: Adolf Dassler designed Adidas sports shoes from 1918 onward, while his brother Rudolf Dassler designed Puma sports shoes from 1924 onward.

Chapter 8

Creators and Creations in Nuclear Science and Engineering

Ins Ewige wiederholen...
Keiner gönnt das Reich
Dem andern; dem gönnt's keiner,
der's mit Kraft erwarb
Und kräftig herrscht.
Denn jeder, der sein innres Selbst
Nicht zu regieren weiß,
regierte gar zu gern
Des Nachbars Willen,
eignem stolzem Sinn gemäß...
Hier aber ward ein großes Beispiel
durchgekämpft:
Wie sich Gewalt
Gewaltigerem entgegenstellt, [...]
Das wird sich messen.
Weiß die Welt doch, wem's gelang.
Wachfeuer glühen,
rote Flammen spendende,
Der Boden haucht
vergoßnen Blutes Widerschein, [...]
Der Zelten Trug verschwindet,
Feuer brennen blau.
Doch über mir!
welch unerwartet Meteor?
Es leuchtet und beleuchtet
körperlichen Ball.

It repeats eternally...
No one freely gives the realm
To another;
to the one whose power won it
And whose strength rules.
For everyone, who does not even know
How to govern his own inner self,
would all too gladly rule over
His neighbour's will,
prompted by his own proud mind...
But here a great example was
fought to the end,
How force battles
against a greater force, [...]
This is tested.
The world knows who won.
Bonfires glow,
sending out red flames:
The ground is soaked
with images of spilled blood, [...]
The illusion of dwellings vanishes;
the fires burn blue.
But overhead,
what sudden meteor is this?
It shines and illuminates
the whole world.

Johann von Goethe. 1832. *Faust Part Two.*
Act II. Klassische Walpurgisnacht. Erichtho.

A huge number of innovators and innovations in the field of nuclear science and engineering came from the predominantly German-speaking central European research world.[1] German-speaking contributions to early nuclear science are well documented and widely accepted, and include:

8.1. Nuclear diagnostics and therapeutics

8.2. Radiation detectors

8.3. Particle accelerators

8.4. Models of the atomic nucleus

8.5. Nuclear fission reactions

8.6. Nuclear fusion reactions

German-speaking contributions to specific engineering applications of that science are a much more complex topic, and are far less well known by the general public in the modern world. In fact, German-speaking scientists played decisive roles not just in the world's first nuclear engineering program, but in all three of the world's first nuclear engineering programs:

8.7. The World War II and postwar U.S./U.K. nuclear program

8.8. The wartime German nuclear program (For the full presentation and analysis of evidence that the wartime German nuclear program was much larger and more advanced than has been generally recognized, see Appendix D.)

8.9. The postwar Soviet nuclear program

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[1] In addition to specific references that are cited in different areas throughout this chapter, this chapter makes use of general biographical and project information from: ACLS 2000; Albrecht et al. 1992; Ash and Söllner 1996; Bar-Zohar 1967; Bower 1987; Bunch and Hellemans 2004; Challoner 2009; Cornwell 2003; Crim 2018; EB 1911, 2010; Gillispie 1970–1990; Gimbel 1990a; Glatt 1994; Hall 2019a; István Hargittai 2006, 2011; Linda Hunt 1991; Impey et al. 2008; Jacobsen 2014; Koertge 2007; Kurowski 1982; Lasby 1971; Lusar 1956, 1971; Medawar and Pyke 2000; Mick 2000; Murray 2003; Nachmansohn 1979; NDB 1953–2020; Neufeld 2012; Nouzille and Huwart 1999; O'Reagan 2014, 2019; Porter 1994; Charles Walker 1946; Peter Watson 2010; Weitensfelder 2009.

I have deliberately left a blank space where images of some creators or creations should go. Those are people or projects that I felt were important enough that they should definitely be shown in this book, yet I have not yet been able to locate a suitable image that I have permission to use, despite my searches in Europe and in the United States. If readers have any relevant images and could send them to me, I would be very grateful and will include them in future editions of this book. Even where a suitable photo cannot be located, I believe that leaving a blank space pays tribute both to the scientific importance of that creator or creation and to how that historical fact has been very nearly forgotten.

There is significant evidence that German-speaking scientists and their technologies played critical roles in additional nuclear programs as well (in France, Israel, etc.), but for reasons of length this book will only focus on those earliest three programs. (Moreover, despite the loss of enormous numbers of nuclear scientists and resources to the United States, Soviet Union, United Kingdom, France, and other countries after the war, West Germany *still* had enough nuclear scientists and industry left to propose its own serious nuclear weapons program until that was terminated for political reasons [Kollert 2000].)

Some well-known aspects of nuclear science were discovered outside the German-speaking world.[2] Marie and Pierre Curie, as well as their daughter and son-in-law Irène and Frédéric Joliot-Curie, characterized several radioactive elements at their Paris laboratory. Ernest Rutherford pioneered the methods of experimental nuclear physics as he moved his lab from McGill University in Montreal to the University of Manchester to the University of Cambridge. Enrico Fermi conducted early nuclear physics experiments at his lab in Rome, before moving to the United States, where he played a key role in the Manhattan Project.

On the other hand, an enormous number of major early nuclear discoveries came from the German-speaking world, as illustrated by the examples in this chapter.[3]

8.1 Nuclear Diagnostics and Therapeutics

Creators from the German-speaking world developed the major methods of nuclear diagnostics and therapeutics that are still used today, including:

8.1.1. X-rays

8.1.2. Radioisotopes and isotope labeling

8.1.3. Nuclear magnetic resonance, or magnetic resonance imaging

8.1.1 X-Rays

In 1895, Wilhelm Röntgen (German, 1845–1923) discovered X-rays, which have often been called Röntgen rays ever since. Ludwig Zehnder (Swiss, 1854–1949, also known for the Mach-Zehnder interferometer—p. 1029) was making detailed whole-body X-ray photographs of humans by 1896; see Fig. 8.1. Of course, X-rays are still widely used for everything from medical exams and dental checkups to airport baggage screening and mechanical parts inspections.

Wilhelm Röntgen won the first Nobel Prize in Physics in 1901. At that first Nobel Prize ceremony, C. T. Odhner, President of the Royal Swedish Academy of Sciences, explained why the importance of Röntgen's work was already evident to the world just six years after his discovery [https://www.nobelprize.org/prizes/physics/1901/ceremony-speech/]:

---

[2] See for example: Beyer 1949; Cronin 2004; Curie 1938; Fermi 1950; Fermi 1987; L'Annunziata 2016; Reeves 2008; Segrè 1970; Weart 1979.

[3] See for example: Bethe 1991, 1997; Blatt and Weisskopf 1952; Brown and Lee 2006; Otto Hahn 1968; Irving 1967; L'Annunziata 2016; Nachmansohn 1979; Rife 1999; Schweber 2012; Sime 1996; Szanton 1992; Wigner 1967.

> The Academy awarded the Nobel Prize in Physics to Wilhelm Conrad Röntgen, Professor in the University of Munich, for the discovery with which his name is linked for all time: the discovery of the so-called Röntgen rays or, as he himself called them, X-rays. These are, as we know, a new form of energy and have received the name "rays" on account of their property of propagating themselves in straight lines as light does. The actual constitution of this radiation of energy is still unknown. Several of its characteristic properties have, however, been discovered first by Röntgen himself and then by other physicists who have directed their researches into this field. And there is no doubt that much success will be gained in physical science when this strange energy form is sufficiently investigated and its wide field thoroughly explored. Let us remind ourselves of but one of the properties which have been found in Röntgen rays; that which is the basis of the extensive use of X-rays in medical practice. Many bodies, just as they allow light to pass through them in varying degrees, behave likewise with X-rays, but with the difference that some which are totally impenetrable to light can easily be penetrated by X-rays, while other bodies stop them completely. Thus, for example, metals are impenetrable to them; wood, leather, cardboard and other materials are penetrable and this is also the case with the muscular tissues of animal organisms. Now, when a foreign body impenetrable to X-rays, e.g. a bullet or a needle, has entered these tissues its location can be determined by illuminating the appropriate part of the body with X-rays and taking a shadowgraph of it on a photographic plate, whereupon the impenetrable body is immediately detected. The importance of this for practical surgery, and how many operations have been made possible and facilitated by it is well known to all. If we add that in many cases severe skin diseases, e.g. lupus, have been successfully treated with Röntgen rays, we can say at once that Röntgen's discovery has already brought so much benefit to mankind that to reward it with the Nobel Prize fulfils the intention of the testator to a very high degree.

Leopold Freund (Austrian, 1868–1943) and Eduard Schiff (Austrian, 1849–1913) developed and employed radiation therapy from 1896 onward (Fig. 8.2). As shown in Fig. 8.3, Freund wrote the first medical textbook on radiation therapy in 1902 and published it in 1903 [Leopold Freund 1903]. Translations of the book in English and other languages were published in 1904, so Freund truly founded and shaped the field of radiation therapy worldwide. Freund also invented and successfully demonstrated the first chemical sunscreen, Antilux, in 1922 (p. 126).

Radiologist H. Dieter Kogelnik wrote about the historical and scientific importance of Leopold Freund in that field [Kogelnik 1997]:

> There is an increasing acceptance and knowledge of the fact that the inauguration of radiotherapy as a new scientific speciality was performed by Leopold Freund 100 years ago. With a clear and logical rationale, Freund provided the first scientific proof of the biological effectiveness of X-rays on a 5-year-old patient and performed the world's first successful treatment with X-rays. Before Freund's historical experimental treatments, which started in Vienna on November 24th, 1896, there were several suggestions and attempts at the therapeutic use of X-rays, however none of these mostly one-of-a-kind attempts was successful, and there was no scientific proof of a therapeutic effectiveness of X-rays in these previous experiments.

Carl H. F. Müller (German, 1845–1912) began producing vacuum tubes in 1880 and X-ray tubes in 1896. His company and its researchers remained at the forefront of producing instruments for nuclear science until 1945. Advanced German X-ray tubes—and information on how to make them—were publicly heralded as important prizes that the United States obtained from Germany after World War II (pp. 423, 3958–3970).

During the period 1922–1924, Dirk Coster (Dutch, 1889–1950) developed X-ray spectroscopy, or methods to separate different wavelengths of X-rays and use them to make new discoveries. Using X-ray spectroscopy, Coster and George de Hevesy (Hungarian, 1885–1966) discovered hafnium in 1923 (p. 439).

Two other especially noteworthy scientists who worked on the medical implications and applications of radiation were Nikolai Timoféeff-Ressovsky (Russian but worked in Germany 1925–1945, lived 1900–1981) and Karl Günter Zimmer (German, 1911–1988). Along with Max Delbrück, in 1935 they published a groundbreaking paper on the effects of radiation on genetic mutations and structure (p. 103). They also studied applications of radiation in neuroscience and other areas of biology. In 1945, Timoféeff-Ressovsky, Zimmer, and some of their colleagues moved to Russia and continued to study the biological effects of radiation as part of the German-speaking scientific community there.

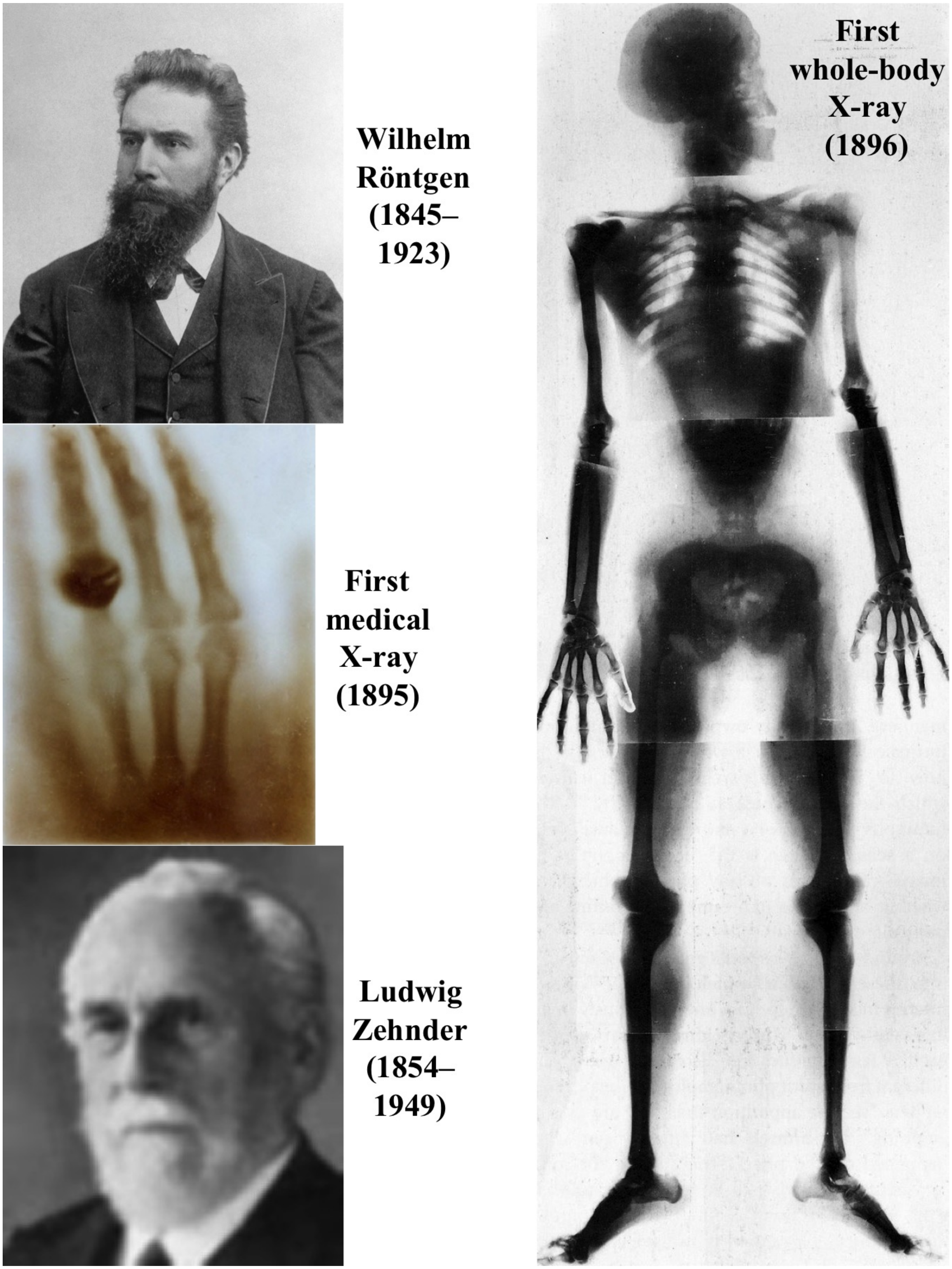
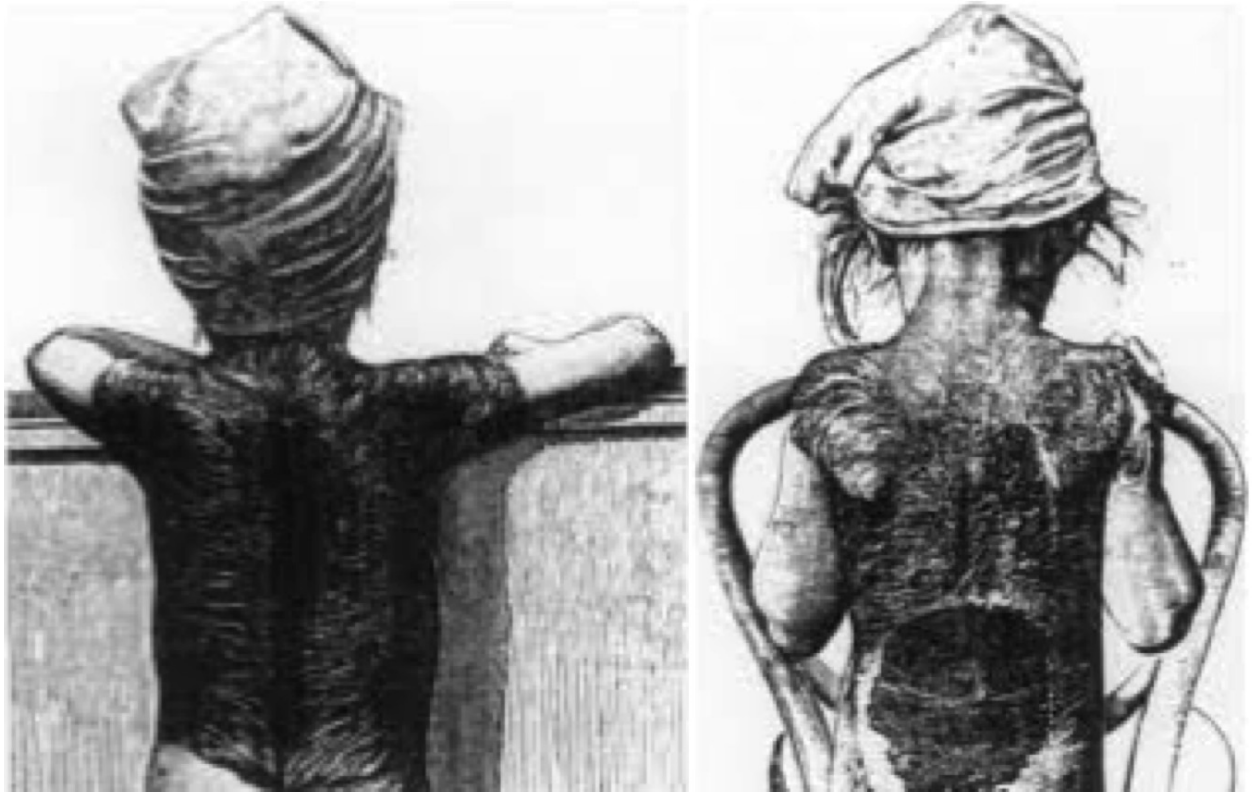

Wilhelm Röntgen (1845–1923)
First medical X-ray (1895)
Ludwig Zehnder (1854–1949)
First whole-body X-ray (1896)

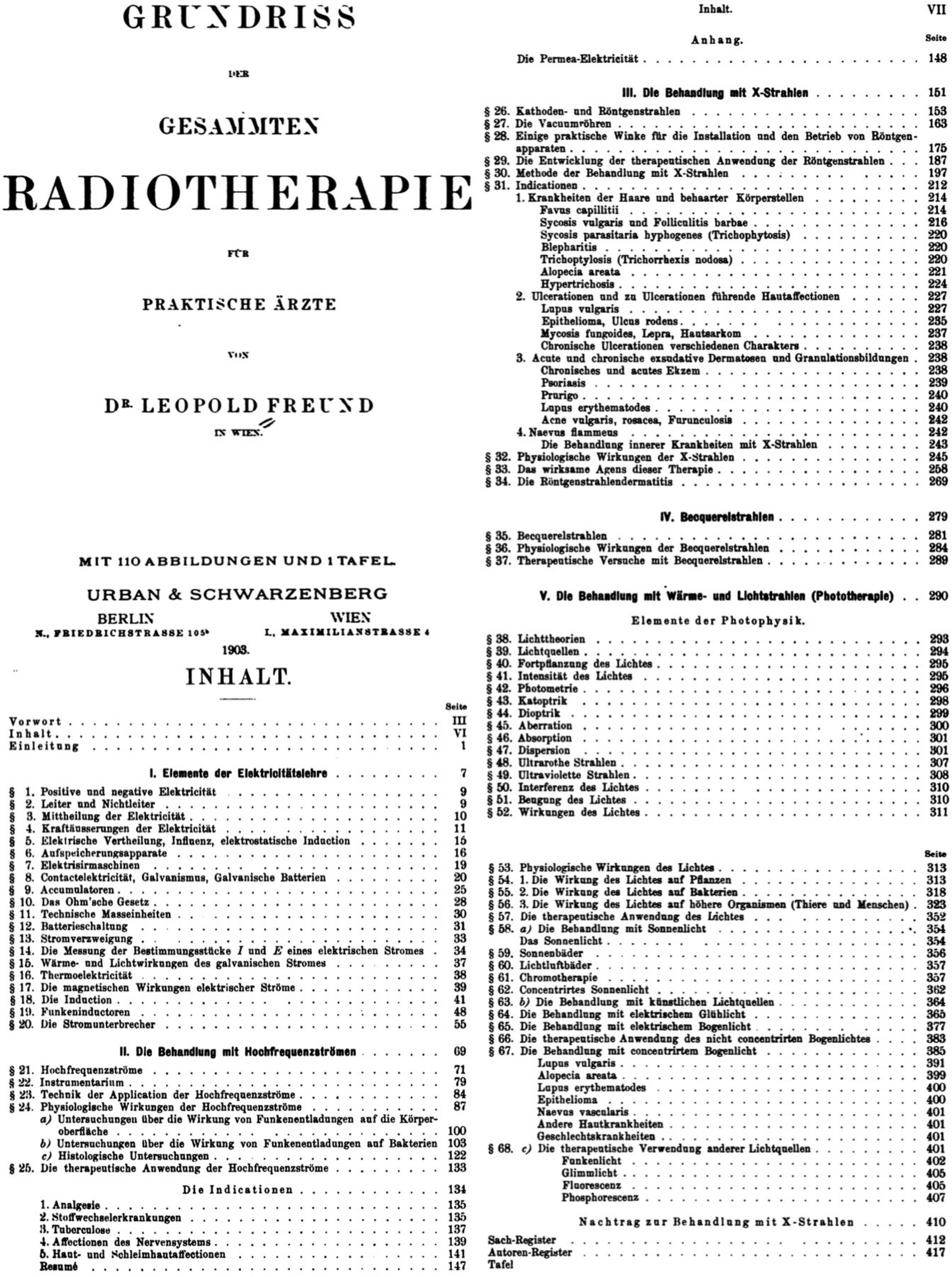
Figure 8.1: Wilhelm Röntgen discovered X-rays (often called Röntgen rays) and made the first human X-ray in 1895. Ludwig Zehnder made the first whole-body X-ray (a composite of nine X-ray films) in 1896.

Leopold Freund (1868–1943) **Eduard Schiff (1849–1913)**



Radiation therapy (1896)

Figure 8.2: Leopold Freund and Eduard Schiff invented radiation therapy. In 1896, they used X-rays to successfully treat a young girl with hairy growths on her entire back. They continued to develop and employ radiation therapy in the following years.



GRUNDRISS

DER

GESAMMTEN

RADIOTHERAPIE

FÜR

PRAKTISCHE ÄRZTE

VON

DR. LEOPOLD FREUND

IN WIEN.

MIT 110 ABBILDUNGEN UND 1 TAFEL.

URBAN & SCHWARZENBERG
BERLIN N., FRIEDRICHSTRASSE 105ᵇ
WIEN I., MAXIMILIANSTRASSE 4
1903.

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Figure 8.3: Leopold Freund wrote the first medical textbook on radiation therapy in 1902 and published it in 1903 [Leopold Freund 1903].

8.1.2 Radioisotopes and Isotope Labeling

Different isotopes of the same chemical element have the same number of protons and same number of electrons (and hence the same chemical properties), but different numbers of neutrons; that difference in neutron number creates a measurable mass difference, and also makes some isotopes radioactive. Isotopes that are radioactive can be extremely useful either for diagnostics or for radiation therapy. Even isotopes that are not radioactive can be detected by their mass differences and thus can be useful in chemistry and biology experiments.

Isotope labeling of chemical molecules was developed by George de Hevesy (Hungarian, 1885–1966), Hilde Levi (German, 1909–2003), Friedrich Paneth (Austrian, 1887–1958), and Rudolf Schoenheimer (German, 1898–1941); see Fig. 8.4. The ability to follow labeled molecules as they pass through chemical reactions, biological systems, and the environment revolutionized our understanding of chemistry, biology, and earth science. Radioisotope labeled molecules continue to be widely used for medical diagnostics and cancer therapeutics. De Hevesy won a Nobel Prize in Chemistry in 1943. Professor A. Westgren, member of the Nobel Committee for Chemistry, explained how extensive de Hevesy's research was [https://www.nobelprize.org/prizes/chemistry/1943/ceremony-speech/]:

> This discovery was made some ten years ago and the study of chemical processes by means of radioactive markers has since then been carried to such a point that it is now widely used in laboratories throughout the world. De Hevesy has remained the prime mover in this new field of activity and much first-class and important research has been carried out by him and his co-workers.
>
> Exceptionally valuable results have thus been obtained in biology. An isotope of radioactive phosphorus, which can be obtained by exposing sulphur to neutron radiation or ordinary phosphorus to radiation from nuclei of heavy hydrogen, has mostly been used. This radioactive phosphorus is sufficiently long-lasting for tests of this nature. It has a half-life of approximately 14.8 days. De Hevesy produced physiological solutions of sodium phosphate containing this marker and injected them into animals and humans. The distribution of the phosphorus was determined at certain intervals. A study of blood samples showed that the phosphorus thus introduced quickly left the blood. In human blood the radio-phosphorus content had fallen after only 2 hours to a mere 2% of its initial value. It diffuses into the extra-cellular body fluid and gradually changes places with the phosphorus atoms of the tissues, organs and skeleton. After some time it can even be found, though in very small quantities, in the enamel of the teeth. Exchanges small and slow as they may be, therefore occur between the outer hard parts of the teeth and the inner tissues of the bones and the lymph. Most of the phosphorus introduced, finds its way into the skeleton, muscles, liver and gastro-intestinal organs. Elimination of phosphorus from living organisms has also been studied by this method.
>
> Phosphorus is an extremely important element in biological processes. The knowledge of its functions in living organisms which has been acquired thanks to the use of radioactive markers is therefore of the very greatest interest. De Hevesy succeeded in detecting where and at what speed the various organic compounds of phosphorus are able to form and the paths which they take in the animal organism. In order to form from a phosphate which has been injected into the blood they must first penetrate into the cells. Acid-soluble compounds of phosphorus form rapidly, whereas phosphatides closely related to

> fatty substances are slower-forming. These latter form mainly in the liver, whence they are carried by the blood plasma to the places where they will be consumed. De Hevesy showed that the phosphatides of the chicken embryo are produced in the embryo itself and that they cannot be extracted from the egg yolk.
>
> De Hevesy also carried out several investigations with radioactive sodium and potassium. He studied how physiological saline containing radioactive sodium which was injected into a human subject first spread into the blood and then slowly penetrated into the cells; he also studied the manner in which it is excreted. After 24 hours the blood corpuscles had lost approximately half their sodium content.
>
> In addition to the above-mentioned markers, several other active isotopes, such as magnesium, sulphur, calcium, chlorine, manganese, iron, copper and zinc, have been used for this type of research. In the case of the lighter elements it has also been possible to use inactive isotopes such as heavy hydrogen, with an atomic weight of 2, nitrogen, with an atomic weight of 15, and oxygen, with an atomic weight of 18. It is of course less easy to determine the content of an inactive than of an active marker, but this can be done by determinations of density or mass-spectrographically. To determine the concentration of deuterium, or heavy hydrogen, which is twice as heavy as ordinary hydrogen, is a relatively easy matter. De Hevesy used deuterium as marker in many tests. He then noticed that a person who has drunk water containing heavy hydrogen excretes deuterium in the urine after only 26 minutes. Frogs and fishes swimming in water containing deuterium absorb it and, after about 4 hours, are in equilibrium with the medium as far as the deuterium is concerned. Heavy nitrogen and heavy oxygen have also been used in many investigations.

Technetium, which is especially useful for radioisotope labeling due to its short half-life and readily detectable gamma rays, was discovered in 1925 by Otto Berg (German, 1873–1939), Walter Noddack (German, 1893–1960), and Ida Tacke Noddack (German, 1896–1978); see p. 436.

Similarly, Berta Karlik (Austrian, 1904–1990), shown in Fig. 8.5, worked out the radioactive decay process that produces astatine, a previously undiscovered element (number 85) and ultimately an important radioactive treatment for cancer.[4]

Ulrich Henschke (German, 1914–1980) invented and commercialized a variety of brachytherapy methods for treating cancer with very localized radioactive sources or tightly targeted radiation beams. Henschke also made important contributions in several other unrelated fields. See p. 2514 for more information.

German-speaking scientists also led the rest of the world in research on all other aspects of cancer causes, prevention, and treatment (p. 113).

---

[4] As an aside, for this period in history, women appear to have been remarkably numerous and successful in the greater German-speaking nuclear physics community. Hilde Levi, Ida Tacke Noddack, and Berta Karlik have already been mentioned, and Marietta Blau, Erika Cremer, Klara Döpel, Maria Goeppert Mayer, and Lise Meitner are discussed in later sections. While these were some of the most prominent women in the nuclear physics community, there were a number of others as well. Unfortunately, even these most prominent women have been largely forgotten by history, except for Meitner, who has been the subject of two major biographies in recent decades [Rife 1999; Sime 1996]. It would be interesting to study whether other scientific fields had similarly large populations of female scientists who have been neglected by historians, or if there were certain factors that allowed women to go further in nuclear physics than in many other fields of science and engineering at that time. (Of course, Marie Curie and her daughter Irène Joliot-Curie are well-known examples of women who were successful in nuclear physics outside the

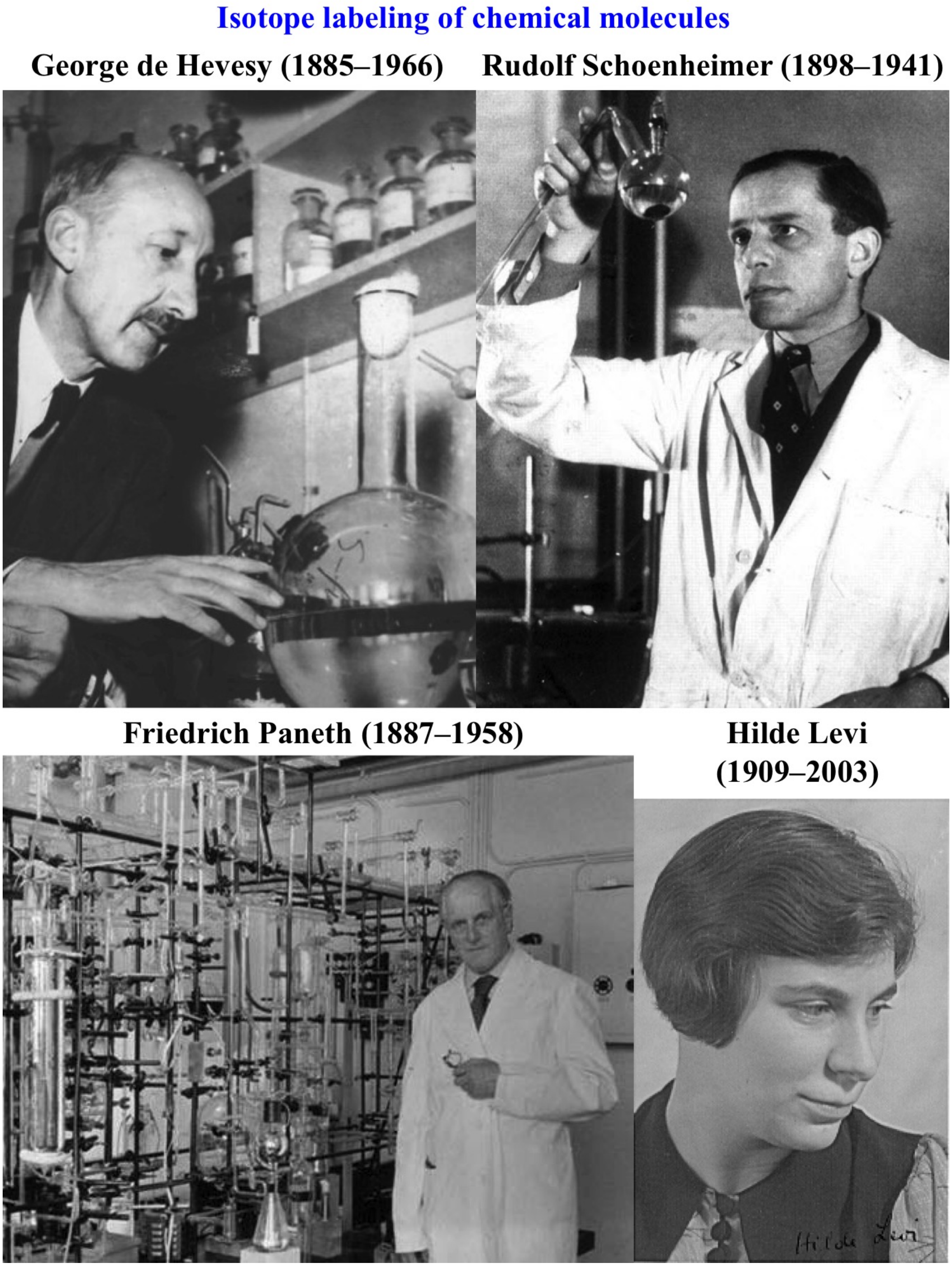

Isotope labeling of chemical molecules
George de Hevesy (1885–1966)
Rudolf Schoenheimer (1898–1941)
Friedrich Paneth (1887–1958)
Hilde Levi
(1909–2003)
Hilde Levi

Figure 8.4: George de Hevesy, Hilde Levi, Friedrich Paneth, and Rudolf Schoenheimer developed isotope labeling of chemical molecules.

Berta Karlik (1904–1990)

Astatine

Figure 8.5: Berta Karlik worked out the radioactive decay process that produces astatine, a previously undiscovered element (number 85) and ultimately an important radioactive treatment for cancer.

8.1.3 Nuclear Magnetic Resonance (NMR)/Magnetic Resonance Imaging (MRI)

Nuclear magnetic resonance (NMR), also called magnetic resonance imaging (MRI), does not involve radiation or radioactivity, but rather uses intense magnetic fields to identify different types of atomic nuclei. Thus it can be used to identify various types of atoms and their relative locations within a chemical molecule, or to track the locations of oxygen or other atoms being used within the human body.

Pieter Zeeman (Dutch, 1865–1943) and Hendrik Lorentz (Dutch, 1853–1928) discovered that applied magnetic fields shift the energy levels of electrons orbiting in atoms, and therefore the frequencies of electromagnetic waves that they absorb and emit. For demonstrating and explaining what is now known as the Zeeman effect, both Zeeman and Lorentz won the Nobel Prize in Physics in 1902 (p. 891).

Beginning in the 1930s, I. I. Rabi (Austro-Hungarian by birth and educated in the German-speaking scientific community, 1898–1988) and Felix Bloch (Swiss, 1905–1983) demonstrated that sufficiently strong magnetic fields could create a Zeeman-type effect not just of the electrons orbiting in an atom, but of the nucleus at the center of an atom (Fig. 8.6). Under such conditions, the atomic nuclei of different chemical elements, or different isotopes of the same element, have slightly different magnetic signatures that can be detected using the fields.

For laying the foundations for NMR/MRI, Rabi won the Nobel Prize in Physics in 1944. At the award ceremony, Professor E. Hulthén of the Nobel Committee for Physics praised the cleverness and utility of Rabi's accomplishments [https://www.nobelprize.org/prizes/physics/1944/ceremony-speech/]:

> Let us now for a moment touch upon Rabi's achievements in this field. Returning to the essential point of the problem, let us put the question: How does the atom react to the magnetic field? According to a theorem stated by the English mathematician Larmor, this influence may be ascribed to a relatively slow precession movement on the part of the electron and the atomic nucleus around the field direction—a gyromagnetic effect most closely recalling the gyroscopic movement performed by a top when it spins around the vertical line. If the strength of the magnetic field is known, the magnetic factor of the electron and of the atomic nucleus can also be estimated by this means, provided that we can observe and measure these precessional frequencies. Rabi solved the problem in a manner as simple as it was brilliant. Within the magnetic field was inserted a loop of wire, attached to an oscillating circuit the frequency of which could be varied in the same manner as we tune in our radio receiving set to a given wavelength. Now, when the atomic beam passes through the magnetic field, the atoms are only influenced on condition that they precess in time with the electric current in the oscillating circuit. This influence might perhaps be described graphically: the nucleus performs a vault (salto)—the technical term for which is a "quantum jump"—thereby landing in another positional direction to the field. But this means that the atom has lost all chance of reaching the detector and of being registered by it. The effect of these quantum jumps is observable by the fact that the detector registers a marked resonance minimum, the frequency position of the registration being determined with the extraordinary precision achievable with the radio frequency gauge. By this method Rabi has literally established

---

German-speaking world.)

> radio relations with the most subtile particles of matter, with the world of the electron and of the atomic nucleus.

Felix Bloch won the Nobel Prize in Physics in 1952 for his own role in the development of NMR/MRI and related techniques. Professor E. Hulthén addressed him at the award ceremony [https://www.nobelprize.org/prizes/physics/1952/ceremony-speech/]:

> Professor Bloch. It would be difficult in the few minutes at my disposal to try to give the main features of the nuclear induction method for which you have been awarded your Nobel Prize. It would be still more difficult for me to give an exhaustive account of the ways that led you to this invention.
>
> You began your career as a theoretical physicist, well-known for your fundamental contributions to the theory of metals.
>
> When, quite unexpectedly, you went over to experimental research, this must have been, I feel, with deliberation and assurance. For you had in your kitbag a tool of extraordinary value, the method for the magnetic polarization of a beam of neutrons. The inestimable value of possessing a good idea, of indefatigably testing and perfecting it, is best illustrated by your precision-measurements of the magnetic moment of the neutron, one of the most difficult and at the same time most important tasks in nuclear physics.
>
> But ideas give birth to new ideas, and it was, as I understand, in this way that you hit upon the excellent notion of eliminating the difficult absolute determination of the magnetic field by a direct measurement of the neutron moment in units of the proton cycle (the nuclear magneton). According to your own account it was this solution which finally led you to the nuclear induction method.

Nicolaas Bloembergen (Dutch, 1920–2017, Fig. 6.63) was one of the major developers of early laboratory systems for NMR analysis. He won the Nobel Prize in Physics in 1981 for some of his other research on lasers. See p. 1033 for more information.

NMR/MRI was further developed by a number of scientists from the 1950s to the 1970s (including the American chemist Paul Lauterbur and the British physicist Peter Mansfield) and is now widely used for medical diagnostics and chemical analysis.

Richard Ernst (Swiss, 1933–, p. 607) developed NMR spectroscopy methods that are useful for studying chemical molecules and biological systems. For that work, he won the Nobel Prize in Chemistry in 1991. See p. 596 for more information.

Kurt Wüthrich (Swiss, 1938–, p. 614) developed methods to use NMR to study large molecules. For that innovation, he won the Nobel Prize in Chemistry in 2002 (p. 604).

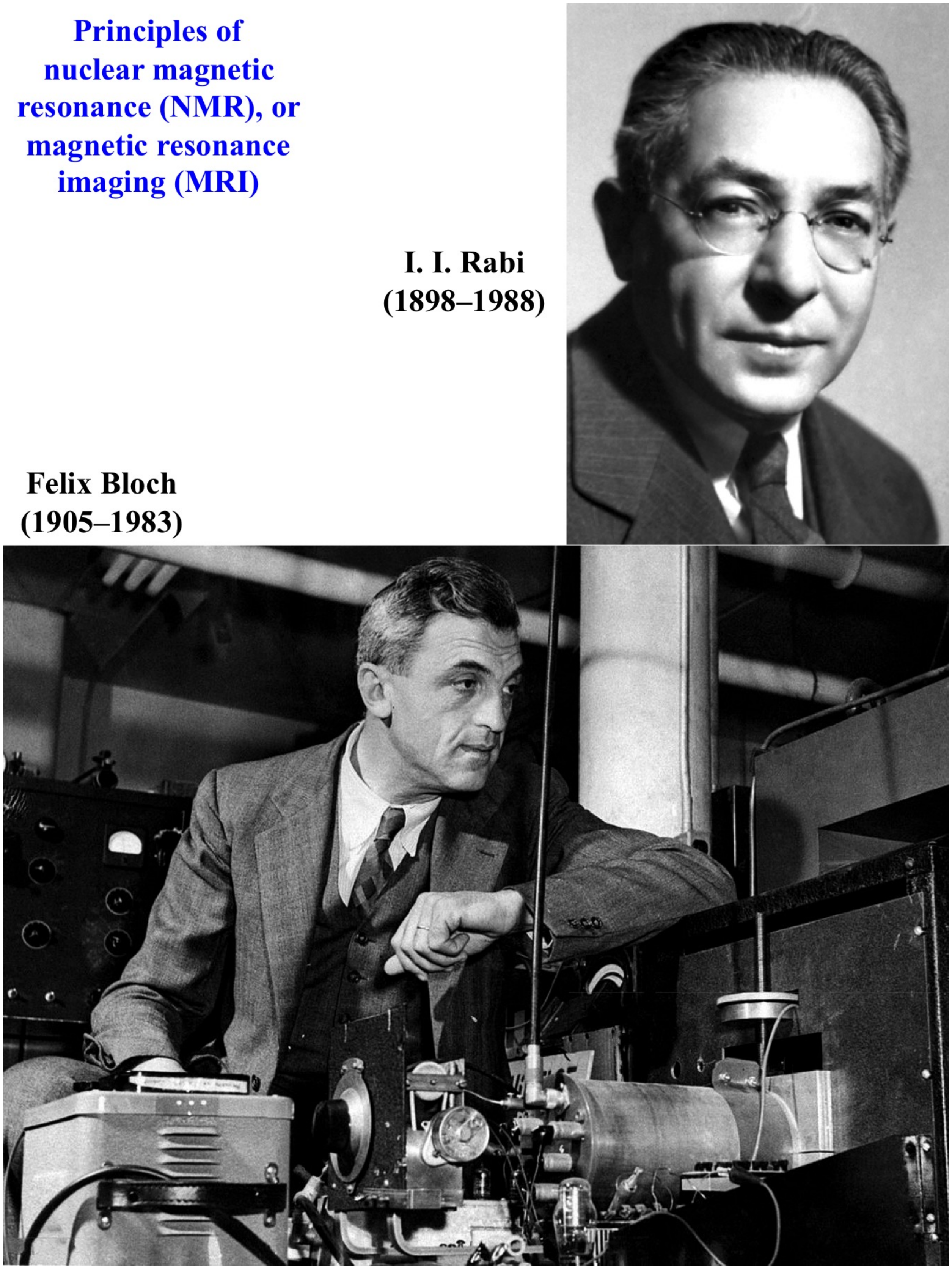

Principles of nuclear magnetic resonance (NMR), or magnetic resonance imaging (MRI)
I. I. Rabi (1898–1988)
Felix Bloch (1905–1983)

Figure 8.6: I. I. Rabi and Felix Bloch developed the principles of nuclear magnetic resonance (NMR), or magnetic resonance imaging (MRI).

8.2 Radiation Detectors

German-speaking scientists developed the major types of radiation detectors that are still widely used today, including electrical methods of detection (Section 8.2.1), optical methods of detection (Section 8.2.2), and more advanced methods such as Mössbauer spectroscopy (Section 8.2.3).

8.2.1 Electrical Detection of Radiation

German-speaking creators invented electrical methods of detecting radiation. Hans Geiger (German, 1882–1945) and Walther Müller (German, 1905–1979) developed Geiger counters or Geiger-Müller tubes between 1908 and 1928, while Heinrich Greinacher (Swiss, 1880–1974) developed similar proportional or spark counters in 1920. See Fig. 8.7.

Marc Shampo and his scientific colleagues gave an overview of Geiger's contributions [Shampo et al. 2011]:

> The German physicist Hans Wilhelm Geiger is best known as the inventor of the Geiger counter to measure radiation. In 1908, Geiger introduced the first successful detector of individual alpha particles. Later versions of this counter were able to count beta particles and other ionizing radiation. The introduction in July 1928 of the Geiger-Müller counter marked the introduction of modern electrical devices into radiation research. [...]
>
> In 1925, Geiger accepted his first teaching position, which was at the University of Kiel, Germany. Here, he and Walther Müller improved the sensitivity, performance, and durability of the counter, and it became known as the "Geiger-Müller counter." It could detect not only alpha particles but also beta particles (electrons) and ionizing photons. The counter was essentially in the same form as the modern counter.
>
> In 1929, Geiger moved to the University of Tübingen (Germany), where he was named professor of physics and director of research at the Institute of Physics. In 1929, while at the Institute, Geiger made his first observations of a cosmic-ray shower. Geiger continued to investigate cosmic rays, artificial radioactivity, and nuclear fission after accepting a position in 1936 at the Technische Hochschule in Berlin, a position he held until his death. In 1937, with Otto Zeiller, Geiger used the counter to measure a cosmic-ray shower.

Walther Bothe (German, 1891–1957, photo on p. 1611) developed methods of detecting a variety of different types of radiation, including alpha particles in 1927, cosmic rays in 1929, and neutrons in 1930. For this work, he won the Nobel Prize in Physics in 1954. Professor I. Waller, a member of the Nobel Committee for Physics, described Bothe's accomplishments [https://www.nobelprize.org/prizes/physics/1954/ceremony-speech/]:

> Professor Walther Bothe, who shares this year's Nobel Prize with Professor Born, began his scientific activity as a theoretical physicist.
>
> The work for which he has now been rewarded with the Nobel Prize was carried out by him in Berlin actually as an experimental physicist. These labours were based on a new use of counter tubes. A counter tube has the property of transmitting an electric current when a charged particle, e.g. an electron, passes through it; and also, with special contrivances, when a light particle collides with it. Bothe's idea was to use two counter tubes in such a manner that the two tubes would only register simultaneous

> collisions. Such coincidences can only come from two particles emitted in the same elemental process, or from a particle which has travelled through both tubes at high velocity so that the time it takes for the particle's passing from one tube to the other can be neglected.
>
> Bothe used this coincidence method in 1925 and also with improved apparatus about ten years later in order to decide whether the energy rule as well as its complement, the so-called impulse rule, is valid for every collision between a light particle and an electron—as Einstein and Compton assumed—or whether those rules are valid only on average for a large number of collisions—as Bohr and his collaborators had inferred. By investigating light particles and electrons by the coincidence method, Bothe and his co-workers were able to show convincingly that the rules mentioned are valid for every individual collision. This result was of great significance in principle. The coincidence method has been widely used in the study of cosmic radiation and is one of the most important experimental aids in the investigation of cosmic radiation. This method was first used in this way by Bothe when he was working with Kolhörster who had already given important contributions in the field of cosmic radiation. Bothe and Kolhörster used the coincidence method to pick out those particles in the cosmic radiation which had travelled through two counter tubes. The absorption of cosmic radiation into various materials was determined by placing layers of these substances between the tubes and studying the corresponding reduction in the number of coincidences. It was found that these particles are absorbed at about the same extent as the total cosmic radiation. From the experiments the particularly important result was obtained, that at sea level, cosmic radiation consists in the main of particles of very high penetration.
>
> Bothe and other researchers later improved the coincidence method and extended its field of application. This method has now become one of the most important aids in the study of both nuclear reactions and cosmic radiation.
>
> By many other discoveries and penetrating investigations also, Bothe has enriched our knowledge in these fields in very great measure and has provided an important stimulus to other researchers.

For more information on the contributions of the German-speaking world to the detection and analysis of cosmic rays, see p. 804.

8.2.2 Optical Detection of Radiation

German-speaking scientists also created the major optical methods of detecting radiation (Fig. 8.8).

As already described, Wilhelm Röntgen and Ludwig Zehnder developed X-ray photography in 1895 and 1896 (p. 1508).

Marietta Blau (Austrian, 1894–1970) demonstrated that photographic film could also be used to make practical particle detectors during the period 1927–1937.

Hartmut Kallmann (German, 1896–1978) created organic scintillator particle detectors that emitted light when radiation passed through them.

Karl Przibram (Austrian, 1878–1973) developed inorganic scintillator detectors with that same property.

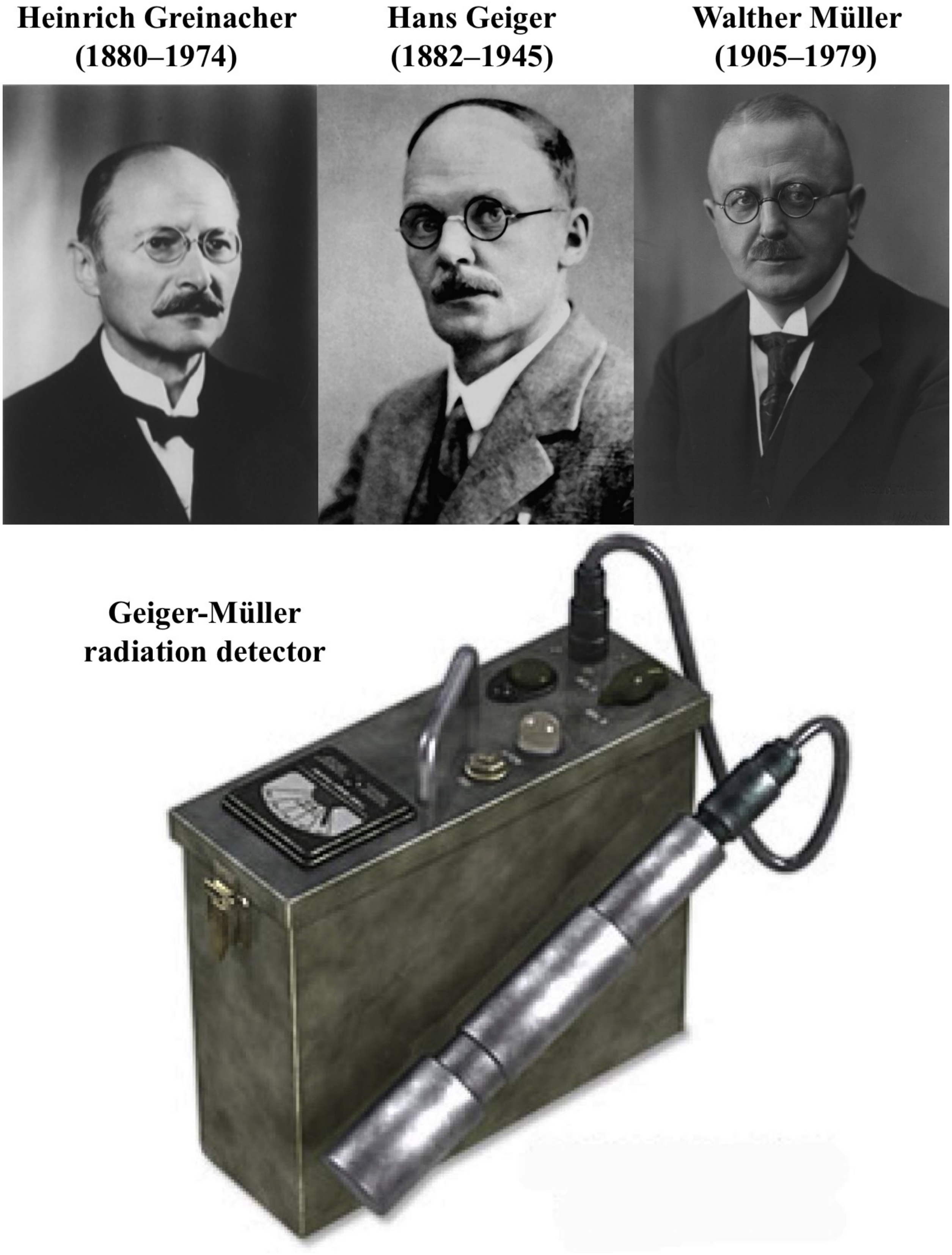

Heinrich Greinacher
(1880–1974)
Hans Geiger
(1882–1945)
Walther Müller
(1905–1979)
Geiger-Müller
radiation detector

Figure 8.7: Geiger-Müller radiation detectors were developed by Hans Geiger and Walther Müller. Similar proportional and spark counter radiation detectors were developed by Heinrich Greinacher.

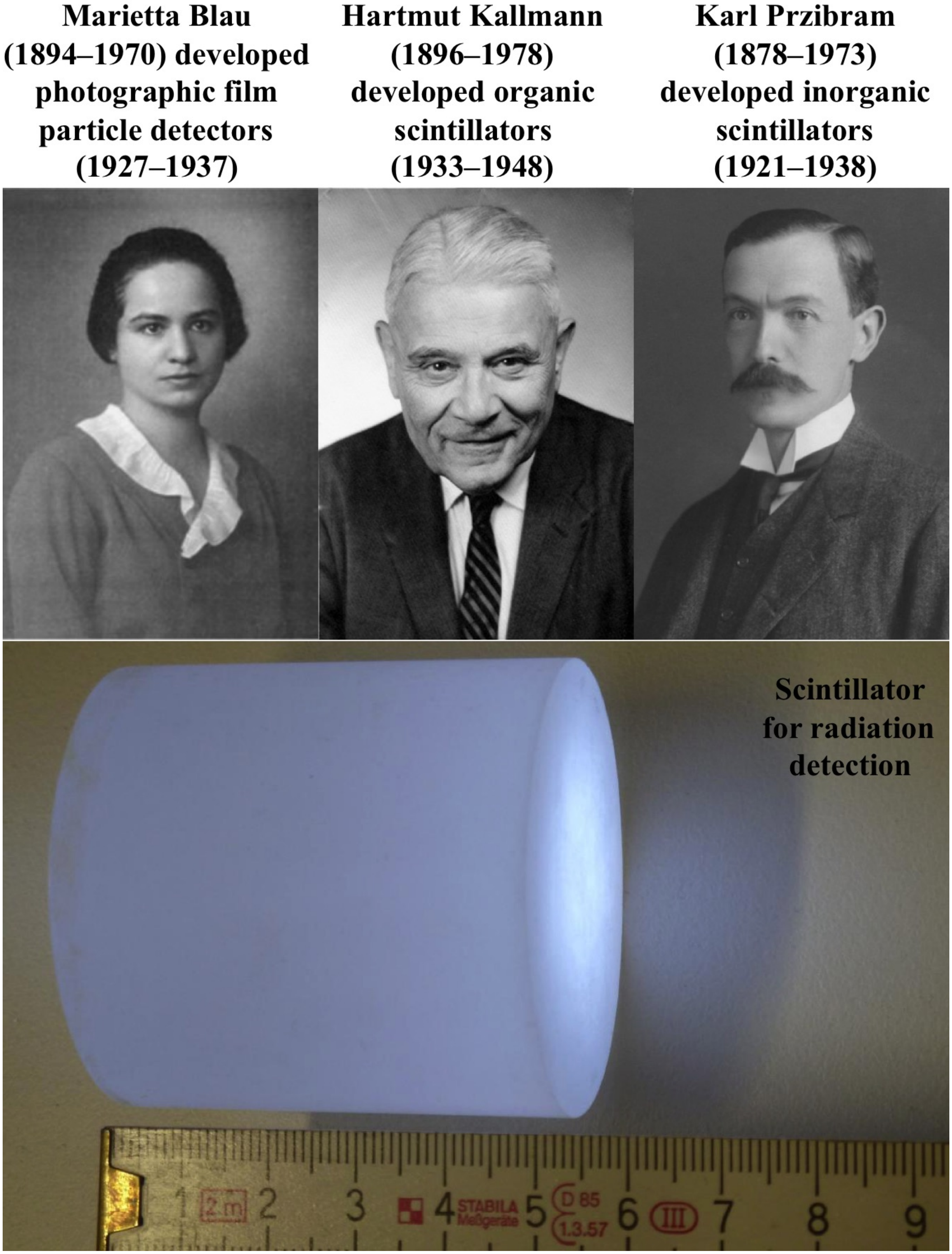
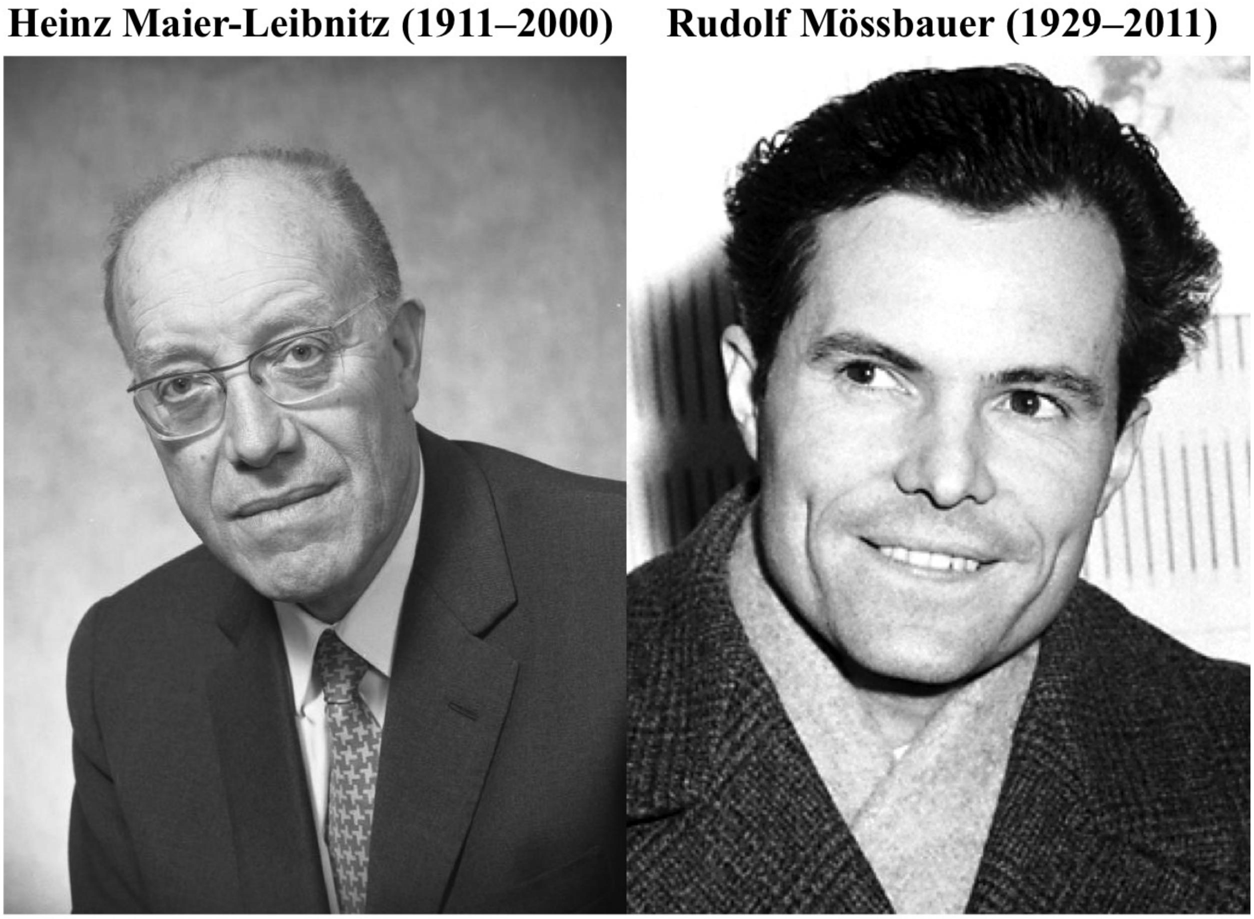

Marietta Blau (1894–1970) developed photographic film particle detectors (1927–1937)
Hartmut Kallmann (1896–1978) developed organic scintillators (1933–1948)
Karl Przibram (1878–1973) developed inorganic scintillators (1921–1938)
Scintillator for radiation detection
1 2m 2 3 4 STABILA Meßgeräte 5 D 85 1.3.57 6 III 7 8 9

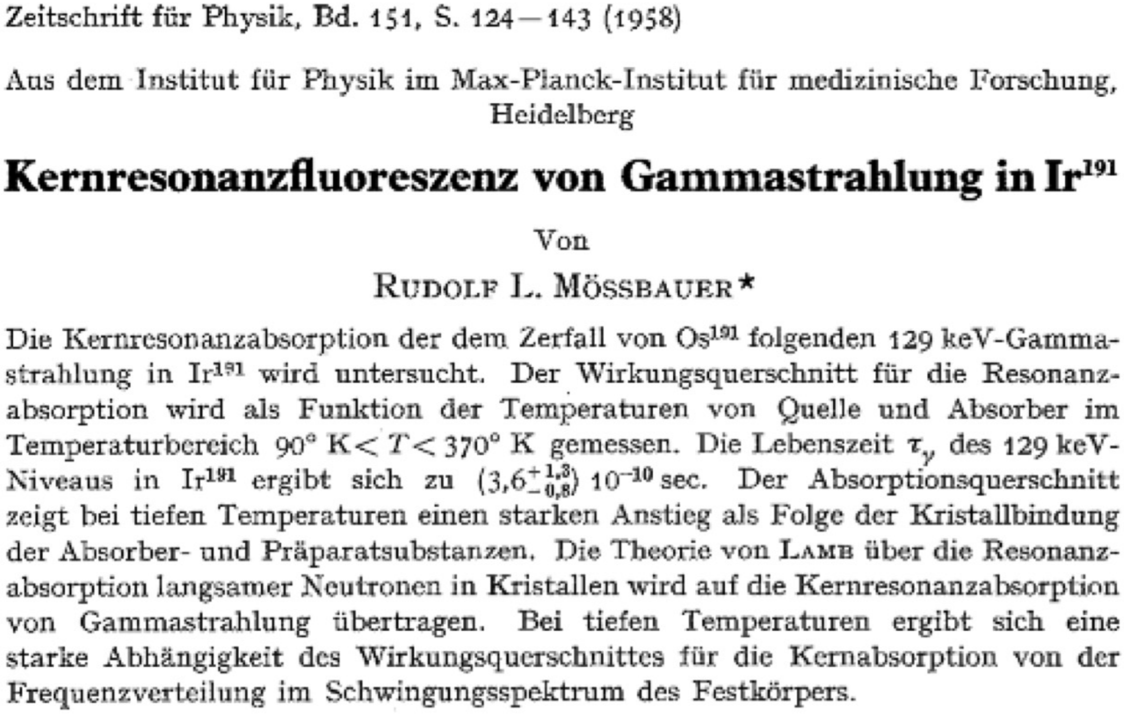
Figure 8.8: Marietta Blau developed photographic film particle detectors, Hartmut Kallmann created organic scintillator particle detectors, and Karl Przibram developed inorganic scintillator detectors.

8.2.3 Mössbauer Spectroscopy

Following the suggestions of his doctoral thesis advisor Heinz Maier-Leibnitz (German, 1911–2000), during the period 1953–1958 Rudolf Mössbauer (German, 1929–2011) developed recoilless nuclear resonance absorption, which became known as the Mössbauer effect or Mössbauer spectroscopy (Fig. 8.9). Mössbauer won the Nobel Prize in Physics in 1961. Professor I. Waller of the Nobel Committee for Physics described the significance of this work [https://www.nobelprize.org/prizes/physics/1961/ceremony-speech/]:

> Professor Rudolf Mössbauer's investigations concern the emission and absorption of gamma radiation by the atomic nuclei. This radiation is of the same kind as the light and the radio waves. It is well known that incoming radio waves can be received only if the receiver is tuned to the same frequency as the sender. Resonance is then taking place. It has since long been tried to observe the corresponding phenomenon for nuclei, where it is called "resonance absorption". The method was to let gamma radiation from some kind of nuclei act upon other nuclei of exactly the same kind. There is however a certain difficulty connected with this experiment. The gamma radiation can be considered as made up of particles. When emitting a gamma particle the atom receives a recoil whereby the energy and therefore also the frequency of the gamma radiation is decreased. The same phenomenon occurs when the gamma particle is absorbed in the receiving nucleus. The resonance will be completely destroyed if the frequency change is not compensated for, as had been done already before Mössbauer's work. Mössbauer discovered experimentally and showed also theoretically that for atoms bound in a solid, an appreciable part of the radiation can be emitted without frequency change whereby the resonance absorption can be studied directly. This discovery was published by Mössbauer in 1958. Because of the very small width of the gamma lines the resonance is very sharp and can, as Mössbauer found, be influenced and finally inhibited by the Doppler effect if the source or the absorber for the gamma radiation is moved. The velocities required depend upon the sharpness of the gamma line and can be as small as some millimeters per hour.
>
> Mössbauer's discovery has been received with considerable interest. Research on the Mössbauer effect has been started at a great number of places. It has thereby been possible to verify in the laboratory, fundamental consequences of Einstein's theory of relativity. Other important applications depend on the separation and displacement of nuclear energy levels which occur in solids because of the influence of the surroundings. Many phenomena of this kind can in spite of their smallness be studied by the Mössbauer effect. It has been possible in this way to get most important information on the properties of solids.
>
> Mössbauer made his discovery when he investigated the resonance absorption on the suggestion of Professor Maier-Leibnitz in München. He found then some unexpected results which he investigated systematically and was thereby led to his discovery. [...]
>
> Professor Mössbauer. While doing research for your doctor's thesis you have discovered an unexpected effect which now bears your name. You have explained this effect experimentally and theoretically, and thereby created a device which is of fundamental importance in numerous realms of physics, and which is nowadays being investigated and put to use in a large number of physical laboratories. By your discovery it has become possible to examine precisely, numerous important phenomena formerly beyond or at the limit of attainable accuracy of measurement.


Heinz Maier-Leibnitz (1911–2000)
Rudolf Mössbauer (1929–2011)


Zeitschrift für Physik, Bd. 151, S. 124—143 (1958)

Aus dem Institut für Physik im Max-Planck-Institut für medizinische Forschung, Heidelberg

Kernresonanzfluoreszenz von Gammastrahlung in Ir^{191}

Von

RUDOLF L. MÖSSBAUER *

Die Kernresonanzabsorption der dem Zerfall von Os^{191} folgenden 129 keV-Gammastrahlung in Ir^{191} wird untersucht. Der Wirkungsquerschnitt für die Resonanzabsorption wird als Funktion der Temperaturen von Quelle und Absorber im Temperaturbereich $90° \mathrm{K} < T < 370° \mathrm{K}$ gemessen. Die Lebenszeit τ_γ des 129 keV-Niveaus in Ir^{191} ergibt sich zu $(3{,}6^{+1{,}3}_{-0{,}8})\, 10^{-10}$ sec. Der Absorptionsquerschnitt zeigt bei tiefen Temperaturen einen starken Anstieg als Folge der Kristallbindung der Absorber- und Präparatsubstanzen. Die Theorie von LAMB über die Resonanzabsorption langsamer Neutronen in Kristallen wird auf die Kernresonanzabsorption von Gammastrahlung übertragen. Bei tiefen Temperaturen ergibt sich eine starke Abhängigkeit des Wirkungsquerschnittes für die Kernabsorption von der Frequenzverteilung im Schwingungsspektrum des Festkörpers.

Figure 8.9: Following the suggestions of Heinz Maier-Leibnitz, Rudolf Mössbauer developed recoilless nuclear resonance absorption, or Mössbauer spectroscopy.

8.3 Particle Accelerators and Ion Traps

Both particle accelerators and ion traps are important scientific tools for studying the fundamental physical properties of ions and other particles under different conditions:

> Particle accelerators (Section 8.3.1) are designed to increase the kinetic energy of particles as much as possible.
>
> Ion traps (Section 8.3.2) are intended to reduce the energy of particles as much as possible, in order to hold them relatively still for measurements.

8.3.1 Particle Accelerators

Although it is not widely known, German-speaking scientists invented particle accelerators in the 1920s and did an enormous amount of work before, during, and after World War II to develop them for various applications [Dippel 1992; Pancheri 2022; Sørheim 2020; Waloschek 2004, 2007, 2012; Burghard Weiss 1996].

Rolf Wideröe (Norwegian but studied and worked in Germany, 1902–1996) designed the first particle accelerators in 1923 and spent decades developing and building particle accelerators. See Fig. 8.10.

Max Steenbeck (German, 1904–1981, Fig. 8.11) began developing particle accelerators in 1927 and invented the first practical betatron (circular particle accelerator for electrons) in 1935.

Many other German-speaking scientists also developed and tested particle accelerators, including:

Manfred von Ardenne (German, 1907–1997)

Otto Baier (German?, 19??–19??)

Walther Bothe (German, 1891–1957)

Walter Dällenbach (Swiss, 1892–1990)

K. Fink (German?, 19??–19??)

Siegfried Flügge (German, 1912–1997)

Richard Gans (German, 1880–1954)

Rudolf Kollath (German, 1900–1978)

Helmuth Kulenkampff (German, 1895–1971)

H. Lange (German?, 19??–19??)

H. Salow (German?, 19??–19??)

Ernst Schiebold (German, 1894–1963)

Heinz Schmellenmeier (German, 1909–1994)

W. Schmitz (German?, 19??–19??)

Gerhard Schumann (German, 1911–19??)

Bruno Touschek (Austrian, 1921–1978)

A. Weckesser (German?, 19??–19??)

W. Wiebe (German?, 19??–19??)

In the German-speaking world, work on particle accelerators focused on at least four different but overlapping areas:

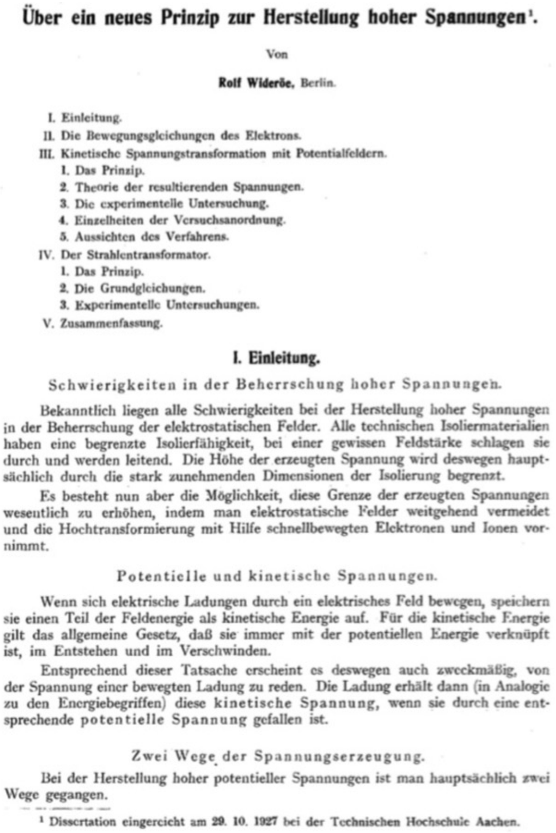
- Developing particle accelerator technology itself, including reaching higher and higher energies and numbers of particles in the beam.
- Using particle accelerators to answer fundamental questions in nuclear physics and other aspects of physics.
- Electronuclear breeding of weapons-grade fission fuel, and other applications relevant to developing nuclear weapons and nuclear reactors (see pp. 3954–4022, 4504–4510, and 5133–5134).
- Directed energy weapons (Section C.1). Many different versions of such weapons were under development during the war; they would have fired a beam of high-energy electrons and/or ions, or in some cases they would have harnessed the energy from those charged particles to produce an intense beam of X-rays, a burst of high-energy neutrons, or other forms of radiation. If some of the reports available in archives are correct, at least some of these weapons apparently reached the stage of successful tests against laboratory animals or solid targets.

In the 1930s, the U.S. physicists Ernest Lawrence and Donald Kerst discovered the early accelerator designs and writings of Rolf Wideröe and Max Steenbeck, copied them, and attained far greater fame than Wideröe and Steenbeck as the "inventors" of particle accelerators.

By the end of World War II, a number of advanced particle accelerators of various types had been built in the German-speaking world. The accelerators were seized and closely studied by different Allied countries after the war.

For more information on particle accelerators, see Section C.1 and pp. 3954–4022, 4504–4510, and 5133–5134. Much more archival research should be conducted to unearth new information on the development of particle accelerators in the German-speaking world, in order to determine exactly how far it progressed and how much it influenced programs in other countries.

Rolf Wideröe (1902–1996)
Particle accelerators (1923–)



Über ein neues Prinzip zur Herstellung hoher Spannungen[1].

Von

Rolf Wideröe, Berlin.

I. Einleitung.
II. Die Bewegungsgleichungen des Elektrons.
III. Kinetische Spannungstransformation mit Potentialfeldern.
  1. Das Prinzip.
  2. Theorie der resultierenden Spannungen.
  3. Die experimentelle Untersuchung.
  4. Einzelheiten der Versuchsanordnung.
  5. Aussichten des Verfahrens.
IV. Der Strahlentransformator.
  1. Das Prinzip.
  2. Die Grundgleichungen.
  3. Experimentelle Untersuchungen.
V. Zusammenfassung.

I. Einleitung.

Schwierigkeiten in der Beherrschung hoher Spannungen.

Bekanntlich liegen alle Schwierigkeiten bei der Herstellung hoher Spannungen in der Beherrschung der elektrostatischen Felder. Alle technischen Isoliermaterialien haben eine begrenzte Isolierfähigkeit, bei einer gewissen Feldstärke schlagen sie durch und werden leitend. Die Höhe der erzeugten Spannung wird deswegen hauptsächlich durch die stark zunehmenden Dimensionen der Isolierung begrenzt.

Es besteht nun aber die Möglichkeit, diese Grenze der erzeugten Spannungen wesentlich zu erhöhen, indem man elektrostatische Felder weitgehend vermeidet und die Hochtransformierung mit Hilfe schnellbewegten Elektronen und Ionen vornimmt.

Potentielle und kinetische Spannungen.

Wenn sich elektrische Ladungen durch ein elektrisches Feld bewegen, speichern sie einen Teil der Feldenergie als kinetische Energie auf. Für die kinetische Energie gilt das allgemeine Gesetz, daß sie immer mit der potentiellen Energie verknüpft ist, im Entstehen und im Verschwinden.

Entsprechend dieser Tatsache erscheint es deswegen auch zweckmäßig, von der Spannung einer bewegten Ladung zu reden. Die Ladung erhält dann (in Analogie zu den Energiebegriffen) diese kinetische Spannung, wenn sie durch eine entsprechende potentielle Spannung gefallen ist.

Zwei Wege der Spannungserzeugung.

Bei der Herstellung hoher potentieller Spannungen ist man hauptsächlich zwei Wege gegangen.

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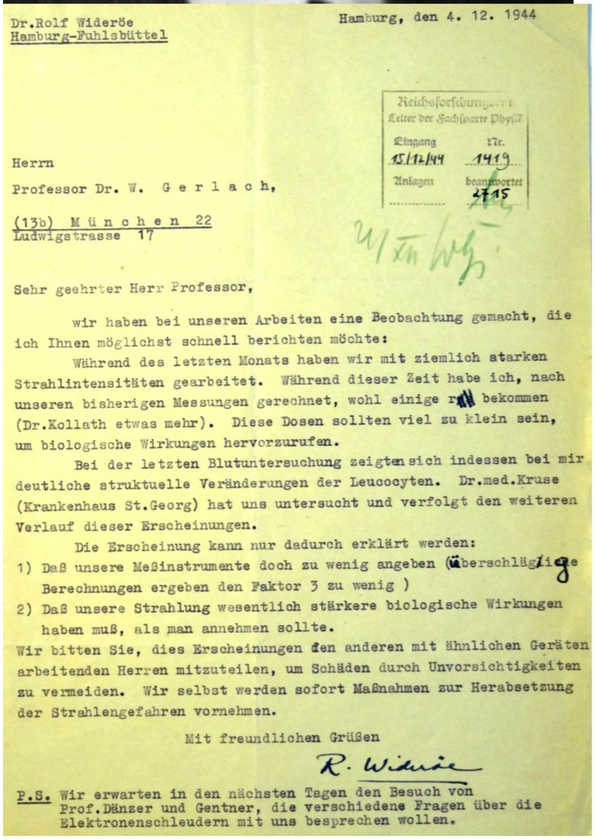
[1] Dissertation eingereicht am 29. 10. 1927 bei der Technischen Hochschule Aachen.



Dr.Rolf Wideröe
Hamburg-Fuhlsbüttel

Hamburg, den 4. 12. 1944

Reichsforschungsrat
Leiter der Fachsparte Physik
Eingang 15/12/44 Nr. 1419
Anlagen beantwortet 2715

Herrn
Professor Dr. W. Gerlach,

(13b) München 22
Ludwigstrasse 17

21/XII Wz.

Sehr geehrter Herr Professor,

wir haben bei unseren Arbeiten eine Beobachtung gemacht, die ich Ihnen möglichst schnell berichten möchte:

Während des letzten Monats haben wir mit ziemlich starken Strahlintensitäten gearbeitet. Während dieser Zeit habe ich, nach unseren bisherigen Messungen gerechnet, wohl einige r bekommen (Dr.Kollath etwas mehr). Diese Dosen sollten viel zu klein sein, um biologische Wirkungen hervorzurufen.

Bei der letzten Blutuntersuchung zeigten sich indessen bei mir deutliche struktuelle Veränderungen der Leucocyten. Dr.med.Kruse (Krankenhaus St.Georg) hat uns untersucht und verfolgt den weiteren Verlauf dieser Erscheinungen.

Die Erscheinung kann nur dadurch erklärt werden:

1) Daß unsere Meßinstrumente doch zu wenig angeben (überschlägige Berechnungen ergeben den Faktor 3 zu wenig)
2) Daß unsere Strahlung wesentlich stärkere biologische Wirkungen haben muß, als man annehmen sollte.

Wir bitten Sie, dies Erscheinungen den anderen mit ähnlichen Geräten arbeitenden Herren mitzuteilen, um Schäden durch Unvorsichtigkeiten zu vermeiden. Wir selbst werden sofort Maßnahmen zur Herabsetzung der Strahlengefahren vornehmen.

Mit freundlichen Grüßen

R. Wideröe

P.S. Wir erwarten in den nächsten Tagen den Besuch von Prof.Dänzer und Gentner, die verschiedene Fragen über die Elektronenschleudern mit uns besprechen wollen.

NARA RG 319 Entry NM3-82A, Box 6, Folder ALSOS G-20

DECLASSIFIED
Authority NND755001

Oct. 23, 1951 R. WIDERÖE **2,572,551**

MAGNETIC INDUCTION ACCELERATOR

Filed June 4, 1947 4 Sheets-Sheet 1

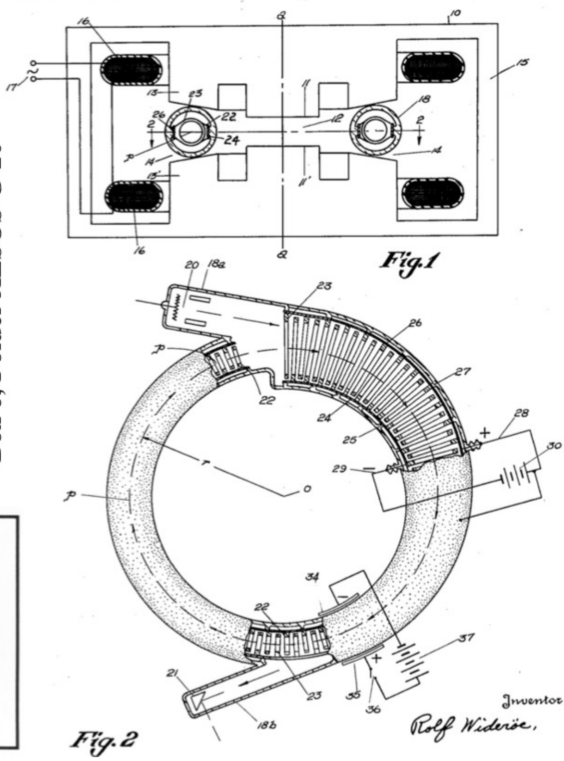
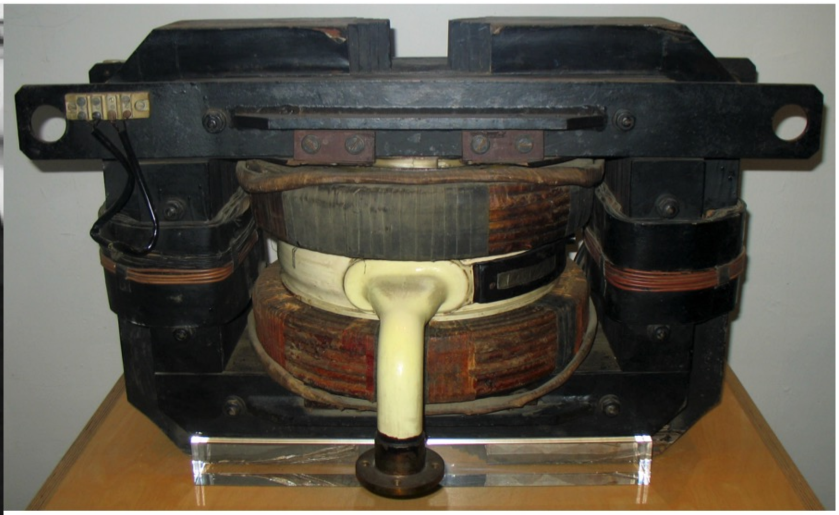
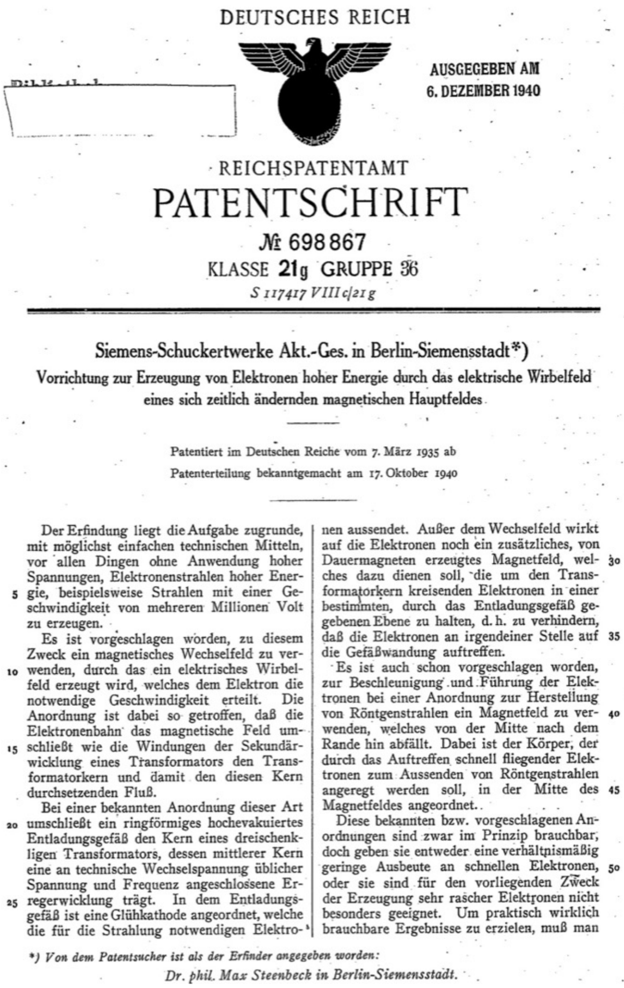


Fig.2

Figure 8.10: Rolf Wideröe designed the first particle accelerators in 1923 and spent decades developing and building particle accelerators.

Max Steenbeck (1904–1981) **Particle accelerators (1927 onward)**





DEUTSCHES REICH

AUSGEGEBEN AM
6. DEZEMBER 1940

REICHSPATENTAMT
PATENTSCHRIFT
№ 698 867
KLASSE 21g GRUPPE 36
S 117417 VIII c/21 g

Siemens-Schuckertwerke Akt.-Ges. in Berlin-Siemensstadt*)

Vorrichtung zur Erzeugung von Elektronen hoher Energie durch das elektrische Wirbelfeld eines sich zeitlich ändernden magnetischen Hauptfeldes

Patentiert im Deutschen Reiche vom 7. März 1935 ab
Patenterteilung bekanntgemacht am 17. Oktober 1940

Der Erfindung liegt die Aufgabe zugrunde, mit möglichst einfachen technischen Mitteln, vor allen Dingen ohne Anwendung hoher Spannungen, Elektronenstrahlen hoher Energie, beispielsweise Strahlen mit einer Geschwindigkeit von mehreren Millionen Volt zu erzeugen.

Es ist vorgeschlagen worden, zu diesem Zweck ein magnetisches Wechselfeld zu verwenden, durch das ein elektrisches Wirbelfeld erzeugt wird, welches dem Elektron die notwendige Geschwindigkeit erteilt. Die Anordnung ist dabei so getroffen, daß die Elektronenbahn das magnetische Feld umschließt wie die Windungen der Sekundärwicklung eines Transformators den Transformatorkern und damit den diesen Kern durchsetzenden Fluß.

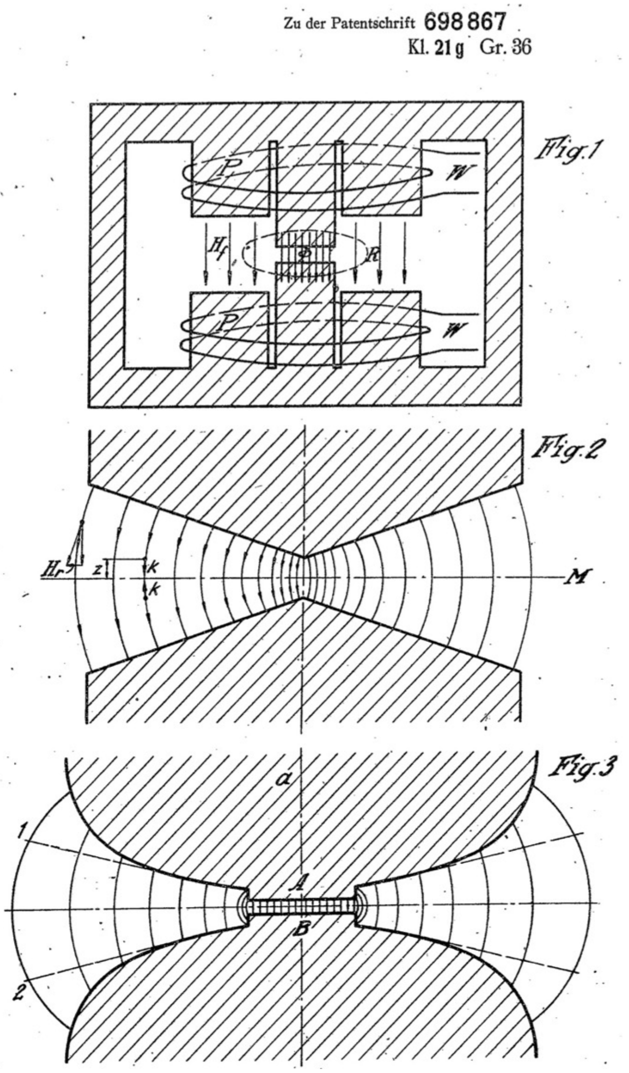
Bei einer bekannten Anordnung dieser Art umschließt ein ringförmiges hochevakuiertes Entladungsgefäß den Kern eines dreischenkligen Transformators, dessen mittlerer Kern eine an technische Wechselspannung üblicher Spannung und Frequenz angeschlossene Erregerwicklung trägt. In dem Entladungsgefäß ist eine Glühkathode angeordnet, welche die für die Strahlung notwendigen Elektronen aussendet. Außer dem Wechselfeld wirkt auf die Elektronen noch ein zusätzliches, von Dauermagneten erzeugtes Magnetfeld, welches dazu dienen soll, die um den Transformatorkern kreisenden Elektronen in einer bestimmten, durch das Entladungsgefäß gegebenen Ebene zu halten, d. h. zu verhindern, daß die Elektronen an irgendeiner Stelle auf die Gefäßwandung auftreffen.

Es ist auch schon vorgeschlagen worden, zur Beschleunigung und Führung der Elektronen bei einer Anordnung zur Herstellung von Röntgenstrahlen ein Magnetfeld zu verwenden, welches von der Mitte nach dem Rande hin abfällt. Dabei ist der Körper, der durch das Auftreffen schnell fliegender Elektronen zum Aussenden von Röntgenstrahlen angeregt werden soll, in der Mitte des Magnetfeldes angeordnet.

Diese bekannten bzw. vorgeschlagenen Anordnungen sind zwar im Prinzip brauchbar, doch geben sie entweder eine verhältnismäßig geringe Ausbeute an schnellen Elektronen, oder sie sind für den vorliegenden Zweck der Erzeugung sehr rascher Elektronen nicht besonders geeignet. Um praktisch wirklich brauchbare Ergebnisse zu erzielen, muß man

---

*) *Von dem Patentsucher ist als der Erfinder angegeben worden:*
Dr. phil. Max Steenbeck in Berlin-Siemensstadt.



Zu der Patentschrift **698 867**
Kl. **21 g** Gr. 36

Figure 8.11: Max Steenbeck began developing particle accelerators in 1927 and invented the betatron for accelerating electrons.

8.3.2 Ion Traps

As shown in Fig. 8.12, Frans Penning (Dutch, 1894–1953), Wolfgang Paul (German, 1913–1993, not to be confused with the theoretical physicist Wolfgang Pauli), and Hans Dehmelt (German, 1922–2017) developed electromagnetic mass spectrometers and electromagnetic ion traps (Penning traps) to confine small numbers of ions of different elements for direct measurements. For that work, Paul and Dehmelt won the Nobel Prize in Physics in 1989. Professor Ingvar Lindgren of the Royal Swedish Academy of Sciences explained the importance of their innovations [https://www.nobelprize.org/prizes/physics/1989/ceremony-speech/]:

> An atom has certain fixed energy levels, and transition between these levels can take place by means of emission or absorption of electromagnetic radiation, such as light. Transition between closely spaced levels can be induced by means of radio-frequency radiation, and this forms the basis for so-called resonance methods. The first method of this kind was introduced by Professor I. Rabi in 1937, and the same basic idea underlies the resonance methods developed later, such as nuclear magnetic resonance (NMR), electron-spin resonance (ESR) and optical pumping. [...]
>
> The dream of the spectroscopist is to be able to study a single atom or ion under constant conditions for a long period of time. In recent years, this dream has to a large extent been realized. The basic tool is here the ion trap, which was introduced in the 1950s by another of this year's laureates, Wolfgang Paul in Bonn. His technique was further refined by the third laureate, Hans Dehmelt, and his co-workers in Seattle into what is now known as ion-trap spectroscopy.
>
> Dehmelt and his associates used this spectroscopy primarily for studying electrons, and in 1973 they succeeded for the first time in observing a single electron in an ion trap, and in confining it there for weeks and months. One property of the electron, its magnetic moment, was measured to 12 digits, 11 of which have later been verified theoretically. This represents a most stringent test of the atomic theory known as quantum electrodynamics (QED).
>
> In a similar way, Dehmelt and others were later able to trap and study a single ion, which represents a true landmark in the history of spectroscopy. The technique is now being used in development of improved atomic clocks, in particular at the National Institute for Standards and Technology (formerly the National Bureau of Standards) in Boulder, Colorado.

Frans Penning (1894–1953) **Wolfgang Paul (1913–1993)** **Hans Dehmelt (1922–2017)**

Electromagnetic Penning trap for ions
(shown as oval blue cloud)

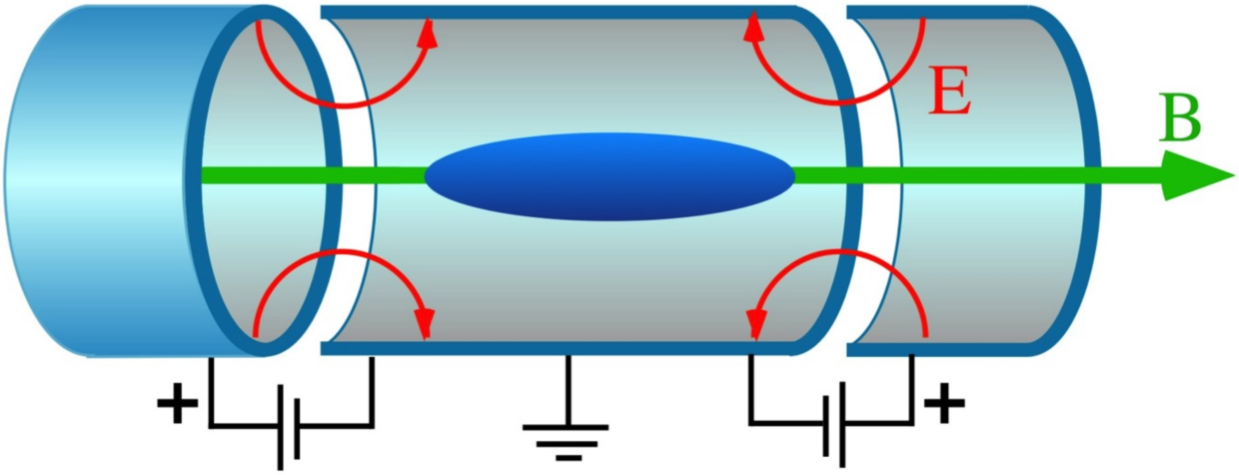


Figure 8.12: Frans Penning, Wolfgang Paul, and Hans Dehmelt developed electromagnetic mass spectrometers and electromagnetic ion traps.

8.4 Models of the Atomic Nucleus

Scientists from the German-speaking world discovered all three of the building blocks of atoms: electrons, protons, and neutrons (Section 5.2.3).

German-speaking scientists were also directly responsible for developing detailed mathematical models of the behavior of the protons and neutrons in the atomic nucleus. These models are necessary for predicting various types of radioactive decays and nuclear reactions [Karen Johnson 2004; Shaviv 2012]. See Figs. 8.13–8.16.

For simplicity, these nuclear models may be divided into two broad categories:

> The liquid drop model (Section 8.4.1) essentially treats the nucleus like a continuous drop of liquid rather than a collection of individual particles, although it does incorporate quantum corrections for interactions between the individual particles.
>
> The shell model (Section 8.4.2) refines the liquid drop model by also considering the different energy levels or shells that particles within the nucleus can occupy, and the maximum allowable numbers of particles per shell.

8.4.1 Liquid Drop Model

Serious study of the internal structure of the nucleus arguably began in 1913, when Kasimir Fajans (Polish, 1887–1975) first worked out the radioactive displacement law of how alpha and beta radioactive decay transform one element into another.

In 1935, Carl Friedrich von Weizsäcker (German, 1912–2007) published a remarkably comprehensive and detailed mathematical model of the structure and energy levels of the nucleus (Figs. 8.15–8.16). It is still widely used today to accurately predict nuclear decays and reactions, and is known as the von Weizsäcker semi-empirical mass formula. Hans Bethe (German, 1906–2005) modified and utilized von Weizsäcker's formula in his own research. George Stetter (Austrian, 1895–1988) also conducted very early and very meticulous comparisons of theoretical and experimental results of nuclear energy levels and masses (Fig. 8.15).

George Gamow (Russian but educated and worked in Germany, lived 1904–1968) applied quantum physics to nuclear models in order to explain the rates of alpha decay [Gamow 1932].

Victor Weisskopf (Austrian, 1908–2002) and John (Johann) M. Blatt (Austrian, 1921–1990) produced what was at the time (and arguably remains, apart from coverage of the shell model) the most comprehensive theoretical compilation of information on nuclear structure [Blatt and Weisskopf 1952].

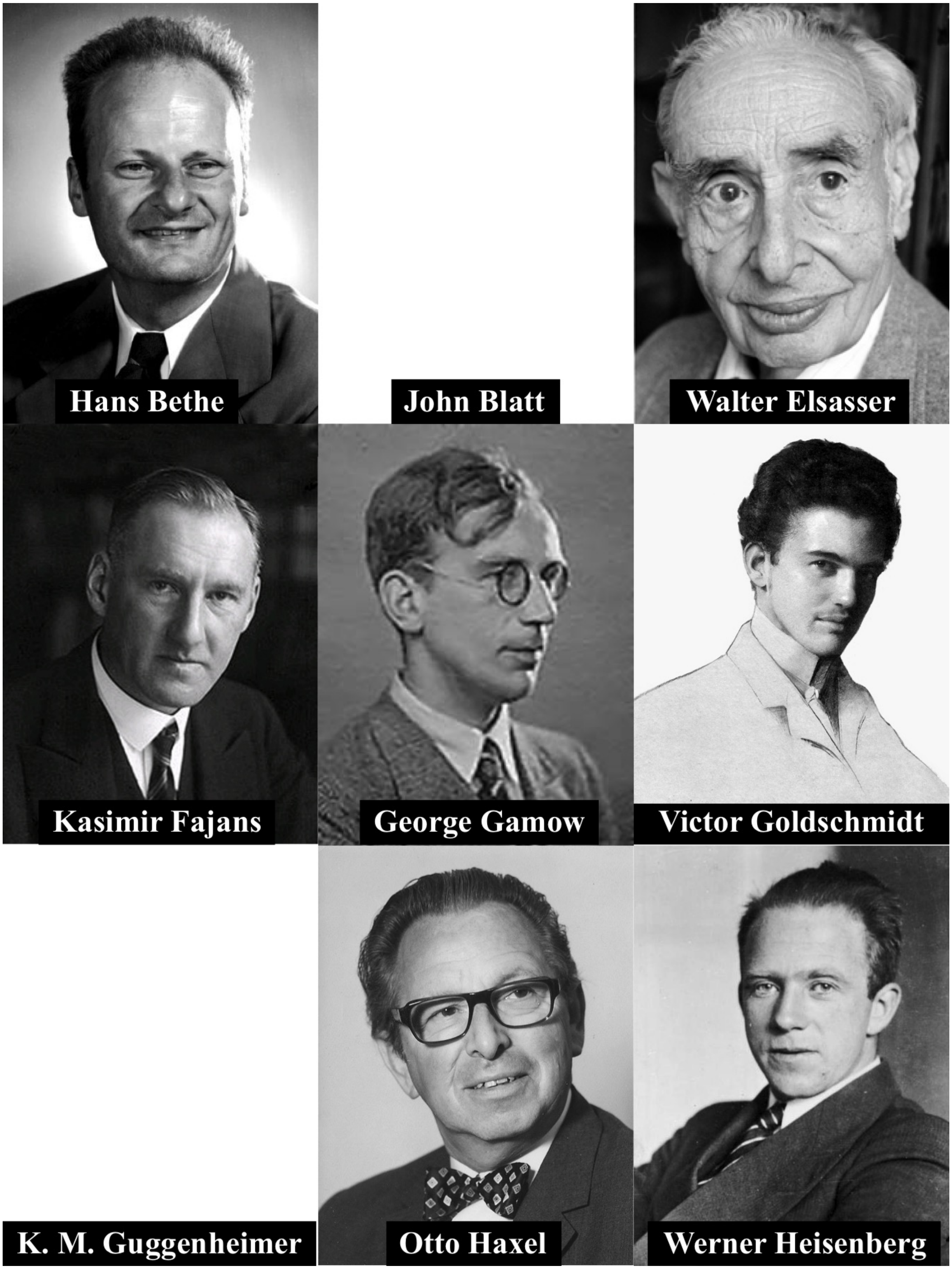

Hans Bethe
John Blatt
Walter Elsasser
Kasimir Fajans
George Gamow
Victor Goldschmidt
K. M. Guggenheimer
Otto Haxel
Werner Heisenberg

Figure 8.13: Mathematical models of nuclear structure and decays were developed or improved by Hans Bethe, John (Johann) Blatt, Walter Elsasser, Kasimir Fajans, George Gamow, Victor Goldschmidt, K. M. Guggenheimer, Otto Haxel, and Werner Heisenberg.

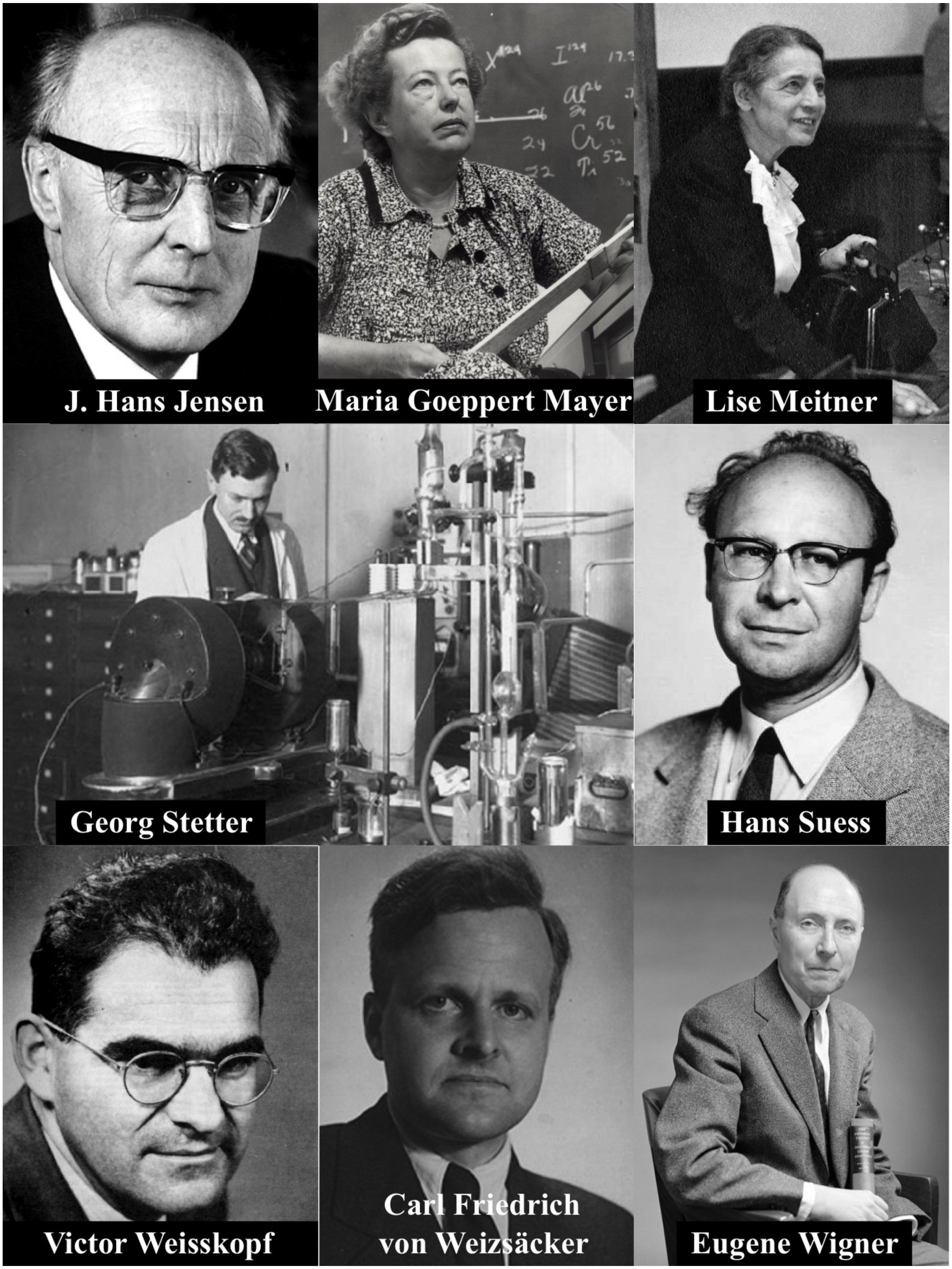
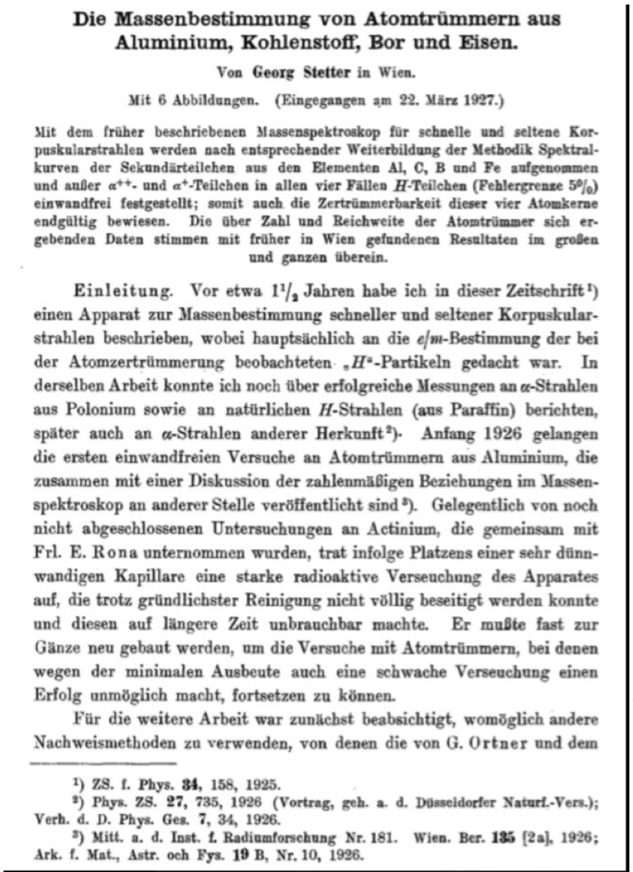

J. Hans Jensen
Maria Goeppert Mayer
Lise Meitner
Georg Stetter
Hans Suess
Victor Weisskopf
Carl Friedrich von Weizsäcker
Eugene Wigner

Figure 8.14: Mathematical models of nuclear structure and decays were also developed or improved by Johannes Hans Jensen, Maria Goeppert Mayer, Lise Meitner, Georg Stetter, Hans Suess, Victor Weisskopf, Carl Friedrich von Weizsäcker, and Eugene Wigner.



Die Massenbestimmung von Atomtrümmern aus Aluminium, Kohlenstoff, Bor und Eisen.

Von **Georg Stetter** in Wien.

Mit 6 Abbildungen. (Eingegangen am 22. März 1927.)

Mit dem früher beschriebenen Massenspektroskop für schnelle und seltene Korpuskularstrahlen werden nach entsprechender Weiterbildung der Methodik Spektralkurven der Sekundärteilchen aus den Elementen Al, C, B und Fe aufgenommen und außer α^{++}- und α^{+}-Teilchen in allen vier Fällen *H*-Teilchen (Fehlergrenze 5%) einwandfrei festgestellt; somit auch die Zertrümmerbarkeit dieser vier Atomkerne endgültig bewiesen. Die über Zahl und Reichweite der Atomtrümmer sich ergebenden Daten stimmen mit früher in Wien gefundenen Resultaten im großen und ganzen überein.

Einleitung. Vor etwa 1½ Jahren habe ich in dieser Zeitschrift[1] einen Apparat zur Massenbestimmung schneller und seltener Korpuskularstrahlen beschrieben, wobei hauptsächlich an die *e/m*-Bestimmung der bei der Atomzertrümmerung beobachteten „*H*"-Partikeln gedacht war. In derselben Arbeit konnte ich noch über erfolgreiche Messungen an α-Strahlen aus Polonium sowie an natürlichen *H*-Strahlen (aus Paraffin) berichten, später auch an α-Strahlen anderer Herkunft[2]. Anfang 1926 gelangen die ersten einwandfreien Versuche an Atomtrümmern aus Aluminium, die zusammen mit einer Diskussion der zahlenmäßigen Beziehungen im Massenspektroskop an anderer Stelle veröffentlicht sind[3]. Gelegentlich von noch nicht abgeschlossenen Untersuchungen an Actinium, die gemeinsam mit Frl. E. Rona unternommen wurden, trat infolge Platzens einer sehr dünnwandigen Kapillare eine starke radioaktive Verseuchung des Apparates auf, die trotz gründlichster Reinigung nicht völlig beseitigt werden konnte und diesen auf längere Zeit unbrauchbar machte. Er mußte fast zur Gänze neu gebaut werden, um die Versuche mit Atomtrümmern, bei denen wegen der minimalen Ausbeute auch eine schwache Verseuchung einen Erfolg unmöglich macht, fortsetzen zu können.

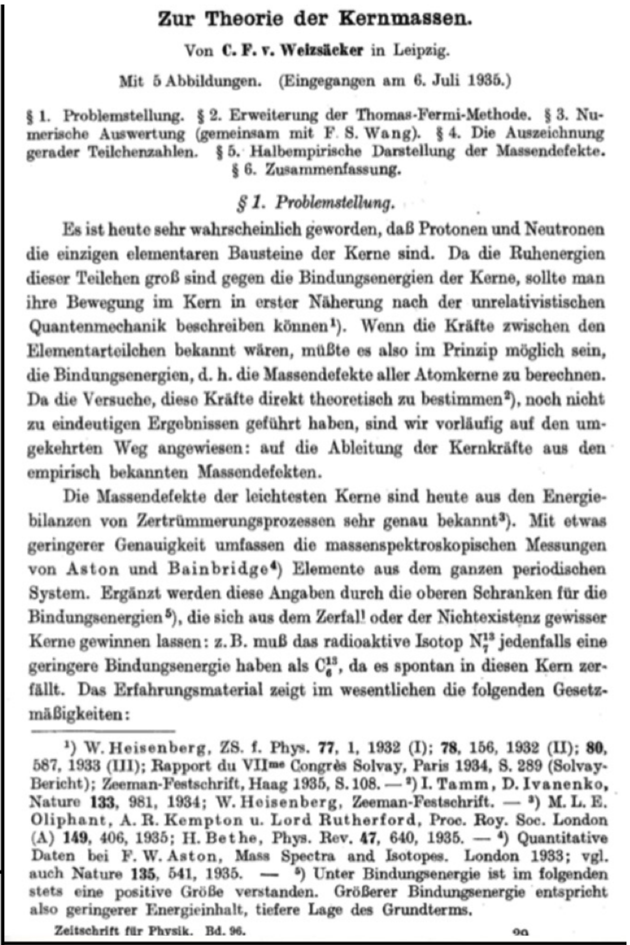
Für die weitere Arbeit war zunächst beabsichtigt, womöglich andere Nachweismethoden zu verwenden, von denen die von G. Ortner und dem

---

[1] ZS. f. Phys. **34**, 158, 1925.

[2] Phys. ZS. **27**, 735, 1926 (Vortrag, geh. a. d. Düsseldorfer Naturf.-Vers.); Verh. d. D. Phys. Ges. **7**, 34, 1926.

[3] Mitt. a. d. Inst. f. Radiumforschung Nr. 181. Wien. Ber. **135** [2a], 1926; Ark. f. Mat., Astr. och Fys. **19** B, Nr. 10, 1926.



Zur Theorie der Kernmassen.

Von **C. F. v. Weizsäcker** in Leipzig.

Mit 5 Abbildungen. (Eingegangen am 6. Juli 1935.)

§ 1. Problemstellung. § 2. Erweiterung der Thomas-Fermi-Methode. § 3. Numerische Auswertung (gemeinsam mit F. S. Wang). § 4. Die Auszeichnung gerader Teilchenzahlen. § 5. Halbempirische Darstellung der Massendefekte. § 6. Zusammenfassung.

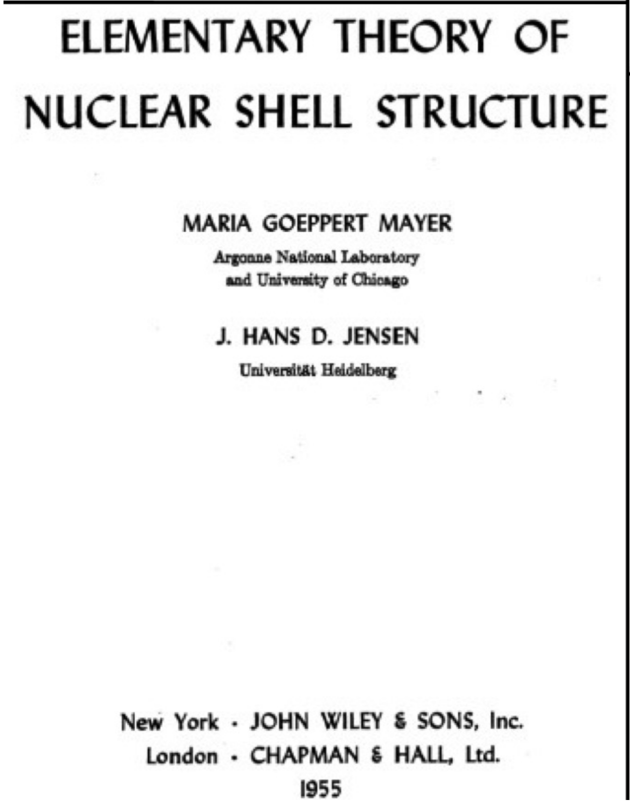
§ 1. Problemstellung.

Es ist heute sehr wahrscheinlich geworden, daß Protonen und Neutronen die einzigen elementaren Bausteine der Kerne sind. Da die Ruhenergien dieser Teilchen groß sind gegen die Bindungsenergien der Kerne, sollte man ihre Bewegung im Kern in erster Näherung nach der unrelativistischen Quantenmechanik beschreiben können[1]. Wenn die Kräfte zwischen den Elementarteilchen bekannt wären, müßte es also im Prinzip möglich sein, die Bindungsenergien, d. h. die Massendefekte aller Atomkerne zu berechnen. Da die Versuche, diese Kräfte direkt theoretisch zu bestimmen[2], noch nicht zu eindeutigen Ergebnissen geführt haben, sind wir vorläufig auf den umgekehrten Weg angewiesen: auf die Ableitung der Kernkräfte aus den empirisch bekannten Massendefekten.

Die Massendefekte der leichtesten Kerne sind heute aus den Energiebilanzen von Zertrümmerungsprozessen sehr genau bekannt[3]. Mit etwas geringerer Genauigkeit umfassen die massenspektroskopischen Messungen von Aston und Bainbridge[4] Elemente aus dem ganzen periodischen System. Ergänzt werden diese Angaben durch die oberen Schranken für die Bindungsenergien[5], die sich aus dem Zerfall oder der Nichtexistenz gewisser Kerne gewinnen lassen: z. B. muß das radioaktive Isotop N_7^{13} jedenfalls eine geringere Bindungsenergie haben als C_6^{13}, da es spontan in diesen Kern zerfällt. Das Erfahrungsmaterial zeigt im wesentlichen die folgenden Gesetzmäßigkeiten:

---

[1] W. Heisenberg, ZS. f. Phys. **77**, 1, 1932 (I); **78**, 156, 1932 (II); **80**, 587, 1933 (III); Rapport du VII^{me} Congrès Solvay, Paris 1934, S. 289 (Solvay-Bericht); Zeeman-Festschrift, Haag 1935, S. 108. — [2] I. Tamm, D. Ivanenko, Nature **133**, 981, 1934; W. Heisenberg, Zeeman-Festschrift. — [3] M. L. E. Oliphant, A. R. Kempton u. Lord Rutherford, Proc. Roy. Soc. London (A) **149**, 406, 1935; H. Bethe, Phys. Rev. **47**, 640, 1935. — [4] Quantitative Daten bei F. W. Aston, Mass Spectra and Isotopes. London 1933; vgl. auch Nature **135**, 541, 1935. — [5] Unter Bindungsenergie ist im folgenden stets eine positive Größe verstanden. Größerer Bindungsenergie entspricht also geringerer Energieinhalt, tiefere Lage des Grundterms.

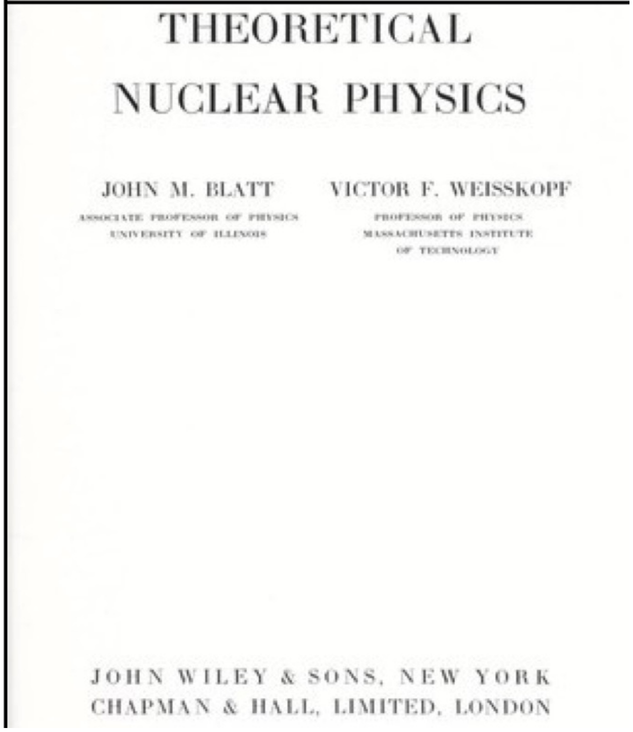


ELEMENTARY THEORY OF NUCLEAR SHELL STRUCTURE

MARIA GOEPPERT MAYER
Argonne National Laboratory
and University of Chicago

J. HANS D. JENSEN
Universität Heidelberg

New York · JOHN WILEY & SONS, Inc.
London · CHAPMAN & HALL, Ltd.
1955



THEORETICAL NUCLEAR PHYSICS

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JOHN WILEY & SONS, NEW YORK
CHAPMAN & HALL, LIMITED, LONDON

Figure 8.15: Just a few examples of seminal works on nuclear models by German-speaking scientists.

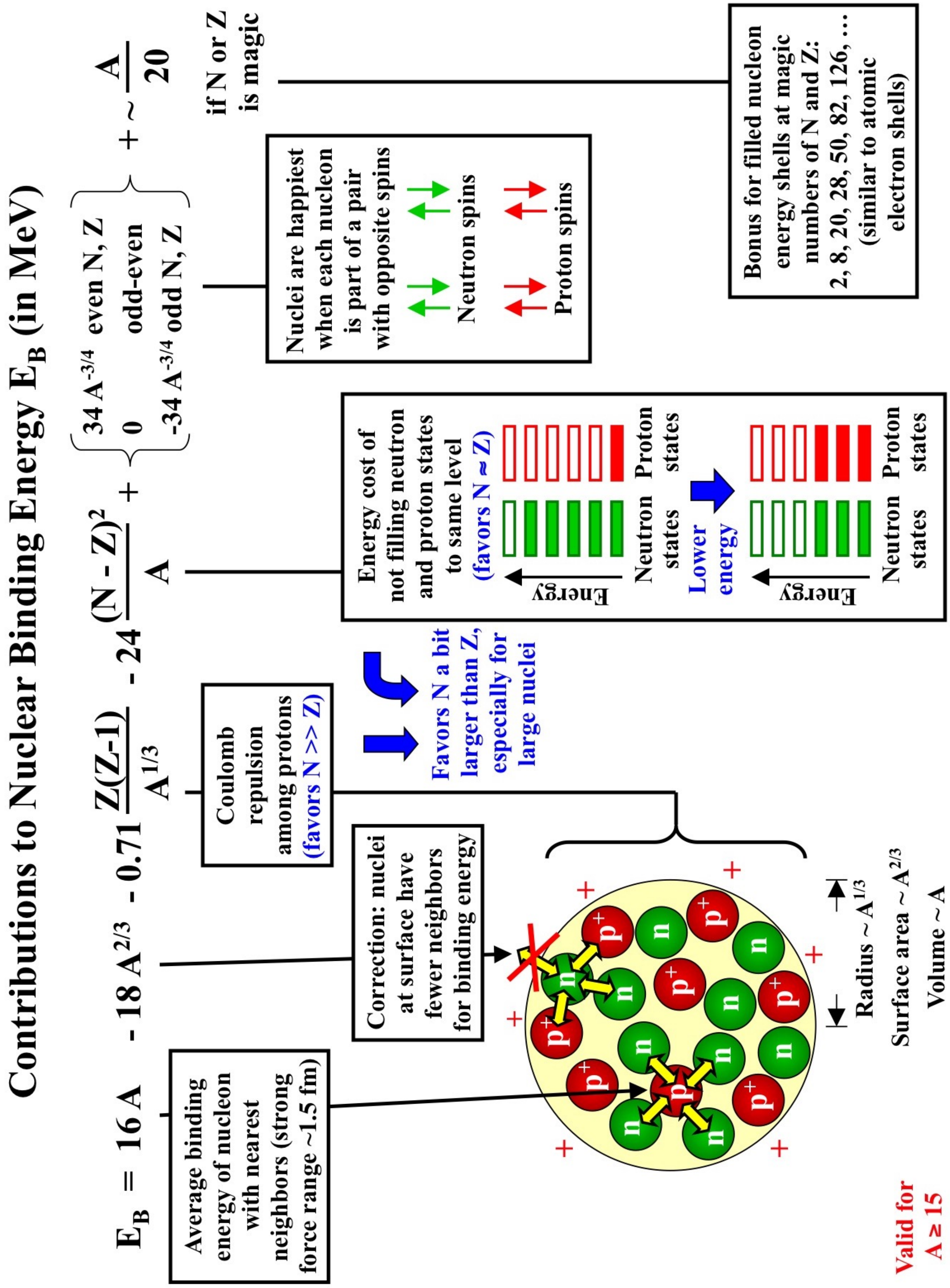

Contributions to Nuclear Binding Energy E_B (in MeV)
$E_B = 16\,A - 18\,A^{2/3} - 0.71\,\frac{Z(Z-1)}{A^{1/3}} - 24\,\frac{(N-Z)^2}{A} + \begin{cases} 34\,A^{-3/4} & \text{even N, Z} \\ 0 & \text{odd-even} \\ -34\,A^{-3/4} & \text{odd N, Z} \end{cases} + \sim\frac{A}{20}$ if N or Z is magic
Average binding energy of nucleon with nearest neighbors (strong force range ~1.5 fm)
Correction: nuclei at surface have fewer neighbors for binding energy
Coulomb repulsion among protons (favors N >> Z)
Favors N a bit larger than Z, especially for large nuclei
Energy cost of not filling neutron and proton states to same level (favors N ≈ Z)
Energy
Neutron states
Proton states
Lower energy
Energy
Neutron states
Proton states
Nuclei are happiest when each nucleon is part of a pair with opposite spins
Neutron spins
Proton spins
Bonus for filled nucleon energy shells at magic numbers of N and Z: 2, 8, 20, 28, 50, 82, 126, … (similar to atomic electron shells)
n
p+
+
Radius ~ $A^{1/3}$
Surface area ~ $A^{2/3}$
Volume ~ A
Valid for A ≥ 15

Figure 8.16: Nuclear binding energies in millions of electron-volts (MeV) as given by the von Weizsäcker semi-empirical mass formula with shell model corrections, for nuclei with Z protons, N neutrons, and $A = Z + N$ nucleons.

8.4.2 Shell Model

The most puzzling detail of nuclear models was working out the shell model of the "magic numbers" of protons and neutrons that are required to fill different energy levels or shells within the nucleus. Victor Goldschmidt (Swiss, 1888–1947), Walter Elsasser (German, 1904–1991), and Kurt M. Guggenheimer (German, 19??–19??) made very insightful proposals in the 1930s that partially explained the shell model's magic numbers. (Elsasser was a brilliant polymath who, among other insights, also developed the dynamo model that explains how the Earth's magnetic field is generated by the Earth's core—see p. 740 [Rubin 1995].) The final details of the shell model were worked out in the 1940s by Otto Haxel (German, 1909–1998), Johannes Hans Jensen (German, 1907–1973), Maria Goeppert Mayer (German, 1906–1972), Hans Suess (Austrian, 1909–1993), and Eugene Wigner (Hungarian, 1902–1995).

Johannes Hans Jensen, Maria Goeppert Mayer, and Eugene Wigner won the 1963 Nobel Prize in Physics for their contributions to nuclear models. Professor I. Waller of the Nobel Committee for Physics gave an overview of their contributions, as well as those of Walter Elsasser, Otto Haxel, and Hans Suess [https://www.nobelprize.org/prizes/physics/1963/ceremony-speech/]:

> In order to be able to calculate the motion of the nucleons it was, however, necessary to know also the forces which act between them. A very important step in the investigation of these forces was taken by Wigner in 1933 when he found, deducing from some experiments, that the force between two nucleons is very weak except when their distance apart is very small but that the force is then a million times stronger than the electric forces between the electrons in the outer part of the atoms. Wigner discovered later other important properties of the nuclear forces.
>
> Notwithstanding the efforts of many physicists our knowledge of the nuclear forces is yet rather incomplete. It was therefore fundamentally important that Wigner could show that most essential properties of the nuclei follow from generally valid symmetries of the laws of motion. Earlier Wigner had performed pioneering work by studying such symmetries in the laws of motion for the electrons and had made important discoveries by investigating e.g. those symmetries which express the fact that the laws mentioned make no difference between left and right and that backward in time according to them is equivalent to forward in time. These investigations were extended by Wigner to the atomic nuclei at the end of the 1930's and he explored then also the newly discovered symmetry property of the force between two nucleons to be the same whether either of the nucleons is a proton or a neutron. This work by Wigner and his other investigations of the symmetry principles in physics are important far beyond nuclear physics proper. His methods and results have become an indispensable guide for the interpretation of the rich and complicated picture which has emerged from recent years' experimental research on elementary particles. [...]
>
> Wigner has made many other important contributions to nuclear physics. He has given a general theory of nuclear reactions and has made decisive contributions to the practical use of nuclear energy. He has, often in collaboration with younger scientists, broken new paths in many other domains of physics.

It was found during the 1920's and in particular during the 1930's that the protons and the neutrons each form particularly stable systems in an atomic nucleus when the numbers of either kind of nucleons is one of the so-called magic numbers 2, 8, 20, 28, 50, 82 and 126. Several physicists, in particular Elsasser, tried to interpret the magic numbers in analogy to Niels Bohr's successful explanation of the periodic system of the elements. It was then assumed that the nucleons move in orbits in a common field of force and that these orbits are arranged in so-called shells which are energetically well separated. The magic numbers should correspond to complete shells. This interpretation was successful for light nuclei. It was, however, not possible to explain more than the three first magic numbers and for many years another model dominated.

A paper published by Goeppert Mayer in 1948 marked the beginning of a new era in the appreciation of the shell model. For the first time convincing evidence was there given for the existence of the higher magic numbers and it was stressed that the experiments support the existence of closed shells very strongly.

Somewhat later Goeppert Mayer and independently Haxel, Jensen and Suess published the new idea, which was needed for the explanation of the higher magic numbers. The idea was that a nucleon should have different energies when it “spins” in the same or opposite sense as it revolves around the nucleus.

Goeppert Mayer and Jensen collaborated later on the development of the shell model. They published together a book, where they applied the model to the extensive experimental material on atomic nuclei. They gave convincing evidence for the great importance of the shell model in systematizing this material and predicting new phenomena concerning the ground state and the low excited states of the nuclei. The general methods introduced by Wigner have been most important for the applications of the shell model. It has also been possible to give a deeper justification of the shell model. Its fundamental importance has thereby been further confirmed.

8.5 Nuclear Fission Reactions

Fission is the separation of a large (parent) nucleus into two smaller nuclei, and it can be either spontaneous (essentially a form of radioactive decay) or induced by neutron absorption. In addition to the two smaller nuclei, fission also generally produces a few loose neutrons and a large amount of energy. If the loose neutrons from one fission reaction are absorbed by other nuclei and cause them to fission as well, leading to the release of still more fission-inducing neutrons, a chain reaction can occur. Because a chain reaction can cause many nuclei to undergo fission and release their energy within a short period of time, it can be used to create everything from controlled fission power reactors to uncontrolled fission explosives.

In 1934, fission reactions were first theoretically predicted by Ida Tacke Noddack (German, 1896–1978), who together with her husband Walter Noddack (German, 1893–1960) had previously discovered the elements rhenium and technetium (p. 436). See Figs. 8.17–8.18. In the following quote from her often-overlooked but astonishing paper, Ida Noddack correctly predicted both neutron-induced fission of uranium and neutron capture/beta decay in uranium to produce element 93 (later named neptunium), which would beta decay to element 94 (later named plutonium) that could be easily chemically separated from the remaining parent uranium [Noddack 1934]:

Man kann ebensogut annehmen, daß bei dieser neuartigen Kernzertrümmerung durch Neutronen erheblich andere “Kernreaktionen” stattfinden, als man sie bisher bei der Einwirkung von Protonen- und α-Strahlen auf Atomkerne beobachtet hat. Bei den letztgenannten Bestrahlungen findet man nur Kernumwandlungen unter Abgabe von Elektronen, Protonen und Heliumkernen, wodurch sich bei schweren Elementen die Masse der bestrahlten Atomkerne nur wenig ändert, da nahe benachbarte Elemente entstehen. Es wäre denkbar, daß bei der Beschießung schwerer Kerne mit Neutronen diese Kerne in mehrere größere Bruchstücke zerfallen, die zwar Isotope bekannter Elemente, aber nicht Nachbarn der bestrahlten Elemente sind.	One could assume equally well that when neutrons are used to produce nuclear disintegrations, some distinctly new nuclear reactions take place which have not been observed previously with proton or alpha-particle bombardment of atomic nuclei. In the past one has found that transmutations of nuclei only take place with the emission of electrons, protons, or helium nuclei, so that the heavy elements change their mass only a small amount to produce near neighboring elements. When heavy nuclei are bombarded by neutrons, it is conceivable that the nucleus breaks up into several large fragments, which would of course be isotopes of known elements but would not be neighbors of the irradiated element.
[...] aus dem β-strahlenden Element 93 das Element 94 entstehen müßte. Dieses Element sollte man verhältnismäßig leicht chemisch von 93 trennen können.	[...] Beta decay of element 93 must produce element 94. It should be relatively easy to separate this element chemically from element 93.

At the Kaiser Wilhelm Institute for Chemistry in Berlin-Dahlem, Otto Hahn (German, 1879–1968) and Fritz Strassmann (German, 1902–1980) experimentally demonstrated neutron-induced fission of uranium into lighter elements in 1938 (Fig. 8.18), and published their results in January 1939 [Hahn and Strassmann 1939]:

> [...] Bei der energetisch nicht leicht zu verstehenden Bildung von Radiumisotopen aus Uran beim Beschießen mit langsamen Neutronen war eine besonders gründliche Bestimmung des chemischen Charakters der neu entstehenden künstlichen Radioelemente unerläßlich. Durch die Abtrennung einzelner analytischer Gruppen von Elementen aus der Lösung des bestrahlten Urans wurde außer der großen Gruppe der Transurane eine Aktivität stets bei den Erdalkalien (Trägersubstanz Ba), den seltenen Erden (Trägersubstanz La) und bei Elementen der vierten Gruppe des Periodischen Systems (Trägersubstanz Zr) gefunden. Eingehender untersucht wurden zunächst die Bariumfällungen, die offensichtlich die Anfangsglieder der beobachteten isomeren Reihen enthielten. Es soll gezeigt werden, daß Transurane, Uran, Protactinium, Thorium und Actinium sich stets leicht und vollständig von der mit Barium ausfallenden Aktivität trennen lassen. [...]

> [...] Since it is not easy to understand from energy considerations how radium isotopes can be produced when uranium is bombarded with slow neutrons, a very careful determination of the chemical properties of the new artificially made radioelements was necessary. Various analytic groups of elements were separated from a solution containing the irradiated uranium. Besides the large group of transuranic elements, some radioactivity was always found in the alkaline-earth group (barium carrier), the rare-earth group (lanthanum carrier), and also with elements in group IV of the periodic table (zirconium carrier). The barium precipitate was the first to be investigated more thoroughly, since it apparently contains the parent isotopes of the observed isomeric series. The goal was to show that the transuranic elements, and also uranium, protactinium, thorium, and actinium could always be separated easily and completely from the activity which precipitates with barium. [...]

The fission reaction results of Hahn and Strassmann were further analyzed in 1939 by Lise Meitner (Austrian, 1878–1968, Fig. 8.18) and her nephew Otto Frisch (Austrian, 1904–1979, photo on p. 1554). The news of fission reactions provoked strong scientific and political responses around the world, immediately launched major nuclear programs in Germany, the United States, and the United Kingdom, aroused interest that eventually gave rise to serious nuclear programs in many other countries, and of course made possible everything from fission reactors to fission bombs.

For his research on fission, Otto Hahn won the 1944 Nobel Prize in Chemistry, which was delayed by the war as well as his postwar internment at Farm Hall in the United Kingdom (p. 3336). In awarding the Prize, Professor A. Westgren of the Nobel Committee in Chemistry noted [https://www.nobelprize.org/prizes/chemistry/1944/ceremony-speech/]:

> In collaboration with Lise Meitner, with whom he has worked for nearly thirty years, Hahn studied from 1936 to 1938 the products obtained by projecting neutrons on to the heaviest elements, thorium and uranium. [...] But towards the end of 1938, Hahn, in an investigation carried out with one of his young colleagues, F. Strassmann, found that one of the products formed through the reaction of uranium with neutrons and which had been assumed to be a kind of radium, behaved chemically in fact like barium. In

> January 1939 Hahn announced this discovery and expressed in very discreet terms the daring opinion that on being allied with neutrons, the atoms of the heaviest elements could split in half as it were and produce elements belonging to the middle of the Periodic Table of the elements. [...]
>
> Hahn's discovery caused great surprise and evoked lively interest among the world's scientists. It was immediately made the object of important theoretical investigations by Lise Meitner and Frisch, who based their study on the theory of the structure of atomic nuclei developed by Bohr. [...]
>
> Without equal in the art of the chemical identification of radioactive elements in minute quantities, Hahn, together with his colleagues, paved the way for the chemical research which had to be carried out on the numerous products of the splitting of heavy atomic nuclei. [...]
>
> The discovery of nuclear fission is very momentous and indeed dangerous, but even more, it is full of promise. [...]
>
> Hahn's work has been inspired throughout by an invincible desire to solve the problems which he has encountered.

For much more information on the history of nuclear fission research in the German-speaking world, see Appendix D.

Fission Process

$$\frac{E_{\text{Coulomb}}}{E_{\text{surface}}} \propto \frac{Z^2}{A} \sim \begin{array}{l}\text{0.4 Z}\\ \text{for heavy}\\ \text{nuclei}\end{array}$$

Fission barrier height:

$V_B \sim 9\,A^{2/3}\,[1 - (Z^2/A)/49]$ MeV

$$+\begin{cases} 0.3\ \text{MeV} & \text{if odd-odd}\\ 0\ \text{MeV} & \text{if odd-even}\\ -0.3\ \text{MeV} & \text{if even-even}\end{cases}$$

+ shell corrections

~ 5.6 MeV for even U/Pu isotopes

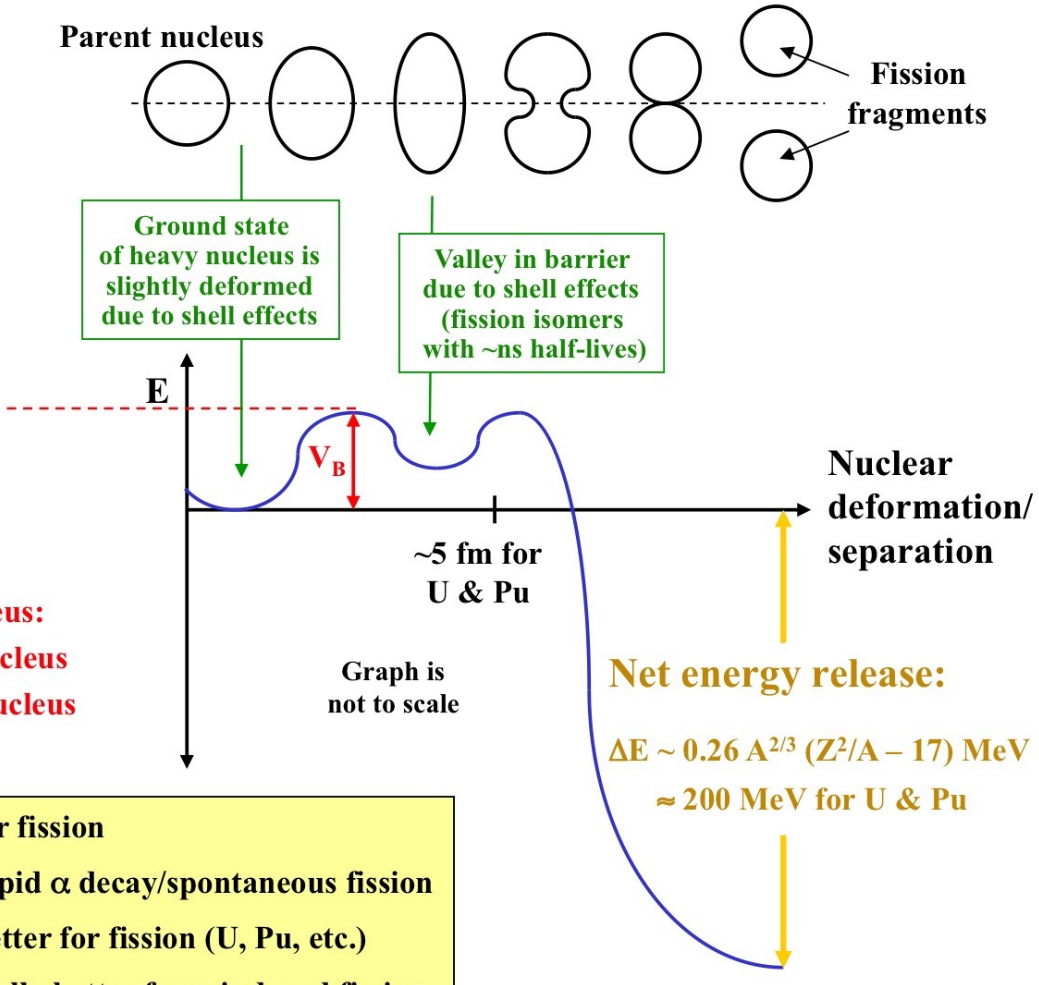
~ 6.2 MeV for odd U/Pu isotopes

Captured neutron adds energy to nucleus:

~ 5 MeV for even U/Pu compound nucleus

~ 6.5 MeV for even-odd compound nucleus

- Z < 90: barrier too high for fission
- Z > 96: barrier too low; rapid α decay/spontaneous fission
- Even-Z nuclei generally better for fission (U, Pu, etc.)
- Odd-N target nuclei generally better for n-induced fission (^{235}U vs. ^{238}U, etc.)


Parent nucleus
Fission fragments
Ground state of heavy nucleus is slightly deformed due to shell effects
Valley in barrier due to shell effects (fission isomers with ~ns half-lives)
E
V_B
Nuclear deformation/ separation
~5 fm for U & Pu
Graph is not to scale

Net energy release:

$\Delta E \sim 0.26\,A^{2/3}\,(Z^2/A - 17)$ MeV

≈ 200 MeV for U & Pu

Figure 8.17: The fission reaction rate depends on the potential energy peak or fission barrier that one nucleus must pass through in order to become two separate nuclei. The parent nucleus undergoing fission has Z protons, N neutrons, and $A = Z + N$ nucleons.

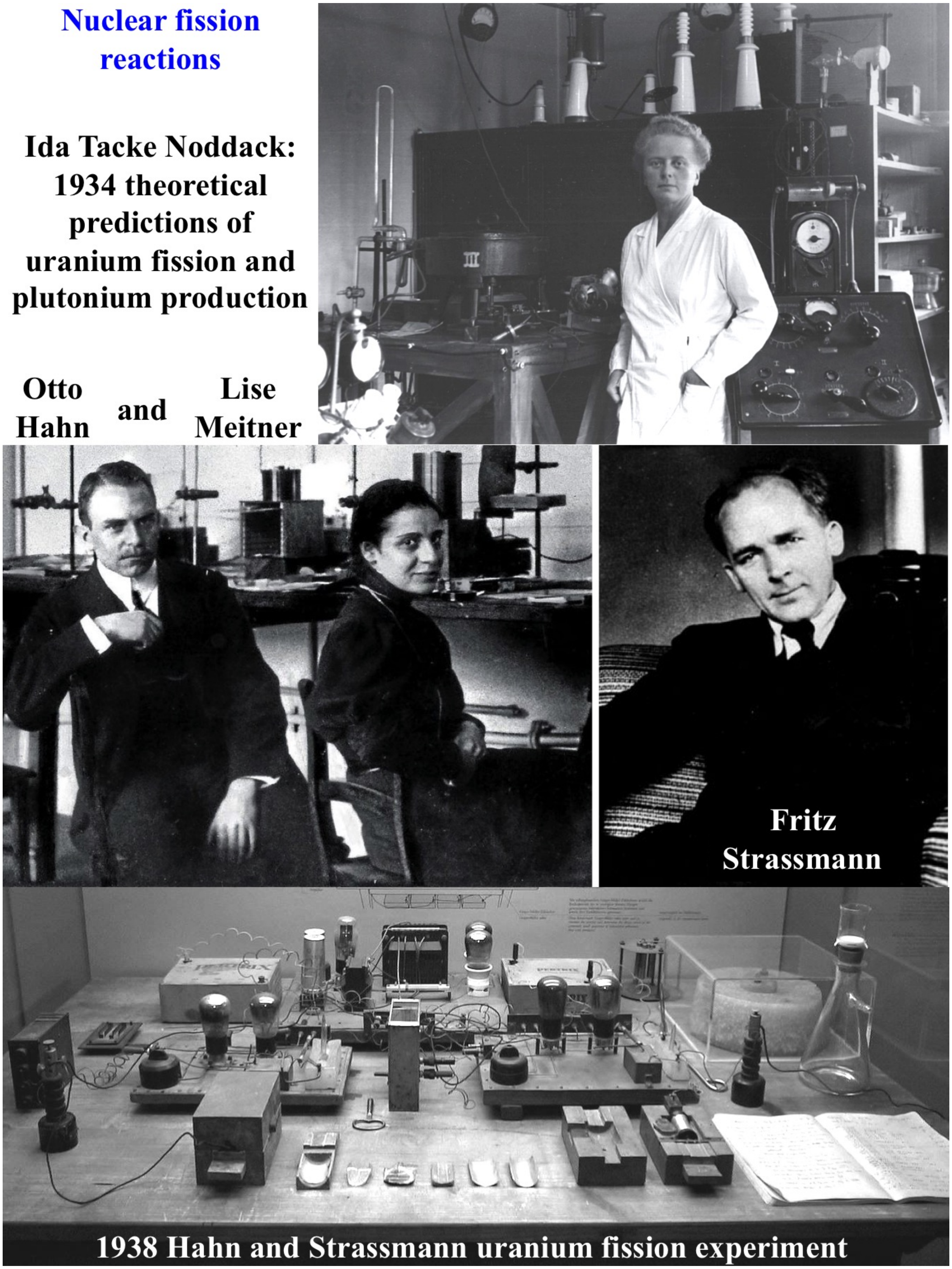

Nuclear fission reactions
Ida Tacke Noddack: 1934 theoretical predictions of uranium fission and plutonium production
Otto Hahn
and
Lise Meitner
Fritz Strassmann
1938 Hahn and Strassmann uranium fission experiment

Figure 8.18: In 1934, Ida Tacke Noddack accurately predicted both the neutron-induced fission of uranium and the production of a new fissile element 94 (later named plutonium) via neutron capture in uranium. Otto Hahn and Fritz Strassmann demonstrated uranium fission reactions in their 1938 experiment, and then Lise Meitner and her nephew Otto Frisch provided further theoretical analysis.

8.6 Nuclear Fusion Reactions

In fusion, two small nuclei join together to form a larger nucleus, generally releasing a large amount of energy in the process. Forcing small nuclei together even though they are positively charged and repel each other typically requires enormous thermal energies (temperatures) and pressures. If fusion fuel is so dense and so well confined that the energy released by one fusion reaction is trapped within the fuel and triggers additional fusion reactions, a chain reaction of fusion reactions can occur (analogous to the chain reaction of fission reactions). Stars and hydrogen bombs are both sufficiently large and dense to trap the fusion energy and sustain a fusion chain reaction. To date it has not been possible to create a practical fusion reactor, though, since too much of the fusion energy escapes from any system that is smaller (and less destructive) than a hydrogen bomb.

Fusion reactions such as those that power the sun and other stars were proposed and theoretically analyzed by Fritz Houtermans (German, 1903–1966) and his student Robert Atkinson (British but studied in Germany, 1898–1982) in 1928, and published in 1929 (Figs. 8.19–8.20). The abstract from that paper demonstrates the remarkable and very early insight that Houtermans and Atkinson had [Atkinson and Houtermans 1929a]:

> Die quantenmechanische Wahrscheinlichkeit dafür, daß ein Proton in einen Atomkern eindringt, wird nach der Methode von Gamow berechnet. Dabei zeigt sich, daß unter den Temperatur- und Dichteverhältnissen im Innern der Sterne die Eindringung von Protonen, nicht aber von α-Teilchen, in leichtere Elemente genügend häufig vorkommt, um dort einen Aufbau dieser Elemente wahrscheinlich erscheinen zu lassen. Daraus ergibt sieh die Möglichkeit, die Energieentwicklung der Sterne auss den Massendefekten der Elemente zu erklären, wobei die Annahme von Sechserstößen für den He-Aufbau vermieden wird. Hieran schließen sich einige weitere hypothetische Betrachtungen über den Aufbau der schwereren Elemente.

> The quantum-mechanical probability of a proton penetrating into an atomic nucleus is calculated by Gamow's method. It is found that for the temperature and density values in the interior of the stars, the penetration of protons, but not of alpha particles, into lighter elements is sufficiently frequent to make a fusion of these elements probable. This gives us the possibility of explaining the energy production of the stars by the mass defects of the elements, avoiding the assumption of six steps for the production of helium. This is followed by a few other hypothetical considerations on the structure of the heavier elements.

The detailed theory of fusion reactions was refined during the period 1937–1939 by Carl Friedrich von Weizsäcker and Hans Bethe (German, 1906–2005). For that work, Bethe won a Nobel Prize in Physics in 1967. In the award ceremony speech for Bethe, Professor O. Klein of the Swedish Academy of Sciences explained [https://www.nobelprize.org/prizes/physics/1967/ceremony-speech/]:

> [...] At that time it was already apparent that Bethe belonged to the small group of young theoretical physicists who through skill and knowledge were particularly qualified for tackling the many theoretical problems turning up in close connection with the rapidly appearing experimental discoveries. The centre of these problems was to find the properties of the force that keeps the protons and neutrons together in the nucleus, the counterpart of the electric force which binds the atomic electrons to the nucleus.

> Bethe's contributions to the solution of these problems have been numerous and are still continuing. They put him clearly in the first row among the workers in this field – as in several other fields. Moreover, about the middle of the thirties he wrote, partly alone, partly together with some colleagues, what nuclear physicists at the time used to call the Bethe bible, a penetrating review of about all that was known of atomic nuclei, experimental as well as theoretical.
>
> This extensive and profound knowledge of his regarding atomic nuclei together with a rare gift of rapidly grasping the essence of a physical problem and finding ways of solving it explains that Bethe could so swiftly do the work awarded by the Nobel Prize. He started his work after a conference taking place in Washington in March 1938 and the paper containing a thorough description of it was delivered for print at the beginning of September the same year. During that conference and afterwards he seems also to have acquired the necessary astrophysical knowledge. [...]
>
> [...] If it were not for the quantum-mechanical tunnel effect studied very closely in this connection by Gamow – who must be considered the main forerunner of Bethe with respect to the application of nuclear physics to astronomy – even the velocities of the protons at the high temperature of the sun would not be able to produce any such processes. But through this effect the required slow reactions do occur. [...]
>
> A very important part of his work resulted in eliminating a great number of thinkable nuclear processes under the conditions at the centre of the sun, after which only two possible processes remained. The simplest of them begins with two protons colliding and forming a nucleus of heavy hydrogen, the surplus of electric charge vanishing in the form of a positive electron. After capturing a few more protons the result of the process is the formation of a helium nucleus from four protons. Thereby the energy release from a given weight of hydrogen is nearly 20 million times greater than that produced by burning the same weight of carbon into carbon dioxide. The second process is more complicated. It requires the presence of carbon which, however, will practically not be consumed but acts as a catalyst, the result being the same as in the former process. It should be mentioned that the first process had been proposed a few years earlier by Atkinson and later discussed by von Weizsacker, who also considered the second process independently of and at about the same time as Bethe. [...]

For much more information on the history of nuclear fusion research in the German-speaking world, see Section D.9.

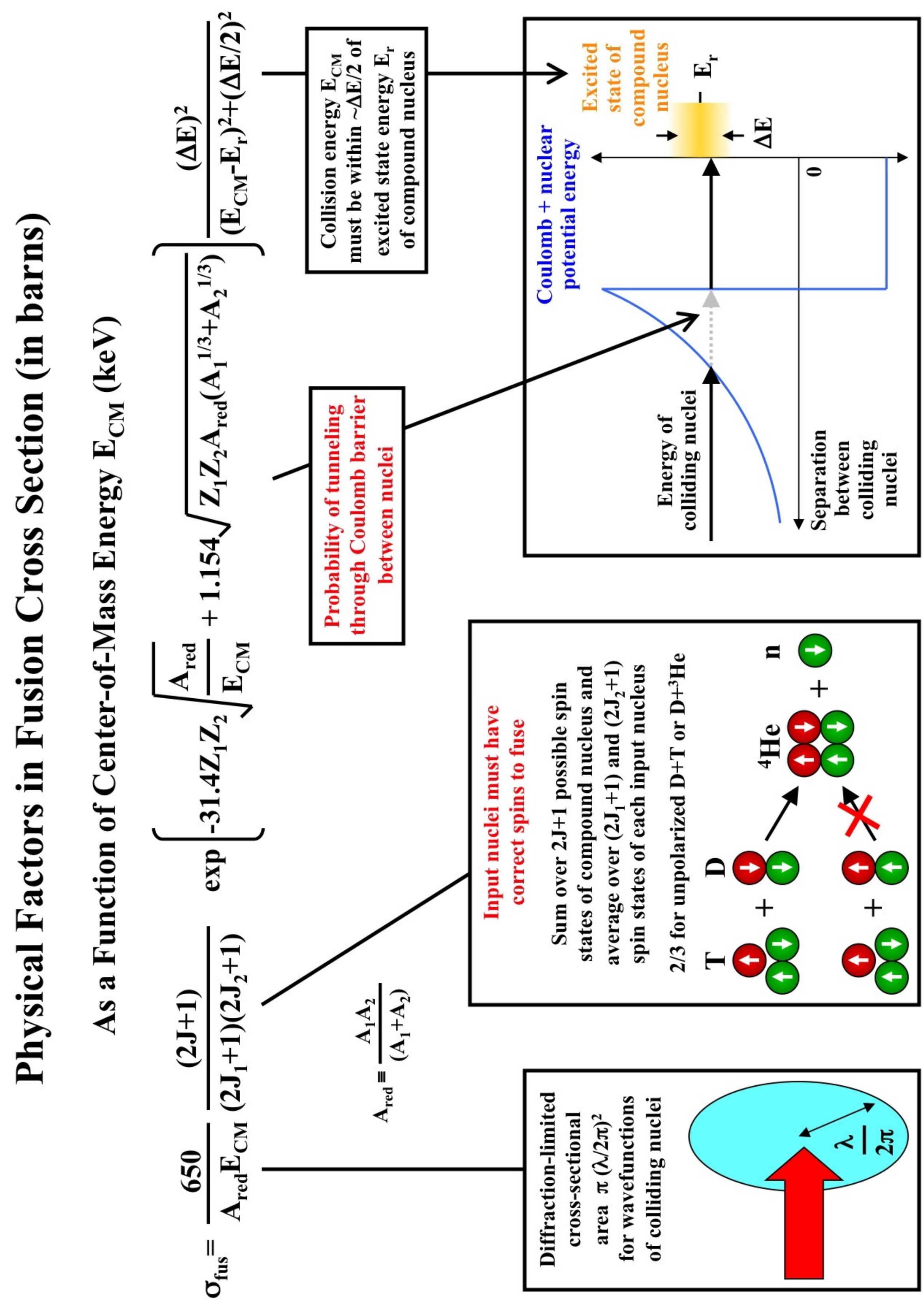

Physical Factors in Fusion Cross Section (in barns)
As a Function of Center-of-Mass Energy E_{CM} (keV)
$\sigma_{fus} = \frac{650}{A_{red}E_{CM}} \frac{(2J+1)}{(2J_1+1)(2J_2+1)} \exp\left[-31.4 Z_1 Z_2 \sqrt{\frac{A_{red}}{E_{CM}}} + 1.154\sqrt{Z_1 Z_2 A_{red}(A_1^{1/3}+A_2^{1/3})}\right] \frac{(\Delta E)^2}{(E_{CM}-E_r)^2+(\Delta E/2)^2}$
$A_{red} \equiv \frac{A_1 A_2}{(A_1+A_2)}$
Diffraction-limited cross-sectional area $\pi(\lambda/2\pi)^2$ for wavefunctions of colliding nuclei
$\frac{\lambda}{2\pi}$
Input nuclei must have correct spins to fuse
Sum over 2J+1 possible spin states of compound nucleus and average over $(2J_1+1)$ and $(2J_2+1)$ spin states of each input nucleus
2/3 for unpolarized D+T or D+^{3}He
T
+
D
^{4}He
+
n
Probability of tunneling through Coulomb barrier between nuclei
Energy of colliding nuclei
Separation between colliding nuclei
Coulomb + nuclear potential energy
0
ΔE
E_r
Excited state of compound nucleus
Collision energy E_{CM} must be within ~ΔE/2 of excited state energy E_r of compound nucleus

Figure 8.19: The fusion reaction rate is expressed in terms of the reaction cross section formula, which contains four different factors that describe different physical effects.

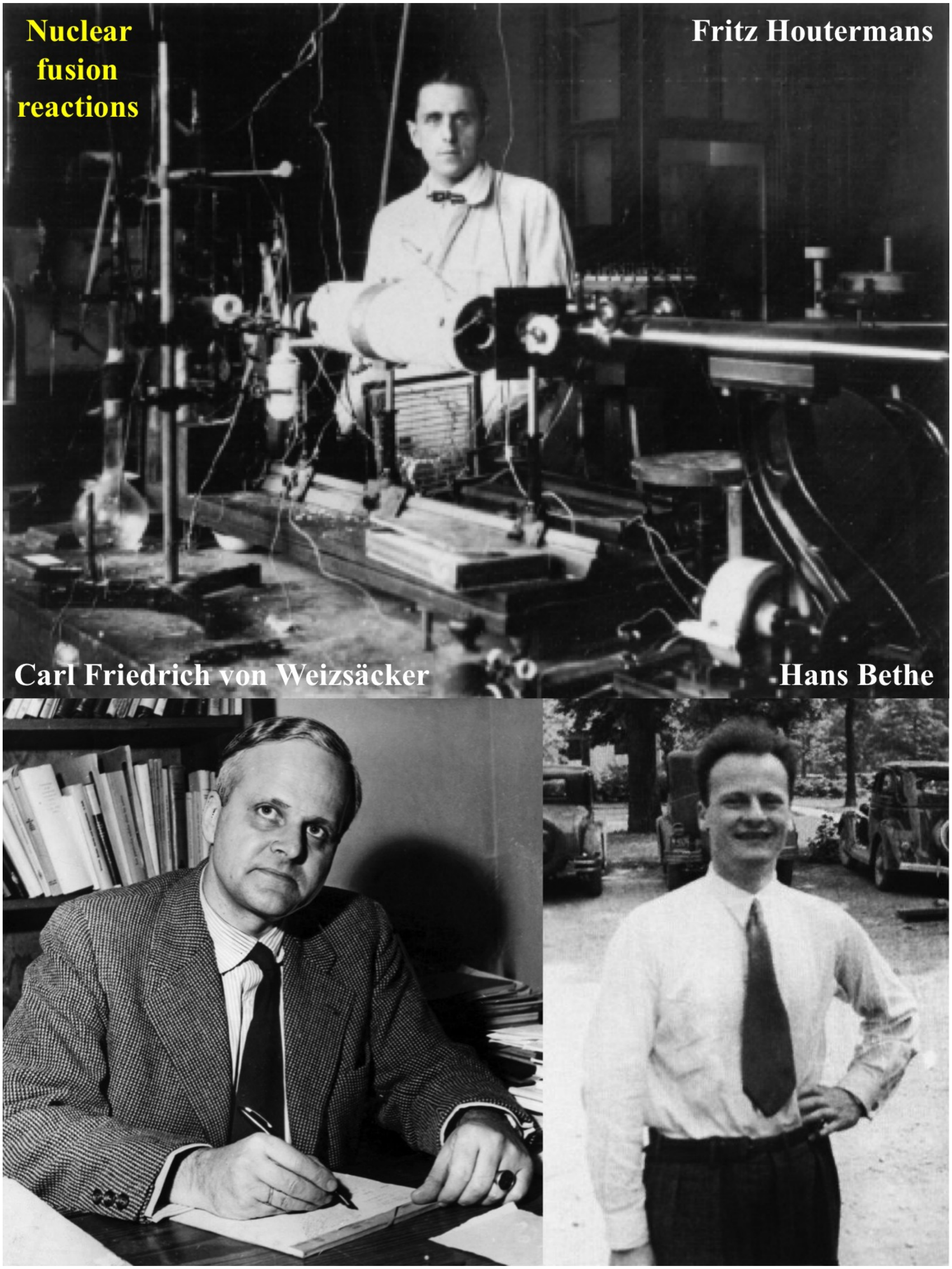

Nuclear fusion reactions
Fritz Houtermans
Carl Friedrich von Weizsäcker
Hans Bethe

Figure 8.20: Friedrich “Fritz” Houtermans and his student Robert Atkinson described and calculated nuclear fusion reactions in stars in 1928–1929. Carl Friedrich von Weizsäcker and Hans Bethe refined those calculations 1937–1939.

8.7 Nuclear Engineering in the United States and United Kingdom

A large number of scientists who were trained in the German-speaking research world moved temporarily or permanently to the United States and/or United Kingdom and made vital contributions to those countries' nuclear programs both during and after World War II.[5] Some examples of German-speaking and German-educated scientists who played critical roles in the U.S./U.K. nuclear programs are listed in Table 8.1 and shown in Figs. 8.21–8.27. The table and figures also list a few other scientists who were very closely coupled into the German research system during their careers, such as Niels Bohr, a Dane, and Enrico Fermi, an Italian. Note that even the American-born J. Robert Oppenheimer, who was the scientific director of the wartime nuclear program, the Manhattan Project, had a German father and second-generation German-American mother, was raised speaking German, repeatedly visited family in Germany during his childhood, and received his Ph.D. in Germany under Max Born at Göttingen University.

The U.S. nuclear program was initiated by a 2 August 1939 letter to Franklin Roosevelt from two refugees from the German-speaking scientific world, Albert Einstein (who signed the letter) and Leo Szilard (who helped write the letter) [Fig. 8.21 and https://www.atomicarchive.com/resources/documents/beginnings/einstein.html]:

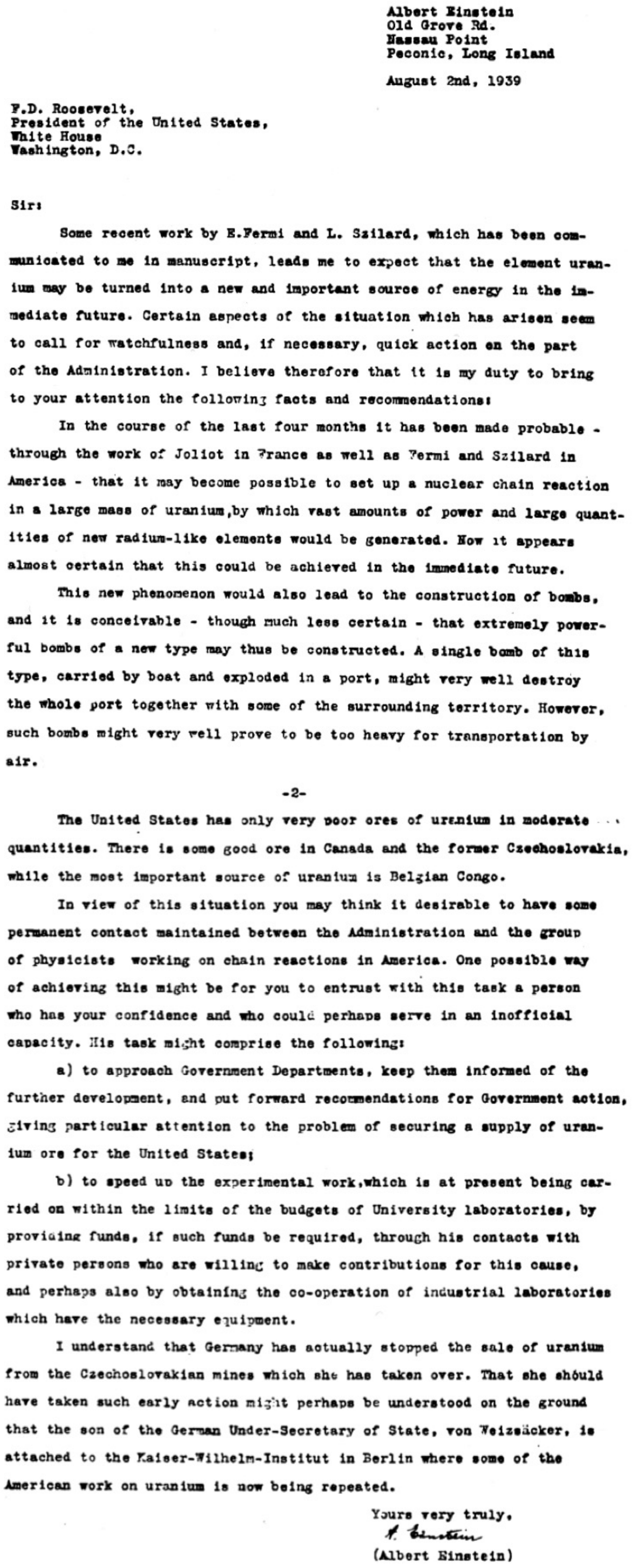
> Albert Einstein
> Old Grove Rd.
> Nassau Point
> Peconic, Long Island
>
> August 2nd, 1939
>
> F.D. Roosevelt,
> President of the United States,
> White House
> Washington, D.C.
>
> Sir:
>
> Some recent work by E. Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:
>
> In the course of the last four months it has been made probable—through the work of Joliot in France as well as Fermi and Szilard in America—that it may become possible

---

[5] Bethe 1991, 1997; Bird and Sherwin 2005; Blatt and Weisskopf 1952; Brown and Lee 2006; Coster-Mullen 2012; Ford 2015; Groves 1962; Chuck Hansen 1988, 2007; István Hargittai 2006, 2010; Hawkins et al. 1983; Hoddeson et al. 1993; Jungk 1958; Kelly 2007; Lanouette and Silard 1992; Medawar and Pyke 2000; Nachmansohn 1979; Bruce Cameron Reed 2015a, 2019; Rhodes 1986, 1995; Schweber 2012; Serber 1992; Smyth 1945; Sublette 2019; Szanton 1992; Teller 1979; Teller and Shoolery 2001; Teller et al. 1968; Ulam 1991; Weart and Szilard 1978; Weinberg and Wigner 1958; Weisskopf 1972, 1989; Wigner 1967.

> to set up a nuclear chain reaction in a large mass of uranium, by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.
>
> This new phenomenon would also lead to the construction of bombs, and it is conceivable—though much less certain—that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove too heavy for transportation by air.
>
> The United States has only very poor ores of uranium in moderate quantities. There is some good ore in Canada and the former Czechoslovakia, while the most important source of uranium is Belgian Congo.
>
> In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of physicists working on chain reactions in America. One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an unofficial capacity. His task might comprise the following:
>
> a) to approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States;
>
> b) to speed up the experimental work, which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the co-operation of industrial laboratories which have the necessary equipment.
>
> I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsäcker, is attached to the Kaiser-Wilhelm-Institut in Berlin where some of the American work on uranium is now being repeated.
>
> Yours very truly,
>
> Albert Einstein

Einstein's letter prompted Franklin Roosevelt to authorize the initiation of what would become the Manhattan Project, and of course Einstein's famous equation $E = mc^2$ was the foundation for how a tiny fraction of the mass of fission fuel could be converted into an enormous (and potentially enormously destructive) amount of energy. In March 1940, Einstein and Szilard wrote a second letter to Roosevelt that successfully persuaded him to accelerate the nuclear program. Later, Einstein carried out calculations to help the United States use gaseous diffusion to enrich uranium (concentrate the fissionable U-235 isotope of uranium). Separately, he worked with the U.S. Navy on various military projects. Nonetheless, U.S. government officials such as J. Edgar Hoover distrusted Einstein's longtime inclination toward pacifism and excluded him from the official Manhattan Project [Isaacson 2007, pp. 469–486].



Albert Einstein
Old Grove Rd.
Nassau Point
Peconic, Long Island

August 2nd, 1939

F.D. Roosevelt,
President of the United States,
White House
Washington, D.C.

Sir:

Some recent work by E.Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable - through the work of Joliot in France as well as Fermi and Szilard in America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium,by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable - though much less certain - that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

-2-

The United States has only very poor ores of uranium in moderate quantities. There is some good ore in Canada and the former Czechoslovakia, while the most important source of uranium is Belgian Congo.

In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of physicists working on chain reactions in America. One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an inofficial capacity. His task might comprise the following:

a) to approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States;

b) to speed up the experimental work,which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the co-operation of industrial laboratories which have the necessary equipment.

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsäcker, is attached to the Kaiser-Wilhelm-Institut in Berlin where some of the American work on uranium is now being repeated.

Yours very truly,
A. Einstein
(Albert Einstein)

Figure 8.21: The U.S. nuclear program was initiated by a 2 August 1939 letter to Franklin Roosevelt from two refugees from the German-speaking scientific world, Albert Einstein (who signed the letter) and Leo Szilard (who helped write the letter).

Name	**Born**	**Lived**	**German world**	**Scientific contributions**
Hans Bethe	German	1906–2005	Education, work	Fission-/H-bomb theory
Felix Bloch	Swiss	1905–1983	Education, work	Fission reactions
Niels Bohr	Danish	1885–1962	Work	Neutron initiator
Karl-Friedrich Bonhoeffer	German	1899–1957	Education, work	Fission reactors
Gregory Breit	Russian	1899–1981	Work	Bomb design
Egon Bretscher	Swiss	1901–1973	Education, work	Plutonium, H bomb
Rudolf Brill	German	1899–1989	Education, work	Nuclear chemistry
Englebert Broda	Austrian	1910–1983	Education, work	Fission reactions
Adolf Busemann	German	1901–1986	Education, work	Shock waves
Frederic de Hoffmann	German	1924–1989	Education	H bomb, reactors
Martin Deutsch	Austrian	1917–2002	Family, education	Fission measurements
Rudolf Edse	German	1913–1998	Education, work	Nuclear chemistry
Albert Einstein	German	1879–1955	Education, work	Letters to FDR, gaseous diffusion
Wilhelm Eitel	German	1891–1979	Education, work	Materials science
Gerhard Falck (?)	German	19??–19??	Education, work	Uranium?
Enrico Fermi	Italian	1901–1954	Work	Reactors, H bomb
Wolfgang Finkelnburg	German	1905–1967	Education, work	Fission reactors
Rudolf Fleischmann	German	1903–2002	Education, work	Isotope separation
Siegfried Flügge	German	1912–1997	Education, work	Many aspects of fission and H-bombs
James Franck	German	1882–1964	Education, work	Plutonium
Herbert Freundlich	German	1880–1941	Education, work	MAUD Committee
Otto Frisch	Austrian	1904–1979	Education, work	Critical mass
Klaus Fuchs	German	1911–1988	Education	Implosion, H bomb
George Gamow	Russian	1904–1968	Education, work	H bomb
Gertrude Goldhaber	German	1911–1998	Education	Spontaneous fission
Maurice Goldhaber	Austrian	1911–2011	Education	Neutron moderation/reactions
Samuel Goudsmit	Dutch	1902–1978	Education, work	Investigation of German program
Wilhelm Groth	German	1904–1977	Education, work	Centrifuges, H-bomb
Dieter Gruen	German	1922–	Family, education	U enrichment, fission reactors
Gottfried Guderley	German	1910–1997	Education, work	Shock waves
Eugene Guth	Hungarian	1905–1990	Education, work	Nuclear physics, Oak Ridge, polymers
Hans von Halban	German	1908–1964	Education, work	Reactors
Paul Harteck	Austrian	1902–1985	Education, work	Many aspects of fission and H-bombs
Richard Herzog	Austrian	1911–1999	Education, work	Isotope separation
Lilli (Schwenk) Hornig	Czech	1921–2017	Family, education	Plutonium, explosive lenses
Johannes Hans Jensen	German	1907–1973	Education, work	Nuclear theory, isotope separation
Willibald Jentschke	Austrian	1911–2002	Education, work	Many aspects of fission and H-bombs
Ulrich Jetter	German	1914–??	Education, work	H-bombs
Georg Joos	German	1894–1959	Education, work	Fission applications
Hartmut Kallmann	German	1896–1978	Education, work	Fission, fusion, radiation detectors

Table 8.1: Examples of German-speaking creators (and some scientists who were very strongly coupled to the German-speaking world) who contributed to the wartime and postwar U.S./U.K. nuclear programs, their nationality by birth, the years they lived, their background in the German-speaking world, and their major contributions to the U.S./U.K. programs.

Name	**Born**	**Lived**	**German world**	**Scientific contributions**
Hans Kammler	German	1901–??	Education, work	Bomb designs/components
Nicholas Kemmer	Russian	1911–1998	Education, work	Plutonium
George Kistiakowsky	Russian	1900–1982	Education	Implosion
Gerald Klein	German	19??–19??	Education, work	Nuclear devices
Stanley Kronenberg	Polish	1927–2000	Education	Nuclear bomb tests
Heinrich Gerhard Kuhn	German	1904–1994	Education, work	Gaseous diffusion
Nicholas Kurti	Hungarian	1908–1998	Education, work	Gaseous diffusion
Heinz London	German	1907–1970	Education, work	MAUD Committee
Heinz Maier-Leibnitz	German	1911–2000	Education, work	Fission reactors
Werner Maurer	German	19??–19??	Education, work	Fission reactors
Maria Goeppert Mayer	German	1906–1972	Education	U enrichment, H bomb
Kurt Mendelssohn	German	1906–1980	Education, work	MAUD Committee
Hans Mohaupt	Swiss	1915–2001	Education, work	Shaped charges
Stanisław Mrozowski	Polish	1902–1999	Education, work	U enrichment
John von Neumann	Hungarian	1903–1957	Education, work	Implosion, H bomb
Klara Dan von Neumann	Hungarian	1911–1963	Education, work	Computation
Lothar Nordheim	German	1899–1985	Education, work	Reactors, plutonium
J. Robert Oppenheimer	American	1904–1967	Family, education	Director
Friedrich Paneth	Austrian	1887–1958	Education, work	Nuclear chemistry
Wolfgang Panofsky	German	1919–2007	Family, education	Shockwaves
Rudolf Peierls	German	1907–1995	Education	Bomb design
George Placzek	Czech	1905–1955	Education, work	Reactors, bomb theory
I. I. Rabi	Austrian	1898–1988	Work	Bomb theory
Eugene Rabinowitch	Russian	1901–1973	Education, work	Reactors
Joseph Rotblat	Polish	1908–2005	Education	Radiation
Heinz Schlicke (?)	German	1912–2006	Education, work	Detonators?
Otto Schwede	German	1912–2005	Education, work	U enrichment
Emilio Segrè	Italian	1905–1989	Education	Fission measurements
Franz Simon	German	1893–1956	Education, work	U enrichment
Kurt Starke	German	1911–2000	Education, work	Enrichment, breeding, extraction
Ernst Stuhlinger	German	1913–2008	Education, work	Reactors, particle accelerators
Hans Suess	Austrian	1909–1993	Education, work	Nuclear theory, D_2O, enrichment
Leo Szilard	Hungarian	1898–1964	Education, work	Reactors
Edward Teller	Hungarian	1908–2003	Education, work	H bomb
Stanislaw Ulam	Polish	1909–1984	Education	Implosion, H bomb
Victor Weisskopf	Austrian	1908–2002	Education, work	Fission bomb theory
Wilhelm Westphal	German	1882–1978	Education, work	Fission applications
Eugene Wigner	Hungarian	1902–1995	Education, work	Reactors, plutonium
Friedwardt Winterberg	German	1929–	Education, work	Many aspects of fission/H-bombs
Karl Wirtz	German	1910–1994	Education, work	Heavy water, enrichment, reactors
Gernot Zippe	Austrian	1917–2008	Education, work	Uranium centrifuges

Table 8.1 (continued).

Likewise, the U.K. nuclear program was also initiated by two refugees from the German-speaking world, Otto Frisch and Rudolf Peierls. In a March 1940 memorandum to the U.K. government, they wrote [https://www.atomicarchive.com/resources/documents/beginnings/frisch-peierls.html]:

> The attached detailed report concerns the possibility of constructing a "super-bomb" which utilises the energy stored in atomic nuclei as a source of energy. The energy liberated in the explosion of such a super-bomb is about the same as that produced by the explosion of 1,000 tons of dynamite. This energy is liberated in a small volume, in which it will, for an instant, produce a temperature comparable to that in the interior of the sun. The blast from such an explosion would destroy life in a wide area. The size of this area is difficult to estimate, but it will probably cover the center of a big city.
>
> In addition, some part of the energy set free by the bomb goes to produce radioactive substances, and these will emit very powerful and dangerous radiations. The effects of these radiations is greatest immediately after the explosion, but it decays only gradually and even for days after the explosion any person entering the affected area will be killed.
>
> Some of this radioactivity will be carried along with the wind and will spread the contamination; several miles downwind this may kill people.
>
> In order to produce such a bomb it is necessary to treat a substantial amount of uranium by a process which will separate from the uranium its light isotope (U235) of which it contains about 0.7 percent. Methods for the separation of such isotopes have recently been developed. They are slow and they have not until now been applied to uranium, whose chemical properties give rise to technical difficulties. But these difficulties are by no means insuperable. We have not sufficient experience with large-scale chemical plant to give a reliable estimate of the cost, but it is certainly not prohibitive.
>
> It is a property of these super-bombs that there exists a "critical size" of about one pound. A quantity of the separated uranium isotope that exceeds the critical amount is explosive; yet a quantity less than the critical amount is absolutely safe. The bomb would therefore be manufactured in two (or more) parts, each being less than the critical size, and in transport all danger of a premature explosion would be avoided if these parts were kept at a distance of a few inches from each other. The bomb would be provided with a mechanism that brings the two parts together when the bomb is intended to go off. [...]

The U.S. and U.K. nuclear programs eventually joined together for the duration of the war under the umbrella of the Manhattan Project. As listed in Table 8.1 and shown in Figs. 8.28–8.30, German-speaking and German-trained scientists played critical roles in all areas of the Manhattan Project, including enriching uranium, developing fission reactors, producing plutonium, and creating fission bombs. The fission reactor technologies that they developed were ultimately used to power everything from nuclear submarines to commercial electric generation plants.

There is also evidence that some scientists who had spent the war in Germany may have materially contributed to the U.S. nuclear program in the crucial final months of the war (see p. 4692 for more details). For example, when the German submarine U-234 surrendered to the United States in May 1945, it was found to contain 560 kg of uranium oxide (possibly enriched), infrared fuses that may have been suitable for implosion bombs, at least two experts on those materials (Gerhard Falck for the uranium and Heinz Schlicke for the infrared fuses), and potentially other nuclear-related materials and information. As another important example, Hans Kammler, who was in charge of virtually all advanced German weapons programs (including the nuclear program) by the end of the war, was secretly captured and kept indefinitely by the United States for extended interrogations (see pp. 4931–4959). In view of the fact that the United States never turned him over to the Nuremberg war crimes trials or even informed those trials that Kammler was alive and in U.S. custody, it seems likely that Kammler provided the United States with valuable information and/or materials. It is possible that assistance from these and other German sources may have appreciably accelerated the delivery schedule for the first U.S. fission bombs and also helped the postwar U.S. nuclear program. Much more archival research is needed to address this question.

After the war, many of these German-speaking and German-educated scientists (most notably Edward Teller and Stanislaw Ulam) went on to create the first U.S. fusion bombs (hydrogen or H-bombs) in 1952 and 1954. Postwar U.S./U.K. nuclear programs were also aided directly or indirectly by an influx of many additional German and Austrian scientists who were from or at least had knowledge of the German nuclear program, such as Karl-Friedrich Bonhoeffer, Wernher von Braun, Rudolf Brill, Adolf Busemann, Walter Dornberger, Rudolf Edse, Krafft Ehricke, Wilhelm Eitel, Gerhard Falck, Karl Fiebinger, Wolfgang Finkelnburg, Rudolf Fleischmann, Siegfried Flügge, Walter Glaser, Wilhelm Groth, Gottfried Guderley, Paul Harteck, Otto Haxel, Richard Herzog, Johannes Hans Jensen, Willibald Jentschke, Ulrich Jetter, Georg Joos, Hartmut Kallmann, Hans Kammler, Gerald Klein, Stanley Kronenberg, Heinz Maier-Leibnitz, Werner Maurer, Hugo Neuert, Walter Nielsch (?), Edgar Petersen, Heinz Schlicke, Otto Schwede, Erich Schumann, Edmund Sorg, Kurt Starke, Ernst Stuhlinger, Hans Suess, Herbert Wagner, Wilhelm Westphal, Friedwardt Winterberg, Karl Wirtz, Gernot Zippe, etc. (p. 4992).

For more information on the influence of the wartime German nuclear program on the wartime and postwar U.S./U.K. nuclear programs, see Sections 8.8.14 and D.14.

Klaus Fuchs, who had spent many years working on the U.S./U.K. fission and fusion bomb programs, was discovered in 1950 to have been forwarding details of those programs to the Soviet Union throughout that time; he was imprisoned in the United Kingdom before being handed over to East Germany in 1959. Some scientists such as Rudolf Fleischmann, Siegfried Flügge, and Johannes Hans Jensen returned to Europe sooner or later. However, most of the German-trained scientists continued their careers in nuclear and defense fields in the United States, in some cases exerting their influence for many decades (Edward Teller died in 2003 and Hans Bethe died in 2005).

Of course, the massive U.S. nuclear weapons program was built up by U.S. industries, and employed many notable U.S.-born scientists, such as Ernest Lawrence, Glenn Seaborg, and John Wheeler and his freshly graduated student Richard Feynman. Nonetheless, for a program that involved over 100,000 people and was critical to the U.S. war effort, it is remarkable how many of the key innovations were made by scientists who came from the German-speaking world. One must wonder how rapidly the U.S. nuclear program would have advanced if it had not had the benefit of any personnel or information from the greater German-speaking scientific world.

Even the Atomic Heritage Foundation, based in Washington D.C. and founded to celebrate the history and success of the United States nuclear program, has publicly recognized the role that scientists from the greater German-speaking world played in that program [www.atomicheritage.org/article/scientist-refugees-and-manhattan-project]:

> One of the ironies of Hitler's desire for racial purity was that it drove out of continental Europe or into the camps many individuals who would have been extremely useful to the Axis war effort. Nowhere was this more evident than in the effort to produce an atomic bomb. A startling proportion of the most famous names on the project belonged to scientists who came to England or America to flee from the Axis. The large number of refugees and immigrants working on the Manhattan Project gave the American nuclear program an international character unusual in such a top-secret program—and unique amongst the nuclear programs that followed in other countries—and helped give life in Los Alamos, NM during the war its unique character.

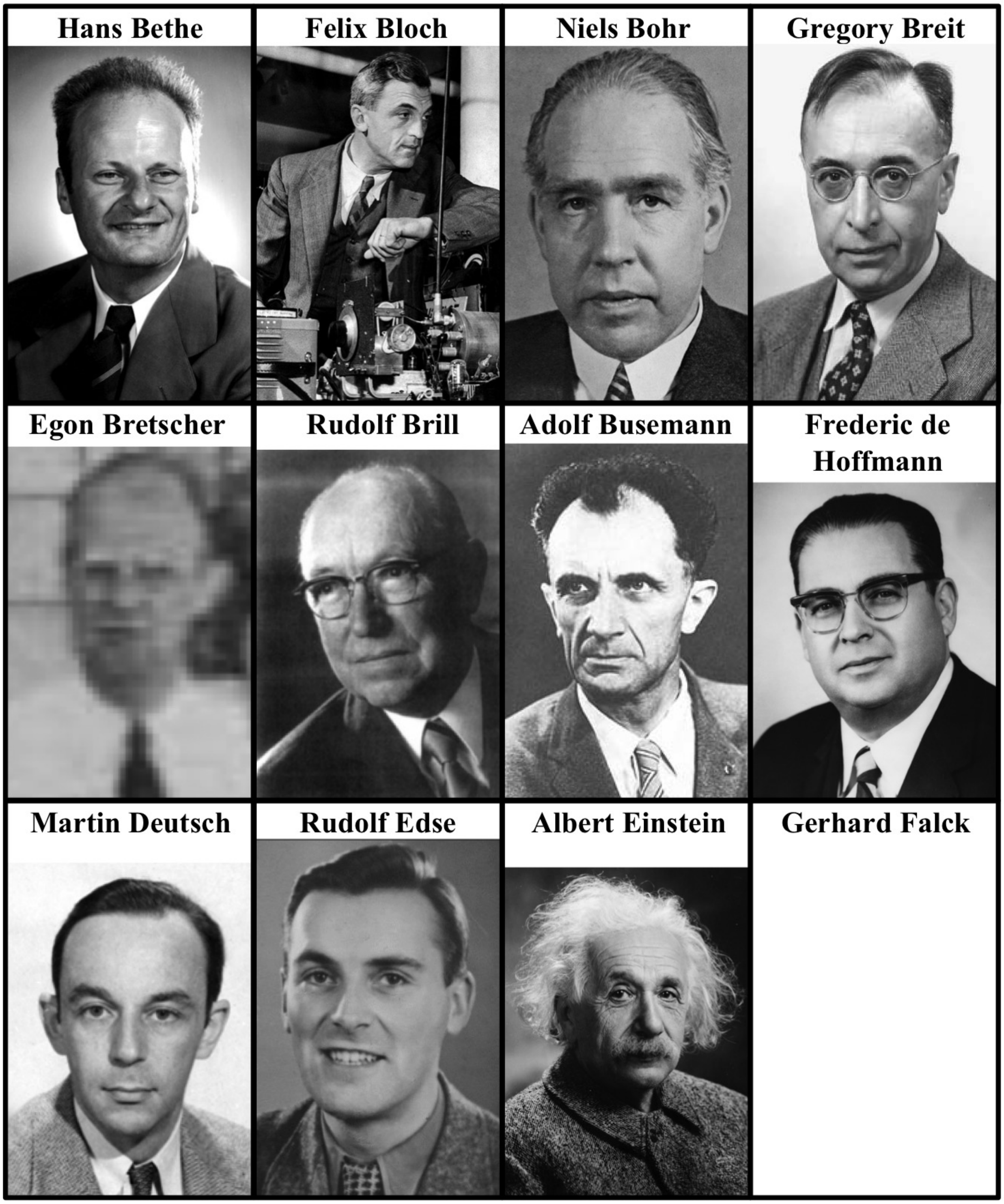

Hans Bethe
Felix Bloch
Niels Bohr
Gregory Breit
Egon Bretscher
Rudolf Brill
Adolf Busemann
Frederic de Hoffmann
Martin Deutsch
Rudolf Edse
Albert Einstein
Gerhard Falck

Figure 8.22: Examples of German-speaking scientists (and some scientists who were very strongly coupled to the German-speaking world) who contributed to the wartime and postwar U.S./U.K. nuclear programs.

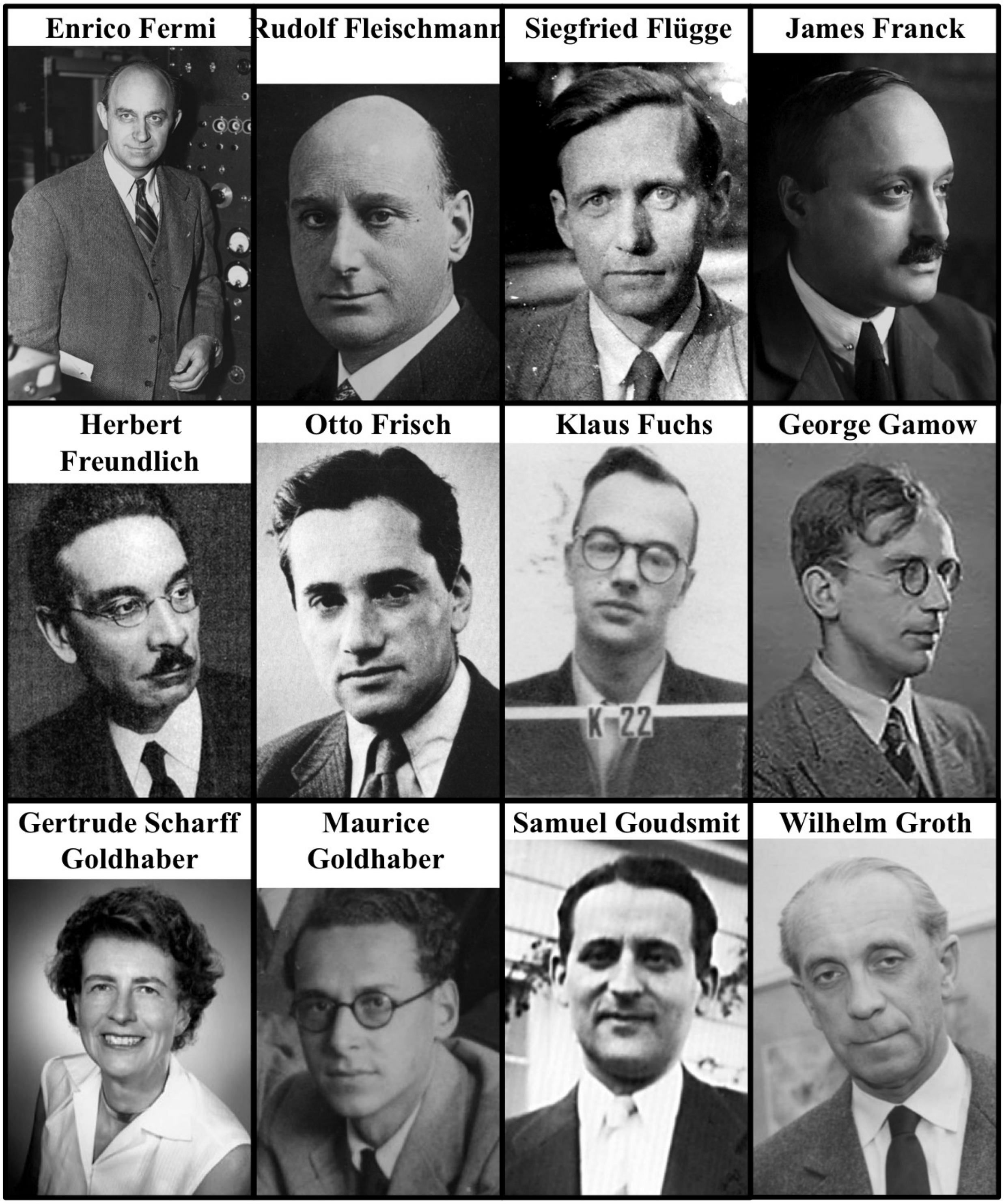

Enrico Fermi
udolf Fleischman
Siegfried Flügge
James Franck
Herbert Freundlich
Otto Frisch
Klaus Fuchs
K 22
George Gamow
Gertrude Scharff Goldhaber
Maurice Goldhaber
Samuel Goudsmit
Wilhelm Groth

Figure 8.23: More examples of German-speaking scientists (and some scientists who were very strongly coupled to the German-speaking world) who contributed to the wartime and postwar U.S./U.K. nuclear programs.

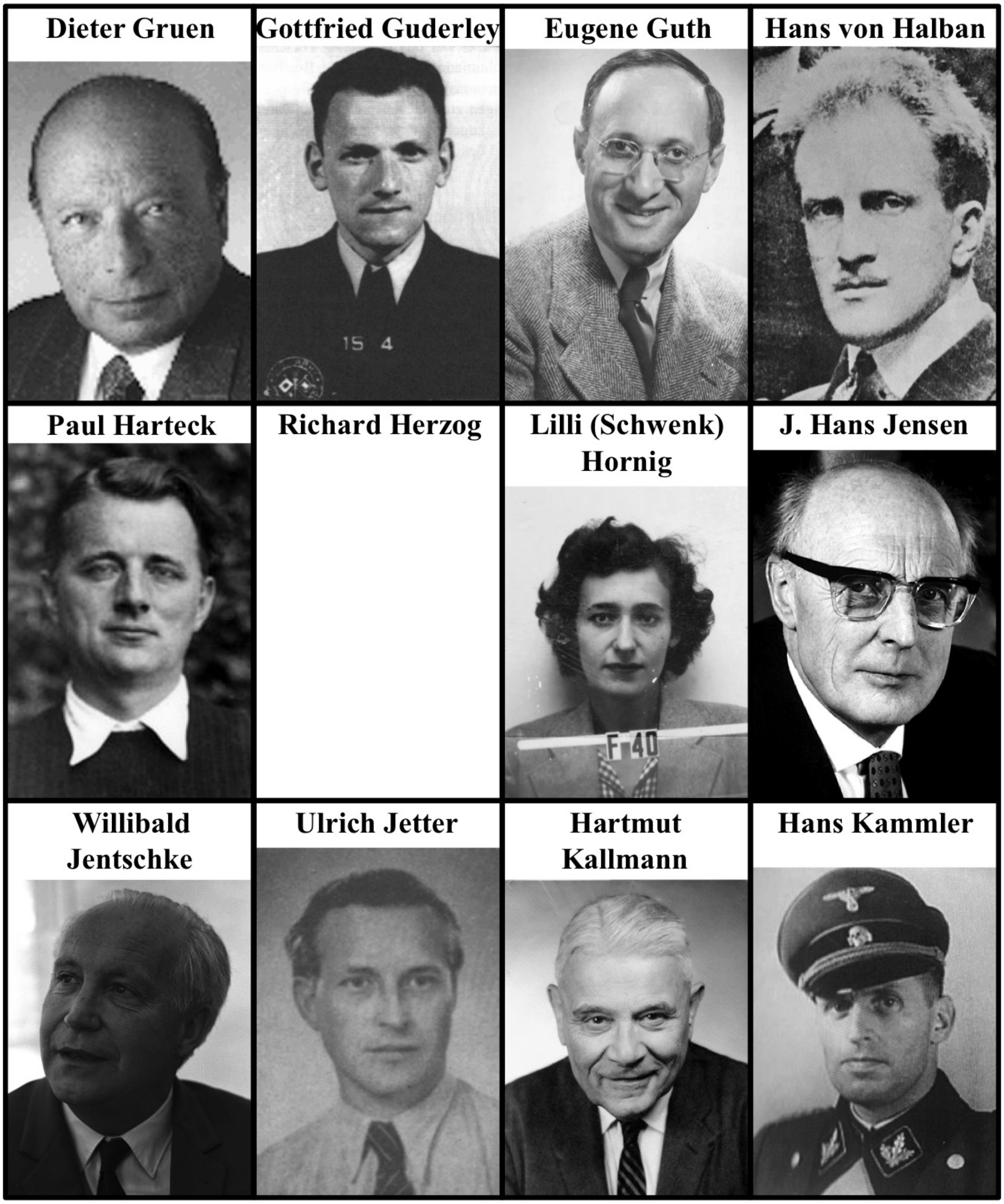

Dieter Gruen
Gottfried Guderley
Eugene Guth
Hans von Halban
Paul Harteck
Richard Herzog
Lilli (Schwenk) Hornig
J. Hans Jensen
Willibald Jentschke
Ulrich Jetter
Hartmut Kallmann
Hans Kammler
15 4
F 40

Figure 8.24: More examples of German-speaking scientists (and some scientists who were very strongly coupled to the German-speaking world) who contributed to the wartime and postwar U.S./U.K. nuclear programs.

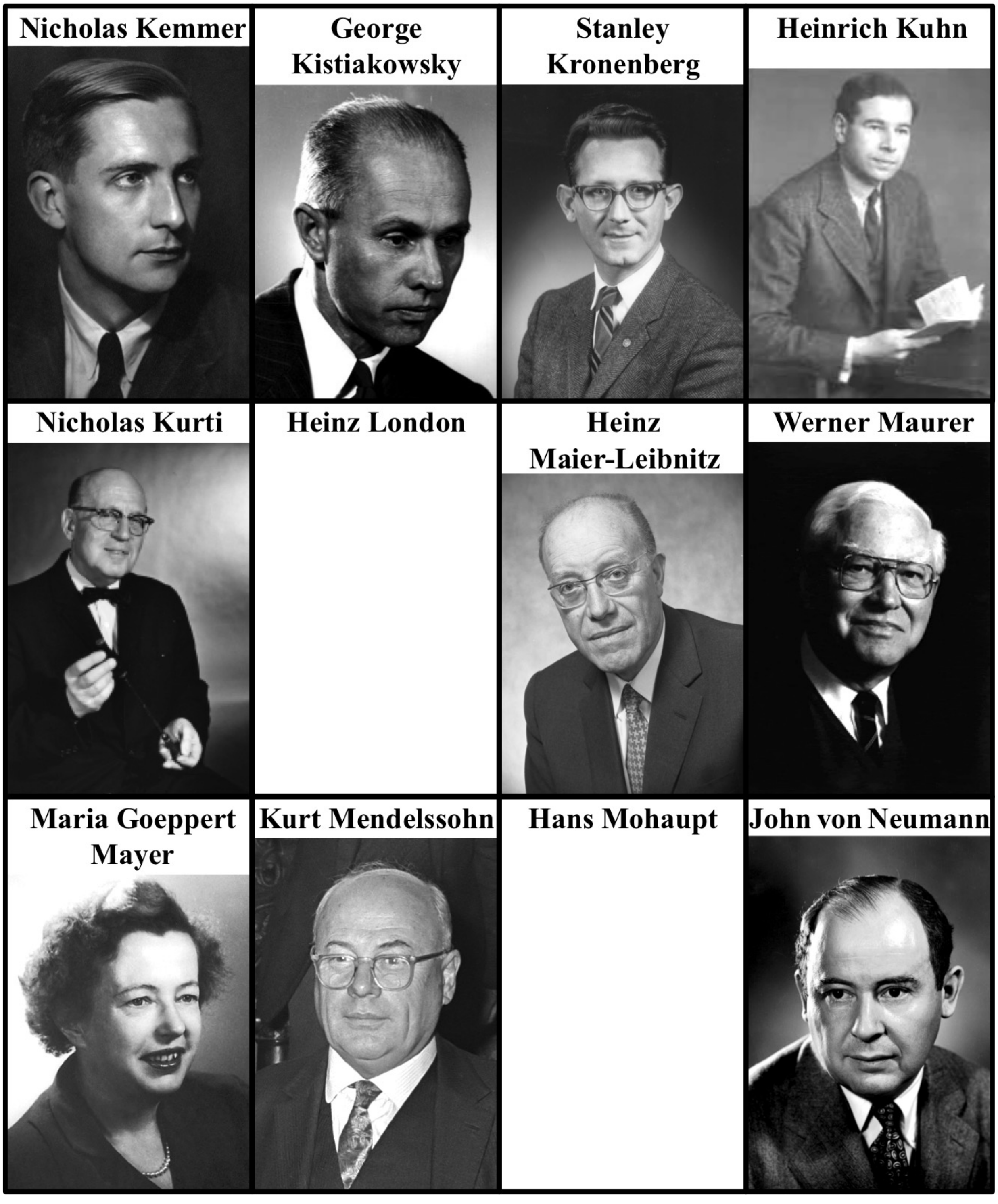

Nicholas Kemmer
George Kistiakowsky
Stanley Kronenberg
Heinrich Kuhn
Nicholas Kurti
Heinz London
Heinz Maier-Leibnitz
Werner Maurer
Maria Goeppert Mayer
Kurt Mendelssohn
Hans Mohaupt
John von Neumann

Figure 8.25: More examples of German-speaking scientists (and some scientists who were very strongly coupled to the German-speaking world) who contributed to the wartime and postwar U.S./U.K. nuclear programs.

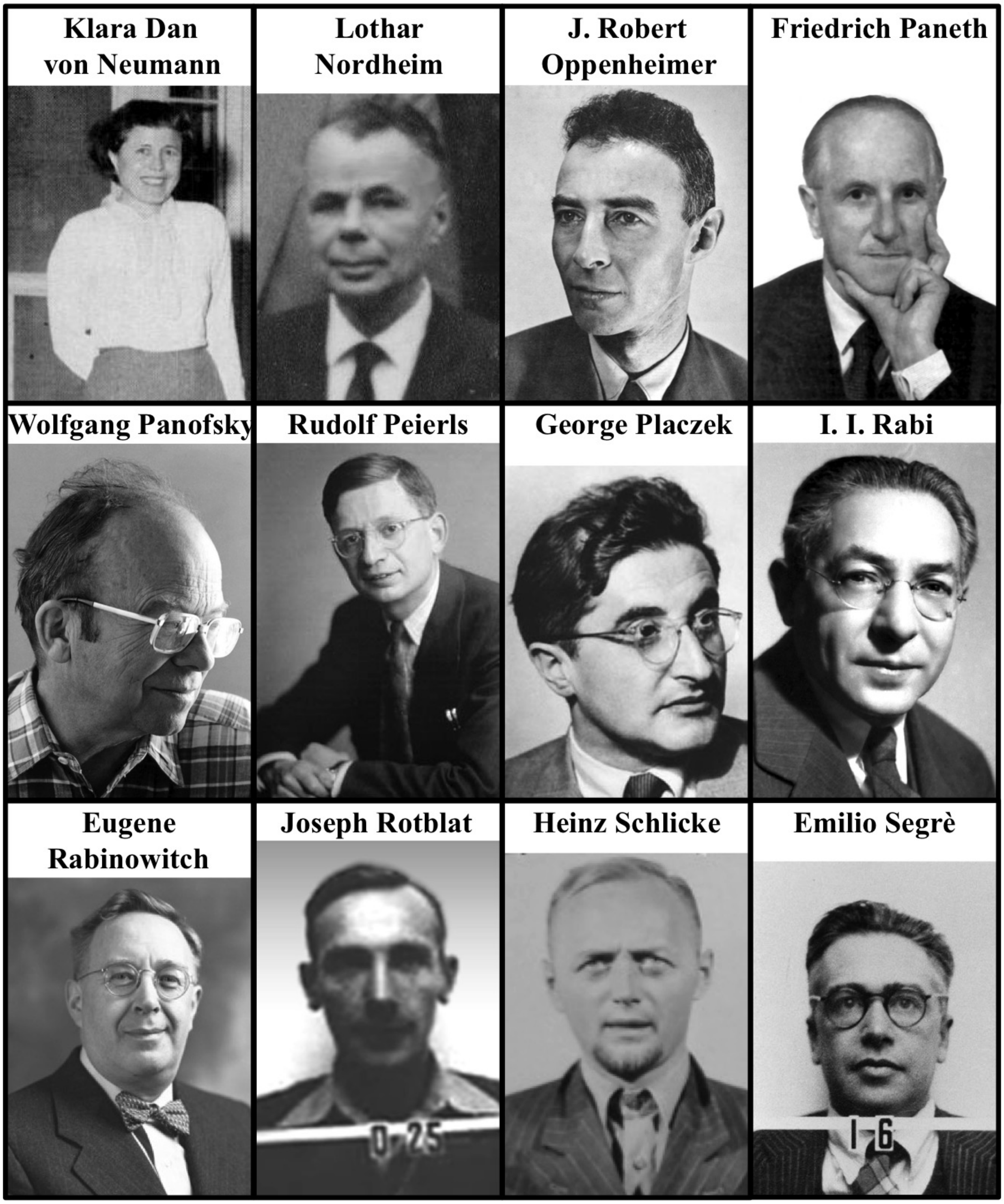

Klara Dan von Neumann
Lothar Nordheim
J. Robert Oppenheimer
Friedrich Paneth
Wolfgang Panofsky
Rudolf Peierls
George Placzek
I. I. Rabi
Eugene Rabinowitch
Joseph Rotblat
Heinz Schlicke
Emilio Segrè

Figure 8.26: More examples of German-speaking scientists (and some scientists who were very strongly coupled to the German-speaking world) who contributed to the wartime and postwar U.S./U.K. nuclear programs.

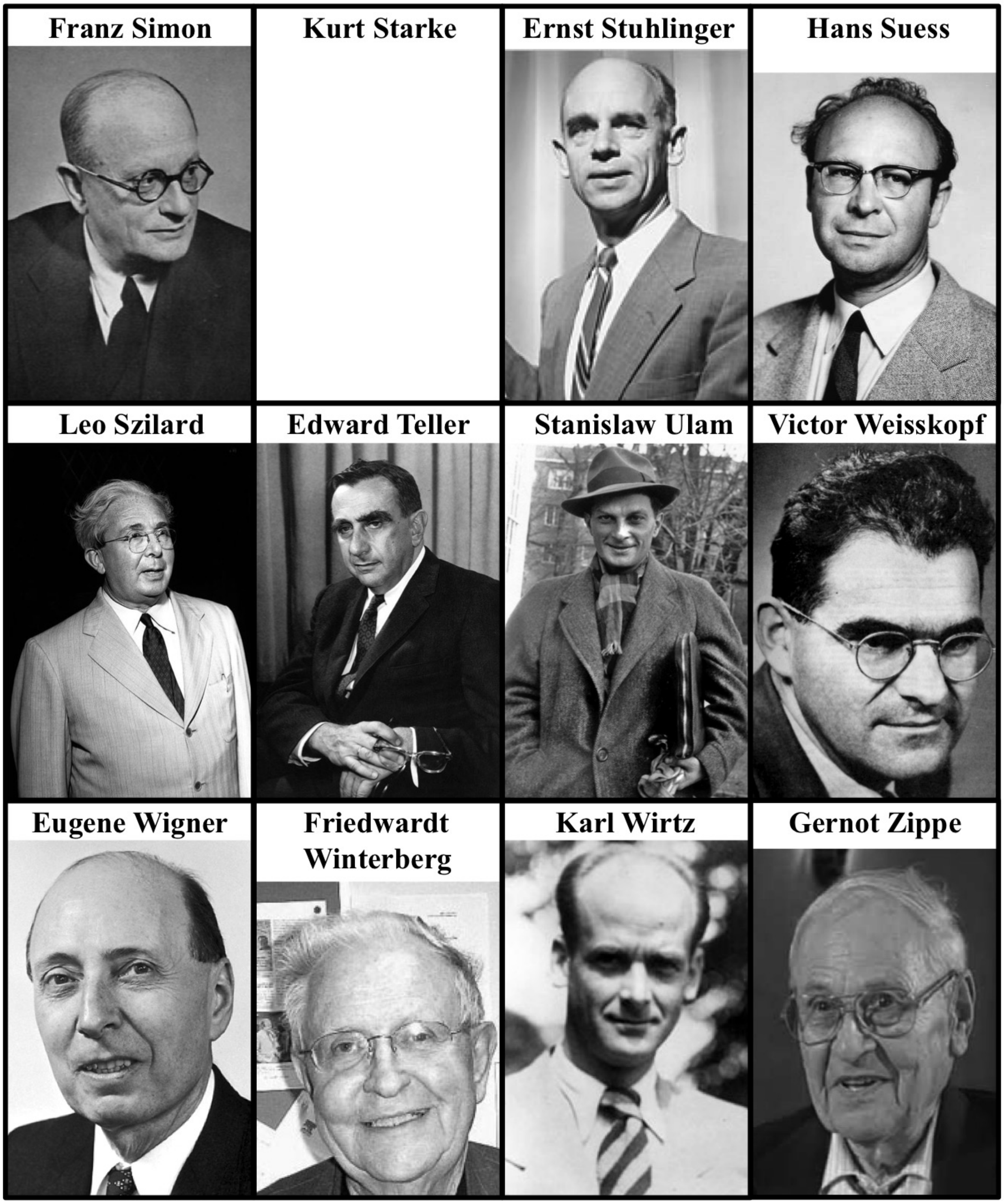

Franz Simon
Kurt Starke
Ernst Stuhlinger
Hans Suess
Leo Szilard
Edward Teller
Stanislaw Ulam
Victor Weisskopf
Eugene Wigner
Friedwardt Winterberg
Karl Wirtz
Gernot Zippe

Figure 8.27: More examples of German-speaking scientists (and some scientists who were very strongly coupled to the German-speaking world) who contributed to the wartime and postwar U.S./U.K. nuclear programs.

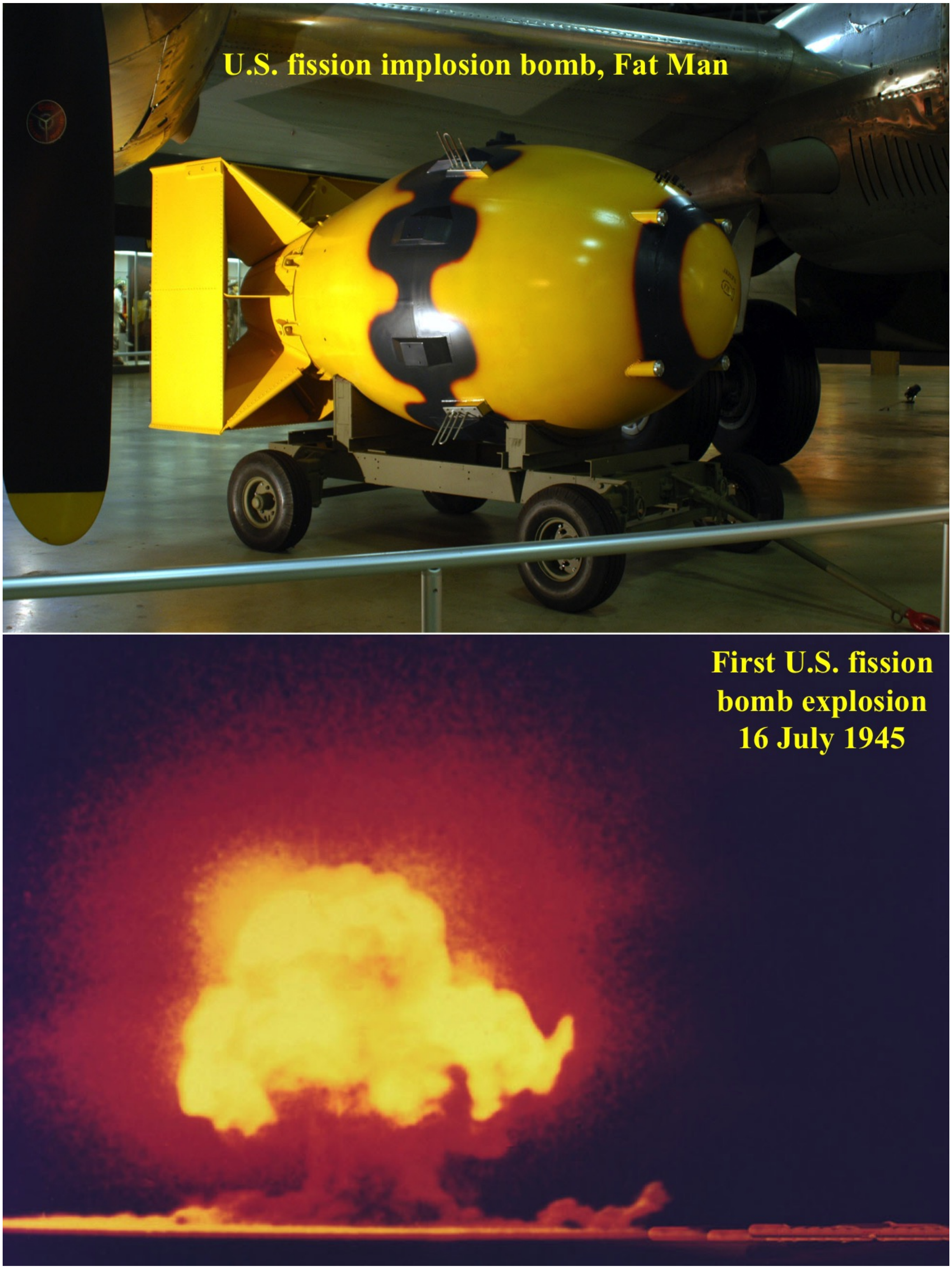

U.S. fission implosion bomb, Fat Man
First U.S. fission bomb explosion 16 July 1945

Figure 8.28: Examples of early U.S. nuclear weapons: a replica of the Fat Man design (called the Gadget without the external aerodynamic casing—see p. 5155), the first U.S. fission implosion bomb, and the explosion of the first U.S. fission implosion bomb on 16 July 1945.

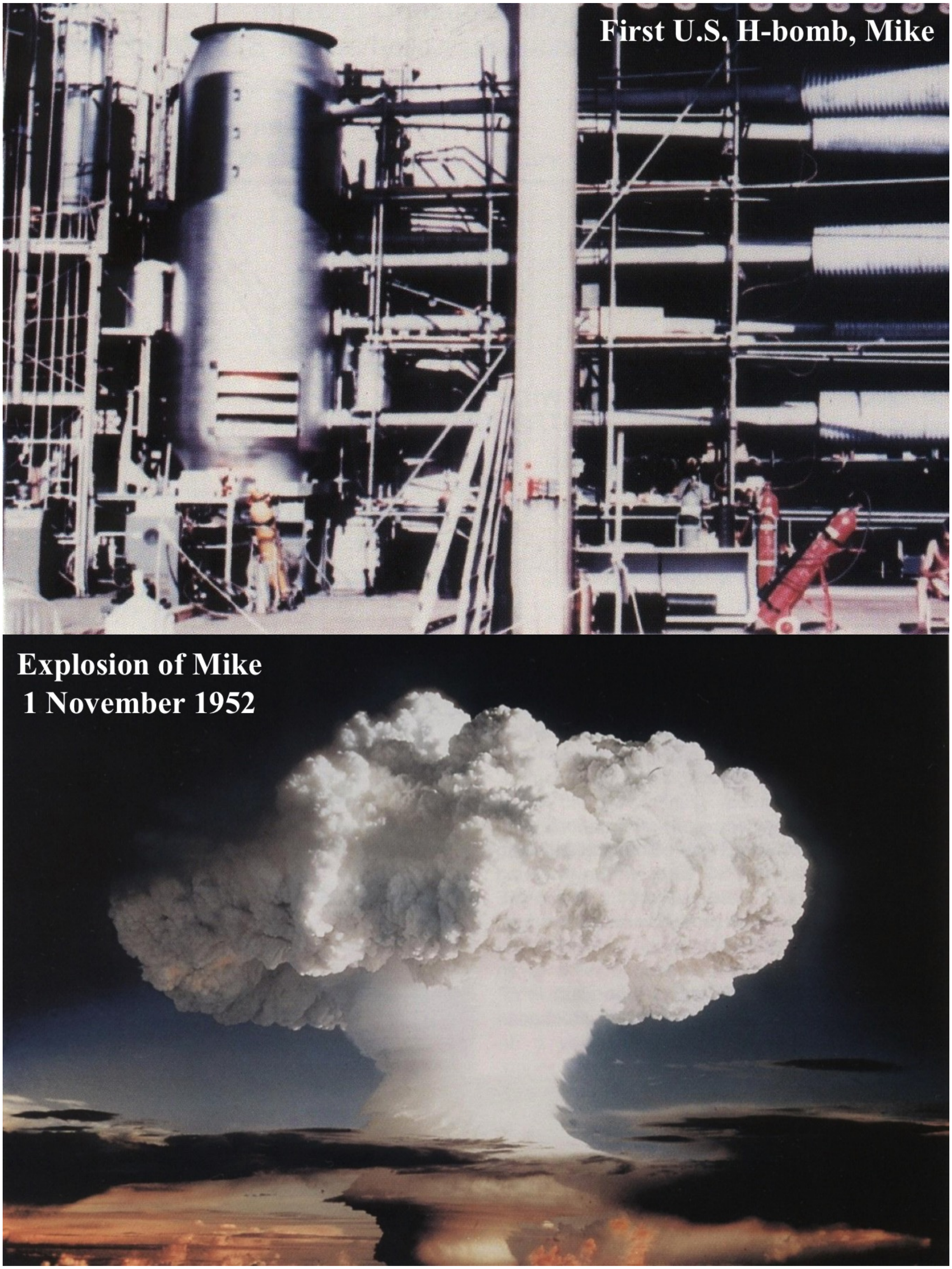
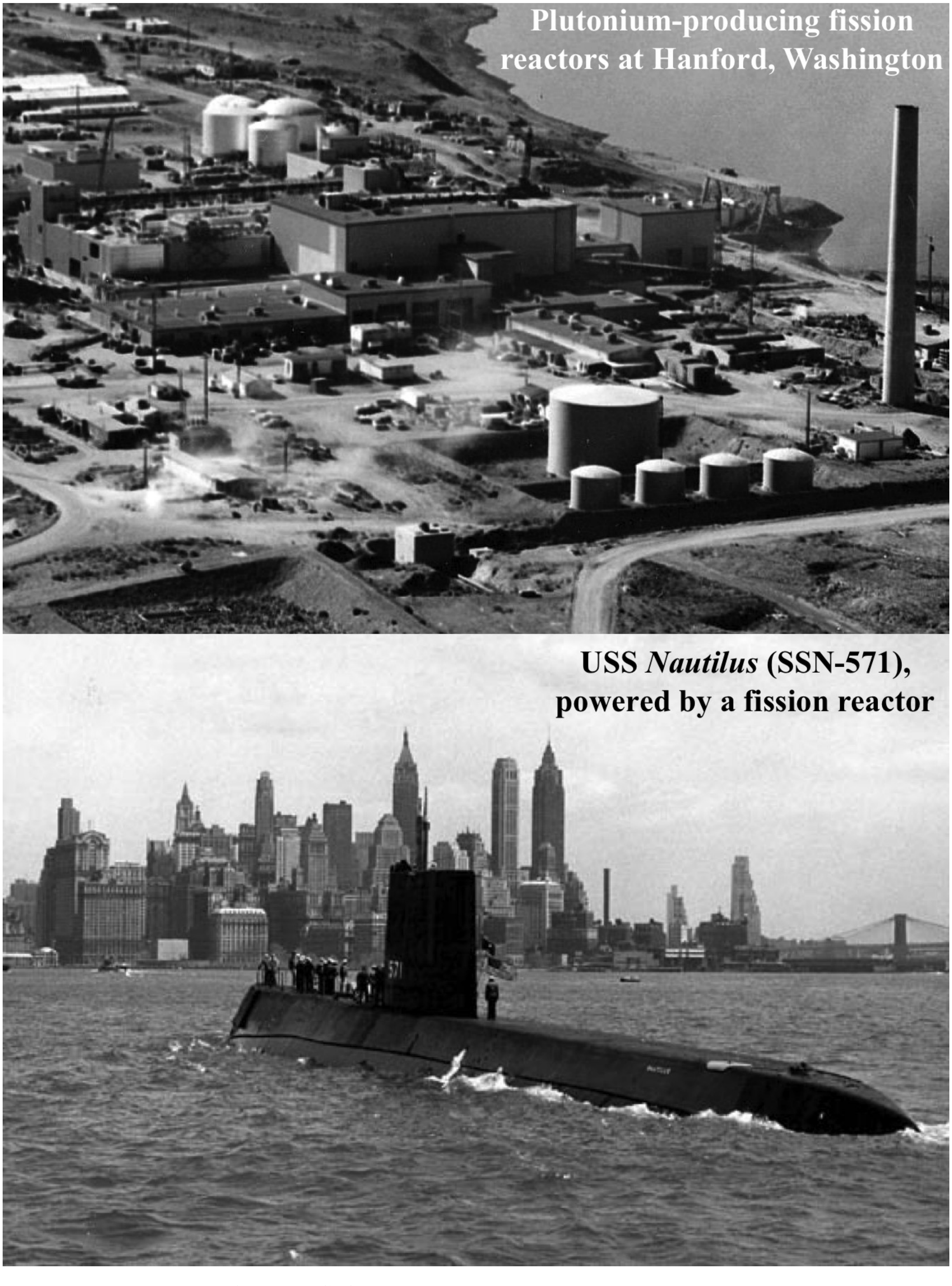

First U.S. H-bomb, Mike
Explosion of Mike
1 November 1952

Figure 8.29: Examples of early U.S. nuclear weapons: Mike, the first U.S. hydrogen bomb, and the explosion of Mike on 1 November 1952.



Plutonium-producing fission reactors at Hanford, Washington

USS *Nautilus* (SSN-571), powered by a fission reactor

Figure 8.30: Examples of early U.S. fission reactors: plutonium-producing reactors were constructed at Hanford, Washington during the period 1943–1963; the USS *Nautilus* (SSN-571), the first submarine powered by a fission reactor, was launched in 1954.

8.8 Nuclear Engineering in the Third Reich

This section presents evidence which suggests that the World War II German nuclear program was much larger and much more advanced than has previously been generally understood. While this claim may seem controversial, much of the relevant archival evidence has only been declassified and rediscovered in recent years, and was not publicly available when earlier historical assessments were made. The evidence presented here covers:

8.8.1. Flaws in the conventional historical view of the German program.

8.8.2. The fundamental scientific knowledge and planning of the program.

8.8.3. Sources of uranium and thorium.

8.8.4. Enrichment of uranium-235.

8.8.5. Fission reactors for breeding plutonium-239 and/or uranium-233.

8.8.6. Electronuclear systems for breeding plutonium-239 and/or uranium-233.

8.8.7. The production of other potentially nuclear-related materials.

8.8.8. Fission bomb designs.

8.8.9. Hydrogen bomb designs.

8.8.10. An October 1944 test explosion on the Baltic coast.

8.8.11. A circa November 1944 test explosion in Poland.

8.8.12. March 1945 test explosions in Thuringia.

8.8.13. Axis belief in the reality of German nuclear weapons.

8.8.14. Allied belief in the reality of German nuclear weapons.

8.8.15. Further research that is needed.

For a far more detailed presentation of the currently available evidence, see Appendix D. As explained in Section 8.8.15, much more work is needed to uncover and evaluate evidence regarding the true history and extent of the wartime nuclear program.

8.8.1 Flaws in the Conventional Historical View of the German Program

The conventional historical view that has been held from 1945 to the present is that the World War II German nuclear program was very small and poorly funded, that Germany was still trying to complete its first prototype fission reactor when the war ended, and that Germany never even made a serious attempt to develop nuclear weapons.[6] This view is based on three categories of evidence, although each category has its own limitations as summarized below and in Section D.1:

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[6] E.g., Goudsmit 1945, Goudsmit 1947; Groves 1962; Hentschel and Hentschel 1996; Hoffmann 2023; Irving 1967; Pash 1969; Popp 2016, 2021; Powers 1993; Rhodes 1986; Rose 1998; Walker 1989, 1995, 2020, 2024a, 2024b.

1. The U.S.-led Alsos Mission searching for evidence of nuclear-related work at the end of the war found the incomplete fission reactor at Haigerloch, some papers on basic nuclear physics, and apparently not much else, according to the public accounts. Unfortunately, the Alsos Mission failed to properly investigate numerous specific organizations, scientists, and locations that could have revealed a more advanced nuclear program. If any more advanced nuclear work had in fact been discovered, that information would have been automatically classified at the time, and could remain classified or buried in archives and unreleased to this day.[7]

2. Ten German nuclear scientists (Erich Bagge, Kurt Diebner, Walther Gerlach, Otto Hahn, Paul Harteck, Werner Heisenberg, Horst Korsching, Max von Laue, Carl Friedrich von Weizsäcker, and Karl Wirtz) rounded up by the Alsos Mission were kept under house arrest from July 1945 until January 1946 at Farm Hall in the United Kingdom, where their private conversations were recorded without their knowledge. The transcripts, which were not released to the public until 1992, record the scientists' surprise at news of the 6 August 1945 Hiroshima bombing and do not reveal significant apparent knowledge of nuclear weapons design and development. However, a huge number of relevant nuclear scientists were not at Farm Hall. There is evidence that those who were there suspected surveillance and conducted their conversations accordingly. The preserved transcripts document only a small fraction of the discussions that would have occurred among ten people and their British attendants during those six months. Moreover, the transcripts are English translations, which may not accurately reflect the original German conversations. Both the original recordings and the original German transcripts are said to have been permanently lost, a shocking lapse for such an important operation.[8]

3. In their public interviews and writings in the years after the war, German nuclear scientists professed a lack of desire, plans, materials and/or political support to produce nuclear weapons for the Third Reich. On the other hand, only a small number of nuclear scientists went on the public record. It is not clear how much of what they said was factual history versus personal spin meant to avoid postwar criticism; the answer may vary for different scientists in question. Certainly it would have been in their best personal interests to downplay their support for weapons-related work as much as possible.[9]

With access to some of the previously unavailable former Soviet and East German archives and witness testimony, as well as newly discovered and released U.S. and British documents, beginning in the 1990s several authors argued (with varying degrees of success and accuracy) that wartime German work on nuclear weapons was actually much more extensive, involved many more scientists, and progressed much further than had been accepted by the conventional historical narrative.[10]

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[7] See Section D.1; Goudsmit 1945, 1947; Groves 1962; Pash 1969.

[8] See p. 3336; Bernstein 2001; Frank 1993; Hoffmann 2023.

[9] Cassidy 1992, 2009; Heisenberg 1953, 1971; Irving 1967; Powers 1993; NYT 1948-12-28 p. 10.

[10] E.g., Frank Döbert in *Walpersberg Geschichts- und Forschungsjournal* 2015, 2016; Eilers 2007, 2015; Fengler 2014; Fengler and Sachse 2012; *Geheimnis Jonastal* 2002–2024; Georg 2009; Henshall 1998, 2000, 2002; Hirschfeld and Brooks 1996; Hydrick 1998, 2016; Karlsch 2005, 2006, 2011; Karlsch and Laufer 2002; Karlsch and Petermann 2007; Karlsch and Zeman 2016; Mayer and Mehner 2001, 2002, 2004a, 2004b, 2009, 2010; Mehner 2004; Nagel 2003, 2011, 2012a, 2016; Oleynikov 2000; Petermann 2000; Schmitzberger 2004; Stevens 2007; Sulzer and Brauburger 2015; Matthias Uhl quoted in Schauka 2015; Wilcox 2019; Zeman and Karlsch 2008.

8.8.2 Fundamental Knowledge and Planning

There is ample documentation that the German nuclear program began very early and with great determination (Section D.2).[11]

In 1934, Ida Tacke Noddack accurately predicted both the neutron-induced fission of uranium and the production of a new fissile element 94 (later named plutonium-239, ^{239}Pu) via neutron capture in uranium (p. 1537).

Also in 1934, the experimental nuclear physicist Kurt Diebner (German, 1905–1964) began working closely with the implosion expert Erich Schumann (German, 1898–1985) at the Heereswaffenamt (Army Ordnance Office), which seems to indicate just how early the military applications and necessary methods of nuclear technologies were envisioned (p. 3376). Both Diebner and Schumann appear to have played hugely important roles in the development of nuclear weapons through the end of the war.

Germany seized control of the St. Joachimsthal (or Jáchymov) uranium mine in Czech territory in 1938 and made the mining and shipment of uranium from there to sites in Germany and Austria a high priority throughout the entire war [Hayes 2004, pp. 132–133, 235, 243]. See also p. 3998.

German organizations began operating and receiving shipments from a uranium mine at Buchovo (or Buhovo), a suburb of Sofia, Bulgaria, in 1938 [Hayes 2004, p. 235; https://ejatlas.org/conflict/life-after-the-uranium-mines-in-buhovo-bulgaria]. See also p. 4588.

Germany also acquired control of a number of other sources of uranium and thorium (Section 8.8.3).

At the Kaiser Wilhelm Institute (KWI) for Chemistry, Otto Hahn and Fritz Strassmann experimentally confirmed Noddack's prediction of the neutron-induced fission of uranium into lighter elements in 1938. They published their results in January 1939 (p. 1538).

In April 1939, Paul Harteck (Austrian, 1902–1985) and Wilhelm Groth (German, 1904–1977) at the University of Hamburg informed the German War Office that nuclear fission could be harnessed to create a strategically decisive bomb many orders of magnitude more powerful than conventional explosives (p. 3364). Harteck and Groth worked on many different important aspects of the German nuclear program throughout the war.

No later than April 1939, the German government was conducting very secret, high-level meetings of nuclear scientists and government officials concerning a program for the strategic military applications of nuclear physics (p. 3376).

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[11] For comparison with the German timeline, it is instructive to consider the wartime U.S. nuclear program. Despite Albert Einstein's letter to Franklin Roosevelt in August 1939 (p. 1548), the U.S. program languished in committee meetings until it was jolted into action in the aftermath of Pearl Harbor. Leslie Groves was not appointed to head the newly dubbed Manhattan Project until September 1942, and construction of the buildings for the Los Alamos, Oak Ridge, and Hanford facilities did not even begin until early 1943. Serious design work on the Gadget/Fat Man implosion bomb did not begin until August 1944 [Groves 1962; Bruce Cameron Reed 2019; Rhodes 1986].

In June 1939, Siegfried Flügge (German, 1912–1997), a nuclear physicist at the KWI for Chemistry, published calculations showing the feasibility of using pure uranium-235 fuel and fast neutrons to create an explosive chain reaction, estimating both the time scale and energy release for the explosion. He stated: "The energy release happens in such a short time that we are dealing with an extraordinarily violent explosion." In the same article, he explicitly proposed water-moderated fission power reactors using thermal neutrons, derived and used the neutron diffusion and kinetics equations that are still taught in modern nuclear engineering textbooks, and correctly stated that cadmium could be used as a neutron absorber to maintain control of the neutron-induced fission reactions (p. 3366). Due to this and his other papers, Flügge apparently became the chief theorist of the German nuclear weapons program. He ended up working simultaneously for many different organizations that were all involved in the nuclear program—including the KWI, Reichspost (Postal Service), Heereswaffenamt, Reichsforschungsrat (Reich Research Council), SS, and universities—apparently serving to coordinate the scientific details of all of their activities (p. 4998).

Georg Stetter (Austrian, 1895–1988) led a large and advanced nuclear physics group at the University of Vienna. In June 1939, he filed a patent application that included a remarkably detailed description of a fission reactor (p. 3372). Stetter and all of his fellow Austrians seem to have played large roles in the German nuclear weapons program throughout the war.

Around 1939, the experimental physicist and inventor Manfred von Ardenne (German, 1907–1997) joined up with Wilhelm Ohnesorge, the very science-minded and deep-pocketed head of the Reichspost (government postal service, but like an even more advanced version of the U.S. Bell Laboratories), to conduct nuclear-weapons-related work (p. 3376). Due to Ohnesorge's strong support, the Reichspost was one of the most important organizations in the nuclear weapons program throughout the war.

Germany began ordering heavy water from Vemork, Norway in December 1939 (p. 4031). Heavy water would make an excellent moderator to facilitate the operation of a uranium reactor to produce power and/or plutonium.

No later than 1940, Carl Friedrich von Weizsäcker (German, 1912–2007) understood that ^{239}Pu could be used to create a bomb. No later than 1941, von Weizsäcker, Fritz Houtermans (German, 1903–1966), Josef Schintlmeister (Austrian, 1908–1971), and Friedrich Hernegger provided many more details about the properties, production, and military applications of plutonium. See pp. 3794–3826.

During the war, Houtermans and other scientists in the German program also understood how uranium-233 (^{233}U) could be bred from natural thorium-232 (^{232}Th) and used to create a bomb (pp. 3832–3836).

As shown in Fig. 8.31, the wartime nuclear program was spread among the Heereswaffenamt, Kriegsmarine (Navy), Luftwaffe (Air Force), Reichspost, SS, several Kaiser Wilhelm Institutes (KWI), Physikalische-Techische Reichsanstalt (Physical-Technical Reich Institute), several universities, a number of companies, and groups in Czechoslovakia, Poland, Denmark, Norway, and elsewhere.[12] In the early years of the war, the work of these many groups was coordinated by the Heereswaffenamt. From 1942 until the end of the war, the coordination was managed by the SS.

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[12] See pp. 3376–3403; Irving 1967; Karlsch 2005, Karlsch and Petermann 2007; Nagel 2003, 2011, 2012a, 2016.

For an incomplete list of some of the more important scientists and engineers in the program, see pp. 1568, 1611–1629.[13] Many of those German-speaking nuclear experts subsequently worked in the postwar Soviet nuclear weapons program (Figs. 8.52–8.55), whereas others visited or moved to the United States or United Kingdom and apparently aided their programs (Figs. 8.22–8.27). Still others went to France or other countries after the war.

Note that for the last 75+ years, conventional histories of the German nuclear program have generally only covered a very small and relatively minor part of what was actually a far larger program.

Because the German nuclear program was so widely dispersed, it was much more resistant to Allied bombing and Allied intelligence; unfortunately that has also made it far more difficult for modern historians to reconstruct the details of the wartime nuclear program and its scientific accomplishments. Adding to the complications for both wartime intelligence and modern historians, the German nuclear program was highly compartmentalized, with individual people and groups only knowing as much as they needed to do their parts, just as the German chemical weapons program and the other most secretive programs were.

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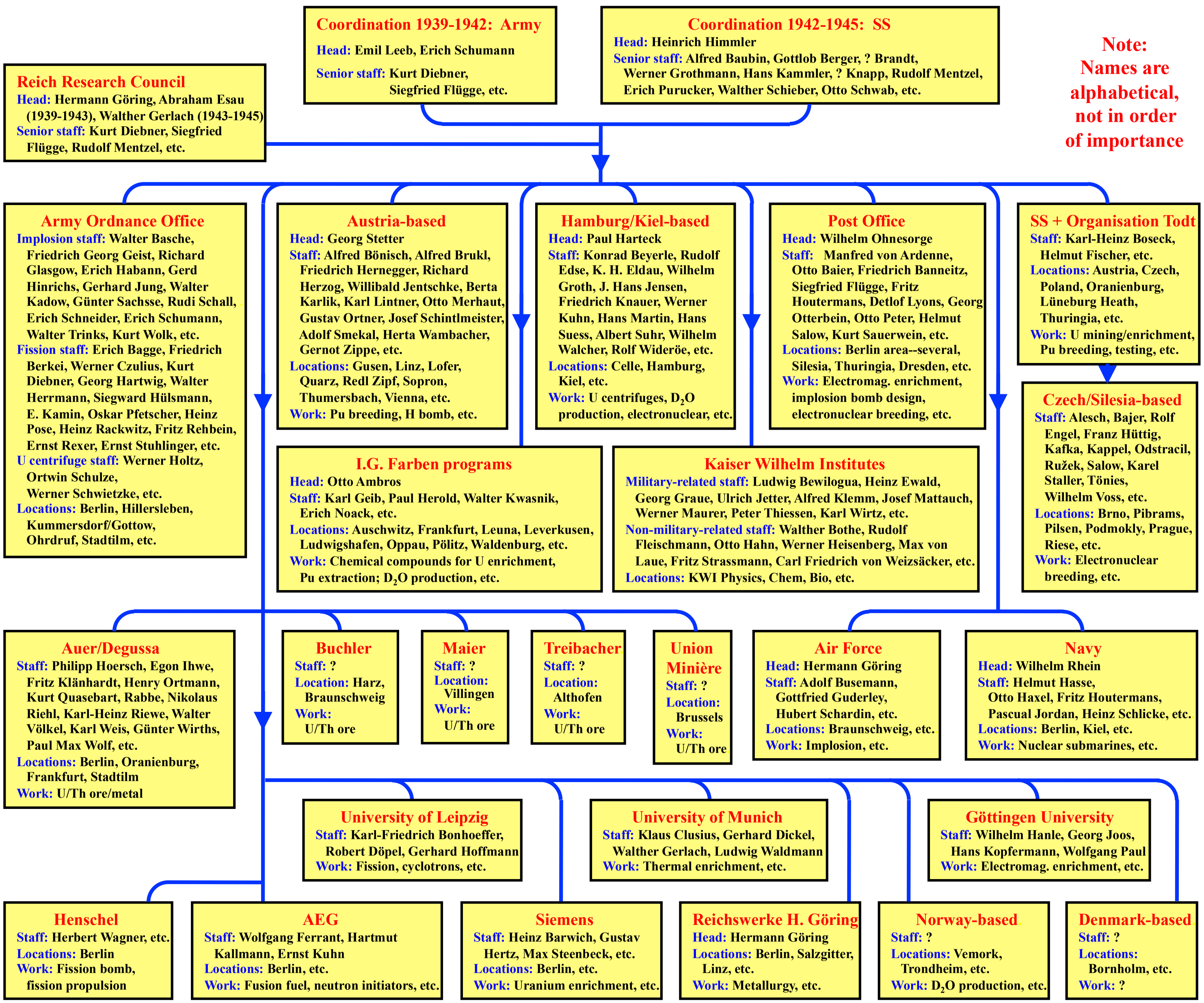
[13] This list has been compiled from sources throughout the Bibliography and Appendix D, but most of the names can be found in: Hentschel and Hentschel 1996; Hoffmann 2023; Irving 1967; Karlsch 2005, Karlsch and Petermann 2007; Nagel 2003, 2011, 2012a, 2016 Powers 1993 Rose 1998; Walker 1989, 1995, 2020, 2024a, 2024b.



Note: Names are alphabetical, not in order of importance

Reich Research Council
Head: Hermann Göring, Abraham Esau (1939-1943), Walther Gerlach (1943-1945)
Senior staff: Kurt Diebner, Siegfried Flügge, Rudolf Mentzel, etc.

Coordination 1939-1942: Army
Head: Emil Leeb, Erich Schumann
Senior staff: Kurt Diebner, Siegfried Flügge, etc.

Coordination 1942-1945: SS
Head: Heinrich Himmler
Senior staff: Alfred Baubin, Gottlob Berger, ? Brandt, Werner Grothmann, Hans Kammler, ? Knapp, Rudolf Mentzel, Erich Purucker, Walther Schieber, Otto Schwab, etc.

Army Ordnance Office
Implosion staff: Walter Basche, Friedrich Georg Geist, Richard Glasgow, Erich Habann, Gerd Hinrichs, Gerhard Jung, Walter Kadow, Günter Sachsse, Rudi Schall, Erich Schneider, Erich Schumann, Walter Trinks, Kurt Wolk, etc.
Fission staff: Erich Bagge, Friedrich Berkei, Werner Czulius, Kurt Diebner, Georg Hartwig, Walter Herrmann, Siegward Hülsmann, E. Kamin, Oskar Pfetscher, Heinz Pose, Heinz Rackwitz, Fritz Rehbein, Ernst Rexer, Ernst Stuhlinger, etc.
U centrifuge staff: Werner Holtz, Ortwin Schulze, Werner Schwietzke, etc.
Locations: Berlin, Hillersleben, Kummersdorf/Gottow, Ohrdruf, Stadtilm, etc.

Austria-based
Head: Georg Stetter
Staff: Alfred Bönisch, Alfred Brukl, Friedrich Hernegger, Richard Herzog, Willibald Jentschke, Berta Karlik, Karl Lintner, Otto Merhaut, Gustav Ortner, Josef Schintlmeister, Adolf Smekal, Herta Wambacher, Gernot Zippe, etc.
Locations: Gusen, Linz, Lofer, Quarz, Redl Zipf, Sopron, Thumersbach, Vienna, etc.
Work: Pu breeding, H bomb, etc.

Hamburg/Kiel-based
Head: Paul Harteck
Staff: Konrad Beyerle, Rudolf Edse, K. H. Eldau, Wilhelm Groth, J. Hans Jensen, Friedrich Knauer, Werner Kuhn, Hans Martin, Hans Suess, Albert Suhr, Wilhelm Walcher, Rolf Wideröe, etc.
Locations: Celle, Hamburg, Kiel, etc.
Work: U centrifuges, D_2O production, electronuclear, etc.

Post Office
Head: Wilhelm Ohnesorge
Staff: Manfred von Ardenne, Otto Baier, Friedrich Banneitz, Siegfried Flügge, Fritz Houtermans, Detlof Lyons, Georg Otterbein, Otto Peter, Helmut Salow, Kurt Sauerwein, etc.
Locations: Berlin area--several, Silesia, Thuringia, Dresden, etc.
Work: Electromag. enrichment, implosion bomb design, electronuclear breeding, etc.

SS + Organisation Todt
Staff: Karl-Heinz Boseck, Helmut Fischer, etc.
Locations: Austria, Czech, Poland, Oranienburg, Lüneburg Heath, Thuringia, etc.
Work: U mining/enrichment, Pu breeding, testing, etc.

I.G. Farben programs
Head: Otto Ambros
Staff: Karl Geib, Paul Herold, Walter Kwasnik, Erich Noack, etc.
Locations: Auschwitz, Frankfurt, Leuna, Leverkusen, Ludwigshafen, Oppau, Pölitz, Waldenburg, etc.
Work: Chemical compounds for U enrichment, Pu extraction; D_2O production, etc.

Kaiser Wilhelm Institutes
Military-related staff: Ludwig Bewilogua, Heinz Ewald, Georg Graue, Ulrich Jetter, Alfred Klemm, Josef Mattauch, Werner Maurer, Peter Thiessen, Karl Wirtz, etc.
Non-military-related staff: Walther Bothe, Rudolf Fleischmann, Otto Hahn, Werner Heisenberg, Max von Laue, Fritz Strassmann, Carl Friedrich von Weizsäcker, etc.
Locations: KWI Physics, Chem, Bio, etc.

Czech/Silesia-based
Staff: Alesch, Bajer, Rolf Engel, Franz Hüttig, Kafka, Kappel, Odstracil, Ružek, Salow, Karel Staller, Tönies, Wilhelm Voss, etc.
Locations: Brno, Pibrams, Pilsen, Podmokly, Prague, Riese, etc.
Work: Electronuclear breeding, etc.

Auer/Degussa
Staff: Philipp Hoersch, Egon Ihwe, Fritz Klänhardt, Henry Ortmann, Kurt Quasebart, Rabbe, Nikolaus Riehl, Karl-Heinz Riewe, Walter Völkel, Karl Weis, Günter Wirths, Paul Max Wolf, etc.
Locations: Berlin, Oranienburg, Frankfurt, Stadtilm
Work: U/Th ore/metal

Buchler
Staff: ?
Location: Harz, Braunschweig
Work: U/Th ore

Maier
Staff: ?
Location: Villingen
Work: U/Th ore

Treibacher
Staff: ?
Location: Althofen
Work: U/Th ore

Union Minière
Staff: ?
Location: Brussels
Work: U/Th ore

Air Force
Head: Hermann Göring
Staff: Adolf Busemann, Gottfried Guderley, Hubert Schardin, etc.
Locations: Braunschweig, etc.
Work: Implosion, etc.

Navy
Head: Wilhelm Rhein
Staff: Helmut Hasse, Otto Haxel, Fritz Houtermans, Pascual Jordan, Heinz Schlicke, etc.
Locations: Berlin, Kiel, etc.
Work: Nuclear submarines, etc.

University of Leipzig
Staff: Karl-Friedrich Bonhoeffer, Robert Döpel, Gerhard Hoffmann
Work: Fission, cyclotrons, etc.

University of Munich
Staff: Klaus Clusius, Gerhard Dickel, Walther Gerlach, Ludwig Waldmann
Work: Thermal enrichment, etc.

Göttingen University
Staff: Wilhelm Hanle, Georg Joos, Hans Kopfermann, Wolfgang Paul
Work: Electromag. enrichment, etc.

Henschel
Staff: Herbert Wagner, etc.
Locations: Berlin
Work: Fission bomb, fission propulsion

AEG
Staff: Wolfgang Ferrant, Hartmut Kallmann, Ernst Kuhn
Locations: Berlin, etc.
Work: Fusion fuel, neutron initiators, etc.

Siemens
Staff: Heinz Barwich, Gustav Hertz, Max Steenbeck, etc.
Locations: Berlin, etc.
Work: Uranium enrichment, etc.

Reichswerke H. Göring
Head: Hermann Göring
Locations: Berlin, Salzgitter, Linz, etc.
Work: Metallurgy, etc.

Norway-based
Staff: ?
Locations: Vemork, Trondheim, etc.
Work: D_2O production, etc.

Denmark-based
Staff: ?
Locations: Bornholm, etc.
Work: ?

Figure 8.31: Very tentative organizational chart of the German nuclear program.

8.8.3 Sources of Uranium and Thorium

Scientists such as Nikolaus Riehl (German, 1901–1990), Günter Wirths (German, 1911–2005), Egon Ihwe (German, 18??–19??), and many others played vital roles in the processing of uranium and thorium for the German nuclear weapons program (Section D.3). Many of those scientists went on the play equally important roles in the postwar Soviet nuclear weapons program (Section 8.9).

During the war, Germany had access to large amounts of natural uranium and thorium ore by (see map on p. 3405):

- Acquiring at least 1200 tons, and according to some well-informed sources 3500 tons, of uranium compounds (originally mined in the Belgian Congo) from Union Minière in Brussels [e.g., pp. 3335, 3408–3414].
- Expanding uranium mining at St. Joachimsthal (Jachymov), Bohemia [e.g., pp. 3418–3429, 3445, 3469–3470, 4978–4984; Hayes 2004, pp. 132–133, 235, 243].
- Mining uranium at Příbram/Przibram/Pibrans, Bohemia [e.g, pp. 3424, 3470, 3751–3754].
- Mining uranium at Schmiedeberg, Silesia [e.g., pp. 3328, 3424, 3429, 3445, 3471].
- Possibly using any of several uranium deposits in Thuringia [e.g., pp. 3468–3469; Zeman and Karlsch 2008].
- Mining uranium at Schneeberg, Saxony [e.g., pp. 3416, 3424, 3426–3428, 3433–3437, 3445, 3456, 3468–3469, 3708, 4922; Zeman and Karlsch 2008].
- Mining uranium at Johanngeorgenstadt, Saxony [e.g., pp. 3416, 3424, 3426–3428, 3433–3437, 3456, 3468–3469, 3708, 4922; Zeman and Karlsch 2008].
- Mining uranium at Freiberg, Saxony [e.g., pp. 3424, 3426–3429, 3445, 3468–3469].
- Mining uranium at Durrnaul near Marienbad [e.g., p. 3424].
- Mining or planning to mine uranium at Mladkov/Wichstadt, Bohemia [e.g., p. 3425].
- Operating and receiving shipments from Bulgarian uranium mines such as a mine at Buchovo (or Buhovo, a suburb of Sofia), since 1938 [e.g., Hayes 2004, p. 235; https://ejatlas.org/conflict/life-after-the-uranium-mines-in-buhovo-bulgaria]. See also pp. 3446, 3470, 4588.
- Mining uranium at Băiţa-Plai and other sites in Romania [e.g., pp. 3449–3455, 3471].
- Acquiring uranium from mines at Viseu and Guarda, Portugal [e.g., p. 3445; Hayes 2004, p. 235].
- Procuring all available monazite thorium ore in occupied Europe [e.g., Irving 1967].
- Exploiting other possible sources—Spain, Scandinavia, etc.?

One 1946 U.S. intelligence report on Czech uranium mines noted, “The Germans put mining on a high priority and only mining was done throughout the 6 years occupation. The ore was delivered by special planes to Germany and Austria” (p. 3998). Another 1946 U.S. intelligence report added: “The Germans continued operations in this mine to the very last moment” (p. 4981).

Thus Germany began actively mining uranium in 1938 and continued until the end of the war. During that time, Germany had access to (1) the same quality and a comparable quantity of Congolese uranium that served the Manhattan Project well, (2) Central/Eastern European uranium mines that later served the Soviet nuclear program well, and (3) additional uranium mines too.

Germany processed uranium and thorium ore to uranium oxide and thorium oxide, and thence to uranium or thorium metal or to a variety of useful chemical compounds—uranium hexafluoride, uranium tetrachloride, uranium nitrate, etc.—at numerous locations including (see map on p. 3407):

- Union Minière in Brussels [e.g., pp. 3335, 3408–3414; Irving 1967, p. 65].
- Auer in Oranienburg, Katowice/Kattowitz, and other locations [e.g., pp. 3446, 3458, 3461–3463, 3465, 4980; Nagel 2016].
- Buchler in Braunschweig [e.g., pp. 3420, 3430–3431, 3458, 3460–3463, 3465, 4980].
- Treibacher Chemische Werke in Althofen, Austria [e.g., pp. 3420, 3432–3437, 3458, 3460, 4980; Gollmann 1994].
- Degussa in Frankfurt, Berlin, Stadtilm, and possibly other locations [e.g., pp. 3458, 3461–3465; Hayes 2004; Nagel 2016].
- Chemische Fabrik Grünau in Berlin [e.g., pp. 3438–3439, 3461–3463].
- I.G. Farben in Leverkusen and other locations [e.g., pp. 3488–3489, 3492–3493, 3678–3680, 3748–3750, 4440–4477; Mader 1965, pp. 193–202, 229-233].
- Krupp in Essen [e.g., pp. 3458, 3461–3463, 3465–3467].
- W. de Boer in Hamburg and Wittingen [e.g., pp. 3458, 3461–3463, 3465].
- Radium-Chemie AG in Frankfurt [e.g., pp. 3440–3441, 3458, 3465].
- W. Maier KG Radiumchemische Industrie und Laboratorium in Villingen-Schwenningen am Neckar and other locations [e.g., Oleynikov 2000].
- Příbram/Przibram/Pibrans, Bohemia [e.g., pp. 3423, 3751–3754].
- Facilities in Dresden [e.g., pp. 3423, 3426].
- Reichswerke Hermann Göring in Linz and other locations [e.g., pp. 3877–3880].
- Possibly other facilities.

At the end of the war, Allied countries removed over 2800 tons of uranium and thorium compounds from former German-controlled territory (p. 3456). In addition, in 1974, Alwin Urff, deputy technical plant manager of the Asse nuclear disposal site in Germany, stated: “When we began storage in 1967, our company first sank radioactive waste from the last war, that uranium waste which arose in the preparation of the German atomic bomb” (p. 3472).

8.8.4 Enrichment of ^{235}U

Only 0.72% of natural uranium is ^{235}U, the fissile isotope. In order to achieve high concentrations of ^{235}U for a fission bomb, it is necessary to enrich or separate ^{235}U from the other uranium isotopes (Section D.4).

Uranium is converted into the gaseous compound uranium hexafluoride (UF_6) for most enrichment processes (except uranium tetrachloride for electromagnetic separation). UF_6 is highly corrosive to most materials except nickel. German reports captured by the Alsos Mission demonstrate that at least as early as 1940, the German program was fully aware of this information and capable of producing UF_6, and that much of that production capability was at I.G. Farben. Some especially noteworthy researchers in the development and handling of UF_6 were Erich Noack (German, 19??–19??) and Walter Kwasnik (German, 19??–19??) at I.G. Farben Leverkusen, and Paul Harteck and Wilhelm Groth in Hamburg (Section D.4.1).

Georg Bredig (German, 1868–1944) demonstrated the first gas centrifuges in 1895, and the technology was further developed by Fritz Haber (German, 1868–1934) and other researchers. By the time of the Third Reich, gas centrifuges for uranium isotope enrichment were built, tested, and even mass-produced by engineers all over the greater German-speaking world (Section D.4.2). Some of the key personnel included Konrad Beyerle (German, 1900–1979), Klaus Clusius (German, 1903–1963), K. H. Eldau (German, 19??–19??), Wilhelm Groth, Paul Harteck, Helmuth Hausen (German, 1895–1987), Werner Holtz (German, 19??–19??), Johannes Hans Jensen (German, 1907–1973, later won a Nobel Prize for the nuclear shell model), Werner Kuhn (Swiss, 1899–1963), Detlof Lyons (German, 19??–19??, also worked for the Reichspost), Hans Martin (German, 19??–19??), R. Schlatterer (German?, 18??–19??), Ortwin Schulze (German, 19??–19??), Werner Schwietzke (German, 1910–1987), Hans Suess (Austrian, 1909–1993), and Albert Suhr (German, 1920–1996).

Currently available documents indicate that gas centrifuges were produced by:

- Anschütz in Kiel (pp. 3494–3515).
- PHYWE (Physicalische Werkstatte) in Göttingen (pp. 3542–3544), which also made extremely advanced liquid centrifuges for biochemical research (pp. 2397–2399).
- Linde Eismaschinen in Munich (pp. 3498–3507), which had decades of experience with gas handling and rotating compressor machinery.
- Hellige in Freiburg (pp. 3512–3540).
- Hellige in Breslau/Wrocław (p. 4522).
- One or more factories in Switzerland for export to Germany (pp. 3545–3548).
- Quite possibly other locations as well.

How many uranium gas centrifuges were produced by or for Germany during the war? At what sites were they installed and operated? How much enriched uranium did they produce in total, and how highly enriched was it? Can files that would answer these questions be located in various national archives and declassified?

Centrifugation proved so superior to the U.S. Manhattan Project's enrichment methods that the German gas centrifuge designs are now the worldwide standard for uranium enrichment (pp. 3549–3553). The evidence clearly shows that the technology was developed and demonstrated over the course of half a century (1895–1945) by German scientists and engineers, and spread by German scientists and engineers (as well as the prototypes and documentation they had produced) to other countries after the war. The Soviet Union was one of those countries to which the technology spread (via scientists such as Max Steenbeck and Gernot Zippe), but not the origin of the technology [Benedict et al. 1981; Glaser 2008; Helmbold 2016; Kemp 2009, 2012, 2017; NYT 2004-03-23].

Manfred von Ardenne (German, 1907–1997), Heinz Ewald (German, 1914–1992), Wolfgang Paul (German, 1913–1993), Wilhelm Walcher (German, 1910–2005), and many others worked in teams to develop electromagnetic separators (called calutrons in the United States) to enrich uranium (Section D.4.3). By 1941, von Ardenne and his collaborators had built and successfully demonstrated a prototype electromagnetic separator, and were trying to persuade German industry to mass-produce such separators. In March 1942 Ewald delivered a final report on calculations for the optimal performance of electromagnetic separators. According to a June 1944 OSS report, von Ardenne, Siegfried Flügge, and the Reichspost (which was working closely with the SS) had supervised the construction of three secretive high-voltage facilities at undisclosed locations. Were those three electromagnetic enrichment facilities? Von Ardenne became a central figure in the Soviet nuclear weapons program after the war.

Gustav Hertz (German, 1887–1975) patented gaseous diffusion separation in 1923 and a gaseous diffusion cascade system in 1925. Hertz, Erika Cremer (German, 1900–1996), Hubert Krüger (German, 18??–19??), Rudolf Fleischmann (German, 1903–2002), Erich Bagge (German, 1912–1996), and others built and demonstrated prototype gaseous diffusion enrichment systems before and during the war (Section D.4.4). Hertz's secret wartime work was deemed so important by the German government that he was allowed to live and work in relative comfort throughout the war despite his Jewish ancestry. After the war, he played a vital role in the Soviet nuclear program.

After the war, leftover wartime factories in Neustadt an der Orla, East Germany, were already perfectly set up to make high-quality nickel membrane filters for gaseous diffusion enrichment plants (pp. 3633–3638, 5052, 5055–5057). Manufacturing the filters was so difficult that even years after the war, Soviet plants could not make comparable items. What exactly did these German factories do during the war?

Stanisław Mrozowski (Polish, 1902–1999), K. Zuber (Swiss, 19??–19??), Werner Kuhn, Hans Martin, K. H. Eldau, Paul Harteck, and others developed photochemical methods of isotope separation, demonstrated them with elements such as mercury, and worked to apply them to uranium (Section D.4.5). Although it is currently unclear how far that work progressed during the war, it became the basis of laser isotope separation after the war. (For early work toward lasers in the German-speaking world, see Section C.3).

As a basis for comparison, one can consider the U.S. uranium enrichment facility at Oak Ridge, Tennessee. For the 12 months ending 1 September 1945, the total electrical consumption for Oak Ridge (Y-12 calutrons + K-25 gaseous diffusion + all other nuclear facilities + the town itself) was 1659 GW hr for the year, or 0.189 GW time-averaged (pp. 5122–5123).

At the end of 1944 the Greater German Reich (Grossdeutsches Reich) had a total known electrical production capacity of at least 22–23 GW, despite territorial losses, extensive bombing, and ongoing repairs (pp. 2102–2106). Including secretive or specialized power plants for classified or dedicated projects within the Greater German Reich that were not known to the Allied investigators plus the electrical production capacities of other countries that were occupied by Germany, allied with Germany, or nominally neutral but exporting aid to Germany, a reasonable estimate of the total electrical production capacity supporting the German war effort is roughly double the 22–23 GW figure, or ∼44–46 GW.

Using the average total electrical consumption of Oak Ridge during the final year of the war, Germany could have powered a fully equal facility by using less than 1% of the known wartime electrical capacity in the Greater German Reich, or less than 0.5% of the estimated total electrical production capacity that was available to aid Germany during the war. German centrifuges would have been more energy-efficient than U.S. enrichment methods, and the German implosion design would have needed much less ^{235}U than the U.S. Little Boy, so German uranium enrichment plants may have required far less total electrical power than Oak Ridge.

If Germany scaled up any of its proven uranium enrichment methods during the war, rather than building one giant Oak-Ridge-like plant that could be highly vulnerable to Allied bombing, it would have distributed its enrichment capability among a number of (especially underground) locations. Indeed, that is exactly what was done, according to a declassified October 1944 OSS report based on information from Adolf Schneider, a senior manager of the Deutsche Waffen und Munitions-Fabrik (pp. 4400–4403).

Archival documents, most of which are found in the declassified files of the OSS and the Manhattan Project's Foreign Intelligence Unit, mention dozens of highly suspicious sites that might have been used for that purpose and that have never been properly investigated, at least not publicly (Section D.4.6). Just a few illustrative examples are given below.

An October 1943 OSS intelligence report from Frederick Loofbourow described what sound like underground uranium enrichment facilities staffed by hundreds of workers near Lüneburger Heide. There were also other reports of nuclear-related work at Lüneburger Heide (pp. 4176–4182, 4406).

A May 1944 OSS intelligence report described what sound like two massive uranium enrichment facilities, each with 30,000 workers, run by I.G. Farben in Opava and Ostrava in eastern Czech territory (p. 3748).

Julius Schaub, Hitler's chief adjutant, stated there was another 30,000-worker uranium enrichment facility at an underground site in Thuringia (4635–4639).

Several sources mentioned Reichspost enrichment facilities on the outskirts of Berlin (pp. 3608–3617, 3708–3709, 4635–4639).

Throughout the war, large amounts of electricity were consumed by high-security weapons work that produced no obvious products (Sections D.4.6 and 8.8.11).

In September 1946, General Leslie Groves (the head of the U.S. nuclear weapons program) sent Percival C. Keith (the construction chief of the Oak Ridge enrichment plant) on a two-week Top Secret mission to Czechoslovakia (pp. 3770–3771). What target would involve Groves, require the specific expertise of Keith, and justify the great risk if Keith were captured by Czech or Soviet forces? Was Keith's mission to help inspect, remove, or destroy key components of a wartime enrichment facility?

As a quantitative example of what might have been required of a German enrichment facility, one can consider the case of electromagnetic separation, using the U.S. calutrons at the Oak Ridge Y-12 plant for reference. In early 1945, Y-12 was producing approximately 0.2 kg ^{235}U per day, or approximately 73 kg/year. The U.S. electromagnetic separation plant was designed to produce so much ^{235}U because the United States planned to use that uranium in Little Boy, a gun-type fission bomb that needed over 60 kg of fuel since it did not compress the fuel and had a very low efficiency. The U.S. plant provided enough uranium for approximately one bomb of that design per year.

The sources that describe the German fission bomb design all indicate that it was an implosion bomb (Section 8.8.8), which compresses the fuel, is much more efficient than a gun-type bomb, and therefore requires roughly 1/10 as much fuel as a gun-type bomb. If a German enrichment facility were designed to produce enough ^{235}U for one full-sized bomb per year (or several test bombs with smaller amounts of fuel and smaller explosive yields, as described by the sources), a German electromagnetic enrichment plant could have been roughly 1/10 the size of the U.S. Y-12 plant, as extrapolated in Table 8.2. Likewise, Table 8.3 shows the extrapolated characteristics of a hypothetical German centrifuge separation plant. If that same production capacity were distributed among several production plants to minimize the risk of Allied bombing (p. 4400), each plant would have been even smaller.

Characteristic	**U.S. Y-12 Plant**	**Hypothetical German Plant**
^{235}U production rate	73 kg/year	$\sim$ 7 kg/year
Number of ion beams	3120	$\sim$ 310
Number of workers	22,482	$\sim$ 2,200
Facility floor space	$\sim$ 400,000 m^2	$\sim$ 40,000 m^2
Electric power consumption	200 MW	$\sim$ 20 MW
Cost (1940s U.S. dollars)	$477,631,000	$\sim$ $48,000,000

Table 8.2: Known characteristics of the U.S. electromagnetic separation plant and extrapolated characteristics of a hypothetical German electromagnetic separation plant. (See Section D.15.2.A for details.)

Characteristic	**Hypothetical German Plant**
^{235}U production rate	$\sim$ 7 kg/year
Number of centrifuges	$\sim$ 467
Number of workers	$<$ 1,400
Facility floor space	$<$ 4,200 m^2
Electric power consumption	$<$ 1 MW
Cost (1940s U.S. dollars)	$<$ $48,000,000

Table 8.3: Extrapolated characteristics of a hypothetical German centrifuge separation plant. (See Section D.15.2.C for details.)

8.8.5 Fission Reactors for Breeding ^{239}Pu and/or ^{233}U

The available documentation shows that German scientists were aware that either ^{239}Pu or ^{233}U would make good fuel for fission bombs (Section D.5) and could be produced in a fission reactor by the following respective processes:

$$^{238}_{92}\mathrm{U} + \mathrm{n} \xrightarrow{(\mathrm{n},\gamma)} {}^{239}_{92}\mathrm{U} \quad \beta \xrightarrow{23.5\ \mathrm{min}} {}^{239}_{93}\mathrm{Np} \quad \beta \xrightarrow{2.36\ \mathrm{days}} {}^{239}_{94}\mathrm{Pu} \tag{8.1}$$

$$^{232}_{90}\mathrm{Th} + \mathrm{n} \xrightarrow{(\mathrm{n},\gamma)} {}^{233}_{90}\mathrm{Th} \quad \beta \xrightarrow{21.8\ \mathrm{min}} {}^{233}_{91}\mathrm{Pa} \quad \beta \xrightarrow{27.0\ \mathrm{days}} {}^{233}_{92}\mathrm{U} \tag{8.2}$$

^{237}Np fission fuel [Sanchez et al. 2008] could also have been bred in fission reactors (e.g., by knocking a neutron out of ^{238}U), although it probably would have been more difficult to produce in quantity than ^{239}Pu or ^{233}U [Benedict et al. 1981].

Ludwig Bewilogua (German, 1906–1983), Kurt Diebner, Paul Harteck, Otto Haxel (German, 1909–1998), and many others worked in teams trying to develop suitable fission reactors.

By far the best known German reactor was the one built by Werner Heisenberg's group, first located at the KWI for Physics in Berlin-Dahlem, and later moved to Haigerloch (pp. 3843–3853). It never achieved criticality (a self-sustaining neutron chain reaction) during the war. There were also smaller subcritical fission experiments, such as those built by Robert Döpel's team in Leipzig and Paul Harteck's team in Hamburg.[14]

Throughout the war, Kurt Diebner's Heereswaffenamt group built a series of reactor experiments of increasing size and complexity at Gottow (Kummersdorf) through 1944, and at Stadtilm in 1945 (pp. 3854–3868). According to official histories, Diebner's reactor experiments never achieved criticality during the war. In fact, there is some evidence that they may have achieved criticality in late 1944 and/or early 1945 [Karlsch 2005; Nagel 2016]. However, even if Diebner's reactor did go critical, it was a small experimental system, not a large production reactor for breeding useful quantities of ^{239}Pu or ^{233}U.

There is some evidence that a number of other, larger fission reactors were under construction during the war, and that some of them may have even been operational. Just a few examples are cited here; for more information, see pp. 3840–3953.

There may have been fission reactors and a fuel reprocessing facility near Königsberg (now Kaliningrad) in East Prussia (pp. 3928–3933). Heinrich Himmler's close diplomatic contact, Muhammad Amin Al-Husayni, the Grand Mufti of Jerusalem, reported those reactors after the war (pp. 4578–4579): "After 1945 the Grand Mufti said that the enemy espionage by 'Jewish, English and American intelligence services' caused 'the greatest damage.' They were able to discover the locations of 'atomic reactors' in East Prussia."

As already noted, Siegfried Flügge, who was probably the top nuclear physicist in the German nuclear weapons program, worked for many different organizations that were involved in the program, apparently serving to coordinate the scientific details of all of their activities. Among his many other urgent and nuclear-focused duties, he was appointed to a professorship at the University of Königsberg in 1944, late in the war as Russian forces were advancing (p. 4998). That appointment only makes sense if there was a nuclear facility there that was deemed critical to the war, such as fission reactors breeding plutonium for nuclear weapons.

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[14] Goudsmit 1947; Groves 1962; Irving 1967; Pash 1969; Powers 1993; Walker 1989.

During the war, Königsberg had a large staff of inorganic chemists with world-class expertise in methods that would have been useful for reprocessing irradiated fuel from fission reactors. After the war, many of those chemists were interrogated by at least two teams from the U.S. Alsos Mission, which suggests that U.S. officials suspected the Königsberg chemists had been involved in nuclear work (pp. 3930–3933).

There were tens of thousands of forced laborers working in and near Königsberg during the war. They are known to have worked with toxic chemicals such as ship paints and suffered the consequences [Jasiński 1994]. This labor pool might also have been used for hazardous nuclear work.

During the period 26–30 August 1944, U.K. Royal Air Force bombers, operating at the very limits of their range, devastated targets in and near Königsberg (p. 3928). That only makes sense if there were targets of great military value and urgency, such as a nuclear facility on the verge of producing enough fuel for nuclear weapons. It also explains the Grand Mufti's comment.

Despite the Allied bombings and fierce offensives by Soviet forces, German troops successfully defended East Prussia until April 1945, rather than retreating to more central areas of Germany and using their strength to defend those. Once again, that only makes sense if there were something in East Prussia that Germany considered to be of great strategic significance until the very end of the war.

After the war, East Prussia was claimed as Soviet territory, even though it was geographically disconnected from any other Soviet territory, rather than allotting it to the surrounding countries, Poland or Lithuania. Again, that suggests something rather unusual was found there. (Of course, it did also provide a desirable seaport for the Soviet Union.)

There are a number of archival documents, witness statements, aerial photographs, and other evidence strongly suggesting that part of the Bergkristall tunnel complex at St. Georgen an der Gusen (near Linz, Austria) was conducting nuclear-weapons-related work during the war (pp. 3874–3920). From some of the evidence, it sounds as if the complex may have included a fission reactor and fuel reprocessing facility. German forces sealed the entrances and air shafts to that part of the tunnel complex shortly before the end of the war, and they have remained sealed for 75+ years. U.S. officials inspected this site and interrogated witnesses after the war (pp. 4962–4970). Their reports on what they found and learned there have never been publicly released. Air and water samples taken from the site in recent years have remarkably high levels of radioactivity, which may or may not be due to purely natural causes. Until all of the documentary evidence is available, and/or until the site can be properly excavated and analyzed, the true nature of this facility cannot be settled.

According to U.S. intelligence reports, there was a highly secret, heavy concrete installation at the I.G. Farben Leverkusen plant that may have been a fission reactor (pp. 3934–3935). It is known that I.G. Farben Leverkusen was doing extensive work involving uranium hexafluoride throughout the war (Section 8.8.4), and that other I.G. Farben facilities were producing many other potentially nuclear-related materials (Section 8.8.7).

According to some sources, a fission reactor was built and operated by the SS, likely in an underground facility in Thuringia, and was reported to have been operational in March 1945 (pp. 3865–3868).

A possible fission reactor at Unterraderach near Friedrichshafen (on the coast of the Obersee Bodensee) was reported to have been operational in 1944 (pp. 3921–3925).

A fission reactor at an underground facility in Berlin-Lichterfelde was reported to have been operational in 1944 (pp. 3926–3928).

According to other sources, there may have been a fission reactor at Bodenbach/Krizik-Werke/Weser-Werke/Podmokly (pp. 3936–3937, 3987–3998).

There is evidence that there may have been additional fission reactors at other locations (pp. 3938–3953).

Heavy water (D_2O) is an excellent moderator for fission reactors. Germany appears to have been producing heavy water in at least 25 plants all over Europe (including several run by I.G. Farben, Section 8.8.7), despite the difficulties of Allied bombing and the urgent wartime needs to produce other materials and products. This additional evidence strongly suggests that Germany possessed operational fission reactors, or at least was trying to get reactors operational as soon as possible.

The Soviet Union demonstrated its first fission reactor (F-1) on 25 December 1946, only about 12 months after its captured German nuclear scientists were able to begin setting up the captured German nuclear materials (including at least 300 tons of German-produced uranium oxide, which fueled both F-1 and the larger second Soviet reactor for breeding Pu-239); see Section 8.9. If German scientists and German materials accomplished that feat so quickly after starting over in the Soviet Union after the war, they certainly could have done it in German territory during the war.

If uranium or thorium is left in a fission reactor too long, much of the ^{239}Pu and/or ^{233}U that had initially been created by neutron bombardment will be fissioned and destroyed by later neutrons. Moreover, prolonged neutron exposure can also breed undesirable isotopes—especially ^{240}Pu from natural uranium or ^{232}U from natural thorium—that are highly radioactive and therefore greatly complicate the handling of that fuel in reprocessing and in bombs. For both of those reasons, large amounts of uranium or thorium fuel are generally moved in and out of breeder reactors over fairly short periods of time.

In the wartime U.S. nuclear program, the main reactors breeding plutonium were three reactors in Hanford, Washington, dubbed reactors B, D, and F. When fully operational, each of those reactors produced approximately 250 MW of thermal power from approximately 250 tons of natural uranium, or about 1 MW/ton. At that power, each reactor bred approximately 0.19 kg of ^{239}Pu per day, or approximately 69 kg per year. To limit the production of ^{240}Pu, the 250 tons of reactor fuel was removed after approximately 100 days, and then the reactor was restarted with fresh natural uranium fuel [Bruce Cameron Reed 2015a, 2019]. Comparing the ^{239}Pu production rate of 0.19 kg/day to the rate of using natural uranium, 250 tons/100 days = 2.5 tons/day, the amount of ^{239}Pu bred per ton of natural uranium was

$$\frac{\text{Bred Pu-239}}{\text{Natural uranium}} \approx \frac{0.19\text{ kg/day}}{2.5\text{ tons/day}} \approx 0.076\ \frac{\text{kg}}{\text{ton}} \tag{8.3}$$

Note that the amount of fissionable ^{239}Pu produced from a ton of natural uranium is roughly 100 times smaller than the maximum amount of fissionable ^{235}U (7.2 kg) that could be extracted from that same ton of natural uranium via the enrichment methods of the previous section. Again, this low level of production is due to the need to avoid creating much ^{240}Pu in the fuel. As a result, a fission fuel breeding program would use ∼100 times more uranium than a fission fuel enrichment program (unless the irradiated uranium were reused in the breeder reactor after the plutonium had been removed, which may or may not have been practical under the urgent pressures of the war).

Counterbalancing that disadvantage is the advantage that a breeder reactor and the accompanying chemical purification processes handle fission fuel in a very dense solid or liquid state, whereas enrichment methods handle fission fuel in a far less dense gaseous or plasma state. Therefore the equipment for breeding would be much more compact, and could potentially be built and operated by fewer people, than the equipment for enrichment.

As long as the reactor is large enough to have a self-sustaining fission chain reaction, these characteristics can be scaled up or down in a linear fashion, using the approximate numbers in Table 8.4 as a basis for reference [Kemp 2005]. For example, if each Hanford reactor held 250 tons of natural uranium and produced approximately 69 kg of ^{239}Pu per year, a hypothetical German reactor holding approximately 22 tons of natural uranium could produce approximately 6 kg of ^{239}Pu per year, enough for one full-sized ∼20 kiloton implosion bomb (like the U.S. Gadget and Fat Man bombs) per year. From Eq. 8.3, producing 6 kg of plutonium would require processing approximately 79 tons of uranium.

Characteristic	**Approximate value (scales linearly)**
Thermal power	25 MW
Reactor core volume	100 m^3
Moderator	150 tons of graphite, or 80 tons of heavy water, or some of both
Natural uranium in reactor	25 tons
Replace uranium every	100 days
Uranium consumption rate	91 tons/year
Plutonium production rate	6.9 kg/year
Cost (1940s U.S. dollars)	$6,000,000

Table 8.4: Approximate characteristics of a breeder reactor for producing ^{239}Pu.

^{232}Th is useful for breeding ^{233}U but cannot sustain a fission chain reaction on its own. The reactor would need to contain natural uranium or uranium enriched in ^{235}U. On the order of $\sim$90% of the neutrons from the uranium would be needed to sustain the chain reaction, so only $\sim$10% of the neutrons could be spared to breed ^{233}U from ^{232}Th, and hence only $\sim$10% of the total fuel in the reactor could be thorium. Thus a fission reactor for breeding ^{233}U might be $\sim$10 times larger in volume or mass than a reactor for breeding ^{239}Pu. (Of course, plutonium would also be bred within the $\sim$90% of the reactor fuel that was uranium, and that plutonium could be extracted as well.) For this reason, it seems likely that the German nuclear program would have generally preferred producing ^{239}Pu instead of ^{233}U, although scientists may have certainly tried ^{233}U (especially because of the large amount of thorium that was available to the German nuclear program).

Many highly radioactive isotopes with short half-lives are created when fuel is bombarded with neutrons in a fission reactor, so it is customary to let the fuel "cool off" for a month or so after being removed from the breeder reactor before it is processed by people. Since the German nuclear program would have had a great sense of urgency and likely did not value the lives of its low-level workers, it might have processed irradiated fuel with a much shorter cooling off period.

There is some evidence that Germany developed chemical reprocessing methods to extract and purify the bred ^{239}Pu or ^{233}U (p. 3826). Although it is currently unknown just how far that work progressed during the war, or in what geographic locations, the scientific details of reprocessing constrain where and how it could have been done, and may guide historians in locating relevant documents and geographic sites:

- Due to the relatively sophisticated chemistry involved in reprocessing (p. 5135) and the fact that it would be tied to secret weapons development, it seems probable that any such reprocessing would have been run by I.G. Farben, or at the very least would have intimately involved I.G. Farben.

- Because of the large amount of irradiated uranium or thorium fuel that would need to be processed for a much smaller amount of ^{239}Pu or ^{233}U, and because of the great personal danger involved in exposure to the associated high levels of radiation and toxic chemicals, it also seems likely that any such work in wartime Germany would have involved slave labor and high fatalities (at least if it advanced beyond small-scale proof-of-concept laboratory experiments).

- Because of the large amount of material to be processed and the extreme danger in handling it, chemical reprocessing would probably have been conducted at or near the fission reactor(s) or electronuclear breeding site(s) where the ^{239}Pu or ^{233}U was bred.

- For cooling of the fission reactor and for both cooling and chemical steps during reprocessing, a breeding/reprocessing facility would likely be located very close to an abundant source of fresh water.

Tritium could also be bred from lithium and/or heavy water by neutron bombardment in a fission reactor. Tritium would be very useful for fusion boosting of fission bombs and/or for hydrogen bombs (Section 8.8.9).

8.8.6 Electronuclear Breeding of ^{239}Pu and/or ^{233}U

Even without a fission reactor, it is possible to produce significant amounts of ^{239}Pu or ^{233}U via electronuclear breeding (Section D.6). In this process, a particle accelerator fires a beam of high-energy charged particles (typically protons, deuterons, or electrons with a kinetic energy of many millions of electron-volts or MeV) at a target containing ^{238}U or ^{232}Th. When those energetic charged particles strike the nuclei of the target material, they knock some neutrons free; those neutrons are absorbed by the ^{238}U to become ^{239}Pu, or by ^{232}Th to become ^{233}U, as shown in Eqs. (8.1)–(8.2). In more sophisticated and efficient systems, the target may also contain an initial layer of lithium or beryllium atoms, which are especially good at releasing neutrons when struck by high-energy charged particles. If furthermore the target is immersed in a neutron moderator (such as heavy water or pure graphite) and surrounded by a neutron reflector (such as beryllium), each neutron that is originally generated can lead to a cascade of several more neutrons by subcritical fission reactions, yielding several atoms of bred fuel per charged particle in the beam. If the target is lithium without uranium or thorium, electronuclear breeding can be used to produce tritium.

Electronuclear breeding was seriously pursued by the United States and other countries after World War II, and even now is of concern as a proliferation risk for how new countries could produce nuclear weapons.[15]

Archival documents show that in German-controlled areas from the Netherlands to Czech territory, a considerable number of high-energy particle accelerators were produced and used as high priorities during the war. Rolf Wideröe (Norwegian but studied and worked in Germany, 1902–1996), Max Steenbeck (German, 1904–1981), Walter Dällenbach (Swiss, 1892–1990), Walther Bothe (German, 1891–1957), and many others worked to design, build, and test the accelerators (pp. 3020–3091, 3954–4022, 4504–4510).

Purely scientific research would not have been sufficient justification for all of the funding, labor, and materials that went into these accelerators when war needs and shortages were so dire. While accelerators would certainly be useful for measuring fundamental nuclear properties that are relevant to designing nuclear reactors and bombs, one or two modest accelerators would have been sufficient for that purpose. Indeed, Germany already had access to the Joliot-Curie cyclotron in Paris for such measurements.

Most of the accelerators appear to have been closely linked with the German nuclear weapons program and treated as a high priority for that program until the very end of the war. Electronuclear breeding seems to be the best explanation.

In August 1945, after some nuclear-related censorship of the U.S. press had been lifted, newspapers belatedly reported that sabotage and U.S. bombing had delayed German nuclear weapons work in Czech territory, probably a reference to cyclotrons that were produced there: "A shattering American air raid, Czech sabotage and an accident frustrated German experiments in Czechoslovakia seeking to develop an atomic bomb, newspaper accounts said here today" (p. 3979).

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[15] Barashenkov et al. 1987; Barber and George 1959; Chichester 2009; Kemp 2005; Livdahl 1981; Magill and Peerani 1999; Riendeau et al. 1999; Van Atta 1977.

In November 1945, *Time* magazine reported evidence of secret wartime German work to mass-produce cyclotrons in Czech territory for a nuclear weapons program (p. 3987).

In May 1945, the Soviet physicist Georgy Flerov was sent by Joseph Stalin and Igor Kurchatov to investigate the German nuclear program. In 1983, Flerov described his interrogation of a German cyclotron expert who had been captured by Soviet forces at the end of the war. The German physicist told of at least one highly secret underground SS/Reichspost installation in the Riese complex in Silesia that was using multiple cyclotrons for urgent war-related work—most likely electronuclear breeding (p. 4504).

Werner Grothmann, Heinrich Himmler's chief adjutant, independently confirmed that there was a high-priority, highly secret, joint SS/Reichspost program to breed plutonium without a reactor—electronuclear breeding—in underground installations using particle accelerators that had been manufactured in Czech territory and in Austria (p. 4024).

Simple physics calculations (pp. 5133–5134) demonstrate that electronuclear breeding of kilograms of ^{239}Pu or ^{233}U for a fission bomb, or tens of grams of tritium for fusion boosting a bomb, would potentially have been quite feasible (though technically challenging) for the wartime German program.[16] Of course, any ^{239}Pu or ^{233}U created via electronuclear breeding would still have needed to be chemically extracted from the target material, just as with breeding in a fission reactor (p. 5135).

It is important for historians to search for more evidence of a wartime electronuclear breeding program (both in archival documents and at physical sites that may have been involved in this work), and to ascertain just how far any such electronuclear program actually progressed during the war.

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[16] ^{237}Np fission fuel [Sanchez et al. 2008] could also have been bred using accelerators (e.g., by knocking a neutron out of ^{238}U), although it probably would have been more difficult to produce in quantity than ^{239}Pu or ^{233}U [Benedict et al. 1981].

8.8.7 Production of Other Potentially Nuclear-Related Materials

During the war, Germany produced large quantities of materials that had non-nuclear applications, yet would also have been extremely useful for a nuclear weapons program (Section D.7). From archival documents that are currently available, it is not possible to determine whether or how much of each material was used for nuclear applications, but clearly the materials were readily available if some quantity of them had been requisitioned by a high-priority nuclear program.

Any nuclear-related production programs in wartime Germany would have had access to a larger labor pool than comparable programs in the United States. The population of the greater German-speaking world was equal to or somewhat greater than that of the United States at the time (Section 10.1.1). Including the populations of countries that were allied with or occupied by Germany, the total population of German-controlled territory was far larger than that of the United States.

Likewise, the gross domestic product (GDP, a measure of economic and industrial resources) of German-controlled territory was roughly comparable to or by some measures even greater than that of the United States (pp. 2100–2101).

Just as importantly, the electrical power production of German-controlled Europe was fairly comparable to or even greater than that of the United States (pp. 2100–2104). Germany had access to power plants and fuel sources throughout most of Europe, and also built more during the war (e.g., pp. 3755–3759), so energy would not have been a limiting factor for nuclear-related production.

Deuterium can serve as a great fusion fuel and source for producing neutrons and tritium, and an excellent neutron moderator for fission reactors when in the form of deuterated (heavy) water. According to official histories, heavy water was only produced in significant quantities at the Norsk Hydro hydrogen factory in Vemork, Norway, which was famously attacked by Allied forces and the Norwegian Resistance and forced to shut down. In fact, documents indicate that heavy water production facilities for the German nuclear program were known or reported to be located at sites all over German-occupied Europe (see map on p. 4030):

1. Vemork, Norway (pp. 4031–4039).
2. Såheim, Norway (p. 4040).
3. Notodden, Norway (p. 4041).
4. I.G. Farben Leuna Werke, low-pressure production plant (pp. 4042–4050).
5. I.G. Farben Leuna Werke, high-pressure production plant (pp. 4042–4050).
6. I.G. Farben Bitterfeld (pp. 4050–4051) [Karlsch 2005, p. 110; Sadovsky 2011b].
7. I.G. Farben Halle (pp. 4052–4055).
8. Kiel, probably adjacent to the Deutsche Werke Kiel (pp. 4056–4061).
9. Dräger Werke, Lübeck (pp. 4062–4063).
10. Müggenberg (pp. 4064–4065).
11. Chemische Fabrik Griesheim-Elektron, Frankfurt am Main (pp. 3678–3680, 4066–4067).

12. Berlin plant (p. 4068).
13. Linde plant, Munich (p. 4068).
14. Montecatini plant, Sinigo-Merano, Italy (p. 4069).
15. Montecatini plant, Cotrone/Crotone, Italy (p. 4069).
16. I.G. Farben Auschwitz in Poland (pp. 4069, 4452).
17. Plant near the Schmiedeberg (now Kowary, Poland) uranium mine (p. 4069).
18. Plant near Breslau (now Wrocław, Poland; pp. 4070–4071).
19. Weer, near Wattens, Tyrol, in the Austrian Alps (pp. 4072–4077).
20. B9 Quarz underground complex near Roggendorf and Melk, Austria (p. 4078–4079).
21. Degussa plant at Rheinfelden, Austria (pp. 4080–4081).
22. Austrian Chemical Works plant at Weissenstein, Austria (pp. 4080–4081).
23. Siemens and Halske plant in Lehesten (pp. 3689, 3696, 4080).
24. Bayrische Stickstoffwerke in Piesteritz (pp. 4082, 4452–4453).
25. Pardubice/Wesser, Czechia (pp. 3446, 4082–4083).
26. Other possible locations (pp. 4084–4086).

Thus Germany was producing large quantities of heavy water in a very determined fashion at numerous plants all over Europe, despite the difficulties of Allied bombing and the urgent wartime needs to produce other materials and products. The existence of this massive, high priority, highly secretive heavy water production program strongly suggests that one or more fission reactors may have actually been operational during the war. At the very least, it seems to indicate that Germany was trying to get reactors operational as soon as possible. Germany may have also needed significant quantities of deuterium/heavy water for electronuclear breeding of fission fuel and/or for fusion fuel production.

Lithium was utilized for processing ceramics, glass, and metals, but it would also have been extremely useful for producing tritium, neutrons, and/or fusion reactions. Germany produced hundreds of tons of lithium and lithium compounds during the war (p. 4090). Alfred Klemm developed methods to separate the naturally occurring ^{6}Li and ^{7}Li isotopes, which would have been required only for nuclear applications (pp. 4344–4347). Klemm also knew of work on tritium being conducted by other scientists (p. 4346).

High-quality graphite was widely used for high-temperature exhaust steering rudders on the A-4 (V-2) and other rockets, and was utilized for making electrodes, filters, and other components too. However, graphite could also have been quite useful as a neutron moderator to slow down neutrons and promote chain reactions in a fission reactor. Germany produced many tens of thousands of tons of graphite during the war (p. 4110).

While some historians have claimed that the German nuclear program was unwise to choose heavy water instead of graphite as a reactor moderator, the actual historical and scientific record suggests otherwise.

First of all, it is far from certain that the German program did exclude graphite. For example, I.G. Farben's Bitterfeld facility was mass-producing both graphite (p. 4110) and heavy water (p. 4050) as well as other nuclear-related materials (pp. 4128, 4133, 4136). Similarly, Griesheim plants were producing both graphite (pp. 4114–4116) and heavy water (pp. 4066–4067), with other nuclear-related facilities such as Degussa in the same area [Hayes 2004; Nagel 2016]. Graphite was also mass-produced at the Siemens Plania Werke in Racibórz/Ratibor, Poland (pp. 4110–4114), near a reported heavy water plant at Auschwitz (pp. 4069, 4452) and reported uranium enrichment plants at Opava and Ostrava (p. 3749).

It may well be that the German program was aware that graphite could be used as a moderator but preferred heavy water for several reasons:

- The "moderating ratio," the ratio of how strongly a moderating material slows down neutrons vs. how strongly it absorbs neutrons, is ∼25–100 times larger for heavy water than for graphite (depending on the purity of the heavy water). Since heavy water is far more effective than graphite at slowing neutrons without absorbing them, much less moderator and/or natural uranium would be required for a reactor to achieve criticality, or the reactor could be more easily loaded with other neutron-absorbing materials such as lithium for tritium production. Because of these advantages, the United States built five heavy water reactors at the Savannah River Site in the 1950s and used them to breed over 36,000 kg of plutonium during the Cold War.[17]

- Using heavy water would avoid "Wigner's disease," in which irradiated graphite swells, stores/releases large amount of energy, and creates problems in a reactor, as caused major headaches in both the United States (diagnosed by Eugene Wigner) and the Soviet Union (e.g., the January 1949 Chelyabinsk Reactor A accident that shortened Igor Kurchatov's life) [Kojevnikov 2004, p. 151; Bruce Cameron Reed 2019, pp. 260–261; Rhodes 1995, p. 277].

- Graphite is flammable and could cause or contribute to a catastrophic reactor accident, as in the 1957 Windscale reactor fire in the U.K. nuclear weapons program [Lorna Arnold 2007; Mahaffey 2014, p. 176].

- While being used as a moderator for fission reactions, heavy water will simultaneously breed tritium. Further tritium can be bred by inserting lithium into the heavy water reactor (which can spare more neutrons for that purpose than a graphite reactor could, since the moderating ratio of heavy water is much higher). For example, the five heavy water reactors at the U.S. Savannah River Site produced around 200 kg of tritium during the Cold War [Høibråten 2020]. There is evidence that the wartime German program wanted fusion fuels such as tritium for (a) neutron initiators in fission bombs, (b) fusion neutron boosting in fission bombs, and (c) fusion fuel for a megaton-level H-bomb (Section D.9).

- Using heavy water for reactors would leave all of Germany's graphite available for other urgent applications, such as electrodes, rocket exhaust steering rudders, and steel production.

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[17] DOE 1996; Glasstone 1958, pp. 464–465; Glasstone and Sesonske 1981, pp. 470, 786;
https://ansn.iaea.org/Common/topics/OpenTopic.aspx?ID=19022
https://nucleus.iaea.org/sites/graphiteknowledgebase/wiki/Wiki%20Pages/Nuclear%20Properties.aspx

Beryllium was used for producing certain metal alloys, but it also could have been quite useful as a neutron reflector and multiplier in a fission reactor, electronuclear breeding system, or fission bomb. Wartime production of beryllium was in the tons (p. 4096).

Boron was needed for producing certain types of glass, ceramics, and metals, but it also would have been very useful as a neutron absorber. Large quantities of boron were produced in wartime Germany (p. 4104).

Fluorine was used for various industrial chemical production processes, but it also would have been essential for producing uranium hexafluoride for the enrichment of ^{235}U. Wartime production of fluorine was in the thousands of tons (p. 4118).

Aluminum was employed for fabricating a wide variety of metal structures and packaging. On the other hand, aluminum could have been quite useful as cladding around fission fuel in a reactor, or as spherical pusher and casing shells in a fission bomb as described in Section 8.8.8. Thousands of tons of aluminum were produced in wartime Germany (p. 4126).

Calcium was used in making certain metal alloys, but it also would have been extremely useful in key steps of the purification of thorium, uranium, and/or plutonium. Germany produced thousands of tons of calcium during the war, and is even documented to have utilized calcium to purify thorium and uranium (p. 4132).

Nickel was needed for nickel-cadmium batteries and certain alloys. Yet because nickel is much more resistant than other metals to corrosion by uranium hexafluoride (used in uranium enrichment), it would have been invaluable in a nuclear program. Wartime production of nickel was many thousands of tons (p. 4138).

Zirconium was used for high-temperature metals and ceramics in non-nuclear applications, but its high temperature resistance and other properties also would have made it ideal as a fuel cladding material in fission reactors. Tons of zirconium were produced in wartime Germany. There was also an apparently related story about the SS *Flying Enterprise*, which sank on 10 January 1952 while carrying cargo from Hamburg to the United States. Its captain, Kurt Carlsen, later told interviewers such as Bjarne Bekker that the cargo included five tons of zirconium, left over from the wartime German nuclear program, which was salvaged from his sunken ship and used in the first U.S. nuclear submarine, USS *Nautilus* (p. 4142).

Cadmium was important for nickel-cadmium batteries and soldering, but it also could have been extremely useful as a neutron absorber. Germany produced thousands of tons of cadmium during the war (p. 4148). Germany also possessed methods for electroplating thin layers of materials such as cadmium onto aluminum. Such methods are potentially quite relevant for creating a neutron-absorbing cadmium layer on a spherical aluminum pusher as in the German fission implosion bomb described in March 1945 (Section 8.8.8).

Some sites were producing multiple nuclear-related materials at the same location. For example, I.G. Farben's Bitterfeld facility is documented to have been producing heavy water (p. 4050), graphite (p. 4110), aluminum (p. 4128), and calcium (pp. 4133, 4136); Bitterfeld may have produced other relevant materials as well.

Intriguingly, significant quantities of many of these nuclear-related materials were also shipped to Japan, Germany's wartime ally, along with at least 560 kg of (possibly enriched) uranium and other cutting-edge military technologies (pp. 4094, 4103, 4858–4892).

8.8.8 Fission Bomb Designs

A number of independent sources provided information about wartime German fission bomb designs (Section D.8).

No later than 1940, the mathematicians Walter Hantzsche (German, 19??–19??) and Hilmar Wendt (German, 1913–19??) derived pressure, density, and temperature solutions that are applicable to spherical and cylindrical implosion bomb configurations, and that are still used today (pp. 4166–4169).

No later than 1942, Gottfried Guderley (German, 1910–1997), a hydrodynamics expert working for the German military, performed very similar calculations for spherical and cylindrical implosions (pp. 4170–4171).

As already noted in Section 8.8.4, a 1943 U.S. intelligence report stated that "several factories and hundreds of workers" in underground facilities near Lüneburger Heide were producing a special new type of explosive that was so energetic that one kilogram of the new material would have a blast radius of several kilometers, and that would be placed into bombs of a highly unusual spherical design (p. 4176).

In November 1944, *Time* magazine published a news report that Germany was developing a fission bomb with a spherical implosion design. The implications of the article were so clear that Leslie Groves, the military leader of the Manhattan Project, had a strong reaction when he found out (p. 4185).

A 23 March 1945 letter from General Ivan Ilyichev, chief of intelligence for the Soviet army, to Joseph Stalin reported that the Germans had an atomic bomb and described it in considerable detail as a 2-ton, 1.3-meter-diameter spherical implosion device with multiple concentric layers and a ^{235}U core (Fig. 8.32, Table 8.5, and Section 8.8.12).

Erich Schumann (German, 1898–1985), the Heereswaffenamt's head physicist, was an expert on shaped-charge explosives and X-ray diagnostics for explosives, Wernher von Braun's Ph.D. thesis advisor for the development of rockets, and a key figure in Germany's biological warfare program and other advanced research programs. No later than 1940, he, Walter Trinks (German, 1910–1995), Rudi Schall (German, 1913–2002), and others began investigating the use of shaped-charge explosives (especially spherical, but also other geometries) and explosive lenses to generate implosive shock waves strong enough to initiate fission and fusion reactions and produce a large nuclear explosion, and Schumann continued to advance that work throughout the war. Schumann filed approximately 40 secret patents on this work during the war, which ultimately led to several unclassified postwar patents. Those published patents described designs extremely similar to the design that Ilyichev said was tested in March 1945: spherical implosion bombs with a total mass of approximately 2 tons, an outer layer of segmented explosive lenses, inner spherical layers of cadmium, uranium, and other materials, and fusion fuel in the center (pp. 4187–4255). (Since the United States possessed much of this evidence, one must wonder why Samuel Goudsmit knowingly gave false testimony to the U.S. Senate by claiming that Schumann was mainly just interested in "the physics of piano strings"—see pp. 3294–3297, 3301.)

In November 1945, the German economist Erwin Respondek wrote that Erich Schumann had been involved in the development of an atomic bomb that used uranium fuel and a neutron initiator (and apparently Schumann's expertise, conventional explosives for spherical implosion), and that the problem was "solved" in 1944 (p. 4194).

Adolf Busemann (German, 1901–1986), Rolf Engel (German, 1912–1993), Hubert Schardin (German, 1902–1965), and others also played major roles in the development of implosion bombs [Karlsch 2005; Krehl 2009].

A Top Secret U.S. cable from March 1946 stated that a "capable young engineer" in Poland knew that atomic bomb casings included a layer of cadmium, which was true for the implosion bomb designs described by both Ilyichev and Schumann (p. 4255).

1946 U.S. intelligence documents described how SS General Hans Kammler's deputy Erich Purucker and a car full of German atomic bomb plans were captured by Russian forces in May 1945 (p. 4914).

After the war, Kurt Diebner discussed spherical implosion bomb designs, specifically showing a hollow spherical pit of fission fuel with fusion fuel in the center, likely based on the wartime work in which he had participated (pp. 4260–4267).

German witnesses described secretive and mysterious work that had been conducted during the war to produce and test nesting aluminum spheres that apparently matched the description of those in the implosion bomb designs (p. 4270).

Werner Grothmann recounted the development of an atomic bomb that "possessed a spherical shape with a diameter of over one meter. It was very heavy, even though the bomb body itself was supposed to be out of aluminum. It was said, if one reduces the weight, the yield is not as high" (pp. 4271–4273).

All of these independent sources appear to have been describing the same spherical implosion fission bomb design, or very closely related variations of the same basic design. Their details have been correlated and compared with fundamental physics and unclassified documents about the first U.S. implosion bombs (Gadget, tested in New Mexico on 16 July 1945, and its fully packaged version, Fat Man, dropped on Nagasaki on 9 August 1945) and other nuclear weapon designs.[18] Based on this information, approximate design parameters have been calculated for the German spherical implosion bomb, specifically the version that Ilyichev reported was tested in Thuringia in March 1945. The results are summarized in Table 8.5. For much more information, see Section D.15.5.

The implosion design described by Ilyichev and the other sources seems very detailed, physically feasible, and deeply grounded in experimental and engineering details. While similar to the U.S. Gadget/Fat Man, it does not appear to be a carbon copy of that design, suggesting that it was arrived at independently and not by any German espionage of the U.S. program. In fact, in some respects the German design was several years more advanced than U.S. designs. The German design seems to have been far more than an abstract concept that was never reduced to practice, or a hasty idea that was thrown together at the end of the war. It appears to have been the end product of a well-funded, long-running, highly scientifically skilled nuclear weapons development program.

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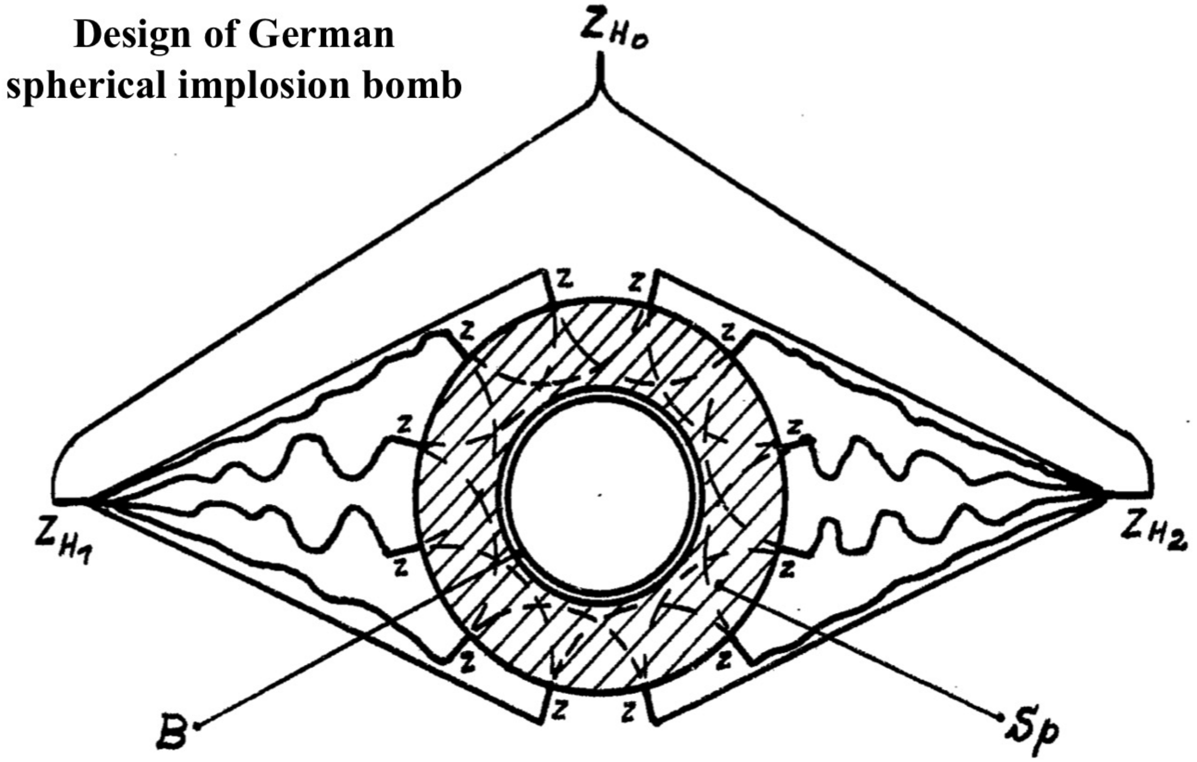
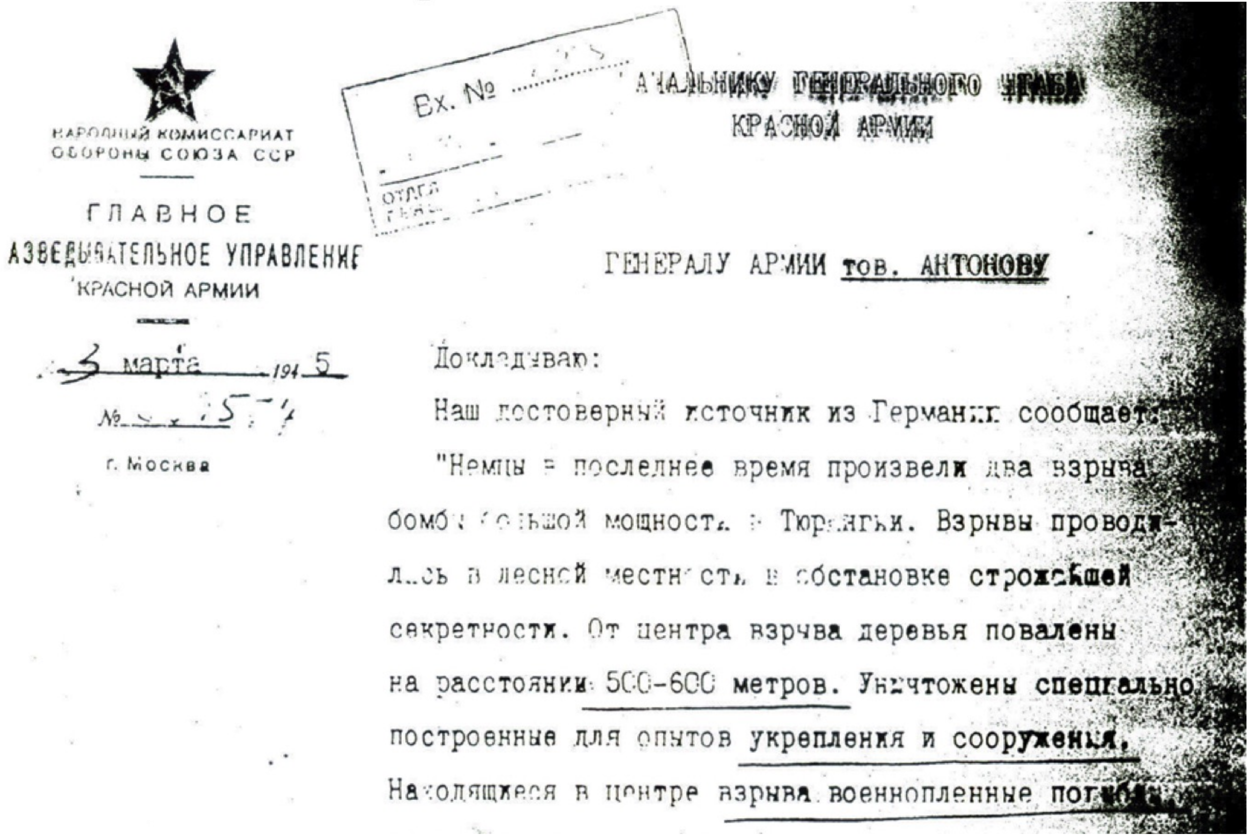
[18] E.g., Coster-Mullen 2012; Goncharov 1996a, 1996b; Goncharov and Riabev 2001; Gsponer and Hurni 2009; Chuck Hansen 1988, 2007; Bruce Cameron Reed 2015a, 2019; Serber 1992; Sublette 2019; Wellerstein and Geist 2017; Winterberg 2010.



Design of German spherical implosion bomb

March 1945 Soviet report on German fission bomb test explosions



НАРОДНЫЙ КОМИССАРИАТ
ОБОРОНЫ СОЮЗА ССР

ГЛАВНОЕ
АЗВЕДЫВАТЕЛЬНОЕ УПРАВЛЕНИЕ
КРАСНОЙ АРМИИ

3 марта 1945
№ [illegible]
г. Москва

Вх. №

НАЧАЛЬНИКУ ГЕНЕРАЛЬНОГО ШТАБА
КРАСНОЙ АРМИИ

ГЕНЕРАЛУ АРМИИ тов. АНТОНОВУ

Докладываю:

Наш достоверный источник из Германии сообщает:

"Немцы в последнее время произвели два взрыва бомбы большой мощности в Тюрингии. Взрывы проводились в лесной местности в обстановке строжайшей секретности. От центра взрыва деревья повалены на расстоянии 500-600 метров. Уничтожены специально построенные для опытов укрепления и сооружения. Находящиеся в центре взрыва военнопленные пог

Figure 8.32: Examples of some of the evidence for the development of a fission implosion bomb in wartime Germany. Above: Erich Schumann's schematic design for a spherical implosion bomb (Section D.8). Below: the beginning of a March 1945 Soviet intelligence report giving Joseph Stalin details about successful German tests of a fission implosion bomb (Section D.12).

Component	Gadget/Fat Man	Thuringian Device
Neutron initiator	$\sim$ 7 g beryllium/polonium-210 "urchin" 1.25 cm radius	Deuterium + lithium with high voltage $\sim$ 1.25 cm radius and/or external 6 MeV betatron
Pit	6.2 kg ^{239}Pu 4.6 cm radius	**For test:** <1 kg inner layer of ^{235}U with $\sim$ 5–10 kg natural or low-enriched U outer layer **For deployment:** $\sim$ 5–10 kg ^{235}U $\sim$ 5 cm radius
Tamper/ reflector	108 kg natural U 11.1 cm radius	$\sim$ 100 kg natural U $\sim$ 11 cm radius
Neutron absorber	Boron-10 plastic 3.2 mm thick	$\sim$ 1.3 kg cadmium $\sim$ 1 mm thick
Pusher	130 kg aluminum 23.5 cm radius	$\sim$ 130 kg aluminum $\sim$ 23 cm radius
Explosive	Composition B and baratol 2500 kg, segmented $\sim$ 70 cm radius	TNT, RDX, and liquid oxygen $\sim$ 1400 kg, segmented $\sim$ 63 cm radius
Explosive case	$\sim$ 180 kg aluminum 72.5 cm radius	$\sim$ 140 kg aluminum $\sim$ 64 cm radius
Ballistic case	Steel 4.5 mm thick 75 cm radius	$\sim$ 190 kg steel $\sim$ 4.5 mm thick 65 cm radius
Overall radius	75 cm	$\sim$ 65 cm
Total mass	3000 kg (bomb only) 4670 kg (with shell and fins)	$\sim$ 2000 kg
Delivery system	Boeing B-29 heavy bomber	A-4, A-9, or A-9/A-10 ballistic missile
Explosive yield	20 kilotons	**For test:** < 1 kiloton **For deployment:** $\sim$ 5–100 kilotons

Table 8.5: Comparison of the U.S. Gadget/Fat Man implosion design (from unclassified sources) with extrapolated design parameters of the March 1945 Thuringian device (Section D.15.5). The explosive yield of the German design was highly dependent on how much fission and fusion fuel were used.

Neutron initiator. A neutron initiator provides neutrons to start a fission chain reaction at the optimal time during implosion. Gadget/Fat Man used a crude polonium-210/beryllium "urchin" initiator that produced $\sim 2 \times 10^8$ neutrons/sec when crushed at the center of the bomb [Reed 2019, p. 305]. Ilyichev and other sources reported that the neutron initiator at the center of the German bomb used fusion fuel (e.g., deuterium + lithium) stimulated by high voltage (similar to the high-voltage fusion neutron initiators used by modern nuclear weapons). During the final two years of the war, the C. H. F. Müller company in Hamburg produced and delivered at least five high-voltage fusion neutron generators that produced up to 2×10^{11} neutrons/sec, 1000 times higher than the U.S. urchin (pp. 3963, 4318). Hans Ritz, the managing director of C. H. F. Müller, told Allied investigators in May 1945 that his company's work was important for nuclear weapons (pp. 4318–4320). A Dutch physicist told postwar Allied investigators that "the S.S. placed high importance on obtaining neutron generators" from Müller and other suppliers for secret "new weapons" (p.

4314). After the war, Kurt Diebner patented a high-voltage fusion neutron initiator at the center of an implosion bomb (pp. 4260–4261).

In addition to serving as a neutron initiator, the fusion fuel at the center of the German bomb design could have caused significant fusion boosting of the explosive yield of the bomb. Fusion reactions produce copious neutrons, which would promote many fission reactions in the surrounding pit, greatly increasing the number of fission reactions and hence the yield before the bomb flew apart and the reactions stopped. Fusion boosting was not even tested by the United States until the Greenhouse Item test in 1951 [https://nuclearweaponarchive.org/Usa/Tests/Grnhouse.html]; it is now commonly used in nuclear weapons.

Ilyichev also referred to a second neutron initiator: an external compact betatron directing electrons with energies of at least 6 MeV toward the center. The $\geq$6 MeV electrons would produce $\leq$6 MeV gamma-ray photons in the uranium via bremsstrahlung and other absorptive processes, the photons would induce photofission reactions in the uranium, and neutrons would be released. This second neutron initiator would have further increased the number of initial neutrons and hence the yield. It also would have served as a backup initiator in case the fusion neutron initiator failed to fire at the right time. Several manufacturers produced betatrons during the war; in particular, Siemens-Reiniger in Erlangen built compact 6-MeV and 7-MeV betatrons. The United States did not use a betatron as a neutron initiator in a bomb until the George test of Operation Tumbler-Snapper in 1952 (pp. 3088–3089, 3957–3970, 5160).

Pit. Ilyichev described the pit of the Thuringian device as a hollow sphere of ^{235}U that was imploded to achieve criticality. Gadget/Fat Man used a hollow spherical pit with 6.2 kg ^{239}Pu. Since the Thuringian device appears to have been fairly comparable in overall size and design, it seems reasonable to assume that it could have accommodated a pit of up to 5–10 kg of ^{235}U. Much less ^{235}U may have been used in the test explosions, especially if the central fusion fuel provided a significant number of neutrons. Multiple independent sources appear to have mentioned the wartime German production of fission pits with masses between 1 and 8 kg (pp. 3350–3351, 3827–3830, 4176, 4183, 4207–4210, 4411, 4564, 4635–4639, 4903).

Tamper/reflector. Ilyichev listed a "delay mechanism" between the "sphere made of metal uranium 235" and the aluminum "protective casing." Gadget/Fat Man used a 108 kg natural uranium tamper between the pit and the aluminum pusher to "delay" the expansion of the fissioning center and to reflect escaping neutrons, thereby increasing the yield. The German tamper probably also used around 100 kg of natural uranium. Elsewhere in his report, Ilyichev appears to have simply lumped the uranium pit and uranium tamper together in describing the inner part of the bomb as being "filled with uranium." Uranium metal was available from suppliers such as Auergesellschaft, Degussa, Buchler, and Treibacher.

Pusher. Ilyichev stated: "The uranium sphere is encased in a protective aluminum casing." Gadget/Fat Man used a 130 kg aluminum "pusher" between the conventional explosive and the uranium reflector/tamper. Because the aluminum pusher's density was higher than that of the explosive but lower than that of the uranium, the pusher helped to efficiently transfer the implosive shock wave from the explosive to the uranium. The Thuringian device apparently used the same approach. The wartime German aluminum industry was enormous and highly capable, and witnesses described secretive work that had been conducted during the war to produce and test nesting aluminum spheres closely resembling the description of those in the implosion bomb designs (pp. 4126–4131, 4270).

Neutron absorber. Ilyichev, Schumann, and the "capable young engineer" in Poland mentioned a layer of neutron-absorbing cadmium to prevent stray neutrons from initiating fission reactions in the core at the wrong time. Gadget/Fat Man used a layer rich in boron-10 for that same purpose. Wartime German companies such as Kampschulte, Blasberg, and Wilhelm Meyer did electroplating of aluminum components, including electroplating with cadmium, and would have been capable of producing a cadmium-electroplated aluminum pusher (pp. 4148–4152).

Explosive. Ilyichev said the Thuringian device used specially shaped segments of TNT, although that might mean any of several TNT-related explosives that were widely produced by Germany during the war. Erich Schumann and Walter Trinks demonstrated a sophisticated knowledge of TNT, hexogen/RDX, other explosives, and explosive lenses using combinations of those materials. Schumann and his colleagues began working on explosive lenses no later than 1940, and by 1942–1943 they were testing large explosive lenses (pp. 4211–4219). Based on information from Ilyichev, Schumann, and Trinks, the explosive layer's mass appears to have been approximately 1400 kg.

TNT molecules ($C_7H_5N_3O_6$) contain relatively few oxygen atoms and normally release their explosive energy by decomposing into a number of smaller oxygen-deficient molecules. Without providing added oxygen, detonation releases 4.184 GJ of energy per ton of TNT. If enough liquid oxygen were provided, detonation could release up to 14.5 GJ per ton of TNT. Thus with liquid oxygen, the $\sim$1400 kg of explosives in the Thuringian device could easily have been quite comparable to or even significantly more powerful than the 2500 kg of explosives in the Gadget/Fat Man design.

Explosive case. According to Ilyichev: "TNT is covered by a protective layer made of a light aluminum alloy." If the aluminum explosive case had an outside radius of $R = 64$ cm (just smaller than Ilyichev's quoted radius for the outer steel case), a thickness of 1 cm, and a density of 2.70 g/cm^3, its mass would have been approximately 140 kg.

Ballistic case. Ilyichev stated: "An exterior casing of armored steel is installed above the blasting mechanism." Steel alloys have densities in the range of 7.75–8.05 g/cm^3, so one may use an average density of 7.9 g/cm^3. If the Thuringian device had a steel ballistic case with an outside radius of $R = 65$ cm and the same thickness as Fat Man's case (0.45 cm), the mass of the case would have been approximately 190 kg.

Total mass. The component masses for the Thuringian device in Table 8.5 add up to a total mass of approximately 2000 kg, just as Ilyichev and Schumann reported. Thus the German bomb had a total deployed mass less than half that of the first U.S. fission bombs (4670 kg for Fat Man), yet could have had a comparable or even greater yield.

Smaller version. In addition to the two-ton spherical fission implosion bomb described above, several sources discussed the wartime development of a smaller fission bomb. It was described as a tactical, nonspherical, two-point-ignition, fission implosion bomb that was externally similar to a standard German 250 kg bomb, had a full yield likely less than one kiloton, and was potentially ready for deployment (pp. 4246–4248, 4271–4277, 5030).

Delivery vehicles. It took the United States several years to reduce the size and mass of fission bombs from its initial Fat Man and Little Boy designs. According to dozens of independent sources (p. 5821), the German fission bombs were intended to be launched on a rocket; the United States was not prepared to do that until 1958 (after extensive help from hundreds of German-speaking scientists and engineers it had acquired). During the war, jet bombers and submarine-launched missiles were also under development as delivery vehicles for the fission bombs (p. 5820).

8.8.9 Hydrogen Bomb Designs

Wolfgang Ferrant (German?, ??–??), Ulrich Jetter (German, 1914–??), Alfred Klemm (German, 1913–2013), Karl Lintner (Austrian, 1917–2015), Josef Mattauch (Austrian, 1895–1976), Erich Schumann, Georg Stetter (Austrian, 1895–1988), Walter Trinks, and many others worked in teams that researched and produced significant amounts of fusion fuels and potential methods to use them (Section D.9).

German patents, articles, and other documents from 1933 through 1945 discussed how to produce fusion reactions in high-voltage tubes (pp. 3958–3970 and 4281–4327). That technology would have been very useful as a fusion neutron initiator in a fission bomb, as described by Kurt Diebner (p. 4261) and Ivan Ilyichev (p. 4485).

In postwar papers apparently based on wartime work, Erich Schumann and Walter Trinks (pp. 4187–4255) and Kurt Diebner (pp. 4260–4267) described spherical implosion bomb designs with a center of fusion fuel inside a spherical shell of fission fuel. That "fusion boosting" approach could have greatly increased the yield of a fission bomb by supplying far more neutrons to induce fission reactions.

A number of documents show that there was wartime work using lithium and deuterium together as fusion fuel (pp. 4305–4341). Because lithium deuteride is solid and not a gas or cryogenic liquid, it makes an ideal fuel for hydrogen bombs.

During the war, Alfred Klemm (under the direction of Josef Mattauch) perfected a method to separate the lithium-6 isotope from the predominant lithium-7 in natural lithium (pp. 4344–4347). That would only be useful for nuclear applications. Klemm also stated that there was wartime work to produce tritium, another very potent fusion fuel (p. 4346).

In 1950, Ulrich Jetter (German, 1914–??) published a detailed proposal that fusion bombs could use lithium-6 deuteride as readily storable solid fuel, rather than the much more troublesome cryogenic deuterium and tritium (p. 4348). Based on the other documents available, Jetter's description appears to be directly based on wartime German work. According to conventional histories, lithium-6 deuteride was first considered in the United States by Edward Teller in 1947 and in the Soviet Union by Vitaly Ginzberg in 1949, was first tested by the United States in 1954, and is commonly used in modern H bombs.[19]

In 1946, several scientists and engineers reported that during the war, Germany had been working on a 6-ton radioactive bomb, as well as methods to deliver it by rockets or aircraft (pp. 4338, 4350–4363, and 5343). Such a massive bomb would have been very challenging to deliver, and could presumably only have been justified if it were a hydrogen bomb. Conventional explosives, a "dirty bomb" of conventional explosives with radioactive material, chemical weapons, biological weapons, and even fission bombs could have been packaged into much smaller and much more easily deliverable sizes (and if necessary, several of them could have been delivered separately to the same target).

A 1946 U.S. intelligence document mentioned wartime German research on H-bomb development as well as nuclear-armed ballistic missiles (p. 4368).

In 1944–1945, several independent sources reported that Germany was developing a bomb with a six-mile blast radius, which is characteristic of the several-megaton energy of an H bomb, in stark contrast to the much smaller several-kiloton energy of a plain fission bomb (pp. 4365–4367).

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[19] Goncharov 1996a, 1996b; Chuck Hansen 1988, 2007; Rhodes 1995; Sublette 2019; Wellerstein and Geist 2017.

From the currently available sources, the detailed design of the German H-bomb is unclear. However, according to unclassified references, there are two major types of H-bomb designs.[20]

The simpler one to build is what the Soviets later called a "layer cake" (*sloika*), a spherical implosion bomb with layers of fusion fuel interspersed with layers of fission fuel. The fusion reactions contribute only a modest amount of energy, but a huge number of neutrons that enable the consumption of far more fission fuel than would otherwise be possible. The postwar Soviet nuclear program was heavily dependent upon German scientists, materials, and ideas, and the first Soviet H-bomb (Joe-4 or RDS-6, tested on 12 August 1953; see p. 1638) employed the layer cake design, with a weight of 4.5 tons, diameter of 1.5 meters, and explosive yield of 400 kilotons. Joe-4's yield could have been higher if its surrounding layer of conventional explosives had been better able to compress the layers of fission and fusion fuel [Wellerstein and Geist 2017]. If there was a wartime German design that was very similar but had 1.5 tons more of surrounding conventional explosives (total weight of 6 tons), its diameter would have been around 1.8 meters, and its explosive yield could easily have been in the 1.5-megaton range (corresponding to a six-mile blast radius).

The second major type of H-bomb is a "two-stage" design, in which the dense outer bomb casing surrounds both a fission implosion bomb (the first stage) and a neighboring mass of fusion fuel (the second stage). When the fission bomb detonates, its heat and pressure ignite fusion reactions in the adjacent fusion fuel. If the outer bomb casing is made of fission fuel (even natural uranium), high-energy neutrons from the fusion reactions can trigger extensive fission reactions in the outer bomb casing, making it effectively a third stage of the explosion. Friedwardt Winterberg, who worked very closely with Kurt Diebner after the war, published a highly distinctive ellipsoidal two-stage H-bomb design that looks rather different than standard U.S. H-bomb designs, but that is deeply steeped in earlier German hydrodynamics and physics research (p. 4373). A surviving 1944 sketch from Walther Gerlach shows an ellipsoid in conjunction with nuclear reactions involving deuterium, which seems to support the wartime origin of Winterberg's ellipsoidal H-bomb design (p. 4377).

Werner Grothmann stated that the German nuclear program was developing several different bomb types, including a hydrogen bomb. He said that the hydrogen bomb looked like a "swollen bomb" (ellipsoidal?), would have been a hundred times more powerful than a fission bomb (megatons vs. tens of kilotons), and was expected to be ready in 1946 (which suggests that it had already progressed far in its development by 1945); see pp. 3401 and 4272. Other sources expected the German hydrogen bomb to be ready even sooner, sometime in 1945, if the war had continued (pp. 4367, 4334, 4359).

In 1947, when Edward Teller was trying unsuccessfully to invent a workable design for the U.S. hydrogen bomb, he sent a highly unusual, specific, and urgent request for Siegfried Flügge to help him with a "physics... program... of interest and importance to the national security," stating that Flügge would "be of marked assistance in carrying out the aforementioned program" (p. 4996). Flügge was indeed brought to the United States, and it has never been publicly revealed what he worked on. In fact, late in the war and after the war, there was a large influx of scientists and engineers who came to the United States and/or United Kingdom and who were from or had knowledge of the German nuclear program (p. 1608). Many of those scientists appear to have been closely tied to the wartime German work on H-bombs, and may have especially aided the U.S. H-bomb development program between 1945 and 1954.

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[20] Goncharov 1996a, 1996b; Chuck Hansen 1988, 2007; Rhodes 1995; Sublette 2019; Wellerstein and Geist 2017.

8.8.10 October 1944 Test Explosion on the Baltic Coast

A number of sources reported a test explosion on the Baltic coast in October 1944 (Section D.10).

A May 1944 U.S. Army Air Forces intelligence document listed numerous research and development sites in Germany. It correctly identified the rocket and jet propulsion work being conducted at Peenemünde and the experiments being conducted at many other highly classified locations, but noted that the "most secret research" was conducted on Rügen and Usedom islands—research even more secret than the rockets and jets (p. 4393).

In August 1944, a German prisoner of war reported that "experiments are conducted on an estate in Pomerania and it is alleged that this explosive is capable of destroying everything in a radius of several kilometers" (p. 4396).

On 20 October 1944, the U.S. physicist and intelligence analyst Philip Morrison mentioned "recent reports of Baltic explosions" that were being investigated by the Manhattan Project as possible tests of a German atomic bomb (p. 4398).

A 21 October 1944 OSS intelligence report described the October test: "The Germans have completed a weapon which is founded on the principle of the disintegration of matter (Atomzertruemmerung). Experiments have been performed which have proved conclusive[...] The radius of action is supposed to be about three kilometers" (pp. 4400–4403).

A 19 January 1945 U.S. military intelligence summary covering many areas of advanced German research included a subject heading for "ATOMIC BOMB," under which it mentioned "close surveillance of the area in which tests are alleged to have taken place" (p. 4404). The report focused largely on the most recent work being conducted on the Baltic coast, suggesting that the tests occurred in late 1944 on the Baltic coast.

In May 1945, German prisoner of war Friedrich Olmes said there had been "experiments with the atom-splitting bomb" and "practical experiments were conducted on the Baltic coast" (p. 4406).

A 19 August 1945 U.S. Army Air Forces intelligence report entitled "Investigations, Research, Developments, and Practical Use of the German Atomic Bomb" presented testimony by Rudolf Zinsser, a German pilot captured by U.S. forces, that in October 1944 he flew near the massive explosion of a new German bomb on or near the Baltic coast, describing in detail a very large mushroom cloud and severe electrical disturbances (p. 4408). After further investigation, rather than dismissing Zinsser's report, the United States decided to upgrade it from Secret to Top Secret in October 1945 (p. 4422).

In testimony in 1955, 1984, and 2005, Italian military correspondent Luigi Romersa stated that by a special arrangement between Benito Mussolini and Adolf Hitler, on 12 October 1944 he witnessed the massive explosion of a new German bomb on the Baltic coast (apparently Rügen island), had to wait in a bunker for many hours afterward for the site to become less dangerous (short radioactive half-lives?), and then had to wear a special protective suit when inspecting the leveled test site afterward (pp. 4427–4434).

Werner Grothmann stated in 2000–2002 interviews that there was a successful atomic bomb test in October 1944 (p. 4436).

In a 13 March 2005 television interview, Elisabeth Mestlin stated that she observed a massive explosion on Rügen from a neighboring island on 12 October 1944 (p. 4435).

8.8.11 Circa November 1944 Test Explosion in Poland

Multiple sources reported a test explosion in Poland in approximately November 1944 (Section D.11).

A Top Secret U.S. cable from Warsaw in March 1946 stated: “Information has been given this Embassy by a capable young engineer working in the zinc industry, that one of the best if not the only material for atomic bomb containers is cadmium” (p. 4255). This “capable young engineer” in Poland knew that atomic bomb casings included a layer of cadmium, which was true for the implosion bomb designs described by both Ilyichev and Schumann (Section 8.8.8). The Polish engineer’s knowledge suggests that German-run industry in wartime Poland was involved in developing and/or testing an atomic bomb.

Robert Jackson, chief U.S. prosecutor at the Nuremberg trials, stated on 21 June 1946 that he had received evidence that a new bomb design producing very intense heat had killed 20,000 Jewish prisoners in a specially constructed test village in Poland (p. 4458).

In August 1946, a FIAT intelligence document mentioned that there had been a number of unconfirmed reports that “about Christmas 1944, successful experiments were conducted in Pomerania with V-1 and atomic warheads, radio directed. The ensuing crater was 2 km in diameter” (p. 4460). There was also an August 1944 report of nuclear weapons development work in Pomerania (p. 4396).

In December 1946, Otto Hahn said that there had been rumors that “atom bomb tests had been carried out in Poland during the last year of the war which were supposed to have had an effect similar to the first atom bomb dropped on Hiroshima though on a considerably smaller scale” (p. 4460).

Gezo Mansfeldt, a survivor of Auschwitz, reported in December 1946 that he was frequently interrogated by Soviet officials about high-security wartime production work at Auschwitz and that he “learned of the atomic bomb tests” that were apparently related to that work (p. 4463).

A 1947 U.S. intelligence report stated that the Germans built a heavy water production plant near Auschwitz and that it was removed by the Soviets (p. 4463). Heavy water would only be useful for nuclear work, and the production of heavy water near Auschwitz suggests the presence of other nuclear work in Poland.

Another 1947 intelligence report discussed wartime nuclear weapons work at Tucheler Heide in Poland, including the production of ^{235}U and ^{239}Pu and apparently even 1–5 kg fission pits for atomic bombs (p. 4902).

In 1947, Heinrich Himmler’s physical therapist, Felix Kersten, stated that Franz Göring, a senior SS security official, had told him late in the war that a new bomb design producing several thousand degrees of heat had killed 20,000 Jewish prisoners at a test site in Poland (p. 4470).

Heinrich Himmler’s personal astrologer, Wilhelm Wulff, confirmed that Franz Göring had told him the same story about an atomic bomb test in Poland (p. 4471).

Werner Grothmann stated that there was a successful atomic bomb test in or around November 1944 (p. 4436).

8.8.12 March 1945 Test Explosions in Thuringia

A number of sources reported test explosions in Thuringia in March 1945 (Section D.12).

A 15 November 1944 letter from General Ivan Ilyichev to Joseph Stalin reported that the Germans in Thuringia were preparing under hurried but very high security conditions to test a new spherical "bomb of unusual construction" with a "large destructive power" that might be an atomic bomb (p. 4481).

A 23 March 1945 letter from General Ilyichev to Joseph Stalin reported that the Germans in Thuringia had recently conducted two very high-security test explosions of a new bomb design, described in considerable detail as a 2-ton, 1.3-meter-diameter spherical implosion device with multiple concentric layers and a ^{235}U core that created a "massive radioactive effect," incinerated or burned nearby prisoners of war, and destroyed buildings and trees within a radius of 500–600 meters (Fig. 8.32 bottom and p. 4485).

In a 30 March 1945 letter from Igor Kurchatov to General Ilyichev, Kurchatov repeated and analyzed the details reported in the 23 March 1945 letter, said it gave a "very believable description of the construction of the bomb," and requested further information (p. 4496).

21 and 29 May 1945 letters from Georgy Flerov to Igor Kurchatov reported that Flerov was currently in Dresden and en route to study the alleged German atomic test site using Geiger counters. Flerov also requested that former prisoners of war returning from Germany to the Soviet Union should be interviewed to learn if any of them knew anything about the test (p. 4503).

After all of those Soviet investigations, an October 1945 report from Marshal Georgy Zhukov to Stalin stated: "Based on the collected materials, it can be concluded that the German scientists in the field of theoretical and practical research and application of atomic energy have achieved good results up to the creation of the atomic bomb" (p. 4523).

A 1946 Russian interrogation summary reported that Robert Döpel stated that there was an atomic bomb test on a German military base before the end of the war (p. 4530).

It seems there is or at least was considerably more information about the apparent German nuclear tests in Russian government archives, including even a captured German film entitled "Film of the Launch of a V-2 and the Explosion of an Atomic Bomb" (p. 4533). At a bare minimum, there are probably documents identifying the Soviet spy who provided the information given in Ilyichev's two reports, documents reporting the suspected test site location to Flerov (which he seemed to know, but which was not in Ilyichev's two reports), documents reporting what (if anything) Flerov ultimately found, and documents describing the "collected materials" to which Zhukov referred.

21 March 1945 and 9 June 1945 U.S. aerial reconnaissance photos of the Ohrdruf Truppenübungsplatz military base appeared to show a large circular area of possible blast damage, as well as surrounding buildings and vegetation that may have been affected by blast and/or radioactive fallout, whereas a 12 August 1944 aerial reconnaissance photo did not show those features (pp. 4541–4545). There are also other potential craters of interest in the immediate vicinity.

In what appears to be a transcript of her testimony before an East German government inquiry on 16 May 1962, Cläre Werner, a wartime lookout at the Veste Wachsenburg castle near the Ohrdruf military base, reported witnessing a large nearby test explosion on 4 March and another one on 12 March 1945, as well as being informed of the historic nature of the explosions by visiting military and SS officials. She reported that she and some other local residents suffered from symptoms that sound like radiation sickness. Although there are unresolved questions about the nature and the chain of custody of the 1962 transcript, Cläre Werner confirmed the key points of her testimony in several interviews conducted between 1998 and 2003 (p. 4551).

In a transcript of his apparent testimony before the same East German government inquiry on 16 May 1962, Heinz Wachsmut reported being conscripted into a unique work assignment for the afternoon and evening of 5 March 1945 in Thuringia. He reported encountering large numbers of living, dying, and dead people suffering from what sounds like radiation sickness and burns in the aftermath of what the SS told him was a history-making test explosion. Under the close supervision of the SS, he was instructed to wear protective gear, and he burned approximately 450 bodies on woodpiles and saw a total of approximately 700 bodies being burned. (It is not clear if all of those were victims of the test explosion, or if some were victims of the daily harsh treatment of prisoners.) Afterward his protective gear and clothing were burned, he was instructed to wash himself thoroughly, and he was unable to eat for days afterward possibly due to radiation sickness. While there are again unresolved questions about the 1962 transcript, the family of Heinz Wachsmut confirmed that he had described the same events and details to them (p. 4557).

In transcripts of his testimony before East German government inquiries in 1966, Erich Rundnagel, a plumber who had worked for Kurt Diebner's nuclear research group in Thuringia during the war, reported that the scientists had told him they had two eight-kilogram atomic bombs (most likely fission pits for atomic bombs) in their safe (p. 4564).

Colonel Oscar Koch, one of George Patton's top intelligence officers, stated that a German prisoner of war described the massive explosion of a new bomb type in Thuringia in March 1945 (p. 4566).

Werner Grothmann stated in 2000–2002 interviews that there was an atomic bomb test in Thuringia on 4 March 1945 (p. 4436).

The explosive yield of the Thuringian device would have strongly depended on how much fission and fusion fuel were used. If the Thuringian device had been furnished with a $\sim$5–10 kg pit of weapons-grade fission fuel comparable to that in Gadget/Fat Man, it seems likely that it would have had a comparable yield in the $\sim$20-kiloton range. If significant fusion neutron boosting occurred from the fusion fuel at the center, the device could have fissioned far more of its fission fuel and hence achieved far larger yields—potentially up to $\sim$100 kilotons for a $\sim$10 kg pit with $\sim$50% efficiency. In fact, a number of independent contemporary sources gave the expected blast radius of the deployed device as 2–4 km (likely depending upon the amount of fuel used), corresponding to explosive yields in the range of 13–100 kilotons (p. 5168).

Ilyichev reported the blast radius of the tests was 500–600 meters. That would correspond to a yield equivalent to roughly 200–350 tons of TNT (p. 5141). To conserve weapons-grade fuel, minimize the mess made in central Germany, and avoid Allied detection, scientists would have been strongly motivated to keep the test explosion as small as possible by using just enough fuel to briefly achieve criticality during peak compression.

People at the test site would have been exposed to the prompt radiation (gamma, neutrons, and beta) released during the explosion. For a fission explosion of 200–350 tons, the lethality [10 Grays (Gy)] radius for this prompt radiation is ∼500 meters, very comparable to the blast radius [Glasstone and Dolan 1977, p. 333].

The test would also produce radioactive fallout, which would emit 80% of its total radiation within the first 24 hours and the remaining 20% more gradually over the following days, months, and years [Glasstone and Dolan 1977, pp. 390–397]. The area over which the fallout was distributed would depend on local winds and topography. Using a plausible area of ∼100 km^2 and the estimated yield of 200–350 tons, the radioactive exposure from the fallout averaged over the whole area would be ∼0.15–0.26 Gy/hr at 1 hour, or ∼1.1–2.0 Gy for the first 24 hours (p. 5146). Noticeable symptoms of radiation sickness would begin at a cumulative exposure of ∼1 Gy, very serious illness at ∼2 Gy, and fairly consistent lethality (within hours or days after exposure) at ∼10 Gy [Glasstone and Dolan 1977, pp. 575–587]. Ilyichev reported that most of the civilian population in the surrounding area had been evacuated; even those who were not may not have had enough outdoor exposure to develop symptoms. Any German teams surveying the after-effects of the explosion in nearby areas with Geiger counters would certainly have noticed the radioactive fallout.

Data from U.S. nuclear tests suggests that the fallout dosage immediately around a test site is ∼10–100 times higher than that in the much larger surrounding area that receives significant fallout, with a geometric mean value of ∼30 times higher (depending on local winds and geography) [Glasstone and Dolan 1977, pp. 419–439]. Using that mean value to multiply the area-averaged dose, ballpark values for the radiation dose right at the Thuringian test site would be ∼4.5–7.9 Gy/hr at 1 hour, or ∼34–59 Gy for the first 24 hours, lethal doses that may help to account for the lack of later witnesses.

Thus the explosion's prompt radiation at the test site, the radioactive fallout at the test site within the first 24 hours, and the radioactive fallout in nearby towns within 24 hours would easily fit Ilyichev's description that a "massive radioactive effect was observed."

After 75+ years, the radioactivity of the fallout would have dropped to $\sim 2\times10^{-9}$ of its radioactivity 1 hour after the explosion [Glasstone and Dolan 1977, p. 393], or $2.6\text{–}4.6\times10^{-6}$ Gy/yr averaged over the area and $7\text{–}14\times10^{-5}$ Gy/year at the test site. The residual radioactivity at the test site would be at least ∼10–30 times smaller than the natural background radiation ($1\text{–}2\times10^{-3}$ Gy/yr) and hence extremely difficult to detect. In fact, after 75+ years of water, wind, and human activity, the fallout could easily have become scattered over a significantly larger area than the initial area assumed here, and/or become buried to varying depths in the ground, making it even harder to detect than has been calculated here.

Therefore modern measurements of residual radioactivity cannot prove or disprove whether the March 1945 Thuringian nuclear tests (or other possible wartime German nuclear tests) occurred.

Other scientific methods (especially using mass spectrometry, particle-induced X-ray emission, neutron activation analysis, or other highly sensitive methods; looking for ^{238}U from the tamper; and comparing data at and away from the test sites to eliminate background signals), may or may not be able to detect signs of the tests.

8.8.13 Wartime/Postwar Axis Belief in the Reality of German Nuclear Weapons

Among Axis officials in positions of knowledge, there was a widespread belief in the reality of German nuclear weapons, both during and after the war (Section D.13).

One of Heinrich Himmler's closest diplomatic contacts, Grand Mufti Amin al-Husaini of Jerusalem, said Himmler had informed him in July 1943 that Germany was developing an atomic bomb (p. 4578).

Himmler's political rival, Albert Speer, confirmed that Himmler was keenly interested in developing an atomic bomb during the war (p. 4593).

Hans Ulrich Rudel, the most decorated German pilot of the war, reported that in March 1944 Hitler told him that (1) atomic bombs were at a highly advanced stage of development and (2) the bombs were intended to be delivered via V-type rockets (p. 4591).

On 5 August 1944, Hitler informed the Romanian Prime Minister Ion Antonescu that Germany had developed and would use a V-series weapon with "such a tremendous effect that all human life would be destroyed within a radius of three to four kilometers from the impact point" (p. 4594).

On 16 December 1944, Benito Mussolini stated that "thousands of German scientists are working day and night" to develop new weapons that would change the war, apparently in reference to information he received via Luigi Romersa (p. 4603).

In 16 November 1944 and 9 February 1945 letters from FBI Director J. Edgar Hoover to Franklin Roosevelt's top advisor Harry Hopkins, Hoover reported that intercepted messages from Germany to German spies in the U.S. asked the spies about "the probable reaction of the people of the United States if Germany used the explosive power obtained through the splitting of the uranium atom," high-priority targets in the United States that Germany could bomb, and methods that U.S. laboratories used to avoid criticality accidents with large quantities of enriched uranium, suggesting that Germany possessed large quantities of enriched uranium (pp. 4604–4625).

Widespread German reports from late 1944 through 1945 claimed that Germany was on the verge of deploying atomic bombs and missiles for them (p. 4627).

On 14 February 1945, Hitler told one of his doctors: "In no time at all, I'm going to start using my Victory weapon and then the war will come to a glorious end. Some time ago we solved the problem of nuclear fission, and we have developed it so far that we can exploit the energy for armaments purposes. They won't know what hit them! It's the weapon of the future. With it Germany's future is assured" (p. 4634).

Heinrich Himmler's physical therapist, Felix Kersten, and his personal astrologer, Wilhelm Wulff, independently wrote that in early March 1945, Himmler was very optimistic about the imminent success of an atomic bomb (pp. 4470, 4471).

Henry Picker, a close confidant of Hitler, wrote that before the war ended, prototype fission bombs were completed and ready, and facilities for mass-producing the bombs had been built (pp. 4635–

4639).

In 2000–2002 interviews, Werner Grothmann described how an extensive program run by Heinrich Himmler developed, tested, and debated the deployment of atomic bombs (p. 4668).

In a 1 April 1945 telegram to Allied leaders, Allen Dulles reported that Luftwaffe General Albert Kesselring mentioned deliberations among Hitler's top staff about whether to use a final secret weapon, referred to as the "desperation weapon," that would cause a "terrible blood bath" (p. 4670).

In a September 1945 interrogation, the father of an SS officer told Americans about deliberations among Hitler's top staff over an atomic bomb in April 1945 (p. 4670).

In Otto Hahn's autobiography, he wrote that he had heard from reliable sources that there were at least three completed atomic bombs at the end of the war (p. 4182). Lending additional credibility to Hahn's story, the bombs were said to be at Lüneburger Heide, which wartime Allied intelligence reports had identified as the site of what sounded like large underground uranium enrichment facilities producing fuel for spherical implosion bombs (Section 8.8.4). There were also other reports of nuclear-related work at Lüneburger Heide (pp. 4176–4181, 4406).

Former SS officer Erwin Bartmann reported very similar information from his insider knowledge of conversations among Hitler, Göring, and others—there were specific mentions of "three special bombs" and even up to nine completed bombs by the end of the war (p. 4667).

Shortly after the war, German rocket engineers Wernher von Braun and Walter Dornberger, as well as American officials who examined the German rocket program, reported that Germany planned to use its rockets to carry a "much more powerful explosive," presumably atomic bombs (p. 4681).

In the end, Germany never used nuclear weapons in combat. Franklin Roosevelt and Winston Churchill had made it clear that if Germany used anything other than conventional weapons in the war, the Allies would respond by killing millions of German civilians with crude but effective WWI-style chemical weapons (mustard agent and phosgene) or other means (pp. 2632–2651). German leaders appear to have concluded that they did not have a sufficient number of nuclear weapons and/or sufficiently reliable delivery vehicles to overcome that threat and alter the ultimate outcome of the war. Individual German political or military leaders may have also feared even greater postwar prosecutions if they used nuclear weapons, or considered it more personally beneficial to try to trade German nuclear and other technologies to the Allies than to employ them against the Allies.

8.8.14 Wartime/Postwar Allied Belief in the Reality of German Nuclear Weapons

Both during and after the war, highly placed Allied officials expressed belief in the reality of advanced German nuclear weapons programs. In fact, it appears that after the war, the four major Allied countries found and benefited from materials and expertise from the German nuclear weapons program (Section D.14). All of the relevant wartime and postwar reports with the detailed evidence remain classified or missing entirely from archives. Nonetheless, enough sources are available to prove that those reports did indeed exist, and presumably still do exist. This section gives numerous examples, although it is by no means exhaustive. See Appendix D for much more information.

In two December 1943 cables to Washington, the U.S. Military Attaché in Istanbul warned that "an engineer of the Todt organization revealed in Sofia that the Germans now possess a new type of incendiary far surpassing anything yet used in warfare. The engineer intimated that London would suffer a fate worse than that of Berlin or Hamburg in the near future." The reports added: "The Germans have a weapon in preparation which is more devastating than anything we have ever seen" (p. 4588). Germany had been mining uranium in Sofia since 1938 (Section 8.8.3).

In July 1944, Manhattan Project physicists Philip Morrison and Karl Cohen analyzed available intelligence on the German nuclear program and concluded (p. 4739):

> Recent evidence essentially confirms our earlier general statements on enemy bomb production. The reports now at hand lead us to conclude:
>
> 1. A German "Y" [enrichment] project has been underway since early 1943.
> 2. A D_2O pile is in operation, but we do not believe that this is on production level.
> 3. It is implied that a separation method is operating at a production level, for it is surely improbable that the enemy will organize a utilization group without something to use.
>
> We include a time schedule, and a technical discuss of the probable means employed.
>
> Enemy production of devices can be as high as:
>
> 1. 1 device every 3 months—on the assumption that 30 kg of material are required per device.
> 2. 1 device every month—on the assumption that 10 kg of material are required per device.
>
> In either case the first completed device could be in enemy hands now.

The *Daily Telegraph and Morning Post* reported that in August 1944, the British government had intelligence that Germany was preparing "an atomic bomb" with "an explosive radius of more than two miles," or three kilometers (p. 5011). As noted in Section 8.8.5, the Royal Air Force went to extreme lengths to bomb what appears to have been a German fission reactor and fuel reprocessing complex near Königsberg during the period 26–30 August 1944 (p. 3928).

In September 1944, the *Los Angeles Times* reported that invading U.S. troops in France had found evidence that Germany was preparing a rocket-launched bomb "with an explosive radius of three kilometers" (p. 5012).

Margaret Suckley, Franklin Roosevelt's secretary, wrote in her diary on 9 December 1944 that Roosevelt had received reliable reports that the Germans had successfully developed a bomb capable of killing everything within a mile and that the German program was "way ahead" of similar U.S. research (p. 4703).

A tantalizing December 1944 summary report from the Manhattan Project's Foreign Intelligence Unit concluded (p. 4703):

> 1. Intelligence indicates that the enemy is working in the project field. It is likely that he has undertaken one or several of the various processes for the production of bombs on a small scale and to have organized an installation equivalent to our project on final utilization. (TAB A).
>
> 2. The various methods for the production of U-233, U-235 and Pu-239 have been considered in the light of scientific development, basic materials, and industrial effort required. (TAB B). The liquid thermal diffusion process for production of U-235 on a moderate scale and the pile process using heavy water for the production of Pu-239 on a small scale appear to be the most likely possibilities; the production of U-233 on a useful scale appears to be unlikely. Activities inferred from the intelligence and other reports indicate that these processes could have come into operation during 1943. (TAB C).
>
> 3. On the basis of the above analysis it is possible for the enemy to have at least one device in his hands now, but it is improbable for him to have more than three.
>
> [Handwritten in lower right corner:] Cross referenced in Enemy Prod.[uction] of Devices—G[roves?]

Unfortunately, instead of TAB A, the collected intelligence evidence for the German nuclear weapons program, the NARA file only includes a note stating: "In the review of this file this item was removed because access to it is restricted" (p. 4707).

In March 1945, Gerard Kuiper, a highly knowledgeable investigator in the Alsos Mission, wrote a letter that contradicted what the heads of Alsos were claiming at that time (p. 4766): "One is again surprised to see quotations from U.S. senators who think that the war will be over 'within a few days'. It would be wiser to worry about the chance we still have of losing it if certain high explosives are developed in time. This possibility may, incidentally, be one reason why the Germans are not giving in."

Rather than heading toward the logical objective of Berlin to topple the German government and beat Soviet forces to the prize, U.S. troops under Generals Patton, Bradley, and Eisenhower rushed straight toward Thuringia. Justifications for this strategy have ranged from preventing Hitler from fleeing south to liberating concentration camps. However, at the very least it seems like an intriguing coincidence that Patton, Bradley, Eisenhower, and other top Allied officials were personally inspecting the Ohrdruf Truppenübungsplatz military base all together on 12 April 1945

(U.S. forces captured the base on 4 April), only a month after the possible nuclear weapons tests at that site (Section 8.8.12) [Karlsch 2005, p. 218]. Other than photos of the generals and some of the concentration camp victims, none of what must have been numerous detailed written reports about what technologies or documents the U.S. forces found at that and nearby facilities have ever been declassified and released to the public.

A 31 May 1945 cable from Eisenhower to Washington, D.C. reported: "A laboratory containing equipment and documents related to experimental work on atomic bombs and AA rockets was located near Lofer, E 7399 by Third US Army" (p. 4974). Eisenhower later told *The New York Times* how seriously he regarded the German nuclear program: "My main concern was that the Germans did not get the atomic bomb to use on us" (pp. 5033–5034).

In fact, at the end of the war, Allied investigators personally inspected many sites that conducted work related to the German nuclear weapons program, including sites in Germany (Lüneburger Heide, Hillersleben, I.G. Farben installations, numerous locations in Thuringia, etc.), Austria (St. Georgen an der Gusen, Ebensee, Redl-Zipf, Lofer, etc.), Czech territory (Pilsen, Podmokly, St. Joachimsthal/Jáchymov, etc.), and elsewhere (pp. 3670–3677, 4962–4985). Detailed reports on what they discovered and learned about the German nuclear program have never been publicly released.

In May 1945, the German submarine U-234 surrendered to the United States. It contained 560 kg of uranium oxide (possibly enriched), bomb detonators, other materials, plans, and technical experts that would have shed light on the German nuclear program. Other submarines carried additional relevant materials, documents, and personnel (Section D.14.5). Where are the many tons of documents, prototypes, and other cargo from the U-234 and the other submarines, as well as all of the reports on the German nuclear and other technology programs that the United States compiled in the process of investigating the submarines' cargoes and interrogating their passengers?

By the end of the war, SS General (and Dr. Ing.) Hans Kammler controlled and knew the details of virtually all German secret weapons research and development programs, including the nuclear weapons program. According to official histories, Kammler died in early May 1945. However, multiple documents in U.S. government archives prove that he surrendered to U.S. forces in May 1945 and was alive and being interrogated by the United States for many months (and perhaps even many years) after the war (pp. 4914–4961). The U.S. government must possess lengthy transcripts or even audio/video recordings of Kammler's interrogations. It would also possess any documents and materials that Kammler had with him when he was captured, or that he was able to direct the Americans to afterward. Kammler's interrogations and documents would almost certainly have provided the United States with considerable detail about the German nuclear program and other very advanced developments. (Albert Speer's capture and interrogation resulted in many shelves full of documents.) How can all of that Kammler material be located and declassified from U.S. government archives?

When nuclear-related censorship was relaxed somewhat after the U.S. atomic bombings of Japan in August 1945, Allied officials made a stunning admission to *Newsweek* (p. 5022): "Since the surrender of the Nazi armies, Allied officers have revealed that Germany would have been able to strike with atomic bombs by January 1945, if the invasion had not come six months before. The highest Allied officials knew that such explosives could have won the war for the Axis."

In a 25 August 1945 press release, the U.S. Office of War Information stated that "Germany's inner war secrets" included "experiments with the atomic bomb," that "Germans made significant progress in the development of an atomic bomb," and that not all "of the secrets. . . may be disclosed at this time" (p. 5023).

A 31 August 1945 U.S. report mentioned "Gerald Klein (Dr.), Dipl.-Eng., Manager of LGW. . . Worked at Peenemünde and later became group director of atomic devices in RLM. At present being used by the British. Evacuated by 'T' Force" (p. 5010). Klein was listed as the manager of "LGW," which was the Luftgerätewerk Hakenfelde A.G., part of the huge Siemens electrical company. If wartime Germany never had atomic devices or even serious plans to make them, as maintained by official histories, why did the RLM or Reichsluftfahrtministerium (Ministry of Aviation) have an entire group dedicated to atomic devices, of which Dr. Klein was the director? Where are the U.K. and U.S. reports on Klein, the organizations named, and the nuclear work?

A remarkable 14 September 1945 OSS cable hinted at far more detailed knowledge about the German nuclear weapons program than has ever been publicly released (p. 5045):

> Our work on this subject is to correlate and cooperate with specially appointed general who has charge of the whole AZUSA [German nuclear] situation and has overall responsibility. [...]
>
> On present sub feature of AZUSA about assisting locating German scientists, special general asked to have the information sent only to Calvert, London Embassy, or to Washington. [...]
>
> This now done and all AZUSA information obtained by OSS in ETO and applicable in ETO situations now to be coordinated only between you or Wisner Sibert and Calvert and advising OSS Washington of resulting decisions or information. This insures desired maximum security with fewest number persons involved. Copies of any reports to be sent OSS Washington without delay and showing action taken.
>
> This subject so tight at this time we are playing very close with special general.

Does this OSS cable show that the U.S. started to really appreciate the full extent of the wartime German nuclear program by September 1945, and took steps to limit that knowledge to the "fewest number persons"? Is that why Zinsser's report of a German atomic bomb test was upgraded from Secret to Top Secret in early October 1945 (Section 8.8.10)? Who was the "special general" mentioned in this cable—Leslie Groves or someone else?

The joint chairs of CIOS, U.S. General Thomas Jeffries Betts, Deputy G-2 of SHAEF, and U.K. Ministry of Supply chief advisor and F.R.S. Professor Reginald Patrick Linstead, wrote a 15 September 1945 final report based on specific discoveries by their CIOS investigators (p. 5030):

> Certain items have been omitted because of security considerations. . . Of particular significance were the statements, made by German experts in the rocket and controlled missile field, that much of the priority accorded their work by the German High Command was in anticipation of the use of atomic explosives. These authorities stated that KWI had repeatedly assured Hitler that an atomic explosive would be available for use within a comparatively short time. During the last months of work by the Peenemünde staff, V-weapons were designed with much smaller war-heads. Quite possibly this trend was in anticipation of the successful development of a German atomic explosive.

Thus the CIOS chairs directly contradicted the public statements of the Alsos Mission and confirmed that there was indeed a German program to develop an atomic bomb, and that it was far more than a paper design program—its hardware had passed through sufficient development, production, and testing by the end of the war that it was ready or nearly ready to be used in combat.

In September and October 1945, General George C. Marshall made several noteworthy public statements: (1) "German technological advances such as in the development of atomic explosives made it imperative that we attack before these terrible weapons could be turned against us." (2) "At the close of the German war in Europe they [U.S. factories] were just on the outer fringes of the range of fire from an enemy in Europe. Goering stated after his capture that it was a certainty the eastern American cities would have been under rocket bombardment had Germany remained undefeated for two more years. The first attacks would have started much sooner." (3) "It is not hard to predict that supersonic atomic rockets will have a profound influence on any war that ever again has to be fought" (p. 5031).

T. M. Odarenko, a longtime physicist from Bell Telephone, was one of the senior scientists involved in transferring advanced electronics and other technologies from Germany and Austria to the United States after the war. He wrote of encountering a large group of refugee nuclear scientists in Austria (pp. 4788–4785):

> Among these evacuees there is a very large group of capable scientists who worked in the field of nuclear physics and chemistry and who have been carrying this work with such facilities as they have been able to assemble. There are two (or possibly more) institutes which were directly involved before the end of the war in a secret German project called "Uranmotor" whose purpose was to split uran[ium] atoms in order to obtain a powerful source of intra-atomic energy. It is apparent that the end result of this work is a method of obtaining an explosive release of atomic energy, or atomic bomb.
>
> ——
>
> Contrary to the statements, attributed by the U.S. newspapers to the various U.S. atomic experts, that it "would take the Germans some 100 years to solve the problem of atomic disintegration on an explosive basis" (for the manufacture of bombs), the opinion of the members of the Institute themselves was that, given a supply of radium and uranium, and permitting their return to Vienna, where certain of their materials and equipments are stored, they would be able to "complete their work" in some 3 to 6 months. Some small scale experiments were claimed to be performed successfully by the Institute before the end of the war in Europe.
>
> That these claims of the Institute are not to be disregarded too readily would follow from the fact that Prof. Smyth spent considerable time with the Institute, revisited them several times, and thought it necessary to insist on the most stringent type of control over the scientific activities of the group, as well as on close individual observations. Perhaps equally significant are the indications of the substantial interest of the Russians in several members of the Institute.

"Prof. Smyth" was Charles P. Smyth, a Princeton chemistry professor and member of the Alsos Mission, who reported to Leslie Groves. Odarenko's reports on the nuclear scientists were also forwarded to Groves.[21] As a result of the reports of Odarenko and Smyth, the Austrian nuclear scientists were closely monitored and controlled for years by U.S. intelligence and military agencies. For example, the leader of the Austrian group, Georg Stetter, was kept under virtual house arrest by U.S. agents in Austria from 1945 until the 1950s, nearly destroying his career (pp. 4798–4800).

A large number of Alsos-related documents from Samuel Goudsmit's files remain classified (pp. 4772–4779). Likewise, some very important German-related files from the Manhattan Project's Foreign Intelligence Unit and the OSS remain classified and unavailable (pp. 4812–4827) [NARA RG 77, Entry UD-22A; NARA RG 226]. Even Lt. Col. George R. Eckman's "Final Report on the ALSOS Mission," written in December 1945, seems to be missing from modern archives (p. 3333). There may be countless other relevant files whose absence is not even noted in the archives.

There is evidence that Dutch intelligence provided important information about the German nuclear weapons program to the United States during and after the war (pp. 4832–4853). Samuel Goudsmit's entire folder of Dutch intelligence on the German nuclear program remains classified and unavailable.

Likewise, there is evidence that French intelligence gave important information about the German nuclear weapons program to the United States (pp. 4854–4855).

Werner Grothmann stated that the fission fuel and components of at least one German atomic bomb were found and removed from Germany by U.S. forces in 1945 (pp. 5040–5043). An archived card catalog of U.S. intelligence reports on Germany shows that there were postwar reports containing detailed information on the German atomic bomb, including a 2 January 1946 document labelled "Blueprints of Atomic Bomb," a 28 March 1946 report on "Atom Bomb Research in Germany & Influence on Developments in Soviet Russia," a 4 June 1947 report entitled "Atomic Bomb," a 25 July 1947 report on "Atomic Bomb Detonating Plans," and others. The reports themselves are still classified and unavailable to the public (pp. 5074–5075).

In private, General Leslie Groves wrote a February 1946 secret memorandum revealing (p. 4806):

> Government measures to encourage the long term exploitation of German scientists by the United States are desirable, particularly with reference to nuclear physicists and chemists who might be of some service to scientists in this country in the field of atomic energy. . . I suggest, therefore, a fifth category, defined as, those German scientists of outstanding ability in the field of nuclear physics and chemistry who, by their past reputation and present knowledge, would be of more value to the national interest of this country if they could be employed here rather than in any other country. . . However, it is extremely important that these persons be prevented from giving their services to a potential enemy of the United States.

In public, though, Groves knowingly and repeatedly made false claims that Germany's nuclear scientists had been few in number and hopelessly backward [Groves 1962].

At the "Ashcan" interrogation center after the war, Hermann Goering told his Allied interrogators that "Germany was within 90 days of producing its first atom bomb when the war ended" (p. 4894).

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[21] NARA RG 77, Entry UD-22A, Box 174, Folder 10.10 Austria: Personnel. Shuler to Leslie R. Groves, 26 November 1945, Subject: Problem of Displaced Scientists in American Zone of Austria.

In similar postwar interrogations, Wilhelm Voss, the former director of the Skoda works, told Allied interrogators about the organization and results of the German nuclear weapons program (p. 4914).

A U.S. Department of Commerce press release praised wartime German scientific accomplishments that were more advanced than those of the United States and that were being transferred to the United States to improve its programs: “Spectacular accomplishments in uranium, nitrogen, oxygen recovery, plastics, nuclear physics and many other fields, have been uncovered in the investigation of the chemicals field alone” (p. 5066).

In July 1946, the U.S. *Army Air Forces Review* published an article stating, “it is still a matter of scientific conjecture just how many weeks—or days—it might have taken Germany to be ready with her atomic devices for the V-2s” (p. 5038).

In 1946, U.S. Army Air Forces Colonel George Woods wrote of “Germany’s Plans for the ‘A-9’ with Atomic Bomb”: “it is well known that the Germans originally had hoped to have their atomic bomb developments completed by the end of 1944.” See p. 5073.

Top Secret 1946 cables from the U.S. Joint Chiefs of Staff to General Joseph T. McNarney (the military governor of the U.S.-occupied zone of Germany and also the commander in chief of the U.S. Forces of Occupation in Europe) ordered him (pp. 5065–5066):

> Except for most cogent reasons you will not permit representatives of nations other than British Commonwealth (excluding Eire) to have access in any U.S. zone of occupation under your jurisdiction to technical information on the following subjects or to related intelligence targets:
>
> ——
>
> Applied and theoretical nuclear physics, including design and operation of devices for producing highly energetic particles, and isotope separation.

These Top Secret Orders from the highest level were written over a year after the end of the war in Europe, after the U.S. had had time to investigate wartime German programs in detail, and they specifically noted advanced nuclear-weapons-related work.

In a 17 August 1946 interrogation, Edmund Sorg described a piloted version of the V-1 cruise missile armed with an atomic bomb (p. 4896).

In discussing German rockets as weapons in an August 1947 interview, General William L. Richardson said “there is evidence to believe that the Germans intended to utilize an atomic warhead which would have made this weapon extremely deadly” (pp. 5035–5036). General Richardson would have been a highly knowledgeable and very sober source for this information. What “evidence” did he have?

In a 19 August 1947 intelligence report that is still heavily censored, Edmund Tilley discussed wartime nuclear weapons work at Tucheler Heide in Poland, including the production of ^{235}U and ^{239}Pu and apparently even 1–5 kg fission pits for atomic bombs. According to Tilley, one of the German scientists most directly responsible for that work, “Dr. Niels” (Walter Nielsch?), had already been taken to the United States for interrogation and/or work (p. 4902).

Many German and Austrian scientists who appear to have been involved in the nuclear program visited or worked in the United States and/or United Kingdom after the war. They may have provided information about wartime German work and aided the U.S./U.K. nuclear programs. Even basic files for some scientists are still not available to the public. For example, virtually the entire "Foreign Scientist Case File" (Paperclip file) of nuclear physicist Otto Haxel has been redacted in response to recent Freedom of Information Act Requests, and Wernher von Braun's Paperclip file is missing entirely. The late-wartime and postwar influx of scientists and engineers who were from or at least had knowledge of the German nuclear program included (pp. 4931–4959, 4858, 4992):

Karl-Friedrich Bonhoeffer
Wernher von Braun
Rudolf Brill
Adolf Busemann
Walter Dornberger
Rudolf Edse
Krafft Ehricke
Wilhelm Eitel
Gerhard Falck
Karl Fiebinger
Wolfgang Finkelnburg
Rudolf Fleischmann
Siegfried Flügge
Walter Glaser
Wilhelm Groth
Gottfried Guderley
Paul Harteck
Otto Haxel
Richard Herzog
Johannes Hans Jensen
Willibald Jentschke
Ulrich Jetter
Georg Joos
Hartmut Kallmann
Hans Kammler
Gerald Klein
Stanley Kronenberg
Heinz Maier-Leibnitz
Werner Maurer
Hugo Neuert
"Dr. Niels" (Walter Nielsch?)
Edgar Petersen
Heinz Schlicke
Erich Schumann
Otto Schwede
Edmund Sorg
Kurt Starke
Ernst Stuhlinger
Hans Suess
Herbert Wagner
Wilhelm Westphal
Friedwardt Winterberg
Karl Wirtz
Gernot Zippe
Etc.

This list is far from exhaustive. Furthermore, a large number of additional scientists were interrogated in Europe. The complete interrogation reports and all other files on all of these scientists and engineers should be sought and released. (Kronenberg and Winterberg came later but were educated by scientists from the wartime nuclear program and appear to have learned some of their secrets.)

From examples such as those given throughout this section and Appendix D, it is clear that there is an enormous amount of information about the wartime German nuclear weapons program that remains classified and/or hidden by various governments. Why is that the case, if the German program was as small and as primitive as government officials and historians have maintained for 75+ years? What is the true history of the German program? What is the true history of Allied knowledge about the German program, both during and after the war? Where is all of the relevant archival and physical evidence stored now?

8.8.15 Further Research That Is Needed

The very incomplete information that is currently available about the wartime German nuclear weapons program, as summarized above and in more detail in Appendix D, appears to best match the pattern of a large and advanced program, not the small and primitive program that has generally been depicted for the last 75+ years (Section D.15). Some readers may object to this claim, but historians should actively search for additional information that could help to confirm or refute this picture:

- Any relevant records in U.S., U.K., French, Russian, or other national archives should be located, declassified, and released to the public. Even from the currently available evidence, it is abundantly clear than highly relevant documents (wartime intelligence on German nuclear tests and progress; postwar interrogations of Hans Kammler, German and Austrian nuclear scientists, and other key players; reports on postwar investigations of nuclear-related sites and submarines; etc.) remain classified and unavailable to the public. The war ended 75+ years ago, and government censorship of all those historical documents must finally end.

- Any relevant information in personal collections (war diaries, preserved documents, photographs, etc.) should be located, authenticated, and analyzed with the other available data.

- Thorough scientific analyses of suspected test sites should be conducted (especially using mass spectrometry, particle-induced X-ray emission, neutron activation analysis, or other highly sensitive methods; looking for ^{238}U from the tamper; and comparing data at and away from the test sites to eliminate background signals), although after 75+ years of radioactive decay and weathering, even the most diligent testing might be inconclusive.

- Extensive and meticulous industrial archaeological digs should be conducted at sites suspected to have been involved in developing or storing nuclear materials or nuclear weapons. Even if much of the material at those sites had been removed by German or Allied forces, any remaining evidence could provide conclusive proof about the nature and extent of the wartime nuclear program.

Until those searches have been thoroughly conducted, historians and scientists should cease making authoritative-sounding declarations that the nuclear program was small and unsuccessful, since there is already a great deal of evidence to the contrary.

If the German nuclear weapons program was indeed successful, one can understand why the major countries involved would have wanted to conceal that fact at the end of World War II and the beginning of the Cold War. Individual Germans with knowledge of the program would not want to appear guilty of additional acts for which they might be punished after the war. Key German players may have been rewarded for offering the fruits of the nuclear program to Allied nations and remaining silent. For purposes of internal morale and external public image, Allied countries would prefer to claim that such technological accomplishments were really their own, and in any case would be highly motivated to try to protect any new weapons technologies from rival Allied nations in the incipient Cold War.

Likewise, if the German nuclear weapons program was successful, one can also understand why the major countries involved might desire to preserve that secret even 75+ years later. The German and

Austrian governments might not want yet another Third Reich offense from their past for which they would need to apologize. Former Allied countries might not want to admit that their wartime and postwar technological prowess was not as great as they had boasted for so many decades, or that that of their vanquished enemy was greater than they had claimed for so long. In any event, routine security classification rules would prevent the release of archival documents with useful details about nuclear weapons designs and production methods, no matter what their age, history, and country of origin might have been (even though far more dangerous, detailed, and up-to-date information is now readily available to everyone on the internet).

Yet if the German nuclear weapons program truly was more successful than the governments have previously admitted, on the whole it would seem far more beneficial for all countries to finally acknowledge that fact than to continue to deny it:

1. As with "truth and reconciliation commissions" in other countries, Germany and Austria could finally acknowledge and address the full extent of the Third Reich's actions, their current citizens (who were too young to have been involved in any of those events) could have a detailed understanding of those actions and history, and these countries could move forward with that chapter fully closed, rather than still having to hide or fear further revelations in the indefinite future.

2. Carefully inspecting and cleaning up any sites involved in producing or storing nuclear materials would prevent contamination of local drinking water, farms, and homes with radioactive isotopes, heavy metals, solvents, or other toxic chemicals.

3. Elucidating all the concentration camp prisoners who died in the preparation, production, and testing of nuclear weapons would finally bring justice to what may be many thousands of currently forgotten victims of the war.

4. The media-consuming public in former Allied countries seems fascinated with and proud of their countries' roles in World War II, so they should be extremely interested in new details about that war, and should in fact find it exciting to learn that their victory was even more hard-won and more consequential than previously known (somewhat similar to how sports fans are more excited by especially close or high-stakes wins).

5. Everyone would gain a much better understanding of the strategic decisions made by all countries during and after the war, making more sense of events and actions that have previously not been as well explained in the history books.

6. All nations would benefit tremendously by learning exactly how revolutionary technologies have been created in the past, so that they could better create and enjoy the benefits of new revolutionary technologies in the future.

For much more information on the German nuclear weapons program, see Appendix D.

For information on wartime German programs to develop intercontinental jets, rockets, and other delivery vehicles for nuclear weapons, see Appendix E.

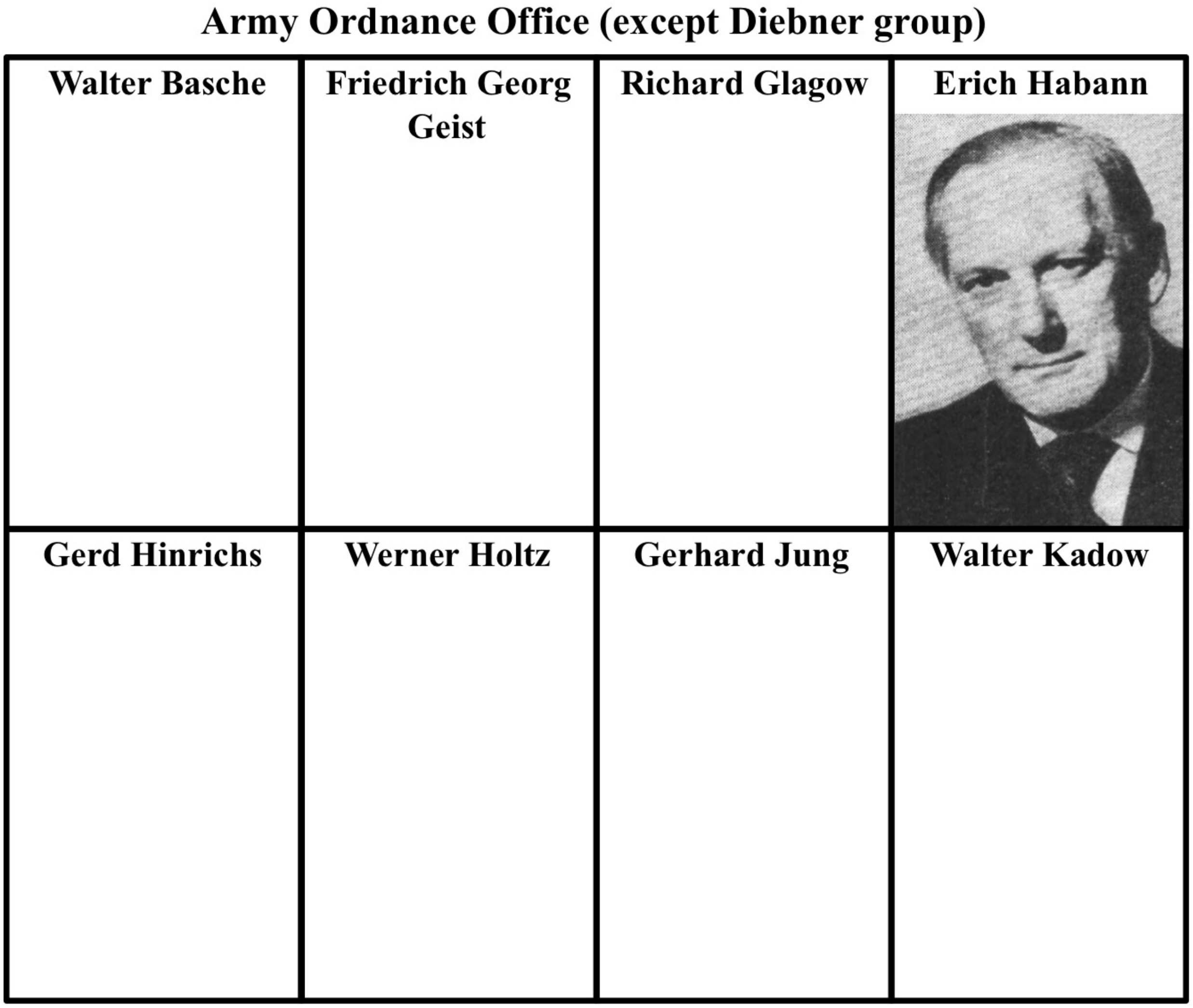

Army Ordnance Office (except Diebner group)
Walter Basche
Friedrich Georg Geist
Richard Glagow
Erich Habann
Gerd Hinrichs
Werner Holtz
Gerhard Jung
Walter Kadow

Figure 8.33: Examples of scientists and engineers at the Army Ordnance Office (Heereswaffenamt) who played critical roles in the development of nuclear technologies in wartime Germany.

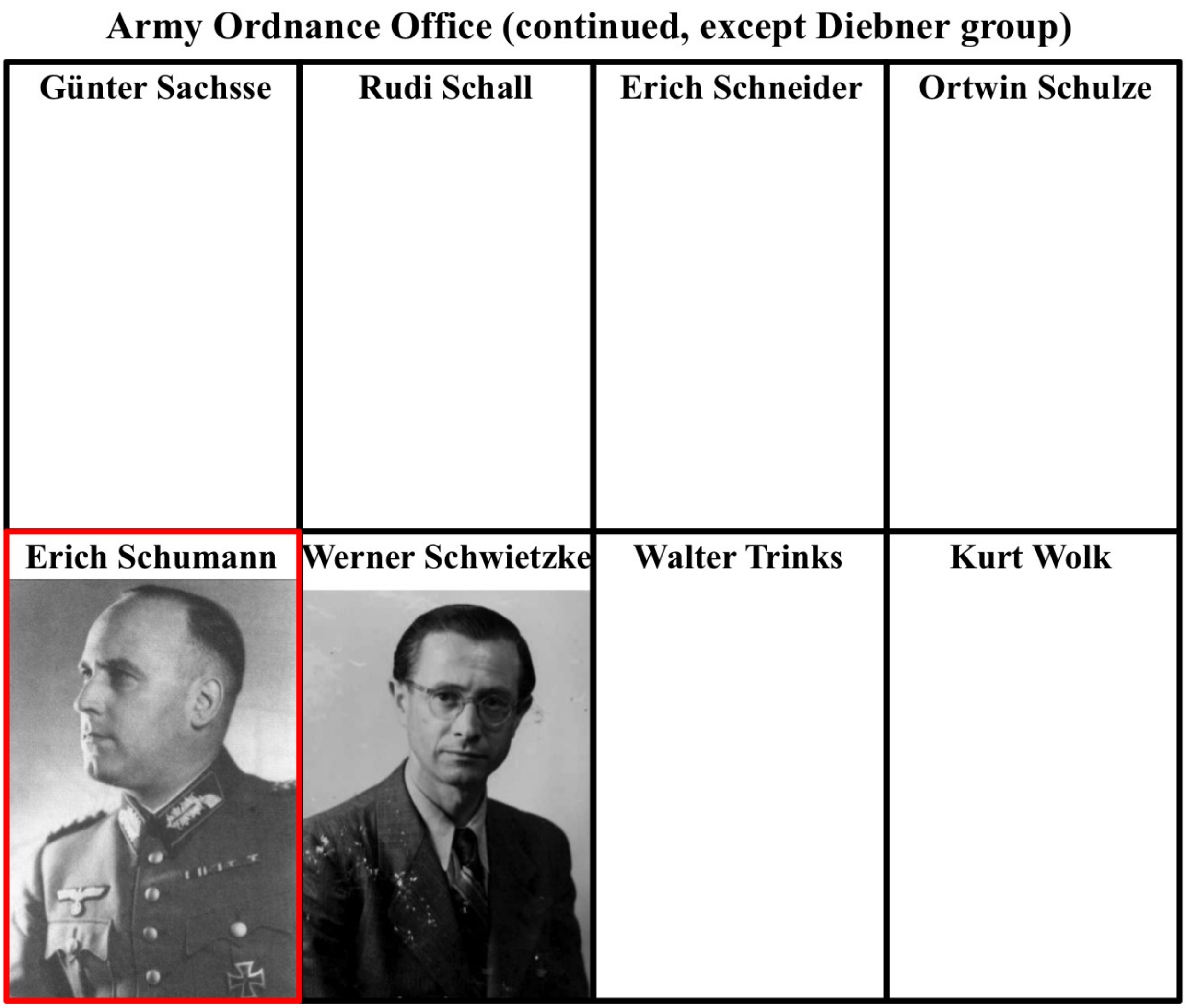

Army Ordnance Office (continued, except Diebner group)
Günter Sachsse
Rudi Schall
Erich Schneider
Ortwin Schulze
Erich Schumann
Werner Schwietzke
Walter Trinks
Kurt Wolk

Figure 8.34: More examples of scientists and engineers at the Army Ordnance Office (Heereswaffenamt) who played critical roles in the development of nuclear technologies in wartime Germany. Erich Schumann was the head scientist.

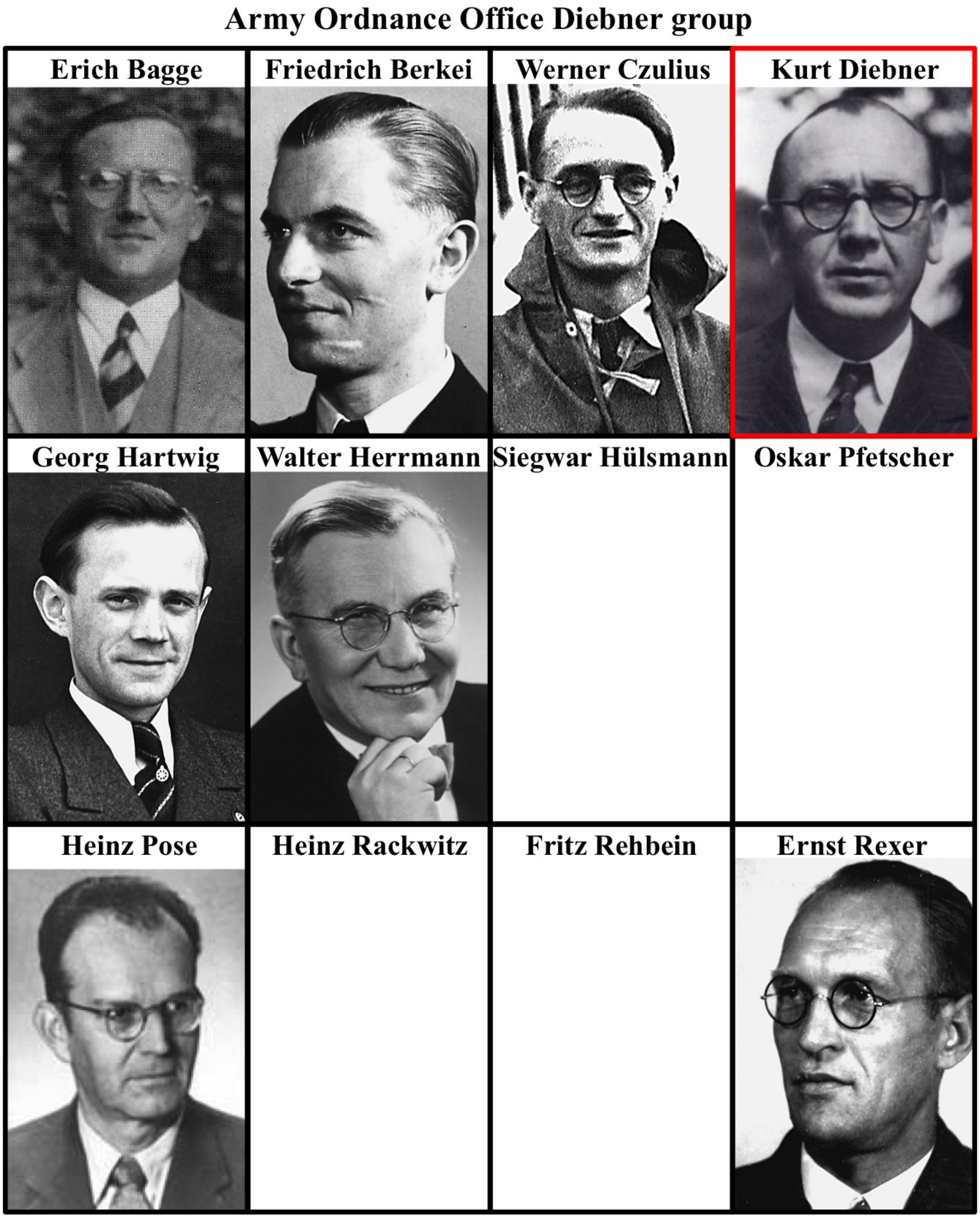
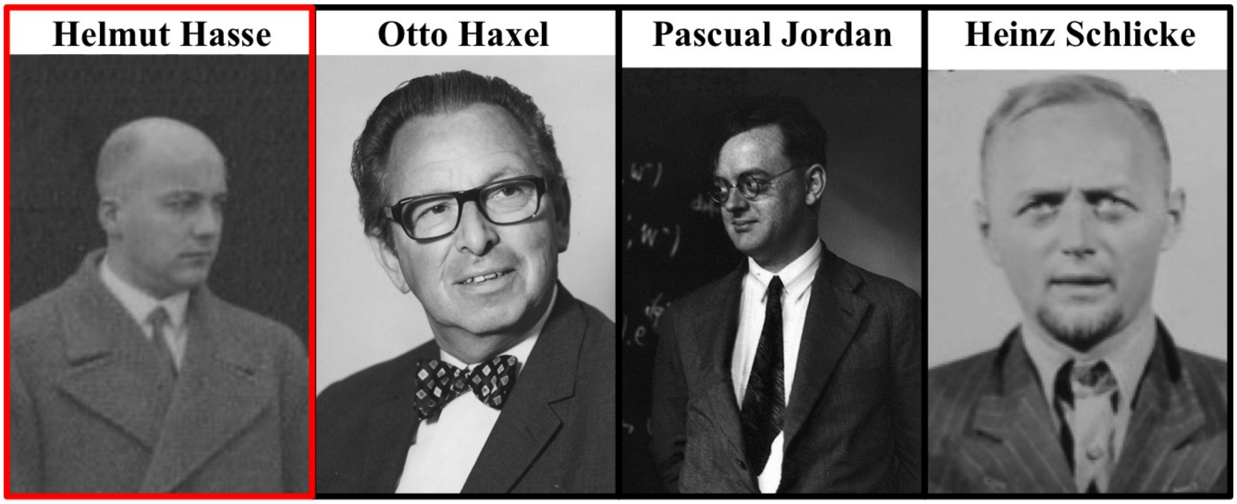

Army Ordnance Office Diebner group
Erich Bagge
Friedrich Berkei
Werner Czulius
Kurt Diebner
Georg Hartwig
Walter Herrmann
Siegwar Hülsmann
Oskar Pfetscher
Heinz Pose
Heinz Rackwitz
Fritz Rehbein
Ernst Rexer

Figure 8.35: Examples of scientists and engineers in Kurt Diebner's group at the Army Ordnance Office (Heereswaffenamt) who played critical roles in the development of nuclear technologies in wartime Germany.

Navy (Kriegsmarine)


Helmut Hasse
Otto Haxel
Pascual Jordan
Heinz Schlicke

Air Force (Luftwaffe)

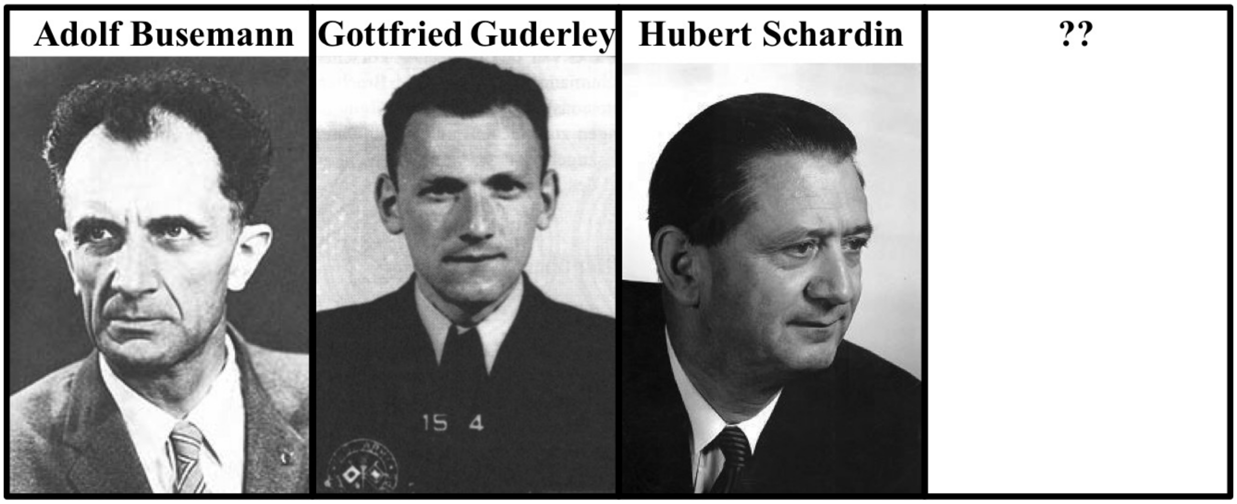

Adolf Busemann
Gottfried Guderley
Hubert Schardin
??

Figure 8.36: Examples of scientists and engineers at Navy (Kriegsmarine, under chief scientist Helmut Hasse) and Air Force (Luftwaffe) laboratories who played critical roles in the development of nuclear technologies in wartime Germany.

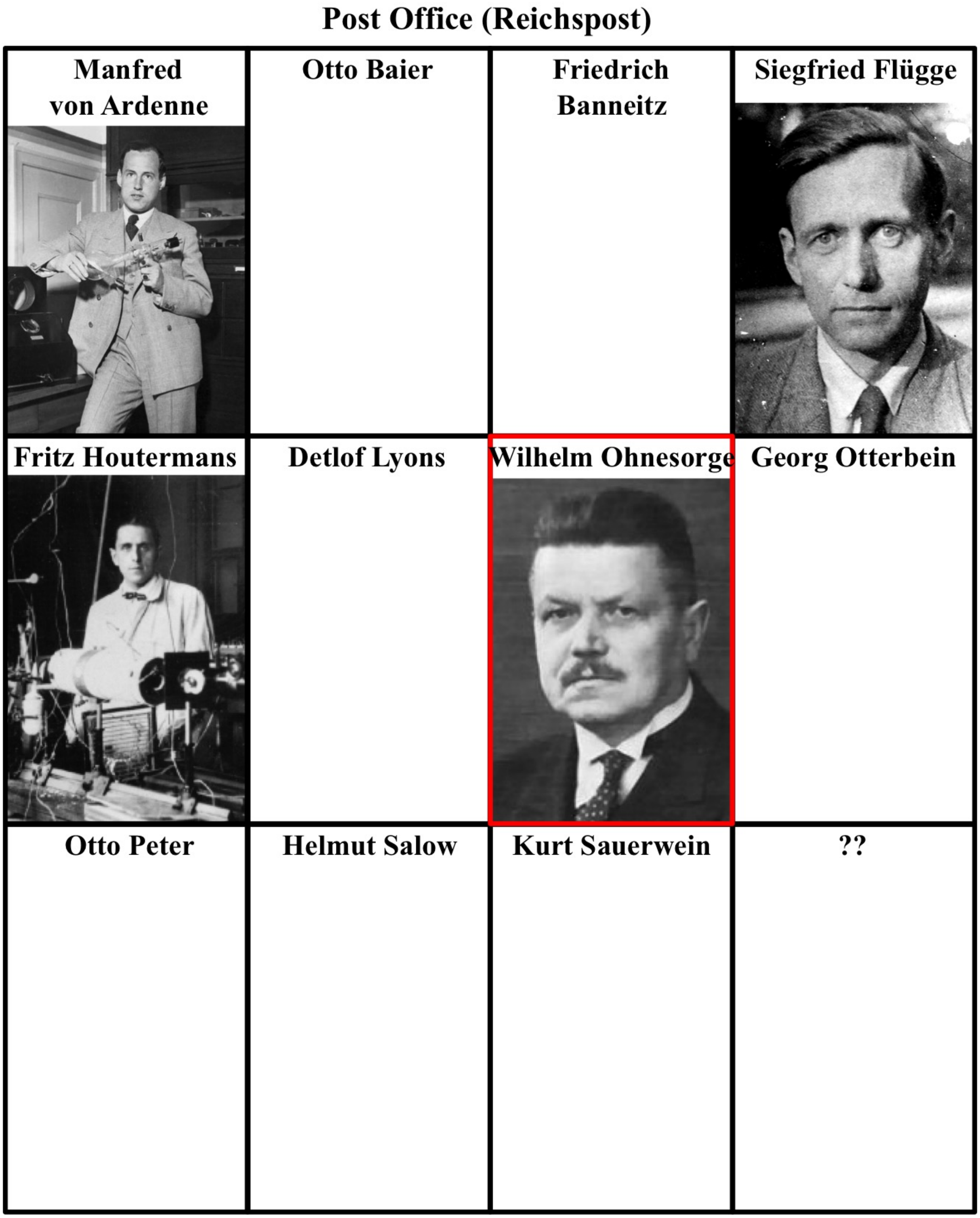

Post Office (Reichspost)
Manfred von Ardenne
Otto Baier
Friedrich Banneitz
Siegfried Flügge
Fritz Houtermans
Detlof Lyons
Wilhelm Ohnesorge
Georg Otterbein
Otto Peter
Helmut Salow
Kurt Sauerwein
??

Figure 8.37: Examples of scientists and engineers at Post Office (Reichspost, led by Wilhelm Ohnesorge) laboratories who played critical roles in the development of nuclear technologies in wartime Germany.

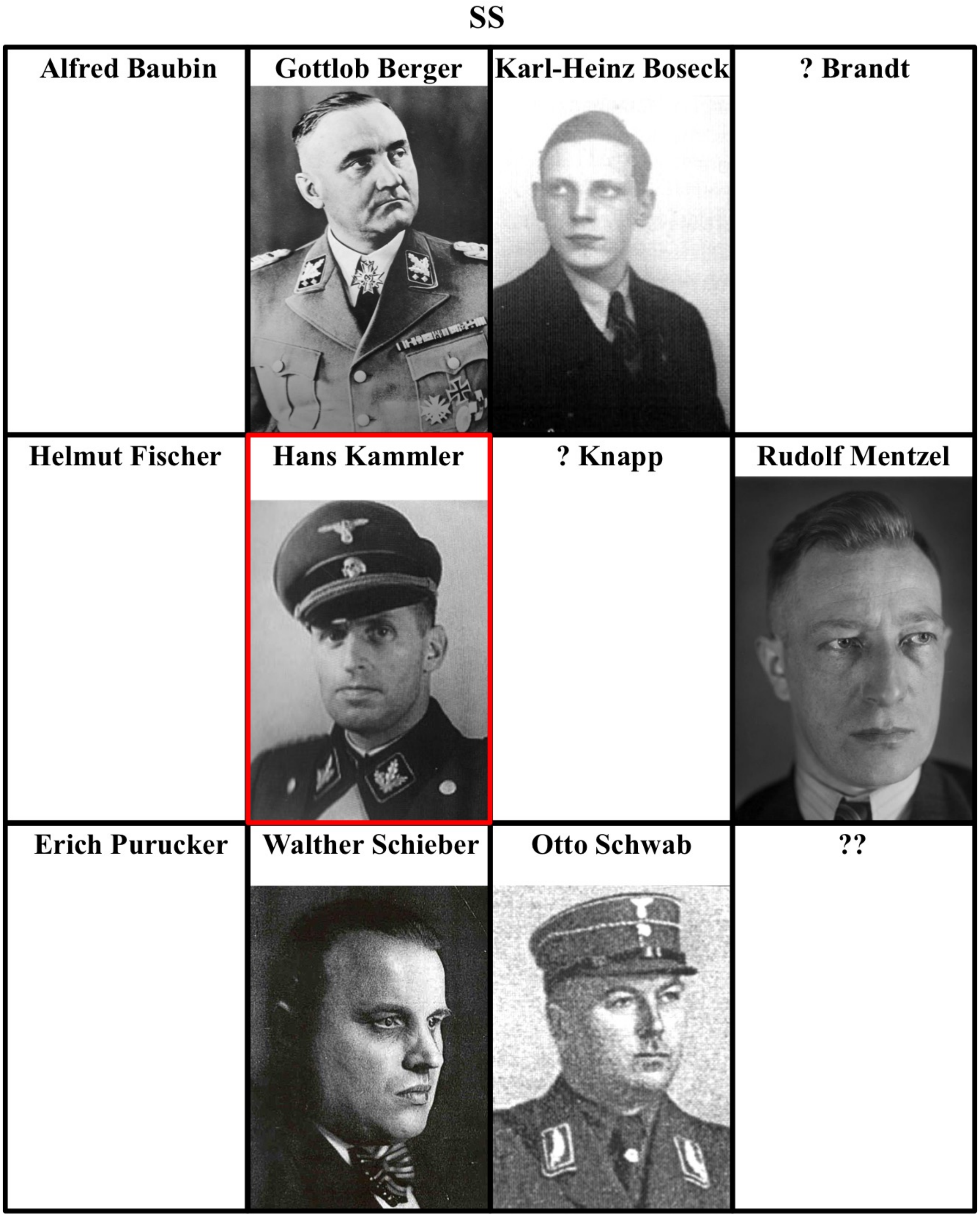

SS
Alfred Baubin
Gottlob Berger
Karl-Heinz Boseck
? Brandt
Helmut Fischer
Hans Kammler
? Knapp
Rudolf Mentzel
Erich Purucker
Walther Schieber
Otto Schwab
??

Figure 8.38: Examples of scientists and engineers in the SS (ultimately led by Hans Kammler) who played critical roles in the development of nuclear technologies in wartime Germany.

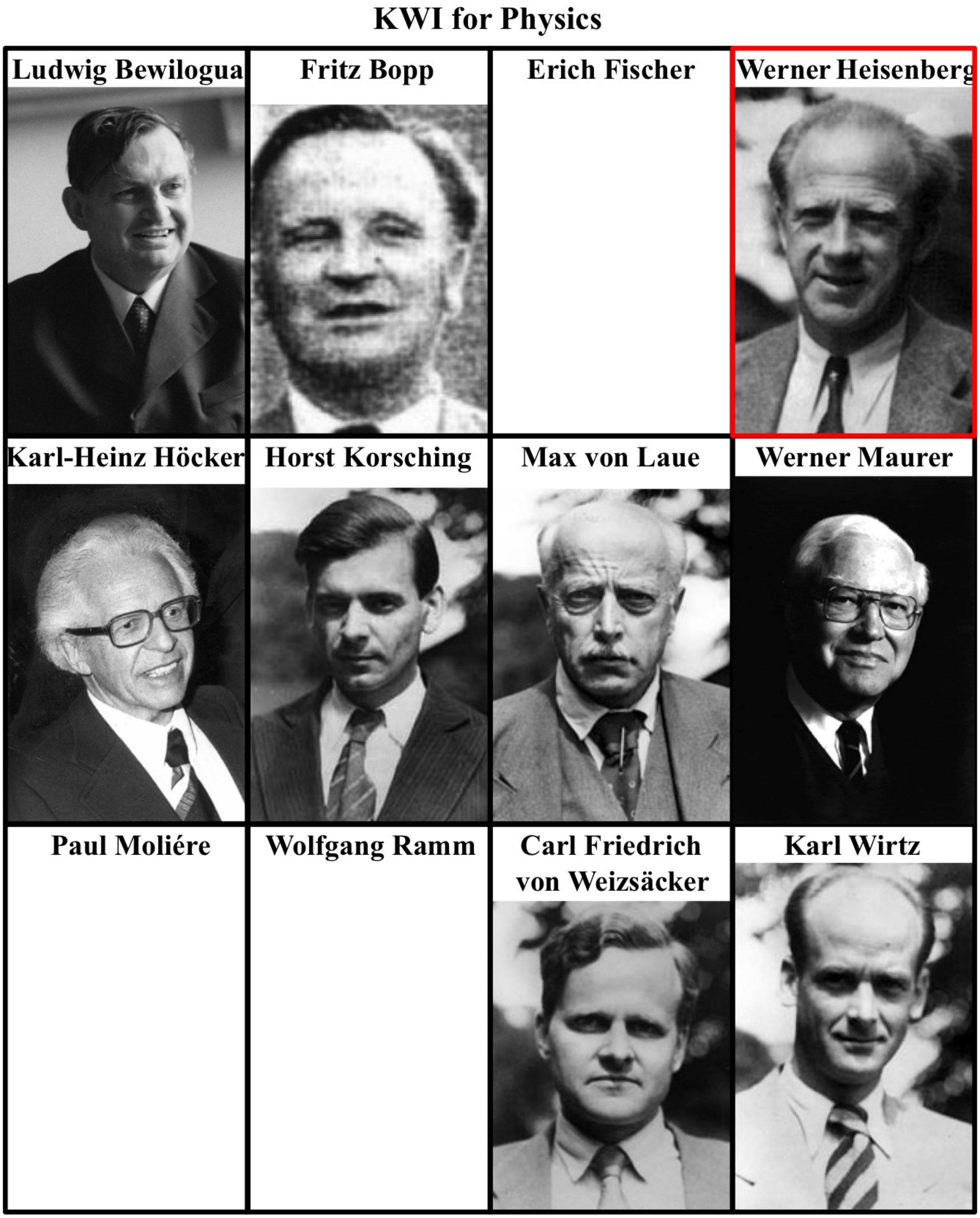

KWI for Physics
Ludwig Bewilogua
Fritz Bopp
Erich Fischer
Werner Heisenberg
Karl-Heinz Höcker
Horst Korsching
Max von Laue
Werner Maurer
Paul Moliére
Wolfgang Ramm
Carl Friedrich von Weizsäcker
Karl Wirtz

Figure 8.39: Examples of scientists and engineers at the Kaiser Wilhelm Institute (KWI) for Physics who played critical roles in the development of nuclear technologies in wartime Germany. Werner Heisenberg was the head scientist.

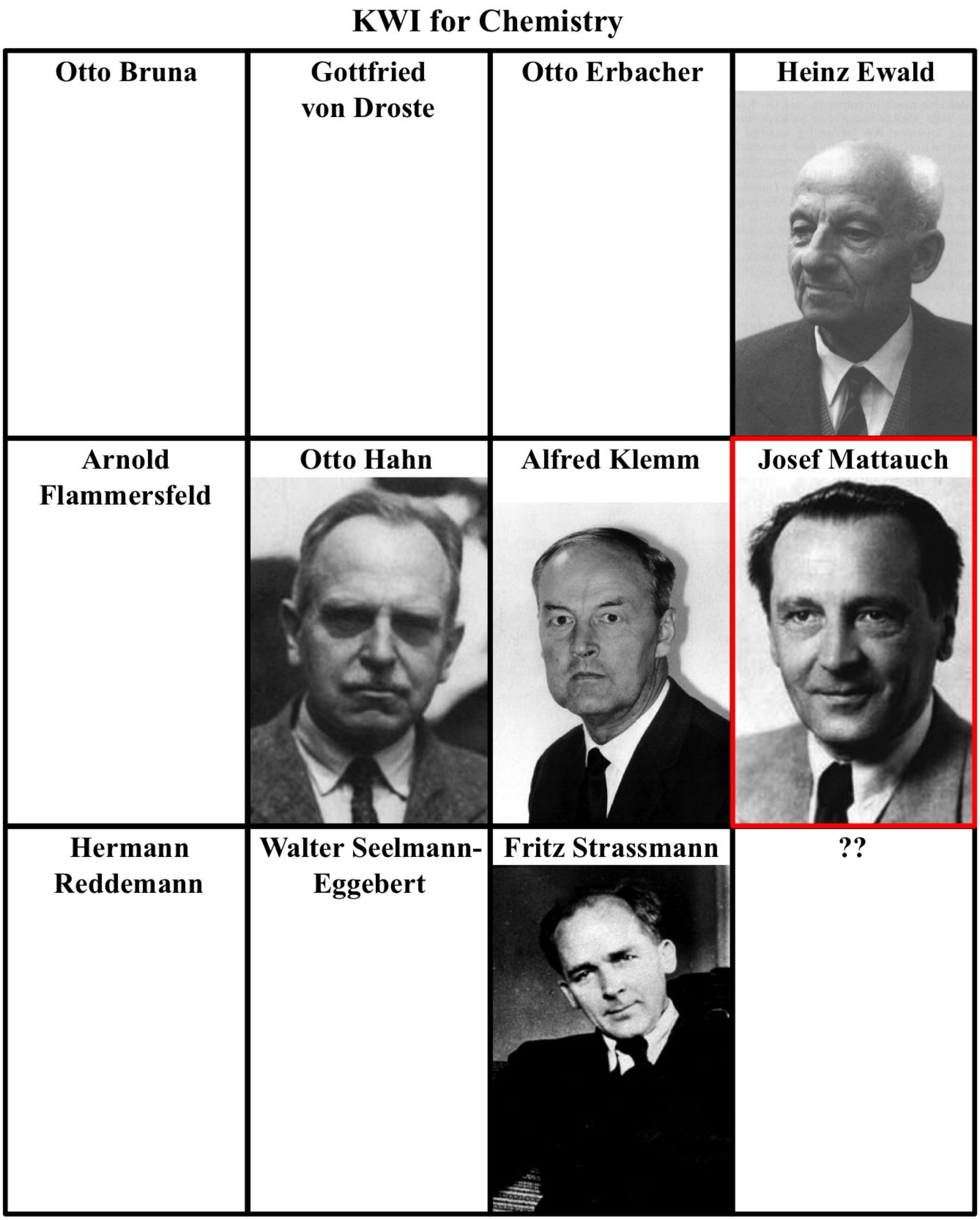

KWI for Chemistry
Otto Bruna
Gottfried von Droste
Otto Erbacher
Heinz Ewald
Arnold Flammersfeld
Otto Hahn
Alfred Klemm
Josef Mattauch
Hermann Reddemann
Walter Seelmann-Eggebert
Fritz Strassmann
??

Figure 8.40: Examples of scientists and engineers at the Kaiser Wilhelm Institute (KWI) for Chemistry who played critical roles in the development of nuclear technologies in wartime Germany. Josef Mattauch was the head scientist.

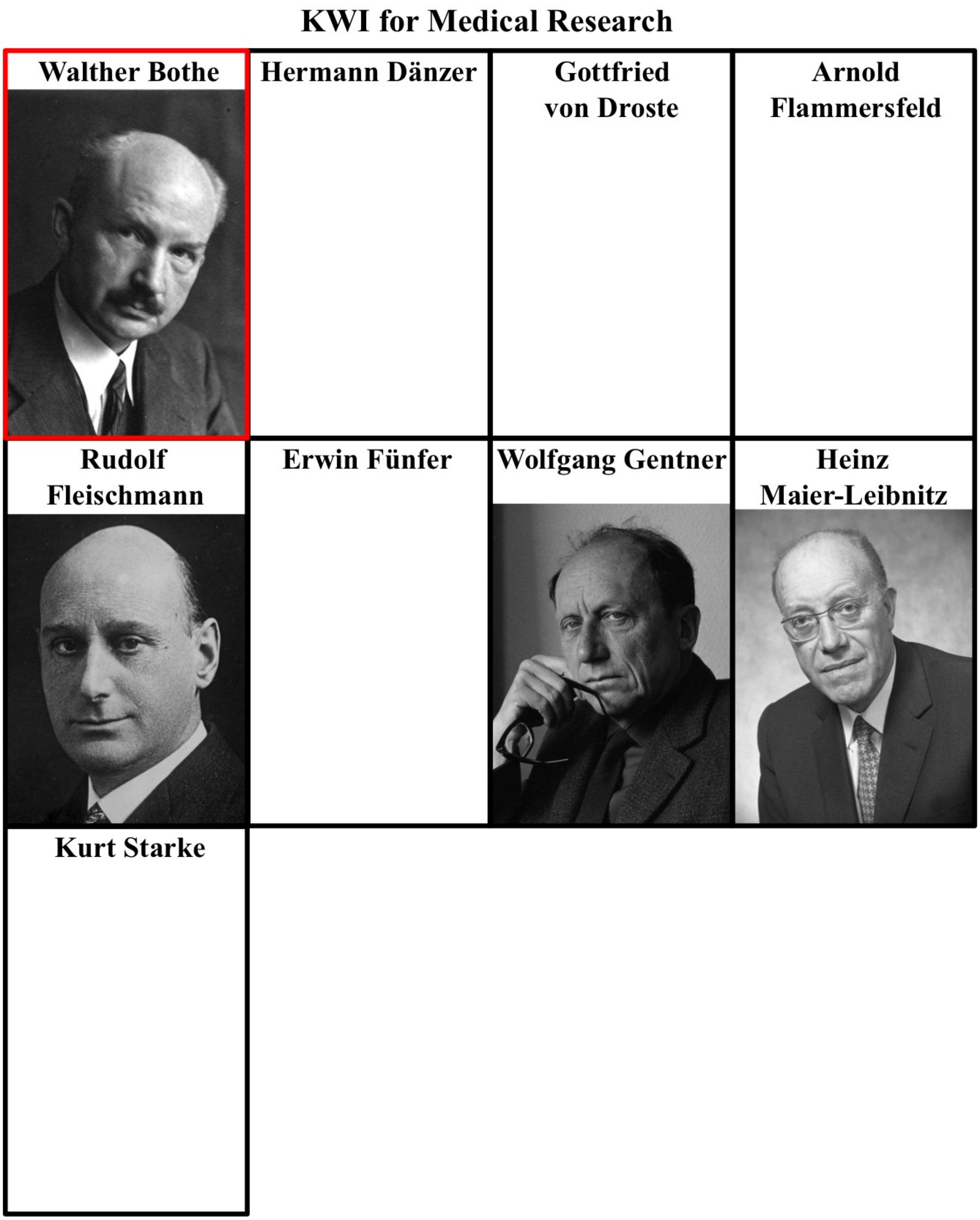
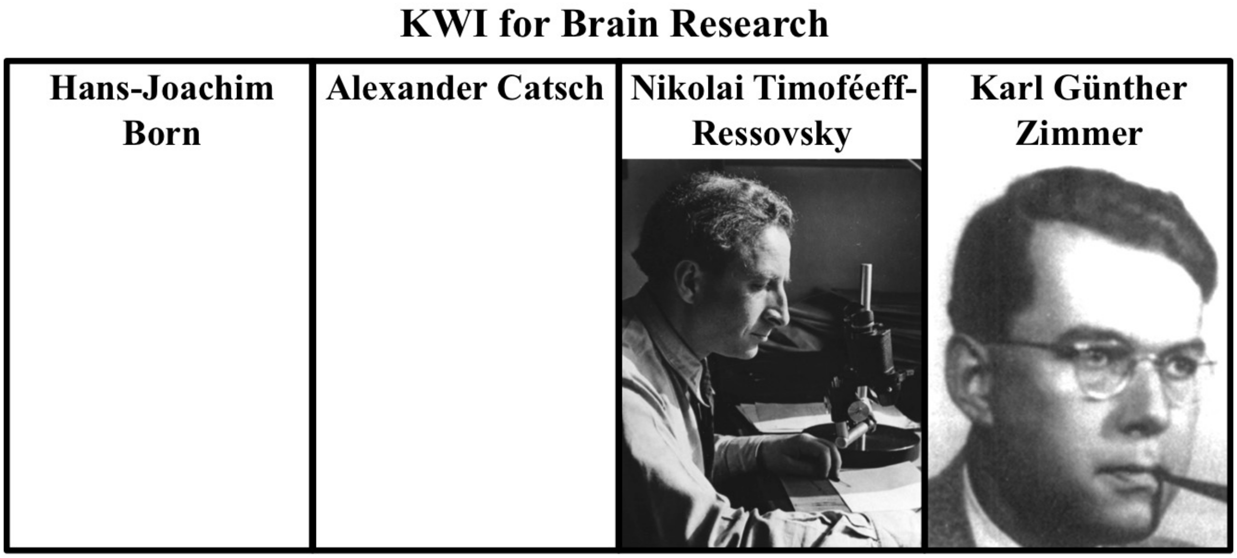
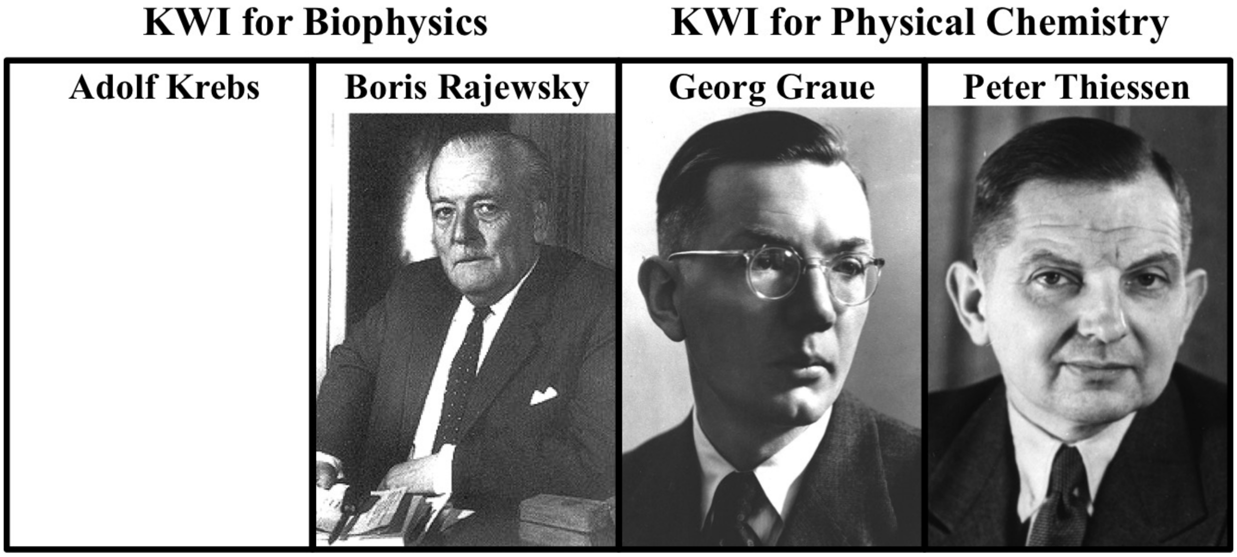

KWI for Medical Research
Walther Bothe
Hermann Dänzer
Gottfried von Droste
Arnold Flammersfeld
Rudolf Fleischmann
Erwin Fünfer
Wolfgang Gentner
Heinz Maier-Leibnitz
Kurt Starke

Figure 8.41: Examples of scientists and engineers at the Kaiser Wilhelm Institute (KWI) for Medical Research who played critical roles in the development of nuclear technologies in wartime Germany. Walther Bothe was the head scientist.



KWI for Brain Research

Hans-Joachim Born
Alexander Catsch
Nikolai Timoféeff-Ressovsky
Karl Günther Zimmer

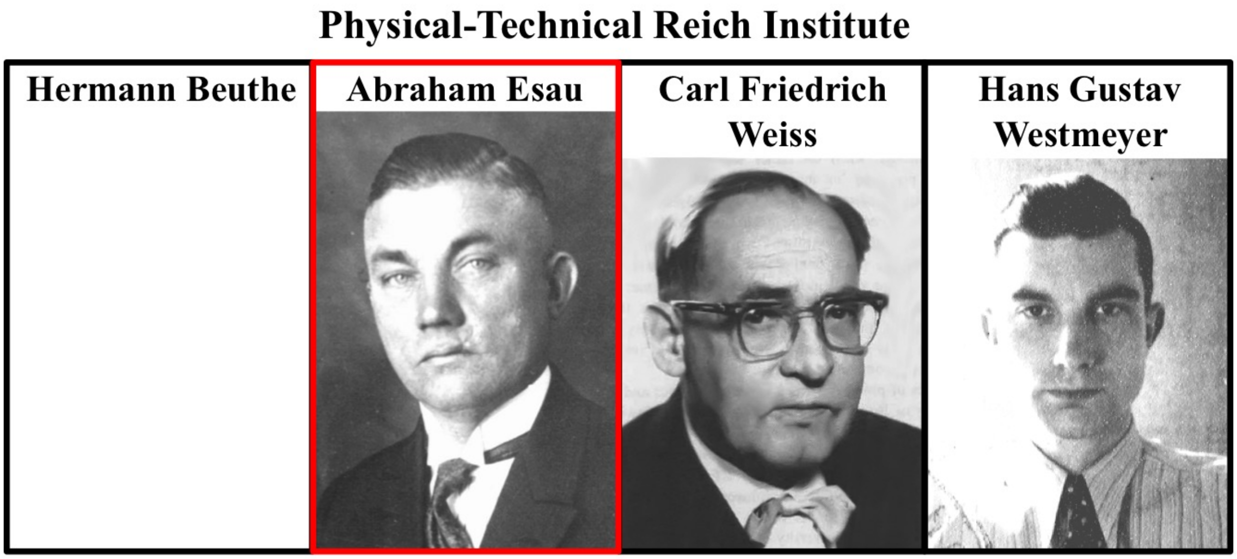


KWI for Biophysics

KWI for Physical Chemistry

Adolf Krebs
Boris Rajewsky
Georg Graue
Peter Thiessen

Figure 8.42: Examples of scientists and engineers at the Kaiser Wilhelm Institutes (KWI) for Brain Research, Biophysics, and Physical Chemistry who played critical roles in the development of nuclear technologies in wartime Germany.


Physical-Technical Reich Institute
Hermann Beuthe
Abraham Esau
Carl Friedrich Weiss
Hans Gustav Westmeyer

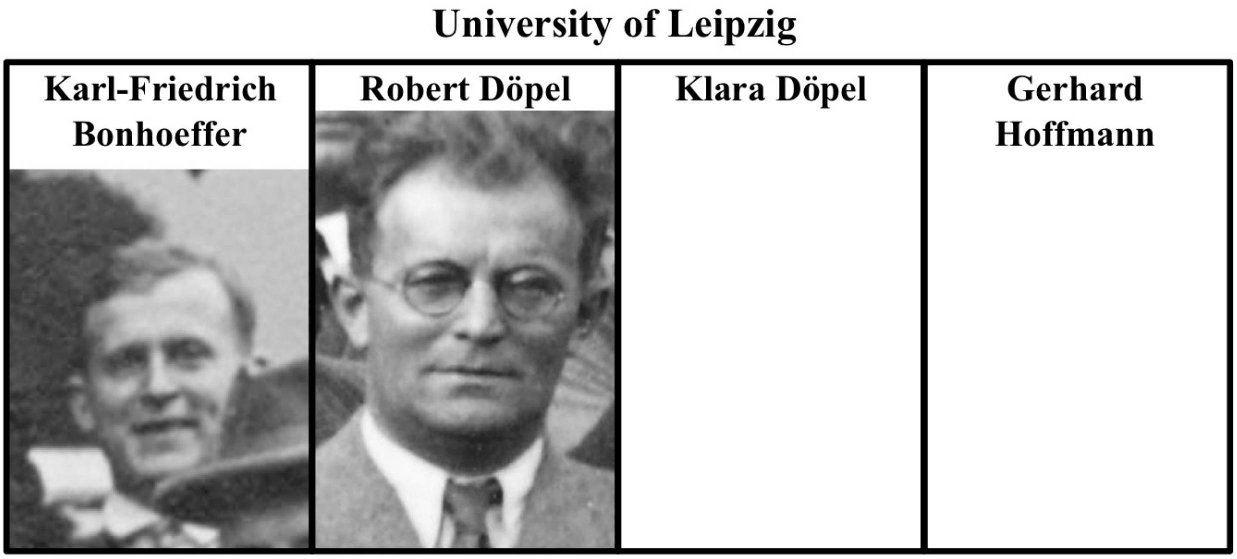
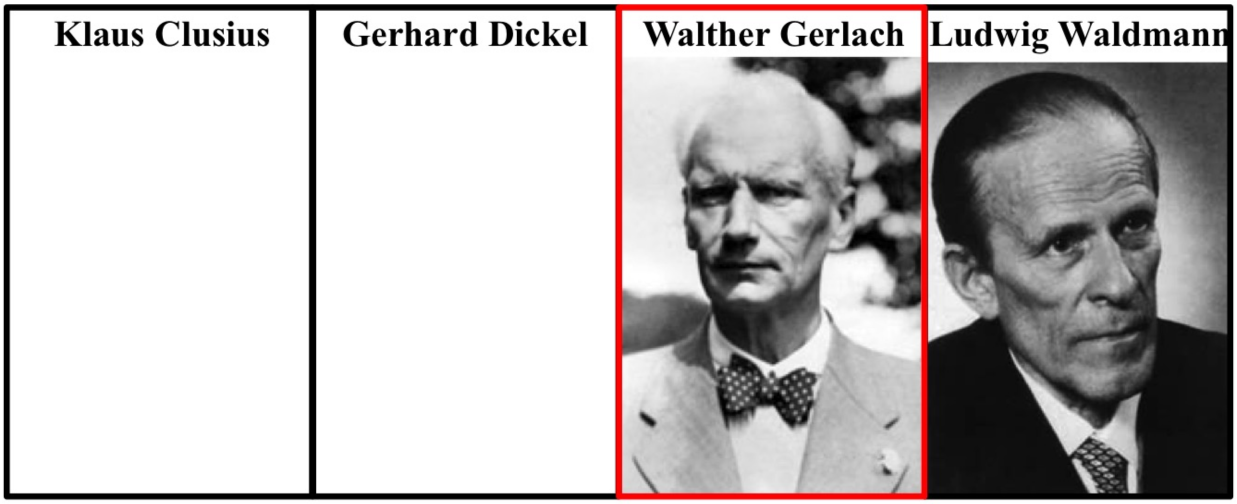

University of Leipzig
Karl-Friedrich Bonhoeffer
Robert Döpel
Klara Döpel
Gerhard Hoffmann

Figure 8.43: Examples of scientists and engineers at the Physical-Technical Reich Institute (Physikalische-Techische Reichsanstalt, PTR) and the University of Leipzig who played critical roles in the development of nuclear technologies in wartime Germany. Abraham Esau was the head scientist of the PTR, and was in charge of large parts of the German nuclear program early in the war.

University of Munich


Klaus Clusius
Gerhard Dickel
Walther Gerlach
Ludwig Waldmann

Göttingen University

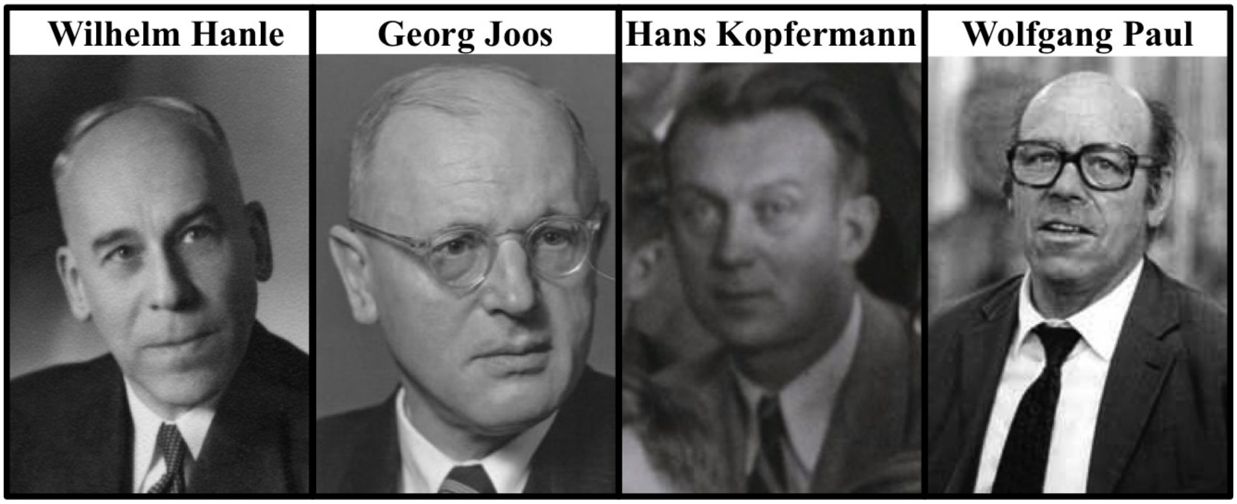

Wilhelm Hanle
Georg Joos
Hans Kopfermann
Wolfgang Paul

Figure 8.44: Examples of scientists and engineers at the University of Munich and Göttingen University who played critical roles in the development of nuclear technologies in wartime Germany. Walther Gerlach was in charge of large parts of the German nuclear program later in the war.

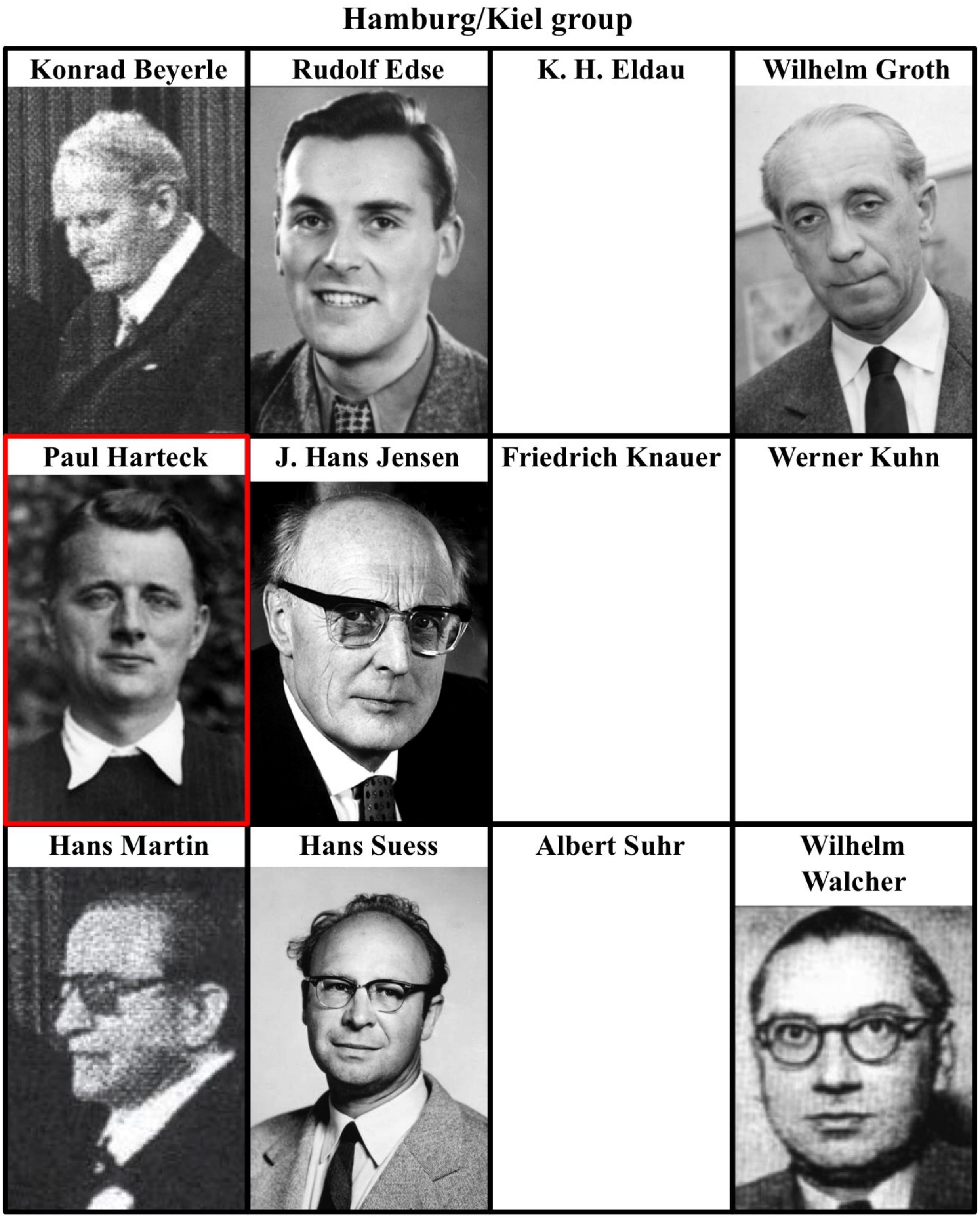

Hamburg/Kiel group
Konrad Beyerle
Rudolf Edse
K. H. Eldau
Wilhelm Groth
Paul Harteck
J. Hans Jensen
Friedrich Knauer
Werner Kuhn
Hans Martin
Hans Suess
Albert Suhr
Wilhelm Walcher

Figure 8.45: Examples of scientists and engineers at the University of Hamburg and elsewhere in the Hamburg/Kiel area who played critical roles in the development of nuclear technologies in wartime Germany. Paul Harteck was the head scientist.

University of Vienna
Alfred Bönisch
Alfred Brukl
Friedrich Hernegger
Richard Herzog
Willibald Jentschke
Berta Karlik
Karl Lintner
Otto Merhaut
Gustav Ortner
Josef Schintlmeister
Georg Stetter
Herta Wambacher

Figure 8.46: Examples of scientists and engineers at the University of Vienna who played critical roles in the development of nuclear technologies in wartime Germany. Georg Stetter was the head scientist.

Auer/Degussa

Philipp Hoersch	**Egon Ihwe**	**Fritz Klänhardt**	**Henry Ortmann**
Kurt Quasebart	**?? Rabbe**	**Nikolaus Riehl**	**Karl-Heinz Riewe**
Walter Völkel	**Karl Weis**	**Günter Wirths**	**Paul Max Wolf**

Figure 8.47: Examples of scientists and engineers at Auergesellschaft/Degussa company laboratories who played critical roles in the development of nuclear technologies in wartime Germany.

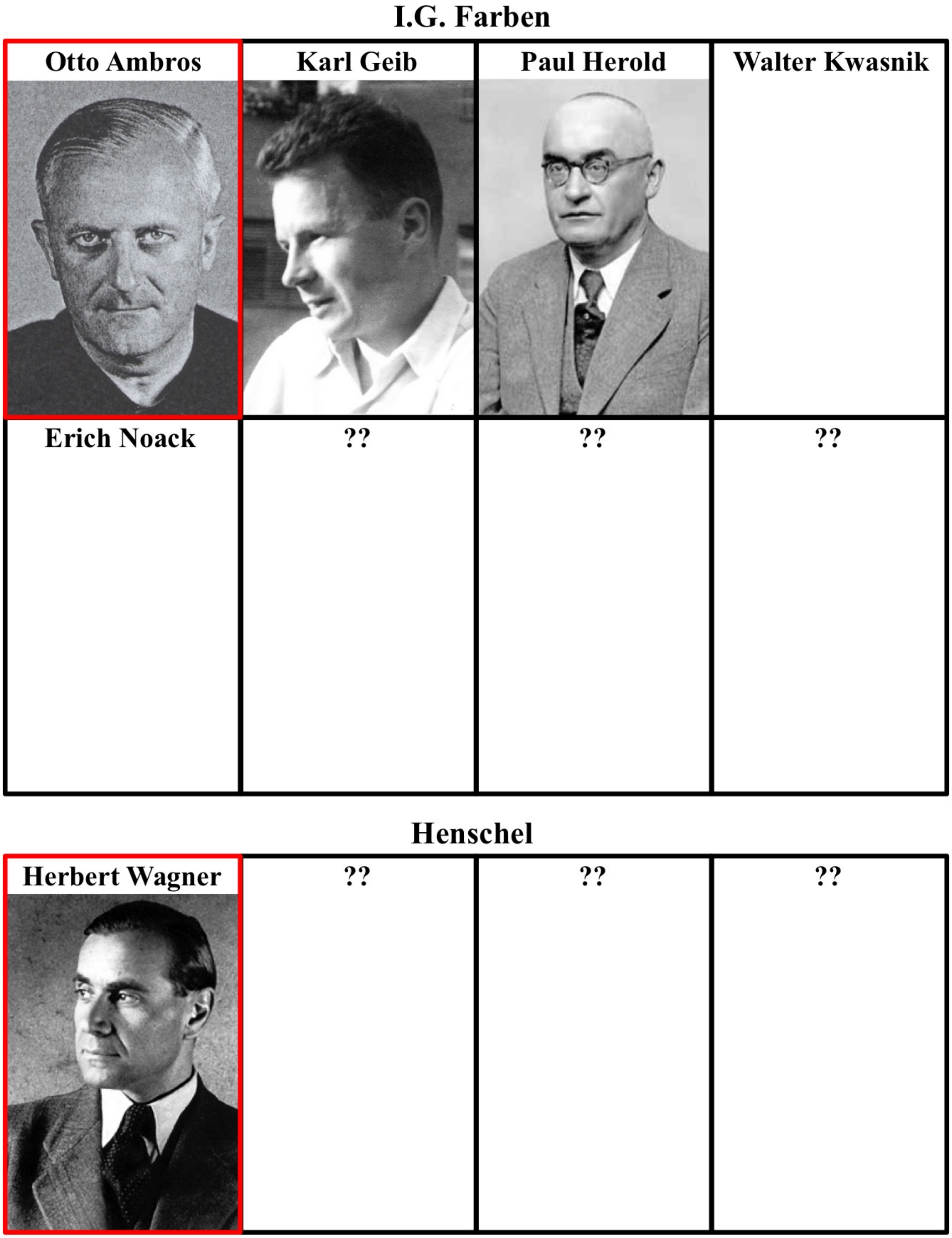

I.G. Farben
Otto Ambros
Karl Geib
Paul Herold
Walter Kwasnik
Erich Noack
??
??
??
Henschel
Herbert Wagner
??
??
??

Figure 8.48: Examples of scientists and engineers at I.G. Farben and Henschel company laboratories who played critical roles in the development of nuclear technologies in wartime Germany. Otto Ambros was the head scientist at I.G. Farben, and Herbert Wagner was the lead scientist at Henschel.

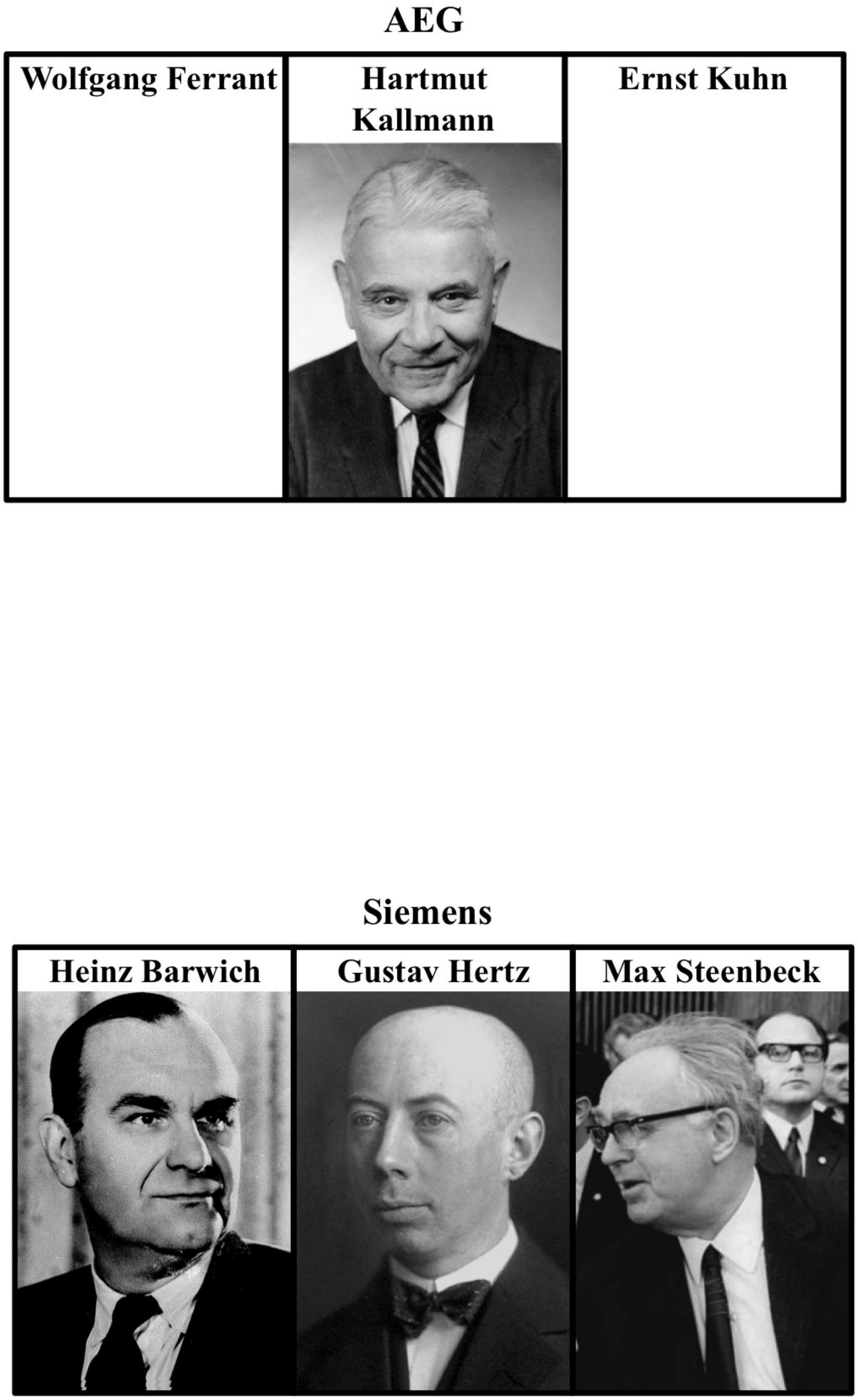

AEG
Wolfgang Ferrant
Hartmut Kallmann
Ernst Kuhn
Siemens
Heinz Barwich
Gustav Hertz
Max Steenbeck

Figure 8.49: Examples of scientists and engineers at AEG and Siemens company laboratories who played critical roles in the development of nuclear technologies in wartime Germany.

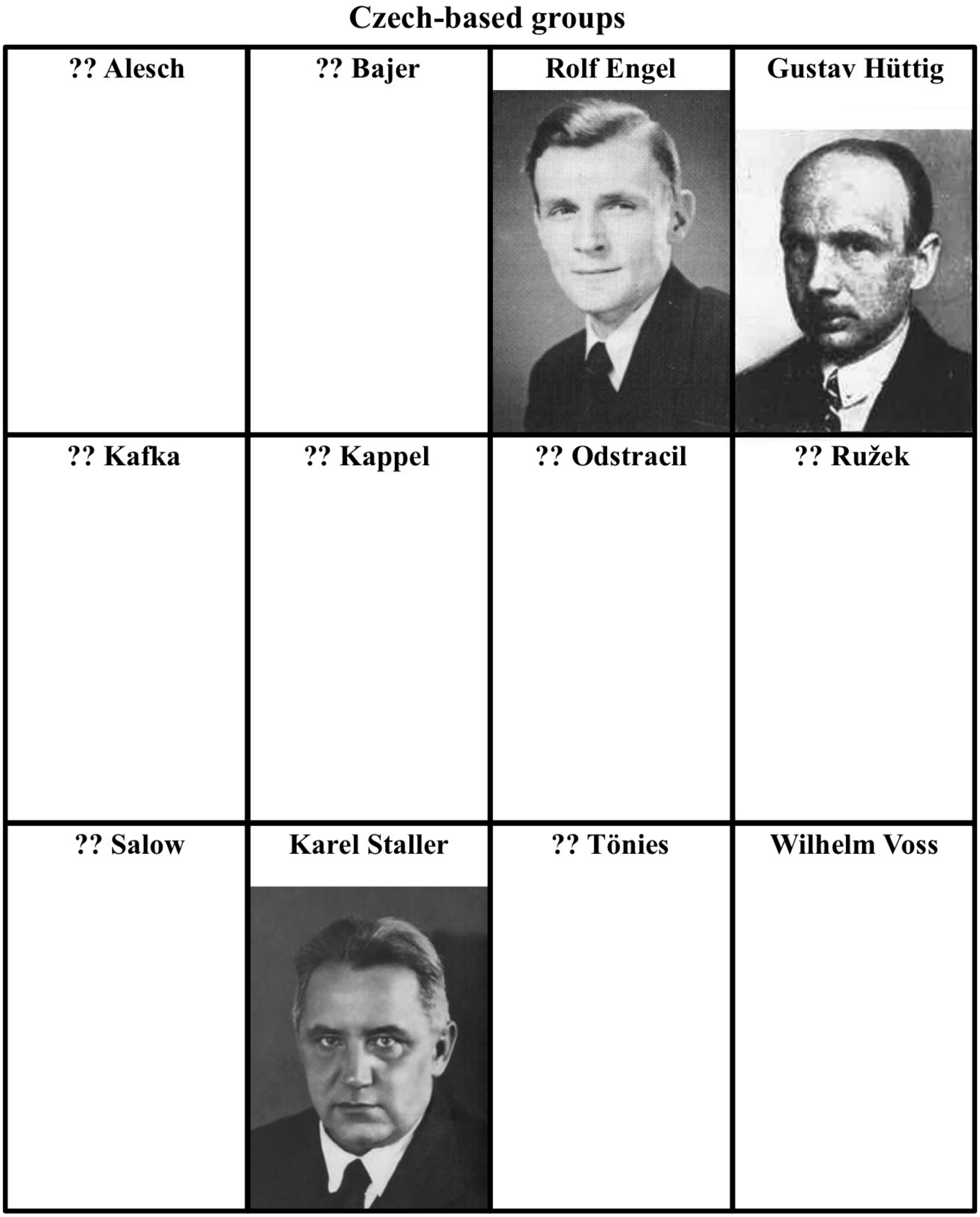

Czech-based groups
?? Alesch
?? Bajer
Rolf Engel
Gustav Hüttig
?? Kafka
?? Kappel
?? Odstracil
?? Ružek
?? Salow
Karel Staller
?? Tönies
Wilhelm Voss

Figure 8.50: Examples of scientists and engineers in Czech-based research groups and companies who played critical roles in the development of nuclear technologies in wartime Germany.

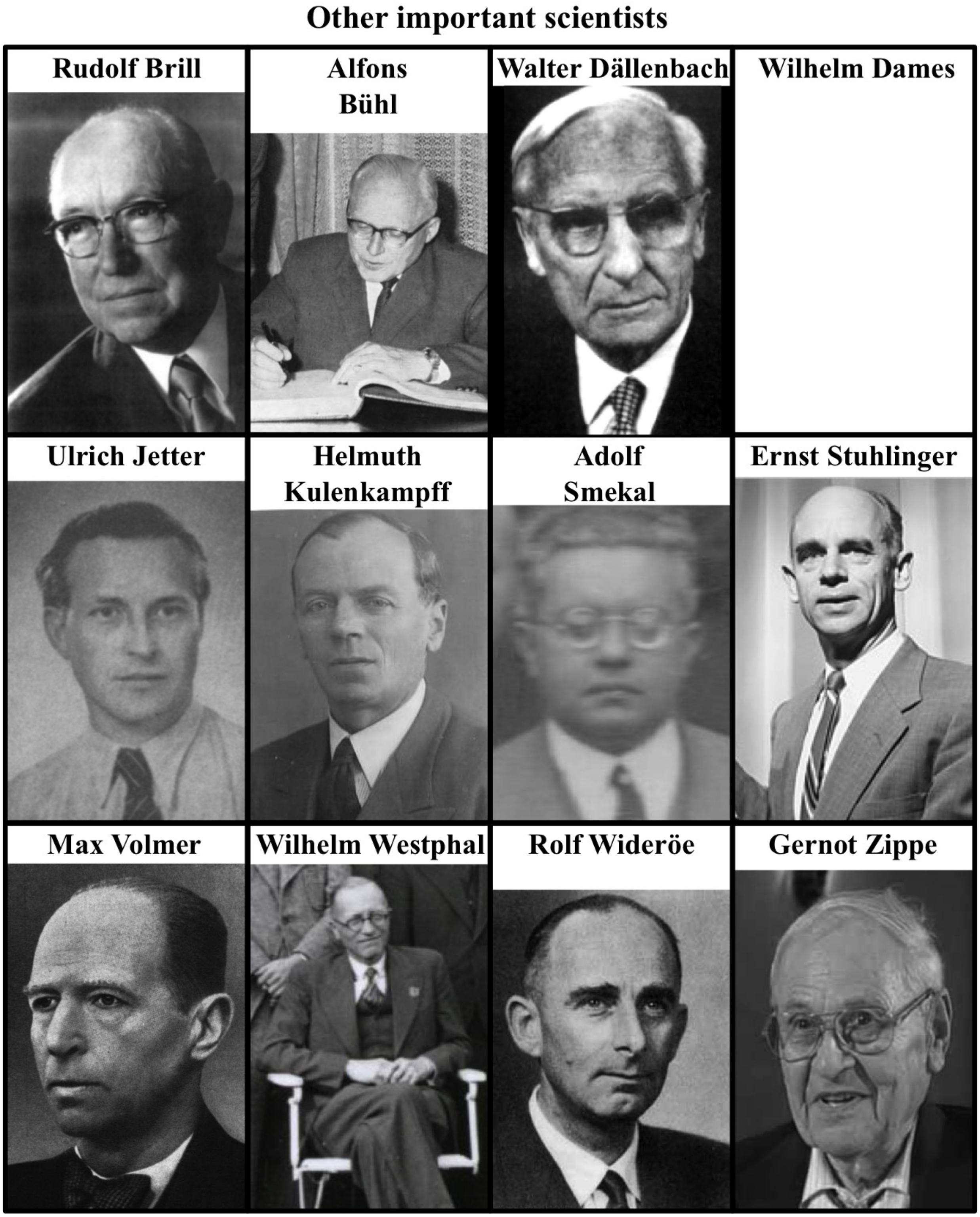

Other important scientists
Rudolf Brill
Alfons Bühl
Walter Dällenbach
Wilhelm Dames
Ulrich Jetter
Helmuth Kulenkampff
Adolf Smekal
Ernst Stuhlinger
Max Volmer
Wilhelm Westphal
Rolf Wideröe
Gernot Zippe

Figure 8.51: Other examples of scientists and engineers who played critical roles in the development of nuclear technologies in wartime Germany.

8.9 Nuclear Engineering in the Soviet Union

German-trained scientists and engineers, as well as German-produced designs, materials, and equipment, made enormous contributions to the postwar Soviet nuclear program.[22]

The Soviet nuclear program employed (at least) many hundreds of German-speaking scientists and engineers. Just the Soviet nuclear institute run by Manfred von Ardenne was staffed with almost 300 Germans [Oleynikov 2000]. At least several hundred more worked at other nuclear institutes and facilities in the Soviet Union.[23] Including German-speaking scientists and engineers in industries that directly supported the nuclear program (geology, chemistry, materials science, electronics, aerospace, etc.), the total number of German-speaking specialists who contributed to the program was likely in the thousands. For examples of some German-speaking scientists who aided the Soviet nuclear program, see Figs. 8.52–8.55. Some of the major contributions included:

- Klaus Fuchs, a German physicist who worked in the U.S./U.K. nuclear program for many years, gave the Soviet Union detailed plans of U.S. nuclear bombs and production systems (which had been designed and developed with the critical contributions of a large number of German-speaking and German-trained scientists, as discussed in Section 8.7).

- Erich Purucker (German, 1893–1957), Hans Kammler's chief assistant in running the wartime German nuclear program, was captured by Soviet troops in May 1945 along with a car full of German nuclear weapons plans, and held in the Soviet Union for the rest of his life. See p. 4914 for more details.

- E. Baroni (German, ??-??), Henry Ortmann (German, 1908–1988), Nikolaus Riehl (German, 1901–1990), Herbert Schmitz (German, ??–??), Herbert Thieme (German, 1902–??), Günther Wirths (German, 1911–2005), and many other German and Austrian scientists processed uranium ore to uranium oxide, uranium metal, and uranium hexafluoride. Joseph Stalin personally awarded Riehl the title "Hero of the Socialist Labor" and gave him a first class Stalin Prize; he gave Thieme and Wirths second class Stalin Prizes.

- Heinz Barwich (German, 1911–1966), Fritz Bernhard (German, 1913–??), Gustav Hertz (German, 1887–1975), Hans Gerhard Krüger (German, 1912–??), Justus Mühlenpfordt (German, 1911–2000), Reinhold Reichmann (German, ??–??), Werner Schütze (German, ??–??), Peter Thiessen (German, 1899–1990), and many other German and Austrian scientists produced gaseous diffusion systems to enrich uranium-235, apparently based on wartime German gaseous diffusion technology. Joseph Stalin gave Thiessen a first class Stalin Prize, and Barwich, Hertz, Reichmann, and Schütze second class Stalin Prizes.

---

[22] Albrecht et al. 1992; von Ardenne 1990, 1997; Barkleit 2008; Barwich and Barwich 1970; Boch and Karlsch 2011; Fengler 2014; Fengler and Sachse 2012; Goncharov 1996a, 1996b; Goncharov and Riabev 2001; Graham 1993; Heinemann-Gruder 1992; Holloway 1994; Karlsch 2011; Karlsch and Laufer 2002; Karlsch and Zeman 2016; Kozyrev 2005; Kruglov 2002; Maddrell 2006; Mick 2000; Nagel 2016; Naimark 1995; Oleynikov 2000; Pondrom 2018; Riabev 1998, 2002a, 2002b, 2002c, 2002d; 2006a; 2006b; 2006c; Riehl and Seitz 1993; Siddiqi 2009; Sokolov 1955; Wellerstein and Geist 2017; West 2004; Yudin; Zeman and Karlsch 2008; *News Chronicle* 1945-10-15 p. 1; NYT 1945-10-15 p. 4, 1945-10-31 p. 6, 1946-01-29 p. 1, 1946-11-28 p. 16, 1946-12-06 p. 17, 1947-02-24 p. 1, 1948-05-26 p. 3, 1948-12-28 p. 10b; *Spokane Daily Chronicle* 1948-03-16 p. 6; *Sydney Morning Herald* 1946-04-20 p. 2; *Times* 1945-05-15, 1945-05-18; https://nsarchive.gwu.edu/briefing-book/nuclear-vault/2018-04-06/cia-debriefed-soviet-h-bomb-eye-witness-1957

[23] Rainer Karlsch, unpublished Soviet archival list of personnel files.

- Fritz Lange (German, 1899–1987), Rudolf Scheffel (German, 19??–19??), Max Steenbeck (German, 1904–1981), Eberhard Steudel (German, 1906–19??), Gernot Zippe (Austrian, 1917–2008), and many other German and Austrian scientists produced gas centrifuges to enrich uranium-235, apparently based on wartime German gas centrifuge technology.

- Manfred von Ardenne (German, 1907–1997), Werner Schütze, Max Steenbeck, and many other German and Austrian scientists produced electromagnetic separators to enrich uranium-235, apparently based on wartime German electromagnetic separation technology.

- Hans-Joachim Born (German, 1909–1987), Alexander Catsch (German, 1913–1976), Nikolai Timoféeff-Ressovsky (Russian but German educated, 1900–1981), Karl Günter Zimmer (German, 1911–1988), and other German and Austrian scientists elucidated the biological effects of radiation, as well as methods to protect against it, based on their earlier research in Germany.

- Victor Karl Bayerl, Ludwig Bewilogua (German, 1906–1983), Werner Czulius (Austrian, 1914–2007), Karl-Hermann Geib (German, 1908–1949), Paul Herold (German, ??–1951), Walter Herrmann (German, 1910–1987), Paul Heylandt (German, 1884–1947), Hans Gerhard Krüger, Hans-Jürgen von Oertzen (German, 1907–??), Heinz Pose (German, 1905–1975), K. Renker (German, ??–??), Ernst Rexer (German, 1902–1983), Gustav Richter (German, 1911–1999), Karl-Heinz Riewe (German, 1907–??), Adrian Rosen (German, ??–??), Herbert Schmitz, Max Volmer (German, 1885–1965), Carl Friedrich Weiss (German, 1901–1981), Hans Westmeyer (German, 1910–??), and many other German and Austrian scientists developed fission reactors for breeding plutonium-239 from natural uranium-238, based on wartime German technology.

- Manfred von Ardenne, Gustav Hertz, Carl Kober (German, 1913–??), Josef Schintlemeister (Austrian, 1908–1971), Werner Schütze, and other German and Austrian scientists developed methods of producing and using lithium and tritium in H-bombs, apparently based on wartime German and Austrian work. (See p. 4347 as well as the rest of Section D.9.) Von Ardenne was awarded two first class Stalin Prizes for his multiple contributions in the Soviet Union, including the purification of lithium-6 for H-bombs.

Even Pavel Oleynikov, a former group leader of the Chelyabinsk-70 nuclear weapons complex in Russia, admitted that German scientists, technologies, ideas, and materials had had a profound effect on the development of nuclear weapons in the Soviet Union [Oleynikov 2000]:

> It is hard to fully explore the German contributions to the Soviet atomic project without performing a detailed examination of the whole Soviet atom bomb effort. What is clear from the available evidence is that German involvement had several very important implications for the Soviet Union and the world:
>
> - German resources jump-started the Soviet program and saved it up to five years of time. If not for this time, the USSR could hardly have been as aggressive as it was in seeking global dominance. Very likely, the USSR could not have wielded its influence in Asia, and the whole course of regional history (e.g., the Korean War) would have been different. [...]

> - Participation of German scientists in the development of new uranium enrichment methods revolutionized the whole uranium fuel industry. The work of Max Steenbeck and Gernot Zippe shaped the European and Japanese enrichment plants, and was used by several later proliferators (e.g., Pakistan and Iraq) as well.
>
> In sum, although the Soviets would have eventually developed nuclear weapons on their own, they benefited considerably from German technology, expertise, and raw materials. The German contributions undoubtedly accelerated the program by several years and enhanced the Soviets' stature on the world stage. An accurate and complete history of the Soviet bomb program must acknowledge the importance of the Germans' contributions.

At a minimum, the contributions of all of those German-trained scientists and all of the nuclear-related materials taken from Germany appear to have accelerated Soviet development of fission and fusion bombs by many years (Figs. 8.56–8.57). Although some historians have studied this area, much more detailed investigations are needed, especially if unrestricted access to former Soviet archives becomes available.

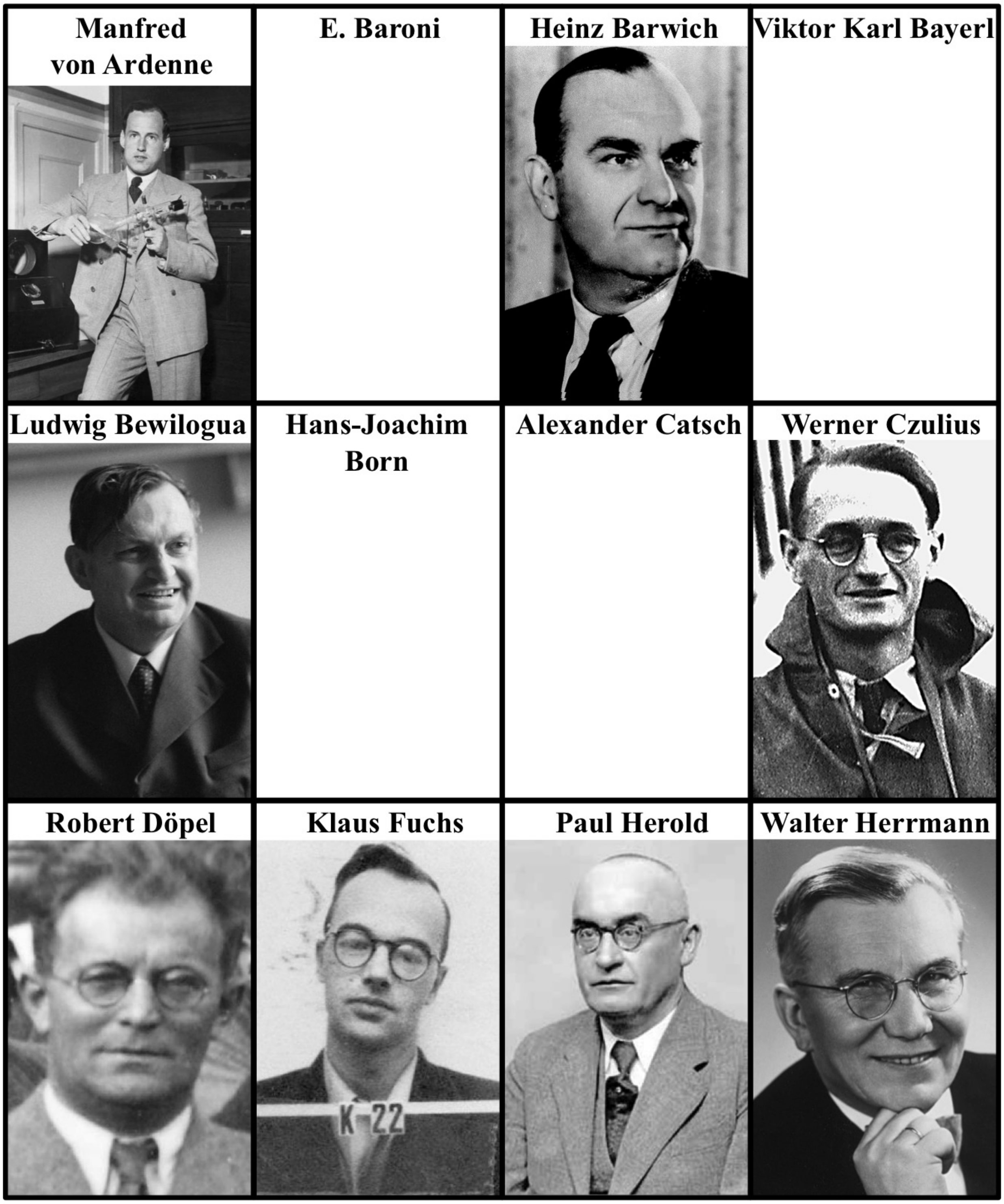

Manfred von Ardenne
E. Baroni
Heinz Barwich
Viktor Karl Bayerl
Ludwig Bewilogua
Hans-Joachim Born
Alexander Catsch
Werner Czulius
Robert Döpel
Klaus Fuchs
K 22
Paul Herold
Walter Herrmann

Figure 8.52: Examples of German-speaking scientists who played critical roles in the development of nuclear weapons in the Soviet Union.

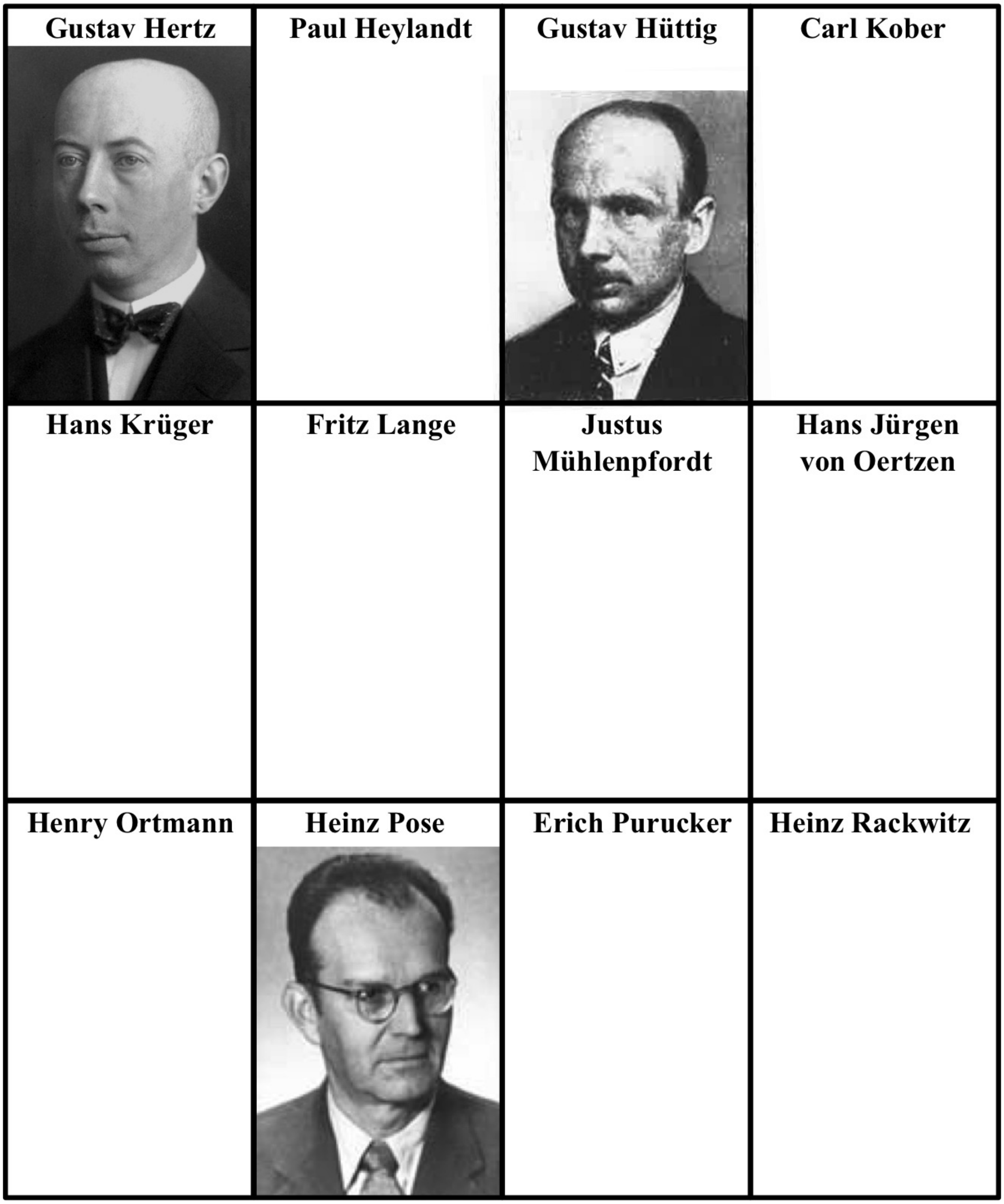

Gustav Hertz
Paul Heylandt
Gustav Hüttig
Carl Kober
Hans Krüger
Fritz Lange
Justus Mühlenpfordt
Hans Jürgen von Oertzen
Henry Ortmann
Heinz Pose
Erich Purucker
Heinz Rackwitz

Figure 8.53: More examples of German-speaking scientists who played critical roles in the development of nuclear weapons in the Soviet Union.

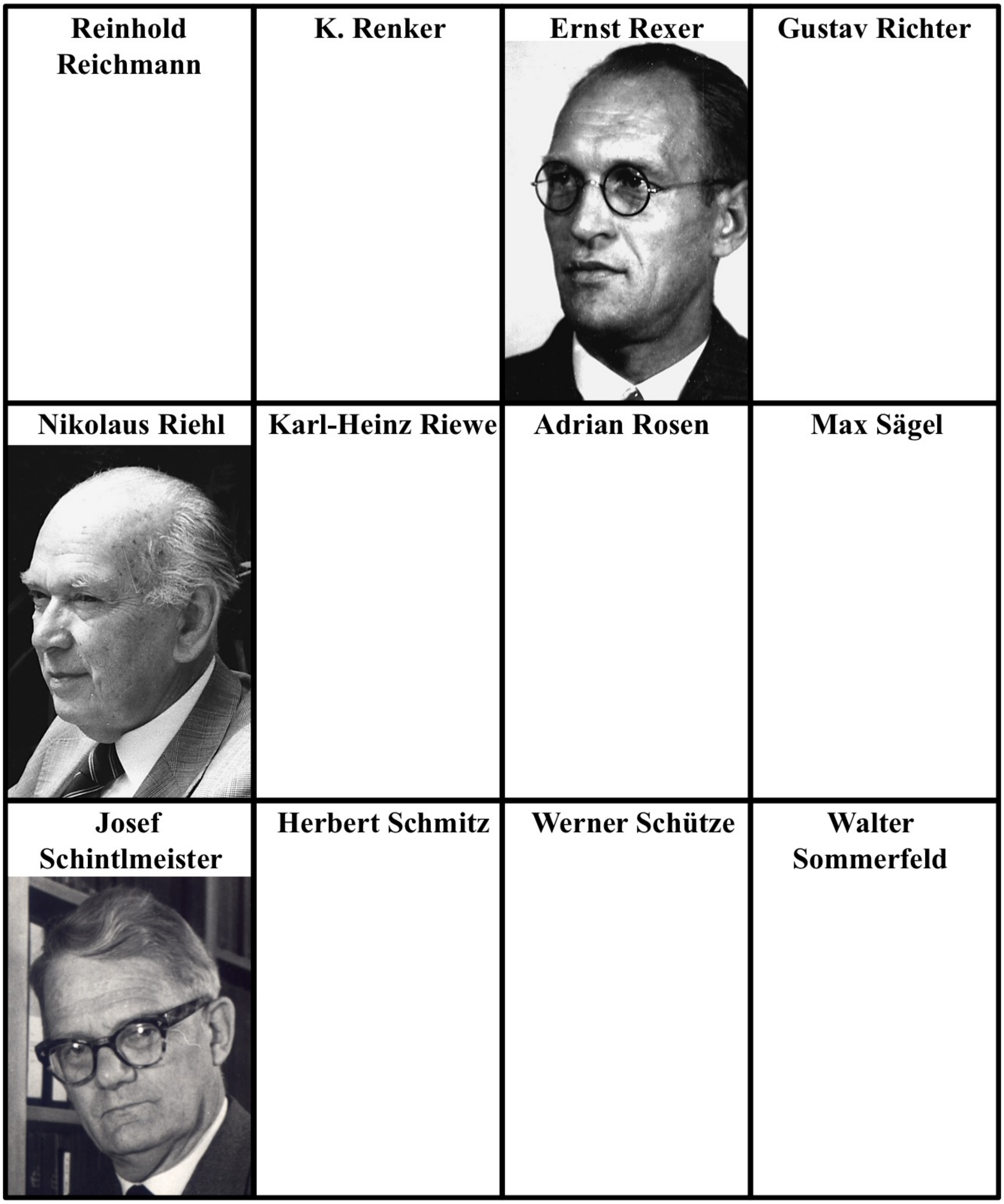

Reinhold Reichmann
K. Renker
Ernst Rexer
Gustav Richter
Nikolaus Riehl
Karl-Heinz Riewe
Adrian Rosen
Max Sägel
Josef Schintlmeister
Herbert Schmitz
Werner Schütze
Walter Sommerfeld

Figure 8.54: More examples of German-speaking scientists who played critical roles in the development of nuclear weapons in the Soviet Union.

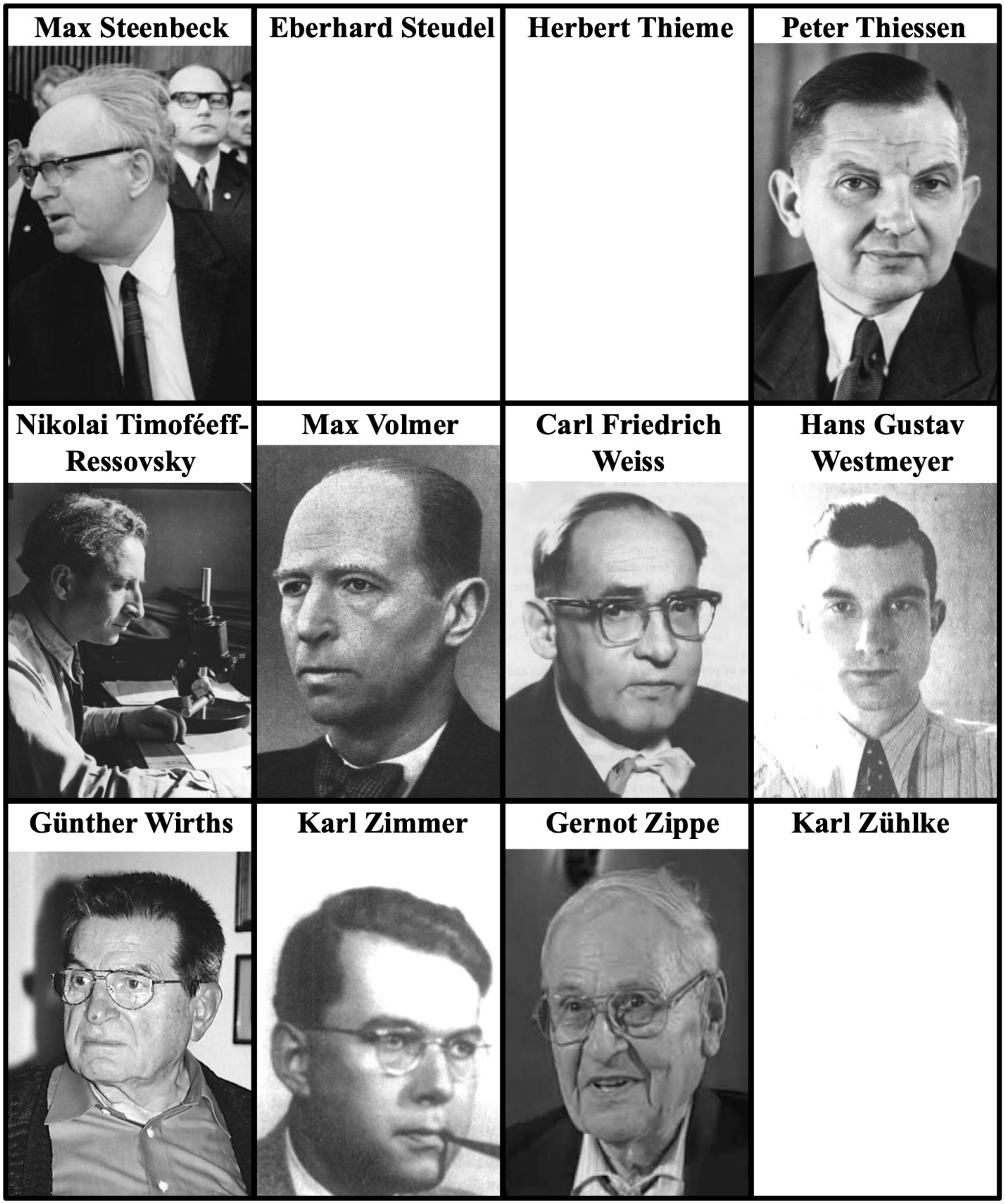

Max Steenbeck
Eberhard Steudel
Herbert Thieme
Peter Thiessen
Nikolai Timoféeff-Ressovsky
Max Volmer
Carl Friedrich Weiss
Hans Gustav Westmeyer
Günther Wirths
Karl Zimmer
Gernot Zippe
Karl Zühlke

Figure 8.55: More examples of German-speaking scientists who played critical roles in the development of nuclear weapons in the Soviet Union.

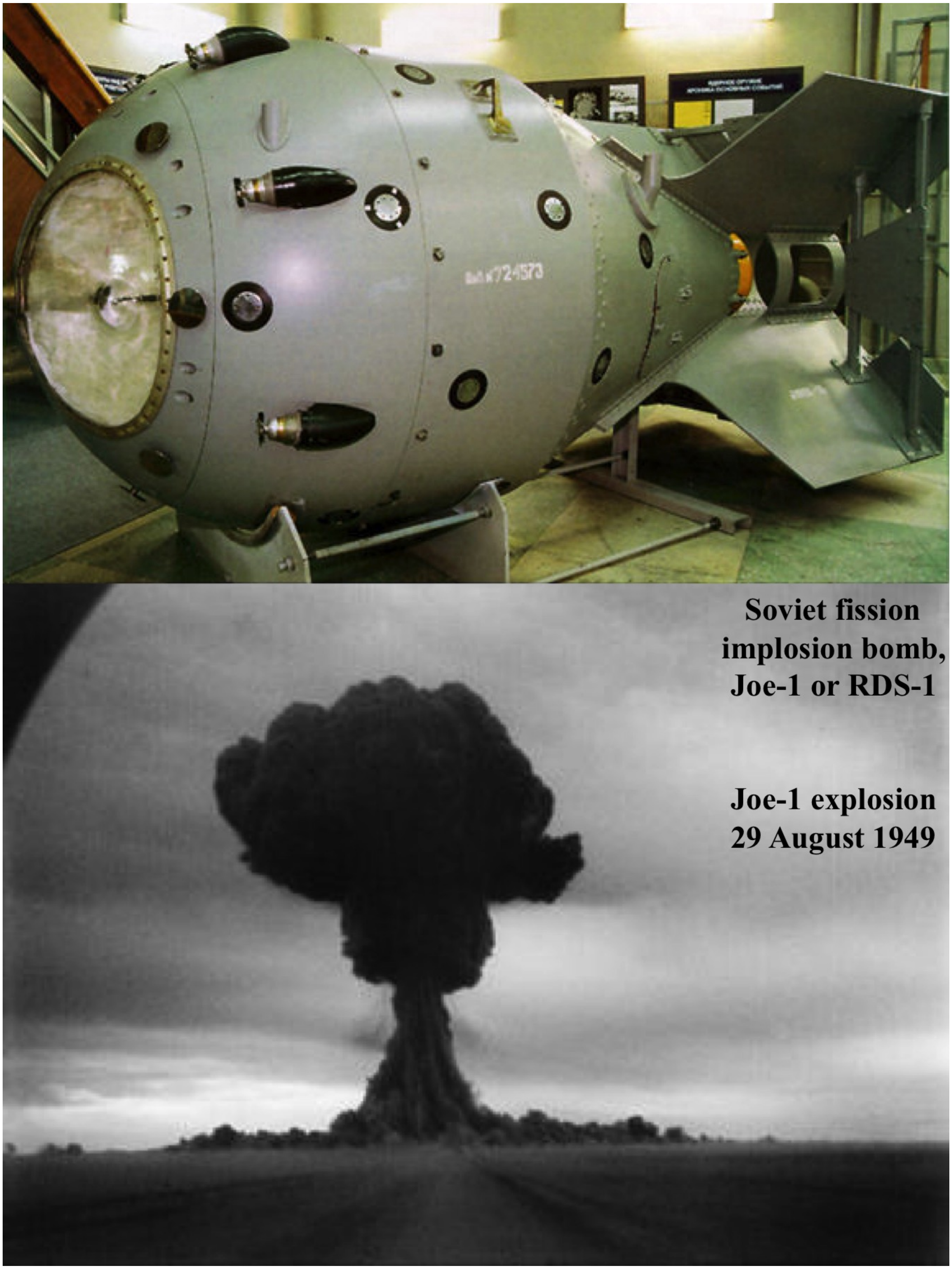

Soviet fission implosion bomb, Joe-1 or RDS-1
Joe-1 explosion 29 August 1949

Figure 8.56: Examples of early Soviet nuclear weapons: a replica of Joe-1 or RDS-1, the first Soviet fission implosion bomb, and the explosion of Joe-1 on 29 August 1949.

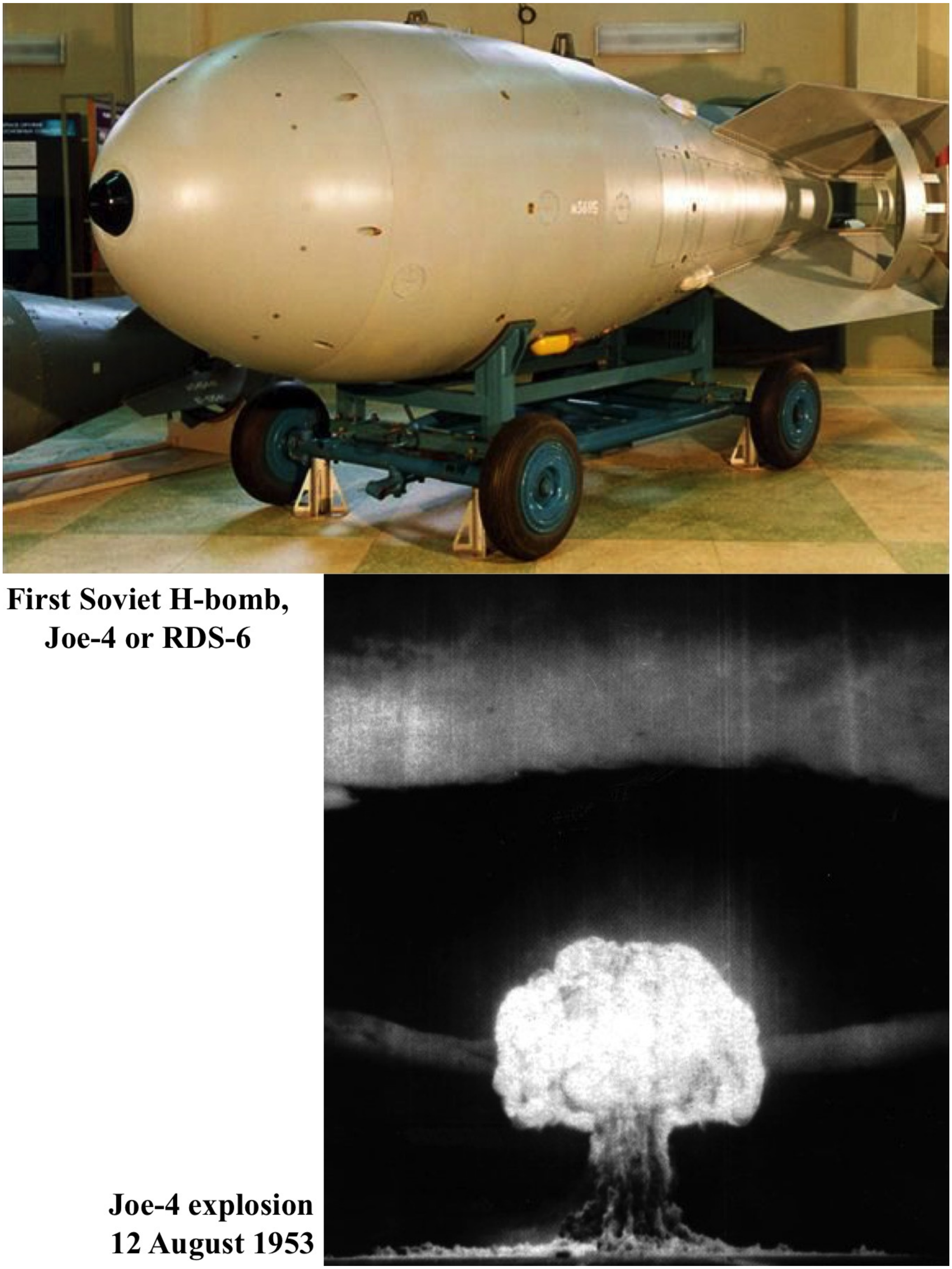

First Soviet H-bomb,
Joe-4 or RDS-6
Joe-4 explosion
12 August 1953

Figure 8.57: Examples of early Soviet nuclear weapons: a replica of Joe-4 or RDS-6, the first Soviet hydrogen bomb, and the explosion of Joe-4 on 12 August 1953.

Chapter 9

Creators and Creations in Aerospace Engineering

Dieses merkt Euch, Ihr stolzen Männer der Tat. Ihr seid nichts als unbewußte Handlanger der Gedankenmänner, die oft in demütigster Stille Euch all Euer Tun aufs Bestimmteste vorgezeichnet haben.

Mark this well, you proud men of action. You are nothing but the unconscious hands of the men of thought, who have often, in the most humble silence, directed all your actions in advance.

Heinrich Heine. 1834. *Zur Geschichte der Religion und Philosophie in Deutschland* [*History of Religion and Philosophy in Germany*] Book III, paragraph 3.

This chapter gives an overview of some innovations in aerospace engineering that have played major roles in the modern world and that were invented or discovered by scientists and engineers who were trained in the predominantly German-speaking central European research world in the nineteenth and early twentieth centuries.[1]

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[1] In addition to specific references that are cited in different areas throughout this chapter, this chapter makes use of general biographical and project information from: ACLS 2000; Albrecht et al. 1992; Ash and Söllner 1996; Bar-Zohar 1967; Bower 1987; Bunch and Hellemans 2004; Challoner 2009; Cornwell 2003; Crim 2018; EB 1911, 2010; Gillispie 1970–1990; Gimbel 1990a; Glatt 1994; Hall 2019a; István Hargittai 2006, 2011; Linda Hunt 1991; Impey et al. 2008; Jacobsen 2014; Koertge 2007; Kurowski 1982; Lasby 1971; Lusar 1956, 1971; Medawar and Pyke 2000; Mick 2000; Murray 2003; Nachmansohn 1979; NDB 1953–2020; Neufeld 2012; Nouzille and Huwart 1999; O'Reagan 2014, 2019; Porter 1994; Charles Walker 1946; Peter Watson 2010; Weitensfelder 2009.

For general overviews of large portions of the history of aerospace engineering in the German-speaking world, see: Benecke and Quick 1957; von Braun et al. 1985; Coats and Carbonel 2002; Freeman 1993, 2008; Griehl 1990, 2003, 2004, 2005, 2015; Hirschel et al. 2004; Kay 2002; Lommel 2000, 2002, 2005; Jürgen Michels 1997; Myhra 1998a, 1998b, 2000a, 2000b, 2001, 2002, 2003; Michael Neufeld 1995, 2002, 2003, 2004, 2007, 2012; Ordway and Sharpe 1979; Samuel 2004, 2010; Smith and Creek 1982, 1992, 2001; Smith and Kay 2002; Stüwe 1999, 2014, 2015; Trischler 1992a, 1992b; Trischler and Schrogl 2007; Frank Winter 1983, 1990.

Creators from the German-speaking world made major contributions to:

9.1. Lighter-than-air craft

9.2. Aerodynamics and aircraft design

9.3. Jet engines and jet aircraft

9.4. Parachutes and ejection seats

9.5. Helicopters

9.6. Small missiles and smart bombs

9.7. Large liquid propellant rockets

9.8. Submarine-launched and solid propellant rockets

9.9. Rocket planes and space planes

9.10. Space exploration

9.1 Lighter-Than-Air Craft

Lighter-than-air craft use low-density gas (hot air, hydrogen, or helium) rather than powered engines to stay aloft. The simplest lighter-than-air craft is a balloon, and the French brothers Joseph-Michel and Jacques-Étienne Montgolfier are believed to have conducted the first piloted hot-air balloon flights in 1783. By the late nineteenth century, balloons were a well developed and widely utilized technology. However, their greatest weakness was that they were at the mercy of the prevailing winds and nearly impossible to guide.

I have deliberately left a blank space where images of some creators or creations should go. Those are people or projects that I felt were important enough that they should definitely be shown in this book, yet I have not yet been able to locate a suitable image that I have permission to use, despite my searches in Europe and in the United States. If readers have any relevant images and could send them to me, I would be very grateful and will include them in future editions of this book. Even where a suitable photo cannot be located, I believe that leaving a blank space pays tribute both to the scientific importance of that creator or creation and to how that historical fact has been very nearly forgotten.

German-speaking creators played leading roles in transforming spherical, unpowered balloons that could not be guided into long, aerodynamic, internal-combustion-engine-powered, propeller-driven airships that could follow any desired course, even between continents [Danelek and Davis 2011; Hirschel et al. 2004].[2]

Those German-speaking creators developed:

1. Non-rigid airships, in which the giant envelope holding the low-density gas is simply an inflatable sack like a balloon.

2. Semi-rigid airships, in which the envelope is partially supported by a skeleton of light-weight materials such as aluminum or wood to hold its shape.

3. Rigid airships, in which the envelope is fully supported by a stiff skin of light-weight materials such as aluminum or wood to hold its shape regardless of gas pressure.

Some of the earliest German-speaking pioneers of powered airships are shown in Fig. 9.1:

- Paul Haenlein (German, 1835–1905) built and tested a small semi-rigid airship with an internal combustion engine in 1872.

- Hermann Ganswindt (German, 1856–1934) was a very creative inventor who experimented with early forms of both lighter-than-air and heavier-than air flying machines; see pp. 1798 and 1953.

- Georg Baumgarten (German, 1837–1884) and Friedrich Wölfert (German, 1850–1897) built and tested a series of non-rigid airships 1880–1897. They probably would have had a much greater ultimate impact, but Baumgarten died along the way, and Wölfert died in the crash of the final airship.

David Schwarz (Austro-Hungarian/Croatian, 1850–1897), his wife Melania Kaufmann Schwarz (Austro-Hungarian?, 1858–19??), and Carl Berg (German, 1851–1906) developed the first rigid airship, the Schwarz II, which first flew in Berlin in 1897; see Fig. 9.2. David Schwarz died of heart failure only months before the first flight of his invention, but Melania Schwarz and Carl Berg finished the project. Berg, who had developed and supplied aluminum alloys for that project, continued to do so for other airships.

After Count Ferdinand von Zeppelin (German, 1838–1917) retired from the German army in 1890, he wanted to realize the full potential of airships, which had so far only been small, unreliable prototypes. Along with Heinrich Müller-Breslau (German, 1851–1925), Theodor Kober (German, 1865–1930), Carl Berg, and other engineers, he developed a series of increasingly sophisticated rigid airships or Zeppelins, beginning with the LZ 1, which first flew in 1900, as shown in Fig. 9.3. Examples of later Zeppelins depicted in Fig. 9.4 included the LZ 3 (first flight 1906, and here shown over Berlin in 1909), LZ 72 (first flight 1916), and LZ 129 *Hindenburg* (first flight in 1936 and destroyed in 1937).

---

[2] There were some French engineers who tested early airships that used other power sources which were too weak and/or short-lived to be practical: Henri Giffard (1825–1882) with his steam-powered airship (1852), and Arthur Krebs (1850–1935) and Charles Renard (1847–1905) with their battery-powered airship (1884).

Encyclopedia Britannica explained the progression of Zeppelin's team from initial prototypes to a working fleet [EB 2010]:

> He retired in 1890 and devoted the rest of his life to the creation of the rigid airship for which he is known.
>
> Zeppelin struggled for 10 years to produce his lighter-than-air craft. The initial flight (July 2, 1900) of the LZ-1 from a floating hangar on Lake Constance, near Friedrichshafen, Ger., was not entirely successful, but it had the effect of promoting the airship to the degree that public subscriptions and donations thereafter funded the count's work. The German government was quick to perceive the advantage of airships over the as yet poorly developed airplanes, and when Zeppelin achieved 24-hour flight in 1906, he received commissions for an entire fleet. More than 100 zeppelins were used for military operations in World War I. A passenger service known as Delag (Deutsche-Luftschiffahrts AG) was established in 1910, but Zeppelin died before attaining his goal of transcontinental service.

In addition to his work on airships, Heinrich Müller-Breslau made many other important contributions to structural engineering and the theory of stress and strain.

As shown in Fig. 9.5, Johann Schütte (German, 1873–1940) and Karl Lanz (German, 1873–1921) rivaled Zeppelin with their own series of increasingly sophisticated airships that tended to use wood instead of aluminum.

Hans Groß (German, 1860–1924) and Nikolaus Basenach (German, 1875–1951) developed a series of semi-rigid airships, such as the Groß-Basenach M I airship (first flight in 1908 and enlarged in 1913, Fig. 9.6).

August von Parseval (German, 1861–1942), August Riedinger (German, 1845–1919), and Rudolf von Sigsfeld (German, 1861–1902) developed increasingly sophisticated non-rigid airships, such as the Parseval Versuchsluftschiff (1907) and PL19 airship (1914), as shown in Fig. 9.7.

Auguste Piccard (Swiss, 1884–1962) and Paul Kipfer (Swiss, 1905–1980) created and tested high-altitude balloons and used them to make measurements of the upper atmosphere and of cosmic rays. Jean Piccard (Swiss, 1884–1963), Auguste Piccard's twin brother, also invented and tested many high-altitude balloon designs. See Fig. 9.8.

See also some of the early balloonists and pioneers of aerospace medicine and meteorology on pp. 391 and 777–778.

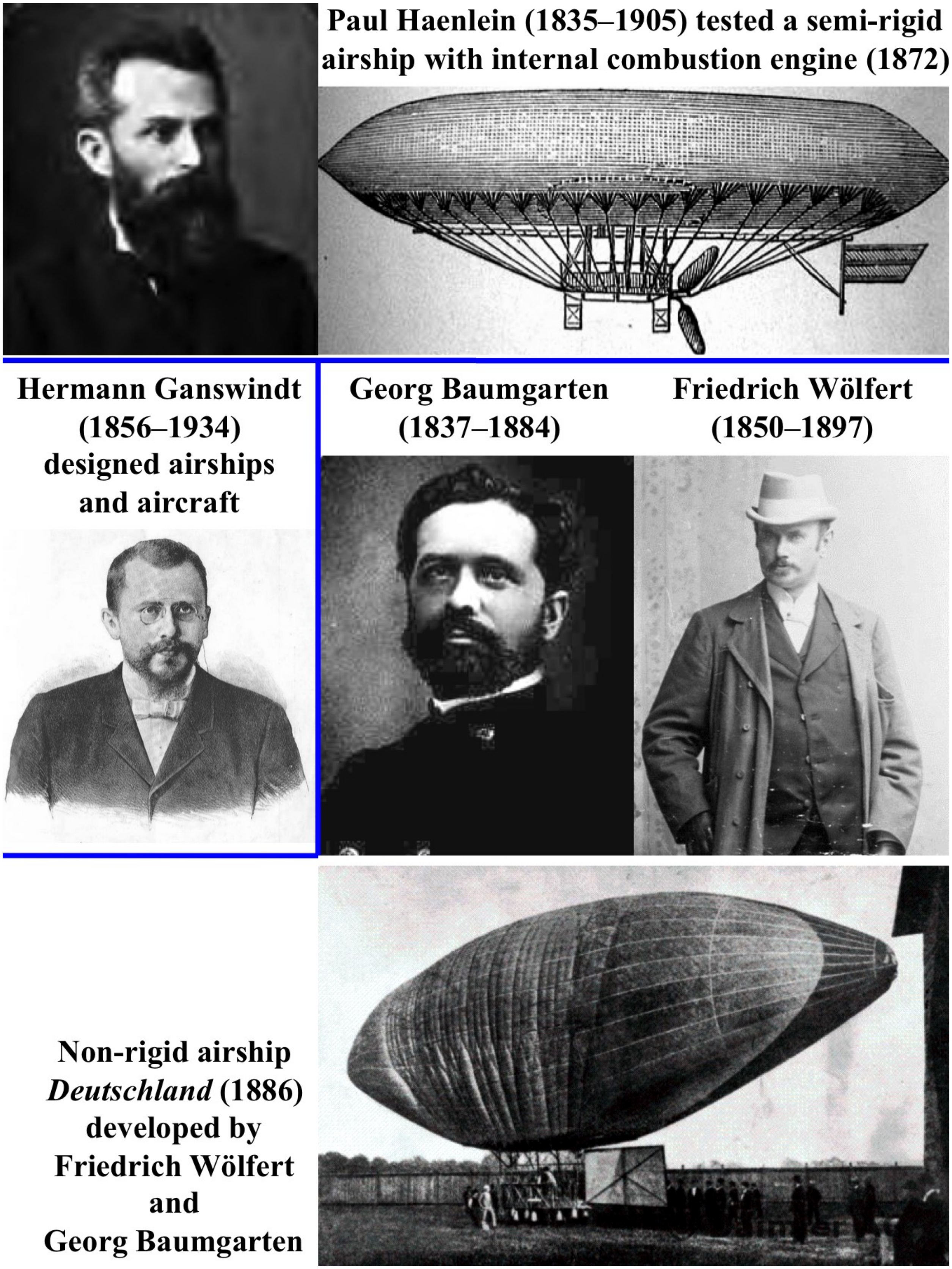

Paul Haenlein (1835–1905) tested a semi-rigid airship with internal combustion engine (1872)
Hermann Ganswindt (1856–1934) designed airships and aircraft
Georg Baumgarten (1837–1884)
Friedrich Wölfert (1850–1897)
Non-rigid airship *Deutschland* (1886) developed by Friedrich Wölfert and Georg Baumgarten

Figure 9.1: Some of the earliest German-speaking creators of airships were Paul Haenlein, Hermann Ganswindt, and Georg Baumgarten and Friedrich Wölfert.

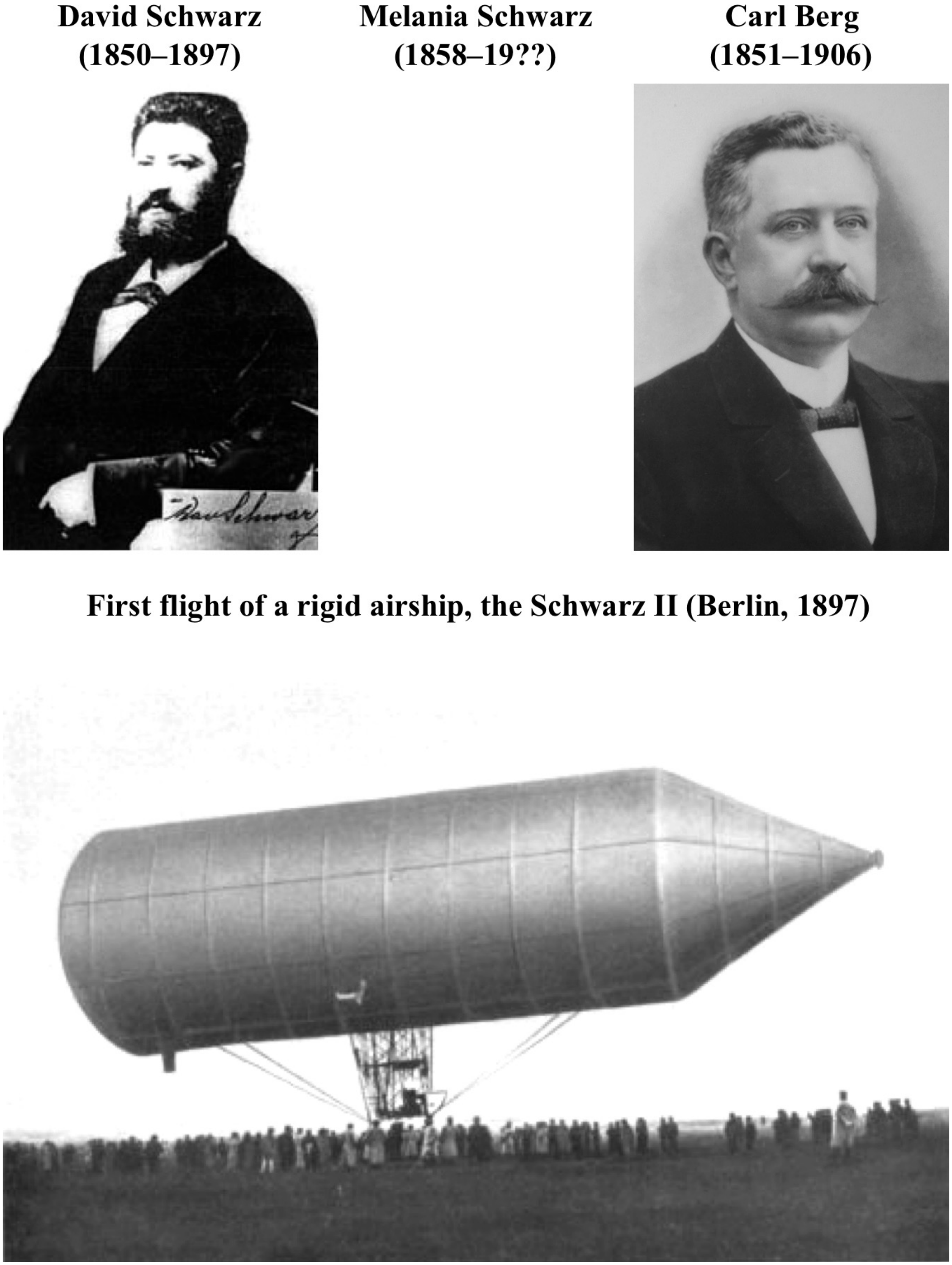
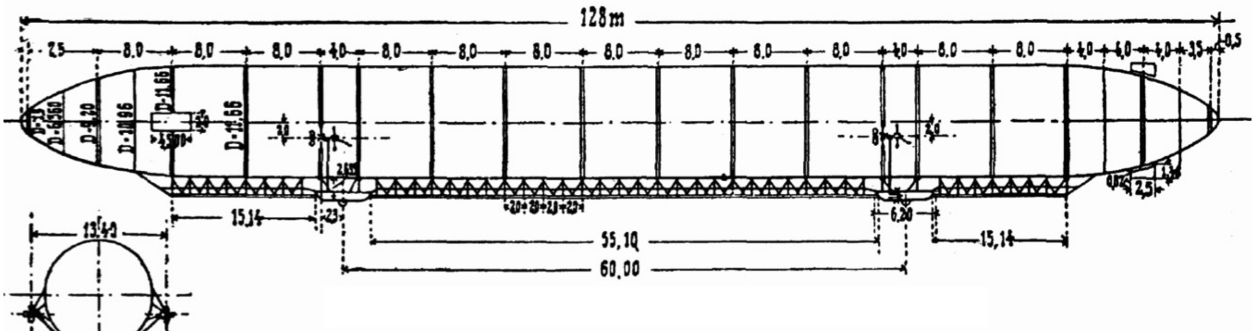

David Schwarz
(1850–1897)
Melania Schwarz
(1858–19??)
Carl Berg
(1851–1906)
First flight of a rigid airship, the Schwarz II (Berlin, 1897)

Figure 9.2: David Schwarz, his wife Melania Kaufmann Schwarz, and Carl Berg developed and demonstrated the first rigid airship, the Schwarz II, in Berlin in 1897.

Ferdinand von Zeppelin (1838–1917) **Heinrich Müller-Breslau (1851–1925)** **Theodor Kober (1865–1930)**



Luftschiff Zeppelin LZ 1

First flight of Zeppelin LZ 1 (1900) **One of LZ 1's Daimler engines**

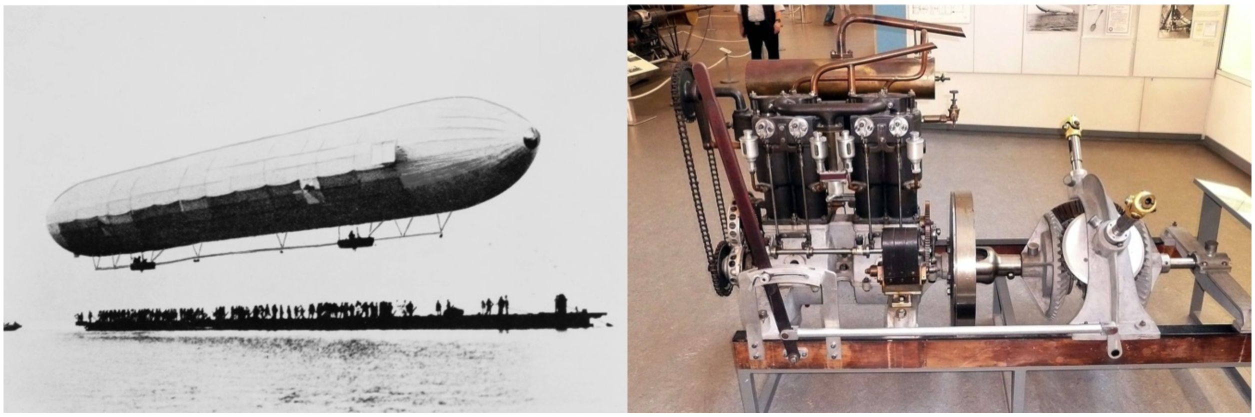
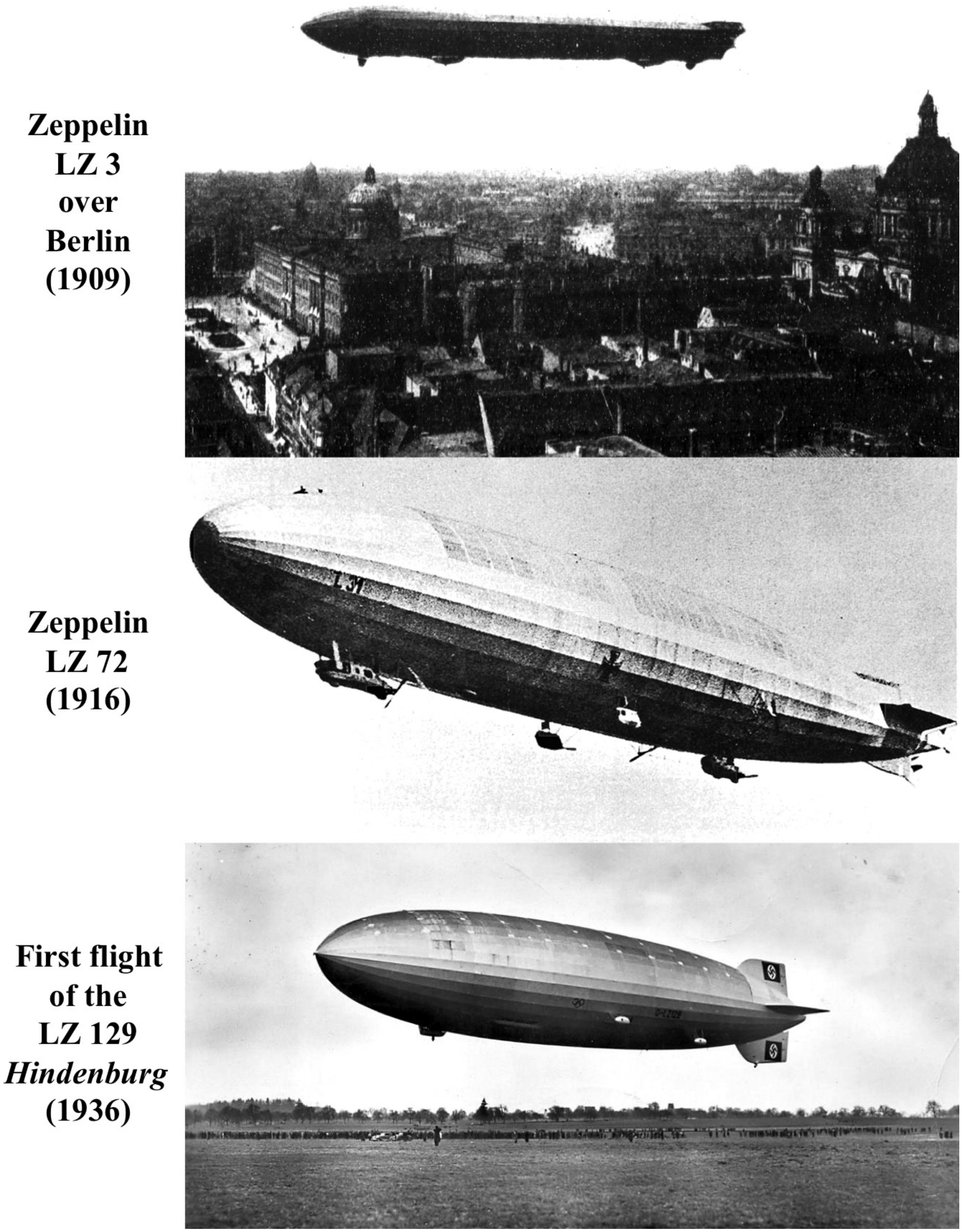


Figure 9.3: Ferdinand von Zeppelin, Heinrich Müller-Breslau, Theodor Kober, and Carl Berg developed a series of increasingly sophisticated rigid airships or Zeppelins, beginning with the LZ 1, which first flew in 1900.

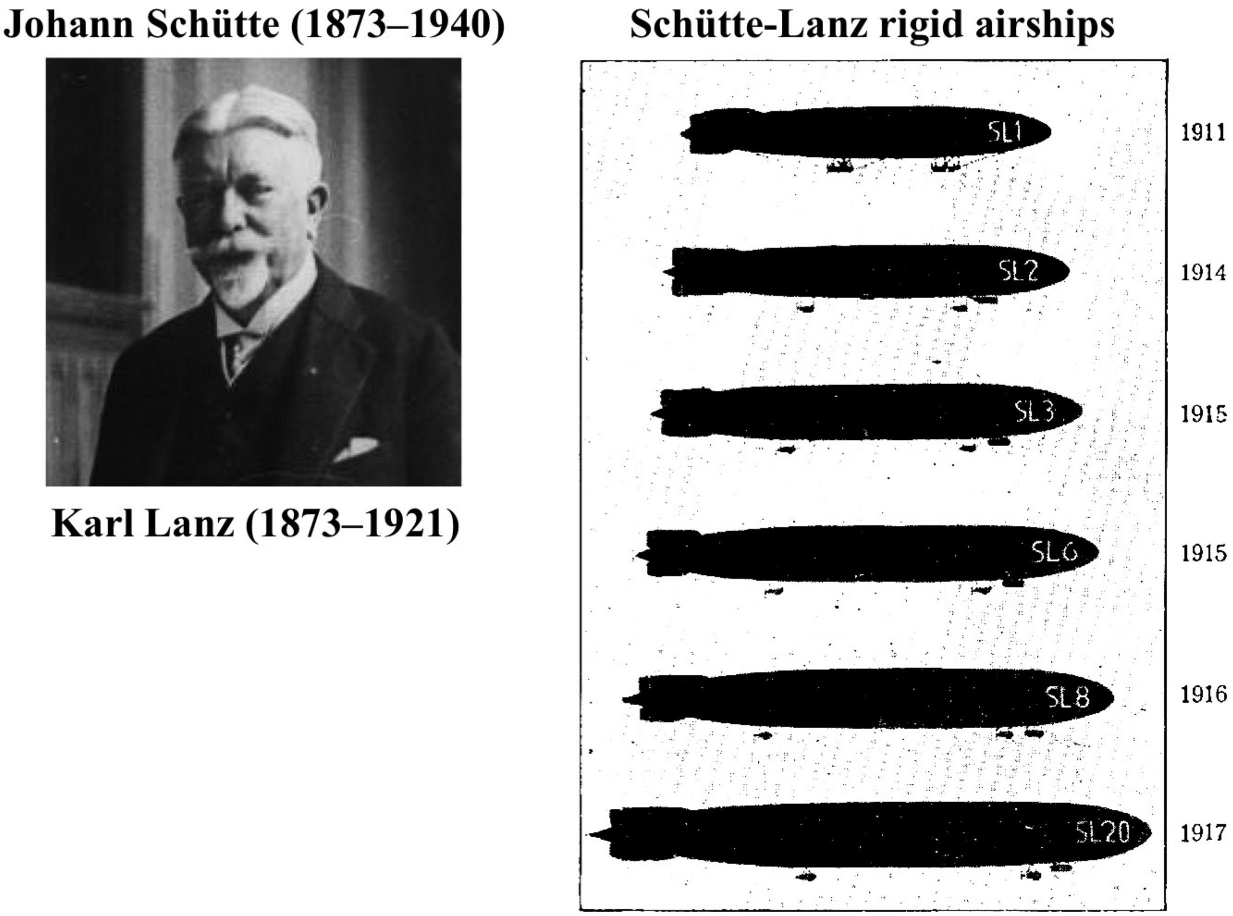


Zeppelin LZ 3 over Berlin (1909)

Zeppelin LZ 72 (1916)

First flight of the LZ 129 *Hindenburg* (1936)

Figure 9.4: Examples of later Zeppelins included the LZ 3 (first flight 1906, and here shown over Berlin in 1909), LZ 72 (first flight 1916), and LZ 129 *Hindenburg* (first flight in 1936 and destroyed in 1937).


Johann Schütte (1873–1940)
Karl Lanz (1873–1921)
Schütte-Lanz rigid airships
SL1
1911
SL2
1914
SL3
1915
SL6
1915
SL8
1916
SL20
1917

SL22 rigid airship (1918)

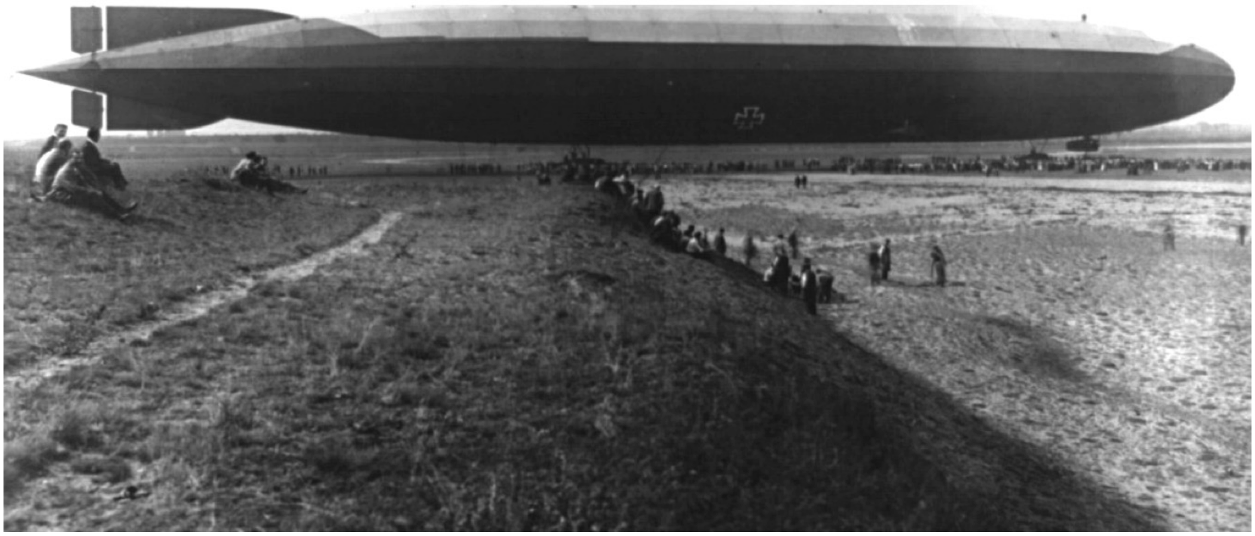


Figure 9.5: Johann Schütte and Karl Lanz rivaled Zeppelin with their own series of increasingly sophisticated airships that tended to use wood instead of aluminum.

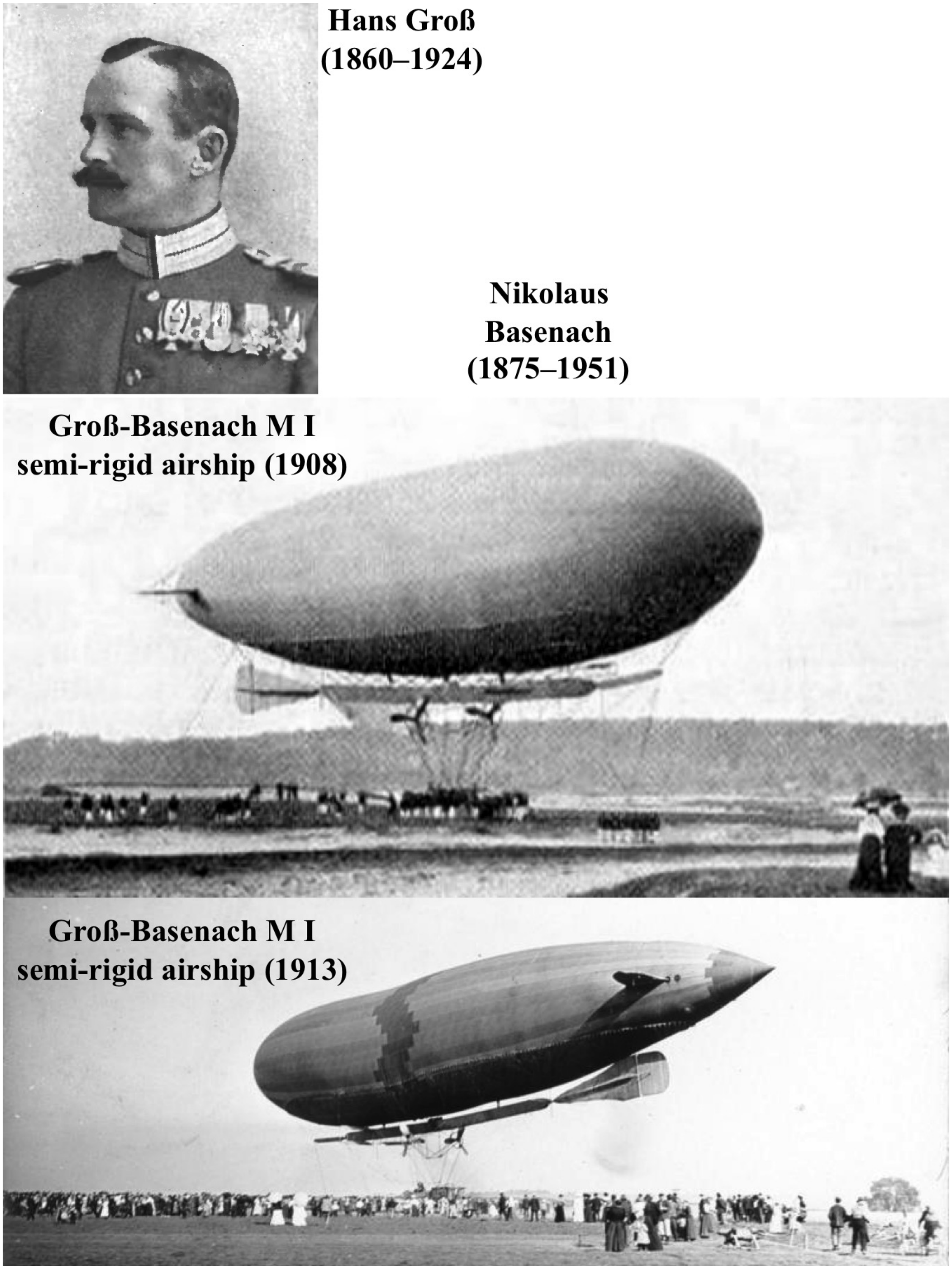

Hans Groß
(1860–1924)
Nikolaus
Basenach
(1875–1951)
Groß-Basenach M I
semi-rigid airship (1908)
Groß-Basenach M I
semi-rigid airship (1913)

Figure 9.6: Hans Groß and Nikolaus Basenach developed a series of semi-rigid airships, such as the Groß-Basenach M I airship (first flight in 1908 and enlarged in 1913).

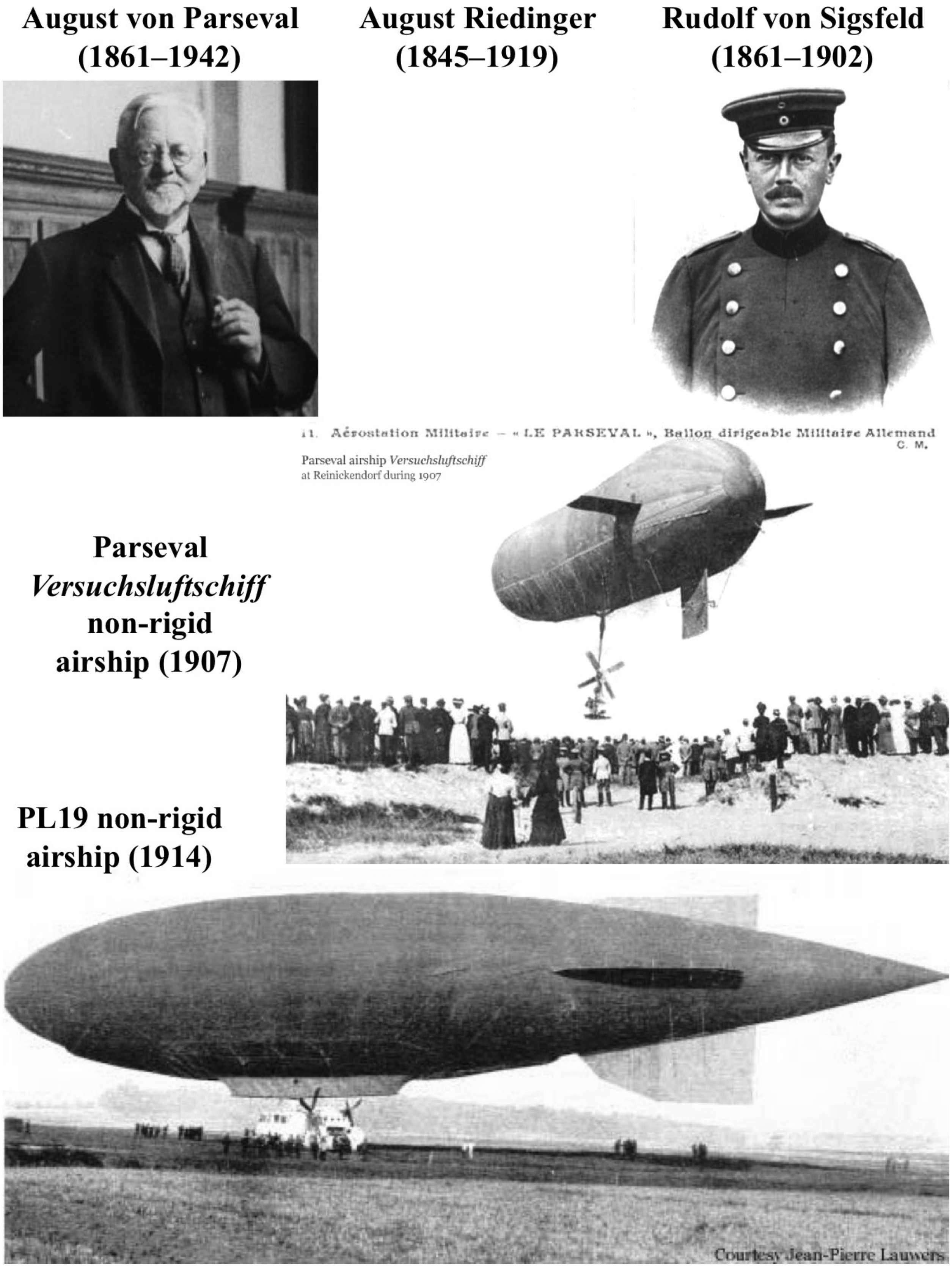

August von Parseval (1861–1942)
August Riedinger (1845–1919)
Rudolf von Sigsfeld (1861–1902)
11. Aérostation Militaire — « LE PARSEVAL », Ballon dirigeable Militaire Allemand
C. M.
Parseval airship Versuchsluftschiff at Reinickendorf during 1907
Parseval Versuchsluftschiff non-rigid airship (1907)
PL19 non-rigid airship (1914)
Courtesy Jean-Pierre Lauwers

Figure 9.7: August von Parseval, August Riedinger, and Rudolf von Sigsfeld developed increasingly sophisticated non-rigid airships, such as the Parseval Versuchsluftschiff and PL19 airship.

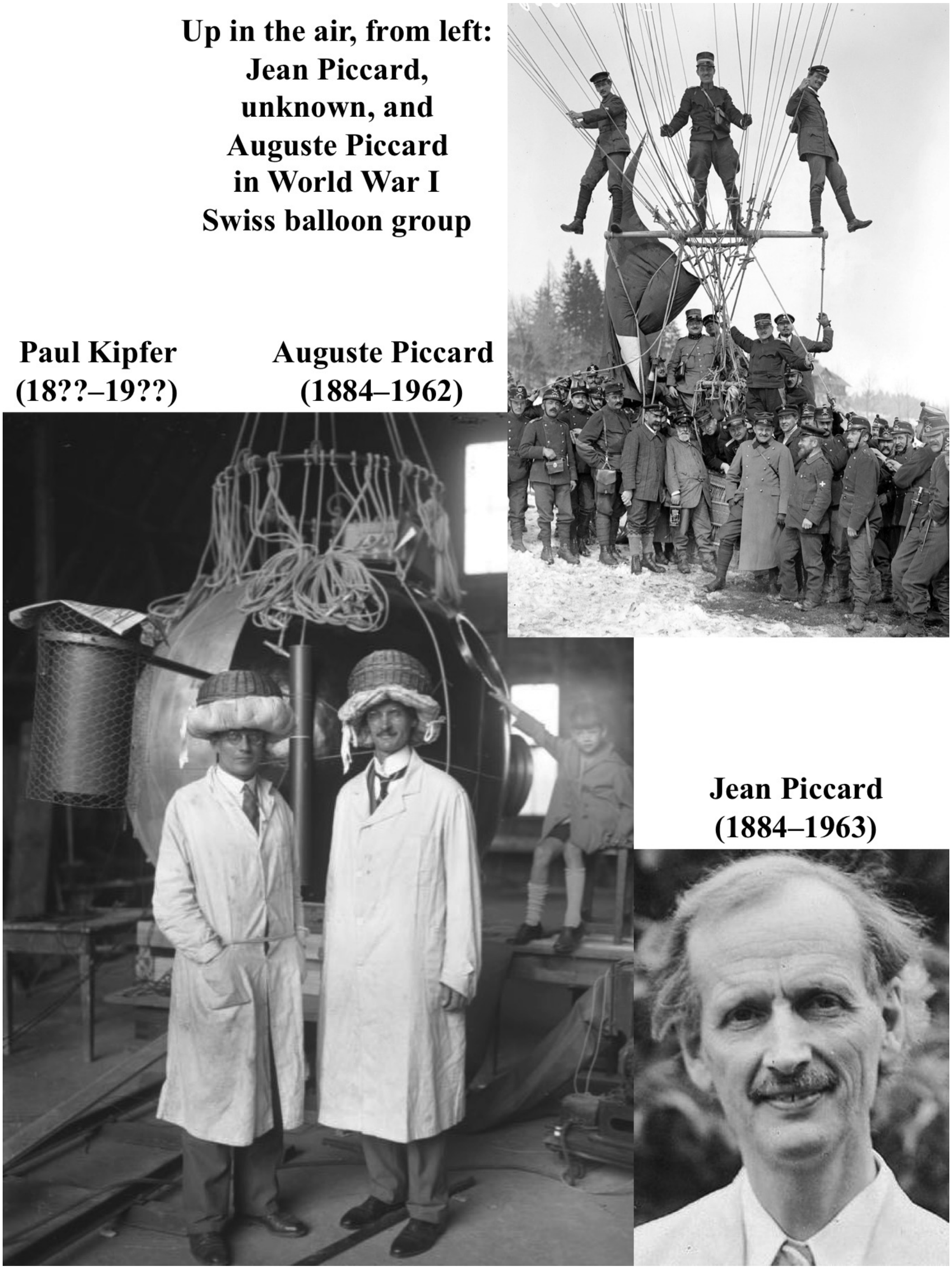

Up in the air, from left:
Jean Piccard,
unknown, and
Auguste Piccard
in World War I
Swiss balloon group
Paul Kipfer
(18??–19??)
Auguste Piccard
(1884–1962)
Jean Piccard
(1884–1963)

Figure 9.8: Paul Kipfer and Auguste Piccard, as well as Auguste's twin brother Jean Piccard who later worked separately, created and tested very high-altitude balloons.

9.2 Aerodynamics and Aircraft Design

German-speaking creators played such a dominant role for nearly a century in the development of aerodynamics and aerodynamics-guided aircraft designs that only a few examples of those creators and their creations can be mentioned here, representing the following areas:[3]

9.2.1. First aircraft

9.2.2. Aerodynamics experiments and theory

9.2.3. Specialized aircraft

9.2.4. High-speed aircraft design

For closely related contributions by German-speaking creators to jet engines and jet aircraft, see Section 9.3.

9.2.1 First Aircraft

George Cayley (English, 1773–1857) built the first known successful piloted glider in 1853. Although Cayley does not fall within the scope of this book, he deserves to be studied and remembered far more in his own right [Dee 2007]. Cayley's demonstration caught the attention of people around the world, and especially engineers in rapidly industrializing Germany.

As shown in Fig. 9.9, Otto Lilienthal (German, 1848–1896) developed and flew very innovative gliders with improved lift and maneuverability. He would likely have gone on to make the first powered airplane flights if he had not died from a glider crash in 1896 [Harsch et al. 2008; Heinzerling and Trischler 1991]. Oxford University's *Biographical Dictionary of Scientists* described Lilienthal's importance in the history of flight [Porter 1994, p. 432]:

> Lilienthal [...] was a German engineer whose experiments with gliders helped to found the science of aeronautics. But for his premature death in a flying accident, he might well have beaten the Wright brothers to the achievement of powered flight. [...]
>
> Lilienthal flew the first of his famous series of gliders in 1891, and continued, until his final fatal glide in 1896, to hold to his fundamental conviction that the key to eventual powered flight was in glider-flying, in which pilots could master the elements of control and design. [...] The step to powered flight was a straightforward progression from advanced gliding. The Wrights' breakthrough was a simple extension of their own work with gliders, which in turn was greatly helped by Lilienthal's many glides and careful observations. Among other things, he had demonstrated the superiority of cambered wings over flat wings—the principle of the aerofoil.

Gustav Weisskopf (German, 1874–1927) very closely studied the work of Lilienthal, then moved to the United States, where he became known as Gustave Whitehead. Weisskopf settled in Connecticut, where he built a long series of powered aircraft prototypes. There is considerable evidence that

---

[3] E.g., see: Amtmann 1988; Anderson 1997; Beauvais 2002; Bohr 2013; Brinchman 2015; Budrass 1998; Butler 1994, 2007; Chant 1999; Danelek and Davis 2011; Eckert 2017; Gorn 1992; Griehl 1990, 2004, 2005, 2015; Hanle 1982; Heinzerling and Trischler 1991; Herwig and Rode 2000, 2003; Hirschel et al. 2004; von Kármán 1945, 1967; Krehl 2009; Lommel 2000, 2002; Hans-Ulrich Meier 2010; Myhra 1998a, 1998b, 2000a, 2000b; Rotta 1990; Samuel 2004, 2010; Schick and Meyer 1997; Smith and Creek 1982, 1992, 2001; Smith and Kay 2002; Stüwe 1999, 2014, 2015; Trischler 1992a, 1992b; Trischler and Schrogl 2007; Vajda and Dancey 1998; Wegener 1996; CIOS XXVIII-47.

Weisskopf successfully conducted the first piloted flights of a powered airplane in 1901, covering a distance of approximately half a mile on the first flight, and several miles in subsequent flights:

1. Multiple witnesses reported that Weisskopf's airplane flew.
2. Many contemporaneous newspaper articles reported that his airplane flew.
3. Many contemporaneous newspaper articles reported that there were photographs showing Weisskopf's airplane flying (although the photographs cannot be located now).
4. Modern replicas of his aircraft successfully flew in tests made in the 1980s and 1990s.

If those claims are true, Weisskopf's first piloted, powered flight occurred over two years before the Wright Brothers' far more famous first flight, was much longer than the Wright Brothers' first flight, and was subsequently improved and repeated several times.

The details of Weisskopf's claims and the details of the evidence are still hotly debated.[4] Nonetheless, they seem to deserve far more open-minded and serious historical attention than they have generally received.

Surprisingly, the major relevant museums and scholars in the United States are legally forbidden from just that sort of open-minded and serious evaluation of the historical evidence. In 1948, the estate of the Wright family donated the Wright brothers' 1903 airplane to the Smithsonian Institution and the United States under extraordinary conditions that were agreed to in a legally binding contract (Figs. 9.11–9.12). That contract stipulated that the Wright airplane must be displayed immediately inside the museum entrance—accompanied by specific language stating that it was the first airplane—and that the museum and any affiliated organizations were legally forbidden to question whether there might have been any earlier successful airplanes:

> [...] Neither the Smithsonian Institution or its successors nor any museum or other agency, bureau or facilities, administered for the United States of America by the Smithsonian Institution or its successors, shall publish or permit to be displayed a statement or label in connection with or in respect of any aircraft model or design of earlier date than the Wright Aeroplane of 1903, claiming in effect that such aircraft was capable of carrying a man under its own power in controlled flight.
>
> 3. The title and right of possession to be transferred by the Vendors hereunder shall remain vested in the United States of America only so long as there shall be no deviation by the Vendee from the requirements of the foregoing paragraph[...]

Thus the major science history museums, curators, historians, and scholars of the United States are legally obligated to ignore any evidence that Gustav Weisskopf or anyone else may have been successful before the Wright brothers, or else they will lose the world-famous exhibit that hangs in the very center of the National Air and Space Museum in Washington, D.C. This 1948 contract was the culmination of many decades of action by the Wright family and their powerful allies against the relatively undefended and impoverished legacy of Gustav Weisskopf, which might also explain why some of the documentary evidence for Weisskopf's flights (such as numerous photographs that were described in contemporaneous accounts) disappeared over the years.

---

[4] Brinchman 2015; Brown 2016; Crouch 2002, 2013; Danelek and Davis 2011; O'Dwyer 1978; Randolph 1966; Schlenoff 2014; NYT 2015-04-18 p. A15; http://gustavewhitehead.info.

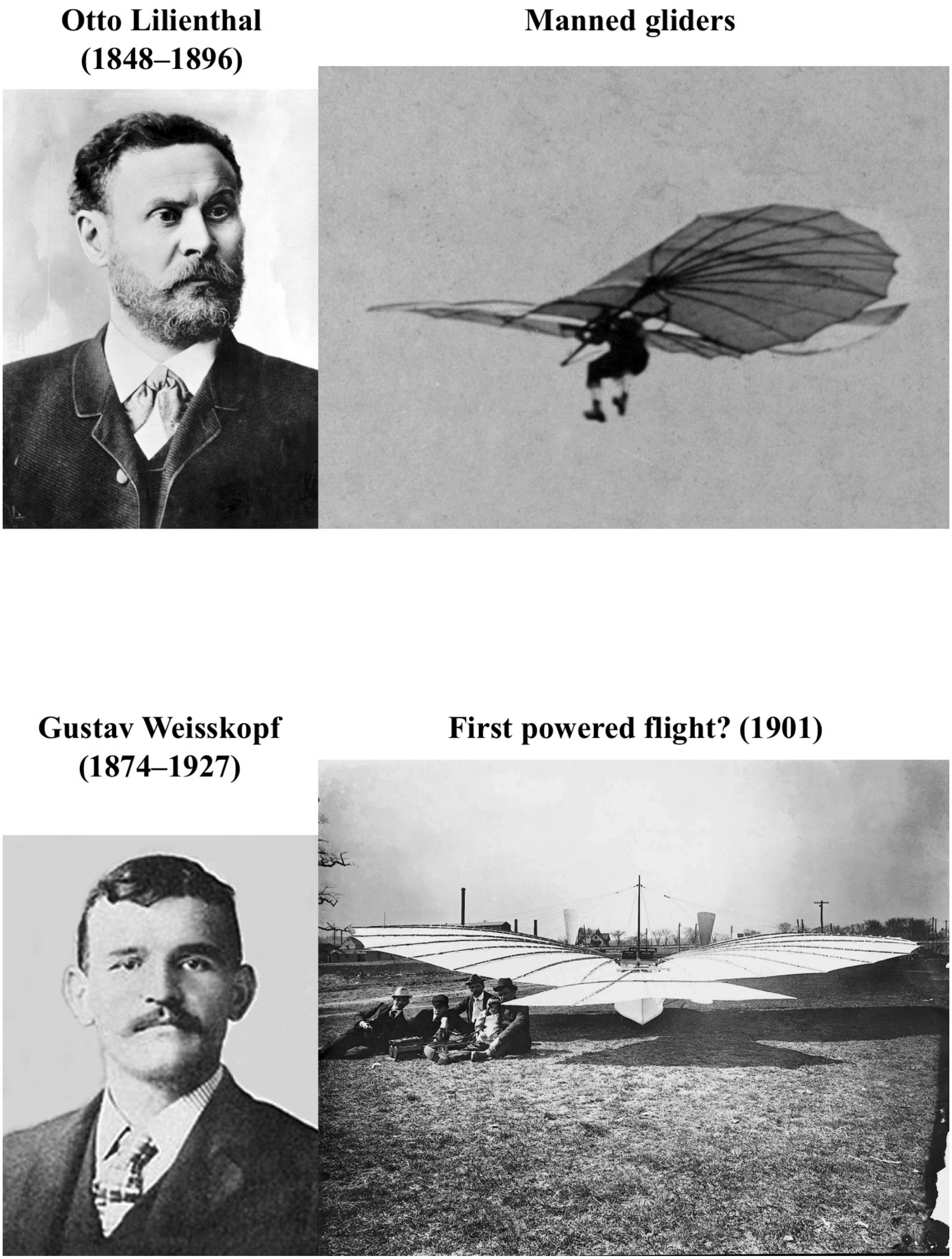
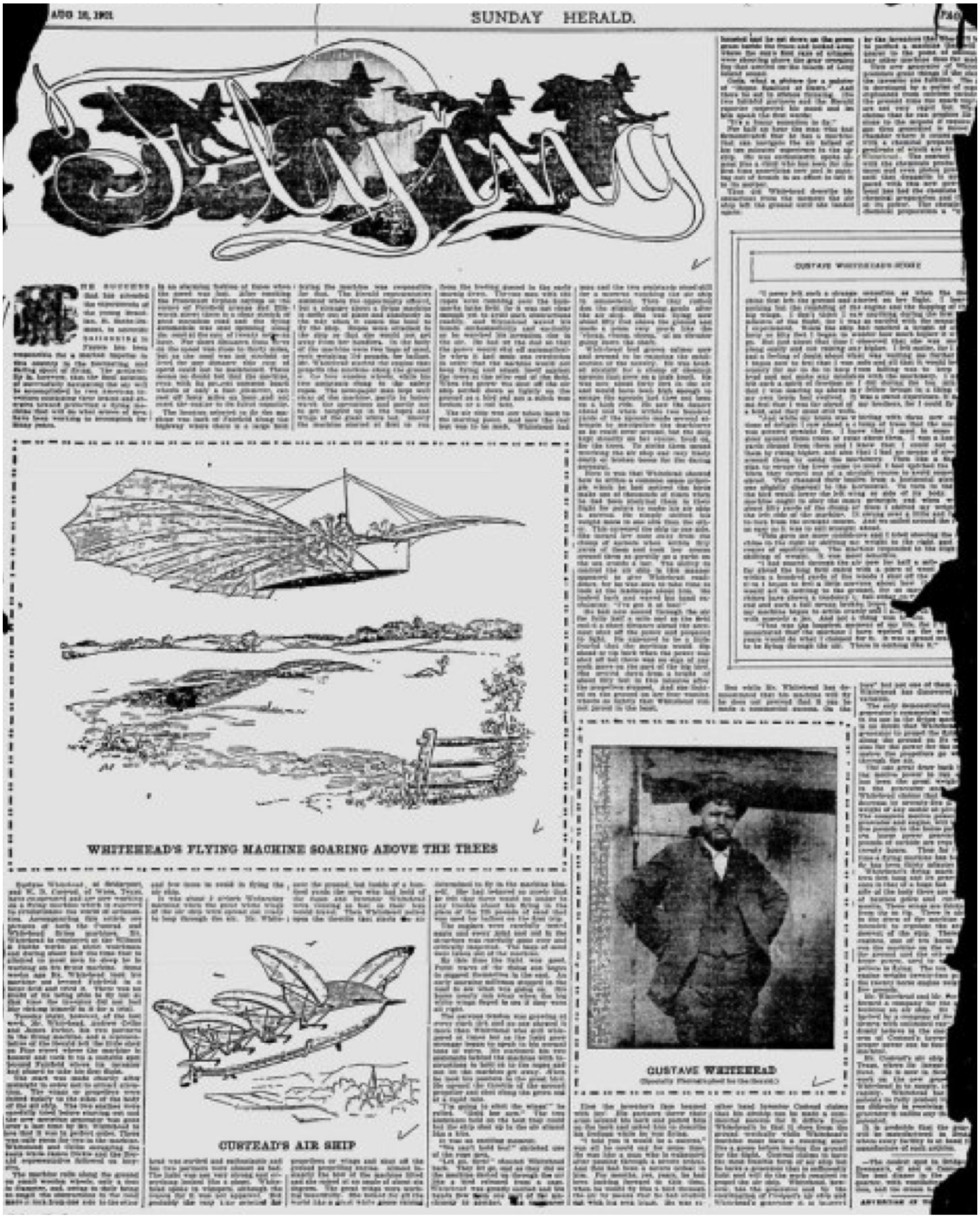

Otto Lilienthal
(1848–1896)
Manned gliders
Gustav Weisskopf
(1874–1927)
First powered flight? (1901)

Figure 9.9: Otto Lilienthal developed and flew gliders, and there is significant evidence that Gustav Weisskopf/Gustave Whitehead conducted the first powered flight in 1901.



AUG 18, 1901

SUNDAY HERALD.

Flying

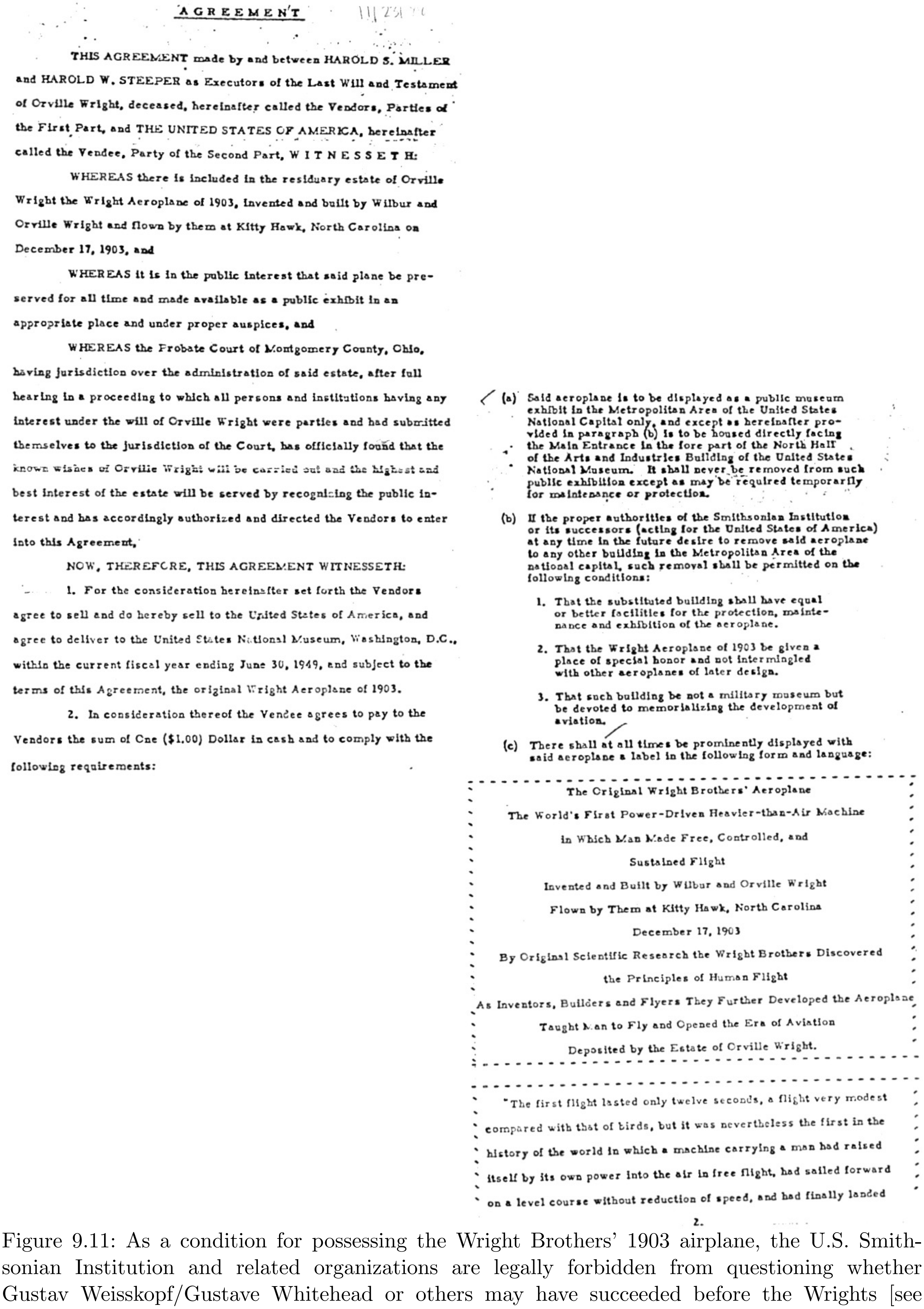
WHITEHEAD'S FLYING MACHINE SOARING ABOVE THE TREES

GUSTAVE WHITEHEAD'S STORY

GUSTAVE WHITEHEAD

CUSTEAD'S AIR SHIP

Figure 9.10: Many local Bridgeport, Connecticut newspaper articles reported that Gustav Weisskopf/Gustave Whitehead successfully conducted the first powered flights in 1901 [see this and many other examples of 1901 newspaper articles at http://gustavewhitehead.info].



AGREEMENT

THIS AGREEMENT made by and between HAROLD S. MILLER and HAROLD W. STEEPER as Executors of the Last Will and Testament of Orville Wright, deceased, hereinafter called the Vendors, Parties of the First Part, and THE UNITED STATES OF AMERICA, hereinafter called the Vendee, Party of the Second Part, WITNESSETH:

WHEREAS there is included in the residuary estate of Orville Wright the Wright Aeroplane of 1903, invented and built by Wilbur and Orville Wright and flown by them at Kitty Hawk, North Carolina on December 17, 1903, and

WHEREAS it is in the public interest that said plane be preserved for all time and made available as a public exhibit in an appropriate place and under proper auspices, and

WHEREAS the Probate Court of Montgomery County, Ohio, having jurisdiction over the administration of said estate, after full hearing in a proceeding to which all persons and institutions having any interest under the will of Orville Wright were parties and had submitted themselves to the jurisdiction of the Court, has officially found that the known wishes of Orville Wright will be carried out and the highest and best interest of the estate will be served by recognizing the public interest and has accordingly authorized and directed the Vendors to enter into this Agreement,

NOW, THEREFORE, THIS AGREEMENT WITNESSETH:

1. For the consideration hereinafter set forth the Vendors agree to sell and do hereby sell to the United States of America, and agree to deliver to the United States National Museum, Washington, D.C., within the current fiscal year ending June 30, 1949, and subject to the terms of this Agreement, the original Wright Aeroplane of 1903.

2. In consideration thereof the Vendee agrees to pay to the Vendors the sum of One ($1.00) Dollar in cash and to comply with the following requirements:

(a) Said aeroplane is to be displayed as a public museum exhibit in the Metropolitan Area of the United States National Capital only, and except as hereinafter provided in paragraph (b) is to be housed directly facing the Main Entrance in the fore part of the North Half of the Arts and Industries Building of the United States National Museum. It shall never be removed from such public exhibition except as may be required temporarily for maintenance or protection.

(b) If the proper authorities of the Smithsonian Institution or its successors (acting for the United States of America) at any time in the future desire to remove said aeroplane to any other building in the Metropolitan Area of the national capital, such removal shall be permitted on the following conditions:

1. That the substituted building shall have equal or better facilities for the protection, maintenance and exhibition of the aeroplane.
2. That the Wright Aeroplane of 1903 be given a place of special honor and not intermingled with other aeroplanes of later design.
3. That such building be not a military museum but be devoted to memorializing the development of aviation.

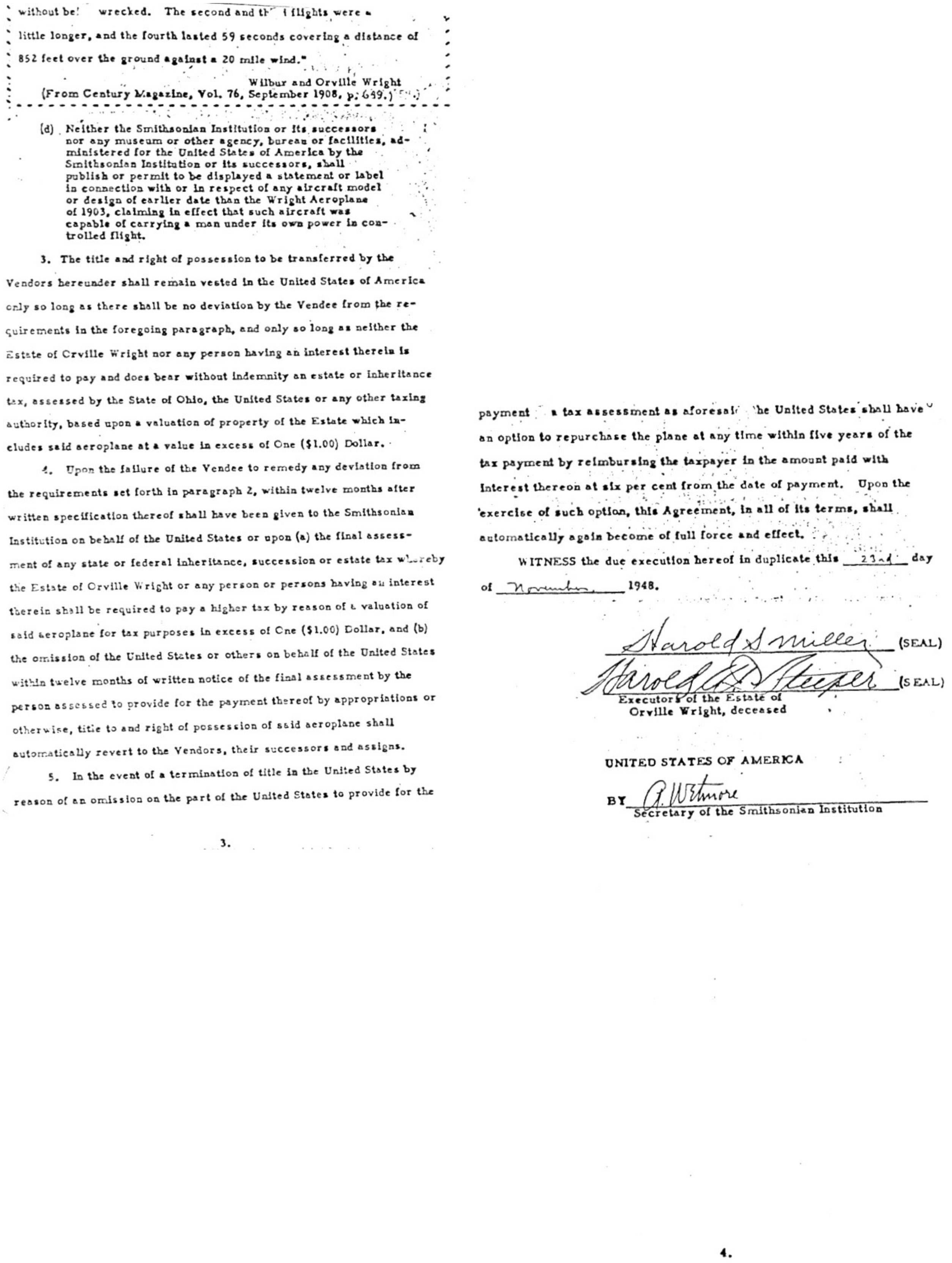
(c) There shall at all times be prominently displayed with said aeroplane a label in the following form and language:

The Original Wright Brothers' Aeroplane
The World's First Power-Driven Heavier-than-Air Machine
in Which Man Made Free, Controlled, and
Sustained Flight
Invented and Built by Wilbur and Orville Wright
Flown by Them at Kitty Hawk, North Carolina
December 17, 1903
By Original Scientific Research the Wright Brothers Discovered
the Principles of Human Flight
As Inventors, Builders and Flyers They Further Developed the Aeroplane
Taught Man to Fly and Opened the Era of Aviation
Deposited by the Estate of Orville Wright.

"The first flight lasted only twelve seconds, a flight very modest compared with that of birds, but it was nevertheless the first in the history of the world in which a machine carrying a man had raised itself by its own power into the air in free flight, had sailed forward on a level course without reduction of speed, and had finally landed

2.

Figure 9.11: As a condition for possessing the Wright Brothers' 1903 airplane, the U.S. Smithsonian Institution and related organizations are legally forbidden from questioning whether Gustav Weisskopf/Gustave Whitehead or others may have succeeded before the Wrights [see http://gustavewhitehead.info/smithsonian-conspiracy-to-deny-whitehead-flew-first/ for this and additional related documents and information].



without be! wrecked. The second and th i flights were a little longer, and the fourth lasted 59 seconds covering a distance of 852 feet over the ground against a 20 mile wind."

Wilbur and Orville Wright
(From Century Magazine, Vol. 76, September 1908, p. 649.)

(d) Neither the Smithsonian Institution or its successors nor any museum or other agency, bureau or facilities, administered for the United States of America by the Smithsonian Institution or its successors, shall publish or permit to be displayed a statement or label in connection with or in respect of any aircraft model or design of earlier date than the Wright Aeroplane of 1903, claiming in effect that such aircraft was capable of carrying a man under its own power in controlled flight.

3. The title and right of possession to be transferred by the Vendors hereunder shall remain vested in the United States of America only so long as there shall be no deviation by the Vendee from the requirements in the foregoing paragraph, and only so long as neither the Estate of Orville Wright nor any person having an interest therein is required to pay and does bear without indemnity an estate or inheritance tax, assessed by the State of Ohio, the United States or any other taxing authority, based upon a valuation of property of the Estate which includes said aeroplane at a value in excess of One ($1.00) Dollar.

4. Upon the failure of the Vendee to remedy any deviation from the requirements set forth in paragraph 2, within twelve months after written specification thereof shall have been given to the Smithsonian Institution on behalf of the United States or upon (a) the final assessment of any state or federal inheritance, succession or estate tax whereby the Estate of Orville Wright or any person or persons having an interest therein shall be required to pay a higher tax by reason of a valuation of said aeroplane for tax purposes in excess of One ($1.00) Dollar, and (b) the omission of the United States or others on behalf of the United States within twelve months of written notice of the final assessment by the person assessed to provide for the payment thereof by appropriations or otherwise, title to and right of possession of said aeroplane shall automatically revert to the Vendors, their successors and assigns.

5. In the event of a termination of title in the United States by reason of an omission on the part of the United States to provide for the

3.

payment a tax assessment as aforesai he United States shall have an option to repurchase the plane at any time within five years of the tax payment by reimbursing the taxpayer in the amount paid with interest thereon at six per cent from the date of payment. Upon the exercise of such option, this Agreement, in all of its terms, shall automatically again become of full force and effect.

WITNESS the due execution hereof in duplicate this 23rd day of November 1948.

Harold S Miller (SEAL)
Harold [illegible] Stecker (SEAL)
Executors of the Estate of
Orville Wright, deceased

UNITED STATES OF AMERICA

BY A. Wetmore
Secretary of the Smithsonian Institution

4.

Figure 9.12: As a condition for possessing the Wright Brothers' 1903 airplane, the U.S. Smithsonian Institution and related organizations are legally forbidden from questioning whether Gustav Weisskopf/Gustave Whitehead or others may have succeeded before the Wrights [see http://gustavewhitehead.info/smithsonian-conspiracy-to-deny-whitehead-flew-first/ for this and additional related documents and information].

9.2.2 Aerodynamics Experiments and Theory

Two brilliant Swiss mathematicians laid the foundations for the mathematical theory of fluid mechanics and aerodynamics in the 1700s:

- Daniel Bernoulli (Swiss, 1700–1782) developed the Bernoulli equation for incompressible, inviscid fluid flow, and published it in 1738 (Fig. 9.13). The Bernoulli equation is useful for designing barometers, finding the aerodynamic lift of aircraft wings, calculating the aerodynamic drag on vehicles and parachutes, explaining meteorological phenomena, and analyzing other applications. Bernoulli also made important contributions to mathematics and to the theory of flexible beams.

- Leonhard Euler (Swiss, 1707–1783) developed the more general Euler equations for fluid flow, which greatly extend the Bernoulli equation for many other conditions and applications, and published them in 1757 (Fig. 9.14). He also made extensive contributions to calculus, complex number theory, topology and graph theory, mechanical stress and strain calculations, astronomy, optics, logic, and other topics [Calinger 2015; Richeson 2008].

As illustrated in Fig. 9.15, Ernst Mach (Austrian, 1838–1916), his son Ludwig Mach (Austrian, 1868–1951), and Peter Salcher (Austrian, 1848–1928) conducted the first experiments to visualize shock waves around a bullet traveling faster than the speed of sound through air. The speed of an object compared to the speed of sound is now called the Mach number.

Ernst Mach excelled both at experimental technique—as demonstrated by his ability to capture detailed images of a bullet in flight without any electronic timing equipment—and at finding the correct theoretical interpretation of the new phenomena that he observed. He made many contributions to aerodynamics and aerodynamic measurements, as listed by science historian Peter Krehl [Krehl 2009, p. 1118]:

> Ernst Mach, who had planned supersonic ballistic experiments several years before Prof. Peter Salcher, an Austrian physicist at the Imperial Navy, eventually succeeded in photographing them (1886). Mach immediately gave a correct interpretation of the head wave and the lines emanating from projectile surfaces. These supersonic flow phenomena were later connected with his name, such as the *Mach angle*, *Mach cone*, *Mach head wave*, *Mach line*, and *Mach wave*. Furthermore, Mach also studied the oblique interaction of shock waves, thereby discovering irregular reflection (*Mach reflection effect*) and the origin of a new shock wave (*Mach disk*, *Mach front*, *Mach stem*), which since the 1940s has stimulated worldwide research activities to better understand this puzzling "Mach effect."

In addition to his work in aerodynamics, Ernst Mach made important contributions to many other unrelated fields, as explained by aerodynamics expert and historian John D. Anderson, Jr. [Anderson 1997, pp. 375–376]:

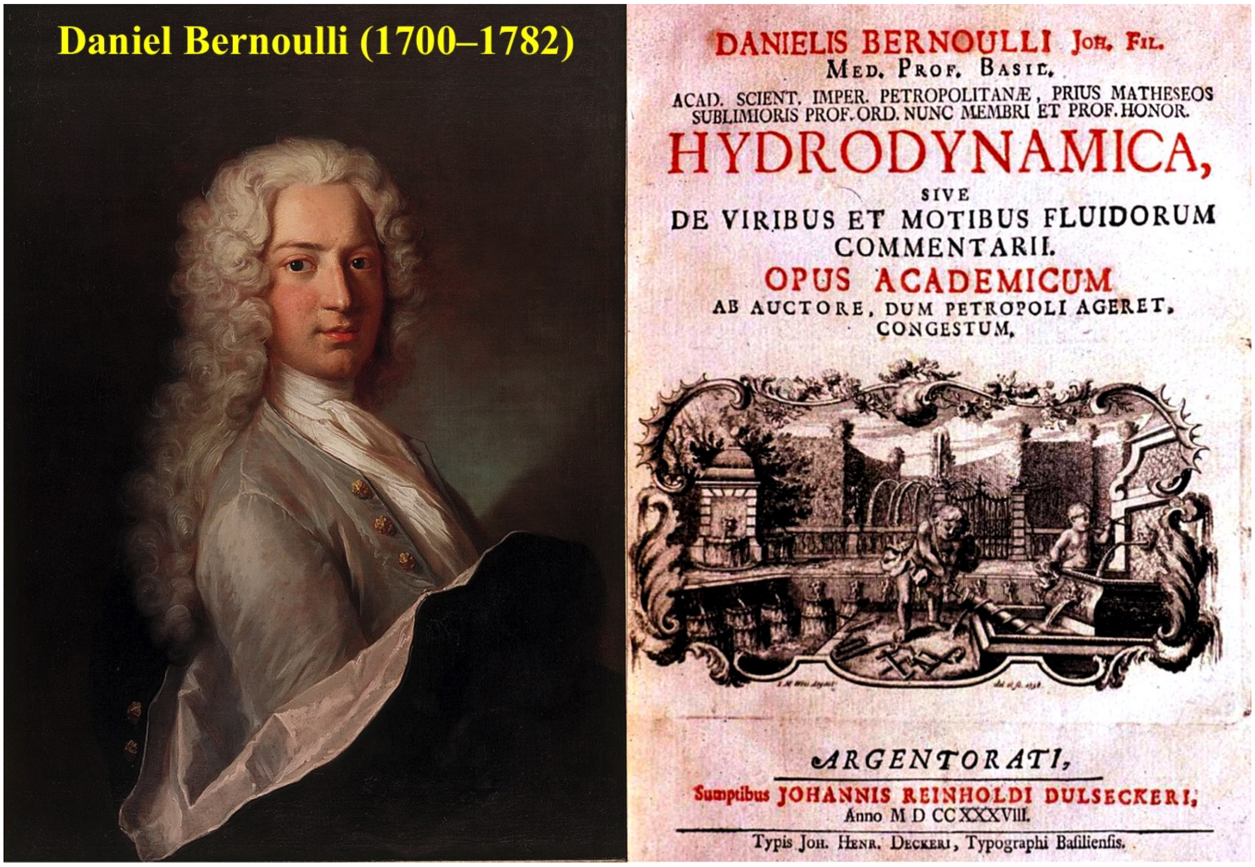
> Mach entered the University of Vienna, where he excelled, spurred by interest in mathematics, physics, philosophy, and history. In 1860 he received a Ph.D. in physics, with a thesis entitled "On Electrical Discharge and Induction." By 1864 he was a professor

> of physics at the University of Graz. (The variety and depth of his intellectual interests were attested by the fact that he was offered, but turned down, a chair in *surgery* at the University of Salzburg, preferring to go to Graz.) In 1867, Mach became a professor of experimental physics at the University of Prague, a position he would occupy for the next 28 years.
>
> In the modern technological world, engineers and scientists are virtually forced to concentrate their efforts in narrow areas of specialization, but in Mach's time one could still contemplate the Renaissance man, and Mach was a supreme generalist. A listing of Mach's contributions and writings would include works on physical optics, the history of science, mechanics, philosophy, the origins of relativity theory, supersonic flow, thermodynamics, the sugar cycle in grapes, the physics of music, and classical literature. He even wrote on world affairs: one of Mach's papers commented on the "absurdity committed by the statesman who regards the individual as existing solely for the sake of the state," which provoked strong criticism from Lenin. We can only regard him with awe and envy, for Mach, in the words of the American philosopher William James, knew "everything about everything."

For some of Ernst Mach's other accomplishments, see pp. 298, 307, 874, and 878. For some of his son Ludwig Mach's other accomplishments, see p. 1029.

Like Ernst Mach, Ludwig Prandtl (German, 1875–1953) was enormously talented at both experimental methods of measuring aerodynamic effects and theoretical methods of explaining those effects. Yet whereas Mach divided his time among several other unrelated fields, Prandtl spent his long career focused on aerodynamics, building the most advanced wind tunnels in the world from 1907 onward, and discovering and calculating a wide range of aerodynamic phenomena (Figs. 9.16–9.17, 9.42). *Encyclopedia Britannica* labelled Prandtl the "father of aerodynamics" [EB 2010]:

> German physicist who is considered to be the father of aerodynamics. [...]
>
> Prandtl made decisive advances in boundary-layer and wing theories, and his work became the fundamental material of aerodynamics. He was an early pioneer in streamlining dirigibles, and his advocacy of monoplanes greatly advanced heavier-than-air aviation. He contributed the Prandtl-Glauert rule for subsonic airflow to describe the compressibility effects of air at high speeds. In addition to his important advances in the theories of supersonic flow and turbulence, he made notable innovations in the design of wind tunnels and other aerodynamic equipment. He also devised a soap-film analogy for analyzing the torsion forces of structures with noncircular cross sections.



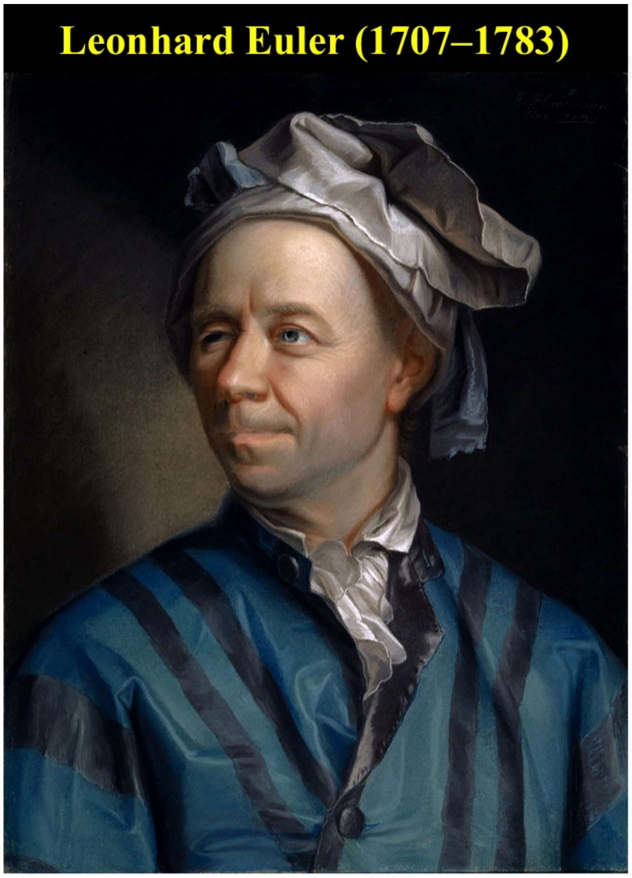
DANIELIS BERNOULLI Joh. Fil.
Med. Prof. Basil.
ACAD. SCIENT. IMPER. PETROPOLITANÆ, PRIUS MATHESEOS
SUBLIMIORIS PROF. ORD. NUNC MEMBRI ET PROF. HONOR.
HYDRODYNAMICA,
SIVE
DE VIRIBUS ET MOTIBUS FLUIDORUM
COMMENTARII.
OPUS ACADEMICUM
AB AUCTORE, DUM PETROPOLI AGERET,
CONGESTUM.

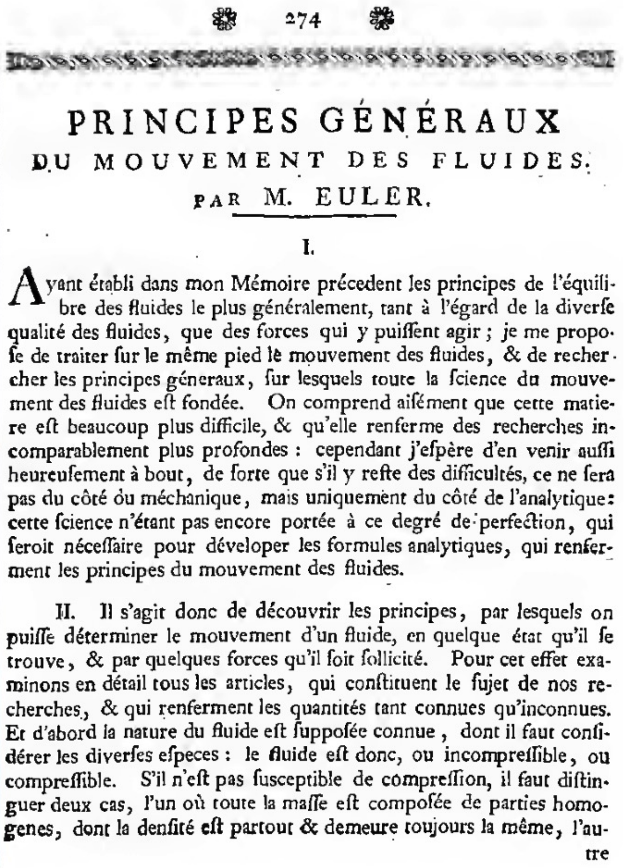
ARGENTORATI,
Sumptibus JOHANNIS REINHOLDI DULSECKERI,
Anno M D CC XXXVIII.
Typis Joh. Henr. Deckeri, Typographi Baſilienſis.

Bernoulli equation for incompressible, inviscid fluid flow

$$\overbrace{\frac{1}{2}\rho v^2}^{\substack{\text{Kinetic energy}\\ \text{per volume}}} + \overbrace{\rho g H}^{\substack{\text{Gravitational}\\ \text{potential energy}\\ \text{per volume}}} + \overbrace{p}^{\substack{\text{Pressure}\\ \text{potential energy}\\ \text{per volume}}} = \overbrace{\text{constant (along a streamline)}}^{\substack{\text{Total energy}\\ \text{per volume}}}$$

Figure 9.13: Daniel Bernoulli developed the Bernoulli equation for incompressible, inviscid fluid flow, and published it in 1738.





274

PRINCIPES GÉNÉRAUX
DU MOUVEMENT DES FLUIDES.
PAR M. EULER.

I.

Ayant établi dans mon Mémoire précedent les principes de l'équilibre des fluides le plus généralement, tant à l'égard de la diverſe qualité des fluides, que des forces qui y puiſſent agir ; je me propoſe de traiter ſur le même pied lè mouvement des fluides, & de rechercher les principes géneraux, ſur lesquels toute la ſcience du mouvement des fluides eſt fondée. On comprend aiſément que cette matiere eſt beaucoup plus difficile, & qu'elle renferme des recherches incomparablement plus profondes : cependant j'eſpère d'en venir auſſi heureuſement à bout, de ſorte que s'il y reſte des difficultés, ce ne ſera pas du côté du méchanique, mais uniquement du côté de l'analytique: cette ſcience n'étant pas encore portée à ce degré de perfection, qui ſeroit néceſſaire pour déveloper les formules analytiques, qui renferment les principes du mouvement des fluides.

II. Il s'agit donc de découvrir les principes, par lesquels on puiſſe déterminer le mouvement d'un fluide, en quelque état qu'il ſe trouve, & par quelques forces qu'il ſoit ſollicité. Pour cet effet examinons en détail tous les articles, qui conſtituent le ſujet de nos recherches, & qui renferment les quantités tant connues qu'inconnues. Et d'abord la nature du fluide eſt ſuppoſée connue, dont il faut conſidérer les diverſes eſpeces : le fluide eſt donc, ou incompreſſible, ou compreſſible. S'il n'eſt pas ſuſceptible de compreſſion, il faut diſtinguer deux cas, l'un où toute la maſſe eſt compoſée de parties homogenes, dont la denſité eſt partout & demeure toujours la même, l'au-
tre

Euler equations for fluid flow

$$\overbrace{\frac{\partial \rho}{\partial t}}^{\text{Change in mass}} + \overbrace{\nabla\cdot(\rho\mathbf{v})}^{\text{Mass outflow}} = \overbrace{0}^{\text{Conserved}}$$

Continuity equation (differential form)

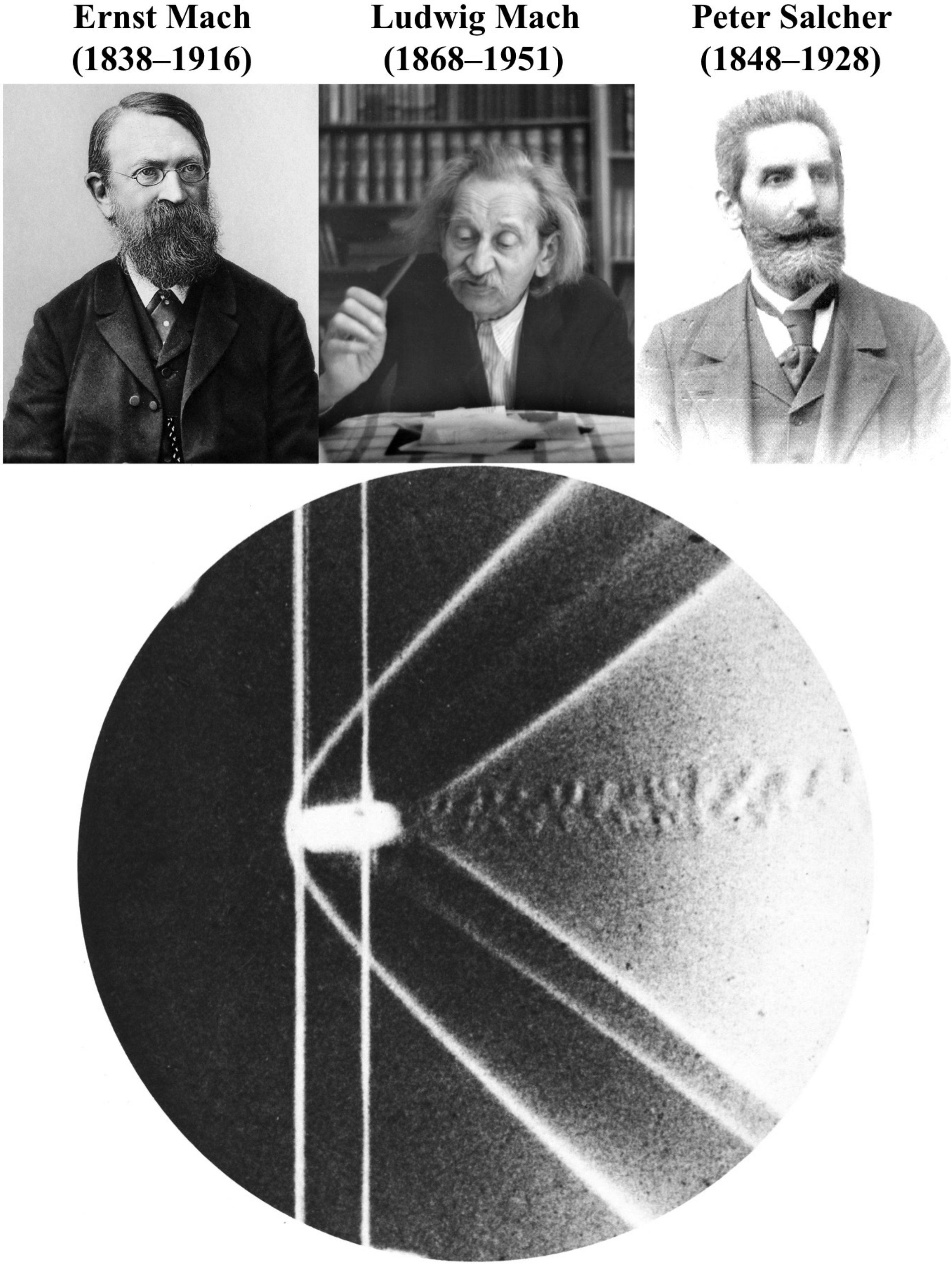
$$\overbrace{\rho\left(\frac{\partial}{\partial t}+\mathbf{v}\cdot\nabla\right)\mathbf{v}}^{\text{Mass}\,\times\,\text{acceleration}} = \overbrace{\rho\mathbf{g}}^{\substack{\text{Gravitational}\\ \text{force}}} - \overbrace{\nabla p}^{\substack{\text{Pressure}\\ \text{force}}} + \overbrace{\mathbf{F}_{\text{viscous}}}^{\substack{\text{Viscous}\\ \text{forces}}}$$

Momentum equation (differential form)

$$\overbrace{\frac{\partial}{\partial t}\left[\rho\left(u+\frac{v^2}{2}+gH\right)\right]}^{\text{Change in energy}} + \overbrace{\nabla\cdot\left[\rho\left(u+\frac{v^2}{2}+gH\right)\mathbf{v}\right]}^{\text{Energy outflow}}$$
$$= \underbrace{\dot{q}_{\text{input}}}_{\substack{\text{Input heat}\\ \text{energy}}} + \underbrace{\dot{w}_{\text{input}}}_{\substack{\text{Input work}\\ \text{energy}}} - \underbrace{\nabla\cdot(p\mathbf{v})}_{\substack{\text{Output work energy}\\ \text{by expanding pressure}}} + \underbrace{\phi_{\text{viscous}}}_{\substack{\text{Input energy from}\\ \text{friction with surroundings}}}$$

Energy equation (differential form)

Figure 9.14: Leonhard Euler developed the more general Euler equations for fluid flow, and published them in 1757.



Ernst Mach
(1838–1916)

Ludwig Mach
(1868–1951)

Peter Salcher
(1848–1928)

Figure 9.15: Ernst Mach, his son Ludwig Mach, and Peter Salcher conducted the first experiments to visualize shock waves around a bullet traveling faster than the speed of sound through air.

Ludwig Prandtl (1875–1953), the "father of aerodynamics"

Photographed in 1904 with a water canal for fluid mechanics measurements, shortly before he began building a series of world-leading wind tunnels

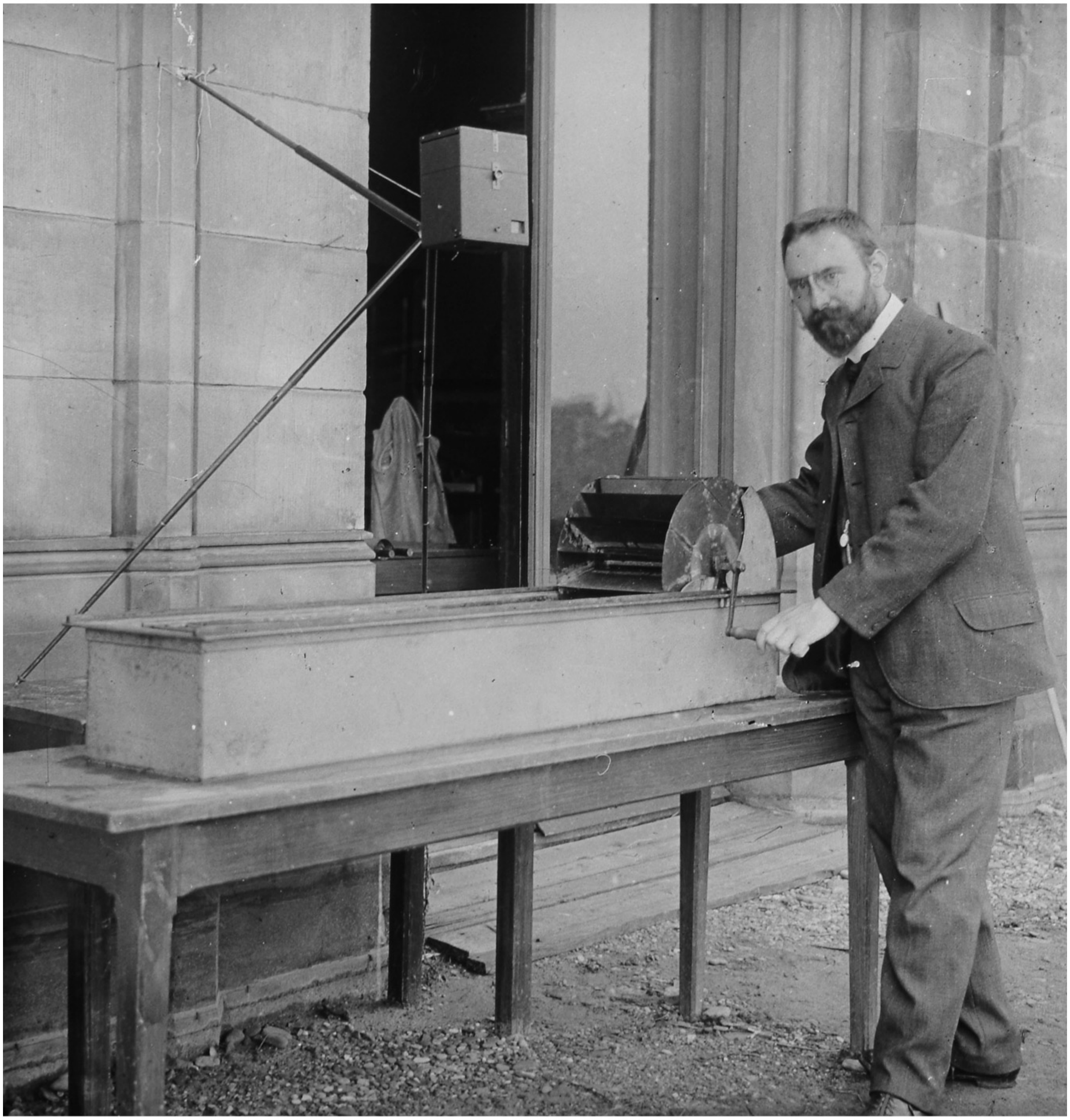
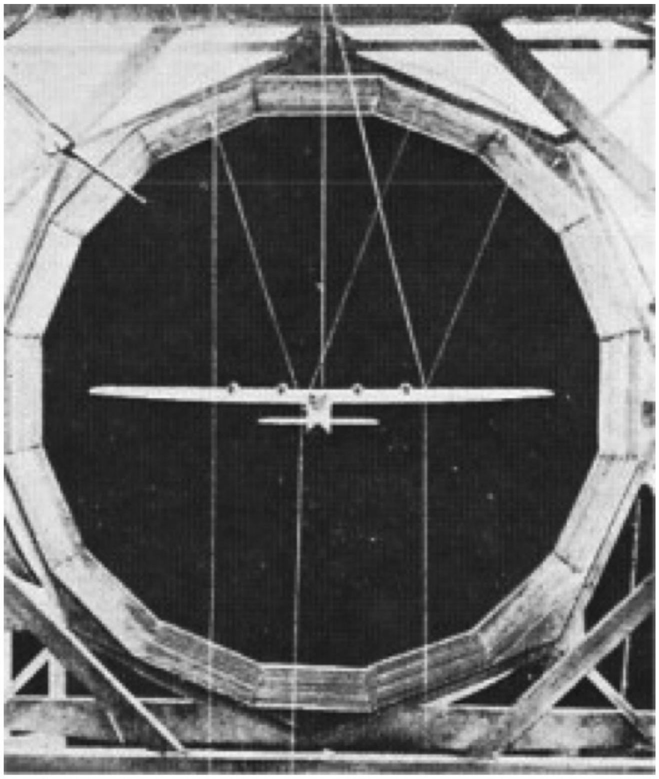


Figure 9.16: Ludwig Prandtl was the "father of aerodynamics." In this 1904 photograph, he was using a water canal for fluid mechanics measurements, shortly before he began building a series of world-leading wind tunnels.

**Aerodynamische
Versuchsanstalt
(AVA) Göttingen
subsonic
wind tunnel
(1907 onward)**

**Designed and run
by Ludwig Prandtl
and his students
and collaborators**



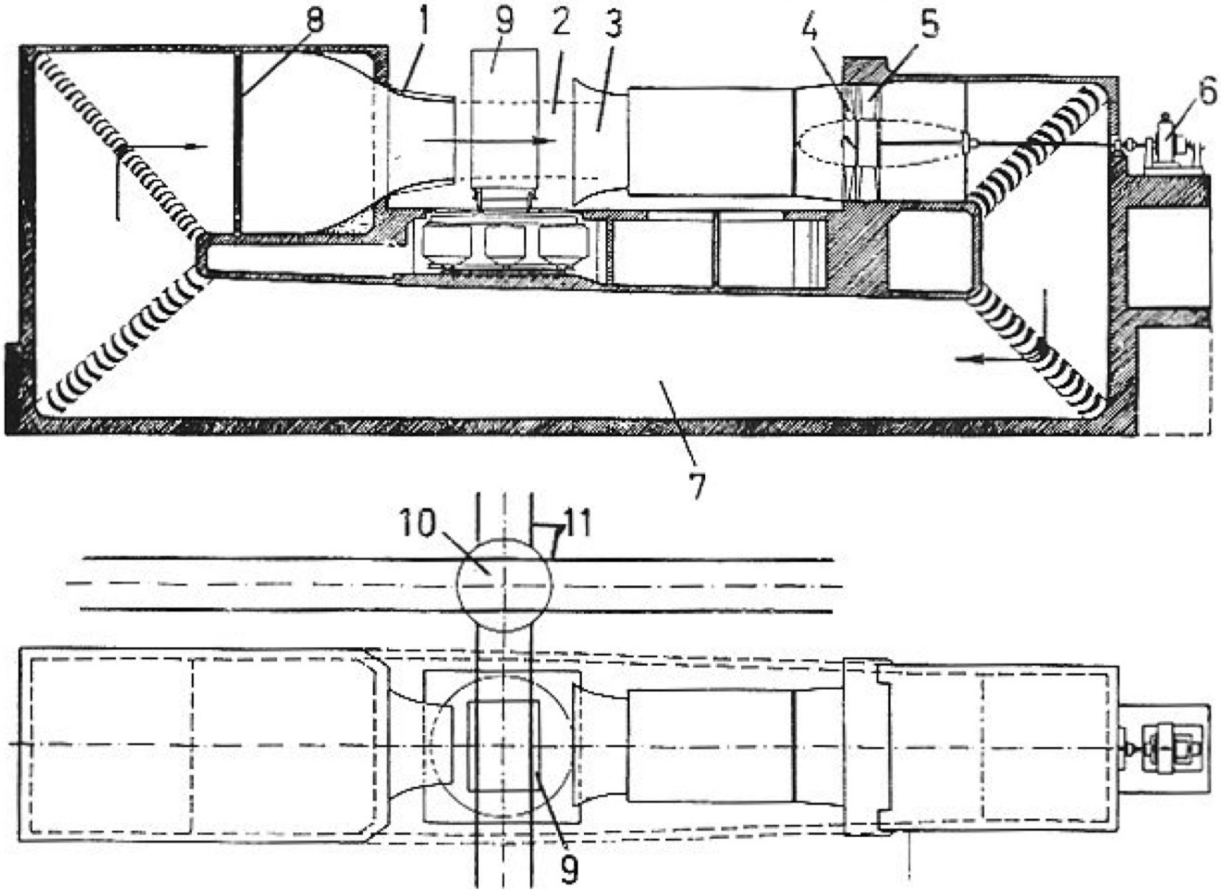


Figure 9.17: Ludwig Prandtl and his students and collaborators designed and operated the Aerodynamische Versuchsanstalt (AVA) subsonic wind tunnel at Göttingen from 1907 onward [http://www.histaviation.com].

During his several decades at the Aerodynamische Versuchsanstalt (AVA) at Göttingen University, Prandtl was also a prolific teacher and mentor for countless students and lab assistants who themselves went on to make major contributions to aerodynamics, wind tunnel experiments, and other aspects of aerospace engineering. Looking at all the resulting innovators and innovations, one gets the impression that most of the field of aerodynamics can be traced to Prandtl and/or his students.[5] [See Eckert 2017 for much more information on Prandtl.]

Albert Betz (German, 1885–1968) was one of Prandtl's students, continued to work with Prandtl at the AVA after that, and eventually succeeded Prandtl as director of the AVA. In 1919, Betz applied the principles of aerodynamics to calculate the efficiency of power-producing wind turbines and to design wind turbine blades with the highest possible efficiency (Fig. 9.18). Such wind turbines are now used all over the world. Betz made many other contributions to aerodynamics over his career, including working on the AVA wind tunnels, testing and implementing Adolf Busemann's designs for swept-back aircraft wings (p. 1696), and developing axial flow compressor blades for jet engines (p. 1733).

The early wind tunnels that were constructed by Ludwig Prandtl and his students were subsonic, producing wind speeds slower than the speed of sound (Fig. 9.17). Subsonic wind tunnels have continued to be used worldwide to test the aerodynamics of subsonic aircraft, automobiles, models of buildings, etc. For example, Fig. 9.19 shows the Deutsche Forschungsanstalt für Luftfahrt (DFL) subsonic wind tunnel at Braunschweig-Völkenrode that began operation in 1940. It was so large that whole aircraft could be tested in it, instead of subscale models.

Max Munk (German, 1890–1986) studied aircraft wing (airfoil) design and wind tunnel design under Ludwig Prandtl and graduated from Göttingen University in 1918 with two Ph.D. degrees, in both physics and mathematics. In 1920, he moved to the United States. In 1921, he designed the Variable Density Tunnel at the NACA (later NASA) Langley Research Center (Fig. 9.20). He completed that subsonic wind tunnel in 1923 and oversaw its operation for several years. Munk's wind tunnel was so advanced compared to other apparatus then available in the United States that it was used until the 1940s, when it was superseded by new German-designed wind tunnels.

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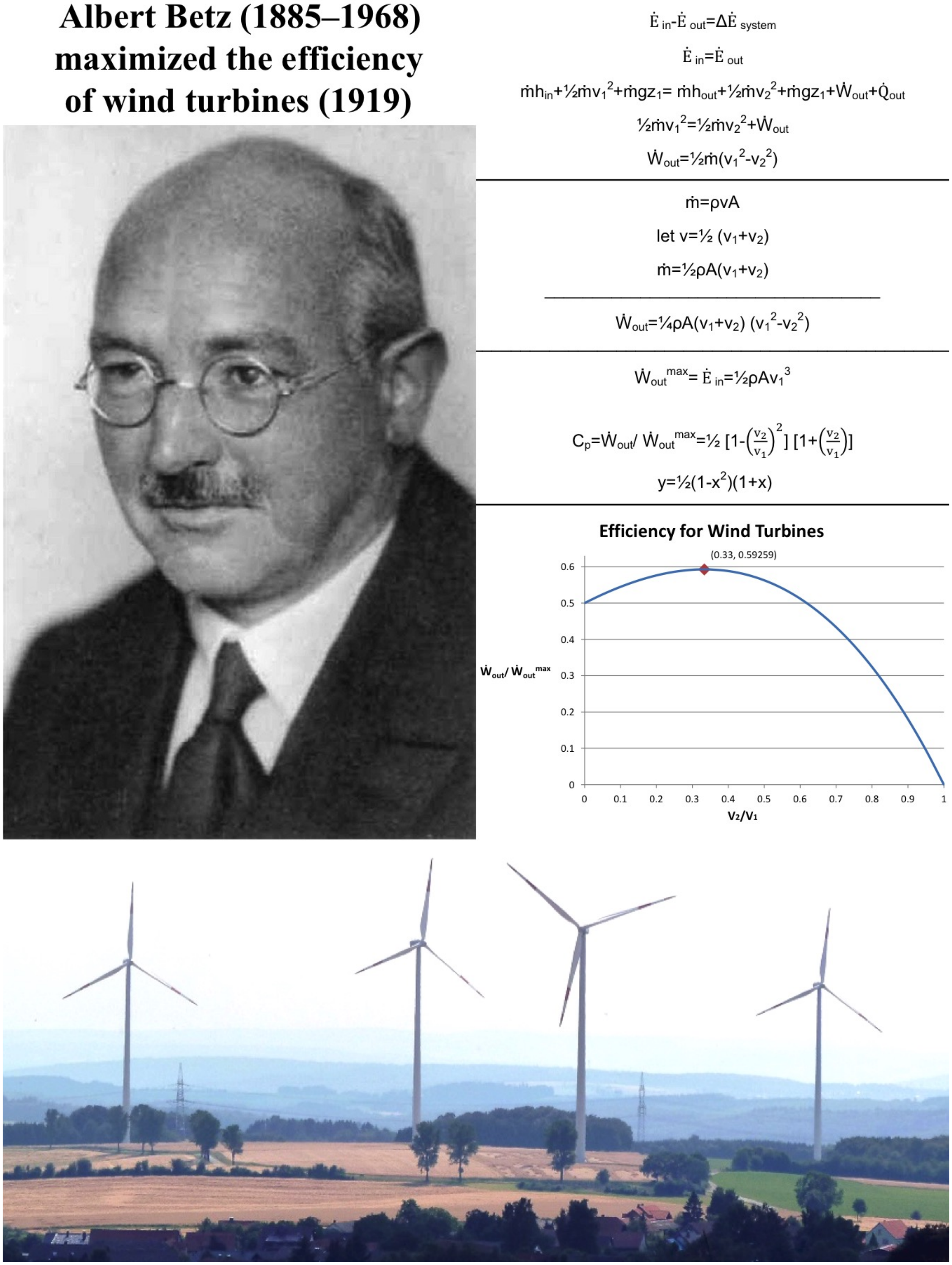
[5] One should also note the work of Frederick Lanchester (English, 1868–1946), a contemporary of Prandtl who had some similar insights in aerodynamics but unfortunately was not able to find much support for them within the British system at the time.



Albert Betz (1885–1968) maximized the efficiency of wind turbines (1919)

$$\dot{E}_{in}-\dot{E}_{out}=\Delta\dot{E}_{system}$$

$$\dot{E}_{in}=\dot{E}_{out}$$

$$\dot{m}h_{in}+\tfrac{1}{2}\dot{m}v_1^2+\dot{m}gz_1=\dot{m}h_{out}+\tfrac{1}{2}\dot{m}v_2^2+\dot{m}gz_1+\dot{W}_{out}+\dot{Q}_{out}$$

$$\tfrac{1}{2}\dot{m}v_1^2=\tfrac{1}{2}\dot{m}v_2^2+\dot{W}_{out}$$

$$\dot{W}_{out}=\tfrac{1}{2}\dot{m}(v_1^2-v_2^2)$$

$$\dot{m}=\rho vA$$

let $v=\tfrac{1}{2}(v_1+v_2)$

$$\dot{m}=\tfrac{1}{2}\rho A(v_1+v_2)$$

$$\dot{W}_{out}=\tfrac{1}{4}\rho A(v_1+v_2)(v_1^2-v_2^2)$$

$$\dot{W}_{out}^{max}=\dot{E}_{in}=\tfrac{1}{2}\rho Av_1^3$$

$$C_p=\dot{W}_{out}/\dot{W}_{out}^{max}=\tfrac{1}{2}\left[1-\left(\frac{v_2}{v_1}\right)^2\right]\left[1+\left(\frac{v_2}{v_1}\right)\right]$$

$$y=\tfrac{1}{2}(1-x^2)(1+x)$$

Efficiency for Wind Turbines
(0.33, 0.59259)
Ẇout/ Ẇout max
0
0.1
0.2
0.3
0.4
0.5
0.6
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
v₂/v₁

Figure 9.18: Albert Betz maximized the efficiency of wind turbines in 1919. His innovations have become increasingly important as larger amounts of electricity are generated from wind power worldwide.

Deutsche Forschungsanstalt für Luftfahrt (DFL)
Braunschweig-Völkenrode subsonic wind tunnel (1940)

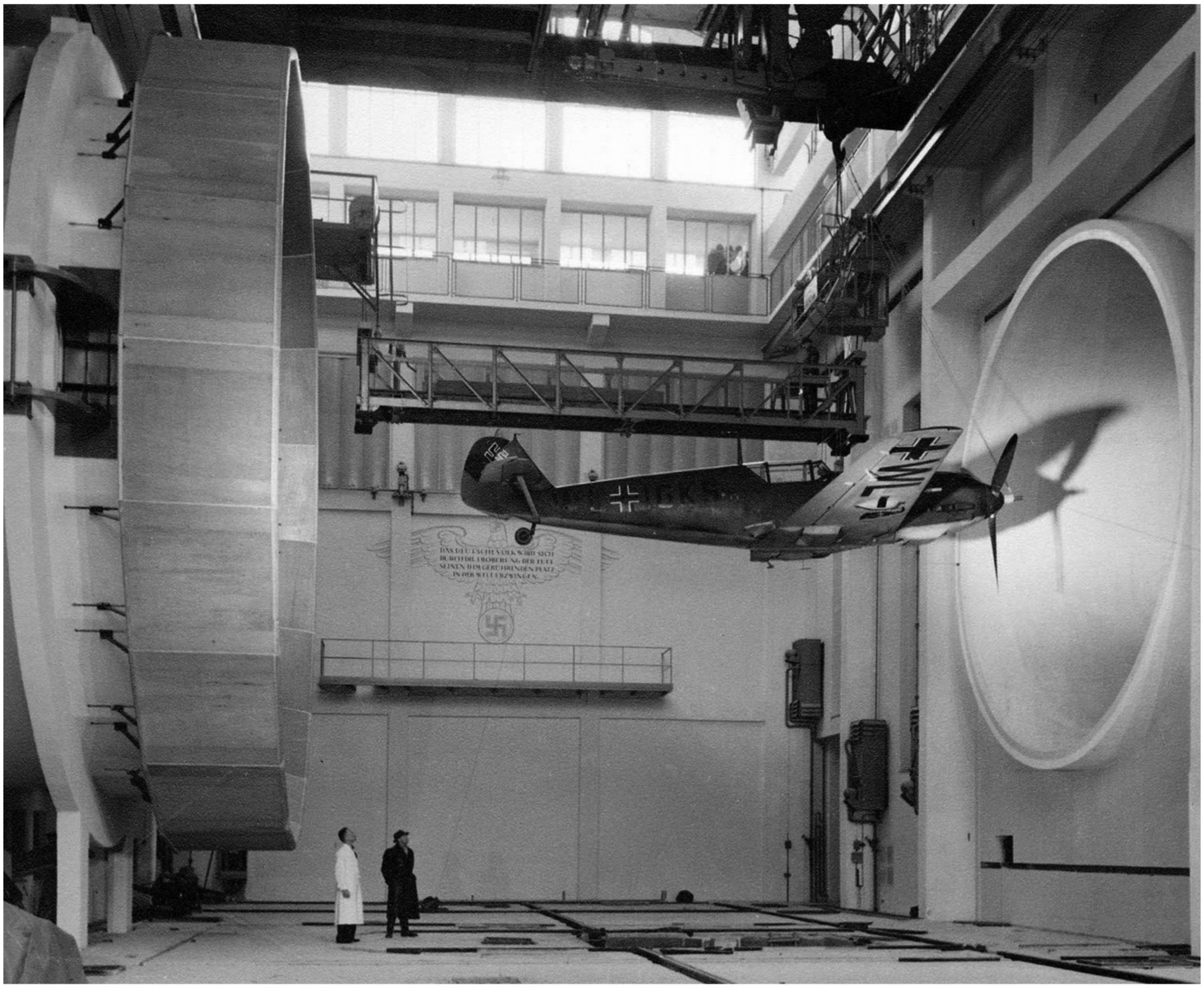

DAS DEUTSCHE VOLK WIRD SICH
DURCH DIE EROBERUNG DER LUFT
SEINEN IHM GEBÜHRENDEN PLATZ
IN DER WELT ERZWINGEN.

Figure 9.19: The Deutsche Forschungsanstalt für Luftfahrt (DFL) wind tunnel at Braunschweig-Völkenrode began operation in 1940. It was so large that whole aircraft could be tested in it, instead of subscale models.

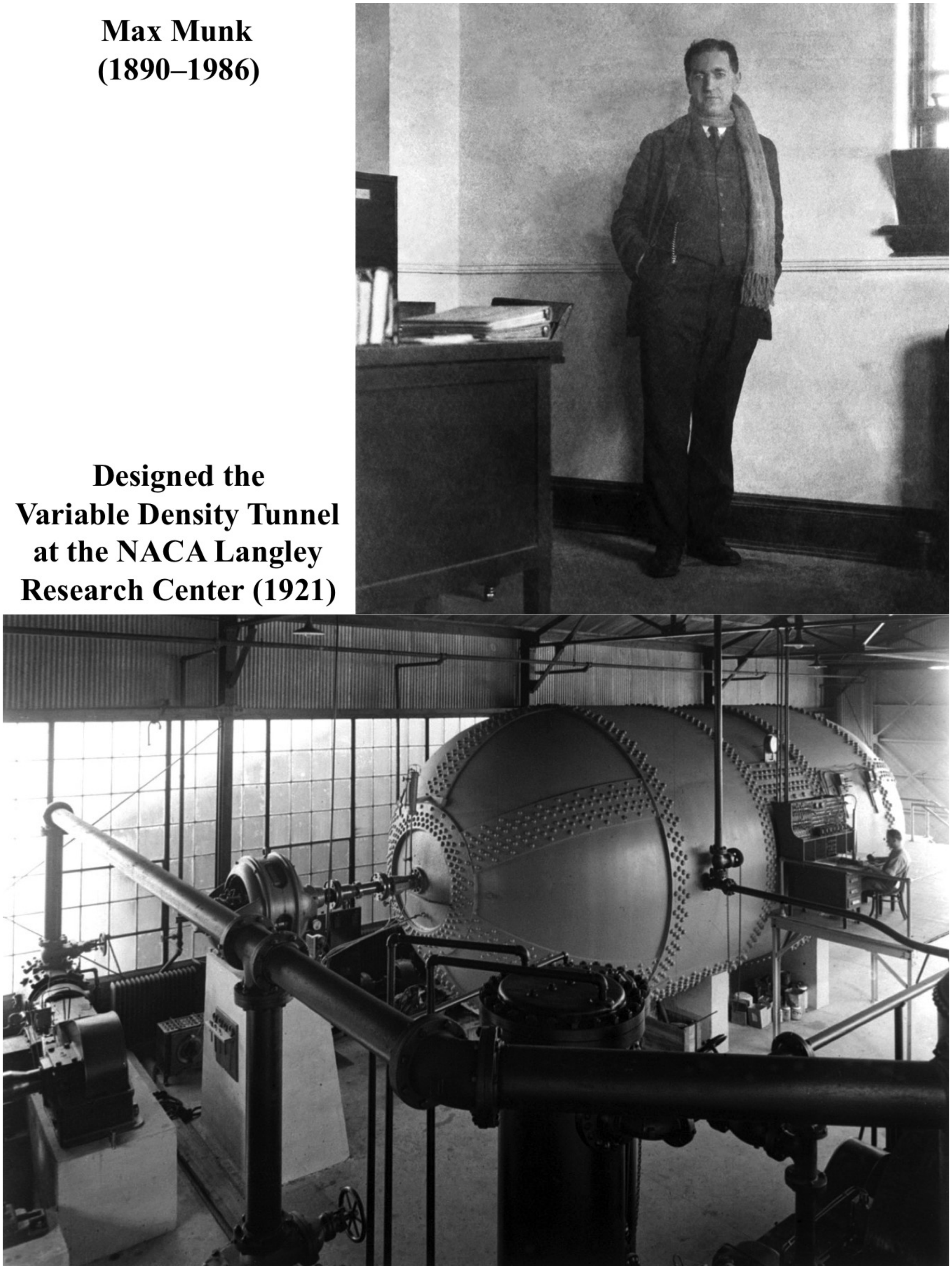

Max Munk
(1890–1986)
Designed the
Variable Density Tunnel
at the NACA Langley
Research Center (1921)

Figure 9.20: Max Munk, one of Prandtl's former students and assistants, immigrated to the United States. In 1921 he designed the best U.S. wind tunnel at that time, the Variable Density Tunnel at the NACA Langley Research Center. It began operation in 1923 and was used until the 1940s, when it was superseded by new German-designed wind tunnels.

In 1917, Prandtl designed the first supersonic wind tunnel, capable of producing wind speeds faster than the speed of sound. Unfortunately World War II and the financial impacts of Allied reparations payments in the 1920s prevented Prandtl from immediately finding the support and resources necessary to build supersonic wind tunnels. When more funding became available in the early 1930s, there was a boom in building supersonic wind tunnels in the German-speaking world.

Jakob Ackeret (Swiss, 1898–1981, p. 1696), one of Prandtl's protégés, began operating a supersonic wind tunnel at ETH Zurich in 1933. It was initially capable of attaining wind speeds up to Mach 2. The ETH Zurich wind tunnel facility has been repeatedly upgraded over the years and is still in operation.

Rudolf Hermann (German, 1904–1991, Fig. 9.24) and Carl Wieselsberger (German, 1887–1941, Fig. 9.25), former students of Prandtl, built a wind tunnel at the Technical University of Aachen that could achieve wind speeds up to Mach 3.

In 1936, Rudolf Hermann designed the Heeresversuchsanstalt (HVA) supersonic/hypersonic wind tunnel for the German army's rocket program (Fig. 9.21). The HVA wind tunnel was the most advanced facility of its type in the world at that time. It was run by Hermann Kurzweg (German, 1908–2000, Fig. 9.24) and his team at Peenemünde during the period 1939–1943, moved to Kochel for 1943–1945 to avoid Allied bombing, and taken to the U.S. Naval Ordnance Laboratory in 1945. The HVA tunnel could attain a range of speeds up to Mach 5.2. In 1944, it attained Mach 9.5 after being modified. Rudolf Hermann's wind tunnel was critically important for the development of rockets such as the A-4 (V-2), and he was rewarded for it along with Wernher von Braun and other top members of the rocket team (p. 5384).

Prandtl and his collaborators began operated a supersonic wind tunnel at the AVA in 1938. In 1955 at the AVA, Hubert Ludwieg (German, 1912–2000, Fig. 9.24), yet another former student of Prandtl, created what became known as the Ludwieg tube, a wind tunnel capable of speeds from Mach 3 to Mach 12.

At the end of World War II, the very advanced Zitteraal wind tunnel was under construction at Ötztal, Austria, as shown in Fig. 9.22. After the war, it was taken to Modane, France, where it formed the basis of the ONERA (Office National d'Etudes et de Recherches Aérospatiales) wind tunnel laboratory. It is still in use there and still the largest of its kind.

In all, there were over 70 subsonic, transonic, supersonic, and hypersonic wind tunnels in the greater German-speaking world at the end of World War II. Many aircraft companies, military laboratories, and universities had important wind tunnel facilities. Most of those wind tunnels were seized by Allied forces and taken to the United States, United Kingdom, France, and Soviet Union, along with vast amounts of aerodynamic information and most of the experts on aerodynamics and wind tunnels.

As presented in Figs. 9.23–9.25, some other creators who developed wind tunnels and/or analyzed their results included:

Hans Amtmann (German, 1906–2007), aircraft and rocket design

Paul Richard Heinrich Blasius (German, 1883–1970), boundary layers

Carl Cranz (German, 1858–1945), ballistics and high-speed diagnostics

Siegfried Erdmann (German, 1916–2002), supersonic and hypersonic wind tunnels

Irmgard Flügge-Lotz (German, 1903–1974), aerodynamic control systems

Kurt Otto Friedrichs (German, 1901–1982), fluid dynamics and theory of elasticity

Georg Fuhrmann (German, 18??–19??), subsonic wind tunnel design/measurements

Erich Groth (German, 19??–19??), high-speed aerodynamics and aircraft design

Axel Kolb (German, 1917–2009), aerodynamics and wind tunnels

Klaus Oswatitsch (Austrian, 1910–1993), hypersonic aerodynamics

Hermann Schlichting (German, 1907–1982), boundary layers

Walter Tollmien (German, 1900–1968), boundary layers

Otto Walchner (German, 19??–19??), supersonic and hypersonic aerodynamics

Peter Wegener (German, 1917–2008), supersonic and hypersonic wind tunnels

Theodor Wilhelm Zobel (German, 1906–1953) worked on high-speed aerodynamics, wind tunnels, tests of Otto Frenzl's supersonic area rule (p. 1701), and Schlieren interferometry measurement systems for wind tunnels, first in Germany during the war and then in the United States after the war (Fig. 9.26). Hans Amtmann, another German aerospace expert who came to the United States in Operation Paperclip, eulogized Zobel [Amtmann 1988, pp. 115–116]:

> Dr. Theodor Zobel, former chief of the high-speed aerodynamic section of the Aerodynamic Research Center in Brunswick. He developed the Schlieren Interferometer, an optical measuring device to measure the flow of air around an airfoil without disturbing the flow. This was one of the most important contributions to supersonic research. His work saved the United States several years of expensive research time.

Theodore von Kármán (Hungarian, 1881–1963) earned his Ph.D. under Prandtl in 1908, worked on aerodynamics in Germany and Austria until 1930, and then moved to the United States. From then until the end of his life, Von Kármán was a tireless advocate trying to persuade the United States to improve its funding and level of research for wind tunnels, aerodynamics, and other aspects of aerospace engineering (Fig. 9.27). At the end of World War II, he served as a top U.S. government advisor guiding the transfer of German-speaking scientists and technologies to the United States, working closely with U.S. Army Air Forces General Henry Arnold (p. 2204).

In February 1963, near the very end of von Kármán's life, President John F. Kennedy awarded the first U.S. National Medal of Science to von Kármán (Fig. 9.27) and praised the importance of his work [https://www.jfklibrary.org/asset-viewer/archives/JFKPOF/042/JFKPOF-042-040]:

> Gentlemen, Dr. von Kármán, it is a great pleasure for me to select you as the first recipient of the National Medal of Science. I know of no one else who more completely represents all of the areas with which this award is appropriately concerned—science, engineering, and education.
>
> This Nation, and indeed the entire free world, holds you in the highest esteem and respect for your devoted service, for your scientific achievements, and for your warmly human gifts as a teacher and counsellor. Your assistance to the United States Air Force and to the NATO Advisory Group for Aeronautical Research and Development have been outstanding. We also are deeply indebted to you for your continuing efforts in the promotion of international cooperation in science and in engineering.
>
> It is hard to visualize what the world would be like without aircraft and jet propulsion, or without the vision we have, just entering the realm of reality, of exploring space. I am especially glad to present this first National Medal of Science to one of the pioneers who has helped make all of this new and exciting age possible.

Many creators who were primarily mathematicians also made important contributions to methods of solving complex aerodynamics equations. See for example:

Martin Wilhelm Kutta (German, 1867–1944), p. 830

Richard von Mises (Austro-Hungarian, 1883–1953), p. 831

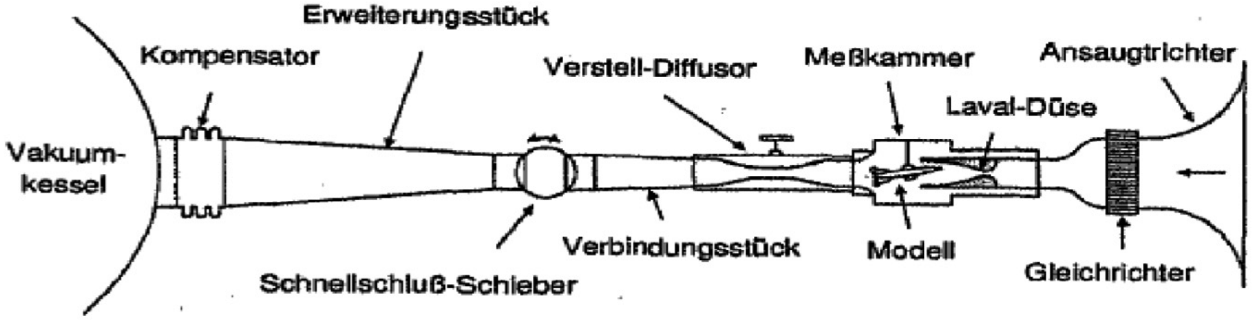
John von Neumann (Hungarian, 1903–1957), p. 831

Carl Runge (German, 1856–1927), p. 833

Karl Hermann Amandus Schwarz (German, 1843–1921), p. 833

Heeresversuchsanstalt (HVA) supersonic/hypersonic wind tunnel
Variable speeds up to Mach 5.2
Attained Mach 9.5 in 1944 after modifications

Designed by Rudolph Hermann in 1936
Operational at Peenemünde 1939–1943
Moved to Kochel for 1943–1945
Taken to U.S. Naval Ordnance Laboratory in 1945


Erweiterungsstück
Kompensator
Verstell-Diffusor
Meßkammer
Ansaugtrichter
Laval-Düse
Vakuum-kessel
Verbindungsstück
Modell
Gleichrichter
Schnellschluß-Schieber

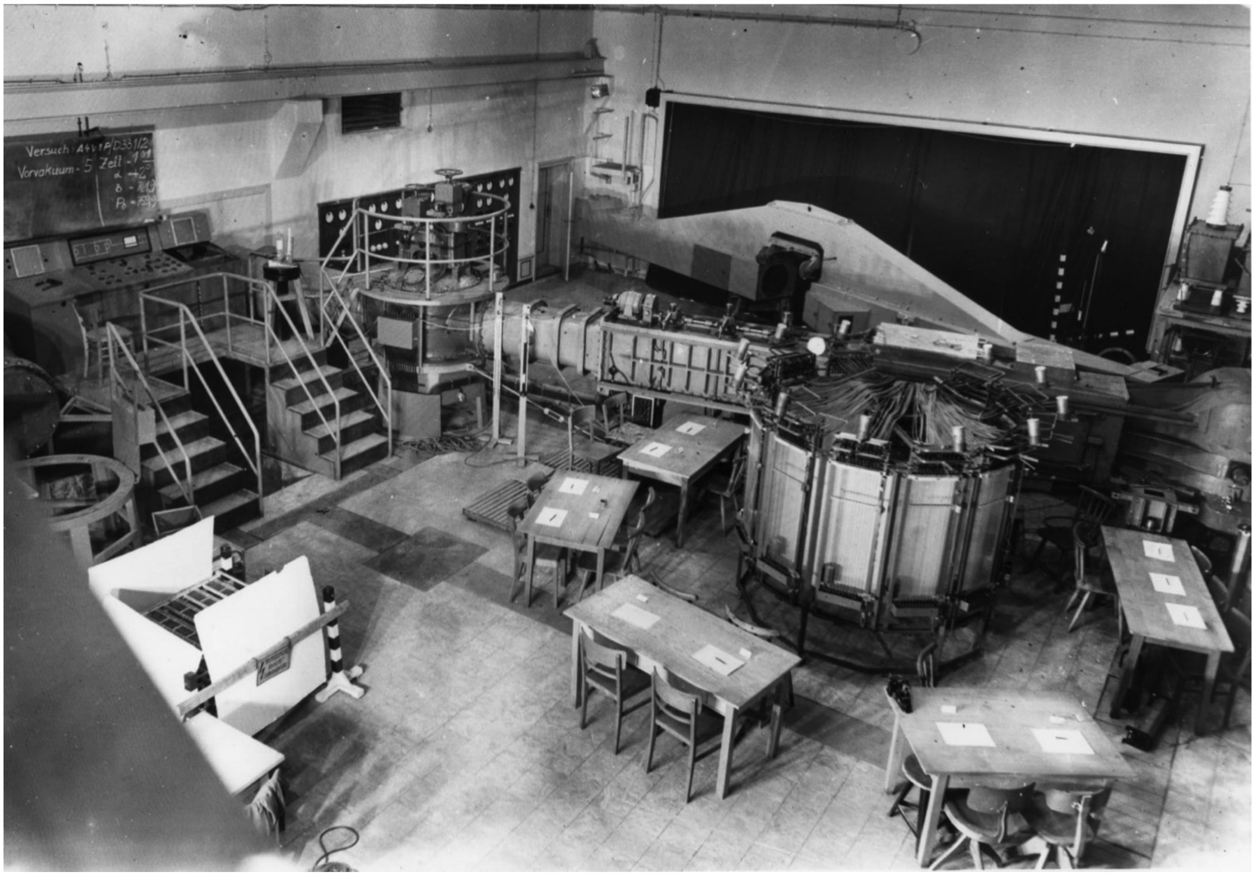


Figure 9.21: The Heeresversuchsanstalt (HVA) supersonic/hypersonic wind tunnel could attain a range of speeds up to Mach 5.2. In 1944, it attained Mach 9.5 after being modified. The HVA wind tunnel was designed by Rudolf Hermann in 1936. It was operational at Peenemünde 1939–1943, moved to Kochel for 1943–1945, and taken to the U.S. Naval Ordnance Laboratory in 1945.

NARA Still Pictures, RG 111 SCA---Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941-1954. Captured German Equipment, German, Box 3344, Book 5, SC 209555.

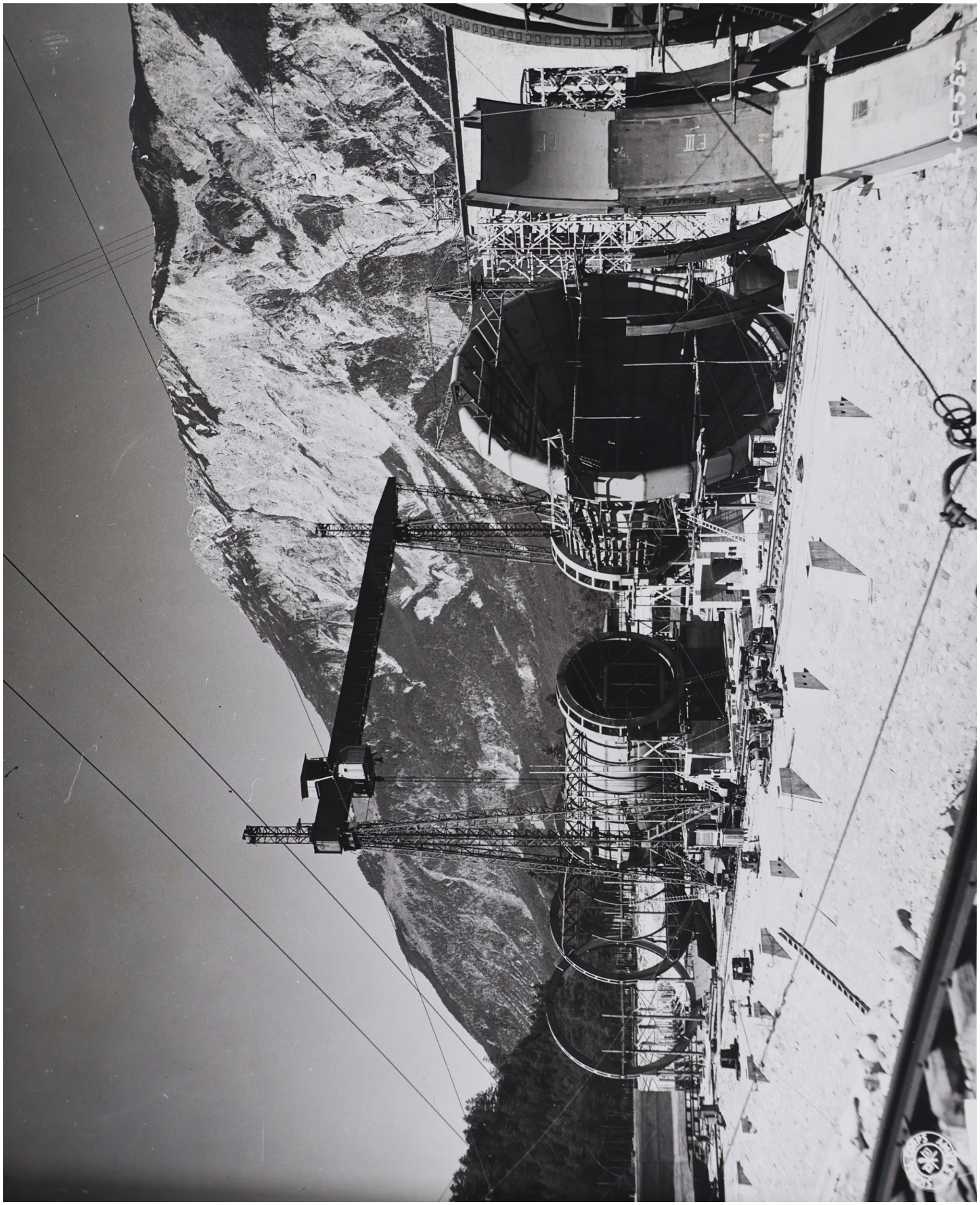


Figure 9.22: The Zitteraal wind tunnel at Ötztal, Austria, was under construction at the end of World War II. After the war, it was taken to Modane, France, where it formed the basis of the ONERA wind tunnel laboratory. It is still in use there and still the largest of its kind. [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3344, Book 5, SC 209555.]

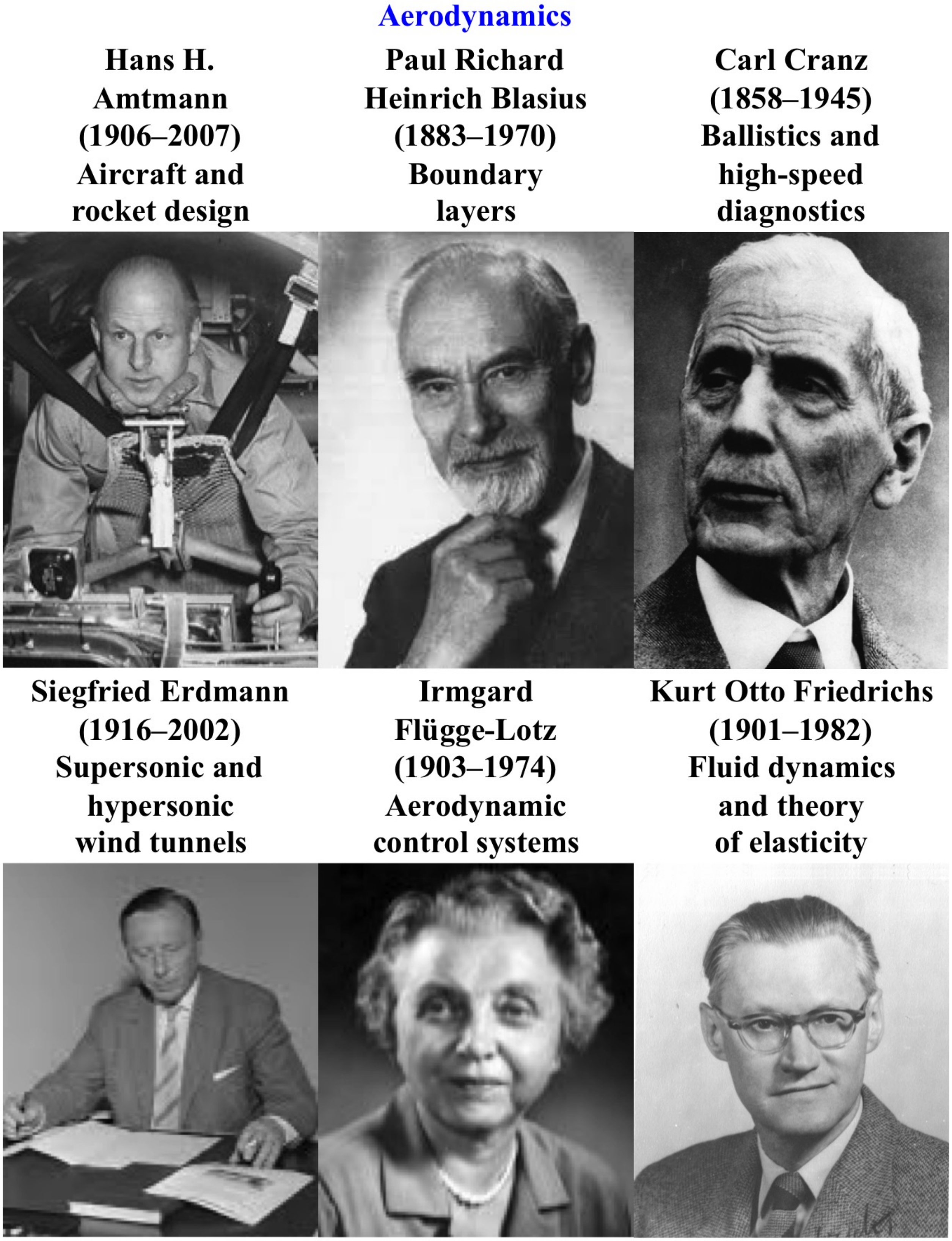

Aerodynamics
Hans H. Amtmann (1906–2007) Aircraft and rocket design
Paul Richard Heinrich Blasius (1883–1970) Boundary layers
Carl Cranz (1858–1945) Ballistics and high-speed diagnostics
Siegfried Erdmann (1916–2002) Supersonic and hypersonic wind tunnels
Irmgard Flügge-Lotz (1903–1974) Aerodynamic control systems
Kurt Otto Friedrichs (1901–1982) Fluid dynamics and theory of elasticity

Figure 9.23: Other creators who developed wind tunnels and/or analyzed their results included Hans Amtmann, Paul Richard Heinrich Blasius, Carl Cranz, Siegfried Erdmann, Irmgard Flügge-Lotz, and Kurt Otto Friedrichs.

Aerodynamics

Georg Fuhrmann
(18??–19??)
Subsonic wind tunnel design/ measurements

Erich Groth
(19??–19??)
High-speed aerodynamics and aircraft design

Rudolf Hermann
(1904–1991)
Supersonic and hypersonic wind tunnels

Axel Kolb
(1917–2009)
Aerodynamics and wind tunnels

Hermann Kurzweg
(1908–2000)
Supersonic and hypersonic wind tunnels

Hubert Ludwieg
(1912–2000)
Supersonic and hypersonic wind tunnels

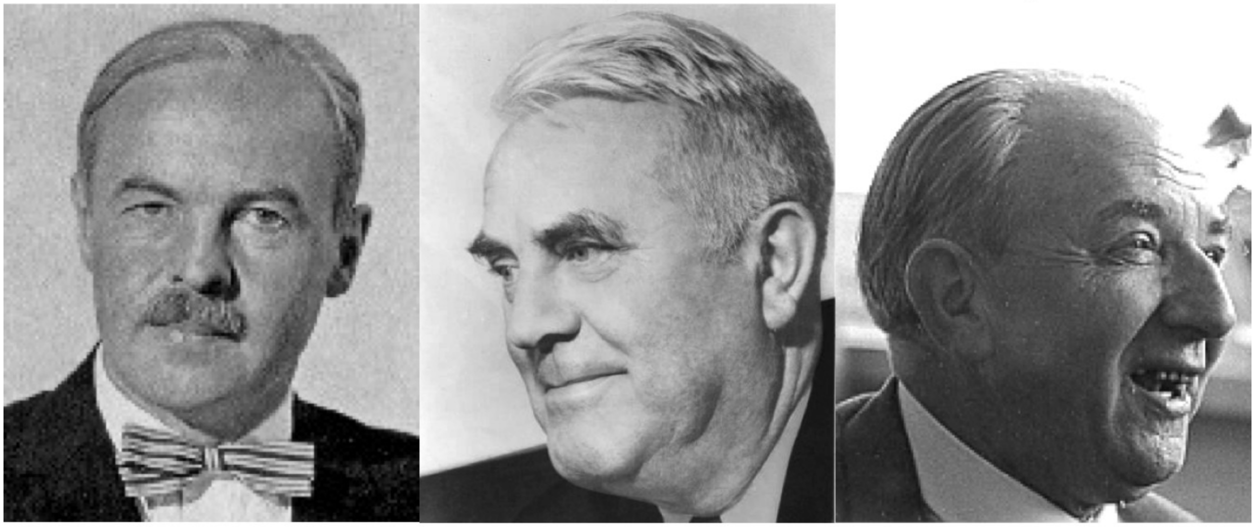
Figure 9.24: Other creators who developed wind tunnels and/or analyzed their results included Georg Fuhrmann, Erich Groth, Rudolf Hermann, Axel Kolb, Hermann Kurzweg, and Hubert Ludwieg.

Aerodynamics

Klaus Oswatitsch (1910–1993)
Hypersonic aerodynamics

Hermann Schlichting (1907–1982)
Boundary layers

Walter Tollmien (1900–1968)
Boundary layers



Otto Walchner (19??–19??)
Supersonic and hypersonic aerodynamics

Peter Wegener (1917–2008)
Supersonic and hypersonic wind tunnels

Carl Wieselsberger (1887–1941)
Subsonic and supersonic wind tunnels

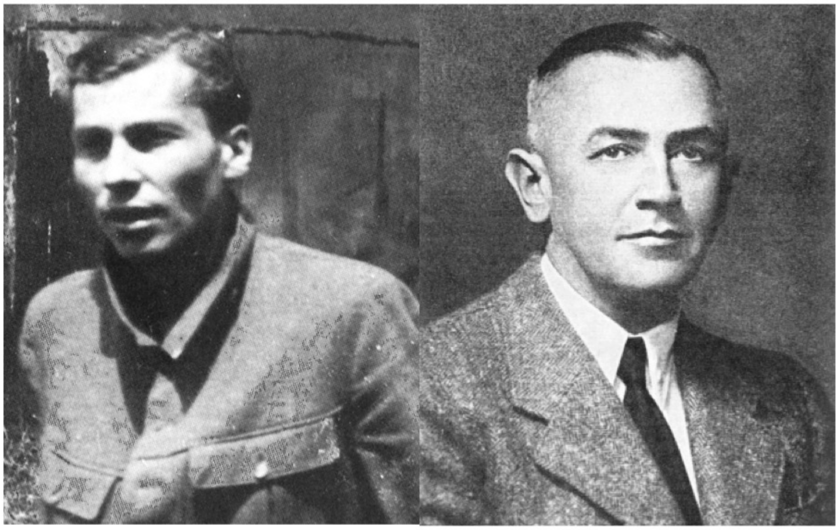
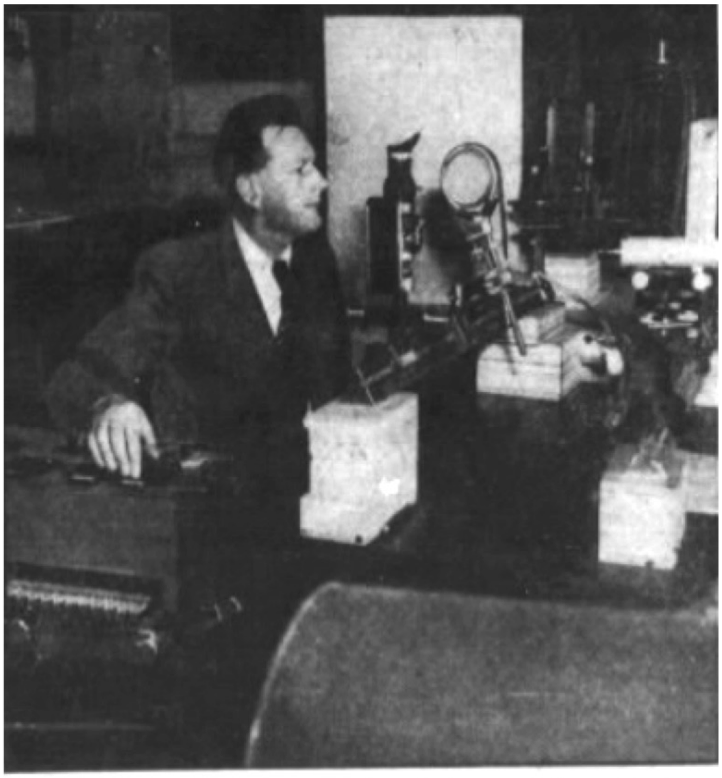


Figure 9.25: Other creators who developed wind tunnels and/or analyzed their results included Klaus Oswatitsch, Hermann Schlichting, Walter Tollmien, Otto Walchner, Peter Wegener, and Carl Wieselsberger.

Theodor Wilhelm Zobel
(1906–1953)

Worked on
high-speed
aerodynamics,
wind tunnels,
the area rule,
and Schlieren
interferometry

Dr. Theodor Zobel, former chief of high speed aerodynamics unit, Brunswick, Germany, explains operation of device to measure airflow.



Dr. Zobel's apparatus for measuring airflow—a Schlieren-Interferometer—brought here because materials were not available in U. S.

Figure 9.26: Theodor Wilhelm Zobel worked on high-speed aerodynamics, wind tunnels, the area rule, and Schlieren interferometry, first in Germany during the war and then in the United States after the war [*Dayton Daily News*, 8 December 1946, p. 55].

Theodore von Kármán
(1881–1963)

Figure 9.27: Aerodynamicist Theodore von Kármán directing work at the U.S. Jet Propulsion Laboratory in 1940 (above), and receiving the National Medal of Science from President Kennedy in 1963 (below).

9.2.3 Specialized Aircraft

Using the principles of aerodynamics, German-speaking engineers developed a wide range of aircraft that were specialized for various applications, and aircraft following those general designs have been used around the world. This section only presents a few examples, although many more could be cited.

Some major aircraft designers are shown in Figs. 9.28–9.29.

Claude Dornier (German, 1884–1969, Fig. 9.28) was most famous for his company's 12-engine Dornier Do X flying boat (first flight 1929), which had multiple decks, luxury accommodations, and room for over 150 people (Fig. 9.30). He also designed the Dornier Do 17 light bomber (1934) and numerous other aircraft throughout his long career. After World War II, Dornier worked in France, Spain, Switzerland, and West Germany.

German-speaking engineers invented dedicated ground-attack aircraft with the pilot and engines protected inside an armored "bathtub":

- In 1917, Otto Mader (German, 1880–1944, Fig. 9.29) and Hugo Junkers (German, 1859–1935, Fig. 9.28) created the first armored ground-attack aircraft, the Junkers J.I (Fig. 9.31). Hugo Junkers built a wide range of aircraft until his death, and his company played a major role in the development of jet engines after his death.

- The Henschel company introduced the Hs 129 armored ground-attack aircraft in 1939, and ultimately equipped it with a 7.5 cm automatic antitank gun in 1944 (Fig. 9.32). In this final configuration, the Hs 129 was the most powerful tank-killing aircraft in the world at the time.

- The Junkers company appears to have designed an even more advanced armored ground-attack aircraft to succeed the Hs 129 [Herwig and Rode 2003, pp. 36–37]. Aviation historians should thoroughly search archives to find more information on this design, how far it progressed during the war, and how much it (and the Hs 129) influenced the U.S. A-10 Thunderbolt II three decades later.

During World War I, Anton Fokker (Dutch, 1890–1939) and Reinhold Platz (German, 1886–1966) designed and mass-produced very effective early fighter aircraft, including the Fokker Eindecker E.III monoplane (1915), Doppeldecker D.VII biplane (1918), and Dreidecker Dr.I triplane (1917). See Fig. 9.33.

Robert Thelen (German, 1884–1968), the chief designer of Albatros-Flugzeugwerke, also created biplane fighter aircraft during World War I (Fig. 9.34). Today the Albatros and Fokker fighters are best remembered as the preferred vehicles of the "Red Baron" Manfred von Richthofen (German, 1892–1918).

As shown in Fig. 9.35, Willy Messerschmitt (German, 1898–1978) and Robert Lusser (German, 1899–1969) developed the Messerschmitt Bf 109 piston-propeller fighter aircraft by 1935. The Bf 109's performance and features were a major step beyond earlier fighters, and the Bf 109 was extensively used by Germany until 1945.

The Messerschmitt Bf 109 seems to have strongly influenced the design of the British Supermarine Spitfire, which appeared as a first prototype in 1936 and began production in 1938. Beverley Shenstone, the head aerodynamics expert for the Spitfire design, had previously worked in Germany [Cole 2012, 2015].

Edgar Schmüd (German, 1899–1985), an aircraft designer, immigrated to the United States in 1931 and went to work for North American Aviation. Using his knowledge, details of the German Bf 109 and the German-inspired Spitfire, and other German design information, Schmüd developed the North American P-51 Mustang piston-propeller fighter in 1940. Subsequently the P-51 was widely used by the United States and United Kingdom during the war. The extreme similarity of Schmüd's 1940 P-51 design to Messerschmitt's 1935 Bf 109 design is evident in Fig. 9.35. In fact, the P-51 so closely resembled the Messerschmitt Bf 109 that at least one P-51 was shot down by Allied forces who mistook it for a Bf 109, and the other P-51s had to be painted with yellow bands on the wings to distinguish them from Bf 109s [Ray Wagner 2000, p. 94]. The resemblance throughout the design was so uncanny that even one of the P-51's own test pilots mistakenly believed that Schmüd must have been one of the designers of the original Bf 109 [Ray Wagner 2000, p. 104].

In 1947, Schmüd likewise developed the North American F-86 Sabre jet fighter based directly on the wartime Messerschmitt Me P.1101 and Focke-Wulf Ta 183 jet fighters (see p. 1775). Schmüd also developed the North American F-100 Super Sabre (1953), the Northrop F-5 Freedom Fighter (1959), and the Northrop T-38 Talon trainer (1959, widely used by NASA for astronaut training) [Ray Wagner 2000].

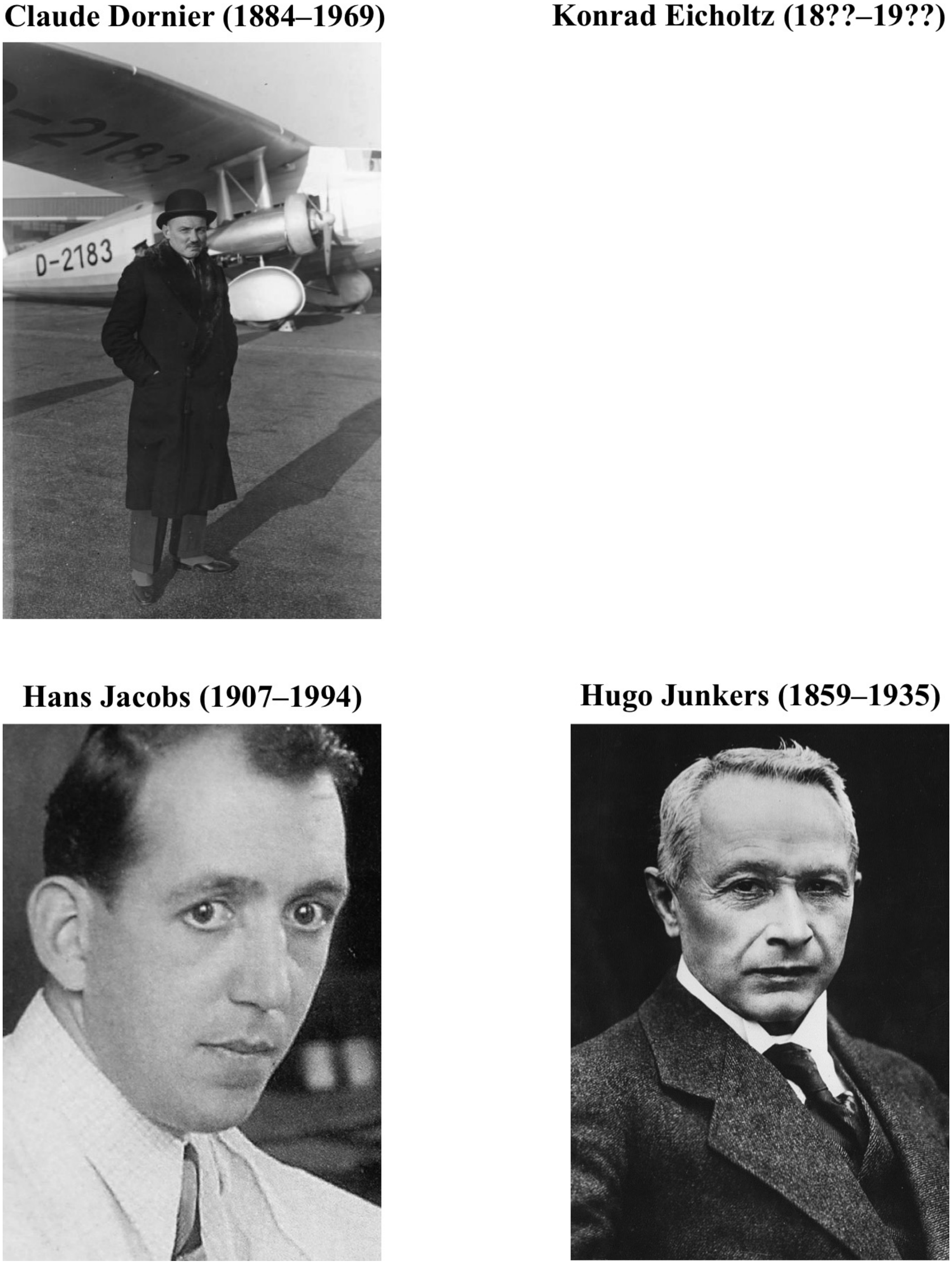
German-speaking engineers developed specialized gliders for military troops and cargo. Due to the gliders' speed, agility, and low noise, they were used for a number of highly creative and successful assaults during World War II. Some major examples included (Fig. 9.36):

- The Deutsche Forschungsanstalt für Segelflug DFS 230, which was designed by Hans Jacobs (German, 1907–1994, Fig. 9.28) and first flew in 1937.
- The Gotha Go 242, which was designed by Albert Kalkert (German, 1902–1977, Fig. 9.29) and first flew in 1941. (There is some evidence that suggests that Kalkert may have been involved in building or trying to build a Horten H.XVIII flying wing intercontinental bomber during the war—see pp. 5227–5231).
- The Messerschmitt Me 321 Gigant, which first flew in 1941.

The Arado Ar 232, first flown in 1941, was the world's first special-purpose cargo aircraft, establishing now-standard features such as a rear cargo ramp, low boxy fuselage, high wing, high tail, and rugged landing gear. It was followed in 1942 by the Junkers Ju 290, designed by Konrad Eicholtz (German, 18??–19??, Fig. 9.28), and the Messerschmitt Me 323 Gigant (the largest land-based cargo aircraft in the world at the time—only the Blohm & Voss BV 238 flying boat was larger). See Fig. 9.37.

German-speaking creators also produced aircraft with highly creative airframe designs. Two examples (among many others that could be cited) were the asymmetrical Blohm & Voss BV 141 reconnaissance aircraft (1938), designed by Richard Vogt (German, 1894–1979, p. 1682), and the twin-boom Focke Wulf Fw 189 Uhu reconnaissance aircraft (1938), designed by Kurt Tank (German, 1898–1983, p. 1682). See Fig. 9.38. Vogt was famous for the wide range of unusual aircraft designs he produced during the war, and he worked for the U.S. Air Force, Curtiss-Wright, and Boeing after the war. Tank designed fighter aircraft at Focke-Wulf during the war, and after the war developed a wide range of aircraft and missiles in Argentina, India, and West Germany.

Even German designs that were not actually built during World War II continued to exert a strong influence on aircraft that were built long after the war. For example, Richard Vogt's 1944 design for the Blohm & Voss P 202 oblique wing aircraft directly inspired the design of the NASA AD-1 oblique wing aircraft, which was first flown in 1979 (Fig. 9.39). As shown in Fig. 9.40, Vogt's 1945 outboard tail swept-wing design for the Blohm & Voss P 212 (and the rest of his P 208–215 design series from 1944–1945) similarly appears to have directly inspired the design of the Virgin Galactic SpaceShipTwo, which made its first suborbital flight in 2018.



Claude Dornier (1884–1969)

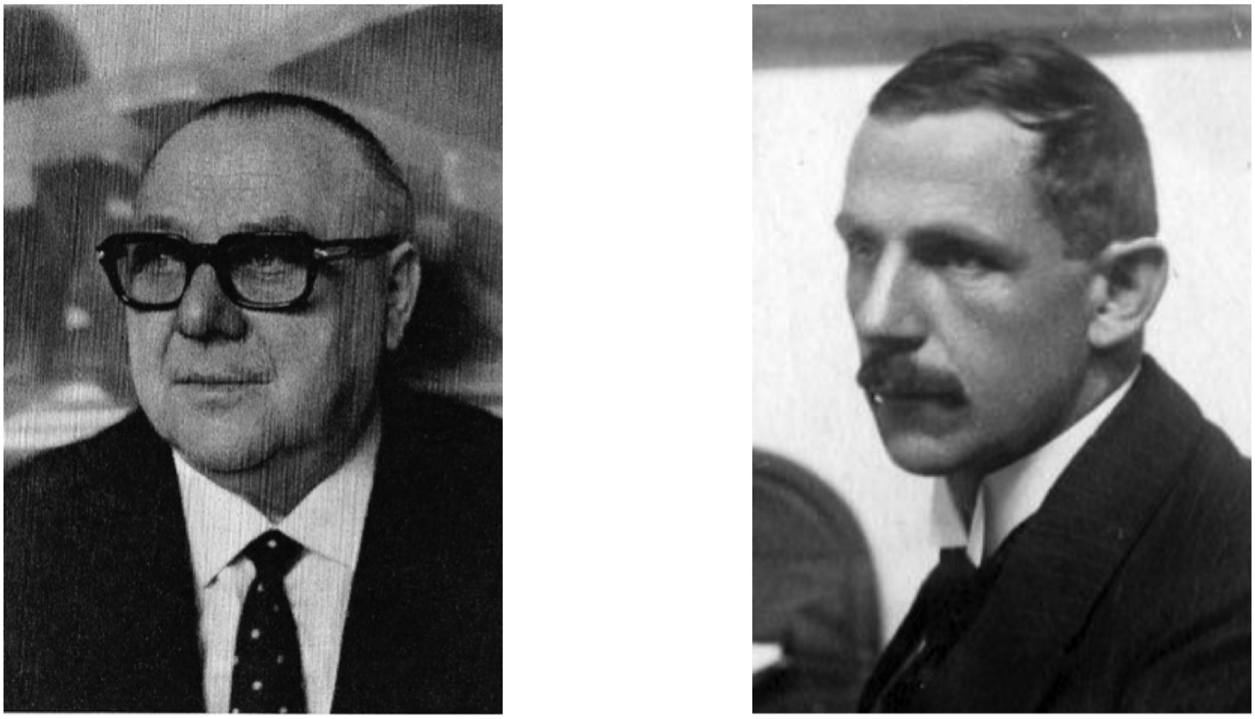
Konrad Eicholtz (18??–19??)

Hans Jacobs (1907–1994)

Hugo Junkers (1859–1935)

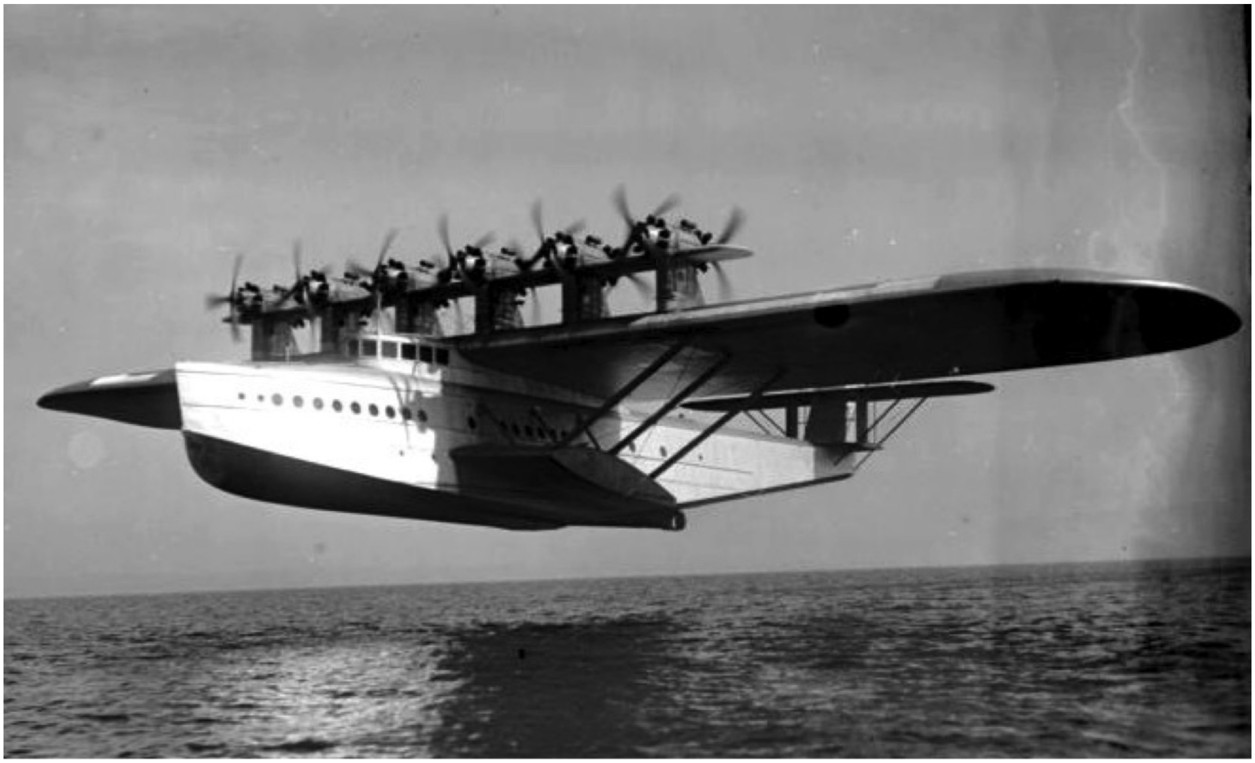
Figure 9.28: Some major aircraft designers included Claude Dornier, Konrad Eicholtz, Hans Jacobs, and Hugo Junkers.

Albert Kalkert (1902–1977) **Otto Mader (1880–1944)**



Kurt Tank (1898–1983) **Richard Vogt (1894–1979)**

Figure 9.29: Other major aircraft designers included Albert Kalkert, Otto Mader, Kurt Tank, and Richard Vogt.



Dornier Do X flying boat (1929) designed by Claude Dornier

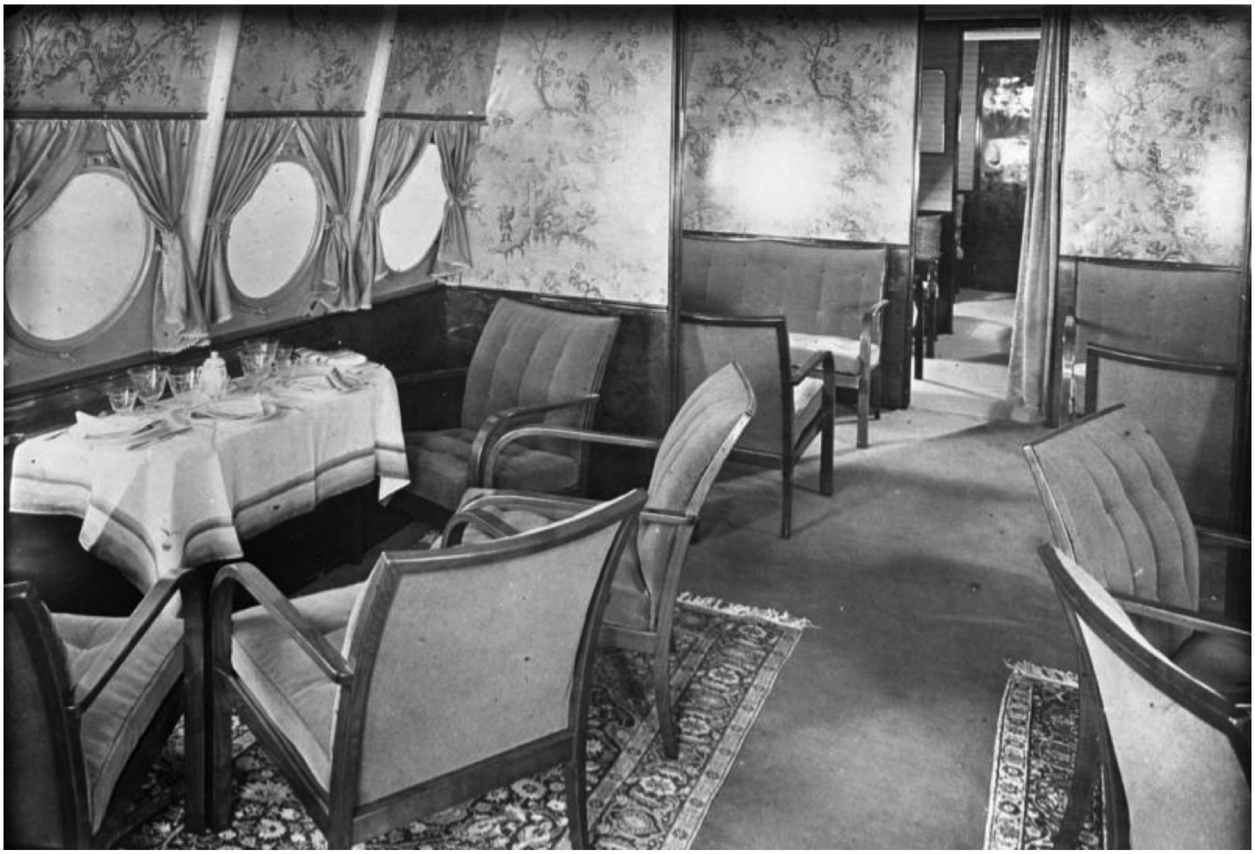


Figure 9.30: In 1929, Claude Dornier created the Dornier Do X flying boat, which had multiple decks, luxury accommodations, and room for over 150 people.

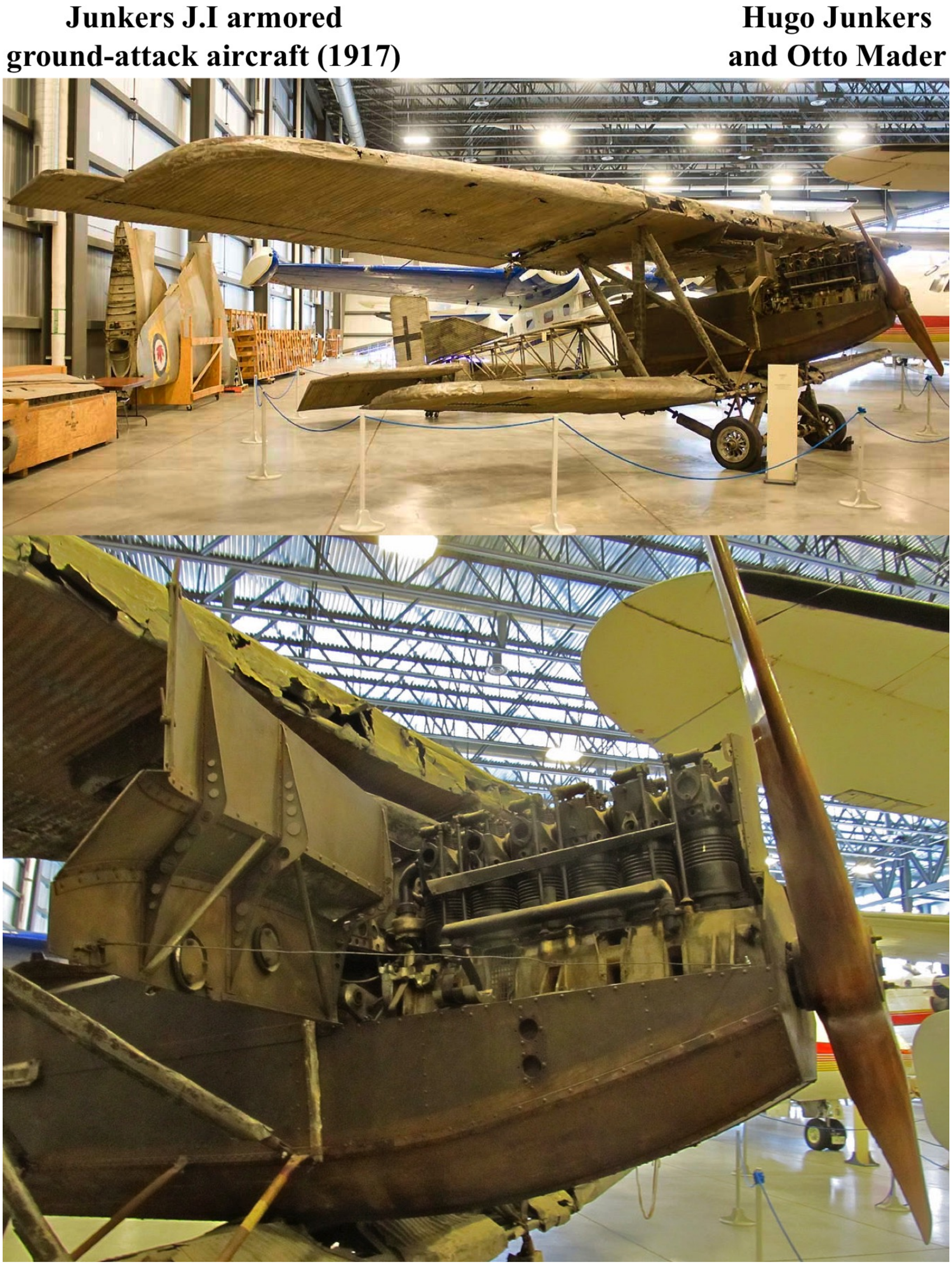
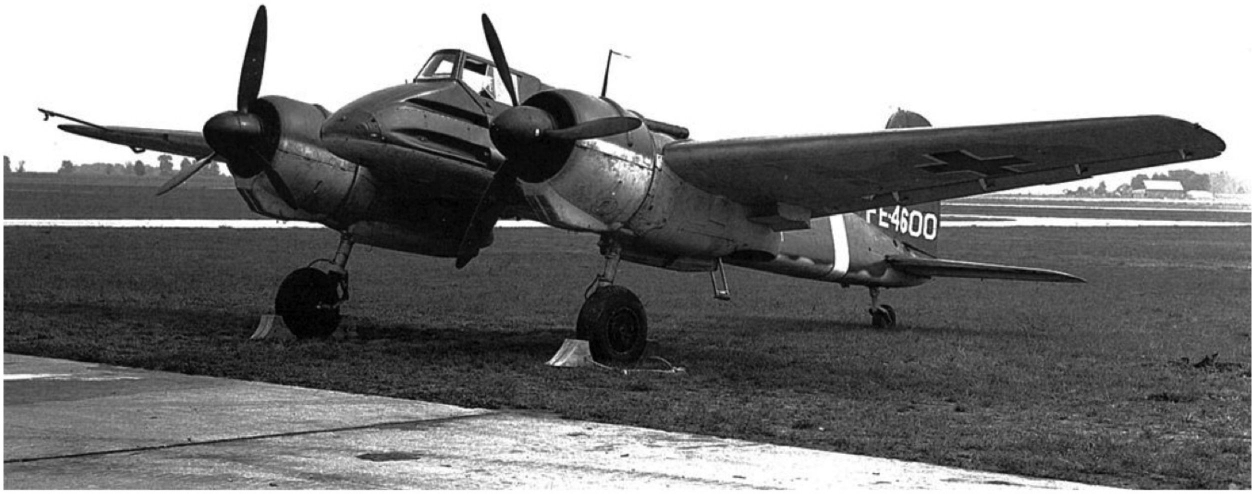

Junkers J.I armored ground-attack aircraft (1917)
Hugo Junkers and Otto Mader

Figure 9.31: In 1917, Otto Mader and Hugo Junkers created the first armored ground-attack aircraft, the Junkers J.I.

Henschel Hs 129 armored ground-attack aircraft (1939)



Equipped with 7.5 cm automatic antitank gun (1944)

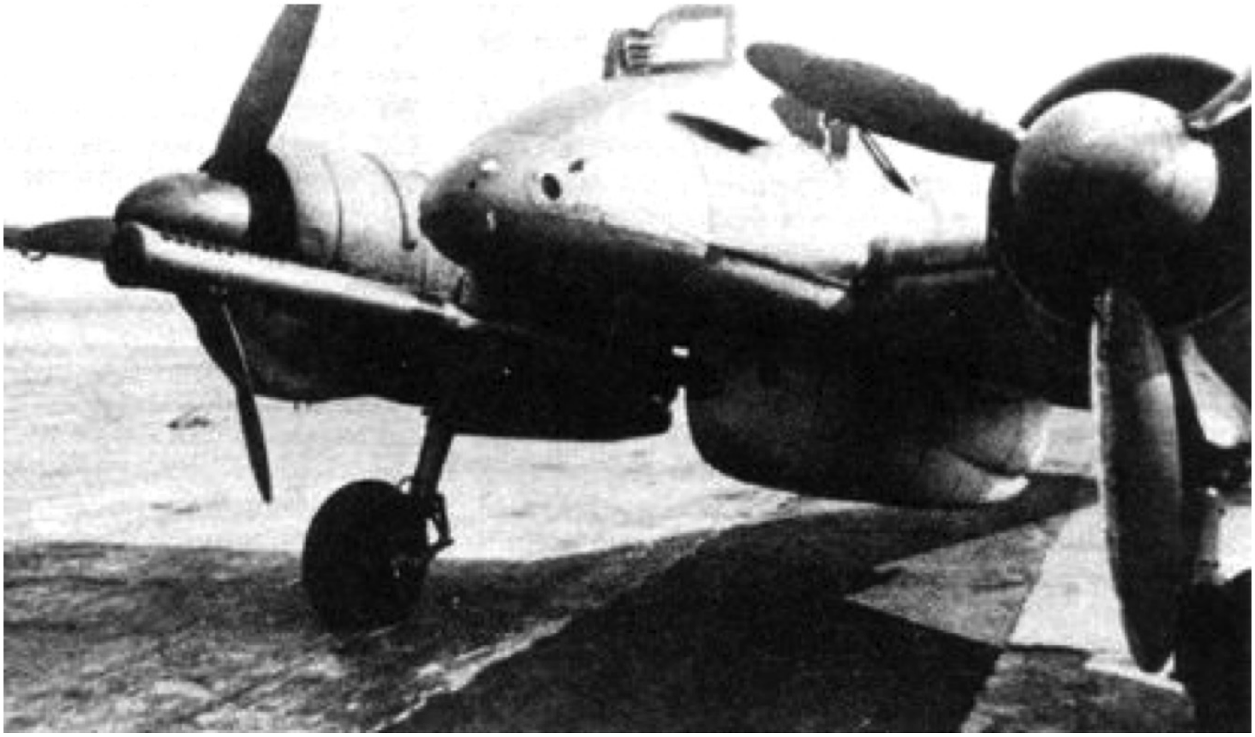
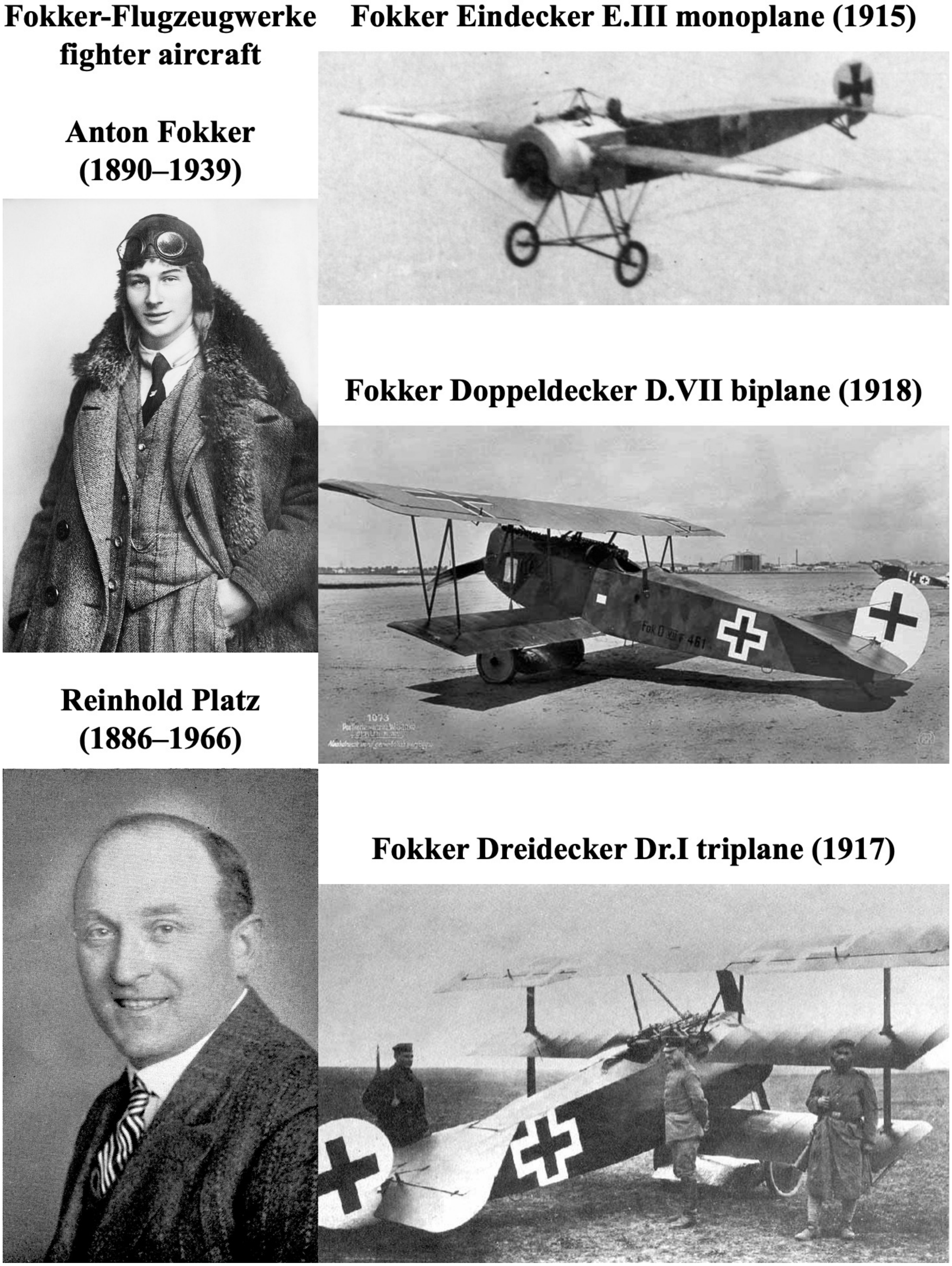


Figure 9.32: Henschel introduced the Hs 129 armored ground-attack aircraft in 1939, and equipped it with a 7.5 cm automatic antitank gun in 1944.



Fokker-Flugzeugwerke fighter aircraft

Fokker Eindecker E.III monoplane (1915)

Anton Fokker (1890–1939)

Fokker Doppeldecker D.VII biplane (1918)

Reinhold Platz (1886–1966)

Fokker Dreidecker Dr.I triplane (1917)

Figure 9.33: Anton Fokker and Reinhold Platz created monoplane, biplane, and triplane fighter aircraft during World War I.

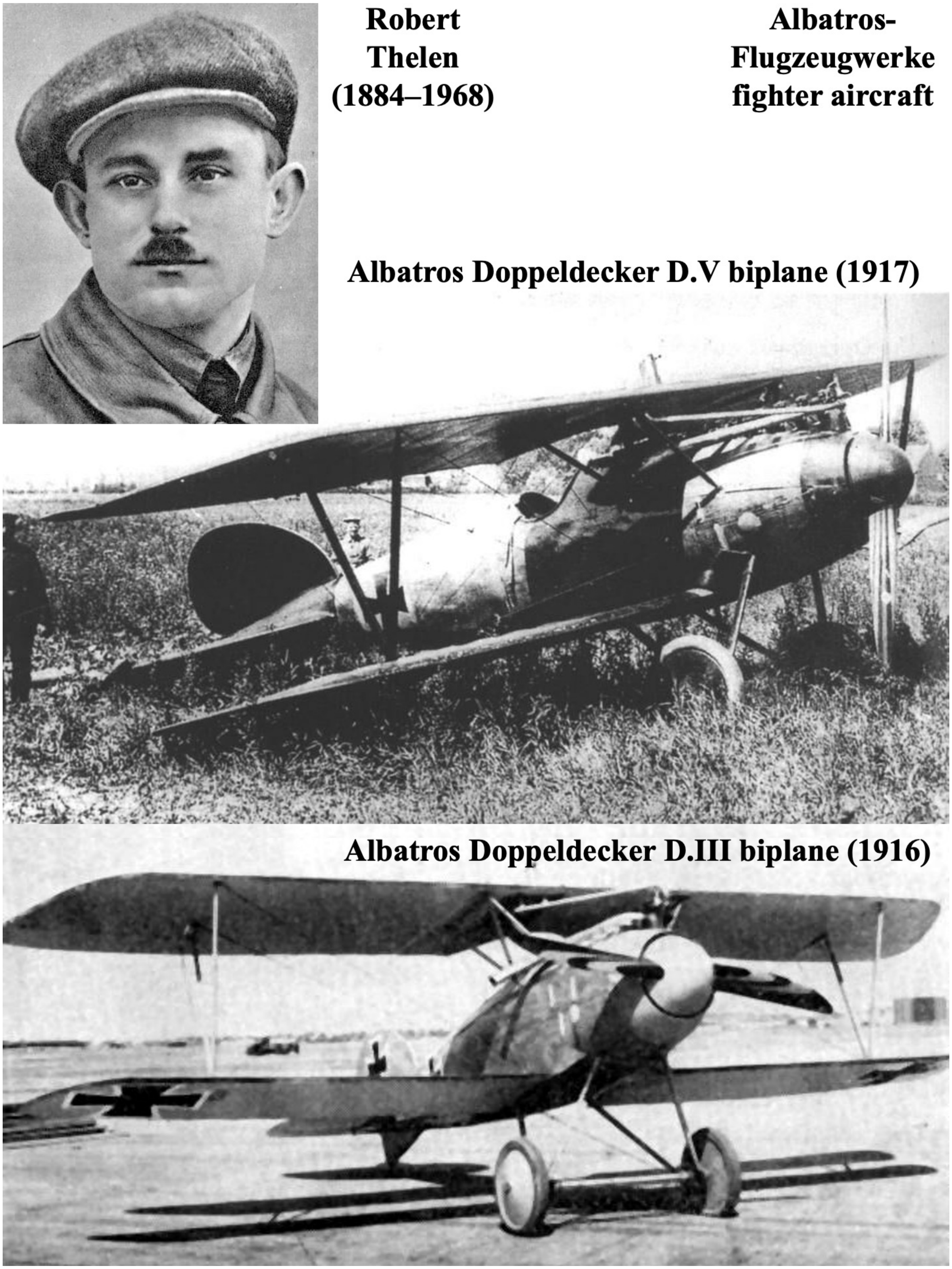

Robert
Thelen
(1884–1968)
Albatros-
Flugzeugwerke
fighter aircraft
Albatros Doppeldecker D.V biplane (1917)
Albatros Doppeldecker D.III biplane (1916)

Figure 9.34: Robert Thelen, the chief designer of Albatros-Flugzeugwerke, created biplane fighter aircraft during World War I.

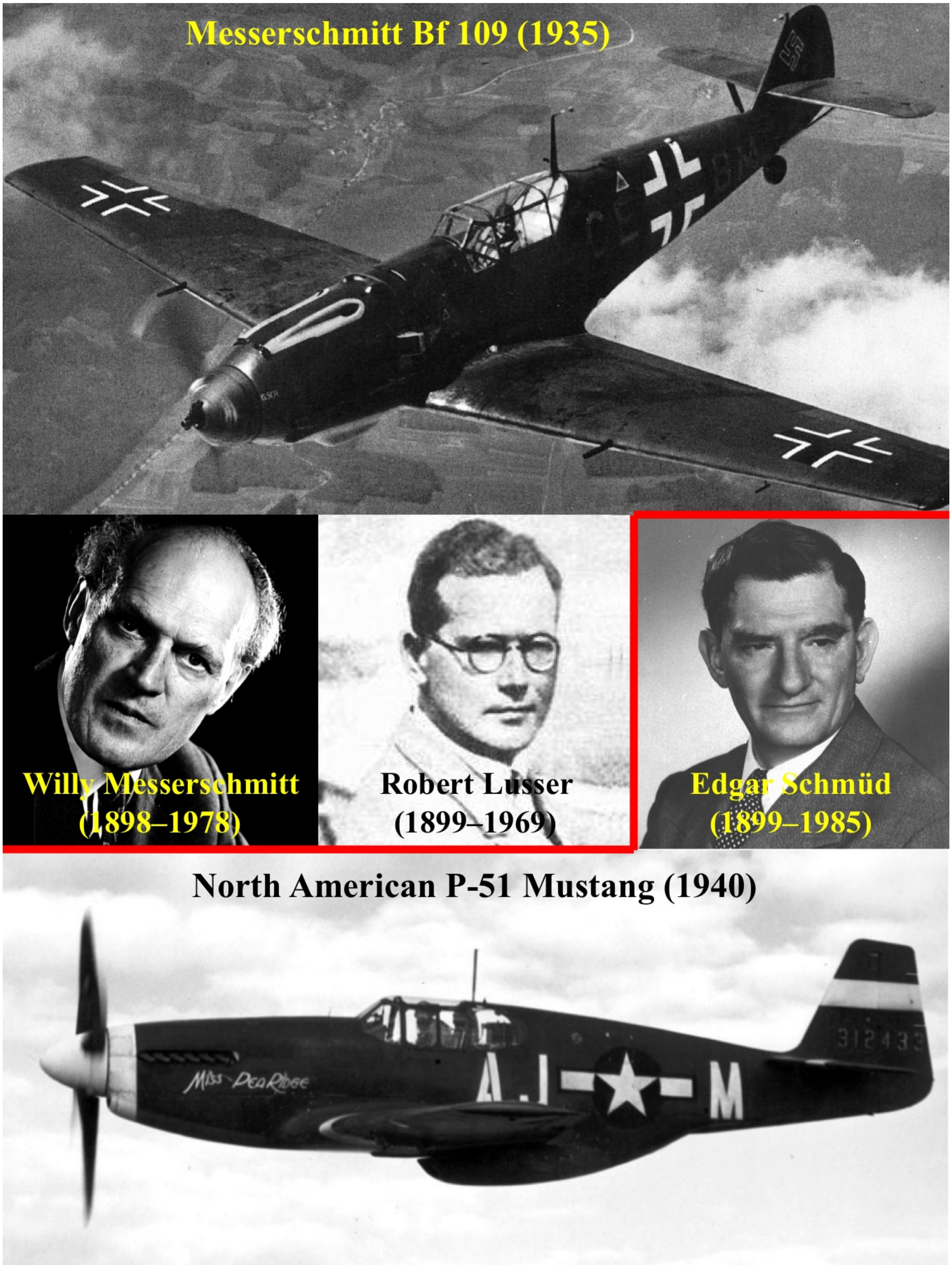
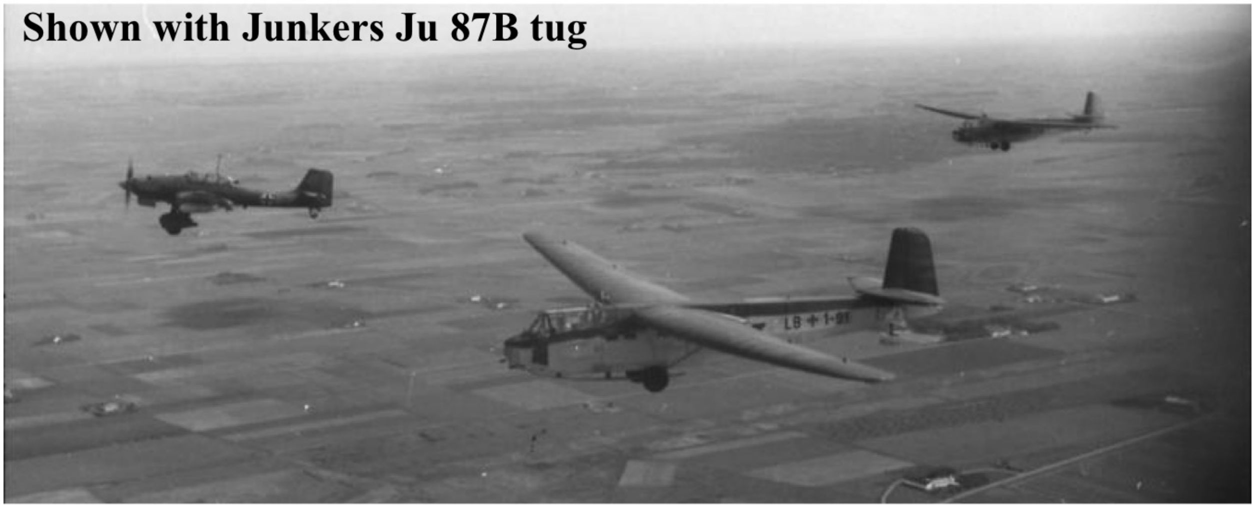

Messerschmitt Bf 109 (1935)
Willy Messerschmitt
(1898–1978)
Robert Lusser
(1899–1969)
Edgar Schmüd
(1899–1985)
North American P-51 Mustang (1940)

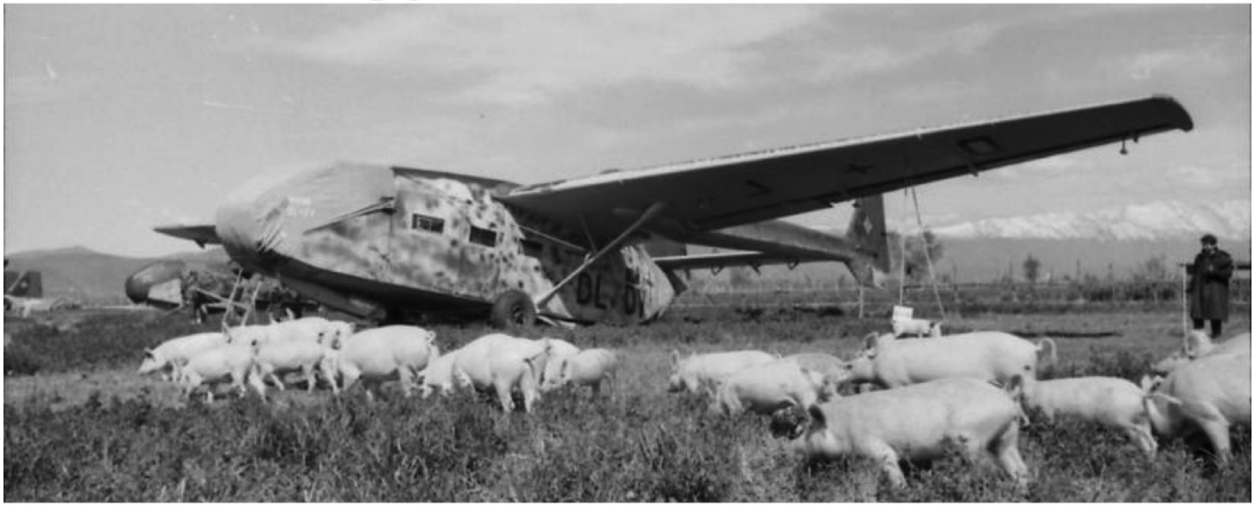
Figure 9.35: Willy Messerschmitt and Robert Lusser developed the Messerschmitt Bf 109 fighter (1935), which was extensively used by Germany until 1945. Edgar Schmüd, a German aircraft designer, immigrated to the United States. Using his knowledge, details of the Messerschmitt Bf 109, and other German design information, Schmüd developed the North American P-51 Mustang (1940), which was widely used by the United States and United Kingdom during the war.

DFS 230 troop glider (1937) **Hans Jacobs**



Shown with Junkers Ju 87B tug

Gotha Go 242 troop glider (1941) **Albert Kalkert**



Messerschmitt Me 321 Gigant cargo glider (1941)

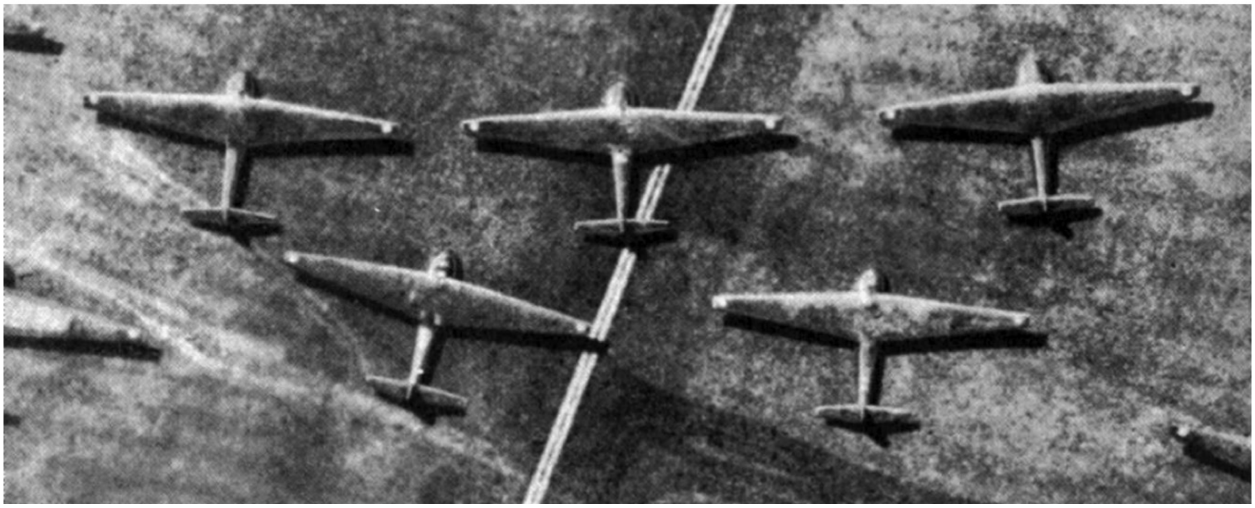
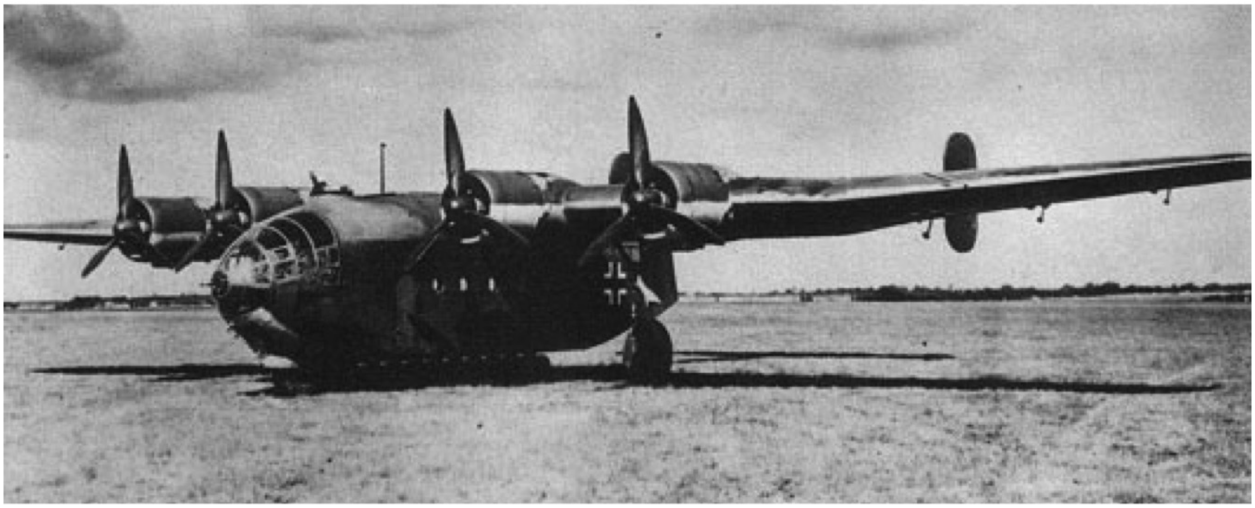
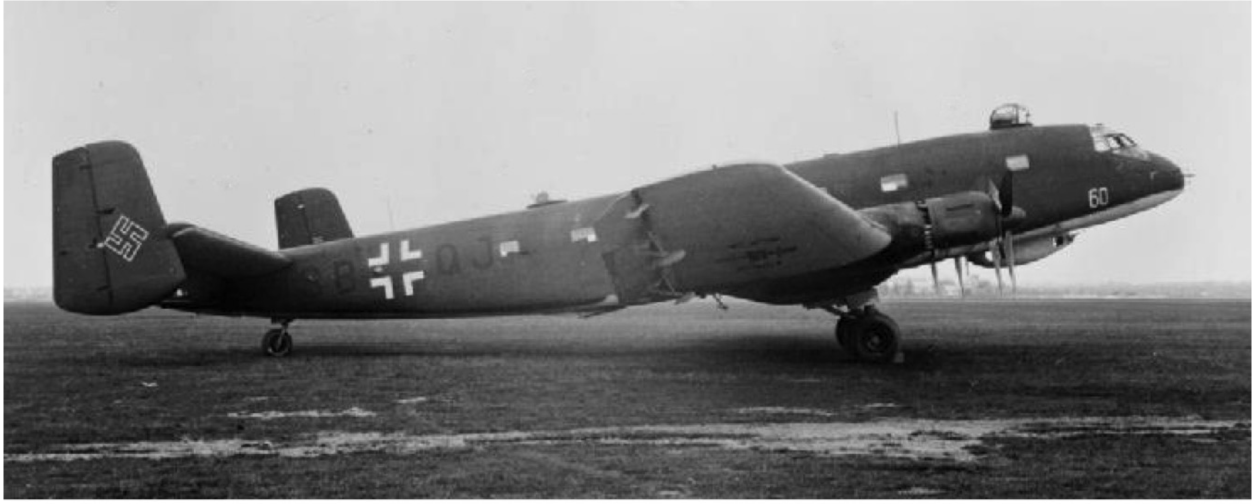


Figure 9.36: German-speaking engineers developed specialized gliders for military troops and cargo, such as the Deutsche Forschungsanstalt für Segelflug DFS 230, Gotha Go 242, and Messerschmitt Me 321 Gigant.

Arado Ar 232 cargo aircraft (1941)



Junkers Ju 290 cargo aircraft (1942) **Konrad Eicholtz**



Messerschmitt Me 323 Gigant cargo aircraft (1942)

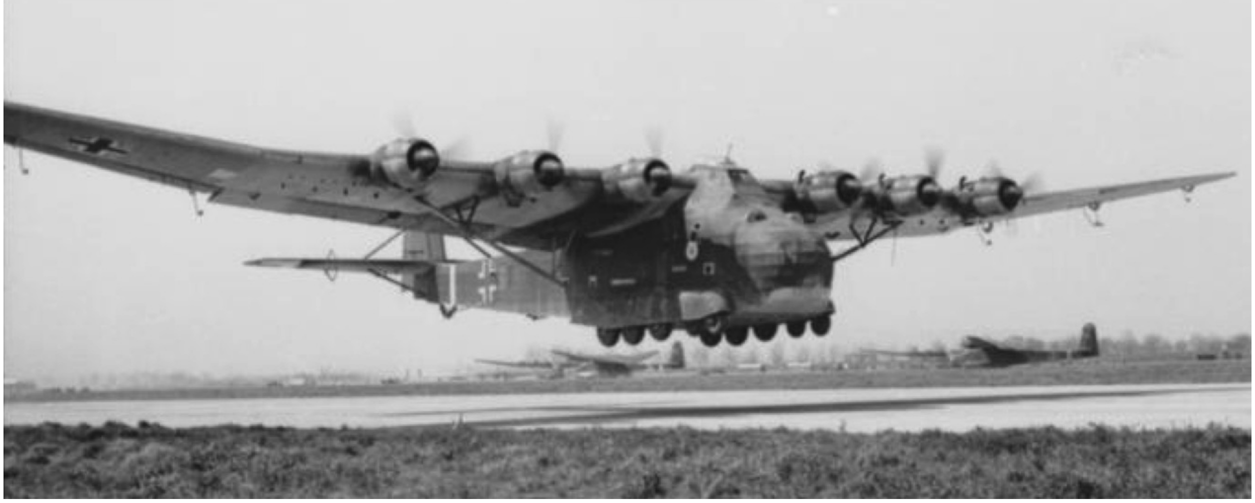
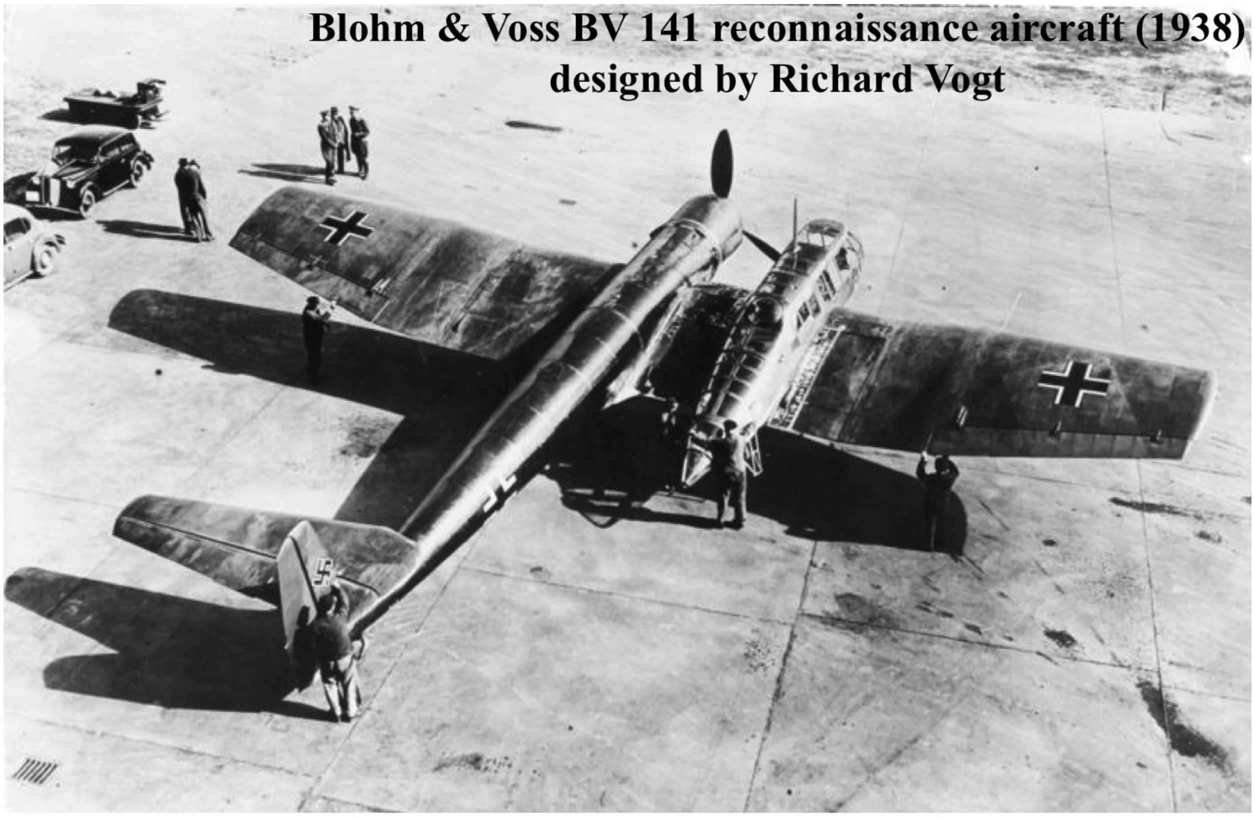


Figure 9.37: The Arado Ar 232 was the world's first special-purpose cargo aircraft, and was followed by the Junkers Ju 290 and Messerschmitt Me 323 Gigant.


Blohm & Voss BV 141 reconnaissance aircraft (1938)
designed by Richard Vogt

**Focke Wulf Fw 189 Uhu reconnaissance aircraft (1938)
designed by Kurt Tank**

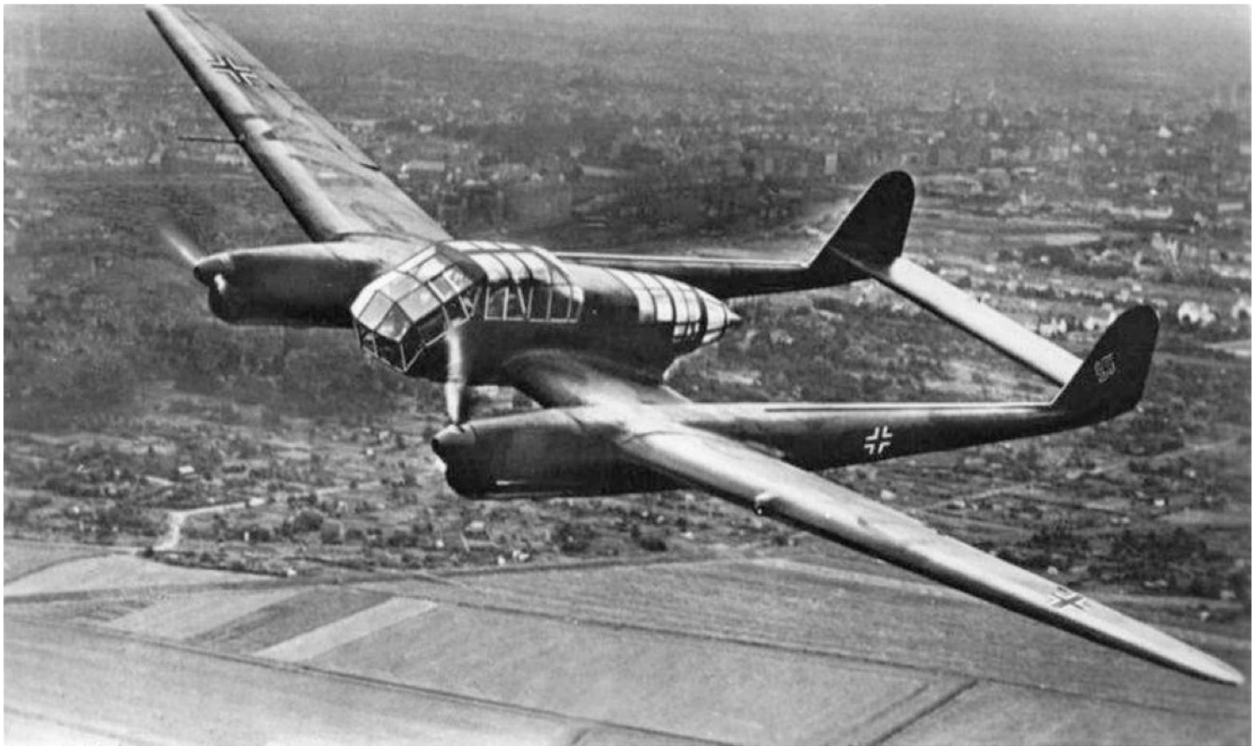
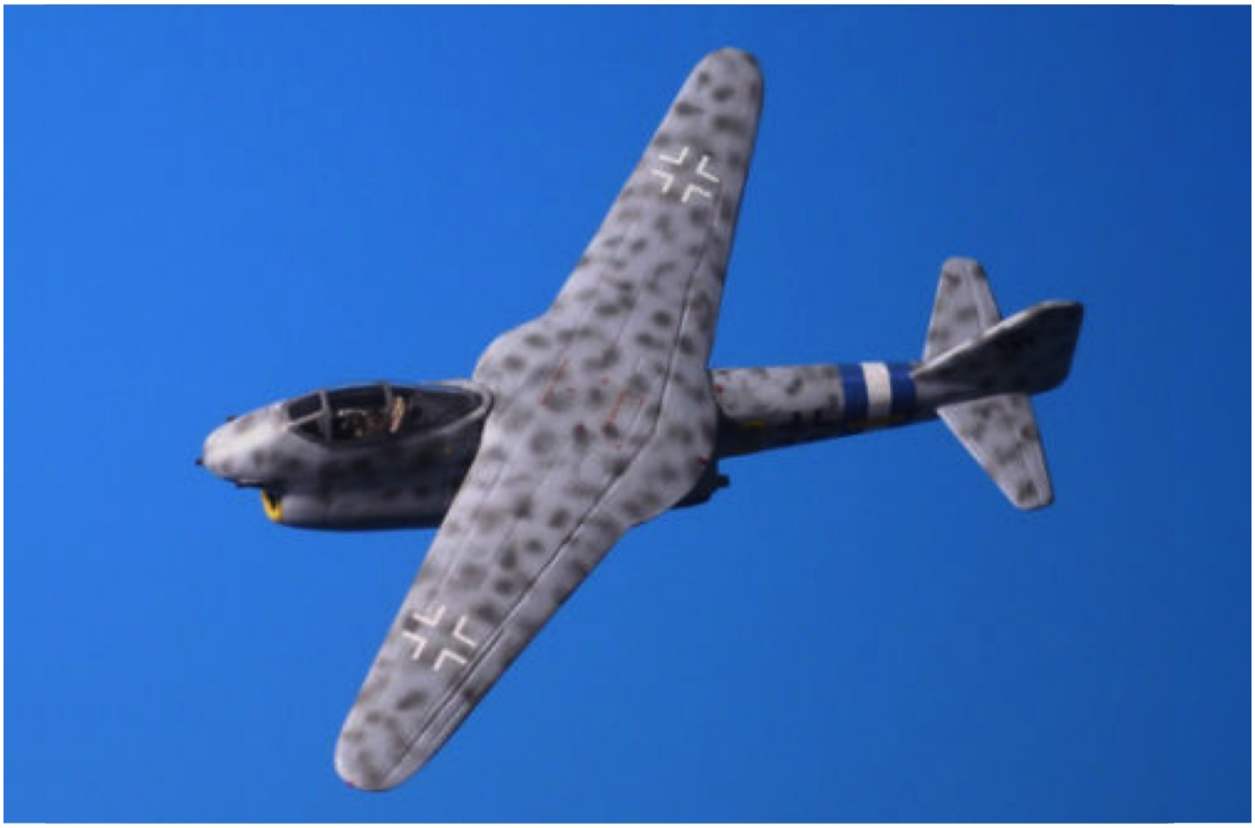
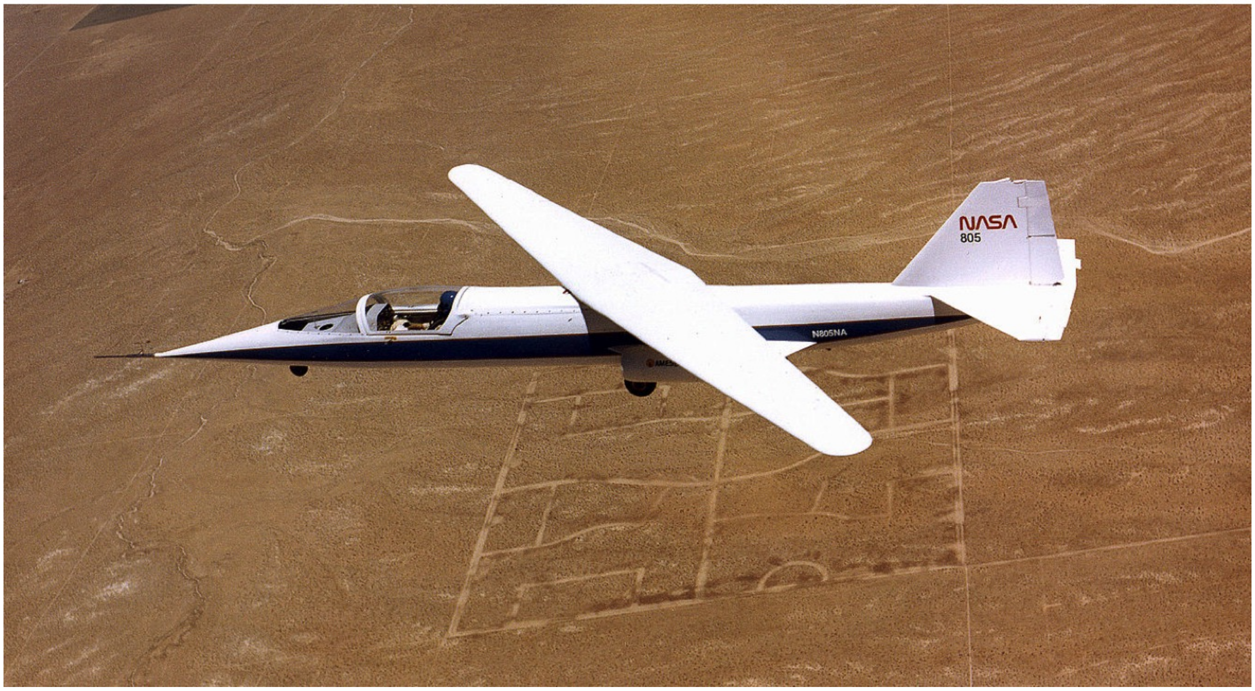


Figure 9.38: Examples of aircraft with highly creative airframe designs include Richard Vogt's Blohm & Voss BV 141 reconnaissance aircraft (1938) and Kurt Tank's Focke Wulf Fw 189 Uhu reconnaissance aircraft (1938).



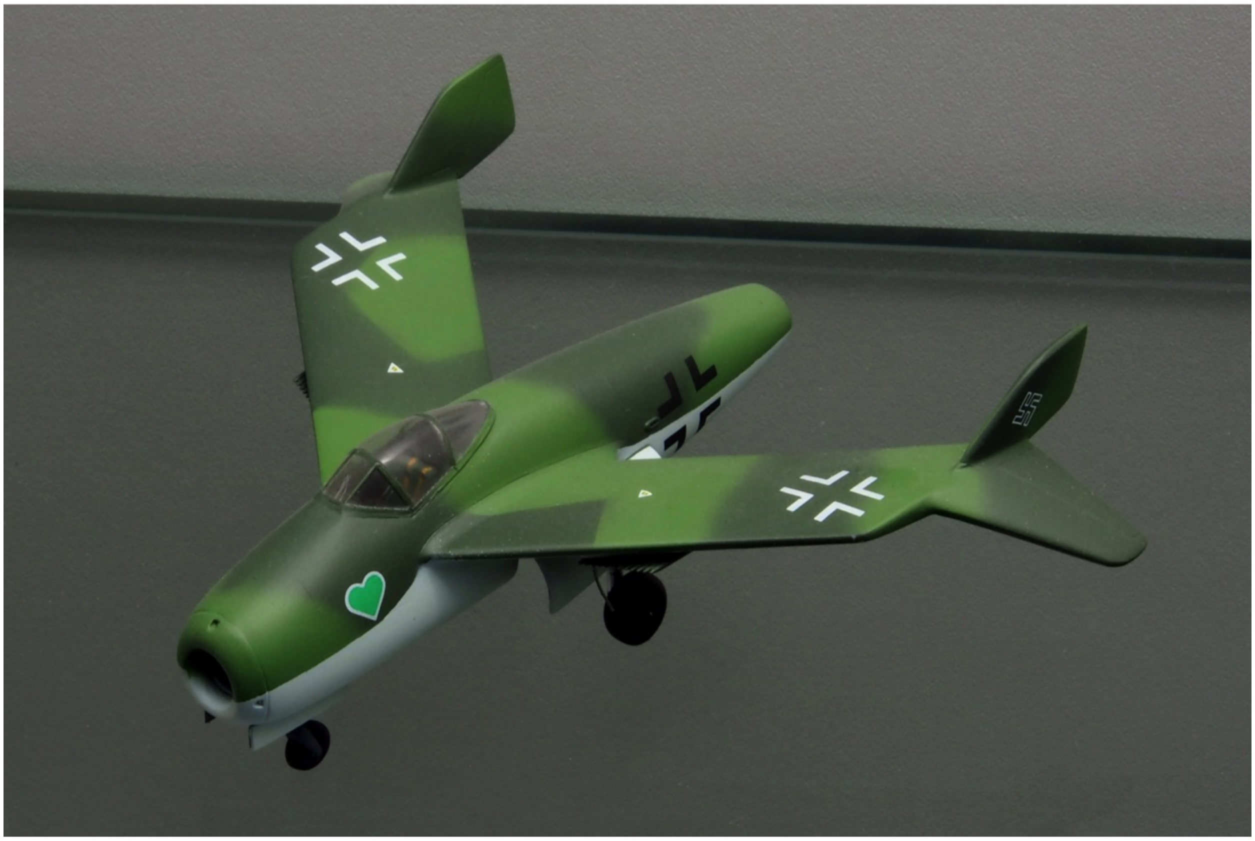
Blohm & Voss P 202 oblique wing aircraft (designed in 1944 by Richard Vogt)



NASA AD-1 oblique wing aircraft (1979)

Figure 9.39: Richard Vogt's 1944 design for the Blohm & Voss P 202 oblique wing aircraft directly inspired the design of the NASA AD-1 oblique wing aircraft, which was first flown in 1979.

Blohm & Voss P 212 (designed in 1945 by Richard Vogt)



Virgin Galactic SpaceShipTwo (first suborbital flight 2018)

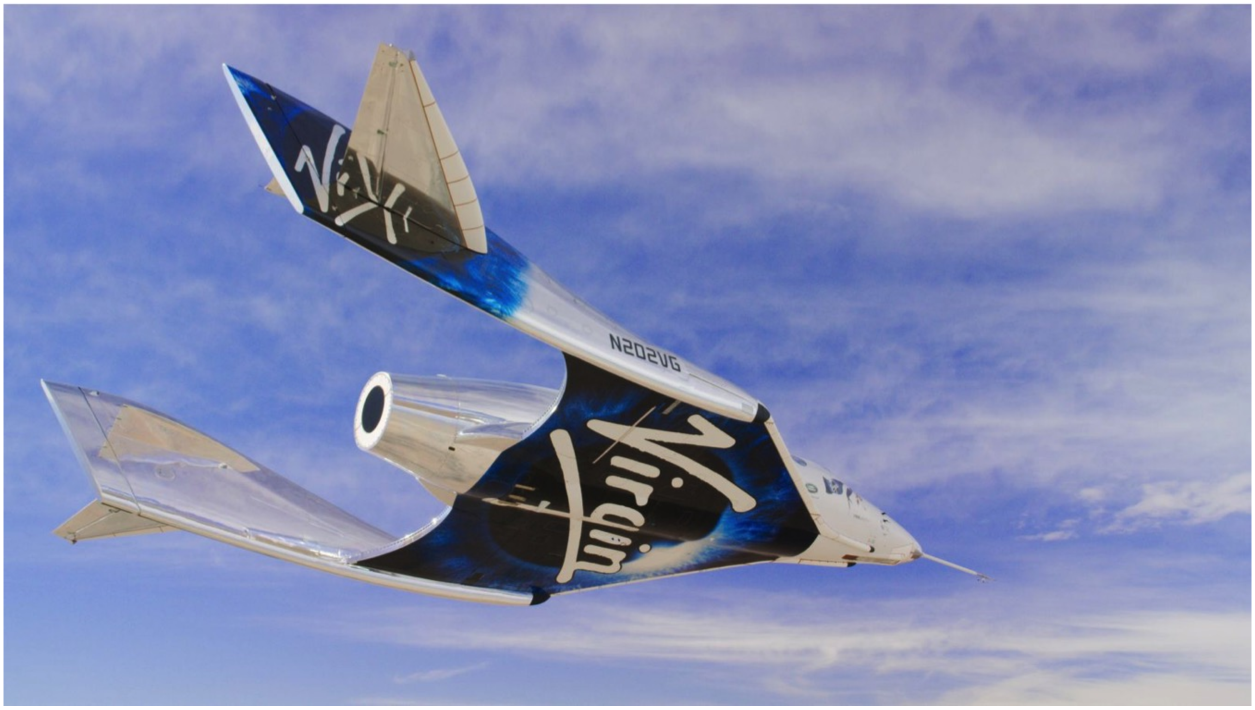


Figure 9.40: Richard Vogt's 1945 outboard tail swept-wing design for the Blohm & Voss P 212 appears to have directly inspired the design of the Virgin Galactic SpaceShipTwo, which made its first suborbital flight in 2018.

9.2.4 High-Speed Aircraft Design

Much of the German-speaking work before, during, and after World War II focused on the best aerodynamic shapes of aircraft wings and bodies. The best shapes and their performance characteristics depend on the speed of aircraft through the air, or equivalently the speed of airflow around the aircraft.

An airfoil is a cross-section through an aircraft wing along the direction of incoming flow (Fig. 9.41). Airfoils are usually cambered, with asymmetric upper and lower surfaces. For an angle of attack α between a surface and incoming flow, the force normal to the surface may be separated into drag and lift components. A cambered airfoil produces zero lift at a negative angle of attack $\alpha_{L=0}$, linearly increasing lift for increasing angles of attack, and decreasing lift (stalling) above α_{stall}. Its drag is much smaller but increases parabolically.

At very low speeds, airflow is not especially compressible—its density remains approximately constant. However, at higher and higher speeds, airflow becomes more and more compressible; the air gets squished when it suddenly runs into an object. No later than 1922, based on wind tunnel data and his own theoretical derivations, Ludwig Prandtl discovered mathematical rules that describe compressible flow around subsonic aircraft (Fig. 9.42). In 1928, Hermann Glauert (English, 1892–1934) independently (apparently) rediscovered Prandtl's equations for compressible flow around subsonic aircraft, so in the English-speaking world those equations are often called the Prandtl–Glauert transformation or method. (Incidentally, although Glauert was born in England, his parents were both German.)

In 1925, Jakob Ackeret (Swiss, 1898–1981), who was one of Prandtl's assistants at that time, found a way to extend Prandtl's compressible flow equations to cover supersonic speeds. Ackeret himself had a long and distinguished career in aerodynamics and wind tunnel experiments.

In 1935, Adolf Busemann (German, 1901–1986) used the compressible flow rules to design swept-wing aircraft. Busemann realized that the faster an aircraft goes, the more swept-back its wings should be, in order to maximize the aerodynamic lift and minimize the drag from the wings. Hubert Ludwieg confirmed the efficiency of the swept-wing design in wind tunnel tests, and then Albert Betz incorporated swept-back wings into several Messerschmitt aircraft. By the end of World War II, numerous German aerospace vehicles employed the swept-wing design (see for example pp. 1770, 1773–1775, 1842, 1912, 1922, 1926–1931), in stark contrast to Allied aircraft that continued through 1945 to use less efficient wings that stuck straight out to the sides. After the war, Busemann and other German-speaking aerodynamics experts helped to produce swept-wing aircraft, supersonic aircraft, and spacecraft in the United States.

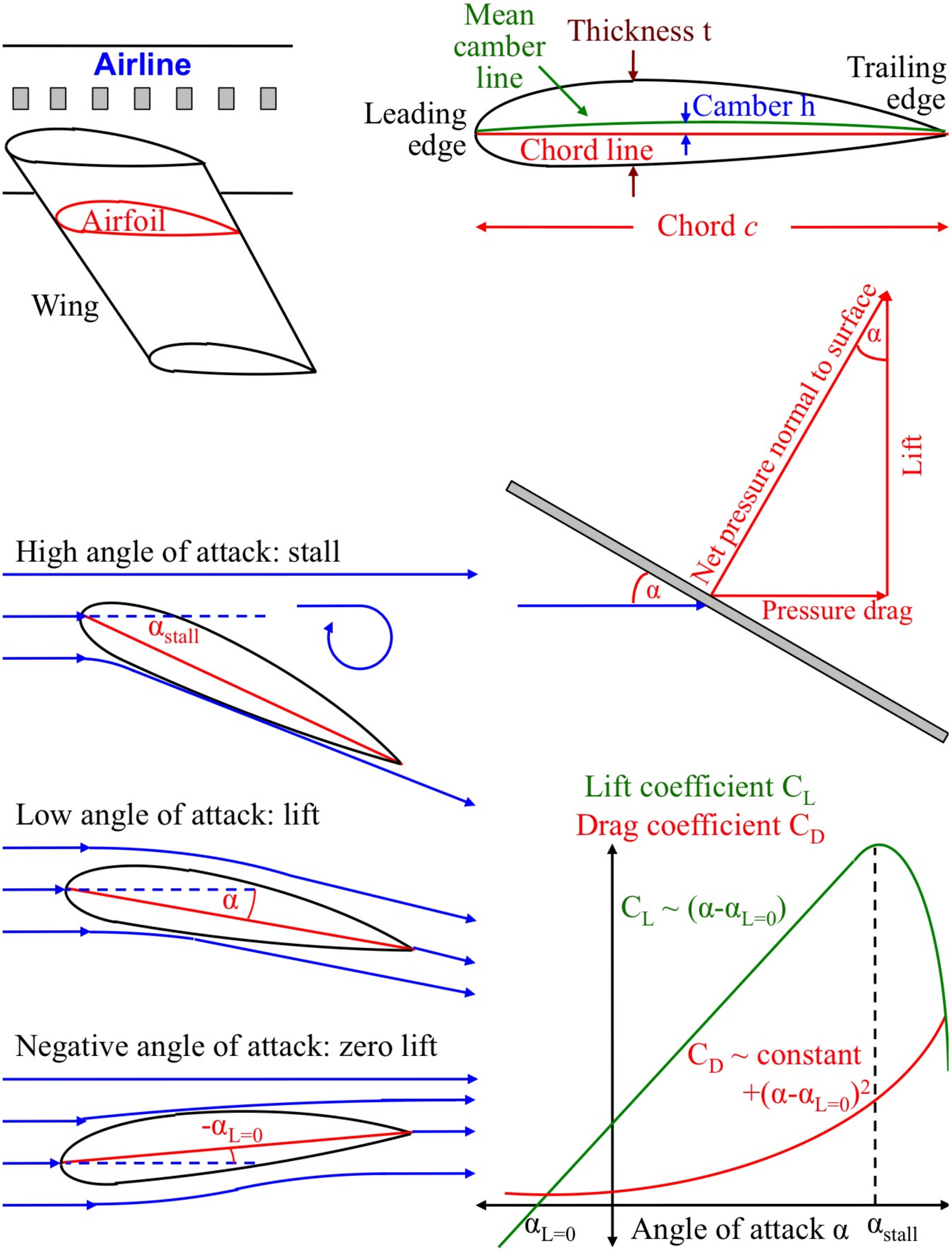

Airline
Airfoil
Wing
Mean camber line
Thickness t
Trailing edge
Leading edge
Camber h
Chord line
Chord c
Net pressure normal to surface
α
Lift
α
Pressure drag
High angle of attack: stall
α_{stall}
Low angle of attack: lift
α
Negative angle of attack: zero lift
$-\alpha_{L=0}$
Lift coefficient C_L
Drag coefficient C_D
$C_L \sim (\alpha-\alpha_{L=0})$
$C_D \sim$ constant $+(\alpha-\alpha_{L=0})^2$
$\alpha_{L=0}$
Angle of attack α
α_{stall}

Figure 9.41: An airfoil is a cross-section through an aircraft wing along the direction of incoming flow. Airfoils are usually cambered, with asymmetric upper and lower surfaces. For an angle of attack α between a surface and incoming flow, the force normal to the surface may be separated into drag and lift components. A cambered airfoil produces zero lift at a negative angle of attack $\alpha_{L=0}$, linearly increasing lift for increasing angles of attack, and decreasing lift (stalling) above α_{stall}. Its drag is much smaller but increases parabolically.

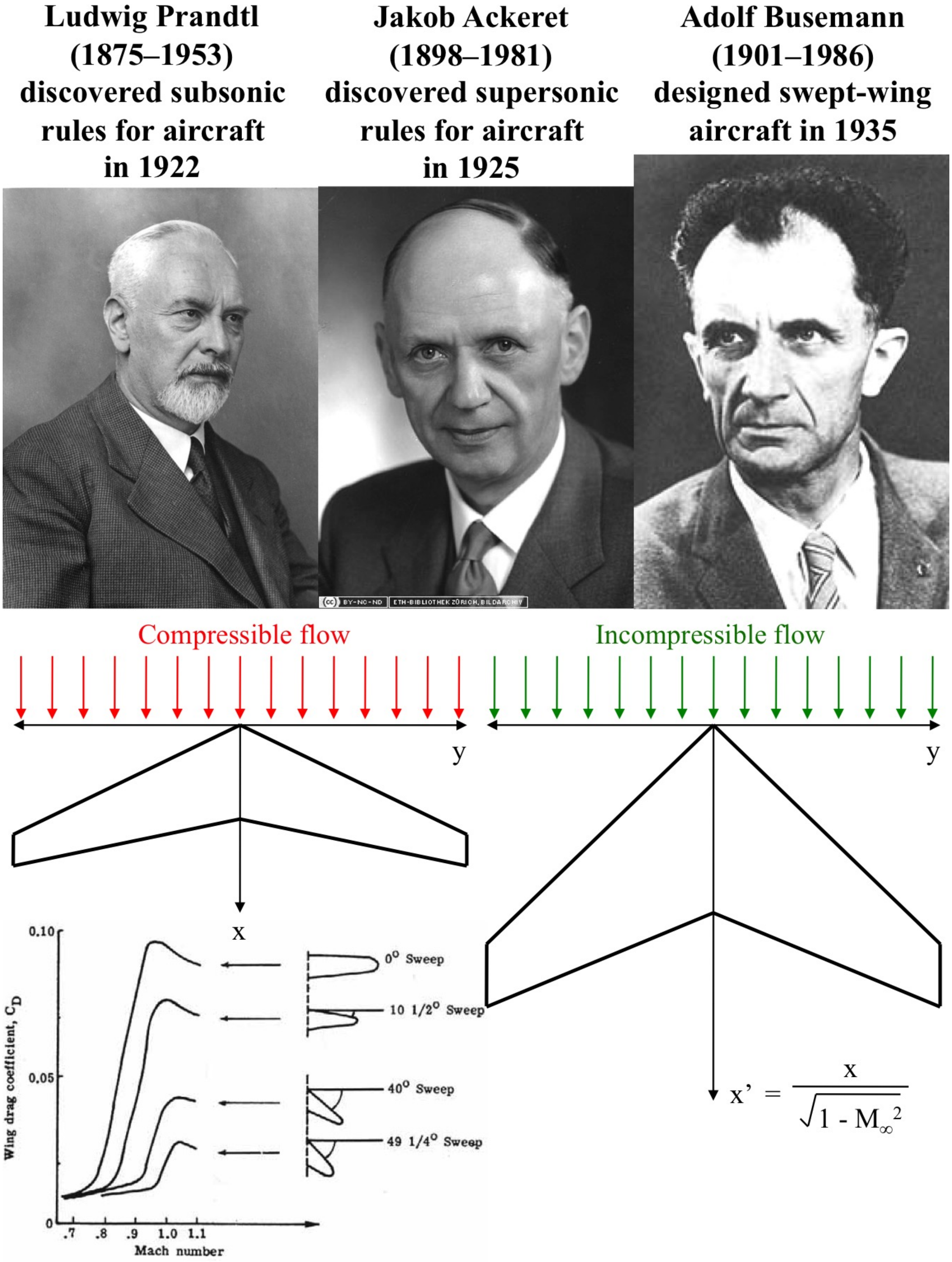

Ludwig Prandtl
(1875–1953)
discovered subsonic
rules for aircraft
in 1922
Jakob Ackeret
(1898–1981)
discovered supersonic
rules for aircraft
in 1925
Adolf Busemann
(1901–1986)
designed swept-wing
aircraft in 1935
(cc) BY-NC-ND ETH-BIBLIOTHEK ZÜRICH, BILDARCHIV
Compressible flow
Incompressible flow
y
y
x
x' = x / √(1 - M∞²)
0.10
0.05
0
Wing drag coefficient, C_D
.7 .8 .9 1.0 1.1
Mach number
0° Sweep
10 1/2° Sweep
40° Sweep
49 1/4° Sweep

Figure 9.42: Ludwig Prandtl discovered subsonic compressible-flow rules for aircraft in 1922, Jakob Ackeret extended them to supersonic speeds in 1925, and Adolf Busemann designed swept-wing aircraft in 1935.

Winglets (wing tips bent up and/or down) improve the efficiency of wings by reducing wing-tip vortices, the undesirable leakage of higher-pressure air below the wing to the lower-pressure region above the wing. The abstract idea of winglets dates back to even before powered flight (e.g., they are mentioned in an 1897 patent by Frederick Lanchester), but most of their experimental development and demonstration appears to have been conducted in the German-speaking world in the 1920s through the early 1940s. They were actively utilized in German aircraft such as the Hamburger Flugzeugbau Ha 137 (designed by Richard Vogt, first flown in 1935) and the Heinkel He 162 jet fighter (designed by Alexander Lippisch and others, first flown in 1944). See Figure 9.43. Some other examples of early German aircraft or aircraft designs with winglets included the Espenlaub-Lippisch E2 (1921), Fieseler F 3 Wespe (1932), DFS 193 (1936), Gotha Go 147 (1936), Lippisch Delta I (1930), Lippisch Delta III (1934), Lippisch Delta IV (1936), Lippisch Delta V (1937), etc.[6]

In 1940, Bernhard Göthert (German, 1907–1988) and K. A. Kawalki (Polish?, 19??–19??) developed and demonstrated supercritical airfoils or wings that enabled aircraft to travel at higher speeds with less drag, and ultimately to break the sound barrier with less difficulty (Fig. 9.44). Normally, the curvature of an airfoil makes airflow above the wing faster than flow below it, which in turn makes the air pressure lower above the airfoil that below it, creating a net upward lift force on the airfoil that keeps the aircraft aloft. For aircraft at high subsonic speeds, this effect can accelerate air above the wings to the speed of sound, creating a strong shock wave, a separated boundary layer, and higher drag. By making the upper surface of the wings flatter or supercritical, aircraft can travel closer to the speed of sound before high-drag transonic flow occurs. After the war, Göthert came to the United States, where he became chief scientist of the Air Force Systems Command and helped to develop everything from the Saturn V rocket to the F-111 fighter [https://www.latimes.com/archives/la-xpm-1988-04-01-mn-489-story.html].[6]

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[6] Despite abundant documentation for the invention, development, and demonstration of winglets, supercritical airfoils, and the area rule by these German-speaking creators, many history books [e.g., Anderson 1997] erroneously assign credit for all of these creations to a much later American, Richard Whitcomb (1921–2009). Whitcomb only had a bachelor's degree in engineering, but he seems to have had great ambitions to advance in his career. Whitcomb took a job at the NACA (later NASA) Langley Research Center where many of the German-speaking aerodynamics experts worked or visited after the war, and he stayed there until he chose early retirement in 1980.

After the war, Adolf Busemann worked at the Langley Research Center and gave detailed presentations summarizing earlier German work and knowledge about supersonic aerodynamics. Whitcomb is known to have attended at least one of Busemann's major talks on that topic in 1951. It appears that Whitcomb learned of the area rule from Busemann (or other German sources, such as the huge amount of documentation that NACA received on wartime German work—e.g., p. 1702) and then wrote a paper in 1952 announcing it as his own new discovery [Mack 1998, p. 138]. The principle has been known as the "Whitcomb area rule" ever since. Proper credit was not given to Frenzl and his colleagues who had actually developed and tested it a decade earlier, or even to scientists such as Busemann and Theodore von Kármán who guided the transfer of German aerodynamics knowledge to the United States.

Whitcomb also claimed and received credit for first developing supercritical airfoils in the 1960s. Recognition was not given to Göthert and Kawalki who had actually invented and demonstrated supercritical airfoils over 20 years earlier, or to the other German-speaking aerodynamics experts involved in transferring the information to the United States.

Then in the 1970s, Whitcomb claimed and received credit for developing winglets. Once again, no recognition was given to the German-speaking aerodynamics experts who had actually conducted or transferred that work.

For all of his alleged inventions, Whitcomb was showered with national awards and became a department head at the Langley Research Center. Most of the German-speaking creators who had actually developed, demonstrated, and transferred those technologies died in obscurity.

Downward folding wingtips for compression lift appear similar to winglets but serve a different purpose. Folding wingtips (such as those on the XB-70 Valkyrie, pp. 1754–1755) catch part of the shock waves of a supersonic aircraft and increase the under-wing pressure to increase lift. Officially that was discovered in the United States in the 1950s. Yet that feature was already present in wartime German jet designs (e.g., Heinkel He P.1078 A and B versions, p. 5224) and it resurfaced in the XB-70, which was heavily reliant on German expertise (p. 1750). More archival research should be conducted to determine how much work on compression lift was conducted in wartime Germany, and how much that work influenced postwar projects in the United States and other countries.

Otto Frenzl (Austrian, 1909–1996) discovered the area rule for supersonic flight in 1943 and filed a patent on it with aircraft designers Heinrich Hertel (German, 1901–1982) and Werner Hempel (German, 1910–??). If airflow moving near or above the speed of sound longitudinally down a vehicle encounters a sudden change in the vehicle's cross-sectional area, the flow cannot easily move out of the way; it is forcibly compressed or rarified and may separate from the vehicle's surface or create a shock wave. By keeping the cross-sectional area relatively constant down the length of a vehicle, one can avoid such effects and thereby minimize the drag coefficient. For example, an aircraft's body should begin to narrow at the point where wings begin, as shown in Fig. 9.45. This was a critical discovery for creating aircraft that could easily break the sound barrier to move from subsonic to supersonic speeds. After the war, Frenzl and Hertel developed aircraft in France and West Germany, and Hempel worked for the Soviet Union. Theodor Zobel confirmed the area rule in wartime Germany and continued his work in the United States after the war (Fig. 9.26).[6]

The advantages of blunt leading surfaces for atmospheric reentry, in order to create detached shock waves and reduce vehicle heating, were discovered, analyzed, and advocated by Rudolf Hermann (German, 1904–1991, Fig. 9.24), Adolf Busemann (Fig. 9.42), and Gottfried Guderley (German, 1910–1997, Fig. 8.36) during World War II [NARA RG 319, Entry NM3-82, Box 1568, HEC 842]. This information was transferred to U.S. and U.K. officials in 1945–1946 interrogations of the German experts, and it was subsequently exploited in postwar U.S. and U.K. aerospace programs. See Figs. 9.46–9.47.[7] Most conventional English-language histories erroneously ascribe the original discovery of these principles to Harry Julian Allen, an American bureaucrat at NACA, in the 1950s [e.g., Anderson 1997], long after the actual discovery and official transfer.

Sighard Hoerner (German, 1906–1971, Fig. 9.48) conducted aerodynamics research in Germany during World War II and in the United States after the war. He strongly promoted the use of advanced German aerodynamics insights and aircraft design principles in the postwar United States.

Alexander Lippisch (German, 1894–1976, Fig. 9.49) applied high-speed aerodynamics to aircraft design and had an enormous impact over his long career. He proposed and strongly advocated for delta-wing designs, winglets, and tailless aircraft, and he influenced other wartime designs (such as those of the Horten brothers, pp. 1768, 1773–1774) and postwar designs (such as the Avro Vulcan, p. 5226). He also invented and demonstrated rocket planes (pp. 1920, 1922–1923, 1926).

Similarly, Hans Multhopp (German, 1913–1972, Fig. 9.49) applied the principles of high-speed aerodynamics to develop very advanced prototype jet aircraft (such as the Focke-Wulf Ta 183, p. 1775) in Germany during the war, and jet fighters and lifting bodies (subscale prototypes for the later U.S. Space Shuttle—see p. 1933) in the United States after the war.

Dietrich Küchemann (German, 1911–1976) and Johanna Weber (German, 1910–2014), shown in Fig. 9.50, also did extensive work on supersonic aerodynamics during World War II. After the war, they both moved to the United Kingdom and played key roles in the postwar development of supersonic aircraft such as Concorde passenger plane and Victor jet bomber, as well as subsonic aircraft such as the Airbus A300.

---

[7] Figures 9.46–9.47 show excerpts from HEC 842, rough notes made by the Allied interrogators of the German experts. The German experts clearly specified a blunt nose with a detached shock, and the Allied interrogators revealed their own ignorance by continuing to draw a sharp nose. Can the more polished final Allied reports be found? Can the original German documents be found? The initial German discovery was Rudolf Hermann's experimental measurements of the best reentry vehicle shapes for German long-range missiles in the hypersonic wind tunnel of the Heeresversuchsanstalt. Adolf Busemann and Gottfried Guderley provided the theoretical analysis and applications of those results.

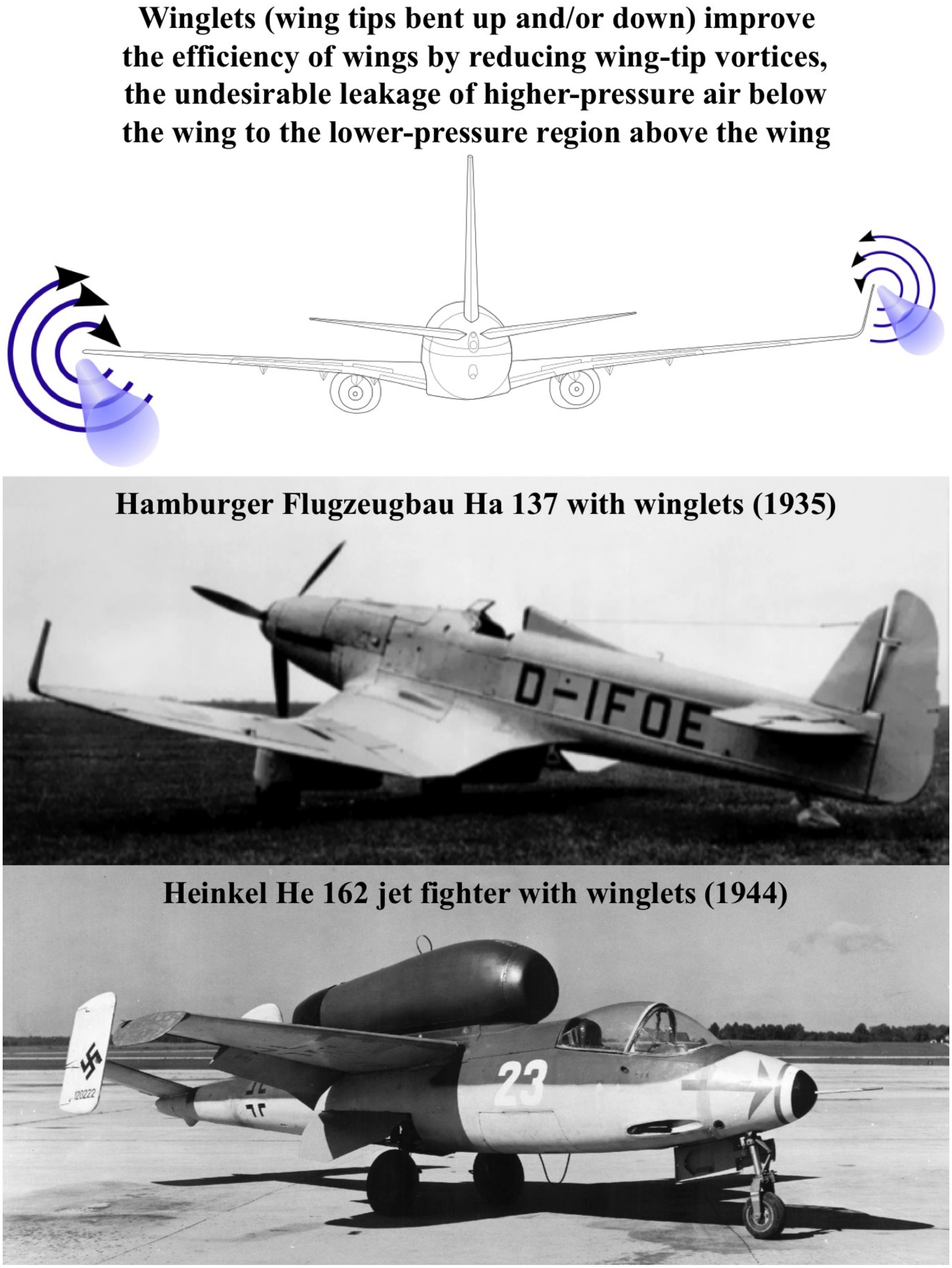
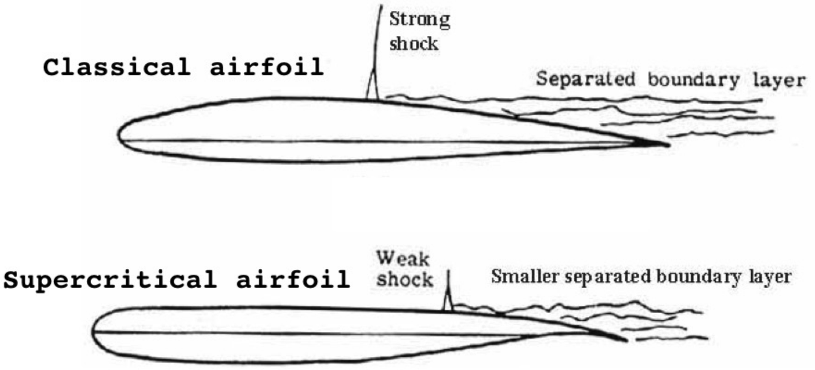

Winglets (wing tips bent up and/or down) improve the efficiency of wings by reducing wing-tip vortices, the undesirable leakage of higher-pressure air below the wing to the lower-pressure region above the wing
Hamburger Flugzeugbau Ha 137 with winglets (1935)
D-IFOE
Heinkel He 162 jet fighter with winglets (1944)
23
120222

Figure 9.43: Winglets (wing tips bent up and/or down) improve the efficiency of wings by reducing wing-tip vortices, the undesirable leakage of higher-pressure air below the wing to the lower-pressure region above the wing. Examples of German aircraft that employed winglets included the Hamburger Flugzeugbau Ha 137 (1935) and the Heinkel He 162 jet fighter (1944).

Bernhard Göthert (1907–1988) **K. A. Kawalki (??–??)**

Developed supercritical airfoils for high speeds 1940–1944


Strong shock
Classical airfoil
Separated boundary layer
Weak shock
Supercritical airfoil
Smaller separated boundary layer

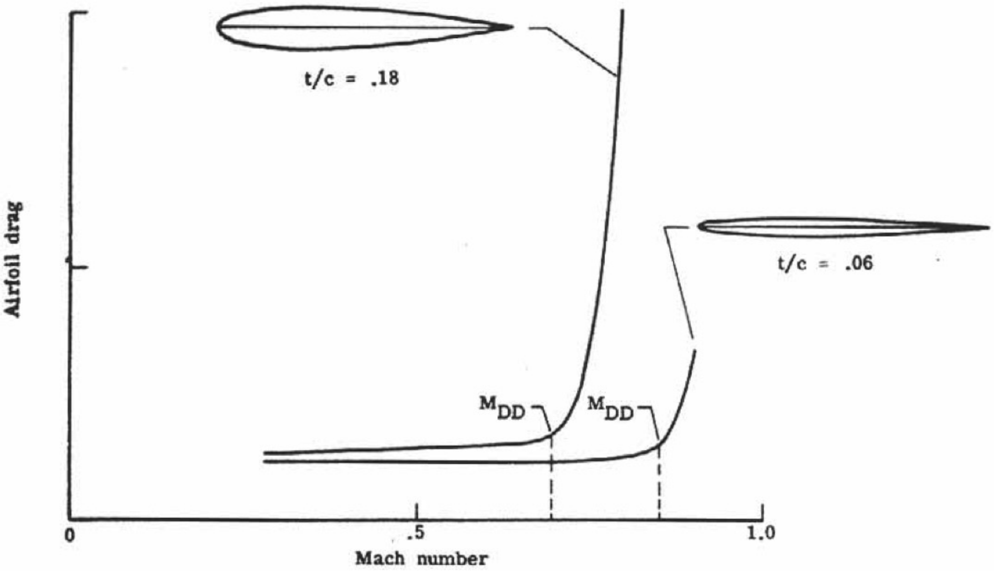


Figure 9.44: Bernhard Göthert and K. A. Kawalki developed supercritical airfoils for high-speed aircraft in 1940.

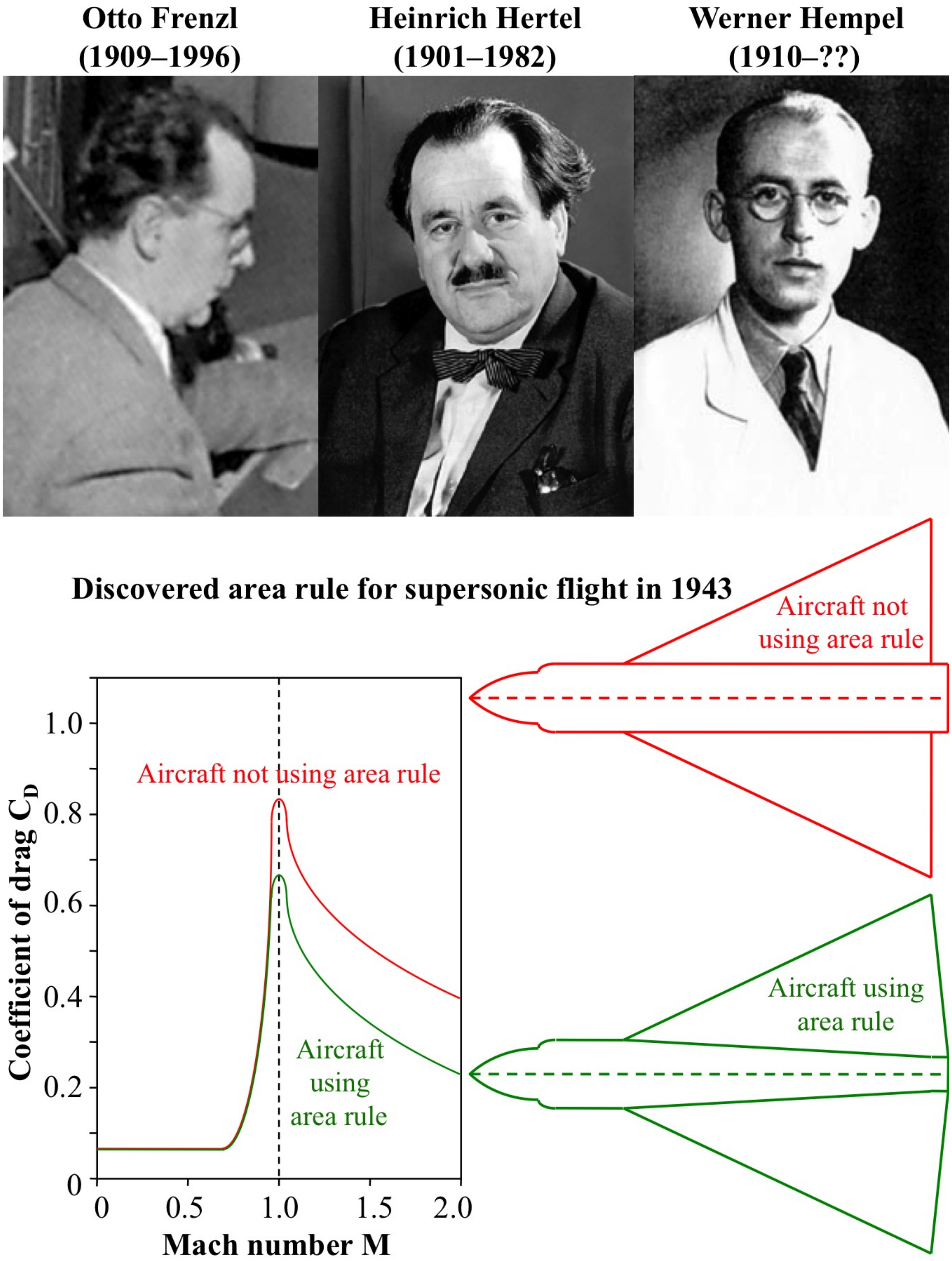
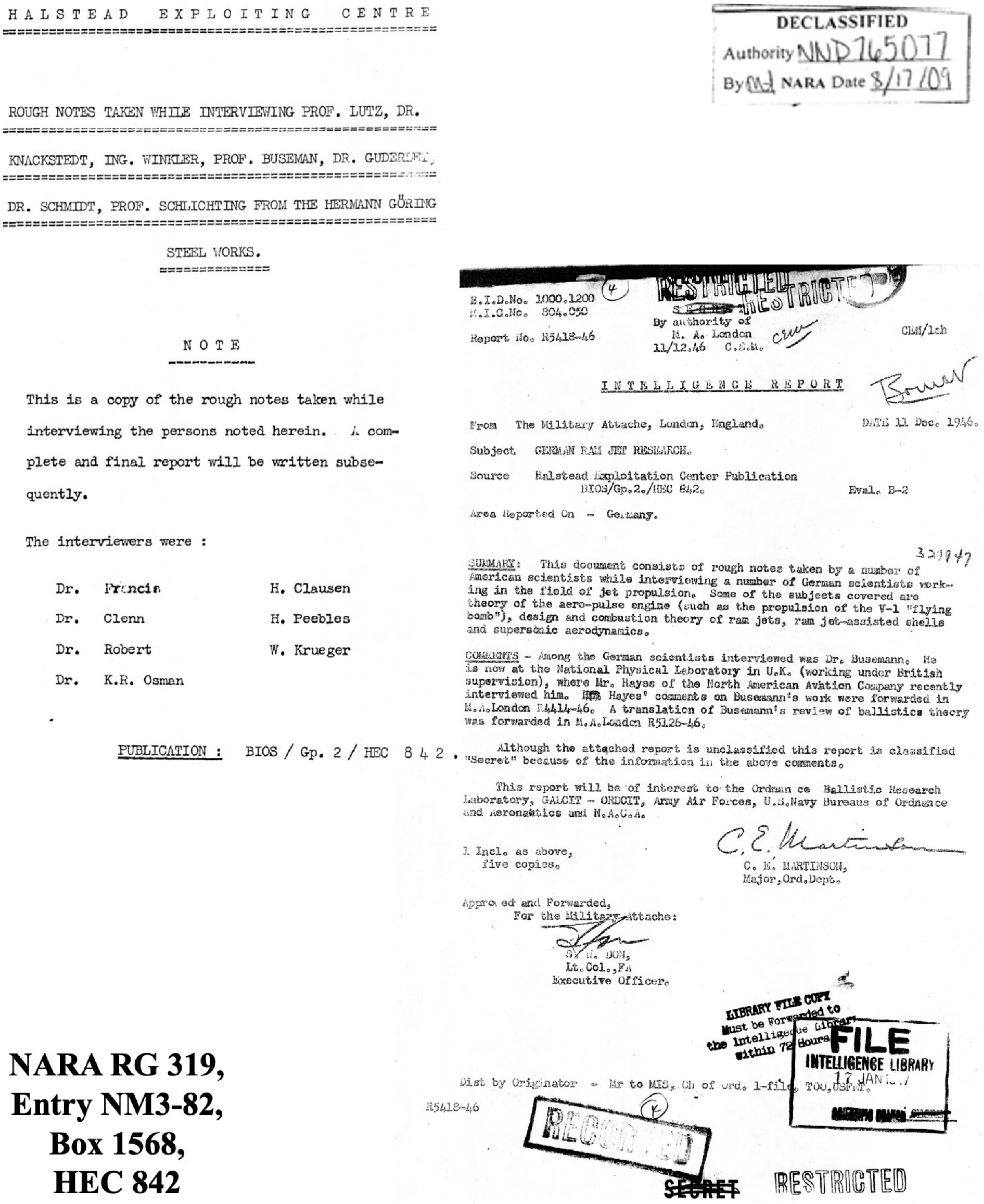


Figure 9.45: Otto Frenzl discovered the area rule for supersonic flight in 1943 and filed a patent on it with aircraft designers Heinrich Hertel and Werner Hempel.



HALSTEAD EXPLOITING CENTRE

ROUGH NOTES TAKEN WHILE INTERVIEWING PROF. LUTZ, DR. KNACKSTEDT, ING. WINKLER, PROF. BUSEMAN, DR. GUDERLEY, DR. SCHMIDT, PROF. SCHLICHTING FROM THE HERMANN GÖRING STEEL WORKS.

NOTE

This is a copy of the rough notes taken while interviewing the persons noted herein. A complete and final report will be written subsequently.

The interviewers were :

Dr. Francis
Dr. Clenn
Dr. Robert
Dr. K.R. Osman
H. Clausen
H. Peebles
W. Krueger

PUBLICATION : BIOS / Gp. 2 / HEC 8 4 2 .

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Authority NND765077
By NARA Date 8/17/09

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M. A. London
11/12.46 C.E.M. CEM

B.I.D.No. 1000.1200 (4)
M.I.G.No. 804.050
Report No. R5418-46

CEM/lah

INTELLIGENCE REPORT

Bower

From The Military Attache, London, England. DATE 11 Dec. 1946.

Subject GERMAN RAM JET RESEARCH.

Source Halstead Exploitation Center Publication BIOS/Gp.2./HEC 842. Eval. B-2

Area Reported On - Germany.

329947

SUMMARY: This document consists of rough notes taken by a number of American scientists while interviewing a number of German scientists working in the field of jet propulsion. Some of the subjects covered are theory of the aero-pulse engine (such as the propulsion of the V-1 "flying bomb"), design and combustion theory of ram jets, ram jet-assisted shells and supersonic aerodynamics.

COMMENTS - Among the German scientists interviewed was Dr. Busemann. He is now at the National Physical Laboratory in U.K. (working under British supervision), where Mr. Hayes of the North American Avation Company recently interviewed him. Hayes' comments on Busemann's work were forwarded in M.A.London R4414-46. A translation of Busemann's review of ballistics theory was forwarded in M.A.London R5126-46.

Although the attached report is unclassified this report is classified "Secret" because of the information in the above comments.

This report will be of interest to the Ordnan ce Ballistic Research Laboratory, GALCIT - ORDCIT, Army Air Forces, U.S.Navy Bureaus of Ordnance and Aeronautics and N.A.C.A.

1 Incl. as above,
five copies.

C. E. Martinson
C. E. MARTINSON,
Major,Ord.Dept.

Approved and Forwarded,
For the Military Attache:

S. W. DON,
Lt.Col.,FA
Executive Officer.

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NARA RG 319, Entry NM3-82, Box 1568, HEC 842

Figure 9.46: The advantages of blunt leading surfaces for atmospheric reentry, in order to create detached shock waves and reduce vehicle heating, were discovered, analyzed, and advocated by Rudolf Hermann, Adolf Busemann, and Gottfried Guderley during World War II, then transferred to the U.S. and U.K. after the war [NARA RG 319, Entry NM3-82, Box 1568, HEC 842].

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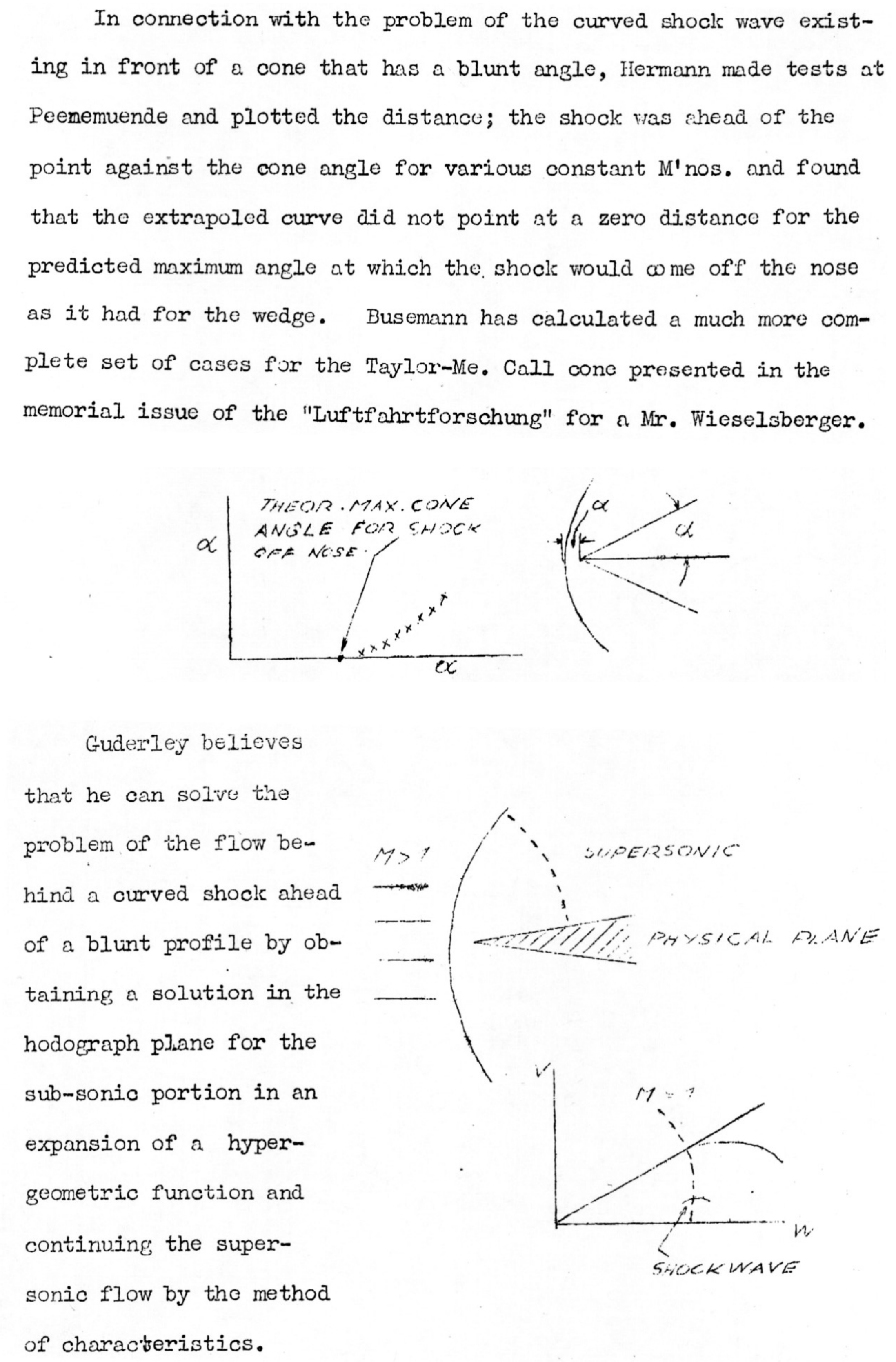
By NARA Date 8/17/09



In connection with the problem of the curved shock wave existing in front of a cone that has a blunt angle, Hermann made tests at Peenemuende and plotted the distance; the shock was ahead of the point against the cone angle for various constant M'nos. and found that the extrapoled curve did not point at a zero distance for the predicted maximum angle at which the shock would come off the nose as it had for the wedge. Busemann has calculated a much more complete set of cases for the Taylor-Mc. Call cone presented in the memorial issue of the "Luftfahrtforschung" for a Mr. Wieselsberger.

Guderley believes that he can solve the problem of the flow behind a curved shock ahead of a blunt profile by obtaining a solution in the hodograph plane for the sub-sonic portion in an expansion of a hypergeometric function and continuing the supersonic flow by the method of characteristics.

NARA RG 319, Entry NM3-82,
Box 1568, HEC 842, pp. 10, 17

Figure 9.47: The advantages of blunt leading surfaces for atmospheric reentry, in order to create detached shock waves and reduce vehicle heating, were discovered, analyzed, and advocated by Rudolf Hermann, Adolf Busemann, and Gottfried Guderley during World War II, then transferred to the U.S. and U.K. after the war [NARA RG 319, Entry NM3-82, Box 1568, HEC 842, pp. 10, 17].

Sighard Hoerner (1906–1971) conducted aerodynamics research in Germany during World War II and in the United States after the war. He was an important conduit for the transfer of advanced German knowledge about aerodynamics and aircraft design.

FLUID-DYNAMIC DRAG

theoretical, experimental and statistical information
presented by Dr.-Ing. S. F. HOERNER
1965

FLUID-DYNAMIC LIFT

Information on Lift and its Derivatives,
in Air and in Water
presented by Dr.-Ing. S. F. HOERNER
Co-author and Editor
H. V. BORST
1975

Figure 9.48: Sighard Hoerner (1906–1971) conducted aerodynamics research in Germany during World War II and in the United States after the war [http://hoernerfluiddynamics.com]. He was an important conduit for the transfer of advanced German knowledge about aerodynamics and aircraft design.

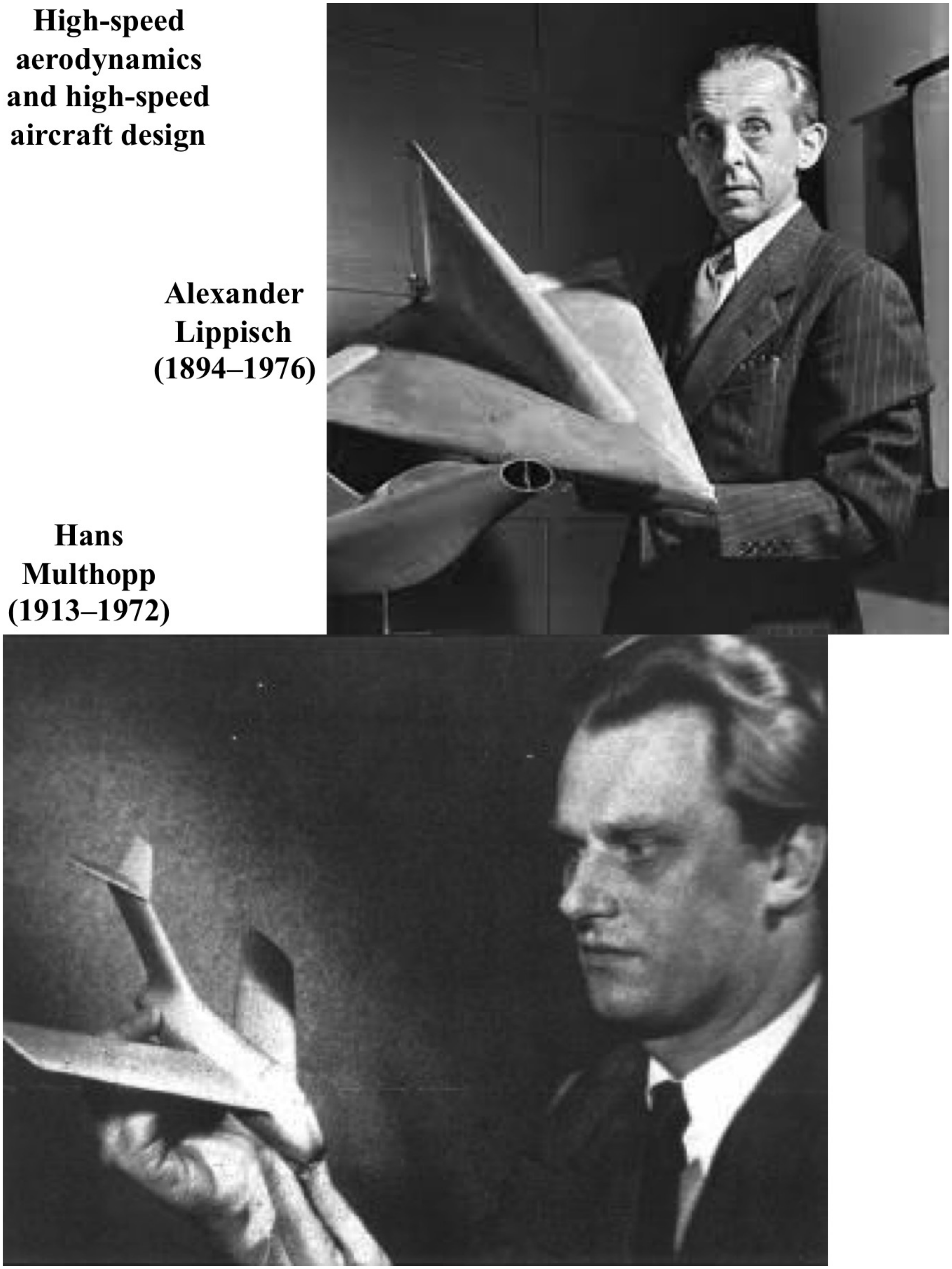

High-speed aerodynamics and high-speed aircraft design
Alexander Lippisch (1894–1976)
Hans Multhopp (1913–1972)

Figure 9.49: Alexander Lippisch and Hans Multhopp made many major contributions to high-speed aerodynamics and high-speed aircraft design.

Dietrich Küchemann (1911–1976)
Johanna Weber (1910–2014)
Postwar development of supersonic aircraft such as Concorde
BRITISH AIRWAYS

Figure 9.50: Dietrich Küchemann and Johanna Weber studied supersonic aerodynamics during World War II and played key roles in the postwar development of supersonic aircraft such as Concorde.

9.3 Jet Engines and Jet Aircraft

During the 1930s and early 1940s, German-speaking scientists and engineers developed the first practical jet engines (Section 9.3.1) and installed them in a wide variety of revolutionary aircraft (Section 9.3.2). After the war, experts, hardware, and designs from the German-speaking world spread those jet technologies around the world. That German expertise provided the modern world with jet-powered passenger planes, fighters, and bombers, as well as closely related gas turbine engines that are used in power plants and in land and sea vehicles.[8]

9.3.1 Jet Engines

A turbojet engine (Turbinen-Luftstrahltriebwerk or TL in German) is a type of gas turbine engine that forcibly sucks in air, burns it with fuel, extracts a little energy from the process (turbo for turbine) to power the air intake, and expels the rest of the energy out the back with a high-speed, high-temperature exhaust (jet). Because the exhaust has both a large mass flow rate and a large velocity, its new rearward momentum is large, and hence it imparts a large forward thrust force to the engine, potentially larger than the thrust of a comparable propeller engine. However, because so much of the combustion energy ends up as kinetic and thermal energy in the exhaust and not as new forward kinetic energy of the aircraft, at moderate flying speeds the energy (fuel) efficiency of a turbojet is much lower than that of a propeller engine. Figure 9.51 shows the components and idealized gas pressures and temperatures in a typical turbojet engine:

- The diffuser impedes the incoming flow to slow it down, converting the initial kinetic energy of the flow to increased pressure (potential energy) and temperature (thermal energy).

- Since passive stagnation effects only cause a small increase in pressure even at high subsonic speeds, turbojet engines include an active, powered compressor that forcibly raises the pressure (and temperature) of the flow, thereby preparing the air to burn more efficiently with fuel in the subsequent burner section. (The compressor can also be viewed as actively sucking air into the engine, even if the external air speed is negligible, as it is when the aircraft is first started.) Typical axial compressor designs use alternating rotating and stationary blades (rotors and stators) as shown in the figure to squeeze the air as it passes through.

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[8] Amtmann 1988; Bohr 2013; Brix 2022; Butler 1994, 2007; Christensen 2002; Christopher 2013; Cole 2015; Conner 2001; Constant 1980; Cooke and Ingells 1945; Daso 2002; Diedrich 1999; Dorr 2013; Duffy 2012; Erfurth 2006; Forsyth and Creek 2007; Franz 1985; General Electric 1979; von Gersdorff et al. 2004; Gleichmann 2013; Gleichmann and Bock 2009; Griehl 1990, 2004, 2005; Griehl 2015; Gunston 2006a, 2006b; Herwig and Rode 2000, 2003; Hill and Peterson 1991; Hirschel et al. 2004; Hyland and Gill 1998; Jacobsen 2011, 2014; Jakobs et al. 2009; Johnsen 2014; Kay 2002; Kerrebrock 1992; Kober 1990; Leist and Wiening 1963; Leyes and Fleming 1999; Lichtfuss and Schubert 2014; Longden 2009; Masters 1982; Hans-Ulrich Meier 2010; Miranda 2015; Myhra 1998a, 1998b, 2000a; Nowarra 1988; Pavelec 2007; Samuel 2004, 2010; Schick and Meyer 1997; Shepelev and Ottens 2015; Simons 2016; Smith and Creek 1992, 2001; Smith and Kay 2002; Thomas 1946; Vajda and Dancey 1998; CIOS XXV-9, XXVI-27, XXVI-28, XXVI-29, XXVI-30, XXXII-41; *Air World* 1946; *Chicago Daily Tribune* 1945-06-29 p. 4; *Daily Telegraph* 1, 2, 5, 9 Oct. 1945, p. 4 each issue; *L.A. Times* 1945-06-29; NYT 1945-06-08, 1945-07-26 p. 6, 1948-04-15 p. 17, 1948-12-04 p. 3; *Washington Post* 1945-06-29.

- The burner or combustion chamber (combustor) burns the incoming air with a much smaller amount of fuel to raise the temperature of the flow as high as possible without melting the blades in the subsequent turbine section.

- The turbine must extract enough work energy out of the gas after the burner to put the necessary work energy into powering the compressor before the burner.

- The nozzle decreases the pressure of the flow until it reaches the ambient pressure of the external air, converting that initial high-pressure potential energy into kinetic energy to maximize the exhaust velocity.

- Optionally, an afterburner can add extra fuel to the air just before the nozzle. Burning that extra fuel raises the pressure entering the nozzle and hence the thrust force produced by the engine, albeit at the expense of consuming fuel even faster than a plain turbojet engine would.

While a turbojet is a very powerful and compact engine, the propulsive efficiency of a turbojet is relatively low at subsonic aircraft speeds, since the engine's exhaust velocity is so high. To raise the efficiency of a turbojet engine for subsonic travel, it can be directly coupled to a large fan for airplane flight (a turbofan), propeller blades for airplane flight (a turboprop), or rotor blades for helicopter flight (a turboshaft engine), as shown in Fig. 9.52.

In a turbofan or bypass engine (Zweistrom-Turbinen-Luftstrahltriebwerk or ZTL in German), the inlet air can pass either through a relatively conventional turbojet engine (sometimes called the hot flow since it is heated by combustion), or else through a large enclosed fan (sometimes called the cold flow since it does not experience combustion). The bypass ratio β is defined as the ratio of the mass flow rates in the cold and hot flows. Compared to a pure turbojet engine, more of the exhaust energy in this turbojet is extracted in the turbine and less in the nozzle, which decreases the hot flow exhaust velocity. Because the turbine extracts more energy, it can power not only the compressor for the hot flow, but also the fan for the cold flow. The fan may be an enlarged front compressor blade through which both hot and cold flows pass, or it may be a separate blade whose speed has been appropriately geared down from the main turbine shaft. As the cold flow is merely accelerated by a fan and not heated by combustion to high temperatures, its exhaust velocity is rather low. Thus both the hot and cold fractions of the flow have lower exhaust velocities than the exhaust of a simple turbojet, improving the propulsive efficiency of the engine and lowering the fuel consumption rate.

Whereas the fan of a turbofan engine can operate at high-subsonic and supersonic speeds, at lower subsonic speeds it may be replaced by an ordinary airplane propeller, further increasing the efficiency. The propeller is still driven by the turbine of a turbojet engine, so this variation is called a turboprop engine (Propeller-Turbinen-Luftstrahltriebwerk or PTL in German). A turbojet engine designed for this purpose extracts almost all of the available exhaust energy in the turbine and not the nozzle, in order to send as much power as possible to the propeller. The propeller typically has a much larger diameter than the compressor and turbine blades, yet its tips should not approach the speed of sound to avoid compressibility losses. Therefore, a gearbox usually gears down power transmitted from the turbine shaft to a separate propeller shaft that rotates ~ 15 times more slowly. Turboprop engines are basically turbofan engines with a very high bypass ratio ($\beta > 50$) so that the large majority of the thrust comes from the cold propeller flow and not the hot turbojet flow. Because of their efficiency, they are widely used to power small, low-subsonic-speed aircraft.

Just as the shaft power from a turbojet engine can be geared down to drive an airplane propeller, it can also be geared down to power a helicopter rotor. This variation is called a turboshaft engine. The power shaft may be taken from either the compressor end (as shown in the figure) or the turbine end. In addition to aerospace applications, turboshaft gas turbine engines make excellent power sources for other machines ranging from military tanks to submarines to electric power plants.

At supersonic speeds (say Mach ∼2–3), the pressure increase due to stagnation effects in the diffuser is so large that there is no need for an active compressor, and thus there is also no need for a turbine to power a compressor, as shown in Fig. 9.53. Under these conditions, with the moving parts inside a turbojet removed, the engine becomes a much simpler ramjet. To operate at hypersonic speeds (Mach 5 and higher), the interior contours of the engine can be modified to make it a supersonic combustion ramjet (scramjet). A ramjet engine can even be modified to operate at subsonic speeds where the stagnation compression is relatively small, becoming a pulsejet whose operation continually alternates between air intake and air combustion.

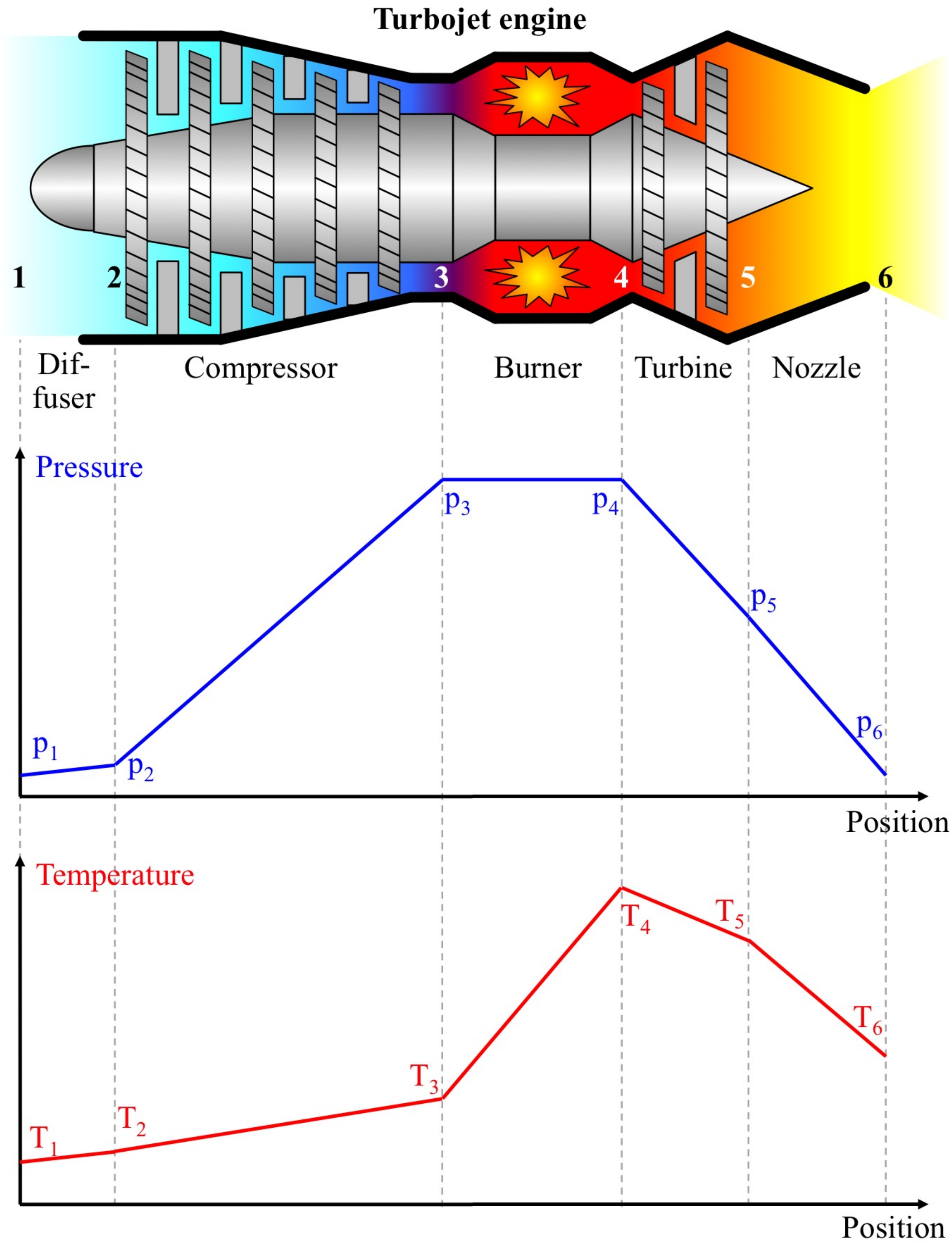
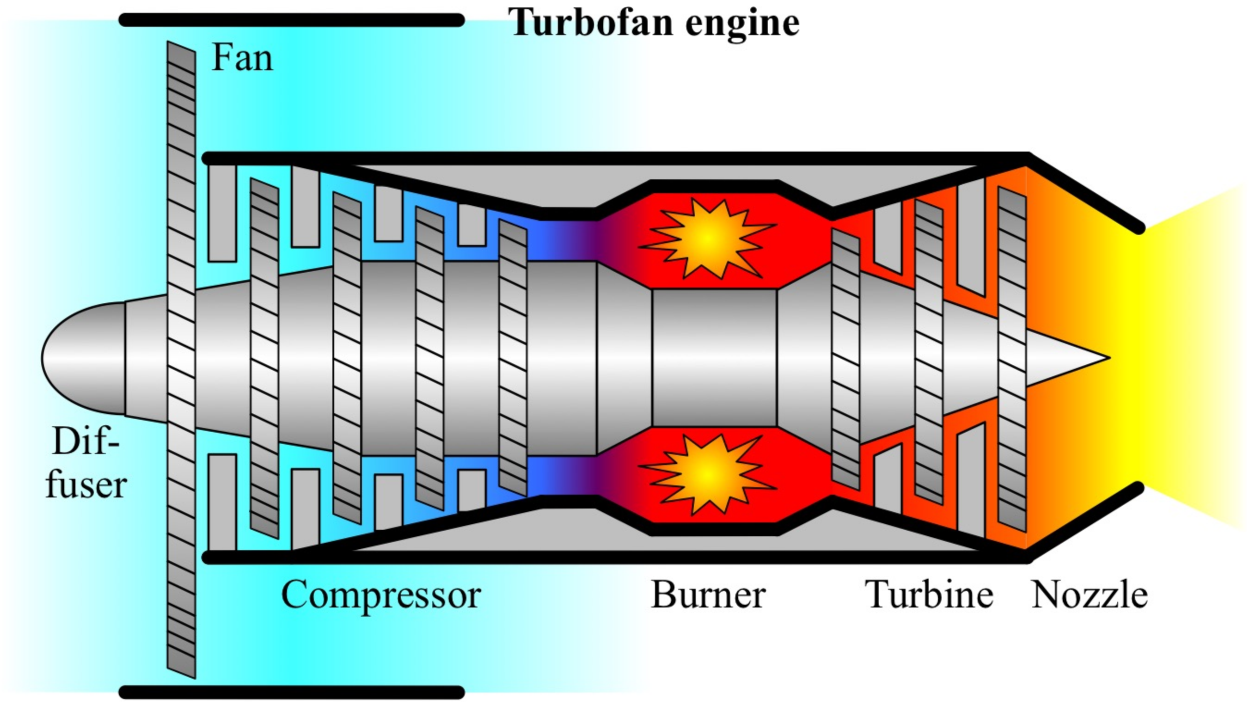

Turbojet engine
1
2
3
4
5
6
Dif-
fuser
Compressor
Burner
Turbine
Nozzle
Pressure
p_1
p_2
p_3
p_4
p_5
p_6
Position
Temperature
T_1
T_2
T_3
T_4
T_5
T_6
Position

Figure 9.51: Turbojet engine design, showing a simplified view of its major components—the diffuser, compressor, burner, turbine, and nozzle—as well as simple models of the pressure and temperature at each point in the engine.


Turbofan engine
Fan
Dif-
fuser
Compressor
Burner
Turbine
Nozzle

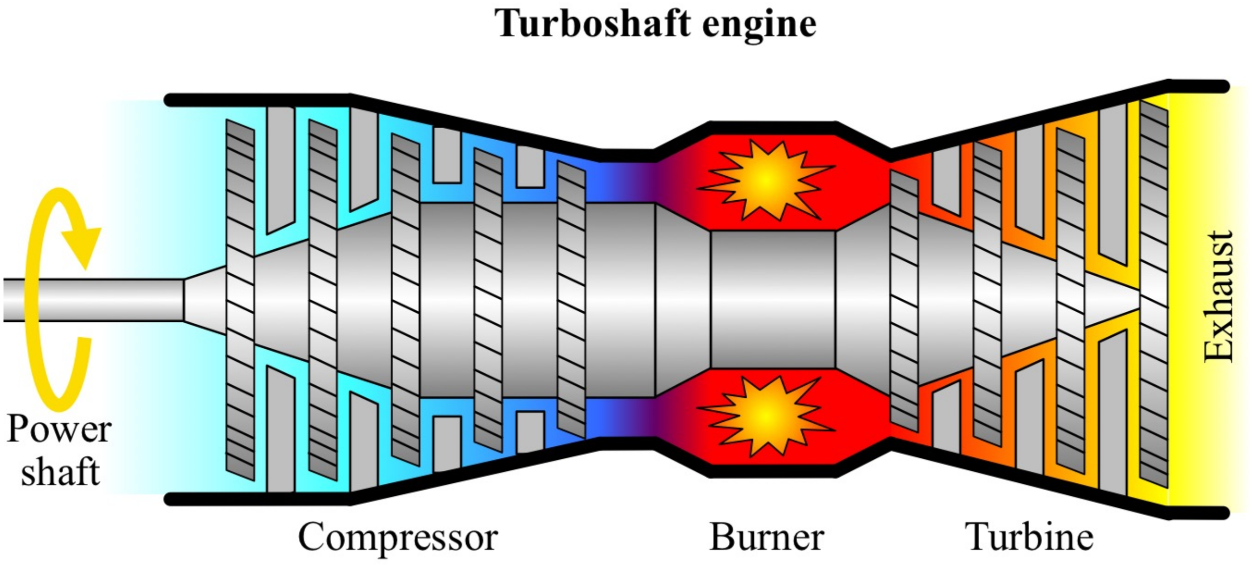

Turboshaft engine
Power
shaft
Compressor
Burner
Turbine
Exhaust

Figure 9.52: A turbojet engine design may be modified to become a turbofan design (above), or a turboshaft or turboprop design (below). In a turboshaft or turboprop design, the power shaft may be taken either from the compressor end as shown or from the turbine end, and generally transfers its power via a series of gears to an aircraft propeller or helicopter rotor shaft spinning at fewer revolutions per minute.

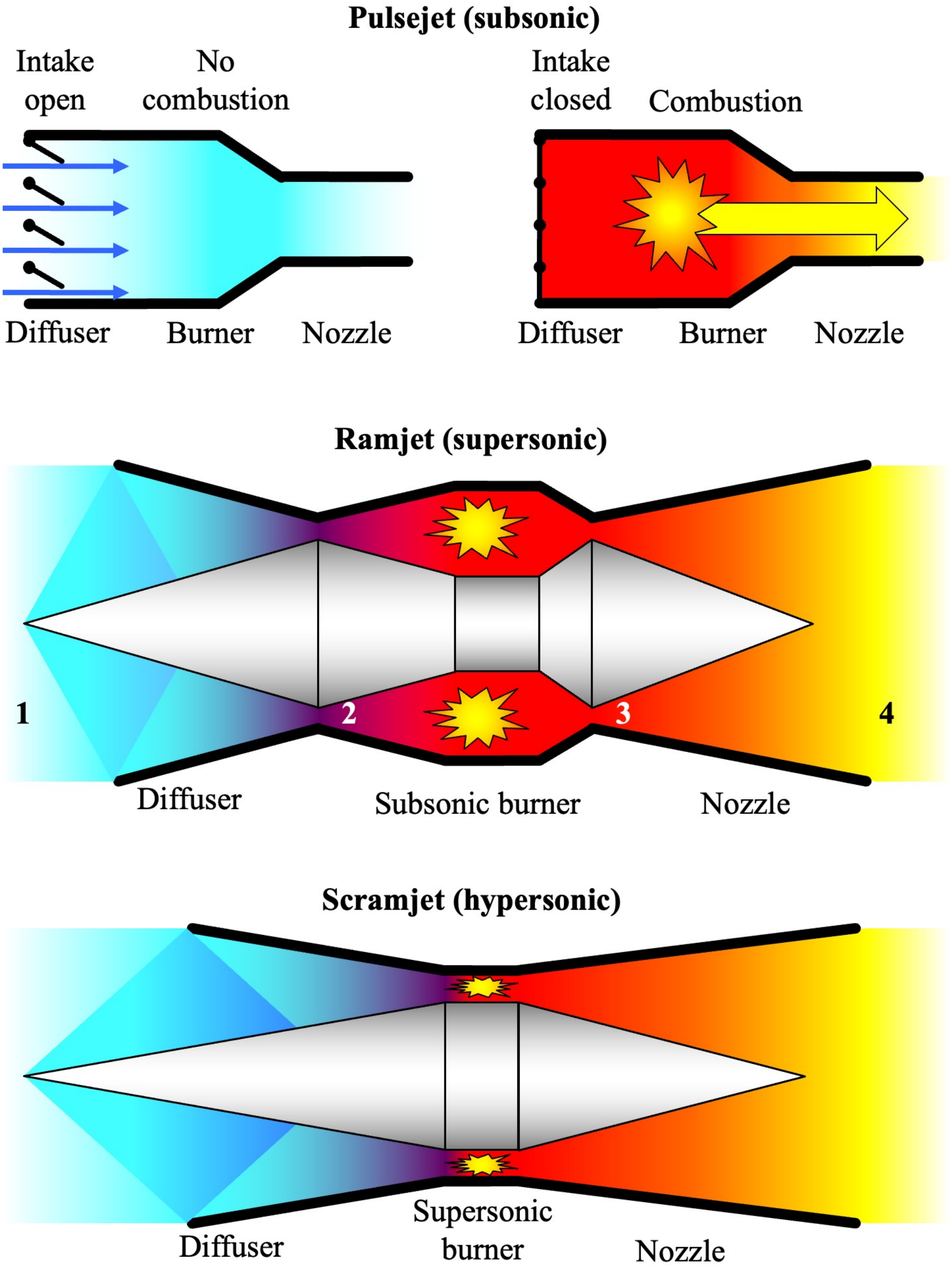

Pulsejet (subsonic)
Intake open
No combustion
Intake closed
Combustion
Diffuser
Burner
Nozzle
Diffuser
Burner
Nozzle
Ramjet (supersonic)
1
2
3
4
Diffuser
Subsonic burner
Nozzle
Scramjet (hypersonic)
Diffuser
Supersonic burner
Nozzle

Figure 9.53: Bladeless aircraft engines include a pulsejet for subsonic speeds, a ramjet for supersonic speeds, and a supersonic combustion ramjet (scramjet) for hypersonic speeds.

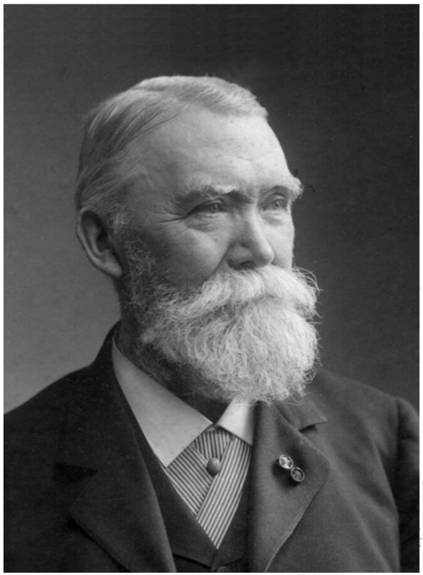
Beginning in the nineteenth century, a long line of German-speaking creators invented, built, demonstrated, and improved gas turbine engines, first for stationary power applications or land vehicles and ultimately for aircraft. Some of the key early figures included:

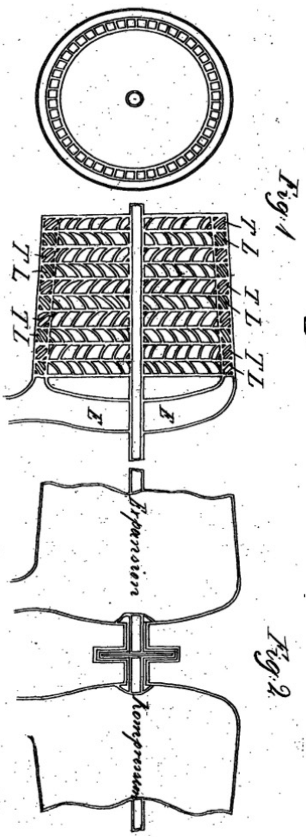
- Franz Stolze (German, 1836–1910) began developing gas turbine engines in the 1860s and continued building test models and filing patents into the early 1900s (Fig. 9.54).
- Joseph Wertheim (German, 1834–1899) filed patent applications on gas turbine engines beginning in 1876 (Fig. 9.55).
- Christian Bröker (German, 18??–19??) filed patent applications on gas turbine engines in 1889 (Fig. 9.56).
- Aurel Stodola (Austro-Hungarian Slovak, 1859–1942) developed gas turbine engines from the 1890s through the 1930s (Figs. 9.57–9.58).
- Hans Holzwarth (German, 1877–1953) filed a large number of patent applications on gas turbine engines from around 1900 through the 1930s (Fig. 9.59). He built the first fully functional gas turbine engine in 1906 and later founded his own company that manufactured and sold gas turbine engines for industrial power production.
- Wilhelm Pape (German, 18??–19??) filed many patent applications on gas turbine engines from the 1910s through the 1920s (Fig. 9.60).
- Karl Röder (German, 1881–1965) filed numerous patent applications on gas turbine engines and built working versions from the 1910s through the 1930s (Fig. 9.61). As a professor at the University of Hannover, he also taught younger gas turbine engineers.
- Karl Enders (German, 18??–19??) filed a patent application on gas turbine engines in 1925 (Fig. 9.62).
- Oscar Hart (German, 18??–19??) and Joseph Hetterich (German, 18??–19??) filed a patent application on gas turbine engines in 1925 (Fig. 9.63).
- Hermann Oberth (Austro-Hungarian, 1894–1989), best known for his work on rockets (Section 9.7.1) and early space station designs (Section 9.10.2), also created very early designs for jet engines. He filed a patent application on gas turbine engines for aircraft in 1925 (Fig. 9.64).

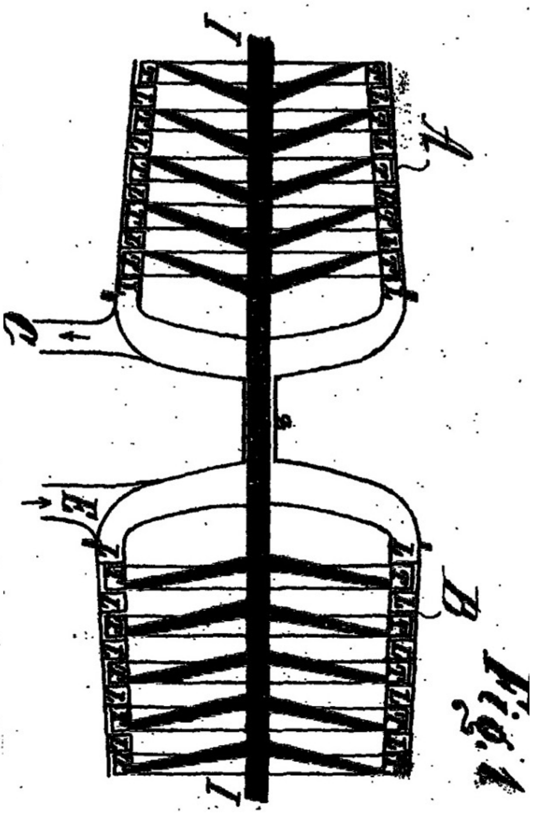
Some engineers outside the German-speaking world also proposed or worked on early gas turbine engines, although they tended to be fewer in number, more isolated, and often less able to find the support and resources required to fully realize their ideas. Some noteworthy figures were Ægidius Elling (1861–1949) in Norway, Gustaf de Laval (1845–1913) and the brothers Birger Ljungström (1872–1948) and Fredrik Ljungström (1875–1964) in Sweden, Maxime Guillaume (1888–19??) and René Anxionnaz (1894–19??) in France, and Charles Parsons (1854–1931) in the United Kingdom.

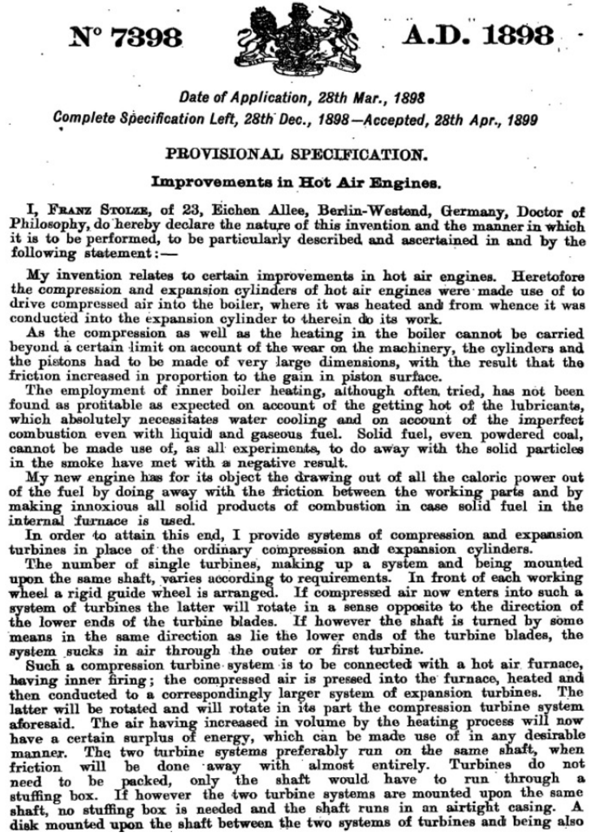
Franz Stolze
(1836–1910)

Gas turbine engines
(1860s–1900s)









N° 7398 **A.D. 1898**

Date of Application, 28th Mar., 1898
Complete Specification Left, 28th Dec., 1898—Accepted, 28th Apr., 1899

PROVISIONAL SPECIFICATION.

Improvements in Hot Air Engines.

I, Franz Stolze, of 23, Eichen Allee, Berlin-Westend, Germany, Doctor of Philosophy, do hereby declare the nature of this invention and the manner in which it is to be performed, to be particularly described and ascertained in and by the following statement:—

My invention relates to certain improvements in hot air engines. Heretofore the compression and expansion cylinders of hot air engines were made use of to drive compressed air into the boiler, where it was heated and from whence it was conducted into the expansion cylinder to therein do its work.

As the compression as well as the heating in the boiler cannot be carried beyond a certain limit on account of the wear on the machinery, the cylinders and the pistons had to be made of very large dimensions, with the result that the friction increased in proportion to the gain in piston surface.

The employment of inner boiler heating, although often tried, has not been found as profitable as expected on account of the getting hot of the lubricants, which absolutely necessitates water cooling and on account of the imperfect combustion even with liquid and gaseous fuel. Solid fuel, even powdered coal, cannot be made use of, as all experiments, to do away with the solid particles in the smoke have met with a negative result.

My new engine has for its object the drawing out of all the caloric power out of the fuel by doing away with the friction between the working parts and by making innoxious all solid products of combustion in case solid fuel in the internal furnace is used.

In order to attain this end, I provide systems of compression and expansion turbines in place of the ordinary compression and expansion cylinders.

The number of single turbines, making up a system and being mounted upon the same shaft, varies according to requirements. In front of each working wheel a rigid guide wheel is arranged. If compressed air now enters into such a system of turbines the latter will rotate in a sense opposite to the direction of the lower ends of the turbine blades. If however the shaft is turned by some means in the same direction as lie the lower ends of the turbine blades, the system sucks in air through the outer or first turbine.

Such a compression turbine system is to be connected with a hot air furnace, having inner firing; the compressed air is pressed into the furnace, heated and then conducted to a correspondingly larger system of expansion turbines. The latter will be rotated and will rotate in its part the compression turbine system aforesaid. The air having increased in volume by the heating process will now have a certain surplus of energy, which can be made use of in any desirable manner. The two turbine systems preferably run on the same shaft, when friction will be done away with almost entirely. Turbines do not need to be packed, only the shaft would have to run through a stuffing box. If however the two turbine systems are mounted upon the same shaft, no stuffing box is needed and the shaft runs in an airtight casing. A disk mounted upon the shaft between the two systems of turbines and being also

No. 667,744. Patented Feb. 12, 1901.
F. STOLZE.
HOT AIR ENGINE.
(Application filed Mar. 23, 1898.)
(No Model.)

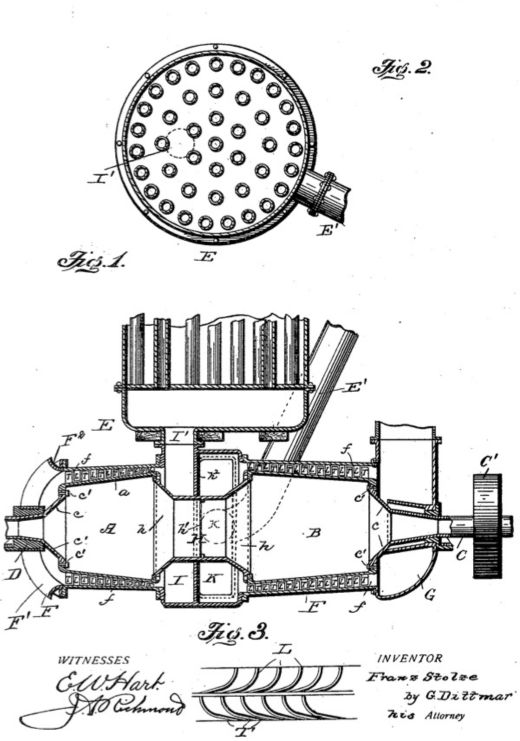
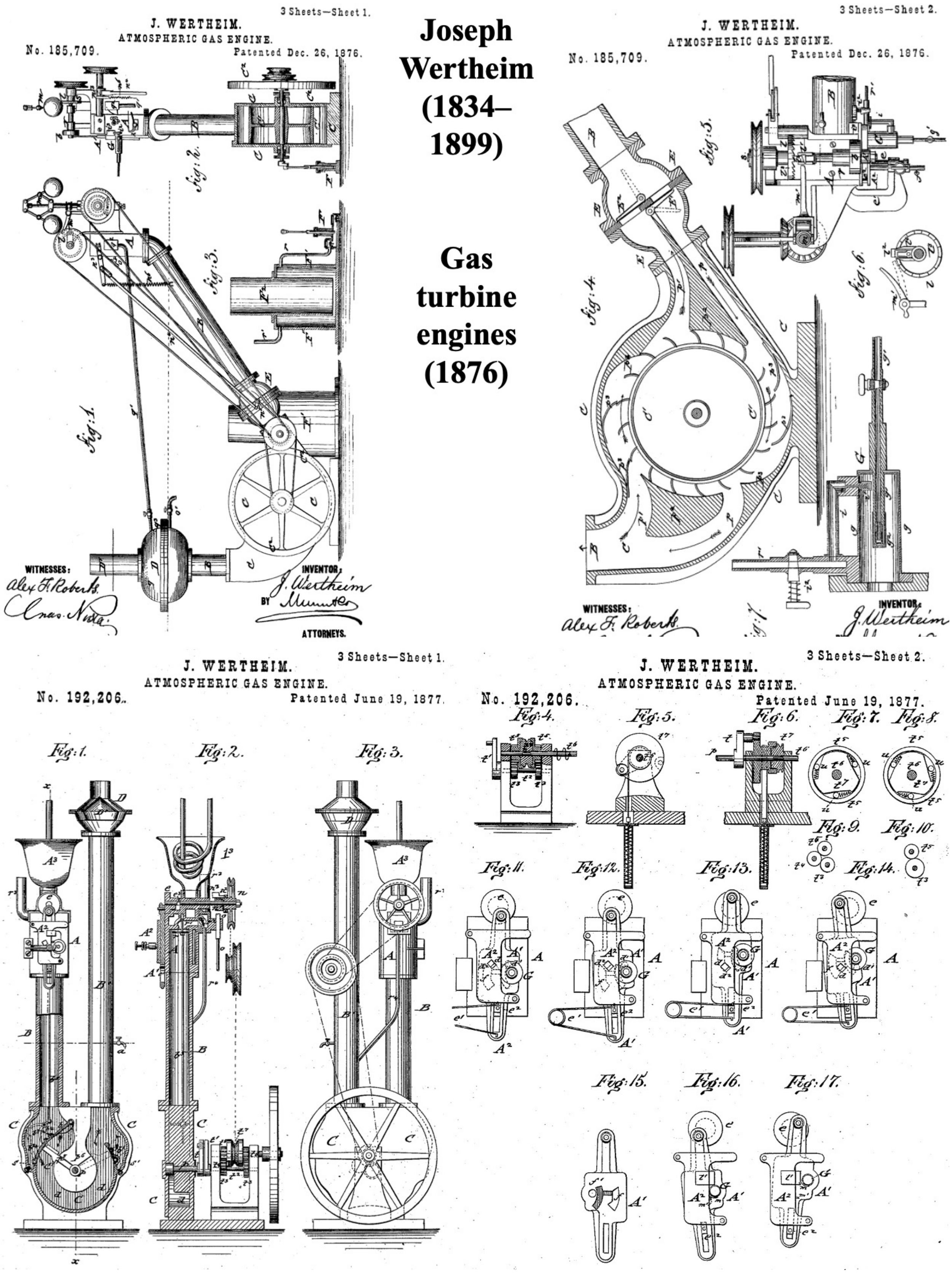


Figure 9.54: Franz Stolze (1836–1910) began developing gas turbine engines in the 1860s.


3 Sheets—Sheet 1.
J. WERTHEIM.
ATMOSPHERIC GAS ENGINE.
No. 185,709.
Patented Dec. 26, 1876.
Fig: 1.
Fig: 2.
Fig: 3.
WITNESSES:
Alex F. Roberts
Chas. Nida
INVENTOR:
J. Wertheim
BY Munn & Co
ATTORNEYS.
3 Sheets—Sheet 2.
J. WERTHEIM.
ATMOSPHERIC GAS ENGINE.
No. 185,709.
Patented Dec. 26, 1876.
Fig: 4.
Fig: 5.
Fig: 6.
Fig: 7.
WITNESSES:
Alex F. Roberts
INVENTOR:
J. Wertheim
3 Sheets—Sheet 1.
J. WERTHEIM.
ATMOSPHERIC GAS ENGINE.
No. 192,206.
Patented June 19, 1877.
Fig: 1.
Fig: 2.
Fig: 3.
3 Sheets—Sheet 2.
J. WERTHEIM.
ATMOSPHERIC GAS ENGINE.
No. 192,206.
Patented June 19, 1877.
Fig: 4.
Fig: 5.
Fig: 6.
Fig: 7.
Fig: 8.
Fig: 9.
Fig: 10.
Fig: 11.
Fig: 12.
Fig: 13.
Fig: 14.
Fig: 15.
Fig: 16.
Fig: 17.

Joseph Wertheim (1834–1899)

Gas turbine engines (1876)

Figure 9.55: Joseph Wertheim filed patent applications on gas turbine engines beginning in 1876.

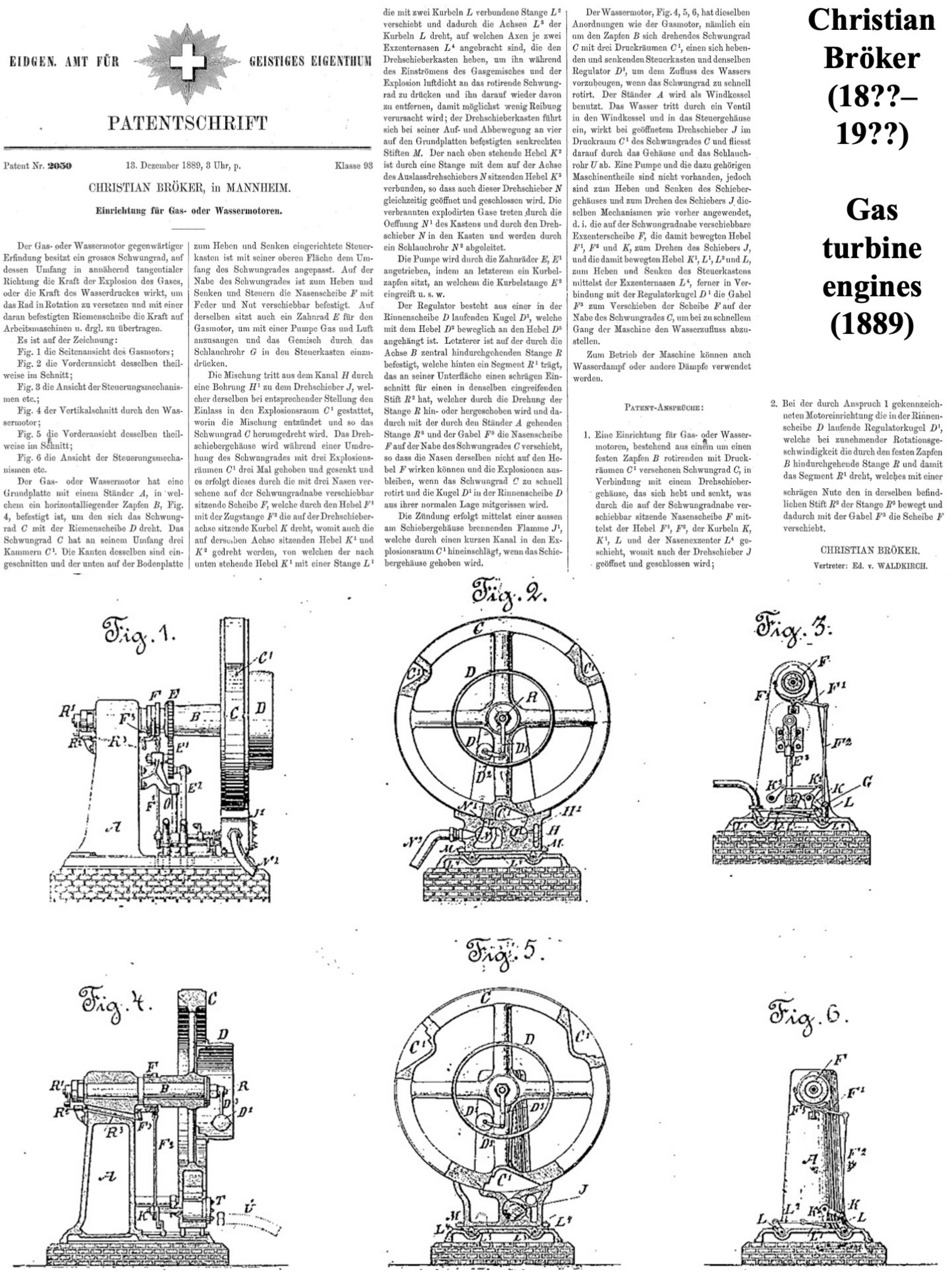


Fig. 1.
Fig. 2.
Fig. 3:
Fig. 4.
Fig. 5.
Fig. 6.

Christian Bröker (18??–19??)

Gas turbine engines (1889)

EIDGEN. AMT FÜR GEISTIGES EIGENTHUM

PATENTSCHRIFT

Patent Nr. **2050** 13. Dezember 1889, 3 Uhr, p. Klasse 93

CHRISTIAN BRÖKER, in MANNHEIM.

Einrichtung für Gas- oder Wassermotoren.

Der Gas- oder Wassermotor gegenwärtiger Erfindung besitzt ein grosses Schwungrad, auf dessen Umfang in annähernd tangentialer Richtung die Kraft der Explosion des Gases, oder die Kraft des Wasserdruckes wirkt, um das Rad in Rotation zu versetzen und mit einer daran befestigten Riemenscheibe die Kraft auf Arbeitsmaschinen u. drgl. zu übertragen.

Es ist auf der Zeichnung:

Fig. 1 die Seitenansicht des Gasmotors;

Fig. 2 die Vorderansicht desselben theilweise im Schnitt;

Fig. 3 die Ansicht der Steuerungsmechanismen etc.;

Fig. 4 der Vertikalschnitt durch den Wassermotor;

Fig. 5 die Vorderansicht desselben theilweise im Schnitt;

Fig. 6 die Ansicht der Steuerungsmechanismen etc.

Der Gas- oder Wassermotor hat eine Grundplatte mit einem Ständer A, in welchem ein horizontalliegender Zapfen B, Fig. 4, befestigt ist, um den sich das Schwungrad C mit der Riemenscheibe D dreht. Das Schwungrad C hat an seinem Umfang drei Kammern C^1. Die Kanten desselben sind eingeschnitten und der unten auf der Bodenplatte zum Heben und Senken eingerichtete Steuerkasten ist mit seiner oberen Fläche dem Umfang des Schwungrades angepasst. Auf der Nabe des Schwungrades ist zum Heben und Senken und Steuern die Nasenscheibe F mit Feder und Nut verschiebbar befestigt. Auf derselben sitzt auch ein Zahnrad E für den Gasmotor, um mit einer Pumpe Gas und Luft anzusaugen und das Gemisch durch das Schlauchrohr G in den Steuerkasten einzudrücken.

Die Mischung tritt aus dem Kanal H durch eine Bohrung H^1 zu dem Drehschieber J, welcher derselben bei entsprechender Stellung den Einlass in den Explosionsraum C^1 gestattet, worin die Mischung entzündet und so das Schwungrad C herumgedreht wird. Das Drehschiebergehäuse wird während einer Umdrehung des Schwungrades mit drei Explosionsräumen C^1 drei Mal gehoben und gesenkt und es erfolgt dieses durch die mit drei Nasen versehene auf der Schwungradnabe verschiebbar sitzende Scheibe F, welche durch den Hebel F^1 mit der Zugstange F^2 die auf der Drehschieberachse sitzende Kurbel K dreht, womit auch die auf derselben Achse sitzenden Hebel K^1 und K^2 gedreht werden, von welchen der nach unten stehende Hebel K^1 mit einer Stange L^1 die mit zwei Kurbeln L verbundene Stange L^2 verschiebt und dadurch die Achsen L^3 der Kurbeln L dreht, auf welchen Axen je zwei Exzenternasen L^4 angebracht sind, die den Drehschieberkasten heben, um ihn während des Einströmens des Gasgemisches und der Explosion luftdicht an das rotirende Schwungrad zu drücken und ihn darauf wieder davon zu entfernen, damit möglichst wenig Reibung verursacht wird; der Drehschieberkasten führt sich bei seiner Auf- und Abbewegung an vier auf den Grundplatten befestigten senkrechten Stiften M. Der nach oben stehende Hebel K^2 ist durch eine Stange mit dem auf der Achse des Auslassdrehschiebers N sitzenden Hebel K^3 verbunden, so dass auch dieser Drehschieber N gleichzeitig geöffnet und geschlossen wird. Die verbrannten explodirten Gase treten durch die Oeffnung N^1 des Kastens und durch den Drehschieber N in den Kasten und werden durch ein Schlauchrohr N^2 abgeleitet.

Die Pumpe wird durch die Zahnräder E, E^1 angetrieben, indem an letzterem ein Kurbelzapfen sitzt, an welchem die Kurbelstange E^2 eingreift u. s. w.

Der Regulator besteht aus einer in der Rinnenscheibe D laufenden Kugel D^1, welche mit dem Hebel D^2 beweglich an den Hebel D^3 angehängt ist. Letzterer ist auf der durch die Achse B zentral hindurchgehenden Stange R befestigt, welche hinten ein Segment R^1 trägt, das an seiner Unterfläche einen schrägen Einschnitt für einen in denselben eingreifenden Stift R^2 hat, welcher durch die Drehung der Stange R hin- oder hergeschoben wird und dadurch mit der durch den Ständer A gehenden Stange R^3 und der Gabel F^3 die Nasenscheibe F auf der Nabe des Schwungrades C verschiebt, so dass die Nasen derselben nicht auf den Hebel F wirken können und die Explosionen ausbleiben, wenn das Schwungrad C zu schnell rotirt und die Kugel D^1 in der Rinnenscheibe D aus ihrer normalen Lage mitgerissen wird.

Die Zündung erfolgt mittelst einer aussen am Schiebergehäuse brennenden Flamme J^1, welche durch einen kurzen Kanal in den Explosionsraum C^1 hineinschlägt, wenn das Schiebergehäuse gehoben wird.

Der Wassermotor, Fig. 4, 5, 6, hat dieselben Anordnungen wie der Gasmotor, nämlich ein um den Zapfen B sich drehendes Schwungrad C mit drei Druckräumen C^1, einen sich hebenden und senkenden Steuerkasten und denselben Regulator D^1, um dem Zufluss des Wassers vorzubeugen, wenn das Schwungrad zu schnell rotirt. Der Ständer A wird als Windkessel benutzt. Das Wasser tritt durch ein Ventil in den Windkessel und in das Steuergehäuse ein, wirkt bei geöffnetem Drehschieber J im Druckraum C^1 des Schwungrades C und fliesst darauf durch das Gehäuse und das Schlauchrohr U ab. Eine Pumpe und die dazu gehörigen Maschinentheile sind nicht vorhanden, jedoch sind zum Heben und Senken des Schiebergehäuses und zum Drehen des Schiebers J dieselben Mechanismen wie vorher angewendet, d. i. die auf der Schwungradnabe verschiebbare Exzenterscheibe F, die damit bewegten Hebel F^1, F^2 und K, zum Drehen des Schiebers J, und die damit bewegten Hebel K^1, L^1, L^2 und L, zum Heben und Senken des Steuerkastens mittelst der Exzenternasen L^4, ferner in Verbindung mit der Regulatorkugel D^1 die Gabel F^3 zum Verschieben der Scheibe F auf der Nabe des Schwungrades C, um bei zu schnellem Gang der Maschine den Wasserzufluss abzustellen.

Zum Betrieb der Maschine können auch Wasserdampf oder andere Dämpfe verwendet werden.

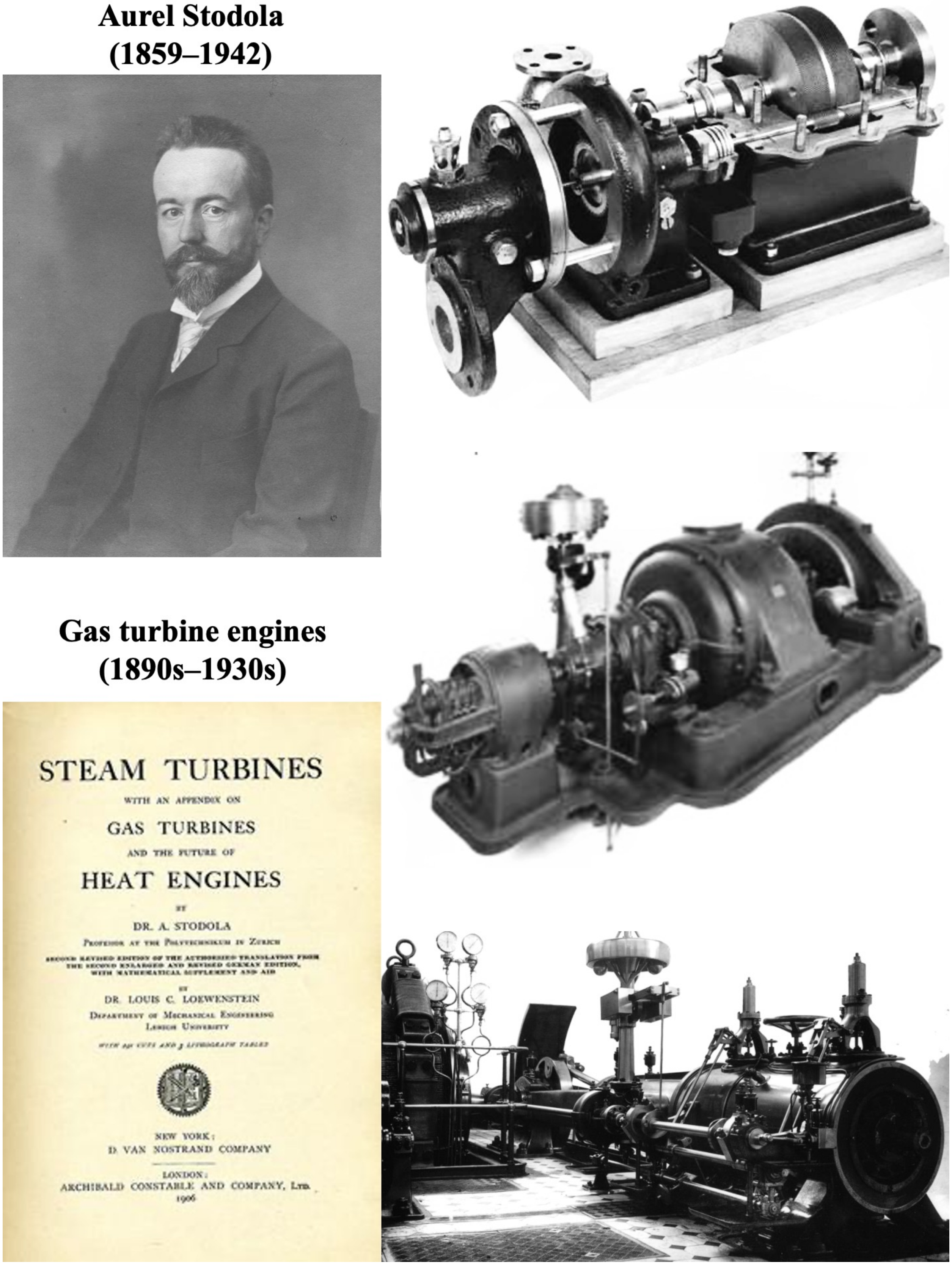
PATENT-ANSPRÜCHE:

1. Eine Einrichtung für Gas- oder Wassermotoren, bestehend aus einem um einen festen Zapfen B rotirenden mit Druckräumen C^1 versehenen Schwungrad C, in Verbindung mit einem Drehschiebergehäuse, das sich hebt und senkt, was durch die auf der Schwungradnabe verschiebbar sitzende Nasenscheibe F mittelst der Hebel F^1, F^2, der Kurbeln K, K^1, L und der Nasenexzenter L^4 geschieht, womit auch der Drehschieber J geöffnet und geschlossen wird;
2. Bei der durch Anspruch 1 gekennzeichneten Motoreinrichtung die in der Rinnenscheibe D laufende Regulatorkugel D^1, welche bei zunehmender Rotationsgeschwindigkeit die durch den festen Zapfen B hindurchgehende Stange R und damit das Segment R^1 dreht, welches mit einer schrägen Nute den in derselben befindlichen Stift R^2 der Stange R^3 bewegt und dadurch mit der Gabel F^3 die Scheibe F verschiebt.

CHRISTIAN BRÖKER.

Vertreter: Ed. v. WALDKIRCH.

Figure 9.56: Christian Bröker filed patent applications on gas turbine engines in 1889.

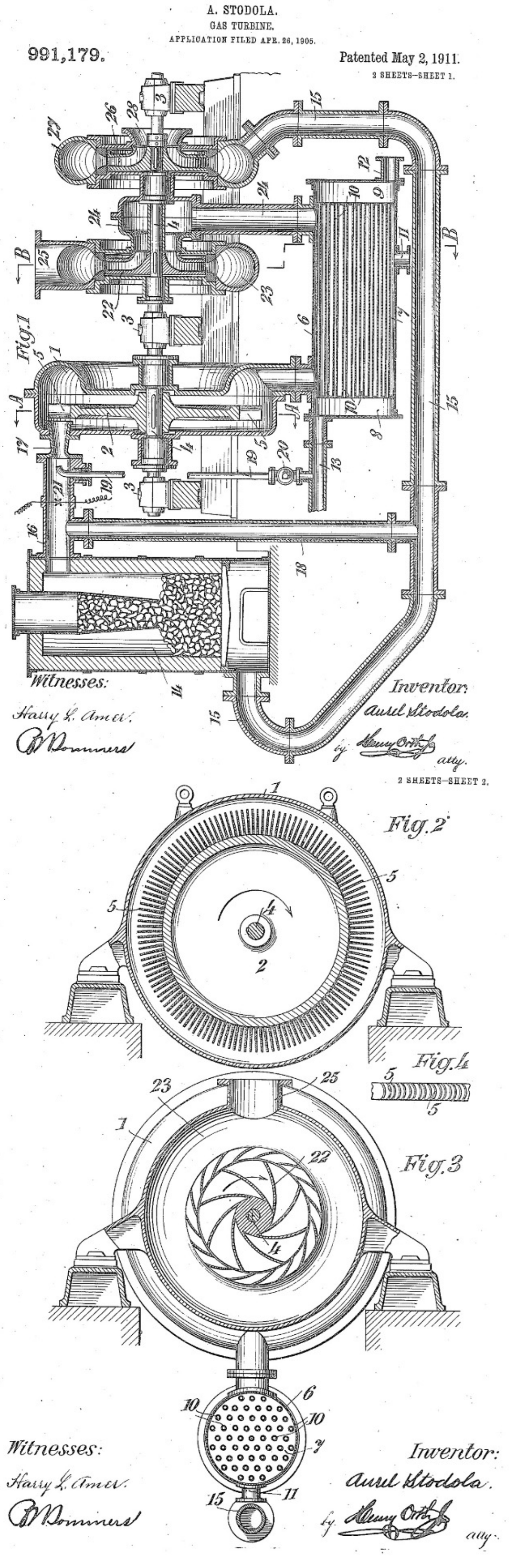


STEAM TURBINES
WITH AN APPENDIX ON
GAS TURBINES
AND THE FUTURE OF
HEAT ENGINES
BY
DR. A. STODOLA
PROFESSOR AT THE POLYTECHNIKUM IN ZURICH
SECOND REVISED EDITION OF THE AUTHORIZED TRANSLATION FROM
THE SECOND ENLARGED AND REVISED GERMAN EDITION,
WITH MATHEMATICAL SUPPLEMENT AND AID
BY
DR. LOUIS C. LOEWENSTEIN
DEPARTMENT OF MECHANICAL ENGINEERING
LEHIGH UNIVERSITY
WITH 241 CUTS AND 3 LITHOGRAPH TABLES

NEW YORK:
D. VAN NOSTRAND COMPANY

LONDON:
ARCHIBALD CONSTABLE AND COMPANY, LTD.
1906

Figure 9.57: Aurel Stodola developed gas turbine engines from the 1890s through the 1930s.


A. STODOLA.
GAS TURBINE.
APPLICATION FILED APR. 26, 1905.
991,179.
Patented May 2, 1911.
2 SHEETS—SHEET 1.
Fig.1
Witnesses:
Harry L. Amer.
Inventor:
Aurel Stodola.
by Henry Orth Jr
atty.
2 SHEETS—SHEET 2.
Fig.2
Fig.4
Fig.3
Witnesses:
Harry L. Amer.
Inventor:
Aurel Stodola.
by Henry Orth Jr
atty.

Aurel Stodola (1859–1942)

Gas turbine engines (1890s–1930s)

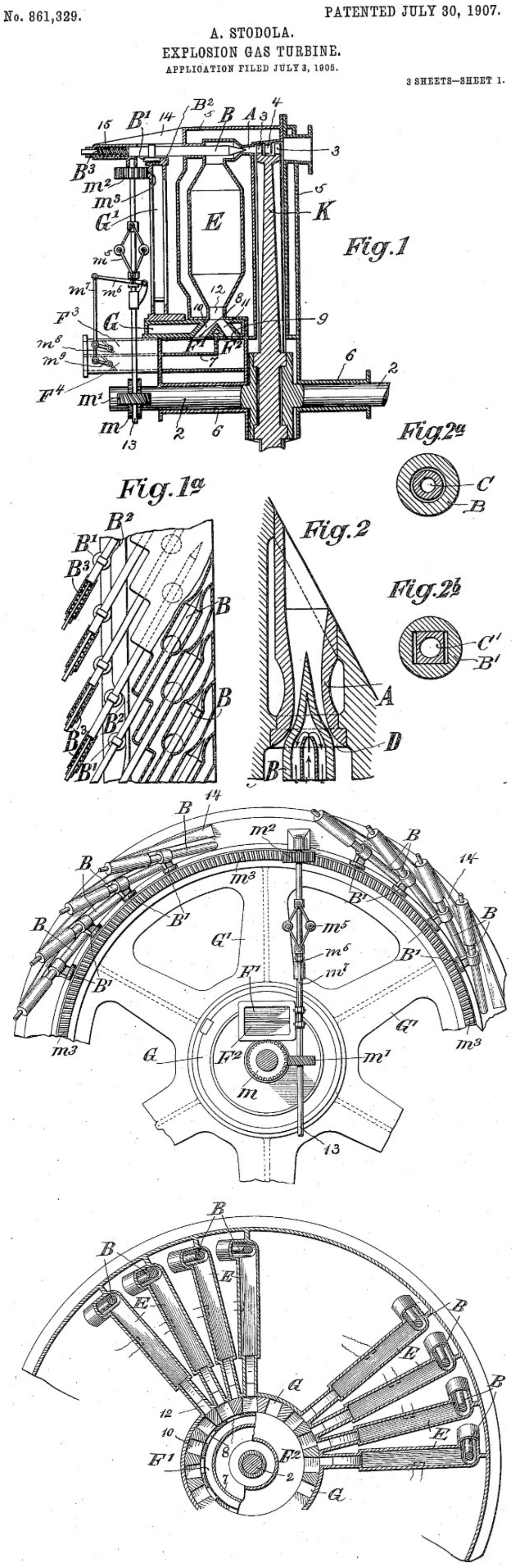
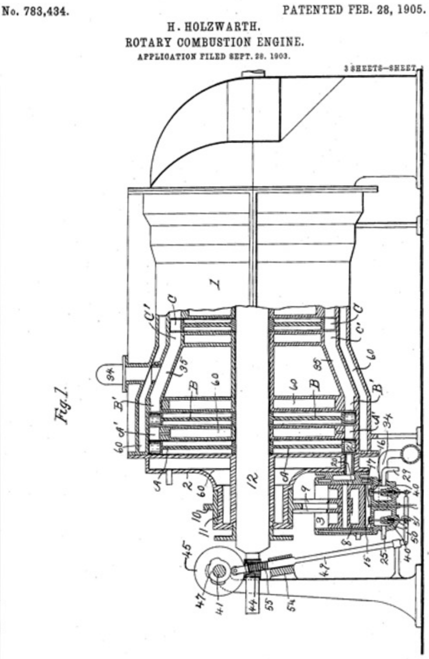
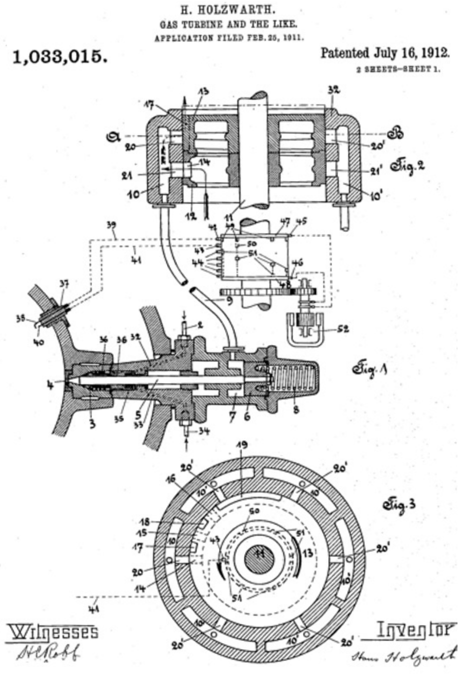
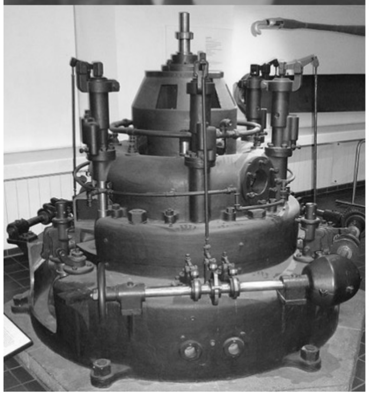

No. 861,329.
PATENTED JULY 30, 1907.
A. STODOLA.
EXPLOSION GAS TURBINE.
APPLICATION FILED JULY 3, 1905.
3 SHEETS—SHEET 1.
Fig.1
Fig.1a
Fig.2
Fig.2a
Fig.2b

Figure 9.58: Aurel Stodola developed gas turbine engines from the 1890s through the 1930s.

Hans Holzwarth
(1877–1953)


No. 783,434. PATENTED FEB. 28, 1905.
H. HOLZWARTH.
ROTARY COMBUSTION ENGINE.
APPLICATION FILED SEPT. 28, 1903.
3 SHEETS—SHEET 1.

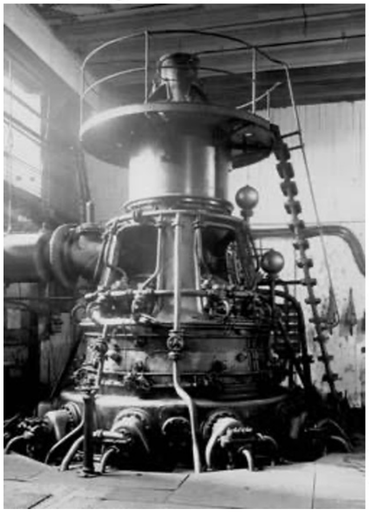

H. HOLZWARTH.
GAS TURBINE AND THE LIKE.
APPLICATION FILED FEB. 25, 1911.
1,033,015. Patented July 16, 1912.
2 SHEETS—SHEET 1.

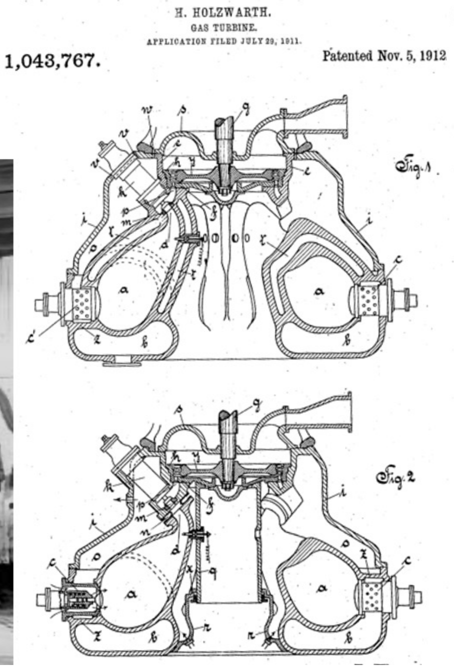


Holzwarth gas turbine engine (1906)

Holzwarth gas turbine engines patents (1900s–1930s)

Holzwarth gas turbine engine (1914)




H. HOLZWARTH.
GAS TURBINE.
APPLICATION FILED JULY 29, 1911.
1,043,767. Patented Nov. 5, 1912

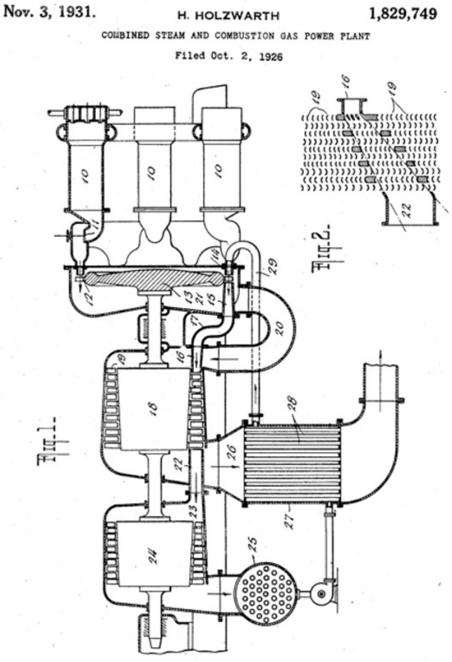
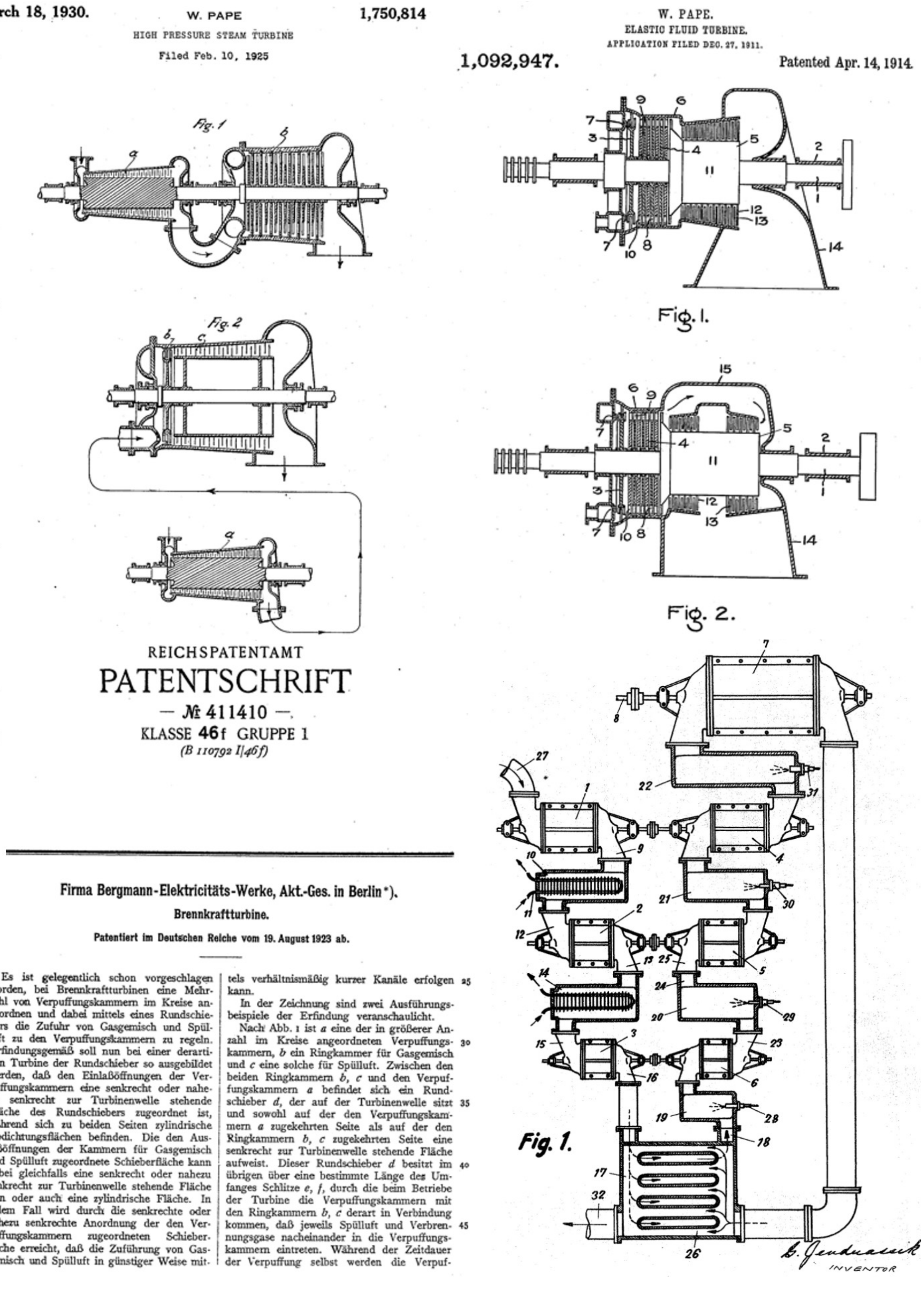

Nov. 3, 1931. H. HOLZWARTH 1,829,749
COMBINED STEAM AND COMBUSTION GAS POWER PLANT
Filed Oct. 2, 1926

Figure 9.59: Hans Holzwarth filed a large number of patent applications on gas turbine engines from around 1900 through the 1930s.

Wilhelm Pape (18??–19??) Gas turbine engines (1910s–1920s)



March 18, 1930. W. PAPE 1,750,814

HIGH PRESSURE STEAM TURBINE

Filed Feb. 10, 1925

W. PAPE.

ELASTIC FLUID TURBINE.

APPLICATION FILED DEC. 27, 1911.

1,092,947. Patented Apr. 14, 1914.

Fig. 1
a
b
Fig. 2
b
c
a
1
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Fig. 1.
Fig. 2.
Fig. 1.
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32
G. Jendrassik
INVENTOR

REICHSPATENTAMT

PATENTSCHRIFT

— № 411410 —

KLASSE 46f GRUPPE 1

(B 110792 I/46f)

Firma Bergmann-Elektricitäts-Werke, Akt.-Ges. in Berlin*).

Brennkraftturbine.

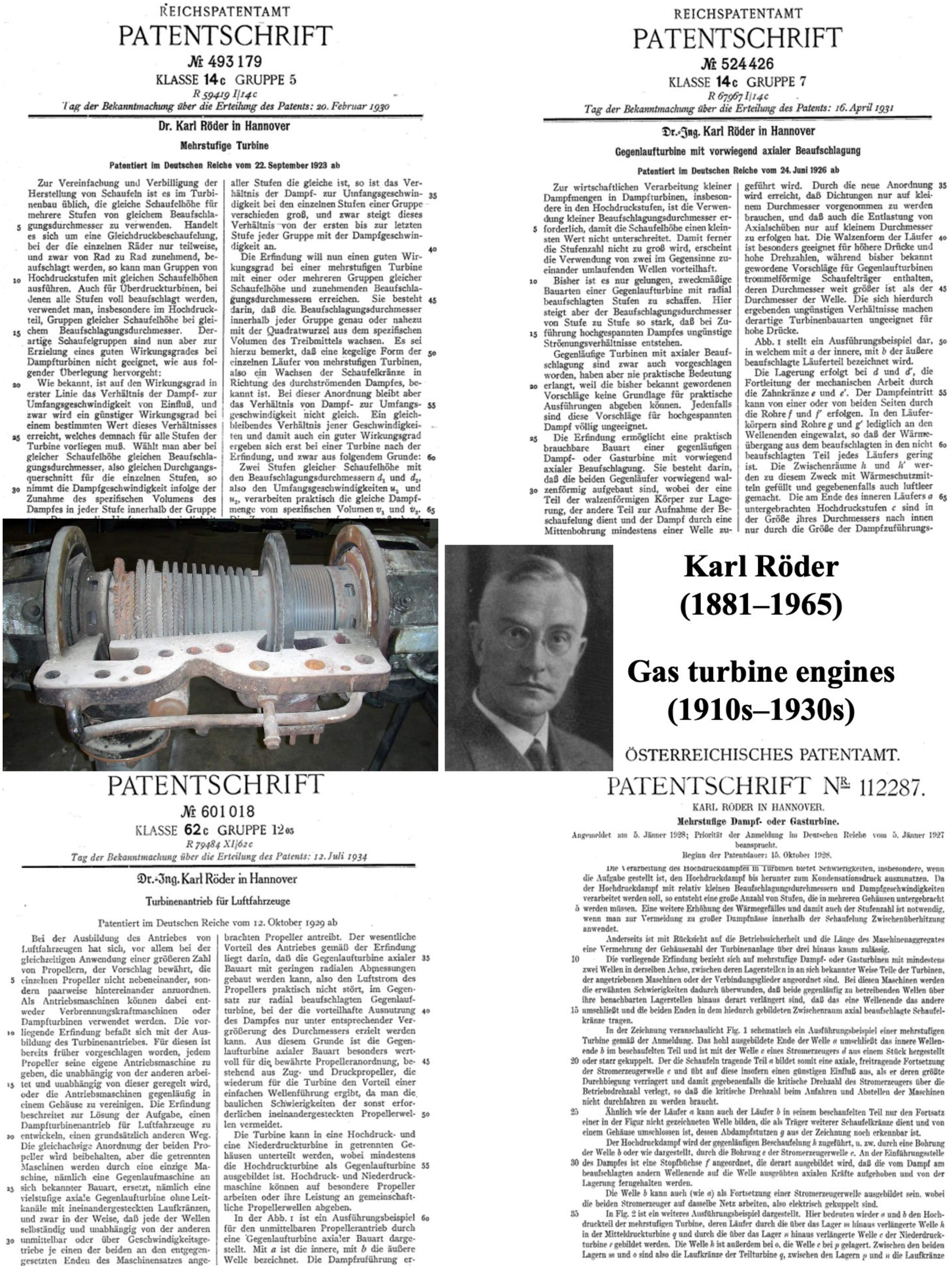
Patentiert im Deutschen Reiche vom 19. August 1923 ab.

Es ist gelegentlich schon vorgeschlagen worden, bei Brennkraftturbinen eine Mehrzahl von Verpuffungskammern im Kreise anzuordnen und dabei mittels eines Rundschiebers die Zufuhr von Gasgemisch und Spülluft zu den Verpuffungskammern zu regeln. Erfindungsgemäß soll nun bei einer derartigen Turbine der Rundschieber so ausgebildet werden, daß den Einlaßöffnungen der Verpuffungskammern eine senkrecht oder nahezu senkrecht zur Turbinenwelle stehende Fläche des Rundschiebers zugeordnet ist, während sich zu beiden Seiten zylindrische Abdichtungsflächen befinden. Die den Auslaßöffnungen der Kammern für Gasgemisch und Spülluft zugeordnete Schieberfläche kann dabei gleichfalls eine senkrecht oder nahezu senkrecht zur Turbinenwelle stehende Fläche sein oder auch eine zylindrische Fläche. In jedem Fall wird durch die senkrechte oder nahezu senkrechte Anordnung der den Verpuffungskammern zugeordneten Schieberfläche erreicht, daß die Zuführung von Gasgemisch und Spülluft in günstiger Weise mittels verhältnismäßig kurzer Kanäle erfolgen kann.

In der Zeichnung sind zwei Ausführungsbeispiele der Erfindung veranschaulicht.

Nach Abb. 1 ist *a* eine der in größerer Anzahl im Kreise angeordneten Verpuffungskammern, *b* ein Ringkammer für Gasgemisch und *c* eine solche für Spülluft. Zwischen den beiden Ringkammern *b*, *c* und den Verpuffungskammern *a* befindet sich ein Rundschieber *d*, der auf der Turbinenwelle sitzt und sowohl auf der den Verpuffungskammern *a* zugekehrten Seite als auf der den Ringkammern *b*, *c* zugekehrten Seite eine senkrecht zur Turbinenwelle stehende Fläche aufweist. Dieser Rundschieber *d* besitzt im übrigen über eine bestimmte Länge des Umfanges Schlitze *e*, *f*, durch die beim Betriebe der Turbine die Verpuffungskammern mit den Ringkammern *b*, *c* derart in Verbindung kommen, daß jeweils Spülluft und Verbrennungsgase nacheinander in die Verpuffungskammern eintreten. Während der Zeitdauer der Verpuffung selbst werden die Verpuf-

Figure 9.60: Wilhelm Pape filed many patent applications on gas turbine engines from the 1910s through the 1920s.


Karl Röder
(1881–1965)
Gas turbine engines
(1910s–1930s)

REICHSPATENTAMT
PATENTSCHRIFT
№ 493 179
KLASSE 14c GRUPPE 5
R 59419 I/14c
Tag der Bekanntmachung über die Erteilung des Patents: 20. Februar 1930

Dr. Karl Röder in Hannover

Mehrstufige Turbine

Patentiert im Deutschen Reiche vom 22. September 1923 ab

Zur Vereinfachung und Verbilligung der Herstellung von Schaufeln ist es im Turbinenbau üblich, die gleiche Schaufelhöhe für mehrere Stufen von gleichem Beaufschlagungsdurchmesser zu verwenden. Handelt es sich um eine Gleichdruckbeschaufelung, bei der die einzelnen Räder nur teilweise, und zwar von Rad zu Rad zunehmend, beaufschlagt werden, so kann man Gruppen von Hochdruckstufen mit gleichen Schaufelhöhen ausführen. Auch für Überdruckturbinen, bei denen alle Stufen voll beaufschlagt werden, verwendet man, insbesondere im Hochdruckteil, Gruppen gleicher Schaufelhöhe bei gleichem Beaufschlagungsdurchmesser. Derartige Schaufelgruppen sind nun aber zur Erzielung eines guten Wirkungsgrades bei Dampfturbinen nicht geeignet, wie aus folgender Überlegung hervorgeht:

Wie bekannt, ist auf den Wirkungsgrad in erster Linie das Verhältnis der Dampf- zur Umfangsgeschwindigkeit von Einfluß, und zwar wird ein günstiger Wirkungsgrad bei einem bestimmten Wert dieses Verhältnisses erreicht, welches demnach für alle Stufen der Turbine vorliegen muß. Wählt man aber bei gleicher Schaufelhöhe gleichen Beaufschlagungsdurchmesser, also gleichen Durchgangsquerschnitt für die einzelnen Stufen, so nimmt die Dampfgeschwindigkeit infolge der Zunahme des spezifischen Volumens des Dampfes in jeder Stufe innerhalb der Gruppe aller Stufen die gleiche ist, so ist das Verhältnis der Dampf- zur Umfangsgeschwindigkeit bei den einzelnen Stufen einer Gruppe verschieden groß, und zwar steigt dieses Verhältnis von der ersten bis zur letzten Stufe jeder Gruppe mit der Dampfgeschwindigkeit an.

Die Erfindung will nun einen guten Wirkungsgrad bei einer mehrstufigen Turbine mit einer oder mehreren Gruppen gleicher Schaufelhöhe und zunehmenden Beaufschlagungsdurchmessern erreichen. Sie besteht darin, daß die Beaufschlagungsdurchmesser innerhalb jeder Gruppe genau oder nahezu mit der Quadratwurzel aus dem spezifischen Volumen des Treibmittels wachsen. Es sei hierzu bemerkt, daß eine kegelige Form der einzelnen Läufer von mehrstufigen Turbinen, also ein Wachsen der Schaufelkränze in Richtung des durchströmenden Dampfes, bekannt ist. Bei dieser Anordnung bleibt aber das Verhältnis von Dampf- zur Umfangsgeschwindigkeit nicht gleich. Ein gleichbleibendes Verhältnis jener Geschwindigkeiten und damit auch ein guter Wirkungsgrad ergeben sich erst bei einer Turbine nach der Erfindung, und zwar aus folgendem Grunde:

Zwei Stufen gleicher Schaufelhöhe mit den Beaufschlagungsdurchmessern d_1 und d_2, also den Umfangsgeschwindigkeiten u_1 und u_2, verarbeiten praktisch die gleiche Dampfmenge vom spezifischen Volumen v_1 und v_2.

REICHSPATENTAMT
PATENTSCHRIFT
№ 524 426
KLASSE 14c GRUPPE 7
R 67967 I/14c
Tag der Bekanntmachung über die Erteilung des Patents: 16. April 1931

Dr.-Ing. Karl Röder in Hannover

Gegenlaufturbine mit vorwiegend axialer Beaufschlagung

Patentiert im Deutschen Reiche vom 24. Juni 1926 ab

Zur wirtschaftlichen Verarbeitung kleiner Dampfmengen in Dampfturbinen, insbesondere in den Hochdruckstufen, ist die Verwendung kleiner Beaufschlagungsdurchmesser erforderlich, damit die Schaufelhöhe einen kleinsten Wert nicht unterschreitet. Damit ferner die Stufenzahl nicht zu groß wird, erscheint die Verwendung von zwei im Gegensinne zueinander umlaufenden Wellen vorteilhaft.

Bisher ist es nur gelungen, zweckmäßige Bauarten einer Gegenlaufturbine mit radial beaufschlagten Stufen zu schaffen. Hier steigt aber der Beaufschlagungsdurchmesser von Stufe zu Stufe so stark, daß bei Zuführung hochgespannten Dampfes ungünstige Strömungsverhältnisse entstehen.

Gegenläufige Turbinen mit axialer Beaufschlagung sind zwar auch vorgeschlagen worden, haben aber nie praktische Bedeutung erlangt, weil die bisher bekannt gewordenen Vorschläge keine Grundlage für praktische Ausführungen abgeben können. Jedenfalls sind diese Vorschläge für hochgespannten Dampf völlig ungeeignet.

Die Erfindung ermöglicht eine praktisch brauchbare Bauart einer gegenläufigen Dampf- oder Gasturbine mit vorwiegend axialer Beaufschlagung. Sie besteht darin, daß die beiden Gegenläufer vorwiegend walzenförmig aufgebaut sind, wobei der eine Teil der walzenförmigen Körper zur Lagerung, der andere Teil zur Aufnahme der Beschaufelung dient und der Dampf durch eine Mittenbohrung mindestens einer Welle zugeführt wird. Durch die neue Anordnung wird erreicht, daß Dichtungen nur auf kleinem Durchmesser vorgenommen zu werden brauchen, und daß auch die Entlastung von Axialschüben nur auf kleinem Durchmesser zu erfolgen hat. Die Walzenform der Läufer ist besonders geeignet für höhere Drücke und hohe Drehzahlen, während bisher bekannt gewordene Vorschläge für Gegenlaufturbinen trommelförmige Schaufelträger enthalten, deren Durchmesser weit größer ist als der Durchmesser der Welle. Die sich hierdurch ergebenden ungünstigen Verhältnisse machen derartige Turbinenbauarten ungeeignet für hohe Drücke.

Abb. 1 stellt ein Ausführungsbeispiel dar, in welchem mit a der innere, mit b der äußere beaufschlagte Läuferteil bezeichnet wird.

Die Lagerung erfolgt bei d und d', die Fortleitung der mechanischen Arbeit durch die Zahnkränze e und e'. Der Dampfeintritt kann von einer oder von beiden Seiten durch die Rohre f und f' erfolgen. In den Läuferkörpern sind Rohre g und g' lediglich an den Wellenenden eingewalzt, so daß der Wärmeübergang aus dem beaufschlagten in den nicht beaufschlagten Teil jedes Läufers gering ist. Die Zwischenräume h und h' werden zu diesem Zweck mit Wärmeschutzmitteln gefüllt und gegebenenfalls auch luftleer gemacht. Die am Ende des inneren Läufers a untergebrachten Hochdruckstufen c sind in der Größe ihres Durchmessers nach innen nur durch die Größe der Dampfzuführungs-

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PATENTSCHRIFT
№ 601 018
KLASSE 62c GRUPPE 12₀₅
R 79484 XI/62c
Tag der Bekanntmachung über die Erteilung des Patents: 12. Juli 1934

Dr.-Ing. Karl Röder in Hannover

Turbinenantrieb für Luftfahrzeuge

Patentiert im Deutschen Reiche vom 12. Oktober 1929 ab

Bei der Ausbildung des Antriebes von Luftfahrzeugen hat sich, vor allem bei der gleichzeitigen Anwendung einer größeren Zahl von Propellern, der Vorschlag bewährt, die einzelnen Propeller nicht nebeneinander, sondern paarweise hintereinander anzuordnen. Als Antriebsmaschinen können dabei entweder Verbrennungskraftmaschinen oder Dampfturbinen verwendet werden. Die vorliegende Erfindung befaßt sich mit der Ausbildung des Turbinenantriebes. Für diesen ist bereits früher vorgeschlagen worden, jedem Propeller seine eigene Antriebsmaschine zu geben, die unabhängig von der anderen arbeitet und unabhängig von dieser geregelt wird, oder die Antriebsmaschinen gegenläufig in einem Gehäuse zu vereinigen. Die Erfindung beschreitet zur Lösung der Aufgabe, einen Dampfturbinenantrieb für Luftfahrzeuge zu entwickeln, einen grundsätzlich anderen Weg. Die gleichachsige Anordnung der beiden Propeller wird beibehalten, aber die getrennten Maschinen werden durch eine einzige Maschine, nämlich eine Gegenlaufmaschine an sich bekannter Bauart, ersetzt, nämlich eine vielstufige axiale Gegenlaufturbine ohne Leitkanäle mit ineinandergesteckten Laufkränzen, und zwar in der Weise, daß jede der Wellen selbständig und unabhängig von der anderen unmittelbar oder über Geschwindigkeitsgetriebe je einen der beiden an den entgegengesetzten Enden des Maschinensatzes angebrachten Propeller antreibt. Der wesentliche Vorteil des Antriebes gemäß der Erfindung liegt darin, daß die Gegenlaufturbine axialer Bauart mit geringen radialen Abmessungen gebaut werden kann, also den Luftstrom des Propellers praktisch nicht stört, im Gegensatz zur radial beaufschlagten Gegenlaufturbine, bei der die vorteilhafte Ausnutzung des Dampfes nur unter entsprechender Vergrößerung des Durchmessers erzielt werden kann. Aus diesem Grunde ist die Gegenlaufturbine axialer Bauart besonders wertvoll für die bewährte Propelleranordnung, bestehend aus Zug- und Druckpropeller, die wiederum für die Turbine den Vorteil einer einfachen Wellenführung ergibt, da man die baulichen Schwierigkeiten der sonst erforderlichen ineinandergesteckten Propellerwellen vermeidet.

Die Turbine kann in eine Hochdruck- und eine Niederdruckturbine in getrennten Gehäusen unterteilt werden, wobei mindestens die Hochdruckturbine als Gegenlaufturbine ausgebildet ist. Hochdruck- und Niederdruckmaschine können auf besondere Propeller arbeiten oder ihre Leistung an gemeinschaftliche Propellerwellen abgeben.

In der Abb. 1 ist ein Ausführungsbeispiel für den unmittelbaren Propellerantrieb durch eine Gegenlaufturbine axialer Bauart dargestellt. Mit a ist die innere, mit b die äußere Welle bezeichnet. Die Dampfzuführung er-

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ÖSTERREICHISCHES PATENTAMT.

PATENTSCHRIFT Nr. 112287.

KARL RÖDER IN HANNOVER.

Mehrstufige Dampf- oder Gasturbine.

Angemeldet am 5. Jänner 1928; Priorität der Anmeldung im Deutschen Reiche vom 5. Jänner 1927 beansprucht.
Beginn der Patentdauer: 15. Oktober 1928.

Die Verarbeitung des Hochdruckdampfes in Turbinen bietet Schwierigkeiten, insbesondere, wenn die Aufgabe gestellt ist, den Hochdruckdampf bis herunter zum Kondensationsdruck auszunutzen. Da der Hochdruckdampf mit relativ kleinen Beaufschlagungsdurchmessern und Dampfgeschwindigkeiten verarbeitet werden soll, so entsteht eine große Anzahl von Stufen, die in mehreren Gehäusen untergebracht werden müssen. Eine weitere Erhöhung des Wärmegefälles und damit auch der Stufenzahl ist notwendig, wenn man zur Vermeidung zu großer Dampfnässe innerhalb der Schaufelung Zwischenüberhitzung anwendet.

Anderseits ist mit Rücksicht auf die Betriebssicherheit und die Länge des Maschinenaggregates eine Vermehrung der Gehäusezahl der Turbinenanlage über drei hinaus kaum zulässig.

Die vorliegende Erfindung bezieht sich auf mehrstufige Dampf- oder Gasturbinen mit mindestens zwei Wellen in derselben Achse, zwischen deren Lagerstellen in an sich bekannter Weise Teile der Turbinen, der angetriebenen Maschinen oder der Verbindungsglieder angeordnet sind. Bei diesen Maschinen werden die erwähnten Schwierigkeiten dadurch überwunden, daß beide gegenläufig zu betreibenden Wellen über ihre benachbarten Lagerstellen hinaus derart verlängert sind, daß das eine Wellenende das andere umschließt und die beiden Enden in dem hiedurch gebildeten Zwischenraum axial beaufschlagte Schaufelkränze tragen.

In der Zeichnung veranschaulicht Fig. 1 schematisch ein Ausführungsbeispiel einer mehrstufigen Turbine gemäß der Anmeldung. Das hohl ausgebildete Ende der Welle a umschließt das innere Wellenende b im beschaufelten Teil und ist mit der Welle c eines Stromerzeugers d aus einem Stück hergestellt oder starr gekuppelt. Der die Schaufeln tragende Teil a bildet somit eine axiale, freitragende Fortsetzung der Stromerzeugerwelle c und übt auf diese insofern einen günstigen Einfluß aus, als er deren größte Durchbiegung verringert und damit gegebenenfalls die kritische Drehzahl des Stromerzeugers über die Betriebsdrehzahl verlegt, so daß die kritische Drehzahl beim Anfahren und Abstellen der Maschinen nicht durchfahren zu werden braucht.

Ähnlich wie der Läufer a kann auch der Läufer b in seinem beschaufelten Teil nur den Fortsatz einer in der Figur nicht gezeichneten Welle bilden, die als Träger weiterer Schaufelkränze dient und von einem Gehäuse umschlossen ist, dessen Abdampfstutzen g aus der Zeichnung noch erkennbar ist.

Der Hochdruckdampf wird der gegenläufigen Beschaufelung h zugeführt, u. zw. durch eine Bohrung der Welle b oder wie dargestellt, durch die Bohrung e der Stromerzeugerwelle c. An der Einführungsstelle des Dampfes ist eine Stopfbüchse f angeordnet, die derart ausgebildet wird, daß die vom Dampf am beaufschlagten andern Wellenende auf die Welle ausgeübten axialen Kräfte aufgehoben und von der Lagerung ferngehalten werden.

Die Welle b kann auch (wie a) als Fortsetzung einer Stromerzeugerwelle ausgebildet sein, wobei die beiden Stromerzeuger auf dasselbe Netz arbeiten, also elektrisch gekuppelt sind.

In Fig. 2 ist ein weiteres Ausführungsbeispiel dargestellt. Hier bedeuten wieder a und b den Hochdruckteil der mehrstufigen Turbine, deren Läufer durch die über das Lager m hinaus verlängerte Welle h in der Mitteldruckturbine q und durch die über das Lager n hinaus verlängerte Welle c der Niederdruckturbine r gebildet werden. Die Welle h ist außerdem bei o, die Welle c bei p gelagert. Zwischen den beiden Lagern m und o sind also die Laufkränze der Teilturbine q, zwischen den Lagern p und n die Laufkränze

Figure 9.61: Karl Röder filed numerous patent applications on gas turbine engines from the 1910s through the 1930s.

Karl Enders (18??–19??)

Gas turbine engines (1925)

Bild 1.

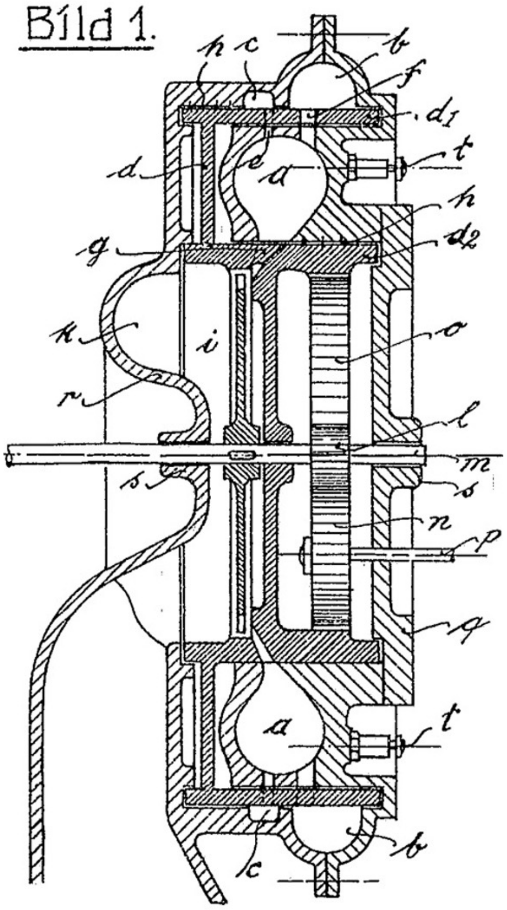
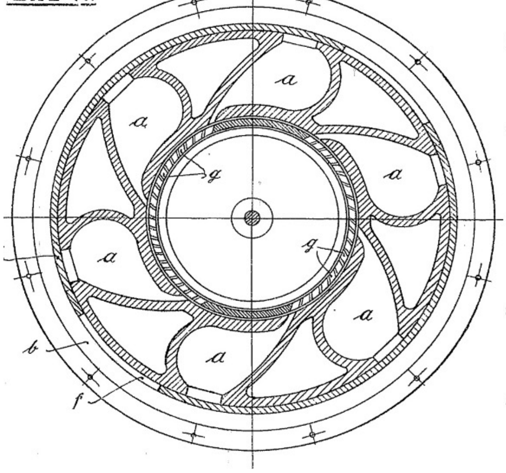


Bild 2.



REICHSPATENTAMT

PATENTSCHRIFT

№ 451778

KLASSE **46**f GRUPPE 1

E 33404 I/46f

Tag der Bekanntmachung über die Erteilung des Patents: 13. Oktober 1927

Karl Enders in Dresden

Brennkraftturbine mit um die Welle liegenden Brennkammern

Patentiert im Deutschen Reiche vom 6. Dezember 1925 ab

Die Erfindung betrifft Brennkraftturbinen mit um die Welle liegenden Brennkammern, deren Ein- und Auslässe durch um die Laufradachse umlaufende Schieber geregelt werden.

Man hat bereits Turbinen vorgeschlagen, bei denen das Laufrad selbst als zylindrischer Drehschieber zur Regelung des Treibmittelaustrittes ausgebildet ist, und zwar derart, daß sich auf dem Umfange des Radkörpers Gruppen von Laufschaufeln und Steuerflächen abwechseln. Die Zahl der Gruppen wird hierbei von der Zahl der Brennkammern bestimmt. Der Gesamtwirkungsgrad solcher Anordnungen ist jedoch ein schlechter, einmal, weil eine große Zahl von Verbrennungen auf einen Umlauf des Laufrades kommt, sodann aber auch, weil bei einer großen Drehzahl und Umlaufgeschwindigkeit der Steuerflächen sich unzureichende und nicht überwachbare Verhältnisse bei der Füllung, Entspannung und Spülung ergeben. Dadurch ist die Erreichung höherer Geschwindigkeiten praktisch unmöglich.

Nun hat man weiter bereits von der Laufradachse untersetzt angetriebene und um diese umlaufende Drehschieber vorgesehen, um durch sie den Austritt der Gase zu regeln und durch eine Düse auf den im Inneren des Schiebers befindlichen Laufradkranz geleitet.

Durch die Erfindung sollen neue Vorteile erreicht werden. Sie besteht darin, daß die Steuerflächen durch einen besonderen, für Auslaßregelungen an sich bekannten, auf der Laufradachse der Turbine lose drehbaren Drehschieber, der untersetzt angetrieben wird, gebildet werden. Diese Anordnung beseitigt die Ventile an der Turbine völlig, insbesondere auch auf der Treibmitteleinlaßseite.

Ein weiterer Vorteil der Erfindung besteht darin, daß die Brennkammern nach außen gelegt sind, um so für das Gehäuse und den Drehschieber eine große Kühlfläche zu erhalten. Die Austrittsregelung der Gase aus den Kammern erfolgt erfindungsgemäß durch Gruppen von düsenförmigen Kanälen im Regelungsschlitz des Drehschiebers über einen Bereich zwischen den Austrittsöffnungen mindestens zweier benachbarter Brennkammern. Auf diese Weise wird dem Austritt der Gase ein größerer Zeitraum gelassen als bisher und gleichzeitig ihnen über die Gesamtdauer des Austrittes die gleiche Richtung gegeben.

Die in der Zeichnung dargestellte Ausführungsform stellt einen neuen Typ von Brennkraftturbinen dar, der insbesondere eine enge Bauart aufweist, die die Ausnutzung der Gase in mehreren Stufen gestattet. Die Anordnung der Innenverzahnung am Drehschieber bietet hierbei nicht unwesentliche bauliche Vorteile.

Bild 1 zeigt einen durch die Turbine mit Ausnahme der Übersetzungsräder gelegten Längsschnitt,

Bild 2 einen Querschnitt hierzu in der Richtung I zu I in Bild 1.

Die Brennkammern *a* sind am Umfange der Turbine angeordnet. Sie haben je eine äußere und eine innere zylindrische Begrenzungsfläche d_1 und d_2, in denen die Ein- und Austrittsöffnungen für den Betriebsstoff untergebracht sind. Äußere Ringkanäle *b* und *c* sind für die Zuführung von Gasgemisch und Spülluft vorgesehen. Der Drehschieber *d* besitzt in seinen zylindrischen Flächen d_1 und d_2 entsprechende Öffnungen *e* und *f* zur Regelung von Gemisch und Spülluft sowie düsenförmige Austrittsöffnungen *g* für die Gase, während die übrige Fläche jeweils die Brennkammern während der Verdichtungszeiten bis zur erfolgten Zündung geschlossen hält. *h* sind Labyrinthdichtungen, und *i* ist das Laufrad. Die Abgase werden im Raum *k* gesammelt und abgeführt. Zusammen mit dem Laufrad *i* ist auch ein Zahnrad *l* auf der Turbinenwelle *m* befestigt, das mit zwei Zwischenrädern *n* und *o* im Eingriff steht, von denen wenigstens *n* mit einer Achse *p* im Deckel *q* der Turbine fest gelagert ist. Dieser sowie der Gehäusedeckel *r* enthalten die Lager *s* der Welle *m*. *t* sind Zündkerzen.

Die anderen zum Betrieb der Turbine gehörigen Teile sind nicht mit eingezeichnet.

Im Ausführungsbeispiel sind sechs Brennkammern gezeichnet. Der Drehschieber ist symmetrisch mit zwei Gruppen von Ein- und Austrittsöffnungen für Gasgemisch und Spülluft und für gespannte Gase gezeichnet. Das Übersetzungsverhältnis betrage 6 : 1. Auf eine Umdrehung des Drehschiebers kommen demnach sechs Umläufe des Laufrades und zwölf Zündungen.

Bei einer größeren Zahl von Brennkammern kann man die Gruppeneinteilung noch weiter treiben, so daß beispielsweise bei 12 Kammern die 1, 4, 7, 10; 2, 5, 8, 11; 3, 6, 9, 12 gleichzeitig arbeiten.

PATENTANSPRÜCHE:

1. Brennkraftturbine mit um die Welle liegenden Brennkammern, deren Ein- und Auslässe durch um die Laufradachse umlaufende Steuerflächen geregelt werden, dadurch gekennzeichnet, daß die Steuerflächen durch einen besonderen, für Auslaßregelungen an sich bekannten, auf der Laufradachse lose drehbaren, untersetzt angetriebenen Drehschieber gebildet werden.

2. Brennkraftturbine nach Anspruch 1, dadurch gekennzeichnet, daß von den zwei konzentrischen Zylindersteuerflächen des Drehschiebers die äußere den Einlaß der außerhalb gelegenen Gas- und Luftzuleitungen nach den zwischen beiden gelegenen Brennkammern und die innere den Auslaß aus diesen nach den Laufradschaufeln überwacht und daß die Auslaßdüsen in dem inneren Zylinder den bis dahin von außen nach innen gerichteten Weg der Arbeitsmittel in einen axial oder nahezu axial gerichteten gegen die Laufradschaufeln umlenken.

3. Brennkraftturbine nach Anspruch 1, dadurch gekennzeichnet, daß der den Auslaß der gespannten Gase freigebende Regelungsschlitz sich über einen Bereich zwischen mindestens zwei benachbarten Brennkammeraustrittsöffnungen erstreckt und in diesem düsenförmige Kanäle (*g*) vorgesehen sind, die dem Betriebsmittel über die Gesamtdauer des Austritts die gleiche Richtung geben.

4. Brennkraftturbine nach Anspruch 1 und 2, gekennzeichnet durch eine Innenverzahnung am Drehschieber.

Figure 9.62: Karl Enders filed a patent application on gas turbine engines in 1925.

Oscar Hart (18??–19??) and Joseph Hetterich (18??–19??)

Gas turbine engines (1925)

REICHSPATENTAMT

PATENTSCHRIFT

№ 476033

KLASSE **46**f GRUPPE 1

H 103536 I/46f

Tag der Bekanntmachung über die Erteilung des Patents: 25. April 1929

Oscar Hart und Joseph Hetterich in München

Brennkraftturbine mit umlaufenden, auf einem Radkranz angeordneten Brennkammern

Patentiert im Deutschen Reiche vom 18. September 1925 ab

Gegenstand der Erfindung ist eine Brennkraftturbine mit umlaufenden, auf einem Radkranz angeordneten Brennkammern. Die bekannten Brennkraftturbinen dieser Art sind so beschaffen, daß die Beschickung und Entlüftung der Brennkammern sowie die Abströmung der Verbrennungsgase seitlich, also in axialer Richtung, und die Zündung des Gasgemisches gleichzeitig mit dem Abströmen in die Leitschaufeln erfolgen. Hieraus ergeben sich verschiedene Nachteile, welche die Bedienung der Maschine erschweren und deren Wirkungsgrad vermindern. Die seitliche Beschickung erfordert zwangläufig den Einbau der Steuerungsorgane, Ventile und Zündeinrichtungen im Innern der Maschine, so daß sie schwer zugänglich sind und Betriebsstörungen beim unregelmäßigen Arbeiten dieser Organe nur durch schwierige und zeitraubende Arbeiten behoben werden können. Das mit der Zündung gleichzeitig abströmende Gasgemisch verbrennt nicht gleichmäßig und unvollständig, wodurch sich ein uneinheitlicher, die Leistung der Turbine herabsetzender Verpuffungsdruck ergibt.

Mit der Erfindung wird die Beseitigung dieser Nachteile bezweckt. Die neue Erfindung besteht darin, daß die Beschickung und Entlüftung der Brennkammern radial von außen, die Abströmung der Verbrennungsgase dagegen beiderseits des Triebrades axial erfolgt, wobei die das Triebrad seitlich einschließenden Leitschaufelauslässe hinter der zugehörigen Zündstelle ansetzen.

Der Einbau der Zündmittel, Ventile und Steuerorgane in Radialkanälen ist einfach durchzuführen, ebenso lassen sich diese Organe leicht überwachen, regeln, instand halten und instand setzen, wodurch der Betrieb wesentlich gefördert wird. Die Zurücksetzung der Leitschaufelauslässe führt zur gleichmäßigen und vollständigen Verbrennung des Gemisches, so daß sich der Druck der Verbrennungsgase jeder Brennkammer zu einem gleichmäßigen Verpuffungsdruck ausgleichen kann.

Auf der Zeichnung ist eine Brennkraftturbine nach der Erfindung in einer Ausführungsform beispielsweise in Abb. 1 im Querschnitt und in Abb. 2 im Höhenschnitt dargestellt. Abb. 3 zeigt die Anordnung von einzelnen Teilen der Turbine.

Hierbei ist 1 das in der Mitte der Turbine befindliche, von der hohlen Welle 9 mitgenommene Triebrad, welches in seinem Kranz in bekannter Weise eine Anzahl, z. B. fünf, Brennkammern 2 enthält, welche gegen das Gehäuse 3 bei 4 abgedichtet sind. Aus jeder Brennkammer führen winklig zur Achse liegende Düsen 5 in die Seitenwände des Triebrades 1. Dieses ist durch eine Mittelwand 6 geteilt, welche nahe ihrem Rande Durchlässe 7 besitzt. Beide Triebradhälften stehen mittels Bohrungen 8 mit der Hohlwelle 9 zwecks Erzielung einer Umlaufkühlung in Verbindung. Beiderseits des Triebrades sitzen auf der Welle 9 ein oder mehrere am Umfange mit Schaufeln 11 besetzte Laufräder 10.

Zwischen dem Triebrad 1 und den sich anschließenden Laufrädern 10 und, wenn mehrere der letzteren vorhanden sind, auch zwischen je zwei benachbarten Laufrädern sind an ringförmigen Zwischenwänden des Gehäuses Leitschaufeln 12 vorgesehen, welche, entsprechend der Aufeinanderfolge der Verbrennungsvorgänge, nur auf einem Teil des Umfangs ihrer Träger, also absatzweise, angeordnet sind. Im Gehäuse vorgesehene Ringkanäle 13 dienen zur Ableitung der Abgase; der Gehäusemantel 14 bildet einen Teil der Kühlung.

Gemäß der Erfindung sind nun die zum Betriebe der Turbine erforderlichen, vom Triebrad 1 gesteuerten Kanalsätze, und zwar Brennstoffeinlaß 15, Zündkanal 16 und Entlüftungskanal 17, radial im Gehäuse angeordnet. Wie aus Abb. 2 ersichtlich, sind bei der gewählten Ausführungsform drei solcher Kanalsätze vorgesehen.

Die Leitschaufeln 12 setzen erfindungsgemäß etwas hinter dem zugehörigen Zündkanal 16 an und enden in der Nähe des Entlüftungskanals 17.

Die Wirkungsweise der Turbine ist folgende: Die jeweils dem Brennstoffeinlaß 15 gegenüberliegende Brennkammer 2 wird radial von außen mit dem flüssigen oder gasförmigen Brennstoff beschickt, wozu sowohl ein gesteuertes Einlaßventil als auch ein Einlaßschlitz in Verbindung mit einem unter Druck stehenden Brennstoffgemischbehälter Verwendung finden kann.

Nach dem Anwerfen der Turbine kommt die beschickte Brennkammer 2 zum Zündkanal 16 mit Zündkerze oder Glührohr, wodurch sich das Gasgemisch entzündet, ohne jedoch sofort abströmen zu können, da die Leitschaufeln 12 erst hinter der Zündstelle 16 ansetzen. Dadurch ergibt sich einerseits eine Reihenzündung und andererseits eine Ausgleichung des Verpuffungsdrucks der Verbrennungsgase, welche dann gleichförmig und vollständig verbrannt seitlich, also axial zu den Leitschaufeln 12, abströmen und die Turbine in Bewegung halten. Die beschickte Brennkammer kommt sodann in den Bereich des Entlüftungskanals 17 und wird, z. B. mittels eines Schleudergebläses, radial entlüftet, welches auch die Leitschaufeln 12 und Laufradschaufeln 11 entlüftet und kühlt. Die neuerliche Beschickung der entleerten Brennkammern erfolgt erst dann wieder, wenn die Düse 5 gegen die Leitschaufeln 12 abgeschlossen ist.

Die Taktvorgänge spielen sich dabei in der Weise ab, daß die Zündungen nach Maßgabe der Brennkammernstellung gegenüber den Zündkanälen erfolgen.

PATENTANSPRUCH:

Brennkraftturbine mit umlaufenden, auf einem Radkranz angeordneten Brennkammern, dadurch gekennzeichnet, daß die Beschickung und Entlüftung der Brennkammern (2) radial von außen und die Abströmung der Verbrennungsgase beiderseits des Triebrades (1) axial erfolgt, wobei die das Triebrad seitlich einschließenden Leitschaufelauslässe (12) zur Erzielung einer gleichförmigen und vollständigen Verbrennung des Gemisches hinter der zugehörigen Zündstelle (16) ansetzen, so daß sich der Druck der Verbrennungsgase jeder Kammer (2) vor dem Abströmen durch die Leitschaufelauslässe (12) zu einem gleichmäßigen Verpuffungsdruck ausgleichen kann.

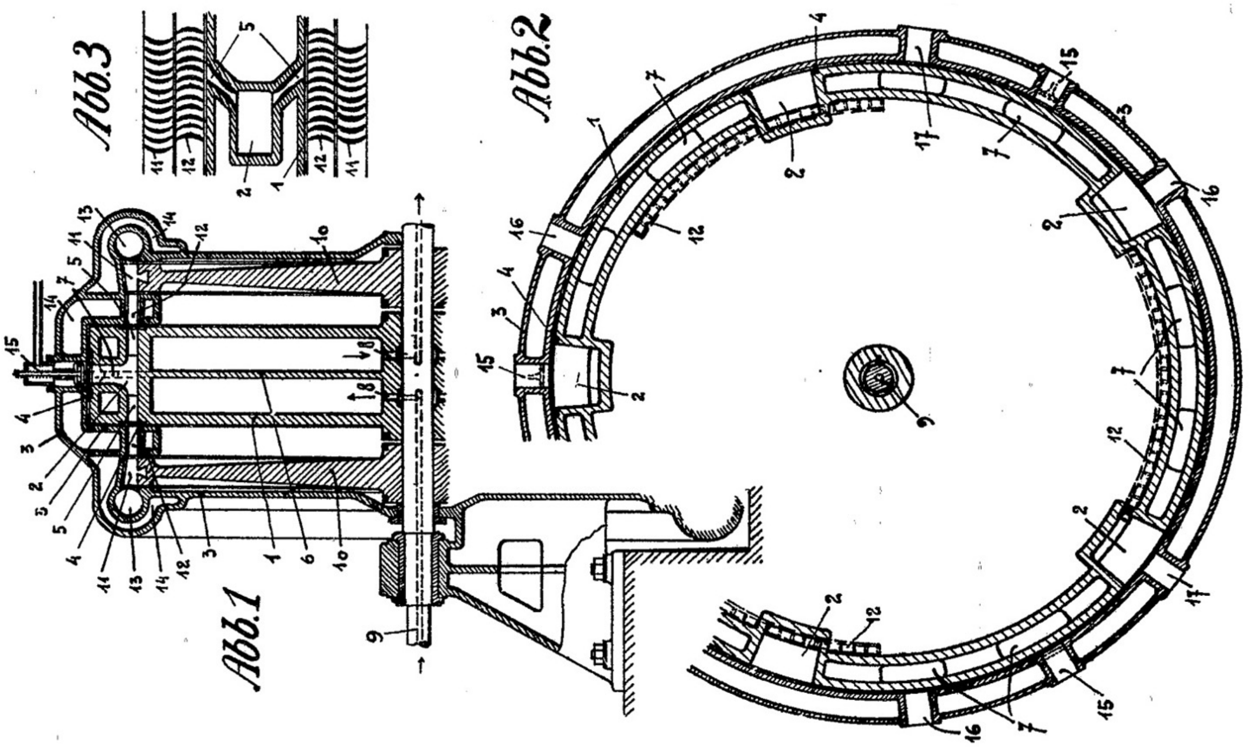
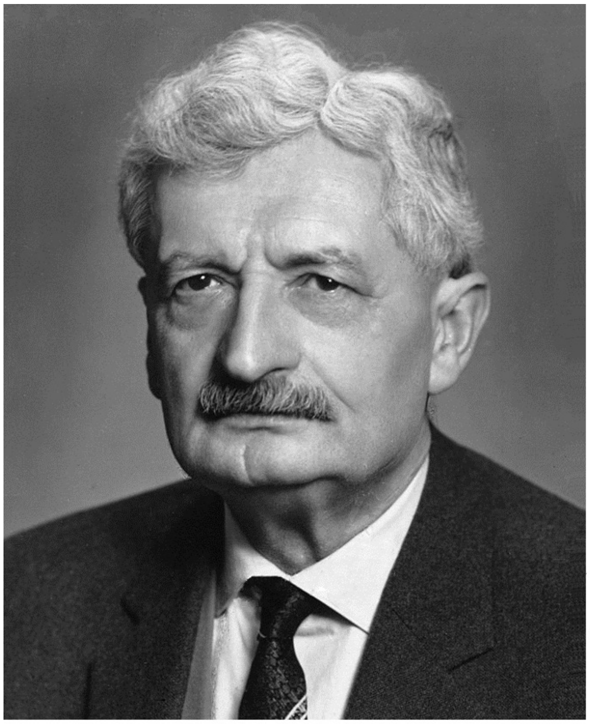
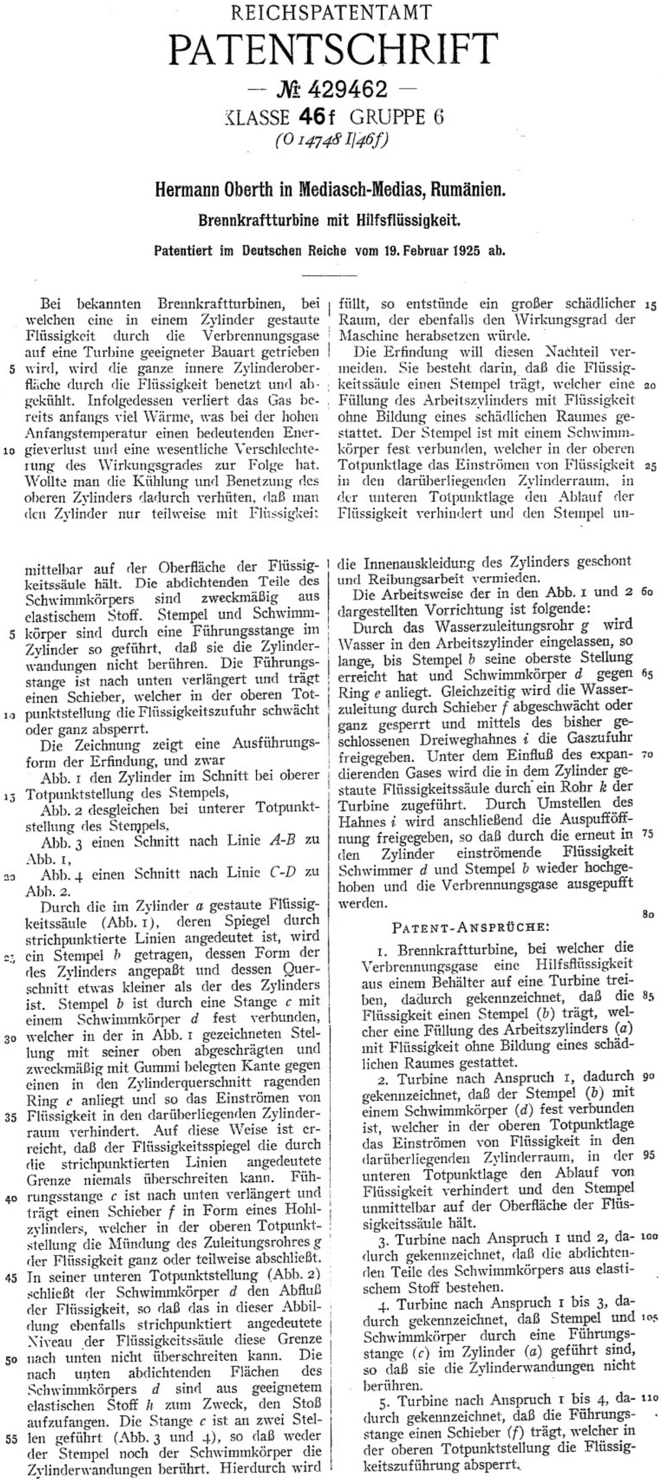


Figure 9.63: Oscar Hart and Joseph Hetterich filed a patent application on gas turbine engines in 1925.



Hermann Oberth (1894–1989)

Gas turbine engines (1925)



REICHSPATENTAMT
PATENTSCHRIFT
— № 429462 —
KLASSE **46**f GRUPPE 6
(O 14748 I/46f)

Hermann Oberth in Mediasch-Medias, Rumänien.

Brennkraftturbine mit Hilfsflüssigkeit.

Patentiert im Deutschen Reiche vom 19. Februar 1925 ab.

Bei bekannten Brennkraftturbinen, bei welchen eine in einem Zylinder gestaute Flüssigkeit durch die Verbrennungsgase auf eine Turbine geeigneter Bauart getrieben wird, wird die ganze innere Zylinderoberfläche durch die Flüssigkeit benetzt und abgekühlt. Infolgedessen verliert das Gas bereits anfangs viel Wärme, was bei der hohen Anfangstemperatur einen bedeutenden Energieverlust und eine wesentliche Verschlechterung des Wirkungsgrades zur Folge hat. Wollte man die Kühlung und Benetzung des oberen Zylinders dadurch verhüten, daß man den Zylinder nur teilweise mit Flüssigkeit füllt, so entstünde ein großer schädlicher Raum, der ebenfalls den Wirkungsgrad der Maschine herabsetzen würde.

Die Erfindung will diesen Nachteil vermeiden. Sie besteht darin, daß die Flüssigkeitssäule einen Stempel trägt, welcher eine Füllung des Arbeitszylinders mit Flüssigkeit ohne Bildung eines schädlichen Raumes gestattet. Der Stempel ist mit einem Schwimmkörper fest verbunden, welcher in der oberen Totpunktlage das Einströmen von Flüssigkeit in den darüberliegenden Zylinderraum, in der unteren Totpunktlage den Ablauf der Flüssigkeit verhindert und den Stempel unmittelbar auf der Oberfläche der Flüssigkeitssäule hält. Die abdichtenden Teile des Schwimmkörpers sind zweckmäßig aus elastischem Stoff. Stempel und Schwimmkörper sind durch eine Führungsstange im Zylinder so geführt, daß sie die Zylinderwandungen nicht berühren. Die Führungsstange ist nach unten verlängert und trägt einen Schieber, welcher in der oberen Totpunktstellung die Flüssigkeitszufuhr schwächt oder ganz absperrt.

Die Zeichnung zeigt eine Ausführungsform der Erfindung, und zwar

Abb. 1 den Zylinder im Schnitt bei oberer Totpunktstellung des Stempels,

Abb. 2 desgleichen bei unterer Totpunktstellung des Stempels,

Abb. 3 einen Schnitt nach Linie *A-B* zu Abb. 1,

Abb. 4 einen Schnitt nach Linie *C-D* zu Abb. 2.

Durch die im Zylinder *a* gestaute Flüssigkeitssäule (Abb. 1), deren Spiegel durch strichpunktierte Linien angedeutet ist, wird ein Stempel *b* getragen, dessen Form der des Zylinders angepaßt und dessen Querschnitt etwas kleiner als der des Zylinders ist. Stempel *b* ist durch eine Stange *c* mit einem Schwimmkörper *d* fest verbunden, welcher in der in Abb. 1 gezeichneten Stellung mit seiner oben abgeschrägten und zweckmäßig mit Gummi belegten Kante gegen einen in den Zylinderquerschnitt ragenden Ring *e* anliegt und so das Einströmen von Flüssigkeit in den darüberliegenden Zylinderraum verhindert. Auf diese Weise ist erreicht, daß der Flüssigkeitsspiegel die durch die strichpunktierten Linien angedeutete Grenze niemals überschreiten kann. Führungsstange *c* ist nach unten verlängert und trägt einen Schieber *f* in Form eines Hohlzylinders, welcher in der oberen Totpunktstellung die Mündung des Zuleitungsrohres *g* der Flüssigkeit ganz oder teilweise abschließt. In seiner unteren Totpunktstellung (Abb. 2) schließt der Schwimmkörper *d* den Abfluß der Flüssigkeit, so daß das in dieser Abbildung ebenfalls strichpunktiert angedeutete Niveau der Flüssigkeitssäule diese Grenze nach unten nicht überschreiten kann. Die nach unten abdichtenden Flächen des Schwimmkörpers *d* sind aus geeignetem elastischen Stoff *h* zum Zweck, den Stoß aufzufangen. Die Stange *c* ist an zwei Stellen geführt (Abb. 3 und 4), so daß weder der Stempel noch der Schwimmkörper die Zylinderwandungen berührt. Hierdurch wird die Innenauskleidung des Zylinders geschont und Reibungsarbeit vermieden.

Die Arbeitsweise der in den Abb. 1 und 2 dargestellten Vorrichtung ist folgende:

Durch das Wasserzuleitungsrohr *g* wird Wasser in den Arbeitszylinder eingelassen, so lange, bis Stempel *b* seine oberste Stellung erreicht hat und Schwimmkörper *d* gegen Ring *e* anliegt. Gleichzeitig wird die Wasserzuleitung durch Schieber *f* abgeschwächt oder ganz gesperrt und mittels des bisher geschlossenen Dreiweghahnes *i* die Gaszufuhr freigegeben. Unter dem Einfluß des expandierenden Gases wird die in dem Zylinder gestaute Flüssigkeitssäule durch ein Rohr *k* der Turbine zugeführt. Durch Umstellen des Hahnes *i* wird anschließend die Auspufföffnung freigegeben, so daß durch die erneut in den Zylinder einströmende Flüssigkeit Schwimmer *d* und Stempel *b* wieder hochgehoben und die Verbrennungsgase ausgepufft werden.

PATENT-ANSPRÜCHE:

1. Brennkraftturbine, bei welcher die Verbrennungsgase eine Hilfsflüssigkeit aus einem Behälter auf eine Turbine treiben, dadurch gekennzeichnet, daß die Flüssigkeit einen Stempel (*b*) trägt, welcher eine Füllung des Arbeitszylinders (*a*) mit Flüssigkeit ohne Bildung eines schädlichen Raumes gestattet.
2. Turbine nach Anspruch 1, dadurch gekennzeichnet, daß der Stempel (*b*) mit einem Schwimmkörper (*d*) fest verbunden ist, welcher in der oberen Totpunktlage das Einströmen von Flüssigkeit in den darüberliegenden Zylinderraum, in der unteren Totpunktlage den Ablauf von Flüssigkeit verhindert und den Stempel unmittelbar auf der Oberfläche der Flüssigkeitssäule hält.
3. Turbine nach Anspruch 1 und 2, dadurch gekennzeichnet, daß die abdichtenden Teile des Schwimmkörpers aus elastischem Stoff bestehen.
4. Turbine nach Anspruch 1 bis 3, dadurch gekennzeichnet, daß Stempel und Schwimmkörper durch eine Führungsstange (*c*) im Zylinder (*a*) geführt sind, so daß sie die Zylinderwandungen nicht berühren.
5. Turbine nach Anspruch 1 bis 4, dadurch gekennzeichnet, daß die Führungsstange einen Schieber (*f*) trägt, welcher in der oberen Totpunktstellung die Flüssigkeitszuführung absperrt.

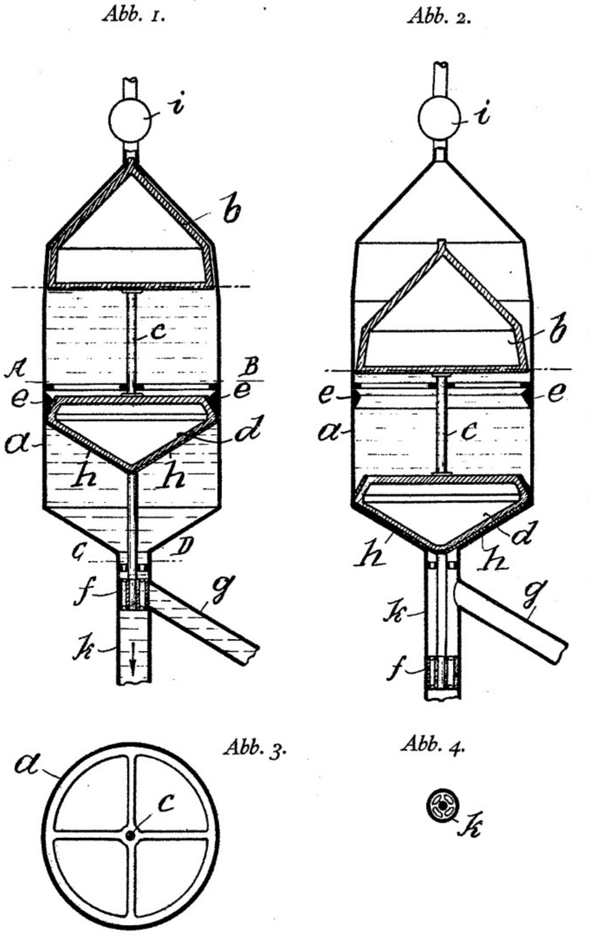


Figure 9.64: Hermann Oberth filed a patent application on gas turbine engines for aircraft in 1925.

One of the most important figures in the development of jet technology was Hans von Ohain (German, 1911–1998), a young physicist who dreamed of creating practical jet engines and aircraft. Working with the mechanic Max Hahn (German, 18??–19??), von Ohain designed his first prototype jet engine in 1933 and demonstrated it in 1935 (Fig. 9.65, top). Von Ohain's biographer Margaret Conner described the prototype [Conner 2001, pp. 38–39]:

> Von Ohain said that in a little storage room behind the shop, "We made a little model according to my own sketches. It was about three feet in diameter and about one foot wide. The blades were made of heavy sheet metal. Almost nothing was welded because Hahn was more a man for clean machining operations, and for fastening with bolts and nuts." It was a pancake engine for either vertical or horizontal thrust, a very light design. [...]
>
> Von Ohain moved his device to the back room of the Bartels and Becker garage. It was exciting to von Ohain and Hahn if the device worked at all. Each time the model was tested, long yellow flames streaked out. [...] Max Hahn, normally very stern and skeptical, seemed in this instance to be quite positive and optimistic. He conceded, in a rare glimpse of a sense of humor, "At least the flames came out of the right place," and with high velocity. The engine did not self-sustain but did result in the unloading of the starter [doing the work of the starter motor when burning]. Instead of the pounding of the conventional engine there was a smooth flow of power, and a new sound, a piercing whistle.

The 1935 prototype jet engine of von Ohain and Hahn caught the attention of Ernst Heinkel (German, 1888–1958), a politically very powerful aircraft manufacturer who hired them in 1936 and provided them with all the resources and long-term support needed to build and test improved versions such as the HeS 1 (Fig. 9.65, bottom) [Conner 2001, pp. 61–62]:

> The project engine was designated the He S 1, He S for *Heinkel-Strahltriebwerk* (Heinkel jet engine). The He S 1 engine was made essentially of sheet steel fabricated at the Marienehe works and disks created at a nearby shipyard. It consisted of a back-to-back radial compressor and a radial inflow turbine. The rotor diameter was 12 inches (300 mm). The demonstrator combustor did not present any significant problems. The engine operated at a speed of 10,000 rpm and produced a thrust of 250 lbs (1.1 kN). It performed flawlessly under design conditions and during transient acceleration and deceleration. The sound was smoothed and focused, and the size of the unit was suitable for an aircraft. [...]
>
> The He S 1 engine was completed and installed in the test bed about the end of February 1937. Von Ohain said that the first test took place in March 1937.

A further improved engine, the HeS 3 (Figs. 9.66– 9.67), was first run in March 1938. It was then installed in a Heinkel He 178 aircraft, which in August 1939 became the world's first operational jet plane. Sterling Pavelec, professor of aerospace history at the USAF Air Command and Staff College, described the first test flight [Pavelec 2007, p. 22]:

> On August 27, 1939, Heinkel test pilot Erich Warsitz lifted off the airfield at Marienehe completing the first ever jet flight. The Heinkel team had ushered in a new era of aeronautical engineering. [...]
>
> The HeS 3b turbojet that powered the Günther's He 178 V1 produced 500 kg (1,100 lbs) thrust. The plane was designed around the engine, with the air intake in the nose and a tubular frame that housed the centrifugal-flow engine. Warsitz took off for the first time in a turbojet-powered aircraft and achieved a top speed—with the wheels down—of 300 kmph (187 mph). Warsitz was also the first to suffer a jet bird strike, which cut his flight short, but without substantial damage to the airplane or engine.

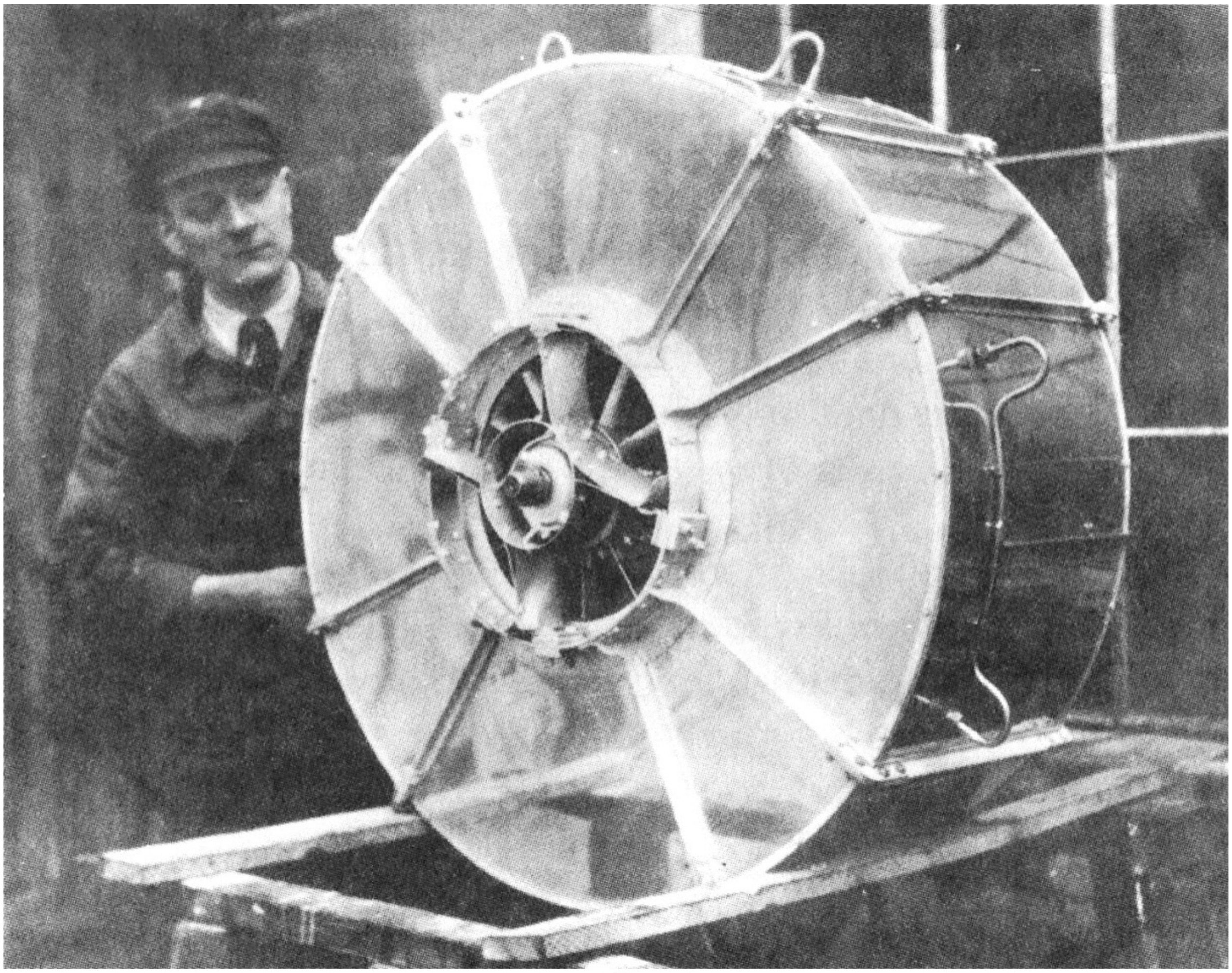
That initial single-engine jet aircraft was followed by the twin-engine He 280 jet aircraft in early 1941, using the newest HeS 8 engines (Fig. 9.68, first run September 1940) [Pavelec 2007, p. 28]:

> The He 280 airframe was prepared, and the anticipated HeS 8a engines were finally ready by March 1941. [...] The first engines were delivered, the plane was readied, and the chief test pilot Fritz Schäfer was able to make the first flight in the twin-engine He 280 on March 30, 1941. The plane tested well[....]

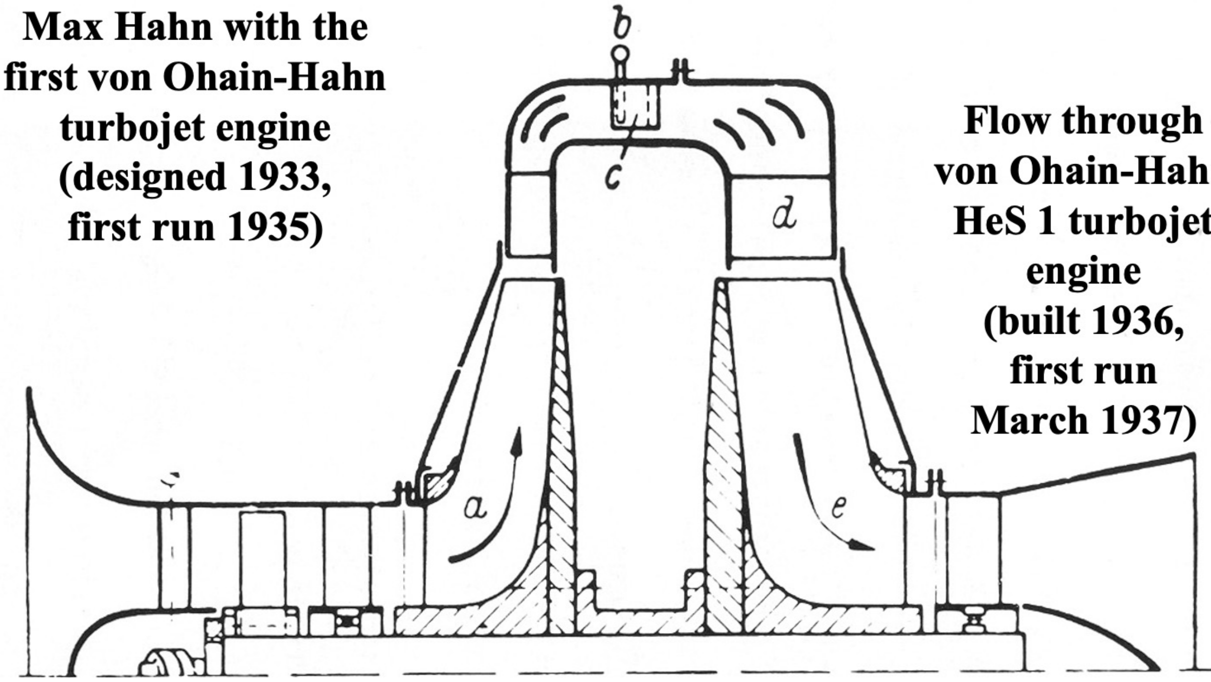
Von Ohain and his collaborators such as Max Hahn and Wilhelm Gundermann (German, 1904–1997) developed a long series of ever-improving jet engines in the 1930s and 1940s. Figure 9.69 shows Heinkel and von Ohain celebrating the flight of the He 178 in 1939; it also shows von Ohain's last known completed wartime engine, the He S 011, which he developed with Max Adolf Müller (German, 1901–1962) in 1943.

In addition to the He 178 and the twin-engine He 280 jet fighter, Heinkel's wartime team developed He 162 jet fighters (p. 1699) and apparently even intercontinental jet bombers (Section E.1).

After the war, von Ohain helped develop a wide range of jet and rocket engines in the United States.

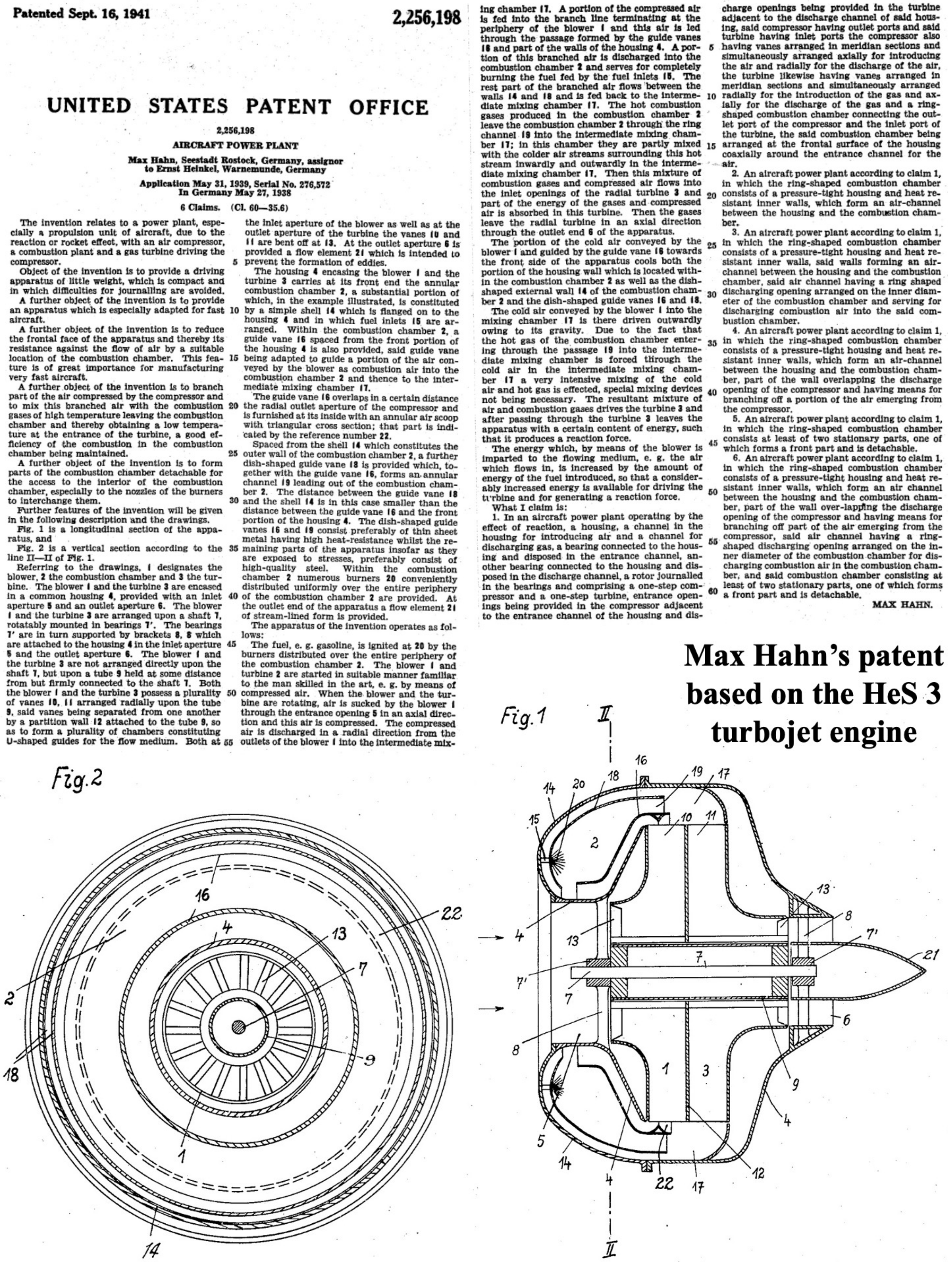


Max Hahn with the first von Ohain-Hahn turbojet engine (designed 1933, first run 1935)



Flow through von Ohain-Hahn HeS 1 turbojet engine (built 1936, first run March 1937)

Figure 9.65: Top: Max Hahn with the first von Ohain-Hahn turbojet engine (designed 1933, first run 1935). Bottom: Flow through von Ohain-Hahn HeS 1 turbojet engine (built 1936, first run March 1937).



Patented Sept. 16, 1941 **2,256,198**

UNITED STATES PATENT OFFICE

2,256,198

AIRCRAFT POWER PLANT

Max Hahn, Seestadt Rostock, Germany, assignor
to Ernst Heinkel, Warnemunde, Germany

Application May 31, 1939, Serial No. 276,572
In Germany May 27, 1938

6 Claims. (Cl. 60—35.6)

The invention relates to a power plant, especially a propulsion unit of aircraft, due to the reaction or rocket effect, with an air compressor, a combustion plant and a gas turbine driving the compressor.

Object of the invention is to provide a driving apparatus of little weight, which is compact and in which difficulties for journalling are avoided.

A further object of the invention is to provide an apparatus which is especially adapted for fast aircraft.

A further object of the invention is to reduce the frontal face of the apparatus and thereby its resistance against the flow of air by a suitable location of the combustion chamber. This feature is of great importance for manufacturing very fast aircraft.

A further object of the invention is to branch part of the air compressed by the compressor and to mix this branched air with the combustion gases of high temperature leaving the combustion chamber and thereby obtaining a low temperature at the entrance of the turbine, a good efficiency of the combustion in the combustion chamber being maintained.

A further object of the invention is to form parts of the combustion chamber detachable for the access to the interior of the combustion chamber, especially to the nozzles of the burners to interchange them.

Further features of the invention will be given in the following description and the drawings.

Fig. 1 is a longitudinal section of the apparatus, and

Fig. 2 is a vertical section according to the line II—II of Fig. 1.

Referring to the drawings, 1 designates the blower, 2 the combustion chamber and 3 the turbine. The blower 1 and the turbine 3 are encased in a common housing 4, provided with an inlet aperture 5 and an outlet aperture 6. The blower 1 and the turbine 3 are arranged upon a shaft 7, rotatably mounted in bearings 7′. The bearings 7′ are in turn supported by brackets 8, 8 which are attached to the housing 4 in the inlet aperture 5 and the outlet aperture 6. The blower 1 and the turbine 3 are not arranged directly upon the shaft 7, but upon a tube 9 held at some distance from but firmly connected to the shaft 7. Both the blower 1 and the turbine 3 possess a plurality of vanes 10, 11 arranged radially upon the tube 9, said vanes being separated from one another by a partition wall 12 attached to the tube 9, so as to form a plurality of chambers constituting U-shaped guides for the flow medium. Both at the inlet aperture of the blower as well as at the outlet aperture of the turbine the vanes 10 and 11 are bent off at 13. At the outlet aperture 6 is provided a flow element 21 which is intended to prevent the formation of eddies.

The housing 4 encasing the blower 1 and the turbine 3 carries at its front end the annular combustion chamber 2, a substantial portion of which, in the example illustrated, is constituted by a simple shell 14 which is flanged on to the housing 4 and in which fuel inlets 15 are arranged. Within the combustion chamber 2, a guide vane 16 spaced from the front portion of the housing 4 is also provided, said guide vane being adapted to guide a portion of the air conveyed by the blower as combustion air into the combustion chamber 2 and thence to the intermediate mixing chamber 17.

The guide vane 16 overlaps in a certain distance the radial outlet aperture of the compressor and is furnished at its inside with an annular air scoop with triangular cross section; that part is indicated by the reference number 22.

Spaced from the shell 14 which constitutes the outer wall of the combustion chamber 2, a further dish-shaped guide vane 18 is provided which, together with the guide vane 16, forms an annular channel 19 leading out of the combustion chamber 2. The distance between the guide vane 18 and the shell 14 is in this case smaller than the distance between the guide vane 16 and the front portion of the housing 4. The dish-shaped guide vanes 16 and 19 consist preferably of thin sheet metal having high heat-resistance whilst the remaining parts of the apparatus insofar as they are exposed to stresses, preferably consist of high-quality steel. Within the combustion chamber 2 numerous burners 20 conveniently distributed uniformly over the entire periphery of the combustion chamber 2 are provided. At the outlet end of the apparatus a flow element 21 of stream-lined form is provided.

The apparatus of the invention operates as follows:

The fuel, e. g. gasoline, is ignited at 20 by the burners distributed over the entire periphery of the combustion chamber 2. The blower 1 and turbine 2 are started in suitable manner familiar to the man skilled in the art, e. g. by means of compressed air. When the blower and the turbine are rotating, air is sucked by the blower 1 through the entrance opening 5 in an axial direction and this air is compressed. The compressed air is discharged in a radial direction from the outlets of the blower 1 into the intermediate mixing chamber 17. A portion of the compressed air is fed into the branch line terminating at the periphery of the blower 1 and this air is led through the passage formed by the guide vanes 16 and part of the walls of the housing 4. A portion of this branched air is discharged into the combustion chamber 2 and serves for completely burning the fuel fed by the fuel inlets 15. The rest part of the branched air flows between the walls 14 and 18 and is fed back to the intermediate mixing chamber 17. The hot combustion gases produced in the combustion chamber 2 leave the combustion chamber 2 through the ring channel 19 into the intermediate mixing chamber 17; in this chamber they are partly mixed with the colder air streams surrounding this hot stream inwardly and outwardly in the intermediate mixing chamber 17. Then this mixture of combustion gases and compressed air flows into the inlet openings of the radial turbine 3 and part of the energy of the gases and compressed air is absorbed in this turbine. Then the gases leave the radial turbine in an axial direction through the outlet end 6 of the apparatus.

The portion of the cold air conveyed by the blower 1 and guided by the guide vane 16 towards the front side of the apparatus cools both the portion of the housing wall which is located within the combustion chamber 2 as well as the dish-shaped external wall 14 of the combustion chamber 2 and the dish-shaped guide vanes 16 and 18.

The cold air conveyed by the blower 1 into the mixing chamber 17 is there driven outwardly owing to its gravity. Due to the fact that the hot gas of the combustion chamber entering through the passage 19 into the intermediate mixing chamber is forced through the cold air in the intermediate mixing chamber 17 a very intensive mixing of the cold air and hot gas is effected, special mixing devices not being necessary. The resultant mixture of air and combustion gases drives the turbine 3 and after passing through the turbine 3 leaves the apparatus with a certain content of energy, such that it produces a reaction force.

The energy which, by means of the blower is imparted to the flowing medium, e. g. the air which flows in, is increased by the amount of energy of the fuel introduced, so that a considerably increased energy is available for driving the turbine and for generating a reaction force.

What I claim is:

1. In an aircraft power plant operating by the effect of reaction, a housing, a channel in the housing for introducing air and a channel for discharging gas, a bearing connected to the housing and disposed in the entrance channel, another bearing connected to the housing and disposed in the discharge channel, a rotor journalled in the bearings and comprising a one-step compressor and a one-step turbine, entrance openings being provided in the compressor adjacent to the entrance channel of the housing and discharge openings being provided in the turbine adjacent to the discharge channel of said housing, said compressor having outlet ports and said turbine having inlet ports the compressor also having vanes arranged in meridian sections and simultaneously arranged axially for introducing the air and radially for the discharge of the air, the turbine likewise having vanes arranged in meridian sections and simultaneously arranged radially for the introduction of the gas and axially for the discharge of the gas and a ring-shaped combustion chamber connecting the outlet port of the compressor and the inlet port of the turbine, the said combustion chamber being arranged at the frontal surface of the housing coaxially around the entrance channel for the air.

2. An aircraft power plant according to claim 1, in which the ring-shaped combustion chamber consists of a pressure-tight housing and heat resistant inner walls, which form an air-channel between the housing and the combustion chamber.

3. An aircraft power plant according to claim 1, in which the ring-shaped combustion chamber consists of a pressure-tight housing and heat resistant inner walls, said walls forming an air-channel between the housing and the combustion chamber, said air channel having a ring shaped discharging opening arranged on the inner diameter of the combustion chamber and serving for discharging combustion air into the said combustion chamber.

4. An aircraft power plant according to claim 1, in which the ring-shaped combustion chamber consists of a pressure-tight housing and heat resistant inner walls, which form an air-channel between the housing and the combustion chamber, part of the wall overlapping the discharge opening of the compressor and having means for branching off a portion of the air emerging from the compressor.

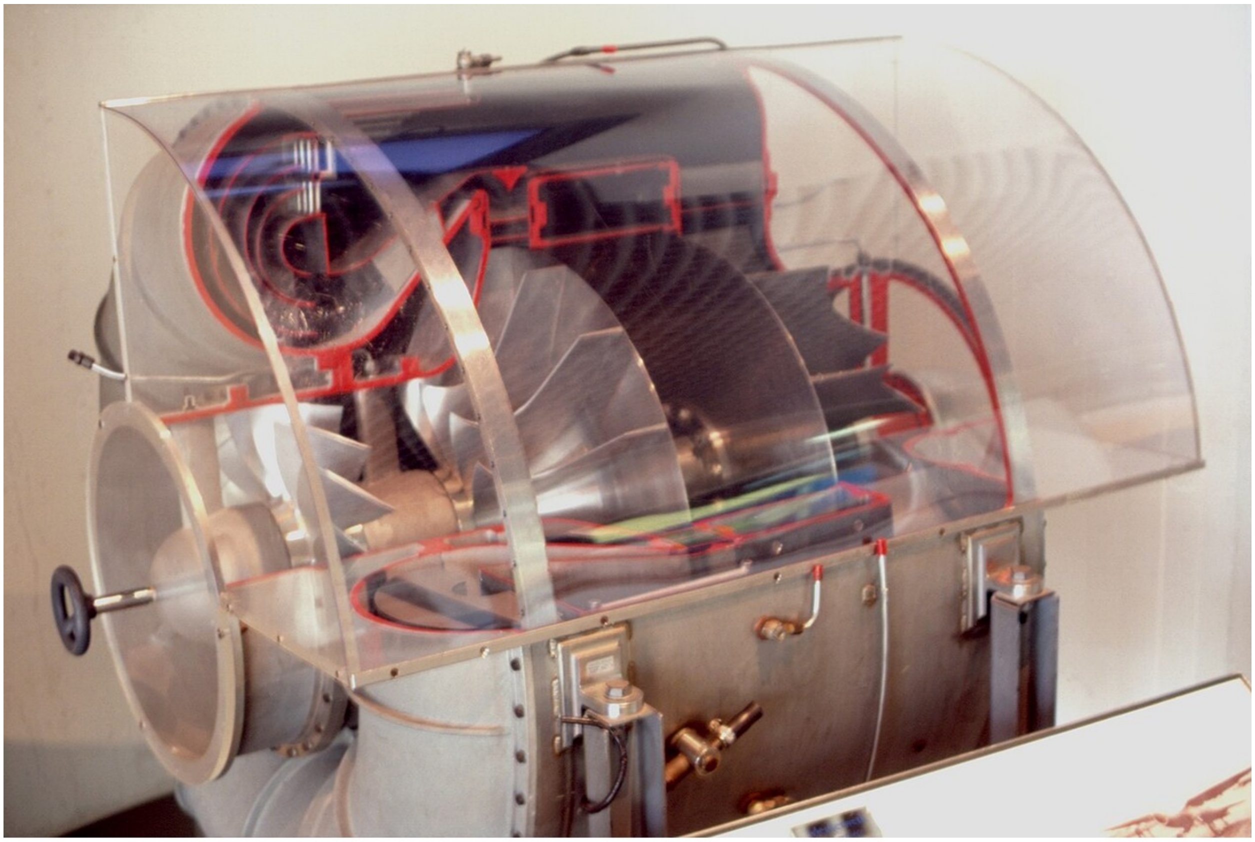
5. An aircraft power plant according to claim 1, in which the ring-shaped combustion chamber consists at least of two stationary parts, one of which forms a front part and is detachable.

6. An aircraft power plant according to claim 1, in which the ring-shaped combustion chamber consists of a pressure-tight housing and heat resistant inner walls, which form an air channel between the housing and the combustion chamber, part of the wall over-lapping the discharge opening of the compressor and having means for branching off part of the air emerging from the compressor, said air channel having a ring-shaped discharging opening arranged on the inner diameter of the combustion chamber for discharging combustion air in the combustion chamber, and said combustion chamber consisting at least of two stationary parts, one of which forms a front part and is detachable.

MAX HAHN.

Max Hahn's patent based on the HeS 3 turbojet engine

Figure 9.66: Max Hahn's patent based on the HeS 3 turbojet engine.



HeS 3 turbojet engine (first run March 1938)

First jet aircraft, Heinkel He 178 with HeS 3 engine (first flown 27 August 1939)

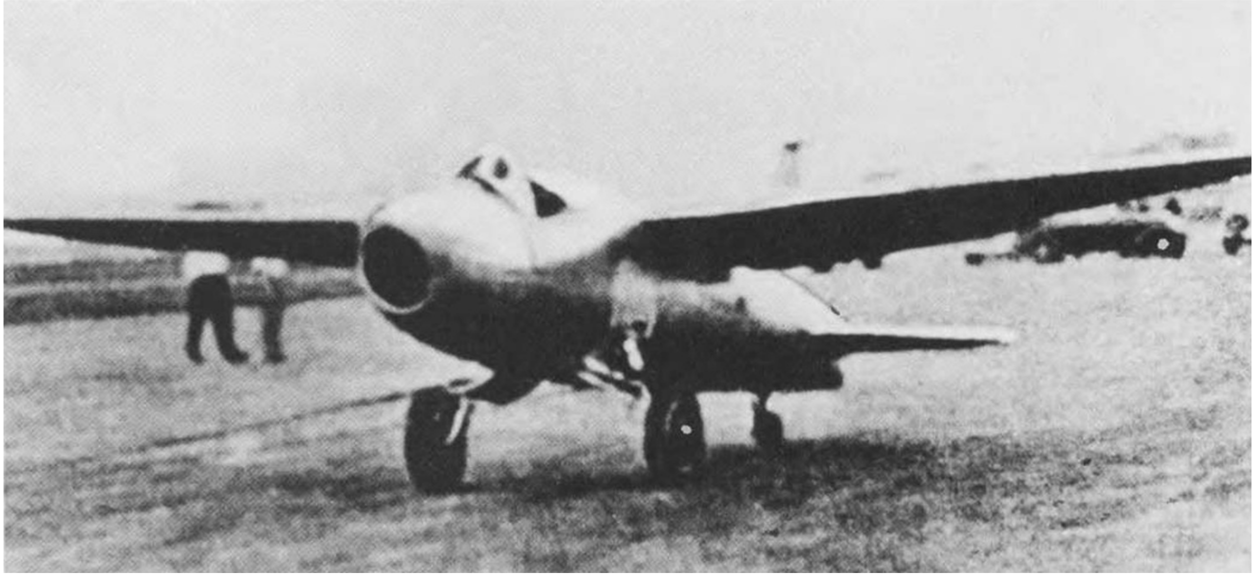


Figure 9.67: Top: HeS 3 turbojet engine (first run March 1938). Bottom: First jet aircraft, Heinkel He 178 with HeS 3 engine (first flown 27 August 1939).

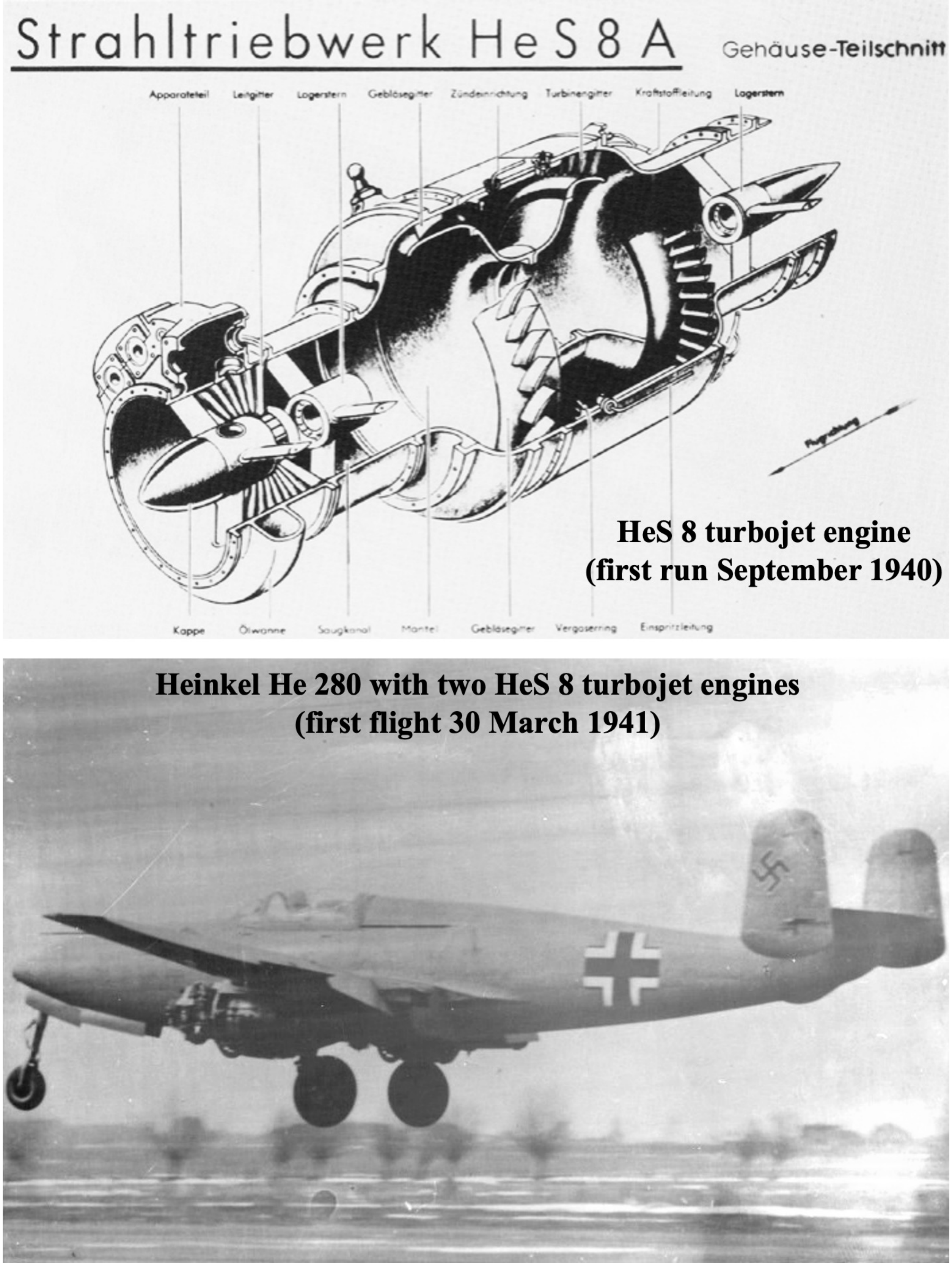
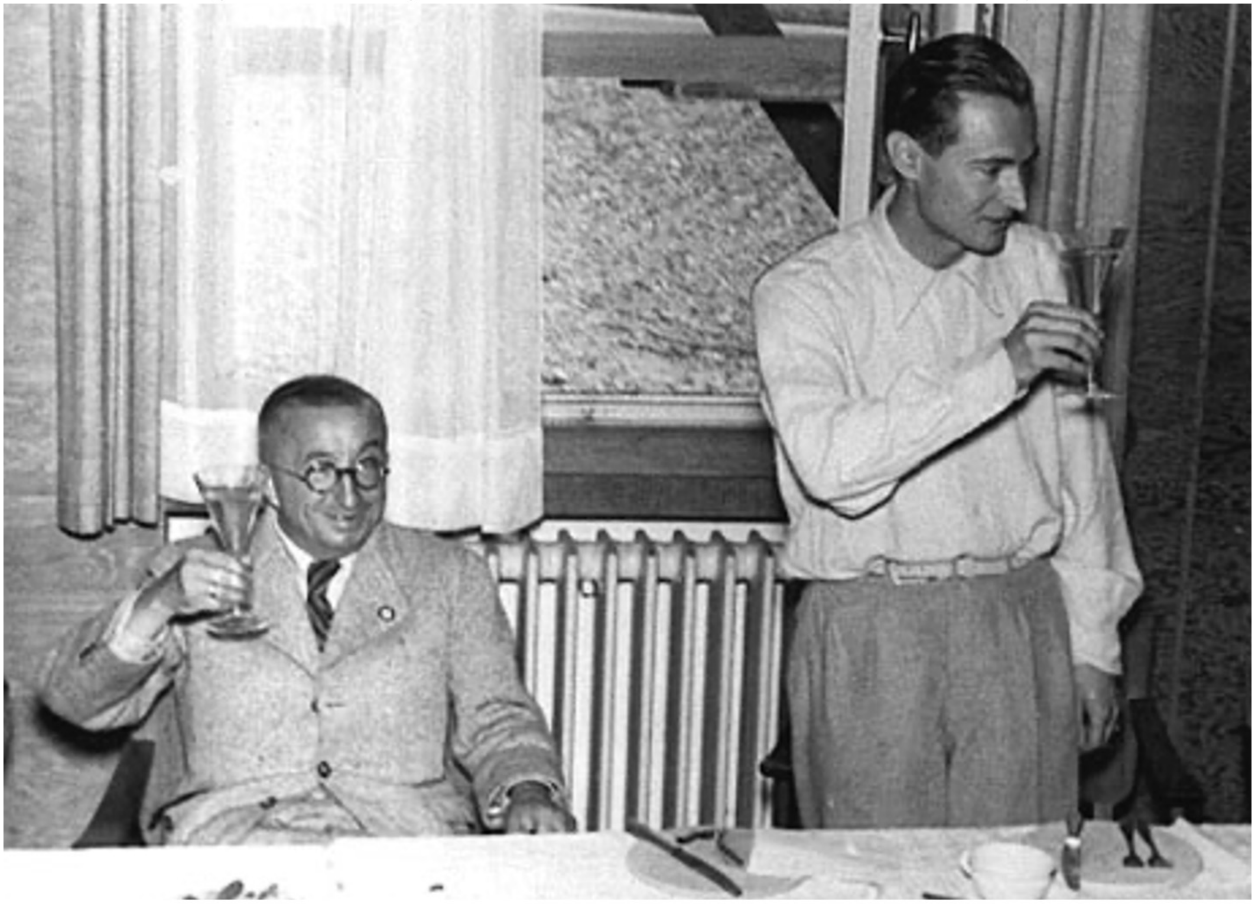

Strahltriebwerk HeS 8 A
Gehäuse-Teilschnitt
Apparateteil
Leitgitter
Lagerstern
Gebläsegitter
Zündeinrichtung
Turbinengitter
Kraftstoffleitung
Lagerstern
Flugrichtung
HeS 8 turbojet engine
(first run September 1940)
Kappe
Ölwanne
Saugkanal
Mantel
Gebläsegitter
Vergaserring
Einspritzleitung
Heinkel He 280 with two HeS 8 turbojet engines
(first flight 30 March 1941)

Figure 9.68: Top: HeS 8 turbojet engine (first run September 1940). Bottom: Heinkel He 280 with two HeS 8 turbojet engines (first flight 30 March 1941).

Ernst Heinkel
(1888–1958)

Hans von Ohain
(1911–1998)



Ohain-Müller HeS 011 turbojet engine (first run September 1943)

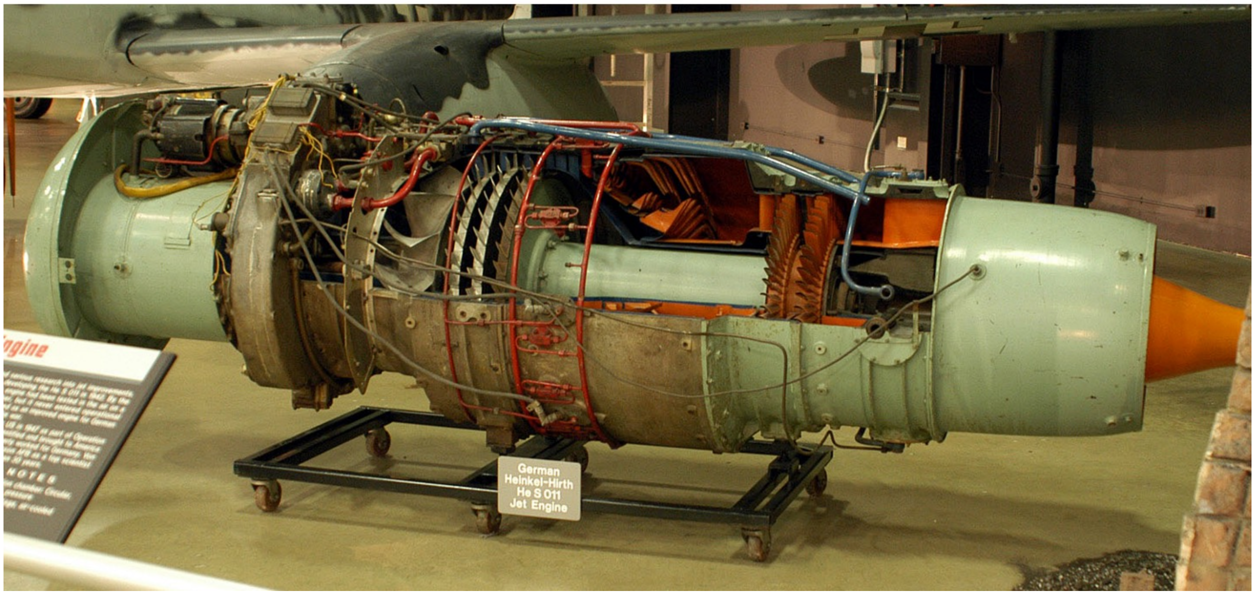


Figure 9.69: Top: Ernst Heinkel and Hans von Ohain celebrating the flight of the first jet aircraft, the Heinkel He 178, in 1939. Bottom: The HeS 011 turbojet engine, developed by von Ohain and Max Adolf Müller (first run September 1943).

Albert Betz (German, 1885–1968) and Walter Encke (German, 1888–1982), shown in Fig. 9.70, developed axial-flow compressors, which were utilized in most wartime German jet engines and virtually all modern jet engines. Betz also developed highly efficient wind turbine designs that are now used worldwide (p. 1665).

Herbert Wagner (Austrian, 1900–1982) and Max Adolf Müller (German, 1901–1962) led a team that was working to develop axial-flow compressors and prototype turbojet, turbofan, and turboprop engines at Junkers in the 1930s, as shown in Figs. 9.71–9.75. Due to management difficulties at Junkers, in 1939 Wagner left Junkers to create guided missiles and smart bombs at Henschel (see Section 9.6). Müller and most of the rest of Wagner's jet engine team (such as Rudolf Friedrich, German, 1909–1998) joined von Ohain's jet engine development program at Heinkel. Wagner also worked on German nuclear weapons programs during the war (p. 4165). After the war, Wagner developed a wide range of guided missiles and smart bombs in the United States, and Müller designed jet engines and related technologies in the United Kingdom.

After Wagner and Müller left the Junkers company, Anselm Franz (Austrian, 1900–1994) quickly rebuilt the jet engine program and engineering team at Junkers in 1939. Franz and his team designed and demonstrated the Jumo (Junkers Motors) 004 axial-flow turbojet engine (first run in 1940, Fig. 9.76); at least 8000 Jumo 004 engines were produced during the war. Franz and his team also developed other engines such as the Jumo 022 turboprop engine (Fig. 9.84).

After the war, Anselm Franz moved to the United States and joined the Lycoming company, along with many members of his Junkers jet engine team, including Heinrich Adenstedt (German, 1910–1991), Hans Berkner (German, 19??–19??), Friedrick Bielitz (German, 19??–19??), Siegfried Decher (German, 19??–19??), Heinz Moellmann (German, 19??–19??), and Wolfgang Stein (German, 19??–19??). At Lycoming, they produced the T53 and T55 turboshaft engines (which became widely used in helicopters and turboprop planes), PLF1 turbofan engine (the first high-bipass turbofan engine, important for jet airliners), AGT1500 turboshaft engine (for tanks and other land and sea vehicles, as well as stationary power plants, p. 1381), and other jet and gas turbine engines (pp. 1740–1743).

Early turbojet engines were challenged by overheating of the central components, especially the turbine blades, which shortened the operational lifetime of an engine before it needed to be rebuilt or replaced. That challenge arose both because of the extremely high temperatures achieved inside the engines and also because of the shortage of major high-temperature metals due to Allied blockades and bombing. In response, engineers such as Hermann Hagen (German, 19??–19??), Karl Leist (for his DB 007 engine), Paul Leistritz (German, 18??–1957), and Christian Lorenzen (German, 19??–19??) developed methods of directly cooling the blades inside a turbine. Many other scientists and engineers developed novel high-temperature ceramics (p. 667) and new high-temperature metal alloys (p. 689) that could be fabricated into turbine blades. For example, both in Germany during the war and in the United States after the war, Anselm Franz collaborated very closely with Heinrich Adenstedt (German, 1910–1991, pp. 697–698), an expert on high-temperature metal alloys. Such high-temperature ceramics and alloys are still widely used in a variety of modern engine types.

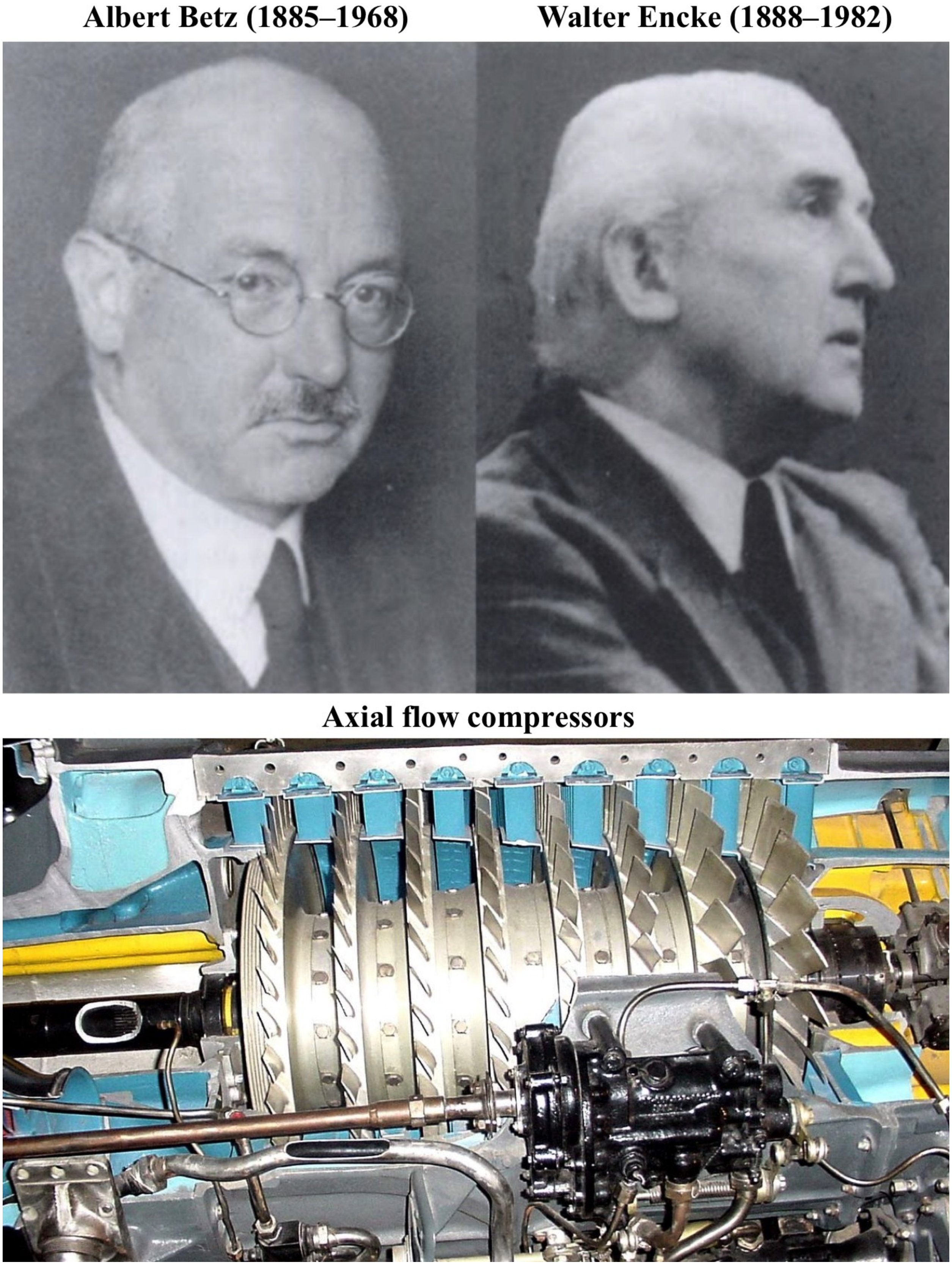

Albert Betz (1885–1968)
Walter Encke (1888–1982)
Axial flow compressors

Figure 9.70: Albert Betz and Walter Encke developed axial flow compressors.

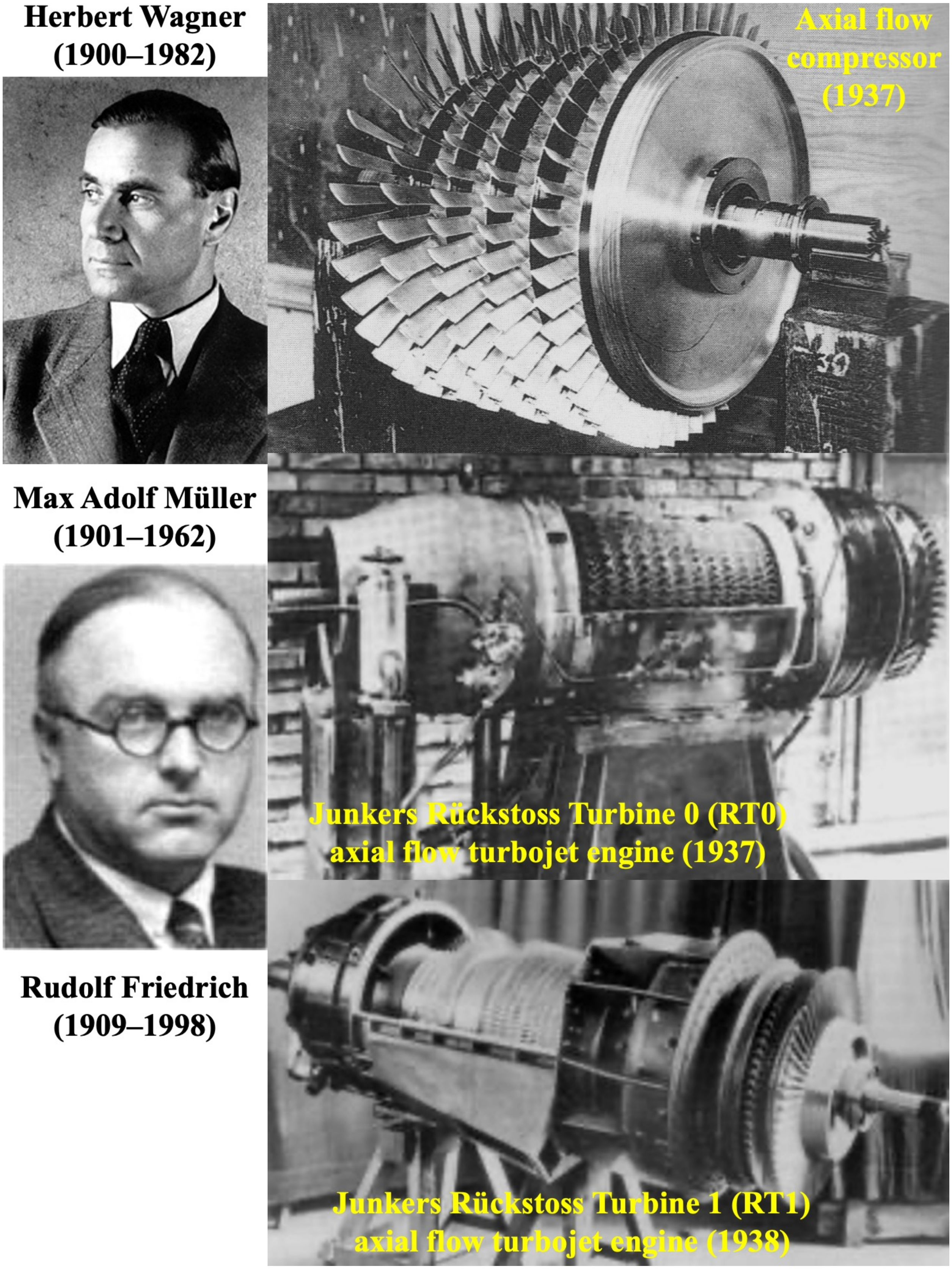
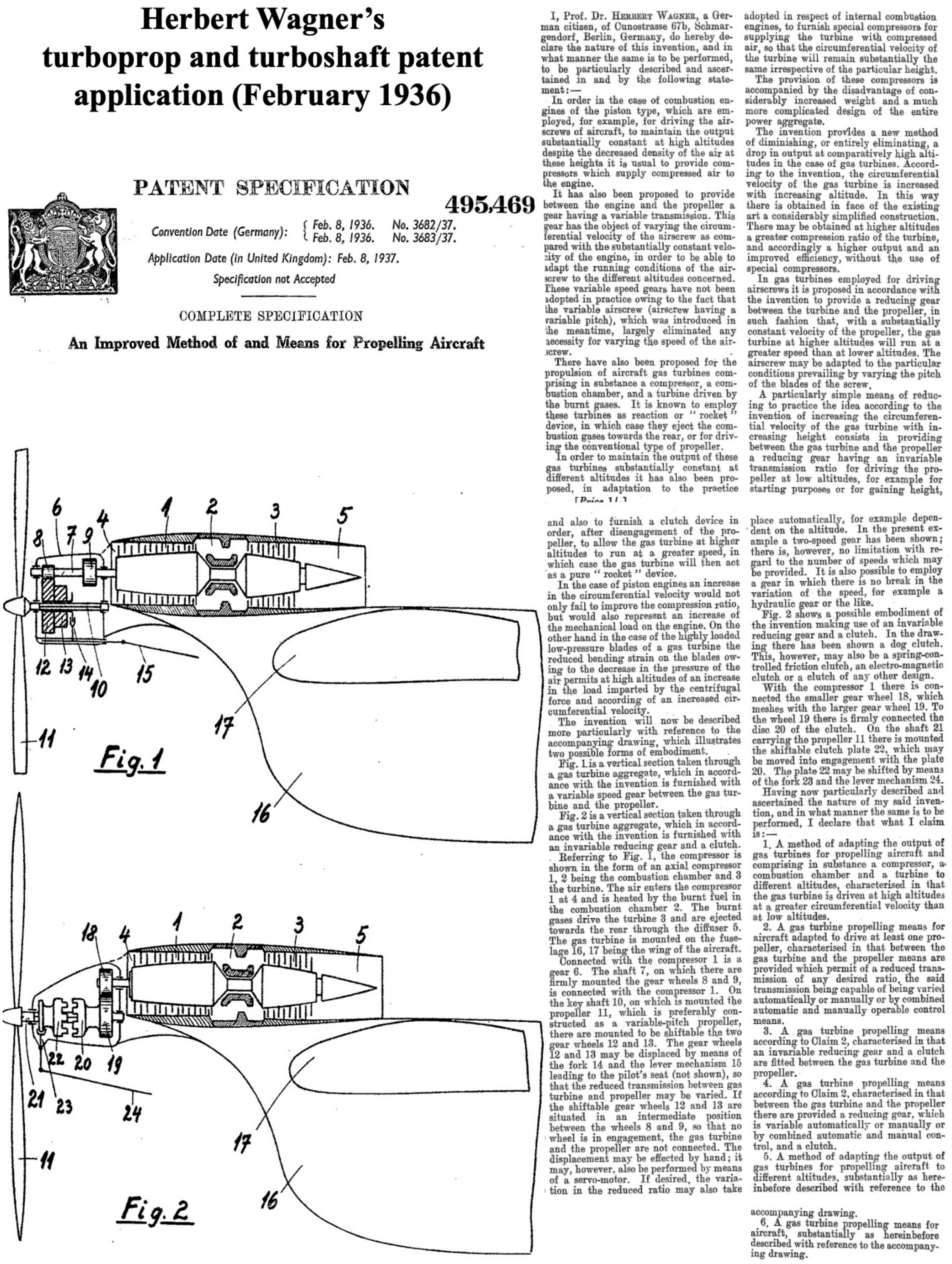

Herbert Wagner
(1900–1982)
Axial flow
compressor
(1937)
Max Adolf Müller
(1901–1962)
Junkers Rückstoss Turbine 0 (RT0)
axial flow turbojet engine (1937)
Rudolf Friedrich
(1909–1998)
Junkers Rückstoss Turbine 1 (RT1)
axial flow turbojet engine (1938)

Figure 9.71: Herbert Wagner, Max Adolf Müller, and Rudolf Friedrich led a team that was working to develop prototype turbojet, turbofan, and turboprop engines at Junkers in the 1930s.



Herbert Wagner's turboprop and turboshaft patent application (February 1936)

PATENT SPECIFICATION

495,469

Convention Date (Germany): { Feb. 8, 1936. No. 3682/37.
Feb. 8, 1936. No. 3683/37.

Application Date (in United Kingdom): Feb. 8, 1937.

Specification not Accepted

COMPLETE SPECIFICATION

An Improved Method of and Means for Propelling Aircraft

I, Prof. Dr. HERBERT WAGNER, a German citizen, of Cunostrasse 67b, Schmargendorf, Berlin, Germany, do hereby declare the nature of this invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

In order in the case of combustion engines of the piston type, which are employed, for example, for driving the airscrews of aircraft, to maintain the output substantially constant at high altitudes despite the decreased density of the air at these heights it is usual to provide compressors which supply compressed air to the engine.

It has also been proposed to provide between the engine and the propeller a gear having a variable transmission. This gear has the object of varying the circumferential velocity of the airscrew as compared with the substantially constant velocity of the engine, in order to be able to adapt the running conditions of the airscrew to the different altitudes concerned. These variable speed gears have not been adopted in practice owing to the fact that the variable airscrew (airscrew having a variable pitch), which was introduced in the meantime, largely eliminated any necessity for varying the speed of the airscrew.

There have also been proposed for the propulsion of aircraft gas turbines comprising in substance a compressor, a combustion chamber, and a turbine driven by the burnt gases. It is known to employ these turbines as reaction or " rocket " device, in which case they eject the combustion gases towards the rear, or for driving the conventional type of propeller.

In order to maintain the output of these gas turbines substantially constant at different altitudes it has also been proposed, in adaptation to the practice adopted in respect of internal combustion engines, to furnish special compressors for supplying the turbine with compressed air, so that the circumferential velocity of the turbine will remain substantially the same irrespective of the particular height.

The provision of these compressors is accompanied by the disadvantage of considerably increased weight and a much more complicated design of the entire power aggregate.

The invention provides a new method of diminishing, or entirely eliminating, a drop in output at comparatively high altitudes in the case of gas turbines. According to the invention, the circumferential velocity of the gas turbine is increased with increasing altitude. In this way there is obtained in face of the existing art a considerably simplified construction. There may be obtained at higher altitudes a greater compression ratio of the turbine, and accordingly a higher output and an improved efficiency, without the use of special compressors.

In gas turbines employed for driving airscrews it is proposed in accordance with the invention to provide a reducing gear between the turbine and the propeller, in such fashion that, with a substantially constant velocity of the propeller, the gas turbine at higher altitudes will run at a greater speed than at lower altitudes. The airscrew may be adapted to the particular conditions prevailing by varying the pitch of the blades of the screw.

A particularly simple means of reducing to practice the idea according to the invention of increasing the circumferential velocity of the gas turbine with increasing height consists in providing between the gas turbine and the propeller a reducing gear having an invariable transmission ratio for driving the propeller at low altitudes, for example for starting purposes or for gaining height,

[Price 1/-]

and also to furnish a clutch device in order, after disengagement of the propeller, to allow the gas turbine at higher altitudes to run at a greater speed, in which case the gas turbine will then act as a pure " rocket " device.

In the case of piston engines an increase in the circumferential velocity would not only fail to improve the compression ratio, but would also represent an increase of the mechanical load on the engine. On the other hand in the case of the highly loaded low-pressure blades of a gas turbine the reduced bending strain on the blades owing to the decrease in the pressure of the air permits at high altitudes of an increase in the load imparted by the centrifugal force and according of an increased circumferential velocity.

The invention will now be described more particularly with reference to the accompanying drawing, which illustrates two possible forms of embodiment.

Fig. 1 is a vertical section taken through a gas turbine aggregate, which in accordance with the invention is furnished with a variable speed gear between the gas turbine and the propeller.

Fig. 2 is a vertical section taken through a gas turbine aggregate, which in accordance with the invention is furnished with an invariable reducing gear and a clutch.

Referring to Fig. 1, the compressor is shown in the form of an axial compressor 1, 2 being the combustion chamber and 3 the turbine. The air enters the compressor 1 at 4 and is heated by the burnt fuel in the combustion chamber 2. The burnt gases drive the turbine 3 and are ejected towards the rear through the diffuser 5. The gas turbine is mounted on the fuselage 16, 17 being the wing of the aircraft.

Connected with the compressor 1 is a gear 6. The shaft 7, on which there are firmly mounted the gear wheels 8 and 9, is connected with the compressor 1. On the key shaft 10, on which is mounted the propeller 11, which is preferably constructed as a variable-pitch propeller, there are mounted to be shiftable the two gear wheels 12 and 13. The gear wheels 12 and 13 may be displaced by means of the fork 14 and the lever mechanism 15 leading to the pilot's seat (not shown), so that the reduced transmission between gas turbine and propeller may be varied. If the shiftable gear wheels 12 and 13 are situated in an intermediate position between the wheels 8 and 9, so that no wheel is in engagement, the gas turbine and the propeller are not connected. The displacement may be effected by hand; it may, however, also be performed by means of a servo-motor. If desired, the variation in the reduced ratio may also take place automatically, for example dependent on the altitude. In the present example a two-speed gear has been shown; there is, however, no limitation with regard to the number of speeds which may be provided. It is also possible to employ a gear in which there is no break in the variation of the speed, for example a hydraulic gear or the like.

Fig. 2 shows a possible embodiment of the invention making use of an invariable reducing gear and a clutch. In the drawing there has been shown a dog clutch. This, however, may also be a spring-controlled friction clutch, an electro-magnetic clutch or a clutch of any other design.

With the compressor 1 there is connected the smaller gear wheel 18, which meshes with the larger gear wheel 19. To the wheel 19 there is firmly connected the disc 20 of the clutch. On the shaft 21 carrying the propeller 11 there is mounted the shiftable clutch plate 22, which may be moved into engagement with the plate 20. The plate 22 may be shifted by means of the fork 23 and the lever mechanism 24.

Having now particularly described and ascertained the nature of my said invention, and in what manner the same is to be performed, I declare that what I claim is:—

1. A method of adapting the output of gas turbines for propelling aircraft and comprising in substance a compressor, a combustion chamber and a turbine to different altitudes, characterised in that the gas turbine is driven at high altitudes at a greater circumferential velocity than at low altitudes.

2. A gas turbine propelling means for aircraft adapted to drive at least one propeller, characterised in that between the gas turbine and the propeller means are provided which permit of a reduced transmission of any desired ratio, the said transmission being capable of being varied automatically or manually or by combined automatic and manually operable control means.

3. A gas turbine propelling means according to Claim 2, characterised in that an invariable reducing gear and a clutch are fitted between the gas turbine and the propeller.

4. A gas turbine propelling means according to Claim 2, characterised in that between the gas turbine and the propeller there are provided a reducing gear, which is variable automatically or manually or by combined automatic and manual control, and a clutch.

5. A method of adapting the output of gas turbines for propelling aircraft to different altitudes, substantially as hereinbefore described with reference to the accompanying drawing.

6. A gas turbine propelling means for aircraft, substantially as hereinbefore described with reference to the accompanying drawing.

Figure 9.72: Herbert Wagner's turboprop and turboshaft patent application (February 1936).

REICHSPATENTAMT

PATENTSCHRIFT

№ 768 103

KLASSE **46f** GRUPPE 7₀₃

J 58734 Ia/46f

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(§ 20 des Ersten Gesetzes zur Änderung und Überleitung von Vorschriften auf dem Gebiet des gewerblichen Rechtsschutzes vom 8. Juli 1949)

Junkers Flugzeug- und Motorenwerke A. G., Dessau*)

Verbrennungskammer für mit Gleichdruckverbrennung arbeitende Gasturbinen

Patentiert im Deutschen Reich vom 5. März 1936 an
Patenterteilung bekanntgemacht am 18. Mai 1955

Die Erfindung betrifft eine Verbrennungskammer für mit Gleichdruckverbrennung arbeitende Gasturbinenanlagen, die je aus einem Luftverdichter, einer Turbine und der unmittelbar zwischen diesen angeordneten Verbrennungskammer bestehen und die insbesondere zum Antrieb von Luftfahrzeugen verwendet werden sollen. Der Luftverdichter, der als axial oder radial durchströmtes Gebläse ausgebildet sein kann, speist die Verbrennungskammer mit verdichteter Luft, die hier unter Zutritt von Brennstoff verbrennt; die Verbrennungsgase gelangen aus der Verbrennungskammer in die Turbine, beaufschlagen deren Beschaufelung und versetzen den Turbinenläufer in Drehung.

Es ist an sich bekannt, die metallischen Wände der Verbrennungskammer einer Gasturbine mit feuerfestem Baustoff auszukleiden, um so die sonst unter der unmittelbaren Einwirkung der heißen Verbrennungsgase stehenden Wände der Verbrennungskammer vor Zerstörung zu schützen. Es ist ferner vorgeschlagen worden, insbesondere bei Anordnung einer axial durchströmten Turbine und eines unmittelbar von der Turbine angetriebenen axial durchströmten Verdichters, die Verbrennungskammer unmittelbar zwischen der letzten Stufe des Verdichters und der ersten Stufe der Gasturbine anzuordnen. Eine solche Anordnung hat jedoch den Nachteil, daß die Beschaufelung der letzten Stufe des Verdichters und die Beschaufelung der ersten Stufe der Gasturbine unter der unmittelbaren Einwirkung der Wärmestrahlung aus dem Verbrennungsraum stehen. Diese Strahlung ist so groß, daß eine solche Turbinenanlage bisher nicht betriebsfähig war, da die Beschaufelungen des Verdichters als auch der Gasturbine in kürzester Zeit unter der zusätzlichen Einwirkung der Wärmestrahlung aus dem Verbrennungsraum zerstört wurden.

Es ist Aufgabe der Erfindung, eine unmittelbar zwischen Luftverdichter und Turbine einer mit Gleichdruckverbrennung arbeitenden Gasturbine angeordnete Verbrennungskammer zu schaffen, die die schädliche Einwirkung der Wärmestrahlung auf die unmittelbar anschließenden Beschaufelungen vermeidet. Dies wird gemäß der Erfindung dadurch erreicht, daß in den Verbrennungsraum ein Vorsprung oder mehrere Vorsprünge so weit hineinragen, daß sie die wärmeempfindlichen Teile, insbesondere die Beschaufelungen des Luftverdichters und der Turbine, gegen Wärmestrahlung aus dem Verbrennungsraum decken. Hat die Kammer die Form eines Ringes, dann werden die Vorsprünge als ringförmige Rippen oder Wülste ausgebildet, deren radiale Erhebung über die ursprünglichen Mantellinien der äußeren oder inneren Brennraumauskleidung mindestens gleich der Kopfhöhe der letzten Schaufel des Luftverdichters oder der Kopfhöhe der ersten Schaufel der Turbine ist.

In der Zeichnung ist ein Ausführungsbeispiel des Erfindungsgegenstandes im mittleren Längsschnitt durch den Mittelteil einer mit Gleichdruckverbrennung arbeitenden Gasturbine mit ringförmiger Verbrennungskammer veranschaulicht.

Der Luftverdichter 1 ist mit der Gasturbine 2 durch eine Welle 3 verbunden. Um die Welle 3 herum ist innerhalb eines Gehäuses 4 eine ringförmige Verbrennungskammer 5 angeordnet. Die aus der letzten Schaufelreihe 6 des Verdichters 1 austretende verdichtete Luft strömt durch eine ringförmige Öffnung 7 der Verbrennungskammer 5 zu, wo ihr durch eine Düse oder mehrere Düsen 8 Brennstoff zugeführt wird; das Gemisch verbrennt, und die Brenngase strömen durch eine ringförmige Öffnung 9 der Brennkammer 5 zu der ersten Laufschaufelreihe 10 der Turbine 2. Der Verbrennungsraum 5 ist mit Schamotteauskleidungen 11 und 12 versehen, die von Blechen 13 und 14 gestützt werden. Die innere Auskleidung 12 besitzt an ihrem dem Luftverdichter 1 zugewandten Ende eine in den Verbrennungsraum 5 hineinragende ringförmige Rippe 15 und an ihrem der Turbine 2 zugewandten Ende eine entsprechende Rippe 16, während die äußere Auskleidung 11 mit einer ebenfalls ringförmigen wulstartigen Rippe 17 in den mittleren Teil des Verbrennungsraumes 5 hineinragt. Die Querschnittsform der Rippen 15, 16, 17 sowie ihre radiale Erhebung h_1, h_2, h_3 über die ursprünglichen Mantellinien *a* und *i* der äußeren oder inneren Brennraumauskleidung sind im Verhältnis zur Lage und zur Kopfhöhe der Schaufeln 6 und 10 so gewählt, daß sie diese vor der Wärmeanstrahlung aus dem Verbrennungsraum 5 schützen. Durch die wulstartige Formgebung, insbesondere der mittleren Rippe 17, wird gleichzeitig die Durchwirbelung der Brenngase und damit der Verbrennungsvorgang gefördert.

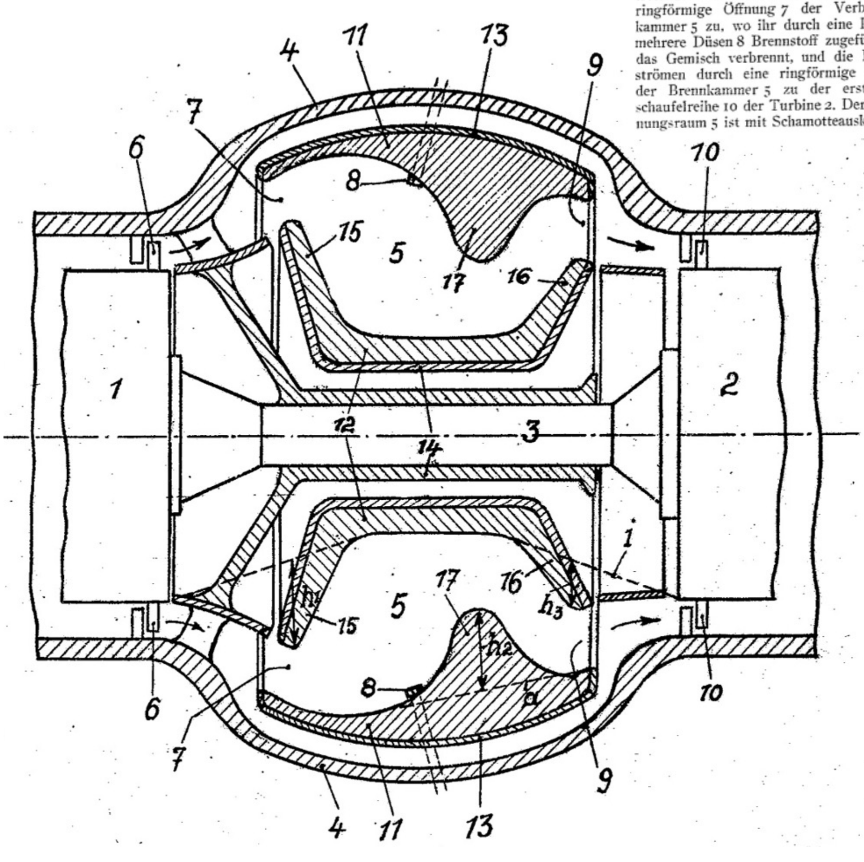
PATENTANSPRÜCHE:

1. Unmittelbar zwischen Luftverdichter und einer mit Gleichdruckverbrennung arbeitenden Gasturbine angeordnete Verbrennungskammer, dadurch gekennzeichnet, daß in den Verbrennungsraum (5) ein Vorsprung oder mehrere Vorsprünge (15, 16, 17) so weit hineinragen, daß sie die wärmeempfindlichen Teile, insbesondere die Beschaufelungen des Luftverdichters und der Turbine gegen Wärmeanstrahlung aus dem Verbrennungsraum decken.

2. Verbrennungskammer nach Anspruch 1, dadurch gekennzeichnet, daß die Kammer (5) die Form eines Ringes hat und die Vorsprünge (15, 16, 17) als ringförmige Rippen oder Wülste ausgebildet sind, deren radiale Erhebung (h_1, h_2, h_3) über die ursprünglichen Mantellinien (*a* und *i*) der äußeren oder inneren Brennraumauskleidung hinaus mindestens gleich der Kopfhöhe der letzten Schaufel (6) des Luftverdichters oder der Kopfhöhe der ersten Schaufel (10) der Turbine ist.

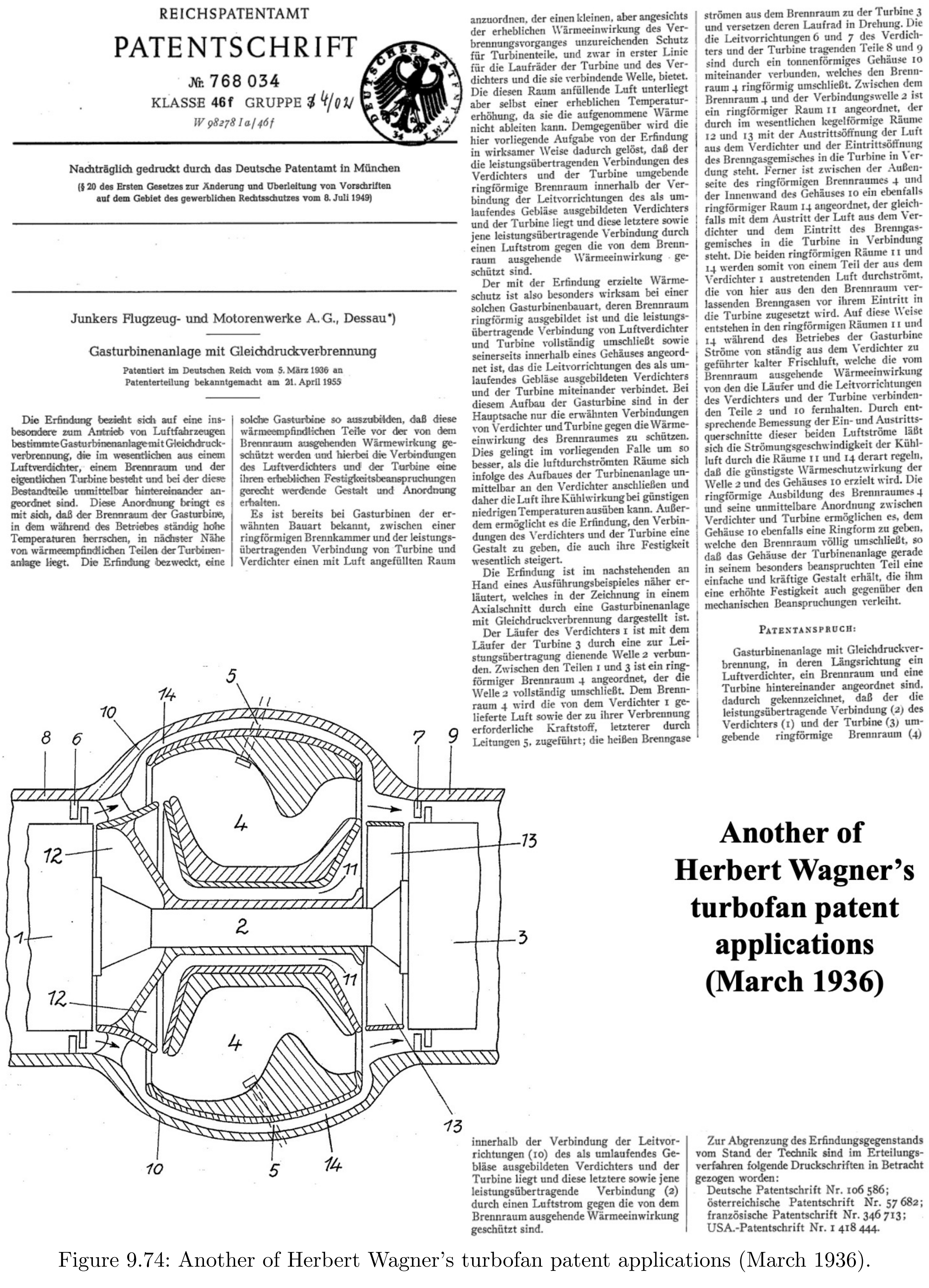
Zur Abgrenzung des Erfindungsgegenstands vom Stand der Technik sind im Erteilungsverfahren folgende Druckschriften in Betracht gezogen worden:

Deutsche Patentschrift Nr. 255 499;
französische Patentschrift Nr. 741 433;
USA.-Patentschriften Nr. 985 793,
1 418 444, 1 960 810.



One of Herbert Wagner's turbofan patent applications (March 1936)

Figure 9.73: One of Herbert Wagner's turbofan patent applications (March 1936).



REICHSPATENTAMT

PATENTSCHRIFT

№ 768 034

KLASSE **46f** GRUPPE 34/02

W 98278 Ia/46f

Nachträglich gedruckt durch das Deutsche Patentamt in München

(§ 20 des Ersten Gesetzes zur Änderung und Überleitung von Vorschriften
auf dem Gebiet des gewerblichen Rechtsschutzes vom 8. Juli 1949)

Junkers Flugzeug- und Motorenwerke A.G., Dessau*)

Gasturbinenanlage mit Gleichdruckverbrennung

Patentiert im Deutschen Reich vom 5. März 1936 an
Patenterteilung bekanntgemacht am 21. April 1955

Die Erfindung bezieht sich auf eine insbesondere zum Antrieb von Luftfahrzeugen bestimmte Gasturbinenanlage mit Gleichdruckverbrennung, die im wesentlichen aus einem Luftverdichter, einem Brennraum und der eigentlichen Turbine besteht und bei der diese Bestandteile unmittelbar hintereinander angeordnet sind. Diese Anordnung bringt es mit sich, daß der Brennraum der Gasturbine, in dem während des Betriebes ständig hohe Temperaturen herrschen, in nächster Nähe von wärmeempfindlichen Teilen der Turbinenanlage liegt. Die Erfindung bezweckt, eine solche Gasturbine so auszubilden, daß diese wärmeempfindlichen Teile vor der von dem Brennraum ausgehenden Wärmewirkung geschützt werden und hierbei die Verbindungen des Luftverdichters und der Turbine eine ihren erheblichen Festigkeitsbeanspruchungen gerecht werdende Gestalt und Anordnung erhalten.

Es ist bereits bei Gasturbinen der erwähnten Bauart bekannt, zwischen einer ringförmigen Brennkammer und der leistungsübertragenden Verbindung von Turbine und Verdichter einen mit Luft angefüllten Raum anzuordnen, der einen kleinen, aber angesichts der erheblichen Wärmeeinwirkung des Verbrennungsvorganges unzureichenden Schutz für Turbinenteile, und zwar in erster Linie für die Laufräder der Turbine und des Verdichters und die sie verbindende Welle, bietet. Die diesen Raum anfüllende Luft unterliegt aber selbst einer erheblichen Temperaturerhöhung, da sie die aufgenommene Wärme nicht ableiten kann. Demgegenüber wird die hier vorliegende Aufgabe von der Erfindung in wirksamer Weise dadurch gelöst, daß der die leistungsübertragenden Verbindungen des Verdichters und der Turbine umgebende ringförmige Brennraum innerhalb der Verbindung der Leitvorrichtungen des als umlaufendes Gebläse ausgebildeten Verdichters und der Turbine liegt und diese letztere sowie jene leistungsübertragende Verbindung durch einen Luftstrom gegen die von dem Brennraum ausgehende Wärmeeinwirkung geschützt sind.

Der mit der Erfindung erzielte Wärmeschutz ist also besonders wirksam bei einer solchen Gasturbinenbauart, deren Brennraum ringförmig ausgebildet ist und die leistungsübertragende Verbindung von Luftverdichter und Turbine vollständig umschließt sowie seinerseits innerhalb eines Gehäuses angeordnet ist, das die Leitvorrichtungen des als umlaufendes Gebläse ausgebildeten Verdichters und der Turbine miteinander verbindet. Bei diesem Aufbau der Gasturbine sind in der Hauptsache nur die erwähnten Verbindungen von Verdichter und Turbine gegen die Wärmeeinwirkung des Brennraumes zu schützen. Dies gelingt im vorliegenden Falle um so besser, als die luftdurchströmten Räume sich infolge des Aufbaues der Turbinenanlage unmittelbar an den Verdichter anschließen und daher die Luft ihre Kühlwirkung bei günstigen niedrigen Temperaturen ausüben kann. Außerdem ermöglicht es die Erfindung, den Verbindungen des Verdichters und der Turbine eine Gestalt zu geben, die auch ihre Festigkeit wesentlich steigert.

Die Erfindung ist im nachstehenden an Hand eines Ausführungsbeispieles näher erläutert, welches in der Zeichnung in einem Axialschnitt durch eine Gasturbinenanlage mit Gleichdruckverbrennung dargestellt ist.

Der Läufer des Verdichters 1 ist mit dem Läufer der Turbine 3 durch eine zur Leistungsübertragung dienende Welle 2 verbunden. Zwischen den Teilen 1 und 3 ist ein ringförmiger Brennraum 4 angeordnet, der die Welle 2 vollständig umschließt. Dem Brennraum 4 wird die von dem Verdichter 1 gelieferte Luft sowie der zu ihrer Verbrennung erforderliche Kraftstoff, letzterer durch Leitungen 5, zugeführt; die heißen Brenngase strömen aus dem Brennraum zu der Turbine 3 und versetzen deren Laufrad in Drehung. Die die Leitvorrichtungen 6 und 7 des Verdichters und der Turbine tragenden Teile 8 und 9 sind durch ein tonnenförmiges Gehäuse 10 miteinander verbunden, welches den Brennraum 4 ringförmig umschließt. Zwischen dem Brennraum 4 und der Verbindungswelle 2 ist ein ringförmiger Raum 11 angeordnet, der durch im wesentlichen kegelförmige Räume 12 und 13 mit der Austrittsöffnung der Luft aus dem Verdichter und der Eintrittsöffnung des Brenngasgemisches in die Turbine in Verdung steht. Ferner ist zwischen der Außenseite des ringförmigen Brennraumes 4 und der Innenwand des Gehäuses 10 ein ebenfalls ringförmiger Raum 14 angeordnet, der gleichfalls mit dem Austritt der Luft aus dem Verdichter und dem Eintritt des Brenngasgemisches in die Turbine in Verbindung steht. Die beiden ringförmigen Räume 11 und 14 werden somit von einem Teil der aus dem Verdichter 1 austretenden Luft durchströmt, die von hier aus den den Brennraum verlassenden Brenngasen vor ihrem Eintritt in die Turbine zugesetzt wird. Auf diese Weise entstehen in den ringförmigen Räumen 11 und 14 während des Betriebes der Gasturbine Ströme von ständig aus dem Verdichter zugeführter kalter Frischluft, welche die vom Brennraum ausgehende Wärmeeinwirkung von den die Läufer und die Leitvorrichtungen des Verdichters und der Turbine verbindenden Teile 2 und 10 fernhalten. Durch entsprechende Bemessung der Ein- und Austrittsquerschnitte dieser beiden Luftströme läßt sich die Strömungsgeschwindigkeit der Kühlluft durch die Räume 11 und 14 derart regeln, daß die günstigste Wärmeschutzwirkung der Welle 2 und des Gehäuses 10 erzielt wird. Die ringförmige Ausbildung des Brennraumes 4 und seine unmittelbare Anordnung zwischen Verdichter und Turbine ermöglichen es, dem Gehäuse 10 ebenfalls eine Ringform zu geben, welche den Brennraum völlig umschließt, so daß das Gehäuse der Turbinenanlage gerade in seinem besonders beanspruchten Teil eine einfache und kräftige Gestalt erhält, die ihm eine erhöhte Festigkeit auch gegenüber den mechanischen Beanspruchungen verleiht.

Patentanspruch:

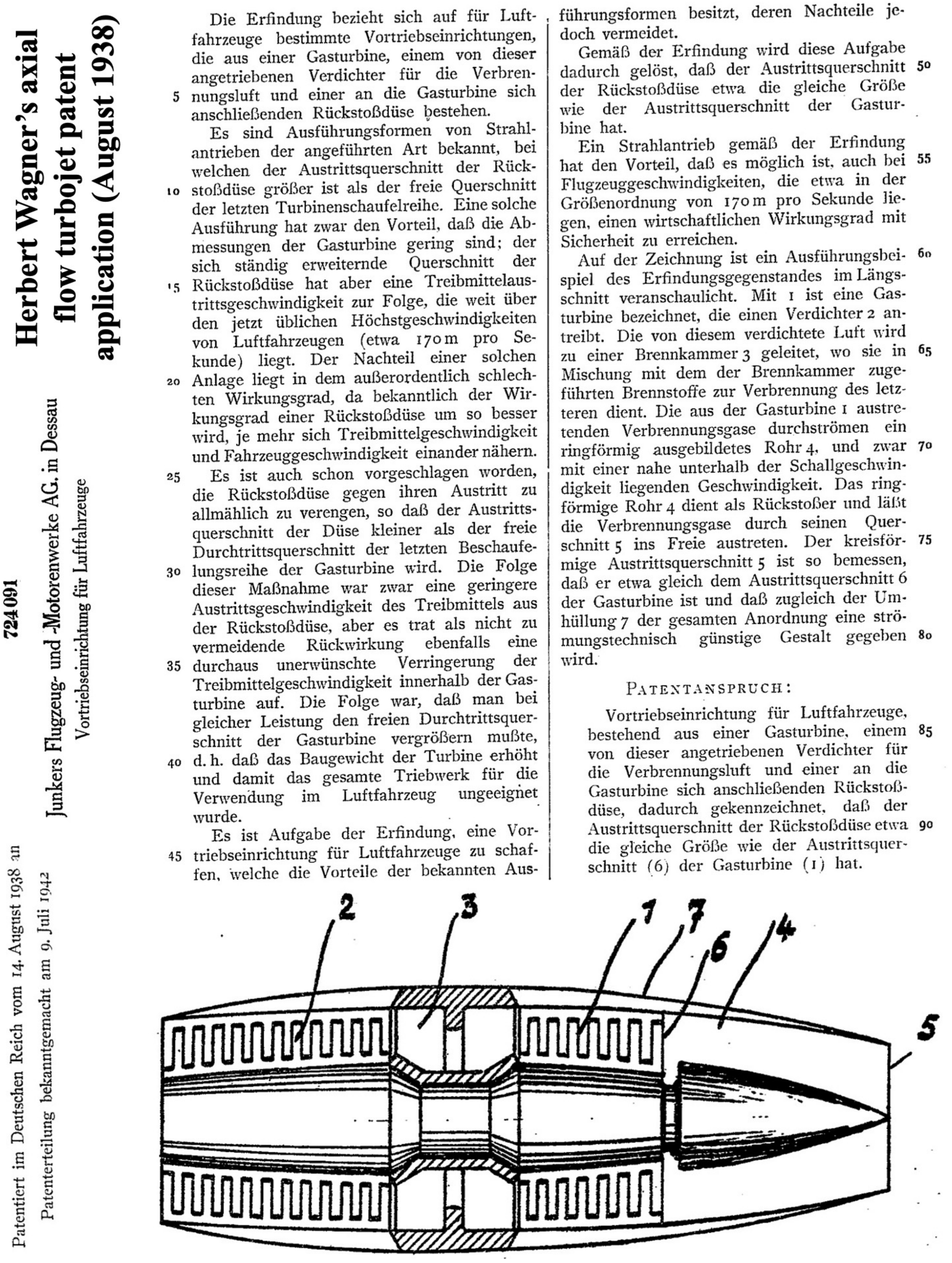
Gasturbinenanlage mit Gleichdruckverbrennung, in deren Längsrichtung ein Luftverdichter, ein Brennraum und eine Turbine hintereinander angeordnet sind, dadurch gekennzeichnet, daß der die leistungsübertragende Verbindung (2) des Verdichters (1) und der Turbine (3) umgebende ringförmige Brennraum (4) innerhalb der Verbindung der Leitvorrichtungen (10) des als umlaufendes Gebläse ausgebildeten Verdichters und der Turbine liegt und diese letztere sowie jene leistungsübertragende Verbindung (2) durch einen Luftstrom gegen die von dem Brennraum ausgehende Wärmeeinwirkung geschützt sind.

Zur Abgrenzung des Erfindungsgegenstands vom Stand der Technik sind im Erteilungsverfahren folgende Druckschriften in Betracht gezogen worden:

Deutsche Patentschrift Nr. 106 586;
österreichische Patentschrift Nr. 57 682;
französische Patentschrift Nr. 346 713;
USA.-Patentschrift Nr. 1 418 444.

Another of Herbert Wagner's turbofan patent applications (March 1936)

Figure 9.74: Another of Herbert Wagner's turbofan patent applications (March 1936).



Herbert Wagner's axial flow turbojet patent application (August 1938)

724 091

Junkers Flugzeug- und -Motorenwerke AG. in Dessau

Vortriebseinrichtung für Luftfahrzeuge

Patentiert im Deutschen Reich vom 14. August 1938 an

Patenterteilung bekanntgemacht am 9. Juli 1942

Die Erfindung bezieht sich auf für Luftfahrzeuge bestimmte Vortriebseinrichtungen, die aus einer Gasturbine, einem von dieser angetriebenen Verdichter für die Verbrennungsluft und einer an die Gasturbine sich anschließenden Rückstoßdüse bestehen.

Es sind Ausführungsformen von Strahlantrieben der angeführten Art bekannt, bei welchen der Austrittsquerschnitt der Rückstoßdüse größer ist als der freie Querschnitt der letzten Turbinenschaufelreihe. Eine solche Ausführung hat zwar den Vorteil, daß die Abmessungen der Gasturbine gering sind; der sich ständig erweiternde Querschnitt der Rückstoßdüse hat aber eine Treibmittelaustrittsgeschwindigkeit zur Folge, die weit über den jetzt üblichen Höchstgeschwindigkeiten von Luftfahrzeugen (etwa 170 m pro Sekunde) liegt. Der Nachteil einer solchen Anlage liegt in dem außerordentlich schlechten Wirkungsgrad, da bekanntlich der Wirkungsgrad einer Rückstoßdüse um so besser wird, je mehr sich Treibmittelgeschwindigkeit und Fahrzeuggeschwindigkeit einander nähern.

Es ist auch schon vorgeschlagen worden, die Rückstoßdüse gegen ihren Austritt zu allmählich zu verengen, so daß der Austrittsquerschnitt der Düse kleiner als der freie Durchtrittsquerschnitt der letzten Beschaufelungsreihe der Gasturbine wird. Die Folge dieser Maßnahme war zwar eine geringere Austrittsgeschwindigkeit des Treibmittels aus der Rückstoßdüse, aber es trat als nicht zu vermeidende Rückwirkung ebenfalls eine durchaus unerwünschte Verringerung der Treibmittelgeschwindigkeit innerhalb der Gasturbine auf. Die Folge war, daß man bei gleicher Leistung den freien Durchtrittsquerschnitt der Gasturbine vergrößern mußte, d. h. daß das Baugewicht der Turbine erhöht und damit das gesamte Triebwerk für die Verwendung im Luftfahrzeug ungeeignet wurde.

Es ist Aufgabe der Erfindung, eine Vortriebseinrichtung für Luftfahrzeuge zu schaffen, welche die Vorteile der bekannten Ausführungsformen besitzt, deren Nachteile jedoch vermeidet.

Gemäß der Erfindung wird diese Aufgabe dadurch gelöst, daß der Austrittsquerschnitt der Rückstoßdüse etwa die gleiche Größe wie der Austrittsquerschnitt der Gasturbine hat.

Ein Strahlantrieb gemäß der Erfindung hat den Vorteil, daß es möglich ist, auch bei Flugzeuggeschwindigkeiten, die etwa in der Größenordnung von 170 m pro Sekunde liegen, einen wirtschaftlichen Wirkungsgrad mit Sicherheit zu erreichen.

Auf der Zeichnung ist ein Ausführungsbeispiel des Erfindungsgegenstandes im Längsschnitt veranschaulicht. Mit 1 ist eine Gasturbine bezeichnet, die einen Verdichter 2 antreibt. Die von diesem verdichtete Luft wird zu einer Brennkammer 3 geleitet, wo sie in Mischung mit dem der Brennkammer zugeführten Brennstoffe zur Verbrennung des letzteren dient. Die aus der Gasturbine 1 austretenden Verbrennungsgase durchströmen ein ringförmig ausgebildetes Rohr 4, und zwar mit einer nahe unterhalb der Schallgeschwindigkeit liegenden Geschwindigkeit. Das ringförmige Rohr 4 dient als Rückstoßer und läßt die Verbrennungsgase durch seinen Querschnitt 5 ins Freie austreten. Der kreisförmige Austrittsquerschnitt 5 ist so bemessen, daß er etwa gleich dem Austrittsquerschnitt 6 der Gasturbine ist und daß zugleich der Umhüllung 7 der gesamten Anordnung eine strömungstechnisch günstige Gestalt gegeben wird.

PATENTANSPRUCH:

Vortriebseinrichtung für Luftfahrzeuge, bestehend aus einer Gasturbine, einem von dieser angetriebenen Verdichter für die Verbrennungsluft und einer an die Gasturbine sich anschließenden Rückstoßdüse, dadurch gekennzeichnet, daß der Austrittsquerschnitt der Rückstoßdüse etwa die gleiche Größe wie der Austrittsquerschnitt (6) der Gasturbine (1) hat.

Figure 9.75: Herbert Wagner's axial flow turbojet patent application (August 1938).

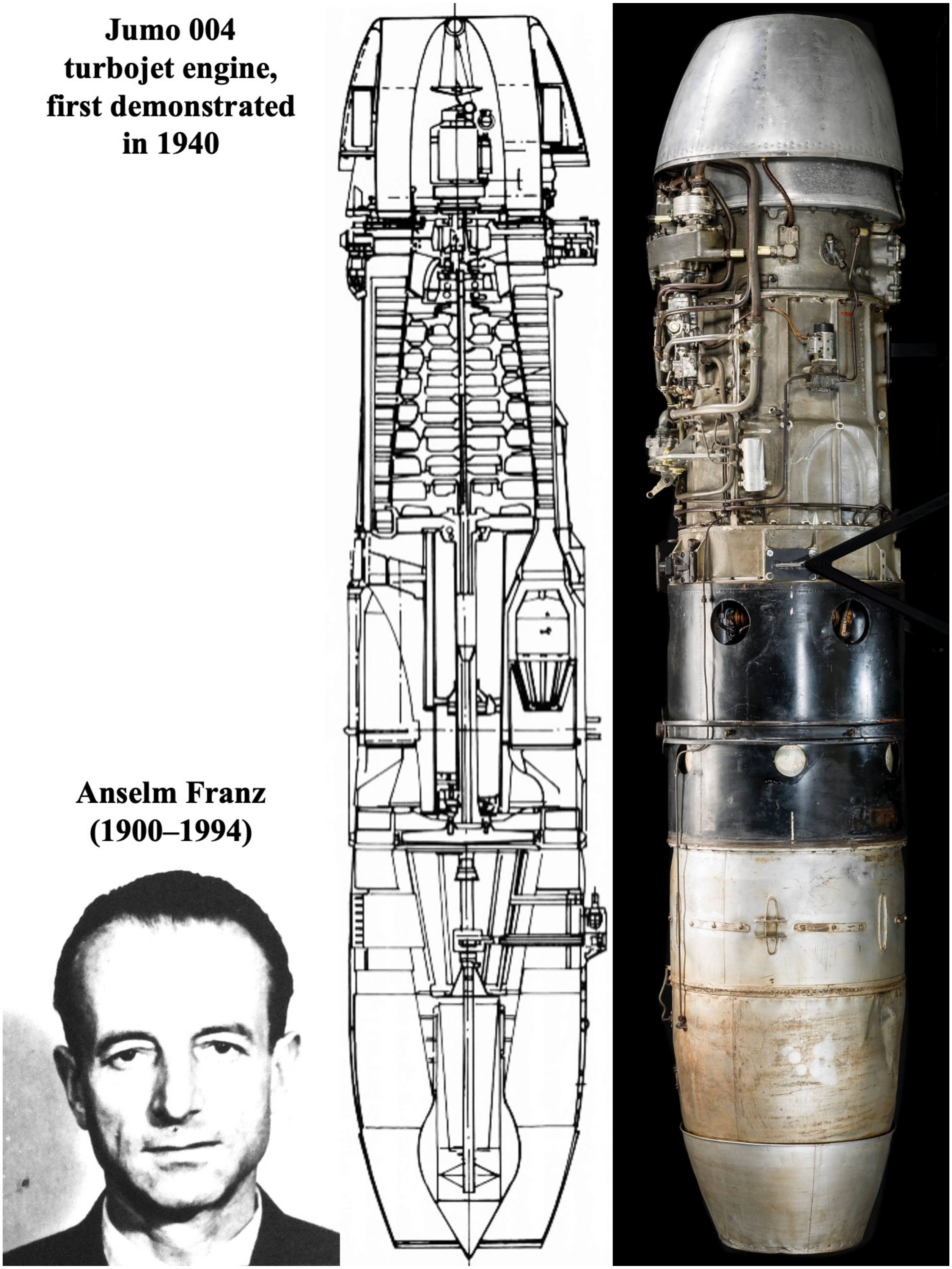
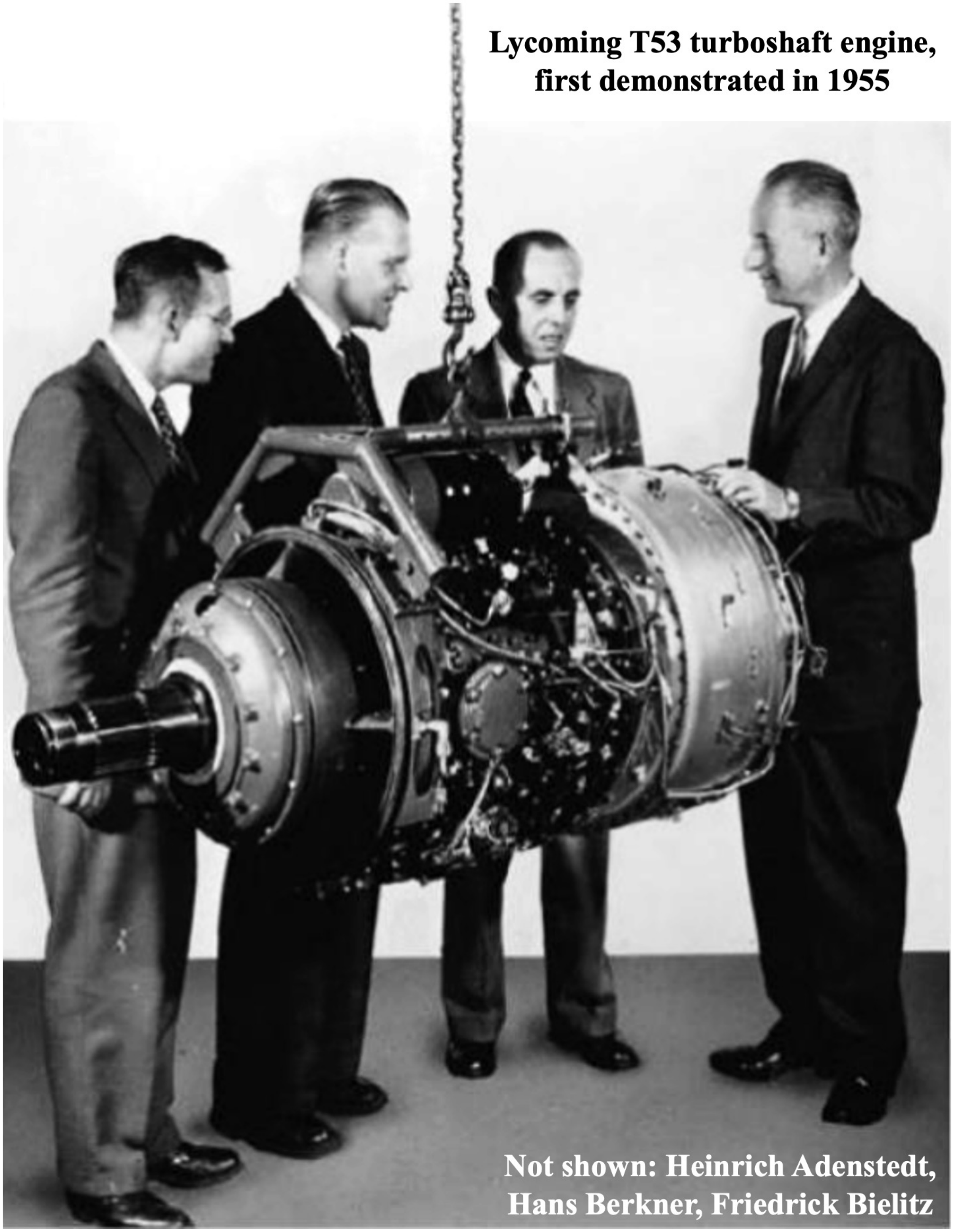

Jumo 004
turbojet engine,
first demonstrated
in 1940
Anselm Franz
(1900–1994)

Figure 9.76: During the war, Anselm Franz led a team that developed and mass-produced the Jumo (Junkers Motors) 004 turbojet engine and also developed other engines such as the Jumo 022 turboprop engine (p. 1748).

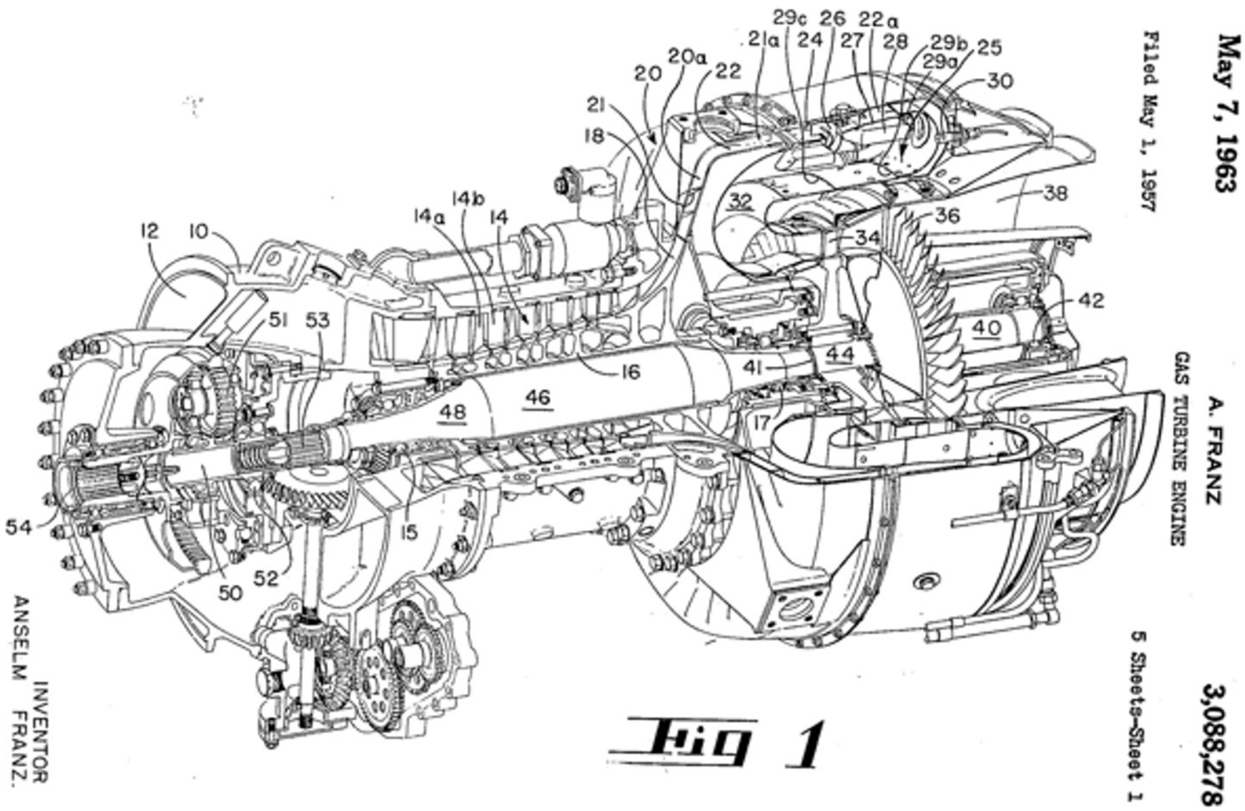


Heinz Moellmann, Siegfried Decher, Wolfgang Stein, Anselm Franz

Lycoming T53 turboshaft engine, first demonstrated in 1955

Not shown: Heinrich Adenstedt, Hans Berkner, Friedrick Bielitz

Figure 9.77: After the war, Anselm Franz led a team including Heinrich Adenstedt, Hans Berkner, Friedrick Bielitz, Siegfried Decher, Heinz Moellmann, and Wolfgang Stein to produce the Lycoming T53 and T55 turboshaft engines, PLF1 high-bypass turbofan engine, AGT1500 turboshaft tank engine (p. 1381), and other engines.


May 7, 1963
A. FRANZ
GAS TURBINE ENGINE
Filed May 1, 1957
5 Sheets-Sheet 1
3,088,278
Fig 1
INVENTOR
ANSELM FRANZ.
10
12
14
14a
14b
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21a
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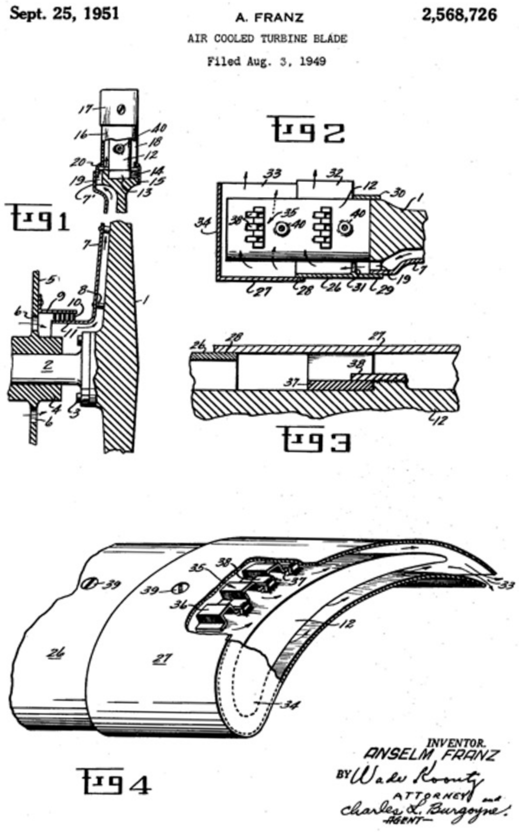

Sept. 25, 1951
A. FRANZ
2,568,726
AIR COOLED TURBINE BLADE
Filed Aug. 3, 1949
Fig 1
Fig 2
Fig 3
Fig 4
INVENTOR.
ANSELM FRANZ
BY Wade Koontz
ATTORNEY and
Charles L. Burgoyne
AGENT

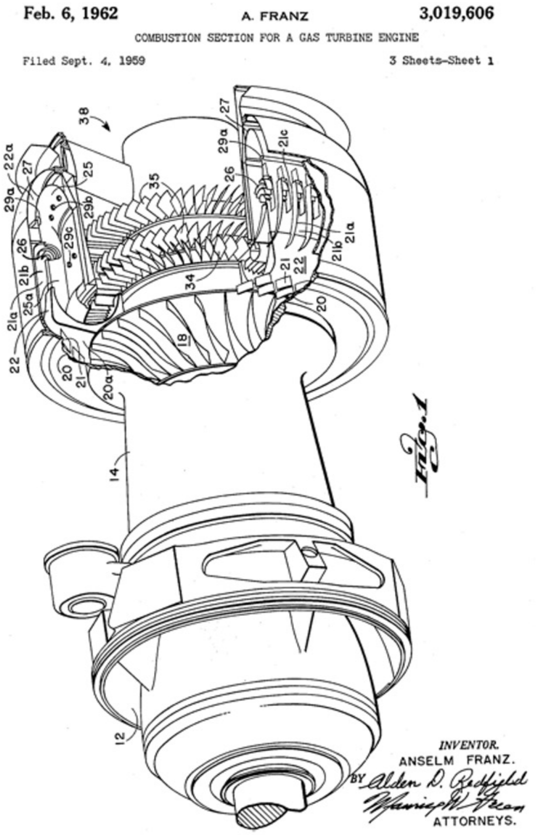
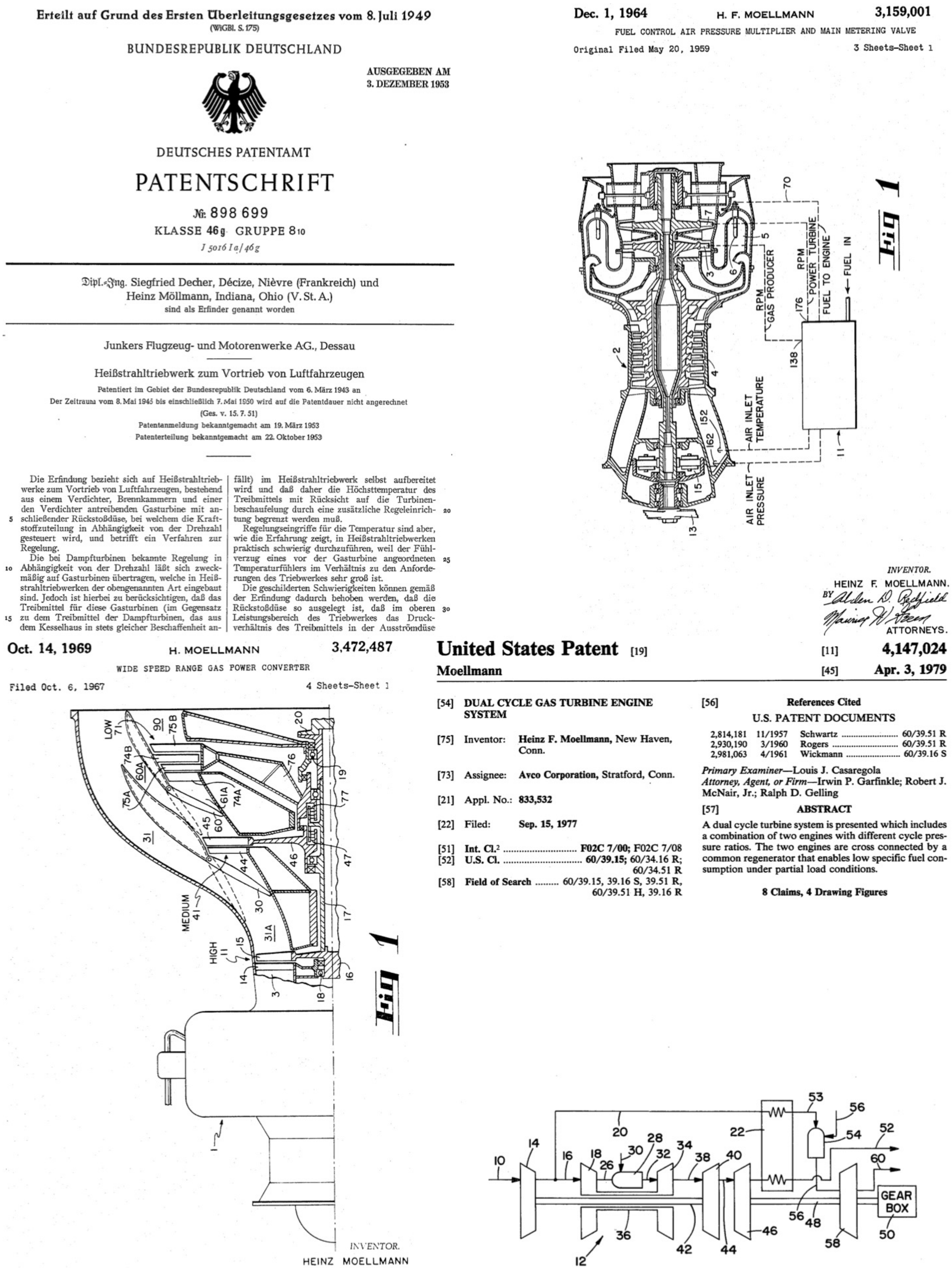

Feb. 6, 1962
A. FRANZ
3,019,606
COMBUSTION SECTION FOR A GAS TURBINE ENGINE
Filed Sept. 4, 1959
3 Sheets-Sheet 1
Fig. 1
INVENTOR.
ANSELM FRANZ.
BY Alden D. Redfield
ATTORNEYS.

Figure 9.78: Examples of jet engine patents by Anselm Franz.



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
3. DEZEMBER 1953

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 898 699

KLASSE 46g GRUPPE 8₁₀

J 5016 Ia/46g

Dipl.-Ing. Siegfried Decher, Décize, Nièvre (Frankreich) und
Heinz Möllmann, Indiana, Ohio (V. St. A.)
sind als Erfinder genannt worden

Junkers Flugzeug- und Motorenwerke AG., Dessau

Heißstrahltriebwerk zum Vortrieb von Luftfahrzeugen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 6. März 1943 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
(Ges. v. 15. 7. 51)
Patentanmeldung bekanntgemacht am 19. März 1953
Patenterteilung bekanntgemacht am 22. Oktober 1953

Die Erfindung bezieht sich auf Heißstrahltriebwerke zum Vortrieb von Luftfahrzeugen, bestehend aus einem Verdichter, Brennkammern und einer den Verdichter antreibenden Gasturbine mit anschließender Rückstoßdüse, bei welchem die Kraftstoffzuteilung in Abhängigkeit von der Drehzahl gesteuert wird, und betrifft ein Verfahren zur Regelung.

Die bei Dampfturbinen bekannte Regelung in Abhängigkeit von der Drehzahl läßt sich zweckmäßig auf Gasturbinen übertragen, welche in Heißstrahltriebwerken der obengenannten Art eingebaut sind. Jedoch ist hierbei zu berücksichtigen, daß das Treibmittel für diese Gasturbinen (im Gegensatz zu dem Treibmittel der Dampfturbinen, das aus dem Kesselhaus in stets gleicher Beschaffenheit anfällt) im Heißstrahltriebwerk selbst aufbereitet wird und daß daher die Höchsttemperatur des Treibmittels mit Rücksicht auf die Turbinenbeschaufelung durch eine zusätzliche Regeleinrichtung begrenzt werden muß.

Regelungseingriffe für die Temperatur sind aber, wie die Erfahrung zeigt, in Heißstrahltriebwerken praktisch schwierig durchzuführen, weil der Fühlverzug eines vor der Gasturbine angeordneten Temperaturfühlers im Verhältnis zu den Anforderungen des Triebwerkes sehr groß ist.

Die geschilderten Schwierigkeiten können gemäß der Erfindung dadurch behoben werden, daß die Rückstoßdüse so ausgelegt ist, daß im oberen Leistungsbereich des Triebwerkes das Druckverhältnis des Treibmittels in der Ausströmdüse

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Dec. 1, 1964 H. F. MOELLMANN 3,159,001

FUEL CONTROL AIR PRESSURE MULTIPLIER AND MAIN METERING VALVE

Original Filed May 20, 1959 3 Sheets-Sheet 1

INVENTOR.
HEINZ F. MOELLMANN
BY Alden D. Redfield
ATTORNEYS.

Oct. 14, 1969 H. MOELLMANN 3,472,487

WIDE SPEED RANGE GAS POWER CONVERTER

Filed Oct. 6, 1967 4 Sheets-Sheet 1

INVENTOR.
HEINZ MOELLMANN

United States Patent [19] [11] 4,147,024
Moellmann [45] Apr. 3, 1979

[54] DUAL CYCLE GAS TURBINE ENGINE SYSTEM

[75] Inventor: Heinz F. Moellmann, New Haven, Conn.

[73] Assignee: Avco Corporation, Stratford, Conn.

[21] Appl. No.: 833,532

[22] Filed: Sep. 15, 1977

[51] Int. Cl.² F02C 7/00; F02C 7/08
[52] U.S. Cl. .... 60/39.15; 60/34.16 R; 60/34.51 R
[58] Field of Search .... 60/39.15, 39.16 S, 39.51 R, 60/39.51 H, 39.16 R

[56] References Cited

U.S. PATENT DOCUMENTS

2,814,181	11/1957	Schwartz	60/39.51 R
2,930,190	3/1960	Rogers	60/39.51 R
2,981,063	4/1961	Wickmann	60/39.16 S

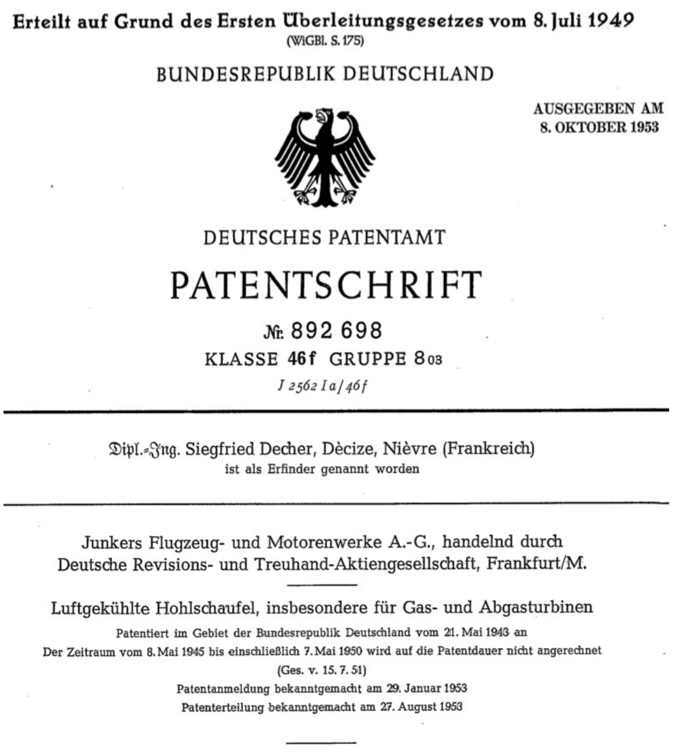
Primary Examiner—Louis J. Casaregola
Attorney, Agent, or Firm—Irwin P. Garfinkle; Robert J. McNair, Jr.; Ralph D. Gelling

[57] ABSTRACT

A dual cycle turbine system is presented which includes a combination of two engines with different cycle pressure ratios. The two engines are cross connected by a common regenerator that enables low specific fuel consumption under partial load conditions.

8 Claims, 4 Drawing Figures

Figure 9.79: Examples of jet engine patents by Heinz Moellmann.



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
8. OKTOBER 1953

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 892 698

KLASSE **46f** GRUPPE 8$_{03}$

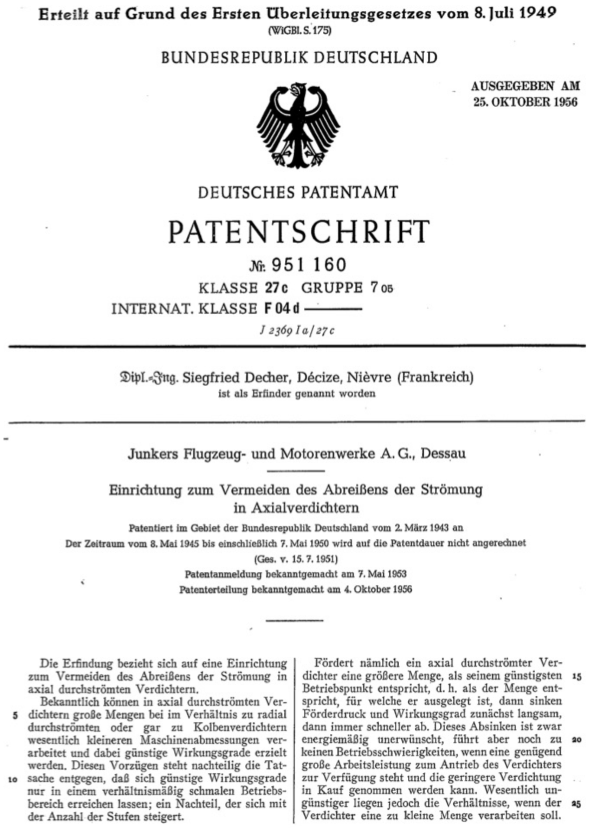
J 2562 I a / 46 f

Dipl.-Ing. Siegfried Decher, Dècize, Nièvre (Frankreich)
ist als Erfinder genannt worden

Junkers Flugzeug- und Motorenwerke A.-G., handelnd durch
Deutsche Revisions- und Treuhand-Aktiengesellschaft, Frankfurt/M.

Luftgekühlte Hohlschaufel, insbesondere für Gas- und Abgasturbinen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 21. Mai 1943 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
(Ges. v. 15. 7. 51)
Patentanmeldung bekanntgemacht am 29. Januar 1953
Patenterteilung bekanntgemacht am 27. August 1953



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
25. OKTOBER 1956

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 951 160

KLASSE **27c** GRUPPE 7$_{05}$
INTERNAT. KLASSE **F 04 d**

J 2369 I a / 27 c

Dipl.-Ing. Siegfried Decher, Décize, Nièvre (Frankreich)
ist als Erfinder genannt worden

Junkers Flugzeug- und Motorenwerke A. G., Dessau

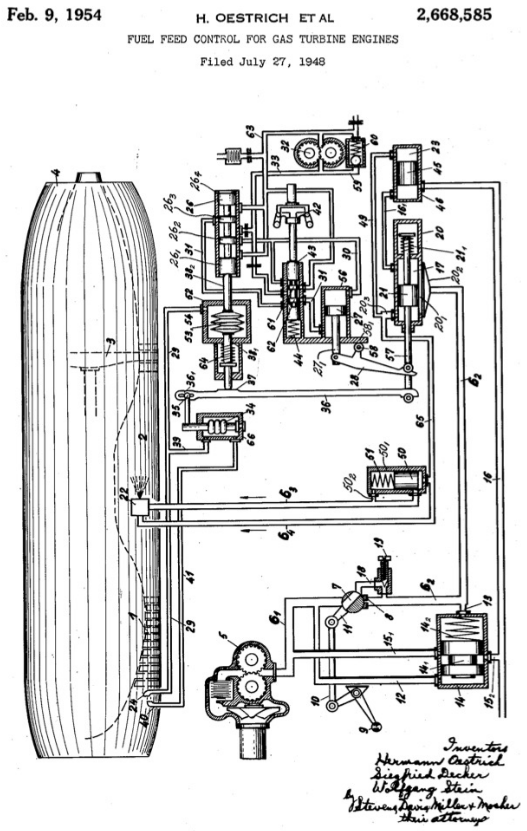
Einrichtung zum Vermeiden des Abreißens der Strömung in Axialverdichtern

Patentiert im Gebiet der Bundesrepublik Deutschland vom 2. März 1943 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
(Ges. v. 15. 7. 1951)
Patentanmeldung bekanntgemacht am 7. Mai 1953
Patenterteilung bekanntgemacht am 4. Oktober 1956

Die Erfindung bezieht sich auf eine Einrichtung zum Vermeiden des Abreißens der Strömung in axial durchströmten Verdichtern.

Bekanntlich können in axial durchströmten Verdichtern große Mengen bei im Verhältnis zu radial durchströmten oder gar zu Kolbenverdichtern wesentlich kleineren Maschinenabmessungen verarbeitet und dabei günstige Wirkungsgrade erzielt werden. Diesen Vorzügen steht nachteilig die Tatsache entgegen, daß sich günstige Wirkungsgrade nur in einem verhältnismäßig schmalen Betriebsbereich erreichen lassen; ein Nachteil, der sich mit der Anzahl der Stufen steigert.

Fördert nämlich ein axial durchströmter Verdichter eine größere Menge, als seinem günstigsten Betriebspunkt entspricht, d. h. als der Menge entspricht, für welche er ausgelegt ist, dann sinken Förderdruck und Wirkungsgrad zunächst langsam, dann immer schneller ab. Dieses Absinken ist zwar energiemäßig unerwünscht, führt aber noch zu keinen Betriebsschwierigkeiten, wenn eine genügend große Arbeitsleistung zum Antrieb des Verdichters zur Verfügung steht und die geringere Verdichtung in Kauf genommen werden kann. Wesentlich ungünstiger liegen jedoch die Verhältnisse, wenn der Verdichter eine zu kleine Menge verarbeiten soll.

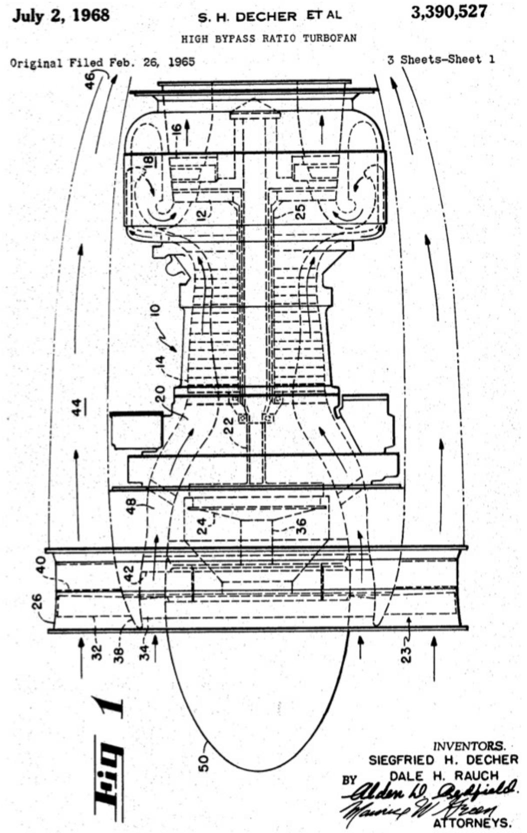


Feb. 9, 1954 H. OESTRICH ET AL **2,668,585**

FUEL FEED CONTROL FOR GAS TURBINE ENGINES

Filed July 27, 1948

Inventors
Hermann Oestrich
Siegfried Decher
Wolfgang Stein
by Stevens, Davis, Miller & Mosher
their attorneys



July 2, 1968 S. H. DECHER ET AL **3,390,527**

HIGH BYPASS RATIO TURBOFAN

Original Filed Feb. 26, 1965 3 Sheets-Sheet 1

Fig 1

INVENTORS.
SIEGFRIED H. DECHER
DALE H. RAUCH
BY Alden D. Redfield.
ATTORNEYS.

Figure 9.80: Examples of jet engine patents by Siegfried Decher.

Bruno Bruckmann (Austrian, 1902–1997), Peter Kappus (German, 1910–2008), Hermann Östrich (German, 1903–1973), R. Walter Brisken (German, 1914–2011), and others developed the BMW 003 axial-flow turbojet engine (first run in 1940, Fig. 9.81). At least 3500 BMW 003 engines were produced during the war. The BMW team also built prototypes of the larger, more advanced BMW 018 axial-flow turbojet engine, and they were developing the BMW 028 turboprop engine (p. 1748).

Norbert Riedel (Austrian, 1912–1963) built turbojet starter motors and also motorcycles.

Karl Leist (German, 1901–1960) built and demonstrated the first functional turbofan engine, the Daimler-Benz DB 007, also known as the Zweikreis Turbinen-Luftstrahltriebwerk ZTL 6001 (began development 1939, first run 1 April 1943). See pp. 1746, 5233–5241. At least three DB 007 turbofan engines were produced. The Heinkel company was also developing turbofan engines.

György Jendrassik (Austro-Hungarian, 1898–1954) designed the Jendrassik Cs-1 turboprop engine in 1937 and first ran it in a test stand in 1940 (Fig. 9.83).

During the war, there were several notable turboprop engine development projects, including the Jumo 022 (p. 1748), BMW 028 (p. 1748), and Heinkel He S 021 (a turboprop version of the He S 011, p. 1731).

Ferdinand Brandner (Austrian, 1903–1986) worked at Junkers during the war developing engines such as the Jumo 012 turbojet and Jumo 022 turboprop. After the war, he built copies (NK-12) of the Jumo 022 turboprop in Russia and then developed jet engines (such as the Egyptian E-300) in several other countries. See Fig. 9.85.

According to official histories, none of the turbofan or turboprop engines were used on aircraft before the end of the war. However, historians should carefully investigate whether some of the turbofan or turboprop work may have actually progressed further during the war, and how much it influenced postwar work on turbofan and turboprop engines, in view of:

1. The high priority placed on intercontinental jet bombers in the final years of the war.

2. The significantly higher fuel efficiency and hence longer range enabled by turbofan and turboprop engines compared to turbojet engines.

3. The great secrecy with which both wartime German scientists and postwar Allied investigators would have handled jet engine technology that was so advanced and had such strategic implications for intercontinental bombing.

For more information on wartime programs to develop intercontinental jet bombers, see Sections E.1 and E.6.

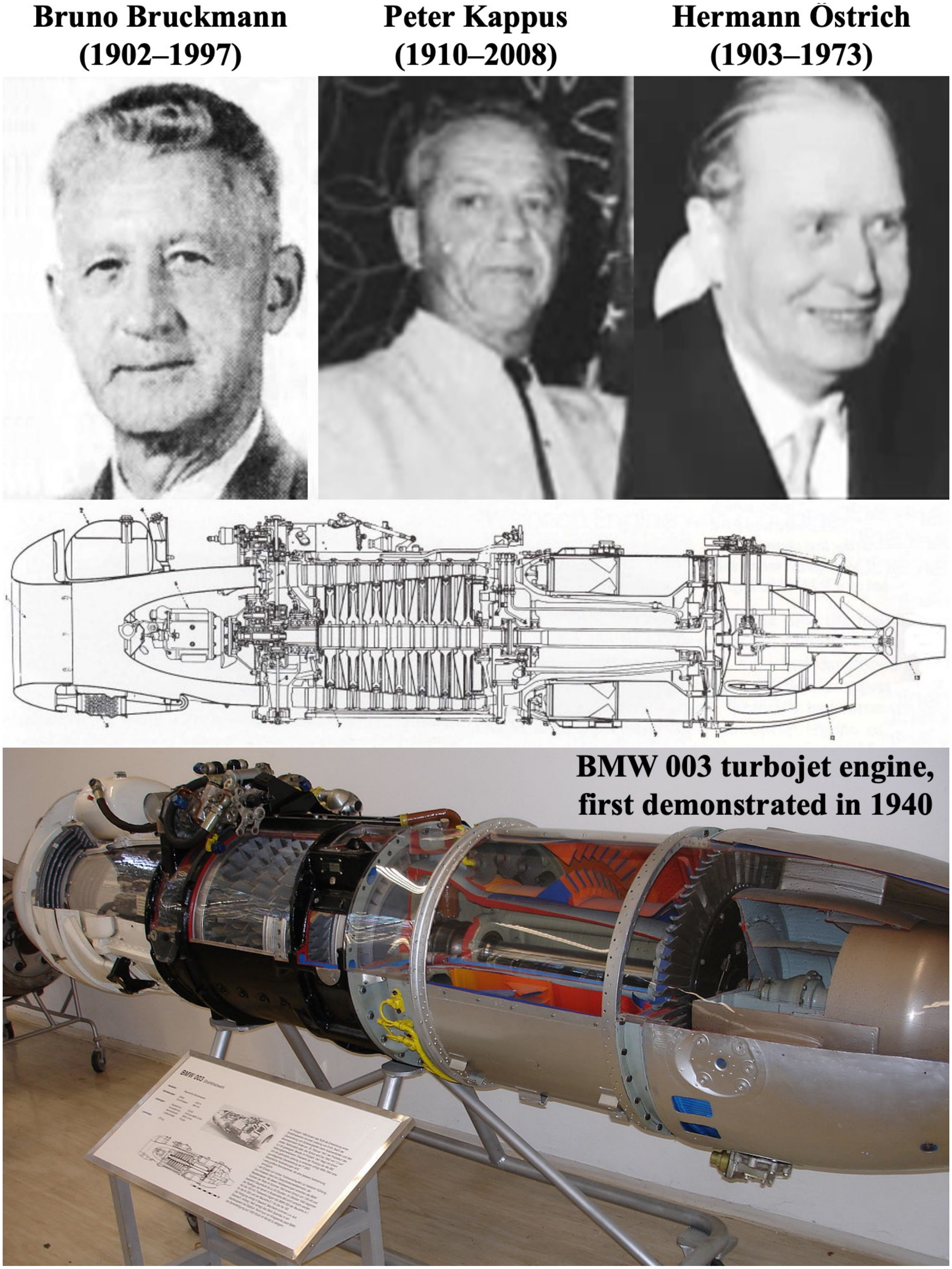

Bruno Bruckmann (1902–1997)
Peter Kappus (1910–2008)
Hermann Östrich (1903–1973)
BMW 003 turbojet engine, first demonstrated in 1940
BMW 003

Figure 9.81: Bruno Bruckmann, Peter Kappus, and Hermann Östrich led the team that developed and mass-produced the BMW 003 turbojet engine.

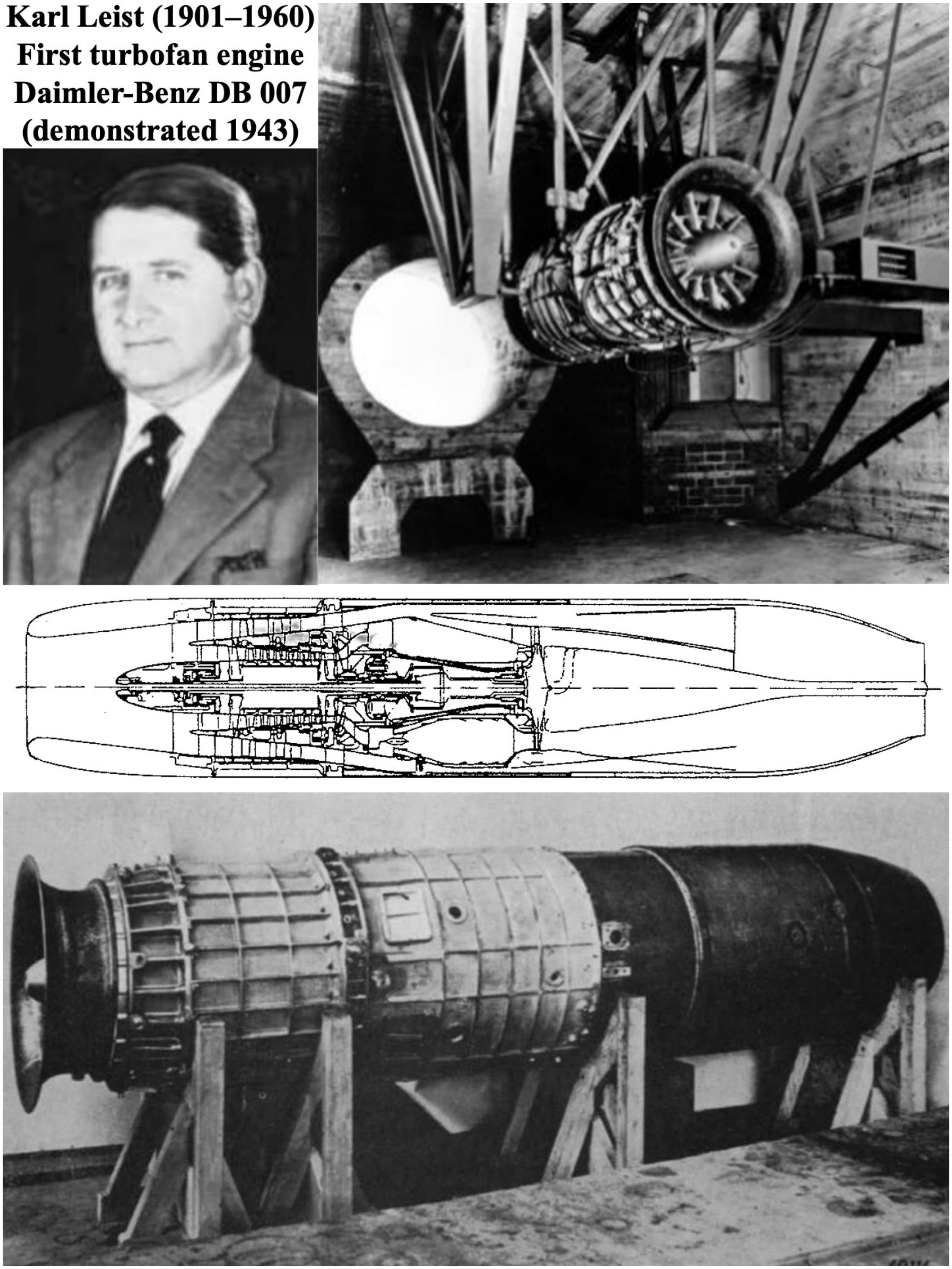

Karl Leist (1901–1960)
First turbofan engine
Daimler-Benz DB 007
(demonstrated 1943)

Figure 9.82: Karl Leist built and demonstrated the first fully functional turbofan engine, the Daimler-Benz DB 007, in 1943.

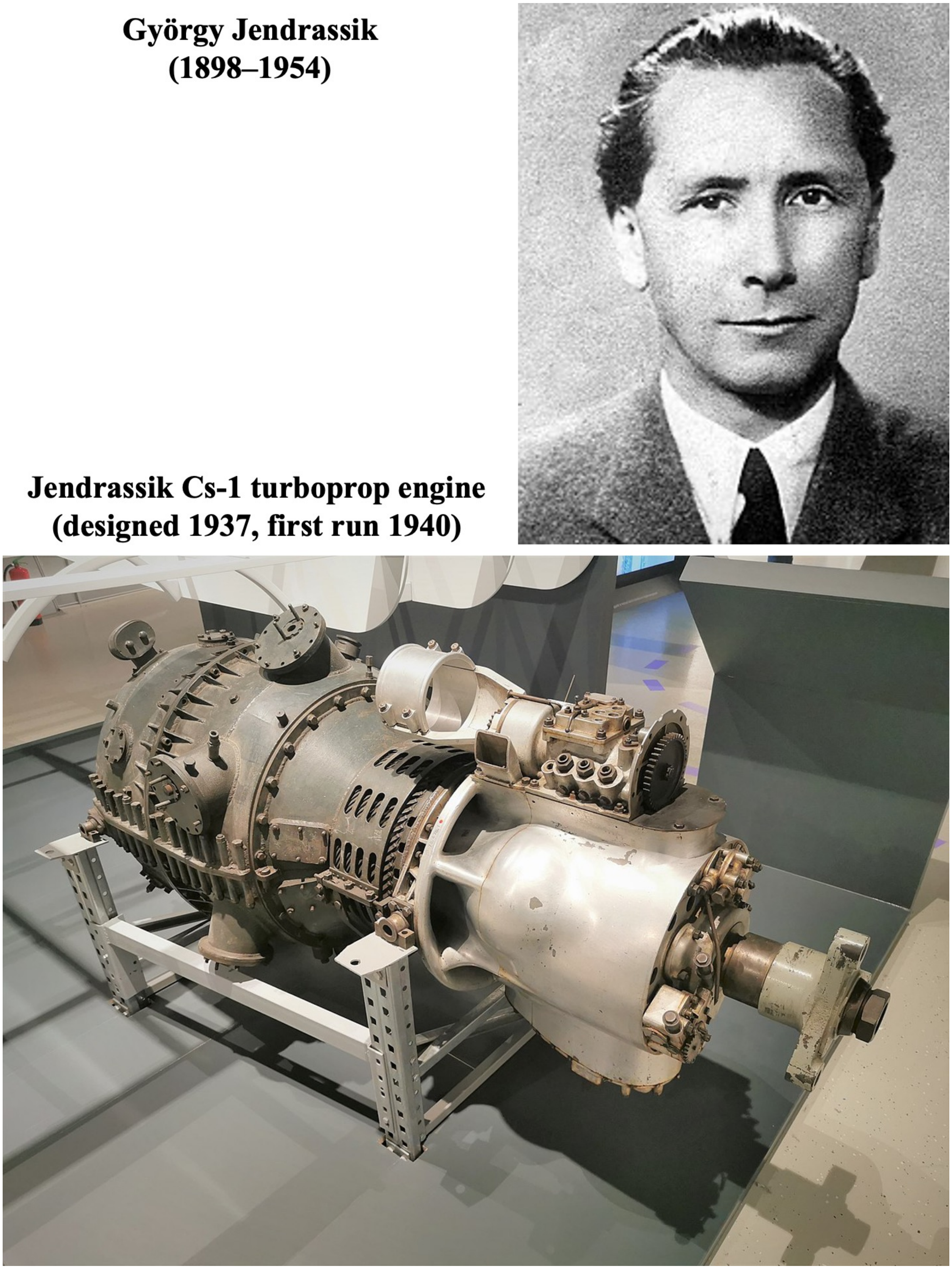
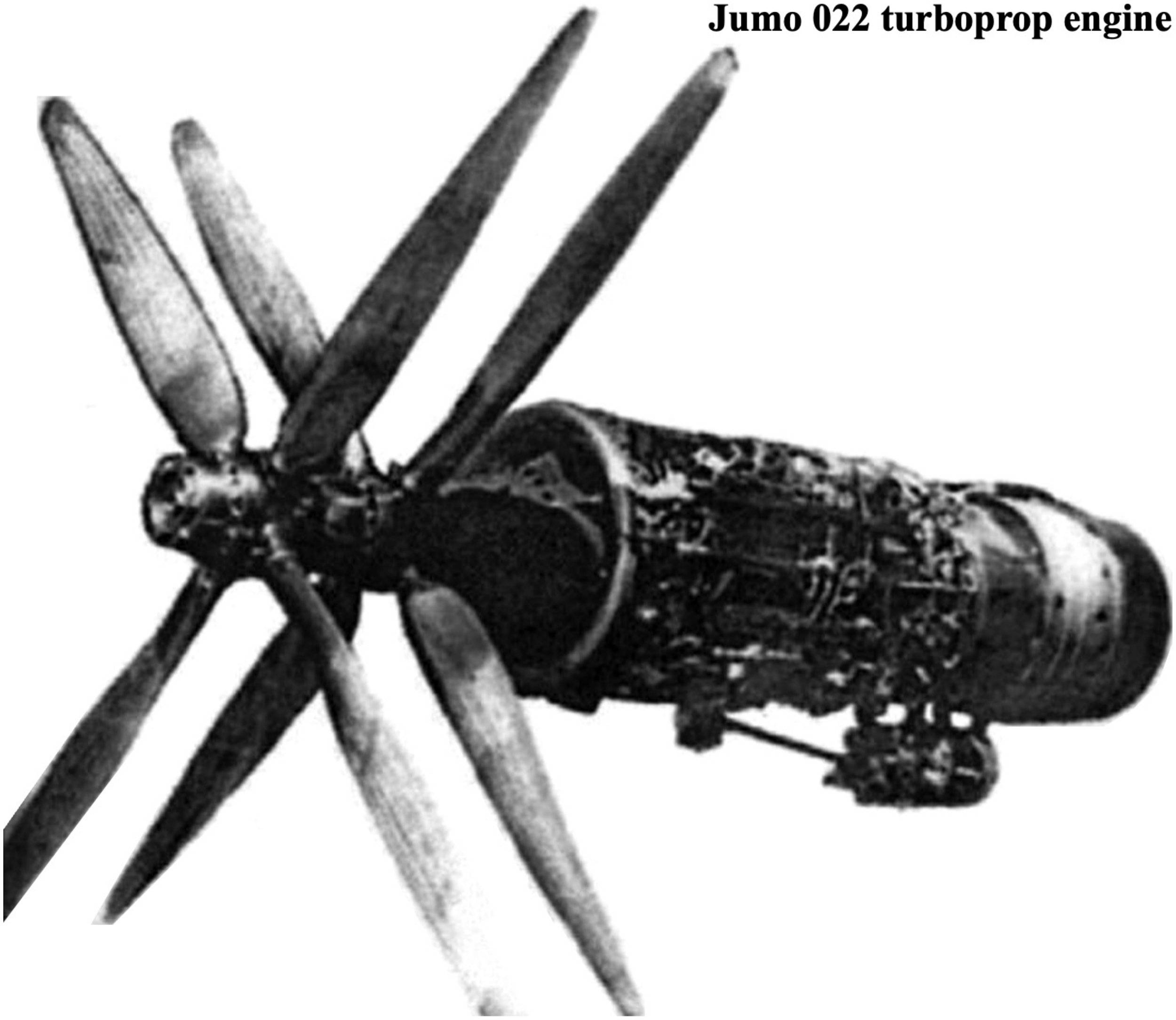

György Jendrassik
(1898–1954)
Jendrassik Cs-1 turboprop engine
(designed 1937, first run 1940)

Figure 9.83: György Jendrassik designed the Jendrassik Cs-1 turboprop engine in 1937 and first ran it in a test stand in 1940.


Jumo 022 turboprop engine

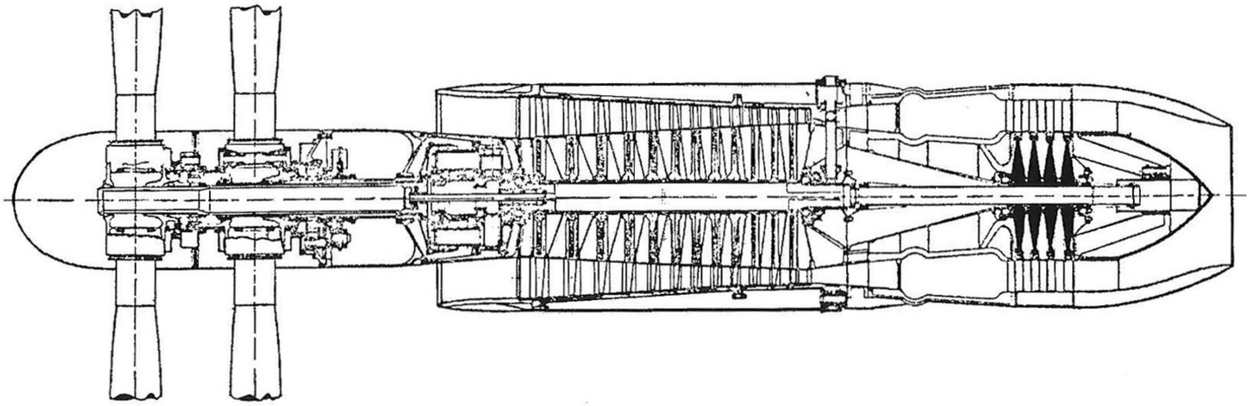

BMW 028 turboprop engine

Figure 9.84: Turboprop engines under development during the war included the Junkers Jumo 022 (a postwar Soviet copy, NK-12, is shown), the BMW 028, and a turboprop version of the Heinkel He S 011 (p. 1731) dubbed the He S 021.

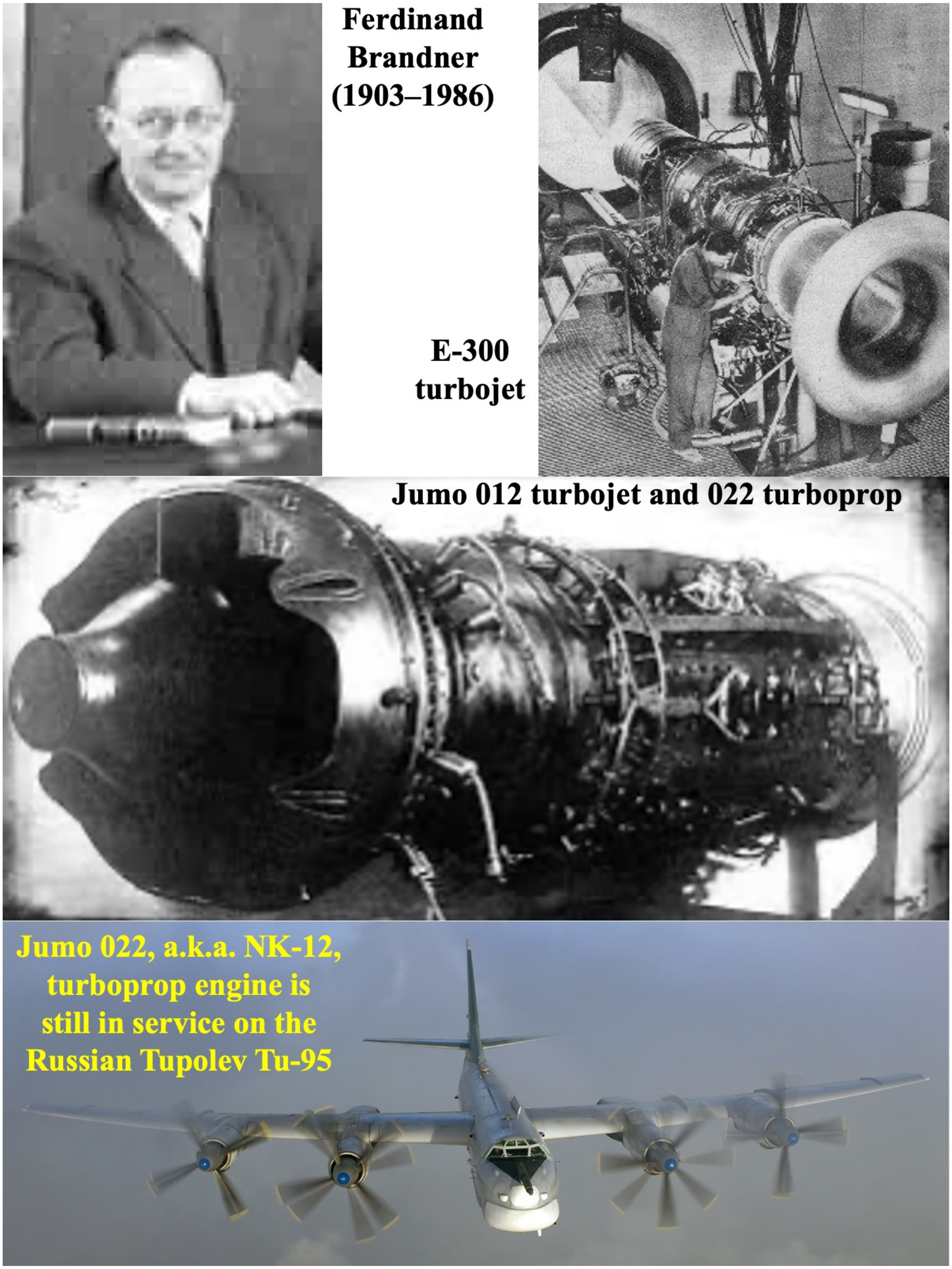

Ferdinand Brandner (1903–1986)
E-300 turbojet
Jumo 012 turbojet and 022 turboprop
Jumo 022, a.k.a. NK-12, turboprop engine is still in service on the Russian Tupolev Tu-95

Figure 9.85: Ferdinand Brandner worked at Junkers during the war developing engines such as the Jumo 012 turbojet and Jumo 022 turboprop. After the war, he built copies (NK-12) of the Jumo 022 turboprop in Russia and then developed jet engines (such as the Egyptian E-300) in several other countries.

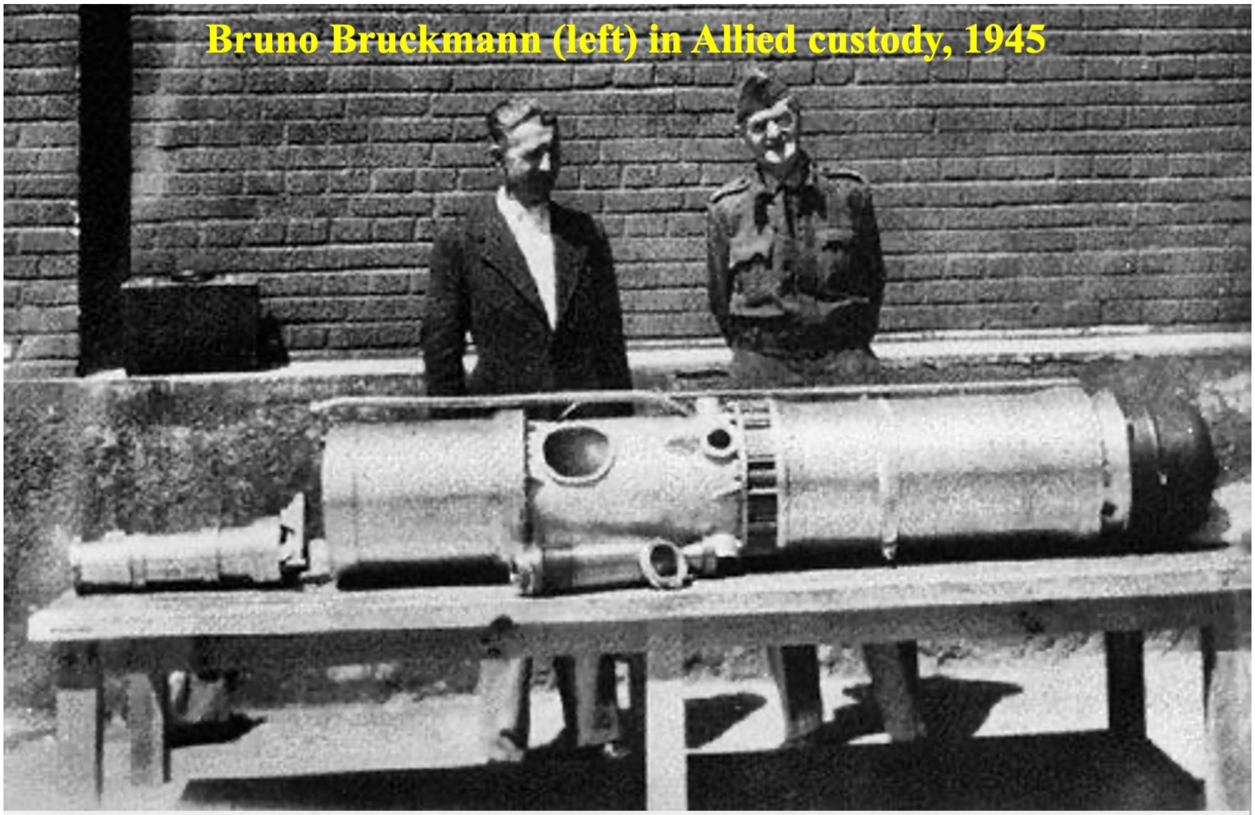
After the war, Bruno Bruckmann and Peter Kappus from the BMW group moved to the United States and designed jet engines for General Electric. See Figs. 9.86–9.97. Some of their postwar GE engines included the J47 turbojet engine (first run 1947, while Bruckmann and Kappus were still officially based at Wright Field but working with GE in nearby Evendale, Ohio), J73 turbojet engine (first run 1953), J79 or CJ805 turbojet engine (first run 1954), and TF35 or CJ805-23 turbofan engine (first run 1956). One of the most impressive projects by Bruckmann and Kappus was the YJ-93 engines for the Mach 3+ XB-70 Valkyrie (Figs. 9.89–9.90). The XB-70 made its first flight in 1964, and *Life* magazine highlighted Bruckmann's accomplishments [Wheeler 1965]:

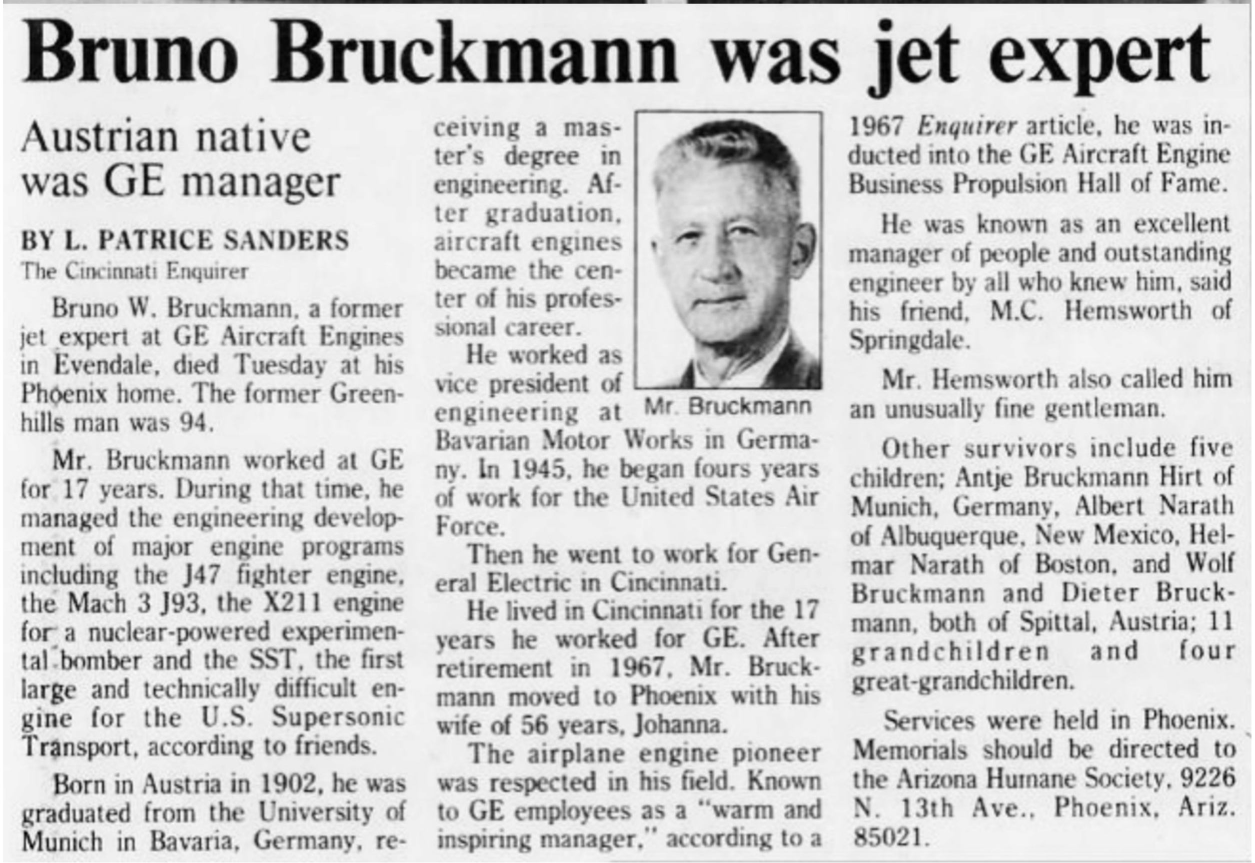
> Bruno Bruckmann. G.E. assigned him to build the engines for the B-70. Bruckmann was born in 1902, the son of a pulp mill director, in the village of Mühlbach in the Italian-Austrian Alps. With an engineering degree from the Technische Hochschule of Munich he eventually went to work at the Bayerische Motoren Werke designing aircraft engines. He started building primitive jets for Hitler in 1939 and, by 1941, hitched his first two practicable engines to a Messerschmitt. The jets were so feeble that a standard piston engine had to be glued on for insurance.
>
> When the war ended, B.M.W. had been bombed out of four different plants and the jet works had been moved for safekeeping into salt mines 2,000 feet underground. In 1946 the U.S. Air Force "invited" Bruckmann to come for a lengthy visit to the U.S. He is tall, precise, silver-haired and looks and sounds like a casting director's dream of a Prussian nobleman.
>
> "It wasn't a social invitation. Perhaps I could have refused it—although that might have made the Air Force unhappy," Bruckmann said recently, "But I was not going to refuse. After all, I was aware the Russians might *invite* me." [...]
>
> Most of the other revolutions Bruckmann wrought are classified Pentagon secrets. They include such exotic concepts as the internal use of rare new alloys, or using fuel to soak the heat out of lubricating oils, or an exacting process of tuning lengths of pipe like a violin to cut out sympathetic vibrations. The results add up to a monster engine, doubling the output of its predecessor and delivering 30,000 pounds of thrust, or six pounds of push for every pound it weighs, capable of sustained operation in ferocious temperatures of more than 2,500^o F in the afterburners. They called it the YJ-93.

Bruckmann and Kappus even designed jet engines that heated the air via nuclear fission instead of chemical combustion reactions. For example, they developed the GE X211 nuclear turbojet engine, which was first demonstrated in 1958 (Fig. 9.91). Two GE X211 engines would have powered the proposed Convair NX-2 bomber, which was cancelled before it could be completed [Carpenter 2003].

Kappus was also a longtime designer and proponent of vertical takeoff and landing (VTOL) aircraft. In September 1957 (before Sputnik!), he filed a patent application on a VTOL vehicle that was ultimately implemented as the Lunar Landing Research Vehicle to train astronauts to land the Apollo Lunar Module (first flight 1964, with the vehicle's legs and pilot's position modified to resemble the final Lunar Module design, Fig. 9.95). Beginning in 1957, he filed several patent applications on VTOL aircraft with downward-pointing ducted fans in the wings and/or body (Figs. 9.96–9.97). That approach was successfully implemented in aircraft such as the Ryan XV-5 Vertifan (first flight 1964) and the Lockheed Martin F-35B (first flight 2008).

After the war, R. Walter Brisken from the wartime BMW jet engine group also moved to General Electric, where he developed the GE LM2500 gas turbine power plant that has been widely employed in ships and industrial applications since the 1960s (Fig. 9.98).


Bruno Bruckmann (left) in Allied custody, 1945



Bruno Bruckmann was jet expert

Austrian native was GE manager

BY L. PATRICE SANDERS
The Cincinnati Enquirer

Bruno W. Bruckmann, a former jet expert at GE Aircraft Engines in Evendale, died Tuesday at his Phoenix home. The former Greenhills man was 94.

Mr. Bruckmann worked at GE for 17 years. During that time, he managed the engineering development of major engine programs including the J47 fighter engine, the Mach 3 J93, the X211 engine for a nuclear-powered experimental bomber and the SST, the first large and technically difficult engine for the U.S. Supersonic Transport, according to friends.

Born in Austria in 1902, he was graduated from the University of Munich in Bavaria, Germany, receiving a master's degree in engineering. After graduation, aircraft engines became the center of his professional career.

He worked as vice president of engineering at Bavarian Motor Works in Germany. In 1945, he began fours years of work for the United States Air Force.

Mr. Bruckmann

Then he went to work for General Electric in Cincinnati.

He lived in Cincinnati for the 17 years he worked for GE. After retirement in 1967, Mr. Bruckmann moved to Phoenix with his wife of 56 years, Johanna.

The airplane engine pioneer was respected in his field. Known to GE employees as a "warm and inspiring manager," according to a 1967 *Enquirer* article, he was inducted into the GE Aircraft Engine Business Propulsion Hall of Fame.

He was known as an excellent manager of people and outstanding engineer by all who knew him, said his friend, M.C. Hemsworth of Springdale.

Mr. Hemsworth also called him an unusually fine gentleman.

Other survivors include five children; Antje Bruckmann Hirt of Munich, Germany, Albert Narath of Albuquerque, New Mexico, Helmar Narath of Boston, and Wolf Bruckmann and Dieter Bruckmann, both of Spittal, Austria; 11 grandchildren and four great-grandchildren.

Services were held in Phoenix. Memorials should be directed to the Arizona Humane Society, 9226 N. 13th Ave., Phoenix, Ariz. 85021.

Figure 9.86: Top: Bruno Bruckmann in Allied custody, 1945. Bottom: Bruckmann's obituary [*Cincinnati Enquirer*, 15 June 1997, p. 32].

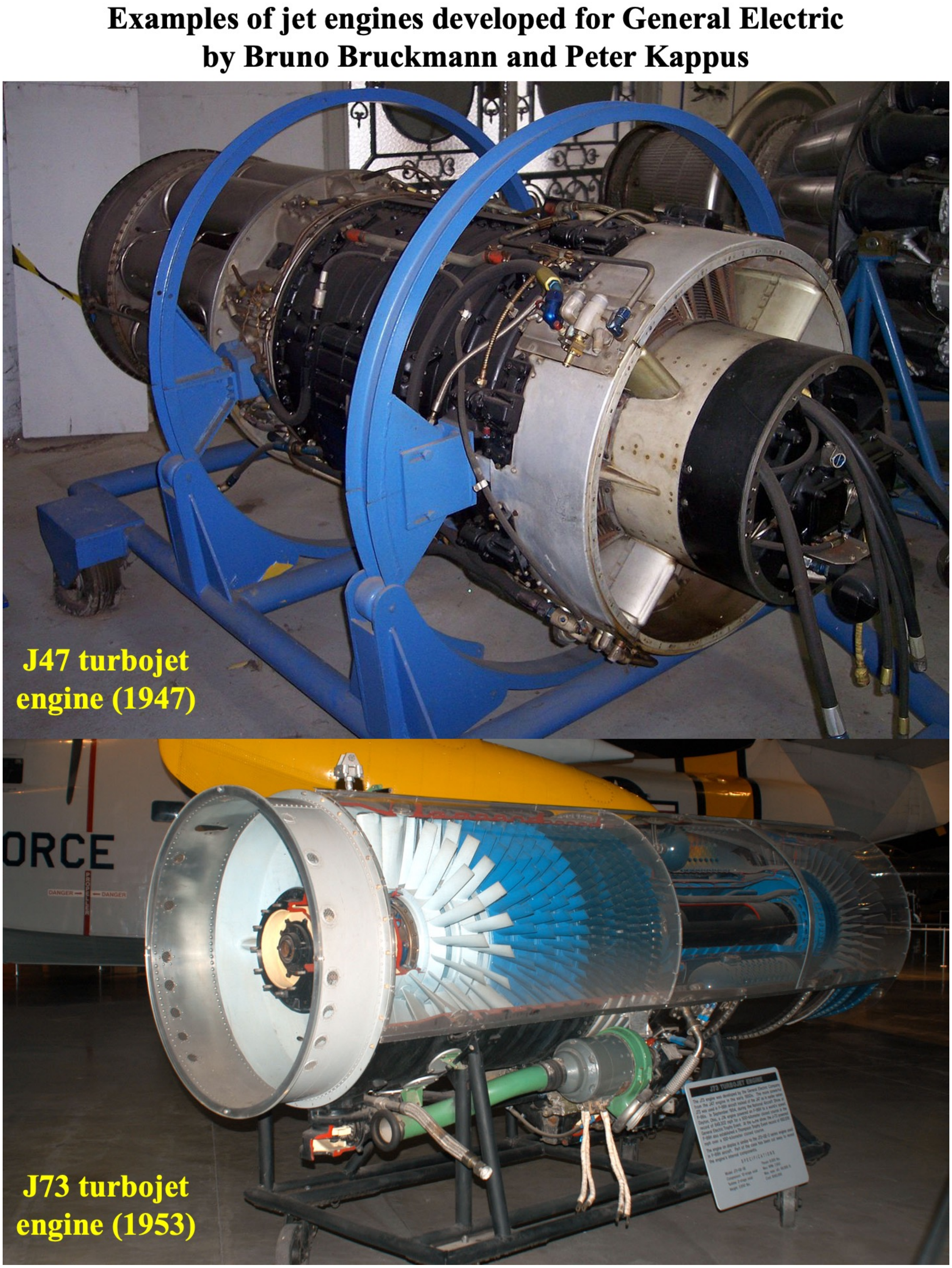
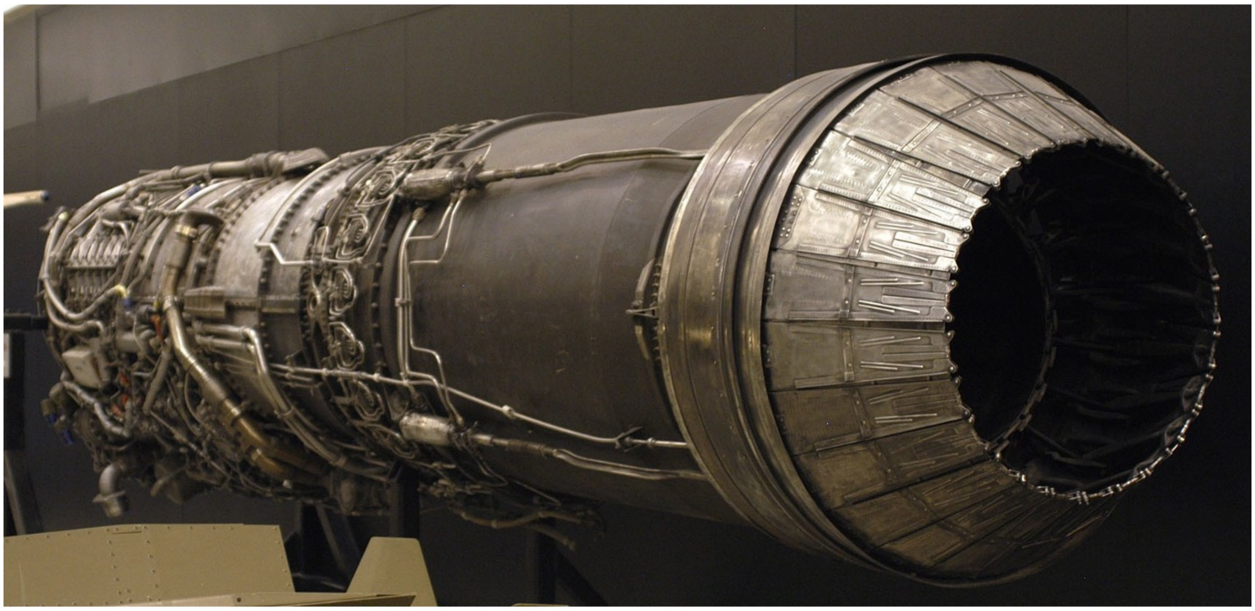

Examples of jet engines developed for General Electric by Bruno Bruckmann and Peter Kappus
J47 turbojet engine (1947)
ORCE
J73 turbojet engine (1953)

Figure 9.87: Some examples of postwar jet engines developed for General Electric by Bruno Bruckmann and Peter Kappus include the J47 turbojet engine (first run 1947) and the J73 turbojet engine (first run 1953).

Examples of jet engines developed for General Electric
by Bruno Bruckmann and Peter Kappus

J79 (CJ805) turbojet engine (1954)



TF35 (CJ805-23) turbofan engine (1956)

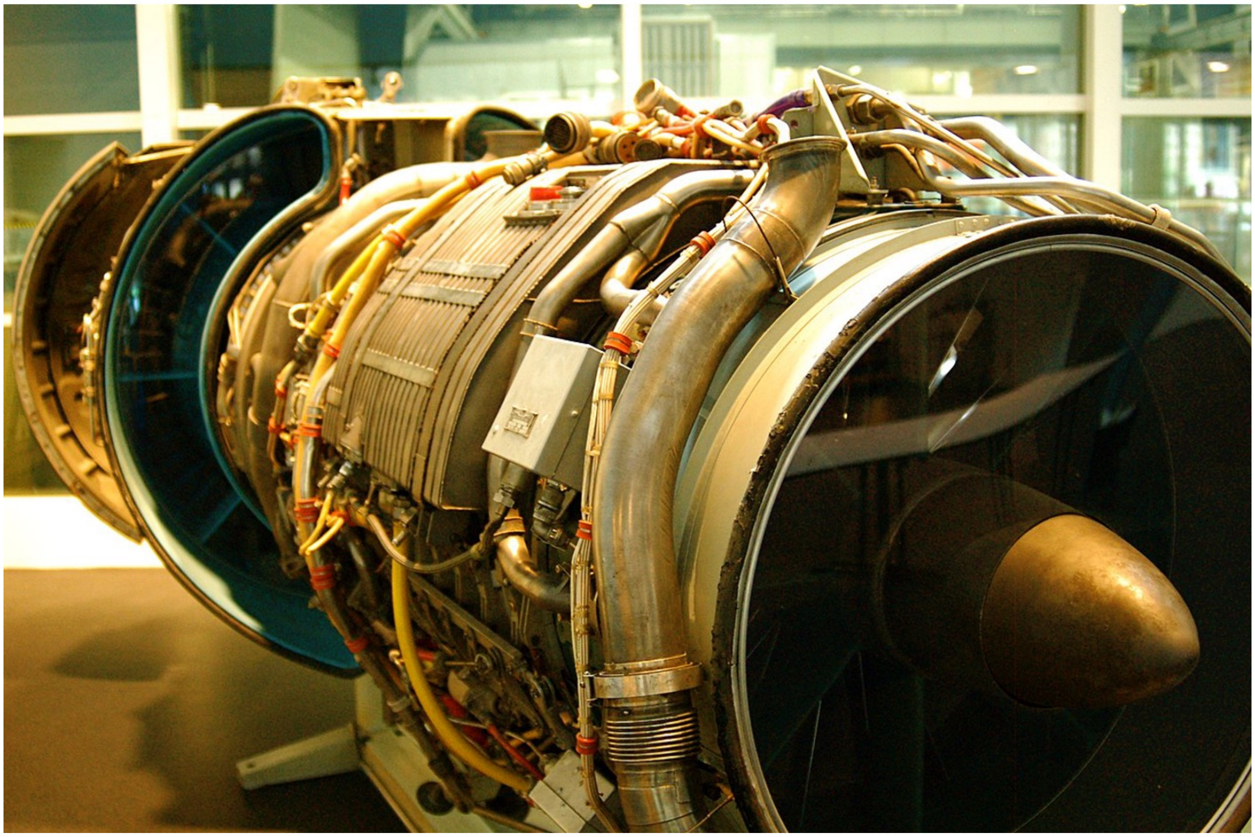


Figure 9.88: Other examples of postwar jet engines developed for General Electric by Bruno Bruckmann and Peter Kappus include the J79 or CJ805 turbojet engine (first run 1954) and the TF35 or CJ805-23 turbofan engine (first run 1956).

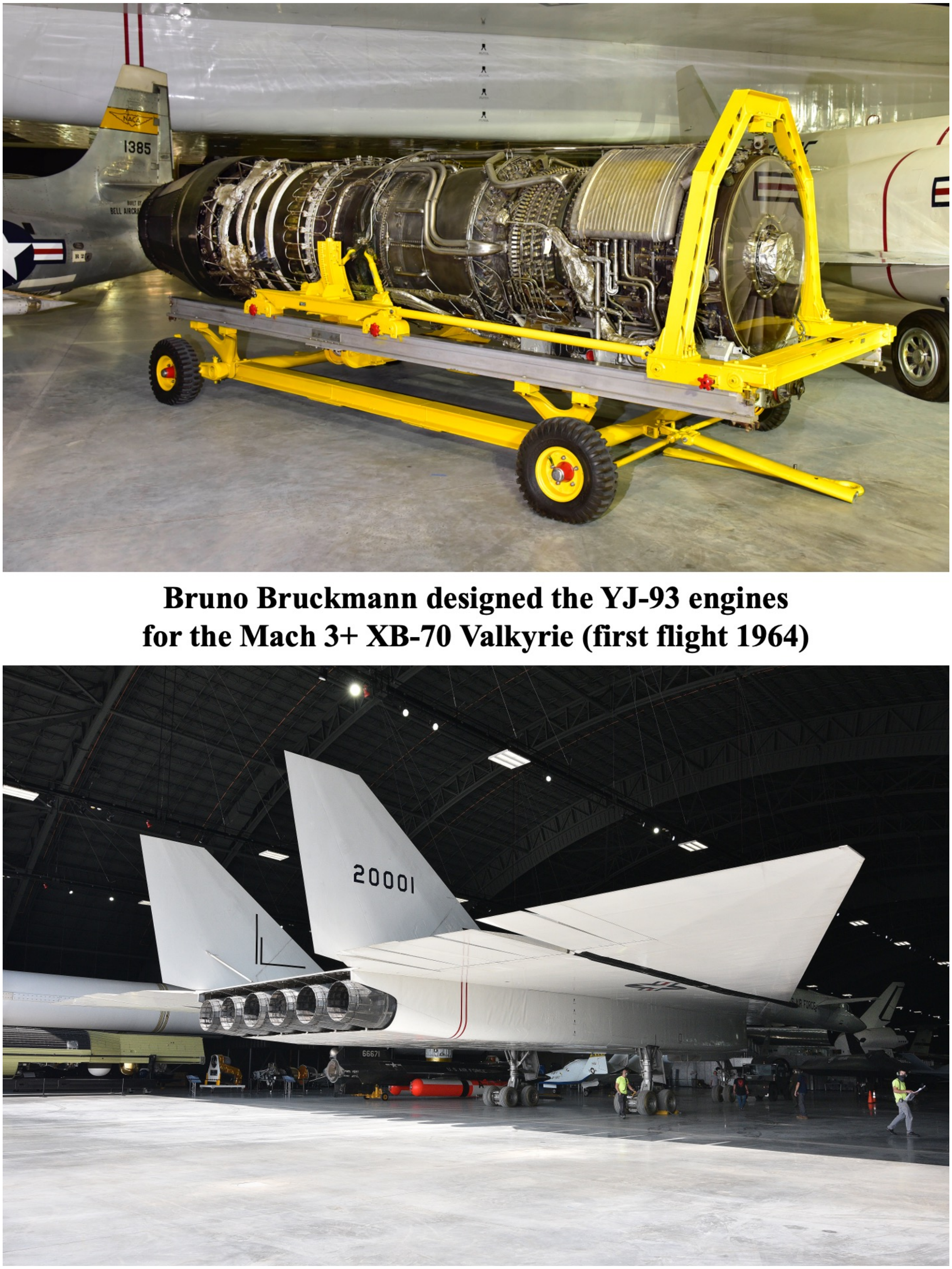

NACA
1385
Bruno Bruckmann designed the YJ-93 engines
for the Mach 3+ XB-70 Valkyrie (first flight 1964)
20001

Figure 9.89: Bruno Bruckmann designed the engines for the Mach 3+ XB-70 Valkyrie (first flight 1964).

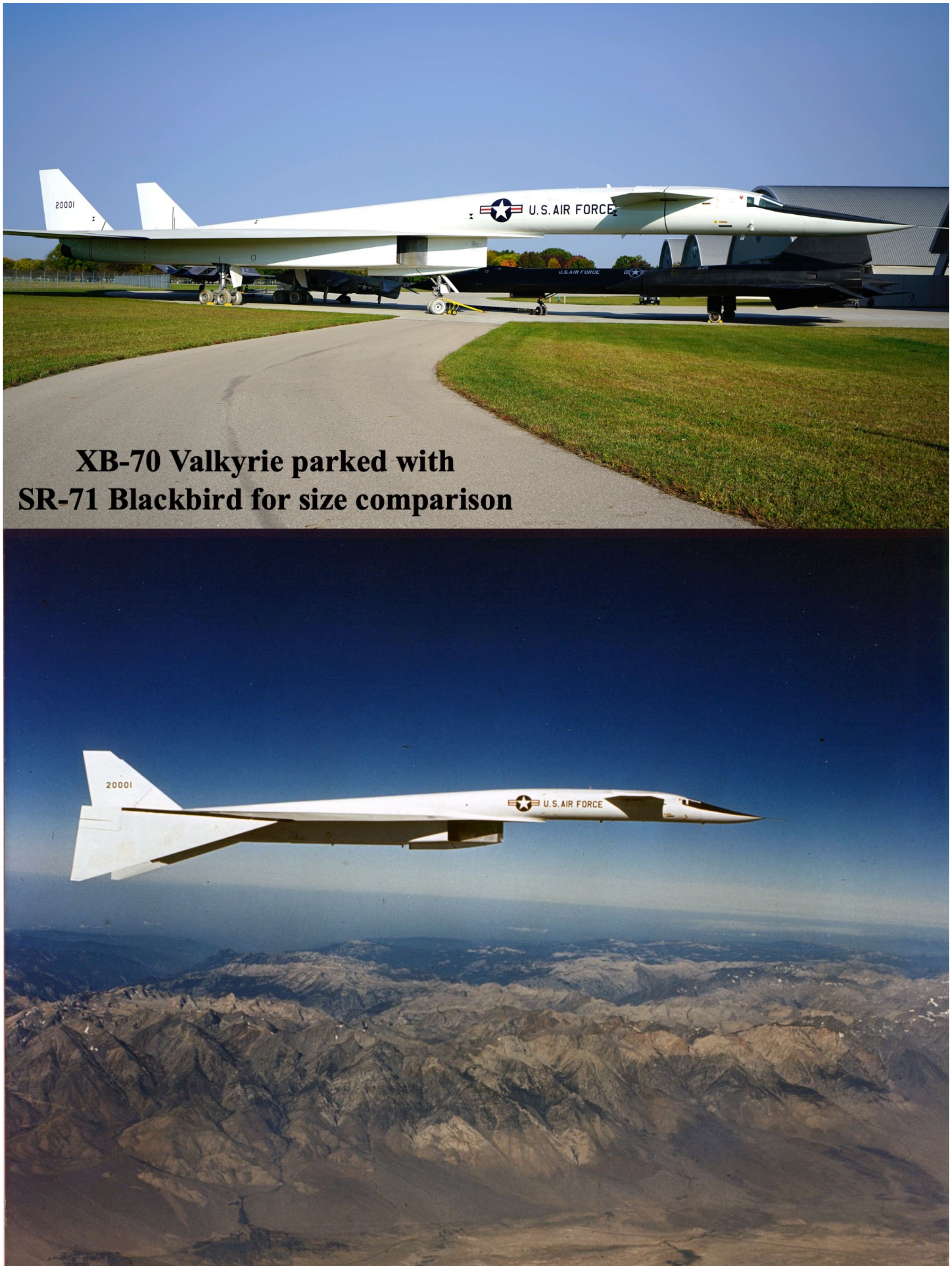

20001
U.S. AIR FORCE
XB-70 Valkyrie parked with
SR-71 Blackbird for size comparison
20001
U.S. AIR FORCE

Figure 9.90: Bruno Bruckmann designed the engines for the Mach 3+ XB-70 Valkyrie (first flight 1964).

Bruno Bruckmann designed the GE X211 nuclear turbojet engine (first demonstrated in 1958)

Two GE X211 engines would have powered the proposed Convair NX-2 bomber

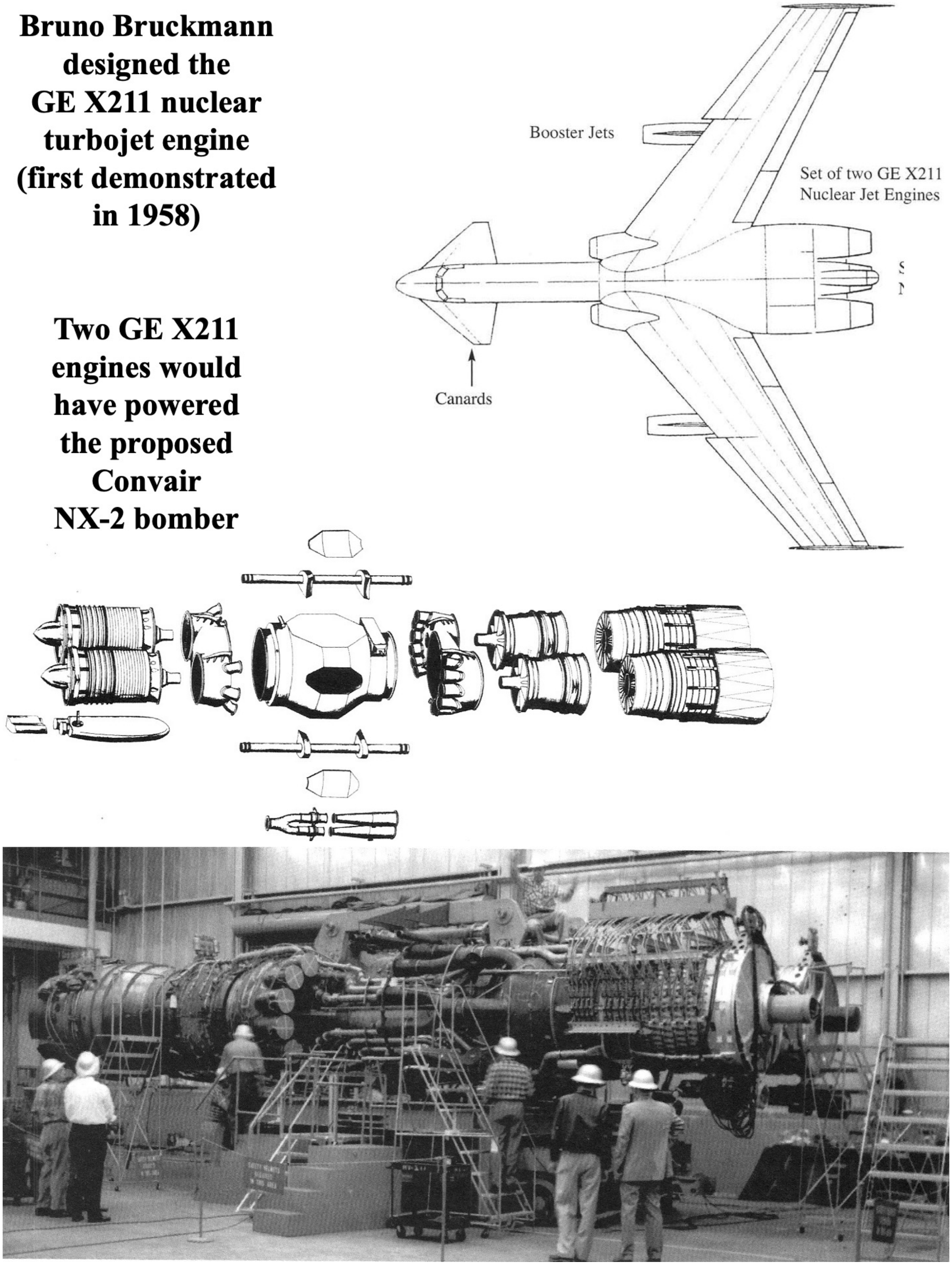
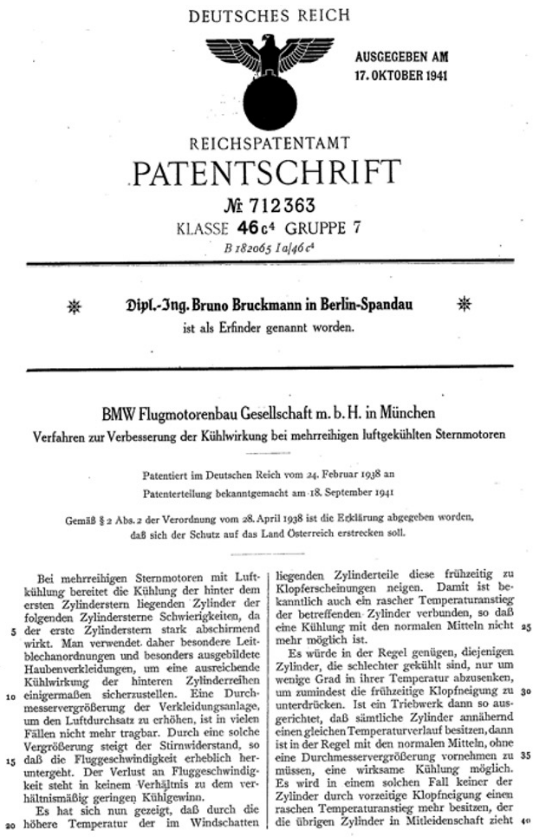

Booster Jets
Set of two GE X211 Nuclear Jet Engines
Canards

Figure 9.91: Bruno Bruckmann designed the GE X211 nuclear turbojet engine (first demonstrated in 1958). Two GE X211 engines would have powered the proposed Convair NX-2 bomber [Carpenter 2003].



DEUTSCHES REICH

AUSGEGEBEN AM
17. OKTOBER 1941

REICHSPATENTAMT
PATENTSCHRIFT
№ 712363
KLASSE **46**c^4 GRUPPE 7
B 182065 Ia/46c^4

Dipl.-Ing. Bruno Bruckmann in Berlin-Spandau
ist als Erfinder genannt worden.

BMW Flugmotorenbau Gesellschaft m. b. H. in München
Verfahren zur Verbesserung der Kühlwirkung bei mehrreihigen luftgekühlten Sternmotoren

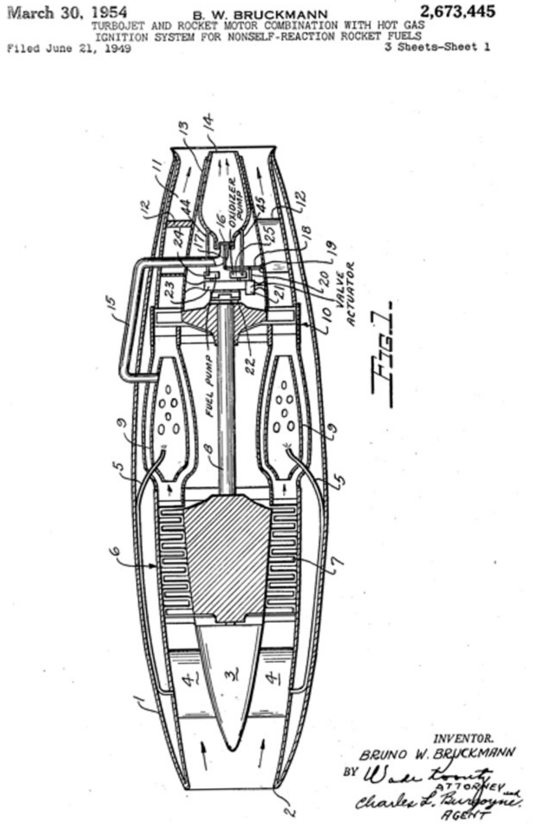
Patentiert im Deutschen Reich vom 24. Februar 1938 an
Patenterteilung bekanntgemacht am 18. September 1941

Gemäß § 2 Abs. 2 der Verordnung vom 28. April 1938 ist die Erklärung abgegeben worden, daß sich der Schutz auf das Land Österreich erstrecken soll.

Bei mehrreihigen Sternmotoren mit Luftkühlung bereitet die Kühlung der hinter dem ersten Zylinderstern liegenden Zylinder der folgenden Zylindersterne Schwierigkeiten, da der erste Zylinderstern stark abschirmend wirkt. Man verwendet daher besondere Leitblechanordnungen und besonders ausgebildete Haubenverkleidungen, um eine ausreichende Kühlwirkung der hinteren Zylinderreihen einigermaßen sicherzustellen. Eine Durchmesservergrößerung der Verkleidungsanlage, um den Luftdurchsatz zu erhöhen, ist in vielen Fällen nicht mehr tragbar. Durch eine solche Vergrößerung steigt der Stirnwiderstand, so daß die Fluggeschwindigkeit erheblich heruntergeht. Der Verlust an Fluggeschwindigkeit steht in keinem Verhältnis zu dem verhältnismäßig geringen Kühlgewinn.

Es hat sich nun gezeigt, daß durch die höhere Temperatur der im Windschatten liegenden Zylinderteile diese frühzeitig zu Klopferscheinungen neigen. Damit ist bekanntlich auch ein rascher Temperaturanstieg der betreffenden Zylinder verbunden, so daß eine Kühlung mit den normalen Mitteln nicht mehr möglich ist.

Es würde in der Regel genügen, diejenigen Zylinder, die schlechter gekühlt sind, nur um wenige Grad in ihrer Temperatur abzusenken, um zumindest die frühzeitige Klopfneigung zu unterdrücken. Ist ein Triebwerk dann so ausgerichtet, daß sämtliche Zylinder annähernd einen gleichen Temperaturverlauf besitzen, dann ist in der Regel mit den normalen Mitteln, ohne eine Durchmesservergrößerung vornehmen zu müssen, eine wirksame Kühlung möglich. Es wird in einem solchen Fall keiner der Zylinder durch vorzeitige Klopfneigung einen raschen Temperaturanstieg mehr besitzen, der die übrigen Zylinder in Mitleidenschaft zieht



March 30, 1954 B. W. BRUCKMANN 2,673,445
TURBOJET AND ROCKET MOTOR COMBINATION WITH HOT GAS
IGNITION SYSTEM FOR NONSELF-REACTION ROCKET FUELS
Filed June 21, 1949 3 Sheets-Sheet 1

Fig. 1.
OXIDIZER PUMP
FUEL PUMP
VALVE ACTUATOR
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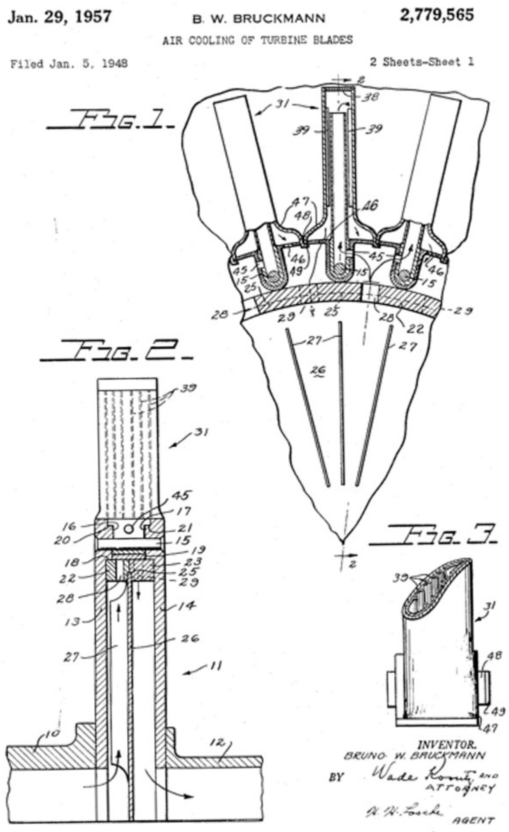
INVENTOR.
BRUNO W. BRUCKMANN
BY Wade Koontz
ATTORNEY and
Charles L. Burgoyne
AGENT



Jan. 29, 1957 B. W. BRUCKMANN 2,779,565
AIR COOLING OF TURBINE BLADES
Filed Jan. 5, 1948 2 Sheets-Sheet 1

Fig. 1.
Fig. 2.
Fig. 3.
2
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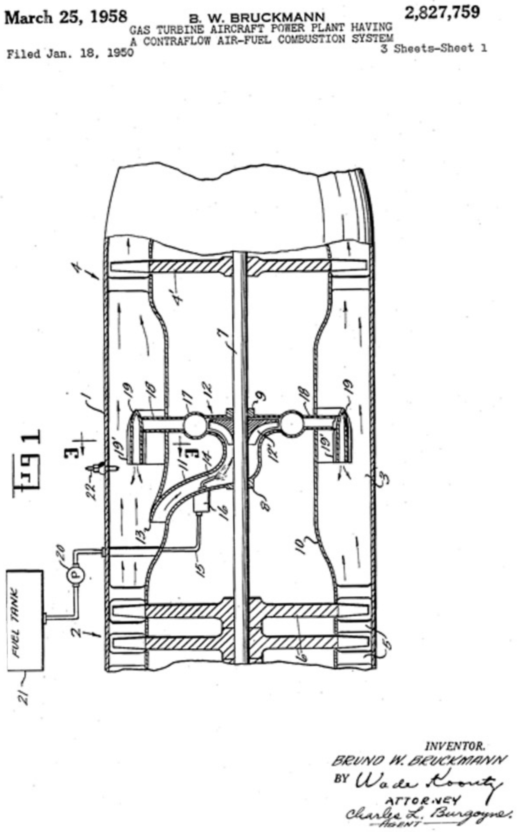
49
INVENTOR.
BRUNO W. BRUCKMANN
BY Wade Koontz AND
ATTORNEY
W. H. Losche
AGENT



March 25, 1958 B. W. BRUCKMANN 2,827,759
GAS TURBINE AIRCRAFT POWER PLANT HAVING
A CONTRAFLOW AIR-FUEL COMBUSTION SYSTEM
Filed Jan. 18, 1950 3 Sheets-Sheet 1

Fig 1
FUEL TANK
P
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18
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20
21
22
INVENTOR.
BRUNO W. BRUCKMANN
BY Wade Koontz
ATTORNEY
Charles L. Burgoyne
AGENT

Figure 9.92: Examples of jet engine patents by Bruno Bruckmann.

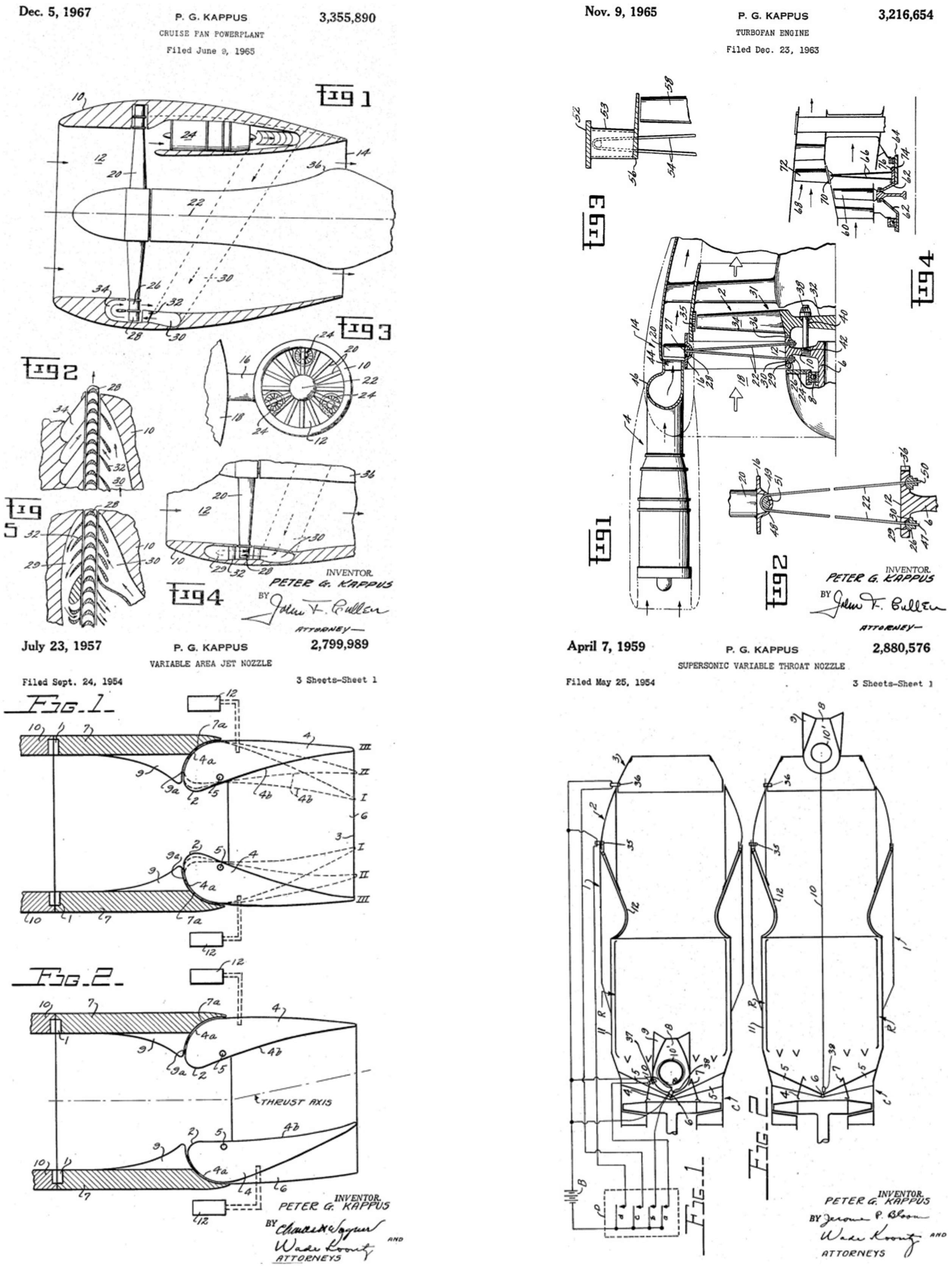
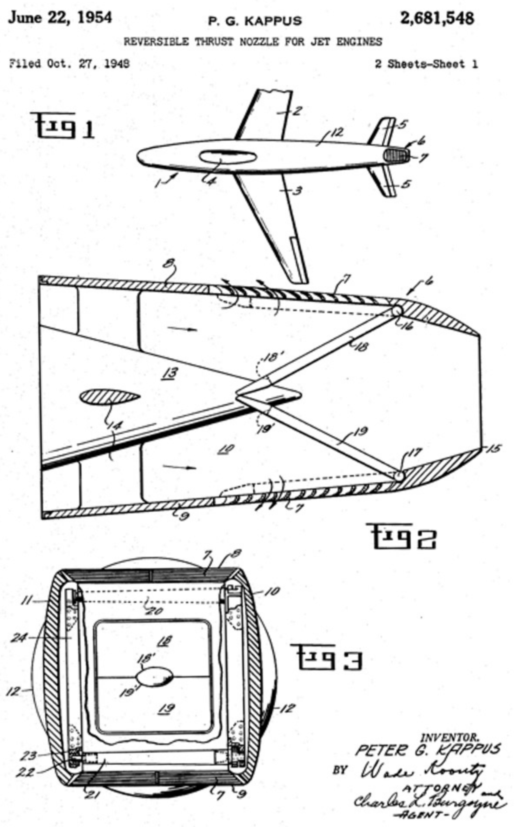

Dec. 5, 1967
P. G. KAPPUS
3,355,890
CRUISE FAN POWERPLANT
Filed June 9, 1965
FIG 1
FIG 2
FIG 3
FIG 4
FIG 5
INVENTOR.
PETER G. KAPPUS
BY John F. Cullen
ATTORNEY
Nov. 9, 1965
P. G. KAPPUS
3,216,654
TURBOFAN ENGINE
Filed Dec. 23, 1963
FIG 1
FIG 2
FIG 3
FIG 4
INVENTOR.
PETER G. KAPPUS
BY John F. Cullen
ATTORNEY
July 23, 1957
P. G. KAPPUS
2,799,989
VARIABLE AREA JET NOZZLE
Filed Sept. 24, 1954
3 Sheets-Sheet 1
FIG. 1
FIG. 2
THRUST AXIS
INVENTOR.
PETER G. KAPPUS
BY Charles W. Wagner AND Wade Koontz
ATTORNEYS
April 7, 1959
P. G. KAPPUS
2,880,576
SUPERSONIC VARIABLE THROAT NOZZLE
Filed May 25, 1954
3 Sheets-Sheet 1
FIG. 1
FIG. 2
INVENTOR.
PETER G. KAPPUS
BY Jerome P. Bloom AND Wade Koontz
ATTORNEYS

Figure 9.93: Examples of jet engine patents by Peter Kappus.


June 22, 1954 P. G. KAPPUS 2,681,548

REVERSIBLE THRUST NOZZLE FOR JET ENGINES

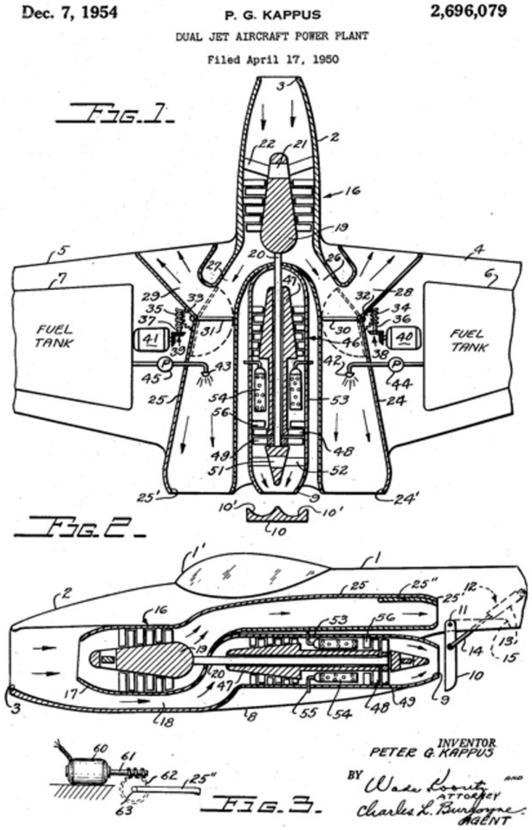
Filed Oct. 27, 1948 2 Sheets-Sheet 1

FIG 1

FIG 2

FIG 3

INVENTOR.
PETER G. KAPPUS
BY Wade Koontz
ATTORNEY and
Charles L. Burgoyne
AGENT


Dec. 7, 1954 P. G. KAPPUS 2,696,079

DUAL JET AIRCRAFT POWER PLANT

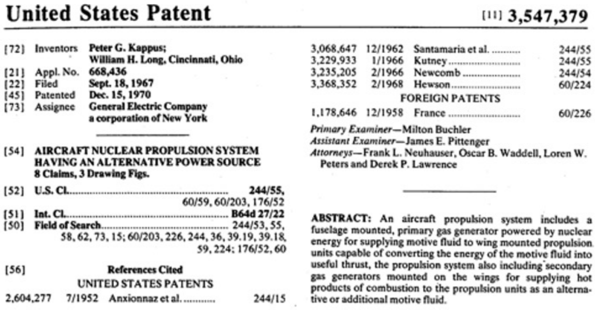
Filed April 17, 1950

FIG. 1

FIG. 2

FIG. 3

INVENTOR
PETER G. KAPPUS
BY Wade Koontz AND
ATTORNEY
Charles L. Burgoyne
AGENT


United States Patent

[11] 3,547,379

[72] Inventors **Peter G. Kappus; William H. Long, Cincinnati, Ohio**
[21] Appl. No. **668,436**
[22] Filed **Sept. 18, 1967**
[45] Patented **Dec. 15, 1970**
[73] Assignee **General Electric Company a corporation of New York**

[54] **AIRCRAFT NUCLEAR PROPULSION SYSTEM HAVING AN ALTERNATIVE POWER SOURCE**
8 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **244/55,** 60/59, 60/203, 176/52
[51] **Int. Cl.** **B64d 27/22**
[50] **Field of Search** 244/53, 55, 58, 62, 73, 15; 60/203, 226, 244, 36, 39.19, 39.18, 59, 224; 176/52, 60

[56] **References Cited**

UNITED STATES PATENTS

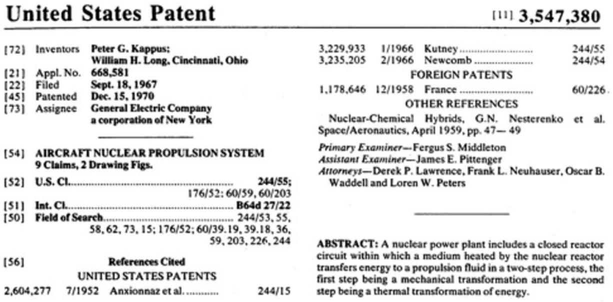
2,604,277	7/1952	Anxionnaz et al.	244/15
3,068,647	12/1962	Santamaria et al.	244/55
3,229,933	1/1966	Kutney	244/55
3,235,205	2/1966	Newcomb	244/54
3,368,352	2/1968	Hewson	60/224

FOREIGN PATENTS

1,178,646	12/1958	France	60/226

Primary Examiner—Milton Buchler
Assistant Examiner—James E. Pittenger
Attorneys—Frank L. Neuhauser, Oscar B. Waddell, Loren W. Peters and Derek P. Lawrence

ABSTRACT: An aircraft propulsion system includes a fuselage mounted, primary gas generator powered by nuclear energy for supplying motive fluid to wing mounted propulsion units capable of converting the energy of the motive fluid into useful thrust, the propulsion system also including secondary gas generators mounted on the wings for supplying hot products of combustion to the propulsion units as an alternative or additional motive fluid.


United States Patent

[11] 3,547,380

[72] Inventors **Peter G. Kappus; William H. Long, Cincinnati, Ohio**
[21] Appl. No. **668,581**
[22] Filed **Sept. 18, 1967**
[45] Patented **Dec. 15, 1970**
[73] Assignee **General Electric Company a corporation of New York**

[54] **AIRCRAFT NUCLEAR PROPULSION SYSTEM**
9 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **244/55;** 176/52; 60/59, 60/203
[51] **Int. Cl.** **B64d 27/22**
[50] **Field of Search** 244/53, 55, 58, 62, 73, 15; 176/52; 60/39.19, 39.18, 36, 59, 203, 226, 244

[56] **References Cited**

UNITED STATES PATENTS

2,604,277	7/1952	Anxionnaz et al.	244/15
3,229,933	1/1966	Kutney	244/55
3,235,205	2/1966	Newcomb	244/54

FOREIGN PATENTS

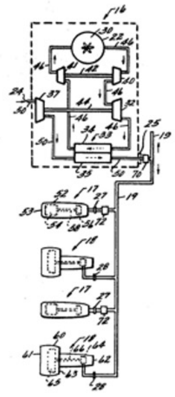
1,178,646	12/1958	France	60/226

OTHER REFERENCES

Nuclear-Chemical Hybrids, G.N. Nesterenko et al. Space/Aeronautics, April 1959, pp. 47— 49

Primary Examiner—Fergus S. Middleton
Assistant Examiner—James E. Pittenger
Attorneys—Derek P. Lawrence, Frank L. Neuhauser, Oscar B. Waddell and Loren W. Peters

ABSTRACT: A nuclear power plant includes a closed reactor circuit within which a medium heated by the nuclear reactor transfers energy to a propulsion fluid in a two-step process, the first step being a mechanical transformation and the second step being a thermal transformation of energy.



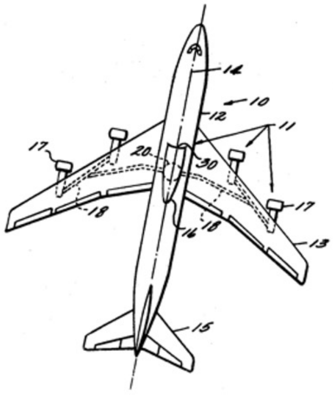
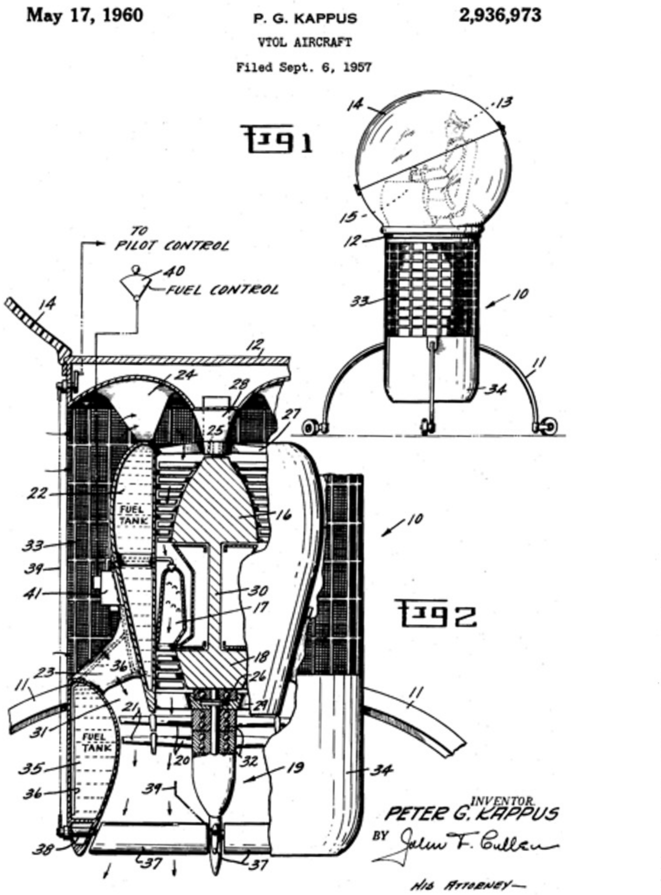


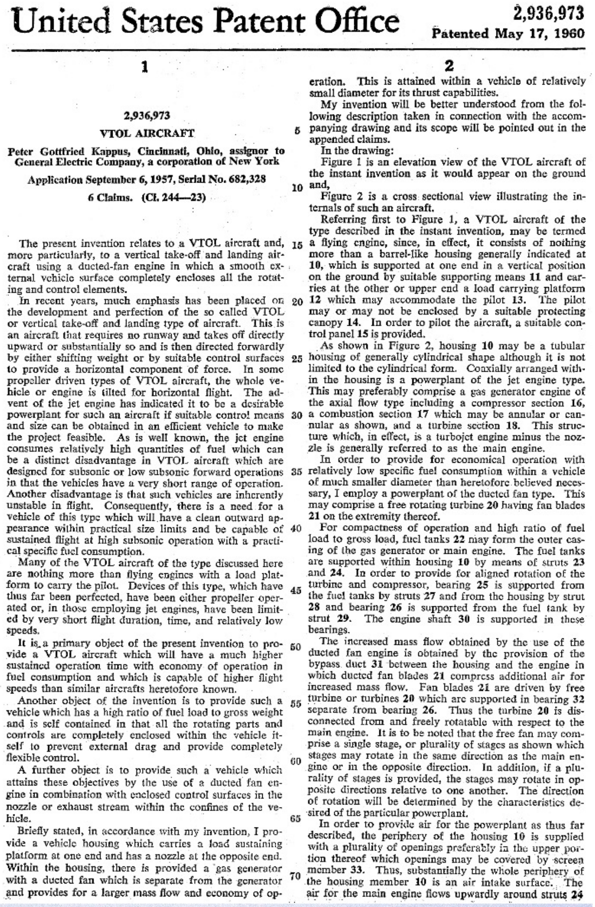
Figure 9.94: Examples of jet engine patents by Peter Kappus.



May 17, 1960 P. G. KAPPUS **2,936,973**

VTOL AIRCRAFT

Filed Sept. 6, 1957



United States Patent Office **2,936,973** **Patented May 17, 1960**

1

2,936,973

VTOL AIRCRAFT

Peter Gottfried Kappus, Cincinnati, Ohio, assignor to General Electric Company, a corporation of New York

Application September 6, 1957, Serial No. 682,328

6 Claims. (Cl. 244—23)

The present invention relates to a VTOL aircraft and, more particularly, to a vertical take-off and landing aircraft using a ducted-fan engine in which a smooth external vehicle surface completely encloses all the rotating and control elements.

In recent years, much emphasis has been placed on the development and perfection of the so called VTOL or vertical take-off and landing type of aircraft. This is an aircraft that requires no runway and takes off directly upward or substantially so and is then directed forwardly by either shifting weight or by suitable control surfaces to provide a horizontal component of force. In some propeller driven types of VTOL aircraft, the whole vehicle or engine is tilted for horizontal flight. The advent of the jet engine has indicated it to be a desirable powerplant for such an aircraft if suitable control means and size can be obtained in an efficient vehicle to make the project feasible. As is well known, the jet engine consumes relatively high quantities of fuel which can be a distinct disadvantage in VTOL aircraft which are designed for subsonic or low subsonic forward operations in that the vehicles have a very short range of operation. Another disadvantage is that such vehicles are inherently unstable in flight. Consequently, there is a need for a vehicle of this type which will have a clean outward appearance within practical size limits and be capable of sustained flight at high subsonic operation with a practical specific fuel consumption.

Many of the VTOL aircraft of the type discussed here are nothing more than flying engines with a load platform to carry the pilot. Devices of this type, which have thus far been perfected, have been either propeller operated or, in those employing jet engines, have been limited by very short flight duration, time, and relatively low speeds.

It is a primary object of the present invention to provide a VTOL aircraft which will have a much higher sustained operation time with economy of operation in fuel consumption and which is capable of higher flight speeds than similar aircrafts heretofore known.

Another object of the invention is to provide such a vehicle which has a high ratio of fuel load to gross weight and is self contained in that all the rotating parts and controls are completely enclosed within the vehicle itself to prevent external drag and provide completely flexible control.

A further object is to provide such a vehicle which attains these objectives by the use of a ducted fan engine in combination with enclosed control surfaces in the nozzle or exhaust stream within the confines of the vehicle.

Briefly stated, in accordance with my invention, I provide a vehicle housing which carries a load sustaining platform at one end and has a nozzle at the opposite end. Within the housing, there is provided a gas generator with a ducted fan which is separate from the generator and provides for a larger mass flow and economy of operation. This is attained within a vehicle of relatively small diameter for its thrust capabilities.

2

My invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing:

Figure 1 is an elevation view of the VTOL aircraft of the instant invention as it would appear on the ground and,

Figure 2 is a cross sectional view illustrating the internals of such an aircraft.

Referring first to Figure 1, a VTOL aircraft of the type described in the instant invention, may be termed a flying engine, since, in effect, it consists of nothing more than a barrel-like housing generally indicated at **10**, which is supported at one end in a vertical position on the ground by suitable supporting means **11** and carries at the other or upper end a load carrying platform **12** which may accommodate the pilot **13**. The pilot may or may not be enclosed by a suitable protecting canopy **14**. In order to pilot the aircraft, a suitable control panel **15** is provided.

As shown in Figure 2, housing **10** may be a tubular housing of generally cylindrical shape although it is not limited to the cylindrical form. Coaxially arranged within the housing is a powerplant of the jet engine type. This may preferably comprise a gas generator engine of the axial flow type including a compressor section **16**, a combustion section **17** which may be annular or cannular as shown, and a turbine section **18**. This structure which, in effect, is a turbojet engine minus the nozzle is generally referred to as the main engine.

In order to provide for economical operation with relatively low specific fuel consumption within a vehicle of much smaller diameter than heretofore believed necessary, I employ a powerplant of the ducted fan type. This may comprise a free rotating turbine **20** having fan blades **21** on the extremity thereof.

For compactness of operation and high ratio of fuel load to gross load, fuel tanks **22** may form the outer casing of the gas generator or main engine. The fuel tanks are supported within housing **10** by means of struts **23** and **24**. In order to provide for aligned rotation of the turbine and compressor, bearing **25** is supported from the fuel tanks by struts **27** and from the housing by strut **28** and bearing **26** is supported from the fuel tank by strut **29**. The engine shaft **30** is supported in these bearings.

The increased mass flow obtained by the use of the ducted fan engine is obtained by the provision of the bypass duct **31** between the housing and the engine in which ducted fan blades **21** compress additional air for increased mass flow. Fan blades **21** are driven by free turbine or turbines **20** which are supported in bearing **32** separate from bearing **26**. Thus the turbine **20** is disconnected from and freely rotatable with respect to the main engine. It is to be noted that the free fan may comprise a single stage, or plurality of stages as shown which stages may rotate in the same direction as the main engine or in the opposite direction. In addition, if a plurality of stages is provided, the stages may rotate in opposite directions relative to one another. The direction of rotation will be determined by the characteristics desired of the particular powerplant.

In order to provide air for the powerplant as thus far described, the periphery of the housing **10** is supplied with a plurality of openings preferably in the upper portion thereof which openings may be covered by screen member **33**. Thus, substantially the whole periphery of the housing member **10** is an air intake surface. The air for the main engine flows upwardly around struts **24**

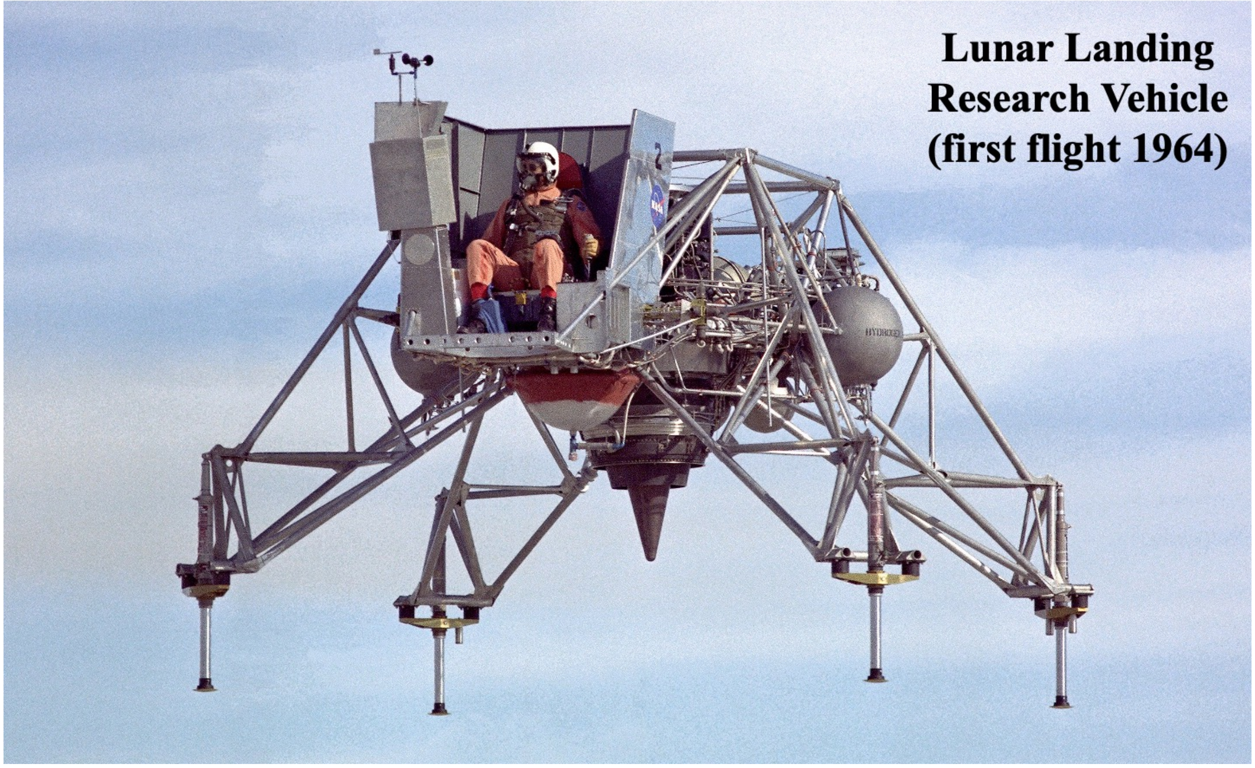
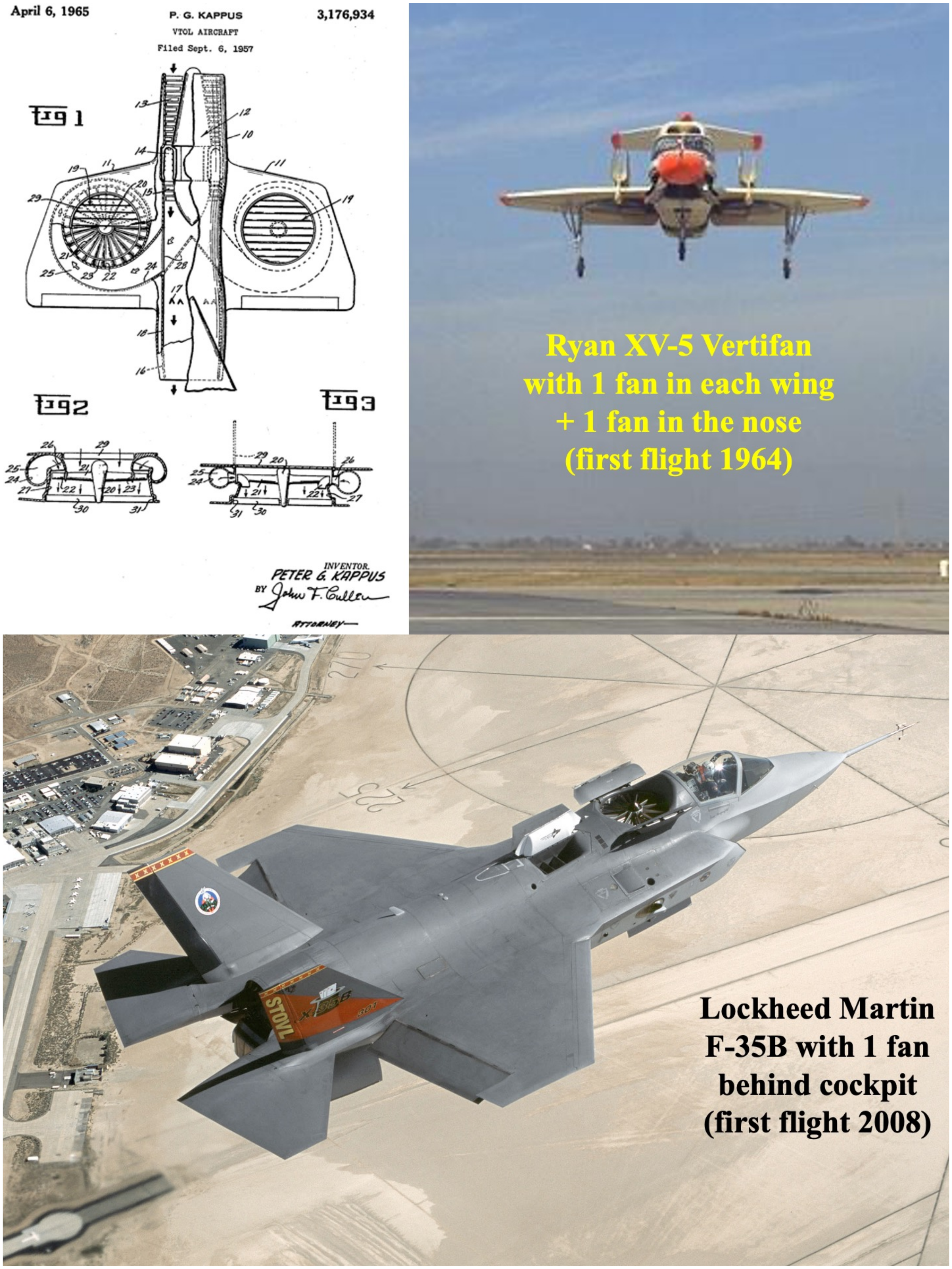


Figure 9.95: In September 1957 (before Sputnik!), Peter Kappus filed a patent application on a VTOL vehicle that was ultimately implemented as the Lunar Landing Research Vehicle to train astronauts to land the Apollo Lunar Module (first flight 1964, with the vehicle's legs and pilot's position modified to resemble the final Lunar Module design).

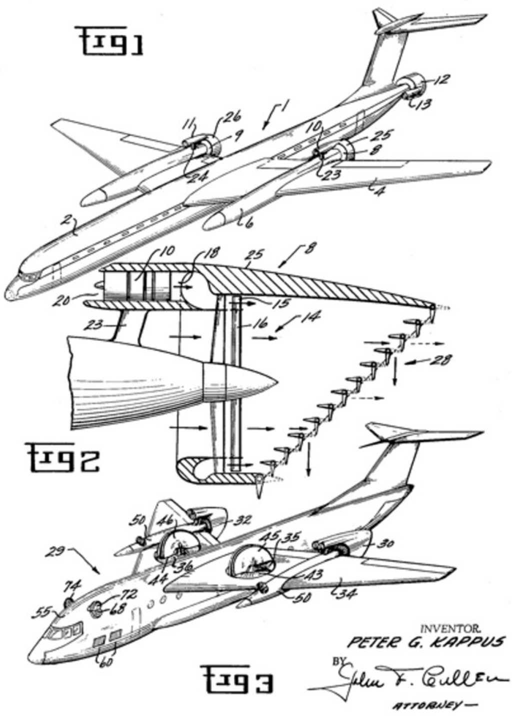

April 6, 1965
P. G. KAPPUS
3,176,934
VTOL AIRCRAFT
Filed Sept. 6, 1957
Fig 1
Fig 2
Fig 3
INVENTOR.
PETER G. KAPPUS
BY John F. Cullen
ATTORNEY
STOVL
X-35B

Ryan XV-5 Vertifan with 1 fan in each wing + 1 fan in the nose (first flight 1964)

Lockheed Martin F-35B with 1 fan behind cockpit (first flight 2008)

Figure 9.96: Beginning in 1957, Peter Kappus filed several patent applications on VTOL aircraft with downward-pointing fans in the wings and/or body (see also Fig. 9.97). That approach was successfully implemented in aircraft such as the Ryan XV-5 Vertifan (first flight 1964) and the Lockheed Martin F-35B (first flight 2008).

Oct. 19, 1965 P. G. KAPPUS 3,212,731
FAN POWERED AIRCRAFT
Filed Sept. 9, 1963 2 Sheets-Sheet 1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INVENTOR.
PETER G. KAPPUS
BY John F. Cullen
ATTORNEY

Oct. 19, 1965 P. G. KAPPUS 3,212,731
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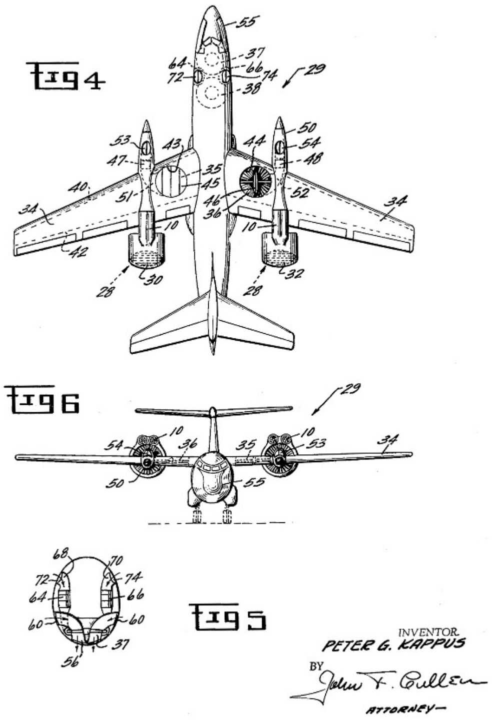
FIG 4
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INVENTOR.
PETER G. KAPPUS
BY John F. Cullen
ATTORNEY

United States Patent

[11] 3,618,875

[72] Inventor Peter G. Kappus
Cincinnati, Ohio
[21] Appl. No. 801,293
[22] Filed Feb. 24, 1969
[45] Patented Nov. 9, 1971
[73] Assignee General Electric Company

[54] **V/STOL AIRCRAFT**
14 Claims, 8 Drawing Figs.

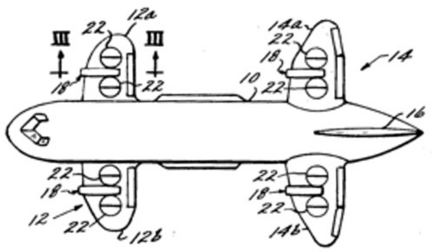
[52] U.S. Cl. 244/12 B, 244/23 B
[51] Int. Cl. B61c 29/04
[50] Field of Search 244/12, 15, 23

[56] **References Cited**
UNITED STATES PATENTS

2,973,166	2/1961	Stahmer	244/23
3,161,374	12/1964	Allred et al.	244/12
3,289,975	12/1966	Hall	244/55
3,131,873	5/1964	Sanders	244/12
3,267,667	8/1966	Erwin	244/23

Primary Examiner—Milton Buchler
Assistant Examiner—Steven W. Weinrieb
Attorneys—Derek P. Lawrence, E. S. Lee, III, Lee H. Sachs, Frank L. Neuhauser and Oscar B. Waddell

ABSTRACT: A V/STOL aircraft comprises a fuselage having tandem wings which are offset lengthwise and vertically. Identical propulsion units are provided in each wing half. Each power unit comprises a pair of gas generators mounted respectively above and below the wing half and a pair of lift fans mounted within the wing structure on opposite sides of the engines. A valve system diverts the hot gas stream of the engines into a plenum chamber formed integrally with the wing structure. The hot gas streams are then directed from the plenum chamber to a tip turbine which powers the lift fans when vertical thrust is desired in operation of the aircraft. When forward speed of the aircraft is great enough for the aircraft wings to have sufficient lift, the hot gas streams are directed through propulsive nozzles providing a forward thrust component. In cruise, one engine of each power unit could be shut down. Each engine and each lift fan has emergency capacity which is automatically brought into play in the event of a failure of a lift fan or engine, with proper adjustments being made to the other power units to maintain balance and controlled operation of the aircraft in the lift mode.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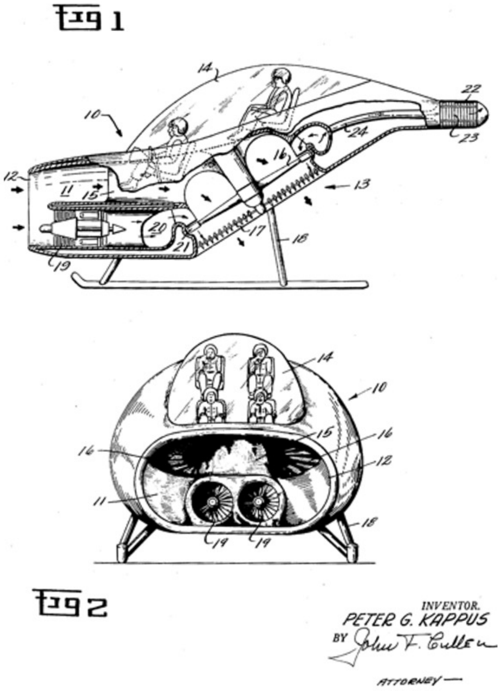
April 12, 1960 P. G. KAPPUS 2,932,468
VTOL AIRCRAFT
Filed Dec. 6, 1957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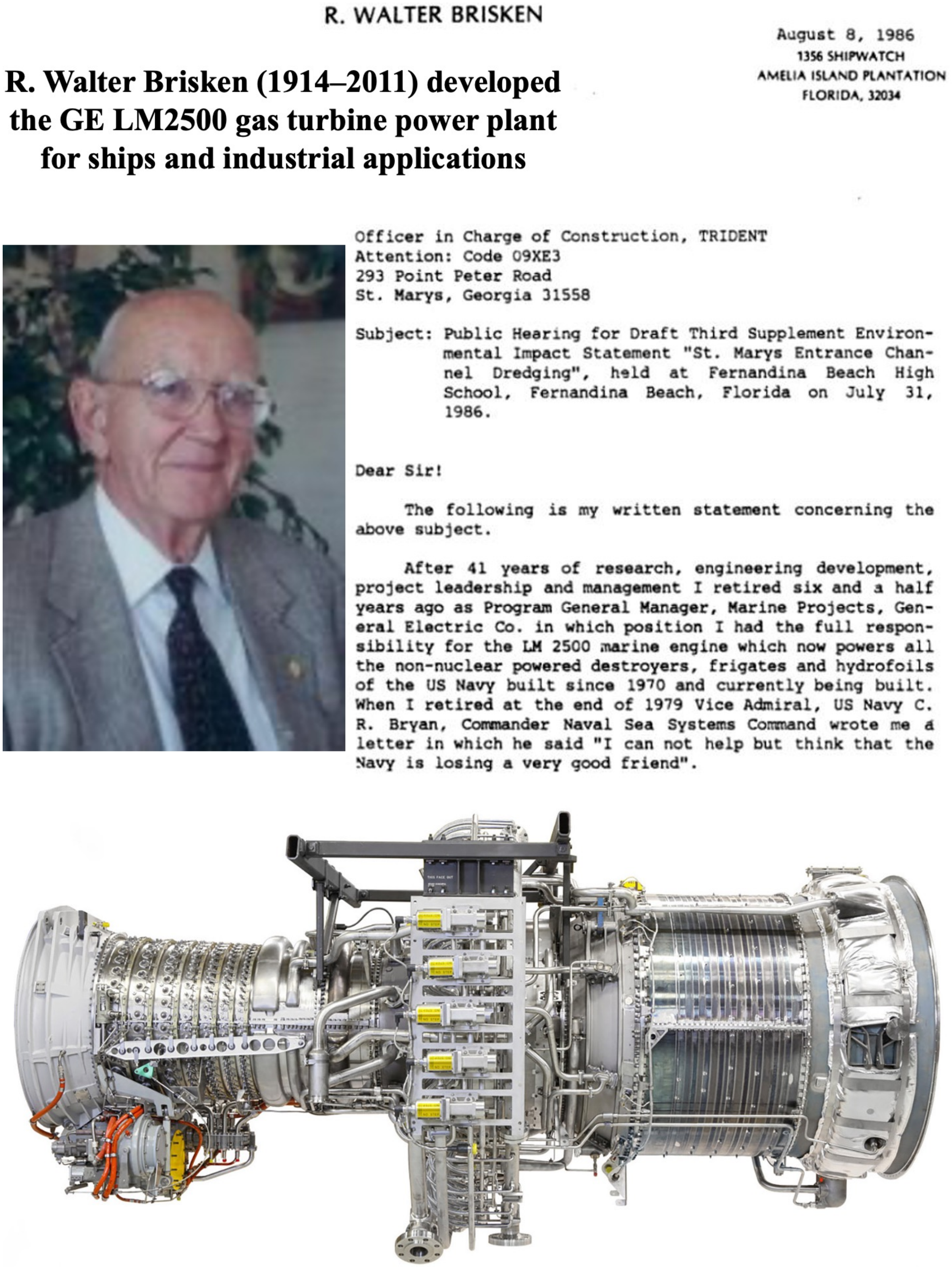
INVENTOR.
PETER G. KAPPUS
BY John F. Cullen
ATTORNEY

Figure 9.97: Other examples of VTOL jet vehicle patents by Peter Kappus.



R. Walter Brisken (1914–2011) developed the GE LM2500 gas turbine power plant for ships and industrial applications

R. WALTER BRISKEN

August 8, 1986
1356 SHIPWATCH
AMELIA ISLAND PLANTATION
FLORIDA, 32034

Officer in Charge of Construction, TRIDENT
Attention: Code 09XE3
293 Point Peter Road
St. Marys, Georgia 31558

Subject: Public Hearing for Draft Third Supplement Environmental Impact Statement "St. Marys Entrance Channel Dredging", held at Fernandina Beach High School, Fernandina Beach, Florida on July 31, 1986.

Dear Sir!

The following is my written statement concerning the above subject.

After 41 years of research, engineering development, project leadership and management I retired six and a half years ago as Program General Manager, Marine Projects, General Electric Co. in which position I had the full responsibility for the LM 2500 marine engine which now powers all the non-nuclear powered destroyers, frigates and hydrofoils of the US Navy built since 1970 and currently being built. When I retired at the end of 1979 Vice Admiral, US Navy C. R. Bryan, Commander Naval Sea Systems Command wrote me a letter in which he said "I can not help but think that the Navy is losing a very good friend".

Figure 9.98: R. Walter Brisken developed the GE LM2500 gas turbine power plant for ships and industrial applications.

Other BMW aircraft engine experts who moved to the United Stated included Rudolf Ammann (German, 19??–19??, an expert on piston aircraft engines and on wind turbines) and Christoph Soestmeyer (German, 19??–19??, an expert on jet engine testbeds to simulate high altitudes, such as the wartime BMW Herbitus facility in Munich).

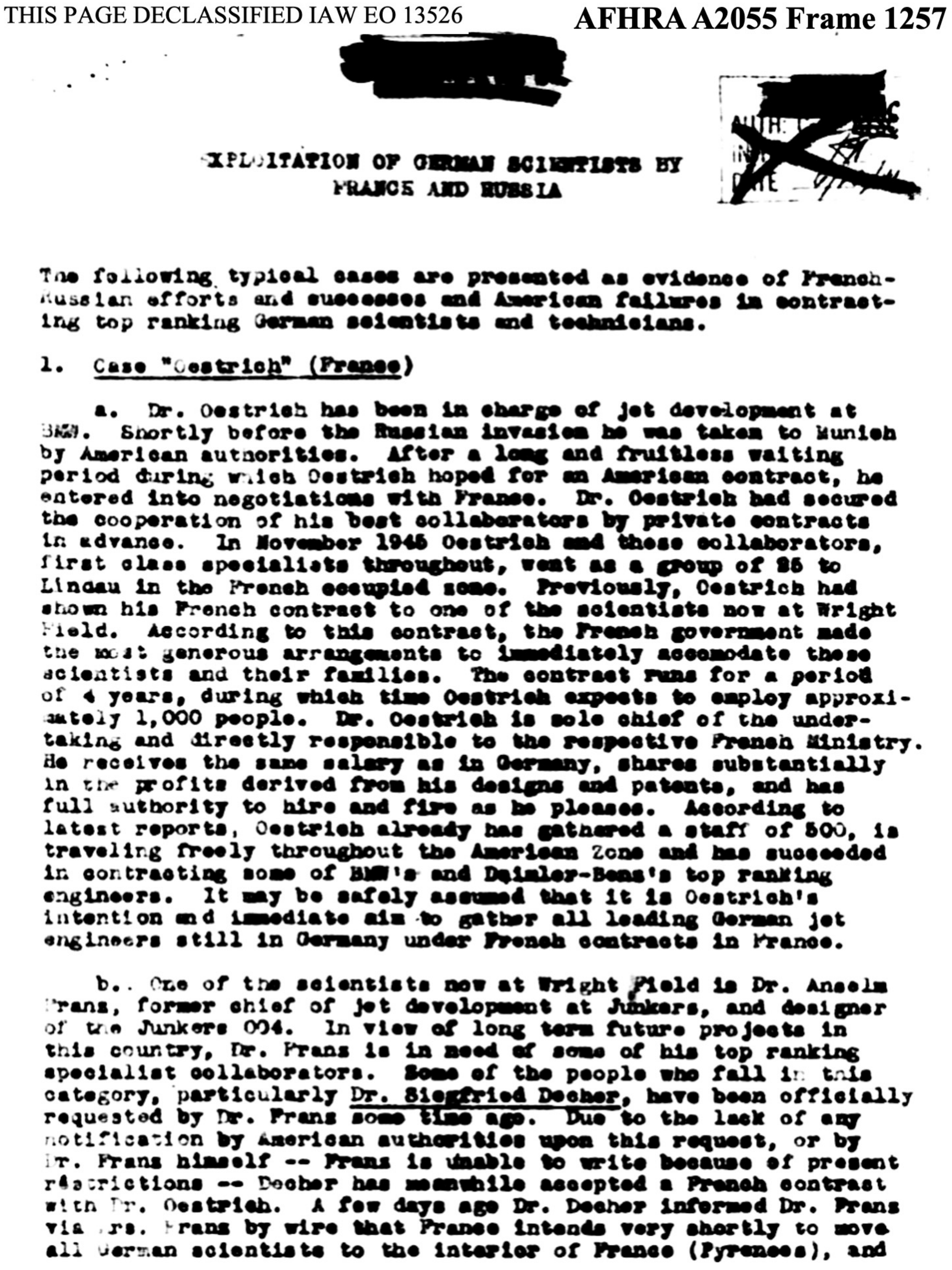
Some other BMW jet experts, such as Hermann Östrich, Hans-Georg Münzberg (Austrian/German, 1916–2000), August Wilhelm Quick (German, 19??–19??), Otto David (German, 19??–19??), and others, developed jet engines and jet aircraft in France after the war (Fig. 9.99).

René Lorin (French, 1877–1933) proposed the general notion of a ramjet in 1913 but did not have the resources to pursue the topic; ramjets are sometimes called Lorin tubes after him. In Germany, separate, well-funded teams led by Otto Pabst (German, 19??–19??), Eugen Sänger (Austrian, 1905–1964), and Hellmuth Walter (German, 1900–1980) developed and demonstrated fully functional ramjets during World War II. Figure 9.100 shows Sänger's ramjet being successfully tested in 1942. In the United States, Fritz Zwicky (Swiss, 1898–1974) designed and proposed ramjets, but was unable to find any financial or political support for such an innovative concept.

Just as ramjets work best at supersonic speeds but can be modified to operate at hypersonic speeds as scramjets, they can also be modified to work at subsonic speeds as pulsejets, as shown in Fig. 9.53. With no active compressor and only minimal compression from stagnation effects, the combustion products could easily escape through the front diffuser of the engine instead of through the rear nozzle as intended. To avoid this problem, the diffuser must be open when taking in air, but closed when combustion occurs. This means that combustion must occur in a pulsed rather than continuous fashion, and the front air inlet must cycle open and closed at the appropriate times during each pulse. In order to imitate continuous combustion, the pulses must occur at fairly high frequency, typically ∼40–50 cycles per second (or Hertz, Hz). The air intake generally uses mechanical shutters or valves that can be opened and closed at such a high frequency.

Paul Schmidt (German, 1898–1976) created the first major pulsejet engine of note—the Argus As 014 engine that ended up being used in the V-1 missile, which is discussed in Section 9.6. Figure 9.101 shows an Argus engine with one side cut open. The engine used mechanical shutters and a pulse frequency of 43 Hz to produce 3.3 kN (750 lb) of thrust during flight. Since there was no active compressor, a steam-driven catapult was used to rapidly accelerate the V-1 to an airspeed where its engine could achieve self-sustaining flight (p. 5279). The V-1 was essentially the world's first cruise (non-ballistic) missile, and became known as the "buzz bomb" because of its engine's very loud and distinctive frequency. The engine's low energy efficiency (due to its minimal compression of the intake air) and inherent problems with vibration were offset by its very simple design and attendant low cost and high thrust-to-weight ratio.

During the Third Reich, many of the jet engine and jet aircraft development programs were funded by the Reichsluftfahrtministerium (Reich Ministry of Aviation). Two individuals there who were especially important in championing and guiding the jet programs were Helmut Schelp (German, 19??–19??) and Hans Mauch (German, 1906–1984). After the war, Helmut Schelp went to the United Kingdom, and Mauch went to the United States. Ultimately Mauch became much better known for his wartime and long postwar work developing prosthetic limbs, rather than for his earlier work on jets; see Sections 2.7.2 and A.2.



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EXPLOITATION OF GERMAN SCIENTISTS BY FRANCE AND RUSSIA

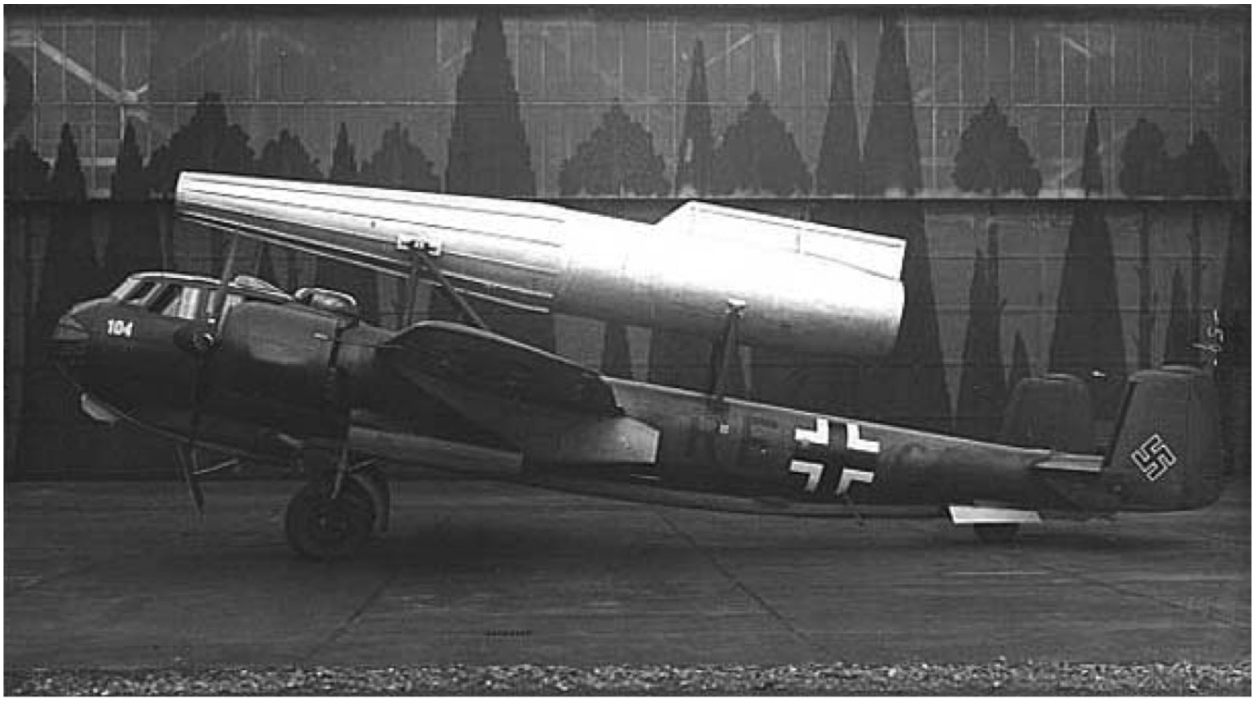
The following typical cases are presented as evidence of French-Russian efforts and successes and American failures in contracting top ranking German scientists and technicians.

1. Case "Oestrich" (France)

a. Dr. Oestrich has been in charge of jet development at BMW. Shortly before the Russian invasion he was taken to Munich by American authorities. After a long and fruitless waiting period during which Oestrich hoped for an American contract, he entered into negotiations with France. Dr. Oestrich had secured the cooperation of his best collaborators by private contracts in advance. In November 1945 Oestrich and these collaborators, first class specialists throughout, went as a group of 25 to Lindau in the French occupied zone. Previously, Oestrich had shown his French contract to one of the scientists now at Wright Field. According to this contract, the French government made the most generous arrangements to immediately accomodate these scientists and their families. The contract runs for a period of 4 years, during which time Oestrich expects to employ approximately 1,000 people. Dr. Oestrich is sole chief of the undertaking and directly responsible to the respective French Ministry. He receives the same salary as in Germany, shares substantially in the profits derived from his designs and patents, and has full authority to hire and fire as he pleases. According to latest reports, Oestrich already has gathered a staff of 500, is traveling freely throughout the American Zone and has succeeded in contracting some of BMW's and Daimler-Benz's top ranking engineers. It may be safely assumed that it is Oestrich's intention and immediate aim to gather all leading German jet engineers still in Germany under French contracts in France.

b. One of the scientists now at Wright Field is Dr. Anselm Franz, former chief of jet development at Junkers, and designer of the Junkers 004. In view of long term future projects in this country, Dr. Franz is in need of some of his top ranking specialist collaborators. Some of the people who fall in this category, particularly Dr. Siegfried Decher, have been officially requested by Dr. Franz some time ago. Due to the lack of any notification by American authorities upon this request, or by Dr. Franz himself -- Franz is unable to write because of present restrictions -- Decher has meanwhile accepted a French contract with Dr. Oestrich. A few days ago Dr. Decher informed Dr. Franz via Mrs. Franz by wire that France intends very shortly to move all German scientists to the interior of France (Pyrenees), and

Figure 9.99: Many German and Austrian experts such as Hermann Östrich developed jet engines and jet aircraft in France after the war. Donald L. Putt. 13 June 1946. Exploitation of German Scientists by France and Russia [AFHRA A2055 Frame 1257].



Eugen Sänger's ramjet being tested
on a Dornier Do 217 aircraft (1942)

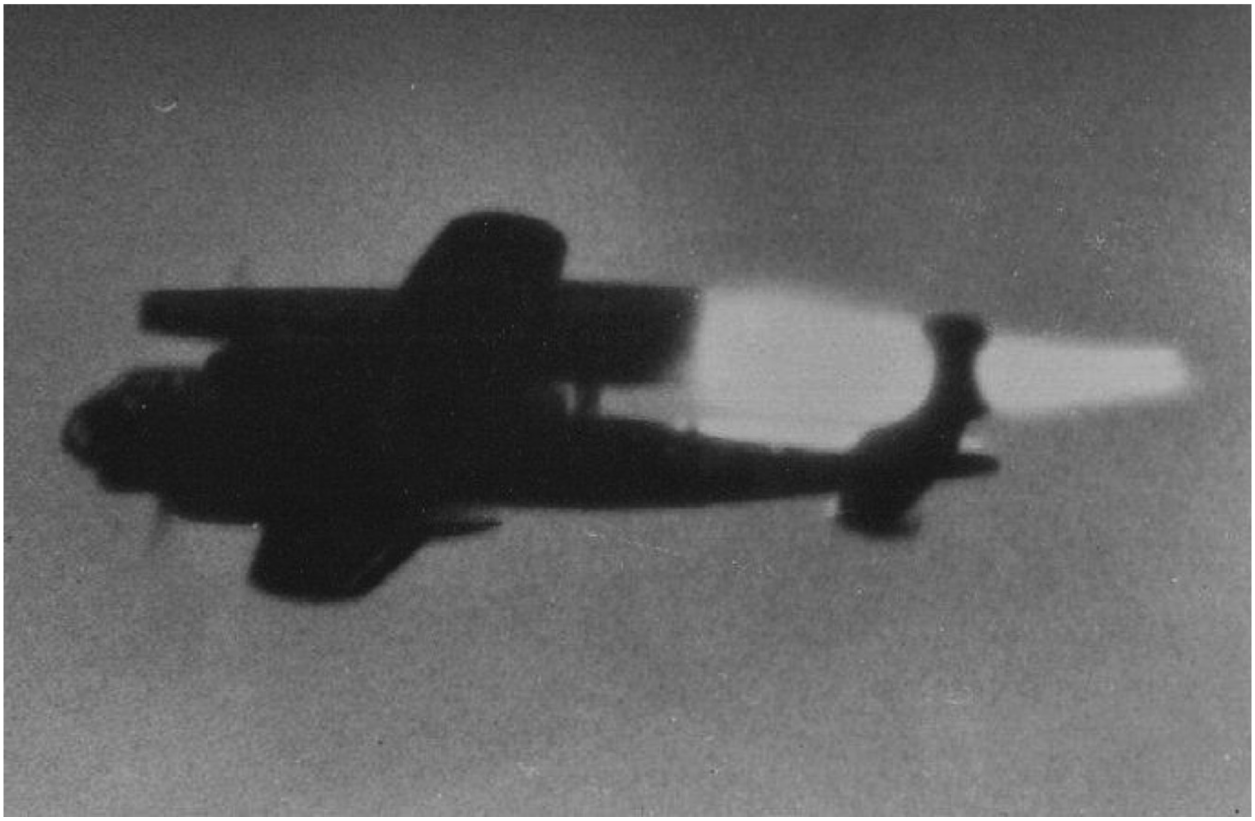
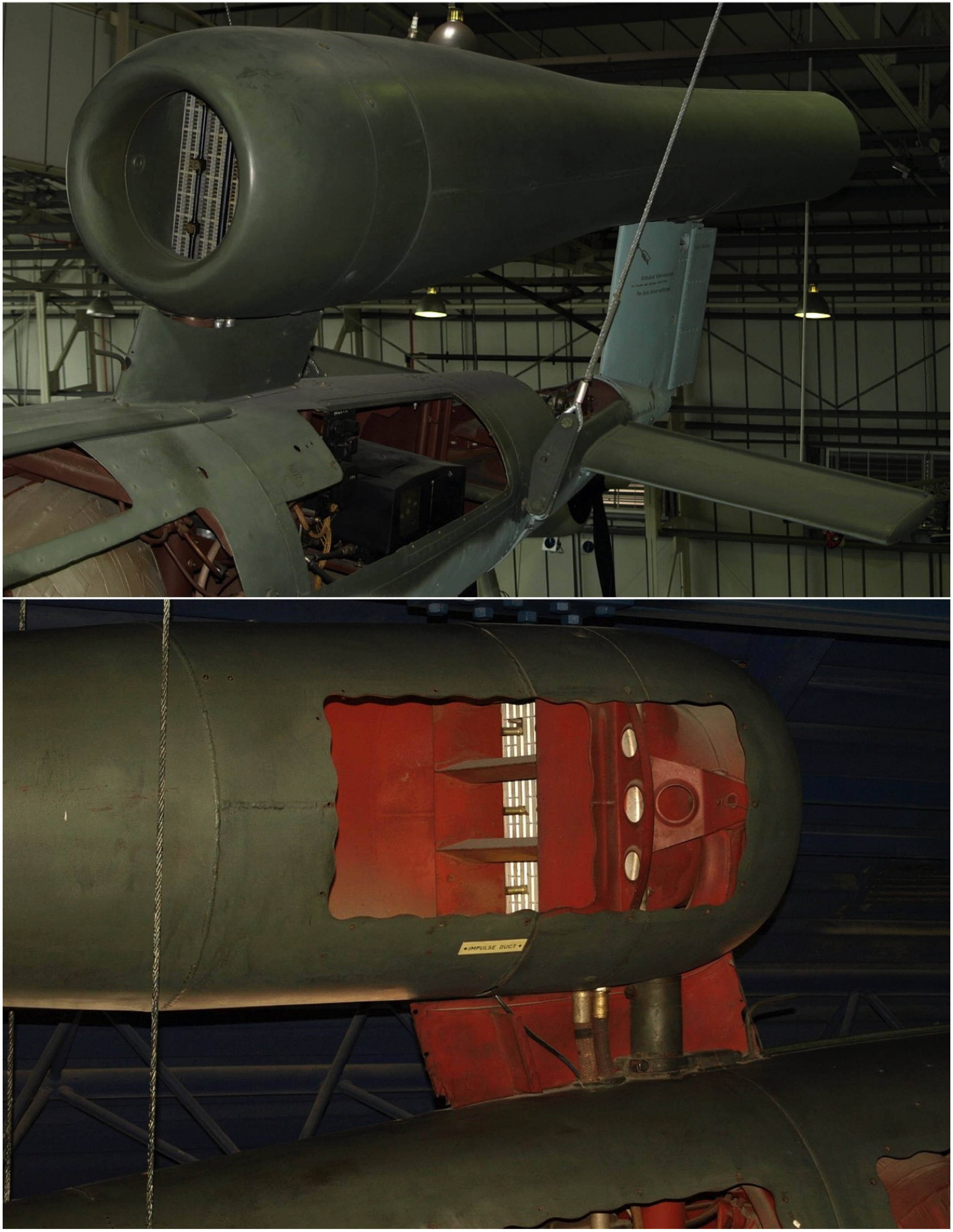


Figure 9.100: Eugen Sänger's ramjet being tested on a Dornier Do 217 aircraft (1942).



Argus As 014 pulsejet engine on V-1 cruise missile

Figure 9.101: Argus As 014 pulsejet engine on V-1 cruise missile.

9.3.2 Jet Aircraft

Willy Messerschmitt (German, 1898–1978), Ludwig Bölkow (German, 1912–2003), and Woldemar Voigt (German, 1907–1980) headed the team that developed and mass-produced the Messerschmitt Me 262 Schwalbe (Swallow) twin-engine jet fighter, which was first flown in 1942; see Fig. 9.102. By the end of the war, there were highly sophisticated underground plants for mass-producing Me 262 fighters despite Allied bombing, such as those at St. Georgen/Gusen and Kahla (pp. 4967–4969, 5214–5217). An upgraded version of the Schwalbe with integrated jet engines and a two-person cockpit, Me 262 HG III, was designed but apparently not built before the end of the war (Fig. 9.103). After the war, Messerschmitt developed jet aircraft for Spain, Egypt, and West Germany; Bölkow created jets and missiles in West Germany; and Voigt worked in the United States.

Walter Blume (German, 1896–1964) led the team that developed and mass-produced the Arado Ar 234 Blitz (Lightning) twin-engine jet bomber, which was first flown in 1943; see Fig. 9.104. After the war, he played a critical role in developing jet fighters and bombers in the Soviet Union.

The German brothers Walter Horten (1913–1998) and Reimar Horten (1915–1994) developed advanced flying wing jet aircraft, as shown in Figs. 9.105–9.106.[9] Their earliest prototypes were sailplanes, before they were able to obtain jet engines from Jumo or BMW. They designed and built the twin-engine Horten Ho 229 stealth fighter, which they first demonstrated in 1944. They also designed the six-engine Horten H.XVIII intercontinental stealth bomber in 1944; there is some evidence that it may have been built or under construction when the war ended—see pp. 5227–5231. After the war, Reimar Horten developed aircraft in Argentina while Walter Horten developed aircraft in West Germany. In addition to the all-wing approach, an important feature of the Horten brothers' designs was their stealthy reduced radar cross sections, due to vehicle shapes that minimized direct radar returns, buried engines, minimization of metal components, and use of special coatings. (For more information on the German creation of stealth technology, see Section 6.8.2.) The strong influence of the Horten brothers' designs was felt even many decades later in the U.S. stealth fighter and stealth bomber.

As shown in Fig. 9.107, postwar jet fighters such as the U.S. F-86 Sabre and Soviet MiG-15 were directly derived from wartime German designs such as the Messerschmitt Me P.1101 (designed by Woldemar Voigt and Ludwig Bölkow) and Focke-Wulf Ta 183 (designed by Hans Multhopp and Kurt Tank).

In fact, the F-86 was developed by Edgar Schmüd (German, 1899–1985), an aircraft designer who immigrated to the United States before World War II (pp. 1679, 1688). In addition to the Me P.1101 and Focke-Wulf Ta 183, Schmüd drew upon other German-developed technologies. As just one example, in 1952, *Life* magazine reported [Campion 1952]:

> In the summer of 1945 two peculiarly interesting objects, sent by air force intelligence, arrived at the North American Aviation Co.'s Los Angeles plant. One was the wing of the latest German jet fighter, a Messerschmitt 262, and its batlike design was startling to the company's engineers who had never seen anything like it on a plane before. The other, of even greater interest, was a secret record of German wind-tunnel experiments

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[9] Horten and Selliger 2012; Jorgensen 2009; Myhra 1998b; Shepelev and Ottens 2015.

> on the aerodynamic behavior of radically swept-back wings. Conclusive and exhaustingly thorough, the data (which the Russians also lifted from the files of the Luftwaffe) saved North American three laborious years of research in designing the Air Force's fastest fighter now in operation, the F-86 Sabre jet. As sketched out on the company's drawing boards, the F-86 was to be equipped with the conventional straight wing. But by adapting the German innovations, North American was able to convert its design from straight to swept-back in only four weeks.

Edgar Schmüd also created the North American P-51 Mustang (1940, based on the 1935 Messerschmitt Bf 109), the North American F-100 Super Sabre (1953), the Northrop F-5 Freedom Fighter (1959), and the Northrop T-38 Talon trainer (1959, widely used by NASA for astronaut training) [Ray Wagner 2000].

Brunolf Baade (German, 1904–1969) and Günther Bock (German, 1898–1970) designed jet aircraft such as Ju 287 bomber prototype (with forward-sweeping wings, first flown in 1944) at Junkers in Germany during the war, and others such as the Tu-95 "Bear" bomber (with back-swept wings, first flown in 1952) at Tupolev in the Soviet Union after the war. They also designed a civilian airliner version of the Tu-95, the Tupolev Tu-114. In those wartime and postwar projects, they collaborated with engine designer Ferdinand Brandner. See Fig. 9.108.

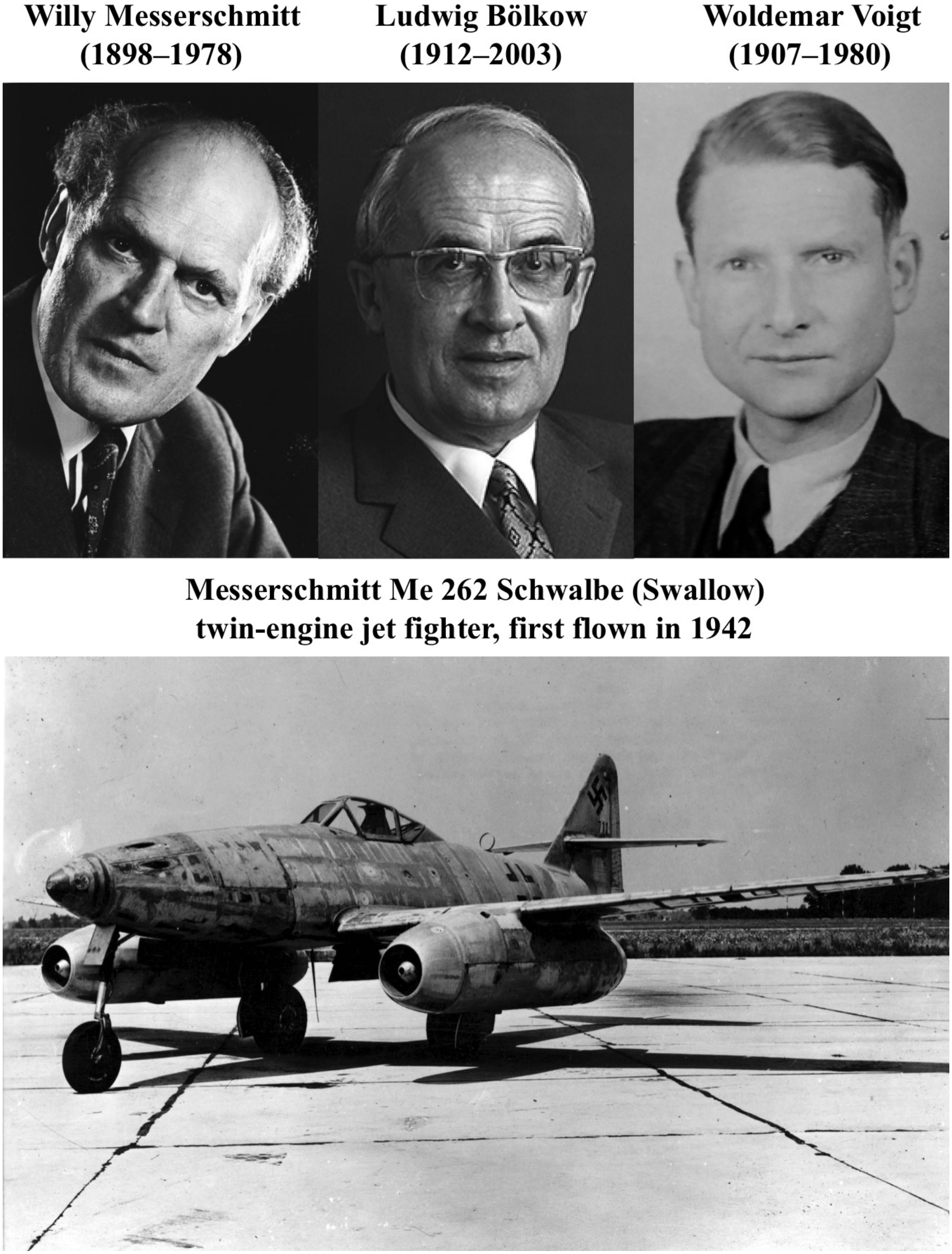
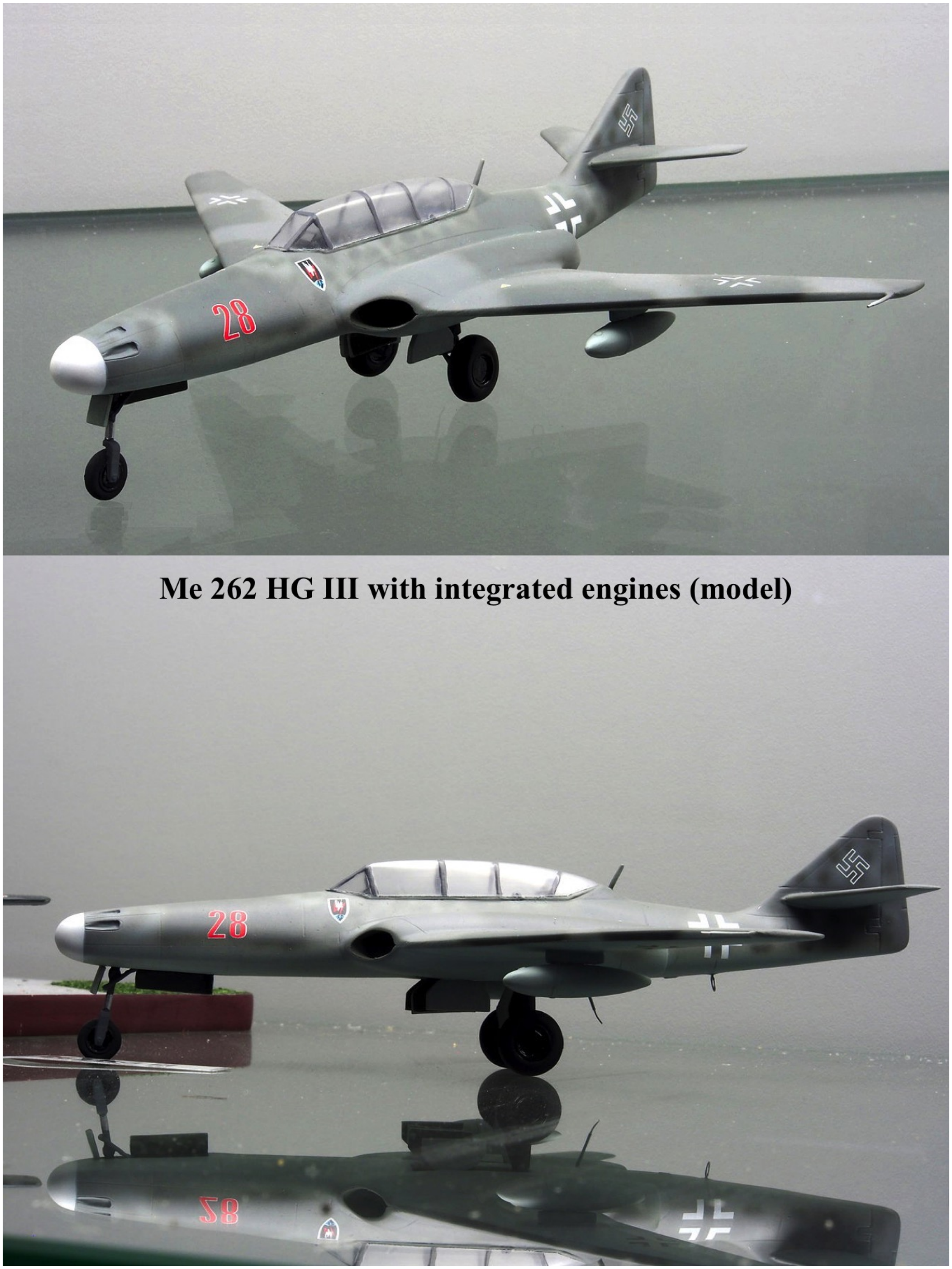
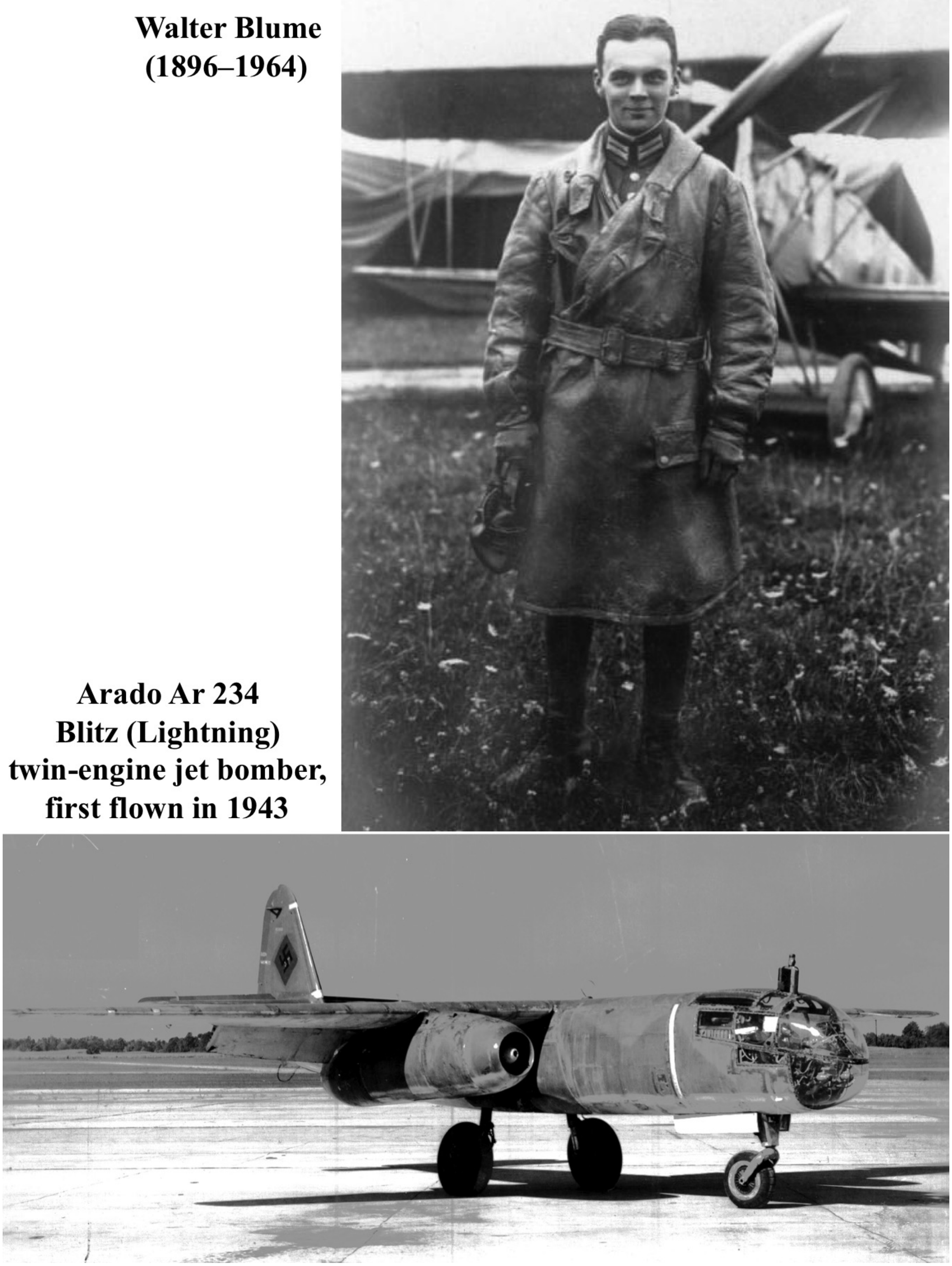

Willy Messerschmitt (1898–1978)
Ludwig Bölkow (1912–2003)
Woldemar Voigt (1907–1980)
Messerschmitt Me 262 Schwalbe (Swallow) twin-engine jet fighter, first flown in 1942

Figure 9.102: Willy Messerschmitt, Ludwig Bölkow, and Woldemar Voigt headed the team that developed and mass-produced the Messerschmitt Me 262 Schwalbe (Swallow) twin-engine jet fighter, which was first flown in 1942.



Me 262 HG III with integrated engines (model)

Figure 9.103: An upgraded version of the Messerschmitt Schwalbe with integrated jet engines and a two-person cockpit, Me 262 HG III, was designed but apparently not built before the end of the war.



Walter Blume
(1896–1964)

Arado Ar 234
Blitz (Lightning)
twin-engine jet bomber,
first flown in 1943

Figure 9.104: Walter Blume led the team that developed and mass-produced the Arado Ar 234 Blitz (Lightning) twin-engine jet bomber, which was first flown in 1943.

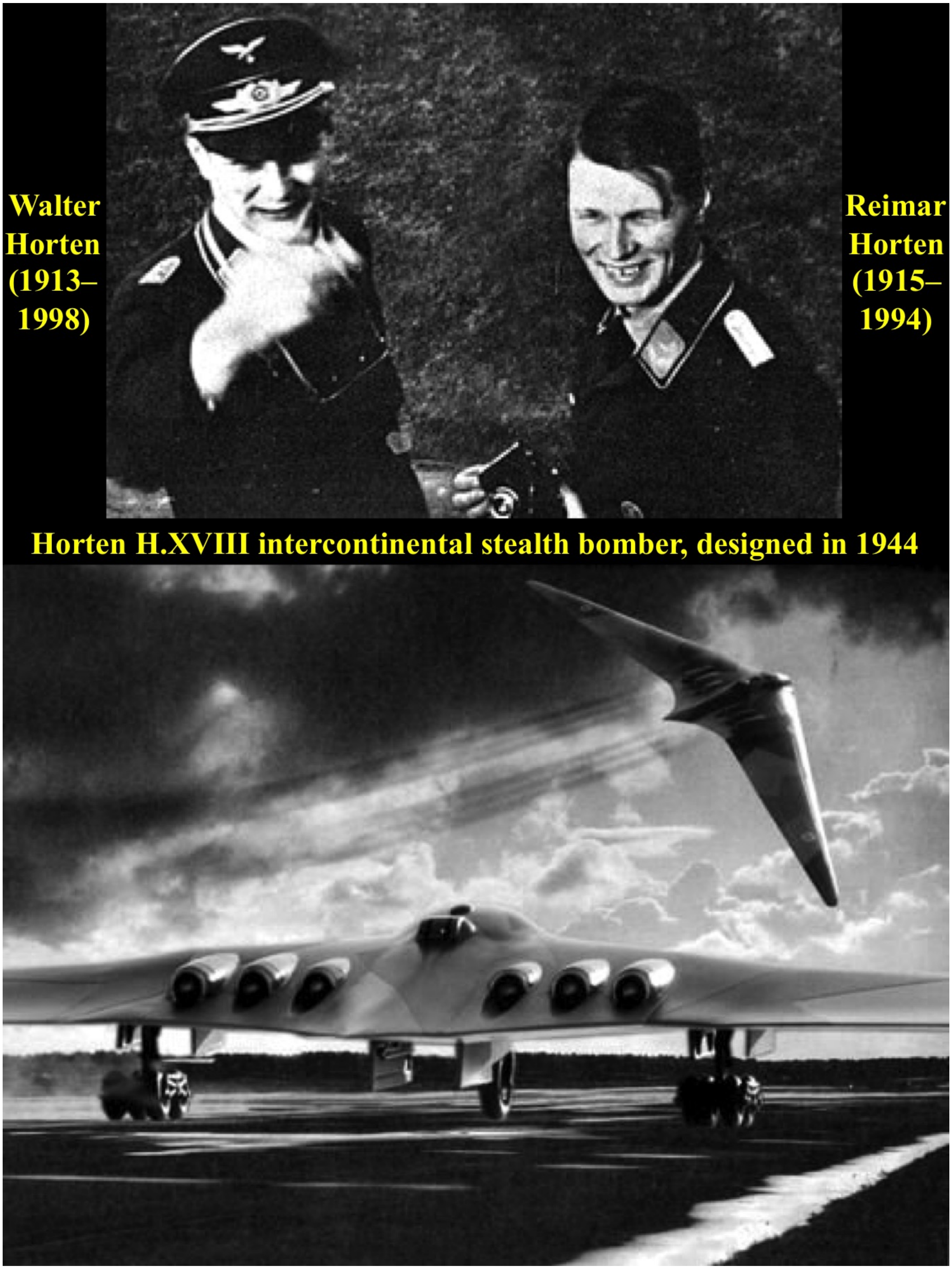

Walter Horten (1913–1998)
Reimar Horten (1915–1994)
Horten H.XVIII intercontinental stealth bomber, designed in 1944

Figure 9.105: The brothers Walter and Reimar Horten developed advanced flying wing jet aircraft, such as the twin-engine Horten Ho 229 stealth fighter (demonstrated in 1944) and the six-engine Horten H.XVIII intercontinental stealth bomber (designed in 1944 and possibly built or under construction when the war ended—see pp. 5227–5231).

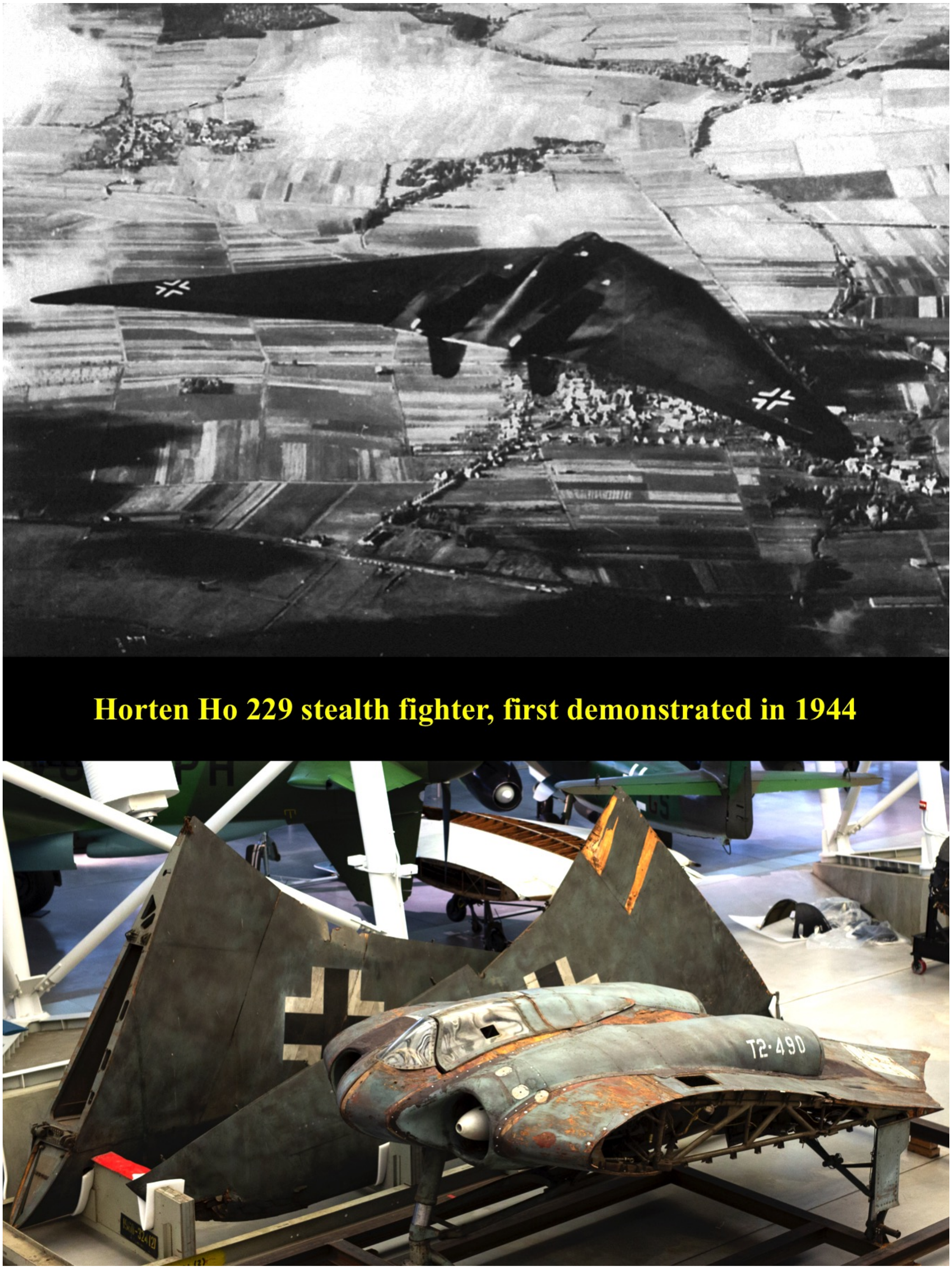
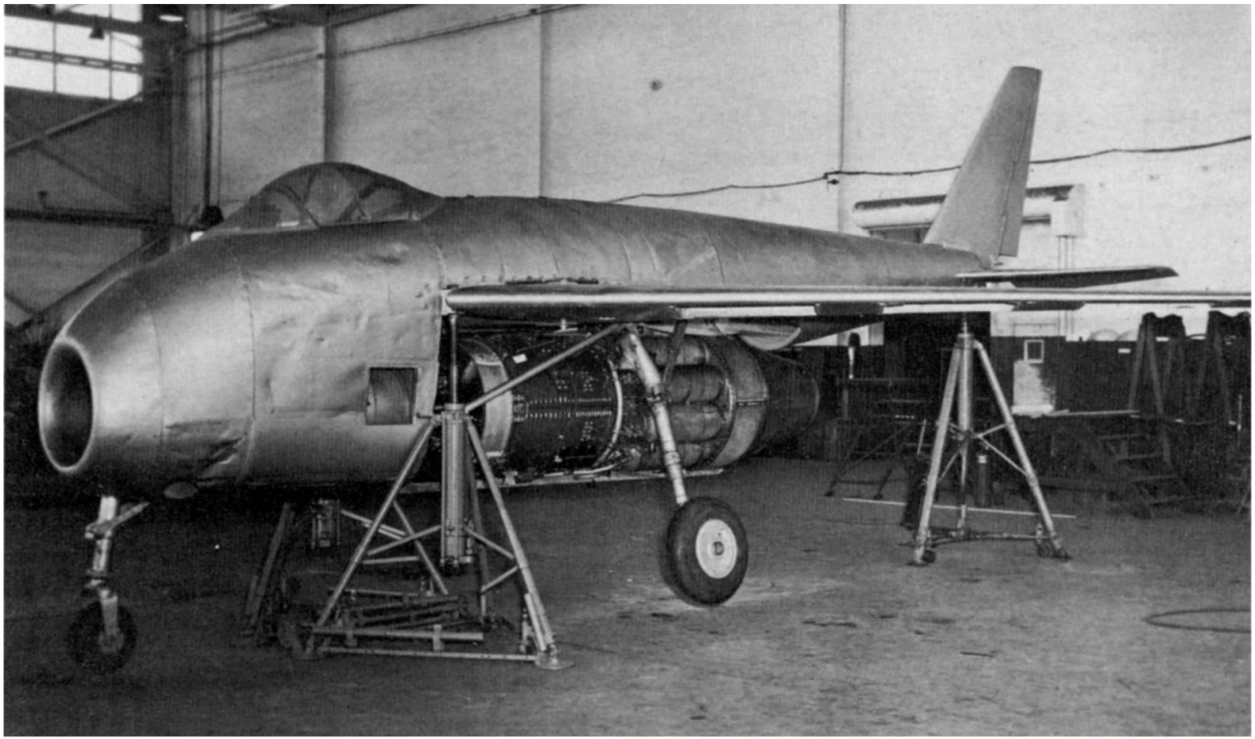
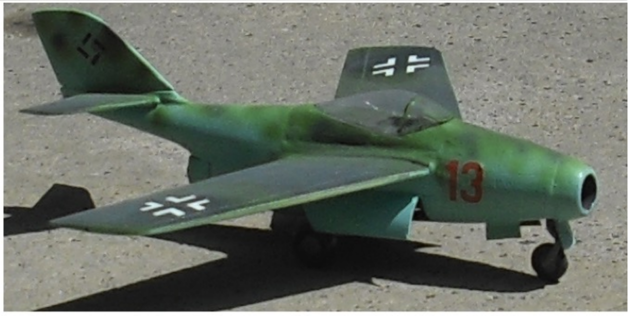

Horten Ho 229 stealth fighter, first demonstrated in 1944
T2-490

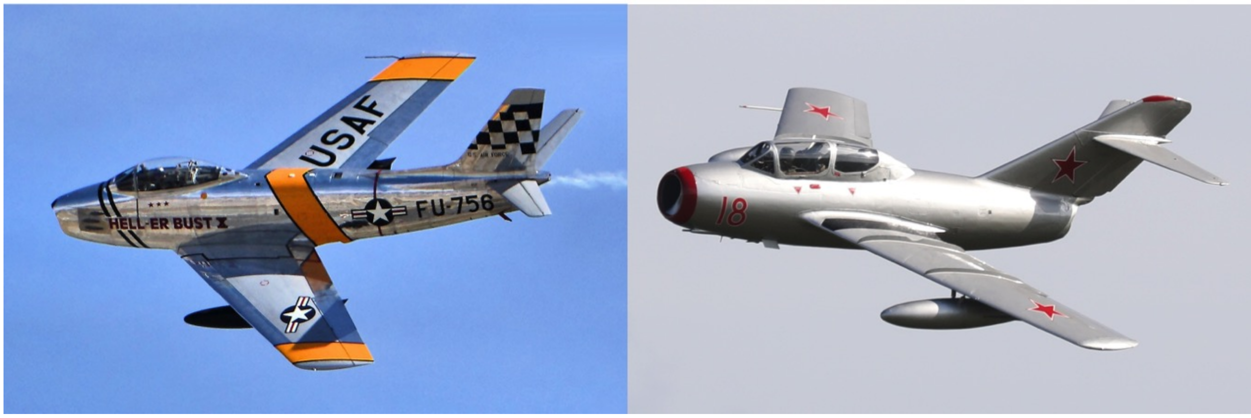
Figure 9.106: The brothers Walter and Reimar Horten developed advanced flying wing jet aircraft, such as the twin-engine Horten Ho 229 stealth fighter, which they first demonstrated in 1944.



Messerschmitt Me P.1101 (1944–1945)



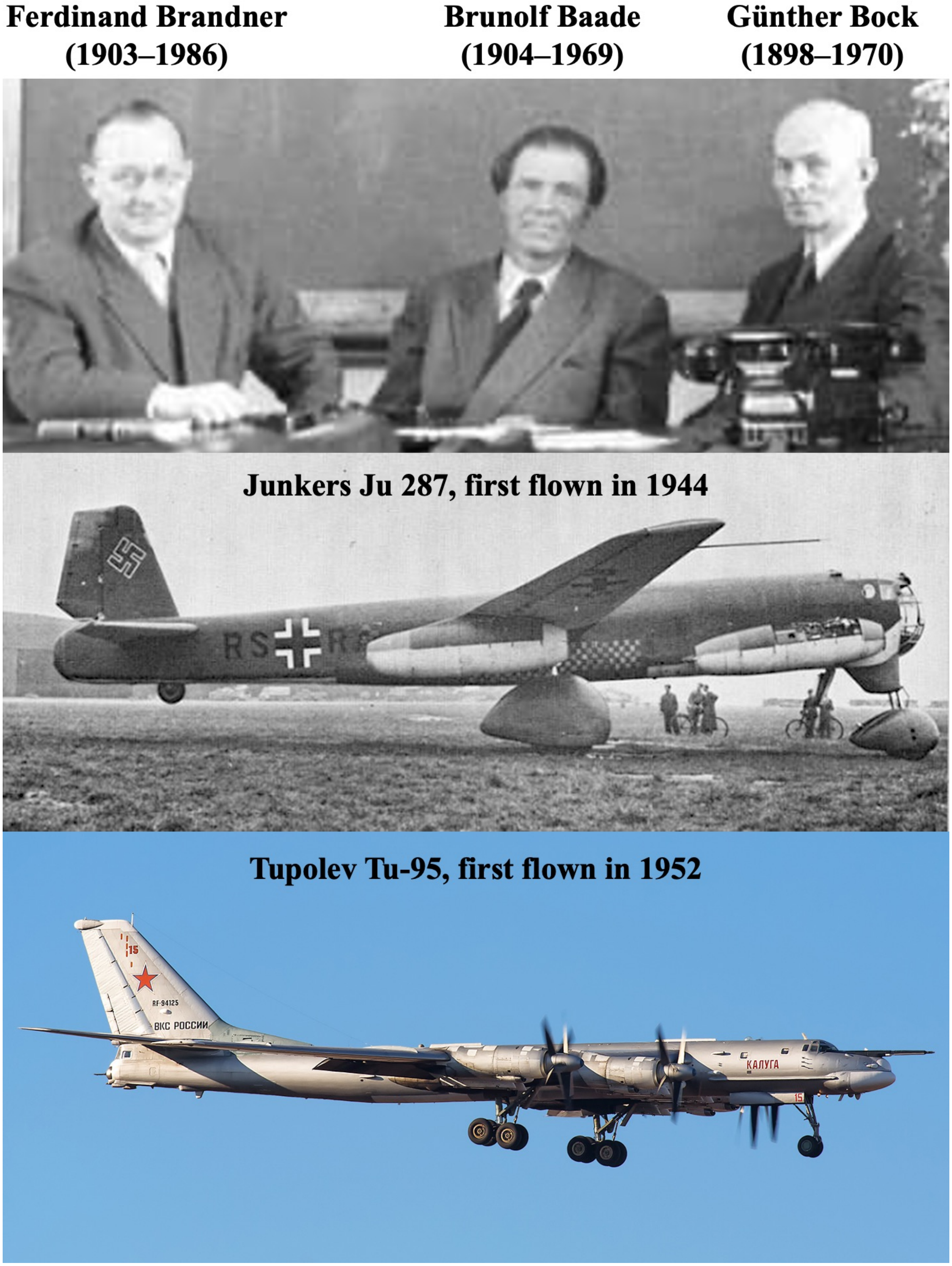
Focke-Wulf Ta 183 (designed 1944; model shown)



U.S. F-86 Sabre (1947)

Soviet MiG-15 (1947)

Figure 9.107: Postwar jet fighters such as the U.S. F-86 Sabre and Soviet MiG-15 were directly derived from wartime German jets such as the Messerschmitt Me P.1101 and Focke-Wulf Ta 183.



Ferdinand Brandner (1903–1986)

Brunolf Baade (1904–1969)

Günther Bock (1898–1970)

Junkers Ju 287, first flown in 1944

Tupolev Tu-95, first flown in 1952

Figure 9.108: Brunolf Baade and Günther Bock (shown with engine designer Ferdinand Brandner, with whom they collaborated) designed jet aircraft such as Ju 287 at Junkers in Germany during the war, and others such as Tu-95 at Tupolev in the Soviet Union after the war.

Sterling Pavelec, professor of aerospace history at the USAF Air Command and Staff College, explained the fundamental motivation and the ultimate impact of the German jet programs [Pavelec 2007, pp. 148, 154–156]:

> Even before the end of the war the Allies realized that the Germans had had an enormous impact on the evolution of military technology. In the final year of the war in Europe, the Germans led in nearly all fields of military technology, industrial capability, and theoretical knowledge. Some of the most impressive gains were in the fields of rocket technology (both manned and unmanned), turbojet aircraft, submarine technology[....] By the end of the war each of the major Allies—the British, the Americans, and the Soviets—were poised to capture German technology for future considerations. [...]
>
> Turbojets were devised, designed, and developed for their revolutionary potential. The Germans were the first—and in the end the best—in developing turbojet technology during the war for a number of reasons. Initially, turbojet development was a natural evolution of German academic predisposition. The advanced theoretical knowledge in the institutes of higher learning in Germany translated directly into conditions for developing nontraditional aircraft and power plants. The "shackles" of Versailles actually forced the Germans to start fresh without technological baggage. The young Doctor of Physics, Hans von Ohain, searching for "elegance" in flight, wanted to develop an alternative to the dirty, noisy, and rough propeller engine. Fortunately, for Germany, his ideas were accepted by an aviation industrialist who was searching for speed and efficiency. German aircraft designers were looking for revolutionary technology at the exact time it was becoming available. And that is not all; Dr. Franz, responsible for the development of the German axial-flow designs, also found the right time and climate for acceptance. His theories were proven correct; the Germans were the first to develop working, efficient axial-flow turbojets. Further, the Germans were devoted to increasingly higher theoretical advancement. In all forms of military hardware, the Germans were dedicated to developing the highest quality weapons by pursuing the boundaries of theoretical knowledge. [...]
>
> What held up the development of German turbojet aircraft was the lack of raw materials—chrome, nickel, and molybdenum—in Germany. Substitutes were found; the machines were built. [...] The Germans made do with what they had because they had to. There were no other alternatives. And still the Me 262—and later Ar 234 and He 162—were better than any Allied turbojet aircraft built during the same period.
>
> The longevity of the German turbojet program is evident in the impact on postwar military and civilian applications. The Americans virtually copied most German theoretical data and applied it directly to experimental programs. Further, German aeronautical engineers, designers, and technicians were brought to the United States to advance theoretical knowledge for their new bosses. The impact of German turbojet engineering was substantial.
>
> During World War II, the Americans and British were content to continue testing and with the development of conservative designs. Neither of the Western Allies felt the pressing need for turbojet aircraft throughout the war. [...]
>
> The Allies did not need turbojet aircraft to beat the Germans; the Germans needed their turbojet aircraft to have any hope of combatting the Allied bombers over Germany. The Germans did it first and did it right; and after the war, the Germans kept doing it for the powers that combined to defeat them in World War II.

For evidence that appears to demonstrate the development of even more advanced jet aircraft, including intercontinental jet bombers, in wartime Germany, see Appendix E.

Whether Whittle?

In the English-speaking world, the British engineer Frank Whittle is widely considered the inventor of the jet engine, or at the very least the co-inventor before or in parallel with the German engineers. For example, Oxford's *Biographical Dictionary of Scientists* says of Frank Whittle: "British engineer and inventor of the jet engine. The developments from his original designs were used first in the Gloster Meteor at the end of World War II. Direct descendents of these engines are now the sources of power for all kinds of military and civil aircraft" [Porter 1994, pp. 721–722]. The biographical dictionary never mentions Hans von Ohain or any other German-speaking inventors of jet engines and jet aircraft, apart from briefly remarking that "the Germans had produced the Messerschmitt Me 262 slightly earlier" than the British. The Oxford scholars do not even attempt to explain why all of the modern engines that are "now the sources of power for all kinds of military and civil aircraft" look absolutely nothing like Whittle's engines of which they are allegedly "direct descendents," yet instead bear an uncanny resemblance to the German engines.

Hill and Peterson's *Mechanics and Thermodynamics of Propulsion*, which has been the gold standard textbook of aerospace propulsion since its first edition in 1965, accurately summarized Whittle's jet milestones [Hill and Peterson 1991, p. 17]:

> [...A] company called Power Jets was formed in March 1936 that set to work on the development of a new engine while Whittle was still finishing his degree program. After enormous technical, financial, and bureaucratic difficulties, Whittle was able to run the engine for 20 minutes at 16,000 rpm on June 30, 1939, in a demonstration that at last convinced the authorities that his concept was valid and worthy of substantial support. On May 15, 1941, the first British jet aircraft, the Gloster Meteor, powered by the Whittle engine, flew from Cranwell in Lincolnshire.

After Whittle had demonstrated his engine, the older and very experienced British piston engine designer Frank Halford (1894–1955) stepped in and streamlined Whittle's engine as much as he could, leading to the Halford H-1 or de Havilland Goblin turbojet engine.

The United States actually produced a wartime jet, the Bell P-59 Airacomet, that used Whittle's jet engine design. Because of the engine's weight and inefficiency, the P-59 had a slower top speed and shorter range than even the piston-propeller P-51 Mustang. An improved U.S. jet, the Lockheed P-80 or F-80 Shooting Star, was also under development during the war but did not really come into much use until the postwar period.

Whereas all of Whittle's and Halford's engines and the earliest von Ohain prototype engines used centrifugal flow, most of the wartime German-produced engines employed axial flow and thus looked far more similar to jet engines used today.

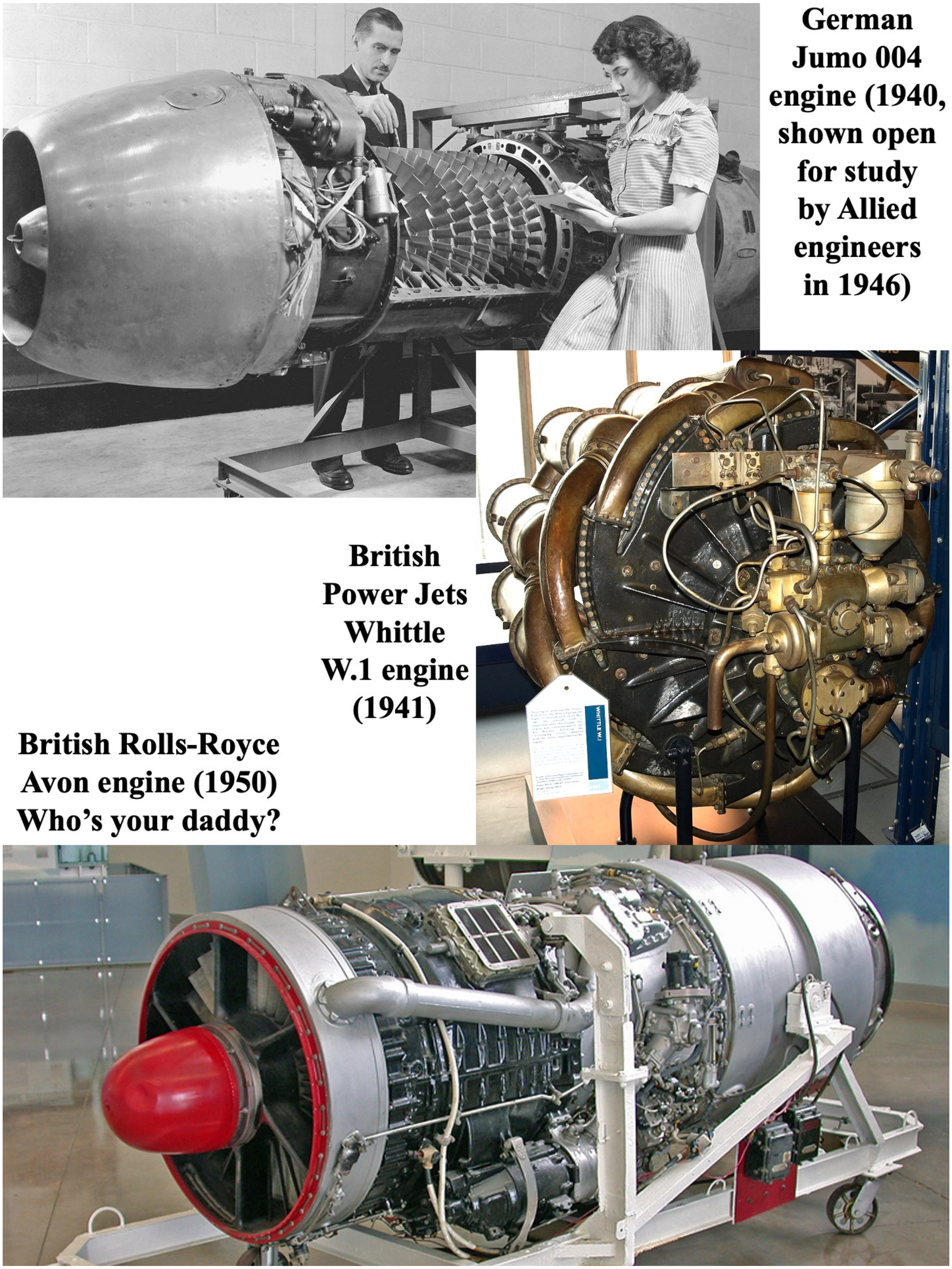
U.K. and U.S. jets produced during or soon after the war used the Whittle or Halford engine designs. However, the German jet engineers, designs, and prototypes were scooped up by Allied countries in 1945 and rapidly became the basis for turbojet, turbofan, turboprop, turboshaft, and ramjet engine designs that have been used worldwide ever since.

Kelly Johnson, the lead designer of the Lockheed P-80/F-80, compared wartime German and U.S./U.K. jets [Johnson and Smith 1989, pp. 95–96, 102–104]:

> The Air Corps commissioned use of the [Whittle jet] engine in the Bell P-59, originally designed as a propeller-driven airplane. When the jet-powered version flew in 1943, the performance was hardly better than that of the piston-powered P-38 and P-51. [...]
>
> The Germans by this time already had a number of jet-powered Me-262s in combat, and these planes were much faster than anything we had. They were well into the jet age while we were just starting. The Me-262 was a very good airplane, designed by Willy Messerschmitt, whose talent I respected. [...]
>
> The main concern turned out to be attack from the rear quadrant, where the German jets could overtake our aircraft, fly at any matching speed, and have considerably more time to aim and fire. [...]
>
> The war in Europe ended before the F-80 could be proved in combat there. But development, testing, and production continued.
>
> When the Air Corps team went to Germany after the war to inspect military capabilities, we at Lockheed were invited. [...]
>
> We found that the Germans had been flying the only axial flow jet engine in the world, fundamentally more efficient than the centrifugal compressors of the British jets because it was of simpler design. The flow went straight into the inlet and progressed in a straight line through the engine and out the exhaust. In centrifugal flow, the air goes in two sides of a rotor, flows perpendicular to the flight path of the airplane, enters the burner cans, then goes through the rest of the machine; so that it changes flow 90 degrees at least twice.

As explained by Kelly Johnson, Whittle's engine was very heavy, complex, and inefficient compared to the German designs, which were both earlier and more advanced. In the years following the war, even the British military and British companies abandoned Whittle's design and adopted the German designs (see for example Fig. 9.109).

It appears that the early U.K./U.S. jet engines were hampered not only by an inferior design, but also by a wartime research system that provided far less financial and political support than jet creators received in Germany. Moreover, during the war, the United States simply copied the British engine designs without even really trying to significantly innovate and improve upon them, as the German engineers were constantly doing with their own designs. U.S./U.K. support for jet innovation drastically increased after the war, once the performance of the German jets and the rising Cold War tensions with the Soviet Union became clear.



German Jumo 004 engine (1940, shown open for study by Allied engineers in 1946)

British Power Jets Whittle W.1 engine (1941)

British Rolls-Royce Avon engine (1950) Who's your daddy?

Figure 9.109: The British Rolls-Royce Avon turbojet engine began as a design project in 1945 and entered production in 1950. Does this postwar British engine look like wartime German engines such as the Jumo 004 or wartime British engines such as the Whittle W.1? Hint: What engines, information, and engine designers suddenly became available to British companies in 1945?

As shown in this section and summarized in Table 9.1, Whittle's British team was at least two years behind the German engineers at every step along the way in the development of jet engines and jet aircraft. In addition to these obvious differences in dates, the historical evidence shows that the German jet engines and jet aircraft were more sophisticated, more capable, and produced in greater numbers and greater varieties than their British counterparts.

If runners A and B are in a race, and runner B crosses the finish line two years after runner A, it would not be even remotely accurate or honest to say that runner B was the winner of the race, or even the co-winner. The evidence for the development of jets is clear, and historians must be clear as well. Frank Whittle was a talented engineer, but he was just one among countless engineers who worked on jet engines in the years following their invention and development by Hans von Ohain and the other German pioneers of the field.

The skies around the world today are filled with jet engines and jet aircraft that are directly descended from those created by the German engineers. Whittle's engines are evolutionary dead ends that can only be found in museums (Fig. 9.109).

Jet milestone	**German engineers**	**Whittle team**
First patent application	1925	1930
First proof-of-concept turbojet engine	1935	1938
First practical turbojet engine	1937	1939
First jet-powered flight	1939	1941
First twin-engine jet fighter	1941	1943

Table 9.1: Major milestones in the development of jet engines and jet aircraft, comparing the German engineers and Whittle's British team.

9.4 Parachutes and Ejection Seats

German-speaking scientists and engineers developed and demonstrated application-specific parachutes (Section 9.4.1) as well as ejection seats (Section 9.4.2) [Harsch 2006a, 2017, 2018; Hirschel et al. 2004; BIOS 466; FIAT 465; NavTecMisEu 247-45].

9.4.1 Parachutes

Hermann Lattemann (German, 1852–1894) and Katharina Paulus (German, 1868–1935) developed collapsible parachutes and backpack parachutes beginning in 1890 (Fig. 9.110). Lattemann died testing one of the parachutes in 1894, and Paulus continued to perfect the invention, producing a final product in 1910.

The parachute designers Gerhard Sedlmayr and Holger Hansen described the contributions of several other creators to parachute development; see Figs. 9.111–9.117 [Hirschel et al. 2004, pp. 309–315]:

> The second procedure—a stepwise deceleration—was developed by Waldemar Müller in 1924; here, a small auxiliary parachute is applied (free bag deployment), which, after being exposed to the flow, deploys and pulls the main parachute from the packing case and stretches it. The auxiliary parachute is connected to the apex of the main parachute by a short interconnecting cord. To improve the automatic procedures, the auxiliary parachute is, for instance, equipped with a steel spring so that it opens immediately after being released from the packing case. [...]
>
> Spherical canopies tend to oscillations if they are excited by small disturbances. At especially unfavourable circumstances, spherical canopies may even amplify these movements. To let air escape from the parachute canopy, an opening was placed at the apex of the parachute canopy, which resulted in a reduction of the pendulum-like oscillations. [...]
>
> Two essential brake parachutes originated which are still widely applied today. In 1933, Theodor W. Knacke started his theoretical and practical investigations to achieve the most effective deceleration of an aircraft in the air and during landing. In 1938, the development of the FIST [Flugtechnisches Institut der Technischen Hochschule Stuttgart] ribbon parachute was carried out by Georg Madelung and Theodor W. Knacke (first landing in 1939), and in 1941, the development of the guide-surface parachute by Helmut Heinrich. For the first time, parachutes became technically very efficient due to extensive theoretical research and numerous systematic experimental developments. [...]
>
> During 1933 and 1945, practical investigations of about 10,000 parachute drops were performed at the test center Rechlin from aircraft. More than half of these drops were filmed by high-speed cameras and documented. [...]
>
> In about 1937, the employees of the FIST (Georg Madelung, Theodor W. Knacke, Rudolf

> Isermann and Albert Keller) had the idea to build a parachute whose canopy consisted only of ribbons. [...] It still bears the name of the institute where it was developed, viz., "FIST ribbon parachute"; it is still being utilised today as recovery parachute, e.g., for reconnaissance drones, and as brake parachute for aircraft, landing space capsules and the Space Shuttle.
>
> After development work on a parachute canopy that consisted only of ribbons, the first trials started in 1938. [...]
>
> Under the supervision of Theodor W. Knacke, the FIST ribbon parachutes were further developed after 1946 in the USA, and various versions of the ribbon parachute resulted and were employed as brake and recovery parachutes. Probably the most attention-getting application of the further advanced ribbon parachute was the combination of several such chutes to a landing system for manned space flight up to the Apollo program of NASA. [...]
>
> The guide surface parachute of Helmut Heinrich was utilised in the unmanned spaceflight programs in conjunction with the Mars probe Viking and the Venus probe. [...]
>
> Based on the experiences with ribbon parachutes, the concept was again revised at FIST, and in 1940, Georg Pirzer and Friedrich Weinig started with the development of an entirely new ribbon parachute, the so-called "Great-circle Ribbon Parachute (Wako Canopy Parachute)". This design exhibits an up to now unprecedented performance.

After World War II, German designs for parachutes were widely adopted by other countries and used in a variety of aerospace projects, including the U.S. Apollo and Space Shuttle programs [Hirschel et al. 2004; BIOS 466; FIAT 465]. See Figs. 9.112–9.117.

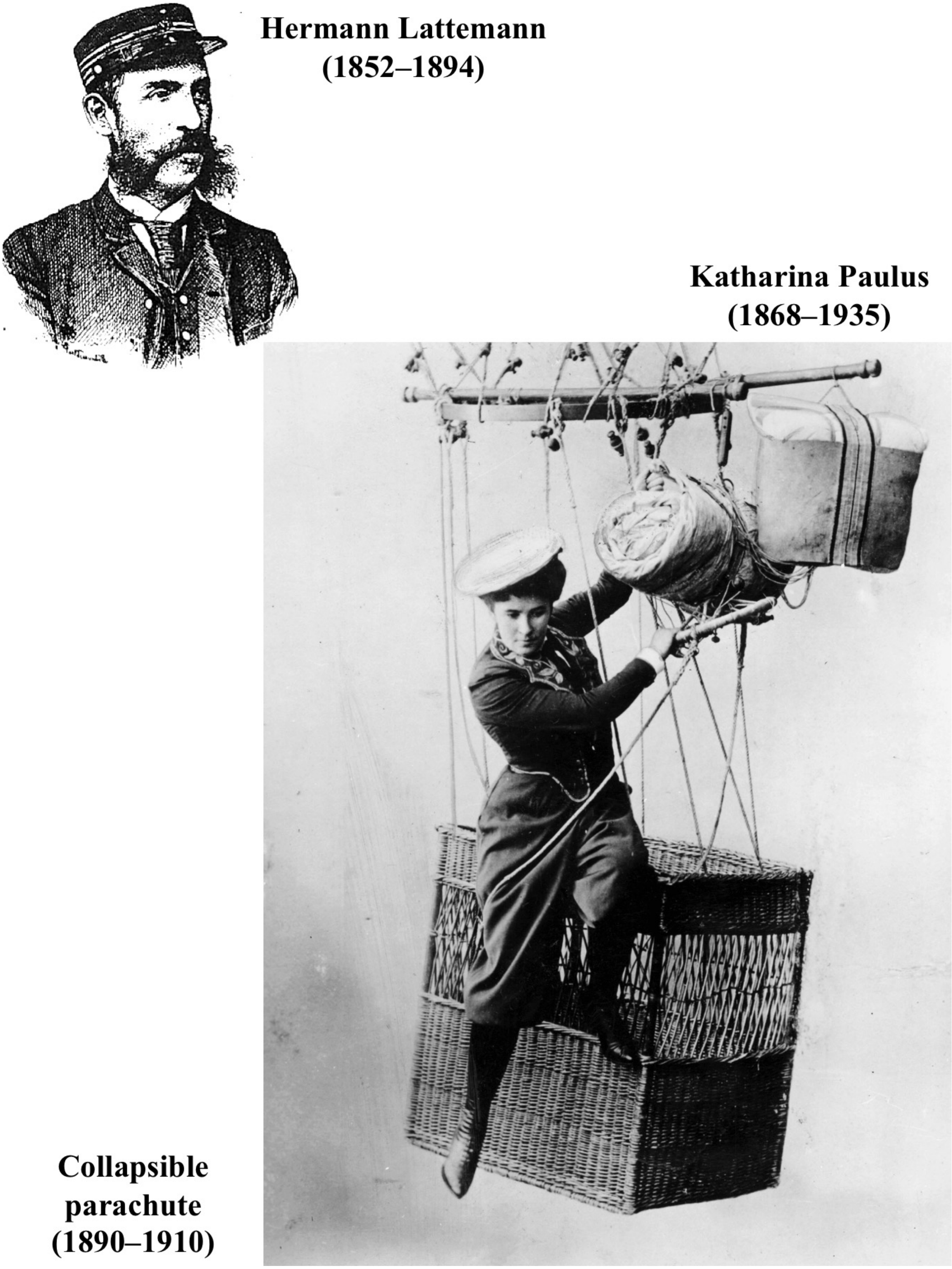

Hermann Lattemann
(1852–1894)
Katharina Paulus
(1868–1935)
Collapsible
parachute
(1890–1910)

Figure 9.110: Hermann Lattemann and Katharina Paulus developed collapsible parachutes and backpack parachutes during the period 1890–1910.

Parachutes optimized for specific applications

Rudolf Isermann
(18??–19??)

Albert Keller
(18??–19??)

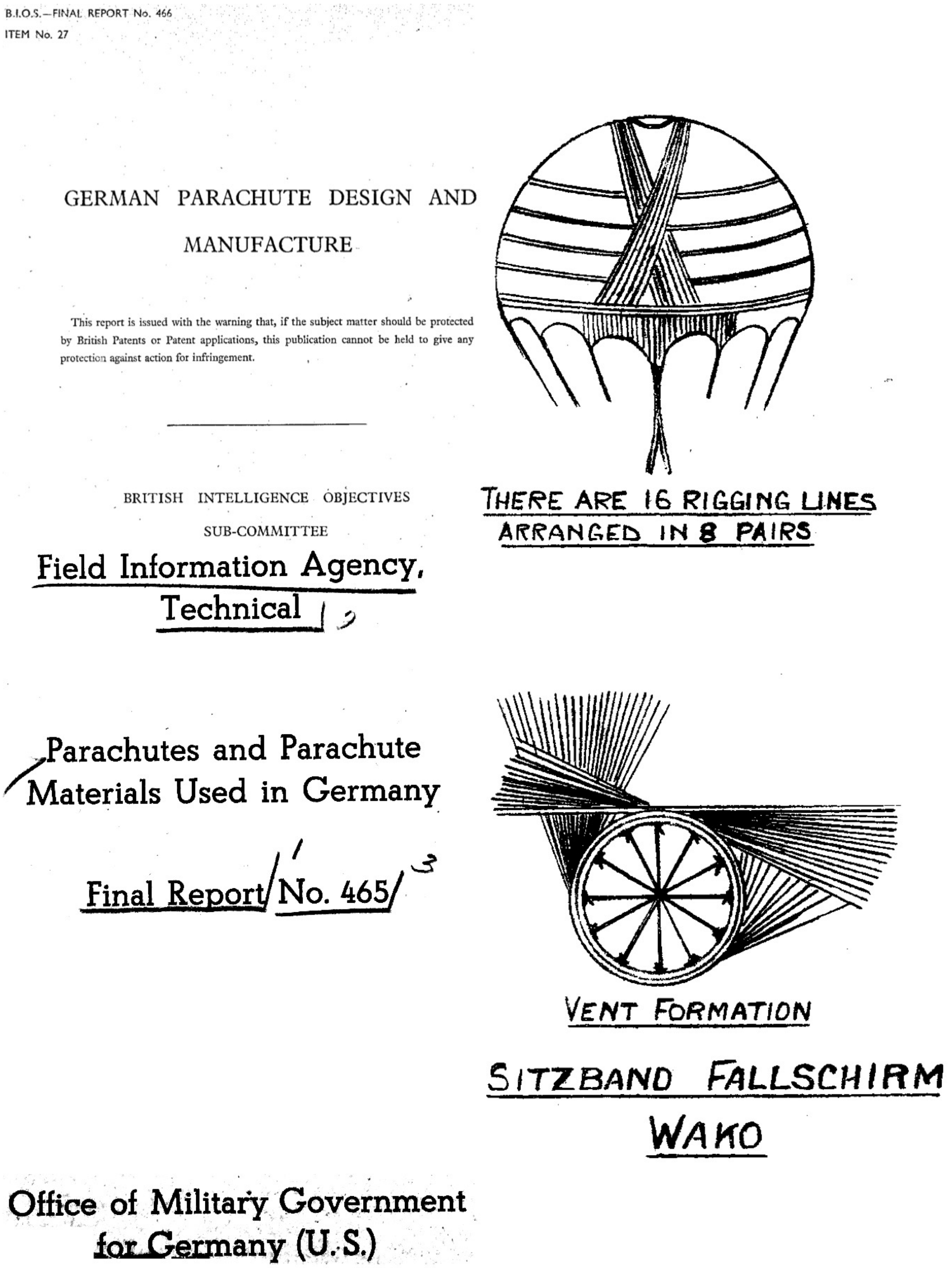
Georg Madelung
(1889–1972)

Waldemar Müller
(18??–19??)

Georg Pirzer
(18??–19??)

Friedrich Weinig
(18??–19??)

Figure 9.111: Creators who developed parachutes optimized for specific applications included Helmut Heinrich (Fig. 9.116), Rudolf Isermann, Albert Keller, Theodor Knacke (Fig. 9.116), Georg Madelung, Waldemar Müller, Georg Pirzer, and Friedrich Weinig.



B.I.O.S.—FINAL REPORT No. 466
ITEM No. 27

GERMAN PARACHUTE DESIGN AND MANUFACTURE

This report is issued with the warning that, if the subject matter should be protected by British Patents or Patent applications, this publication cannot be held to give any protection against action for infringement.

BRITISH INTELLIGENCE OBJECTIVES
SUB-COMMITTEE

Field Information Agency,
Technical

Parachutes and Parachute Materials Used in Germany

Final Report No. 465

Office of Military Government
for Germany (U.S.)

THERE ARE 16 RIGGING LINES ARRANGED IN 8 PAIRS
VENT FORMATION
SITZBAND FALLSCHIRM
WAKO

Figure 9.112: Allied countries studied and copied parachute designs from Germany after World War II [BIOS 466; FIAT 465].

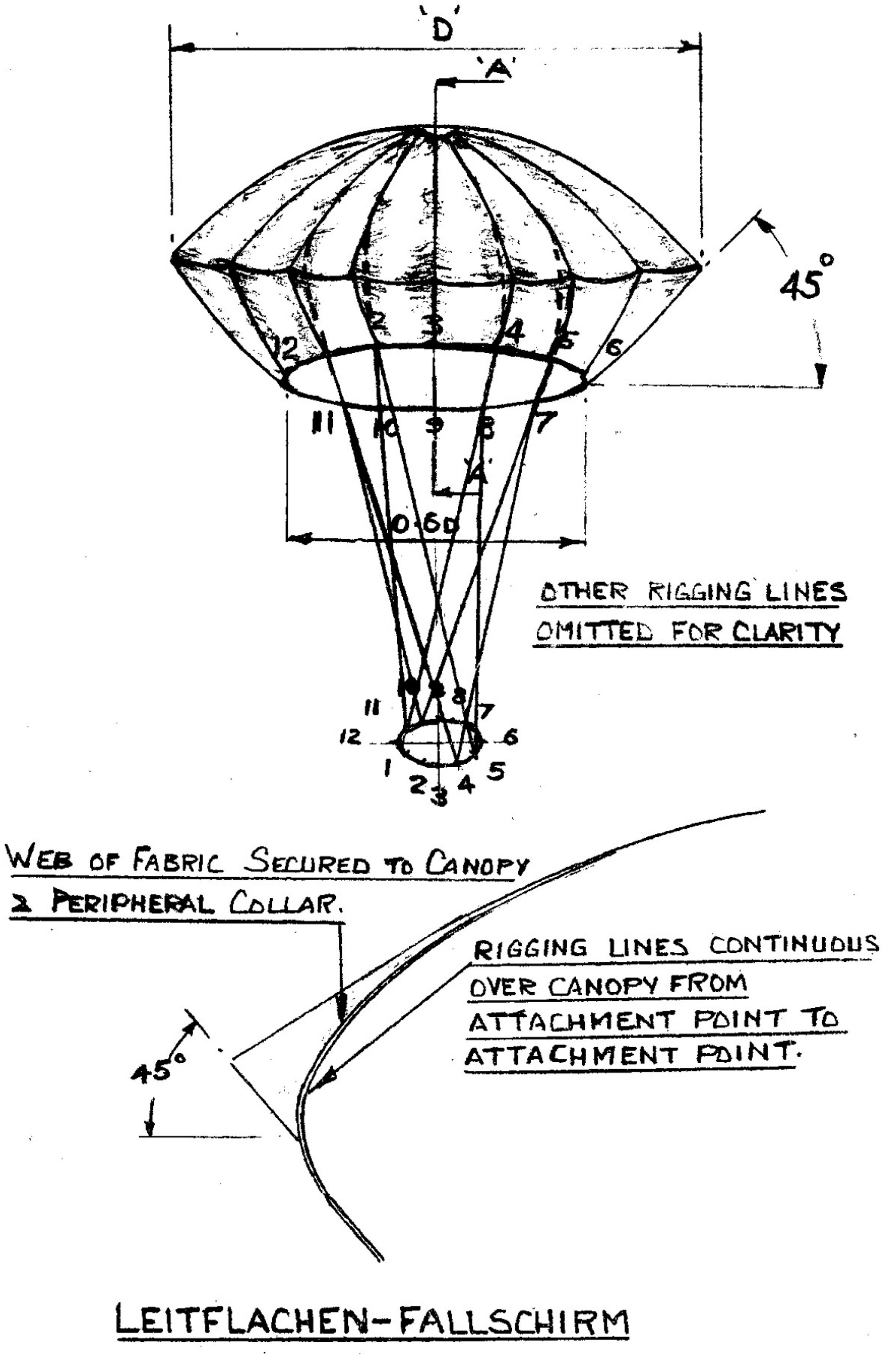

'D'
'A'
45°
12
1
2
3
4
5
6
11
10
9
8
7
'A'
0.6D
OTHER RIGGING LINES OMITTED FOR CLARITY
11
12
1
2
3
4
5
6
7
8
10
WEB OF FABRIC SECURED TO CANOPY
& PERIPHERAL COLLAR.
RIGGING LINES CONTINUOUS OVER CANOPY FROM ATTACHMENT POINT TO ATTACHMENT POINT.
45°
LEITFLACHEN-FALLSCHIRM

Figure 9.113: Allied countries studied and copied parachute designs from Germany after World War II [BIOS 466].

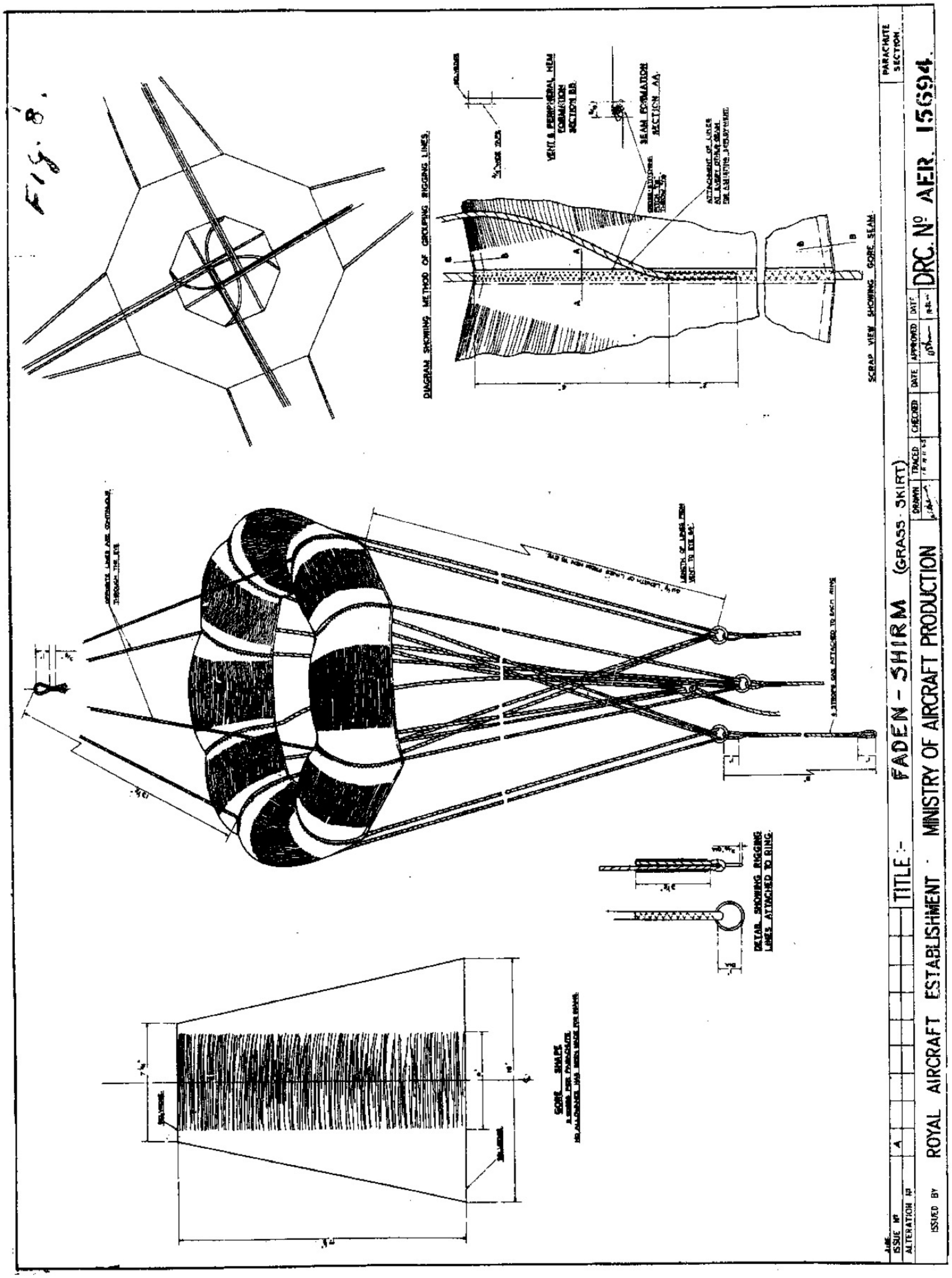


Fig. 8.
DIAGRAM SHOWING METHOD OF GROUPING RIGGING LINES.
VENT & PERIPHERAL HEM FORMATION SECTION BB.
SEAM FORMATION SECTION AA.
SCRAP VIEW SHOWING GORE SEAM.
DETAIL SHOWING RIGGING LINES ATTACHED TO RING.
GORE SHAPE
A
B
PARACHUTE SECTION
ISSUE Nº
ALTERATION Nº
ISSUED BY
ROYAL AIRCRAFT ESTABLISHMENT · MINISTRY OF AIRCRAFT PRODUCTION
TITLE :- FADEN - SHIRM (GRASS SKIRT)
DRAWN
TRACED
CHECKED
DATE
APPROVED
DATE
DRG. Nº AER. 15694.

Figure 9.114: Allied countries studied and copied parachute designs from Germany after World War II [BIOS 466].

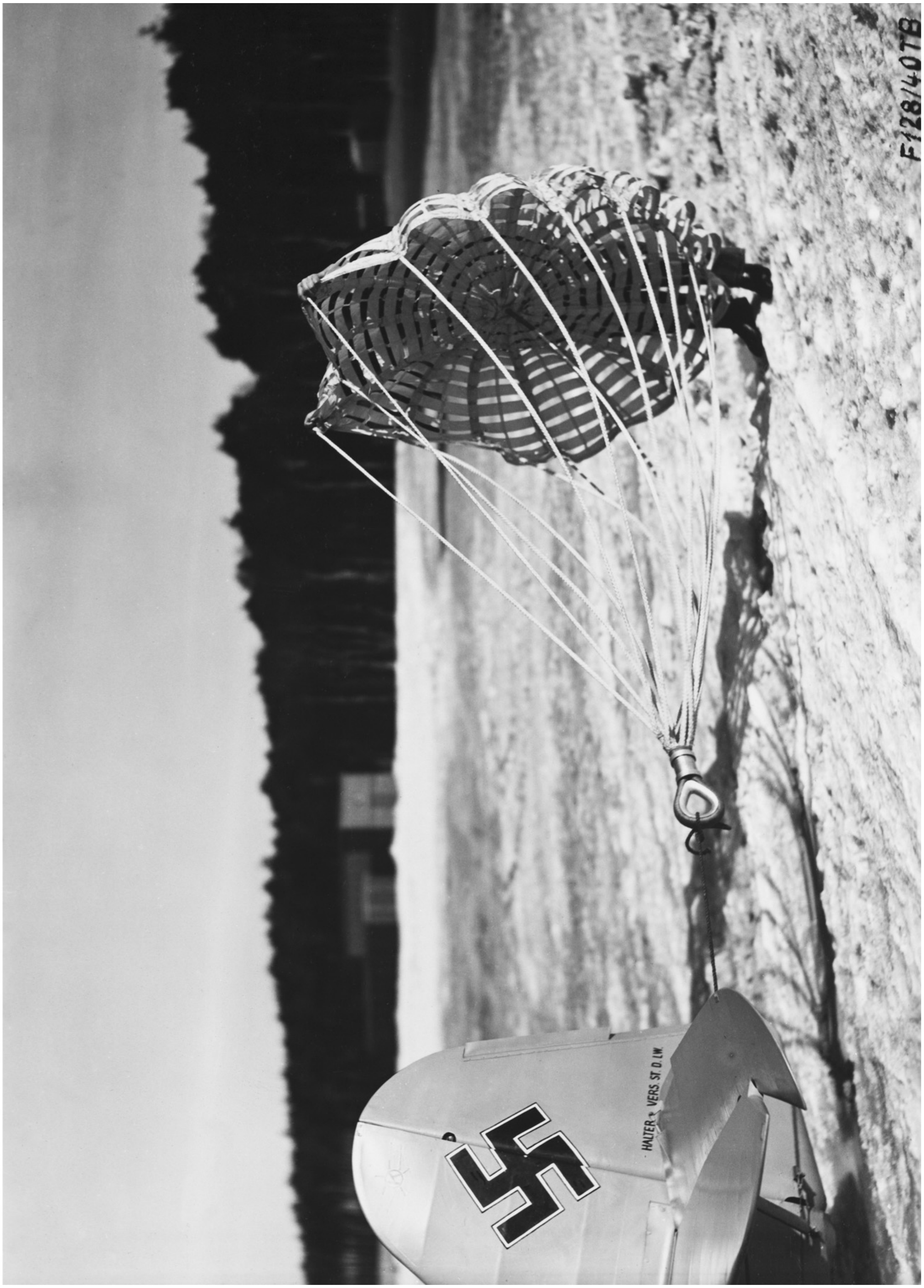

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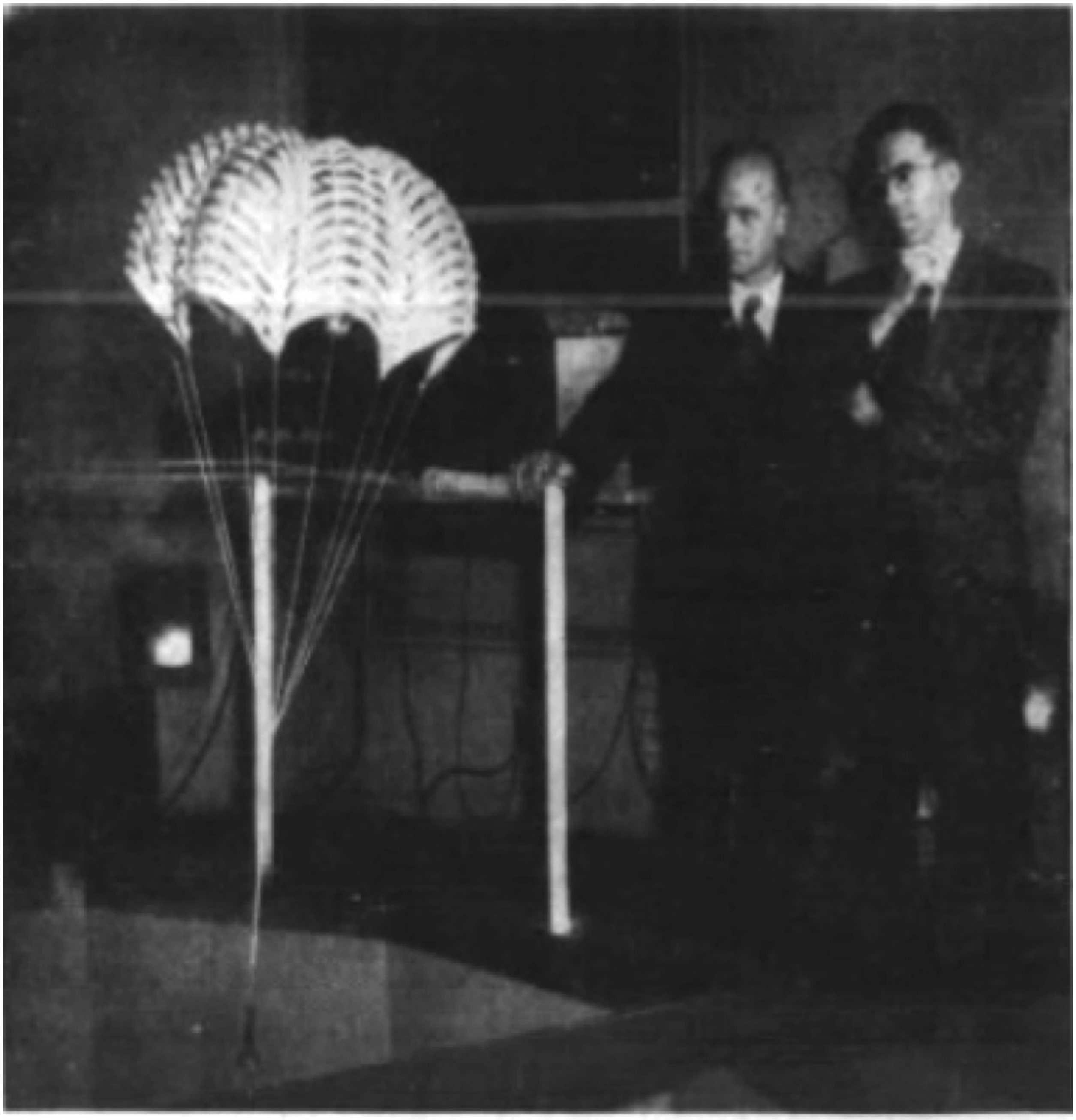
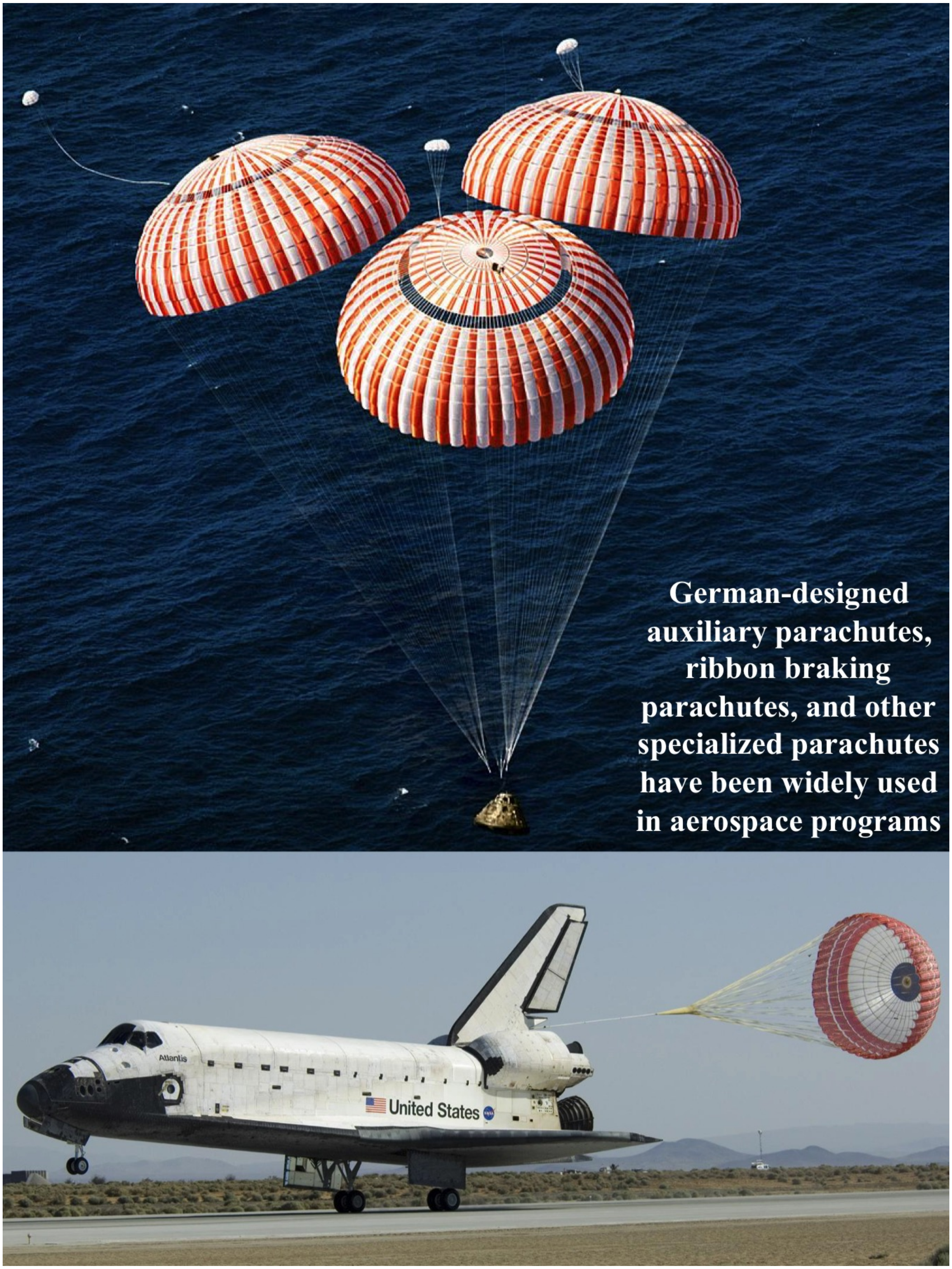
Figure 9.115: Demonstration of a ribbon braking parachute deployed by a German aircraft, ca. 1940 [Deutsches Museum Archive, photo 39529].

Helmut Heinrich (18??–19??) **Theodor Knacke (1910–2001)**



Dr. Helmut Heinrich, left, and Dr. Theodor Knacke, right, demonstrate one model of German ribbon parachute in field wind tunnel.

Figure 9.116: Demonstration of a ribbon braking parachute at Wright Field, Ohio, by parachute designers Helmut Heinrich and Theodor Knacke in 1946 [*Dayton Daily News*, 8 December 1946, p. 55].



German-designed auxiliary parachutes, ribbon braking parachutes, and other specialized parachutes have been widely used in aerospace programs
Atlantis
United States

Figure 9.117: German-designed auxiliary parachutes, ribbon braking parachutes, and other specialized parachutes have been widely used in aerospace applications ranging from Apollo capsules to the Space Shuttle.

9.4.2 Ejection Seats

Whereas pilots could simply grab a parachute and jump out of a malfunctioning lower-speed airplane, the advent of jet aircraft meant that a pilot attempting to bail out might be pinned inside the opened cockpit or blown into the tail of the aircraft by the very high-speed airflow. Thus higher flying speeds necessitated the development of a method to automatically, forcefully, and safely propel the pilot and parachute away from a malfunctioning aircraft.

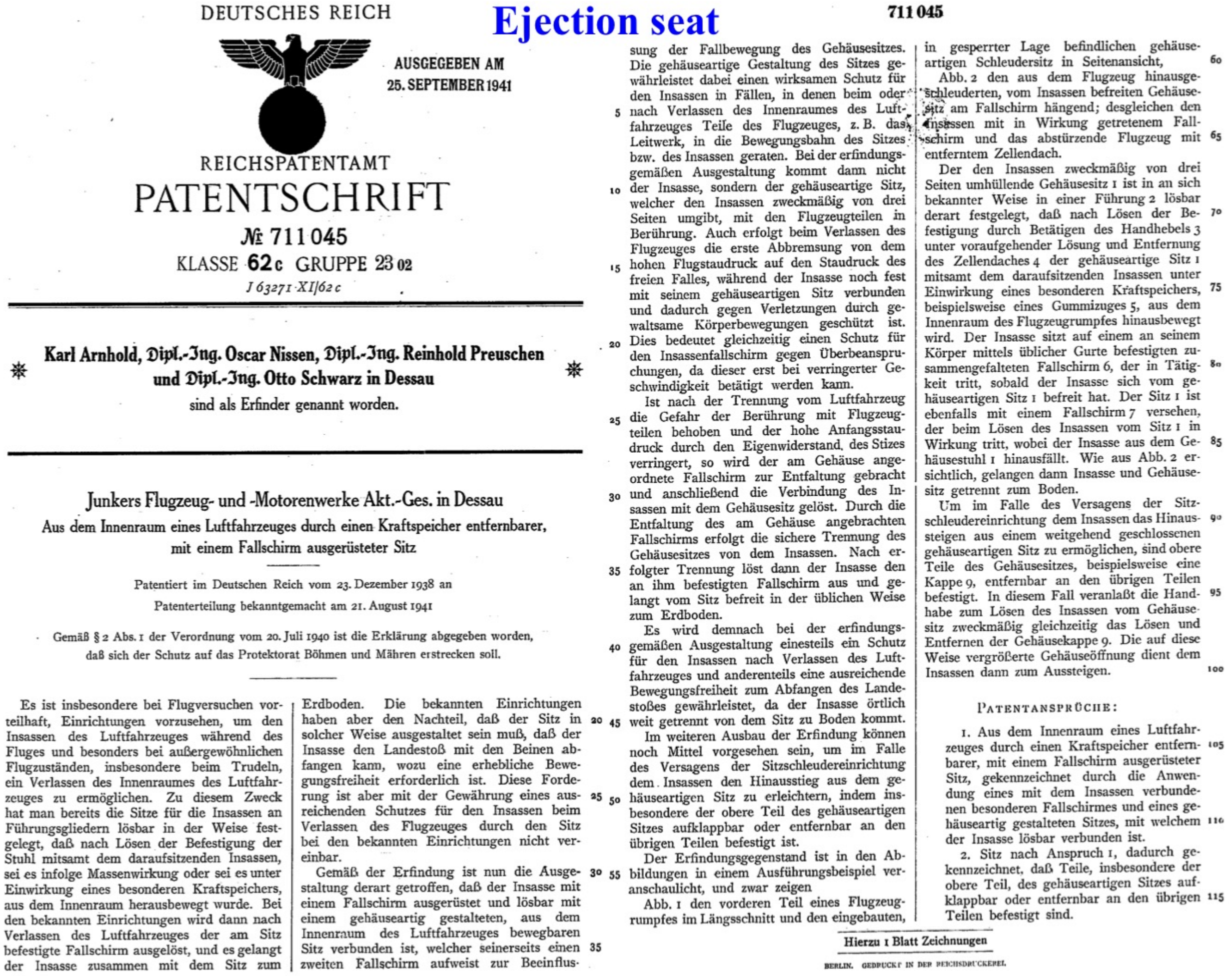
At the Junkers aircraft company, Karl Arnhold (German, 19??–19??), Oscar Nissen (German, 19??–19??), Reinhold Preuschen (German, 19??–19??), and Otto Schwarz (German, 19??–19??) invented and patented aircraft ejection seats in 1938; see Figs. 9.118–9.119. In 1943, Erich Dietz (German, 19??–19??) filed a further patent application on improvements to ejection seats, as illustrated in Fig. 9.120.

Under the leadership of Ernst Heinkel (German, 1888–1958), engineers at the Heinkel aircraft company also developed ejection seats and made them standard equipment on a number of wartime aircraft. Figure 9.121 shows an ejection seat for a Heinkel 162 jet fighter, as well as an ejection seat in action in 1941.

After the war, the Junkers and Heinkel ejection seat technology was eagerly adopted by other countries, and such ejection seats have been used worldwide ever since.

In September 1945, R. P. Linstead and T. J. Betts, the British and American chairs of the Combined Intelligence Objectives Subcommittee (CIOS), listed a number of important German innovations for ejection seats and parachutes [AFHRA A5186 electronic version pp. 904–1026, Ch. 4, pp. 58–59]:

> The field of German aero-medical research was the subject of energetic investigation by United States and British specialists. The emergency oxygen bail-out system employed by the Luftwaffe in high altitude flying was regarded as of particular interest. This system permitted the use of the same oxygen mask by the pilot after leaving the plane. The device consisted of eight tubular bottles of oxygen connected in series by means of high pressure tubing. A three-way switch was employed which provided for normal supply, automatic disconnection prior to bail-out, and switching to the bail-out or emergency supply prior to parachute descent. As a result of this method, delays and complications arising from the necessity of changing masks prior to leaving the plane are eliminated.
>
> The Germans had developed ejection seats to permit pilots to leave high speed aircraft without injury. This equipment operated with a cordite charge which expelled the pilot from the cockpit so that his body was prevented from coming in contact with the tail surface or vertical fin of the plane.
>
> Much information was obtained concerning new types of parachutes developed by the enemy. These types included the non-pendulating parachute which was designed to equalize air turbulence on either side of the 'chute and thus avoid the possibility of accidental collapse and failures which characterize conventional types. Another development was the shock-free parachute consisting of a small pilot 'chute of air permeable construction to cushion the initial shock of release prior to opening of the main 'chute. A third type of parachute is known as the ribbon 'chute; this design provided for variable air orifices so that the rate of descent can be controlled. [...]
>
> Samples of froth clothing were obtained, i.e., flying clothing, treated with a chemical compound which generated heat by chemical reaction when placed in contact with cold water.



Ejection seat

DEUTSCHES REICH

AUSGEGEBEN AM
25. SEPTEMBER 1941

REICHSPATENTAMT

PATENTSCHRIFT

№ 711 045

KLASSE **62c** GRUPPE 23 02

J 63271 XI/62c

**Karl Arnhold, Dipl.-Ing. Oscar Nissen, Dipl.-Ing. Reinhold Preuschen
und Dipl.-Ing. Otto Schwarz in Dessau**
sind als Erfinder genannt worden.

Junkers Flugzeug- und -Motorenwerke Akt.-Ges. in Dessau
Aus dem Innenraum eines Luftfahrzeuges durch einen Kraftspeicher entfernbarer,
mit einem Fallschirm ausgerüsteter Sitz

Patentiert im Deutschen Reich vom 23. Dezember 1938 an

Patenterteilung bekanntgemacht am 21. August 1941

Gemäß § 2 Abs. 1 der Verordnung vom 20. Juli 1940 ist die Erklärung abgegeben worden, daß sich der Schutz auf das Protektorat Böhmen und Mähren erstrecken soll.

Es ist insbesondere bei Flugversuchen vorteilhaft, Einrichtungen vorzusehen, um den Insassen des Luftfahrzeuges während des Fluges und besonders bei außergewöhnlichen Flugzuständen, insbesondere beim Trudeln, ein Verlassen des Innenraumes des Luftfahrzeuges zu ermöglichen. Zu diesem Zweck hat man bereits die Sitze für die Insassen an Führungsgliedern lösbar in der Weise festgelegt, daß nach Lösen der Befestigung der Stuhl mitsamt dem daraufsitzenden Insassen, sei es infolge Massenwirkung oder sei es unter Einwirkung eines besonderen Kraftspeichers, aus dem Innenraum herausbewegt wurde. Bei den bekannten Einrichtungen wird dann nach Verlassen des Luftfahrzeuges der am Sitz befestigte Fallschirm ausgelöst, und es gelangt der Insasse zusammen mit dem Sitz zum Erdboden. Die bekannten Einrichtungen haben aber den Nachteil, daß der Sitz in solcher Weise ausgestaltet sein muß, daß der Insasse den Landestoß mit den Beinen abfangen kann, wozu eine erhebliche Bewegungsfreiheit erforderlich ist. Diese Forderung ist aber mit der Gewährung eines ausreichenden Schutzes für den Insassen beim Verlassen des Flugzeuges durch den Sitz bei den bekannten Einrichtungen nicht vereinbar.

Gemäß der Erfindung ist nun die Ausgestaltung derart getroffen, daß der Insasse mit einem Fallschirm ausgerüstet und lösbar mit einem gehäuseartig gestalteten, aus dem Innenraum des Luftfahrzeuges bewegbaren Sitz verbunden ist, welcher seinerseits einen zweiten Fallschirm aufweist zur Beeinflussung der Fallbewegung des Gehäusesitzes. Die gehäuseartige Gestaltung des Sitzes gewährleistet dabei einen wirksamen Schutz für den Insassen in Fällen, in denen beim oder nach Verlassen des Innenraumes des Luftfahrzeuges Teile des Flugzeuges, z. B. das Leitwerk, in die Bewegungsbahn des Sitzes bzw. des Insassen geraten. Bei der erfindungsgemäßen Ausgestaltung kommt dann nicht der Insasse, sondern der gehäuseartige Sitz, welcher den Insassen zweckmäßig von drei Seiten umgibt, mit den Flugzeugteilen in Berührung. Auch erfolgt beim Verlassen des Flugzeuges die erste Abbremsung von dem hohen Flugstaudruck auf den Staudruck des freien Falles, während der Insasse noch fest mit seinem gehäuseartigen Sitz verbunden und dadurch gegen Verletzungen durch gewaltsame Körperbewegungen geschützt ist. Dies bedeutet gleichzeitig einen Schutz für den Insassenfallschirm gegen Überbeanspruchungen, da dieser erst bei verringerter Geschwindigkeit betätigt werden kann.

Ist nach der Trennung vom Luftfahrzeug die Gefahr der Berührung mit Flugzeugteilen behoben und der hohe Anfangsstaudruck durch den Eigenwiderstand des Stizes verringert, so wird der am Gehäuse angeordnete Fallschirm zur Entfaltung gebracht und anschließend die Verbindung des Insassen mit dem Gehäusesitz gelöst. Durch die Entfaltung des am Gehäuse angebrachten Fallschirms erfolgt die sichere Trennung des Gehäusesitzes von dem Insassen. Nach erfolgter Trennung löst dann der Insasse den an ihm befestigten Fallschirm aus und gelangt vom Sitz befreit in der üblichen Weise zum Erdboden.

Es wird demnach bei der erfindungsgemäßen Ausgestaltung einesteils ein Schutz für den Insassen nach Verlassen des Luftfahrzeuges und anderenteils eine ausreichende Bewegungsfreiheit zum Abfangen des Landestoßes gewährleistet, da der Insasse örtlich weit getrennt von dem Sitz zu Boden kommt.

Im weiteren Ausbau der Erfindung können noch Mittel vorgesehen sein, um im Falle des Versagens der Sitzschleudereinrichtung dem Insassen den Hinausstieg aus dem gehäuseartigen Sitz zu erleichtern, indem insbesondere der obere Teil des gehäuseartigen Sitzes aufklappbar oder entfernbar an den übrigen Teilen befestigt ist.

Der Erfindungsgegenstand ist in den Abbildungen in einem Ausführungsbeispiel veranschaulicht, und zwar zeigen

Abb. 1 den vorderen Teil eines Flugzeugrumpfes im Längsschnitt und den eingebauten,

711 045

in gesperrter Lage befindlichen gehäuseartigen Schleudersitz in Seitenansicht,

Abb. 2 den aus dem Flugzeug hinausgeschleuderten, vom Insassen befreiten Gehäusesitz am Fallschirm hängend; desgleichen den Insassen mit in Wirkung getretenem Fallschirm und das abstürzende Flugzeug mit entferntem Zellendach.

Der den Insassen zweckmäßig von drei Seiten umhüllende Gehäusesitz 1 ist in an sich bekannter Weise in einer Führung 2 lösbar derart festgelegt, daß nach Lösen der Befestigung durch Betätigen des Handhebels 3 unter voraufgehender Lösung und Entfernung des Zellendaches 4 der gehäuseartige Sitz 1 mitsamt dem daraufsitzenden Insassen unter Einwirkung eines besonderen Kraftspeichers, beispielsweise eines Gummizuges 5, aus dem Innenraum des Flugzeugrumpfes hinausbewegt wird. Der Insasse sitzt auf einem an seinem Körper mittels üblicher Gurte befestigten zusammengefalteten Fallschirm 6, der in Tätigkeit tritt, sobald der Insasse sich vom gehäuseartigen Sitz 1 befreit hat. Der Sitz 1 ist ebenfalls mit einem Fallschirm 7 versehen, der beim Lösen des Insassen vom Sitz 1 in Wirkung tritt, wobei der Insasse aus dem Gehäusestuhl 1 hinausfällt. Wie aus Abb. 2 ersichtlich, gelangen dann Insasse und Gehäusesitz getrennt zum Boden.

Um im Falle des Versagens der Sitzschleudereinrichtung dem Insassen das Hinaussteigen aus einem weitgehend geschlossenen gehäuseartigen Sitz zu ermöglichen, sind obere Teile des Gehäusesitzes, beispielsweise eine Kappe 9, entfernbar an den übrigen Teilen befestigt. In diesem Fall veranlaßt die Handhabe zum Lösen des Insassen vom Gehäusesitz zweckmäßig gleichzeitig das Lösen und Entfernen der Gehäusekappe 9. Die auf diese Weise vergrößerte Gehäuseöffnung dient dem Insassen dann zum Aussteigen.

PATENTANSPRÜCHE:

1. Aus dem Innenraum eines Luftfahrzeuges durch einen Kraftspeicher entfernbarer, mit einem Fallschirm ausgerüsteter Sitz, gekennzeichnet durch die Anwendung eines mit dem Insassen verbundenen besonderen Fallschirmes und eines gehäuseartig gestalteten Sitzes, mit welchem der Insasse lösbar verbunden ist.

2. Sitz nach Anspruch 1, dadurch gekennzeichnet, daß Teile, insbesondere der obere Teil, des gehäuseartigen Sitzes aufklappbar oder entfernbar an den übrigen Teilen befestigt sind.

Hierzu 1 Blatt Zeichnungen

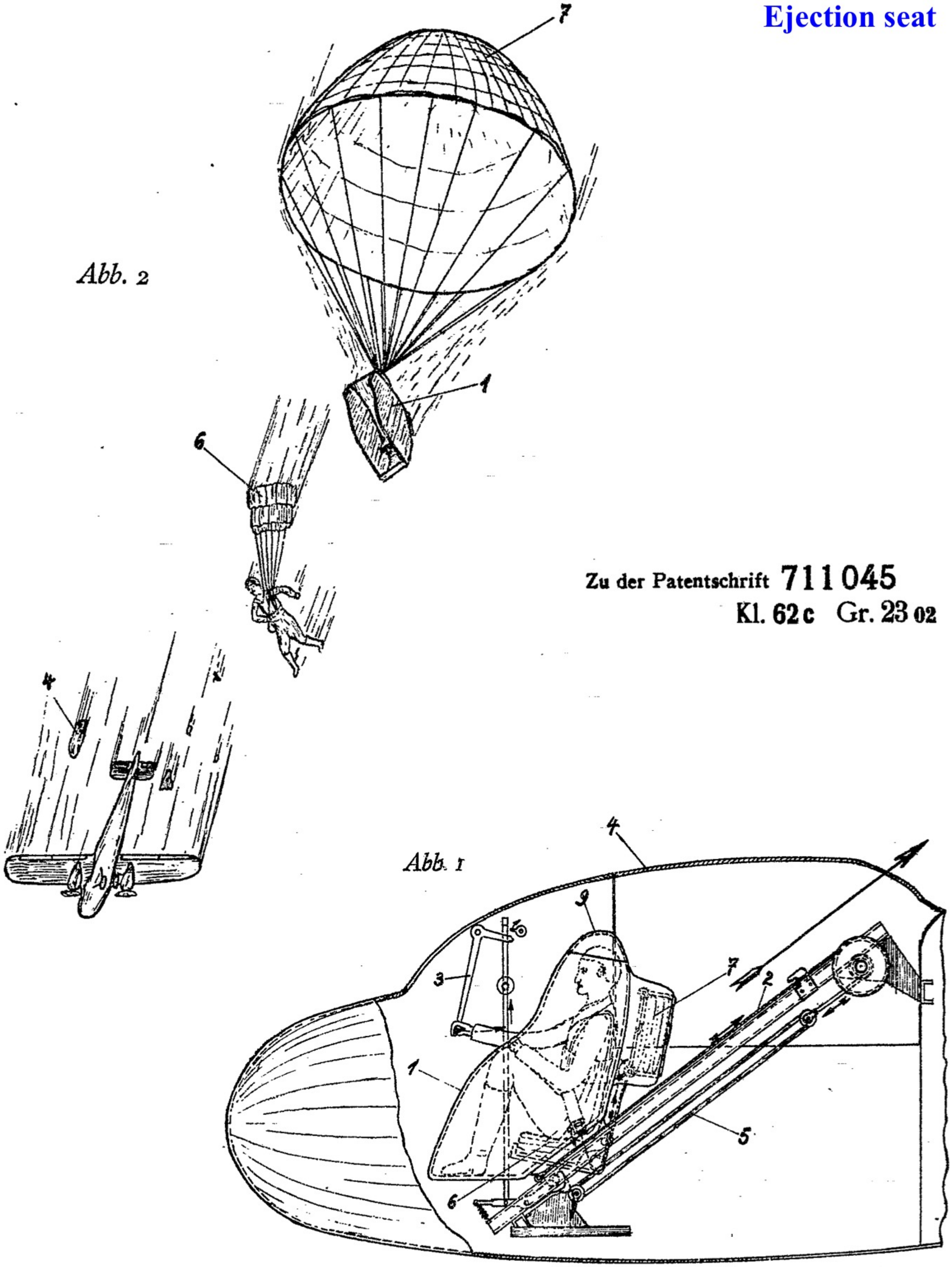
BERLIN. GEDRUCKT IN DER REICHSDRUCKEREI

Karl Arnhold (19??–19??) **Oscar Nissen (19??–19??)**

Reinhold Preuschen (19??–19??) **Otto Schwarz (19??–19??)**

Figure 9.118: Karl Arnhold, Oscar Nissen, Reinhold Preuschen, and Otto Schwarz at Junkers filed a patent application on aircraft ejection seats in 1938.

Ejection seat


7
Abb. 2
1
6
4
Zu der Patentschrift 711 045
Kl. 62c Gr. 23 02
Abb. 1
4
9
10
3
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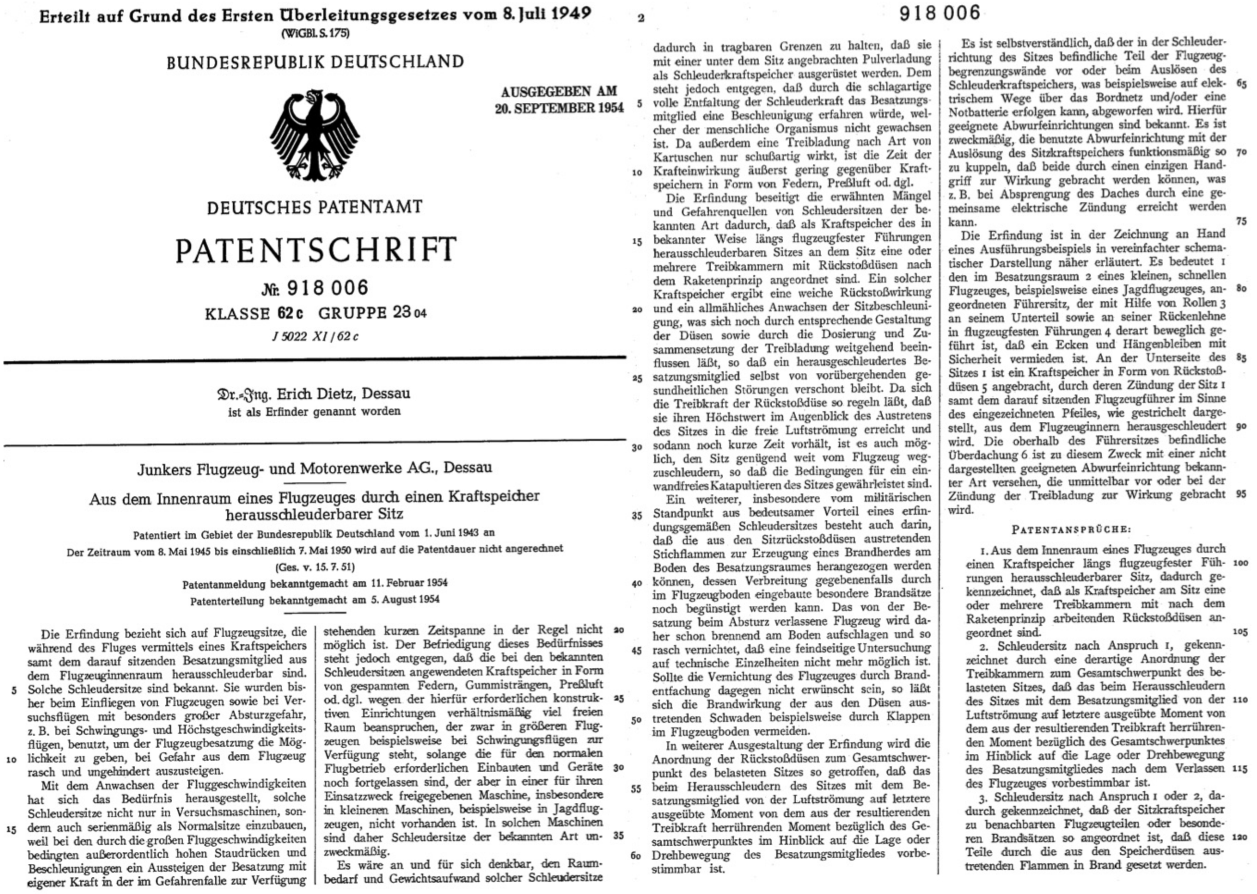
2
1
5
6

Figure 9.119: Karl Arnhold, Oscar Nissen, Reinhold Preuschen, and Otto Schwarz at Junkers filed a patent application on aircraft ejection seats in 1938.



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
20. SEPTEMBER 1954

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 918 006
KLASSE **62c** GRUPPE 23_{04}
J 5022 XI / 62 c

Dr.-Ing. Erich Dietz, Dessau
ist als Erfinder genannt worden

Junkers Flugzeug- und Motorenwerke AG., Dessau

Aus dem Innenraum eines Flugzeuges durch einen Kraftspeicher herausschleuderbarer Sitz

Patentiert im Gebiet der Bundesrepublik Deutschland vom 1. Juni 1943 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
(Ges. v. 15. 7. 51)
Patentanmeldung bekanntgemacht am 11. Februar 1954
Patenterteilung bekanntgemacht am 5. August 1954

Die Erfindung bezieht sich auf Flugzeugsitze, die während des Fluges vermittels eines Kraftspeichers samt dem darauf sitzenden Besatzungsmitglied aus dem Flugzeuginnenraum herausschleuderbar sind. Solche Schleudersitze sind bekannt. Sie wurden bisher beim Einfliegen von Flugzeugen sowie bei Versuchsflügen mit besonders großer Absturzgefahr, z. B. bei Schwingungs- und Höchstgeschwindigkeitsflügen, benutzt, um der Flugzeugbesatzung die Möglichkeit zu geben, bei Gefahr aus dem Flugzeug rasch und ungehindert auszusteigen.

Mit dem Anwachsen der Fluggeschwindigkeiten hat sich das Bedürfnis herausgestellt, solche Schleudersitze nicht nur in Versuchsmaschinen, sondern auch serienmäßig als Normalsitze einzubauen, weil bei den durch die großen Fluggeschwindigkeiten bedingten außerordentlich hohen Staudrücken und Beschleunigungen ein Aussteigen der Besatzung mit eigener Kraft in der im Gefahrenfalle zur Verfügung stehenden kurzen Zeitspanne in der Regel nicht möglich ist. Der Befriedigung dieses Bedürfnisses steht jedoch entgegen, daß die bei den bekannten Schleudersitzen angewendeten Kraftspeicher in Form von gespannten Federn, Gummisträngen, Preßluft od. dgl. wegen der hierfür erforderlichen konstruktiven Einrichtungen verhältnismäßig viel freien Raum beanspruchen, der zwar in größeren Flugzeugen beispielsweise bei Schwingungsflügen zur Verfügung steht, solange die für den normalen Flugbetrieb erforderlichen Einbauten und Geräte noch fortgelassen sind, der aber in einer für ihren Einsatzzweck freigegebenen Maschine, insbesondere in kleineren Maschinen, beispielsweise in Jagdflugzeugen, nicht vorhanden ist. In solchen Maschinen sind daher Schleudersitze der bekannten Art unzweckmäßig.

Es wäre an und für sich denkbar, den Raumbedarf und Gewichtsaufwand solcher Schleudersitze

2 918 006

dadurch in tragbaren Grenzen zu halten, daß sie mit einer unter dem Sitz angebrachten Pulverladung als Schleuderkraftspeicher ausgerüstet werden. Dem steht jedoch entgegen, daß durch die schlagartige volle Entfaltung der Schleuderkraft das Besatzungsmitglied eine Beschleunigung erfahren würde, welcher der menschliche Organismus nicht gewachsen ist. Da außerdem eine Treibladung nach Art von Kartuschen nur schußartig wirkt, ist die Zeit der Krafteinwirkung äußerst gering gegenüber Kraftspeichern in Form von Federn, Preßluft od. dgl.

Die Erfindung beseitigt die erwähnten Mängel und Gefahrenquellen von Schleudersitzen der bekannten Art dadurch, daß als Kraftspeicher des in bekannter Weise längs flugzeugfester Führungen herausschleuderbaren Sitzes an dem Sitz eine oder mehrere Treibkammern mit Rückstoßdüsen nach dem Raketenprinzip angeordnet sind. Ein solcher Kraftspeicher ergibt eine weiche Rückstoßwirkung und ein allmähliches Anwachsen der Sitzbeschleunigung, was sich noch durch entsprechende Gestaltung der Düsen sowie durch die Dosierung und Zusammensetzung der Treibladung weitgehend beeinflussen läßt, so daß ein herausgeschleudertes Besatzungsmitglied selbst von vorübergehenden gesundheitlichen Störungen verschont bleibt. Da sich die Treibkraft der Rückstoßdüse so regeln läßt, daß sie ihren Höchstwert im Augenblick des Austretens des Sitzes in die freie Luftströmung erreicht und sodann noch kurze Zeit vorhält, ist es auch möglich, den Sitz genügend weit vom Flugzeug wegzuschleudern, so daß die Bedingungen für ein einwandfreies Katapultieren des Sitzes gewährleistet sind.

Ein weiterer, insbesondere vom militärischen Standpunkt aus bedeutsamer Vorteil eines erfindungsgemäßen Schleudersitzes besteht auch darin, daß die aus den Sitzrückstoßdüsen austretenden Stichflammen zur Erzeugung eines Brandherdes am Boden des Besatzungsraumes herangezogen werden können, dessen Verbreitung gegebenenfalls durch im Flugzeugboden eingebaute besondere Brandsätze noch begünstigt werden kann. Das von der Besatzung beim Absturz verlassene Flugzeug wird daher schon brennend am Boden aufschlagen und so rasch vernichtet, daß eine feindseitige Untersuchung auf technische Einzelheiten nicht mehr möglich ist. Sollte die Vernichtung des Flugzeuges durch Brandentfachung dagegen nicht erwünscht sein, so läßt sich die Brandwirkung der aus den Düsen austretenden Schwaden beispielsweise durch Klappen im Flugzeugboden vermeiden.

In weiterer Ausgestaltung der Erfindung wird die Anordnung der Rückstoßdüsen zum Gesamtschwerpunkt des belasteten Sitzes so getroffen, daß das beim Herausschleudern des Sitzes mit dem Besatzungsmitglied von der Luftströmung auf letztere ausgeübte Moment von dem aus der resultierenden Treibkraft herrührenden Moment bezüglich des Gesamtschwerpunktes im Hinblick auf die Lage oder Drehbewegung des Besatzungsmitgliedes vorbestimmbar ist.

Es ist selbstverständlich, daß der in der Schleuderrichtung des Sitzes befindliche Teil der Flugzeugbegrenzungswände vor oder beim Auslösen des Schleuderkraftspeichers, was beispielsweise auf elektrischem Wege über das Bordnetz und/oder eine Notbatterie erfolgen kann, abgeworfen wird. Hierfür geeignete Abwurfeinrichtungen sind bekannt. Es ist zweckmäßig, die benutzte Abwurfeinrichtung mit der Auslösung des Sitzkraftspeichers funktionsmäßig so zu kuppeln, daß beide durch einen einzigen Handgriff zur Wirkung gebracht werden können, was z. B. bei Absprengung des Daches durch eine gemeinsame elektrische Zündung erreicht werden kann.

Die Erfindung ist in der Zeichnung an Hand eines Ausführungsbeispiels in vereinfachter schematischer Darstellung näher erläutert. Es bedeutet 1 den im Besatzungsraum 2 eines kleinen, schnellen Flugzeuges, beispielsweise eines Jagdflugzeuges, angeordneten Führersitz, der mit Hilfe von Rollen 3 an seinem Unterteil sowie an seiner Rückenlehne in flugzeugfesten Führungen 4 derart beweglich geführt ist, daß ein Ecken und Hängenbleiben mit Sicherheit vermieden ist. An der Unterseite des Sitzes 1 ist ein Kraftspeicher in Form von Rückstoßdüsen 5 angebracht, durch deren Zündung der Sitz 1 samt dem darauf sitzenden Flugzeugführer im Sinne des eingezeichneten Pfeiles, wie gestrichelt dargestellt, aus dem Flugzeuginnern herausgeschleudert wird. Die oberhalb des Führersitzes befindliche Überdachung 6 ist zu diesem Zweck mit einer nicht dargestellten geeigneten Abwurfeinrichtung bekannter Art versehen, die unmittelbar vor oder bei der Zündung der Treibladung zur Wirkung gebracht wird.

PATENTANSPRÜCHE:

1. Aus dem Innenraum eines Flugzeuges durch einen Kraftspeicher längs flugzeugfester Führungen herausschleuderbarer Sitz, dadurch gekennzeichnet, daß als Kraftspeicher am Sitz eine oder mehrere Treibkammern mit nach dem Raketenprinzip arbeitenden Rückstoßdüsen angeordnet sind.

2. Schleudersitz nach Anspruch 1, gekennzeichnet durch eine derartige Anordnung der Treibkammern zum Gesamtschwerpunkt des belasteten Sitzes, daß das beim Herausschleudern des Sitzes mit dem Besatzungsmitglied von der Luftströmung auf letztere ausgeübte Moment von dem aus der resultierenden Treibkraft herrührenden Moment bezüglich des Gesamtschwerpunktes im Hinblick auf die Lage oder Drehbewegung des Besatzungsmitgliedes nach dem Verlassen des Flugzeuges vorbestimmbar ist.

3. Schleudersitz nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß der Sitzkraftspeicher zu benachbarten Flugzeugteilen oder besonderen Brandsätzen so angeordnet ist, daß diese Teile durch die aus den Speicherdüsen austretenden Flammen in Brand gesetzt werden.

Erich Dietz
(19??–19??)

Ejection seat

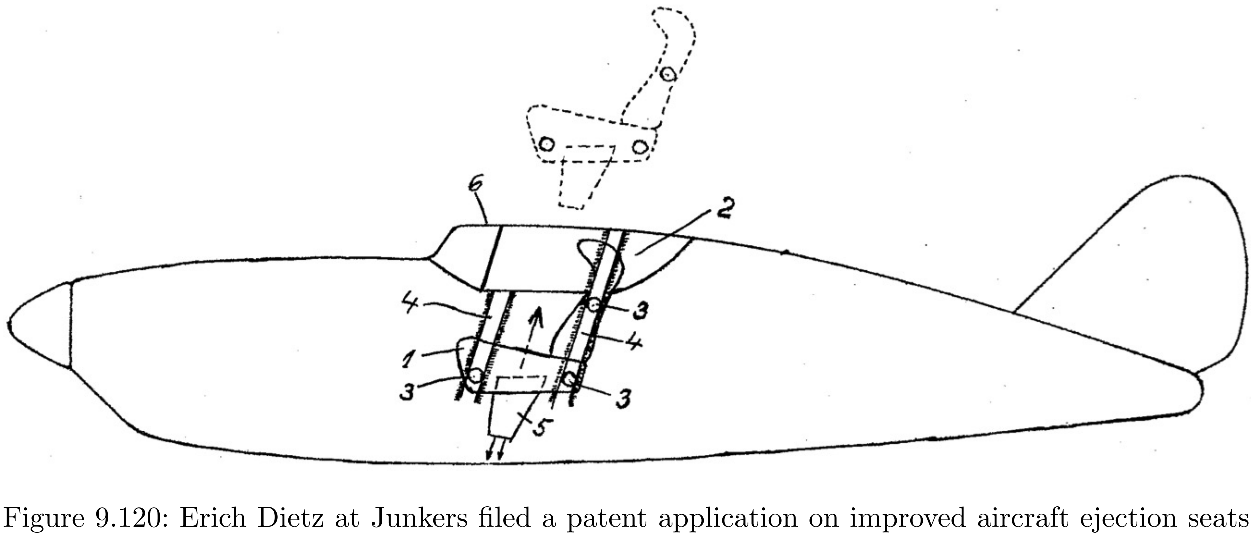
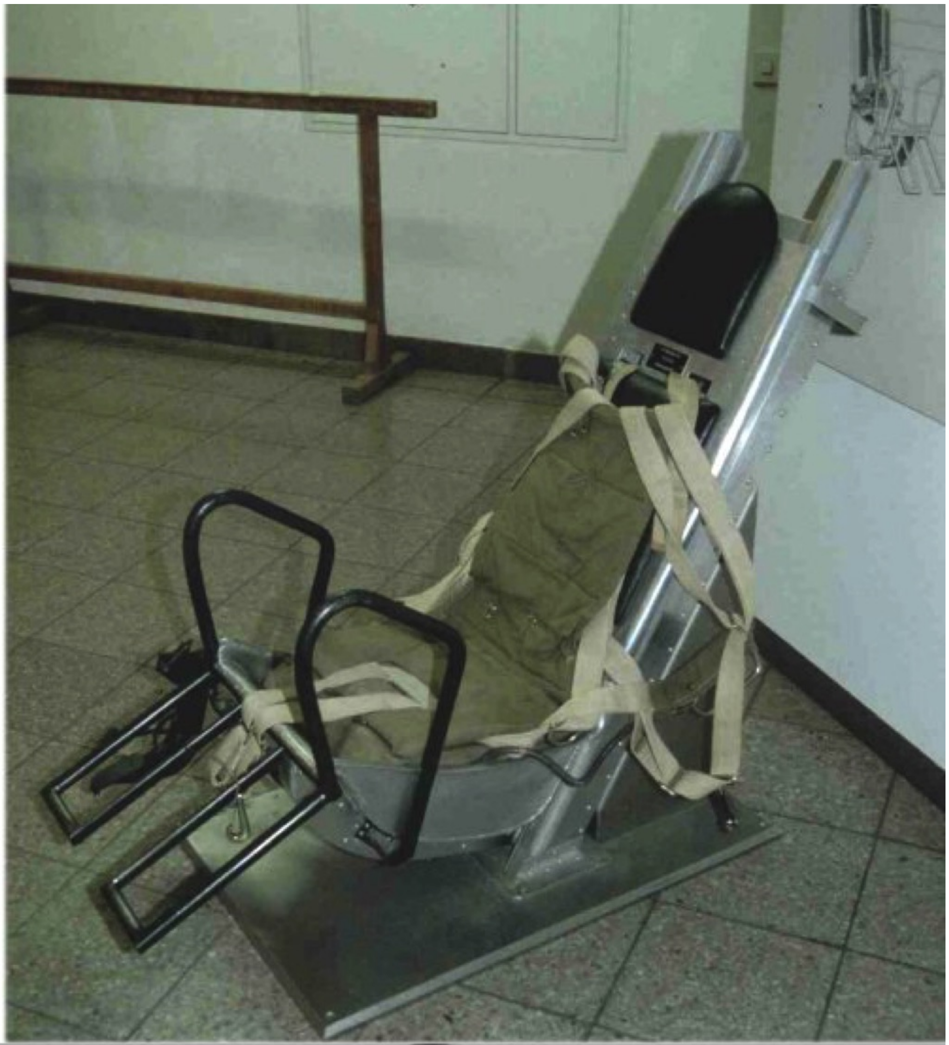


Figure 9.120: Erich Dietz at Junkers filed a patent application on improved aircraft ejection seats in 1943.

Ejection seat



Heinkel ejection seat for He 162 jet fighter

Ejection seat in action (1941)

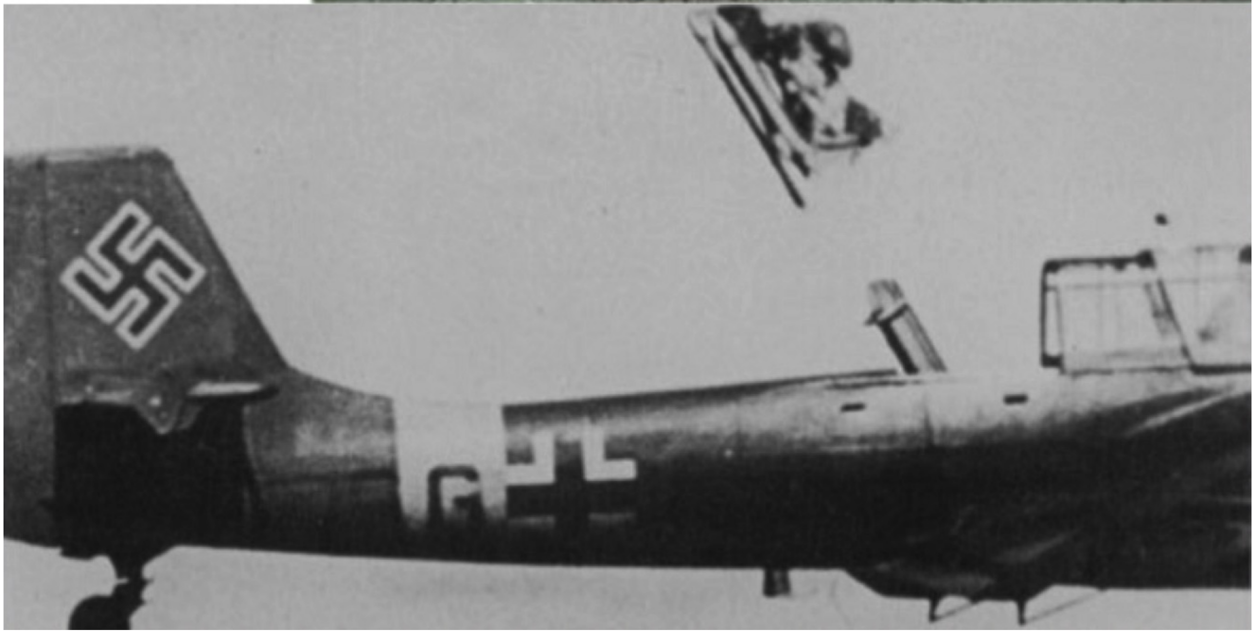


Figure 9.121: Under the leadership of Ernst Heinkel, engineers at the Heinkel aircraft company also developed ejection seats. Above: an ejection seat for a Heinkel He 162 jet fighter. Below: an ejection seat in action in 1941.

9.5 Helicopters

German-speaking creators dominated the development of helicopters. They labored in the late nineteenth and early twentieth centuries to develop proto-helicopters, finally produced the world's first fully functional helicopters in 1936, mass-produced and fielded state-of-the-art helicopters during World War II, and played critical roles in the worldwide helicopter industry after the war.[10]

This section covers:

9.5.1. Proto-helicopters and autogyros

9.5.2. Henrich Focke's helicopter team

9.5.3. Anton Flettner's helicopter team

9.5.4. Friedrich von Doblhoff's helicopter team

9.5.5. Backpack helicopters

9.5.6. Electric helicopters

9.5.7. Transfer of helicopter technologies to other countries

9.5.1 Proto-Helicopters and Autogyros

The general idea of helicopters had been around since at least Leonardo da Vinci's designs for a cloth aerial screw, but the practical implementation of that idea was long hindered by two challenges: (1) making the helicopter powerful enough to support its own weight, and (2) making the helicopter stable enough that it would not rapidly spin out of control if it did lift off. With the advent of sufficiently powerful engines by the late nineteenth century, engineers worldwide began trying to build a functional helicopter.

Helicopters behave quite differently than other aircraft. In particular, a helicopter's main rotor may be regarded as a rotating wing that is always moving forward and thus can generate lift even if the helicopter itself is motionless. This confers on helicopters both their advantages, such as their ability to hover or even fly backwards, and their disadvantages, such as their high fuel consumption and limited speed relative to fixed-wing aircraft.

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[10] See for example: Coats and Carbonel 2002; Hirschel et al. 2004; Jackson 2014; Johnston 1996; Leishman 2006; Myhra 2003; Nowarra 1990; NYT 1946-05-13 p. 4; BIOS Overall 8; CIOS XXXI-5; CIOS XXXI-11; FIAT 176; FIAT 177; FIAT 178; FIAT 604.

Figure 9.122 shows the airflow through a helicopter rotor. As shown in the upper half of the figure, the forces involved are less complex for purely vertical flight, and therefore it was less challenging for prototype helicopters to simply hover than for them to travel horizontally. To move forward or in another horizontal direction, a helicopter must tilt slightly toward the chosen direction, so that the rotor thrust has components causing both vertical lift and horizontal propulsion. Airflow to and from the rotor is then altered as shown in the lower half of the figure. The velocity of air far upstream from the rotor is inclined at an angle of attack α relative to the rotor.

Of course, a helicopter must have some method of counteracting the rotor torque so that the helicopter body will not spin wildly in the opposite direction from the rotor's rotation. Often a tail fin and tail rotor aimed to the side serve this purpose, though some helicopters simply avoid the problem by having two counter-rotating rotors on top.

The autogyro, another predecessor of true helicopters, should also be considered. This was an airplane with an unpowered, free-spinning rotor on top that was tilted slightly toward the rear of the craft. As the autogyro flew forward with its primary aircraft engine, the airflow spun the rotor, creating extra lift. This effect made the autogyro virtually stall proof at low forward speeds, although it could not hover completely motionless like a true helicopter with a powered rotor.

Almost all of the important early helicopter experimenters came from the greater German-speaking world. In general, prior to 1936, their early prototype helicopters could hover but not move forward without becoming unstable, and their closely related autogyro prototypes from the same period could move forward but not hover in place.

Early helicopter experimenters included:

- Hermann Ganswindt (German, 1856–1934) had many aerospace ideas that were far ahead of their time, designed a helicopter in 1884, and may have tested a prototype helicopter in 1901. See Fig. 9.123.

- Ján Bahýl' (Austro-Hungarian Slovak, 1856–1916) patented a helicopter design in 1895 and briefly flew a prototype in 1905, as shown in Fig. 9.124.

- István Petróczy (Hungarian, 1874–1957), Theodore von Kármán (Hugarian, 1881–1963), and Vilém Žurovec (Czech, 1883–1935) created proto-helicopters such as the electric-powered PKZ-1 (1918) and gasoline-powered PKZ-2 (1918). See Fig. 9.125.

- Emil(e) Berliner (German, 1851–1929) moved to the United States, where he built and tested prototype helicopters and autogyros 1909–1929, as illustrated in Fig. 9.126. Toward the end of his life, he was also assisted by one of his sons, Henry Berliner (1895–1970).

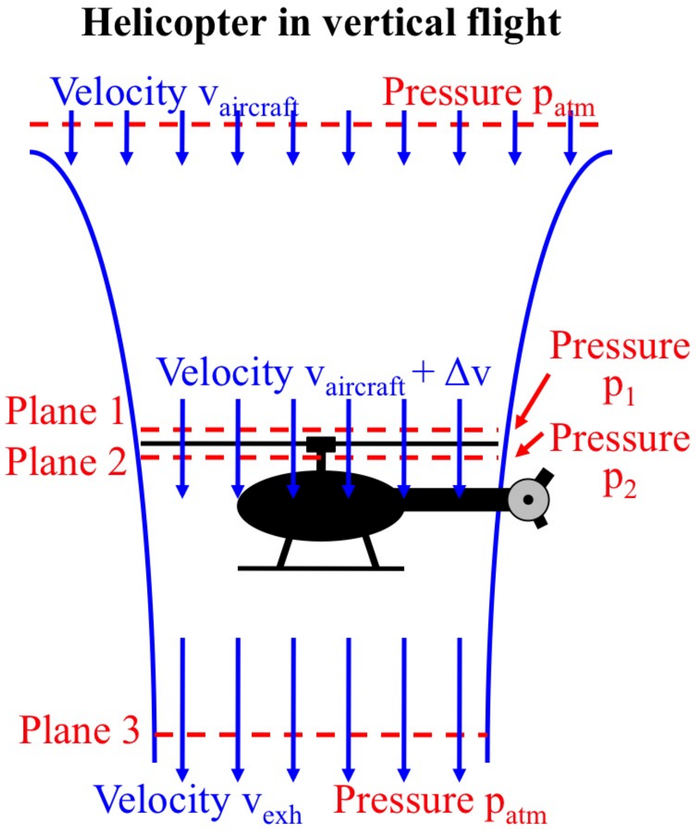
- Engelbert Zaschka (German, 1895–1955) built and patented a prototype helicopter, which he dubbed Rotary Wing, in 1927. See Fig. 9.127.

- Albert Gillis von Baumhauer (Dutch, 1891–1939) experimented with a helicopter prototype 1924–1930 (Fig. 9.128) but never could overcome its instability problems, which ultimately destroyed the prototype.

- In the 1920s and early 1930s, Oskár von Asboth (Hungarian, 1891–1960) built several helicopter prototypes that could hover but that became unstable when they tried to move. See Fig. 9.129.

- Raoul Hafner (Austrian, 1905–1980) built prototype autogyros in the 1920s and 1930s, first in Austria and then in the United Kingdom. While in Austria, he collaborated with Bruno Nagler (Austrian, 1901–1979) to create proto-helicopters such as the Hafner-Nagler R.I Revoplane (1929), shown in Fig. 9.130.

- Walter Rieseler (German, 1890–1937) built prototype autogyros and helicopters in the 1920s and 1930s but died in 1937, just as helicopter technology was finally coming to fruition. See Fig. 9.131.


Helicopter in vertical flight
Velocity $v_{aircraft}$
Pressure p_{atm}
Velocity $v_{aircraft} + \Delta v$
Plane 1
Plane 2
Pressure p_1
Pressure p_2
Plane 3
Velocity v_{exh}
Pressure p_{atm}

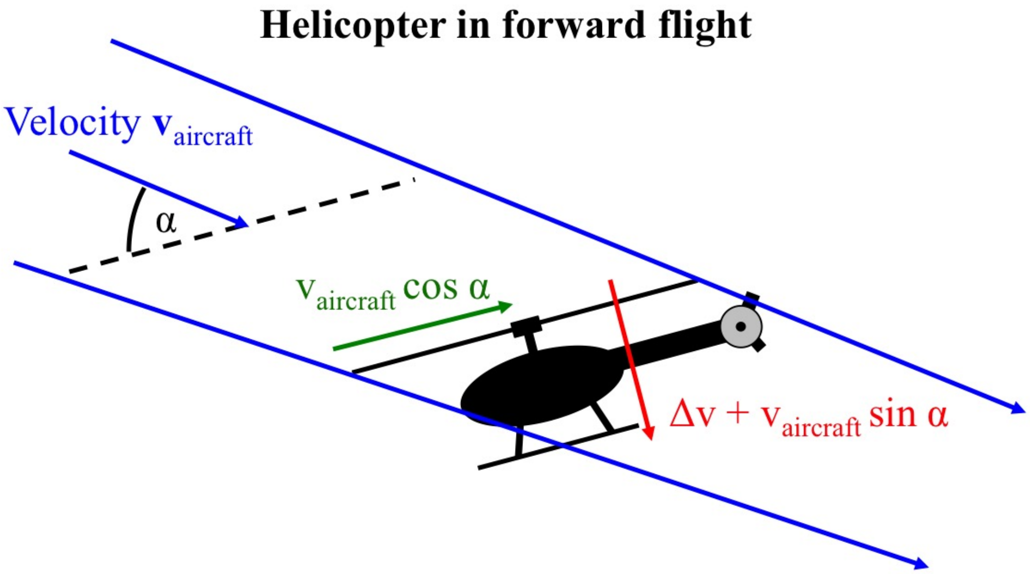
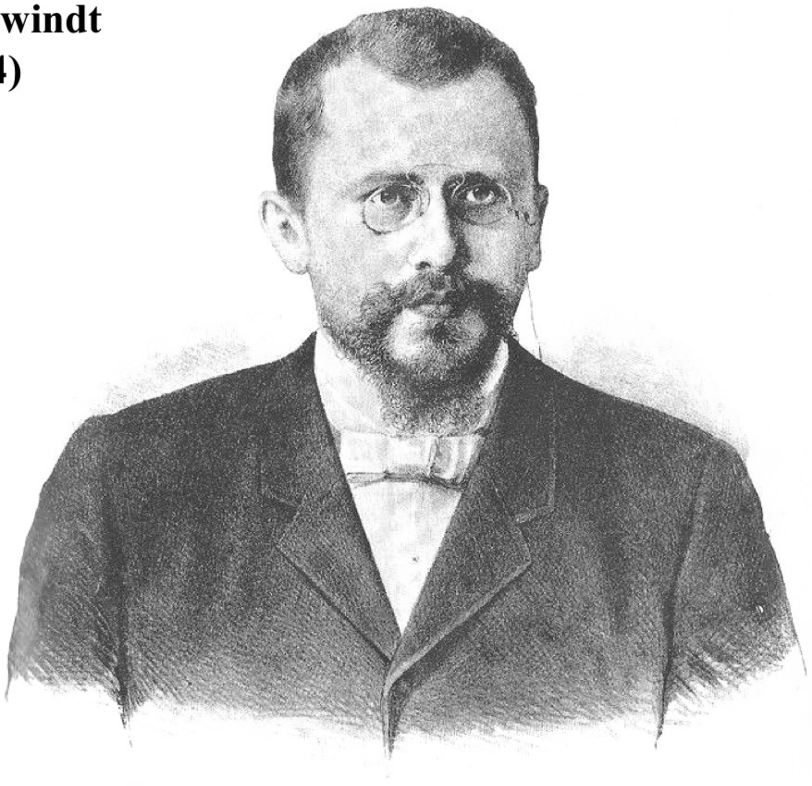

Helicopter in forward flight
Velocity $\mathbf{v}_{aircraft}$
α
$v_{aircraft} \cos \alpha$
$\Delta v + v_{aircraft} \sin \alpha$

Figure 9.122: Airflow through a helicopter rotor for a helicopter in vertical flight (above) and a helicopter in forward flight (below).

Hermann Ganswindt (1856–1934)



Ganswindt proto-helicopter design (1884)

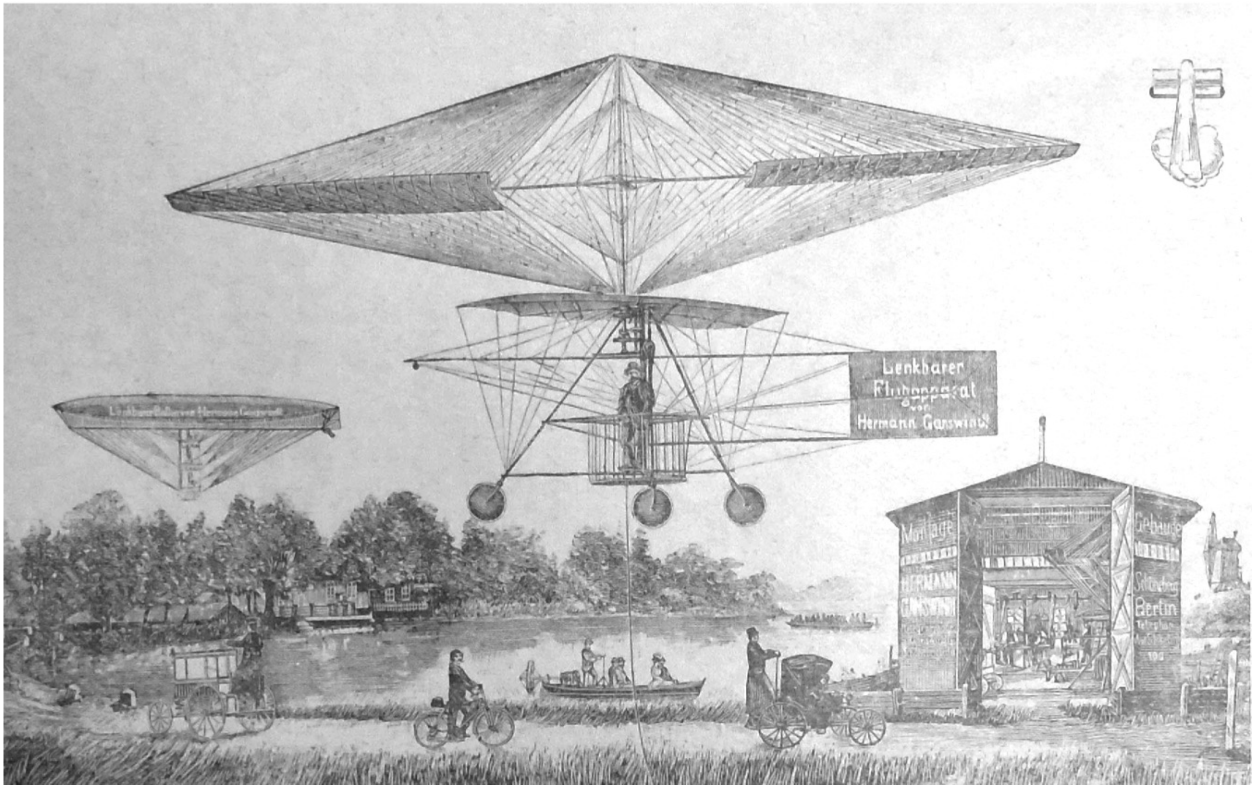

Lenkbarer
Flugapparat
von
Hermann Ganswindt
Montage
HERMANN
GANSWINDT
Gebäude
Schöneberg
Berlin
Telephon
100

Figure 9.123: Hermann Ganswindt designed proto-helicopters such as this 1884 design.

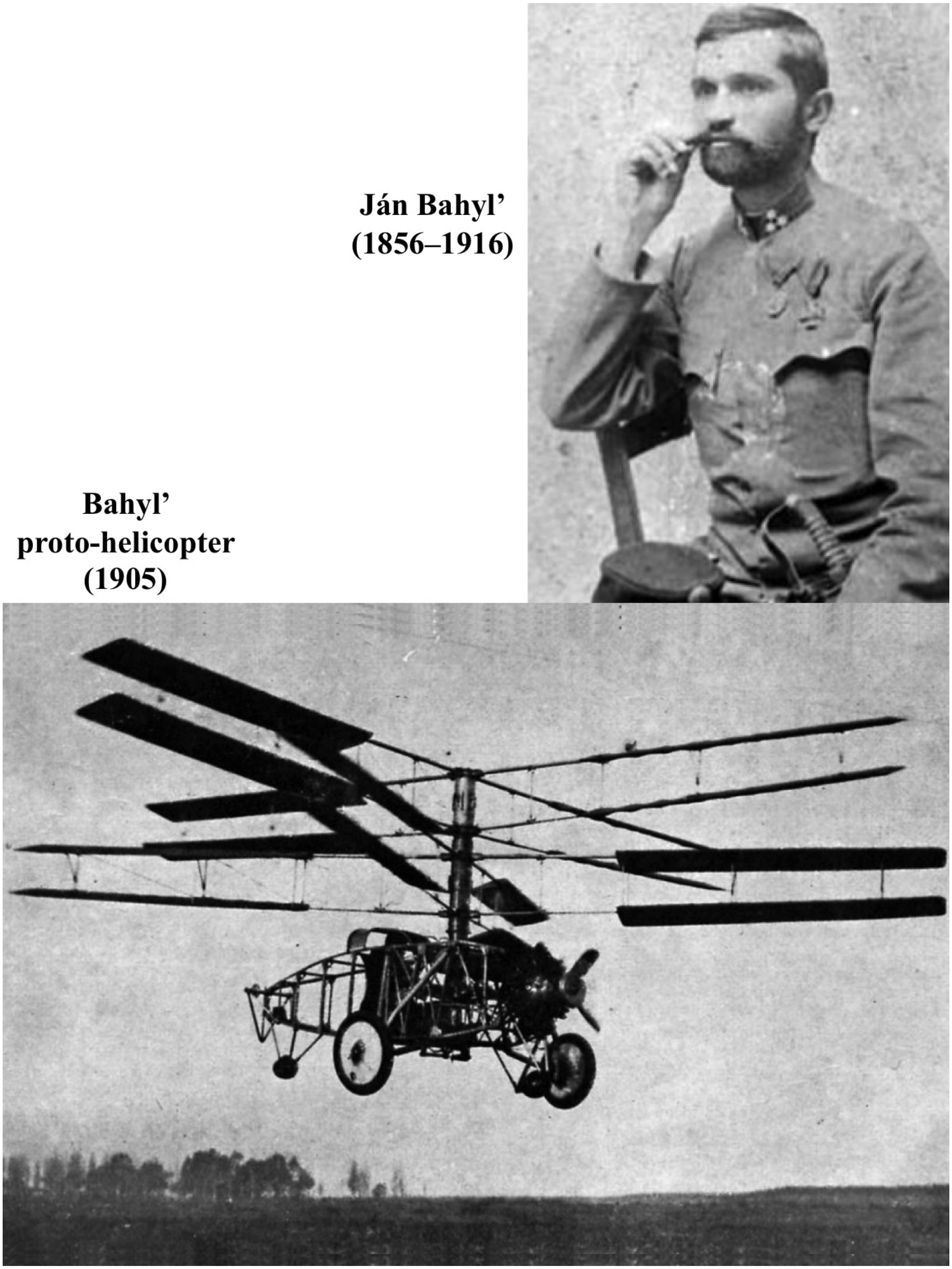

Ján Bahyl’
(1856–1916)
Bahyl’
proto-helicopter
(1905)

Figure 9.124: Ján Bahyl’ created proto-helicopters such as this 1905 prototype.

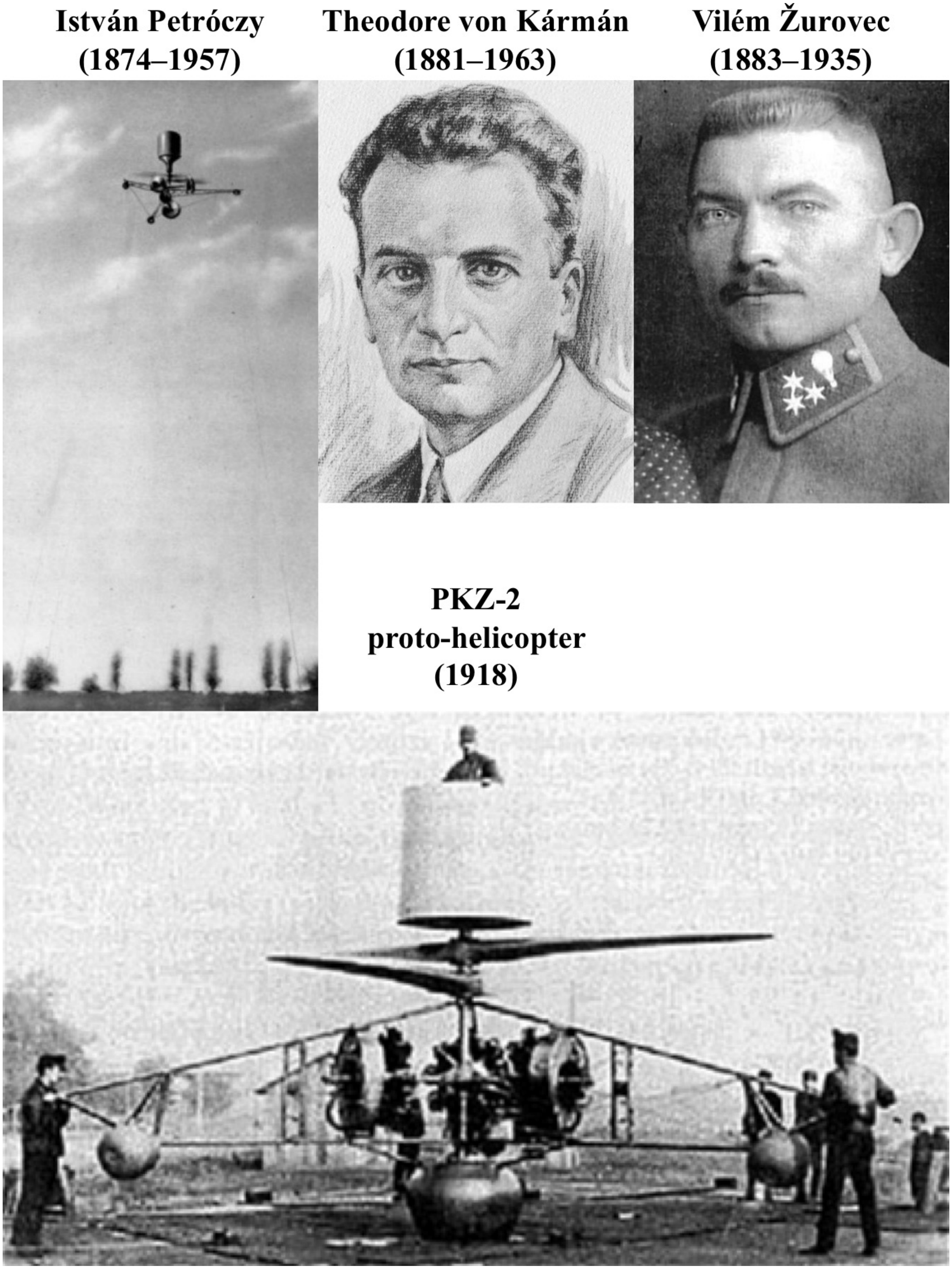
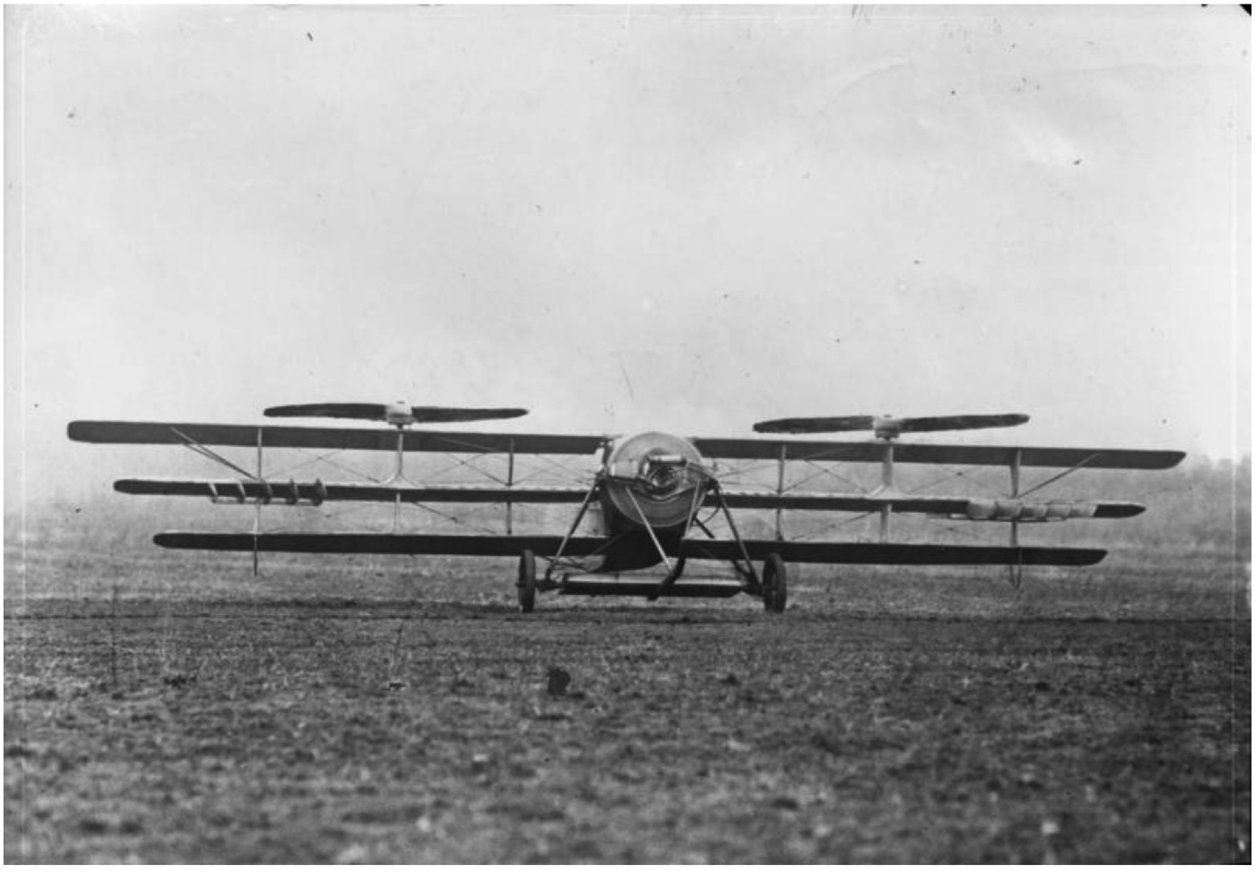

István Petróczy
(1874–1957)
Theodore von Kármán
(1881–1963)
Vilém Žurovec
(1883–1935)
PKZ-2
proto-helicopter
(1918)

Figure 9.125: István Petróczy, Theodore von Kármán, and Vilém Žurovec created proto-helicopters such as the electric-powered PKZ-1 (1918) and gasoline-powered PKZ-2 (1918).

Emil Berliner
(1851–1929)



Berliner
Helicopter No. 5
autogyro (1923)

Figure 9.126: Emil Berliner created proto-helicopters and autogyros such as the Berliner Helicopter No. 5 (1923).

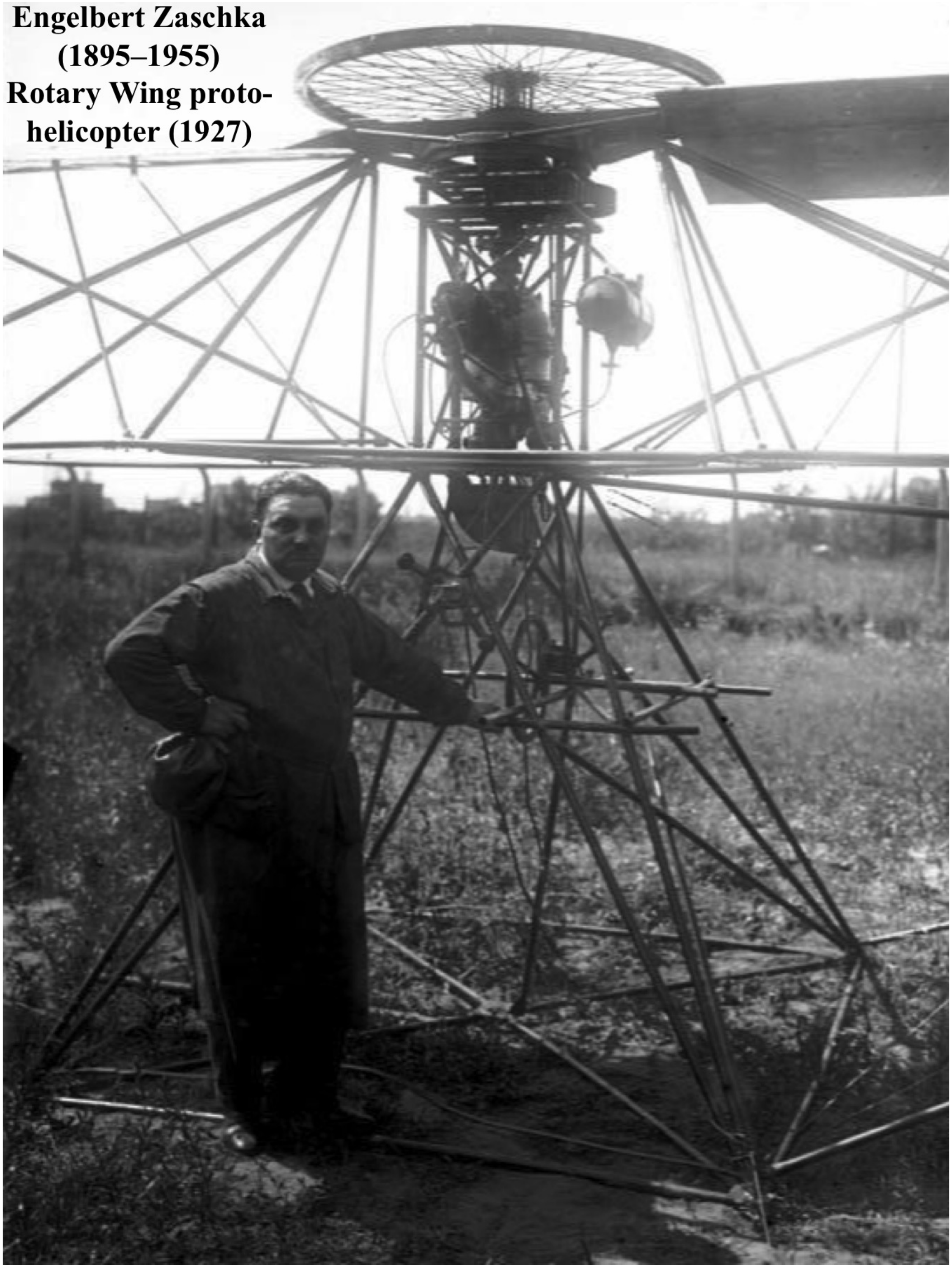

Engelbert Zaschka
(1895–1955)
Rotary Wing proto-
helicopter (1927)

Figure 9.127: Engelbert Zaschka created proto-helicopters such as the Rotary Wing (1927).

Albert Gillis
von Baumhauer
(1891–1939)

Von Baumhauer
proto-helicopter
(1924–1930)

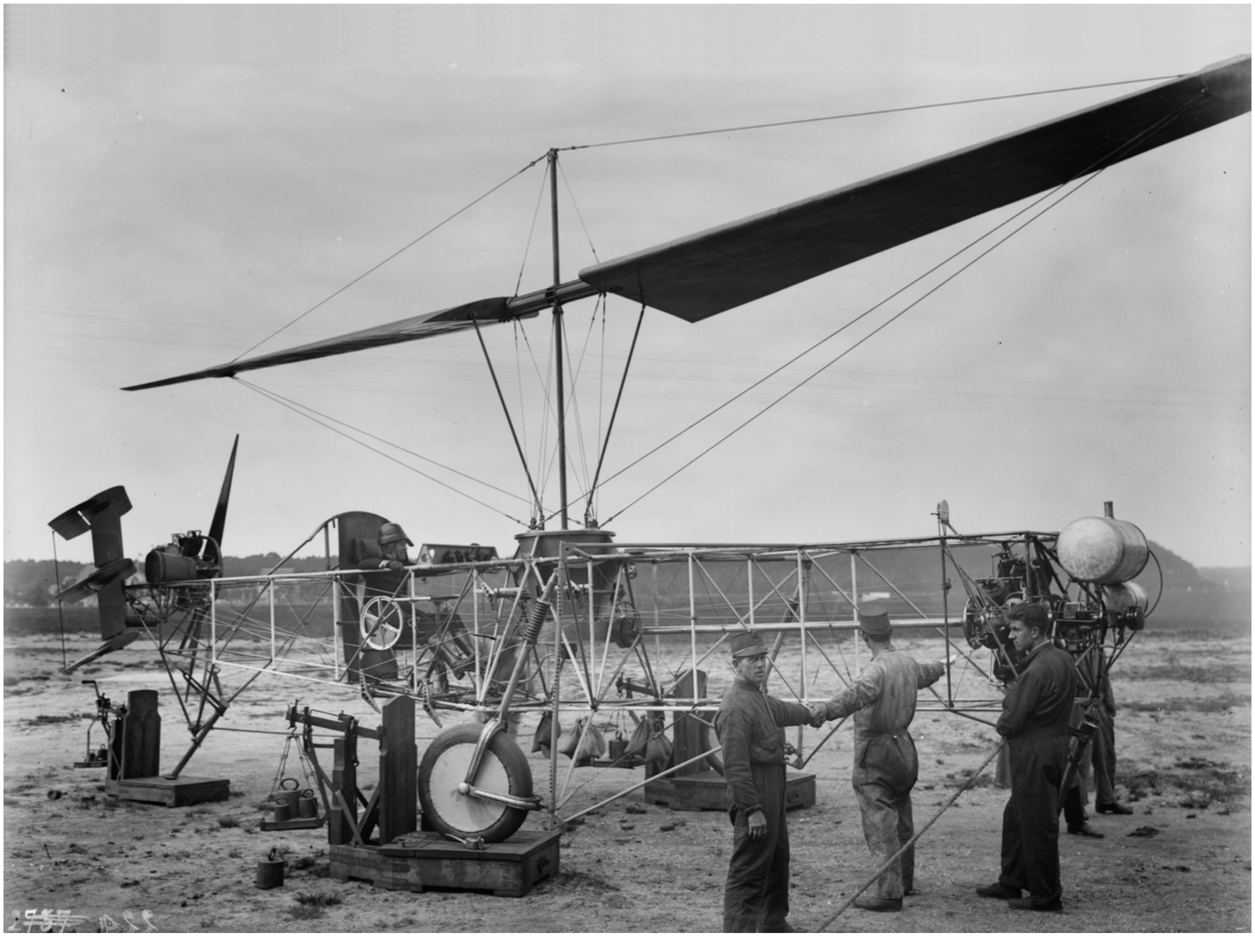


Figure 9.128: Albert Gillis von Baumhauer created proto-helicopters such as this 1925 test model.

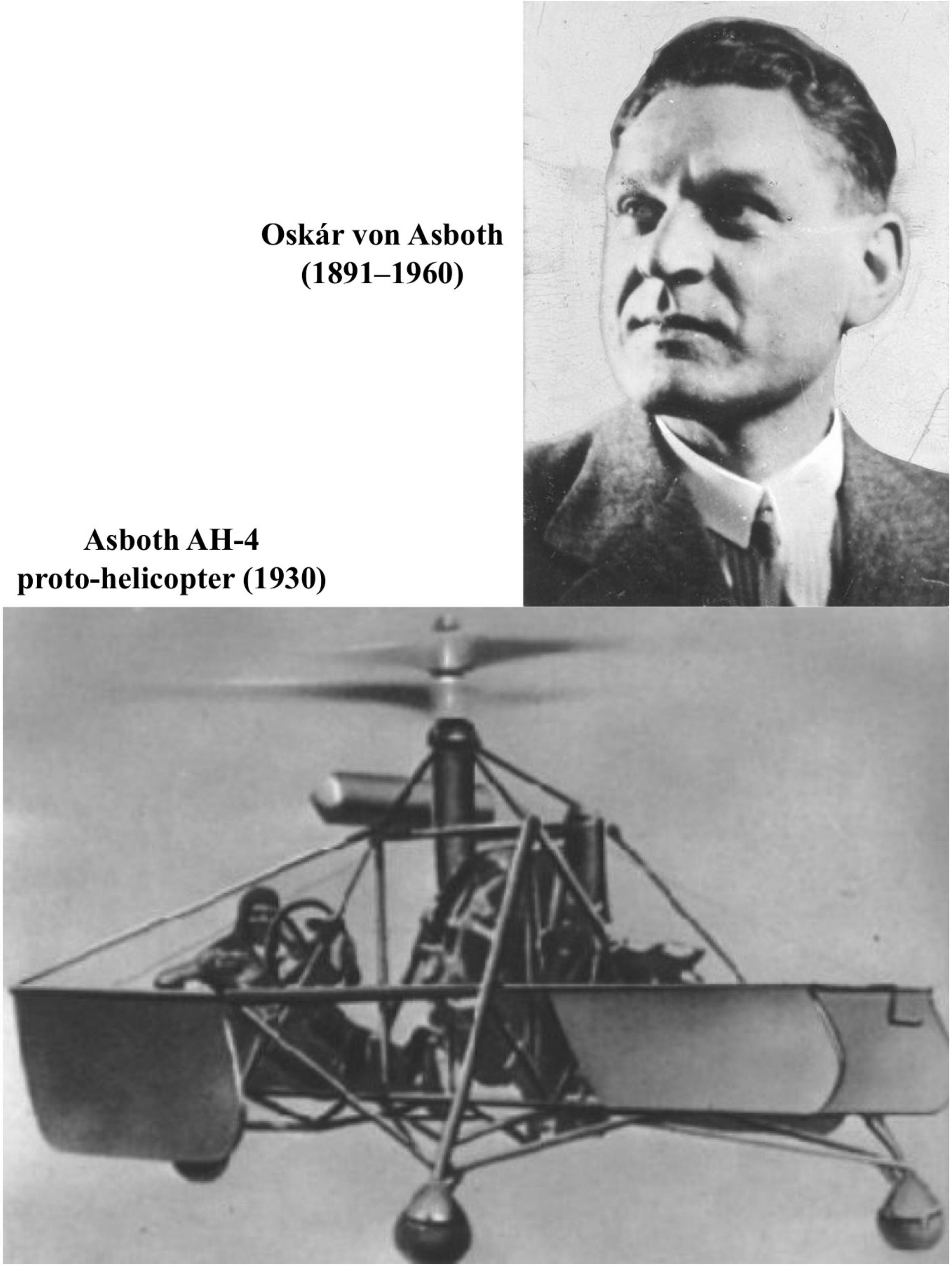
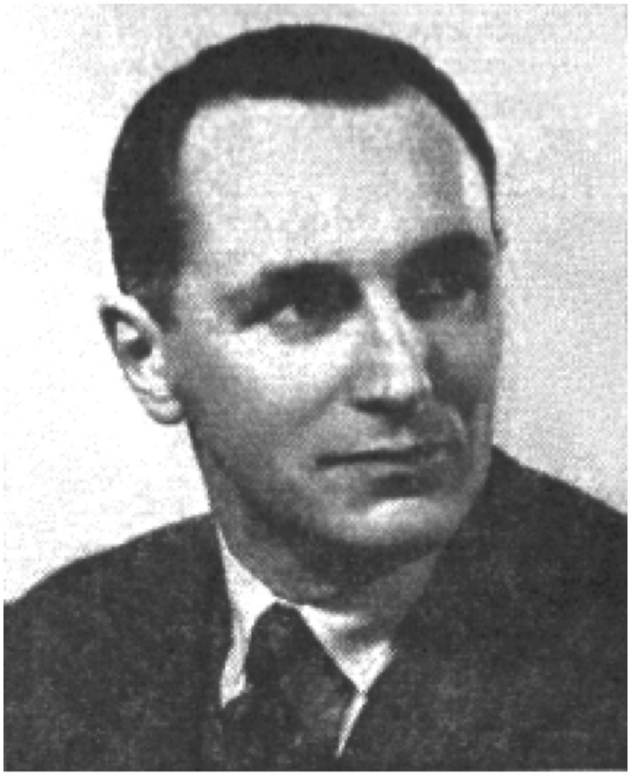

Oskár von Asboth
(1891–1960)
Asboth AH-4
proto-helicopter (1930)

Figure 9.129: Oskár von Asboth created proto-helicopters such as the Asboth AH-4 (1930).

Raoul Hafner (1905–1980) **Bruno Nagler (1901–1979)**



Hafner-Nagler R.I Revoplane proto-helicopter (1929)

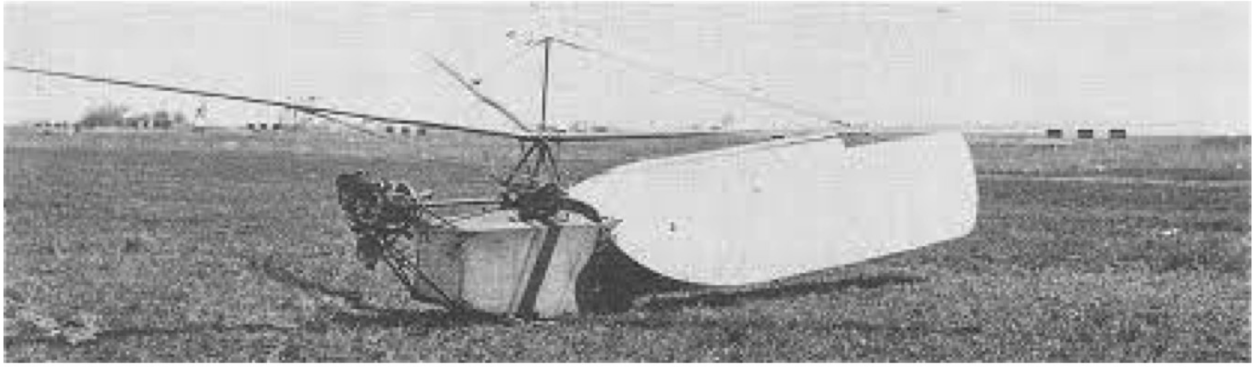


Figure 9.130: Raoul Hafner and Bruno Nagler created proto-helicopters such as the Hafner-Nagler R.I Revoplane (1929).

Walter Rieseler
(1890–1937)

Rieseler RI
proto-helicopter (1936)

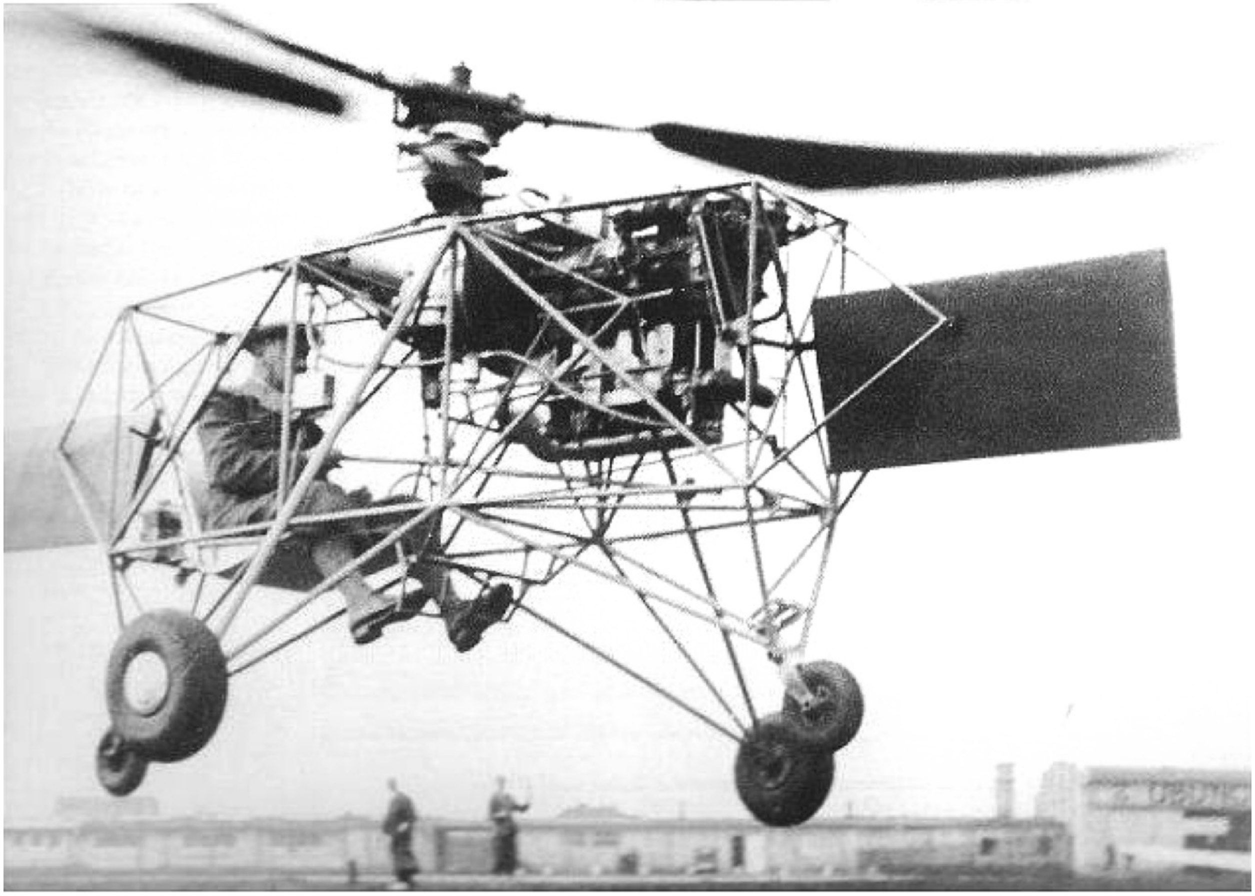


Figure 9.131: Walter Rieseler created proto-helicopters such as the Rieseler RI (1936).

In the 1930s and early 1940s, at least three German-speaking teams—led by Henrich Focke, Anton Flettner, and Friedrich von Doblhoff—finally developed fully functional large helicopters that were able to both hover and move in a stable fashion.

9.5.2 Henrich Focke's Helicopter Team

In 1936, Henrich Focke (German, 1890–1979) created the Focke-Wulf Fw 61, the world's first fully functional helicopter, as shown in Fig. 9.132.

His engineering team included:

- Harry Duda (German, 19??–19??, mechanical design and manufacturing)
- Hans Gerd Eyting (German, 19??–19??, mechanical design and manufacturing)
- Reinhold Gensel (German, 19??–19??, design)
- ?? Helme (German, 19??–19??, mechanical design and control)
- K. Jäckel (German, 19??–19??, aerodynamics and stability)
- Walter Just (German, 1909–1980, aerodynamics and stability)
- Paul Klages (German, 1899–1959, mechanical design and overall development)
- Heinrich Papenhausen (German, 19??–19??, statics and material testing)
- Friedrich Schaper (German, 19??–19??, statics)
- Erich Schweym (German, 19??–19??, aerodynamics and stability)
- Herbert Spranger (German, 19??–19??, development and aerodynamics)
- Enno Springmann (German, 19??–19??, mechanical design)

The Fw 61's development also involved several test pilots, the first of whom was Ewald Rohlfs (German, 1911–1984). In February 1938, the famous pilot Hanna Reitsch (German, 1912–1979, Fig. 9.217) demonstrated the Fw 61 in a crowded indoor sports arena in Berlin every day for three weeks to show the public how controllable and reliable the newly invented helicopter was (Fig. 9.132).

The Focke team subsequently developed other helicopters such as the Focke-Achgelis Fa 223 Drache (Dragon) twin-rotor cargo helicopter (Fig. 9.133). The Fa 223 was first flown in 1940, went into series production, and was used in the war.

In 1942, they designed the larger Focke-Achgelis Fa 284 heavy cargo helicopter (Fig. 9.134) and the four-rotor Fa 325 Krabbe heavy cargo helicopter (Fig. 9.135), but Allied attacks halted construction on those projects.

Focke's team produced a prototype of the Fa 269 tilt-rotor VTOL (vertical takeoff and landing) aircraft that was actually rather similar to the modern U.S. V-22 Osprey (Fig. 9.136). However, it was destroyed by Allied bombing in 1944.

In 1942, Focke and his team developed the novel and useful Focke-Achgelis Fa 330 Bachstelze rotor kite, which could be deployed and towed by a submarine (via a 150-meter cable) as an aerial lookout. (Fig. 9.137).

In 1939, Focke's team designed the Rochen, a winged VTOL aircraft with counter-rotating rotors in a ducted fan (Fig. 9.138). Focke's design lives on in examples such as the Sikorsky Cypher II or Dragon Warrior drone (2000).

They also designed the even more radical Focke-Wulf Triebflügel jet-powered rotary-wing VTOL aircraft (Figs. 9.139–9.140). It had wing-tip ramjets and was designed to take off and land vertically but fly horizontally. The Triebflügel was designed in 1944; it is unclear how far experimental work got by the end of the war.

Closely related to the Focke-Wulf Triebflügel were the Heinkel Wespe and Heinkel Lerche (Fig. 9.141 shows the Lerche; the Wespe was highly similar but somewhat smaller), which were also designed but apparently not completed during the war. After the war, the Triebflügel and Lerche/Wespe designs (and perhaps some of the engineers who worked on them?) directly inspired similar projects such as the Lockheed XFV Salmon (1954) and Convair XFY Pogo (1954). While the Lockheed XFV could fly vertically or horizontally but could not make the transition between those two modes, the Convair XFY was completely successful at demonstrating the feasibility of taking off vertically, transitioning from vertical to horizontal flight, flying horizontally, transitioning from horizontal to vertical flight, and landing vertically.

As shown in Fig. 9.142, the wartime German Lerche/Wespe- and Triebflügel-type designs (for aircraft that could take off and land on their tails but pitch over by 90^o to fly horizontally) still live on in modern unmanned aerial vehicles (UAVs) such as the University of Kansas XQ-138 drone and the Martin UAV V-BAT drone.

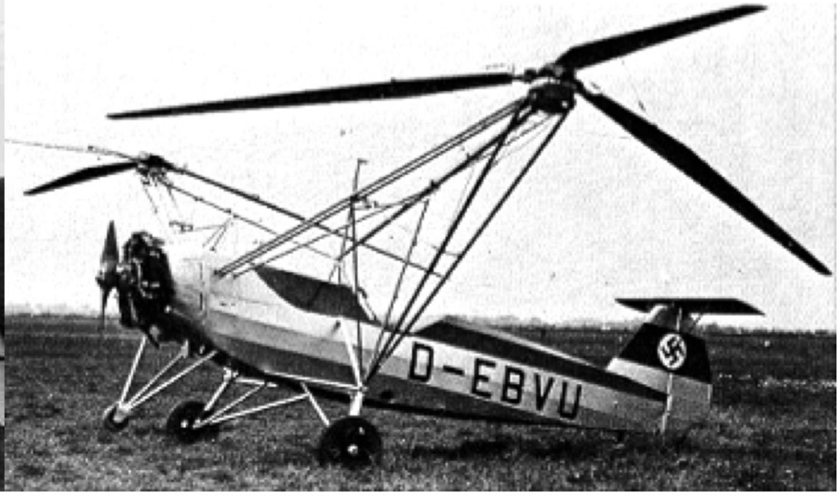
After the war, Henrich Focke and other members of his team produced helicopters for France, the Netherlands, Brazil, and West Germany.

Henrich Focke (1890–1979)

Walter Just (1909–1980)

Paul Klages (1899–1959)

Focke-Wulf Fw 61 helicopter, first flown in 1936



Fw 61 demonstrated in crowded indoor arena in Berlin by test pilot Hanna Reitsch (1938)

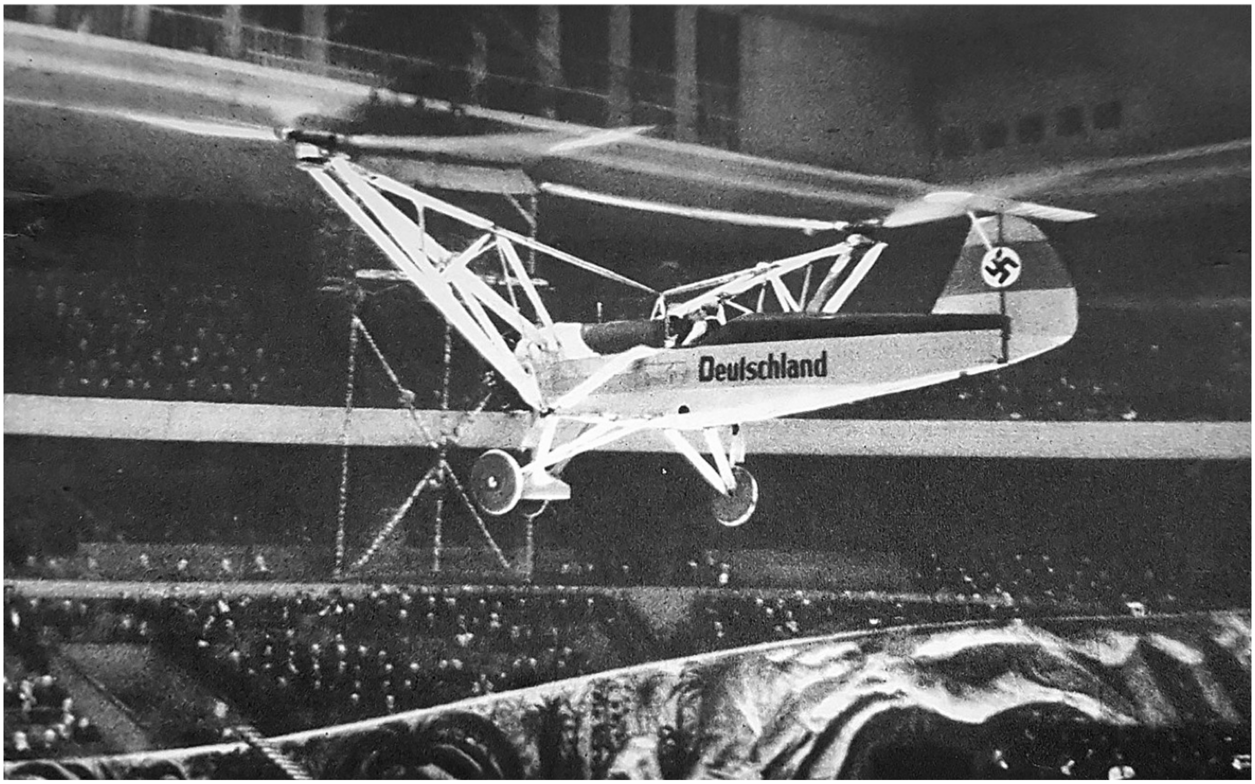


Figure 9.132: Henrich Focke and his team, including Walter Just and Paul Klages, created the world's first fully functional helicopter, the Focke-Wulf Fw 61, in 1936. In 1938, test pilot Hanna Reitsch (Fig. 9.217) demonstrated the Fw 61 in a crowded indoor arena in Berlin.

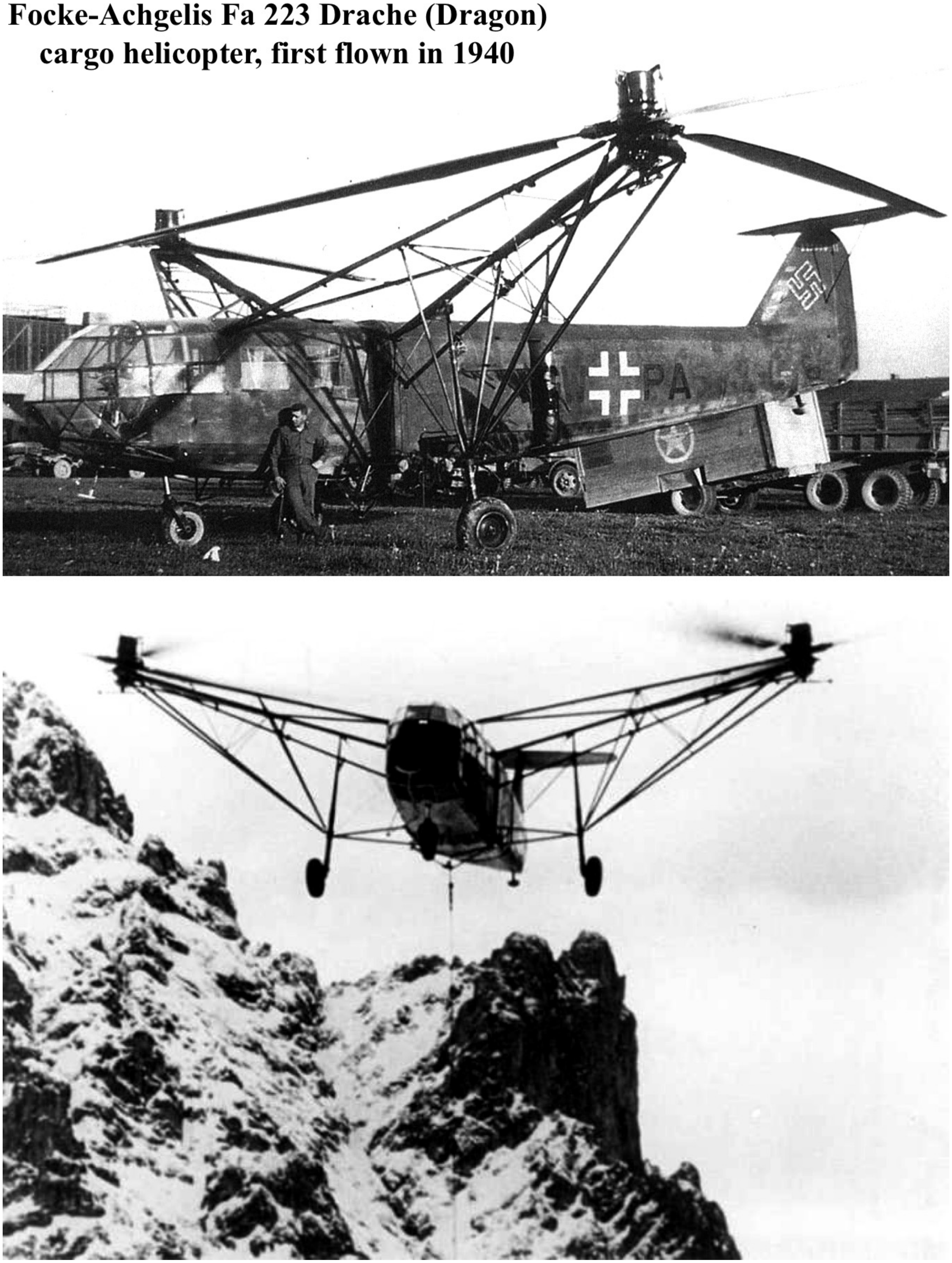

Focke-Achgelis Fa 223 Drache (Dragon)
cargo helicopter, first flown in 1940

Figure 9.133: Henrich Focke and his team created the much more advanced Focke-Achgelis Fa 223 Drache (Dragon) dual-rotor cargo helicopter in 1940.

Focke-Achgelis Fa 284 heavy cargo helicopter
(designed in 1942 but Allied attacks halted its construction)

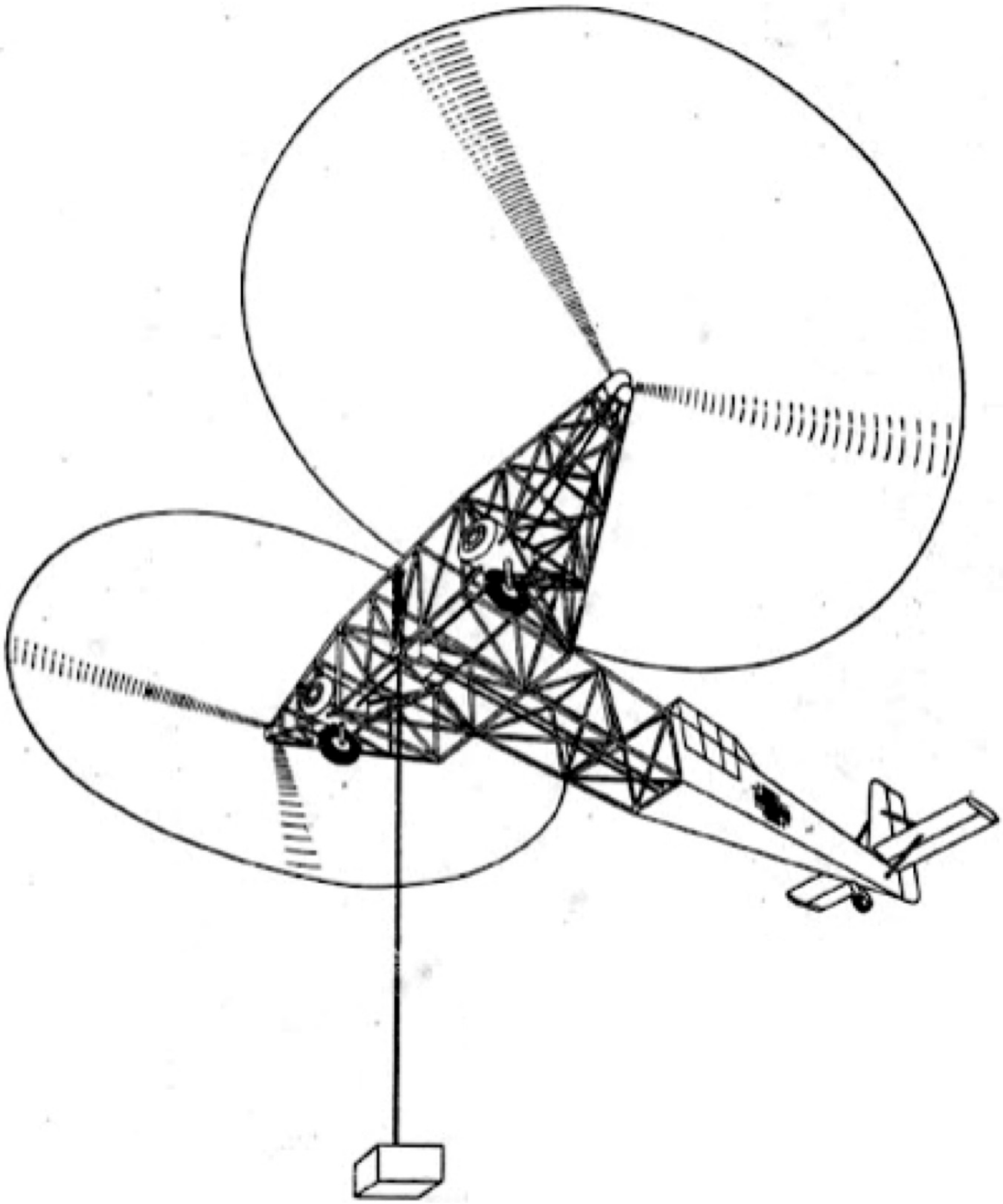
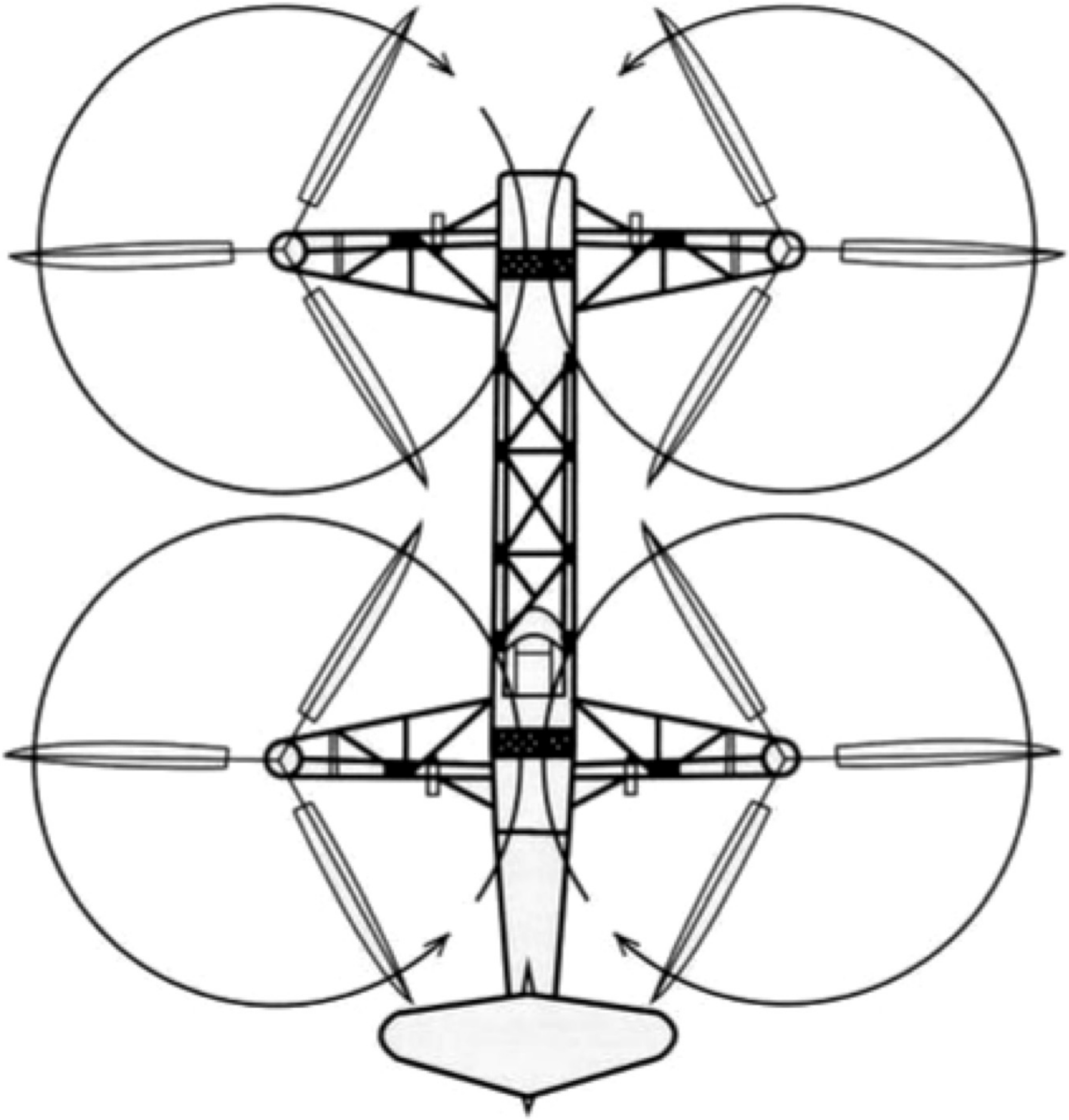
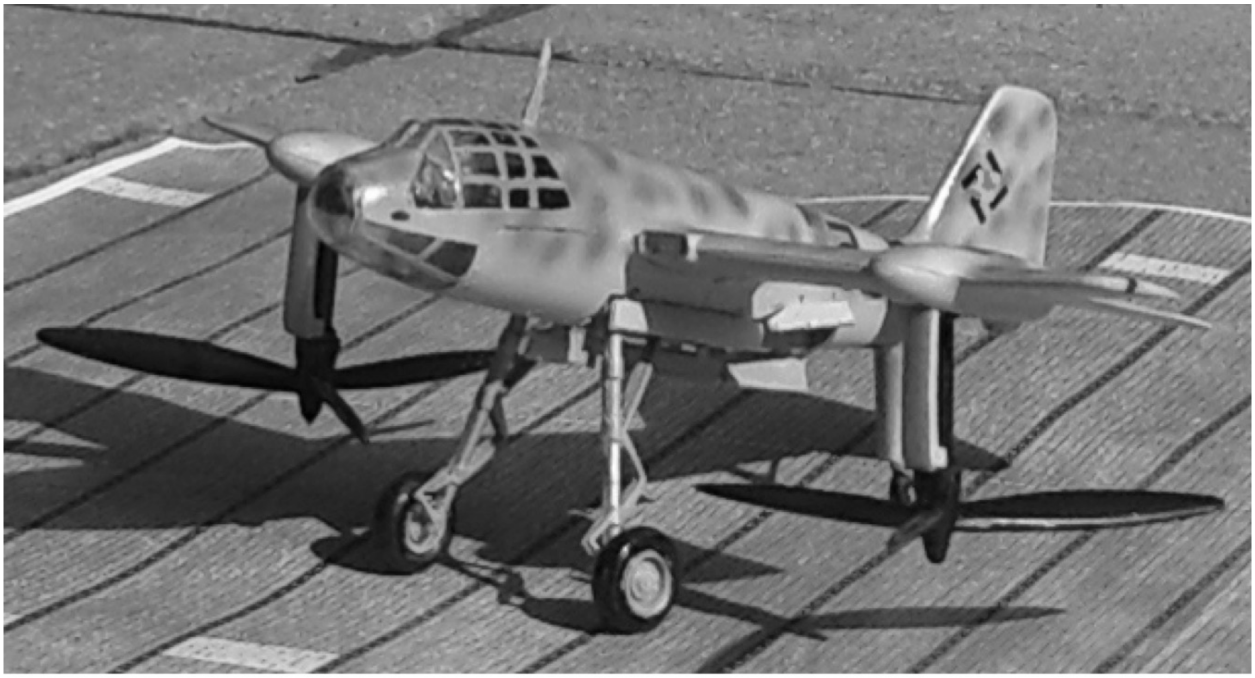


Figure 9.134: Henrich Focke and his team designed the Focke-Achgelis Fa 284 heavy cargo helicopter in 1942, but Allied attacks halted its construction.



Focke-Achgelis Fa 325 Krabbe heavy cargo helicopter
(designed in 1942 but Allied attacks halted its construction)

Figure 9.135: Henrich Focke and his team designed the Focke-Achgelis Fa 325 Krabbe heavy cargo helicopter in 1942, but Allied attacks halted its construction.



Focke-Achgelis Fa 269 tilt-rotor VTOL aircraft, designed in 1943 but destroyed by Allied bombing in 1944 (model above, drawing below)

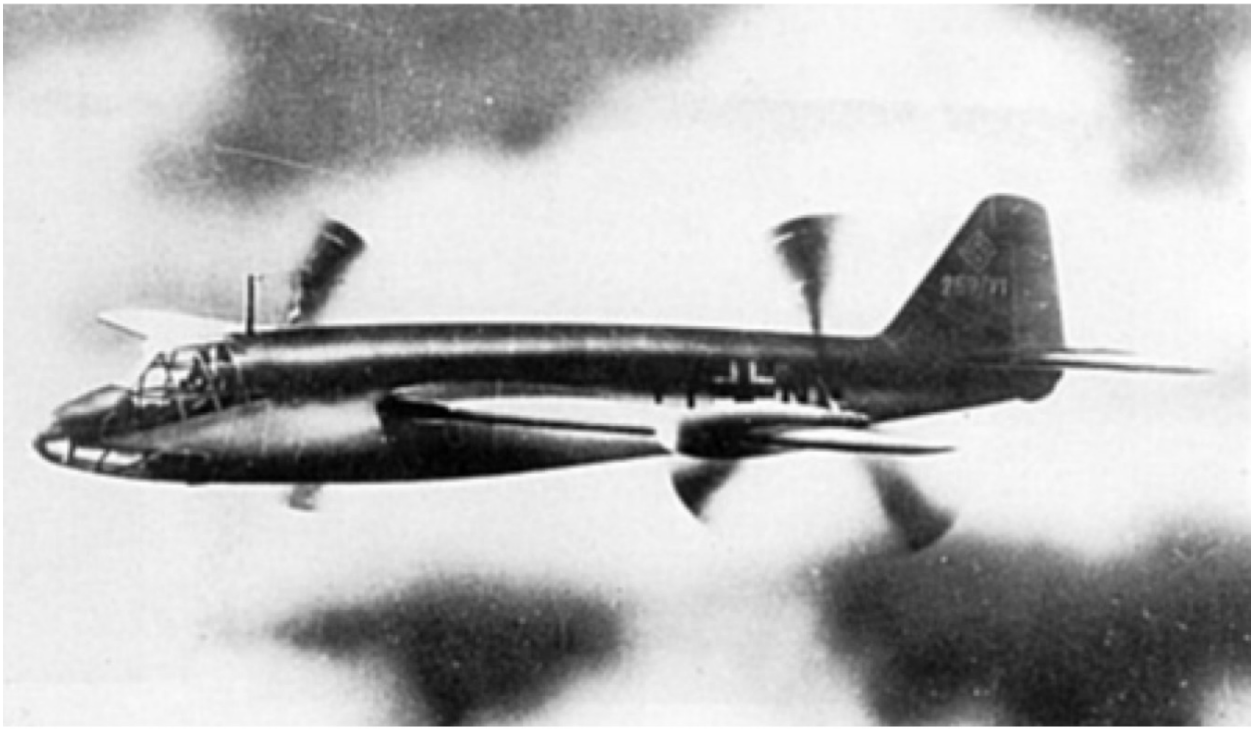


Figure 9.136: Henrich Focke and his team were developing a prototype tilt-rotor VTOL aircraft, the Focke-Achgelis Fa 269, that was destroyed by Allied bombing in 1944.

Focke-Achgelis Fa 330 Bachstelze rotor kite

Could be deployed and towed by a submarine as an aerial lookout

First flown in 1942

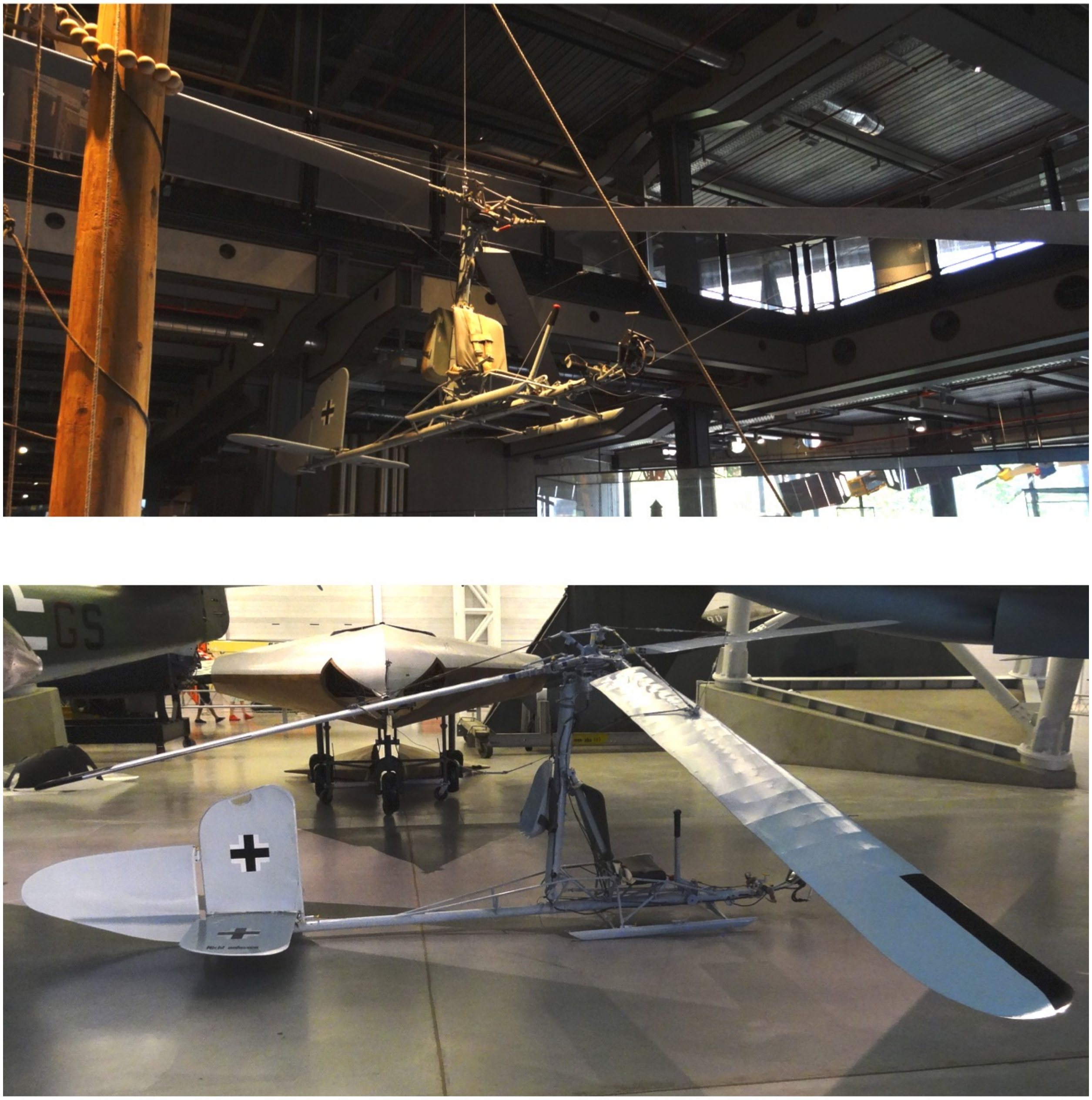


Figure 9.137: In 1942, Henrich Focke and his team developed the Focke-Achgelis Fa 330 Bachstelze rotor kite, which could be deployed and towed by a submarine (via a 150-meter cable) as an aerial lookout.

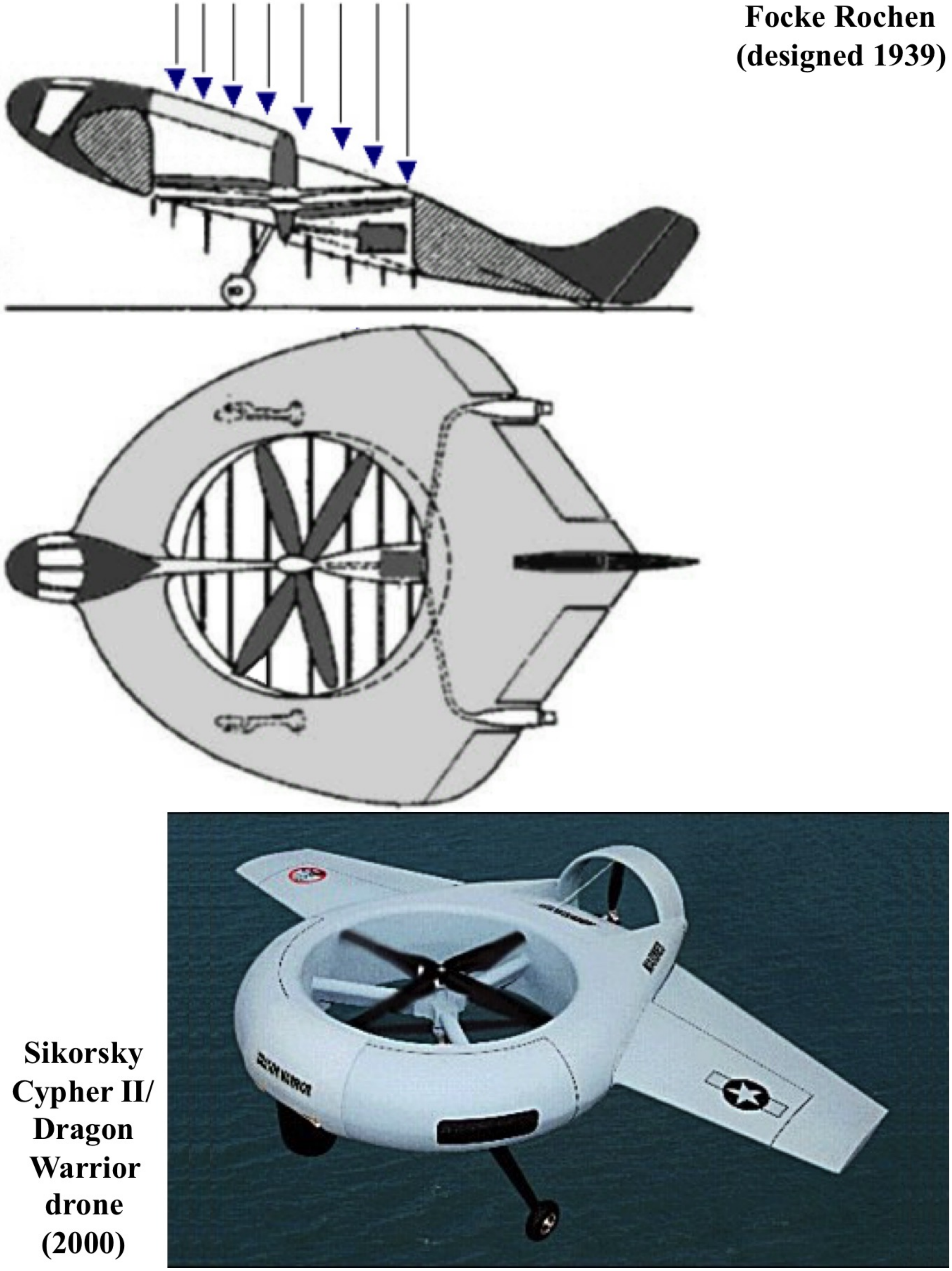

Focke Rochen
(designed 1939)
Sikorsky Cypher II/ Dragon Warrior drone (2000)

Figure 9.138: In 1939, Henrich Focke and his team designed the Rochen, a winged VTOL aircraft with counter-rotating rotors in a ducted fan. Focke's design lives on in examples such as the Sikorsky Cypher II or Dragon Warrior drone (2000).

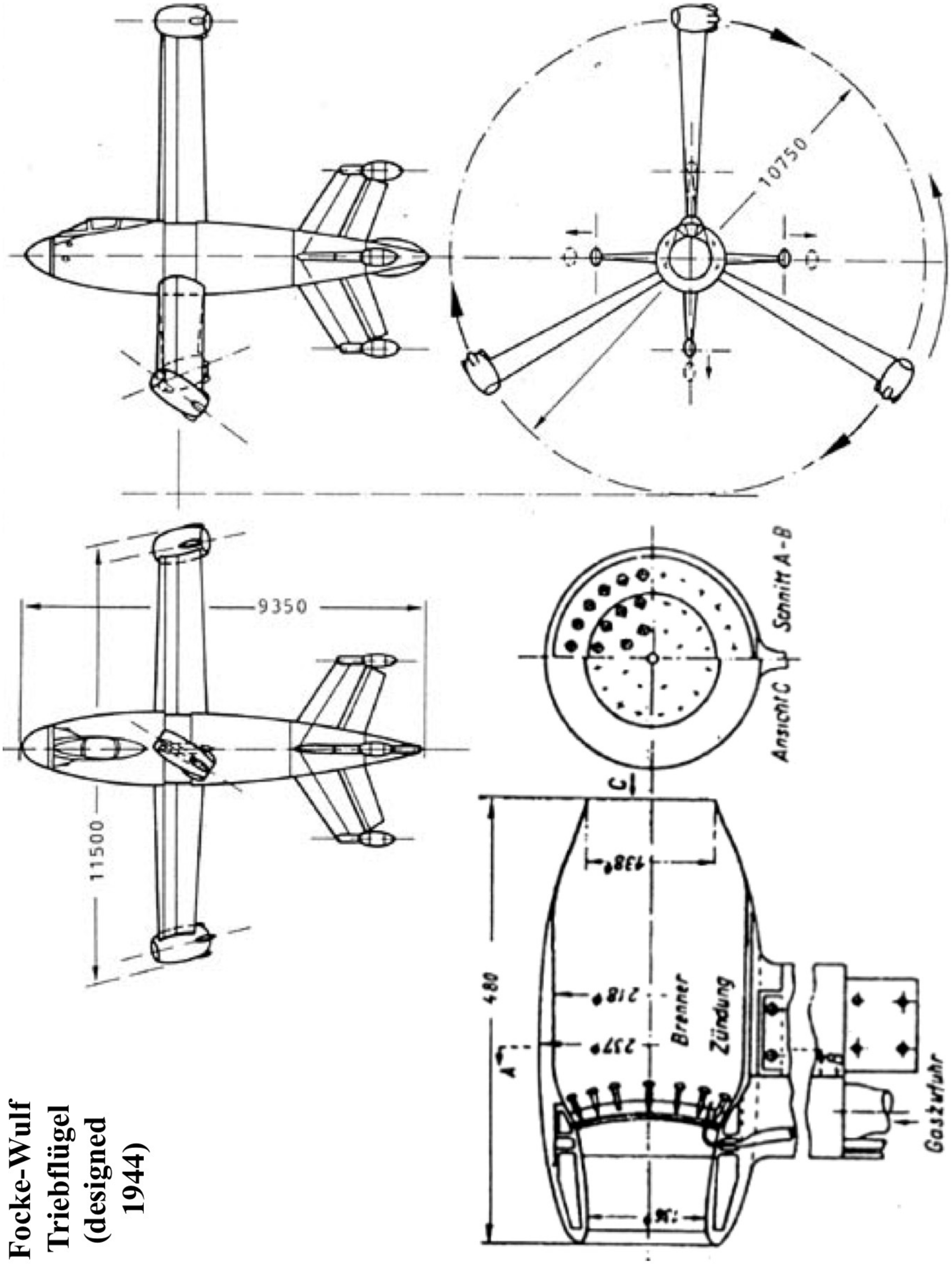

10750
9350
11500
Schnitt A-B
Ansicht C
C
138
480
218
237
A
Brenner
Zündung
Gaszufuhr
Focke-Wulf Triebflügel (designed 1944)

Figure 9.139: The Focke-Wulf Triebflügel was a highly innovative rotary-wing aircraft powered by wing-tip ramjets that was designed to take off and land vertically but fly horizontally. It was designed in 1944; it is unclear how far experimental work got by the end of the war.

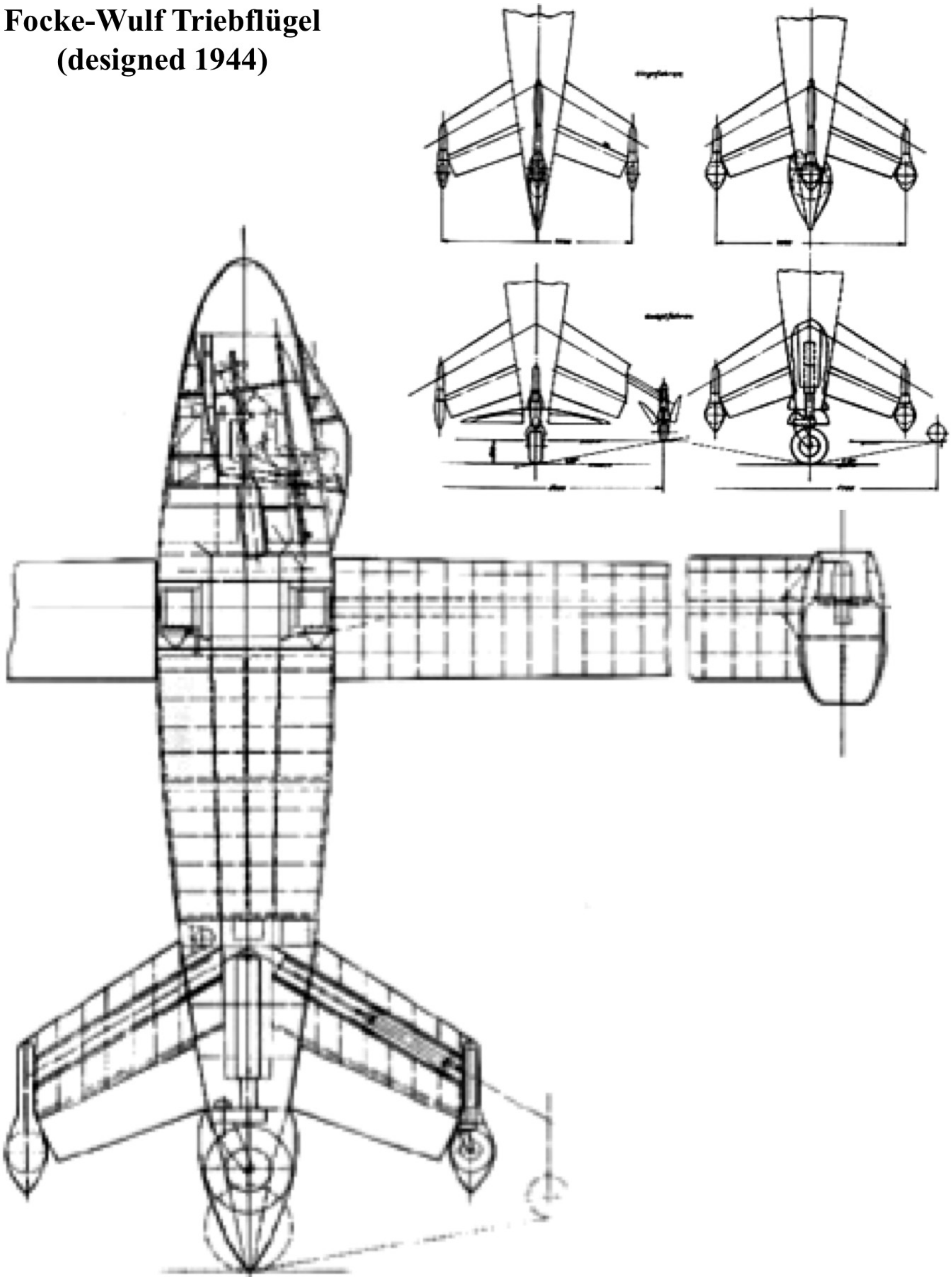
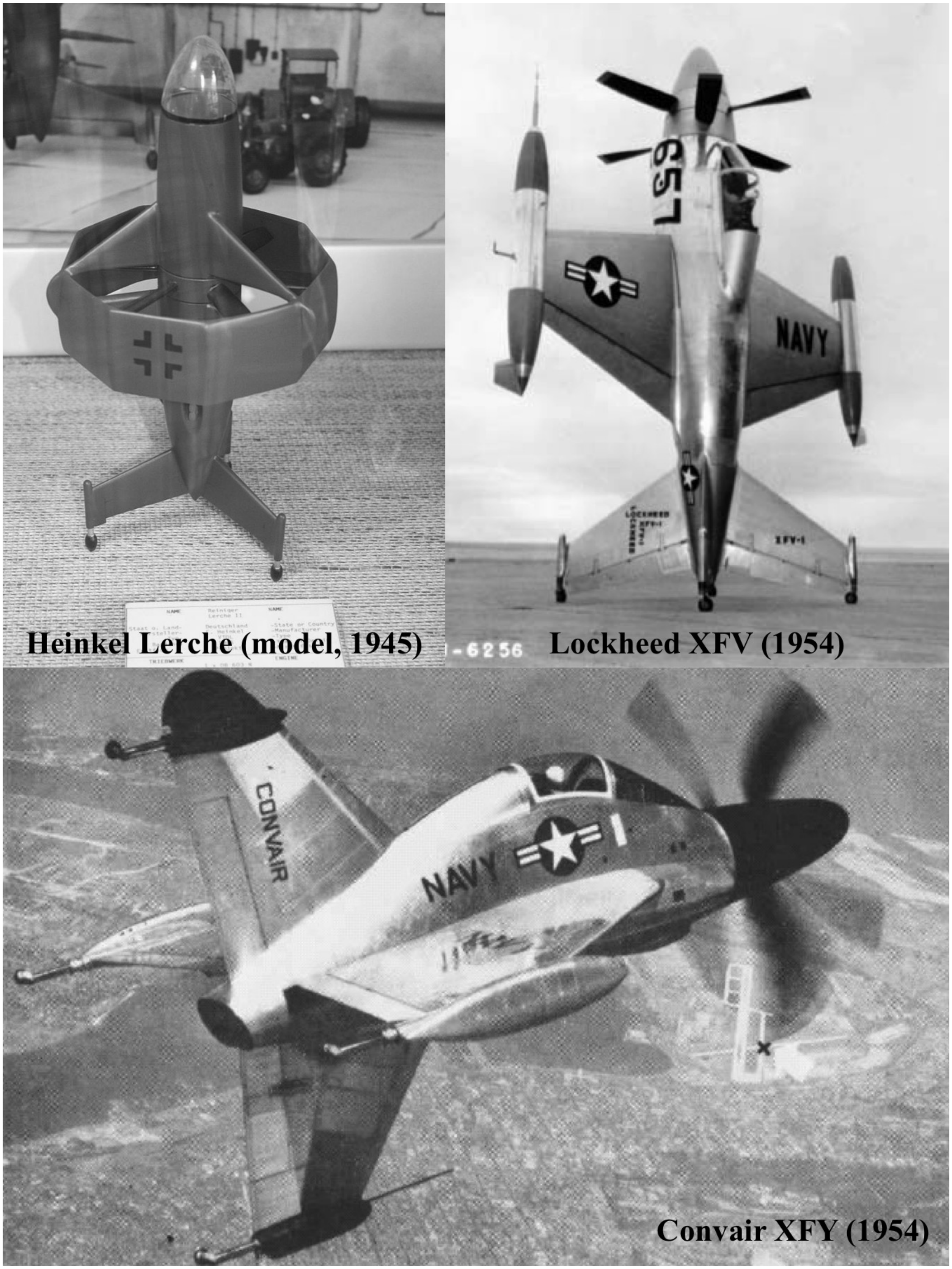

Focke-Wulf Triebflügel
(designed 1944)

Figure 9.140: The Focke-Wulf Triebflügel was a highly innovative rotary-wing aircraft powered by wing-tip ramjets that was designed to take off and land vertically but fly horizontally. It was designed in 1944; it is unclear how far experimental work got by the end of the war.



Heinkel Lerche (model, 1945)

Lockheed XFV (1954)

Convair XFY (1954)

657
NAVY
LOCKHEED
XFV-1
-6256
CONVAIR
NAVY
1

Figure 9.141: Closely related to the Focke-Wulf Triebflügel were the wartime Heinkel Lerche (model, 1945, larger than but otherwise highly similar to the proposed 1944 Heinkel Wespe) and the postwar Lockheed XFV Salmon (1954) and Convair XFY Pogo (1954).

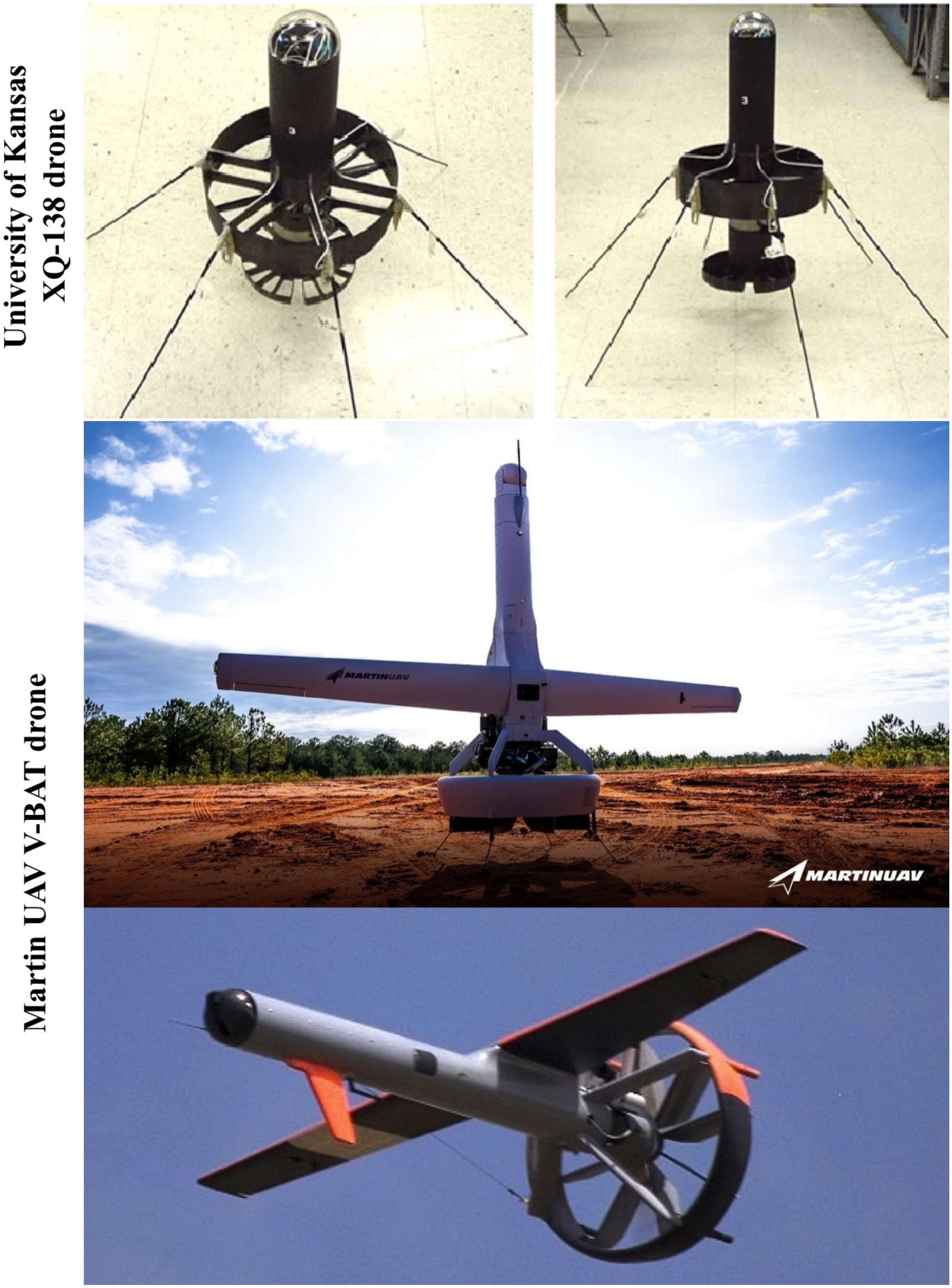

University of Kansas XQ-138 drone
Martin UAV V-BAT drone
MARTINUAV
MARTINUAV

Figure 9.142: The wartime German Lerche/Wespe- and Triebflügel-type designs (for aircraft that could take off and land on their tails but pitch over by 90^o to fly horizontally) still live on in modern unmanned aerial vehicles (UAVs) such as the University of Kansas XQ-138 drone and the Martin UAV V-BAT drone.

9.5.3 Anton Flettner's Helicopter Team

As shown in Fig. 9.143, Anton Flettner (German, 1885-1961) also demonstrated his own fully functional helicopter, the Flettner Fl 185, in 1936 very soon after Focke. Previously Flettner had invented battlefield robots (p. 1208) and rotor ships (p. 1484).

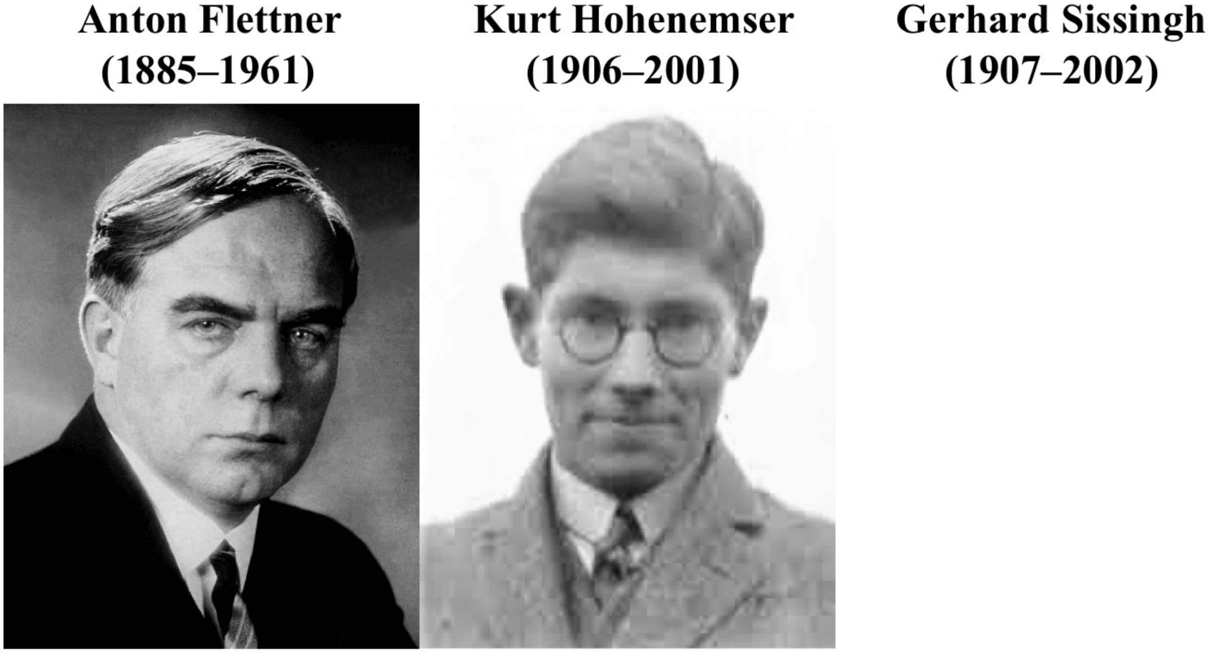
In addition to several test pilots, his engineering team included:

- Emil Arnold (German, 19??–19??, chief designer)
- Willi Deilitz (German, 19??–19??, test facilities)
- Heinz Gundlach (German, 19??–19??, designer)
- Kurt Hohenemser (German, 1906–2001, aerodynamics and stability)
- ?? Küchler (German, 19??–19??, transmissions)
- Oskar Nagel (German, 19??–19??, project designer)
- Xaver Schleicher (German, 19??–19??, flight mechanics)
- Joseph Schmidt (German, 19??–19??, flight-test engineer)
- Gerhard Siegel (German, 19??–19??, statics)
- Gerhard Sissingh (German, 1907–2002, aerodynamics)

Flettner's team went on to create other helicopters such as the much more advanced Fl 282 Kolibri (Humming Bird) reconnaissance helicopter. The Fl 282 was first flown in 1941, went into series production, and was used in the war. See Fig. 9.144.

Flettner and his team also developed the Fl 265 helicopter/autogyro (1938), the improved Fl 285 reconnaissance helicopter (1944, Fig. 9.145 top), and the large Fl 339 passenger/cargo helicopter prototype, which apparently was not completed before the end of the war (Fig. 9.145 bottom).

After the war, Flettner, Hohenemser, and Sissingh produced helicopters in the United States.



Anton Flettner
(1885–1961)
Kurt Hohenemser
(1906–2001)
Gerhard Sissingh
(1907–2002)

Flettner Fl 185 helicopter, first flown in 1936

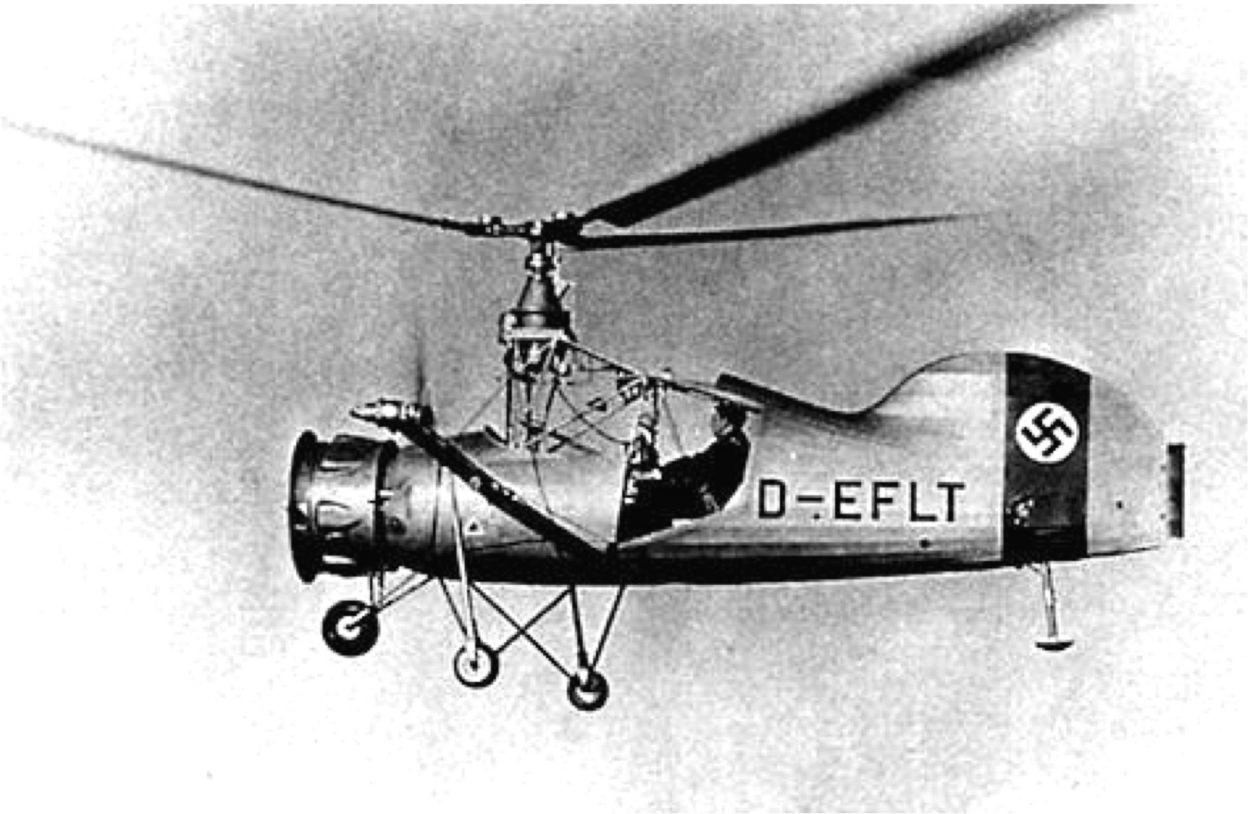
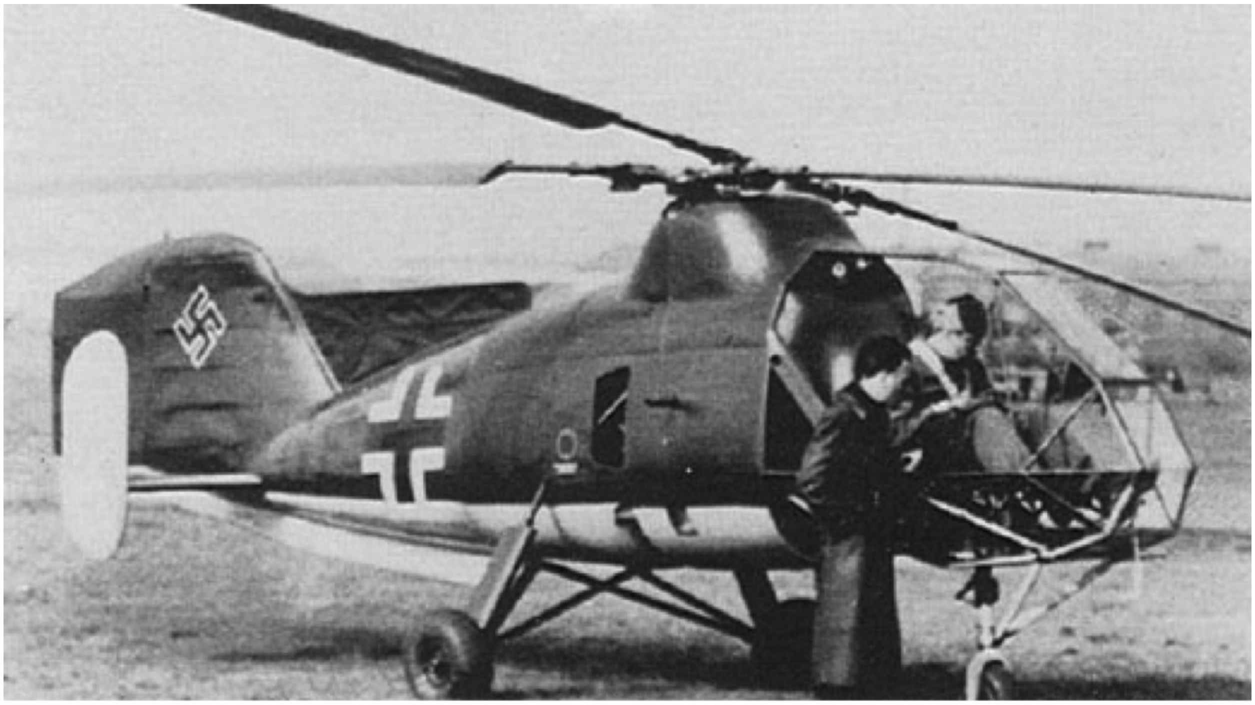


Figure 9.143: Anton Flettner and his team including Kurt Hohenemser and Gerhard Sissingh created their first fully functional helicopter, the Fl 185, in 1936.



Flettner Fl 282 Kolibri (Humming Bird) helicopter, first flown in 1941

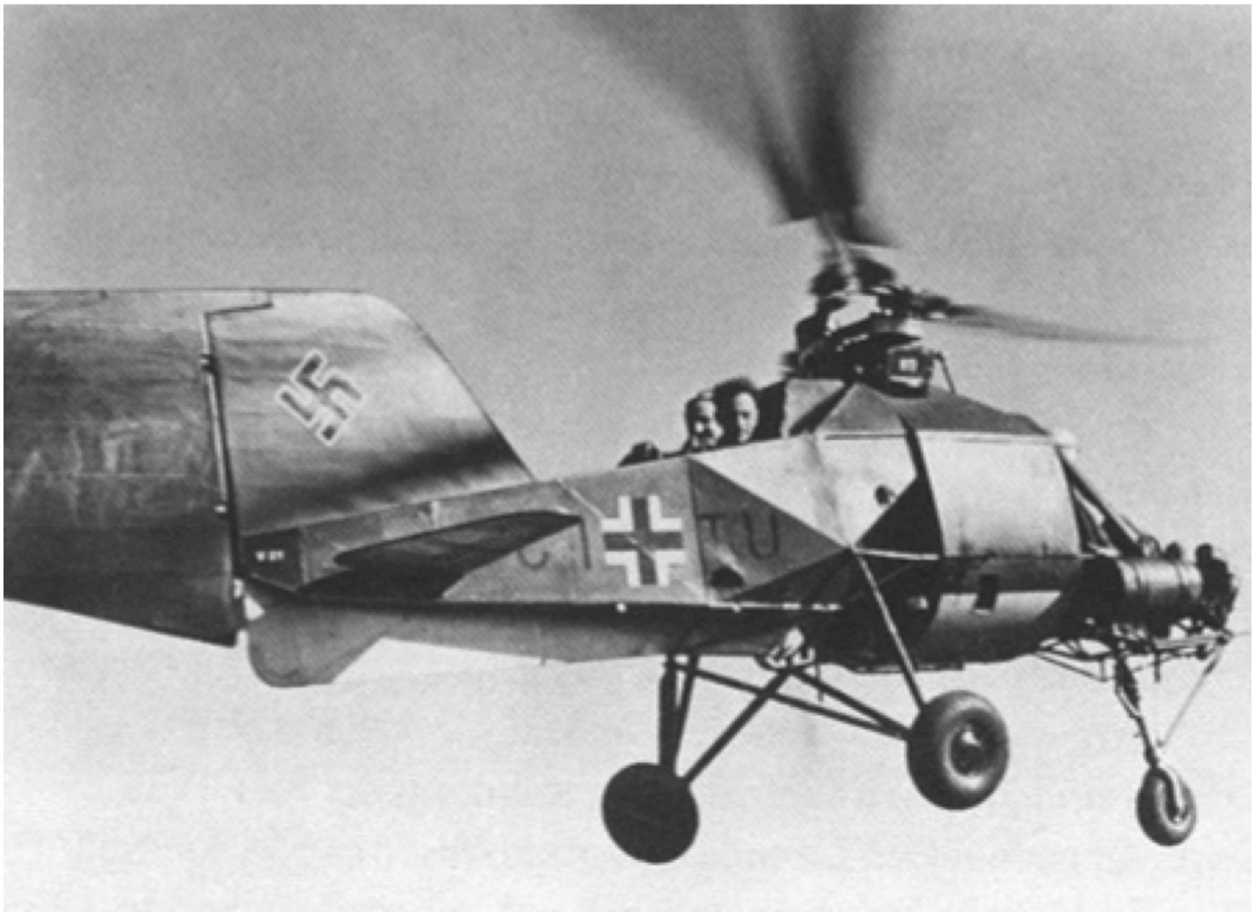
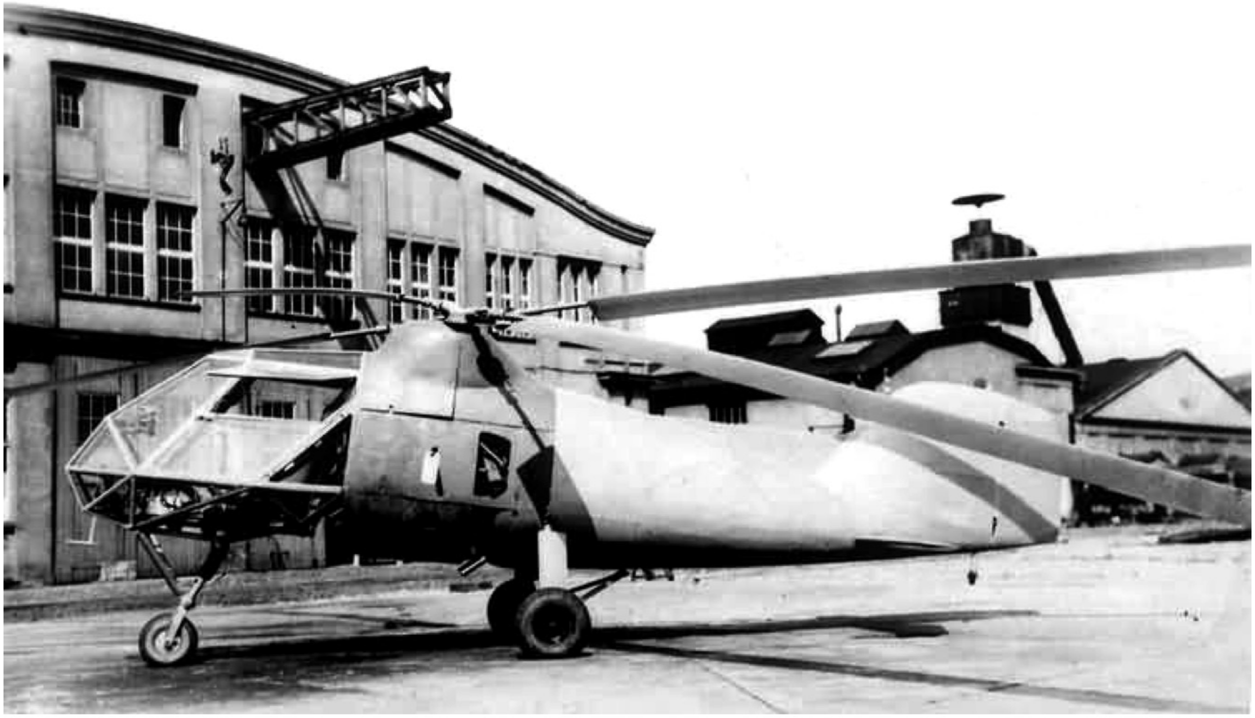


Figure 9.144: Anton Flettner and his team produced the much more advanced Fl 282 Kolibri (Humming Bird) reconnaissance helicopter in 1941.

Flettner Fl 285 reconnaissance helicopter (1944)



Flettner Fl 339 passenger/cargo helicopter (designed in 1944 but not completed before the end of the war)

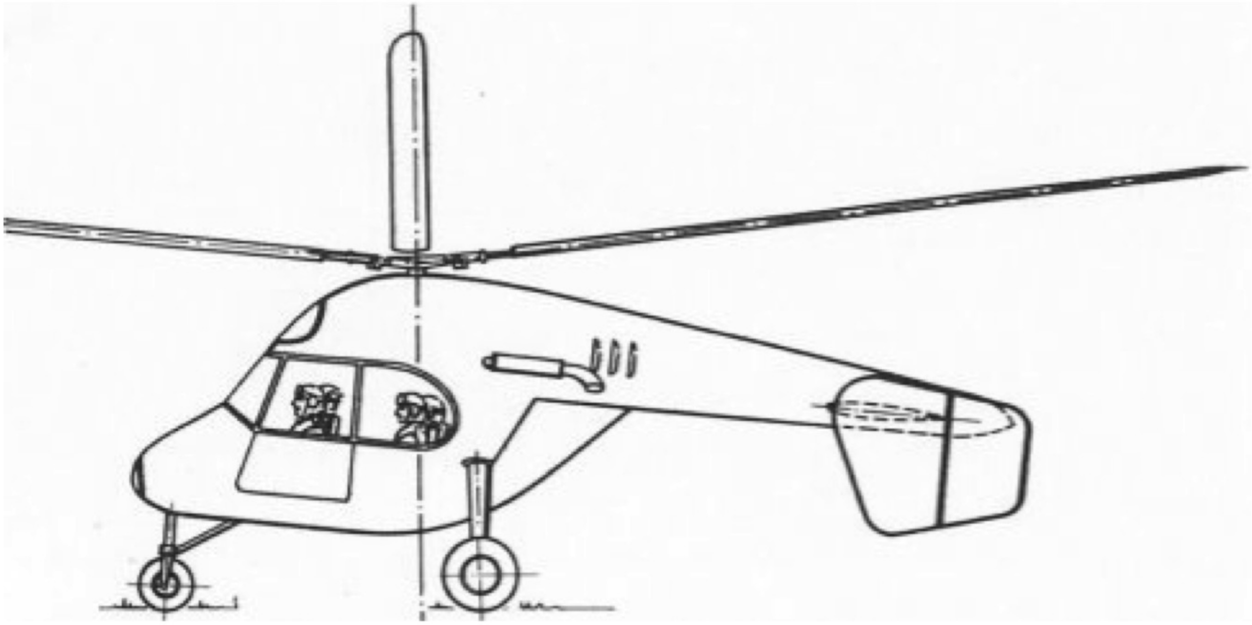


Figure 9.145: By the end of the war, Flettner's team had produced the improved Flettner Fl 285 reconnaissance helicopter and was building the much larger Fl 339 passenger/cargo helicopter.

9.5.4 Friedrich von Doblhoff's Helicopter Team

In 1943, Friedrich von Doblhoff (Austrian, 1916–2000) demonstrated the prototype WNF 342 submarine-launched helicopter, which featured a rotor that was directly powered by small jet engines at the rotor tips; see Fig. 9.146.

Some of the other members of his engineering team were:

- Alexander Czernin (Austrian, 19??–19??, mechanical design)
- Theodor Laufer (Austrian, 1875–1951, aerodynamics and stability)
- Kurt Löffler (Austrian, 19??–19??, detailed design)
- August Stepan (Austrian, 1915–2003, structural design)
- M. Vordren (Austrian, 19??–19??, detailed design)

After the war, von Doblhoff developed helicopters in the United States, Czernin and Stepan built helicopters in the United Kingdom, Stepan later developed helicopters in West Germany (including the revolutionary MBB Bo 105), and Laufer built helicopters in France. Several of the postwar helicopters designed by former von Doblhoff team members were propelled by the same tip-jet rotor approach as the wartime WNF 342, including the McDonnell XV-1 military helicopter, Fairey Jet Gyrodyne test prototype, and Fairey Rotodyne passenger vehicle (Fig. 9.147).

9.5.5 Backpack Helicopters

Special mention should go to three innovators who created and successfully demonstrated prototype "backpack" helicopters during the war:

- Paul Baumgärtl (Austrian, 1920–2012) produced and tested a series of one-person helicopters that he called Heliofly (Fig. 9.148). Baumgärtl's prototypes included Heliofly I (1941), which attached directly to the back of the pilot, and Heliofly III (1943), which was essentially a flying chair for the pilot.
- Beginning in 1940, Bruno Nagler (Austrian, 1901–1979) and Franz Rolz (Austrian, 19??–19??) demonstrated the NR 54 and NR 55 prototype helicopters, which could be folded up and carried as a backpack, or unfolded into a helicopter for use by a seated pilot (Fig. 9.149). After the war, Nagler moved to the United States, where he continued to develop and demonstrate portable helicopters such as the strap-on backpack Heliglider (1952).

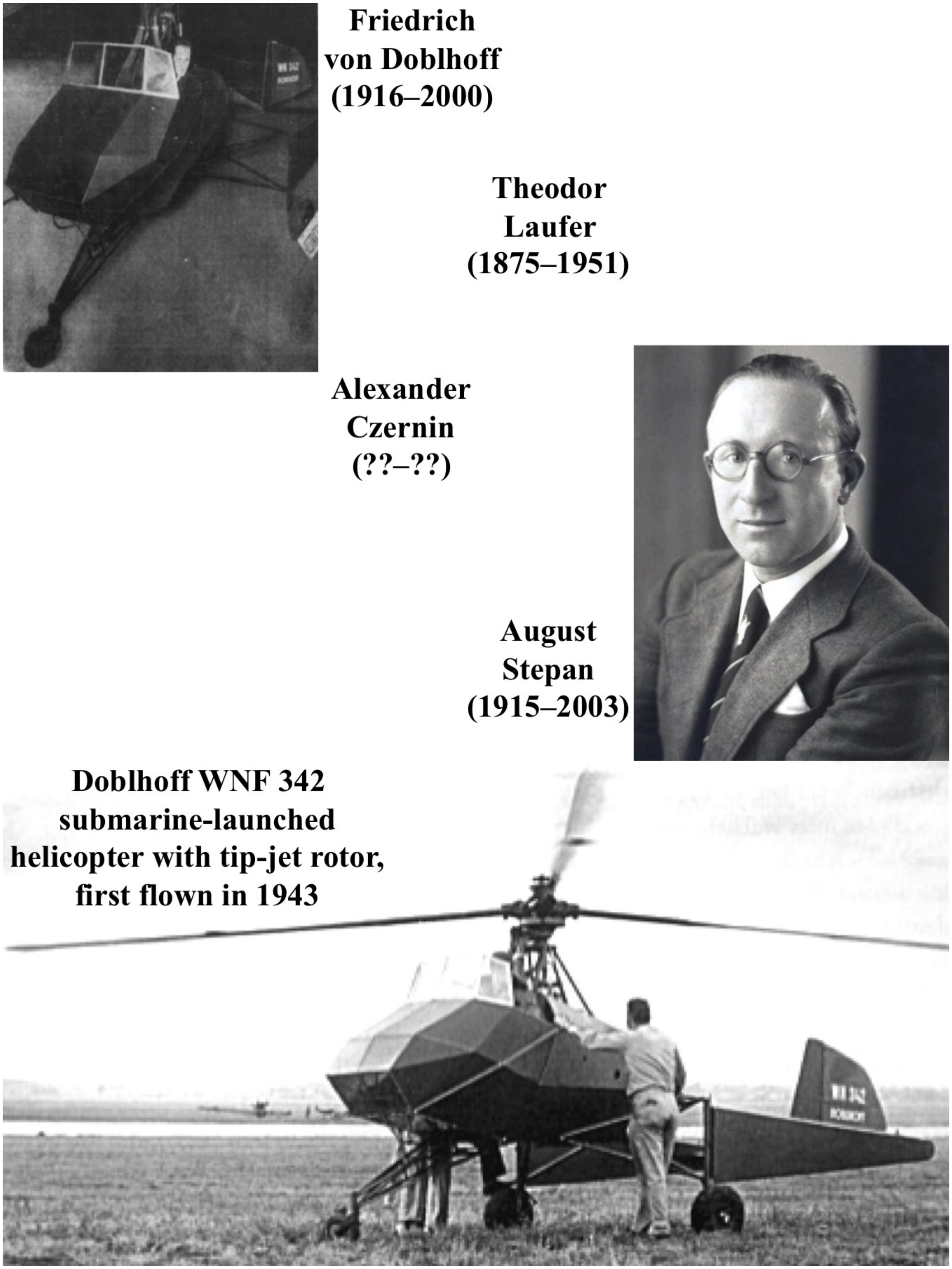
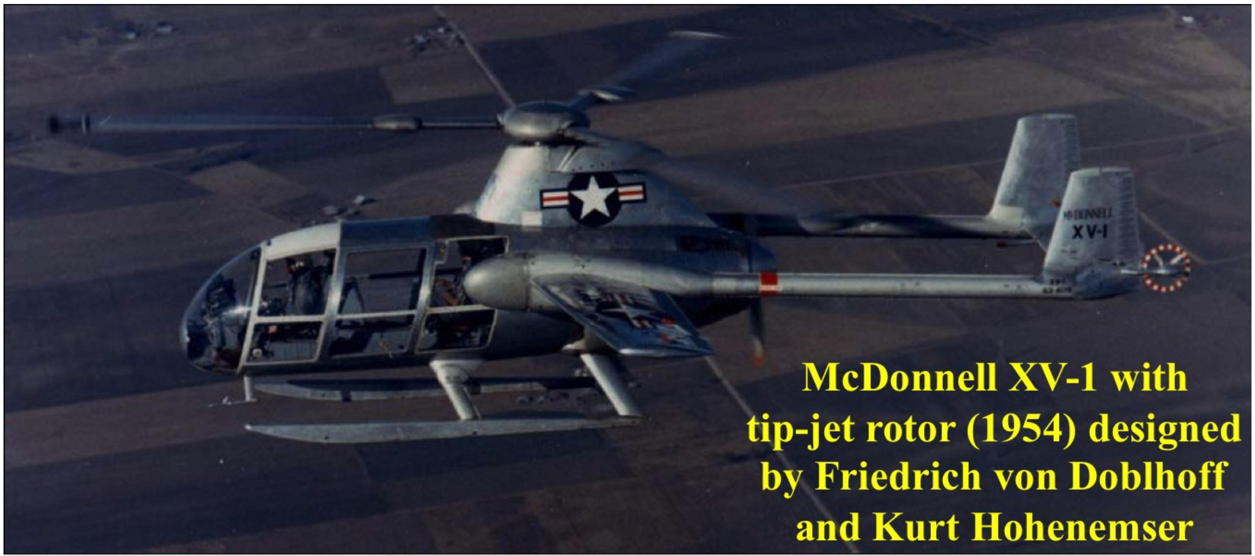
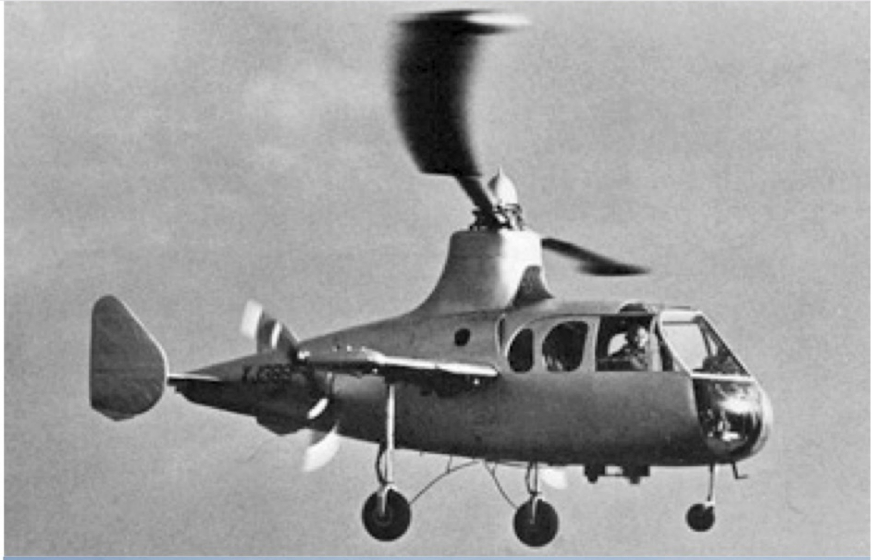

Friedrich
von Doblhoff
(1916–2000)
Theodor
Laufer
(1875–1951)
Alexander
Czernin
(??–??)
August
Stepan
(1915–2003)
Doblhoff WNF 342
submarine-launched
helicopter with tip-jet rotor,
first flown in 1943
WN 342

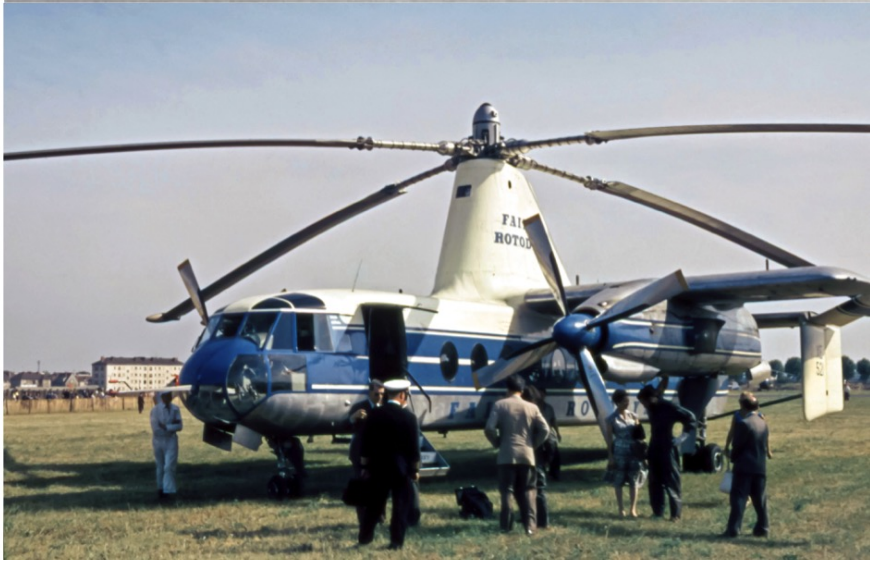
Figure 9.146: Friedrich von Doblhoff and his team including Theodor Laufer, Alexander Czernin, and August Stepan created helicopters propelled by tip-jet rotors, such as the Doblhoff WNF 342 submarine-launched jet helicopter, which was first flown in 1943.



McDonnell XV-1 with tip-jet rotor (1954) designed by Friedrich von Doblhoff and Kurt Hohenemser



Fairey Jet Gyrodyne with tip-jet rotor (1954) designed by August Stepan and Alexander Czernin



Fairey Rotodyne with tip-jet rotor (1957) designed by August Stepan and Alexander Czernin

Figure 9.147: After the war, members of Friedrich von Doblhoff's team continued to develop helicopters propelled by tip-jet rotors, such as the McDonnell XV-1 military helicopter, Fairey Jet Gyrodyne test prototype, and Fairey Rotodyne passenger vehicle.

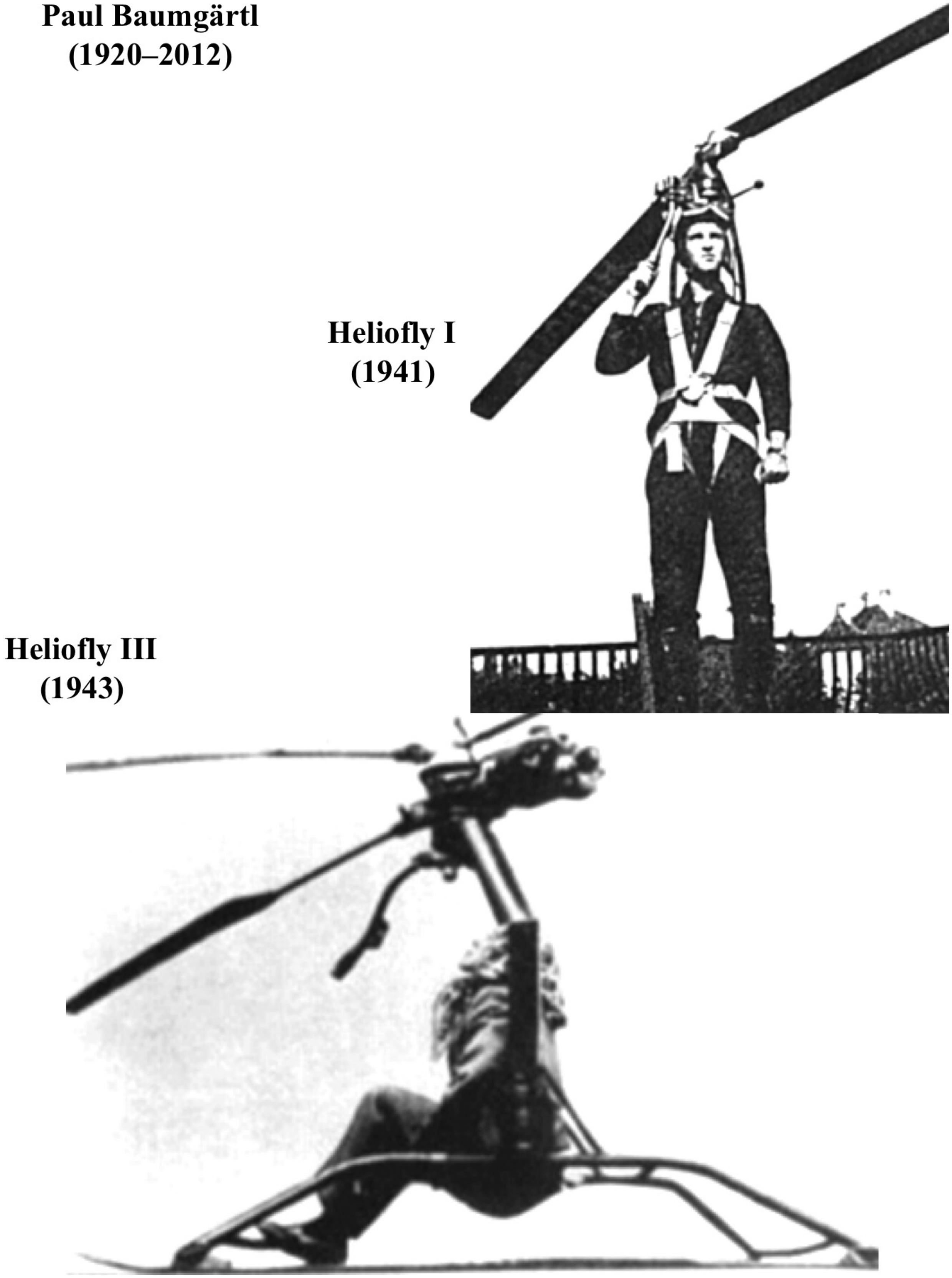
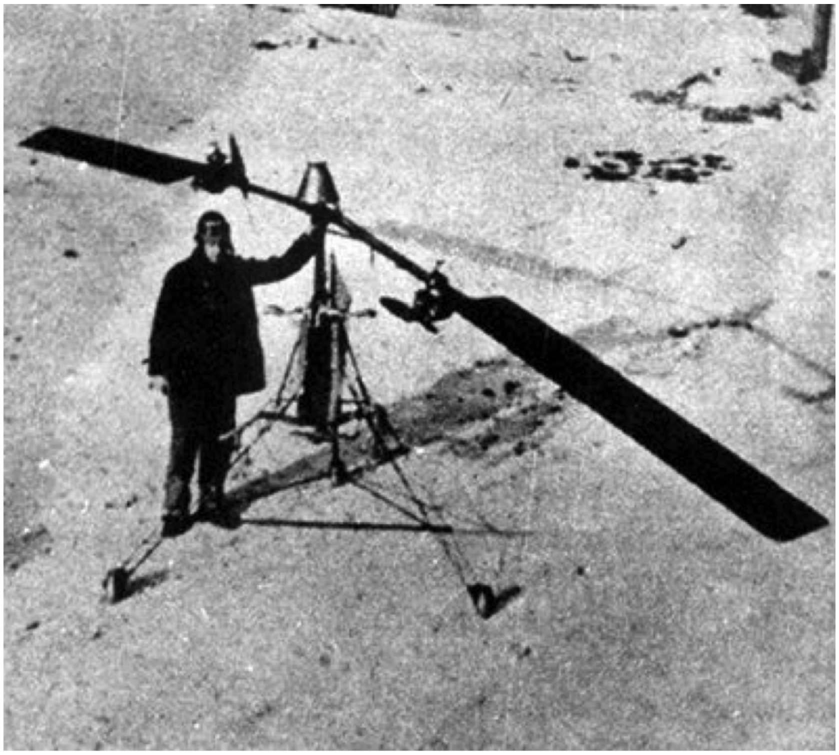

Paul Baumgärtl
(1920–2012)
Heliofly I
(1941)
Heliofly III
(1943)

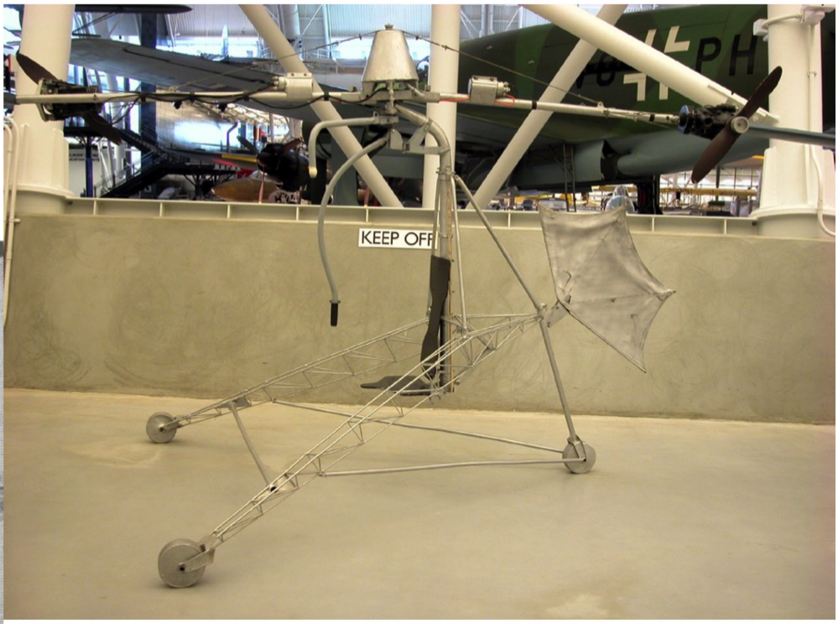
Figure 9.148: Paul Baumgärtl designed and successfully demonstrated several portable, single-person helicopters during the war.

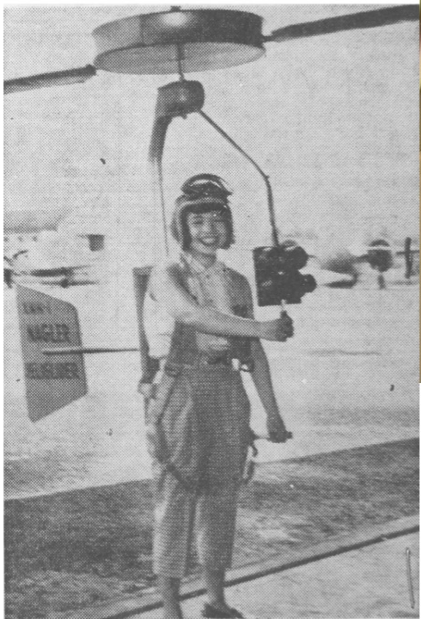
Bruno Nagler (1901–1979)

Franz Rolz (??–??)



Nagler-Rolz NR 54 V2 (1941)





Nagler Heliglider (1952)

Figure 9.149: Bruno Nagler and Franz Rolz designed and successfully demonstrated several portable, single-person helicopters during and shortly after the war.

9.5.6 Electric Helicopters

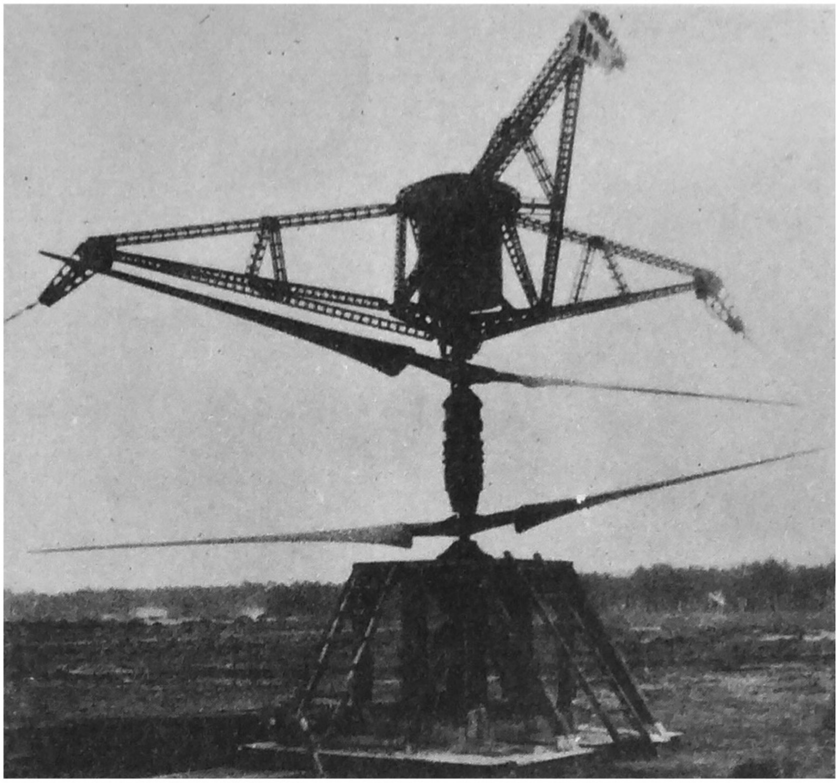
The PKZ-1 proto-helicopter that was built by István Petróczy, Theodore von Kármán, and Vilém Žurovec (Fig. 9.125) in 1918 demonstrated the potential of electric-powered helicopters.

While most helicopters focused on fuel-burning engines of various types, R. Schmidt (German, ??–??) and G. Kirchberg (German?, ??–??), engineers working at the electrical equipment company AEG, continued the development of electric helicopters. Beginning in 1933, they built and demonstrated a series of increasingly sophisticated electric helicopters that could be launched from a truck and that remained tethered by power cables to a ground-based electric generator. Figure 9.150 shows the final (1945) version of the helicopter, in which the hovering vehicle and its attached cables could function as a large radio antenna. By sending the helicopter aloft from the truck, the system could act as a portable radio tower [FIAT 604].

Electric helicopter/quad-copter drones are now quite common, and they are deeply indebted to these first electric helicopters.

R. Schmidt
(19??–19??)

Electric helicopter launched from a truck and connected via power cables to a ground-based generator (1933–1945)



G. Kirchberg
(19??–19??)

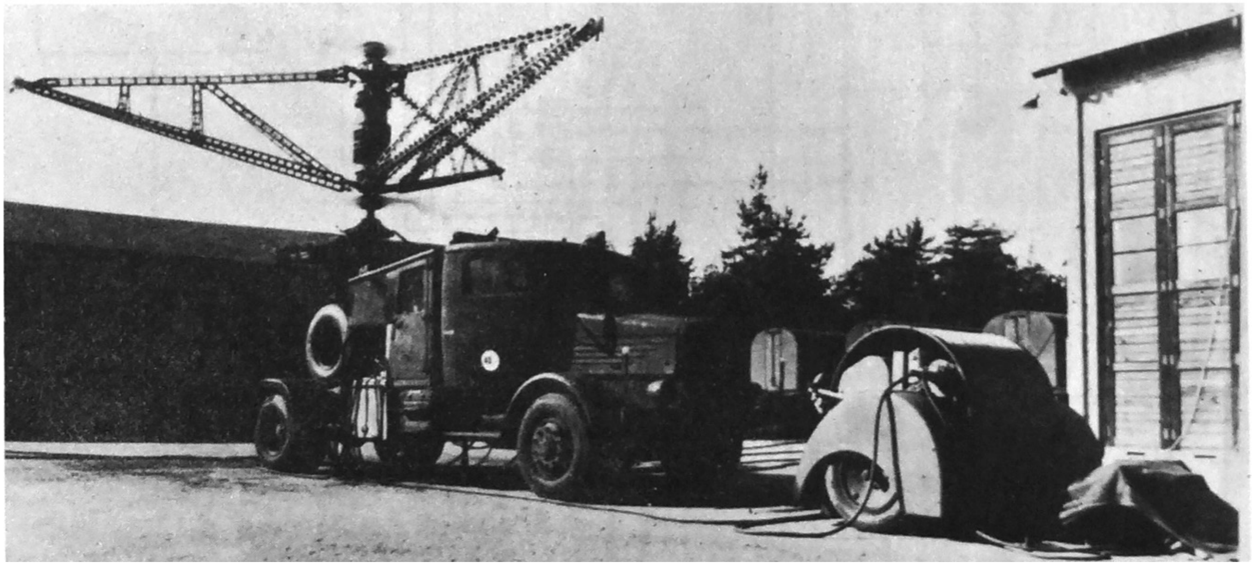


Figure 9.150: R. Schmidt and G. Kirchberg developed an electric helicopter launched from a truck and connected via power cables to a ground-based generator. The helicopter and its attached cables were designed to function as a giant radio antenna, effectively making the whole system a portable radio tower [FIAT 604].

9.5.7 Transfer of Helicopter Technologies to Other Countries

Outside the German-speaking world, the closest competitor in helicopter development was probably Igor Sikorski (1889–1972), a Russian engineer who emigrated to the United States. By May 1940, he had created a prototype helicopter (VS-300) that could hover but became unstable if it tried to move forward, the same problem that had plagued German prototypes of earlier decades. A version that could both hover and move forward, the R-4, was first demonstrated in 1942, six years after the first fully functional Focke and Flettner helicopters, and presumably after the details of the various Focke and Flettner designs would have become available in the West to aid Sikorski's experiments. However, the early R-4 versions still had a number of issues, and in order to resolve those, the R-4 design had to go through a series of further modifications, prototypes, and tests for two more years. The first actually useful versions of R-4 helicopters were finally fielded in the war in small numbers by the United States in 1944 and the United Kingdom in 1945, 4–5 years after Germany's first fully operational helicopters had been mass-produced and deployed.

Not only were the German helicopters produced many years earlier than U.S. helicopters, but they were technically superior, according to U.S. officials. Even compared to U.S.-built helicopters of 1946, the *New York Times* practically gushed about the performance of the 1940 Fa 223 Drache (Dragon) twin-rotor cargo helicopter [NYT 1946-05-13 p. 4]:

> The Germans built ten big helicopters able to climb eighteen feet a second with ten passengers aboard and a full load of fuel before the Allies bombed out the manufacturing plant at Bremen, the Commerce Department disclosed tonight.
>
> The Department made available a report giving specifications of the helicopter which has many unusual features, including a different method for suspending the engine in the craft, which can fly up, down, forward, backward, or sideways.

In the United States after the war, German-speaking helicopter engineers collaborated with German-speaking turbojet engine designers such as Anselm Franz to produce more energy-efficient helicopters powered by turboshaft engines such as the Lycoming T53 and T55 engines (see p. 1740). Such turboshaft-powered helicopters are still the standard helicopter design. By the Korean War, helicopters were routinely used for medical evacuations, and by the Vietnam War, helicopters were the preferred platform for virtually all aerial tasks except bombing.

As already noted, several key engineers from the original Focke, Flettner, and von Doblhoff helicopter teams also developed helicopters in the United Kingdom, France, and other countries after the war. The Soviet Union was late to field fully functional helicopters, but (apparently) with the help of captured German designs and engineers, it began serial production of the small Mi-1 Hare helicopter in 1950, followed by more advanced helicopters in the 1950s and beyond.

9.6 Small Missiles and Smart Bombs

German-speaking engineers developed precision-guided missiles and smart bombs that were the direct forerunners of modern guided weapons.[11] The wartime (Section 9.6.1) and postwar (Section 9.6.2) missile programs were so numerous and so large, and employed so many German-speaking engineers, that only a few examples are mentioned here.

9.6.1 Wartime Missiles and Smart Bombs

While many of the most important and best known advances in missiles and smart bombs occurred just before and during World War II, some remarkable work was actually conducted just before and during World War I [Everett 2015; Trenkle 1987]. As shown in Fig. 9.151, Siemens-Halske engineers developed and successfully demonstrated the first wire-guided glide bombs in 1914. Siemens-Halske also worked with Mannesmann-Mulag to create and demonstrate the even more ambitious Fledermaus radio-controlled explosive airplane in 1916. Those nearly forgotten programs deserve greater recognition and more archival research by military and aerospace historians.

Paul Schmidt (German, 1898–1976, designer of the Argus As 014 pulsejet engine), Fritz Gosslau (German, 1898–1965, missile designer), and Robert Lusser (German, 1899–1969, missile designer) led teams that created the V-1 or Fieseler Fi 103 cruise missile, first flown in 1942, which was powered by a novel pulsejet engine (Figs. 9.101 and 9.152).[12] During the war, versions of the V-1 cruise missile that were piloted and/or air-launched were also produced and demonstrated (Fig. 9.153). After the war, Schmidt, Gosslau, and Lusser worked for the United States to produce missiles and other technologies.

As shown in Fig. 9.154, Herbert Wagner (Austrian, 1900–1982) led a team that created precision-guided weapons such as the Henschel Hs 293 smart bomb, guided by a miniaturized onboard camera and first demonstrated in 1942, and the Henschel Hs 117 Schmetterling (Butterfly) surface-to-air and air-to-air missile, also guided by a miniaturized onboard camera and first demonstrated in 1944. The miniaturized camera and television system are shown on pp. 1008–1010. Wagner was an extremely versatile and prolific inventor. In the 1930s, he created some of the first jet engines, and his designs strongly influenced subsequent jet engine developers (pp. 1734–1738). He also worked on German nuclear weapons programs during the war (p. 4165). After the war, Wagner developed a wide range of guided missiles and smart bombs in the United States.

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[11] See for example: Griehl 2003; Miranda and Mercado 1996; Putt 1946a, 1946b; Stüwe 1999; Stüwe 2014; Stüwe 2015; Zaloga and Laurier 2019; NYT 1944-12-05; CIOS XXVII-66; CIOS XXVIII-56; CIOS XXIX-55; CIOS XXXII-125; AFHRA A5729 electronic version p. 255ff.

[12] Hellmold 1999; Hölsken 1994; Irving 1965; Jackson 2014; Jones 1978; King and Kutta 1998; Lommel 2005; Myhra 2001.

Max Kramer (German, 1903–1986) created precision-guided weapons such as the Ruhrstahl SD 1400 X (Fritz X) radio-guided or wire-guided (to avoid radio jamming) smart bomb, first operational in 1943, and the Ruhrstahl X-4 air-to-air guided missile in 1944, as well as the Ruhrstahl X-7 anti-tank missile; see Fig. 9.155. After the war, Kramer worked in the United States to develop additional missiles and aircraft and to reduce drag on submarines. Kramer's wartime missiles also had a profound influence on the development of postwar missiles in other countries; for example, the French SS.10 anti-tank missile was directly based on the Ruhrstahl X-7.

Note that Wagner's and Kramer's smart bombs were developed and deployed nearly a half century before U.S. smart bombs directly based on that technology were first widely publicized in the 1990 Gulf War.

Heinrich Klein (German, 19??–19??) led the Rheinmetall-Borsig team that created the Rheintochter two-stage, radio-guided, surface-to-air missile, which was first demonstrated in 1943 (p. 1912). Klein's team also created the larger Rheinbote four-stage missile, first launched in 1943 (p. 1913) [Klein 1977; Margry 2001; Mills 2020, 2022]. In fact, according to a 1947 French military document, during the war Klein was even personally involved in "the construction of flying rockets... capable of crossing the Atlantic in 40 minutes" (p. 5452).

Ludwig Roth (German, 1909–1967) led the team at Peenemünde that developed the Wasserfall surface-to-air missile, which was essentially a miniature version of the A-4 (V-2) rocket. See Fig. 9.156. The Wasserfall was first demonstrated in 1944, and was designed to be either radio- or radar-guided. After the war, Roth moved to the United States to continue developing missiles and rockets. The Wasserfall was copied and became the Hermes series of U.S. missiles, and its technologies were incorporated into other postwar missiles [Mills 2020, 2022].

Messerschmitt's Oberbayerische Forschungsanstalt in Oberammergau developed the Enzian surface-to-air missile, which was first demonstrated in 1944. See Fig. 9.157. It was designed to use either radio guidance or infrared homing to find its target.

A team led by Klaus Scheufelen (German, 1913–2008) developed the Taifun surface-to-air missile, which was first demonstrated in January 1945 (Fig. 9.158). Scheufelen continued to develop missiles and rockets in the United States after the war.

U.S. Army Air Forces Colonel (later General) Donald Putt, who recruited many of these German-speaking engineers at the end of World War II and supervised their postwar work in the United States, gave an unclassified public overview of their wartime accomplishments in 1946 [Putt 1946b]:

> The Germans were preparing rocket surprises for the whole world in general and England in particular, which would have, it is believed, changed the course of the war if the invasion had been postponed for so short a time as six months. Many of Germany's research laboratories and several large commercial firms concentrated on this field of endeavor. This tremendous effort resulted in 138 guided missiles and assorted devices, including their modifications. [...]
>
> The stupendous effort in basic research expended by the Germans in the guided missile field was designed to cover the complete field of potentialities for such weapons. The losses incurred in Germany by heavy bomber raids can in no way be charged to lack

of preliminary research on missiles. Weapons of this category were divided into the following classifications:

A. Ground to air.

B. Air to air.

C. Air to ground.

D. Ground to ground.

E. Underwater to underwater.

F. Underwater to ground.

G. Underwater to air.

Moreover, every known type of remote control and fusing means was exploited. These included radio control, wire control, radar, continuous wave, acoustics, infrared, light beams, and magnetics.

Likewise, all methods of employing jet propulsion for subsonic and supersonic speeds were exploited.

In all, it was estimated that one-third of the aerodynamics research in Germany was devoted to problems of guided missiles. [...]

Some of the classes of German missiles based on intended use are:

A. The Beethoven [...] was an air-to-ground missile. [...]

B. The Enzian [...] was a ground-to-air missile. [...]

C. The Wasserfall was a ground-to-air missile. [...]

D. The X-4 was an air-to-air missile. [...]

E. The Fitz X [...] was an air-to-ground missile. This German bomb was released from aircraft flying at a minimum altitude of 22,000 ft. It was gyrostabilized and visibly guided into the target by radio. The Fritz X was ready for operational use in January, 1943, and was first employed successfully against our shipping and assault forces at Salerno. The warhead on this bomb was armor-piercing and carried a charge of 2530 lb of standard explosive.

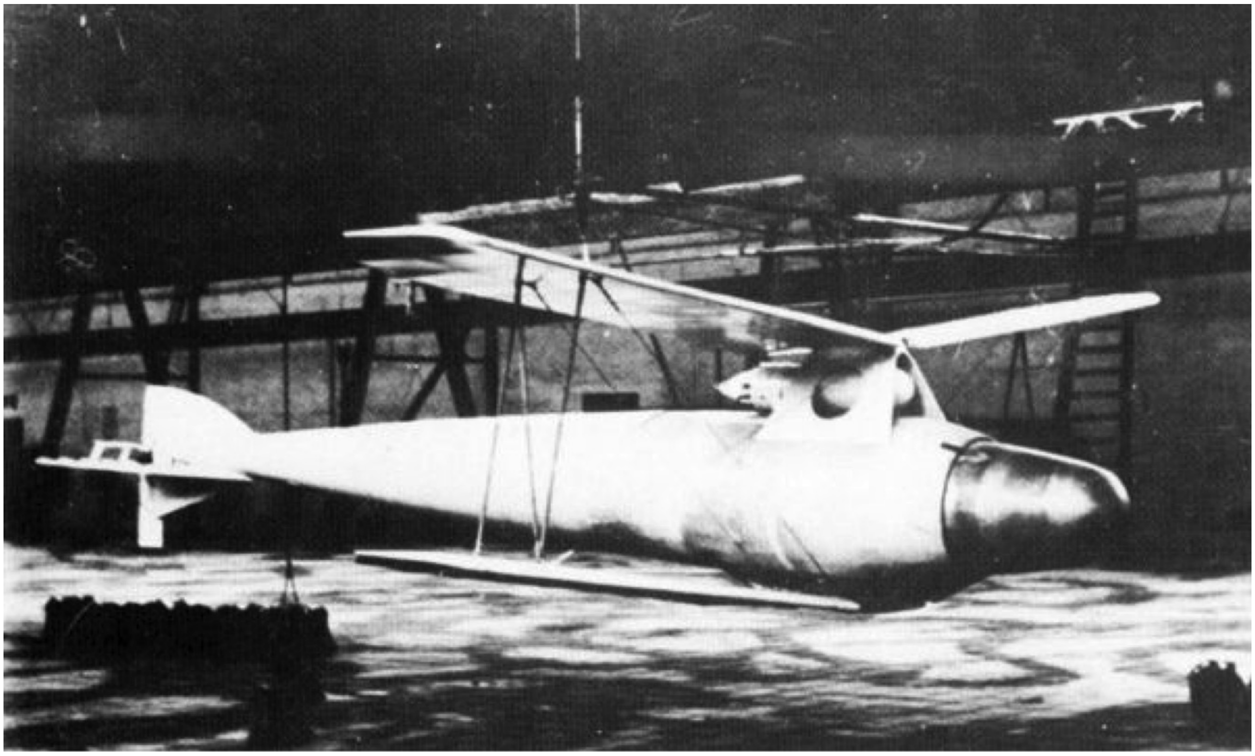
F. The Hs-298 [...] was an air-to-air missile. [...]

G. The Hs-117 [...] was a ground-to-air missile. It was named Schmetterling or butterfly, and was a rocket-propelled, radio-controlled missile to be launched from

> the ground against bomber formations. It accelerated to a speed of 560 mph, and was steadied in flight by a pendulum device. The take-off rocket burned out and were jettisoned; the main propulsion unit then drove the missile until it was detonated by a proximity fuse. Large-scale production began January, 1945, in an underground factory in Nordhausen.
>
> H. The Rheintochter [...] was a ground-to-air missile. It was a rocket-propelled anti-aircraft weapon and was controlled in flight by radio. It traveled at a speed of 1100 mph and carried an explosive charge of 330 lb, equipped with a proximity fuse, to a ceiling of 48,000 ft. The starting rocket, attached to the base, was blown off after combustion was completed. Development did not go beyond the test firing stage, but experiments were still being conducted as late as February, 1945. The code name Rheintochter means daughter of the Rhine.
>
> I. The FZG-76 [...] was a ground-to-ground missile. [...]
>
> In conclusion may I state that the Germans in the guided missile field were 10 years in advance of similar American development.

As just one more example of countless statements from the U.S. military about the effectiveness of German missiles, consider: Says Nazis Had New Rocket, *New York Times* 1946-01-18 p. 6:

> Germany developed a new rocket a month before V-E Day which proved so accurate that it almost ended Allied bombing attacks, Col. Leslie Simon, director of the Aberdeen Ballistics Research Laboratory, said today before 300 scientists and engineers meeting here. He declared that the weapon enabled the Germans to bring down our bombers "almost at will." The new rockets were mounted in groups of twenty-four on fast German interceptor planes.



Siemens-Halske wire-guided glide bomb (1914)

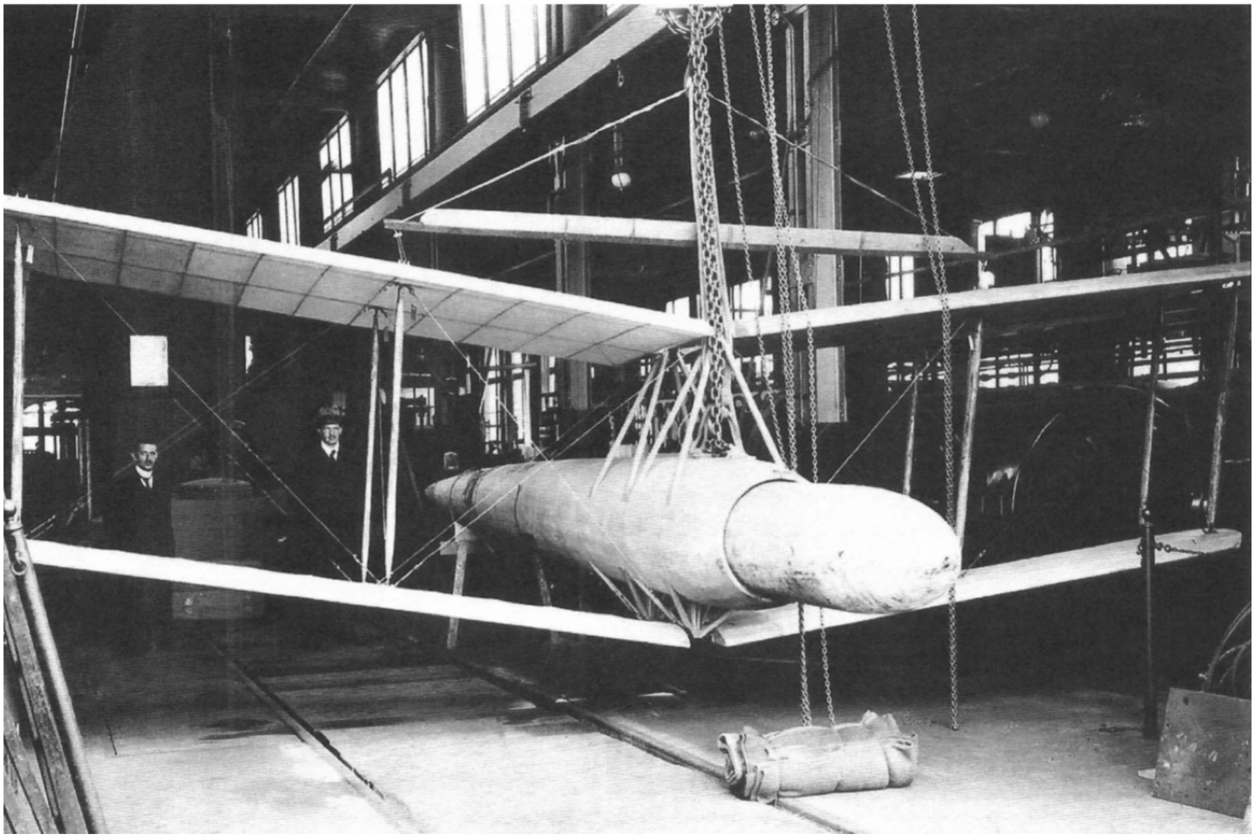


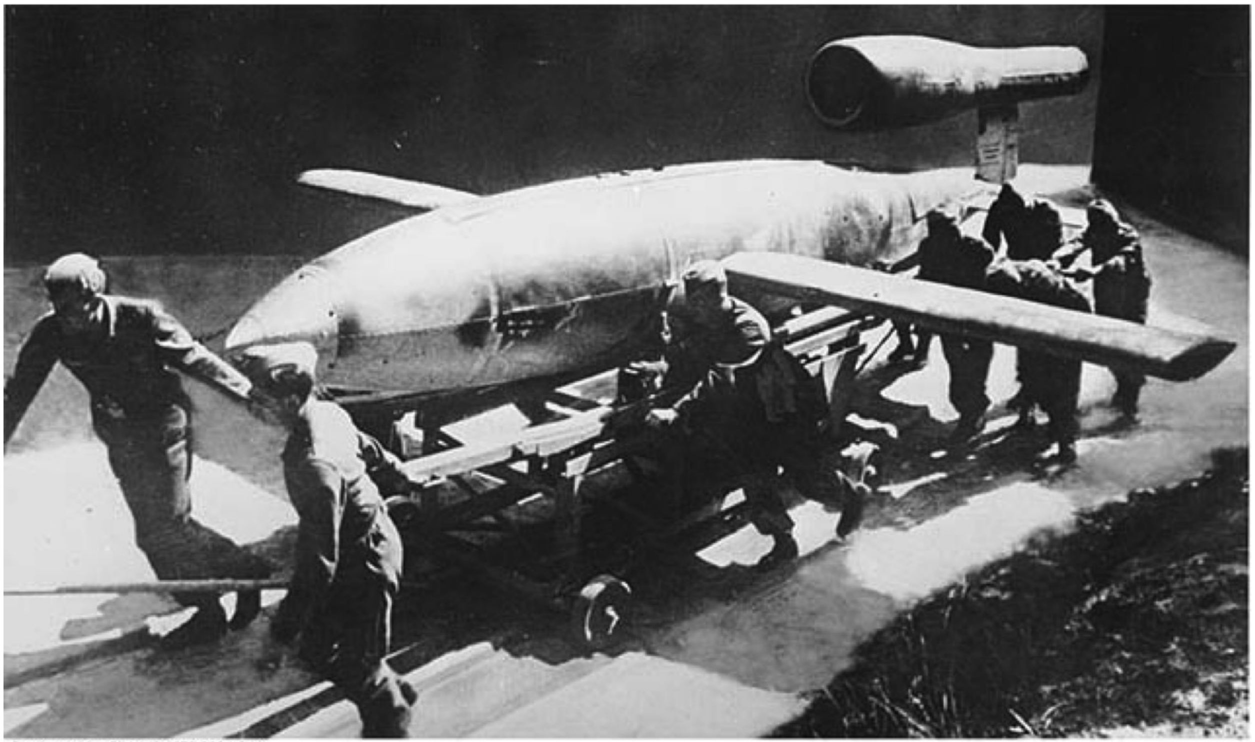
Figure 9.151: Siemens-Halske engineers developed the first wire-guided glide bombs in 1914.

Fritz Gosslau (1898–1965)

Robert Lusser (1899–1969)

Paul Schmidt (1898–1976)

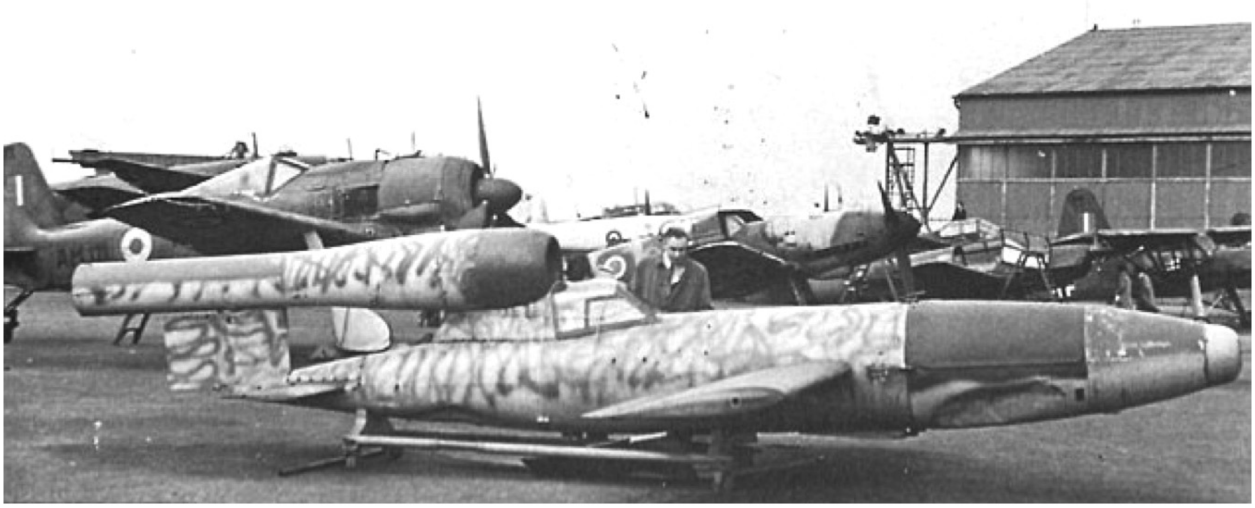
Fieseler Fi 103 (V-1) cruise missile, first flown in 1942



Bundesarchiv, Bild 146-1973-029A-24A
Foto: Lysiak | 1944/1945

Figure 9.152: Paul Schmidt, Fritz Gosslau, and Robert Lusser created the V-1 or Fieseler Fi 103 cruise missile, first flown in 1942, which was powered by a novel pulsejet engine.

Piloted V-1 (1945)



Heinkel He 111 with unpiloted V-1 under the wing as an air-launched cruise missile

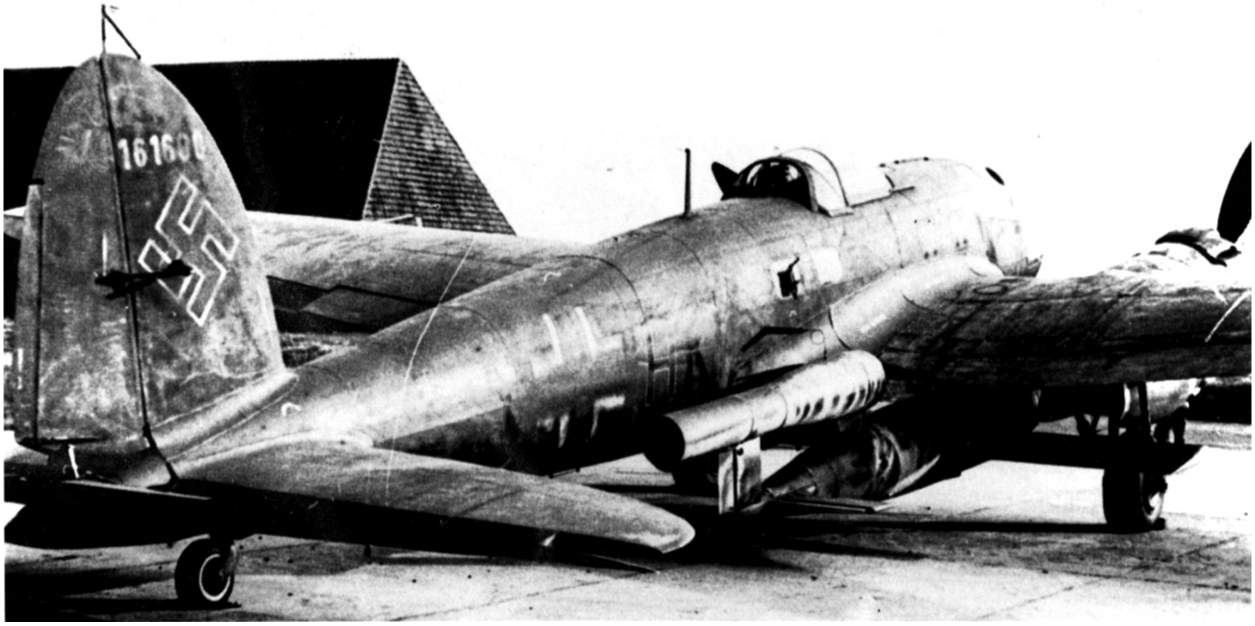
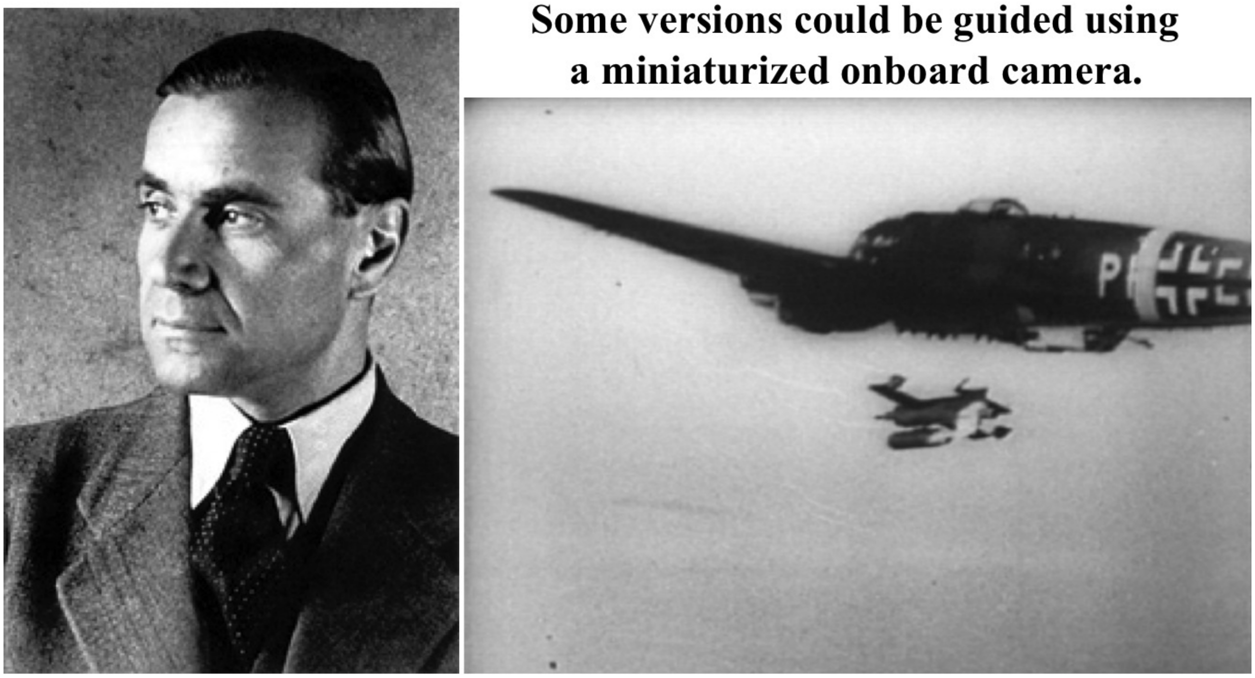


Figure 9.153: During the war, versions of the V-1 cruise missile that were piloted and/or air-launched were also produced and demonstrated.



Herbert Wagner (1900–1982)

Henschel Hs 293 smart bomb, first demonstrated in 1942. Some versions could be guided using a miniaturized onboard camera.

Henschel Hs 117 Schmetterling (Butterfly) surface-to-air and air-to-air missile, first demonstrated in 1944. Some versions could also be guided by a miniaturized onboard camera.

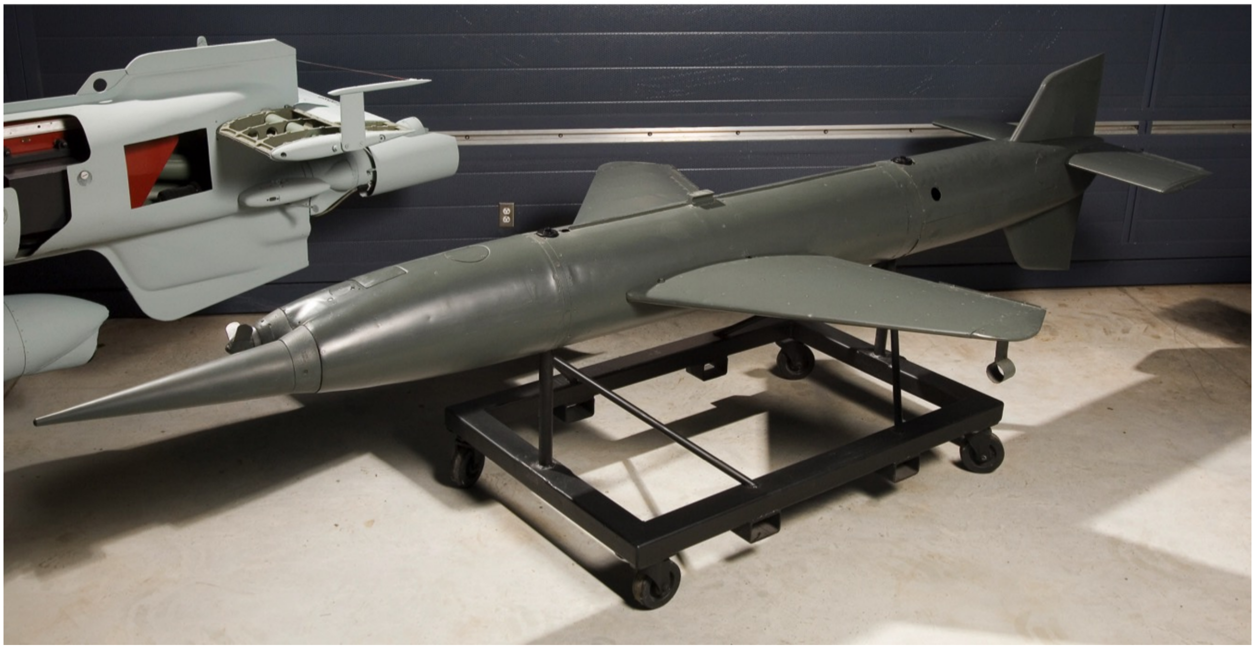


Figure 9.154: Herbert Wagner created precision guided weapons such as the Henschel Hs 293 smart bomb, first demonstrated in 1942, and the Henschel Hs 117 Schmetterling (Butterfly) surface-to-air and air-to-air missile, first demonstrated in 1944. Some versions of these weapons were guided by a miniaturized onboard camera (pp. 1008–1010).

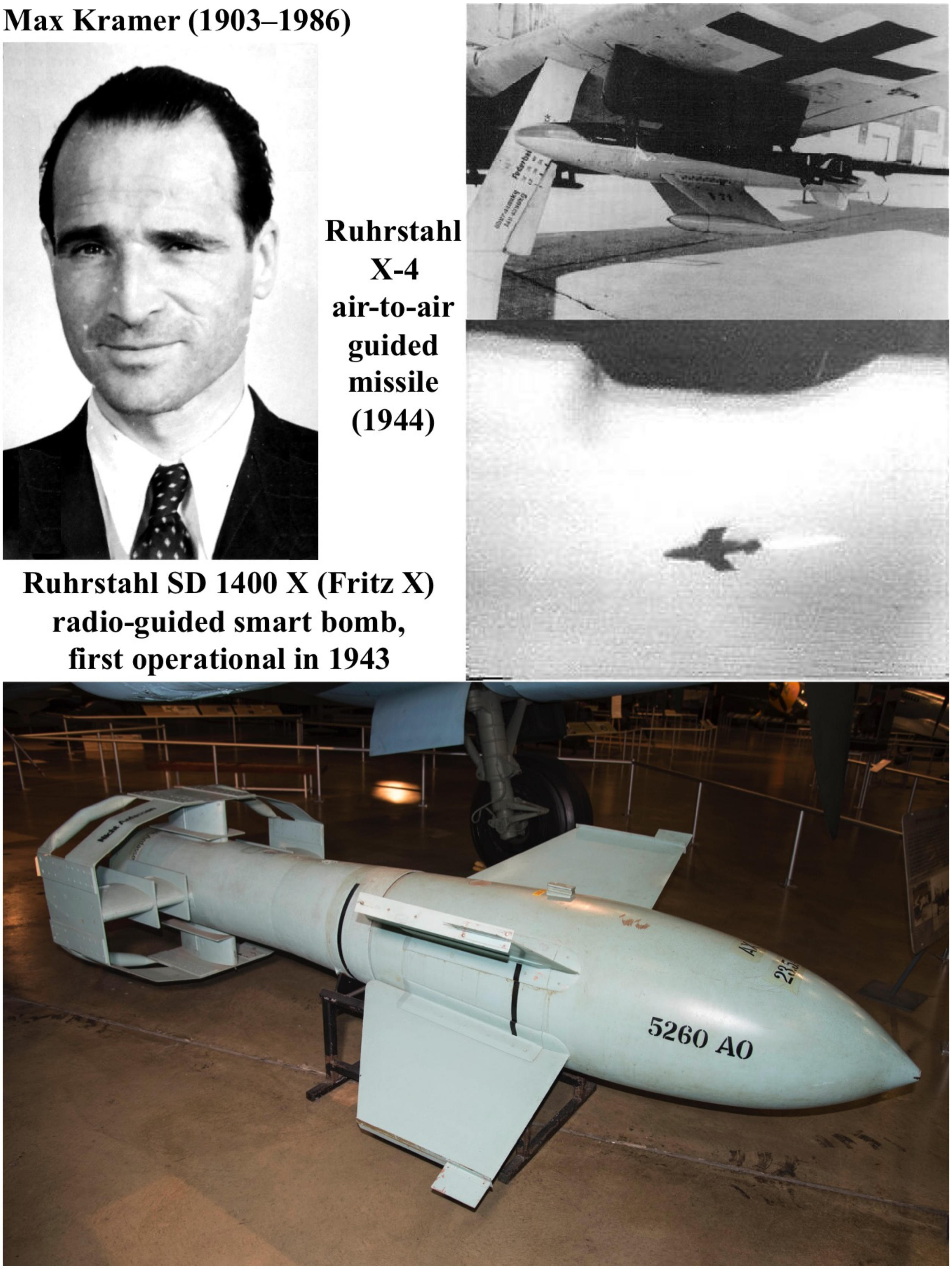

Max Kramer (1903–1986)
Ruhrstahl X-4 air-to-air guided missile (1944)
Ruhrstahl SD 1400 X (Fritz X) radio-guided smart bomb, first operational in 1943
5260 AO

Figure 9.155: Max Kramer created precision guided weapons such as the Ruhrstahl SD 1400 X (Fritz X) radio-guided smart bomb, first operational in 1943, and the Ruhrstahl X-4 air-to-air guided missile in 1944.

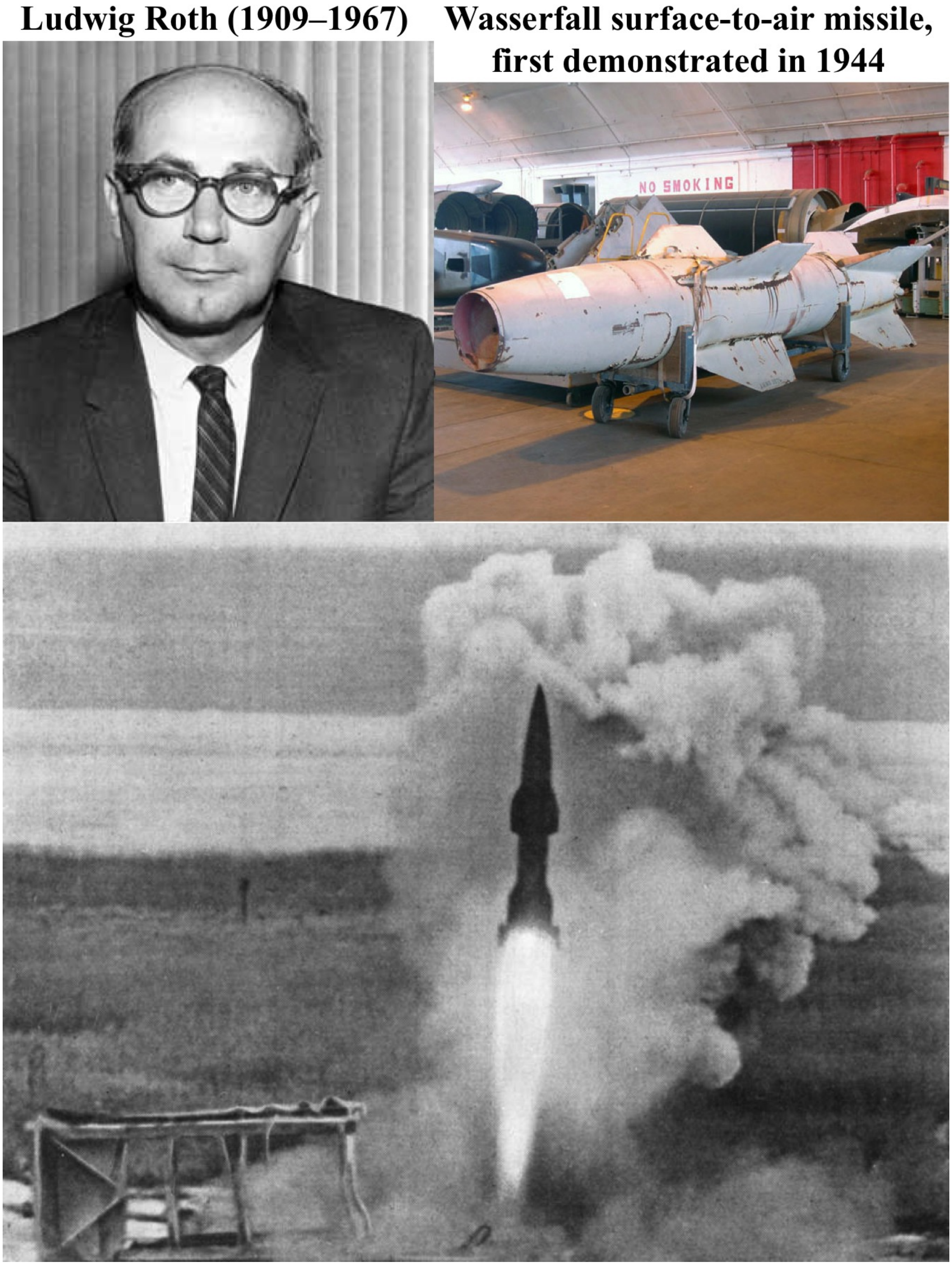

Ludwig Roth (1909–1967)
Wasserfall surface-to-air missile, first demonstrated in 1944
NO SMOKING

Figure 9.156: A team led by Ludwig Roth developed the Wasserfall surface-to-air missile, which was first demonstrated in 1944.

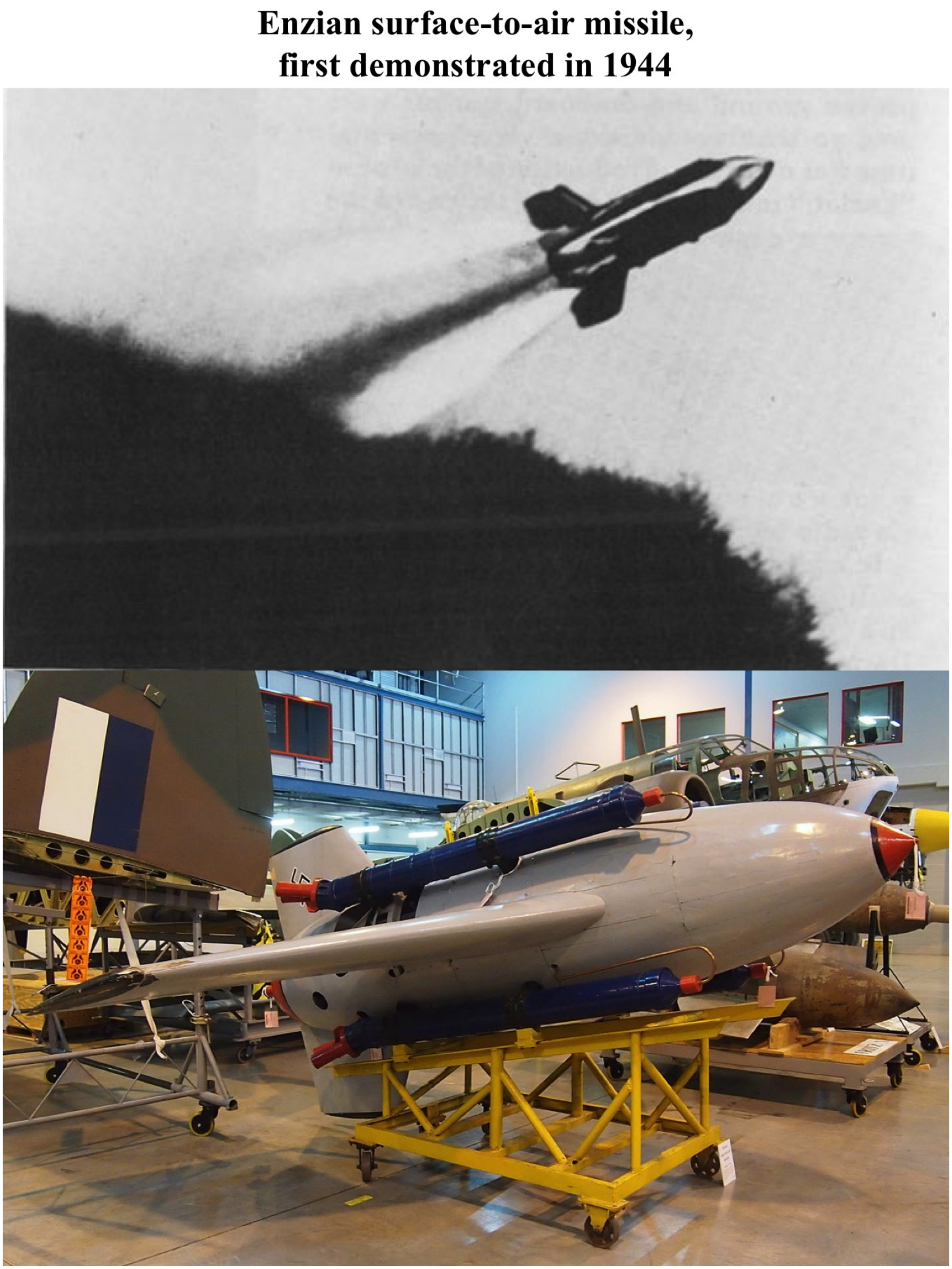
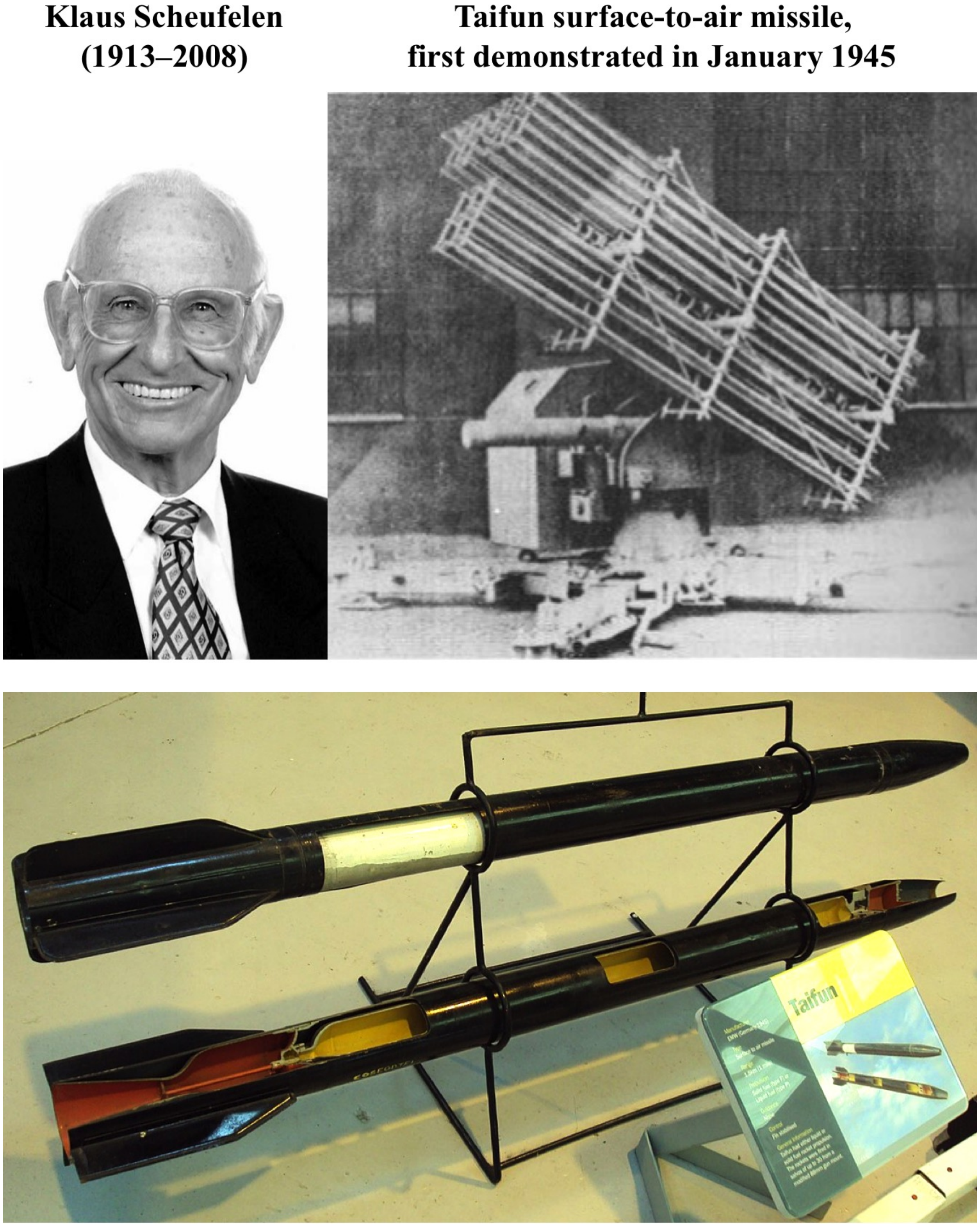

Enzian surface-to-air missile,
first demonstrated in 1944

Figure 9.157: Enzian surface-to-air missile, first demonstrated in 1944.



Klaus Scheufelen (1913–2008)

Taifun surface-to-air missile, first demonstrated in January 1945

Figure 9.158: A team led by Klaus Scheufelen developed the Taifun surface-to-air missile, which was first demonstrated in January 1945.

NARA Still Pictures, RG 111 SCA---Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941-1954. Captured German Equipment, German, Box 3347, Book 8, SC 231474.

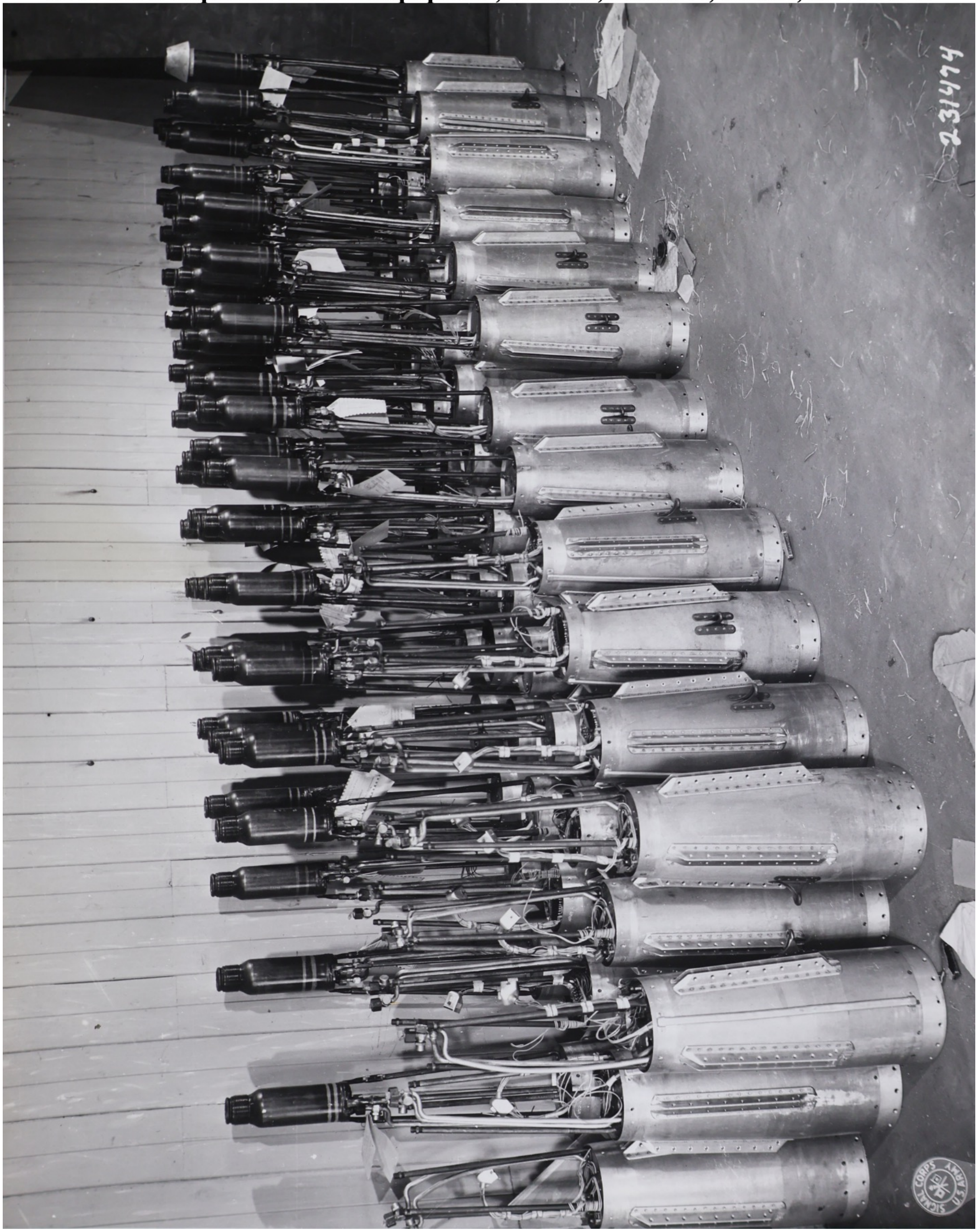


Figure 9.159: “Sections of new German F.X.3 experimental, self-propelled radio rockets, awaiting assembly, are stacked in a small factory in Hövelhof, Germany. The factory where these rockets were being manufactured was discovered by Antiaircraft Artillery Brigade, XVIth Corps, U.S. Ninth Army. 5/12/45” [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3347, Book 8, SC 231474.]

9.6.2 Postwar Missiles and Smart Bombs

The wartime missiles shown in this section are among the better-known German technological accomplishments. What is less well known is that those wartime missiles were not an engineering dead end. The scientists, engineers, prototypes, designs, methods, and experience from those programs were all used to create a wide variety of missiles that have been used around the world ever since [Mills 2020, 2022].

Figures 9.160–9.162 show just one example—some of the German-speaking scientists who developed U.S. missiles at the Naval Air Missile Test Center, Point Mugu, California. They included:

Alexis Dember (German, 1912–2002)

Willy Fiedler (German, 1908–1998)

Ernst Friedrich (German, 19??–19??)

Wilfried Hell (German, 1914–2010)

Werner Hohenner (German, 1907–2000)

Hans Hollmann (German, 1899–1960)

Edgar Kutzscher (German, 1906–19??)

Reinhard Lahde (German, 1908–1999)

Johann Ludloff (German, 19??–19??)

Robert Lusser (German, 1899–1969)

Otto Schwede (German, 1912–2005)

Theodore Sturm (German, 19??–19??)

Herbert Wagner (Austrian, 1900–1982)

Etc.

These and other German-speaking scientists were responsible for the postwar development of cruise missiles in the United States and other countries. As a starting point, the V-1 was directly copied and deployed by the United States, renamed as the Loon missile [p. 1896; Quigg 2014]. Using captured German prototypes, factories, and engineers, the Soviet Union also copied and deployed the V-1, designating it as the 10Kh missile. The German-speaking scientists then created a long line of more advanced cruise missiles, ranging from late 1940s–1950s examples (e.g., U.S. SM-62 Snark, SM-64 Navaho, MGM-1 Matador, SSM-N-6 Rigel, and SSM-N-8 Regulus; Soviet P-5 Pyatyorka) to modern cruise missiles (e.g., U.S. BGM-109 Tomahawk and AGM-86 Air-Launched Cruise Missile (ALCM); Russian Kh-55 and Kh-101).

As another example of direct technology transfer from the German-speaking world, the Bell GAM-63 RASCAL (RAdar SCAnning Link) air-launched cruise missile was designed by Walter Dornberger (German, 1895–1980, Fig. 9.223) in 1946 and first launched in 1953; see Fig. 9.164. Essentially it was a German-derived liquid propellant rocket that was intermediate in size between the Wasserfall (p. 1844) and A-4/V-2 (p. 1860) and was deployed like the air-launched V-1 (p. 1841). There was also a British version of the RASCAL, the Avro Blue Steel (Fig. 9.165), which was deployed in 1963. (Dornberger had worked for the British immediately after the war, before going to the United States.)

The German-speaking scientists also developed a wide range of other postwar missile types, including for example:

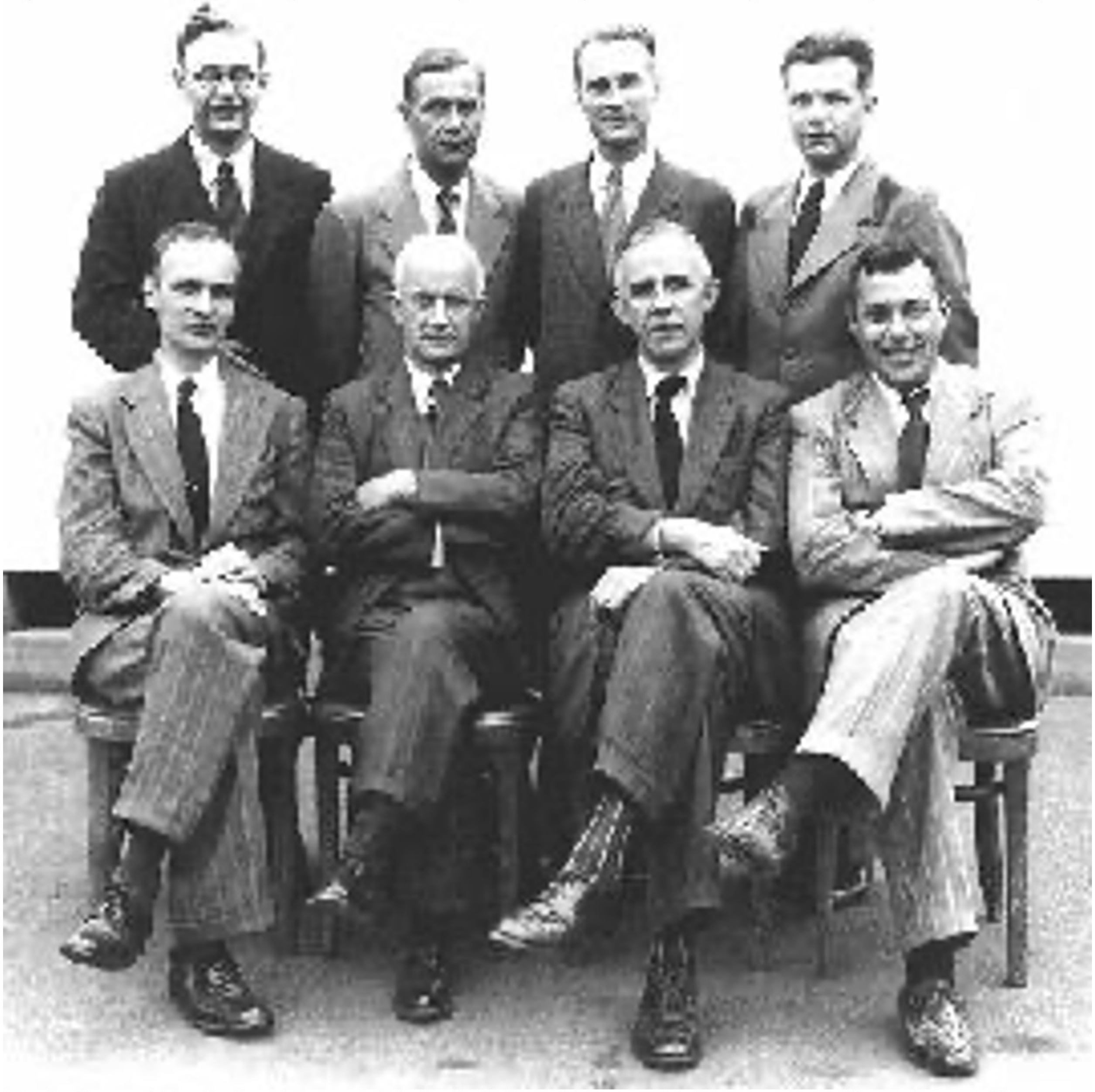
- AGM-12 Bullpup air-to-ground missile
- SSM-A-23 Dart anti-tank missile
- AIM-4 Falcon air-to-air missile (p. 1155)
- AGM-84/RGM-84/UGM-84 Harpoon anti-ship missile
- MIM-23 Hawk surface-to-air missile
- AAM-N-4 Oriole air-to-air missile
- MGM-51 Shillelagh anti-tank missile
- AIM-9 Sidewinder air-to-air missile (p. 1155)
- AIM-7 Sparrow air-to-air missile

Furthermore, German-speaking scientists and engineers created a wide variety of missile guidance, tracking, and homing systems during the war, and continued to develop those technologies in other countries after the war. For infrared and heat-seeking targeting systems for missiles, see pp. 1131–1155. For radio and acoustic proximity fuses and homing devices, see pp. 1254–1258, 5411.

For German-speaking contributions to larger rockets, see Sections 9.7–9.8 and Appendix E.

Naval Air Missile Test Center, Point Mugu, California (ca. 1950)

Wilfried Hell (1914–2010) Herbert Wagner (1900–1982) Werner Hohenner (1907–2000) Edgar Kutzscher (1906–19??)



Reinhard Lahde (1908–1999) Ernst Friedrich (19??–19??) Hans Hollmann (1899–1960) Theodore Sturm (19??–19??)

Not shown: Alexis Dember (1912–2002),
Willy Fiedler (1908–1998), Johann Ludloff (19??–19??),
Robert Lusser (1899–1969), Otto Schwede (1912–2005), etc.

Figure 9.160: Examples of German-speaking scientists who developed U.S. missiles at the Naval Air Missile Test Center, Point Mugu, California.

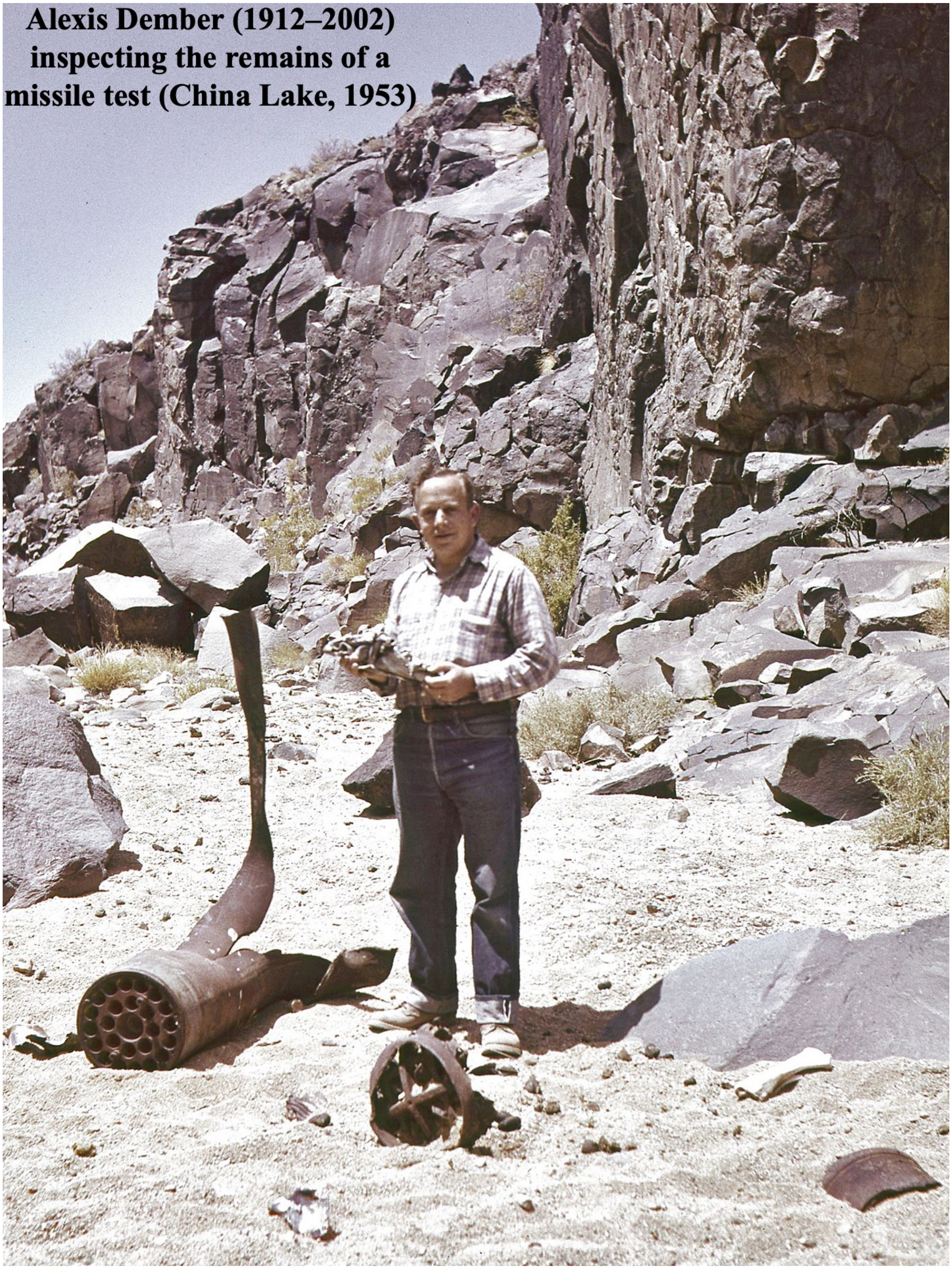
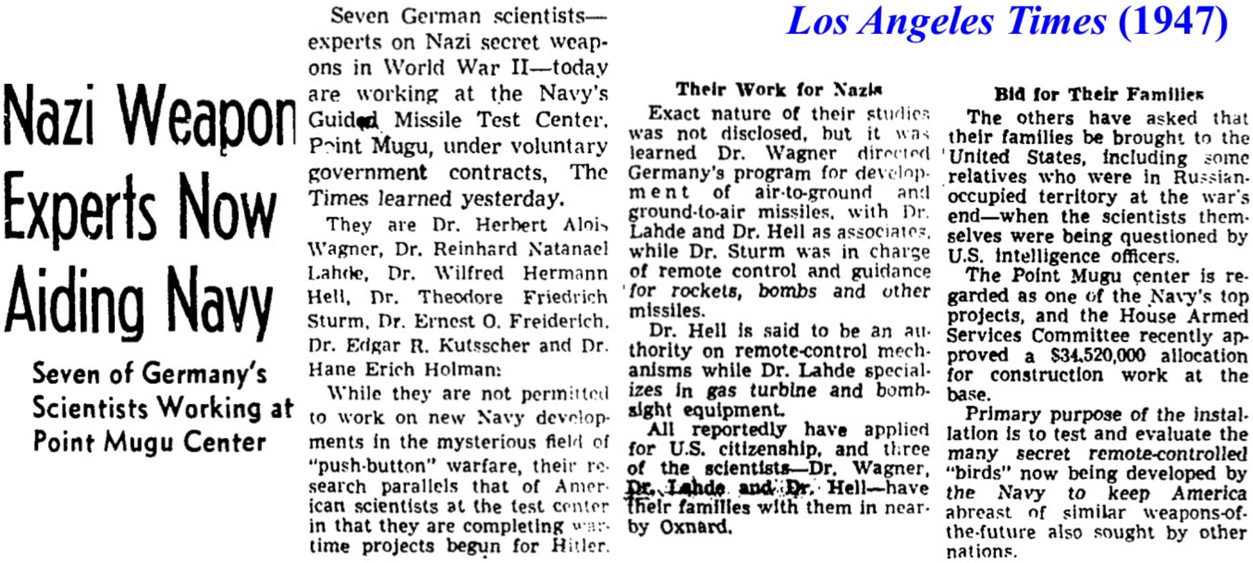

Alexis Dember (1912–2002)
inspecting the remains of a
missile test (China Lake, 1953)

Figure 9.161: Alexis Dember inspecting the remains of a missile test at the Naval Ordnance Test Station at China Lake, California in 1953.



Los Angeles Times (1947)

Nazi Weapon Experts Now Aiding Navy

Seven of Germany's Scientists Working at Point Mugu Center

Seven German scientists—experts on Nazi secret weapons in World War II—today are working at the Navy's Guided Missile Test Center, Point Mugu, under voluntary government contracts, The Times learned yesterday.

They are Dr. Herbert Alois Wagner, Dr. Reinhard Natanael Lahde, Dr. Wilfred Hermann Hell, Dr. Theodore Friedrich Sturm, Dr. Ernest O. Freiderich, Dr. Edgar R. Kutsscher and Dr. Hane Erich Holman.

While they are not permitted to work on new Navy developments in the mysterious field of "push-button" warfare, their research parallels that of American scientists at the test center in that they are completing war-time projects begun for Hitler.

Their Work for Nazis

Exact nature of their studies was not disclosed, but it was learned Dr. Wagner directed Germany's program for development of air-to-ground and ground-to-air missiles, with Dr. Lahde and Dr. Hell as associates, while Dr. Sturm was in charge of remote control and guidance *for rockets, bombs* and other missiles.

Dr. Hell is said to be an authority on remote-control mechanisms while Dr. Lahde specializes in gas turbine and bombsight equipment.

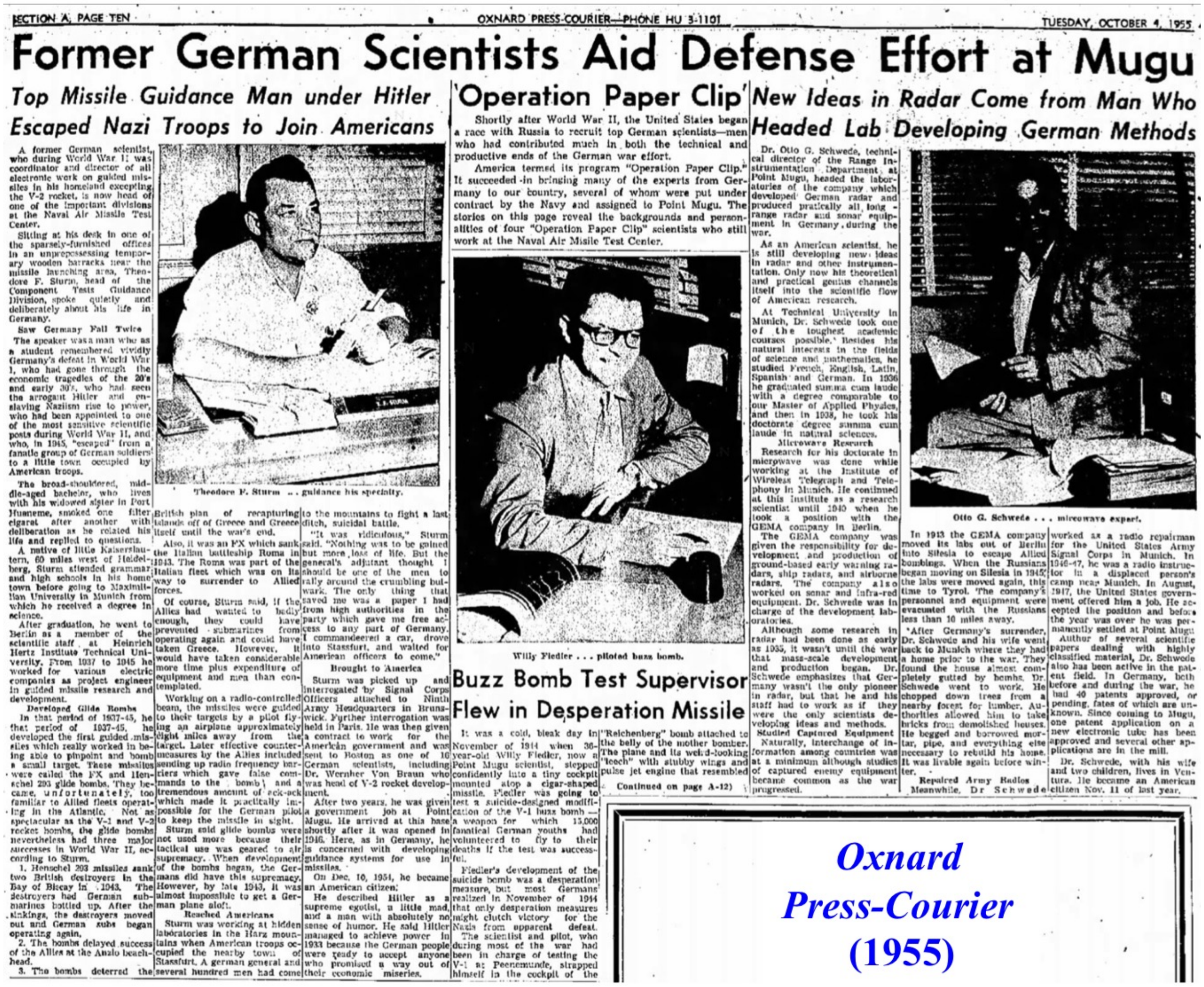
All reportedly have applied for U.S. citizenship, and three of the scientists—Dr. Wagner, Dr. Lahde and Dr. Hell—have their families with them in nearby Oxnard.

Bid for Their Families

The others have asked that their families be brought to the United States, including some relatives who were in Russian-occupied territory at the war's end—when the scientists themselves were being questioned by U.S. intelligence officers.

The Point Mugu center is regarded as one of the Navy's top projects, and the House Armed Services Committee recently approved a $34,520,000 allocation for construction work at the base.

Primary purpose of the installation is to test and evaluate the many secret remote-controlled "birds" now being developed by the Navy to keep America abreast of similar weapons-of-the-future also sought by other nations.



SECTION A, PAGE TEN — OXNARD PRESS-COURIER—PHONE HU 3-1101 — TUESDAY, OCTOBER 4, 1955

Former German Scientists Aid Defense Effort at Mugu

Top Missile Guidance Man under Hitler Escaped Nazi Troops to Join Americans

A former German scientist, who during World War II was coordinator and director of all electronic work on guided missiles in his homeland excepting the V-2 rocket, is now head of one of the important divisions at the Naval Air Missile Test Center.

Sitting at his desk in one of the sparsely-furnished offices in an unprepossessing temporary wooden barracks near the missile launching area, Theodore F. Sturm, head of the Component Tests Guidance Division, spoke quietly and deliberately about his life in Germany.

Saw Germany Fall Twice

The speaker was a man who as a student remembered vividly Germany's defeat in World War I, who had gone through the economic tragedies of the 20's and early 30's, who had seen the arrogant Hitler and enslaving Naziism rise to power, who had been appointed to one of the most sensitive scientific posts during World War II, and who, in 1945, "escaped" from a fanatic group of German soldiers to a little town occupied by American troops.

Theodore F. Sturm . . . guidance his specialty.

The broad-shouldered, middle-aged bachelor, who lives with his widowed sister in Port Hueneme, smoked one filter cigaret after another with deliberation as he related his life and replied to questions.

A native of little Kaiserslautern, 60 miles west of Heidelberg, Sturm attended grammar and high schools in his home town before going to Maximillian University in Munich from which he received a degree in science.

After graduation, he went to Berlin as a member of the scientific staff at Heinrich Hertz Institute Technical University. From 1937 to 1945 he worked for various electric companies as project engineer in guided missile research and development.

Developed Glide Bombs

In that period of 1937-45, he that period of 1937-45, he developed the first guided missiles which really worked in being able to pinpoint and bomb a small target. These missiles were called the FX and Henschel 293 glide bombs. They became, unfortunately, too familiar to Allied fleets operating in the Atlantic. Not as spectacular as the V-1 and V-2 rocket bombs, the glide bombs nevertheless had three major successes in World War II, according to Sturm.

1. Henschel 293 missiles sank two British destroyers in the Bay of Biscay in 1943. The destroyers had German submarines bottled up. After the sinkings, the destroyers moved out and German subs began operating again.
2. The bombs delayed success of the Allies at the Anzio beachhead.
3. The bombs deterred the British plan of recapturing islands off of Greece and Greece itself until the war's end.

Also, it was an FX which sank the Italian battleship Roma in 1943. The Roma was part of the Italian fleet which was on its way to surrender to Allied forces.

Of course, Sturm said, if the Allies had wanted to badly enough, they could have prevented submarines from operating again and could have taken Greece. However, it would have taken considerable more time plus expenditure of equipment and men than contemplated.

Working on a radio-controlled beam, the missiles were guided to their targets by a pilot flying an airplane approximately eight miles away from the target. Later effective countermeasures by the Allies included sending up radio frequency barriers which gave false commands to the bombs and a tremendous amount of ack-ack which made it practically impossible for the German pilot to keep the missile in sight.

Sturm said glide bombs were not used more because their tactical use was geared to air supremacy. When development of the bombs began, the Germans did have this supremacy. However, by late 1943, it was almost impossible to get a German plane aloft.

Reached Americans

Sturm was working at hidden laboratories in the Harz mountains when American troops occupied the nearby town of Stassfurt. A german general and several hundred men had come to the mountains to fight a last ditch, suicidal battle.

"It was ridiculous," Sturm said. "Nothing was to be gained but more loss of life. But the general's adjutant thought I should be one of the men to rally around the crumbling bulwark. The only thing that saved me was a paper I had from high authorities in the party which gave me free access to any part of Germany. I commandeered a car, drove into Stassfurt, and waited for American officers to come."

Brought to America

Sturm was picked up and interrogated by Signal Corps Officers attached to Ninth Army Headquarters in Brunswick. Further interrogation was held in Paris. He was then given a contract to work for the American government and was sent to Boston as one of 16 German scientists, including Dr. Wernher Von Braun who was head of V-2 rocket development.

After two years, he was given a government job at Point Mugu. He arrived at this base shortly after it was opened in 1946. Here, as in Germany, he is concerned with developing guidance systems for use in missiles.

On Dec. 10, 1954, he became an American citizen.

He described Hitler as a supreme egotist, a little mad, and a man with absolutely no sense of humor. He said Hitler managed to achieve power in 1933 because the German people were ready to accept anyone who promised a way out of their economic miseries.

'Operation Paper Clip'

Shortly after World War II, the United States began a race with Russia to recruit top German scientists—men who had contributed much in both the technical and productive ends of the German war effort.

America termed its program "Operation Paper Clip." It succeeded in bringing many of the experts from Germany to our country, several of whom were put under contract by the Navy and assigned to Point Mugu. The stories on this page reveal the backgrounds and personalities of four "Operation Paper Clip" scientists who still work at the Naval Air Misile Test Center.

Willy Fiedler . . . piloted buzz bomb.

Buzz Bomb Test Supervisor Flew in Desperation Missile

It was a cold, bleak day in November of 1944 when 36-year-old Willy Fiedler, now a Point Mugu scientist, stepped confidently into a tiny cockpit mounted atop a cigar-shaped missile. Fiedler was going to test a suicide-designed modification of the V-1 buzz bomb — a weapon for which 15,000 fanatical German youths had volunteered to fly to their deaths if the test was successful.

Fiedler's development of the suicide bomb was a desperation measure, but most Germans realized in November of 1944 that only desperation measures might clutch victory for the Nazis from apparent defeat.

The scientist and pilot, who during most of the war had been in charge of testing the V-1 at Peenemunde, strapped himself in the cockpit of the "Reichenberg" bomb attached to the belly of the mother bomber. The plane and its weird-looking "leech" with stubby wings and pulse jet engine that resembled

Continued on page A-12)

New Ideas in Radar Come from Man Who Headed Lab Developing German Methods

Dr. Otto G. Schwede, technical director of the Range Instrumentation Department at Point Mugu, headed the laboratories of the company which developed German radar and produced pratically all long-range radar and sonar equipment in Germany during the war.

As an American scientist, he is still developing new ideas in radar and other instrumentation. Only now his theoretical and practical genius channels itself into the scientific flow of American research.

At Technical University in Munich, Dr. Schwede took one of the toughest academic courses possible. Besides his natural interests in the fields of science and mathematics, he studied French, English, Latin, Spanish and German. In 1936 he graduated summa cum laude with a degree comparable to our Master of Applied Physics, and then in 1938, he took his doctorate degree summa cum laude in natural sciences.

Microwave Research

Research for his doctorate in microwave was done while working at the Institute of Wireless Telegraph and Telephony in Munich. He continued at this Institute as a research scientist until 1940 when he took a position with the GEMA company in Berlin.

The GEMA company was given the responsibility for development and production of ground-based early warning radars, ship radars, and airborne radars. The company also worked on sonar and infra-red equipment. Dr. Schwede was in charge of the development laboratories.

Although some research in radar had been done as early as 1935, it wasn't until the war that mass-scale development and production began. Dr. Schwede emphasizes that Germany wasn't the only pioneer in radar, but that he and his staff had to work as if they were the only scientists developing ideas and methods.

Studied Captured Equipment

Naturally, interchange of information among countries was at a minimum although studies of captured enemy equipment became common as the war progressed.

Otto G. Schwede . . . mircowave expert.

In 1943 the GEMA company moved its labs out of Berlin into Silesia to escape Allied bombings. When the Russians began moving on Silesia in 1945, the labs were moved again, this time to Tyrol. The company's personnel and equipment were evacuated with the Russians less than 10 miles away.

After Germany's surrender, Dr. Schwede and his wife went back to Munich where they had a home prior to the war. They found the house almost completely gutted by bombs. Dr. Schwede went to work. He chopped down trees from a nearby forest for lumber. Authorities allowed him to take bricks from demolished houses. He begged and borrowed mortar, pipe, and everything else necessary to rebuild his home. It was livable again before winter.

Repaired Army Radios

Meanwhile, Dr Schwede worked as a radio repairman for the United States Army Signal Corps in Munich. In 1946-47, he was a radio instructor in a displaced person's camp near Munich. In August, 1947, the United States government offered him a job. He accepted the position and before the year was over he was permanently settled at Point Mugu.

Author of several scientific papers dealing with highly classified material, Dr. Schwede also has been active in the patent field. In Germany, both before and during the war, he had 40 patents approved, or pending, fates of which are unknown. Since coming to Mugu, one patent application on a new electronic tube has been approved and several other applications are in the mill.

Dr. Schwede, with his wife and two children, lives in Ventura. He became an American citizen Nov. 11 of last year.

Oxnard Press-Courier (1955)

Figure 9.162: Examples of German-speaking scientists who developed U.S. missiles at the Naval Air Missile Test Center, Point Mugu, California.

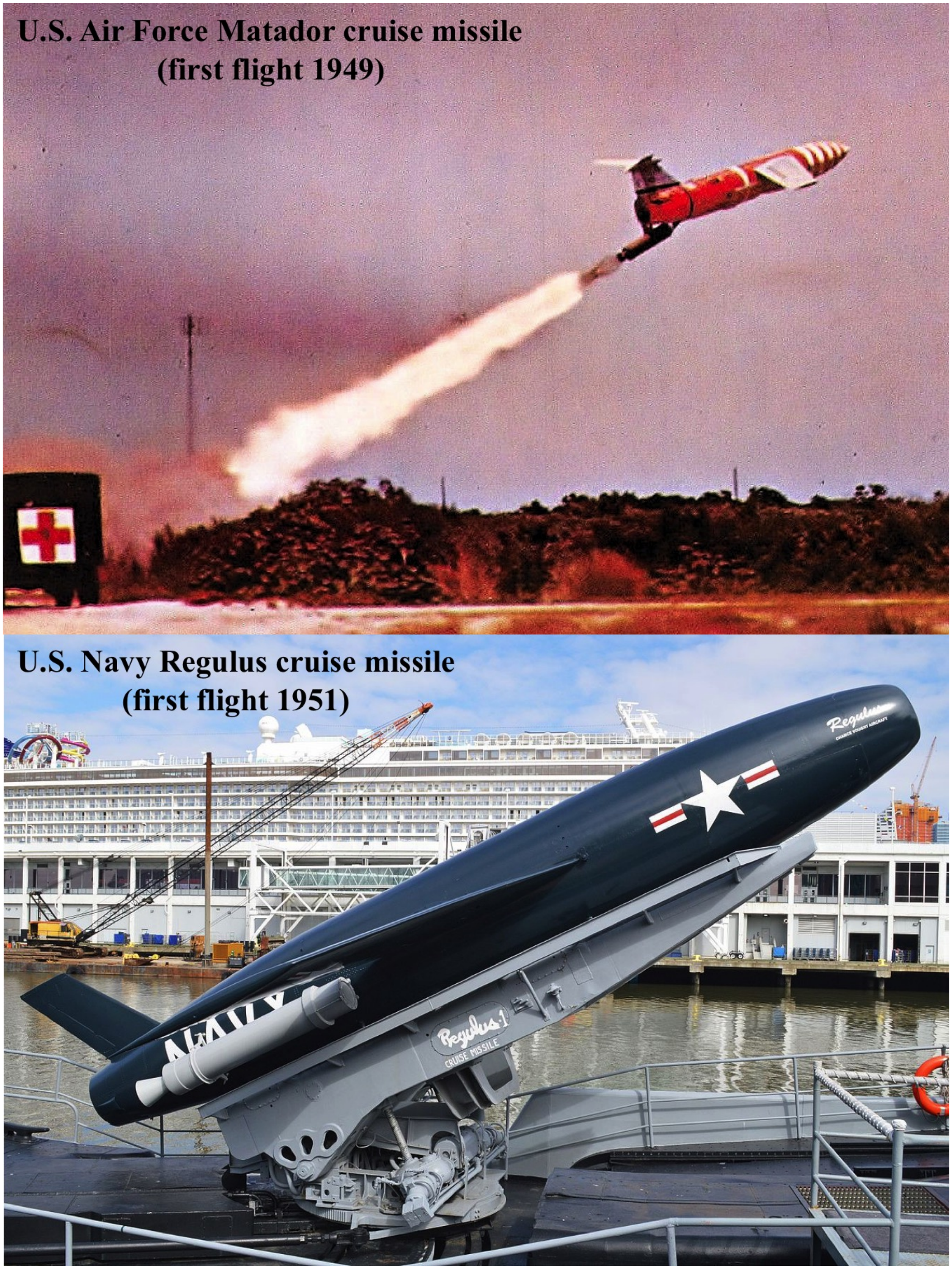
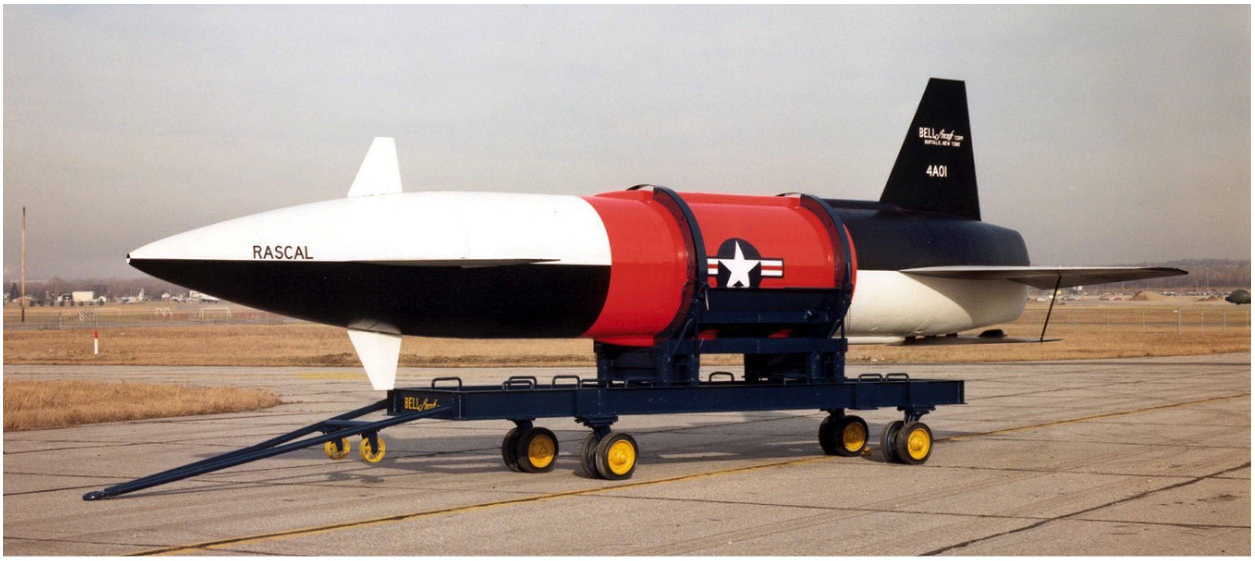

U.S. Air Force Matador cruise missile
(first flight 1949)
U.S. Navy Regulus cruise missile
(first flight 1951)
Regulus
CHANCE VOUGHT AIRCRAFT
NAVY
Regulus-1
CRUISE MISSILE

Figure 9.163: German hardware and knowledge and German-speaking scientists led to the development of the U.S. Air Force Matador cruise missile (first flight 1949), U.S. Navy Regulus cruise missile (first flight 1951), and other postwar cruise missiles.



Bell GAM-63 RASCAL air-launched cruise missile (designed by Walter Dornberger in 1946, first launched in 1953)

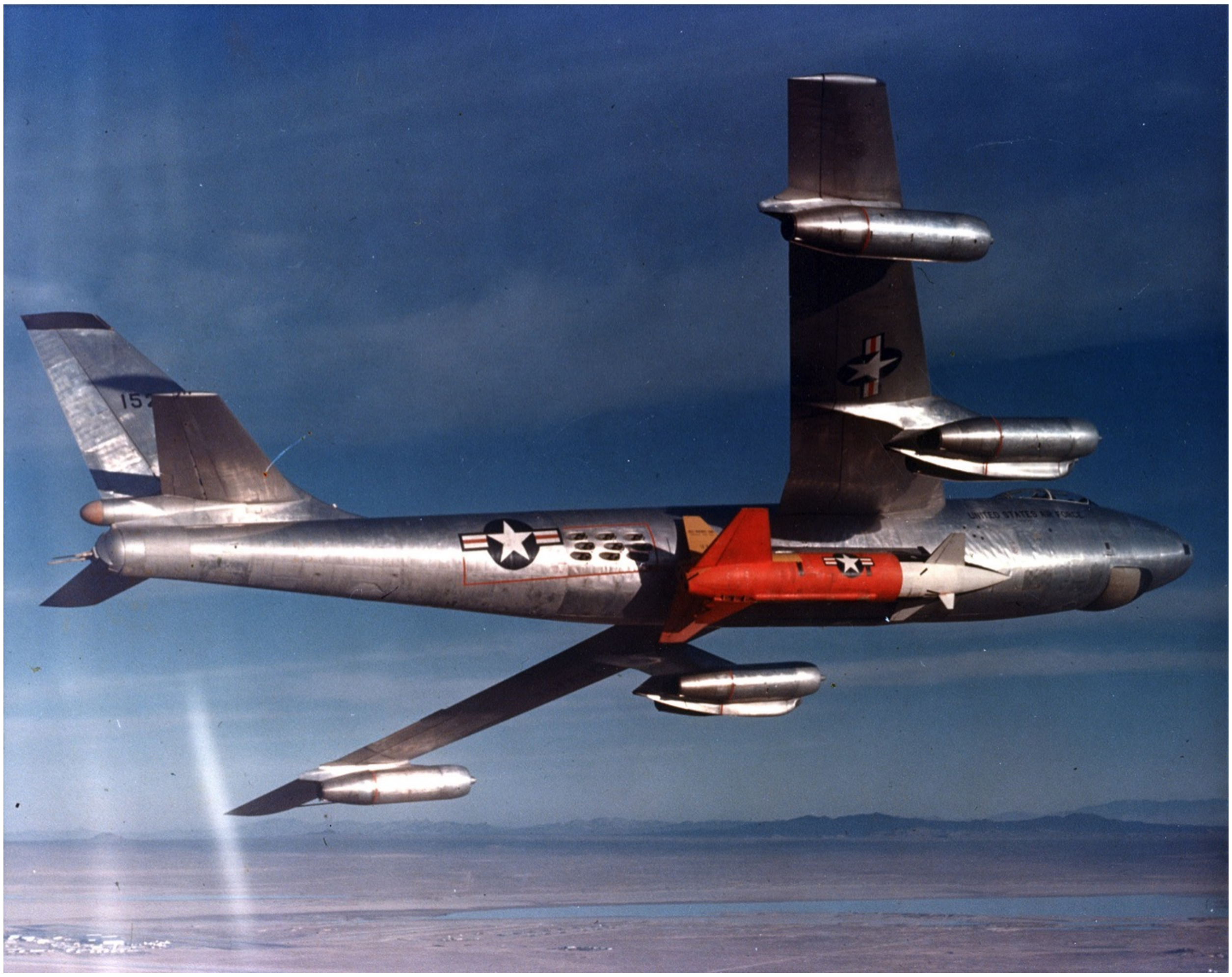
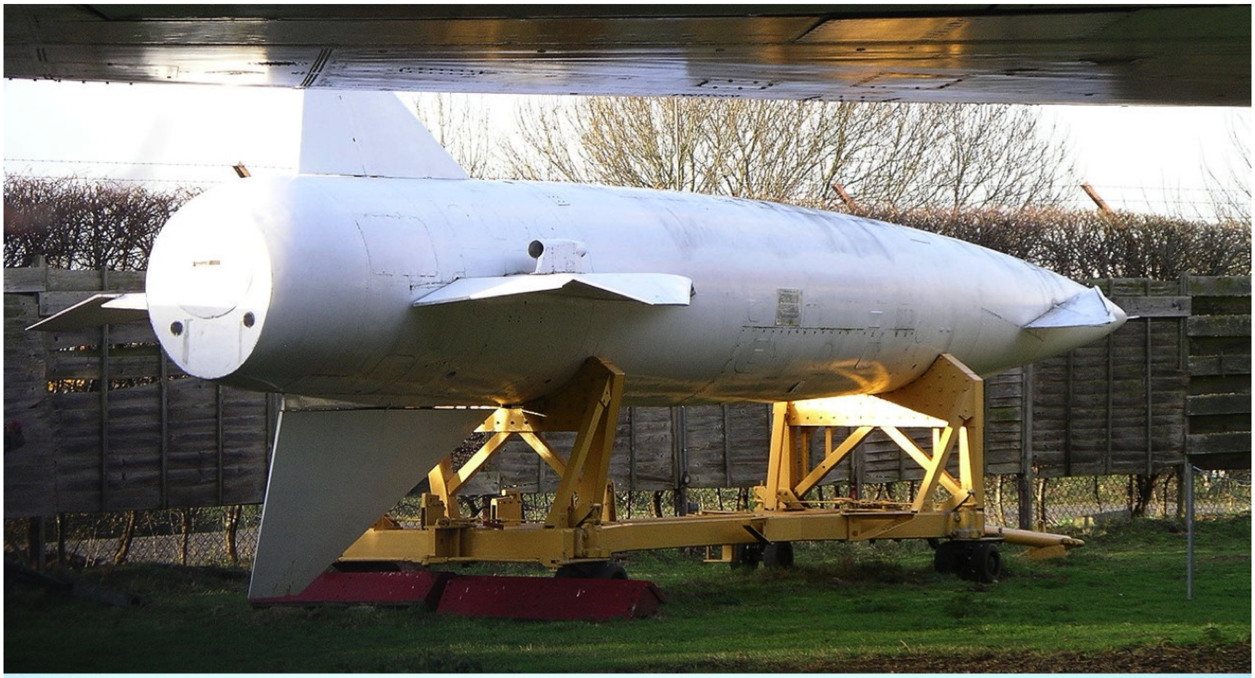


Figure 9.164: The Bell GAM-63 RASCAL air-launched cruise missile was designed by Walter Dornberger in 1946 and first launched in 1953. Essentially it was a German-derived liquid propellant rocket that was intermediate in size between the Wasserfall (p. 1844) and A-4/V-2 (p. 1860) and was deployed like the air-launched V-1 (p. 1841).



The Avro Blue Steel air-launched cruise missile carried by Vulcan and Victor bombers (deployed in 1963) was essentially the British version of Walter Dornberger's Bell GAM-63 RASCAL

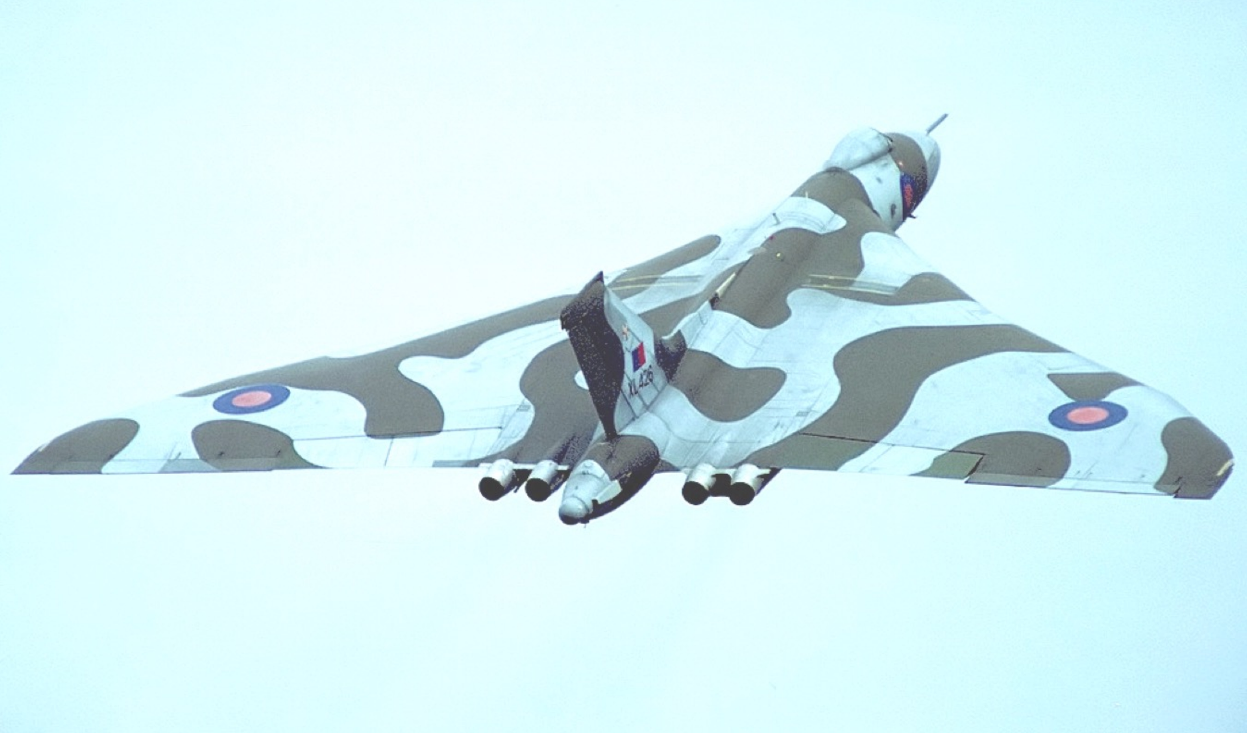


Figure 9.165: The Avro Blue Steel air-launched cruise missile carried by Vulcan and Victor bombers (deployed in 1963) was essentially the British version of Walter Dornberger's Bell GAM-63 RASCAL (p. 1854).

9.7 Large Liquid Propellant Rockets

Perhaps the best-known contributions (though dimming with time as the memories become more distant) of German-speaking scientists were the development of large rockets and spacecraft. German-speaking creators led the development of all types of rocket-related technologies in Germany during World War II and in countries around the world after the war.

Probably the most publicly visible rocket-related technology is liquid propellant rockets, which carry a liquid fuel and liquid oxidizer and burn them together to produce thrust, as shown in Fig. 9.166 [Hill and Peterson 1991; Huzel and Huang 1992; George Sutton 1992]. As illustrated in the upper part of the figure, the fuel and oxidizer are burned in a special combustion chamber, generating a gas that initially has a very high temperature (thermal energy) and high pressure (potential energy) but little velocity (kinetic energy). That gas then expands as it flows out through a nozzle, converting much of the initial thermal and potential energy into kinetic energy of a high-velocity exhaust stream. As shown in the lower part of the figure, it is necessary to pressurize the oxidizer and fuel from the storage tanks before they can be injected into the combustion chamber, since the gas pressure inside the combustion chamber is so high. Smaller, simpler liquid propellant rockets use high-pressure gas to pressurize the propellant in the tanks, but larger liquid propellant rockets usually use a turbopump to raise the pressure of the fuel and oxidizer just before they are injected into the combustion chamber. Small amounts of fuel and oxidizer are diverted to power the turbopump, or sometimes the turbopump is powered by an entirely separate supply of propellant. In order to cool the engine and to preheat the fuel, usually fuel first detours through coils wrapping the combustion chamber and nozzle.

This section covers the development of liquid propellant rockets by German-speaking creators who worked in:

9.7.1. Pre-war and wartime German rocket programs

9.7.2. Postwar U.S. and U.K. rocket programs

9.7.3. Postwar Soviet rocket programs

9.7.4. Postwar French rocket programs

German-speaking scientists also made important contributions to postwar rocket programs in many other countries around the world, but those are not covered here.

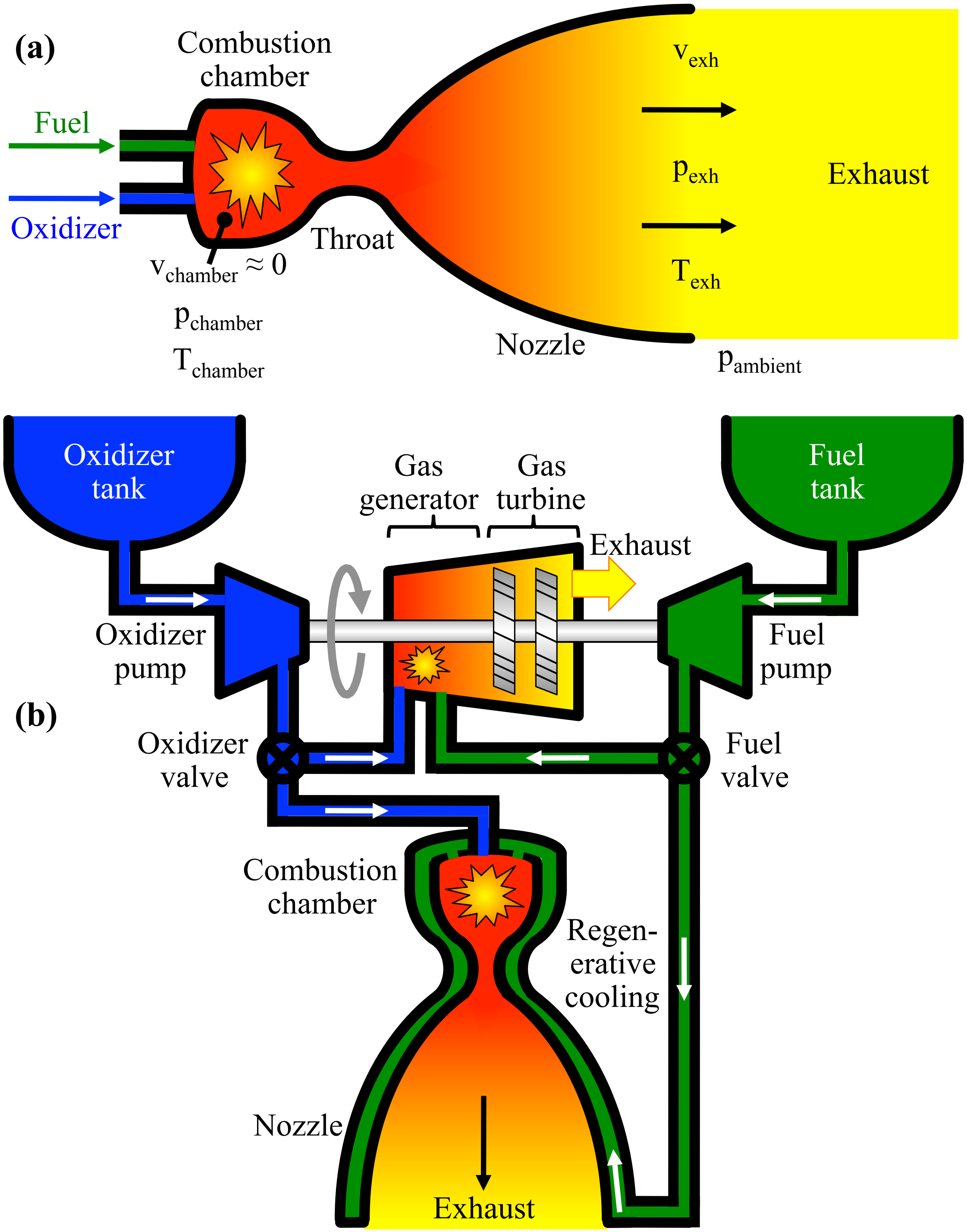

(a)
Combustion chamber
Fuel
Oxidizer
$v_{\text{chamber}} \approx 0$
p_{chamber}
T_{chamber}
Throat
Nozzle
v_{exh}
p_{exh}
T_{exh}
Exhaust
p_{ambient}
(b)
Oxidizer tank
Gas generator
Gas turbine
Exhaust
Fuel tank
Oxidizer pump
Fuel pump
Oxidizer valve
Fuel valve
Combustion chamber
Regen-erative cooling
Nozzle
Exhaust

Figure 9.166: Liquid propellant rocket design. (a) Burning of fuel and oxidizer in the combustion chamber generates hot gas with velocity $v_{\text{chamber}} \approx 0$, pressure p_{chamber}, and temperature T_{chamber}, which expands in the nozzle until it has exhaust values v_{exh}, p_{exh}, and T_{exh}. (b) Pumps raise the pressure of oxidizer and fuel from the storage tanks and inject it into the combustion chamber. Along the way, fuel detours through coils wrapping the combustion chamber and nozzle, cooling the engine and preheating the fuel. Small amounts of oxidizer and fuel are diverted to burn in a gas generator, producing hot exhaust that powers a gas turbine and thereby the pumps.

9.7.1 Pre-War and Wartime German Rocket Programs

Hermann Oberth (Austro-Hungarian, 1894–1989), shown in Fig. 9.167, began experimenting with rockets in 1908 when he was only 14. By the early 1920s, he was publishing detailed and highly influential designs and analyses of rockets [Oberth 1929, 1984].

Oberth was the scientific consultant for Fritz Lang's 1929 film, *Frau im Mond* (*Woman in the Moon*, p. 1971),[13] which depicted how astronauts could use a rocket to travel to the moon, and which profoundly influenced a whole generation of young German rocket engineers such as Werner von Braun (German, 1912–1977). Among other prophetic details, the film showed the construction of the rocket in a large vehicle assembly building, the transport of the rocket to a launch pad, a countdown to the launch, horizontal couches for the astronauts during launch, the use and ejection of multiple rocket stages during the ascent, the effects of zero gravity in space, etc.

Oberth advised and assisted the younger rocket engineers during the 1930s and 1940s, and continued to promote spaceflight in Europe and the United States after the war.

In the early development of liquid propellant rockets, the closest competitor outside the German-speaking world was probably Robert Goddard (American, 1882–1945) [Lehman 1988]. Despite Goddard's promising ideas and experiments, he never was able to obtain much U.S. political and financial support for his research, in stark contrast to the enormous support that the German-speaking engineers received. By the time of Goddard's death in 1945, German rockets were many years ahead of anything that Goddard had been able to accomplish with his limited support.

From 1933 to 1945, Wernher von Braun (German, 1912–1977) led a team that developed a series of increasingly sophisticated liquid propellant rockets, initially at Kummersdorf, then at Peenemünde. Von Braun was closely backed by the strong political support of Walter Dornberger (German, 1895–1980, Fig. 9.223), a general in the German army. By far their most famous creation was the A-4 or V-2 rocket, which was first launched in 1942 and was capable of reaching altitudes over 200 km (beyond the earth's atmosphere and well into outer space). See Fig. 9.168.[14]

Although German-designed rockets certainly went all the way to the moon after the war, there is considerable evidence that even wartime German rockets may have advanced significantly beyond the single-stage A-4 or V-2 rocket. As presented in Appendix E, there is documentation reporting wartime research, development, and even testing of larger rockets with longer ranges and larger payloads, two-stage intercontinental ballistic missiles, submarine-launched missiles, advanced solid propellant rockets, prototype manned space planes (A-9 and Silbervogel), and advanced rocket engines (hydrogen/oxygen, ion, and fission thermal). Appendix E gives an overview of currently known evidence for these wartime advanced rocket developments, but this is clearly another area where much more archival research is needed to clarify exactly what work was done and by whom, and precisely how it guided postwar missile, rocket, and space programs in the United States, the Soviet Union, and other countries.

---

[13] Bogdanovich 1967; Eisenschitz and Bertetto 1994; Eisner 1977; Jenkins 1981; McGilligan 1997.

[14] The history of the Peenemünde A-4 rocket program has already been so well documented that it will not be covered in any detail here. For much more information, see for example: Bode and Kaiser 2013; Dornberger 1958, 1994; Erichsen and Hoppe 2011; Gildenhaar and Gildenhaar 2013a; Hölsken 1994; Irving 1965; Jones 1978; King and Kutta 1998; Klee and Merk 1963; Knight 1946; Ley 1968; McGovern 1964; Jürgen Michels 1997; Miranda and Mercado 1996; Neufeld 1995; Ordway and Sharpe 1979; Putt 1946a, 1946b; CIOS XXXII-125; digipeer.de; v2rocket.com.

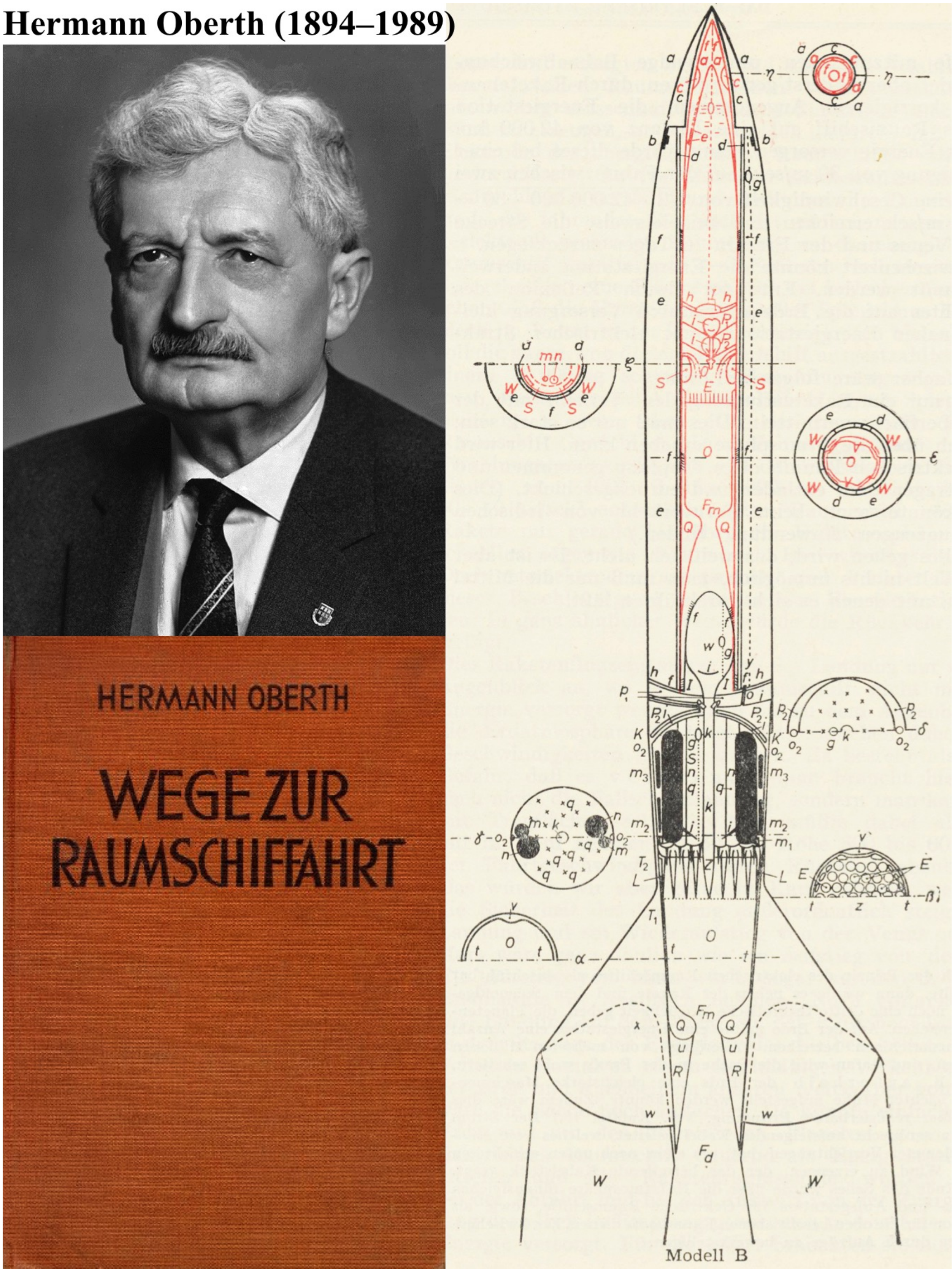

Hermann Oberth (1894–1989)
HERMANN OBERTH
WEGE ZUR RAUMSCHIFFAHRT
Modell B

Figure 9.167: Hermann Oberth began experimenting with rockets in 1908 and published detailed and highly influential designs and analyses of rockets in the 1920s.

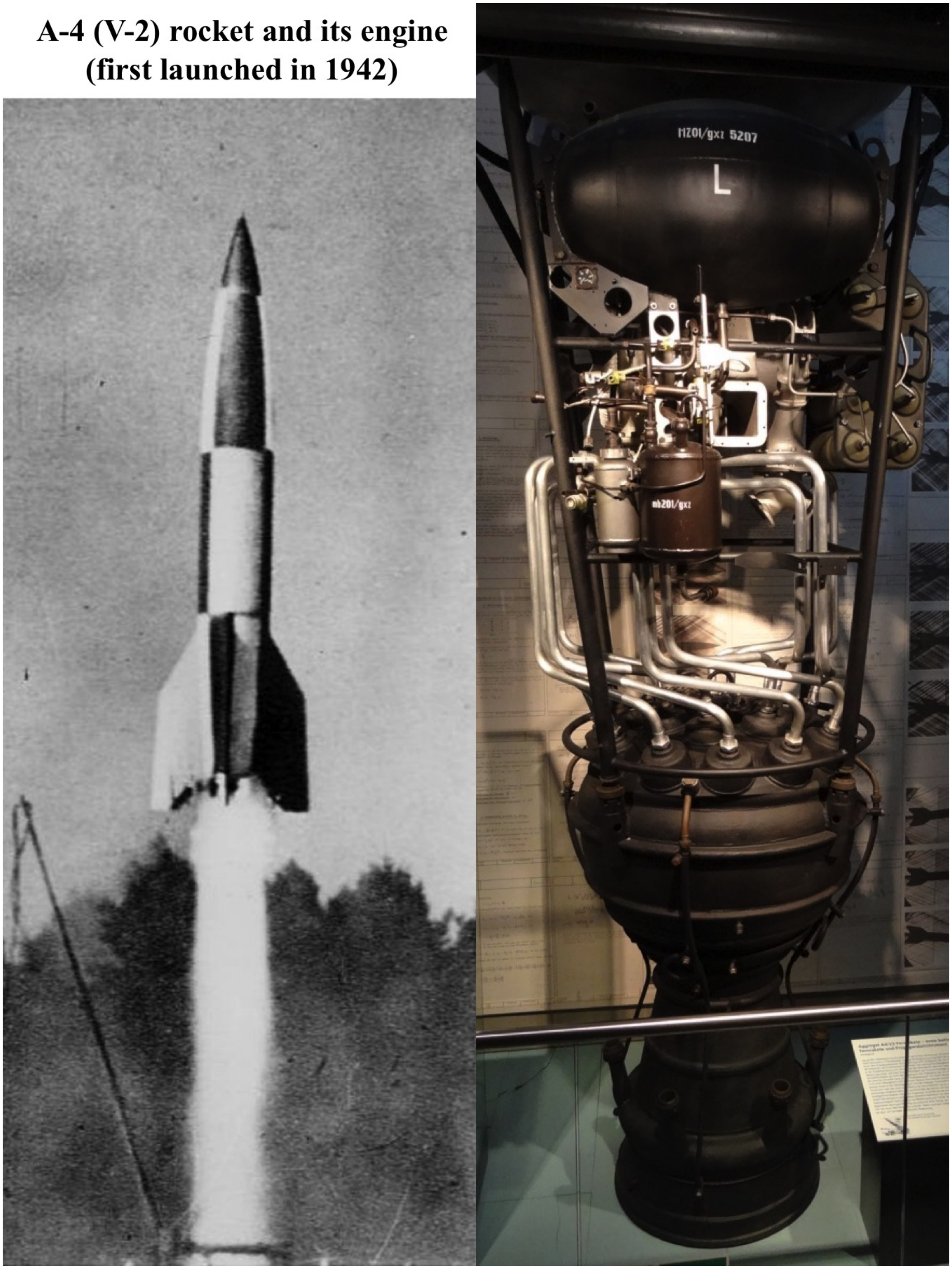

A-4 (V-2) rocket and its engine
(first launched in 1942)
MZ01/gxz 5207
L
mb201/gxz

Figure 9.168: The A-4 (V-2) rocket, first launched in 1942 and capable of reaching altitudes over 200 km, was designed and developed by a team led by Wernher von Braun.

9.7.2 Postwar U.S. and U.K. Rocket Programs

At the end of the war, von Braun and much of his team moved to the United States, where they spent a quarter-century developing a series of even larger rockets, both for ballistic missile programs (Fig. 9.169) and also for the space program. Their work culminated in the Saturn V rocket that carried the Apollo missions to the moon in 1968–1972 (Figs. 9.170–9.171). Dornberger also moved to the United States and worked separately on a series of rocket planes, culminating in the U.S. Space Shuttle (pp. 1854 and 1927–1932).[15]

U.S. Army Lt. Colonel William E. Winterstein worked very closely with von Braun immediately after his arrival in the United States, and he later emphasized how long von Braun had planned and lobbied for manned missions to the moon [Winterstein 2005, pp. 34–35]:

> Among the many discussions I had with Wernher [von Braun] during those days was the theme of space exploration. The first step, naturally, was a voyage to the Moon. This was his lifelong ambition. At that time, the outlook for any rocket research for such a project was unfavorable. [...]
>
> In the summer of 1946, I asked Wernher "If we could give you all of the money you wanted, how much, and how long, would it take you to put Man on the Moon?" Several weeks later, he said: "Give us three billion dollars, and ten years, and we will go to the moon and back." At the time, I thought it was merely very interesting information, never dreaming of their importance.
>
> It was fifteen years later that similar words, concerning the time frame at least, were uttered by President Kennedy to a joint session of Congress on May 25th 1961. "Before this decade is out," described the time frame. Prior to President Kennedy's address to Congress, Dr. von Braun had convinced the President that the trip to the Moon was technologically possible. This further convinced me that Wernher must have done a lot of planning for a Moon mission, years before he gave me the same information concerning the time element in 1946.

Of course, von Braun and his team ultimately did exactly what they had long envisioned, once the United States finally committed the necessary amount of funding after many years of bureaucratic indecision and delays. Yet if von Braun's team had had the full financial and political support of the United States from 1945 onward, how soon might the United States have sent the first astronaut into space, or sent the first astronauts to the Moon? How much further into space might the United States have progressed after that? (And what did von Braun's apparently very knowledgeable 1946 statement to Winterstein suggest about how far the development of rockets more advanced than the A-4 had progressed in wartime Germany? See Sections E.2, E.5, and E.7.)

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[15] Likewise, the history of postwar liquid propellant rockets has been so well documented that it will not be covered in any detail here. For more information, see: Bilstein 1980; von Braun et al. 1985; Franklin 1987; Freeman 1993; Huzel 1962; Huzel and Huang 1992; Koelle 1961; Kurowski 2001; Ley 1968; Mader 1963; Jürgen Michels 1997; Neufeld 2007; Powell-Willhite 2007; Stuhlinger and Ordway 1994a, 1994b; NYT 1945-05-23 p. 4, 1946-04-12 p. 11, 1946-04-22 p. 6, 1946-05-07 p. 3, 1946-06-29 p. 11, 1947-03-02 p. 17, 1947-06-22 p. E-7, 1948-04-03 p. 27.

When Wernher von Braun died in 1977, President Jimmy Carter issued a public statement [Carter 1977, p. 1125]:

> To millions of Americans, Wernher von Braun's name was inextricably linked to our exploration of space and to the creative application of technology. He was not only a skillful engineer but also a man of bold vision; his inspirational leadership helped mobilize and maintain the effort we needed to reach the Moon and beyond.
>
> Not just the people of our Nation but all the people of the world have profited by his work. We will continue to profit from his example.

Of course, von Braun was only one person, but President Carter's statement demonstrates how critical the German-speaking scientists had been for the space and ballistic missile programs in the United States. John Becklake, a historian of science at London's Science Museum, described the contributions of the German-speaking scientists in more detail [Becklake 1994]:

> Twenty-five years ago, in July 1969, the first men landed on the Moon. These pioneering spacefarers, Neil Armstrong and Buzz Aldrin, were launched on this mission by America's massive Saturn V rocket. Twenty-five years before this, on 8 September 1944, the first operational V2 missile was fired at Paris from a mobile launch site in the Ardennes region of France. Both of these rockets were developed by the same team of German engineers, led by Wernher von Braun. [...]
>
> The accomplishments of this US-based team, now expanded to include local engineers, are legendary—they developed the US's first long range missile (Redstone), provided the launch vehicle that orbited America's first satellite and later, under the auspices of the civil space agency, NASA, developed the Saturn family of rockets. This included the Saturn V rocket that sent the Apollo astronauts to the Moon. So influential were von Braun and his team in almost every major rocket activity in Germany and the US between 1930 and 1970, that this volume [a biography of von Braun] effectively represents a history of rocketry in the Western world.

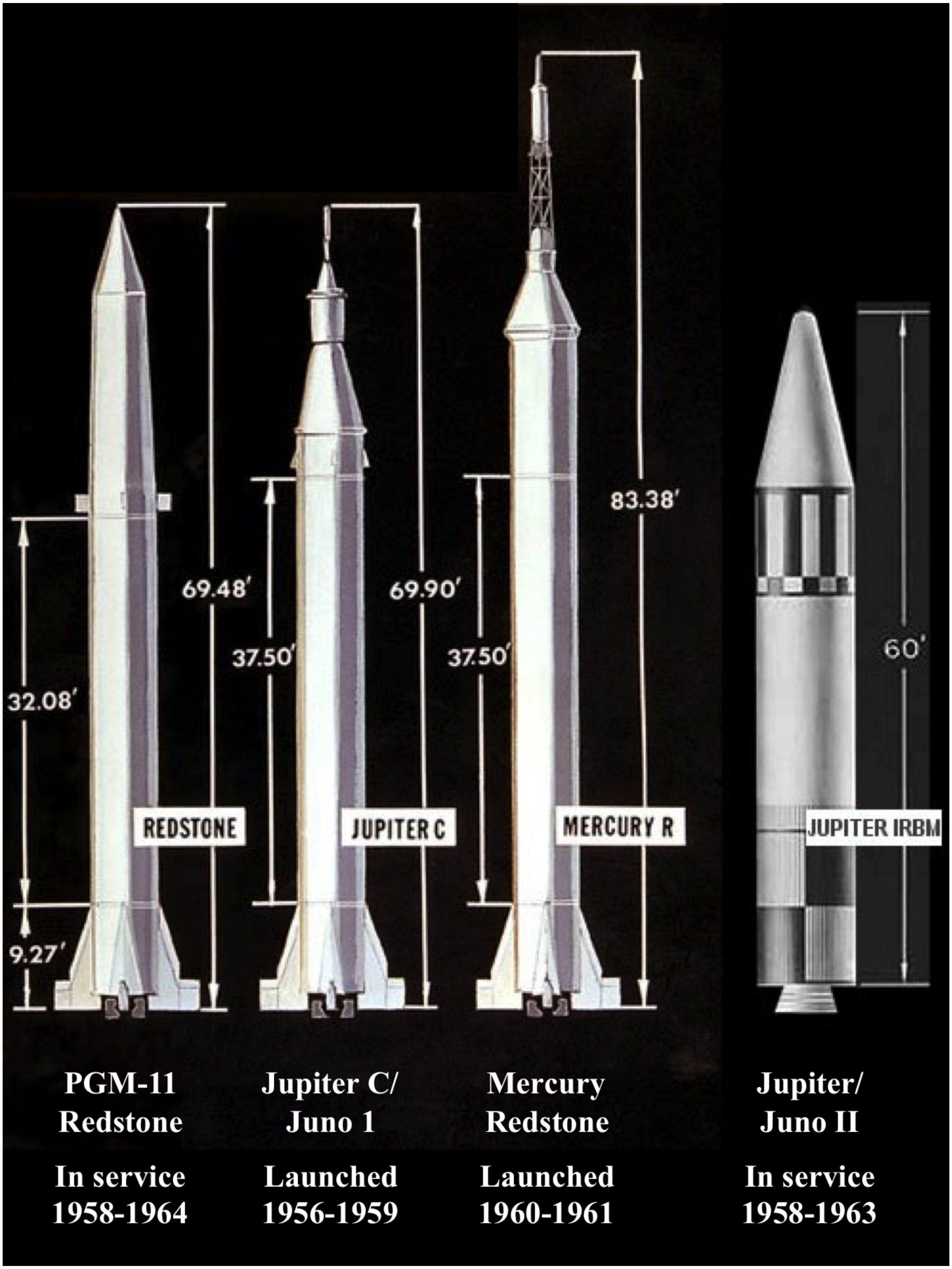

32.08′
9.27′
69.48′
REDSTONE
37.50′
69.90′
JUPITER C
37.50′
83.38′
MERCURY R
60′
JUPITER IRBM
PGM-11
Redstone
In service
1958-1964
Jupiter C/
Juno 1
Launched
1956-1959
Mercury
Redstone
Launched
1960-1961
Jupiter/
Juno II
In service
1958-1963

Figure 9.169: Examples of early U.S. ballistic missiles derived directly from German creators and creations.

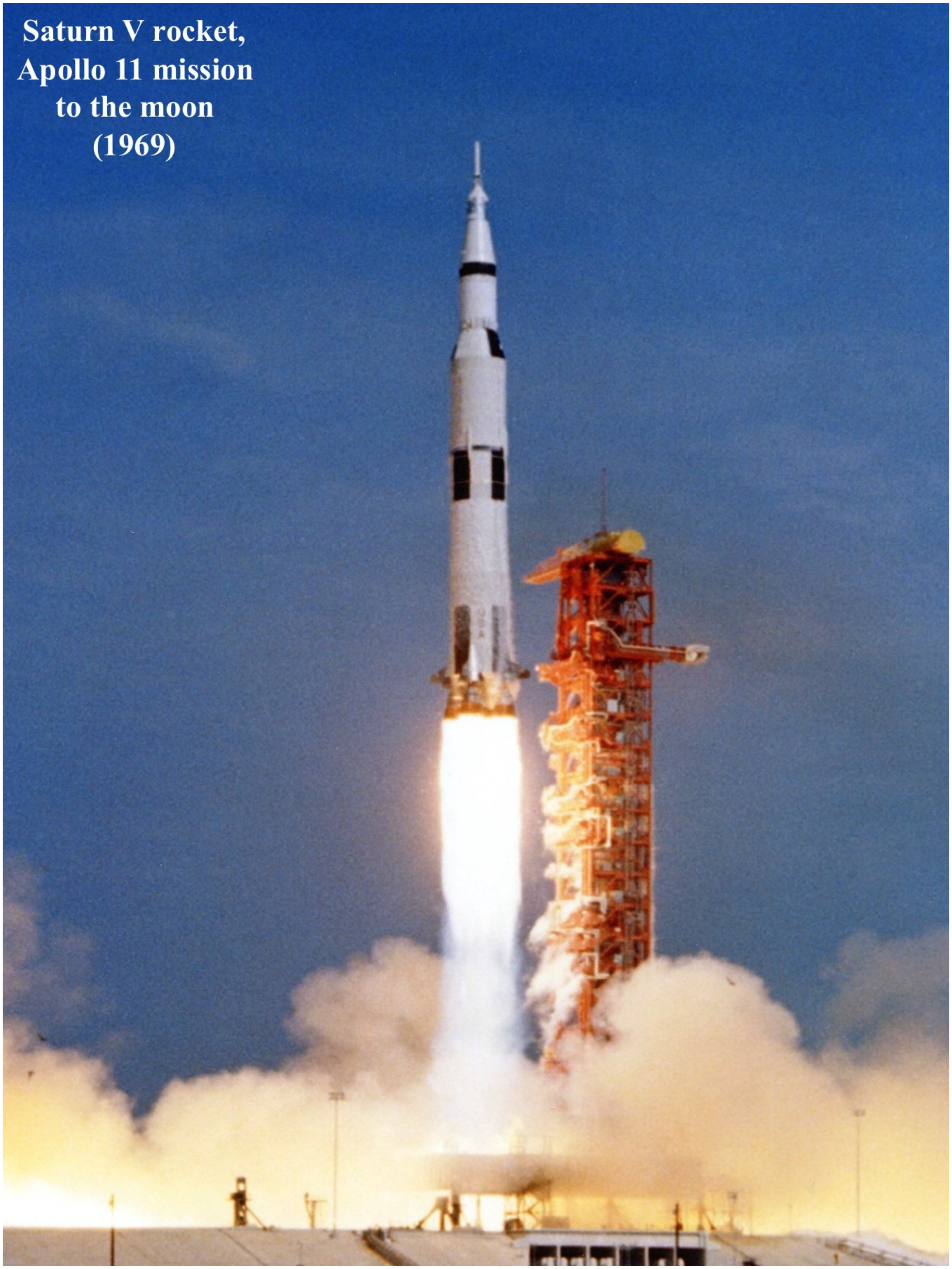
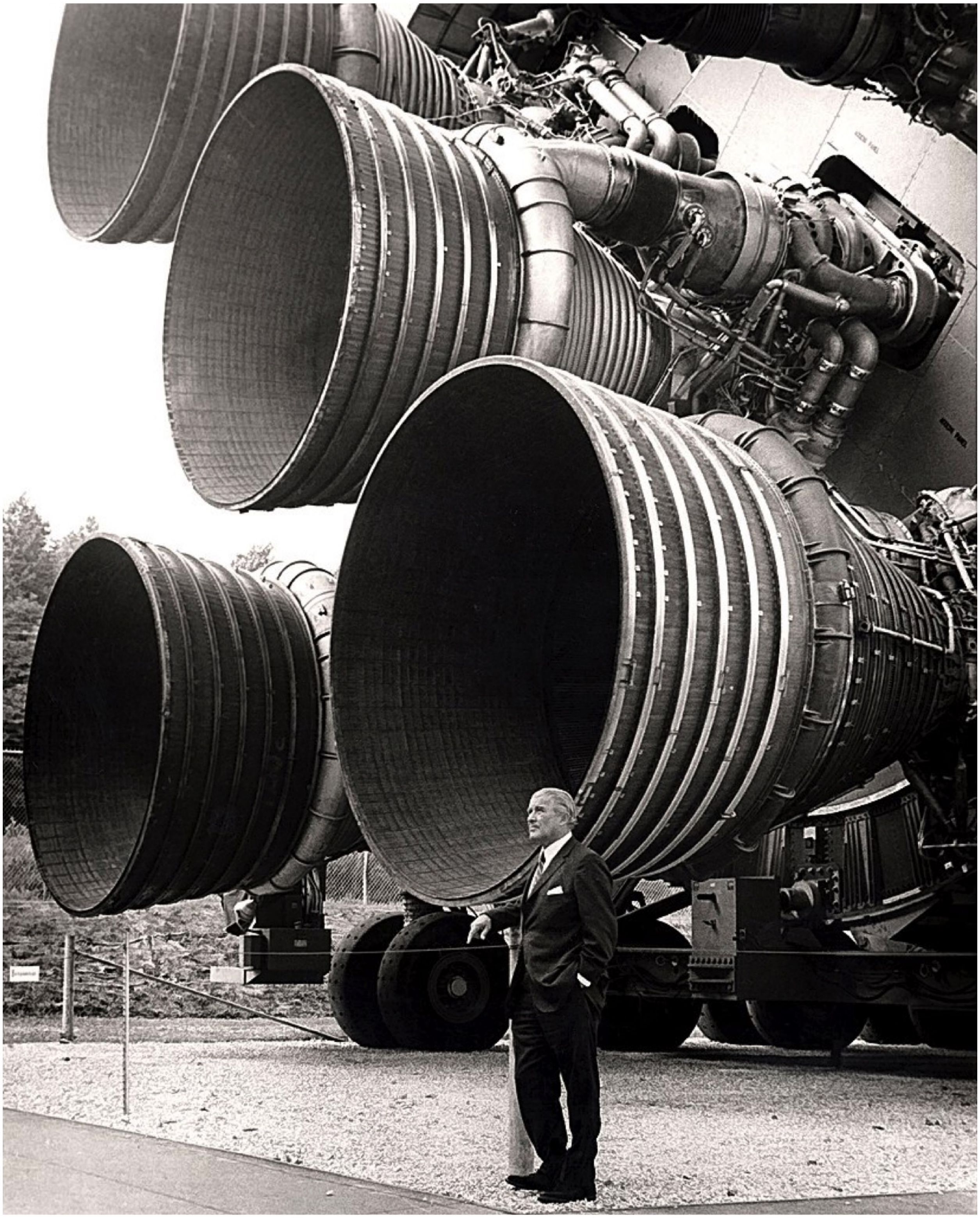

Saturn V rocket,
Apollo 11 mission
to the moon
(1969)

Figure 9.170: The Saturn V rocket, which carried the Apollo 11 mission to the moon in 1969, was also designed and developed by Wernher von Braun's team.



Wernher von Braun with F-1 engines for Saturn V rocket

Figure 9.171: Wernher von Braun with the F-1 engines for the Saturn V rocket.

The two photographs in Fig. 9.172 illustrate how numerous and influential German-speaking creators were in the U.S. ballistic missile and space programs.

The upper photograph in Fig. 9.172 shows the attendees of a 1959 meeting at the Army Ballistic Missile Agency. From left to right, they were:

Name	Born	Lived	Role
Ernst Stuhlinger	German	1913–2008	
Frederick von Saurma	German	1908–1961	
Fritz Mueller	German	1907–2001	
Hermann Weidner	German	1912–2008	
Erich Neubert (in back)	German	1910–1999	
William Mrazek	German	1911–1992	
Karl Heimburg	German	1910–1997	
Arthur Rudolph	German	1906–1996	
Otto Hoberg	German	1912–1991	
Wernher von Braun	German	1912–1977	
Oswald Lange	German	1912–2000	
Bruce Medaris	American	1902–1990	U.S. Army General
Helmut Hölzer	German	1912–1996	
Hans Maus	German	1905–1999	
Ernst Geissler	German	1915–1989	
Hans Hueter	German	1906–1970	
George Constan	American	1909–1986	Manager, Michoud Assembly Facility

The lower photograph in Fig. 9.172 shows the attendees of a 1961 meeting at NASA. From left to right, they were:

Name	Born	Lived	Role
Werner Kuers	German	1907–1983	Director, Manufacturing Engineering Division
Walter Häussermann	German	1914–2010	Director of the Astrionics Division
William Mrazek	German	1911–1992	Propulsion and Vehicle Engineering Division
Wernher von Braun	German	1912–1977	Director of Marshall Space Flight Center
Dieter Grau	German	1913–2014	Director of the Quality Assurance Division
Oswald Lange	German	1912–2000	Director of the Saturn Systems Office
Erich W. Neubert	German	1910–1999	Assoc. Deputy Director, Research/Development

For a more extensive list of German-speaking scientists/engineers who worked in postwar U.S. and U.K. rocket and missile programs, see Table 9.2. (There was a relatively free exchange of German-speaking scientists and information between the U.S. and U.K. programs, so they are treated together here.) Even this list represents only a fraction of the many hundreds of German-speaking scientists and engineers who worked in all parts of NASA, military research centers, and aerospace and electronics companies to make the U.S. and U.K. missile, rocket, and space programs possible.

For examples of U.K. rockets designed by German-speaking scientists, including Black Knight, Blue Streak, Europa, and Black Arrow, see pp. 1870–1872 and p. 5576.

The German-speaking creators developed these revolutionary inventions from scratch to fully mature technologies during their careers. Even now, many decades later, these same German creations are still repackaged by others as “new” inventions (Fig. 9.177).

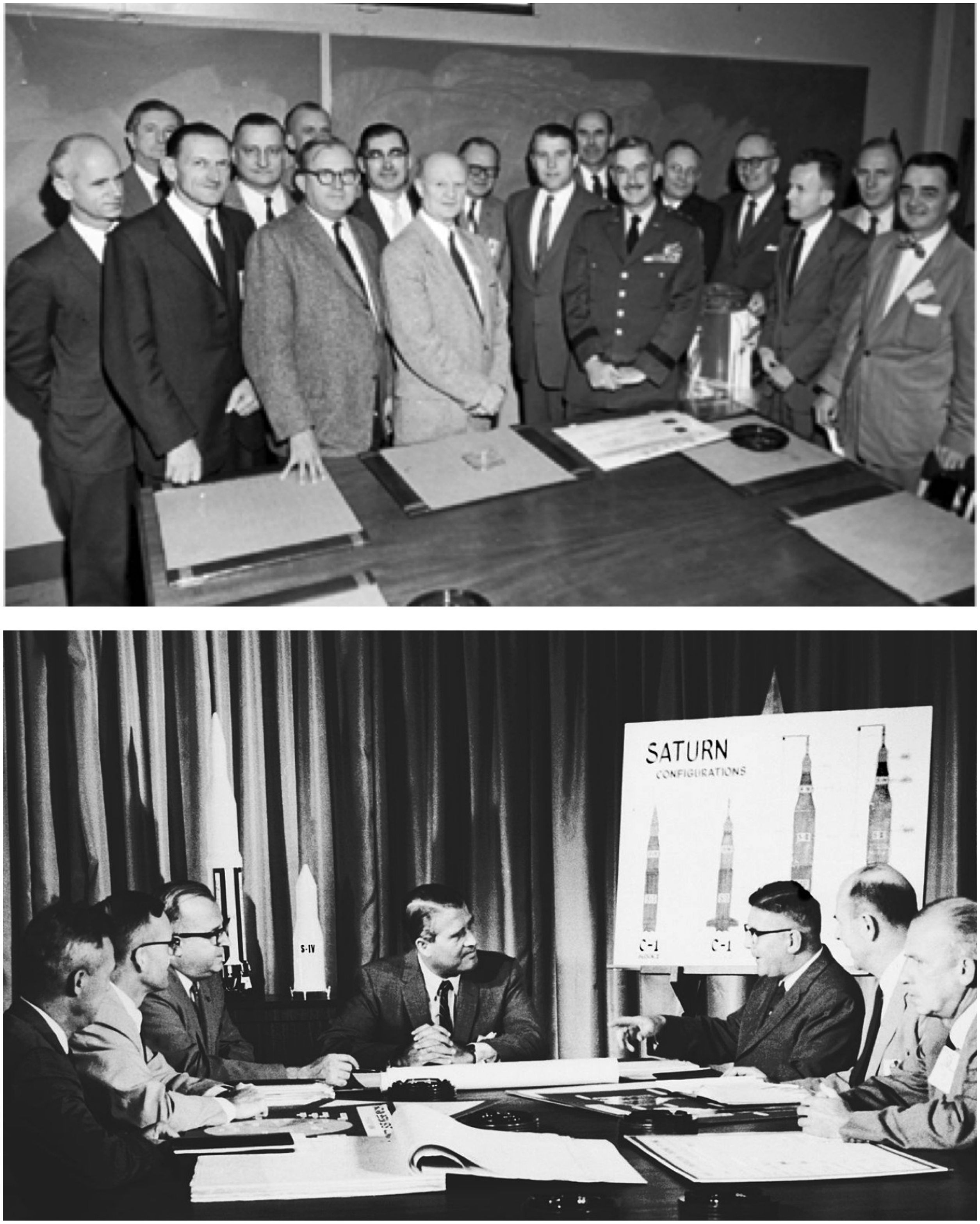
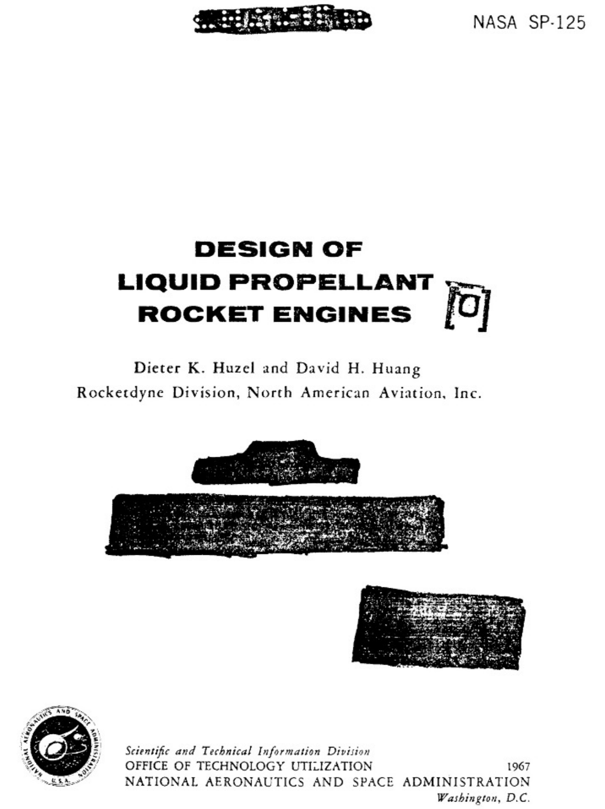

SATURN
CONFIGURATIONS
C-1
C-1
S-IV

Figure 9.172: Examples of German-speaking designers and managers in the U.S. rocket programs. Above: 1959 meeting at the Army Ballistic Missile Agency. Below: 1961 meeting at NASA.

Dieter Huzel
(1912–1994)



[redacted] NASA SP-125

DESIGN OF
LIQUID PROPELLANT
ROCKET ENGINES

Dieter K. Huzel and David H. Huang
Rocketdyne Division, North American Aviation, Inc.

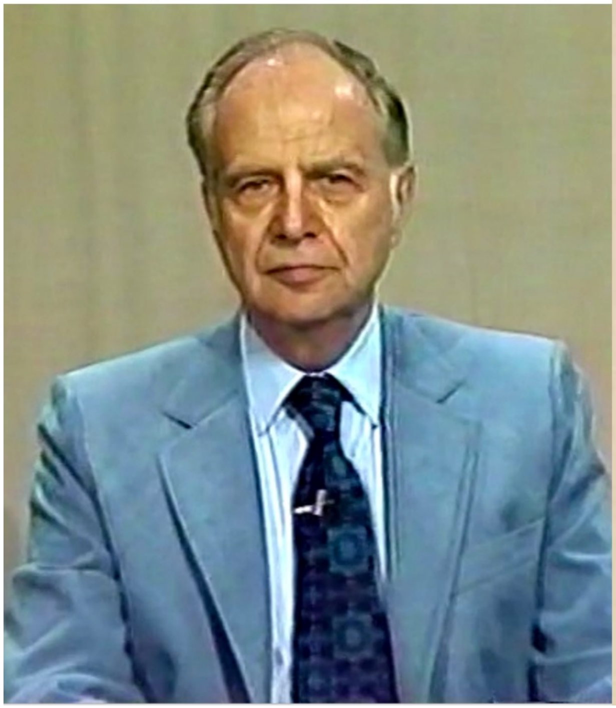
[redacted]

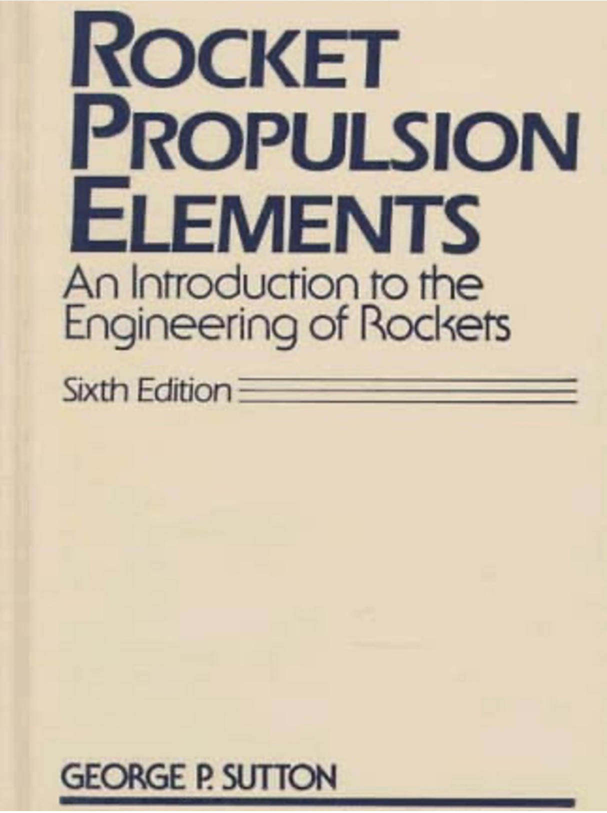
[redacted]

[redacted]

Scientific and Technical Information Division
OFFICE OF TECHNOLOGY UTILIZATION 1967
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C.

Georg Paul Schulhof, a.k.a.
George P. Sutton (1920–2020)





ROCKET
PROPULSION
ELEMENTS
An Introduction to the
Engineering of Rockets
Sixth Edition

GEORGE P. SUTTON

Figure 9.173: Two prominent figures (among many others) in transferring rocket engine technology from the German-speaking world to the United States were: (1) Dieter Huzel, who had been part of von Braun's team since Peenemünde and led postwar rocket engine development at North American Aviation Rocketdyne. (2) Georg Paul Schulhof, a.k.a. George P. Sutton, who moved from Austria to the United States in 1938 and worked with Huzel, Theodore von Kármán, Fritz Zwicky, and others to transfer German-speaking scientists, documents, information, and technologies to North American Aviation Rocketdyne, Aerojet, and other organizations. See pp. 5498–5500.

Andreas Alexandrakis
Wilhelm Angele
Herbert Axter
Erich Ball
Oscar Bauschinger
Gerd de Beek
Rudolf Beichel
Anton Beier
Herbert Bergeler
Hermann Beuderftig
Josef Boehm
Gerhard Braun
Magnus von Braun
Wernher von Braun
Erhardt Bruenecke
Theodor Buchhold
Walter Burose
Rudolf Buschmann
Werner Dahm
Konrad Dannenberg
Kurt Debus
Heinrich Determann
Friedrich Dhom
Herbert Dobrick
Walter Dornberger
Gerhard Drawe
Friedrich Duerr
Ernst Eckert
Rudolf Edse
Krafft Ehricke
Otto Eisenhardt
Willy Fiedler
Hans Fichtner
Alfred Finzel
Edward Fischel
Karl Fleischer
Hans Friedrich
Herbert Fuhrmann
Ernst Geissler
Werner Gengelbach
Dieter Grau
Hans Gruene
Herbert Guendel
Johann Gustav
Karl Hager
Guenther Haukohl
Walter Häussermann
Karl Heimburg
Emil Hellebrand
Gerhard Heller
Bruno Helm
Alfred Henning
Rudolf Hermann
Bruno Heusinger
Guenther Hintze
Otto Hirschler
Otto Hoberg
Rudolf Hoelker
Helmut Hoelzer
Oscar Holderer
Helmut Horn
Hans Hosenthien
Hans Hueter
Dieter Huzel
Walter Jacobi
Wilhelm Jungert
Hans Kammler
Erich Kaschig
Karl Klager
Ernst Klauss
Johann Klein
Georg E. Knausenberger
Heinz-Hermann Koelle
Max Kramer
Hubert Kroh
Werner Kuers
Joachim Kuettner
Hermann Kurzweg
Hermann Lange
Oswald Lange
Willy Ley[†]
Hans Lindenberg
Hans Lindenmayr
Kurt Lindner
Hannes Luehersen
Carl Mandel
William Mrazek
Hans Maus
Helmut Merk
Joseph Michel
Hans Milde
Heinz Millinger
Rudolf Minning
William Mrazek
J. W. Muehlner
Fritz Mueller
Heinz E. Mueller
Rudolf Nebel
Erich Neubert
Kurt Neuhoefer
Wolfgang Noeggerath
Max Novak
Adolf Oberth
Hermann Oberth
Robert Paetz
Hans Palaoro
Kurt Patt
Hans Paul
Karl Pohlhausen
Theodor Poppel
Willibald P. Prasthofer
Jesco von Puttkamer
Eberhard Rees
Gerhard Reisig
Georg Rickhey
Walther Johannes Riedel
Werner Rosinski
Ludwig Roth
Heinrich Rothe
Arthur Rudolph
Harry Ruppe
Friedrich von Saurma
Heinz Schnarowski
Klaus Scheufelen
Martin Schilling
Rudolf Schlidt
Helmuth Schlitt
Helmut H. Schmidt
Albert Schuler
Georg Paul Schulhof,
a.k.a. George P. Sutton[††]
William August Schulze
Friedrich Schwarz
Walter Schwidetzky
Karl Sendler
Eberhard Spohn
Werner Sieber
Fridtjof Speer
Ernst Steinhoff
Hermann Steuding?
Wolfgang Steurur
Ernst Stuhlinger
Johann Tschinkel
Bernhard Tessmann
Adolf Thiel
Georg von Tiesenhausen
Werner Tiller
Arthur Urbanski
Fritz Vandersee
Werner Voss
Theodor Vowe
Herbert Wagner
Hermann Weidner
Günter Wendt
Walter Wiesman
Albin Wittmann
Hugo Woerdemann
Albert Zeiler
Helmut Zoike

Table 9.2: Some German-speaking scientists and engineers in postwar U.S. and U.K. rocket and missile programs. [†]Willy Ley came to the United States in 1935. [††]Georg Paul Schulhof, later and much better known as George P. Sutton, came to the United States in 1938.

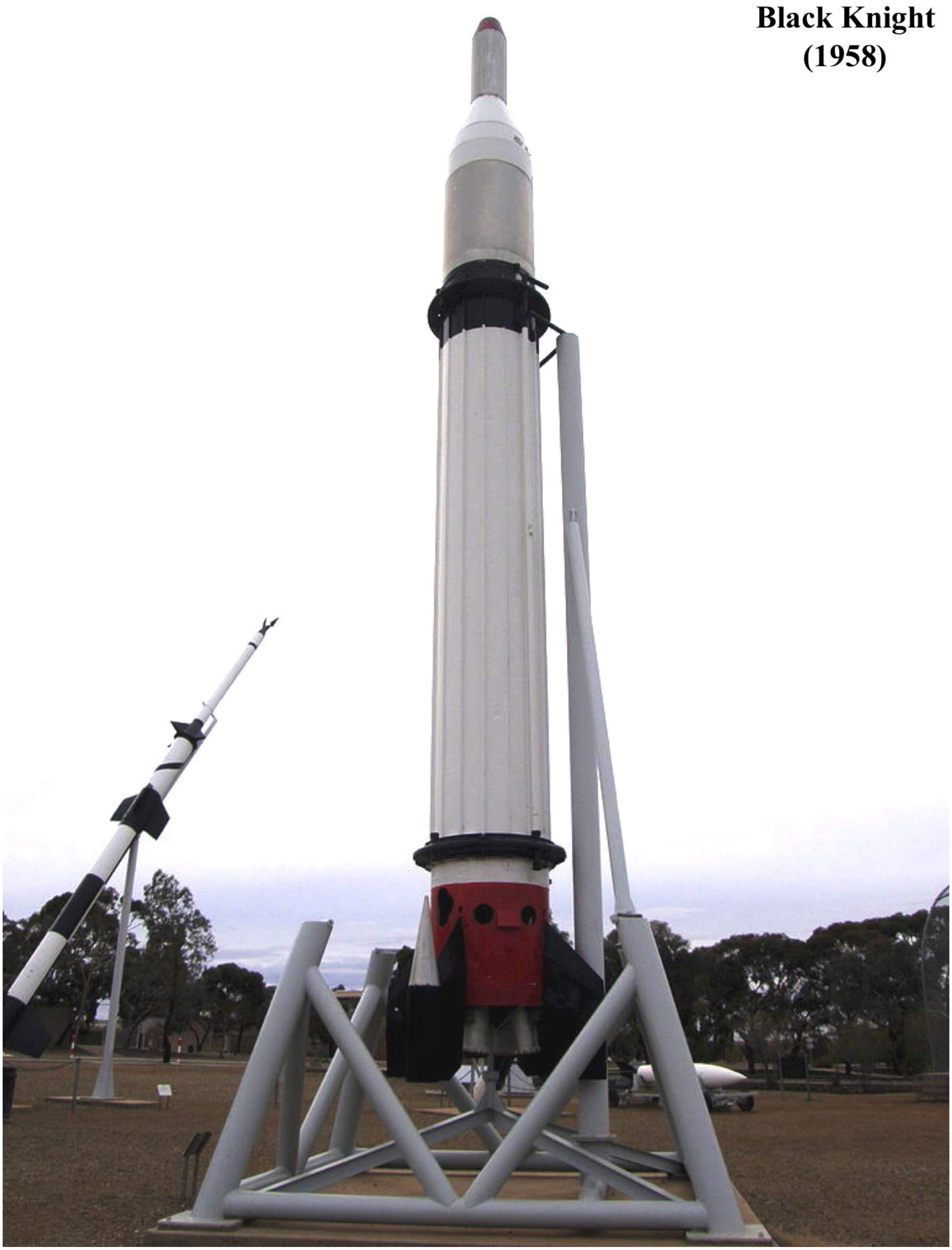


Figure 9.174: German-speaking rocket engineers designed the British Black Knight, which was first launched in 1958. See also p. 5576.

Blue Streak (1964)

Renamed Europa with upper stages (1968)

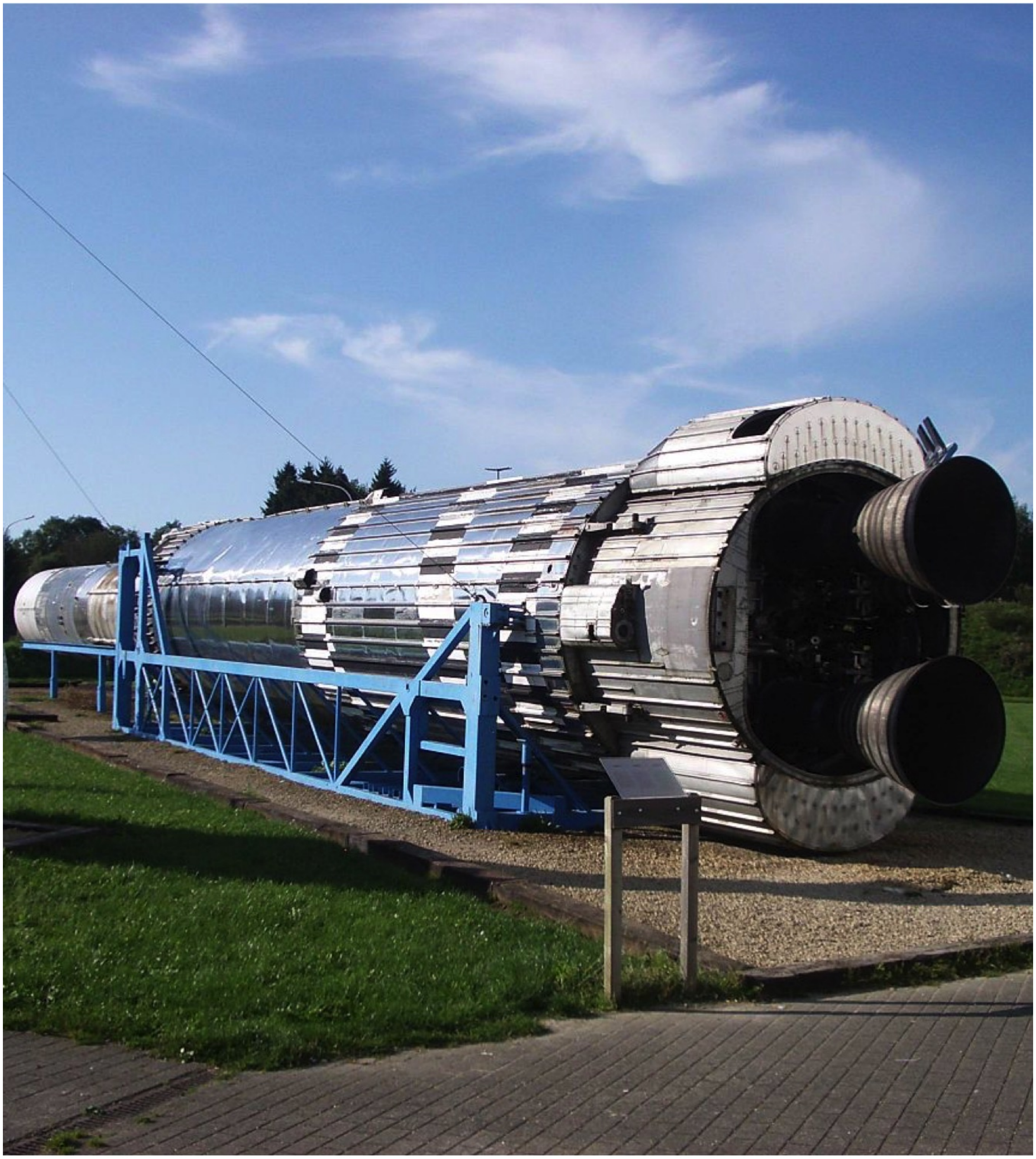


Figure 9.175: German-speaking rocket engineers designed the British Blue Streak, which was first launched in 1964. With upper stages mounted on top, it was renamed Europa and launched in 1968. See also p. 5576.

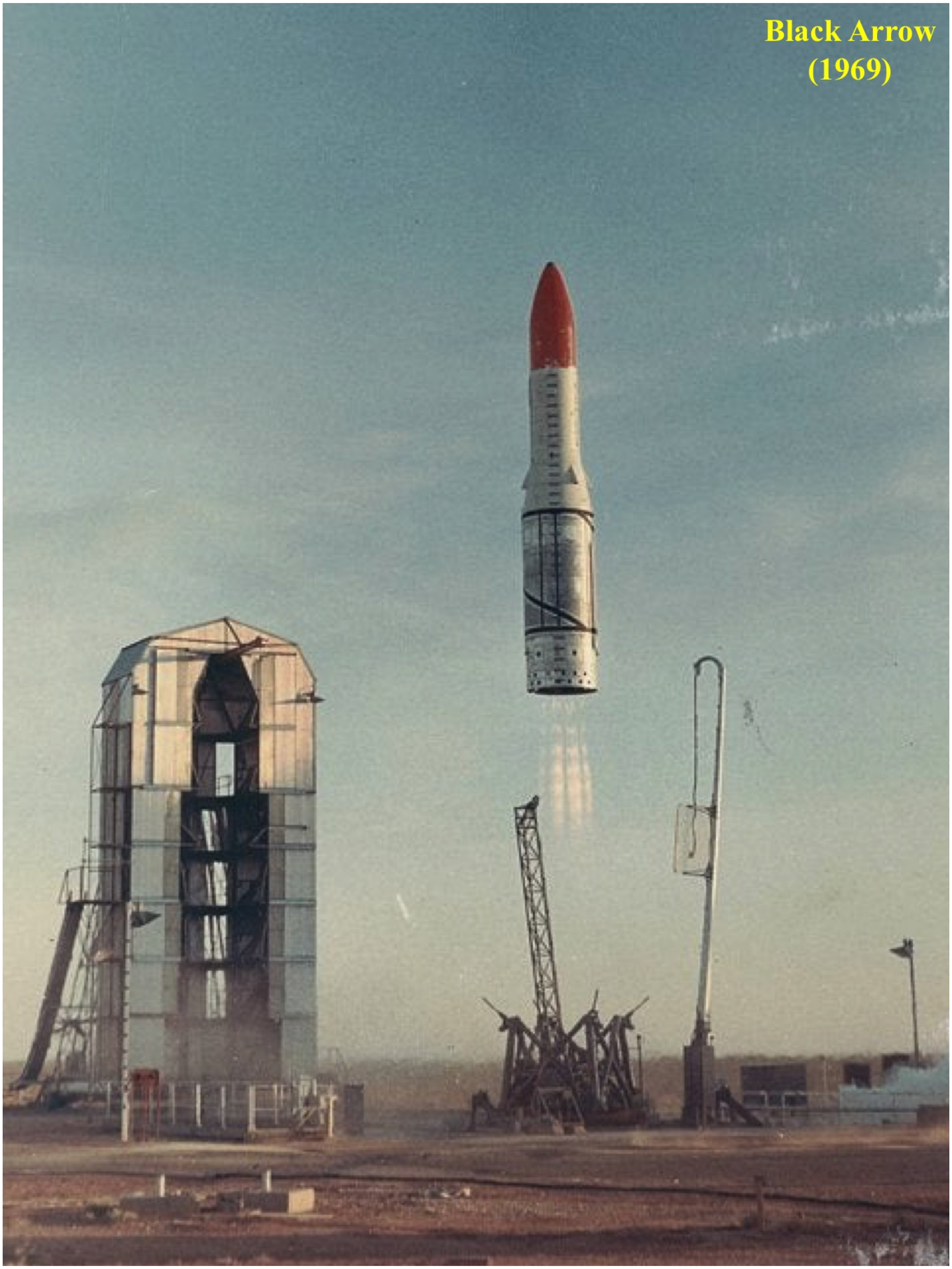


Figure 9.176: German-speaking rocket engineers designed the British Black Arrow, which was first launched in 1969. See also p. 5576.

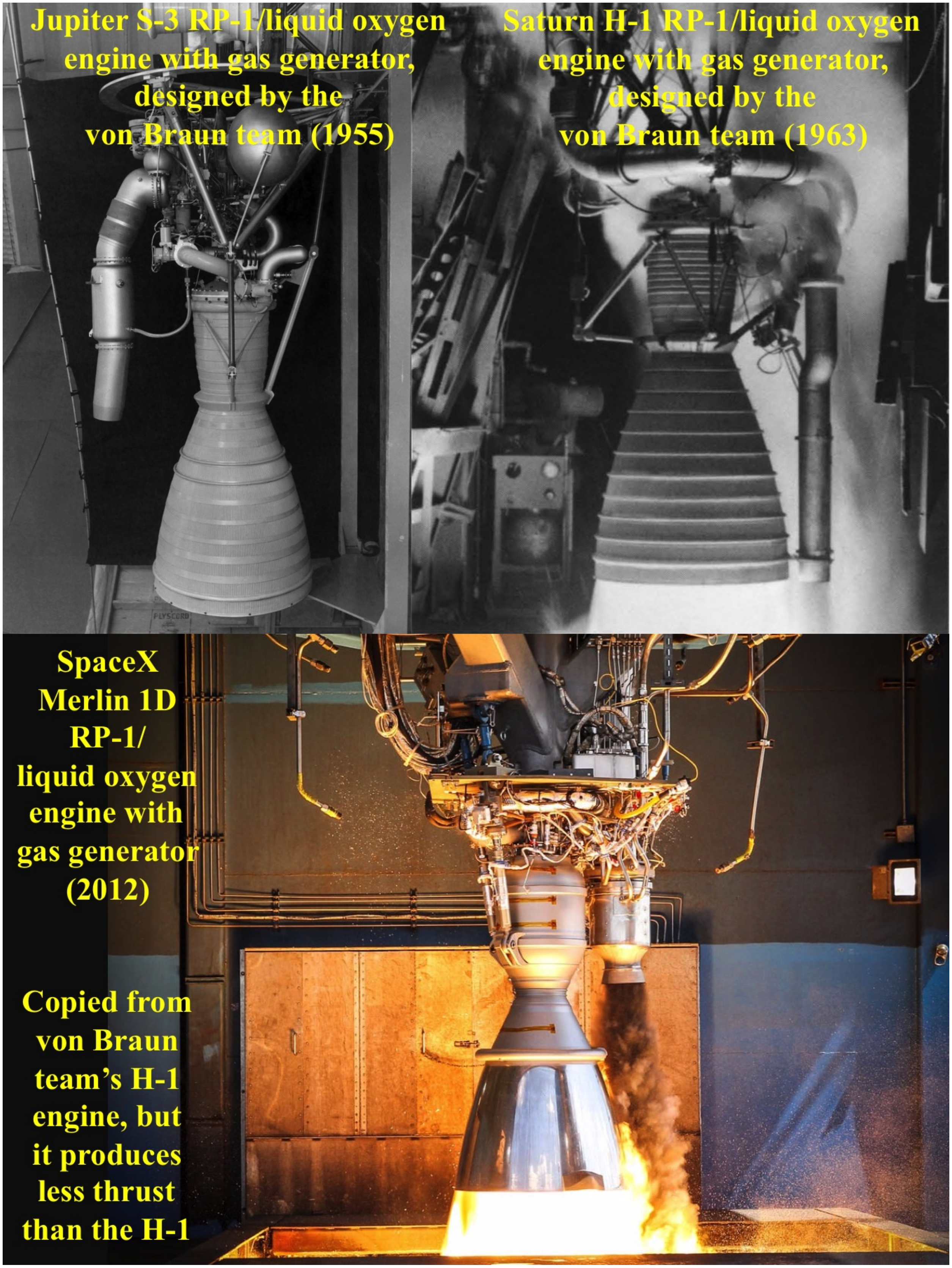

Jupiter S-3 RP-1/liquid oxygen engine with gas generator, designed by the von Braun team (1955)
Saturn H-1 RP-1/liquid oxygen engine with gas generator, designed by the von Braun team (1963)
SpaceX Merlin 1D RP-1/ liquid oxygen engine with gas generator (2012)
Copied from von Braun team's H-1 engine, but it produces less thrust than the H-1

Figure 9.177: Based on their earlier A-4 and Redstone engines, Wernher von Braun's team designed RP-1/liquid oxygen engines with gas generators: the Jupiter S-3 (first operational in 1955) and the Saturn H-1 (first operational in 1963). The much-hyped SpaceX Merlin 1D engine (first operational in 2012) was directly copied from the H-1 engine yet produces less thrust than the H-1.

9.7.3 Postwar Soviet Rocket Programs

German-speaking engineers, designs, and materials also greatly contributed to the development of missiles, rockets, and spacecraft in the Soviet Union.[16]

Huge numbers of German-speaking scientists and engineers were employed (willingly or otherwise) in postwar Soviet rocket and missile programs (p. 2064). Table 9.3 lists some examples. Helmut Gröttrup (German, 1916–1981) was the most prominent scientific leader and coordinator among the German-speaking engineers. Figure 9.178 shows an October 1947 photo at the Kapustin Yar rocket testing site, where Gröttrup posed with Karl Viktor Stahl, Johannes Hoch, Fritz Viebach, and Hans-Albert Vilter.

Figure 9.179 presents the first three major types of Soviet ballistic missiles (see also p. 5797):

- The SS-1 or R-1 Scunner was basically just an A-4/V-2 rocket (14 meters long) that was manufactured by Germans under Soviet control and used 1950–1953.
- The SS-2 or R-2 Sibling was a longer, upgraded A-4 (18 meters long) that was in service 1953–1956. Not only was it produced by German engineers, but it appears to have been copied from 18-meter extended A-4 rockets that were secretly developed and tested in Germany during the war (p. 5794).
- The SS-3 or R-5M Shyster, also shown in Fig. 9.180, was an even longer upgraded A-4 (21 meters long) that was in service 1956–1967. It was again created by German engineers, also apparently based on wartime work (p. 5794). In fact, with its 1200 km range, capable of delivering a nuclear warhead to anywhere in the United Kingdom from dedicated launch sites near Peenemünde, the SS-3 appears to have been the very embodiment of wartime German plans (p. 5575).

Later Soviet rockets, including those still used by Russia today, were also the product of German-speaking engineers working in the Soviet Union:

- The clustered design of the R-7 or SS-6 Sapwood and all later Russian rockets was directly derived from Helmut Gröttrup's G-5 design, as illustrated in Fig. 9.181 [http://www.astronautix.com/g/g-5.html].
- The RD-107/RD-108 engines of the R-7 and all later Russian rockets were directly derived from engine designs by Werner Baum (German, 1918–20??), as shown in Fig. 9.182 [Przybilski 2002a].
- Figure 9.183 illustrates how Helmut Gröttrup's rocket designs and Werner Baum's engines were used for the R-7, Sputnik, Vostok, Voshkod, and Soyuz launchers.
- Soyuz rockets are still used by Russia for launches to the International Space Station (Fig. 9.184).

---

[16] For much more information, see: Chertok 2005–2012; Robert Godwin 2001; Harford 1997; Oberg 1981; Phelan 2013; Przybilski 1999, 2002a; Reinke 2007, pp. 36–37; Siddiqi 2000; Uhl 2001; *Scientific Intelligence Review* 1946; NYT 1947-05-18 p. 45.

Albert Adolf
Werner Albring
Helmut Anders
Erich Apel
Willi Aporius
Herbert Auler
Gerhard Bart
Werner Baum
Heinz Bauschke
Karl Begel
Siegfried Bergemann
Erich Bischof
Kurt Blasig
Josef Blass
Friedrich Bönisch
Karl Borkmann
Kurt Briese
Hugo Brötler
Bernhard Buckdolf
Günter Bujak
Wilhelm Burchard
Alfons Busselt
Gerhardt Butke
Heinz Büttner
Rudolf Chwalczyk
Erich Drews
Hans Eiseler
Josef Eitzenberger
Fritz Engelmann
Helmut Faulstick
Georg Gasch
Bernhardt Gerhardt
Paul Gerold
Alfred Grevesmühl
Helmut Gröttrup
Alfred Grünert
Micheslaw Gudakovskij
Heinz Hasse
Werner Haase
Erich Habann
Karl Harnisch
Alfred Hecker
Karl Held
Bruno Henning
Walter Hensch
Anton Herr
Rudolf Herrman
Johannes Hoch
Heinz Jaffke
Alois Jasper
Anton Kahler
Heinrich Kindler
Alfred Kirchner
Alfred Klippel
Alfred Klose
Wilhelm Knack
Heinz Knittel
G. Kraut
Hans Kuhl
Gerhard Lange
Erich Langenbach
Ernst Lehmann
Ludwig Leihfeld
Werner Lessing
Josef Linke
Kurt Magnus
Fritz Mattheis
Franz Matthes
Otto Meier
Emil Mende
Heinz Moser
Rudolf Müller
Werner Müller
Herbert Mummert
Horst Nehrkorn
Peter Neidhardt
Lisa Neumeister
Friedrich Nikolaus
Friedrich Otto
Walter Pauer
Max Pehle
Arthur Pilz
Bertold Podeschva
Josef Poitner
Max Pole
Hans Prost
Oswald Putze
Siegfried Reinhard
Helmut Ritter
Fritz Rockstuhl
Erwin Rossler
Paul Rothe
Walter Rüdiger
Ferdinand Rule
Franz Schadt
Waldemar Schellhorn
Konrad Schidlo
Walter Schierhorn
Walter Scholz
Heribert Schröder
Werner Schulz
Wilhelm Schütz
Willi Schwarz
Gerhard Siegmund
Willi Sommer
Karl Viktor Stahl
Felix/Ferdinand Stolpe
Heinrich Strützing
Hubert Tacke
Rosemarie Tannhäuser
Paul Täubert
H. Tellmann
Wolf Trommsdorff
Robert Tschechner
Joachim Umpfenbach
Harmm Verger
Fritz Viebach
Hans-Albert Vilter
Willi Vredl
Karl Wilhelm
Henrik Winskowski
Waldemar Wolff
Kurt Wohlfahrt
Willi Zeleskij
Heinz Zershinskij
Herman Zimpe

Table 9.3: Some German-speaking scientists and engineers in postwar Soviet rocket and missile programs.

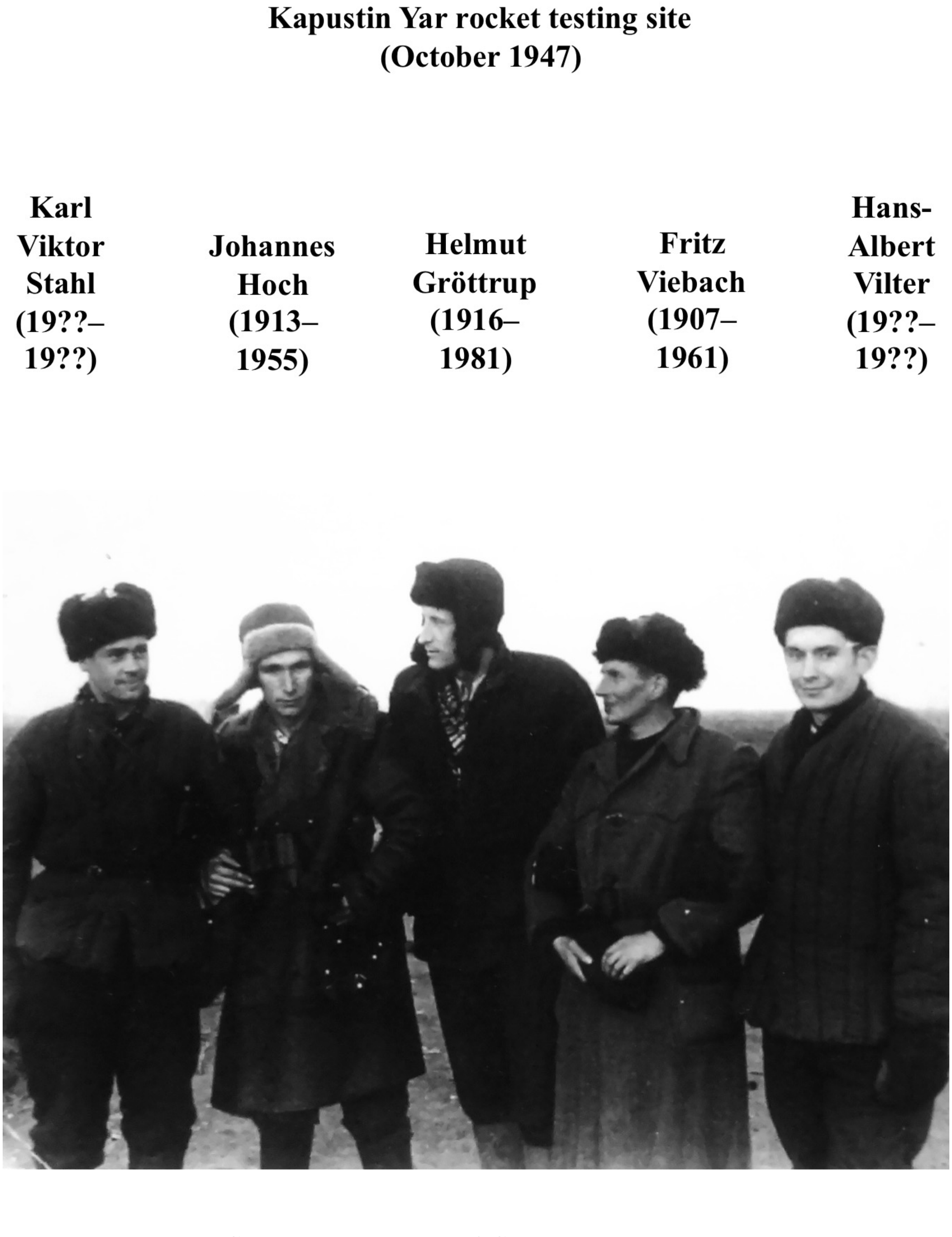

Kapustin Yar rocket testing site
(October 1947)
Karl Viktor Stahl (19??–19??)
Johannes Hoch (1913–1955)
Helmut Gröttrup (1916–1981)
Fritz Viebach (1907–1961)
Hans-Albert Vilter (19??–19??)

Figure 9.178: Helmut Gröttrup led the team of German-speaking engineers that designed and developed postwar Soviet rockets. In this October 1947 photo at the Kapustin Yar rocket testing site, he posed with Karl Viktor Stahl, Johannes Hoch, Fritz Viebach, and Hans-Albert Vilter.

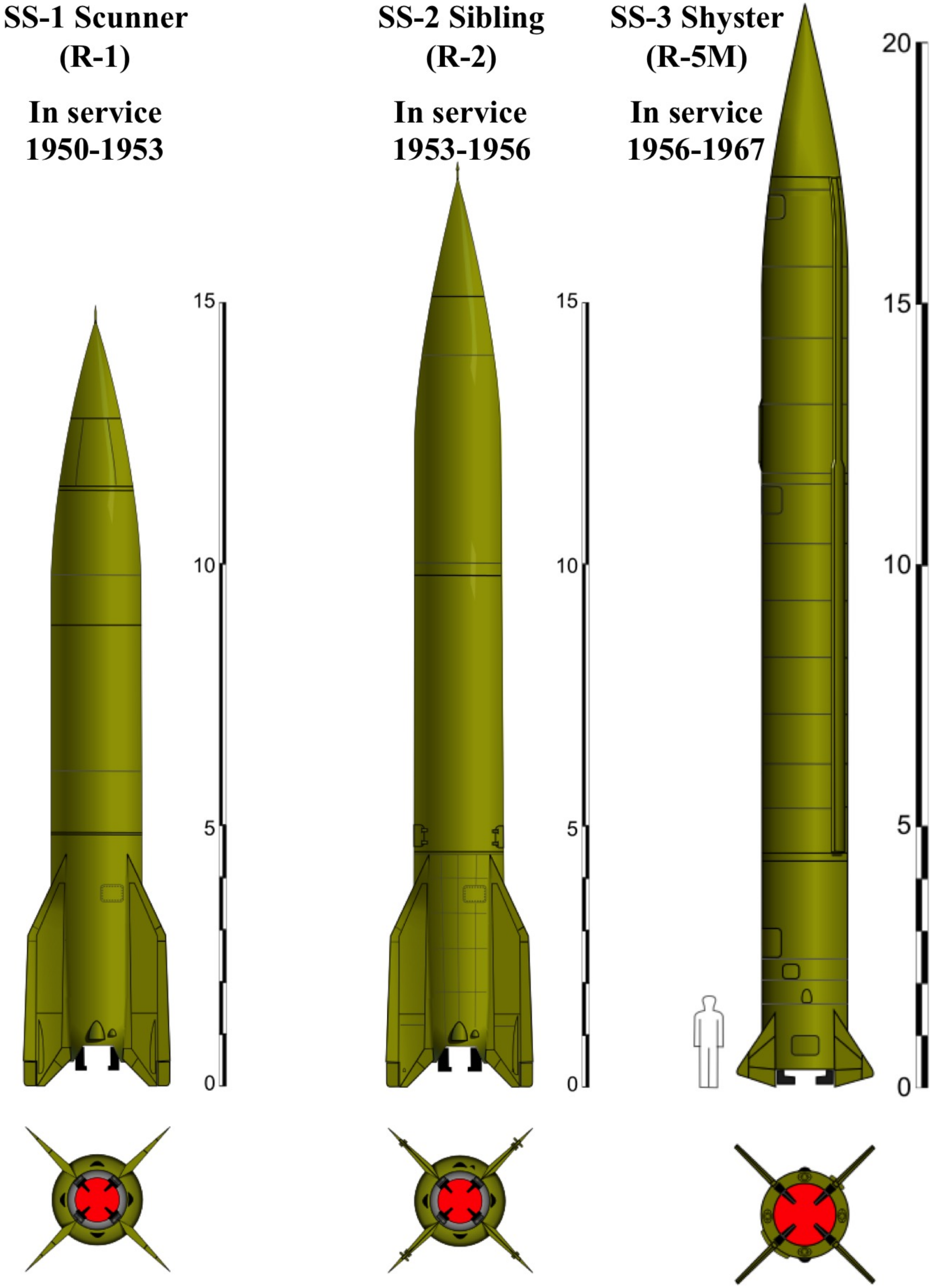

SS-1 Scunner
(R-1)
In service
1950-1953
SS-2 Sibling
(R-2)
In service
1953-1956
SS-3 Shyster
(R-5M)
In service
1956-1967
15
10
5
0
15
10
5
0
20
15
10
5
0

Figure 9.179: Examples of early Soviet ballistic missiles derived directly from German creators and creations.

SS-3
Shyster
(R-5M)

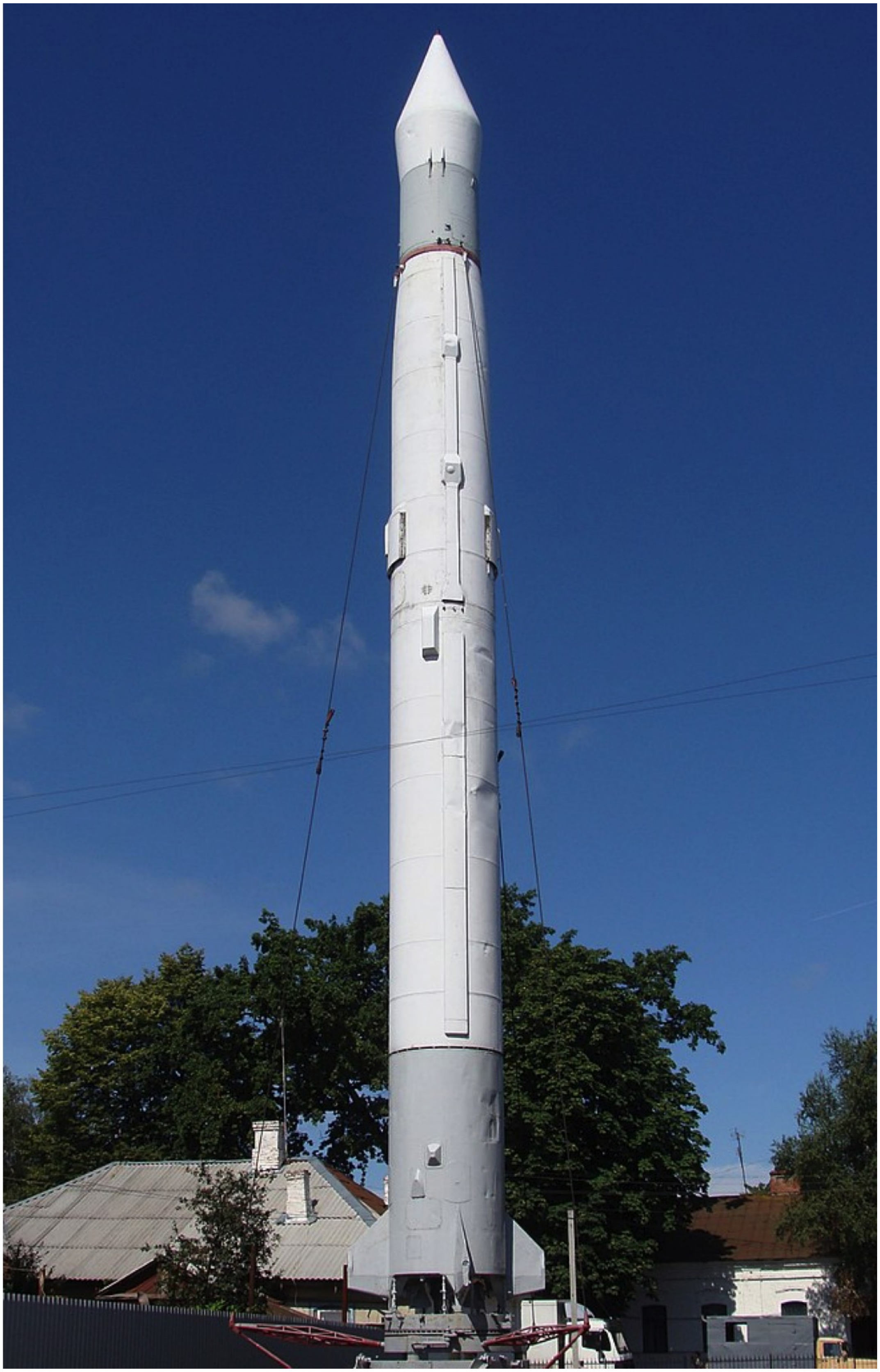
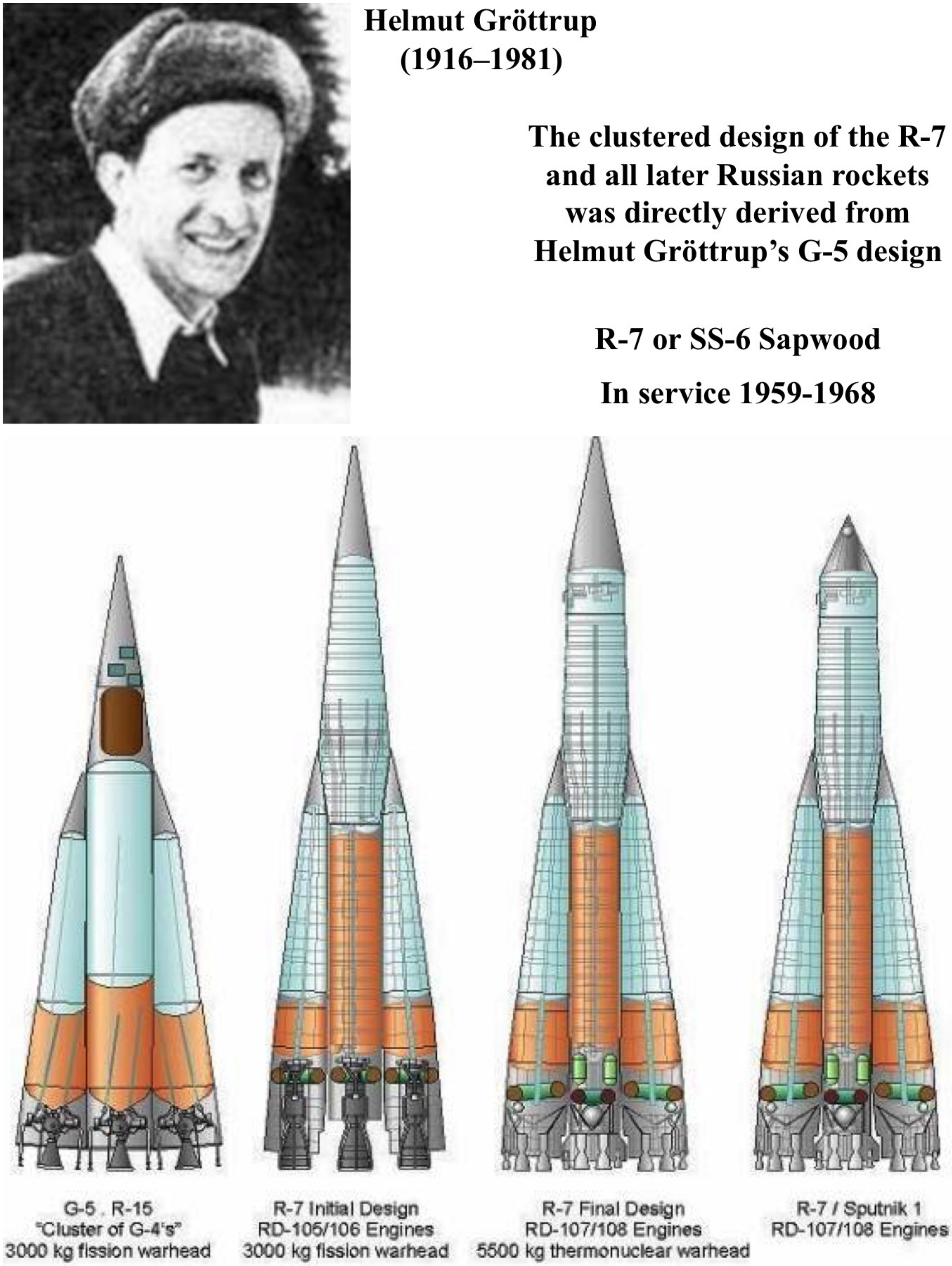


Figure 9.180: The SS-3 Shyster (R-5M) ballistic missile was derived directly from German creators and creations.



Helmut Gröttrup (1916–1981)

The clustered design of the R-7 and all later Russian rockets was directly derived from Helmut Gröttrup's G-5 design

R-7 or SS-6 Sapwood

In service 1959-1968

G-5 , R-15
"Cluster of G-4's"
3000 kg fission warhead
R-7 Initial Design
RD-105/106 Engines
3000 kg fission warhead
R-7 Final Design
RD-107/108 Engines
5500 kg thermonuclear warhead
R-7 / Sputnik 1
RD-107/108 Engines

Figure 9.181: The clustered design of the R-7 and all later Russian rockets was directly derived from Helmut Gröttrup's G-5 design [http://www.astronautix.com/g/g-5.html].

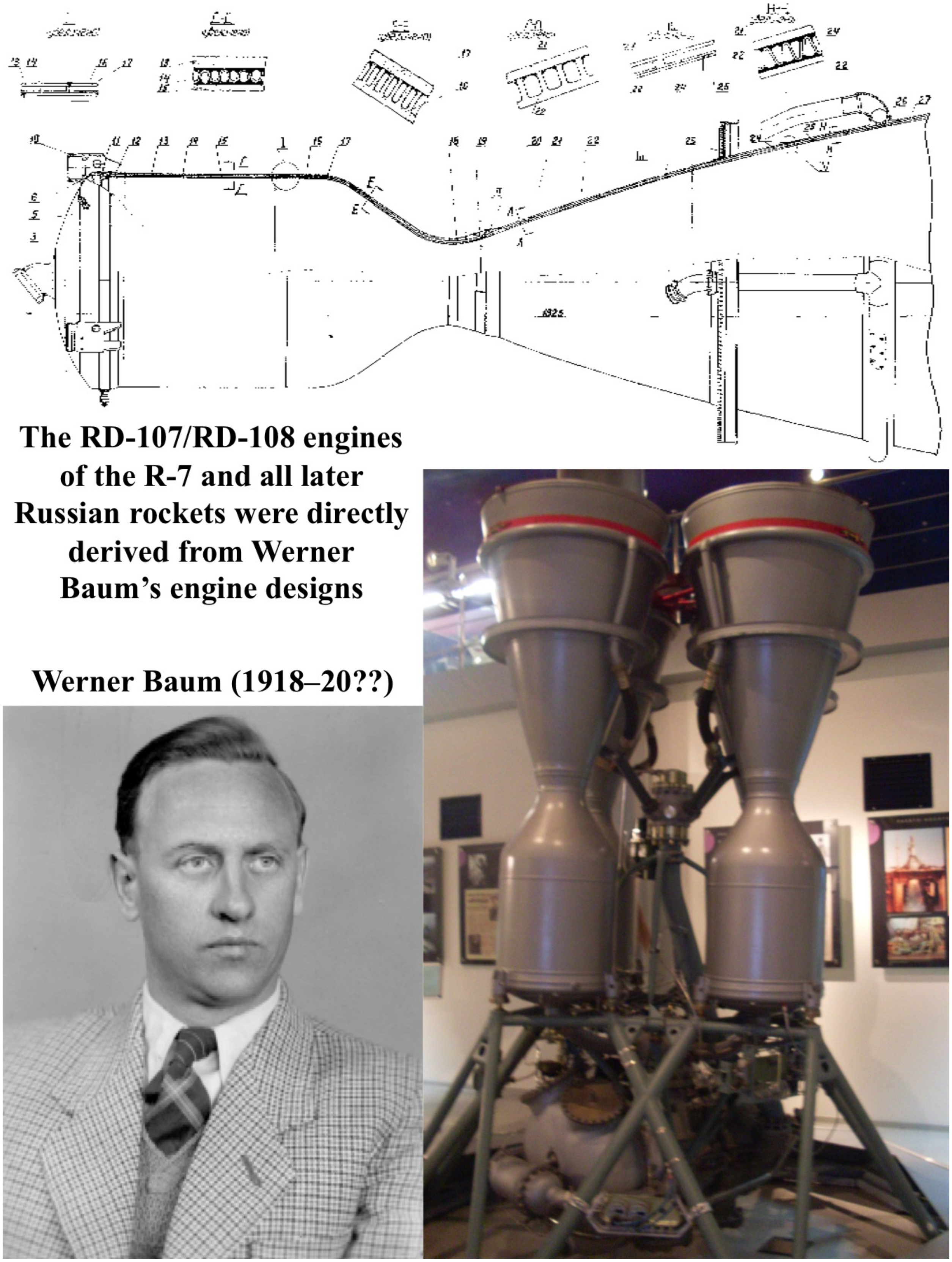

The RD-107/RD-108 engines
of the R-7 and all later
Russian rockets were directly
derived from Werner
Baum's engine designs
Werner Baum (1918–20??)

Figure 9.182: The RD-107/RD-108 engines of the R-7 and all later Russian rockets were directly derived from Werner Baum's engine designs [Przybilski 2002a].

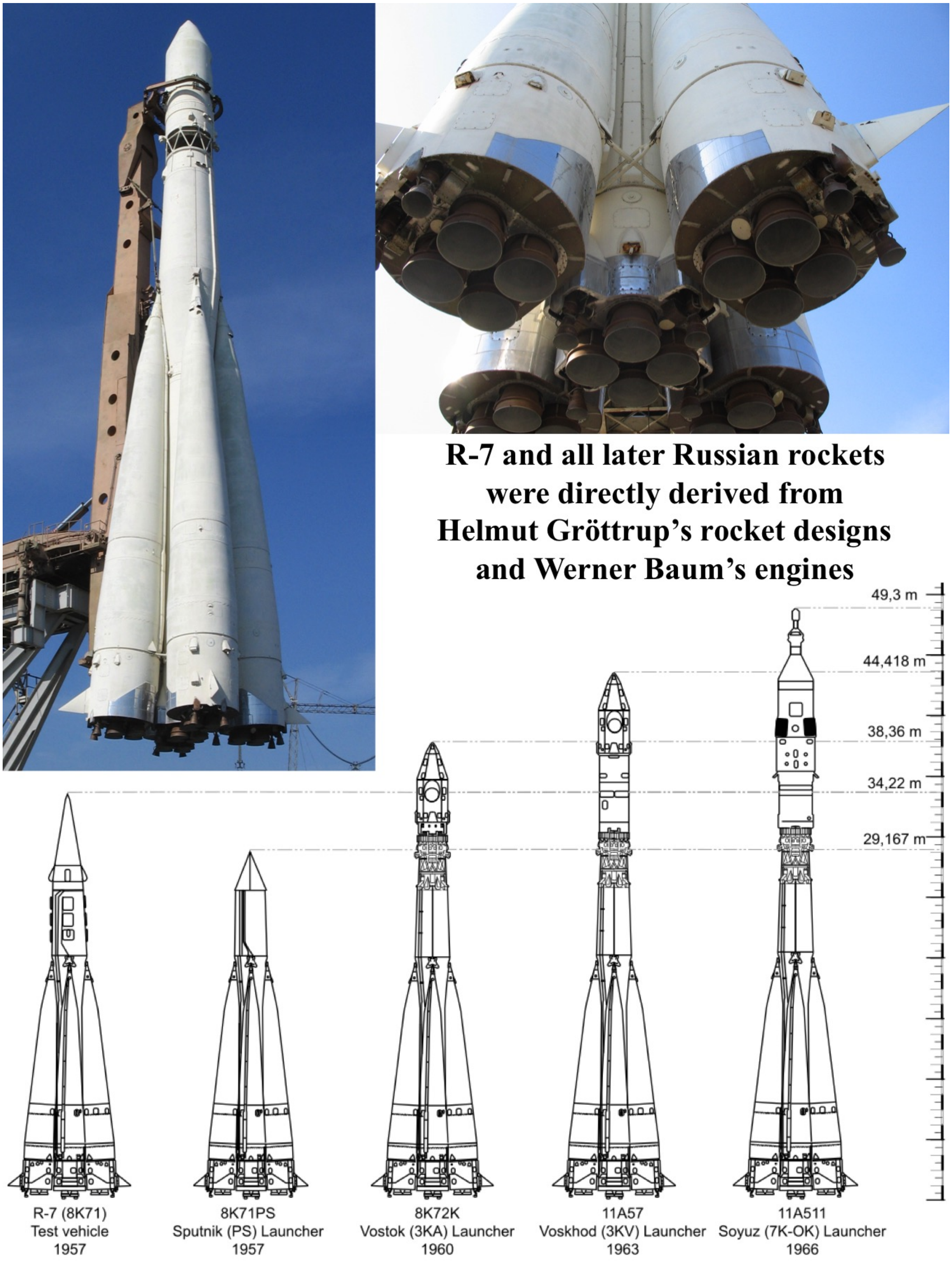

R-7 and all later Russian rockets were directly derived from Helmut Gröttrup's rocket designs and Werner Baum's engines
49,3 m
44,418 m
38,36 m
34,22 m
29,167 m
R-7 (8K71)
Test vehicle
1957
8K71PS
Sputnik (PS) Launcher
1957
8K72K
Vostok (3KA) Launcher
1960
11A57
Voskhod (3KV) Launcher
1963
11A511
Soyuz (7K-OK) Launcher
1966

Figure 9.183: R-7 and later Russian rockets through current Soyuz launchers were directly derived from Helmut Gröttrup's rocket designs and Werner Baum's engines.

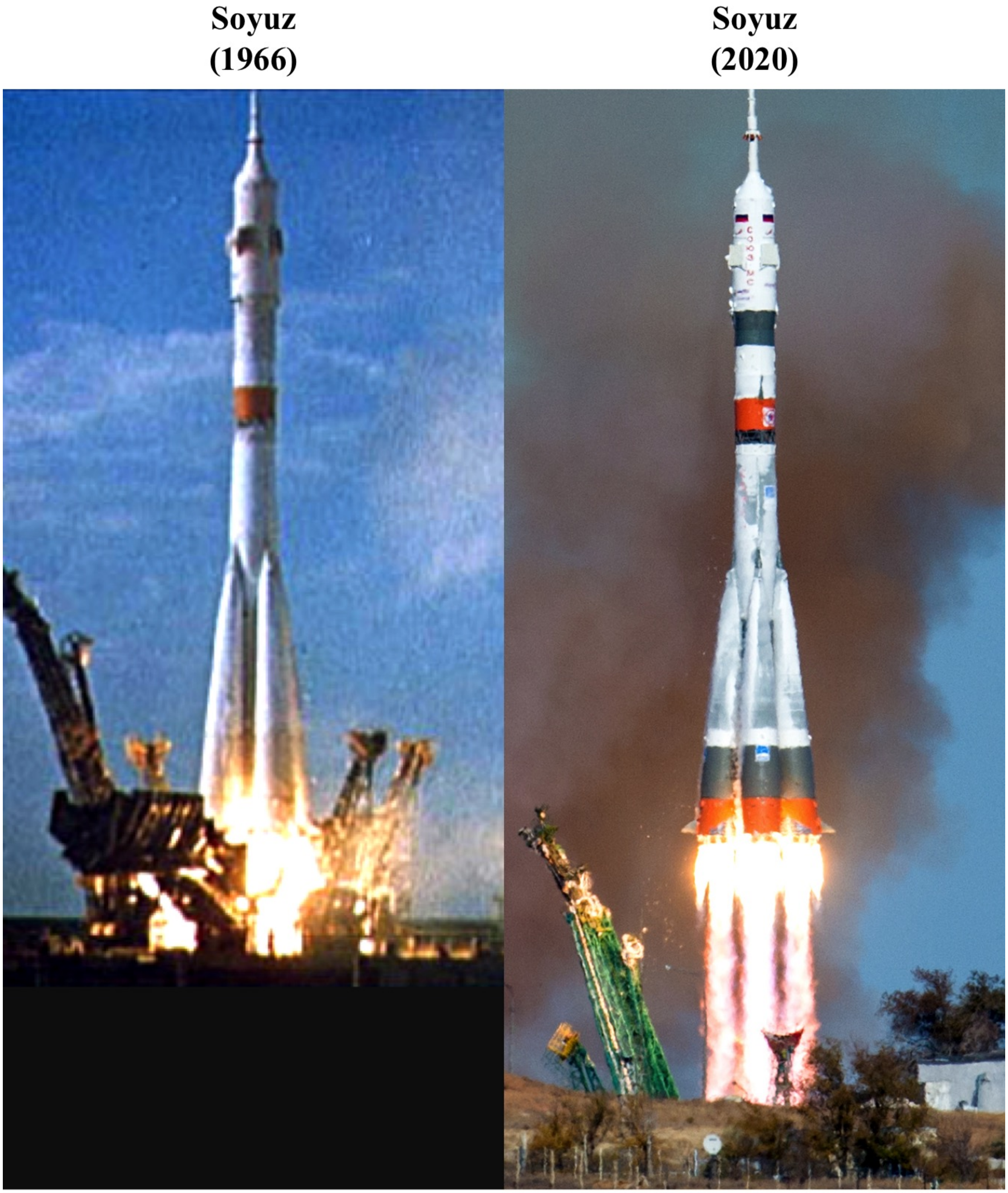


Figure 9.184: Even the most recent Russian rockets such as Soyuz (1966–present) are directly based on German rocket designs and German rocket engines. For more information, see pp. 1875–1881.

9.7.4 Postwar French Rocket Programs

Similarly, German-speaking scientists and engineers made major contributions to postwar programs in France. Writing for *L'Express*, investigative journalists Vincent Nouzille and Olivier Huwart researched unclassified French government records and described the recruitment and ultimate technological impact of over 1000 German and Austrian scientists and engineers in France after the war, especially with regard to missiles and other aerospace technologies [Nouzille and Huwart 1999].

For some examples of German-speaking contributions to postwar French rockets, including Véronique, Diamant, and Ariane, see Table 9.4 and Figs. 9.185–9.189 [Jürgen Michels 1997]. Later the German-designed Viking engine and other Ariane technologies were licensed to India, which built copies for its space program (p. 1889).

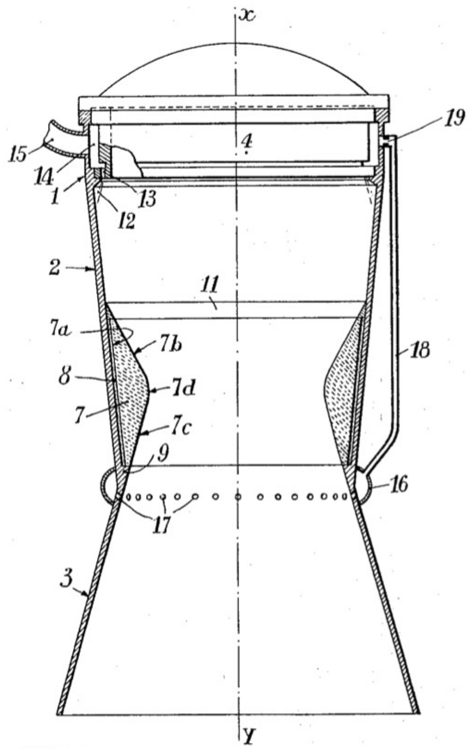
For more information on German-designed rockets in France, see pp. 5576–5584.

Bachmann
F. Bayer
Behnke
Bernkopf
Billig
Bodenstein
Uwe Bödewadt
Boese
Bornscheuer
Karl-Heinz Bringer
Büchner
Buhl
Deucker
Dollhopf
Rolf Engel
Fabian
Fölster
Frey
Gardian
Görtz
Grater
I. Gross
Martin Haas
Helmut Habermann
Rudolf Hackh
Heine
Joseph Himpan
Höhne
Hüttenberger
Rolf Jauernick
Just
Kauba
Keiner
Kieffer
Klar
Hans Kleinwächter
Kohl
König
Otto Kraehe
Krämer
Laebe
Lammerhirt
Lang
Liesegang
Lörtsch
Menke
Mosch
Otto Müller
Netterscheim
Wolfgang Pilz
Willibald P. Prasthofer
Rudolf Reichel
Ernst Runge
Eugen Sänger
Irene Sänger-Bredt
Schabert
Karl Scheidt
Schlotzer
C. Schmidt
W. Schmidt
Schmoll
Schnapper
Oskar Scholze
Schossig
Schubert
Schuran
Joachim Seidel
Sohn
Störk
Strobel
Stumke
Hermann Teichmann
Voigt
Walther
Helmut Weiss
Weissenborn
Woytech
Wüterich
Wolfgang Zangl
Helmut von Zborowski

Table 9.4: Some German-speaking scientists and engineers in postwar French rocket and missile programs.

Karl-Heinz Bringer (1908–1999)
Rocket engines in wartime
Germany and postwar France

Feb. 14, 1967 H. BRINGER 3,303,654
COMBUSTION CHAMBER FOR RAM-JETS OR ROCKET POWER
UNITS EMPLOYING A COOLING FILM OF LIQUID FUEL
Filed Nov. 5, 1964


x
19
4
15
14
1
13
12
2
11
7a
7b
18
8
7d
7
7c
9
16
17
3
Y

United States Patent [11] **3,601,993**

[72] Inventor **Henri Bringer**
26 Allee des Penitents, Vernon 27, France
[21] Appl. No. **24,993**
[22] Filed **Apr. 2, 1970**
[45] Patented **Aug. 31, 1971**
[32] Priority **Apr. 3, 1969**
[33] **France**
[31] **PV 6910190**

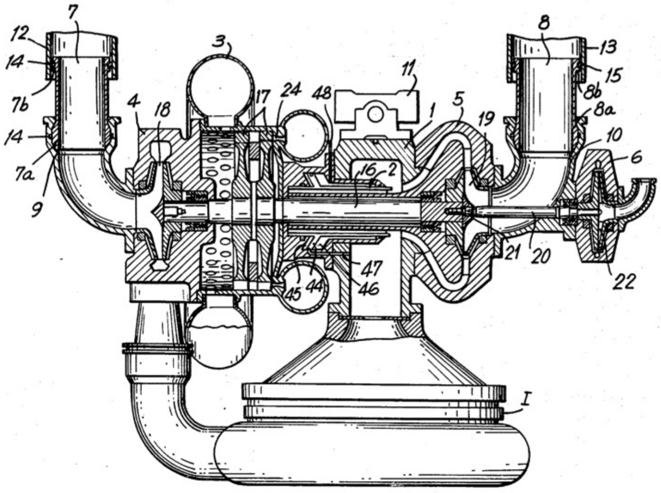
[54] **TURBOPUMP FOR ROCKET ENGINES**
10 Claims, 3 Drawing Figs.
[52] **U.S. Cl.** **60/240,** 60/39.26, 60/39.27, 60/39.3
[51] **Int. Cl.** **F02k 3/00**
[50] **Field of Search** 60/240, 39.26, 39.27, 39.3

[56] **References Cited**
UNITED STATES PATENTS

2,728,192	12/1955	Ross	60/39.26 X
3,137,128	6/1964	Francais	60/240 X
3,215,352	11/1965	Meraz	60/240 UX
3,433,022	3/1969	Lovingham	60/240 X
3,527,056	9/1970	Hoffman	60/240 X

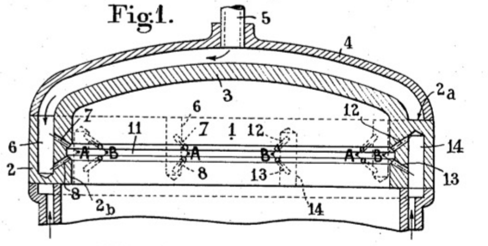
Primary Examiner—Clarence R. Gordon
Attorney—Waters, Roditi, Schwartz & Nissen

ABSTRACT: A turbopump is provided for a liquid-fuel rocket engine using two power propellants, namely a noncryogenic oxidizer and a noncryogenic fuel. The turbopump feeds the rocket engine at high pressure. The pump-driving turbine of the turbopump is fed by gases from a generator produced by the combustion of the two propellants and cooled by the injection of water. A regulator is connected between the generator and the propellant pumps of the turbopump to control the speed of the turbine in accordance with engine combustion pressure to maintain a substantially constant pressure. The propellants are fed to the engine injection via a balancing device which regulates the propellant delivery pressures so that they are equalized.


7
12
14
7b
14
7a
9
4
18
3
17
24
48
11
1
5
19
8
13
15
8b
8a
10
6
16
2
21
20
22
47
46
45
44
I

Sept. 24, 1968 H. BRINGER 3,402,552
LIQUID INJECTION DEVICE
Filed Nov. 5, 1964

Fig.1.


5
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2a
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12
12
6
14
2
13
8
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13
2b
14

Fig.2.

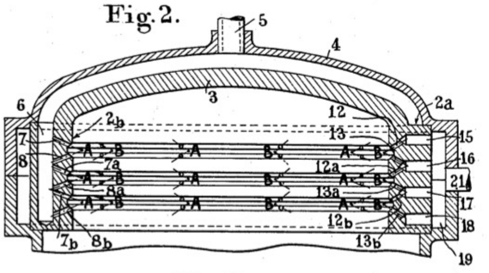

5
4
6
3
2a
2b
12
13
7
15
8
7a
12a
16
8a
13a
21
17
18
7b
8b
12b
13b
19

Fig.3.

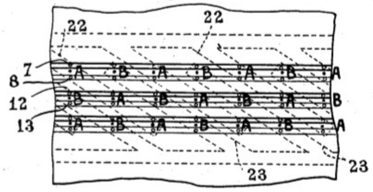
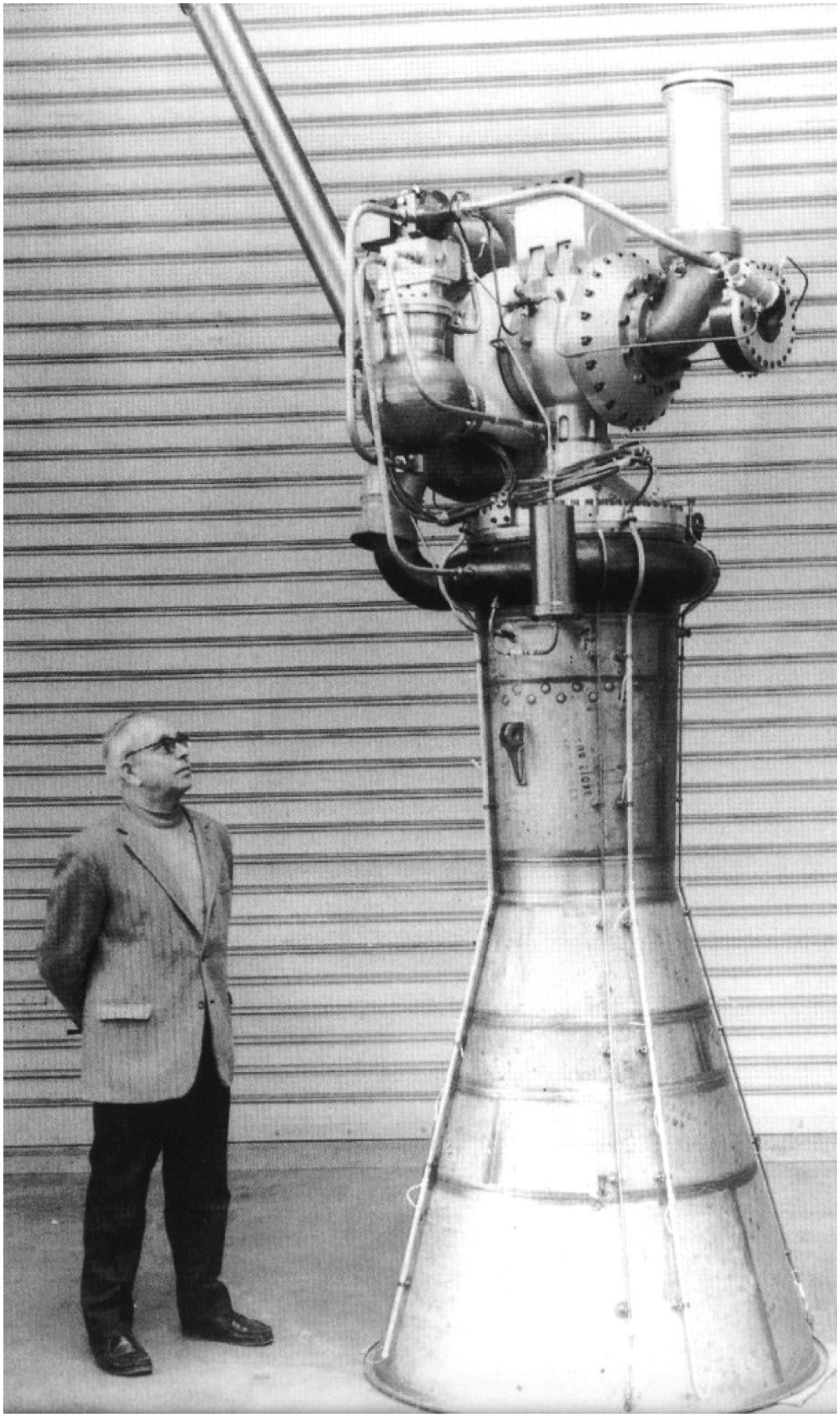

22
22
7
8
12
13
A
B
23
23

Figure 9.185: Karl-Heinz Bringer designed and demonstrated a long series of sophisticated rocket engines in wartime Germany and postwar France, culminating in the Viking engine for the Ariane rockets.



Karl-Heinz Bringer (1908–1999)

Viking rocket engine (developed in 1965, used in Ariane rockets)

Figure 9.186: Karl-Heinz Bringer led a team of German-speaking engineers that designed and developed postwar French rocket engines, such as the Viking engine for the Ariane rockets. Later the Viking engine and other Ariane technologies were licensed to India, which built copies for its space program (p. 1889).

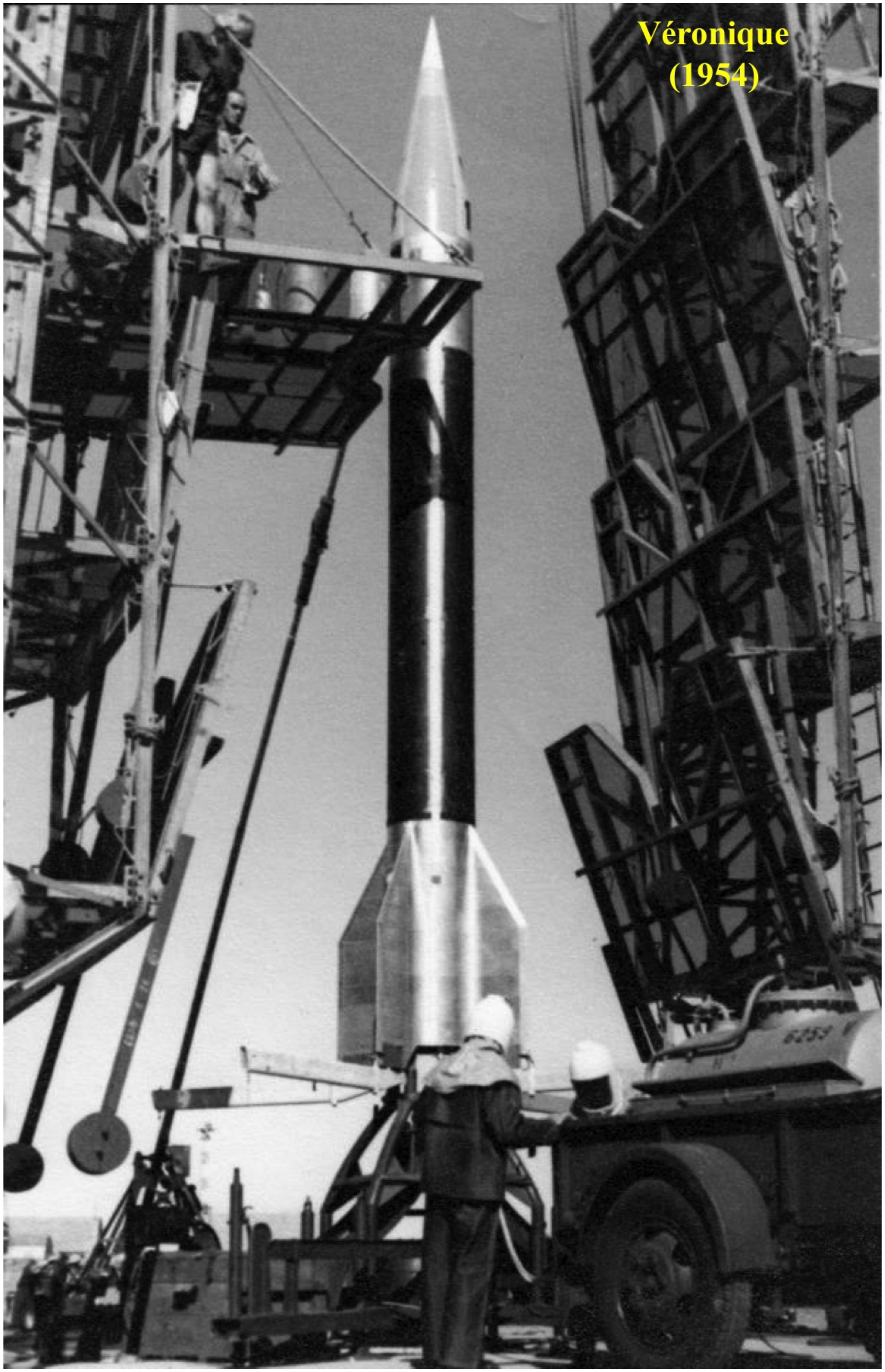


Figure 9.187: German-speaking rocket engineers designed the French Véronique, an A-4/V-2-like rocket that was first launched in 1954.

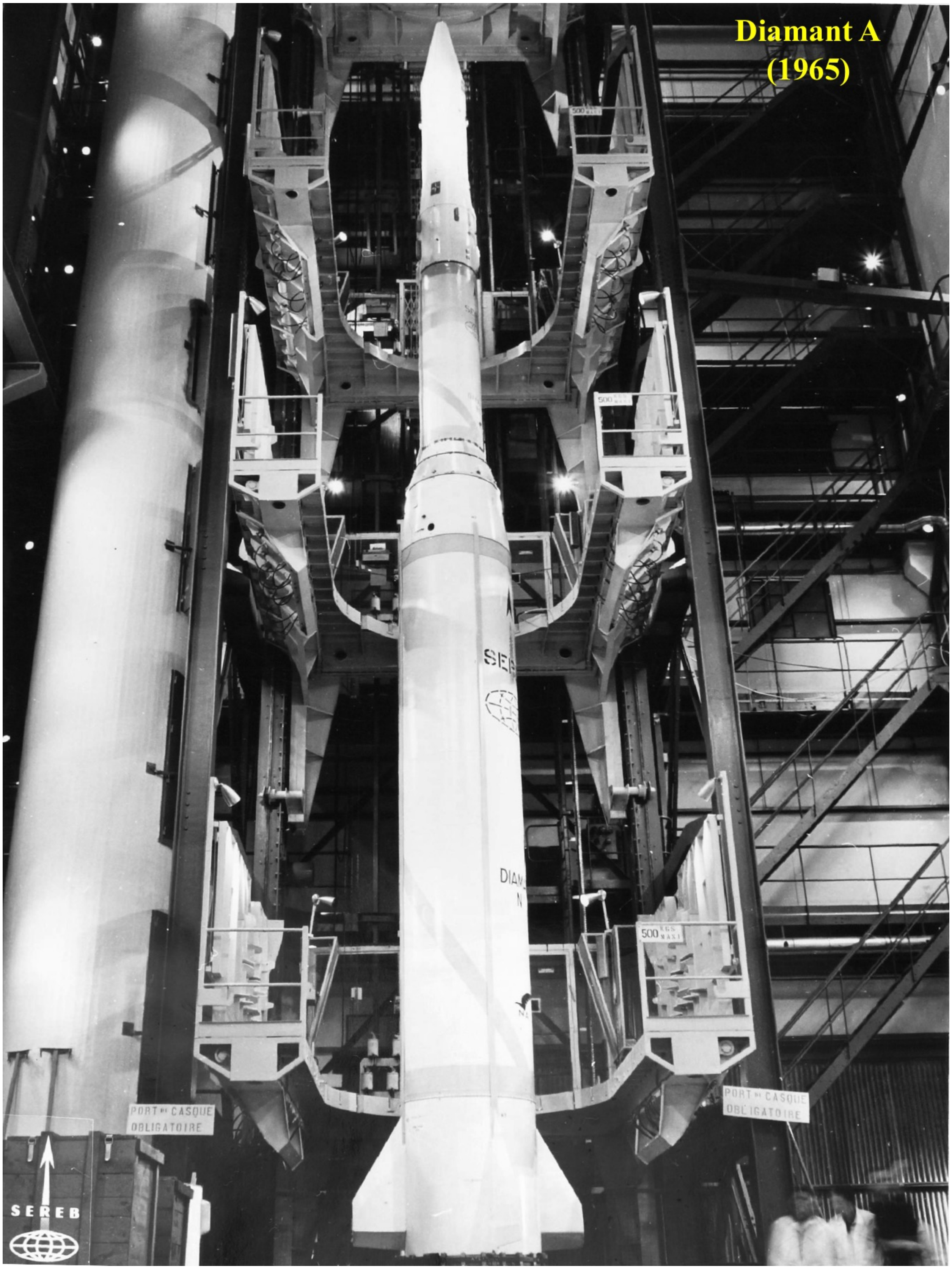

Diamant A
(1965)
500
500
500
SEREB
DIAM
N
PORT DU CASQUE
OBLIGATOIRE
PORT DU CASQUE
OBLIGATOIRE
SEREB

Figure 9.188: German-speaking rocket engineers designed the French Diamant, which was first launched in 1965.

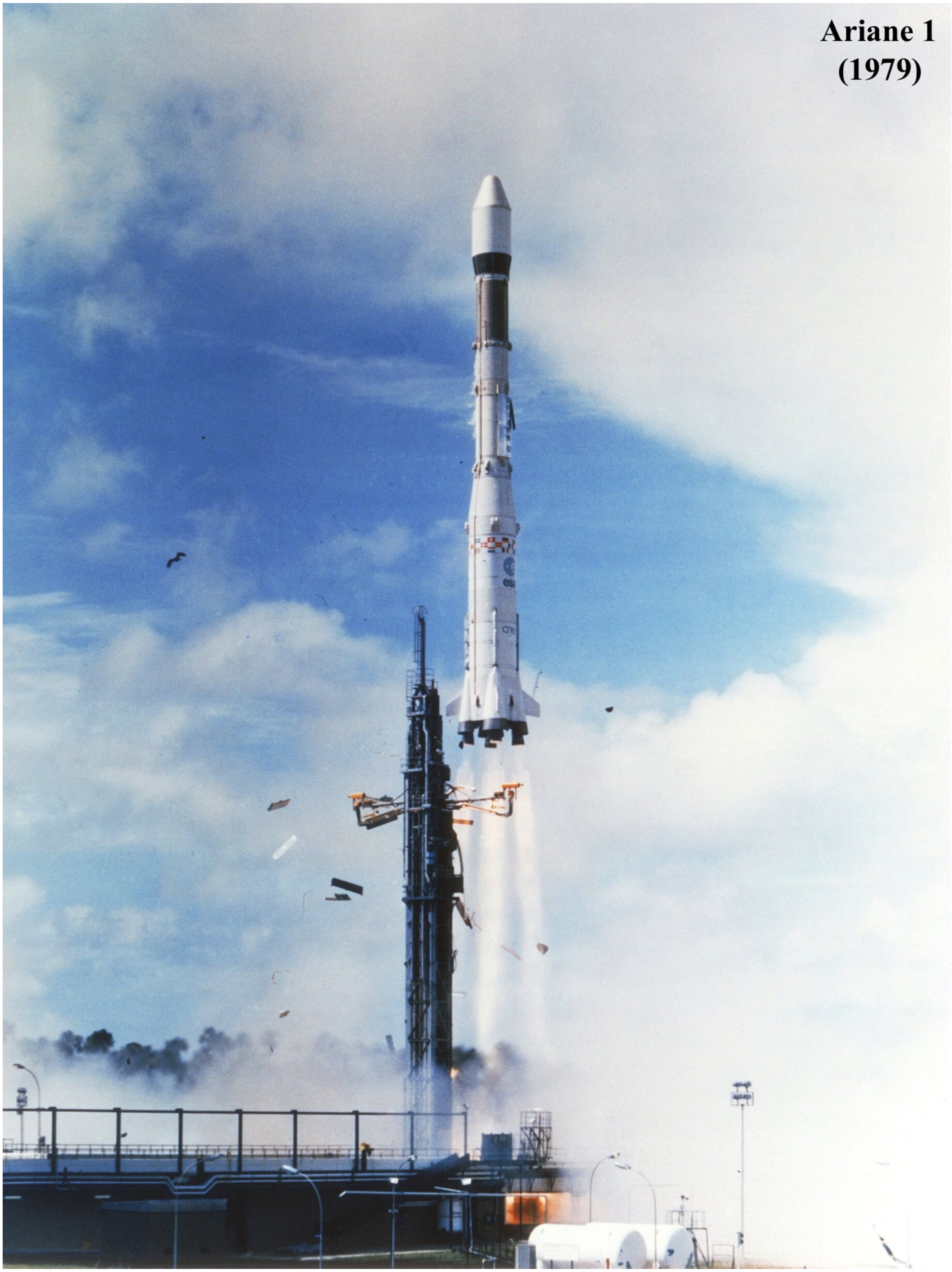


Figure 9.189: German-speaking rocket engineers designed the French Ariane, which was first launched in 1979.

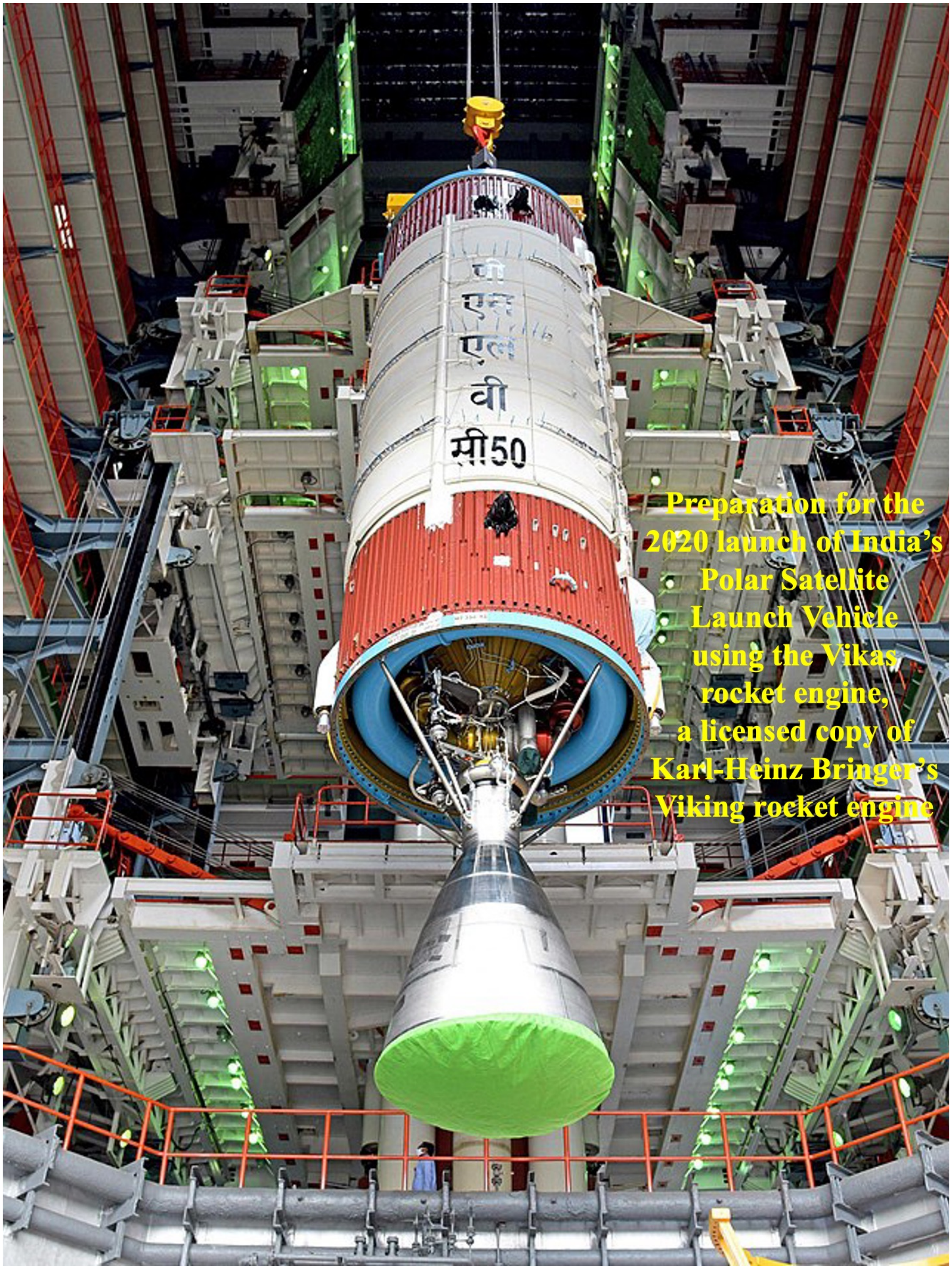

पी
एस
एल
वी
सी50
Preparation for the
2020 launch of India's
Polar Satellite
Launch Vehicle
using the Vikas
rocket engine,
a licensed copy of
Karl-Heinz Bringer's
Viking rocket engine

Figure 9.190: Preparation for the 2020 launch of India's Polar Satellite Launch Vehicle using the Vikas rocket engine, a licensed copy of Karl-Heinz Bringer's Viking rocket engine, as well as other German-designed Ariane technologies. See also: https://www.b14643.de/Spacerockets/Specials/VIKAS_engines/Vikas.htm

9.8 Submarine-Launched and Solid Propellant Rockets

Section 9.8.1 concerns submarine-launched missiles that were developed or were under development during the war, as well as the postwar influence of such projects and German-speaking scientific experts.

Section 9.8.2 covers the wartime and postwar development of solid propellant rockets.

Not all submarine-launched missiles used solid propellant, and not all solid propellant rockets were designed to be launched from submarines, but the two histories are so deeply intertwined (because solid propellant is especially desirable for submarine-launched rockets) that they are presented together here.

A number of supporting documents are presented in Appendix E.

9.8.1 Submarine-Launched Missiles

Several submarine-launched missile prototypes and designs were developed in wartime Germany:

- In May 1942, there was a series of successful tests to launch small Nebelwerfer rockets from a submerged submarine (U-511). Those tests were documented in a June 1942 report [Bundesarchiv Militärarchiv Freiburg RH 8/369]. See pp. 1892 and 5631–5639.

- Based on those successful initial tests, during 1942–1945, the German Navy sponsored the development of a whole series of increasingly sophisticated short-range rockets that could be launched from a submerged submarine. Those rockets were successfully demonstrated at Toplitz See, Austria. The rockets and testing equipment were all destroyed at the end of the war as American forces approached. After the war, though, U.S. Navy investigators interrogated several of the engineers who were involved in the project and wrote a report about their work [NavTecMisEu 500-45]. See pp. 1893 and 5640–5645.

- Also based on the 1942 tests and the proposal by Lafferenz, engineers from Peenemünde began working on the “Prüfstand XII” project to transport and launch A-4 (V-2) rockets from specially designed underwater cargo containers that could be towed by submarines. For examples from a large collection of 1944 design drawings [Bundesarchiv Militärarchiv Freiburg RH 8/4067K], see pp. 1894 and 5646–5654. Although in Dornberger’s postwar public statements he said that nothing ever came of the project, it is unclear how far the project may have actually progressed. There were reports that at least one Prüfstand XII unit may have been constructed and tested before the end of the war.

- There were also wartime programs to launch modified V-1 cruise missiles from German submarines (pp. 5618–5627).

These and other wartime German projects were continued in other countries after the war, with the aid of German-speaking scientists and captured German hardware and plans:

- As part of Operation Sandy, the U.S. Navy launched an A-4 (V-2) rocket from the deck of the USS Midway on 6 September 1947, demonstrating that an A-4 rocket could indeed be transported and launched at sea (p. 1895).

- Beginning in February 1947, Loon missiles, U.S. copies of German V-1 cruise missiles [Quigg 2014], were launched from the USS *Cusk* submarine, based on wartime German developments and implemented by German-speaking scientists at Point Mugu Naval Air Missile Test Center. That program was even marketed as a great American achievement in magazines (e.g., p. 1896) and in a fictionalized Hollywood film (*The Flying Missile*, 1950, Columbia Pictures). See also p. 5627.

- German-speaking scientists and technologies were used to develop a series of more advanced U.S. cruise missiles beginning in the late 1940s (pp. 1850–1854).

- Wernher von Braun's team was directly involved in developing Jupiter, a liquid propellant ballistic missile designed to be launched from submarines (but ultimately only deployed on land; see p. 1897).

- German-speaking scientists were deeply involved in the development of U.S. solid propellant submarine-launched ballistic missiles (SLBMs) in ways that have never been fully disclosed to the public (pp. 1902–1904 and 5700–5736).

- In 1962, Robert Truax at Aerojet proposed to greatly scale up the "Prüfstand XII" approach to create the Sea Dragon, a sea-launched rocket that would have been larger than even a Saturn V (p. 5655).

- The Soviet Union also investigated versions of the "Prüfstand XII" approach as part of its postwar Golem program to develop SLBMs.[17]

- The first Soviet SLBM, the R-11FM Zemlya (SS-1B SCUD-A), was directly based on the German Wasserfall (first launched in 1944). Like the Wasserfall, it used storable liquid propellants. The R-11FM was first launched from a submarine on 16 September 1955. See pp. 1898–1899.

- Later generations of Soviet SLBMs, such as the R-13 (SS-N-4, first launched in 1959) and R-21 (SS-N-5, first launched in 1962) were scaled up from the R-11FM and again were directly based on German-developed technologies and propellants (p. 1900).

- German-speaking scientists and technologies likely also had a great impact on the postwar submarine-launched missile programs of other countries (e.g., p. 5660).

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[17] www.globalsecurity.org/wmd/world/russia/golem.htm

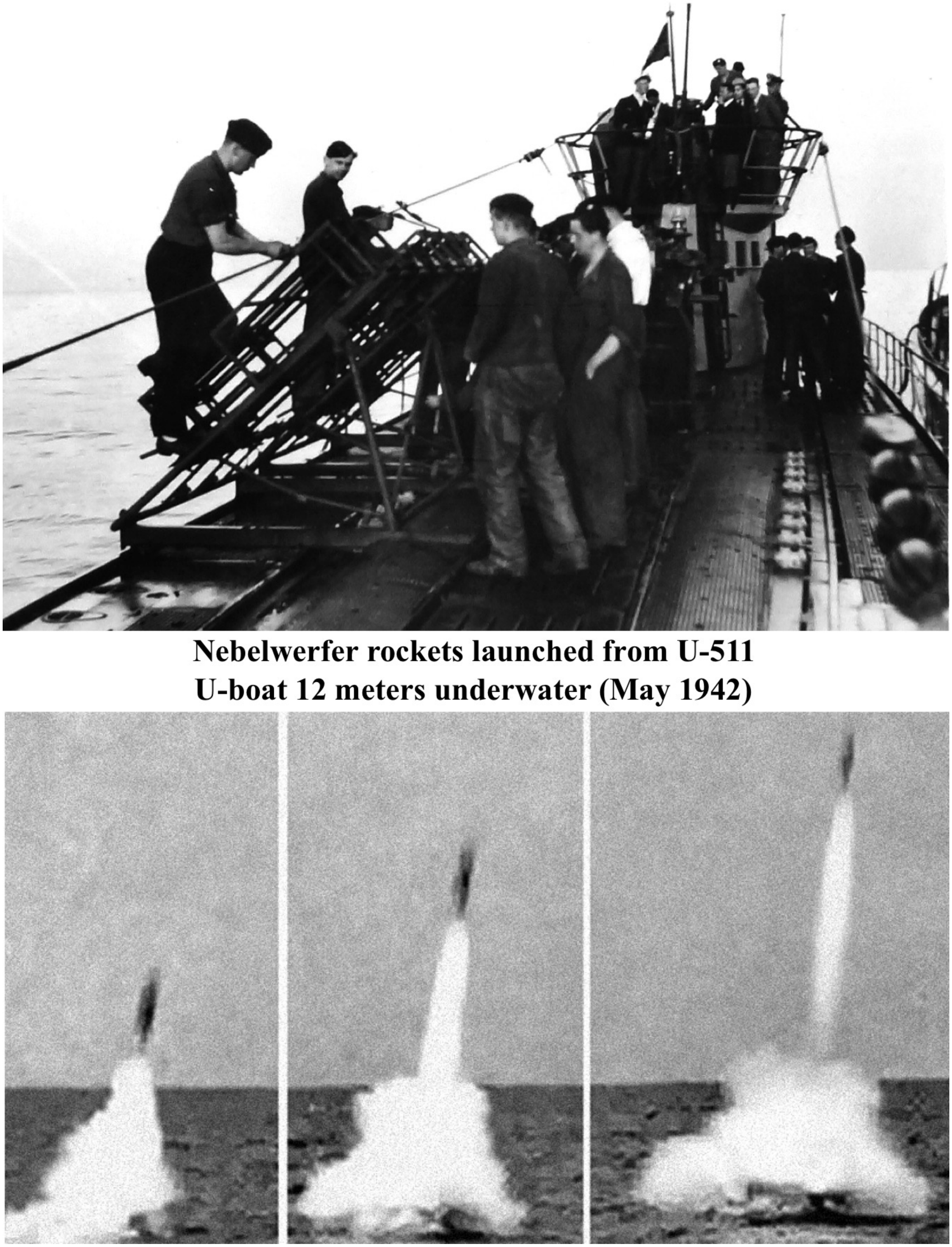
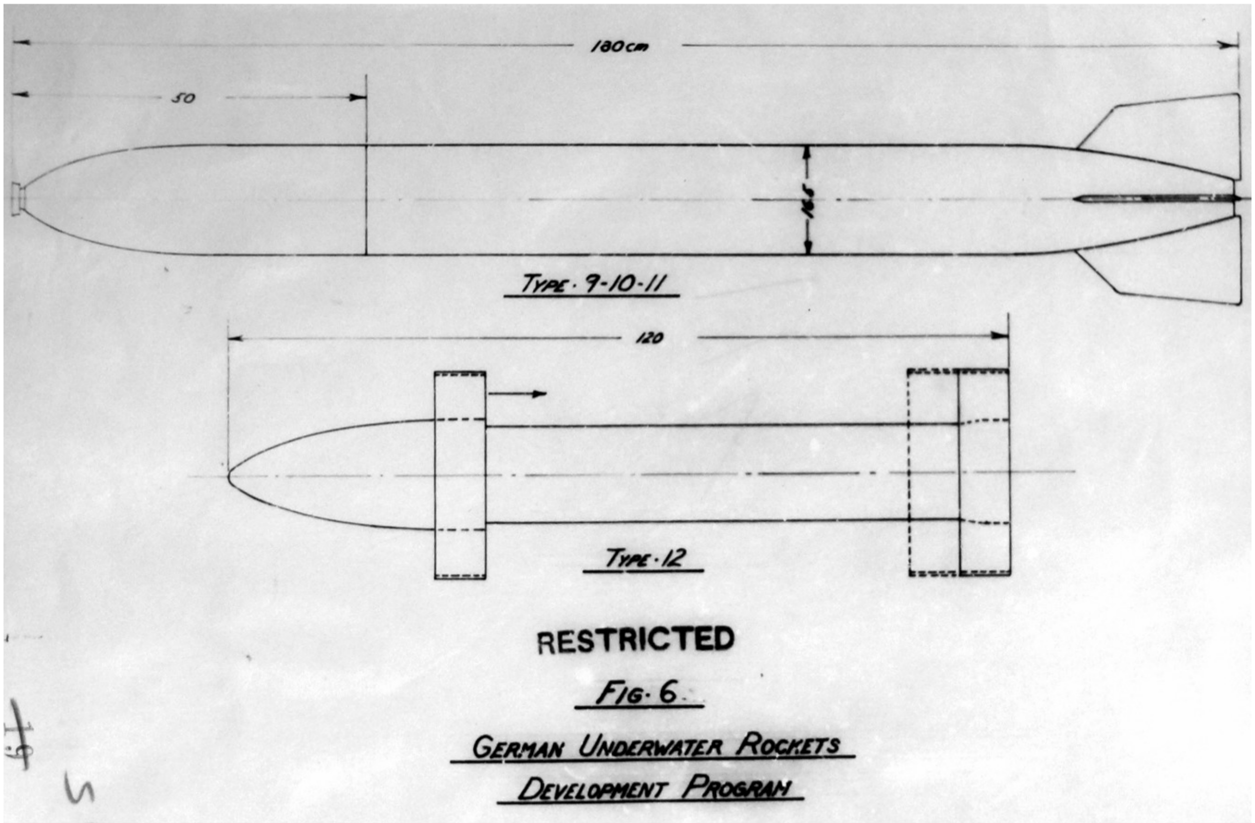
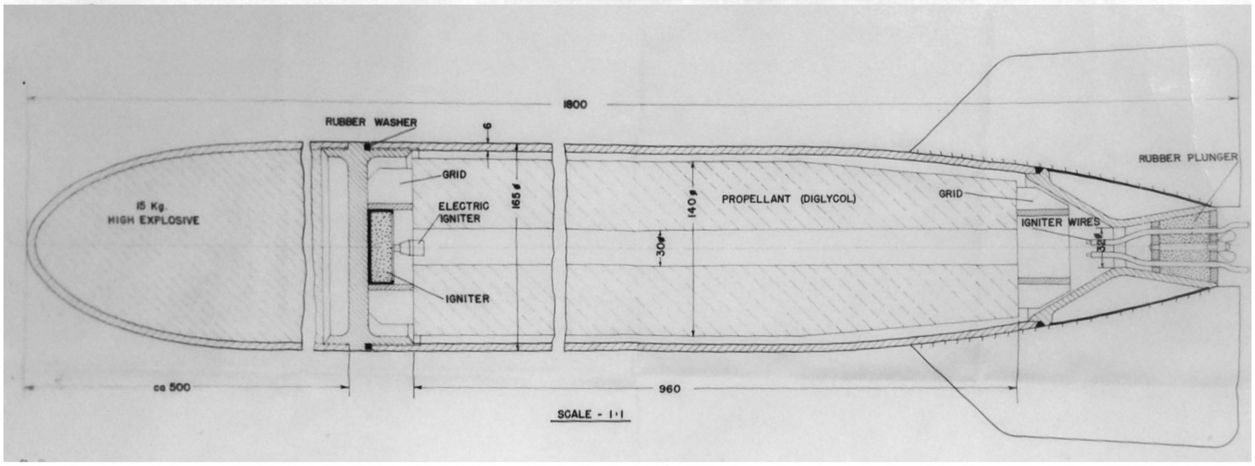

Nebelwerfer rockets launched from U-511
U-boat 12 meters underwater (May 1942)

Figure 9.191: Photographs from a 1942 report describing a series of successful tests to launch small rockets from a submerged submarine [Bundesarchiv Militärarchiv Freiburg RH 8/369].

A long series of increasingly sophisticated submarine-launched rockets were developed and successfully demonstrated at Toplitz See, Austria (1942–1945)


180cm
50
16.5
TYPE · 9-10-11
120
TYPE · 12
RESTRICTED
FIG · 6
GERMAN UNDERWATER ROCKETS
DEVELOPMENT PROGRAM


1800
RUBBER WASHER
6
GRID
ELECTRIC IGNITER
IGNITER
165ø
15 Kg. HIGH EXPLOSIVE
140ø
30ø
PROPELLANT (DIGLYCOL)
GRID
IGNITER WIRES
32ø
RUBBER PLUNGER
ca 500
960
SCALE - 1:1

DECLASSIFIED
Authority NW 54481

Figure 9.192: Drawings from a postwar report on a long series of increasingly sophisticated submarine-launched rockets that were developed 1942–1945 and successfully demonstrated at Toplitz See, Austria [NavTecMisEu 500-45].

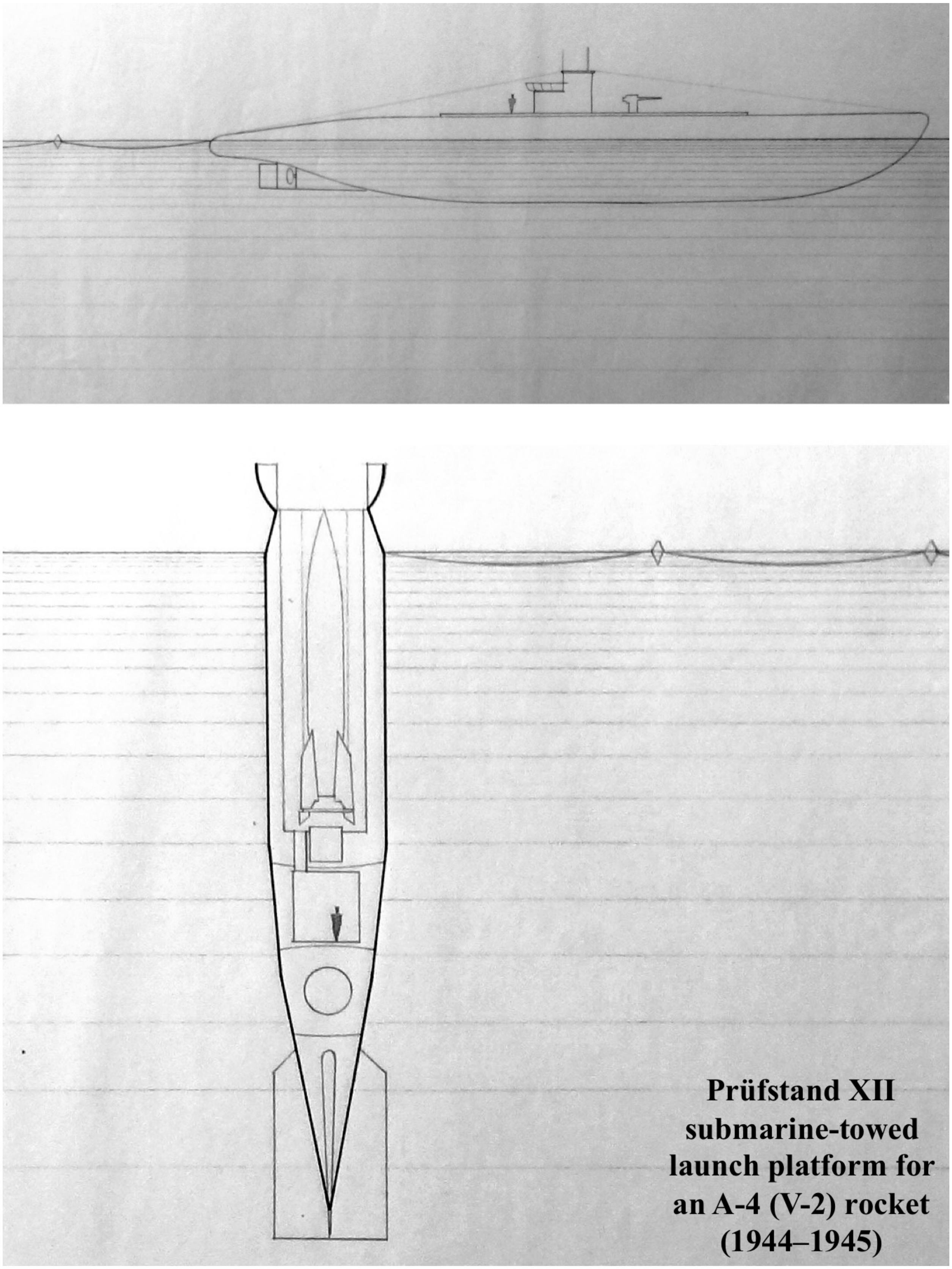

Prüfstand XII
submarine-towed
launch platform for
an A-4 (V-2) rocket
(1944–1945)

Figure 9.193: 1944 drawings from the "Prüfstand XII" project to transport and launch A-4 (V-2) rockets from specially designed underwater cargo containers that could be towed by submarines [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

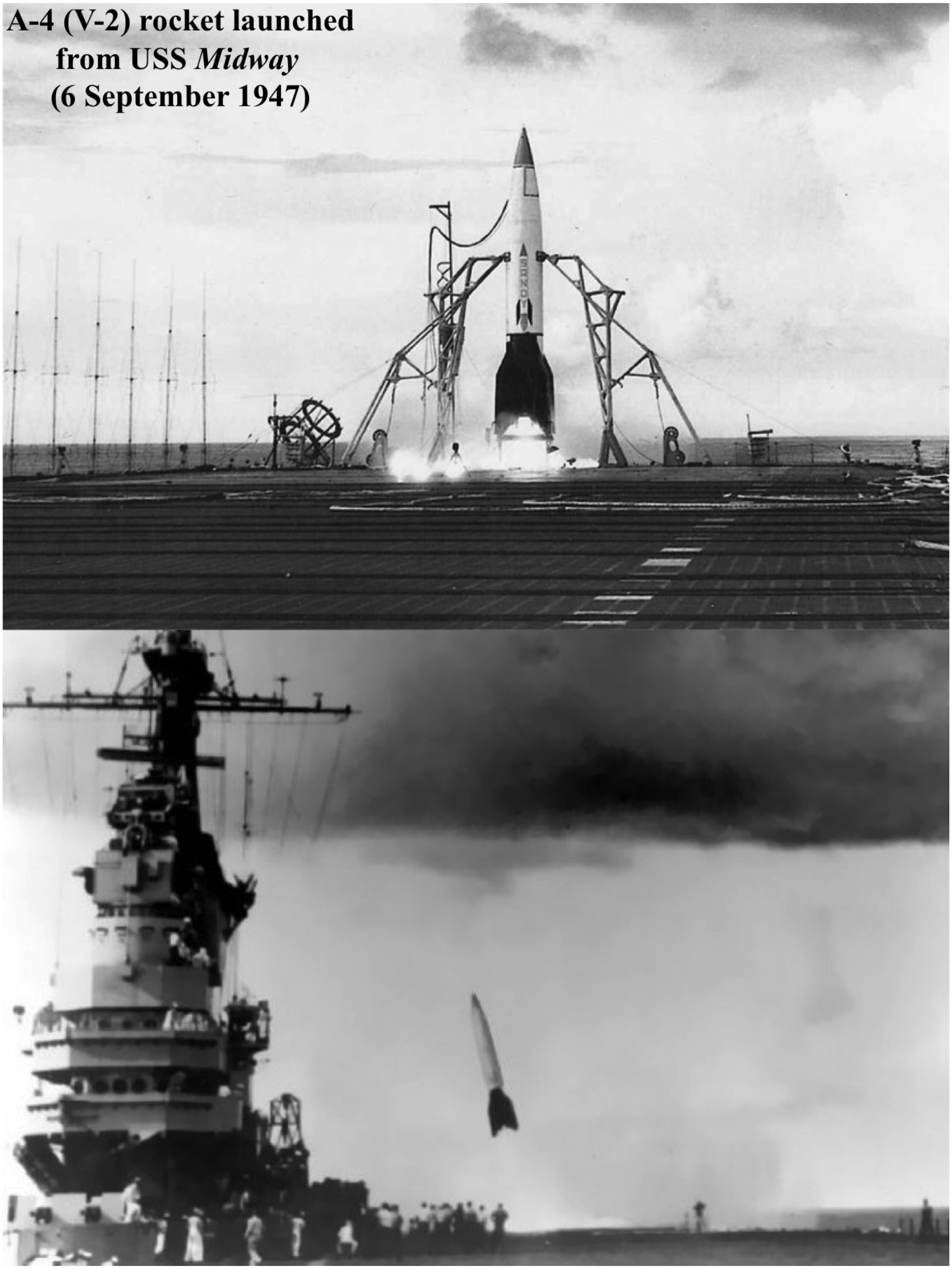

A-4 (V-2) rocket launched
from USS *Midway*
(6 September 1947)

Figure 9.194: As part of Operation Sandy, the U.S. Navy launched an A-4 (V-2) rocket from the deck of the USS Midway on 6 September 1947 [http://www.cv41.org/photos/gallery/main.php?g2_itemId=17451].

U.S. copies of V-1 cruise missile ("Loon") launched from U.S. submarine USS *Cusk* (first launched 12 February 1947)

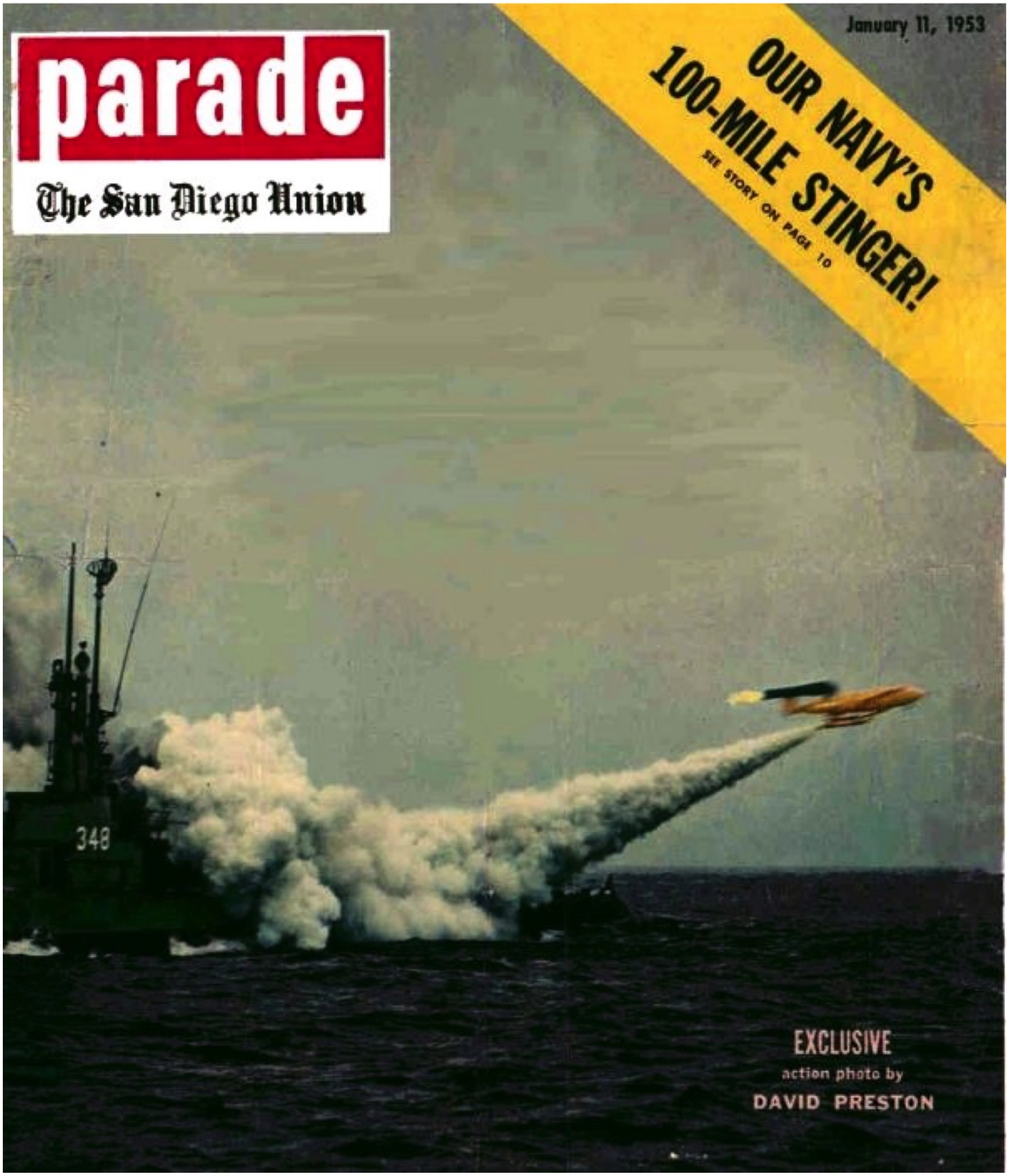

parade
The San Diego Union
January 11, 1953
OUR NAVY'S 100-MILE STINGER!
SEE STORY ON PAGE 10
348
EXCLUSIVE
action photo by
DAVID PRESTON

Figure 9.195: Loon, a U.S. copy of the V-1 cruise missile, launched from the USS *Cusk* submarine, based on wartime German developments and implemented by German-speaking scientists at Point Mugu Naval Air Missile Test Center [http://www.usscusk.com/1953.htm].

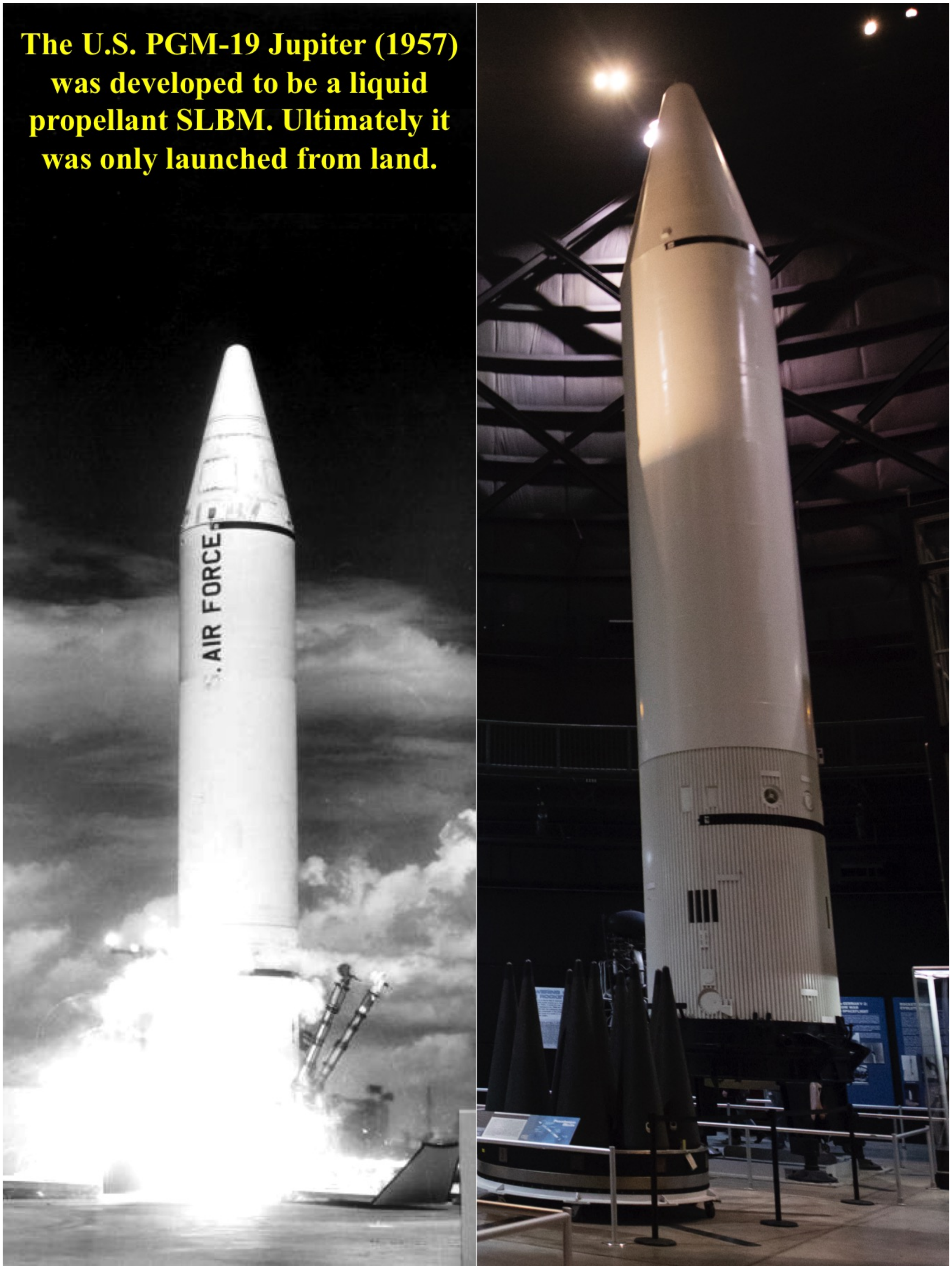

The U.S. PGM-19 Jupiter (1957) was developed to be a liquid propellant SLBM. Ultimately it was only launched from land.
S. AIR FORCE

Figure 9.196: The U.S. PGM-19 Jupiter, first launched in 1957, was developed to be a liquid propellant SLBM. Ultimately it was only launched from land.

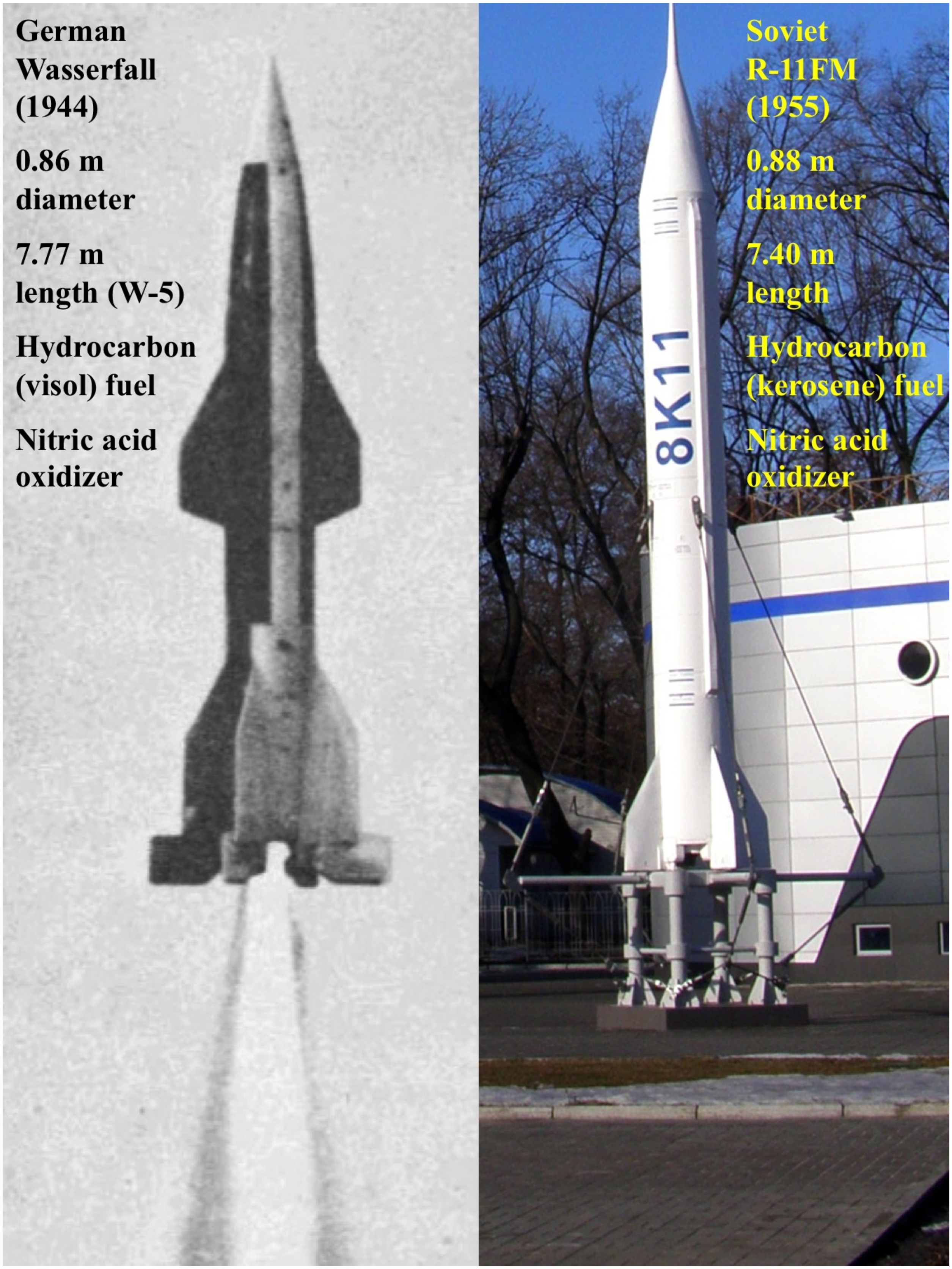
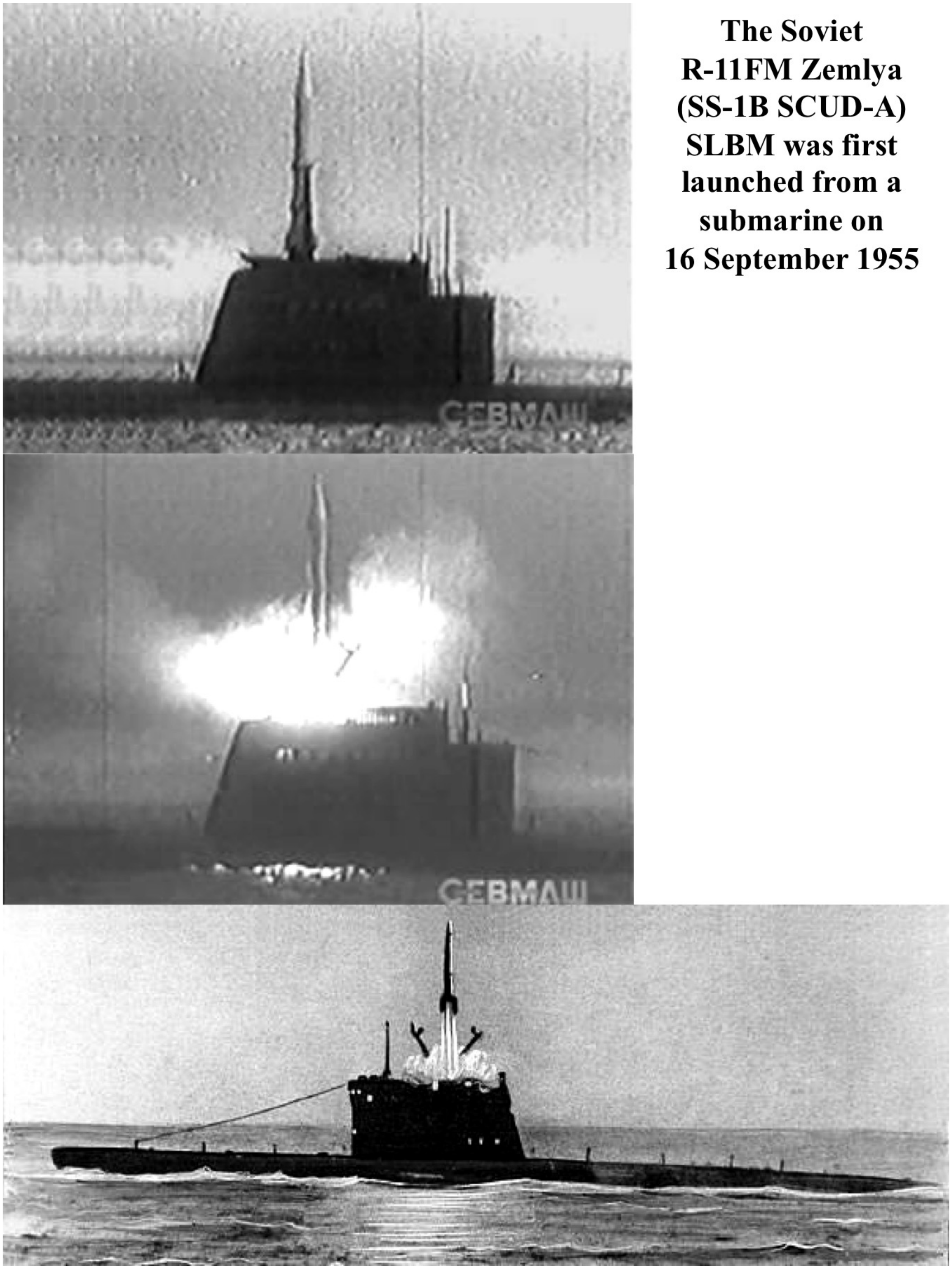

German Wasserfall (1944)
0.86 m diameter
7.77 m length (W-5)
Hydrocarbon (visol) fuel
Nitric acid oxidizer
Soviet R-11FM (1955)
0.88 m diameter
7.40 m length
Hydrocarbon (kerosene) fuel
Nitric acid oxidizer
8K11

Figure 9.197: The first Soviet SLBM, the R-11FM Zemlya (SS-1B SCUD-A, first launched in 1955), was directly based on the German Wasserfall (first launched in 1944). Like the Wasserfall, it used storable liquid propellants.



**The Soviet
R-11FM Zemlya
(SS-1B SCUD-A)
SLBM was first
launched from a
submarine on
16 September 1955**

Figure 9.198: The Soviet R-11FM Zemlya (SS-1B SCUD-A) SLBM was first launched from a submarine on 16 September 1955.

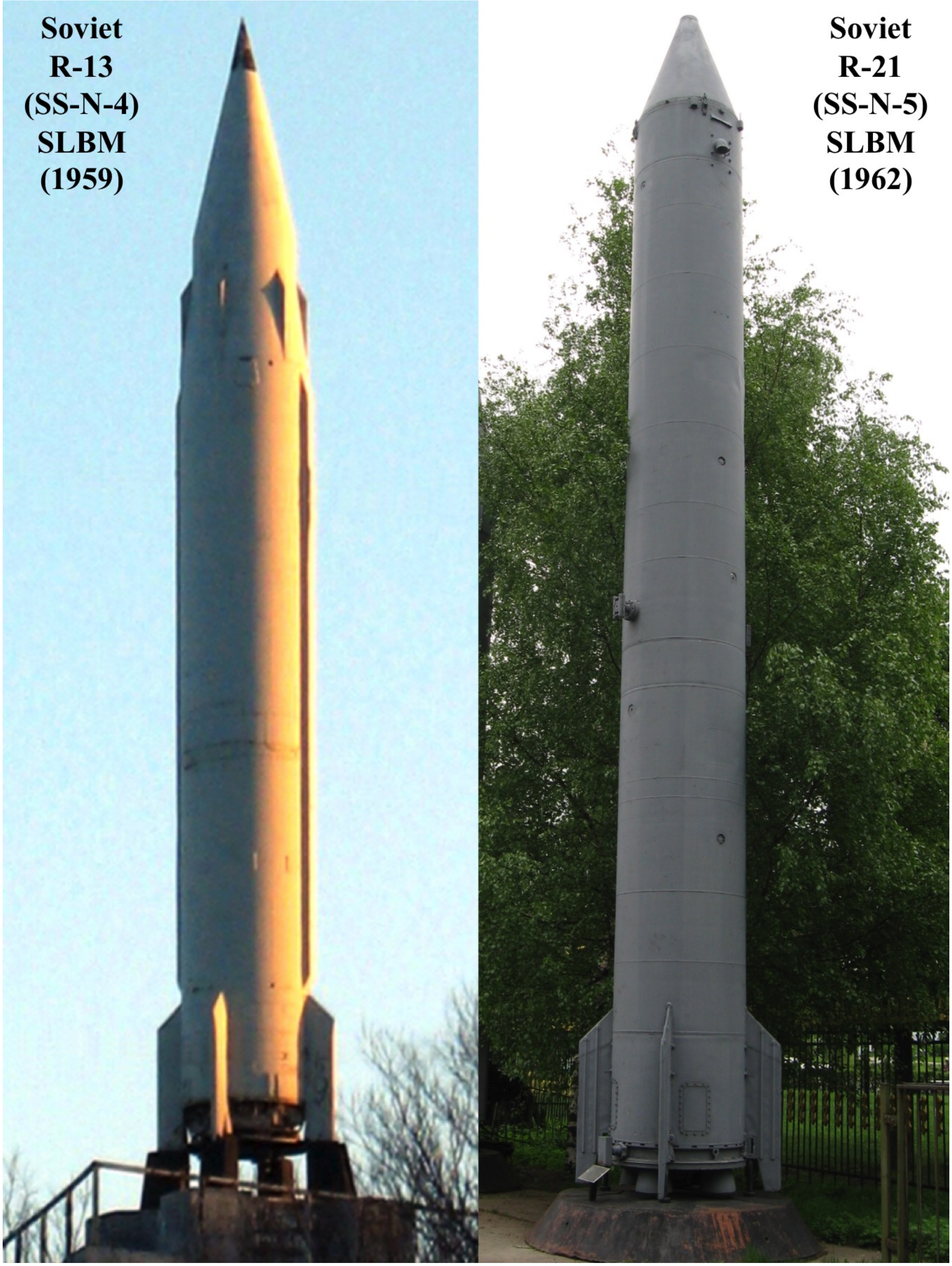

Soviet
R-13
(SS-N-4)
SLBM
(1959)
Soviet
R-21
(SS-N-5)
SLBM
(1962)

Figure 9.199: Later generations of Soviet SLBMs, such as the R-13 (SS-N-4, first launched in 1959) and R-21 (SS-N-5, first launched in 1962) were scaled up from the R-11FM and again were directly based on German-developed technologies and propellants.

9.8.2 Solid Propellant Rockets

German-speaking creators made huge contributions to large solid propellant rockets.[18] Although solid propellant rockets have lower exhaust velocities than liquid propellant rockets, they can generally be stored for years without degradation. Therefore, they are primarily used for military rockets and "off-the-shelf" boosters that can be strapped to the side of the first stage of a spacecraft launch vehicle. For submarine-launched rockets, where it is necessary to be able to store the rockets stably and safely for years and yet fire them on very short notice, solid propellants are highly preferable to liquid propellants.

Most large solid propellant rockets typically contain a mixture of:[19]

- $\sim$ 70% (by mass) powdered crystalline oxidizer, usually ammonium perchlorate but sometimes potassium perchlorate, ammonium nitrate, potassium nitrate, cyclotrimethylene trinitramine (RDX), or cyclotetramethylene tetranitramine (HMX).
- $\sim$ 15% powdered metal fuel, usually aluminum but sometimes magnesium, zinc, or zirconium.
- $\sim$ 15% binder, a polymer that both holds the powdered oxidizer and metal fuel in place (while withstanding high thermal and mechanical stresses) and also serves as additional fuel that can react with the oxidizer. Binders are usually derivatives of polybutadiene (buna synthetic rubber), polyurethane, polyalkylene, or polyvinyl chloride.
- $\sim$ 1% or less of other ingredients that may act as curing agents (to cross-link the polymer binder), plasticizers (to make the propellant more flexible and therefore less likely to crack), stabilizers (to slow chemical degradation of the propellant during years of storage), etc.

Instead of the above propellant mixture, missiles that must minimize their smoke (e.g., so it is harder to see them coming) tend to use double-base propellants such as a mixture of nitroglycerin and nitrocellulose.

As shown in Fig. 9.200, solid propellant burns along its exposed surfaces, releasing hot exhaust gases through the nozzle until the propellant is used up or the thrust termination port is opened. An igniter (not shown) initiates the combustion. For all practical purposes, solid propellant rockets cannot be shut down and restarted later, unlike liquid propellant rockets.

The exposed surfaces in a solid propellant rocket may be molded into different patterns or propellant grain designs (Fig. 9.200). Progressive solid propellant grain designs have cross-sectional patterns of exposed surfaces (e.g., tubular or perforated) such that the exposed surface area and hence the thrust increase as the rocket burns. Neutral grain designs (e.g., rod and tube or star) have approximately the same exposed surface area and thrust during most of their burn time. Regressive grain designs (e.g., slotted or double anchor) have a decreasing exposed surface area and thrust as the rocket burns. For more complicated thrust profiles, solid propellant rockets may even change the grain design along the length of the rocket, or use different solid propellants that are exposed at different times during the engine burn.

---

[18] Benecke and Quick 1957; Christopher 2013; Hahn 1998; Nagel 2011, 2012a; BIOS 27; BIOS 31; BIOS 100; BIOS 571; BIOS 1261; NavTecMisEu 327-45.

[19] [Brooks 1972; Scortia and Cutforth 1971; Hill and Peterson 1991; George Sutton 1992.

Like liquid propellant rockets, solid rockets may be steered by any of several mechanisms during their burn, including tilting the nozzle (if it is connected to the propellant case by a flexible yet heat-resistant seal or joint), injecting fluid into one side of the exhaust to divert the rest of the hot exhaust gas, or moving heat-resistant rudders or vanes that protrude into the exhaust stream.

During World War II, a number of nearly forgotten German-speaking chemists and engineers, such as those shown in Figs. 9.201–9.205, successfully developed and demonstrated advanced solid propellant rockets, including for example:

- The Rochen ammonium perchlorate/polybutadiene short-range missile, first fired in 1944 (Fig. 9.206).
- The Rheintochter two-stage surface-to-air missile, first launched in 1943 (Fig. 9.207).
- The Rheinbote four-stage long-range rocket, first launched in 1943 (Fig. 9.208).
- The V-101, an ammonium perchlorate/polybutadiene propelled, 140-ton, 30-meter-tall, long-range ballistic missile that was under development when the war ended (Fig. 9.209).

Key German innovations of that solid propellant rocket technology included:

1. Ammonium perchlorate oxidizer [BIOS 31; BIOS 571].
2. Polybutadiene “buna” synthetic rubber in the propellant to act as both fuel and binder [BIOS 31; BIOS 571].
3. Plasticizers to enable the propellant to be molded into any desired shape, to adhere tightly to metal walls, and not to be prone to crumbling or brittleness [BIOS 31; BIOS 571].
4. Powdered aluminum as a fuel additive to improve performance [BIOS 27; BIOS 31; BIOS 100; BIOS 477; BIOS 1261; FIAT 1035; HEC 2434; HEC 2485; HEC 2487; NavTecMisEu 327-45].
5. Various grain designs for the combustion surface inside the propellant to give the desired variation of thrust with time [Benecke and Quick 1957, pp. 253–255; Klein 1977; BIOS 31; BIOS 1110; NavTecMisEu 327-45].

As illustrated in Figs. 9.210–9.212, this wartime German technology became the basis for large postwar solid propellant rockets, including satellite launch vehicles such as the U.S. Scout; strap-on solid rocket boosters such as those used with the U.S. Space Shuttle, Titan, and Delta rockets; submarine-launched ballistic missiles such as the U.S. Polaris, Poseidon, and Trident; and solid propellant land-based ballistic missiles such as the U.S. Minuteman and MX.

Although aerospace historian J.D. Hunley focused mainly on the work of American engineers, he could not avoid discussing the important contributions of Karl Klager (Austrian, 1908–2002) to the development of large solid-propellant rockets in the United States after the war [Hunley 1999]:

> Integral to the stories of the propellants used on large rockets and missiles, smaller tactical missiles, and a host of smaller rockets for a variety of rockets and spacecraft were the various binders, fuels, and oxidizers that went into the propellants. For example, the motors for the Polaris A1 missile designed by Aerojet featured a cast, case-bonded polyether-polyester-polyurethane composition with 15 percent aluminum and ammonium perchlorate. Karl Klager at Aerojet has been credited with being largely responsible for developing both the grain and the propellant for these motors, but the story of their development is evidently quite complex. Klager received the U. S. Navy Distinguished Public Services Award in 1958 for his work on the Polaris missile, but the development of some of the propellant ingredients predates when Klager joined Aerojet in 1950. [...]
>
> Karl Klager, who is credited with the development of HTPB [hydroxyl-terminated polybutadiene], was asked how he came to develop this low-cost, low-viscosity propellant that has become an industry standard. He said only that he started development in 1961 but waited until 1969 to propose the propellant to NASA for the Astrobee D and Astrobee F sounding rockets on which it flew successfully. Perhaps, however, Klager's response regarding how he came to discover unsymmetrical dimethylhydrazine (UDMH) (which is a liquid propellant used on the Bomarc missile, Titan 2 missile, Titan 3 and Titan 4 rockets, and other missiles and rockets) applies equally to HTPB. Klager said that he simply brought his knowledge of the science of chemistry to bear on the need for a propellant. He had earned a Ph.D. in chemistry from the University of Vienna in 1934 and had worked for several chemical firms in Europe from 1931 to 1948 before moving to the United States and starting work for Aerojet in 1950.

The journalist David Beers, who grew up surrounded by the research of his father and his father's coworkers at Lockheed, singled out the importance of Wolfgang Noeggerath for the Polaris solid-propellant missile [Beers 1996, pp. 38–39]:

> "The most beautiful missiles ever fired," a U.S. Navy Rear Admiral pronounced the nuclear-tipped A1X Polaris, having witnessed its successful submarine test on a summer day in 1960. The fully evolved, deployed Polaris, designed under the guidance of Wernher von Braun's friend and fellow former Nazi, Wolfgang Noeggerath, was capable of traveling 2,400 nautical miles in a few minutes and delivering, from its elusively mobile launchpad, three separate warheads to a single target deep within the Soviet Union—facts no doubt beautiful to a nuclear warfare strategist.

The *Baltimore Sun* reported the death of Werner Hohenner (1907–2000) another German scientist who played an important role in the development of the Polaris missile [*Baltimore Sun* 2000-11-29]:

> From 1947 until 1954, Mr. Hohenner was at the Point Mugu Naval Air Weapon Station in California, working in the Naval Ballistic Program that led to the development of the Polaris missile, the first U.S. submarine-launched ballistic missile.
>
> During the rocket's development, Mr. Hohenner prevailed over Mr. von Braun, who insisted that the rocket be fueled by liquid rather than solid fuel.

> "He brought a great knowledge ... in fuel handling, and convinced the Navy that if they followed von Braun's plan to use liquid fuel, which is dangerous, they could plan on losing a sub a year in accidents," said Robert L. Frohmuth, a retired Navy electrical engineer. "It was a breakthrough, and he was the one who got solid fuel missiles started, which are still being used today."
>
> "His greatest achievement was the development of the Polaris," said Mr. Schmitz.
>
> From 1957 until retiring in 1973, Mr. Hohenner was chief scientist at the air arm division at the Westinghouse plant in Linthicum, where he continued his work on weapon systems and ballistic missiles.

Grayson Merrill, a retired Navy Captain, also emphasized the central role of German-speaking scientists in the missile programs [Merrill 2003]:

> Shortly after this I was detailed to witness some V-2 firings at Cuxhaven staged by the British and executed by Germans from Peenemunde. It reinforced, in my mind, the correctness of choosing Point Mugu. After the firings a small group of American observers gathered in a Bremen rathskeller to quaff beer and discuss what we had seen. A rumpled fake Army Colonel named Theodore von Kármán summed up our feelings, "You young fellows must now go home and arrange to put these Germans to work. In the meantime build a test range for the missiles to come."
>
> Almost 20 years later it can be said that Point Mugu has borne out the committee's judgments. [...]
>
> Many of the LOON technical successes are traceable to the "German Scientists" who migrated to Point Mugu. These included Willy Fiedler, Robert Lusser and Otto Schwede. But Dr. Herbert A. Wagner, now deceased, deserves special mention. [...]
>
> I left in 1949 but nevertheless watched with pride as the range expanded in support of such missiles as LARK, SPARROW, REGULUS, RIGEL, POLARIS and TOMAHAWK.

Rolf Engel, Uwe Bödewadt, and Hermann Teichmann (all of whom developed and demonstrated ammonium perchlorate/polybutadiene solid rocket propellants during the war) all went to work for France after the war (p. 1883). Information on their postwar contributions is not publicly available, but presumably they were instrumental in developing modern solid-propellant missiles and rockets in France, and they may have made important contributions in other areas as well.

For much more detailed information on the contributions of German-speaking scientists and engineers to the development of large solid propellant rockets, see Section E.4.

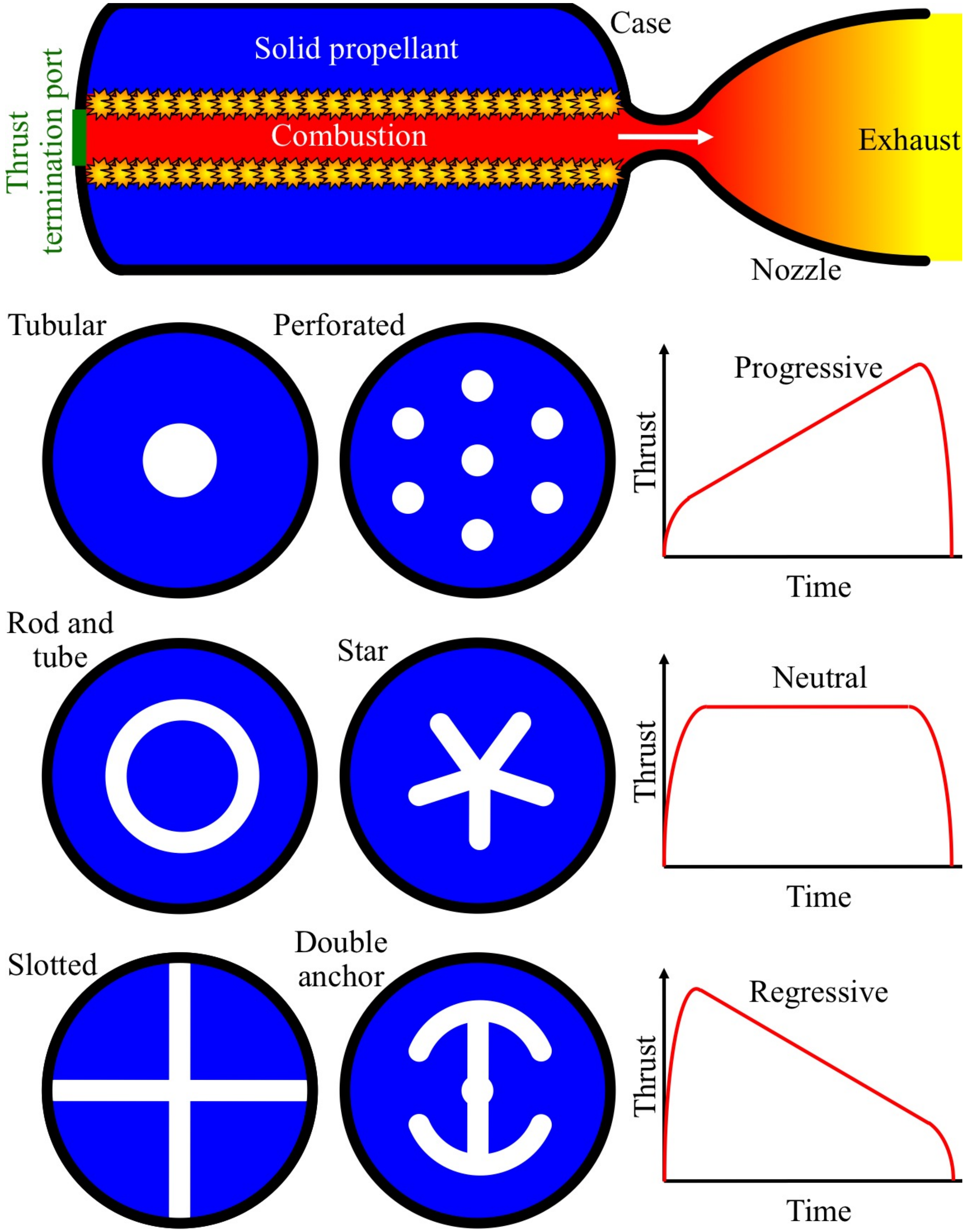

Case
Solid propellant
Thrust termination port
Combustion
Exhaust
Nozzle
Tubular
Perforated
Progressive
Thrust
Time
Rod and tube
Star
Neutral
Thrust
Time
Slotted
Double anchor
Regressive
Thrust
Time

Figure 9.200: In a solid propellant rocket, the propellant burns along its exposed surfaces, releasing hot exhaust gases through the nozzle unless the thrust termination port is opened. Different solid propellant grain designs have different cross-sectional patterns of exposed surfaces such that the exposed surface area and hence the thrust changes in some desired way (increasing, remaining constant, or decreasing) as the rocket burns.

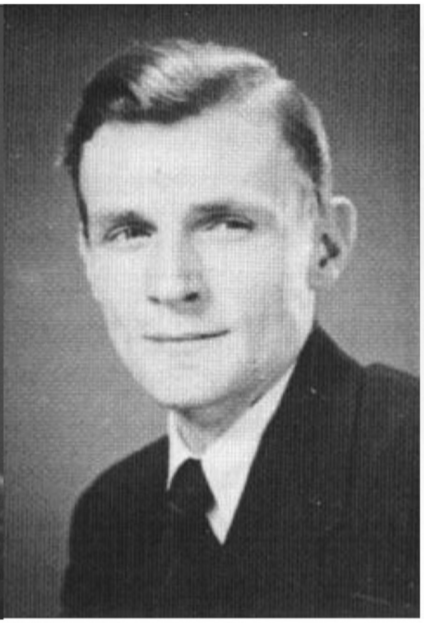
Uwe Bödewadt
(1911–2003)

Gerhard Braun
(19??–19??)

Rudolf Buschmann
(19??–19??)

Rudolf Edse
(1913–1998)

Rolf Engel
(1912–1993)



Willy Fiedler
(1908–1998)

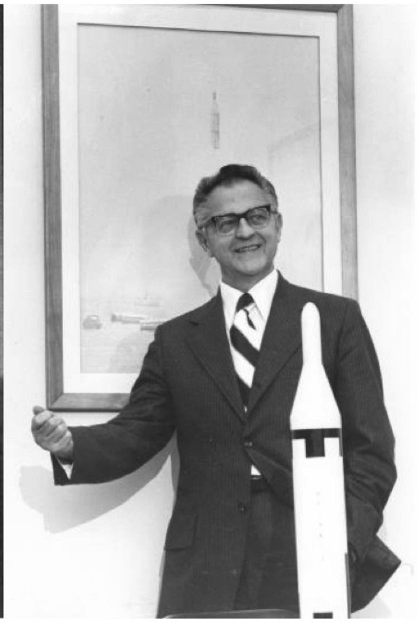
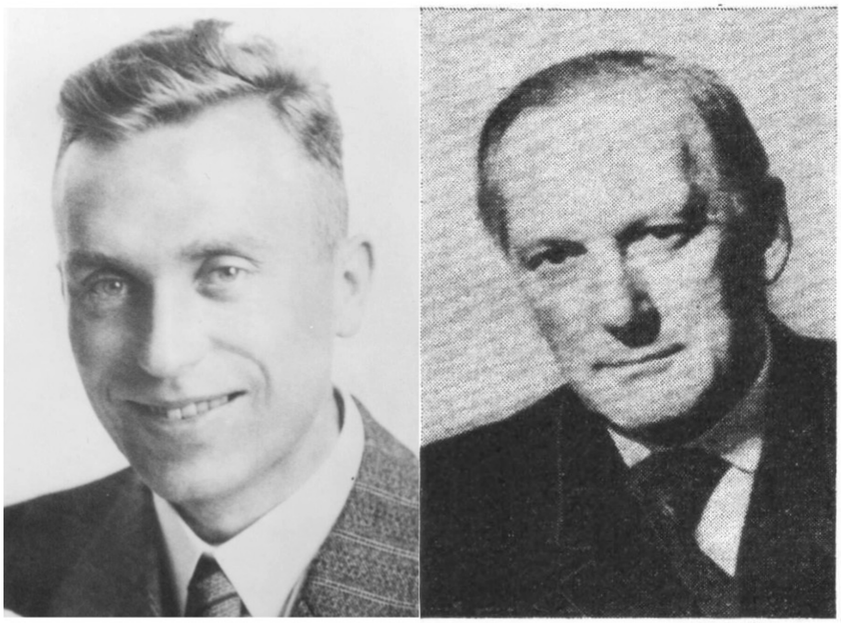


Figure 9.201: Some German-speaking creators of large solid propellant rockets.

Heinz-Otto Glimm
(1911–1945)

Erich Habann
(1892–1968)

Werner Hohenner
(1907–2000)



Erich von Holt
(19??–19??)

Franz Kalscheuer
(1913–2002)

Karl Klager
(1908–2002)

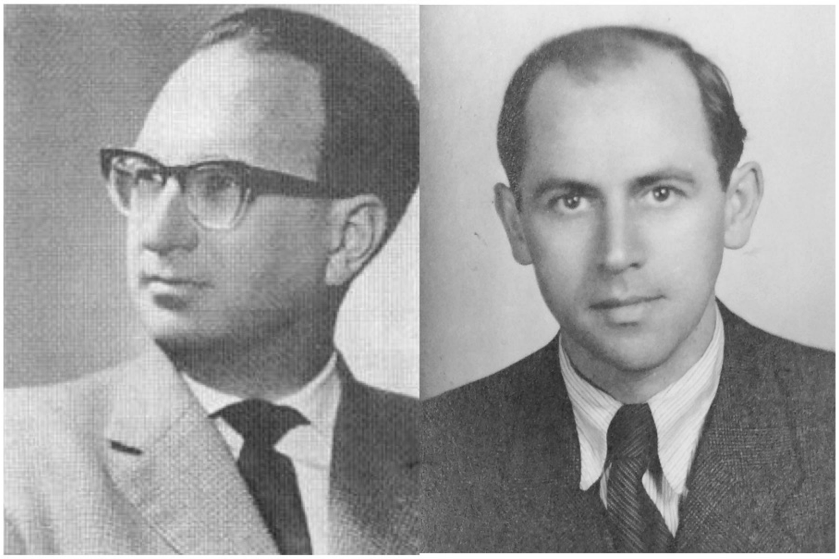


Figure 9.202: More German-speaking creators of large solid propellant rockets.

Heinrich Klein
(19??–19??)

Ernst Knust
(19??–19??)

Heinz Langweiler
(19??–19??)

?? Moßmann
(19??–19??)

Helmut Müller
(19??–19??)

Wolfgang Noeggerath
(1908–1973)

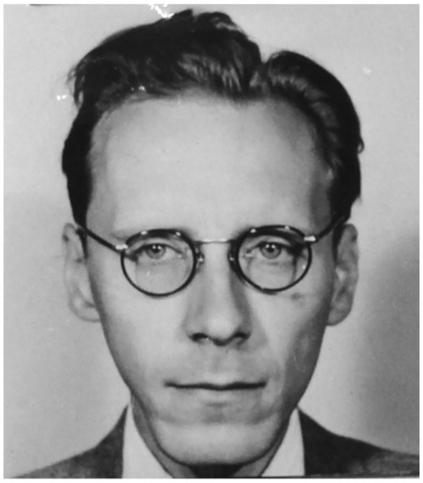


Figure 9.203: More German-speaking creators of large solid propellant rockets.

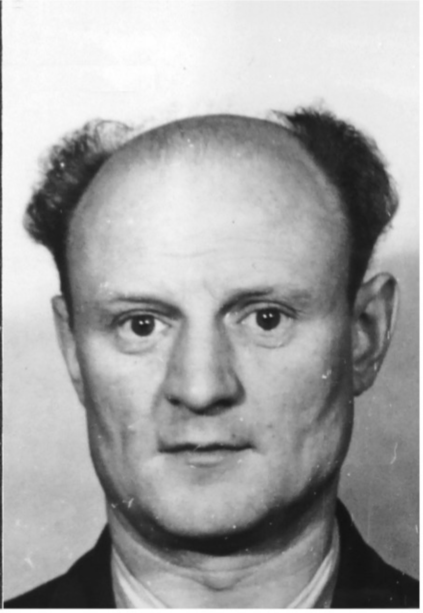
Alfred Nordt
(19??–19??)

Adolf Oberth
(1928–2007)

Wilhelm Orthmann
(1901–1945)

Otto Poppenberg
(1876–1956)

Arthur Rudolph
(1906–1996)



Martin Schilling
(1911–2000)

Figure 9.204: More German-speaking creators of large solid propellant rockets.

Gustav Schweikert
(1890–19??)

Hermann Teichmann
(1913–1976)

Richard Tilling
(1890–1960)

Hermann Vüllers
(19??–19??)

Albert Wolff
(19??–19??)

Wilhelm Zeyss
(1908–20??)

Figure 9.205: More German-speaking creators of large solid propellant rockets.

Rochen short-range missile,
first demonstrated in 1944

(sketch of an early design)

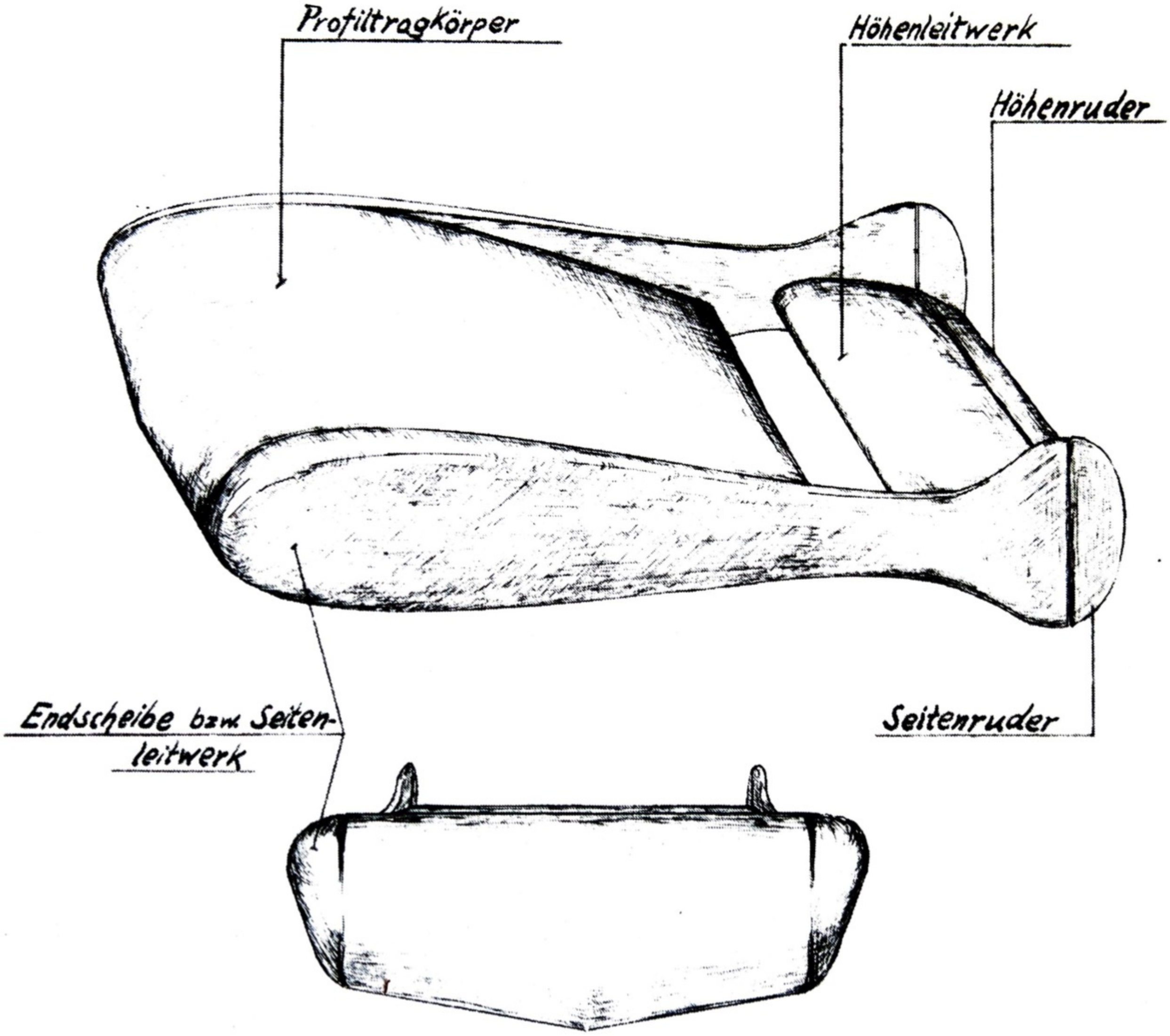

Profiltragkörper
Höhenleitwerk
Höhenruder
Endscheibe bzw. Seiten-
leitwerk
Seitenruder

Figure 9.206: The Rochen short-range missile (first fired in 1944) successfully demonstrated ammonium perchlorate/polybutadiene solid rocket propellant.

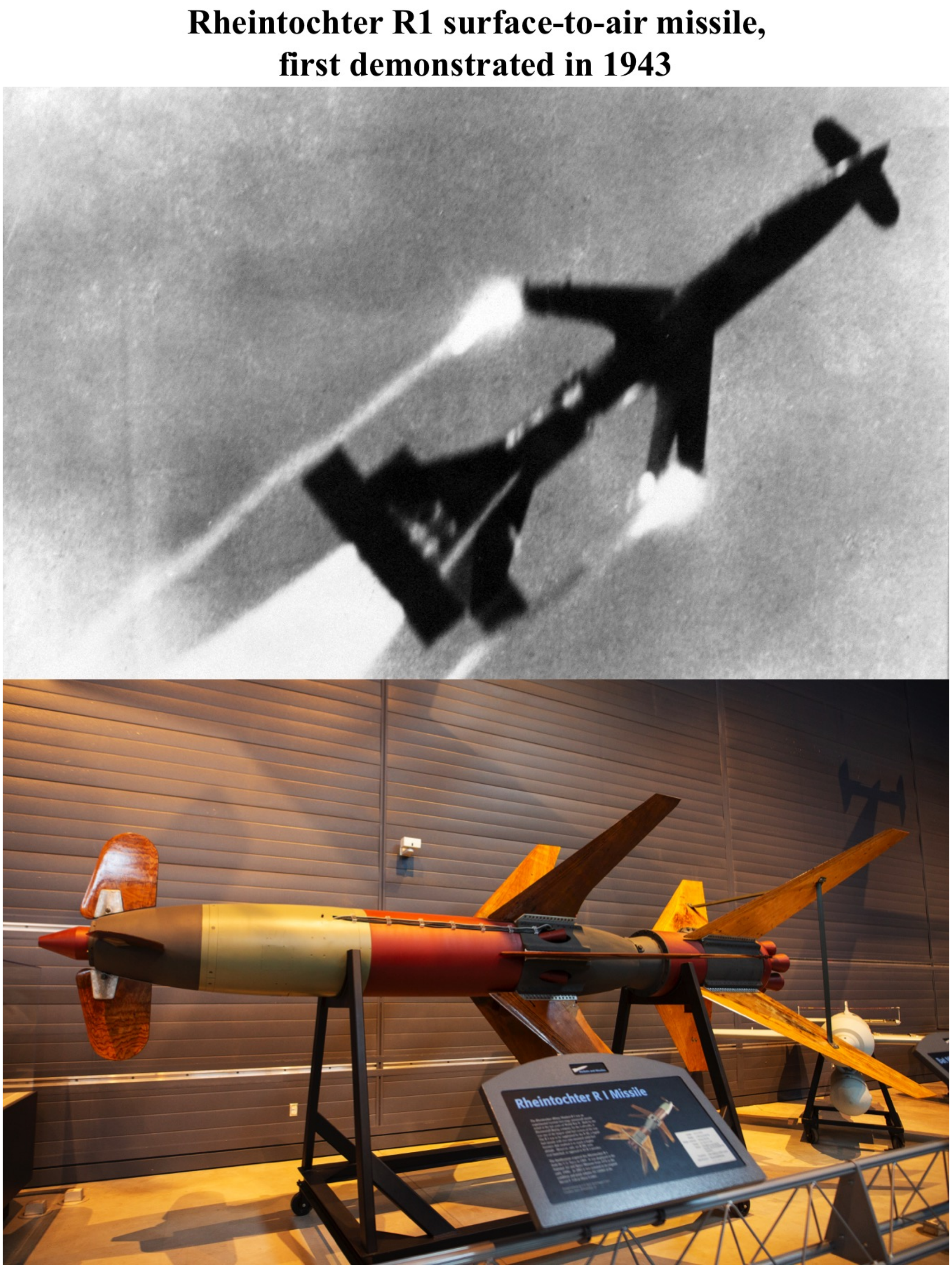

Rheintochter R1 surface-to-air missile,
first demonstrated in 1943
Rheintochter R I Missile

Figure 9.207: Heinrich Klein led the Rheinmetall-Borsig team that created the Rheintochter solid propellant, two-stage, surface-to-air missile, which was first launched in 1943.

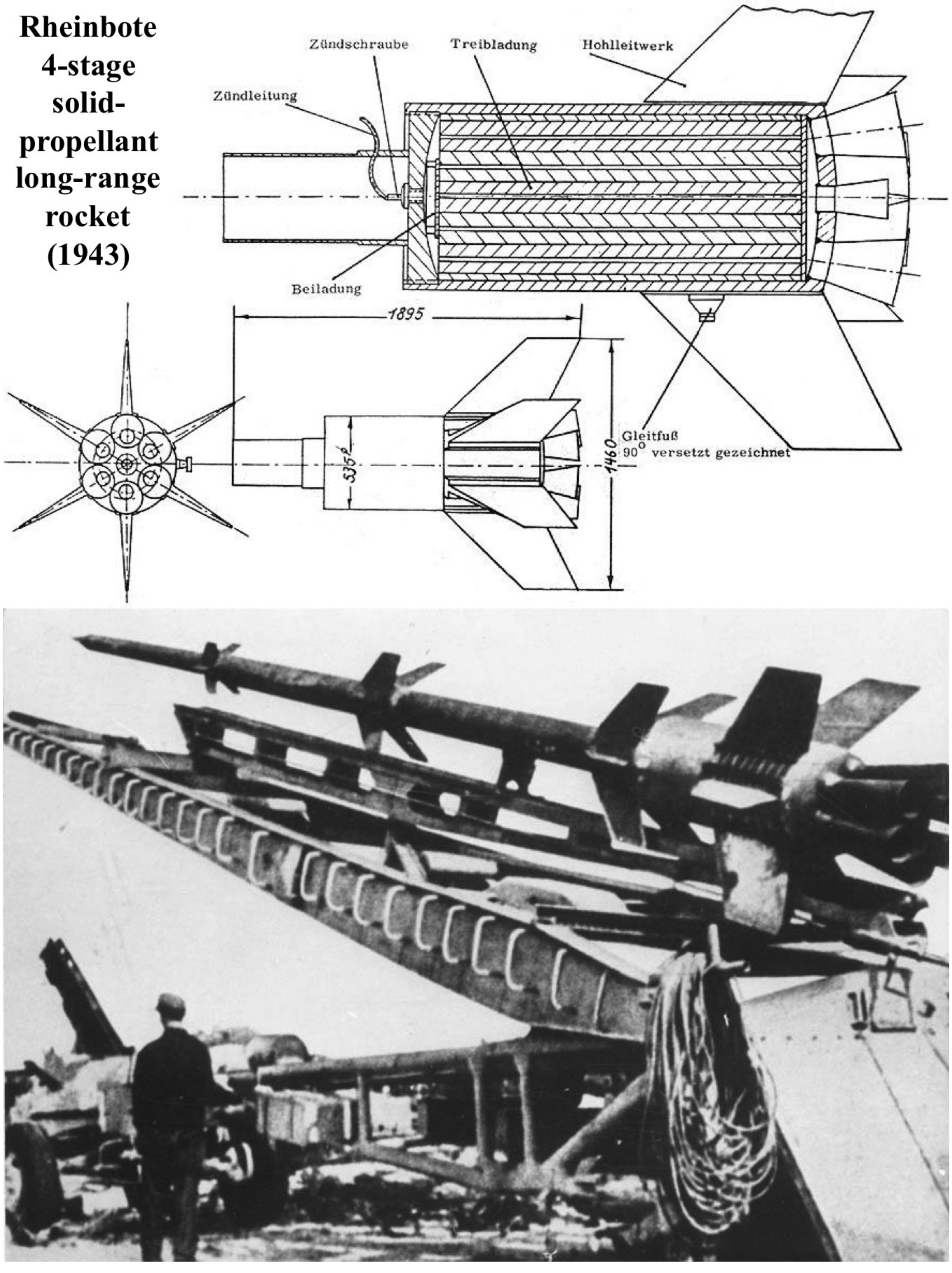
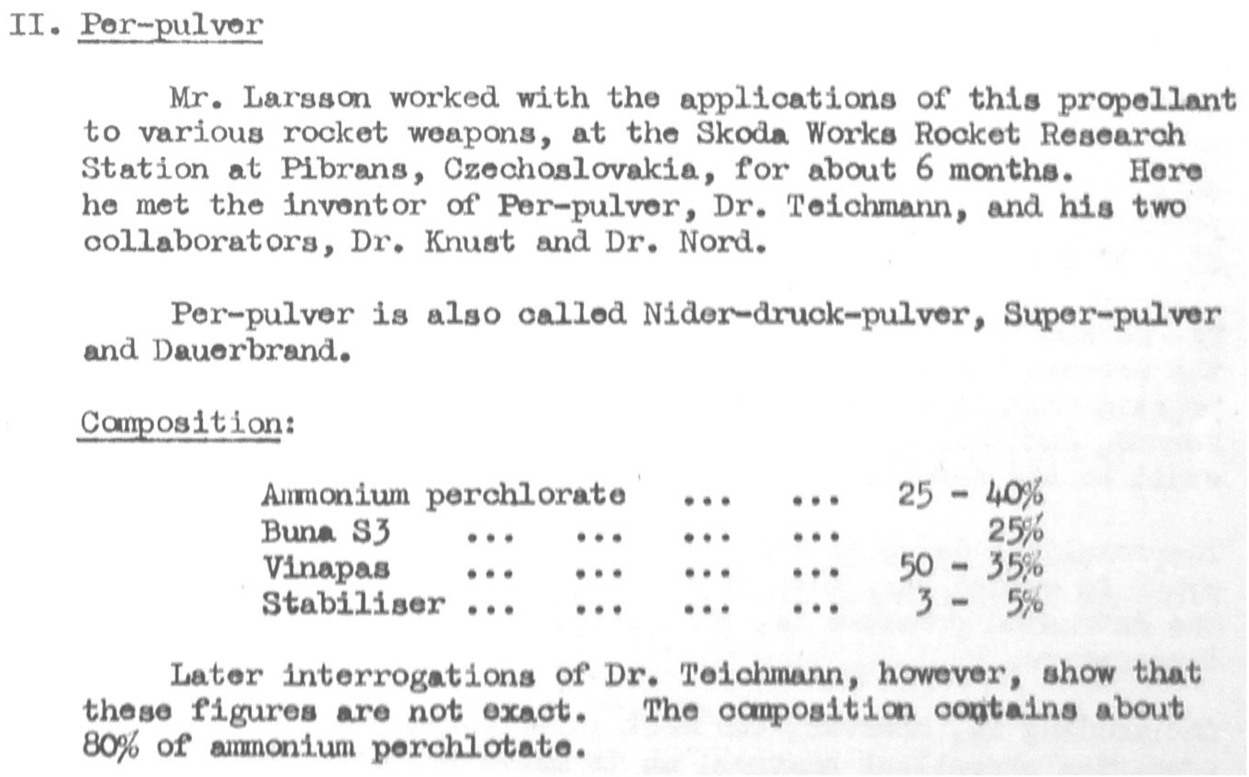

Rheinbote
4-stage
solid-
propellant
long-range
rocket
(1943)
Zündschraube
Treibladung
Hohlleitwerk
Zündleitung
Beiladung
1895
535⌀
1460
Gleitfuß
90° versetzt gezeichnet

Figure 9.208: Heinrich Klein and his Rheinmetall-Borsig team also created the Rheinbote solid propellant, four-stage, long-range rocket, which was first launched in 1943.



II. Per-pulver

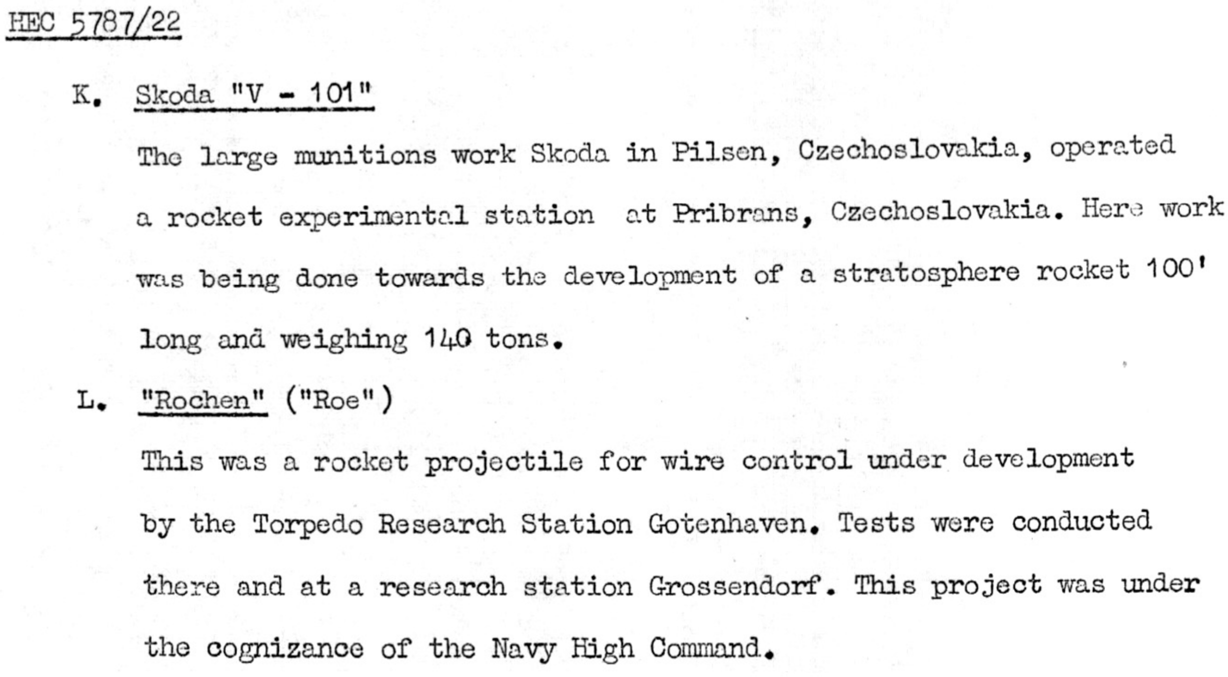
Mr. Larsson worked with the applications of this propellant to various rocket weapons, at the Skoda Works Rocket Research Station at Pibrans, Czechoslovakia, for about 6 months. Here he met the inventor of Per-pulver, Dr. Teichmann, and his two collaborators, Dr. Knust and Dr. Nord.

Per-pulver is also called Nider-druck-pulver, Super-pulver and Dauerbrand.

Composition:

Ammonium perchlorate	25 - 40%
Buna S3	25%
Vinapas	50 - 35%
Stabiliser	3 - 5%

Later interrogations of Dr. Teichmann, however, show that these figures are not exact. The composition contains about 80% of ammonium perchlotate.



HEC 5787/22

K. Skoda "V - 101"

The large munitions work Skoda in Pilsen, Czechoslovakia, operated a rocket experimental station at Pribrans, Czechoslovakia. Here work was being done towards the development of a stratosphere rocket 100' long and weighing 140 tons.

L. "Rochen" ("Roe")

This was a rocket projectile for wire control under development by the Torpedo Research Station Gotenhaven. Tests were conducted there and at a research station Grossendorf. This project was under the cognizance of the Navy High Command.

Figure 9.209: Hermann Teichmann and his collaborators invented and optimized ammonium perchlorate/polybutadiene solid rocket propellants, successfully demonstrated them in the Rochen short-range missile, and were using those propellants to develop a 140-ton, 30-meter-tall, long-range ballistic missile, the Skoda V-101, when the war ended [top: BIOS 571; bottom: HEC 5787].

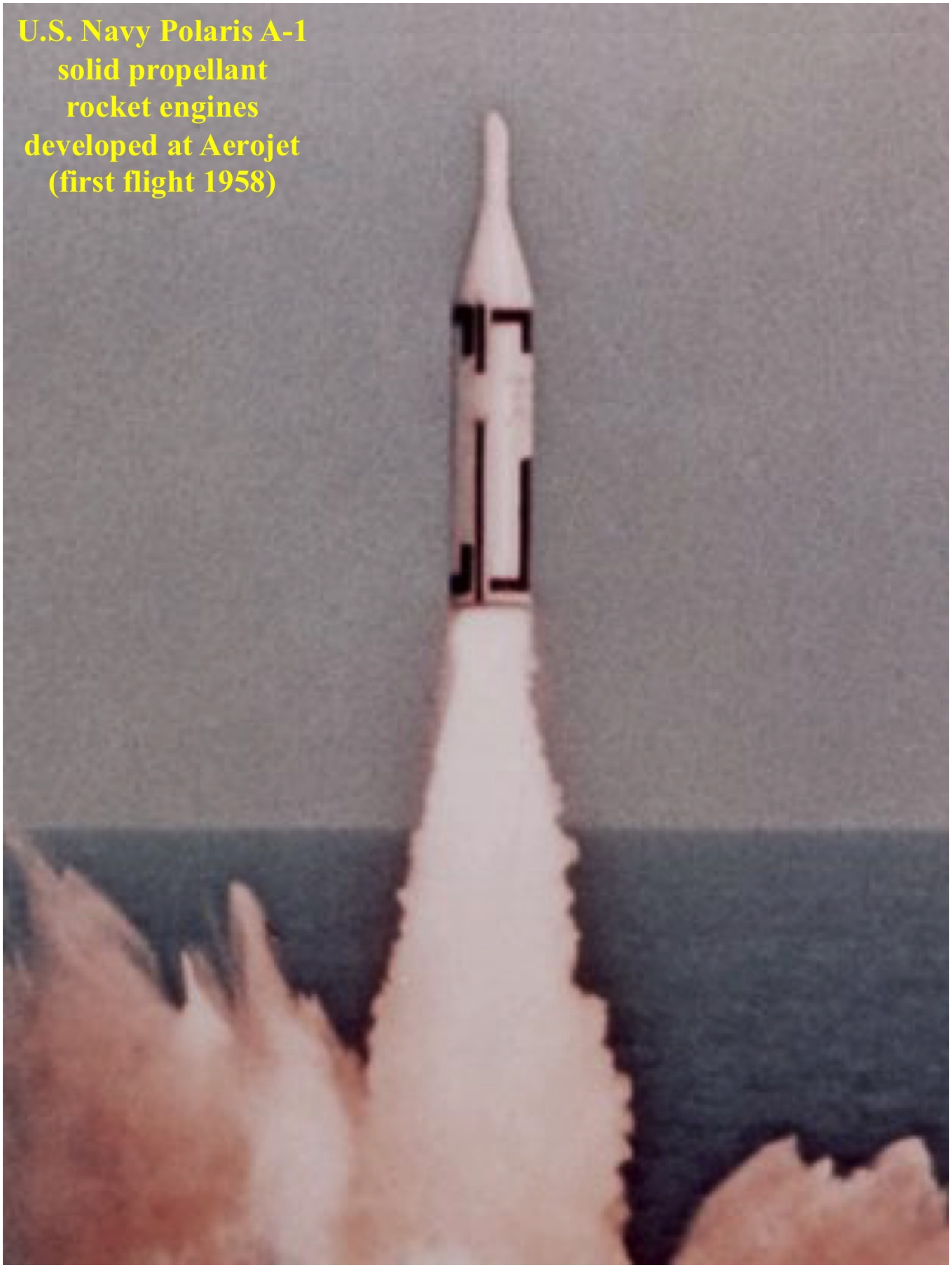

U.S. Navy Polaris A-1
solid propellant
rocket engines
developed at Aerojet
(first flight 1958)

Figure 9.210: German-speaking scientists played major roles in the development of postwar large solid propellant rockets such as the Polaris missiles.

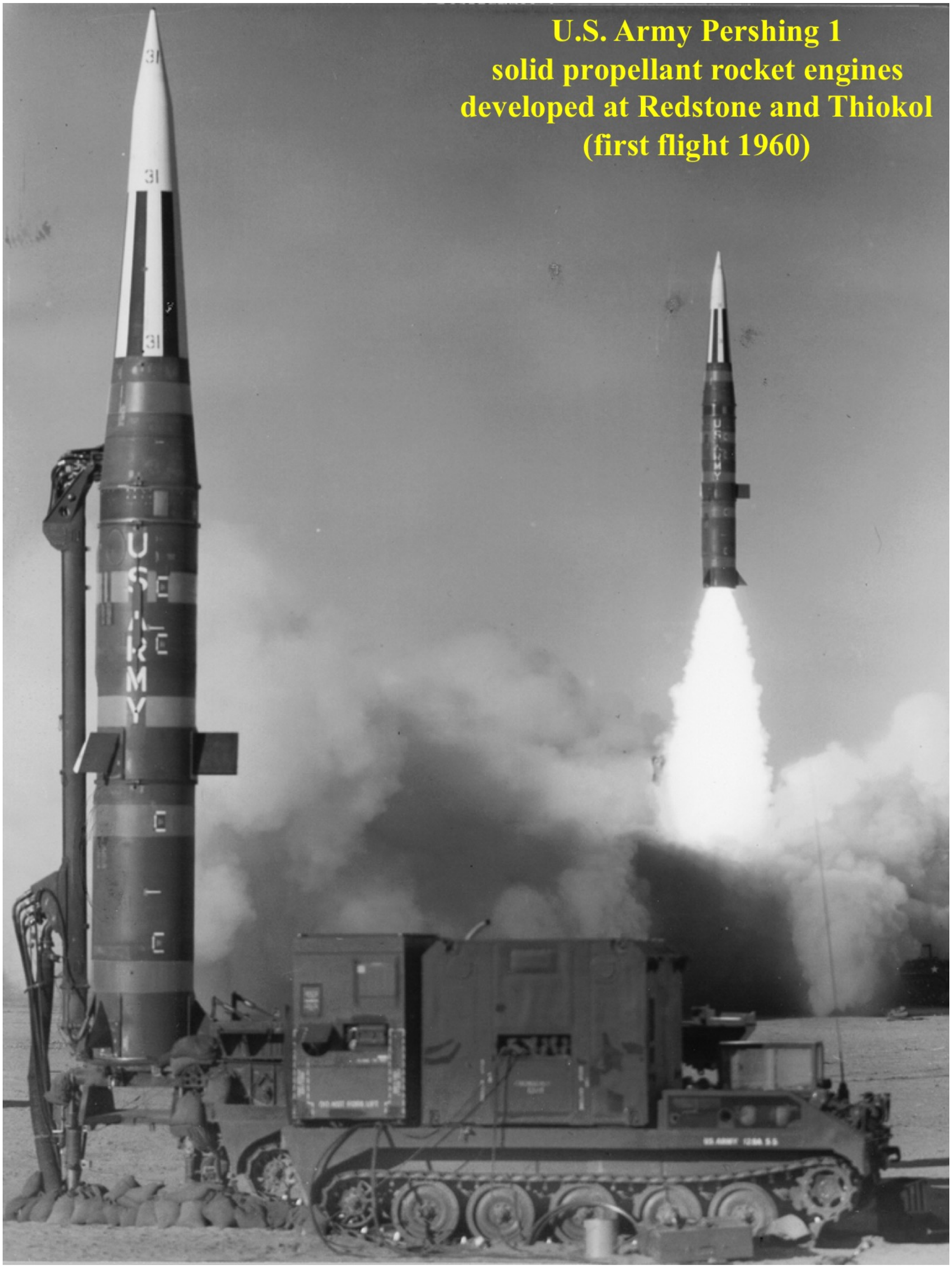

U.S. Army Pershing 1
solid propellant rocket engines
developed at Redstone and Thiokol
(first flight 1960)
U.S. ARMY
31

Figure 9.211: German-speaking scientists played major roles in the development of postwar large solid propellant rockets such as the Pershing missiles.

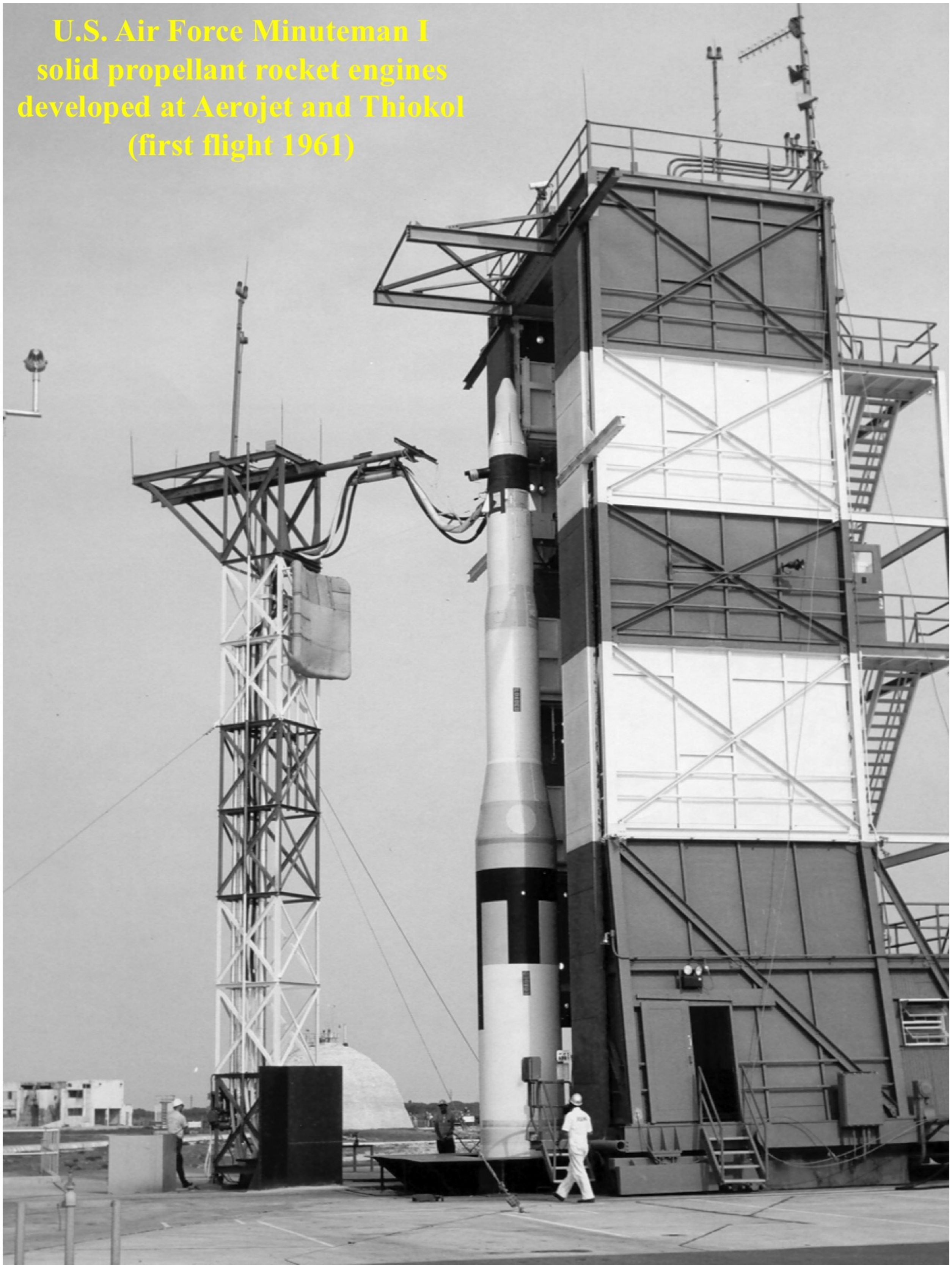

U.S. Air Force Minuteman I
solid propellant rocket engines
developed at Aerojet and Thiokol
(first flight 1961)

Figure 9.212: German-speaking scientists played major roles in the development of postwar large solid propellant rockets such as the Minuteman missiles.

9.9 Rocket Planes and Space Planes

German-speaking creators also led the way in the development of rocket planes (Section 9.9.1) and space planes (Section 9.9.2), from the first rocket plane in 1928 to the U.S. Space Shuttle.[20]

9.9.1 Rocket Planes

German-speaking scientists and engineers designed and tested numerous rocket planes from the 1920s to 1945:[21]

- Alexander Lippisch (German, 1894–1976) designed the first rocket plane, the Lippisch Ente, which was powered by two solid propellant rockets and test flown in 1928. See Fig. 9.213.
- In 1929, Fritz von Opel (German, 1899–1971) funded and piloted the second rocket plane. The Opel RAK.1 was designed and built by Julius Hatry (German, 1906–2000), with solid propellant rockets by Friedrich Sander (German, 1885–1938). See Fig. 9.213.
- In the late 1930s, engineers under Ernst Heinkel began developing and testing rocket planes using liquid propellant rocket engines, provided first by Wernher von Braun and then by Hellmuth Walter (German, 1900–1980). The culmination of that work was the Heinkel He 176, which was successfully test flown in 1939, powered by a Walter rocket engine. See Fig. 9.214.
- Shortly after that, Hellmuth Walter produced the liquid rocket engine, and Alexander Lippisch and Friedrich Otto Ringleb (German, 1900–1966) created the aircraft, for the Messerschmitt Me 163 Komet (Comet) rocket plane, the best-known German rocket plane. The Me 163 was first demonstrated in 1941, and several hundred were produced by the end of the war; see Figs. 9.215–9.216.
- In 1944, Erich Bachem (German, 1906–1960) designed the Bachem Ba 349 Natter rocket plane for vertical take-off. Several dozen were built, but they were still undergoing testing at the end of the war. See Fig. 9.217.
- Felix Kracht (German, 1912–2002) created the DFS (Deutsche Forschungsanstalt für Segelflug) 228, which was designed to be launched from a Dornier Do 217 bomber, then use a Walter rocket to climb to an altitude of up to 25 km. Two prototypes were built in 1944 but were still being tested at the end of the war. Nonetheless, the DFS 228 designs that were captured by the Allies appear to have had an enormous influence on the design of the postwar U.S. U-2 high-altitude spy plane. See Fig. 9.218.

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[20] Chertok 2005–2012, Vol. 1, pp. 262–265; Robert Godwin 2003, pp. 38–51; Myhra 2002; Putt 1946b; R. Dale Reed 1997, pp. 129–130, 136; Eugen Sänger and Bredt 1944; Hartmut Sänger 2006; Frank Winter 1990; NYT 1986-11-05.

[21] Dressel and Griehl 1995; Lommel 2002; Miller 2001; Myhra 2000b; Ranson and Cammann 2003; Späte 1983; CIOS XXVII-67, XXX-81.

- Kracht also created the DFS 346, which was again designed to be launched from a Do 217 bomber but would then have used its streamlined design and its Walter rocket engine to break the sound barrier. A prototype was constructed but not tested before the end of the war. Captured designs for the DFS 346 appear to have had a tremendous influence on the designs for the Bell X-1 and X-1A through X-1E rocket planes that were built and tested in the U.S. after the war. See Fig. 9.218.

- Alexander Lippisch designed and built the DM-1 rocket plane in 1944, and continued to work on the prototype until spring 1945. It was designed for flight at several times the speed of sound, although a suitable propulsion system was not installed before the war ended. (Lippisch considered various propulsion systems, including Walter liquid rocket engines and a ramjet.) Among other influences it exerted, the DM-1 may be regarded as a direct forerunner of lifting bodies that the United States began testing in the 1960s. See Fig. 9.219.

After the war, Lippisch moved to the United States, where he developed a wide range of aerospace technologies at the White Sands Missile Range, Convair, Collins Radio, and his own Lippisch Research Corporation. Walter developed submarines and other technologies in the United Kingdom, United States, and West Germany. Felix Kracht worked on many aerospace projects in France and West Germany, eventually finishing his career as the Senior Vice President of Airbus.

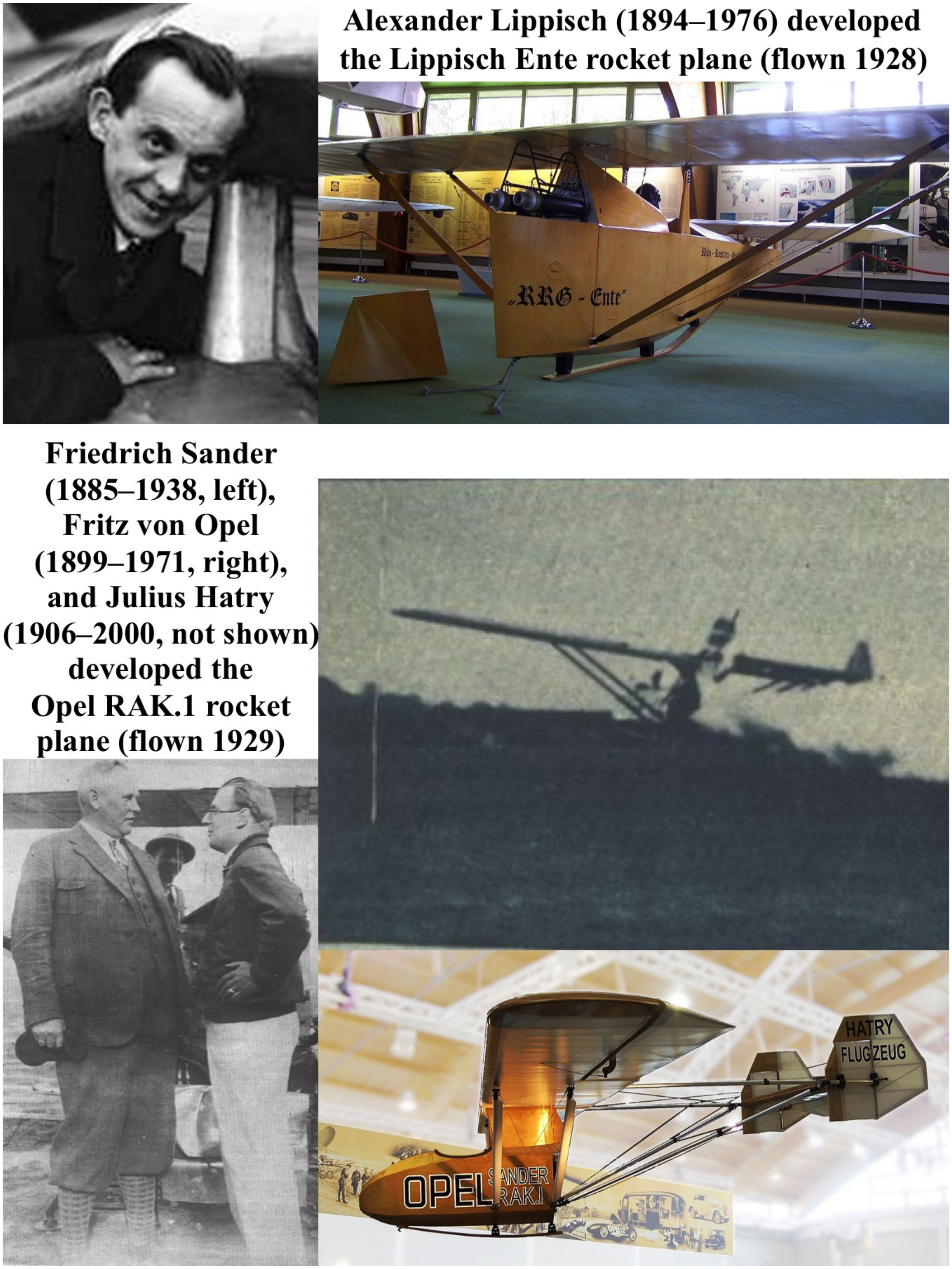
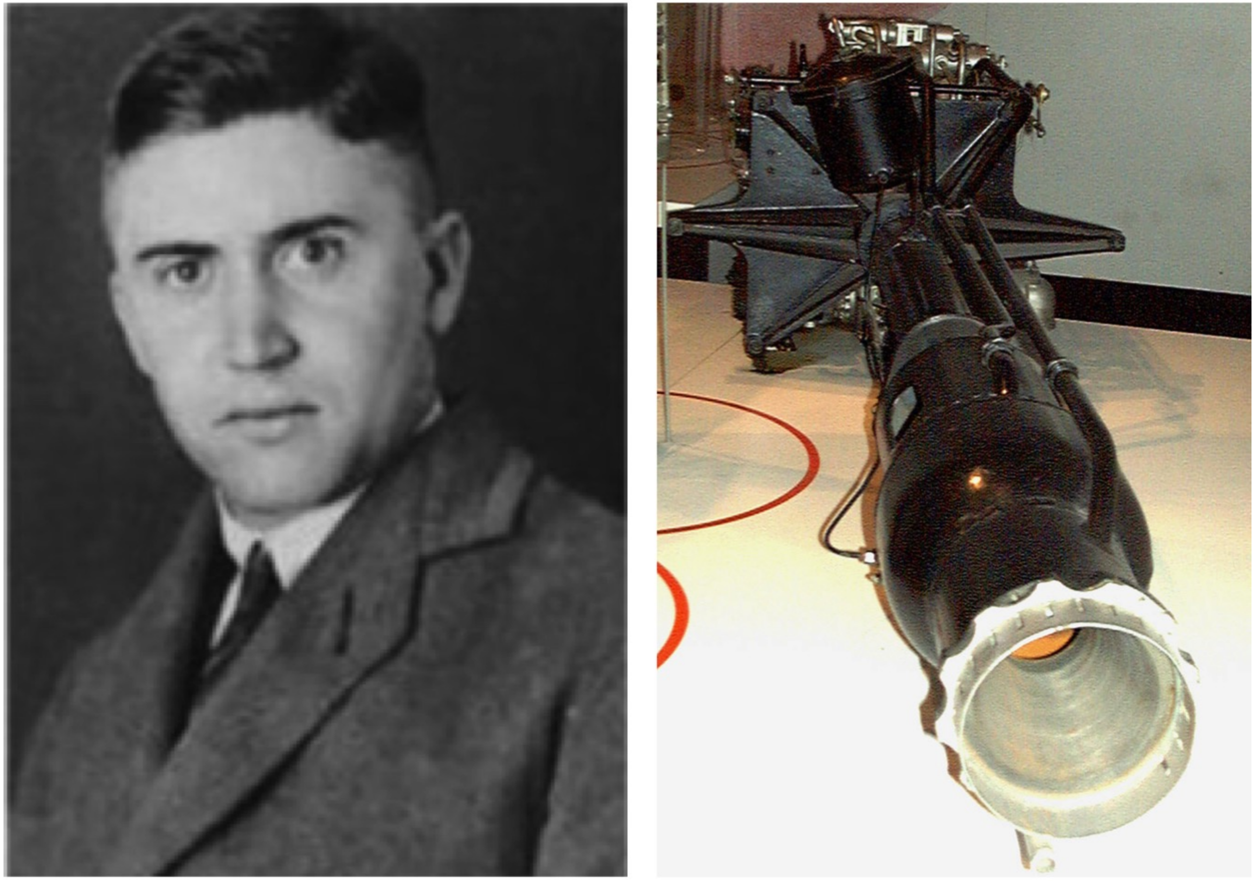
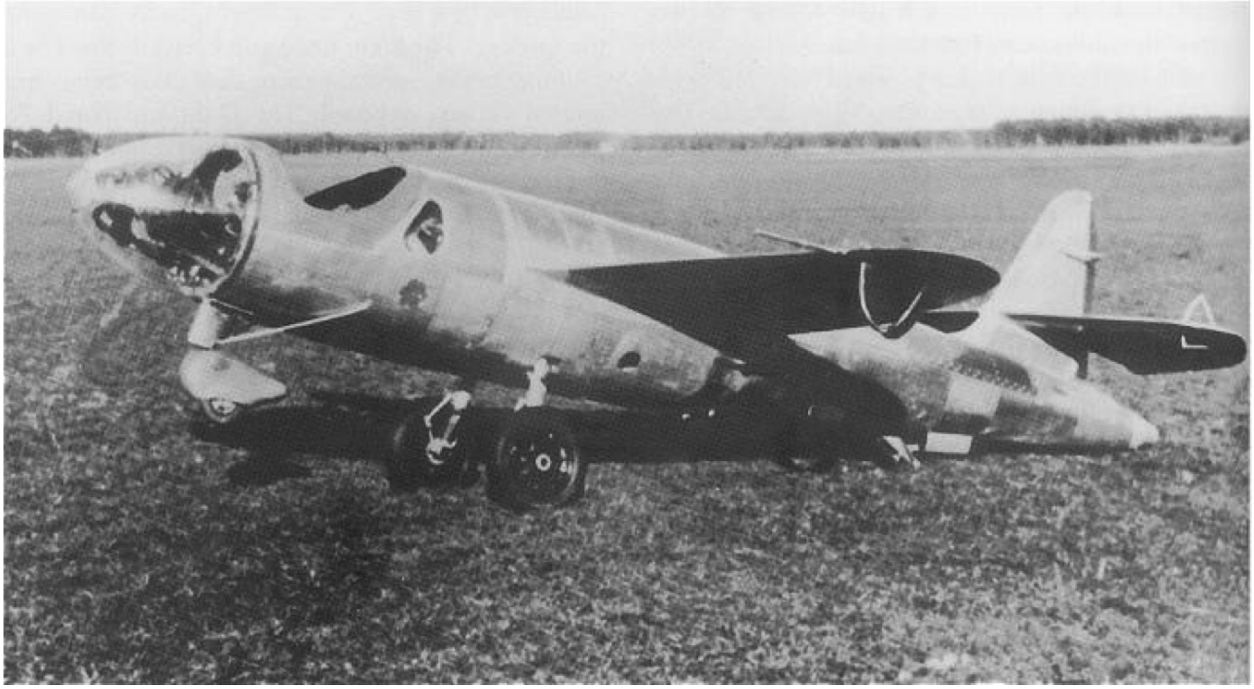

Alexander Lippisch (1894–1976) developed the Lippisch Ente rocket plane (flown 1928)
„RRG - Ente"
Friedrich Sander (1885–1938, left), Fritz von Opel (1899–1971, right), and Julius Hatry (1906–2000, not shown) developed the Opel RAK.1 rocket plane (flown 1929)
HATRY FLUGZEUG
OPEL SANDER RAK.1

Figure 9.213: Alexander Lippisch developed the Lippisch Ente rocket plane. Friedrich Sander, Fritz von Opel, and Julius Hatry developed the Opel RAK.1 rocket plane.



Hellmuth Walter (1900–1980)

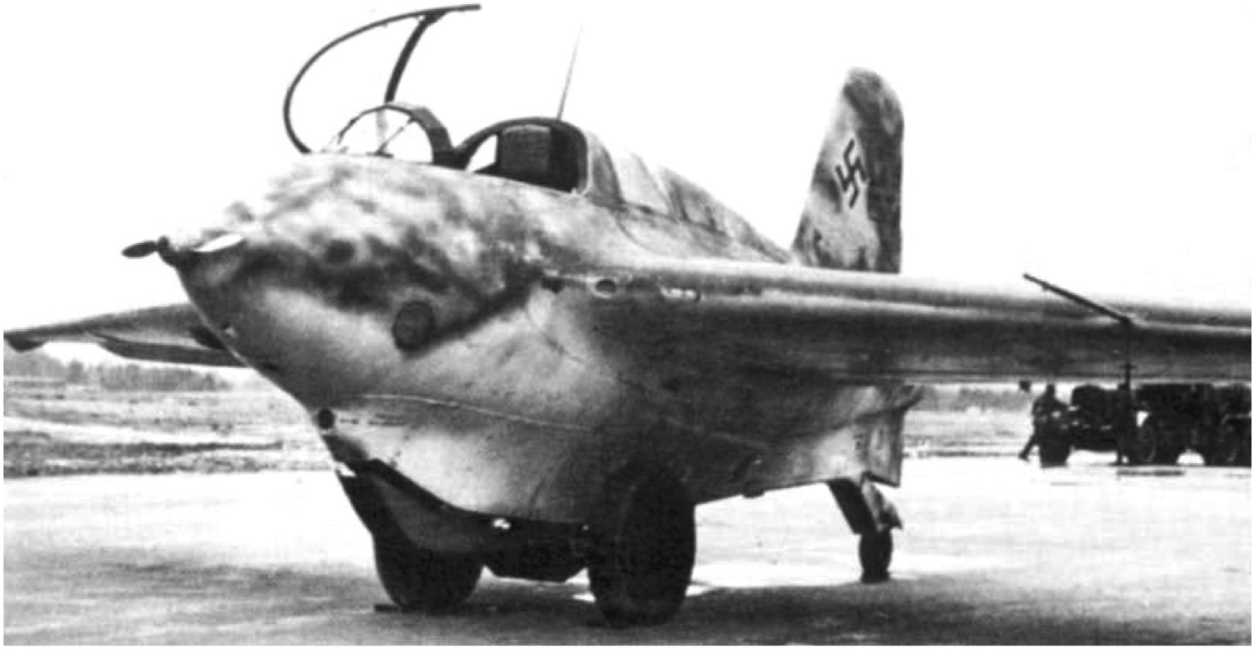
Walter HWK 109-509 engine



Heinkel He 176 rocket plane (flown 1939)

Figure 9.214: Hellmuth Walter designed most German rocket plane engines, such as the HWK 109-509 engine. The Heinkel He 176 rocket plane successfully demonstrated an earlier version of a Walter rocket engine in 1939.

Alexander Lippisch, Friedrich Ringleb, and Hellmuth Walter created the Messerschmitt Me 163 Komet (Comet) rocket plane (1941)



Me 163 in flight

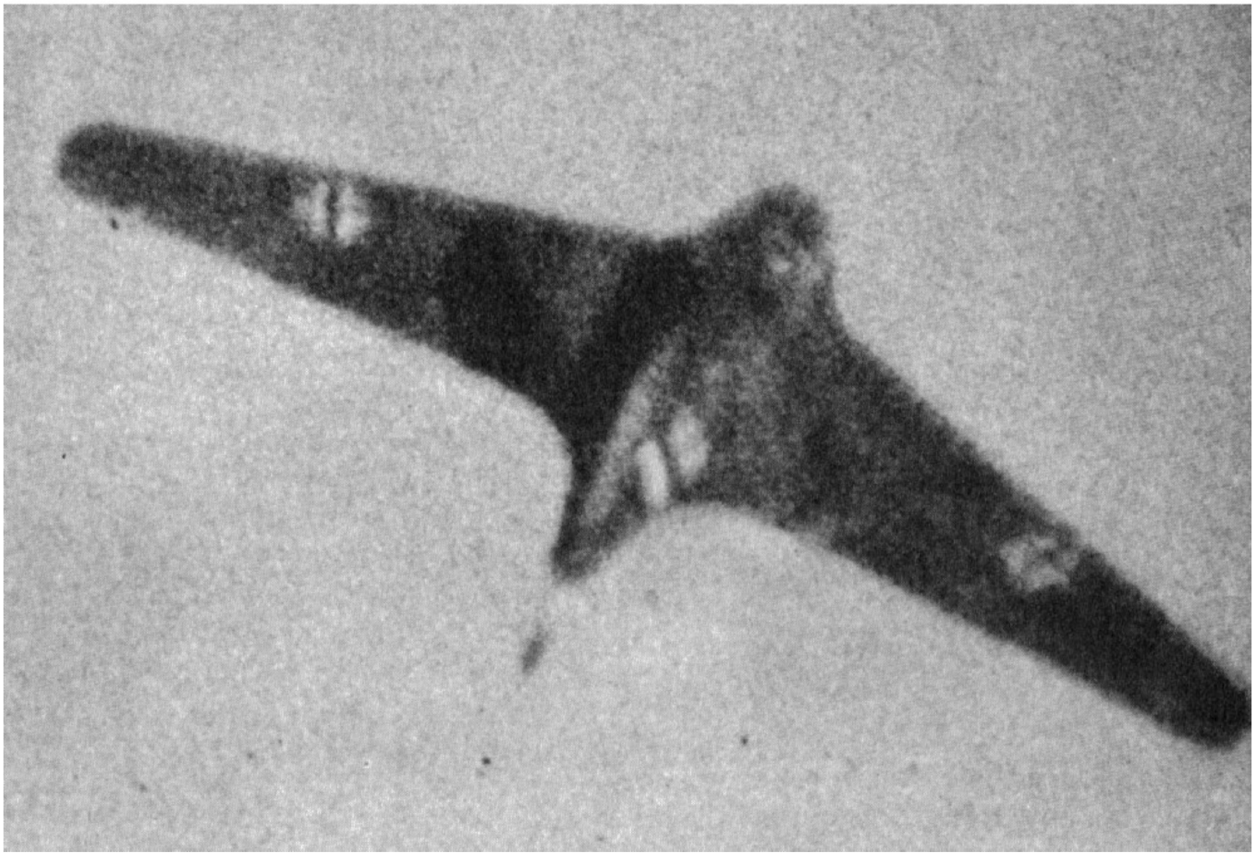
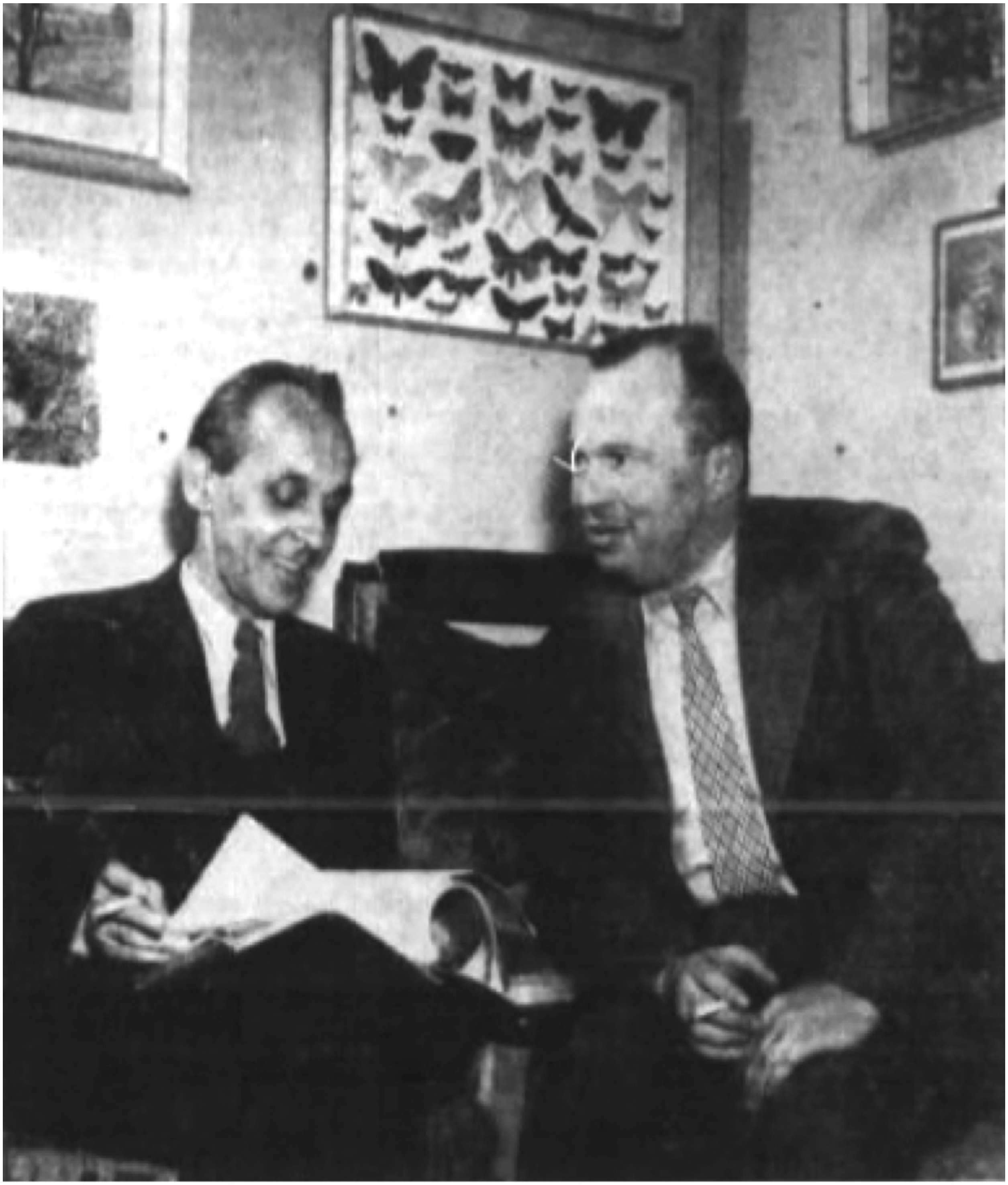


Figure 9.215: Alexander Lippisch and Friedrich Otto Ringleb created the aircraft, and Hellmuth Walter created the rocket engine, for the Messerschmitt Me 163 Komet (Comet) rocket plane, first flown in 1941.



Alexander Lippisch (1894–1976) Friedrich Otto Ringleb (1900–1966)

Me 163 Komet (Comet) rocket plane (1941)
and numerous postwar U.S. aerospace projects

Figure 9.216: Alexander Lippisch and Friedrich Otto Ringleb designed the Messerschmitt Me 163 Komet (Comet) rocket plane (1941) and numerous postwar U.S. aerospace projects [*Dayton Daily News*, 8 December 1946, p. 55].

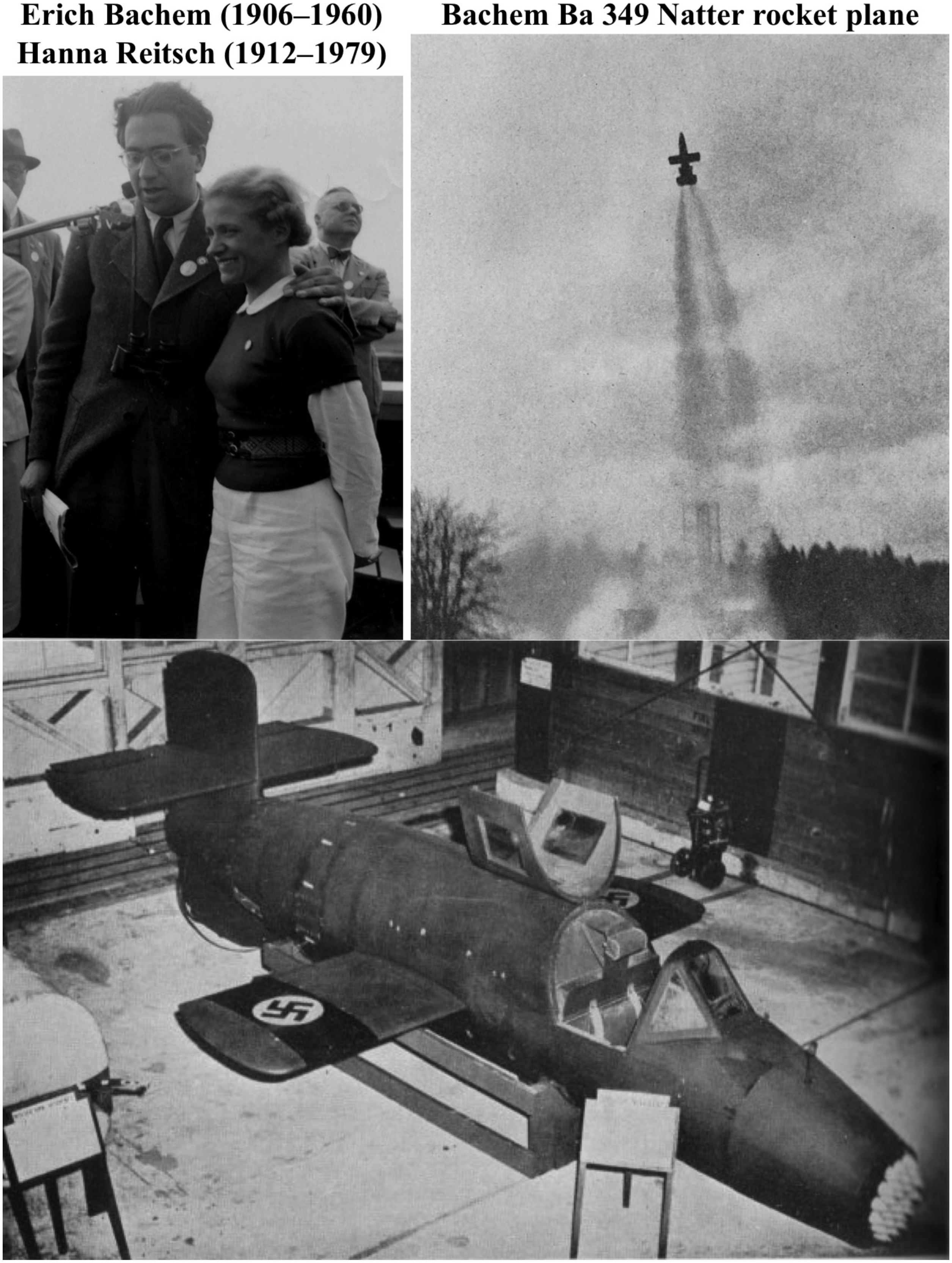
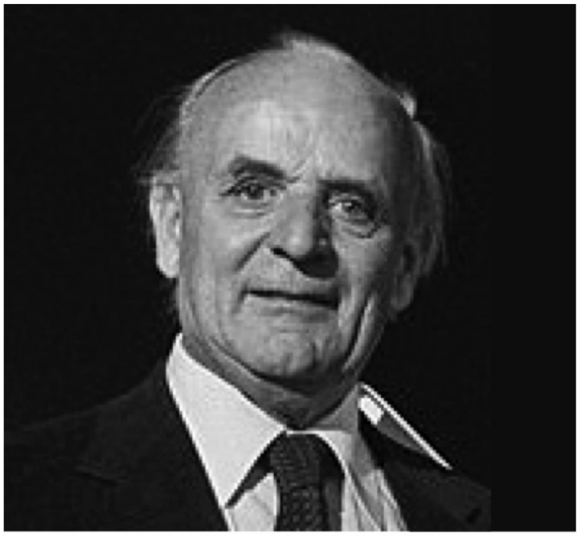
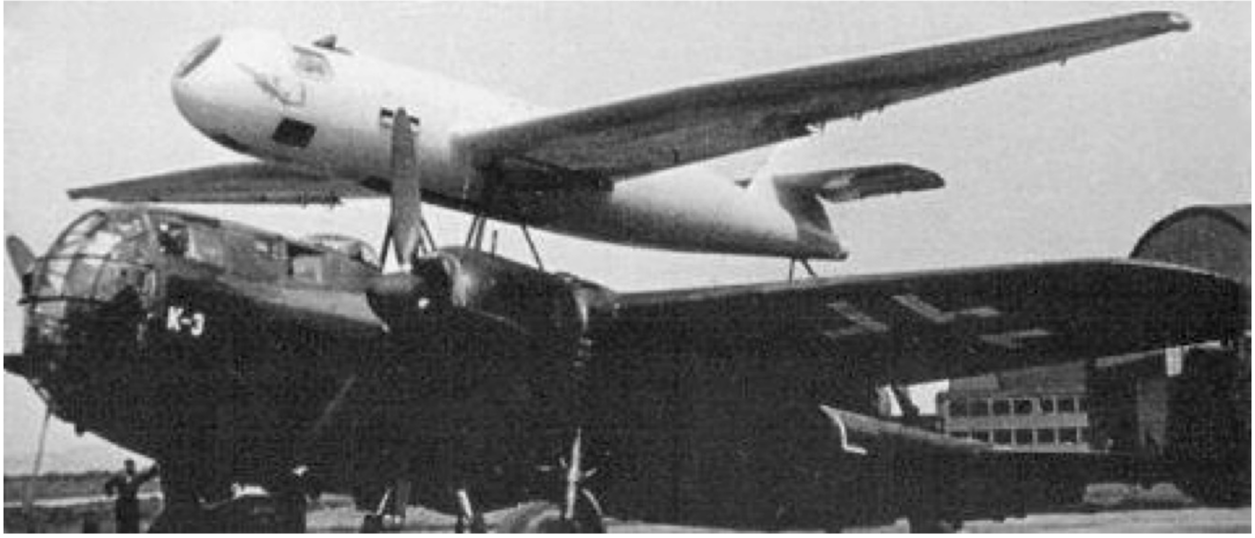

Erich Bachem (1906–1960)
Hanna Reitsch (1912–1979)
Bachem Ba 349 Natter rocket plane

Figure 9.217: Erich Bachem (shown here with famous test pilot Hanna Reitsch) designed and built the Ba 349 Natter, a vertically launched rocket plane.

Felix Kracht
(1912–2002)



DFS 228 rocket plane prototype carried on Do 217 bomber



DFS 346 rocket plane prototype

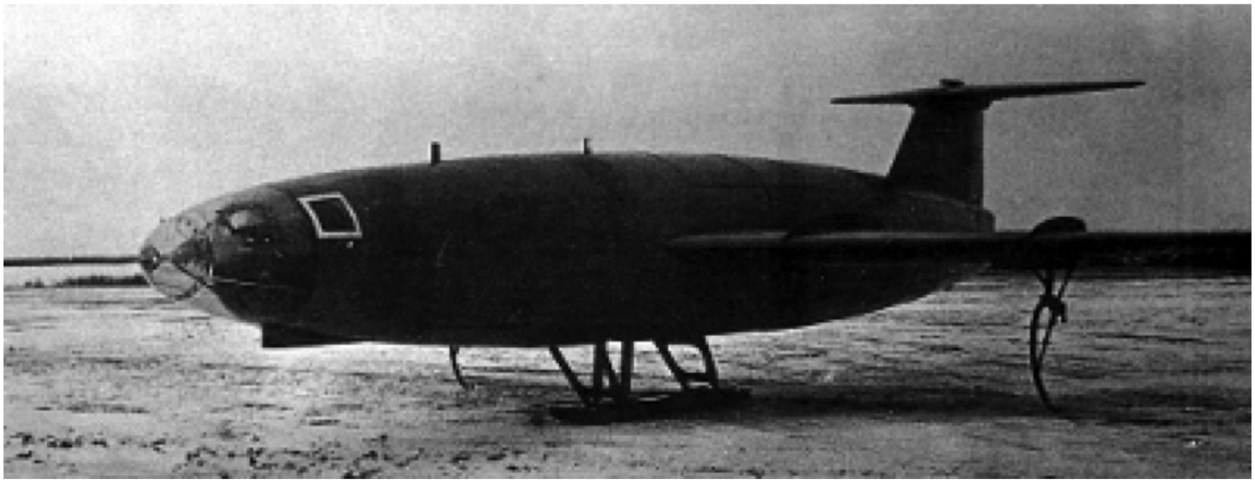
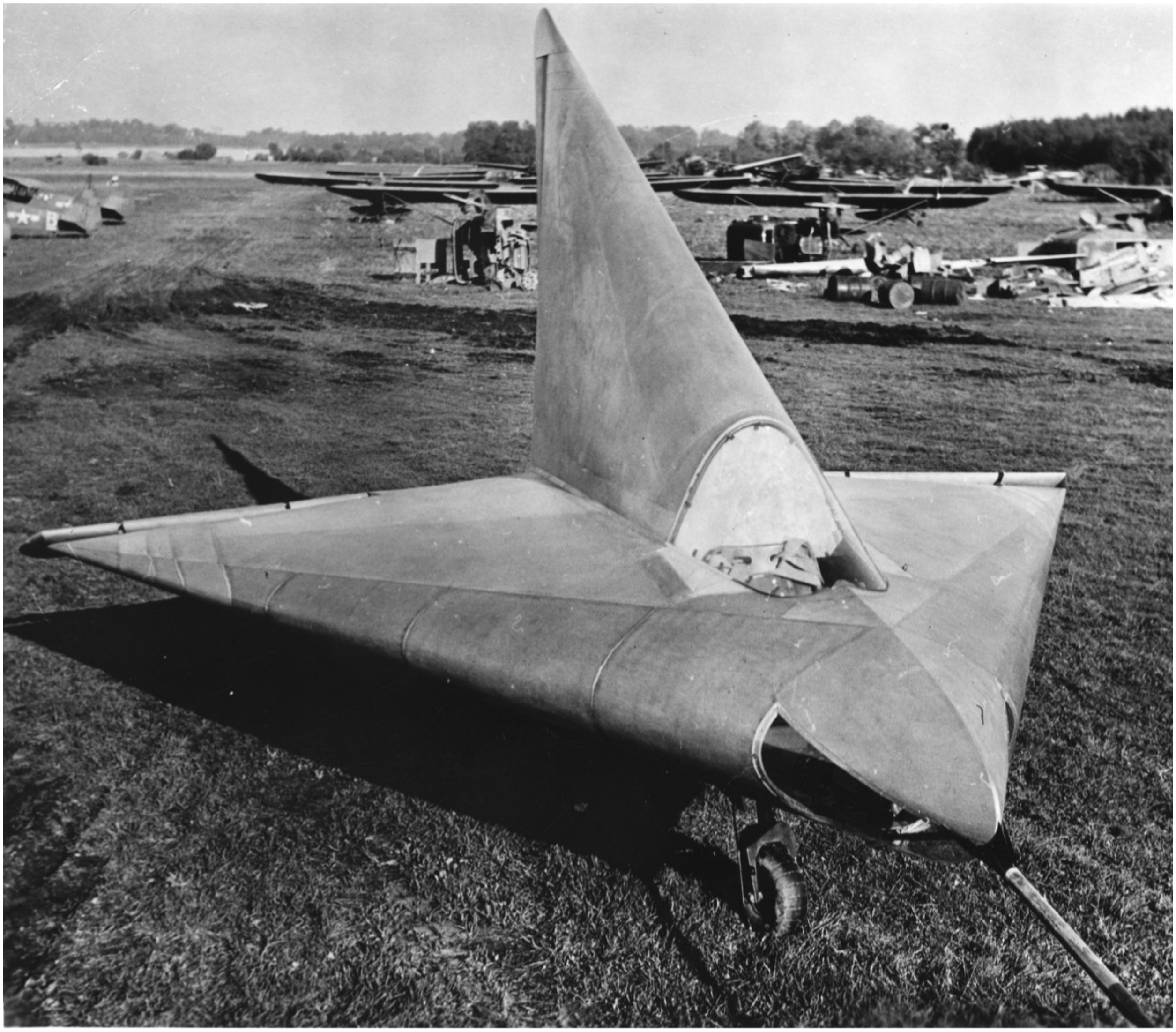


Figure 9.218: Felix Kracht designed rocket planes such as the DFS 228 (predecessor of the U-2 spy plane) and the DFS 346 (predecessor of the Bell X-1 rocket plane).



Alexander Lippisch designed and built the DM-1 rocket plane prototype (1944–1945)

Figure 9.219: Alexander Lippisch created the DM-1 rocket plane prototype, which was designed to travel at several times the speed of sound.

9.9.2 Space Planes

As shown in Fig. 9.220, different types of vehicles can employ different trajectories for reentering the earth's atmosphere from space. In a ballistic reentry, the vehicle cannot generate aerodynamic lift to stay aloft, so it quickly plunges into denser and denser layers of atmosphere, rapidly decelerating due to the large aerodynamic drag force. Ballistic reentry trajectories involve decelerations of at least 8–9 times earth's normal gravity, as well as tremendous heating from atmospheric friction. Ballistic reentry is used by most warheads and was used by the Vostok and Mercury space capsules.

In contrast, lifting reentry trajectories apply to the case in which the vehicle generates aerodynamic lift, which allows the decelerating vehicle to remain much higher, in the thinner parts of the atmosphere, much longer than is possible for a ballistic vehicle with no lift. As a result, vehicles using lifting reentry trajectories experience much smaller decelerations and heating loads, which is why space plane designs are especially attractive. They can also maximize the distance travelled, which was of great interest for long-range bombing during World War II.

As shown in Fig. 9.221, Ludwig Roth (German, 1909–1967), with backing from Wernher von Braun and Walter Dornberger (German, 1895–1980), led the team that developed the A-4b or A-9 winged rocket and launched it in 1945. For evidence that versions of the A-9 designed to accommodate two astronauts may have actually been manufactured during the war, see Section E.2.

As illustrated in Fig. 9.222, Eugen Sänger (1905–1964) and Irene Bredt (1911–1983) designed the Silbervogel space plane, which would have accommodated one astronaut and was even larger than the A-9. They made detailed designs and trajectory calculations for the Silbervogel from the 1930s until 1945. For evidence that prototype hardware for the Silbervogel may have actually been constructed during the war, see Section E.3.

If desired, a vehicle can skip off the upper atmosphere like a fast-moving flat rock skipping off the surface of a pond, and this is called a skip reentry (Fig. 9.220). Both the A-9 and Silbervogel would have used rocket power to achieve a suborbital flight, and then could have repeatedly skipped off the atmosphere to travel part of the way around the Earth before reentering for a final time and bombing a target.[22]

Building upon the wartime work on the manned winged A-9 and Silbervogel, many creators and creations from the German-speaking world played critical roles in postwar programs to develop space planes, including the U.S. Space Shuttle:

- Wernher von Braun and other German-speaking engineers published detailed descriptions and illustrations of a space plane in 1952 in *Collier's* magazine, in order to try to excite U.S. public interest and government funding for such a project [*Collier's* 1952-03-22].

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[22] A more complex reentry trajectory that is closely related to the skip reentry is the double-dip reentry. If a spacecraft is returning from deep space with a huge amount of kinetic energy, its deceleration and aerodynamic heating would be too great if all of its kinetic energy were expended during just one pass into the earth's atmosphere. For this reason, the U.S. Apollo and Soviet Zond capsules that returned from the moon executed a double-dip reentry, making two passes into the atmosphere before landing. The wartime calculations for the A-9 and Silbervogel pioneered this area of reentry trajectory methods, and then German-speaking scientists who went to the United States and Soviet Union after the war helped to implement those methods.

- In 1946, Walter Dornberger began work on the Bell Aerospace GAM-63 RASCAL air-launched cruise missile, a large liquid propellant rocket with wings designed for long-range horizontal flight (p. 1854). In 1952, Dornberger led the Bell Aerospace team that proposed the Bomi (Bomber Missile) space plane, which was heavily based on the wartime Silbervogel designs (p. 1932). In 1954, Dornberger's team designed the X-15 rocket plane, which had many similarities to the wartime manned A-9 designs [Käsmann 2013, p. 105]. After the Bomi proposal was rejected, Dornberger was instrumental in recycling the Bomi and Silbervogel designs to create the X-20 Dyna-Soar space plane; a prototype was built but the program was cancelled in 1963 [Robert Godwin 2003].

- Hans Multhopp (German, 1913–1972, p. 1705) designed the Martin Marietta X-24 lifting body, which first flew in 1969 [R. Dale Reed 1997, pp. 129–130, 136]; see pp. 1933 and 5612.

- In 1965, Walter Dornberger named the newest U.S. space plane program the "Space Shuttle" [Dornberger 1965a, 1965b].

- The U.S. Space Shuttle (Fig. 9.225) incorporated design features, experience, and personnel from the earlier A-9, Silbervogel, Bomi, Dyna-Soar, and X-24 space plane programs [Frank Winter 1990, pp. 42–44, 113–122]; see pp. 5608 and 5610.

- Adolf Busemann (German, 1901–1986) suggested ceramic tiles for thermal insulation on the Space Shuttle, and also contributed his detailed knowledge of hypersonic aerodynamics and heating for the design and reentry [NYT 1986-11-05]; see p. 5611.

- Krafft Ehricke (German, 1917–1984) was deeply involved in space plane projects from Bomi to the Space Shuttle [Freeman 2008].

- The Space Shuttle Main Engines (SSMEs) were directly derived from engine designs with especially high combustion chamber pressures that were developed during and after the war (such as the MBB P111 engine and the Rocketdyne HG-3 engine) by Klaus von Riedel, Karl Stöckel, Hans Georg Paul, Dieter Huzel, and other German-speaking engineers (see pp. 5613–5617).

- The Space Shuttle Solid Rocket Boosters (SRBs) were based on enormous German-speaking contributions to solid propellant rockets (see Sections 9.8 and E.4).

Thus the Silbervogel and the manned winged A-9, as well as the German-speaking scientists who worked on them, led directly to postwar space plane programs such as the X-20 Dyna-Soar, the U.S. Space Shuttle (first launched in 1981, Fig. 9.225), the Soviet Buran (first launched in 1988, Fig. 9.227), and other space planes such as Dream Chaser (Fig. 9.228) [Chertok 2005–2012, Vol. 1, pp. 262–265; Frank Winter 1990, pp. 42–44, 113–122].

For more information on wartime and postwar space plane programs, see Section E.3.

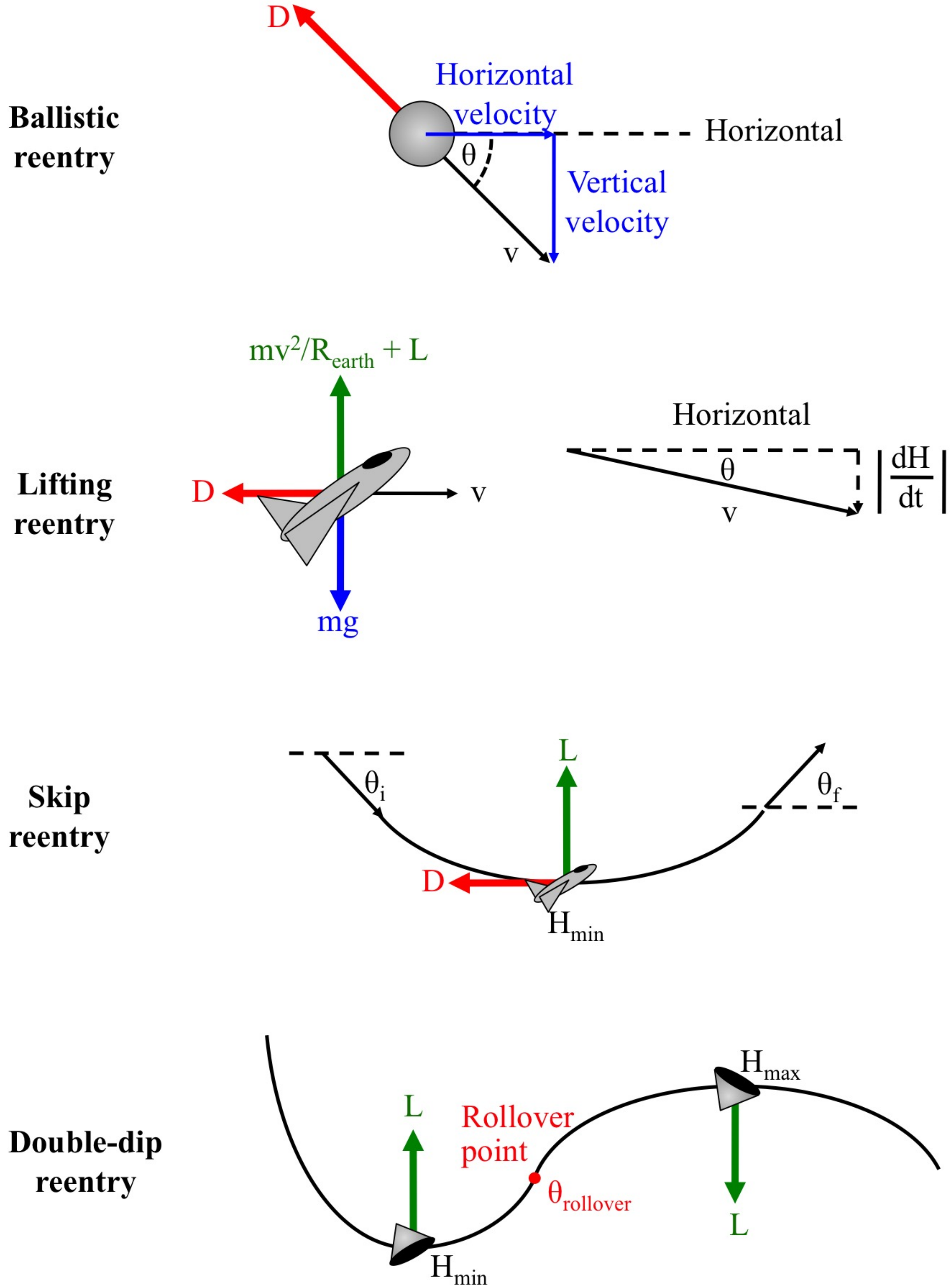
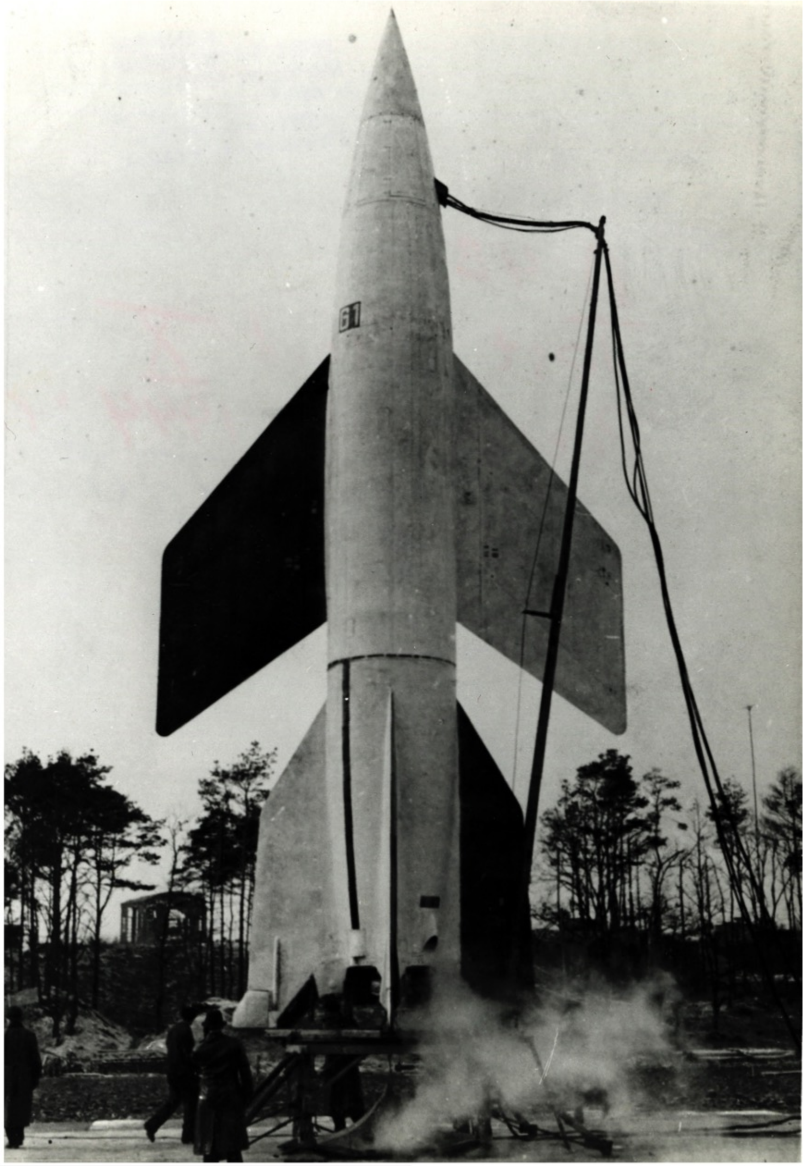
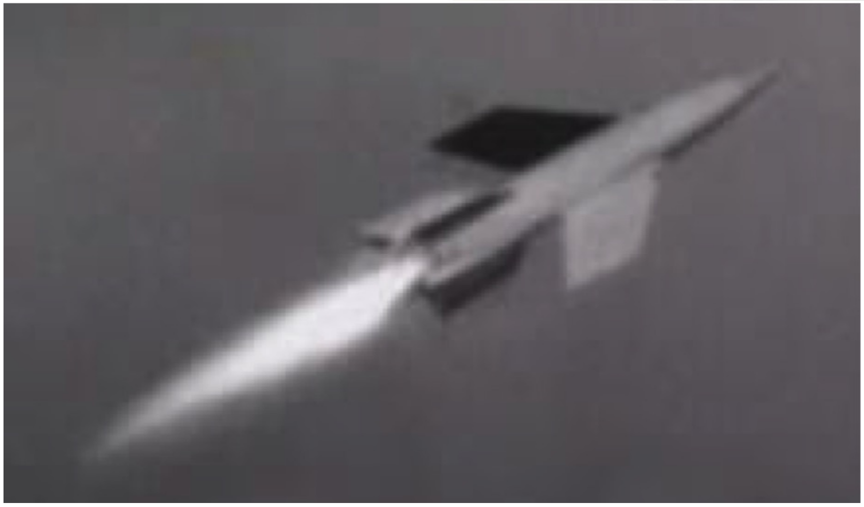

Ballistic reentry
D
Horizontal velocity
Horizontal
θ
Vertical velocity
v
Lifting reentry
$mv^2/R_{earth} + L$
D
v
mg
Horizontal
θ
v
$\left|\frac{dH}{dt}\right|$
Skip reentry
θ_i
L
θ_f
D
H_{min}
Double-dip reentry
H_{max}
L
Rollover point
$\theta_{rollover}$
L
H_{min}

Figure 9.220: Atmospheric reentry approaches include ballistic reentry, lifting-body reentry, skip reentry, and double-dip reentry.

Ludwig Roth
(1909–1967)

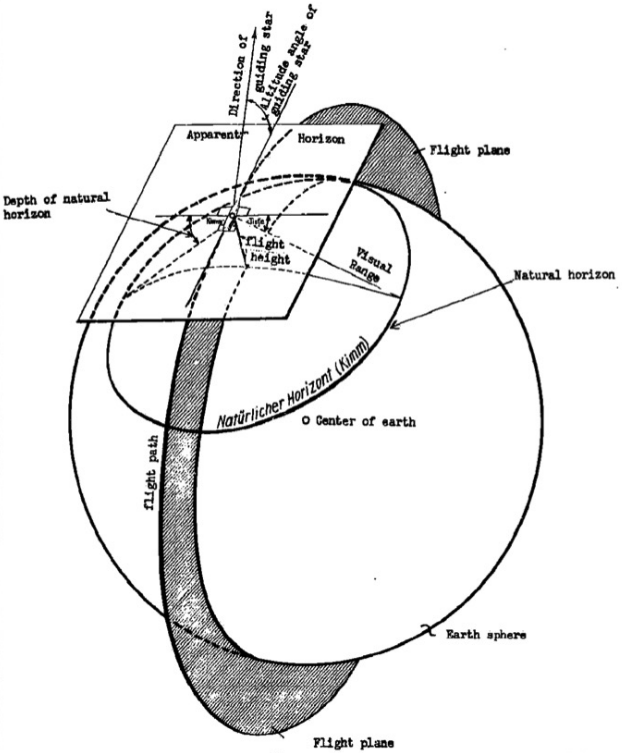




A-4b (A-9)
in flight (1945)

Figure 9.221: Ludwig Roth led the team that developed the A-4b or A-9 winged rocket and launched it in 1945.

Eugen Sänger (1905–1964) and Irene Bredt (1911–1983)


Direction of guiding star
Altitude angle of guiding star
Apparent Horizon
Flight plane
Depth of natural horizon
flight height
Visual Range
Natural horizon
Natürlicher Horizont (Kimm)
Center of earth
flight path
Earth sphere
Flight plane

Silbervogel space plane

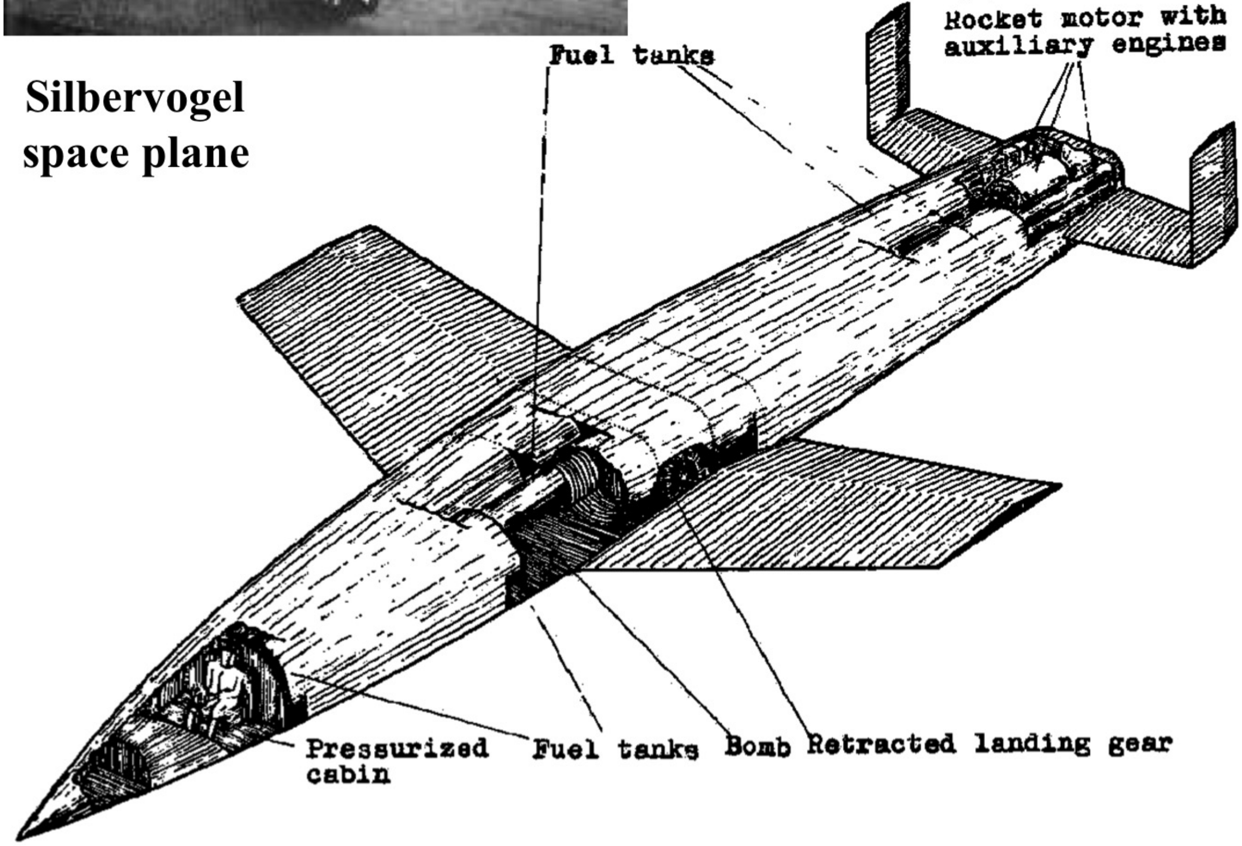
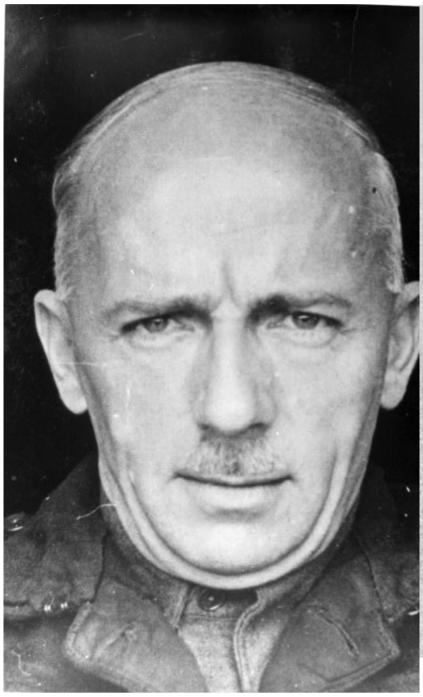
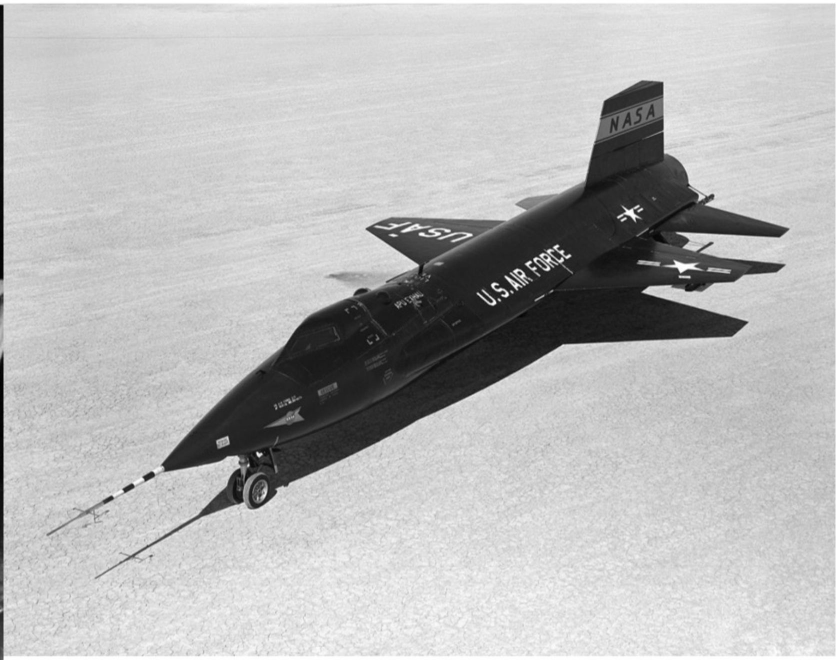

Rocket motor with auxiliary engines
Fuel tanks
Pressurized cabin
Fuel tanks
Bomb
Retracted landing gear

Figure 9.222: Eugen Sänger and Irene Bredt designed the larger Silbervogel space plane and constructed prototype hardware for it during World War II.

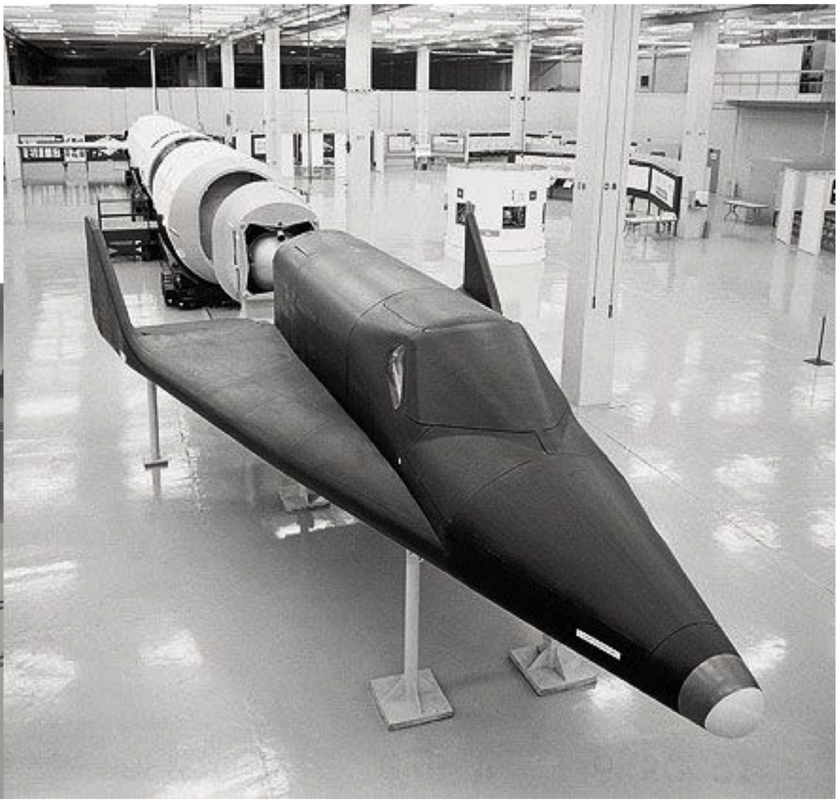
Walter Dornberger (1895–1980)



X-15 rocket plane (first flight 1959)



X-20 Dyna-Soar space plane prototype (cancelled 1963)



Bell Aerospace Bomi (Bomber Missile, proposed 1952)

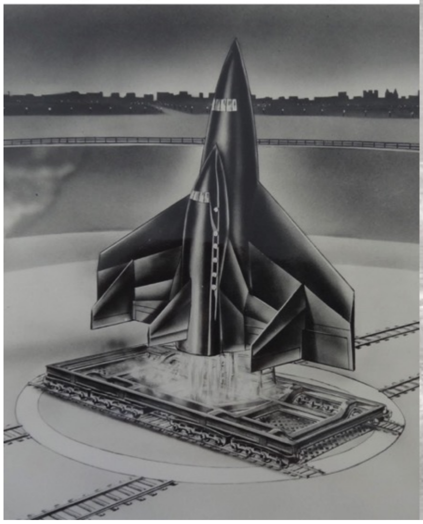


Figure 9.223: Walter Dornberger led the design of the several highly influential postwar rocket planes and space planes, such as the Bomi (Bomber Missile) space plane, the X-15 rocket plane, and the X-20 space plane. He also named NASA's space plane program the Space Shuttle.

Hans Multhopp (1913–1972) **X-24 lifting body (1969)**

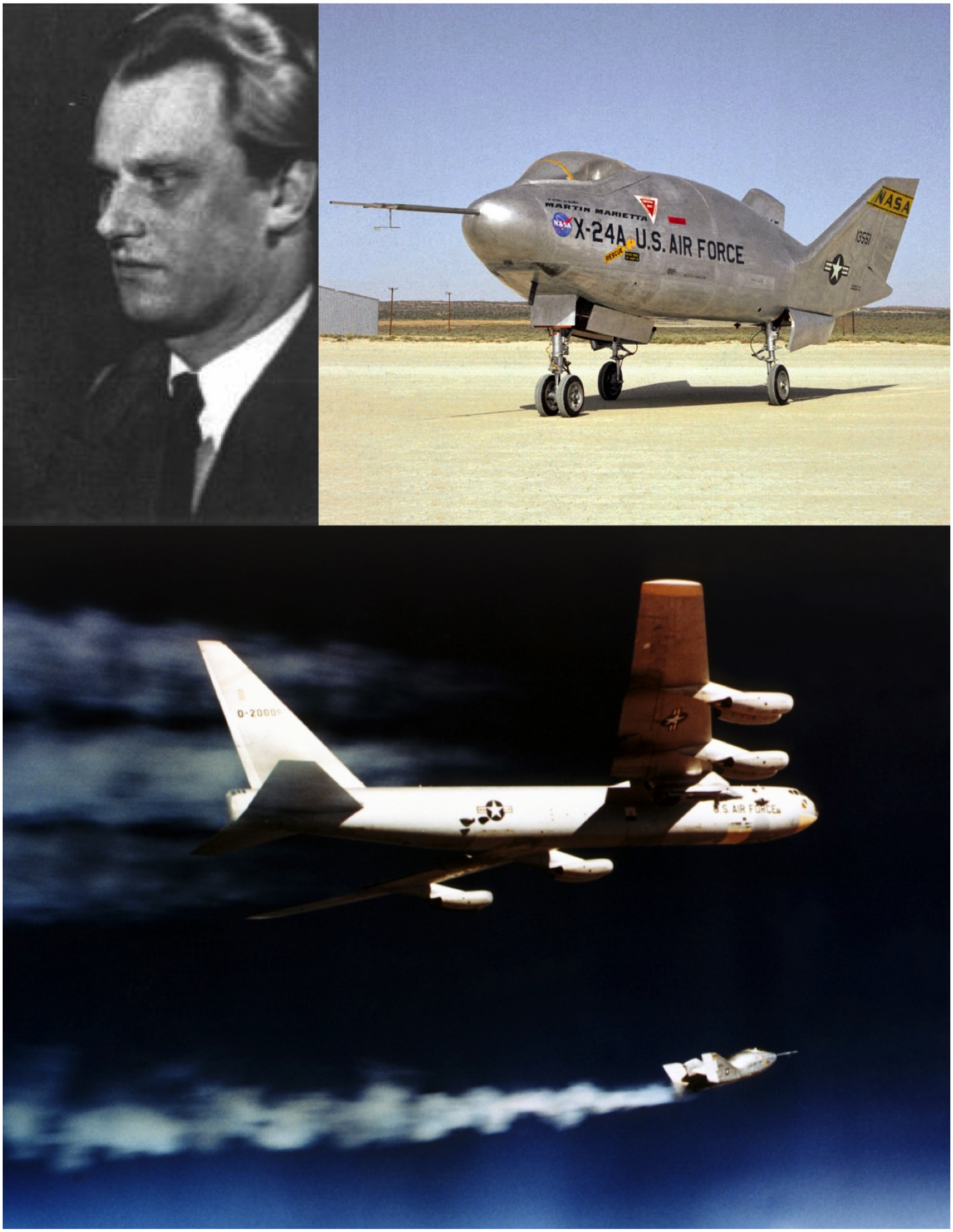

MARTIN MARIETTA
X-24A U.S. AIR FORCE
NASA
13551
RESCUE
U.S. AIR FORCE

Figure 9.224: Hans Multhopp designed the Martin Marietta X-24 lifting body, which first flew in 1969. The modern Sierra Nevada Dream Chaser (p. 1937) is essentially a larger version of Multhopp's design.

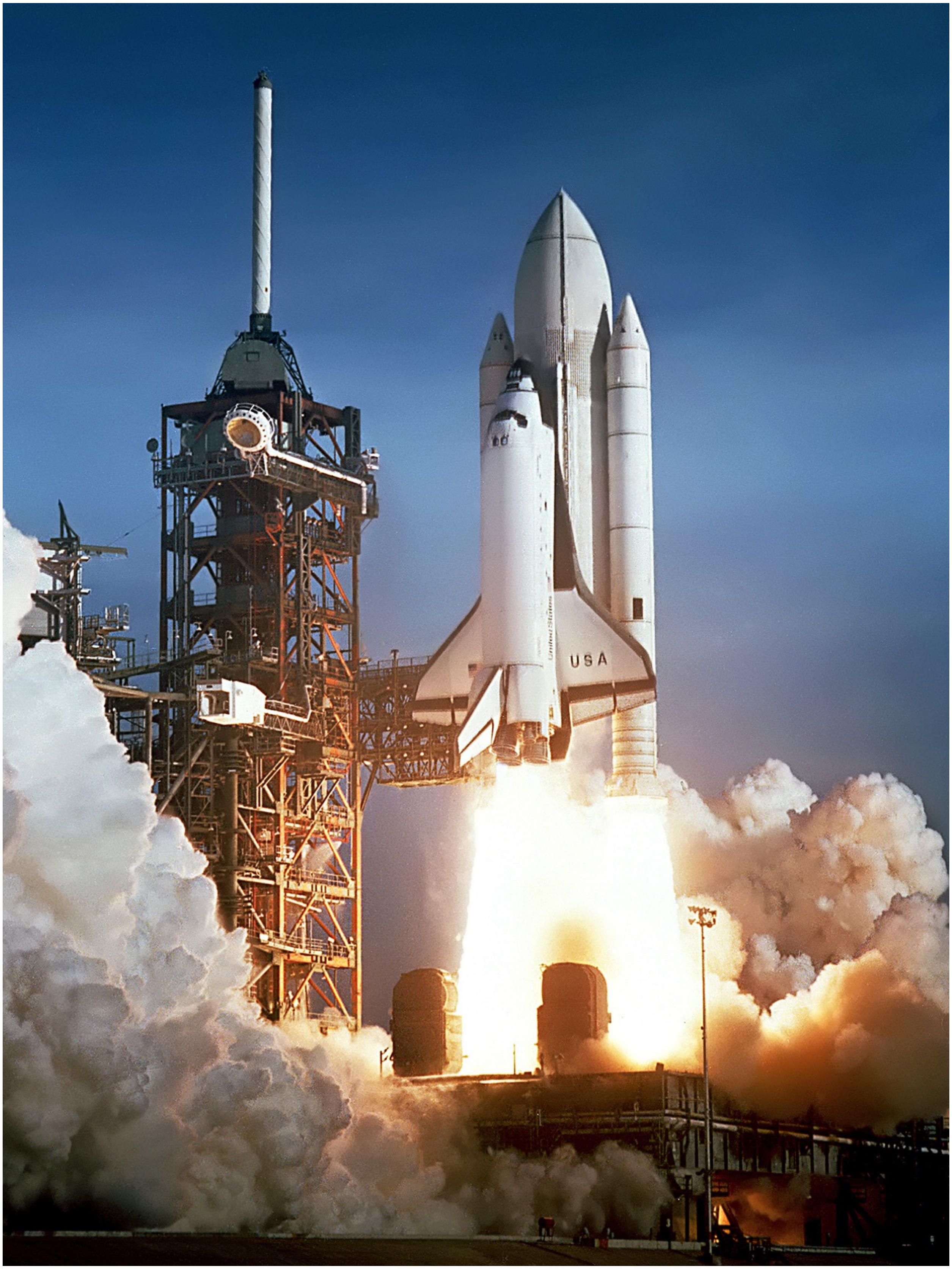

United States
USA

Figure 9.225: First launch of a U.S. Space Shuttle, *Columbia* STS-1, on 12 April 1981.

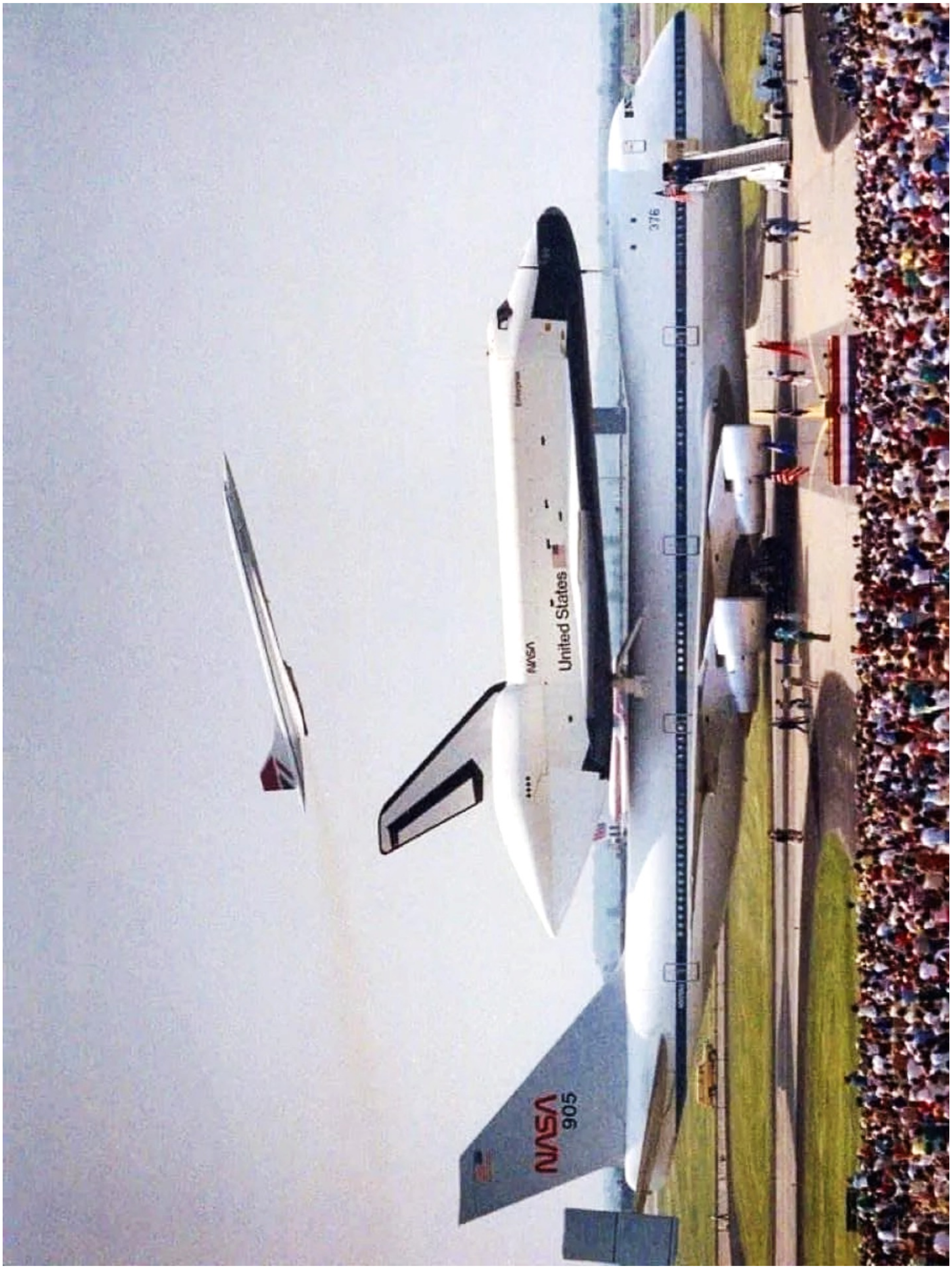

United States
NASA
NASA
905
376

Figure 9.226: A Concorde, Space Shuttle, and 747 together at Washington Dulles International Airport in 1986. These three vehicles were made possible by the work of many German-speaking creators, as shown in this chapter and Appendix E.

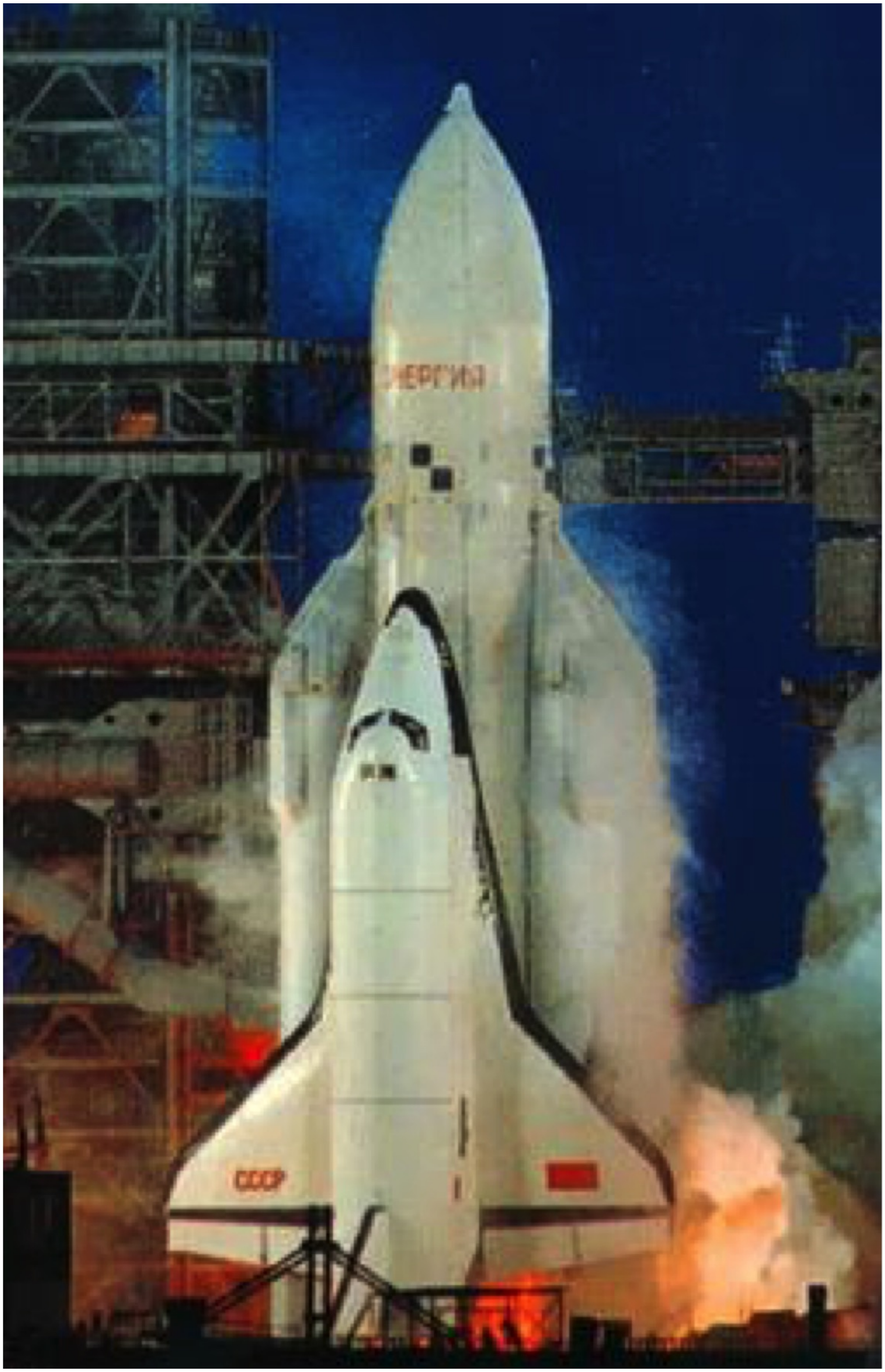


Figure 9.227: First and only launch of the Soviet space shuttle, Buran OK-1K1, on 15 November 1988.

**The Sierra Nevada Corporation's Dream Chaser,
aiming for a first launch in 2022, is one of
the latest vehicles to recycle the designs
of Eugen Sänger, Irene Bredt,
Walter Dornberger, Hans Multhopp,
and the other German-speaking creators**

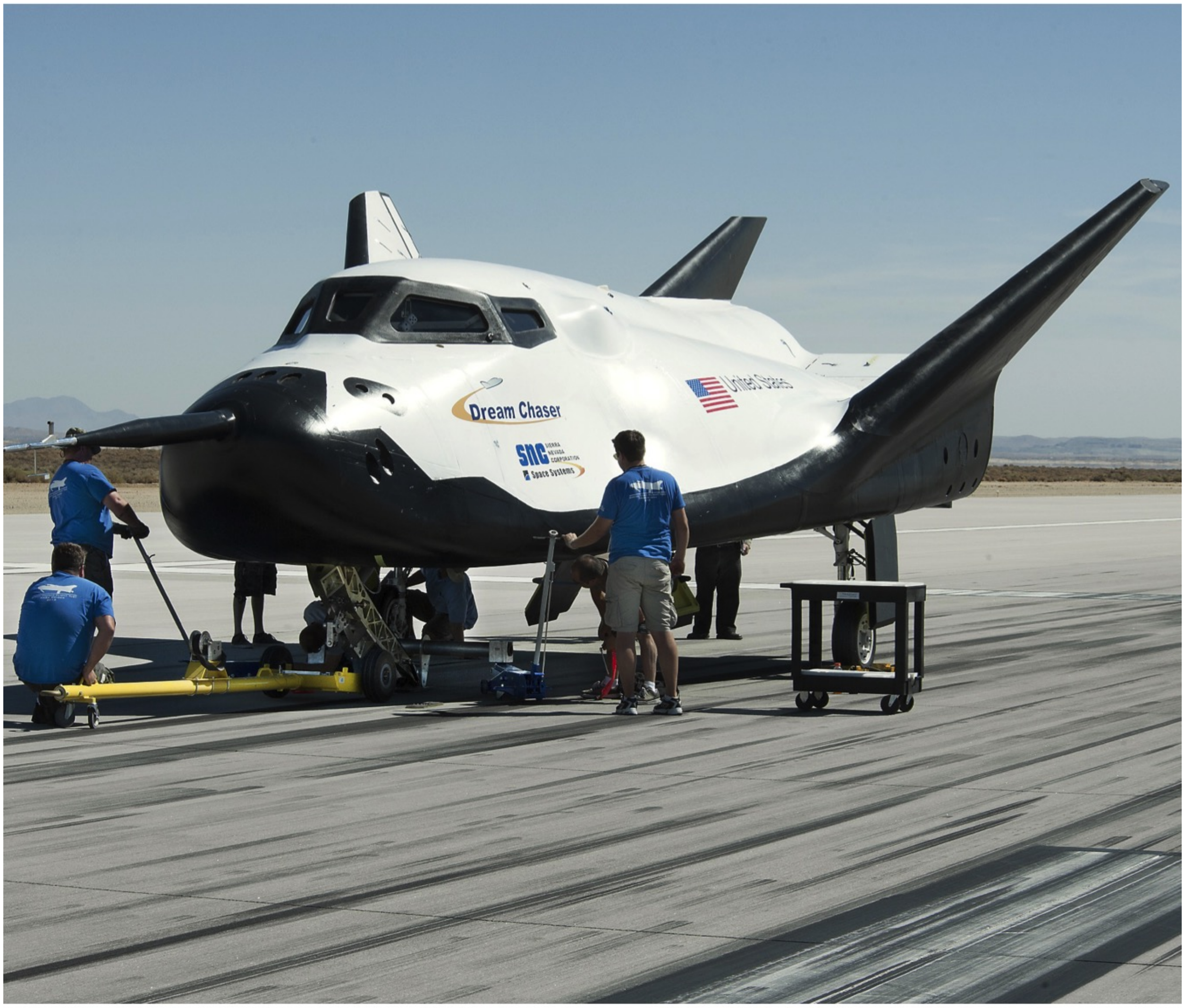

Dream Chaser
SNC SIERRA NEVADA CORPORATION
Space Systems
United States

Figure 9.228: The Sierra Nevada Corporation's Dream Chaser, aiming for a first launch in 2022, is one of the latest vehicles to recycle the designs of Eugen Sänger, Irene Bredt, Walter Dornberger, Hans Multhopp, and the other German-speaking creators. Especially note the striking resemblance to Multhopp's X-24 design (p. 1933); it has simply been made larger to accommodate more people.

9.10 Space Exploration

On top of their work on liquid and solid rocket propulsion and space shuttles, German-speaking creators led the way with regard to other aspects of long-term space exploration, including designing:

9.10.1. Interplanetary trajectories

9.10.2. Space stations

9.10.3. Non-chemical rockets

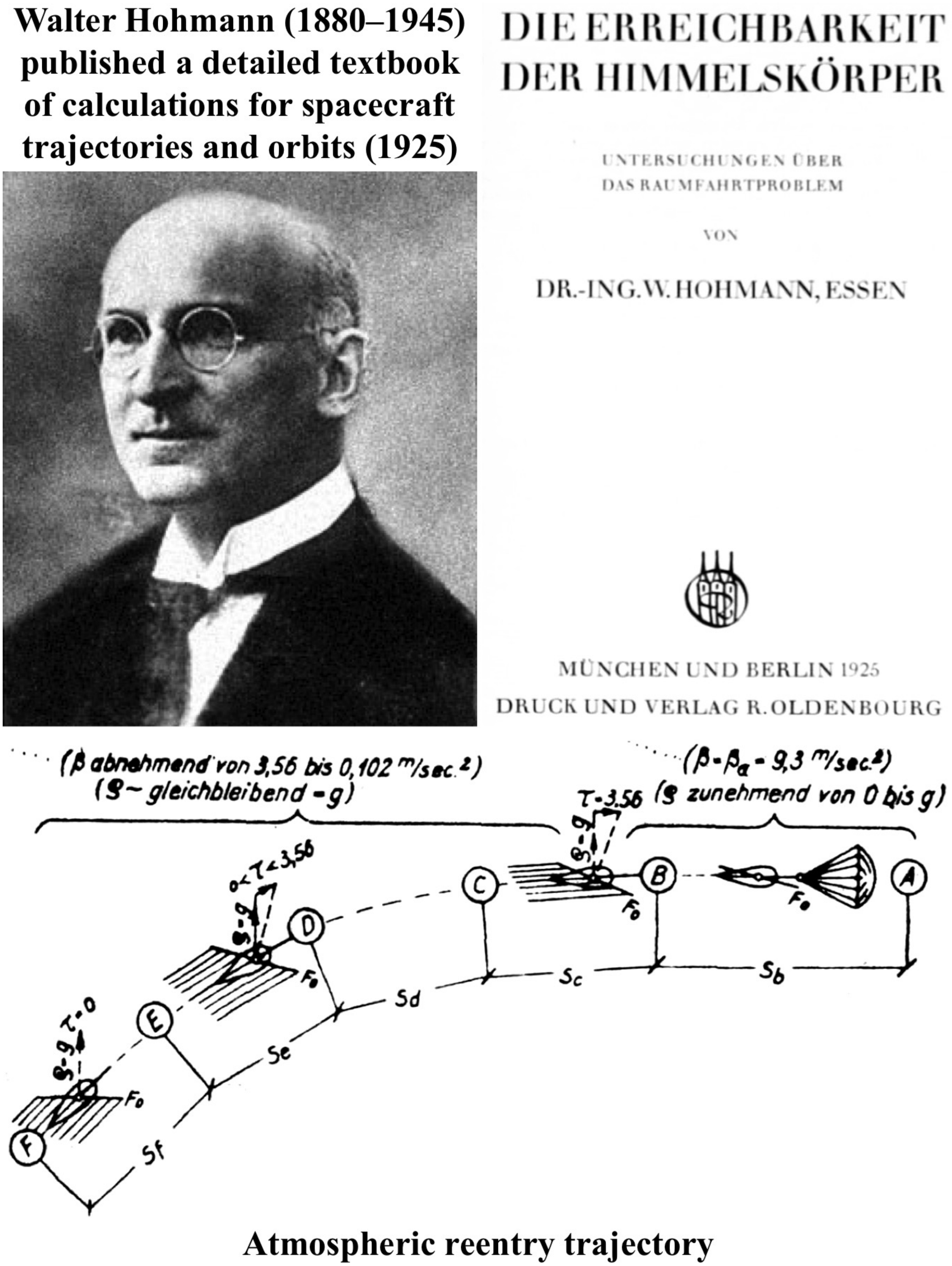
9.10.1 Interplanetary Trajectories

Walter Hohmann (German, 1880–1945) published a detailed textbook of calculations for spacecraft trajectories and orbits in 1925 [Hohmann 1925]. Figures 9.229–9.230 show illustrations from his book for calculations regarding atmospheric reentry, aerobraking, and what are now called Hohmann transfer ellipses—elliptical orbits for transferring from one nearly circular orbit (such as that of a planet) to another (such as that of another planet) with the smallest possible expenditure of energy. The methods that Hohmann proposed and worked out in 1925 have been utilized quite effectively since the 1960s and will continue to be widely used in future space missions.

In 1928, Franz von Hoefft (Austrian, 1882–1954, Fig. 9.231) laid out the first systematic plan for steadily progressing from small initial test rockets to very large rockets capable of carrying people to the moon and to other planets [Ley 1928]. Although von Hoefft did not have the opportunity to realize his vision, Wernher von Braun's team did, with their long series of rockets in Germany in the 1930s and 1940s and then in the United States through the 1960s.

Willy Ley (German, 1906–1969, Fig. 9.231) studied earth science at the University of Berlin but spent the rest of his life promoting rockets and space exploration, writing a large number of highly influential books in that area between 1926 (when he was only 20) and his death in 1969. Ley's activities and his books directly inspired, brought together, and publicized the work of many other scientists and engineers involved with rockets and space exploration.

For information on the contributions of German-speaking scientists to planetary science and astrophysics, see Sections 4.5–4.6.



Walter Hohmann (1880–1945) published a detailed textbook of calculations for spacecraft trajectories and orbits (1925)

DIE ERREICHBARKEIT
DER HIMMELSKÖRPER

UNTERSUCHUNGEN ÜBER
DAS RAUMFAHRTPROBLEM

VON

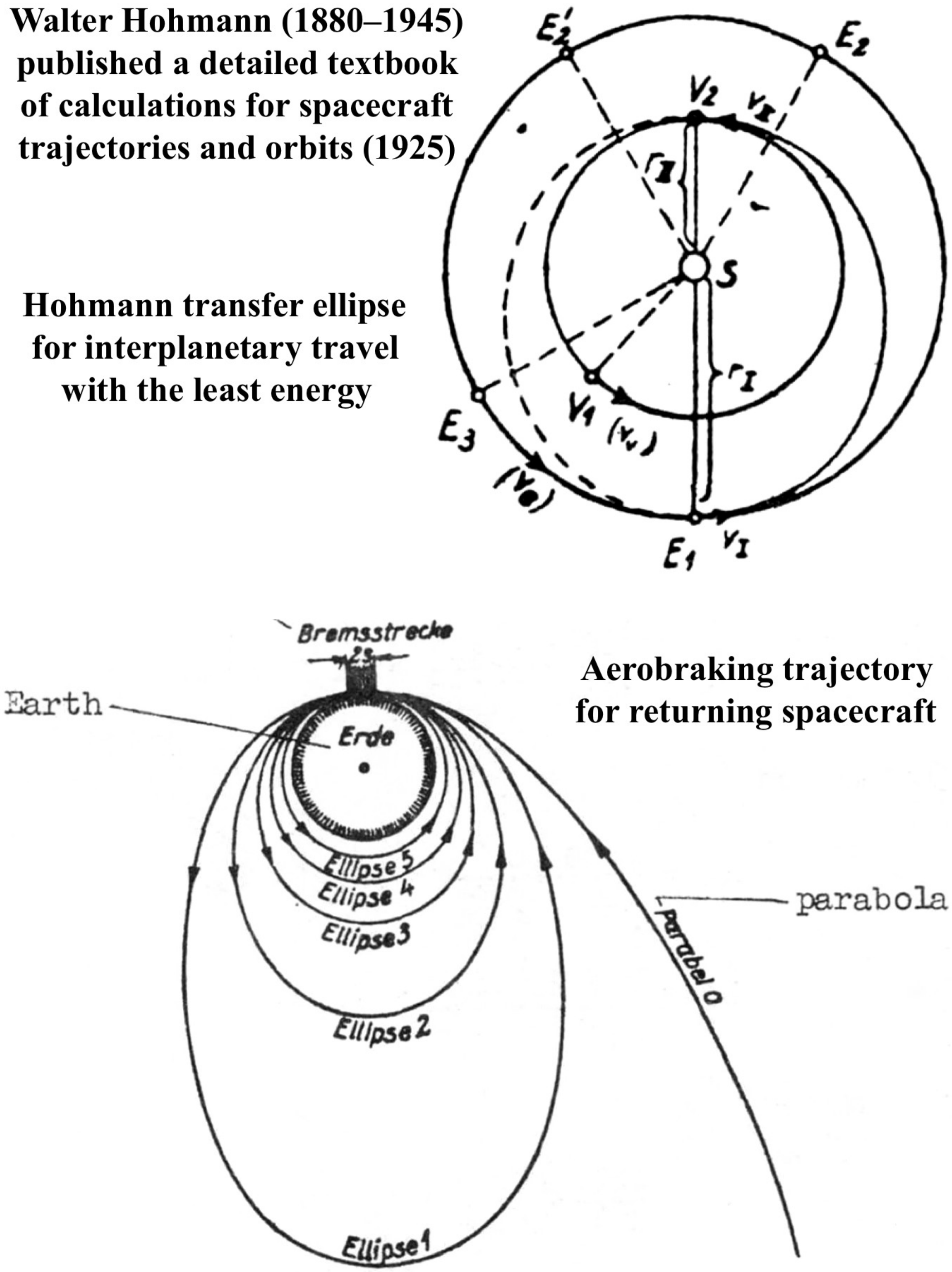
DR.-ING. W. HOHMANN, ESSEN

MÜNCHEN UND BERLIN 1925
DRUCK UND VERLAG R. OLDENBOURG

(β abnehmend von 3,56 bis 0,102 m/sec.²)
(ϱ ~ gleichbleibend = g)
(β = β_a = 9,3 m/sec.²)
(ϱ zunehmend von 0 bis g)
τ = 3,56
ϱ = g
0 < τ < 3,56
ϱ = g
ϱ = g, τ = 0
A
B
C
D
E
F
F₀
F₀
F₀
F₀
F₀
S_b
S_c
S_d
S_e
S_f

Atmospheric reentry trajectory

Figure 9.229: Walter Hohmann published a detailed textbook of calculations for spacecraft trajectories and orbits in 1925.



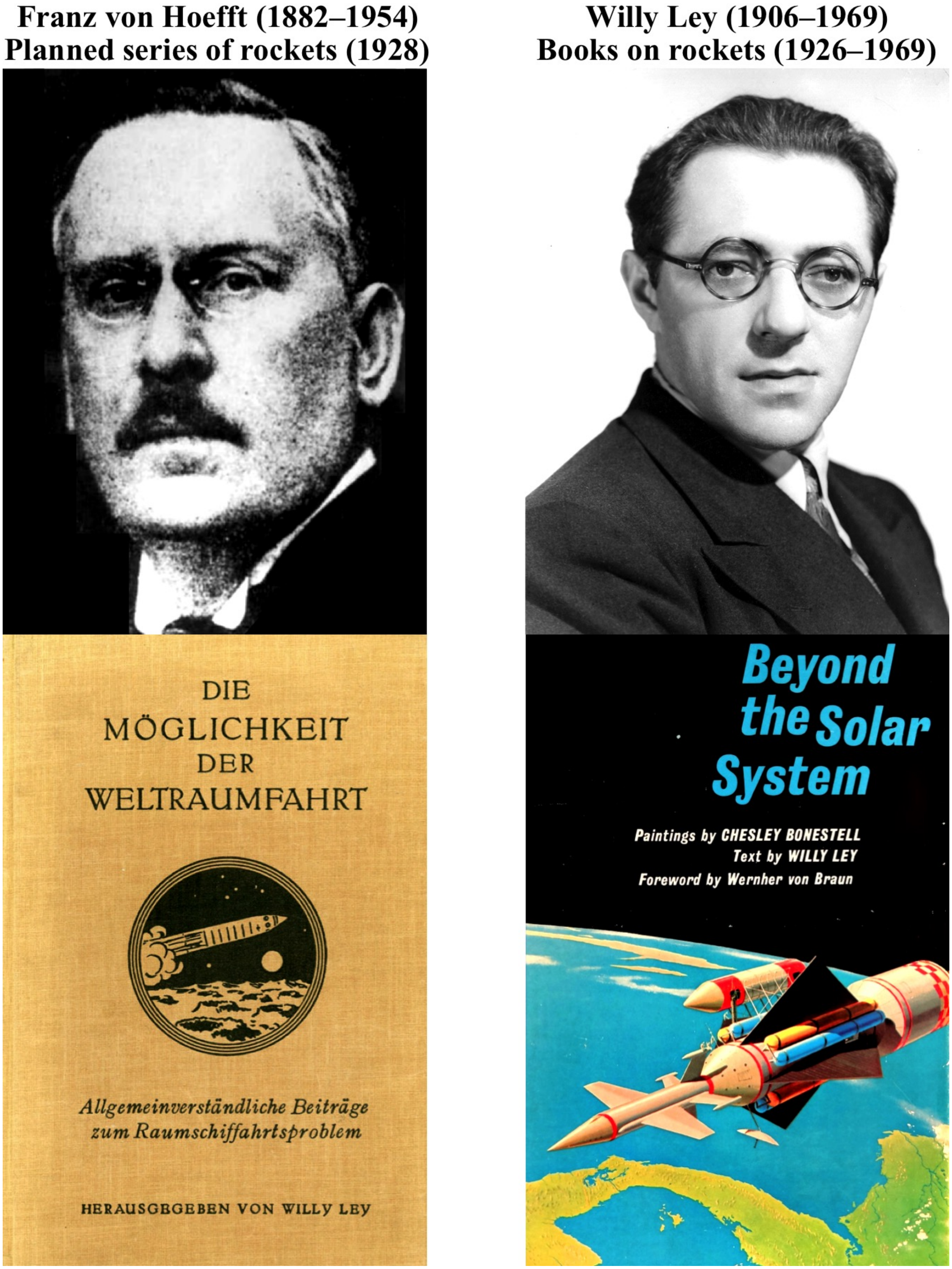
Walter Hohmann (1880–1945) published a detailed textbook of calculations for spacecraft trajectories and orbits (1925)

Hohmann transfer ellipse for interplanetary travel with the least energy

Aerobraking trajectory for returning spacecraft

E₂'
E₂
V₂
v_II
r_II
S
r_I
V₁
(v_v)
E₃
(v_0)
E₁
v_I
Bremsstrecke
2s
Earth
Erde
Ellipse 5
Ellipse 4
Ellipse 3
Ellipse 2
Ellipse 1
parabola
Parabel 0

Figure 9.230: Walter Hohmann published a detailed textbook of calculations for spacecraft trajectories and orbits in 1925.



Franz von Hoefft (1882–1954)
Planned series of rockets (1928)

Willy Ley (1906–1969)
Books on rockets (1926–1969)

DIE
MÖGLICHKEIT
DER
WELTRAUMFAHRT
Allgemeinverständliche Beiträge
zum Raumschiffahrtsproblem
HERAUSGEGEBEN VON WILLY LEY
Beyond the Solar System
Paintings by CHESLEY BONESTELL
Text by WILLY LEY
Foreword by Wernher von Braun

Figure 9.231: In 1928, Franz von Hoefft published papers describing a planned series of rockets ranging from small test rockets to large rockets capable of carrying people to the moon and to other planets. Between 1926 and his death in 1969, Willy Ley published a large number of popular books advocating for rockets and space exploration.

9.10.2 Space Stations

German-speaking scientists led the development of space stations from their initial conception through Skylab to the International Space Station.

In 1928, Hermann Potočnik (Austrian/Slovene, 1892–1929), under the pen name of "Hermann Noordung," published a book with detailed designs of a large, circular, rotating space station, as shown in Fig. 9.232 [Noordung 1928]. Potočnik's designs accurately accounted for everything from the solar energy requirements of the space station's power plant to the artificial gravity in its living quarters. He described and correctly calculated a geosynchronous orbit for the space station. Potočnik's book also incorporated many of Hohmann's proposed methods for interplanetary missions. Unfortunately Potočnik died from tuberculosis (which he had contracted during World War I) when he was only 36; if he had lived he might have helped to realize some of his visions.

Guido von Pirquet (Austrian, 1880–1966) and Hermann Oberth (German, 1894–1989) separately designed space stations in 1928 and 1929 [Ley 1928; Oberth 1929]. See Fig. 9.233. Oberth pointed out that such a station could for example tend large space-based mirrors to reflect sunlight on the earth. Depending on they were used, such mirrors might improve everything from agriculture to power production to weather, or they might incinerate opposing countries. Von Pirquet explained in detail how a space station could be used to refuel spacecraft for interplanetary missions.

Krafft Ehricke (German, 1917–1984), one of the later pioneers of space exploration and advanced rocket propulsion (p. 1957), paid credit to these creators who first worked out the mathematical and physical details of space travel [Ehricke 1960, pp. 19–25]:

> In Germany the most theoretical book on space flight, aside from Oberth's book, was written by Walter Hohmann and published in 1925 under the title, *Die Erreichbarkeit der Himmelskörper* (The Accessibility of the Celestial Bodies). It consisted of a systematic treatment of the departure from the Earth, return to the Earth (re-entry), free coasting in space, circumnavigation of other celestial bodies, and landing on these. Hohmann's departure from the Earth was accomplished by means of vertical ascent. Lateral motion, for instance to enter a circular orbit or another cosmic orbit, was to be given after the vehicle had reached its summit point outside the atmosphere. In his discussion of the return to the Earth, Hohmann proposed to use the atmosphere as a brake. [...]
>
> Hohmann was fully aware of the aerodynamic heating problem. He stated that it is important to transform as much of the kinetic energy of the vehicle as possible into vortex motion of the air. [...] For free coasting in space and the circumnavigation of other celestial bodies *transfer ellipses* were considered; Hohmann showed that the *cotangential* ellipse would be the most economical, but would require an increasingly long transfer time when applied to the outer planets of the solar system. He, therefore, also considered "fast" ellipses which intersect the orbit of the target planet at an angle and require, upon arrival, not only a change in scalar velocity, but also in direction. Hohmann was the first to discuss analytically the landing on other celestial bodies, specifically Venus and Mars. However, he believed that the atmospheric conditions on Mars may not be adequate for an exclusively aerodynamic descent, and that retrothrust must be employed. [...]

> Austria contributed two outstanding space flight pioneers of the early 20th century, Guido von Pirquet and Franz von Hoefft. Von Pirquet was the first to investigate systematically the significance of a terrestrial satellite station for interplanetary flight. While Oberth had only mentioned in passing that such satellites could be used as propellant depots, von Pirquet became convinced that, for the realization of space flight with chemical vehicles, refueling on a satellite would be a necessary condition. [...] Although Pirquet's analyses, like Hohmann's, extended as far as to include circumnavigation of Jupiter, his development approach was quite realistic. [...]
>
> Von Hoefft [...] contributed three fundamental thoughts: The balloon-launched, high-altitude rocket; the flat-bottom glide rocket; and the non-aerodynamic configuration of satellite-launched space ships. Von Hoefft visualized eight development steps, each characterized by a particular project. In a sense he is, therefore, the first to present an organic plan for the development of space flight, from a simple balloon-launched sounding rocket RH I to the interstellar vehicle RH VIII. [...]
>
> With this development plan, von Hoefft displayed a remarkable combination of practical sense and vision. Together with his sincere enthusiasm for the cause of space flight, this makes him one of the outstanding pioneers in this field.
>
> In this era of the thinkers, another interesting idea was contributed by H. Noordung. [...] Here Noordung contributed the first engineering concept of such a space station, or rather what he called its "living unit". He introduced the rotating wheel shape in order to provide centrifugal force as a sort of artificial gravity for the crew. [...] He placed his space station into a very high orbit, about 20,000 n. mi. out where it would complete one revolution in 24 hr.
>
> Thus, when the remarkable 1920's drew to a close, the foundations of the new science of rocket flight and astronautics were established.

Plans for a space station and space mirror were seriously considered by the German government during World War II, especially with regard to potential military applications, as illustrated in Fig. 9.234 [NYT 1945-06-29 p. 1, 1945-06-30 p. 3; *Life* 1945-07-23 p. 78; *Time* 1946-09-02 p. 52].

After the war, Hermann Oberth, Wernher von Braun, Willy Ley, and many other German-speaking scientists continued to design and advocate for space stations in the United States [e.g., *Collier's* 1952-03-22]. Figure 9.235 shows a 1952 space station design from von Braun's team, drawn by Chesley Bonestell, based on earlier designs by Potočnik, von Pirquet, and Oberth.

In addition to the large wheel designs, the German-speaking scientists also proposed simpler space station designs as a starting point. Wernher von Braun, Heinz-Hermann Koelle (German, 1925–2011), and others proposed converting the empty upper stage of a Saturn-class rocket into a space station no later than 1959 for the U.S. Army's Project Horizon project. When von Braun's group was transferred from the Army to the recently formed NASA, the project for converting the upper stage of a Saturn V into a space station first became part of NASA's Future Projects Office, then part of the Apollo Applications Program. That project resulted in Skylab, the first U.S. space station, which was launched in 1973 (Figs. 9.236–9.238).[23]

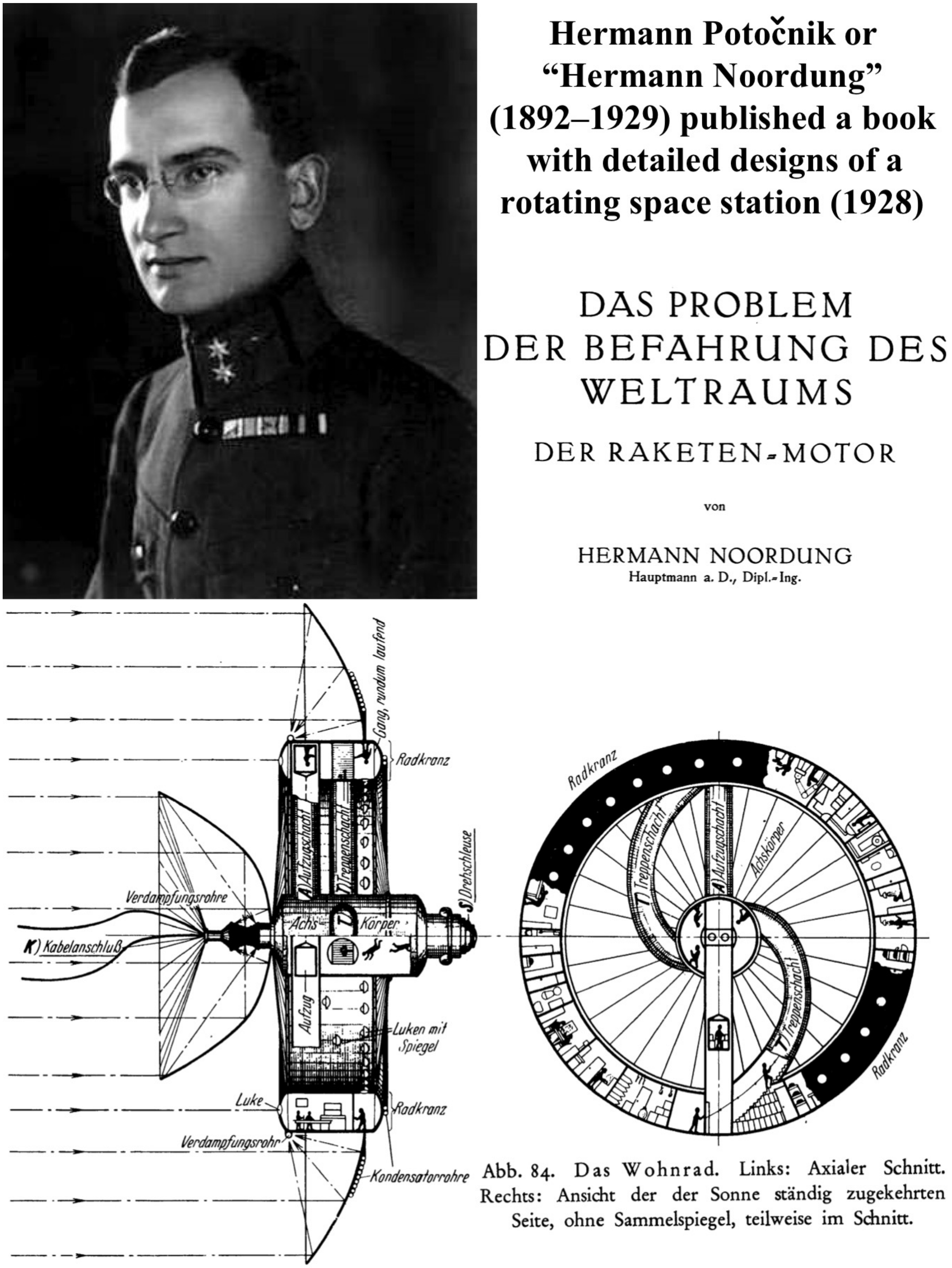
---

[23] Belew 1977; Benson and Compton 1983; Heppenheimer 1997; Michael Neufeld 2007; Newkirk et al. 1977; Shayler et al. 2018; Frank Winter 2019; https://www.nasa.gov/centers/marshall/history/skylab.html

The Skylab design was actually capable of far more than the United States did with it; von Braun's team envisioned it to transport and house astronauts during manned flybys of Venus and Mars in the 1970s [Portree 2012].

Oberth, von Braun, Krafft Ehricke, and other creators also produced many other detailed designs for manned missions to or bases on the moon, Mars, and elsewhere [e.g., von Braun 1991; Freeman 2008]. While those ideas have not been utilized yet, perhaps they will be in the future.

Even the current International Space Station came about largely because of the longtime political advocacy of Hans Mark (Austrian/German, 1929–), one of the sons of the chemist Herman(n) Mark (p. 655) [Hans Mark 1987]. See Fig. 9.239. (Herman Mark's other son, Peter Mark, 1931–1979, conducted important research on electronics at Polaroid and Princeton until his early death.)



Hermann Potočnik or “Hermann Noordung” (1892–1929) published a book with detailed designs of a rotating space station (1928)

DAS PROBLEM
DER BEFAHRUNG DES
WELTRAUMS

DER RAKETEN-MOTOR

von

HERMANN NOORDUNG
Hauptmann a. D., Dipl.-Ing.

Gang, rundum laufend
Radkranz
A) Aufzugschacht
T) Treppenschacht
S) Drehschleuse
Verdampfungsrohre
K) Kabelanschluß
Achs Körper
Aufzug
Luken mit Spiegel
Luke
Radkranz
Verdampfungsrohr
Kondensatorrohre
Radkranz
T) Treppenschacht
A) Aufzugschacht
Achskörper
T) Treppenschacht
Radkranz

Abb. 84. Das Wohnrad. Links: Axialer Schnitt. Rechts: Ansicht der der Sonne ständig zugekehrten Seite, ohne Sammelspiegel, teilweise im Schnitt.

Figure 9.232: Hermann Potočnik, under the pen name of “Hermann Noordung,” published a book with detailed designs of a large, circular, rotating space station in 1928.

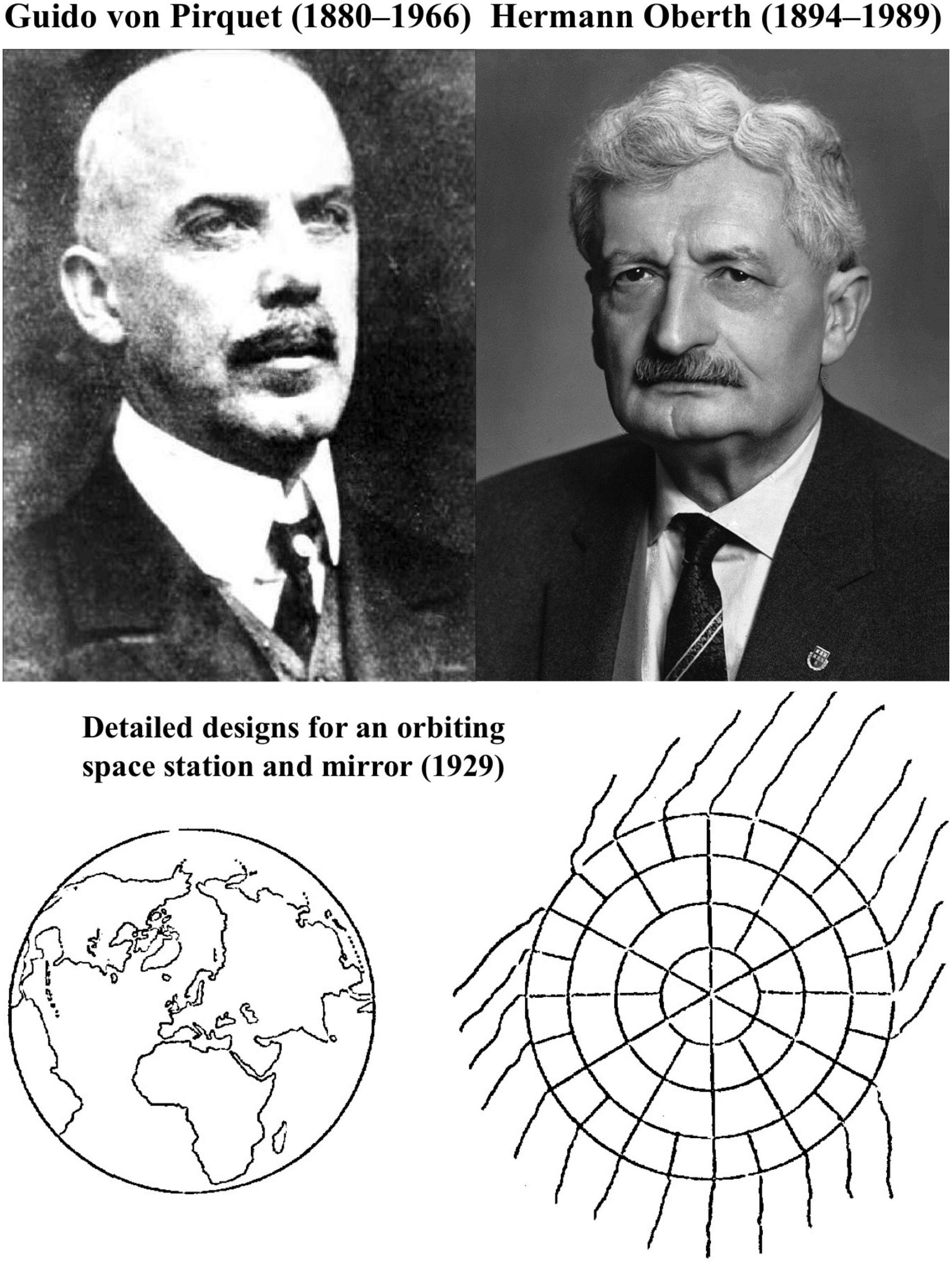
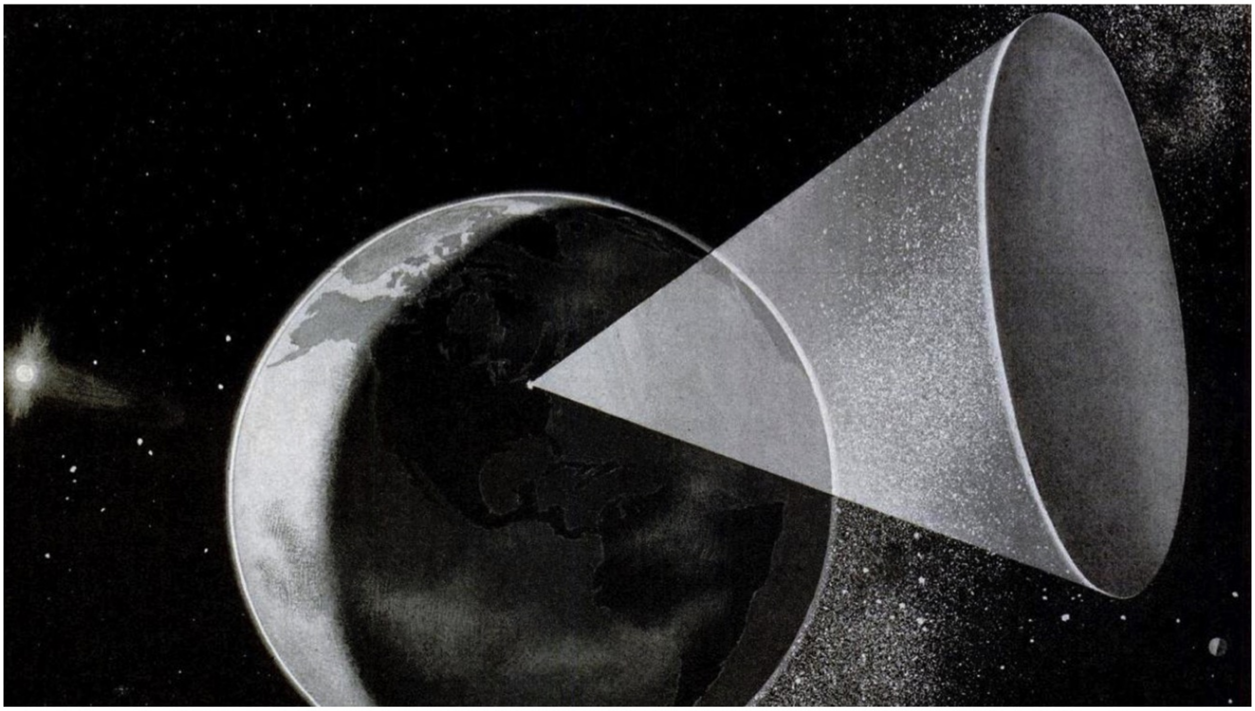
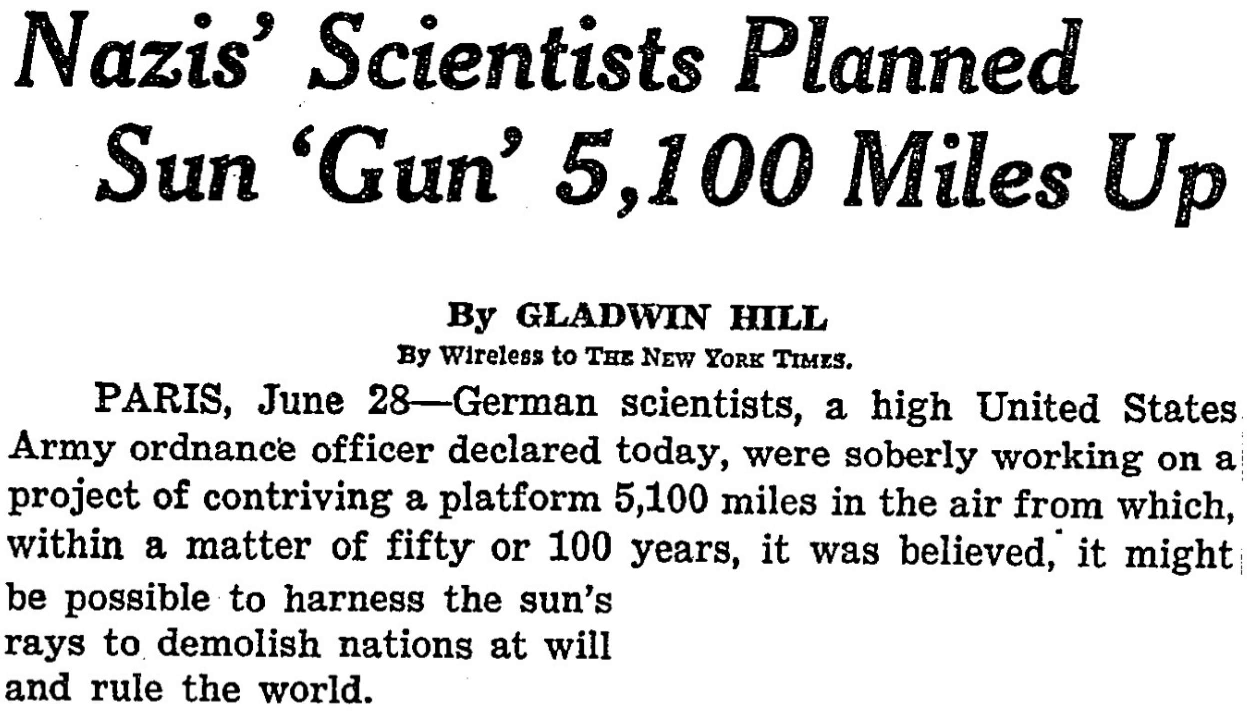

Guido von Pirquet (1880–1966)
Hermann Oberth (1894–1989)
Detailed designs for an orbiting space station and mirror (1929)

Figure 9.233: Guido von Pirquet and Hermann Oberth separately designed space stations in 1929. Oberth's station featured a kilometers-wide mirror to focus sunlight on areas of the Earth for either peaceful or military applications.

Plans for orbiting space station and mirror (1939–1945)





Nazis' Scientists Planned Sun 'Gun' 5,100 Miles Up

By GLADWIN HILL

By Wireless to THE NEW YORK TIMES.

PARIS, June 28—German scientists, a high United States Army ordnance officer declared today, were soberly working on a project of contriving a platform 5,100 miles in the air from which, within a matter of fifty or 100 years, it was believed, it might be possible to harness the sun's rays to demolish nations at will and rule the world.

Figure 9.234: Plans for an orbiting space station and space mirror were seriously studied during World War II.

1952 space station design from Wernher von Braun's team, drawn by Chesley Bonestell

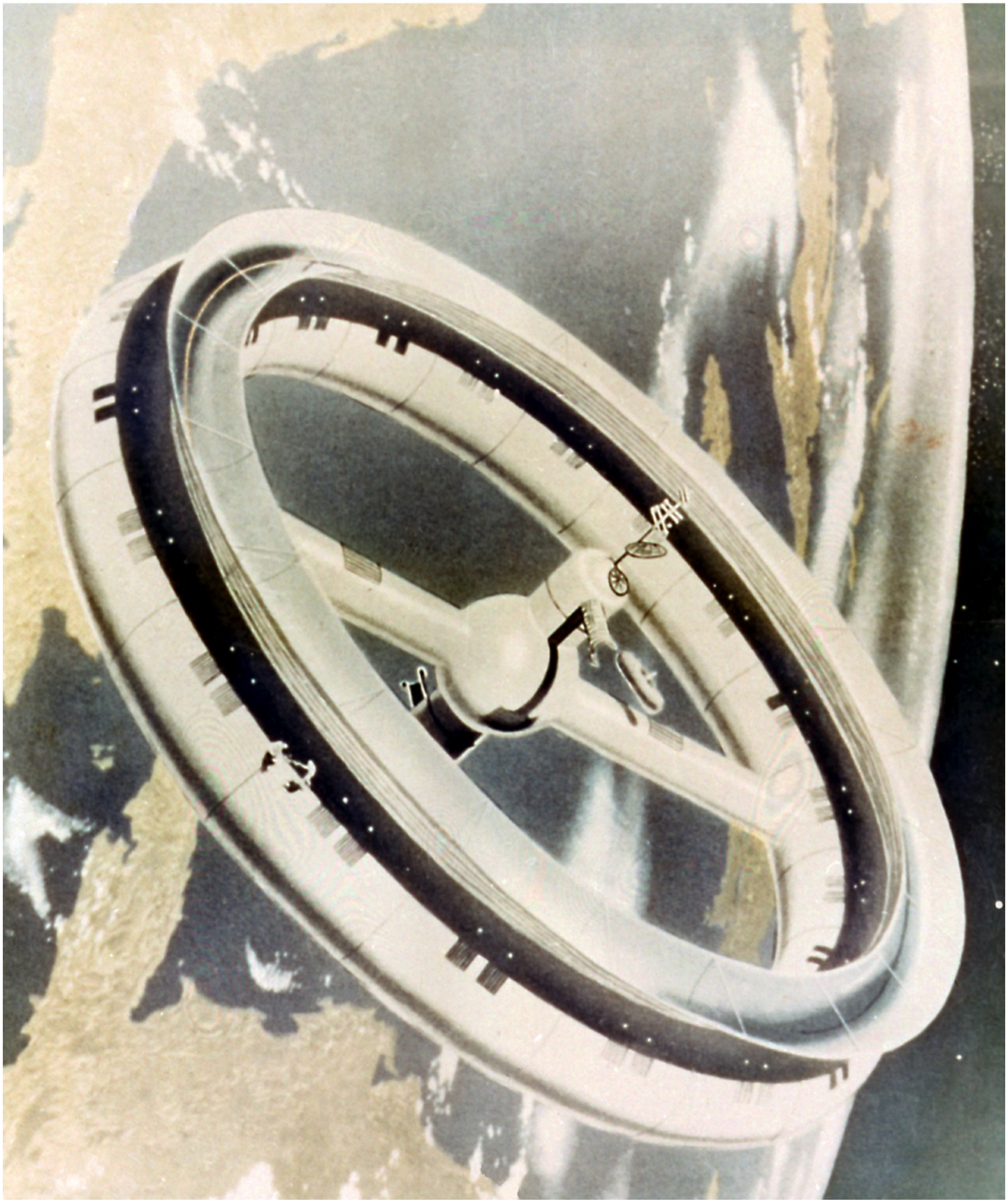
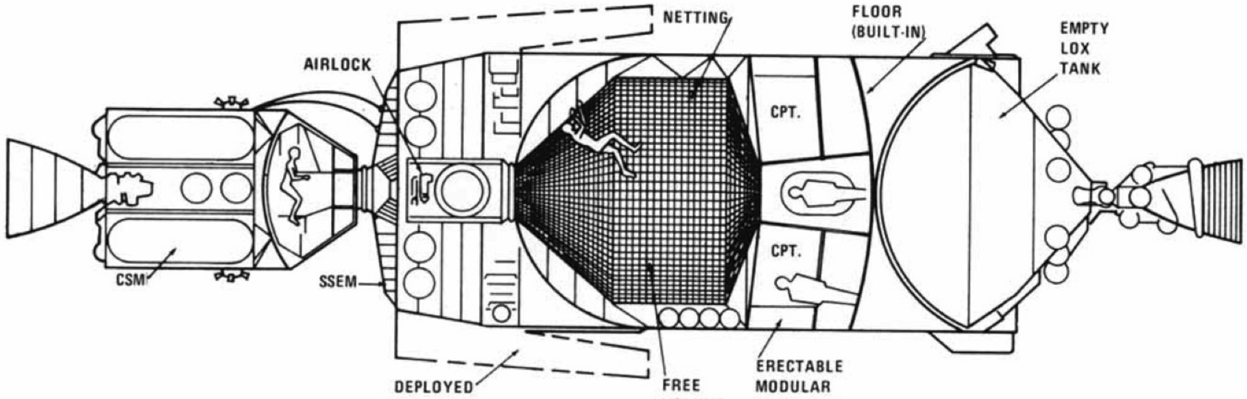
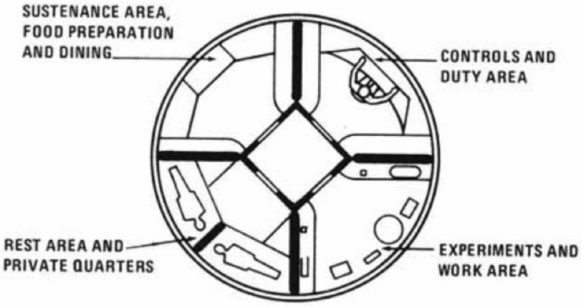
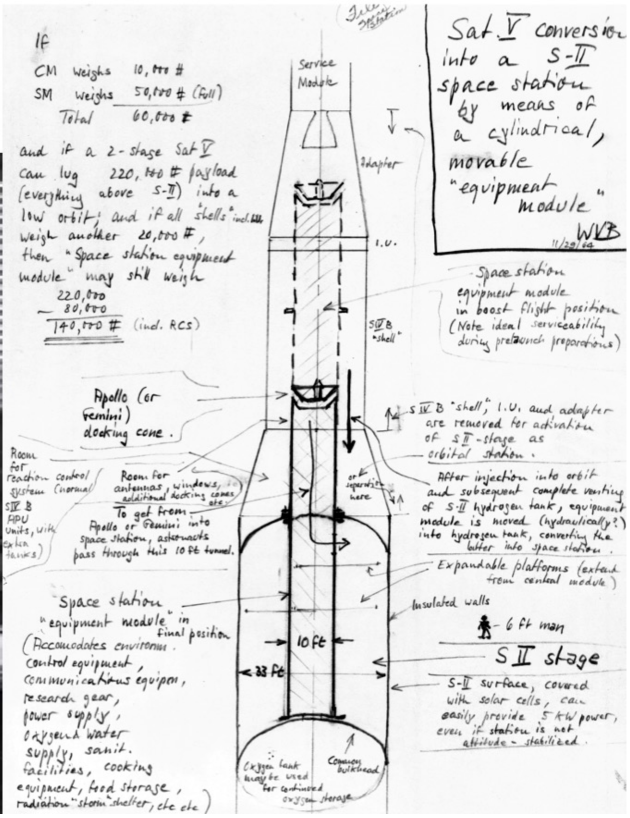


Figure 9.235: A 1952 space station design from Wernher von Braun's team, drawn by Chesley Bonestell, based on earlier designs by Hermann Potočnik, Guido von Pirquet, and Hermann Oberth.


NETTING
FLOOR (BUILT-IN)
EMPTY LOX TANK
AIRLOCK
CPT.
CPT.
CSM
SSEM
DEPLOYED SLA PETAL
FREE VOLUME
ERECTABLE MODULAR QUARTERS


SUSTENANCE AREA, FOOD PREPARATION AND DINING
CONTROLS AND DUTY AREA
REST AREA AND PRIVATE QUARTERS
EXPERIMENTS AND WORK AREA

Beginning no later than 1959, Wernher von Braun (below left), Heinz-Hermann Koelle (below right), and others in their group designed space stations converted from the empty upper stage of a Saturn rocket


Service Module
Adapter
I.U.
SIV B "shell"
10 ft
33 ft
Insulated walls
6 ft man
S II stage
Common bulkhead
or separation here

If
CM weighs 10,000 #
SM weighs 50,000 # (full)
Total 60,000 #

and if a 2-stage Sat V can lug 220,000 # payload (everything above S-II) into a low orbit; and if all "shells" incl. [illegible] weigh another 20,000 #, then "Space station equipment module" may still weigh
220,000
− 80,000
140,000 # (incl. RCS)

Sat. V conversion into a S-II space station by means of a cylindrical, movable "equipment module"

WVB 11/29/64

Space station equipment module in boost flight position (Note ideal serviceability during prelaunch preparations)

Apollo (or Gemini) docking cone.

Room for reaction control system (normal SIV B APU units, with extra tanks)

Room for antennas, windows, additional docking cones etc.

To get from Apollo or Gemini into space station, astronauts pass through this 10 ft tunnel.

SIV B "shell," I.U. and adapter are removed for activation of SII-stage as orbital station.

After injection into orbit and subsequent complete venting of S-II hydrogen tank, equipment module is moved (hydraulically?) into hydrogen tank, converting the latter into space station.

Expandable platforms (extend from central module)

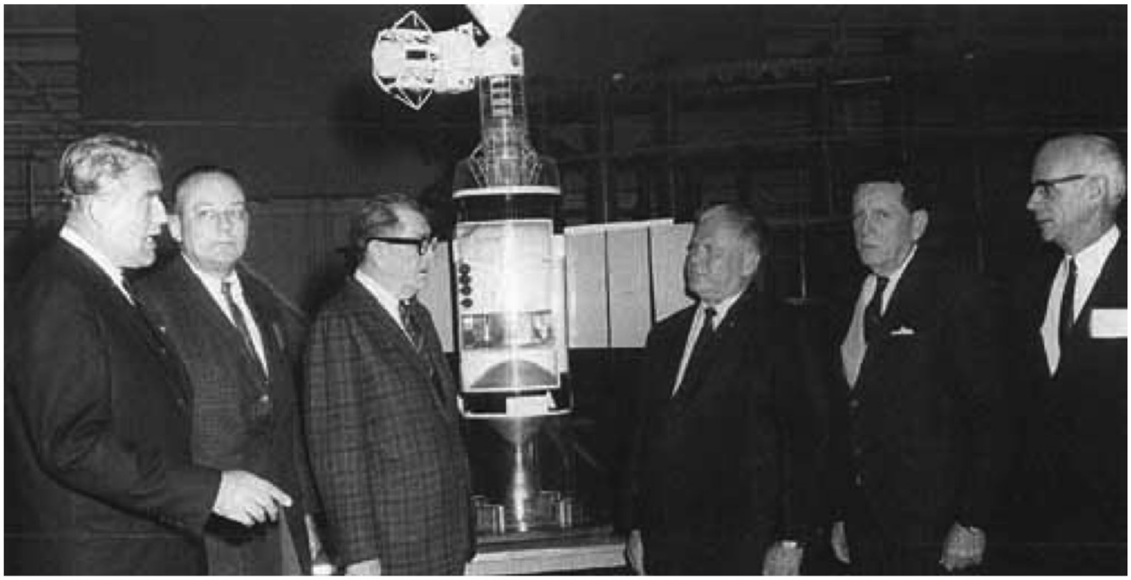
Space station "equipment module" in final position (Accomodates environm. control equipment, communications equipm, research gear, power supply, oxygen & water supply, sanit. facilities, cooking equipment, food storage, radiation "storm" shelter, etc etc)

S-II surface, covered with solar cells, can easily provide 5 KW power, even if station is not attitude-stabilized.

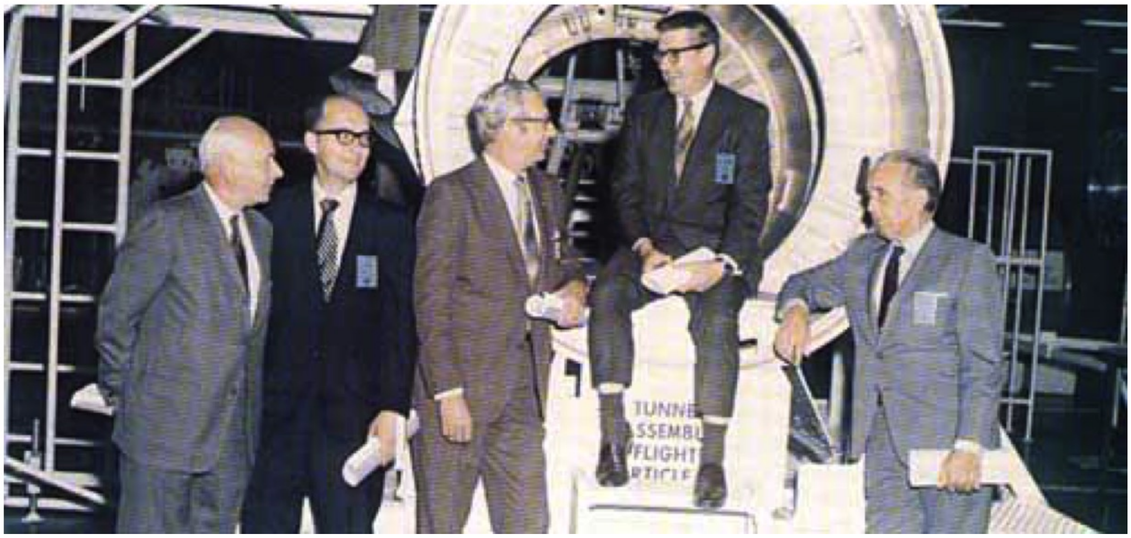
Oxygen tank may be used for continued oxygen storage

Figure 9.236: Beginning no later than 1959, Wernher von Braun, Heinz-Hermann Koelle, and others in their group designed space stations converted from the empty upper stage of a Saturn rocket.

Wernher von Braun (left) and Walter Häussermann (back) with Skylab mockup (October 1968)



Wernher von Braun (left) and Ernst Stuhlinger (right) with Skylab model (March 1969)



Eberhard Rees (left) and Kurt Debus (right) with Skylab hardware (April 1971)

Figure 9.237: NASA photographs illustrate the central role that German-speaking scientists such as Wernher von Braun, Walter Häussermann, Ernst Stuhlinger, Eberhard Rees, and Kurt Debus played in the design and development of the Skylab space station [Belew 1977].

Skylab space station, the converted upper stage of a Saturn V (launched in 1973)

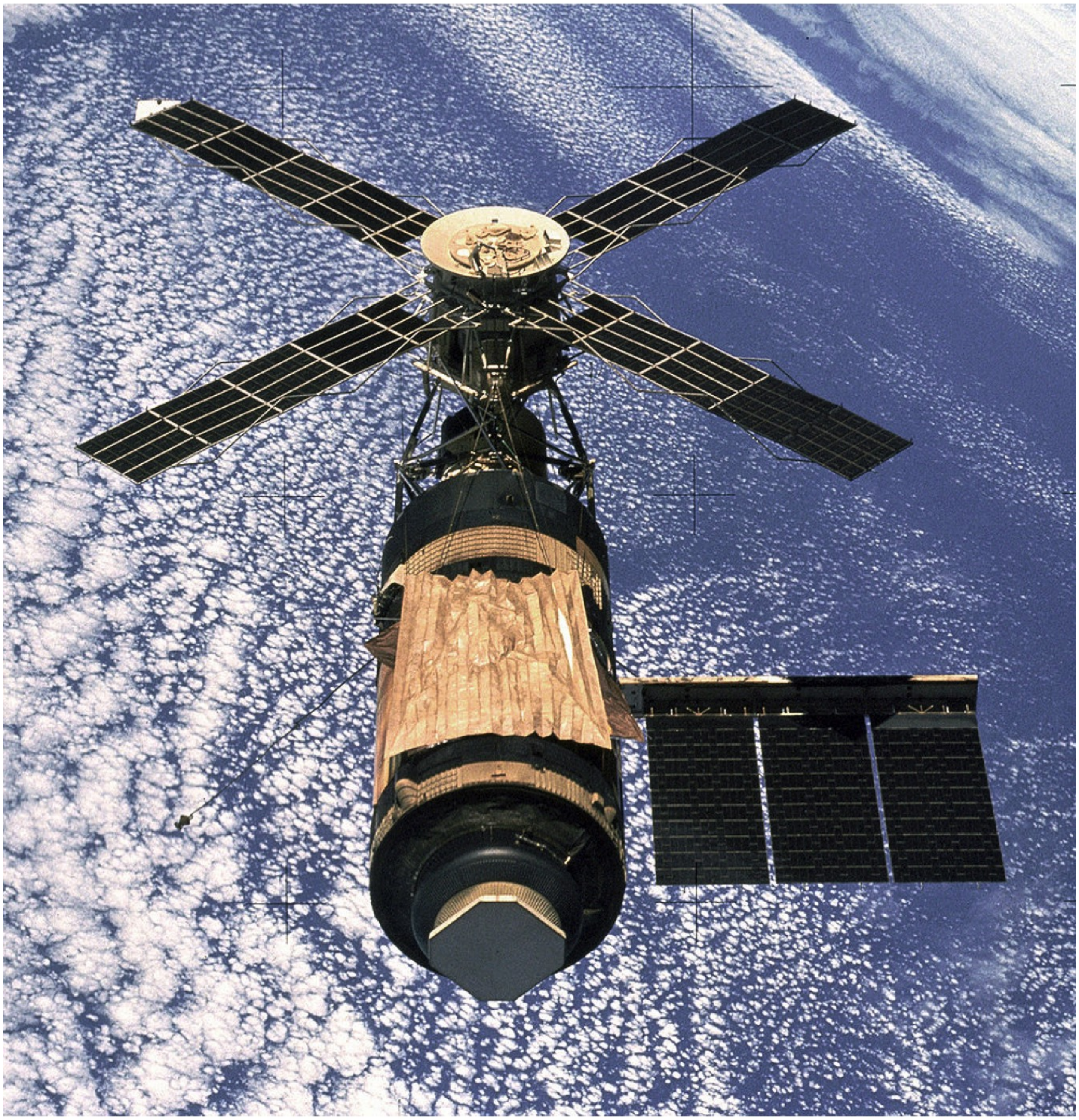
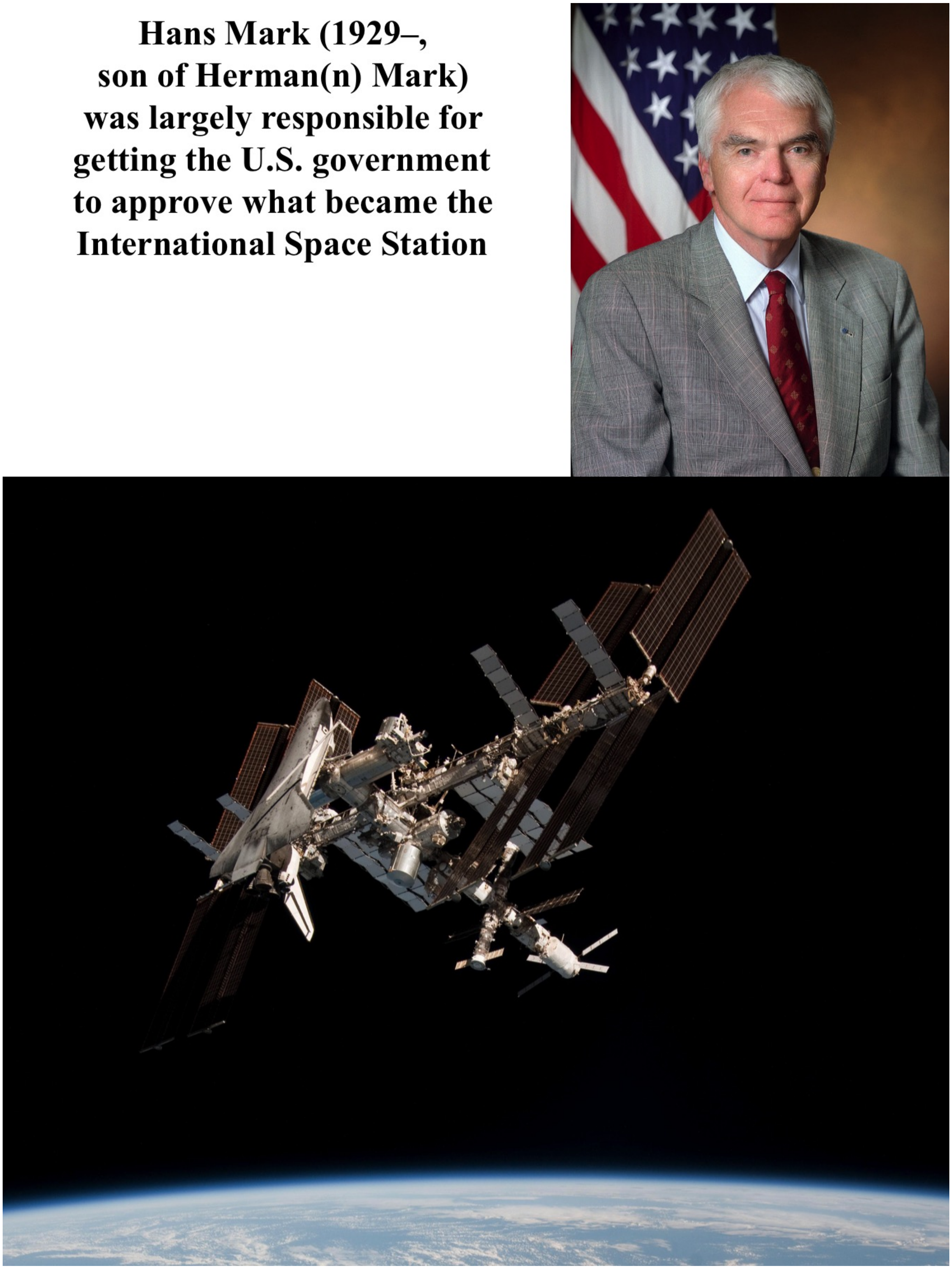


Figure 9.238: Skylab, the first U.S. space station, was built from the converted upper stage of a Saturn V rocket, and was launched in 1973.



Hans Mark (1929–,
son of Herman(n) Mark)
was largely responsible for
getting the U.S. government
to approve what became the
International Space Station

Figure 9.239: Hans Mark, the son of the chemist Herman(n) Mark, was largely responsible for getting the U.S. government to approve what became the International Space Station.

9.10.3 Non-Chemical Rockets

Whereas most rockets employ chemical reactions, non-chemical (i.e., nuclear) rockets could deliver much higher performance for deep space missions (Figs. 9.240–9.241). German-speaking scientists began the development of such advanced rocket propulsion systems during World War II and continued to lead their development after the war.

Fission thermal rockets store energy onboard in the form of a relatively conventional fission reactor, which is powered by suitable fuel such as uranium-233, uranium-235, or plutonium-239. Like chemical rockets, fission thermal rockets also store propellant onboard, yet unlike chemical rockets, fission thermal rockets do not require the propellant to undergo chemical reactions and release energy of its own. The propellant is simply heated by the reactor to achieve very high temperatures and pressures, then expelled out of the rocket nozzle, as shown in the upper part of Fig. 9.240. Minimizing the molecular weight of the expelled propellant maximizes the exhaust velocity, so most proposed fission thermal rockets use hydrogen propellant. The temperature to which the propellant is heated is limited by how hot the fission reactor can become without melting the fission fuel or other reactor components, but that still yields an exhaust velocity roughly twice that of the best chemical rocket engine.

The upper part of Fig. 9.242 shows that scientists at Peenemünde and the Reichspost began programs on nuclear rocket propulsion no later than 1942. Manfred von Ardenne (German, 1907–1997), Wernher von Braun, Krafft Ehricke (German, 1917–1984), Werner Heisenberg (1901–1976), Franz Josef Neugebauer (German, 1897–1983), Hans von Ohain (German, 1911–1998), Ernst Stuhlinger (German, 1913–2008), and others worked on fission thermal propulsion during the war (pp. 5757–5773). After the war, von Braun, Ehricke, Neugebauer, Stuhlinger, and others continued to seriously develop fission thermal propulsion in the United States, as shown in Figs. 9.242–9.243.

In contrast to fission thermal propulsion, fission pulse propulsion employs fission reactions that occur outside of the rocket, and therefore are not constrained by the melting temperatures of the fission fuel or any rocket components. Thus the fission reactions can reach the highest possible temperatures—those of a fission explosion. Small fission bombs could be ejected from the rear of the spacecraft; they would explode near the spacecraft, and some fraction of the blast would be intercepted by a thick ablative "pusher plate," transferring momentum while protecting the rest of the spacecraft (Fig. 9.240 bottom). To smooth out the violent shocks of intermittent explosions into more continuous and more survivable acceleration for the spacecraft, the pusher plate would be connected to the rest of the spacecraft by giant compressible shock absorbers. The heat, radiation, and shock to which the vehicle would be subjected pose formidable constraints on the materials and engineering design, yet the prospect of achieving both very high exhaust velocities and high thrust-to-weight ratios with an available energy source (fission explosives) is quite attractive.

Most books on the subject say that nuclear pulse propulsion was first proposed after World War II by Stanislaw Ulam (Polish, 1909–1984), who was a creator from the greater German-speaking world [e.g., Dyson 2002, p. 2]. In fact, this approach was first proposed and explored by even earlier German-speaking creators.

External pulse propulsion by conventional chemical explosives was first proposed by Hermann Ganswindt (German, 1856–1934) [Ron Miller 1993, pp. 75–76; Ron Miller 2016, p. 48].

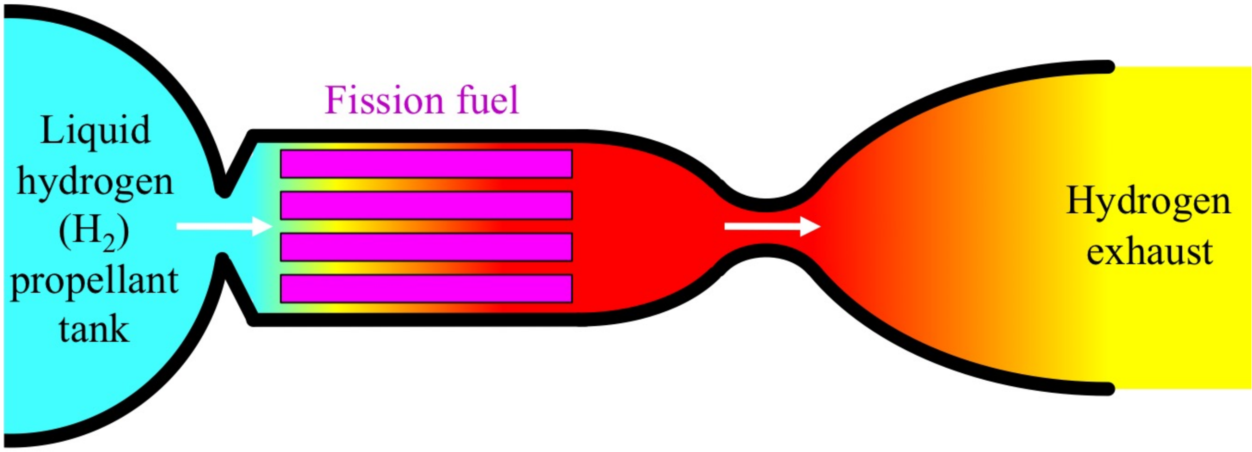
The sources on p. 5771 show that external pulse propulsion by nuclear explosives was first proposed in approximately 1942 by Wernher von Braun. Considering the German military's great wartime interest in and funding for rockets, nuclear weapons, and revolutionary methods of delivering heavy payloads long distances, it seems likely that fission pulse propulsion was seriously considered during the war, although little relevant documentation is currently available to the public. By the end of the war, work in this area had apparently progressed at least as far as creating small test models powered by conventional chemical explosives, which is as far as the postwar work ever progressed in the United States before the U.S. program was cancelled.

Electric rocket propulsion, or an ion-electron thruster, uses energy (heat, electric voltage, resonant electromagnetic waves, high-energy electrons from an electron gun, or other methods) to ionize initially electrically neutral propellant atoms into positively charged ions and negatively charged electrons, as shown in the upper half of Fig. 9.241. The positively charged ions are accelerated by the voltage difference between two electrically charged grids and ejected from the rear of the spacecraft at some desired velocity. To prevent the spacecraft from accumulating more and more net negative electric charge (as a result of the lost ions) that would actually draw the ejected ions back to the spacecraft, electrons that have been stripped off the ions must also be ejected, generally by harvesting them from the ionization chamber and firing them from electron guns toward the departing ion exhaust. This method of particle acceleration can produce much higher exhaust velocities than chemical combustion or even fission thermal rockets. However, because charged particle beams have far lower densities than flows of more traditional rocket propellant, their thrust is very low. Thus electric propulsion is best for deep space missions where a low thrust applied over the course of months or even years can yield useful final velocities or changes in the spacecraft's orbit. Although ion-electron thrusters could be powered by solar panels or any other source of electrical energy, it is usually proposed to power them with a fission reactor.

Electric rocket propulsion systems were first proposed by Hermann Oberth in 1929 (p. 5772). Experimental development of electric propulsion in Germany began no later than 1937 and continued until at least 1944 (p. 5311). Ernst Stuhlinger, Wernher von Braun, and other German-speaking scientists continued to develop and promote electric propulsion after the war (pp. 1958, 5772). Currently very few documents on the wartime electric propulsion program are publicly available, but it seems likely that Oberth, Stuhlinger, and von Braun were involved in it as well.

Antimatter rockets, first proposed by Eugen Sänger, would store matter and antimatter propellant, then carefully combine them to create very high-energy exhaust (Figs. 9.241 and 9.243). For equal amounts of matter and antimatter, 100% of the combined propellant mass could be converted to energy, versus $< 1\%$ for nuclear reactions, so antimatter propulsion could yield the maximum performance obtainable from a rocket, with exhaust velocities approaching the speed of light. For maximum density, the antimatter could be stored as anti-atoms such as anti-hydrogen (an antiproton plus a positron, or antimatter electron), safely isolated from any matter by electric and/or magnetic fields. Annihilation of an antiproton with a proton creates $\sim 2/3$ charged and $\sim 1/3$ uncharged pions; the charged pions can be directed out a magnetic nozzle before they decay into gamma rays, although the neutral pions would be nearly impossible to direct.

Nuclear thermal rocket propulsion


Fission fuel
Liquid hydrogen (H_2) propellant tank
Hydrogen exhaust

Nuclear pulse rocket propulsion

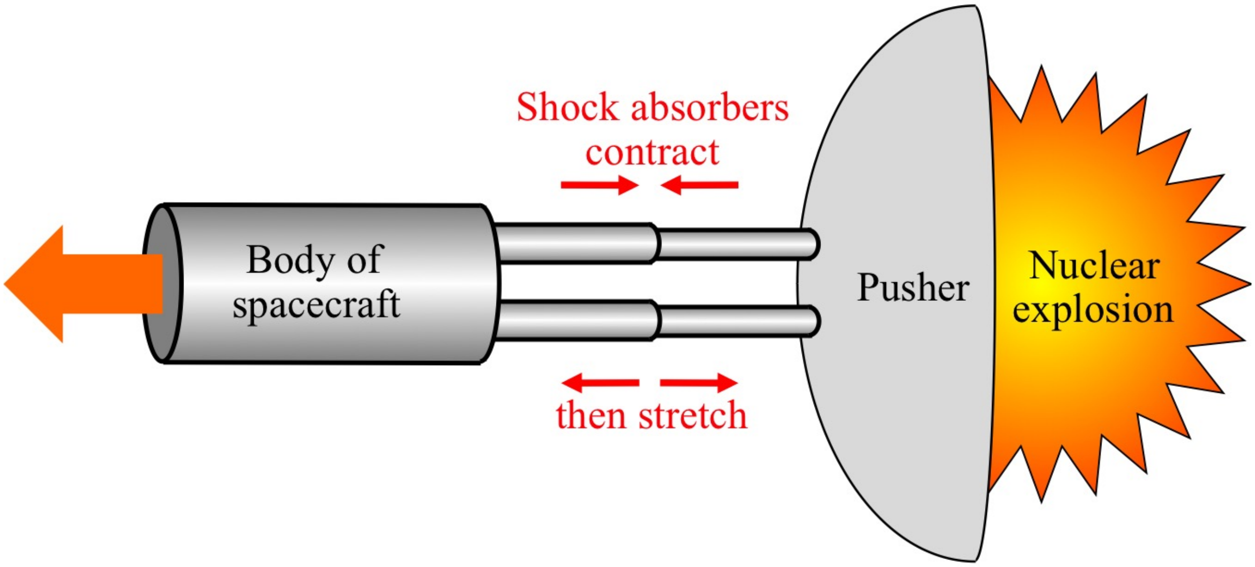
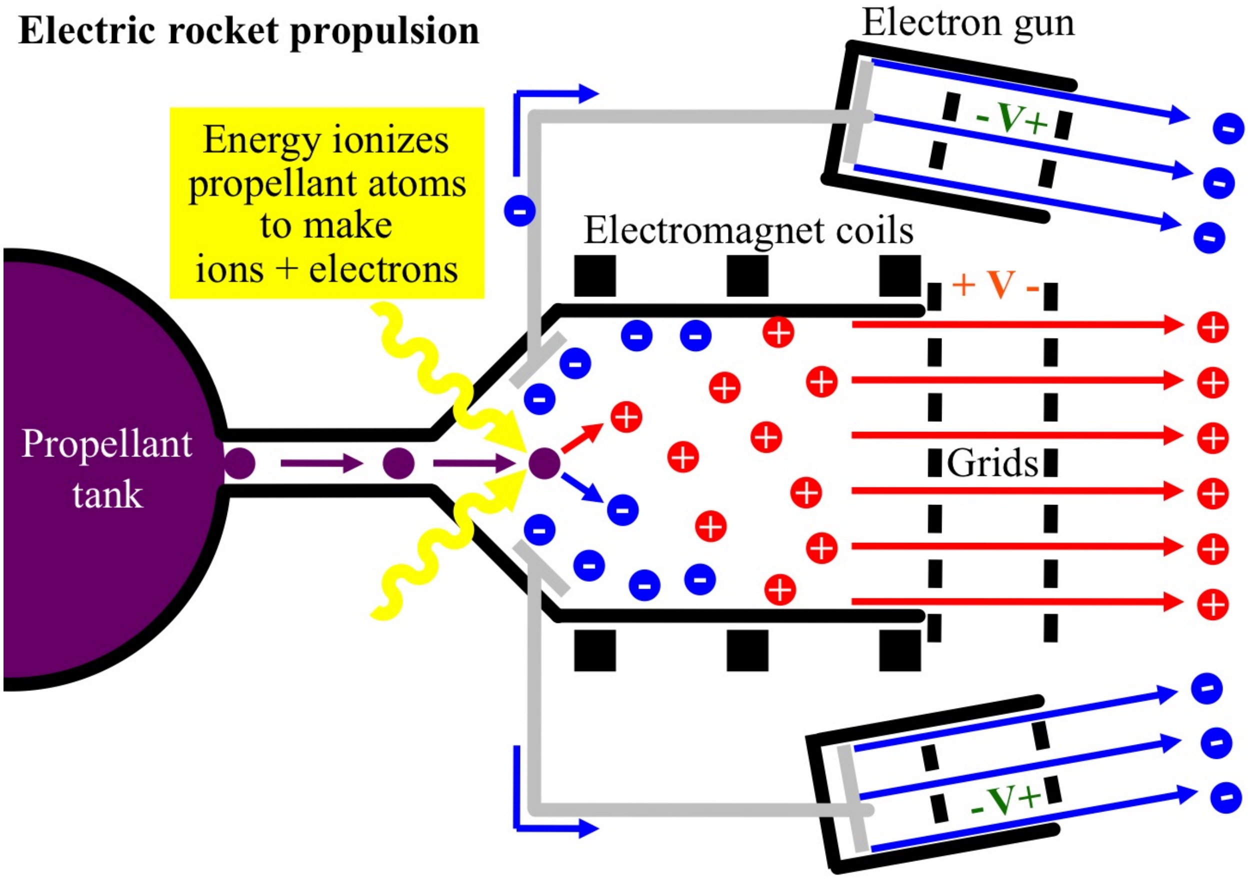

Shock absorbers contract
then stretch
Body of spacecraft
Pusher
Nuclear explosion

Figure 9.240: Nuclear rocket propulsion approaches. Above: fission thermal rocket propulsion, in which hydrogen propellant is heated by an internal fission reactor. Below: nuclear pulse propulsion, in which small nuclear bombs are ejected from a spacecraft and explode outside the spacecraft, pushing the spacecraft.


Electric rocket propulsion
Electron gun
-V+
Energy ionizes propellant atoms to make ions + electrons
Electromagnet coils
+ V -
Propellant tank
Grids
-V+

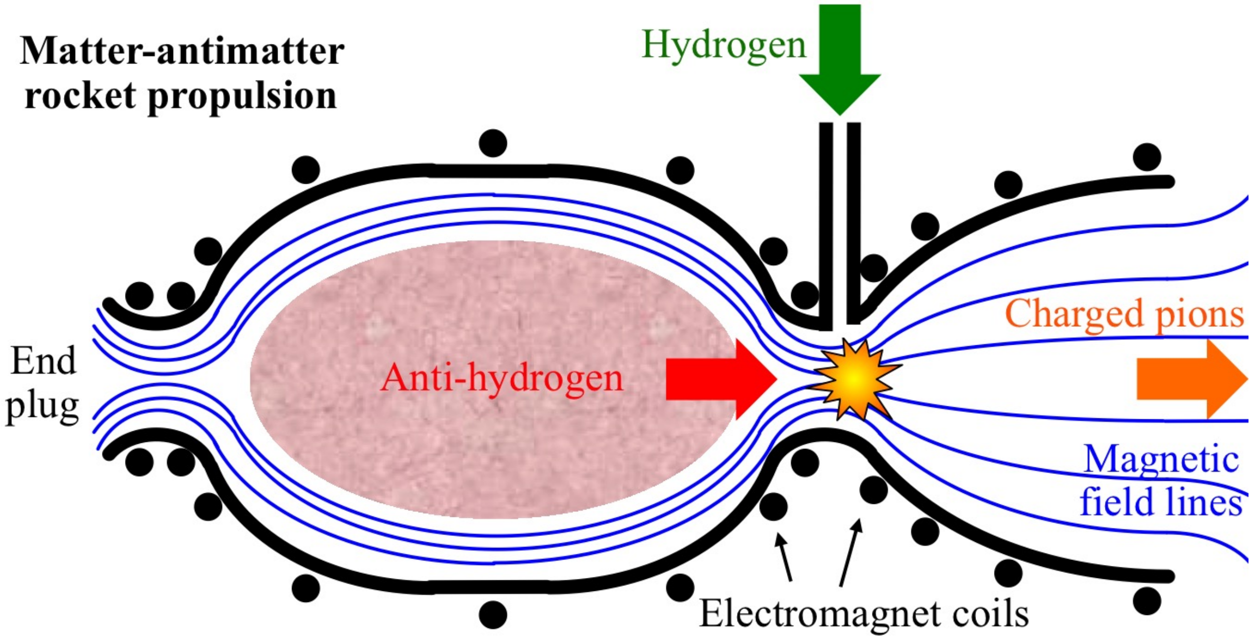
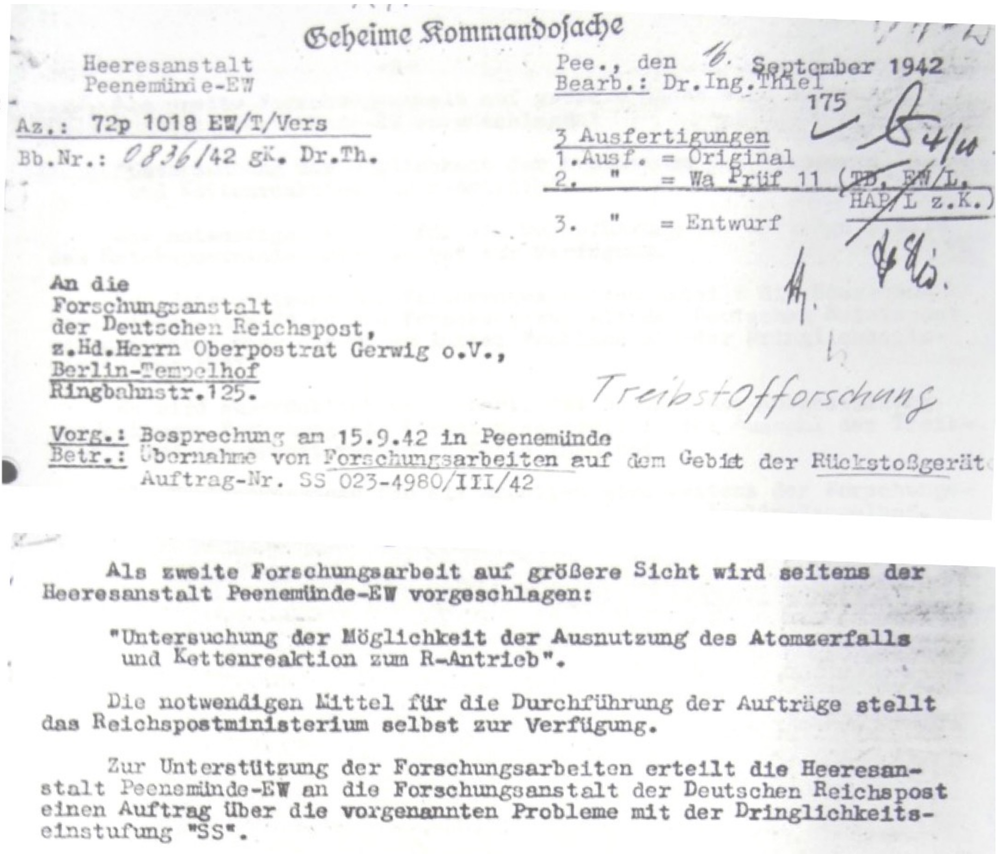

Matter-antimatter rocket propulsion
Hydrogen
Charged pions
End plug
Anti-hydrogen
Magnetic field lines
Electromagnet coils

Figure 9.241: Rocket propulsion by an ion-electron thruster (above, also called electric rocket propulsion) and matter-antimatter annihilation (below).

Scientists at Peenemünde and the Reichspost began a program on nuclear rocket propulsion no later than 1942



Geheime Kommandoſache

Heeresanstalt
Peenemünde-EW

Pee., den 16. September 1942
Bearb.: Dr.Ing.Thiel
175

Az.: 72p 1018 EW/T/Vers
Bb.Nr.: 0836/42 gK. Dr.Th.

3 Ausfertigungen
1.Ausf. = Original
2. " = Wa Prüf 11 (TD, EW/L, HAP/L z.K.)
3. " = Entwurf

An die
Forschungsanstalt
der Deutschen Reichspost,
z.Hd.Herrn Oberpostrat Gerwig o.V.,
Berlin-Tempelhof
Ringbahnstr.125.

Treibstofforschung

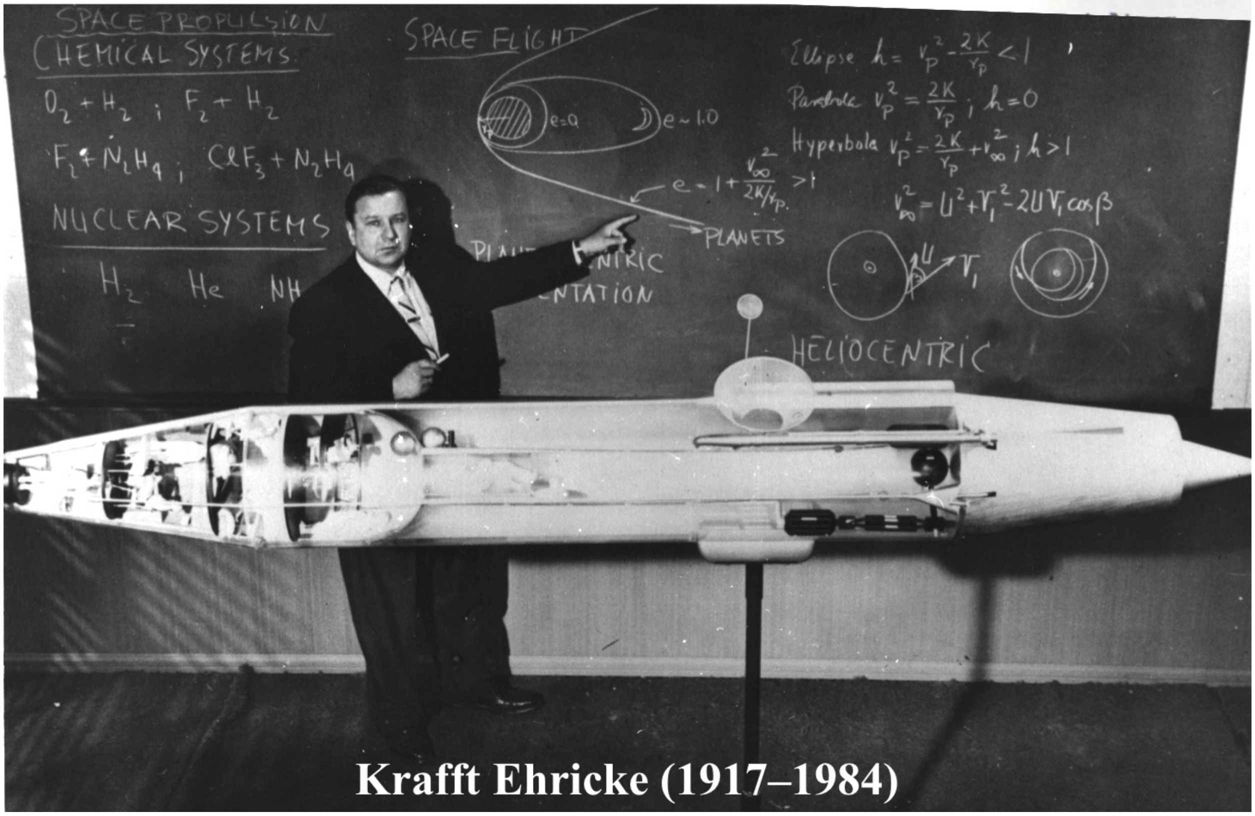
Vorg.: Besprechung am 15.9.42 in Peenemünde
Betr.: Übernahme von Forschungsarbeiten auf dem Gebiet der Rückstoßgerät
Auftrag-Nr. SS 023-4980/III/42

Als zweite Forschungsarbeit auf größere Sicht wird seitens der Heeresanstalt Peenemünde-EW vorgeschlagen:

"Untersuchung der Möglichkeit der Ausnutzung des Atomzerfalls und Kettenreaktion zum R-Antrieb".

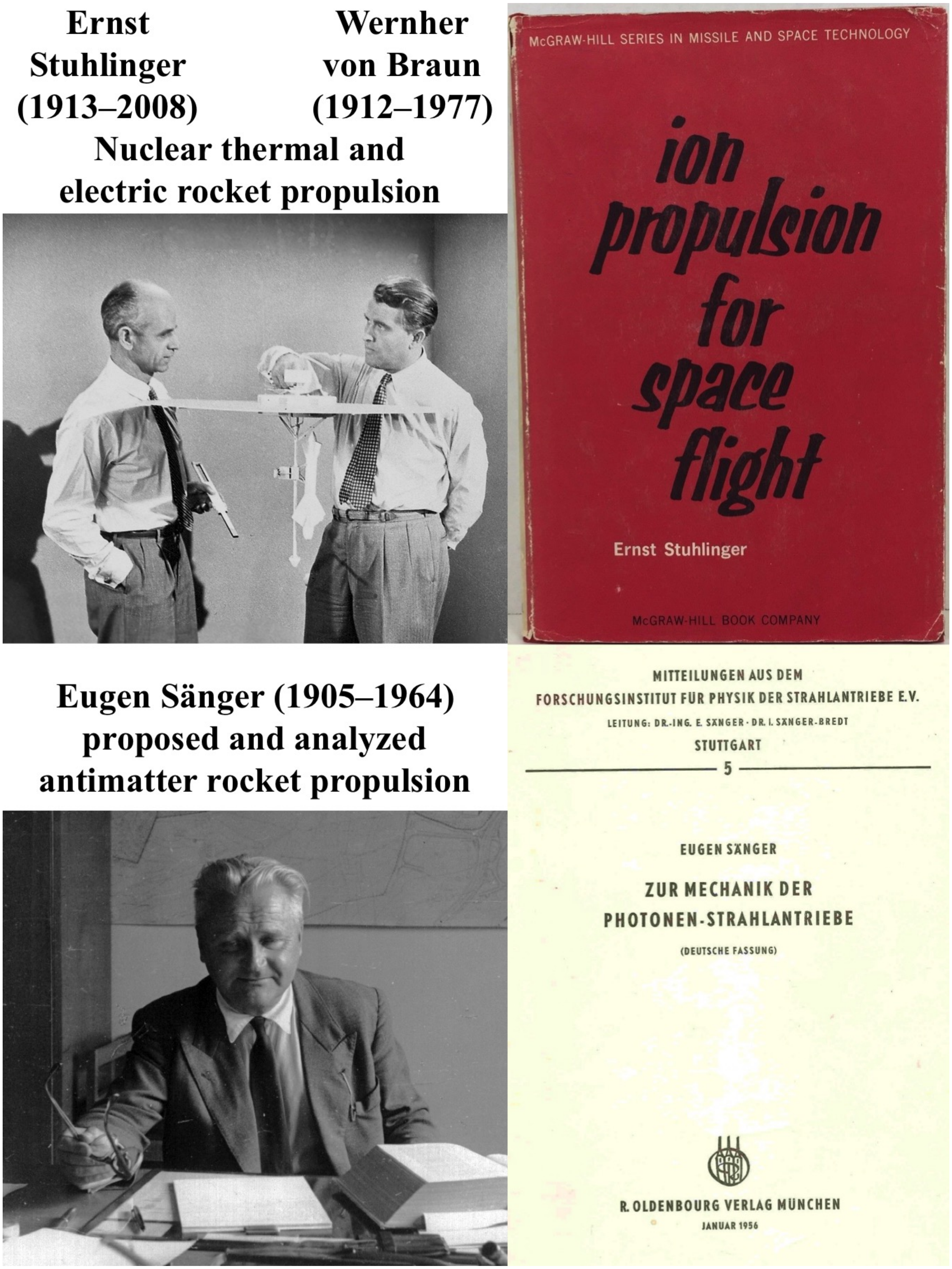
Die notwendigen Mittel für die Durchführung der Aufträge stellt das Reichspostministerium selbst zur Verfügung.

Zur Unterstützung der Forschungsarbeiten erteilt die Heeresanstalt Peenemünde-EW an die Forschungsanstalt der Deutschen Reichspost einen Auftrag über die vorgenannten Probleme mit der Dringlichkeitseinstufung "SS".


SPACE PROPULSION
CHEMICAL SYSTEMS
$O_2 + H_2$; $F_2 + H_2$
$F_2 + N_2H_4$; $ClF_3 + N_2H_4$
NUCLEAR SYSTEMS
H_2 He NH
SPACE FLIGHT
e=0
e~1.0
$e = 1 + \frac{v_\infty^2}{2K/r_p} > 1$
PLANETS
PLANETOCENTRIC ORIENTATION
Ellipse $h = v_p^2 - \frac{2K}{r_p} < 1$
Parabola $v_p^2 = \frac{2K}{r_p}$; $h=0$
Hyperbola $v_p^2 = \frac{2K}{r_p} + v_\infty^2$; $h>1$
$v_\infty^2 = U^2 + V_1^2 - 2UV_1\cos\beta$
HELIOCENTRIC

Krafft Ehricke (1917–1984)

Figure 9.242: Scientists such as Krafft Ehricke at Peenemünde and the Reichspost began programs on nuclear rocket propulsion no later than 1942, and continued their work in the United States.


Ernst Stuhlinger (1913–2008)
Wernher von Braun (1912–1977)
Nuclear thermal and electric rocket propulsion
Eugen Sänger (1905–1964) proposed and analyzed antimatter rocket propulsion

McGRAW-HILL SERIES IN MISSILE AND SPACE TECHNOLOGY

ion propulsion for space flight

Ernst Stuhlinger

McGRAW-HILL BOOK COMPANY

MITTEILUNGEN AUS DEM
FORSCHUNGSINSTITUT FÜR PHYSIK DER STRAHLANTRIEBE E.V.
LEITUNG: DR.-ING. E. SÄNGER · DR. I. SÄNGER-BREDT
STUTTGART

5

EUGEN SÄNGER

ZUR MECHANIK DER
PHOTONEN-STRAHLANTRIEBE

(DEUTSCHE FASSUNG)

R. OLDENBOURG VERLAG MÜNCHEN
JANUAR 1956

Figure 9.243: Ernst Stuhlinger, Wernher von Braun, and others worked on both nuclear thermal and nuclear electric propulsion in Germany during the war and in the United States after the war. Eugen Sänger was the first scientist to propose and analyze antimatter rocket propulsion systems.

Chapter 10

Creating the Creators

Gaben, wer hätte sie nicht?	Gifts, who is without them?
Talente—Spielzeug für Kinder.	Talents—mere toys for children.
Erst der Ernst macht den Mann,	Seriousness makes the man,
Erst der Fleiss das Genie.	Application the genius.

Theodor Fontane. 1908. Unter ein Bildnis Adolf Menzels.
Gedichte. Stuttgart/Berlin. p. 325.

Chapters 2–9 and Appendices A–E give an overview of a representative (though certainly not exhaustive) set of revolutionary creators and creations that came out of the predominantly German-speaking research world of the nineteenth and early twentieth centuries. There are many indications that systemic innovation-promoting factors were largely responsible for the production of those creators and creations:

- The German-speaking creators and creations came from a relatively small geographical region within a limited period of time, which should prompt close examination of the systemic practices of that place and time that may have contributed to their success.
- That place and time produced a truly enormous number of revolutionary innovations. In fact, it is difficult to identify as many revolutionary innovations that have been wholly developed by the modern research world (not counting innovations that were made by the earlier German-speaking world but adopted and polished by the modern world).
- The former German-speaking world produced that huge number of revolutionary innovations despite having far fewer researchers than the modern world.
- The earlier German-speaking world produced that large number of revolutionary innovations despite having far less research funding than the modern world.
- The former German-speaking world produced so many revolutionary innovations despite having far less political stability than the modern world. It remained highly productive in spite of forces including German unification, Kaiser Wilhelm II's autocracy, World War I, the financial and political crises of the Weimar period, the savagery of the Third Reich, and the devastation of World War II.

- The earlier German-speaking world was not merely holding its position ahead of international competitors, but rather was actually accelerating further and further ahead of other countries. At the beginning of the nineteenth century, scientific fields were generally dominated by researchers in France, the United Kingdom, and a few other countries, and scientific research projects and science/engineering-based industry in the German-speaking world were scarce or lagged years behind the international competition. German-speaking scientists and engineers seriously entered most fields sometime during the nineteenth century, starting from that position of being far behind. As illustrated by the innovators and innovations in Chapters 2–9 and the appendices, by the end of the nineteenth century, German-speaking scientists were ahead in most fields. By 1945, they had overwhelmingly dominated most fields, contributing most of the major new innovations in each field and running years ahead of their competitors, in many cases by a decade or more (e.g., rockets, chemical synthesis, etc.).

Motivated by the above facts, Section 10.1 first compares the size of the early German-speaking research world to that of the modern U.S. and global innovation systems.

Section 10.2 then identifies several specific factors within the German-speaking world that promoted revolutionary innovation:

10.2.1. Science was socially glorified, from children's activities and amateur science clubs to prestigious jobs and government-lauded scientific heroes.

10.2.2. A century-long steady exponential increase in funding gave scientists, employers, and sponsors much more freedom to pursue higher-risk and/or longer-term research.

10.2.3. Many Ph.D. students were encouraged to propose their own research topics and to pursue them independently.

10.2.4. Scientists received their final degrees nearly a decade earlier in life, and independent research funding up to two decades earlier, than modern scientists do.

10.2.5. Scientists who made major contributions to multiple disciplines, and fraternization among scientists from different disciplines, were much more common than in the modern world.

10.2.6. Instead of peer review, an autocratic yet farsighted scientific management culture of "enlightened despots" granted stable jobs and funding to the most promising creators and creations.

10.2.7. Both scientists and sponsors used a systems analysis approach to focus on the most important problems and the most effective innovations to address those problems.

10.2.8. The lack of natural resources spurred the creation of a wide range of innovative alternatives.

10.2.9. International rivalry (both economic and military) was a powerful driving force for innovation.

10.2.10. German-speaking companies were less afraid of losing their own innovations to each other than of being outstripped by foreign countries, giving them a strong motivation to innovate.

10.2.11. There are also other possible factors that should be investigated by future researchers.

10.1 Comparison of Innovation System Size

Before studying factors that promoted innovation in the German-speaking world, one should first consider the total population of the German-speaking world and the size of its innovation system relative to numbers for the modern world.

10.1.1 Total Population and Scientific Innovators in the German-Speaking World

The population of the German-speaking world was spread among several countries, and those countries, their borders, and their populations changed over time. Table 10.1 gives the populations in millions of people for a few key years.

Country	**1871**	**1900**	**1914**
Austria-Hungary	36.0	45.2	52.5
Germany	41.1	56.4	67.0
Netherlands	3.6	5.1	6.3
Switzerland	2.7	3.3	3.8
TOTAL	**83.4**	**110.0**	**129.6**

Country	**1939**
Austria	6.7
Czechoslovakia	14.8
Germany (within 1937 borders)	69.5
Hungary	9.2
Netherlands	8.8
Poland	34.8
Switzerland	4.2
TOTAL	**148.0**

Table 10.1: Populations (in millions of people) of central European countries that were involved in the German-speaking research world. The 1939 data covers approximately the same geographical area as the data from the earlier years, but some of the country names are different due to the altered borders [Mitchell 1975; https://www.destatis.de; https://www.statistik.at; https://www.cbs.nl; https://www.bfs.admin.ch].

Of course, in some of the countries listed in Table 10.1, only some fraction of the population was actually German-speaking or interacted directly or indirectly with the German-speaking research world. Although the total population was steadily increasing apart from wars, ∼100–130 million people is a good general estimate for the total population of the German-speaking world during the early twentieth century.

Like the postwar U.S. research system, the earlier German-speaking research world was divided into three sectors: academic, corporate, and government laboratories.

1. Many universities had very diverse and advanced research programs, especially those in Berlin, Munich, Göttingen, Vienna, Zurich, Prague, etc.

2. Many German companies maintained very large, very well-funded laboratories where company researchers were encouraged to keep inventing and developing 10–20 years worth of future products for the corporate pipeline. Those companies included the various chemical and pharmaceutical companies that ultimately consolidated into I.G. Farben, electrical companies such as Siemens, AEG, and Telefunken, aerospace companies such as Heinkel and Junkers, etc.

3. Government laboratories included multiple labs run by each branch of the military, various dedicated biology and medical labs, the many different Kaiser Wilhelm Institutes (now called the Max Planck Institutes) in different scientific fields, and even advanced electronics and nuclear laboratories run by the German postal service (Reichspost).

Also like the U.S. system, much of the German-speaking university and corporate research was sponsored by the government, with the rest being funded by companies investing in their own labs and also investing in long-term partnerships with universities and with the Kaiser Wilhelm Institutes.

Good estimates of the total number of people involved in the historical German-speaking research world are difficult to find and depend greatly on the definitions one uses. Some relevant data that can be considered includes:

- Werner Osenberg, head of the planning board of the Reichsforschungsrat (German Research Council), compiled a list of 15,000 significant scientists, engineers, medical research doctors, and technicians during the period 1943–1945 [Jacobsen 2014, p. 41]. (He also listed 1400 research facilities.) Estimates are that ∼15–33% of scientists and engineers fled or were forcibly removed from the German-speaking research world during the Third Reich, primarily due to persecution of those with Jewish ancestry or spouses [Ash and Söllner 1996, p. 7]. This suggests a prewar number of ∼20,000 noteworthy scientists and engineers.

- Over 2000 German-speaking scientists and engineers emigrated to the United States soon after World War II as part of Operation Paperclip and Paperclip-related programs [Linda Hunt 1991, p. 1], over 3000 were employed (willingly or otherwise) by the Soviet Union [Mick 2000], over 1000 by the United Kingdom [Glatt 1994], over 1000 by France [Nouzille and Huwart 1999], and at least many hundreds by other countries [Michael Neufeld 2012]. Adding up those numbers gives a total of at least ∼7,500 scientists who are known to have gone to other countries. Multiplying that number by a factor of ∼2 to account for those who remained in Germany and Austria or who moved to other countries but were not included in the official totals puts this estimate in good agreement with the 15,000 on the Osenberg list. (Indeed, the captured Osenberg list was used by Allied countries in their efforts to recruit German-speaking scientists after the war.) Again factoring in those who fled the Reich gives a rough prewar estimate close to 20,000 scientists and engineers.

- A maximum of approximately 4300 staff worked at German aviation research establishments during World War II [Hirschel et al. 2004, p. 659]. Because aircraft, missiles, and rockets were a large area of focus during the war, that number seems consistent with the above total estimates derived from the Osenberg list and Allied recruiting.

- Deichmann found 445 biologists in Germany, Austria, and the Sudetenland between 1933 and 1945 [Deichmann 1996]. Considering that Deichmann's list omitted many major researchers conducting biology-related research within the Reich (Kurt Blome, Adolf Butenandt, Gerhard Domagk, Eugen Haagen, Heinrich Kliewe, Richard Kuhn, Walter Schreiber, Erich Traub, etc., perhaps because they were medical doctors or chemists conducting biology research, or perhaps because they were part of military research programs) and did not consider German-speaking researchers beyond those geographical regions, the total number of active biology researchers may have been at least twice Deichmann's figure, say perhaps 1000. In view of the number of other fields (chemistry, physics, engineering, etc.) and their popularity relative to biology, the total estimates derived from the Osenberg list and Allied recruiting efforts again seem quite plausible.

- Using the major innovations identified in this book and considering the key innovators behind them (Chapters 2–9 and the appendices), there appear to have been at least ∼2000 especially important German-speaking creators, not all of whom were alive at the same time. This number agrees well with various 1945–1948 Allied lists of key scientists who had been recruited or were targets of recruitment [NARA RG 330 Entry A1-1A].

Based on this data, at a given time in the early twentieth century, the German-speaking world appears to have had no more than ∼2000 creators who were personally making revolutionary discoveries or inventions.

Those creators were part of a system that was approximately a factor of ten times larger and contained ∼20,000 scientists and engineers who at least had documented track records.

(If one were to generously multiply that number by an additional factor of ∼10 to account for all of the people who may have contributed to the system in any fashion from technicians to teaching aides, the total size of the science and engineering world in German-speaking Europe was at most perhaps ∼200,000 people.)

10.1.2 Comparison with the Modern World

Whereas the German-speaking world had a total population of ∼100–130 million people during the early twentieth century, in 2020 the estimated population of the United States was 330 million, and the estimated population of the whole world was 7.7 billion people [www.worldometers.info/world-population]. Thus the earlier German-speaking world had a total population that was ∼1/3 that of the modern United States, and roughly ∼1/70 of the modern global population.

To compare research system sizes, as of 2015 (the most recent year for which fully analyzed statistics are available), there were over 1.3 million people employed in research in the United States, and over 7 million worldwide, as shown on p. 40. (As with the German-speaking world, one might also inflate these modern numbers by a factor of ∼10 to account for all of those people who obtain science or engineering degrees but do not ultimately do research, or who interact with the system in some other fashion.)

Using the estimate of ∼20,000 German-speaking researchers, the early German-speaking scientific world had less than ∼1/65 as many researchers as the modern U.S. innovation system, and less than ∼1/350 as many people as the modern global research system, yet managed to produce the incredible quantity and quality of innovations illustrated by Chapters 2–9 and Appendices A–E.

If modern innovation systems were as effective as the earlier German-speaking innovation system, one would expect them to have produced revolutionary innovations at a rate ∼65–350 times that of the older German-speaking world. Unfortunately they do not appear to have even equalled the output of revolutionary innovations from the earlier German-speaking world (as already noted, not counting innovations that were originally made by the German-speaking world but later adopted and adapted by the modern world).

For this reason, it is of great interest to seek factors that may account for why the German-speaking world was so successful.

10.2 Systemic Factors Promoting Innovation

The objective of this section is to identify and analyze common factors within the German-speaking world that facilitated the success of so many revolutionary scientific creators and creations. As is demonstrated here, there were at least ten different important factors. What all of those factors had in common, though, was that they generally tended to promote greater freedom to pursue longer-term and riskier potential innovations compared to the modern research world.

10.2.1 Cultural Attitudes Toward Science Education and Research

One important factor underlying the scientific innovations from the German-speaking world appears to be cultural attitudes toward education and research that were deeply embedded in German culture throughout the nineteenth and twentieth centuries. Education and research in general, and science and engineering in particular, were highly esteemed, from children's activities and amateur science clubs to prestigious jobs and government-lauded scientific heroes.

The roots of these cultural attitudes can be traced back at least as far as the eighteenth century. While philosophers who were not also scientists are beyond the scope of this book, several German-speaking philosophers played highly influential roles in shaping the intellectual culture of the German-speaking world. In particular, Immanuel Kant (Prussian, 1724–1804), Johann Fichte (German states, 1762–1814), Georg Wilhelm Friedrich Hegel (German states, 1770–1831), and Friedrich Schelling (German states, 1775–1854) placed great emphasis on inquiring into the laws and details of the universe, weighing and even hybridizing alternative explanations to determine the best one (the dialectic, not unlike the scientific method), and finding ways to improve oneself and to help others [Beardsley 1960; EB 2010; Peter Watson 2010].

As discussed later in Section 10.2.5, a number of more scientifically oriented intellectuals applied these same principles to a wide range of fields in science and engineering. Those founding scientific figures included Athanasius Kircher (German states, 1602–1680), Gottfried Leibniz (Saxony, 1646–1716), Leonhard Euler (Swiss, 1707–1783), Johann Wolfgang von Goethe (German states, 1749–1832), and Alexander von Humboldt (Prussian, 1769–1859).

Wilhelm von Humboldt (Prussian, 1767–1835), Alexander's older brother, founded the University of Berlin (now called the Humboldt University of Berlin) in 1811 and is widely credited with developing and promoting the model of universities conducting both education and research in coordination. Drawing upon the earlier work of intellectuals such as those listed above, he articulated ideals that would be characteristic of German-speaking culture throughout the nineteenth and twentieth centuries [Bruford 1975, pp. 13–17, 24]:

> Everyone must seek out his own individuality and purify it, ridding it of the fortuitous features. It will still be individuality, for a portion of the fortuitous is inseparable from the make-up of every individual, and cannot and should not be removed. It is really only in that way that character is possible, and through character greatness.
>
> —
>
> If we imagine a man whose sole aim in life is to cultivate himself, his intellectual activity must finally be concentrated on discovering (a) *a priori*, the ideal of humanity, and (b) *a posteriori*, a clear picture of mankind in reality. When both are as precise and complete

> as possible in his mind, he should, by comparing them, derive from them rules and maxims for action.
>
> —
>
> The true end of man, not that which his transient wishes suggest to him, but that which eternal immutable reason prescribes, is the highest possible development of his powers into a well-proportioned whole. For culture of this kind freedom is the first and indispensable condition.
>
> —
>
> Thus peasants and craftsmen of all kinds could perhaps be developed into artists, that is, into men who loved their particular work for its own sake, improved it through their own initiative and inventiveness and so cultivated their intellectual powers, ennobled their character and refined their pleasures.
>
> —
>
> In general, perhaps the best thing a man can do with his life is to take away with him a living picture of the world, properly unified. For me in particular no task is more suited, more imposed upon me by my nature.
>
> —
>
> He who can say to himself when he dies: 'I have grasped and made into a part of my humanity as much of the world as I could,' that man has reached fulfillment... In the higher sense of the word, he has really lived.

As voiced by Humboldt, these German cultural ideals emphasized (1) individual initiative and creativity, (2) high levels of education and lifelong learning, (3) acquiring and harnessing a comprehensive knowledge of as many fields as possible, and (4) systems analysis to survey everything and then focus on creating solutions for the most important problems.

In Peter Watson's sweeping survey of German intellectual history, *The German Genius,* he explained how these ideals permeated and influenced the German-speaking world [Peter Watson 2010, pp. 53–54, 829–830]:

> There will be a great deal to say about Bildung in this book. Difficult to translate, in essence it refers to the inner development of the individual, a process of fulfillment through education and knowledge, in effect a secular search for perfection, representing progress and refinement both in knowledge and in moral terms, an amalgam of wisdom and self-realization.
>
> [...I]t is clear from what has gone before that Germany was the first country to boast an educated middle class of any size and that this was all important for its emergence as a great power.
>
> A few statistics will underline this. Prussia enforced school attendance for children between the ages of seven and fourteen from the 1820s (in Britain children were not compelled to go to school until 1880) and by the 1890s had two-and-a-half times as many university students in proportion to population as did England. [...I]n Germany, in 1785 there were 1,225 periodicals published, compared with 260 in France. In 1900 Germany had 4,221 newspapers, France roughly 3,000 (and Russia 125). In the early

> nineteenth century, when England had just four universities, Germany had more than fifty. James Bowen, in his three-volume history of Western education, points out that Germany took the lead in the establishment of scientific societies in the early nineteenth century, published the greatest number of journals in the vernacular, and became the leading language of scientific scholarship. In 1900 illiteracy rates in Germany were 0.5 percent; in Britain they were 1 percent and in France 4 percent. By 1913 more books were published annually in Germany (31,051 new titles) than in any other country in the world. [...]
>
> It was the educated middle class that made the exciting advances in scholarship that so attracted academics from abroad (especially from America), that rendered the bureaucracy of the ever-coalescing German state so efficient and creative and led to the groundbreaking scientific achievements of the second half of the nineteenth century, that transformed Germany economically, and on which so much of modern prosperity—not just in Germany—is based. [...]
>
> The development of modern scholarship, the concept of Bildung, and the innovation of the research-based university were seen at the beginning of the nineteenth century as a form of moral progress. Education was not simply the acquisition of knowledge but looked upon as a process of character development during the course of which a person would learn to form critical judgments, make an original creative contribution, *and* learn about his or her place in society with its duties, rights and obligations. Education as Bildung involved a process of *becoming,* a form of secular perfection or salvation that was, for the educated middle class, the very *point* of life in a world between doubt and Darwin.

Throughout the nineteenth and early twentieth centuries, German-speaking universities expanded and became more advanced, and the social status of people who taught at or graduated from the universities increased in parallel. Ulrich Wengenroth, a scientific historian at the Deutsches Museum in Munich, described that social status [Landes et al. 2010, p. 284]:

> At the same time a new source of respect and status emerged. Kaiser Wilhelm, himself a great admirer of science and engineering, very much against the opposition of the traditional universities created the title of “doctor of engineering” for the *Technische Hochschulen* (institutes of technology). This opened new opportunities for ambitious engineers to gain the kind of respect and recognition that had been the privilege of the humanistic elites of the traditional worlds of learning. And it was a watershed; academic titles in engineering and science soon displaced the Kommenzienrat and the Geheimer Kommenzienrat, while the *Honorarprofessor* (honorary professor), which in everyday life often was stripped of its somewhat depreciating prefix *Honorar* to sound like a bona-fide professorship, carried the status of nobility. Whatever the dubiousness of some honorary degrees, the currency of status and vanity had changed. More prestigious universities would look more closely at the validity of reasons to confer academic distinction. The Honorarprofessor, even if a CEO, would have to teach students and often was interested in fostering common research programs in his company and his university. The academization of entrepreneurial prestige through the twentieth century was as much an expression as a strengthening of a knowledge-based approach to managing product development.

The very high social status and high relative pay for scientists and academics in the German-speaking world were apparently deeply ingrained in the culture, so they persisted throughout the political and financial upheavals of the German-speaking world in the nineteenth and twentieth centuries. Hariolf Grupp and his colleagues remarked on how stable the German scientific system was despite these political instabilities [Shavinina 2003, pp. 1038, 1041]:

> Most astonishingly, the German innovation system was very *stable*, although it witnessed several political system changes in the past century. The total amount of government spending on science and innovation followed similar quantitative tracks after its formation in the 19th century, the First World War and after the Second World War. The respective central power was not a strong pillar in science and technology. Contrary, the science and technology operation was maintained and was always reconstructed by the German states before the central power found ways to establish itself as dominating. However, considerable differences are observed when regarding the strong role of enterprises on innovation after the Second World War, which was—in pecuniar terms—not as visible before. Only after reunification in 1990, the acting power was the federal government at a time when enterprises were largely dominating the financing of R&D. This was definitely different hundred years ago.
>
> In terms of the basic sectorial structures in science and technology, the strong and the weak sides were almost the same whatever regime and territorial boundaries existed. This *persistence* of the innovation system points to a *resistant innovation culture* in and around Germany, which may not be influenced too much by external shocks or incentives, be it in monetary or institutional form. [...] Even the isolation of the former GDR and its subjection under the communist regime could not change much.
>
> There seems to be a specific German understanding of the opening and prosecution of technology trajectories. The industrial research system in Germany was one of the first in the world to be formed and developed. Other countries followed that pattern more or less closely. Yet the subjects of research seemed to be different between the countries and remained largely constant over long periods. Obviously the technical and scientific elites in Germany succeeded to follow their interests in any political system collectively. For the research and education policy this means that soft factors like group identity, schools of thought and personal exchange are more reliable and more efficient government instruments than the traditionally monetary incentive systems. This sustainable culture imprint can only be analyzed and detected in historical time series.

Because this reverence for science was so deeply imbedded in the culture of the German-speaking world, children in that world grew up with dreams of making revolutionary scientific discoveries and inventions. In his published dissertation, Peter Fisher gave an overview of some of the science fiction that was popular in the German-speaking world in the early twentieth century [Fisher 1991, pp. 104, 115, 221]:

> “In cities throughout Germany, people eagerly lined up at newspaper kiosks,” recalled Hans Dominik proudly, “in order to buy the latest part of my serial novel in the *Woche*.” [...] An electrical engineer who had turned to journalism and popular science, Dominik and his publisher, the conservative Scherl Verlag, were the undisputed masters in producing and marketing a type of formula fiction which they called the *technischer Zukunftsroman*. [...]

> Dominik was not the only science fiction author who sought to assuage the readers' feelings of hurt national pride by concocting stories of potent German inventors creating and controlling future upheavals. Other highly successful authors of popular fiction like Otfrid von Hanstein, Fritz Mardicke, and Otto Willi Gail, or amateur writers like Paul Thieme, also tried their hand in the still new genre. [...] The political drift of these stories manifested itself in an appeal for the recognition of Germany's achievements and (supposedly) superior culture—as witnessed by remarkable advances in science and technology—and by thinly veiled threats that these could be employed against hostile nations. [...]
>
> Dominik's protagonists, like those in other German science fiction of the 1920s, were constructs of an imagination hopefully awaiting salvation in the form of an engineer-messiah. Lämmel even spoke of a day of "technological liberation" and an age of "technological Bismarcks." The repeated sense of wonder and mystery that surround these saviors was meant to suggest that they were emanations of a divine will, driven forward to right the wrongs of recent history. [...]
>
> The writers' favorite props—atomic energy, ray guns, powerful submarines, and light-metal and giant aircraft—serve to reveal hitherto unattained power, but usually appear more like magic wands than believable inventions. Yet, despite the vague imagery of the new superweapons, it seems that there was a wide measure of belief in the imminent creation of such revolutionary armaments.
>
> [...T]he fictive scientists and engineers strove to create powerful inventions that would "free" the nation. While the rightist dictators tamed the masses, the inventors controlled the equally awesome forces of technology. [...]
>
> The technological successes imagined by Weimar's science fiction authors expressed an ambivalent mood—a desire for the recognition of spiritual and technological greatness, as well as a wish to avoid another world war.

These science fiction stories were wildly popular and were avidly consumed by children and adults throughout Germany. They emphasized individualism and presented fictional role models for how a young engineer or scientist could invent or discover something so important that it would change the fate of the country or of the entire world (Fig. 10.1). Early films depicted similar stories about creating a life-like robot (Fritz Lang and Thea von Harbou's *Metropolis*, 1927), building a moon rocket (Lang and von Harbou's *Frau im Mond*, 1929), and accomplishing other technological feats (Fig. 10.2).[1]

At the same time, real-life scientific heroes from Albert Einstein to Fritz Haber were lauded by the media and the government (Fig. 10.3). Amateur science societies such as the Society for Space Travel (Verein für Raumschiffahrt) allowed children and adults to conduct their own research and development projects (Fig. 10.4).

It would be difficult to overestimate the importance of all of these fictional and real role models in shaping the interests and individuality of young future scientists and engineers.

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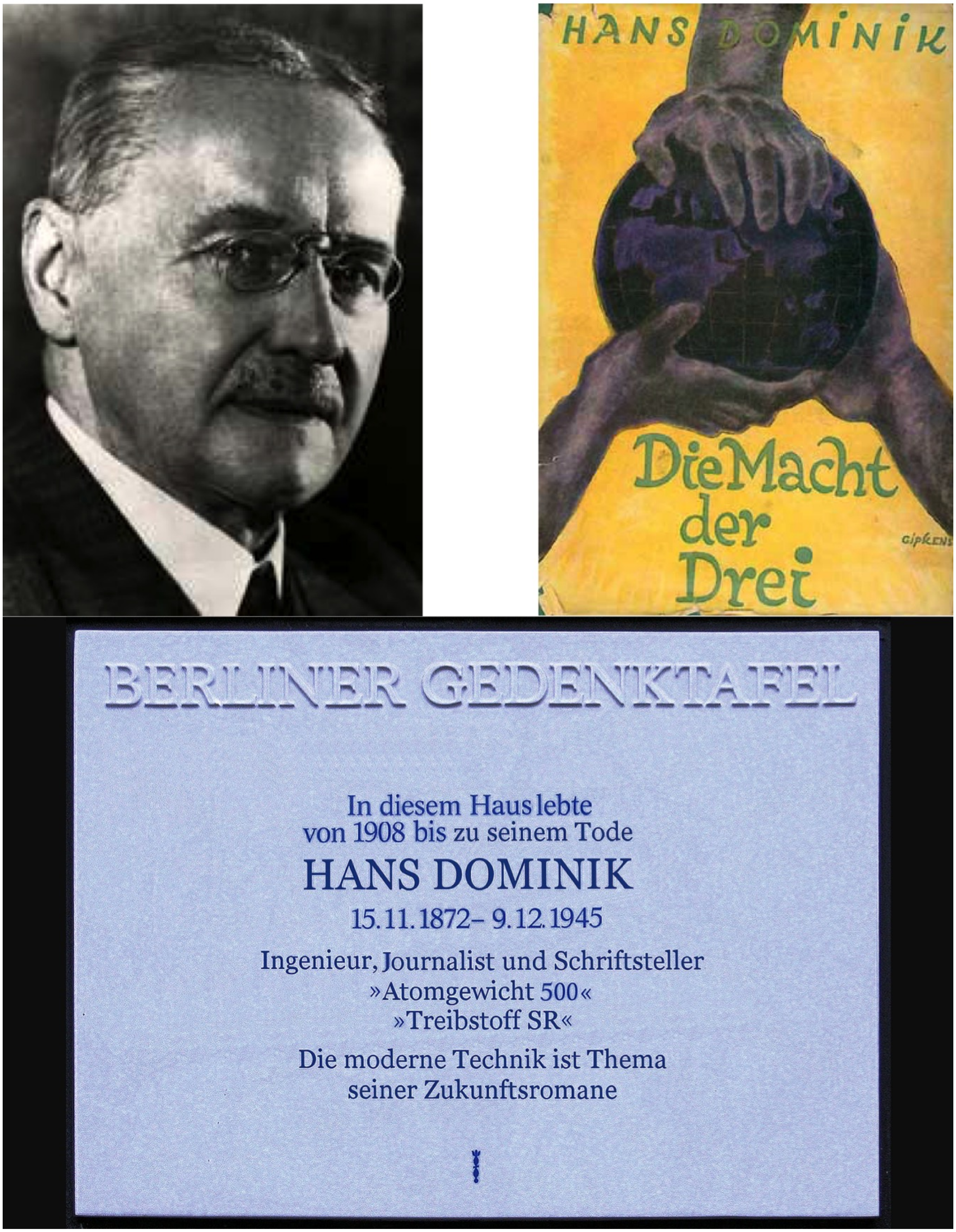
[1] Bogdanovich 1967; Eisenschitz and Bertetto 1994; Eisner 1977; Jenkins 1981; McGilligan 1997.

Hans Dominik (1872–1945) wrote many popular science fiction novels



BERLINER GEDENKTAFEL

In diesem Haus lebte
von 1908 bis zu seinem Tode
HANS DOMINIK
15.11.1872– 9.12.1945
Ingenieur, Journalist und Schriftsteller
»Atomgewicht 500«
»Treibstoff SR«
Die moderne Technik ist Thema
seiner Zukunftsromane

Figure 10.1: Hans Dominik wrote many popular science fiction novels.

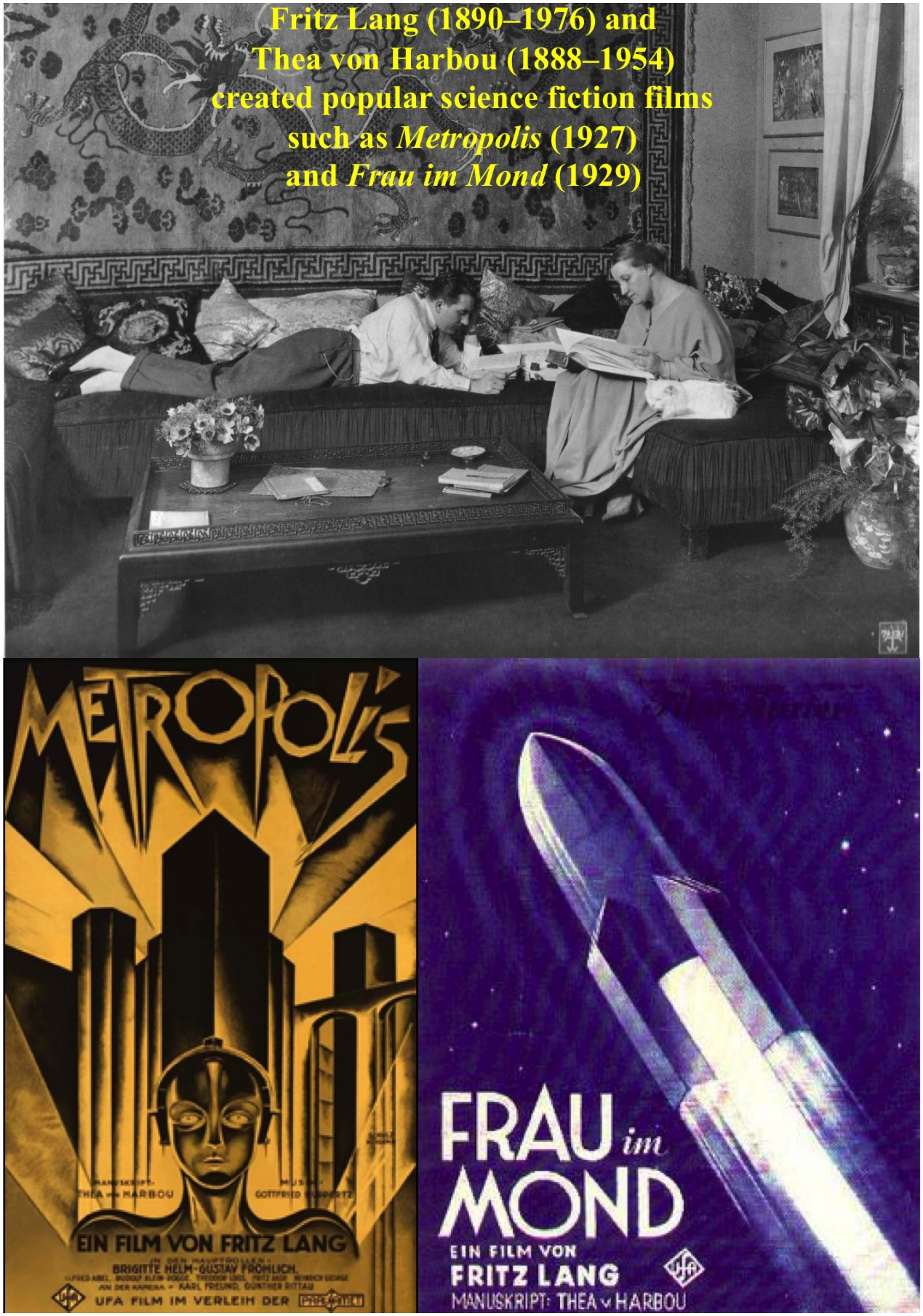

Fritz Lang (1890–1976) and
Thea von Harbou (1888–1954)
created popular science fiction films
such as *Metropolis* (1927)
and *Frau im Mond* (1929)
METROPOLIS
MANUSKRIPT:
THEA von HARBOU
MUSIK:
GOTTFRIED HUPPERTZ
EIN FILM VON FRITZ LANG
IN DEN HAUPTROLLEN:
BRIGITTE HELM - GUSTAV FRÖHLICH
AN DER KAMERA: KARL FREUND, GÜNTHER RITTAU
UFA FILM IM VERLEIH DER PARUFAMET
FRAU im MOND
EIN FILM VON
FRITZ LANG
MANUSKRIPT: THEA v. HARBOU

Figure 10.2: Fritz Lang and Thea von Harbou created popular science fiction films such as *Metropolis* (1927) and *Frau im Mond* (1929).

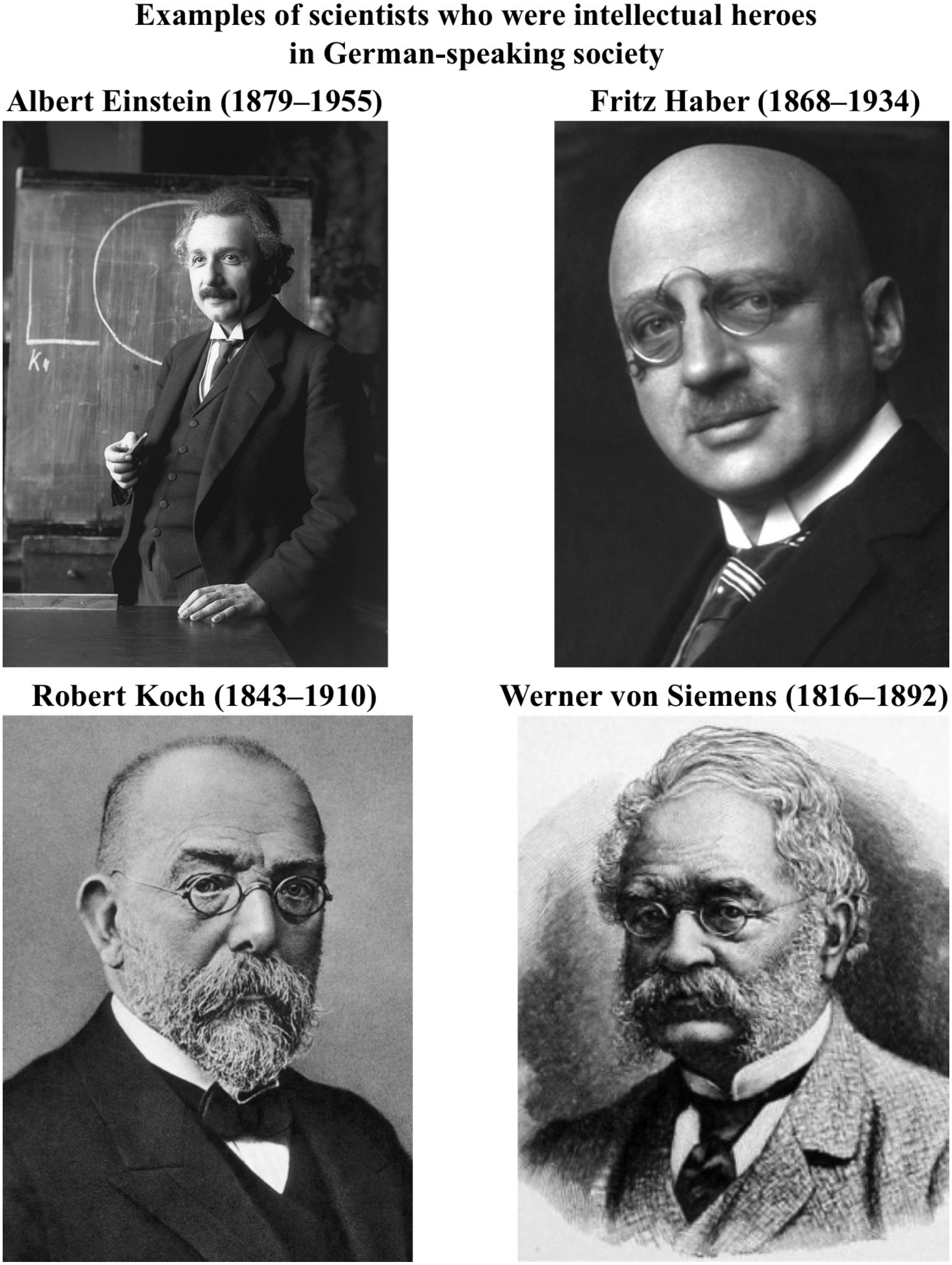
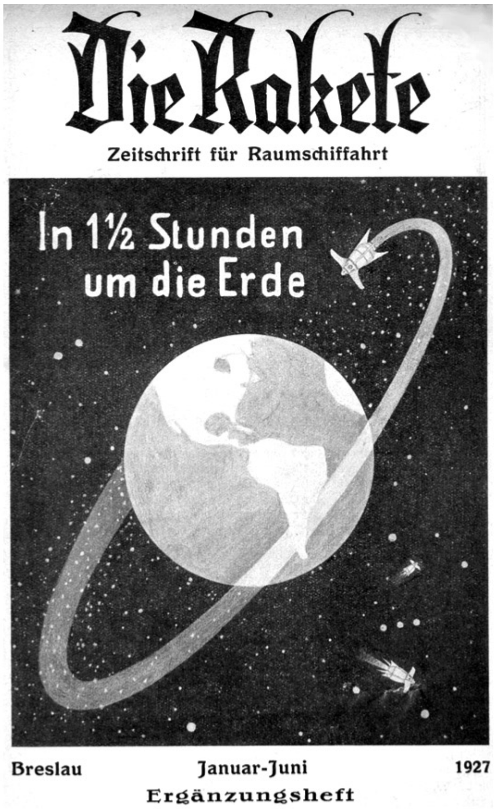

Examples of scientists who were intellectual heroes in German-speaking society
Albert Einstein (1879–1955)
Fritz Haber (1868–1934)
Robert Koch (1843–1910)
Werner von Siemens (1816–1892)

Figure 10.3: Examples of scientists who were intellectual heroes in German-speaking society include physicist Albert Einstein, chemist Fritz Haber, biologist Robert Koch, and electrical engineer Werner von Siemens.

There were many amateur science clubs such as the Verein für Raumschiffahrt (Society for Space Travel), which published its own journal and included members such as Rudolf Nebel (below left) and Wernher von Braun (below right)



Die Rakete

Zeitschrift für Raumschiffahrt

In 1½ Stunden um die Erde

Breslau Januar-Juni 1927

Ergänzungsheft

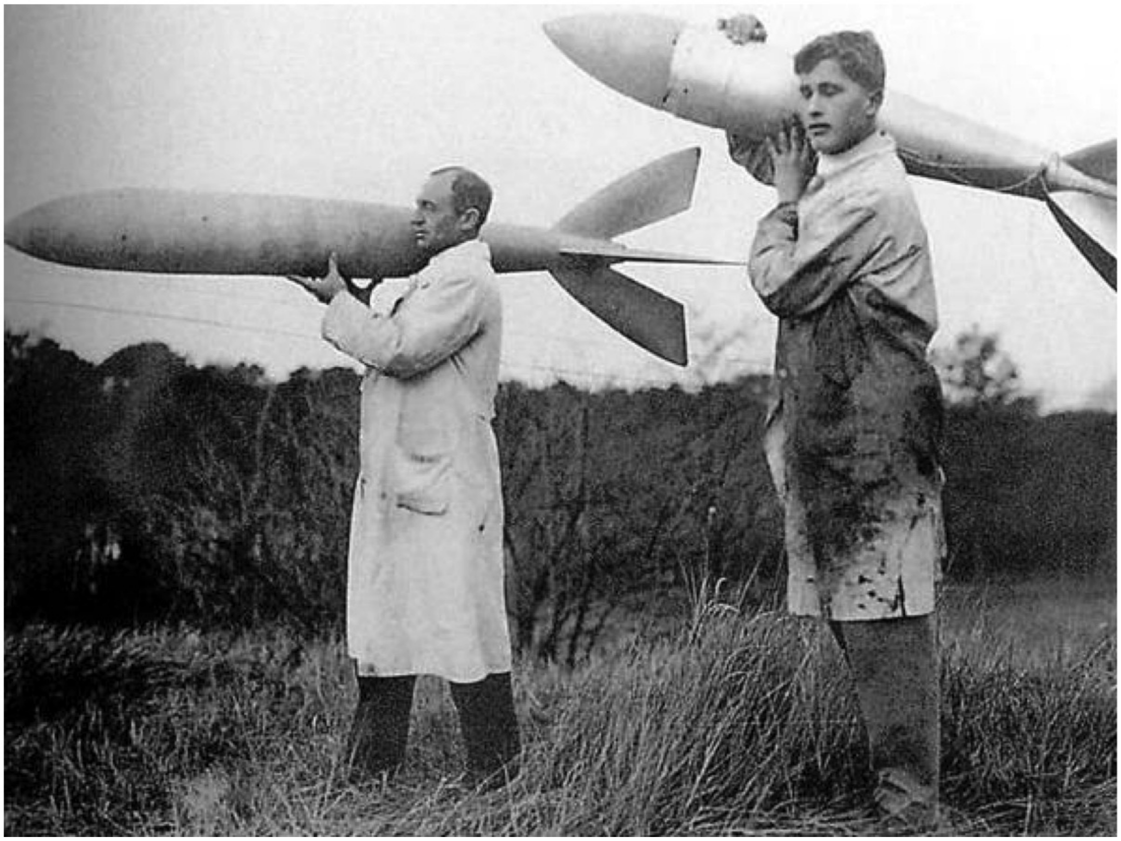


Figure 10.4: There were many amateur science clubs such as the Verein für Raumschiffahrt (Society for Space Travel), which published its own journal and included members such as Rudolf Nebel (lower left) and Wernher von Braun (lower right).

10.2.2 Funding Levels

The amount of funding committed to scientific research obviously has a large effect on the quantity and quality of the resulting work. Data for total public expenditures for science in Germany during the period 1860–1938, converted into inflation-adjusted values (millions of 1913 Reichsmarks), is readily available and summarized in Table 10.2 [Nelson 1993, p. 125].

Year	**Annual budget (millions of marks)**	**Inflation-adjusted (millions of 1913 marks)**	**% of gross domestic product**
1860	6.0	10.7	0.06
1870	10.5	14.7	0.08
1880	27.3	33.6	0.16
1890	32.7	37.4	0.14
1900	53.2	59.9	0.16
1910	91.2	94.8	0.20
1913	101.9	101.9	0.19
1925	282.9	206.8	0.42
1930	359.6	241.3	0.55
1938	513.4	446.6	0.52

Table 10.2: Total public expenditures for science in Germany during the period 1860–1938.

There does not appear to be good data on German industrial research spending during that time. Hariolf Grupp and colleagues summarized this problem [Shavinina 2003, pp. 1021, 1029]:

> Pfetsch undertook adding up scientific expenditure between 1850 and 1975, so that rough estimates about the degree of R&D financing can be derived from this; however, these data records only include *public* expenditure, disregarding the private sector. Consequently, industrial innovation indicators must be researched separately. [...]
>
> It is still difficult to prove the companies' increasing R&D expenditure for such an undeniable success. In particular, no complete data records are available about monetary expenditure or research personnel prior to the end of the Second World War, i.e. the data record established by Pfetsch regarding public scientific expenditure has no counterpart for industry. Today's statistics about R&D expenditure and personnel of the Federal Republic systematically start from the year 1962; certain presumptions allow the reconstruction of the corresponding indicators starting from 1948/1949 [...]

Despite the absence of comprehensive pre-1945 industrial spending data, postwar data shows that during the period 1950–2000, the percentage of total German research expenditures coming from industry instead of government varied between 40% and 60% [Grupp 2002, p. 13], or in other words industrial research spending was roughly equal to government research spending for at least half a century after the war. In the absence of rigorous pre-1945 data, it seems plausible to assume that industrial research spending was also roughly equivalent to government research spending during this period, and that trends in government funding were indicative of trends in total scientific funding.

Similarly, pre-1945 funding data for other geographical regions of the German-speaking world is difficult to find. Nonetheless, it seems reasonable to assume that funding in other German-speaking areas either followed the same trends as the funding in Germany or else was significantly smaller than the German funding. In either case, the rate of increase for German government funding would be a good indicator for the rate of increase for funding for the entire German-speaking research world.

Based on the above data, Fig. 10.5 shows a semilogarithmic plot of total public science funding in Germany from 1860 to 1938 (plotting the data points from Table 10.2 as red circles, measured in inflation-adjusted millions of 1913 marks). Over this 78-year period, funding increased by a factor of 41.7 (red dotted line), equivalent to doubling every 14.5 years on average, or to increasing by a factor of 6.8 over a typical full scientific career of 40 years.

Although the data in Table 10.2 only begins in 1860, German research had been steadily increasing since around 1800, as illustrated by the numerous examples in Chapters 2–9. Likewise, although the data in Table 10.2 ends in 1938, World War II spurred further increases in R&D, as shown by the examples in Appendices A–E. Thus the exponential trend in funding seems to have persisted for at least a full century, and likely more like a century and a half.

Figure 10.6 plots the same data on total public science funding in Germany from 1860 to 1938 from Table 10.2, but instead shown as a percent of gross domestic product (GDP).

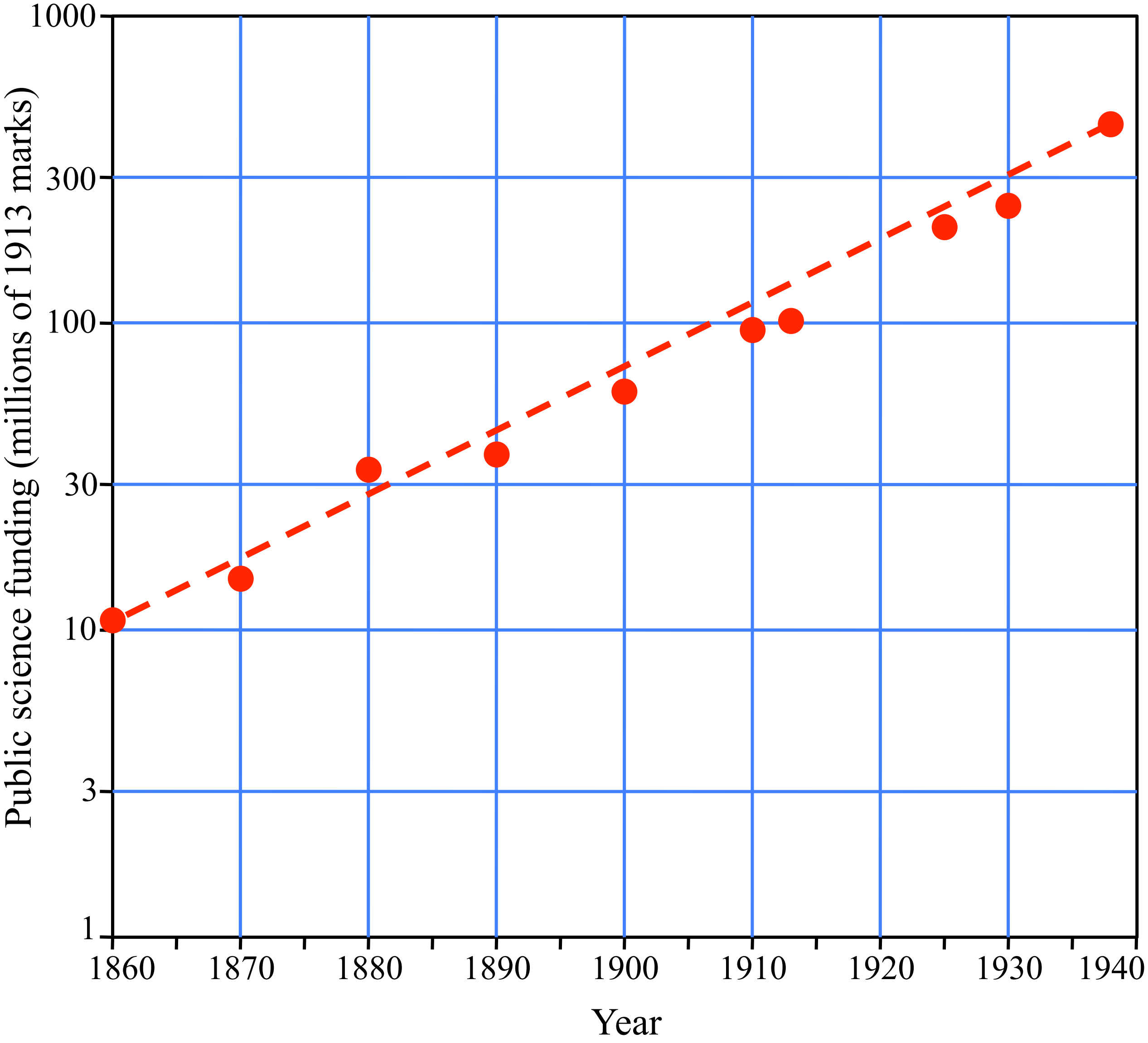


Figure 10.5: Semilogarithmic plot of total public science funding in Germany from 1860 to 1938 (data points as red circles, measured in inflation-adjusted millions of 1913 marks). Over this 78-year period, funding increased by a factor of 41.7 (red dotted line), equivalent to doubling every 14.5 years on average, or to increasing by a factor of 6.8 over a typical career of 40 years.

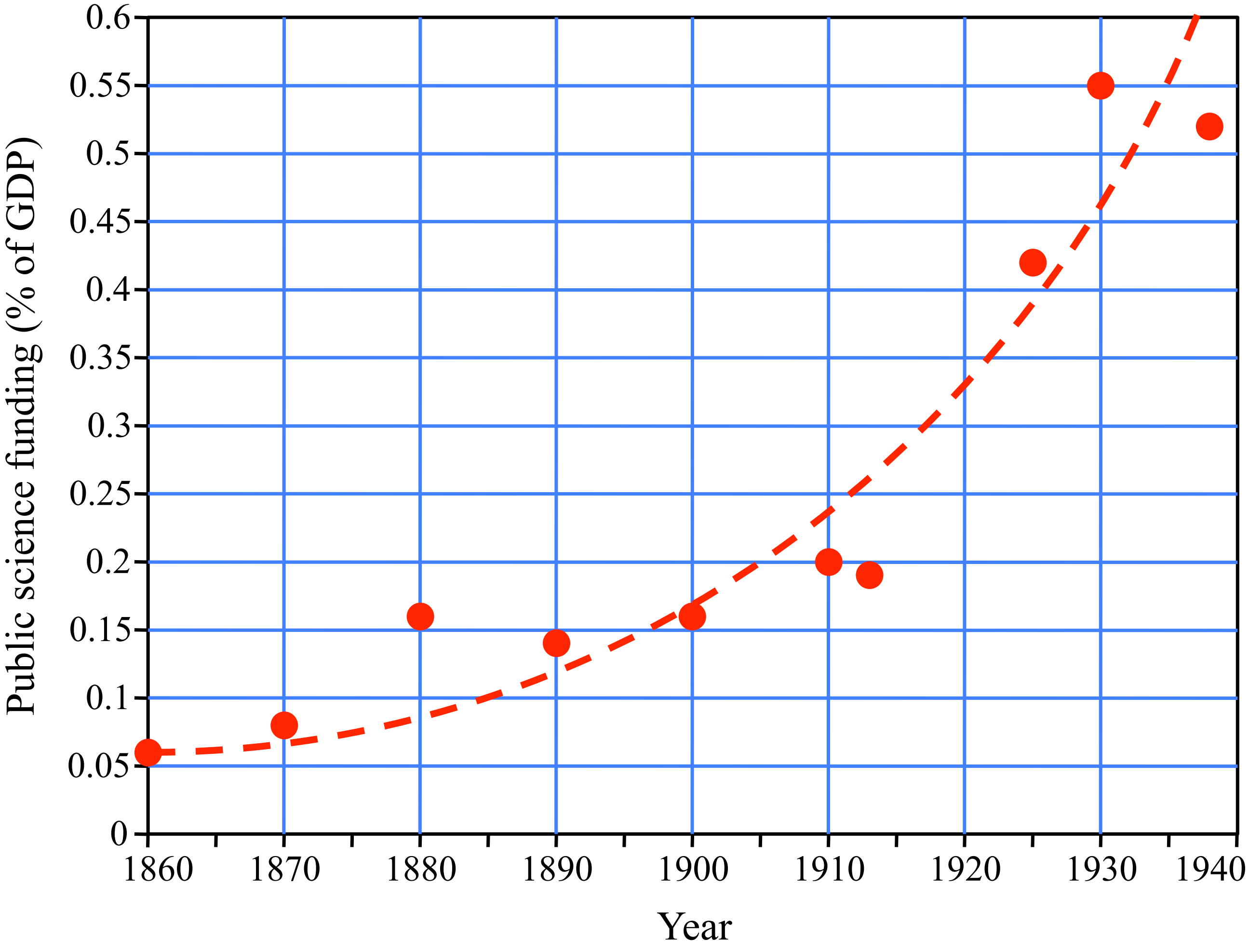


Figure 10.6: Total public science funding in Germany from 1860 to 1938 as a percent of gross domestic product (data points as red circles, extrapolated trend as red dotted line).

In addition to the obvious effect of increased spending resulting in increased research during this more than a century-long period of exponential growth in the German research world, there are less obvious yet critical effects:

- Modern funding levels are nearly flat, and effectively long-term career positions only become available as the people currently holding them retire or die, creating ferocious competition among far too many science graduates for far too few jobs, research grants, and publication slots in high-profile journals. In contrast, because the total funding in the older German-speaking system steadily increased by a factor of 6.8 over typical career times of 40 years, roughly 6.8 times as many graduating students were able to find good jobs in the research system as would have been possible with flat funding levels (assuming that the cost per scientist remained approximately constant). In fact, since some graduating students could find jobs as the German-speaking research world expanded outside Germany, and many graduating students found jobs by emigrating to the United States, United Kingdom, and other countries, the number of graduating students able to find good jobs was significantly higher. The wars in the nineteenth and twentieth centuries also culled a significant percentage of the population. Thus the number of graduating students able to find good research jobs may have been effectively ~ 15 times or more higher for the historical German-speaking world than for the modern research world.

- Greatly increasing the amount of funding and jobs greatly lowered the age at which newly graduated researchers could pursue their own independent research, giving them more years to produce innovations, especially more years when they were young, full of energy, very creative, and less weighed down by family and professional obligations.

- Greatly increasing the amount of funding and jobs greatly reduced the amount of time and energy that researchers had to devote to pursuing funding and jobs, and greatly increased the amount of time and energy that they could devote to conducting actual research.

- Greatly increasing the amount of funding and jobs greatly reduced the pressure both on the researchers and on those responsible for selecting which researchers to support. Reducing that pressure made it much more acceptable for researchers to pursue longer-term work without an immediately demonstrable payoff, as well as more innovative higher-risk work that was less guaranteed to yield results than very incremental, low-risk work. When slots for new researchers were plentiful, it was much easier for employers and sponsors to gamble that some of them would ultimately pay off and some would not.

10.2.3 Mentoring Style

Many creators who were educated in the German-speaking world described the mentorship that they received from their doctoral dissertation advisors. Although there was considerable variation, and not all had a positive experience, a great number of the creators described a style of mentoring that was very different than that typically experienced by Ph.D. students in the modern U.S. system:

- In the German-speaking world, many doctoral advisors (not all, but many) encouraged and supported their students to independently propose and pursue their own research topics and methods. In fact, students were praised and evaluated specifically on how independently they had acted in finding a dissertation topic and carrying out their research on it. In contrast, students in the modern U.S. system are generally expected to work on a specific dissertation topic assigned by their advisor, using the specific methods and materials provided by their advisor, a process which neither teaches nor rewards creativity in young scientists.

- Doctoral advisors in the German-speaking world typically did not claim credit for their students' research. They usually allowed their students to publish or patent the resulting research discoveries by themselves, without adding the doctoral advisor's name to the publication or patent. That was very different than the modern U.S. system, where every resulting publication or patent bears the advisor's name as the authoritative final author, even if the advisor made no real contribution to the actual scientific discovery.

- In the German-speaking world, doctoral advisors generally did not use students as cogs in their own machine. Advisors were expected to serve their students by teaching them, mentoring them, and allowing them to pursue their own independent research. In the modern U.S. system, students typically serve their advisor by carrying out work essential for the advisor's own project, by publishing papers featuring the advisor's name to build up the advisor's reputation, and by helping the advisor to write grant proposals, teach classes, or do anything else requested by the advisor.

- Doctoral advisors in the German-speaking world usually were personally carrying out their own research projects. In laboratories and symposia, various mentors and students were constantly rubbing shoulders as fellow researchers. Such a rich environment provided excellent role models for the students, promoted independence and creativity, and facilitated cross-pollination of ideas among all of the mentors and students. In contrast, doctoral advisors in the modern U.S. system generally spend most of their time writing research grant proposals and issuing orders to their students to carry out specific tasks for those research grants. That modern approach does not give the students good role models for research, does not cultivate independence and creativity, and does not allow many inspiring interactions among all of the mentors and students at the university.

As just a few examples of this mentorship style, the doctoral dissertation experiences of some German-speaking creators are given on the following pages.

Leo Szilard explained that students could either propose their own doctoral dissertation topic or ask their advisor to suggest a topic; Szilard asked his advisor Max von Laue for a topic, but ended up coming up with his own original idea and pursuing that [Weart and Szilard 1978, pp. 9–11]:

> A student of physics had great freedom in those days in Berlin. Boys left high school when they were eighteen years old. They were admitted at the University without any examinations. There were no examinations to pass for four years, during which time the student could study whatever he was interested in. When he was ready to write a thesis, he either thought of a problem of his own or he asked his professor to propose a problem on which he could work. At the better universities, and Berlin belonged to them, a thesis in order to be acceptable had to be a piece of really original work. If the thesis showed the student to be really able and was accepted, the student had to pass an oral exam.
>
> At some point, rather early, I went to von Laue, who was professor of theoretical physics, and asked him whether he would give me a problem on which I could work to get my doctor's degree... I had this problem [in the theory of relativity] which von Laue gave me, but I couldn't make any headway with it. As a matter of fact, I was not even convinced that this was a problem that could be solved. [...]
>
> I went for long walks and I saw something in the middle of the walk; when I came home I wrote it down; next morning I woke up with a new idea and I went for another walk; this crystallized in my mind and in the evening I wrote it down. There was an onrush of ideas, all more or less connected, which just kept on going until I had the whole theory fully developed. It was a very creative period, in a sense the most creative period in my life, where there was a sustained production of ideas. Within three weeks I had produced a manuscript of something which was really quite original.
>
> [...] I took the manuscript to von Laue. I caught him as he was about to leave his class and I told him that while I had not written the paper which he wanted me to write, I had written something else, and I wondered whether he might be willing to read it and tell me whether this could be used perhaps as my dissertation for the Doctor's degree. He looked somewhat quizzically at me, but he took the manuscript. And next morning, early in the morning, the telephone rang. It was von Laue. He said, "Your manuscript has been accepted as your thesis for the Ph.D. degree."

In 1929, Michael Polanyi articulated the German-speaking system of higher education in science [István Hargittai 2016]:

> In Germany the professors grab the students' hands, if he is supposed to be gifted. They are like art collectors whose obsession is discovering talent. They educated me and gave me a position where I could address myself to my abilities. They gave me everything and demanded nothing of me. They trust that who gets to know the joy of scientific work, will never leave it as long as he lives.

Michael Polanyi also practiced the same approach that he had observed and praised. One of his doctoral students was Eugene Wigner. Wigner gave an especially detailed description of how Polanyi mentored him while allowing him to independently pursue his own ideas of how to apply quantum physics to chemical reactions, even though Polanyi himself was not interested in quantum physics [Szanton 1992, pp. 76–81]:

> And there at the Kaiser Wilhelm Institute worked a man who decisively marked my life: Dr. Michael Polanyi. Few people in this century have done such fine work in as many fields as Polanyi. After László Rátz of the Lutheran gimnázium, Polanyi was my dearest teacher. And he taught me even more than Rátz could, because my mind was far more mature. After Rátz and my parents, Polanyi was my greatest influence as a young man. [...]
>
> But his finest gift was to encourage my work in physics, and this he did with all of his very great heart. In all my life, I have never known anyone who used encouragement as skillfully as Polanyi. He was truly an artist of praise. And this praise was vital to me because it was often missing at the great afternoon physics colloquia.
>
> Because Polanyi was a decade my senior and held a far higher position, it was not quite proper for him to befriend me as he did. But Polanyi cared nothing for formal questions of age and status. That was part of his great sweetness. Polanyi was concerned instead that young men should love science and labor to understand it. He was concerned that he could never fully share his love and the knowledge he had gathered.
>
> Like me, Polanyi enjoyed asking questions outside the realm of basic science: Why is the world divided into separate nations? Why do all nations have governments? How should a man live his life in a world filled with evil? Polanyi even taught me some poetry. He made learning a great pleasure.
>
> Dr. Polanyi and I did not always see eye to eye. Polanyi found quantum theory too mathematical for his liking. I was the only one in his lab deeply interested in it. [...]
>
> Polanyi advised my doctoral dissertation at the hochschule. I chose a topic far from the crystallography of Weisenberg or Herman Mark: chemical reaction rates. I wondered: How do colliding atoms form molecules? We knew that hydrogen and oxygen make water in a container, but how soon? How much depends on pressure and how much on temperature? I pursued such questions with elements far more complex than hydrogen and oxygen.
>
> Polanyi was a wonderful advisor. He understood chemical reaction rates both in theory and practice. He accepted my proposal that angular momentum is quantized and that the atoms collide in a proportion consistent with Planck's constant. This idea is now widely known, but then it was rather brash. And studying chemical reaction rates taught me much about nuclear reaction rates that would be useful in future years. [...]
>
> So Herman Mark was a strong teacher, but Michael Polanyi was really the miraculous one. Polanyi loved to ask the fundamental question: "Where does science begin?" He listened to the thoughts of others on this question, but he also had his own well-crafted answer: "When a body of phenomena shows coherence and regularity."
>
> Polanyi loved and honored the scientific method with great truth and devotion. He managed to keep all of science within his fond gaze and a great deal more besides. What a mentor Michael Polanyi was.

Herbert Fraenkel recounted how John von Neumann produced his own revolutionary doctoral dissertation in mathematics, a work that bore the stamp of genius so clearly that Fraenkel and other professors who did not know von Neumann but read the draft dissertation could "recognize the lion by its claw" (*ex ungue leonem* in Latin) [Macrae 1992, pp. 95–96]:

> Around 1922–23, being then professor at Marburg University, I received from Professor Erhard Schmidt of Berlin a long manuscript of an author unknown to me, Johannes von Neumann, with the title "Die Axiomatisierung der Mengenlehre" [The Axiomatization of Set Theory], this being his eventual doctoral dissertation... I was asked to express my views since it seemed incomprehensible. I don't maintain that I understood everything, but enough to see that this was an outstanding work and to recognise "ex ungue leonem."

Hans von Ohain's doctoral advisor at the University of Göttingen was Robert Pohl, an expert on solid state and optical physics. Ohain was already independently pursuing his own longer-term ideas which would lead to the first jet aircraft, but he needed to pick a doctoral dissertation research topic that could be accomplished within a shorter period of time. That topic, a microphone that used light waves instead of electricity to pick up sound waves, was also independently proposed and pursued by Ohain. Ohain described how Pohl gave him general advice, encouraged him to create innovations that were as revolutionary as possible, and allowed him to pursue his ideas on his own [Conner 2001, p. 17]:

> He left me pretty much alone, but we had nice discussions about physics and became better acquainted. He gave me one personal lecture that I remember well: "You know, Hans, the thing is this, either you do good physics or you do really creative applications. I would hate to see you, as my student, making nothing out of technology but doodle signs, so to speak, and nothing really creative." I told him about my ideas on the turbine for aircraft and he said, "When you have something which really revolutionizes technology by employing physics, this is fine, but don't do mediocre stuff." He encouraged me very much to go into the applications area because "You have a flair and a talent for that."

Ohain's independence in proposing and pursuing his doctoral dissertation research topic was central to Pohl's written evaluation of that dissertation when it was completed [Conner 2001, p. 23]:

> The light relay constructed by Mr. von Ohain has meaning, not only for the technical purpose specified in the work, but is also adaptable for application in many physical tasks. Mr. von Ohain conceived the idea for this design entirely on his own and carried out the physical investigation of the relay's characteristics with a refreshing self-reliance. With the completion of the work, not only has he pulled off a great experimental undertaking, but also demonstrated the ease with which he could apply his knowledge of theoretical physics to practical problems. I can without reservation recommend a grade of "Very Good" for Mr. von Ohain's work.

Similarly, Wernher von Braun was able to pursue his own ideas for rockets as a doctoral dissertation, with the support of Erich Schumann as his advisor [Neufeld 2007, p. 68]:

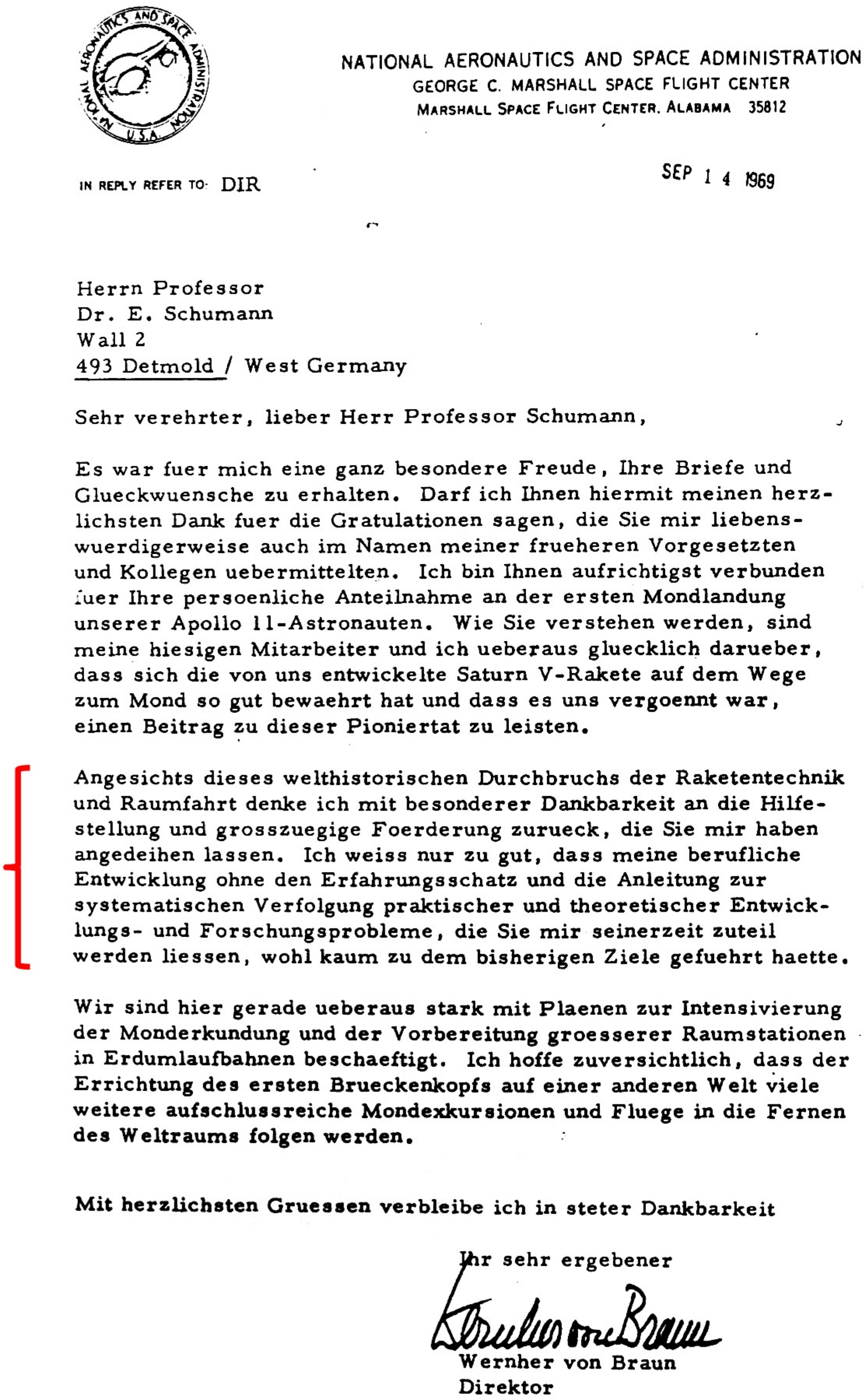
> As spring finally came to northern Germany, von Braun completed his University of Berlin physics dissertation, “Design, Theoretical and Experimental Contributions to the Problem of the Liquid-Fuel Rocket,” in mid-April. A major section on the theory of combustion in a rocket engine can fairly be described as physics, but most of the typescript was actually an engineering treatise on his rocket motors, the A-1 vehicle, and the test instrumentation. Ordnance considered the work so sensitive that the dissertation was given a cover name, “Regarding Combustion Experiments,” a boring and opaque pseudotitle that would appear in his graduation paperwork and on his doctoral diploma. Schumann and Wehnelt, his two examiners in physics, were so impressed with the work that they gave it the Latin distinction “*eximium*”—extraordinary, the highest possible grade.

As shown in Fig. 10.7, in a 14 September 1969 letter (after the first manned moon landing), Wernher von Braun wrote to Erich Schumann [Bundesarchiv Militärarchiv Freiburg N822/6]:

> Angesichts dieses welthistorischen Durchbruchs der Raketentechnik und Raumfahrt denke ich mit besonderer Dankbarkeit an die Hilfestellung und grosszuegige Foerderung zurueck, die Sie mir haben angedeihen lassen. Ich weiss nur zu gut, dass meine berufliche Entwicklung ohne den Erfahrungsschatz und die Anleitung zur systematischen Verfolgung praktischer und theoretischer Entwicklungs- und Forschungsprobleme, die Sie mir seinerzeit zuteil werden liessen, wohl kaum zu dem bisherigen Ziele gefuehrt haette.

> In view of this world-historical breakthrough in rocket technology and space travel, I think back with special gratitude to the support and generous encouragement you have given me. I know only too well that my professional development would hardly have led to my present goals without the wealth of experience and guidance in the systematic pursuit of experimental and theoretical development and research problems that you gave me at the time.

Just as von Ohain and von Braun were allowed to pursue their own revolutionary ideas as students, once they received their Ph.D.s, people like Ernst Heinkel (p. 2009) gave them the freedom and resources to continue to pursue their own ideas. The other creators were similarly successful in being able to continue to pursue their own ideas.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

IN REPLY REFER TO: DIR

SEP 14 1969

Herrn Professor
Dr. E. Schumann
Wall 2
493 Detmold / West Germany

Sehr verehrter, lieber Herr Professor Schumann,

Es war fuer mich eine ganz besondere Freude, Ihre Briefe und Glueckwuensche zu erhalten. Darf ich Ihnen hiermit meinen herzlichsten Dank fuer die Gratulationen sagen, die Sie mir liebenswuerdigerweise auch im Namen meiner frueheren Vorgesetzten und Kollegen uebermittelten. Ich bin Ihnen aufrichtigst verbunden fuer Ihre persoenliche Anteilnahme an der ersten Mondlandung unserer Apollo 11-Astronauten. Wie Sie verstehen werden, sind meine hiesigen Mitarbeiter und ich ueberaus gluecklich darueber, dass sich die von uns entwickelte Saturn V-Rakete auf dem Wege zum Mond so gut bewaehrt hat und dass es uns vergoennt war, einen Beitrag zu dieser Pioniertat zu leisten.

Angesichts dieses welthistorischen Durchbruchs der Raketentechnik und Raumfahrt denke ich mit besonderer Dankbarkeit an die Hilfestellung und grosszuegige Foerderung zurueck, die Sie mir haben angedeihen lassen. Ich weiss nur zu gut, dass meine berufliche Entwicklung ohne den Erfahrungsschatz und die Anleitung zur systematischen Verfolgung praktischer und theoretischer Entwicklungs- und Forschungsprobleme, die Sie mir seinerzeit zuteil werden liessen, wohl kaum zu dem bisherigen Ziele gefuehrt haette.

Wir sind hier gerade ueberaus stark mit Plaenen zur Intensivierung der Monderkundung und der Vorbereitung groesserer Raumstationen in Erdumlaufbahnen beschaeftigt. Ich hoffe zuversichtlich, dass der Errichtung des ersten Brueckenkopfs auf einer anderen Welt viele weitere aufschlussreiche Mondexkursionen und Fluege in die Fernen des Weltraums folgen werden.

Mit herzlichsten Gruessen verbleibe ich in steter Dankbarkeit

Ihr sehr ergebener

Wernher von Braun

Wernher von Braun
Direktor

Figure 10.7: 14 September 1969 letter from Wernher von Braun (after the first manned moon landing) thanking Erich Schumann, who had been his Ph.D. advisor in the 1930s [Bundesarchiv Militärarchiv Freiburg N822/6].

It is interesting to note that this frequent (but not universal) style of mentorship in academia was similar to the frequent (though not universal) style of management in science and engineering companies, suggesting that this tendency was a general (but not universal) element of German-speaking culture. For example, immediately after World War II, Allied investigators visited the Leitz company and wrote a glowing report about what they found [BIOS 1436 pp. 10–11]:

> 60. The main items of production at the time of inspection, besides the Leica camera, were binoculars, projection apparatus and microscopes. The microscopes included the H. Powder Binocular, Students, Panphot and Ortholux. [...]
>
> 61. The Leitz factory is a well-run, happy organisation, this being due in no small measure to the family nature of the business and to its importance in the neighborhood. Discipline is strict without being severe and one gets the impression of great interest by employees of every grade in the work being performed.
>
> 62. This pride in workmanship and the just pride all have in their world-wide reputation for quality work is the permeating spirit of the place and helps greatly to offset apathy caused by the present dismal state of the country.
>
> 63. The products coming from the Leitz works are equal to any turned out before the war although in some cases the finish is inferior due to poor materials, especially paints and enamels.
>
> 64. The team came away with the impression that the Leica camera is still worthy of its pre-eminent position and that the skill of the craftsmen is very much in evidence in the Leitz factory.

Thus many German-speaking companies, like many German-speaking academic labs, treated junior members as craftsmen who should be aided and rewarded in developing their own skills and given their proper place. In the modern U.S. system, unfortunately too many senior people in both academia and industry seem to consider students or employees to be interchangeable, disposable units whose primary purpose is to enrich the professors or executives at the top (see Section 1.1 and references therein).

10.2.4 Average Age for Final Degree

The ages at which the German-speaking creators received their highest degrees (not counting those whose education was delayed by factors such as war, work, or illness) tended to be remarkably low by modern standards, or even by the standards of the early U.S. research system. A major reason is that in the older German-speaking world, students could (and very often did) graduate from the Gymnasium (the German-speaking equivalent of a U.S. high school) at age 18 or so, then directly enter a doctoral program at a university and receive their final degree four or so years later.[2] In contrast, students in most of the modern world (and even in the early U.S. research system) typically spend many years earning a bachelor's degree (and often a master's degree) between the time they graduate from high school and when they finally enter a doctoral program. Modern doctoral programs can also be much longer than those in the earlier German-speaking world, although that does not necessarily mean that they are better.

As a representative data set to illustrate this pattern of ages for final degrees, one can consider scientists who were educated primarily or entirely in the German-speaking world and:

1. Won a Nobel Prize in Physiology or Medicine prior to 1991 (Table 10.3, choosing this cutoff date to exclude most of those who were educated after 1945).

2. Won a Nobel Prize in Chemistry prior to 1991 (Table 10.4).

3. Won a Nobel Prize in Physics prior to 1991 (Table 10.5).

4. Created certain major innovations but did not win a Nobel Prize (Table 10.6, to pick some representative major creators who worked in fields such as engineering, mathematics, earth science, and other areas not considered for Nobel Prizes).

In order to keep the data set focused on the German-speaking educational system, scientists who had some of their training in that system but a significant part of their training outside that system (e.g., Americans such as Irving Langmuir who completed their education in Germany, or Germans such as Ernst Chain who completed their education outside the German-speaking world) are omitted from these tables.

Unless otherwise noted, all of the individuals in these four tables graduated with a Ph.D. Where noted, some received an M.D. (especially among the winners of a Nobel Prize in Physiology or Medicine). As indicated in the tables, a handful of these individuals (such as Albert Einstein) graduated with a final degree that was not a doctorate. As also noted, a few individuals were delayed in receiving their final degree, due to military service, war disruptions, serious illness, or work obligations.

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[2] See for example: Arnold 1882; Ash 1997; Beier 1902; Ben-David 1992; Brown 1911; Herrlitz 2009; Paulsen 1906, 1908; Röhrs 1995; Russell 1899; Schrader 1893; Schwinges 2007.

Students could graduate at any time of year, depending on when their doctoral thesis was completed and approved. In most cases only the year of graduation and not the exact date was readily available. In such cases, the graduation was assumed to have occurred on average in the middle of the year, and the students' ages at graduation calculated accordingly. Any errors caused by this assumption should mostly cancel each other out when averages are taken over entire groups of people.

Nobel Prize	Name	Born	Graduated	Age
1901	Emil von Behring	15 March 1854	1878	24 (M.D.)
1905	Robert Koch	11 December 1843	January 1866	22 (M.D.)
1908	Paul Ehrlich	14 March 1854	1882	28 (M.D., work)
1909	Theodor Kocher	25 August 1841	March 1865	23 (M.D.)
1910	Albrecht Kossel	16 September 1853	1877	23 (M.D.)
1914	Róbert Bárány	22 April 1876	1900	24 (M.D.)
1922	Otto Meyerhof	12 April 1884	1909	25 (M.D.)
1924	Willem Einthoven	21 May 1860	1885	25 (M.D.)
1927	Julius Wagner-Jauregg	7 March 1857	1880	23 (M.D.)
1929	Christiaan Eijkman	11 August 1858	13 July 1883	24 (M.D.)
1930	Karl Landsteiner	14 June 1868	1891	23 (M.D.)
1931	Otto Warburg	8 October 1883	1906	22
1935	Hans Spemann	27 June 1869	1895	25 (work)
1936	Otto Loewi	3 June 1873	1896	23
1937	Albert Szent-Györgyi	16 September 1893	1917	23 (M.D.)
1939	Gerhard Domagk	30 October 1895	1921	25 (M.D., war)
1947	Carl Cori	5 December 1896	1920	23 (M.D.)
1947	Gerty Cori	15 August 1896	1920	23 (M.D.)
1948	Paul Müller	12 January 1899	1925	26 (work)
1949	Walter Hess	17 March 1881	1906	25 (M.D.)
1950	Tadeusz Reichstein	20 July 1897	1922	24 (work)
1953	Hans Krebs	25 August 1900	1925	24 (M.D.)
1953	Fritz Lipmann	12 June 1899	1924	24
1956	Werner Forssmann	29 August 1904	1929	24 (M.D.)
1957	Daniel Bovet	23 March 1907	1929	22
1961	Georg von Békésy	3 June 1899	1926	26 (war)
1964	Feodor Lynen	6 April 1911	March 1937	25
1969	Max Delbrück	4 September 1906	1930	23
1973	Karl von Frisch	20 November 1886	1910	23
1973	Konrad Lorenz	7 November 1903	1928	24 (M.D.)
1973	Nikolaas Tinbergen	15 April 1907	Spring 1932	25
1978	Werner Arber	3 June 1929	1958	29 (military)
1984	Georges Köhler	17 April 1946	April 1974	28 (work)

Table 10.3: Ages at final degree for scientists who were educated primarily or entirely in the German-speaking world and won a Nobel Prize in Physiology or Medicine prior to 1991.

Nobel Prize	**Name**	**Born**	**Graduated**	**Age**
1901	Jacobus van ’t Hoff	30 August 1852	1874	21
1902	Emil Fischer	9 October 1852	1874	21
1905	Adolf von Baeyer	31 October 1835	1858	22
1907	Eduard Buchner	20 May 1860	1888	28 (work)
1909	Wilhelm Ostwald	2 September 1853	1878	24
1910	Otto Wallach	27 March 1847	1869	22
1913	Alfred Werner	12 December 1866	1890	23
1915	Richard Willstätter	13 August 1872	1894	21
1918	Fritz Haber	9 December 1868	May 1891	22
1920	Walther Nernst	25 June 1864	1887	22
1923	Fritz Pregl	3 September 1869	1894	24 (M.D.)
1925	Richard Zsigmondy	1 April 1865	1889	24
1927	Heinrich Wieland	4 June 1877	1901	24
1928	Adolf Windaus	25 December 1876	1900	23
1929	Hans von Euler-Chelpin	15 February 1873	1895	22
1930	Hans Fischer	27 July 1881	1908	26 (M.D.)
1931	Carl Bosch	27 August 1874	1898	23
1931	Friedrich Bergius	11 October 1884	1907	22
1936	Peter Debye	24 March 1884	1908	24
1937	Paul Karrer	21 April 1889	1911	22
1938	Richard Kuhn	3 December 1900	1922	21
1939	Adolf Butenandt	24 March 1903	1927	24
1939	Leopold Ružička	13 September 1887	1910	22
1943	George de Hevesy	1 August 1885	1908	22
1944	Otto Hahn	8 March 1879	1901	22
1950	Otto Diels	23 January 1876	1899	23
1950	Kurt Alder	10 July 1902	1926	23
1953	Hermann Staudinger	23 March 1881	1903	22
1959	Jaroslav Heyrovský	20 December 1890	1918	27 (war)
1963	Karl Ziegler	26 November 1898	1920	21
1967	Manfred Eigen	9 May 1927	1951	24 (war)
1971	Gerhard Herzberg	25 December 1904	1928	23
1973	Ernst Otto Fischer	10 November 1918	1952	33 (war)
1975	Vladimir Prelog	23 July 1906	1929	22
1979	Georg Wittig	16 June 1897	1926	29 (war)
1988	Johann Deisenhofer	30 September 1943	1974	30 (military)
1988	Robert Huber	20 February 1937	1963	26 (military)
1988	Hartmut Michel	18 July 1948	June 1977	28 (military)

Table 10.4: Ages at final degree for scientists who were educated primarily or entirely in the German-speaking world and won a Nobel Prize in Chemistry prior to 1991.

Nobel Prize	Name	Born	Graduated	Age
1901	Wilhelm Röntgen	27 March 1845	1869	24
1902	Hendrik Lorentz	18 July 1853	1875	21
1902	Pieter Zeeman	25 May 1865	1893	28
1905	Philipp Lenard	7 June 1862	1886	24
1909	Karl Braun	6 June 1850	1872	22
1910	Johannes van der Waals	23 November 1837	June 1873	35 (work)
1911	Wilhelm Wien	13 January 1864	1886	22
1913	Heike Kamerlingh Onnes	21 September 1853	1879	25
1914	Max von Laue	9 October 1879	1903	23
1918	Max Planck	23 April 1858	February 1879	20
1919	Johannes Stark	15 April 1874	1897	23
1921	Albert Einstein	14 March 1879	1900	21 (no doctorate)
1925	James Franck	26 August 1882	1906	23
1925	Gustav Hertz	22 July 1887	1911	23
1932	Werner Heisenberg	5 December 1901	1923	21
1933	Erwin Schrödinger	12 August 1887	1910	22
1936	Victor Francis Hess	24 June 1883	1910	26
1943	Otto Stern	17 February 1888	1912	24
1945	Wolfgang Pauli	25 April 1900	July 1921	21
1952	Felix Bloch	23 October 1905	1928	22
1953	Frits Zernike	16 July 1888	1915	26
1954	Max Born	11 December 1882	1906	23
1954	Walther Bothe	8 January 1891	1914	23
1961	Rudolf Mössbauer	31 January 1929	1958	29 (work)
1963	Eugene Wigner	17 November 1902	1925	22
1963	Maria Goeppert Mayer	28 June 1906	1930	23
1963	Johannes Hans Jensen	25 June 1907	1932	24
1967	Hans Bethe	2 July 1906	1928	22
1971	Dennis Gabor	5 June 1900	1927	27 (war)
1984	Simon van der Meer	24 November 1925	1952	26 (war)
1985	Klaus von Klitzing	28 June 1943	1972	28 (work)
1986	Ernst Ruska	25 December 1906	1933	26
1986	Gerd Binnig	20 July 1947	1978	30 (work)
1986	Heinrich Rohrer	6 June 1933	1960	27 (military)
1987	Johannes Georg Bednorz	16 May 1950	1982	32 (work)
1987	Karl Alexander Müller	20 April 1927	1957	30 (war)
1989	Hans Georg Dehmelt	9 September 1922	1950	27 (war)
1989	Wolfgang Paul	10 August 1913	1940	26 (war)

Table 10.5: Ages at final degree for scientists who were educated primarily or entirely in the German-speaking world and won a Nobel Prize in Physics prior to 1991.

Field	**Name**	**Born**	**Graduated**	**Age**
Aerospace	Wernher von Braun	23 March 1912	1934	22
Aerospace	Adolf Busemann	20 April 1901	1924	23
Aerospace	Hans von Ohain	14 December 1911	1935	23
Aerospace	Herbert Wagner	22 May 1900	1923	23 (war)
Biology	Edith Bülbring	27 December 1903	May 1928	24 (M.D.)
Biology	Alfred Kühn	22 April 1885	1908	23
Biology	Erwin Popper	9 December 1879	1903	23 (M.D.)
Chemistry	Gerhard Herzberg	25 December 1904	1928	23
Chemistry	August Kekulé	7 September 1829	1852	22
Earth science	Beno Gutenberg	4 June 1889	1911	22
Earth science	Alfred Wegener	1 November 1880	1905	24 (work)
Electronics	Paul Eisler	1907	1930	23
Electronics	Julius Lilienfeld	18 April 1882	18 February 1905	22
Electronics	Heinz Schlicke	13 December 1912	1937	24
Mathematics	Richard Courant	8 January 1888	1910	22
Mathematics	John von Neumann	28 December 1903	1926	22
Mathematics	Hermann Weyl	9 November 1885	1908	22
Mechanical	Rudolf Diesel	18 March 1858	January 1880	21 (no doctorate)
Mechanical	Wilhelm Nusselt	25 November 1882	1907	24
Optics	Ernst Abbe	23 January 1840	23 March 1861	21
Physics	Edward Teller	15 January 1908	1930	22
Physics	Carl Friedrich von Weizsäcker	28 June 1912	1933	21
Physics	Arnold Sommerfeld	5 December 1868	24 October 1891	22
Physics	Victor Weisskopf	19 September 1908	1931	22
Physics	Hans Geiger	30 September 1882	23 July 1906	23
Physics	Leo Szilard	11 February 1898	1922	24 (war)

Table 10.6: Ages at final degree for selected scientists who were educated primarily or entirely in the German-speaking world and created major innovations but did not win a Nobel Prize.

Table 10.7 summarizes the average ages at graduation for the scientists from Tables 10.3–10.6, excluding those whose education was delayed by war, work, or illness. These German-speaking creators tended to receive their highest degree at:

- Between ages 22 and 23 for a Ph.D. This pattern holds across all fields, as illustrated by the examples in Tables 10.3–10.7.
- Between ages 23 and 24 for an M.D. In the German-speaking world, obtaining an M.D. generally required about one year longer than obtaining a Ph.D.

Using these same methods, Section 11.2.4 analyzes the ages at graduation for scientists who were educated primarily or entirely in the United States and won a Nobel Prize in Physiology or Medicine, Chemistry, or Physics prior to 1991. For ease of comparison, the results of that analysis (again excluding those whose educations were delayed) are also summarized here in Table 10.7. As may be seen, on average those U.S.-educated scientists took approximately two years longer to complete their education than their contemporary counterparts from the German-speaking world. A two-year head start on an independent research career can be quite significant, especially when those are two years when the scientists are at the peak of their creative powers and energies, and presumably less hindered by obligations to family and bureaucracy than they would be later in their careers.

As a further comparison, the current situation in the U.S. educational system is even worse. For those receiving a doctorate in 2017, the median age at graduation was 31.6 [https://ncses.nsf.gov/pubs/nsf19301/data]. That is nearly a decade older than students who received a Ph.D. from the earlier German-speaking world.

Category of people	**Age at graduation from German-speaking world**	**Age at graduation from U.S. system**
Ph.D., Physics Nobel 1901–1990	23.2 years	25.1 years
Ph.D., Chemistry Nobel 1901–1990	22.4 years	24.7 years
Ph.D., Medicine Nobel 1901–1990	23.6 years	25.2 years
M.D., Medicine or Chemistry Nobel	23.8 years	25.0 years
Final degree, all science Nobelists	23.0 years	24.9 years
Ph.D., non-Nobel sample	22.4 years	—
Ph.D., Nobel + non-Nobel sample	22.7 years	25.0 years
M.D., Nobel + non-Nobel sample	23.8 years	25.0 years
Final degree, Nobel + non-Nobel sample	22.9 years	24.9 years

Table 10.7: Ages at final degree for selected scientists educated in German-speaking and U.S. systems.

A modern observer might object that students need to learn much more now, yet physics, chemistry, mathematics, engineering, and other fields had already been well developed by the early twentieth century, and German-speaking students took extensive coursework in them. For example, Hans Bethe's university transcripts show that he took the courses listed in Table 10.8 [Schweber 2012, pp. 402–403, 419–420]:

Differential and Integral Calculus I with Exercises
Higher Arithmetic
Exercises for Higher Arithmetic
Experimental Physics I
The Experimental Foundations of Atomistics
General Chemistry I (Inorganic Chemistry)
Accounting with Exercises
Mechanics
Exercises in Mechanics
Experimental Physics II
General Physical Chemistry
General Chemistry II (Inorganic Chemistry)
Seminar on Inorganic Chemistry
Inorganic Chemistry Laboratory
The Mechanical and Electrical Properties of Matter
The Foundations of Modern Physics
Organization of People and States
Differential Geometry
Special Topics in Theoretical Physics (Quantum Theory, Theory of Relativity)
Modern Spectroscopy
Physics Laboratory for Beginners
Electrochemistry
Chemical Thermodynamics
Seminar on Inorganic Chemistry
Chemical Laboratory in Inorganic Chemistry
Differential Equations in the Real Domain
Exercises in Differential Equations
Mechanics
Advanced Experimental Physics I: Mechanics, Acoustics, Heat
Exercises in Advanced Experimental Physics
Universal Physical Constants and the Methods of Their Determination
Exercises in Theoretical Physics
Physical Laboratory for Advanced Students
General Chemistry II: Atomics
Chemical Laboratory in Inorganic Chemistry
Continuum Mechanics (Carathéodory)
Physical Chemistry II
Chemical Forces and Constitution
Partial Differential Equations of Physics
Exercises—Partial Differential Equations of Physics
Theory of Magnetism
Theory of Band Spectra
Dispersion of Light and X-Rays
Physics Exercises for Advanced Students
Psychology
Introduction to Politics
Electrochemistry
Experiments in Electricity and Light
Theoretical Physics Seminar
Exercises—Mechanics
Selected Problems in Quantum Theory
Experimental Physics for Advanced Students
The Political Parties of the Reichstag
Colloid Chemistry
Experimental Methods, Properties, and the Theory of Crystal Lattices
Continuum Mechanics (Sommerfeld)
Exercises—Continuum Mechanics
Structure of Matter
Electrodynamics
Exercises—Electrodynamics
Quantum Mechanics
Physics of the Sun
Optics
Wave Mechanics
Theoretical Physics Seminar (Summer 1927)
Theoretical Physics Seminar (Winter 1927)
Theoretical Physics Seminar (Summer 1928)

Table 10.8: University courses taken by Hans Bethe.

Lest one worry that the quality of the above courses may not have matched their quantity, it should be noted that the classes on Bethe's transcript were personally taught by Walther Gerlach, Otto Hahn, Arnold Sommerfeld, Wilhelm Wien, and other scientific luminaries.

Bethe's university transcript is fairly typical for German-speaking science students of that time. The courses in a Gymnasium were so extensive, so advanced, and so rigorous that German-speaking students graduated at age 18 or so having already learned much of what modern students learn after high school for their bachelor's degree. Moreover, doctoral dissertations at German-speaking universities tended to focus much more on the novelty of the student's ideas and solutions than on how many years the student had toiled on that research. That allowed students in German-speaking doctoral programs to still spend several years taking a wide range of university courses. In contrast, many modern doctoral programs only allow students to take a few courses before they are expected to spend many years on the research assembly line for the rest of the program.

One might try to argue that modern Ph.D. students accomplish much more than students in the older German-speaking world by spending more of their university years doing research. However, the dissertation research of the German-speaking creators resulted in some of the seminal papers in their fields, whereas modern Ph.D. students may spend years toiling away primarily to pad their Ph.D. advisor's CV with extra papers that few people ever read.

The net effect is that the German-speaking creators were free to pursue independent research careers on average approximately two years sooner than their contemporary peers in the United States, and nearly a decade sooner than modern U.S. scientists. Relative to modern scientists, that means not just nearly a decade of additional work, but nearly a decade of additional work performed when the scientists were at their peak energy and creativity in life, and also generally less weighed down by family and professional obligations. That difference is demonstrated by the dramatic accomplishments of most of the German-speaking creators by the time they had reached 31 or 32 years old, the age at which average Ph.D. students are just finally graduating in the modern United States.

In fact, the real difference is even larger than that. Many (though certainly not all) of the German-speaking creators were able to conduct truly independent research as soon as they obtained their doctoral degrees, if not before. In contrast, scientists who receive a Ph.D. or M.D. in the modern U.S. system typically then have to spend many years following older supervisors' instructions in postdoctoral jobs (often multiple postdoctoral jobs in a row), residencies, or entry-level positions at corporate or government laboratories.

In 2020, the average age at which Ph.D. scientists received their first National Institutes of Health (NIH) research project grant was 43, and the average age at which M.D. scientists received their first NIH research grant was 46 [https://nexus.od.nih.gov/all/2021/11/18/long-term-trends-in-the-age-of-principal-investigators-supported-for-the-first-time-on-nih-r01-awards/]. **Thus many German-speaking creators achieved scientific and creative independence two whole decades in life earlier than scientists in the modern U.S. system.**

As discussed in more detail in Chapter 12, this data suggests that one way to improve the modern innovation system would be to eliminate redundancies between high school and undergraduate education, streamline the graduate school educational process, greatly lower the average ages at which scientists receive their final degrees and their first financial grants, and give young scientists much more independence during their most energetic and creative years.

10.2.5 Interdisciplinary Approach

Scientists who made major contributions to multiple disciplines, and fraternization among scientists from different disciplines, were much more common in the older German-speaking world than in the modern world. That interdisciplinary approach apparently facilitated production of and support for innovators and innovations.

Although broadly supportive innovation systems did not begin to assume a coherent form in the German-speaking world until the early nineteenth century, there were many examples of individual German-speaking creators who arose earlier, and who served as role models for the much larger numbers of later creators. Most of those early role models were strongly interdisciplinary, and they were revered by the German-speaking world for that trait (among others). As shown in Fig. 10.8, some examples included:

- Athanasius Kircher (German states, 1602–1680), who conducted groundbreaking research on geology and microbiology, analyzed Egyptian hieroglyphs, and built novel clocks, image projectors, and musical instruments [Findlen 2004; Joscelyn Godwin 2009].

- Gottfried Leibniz (Saxony, 1646–1716), who made major contributions to math, physics, engineering, computing machinery, geology, paleontology, biology, economics, philosophy, and other subjects [Antognazza 2009].

- Leonhard Euler (Swiss, 1707–1783), who did seminal work in math, physics, engineering, astronomy, optics, fluid mechanics, logic, and other areas [Calinger 2015; Richeson 2008].

- Johann Wolfgang von Goethe (German states, 1749–1832), who was revered for his novels, plays, poetry, memoirs, and studies in geology, paleontology, botany, color, and other fields [Douglas Miller 1988].

- Alexander von Humboldt (Prussian, 1769–1859), who made major contributions to botany, geography, meteorology, archaeology, and other subjects [Wulf 2015].

- Wilhelm von Humboldt (Prussian, 1767–1835), Alexander's older brother, who did important work in linguistics, philosophy, and political science, but had the greatest impact on the development of all levels of education in the German-speaking world [Borsche 1990].

These and other early multidisciplinary role models had a profound impact on the developing German-speaking innovation systems, making the German-speaking world especially enthusiastic about training, employing, and celebrating multidisciplinary scholars. In particular, Wilhelm von Humboldt's ideas were central to the German-speaking education and research systems. As already noted (see p. 1965), those ideas of Bildung included (1) promoting learning for its own sake, not just to enter a career, which encouraged education that was much broader than was actually needed by any specific job, and (2) promoting lifelong learning, long after leaving formal schools, which allowed a person to explore more and more fields over the course of a lifetime.

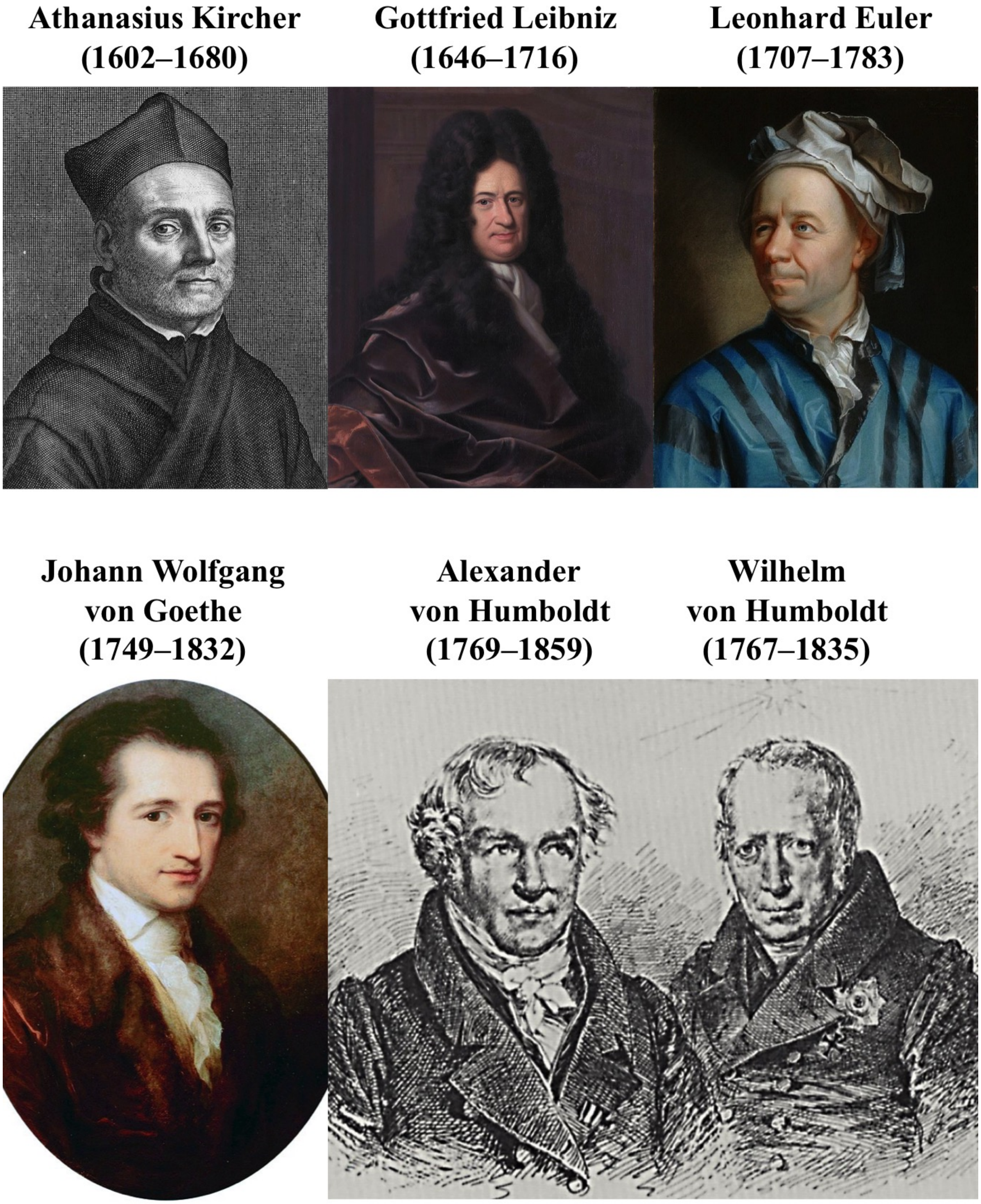

Athanasius Kircher
(1602–1680)
Gottfried Leibniz
(1646–1716)
Leonhard Euler
(1707–1783)
Johann Wolfgang
von Goethe
(1749–1832)
Alexander
von Humboldt
(1769–1859)
Wilhelm
von Humboldt
(1767–1835)

Figure 10.8: Some examples of very early, highly influential interdisciplinary scholars in the German-speaking world included Athanasius Kircher, Gottfried Leibniz, Leonhard Euler, Johann Wolfgang von Goethe, and the brothers Alexander and Wilhelm von Humboldt.

As a result of this longstanding and deeply ingrained multidisciplinary culture in the German-speaking world, there were a large number of creators in the nineteenth and twentieth centuries who made major contributions to multiple fields. Tables 10.9–10.10 list some representative examples. Even scientists who only worked in one field frequently rubbed shoulders with those in other fields, as students, as professors, at seminars and conferences, and in the coffeehouses outside of work. All of these interactions served to promote new insights and innovations within fields and cross-fertilization of ideas between fields.

That broad, interdisciplinary approach is in stark contrast to the microspecialization that is widespread in modern education and research.

Creator	**Fields of creations**
Otto Ambros	Magnetic recording, synthetic rubber, organophosphates
Manfred von Ardenne	Television, electron microscopes, radar, nuclear physics, plasma physics
Heinrich Barkhausen	Magnetic recording, radar
Emil(e) Berliner	Microphone, record player, helicopter
Friedrich Bessel	Astronomy, mathematics
Felix Bloch	Solid state physics, NMR/MRI, nuclear physics, radar
Konrad Bloch	Cholesterol metabolism, hormones, fatty acid metabolism
Karl Braun	Radio, television, radar, semiconductor devices
Adolf Butenandt	Hormones, gene mutations
Peter Debye	Photons, solid state physics, solution chemistry, polymers, X-ray diffraction
Max Delbrück	Quantum electrodynamics, radiation, DNA mutations, bacteriophage
Krafft Ehricke	Rockets, nuclear engineering, solar system
Walter Elsasser	Quantum physics, nuclear physics, geomagnetism, systems biology
Anton Flettner	Teleoperated robots for land, water, and air; rotor ships; helicopters
James Franck	Photoelectric effect, nuclear physics, photosynthesis
Otto Frisch	Quantum physics, nuclear physics, laser scanning
Gustav Fritsch	Neuroanatomy, zoology, astronomy, ethnography
Herbert Fröhlich	Solid state physics, biophysics
George Gamow	Nuclear physics, cosmology, genetic code
Carl Friedrich Gauss	Mathematics, astronomy, electromagnetism, telegraph
Thomas Gold	Astronomy, biophysics, aerospace engineering, geophysics
Peter Goldmark	Television, phonograph, magnetic recording
Hermann Grassmann	Math, physics, linguistics
Helmut Gröttrup	Avionics, rockets, chip card
Erich Habann	Radar, rockets, semiconductors
Hermann von Helmholtz	Vision, hearing, electromagnetism, thermodynamics
Ulrich Henschke	Prostheses, neural interfaces, cancer brachytherapy, flight simulators
Gerhard Herzberg	Molecular spectroscopy, molecular structures, free radicals
George de Hevesy	Chemistry, nuclear physics, biomolecule isotope labels
Fritz Houtermans	Nuclear physics, astrophysics, geophysics

Table 10.9: Some examples of German-speaking creators who made contributions in multiple fields.

Creator	**Fields of creations**
Gustav Franz Hüttig	Nuclear physics, radar, rockets
Theodore von Kármán	Solid state physics, aerodynamics, R&D strategy
Gustav Kirchhoff	Circuits, spectroscopy, elements, thermal radiation
Richard Kuhn	Vitamins, organophosphates, antibiotics
Hermann Lehmann	Hemoglobin, pharmacokinetics
Ernst Mach	Aerodynamics, optics, relativity, hearing/balance
Hans Mauch	Jets, prostheses, neural interfaces, space suits, aviation controls
Walther Nernst	Thermodynamics, chemistry, solid state physics, acoustics
John von Neumann	Mathematics, computers, physics, economics, etc.
Heinrich Olbers	Astronomy, mathematics, ophthalmology, vaccination
Rudolf Peierls	Solid state physics, Manhattan Project
Auguste Piccard	Atmospheric science, cosmic rays, oceanography
Michael Polanyi	Physical chemistry, materials science, medicine, economics, philosophy, epistemology, etc.
Eugen Sänger	Space shuttles, ramjets, antimatter propulsion
Rudolf Schoenheimer	Biomolecule isotope labels, cholesterol/atherosclerosis
Erwin Schrödinger	Quantum physics, color vision, theoretical biology
Erich Schumann	Acoustics, shaped explosive charges, nuclear physics, rockets, biological weapons, chemical weapons
Werner von Siemens	Sea mines, telegraph, electric elevator, dynamos, speaker, trolley
Leo Szilard	Nuclear physics, statistical physics, molecular biology, etc.
Edward Teller	Nuclear physics, physical chemistry, climate change, etc.
Stanislaw Ulam	Nuclear engineering, computers, mathematics, bioinformatics
Rudolf Virchow	Cell biology, pathology, sanitation, archaeology
Herbert Wagner	Wings, jet engines, smart bombs, missiles, nuclear engineering
Hellmuth Walter	Rockets, aircraft, submarines
Emil Wiechert	Electron, electromagnetic fields, seismography, geophysics
Eugene Wigner	Physical chemistry, nuclear engineering, particle physics
Richard Willstätter	Chlorophyll, chromatography, gas mask filters, enzymes
Karl Zimmer	Nuclear physics, DNA mutation
Fritz Zwicky	Jet propulsion, astrophysics, ionic crystals and electrolytes

Table 10.10: More examples of German-speaking creators who made contributions in multiple fields.

10.2.6 Scientific Leadership and Decision-Making Style

During the nineteenth and early twentieth centuries, German-speaking areas in Europe often tended toward rather autocratic styles of government, with examples including numerous regional monarchies before 1871 and some afterward, Otto von Bismarck, Kaiser Wilhelm II, and the Third Reich [Berghahn 2005; Fullbrook 2004; Kitchen 1996; Mann 1968; Thomson 1962]. Perhaps because of this culture, the German-speaking research world during this time was also populated by a number of autocratic leaders. Of course, an autocratic scientific leader can do great harm if that individual is personally malicious and/or scientifically incompetent, as demonstrated by the profoundly negative impact of Joseph Stalin's hand-picked biology leader Trofim Lysenko (1898–1976) on real biologists and real biology research in the Soviet Union for many decades. However, if autocratic scientific leaders are very well-intentioned and well-informed, they can potentially bypass a number of bureaucratic obstacles, champion promising ideas and talented scientists that might otherwise be overlooked by the crowd, and push rapid and sustained progress in key areas of research. The German-speaking research world appears to have greatly benefited from a number of such "enlightened despots" or technocrats during the nineteenth and early twentieth centuries.

These enlightened despots had different individual styles, various opportunities, and differing levels of success. They were all imperfect in their scientific judgment and/or personal character. Indeed, some of them had profound moral flaws that certainly should not be countenanced, let alone emulated. Nonetheless, like their counterparts in the 1940s–1960s U.S. research system (Section 11.2.6), each of these German-speaking despots had three characteristics that could also be useful in the modern research system:

- The strong and direct support of very high authorities (in many cases to the very top of the government).
- A keen eye for revolutionary innovators and innovations.
- The ability to directly offer steady employment and funding for any innovators and innovations they deemed worthy, essentially unencumbered by any bureaucratic processes for application, review, approval, renewal, etc.

There were many examples of such enlightened despots in the German-speaking world; just a few are given in this section.

Justus von Liebig (German, 1803–1873), shown in Fig. 10.9, is considered the founder of organic chemistry and made major discoveries in biochemistry and botany. However, he made an even greater impact by designing the first formal university teaching curriculum and research program for chemistry, successfully lobbying for government funding for it, and recruiting and training over 700 students. Thus he was the father of all of the chemistry research and education system for which Germany became so famous, and the earliest of the enlightened scientific despots presented here. In the next century, the Nobel-Prize-winning chemist Fritz Haber wrote of von Liebig [Farber 1961, p. 537]:

> He felt in himself the call for an accomplishment for which no man's strength and life span could be sufficient. He meant to build up chemistry, of which there was nothing in Germany, and outside of Germany only a modest knowledge in the realm of inanimate nature, so richly and splendidly that there would be order, light, coherence, and system. Through his example and his teaching he meant to show the direction and pave the way for young people, the path which led to an understanding of the events in animate nature, and a new flourishing of industry. What he wanted has become in our day the common will of a great branch of science that he created. What we have gained was accomplished because the succeeding generations stood on his shoulders.

Leopold Graf von Thun und Hohenstein (Austrian, 1811–1888), also shown in Fig. 10.9, was the Austrian minister of education 1849–1860. In that capacity, he had a great impact by reforming Austrian universities and other schools and by hiring very innovative scientists and engineers. *Encyclopedia Britannica* summarized his approach [EB 1911, https://en.wikisource.org/wiki/1911_Encyclopædia_Britannica/Thun-Hohenstein]:

> At first he threw himself with great energy into the task of building up an adequate system of schools. He summoned experienced teachers, Protestant as well as Catholic, from Germany, established middle and higher schools in all parts of the empire, superseded the antiquated textbooks and methods of instruction, and encouraged the formation of learned societies and the growth of a professional spirit and independence among the teachers. It is noticeable that at this time he insisted on the use of German in all schools of higher education. [...] His high social position, his influence at court, his character, as well as his undoubted abilities and learning, not often in Austria found in a man of his rank, gave him great influence.

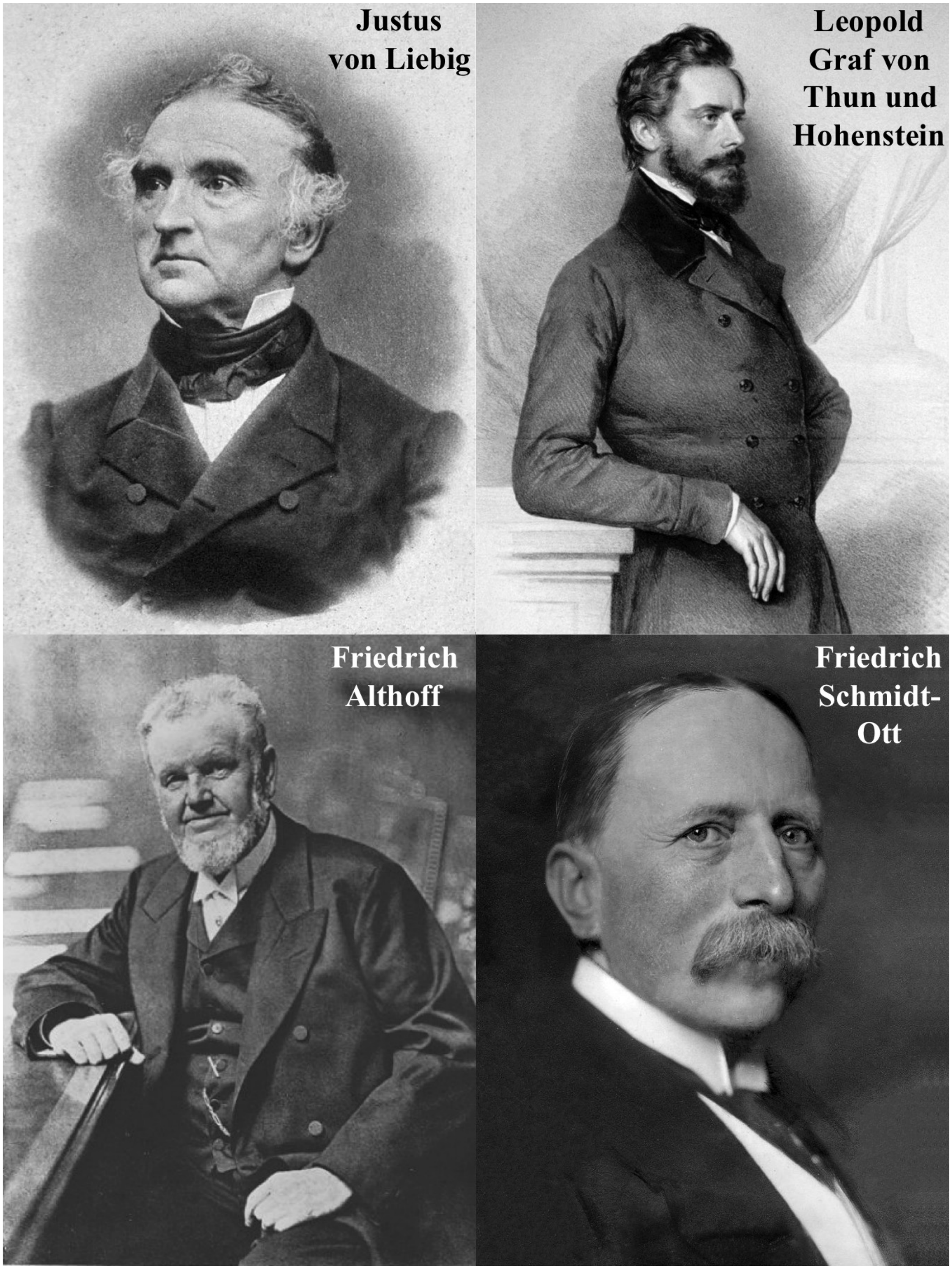

Justus von Liebig
Leopold Graf von Thun und Hohenstein
Friedrich Althoff
Friedrich Schmidt-Ott

Figure 10.9: Examples of scientific "enlightened despots" who had a very large impact on the German-speaking world: Justus von Liebig, Leopold Graf von Thun und Hohenstein, Friedrich Althoff, and Friedrich Schmidt-Ott.

Friedrich Althoff (German, 1839–1908), shown in Fig. 10.9, was perhaps the most important enlightened scientific despot in the history of the German-speaking world [Baumgart 1980; vom Brocke 1991b; Sachse 1928; Senn 1993]. Althoff's major position was the Prussian minister of culture for a quarter of a century, 1882–1907, in which capacity he held state government funding power over educational and research institutions within the Prussian state of the larger unified Germany. Yet because Prussia was the founding and most powerful state of unified Germany, and because Althoff had so many powerful connections and was so talented with Machievellian political methods behind the scenes, his power was immense and reached throughout the German-speaking world, even assisting Arnold Sommerfeld in Bavaria.

Althoff gave direct financial and political support to a large number of scientists who ultimately made major discoveries, many of whom in turn also acted as enlightened despots to offer financial and political support to later talented young scientists. Some scientists and engineers who directly benefited from Althoff's support included:

- **Emil von Behring (German, 1854–1917)**, who would win a Nobel Prize in 1901 for developing therapeutic antibodies.
- **Paul Ehrlich (German, 1854–1915)**, who would win a Nobel Prize in 1908 for his work on immunology and therapeutics.
- **Heinrich Hertz (German, 1857–1894)**, who demonstrated electromagnetic waves and laid the foundation for everything from radio to radar.
- **Felix Klein (German, 1849–1925)**, shown in Fig. 10.10, who introduced a number of innovations in mathematics but even more importantly built up the University of Göttingen as a major research and educational center with direct assistance from Althoff.
- **Robert Koch (German, 1843–1910)**, shown in Fig. 10.10, who would win a Nobel Prize in 1905 for studying bacterial infections.
- **Walther Nernst (German, 1864–1941)**, who would win a Nobel Prize in 1920 for physical chemistry.
- **Max Planck (German, 1858–1947)**, shown in Fig. 10.10, who would win a Nobel Prize in 1918 for quantum physics, handled all theoretical physics papers in the major physics journal, *Annalen der Physik*, almost single-handedly from 1895 until 1943, and educated and supported a large number of young scientists including Max Abraham, Walther Bothe, Gustav Hertz, Erich Kretschmann, Max von Laue, Julius Lilienfeld, Walther Meissner, Lise Meitner, Fritz Reiche, Moritz Schlick, and Walter Schottky.
- **Ludwig Prandtl (German, 1875–1953)**, shown in Fig. 10.10, who pioneered mathematical aerodynamics and was also a strong political advocate for the same agenda as Althoff.
- **Arnold Sommerfeld (German, 1868–1951)**, shown in Fig. 10.11, who pioneered much of quantum and solid state physics, and who found, mentored, and supported a vast number of talented young scientists including Karl Bechert, Hans Bethe, Peter Debye, Paul Epstein, Paul Ewald, Herbert Fröhlich, Erwin Fues, Ernst Guillemin, Werner Heisenberg, Walter Heitler, Helmut Hönl, Ludwig Hopf, Walther Kossel, Adolf Kratzer, Herbert Krömer, Alfred Landé, Otto Laporte, Wilhelm Lenz, Wolfgang Pauli, Linus Pauling, Rudolf Peierls, Walter Rogowski, Werner Romberg, Rudolf Seeliger, Heinrich Welker, and Gregor Wentzel.

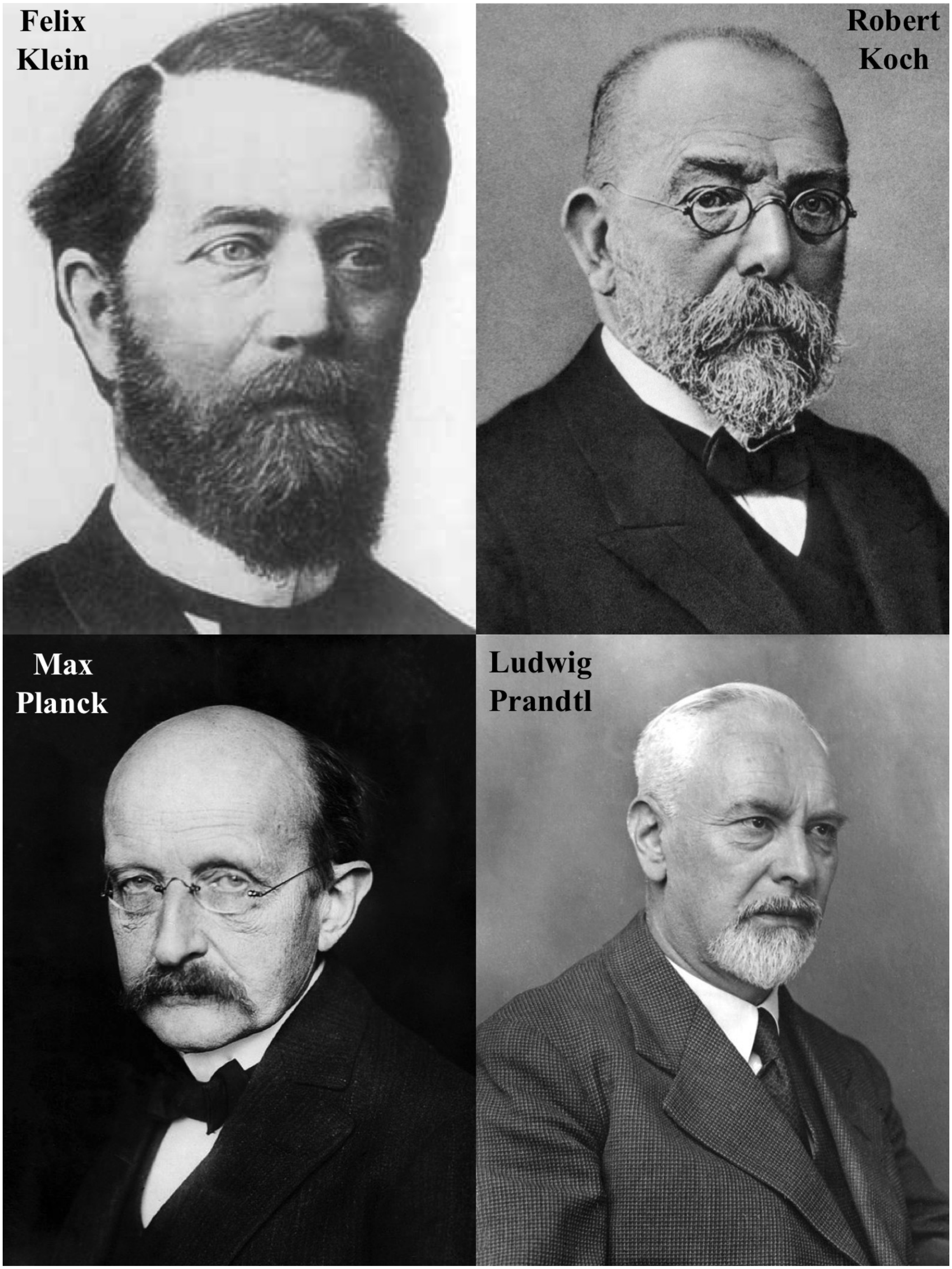

Felix Klein
Robert Koch
Max Planck
Ludwig Prandtl

Figure 10.10: More examples of scientific "enlightened despots" who had a very large impact on the German-speaking world: Felix Klein, Robert Koch, Max Planck, and Ludwig Prandtl.

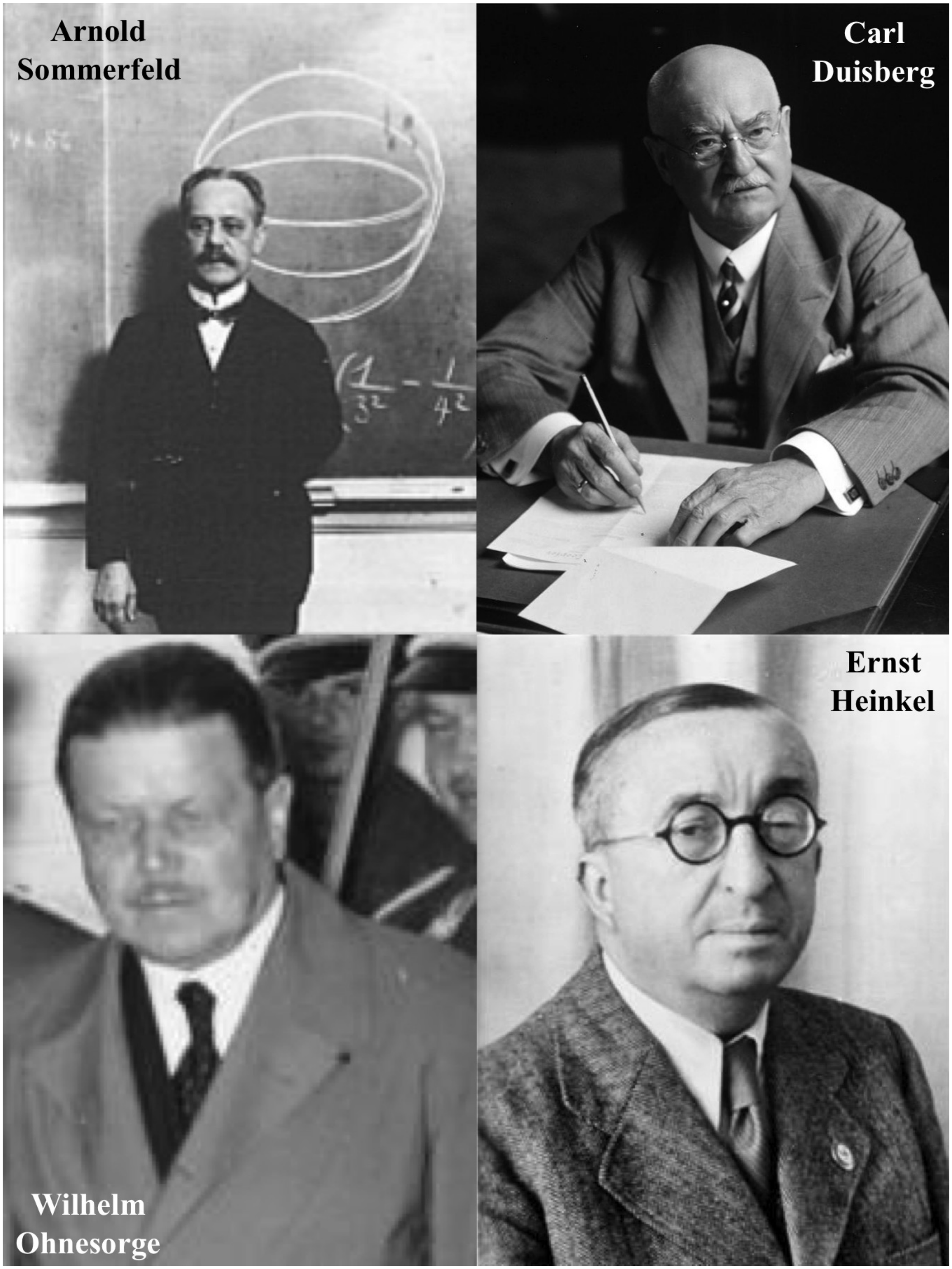

Arnold Sommerfeld
Carl Duisberg
Wilhelm Ohnesorge
Ernst Heinkel

Figure 10.11: More examples of scientific “enlightened despots” who had a very large impact on the German-speaking world: Arnold Sommerfeld, Carl Duisberg, Wilhelm Ohnesorge, and Ernst Heinkel.

As just one example of the enormous impact of Althoff on individual careers, Paul Ehrlich wrote the following note of gratitude to Althoff on 27 July 1907 [Sachse 1928, p. 235]:

> Ich persönlich danke Ihnen meine ganze Karriere und die Möglichkeit, meine Ideen nutzbringend auszugestalten. Als Assistent herumgeschubst, in die engsten Verhältnisse eingezwängt—von der Universität gänzlich ignoriert—kam ich mir ziemlich unnütz vor. Ich habe nie einen Ruf an die kleinste Stelle erhalten und galt als Mensch ohne Fach, d. h. vollkommen unverwertbar. Wenn Sie da nicht mit starker Hand und genialer Initiative für mich eingetreten wären, wenn Sie mir nicht mit rastlosem Eifer und gütiger Freundschaft die Arbeitsmöglichkeiten zurechtgemacht hätten, unter denen ich mich entwickeln konnte, wäre ich vollkommen brachgelegt gewesen.

> I personally thank you for my entire career and the opportunity to make my ideas useful. As an assistant pushed around, squeezed into the tightest conditions—completely ignored by the university—I felt rather useless. I never received a call to the least position and was considered a person without specialty, in other words completely unusable. If you had not been there for me with a strong hand and ingenious initiative, if you had not showered me through untiring zeal and benevolent friendship with employment opportunities, through which I could develop myself, I would have been totally broken down.

In 1911, the German sociologist and political economist Max Weber summed up both the enlightened and the despotic aspects of Althoff's approach to scientific management, as well as their legacy in the German-speaking world [Baumgart 1980, p. 9]:

> Es ist sehr schwierig über diesen Mann zu sprechen. Er war wirklich nicht nur ein guter Mensch im spezifischen Sinne des Wortes, sondern er war ein Mann von sehr weiten Gesichtspunkten,... dem die deutschen Universitäten Dinge verdanken, die in gewissem Sinne unsterblich sind... Und in personaler Hinsicht kann nicht nachdrücklich genug betont werden...: Nepotismus gab es unter ihm nicht... Aber... die Mittel, mit welchen die preußische Unterrichtsverwaltung arbeitete, waren die denkbar rücksichtslosesten. ... Der Einfluss des Althoffschen Systems hat direct korrumpierend gewirkt.

> It is very difficult to talk about this man. He really was not just a good man in the specific sense of the word, but he was a man with a very broad point of view, ... to whom the German universities owe things that are unending in a sense... And in personal terms it cannot be stressed strongly enough...: there was no nepotism under him... But... the means by which the Prussian educational administration worked were the most ruthless conceivable. ... The influence of Althoff's system has had a directly corrupting effect.

Althoff also played a critical role in establishing several whole research institutions, including the many Kaiser Wilhelm Institutes (which had an enormous impact on all scientific fields in the following decades, and became the Max Planck Institutes after World War II), the Koch Institute for Infectious Diseases (Berlin), the Institute for Serum Research and Therapy or the Georg-Speyer-Haus (Frankfurt), the Institute of Hygiene and Experimental Therapy (Marburg), the International Association Against Tuberculosis, the University of Münster, the Royal Academy in Poznan, the Gdansk Institute of Technology, the Wroclaw Institute of Technology, and the early plans of what would become the Friedrich Loeffler Institute on Riems island after Althoff's death. Likewise, Althoff greatly expanded several existing institutions, including the University of Berlin, the University of Göttingen, and the Berlin Charité research hospital.

As already noted, many of Althoff's scientific protégés, such as Felix Klein, Max Planck, Ludwig Prandtl, and Arnold Sommerfeld, became enlightened despots themselves, greatly advancing different parts of the German-speaking research world (Figs. 10.10–10.11). As covered below, Friedrich Schmidt-Ott was arguably Althoff's most powerful and most influential protégé, even though he was not a scientist (just as Althoff was not a scientist). Thus Althoff's protégés, and the people whom they supported, exponentially multiplied the effect that Althoff had on the German-speaking world.

Friedrich Schmidt-Ott (German, 1860–1956), shown in Fig. 10.9, was Friedrich Althoff's assistant for many years. When Althoff retired and then died, Schmidt-Ott continued to play the same role that Althoff had, through his positions in several science funding organizations. Schmidt-Ott was the Prussian minister of culture (like Althoff before him), president of the Emergency Association of German Science (Notgemeinschaft der Deutschen Wissenschaft, which he helped to establish in 1920), a vice president and member of the advisory boards of the Kaiser Wilhelm Institutes, and chairman of the Donor Federation of the Emergency Association of German Science (Stifterverband der Notgemeinschaft der Deutschen Wissenschaft, which he also helped to create in 1920).

In an interview with István Hargittai, the DNA pioneer Erwin Chargaff (see p. 93) recounted his interaction with Schmidt-Ott. The episode also serves as an excellent example of how the enlightened despots made funding decisions [István Hargittai 2000–2006, Vol. I, p. 24]:

> *[Interviewer] How did they decide who should get support?*
>
> It was very different. They didn't believe in peer review, and neither do I, for that matter. I can tell you about my case. I was told by Martin Hahn that if I wanted to supplement what the Department paid me, I should make an application to the Deutsche Notgemeinschaft for a grant. A certain amount would then be branched off to supplement my salary, and I could buy chemicals, etc. I made an application and got an invitation in writing to see, and this was incredible, the chief of the Notgemeinschaft who wasn't even a scientist. His name was Schmidt-Ott and he was an orientalist. I was let into the office of His Excellency, and he made me sit down and we started talking about what books I was reading at that time. Then he asked me about my plans and I told him that I had written a proposal about my work on polysaccharides of tubercle bacilli and so on. He asked me what was a polysaccharide. I explained and then he said that I would soon hear from him. Three days later I had the grant. This is not as stupid as it may seem. If you get the right people they don't have to spend too much time on it. I find it silly when they call this proposal valuable and the other proposal not valuable. Most proposals are half so and half so because one doesn't know yet, and if it is good it may still not work. So the peer reviews are completely useless except that they grow into old boys networks. I think the most important is to get the general behavior, the general way of thinking of the person rather than to decide that this is a marvelous problem. They are not marvelous except in lucky hands, in very gifted hands. The hands you can't look at in a proposal.

As illustrated by the following examples, other enlightened scientific despots at that time or later appear to have arisen independently of Althoff, again perhaps because of the generally autocratic government style that was pervasive in that region at that time.

Carl Duisberg (German, 1861–1935), shown in Fig. 10.11, ran one of the first large corporate research programs at Bayer and then engineered the creation of the even larger research and development entity, I.G. Farben, by the merger of Bayer with other companies, ultimately resulting in a whole range of innovative medical, chemical, and materials science products. Historian Ulrich Marsch described the impact of Duisberg's strategy [Marsch 1994a, pp. 56–59]:

> When IG Farben was founded in late 1925 the organization of research was not a major issue. Decentralization of research had been practiced by all constituent companies for more than forty years was thus simply continued. [...]
>
> IG was under control of the technical men: members of the Managing Board and the key Technical Committee. A decisive element in the technical structure of IG became the TEA-Büro, though it was never meant to play that role. Here the scientific and technical directors of the works and laboratories met and proposed via the Technical Committee, TEA, new projects or investment. We have also seen that the decision to place a product on the market was made by scientifically trained middle managers (heads of works laboratories, and technical commissions) after the successful completion of tests and application processes. Unlike DuPont, where salesmen were more involved in future products, at IG the scientists were in charge.
>
> There are even more differences between IG and DuPont that are worth noting. As it was put recently, IG had a much "leaner" management with fewer hierarchies between production and administration, and especially a closer contact between researchers, research directors and the top management. The project and budget system and the absence of a rigid controlling system of the laboratories' expenses exemplify the relative autonomy of the scientific men inside IG Farben. Also, the existence of independently working individual scientists within the organized research work of the large laboratories and the close contact between those scientists and the research directors shows the importance of the individual scientist right into the 20th century and casts doubts on the absolute priority of team work stressed today. [...]
>
> The argument that the absence of a centralized Research and Development Department at IG caused strategical disadvantages is somewhat misleading: all major German chemical firms before 1925 had grown that way. Putting the main focus only on the Main Laboratories means telling only a small part of the whole story. It was the close connection between research and production and the parallel existence of centralized scientific laboratories, scientific works laboratories, product works laboratories and many technical stations that built the basis for the success of the German chemical companies for more than forty years. IG continued this tradition successfully. The innovative process happened in many locations, and the more research and application sites there were, the more likely was invention and innovation.

Wilhelm Ohnesorge (German, 1872–1962), shown in Fig. 10.11, studied physics as a university student yet made a career in the German Post Office (Reichspost). From that position, he single-handedly turned the Post Office into a strong sponsor of a wide variety of innovative research on particle accelerators, isotope separation, fission reactions and explosives, radar, television, electron microscopy, robotics, and other projects. Ohnesorge gave strong financial and political support to scientists including Manfred von Ardenne, Siegfried Flügge, and others. Helmut Joachim Fischer, a physics Ph.D. who was highly placed in the SS, gave a good description of Ohnesorge [Helmut Fischer 1988, pp. 133–134]:

Die Reichspost hatte von jeher technische Aufgaben zu bewältigen und stützte sich daher auf umfangreiche Forschungs- und Entwicklungsarbeiten auf dem Gebiet der Fernmeldetechnik und anderer für das Postwesen nützlichen Techniken. Dafür gab es in Darmstadt ausgedehnte Laboratorien neben dem Reichspostzentralamt in Berlin-Tempelhof, dessen Präsident Prof. Gladenbeck war.	The Reichspost has always had to cope with technical tasks and therefore relied on extensive research and development work in the field of telecommunications technology and other technologies useful for the postal system. To this end, Darmstadt had extensive laboratories alongside the Reichspost central office in Berlin-Tempelhof, whose president was Prof. Gladenbeck.
Diesen vorgegebenen Rahmen sprengte der ehrgeizige Reichspostminister Ohnesorge. Er hatte einst bei Lenard Physik studiert und interessierte sich allgemeiner für wehrwissenschaftliche Probleme und schaltete zu ihrer Bearbeitung Mitarbeiter und Einrichtungen der Reichspost ein. Reichspost-Forschungsanstalten entstanden in der Nachbarschaft von Berlin in Kleinmachnow und in Miersdorf. Sie betrieben naturwissenschaftliche Grundlagenforschung, und das Institut in Miersdorf unter Dr. Banneitz befaßte sich sogar ernsthaft mit Kernphysik, wobei die Herstellung einer Atombombe angestrebt wurde. Überdies spannte Ohnesorge, der über genügend Geldmittel verfügen konnte und auf die Hilfe des Reichsforschungsrates nicht angewiesen war, auch Hochschulinstitute (wie etwa in Heidelberg) und zudem den tüchtigen Privatforscher Manfred von Ardenne mit seinem eigenen Laboratorium in Berlin-Lichterfelde für seine Forschungsziele ein. Sowohl in Miersdorf als auch im Institut Ardennes begann der Bau je einer 60-Millionen-Volt-Zyklotron-Anlage und von Hochspannungsgeräten, die mit einer Million Volt arbeiten.	The ambitious Reichspost Minister Ohnesorge went beyond this rigid framework. He had once studied physics with Lenard and was more interested in military science problems in general and called in employees and institutions of the Reichspost to deal with them. Reichspost research institutes were established in the vicinity of Berlin in Kleinmachnow and in Miersdorf. They carried out basic scientific research, and the institute in Miersdorf under Dr. Banneitz was even seriously concerned with nuclear physics, with the aim of producing an atomic bomb. In addition, Ohnesorge, who had sufficient funds at his disposal and was not dependent on the help of the Reich Research Council, also employed university institutes (such as Heidelberg) and the capable private researcher Manfred von Ardenne with his own laboratory in Berlin-Lichterfelde for his research goals. Both in Miersdorf and at Ardenne's Institute, construction began on 60 million volt cyclotron facilities and on high-voltage equipment operating at one million volts.

Ernst Heinkel (German, 1888–1958), shown in Fig. 10.11, was the formidable founder and manager of the Heinkel Flugzeugwerke aircraft company. He personally recruited, directly financed, and politically defended a number of revolutionary creators and their creations, including the development of turbojet engines by Hans von Ohain, Herbert Wagner's research group, and others; the development of rocket planes by Wernher von Braun, Hellmuth Walter, and others; the development of advanced airfoils and jet aircraft by Siegfried and Walter Günter and others; the first practical ejection seats in aircraft; and other projects. Heinkel described his recruitment and support of young scientists and engineers [Heinkel 1956, pp. 210–231]:

> In November, 1935, I met a young man, today famous, but who at that time was unknown. Wernher von Braun, since his first year at college, had been passionately interested in the development of rockets.
>
> When I met him he was testing a primitive rocket engine on the artillery testing grounds at Kummersdorf. [...]
>
> "With this rocket engine," von Braun said to me, "one should be able to propel a plane." [...]
>
> This was the beginning of my close association with von Braun. I drove to Kummersdorf, where he was working with some of his friends in a dreary shed. After our first discussions, I delivered to him the fuselage of the He 112 fighter, complete with undercarriage. I also lent him a team of riggers headed by my engineer, Walter Künzel. At the beginning of 1936 this team moved to Kummersdorf. [...]
>
> While these first bench experiments in Kummersdorf—a matter of life or death for those who took part, particularly for the pilot—were being carried out, I received a letter from Professor Pohl, head of the Science Institute at the University of Göttingen. He informed me that he had an assistant, Pabst von Ohain, who was working on a new power unit for airplanes, which did not use a propeller. Von Ohain was very capable. He had already spent his private means carrying out experiments, but now he had reached the end of his resources. Pohl assured me that the young man's ideas were scientifically sound and that it should be possible to put them into practice.
>
> I wrote at once and arranged for von Ohain to come to Warnemünde on March seventeenth. He turned out to be a very likeable young man, scarcely twenty-four years old, a brilliant scientist obviously filled with a burning faith in his idea. He admitted that he as a pure theoretician, and needed both technicians and money to realize his theories. His theories corresponded to what I have already outlined about turbine or jet propulsion, and were primarily concerned with the type of engine that was later known as a centrifugal jet unit.
>
> I hired von Ohain at once, together with a technician named Hahn who had been his assistant in Göttingen. I pledged both of them to utmost secrecy. The same was true for the Günter brothers and Schwärzler, whom I now took into my confidence. Within a month I had a special shed built in Marienehe, completely cut off from the rest of the factory. No one had access to it apart from those directly engaged in the work. I placed this shed at the disposal of Ohain and Hahn.

> When Wagner's jet unit group first approached the Ministry they were told that all preliminary experiments and experiences must be turned over to an aircraft engine works, which alone could guarantee the necessary "practical application." The result was that most of Wagner's people quit Junkers and returned to the Aviation Institute in Berlin. Some of them, however, had apparently heard of the progress of my own work. They applied for jobs in my factory and I took them on. [...]
>
> While the group under Ohain devoted its main attention to an engine with a centrifugal compressor similar to the He S 3, I decided to form a new group, partly composed of the new technicians but under the general direction of Ohain, to undertake the construction of an engine with an axial compressor. I meant to pursue two parallel lines of development in order to determine which one produced the best results. [...]
>
> The second engine group, however, also had its eye on other types of propulsion unit, particularly the mixed type which, designated as a "compound engine," [turboprops or turbofans] is today fairly common in America for large airplanes of moderate speed.
>
> This resulted in the formation of several special divisions which concerned themselves with the development and testing of the most diverse new kinds of engines. The divisions had such code designations as TL (Turbo-jet; *Turbine-Luftstrahl*); STL (ramjet-turbo-jet; *Staurohr-Turbine-Luftstrahl*); or ML (reciprocating engine and jet; *Motor-Luftstrahl*). [...] For the time being I went along with this trend, because nothing can be so instructive as a number of parallel developments. [...]
>
> ...at that stage of development in a new field it was not possible to adopt certain types and write off others, as could be done later. The capable scientists and designers now working together under me already knew the snags to be avoided—for our parallel developments embraced nearly the entire field.
>
> This apparently was also Udet's opinion when finally, at the end of 1939, I won him over to the idea that this new development was of the utmost importance. [...] Udet also found a way to protect me from Mauch's and Schelp's obstructionist tactics...

Adolf Baeumker (German, 1891–1976) ran research programs for the Air Force (Luftwaffe) from a series of increasingly elevated positions during the period 1924–1945 (Fig. 10.12). After the war, he advised both the United States and West Germany on Air Force research programs until the 1960s, proving how widely his talent as a research manager was recognized. Aerospace historian Ernst Hirschel gave a brief overview of Baeumker's importance [Hirschel et al. 2004, p. 72]:

> Baeumker may be considered as one of the first "Science Managers" in Germany. He established the "Aeronautical Research Council" ("Forschungsrat für Luftfahrt"), initiated by Prandtl and von Kármán, to promote the exchange between research and industry. [...] 1935 he created the "Lilienthal-Society" [...] and he founded in 1936 the "German Academy for Aeronautical Research" ("Deutsche Akademie der Luftfahrtforschung"). [...] 1945 he goes to the USA, where he worked for various military offices. 1958 he is transferred to the European Headquarter of the American Air Force (USAFE) in Wiesbaden to work for the cooperation in research and development between the Federal Republic of Germany and the USA. He advises in the sixties German and American head offices in Bonn, among other things, also to unite non-university German aerospace research.

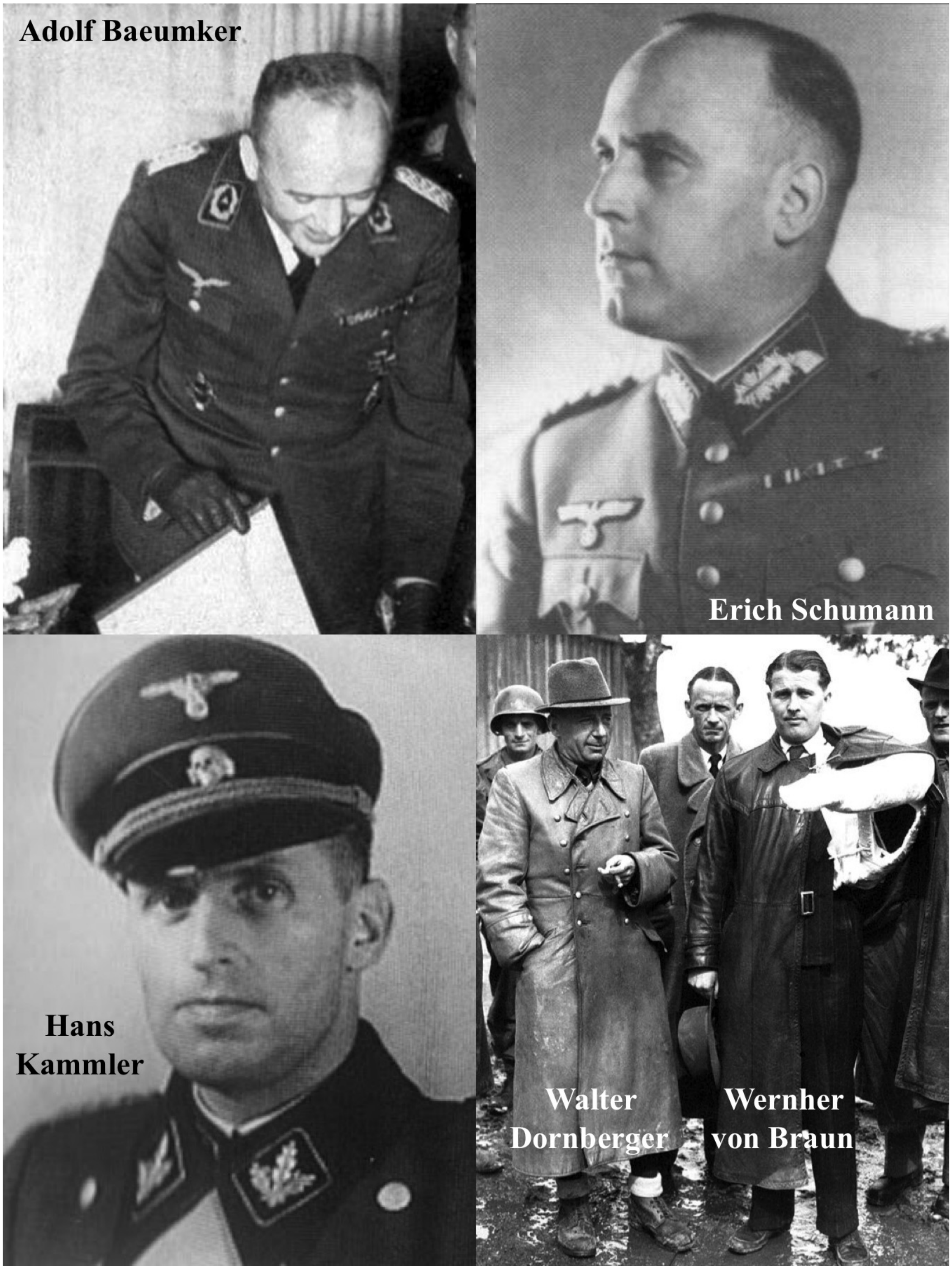

Adolf Baeumker
Erich Schumann
Hans Kammler
Walter Dornberger
Wernher von Braun

Figure 10.12: More examples of scientific "enlightened despots" who had a very large impact on the German-speaking world: Adolf Baeumker, Erich Schumann, Hans Kammler, and Wernher von Braun and Walter Dornberger.

Erich Schumann (German, 1898–1985), shown in Fig. 10.12, was a physics professor at the University of Berlin, chief physicist of the Army Ordnance Office (Heereswaffenamt), and member of the Reich Research Council (Reichsforschungsrat). In those positions, he led or was directly involved in research on rockets (he was Wernher von Braun's doctoral dissertation advisor), armor-penetrating shaped charge conventional explosives, fission reactions and explosives, fusion reactions and explosives, biological weapons, quite likely chemical weapons, and other areas [Nagel 2012a]. Schumann recruited scientists for all of these areas and supported them both financially and politically. Ultimately all of these technologies that he helped to develop became critical components of Cold War military arsenals and strategies for the United States, Soviet Union, and other countries. The historian Rainer Karlsch gave a thumbnail sketch of Schumann, the many hats that he wore, and the many ways that various other people perceived him [Karlsch 2005, pp. 31–32]:

Die Forschungsstelle des HWA ging bei allen Projekten vom Grundsatz aus, die vorhandenen Strukturen, dazu gehörten Universitäten, außeruniversitäre Forschungseinrichtungen und Firmen, in ihrem Sinne zu nutzen und zu steuern. Im HWA selbst wurden nur Forschungen angesiedelt, die aufgrund ihrer militärischen Bedeutung nicht "außer Haus" gegeben werden konnten.	In all its projects, the Army Ordnance Office's research center was based on the principle of using and controlling the existing structures, including universities, non-university research institutions and companies, in their interests. In the Army Ordnance Office itself the only research that was conducted was that which could not be sent "out of the house" due to its military implications.
Leiter der Forschungsabteilung des HWA war seit 1934 Ministerial-dirigent Professor Erich Schumann. Er war in kurzer Zeit zu einem Multifunktionär aufgestiegen. Seit 1929 leitete er die Abteilung für Akustik am Physikalischen Institut der Berliner Universität und lehrte experimentelle und theoretische Physik. Zum Direktor des neu gegründeten II. Physikalischen Instituts wurde er 1934 ernannt. Sein Interesse galt vor allem der Sprengstoffphysik. Gegenüber den Hochschulkreisen war Schumann stets bemüht, seine Rückendeckung durch die Wehrmacht zu betonen. Seine Einstufung als Ministerial-dirigent entsprach beim Heer etwa dem Rang eines Generalmajors. Nicht wenigen seiner Gesprächspartner blieb er als "General" in Erinnerung, beeindruckend in Uniform und durch sein temperamentvolles und dynamisches Auftreten.	Since 1934 Professor Erich Schumann had been head of the research department of the Army Ordnance Office. Within a short time he had become a multifunctional official. From 1929 he headed the Department of Acoustics at the Physics Institute of Berlin University and taught experimental and theoretical physics. He was named director of the newly founded Second Physics Institute in 1934. His main interest was in explosives physics. Schumann was always anxious to emphasize his support by the military to the university circles. His classification as a ministerial official was roughly equivalent to that of a major general in the army. Not a few of his interlocutors remembered him as "General," impressive in uniform and with his spirited and dynamic appearance.

> Über Schumanns Qualitäten als Wissenschaftsorganisator gingen die Meinungen der Zeitgenossen weit auseinander. Die einen sahen in ihm einen fähigen Wissenschaftler und großen Förderer der Kampfstoffforschung und Sprengstoffphysik, die anderen nannten ihn einen Scharlatan, der sich in den Dienst von windigen Projekten stellte. [...] Doch Schumann auf die Rolle eines eitlen Machtmenschen zu reduzieren, hieße seine wissenschaftliche Kompetenz und sein organisatorisches Talent zu unterschätzen.

> The opinions of his contemporaries differed widely about Schumann's qualities as a scientific organizer. Some saw him as a capable scientist and great supporter of warfare research and explosives physics; others called him a charlatan who was at the service of windy projects. [...] But to reduce Schumann to the role of a vain power man would be to underestimate his scientific competence and organizational talent.

Hans Kammler (German, 1901–?), shown in Fig. 10.12, is worthy of special mention [Agoston 1985]. He had a doctoral degree in engineering and rose to the level of General (Obergruppenführer) in the SS. Over the course of World War II, Kammler gained control over more and more of the military's advanced R&D programs. By the end of the war he controlled virtually all of the major programs—rockets, missiles, jets, nuclear technology, directed energy technologies, etc.—and then he mysteriously vanished. New evidence proves that he was secretly captured and interrogated by the United States (pp. 4931–4959). It is unclear how much Kammler contributed to the success of all of those programs versus how much he simply took over already successful programs, but at a minimum it is clear that he had formidable political skills and a strong taste for very innovative, high-impact research. Of course, he also ordered or assisted in the murder of large numbers of people, so he is certainly not a role model. Helmut Fischer, a physics Ph.D. who was highly placed in the SS's security office, succinctly described Kammler [Helmut Fischer 1988, p. 64]:

> Eine besondere Rolle spielte dabei der Leiter der Gruppe C des WVHA [Wirtschafts- und Verwaltungs-Hauptamt], SS-Gruppenführer Hans Kammler. Anlässlich der Erstellung von Bauten in Peenemünde, wo die Vergeltungswaffe V 2 geschaffen wurde, kam Kammler mit den Verantwortlichen für die V-Waffen in Berührung. Er machte sich bald unentbehrlich, riss immer mehr Zuständigkeiten an sich und wurde schliesslich zum massgeblichen Mann für die Fertigung der Vergeltungswaffen. Aber damit nicht genug! Der ehrgeizige Kammler schaltete sich auch in die Forschungs- und Entwicklungsarbeiten zur Konstruktion neuartiger Waffen ein. Dazu erlangte Kammler auch die Befehlsgewalt über die Sondereinheiten der Wehrmacht, die für den Fronteinsatz der V-Waffen aufgestellt worden waren. Kammlers Machtstellung wurde schliesslich so stark, dass Speer als Reichsminister für Rüstung und Kriegsproduktion um seine Stellung fürchsten musste.

> A special role was played by the leader of Group C of the WVHA [Economic and Administrative Main Office], SS-Gruppenführer Hans Kammler. On the occasion of the construction of buildings in Peenemünde, where the reprisal weapon V-2 was created, Kammler came into contact with those responsible for the V-weapons. He soon made himself indispensable, increasingly took over responsibilities and eventually became the key man for the production of retaliatory weapons. But that is not all! The ambitious Kammler also turned to the research and development work on the construction of novel weapons. Kammler also gained command of the special forces of the Armed Forces, which had been set up for the front line of the V-weapons. Kammler's position of power was finally so strong that Speer had to worry about his position as Minister of Armaments and War Production.

Wernher von Braun (German, 1912–1977), Walter Dornberger (German, 1895–1980), and their military and government sponsors provided very strong, driven, focused, long-term support for the development of large liquid propellant rockets; see Fig. 10.12. Boris Chertok, a leader of the Soviet rocket programs from the time they acquired experts and technology in Germany in 1945, described von Braun's management style [Chertok 2005–2012, Vol. 1, pp. 305–306]:

> Von Braun's story is no longer novel, thanks to numerous publications by American, German, and Soviet researchers, and even television documentaries. For that reason I will not cram my memoirs with yet another version of von Braun's biography. Gröttrup said that one of von Braun's very good traits was his striving to attract the most talented people. In doing so, he did not take age into account, and he was not afraid of competition.
>
> Von Braun had been named technical director of Peenemünde-Ost at the age of twenty-five! For Germans this was quite unusual. But this shows how highly they valued his talent, initiative, and rare intuition. According to Gröttrup, von Braun was very attentive to senior, experienced specialists. He made fundamental decisions after having first gathered and listened to diverse opinions. There was no voting; von Braun always had the last word, but he managed not to offend the other staff. In spite of his youth, his authority was not called into question.
>
> Fifty years after this assessment of von Braun's management style, I met with an American engineer named Jerry Clubb, who was a participant in the Apollo-Saturn lunar program, which had been directed by the no longer twenty-five but fifty-five-year-old, world-renowned creator of the first long-range ballistic missiles. The American talked about von Braun's working style in the United States in the same way that I had heard Gröttrup describe it in 1945 over a cup of coffee with whipped cream. [...]
>
> Von Braun had been valued and trusted by Dornberger and the higher military leadership of the infantry forces who had financed the construction of Peenemünde. He did not have to fear intrigue against himself, and he was able to work confidently as the technical director. Dornberger, who had become a general at Peenemünde, had always shielded von Braun. They were a powerful duo.
>
> In spite of various nuances in political views, the main leadership staff had worked rather harmoniously and very selflessly.

Thus the German-speaking research world appears to have greatly benefited from a number of enlightened despots during the nineteenth and early twentieth centuries. As shown in Section 11.2.6, this same sort of enlightened despot approach to identifying and supporting scientific innovators and innovations was also employed by very successful German-inspired U.S. research and development programs during their heyday in the 1940s through 1960s. Innovation experts have argued for bringing back this sort of management approach to improve the modern innovation system, either as an alternative to or as a supplement for the more conservative modern peer-review/consensus-based methods [e.g., p. 2248; Azoulay et al. 2019; Braben 2004, 2008, 2014].

10.2.7 Systems Analysis

One factor in the success of the earlier German-speaking world appears to have been widespread explicit or implicit application of systems analysis. As shown in Fig. 10.13, systems analysis is a top-down approach to:

- First identify a whole range of important problems.
- Then choose the most important problem that can be addressed with the available resources.
- Next enumerate all potential types of solutions to that problem, systematically covering all possibilities and demonstrating that they form a complete set with no omissions.
- Then consider which potential solutions are ruled in or out by laws of nature or by their inherent disadvantages or advantages.
- Finally focus on pursuing the most promising solutions for the most important problems.

This systems analysis mindset appears to have been deeply ingrained in German-speaking culture and can be traced back at least as far as Wilhelm von Humboldt at the beginning of the nineteenth century (see for example the quotes on p. 1965). It was most clearly and fully articulated by Fritz Zwicky (1898–1974), a Swiss physicist who emigrated to the United States and who referred to the systems analysis method as the “morphological approach” [Zwicky 1969, pp. 36–37, 105–108]:

> It has often been stated that it is no longer possible today to know all or even several fields of science well, let alone to contribute materially to their advancement. This erroneous belief, as well as the rather astounding fact that among men of research there are but a very few who can make discoveries and inventions in widely separate fields, proves that the majority of them are either quite incapable of thinking morphologically or they have not yet learned or been taught to view the world as a whole. Contrary to the currently entrenched idea that universality of knowledge is a thing of the past, those who can visualize the true world image will nevertheless be capable of successfully doing research on many diverse subjects. They will also succeed in producing discoveries and inventions that have escaped the specialists in all domains of human activity because such specialists lack that type of universal outlook which, as I hope to show, automatically leads to the recognition of entirely new insights. [...]
>
> (a) Morphological research is totality research, which in a completely unbiased way attempts to derive all the solutions of any given problem.
>
> (b) The morphological approach has developed its own characteristic procedures, such as the method of the morphological box which will be explained and applied in this chapter.
>
> (c) The morphological approach gives us the maximum guarantee that no circumstance is overlooked that might be of importance for the satisfactory accomplishment of any task before us. [...]

> (h) The morphological approach enables us to systematize our inventiveness. It allows us to make discoveries and inventions methodically, and in some cases almost automatically. Without that, we are forced to resort to haphazard procedures of trial and error.
>
> (i) Expressing it pointedly, we may say that the morphologist is a professional genius. In other words, it is his profession to be a genius who is capable of pursuing original research and making discoveries and inventions in all fields of human endeavour. Those who are commonly thought to be geniuses are actually amateurs whose accomplishments in restricted fields are more or less accidental and bear the mark of dilettantism. [...]
>
> For the construction of any morphological box and for the subsequent evaluation of the information that may be contained in it we proceed as follows:
>
> First Step. The problem to be solved must be very concisely formulated.
>
> Second Step. All of the parameters that might be of importance for the solution of the given problem must be localized and analyzed.
>
> Third Step. The morphological box or multidimensional matrix, which contains all of the potential solutions of the given problem, is constructed.
>
> Fourth Step. All the solutions contained in the morphological box are closely scrutinized and evaluated with respect to the purposes that are to be achieved.
>
> Fifth Step. The optimally suitable solutions are being selected and are practically applied, provided the necessary means are available. This reduction to practice requires in general a supplemental morphological study.

This systems approach that was described so explicitly by Zwicky appears implicitly throughout the German-speaking world, both in how the creators selected important problems to address (such as those summarized in Chapters 2–9), and also in how the creators exhaustively explored all viable solutions for those problems (for example a whole range of different types of engines, organic molecules, aerospace vehicles, etc.).

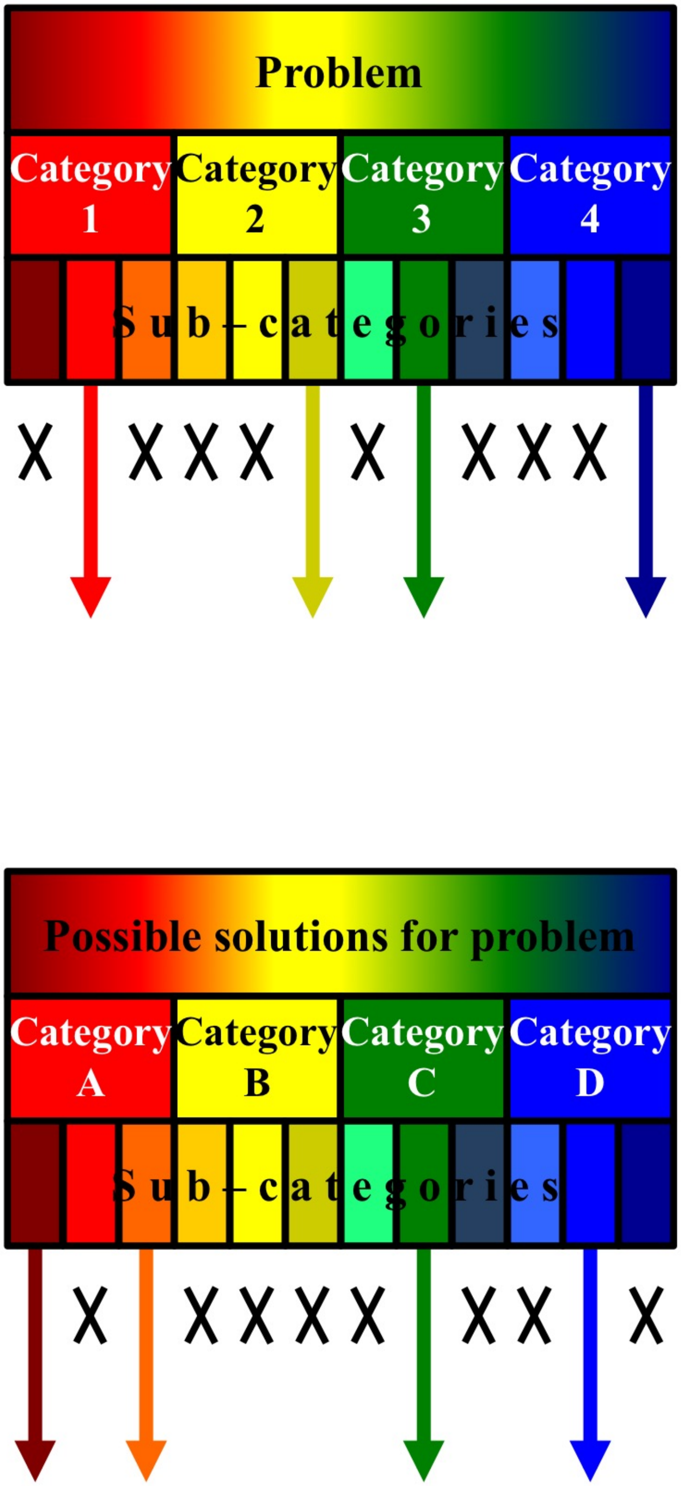
This top-down approach similarly appears to have been the guiding principle for Friedrich Althoff and the other enlightened despots managing the German-speaking world as they decided which creators and creations were the most important to support. For example, as shown on p. 2009 of this chapter, Ernst Heinkel and the engineers working for him used systems analysis to consider all the major types of possible jet engines, and to pursue the most promising ones in parallel in order to determine which ones would be best.

As another example, Donald Putt's postwar U.S. investigations into wartime German missile research reported how systems analysis had been thoroughly exploited to consider all possibilities in the missile programs [Putt 1946a]:

> Many of Germany's research laboratories and several large commercial firms concentrated on this field of endeavor. This tremendous effort resulted in 138 guided missiles and assorted devices, including their modifications. These were of types wholly unknown

> to laymen in the United States. At the outbreak of the war some of these were strictly "out of this world"—to use a current phrase. In addition, German scientists had developed other equipment of a type we had considered impracticable, such as the ram jet.
>
> The stupendous effort in basic research expended by the Germans in the guided missile field was designed to cover the complete field of potentialities for such weapons. The losses incurred in Germany by heavy bomber raids can in no way be charged to lack of preliminary research on missiles. Weapons of this category were divided into the following classifications:
>
> A. Ground to air.
>
> B. Air to air.
>
> C. Air to ground.
>
> D. Ground to ground.
>
> E. Underwater to underwater.
>
> F. Underwater to ground.
>
> G. Underwater to air.
>
> Moreover, every known type of remote control and fusing means was exploited. These included radio control, wire control, radar, continuous wave, acoustics, infrared, light beams, and magnetics.
>
> Likewise, all methods of employing jet propulsion for subsonic and supersonic speeds were exploited.

Fritz Zwicky was trained in the earlier German-speaking world, and by the time he wrote his 1969 book (quoted above) in the United States, he sounded disappointed that like-minded innovators had become so scarce in that time and place. They had been much more common in the German-speaking world.


Problem
Category 1
Category 2
Category 3
Category 4
Sub-categories
X X X X X X X X
Possible solutions for problem
Category A
Category B
Category C
Category D
Sub-categories
X X X X X X X X

State the broadest problem of interest.

List all possible categories of that problem.

Divide into sub-categories, etc.

Eliminate sub-categories that are not desirable or not possible.

Focus on the most important remaining sub-categories.

Choose an important problem or sub-problem.

List all categories of possible solutions for that problem.

Divide into sub-categories, etc.

Eliminate sub-categories that are not desirable or not possible.

Focus on the most important remaining sub-categories.

Figure 10.13: Systems analysis is a methodical, top-down approach for considering all possible categories of problems of interest, and all possible categories of solutions to those problems, in order to identify and focus on the most promising solutions for the most important problems.

10.2.8 Limited Natural Resources

The German-speaking world had tremendous economic and military needs or aspirations, yet extremely limited natural resources that could be harnessed to fulfill those requirements. This limitation provided an incredibly powerful incentive to create revolutionary new technologies, processes, and materials that could meet those needs with the available resources. That was especially true during wartime, yet even between wars, Germany's lack of resources spurred it to develop synthetic materials to be more economically competitive against foreign industry. As shown in Fig. 10.14, examples of that industrial innovation included synthetic dyes, the Haber-Bosch ammonia production process, synthetic rubber (butadiene or buna), a wide variety of plastics, synthesized explosive molecules, ersatz food ingredients and preservatives, synthetic blood plasma, and the development of biotechnology methods to produce industrial and food products.

Ulrich Wengenroth, a scientific historian at the Deutsches Museum in Munich, described those conditions and the resulting German achievements [Landes et al. 2010, pp. 290–291, 295–296]:

> The showcase of German science-based industry was undoubtedly organic chemistry. From the 1880s until well after World War II German companies held a commanding position in most products based on carbon hydrates, especially when it came to high-value products like pharmaceuticals. [...] The main strategy was always the same: analyze a natural product and then find ways to synthesize it cheaply from the tar derivatives the heavy industries and gasworks would abundantly supply. The overabundant supply of first-rate human capital for industrial research, plus the additional incentive of not having access to natural resources for colonies, created a situation that proved to be immensely fortunate. Only the Swiss chemical industry, also with a good supply of academically trained scientists and no colonies, could match the progress of German organic chemistry. It was one of the first examples after the Industrial Revolution when the absence of natural resources proved to be beneficial. Apart from the availability of highly qualified human capital, the German dyestuffs industry benefited from having hit a treasure trove of potential products, and the most innovative entrepreneurs were smart enough to see and fully utilize that potential. [...]
>
> Germany, which was in no position to safeguard its raw material supplies from a vastly superior British navy, during conflict and in preparing for war turned to processing poor raw materials from its own territory and producing *Ersatz* to overcome supply shortages by second-rate material. Enormous ingeniousness and innovativeness were invested in autarchy technologies[...]
>
> The strength of the German chemical industry in synthesizing chemical compounds that were found in nature or compounds close to them was greatly in demand when the country went into World War I. Just before the war, Fritz Haber had created a process to synthesize ammonia, by this being able to produce nitrogen, which had mostly been imported from South America before the war and, more important, before the blockade by the British navy. Nitrogen was indispensable for both ammunition and fertilizers. [...]

> More on the autarchy line like ammonia synthesis were developments of coal hydrogenation that were begun during World War I and completed with the advent of World War II to produce both gasoline and rubber from domestic coal. The R & D strategy was not so different from chemical synthesis in the prewar years, but it steered away from international markets and considerations of competitiveness of the new production lines. What was quite rational, given the resource poverty of Germany and its inability to break a British naval blockade, slowly turned into a new paradigm of a self-sufficient Germany that would not have to negotiate its way on international markets but could retreat into some self-designed cage. While before World War I chemical synthesis was a way to beat prices and quality of products based on natural resources, after the war and very much in the Nazi years it became a gospel of independence for conducting wars.

A lengthy 1946 *Harper's* magazine article [Charles Walker 1946] listed a number of examples of synthetic materials and processes that had been developed in Germany during World War II and eagerly adopted by the United States after the war; see pp. 75 and 421. Tom Bower summarized the importance of those synthetic materials for Germany during the war, and for the United States after the war [Bower 1987, p. 5]:

> The proof of German technical prowess is overwhelmingly established in the hundreds of reports written by Allied investigators who did not shy from describing the Germans' "astonishing achievement" and "superb invention." It was also established by the very survival of Germany during four years of total war despite the prediction during the first two years of war by British intelligence that the German economy and German industry faced imminent and total collapse. The blockade on essential minerals, chemicals, and petroleum products, it was argued, would cripple weapons production. But the very opposite happened, because German scientists developed an astonishing range of substitutes that not only humiliatingly neutralized the Allied blockade but heralded the dawn of a new scientific era. [...] German scientists had pioneered so many inventions that many Allied experts would complain that their plunder could do no more than scratch the surface.

In contrast, the global system in general and the United States in particular have not felt especially resource-limited over the last several decades, and hence have lacked strong incentives to develop new synthetic materials and processes beyond those that were previously imported from the German-speaking world. With rising concerns about climate change, pollution, overuse of natural resources, and related problems, hopefully that attitude will change, and nations worldwide will have strong incentives to develop revolutionary new materials and processes to minimize the impact on the environment.

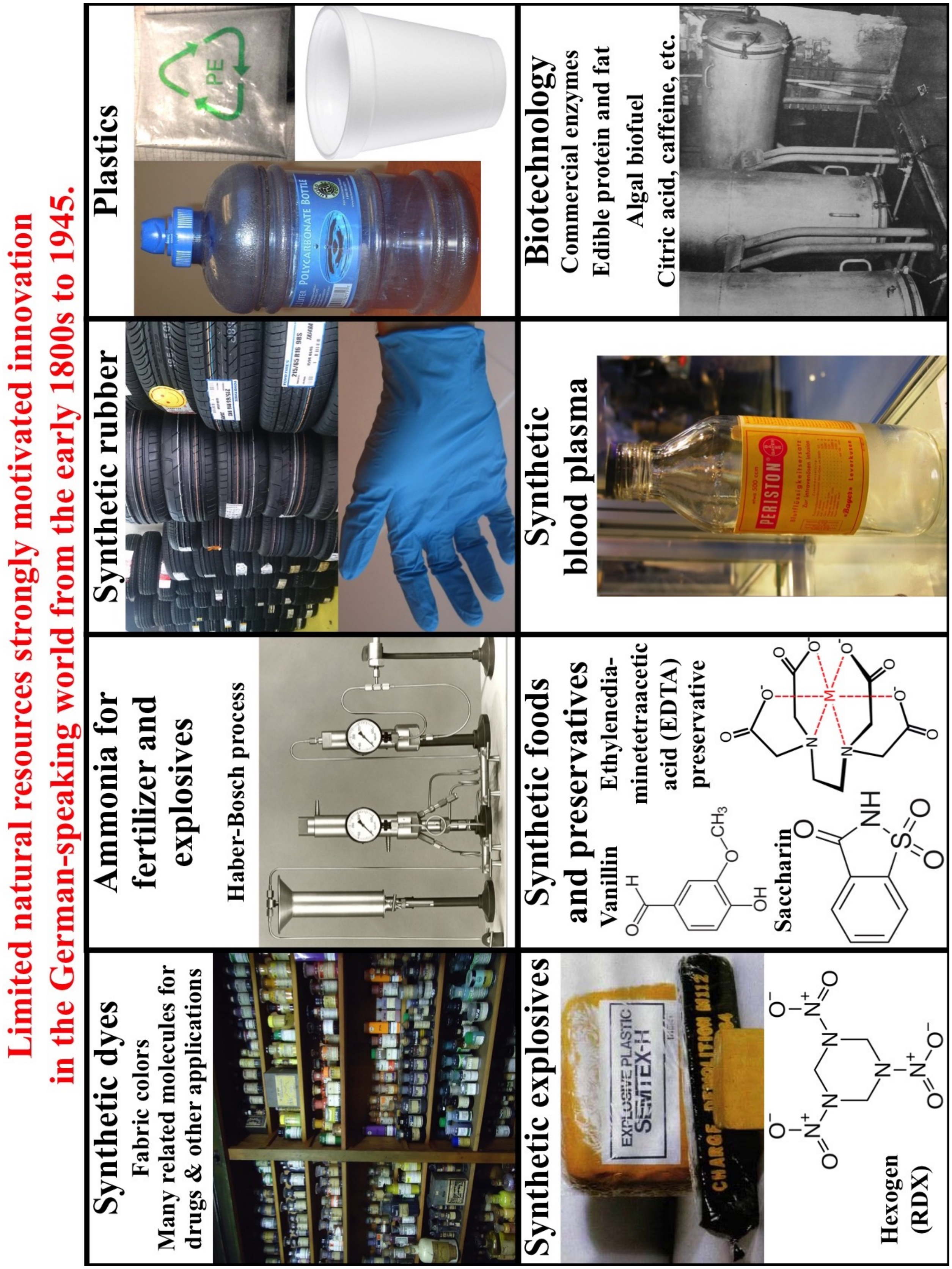

Limited natural resources strongly motivated innovation
in the German-speaking world from the early 1800s to 1945.
Synthetic dyes
Fabric colors
Many related molecules for drugs & other applications
Ammonia for fertilizer and explosives
Haber-Bosch process
Synthetic rubber
Plastics
PE
POLYCARBONATE BOTTLE
Synthetic explosives
EXPLOSIVE PLASTIC SEMTEX-H
CHARGE DEMOLITION M112
Hexogen (RDX)
Synthetic foods and preservatives
Vanillin
Saccharin
Ethylenediaminetetraacetic acid (EDTA) preservative
Synthetic blood plasma
PERISTON
Bayer Leverkusen
Biotechnology
Commercial enzymes
Edible protein and fat
Algal biofuel
Citric acid, caffeine, etc.

Figure 10.14: Limited natural resources strongly motivated innovation in the German-speaking world from the early 1800s to 1945.

10.2.9 International Rivalry

Strong competition can forestall a sense of complacency and can therefore spur innovation. From the early 1800s through 1945, the German-speaking world was highly motivated by both fierce military competition and fierce economic competition with several other countries (Fig. 10.15):

- The United Kingdom was a strong scientific rival and industrial competitor throughout that entire time period, and a staunch foe in World War I (1914–1918) and World War II (1939–1945).
- The United States became a strong industrial competitor from the late nineteenth century onward, and was a vigorous and ultimately victorious opponent in World Wars I and II.
- France was a waning scientific powerhouse in the nineteenth and early twentieth centuries, and a military opponent during the Napoleonic Wars (1803–1815), the Franco-Prussian War (1870–1871), and World Wars I and II.
- Russia was a ferocious military opponent during World Wars I and II.
- There was also significant military and economic rivalry among German-speaking states until German unification in 1871, with some rivalry among Germany, Austria, and Switzerland continuing even after that time.

The international rivalries over industrial products and market share were strong drivers for innovations in the German-speaking world, especially in areas such as the chemical industry, electrical machinery, engines and engine-powered vehicles, and optics. Likewise, the military conflicts and active planning during peacetime for the next military conflict emphasized the development and use of new technologies for military purposes—trains to rapidly move troops and supplies, submarines to attack enemy shipping, poison gases to employ against entrenched opponents, aircraft and rockets to reach other countries, and so forth.

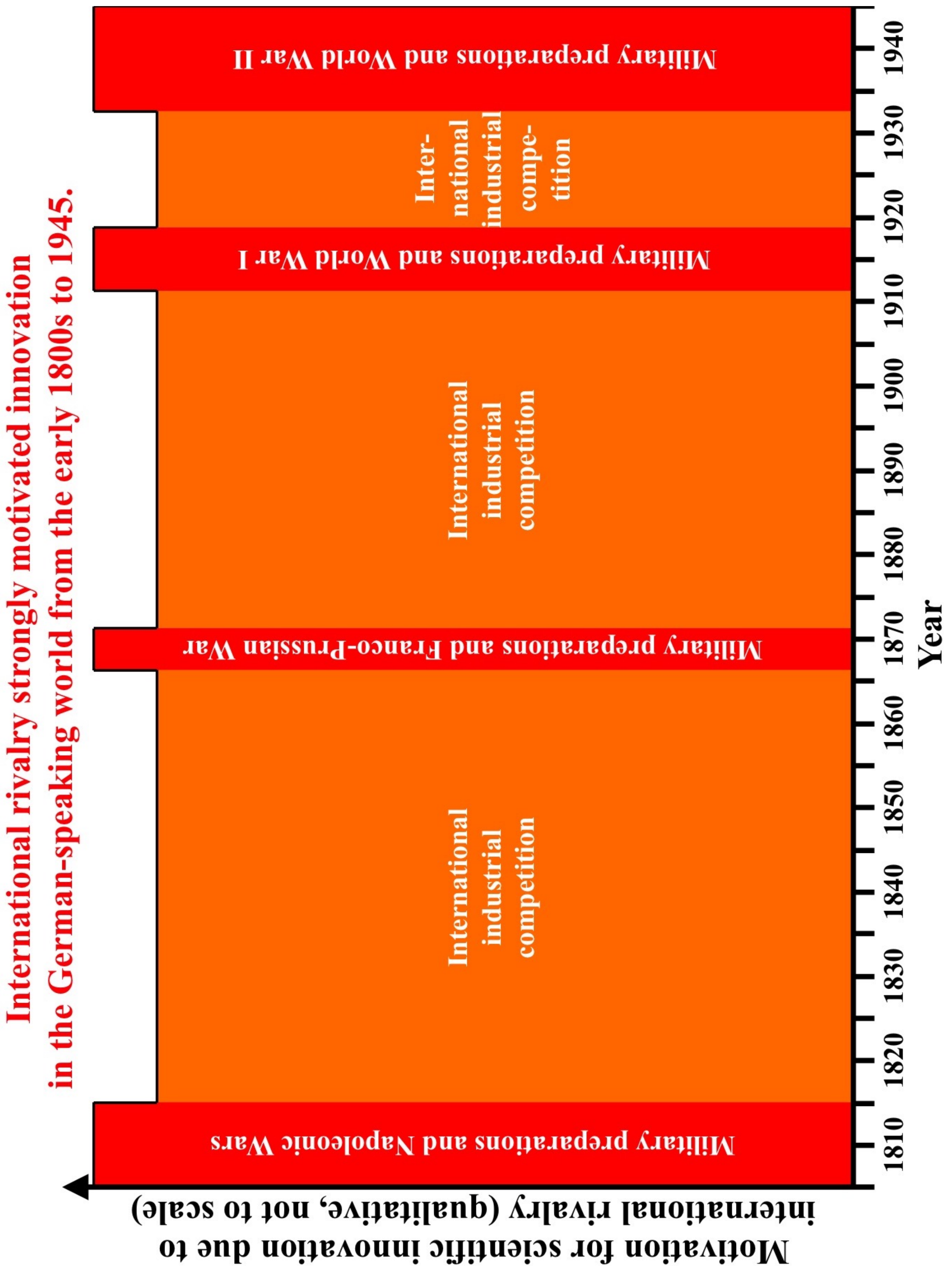


Figure 10.15: International rivalry strongly motivated innovation in the German-speaking world from the early 1800s to 1945.

10.2.10 Industrial Unity of Purpose

Nowadays companies are afraid to create any innovations that they cannot immediately capitalize on themselves, lest any research that they have funded end up benefiting other companies more than their own. In contrast, throughout the late nineteenth and early twentieth centuries, German industry was willing to invest very large sums of money in revolutionary R&D projects. The companies were much more afraid of the possibility that Germany might lose to foreign companies and nations than they were of the possibility that their own company-funded innovations might benefit another German company. Leaders of different German companies were united by a strong sense of common purpose (Fig. 10.16). Ultimately this strong nationalism moved them toward the extreme of massive monopolies like I.G. Farben and the fascist ideology intertwining government and industry.

Ulrich Wengenroth, a scientific historian at the Deutsches Museum in Munich, summarized the history of this German tendency toward "cooperative capitalism" [Landes 2010, pp. 279–280]:

> Cartels mushroomed after the protectionist reversal of the 1870s. They were defended as freedom of contract, and the highest court of the empire in 1897 decided that cartel arrangements were not only legal but binding on all partners and could be enforced. To Alfred Chandler, Jr., this was a watershed setting Germany firmly on the path of cooperative rather than competitive capitalism. By 1897, however, big industry in Germany had already twenty years of intensive cartelization behind it. The climax of cartelization came with the Nazis and their *Zwangskartellgesetz* of 1933, which made cartels mandatory in the interest of Nazi economic planning. After World War II, under pressure from the United States, the cartelization of German industry was largely made illegal if not completely abolished. [...]
>
> Intellectual property rights were hardly protected before 1877 when the German patent law was passed. Before that year, governments of German states, and particularly of Prussia, were reluctant to grant patent protection in an effort to ease transfer of knowledge from abroad. [...] All this changed when Prussia believed that German industry had successfully caught up and was in a position to turn from imitator to bona-fide innovator. The German patent law protected the process rather than the product, thus stimulating research for alternative ways to turn out the same product. This proved to have a highly stimulating effect on corporate research and development.

Wengenroth also gave several examples of how the German propensity for cooperative capitalism greatly benefited the innovation and international competitiveness of German industry in the fields of chemicals, electrical equipment, and machinery [Landes 2010, pp. 290–293]:

> Charts of tar-based products show a wide spectrum from explosives to anesthesia, Bakelite, and a number of synthetic dyestuffs and their intermediates. In protecting processes rather than products the German patent law further stimulated the research drive into ever more fields. It took the German chemical industry's competitors decades and the scrapping of all property rights in the wake of the wars slowly to erode the position it had built by the turn of the century. Only with two paradigm shifts in the industry, from coal to oil and from chemical synthesis to biotechnology, did foreign—mostly

> American—companies draw even with and eventually surpass the “big three,” only two of which are still German with BASF being number one globally, while Hoechst has become part of the French Aventis.
>
> —
>
> An industry that was almost as successful in making the most of the great pool of talent at the many polytechnics was electrical engineering. This industry was governed by two very different titans of German enterprise, Werner Siemens, who had introduced the telegraph to Germany, and Emil Rathenau, the founder of AEG (Allgemeine Electrizitätgesellschaft = General Electric Company). [...]
>
> The outcome on the German market was a duopoly of AEG and Siemens and remained that until the decline of AEG in the 1980s. [...] Although it has been debated whether electrical manufacturing was a science-based industry or an industry-based science in Germany, there is agreement that the close and extensive cooperation of manufacturers and polytechnics greatly helped to solve innumerable problems occurring on the way to innovations that eventually created the high reputation for equipment “made in Germany.”
>
> —
>
> Ludwig Loewe [...] let one of his directors, the twenty-five-year-old Walter Schlesinger, go to the Berlin polytechnic to conduct research in metal cutting using heavy grinding machines. [...] The result was the first ever German dissertation in mechanical engineering, the establishment of a “norm factory” on the premises of Loewe, and the beginning of what was to become the greatest export success of German mechanical industry ever, the DIN (Deutsche Industrie Normen)—German industrial norms used by countries around the world, among them more recently the People’s Republic of China. In creating norms for fits, Schlesinger and his comrades-in-arms—literally, because most breakthroughs happened through World War I—established national norms rather than proprietary factory norms. With national norms, all German industry could participate in decentralized mass production. Products and components designed meeting these norms would always fit together. The test run was arms production in World War I, when a highly decentralized German industry had to turn out components for uniform mass products. [...]
>
> And as Germany moved ahead in creating a system of norms, other countries did not bother to invent something new but adopted DIN norms and later also their electrical counterparts, VDE norms (VDE = German Association of Electrical Manufacturers). There were very few innovations, if any, that helped German industry better to conquer export markets for mechanical and electrical products. Schlesinger and Loewe together had established this path, and others were quick to follow, seeing that agreeing on a common norm helped German business more than going proprietary. It is no surprise that German industry’s tradition of collective action and cooperation was further strengthened by that strategy.

As discussed in Section 11.2.10, many companies in the United States experienced (and greatly benefitted from) a similar unity of purpose during World War II, the Cold War, and the space race, but unfortunately that no longer seems to be true today.

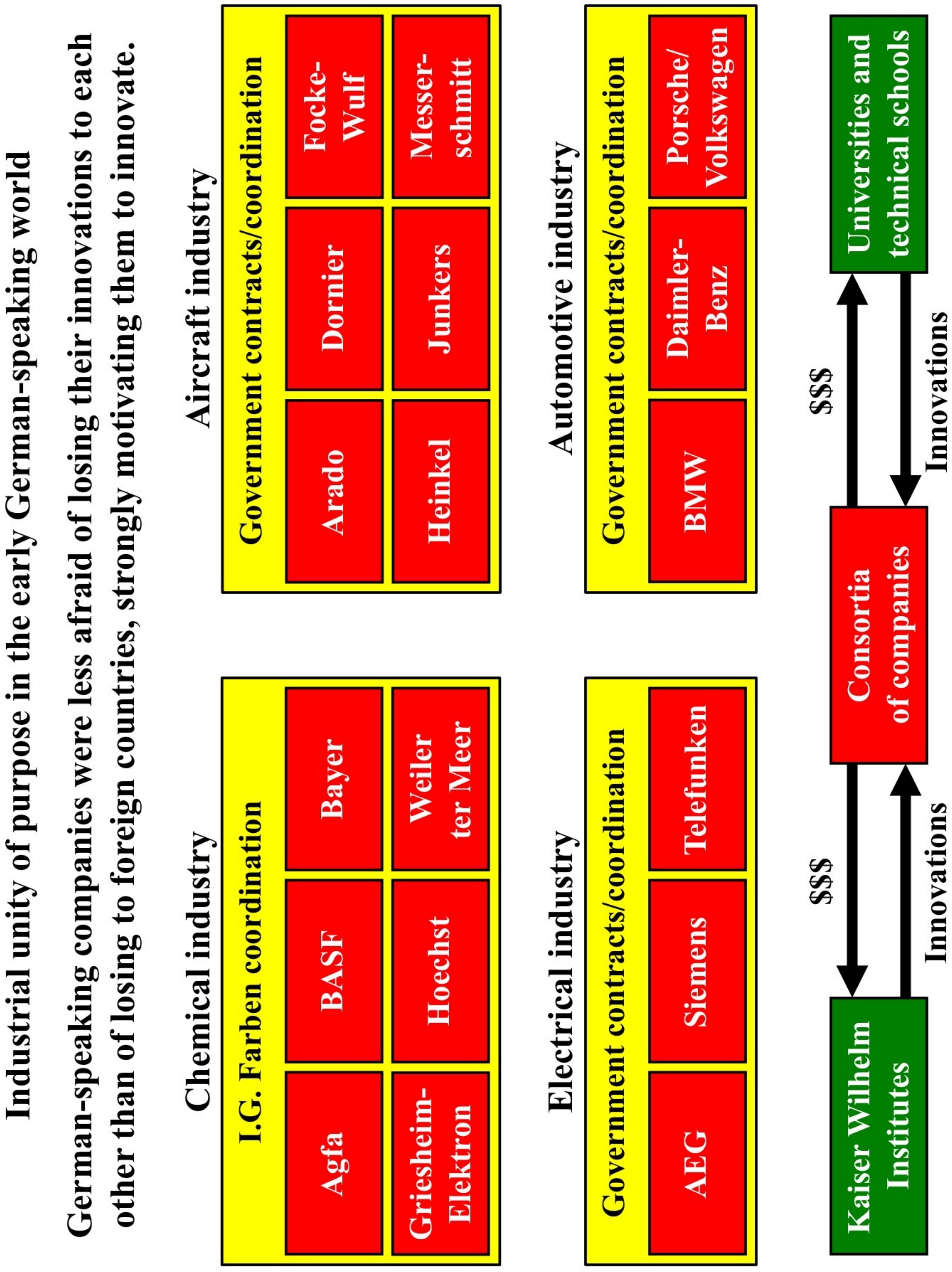

Industrial unity of purpose in the early German-speaking world
German-speaking companies were less afraid of losing their innovations to each other than of losing to foreign countries, strongly motivating them to innovate.
Chemical industry
I.G. Farben coordination
Agfa
BASF
Bayer
Griesheim-Elektron
Hoechst
Weiler ter Meer
Aircraft industry
Government contracts/coordination
Arado
Dornier
Focke-Wulf
Heinkel
Junkers
Messerschmitt
Electrical industry
Government contracts/coordination
AEG
Siemens
Telefunken
Automotive industry
Government contracts/coordination
BMW
Daimler-Benz
Porsche/Volkswagen
Kaiser Wilhelm Institutes
$$$
Innovations
Consortia of companies
$$$
Innovations
Universities and technical schools

Figure 10.16: In the early German-speaking world, companies were less afraid of losing their innovations to each other than of losing to foreign countries, strongly motivating them to innovate.

10.2.11 Other Factors

Among the creators from the German-speaking world, there was a disproportionate percentage of scientists and engineers who were Jewish or who at least had some sort of Jewish family background [Ash and Söllner 1996; Fraser 2012; Gerstl 2014; István Hargittai 2006; Lebrecht 2019; Leff 2019; Medawar and Pyke 2000; Nachmansohn 1979].

Country	**Number of Jews**	**% of local population**
Austria	191,000	2.8%
Germany	525,000	0.75%
Czechoslovakia	357,000	2.4%
Hungary	445,000	5.1%
Netherlands	156,000	1.8%
Poland	3,000,000	9.5%
Switzerland	18,000	0.4%
German-speaking world total	4,700,000	3.2%
Albania	200	0.02%
Belgium	60,000	0.7%
Bulgaria	48,500	0.8%
Denmark	5,700	0.15%
Estonia	4,560	0.4%
Finland	1,800	0.05%
France	250,000	0.6%
Greece	73,000	1.2%
Italy	48,000	0.11%
Latvia	95,600	4.9%
Lithuania	155,000	7.6%
Norway	1,400	0.05%
Portugal	1,200	0.02%
Romania	756,000	4.2%
Soviet Union (western)	2,525,000	3.4%
Spain	4,000	0.02%
Sweden	6,700	0.11%
United Kingdom	300,000	0.65%
Yugoslavia	68,000	0.49%
European total	9,500,000	1.7%
United States	4,300,000	3.4%
Other countries	1,500,000	0.1%
Worldwide total	15,300,000	0.73%

Table 10.11: Jewish population in selected countries in 1933.

Table 10.11 shows the Jewish population in various countries in 1933 [https://www.jewishvirtuallibrary.org; https://encyclopedia.ushmm.org/content/en/article/jewish-population-of-europe-in-1933-population-data-by-country]. People of Jewish background made up only 0.75% of the population of Germany, 3.2% of the population of the greater German-speaking world, 1.7% of the total European population, and 0.73% of the total world population.

Despite being such a small percentage of the total population, people of Jewish background composed 15–33% of the German scientific research system, according to various estimates [Ash and Söllner 1996, p. 7].

Prior to the Third Reich (before 1933), 17% (17 out of 99) of scientific Nobel Prize winners were of Jewish background, as shown in Table 10.12. As of 2013, 25% of scientific Nobel Prize winners were of Jewish background (144 of the 566 winners for 1901–2013 [Gerstl 2014, pp. 82–96]); many of those were from the German-speaking world, were immigrants from the German-speaking world, or were the children of immigrants from the German-speaking world.

By these metrics, people of Jewish family background were ∼10–30 times more likely to be scientific creators than one would expect from overall demographic figures alone.

Nobel Prize	**Year**	**Name**
Medicine	1908	Paul Ehrlich
Medicine	1908	Élie Metchnikoff
Medicine	1914	Róbert Bárány
Medicine	1922	Otto Meyerhof
Medicine	1930	Karl Landsteiner
Medicine	1931	Otto Warburg
Chemistry	1905	Adolf von Baeyer
Chemistry	1906	Henri Moissan
Chemistry	1910	Otto Wallach
Chemistry	1915	Richard Willstätter
Chemistry	1918	Fritz Haber
Physics	1907	Albert Michelson
Physics	1908	Gabriel Lippmann
Physics	1921	Albert Einstein
Physics	1922	Niels Bohr
Physics	1925	James Franck
Physics	1925	Gustav Hertz

Table 10.12: Jewish Nobel Laureates in science prior to the Third Reich (1901–1932).

In his analysis of why such a disproportionately large percentage of Nobel-Prize-winning scientists have been Jewish, Ronald Gerstl proposed that a number of factors were responsible [Gerstl 2014, pp. 70–74]:

> The Jewish family has traditionally been a secure and nurturing unit. The incidences of family violence, abandonment, failure to provide support for wife and children, alcoholism, unwed mothers and other social ills are relatively rare. [...]
>
> Overall, Jewish families in modern times have considerably fewer children than the average birthrate. Consequently Jewish parents have been able to dedicate more time and money to each child's welfare, education and cultural development. [...]
>
> The Jews have a long history of dedication to learning going back to ancient times. Judaism required every Jewish man to study the Torah and the Talmud, which necessitated literacy. [...]
>
> Whereas most other parents in poor or modest circumstances were anxious for their offspring to join the workforce, Jewish parents, including the poor, were willing to make sacrifices so that their children could remain in school as long as possible. [...]
>
> Children of immigrant parents felt the need to succeed to recompense parents for their sacrifices. Beyond the first generation, parents continued to instill high expectations in their offspring. [...]
>
> Centuries of persecution may actually have strengthened Jews' resolve and tenacity. Jews felt like outsiders in many countries in which they dwelled, which may have given them an incentive to prove their worth rather than complacently accept their lot. Often differing from the general culture, Jews have been less likely to cling to conventional wisdom and preconceptions. This allowed them to be more open to change, to adapt more quickly to new circumstances and to perceive new opportunities. [...]
>
> That said, cultural factors and values alone cannot fully explain the extent of Jewish achievements. Some genetic predisposition has to be considered as well, realizing that both are inextricably linked.

Whereas Ronald Gerstl only listed genetic factors as one possible cause among many others, Charles Murray focused on the genetic theory in several publications [Herrnstein and Murray 1996; Murray 2007, 2020]. Other scholars have also argued for and against the genetic theory [e.g., Cochran et al. 2006; Ferguson 2007; Pinker 2006].

Historian of science Noah Efron criticized both the theories about Jewish educational background and those about Jewish genetics, and proposed that Jewish prominence in science was only a transient historical phenomenon caused by the career opportunities that were and were not open to students of Jewish background in certain countries in the late nineteenth and early twentieth centuries [Efron 2006, 2013, 2014]. Efron summarized his arguments [Efron 2013]:

> Elsewhere, rabbis and pundits tried to puzzle out what it is about Jews that make them so super at science.

> Broadly, two sorts of theories have been floated. One is that Jews have primo genes. Charles Murray, the Enterprise Institute scholar and co-author of *The Bell Curve*, set out the case for this a few years ago in an essay in *Commentary* called "Jewish Genius," writing bluntly that "something in the genes explains elevated Jewish IQ." Another theory is that Jews love hitting the books, as Israeli economics laureate Robert Aumann told the army radio station Galei Tzahal: Jewish homes have overflowing bookshelves. Throughout the generations we have given great honor to this intellectual pursuit.
>
> There are good reasons to doubt both sorts of theories. For one thing, Jewish excellence in science is a new thing. When the great Jewish folklorist Joseph Jacobs set out in 1886 to compare the talents of Jews with the talents of other Westerners, he found their performance mediocre in every science save medicine. In the first decades of the 20th century, Princeton psychologist Carl Brigham tested the intelligence of Jews in America, and concluded they "had an average intelligence below those from all other countries except Poland and Italy." Jewish excellence in science is a phenomenon that flowered in the decades before and, especially, after the Second World War; it is too recent a phenomenon to be explained by natural selection, or even by putative ancient cultural traditions.
>
> The real explanation of Jewish success in science lies elsewhere. The 20th century began with massive migrations of Jews, to the United States, to the cities of Russia (and then the Soviet Union), and to Palestine. In each of these new lands, Jews turned to science in great numbers because it promised a way to transcend the old world orders that had for so long excluded most Jews from power, wealth and society. Science, based as it is on values of universality, impartiality and meritocracy, appealed powerfully for Jews seeking to succeed in their new homes. It is not so much what Jews were (smart, bookish) that explains their success in science, as what we wanted to be (equal, accepted, esteemed), and in what sorts of places we wanted to live (liberal and meritocratic societies). [...]
>
> What bugs me about attributing the remarkable prominence of Jews among Nobel laureates to genes or enduring cultural traditions is that doing so suggests that Jewish success in science will inevitably continue as a matter of course. Most likely it won't. The percentages of Jews among new American Ph.D.s in the sciences has declined greatly over the past generation. In Israel, spending on higher education has continued to decline during most of the same period; to many of the growing numbers in Israel who embrace religion, the appeal of science has nearly vanished. The passions that drew Jews to sciences in such great numbers have dissipated.

Whatever the explanation for the large numbers of Jewish creators, family background appears to help but is not sufficient by itself. For example, the modern United States has roughly six million people of Jewish background [Gerstl 2014, pp. 37–38], and millions of people from each of many other family backgrounds. If any one or more of those family backgrounds were automatically the key to producing revolutionary scientific creators, the modern United States would have produced far more revolutionary innovators and innovations than it appears to have. Although the United States has vast numbers of scientists and engineers, very few of those appear to be producing the sorts of truly revolutionary creations that were much more common in the earlier German-speaking world. Thus the most critical factors appear to be systemic approaches, such as those considered in previous sections, that cultivate, support, and reward revolutionary creators and creations.

In addition to the factors already considered in this chapter, it is possible that other factors helped or hindered scientific innovation in the former German-speaking world. In the future, scholars who examine this problem further should evaluate factors such as (but not limited to) the following for the older German-speaking world, the U.S. research system, and other innovation systems, and determine how much if any effect each factor has had on innovation:

- Being an immigrant, or the descendant of people who recently immigrated to that country or region [Hathaway 2017].
  - For immigrants or the children of immigrants who initially have little wealth or status in their new country, a scientific education and career may be one of the few available paths offering the greatest opportunity for elevation in society. In theory (although not always in practice), someone could go from disregarded poverty to social elite by learning enough and working hard enough. Due to discrimination, upfront financial costs, or other societal barriers or prerequisites, there may be few other career paths that are open and that have so much potential. (This was essentially Noah Efron's explanation for the success of Jewish scientists [Efron 2013], but it could apply to scientists coming from other family backgrounds as well.)
  - Perhaps immigrants are a self-selected group with more independent initiative, greater creativity, and more willingness to work hard in order to leave one country and settle in another.
  - Maybe immigrants, or the children of immigrants, feel that they have more to prove or further to rise in their new country, and therefore on average dream bigger and work harder than those whose families have lived in that country for many generations.
  - Perhaps immigrant families, feeling more alone in a foreign country, are more closely knit and more supportive, which could promote more positive personality characteristics and greater success in life.
- Other family backgrounds that are disproportionately frequent or infrequent among innovators (number of siblings, birth order, parental education and careers, religion and religiosity, wealth, geographical location, etc.).
- The ease with which students could transfer among courses, majors, and schools within the educational system.
- The average total cost required to obtain a doctoral (or other final) degree.
- The annual ratio of the number of available good jobs to the number of students graduating with a final science or engineering degree.
- The average age at which children who ultimately became scientists or engineers first decided that they wanted to pursue that educational and career path.
- The average age at which scientists or engineers first obtained a job that gave them the freedom and resources to pursue their own ideas.

- The average age at which scientists or engineers came up with their first major innovation.
- The average age at which scientists or engineers came up with their last major innovation.
- The average number of innovations per year per person in the innovation system. (Exactly how would an innovation be defined?)
- The average number of publications per year per person in the innovation system (although greater quantity does not necessarily mean greater quality, and might in fact be achieved at the expense of quality).
- The average number of patents per year per person in the innovation system (again, quantity may not be indicative of quality).
- The average number of technology startup companies or laboratories per year per person in the innovation system (although widespread, formal startup companies may be a more modern concept, and it may be difficult to find analogous data for older innovation systems).
- The average amount of total research funding per year per person in the innovation system.
- The average salaries for various categories of science, engineering, and medical professionals.
- The average salaries for teachers at different levels and in different fields.
- The average duration of a research project (from conception to viable demonstration).
- The average duration of a research job.
- The average duration of a research career.
- The average number of hours per year that a person in the system spent on research (actual research, not paperwork related to research).
- The average number of hours per year that a person spent on teaching (actual teaching, not paperwork related to teaching).
- The average number of hours per year that a person spent on scientifically directly productive work other than research and teaching (such as reading).
- The average number of hours per year that a person spent on sponsor proposals and reporting requirements. (Even though many would deem these necessary, they can siphon enormous amounts of time and energy away from actual research.)
- The average number of hours per year that a person spent preparing and submitting journal articles, books, etc. for publication. (Although publications are an essential part of a healthy scientific system, when publications are emphasized to an extreme, they can also divert vast amounts of time and energy away from actual research.)

- The average number of hours per year that a person spent on other work that is less directly productive scientifically, such as required meetings, personnel training, human-resources-related tasks, contract administration, ordering, inventory, approvals, evaluations, other paperwork, etc.

- The ease with which researchers could access all the relevant scientific literature (due to financial, physical, or online restrictions).

- The ease with which researchers could access relevant facilities for laboratory experiments or engineering construction.

- The ease with which researchers could exchange ideas with other relevant researchers in technical conferences, seminars, formal organizations, informal or after-hours organizations, etc.

- The average number of technical supporting personnel (e.g., research assistants) per researcher.

- The average number of nontechnical supporting personnel (e.g., clerical and logistics assistants) per researcher.

- How assistants, researchers, managers, and sponsors were evaluated, selected, and promoted (based on good work and talent vs. politics and favoritism, etc.).

- How major decisions on research programs were made by individuals, organizations, and sponsors (short-term vs. long-term gain, logical reasoning vs. hype and hope, etc.).

- The average sizes and compositions of research groups in different fields and research sectors (academic, corporate, and government laboratories).

- The average probability that a research proposal will be funded.

- The fractions of funding awarded by peer review or other processes, and how those processes work.

- The fraction of research projects that led to a viable demonstration. (Even though it may be bad if the fraction is too low, if the fraction is too high, that could indicate that higher-risk, more innovative projects are being avoided instead of pursued.)

- The fraction of viable demonstrations that ultimately led to a final product.

- How innovative research projects were on average, on a scale from evolutionary (straightforward extensions of what is already known) to revolutionary. (Are there objective, quantifiable, reproducible ways in which the innovativeness of projects can be evaluated?)

Ideally, data such as that described above should be plotted versus time to see how things changed over many decades within a given innovation system, as well as how things appear to be similar or different for different innovation systems.

Chapter 11

Immortalizing the Creations and Forgetting the Creators

Was man nicht aufgibt, hat man nie verloren. What is not abandoned is never completely lost.

Friedrich Schiller. 1800. *Maria Stuart*, Act II, Scene 5.

As discussed in Chapter 10, the German-speaking research world had several systemic practices that allowed it to produce a huge number of revolutionary scientific creators and creations. As covered in this chapter, the global research system eagerly adopted the creations of the earlier German-speaking world, yet ultimately largely forgot both the creators and the systemic approaches that had made those creations possible.

Section 11.1 outlines the many ways in which creations and creators were transferred to the global research system, especially the United States, before, during, and after the Third Reich.

Section 11.2 analyzes the general innovation-promoting approaches that the U.S. research system borrowed from the earlier German-speaking world and used with relative success during the 1940s–1960s.

Section 11.3 examines how the modern innovation system began a long, slow decline starting in the 1970s. By that time, most of the German-speaking creators had retired or died, their creations had been refined to the point of diminishing incremental returns, and the research system had abandoned most of the German-like practices it had adopted, greatly reducing its efficiency at producing entirely new revolutionary innovators and innovations.

11.1 Creations and Creators Transferred from the German-Speaking World

Before, during, and after the Third Reich, virtually all of the creations, most of the creators, and a number of the underlying general practices were transferred from the German-speaking world to the global research system, especially the early U.S. research system. The United States and the rest of the global research system spent many decades copying, optimizing, and mass-producing the innovations that had been created by the earlier German-speaking world, resulting in our modern world of jet aircraft, electronics, and pharmaceuticals. Most of the creators who had already died or who remained in German-speaking areas were forgotten by the non-German-speaking world, which often mistakenly attributed their creations to whichever non-German-speaking individuals or organizations had acquired their technical information. Most of the creators who emigrated out of German-speaking areas led well-funded but very quiet lives perfecting their creations and were also ultimately forgotten; only a few, such as Albert Einstein, Edward Teller, and Wernher von Braun, sought or received lasting fame.

11.1.1 Before the Third Reich

Even well before the Third Reich, the German-speaking world had significant influences on the development of research systems in the United States and elsewhere. In particular, some German-speaking scientists left their own world in search of opportunities elsewhere, a number of U.S. scientists were educated in the German-speaking world, universities in the United States and other countries were consciously designed or redesigned to mimic the successful model of universities in the German-speaking world, and many technological patents and factories were forcibly transferred during and after World War I.

Émigrés before the Third Reich

Long before the Third Reich came to power and triggered a mass exodus, a steady stream of German-speaking émigrés moved to the United States (or other countries) to seek new business opportunities. Just a few of the better-known examples of German-speaking creators who moved to the United States before the Third Reich are listed in Table 11.1.

U.S. scientists and engineers educated in the German-speaking world

In addition to German-speaking creators who moved to the United States, there were a large number of Americans who travelled to the German-speaking world for education and training and then returned to the United States. Over 9000 Americans attended German universities (especially Berlin, Göttingen, Halle, and Heidelberg) between 1820 and 1920 [Röhrs 1995, p. 11]. Including Americans who attended before that time or up to the Third Reich, as well as those who went to German-speaking universities in countries other than Germany, probably well over 10,000 Americans studied in the German-speaking world (in science, math, engineering, and other areas) and brought what they had learned back to the United States.

A few examples of prominent U.S.-born scientists and scholars who received at least part of their education in the German-speaking world are listed in Table 11.2.

Name	**Nationality**	**Scientific contributions**
Louis Agassiz	Swiss	Paleontology
Walter Baade	German	Astronomy
John Jacob Bausch Henry Lomb Ernst Grundlach	German German German	Bausch & Lomb lenses, eyeglasses, microscopes, telescopes, etc.
Emil(e) Berliner	German	Microphone, record player, helicopter
Herman Frasch	German	Oil refining, sulfur
Beno Gutenberg	German	Seismology, earthquake magnitudes, etc.
Karl Herzfeld	Austrian	Quantum and statistical physics
Hermann Lemp	Swiss	Diesel-electric locomotives
Julius Edgar Lilienfeld	Austrian	Field effect transistor
Maria Goeppert Mayer	German	Nuclear shell model
Georg(e) Merck	German	Pharmaceuticals
Ottmar Mergenthaler	German	Linotype
Karl Friedrich Meyer	Swiss	Infectious disease prevention
John Roebling	German	Suspension bridges
Charles (Karl) Steinmetz	German	AC electrical devices
Levi Strauss	German	Blue jeans
Nikola Tesla	Serbian	AC electrical devices
Robert Trümpler	Swiss	Astronomy
Gustave Whitehead/Weisskopf	German	First airplane?

Table 11.1: Examples of creators who emigrated to the United States before the Third Reich.

Name	**German education**	**Scientific contributions**
James M. Crafts	Studied with Robert Bunsen	Organic chemistry
William Duane	Ph.D. (Berlin, 1897) under Max Planck	X-rays and radioactive elements
Josiah Gibbs	Studied math and physics under Gustav Kirchhoff and Hermann von Helmholtz	Statistical and thermal physics
Percy Lavon Julian	Ph.D. (Vienna, 1931) with Ernst Späth	Organic chemistry
Irving Langmuir	Ph.D. (Göttingen, 1906) under Walther Nernst	Physical chemistry, General Electric R&D
Arthur Michael	Research assistant for Hofmann, Bunsen	Organic chemistry
J. Robert Oppenheimer	Ph.D. (Göttingen, 1927) under Max Born	Nuclear physics, Manhattan Project
Linus Pauling	Studied quantum theory under Arnold Sommerfeld, Erwin Schrödinger	Chemistry
Ira Remsen	Ph.D. (Göttingen, 1870) with Wilhelm Fittig	Organic chemistry
Howard Robertson	Studied physics under Hermann Weyl, Max Born, and Arnold Sommerfeld	Applied mathematics, cosmology
Edmund Beecher Wilson	Studied developmental biology under Rudolf Leuckart, Carl Ludwig, Theodor Boveri	Developmental biology

Table 11.2: Examples of U.S.-born scientists and scholars who received at least part of their education in the German-speaking world.

Influence on the structure of the U.S. research system before the Third Reich

Up through the nineteenth century, university education in the United States was largely rote learning, with little freedom to choose among courses or to conduct research. Many of the Americans who had been educated in the German-speaking world and returned home wanted to instill U.S. universities with much more freedom, originality, and academic research like what they had witnessed in Europe. This motivation led to the founding of universities such as:

- Massachusetts Institute of Technology in 1861 in Boston (it moved to Cambridge in 1916) [Stratton and Mannix 2005].
- Johns Hopkins University in 1876 in Baltimore, Maryland [Thelin 2019].
- Stanford University in 1891 in Stanford, California [Wels 1999].
- California Institute of Technology in 1891 in Pasadena [Goodstein 1991].

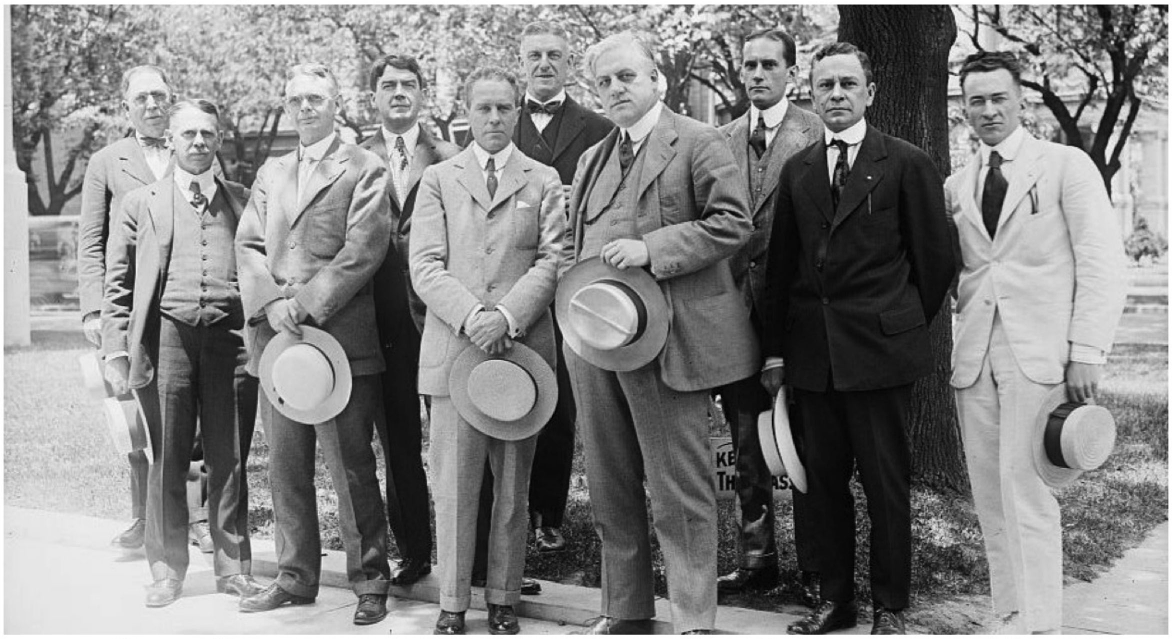
These new schools were intentionally designed to emulate German universities by having faculty and students participate in both courses and original research. Following the success of such schools, older U.S. universities gradually reformed, and by the post-World-War-II era, most major U.S. universities were generally following the same German model [Ben-David 1992; Röhrs 1995; Schwinges 2007; Tanaka 2005].

Just as U.S. universities were deliberately transformed to be more German-like, U.S. companies were also transformed to be more like science- and engineering-based companies in the German-speaking world, by forcibly seizing technological patents and even entire factories from the German-speaking world, as discussed below.

Transferred companies, patents, and other resources

The U.S. Trading with the Enemy Act of 1917 resulted in the large-scale appropriation of resources from German speakers (both those living in Europe and those living in the United States) to the United States government and to certain non-German-speaking U.S. citizens and companies that were politically well connected [Coben 1963; Gross 2014, 2015]. By invoking this and other laws during and after World War I, the U.S. Office of Alien Property Custodian put thousands of German-speaking U.S. residents (both recent immigrants and longtime U.S. residents who had come from Germany, Austro-Hungary, and even Switzerland, which was not a party to World War I) in concentration camps and held them in the camps until 1920, long after the war (Fig. 11.1). From those and countless other German-speaking individuals in the United States and overseas, the Office of the Alien Property Custodian seized over $500 million dollars (as valued then, which would be far more in modern dollars) worth of patents, property, businesses, and possessions. Those permanent seizures included large numbers of patented inventions and processes, as well as the U.S. branches of German and Austro-Hungarian scientific and engineering companies such as Bayer and Merck (p. 2217).

Senior staff of the U.S. Alien Property Custodian's office (1918), which seized over $500 million dollars (as valued then) worth of patents, property, businesses, and possessions from German speakers living in Europe and in the United States



One of the concentration camps for German-speaking residents of the United States during World War I

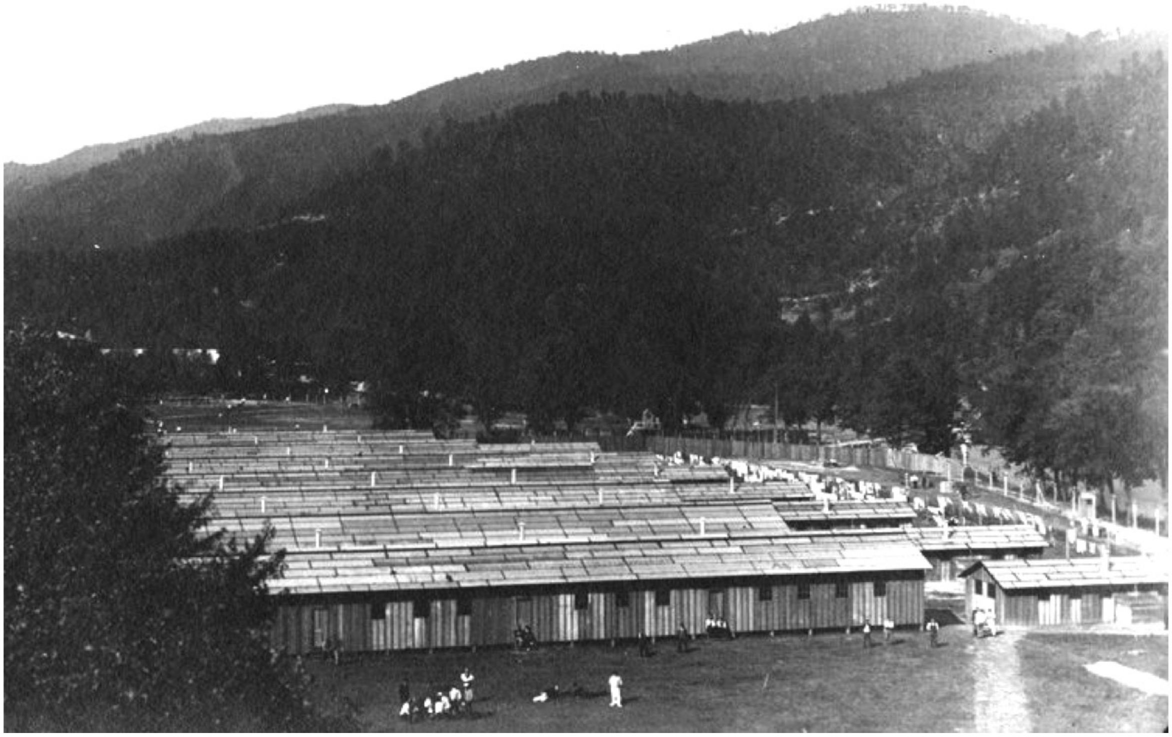


Figure 11.1: During and after World War I, the U.S. Office of the Alien Property Custodian (run by A. Mitchell Palmer, foremost in the upper photograph) put thousands of German-speaking residents of the United States in concentration camps and seized over $500 million dollars (as valued then) worth of patents, property, businesses, and possessions from German speakers living in Europe and in the United States.

The details and impact of these World War I seizures warrant a detailed study, yet unfortunately there does not appear to be a comprehensive modern account. However, the journalist Daniel Gross wrote two articles that gave insights into this history. Gross described the concentration camps and property seizures [Gross 2014]:

> Posselt was a young editor and translator who emigrated from Austria-Hungary in 1914. His nationality—like that of millions of German-speaking immigrants in the United States during World War I—attracted suspicion and anger from nationalistic Americans. In the course of the war, the federal government registered around half a million "enemy alien" civilians, spied on many of them, and sent approximately 6,000 men and a few women to internment camps. Perhaps more strikingly, it seized huge troves of private property with dubious relevance to the war effort, ultimately amassing assets worth more than half a billion dollars—close to the entire federal budget of pre-war America. [...]
>
> [A]t Fort Oglethorpe, Posselt described an odd collection of imprisoned intellectuals. They were allowed to organize courses taught by interned professors of biology, mathematics, literature, and languages. Several dozen musicians, many of whom had been recruited from Europe to join American orchestras, regularly performed to help keep up morale. [...]
>
> In retrospect, American internment policies are troubling, but they're dwarfed by a quieter and more sweeping practice of property seizure. Under the Trading with the Enemy Act, President Wilson appointed an "Alien Property Custodian" named A. Mitchell Palmer to take control of property that might hinder the war effort. Among other things, this meant all property belonging to interned immigrants, regardless of the charges (or lack thereof). "All aliens interned by the government are regarded as enemies," wrote Palmer, "and their property is treated accordingly."
>
> The basic argument was that property seizure prevented immigrants from financially or materially supporting enemies of America. Under Palmer's direction, the Office of the Alien Property Custodian grew to employ hundreds of officials and used several high-profile cases of espionage and industrial sabotage to defend its work. German chemical companies in the United States were particularly vulnerable to seizure: not only did dye and pharmaceutical companies divert raw materials from the war effort, they could also in theory produce explosives.
>
> The agency's powers were remarkably broad, however. In *Munsey's Magazine*, Palmer described the Alien Property Custodian as "the biggest general store in the country," noting that some of the companies seized were involved in "pencil-making in New Jersey, chocolate manufacture in Connecticut, [and] beer-brewing in Chicago." There were small holdings seized from individuals, too. "Among them," he continued with an odd hint of pride, "are some rugs in New York; three horses near Joplin, Mississippi; [and] a carload of cedar logs in the South." (Historians will probably never figure out why Palmer wanted those rugs in New York.) The historian Adam Hodges found that even women who were American citizens, if married to German and Austro-Hungarian immigrants, were classified as enemy aliens— and they alone lost a combined $25 million in property to the government.

> The war ended in November 1918, just a year after the passage of the Trading with the Enemy Act. In that time, the Alien Property Custodian had acquired hundreds of millions of dollars in private property. In a move that was later widely criticized—and that political allies of the Alien Property Custodian likely profited from directly—Palmer announced that all of the seized property would be "Americanized," or sold to U.S. citizens, partly in the hopes of crippling German industries. (His attitude echoed a wider sentiment that the Central Powers deserved to pay dearly for the vast destruction of the war.) In one high-profile example, the chemical company Bayer was auctioned on the steps of its factory in New York. Bayer lost its U.S. patent for aspirin, one of the most valuable drugs ever produced.
>
> "The same peace which frees the world from the menace of autocratic militarism of the German Empire," Palmer argued, "should free it from the menace of its autocratic industrialism as well." Immigrant property, in his view, was just an extension of German and Austro-Hungarian property—which gave America the right to take it. Several lawsuits later disputed his authority to do so, including one that reached the Supreme Court, but his actions were found to be legal under wartime laws. In fact, the agency's reputation was sufficiently intact that President Franklin Roosevelt re-established it during World War II. [...]
>
> The last prisoner wasn't released until April 1920, a full year and a half after the end of the war. As Glidden described it: "When the camps did close scarcely anyone cared or noticed."

As mentioned by Gross, the Alien Property Custodian during the period 1917–1919 was Alexander Mitchell Palmer (1872–1936, closest to the camera in the upper half of Fig. 11.1). Using the over $500 million of property that his office seized, Palmer acquired power and wealth for himself and his political and business associates. His actions while Alien Property Custodian were so highly regarded by the federal government that he was then elevated to the position of Attorney General of the United States 1919–1921, during which time he led the "Palmer raids" that widely terrorized American communities of immigrants from Europe [Coben 1963].

Daniel Gross added more details about this history in another article [Gross 2015]:

> Ties between German and American chemistry were even tighter in the industrial sphere. Many of the United States' prewar dyestuff and pharmaceutical suppliers were actually branches of German corporations. Americans who wanted a competitive education often traveled to German universities to study chemistry, while German chemists who sought new opportunities came to America. During the war, however, the United States subverted and harnessed the resources of its German competition. [...]
>
> Six months after war was declared, suspicious American authorities gained the legal power to act against German companies. Congress passed the Trading with the Enemy Act, and a man named Mitchell Palmer was appointed Alien Property Custodian. Palmer's office began receiving thousands of reports of enemy-held property. Factories and businesses owned by German nationals were seized by the government, along with thousands of valuable chemical patents. Beckers's former employer, the American branch

> of Bayer, was seized. Many of its employees were even imprisoned at Fort Oglethorpe, Georgia, an internment camp that today has been largely forgotten.
>
> World War I helped erode the advantages of German chemistry. When hostilities in Europe finally ended in 1918, the United States was producing four times as much poison gas as Germany. Palmer, perhaps recognizing that his wartime powers would soon wane, quickly disposed of confiscated holdings worth millions of dollars. Bayer was sold at a public auction on the company steps.

After World War I, the U.S. Office of Alien Property Custodian was viewed as so successful that it was revived and extensively used during and after World War II as well (p. 2108).

In addition to the over half-billion 1918 dollars worth of property seized by the Alien Property Custodian, billions of dollars of reparations (in both property and money) were taken from Germany, Austria, and Hungary after the war. The total reparations paid by Germany amounted to at least 67.7 billion marks or 17 billion 1918-era dollars, equivalent to many years worth of spending by the U.S. federal government at that time. In fact, German reparations obligations for World War I continued even long after World War II, and the final payment from Germany to the United States was not made until 3 October 2010 [https://www.deutschlandfunk.de/das-ende-der-reparationszahlungen-vom-1-weltkrieg.795.de.html?dram:article_id=119010]. Separate reparations of property and money were extracted from Austria and Hungary.

Thus during and after World War I, the German-speaking world transferred to the United States and other countries not only technological patents and factories, but also enough money to fund their continued development and operation for decades.

11.1.2 During the Third Reich

There was a great deal of innovation transfer out of the German-speaking world during the Third Reich, 1933–1945. This transfer took the form of large numbers of émigré scientists and engineers, critical knowledge transferred by them or via other routes, and influence on the wartime structure of the U.S. research system.

Émigrés during the Third Reich

The Third Reich's vicious persecution of people who were of Jewish descent and/or who were perceived as political opponents drove roughly 25% of scientists and engineers to leave the German-speaking world. Over half of those moved to the United States, most of the rest moved to the United Kingdom, and a smaller number went to other countries. This mass exodus was the beginning of the end of the German-speaking scientific world, but a great boon for the countries receiving these talented creators [Ash and Söllner 1996; Fraser 2012; István Hargittai 2006; Leff 2019; Medawar and Pyke 2000; Nachmansohn 1979].

Some examples (though by no means an exhaustive list) of German-speaking creators who moved to the United States during this time are listed in Table 11.3. Note that for thoroughness, this list includes Theodore von Kármán, who came to the United States just before the Third Reich (in 1930) but is generally grouped with the Hungarian refugees from the Third Reich dubbed the "Martians," as well as some younger scientists who completed their education in the United States.

Name	**Nationality**	**Scientific contributions**
Robert Adler	Austrian	Ultrasonic signals
Valentine Bargmann	German	Relativistic physics
Peter Bergmann	German	Relativistic physics
Max Bergmann	German	Proteins
Hans Bethe	German	Solar fusion, Manhattan Project
Erwin Biel	Austrian	Climatology
Marietta Blau	Austrian	Particle detectors
Felix Bloch	Swiss	Solid state physics, NMR, Manhattan Project, radar
Konrad Bloch	German	Cholesterol metabolism/hormones, fatty acid metabolism
Richard Brauer	German	Applied mathematics
Richard Courant	German	Applied mathematics
Max Dehn	German	Applied mathematics
Peter Debye	Dutch	Solid state physics, quantum theory, electrolytes
Max Delbrück	German	Gene structure and mutation, phage genetics
Albert Einstein	German	Relativity, statistical physics, quantum physics
Walter Elsasser	German	Earth's magnetic field
Paul Erdös	Hungarian	Applied mathematics
Kasimir Fajans	Polish	Radioactive elements, inorganic chemistry
James Franck	German	Atomic energy levels, photosynthesis, Manhattan Project
George Gamow	Russian	Nuclear physics

Table 11.3: Examples of German-speaking creators who emigrated to the United States during the Third Reich. (Continued on next page.)

Name	**Nationality**	**Scientific contributions**
Kurt Gödel	Austrian	Applied mathematics
Thomas Gold	Austrian	Astrophysics, origin of life
Gerson Goldhaber	German	Particle physics
Gertrude Scharff Goldhaber	German	Nuclear physics, Manhattan Project
Maurice Goldhaber	Austrian	Nuclear and particle physics
Peter Goldmark	Hungarian	Audio/television recording
Victor Hess	Austrian	Discovered cosmic rays
Arthur von Hippel	German	Radar, solid state physics
Theodore von Kármán	Hungarian	Aerodynamics
Walter Kohn	Austrian	Solid state physics
Willy Ley	German	Rockets
Franz Lipmann	German	Coenzyme A
Otto Loewi	Austrian	Neurotransmitters (esp. acetycholine, epinephrine)
Fritz London	German	Superconductivity
Karl Meissner	German	Spectroscopy
Otto Meyerhof	German	Glycolysis and muscle metabolism
Richard von Mises	Austrian	Aerodynamics
Carl Neuberg	German	Biochemistry
John von Neumann	Hungarian	Manhattan Project, computers
Emmy Noether	German	Applied mathematics
Lothar Nordheim	German	Quantum physics, Manhattan Project
Wolfgang Pauli	German	Quantum, exclusion, spin, neutrino
Arno Penzias	German	Big Bang
George Placzek	Czech	Nuclear physics, Manhattan Project
William Prager	German	Applied mathematics
Eugene Rabinowitch	Russian	Photosynthesis, Manhattan Project
Charlotte Riefenstahl	German	Physics
Joseph Rotblat	Polish	Nuclear physics
Erich Rothe	German	Applied mathematics
Rudolf Schoenheimer	German	Biomolecule isotope labels, cholesterol/atherosclerosis
Roman Smoluchowski	Polish	Solid state physics, astrophysics
Jack Steinberger	Germany	Particle physics
Otto Stern	German	Quantum theory, molecular beam epitaxy
Gabor Szego	Hungarian	Applied mathematics
Leo Szilard	Hungarian	Manhattan Project, molecular biology
Edward Teller	Hungarian	Manhattan Project, H bomb
Victor Weisskopf	Austrian	Relativistic quantum theory, Manhattan Project
Hermann Weyl	German	Relativistic quantum theory
Eugene Wigner	Hungarian	Manhattan Project, quantum physics
Fritz Zwicky	Swiss	Jet propulsion, astrophysics

Table 11.3 (continued): Examples of German-speaking creators who emigrated to the United States during the Third Reich.

Likewise, some examples of German-speaking creators who moved to the United Kingdom during this time are listed in Table 11.4, and examples of German-speaking creators who moved to other countries are listed in Table 11.5.

Name	**Nationality**	**Scientific contributions**
Hermann Blaschko	German	Neurotransmitters
Hermann Bondi	Austrian	Cosmology
Max Born	German	Quantum probability and statistical physics
Egon Bretscher	Swiss	Nuclear Physics, Manhattan Project
Edith Bülbring	German	Smooth muscle, neurotransmitters
Ernst Chain	German	Penicillin, fermentation technologies
Robert Eisenschitz	Austrian	Chemistry
Paul Eisler	Austrian	Printed circuit boards, electric window defroster, etc.
Wilhelm Feldberg	German	Neurotransmitters
Erwin Freundlich	German	Astronomy, general relativity tests
Sigmund Freud	Austrian	Psychology
Otto Frisch	German	Nuclear physics, Manhattan Project, laser scanning
Herbert Fröhlich	German	Solid state physics, biophysics
Dennis Gabor	Hungarian	Holography
Ludwig Guttmann	German	Treating spinal injuries
Fritz Haber	German	Ammonia production, chemical warfare (Died in Switzerland en route to Palestine)
Walter Heitler	German	Quantum physics, particle physics
Bernard Katz	German	Neurotransmitters
Nicholas Kemmer	Russian	Particle physics, Manhattan Project
Hans Krebs	German	Biochemical citric acid and urea cycles
Nicholas Kurti	Hungarian	Micro-Kelvin refrigeration and physics
Heinz London	German	Superconductivity
Hermann Lehmann	German	Hemoglobin, pharmacokinetics
Kurt Mendelssohn	German	Nuclear physics, cryogenics
Rudolf Peierls	German	Solid state physics, Manhattan Project
Max Perutz	Austrian	Hemoglobin protein structure
Michael Polanyi	Hungarian	Physical chemistry
Erwin Schrödinger	Austrian	Lots of quantum; color vision, theoretical biology
Francis (Franz) Simon	German	Low temperature physics, Manhattan Project
Rudolf Strauss	German	Automated soldering for printed circuit boards

Table 11.4: Examples of German-speaking creators who emigrated to the United Kingdom during the Third Reich.

Name	**Nationality**	**Moved to**	**Scientific contributions**
Paul Bernays	Swiss/German	Switzerland	Applied mathematics
György Bíró, László Bíró	Hungarian	Argentina	Ballpoint pen
Walter Gordon	German	Sweden	Relativistic quantum physics
Hans von Halban	German	Canada	Nuclear physics
Gerhard Herzberg	German	Canada	Molecular spectroscopy and structures, free radicals
George de Hevesy	Hungarian	Denmark, then Sweden	Radiolabelled molecules
Rudi Lemberg	German	Australia	Porphyrins
Lise Meitner	Austrian	Sweden	Nuclear fission
Karl Przibram	Austrian	Belgium	Nuclear physics
Richard Willstätter	German	Switzerland	Chlorophyll, chromatography, gas mask filters, enzymes

Table 11.5: Examples of German-speaking creators who emigrated to other countries during the Third Reich.

Kurt Mendelssohn, a German scientist who moved to the United Kingdom, described the whole wave of German-speaking creators who emigrated during the Third Reich, as well as their enormous impact on the countries that received them [Mendelssohn 1973, pp. 175–176]:

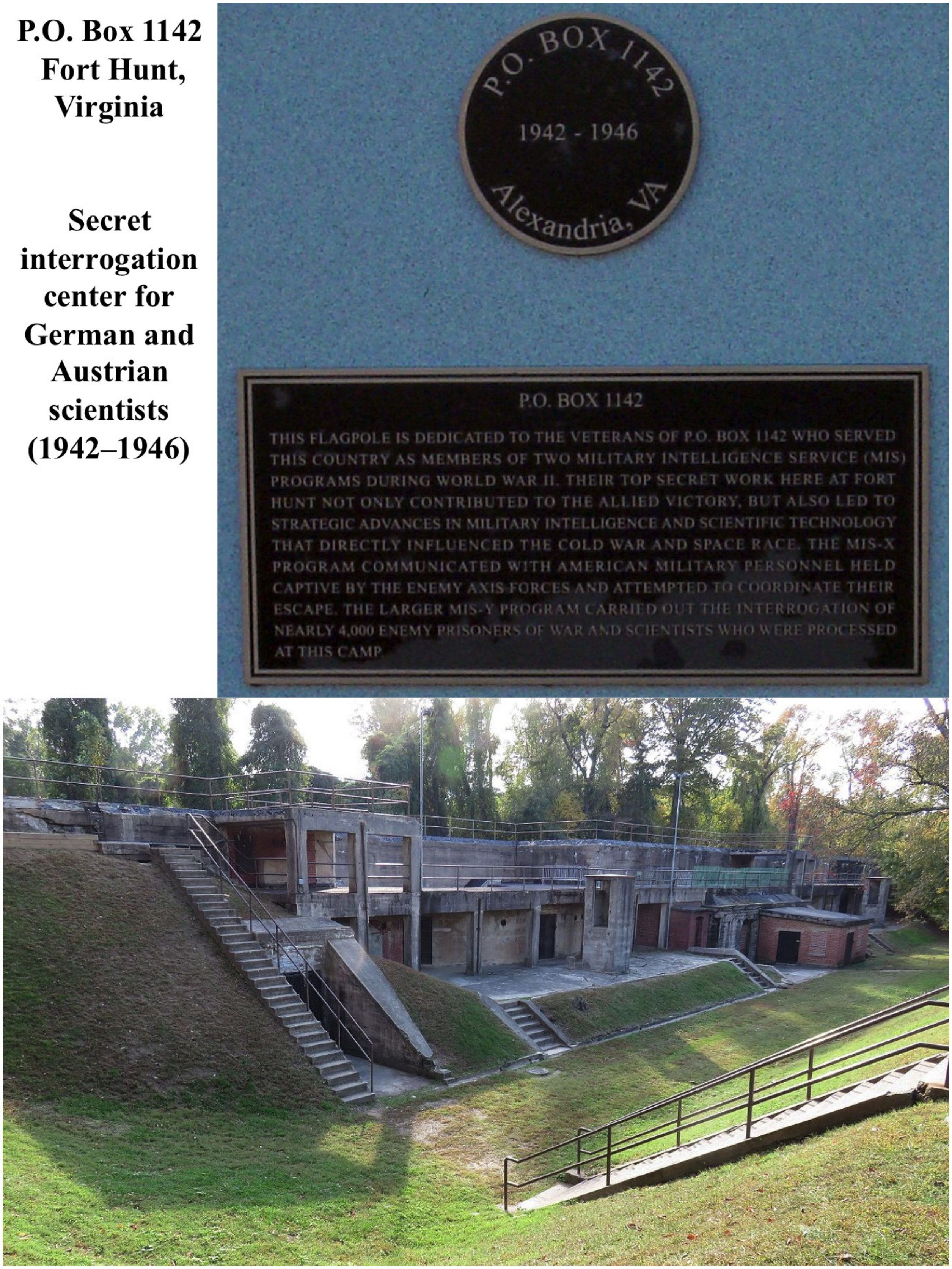
> Oxford may have been the first place where German refugee scientists found an opportunity to continue their work; it did not remain the only one. The new Diaspora covered the world. From England to Australia, from America to India, there was hardly a university which did not give shelter and a place of work to the displaced scholars. They, in turn, did all they could by teaching and research to repay the hospitality they were receiving. Around groups of them, or even individuals, there sprang up new schools, recruited from the local students who, in turn, carried forward the heritage of all that had been good and useful in German academic life. Far from destroying the spirit of German scholarship, the Nazis had spread it all over the world. Only Germany was to be the loser.

Scientific knowledge transferred during the Third Reich

A large amount of scientific knowledge was transferred out of the German-speaking world during this time via several routes:

- Émigré scientists and engineers.
- Captured and interrogated scientists, engineers, and military personnel [for example those interrogated at Fort Hunt, Virginia (pp. 2045, 4883) and Wright Field, Ohio (p. 2046)].
- Published scientific literature and patents.

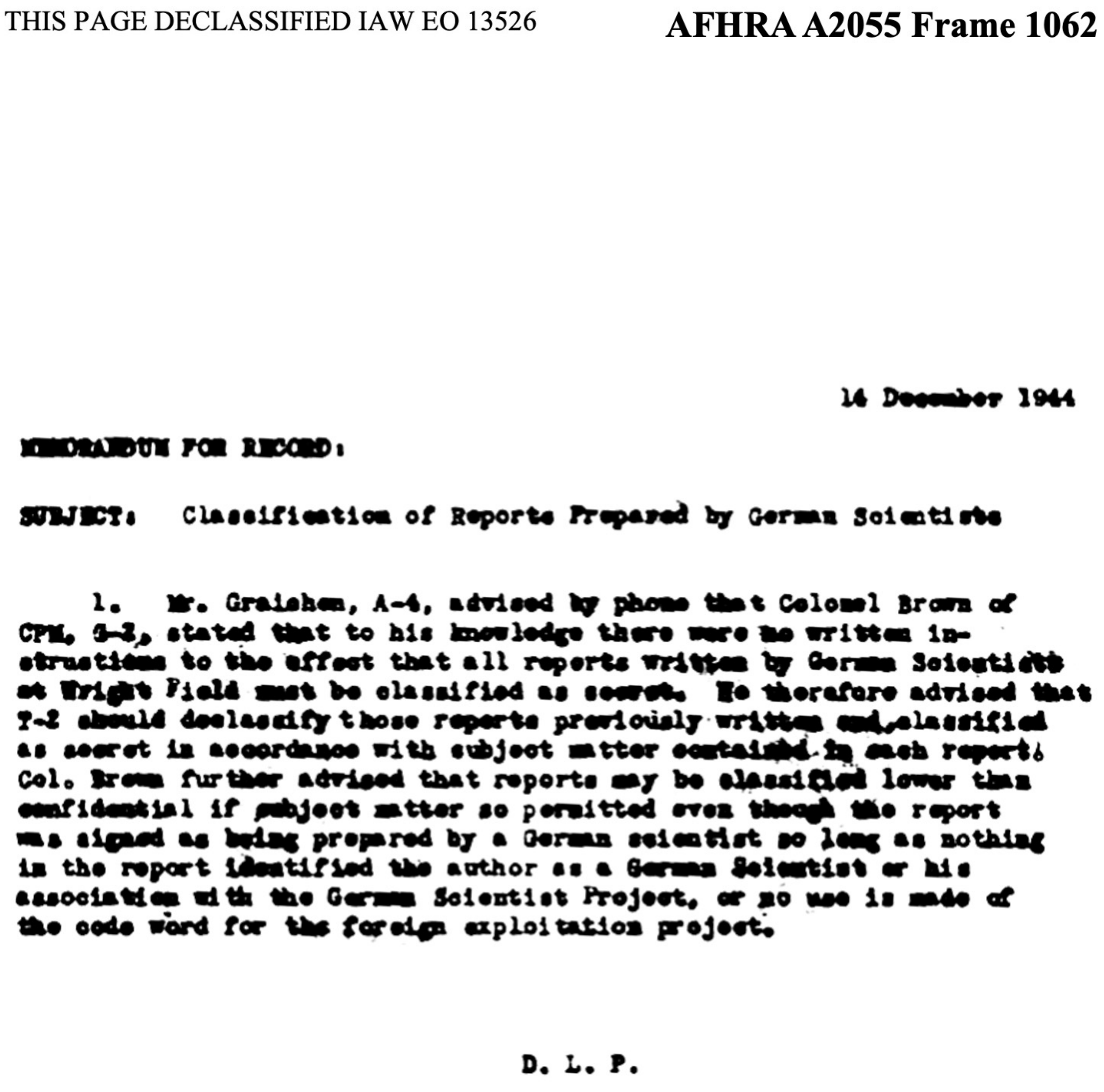
This transferred scientific knowledge was employed by well-funded wartime programs in the United States and United Kingdom.


P.O. Box 1142
Fort Hunt,
Virginia
Secret
interrogation
center for
German and
Austrian
scientists
(1942–1946)
P.O. BOX 1142
1942 - 1946
Alexandria, VA

P.O. BOX 1142

THIS FLAGPOLE IS DEDICATED TO THE VETERANS OF P.O. BOX 1142 WHO SERVED THIS COUNTRY AS MEMBERS OF TWO MILITARY INTELLIGENCE SERVICE (MIS) PROGRAMS DURING WORLD WAR II. THEIR TOP SECRET WORK HERE AT FORT HUNT NOT ONLY CONTRIBUTED TO THE ALLIED VICTORY, BUT ALSO LED TO STRATEGIC ADVANCES IN MILITARY INTELLIGENCE AND SCIENTIFIC TECHNOLOGY THAT DIRECTLY INFLUENCED THE COLD WAR AND SPACE RACE. THE MIS-X PROGRAM COMMUNICATED WITH AMERICAN MILITARY PERSONNEL HELD CAPTIVE BY THE ENEMY AXIS FORCES AND ATTEMPTED TO COORDINATE THEIR ESCAPE. THE LARGER MIS-Y PROGRAM CARRIED OUT THE INTERROGATION OF NEARLY 4,000 ENEMY PRISONERS OF WAR AND SCIENTISTS WHO WERE PROCESSED AT THIS CAMP.

Figure 11.2: From 1942 until 1946, the United States operated "P.O. Box 1142," a highly secret interrogation camp for thousands of captured German and Austrian scientists, engineers, and military personnel at Fort Hunt, Virginia. See p. 4883.



THIS PAGE DECLASSIFIED IAW EO 13526 **AFHRA A2055 Frame 1062**

14 December 1944

MEMORANDUM FOR RECORD:

SUBJECT: Classification of Reports Prepared by German Scientists

1. Mr. Graishen, A-4, advised by phone that Colonel Brown of CPM, G-2, stated that to his knowledge there were no written instructions to the effect that all reports written by German Scientists at Wright Field must be classified as secret. He therefore advised that T-2 should declassify those reports previously written and classified as secret in accordance with subject matter contained in each report. Col. Brown further advised that reports may be classified lower than confidential if subject matter so permitted even though the report was signed as being prepared by a German scientist so long as nothing in the report identified the author as a German Scientist or his association with the German Scientist Project, or no use is made of the code word for the foreign exploitation project.

D. L. P.

Figure 11.3: Beginning in 1944 (or earlier), captured German and Austrian scientists were put to work at Wright Field to transfer their detailed technical knowledge to the United States, as demonstrated by this 14 December 1944 memo from Colonel Donald L. Putt [AFHRA A2055 Frame 1062].

As has already been quoted in Chapter 1, a 1946 U.S. Senate report on the establishment of the National Science Foundation noted that the greatest scientific accomplishments of the United States during World War II were directly derived from earlier German innovations [NSF 1946, p. 6]:

> It should be somewhat humiliating to us to realize that the revolutionary sulfa drugs had their beginning in German research laboratories; that atom splitting was discovered in Berlin; that the basic pioneer work that has led to radio and radar and the enormous American electronic industries was that of a German professor. Penicillin came from England [where it was purified by Ernst Chain, a German refugee]; DDT from Germany and Switzerland.

In October 1945, Howland Sargeant and James Markham from the U.S. Office of the Alien Property Custodian testified before the U.S. Senate and provided much more detail on how extensively the United States used scientific knowledge from German patents, journals, and books during the war [Sargeant and Markham 1945, pp. 675–676, 692–695]:

> Testimony of Howland H. Sargeant, Chief, Division of Patent Administration, Office of the Alien Property Custodian
>
> Since March 1942 the Office of Alien Property Custodian has been administering thousands of patents and patent applications and other forms of industrial property vested from nationals of enemy and enemy-occupied countries. One of the first problems which confronted the Custodian after the entry of this country into World War II was the seizure and administration of patent property owned by the enemy. At that time we knew very little about the problem. We knew only that the enemy, particularly the Germans, owned great numbers of United States patents and that the inventions covered by these patents should be brought into full use in our war program. [...]
>
> Our primary objective in the administration of industrial property has been to make it available readily and immediately to serve all American industry and science. We intended to foster the active use of the store of technical knowledge represented by these patents and applications for patent; and we wanted to encourage further research on these inventions. [...]
>
> The figures we have show, Mr. Chairman, that about 33,000 of the patents that we took over were enemy-owned. [...]
>
> James E. Markham, Alien Property Custodian.
>
> Report on Alien Property Custodian Program of Reproduction of Foreign Scientific Periodicals
>
> [...] The Office of Alien Property Custodian was created to seize enemy property in this country and to administer it for the benefit of the United States. One valuable property of enemies was the right to control, through copyrights and otherwise, the distribution of much enemy-originated scientific literature. Acting under the authority given him, the Custodian has seized these rights and, through a program of periodical republication, has made available to American scientists throughout the war much of the results of

the results of German technical research, both that published just before the war and that published during it. [...]

During the war it was necessary to obtain and use information regarding activities of the enemy along scientific lines just as it was necessary to know what his military activities were. Scientific research in Germany was far advanced; recently a group of eminent American scientists stated:

"If Hitler had prevented the publication in 1939 of the first papers on atomic fission, Germany might have remained for a certain period of time in exclusive possession of a true fundamental secret of atomic power."[1]

> [1] Statement of Drs. David L. Hill, Eugene Rabinowitch, and John A. Simpson, Jr., prepared at the direction of the executive committee of the Atomic Scientists of Chicago and quoted in Life magazine October 29, 1945.

American experts in the scientific field needed ready access to foreign scientific information to buttress scientific research in this country and to keep informed of the results of such research in enemy countries. Scientific literature from enemy countries was in such demand before the war that industrial and research organizations, scientific societies, and libraries annually spent approximately one and one-half million dollars for foreign books and journals. Most of this was spent for German publications. [...]

It was, of course, reasonable to expect that the enemy journals would not reveal exact specifications for the latest antiaircraft equipment or give detailed descriptions of such weapons as the V-1 or V-2 bomb. It is clear, however, from the nature and quality of the materials printed that the German Government throughout the war continued and in some cases even intensified its peacetime policy of encouraging publication of scientific information. The advantages of this kind of dissemination, within Germany and territory occupied by the German Government, as a means of expanding scientific frontiers were obviously considered by the German Government to outweigh the possibility that such information would become generally available to scientific personnel among the enemies of the Reich. The benefits of basic German research in many fields were thus made available to American science. In some cases materials in enemy journals have been of direct and immediate use in military operations. For example, an article in VDI Zeitschrift, concerning engineering problems in constructing German camps was directly utilized in construction of Army barracks.

More frequently, however, the subject matter in the articles served primarily to reveal the trend of enemy research and basic facts which confirmed previously held theories, thus saving thousands of man hours of painstaking investigation. Moreover, such materials presented theories and concepts which were tested on the basis of American experience, and thus became valuable in the war effort. To illustrate, frequent articles in Die Naturwissenschaften and Zeitschrift fuer Physik concerning atomic fission and uranium 238 were effectively utilized by scientists engaged in the Manhattan district project. The editor of Chemical Abstracts, Dr. E. J. Crane, has informed us "There is not the least doubt in my mind of the fact that your republication program was one of the factors which made the atomic bomb possible." Iowa State College reports "This college has received an E [Excellent rating] for its research on the atomic bomb . . . The

> men working on this splitting of the atom used, to a considerable extent, the periodicals which you have reprinted."
>
> The journals reproduced dealt with almost every phase of scientific development of interest to a nation at war. Included among the journals were the leading periodicals in the following fields:
>
> Acoustics
> Aluminum
> Aviation
> Biochemistry
> Ceramics
> Chemistry
> Crystallography
> Electronics
> Engineering
> Enzymology
> Explosives
> Fermentation
> Geology
> Geophysics
> Infectious diseases
> Immunology
> Instruments
> Magnesium
> Mathematics
> Mechanical engineering
> Metallurgy
> Microscopy
> Mineralogy
> Mycology
> Nutrition
> Oils and fats
> Paper chemistry
> Parasitology
> Pathology
> Petroleum
> Pharmacology
> Physics
> Plant pathology
> Plastics
> Rubber
> Spectrochemistry
> Steel and iron
> Textiles
> Virus research
>
> [...] No report concerning reproduction of scientific materials originating in enemy countries after 1941 would be complete without reference to books as well as journals. Scientific books published in Germany in 1941, 1942, 1943, and 1944 were surreptitiously obtained by the Office of Strategic Services. Reproduction of the books was licensed to commercial publishers on a basis calculated to encourage the most extensive publication and dissemination. Nearly 700 works were licensed for republication. The books concerned subjects of direct interest to those engaged in war activities, including analysis of gases, analysis of metals, atomic fission, ballistics, electric amplifiers, electrolytes, electron emission, food analysis, magnesium, magnetic measurement, optics, organic chemistry, sound waves and measurement, synthetics and many others. A list of all books licensed, including those of recent date, is attached as an exhibit. It is noted that the prices charged are substantially less than prewar prices. For example, volumes of Beilstein's Handbuch der Organischen Chemie, which would normally have sold for \$60 before the war, are currently sold for \$12. The books were sold principally to industrial concerns, government agencies and research institutions throughout almost all the allied nations.

Influence on the structure of the U.S. research system during the Third Reich

Many of the general practices that had made the German-speaking world so effective at producing revolutionary creations were at least temporarily adopted by the United States research system, and played a vital role in the successes of its wartime R&D programs. For example, prior to 1940 the United States had little government funding for research, and any government-run laboratories were both small and rare. Beginning in 1940, the United States adopted the German model of large-scale government funding for innovative projects that could be carried out by a combination of new government labs, close ties to industry, and scientists in university laboratories. These general practices are discussed in much more detail in Section 11.2.

11.1.3 After the Third Reich

The largest and yet probably the least well understood (from the modern public's perspective) innovation transfer occurred at the end of the Third Reich. Many thousands of German-speaking scientists and engineers, well over 111,000 tons of German research documentation, more than 750,000 patents, many hundreds of complete factories and laboratories, and untold amounts of supplies, equipment, and prototypes were appropriated by the United States, the Soviet Union, the United Kingdom, France, and other countries after the war, seeding the modern world with a vast array of creations, even as it forgot the names of most of their creators.

Although this massive technology transfer has been nearly forgotten, it was loudly announced and praised by Allied governments and journalists at the time. As just one example among many, *The American Magazine* described "The World's Greatest Treasure Hunt" in its February 1946 issue [Josephs 1946]:

> Those assigned to comb Germany for hidden secrets of weapons, oil production, raw materials, synthetics, engineering, and chemical processes had the same kind of top-priority search orders as the financial treasure hunters, with the added drama of realizing they were taking part in a neck-and-neck race for secrets such as that of the atomic bomb and radar.
>
> One group, in fact, discovered a highly important German system of radar camouflage, consisting of anti-radar coverings and coatings to be employed on submarines and other weapons. When they reached the manufacturing plant they found it practically destroyed. Uncertain whether the device was already in use or had been given to the Japs, the searchers feared they were too late. Then one man came across a file of incoming shipments. That was the clue they needed. By going to the sub-assembly plants and obtaining samples, they were able to piece together the vital data and, within 24 hours, break the secret.
>
> Scientific information sleuths, like Col. Ernest L. McClendon, uncovered vital information, as when he shrewdly tracked down the files of the Berlin Patent Office secreted in a small provincial town. Others also located Nazi plans hidden in the beds of rivers and lakes, on mountaintops, and interspersed within the leaves of poetry books in the library of the University of Munich, which had been moved and hidden in the farming village of Kirchdorf.
>
> In more than 2,000 visits to captured laboratories, factories, and other key spots, our men have so far been able to obtain data showing how the Germans, among other things:
>
> — Had contemplated a piloted missile with a possible range of 3,000 miles which envisaged commercial applications for 17-minute transatlantic passenger crossings.
>
> — Were working on a formula for new war gases they hoped would prove more deadly than any chemical agent yet developed.

— Had perfected a highly advanced jet engine and plans for rocket-assisted plane take-offs. Planes with ceilings higher than our best and V-type weapons far more powerful than those used against England were in their final stages. So were designs for various secret types of guns, gunsights, novel gear and transmission construction, and air-cooled Diesel engines.

— Had specifications and construction details for naval vessels exceeding our largest, and for one-man submarines with high under-water speeds and apparatus for sustained under-water work.

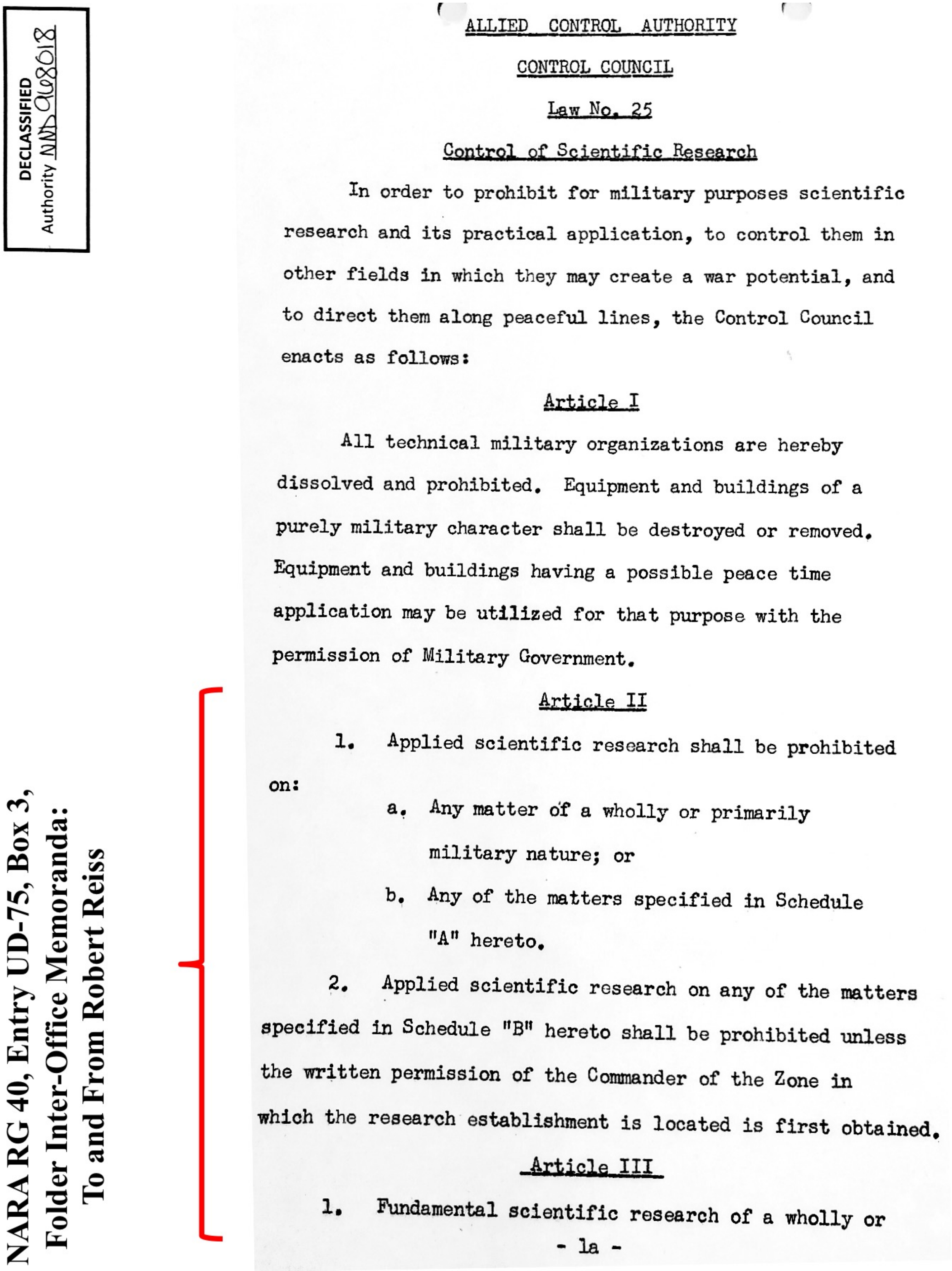
— Had found new uses for many staples. For example, coal. From it they were making synthetic butter, beverage and industrial alcohol, aviation lubricants, soap, and gasoline. And they had improved techniques for the production of synthetic petroleum products and high-grade nitrocellulose from lower-grade wood pulp.

Postwar émigrés

After the war, thousands of scientists in Germany were legally forbidden from continuing to work in their previous research fields, with penalties of imprisonment with hard labor or even execution [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss]. See pp. 2052–2060. In most cases, their only options were to work for Allied countries or to do menial labor in unrelated areas.

The majority of important German-speaking scientists went to work for the United States, the Soviet Union, France, the United Kingdom, or other countries. Each of those categories is discussed in this section.

Even those scientists who remained in Germany or Austria generally had to give up their innovations when Allied countries interrogated them, seized their papers, and appropriated their scientific equipment, as also covered in this section. Their innovations were then copied in Allied countries while the scientists themselves often sank into poverty and obscurity, without the ability to continue their research careers.



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ALLIED CONTROL AUTHORITY

CONTROL COUNCIL

Law No. 25

Control of Scientific Research

In order to prohibit for military purposes scientific research and its practical application, to control them in other fields in which they may create a war potential, and to direct them along peaceful lines, the Control Council enacts as follows:

Article I

All technical military organizations are hereby dissolved and prohibited. Equipment and buildings of a purely military character shall be destroyed or removed. Equipment and buildings having a possible peace time application may be utilized for that purpose with the permission of Military Government.

Article II

1. Applied scientific research shall be prohibited on:
   a. Any matter of a wholly or primarily military nature; or
   b. Any of the matters specified in Schedule "A" hereto.

2. Applied scientific research on any of the matters specified in Schedule "B" hereto shall be prohibited unless the written permission of the Commander of the Zone in which the research establishment is located is first obtained.

Article III

1. Fundamental scientific research of a wholly or

- 1a -

Figure 11.4: After the war, thousands of scientists in Germany were legally forbidden from continuing to work in their previous research fields, with penalties of imprisonment with hard labor or even execution. In most cases, their only options were to work for Allied countries or to do menial labor in unrelated areas [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

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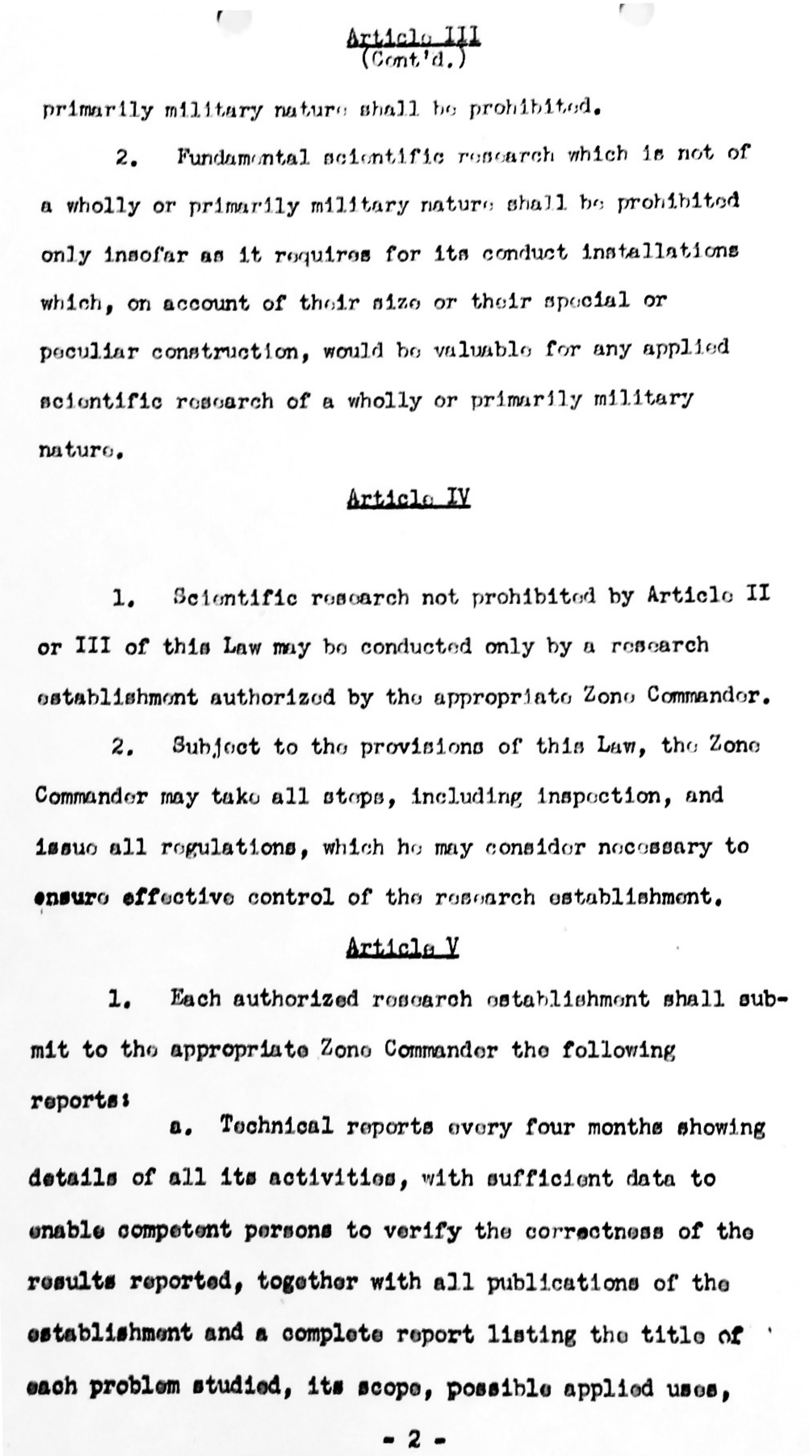
Authority NND 968018



Article III
(Cont'd.)

primarily military nature shall be prohibited.

2. Fundamental scientific research which is not of a wholly or primarily military nature shall be prohibited only insofar as it requires for its conduct installations which, on account of their size or their special or peculiar construction, would be valuable for any applied scientific research of a wholly or primarily military nature.

Article IV

1. Scientific research not prohibited by Article II or III of this Law may be conducted only by a research establishment authorized by the appropriate Zone Commander.

2. Subject to the provisions of this Law, the Zone Commander may take all steps, including inspection, and issue all regulations, which he may consider necessary to ensure effective control of the research establishment.

Article V

1. Each authorized research establishment shall submit to the appropriate Zone Commander the following reports:

a. Technical reports every four months showing details of all its activities, with sufficient data to enable competent persons to verify the correctness of the results reported, together with all publications of the establishment and a complete report listing the title of each problem studied, its scope, possible applied uses,

- 2 -

NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss

Figure 11.5: After the war, thousands of scientists in Germany were legally forbidden from continuing to work in their previous research fields, with penalties of imprisonment with hard labor or even execution. In most cases, their only options were to work for Allied countries or to do menial labor in unrelated areas [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

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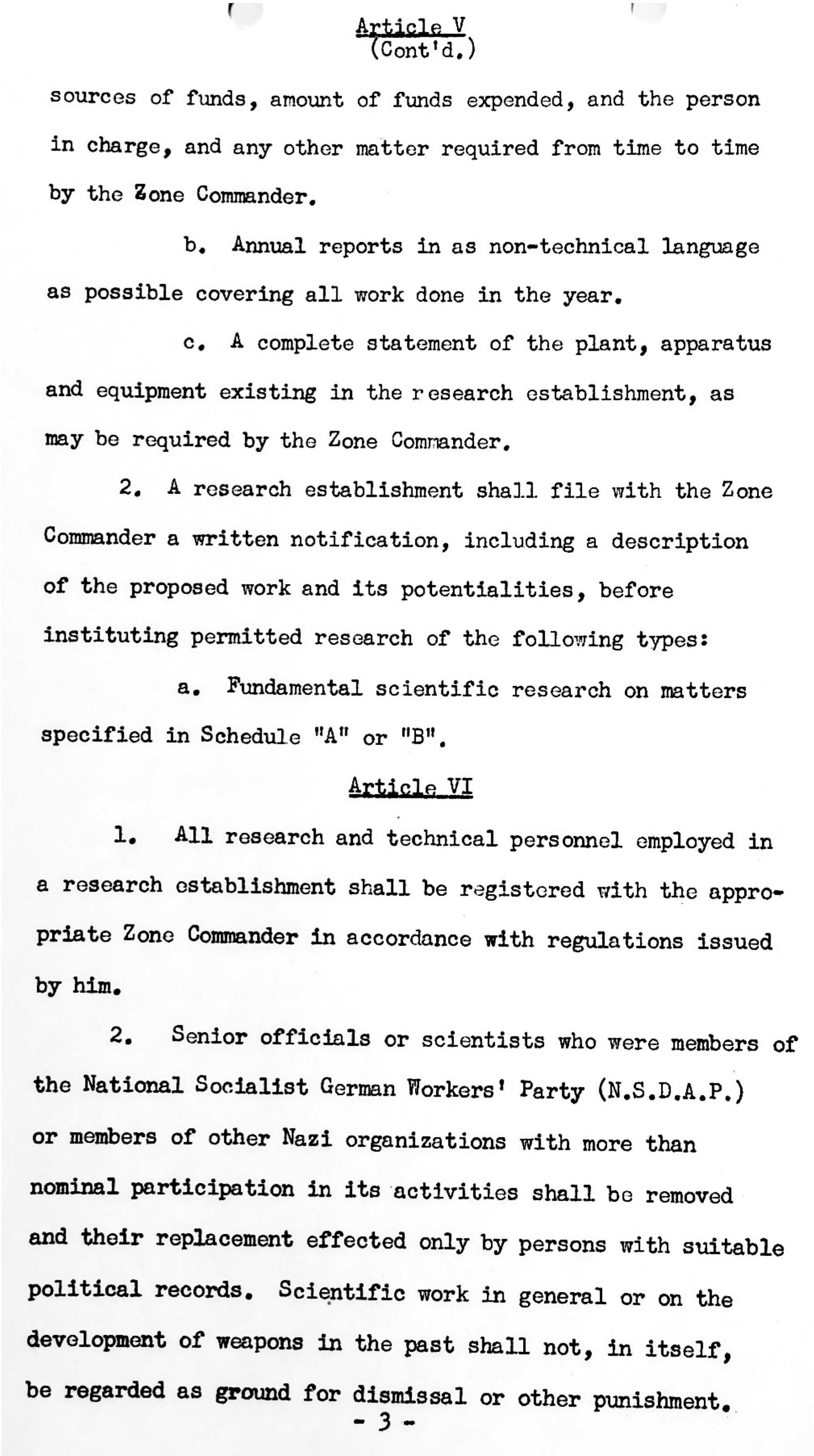
Authority NND 968018

NARA RG 40, Entry UD-75, Box 3,
Folder Inter-Office Memoranda:
To and From Robert Reiss



Article V
(Cont'd.)

sources of funds, amount of funds expended, and the person in charge, and any other matter required from time to time by the Zone Commander.

b. Annual reports in as non-technical language as possible covering all work done in the year.

c. A complete statement of the plant, apparatus and equipment existing in the research establishment, as may be required by the Zone Commander.

2. A research establishment shall file with the Zone Commander a written notification, including a description of the proposed work and its potentialities, before instituting permitted research of the following types:

a. Fundamental scientific research on matters specified in Schedule "A" or "B".

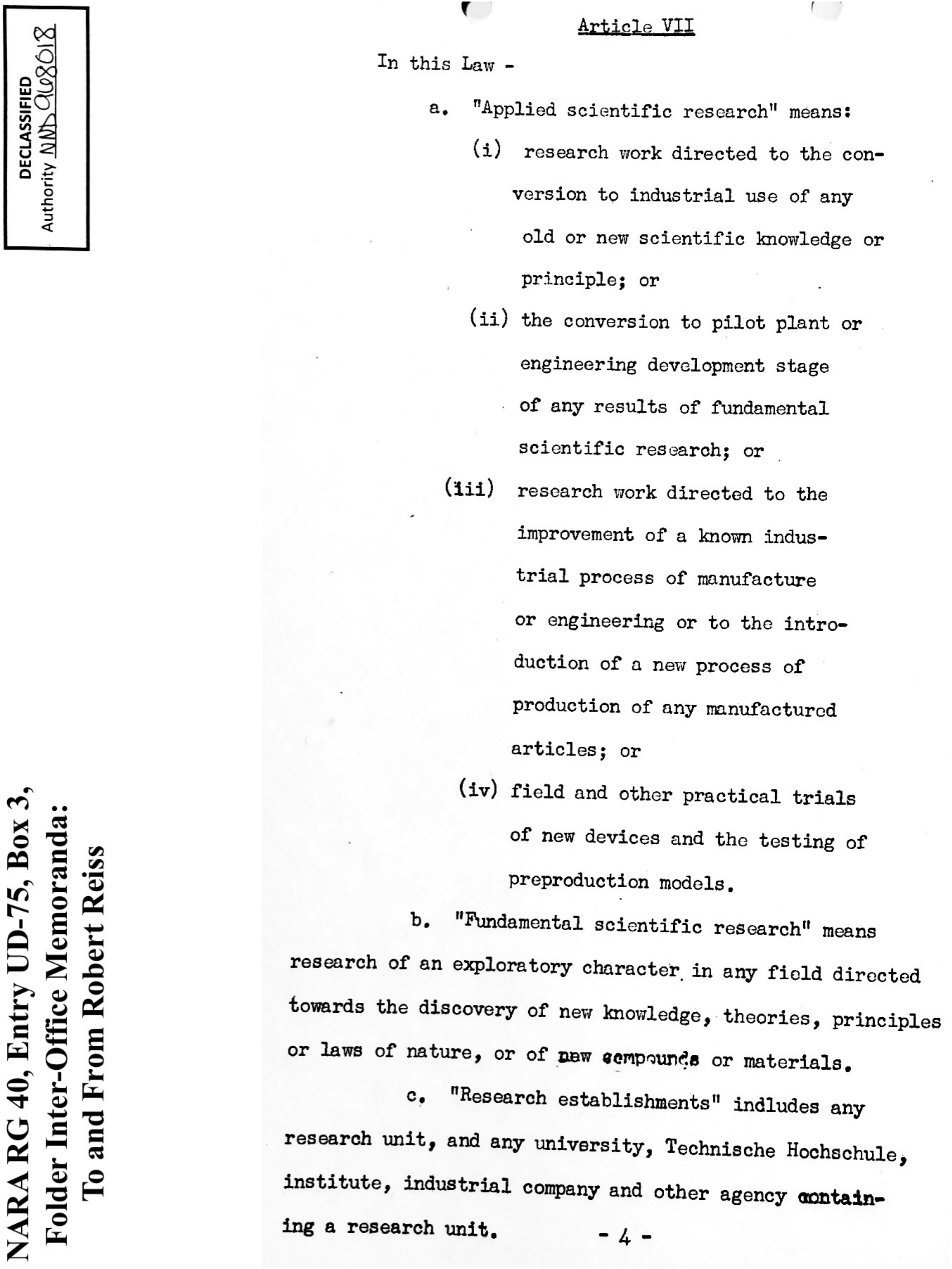
Article VI

1. All research and technical personnel employed in a research establishment shall be registered with the appropriate Zone Commander in accordance with regulations issued by him.

2. Senior officials or scientists who were members of the National Socialist German Workers' Party (N.S.D.A.P.) or members of other Nazi organizations with more than nominal participation in its activities shall be removed and their replacement effected only by persons with suitable political records. Scientific work in general or on the development of weapons in the past shall not, in itself, be regarded as ground for dismissal or other punishment.

- 3 -

Figure 11.6: After the war, thousands of scientists in Germany were legally forbidden from continuing to work in their previous research fields, with penalties of imprisonment with hard labor or even execution. In most cases, their only options were to work for Allied countries or to do menial labor in unrelated areas [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].



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Article VII

In this Law -

a. "Applied scientific research" means:

(i) research work directed to the conversion to industrial use of any old or new scientific knowledge or principle; or

(ii) the conversion to pilot plant or engineering development stage of any results of fundamental scientific research; or

(iii) research work directed to the improvement of a known industrial process of manufacture or engineering or to the introduction of a new process of production of any manufactured articles; or

(iv) field and other practical trials of new devices and the testing of preproduction models.

b. "Fundamental scientific research" means research of an exploratory character in any field directed towards the discovery of new knowledge, theories, principles or laws of nature, or of new compounds or materials.

c. "Research establishments" indludes any research unit, and any university, Technische Hochschule, institute, industrial company and other agency containing a research unit.

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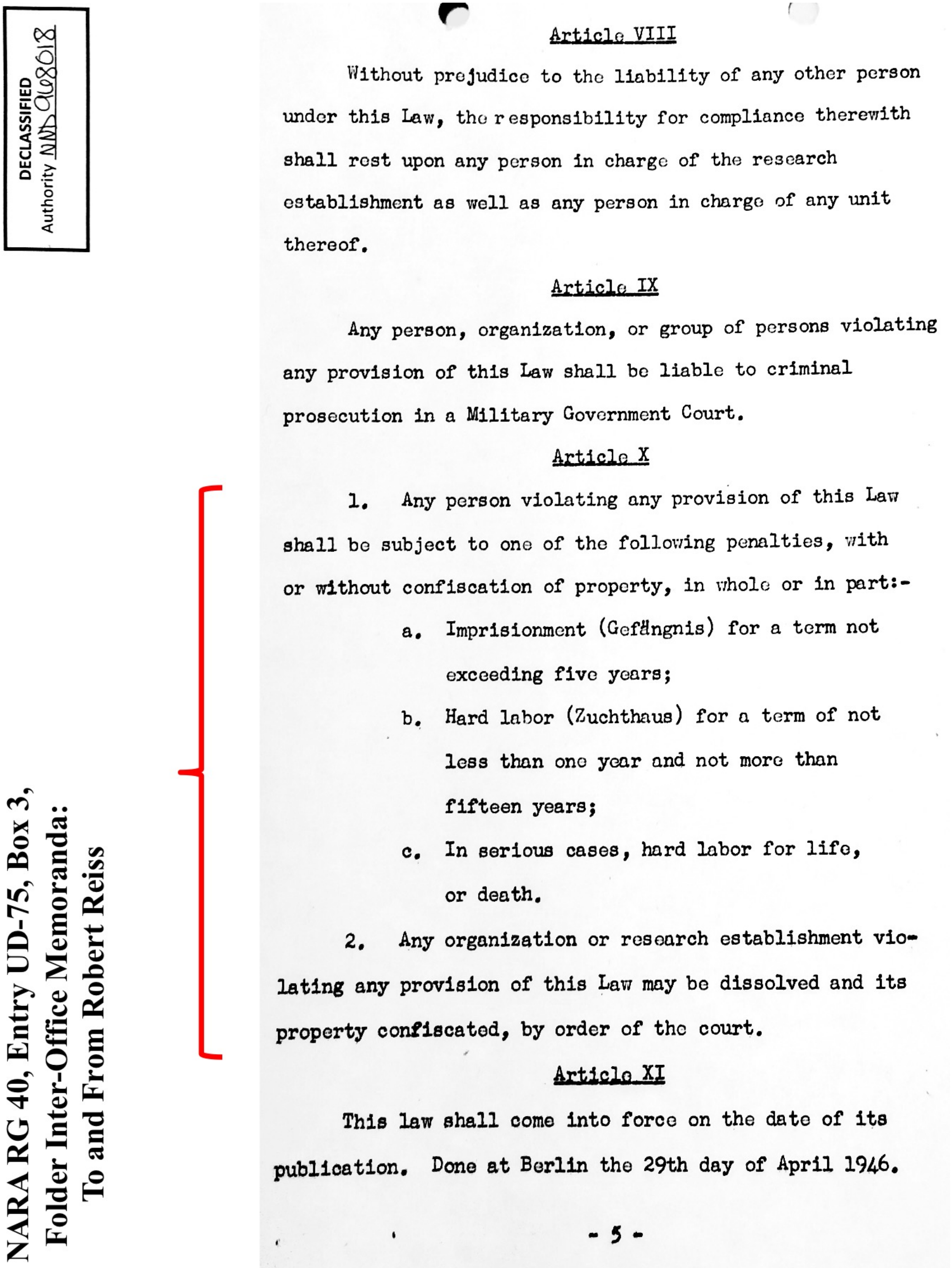
Figure 11.7: After the war, thousands of scientists in Germany were legally forbidden from continuing to work in their previous research fields, with penalties of imprisonment with hard labor or even execution. In most cases, their only options were to work for Allied countries or to do menial labor in unrelated areas [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].



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Article VIII

Without prejudice to the liability of any other person under this Law, the responsibility for compliance therewith shall rest upon any person in charge of the research establishment as well as any person in charge of any unit thereof.

Article IX

Any person, organization, or group of persons violating any provision of this Law shall be liable to criminal prosecution in a Military Government Court.

Article X

1. Any person violating any provision of this Law shall be subject to one of the following penalties, with or without confiscation of property, in whole or in part:-
    a. Imprisionment (Gefängnis) for a term not exceeding five years;
    b. Hard labor (Zuchthaus) for a term of not less than one year and not more than fifteen years;
    c. In serious cases, hard labor for life, or death.
2. Any organization or research establishment violating any provision of this Law may be dissolved and its property confiscated, by order of the court.

Article XI

This law shall come into force on the date of its publication. Done at Berlin the 29th day of April 1946.

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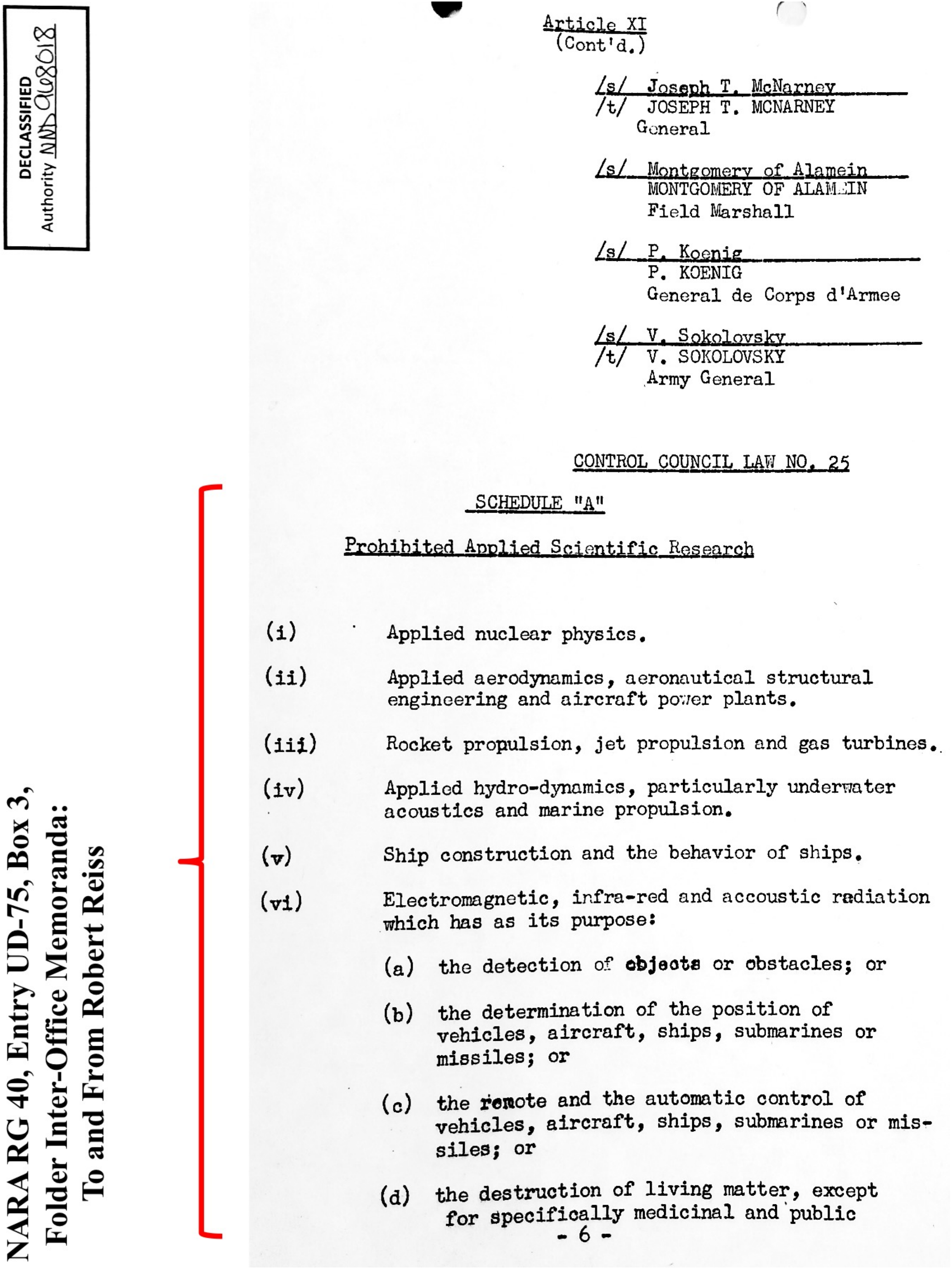
To and From Robert Reiss

Figure 11.8: After the war, thousands of scientists in Germany were legally forbidden from continuing to work in their previous research fields, with penalties of imprisonment with hard labor or even execution. In most cases, their only options were to work for Allied countries or to do menial labor in unrelated areas [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].



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Article XI
(Cont'd.)

/s/ Joseph T. McNarney
/t/ JOSEPH T. MCNARNEY
General

/s/ Montgomery of Alamein
MONTGOMERY OF ALAMEIN
Field Marshall

/s/ P. Koenig
P. KOENIG
General de Corps d'Armee

/s/ V. Sokolovsky
/t/ V. SOKOLOVSKY
Army General

CONTROL COUNCIL LAW NO. 25

SCHEDULE "A"

Prohibited Applied Scientific Research

(i) Applied nuclear physics.

(ii) Applied aerodynamics, aeronautical structural engineering and aircraft power plants.

(iii) Rocket propulsion, jet propulsion and gas turbines.

(iv) Applied hydro-dynamics, particularly underwater acoustics and marine propulsion.

(v) Ship construction and the behavior of ships.

(vi) Electromagnetic, infra-red and accoustic radiation which has as its purpose:

(a) the detection of objects or obstacles; or

(b) the determination of the position of vehicles, aircraft, ships, submarines or missiles; or

(c) the remote and the automatic control of vehicles, aircraft, ships, submarines or missiles; or

(d) the destruction of living matter, except for specifically medicinal and public

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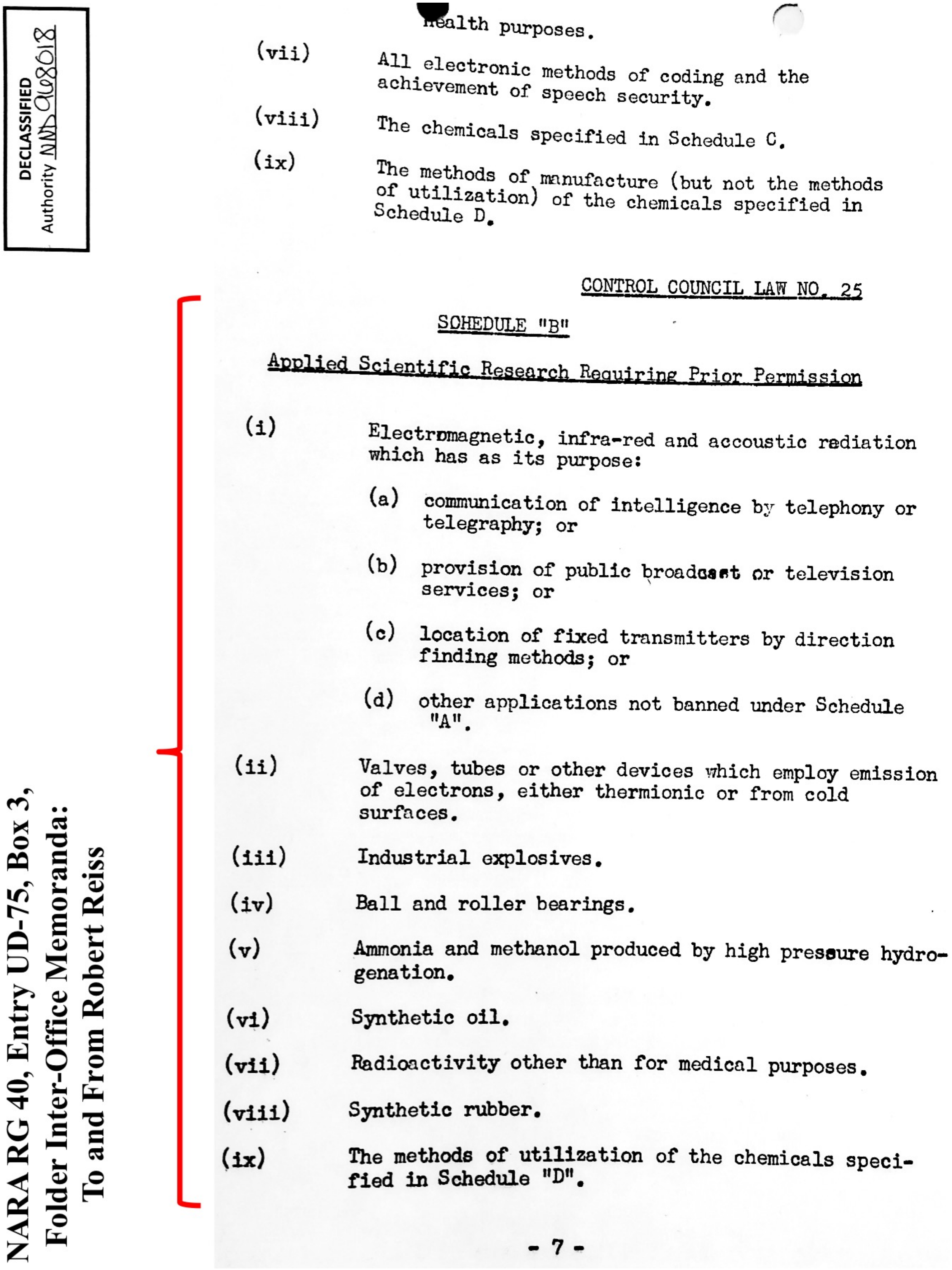
Figure 11.9: After the war, thousands of scientists in Germany were legally forbidden from continuing to work in their previous research fields, with penalties of imprisonment with hard labor or even execution. In most cases, their only options were to work for Allied countries or to do menial labor in unrelated areas [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].



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health purposes.

(vii) All electronic methods of coding and the achievement of speech security.

(viii) The chemicals specified in Schedule C.

(ix) The methods of manufacture (but not the methods of utilization) of the chemicals specified in Schedule D.

CONTROL COUNCIL LAW NO. 25

SCHEDULE "B"

Applied Scientific Research Requiring Prior Permission

(i) Electromagnetic, infra-red and accoustic radiation which has as its purpose:

(a) communication of intelligence by telephony or telegraphy; or

(b) provision of public broadcast or television services; or

(c) location of fixed transmitters by direction finding methods; or

(d) other applications not banned under Schedule "A".

(ii) Valves, tubes or other devices which employ emission of electrons, either thermionic or from cold surfaces.

(iii) Industrial explosives.

(iv) Ball and roller bearings.

(v) Ammonia and methanol produced by high pressure hydrogenation.

(vi) Synthetic oil.

(vii) Radioactivity other than for medical purposes.

(viii) Synthetic rubber.

(ix) The methods of utilization of the chemicals specified in Schedule "D".

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Figure 11.10: After the war, thousands of scientists in Germany were legally forbidden from continuing to work in their previous research fields, with penalties of imprisonment with hard labor or even execution. In most cases, their only options were to work for Allied countries or to do menial labor in unrelated areas [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

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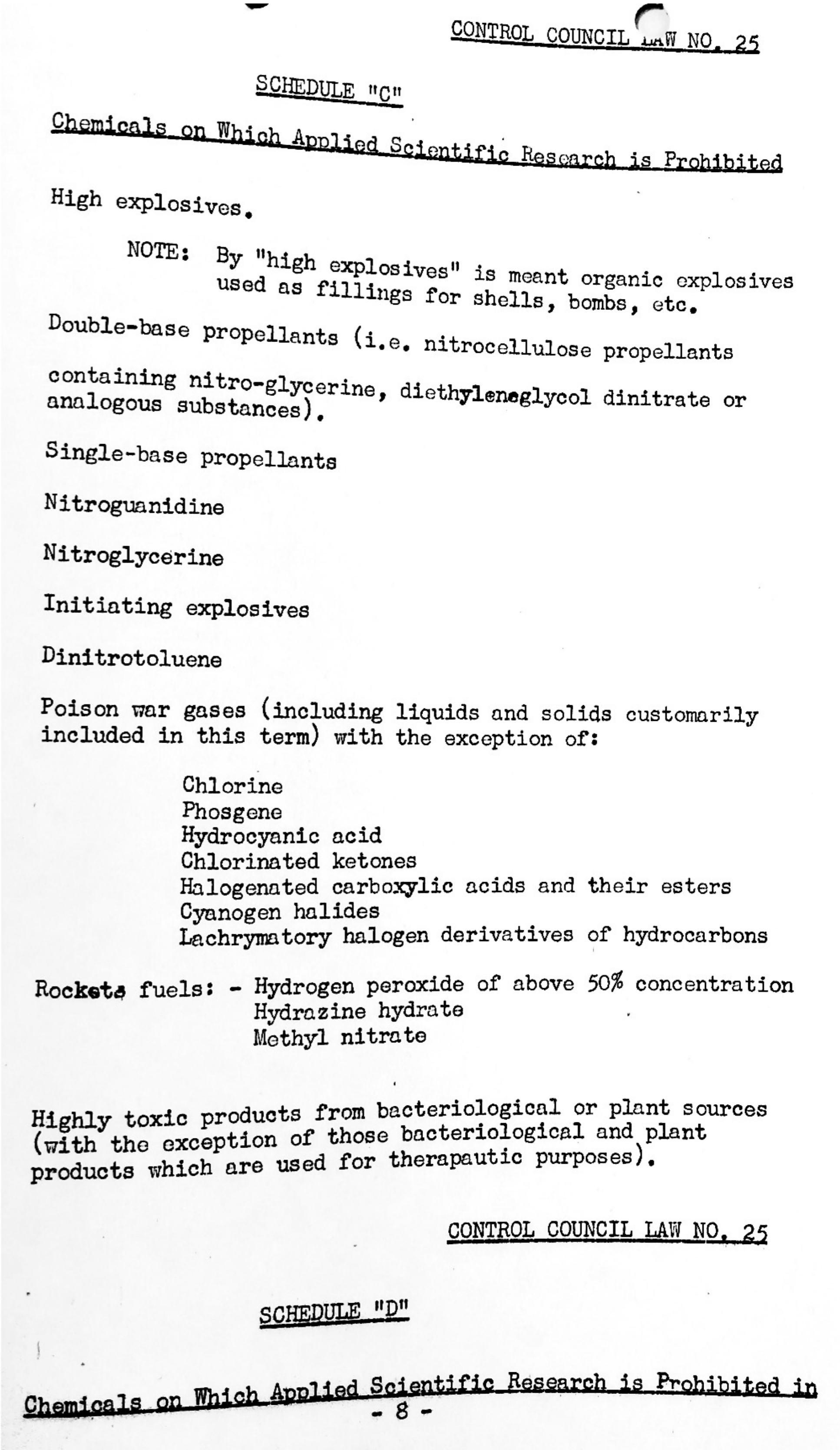

CONTROL COUNCIL LAW NO. 25

SCHEDULE "C"

Chemicals on Which Applied Scientific Research is Prohibited

High explosives.

NOTE: By "high explosives" is meant organic explosives used as fillings for shells, bombs, etc.

Double-base propellants (i.e. nitrocellulose propellants

containing nitro-glycerine, diethyleneglycol dinitrate or analogous substances).

Single-base propellants

Nitroguanidine

Nitroglycerine

Initiating explosives

Dinitrotoluene

Poison war gases (including liquids and solids customarily included in this term) with the exception of:

Chlorine
Phosgene
Hydrocyanic acid
Chlorinated ketones
Halogenated carboxylic acids and their esters
Cyanogen halides
Lachrymatory halogen derivatives of hydrocarbons

Rockets fuels: - Hydrogen peroxide of above 50% concentration
Hydrazine hydrate
Methyl nitrate

Highly toxic products from bacteriological or plant sources (with the exception of those bacteriological and plant products which are used for therapautic purposes).

CONTROL COUNCIL LAW NO. 25

SCHEDULE "D"

Chemicals on Which Applied Scientific Research is Prohibited in

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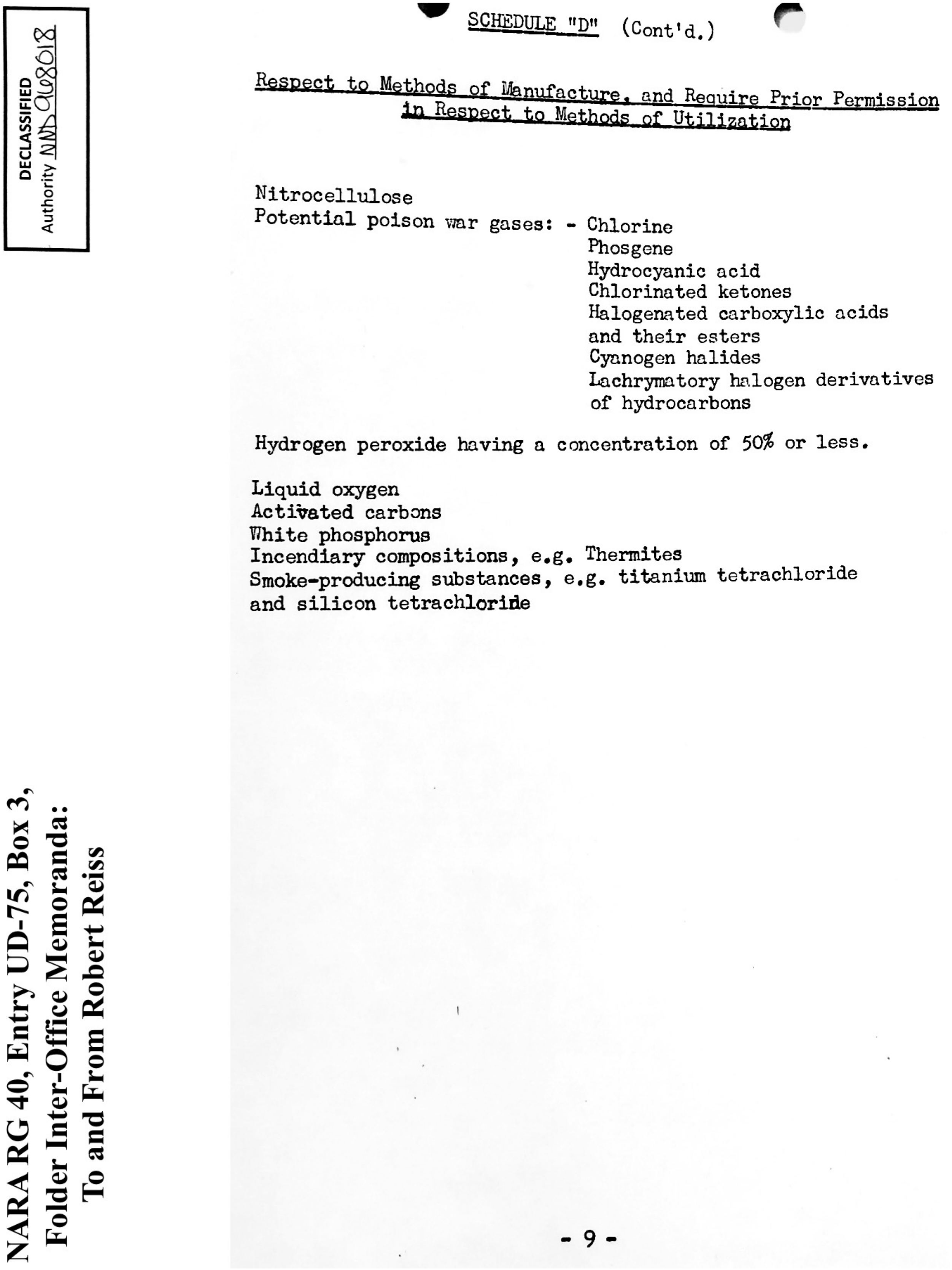
NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss

Figure 11.11: After the war, thousands of scientists in Germany were legally forbidden from continuing to work in their previous research fields, with penalties of imprisonment with hard labor or even execution. In most cases, their only options were to work for Allied countries or to do menial labor in unrelated areas [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].



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SCHEDULE "D" (Cont'd.)

Respect to Methods of Manufacture, and Require Prior Permission in Respect to Methods of Utilization

Nitrocellulose
Potential poison war gases: - Chlorine
Phosgene
Hydrocyanic acid
Chlorinated ketones
Halogenated carboxylic acids and their esters
Cyanogen halides
Lachrymatory halogen derivatives of hydrocarbons

Hydrogen peroxide having a concentration of 50% or less.

Liquid oxygen
Activated carbons
White phosphorus
Incendiary compositions, e.g. Thermites
Smoke-producing substances, e.g. titanium tetrachloride and silicon tetrachloride

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NARA RG 40, Entry UD-75, Box 3,
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To and From Robert Reiss

Figure 11.12: After the war, thousands of scientists in Germany were legally forbidden from continuing to work in their previous research fields, with penalties of imprisonment with hard labor or even execution. In most cases, their only options were to work for Allied countries or to do menial labor in unrelated areas [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

Beginning in 1945, more than 1600 German-speaking scientists and engineers were brought to the United States by Operation Paperclip, which in its earliest phases was also called Operation Overcast [Linda Hunt 1991, p. 1]. Many hundreds more were brought by at least two other Paperclip-related programs, Project 63 and National Interest [Linda Hunt 1991, pp. 1, 200], so the total number of German-speaking specialists bought to the United States in the late 1940s was well over 2000 people. In 1956, U.S. Ambassador to West Germany (and former Harvard president) James Conant described Paperclip as "a continuing U.S. recruitment program which has no parallel in any other Allied country" [NARA RG 59]. By 1966, at least 6000 German-speaking scientists and engineers had moved to the United States [Mick 2000, p. 316]. U.S. recruitment of German-speaking scientists and engineers through these programs continued until at least 1973, nearly three decades after the end of World War II, despite official protests from West Germany and official denials from the United States [Linda Hunt 1991, pp. 141, 221–222].

Tom Bower, who wrote a detailed exposé of the Paperclip program, described the origins of the program and the technological superiority of the German-speaking scientists it brought to the United States [Bower 1987, pp. 3–6]:

> During the cataclysmic life span of the Third Reich, [Wernher] von Braun, [Hubertus] Strughold, and twenty thousand German scientists had revolutionized the weapons of warfare. Twenty-five years later [in the manned moon landings], the Americans were reaping the benefit of their former enemies' youthful genius. [...]
>
> Their recruitment after the war had followed interrogation by American officers. After selection, the chosen German scientists were identified simply with an ordinary paperclip on their personal file. [...]
>
> The fact that all the four Allies—the Americans, the British, the Russians, and the French—became involved in the frantic and at times ruthless competition for German scientists is particularly surprising when one realizes that the use of the Germans was simply not contemplated until as late as 1945. [...]
>
> The answer to the riddle starts in the prewar years, when European engineering students learned German as a second language so that they could read the important scientific literature published by one of the world's industrial giants and its leading technical innovator. It was no coincidence that many of the scientists developing the American atomic bomb in Los Alamos had Teutonic names. Von Braun's rockets were the symbol of Germanic superiority. The substance was considerably broader—in engineering, chemical processes, and industrial design—but, before 1940, this was not appreciated by either the American or British military.
>
> At the outbreak of war, complacent military chiefs and politicians in Washington and London misunderstood the nature of the conflict into which they had been cast. In Berlin, scientists and engineers were the welcome allies of politicians and military chiefs. But in London and Washington the government, the civil service, and the military chiefs largely ignored or even disdained the purveyors of technical information. Allied officers, startled by Hitler's momentous conquests, only gradually stumbled to the realization that their Achilles heel was the technical inferiority of many of their guns, planes, tanks,

and submarines. On the eve of Hitler's final defeat, Allied scientists had narrowed the lead and occasionally overtaken their enemy, but in crucial areas Germany's superiority, even in the last year of the war, had actually increased. Acknowledgment of that reality bred a conviction—some would say a legend—of German scientific supremacy that was not far from the truth. [...] The proof of German technical prowess is overwhelmingly established in the hundreds of reports written by Allied investigators who did not shy from describing the Germans' "astonishing achievement" and "superb invention." It was also established by the very survival of Germany during four years of total war despite the prediction during the first two years of war by British intelligence that the German economy and German industry faced imminent and total collapse. The blockade on essential minerals, chemicals, and petroleum products, it was argued, would cripple weapons production. But the very opposite happened, because German scientists developed an astonishing range of substitutes that not only humiliatingly neutralized the Allied blockade but heralded the dawn of a new scientific era. [...] German scientists had pioneered so many inventions that many Allied experts would complain that their plunder could do no more than scratch the surface.

Since 1945, the genesis of weapons by all four Allies has been dominated by the inheritance of Germany's wartime inventions. Indeed, the Korean War can be viewed, on the technical level, as a trial of strength between two different teams of Germans: those hired by America and those hired by the Soviet Union. The aerial dogfights between Soviet MiG-15s and American F-86 Sabres—both designed by German engineers—dispelled for many their doubts about the expediency of plundering Germany's scientific expertise.

As the war ended, Allied investigators, plunged into the hectic race to find their German competitors, were in turn shocked, excited, and then bewildered as they began to appreciate their own technical ignorance. For them, a haphazard series of interrogations conducted in the turmoil of a distraught and defeated nation was tantalizing and frustrating. The obvious solution was to transport the German experts to America and Britain, following the example of the French and Russians. The American haul, enthusiastically hailed as an Aladdin's cave, was worth alone, according to some American military estimates, "thousands of millions of dollars."

Figure 11.13: Examples of German-speaking creators who emigrated to the United States after the Third Reich.

John Gimbel, who wrote the definitive book on postwar technology transfer, further described the widespread impact that the Paperclip scientists ultimately had in the United States [Gimbel 1990a, pp. 171–172]:

> As we have also seen, the armed services shared their Paperclip specialists with their contractors, on occasion permitting them to shuttle from military installations to private firms and in many instances ultimately releasing them entirely for employment in the private sector. A Joint Intelligence Objectives Agency (JIOA) statistical report of 1951, for example, shows Paperclip specialists working in a variety of private firms and agencies, among them Bendix Aviation Corporation, Grumman Aircraft Company, Packard Motor Company, Hydropress, Incorporated, of New York, Phillips Petroleum Company, Dow Chemical Company, Hydrocarbon Research, and the Universities of Indiana, Chicago, Minnesota, Illinois, Missouri, and others. Clarence G. Lasby, in his pioneering study of Project Paperclip, published in 1971, listed numerous universities (Yale, Wisconsin, Kansas, Ohio State, and others) and corporations (Boeing, Raytheon, General Electric, Bell, Westinghouse, and others) to which Paperclip specialists had gone in the 1950's and 1960's, "frequently in executive positions."

For additional examples of the contributions of Paperclip scientists, see pp. 4890–4892.

Figure 11.13 shows one group of Paperclip scientists (aerospace engineers including Wernher von Braun right of center in the front row) at Fort Bliss, Texas, in 1946.

In addition to thousands of scientists and engineers, the United States and other countries also acquired many of the administrators who had selected, funded, and managed the science and engineering programs. One of the most spectacular examples is that Dr. Ing. Hans Kammler, an SS general who ended up controlling almost all of Germany's advanced weapons programs by the end of the war, was captured by the United States and interrogated at great length after the war; see pp. 4931–4959.

The Soviet Union forcibly removed and held thousands of German-speaking skilled scientific workers (the exact numbers are even murkier than the corresponding figures for the United States), and millions of German-speaking unskilled workers.[1]

The German historian Christoph Mick was able to access some relevant files in Moscow archives for the first time in the 1990s. He reported that he had found documentation for at least 3000 German and Austrian scientists and engineers who had been transferred to the Soviet Union during the period 1945–1947 [Mick 2000, pp. 15–17]:

---

[1] Albrecht et al. 1992; von Ardenne 1990, 1997; Barkleit 2008; Barwich and Barwich 1970; Boch and Karlsch 2011; Fengler 2014; Fengler and Sachse 2012; Graham 1993; Heinemann-Gruder 1992; Holloway 1994; Karlsch and Laufer 2002; Kozyrev 2005; Kruglov 2002; Jürgen Michels 1997; Mick 2000; Nagel 2016; Naimark 1995; Oleynikov 2000; Pondrom 2018; Przybilski 1999, 2002a, 2002b; Riabev 2002a; Riehl and Seitz 1993; Siddiqi 2009; Sokolov 1955; Uhl 2001; Zeman and Karlsch 2008; *News Chronicle* 1945-10-15 p. 1; NYT 1945-10-15 p. 4, 1945-10-31 p. 6, 1946-01-29 p. 1, 1946-11-28 p. 16, 1946-12-06 p. 17, 1947-02-24 p. 1, 1948-05-26 p. 3, 1948-12-28 p. 10b; *Spokane Daily Chronicle* 1948-03-16 p. 6; *Sydney Morning Herald* 1946-04-20 p. 2; *Times* 1945-05-15, 1945-05-18.

Zwischen 1945 und 1947 wurden deutsche und österreichische Wissenschaftler, Techniker und Facharbeiter in die Sowjetunion gebracht, um in Werken, Konstruktionsbüros und Forschungseinrichtungen qualifizierte Arbeit zu verrichten. [...]	Between 1945 and 1947 German and Austrian scientists, technicians and skilled workers were brought to the Soviet Union to carry out qualified work in factories, design offices and research facilities. [...]
Es handelte sich um etwa 3.000 Wissenschaftler, Ingenieure, Techniker und Facharbeiter, zusammen Angehörigen nicht mehr als 8,000 Personen. [...]	There were about 3,000 scientists, engineers, technicians and skilled workers, together with relatives no more than 8,000 persons. [...]
Nach Art und Zeitpunkt der Rekrutierung können fünf Typen von Spezialisten unterschieden werden.	Five types of specialists can be distinguished according to the type and time of recruitment.
1. Die erste Gruppe wurde zusammen mit ihren Familien bereits im Sommer 1945 per Flugzeug in die Sowjetunion gebracht. Angesichts der Zeitumstände kann von einer freiwilligen Wahl keine Rede sein, doch ist kein Fall bekannt, in dem physische Gewalt angewandt wurde. Diese erste Welle betraf vor allem die Atomforscher, es handelt sich um weniger als 100 Personen. Darunter fallen der Privatforscher Manfred von Ardenne, der Physiknobelpreisträger Gustav Hertz, der ehemalige Leiter der Forschungsabteilung der Auer-Gesellschaft, Nikolaus Riehl, und der Direktor des Kaiser-Wilhelm-Instituts für physikalische Chemie in Berlin, Peter Adolf Thiessen.	1. The first group and their families were brought to the Soviet Union by plane as early as summer 1945. Given the circumstances, there was no voluntary choice, but there was no known case of physical violence. This first wave mainly affected nuclear researchers, fewer than 100 people. These include the private researcher Manfred von Ardenne, the Nobel Prize winner in physics Gustav Hertz, the former head of the research department of the Auergesellschaft Nikolaus Riehl, and the director of the Kaiser Wilhelm Institute for Physical Chemistry in Berlin, Peter Adolf Thiessen.
2. Die zweite und mit Abstand größte Gruppe wurde am 22. Oktober 1946 zwangsweise in die Sowjetunion gebracht. Davon betroffen waren etwa 2.200–2.300 Familien, insgesamt 6.700–7.000 Personen. Die Fachleute stammten vor allem aus den Bereichen Flugzeugzellen- und Flugzeugtriebwerksbau, Optik, ballistische und Lenkraketen, Chemie, Elektrotechnik und Marinewaffen.	2. The second and by far the largest group was forcibly brought to the Soviet Union on 22 October 1946. About 2,200–2,300 families were affected, a total of 6,700–7,000 people. The experts came mainly from the fields of airframe and aircraft engine construction, optics, ballistic and guided missiles, chemistry, electrical engineering and naval weapons.

3. Die dritte Gruppe kam zwischen 1946 und 1947 ausgestattet mit Zeitverträgen in die Sowjetunion. Etwa 200–250 Fachkräfte halfen beim Wiederaufbau demontierter Betriebe und wiesen die einheimischen Arbeiter in die Funktionsweise der Maschinen ein. Diese Spezialisten waren meist in der Textil- und Chemieindustrie tätig. Dazu kamen zehn Fachleute für Marinewaffen und einzelne Chemiker und Physiker, die im Atomprojekt eingesetzt wurden.	3. The third group came to the Soviet Union between 1946 and 1947 with temporary contracts. Some 200–250 skilled workers helped rebuild dismantled factories and trained local workers in the operation of the machines. These specialists were mostly employed in the textile and chemical industries. There were also ten specialists for naval weapons and individual chemists and physicists who were employed in the nuclear project.
Diese drei Gruppen waren zwar in ihrer Bewegungsfreiheit stark eingeschränkt, galten aber nicht als Gefangene.	Although these three groups were severely restricted in their freedom of movement, they were not considered prisoners.
4. Davon unterschied sich die vierte Gruppe. Sie bestand aus Häftlingen der sowjetischen Speziallager in der SBZ, die wegen echter oder angeblicher Verstrickung in die Verbrechen des NS-Regimes interniert worden waren. Etwa 50–60 Häftlinge mit technischem Spezialwissen wurden 1946 und 1947 zur Arbeit in Konstruktionsbüros des NKVD/MVD in die Sowjetunion deportiert. Sie arbeiten zunächst im elektrotechnischen Bereich, später wurden sie bei der Entwicklung von lenkbaren Flugabwehrraketen eingesetzt.	4. The fourth group was different from those. It consisted of prisoners from the Soviet special camps in the Soviet Zone who had been interned because of real or alleged involvement in the crimes of the Nazi regime. In 1946 and 1947, about 50–60 prisoners with specialized technical knowledge were deported to the Soviet Union to work in construction offices of the NKVD/MVD. At first they worked in the electrotechnical field; later they were used in the development of guided anti-aircraft missiles.
5. Die fünfte Gruppe wurde aus Kriegsgefangenenlagern rekrutiert. Etwa 200–250 Kriegsgefangene, in der Regel Handwerker, aber auch einzelne Wissenschaftler und Ingenieure, wurden in Einrichtungen des Atomsektors gebracht, in denen bereits deutsche Wissenschaftler tätig waren.	5. The fifth group was recruited from prisoner-of-war camps. Some 200–250 prisoners of war, usually craftsmen, but also individual scientists and engineers, were brought to nuclear facilities where German scientists were already working.

It is important to note that Mick's estimate of 3000 German-speaking scientists is a minimum number. That estimate did not include specialists who were transferred to the Soviet Union after 1947, scientists and engineers who remained in Soviet-controlled East Germany and labored on behalf of the Soviet Union there, and German-speaking scientists from other areas of the former Third Reich (Poland, Czechoslovakia, etc.) who worked for the Soviet Union in those regions or were transferred to the Soviet Union. Thus the total number of German-speaking scientists recruited by the Soviet Union would have been many thousands.

For example, after German reunification, the Stanford University historian Norman Naimark studied some former East German records that described over 6000 specialists who remained in East Germany to work there on behalf of the Soviet Union [Naimark 1995, pp. 230–232]:

> The Soviets removed most of the scientists and technicians important to their armaments industry in the October 22 [1946] operation, and they took others periodically by a variety of means from Western and Eastern zones. [...] But Soviet technical experts understood that they still had a lot to gain in the way of knowledge and expertise from the high level of German technological achievements, industrial infrastructure, and production methods in the Eastern zone. [...] An Administration for the Study of Science and Technology in Germany was attached to SVAG headquarters in Karlshorst. This central administration was to supervise a network of Science and Technology Offices (NTOs) in each of the provinces and many of the large cities in the Eastern zone. [...]
>
> Altogether in the NTOs, 611 Soviet specialists oversaw the work of 6,014 German scientists and technicians, plus 7,067 German workers. Between 1946 and 1948, the NTOs supervised the completion of 7,069 projects, some of which had great practical value for Soviet industry. From German specialists the Soviets learned how to make high-octane gas and carbon fuels. They learned how to produce liquid fuels and build turbines that could be run on liquid fuels. They created a Soviet nylon industry from German accomplishments in that field, and adapted the Buna chemical factories' advancements for the creation of synthetic rubber. Similarly, the technology of the German coal briquette industry was adapted for Soviet use[...] Other Soviet industries that benefited in particular from German technologies developed by the NTOs included ceramics, metal finishing, film developing, and metal plating. Almost 4,000 prototypes of a variety of machines, production stations, and technologies were transferred to the Soviet Union in this period, through the NTOs.

In 1946 in just one Soviet-occupied former German underground factory alone, 2000–3000 German scientists were reported to currently be working for the Soviet Union, continuing wartime German work on nuclear weapons and rockets (p. 3697).

For examples of contemporary articles documenting the transfer of German and Austrian scientists to the Soviet Union, see:

> Russian Seizures [of Austrians] in Austria Aired [NYT 1945-11-22 p. 16].
>
> Russians Said to Use German War Experts [NYT 1946-05-22 p. 4].
>
> Seizure of 3,000 Laid to Russians: Human Reparations [NYT 1946-10-24 p. 14].
>
> 3,000,000 Axis POW on Siberian Projects [NYT 1946-12-17 p. 18].
>
> Former German Officers Reported Sent to Russia [NYT 1946-12-21 p. 4].
>
> Soviet Seen Ready to Shift Workers: Technicians Are Needed in the East [NYT 1946-12-28 p. 7].
>
> Austrians Attack Russian Seizures [of Austrians] [NYT 1948-11-07 p. 13].
>
> Russia Keeps Prisoners [1,000,000 POWs for labor] [NYT 1948-02-01 p. 25].
>
> The Kremlin Picks a German Brain [Littell 1958].

Similarly, large numbers of German-speaking scientists and engineers were recruited by France.[2] Writing for *L'Express*, investigative journalists Vincent Nouzille and Olivier Huwart sifted through government records and described the recruitment and ultimate technological impact of over 1000 German and Austrian scientists and engineers in France after the war [Nouzille and Huwart 1999]:

> Entre 1945 et 1950, plus de 1 000 chercheurs allemands, dont certains nazis, ont été “embauchés” par les autorités françaises. Un apport très secret à la reconstruction de l'industrie militaire et aéronautique du pays. [...]
>
> Plus étonnant: le LRBA n'est pas le seul organisme français à avoir bénéficié, après guerre, de ces “transferts de technologie” très particuliers. Les faits ont longtemps été masqués aux yeux de l'opinion pour cause d'orgueil national et de secret défense. Mais, depuis quelques années, une poignée d'historiens et d'initiés ont commencé de découvrir une réalité insoupçonnée: entre 1945 et 1950, la France a massivement recruté des “cerveaux du IIIe Reich”. Combien? En recoupant ces études avec les archives accessibles et des témoignages directs, L'Express peut avancer qu'ils furent plus d'un millier. Soit nettement moins que les 5 000 savants allemands enrôlés par l'URSS ou les 3 000 recrutés par les Etats-Unis dans le cadre de leur opération “Paperclip”. Mais plus que les quelques dizaines embauchés en Grande-Bretagne. Des nazis? Nombre de ces savants n'étaient, semble-t-il, ni des fanatiques ni des militants. “J'étais un simple ingénieur, sans engagement politique”, dit Kraehe. Toutefois la France, on le verra, ferma les yeux pour attirer quelques figures au passé chargé. Ces recrues avaient-elles un bon niveau de connaissances? “Oui, estime Jacques Villain, historien de la SEP, spécialiste du sujet. La France, principalement dans le domaine aéronautique et militaire, a su attirer des personnalités de premier plan.”

> Between 1945 and 1950, more than 1,000 German researchers, including some Nazis, were “hired” by the French authorities. A highly secret contribution to the reconstruction of the country's military and aviation industry. [...]
>
> More surprisingly, the LRBA is not the only French organization to have benefited after the war from these very specific “technology transfers.” For a long time, the facts were hidden from the eyes of the public because of national pride and military secrecy. But in recent years, a handful of historians and insiders have begun to discover an unsuspected reality: between 1945 and 1950, France massively recruited the “brains of the Third Reich.” How many? By cross-checking these studies with accessible archives and direct testimonies, L'Express can state that there were more than a thousand of them. This is considerably less than the 5,000 German scientists recruited by the USSR or the 3,000 recruited by the United States as part of their “Paperclip” operation. But more than the few dozen hired in Great Britain. Nazis? Many of these scientists were, it seems, neither fanatics nor militants. “I was a simple engineer, without political commitment,” Kraehe says. However, France, as we will see, closed its eyes to attract some figures with a busy past. Did these recruits have a good level of knowledge? “Yes,” says Jacques Villain, SEP historian and specialist in the subject. France, mainly in the aeronautics and military sectors, has been able to attract leading personalities.”

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[2] Defrance 2001; Ludmann-Obier 1986, 1988, 1989; Hans-Ulrich Meier 2010; Nouzille and Huwart 1999; O'Reagan 2019; Teyssier and Hautefeuille 1989; Trichet 2009.

Les noms de ces têtes de file sont inconnus du grand public: Jauernick, Müller, Bringer, Habermann pour les fusées (LRBA et SEP); Oestrich pour les moteurs à réaction à la Snecma [...]; Sänger pour les engins spéciaux à l'arsenal de Châtillon (aujourd'hui Aerospatiale); Schardin et Schall pour les explosifs à l'institut Saint-Louis (ministère de la Défense). A ces leaders il faut ajouter des apports d'équipes allemandes chevronnées—réparties sur tout le territoire [...]—dans le domaine des hélicoptères, des sous-marins, des torpilles, des radars, des moteurs de char, des obus, des souffleries aéronautiques. Et même de la force de frappe[...]

La liste est loin d'être close: "La dispersion des archives et leur fréquente classification militaire empêchent encore d'avoir une vision complète du phénomène, estime Gérard Bossuat, professeur d'histoire à l'université de Cergy-Pontoise, spécialiste des relations franco-allemandes d'après-guerre [3]. Mais une chose est sûre: ce recrutement de savants a été assumé politiquement par le gouvernement et organisé administrativement." Même si la plupart sont repartis en Allemagne dans les années 50, Emmanuel Chadeau, professeur d'histoire à l'université Lille III, estime que "leur présence a permis à certains secteurs de l'industrie française de rattraper au moins cinq ans de retard, voire de réaliser de belles percées". De quoi réviser quelques vérités... [...]

The names of these leaders are unknown to the general public: Jauernick, Müller, Bringer, Habermann for rockets (LRBA and SEP); Oestrich for Snecma jet engines [...]; Sänger for special vehicles at the Châtillon arsenal (now Aerospatiale); Schardin and Schall for explosives at the Saint-Louis Institute (Ministry of Defense). To these leaders must be added the contributions from experienced German teams—spread throughout the country [...]—in the field of helicopters, submarines, torpedoes, radar, tank engines, shells, and aeronautical wind tunnels. And even the strike force[...]

The list is far from over: "The dispersion of archives and their frequent military classification still prevent us from having a complete picture of the situation," says Gérard Bossuat, Professor of History at the University of Cergy-Pontoise, a specialist in Franco-German postwar relations. But one thing is certain: this recruitment of scientists was politically decided by the government and organized administratively." Even though most of them returned to Germany in the 1950s, Emmanuel Chadeau, professor of history at the University of Lille III, believes that "their presence has enabled certain sectors of French industry to catch up at least five years earlier, or even to make significant breakthroughs." Something to revise some truths.... [...]

Pourtant, dans cette chasse souterraine, les Français ne se débrouillent pas mal. Les ordres viennent de très haut. Dès le 16 mai 1945, dans une note classée "très secret"—exhumée des archives de l'armée de terre par l'historienne Marie-France Ludmann-Obier—l'état-major de la Défense nationale alerte le général de Gaulle, chef du gouvernement provisoire, sur l'intérêt des recherches allemandes: "L'activité et l'ampleur des résultats obtenus, dans le domaine des armes secrètes notamment, ont vivement impressionné ceux qui les ont examinés[...]. Certaines personnalités, têtes de file, ont été emmenées en Angleterre, d'autres pressenties pour travailler en Amérique. De notre côté, nous avons emmené temporairement à Paris certaines personnalités [...]". Soucieux de redonner rapidement à la France les moyens d'une grande puissance, le général de Gaulle délivre, le 17 mai 1945, une instruction personnelle et confidentielle: "Il y aura tout lieu de transférer en France les scientifiques ou techniciens allemands de grande valeur pour les interroger à loisir sur leurs travaux et éventuellement les engager à rester à notre disposition."

Les consignes sont claires. Le général Pierre Koenig, qui assure, à Baden-Baden, le commandement en chef des forces françaises dans la zone d'occupation en Allemagne (ZFOA), s'en fait l'ardent promoteur. "Mieux vaut la qualité que le nombre", écrira-t-il en octobre 1946 dans une note secrète, conservée aux archives de la ZFOA, à Colmar. Il prône une "immigration éclairée", de savants, mais aussi de techniciens de "valeur honorable". Avec un argument de poids: "Chaque technicien qui vient se fixer à demeure en France correspond à une diminution du potentiel allemand et à une augmentation du potentiel français; il faut en profiter." Dans une autre lettre, il insiste sur cet avantage qu'il sait temporaire: "Soyons sûrs que du jour où un gouvernement allemand [...] sera reconstitué, il fera tout son possible pour arrêter cette véritable hémorragie humaine, se rendant compte du grave préjudice subi..."

However, in this underground hunt, the French did not do badly. Orders came from very high places. As early as 16 May 1945, in a note classified as "top secret"—exhumed from the army archives by the historian Marie-France Ludmann-Obier—the National Defense Staff alerted General de Gaulle, Head of the Provisional Government, to the importance of German research: "The activity and scale of the results obtained, particularly in the field of secret weapons, greatly impressed those who examined them[...] Some leading people were taken to England; others were approached to work in America. On our side, we temporarily took some people to Paris..." Eager to quickly give France back the resources of a great power, General de Gaulle issued a personal and confidential instruction on 17 May 1945: "There will be every reason to transfer to France German scientists or technicians of great value to question them at will about their work and possibly urge them to remain at our disposal."

The instructions were clear. General Pierre Koenig, who was in charge of the chief command of the French forces in Baden-Baden in the German occupation zone (ZFOA), was the ardent promoter. "Quality is better than number," he wrote in October 1946 in a secret note in the ZFOA archives in Colmar. He advocated "enlightened immigration" of scientists, but also of technicians of "honorable value." With a strong argument: "Each technician who comes to France permanently corresponds to a decrease in German potential and an increase in French potential; we must take advantage of it." In another letter, he insisted on this advantage, which he knew to be temporary: "Let us be sure that from the day a German government is reconstituted, it will do everything possible to stop this real human bleeding, realizing the serious damage suffered..."

> Malgré des moyens limités, la machine administrative française se met en marche. La "section T" laisse la place à la mi-1945 à une "section d'information scientifique" où sont représentées toutes les armes (air, terre, marine), le CNRS et le Centre national des télécoms (Cnet). Cette instance établit des centaines de rapports et rédige plus de 3 500 fiches personnelles sur des savants allemands. Le 19 mars 1946, le ministère de l'Economie nationale détaille la procédure de recrutement, soumise au feu vert de neuf services ministériels (production industrielle, finances, travail, sûreté, consulats, etc.). Une "procédure d'extrême urgence" est tout de même prévue, "dans le cas où un savant ou un technicien serait sur le point de partir à l'étranger et de nous échapper". [...]
>
> Lorsque les cibles valent la peine, tous les arrangements sont possibles. Une liste de souffleurs de verre, très prisés pour l'optique de pointe, est transmise à Paris avec cette précision: "Ces personnes résidant en zone russe [...], il serait recommandable de faire appel aux services du Sdece." Autrement dit: les services secrets français sont chargés des "exfiltrations" des autres zones d'occupation. C'est ainsi qu'en décembre 1945 Ferdinand Porsche est enlevé par des Français dans sa résidence de Zell am See, alors qu'il est surveillé par les Américains. Inventeur de la Coccinelle de Volkswagen et de l'énorme char Maus, Porsche, hitlérien fanatique, est d'abord emprisonné à Dijon, avant d'être affecté quelques mois chez Renault, où il est mal accepté, puis remis en prison.

> Despite limited resources, the French administrative machinery was set in motion. The "T section" gave way in mid-1945 to a "scientific information section" where all military services (air, land, sea), the CNRS and the National Telecommunication Center (Cnet) were represented. This body produced hundreds of reports and more than 3,500 personal files on German scientists. On 19 March 1946, the Ministry of the National Economy detailed the recruitment procedure, subject to the approval of nine ministerial departments (industrial production, finance, labour, security, consulates, etc.). An "extreme urgency procedure" was nevertheless provided for, "in the event that a scientist or technician is about to leave for a foreign country and escape from us." [...]
>
> When the targets were worth it, all arrangements were possible. A list of glassblowers, highly prized for their advanced optics, was sent to Paris with this instruction: "These people residing in the Russian zone [...], it would be advisable to use the services of the Sdece." In other words: the French secret services were responsible for "exfiltrations" from the other occupation zones. Thus in December 1945 Ferdinand Porsche was kidnapped by the French from his residence in Zell am See, while he was under American surveillance. Inventor of the Volkswagen Beetle and the huge Maus tank, Porsche, a Hitlerian fanatic, was first imprisoned in Dijon, before being posted for a few months at Renault, where he was poorly received and then put back in prison.

According to the historians of science Burghard Ciesla and Bernd Krag, the true number of German scientists and engineers working in postwar France was actually much higher than Nouzille and Huwart reported, and was at least several thousand [Hans-Ulrich Meier 2010, p. 678]:

> In 1947 the French authorities selected from the almost 100,000 German prisoners of war about 6700 men as "spécifiquement recrutés." These were mostly members of technical professions and were to work in France in different industrial areas, but also in research and development projects. German experts in the fields of rocket, missile, torpedo, engine, aircraft, helicopter, and tank development as well as experts in material science,

> navy-related fields, ballistics, and handguns were at the same time brought to France after the war. But these were by far not yet all the areas. Regarding the employment of German specialists in France, an order of magnitude of 2000 to 3000 persons may be assumed[...]

Pierre Trichet, a French aerospace engineer retired from the ONERA research center, gave further examples of the contributions of German-speaking scientists and engineers to postwar French programs [Trichet 2009]:

> The four major victorious countries of World War II, the United States, the USSR, Great Britain and France shared, to varying extents, the skills acquired by the Germans in science and technology. These scientists were fewer in number than those who went to the United states or to the Soviet Union, but they nonetheless formed an array that represented a broad spectrum of competencies. German engineers and scientists worked in the years after the war closely and successfully together with their French colleagues. A large German engineering group was initially headed by Fritz Nallinger, developed at the French engine company Turbomeca a number of small gas turbines. The ATAR engine, developed by the group of BMW engineers, headed by Hermann Oestrich, was manufactured by SNECMA in large numbers. Under the technical supervision of Hans Schneider, the newly registered company SEPR started the development of liquid fuel rocket motors. Eugen Sänger contributed as adviser to the design and layout of the French test aircraft Nord 1500 "Griffon" with a combined turbojet-ramjet engine. Under the participation of a German group of engineers, headed by Heinrich Focke, a helicopter development program was started at the SNCASE with the SE3101 which led to the successful French helicopter "Alouette". In continuation of the "Doblhoff-concept" of blade-tip propulsion, the light helicopter SO 1221 "Djinn" was developed at SNCASO under the technical supervision of Theodor Laufer. From a rebuild of the missile Fieseler Fi103 (V1), the homing missile Nord CT10 and CT20 with pulsejet, respectively turbojet engines were realized under participation of German engineers.

Likewise, large numbers of German-speaking scientists and engineers were recruited by the United Kingdom.[3] Over 1000 German-speaking scientists and engineers worked for the U.K. government or companies, either in the United Kingdom or on its behalf in West Germany [Glatt 1994]. They played important roles in postwar British developments in jets, missiles, rockets, submarines, and other areas. The U.K. government was relatively secretive about its use of these German-speaking scientists, quite possibly due to a desire to avoid public questions about employing scientists who had only recently been creating weapons that were bombarding the United Kingdom. Historian Charlie Hall described the U.K. programs for interrogating, recruiting, and exploiting German-speaking scientists [Hall 2019a, pp. 1–2, 4]:

> [...A]fter the war ended, the victorious Allies sought to continue the work of the Third Reich's rocket scientists and bring the technology of the V-2 into their own armories. [...] Under the codename Operation Backfire, this took place through the summer and autumn of early 1945 and culminated in three test-firings in October. All of these took place in the Lower Saxony coastal town of Cuxhaven and were run by the same German troops who had overseen the rocket attacks on London, albeit now under close British

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[3] Bud and Gummett 1999; Edgerton 2006; Glatt 1994; Hall 2019a; O'Reagan 2014, 2019; Paneth 1948.

supervision. [...] Britain, through the utilisation of German technology and expertise, had now entered the ballistic missile era.

Backfire was not the only operation of its type which took place at this time, nor was rocketry the only field in which the British (and the other Allies) were interested. For instance, 125 kilometers to the south-east of Cuxhaven, at Raubkammer, near Munster, experts from the British Chemical Defence Experimental Establishment at Porton Down spent three months conducting a wide range of trials and experiments with the newly discovered German nerve agents, primarily Tabun and Sarin. Elsewhere, Operation Surgeon, run by the Ministry of Aircraft Production and the Ministry of Supply, took over several former Luftwaffe installations and set out to explore German progress in all manner of aeronautical topics. These large investigative projects which sprung up in the summer of 1945 were of huge significance, but only represent a small portion of British interest in German science and technology in the post-war period. British officials had entered Paris within a week of its liberation to explore formerly German-occupied laboratories in the French capital. Royal Navy experts were among the first Allied forces into Kiel and moved quickly to examine the submarine design and construction facilities there. After Germany surrendered, British investigators poured into the country and visited every laboratory, research site and factory of even passing interest, in their quest to learn all they could about German science and technology.

The process did not stop there. In January 1946, the first group of 23 German scientists recruited by Britain after the war arrived in Barrow-in-Furness in Cumbria, to work on submarine technology at the Vickers-Armstrong shipyard. Many more followed over the next two or three years, travelling to Britain to work on rockets, aircraft, chemical warfare, and on a huge range of civil-industrial topics as well. When the British and French launched Concorde, the world's first supersonic commercial airliner, in 1976, few knew that much of the aerodynamics work involved in its design had been completed by German experts who came to Britain as part of a government scheme in the immediate post-war period. Other German specialists did not land such significant roles in Britain after the war, but did contribute to the British military or economy in other ways, often through written reports or interrogations which took place during periods of internment at special camps in Germany and Britain after the war. Some of these individuals were not even detained because they were considered of value to Britain, but rather because it was considered important to keep them out of the employ of the Soviet Union. In this way, German science and technology became a source of much competition in the early Cold War period.

[...I]n the minds of Allied strategists, German military technology was far superior to their own and the perceived benefits to be gained by acquiring this equipment, and the expertise behind it, were extremely tempting. Thus exploitation was born. The supposedly more advanced nation had been defeated, and its victorious occupiers could now claim the scientific and technological spoils of war; their own armouries and industries could make huge leaps forward by standing on the shoulders of their newly vanquished foe. [...]

With full British government sanction, German laboratories and factories were inspected and meticulously pillaged, machinery and prototypes were confiscated, and documents

> and blueprints were shipped back to Britain in their thousands. In addition, expert German personnel were detained, interrogated and, in many cases, recruited to work for the British state or for private companies. No area of expertise was left untouched, from the most highly sensitive military project to the most mundane commercial production techniques; all was considered fair game under the terms of the British exploitation initiative.

German-speaking scientists also went to many countries other than the four major Allies. Through the British Commonwealth, at least 150 moved to Australia [Evan Jones 2002] and at least 41 to Canada [Margolian 2000]. At least 108 went to Argentina and at least 27 to Brazil [Stanley 1999]. At least ∼100 went to Spain, ∼100 to Egypt, and ∼50 to India [Neufeld 2012].

Although the numbers of German-speaking scientists working for various countries as given above are only lower bounds, and the corresponding figures for other countries (Switzerland, Sweden, South Africa, etc.) are not readily available, the total number of scientists and engineers who left the German-speaking world in the years immediately after the war was likely well over 10,000, or the majority of the creators who were still in the German-speaking world in 1945.[4]

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[4] For more information on the transfer of German-speaking scientists, see Albrecht et al. 1992; Bar-Zohar 1967; Bower 1987; Buyer and Jensen 1948; Byrd 1948; Crim 2018; DOW 1945b, 1946; Gimbel 1986, 1990a, 1990b, 1990c; Goudsmit 1947; Glatt 1994; Hall 2019a; Linda Hunt 1985; Morton Hunt 1949; Jacobsen 2014; Jensen 1948; Jösten 1947; Matthias Judt and Ciesla 1996; Kurowski 1982; Lasby 1971; Nagan 1947; O'Reagan 2014, 2019; Simpson 1988.

Postwar transferred equipment

Despite heavy bombing by Allied forces, a large majority of scientific, engineering, and industrial infrastructure and equipment from the German-speaking world survived the war, due to numerous vast underground installations, camouflage, target dispersal, and continuous rebuilding, as shown for example by the following reports:

The Hydra [*Newsweek* 1945-07-09 p. 52]:

> This job of controlling Germany . . . is no short-term business. The Germans are capable and industrious people. They are fired by their desire for revenge and can rebuild an industrial war machine and reorganize it for war purposes in a few short years, regardless of the damage wrought by bombing.
>
> That was how Leo T. Crowley, Foreign Economic Administrator, described the problem of controlling the Reich last week in testimony before a subcommittee of the Senate Military Affairs Committee. "If we were to leave Germany to its own devices and not to institute a program of economic and industrial disarmament, Germany could be far better prepared for war in five years than she was in 1939," Crowley said.
>
> Crowley cited these examples of Germany's capacity to rearm unless severely supervised:
>
> "Allied bombing and military operations accomplished their mission . . . But such military operations, basically selective in their character, were not and could not be executed so as to eliminate permanently a national industrial war potential."
>
> "As it stands today, Germany, except for the United States, is the outstanding armament machine shop in the world."
>
> "[Germany] has one dye plant that can turn out almost as much dye in one year as all the plants in the United States together" . . .
>
> "Practically all of the great iron and steel furnaces of Germany are ready for operation or can be in operation with minor repairs."
>
> "Germany was producing about 1,000,000 metric tons [of nitrogen] in 1939 . . . A large part of the capacity remains or can be rebuilt in a short time."
>
> "Germany did not lack materials for textiles . . . It would appear that little permanent damage has been done to most of the plants."
>
> "According to the best available estimates, the German synthetic-rubber capacity today is more than 100,000 tons."
>
> "In 1944, Germany was producing about 1,000,000 tons of natural petroleum and about 5,500,000 tons of synthetic oil . . . It is believed that a large part of Germany's 1944 capacity for producing petroleum products can be restored within a brief period."

German Industry Grew under Raids: Many Fields Showed Increase in Production During Last Year of War [NYT 1945-08-08 p. 15]:

> Captured records disclosing that the Germans had been able to rebuild plants and expand war production in the face of intensified bombings during the final year of the European war were made public here today to support a Congressional investigating committee's warning that Germany, even in defeat, remained a major threat to world peace. [...]
>
> The records, cited in detail in an official report of the Ministry for Armaments and War Production that were seized last spring, showed that in 1944 three times as many armored fighting vehicles, more than three times as many fighter-bombers and eight times as many night fighters had been produced [as] in 1942.
>
> In a number of war items there was an increase in the last quarter of the year. While there was a decreased production in some fields, increase of air-raid damage and loss of territory, the Ministry reported, it was "still possible to keep the armament industry continuously supplied with the necessary material, a task that could be fulfilled only by drastic measures of control. [...]
>
> "Additional power plants were made available in 1944. [...]
>
> "At the beginning of 1944 the supply of parts and components was the bottleneck of all forms of German armament production. By the autumn of 1944, sufficient reserves of material had been accumulated, with the result that, in spite of more difficult conditions in the basic industry, and also among subcontractors, the output of armaments could be maintained and in some cases even increased."

75% of Industries in Reich Survived [NYT 1945-10-11 p. 6]:

> Despite the almost incessant heavy bombing and the fierce battles fought on German soil, some 75 per cent of Germany's industry is intact or in a reparable condition, Col. James Boyd, chief of the industry division of the Office of Military Government, said today. [...]
>
> He did say, however, that in his opinion roughly 50 per cent of Germany's steel-producing machinery would have to be removed as reparations or destroyed.

Out of that surviving infrastructure, many hundreds (perhaps well over a thousand) of complete factories and laboratories were removed, as may be seen by more examples from contemporary news articles:

Soviet Said to Get Its Yalta Demand: Moscow's Share Believed Half of Movable Reich Property in Potsdam Reparations [NYT 1945-08-05 p. 6]:

> The Potsdam reparations agreement in effect gives the Russians about 50 per cent of the movable German property covered by the accord, officials familiar with the preliminary negotiations on the subject said today.
>
> [...A]bout 45 per cent of German assets of the capital variety covered by the agreement were situated in the Russian zone [East Germany].
>
> This high percentage surprised some persons familiar with pre-war German economy, who were under the impression that the bulk of German industrial installations were in the west, but it was pointed out that during and just before the war the Germans built up their industrial plant in the east, where they located some of the nation's largest and most efficient units.
>
> Added to the 45 per cent of total movable German plant and equipment said to be situated in the Russian zone, the Soviet Government receives, under the agreement, 10 per cent of certain capital equipment in the western zones [West Germany]. [...]
>
> From the remainder of the movable equipment in the western zone, after the Russians get their 10 per cent, the reparations claims of all the United Nations in the war against Germany, except Russia, must be satisfied.

Allies Confiscate 300 Farben Plants: Part of Reich Trust's Factories to be Dismantled and Used to Pay Reparations: Other Assets Also Taken [NYT 1945-10-13 p. 3]:

> The Allies have confiscated the entire holdings in Germany of the octopus-like I. G. Farbenindustrie, without whose vast industrial output the Germans would have been unable to wage war. General Clay, administrator of civil affairs in American-occupied Germany, announced tonight that a part of the 300 plants owned by the huge trust would be dismantled and taken by the Allies as reparations. [...]
>
> General Clay estimated that about 75 per cent of Farbenindustrie's plants in Germany were intact. [...]
>
> Pre-war assets of the trust were estimated at 5,000,000,000 Reichsmarks—$2,000,000,000.
>
> Construction costs alone for the plants all over Germany and in Czechoslovakia amounted to $762,800,000, Colonel Pillsbury estimated.

Germans Report More Removals: Say 310 Plants in Thuringia Have Been Sent To Russia—Fear Wide Unemployment [NYT 1946-10-27 p. 32]:

> According to a report of the reparations department of the Thuringian Land Bureau for Economics, by the end of June, 1946, 310 plants in Thuringia alone had been fully dismantled by the Russians. The report added that during the third quarter of this year 410 Thuringian plants had worked exclusively on reparations deliveries of goods made from German raw materials[...] As of Oct. 1 the entire production quota of Thuringia has been allocated to Soviet occupation forces, the report added.
>
> Representatives of workers in glass factories and optical works in Jena, in their telegram Friday to the Allied Control Council, especially cited the stripping of that basic industry from the one-industry town[...]
>
> Accordingly the Russians apparently have made plans to drop their efforts to conciliate the Germans and instead drain all possible resources out of the country as quickly as possible.

BIOS 290, *The Viscose Continuous and Rayon Staple Fibre Plants of the British, American and French Occupation Zones of Germany*, pp. 2–3:

> The Team visited Germany with one primary object which was to assess the value of any suitable plant likely to be seized as Reparations, in accordance with the Potsdam Agreement.
>
> A very agreeable and secondary objective was the acquisition of any further technical knowledge, and an additional report has therefore been written to supplement the information gathered by the C.I.O.S. earlier in the year. [...]
>
> It will be appreciated that the report of the C.I.O.S. became a very useful charter and enabled us to investigate thoroughly the obviously new departures in the preparation, spinning and finishing of Viscose Yarn and Rayon Staple. It might be of general interest to say that the impression gathered by the team was that the Viscose industry of Germany has developed rapidly along mass production lines with a high degree of endeavour to eliminate handling and to shorten the Viscose preparation times as much as possible by the introduction of many new shredding and mixing devices. [...]
>
> In the Rayon Staple field the output of yarn per spinning position has reached almost fantastic proportions. 15,000 denier is now quite common with an individual filament denier of 1.5. We learned that some spinners are now contemplating an increase to 22,500 denier, using a jet of 15,000 holes of 0.07 m.m. diameter. Spinning pumps of the order of 75.0 ccs. per rev. are already in use. Rheinische Zellwolle use only 5 combination machines to produce 80 tons per day.
>
> We would specially draw attention to our recommendation on the Zellwolle Lehr Spinnerei Research Station at Denkendorf. It is the opinion of the team that this would be a valuable acquisition to the British Rayon Industry.

BIOS 428. *German Rayon and Staple Fibre Industry and Allied Engineering Industry.* p. 3:

> This work was undertaken following the original reconnaissance of the German Rayon and Staple Fibre Industry (Ref. 1) and had as its primary object the evacuation of a number of machines and processes upon which it was considered detailed investigation and development work should be carried out for the benefit of the British Viscose Rayon Industries. [gives long, detailed list of machines to be taken from Germany]

For many more examples, see:

> Allies Will Strip German Economy [NYT 1945-02-02 p. 1].
>
> Russia Said to Strip U.S. [Claimed] Plants in Reich [NYT 1945-07-08 p. 4].
>
> Berlin's Factories Stripped by Soviet [NYT 1945-07-17 p. 2].
>
> Germany Stripped of Industry by Big 3 [NYT 1945-08-03 p. 1].
>
> U.S. Allies to Get 5 Plants In Reich [NYT 1945-09-26 p. 8].
>
> U.S. Will Transfer 11 More Reich Plants [NYT 1945-09-30 p. 25].
>
> Russia Would Take Big Plants in Reich [NYT 1945-10-05 p. 2].
>
> Opel's Equipment Sought by Russians [NYT 1945-10-11 p. 4].
>
> Smash I. G. Farben Empire, Eisenhower Advises Allies [NYT 1945-10-21 p. 1].
>
> 26 German Plants Divided by Allies [NYT 1945-12-11 p. 4].
>
> 26 German Plants Ready for Delivery [NYT 1945-12-23 p. 7].
>
> Factories on Sale in Germany Listed [NYT 1946-01-06 p. 20].
>
> 21 Farben Plants Wiped Out by U.S. [NYT 1946-01-17 p. 14].
>
> Russians to Strip 600 German Mills [NYT 1946-03-24 p. 18].
>
> German Industry Gets Allies' Bill [NYT 1946-03-29 p. 10].
>
> Germany Moving Out Factory Equipment [NYT 1946-04-17 p. 13].
>
> Russians Increase German Industry Reparations in Kind [NYT 1946-07-05 p. 4].
>
> Russia for Seizing 200 German Firms [NYT 1946-07-11 p. 5].
>
> Allies Will Share 11 German Plants [NYT 1946-07-25 p. 6].

Russians Charge Looting of Reparations from Plants in U.S. Zone of Germany [NYT 1946-08-03 p. 7].

200 German Firms Seized by Soviet [NYT 1946-08-26 p. 7].

Transfers of Plants from American Zone to Russia Ahead of Schedule [NYT 1946-08-27 p. 12].

German Plant Ask as U.S. Reparations [NYT 1946-10-09 p. 22].

658 German Plants Listed for Payment [NYT 1946-10-20 p. 30].

Clay Sees End Soon to Occupation Costs [NYT 1946-11-14 p. 18].

10 Soviet Trusts Drain Germany, U.S. Occupation Sources Report [NYT 1946-12-06 p. 1].

Reparation Plan Enters 2 D Phase: U.S. Sends Soviet Equipment from Two German Plants [NYT 1946-12-10 p. 11].

A German Plant Dismantled by the Russians [NYT 1947-07-13 Magazine p. 8].

682 [More] German Plants to be Dismantled [NYT 1947-10-17 p. 8].

28 More Plants in Germany Allotted [to Allies] [NYT 1947-12-23 p. 5].

Marshall Opposes End to Dismantling of German Plants [NYT 1948-02-09 p. 1].

Soviet Dismantles 19 Plants in Zone [NYT 1948-06-02 p. 10].

Farben Liquidation Mapped: New Concerns Are Planned: U.S. and British Officials [NYT 1948-07-25 p. 1].

Britain Clings to Dismantling [of German Factories]: Opposes Change in German Policy [NYT 1948-09-09 p. 10].

French Dismantling 38 [German] Plants [NYT 1948-10-28 p. 10].

Dismantling Feared by French [NYT 1948-11-21 p. 10].

Soviets Hold Up Reparations Debt [NYT 1948-11-28 p. 10].

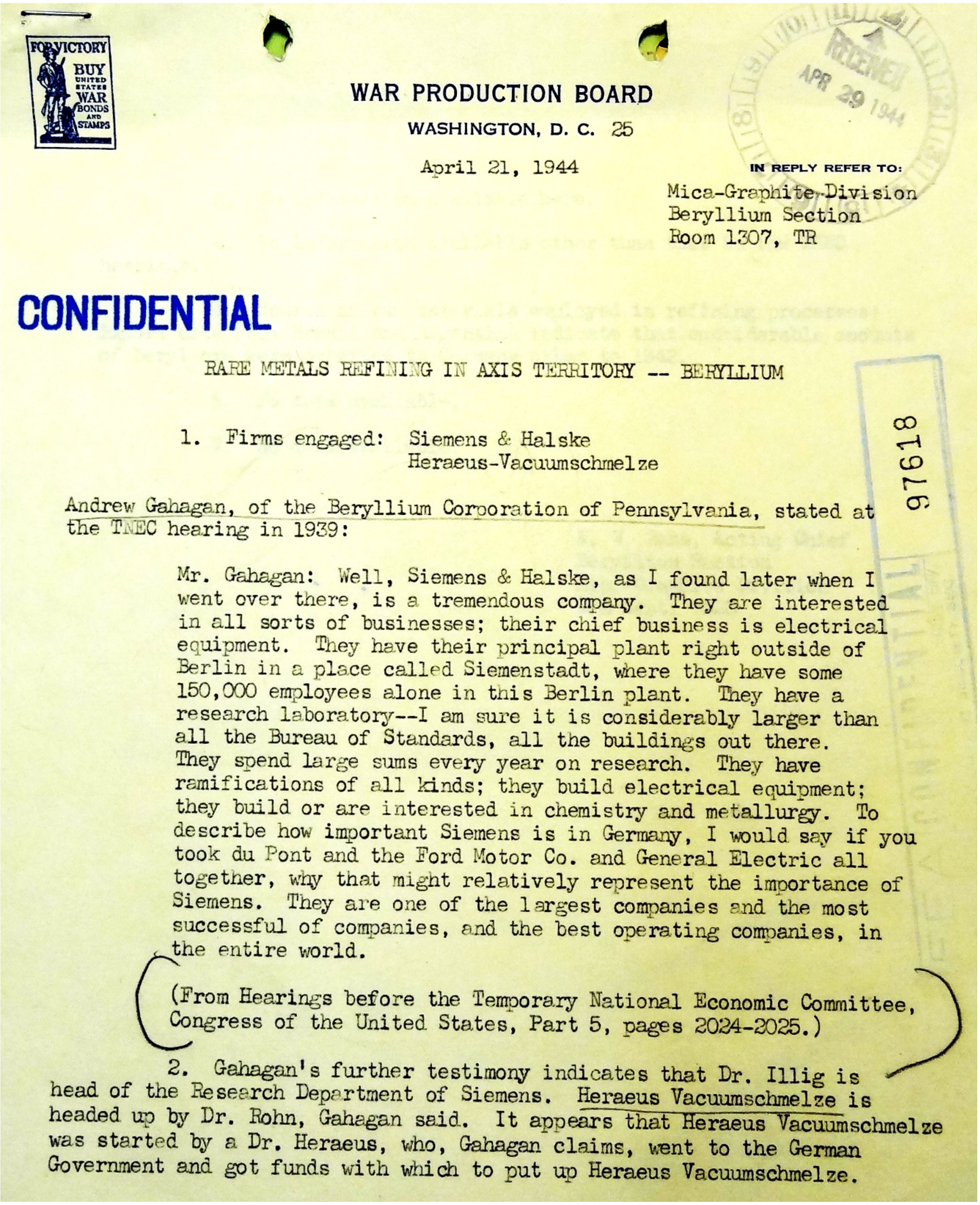
Dismantling Halt by U.S. Protested [NYT 1948-12-05 p. 9].

Allies Weigh Rift on German Plants [NYT 1948-12-07 p. 9].

For even more examples of transferred equipment, see the thousands of BIOS ER, BIOS, BIOS Misc., BIOS Overall, CIOS ER, CIOS, FIAT, *FIAT Review*, JIOA, NavTecMisEu LR, and NavTecMisEu reports in the Bibliography.

DECLASSIFIED
Authority 917017

NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Incl. TA



FOR VICTORY BUY UNITED STATES WAR BONDS AND STAMPS

RECEIVED APR 29 1944

WAR PRODUCTION BOARD
WASHINGTON, D. C. 25

April 21, 1944

IN REPLY REFER TO:
Mica-Graphite Division
Beryllium Section
Room 1307, TR

CONFIDENTIAL

97618

RARE METALS REFINING IN AXIS TERRITORY -- BERYLLIUM

1. Firms engaged: Siemens & Halske
Heraeus-Vacuumschmelze

Andrew Gahagan, of the Beryllium Corporation of Pennsylvania, stated at the TNEC hearing in 1939:

> Mr. Gahagan: Well, Siemens & Halske, as I found later when I went over there, is a tremendous company. They are interested in all sorts of businesses; their chief business is electrical equipment. They have their principal plant right outside of Berlin in a place called Siemenstadt, where they have some 150,000 employees alone in this Berlin plant. They have a research laboratory--I am sure it is considerably larger than all the Bureau of Standards, all the buildings out there. They spend large sums every year on research. They have ramifications of all kinds; they build electrical equipment; they build or are interested in chemistry and metallurgy. To describe how important Siemens is in Germany, I would say if you took du Pont and the Ford Motor Co. and General Electric all together, why that might relatively represent the importance of Siemens. They are one of the largest companies and the most successful of companies, and the best operating companies, in the entire world.
>
> (From Hearings before the Temporary National Economic Committee, Congress of the United States, Part 5, pages 2024-2025.)

2. Gahagan's further testimony indicates that Dr. Illig is head of the Research Department of Siemens. Heraeus Vacuumschmelze is headed up by Dr. Rohn, Gahagan said. It appears that Heraeus Vacuumschmelze was started by a Dr. Heraeus, who, Gahagan claims, went to the German Government and got funds with which to put up Heraeus Vacuumschmelze.

Figure 11.14: An example of the physical size and technological and financial importance of German industrial plants [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

All four major Allied countries claimed huge amounts of German and Austrian equipment. For example, Vincent Nouzille and Olivier Huwart wrote about some of the factories and other equipment that were acquired by France [Nouzille and Huwart 1999]:

Cette histoire débute au printemps de 1945, alors que les armées alliées resserrent leur étau sur le IIIe Reich. Les troupes de la Ire armée française du général de Lattre avancent dans le sud de l'Allemagne. Parmi les unités de reconnaissance qui les précèdent se trouvent des membres de la "section T". Ces experts du renseignement technique sont chargés de repérer les installations militaires et scientifiques allemandes. Si possible avant les autres vainqueurs. Par chance, le sud de l'Allemagne est truffé de dizaines d'usines et de laboratoires, repliés dans cette région moins exposée aux bombardements alliés.	This story began in the spring of 1945, when the Allied armies tightened their grip on the Third Reich. General de Lattre's troops of the First French Army advanced into southern Germany. Among the reconnaissance units preceding them were members of "Section T." These technical intelligence experts were responsible for identifying German military and scientific installations. If possible before the other winners. Fortunately, southern Germany was full of dozens of factories and laboratories, folded back into this region less exposed to Allied bombardments.
La chasse au butin est ouverte. Une équipe du 2e bureau de l'armée de l'air découvre ainsi près d'Oberammergau une vingtaine de caisses plombées, contenant 2 500 documents ultrasecrets du bureau d'études de l'avionneur Messerschmitt. Des trésors inestimables, ramenés à Paris pour être exploités par les industriels. Les formes d'ailes en flèche des futurs chasseurs français Ouragan et Mystère sont inspirées de ces documents.	The hunt for loot was on. A team from the 2nd office of the French Air Force discovered around twenty sealed boxes near Oberammergau, containing 2,500 top secret documents from the design office of the aircraft manufacturer Messerschmitt. Priceless treasures, brought back to Paris to be exploited by industrialists. The arrow-shaped wings of the future French fighters Ouragan and Mystère were inspired by these documents.
Près de 50 000 tonnes de matériels divers sont également envoyées en France durant l'année 1945. Des centaines d'équipements des usines aéronautiques de Dornier et Zeppelin à Friedrichshafen franchissent la frontière. La soufflerie subsonique d'Ötztal, dans le Tyrol autrichien, est démontée avant d'être réinstallée à Modane-Avrieux sous les auspices de l'Onera (Office national d'études et de recherches aéronautiques).	Nearly 50,000 tons of various materials were also sent to France in 1945. Hundreds of pieces of equipment from the Dornier and Zeppelin aeronautical plants in Friedrichshafen were taken across the border. The Ötztal subsonic wind tunnel in Austrian Tyrol was dismantled before being relocated to Modane-Avrieux under the auspices of Onera (Office national d'études et de recherches aéronautiques) [where it is still in use].

Près de 200 usines “civiles” allemandes—comme le complexe chimique BASF d’IG Farben à Ludwigshafen—sont remises en marche par les Français dans la zone d’occupation qui leur est octroyée par les accords de Potsdam de juillet 1945. Cette zone couvre 10% de l’Allemagne et une partie de l’Autriche. Les installations à vocation militaire sont également rouvertes. Dans la région du lac de Constance, 17 usines et laboratoires travailleront, jusqu’à leur déménagement, en 1948, dans le sud de la France, avec du personnel allemand, pour le compte de la marine française. Le physicien Yves Rocard (père de Michel) supervise une partie de ces récupérations. “On s’en est donné à coeur joie, en ramassant des Allemands eux-mêmes”, raconte-t-il dans ses *Mémoires sans concessions* (Grasset, 1988). D’autres scientifiques français viennent évaluer le potentiel scientifique nazi. Le chimiste Henri Moureu, qui a étudié de près les V 2 tombés près de Paris, réussit à visiter en juin 1945 l’usine Mittelwerke-Dora où étaient notamment fabriqués ces engins. Son ami physicien Frédéric Joliot-Curie, directeur du nouveau CNRS, dépêche, quant à lui, plus de 400 missions en Allemagne. Des expéditions parfois risquées: on retrouvera un jour à Vienne le cadavre d’un scientifique français, probablement jugé trop curieux par les Soviétiques...	Nearly 200 German “civilian” factories—such as the BASF chemical complex of IG Farben in Ludwigshafen—were restarted by the French in the zone of occupation granted to them by the Potsdam agreements of July 1945. This area covered 10% of Germany and part of Austria. Military facilities were also being reopened. In the Lake Constance region, 17 factories and laboratories worked with German personnel on behalf of the French navy until they moved to southern France in 1948. The physicist Yves Rocard (Michel’s father) supervised some of these recoveries. “We had a great time, picking up Germans themselves,” he says in his *Mémoires sans concessions* (Grasset, 1988). Other French scientists came to evaluate the Nazi scientific potential. The chemist Henri Moureu, who had closely studied the V-2s that had fallen near Paris, succeeded in visiting the Mittelwerke-Dora factory in June 1945, where these machines were manufactured. His physicist friend Frédéric Joliot-Curie, director of the new CNRS, sent more than 400 missions to Germany. Sometimes risky expeditions: one day in Vienna we found the body of a French scientist, probably considered too curious by the Soviets...

In addition to whole factories and laboratories, untold amounts of supplies, equipment, and prototypes were appropriated by Allied countries after World War II. A 1945 U.S. Navy document [NARA RG 38, Entry 72] listed examples of equipment transported to the United States in one shipment, including a submarine, 39 aircraft, V-1 and V-2 missiles, and other advanced technology prototypes.

Some newspaper headlines illustrate other examples:

> U.S. Navy to Use German Weapons [NYT 1945-06-30 p. 3].
>
> Use of Armament Seized in Europe Asked in Pacific [NYT 1945-07-07 pp. 1, 3].
>
> Ten U-Boats for Russia to be Yielded in Ulster [NYT 1945-11-22 p. 16].
>
> U.S. Plans to Sell German Machines [NYT 1945-11-22 p. 17].
>
> German Guns to Be Tested [NYT 1946-01-25 p. 4].
>
> U.S. to Get 4,209,000 Tons of Germany's Shipping [NYT 1946-04-24 p. 14].
>
> All German Scrap Is Now Allocated [NYT 1948-09-04 p. 19].

As may be seen from these and other newspaper articles, large-scale removals were still going on over 3½ years after German surrender. So many industrial plants and their supplies and equipment were removed, and for so many years, that Germans began to protest that the continuing removals would hinder their ability to peacefully rebuild and support themselves financially. As reported in these articles, western Allied countries responded by threatening to cut off Germany's food supply if any further protests were made:

> Germans Strike Against Removals [NYT 1946-10-29 p. 10].
>
> Clay Will Force Plant Removals [by Threatening Food] [NYT 1947-10-02 p. 8].
>
> German Charges Allies Loot West [Germany] [NYT 1948-01-07 p. 15].
>
> Germans Warned on Food Supplies [If They Protest] [NYT 1948-01-09 p. 17].
>
> Protests Removal of German Plants [NYT 1948-01-20 p. 2].
>
> Farben Attorney Condemns Allies [NYT 1948-06-11 p. 5].
>
> Baden Chiefs Quit Over Dismantling [NYT 1948-08-27 p. 3].
>
> Germans Protest [Plant Dismantling] Restitution Plans [NYT 1948-09-05 p. 19].
>
> Allied Suggestion Provokes German Ire [NYT 1948-11-28 p. 12].
>
> Germans Boycott British over Plant Dismantling [NYT 1948-12-06 p. 3].

The Soviet occupation and exploitation of areas they controlled was much more brutal and lasted until 1990.[5]

---

[5] E.g., Albrecht et al. 1992; von Ardenne 1990, 1997; Barkleit 2008; Barwich and Barwich 1970; Boch and Karlsch 2011; Fengler 2014; Fengler and Sachse 2012; Graham 1993; Heinemann-Gruder 1992; Holloway 1994; Karlsch and Laufer 2002; Kozyrev 2005; Kruglov 2002; Jürgen Michels 1997; Mick 2000; Nagel 2016; Naimark 1995; Oleynikov 2000; Pondrom 2018; Przybilski 1999, 2002a, 2002b; Riabev 2002a; Riehl and Seitz 1993; Siddiqi 2009; Sokolov 1955; Uhl 2001; Zeman and Karlsch 2008; *News Chronicle* 1945-10-15 p. 1; NYT 1945-10-15 p. 4, 1945-10-31 p. 6, 1946-01-29 p. 1, 1946-11-28 p. 16, 1946-12-06 p. 17, 1947-02-24 p. 1, 1948-05-26 p. 3, 1948-12-28 p. 10b; *Spokane Daily Chronicle* 1948-03-16 p. 6; *Sydney Morning Herald* 1946-04-20 p. 2; *Times* 1945-05-15, 1945-05-18.

Soviet exploitation of German industry was also far larger than the number of German plants would seem to indicate. The Soviet Union apparently had a systematic policy of shipping half of a German plant and its workforce to the Soviet Union, forcing the remaining German workers to rebuild and restaff the plant until it was functional again, then shipping half of the rebuilt plant and workers to the Soviet Union, and repeating the process many more times. Thus the number of industrial plants that the Soviet Union extracted from Germany was many times the number of original plants. Even in its divided and war-ravaged state, Germany was mass-producing modern industrial plants for the entire Soviet Union, covering everything from aerospace to electronics to chemical technologies.

This Soviet practice was documented for example in the following U.S. intelligence report: Headquarters Berlin Command, Office of Military Goverment for Germany (US). 11 December 1946. Special Intelligence Memorandum No. 48. Subject: V-2 Production in SovZone. Source: Extremely Reliable. D-138175. [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Soviet Guided Missiles, Rockets and V-Weapons Research, Development and Production Vol. 1, Fldr. 2 of 3. See pp. 2960–2961.]:

> BLEICHERODE in the Harz mountains is still doing fine in the production of V-2 rockets. It was reported from this office that dismantling was going on, but it was stopped as of 1 December. The general procedure for dismantling of installations very dear to the Soviet heart is the following as illustrated best by BLEICHERODE.
>
> As soon as Soviet troops took over the V-2 plants, they did everything in their power to get it reorganized and re-equipped. As soon as this was done, they started production. When they saw that the finished product was satisfactory, they began to dismantle the plant for the first time. The dismantling was not carried through completely, but was halted as soon as about half was taken. Together with the machinery some personnel was taken out, to be shipped to the USSR in order to set up the machinery which was confiscated and complete it with more later.
>
> In the meantime the plant in BLEICHERODE was being rebuilt under supervision of German and Soviet engineers. Once rebuilt, production was started all over again and as soon as satisfactory results were achieved, the dismantling was continued. In this way, Soviet authorities enrich their own country by building up some priceless industries and on the other hand they see to it that the original plant in Germany is reconstructed and re-equipped after each time. Thus, they would be able theoretically to continue an uninterrupted flow of industries from Germany to the Soviet Union.
>
> This procedure is known to have been applied to all V-weapon plants in BLEICHERODE, NORDHAUSEN, GOTHA and BERLIN. In BLEICHERODE the installations were dismantled for the fourth time; in NORDHAUSEN for the sixth time; in Berlin only once; conditions in GOTHA are unknown. [...]

It is helpful to visualize the locations of scientific research, development, and production sites from which various countries removed plants, materials, prototypes, scientists, and information at the end of the war.

Figure 11.15 shows a map of areas controlled directly or indirectly by Germany in 1942. Although much of German research and industry was located within the Greater German Reich (darkest area), there were also major sites in satellite countries from Norway to Bulgaria. At the end of the war, Allied countries seized resources, personnel, and information from sites in the respective regions they regained or occupied.

Figure 11.16 presents a detailed map of the Greater German Reich in 1941, not including satellite countries that were also controlled by Germany. Note that the Greater German Reich covered the territory of not only modern Germany but also modern Austria, Poland, and the Czech Republic, as well as small portions of other countries. At the end of the war, the majority of this territory was occupied by the Soviet Union and therefore was generally not open to inspection by western Allied investigators.

As an example of the distribution of wartime sites that were ultimately seized by Allied countries, Fig. 11.17 shows a map of plants run by or affiliated with I.G. Farben in 1943. The large majority were located within the Greater German Reich (covering modern Germany, Austria, Poland, and the Czech Republic), although a few I.G. Farben plants were located outside that territory (mainly in France). There were also I.G. Farben-associated facilities in Norway that are not shown on this map.

Some (but certainly not all) major sites involved in scientific research, development, and production during World War II are shown in:

- Fig. 11.20 for locations in modern Germany.
- Fig. 11.21 for locations in modern Austria and Hungary.
- Fig. 11.22 for locations in modern Poland and Russia.
- Fig. 11.23 for locations in the modern Czech Republic and Slovakia.

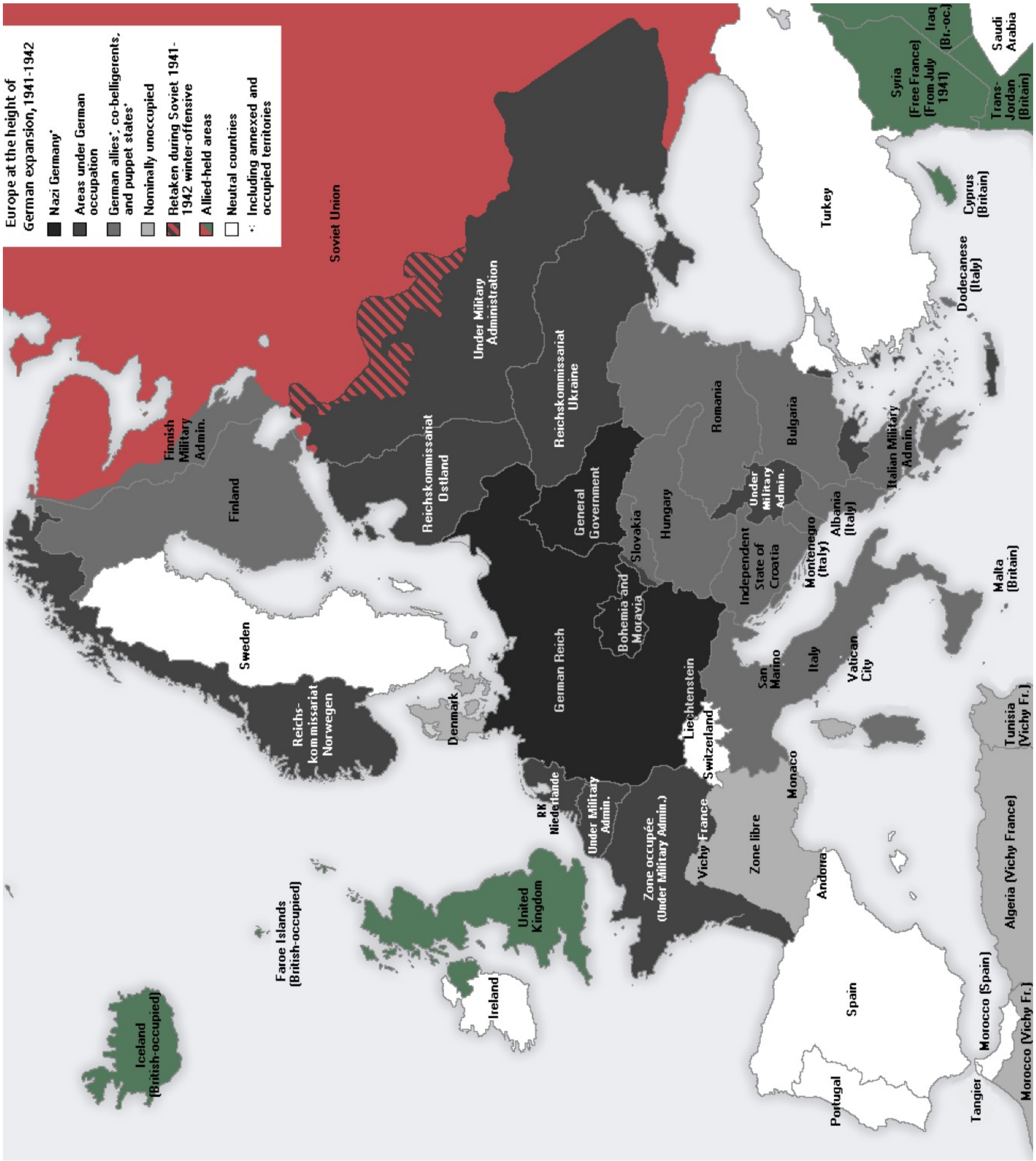

Europe at the height of German expansion, 1941-1942
Nazi Germany*
Areas under German occupation
German allies*, co-belligerents, and puppet states*
Nominally unoccupied
Retaken during Soviet 1941-1942 winter-offensive
Allied-held areas
Neutral countries
*: Including annexed and occupied territories
Soviet Union
Under Military Administration
Reichskommissariat Ukraine
Reichskommissariat Ostland
Finnish Military Admin.
Finland
Sweden
Reichs-kommissariat Norwegen
Denmark
German Reich
General Government
Bohemia and Moravia
Slovakia
Hungary
Romania
Bulgaria
Under Military Admin.
Independent State of Croatia
Montenegro (Italy)
Albania (Italy)
Italian Military Admin.
Italy
San Marino
Vatican City
Liechtenstein
Switzerland
Monaco
RK Niederlande
Under Military Admin.
Zone occupée (Under Military Admin.)
Vichy France
Zone libre
Andorra
Spain
Portugal
Tangier
Morocco (Spain)
Morocco (Vichy Fr.)
Algeria (Vichy France)
Tunisia (Vichy Fr.)
Malta (Britain)
Turkey
Cyprus (Britain)
Dodecanese (Italy)
Syria (Free France) (From July 1941)
Iraq (Br.-oc.)
Saudi Arabia
Trans-Jordan (Britain)
United Kingdom
Ireland
Faroe Islands (British-occupied)
Iceland (British-occupied)

Figure 11.15: Map of areas controlled directly or indirectly by Germany in 1942. Although the majority of German research and industry was located within the Greater German Reich (darkest area), there were also major sites in satellite countries from Norway to Bulgaria. At the end of the war, Allied countries seized materials, scientists, and information from sites in the regions they regained or occupied.

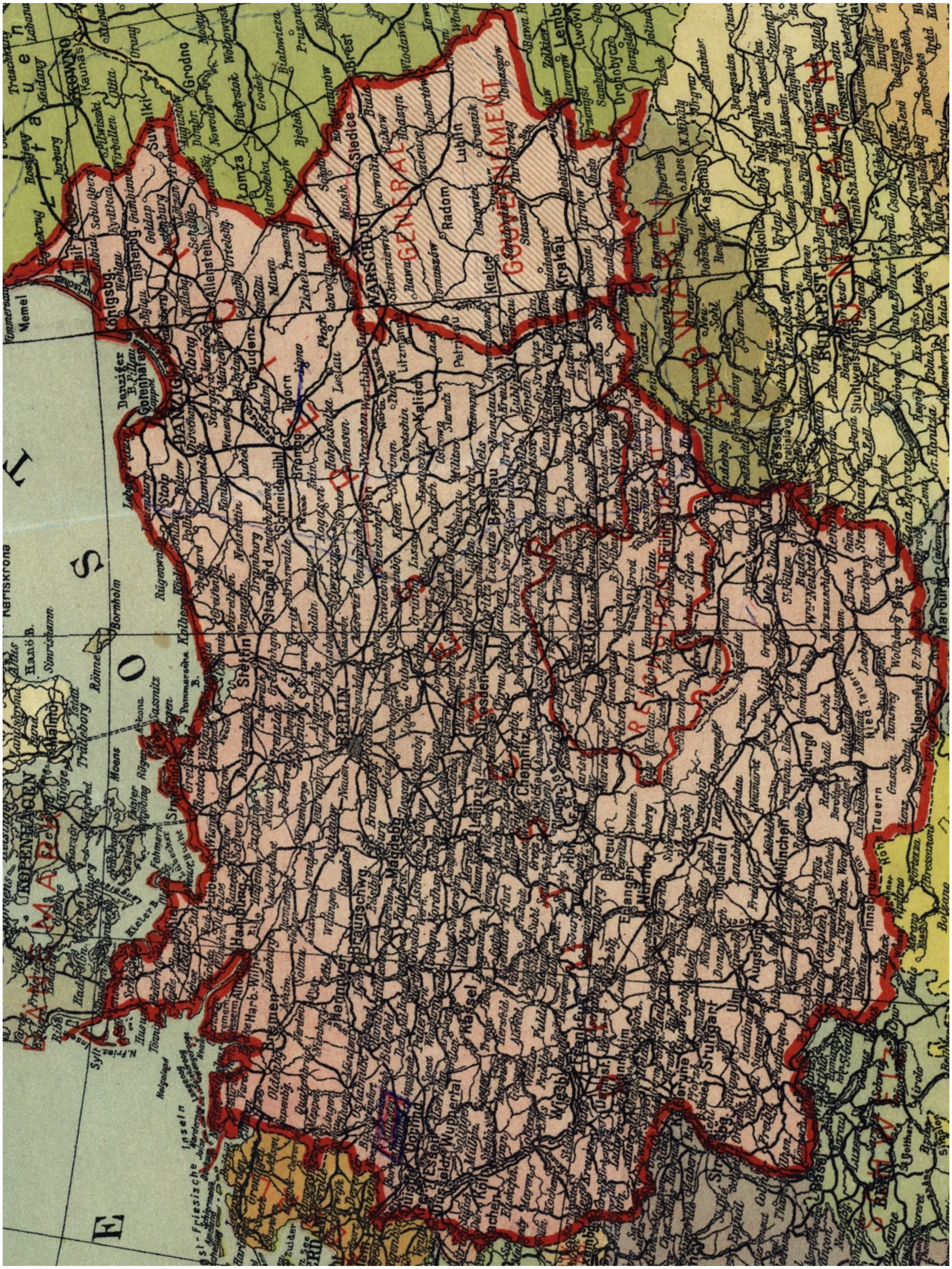

GENERAL GOUVERNEMENT
WARSCHAU
Krakau
Lemberg
Radom
Lublin
Kielce
Brest
Grodno
Königsbg.
Memel
DANZIG
Stettin
BERLIN
Breslau
Leipzig
Chemnitz
Dresden
Magdeburg
Braunschweig
Hannover
Hamburg
Bremen
Kassel
Stuttgart
Augsburg
München
Nürnberg
Wien
Graz
Klagenfurt
Innsbruck
Salzburg
Budapest
Kopenhagen
Bornholm
SLOWAKEI
UNGARN
SCHWEIZ
DÄNEMARK
OSTSEE

Figure 11.16: Map of the Greater German Reich in 1941, not including satellite countries that were also controlled by Germany. At the end of the war, the Soviet Union, United States, United Kingdom, and France seized materials, scientists, and information from sites in the regions they occupied. Note that the majority of this territory was occupied by the Soviet Union and therefore was generally not open to inspection by western Allied investigators.

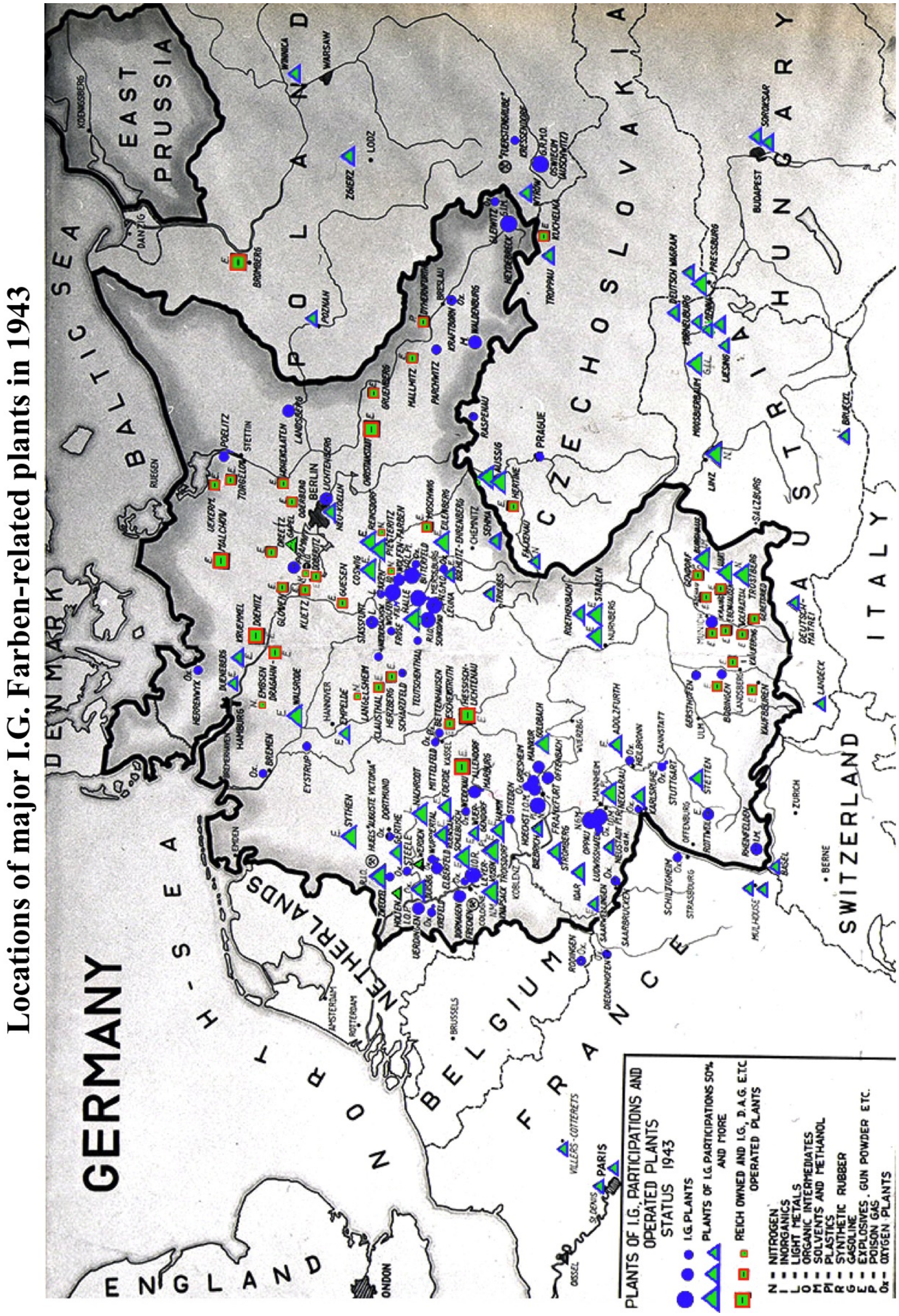

Locations of major I.G. Farben-related plants in 1943
GERMANY
ENGLAND
NORTH-SEA
BALTIC SEA
DENMARK
EAST PRUSSIA
POLAND
NETHERLANDS
BELGIUM
FRANCE
SWITZERLAND
ITALY
CZECHOSLOVAKIA
AUSTRIA
HUNGARY
KOENIGSBERG
DANZIG
WARSAW
LODZ
POZNAN
BROMBERG
STETTIN
BERLIN
HAMBURG
BREMEN
HANNOVER
BRESLAU
PRAGUE
CHEMNITZ
NURNBERG
MUNICH
SALZBURG
LINZ
PRESSBURG
BUDAPEST
OSWIECIM (AUSCHWITZ)
STUTTGART
MANNHEIM
FRANKFURT
KOBLENZ
STRASSBURG
MULHOUSE
BASEL
ZURICH
BERNE
AMSTERDAM
ROTTERDAM
BRUSSELS
PARIS
VILLERS-COTTERETS
LONDON
PLANTS OF I.G., PARTICIPATIONS AND OPERATED PLANTS STATUS 1943
I.G. PLANTS
PLANTS OF I.G. PARTICIPATIONS 50% AND MORE
REICH OWNED AND I.G., D.A.G. E.T.C. OPERATED PLANTS
N - NITROGEN
I - INORGANICS
L - LIGHT METALS
O - ORGANIC INTERMEDIATES
M - SOLVENTS AND METHANOL
Pl - PLASTICS
R - SYNTHETIC RUBBER
G - GASOLINE
E - EXPLOSIVES, GUN POWDER ETC.
P - POISON GAS
Ox - OXYGEN PLANTS

Figure 11.17: Map of plants run by or affiliated with I.G. Farben in 1943. The large majority were located within the Greater German Reich, but that included the territory of modern Austria, Poland, and the Czech Republic in addition to modern Germany. Like other scientific sites, I.G. Farben plants were seized at the end of the war by the countries occupying the corresponding regions.

NARA Still Pictures, RG 111 SCA---Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941-1954. Captured German Equipment, German, Box 3344, Book 5, SC 203875, 203876.

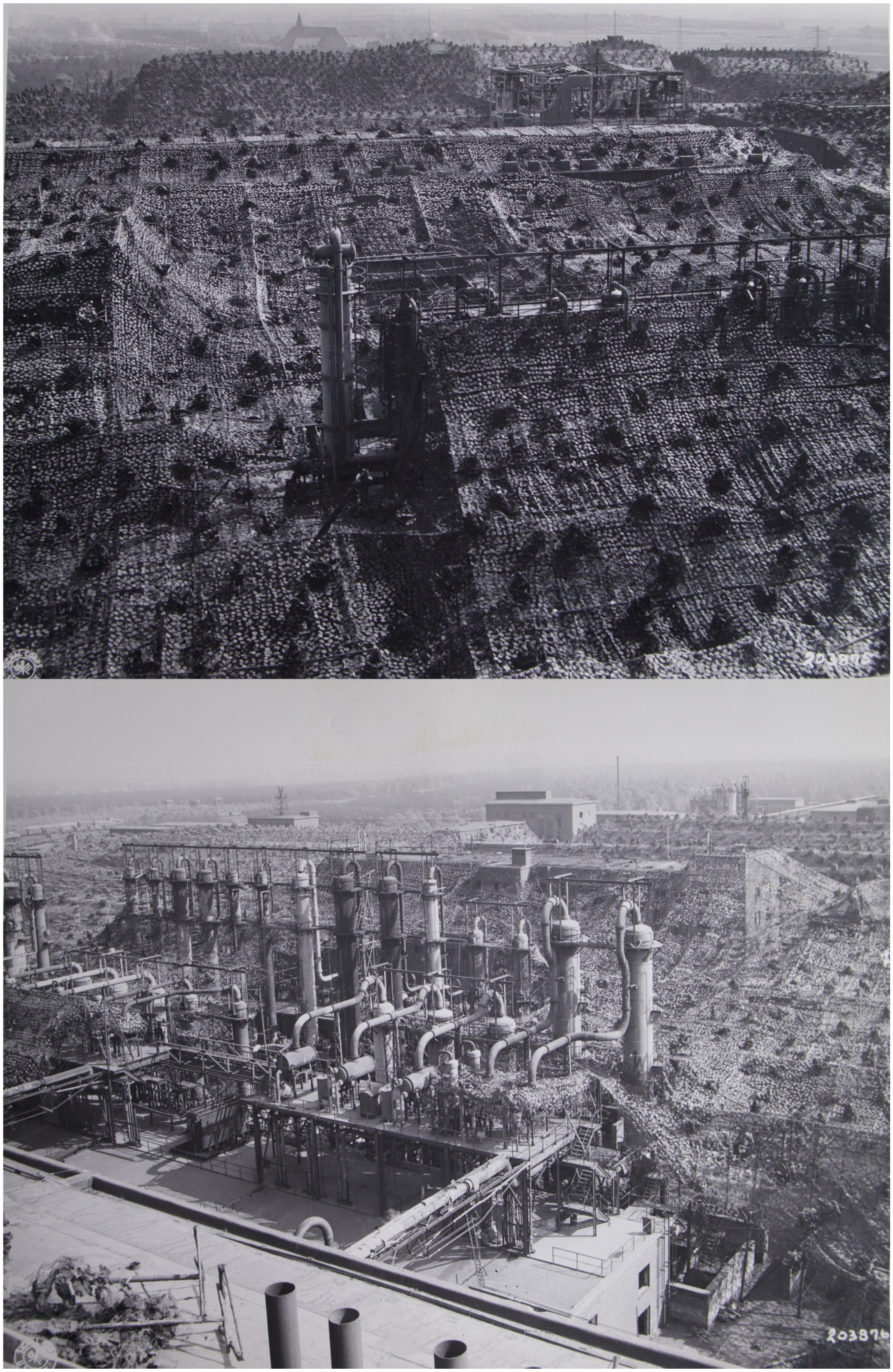


Figure 11.18: Large I.G. Farben buna synthetic rubber plant near Hüls, discovered intact under camouflage netting by the U.S. Army in April 1945 [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3344, Book 5, SC 203875, SC 203876].

NARA Still Pictures, RG 111 SCA---Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941-1954. Captured German Equipment, German, Box 3354, Book 15, SC 282453, 282456.

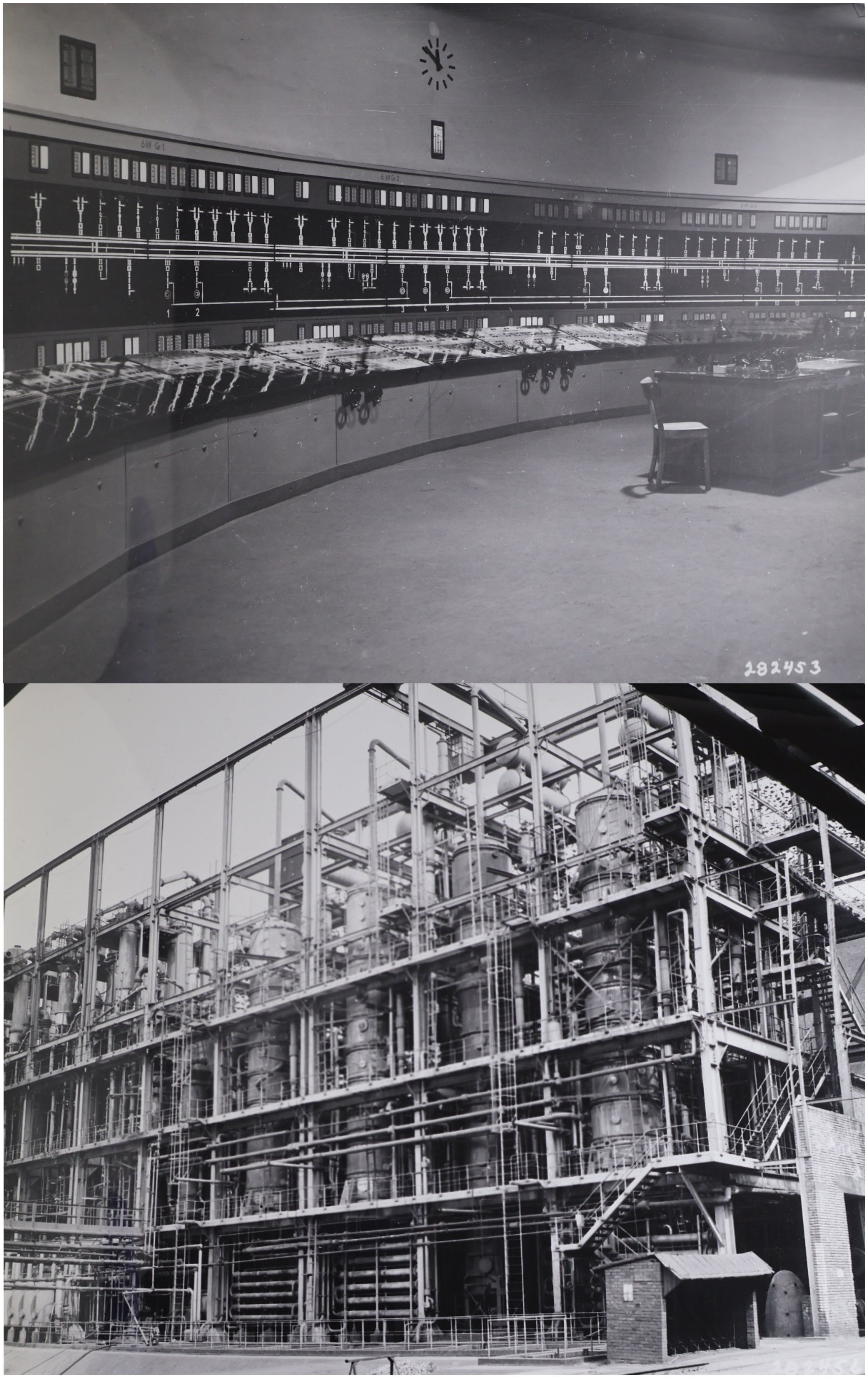


Figure 11.19: Large I.G. Farben buna synthetic rubber plant near Hüls, discovered intact under camouflage netting by the U.S. Army in April 1945 [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3354, Book 15, SC 282453, SC 282456].

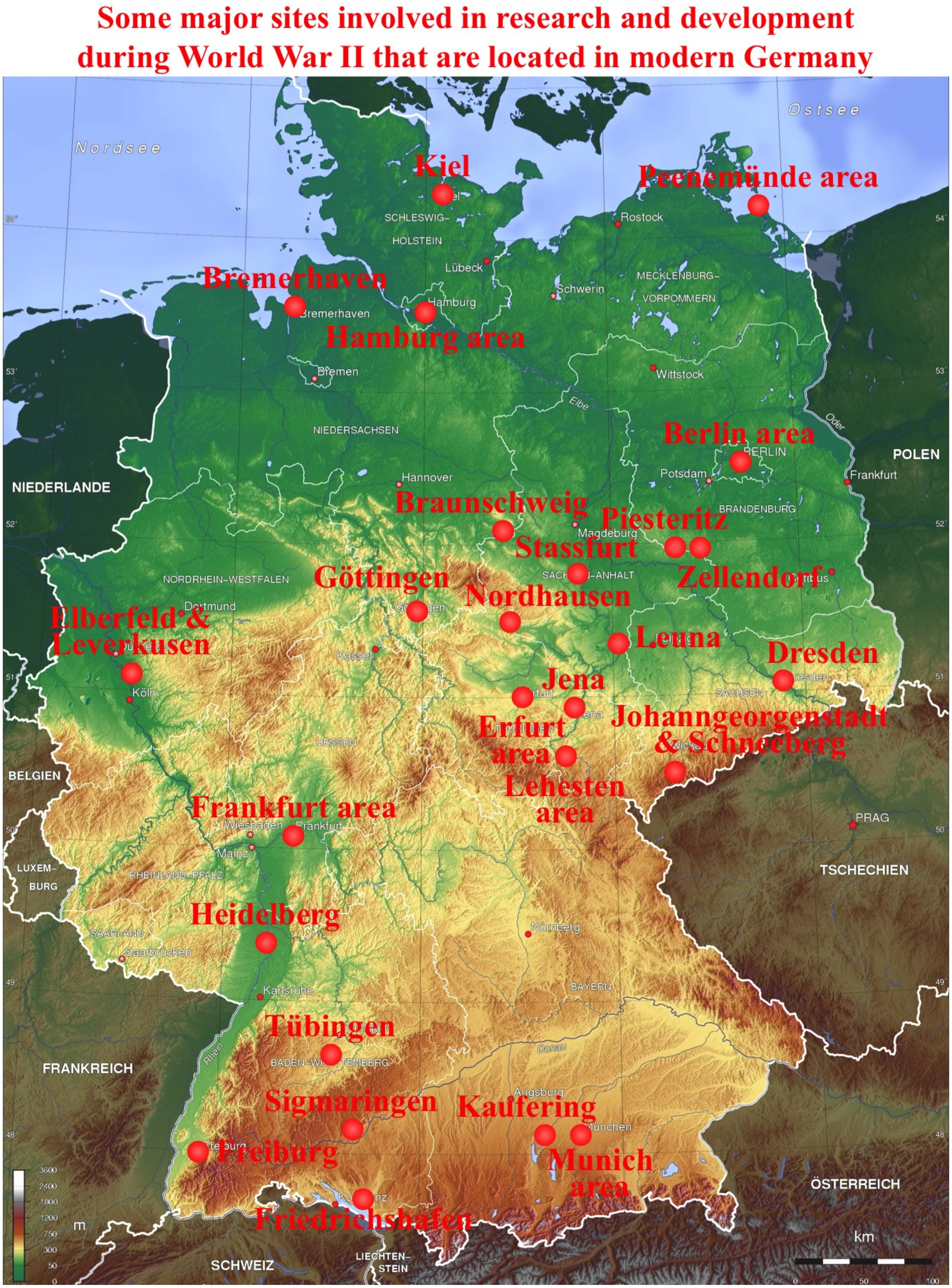

Some major sites involved in research and development
during World War II that are located in modern Germany
Kiel
Peenemünde area
Bremerhaven
Hamburg area
Berlin area
Braunschweig
Piesteritz
Stassfurt
Zellendorf
Göttingen
Nordhausen
Elberfeld &
Leverkusen
Leuna
Dresden
Jena
Johanngeorgenstadt
& Schneeberg
Erfurt
area
Lehesten
area
Frankfurt area
Heidelberg
Tübingen
Sigmaringen
Kaufering
Freiburg
Munich
area
Friedrichshafen
Nordsee
Ostsee
NIEDERLANDE
BELGIEN
LUXEM-
BURG
FRANKREICH
SCHWEIZ
LIECHTEN-
STEIN
ÖSTERREICH
TSCHECHIEN
POLEN
PRAG
SCHLESWIG-
HOLSTEIN
MECKLENBURG-
VORPOMMERN
NIEDERSACHSEN
BRANDENBURG
NORDRHEIN-WESTFALEN
HESSEN
RHEINLAND-PFALZ
SAARLAND
BADEN-WÜRTTEMBERG
BAYERN
SACHSEN
Rostock
Lübeck
Schwerin
Hamburg
Bremerhaven
Bremen
Wittstock
Elbe
Oder
BERLIN
Potsdam
Frankfurt
Hannover
Magdeburg
Dortmund
Kassel
Köln
Wiesbaden
Frankfurt
Mainz
Saarbrücken
Nürnberg
Karlsruhe
Donau
Rhein
Augsburg
München
m
3600
2400
1800
1200
750
300
50
0
km
0
50
100

Figure 11.20: Some major sites involved in research and development during World War II that are located in modern Germany.

Notes for Fig. 11.20, showing sites located in modern Germany:

Berlin area: universities and technical schools; Kaiser Wilhelm Institutes; Kummersdorf and Spandau army research centers; Oranienburg Auer/SS research center; Reichspost research institutes; AEG, Siemens, Degussa, I.G. Farben, and other industry (e.g., pp. 3608, 3694, 3927, 4180, 4182, 4980) [Hayes 2004; Nagel 2016].

Braunschweig: Luftfahrtforschungsanstalt; Göring Werke; SS facilities; Buchler uranium (p. 4980).

Bremerhaven: naval research and development (e.g., p. 1457).

Dresden: Reichspost, AEG, and other laboratories (pp. 4305, 4507).

Elberfeld/Leverkusen area: I.G. Farben plants, including chemical warfare (e.g., pp. 3934–3935).

Erfurt area: numerous underground facilities (pp. 3708–3709, 4436–4438, 4478–4571) and also uranium deposits [Hayes 2004; Nagel 2016; Zeman and Karlsch 2008].

Frankfurt area: universities, research institutes, and industry [Hayes 2004; Nagel 2016].

Freiburg-im-Breisgau area: nuclear and other sites (pp. 3512–3540, 3696).

Friedrichshafen and Unterraderach (pp. 3921–3922).

Göttingen University.

Hamburg area: universities, research institutes, and industry; chemical and nuclear weapons development in Lüneburger Heide/Munster-Lager/Raubkammer (e.g., pp. 3494–3516, 4176–4182, 4406).

Heidelberg: university and Kaiser Wilhelm Institutes.

Jena: Zeiss (e.g., pp. 1270–1274, 1279, 2078); others in surrounding area.

Johanngeorgenstadt and Schneeberg area: uranium mining and use for nuclear development (pp. 3433–3437, 3456–3416, 3708, 4922) [Zeman and Karlsch 2008] .

Kaufering/Landsberg: installation possibly involved in nuclear work (p. 3692).

Kiel: naval research and development; uranium centrifuges (e.g., pp. 3494–3516).

Lehesten/Saalfeld area: underground rocket/aircraft/nuclear facilities (pp. 3689, 3696).

Leuna/Halle: I.G. Farben (e.g., pp. 4042–4054).

Munich area: universities, research institutes, and industry; Tegernsee facility (p. 3696).

Nordhausen: underground factories for rockets, missiles, and aircraft (e.g., pp. 5289–5294).

Peenemünde area of the Baltic coast: Peenemünde test center for rockets, missiles, and aircraft (e.g., pp. 3696, 5277–5288); Friedrich Löffler Institute for infectious disease research on Riems island (e.g., p. 197); military testing facilities on Rügen island (e.g., pp. 4390–4435); military testing facilities on Bornholm island, Denmark (e.g., pp. 3786, 4579); Lübeck, Dräger Werke (e.g., p. 4062); other facilities to produce and test advanced weapons and aircraft.

Piesteritz: chemical and possible nuclear development work (p. 4452).

Sigmaringen (p. 3696).

Stassfurt vicinity: underground Salzbergwerke facility for rocket and nuclear development (p. 3697).

Tübingen: university and research facilities (p. 3696).

Zellendorf: SS nuclear facility (p. 3694).

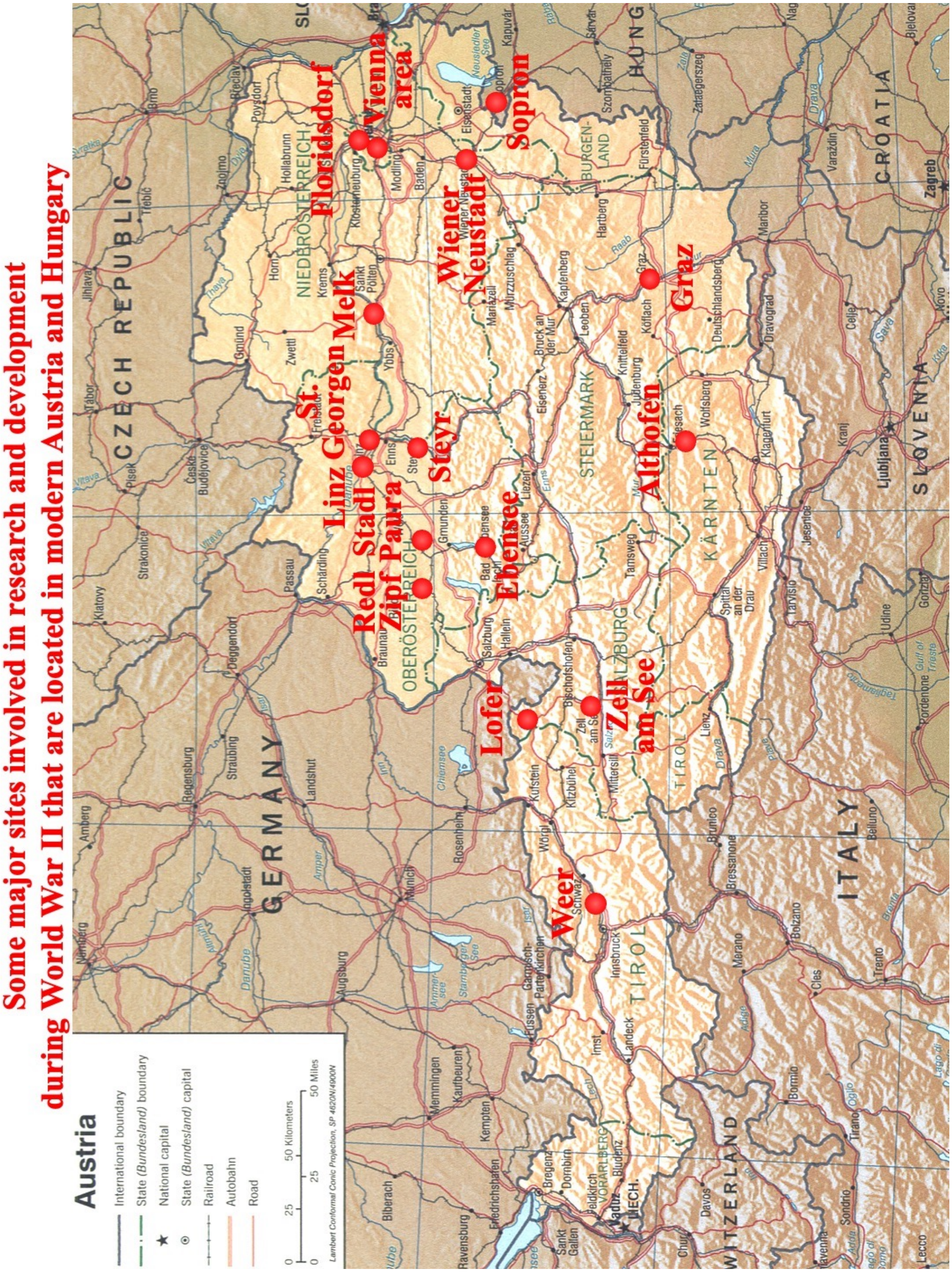

Some major sites involved in research and development
during World War II that are located in modern Austria and Hungary
Weer
Lofer
Zell am See
Redl Zipf
Stadl Paura
Ebensee
Linz
St. Georgen
Steyr
Althofen
Melk
Graz
Wiener Neustadt
Floridsdorf
Vienna area
Sopron
Austria
International boundary
State (Bundesland) boundary
National capital
State (Bundesland) capital
Railroad
Autobahn
Road
0 25 50 Kilometers
0 25 50 Miles
Lambert Conformal Conic Projection, SP 46°N/49°N
GERMANY
CZECH REPUBLIC
HUNGARY
CROATIA
SLOVENIA
ITALY
SWITZERLAND
LIECH.
NIEDERÖSTERREICH
OBERÖSTERREICH
STEIERMARK
KÄRNTEN
SALZBURG
TIROL
VORARLBERG
BURGENLAND

Figure 11.21: Some major sites involved in research and development during World War II that are located in modern Austria and Hungary.

Notes for Fig. 11.21, showing sites located in modern Austria and Hungary:

Althofen: Treibacher Chemische Werke (e.g., pp. 3432–3437, 4980) [Gollmann 1994].

Ebensee: underground facilities for oil production, rocket development, and apparently nuclear-related work (e.g., pp. 3718–3741, 5297–5299).

Floridsdorf (e.g., p. 3696).

Graz (e.g., pp. 4611–4612).

Linz: Reichswerke Hermann Göring and other heavy industries, at least some of which were apparently nuclear-related (e.g., p. 3877).

Lofer (e.g., p. 4974).

Melk vicinity and associated sites: underground facilities that were part of the Quarz development (e.g., p. 3732) [Schmitzberger 2004].

Redl Zipf: underground facility (e.g., pp. 3718–3741).

Sopron, Hungary (e.g., pp. 3746–3747).

Stadl Paura (e.g., pp. 3718–3741).

Steyr.

St. Georgen/Gusen/Langenstein vicinity: underground facilities that were part of the Bergkristall/Gusen/Esche development (e.g., pp. 3874–3920 and 4962–4970).

Vienna area: universities, research institutes, and industry.

Weer: heavy water production plant (e.g., pp. 4072–4077).

Wiener Neustadt vicinity (e.g., pp. 3748, 3732).

Zell am See (e.g., p. 4788).

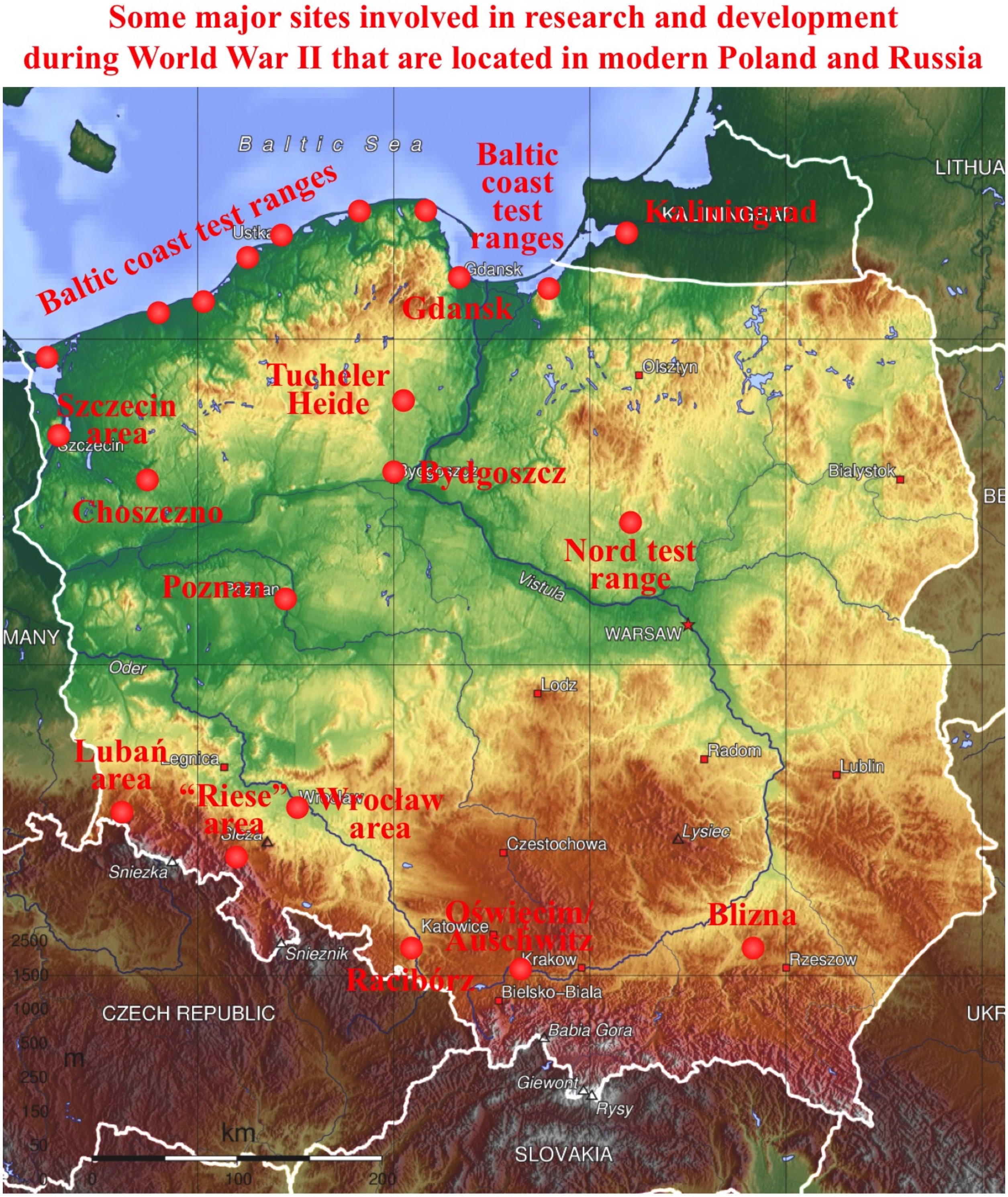

Some major sites involved in research and development
during World War II that are located in modern Poland and Russia
Baltic Sea
Baltic coast test ranges
Ustka
Baltic coast test ranges
Kaliningrad
KALININGRAD
LITHUANIA
Gdansk
Gdansk
Szczecin area
Szczecin
Tucheler Heide
Olsztyn
Bydgoszcz
Bydgoszcz
Choszczno
Bialystok
BE
Nord test range
Poznan
Poznan
Vistula
GERMANY
WARSAW
Oder
Lodz
Lubań area
Legnica
Radom
Lublin
"Riese" area
Wrocław
Wrocław area
Sleza
Czestochowa
Lysiec
Sniezka
Oświęcim/Auschwitz
Blizna
Katowice
Krakow
Rzeszow
Raciborz
Sniezni k
Bielsko-Biala
2500
1500
1000
500
250
150
50
0
m
CZECH REPUBLIC
UKR
Babia Gora
Giewont
Rysy
km
0
100
200
SLOVAKIA

Figure 11.22: Some major sites involved in research and development during World War II that are located in modern Poland and Russia.

Notes for Fig. 11.22, showing sites located in modern Poland and Russia:

Baltic coast/Pomerania: many military test ranges located along most of the coast (e.g., p. 4396, Leba/Rumbke, etc.).

Blizna: SS Truppenübungsplatz Heidelager A-4 (V-2) rocket test/launch site.

Bydgoszcz/Bromberg: underground facility, possibly nuclear-related (e.g., p. 4456).

Choszczno/Arnswalde: secret large underground factory (p. 5560).

Gdansk/Danzig: Anti-radar/anti-sonar; uranium enrichment (pp. 3560, 4406, 4521).

Kaliningrad/Königsberg, Russia: Henschel guided missile development (e.g., p. 3928).

Lubań/Lauban area:

- GEMA-Werke for electronics.
- Leśna/Marklissa: VDM factory for A-4 (V-2) rocket engines.
- Zgorzelec/Görlitz: underground factory for A-4 (V-2) rockets.

Nord test range: Henschel Hs 117 Schmetterling surface-to-air missile development.

Oświęcim/Auschwitz: large I.G. Farben production facility, heavy water production, and possibly other nuclear-related work (e.g., pp. 4443–4477); to the north, Auergesellschaft uranium facility at Katowice/Kattowitz and Messerschmitt Me 163 rocket plane development at Mierzęcice/Udetfeld.

Poznan/Posen:

- Nesselstedt/Reichsinstitut für Krebsforschung biological weapons research (pp. 2562–2575).
- Biological weapons production (e.g., p. 2582).
- Electromagnetic railgun production (e.g., pp. 3245–3246)
- Numerous factories to produce other advanced weapons and aircraft.

Racibórz/Ratibor: Siemens Plania Werke, graphite production for nuclear experiments.

"Riese" area of Lower Silesia (e.g., pp. 4504–4519):

- Ksiaż castle/Schloss Fürstenstein: Jägerstab/SS development.
- Numerous underground facilities, some of which were conducting nuclear work.
- Kowary/Schmiedeberg uranium mine (e.g., p. 3328) and heavy water production plant [Witkowski 2013, p. 224].

Szczecin/Stettin area.

- Mosty/Speck: underground facility, apparently nuclear work [Witkowski 2013, p. 224].
- Stargard and Miedwie Lake/Madüsee: surface-to-air missile development.

Tuchola Forest/Tucheler Heide: military/SS rocket testing and nuclear work (e.g., pp. 4462, 4902–4903) [Dornberger 1958, pp. 227–229].

Wrocław/Breslau area: uranium centrifuges (p. 4522); heavy water (pp. 4070–4071); Rheinmetall missiles; Brzeg Dolny/Dyhernfurth chemical weapons.

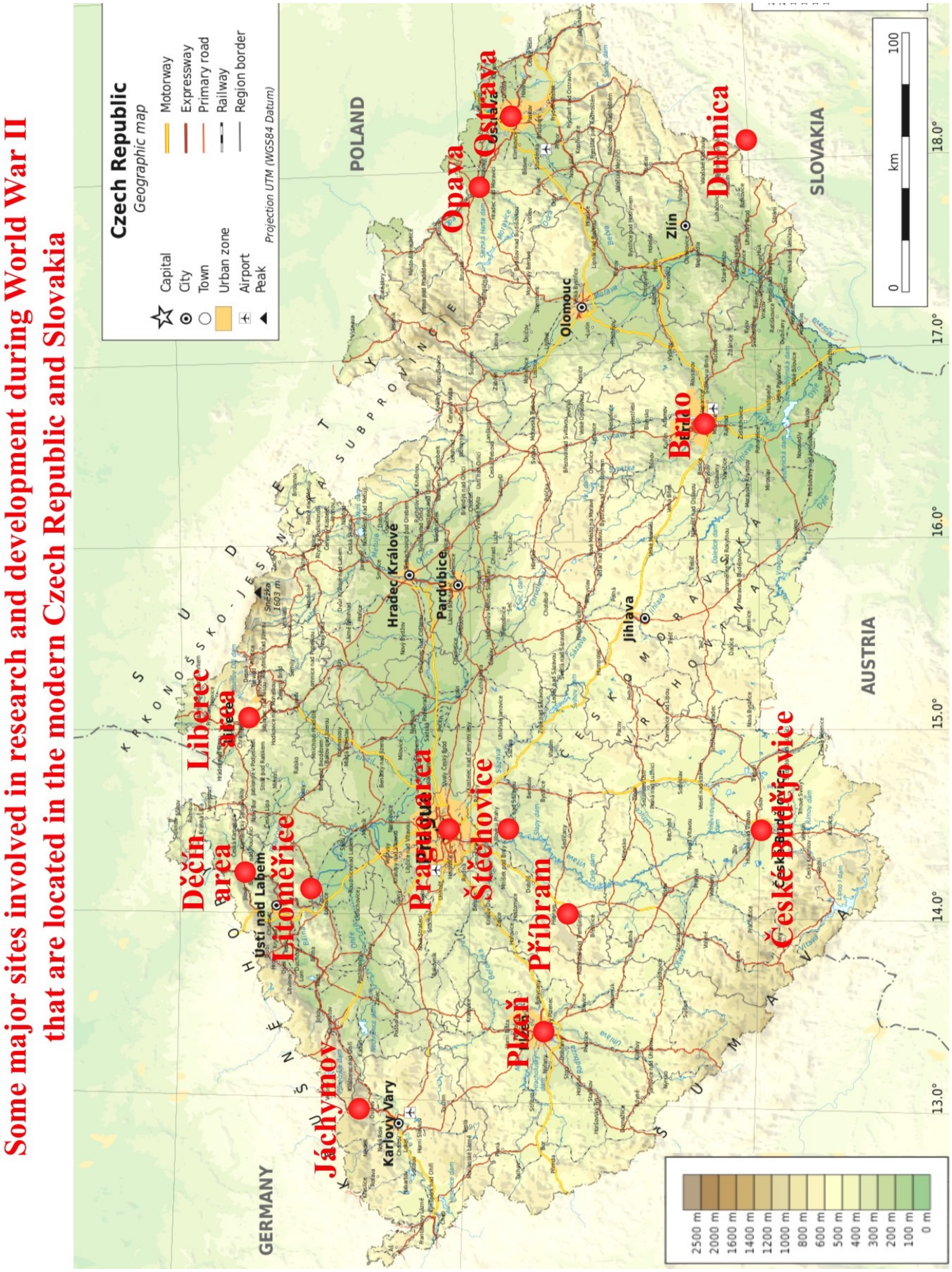

Some major sites involved in research and development during World War II
that are located in the modern Czech Republic and Slovakia
Czech Republic
Geographic map
Capital
City
Town
Urban zone
Airport
Peak
Motorway
Expressway
Primary road
Railway
Region border
Projection UTM (WGS84 Datum)
POLAND
GERMANY
AUSTRIA
SLOVAKIA
Jáchymov
Děčín area
Litoměřice
Liberec area
Prague area
Štěchovice
Příbram
Plzeň
České Budějovice
Brno
Opava
Ostrava
Dubnica
Karlovy Vary
Ústí nad Labem
Hradec Králové
Pardubice
Jihlava
Olomouc
Zlín
Sněžka 1603 m
KRKONOŠE
SUDETY
ČESKOMORAVSKÁ VRCHOVINA
ŠUMAVA
km
0
100
13.0°
14.0°
15.0°
16.0°
17.0°
18.0°
2500 m
2000 m
1600 m
1400 m
1200 m
1000 m
800 m
600 m
500 m
400 m
300 m
200 m
100 m
0 m

Figure 11.23: Some major sites involved in research and development during World War II that are located in the modern Czech Republic and Slovakia.

Notes for Fig. 11.23, showing sites located in the modern Czech Republic and Slovakia:

Brno/Brünn: Waffenwerke-Brünn, SS academy research institute (pp. 3694, 3997).

České Budějovice/Budweis: several Siemens electronics factories for guidance systems, proximity fuses, etc. (pp. 3979–4022, 5503–5566).

Děčín/Tetschen area (pp. 3979–4022, 5503–5566):

- Podmokly/Bodenbach Krizik Works/Weserwerke underground factory.
- Benesov nad Ploucnici/Beneschau AEG electronics factory.
- Schmidding factory for rockets and missiles.
- Neumann und Slabenow factories for metals and electronics.

Dubnica/Dubnitz, Slovakia: Skoda underground facility (p. 3784).

Jáchymov/St. Joachimsthal: uranium mine (pp. 3998, 4980–4984).

Liberec/Reichenberg and Jablonec/Gablonz area (pp. 3979–4022, 5503–5566):

- Bedrichov/Friedrichsthal/Benesov nad Ploucnici AEG factory for V-3 and V-4 rockets/guidance systems.
- Rychnov/Reichenau GETEWENT (Gesellschaft für Technisch-Wirtschaftliche Entwicklung mbH) SS electronics factory.
- Straz nad Nisou/Habendorf Skoda underground factory (p. 5549).
- Tanvald/Tannwald: multiple electronics and semiconductor research facilities (p. 2757).
- Turnov/Turnau aerospace research facility.

Litoměřice/Leitmeritz: Richard I–IV underground factories (p. 3689).

Opava/Tropau: I.G. Farben production plant, apparently involved in nuclear work (p. 3748).

Ostrava/Ostrau and Vitkovice/Witkowitz: I.G. Farben and other industrial production plants, apparently some of which were involved in nuclear work (pp. 3748, 3979–4022).

Plzeň/Pilsen: Skoda/SS research facilities and administrative headquarters (p. 4974).

Prague/Praha/Prag area (pp. 2757, 3137–3156, 3979–4022, 5503–5566):

- Charles University/Prague German University.
- Bohemian/Czech Technical University in Prague.
- Kbely/Gbel airfield.
- Čelakovice/Tschelakowitz cyclotron factory (northeast of Prague).

Příbram/Przibram/Pibrans: Skoda/SS rocket development facility (pp. 3751–3754, 4921, 5696).

Štěchovice/Stechowitz area: Blaumeise underground facilities, apparently nuclear (pp. 3755–3782).

Most of this section demonstrates the size of the industries controlled by Germany by giving examples of the numbers and types of plants built by Germany, the geographical distribution of plants, and the magnitude of the postwar transfer of plants, products, materials, scientists, documents, and other information to Allied countries.

One can also demonstrate the size of the industries controlled by Germany (and subsequently transferred) by two other measures:

1. Gross domestic product (GDP). Table 11.6 summarizes information from economist Mark Harrison [Harrison 1998, pp. 3–13] regarding the economic output of Germany and countries aiding Germany during the war. Prewar (1938) GDP figures are expressed in billions of 1990 U.S. dollars. The 1938 GDP numbers were 351.4 for Germany alone, 1046.5 for Germany plus other Axis/occupied countries, and 1166.7 for Germany plus other Axis/occupied countries plus nominally "neutral" countries that actually gave considerable material support to Germany. Although the only easily available figures are those 1938 numbers, the totals for German-controlled Europe were probably fairly comparable during the war. (Allied bombing and territorial losses toward the end of the war would tend to reduce the totals, whereas German-initiated industrial construction, relocation to avoid Allied bombing, use of low-wage and forced labor, and other policies would tend to increase the totals.)

For comparison, the U.S. GDP (expressed in billions of 1990 U.S. dollars) was 800 in 1938, rising to 1094 in 1941 and reaching a wartime peak of 1499 in 1944. Thus the economic and industrial resources controlled by Germany were roughly comparable to and perhaps even greater than those of the United States (yet outmatched by the combined resources of the United States plus the complete British Commonwealth plus the Soviet Union).

2. Electrical power production. According to the U.S. Strategic Bombing Survey (USSBS), at the end of 1944 the Greater German Reich had a total known electrical production capacity of 22 GW, with at least 16 GW of that currently then in use despite territorial losses, extensive bombing, and ongoing repair work.[6] See pp. 2102–2104. BIOS 342 estimated a total of 23 GW for 1944 (pp. 2105–2106). Note that that total known production capacity of 22–23 GW does not include secretive or specialized power plants for classified or dedicated projects in the Greater German Reich that were either not known to USSBS and BIOS (especially in areas occupied by the Soviet Union after the war) or known but not publicly revealed by USSBS and BIOS. Note also that that 22–23 GW does not include the electrical production capacities of other countries that were occupied by Germany, allied with Germany, or nominally neutral but exporting aid to Germany. Detailed numbers on those extra production capacities are difficult to find, but a reasonable estimate is that adding secretive production within the Greater German Reich and production outside the Greater German Reich would approximately double that 22–23 GW to ∼44–46 GW of total electrical production capacity to aid the German war effort.

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[6] United States Strategic Bombing Survey. 1947. *German Electric Utilities Industry Report.* pp. 1, 4, Exhibit C, Exhibit D. https://books.google.com/books?id=U9Q9TS-FtSgC

Country	**GDP**
Germany	351.4
Other Axis/occupied:	
Austria	24.2
Baltic states	12.9
Belgium	39.6
Bulgaria	10.5
Czechoslovakia	30.3
Denmark	20.9
Finland	12.7
France	185.6
Greece	19.3
Hungary	24.3
Italy	140.8
Netherlands	44.5
Norway	11.6
Poland	76.6
Romania	19.4
Yugoslavia	21.9
Subtotal:	695.1
“Neutrals” supporting Germany:	
Portugal	12.9
Spain	51.1
Sweden	29.8
Switzerland	26.4
Subtotal:	120.2
Total:	1166.7

Table 11.6: Gross domestic product (GDP) figures for Germany and countries that aided Germany during World War II (1938 GDPs, expressed in billions of 1990 U.S. dollars [Harrison 1998, pp. 3–13]. For comparison, the U.S. GDP (expressed in billions of 1990 U.S. dollars) was 800 in 1938.

For comparison, total production of electrical energy in the United States increased from 161,308 GW hr for the year of 1939, or a time-average of 18.4 GW electric power production, to 271,255 GW hr for 1945, or a time-average of 31.0 GW electric power production.[7] Thus the electrical power available to aid Germany was roughly comparable to and possibly even greater than the electrical power production of the United States (though outmatched by the combined electrical power of the United States plus the complete British Commonwealth plus the Soviet Union).

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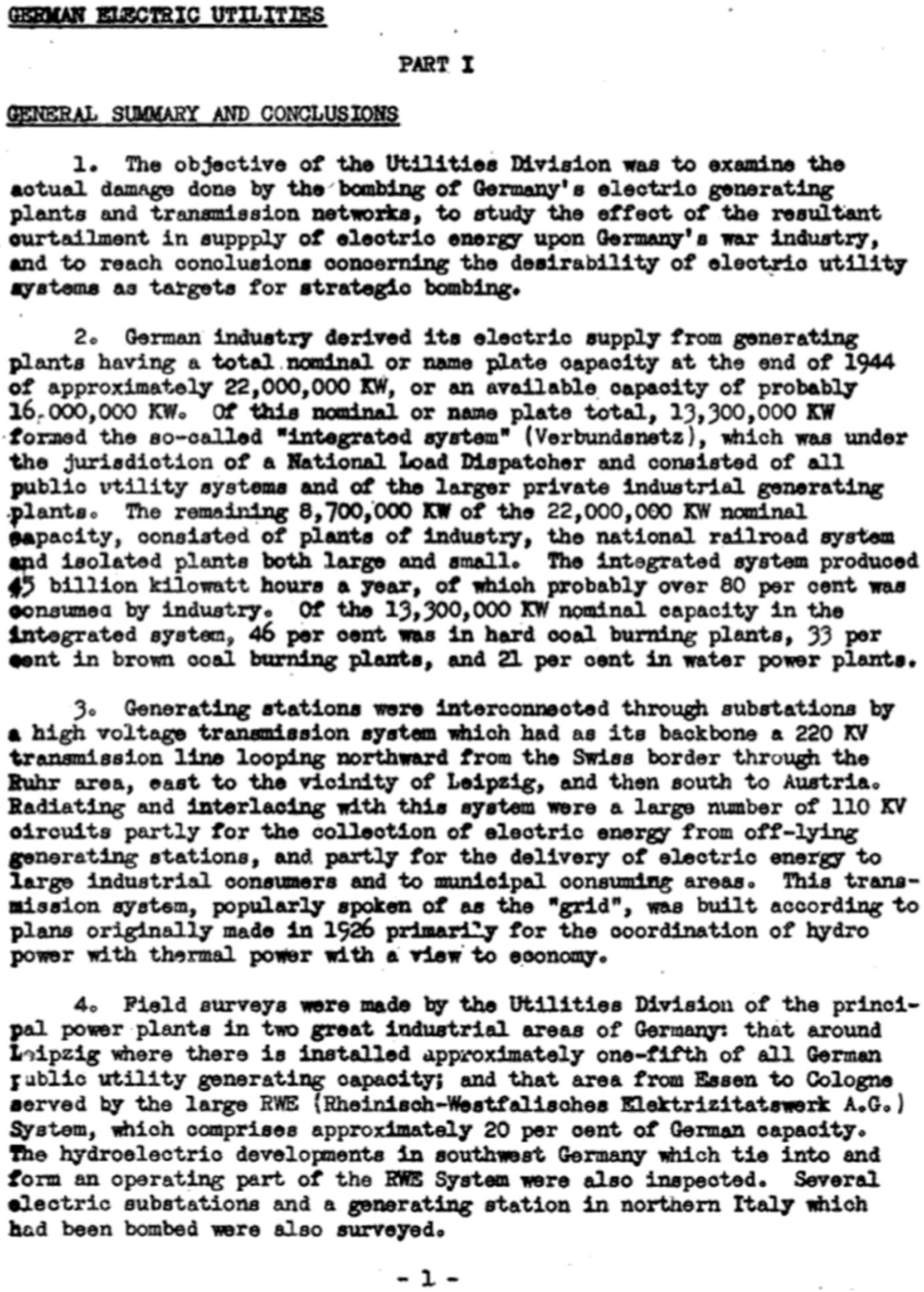
[7] United States Census Bureau. 1949. *Statistical Abstract of the United States.* p. 512.
https://www.census.gov/library/publications/1949/compendia/statab/70ed.html
https://www2.census.gov/library/publications/1949/compendia/statab/70ed/1949-08.pdf



GERMAN ELECTRIC UTILITIES

PART I

GENERAL SUMMARY AND CONCLUSIONS

1. The objective of the Utilities Division was to examine the actual damage done by the bombing of Germany's electric generating plants and transmission networks, to study the effect of the resultant curtailment in suppply of electric energy upon Germany's war industry, and to reach conclusions concerning the desirability of electric utility systems as targets for strategic bombing.

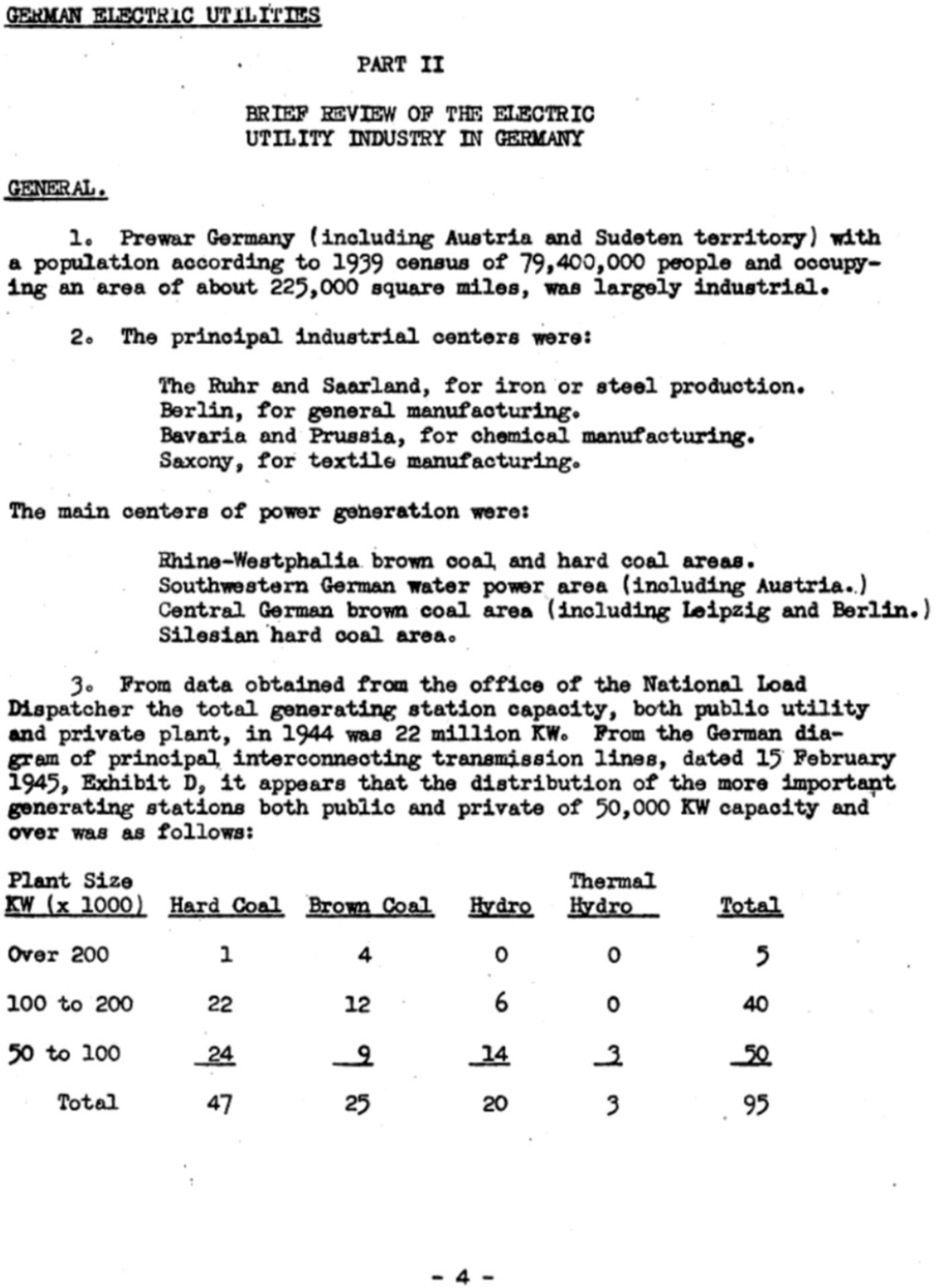
2. German industry derived its electric supply from generating plants having a total nominal or name plate capacity at the end of 1944 of approximately 22,000,000 KW, or an available capacity of probably 16,000,000 KW. Of this nominal or name plate total, 13,300,000 KW formed the so-called "integrated system" (Verbundsnetz), which was under the jurisdiction of a National Load Dispatcher and consisted of all public utility systems and of the larger private industrial generating plants. The remaining 8,700,000 KW of the 22,000,000 KW nominal capacity, consisted of plants of industry, the national railroad system and isolated plants both large and small. The integrated system produced 45 billion kilowatt hours a year, of which probably over 80 per cent was consumed by industry. Of the 13,300,000 KW nominal capacity in the integrated system, 46 per cent was in hard coal burning plants, 33 per cent in brown coal burning plants, and 21 per cent in water power plants.

3. Generating stations were interconnected through substations by a high voltage transmission system which had as its backbone a 220 KV transmission line looping northward from the Swiss border through the Ruhr area, east to the vicinity of Leipzig, and then south to Austria. Radiating and interlacing with this system were a large number of 110 KV circuits partly for the collection of electric energy from off-lying generating stations, and partly for the delivery of electric energy to large industrial consumers and to municipal consuming areas. This transmission system, popularly spoken of as the "grid", was built according to plans originally made in 1926 primarily for the coordination of hydro power with thermal power with a view to economy.

4. Field surveys were made by the Utilities Division of the principal power plants in two great industrial areas of Germany: that around Leipzig where there is installed approximately one-fifth of all German public utility generating capacity; and that area from Essen to Cologne served by the large RWE (Rheinisch-Westfalisches Elektrizitatswerk A.G.) System, which comprises approximately 20 per cent of German capacity. The hydroelectric developments in southwest Germany which tie into and form an operating part of the RWE System were also inspected. Several electric substations and a generating station in northern Italy which had been bombed were also surveyed.

- 1 -

Figure 11.24: United States Strategic Bombing Survey. 1947. *German Electric Utilities Industry Report.* p. 1. https://books.google.com/books?id=U9Q9TS-FtSgC



GERMAN ELECTRIC UTILITIES

PART II

BRIEF REVIEW OF THE ELECTRIC UTILITY INDUSTRY IN GERMANY

GENERAL.

1. Prewar Germany (including Austria and Sudeten territory) with a population according to 1939 census of 79,400,000 people and occupying an area of about 225,000 square miles, was largely industrial.

2. The principal industrial centers were:

The Ruhr and Saarland, for iron or steel production.
Berlin, for general manufacturing.
Bavaria and Prussia, for chemical manufacturing.
Saxony, for textile manufacturing.

The main centers of power generation were:

Rhine-Westphalia brown coal and hard coal areas.
Southwestern German water power area (including Austria.)
Central German brown coal area (including Leipzig and Berlin.)
Silesian hard coal area.

3. From data obtained from the office of the National Load Dispatcher the total generating station capacity, both public utility and private plant, in 1944 was 22 million KW. From the German diagram of principal interconnecting transmission lines, dated 15 February 1945, Exhibit D, it appears that the distribution of the more important generating stations both public and private of 50,000 KW capacity and over was as follows:

Plant Size KW (x 1000)	Hard Coal	Brown Coal	Hydro	Thermal Hydro	Total
Over 200	1	4	0	0	5
100 to 200	22	12	6	0	40
50 to 100	24	9	14	3	50
Total	47	25	20	3	95

- 4 -

Figure 11.25: United States Strategic Bombing Survey. 1947. *German Electric Utilities Industry Report.* p. 4. https://books.google.com/books?id=U9Q9TS-FtSgC

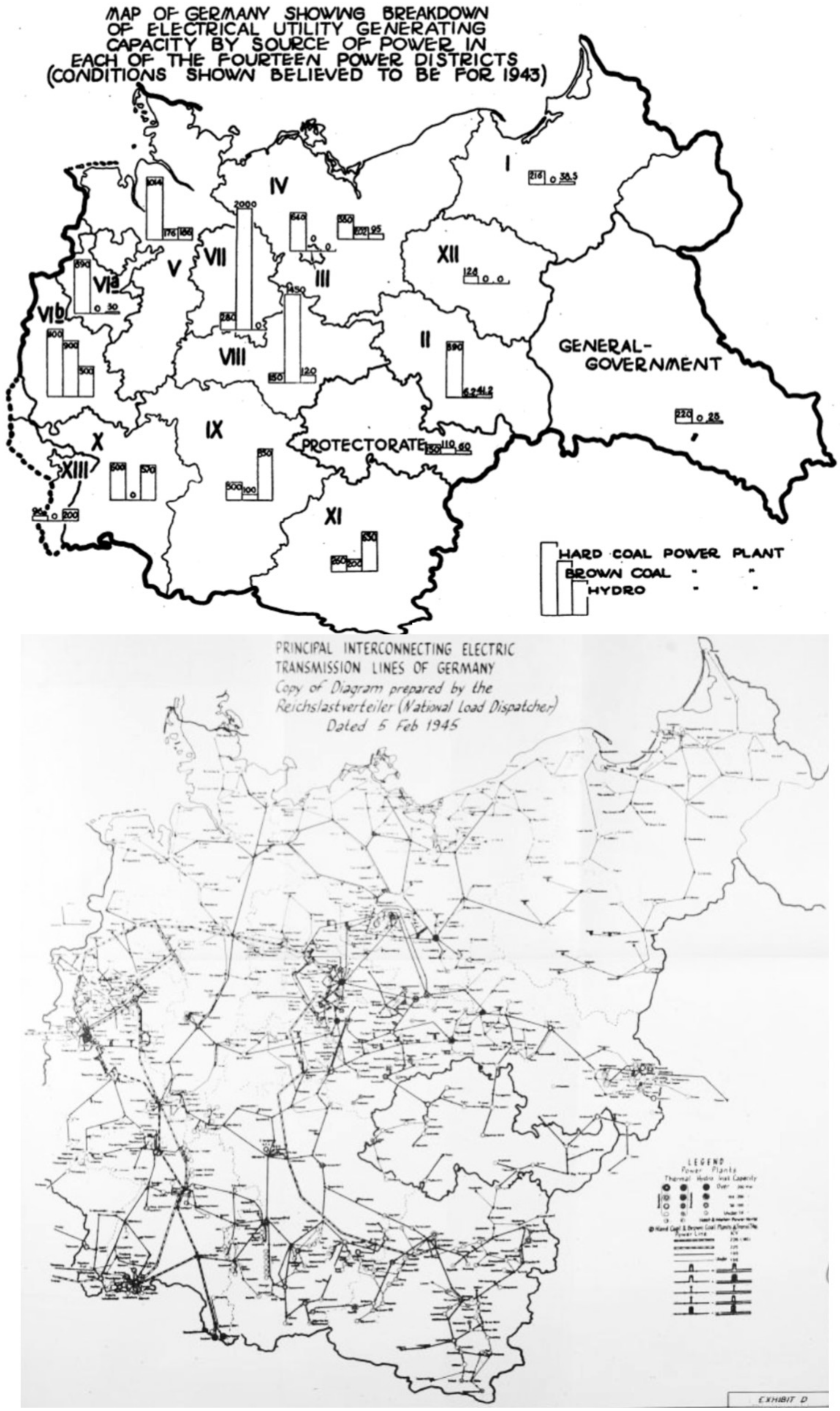
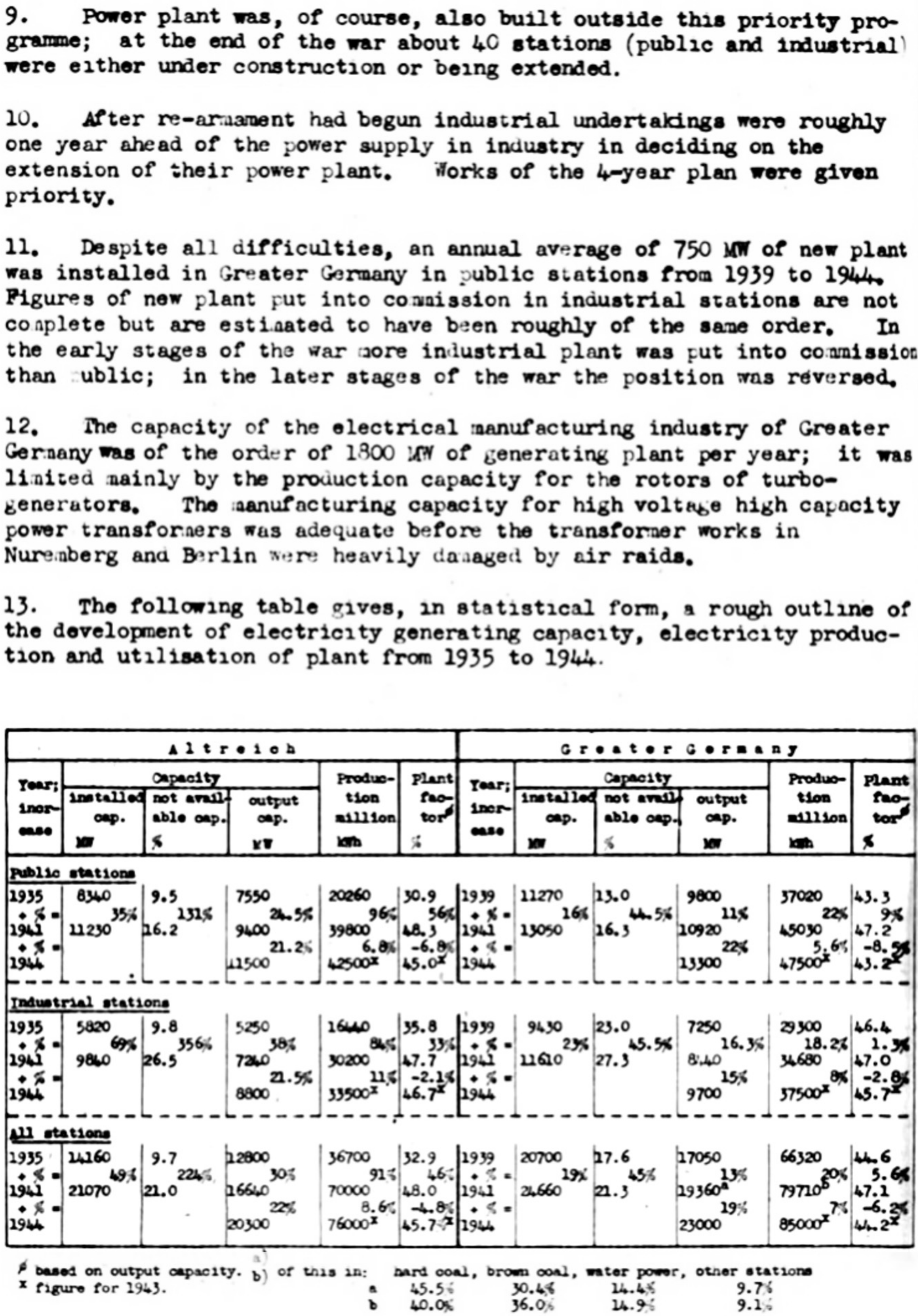

MAP OF GERMANY SHOWING BREAKDOWN OF ELECTRICAL UTILITY GENERATING CAPACITY BY SOURCE OF POWER IN EACH OF THE FOURTEEN POWER DISTRICTS (CONDITIONS SHOWN BELIEVED TO BE FOR 1943)
I
216 0 38.5
IV
1014 176 186
2000
640 0 0
550 202 95
V
VII
III
XII
128 0 0
VIa
890 0 30
VIb
900 900 500
280 0
1450
VIII
150 120
II
390 6.2 41.2
GENERAL-GOVERNMENT
220 0 25
X
IX
PROTECTORATE 150 110 60
XIII
500 0 570
500 100 850
96 0 200
XI
260 200 850
HARD COAL POWER PLANT
BROWN COAL - -
HYDRO - -
PRINCIPAL INTERCONNECTING ELECTRIC TRANSMISSION LINES OF GERMANY
Copy of Diagram prepared by the Reichslastverteiler (National Load Dispatcher)
Dated 5 Feb 1945
LEGEND
Power Plants
EXHIBIT D

Figure 11.26: United States Strategic Bombing Survey. 1947. *German Electric Utilities Industry Report.* Exhibits C and D. https://books.google.com/books?id=U9Q9TS-FtSgC

BIOS 342. *The German Wartime Electricity Supply: Conditions, Development, Trends.*



9. Power plant was, of course, also built outside this priority programme; at the end of the war about 40 stations (public and industrial) were either under construction or being extended.

10. After re-armament had begun industrial undertakings were roughly one year ahead of the power supply in industry in deciding on the extension of their power plant. Works of the 4-year plan were given priority.

11. Despite all difficulties, an annual average of 750 MW of new plant was installed in Greater Germany in public stations from 1939 to 1944. Figures of new plant put into commission in industrial stations are not complete but are estimated to have been roughly of the same order. In the early stages of the war more industrial plant was put into commission than public; in the later stages of the war the position was reversed.

12. The capacity of the electrical manufacturing industry of Greater Germany was of the order of 1800 MW of generating plant per year; it was limited mainly by the production capacity for the rotors of turbo-generators. The manufacturing capacity for high voltage high capacity power transformers was adequate before the transformer works in Nuremberg and Berlin were heavily damaged by air raids.

13. The following table gives, in statistical form, a rough outline of the development of electricity generating capacity, electricity production and utilisation of plant from 1935 to 1944.

Altreich						Greater Germany					
Year; increase	Capacity			Production million kWh	Plant factor ø %	Year; increase	Capacity			Production million kWh	Plant factor ø %
	installed cap. MW	not available cap. %	output cap. kW				installed cap. MW	not available cap. %	output cap. MW		
Public stations											
1935	8340	9.5	7550	20260	30.9	1939	11270	13.0	9800	37020	43.3
+ % =	35%	131%	24.5%	96%	56%	+ % =	16%	44.5%	11%	22%	9%
1941	11230	16.2	9400	39800	48.3	1941	13050	16.3	10920	45030	47.2
+ % =			21.2%	6.8%	-6.8%	+ % =			22%	5.6%	-8.5%
1944			11500	42500[x]	45.0[x]	1944			13300	47500[x]	43.2[x]
Industrial stations											
1935	5820	9.8	5250	16440	35.8	1939	9430	23.0	7250	29300	46.4
+ % =	69%	356%	38%	84%	33%	+ % =	23%	45.5%	16.3%	18.2%	1.3%
1941	9840	26.5	7240	30200	47.7	1941	11610	27.3	8440	34680	47.0
+ % =			21.5%	11%	-2.1%	+ % =			15%	8%	-2.8%
1944			8800	33500[x]	46.7[x]	1944			9700	37500[x]	45.7[x]
All stations											
1935	14160	9.7	12800	36700	32.9	1939	20700	17.6	17050	66320	44.6
+ % =	49%	224%	30%	91%	46%	+ % =	19%	45%	13%	20%	5.6%
1941	21070	21.0	16640	70000	48.0	1941	24660	21.3	19360[a]	79710[b]	47.1
+ % =			22%	8.6%	-4.8%	+ % =			19%	7%	-6.2%
1944			20300	76000[x]	45.7[x]	1944			23000	85000[x]	44.2[x]

ø based on output capacity.

x figure for 1943.

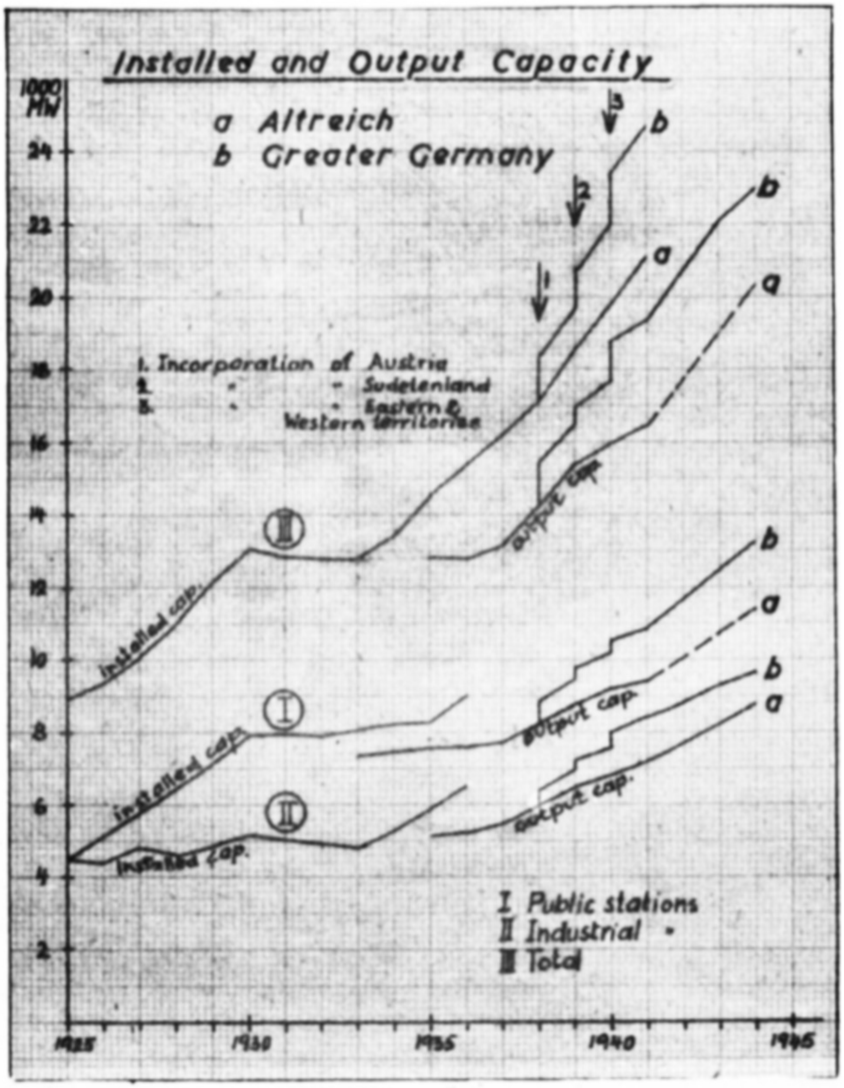
a) b) of this in:	hard coal,	brown coal,	water power,	other stations
a	45.5%	30.4%	14.4%	9.7%
b	40.0%	36.0%	14.9%	9.1%

Figure 11.27: BIOS 342. *The German Wartime Electricity Supply: Conditions, Development, Trends.*

BIOS 342. ***The German Wartime Electricity Supply: Conditions, Development, Trends.***

from the political side, on the supply undertakings, which were publicly accused of having over-invested in 1929 for their own benefit and of having thus misused public funds. This opinion was held even in the highest quarters and, when the quota system for steel was introduced in 1937, the electricity supply industry was at first refused an allocation. This refusal was, perhaps, the alarm signal for the supply undertakings, which now realised that their plant reserves had shrunk and that in the future it might not be at all easy, owing to the shortage of raw materials, to obtain the now necessary permission to build new plant.

Diagram 2



The electricity supply industry reacted quickly, but too late. As a result of numerous interventions and petitions a steel quota was allocated for power supply purposes in the autumn of 1937, but this was adequate neither to enable the supply industry to make good the plant shortage resulting from their own shortsightedness, nor to

Figure 11.28: BIOS 342. *The German Wartime Electricity Supply: Conditions, Development, Trends.*

Postwar transferred German-language documentation

In September 1945, R. P. Linstead and T. J. Betts, the British and American chairs of the Combined Intelligence Objectives Subcommittee (CIOS), bragged about the acquisition and processing of "thousands of bags" of German technical documents from up to 3377 targeted locations and scientists [AFHRA A5186 electronic version pp. 904–1026, Ch. 4, pp. 30, 32–33]:

> This file of CAFT Assessment Reports, giving details on 3,377 assessed targets is probably unique in the European Theatre. It is not a target list in the usual sense of the word, for it is not compiled from intelligence sources and therefore based on inferences regarding what should be found at the target. This file will doubtlessly serve as a primary source for target investigations in Germany for many months to come. [...]
>
> The Secretariat was responsible for the processing and despatch of thousands of bags of documents evacuated by CIOS investigators. It published accession lists giving the brief title of each document, thereby informing all concerned of the nature of documents temporarily available in the London area.

In fact, the United States transferred over 111,000 tons of German-language research documentation within just a three month period to one location (see p. 5258). Considering that the occupation and document removal process lasted several years, that documents were harvested by many different organizations and sent to many different locations, and that similar processes were carried out not just by the United States but also the United Kingdom, France, and Soviet Union, the total amount of transferred technical documents was almost certainly well over 111,000 tons—probably many multiples of that figure, likely over 1,000,000 tons of German technical documents.

The U.S. government then gave U.S. companies such as Bell Laboratories private access to captured German-language documentation [Gimbel 1990a, pp. 68, 71]:

> All of the letters asked for assistance in the recruitment of personnel whom OTS proposed to employ and send to Germany, but letters that went to private firms, such as the Bell Telephone Laboratories, also asked if the firms would be willing and able to send people to Washington for two or three months at company expense to analyze and index "an immense backlog of German technical documents" already on hand. Such "without compensation" (WOC) industrial representatives, who would obviously be in a position to benefit their employers directly, were promised "office space, secretarial and typing help, reproducing facilities, as well as the necessary access to all reports and documents"...
>
> Experts who volunteered would benefit by being the first to scrutinize the material. They could, in fact, use the original German materials for preparing professional articles that OTS would include in a "forthcoming Government Compendium of German wartime technology." Obviously—but apparently this was never stated explicitly—they could also apply what they found to their firms' research or use it in any other way that the firms and agencies that released them and paid them desired.*

> [...] As a matter of fact, the project was never completed and the proposed compendium never appeared, with the result that individuals and firms got private access to "intellectual reparations" that were originally intended for dissemination to the general public. [...]
>
> *For example, one of Bell Laboratories' people was spending half-time in Washington to go over technical literature gathered by OTS "and search for reports that might be of interest to the Laboratories."

For relevant documents, see p. 2967 and many other documents in Section B.5.

Similarly, after the war hundreds of thousands of patents from German-speaking inventors were transferred to the United States. The seizure of the patents by the United States was covered in a number of contemporary newspaper articles, such as the following examples:

To Keep German Patents: Alien Property Custodian Will Avert Return to Reich Owners [NYT 1945-06-06 p. 11]:

> James E. Markham, Alien Property Custodian, said today that every effort would be made to prevent German-controlled-corporations and patents, seized during the war, from returning to German hands.

German Patents To Aid U.S. Plants [NYT 1946-03-14 p. 44]:

> American industry will benefit substantially as a result of the quantities of patents and manufacturing information seized by the American technical group in the United States zone of occupation in Germany and the vast amount of information obtained by the first American technical expedition in the Russian zone, Robert B. MacMullin, chief investigator of the technical industrial intelligence branch of the Department of Commerce, said yesterday[...]
>
> More than 4,000 documents covering a multiplicity of processes and scientific data have been prepared for selection alike by the corporations and the small businessman, he said and two-thirds of those included the German data. The Department of Commerce ultimately, Mr. MacMullin continued, expects to offer 100,000 of such documents, disseminating information hitherto known only to enemy countries.
>
> These patents, Mr. MacMullin emphasized, will enable American manufacturers in many instances to replace their lines with enemy developments.

100,000 German Patents Available [NYT 1946-08-09 p. 8]:

> James E. Markham, Alien Property Custodian, said today that more than 100,000 German patents seized during the war will become available, royalty-free, to countries that signed the patent accord in London last week.

U.S. Said To Seize German Patents: Russian Says That Billions in Reparations Have Been Taken Since Occupation [NYT 1947-02-16 p. 3]:

> An article in [the Soviet paper] The New Times said today that the United States and Britain already had taken from Germany the richest war booty ever obtained by victorious powers. [...]
>
> The longest article of all asserted that the two countries already had extracted "many billions of dollars" worth of reparations from Germany in the form of patents, technical information and the services of scientists and technicians.
>
> Mr. Rubenstein, author of the article, said that although the United States and Britain had not set a total of the reparations due them from Germany, "removal of reparations by them in various forms has been carried on since the beginning of the occupation." [...]
>
> Mr. Rubenstein asserted that in obtaining German patents United States capitalists had "the active help" of United States occupational authorities and the Government in Washington.
>
> "Expert engineers and qualified German scientific workers" were described as appearing in German research institutions, laboratories and industrial plants, learning all the secrets, condensing them and filming them for transmission to the United States.
>
> The writer said that hundreds of United States technicians had been sent to Germany to learn the secrets of her industry and hundreds of German and Austrian scientists had been sent to the United States to do research work and eventually become citizens.

German Patents List: Applications Filed in War Years Available for Allied Countries [NYT 1950-07-02 p. E7]:

> The Office of Technical Services of the Department of Commerce issues a new "finding" guide to wartime German patent applications, which may now be used freely in Allied countries. The guide is a subject index to the 200,000 German applications filed in the Berlin Patent Office over the period 1940–1945.
>
> The Association for the Diffusion of Documentation, Paris, France, compiled the finding guide, now translated for American use. The association is offering, at $3 each, microfilm copies of complete patent applications. The fee not only covers the preparation of the reproduction but the task of locating the application on some one thousand microfilm reels on which the German applications were copied.
>
> Copies of the German patent application finding guide, entitled "Subject Outline of the Unpublished Applications for Patents Filed at the German Patent Office 1940–1945," are available on request from the Office of Technical Services, United States Department of Commerce, Washington.

While early newspaper articles mentioned 100,000–200,000 seized German patents, the actual total appears to have been over 750,000. A 21 April 1947 letter from the Technical Industrial Intelligence Division to R. P. Isaacs stated [NARA RG 40, Entry UD-75, Box 12, Folder Technical Inquiries - H -, Technical Industrial Intelligence Division to R. P. Isaacs, 21 April 1947]:

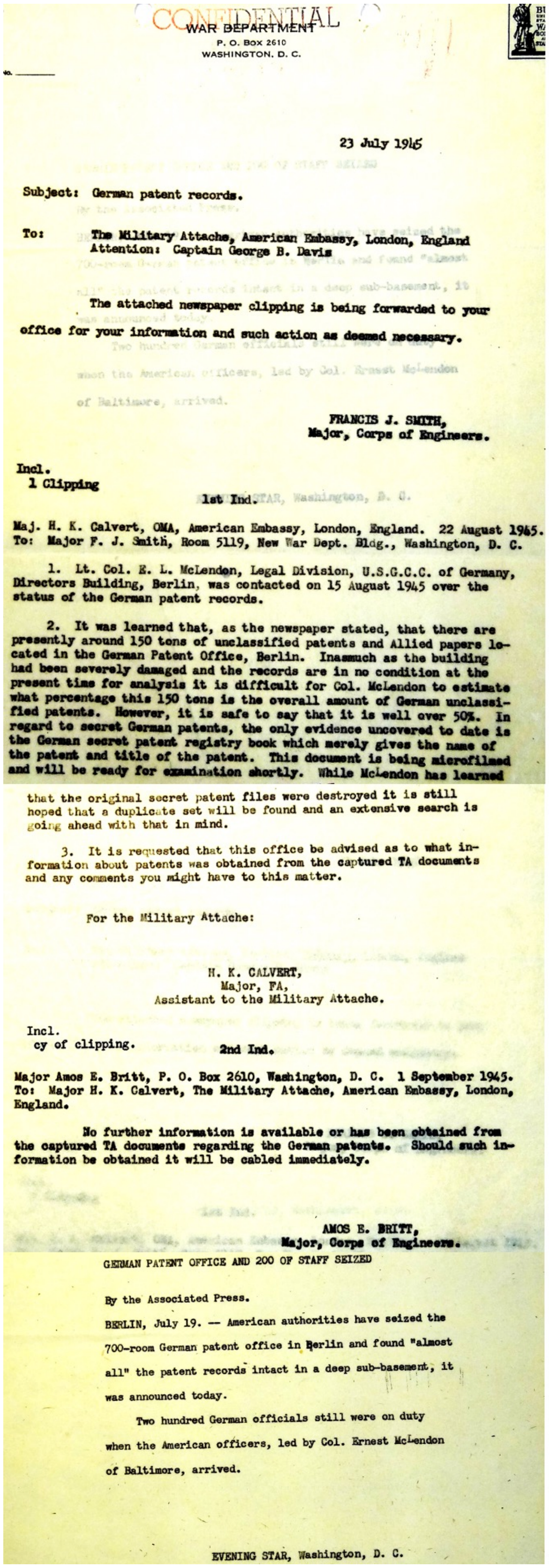
> You will probably be interested in knowing that single copies of almost all German patents issued during the war years up to V-E Day are on numerical file in the Patent Office Library in the Commerce Building. These files of German patents were seized at the Berlin Patent Office and evacuated to the United States in the spring of 1946. The German Patent No. 750986 is the latest one available. Photostatic copies of these patents may be ordered at 20 cents per page from the U.S. Patent Office, Washington 25, D.C.

See Figs. 11.30–11.31 for this complete document. If German Patent No. 750986 was the last known patent by the end of the war, the United States presumably would have possessed and asserted rights to German patents all the way back to the first one. See also the document in Fig. 11.50.

In fact, the total number of seized patents was likely even higher, since it would have included:

- Granted German patents up to at least number 750986.
- Granted Austrian patents.
- Patent applications filed but not granted in Germany by the end of the war.
- Patent applications filed but not granted in Austria by 1938.
- Secret classified German and Austrian patents.
- Patents and patent applications filed in other countries by German and Austrian inventors.

In addition to the United States, the Soviet Union seized huge numbers of German patents, and other countries may have as well.



~~CONFIDENTIAL~~

WAR DEPARTMENT
P. O. Box 2610
WASHINGTON, D. C.

No. ______

23 July 1945

Subject: German patent records.

To: The Military Attache, American Embassy, London, England
Attention: Captain George B. Davis

The attached newspaper clipping is being forwarded to your office for your information and such action as deemed necessary.

FRANCIS J. SMITH,
Major, Corps of Engineers.

Incl.
1 Clipping

1st Ind.

Maj. H. K. Calvert, OMA, American Embassy, London, England. 22 August 1945.
To: Major F. J. Smith, Room 5119, New War Dept. Bldg., Washington, D. C.

1. Lt. Col. E. L. McLendon, Legal Division, U.S.G.C.C. of Germany, Directors Building, Berlin, was contacted on 15 August 1945 over the status of the German patent records.

2. It was learned that, as the newspaper stated, that there are presently around 150 tons of unclassified patents and Allied papers located in the German Patent Office, Berlin. Inasmuch as the building had been severely damaged and the records are in no condition at the present time for analysis it is difficult for Col. McLendon to estimate what percentage this 150 tons is the overall amount of German unclassified patents. However, it is safe to say that it is well over 50%. In regard to secret German patents, the only evidence uncovered to date is the German secret patent registry book which merely gives the name of the patent and title of the patent. This document is being microfilmed and will be ready for examination shortly. While McLendon has learned that the original secret patent files were destroyed it is still hoped that a duplicate set will be found and an extensive search is going ahead with that in mind.

3. It is requested that this office be advised as to what information about patents was obtained from the captured TA documents and any comments you might have to this matter.

For the Military Attache:

H. K. CALVERT,
Major, FA,
Assistant to the Military Attache.

Incl.
cy of clipping.

2nd Ind.

Major Amos E. Britt, P. O. Box 2610, Washington, D. C. 1 September 1945.
To: Major H. K. Calvert, The Military Attache, American Embassy, London, England.

No further information is available or has been obtained from the captured TA documents regarding the German patents. Should such information be obtained it will be cabled immediately.

AMOS E. BRITT,
Major, Corps of Engineers.

GERMAN PATENT OFFICE AND 200 OF STAFF SEIZED

By the Associated Press.

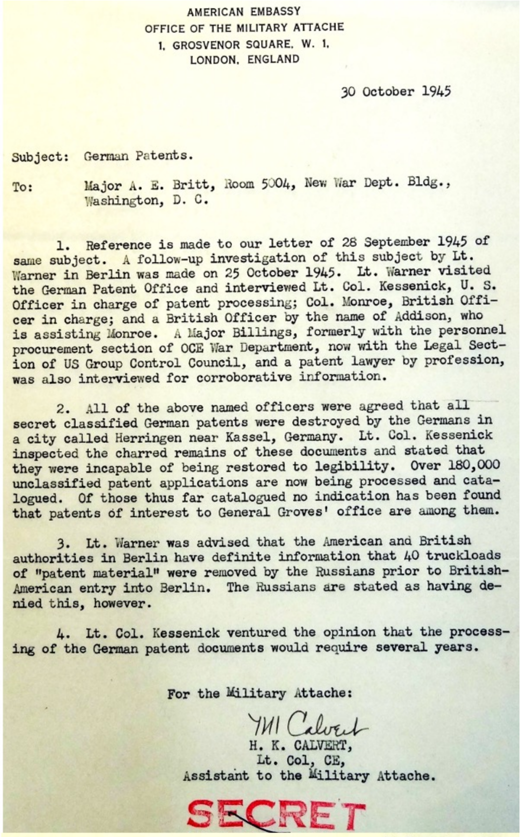
BERLIN, July 19. — American authorities have seized the 700-room German patent office in Berlin and found "almost all" the patent records intact in a deep sub-basement, it was announced today.

Two hundred German officials still were on duty when the American officers, led by Col. Ernest McLendon of Baltimore, arrived.

EVENING STAR, Washington, D. C.

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 169, Folder 32.21 Germ. Res. Gen.



AMERICAN EMBASSY
OFFICE OF THE MILITARY ATTACHE
1, GROSVENOR SQUARE, W. 1.
LONDON, ENGLAND

30 October 1945

Subject: German Patents.

To: Major A. E. Britt, Room 5004, New War Dept. Bldg., Washington, D. C.

1. Reference is made to our letter of 28 September 1945 of same subject. A follow-up investigation of this subject by Lt. Warner in Berlin was made on 25 October 1945. Lt. Warner visited the German Patent Office and interviewed Lt. Col. Kessenick, U. S. Officer in charge of patent processing; Col. Monroe, British Officer in charge; and a British Officer by the name of Addison, who is assisting Monroe. A Major Billings, formerly with the personnel procurement section of OCE War Department, now with the Legal Section of US Group Control Council, and a patent lawyer by profession, was also interviewed for corroborative information.

2. All of the above named officers were agreed that all secret classified German patents were destroyed by the Germans in a city called Herringen near Kassel, Germany. Lt. Col. Kessenick inspected the charred remains of these documents and stated that they were incapable of being restored to legibility. Over 180,000 unclassified patent applications are now being processed and catalogued. Of those thus far catalogued no indication has been found that patents of interest to General Groves' office are among them.

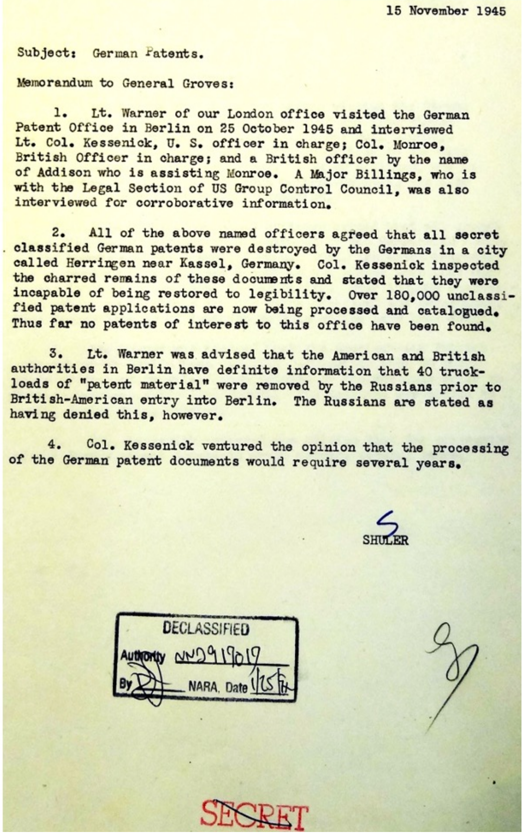
3. Lt. Warner was advised that the American and British authorities in Berlin have definite information that 40 truckloads of "patent material" were removed by the Russians prior to British-American entry into Berlin. The Russians are stated as having denied this, however.

4. Lt. Col. Kessenick ventured the opinion that the processing of the German patent documents would require several years.

For the Military Attache:

HK Calvert
H. K. CALVERT,
Lt. Col, CE,
Assistant to the Military Attache.

~~SECRET~~



15 November 1945

Subject: German Patents.

Memorandum to General Groves:

1. Lt. Warner of our London office visited the German Patent Office in Berlin on 25 October 1945 and interviewed Lt. Col. Kessenick, U. S. officer in charge; Col. Monroe, British Officer in charge; and a British officer by the name of Addison who is assisting Monroe. A Major Billings, who is with the Legal Section of US Group Control Council, was also interviewed for corroborative information.

2. All of the above named officers agreed that all secret classified German patents were destroyed by the Germans in a city called Herringen near Kassel, Germany. Col. Kessenick inspected the charred remains of these documents and stated that they were incapable of being restored to legibility. Over 180,000 unclassified patent applications are now being processed and catalogued. Thus far no patents of interest to this office have been found.

3. Lt. Warner was advised that the American and British authorities in Berlin have definite information that 40 truckloads of "patent material" were removed by the Russians prior to British-American entry into Berlin. The Russians are stated as having denied this, however.

4. Col. Kessenick ventured the opinion that the processing of the German patent documents would require several years.

S
SHULER

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By NARA, Date 1/25/

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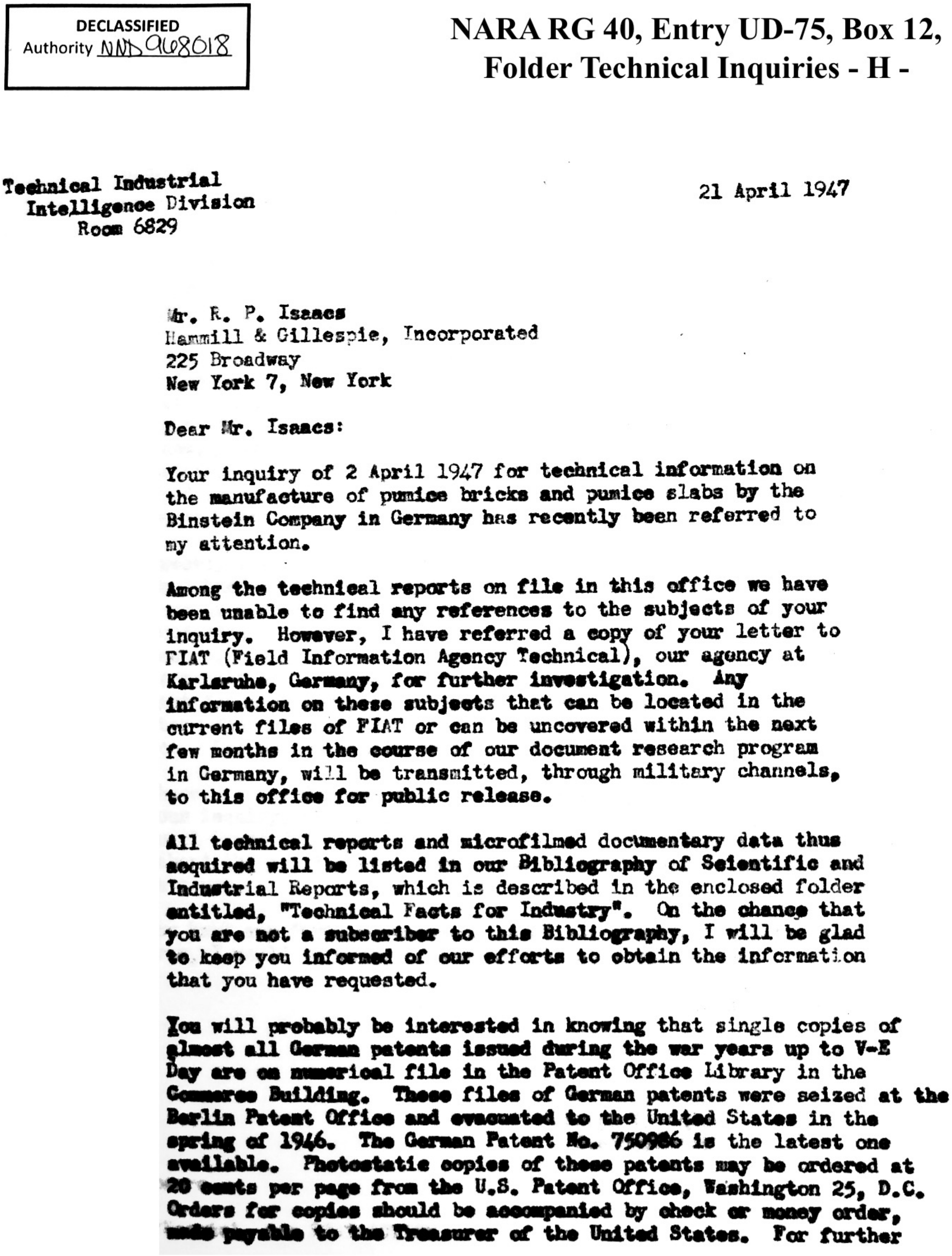
Figure 11.29: [NARA RG 77, Entry UD-22A, Box 169, Folder 32.21 Germ. Res. Gen.]



DECLASSIFIED
Authority NND968018

NARA RG 40, Entry UD-75, Box 12, Folder Technical Inquiries - H -

Technical Industrial
Intelligence Division
Room 6829

21 April 1947

Mr. R. P. Isaacs
Hammill & Gillespie, Incorporated
225 Broadway
New York 7, New York

Dear Mr. Isaacs:

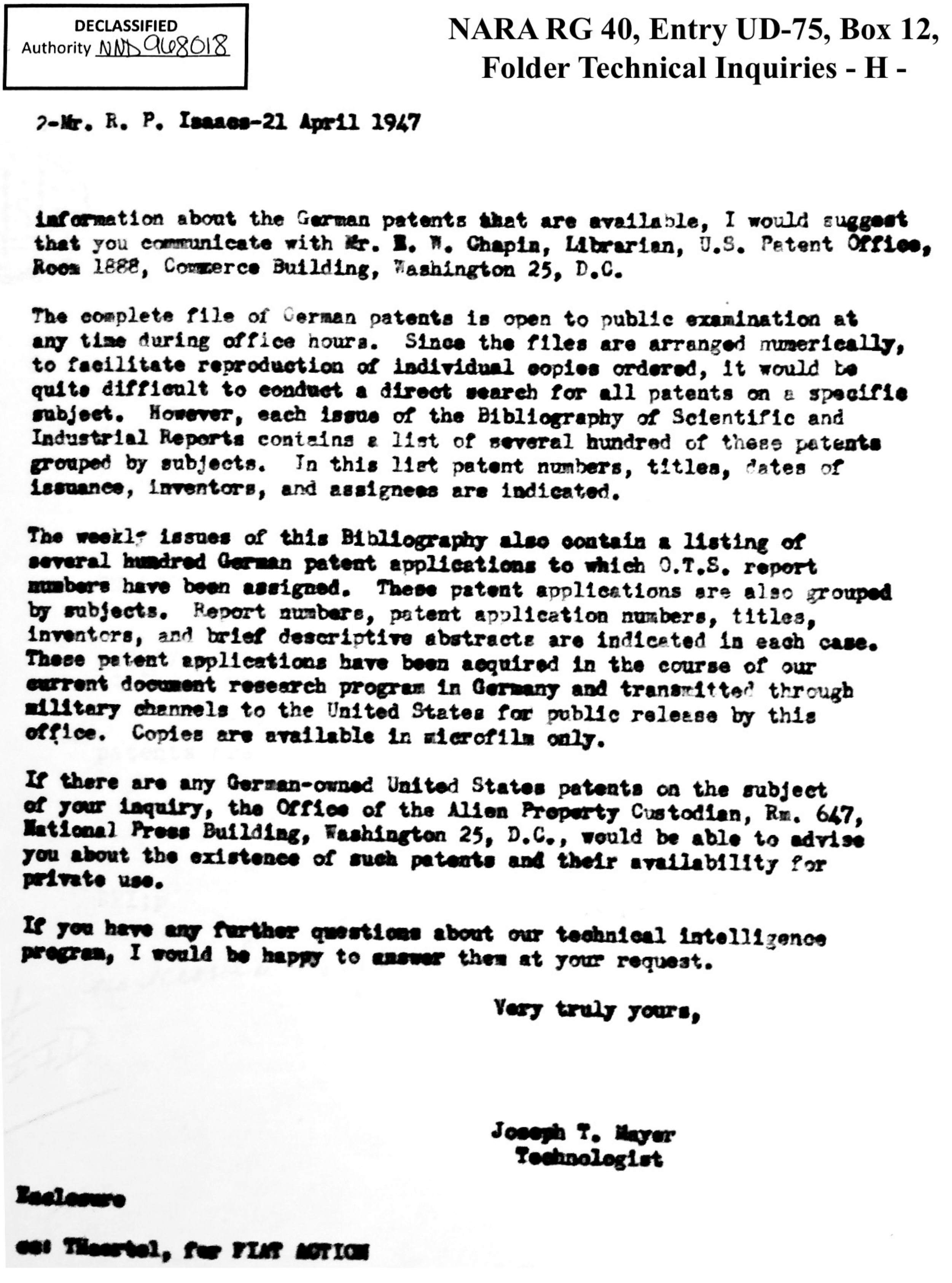
Your inquiry of 2 April 1947 for technical information on the manufacture of pumice bricks and pumice slabs by the Binstein Company in Germany has recently been referred to my attention.

Among the technical reports on file in this office we have been unable to find any references to the subjects of your inquiry. However, I have referred a copy of your letter to FIAT (Field Information Agency Technical), our agency at Karlsruhe, Germany, for further investigation. Any information on these subjects that can be located in the current files of FIAT or can be uncovered within the next few months in the course of our document research program in Germany, will be transmitted, through military channels, to this office for public release.

All technical reports and microfilmed documentary data thus acquired will be listed in our Bibliography of Scientific and Industrial Reports, which is described in the enclosed folder entitled, "Technical Facts for Industry". On the chance that you are not a subscriber to this Bibliography, I will be glad to keep you informed of our efforts to obtain the information that you have requested.

You will probably be interested in knowing that single copies of almost all German patents issued during the war years up to V-E Day are on numerical file in the Patent Office Library in the Commerce Building. These files of German patents were seized at the Berlin Patent Office and evacuated to the United States in the spring of 1946. The German Patent No. 750986 is the latest one available. Photostatic copies of these patents may be ordered at 20 cents per page from the U.S. Patent Office, Washington 25, D.C. Orders for copies should be accompanied by check or money order, made payable to the Treasurer of the United States. For further

Figure 11.30: After the war, more than 750,000 patents from German-speaking inventors were transferred to the United States [NARA RG 40, Entry UD-75, Box 12, Folder Technical Inquiries - H -, Technical Industrial Intelligence Division to R. P. Isaacs, 21 April 1947].



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Authority NND968018

NARA RG 40, Entry UD-75, Box 12, Folder Technical Inquiries - H -

2-Mr. R. P. Isaacs-21 April 1947

information about the German patents that are available, I would suggest that you communicate with Mr. E. W. Chapin, Librarian, U.S. Patent Office, Room 1888, Commerce Building, Washington 25, D.C.

The complete file of German patents is open to public examination at any time during office hours. Since the files are arranged numerically, to facilitate reproduction of individual copies ordered, it would be quite difficult to conduct a direct search for all patents on a specific subject. However, each issue of the Bibliography of Scientific and Industrial Reports contains a list of several hundred of these patents grouped by subjects. In this list patent numbers, titles, dates of issuance, inventors, and assignees are indicated.

The weekly issues of this Bibliography also contain a listing of several hundred German patent applications to which O.T.S. report numbers have been assigned. These patent applications are also grouped by subjects. Report numbers, patent application numbers, titles, inventors, and brief descriptive abstracts are indicated in each case. These patent applications have been acquired in the course of our current document research program in Germany and transmitted through military channels to the United States for public release by this office. Copies are available in microfilm only.

If there are any German-owned United States patents on the subject of your inquiry, the Office of the Alien Property Custodian, Rm. 647, National Press Building, Washington 25, D.C., would be able to advise you about the existence of such patents and their availability for private use.

If you have any further questions about our technical intelligence program, I would be happy to answer them at your request.

Very truly yours,

Joseph T. Mayer
Technologist

Enclosure

cc: Thoertel, for FIAT ACTION

Figure 11.31: After the war, more than 750,000 patents from German-speaking inventors were transferred to the United States [NARA RG 40, Entry UD-75, Box 12, Folder Technical Inquiries - H -, Technical Industrial Intelligence Division to R. P. Isaacs, 21 April 1947].

A detailed 1946 news article provided a great deal of contemporary insight into how all of these German-language materials were used by the U.S. government and industry [Charles Walker 1946]:

> If you always thought of war secrets—as who hasn't?—as coming in sixes and sevens, as a few items of information readily handed on to the properly interested authorities, it may interest you to learn that the war secrets in this collection run into the thousands, that the mass of documents is mountainous, and that there was never before been anything quite comparable to it.
>
> The collection is today chiefly in three places: Wright Field (Ohio), the Library of Congress, and the Department of Commerce. Wright Field is working from a documents "mother lode" of fifteen hundred tons. In Washington, the Office of Technical Services (which has absorbed the Office of the Publication Board, the government agency originally set up to handle the collection) reports that tens of thousands of tons of material are involved. It is estimated that over a million separate items must be handled, and that they, very likely, contain practically all the scientific, industrial and military secrets of Nazi Germany.
>
> One Washington official has called it "the greatest single source of this type of material in the world, the first orderly exploitation of an entire country's brain-power." [...]
>
> The German Patent Office put some of its most secret patents down a sixteen-hundred-foot mine shaft at Heringen, then piled liquid oxygen, in cylinders, on top of them. When the American Joint Intelligence Objectives team found them, it was doubtful that they could be saved. They were legible, but in such bad shape that a trip to the surface would make them disintegrate. Photo equipment and a crew were therefore lowered into the shaft and a complete microfilm record made of the patents there. [...]
>
> For the war secrets, which conventionally used to be counted in scores, will run to three-quarters of a million separate documentary items (two-thirds of them on aeronautics) and will require several years and several hundreds of people to screen and prepare them for wide public use.
>
> Today translators and abstracters of the Office of Technical Services, successor to the OPB, are processing them at the rate of about a thousand a week. Indexing and cataloguing the part of the collection which will be permanently kept may require more than two millions cards; and at Wright Field the task is so complicated that electric punch-card machines are to be installed. A whole new glossary of German-English terms has had to be compiled—something like forty thousand words on new technical and scientific items.
>
> With so many documents, it has, of course, been impossible because of time and money limitations to reprint or reproduce more than a very few. To tell the public what is available, therefore, the OTS issues a bibliography weekly. This contains the newest war secrets information as released—with titles, prices of copies currently available or to be made up, and an abstract of contents.
>
> The original document, or the microfilm copy, is then generally sent to the Library of Congress, which is now the greatest depository. To make them more easily accessible to the public, the Library sends copies, when enough are available, to about 125 so-called "depository" libraries throughout the United States.

> And is the public doing anything with these one-time war secrets? It is—it is eating them up. As many as twenty thousand orders have been filled in a month, and the order rate is now a thousand items a day. Scientists and engineers declare that the information is "cutting years from the time we would devote to problems already scientifically investigated." And American business men...! A run through the Publication Board's letters file shows the following:
>
> The Bendix Company in South Bend, Indiana, writes for a German patent on the record player changer "with records stacked above the turntable." Pillsbury Mills wants to have what is available on German flour and bread production methods. Kendall Manufacturing Company ("Soapine") wants insect repellent compounds. Pioneer Hi-Bred Corn Company, Iowa, asks about "interrogation of research workers at the agricultural high school at Hohenheim." Pacific Mills requests I. G. Farbenindustrie's water-repellent, crease-resistant finish for spun rayon. The Polaroid Company would like something on "the status of exploitation of photography and optics in Germany." (There are, incidentally, ten to twenty thousand German patents yet to be screened.)
>
> The most insatiable customer is Amtorg, the Soviet Union's foreign trade organization. One of its representatives walked into the Publication Board office with the bibliography in hand and said, "I want copies of everything." The Russians sent one order in May for $5,594.00 worth—two thousand separate war secrets reports. In general, they buy every report issued. Americans, too, think there is extraordinarily good prospecting in the war secrets lode. Company executives practically park on the OTS's front doorstep, wanting to be first to get hold of a particular report on publication. Some information is so valuable that to get it a single day ahead of a competitor, may be worth thousands of dollars. But the OTS takes elaborate precautions to be sure that no report is ever available to anyone before general public release.
>
> After a certain American aircraft company had ordered a particular captured war document, it was queried as to whether the information therein had made it or saved it any money. The cost of the report had been a few dollars. The company answered: "Yes—at least a hundred thousand dollars."
>
> A research head of another business firm took notes for three hours in the OTS offices one day. "Thanks very much," he said, as he stood to go, "the notes from these documents are worth at least half a million dollars to my company."
>
> And after seeing the complete report on the German synthetic fiber industry, one American manufacturer remarked:
>
> *This report would be worth twenty million dollars to my company if it could have it exclusively.*
>
> Of course you, and anybody else, can now have it, and lots of other once secret information, for a few dollars. All the war secrets, as released, are completely in the public domain.

Konrad Adenauer, the first post-war Chancellor of West Germany, summarized the extent of the continuing damage to Germany in his memoirs [Adenauer 1966, pp. 147–148]:

> Let me mention the question of German patents in this context. You know that all German patents were released. At the end of 1948 the director of the American Office for Technical Services, Mr. John Green, gave the press a report on his activities, which were concerned with the exploitation of German patents and industrial secrets. What strikes one in this report is the fact that AMTORG was the keenest purchaser. That is Moscow's foreign trade organization. During one month alone the Russians bought more than two thousand Wehrmacht reports on secret German weapons for which they paid six thousand dollars. According to a statement made by an American expert the patents formerly belonging to IG Farben have given the American chemical industry a lead of at least ten years. The damage thus caused to the German economy is huge and cannot be assessed in figures. It is extraordinarily regrettable that the new German inventions cannot be protected either, because Germany is not a member of the Patent Union. Britain has declared that it will respect German inventions regardless of what the peace treaty may say. But America has refused to issue such a declaration. German inventors are therefore not in a position to exploit their own inventions. This puts a considerable brake on German economic development.

Figure 11.32 presents a photo of German and U.S. scientists sorting and translating "tons" of captured German and Austrian technical documents at Wright Field, Ohio, in 1946.

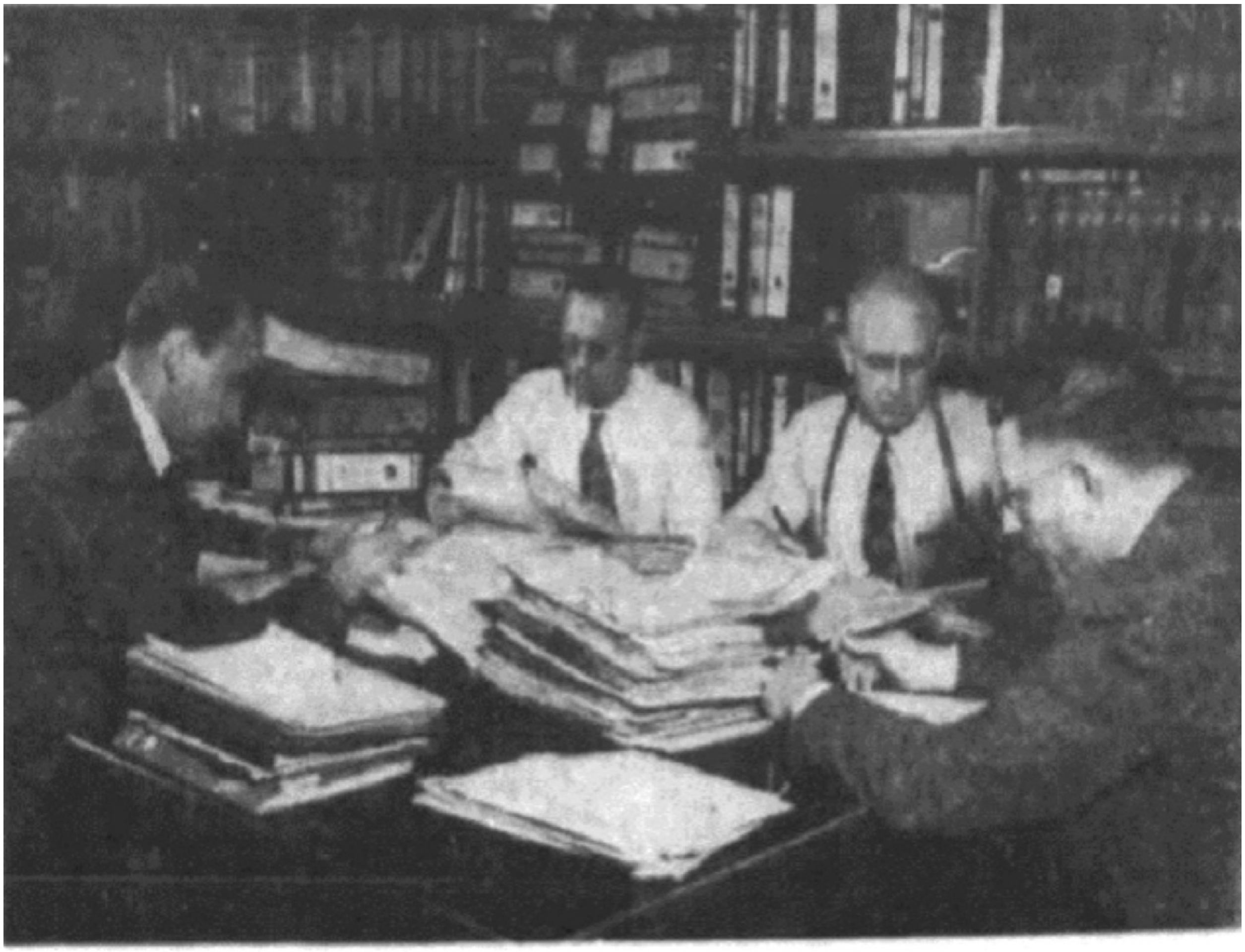
Figures 11.33–11.34 show further examples of rows and rows of bookcases filled with boxes of reports taken from and written about German and Austrian science and engineering programs, collected after World War II and stored at the U.K. Imperial War Museum in Duxford.

One key conduit for the transfer of published and unpublished scientific information out of the German-speaking world was Ján Ludvík Hoch (1923–1991), who was born in Czechoslovakia, moved to the U.K. during the war, and changed his name to Robert Maxwell, by which he ultimately became famous. Because Hoch/Maxwell was fluent in many languages, young, intelligent, and personally extremely ambitious, he found strong support in the British military and intelligence communities during and after the war. Biographer John Preston summarized his role in transferring scientific information [Preston 2021, pp. 20, 22, 25–27]:

> Maxwell's first job in Germany was at the Intelligence Corps headquarters at Iserlohn, 250 miles from Berlin. Along with the other British officers working there, he was given a pseudonym to protect his identity. For the next six months, he became 'Captain Stone', part of a team interrogating German prisoners and others who had worked for the Nazi regime. [...]
>
> Berlin had now been divided into four zones: the French, the British, the Russian and the American. Fluent in Russian, English, and French [as well as his native Czech and German], Maxwell could easily pass from zone to zone without attracting attention. As he'd proved before, he also had a natural bent for subterfuge. All this made him a highly prized asset as far as British Intelligence was concerned. [...]
>
> 'One of my secret jobs was to find out what the Russians were up to, stripping East German industries,' Maxwell told Goodman. [...]
>
> Maxwell also went on a number of undercover trips to Czechoslovakia, then teetering on the brink of a communist takeover—it would become part of the Eastern Bloc in February 1948. According to documents in the Secret Service archive in Prague, Maxwell's

> presence in the country soon attracted the suspicions of the Czech Ministry of the Interior[....]
>
> Springer-Verlag had published books by most of the world's leading scientists, including Albert Einstein and Max Born, the father of quantum mechanics. They also published a large range of scientific journals. The beauty of the business was that the books and journals they produced had a captive readership: every library, every university, every scientific institute, wanted a copy. What's more, the scientists who wrote these books and journals were so thrilled to see their work in print that they scarcely expected to be paid anything in return. [...]
>
> No new academic research had been published during the war, and as a result, Springer had a colossal backlog of material. Sixty-three thousand books, along with tens of thousands of journals, had been removed from Berlin and stored in an enormous warehouse a hundred miles away to escape the Allied bombing. There was also a huge amount of scientific research conducted during the war that had never even been printed due to lack of paper.
>
> [...A]t the time German nationals were forbidden from making large shipments to other countries. Springer was convinced the demand was there. All over the world academics were dying to read about the latest research[....]
>
> In November 1947, 369 'large packets' were sent from Germany to London. By then, Maxwell had been demobbed from the army and had gone back to England to be with Betty and their baby son. He had also secured worldwide distribution rights to all of Springer-Verlag's publications. Four months later, 150 tons of books and another 150 tons of journals were loaded on to a goods train and taken to Bielefeld in western Germany. From there, a convoy of trucks brought them to London. These were followed by another enormous consignment of manuscripts—so large that seven railway carriages were needed to transport it[....]
>
> Where did Maxwell get the money from to set up in business? Certainly not from Ferdinand Springer, who was in no position to fund anything at the time. [...]
>
> Shortly before his death in 2000, Desmond Bristow, a former Intelligence Officer, spoke about MI6's relations with Maxwell: 'It was obvious that Maxwell had been doing odd things for MI6 in Germany, and he suggested we should subsidize him to buy a book business. He effectively became our agent. [...] I was certainly not aware of any other case of MI6 buying a business for anyone.'

After being placed in charge of a (mostly captured German) scientific publishing empire by the intelligence community, Hoch/Maxwell went on to enrich himself by wining and dining influential scientists to persuade them to publish more and more papers and to create more and more scientific journals [Buranyi 2017; Francis 2020; Sarkowski 2001]. Thus Hoch/Maxwell was a highly influential force in corrupting the scientific community from its historical emphasis on publishing quality over quantity to its modern obsession with endless quantity (and exorbitant journal and book prices) while abandoning most concerns about quality, originality, or even correctness (pp. 50–51, 2245–2250, 2262–2263). Although the details are murky, Hoch/Maxwell seems to have had other unsavory effects on society, a tradition that was apparently continued by part of his family and by his younger associate Jeffrey Epstein [p. 2251 and Preston 2021].



Tons of German documents referring to aeronautics are studied by technicians. Two men at left are German, two at right are American.

Figure 11.32: German and U.S. scientists sorting and translating “tons” of captured German and Austrian technical documents at Wright Field, Ohio, in 1946 [*Dayton Daily News*, 8 December 1946, p. 55]. See also p. 5263.

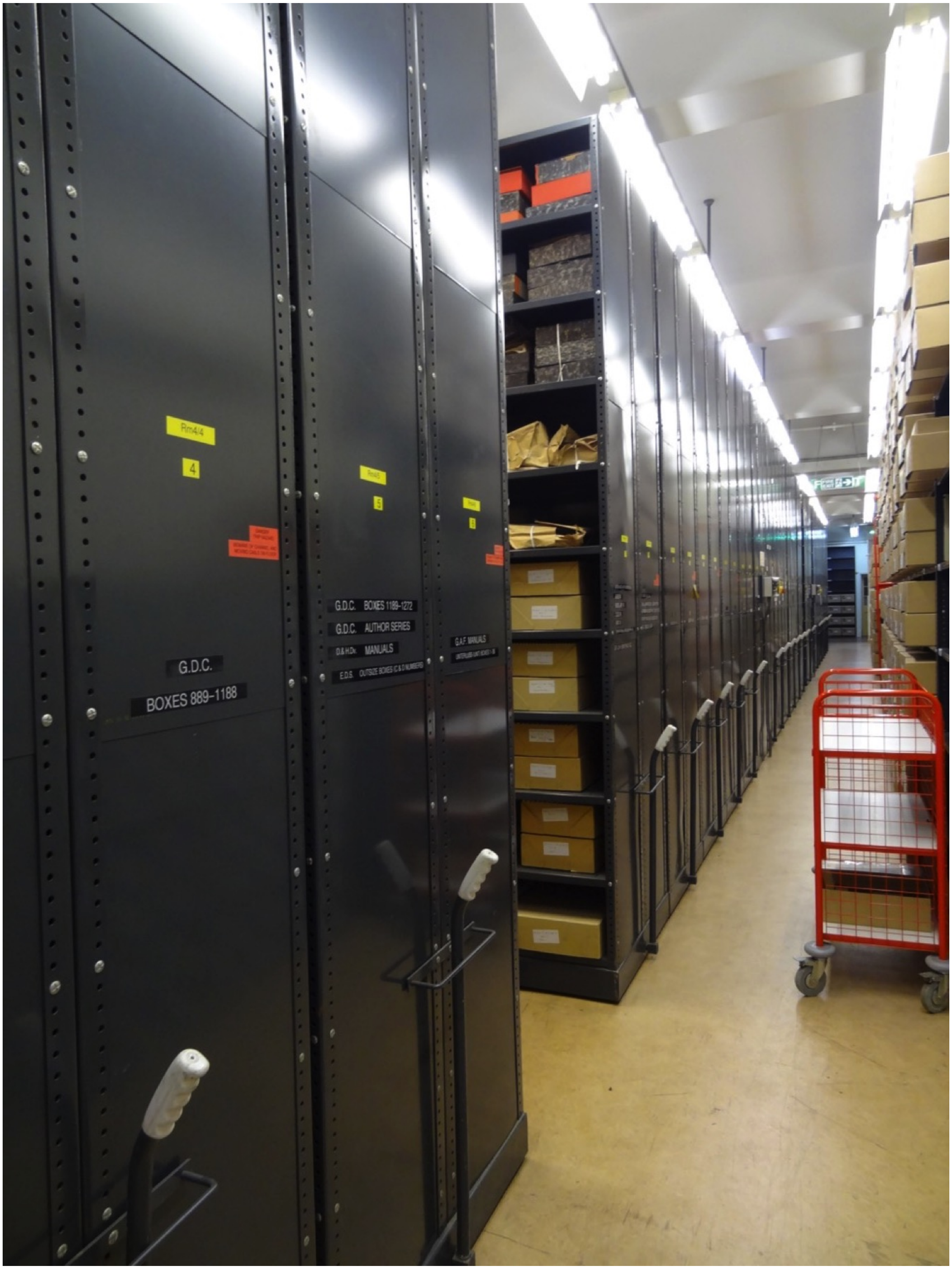

Rm4/4
4
G.D.C.
BOXES 889–1188
G.D.C. BOXES 1189–1272
G.D.C. AUTHOR SERIES
MANUALS
G.A.F. MANUALS

Figure 11.33: Bookcase aisles filled with boxes of reports taken from and written about German and Austrian science and engineering programs, collected after World War II and stored at the U.K. Imperial War Museum (Duxford).

BIOS A
BOX 6
BIOS A
BOX 9
BIOS A
BOX 10
BIOS A
BOX 15
BIOS A
BOX 16
BIOS A
BOX 21
BIOS A
BOX 22

Figure 11.34: Bookcase aisles filled with boxes of reports taken from and written about German and Austrian science and engineering programs, collected after World War II and stored at the U.K. Imperial War Museum (Duxford).

For historians, even worse than the Allied *removal* of German-language documents was the intentional and systematic Allied *destruction* of German-language documents. As shown in Figs. 11.35–11.36, postwar Allied reports explicitly discussed "the denial of certain archives, records, and papers to the Germans" by "the organized destruction of papers... which must not be permitted to fall into German hands after the departure of occupation forces" [NARA RG 40, Entry UD-75, Box 62, Report German Documents Conference].

Unfortunately, those plans for the wholesale destruction of historical documents were not only discussed but actually carried out. Michael Howard was an intelligence officer in the British T-Force, which investigated and removed vast amounts of German technology, including German documents. In two different sections of his memoir, he described the large-scale destruction of documents in the years and decades after the war, in order to forever bury the actual historical events [Howard 2010, pp. 253, 334]:

> From about 1948 the Control Commission for Germany began to destroy their files and documents, and this continued until 1956 when the remaining 240 tons were brought back to the UK. Then the Foreign Office set about them, employing mostly retired officials who had been given a brief, the details of which were never disclosed, but which did not leave much to chance. Today, less than two tons of those documents remain. It was a deliberate attempt to make the task of writing a complete history of a unit whose very name was not to be voiced in the public domain very difficult. Great care has been taken to prevent a cataloguing of what we took out, and above all to avoid setting a monetary value upon it. [...]
>
> The records and documents of the Control Commission for Germany [CCG], including those of T-Force, came ultimately under the aegis of the Foreign & Commonwealth Office, and in 1983 I corresponded with Ellie Blaney, head of the FCO Library and Records. From her I learned that a large quantity of CCG files, including those of T-Force, were destroyed in Germany between 1948 and 1956. The remainder, some 240 tons, were brought to the UK where the destruction continued unabated to the point where by 1986 less than two tons remained. Much of this material remained secret, even after forty years, and some remains so even today (in particular, I suspect, any that quantify the monetary value of the depredations of T-Force). It is still a sensitive and controversial subject.

What quantities of German documents were destroyed by the Allies?

What information did those documents contain that prompted the Allies to destroy them?

Were any copies or microfilms of those documents retained in any countries?

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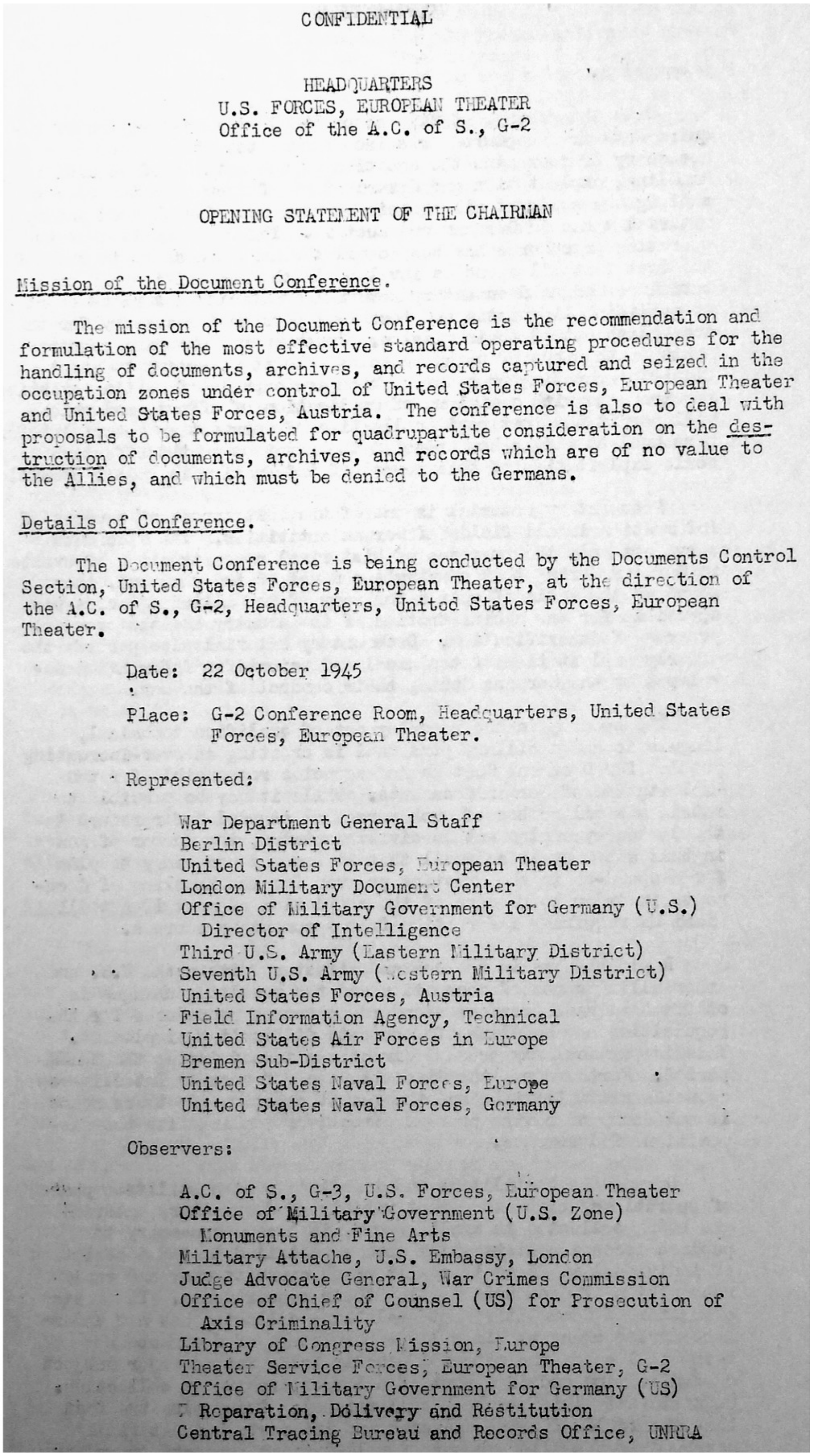
NARA RG 40, Entry UD-75, Box 62, Report
German Documents Conference p. 3



CONFIDENTIAL

HEADQUARTERS
U.S. FORCES, EUROPEAN THEATER
Office of the A.C. of S., G-2

OPENING STATEMENT OF THE CHAIRMAN

Mission of the Document Conference.

The mission of the Document Conference is the recommendation and formulation of the most effective standard operating procedures for the handling of documents, archives, and records captured and seized in the occupation zones under control of United States Forces, European Theater and United States Forces, Austria. The conference is also to deal with proposals to be formulated for quadrupartite consideration on the destruction of documents, archives, and records which are of no value to the Allies, and which must be denied to the Germans.

Details of Conference.

The Document Conference is being conducted by the Documents Control Section, United States Forces, European Theater, at the direction of the A.C. of S., G-2, Headquarters, United States Forces, European Theater.

Date: 22 October 1945

Place: G-2 Conference Room, Headquarters, United States Forces, European Theater.

Represented:

War Department General Staff
Berlin District
United States Forces, European Theater
London Military Document Center
Office of Military Government for Germany (U.S.)
  Director of Intelligence
Third U.S. Army (Eastern Military District)
Seventh U.S. Army (Western Military District)
United States Forces, Austria
Field Information Agency, Technical
United States Air Forces in Europe
Bremen Sub-District
United States Naval Forces, Europe
United States Naval Forces, Germany

Observers:

A.C. of S., G-3, U.S. Forces, European Theater
Office of Military Government (U.S. Zone)
  Monuments and Fine Arts
Military Attache, U.S. Embassy, London
Judge Advocate General, War Crimes Commission
Office of Chief of Counsel (US) for Prosecution of
  Axis Criminality
Library of Congress Mission, Europe
Theater Service Forces, European Theater, G-2
Office of Military Government for Germany (US)
  Reparation, Delivery and Restitution
Central Tracing Bureau and Records Office, UNRRA

Figure 11.35: Postwar Allied reports explicitly discussed "the denial of certain archives, records, and papers to the Germans" by "the organized destruction of papers... which must not be permitted to fall into German hands after the departure of occupation forces" [NARA RG 40, Entry UD-75, Box 62, Report German Documents Conference].

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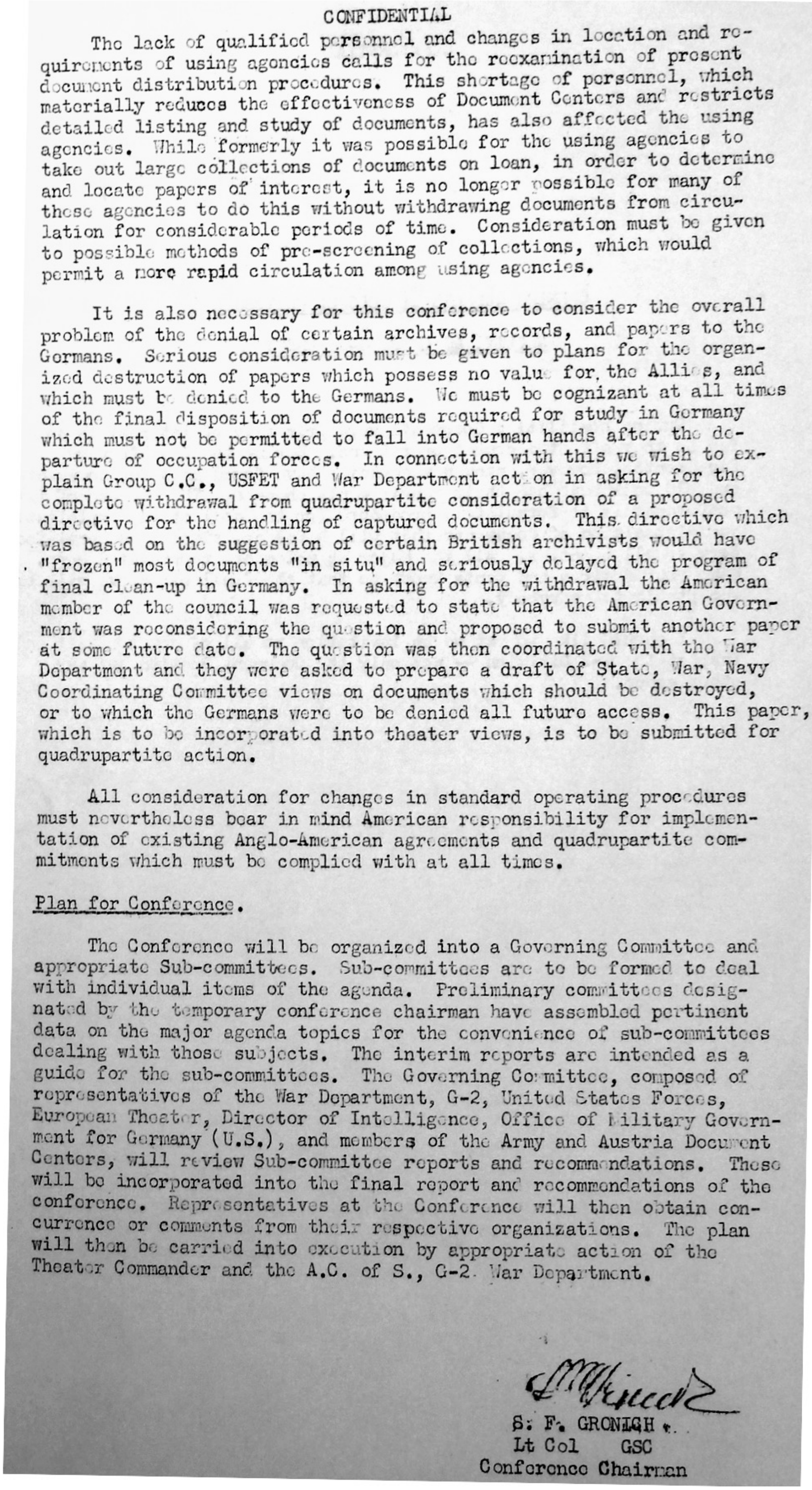
NARA RG 40, Entry UD-75, Box 62, Report German Documents Conference p. 5



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The lack of qualified personnel and changes in location and requirements of using agencies calls for the reexamination of present document distribution procedures. This shortage of personnel, which materially reduces the effectiveness of Document Centers and restricts detailed listing and study of documents, has also affected the using agencies. While formerly it was possible for the using agencies to take out large collections of documents on loan, in order to determine and locate papers of interest, it is no longer possible for many of these agencies to do this without withdrawing documents from circulation for considerable periods of time. Consideration must be given to possible methods of pre-screening of collections, which would permit a more rapid circulation among using agencies.

It is also necessary for this conference to consider the overall problem of the denial of certain archives, records, and papers to the Germans. Serious consideration must be given to plans for the organized destruction of papers which possess no value for the Allies, and which must be denied to the Germans. We must be cognizant at all times of the final disposition of documents required for study in Germany which must not be permitted to fall into German hands after the departure of occupation forces. In connection with this we wish to explain Group C.C., USFET and War Department action in asking for the complete withdrawal from quadrupartite consideration of a proposed directive for the handling of captured documents. This directive which was based on the suggestion of certain British archivists would have "frozen" most documents "in situ" and seriously delayed the program of final clean-up in Germany. In asking for the withdrawal the American member of the council was requested to state that the American Government was reconsidering the question and proposed to submit another paper at some future date. The question was then coordinated with the War Department and they were asked to prepare a draft of State, War, Navy Coordinating Committee views on documents which should be destroyed, or to which the Germans were to be denied all future access. This paper, which is to be incorporated into theater views, is to be submitted for quadrupartite action.

All consideration for changes in standard operating procedures must nevertheless bear in mind American responsibility for implementation of existing Anglo-American agreements and quadrupartite commitments which must be complied with at all times.

Plan for Conference.

The Conference will be organized into a Governing Committee and appropriate Sub-committees. Sub-committees are to be formed to deal with individual items of the agenda. Preliminary committees designated by the temporary conference chairman have assembled pertinent data on the major agenda topics for the convenience of sub-committees dealing with those subjects. The interim reports are intended as a guide for the sub-committees. The Governing Committee, composed of representatives of the War Department, G-2, United States Forces, European Theater, Director of Intelligence, Office of Military Government for Germany (U.S.), and members of the Army and Austria Document Centers, will review Sub-committee reports and recommendations. These will be incorporated into the final report and recommendations of the conference. Representatives at the Conference will then obtain concurrence or comments from their respective organizations. The plan will then be carried into execution by appropriate action of the Theater Commander and the A.C. of S., G-2, War Department.

S. F. GRONICH
Lt Col GSC
Conference Chairman

Figure 11.36: Postwar Allied reports explicitly discussed “the denial of certain archives, records, and papers to the Germans” by “the organized destruction of papers... which must not be permitted to fall into German hands after the departure of occupation forces” [NARA RG 40, Entry UD-75, Box 62, Report German Documents Conference].

Postwar transferred English-language documentation

Beginning even before the war ended and continuing for several years afterward, the United States and United Kingdom sent many thousands of government, university, and industrial investigators into areas formerly controlled by the Third Reich to interview German-speaking scientists and engineers. Under threat of imprisonment—for example at facilities such as "Dustbin" in Germany (p. 2126), "Halstead Exploitation Centre" in the United Kingdom (pp. 2127–2129), or Fort Hunt in the United States (pp. 2045, 4883)—or execution for war crimes, the scientists and engineers were "interrogated" (as the Allies openly called it) for anywhere from days to months at a time, or even repeatedly by different investigators for years after the war, and required to give the Allied investigators detailed explanations, documentation, and hardware for all of their work. In many cases, as described afterward by German-speaking scientists, Allied investigators did not even properly identify themselves, and simply seized all copies of a scientist's work, leaving no trace of where those copies ultimately went.

This policy applied to all research and development activities, not just those with military histories or potential. Allied investigators inspected and wrote detailed reports on the manufacture of items as diverse and as non-military as German:

- Planetarium projectors [BIOS 218].
- Harmonicas [BIOS 227].
- Ice skates [BIOS 506].
- Mattress springs [BIOS 601].
- Fishing rods [BIOS 1086].
- Spoons and forks [BIOS 1647].
- Sewing thread [FIAT 308–312].

Reports such as BIOS 769 (*German Manufacture of Sewing Machines, Garment Making Machines, Cloth Cutting Machines, Sewing Machine Needles*) gave detailed lists of documents and machines to be "evacuated" from Germany and Austria to the United States and United Kingdom for "research" purposes.

In fact, Allied investigators combed not only former Axis countries and territory for innovations they could harvest, but Switzerland as well, even though Switzerland had remained neutral and independent in the war. Numerous reports documented such investigations in Switzerland [e.g., BIOS 1417; CIOS XXXI-22; FIAT 306; FIAT 509]. According to the U.S. State Department's own documents, in 1946 the United States tried to forcibly conscript Jakob Ackeret (1898–1981), even though he was a Swiss citizen, had been born in Zurich, and was a well-known professor of aerodynamics who had been teaching at the university in Zurich since 1931 (pp. 5395–5396). Based on the number of published Allied reports openly documenting their own lack of regard for Swiss sovereignty and intellectual property, it seems unlikely that Ackeret's case was unique.

Even German doll makers and the stuffed toy manufacturer Steiff were exhaustively mined for any design or production secrets that could help U.S. and U.K. toy manufacturers out-compete them in the postwar market [Gimbel 1990a, pp. 165–166; BIOS 1371; BIOS 1622].

That brazen exploitation continued for many years after the war. Mattel's iconic Barbie doll (1959) was directly copied from the earlier German Bild Lilli doll created by Reinhard Beuthien (German, 1911–1970) and Max Weissbrodt (German, 19??–19??). Ruth Handler, the American who claimed to have "invented" Barbie, made millions of dollars, while the true inventors Beuthien and Weissbrodt were largely forgotten [Warnecke 1995]. Toward the end of her life, in 1997, Handler gave an interview in which she confessed that she had simply copied the Lilli doll [BBC 2023]:

> Ruth Handler and her husband Elliot founded the toy company Mattel in a garage workshop in Southern California in 1945; she came up with the idea for the Barbie doll, which was launched in 1959. [...]
>
> Handler had an epiphany, however, when the family went on holiday to Switzerland.
>
> RH: We passed a toy store and there in the window was a beautiful display of an adult-figured doll about 11.5, 12 inches tall, and this doll was sitting on a rope swing dressed in a very European ski clothes, and there were six or seven other of the same dolls each with a different European type ski outfit, where Barbara and I thought the dolls were just gorgeous. We just flipped—the doll's name was Lilli.
>
> A German doll based on a comic strip published in a national newspaper, Lilli was marketed to both children and adults. Even though she was then 15 [in 1956], Barbara wanted one.
>
> RH: She couldn't make up her mind which one she wanted because each ski outfit was different. And so I said to the lady in the store, "Can I buy this style and buy that costume?" And the lady in the store looked at me as if I was nuts. Only a crazy American would ask such a silly question. She said: "No, you want that costume, you buy that doll; you want this costume, you buy this doll." By then my mind had clicked.

Kransberg Castle, or "Dustbin" for 1945–1946 interrogations

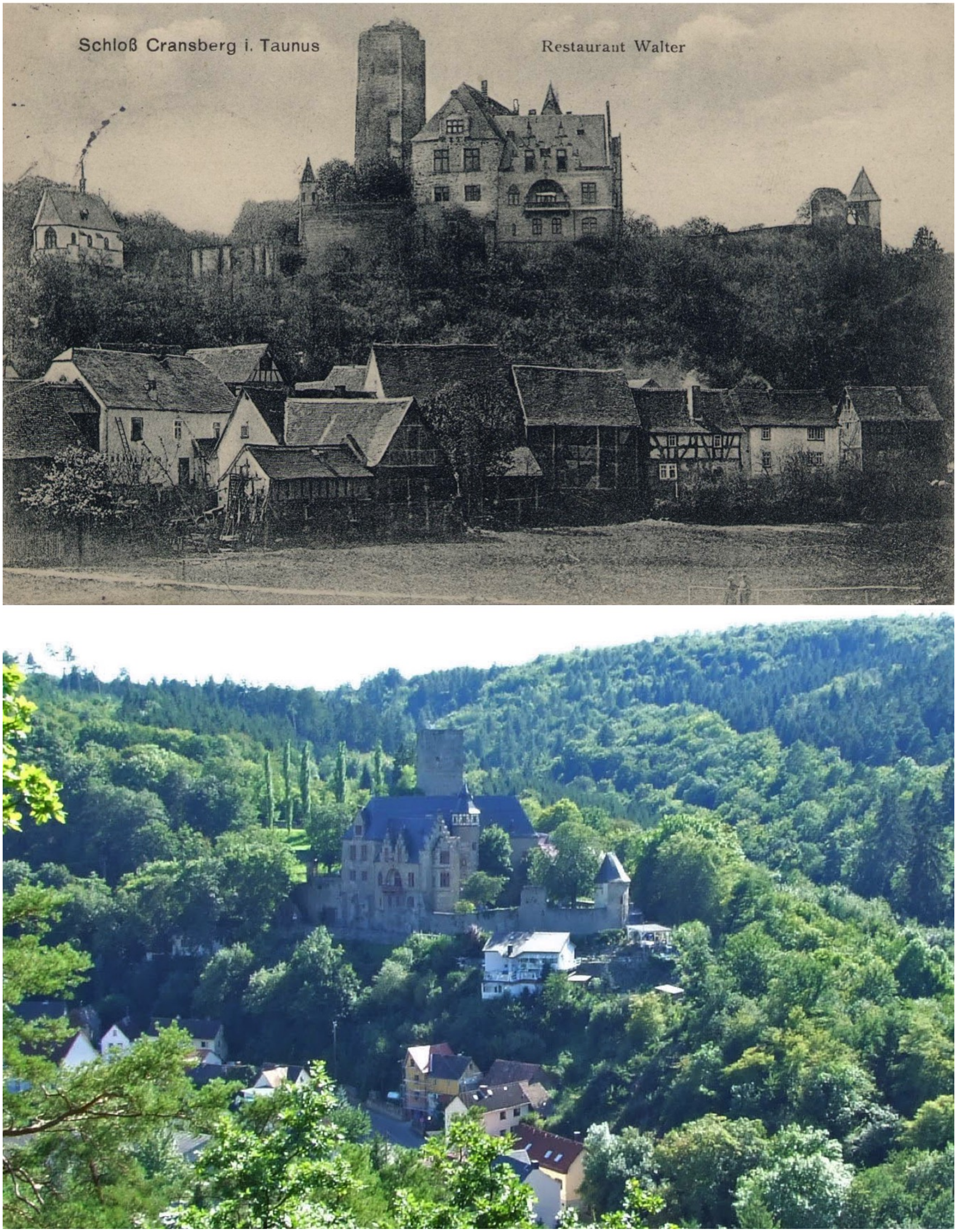
Schloß Cransberg i. Taunus
Restaurant Walter

Figure 11.37: Kransberg Castle, used by U.S. and U.K. forces as the "Dustbin" detention center during 1945–1946 for imprisoning and interrogating scientists, engineers, and military officers with especially valuable scientific knowledge.

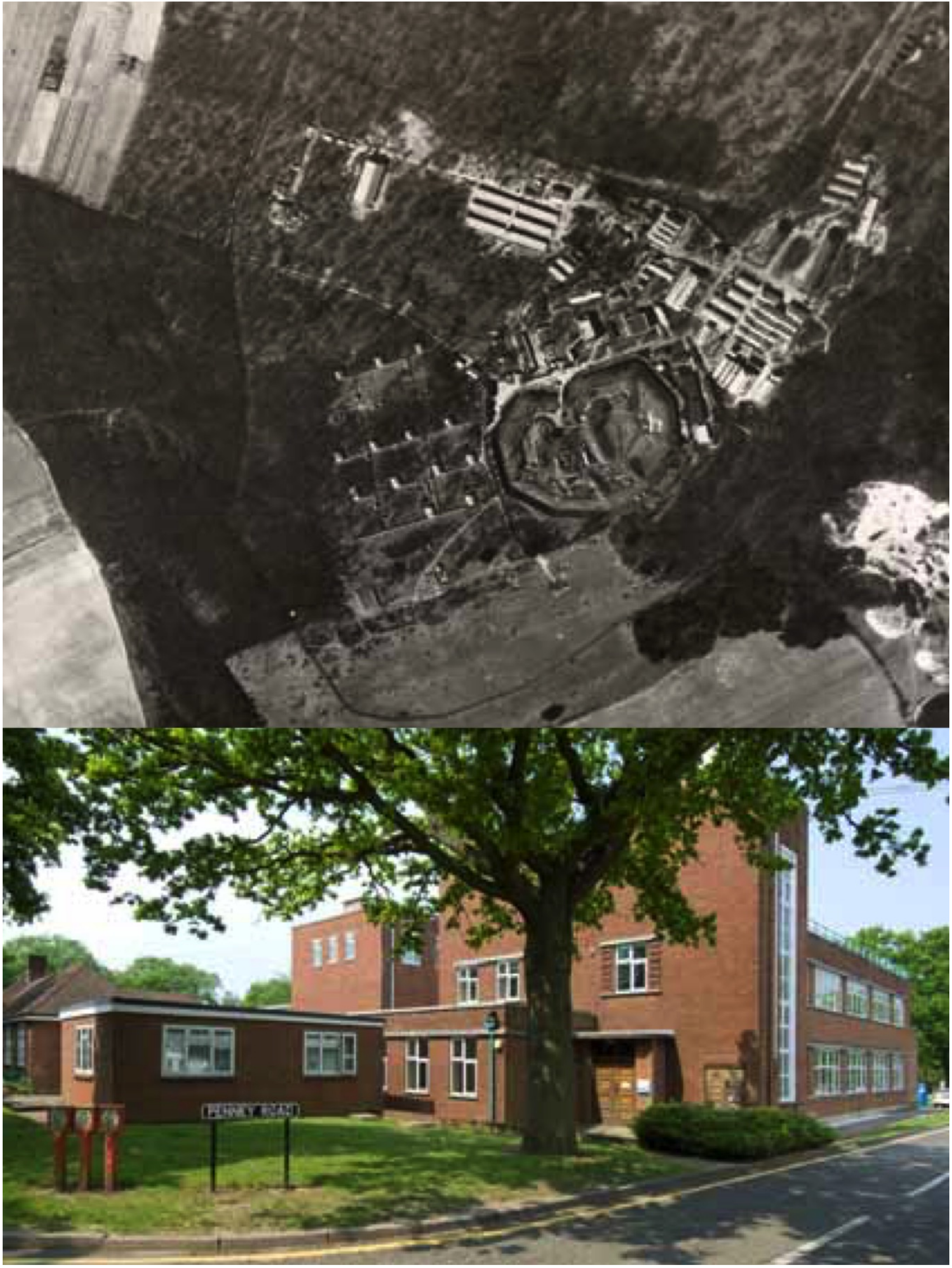

Figure 11.38: Fort Halstead in the United Kingdom, where (a) large numbers of German-speaking scientists were interrogated during and after the war (the “Halstead Exploitation Centre”), (b) thousands of captured German-language reports were translated to English (HEC series reports), and (c) the first British nuclear weapons were developed after the war (likely not a coincidence) [Cocroft 2010]. See also pp. 4166–4169 and 5010.

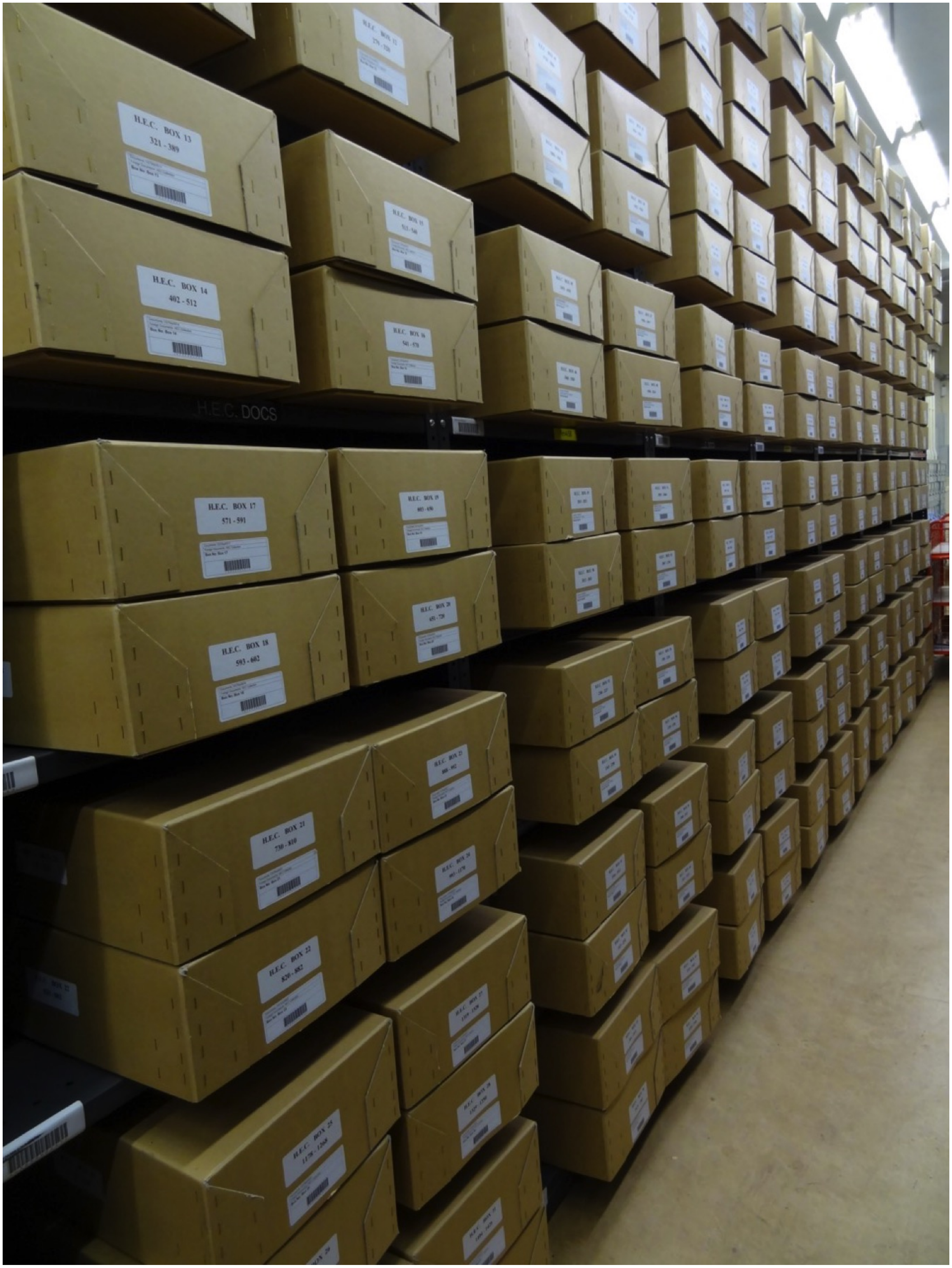

Figure 11.39: Fort Halstead in the United Kingdom, where (a) large numbers of German-speaking scientists were interrogated during and after the war (the "Halstead Exploitation Centre"), (b) thousands of captured German-language reports were translated to English (HEC series reports), and (c) the first British nuclear weapons were developed after the war (likely not a coincidence). See also pp. 4166–4169 and 5010.

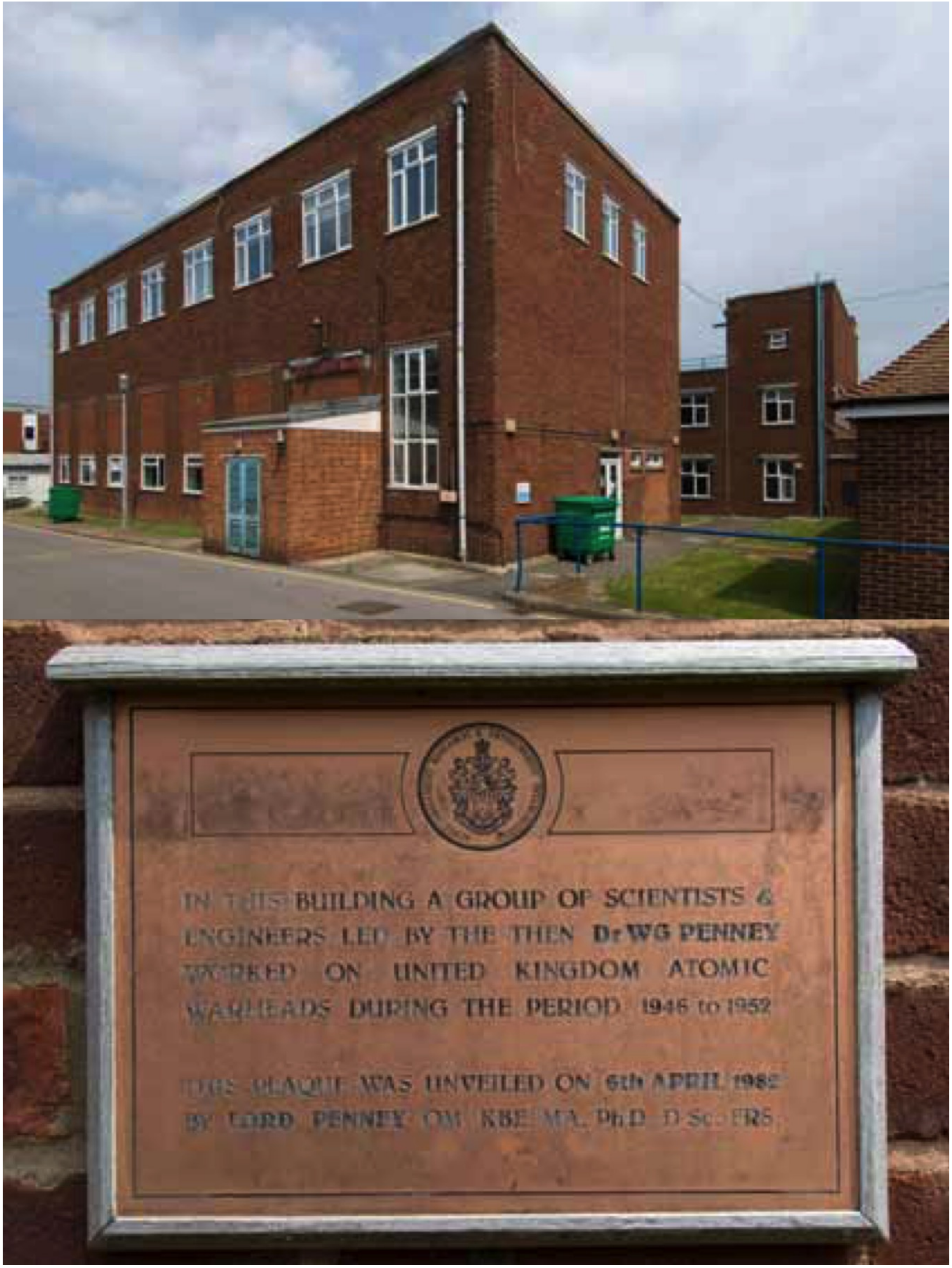
IN THIS BUILDING A GROUP OF SCIENTISTS &
ENGINEERS LED BY THE THEN Dr WG PENNEY
WORKED ON UNITED KINGDOM ATOMIC
WARHEADS DURING THE PERIOD 1946 to 1952
THIS PLAQUE WAS UNVEILED ON 6th APRIL 1982
BY LORD PENNEY OM KBE MA PhD DSc FRS

Figure 11.40: Fort Halstead in the United Kingdom, where (a) large numbers of German-speaking scientists were interrogated during and after the war (the "Halstead Exploitation Centre"), (b) thousands of captured German-language reports were translated to English (HEC series reports), and (c) the first British nuclear weapons were developed after the war (likely not a coincidence) [Cocroft 2010]. See also pp. 4166–4169 and 5010.

The total number of U.S. and U.K. investigators is unclear from existing records, but may well have greatly exceeded the number of German-speaking scientists and engineers being interrogated.

Between 22 August 1944 and 13 July 1945, at least 2197 different U.S. and U.K. investigators visited at least 3377 separate scientific targets (places and/or people) in Europe on behalf of CIOS [AFHRA A5186 electronic version pp. 904–1026, Ch. 4, pp. 29–30]. Those numbers do not include investigators or locations visited during that time by organizations other than CIOS.

The number of U.S. investigators who visited between July 1945 and June 1946 is difficult to locate but must have numbered in the thousands. At least 4994 U.S. FIAT (Field Information Agency, Technical) investigators visited Germany during the 12-month period of 1 July 1946–30 June 1947 [Gimbel 1990a, p. 79]. Of course, that number does not include U.S. investigators from agencies other than FIAT, or investigators from other countries.

At least 1300 U.K. investigators visited Germany just during July–August 1945, and at least 2800 more between then and February 1946 [Glatt 1994, p. 163].

A 1947 *New York Times* article stated that at least 6000 U.S. industry experts had been sent to Germany in search of files, patents, and factories [NYT 1947-05-26 p. 35]:

> German Secrets Net U.S. $1,500,000: 400,000 Copies of Documents Already Sold to Industry—Russia Good Customer.
>
> The United States is collecting reparations from Germany at the rate of $6,000 a week from sale of Nazi wartime technical and scientific inventions.
>
> To date, sale of these hitherto secret inventions and scientific reports to American citizens and corporations has yielded the Commerce Department a gross revenue of $1,500,000, and the amount is still growing.
>
> This has been disclosed by John C. Green, director of the new Office of Technical Services, whose 600 employees have been collecting, classifying and microfilming German patents and documents since the end of the war.
>
> More than 400,000 copies of scientific documents, according to Mr. Green, already have been sold to American concerns at an average fee of $3 to $4 a document. He estimates new orders are coming in from American businessmen at the rate of 1,000 a day.
>
> Mr. Green says that, to his knowledge, this is the only Federal agency in Washington currently collecting reparations from Germany.
>
> Since the end of the war, the agency has processed 75,000 original technological reports and still has on hand 2,000 truckloads—with an estimated 400,000 unprocessed documents—which have been shipped here from Germany.
>
> Many of the processes and inventions are considered “priceless” by officials. Several large United States corporations are said to have been willing to pay as high as $20,000,000 for exclusive rights to a German process.
>
> The Government, however, has laid down the policy that seized scientific information is to be made available to all comers at nominal fees.

> Under this policy, it is estimated that the Russian Government has purchased $17,000 worth of documents totaling nearly 5,000 separate items. The Russian purchasing agency, Amtorg, has been ordering documents at a token price since last year, according to officials.
>
> Although Commerce Department officials at first were reluctant to sell the information to the Russian Government, the State Department laid down the policy that reports should be sold to Amtorg because the material is being made public and anyone could write in and get it.
>
> The German "brain-picking" project is the joint venture of business and Government. To help Commerce employees dig out the documents, United States industry sent 6,000 experts of its own to Germany in the search of I. G. Farben files, patents and factories. [...]

Many documents from this time testify to the large number of investigators who visited individual German and Austrian scientists. For example, BIOS 100, *Development of Panzerfaust*, pp. 1, 15 recorded the visitors (most of whom were apparently not even from known U.S. agencies) for two different scientists, Drs. Langweiler and Kittel (see also p. 558):

> Dr. LANGWEILER [the inventor of Panzerfaust] stated that he had been interviewed 16 times before. On each occasion some of his documents and equipment had been removed. He was finally left with only an incomplete set of drawings of PANZERFAUST 150. No record or report of any of these previous interviews can be found by the writers of this report. [...]
>
> Kittel stated that he had been interrogated in June by an American officer and an American technician. No record of this interrogation can be traced at FIAT, USFET, Third US Army, or Seventh US Army. It is recommended that the report on this previous interrogation should be obtained and circulated to the organisations concerned.

Similarly, BIOS 115, *Report on the Interrogation of Dr. Kurt Stenge*, p. 3, reported the treatment of Dr. Stenge prior to his latest (but probably not last) interrogation:

> Dr. STENGE had previously been kept for a month at Paris where he was submitted to several interrogations, mainly by American investigators, but including one by Commander STUDDERT (sie), R.N. Subsequent to this he lived near MAGDEBURG where he was visited by Commander WASHBURN, R.N., who was stated to have removed all his records.

As another example, the most recent Allied investigators to interrogate Robert Pohl, a solid state physics professor, were surprised that he was not immediately thrilled to see them after all of his previous Allied interrogators (BIOS 870, *Physics of the Solid State*, p. 4):

> Professor Pohl was inclined at first to be cold and formal, presumably because he had been investigated by rather a large number of people in British uniform, but he warmed up increasingly as he understood how much our interests had in common with his own, and from then on the visit was a great success.

Describing the investigators, the *New York Times* wrote [NYT 1947-02-23 pp. SM33–35]:

An American invasion of Germany which started even before V-E Day is now at the peak of operations, with its mission approximately half completed. It is made up of business men, scholars, researchers and technical experts, military and civilian, who have been ferreting out German secrets of science and industry, particularly Nazi wartime developments. [...]

The dollar value of these discoveries cannot be accurately estimated. Yet, an indication was given when an official of the I. G. Farben Company in Germany, handing over a chemical formula to a member of the Commerce Department's Office of Technical Service, which directs the operation, said: "We spent $500,000 in developing this process."

American action in taking these data from Germany gives a new meaning to the old adage that "To the victor belong the spoils," points out John C. Green, director of the OTS. "We are giving worldwide distribution to scientific knowledge; already nationals of twenty-eight countries have received our reports. And, in addition, we are blasting the German-controlled cartels." [...]

Today a startling number of products and processes which offer considerable promise have already been analyzed and are being publicized. Among these are the magnetophone, a sound-recording and reproducing machine using plastic tape (coated with iron oxide) instead of disks, and magnetism instead of needles; a "negative-positive" process for colored moving pictures which accomplishes in two steps what now requires nine; a superior photoelectric cell, used particularly in speaking along a beam of light; an ingenious "fixed paper" condenser; a butter-making machine, and improved processes in mass production of radar and radio chassis, in supersonics, and in acetylene and carbon monoxide chemistry. [...]

Several German cinema films made with the new color process have been exhibited in the Commerce Building in Washington, notably "The Girl of My Dreams" and "Golden City." The color has been described almost lyrically by reviewers. A report on this process is scheduled for release soon.

The "Gudden" photoelectric cell—twenty to fifty times more sensitive than any developed in the United States—was used by the Nazis in the war through the "photophone." With this outfit persons several miles apart, and in situations where telephone wires cannot be strung, can converse over a beam of visible light or invisible infra-red light.

The "fixed paper" condenser, developed by the Robert Bosch Company, is of interest to American makers of electrical and electronic systems, automobiles, radio sets and radar equipment. In it the usual metal foil is replaced by a very thin, vaporized zinc coating, applied directly onto paper separators. Its special features are that it is smaller, cheaper, "heals" automatically after breakdown and may be operated at from 20 to 50 per cent higher voltages than is possible with paper-and-foil capacitors. [...]

The German acetylene processes may turn out to be the most valuable of all, in the making of plastics, drugs, dyes and fuels.

These devices, with hundreds of others, are now finding their way into the hands of American manufacturers for close study.

These U.S. and U.K. investigators wrote over 8000 English-language reports, as shown in Table 11.7.

Report series	**Abbreviation**	**Number**
British Intelligence Objective Subcommittee final reports	BIOS	≥1874
British Intelligence Objective Subcommittee miscellaneous reports	BIOS Misc.	≥110
British Intelligence Objective Subcommittee overall reports	BIOS Overall	≥50
British Intelligence Objective Subcommittee evaluation reports	BIOS ER	≥576
Combined Intelligence Objectives Subcommittee final reports	CIOS	≥1131
Combined Intelligence Objectives Subcommittee evaluation reports	CIOS ER	≥390
Field Information Agency, Technical final reports	FIAT	≥1388
FIAT Review of German Science 1939–1946	*FIAT Review*	84
Joint Intelligence Objectives Agency final reports	JIOA	≥80
Naval Technical Mission in Europe letter reports	NavTecMisEu LR	≥239
Naval Technical Mission in Europe final reports	NavTecMisEu	≥557
Technical Oil Mission reports	TOM	???
Interrogation, interim, and unpublished reports for above agencies		>2000
Total		>8479

Table 11.7: Some major series of English-language reports on German creations.

The U.S. and U.K. governments made almost all of those reports available to anyone (even the Soviet Union) simply for the printing costs of each report copy [Gimbel 1990a, pp. 96, 101]:

> The subjects of the reports offered for sale by the OTS touched virtually every aspect of German industry and technology: acetylene chemistry, synthetic fuels and rubber, synthetic lubricating oils, synthetic fibers and textile manufacturing, ceramics, diesel motors, optics and glass, wind tunnels, heavy presses, infrared, tape recorders and metalized plastic tapes, cold extrusion of steel, electron microscopes, electric condensers, a butter-making machine, fruit juices, a machine to wrap chocolates, a process to preserve soybean oil, white carbon black, cellulose products and wood sugars, dental supplies, synthetic mica flakes, synthetic sapphires for watch, clock, and instrument bearings, color film and color-film processing, quartz clocks, pharmaceuticals, insecticides, synthetic blood plasma, artificial leather, plastics, colors and dyes, soaps and detergents, woodworking machinery, slide fasteners, sewing needles, cheese-making equipment, potentiometers and other precise measuring instruments, milk cans, manure spreaders, motorcycles, and cameras and photographic equipment, among other things.

> Neither the investigators who wrote the Publication Board reports nor the firms that bought them from OTS were obligated to report back on how the reports were used or on the benefits derived from them. Some of them did, however, thus providing a few insights into what remains essentially a closed book.
>
> [...] In May 1947, Robert Reiss, of OTS, listed—albeit without giving details—the names of seven companies known to be using the German acetylene chemical processes, three companies using German circuit-breaker technology, two companies using synthetic mica developed in Germany, two companies using the Fischer-Tropsch synthetic fuels technology brought from Germany, and individual firms that were using information from Germany on radio condensers, tape recorders, phase-contrast microscopes, cold extrusion of steel, and synthetic fibers.

Even though U.S. companies spent a great deal of time and money sending investigators to interview German-speaking creators and procuring copies of English and German documentation on their work, and then soon thereafter produced new products bearing a remarkable resemblance to those German creations, U.S. companies were loath to publicly admit any direct transfer of technological knowledge [Gimbel 1990a, pp. 224 note 26]:

> It is indicative of how hard it is to come by information on American companies' use of German technology that after John C. Green presented some of Reiss's information in testimony before Congress, some firms denied vigorously that they had, in fact, used or benefitted from German technology. For example, Bruce K. Brown, of the Standard Oil Company, denied Green's assertion that Stanolind Oil and Gas Company of Kansas was using Fischer-Tropsch process techniques, arguing that the information was available before the war and that the basic principles were generally known. U.S. research laboratories and pilot plants, he said, had existed in the United States "since well before World War II." But this argument flies in the face of the verifiable fact that the U.S. Technical Oil Mission swarmed over Germany in 1945 and that the American Petroleum Institute and the Bureau of Mines sent several follow-up missions to Germany to gather information on the Fischer-Tropsch process—information that, as we have seen elsewhere in this study, American industry and the American government continued to try to expropriate as late as 1951. [...] Further, W. A. Steiger, the patent attorney for Westinghouse Electric Company, wrote to Congressman Karl Stefan—also in response to Green's testimony before Congress—that the OTS/FIAT operation had been useless to his company. "So far as our company is concerned, I have investigated the situation, and it is my personal opinion that this particular Government activity is of no value to us." [...] Green reacted by informing Steiger that OTS records showed that between 1945 and Feb. 1948, Westinghouse had purchased 388 copies of reports...

Postwar transferred unwritten knowledge

In addition to technical knowledge transferred via documentation written in German or English, a vast amount of knowledge was transferred in unwritten form.

One route for unwritten transfer was of course the knowledge and work of the more than 6000 German-speaking scientists and engineers who ultimately moved to the United States [Mick 2000, p. 316], the more than 9000 who worked for the Soviet Union either in the Soviet Union or in East Germany [Mick 2000, pp. 15–17; Naimark 1995, pp. 230–232], and the thousands of others who worked for the United Kingdom, France, and other countries.

However, a less well known yet still pervasive and highly influential form of unwritten knowledge transfer occurred as the many thousands of Allied investigators took information that they did not record in their reports [Gimbel 1990a, pp. 107–112]:

> These reports and other records of FIAT and OTS provide a basis for illustrating the nature of the scientific and technical know-how removed from Germany, but much of what the Americans gained and the Germans lost remained unreported.
>
> *Incomplete Reports.* Investigators, who were not required to discuss their reasons for wanting to visit specific targets if they thought doing so would reveal industrial or trade secrets of their own, often spent days and weeks at a given location in Germany without including more than a passing reference in their reports to what they did there. Sometimes they admitted quite frankly that they had been "exposed to all sorts of little interesting gadgets and tricks of the trade which are too numerous and detailed, it is believed, to cover in this report." Echoing those words, a FIAT summary report of 20 November 1946 talked about "the various bits of 'know-how', the gadgets and 'tricks of the trade' which investigators observe in passing through the plants, possibly making no particular mental note or record at the time" but which they can use "later when back on the job and facing a problem where the same application can be made." The OTS director, John C. Green, who praised his operation publicly as the source of "the only solid and permanent reparations we are going to get out of this war" and as the provider of "intellectual reparations, prizes of victory which can be shared by every American businessman," nevertheless noted that "in countless cases, a process, device, or tool observed by an investigator in Germany will be passed on to an American firm to increase efficiency and lower costs." Furthermore, in at least one instance he admitted privately that investigators and document screeners were "pocketing some information they obtained instead of including it in their reports or contributing it to microfilmed material."
>
> *Inadequate Reports.* [...] As a case in point Green mentioned the two FIAT reports by C. H. Reynolds, of the Sheffield Corporation, which were judged by the Publication Board to be so poorly done as to be unpublishable, even though Reynolds's own company considered his findings important enough to send him and one of his colleagues back to Germany for more detailed investigations. Meanwhile, the rest of the industry knew nothing of the details of what Reynolds had learned, although they knew about it in general. FIAT's response, though devoid of solutions, shows that Green's case in point was but the tip of the iceberg. [...]

> *No Reports.* In a letter of 11 April 1946 to the Office of Military Government for Germany (OMGUS), whose field-branch office in Stuttgart had complained that FIAT operations were little more than a conveyor belt for industrial espionage, Colonel Ralph M. Osborne, the U.S. chief of FIAT, wrote that even though investigators came from private firms, all of them were under government contracts requiring them to report their findings and prohibiting them from using their positions to secure special information for their own firms. [...]
>
> Without-compensation (WOC) investigators often did not cooperate. Some of them had obviously used FIAT "as a pretext to get into Germany" to conduct their own private affairs; those who had previous business connections in Germany were particularly hard to handle. Many investigators simply used target-assessment reports in the FIAT files as models for their own perfunctory final reports; some of them refused to write reports; and others who had initially refused to write reports wrote inadequate ones when they were pressured to do so.
>
> OTS's solution to the problem of incomplete, inadequate, and nonexistent reports was to open the floodgates and send as many people to Germany as it could, presumably so that as many as possible could get what they wanted for themselves. [...]
>
> In February 1947, John C. Green [...] published "Last Call for Germany." "The opportunity to enter any factory, see any documents, inspect any equipment and interrogate any expert cannot last indefinitely," he warned. "This is American industry's last chance to acquire, at small cost, a wealth of scientific and technical information." [...] Green observed that "victory opened the doors and the files of German factories and laboratories to American investigators." He concluded that "it will be a national tragedy... if we allow the doors to shut before we have added all of the best of Germany's technical knowledge to our own."

Describing this form of unwritten knowledge transfer, Bradley Dewey, president of the American Chemical Society, remarked [Gimbel 1990a, p. 227]:

> ...that most valuable material is not in reports but in the ideas which [the] investigator keeps in his own head.

Postwar influence on the structure of the U.S. research system

Many of the general approaches that had made the German-speaking world so effective at producing revolutionary creators and creations were at least temporarily adopted by the United States research system. As discussed in Section 11.2, those general approaches played a critical role in the successes of the U.S. R&D programs during the 1940s–1960s. Unfortunately, the abandonment of those approaches after that period seems to have greatly contributed to the steady decline in revolutionary innovation from the 1970s to the present, as described in Section 11.3.

Net impact

From archival documents and authoritative sources, it seems clear that:

- By the first several decades of the twentieth century, German-speaking scientists and engineers were generally many years ahead of others in biology and medicine, chemistry and materials science, earth and space science, applied mathematics and physics, electrical and electromagnetic engineering, mechanical engineering, nuclear science and engineering, and aerospace engineering. In many fields, they were over a decade ahead of everyone else, according to postwar Allied investigators.

- German-speaking creators and their creations played critical roles in advancing the scientific and technological levels of other countries in all of those fields to some extent before and during World War II (due to scientific refugees and published information) and to an enormous degree after the war.

- The transfer of German-speaking creators and creations to the United States, United Kingdom, France, Soviet Union, and other countries was equivalent to the transfer of a vast amount of wealth, including past financial investments in making the discoveries and inventions, then-current and future financial income from products based on the discoveries and inventions, and the sheer economic value of thousands of factories, countless amounts of equipment and materials, and thousands of trained specialists that were physically transferred. Allied countries publicly described that transfer as “reparations” and continued to benefit from it for decades after the end of World War II. Germany and Austria suffered the corresponding loss.

In June 1945, U.S. Assistant Secretary of State William L. Clayton testified before the U.S. Senate, openly describing the Allied plan for systematically removing scientific innovations from Germany and Austria [Clayton 1945, pp. 34–37]:

> I should like now to turn to certain questions related to German technological information and scientific research. If we are prepared to acknowledge that German research and scientific development have been important in the past, we must also be prepared to draw the obvious conclusion that the exclusive possession or control of certain kinds of advanced technology by German nationals involves a possible danger to our security and provides German nationals with important assets which in the past have induced other parties to join them in international cartel arrangements.
>
> Our intentions with respect to German research and scientific information may be summarized as follows:
>
> 1. We intend to secure the full disclosure of all existing German technology and invention for the benefit of the United Nations.
>
> 2. Through seizure by the Governments of the United Nations of German-owned patent rights on inventions developed before and during the war, we shall be able to withhold from German nationals the usual technological assets which have proved to be the main inducements for other parties to join the Germans in international cartel arrangements.

> 3. We intend to allow organized research and invention in Germany during the period of military occupation only when we are fully satisfied that such research will not contribute to Germany's future war potential.
>
> [...] Naturally, a considerable portion of the acquired enemy technology has been assigned secret status by the U.K.-U.S. military authorities, since it is in the interest of the two governments that certain classes of information should not be directly or indirectly disclosed to our remaining enemy.

In this testimony before the U.S. Senate, the State Department stated that most revolutionary scientific innovations had been coming exclusively from the German-speaking world. The State Department further admitted that the United States and other countries were not developing revolutionary innovations such as those, which put them at a great economic and military disadvantage.

The solution proposed by the United States was for Allied countries to seize all revolutionary innovations and information on them from the German-speaking world, deny the German-speaking world the right to use its own innovations or economic income from them, and prevent the German-speaking world from creating new revolutionary innovations. The officials did not propose that the United States and other countries should invest the careful thought, funding, labor, time, and effort necessary to create large numbers of new revolutionary innovations of their own; they only proposed to exploit the existing German innovations they seized. Their proposed solution also involved classifying and burying "a considerable portion" of the acquired technology.[8]

In September 1945, R. P. Linstead and T. J. Betts, the British and American chairs of the Combined Intelligence Objectives Subcommittee (CIOS), declared [Fig. 11.41, AFHRA A5186 electronic version pp. 904–1026, Foreword, p. 5]:

> The effective exploitation of German technical development has proven one of the significant results accruing from the conduct of the European War. The value of the scientific knowledge and "know how" thus obtained cannot now be fully measured. That this intelligence contributed to the defeat of Japan is well established. The benefits of this knowledge to British and US industry will be measured in terms of economic progress and well-being for many years to come.

These conclusions regarding the value of German technology that could be "exploited" as "reparations" by Allied countries were publicly stated by people from high-ranking government officials to journalists at that time. A good example from the press is Ian Bevin, Germany Disgorges Her Rich Secrets, *News Chronicle* (London) 21 February 1946 p. 2 (which made extensive use of the September 1945 Linstead and Betts report):

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[8] As demonstrated by the relative dearth of truly new revolutionary innovations over the following decades, that is basically what indeed happened. The United States and other countries harvested and consumed the entire crop of revolutionary innovators and innovations that the German-speaking world had been cultivating for many decades, yet ultimately proved unwilling to properly cultivate a whole new crop of innovators and innovations of their own, or to allow the German-speaking world to properly cultivate a new crop of innovators and innovations. The whole system that had produced so many revolutionary innovators and innovations for over 150 years was deliberately sacrificed for short-term enrichment, resulting in the world of relative stagnation in which we have been living ever since (Sections 1.1 and 11.3). Moreover, apparently many details of the original German-speaking work still remain classified or otherwise buried, depriving historians, scientists, and the public of the knowledge of what truly happened before, during, and after World War II.

> Allied agents have unearthed information of inestimable industrial value. [...]
>
> Technical and scientific knowledge gleaned from conquered Germany has provided the first great reparations payment to the Allies. [...]
>
> Just how the Governments will dispose of German industrial secrets to competitive private enterprises is not yet clear, but, as the information gained from Germany is regarded as a form of reparations, it will presumably be used for national rather than private gain. [...]
>
> These [long list of examples] are only a few of the thousands of discoveries made by CIOS, ranging from major industrial secrets to minor points of manufacturing technique, and adding up to one of the richest war prizes any victor could hope for. All that remains is for the Allies to use the information they have gained, and not let it lie forgotten in the files of Government departments.

For other examples of contemporary press reports, see the *American Magazine* article on p. 2050, *Harper's Magazine* article on p. 2114, and *New York Times* articles on pp. 2130 and 2131.

In March 1946, U.S. Army Colonel Ernest Gruhn, the first director of the Joint Intelligence Objectives Agency, wrote an amazingly candid draft press release that described how dependent the United States was not only on the massive postwar influx of German-speaking creators and creations, but also on earlier German-speaking immigrant scientists as well [Figs. 11.42–11.46. Ernest Gruhn. 14 March 1946. Exploitation of Germany for Technological and Scientific Information. NARA RG 330, Entry A1-1A, Box 4, Folder 383.7 Policy–1946.]:

> After World War I there was no real attempt by the victors to exploit Germany for technical and scientific knowledge. However, long before World War II with Germany had ended, plans were made by the Joint Chiefs of Staff for the complete exploitation of Germany for technical information.
>
> In accordance with these plans, the government is now engaged in exploiting Germany for all the technical and scientific information that can be obtained. Exploitation has involved the sending of several hundred highly qualified American technicians and scientists into Germany close upon the heels of our conquering armies. These investigators have examined manufacturing plans and equipment, records and documents and have interrogated German personnel. The information of industrial value that has been collected is being made available to the public by the Department of Commerce.
>
> Steps are now being taken to extend this exploitation by bringing the best German scientists and technicians to this country so that their talents can be used here. [...]
>
> In the past, the United States has depended to a considerable extent upon German scientists for pure basic scientific research. Such research forms the basis of practical developments. [...]
>
> The exploitation of these highly trained Germans will be of great value to the development of new types of weapons which were being planned by the Germans as the war

> ended. It will also be in the national interest to use them to increase our production potential in many industrial fields. [...]
>
> Closely related to the exploitation of German scientists and technicians is the government program for exploitation of German developments in industrial machinery, tool, equipment and materials. Samples of these are being procured through reparations procedures for shipment to the United States where they are made available for study by American industry on a non-restrictive open-to-the-public basis.
>
> From the above, it is evident that the government is using vacuum cleaner methods to acquire all the technical and scientific information that the Germans have. The value of this information to the United States will probably far exceed any cash reparations.

The U.S. Joint Chiefs of Staff responded to Colonel Gruhn's proposed press release by immediately classifying and burying it; see Fig. 11.47.

In June 1946, U.S. Army Air Forces Major General Curtis LeMay did give a public assessment of the German-language materials transferred after the war [LeMay 1946]:

> At Wright Field, O[hio]., German scientists are now assisting American scientists in translating great masses of captured German scientific documents. These documents reveal, as the materiel at Freeman Field indicates, the extent to which German science had out-distanced American science in basic and applied scientific research and in aircraft development. It has been estimated that the Germans were 10 to 15 years ahead of us in fundamental research.

(For a closely related document, see p. 5263.)

This same estimate that German-speaking innovators were at least a decade ahead of the United States and other countries in a wide variety of fields was independently given by other sources (e.g., pp. 422, 2116). For example, the *New York Times* reported [NYT 1947-05-17 p. 2]:

> German Scientists' Help Said To Save Us 10 Years
>
> The importation of 350 German scientists has "already put the United States ten years ahead of schedule in some fields of research and has saved millions of dollars in research costs," American Army headquarters said today.
>
> The German scientists in the United States are employed on such studies as guided missiles, supersonic planes, jet engines, cancer, photography, meteorology, metallurgy, textiles and cereals—all under the supervision of the War Department.
>
> However, headquarters said, "the War Department will begin soon to release German scientists to American industry under the supervision of the Department of Commerce."

U.S. Army Air Forces Major Alexander de Seversky, who led a five-month study of German technologies at the end of the war, wrote [De Seversky 1952, p. 603]:

> At the end of World War II the Germans were at least a decade ahead of the world in the development of jet engines and supersonic aerodynamics. [...] After V-E Day our scientists and engineers had the opportunity to survey German technological progress. Having secured the necessary data, they came home satisfied that they would be able to start where the Germans left off.

In January 1947, L. B. Kilgore from the U.S. Technical Industrial Intelligence Division (TIID) of the Department of Commerce explicitly described how much German-derived knowledge had been transferred to the United States and how important it was for the country [Figs. 11.48–11.50. L. B. Kilgore. 10 January 1947. Proposal for a Compendium of German War Time Technology, Draft No. 2. NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss.]:

> The accumulation of the technical industrial information, which has resulted from the detailed investigations of the German industry for the past two years by this office, has reached such enormous proportions that it has become difficult to inform the public of the possible benefits available to it. This accumulation of information not only represents the greatest transfer of mass intelligence ever made from one country to another, but it also represents one of the most valuable acquisitions ever made by this country.

In December 1947, U.S. Air Force General Donald Putt explained that German and Austrian scientists were so far ahead of U.S. scientists in a wide range of fields that suitable American scientists could not be found for U.S. programs, that large numbers of German and Austrian scientists were now developing their creations for the U.S. military, and that the United States was making them work for substandard wages compared to what it paid other employees [Figs. 11.51–11.52. Donald Putt to Joseph McNarney. 10 December 1947. German Specialist Program at the Air Materiel Command, Tab F. AFHRA A2056 electronic p. 405–406.]:

> (a) With the exception of those eliminated by a continuous screening process during the one-year probationary period, all specialists now assigned to the various laboratories and activities of Air Materiel Command are outstanding in their respective scientific and engineering fields.
>
> The majority have specific talents and all were associated with German research and development during the war period.
>
> The majority were selected for their work in fields of aeronautical research, such as supersonics, jet and rocket engines, guided missiles, ceramics, jet and rocket fuels, etc., in which American technicians had little or no experience, due to emphasis being placed on other lines of development. Today, however, USAF development is concentrated on those fields in which the Germans had advanced beyond our own knowledge in those same fields.
>
> Millions of dollars were spent by the Germans in research in these fields. By utilization of the German specialists, the Air Force can start where German research left off, rather than spending many dollars of public funds repeating what has already been accomplished or determined to have been unsatisfactory. Not to take advantage of this possibility is short-sighted and unrealistic. [...]

> (e) The German specialists now on duty at Air Materiel Command have been and are now making significant contributions to the development of Air Force items of equipment and to technical and scientific literature. The specialists are an important cog in the Air Force research and development program. [...]
>
> (g) Salaries being paid to the German specialists are less than would be required for equivalent American technicians if they were available.

An official U.S. Air Force program history written in 1948 again stated that German scientists were many years ahead of their American counterparts [Fig. 11.56. Edna Jensen. 1948. *History of AAF Participation in Project Paperclip, May 1945–Mar 1947*, p. 44. AFHRA A2055 electronic p. 747]:

> Recommendations to the Commanding General, U.S. Strategic Air Forces in Europe (Lt. Gen. Carl Spaatz), from his Deputy (Maj. Gen. H. J. Knerr) included the comment, "Occupation of German scientific and industrial establishments has revealed the fact that we have been alarmingly backward in many fields of research. If we do not take this opportunity to seize the apparatus and the brains that developed it and put the combination back to work promptly, we will remain several years behind while we attempt to cover a field already exploited."

Another official U.S. Air Force history written in 1954 yet again confirmed that during and after World War II, German scientists were many years ahead of American scientists in a wide range of fields [Figs. 11.57–11.58. *History of the Air Research and Development Command.* 1954. Chapter IX. Dr. Charles A. Johnson. Project "Paperclip," pp. 258, 265. AFHRA K2838 (15390) electronic pp. 887, 894]:

> World War II had proven that Germany was many years ahead of the United States in a number of scientific and technical fields, notably in propulsion, jet and rocket engines, jet fuels, and guided missiles. While extensive know-how in these scientific areas was in the possession of many outstanding scientists and engineers living in Occupied Germany and the U.S. Zone of Austria, within the United States itself there was a particular shortage of knowledge.
>
> Colonel Donald L. Putt, leading the Air Force Intelligence teams that took over these German research laboratories and experimental stations, made this evaluation: "I visited a great many of them . . . . Their research progress in jet and rocket propulsion, aerodynamics, thermodynamics, supersonics, and other fields was clearly far ahead of anything of the kind we had done."

In 1949, the U.S. Army likewise admitted that German scientists were up to a decade ahead of the U.S. during the war and that in postwar U.S. programs, the German scientists were making enormous contributions in a wide variety of fields that were beyond the capabilities of U.S. scientists (pp. 4890–4892). Senator Harry Byrd reached the same conclusions (pp. 5492–5495).

No less an authority (and a very cautious and conservative one at that) than Dwight Eisenhower wrote in a secret 1945 cable to Washington D.C. that German scientists were even further ahead than that at the end of the war [Ordway and Sharpe 1979, p. 198; Mieczkowski 2013, p. 38]:

> Have in custody over 400 top research development personnel of Peenemünde. Developed V-2. [....] They are anxious to carry on research in whatever country will give them the opportunity, preferably US, second England, third, France. The thinking of the scientific directors of this group is 25 years ahead of US. [...] Immediate action is recommended to prevent loss of whole or part of this group to other interested agencies.

Of course, as illustrated by the evidence throughout this book, it was not only the abstract scientific thinking of the German experts that was years ahead of the United States, but also their test facilities, prototypes, experimental demonstrations, industrial mass production, and use of those new technologies.

The United States was not the only country to benefit from German-speaking creators and their creations. Historian Charlie Hall described the net impact of the technology transfer on the United Kingdom [Hall 2019a, pp. 229–231]:

> [...H]ow much did Britain benefit from the scientific and technological spoils of war? Unfortunately, it is almost impossible to give a definite answer to this question. [...] Some, including Michael Howard who served with T-Force after the war, suspect that the files containing official government valuations have either been destroyed or remain closed to the public. [...]
>
> Turning first to the material spoils, one of the most useful resources which emerged from the British exploitation programme was the collection of BIOS, CIOS, and FIAT Final Reports[...] As we have seen, a government publicity drive brought these reports to the attention of business owners throughout Britain who almost certainly implemented some of the techniques described to increase the efficiency or output of their enterprises—calculating the total value of these improvements would be utterly impossible, but we can be confident that they existed and were fairly widespread. Alongside these reports, BIOS and its related organisations were responsible for the removal of equipment and material too. Under reparations arrangements, Britain received just under 380,000 tons of dismantled German capital equipment[...] A much larger amount of material, most of which would have been far more useful, was taken outside of the official reparations channels and thus remains unaccounted for.
>
> Some material within these removals would have been more valuable than others. For example, under the auspices of Operation Surgeon, some 14,000 tons of aeronautical equipment was removed, including highly specialised wind tunnels and equipment for investigating high-velocity flight at stratospheric altitudes. Much of this went to furnish the new Royal Aircraft Establishment at Farnsborough and would, therefore, have played a direct role in British aeronautical developments moving forward. [...]
>
> It is also worth noting that, from the perspective of British industrial concerns, the greatest benefit of exploitation was not what they gained, but rather what the Germans lost. In short, the damage that exploitation and dismantling wrought to their German rivals allowed them to increase their export capacity at the expense of these German firms. [...]
>
> While the Allies were quick to assert that Germany had lost no more than her leadership in some industries and techniques, many Germans did not agree. [...] Indeed, many of

> these complaints were directed more at the Allied programme of industrial dismantling than at scientific and technological exploitation, though the two schemes ultimately fell under the same broad umbrella. In particular, just as dismantling threatened to severely damage German industry's productive capacity, exploitation was accused of being little more than a 'conveyor belt' for commercial espionage. Both tactics sought to give British business a competitive edge over their renascent German rivals.

As mentioned by Charlie Hall, Michael Howard was an intelligence officer in the British T-Force. In Howard's memoir, he described assisting with the removal of thousands of tons of technology from Germany on a daily or weekly basis, and he speculated on the monetary value of that transferred technology [Howard 2010, pp. 195, 204–205]:

> For ten days we had been victims of the latest false alarm: that everything had to be sent out by the end of the year [1946]. But after ten days of working pretty well night and day, I still had six and a half thousand tons of equipment valued at five million pounds to get out. [...] I never knew who had set that valuation upon the stuff to go, probably its depreciated cost, but it was nowhere near the valuation settled on it in 1948/9. [...]
>
> Coming under fire in some quarters for its very existence, T-Force had a vested interest in putting figures to the results of its work, an extraordinarily difficult and complex calculation. The figure that I mentioned, current by December 1946, might have covered evacuation up to, say, the end of October, but will have referred only to tangibles, i.e. machinery and equipment, upon which it was possible to hang some sort of price-tag, and which were seen as reparations. But what about the intangibles, the intellectual property? A figure produced in 1970 from German sources, for the value of appropriated patents alone, was of the order of £250 million in the coin of post currency-reform (June 1948). On top of these were to be added: 'sharp' battlefield weapons and the means of producing them; industrial processes and the documents and drawings which described them, over the whole field of industry; the knowledge obtained by British scientists and industrialists from their interrogation of their German counterparts and of academics; and access to the records and archives of all of these. I was not shocked or entirely surprised by the figure of £2,000 million quoted privately to me in 1949 by the last remnants of T-Force who had been tasked with making such a valuation (Rufus Harris and Wigg and a handful of others, by now with G Branch, Research Division of the CCG).

Even Howard's descriptions and estimates were only a fraction of the total technology transfer to the British. They did not include transfers that were carried out by organizations other than T-Force, such as the Royal Navy and specific British companies. Moreover, they did not include British exploitation of Austria, or of German technology that the British discovered in formerly German-controlled territory such as France and Norway. They also did not assign a monetary value to the more than 1,000 German-speaking scientists who worked for the United Kingdom after the war. With all of those factors in mind, the total technology transfer to the British was probably quite comparable to that to the United States.

The impacts of the technology transfer on the Soviet Union and France were presumably at least as large as those on the United States and United Kingdom.

John Gimbel quoted the best available estimates of the financial value of the technology transfer to the United States [Gimbel 1990a, p. 152]:

> ...It is perhaps fitting to refer briefly to the discussion of value contained in a manuscript on the history of FIAT, which may be found in the archives records of the OMGUS Historical Office. After commenting that the Russian figure of $10 billion announced by Molotov at the Moscow CFM was too high, the unnamed authors argued that only in time—after tests, trials, and applications—could a precise value be established. Nevertheless the authors "estimated that FIAT activities should save the government and industry in the United States at least five billion dollars." If we were to accept this as a fair global figure, and if we were to make the altogether reasonable assumption that the British received value roughly equal to that of the United States, it would follow that Molotov at the Moscow CFM was right on the button.

Donald Putt and Senator Harry Byrd gave a similar estimate of billions of dollars for the United States (pp. 5492–5495). Considering that these estimates were lower bounds and that the French and especially the staggering Soviet removals were not included, the total value of technologies transferred out of the German-speaking world after the war almost certainly exceeded 20 billion 1940s-era U.S. dollars.

There are at least four factors that were not considered in the above financial estimates, and that could increase the true total value of technologies that were transferred out of the German-speaking world potentially by orders of magnitude beyond the lower bound of 20 billion 1940s-era U.S. dollars:

1. Some of the most valuable technologies that were transferred were either secret or at least not widely known during and immediately after the war, and the historical facts that they were in fact transferred and not spontaneously invented in postwar Allied countries remain classified, buried, or ignored to this day. Examples include oral contraceptives and other advanced pharmaceuticals (p. 354), fuel-air explosives (p. 557), advanced materials (Section 3.8), stealth technology (p. 1234), biotechnology (Section A.1), biological weapons (Section A.3), chemical weapons up through advanced V-series nerve agents (Section A.4), transistors (Section B.1), printed circuits (Section B.2), integrated circuits (Section B.3), light emitting diodes (Section B.4), lasers (Section C.3) and other directed energy technologies (Appendix C), advanced fission bombs (Sections D.14 and D.15.5), hydrogen bombs (Sections D.9 and D.14), intercontinental jets (Section E.1), intercontinental rockets (Section E.2), space planes (Section E.3), submarine-launched and advanced solid propellant rockets (Section E.4), and many others. Because the details of their transfer were obscured, all of these advanced technologies were not included in the earlier financial estimates, yet they certainly should be.

2. The true value of the transfer must reflect what it would cost to fully nullify the transfer now. Obviously this situation is purely hypothetical, yet it is useful nonetheless for calculating the financial value in modern terms. If other countries were to fully repay Germany and Austria now for the cost of all the creators, creations, materials, and services that were transferred in the 1940s, they would need to repay not the original number of 1940s-era dollars (whatever that number may be), but rather the far larger number of modern dollars that would be equivalent, taking inflation into account. Moreover, if the transfer were considered a loan like any other financial transaction, countries would also owe Germany and Austria the interest on that transferred amount that had accumulated and compounded at fair-market rates from the 1940s to the current day.

3. The total value of the German-speaking creators and creations that were transferred must also take into account their true value to the countries that received them, from World War II through the present. The transferred creators and creations formed the basis of whole industries in biotechnology, pharmaceuticals, chemicals and materials, microelectronics and electronic devices, energy, aerospace, and other areas. They provided all types of weapons of mass destruction (biological, chemical, and nuclear), all methods to deliver them (intercontinental jet bombers, cruise missiles, intercontinental ballistic missiles, and submarine-launched missiles), and all of the technologies for modern conventional warfare as well. Therefore, transferred creators and creations allowed certain countries to greatly prosper or even become dominant throughout all the years since the war. What value could one place on the resulting success of those national economies and militaries over all the postwar decades?

4. Likewise, the total value of the German-speaking creators and creations that were transferred must consider the true value of their loss for Germany and Austria. If Germany and Austria—instead of other countries—had had the benefit of all of those creators and creations during all of the postwar decades, what would have been the resulting success of their national economies?

Although one might be tempted to cite the Marshall Plan as an example of money being given back to Germany and Austria, the United States provided less than \$2 billion total to West Germany and Austria under the Marshall Plan, and most of that was simply loans that had to be fully repaid to the United States within a certain period of time [Schain 2001]. Thus Germany and Austria essentially fully funded their own postwar reconstruction and rebirth, in addition to shouldering much of the burden of postwar industrial and scientific development in the United States, United Kingdom, France, Soviet Union, and other countries.

It is possible that all of the countries involved might agree that the true total value of the technology transfer was an appropriate amount for reparations, but at the very least, the true value should be properly calculated, publicly acknowledged, and clearly stated in the history books.[9]

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[9] Just to avoid any misunderstandings, I do not at all mean to disregard or minimize any of the other ethical issues, atrocities, injustices, casualties, losses, and unfortunate effects that were associated with the war, and that have been so thoroughly documented and discussed elsewhere. Rather, I am endeavoring to shed light on this additional issue that has not received much scrutiny to date, and that should be considered along with all of the others. Even more importantly, I would like to emphasize the enormous long-term economic and societal benefits that can be generated if countries fully fund and properly support revolutionary innovators and revolutionary innovations, as demonstrated by these historical examples.

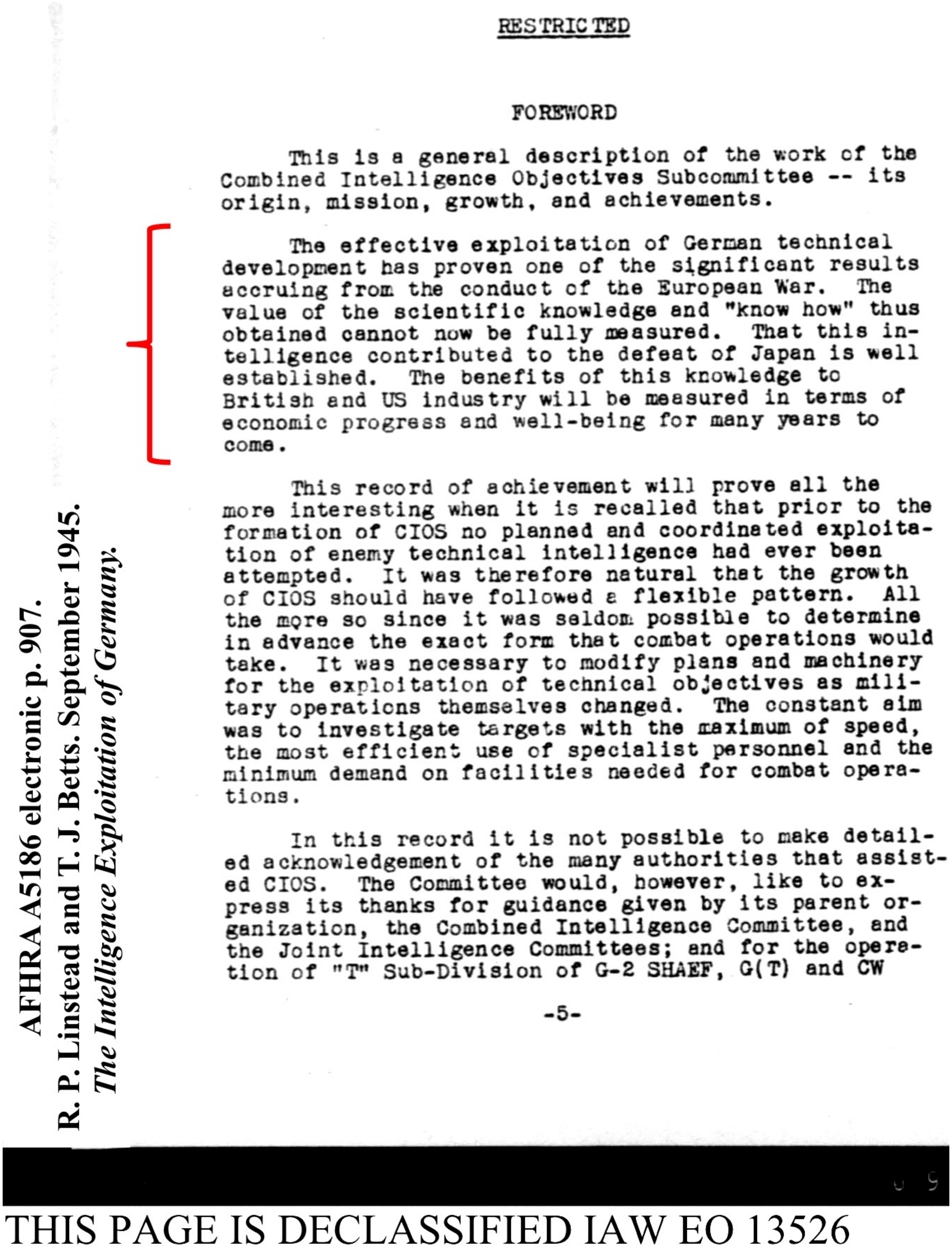
For reasons of length, this study cannot even begin to address the large number of other ethical questions that are already covered so well and in so much detail by many other authors; I highly recommend that all readers seek out those books and study them. See for example: Bar-Zohar 1967; Beyerchen 1977; Black 2012a, 2012b, 2017; Borkin 1978; Bower 1987; Campbell and Harsch 2013; Cornwell 2003; Crim 2018; Deichmann 1996; Joseph Fisher 2017; Friedrich et al. 2017; Geissler 1998a, 1998b, 1999; Gellermann 1986; Georg 2012; Gimbel 1986, 1990a, 1990b, 1990c; Gröhler 1989; Guillemin 2005; Friedrich Hansen 1993; István Hargittai 2006; Harris Paxman 2002; Haunschmied et al. 2007; Hayes 2001; Heim et al. 2009; Hentschel and Hentschel 1996; Linda Hunt 1991; Jacobsen 2014; Jeffreys 2008; Karlsch and Laufer 2002; Kaszeta 2020; Kater 1989; Keynes 2019; Klee 2001; Kurowski 1982; Lasby 1971; Leff 2019; Le Maner and Sellier 2001; Julian Lewis 2002; Lichtblau 2014; Macrakis 1993; Milton Mayer 2017; Medawar and Pyke 2000; Mick 2000; Nachmansohn 1979; Nash 2013; Michael Neufeld 1995, 2002, 2003, 2007; Plumpe 1990; Posner and Ware 2000; Pringle 2006; Renneberg and Walker 1993; Sasuly 1947; Schambach 2011; Sellier 2003; Simpson 1988; Spitz 2005; Stoltzenberg 1994, 2005; Sutton 1976; Szöllösi-Janze 2001, 2015; Tucker 2006; Wachsmann 2015; Bernd Wagner 2000; Jens-Christian Wagner 2011, 2015; Wallace 2004; Whitman 2018.

For reference, the total amount that the United States spent on its own R&D programs (including the Manhattan Project, radar, penicillin, etc.) throughout all of World War II was only approximately 3 billion 1940s-era dollars. The United Kingdom spent much less, and other Allied countries spent relatively little on R&D. For the R&D that the United States and other countries acquired from the German-speaking world, even the lower-bound $20 billion estimate is nearly one order of magnitude larger than the U.S. R&D. Including the other factors listed above, the transferred R&D may well have had a total financial value several orders of magnitude greater than the endogenous R&D.

Thus whether one considers the number of truly revolutionary scientific innovators, the number of revolutionary scientific innovations (Chapter 2–9 and Appendices A–E), or the financial value of the innovators and innovations, the amount of science and technology that was transferred out of the German-speaking world appears to absolutely dwarf the amount that was "home grown" within the other countries. Perhaps the only thing more remarkable than this technology transfer is how nearly it has been forgotten by the modern world.

Charlie Hall gave an impassioned plea for the massive technology transfer from the German-speaking world to be much more widely studied and far more prominently featured in history books [Hall 2019a, p. 238]:

> This wholesale removal of a defeated nation's scientific and technological resources, including recruitment of expert personnel, by its military conquerors, has no parallel in modern history and deserves greater scrutiny. There is, without doubt, more to be said about the exploitation schemes of all four occupying powers, as well as about the involvement of other nations, including those whose participation in the Second World War was peripheral at best. [...] It would be excellent to see exploitation feature more prominently in histories of the military-industrial complex, of scientific intelligence, of post-1945 arms races, of transnational transfers of technology and expertise and of the Second World War and Cold War more generally. This would hopefully lead to a stronger presence for the programme in the public consciousness and would ensure that never again could it be described as a 'forgotten history.'



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FOREWORD

This is a general description of the work of the Combined Intelligence Objectives Subcommittee -- its origin, mission, growth, and achievements.

The effective exploitation of German technical development has proven one of the significant results accruing from the conduct of the European War. The value of the scientific knowledge and "know how" thus obtained cannot now be fully measured. That this intelligence contributed to the defeat of Japan is well established. The benefits of this knowledge to British and US industry will be measured in terms of economic progress and well-being for many years to come.

This record of achievement will prove all the more interesting when it is recalled that prior to the formation of CIOS no planned and coordinated exploitation of enemy technical intelligence had ever been attempted. It was therefore natural that the growth of CIOS should have followed a flexible pattern. All the more so since it was seldom possible to determine in advance the exact form that combat operations would take. It was necessary to modify plans and machinery for the exploitation of technical objectives as military operations themselves changed. The constant aim was to investigate targets with the maximum of speed, the most efficient use of specialist personnel and the minimum demand on facilities needed for combat operations.

In this record it is not possible to make detailed acknowledgement of the many authorities that assisted CIOS. The Committee would, however, like to express its thanks for guidance given by its parent organization, the Combined Intelligence Committee, and the Joint Intelligence Committees; and for the operation of "T" Sub-Division of G-2 SHAEF, G(T) and CW

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AFHRA A5186 electronic p. 907.
R. P. Linstead and T. J. Betts. September 1945.
The Intelligence Exploitation of Germany.

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Figure 11.41: R. P. Linstead and T. J. Betts. September 1945. *The Intelligence Exploitation of Germany.* Foreword, p. 5 [AFHRA A5186 electronic p. 907].

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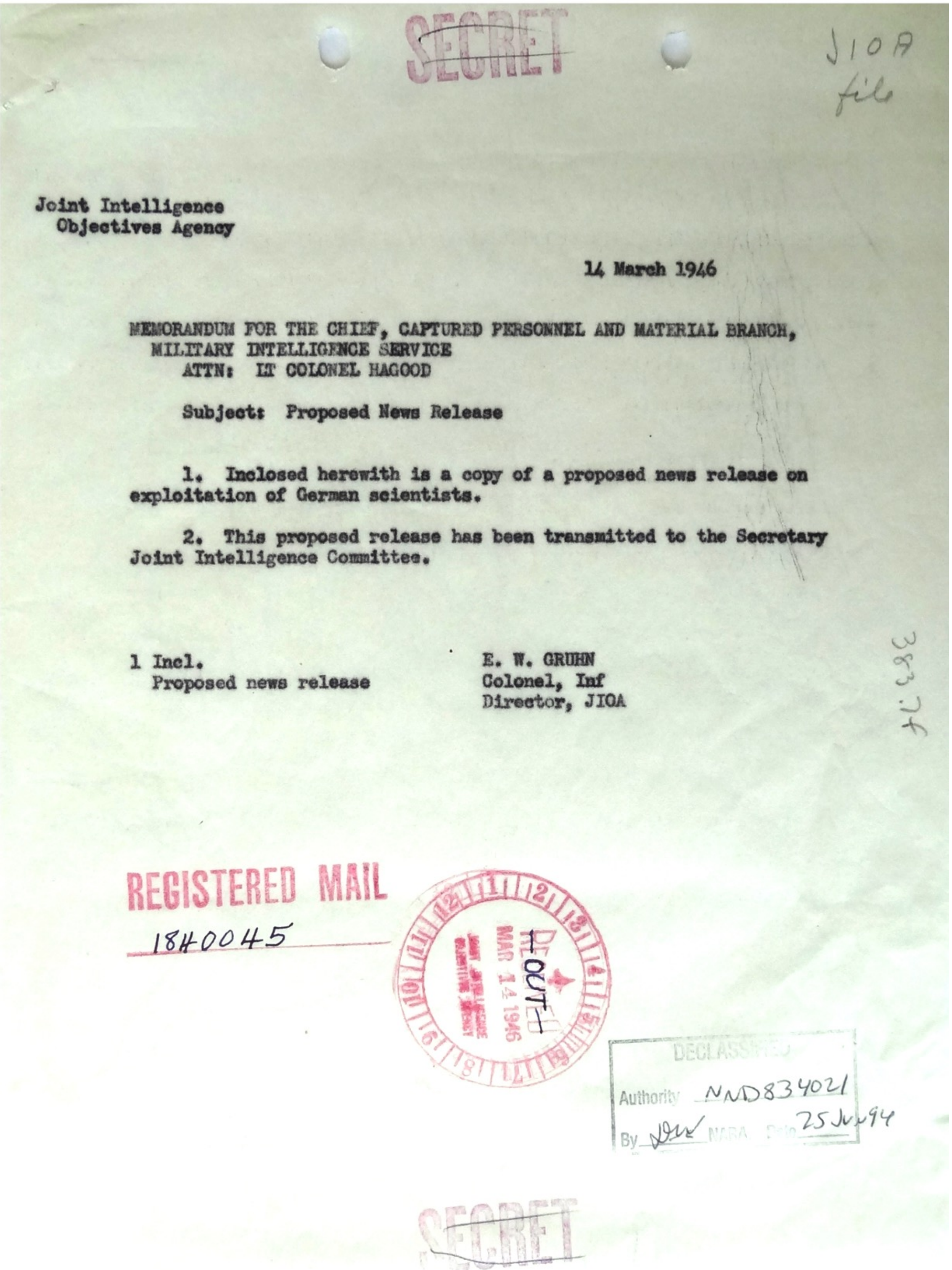

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JIOA
file

Joint Intelligence
Objectives Agency

14 March 1946

MEMORANDUM FOR THE CHIEF, CAPTURED PERSONNEL AND MATERIAL BRANCH,
MILITARY INTELLIGENCE SERVICE
ATTN: LT COLONEL HAGOOD

Subject: Proposed News Release

1. Inclosed herewith is a copy of a proposed news release on exploitation of German scientists.

2. This proposed release has been transmitted to the Secretary Joint Intelligence Committee.

1 Incl.
Proposed news release

E. W. GRUHN
Colonel, Inf
Director, JIOA

383.7f

REGISTERED MAIL
18H0045

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MAR 14 1946
JOINT INTELLIGENCE OBJECTIVES AGENCY

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By NARA Date 25 Jun 94

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Figure 11.42: Ernest Gruhn. 14 March 1946. Exploitation of Germany for Technological and Scientific Information. [NARA RG 330, Entry A1-1A, Box 4, Folder 383.7 Policy–1946].

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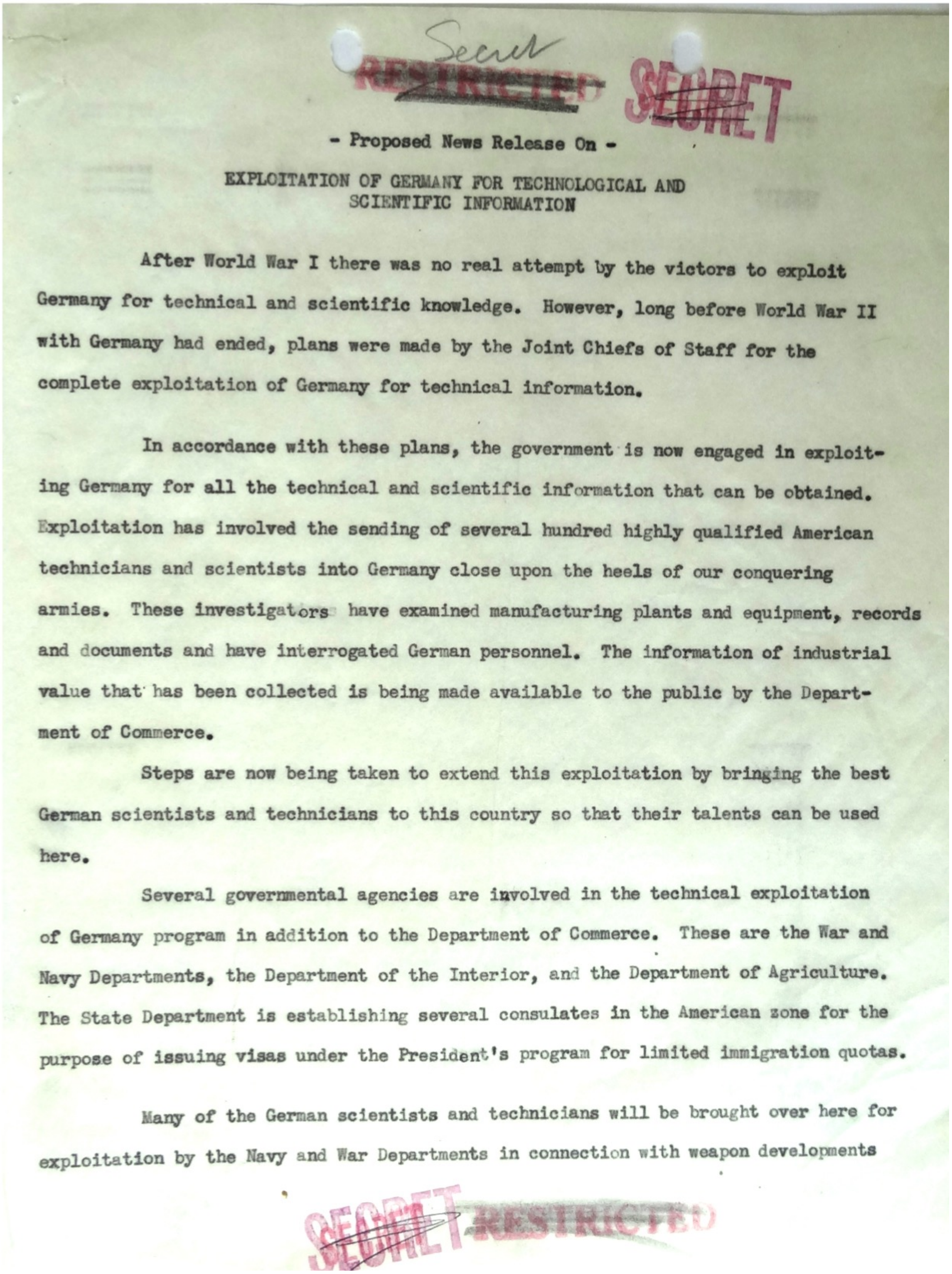

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- Proposed News Release On -

EXPLOITATION OF GERMANY FOR TECHNOLOGICAL AND SCIENTIFIC INFORMATION

After World War I there was no real attempt by the victors to exploit Germany for technical and scientific knowledge. However, long before World War II with Germany had ended, plans were made by the Joint Chiefs of Staff for the complete exploitation of Germany for technical information.

In accordance with these plans, the government is now engaged in exploiting Germany for all the technical and scientific information that can be obtained. Exploitation has involved the sending of several hundred highly qualified American technicians and scientists into Germany close upon the heels of our conquering armies. These investigators have examined manufacturing plants and equipment, records and documents and have interrogated German personnel. The information of industrial value that has been collected is being made available to the public by the Department of Commerce.

Steps are now being taken to extend this exploitation by bringing the best German scientists and technicians to this country so that their talents can be used here.

Several governmental agencies are involved in the technical exploitation of Germany program in addition to the Department of Commerce. These are the War and Navy Departments, the Department of the Interior, and the Department of Agriculture. The State Department is establishing several consulates in the American zone for the purpose of issuing visas under the President's program for limited immigration quotas.

Many of the German scientists and technicians will be brought over here for exploitation by the Navy and War Departments in connection with weapon developments

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Figure 11.43: Ernest Gruhn. 14 March 1946. Exploitation of Germany for Technological and Scientific Information. [NARA RG 330, Entry A1-1A, Box 4, Folder 383.7 Policy–1946].

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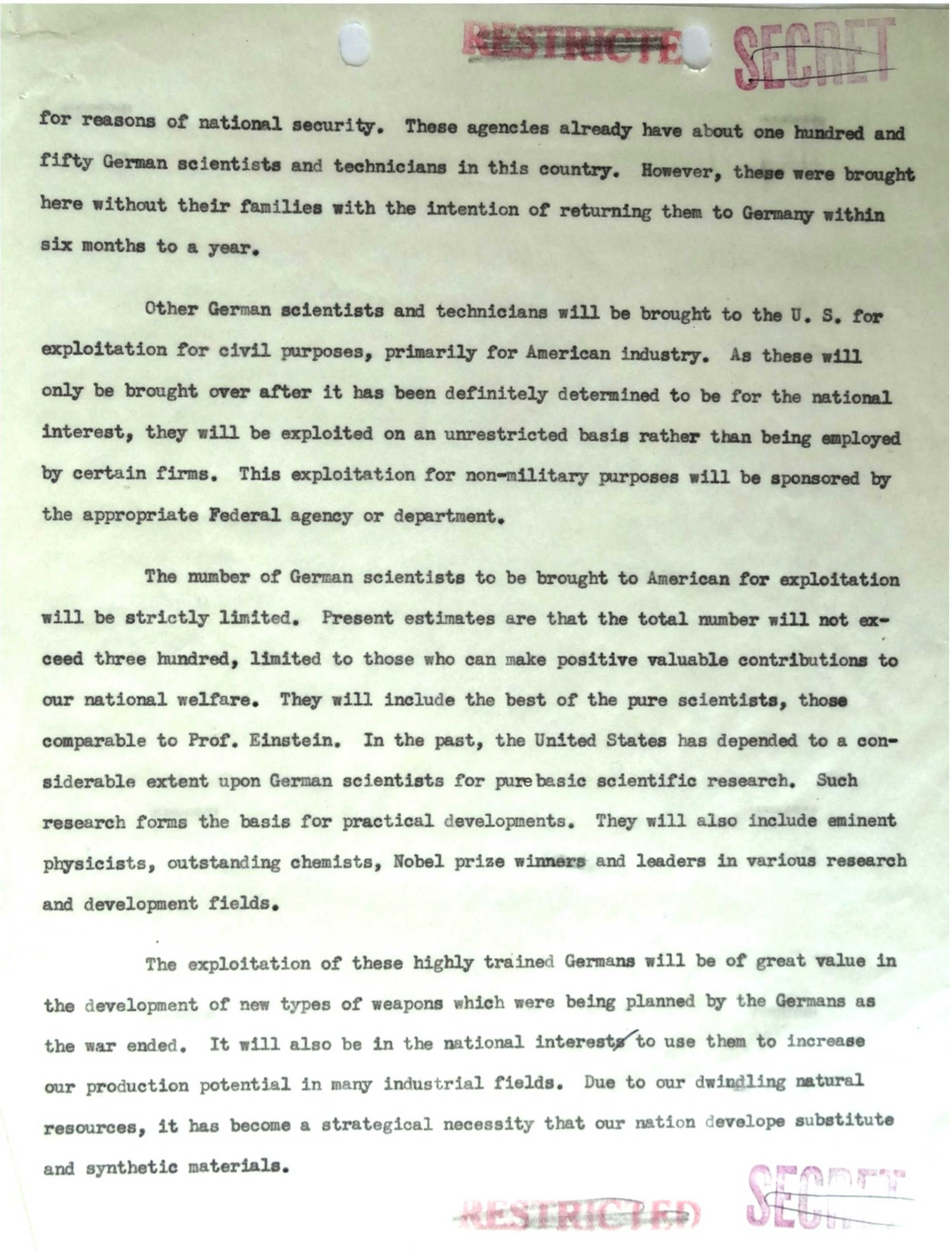

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for reasons of national security. These agencies already have about one hundred and fifty German scientists and technicians in this country. However, these were brought here without their families with the intention of returning them to Germany within six months to a year.

Other German scientists and technicians will be brought to the U. S. for exploitation for civil purposes, primarily for American industry. As these will only be brought over after it has been definitely determined to be for the national interest, they will be exploited on an unrestricted basis rather than being employed by certain firms. This exploitation for non-military purposes will be sponsored by the appropriate Federal agency or department.

The number of German scientists to be brought to American for exploitation will be strictly limited. Present estimates are that the total number will not exceed three hundred, limited to those who can make positive valuable contributions to our national welfare. They will include the best of the pure scientists, those comparable to Prof. Einstein. In the past, the United States has depended to a considerable extent upon German scientists for pure basic scientific research. Such research forms the basis for practical developments. They will also include eminent physicists, outstanding chemists, Nobel prize winners and leaders in various research and development fields.

The exploitation of these highly trained Germans will be of great value in the development of new types of weapons which were being planned by the Germans as the war ended. It will also be in the national interests to use them to increase our production potential in many industrial fields. Due to our dwindling natural resources, it has become a strategical necessity that our nation develope substitute and synthetic materials.

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Figure 11.44: Ernest Gruhn. 14 March 1946. Exploitation of Germany for Technological and Scientific Information. [NARA RG 330, Entry A1-1A, Box 4, Folder 383.7 Policy–1946].

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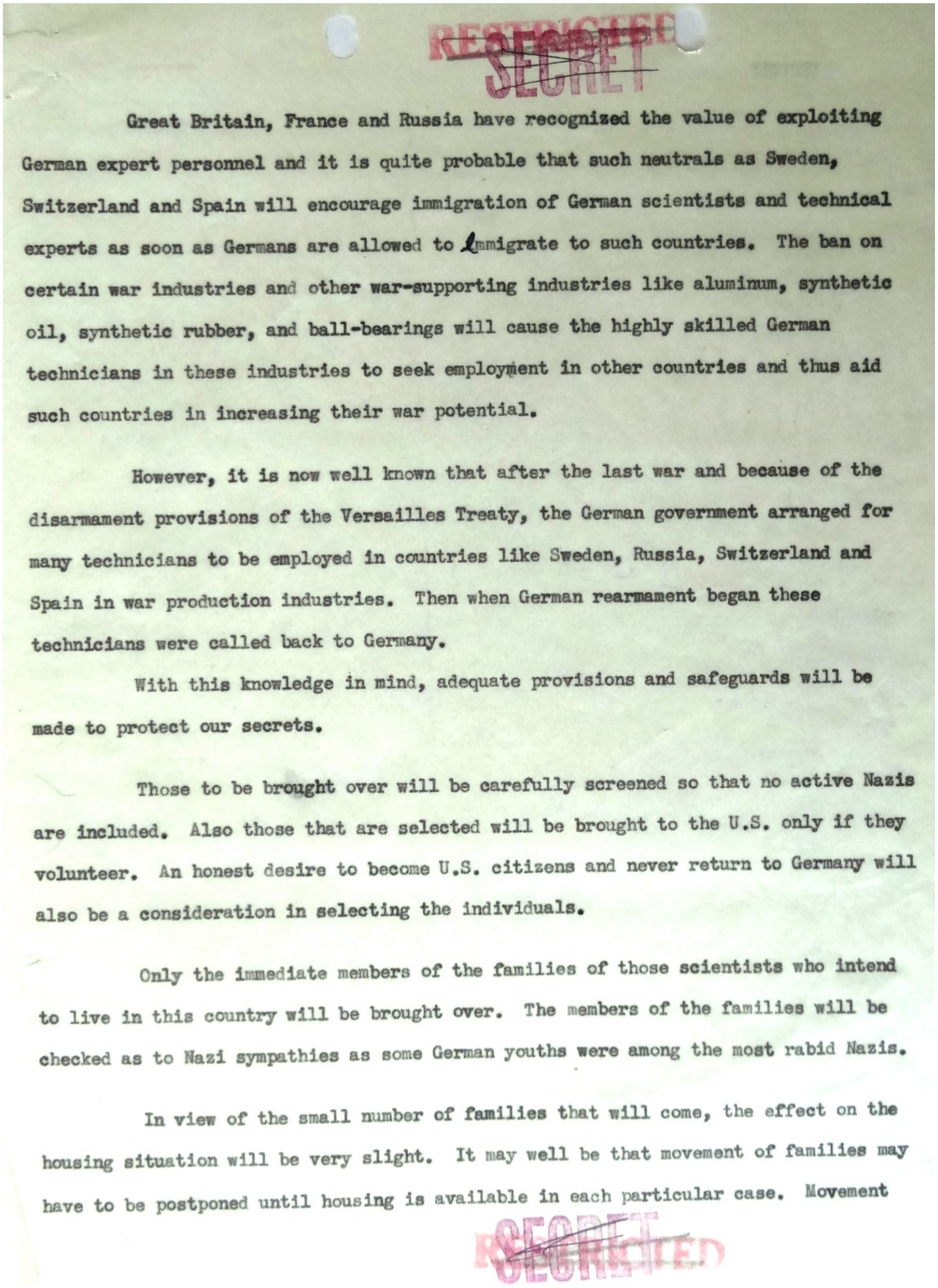

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Great Britain, France and Russia have recognized the value of exploiting German expert personnel and it is quite probable that such neutrals as Sweden, Switzerland and Spain will encourage immigration of German scientists and technical experts as soon as Germans are allowed to immigrate to such countries. The ban on certain war industries and other war-supporting industries like aluminum, synthetic oil, synthetic rubber, and ball-bearings will cause the highly skilled German technicians in these industries to seek employment in other countries and thus aid such countries in increasing their war potential.

However, it is now well known that after the last war and because of the disarmament provisions of the Versailles Treaty, the German government arranged for many technicians to be employed in countries like Sweden, Russia, Switzerland and Spain in war production industries. Then when German rearmament began these technicians were called back to Germany.

With this knowledge in mind, adequate provisions and safeguards will be made to protect our secrets.

Those to be brought over will be carefully screened so that no active Nazis are included. Also those that are selected will be brought to the U.S. only if they volunteer. An honest desire to become U.S. citizens and never return to Germany will also be a consideration in selecting the individuals.

Only the immediate members of the families of those scientists who intend to live in this country will be brought over. The members of the families will be checked as to Nazi sympathies as some German youths were among the most rabid Nazis.

In view of the small number of families that will come, the effect on the housing situation will be very slight. It may well be that movement of families may have to be postponed until housing is available in each particular case. Movement

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Figure 11.45: Ernest Gruhn. 14 March 1946. Exploitation of Germany for Technological and Scientific Information. [NARA RG 330, Entry A1-1A, Box 4, Folder 383.7 Policy–1946].

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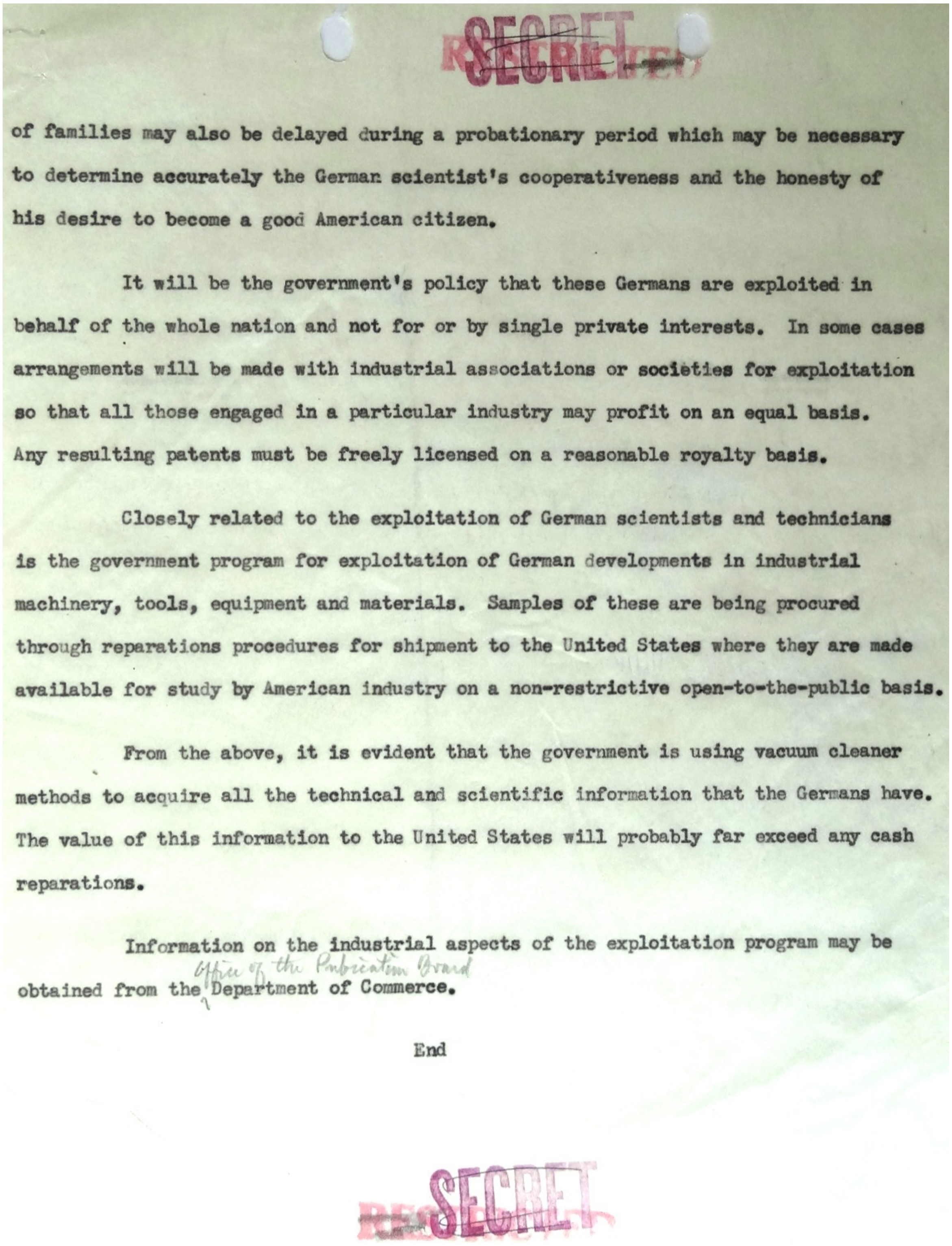

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of families may also be delayed during a probationary period which may be necessary to determine accurately the German scientist's cooperativeness and the honesty of his desire to become a good American citizen.

It will be the government's policy that these Germans are exploited in behalf of the whole nation and not for or by single private interests. In some cases arrangements will be made with industrial associations or societies for exploitation so that all those engaged in a particular industry may profit on an equal basis. Any resulting patents must be freely licensed on a reasonable royalty basis.

Closely related to the exploitation of German scientists and technicians is the government program for exploitation of German developments in industrial machinery, tools, equipment and materials. Samples of these are being procured through reparations procedures for shipment to the United States where they are made available for study by American industry on a non-restrictive open-to-the-public basis.

From the above, it is evident that the government is using vacuum cleaner methods to acquire all the technical and scientific information that the Germans have. The value of this information to the United States will probably far exceed any cash reparations.

Information on the industrial aspects of the exploitation program may be obtained from the Office of the Publication Board Department of Commerce.

End

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Figure 11.46: Ernest Gruhn. 14 March 1946. Exploitation of Germany for Technological and Scientific Information. [NARA RG 330, Entry A1-1A, Box 4, Folder 383.7 Policy–1946].

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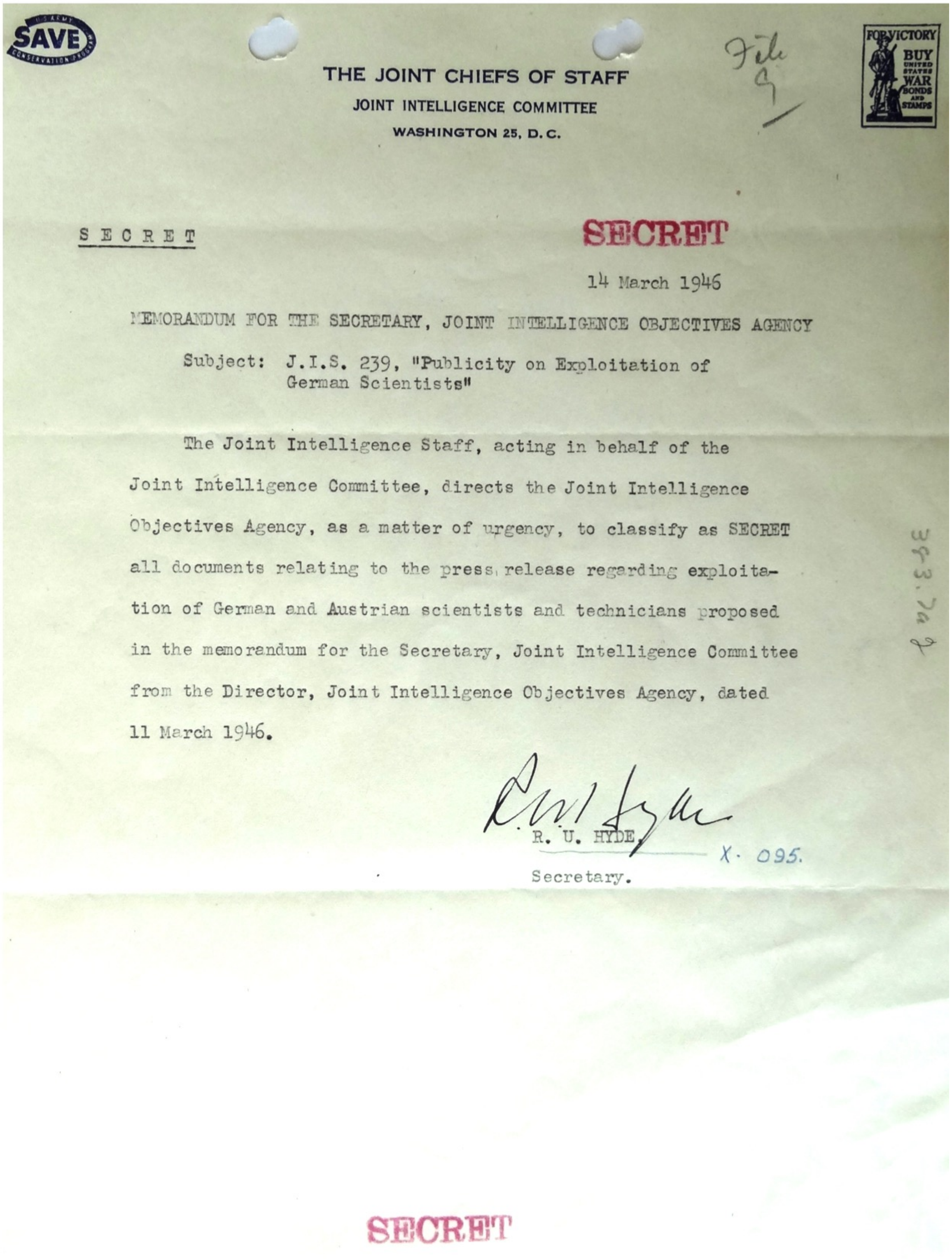

U.S. ARMY SAVE CONSERVATION PROGRAM

FOR VICTORY BUY UNITED STATES WAR BONDS AND STAMPS

File

THE JOINT CHIEFS OF STAFF
JOINT INTELLIGENCE COMMITTEE
WASHINGTON 25, D. C.

SECRET

SECRET

14 March 1946

MEMORANDUM FOR THE SECRETARY, JOINT INTELLIGENCE OBJECTIVES AGENCY

Subject: J.I.S. 239, "Publicity on Exploitation of German Scientists"

The Joint Intelligence Staff, acting in behalf of the Joint Intelligence Committee, directs the Joint Intelligence Objectives Agency, as a matter of urgency, to classify as SECRET all documents relating to the press release regarding exploitation of German and Austrian scientists and technicians proposed in the memorandum for the Secretary, Joint Intelligence Committee from the Director, Joint Intelligence Objectives Agency, dated 11 March 1946.

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R. U. HYDE,
Secretary.

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Figure 11.47: Ernest Gruhn. 14 March 1946. Exploitation of Germany for Technological and Scientific Information. [NARA RG 330, Entry A1-1A, Box 4, Folder 383.7 Policy–1946].

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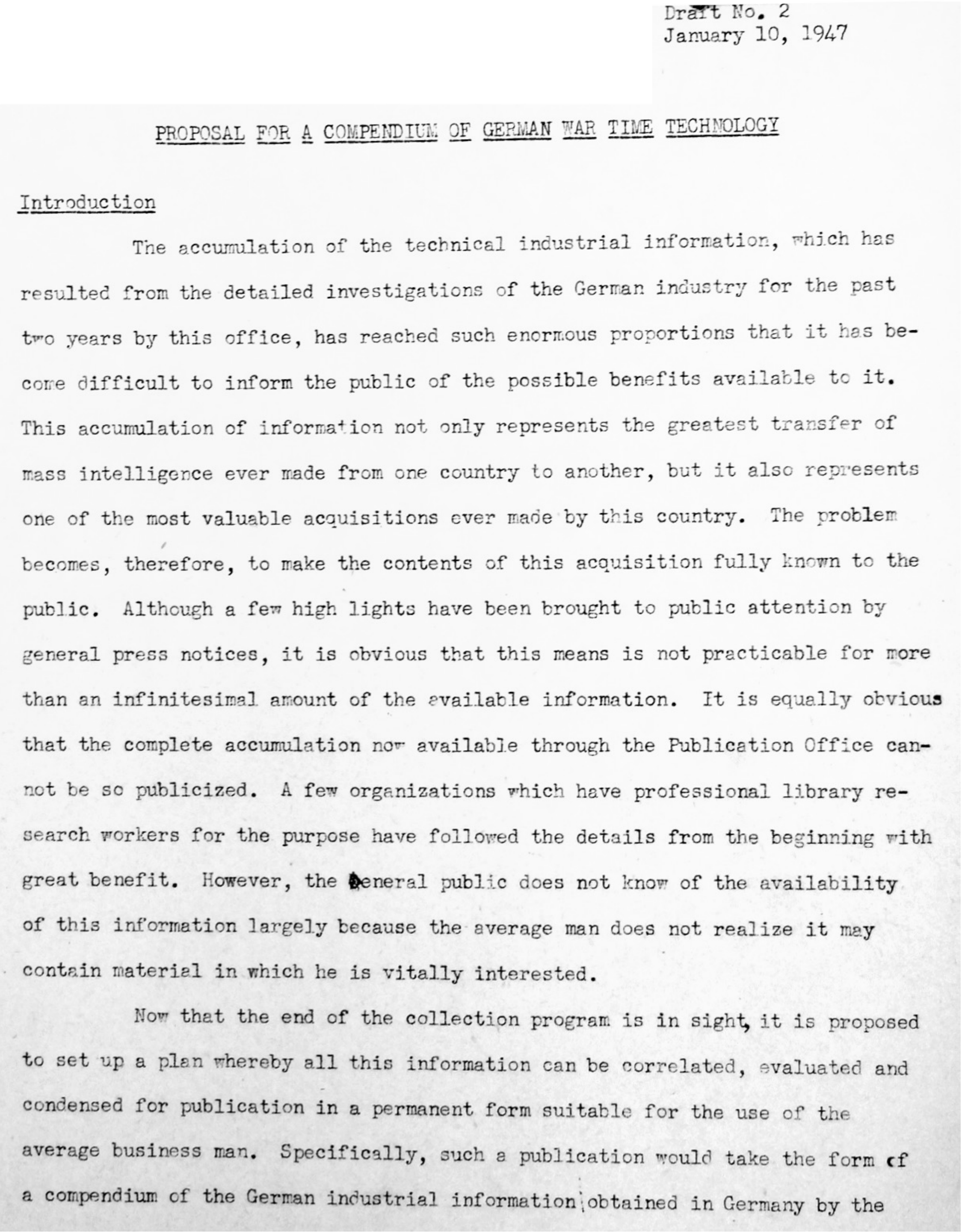

Draft No. 2
January 10, 1947

PROPOSAL FOR A COMPENDIUM OF GERMAN WAR TIME TECHNOLOGY

Introduction

The accumulation of the technical industrial information, which has resulted from the detailed investigations of the German industry for the past two years by this office, has reached such enormous proportions that it has become difficult to inform the public of the possible benefits available to it. This accumulation of information not only represents the greatest transfer of mass intelligence ever made from one country to another, but it also represents one of the most valuable acquisitions ever made by this country. The problem becomes, therefore, to make the contents of this acquisition fully known to the public. Although a few high lights have been brought to public attention by general press notices, it is obvious that this means is not practicable for more than an infinitesimal amount of the available information. It is equally obvious that the complete accumulation now available through the Publication Office cannot be so publicized. A few organizations which have professional library research workers for the purpose have followed the details from the beginning with great benefit. However, the general public does not know of the availability of this information largely because the average man does not realize it may contain material in which he is vitally interested.

Now that the end of the collection program is in sight, it is proposed to set up a plan whereby all this information can be correlated, evaluated and condensed for publication in a permanent form suitable for the use of the average business man. Specifically, such a publication would take the form of a compendium of the German industrial information obtained in Germany by the

Figure 11.48: L. B. Kilgore. 10 January 1947. Proposal for a Compendium of German War Time Technology, Draft No. 2 [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

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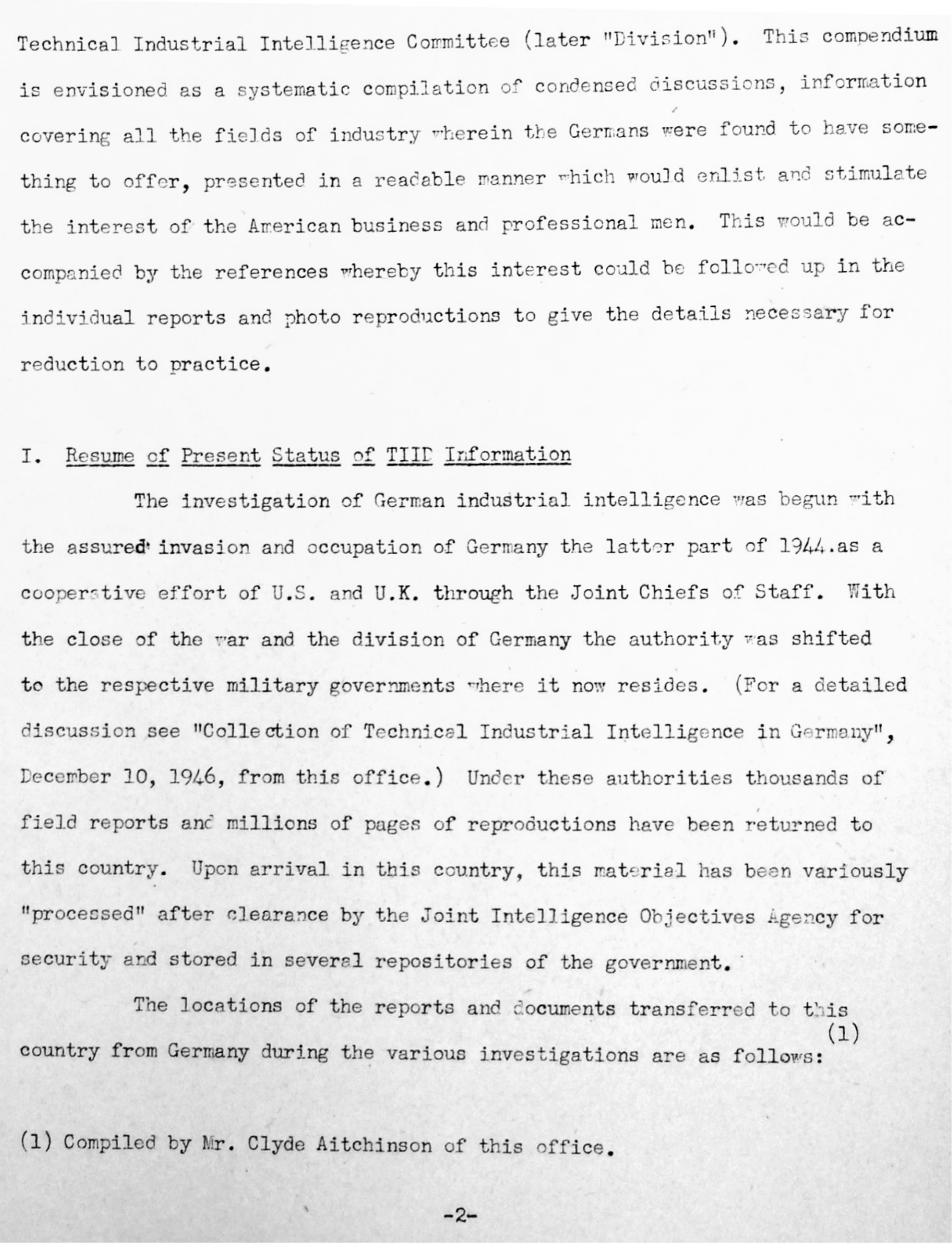

Technical Industrial Intelligence Committee (later "Division"). This compendium is envisioned as a systematic compilation of condensed discussions, information covering all the fields of industry wherein the Germans were found to have something to offer, presented in a readable manner which would enlist and stimulate the interest of the American business and professional men. This would be accompanied by the references whereby this interest could be followed up in the individual reports and photo reproductions to give the details necessary for reduction to practice.

I. Resume of Present Status of TIID Information

The investigation of German industrial intelligence was begun with the assured invasion and occupation of Germany the latter part of 1944.as a cooperative effort of U.S. and U.K. through the Joint Chiefs of Staff. With the close of the war and the division of Germany the authority was shifted to the respective military governments where it now resides. (For a detailed discussion see "Collection of Technical Industrial Intelligence in Germany", December 10, 1946, from this office.) Under these authorities thousands of field reports and millions of pages of reproductions have been returned to this country. Upon arrival in this country, this material has been variously "processed" after clearance by the Joint Intelligence Objectives Agency for security and stored in several repositories of the government.

The locations of the reports and documents transferred to this country from Germany during the various investigations are as follows:(1)

(1) Compiled by Mr. Clyde Aitchinson of this office.

-2-

Figure 11.49: L. B. Kilgore. 10 January 1947. Proposal for a Compendium of German War Time Technology, Draft No. 2 [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

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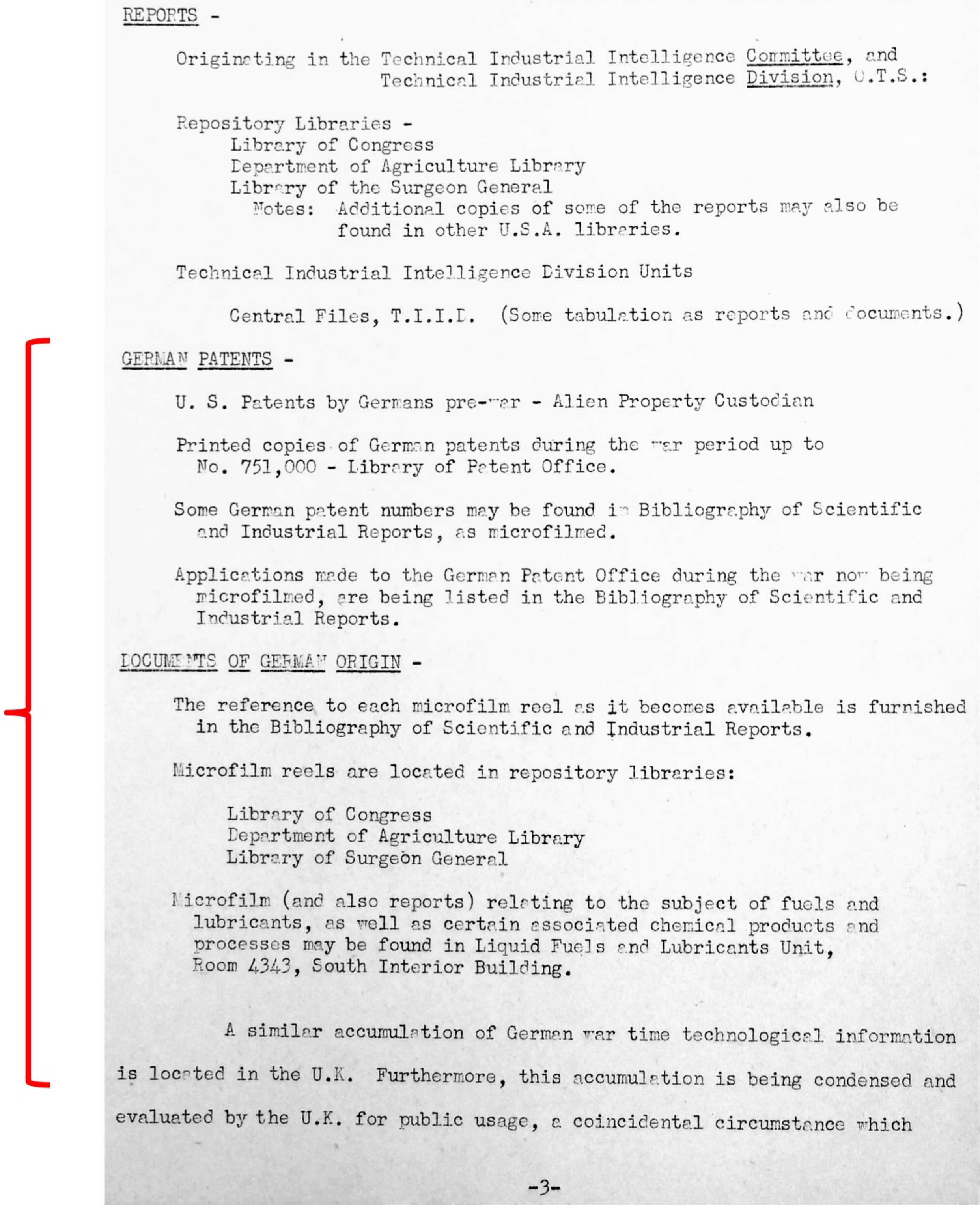
NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss



REPORTS -

Originating in the Technical Industrial Intelligence Committee, and
Technical Industrial Intelligence Division, O.T.S.:

Repository Libraries -
  Library of Congress
  Department of Agriculture Library
  Library of the Surgeon General
    Notes: Additional copies of some of the reports may also be found in other U.S.A. libraries.

Technical Industrial Intelligence Division Units

  Central Files, T.I.I.D. (Some tabulation as reports and documents.)

GERMAN PATENTS -

U. S. Patents by Germans pre-war - Alien Property Custodian

Printed copies of German patents during the war period up to No. 751,000 - Library of Patent Office.

Some German patent numbers may be found in Bibliography of Scientific and Industrial Reports, as microfilmed.

Applications made to the German Patent Office during the war now being microfilmed, are being listed in the Bibliography of Scientific and Industrial Reports.

DOCUMENTS OF GERMAN ORIGIN -

The reference to each microfilm reel as it becomes available is furnished in the Bibliography of Scientific and Industrial Reports.

Microfilm reels are located in repository libraries:

  Library of Congress
  Department of Agriculture Library
  Library of Surgeon General

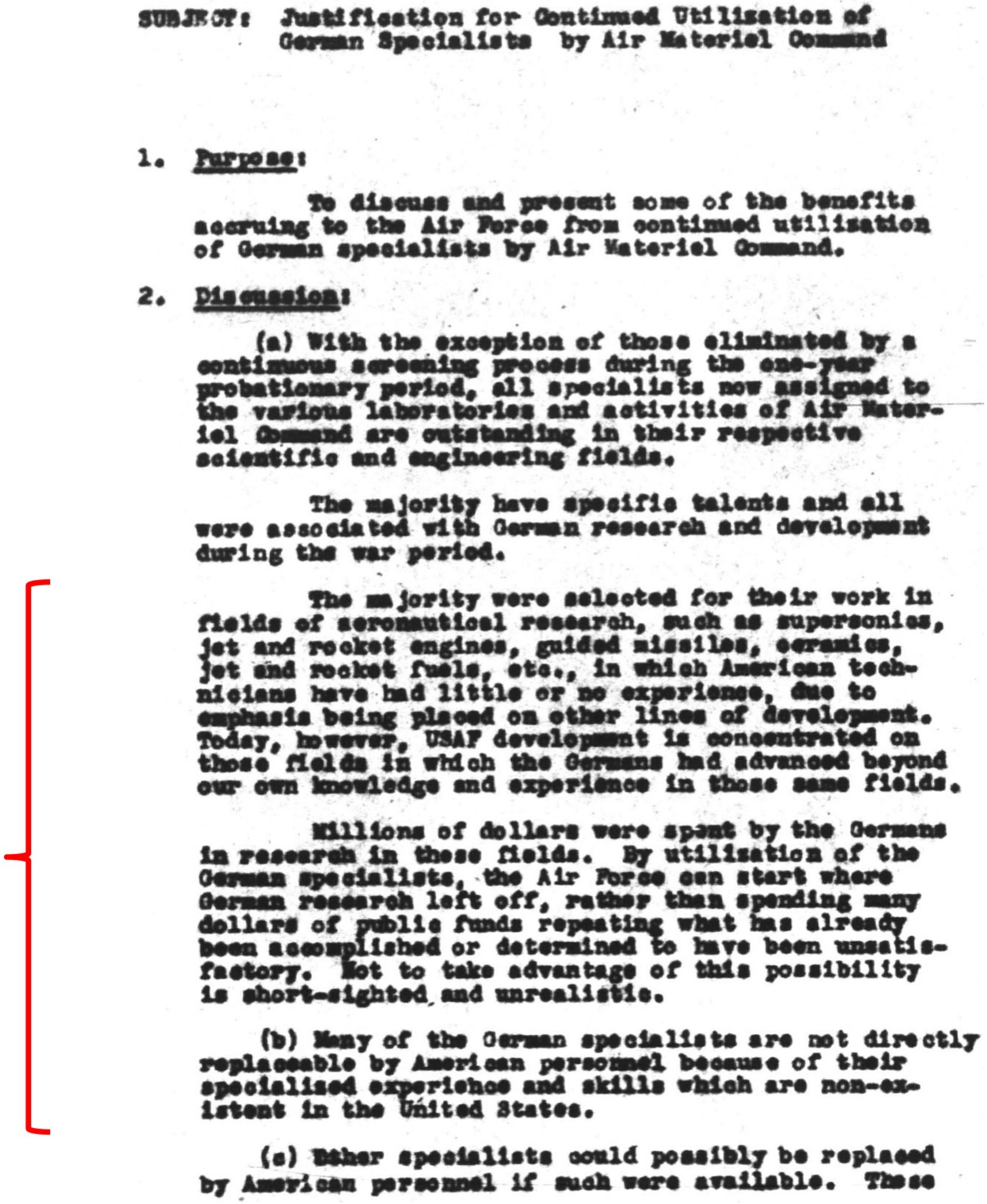
Microfilm (and also reports) relating to the subject of fuels and lubricants, as well as certain associated chemical products and processes may be found in Liquid Fuels and Lubricants Unit, Room 4343, South Interior Building.

A similar accumulation of German war time technological information is located in the U.K. Furthermore, this accumulation is being condensed and evaluated by the U.K. for public usage, a coincidental circumstance which

-3-

Figure 11.50: L. B. Kilgore. 10 January 1947. Proposal for a Compendium of German War Time Technology, Draft No. 2 [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

AFHRA A2056 electronic p. 405.
Donald Putt to Joseph McNarney. 10 December 1947.
German Specialist Program at the Air Materiel Command. Tab F.



SUBJECT: Justification for Continued Utilization of German Specialists by Air Materiel Command

1. Purpose:

To discuss and present some of the benefits accruing to the Air Force from continued utilization of German specialists by Air Materiel Command.

2. Discussion:

(a) With the exception of those eliminated by a continuous screening process during the one-year probationary period, all specialists now assigned to the various laboratories and activities of Air Materiel Command are outstanding in their respective scientific and engineering fields.

The majority have specific talents and all were associated with German research and development during the war period.

The majority were selected for their work in fields of aeronautical research, such as supersonics, jet and rocket engines, guided missiles, ceramics, jet and rocket fuels, etc., in which American technicians have had little or no experience, due to emphasis being placed on other lines of development. Today, however, USAF development is concentrated on those fields in which the Germans had advanced beyond our own knowledge and experience in those same fields.

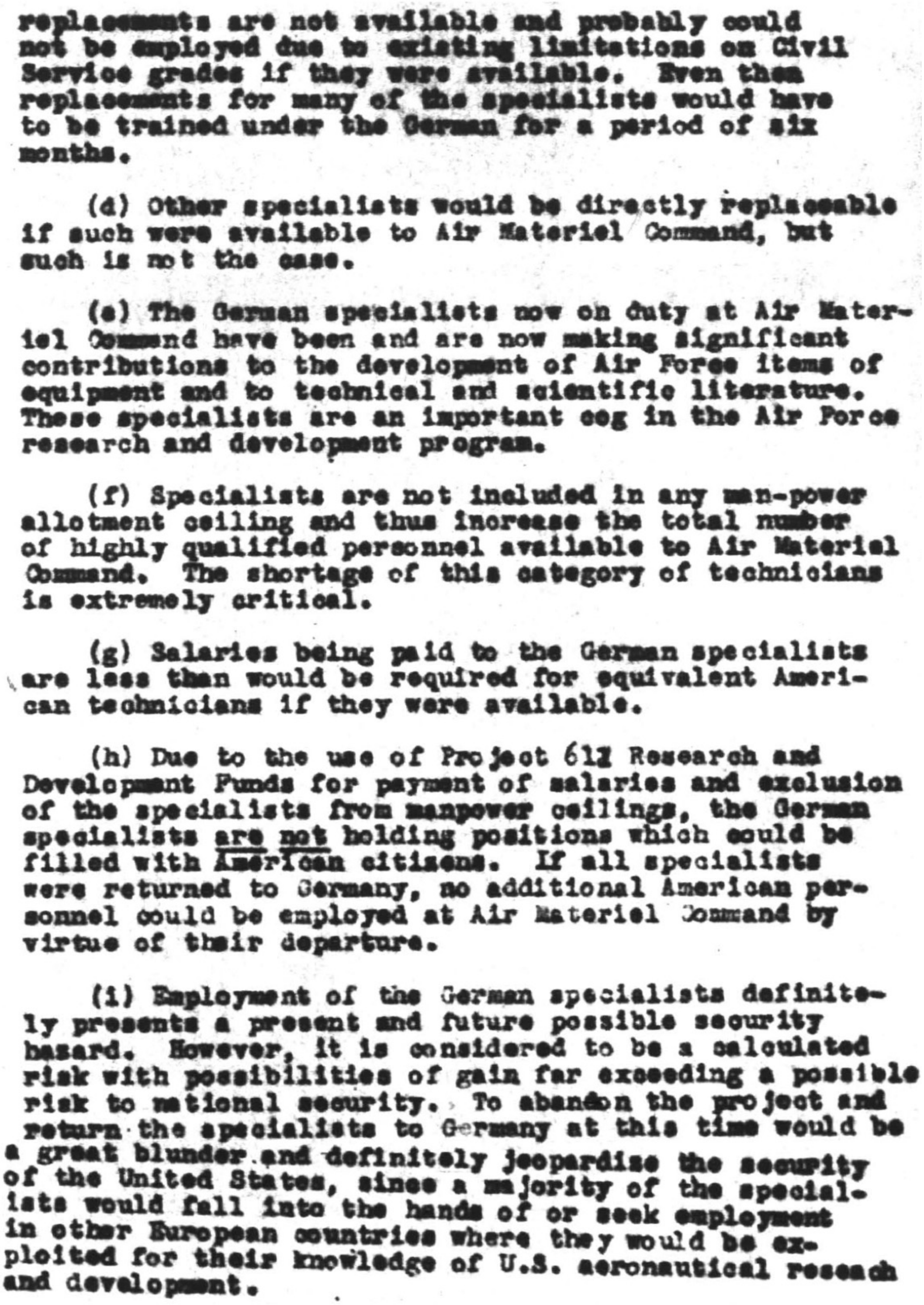
Millions of dollars were spent by the Germans in research in these fields. By utilization of the German specialists, the Air Force can start where German research left off, rather than spending many dollars of public funds repeating what has already been accomplished or determined to have been unsatisfactory. Not to take advantage of this possibility is short-sighted and unrealistic.

(b) Many of the German specialists are not directly replaceable by American personnel because of their specialized experience and skills which are non-existent in the United States.

(c) Other specialists could possibly be replaced by American personnel if such were available. These

Figure 11.51: Donald Putt to Joseph McNarney. 10 December 1947. German Specialist Program at the Air Materiel Command, Tab F [AFHRA A2056 electronic p. 405].

AFHRA A2056 electronic p. 406.
Donald Putt to Joseph McNarney. 10 December 1947.
German Specialist Program at the Air Materiel Command. Tab F.



replacements are not available and probably could not be employed due to existing limitations on Civil Service grades if they were available. Even then replacements for many of the specialists would have to be trained under the German for a period of six months.

(d) Other specialists would be directly replaceable if such were available to Air Materiel Command, but such is not the case.

(e) The German specialists now on duty at Air Materiel Command have been and are now making significant contributions to the development of Air Force items of equipment and to technical and scientific literature. These specialists are an important cog in the Air Force research and development program.

(f) Specialists are not included in any man-power allotment ceiling and thus increase the total number of highly qualified personnel available to Air Materiel Command. The shortage of this category of technicians is extremely critical.

(g) Salaries being paid to the German specialists are less than would be required for equivalent American technicians if they were available.

(h) Due to the use of Project 612 Research and Development Funds for payment of salaries and exclusion of the specialists from manpower ceilings, the German specialists are not holding positions which could be filled with American citizens. If all specialists were returned to Germany, no additional American personnel could be employed at Air Materiel Command by virtue of their departure.

(i) Employment of the German specialists definitely presents a present and future possible security hazard. However, it is considered to be a calculated risk with possibilities of gain far exceeding a possible risk to national security. To abandon the project and return the specialists to Germany at this time would be a great blunder and definitely jeopardize the security of the United States, since a majority of the specialists would fall into the hands of or seek employment in other European countries where they would be exploited for their knowledge of U.S. aeronautical reseach and development.

Figure 11.52: Official U.S. government policy was to underpay German-speaking scientists for their work. Donald Putt to Joseph McNarney. 10 December 1947. German Specialist Program at the Air Materiel Command, Tab F [AFHRA A2056 electronic p. 406].

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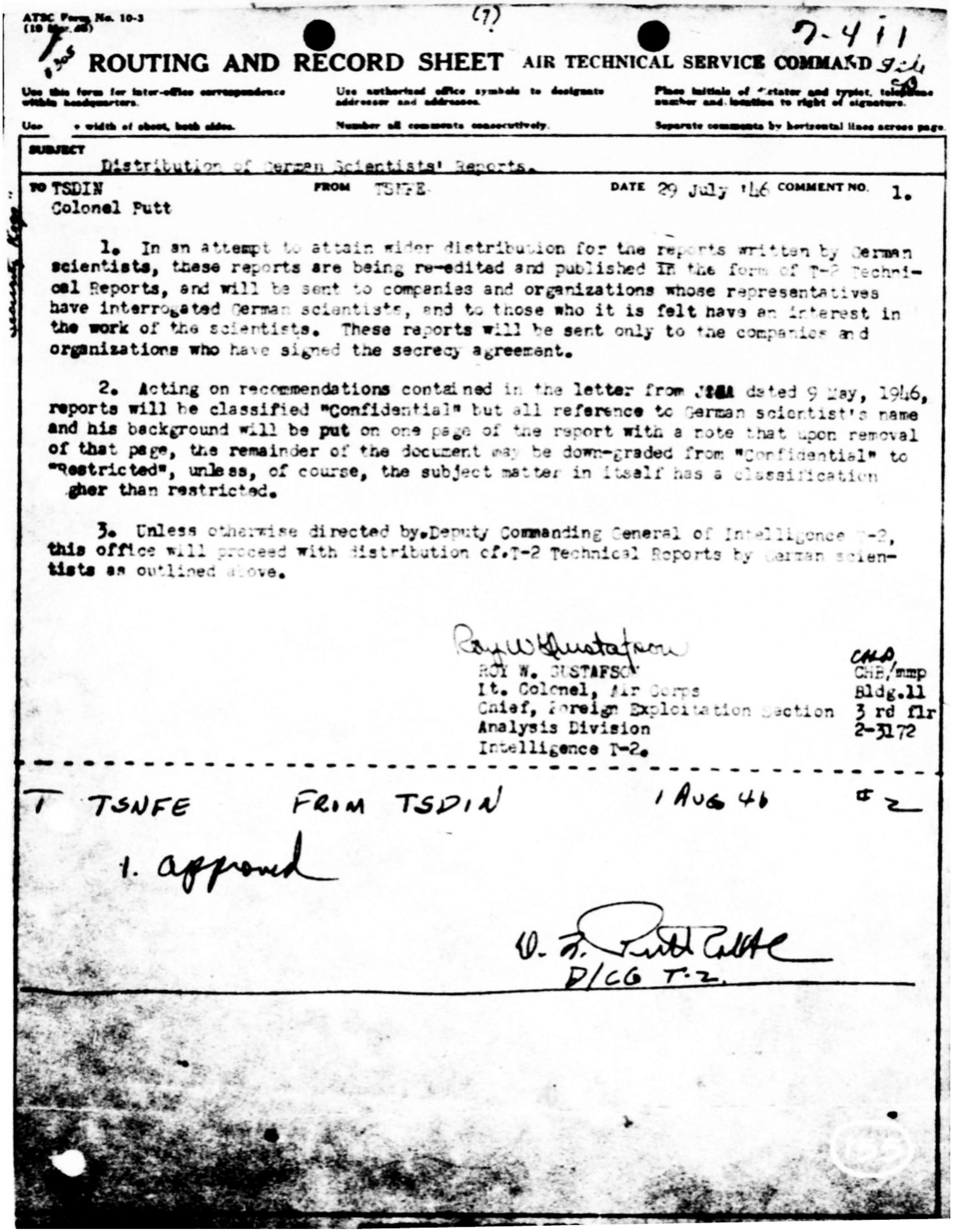


ATSC Form No. 10-3
(19 Mar. 45)

(7) 7-411

ROUTING AND RECORD SHEET AIR TECHNICAL SERVICE COMMAND

Use this form for inter-office correspondence within headquarters. Use authorized office symbols to designate addressor and addressee. Place initials of dictator and typist, telephone number and location to right of signature.

Use full width of sheet, both sides. Number all comments consecutively. Separate comments by horizontal lines across page.

SUBJECT Distribution of German Scientists' Reports.

TO TSDIN FROM TSNFE DATE 29 July '46 COMMENT NO. 1.

Colonel Putt

1. In an attempt to attain wider distribution for the reports written by German scientists, these reports are being re-edited and published IN the form of T-2 Technical Reports, and will be sent to companies and organizations whose representatives have interrogated German scientists, and to those who it is felt have an interest in the work of the scientists. These reports will be sent only to the companies and organizations who have signed the secrecy agreement.

2. Acting on recommendations contained in the letter from JIOA dated 9 May, 1946, reports will be classified "Confidential" but all reference to German scientist's name and his background will be put on one page of the report with a note that upon removal of that page, the remainder of the document may be down-graded from "Confidential" to "Restricted", unless, of course, the subject matter in itself has a classification higher than restricted.

3. Unless otherwise directed by Deputy Commanding General of Intelligence T-2, this office will proceed with distribution of T-2 Technical Reports by German scientists as outlined above.

Roy W. Gustafson

ROY W. GUSTAFSON
Lt. Colonel, Air Corps
Chief, Foreign Exploitation Section
Analysis Division
Intelligence T-2.

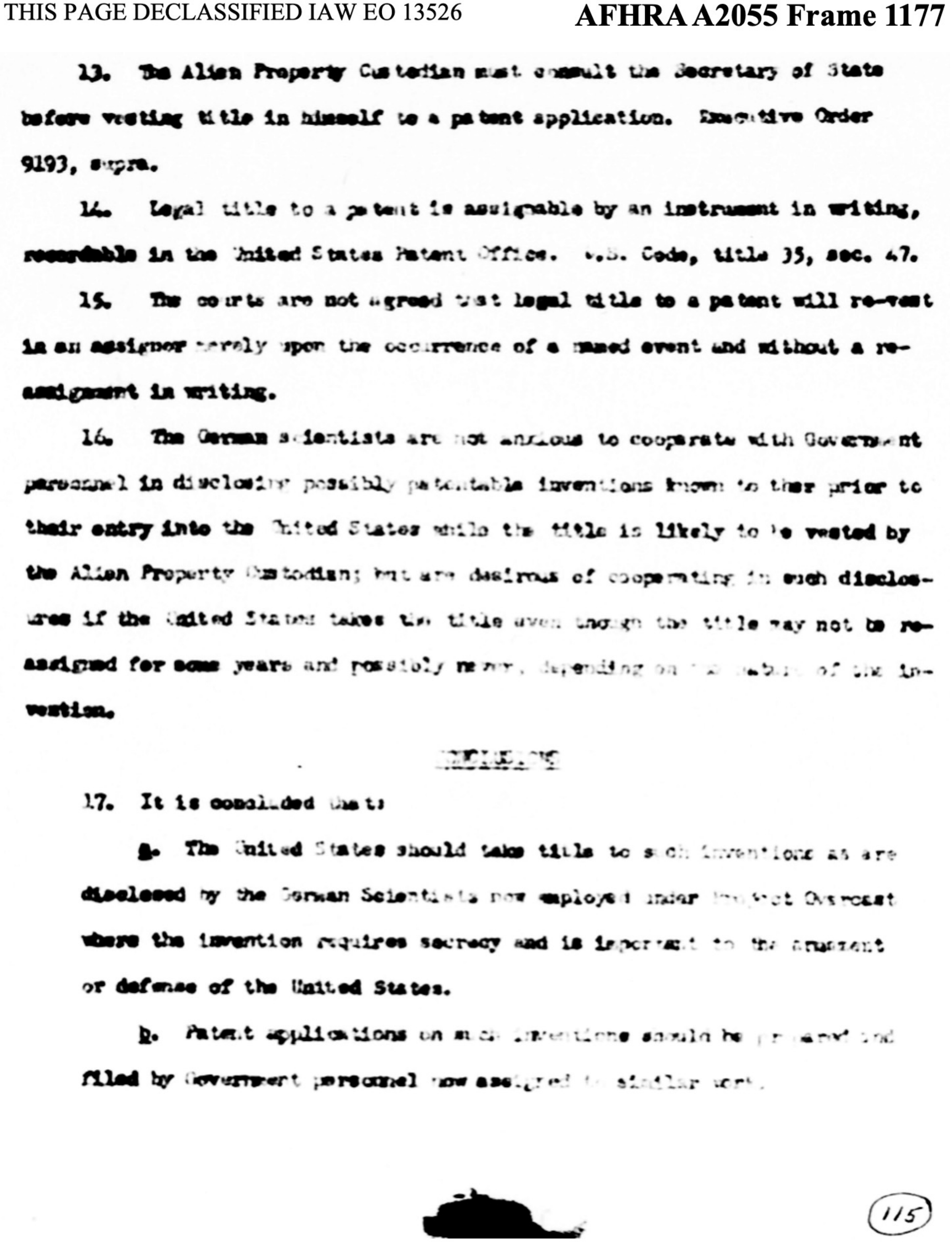
CHB/mmp
Bldg.11
3 rd flr
2-3172

T TSNFE FROM TSDIN 1 AUG 46 # 2

1. approved

D. L. Putt Col
D/CG T-2.

Figure 11.53: Official U.S. government policy was to classify or remove the names of German-speaking scientists from technical reports they wrote for the United States. Roy W. Gustafson. 29 July 1946. Distribution of German Scientists' Reports [AFHRA A2055 Frame 1265].



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AFHRA A2055 Frame 1177

13. The Alien Property Custodian must consult the Secretary of State before vesting title in himself to a patent application. Executive Order 9193, supra.

14. Legal title to a patent is assignable by an instrument in writing, recordable in the United States Patent Office. U.S. Code, title 35, sec. 47.

15. The courts are not agreed that legal title to a patent will re-vest in an assignor merely upon the occurrence of a named event and without a reassignment in writing.

16. The German scientists are not anxious to cooperate with Government personnel in disclosing possibly patentable inventions known to them prior to their entry into the United States while the title is likely to be vested by the Alien Property Custodian; but are desirous of cooperating in such disclosures if the United States takes the title even though the title may not be reassigned for some years and possibly never, depending on the nature of the invention.

CONCLUSIONS

17. It is concluded that:

a. The United States should take title to such inventions as are disclosed by the German Scientists now employed under Project Overcast where the invention requires secrecy and is important to the armament or defense of the United States.

b. Patent applications on such inventions should be prepared and filed by Government personnel now assigned to similar work.

[redacted]

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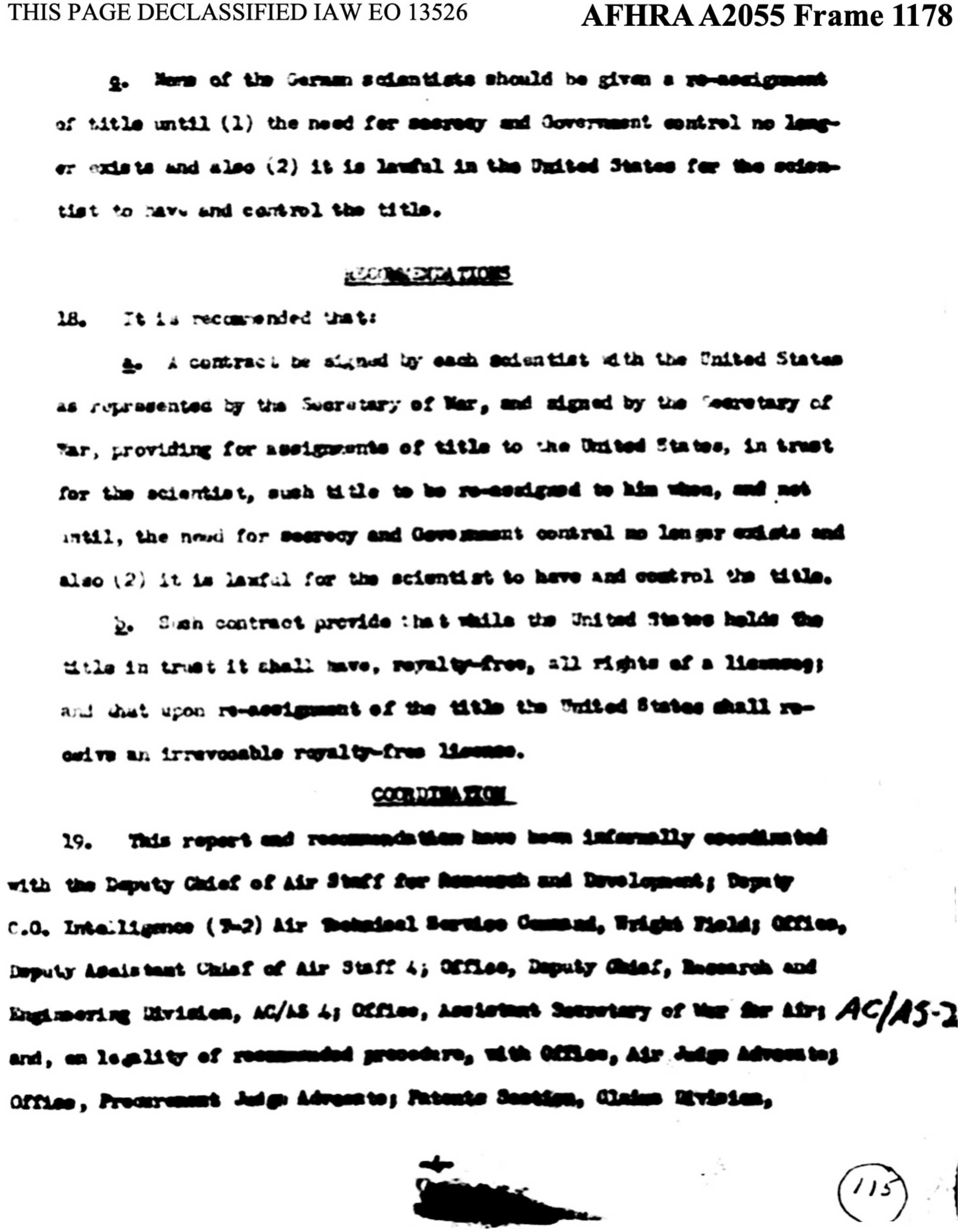
Figure 11.54: Official U.S. government policy was to deny German-speaking scientists ownership of their inventions, or in some cases even to be named as the inventor of that technology. Joseph W. Hazell. 28 February 1946. Project Overcast [AFHRA A2055 Frame 1177].



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AFHRA A2055 Frame 1178

g. None of the German scientists should be given a re-assignment of title until (1) the need for secrecy and Government control no longer exists and also (2) it is lawful in the United States for the scientist to have and control the title.

RECOMMENDATIONS

18. It is recommended that:

a. A contract be signed by each scientist with the United States as represented by the Secretary of War, and signed by the Secretary of War, providing for assignments of title to the United States, in trust for the scientist, such title to be re-assigned to him when, and not until, the need for secrecy and Government control no longer exists and also (2) it is lawful for the scientist to have and control the title.

b. Such contract provide that while the United States holds the title in trust it shall have, royalty-free, all rights of a licensee; and that upon re-assignment of the title the United States shall receive an irrevocable royalty-free license.

COORDINATION

19. This report and recommendation have been informally coordinated with the Deputy Chief of Air Staff for Research and Development; Deputy C.O. Intelligence (T-2) Air Technical Service Command, Wright Field; Office, Deputy Assistant Chief of Air Staff 4; Office, Deputy Chief, Research and Engineering Division, AC/AS 4; Office, Assistant Secretary of War for Air; AC/AS-2 and, on legality of recommended procedure, with Office, Air Judge Advocate; Office, Procurement Judge Advocate; Patents Section, Claims Division,

4

[redacted]

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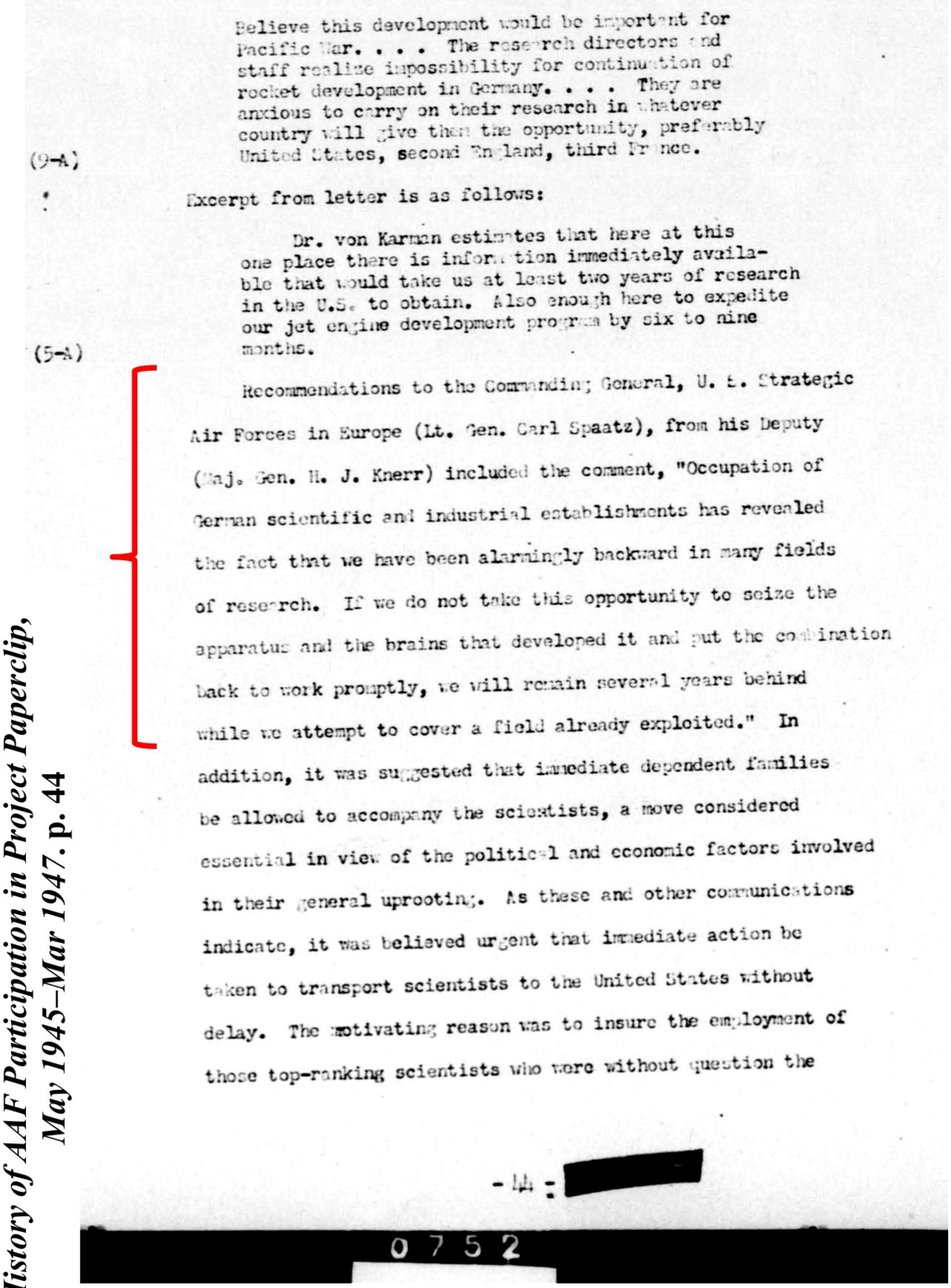
Figure 11.55: Official U.S. government policy was to deny German-speaking scientists ownership of their inventions, or in some cases even to be named as the inventor of that technology. Joseph W. Hazell. 28 February 1946. Project Overcast [AFHRA A2055 Frame 1178].



> Believe this development would be important for Pacific War. . . . The research directors and staff realize impossibility for continuation of rocket development in Germany. . . . They are anxious to carry on their research in whatever country will give them the opportunity, preferably United States, second England, third France.

(9-A)

Excerpt from letter is as follows:

> Dr. von Karman estimates that here at this one place there is information immediately available that would take us at least two years of research in the U.S. to obtain. Also enough here to expedite our jet engine development program by six to nine months.

(5-A)

Recommendations to the Commanding General, U. S. Strategic Air Forces in Europe (Lt. Gen. Carl Spaatz), from his Deputy (Maj. Gen. H. J. Knerr) included the comment, "Occupation of German scientific and industrial establishments has revealed the fact that we have been alarmingly backward in many fields of research. If we do not take this opportunity to seize the apparatus and the brains that developed it and put the combination back to work promptly, we will remain several years behind while we attempt to cover a field already exploited." In addition, it was suggested that immediate dependent families be allowed to accompany the scientists, a move considered essential in view of the political and economic factors involved in their general uprooting. As these and other communications indicate, it was believed urgent that immediate action be taken to transport scientists to the United States without delay. The motivating reason was to insure the employment of those top-ranking scientists who were without question the

- 44 - [redacted]

0752

AFHRA A2055 electronic p. 747. Edna Jensen. 1948. *History of AAF Participation in Project Paperclip, May 1945–Mar 1947*. p. 44

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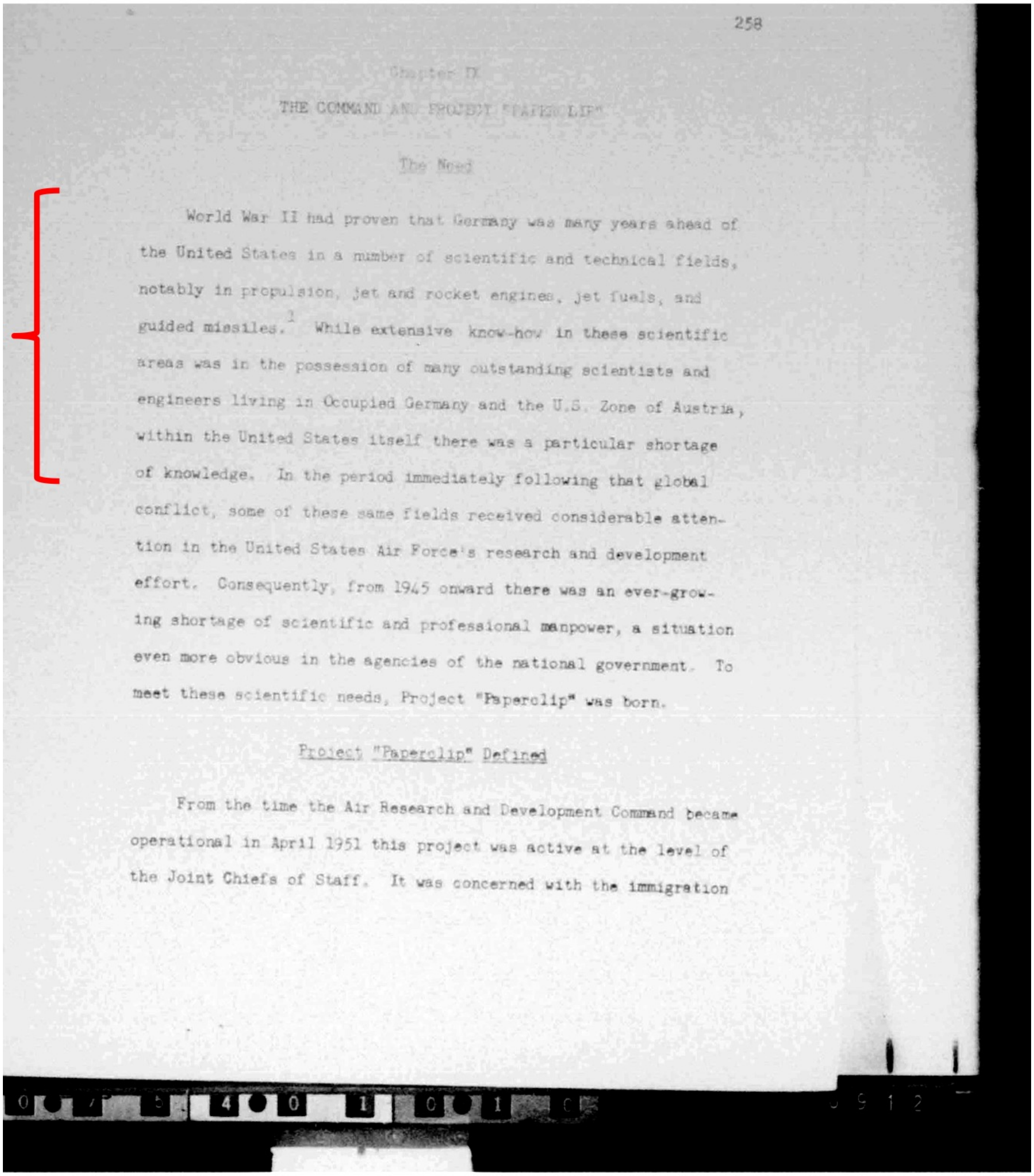
Figure 11.56: Edna Jensen. 1948. *History of AAF Participation in Project Paperclip, May 1945–Mar 1947*, p. 44 [AFHRA A2055 electronic p. 747].

AFHRA K2838 (15390) electronic p. 887.
***History of the Air Research and Development Command*. 1954.**
Chapter IX. Dr. Charles A. Johnson. Project "Paperclip" p. 258.



Chapter IX

THE COMMAND AND PROJECT "PAPERCLIP"

The Need

World War II had proven that Germany was many years ahead of the United States in a number of scientific and technical fields, notably in propulsion, jet and rocket engines, jet fuels, and guided missiles.[1] While extensive know-how in these scientific areas was in the possession of many outstanding scientists and engineers living in Occupied Germany and the U.S. Zone of Austria, within the United States itself there was a particular shortage of knowledge. In the period immediately following that global conflict, some of these same fields received considerable attention in the United States Air Force's research and development effort. Consequently, from 1945 onward there was an ever-growing shortage of scientific and professional manpower, a situation even more obvious in the agencies of the national government. To meet these scientific needs, Project "Paperclip" was born.

Project "Paperclip" Defined

From the time the Air Research and Development Command became operational in April 1951 this project was active at the level of the Joint Chiefs of Staff. It was concerned with the immigration

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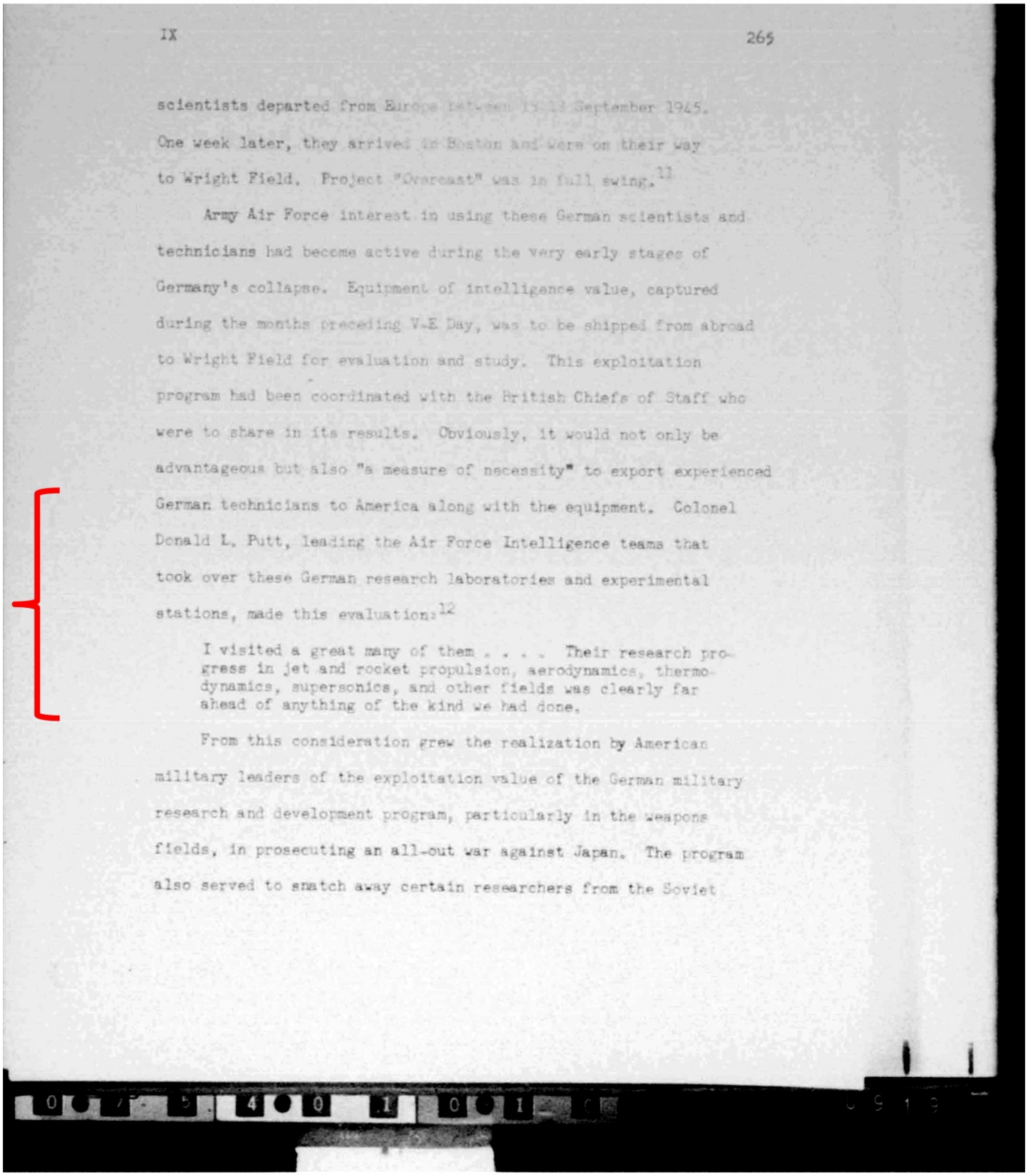
Figure 11.57: *History of the Air Research and Development Command.* 1954. Chapter IX. Dr. Charles A. Johnson. Project "Paperclip," p. 258 [AFHRA K2838 (15390) electronic p. 887].

AFHRA K2838 (15390) electronic p. 894.
History of the Air Research and Development Command. 1954.
Chapter IX. Dr. Charles A. Johnson. Project "Paperclip" p. 265.



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scientists departed from Europe between 11-13 September 1945. One week later, they arrived in Boston and were on their way to Wright Field. Project "Overcast" was in full swing.[11]

Army Air Force interest in using these German scientists and technicians had become active during the very early stages of Germany's collapse. Equipment of intelligence value, captured during the months preceding V-E Day, was to be shipped from abroad to Wright Field for evaluation and study. This exploitation program had been coordinated with the British Chiefs of Staff who were to share in its results. Obviously, it would not only be advantageous but also "a measure of necessity" to export experienced German technicians to America along with the equipment. Colonel Donald L. Putt, leading the Air Force Intelligence teams that took over these German research laboratories and experimental stations, made this evaluation:[12]

> I visited a great many of them . . . . Their research progress in jet and rocket propulsion, aerodynamics, thermodynamics, supersonics, and other fields was clearly far ahead of anything of the kind we had done.

From this consideration grew the realization by American military leaders of the exploitation value of the German military research and development program, particularly in the weapons fields, in prosecuting an all-out war against Japan. The program also served to snatch away certain researchers from the Soviet

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Figure 11.58: *History of the Air Research and Development Command.* 1954. Chapter IX. Dr. Charles A. Johnson. Project "Paperclip," p. 265 [AFHRA K2838 (15390) electronic p. 894].

[The following 3 articles were translated from Russian to German to English.] **The Billion-Dollar Object Germany. 20 Million Dollars for a Single German Patent! *Die Tat* (Zürich), 4 March 1947, p. 5. http://www.e-newspaperarchives.ch/?a=d&d=DTT19470304-01.2.18**

Under the title: “How the USA and England get reparations from Germany”, D. Melnikov writes in the Moscow weekly “New Era,” the latest one to arrive here, among other things:

Neither England nor the USA has yet declared their reparations claims to Germany. However, they have already obtained goods from Germany that significantly exceed the amount of 10 billion dollars.

As Colonel Wilkinson, the head of the industrial department of the American military government in Germany, announced, at the end of last year a number of companies in the western zones were made available as advance payments for the reparation account. However, when the dismantling of these factories began, the Allied authorities used all possible means to stop the shipment of machinery and equipment to the Soviet Union, while the removal of the unique equipment intended for England and the USA was carried out at a rapid pace. The most important companies in the American occupation zone were dismantled. All nickel works, 90% of the aircraft engine factories, 70% of the motorcycle engine factories, a significant (part) of the municipal businesses, the machine tool factories, etc. were exported, etc.

This is the official dismantling program. However, the confiscation of industrial equipment by England and the USA goes far beyond this program, as can be seen even from the sparse press reports. The Anglo-Saxon countries mainly cover their reparations claims through so-called “invisible reparations,” which not only include machinery, but also the industrial products that are continually manufactured. We would like to give some examples.

According to a Reuters report, machines of the latest models from ongoing production at the Fritz Müller works in Ober-Eßlingen were shipped to England in the second half of 1946. At the beginning of January 1947, a significant number of machines were again sent to a number of larger English companies, including numerous unique sample and test machines. At the end of last year, the English authorities confiscated almost the entire finished production of the Siemens-Schuckert-Werke in Müllheim, which produces turbines and turbine components, and transported them to England. In the second half of 1946, as the “Berliner Zeitung” dated 21 January this year reported that 300,000 tons of wood worth 1.5 pounds sterling were shipped from Germany to England. The English military government even has control over all the products from the 20 fountain pen factories in the English occupied zone.

Industrial products are also confiscated in the American zone. According to the orders of the American occupation authorities, over 12,000 tons of aluminum were collected here, melted down and shipped to the USA. The occupation authorities have access to 95 percent of all cameras manufactured by the well-known Munich Agfa factories. End of November last year, the Directorate of the State Council of the American Zone turned to the military government with a request to cancel an order to the shoe factories for the delivery of 245,000 pairs of shoes. Consequently, such deliveries must have taken place.

Another category of reparations that England and the USA receive from Germany are German patents and inventions. The occupation authorities of the western zones have placed their hands on approximately 200,000 patents. At the end of last year, a reporter for the “News Chronicle” managed to gain insight into the report of an Anglo-American special commission that investigated the possibility of exploiting German inventions. The rapporteur places a very high value on the practical value of these inventions. An American manufacturer offered the US government $20 million for the use of a single production process patented in Germany.

Furthermore, England and the USA confiscated the largest part of the German gold reserve, amounting to 160–170 tons, which had been brought to the West by the Hitlerite fascists before the end of the war and was mainly concentrated in the American zone of occupation. In addition, the Swiss government has agreed to hand over the 50 tons of German gold in their country to England and the USA, and the Swedish government has agreed to hand over 7 tons. This means that over 200 tons of German gold are already in the hands of England and the USA. It should also be added that the British and American occupation authorities confiscated an enormous amount of valuables.

Ultimately, the USA, England including the Dominions and France received 470,000 GRT from the German merchant fleet.

The above shows how many reparations the Anglo-Saxon states have already secured within Germany, and yet this information does not yet provide a complete picture. England and the USA have received the extensive German foreign assets in the so-called neutral states as well as in the USA, in England, in Latin American and other countries.

The Berlin newspaper "Die Tribüne" has made an approximate estimate of how much reparations England and the USA have already received and states that the German foreign investments that are to be handed over to England and the USA are estimated at 3.3 billion dollars. The value of the German merchant fleet in the hands of the Allied Western Powers is 2.2 billion dollars. The German gold and the German patents and inventions confiscated by England and the USA are estimated at 5 billion dollars. In total, that's already 10.5 billion dollars, apart from the confiscated industrial products and the German plants and machines confiscated by the British and Americans and bought up at extremely low compulsory prices.

These facts show that England and the USA are satisfying their reparation claims very extensively, and that the reparations paid to them by Germany already exceed the total reparation demand of the Soviet Union (10 billion dollars).

Moscow about the Patent Loot in Germany. *Die Tat* (Zürich), 20 March 1947, p. 5. http://www.e-newspaperarchives.ch/?a=d&d=DTT19470320-01.2.16

"The seizure of German patents by American and English monopolies" is explained in the Moscow weekly "Neue Zeit" among other things:

As is well known, American and English companies, apart from other acquisitions on reparations accounts, have also acquired large quantities of German patents. In order to get a full idea of the value and significance of this part of the reparations revenue, one must understand the importance of patents in the world economy.

Under modern capitalism, patents are a powerful weapon of monopolies. In many cases, the possession of particularly valuable and important patents served as the basis for international cartel agreements.

Before the Second World War, the large trusts of the USA, England, and Germany had concentrated hundreds of thousands of patents in their hands, most of which were never exploited but served as a means of squeezing competitors.

At the American military government in Germany, in Frankfurt am Main, a special apparatus was created under the name Field Information Agency Technical, which was subordinate to General Clay. In this institution there is a special "Technical Intelligence Branch" which has a rich engineering staff in various fields and specialists in photophotography. The US Department of Commerce has a so-called Office of the Publication Board, which, through a decree of President Truman under No. 9604, is responsible for collecting information about scientific and technical achievements, inventions, improvements, etc. in enemy and liberated countries; notice that this recollection has been made mandatory by the decree. This office forwards requests from American industry to the aforementioned bodies of the occupation authorities and informs them of their needs.

John C. Green, the executive secretary of the mentioned publication office, reports in the Journal of the American Chemical Society the following about the methods used in obtaining patents from Germany:

A group of specialist engineers, supported by qualified German scientists and engineers, who have been examined by the military authorities, appear at a research institute, laboratory or company, carefully familiarize themselves with the technological process or research topic and determine which technical or... scientific achievements, inventions and perfections have been achieved here over a longer period of time. Afterwards, German microphotographers, under the supervision of the Americans, photograph these materials on microfilm, while the first working group (that began to collect) goes off to visit the next target. The microfilms are developed in Frankfurt, cataloged using a carefully developed system and sent to the USA. By the fall of 1946, of the 3.5 billion pages of technical documents these groups had produced that were of value to American industry, 3.5 million pages had been microfilmed. John Green shares:

"Among the stacks of data recently discovered and continually microfilmed by the search groups are all the valuable inventions that the IG-Farben industry has applied for patents or was about to do so with the German Patent Office."

Green rightly adds: "Apparently these are reparations in the most productive sense of the word." The above-mentioned publication office at the US Department of Commerce not only deals with the publication of patents, drawings, chemical recipes and the like, it also generously sends scientists and qualified engineers from the industrial trusts to Germany so that they can be on site to familiarize themselves with the activities of the relevant German industrial sectors. These scientists and engineers visit important companies and research laboratories of this or that branch of the economy, collect technical information and write detailed reports. After that they return to their jobs at the concerned companies, which cover all expenses for these business trips.

The listed methods for acquiring German scientific and technical experience are essential additions to the ownership of German patents, since the exploitation of patents is now often only possible if the corresponding production experience is available, which the Americans call "know how" ("wissen wie"). Without such detailed experimental knowledge, the patent can remain dead capital.

In addition to the patents exported from Germany, the Foreign Property Trust Administration in the United States, which was liquidated in the fall of 1946, held in its hands 45,000 patents, about 500,000 copyrights and a number of other technical documents that belonged to German (but also Japanese) citizens in the United States.

This category of reparations, from the strictest industrial secrets to the subordinate problems of production technology, is one of the richest spoils of war that has ever fallen to a victor.

Pravda: German Patents in the US and England. *Die Tat* (Zürich), 7 April 1949, p. 5. http://www.e-newspaperarchives.ch/?a=d&d=DTT19490407-01.2.29

N. Kharlamov writes about this and among other things reports the following:

Anglo-Saxon propaganda has long been campaigning for the complete cessation of reparations deliveries to the countries devastated by Hitler's aggression, whose legally justified demands are ignored because the ruling circles in the USA are focused on and have taken the decision of restoring West Germany's defense industrial potential. The "Voice of America" recently announced that the

United States was not interested in German reparation payments.

On the other hand, we know from numerous clearly established incidents how blatantly unembarrassed the occupation authorities in the western zones of Germany are sounding and acting, and that practically—from the very beginning—the United States and England have extracted, and are still extracting, huge reparations from Germany. The German patents and inventions, which have already brought American and English companies billions of dollars in profits, are just one but nevertheless very striking example of what is happening. The value of the German patents confiscated by the US as "spoils of war" alone was estimated at more than 5 billion dollars by the "Berlin Information Letters" published by the French Military Government in Berlin, an estimation based on original American sources. And it should be taken into account that the exploitation of patents is only a part of the hidden and disguised reparations that the Western powers are taking from Germany.

For over three years, hundreds of engineers and technicians from the American 'Office of Technical Services' have been working to sort, register and examine German patents brought to the United States, documents that weigh a total of more than 10,000 tons!

But not all German patents and documents about technological processes and scientific discoveries crossed the ocean; some remained in Germany and were brought to Höchst am Main, where the American authorities opened a kind of branch of the "New York Central Office for the Processing of German Patents."

Several hundred scholars and engineers select the most valuable documents at this place and record them on microfilms, which are then sent every month to the USA, to the Office for Technical Information. Every month 30,000 meters of microfilmed documents are viewed and prepared for distribution to American companies as is also confirmed by the "Berliner Informationsbriefe" ('Berlin Information Letters'). According to available information, more than 5 million meters of microfilms have already been sent to the USA.

Before the above-mentioned branch was set up in Höchst, the "Technical Intelligence Branch" carefully searched German companies and research institutes for documents on industrial planning, patents, new production methods, technological processes, etc. and found extremely valuable and unique machines and devices that were transported across the Atlantic. But in addition to the organs of the technical service of the US Army, special industrial missions were also busy with this task, which were directly interested in this or that branch of industry, such as the Schröder-Mission, which was launched immediately after Germany's surrender and crossed the Atlantic to obtain material about the latest achievements of German technology in the field of producing synthetic fuel. Supported by US troops, the German chemical companies were carefully combed and the most valuable patents, samples of unique equipment and confidential documents were brought to the US to be studied there with the active participation of German scholars and then incorporated into the American industry. The Office for Technical Information is literally overwhelmed with orders from American companies for German patents. Every day they receive around 20,000 requests from all parts of the country, with orders from large corporations such as Dupont, International Harvester Company, etc. being preferred. Patents worth tens and hundreds of thousands of dollars are sold to the largest monopolies at ridiculous prices of 6 to 17 dollars. In London, an analogous office, the "German Patents Registration Office," where German inventions are registered, sells the patents to the English monopolists for 2 shillings 6 pence! Despite these low prices, the New York headquarters have already collected hundreds of thousands of dollars. As the "Berliner Informationsbriefe" ('Berlin Information Letters') report, this institute recorded a net profit of over 100,000 dollars in 1947 alone.

This huge demand from Anglo-Saxon industry for German patents is quite understandable, since American specialists openly described them as “invaluable,” gold mines of information for both military research and private industry. On November 7, 1948, the “Berliner Zeitung” reported that an American chemical company was using a German process to make synthetic rubber more resistant, others were using German patents to create new textile fibers, and still others were using German polyurethane to make high-quality bristles, fibers and coating compounds. More than 65,000 documents on technical information captured at the chemical plants of the IG group are being used to produce chemicals, dyes, medicines, alloys, and color photographic processes that were previously unknown in the United States.

These “technical achievements”—the American press makes no secret of them—have brought enormous profits to the chemical companies in the USA and made it possible to quadruple the export of chemicals compared to the pre-war years, as the US was able to take control of the former German sales markets, as confirmed by the “Chemical and Engineering News.” The Winthrop Chemical Company produces a German substitute for morphine in large quantities, the Stearns & Co. produces adrenaline derivatives according to German patents and models, and other companies produce a painkiller “Methadone” invented by German chemists, which was previously known and sold as “Drug 10820” in Germany. The Wall Street Journal wrote: “Our country has become the heir to the relinquished empire of the German I.G. Farbenindustrie, and it intends to remain in its possession.”

In England and her Dominions this exploitation takes place in the same manner. In England, for example, cameras were manufactured which are an exact copy of the German “Leica”; in 1949 10,000 such devices were to be exported. On 25 December last year the London radio explained that, through London, Australia had also received 4,000 reports on German technical processes that had been developed by German industry during the war.

Of course, special attention is paid to German patents in the field of war. The Anglo-Saxon intelligence service had very carefully collected the material about the headquarters of German military research centers, so that when they invaded Germany, immediately behind the front troops, technical specialists (so-called “investigation teams”) immediately began to “acquire” the objects assigned to them. These specially trained squads proved to be excellently informed over the personnel and local conditions. For example, when Schongau was taken, an American officer immediately asked for Dr. Steinhoff, the head of the “Electromechanical Works” that had been relocated there, and quickly took him and his 500-man group into custody.

Already by September 1945, these teams had collected 160 different types of rocket projectiles at various stages of their manufacture and sent them to the US along with 150 tons of confidential drawings and documents on aircraft and engine construction, production of flying rockets, etc., which then became the basis for the creation a network of research institutes, laboratories and experimental bases.

England and the countries of the Empire have begun large-scale work on the same basis, which is mainly led by the Research Council for Aeronautics of the Nations of the British Empire, whose principal Director of Scientific Research, Sir Ben Lockspeiser, declared recently in Melbourne that Australia and New Zealand should be made the centers to implement the British research program and that £30 million should be made available to Australia for this research.

The above facts prove that the Western occupying powers received, as disguised reparations, German patents that are worth billions of dollars, and further prove that these patents are intended to be used to prepare for a new war.

[The above 3 articles were written for Soviet political purposes yet contain many interesting details.]

11.2 General Approaches Transferred from the German-Speaking World

After absorbing a huge number of German-speaking creators and creations, the U.S. research system had a very productive period during World War II and in the first decades after the war. During this period, the U.S. system also seems to have followed many of the approaches that had made the earlier German-speaking scientific world so successful, such as rapidly increasing research funding, management of the research system by enlightened despots, and other practices. Most of these approaches did not persist more than a few decades (beyond 1970 or so), which may help explain the apparent decline in the number of revolutionary new innovations in more recent times.

During the 1940s–1960s, the U.S. research system publicly unveiled a number of major inventions and discoveries. As covered in Chapters 2–9, 11.1, and the appendices, those innovations were generally adopted and developed from earlier German-based creations. Nonetheless, their implementation in the United States demonstrated that the U.S. system at that time was capable of carrying out revolutionary work that seems to be much less common now:

- During World War II, high-priority government programs created fission bombs and reactors, developed radar, mass-produced penicillin, and fielded other revolutionary technologies with military applications.

- Similarly, during the Cold War, high-priority government programs developed hydrogen bombs, nuclear submarines, intercontinental ballistic missiles, jet fighters, advanced air defense systems, satellites and spacecraft, computers, and other technologies.

- During the first few postwar decades, U.S. industry produced transistors, lasers, printed and integrated circuits, molecular medicines, new materials, jet airliners, nuclear power plants, and other very innovative products.

- Also during the first few postwar decades, U.S. academia published major discoveries in particle physics (relativistic quantum physics), molecular and cellular biology, and other areas.

This section examines the general approaches that the United States borrowed from the earlier German-speaking world and that facilitated this 1940s–1960s era of productivity in the U.S. research system. As shown later in this chapter, despite the successes that the United States achieved with the German-like general approaches, those approaches were largely abandoned after a few decades.

11.2.1 Cultural Attitudes Toward Science Education and Research

As in the earlier German-speaking world, popular culture in the United States glorified science education and research during the 1940s–1960s. Unfortunately, this attitude appears to have declined starting around 1970 or so. Although it is difficult to quantify such social attitudes with rigorous data, various types of illustrative examples are given here.

U.S. science fiction authors gained increasing prominence in magazines in the 1930s and 1940s, but arguably their greatest impact on children was through juvenile science fiction novels that were written from the late 1940s through the early 1970s, as exemplified by series such as:

- Robert A. Heinlein's juvenile novels. Heinlein was a retired U.S. Navy lieutenant and former engineering student, and was married to a retired Navy lieutenant commander and chemist, Virginia Heinlein [Dick 2008, pp. 341–352]. Heinlein's first novel, *Rocket Ship Galileo* (1947), described how three teenage budding engineers and their adult mentor from the Manhattan Project built a nuclear-powered rocket and traveled to the moon. (Ironically they found that German rocket engineers had secretly already gotten there.) Heinlein wrote a total of 12 juvenile novels through 1958's *Have Space Suit—Will Travel*, each depicting how young people assisted with a further step in space exploration. The popularity of his books prompted other authors such as those listed below to write juvenile science fiction novels [Clute 2017].

- Lester del Rey's juvenile novels. Del Rey was a longtime author, editor, and publisher of science fiction. From 1952 to 1968, he wrote over 20 juvenile novels in which young people created or assisted with projects on space flight (e.g., *Marooned on Mars*, 1952, and *Mission to the Moon*, 1956), submarines (*Attack from Atlantis*, 1953), robotics (*Runaway Robot*, 1965), time travel (*Tunnel Through Time*, 1966), and other innovations [Clute 2017].

- The *Tom Swift Jr.* series, published 1954–1971 by the Stratemeyer Syndicate (which also produced the *Hardy Boys* and *Nancy Drew* novels). Most of the 33 books in this series were written by James Duncan Lawrence, a former mechanical engineer and teacher. As depicted in these books, Tom Swift Jr. was a young inventor who used the resources of his father's large engineering company to build a series of increasingly sophisticated aircraft, spacecraft, submarines, robots, atomic devices, and other creations [Jonathan Cooper 2007; Open Library 2010].

- Bertrand Brinley's *Mad Scientists' Club* stories. Brinley was a retired Army captain, whose Army duties had included (among other things) advising children on how to safely experiment with rockets in the 1950s. Based on that work, he published the detailed nonfiction *Rocket Manual for Amateurs* in 1960, followed by a series of 1960–1974 fictional stories about students who formed the Mad Scientists' Club to create and test their own inventions [Brinley 2010].

- The *Danny Dunn* series, published between 1956 and 1977 by Raymond Abrashkin and Jay Williams. The books focused on discoveries and inventions that were made by young students and adult scientists usually working together. The discoveries and inventions combined some real-world scientific ideas and approaches with very fanciful science fiction adventures designed to appeal to young readers [Clute 2017].

Like their predecessors in the earlier German-speaking world (see p. 1968), these books presented children with fictional role models who through their scientific knowledge, hard work, and individualism created revolutionary innovations, despite both scientific obstacles and human opponents.

These books were extremely popular, became fixtures in public and school libraries in the United States, and inspired countless children to pursue careers in science and engineering. However, by the early 1970s, most books like these ceased to be produced, as shifts in children's interests made such books less marketable. More recent juvenile fiction tends to focus on children (e.g., Harry Potter), superheroes (e.g., Marvel and DC characters), or animals (e.g., cats, dragons, etc.) who are magically granted special powers, instead of having to achieve things using scientific knowledge and hard work.

Just as many German engineers had first become interested in their profession as children by watching films like Fritz Lang's *Frau im Mond* (1929), some of the German-speaking scientists who immigrated to the United States attempted to interest U.S. children in science. Examples included:

- Wernher von Braun, Ernst Stuhlinger, and other German scientists collaborated with Walt Disney to produce several entertaining but educational episodes of the *Disneyland* television series: "Man in Space" (1955), "Man and the Moon" (1955), and "Mars and Beyond" (1957) [Michael Neufeld 2007].
- Heinz Haber and other German scientists collaborated with Disney to produce another *Disneyland* episode, "Our Friend the Atom" (1957), that covered nuclear fission and fusion. Haber also wrote a corresponding children's book [Haber 1956].
- Willy Ley wrote popular descriptions of the science underlying rockets and space travel for numerous magazines and books, and was a consultant for television shows ranging from *Tom Corbett, Space Cadet* (adapted from Heinlein's *Space Cadet* novel) to *Disneyland* [Clute 2017].
- George Gamow wrote the *Mr. Tompkins* series of books from 1940 to 1967 to explain various scientific concepts in ways that children could understand [Gamow 1940, 1945, 1953, 1967].
- While not a scientist, George Pal (György Pál Marczincsak, Hungarian, 1908–1980) was a skilled German-speaking filmmaker who had worked in Prague and Berlin. He fled the Third Reich, and after the war he used his talents to present positive portrayals of fictional scientists to U.S. audiences in films such as *Destination Moon* (1950, adapted from Heinlein's *Rocket Ship Galileo*), *When Worlds Collide* (1951), *The War of the Worlds* (1953, adapted from the H. G. Wells novel but focusing on a scientist), *Conquest of Space* (1955, about a manned mission to Mars), and *The Time Machine* (1960, also adapted from an H. G. Wells novel).

Many scientists and engineers were first inspired by educational science kits that they experimented with as children. The early to mid-twentieth century, and especially the 1940s–1960s, were a golden age for such kits in the United States:

- A. C. Gilbert, an M.D. from Yale University, founded the A. C. Gilbert Company in 1909 in New Haven, Connecticut to produce science- and engineering-related kits for children. His sales steadily increased until World War II but really boomed after the war from the late 1940s until the 1960s. Gilbert's kits included Erector Set engineering construction kits for building everything from robots to locomotives; chemistry sets with dozens of chemicals; high-quality compound microscopes with slide-making accessories; and even the "U-238 Atomic Energy Lab" that provided children with several real uranium ore samples, other radioactive sources, a Geiger counter, a cloud chamber, an electroscope, and other nuclear physics supplies. However, Gilbert died in 1961, his company merged with the rival Porter company in 1967, and the combined company (Gabriel Industries) slowly petered out during the 1970s [Gilbert and McClintock 1954; Jitterbuzz 2017; Bruce Watson 2002].

- Harold Porter founded the Porter Chemical Company (Chemcraft) in 1914 in Hagerstown, Maryland to also produce science and engineering kits. The company's history very much paralleled that of the rival Gilbert company: sales increased until the wartime shortages of World War II, but then blossomed into a golden age from the late 1940s to the 1960s. Porter's products included lavishly equipped chemistry sets but also mineralogy kits, biology dissection sets, and a variety of microscopes. Porter died in 1963, and in 1967 Gabriel Industries bought and merged the Porter and Gilbert companies. The combined Gabriel company operated with declining sales and declining kit quality through the 1970s, changed hands in 1978, and finally ceased operations entirely in 1984 [Tyler 2003].

- The Skil-Craft company started up in the 1950s in Chicago to compete with the Gilbert and Porter companies in the postwar boom of demand for science and engineering kits. During the 1950s and 1960s, Skil-Craft produced high-quality kits in chemistry, microscopy, and other scientific fields. In 1968 they were bought out by Western Publishing/Golden Books, resulting in several 1970 sets in chemistry, biology, microscopy, and geology that combined Skil-Craft's well-thought-out experiments and Golden Books's beautiful illustrations [Fichter 1970a, 1970b; Parker and Martin 1970a, 1970b, 1970c]. Unfortunately, sales declined in the 1970s, the company changed hands in 1979, and operations ended in 1984.

In the 1940s–1960s, scientific innovators and innovations were widely and prominently heralded in news magazines, newspapers, and other media. Scientists and engineers were viewed as national heroes to be rewarded with fame and adulation, and to be presented as role models for young potential future scientists.

One especially illustrative example was the covers of *Time* magazine. *Time* was arguably the preeminent weekly news magazine in the United States during that period, and each issue's cover showcased an individual (or sometimes a group of individuals or an object) that was deemed to be especially important and newsworthy. Most of the covers featured political or military leaders from the United States or other countries, yet during the 1940s–1960s, a surprising number of *Time* covers were science-related, as listed in Tables 11.8 and 11.9. These *Time* covers featured [https://content.time.com/time/coversearch/0,16871,,00.html]:

- Most of the "enlightened despots" from Section 11.2.6 who directed U.S. research and development (e.g., Wernher von Braun, Vannevar Bush, James Conant, Lee DuBridge, Crawford Greenewalt, George W. Merck, Robert Oppenheimer, Hyman Rickover, Simon Ramo and Dean Woolridge, Bernard Shriever, Edward Teller, and Thomas Watson, Jr.).

- Scientists (e.g., Albert Einstein, Alexander Fleming, Edwin Hubble, Willard Libby, Jonas Salk, Glenn Seaborg, etc.).

- Test pilots and astronauts who piloted some of the newest inventions (e.g., Neil Armstrong, John Glenn, Alan Shepard, Chuck Yeager, etc.).

- Revolutionary innovations (e.g., computers, nuclear weapons, rockets, etc.)

- Whole categories of people. In 1961, *Time* declared all "U.S. Scientists" to be its "Men of the Year." It devoted an issue to "Great College Teachers" in 1966, and another issue to breakthroughs in "U.S. Medicine" in 1969.

Year	**Issue**	**Person or object**	**Subject**
1944	April 3	Vannevar Bush	"General of Physics"
1944	May 15	Alexander Fleming	Penicillin
1946	July 1	Albert Einstein	$E = mc^2$
1946	September 23	James Conant	Science education
1948	February 9	Edwin Hubble	Expanding universe
1948	July 19	Howard Hughes	Hughes Aircraft R&D
1948	November 8	J. Robert Oppenheimer	Science education/nuclear physics
1949	April 18	Chuck Yeager	Mach 1 rocket plane
1950	January 23	Mark III Computer	"Can man build a superman?"
1950	August 28	Irving Langmuir	Atmospheric science
1951	April 16	Crawford Greenewalt	Revolutionary new chemicals
1951	July 23	David Sarnoff	Electronics R&D
1952	August 18	George W. Merck	Revolutionary new pharmaceuticals
1952	December 8	Space Pioneer	"Will man outgrow the earth?"
1953	November 16	Igor Sikorsky	Helicopters
1954	January 11	Hyman Rickover	Nuclear-powered submarines
1954	March 29	Jonas Salk	Polio vaccine
1954	April 12	H Bomb	Nuclear weapons development
1954	June 14	J. Robert Oppenheimer	Nuclear weapons/security
1955	March 28	Thomas Watson, Jr.	Computers
1955	May 16	Lee DuBridge	Science education
1955	August 15	Willard Libby	Nuclear R&D
1956	January 30	"The Missile"	Rockets/nuclear technologies
1957	April 1	Bernard Schriever	Missile and rocket technologies
1957	April 29	Simon Ramo & Dean Woolridge	"Engineers"
1957	November 18	Edward Teller	"U.S. Science: Where It Stands Today"
1958	February 17	Wernher von Braun	Space program
1959	January 19	"Space Exploration"	"U.S. v. Russia"
1959	May 4	James Van Allen	Explorer I satellite/radiation belts
1959	September 14	James Conant	"U.S. Public Schools"
1959	July 27	John Heller	Cancer research

Table 11.8: Some science-related covers of *Time* magazine during the 1940s–1950s.

Year	**Issue**	**Person or object**	**Subject**
1960	March 28	Jacques Cousteau	Undersea exploration
1960	June 6	Satellites	Space program
1961	January 2	"U.S. Scientists"	Men of the Year
1961	January 6	Harry Felt	Advanced aircraft, missiles, subs
1961	January 13	Ancel Keys	Human physiology
1961	April 21	Yuri Gagarin	First man in orbit
1961	May 12	Alan Shepard	First American in space
1961	July 7	Leonard Larson	Medical improvements
1961	October 27	Tom Jones (Northrop)	Aerospace industry
1961	November 10	Glenn Seaborg	Nuclear physics
1961	November 17	John Enders	Virology
1962	March 2	John Glenn	First American in orbit
1963	May 24	Gordon Cooper	Another American in orbit
1963	August 23	U.S. Atomic Arsenal	Nuclear weapons development
1964	January 10	Buckminster Fuller	Engineering/architecture
1964	September 25	Nuclear Issue	Nuclear weapons development
1965	March 26	Alexey Leonov	First spacewalk
1965	April 2	"The Computer in Society"	Computers
1965	May 14	"The Communications Explosion"	Communications technologies
1965	June 11	Ed White and James McDivitt	First American spacewalk
1965	August 27	Chris Kraft	NASA Mission Control
1965	December 24	Gemini Rendezvous	Docking in orbit
1966	May 6	Great Teachers	Importance of high-quality education
1967	February 3	Roger Chaffee, Gus Grissom, Ed White	Apollo 1 fire
1967	April 7	The Pill	Oral contraceptives
1968	December 6	Race for the Moon	Space program
1969	January 3	William Anders, Frank Borman, Jim Lovell	Men of the Year (first around Moon)
1969	February 21	U.S. Medicine	Needed medical improvements
1969	March 14	Great Missile Debate	Rockets/nuclear technologies
1969	July 18	Lunar Exploration	Space program
1969	July 25	Neil Armstrong	First men on Moon

Table 11.9: Some science-related covers of *Time* magazine during the 1960s.

While the specific example of *Time* magazine covers has been cited here, this public praise and attention for scientists, engineers, and their accomplishments occurred throughout popular media during the 1940s–1960s. Hollywood made a film celebrating the scientific development of the U.S. atomic bomb (*The Beginning or the End*, 1947), with actors portraying J. Robert Oppenheimer, Enrico Fermi, Vannevar Bush, Albert Einstein, and other scientists and engineers. Countless other films, television shows, and books focusing on real or fictional scientists were produced during the 1940s–1960s. The national news was dominated by the latest plans and accomplishments of the Space Race throughout the late 1950s and the 1960s. In a 1960 speech to the American Association for the Advancement of Science, the British novelist and chemist C. P. Snow proclaimed [Snow 1961]:

> Scientists are the most important occupational group in the world today. At this moment, what they do is of passionate concern to the whole of human society.

This popular support for scientists went up to the highest levels. For example, President Franklin Roosevelt sent a letter to J. Robert Oppenheimer, the physicist in charge of the Manhattan Project, on 29 June 1943 [https://www.albuqhistsoc.org/source-documents/letter-fdr-oppenheimer/]:

> My dear Dr. Oppenheimer:
>
> I have recently reviewed with Dr. Bush the highly important and secret program of research, development and manufacture with which you are familiar. I was very glad to hear of the excellent work which is being done in a number of places in this country under the immediate supervision of General L.R. Groves and the general direction of the Committee of which Dr. Bush is Chairman. The successful solution of the problem is of the utmost importance to the national safety, and I am confident that the work will be completed in as short a time as possible as the result of the wholehearted cooperation of all concerned.
>
> I am writing to you as the leader of one group which is to play a vital role in the months ahead. I know that you and your colleagues are working on a hazardous matter under unusual circumstances. The fact that the outcome of your labors is of such great significance to the nation requires that this program be even more drastically guarded than other highly secret war development. I have therefore given directions that every precaution be taken to insure the security of your project and feel sure that those in charge will see that these orders are carried out. You are fully aware of the reasons why your endeavors and those of your associates must be circumscribed by very special restrictions. Nevertheless, I wish you would express to the scientists assembled with you my deep appreciation of their willingness to undertake the tasks which lie before them in spite of the dangers and the personal sacrifices. I am sure that we can rely on their continued wholehearted and unselfish labors. Whatever the enemy may be planning, American science will be equal to the challenge. With this thought in mind, I send this note of confidence and appreciation.

Although Roosevelt died before the Manhattan Project was completed, later presidents publicly awarded medals of honor to Oppenheimer and many of the other scientists who participated in that and other wartime projects.

As another example of support from the highest levels, President John F. Kennedy made revolutionary scientific and engineering goals the focus of his "Moon speech" at Rice University Stadium in Houston, Texas on 12 September 1962 [https://www.jfklibrary.org/archives/other-resources/john-f-kennedy-speeches/rice-university-19620912; see also Fig. 11.59]:

> Despite the striking fact that most of the scientists that the world has ever known are alive and working today, despite the fact that this Nation's own scientific manpower is doubling every 12 years in a rate of growth more than three times that of our population as a whole, despite that, the vast stretches of the unknown and the unanswered and the unfinished still far outstrip our collective comprehension. [...]
>
> Those who came before us made certain that this country rode the first waves of the industrial revolutions, the first waves of modern invention, and the first wave of nuclear power, and this generation does not intend to founder in the backwash of the coming age of space. We mean to be a part of it—we mean to lead it. For the eyes of the world now look into space, to the moon and to the planets beyond, and we have vowed that we shall not see it governed by a hostile flag of conquest, but by a banner of freedom and peace. We have vowed that we shall not see space filled with weapons of mass destruction, but with instruments of knowledge and understanding.
>
> Yet the vows of this Nation can only be fulfilled if we in this Nation are first, and, therefore, we intend to be first. In short, our leadership in science and in industry, our hopes for peace and security, our obligations to ourselves as well as others, all require us to make this effort, to solve these mysteries, to solve them for the good of all men, and to become the world's leading space-faring nation. [...]
>
> We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too. [...]
>
> The growth of our science and education will be enriched by new knowledge of our universe and environment, by new techniques of learning and mapping and observation, by new tools and computers for industry, medicine, the home as well as the school. Technical institutions, such as Rice, will reap the harvest of these gains.

Like Roosevelt, Kennedy also died before he could see the revolutionary scientific programs he supported come to fruition, but again, later presidents gave public awards to many of the scientists, engineers, and astronauts who were instrumental in those programs.

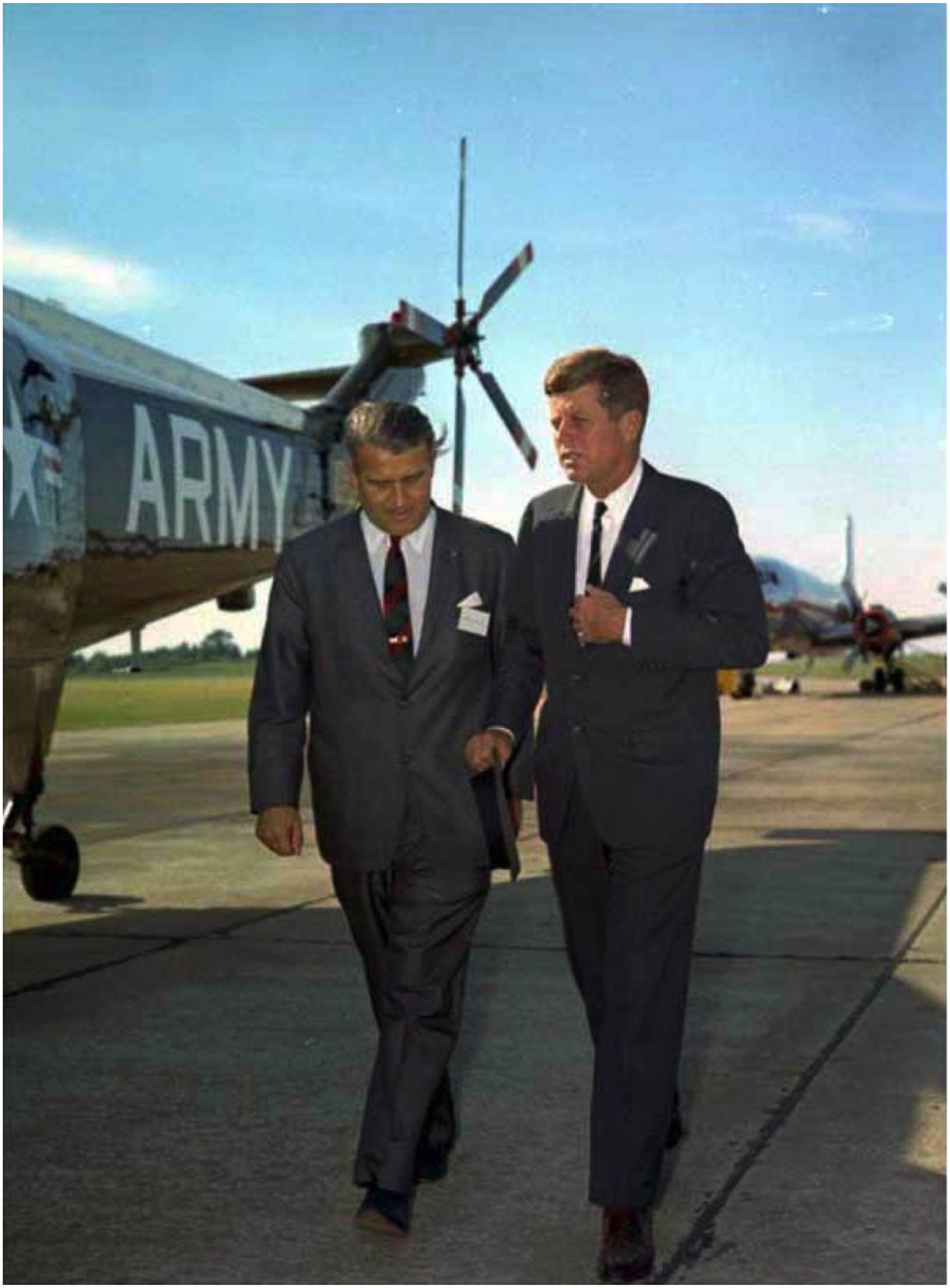


Figure 11.59: Meeting between Wernher von Braun and President John F. Kennedy in Alabama on 19 May 1963.

Unfortunately, by the late 1960s and early 1970s, there was a decline in public interest in and support for science and for scientists in the United States. Some of the factors responsible for that decline included:

- Between the publication of Rachel Carson's book *Silent Spring* in 1962 and the creation of the U.S. Environmental Protection Agency in 1970, there was rising public concern about the personal and environmental risks of new chemicals and new materials that scientists had produced. With the founding of the U.S. Occupational Health and Safety Administration in 1971, there were also greatly increased concerns and lawsuits regarding the safety of new industrial processes, technologies, and products.

- The Space Race between the United States and the Soviet Union, which at the time was probably by far the most visible symbol of scientific progress, essentially came to an abrupt end in 1969 when the United States landed people on the Moon. The Soviet Union chose not to pursue the Space Race beyond that point (for example, by trying to be the first to land people on Mars), and the U.S. government and public rapidly lost interest in sending more people to the Moon or beyond. Without other national scientific goals that were as visible or as compelling as the Space Race, public interest in and support for science education and R&D dropped rapidly.

- By 1972, the majority of U.S. homes had color television, which tempted people with instant and endless gratification instead of applying those extra hours to learn and to create.

- The 1973 and 1979 energy crises and accompanying economic recessions made people, companies, and the government focus more on near-term economic survival than long-term science education and R&D. Later economic booms occurred in other areas of the economy, such as finance and entertainment, drawing further public prestige and interest away from science and engineering.

- Events such as 1970s lawsuits over the U.S. use of the Agent Orange defoliant in Vietnam and the 1979 Three Mile Island nuclear accident tended to create a very negative public perception of science in the United States.

By 2020 and beyond, the U.S. public's general views and treatment of scientists, medical professionals, teachers, other intellectuals, and even basic facts and principles seemed to have fallen very far from the heyday of the mid-twentieth century. Modern examples are too numerous, too well known, and too depressing to recite here.

Looking beyond just science, one could argue that during the 1940s–1960s, there appeared to be widely held U.S. beliefs in doing very high-quality work and in striving to make the world a better place. Millions of Americans worked to overcome the Depression, win World War II, build up U.S. industry, help rebuild Europe and Japan, and oppose the Soviet Union. In contrast, from the 1970s to the current time, it seems that many Americans have been less interested in spending their time and energy to do high-quality work and to improve the world, and more interested in trying to achieve fortune and fame as easily as possible, or in simply withdrawing to be entertained by their various video screens large and small.

11.2.2 Funding Levels

Research and development (R&D) spending is naturally a major factor affecting the performance of the innovation system in the United States or other countries.

Figure 11.60 shows early U.S. federal R&D spending, taken from a highly influential 1947 government report by economist John R. Steelman, who at that time was also the first presidential chief of staff (for Harry Truman) [Steelman 1947]. As shown in the graph, spending was minimal before WWII, reflecting the fact that there was essentially no government-funded research system in the United States, unlike in German-speaking central Europe. U.S. federal R&D spending increased exponentially during WWII, as the government-funded research system came into existence, hired large numbers of talented innovators, and launched programs on revolutionary technologies such as radar, nuclear fission, penicillin mass production, etc. The graph shows that the spending increased more slowly but still exponentially after WWII, with projected increases beyond the current year of 1947 well into the 1950s, as indeed proved to be the case. The figure also explicitly links each funding increase to an increase in the number of "the scientists to do the job."

As an overview of U.S. federal R&D spending from the early postwar period to the present, Fig. 11.61 shows the defense, nondefense, and total spending for government fiscal years (FY, starting October 1 before the corresponding calendar year) since FY 1953, in inflation-adjusted constant FY 2018 dollars. It is especially noteworthy that defense R&D spending doubled practically overnight in FY 1959—that was the first fiscal year of funding that was approved after the October 1957 launch of the Soviet Sputnik satellite. Similarly one can see the rapid increase in nondefense R&D during the early 1960s for the manned space program. There were also increases in military spending during the Reagan administration (1980s) and George W. Bush administration (early 2000s), but the graph shows that those were largely temporary.

To help provide more context for the spending levels, Fig. 11.62 regraphs the U.S. federal R&D spending as a percentage of the U.S. gross domestic product (GDP) for each year. This method can help give a better understanding of how large the research programs were relative to other aspects of the economy, and by extension how much talented labor, resources, and recognition would be drawn to research work versus other occupations in society. Fig. 11.62(a) presents an historical overview for the period 1949–2005, showing that by this measure the total federal R&D funding peaked in 1964 (the time of greatest development work for the space program), began a steep decline around 1967 (once most of the development work for the Apollo-Saturn program had been completed), and continued to decline slowly for decades thereafter. Figure 11.62(b) gives a more detailed graph for the period 1976–2018, showing that the funding has continued to decline to the present, apart from relatively small oscillations (the Reagan and George W. Bush temporary increases in defense spending). In fact, the current total federal R&D spending (approximately 0.7% of GDP) is only about one third of the peak 1964 spending (approximately 2.2% of GDP) and lower than any other post-Sputnik budget.

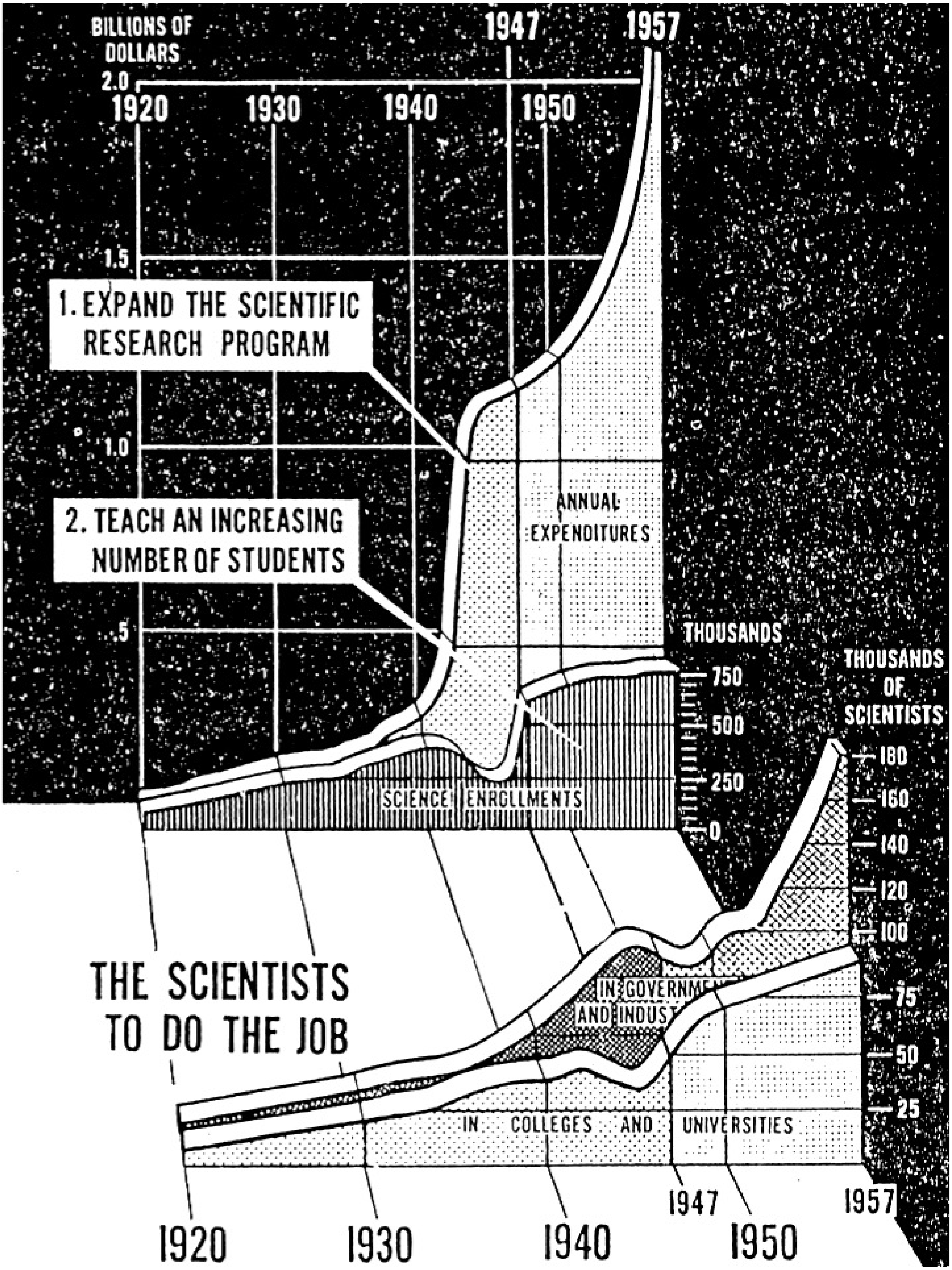


Figure 11.60: This 1947 graph shows that early U.S. federal R&D spending was minimal before World War II, increasing exponentially during the war, and increasing more slowly but still exponentially after the war [Steelman 1947].

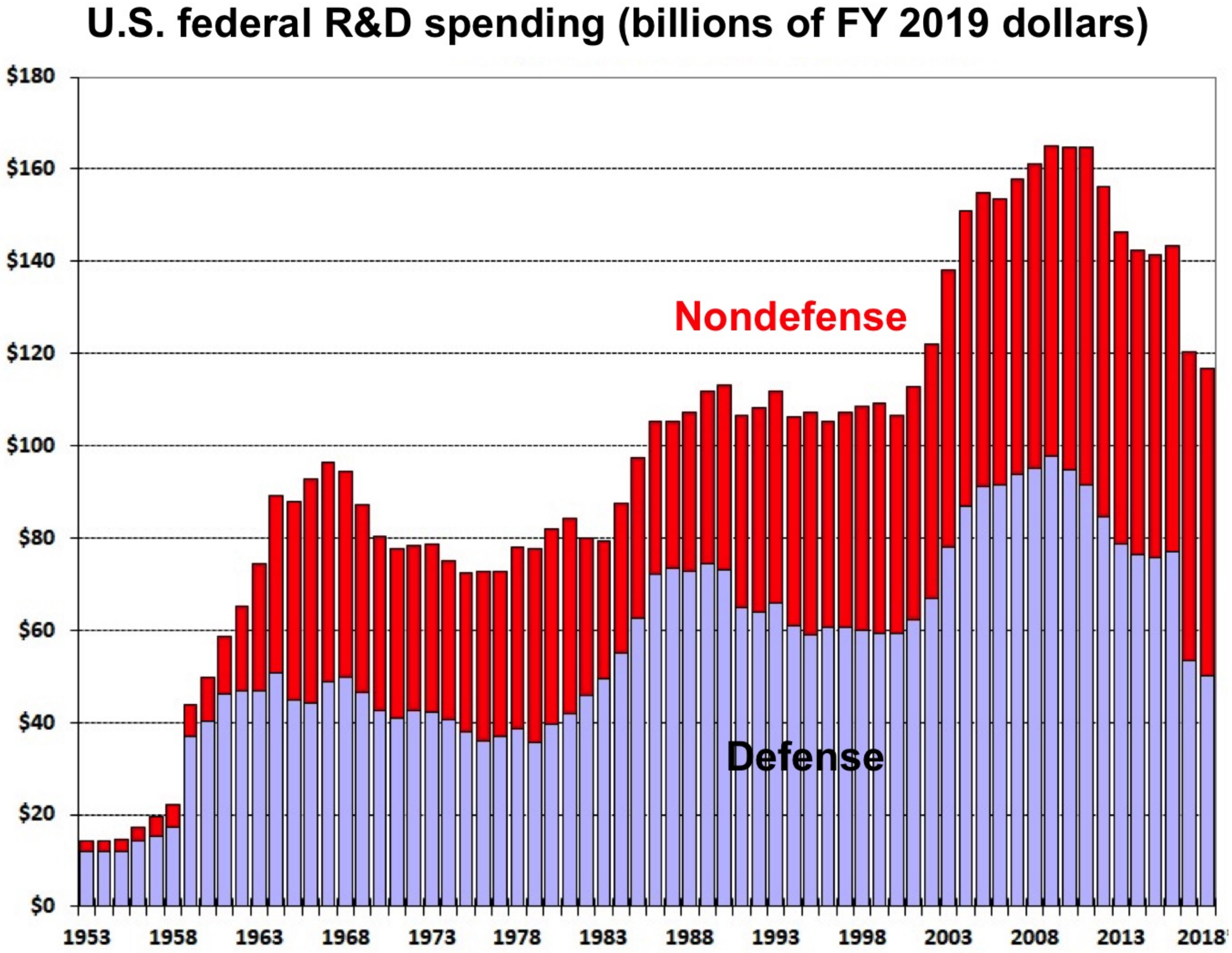


Figure 11.61: U.S. federal R&D spending for government fiscal years (FY, starting October 1 before the corresponding calendar year) since FY 1953, in inflation-adjusted constant FY 2019 dollars. Note the doubling of defense R&D in FY 1959, the first fiscal year of funding that was approved after the October 1957 launch of the Soviet Sputnik satellite, and the rapid increase in nondefense R&D during the early 1960s for the manned space program. Also note the temporary increases in military spending during the Reagan administration (1980s) and George W. Bush administration (early 2000s). The large apparent drop in defense funding in FY2017 is primarily due to a change in what programs were defined as “development” [https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd].

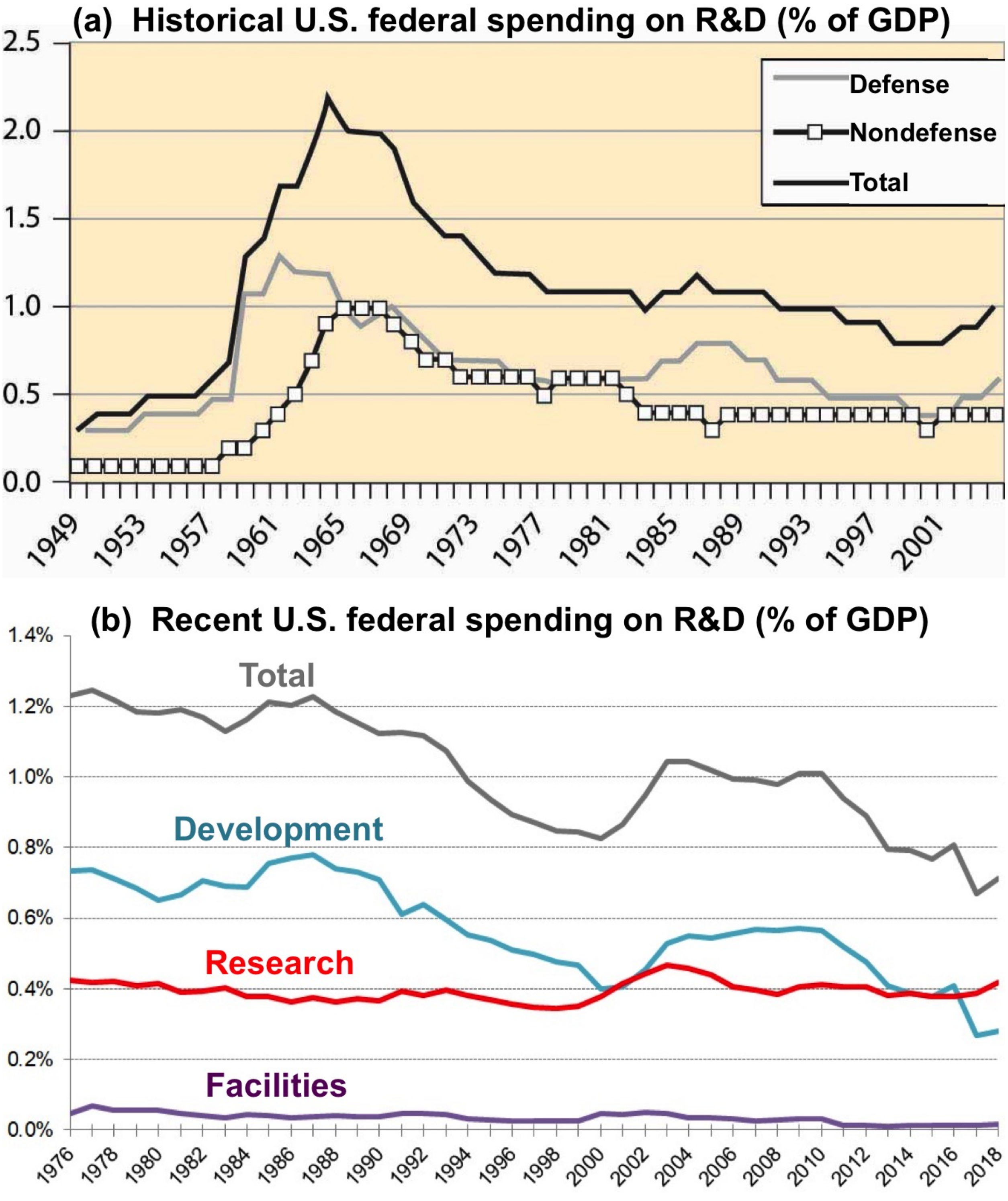


Figure 11.62: U.S. federal R&D spending regraphed as a percentage of the U.S. gross domestic product (GDP) for each year. (a) Historical overview for 1949–2005. (b) More detailed graph for 1976–2018. [https://saylordotorg.github.io/text_introduction-to-economic-analysis/s05-05-government.html#mcafee-ch04_s05_f10; https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd].

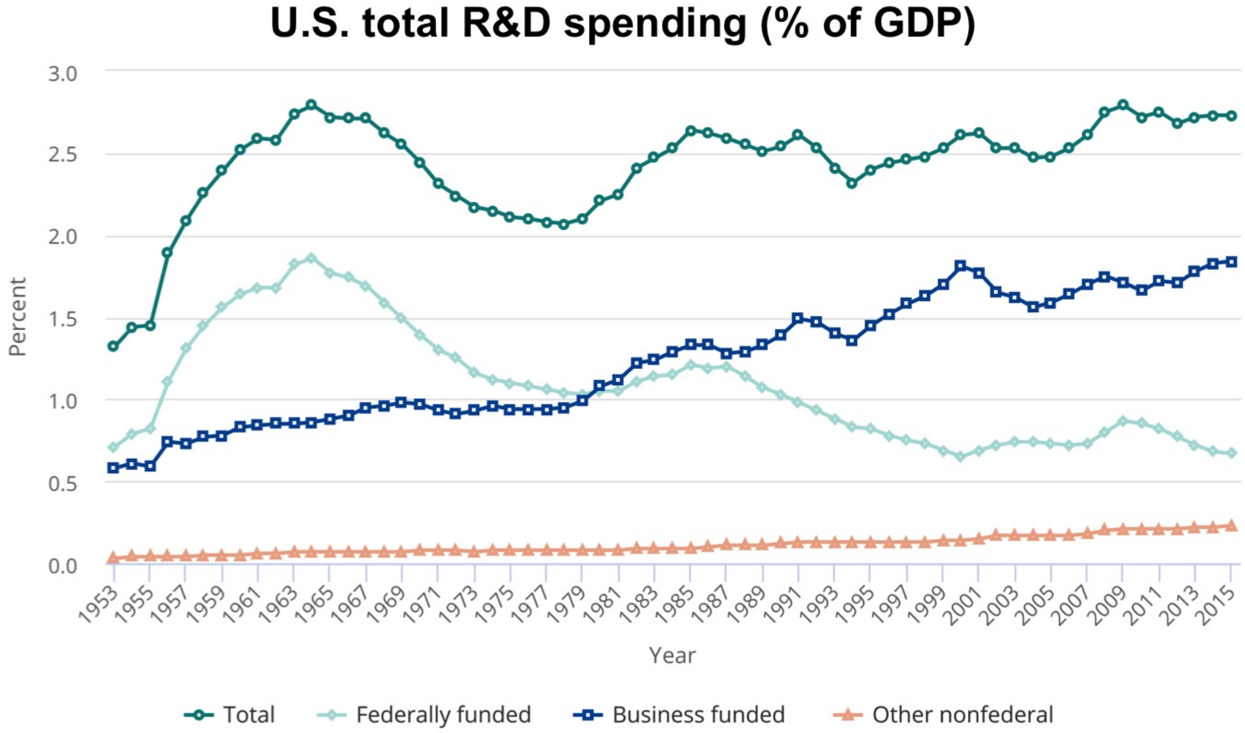


Figure 11.63: U.S. total R&D spending, including federally funded, business funded, and other nonfederal funded work (e.g., by nonprofit foundations or state governments). All spending is expressed as a percentage of the GDP for each year. Taking the numbers at face value, the total U.S. R&D funding as a percentage of GDP has remained roughly constant since the early 1980s. Considering the shift in recent decades from longer-term to much shorter-term R&D, funding for innovative research has actually significantly declined [https://www.nsf.gov/statistics/2018/nsb20181/figures].

Of course, not all R&D spending comes from the federal government. Figure 11.63 shows U.S. total R&D spending, including federally funded, business funded, and other nonfederal funded work. All spending is expressed as a percentage of the GDP for each year:

- As previously shown in Fig. 11.62, the share of federal funding peaked in the 1960s space race and has generally been declining ever since, now down to approximately one third of its earlier peak value.

- Business funding has generally increased steadily, although the quantitative numbers do not indicate the qualitative shift in business R&D from longer-term development of major innovations such as integrated circuits and jet aircraft in the 1950s to immediately marketable products such as smart phone apps in the 2010s.

- Other nonfederal R&D funding (such as by nonprofit foundations and state governments) has been slowly increasing but is still much smaller than federal and business funding.

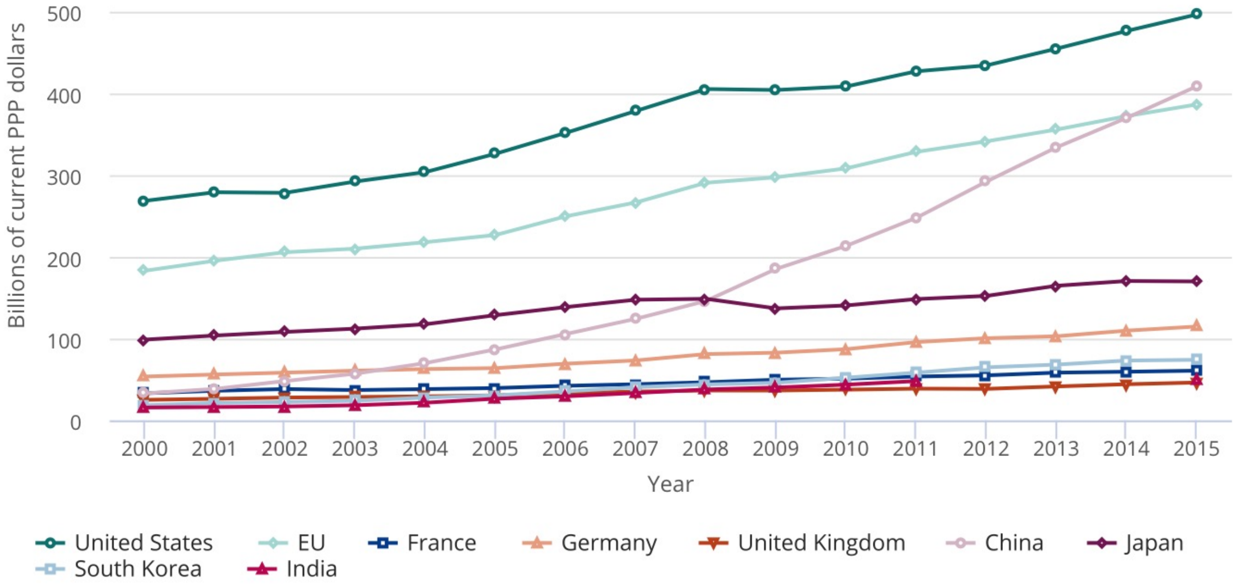
- Even accepting the numbers at face value, the total U.S. R&D funding as a percentage of GDP has remained roughly constant since the early 1980s. With flat funding, effectively the only way for newly graduated scientists and engineers to find a permanent position is to wait for someone older in an existing position to retire or to die. This fact creates pressures that greatly restrict how many new innovators can find employment, and how innovative they are allowed to be under such conservative, resource-limited conditions. Moreover, since over the last several decades more of the available government research jobs have shifted toward bureaucracy, more of the available academic jobs have shifted toward continuous paper and grant writing, and more of the business research jobs have shifted toward producing very short-term, low-risk products, one could argue that the funding for innovative research has significantly declined instead of stayed flat.

For comparison, Fig. 11.64 presents the total R&D spending (from government, industrial, and other sponsors) for a number of other countries, graphed as either purchasing power parity (PPP) dollars or a percentage of each country's GDP for each year. Note that just as R&D spending relative to GDP has been relatively flat in the United States for decades, it has also been fairly flat in most other countries for many years. (As noted for Fig. 11.63, by analyzing the types of R&D activities being supported now versus at earlier times, one might even argue that these apparently flat funding trends have actually been effective declines in innovative research.) From the graph, the most notable exceptions to this trend are China and South Korea, which have each significantly increased their R&D investments. China's R&D increase is especially dramatic, since both China's GDP and its ratio of R&D to GDP have been increasing relatively rapidly.

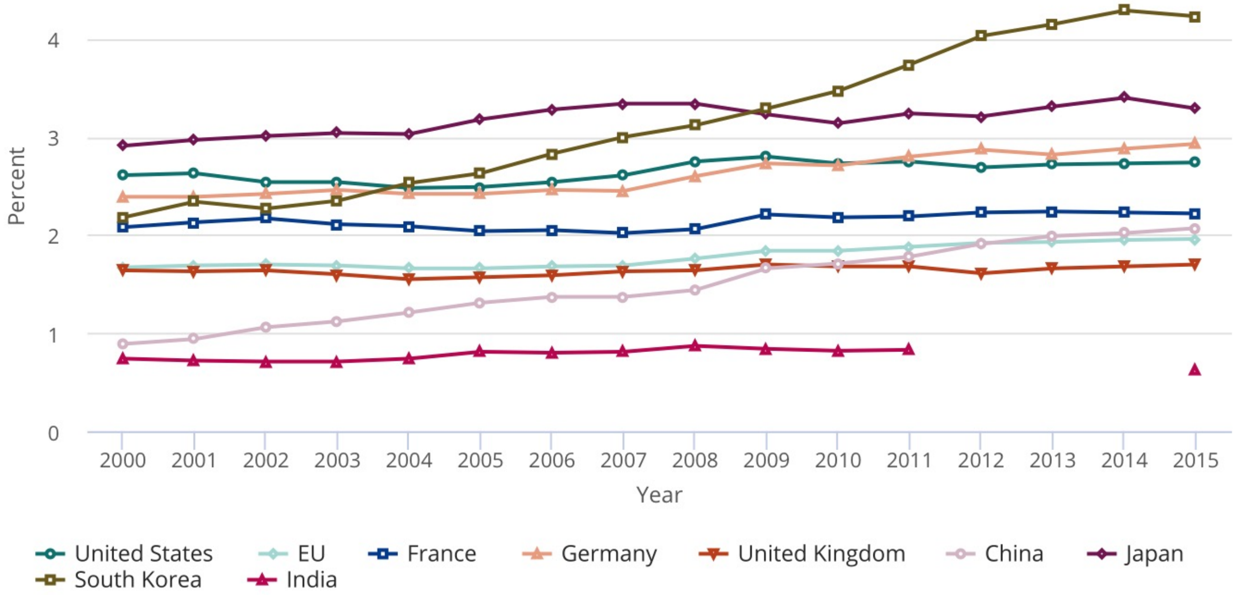
MIT economists Jonathan Gruber and Simon Johnson described the impact of funding changes on the rise and decline of innovation in the United States [Gruber and Johnson 2019, pp. 4–10]:

> In 1938, on the eve of world war, federal and state governments spent a combined 0.076 percent of national income on scientific research, a trivial amount. By 1944, the US government was spending nearly 0.5 percent of national income on science—a sevenfold increase, most of which was channeled through [Vannevar] Bush's organization from 1940. The effects of this unprecedented surge were simply incredible and, for America's enemies, ultimately devastating.

> Then, in 1945, Vannevar Bush had what may be considered his most profound insight. [...]
>
> What was needed next, Bush argued, was a redirection to focus on winning the peace. [...]
>
> From 1940 to 1964, federal funding for research and development increased twentyfold. At its peak in the mid-1960s, this spending amount was around 2 percent of annual gross domestic product—roughly one in every fifty dollars in the United States was devoted to government funding of research and development (equivalent, relative to GDP, to almost $400 billion today). The impact on our economy, on Americans, and on the world was simply transformational. [...]
>
> It is hard to find any aspect of modern life that has not been profoundly affected by innovation that can be traced back either to the Bush-era efforts or to inventions that were supported by various government programs in the years that followed. [...]
>
> Unfortunately, we failed to maintain the [innovation] engine. From the mid-1960s onward, based on concerns about the environmental, military, and ethical implications of unfettered science, compounded by shortsighted budget math, the government curtailed its investments in scientific research. Economic difficulties during the 1970s, followed by the Reagan Revolution and the anti-tax movement, resulted in an even broader retreat from federally funded activities. Most recently, the impact of a global financial crisis in 2008 and consequent economic pressures—known as the Great Recession—have further squeezed investments in the scientific future.
>
> Federal spending on research and development peaked at nearly 2 percent of economic output in 1964 and over the next fifty years fell to only around 0.7 percent of the economy. Converted to the same fraction of GDP today, that decline represents roughly $240 billion per year that we no longer spend on creating the next generation of good jobs.
>
> Should we care? If there is socially beneficial research and product development to be done, surely the innovative companies of today will take this on?
>
> In fact, they won't. [...]
>
> The venture capital sector that has created so many high-tech success stories has, at the same time, avoided the type of very-long-run and capital-intensive investments that lead to technological breakthroughs—and create new industries and jobs.
>
> As a result, the government retreat from research and development has not been fully offset by the private sector.
>
> While we have retreated from Vannevar Bush's innovation engine, the rest of the world is picking up the slack. Total research funding is growing at a much faster rate, relative to the economy, in the rest of the world than it is in the United States, led in many countries by active government policies.



(a) Total R&D spending of various countries in purchasing power parity (PPP) dollars



(b) Total R&D spending of various countries (% of GDP)

Figure 11.64: Total R&D spending for various countries, graphed as (a) purchasing power parity (PPP) dollars, and (b) a percentage of each country's GDP for each year. Note that relative to GDP, R&D spending has been relatively flat for most countries for many years, with the exception of significant investments by China and South Korea [https://www.nsf.gov/statistics/2018/nsb20181/figures].

11.2.3 Mentoring Style

As described in Section 10.2.3, many (though certainly not all) Ph.D. students in the German-speaking world were actively encouraged to independently propose and conduct their own thesis research, thereby honing their skills as highly creative and independent innovators. A number of German-speaking creators described similar experiences during their doctoral research; Section 10.2.3 quoted just a few illustrative examples.

In the early U.S. research system, it is more difficult to find many examples of students who were given such freedom to innovate in pursuing their Ph.D. thesis research. Most thesis topics appear to have been assigned by the Ph.D. advisor, or selected from among a short list of possible topics offered by the advisor, and then closely supervised by the advisor throughout the thesis research. Thus the U.S. students seem to have had fewer opportunities than their German-speaking counterparts to acquire and practice skills at independent innovation early in life.

When biographical and autobiographical accounts of U.S. scientists do reveal that they enjoyed remarkable independence in their Ph.D. thesis research, that independence was often a result of being supervised or assisted by someone who had come from the German-speaking scientific world. For example, historians Lillian Hoddeson and Vicki Daitch described John Bardeen's experiences as a Ph.D. student at Princeton in the 1930s; Bardeen later became the only person to ever win two Nobel Prizes in physics [Hoddeson and Daitch 2002, pp. 50–52, 54–55]:

> Princeton followed suit in 1930, hiring two Hungarian members of the Berlin circle of physics and mathematics, John von Neumann and Eugene Wigner, who were old friends. [...]
>
> Bardeen later wrote that of all his professors at Princeton he was "most stimulated by the two young Hungarians." [...]
>
> In shopping around for a thesis advisor, Bardeen spoke first with [U.S. physicist Edward] Condon, but he found that all of Condon's suggestions concerned filling gaps in the textbook he was then completing with G. H. Shortley, *The Theory of Atomic Spectra.* That "didn't sound too interesting" to Bardeen. [...]
>
> Bardeen decided to throw in his lot with Wigner and never regretted it. He found he needed only occasional meetings to keep his thesis on track. Wigner later told Seitz "that he rarely communicated with Bardeen." But what Bardeen remembered about Wigner was that he always had ways to motivate him with his penetrating questions. Most importantly, Bardeen felt that Wigner instructed him in the art of choosing crucial problems. "He could see what was essential and what the important problems were."
>
> Bardeen also felt that Wigner taught him how to go about attacking problems. The first step was to decompose the problem, either into smaller problems with less scope or into simpler problems that contained the essence of the larger problem. Bardeen said that Wigner stressed reducing to "the simplest possible case, so you can understand that before you go on to something more complicated."

Unfortunately, most Ph.D. thesis advisors in the United States apparently preferred the approach of Condon over that of Wigner (as described by Bardeen), using students as cogs in the machinery to advance the advisors' own research and publications rather than encouraging the students to be as innovative and independent as possible. To succinctly summarize the difference, one might say that the best early German-speaking advisors viewed their roles as *mentors* to offer advice to their students, whereas most native U.S. advisors viewed their roles as *masters* to harness the labor of their students.

In fact, it is remarkable how many creative U.S. scientists studied under German-speaking advisors. In addition to John Bardeen, Eugene Wigner supervised or co-supervised Ph.D. theses for Frederick Seitz, Richard Feynman, and many others. As other examples, Hans Bethe supervised the studies of Jeffrey Goldstone, Roman Jackiw, Freeman Dyson, and others; Victor Weisskopf supervised Ph.D. theses for John David Jackson, Murray Gell-Mann, and other physicists.

Judging from the scarcity of accounts, as the early U.S. research system matured into the modern system, advisors who advocated for students to be as creative and self-directed as possible apparently became ever more scarce. As discussed in the next section, the ages at which students received their Ph.D. also became older. Due to the combination of these two factors, scientists had fewer and fewer opportunities to learn and practice innovation during their formative years.

It should be noted that these problems extend far beyond the United States. The astrophysicist Martin López-Corredoira, who has worked in Spain and Switzerland and gathered information on the academic system worldwide, reported on the common experiences of Ph.D. students in the modern scientific world [López-Corredoira 2013, pp. 62–65]:

> The first contact with research takes place when a graduate student prepares a Ph.D. thesis. [...] If the student wants financial as well as departmental support, then his or her role is to be obedient to, and assimilate, the traditions of the department. [...]
>
> In some cases, the students that do most of the work are not able to write a paper containing their results; the bosses do it instead, as first authors of the paper. Students are told that they do not know how to write their own work. In other cases, when the supervisor sees that things will not have the outcome he or she wants, the supervisor will abandon the student. In some cases, the supervisor steals the student's ideas. In other cases, a student's time as a Ph.D. student is over before the thesis is finished because he or she was exploited by having to carry out other work aside from their thesis, or the boss had no time to attend to the explanations produced by the student. In such cases, the student must struggle to survive while writing up.
>
> Few bosses sit down and work with students. Normally, they spend some time during the early days explaining how to do things. After that, the student must carry out the routine tasks. The boss just provides the ideas, if they have them; otherwise, they just make minor corrections. The student spends weeks or months with the monotonous tasks in the laboratory, observatory, or in front of a computer with annoying calculations or simulations that consume a lot of time, or with analytical calculations, or carrying out bibliographical research or whatever. Students closer to an empirical branch of the sciences spend a long time with the instruments. The boss is usually present as well, but only to initially explain to the student how the machine works, or when something

> unusual happens, or there are extraordinary observations unrelated to the usual routine. Meanwhile the boss manages and generates ideas. [...]
>
> However, spending time thinking about one's own ideas, without permission, is something that is really not encouraged by the system; quite the opposite. Initiative is discouraged with arguments such as what is established is established. Workers for science are created instead of thinkers. [...]
>
> What is wrong with this situation, I continue to ask. Mainly, that [it is] industrial (mass-produced) science, rather than creativity being encouraged, and the period of optimum creativity of a scientist is exhausted with these ups and downs. We must take into account that, in the long history of science, the majority of great ideas were produced by young scientists. If young students, who could potentially produce new ideas, are used as slaves (or perhaps it is better to say "science workers"), then perpetuation of old ideas and intellectual stagnation are rife.

Even though doctoral educational and research programs worldwide were founded based on the model of the earlier German-speaking world, they appear to have strayed further and further from the fundamental principles that made the original German-speaking academic programs so successful at cultivating revolutionary scientific innovators.

11.2.4 Average Age for Final Degree

To compare the ages at which people received their final degree for the brightest American scientists and the brightest German-speaking scientists of the same era, one can use data from Nobel Prize winners. Scientists who were educated in the United States and won a Nobel Prize in Physiology or Medicine, Chemistry, or Physics prior to 1991 are listed in Tables 11.10, 11.11, and 11.12 respectively. The ages at which the scientists received their final degrees are shown in the tables.

In order to keep the data set focused on the U.S. educational system, scientists who had some of their training in that system but a significant part of their training outside that system (e.g., Americans such as Irving Langmuir who completed their education in Germany, or German speakers such as Konrad Bloch who completed their education in the U.S. system) are omitted from these tables.

Unless otherwise noted, all of the individuals in these three tables graduated with a Ph.D. As shown in Table 11.10, many of the winners of a Nobel Prize in Physiology or Medicine had an M.D. instead of a Ph.D. As indicated in the tables, two Nobel Prize winners graduated with a final degree that was not a doctorate. As also noted, a few individuals were delayed in receiving their final degree, due to military service, war disruptions, serious illness, or work obligations.

Students could graduate at any time of year, depending on when their doctoral thesis was completed and approved. In most cases only the year of graduation and not the exact date was readily available. In such cases, the graduation was assumed to have occurred on average in the middle of the year, and the students' ages at graduation calculated accordingly. Any errors caused by this assumption should mostly cancel each other out when averages are taken over entire groups of people.

Nobel Prize	Name	Born	Graduated	Age
1933	Thomas Hunt Morgan	25 September 1866	1890	24
1934	George Whipple	28 August 1878	1905	26 (M.D.)
1934	George Minot	2 December 1885	1912	26 (M.D.)
1934	William Murphy	6 February 1892	1922	30 (M.D.)
1943	Edward Doisy	13 November 1893	1920	26
1944	Joseph Erlanger	5 January 1874	1899	25 (M.D.)
1944	Herbert Gasser	5 July 1888	1915	26 (M.D.)
1946	Hermann Muller	21 December 1890	1960	25
1950	Philip Hench	28 February 1896	1920	25 (M.D.)
1950	Edward Kendall	8 March 1886	1910	25
1954	John Enders	10 February 1897	1930	33 (war)
1954	Frederick Robbins	25 August 1916	1940	24 (M.D.)
1954	Thomas Weller	15 June 1915	1940	25 (M.D.)

Table 11.10: Ages at final degree for scientists who were educated primarily or entirely in the United States and won a Nobel Prize in Physiology or Medicine prior to 1991. (Continued on next page.)

Nobel Prize	**Name**	**Born**	**Graduated**	**Age**
1956	Dickinson Richards	30 October 1895	1923	27 (M.D., war)
1958	George Beadle	22 October 1903	1931	27
1958	Edward Tatum	14 December 1909	1934	24
1958	Joshua Lederberg	23 May 1925	1947	22
1959	Arthur Kornberg	3 March 1918	1941	23 (M.D.)
1962	James Watson	6 April 1928	1950	22
1966	Peyton Rous	5 October 1879	1905	25 (M.D., illness)
1966	Charles Huggins	22 September 1901	1924	23 (M.D.)
1967	Haldan Hartline	22 December 1903	1927	23 (M.D.)
1967	George Wald	18 November 1906	1932	25
1968	Robert Holley	28 January 1922	1947	25
1968	Marshall Nirenberg	10 April 1927	1957	30
1969	Alfred Hershey	4 December 1908	1934	25
1970	Julius Axelrod	30 May 1912	1955	43 (work)
1971	Earl Sutherland	19 November 1915	1942	26 (M.D.)
1972	Gerald Edelman	1 July 1929	1954	24 (M.D.)
1975	David Baltimore	7 March 1938	1964	26
1975	Howard Temin	10 December 1934	1959	24
1976	Baruch Blumberg	28 July 1925	1951	25 (war)
1976	D. Carleton Gajdusek	9 September 1923	1946	22 (M.D.)
1977	Rosalyn Yalow	19 July 1921	1945	23
1978	Daniel Nathans	30 October 1928	1954	25 (M.D.)
1978	Hamilton Smith	23 August 1931	1956	24 (M.D.)
1980	George Snell	19 December 1903	1930	26
1981	Roger Sperry	20 August 1913	1941	27
1983	Barbara McClintock	16 June 1902	1927	25
1985	Michael Brown	13 April 1941	1966	25 (M.D.)
1985	Joseph Goldstein	18 April 1940	1966	26 (M.D.)
1986	Stanley Cohen	17 November 1922	1948	25
1988	Gertrude Elion	23 January 1918	1941	23 (no doctorate)
1988	George Hitchings	18 April 1905	1933	28
1989	J. Michael Bishop	22 February 1936	1962	26 (M.D.)
1989	Harold Varmus	18 December 1939	1966	26 (M.D.)
1990	Joseph Murray	1 April 1919	1944	25 (M.D.)
1990	E. Donnall Thomas	15 March 1920	1946	26 (M.D.)

Table 11.10 (continued): Ages at final degree for scientists who were educated primarily or entirely in the United States and won a Nobel Prize in Physiology or Medicine prior to 1991.

Nobel Prize	**Name**	**Born**	**Graduated**	**Age**
1914	Theodore Richards	31 January 1868	1888	20
1946	James Sumner	19 November 1887	1914	26
1946	John Northrop	5 July 1891	1915	23
1946	Wendell Stanley	16 August 1904	1929	24
1949	William Giauque	12 May 1895	1922	27 (work)
1951	Edwin McMillan	18 September 1907	1933	25
1951	Glenn Seaborg	19 April 1912	1937	25
1954	Linus Pauling	28 February 1901	1925	24
1955	Vincent du Vigneaud	18 May 1901	1927	26
1960	Willard Libby	17 December 1908	1933	24
1961	Melvin Calvin	8 April 1911	1935	24
1965	Robert Woodward	10 April 1917	1937	20
1966	Robert Mulliken	7 June 1896	1921	25 (war)
1972	Christian Anfinsen	26 March 1916	1943	27
1972	Stanford Moore	4 September 1913	1938	24
1972	William Stein	25 June 1911	1938	26
1974	Paul Flory	19 June 1910	1934	23
1976	William Lipscomb	9 December 1919	1946	26
1979	Herbert Brown	22 May 1912	1938	26
1980	Paul Berg	30 June 1926	1952	25
1980	Walter Gilbert	21 March 1932	1957	25
1984	Robert Merrifield	15 July 1921	1949	27
1985	Herbert Hauptman	14 February 1917	1955	38 (work)
1985	Jerome Karle	18 June 1918	1944	25
1986	Dudley Herschbach	18 June 1932	1958	25
1987	Donald Cram	22 April 1919	1947	28
1987	Charles Pedersen	3 October 1904	1927	22 (no doctorate)
1989	Thomas Cech	8 December 1947	1975	27
1990	E. J. Corey	12 July 1928	1950	22

Table 11.11: Ages at final degree for scientists who were educated primarily or entirely in the United States and won a Nobel Prize in Chemistry prior to 1991.

Nobel Prize	Name	Born	Graduated	Age
1923	Robert Millikan	22 March 1868	1895	27
1927	Arthur Compton	10 September 1892	1916	23
1936	Carl Anderson	3 September 1905	1930	24
1937	Clinton Davisson	22 October 1881	1911	29
1939	Ernest Lawrence	8 August 1901	1925	23
1944	I. I. Rabi	29 July 1898	1926	27
1946	Percy Bridgman	21 April 1882	1908	26
1952	Edward Purcell	30 August 1912	1938	25
1955	Willis Lamb	12 July 1913	1938	25
1955	Polykarp Kusch	26 January 1911	1936	25
1956 & 1972	John Bardeen	23 May 1908	1936	28
1956	Walter Brattain	10 February 1902	1929	27
1956	William Shockley	13 February 1910	1936	26
1959	Owen Chamberlain	10 July 1920	1949	28
1960	Donald Glaser	21 September 1926	1950	23
1961	Robert Hofstadter	5 February 1915	1938	23
1964	Charles Townes	28 July 1915	1939	24
1965	Richard Feynman	11 May 1918	1942	24
1965	Julian Schwinger	12 February 1918	1939	21
1968	Luis Alvarez	13 June 1911	1935	25
1969	Murray Gell-Mann	15 September 1929	1951	21
1972	Leon Cooper	28 February 1930	1954	24
1972	John Schrieffer	31 May 1931	1957	26
1975	Leo Rainwater	9 December 1917	1946	28 (war)
1976	Burton Richter	22 March 1931	1956	25
1976	Samuel Ting	27 January 1936	1962	26
1977	Phillip Anderson	13 December 1923	1949	25 (war)
1977	John Van Vleck	13 March 1899	1922	23
1978	Arno Penzias	26 April 1933	1962	29 (war)
1978	Robert Wilson	10 January 1936	1962	26
1979	Sheldon Glashow	5 December 1932	1959	26
1979	Steven Weinberg	3 May 1933	1957	24
1980	James Cronin	29 September 1931	1955	23
1980	Val Fitch	10 March 1923	1954	31 (war)
1981	Arthur Schawlow	5 May 1921	1949	28 (war)
1982	Kenneth Wilson	8 June 1936	1961	25
1983	William Fowler	9 August 1911	1936	24
1988	Leon Lederman	15 July 1922	1951	28
1988	Melvin Schwartz	2 November 1932	1958	25
1988	Jack Steinberger	25 May 1921	1948	27 (war)
1989	Norman Ramsey	27 August 1915	1940	24
1990	Jerome Friedman	28 March 1930	1956	26
1990	Henry Kendall	9 December 1926	1955	28

Table 11.12: Ages at final degree for scientists who were educated primarily or entirely in the United States and won a Nobel Prize in Physics prior to 1991.

Table 11.13 summarizes the average ages at graduation from Tables 11.10–11.12 for the U.S. system, excluding those whose education was delayed by war, work, or illness. For comparison, the corresponding average ages from Tables 10.3–10.6 for the German-speaking world are also included. As may be seen, on average those U.S.-educated scientists took approximately two years longer to complete their education than their contemporary counterparts from the German-speaking world. [For related issues, see Dahlgreen 2016.]

Category of people	**Age at graduation from German-speaking world**	**Age at graduation from U.S. system**
Ph.D., Physics Nobel 1901–1990	23.2 years	25.1 years
Ph.D., Chemistry Nobel 1901–1990	22.4 years	24.7 years
Ph.D., Medicine Nobel 1901–1990	23.6 years	25.2 years
M.D., Medicine or Chemistry Nobel	23.8 years	25.0 years
Final degree, all science Nobelists	23.0 years	24.9 years
Ph.D., non-Nobel sample	22.4 years	—
Ph.D., Nobel + non-Nobel sample	22.7 years	25.0 years
M.D., Nobel + non-Nobel sample	23.8 years	25.0 years
Final degree, Nobel + non-Nobel sample	22.9 years	24.9 years

Table 11.13: Ages at final degree for selected scientists educated in German-speaking and U.S. systems.

As a further comparison, the current situation in the U.S. educational system is even worse. For those receiving a doctorate in 2017, the median age at graduation was 31.6 [https://ncses.nsf.gov/pubs/nsf19301/data]. That is nearly a decade older than students who received a Ph.D. from the earlier German-speaking world.

Each increase in the average age at which scientists and engineers receive their final degree means fewer years for their research careers, especially fewer available years when they are youngest, most creative, most energetic, and least distracted by other factors in their lives (family obligations, serving on committees, etc.):

- By this criterion, scientists in the early U.S. research system graduated approximately two years behind their contemporary German-speaking peers, which might be one factor explaining why those U.S. scientists may have created fewer revolutionary innovations per person than their German-speaking peers.

- Yet scientists in the modern U.S. research system graduate approximately 6.5 years behind even those early U.S. scientists, and nearly a decade behind the early German-speaking creators, which might help explain why the modern system may create even fewer revolutionary innovations per person.

The problem is even worse than those numbers indicate. In general, many (though certainly not all) of the German-speaking creators and the early U.S. scientists were able to conduct truly independent research as soon as they obtained their doctoral degrees, if not before. In contrast, scientists who receive a Ph.D. or M.D. in the modern U.S. system typically then have to spend many years following older supervisors' instructions in postdoctoral jobs, residencies, or entry-level positions at corporate or government laboratories. In 2020, the average age at which Ph.D. scientists received their first National Institutes of Health (NIH) research project grant was 43, and the average age at which M.D. scientists received their first NIH research grant was 46 [https://nexus.od.nih.gov/all/2021/11/18/long-term-trends-in-the-age-of-principal-investigators-supported-for-the-first-time-on-nih-r01-awards/]. Thus many German-speaking creators and early U.S. scientists achieved similar independence on average two whole decades in life earlier than scientists in the modern U.S. system.

As discussed in Chapter 12, this data suggests that one way to improve the modern innovation system would be to eliminate redundancies between high school and undergraduate education, streamline the graduate school educational process, greatly lower the average ages at which scientists receive their final degrees and their first financial grants, and give young scientists much more independence during their most energetic and creative years.

11.2.5 Interdisciplinary Approach

A significant fraction of the German-speaking creators were individuals who had demonstrated that they could be productive in multiple scientific fields in Europe (Section 10.2.5), and that continued to be true for many of the German-speaking creators who moved to the United States before, during, or after the Third Reich. Many examples could be cited; here are just a few of the better known cases:

- Hans Bethe was a vigorous force in fields from astrophysics to international politics [Bethe 1991].
- Carl Djerassi not only helped to develop oral contraceptives, new methods for analytical chemistry, and safer pesticides, but also wrote novels and plays that received worldwide recognition [Carr 2009; http://www.djerassi.com].
- Krafft Ehricke made major advances in rocket design, nuclear engineering, orbital mechanics, and planetary science [Freeman 2008].
- George Gamow advanced our knowledge of both the Big Bang and the genetic code [Gino Segrè 2011].
- John von Neumann made major contributions to everything from nuclear weapons design to computers to economics to political policy [Macrae 1992].
- Leo Szilard was responsible for the beginnings of both the Manhattan Project and molecular biology research in the United States [Lanouette and Silard 1992].
- Herbert Wagner developed jet engines, guided missiles, and nuclear engineering projects [p. 4165; Christopher 2013; Constant 1980].
- Fritz Zwicky was known for his exceptional creativity in fields ranging from jet propulsion to astrophysics [John Johnson, Jr., 2019; Stöckli and Müller 2008].

Among the American-born creators who were active during the golden age of the U.S. system, there appear to have been fewer truly interdisciplinary individuals, although there were a few notable cases; for example:

- John Bardeen made Nobel-prize-winning contributions to both transistors and superconductivity [Hoddeson and Daitch 2002].
- Linus Pauling contributed to quantum physics, chemistry, protein structure, DNA research, and international politics [Serafini 1989].
- Simon Ramo was instrumental in national programs ranging from air defense systems to ballistic missiles, and he was as skilled at business and politics as he was at science and engineering [Ramo 1988].

In modern peer-reviewed committee decisions for research grants and academic tenure, very long lists of papers in the same narrow specialty are especially valued, and it is difficult to find examples of revolutionary innovators who are making major contributions in several very different fields. There are probably still some who have survived within the modern system, but the trend seems to be that interdisciplinary creators were most valued, and therefore most prevalent, in the earlier German-speaking world, still in evidence in the 1940s–1960s U.S. system, and increasingly rare in the decades since.

One might object that modern scientific fields have advanced so far that it is no longer feasible for individuals to acquire sufficient multidisciplinary expertise. However, that objection does not seem valid when one examines the enormous knowledge, expertise, and accomplishments of earlier scientists such as John von Neumann or Enrico Fermi, or when one considers that revolutionary innovations in many fields seem to have matured and stagnated at the level that was created by those same interdisciplinary creators. In other words, if those earlier multidisciplinary creators were revived from the dead today, they would probably be able to quickly catch up on the few truly important developments they had missed, and then continue their work in multiple fields. If individuals could be so successful studying and working in multiple disciplines in the twentieth century, modern students should be able to acquire the same breadth and depth of expertise now.

Certainly most scientists and engineers can be rather specialized and still contribute fully to the system. Nonetheless, there is great value if some small but significant fraction of individuals possesses a much broader interdisciplinary expertise. With that broader view of the entire scientific landscape, they can help to:

1. Guide the system toward more revolutionary areas that might otherwise be overlooked by those with only microspecialized views of known areas.

2. Take successful methodologies, discoveries, and inventions from one area and apply them to make advances in a completely different area.

3. Spot areas that for certain fundamental reasons are scientific dead ends.

4. Effectively communicate the state of scientific fields to scientists in other fields, government leaders, business leaders, students, and the general public.

11.2.6 Scientific Leadership and Decision-Making Style

Just as certain high-level scientific managers in the earlier German-speaking world seem to have operated as enlightened despots in identifying and funding promising creators and creations, a large number of enlightened despots appear to have greatly contributed to the successes of the U.S. research system from the 1940s through the 1960s. Without in any way attempting an exhaustive list, this section provides examples illustrating the impact that individual enlightened despots had on the U.S. research system.

Like the earlier German-speaking enlightened despots, these U.S. enlightened despots had different individual styles, various opportunities, and differing levels of success; they were all imperfect in their scientific judgment and/or personal character (some more than others), and most if not all of them made some strong enemies along the way. Nonetheless, also like their earlier German-speaking counterparts, each of these U.S. despots had:

- The strong and direct support of very high authorities (in many cases actually the U.S. President).
- A keen eye for revolutionary innovators and innovations.
- The ability to directly offer steady employment and funding for any innovators and innovations they deemed worthy, by circumventing the much slower and more risk-averse normal bureaucratic processes for application, review, approval, renewal, etc.

Vannevar Bush (1890–1974), shown in Fig. 11.65, may be viewed as the political father of the U.S. research world,[10] just as Friedrich Althoff may be viewed as the political father of the earlier German-speaking research world (p. 2001). Like Althoff, Bush also installed or aided a number of other enlightened despots, such as those shown in the lower half of Fig. 11.65. Bush was an electrical engineering professor and vice president at the Massachusetts Institute of Technology (MIT) as World War II approached and U.S. government funding for R&D was minimal. Bush became president of the Carnegie Institution for Science in Washington, DC (1939–1955), as well as chair and member of the advisory board of the National Advisory Committee for Aeronautics (NACA, the predecessor of NASA, 1938–1948). In 1940 he successfully lobbied President Franklin Roosevelt to create the National Defense Research Committee (NDRC) and Office of Scientific Research and Development (OSRD), which Bush ran until 1947 and in which capacity he reported directly to the President. Bush's NDRC and OSRD were in charge of creating, funding, and managing all military scientific R&D in the United States during these years, including U.S. developments in nuclear fission reactors and weapons, radar systems, proximity fuses, penicillin mass production, and other innovations. After the war, Bush proposed and successfully lobbied for the establishment of the major U.S. government research sponsoring agencies, including the creation of the National Science Foundation, the Atomic Energy Commission (now called the Department of Energy), and the military Research and Development Board (RDB, predecessor of later Department of Defense research sponsoring offices), as well as major expansions of NACA and the National Institutes of Health (NIH). Bush also strongly promoted corporate research while serving on the board of directors for American Telephone and Telegraph (AT&T, 1949–1962), Merck (1949–1962), and other companies.

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[10] Baxter 1946; Burchard 1948; Bush 1946, 1949, 1960, 1967, 1970; James Conant 1970; Jennet Conant 2002; Schrage 1990; Wiesner 1979; Zachary 1997a, 1997b, 2022.

Vannevar Bush

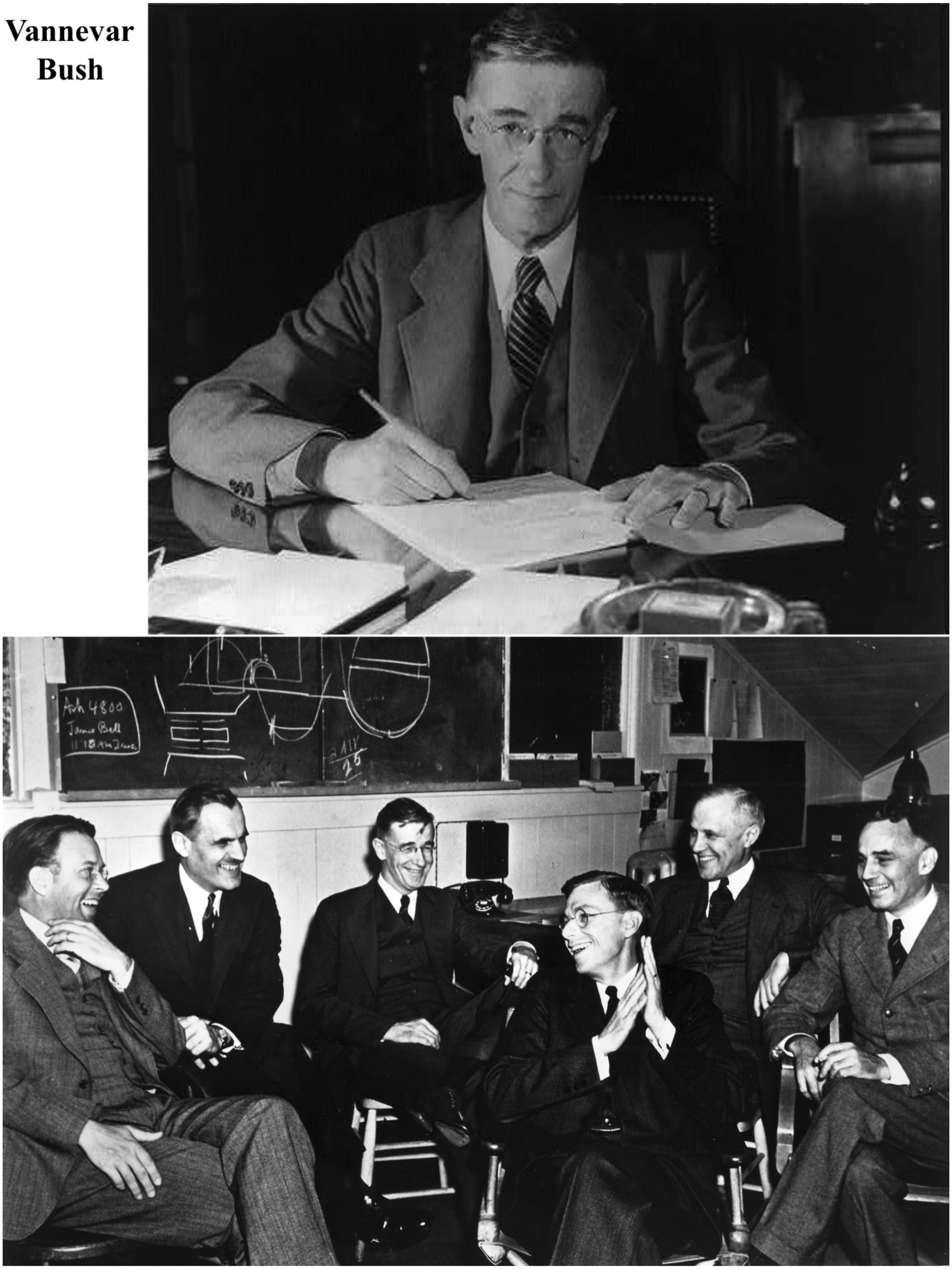

Figure 11.65: Examples of scientific "enlightened despots" who had a large impact on the U.S. system. Above: Vannevar Bush established the entire government-funded research system during and immediately after World War II. Below: March 1940 meeting of Ernest Lawrence, Arthur Compton, Vannevar Bush, James Conant, Karl Compton, and Alfred Loomis (from left to right).

Bush laid out some of his views on scientific innovation in an allegorical essay entitled "The Builders" [Bush 1967, pp. 11–12]:

> The process by which the boundaries of knowledge are advanced, and the structure of organized science is built, is a complex process indeed. It corresponds fairly well with the exploitation of a difficult quarry for its building materials and the fitting of these into an edifice[...]
>
> In these circumstances it is not at all strange that the workers sometimes proceed in erratic ways. There are those who are quite content, given a few tools, to dig away, unearthing odd blocks, piling them up in the view of fellow workers, and apparently not caring whether they fit anywhere or not. Unfortunately there are also those who watch carefully until some industrious group digs out a particularly ornamental block, whereupon they fit it in place with much gusto and bow to the crowd. Some groups do not dig at all, but spend all their time arguing as to the exact arrangement of a cornice or abutment. Some spend all their days trying to pull down a block or two that a rival has put in place. Some, indeed, neither dig nor argue, but go along with the crowd, scratch here and there, and enjoy the scenery. Some sit by and give advice, and some just sit.
>
> On the other hand there are those men of rare vision, who can grasp well in advance just the block that is needed for rapid advance on a section of the edifice to be possible, who can tell by some subtle sense where it will be found, and who have an uncanny skill in cleaning away dross and bringing it surely into the light. These are the master workmen.

Historian G. Pascal Zachary gave an excellent overview of Bush's personality and legacy [Zachary 1997a, pp. 4–5, 7–8]:

> [...] Bush believed Americans should freely give public-spirited experts ultimate authority over the nation's security. He ranked the engineer as first among equals, a sort of super-citizen who could master virtually every activity essential to the smooth functioning of a modern nation. What distinguished the engineer from other experts was his breadth. Bush saw the engineer as a pragmatic polymath; the engineer, he once wrote, "was not primarily a physicist, or a business man, or an inventor but [someone] who would acquire some of the skills and knowledge of each of these and be capable of successfully developing and applying new devices on the grand scale."
>
> This realization that the engineer was the *engine* of 20th-century capitalism qualified Bush as the godfather of high technology and a leading proponent of industrial vitality through innovation, not intrigue. [...] At midcentury, he was among the few who realized the curative power of new ventures. The best way to limit monopoly economic power, he insisted, was through "the advent of small new industrial units, for if these latter have half a chance they can cut rings around the great stodgy concern."
>
> Such contrarian views made Bush a divisive figure. His personality didn't always help either. His philosopher-king aura smacked of arrogance, even meanness to some. He struck his critics as imperious, intimidating and at times even a bully who harbored "a relentless, perhaps insatiable, drive for power." Still he had redeeming qualities. His wit and charm prompted comparisons with the folksy Will Rogers. His intelligence,

> vitality and candor impressed many. He enjoyed a good tussle, refused to back down from anyone and, when opposed, could explode in anger. He rubbed people in authority the wrong way, but he was principled about it. He felt he never angered anyone without good reason. Aware that his penchant for battle cost him good will, he still never shied away from a fight, and he took as much ground as his opponents ceded. "My whole philosophy . . . is very simple," he told a few generals during the war. "If I have any doubt as to whether I am supposed to do a job or not, I do it, and if someone socks me, I lay off." [...]
>
> Acts of importance were the measure of Bush's life, and they are the reason his life deserves study today. His was a political life, wrapped in the enigma of science and invention. An apostle of expertise, he transcended the labels of "liberal" or "conservative" and pursued the progressive ideal of public betterment through the private efforts of people of good will and merit. [...]
>
> In an age of complexity, Bush's habits of mind transcended easy categorization and prefigured the postmodern embrace of contradictions. He was a contrarian, skeptical of easy solutions yet willing to tackle tough problems without a compass. He looked askance at social status based on wealth, but fervently believed that mass opinion should be directed by a "natural aristocracy" of meritorious Americans. He was a pragmatist who thought that knowledge arose from a physical encounter with a stubborn reality. The mathematician Norbert Wiener called him "one of the greatest apparatus men that America has ever seen—he thinks with his hands as well as with his brain." Despite being drenched in a world of particulars, Bush was ultimately a moral thinker whose grand themes were individual self-reliance, democracy with a small *d* and the absolute necessity for thinking men and women to build—with the help of technology—meaningful patterns from the confusing buzz of facts, ideas and emotions that compose the discourse of any era.
>
> Suspicious of big institutions, whether run by public servants, the military or corporations, Bush objected to the pernicious effects of an increasingly bureaucratized society and the potential for mass mediocrity long before such complaints became conventional wisdom. [...]
>
> His great failure and his enduring triumph was his realization that the course of modern history would be shaped by large hierarchical institutions, making plans and settling scores behind closed doors, working best when insulated from public opinion. That these institutions lost their energy and legitimacy as the 20th century waned would not have surprised Bush. Whether overseeing the creation of the atomic bomb or lobbying to fund "pure" research without utilitarian purpose, he believed the beleaguered individual was still of paramount importance.
>
> "The individual to me is everything," he wrote on the eve of World War II. "I would circumscribe him just as little as possible." In the murderous years that followed, he never lost his faith in the power of one.

As Zachary pointed out, a tragic irony is that Bush, who was probably the most powerful enlightened scientific despot in the history of the United States and who empowered or assisted other enlightened despots, helped to set up the key institutions of the U.S. innovation system that ultimately, over the course of the following decades, replaced the individual far-sighted enlightened despots with a faceless bureaucratic system of myopic, risk-averse peer review.

William M. Allen (1900–1985), shown in Fig. 11.66, ran Boeing 1945–1972 when it developed the 707 through 747 jet airliners. As exemplified by those products, he championed major technological steps, large R&D budgets, and long development timelines [Clive Irving 2014; Serling 1992]. *Fortune* magazine named him one of the "10 greatest CEOs of all time" [Collins 2003]:

> "Don't talk too much," Boeing's new chief admonished himself. "Let others talk."
>
> Its planes helped win the war—yet victory in 1945 looked like death for Boeing. Revenues plummeted more than 90% as orders for bombers vanished overnight. And bombers, everyone knew, were what Boeing was all about.
>
> Everyone, that is, but its new leader. An understated lawyer who said he wasn't qualified for the job, Bill Allen never saw Boeing as the bomber company. It was the company whose engineers built amazing flying machines. In 1952 he bet heavily on a new commercial jet, the 707. At the time, Boeing had no business being in the commercial market, or at least that's what potential customers said. ("You make great bombers up there in Seattle. Why don't you stick with that?") Yet Allen's time frames were bigger too. He saw that Boeing could compete by changing the industry. Under his leadership, Boeing built the 707, 727, 737, and 747—four of the most successful bets in industrial history. At a board meeting described by Robert Serling in *Legend & Legacy*, a director said that if the 747 was too big for the market to swallow, Boeing could back out. "Back out?" stiffened Allen. "If the Boeing Aircraft Co. says we will build this airplane, we will build it even if it takes the resources of the entire company." Like today's CEOs, he endured the swarming gnats who think small: short time frames, pennies per share, a narrow purpose. Allen thought bigger—and left a legacy to match.

(Army) Air Force General Henry "Hap" Arnold (1886–1950), shown in Fig. 11.66, was a very strong supporter of developing revolutionary technologies during and after World War II [Henry Arnold 1945, 1949; Bower 1987; Lasby 1971]. He played an especially important role in getting the United States to acquire a large number of creators and creations from the German-speaking world and to support the employment of those innovators and technologies for U.S. military applications. Historian Clarence Lasby described the extent of Arnold's vision [Lasby 1971, pp. 102–103]:

> Henry "Hap" Arnold, Commanding General of the Air Forces, was determined to capitalize on German advances. A stocky, broad-shouldered West Point graduate and former aide to General Billy Mitchell, Arnold had been the most devoted partisan of airpower throughout the 1930's. He was also a visionary, and was fortunate to find a man who appreciated his new concepts for air warfare in Professor Theodore von Kármán, a Hungarian Jew who in 1929 had left the directorship of the Aeronautical Institute of Aachen, Germany, to assume the same position at the Aeronautical Laboratory at Cal Tech. In 1939 Arnold contracted with von Kármán to construct a 40,000-horsepower wind tunnel, the first of its kind, and to develop rockets to assist the takeoff of heavy aircraft. In September 1944 he called upon his ally again, this time to prepare a blueprint for air research for the next twenty to fifty years. When he addressed the scientist's advisory group, he asked them to free their imaginations. "I see a manless Air Force," he said. "I see no excuse for men in fighter planes to shoot down bombers." Unlike the aviators in the Navy, Arnold had no fear of novel weapons. In May 1945 he had sent von Kármán on a special mission to study the Germans' latest developments, and when his own officers proposed the exploitation of the enemy scientists through Overcast, he approved.

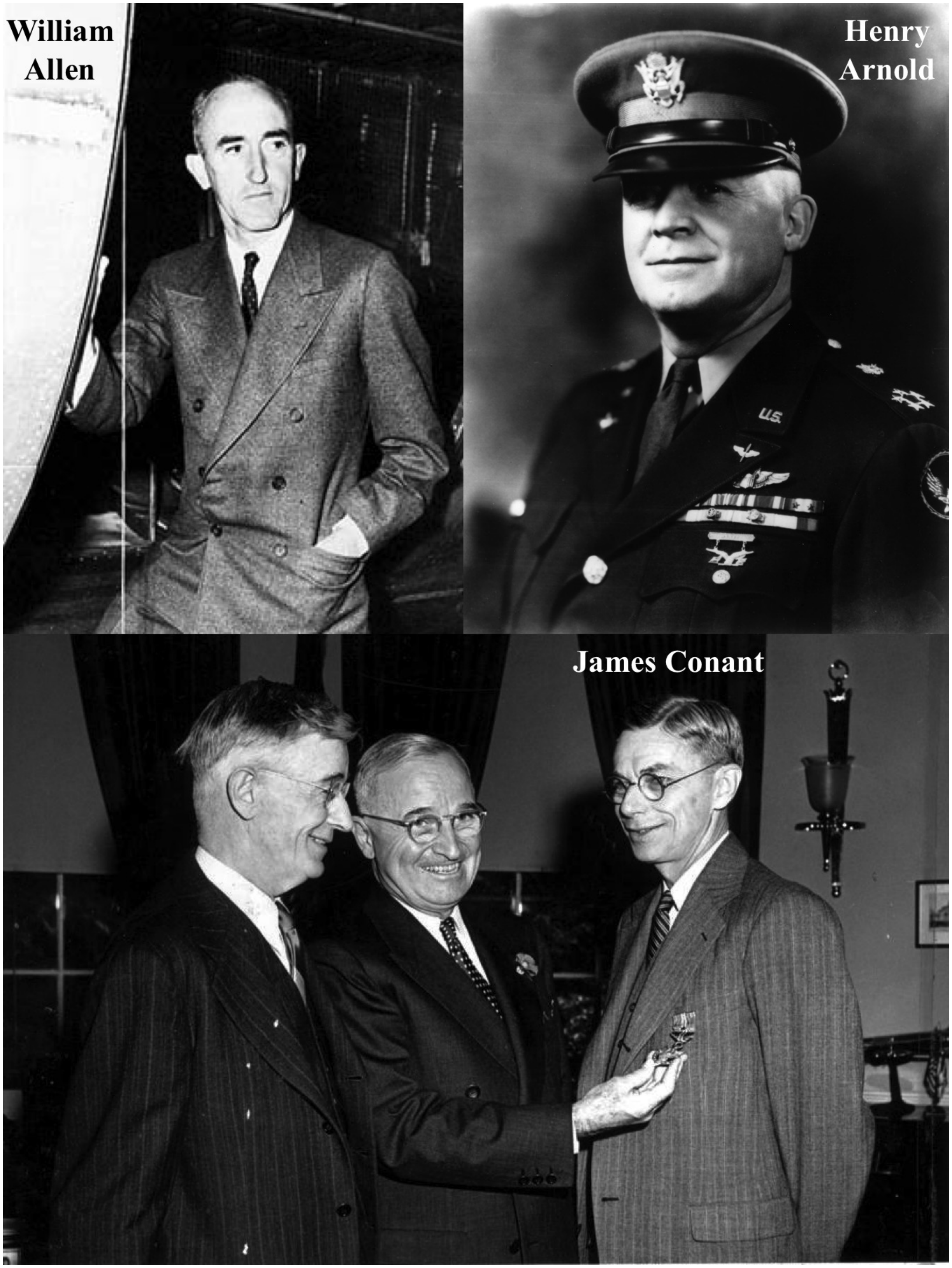

Figure 11.66: More examples of scientific "enlightened despots" who had a very large impact on the U.S. system: William M. Allen ran Boeing 1945–1972 when it developed the 707 through 747 jet airliners. Army Air Forces General Henry Arnold strongly supported revolutionary technologies during and after World War II. James Conant (lower right, with Vannevar Bush and Harry Truman) modernized Harvard University, helped Vannevar Bush run national research during World War II, and was the first U.S. Ambassador to West Germany after the war.

James Conant (1893–1978), shown in Fig. 11.66, modernized Harvard University, helped Vannevar Bush run national research during World War II, and was the first U.S. Ambassador to West Germany after the war [Baxter 1946; James Conant 1970; Jennet Conant 2002, 2017; Zachary 1997a]. According to his obituary [NYT 1978-02-12 p. 1]:

> Dr. Conant led Harvard for 20 years, but the lean, self-effacing six-footer was never in a rut, then or after. He left a brilliant career in chemistry to accept the university's presidency and his resignation in 1953 at the age of 60 marked only the beginning of distinguished roles as diplomat and almost single-handed reformer of, and schoolmaster to, American public education.
>
> As a prelude to his diplomatic service Dr. Conant had served in World War II as a scientific adviser to the Government on the atomic bomb project and was one of those involved in the selection of the target in Japan for the first bomb, which was dropped over Hiroshima Aug. 6, 1945.
>
> Dr. Conant, who spent the major part of his life in the leadership of higher education, perhaps will be best remembered in popular lore as the man who warned of the "social dynamite" accumulating in the cities and who tried to chart a course of improvement for the nation's elementary and secondary schools.
>
> In whatever task he had at hand, he stressed the relevant, the immediate and the practical. He dealt largely in ideas but he liked to see them translated into action, and his habit of sliding back his cuff and glancing at his watch was due more to planning the next step than to impatience.
>
> As an educator Dr. Conant was indifferent to the pressures of politics and consensus and, although he did not seek out controversy, he was unintimidated by it.
>
> He would cling obstinately to his opinions if he thought them right. On the wall of his office at Harvard he kept a framed cartoon with the caption: "Behold the turtle, he makes progress only when his neck is out."

James Conant succinctly summed up his philosophy of scientific management [Jennet Conant 2002, p. vii]:

> To advance scientific knowledge, pick a man of genius, give him money, and let him alone.

Lee DuBridge (1901–1994), shown in Fig. 11.67, directed the MIT Radiation Laboratory 1940–1946 and the California Institute of Technology (Caltech) 1946–1969 [Baxter 1946; Burchard 1948; Jennet Conant 2002; Greenstein 1997; Guerlac 1987]. He facilitated the great wartime successes of the Radiation Laboratory in radar development both by being a strong lobbyist to government for funding and independence for the Laboratory, and also by creating an extraordinarily productive research environment for the scientists working there [Guerlac 1987, p. 297]:

> No full understanding of the administrative eccentricities of the Radiation Laboratory is possible without recognizing that one of its outstanding merits, in the eyes of its own management, was that it was a physicist's world, run for, and as completely as possible by, physicists. Everything was subordinated to producing an environment for research as free and untrammeled as in a university and to preventing research from becoming entangled or impeded by the growing responsibilities thrust upon the organization. [...N]o policy could have been better designed to rid the research man of unwise interference, and to give him unsurpassed opportunities for creative work. The Radiation Laboratory came close to realizing a scientist's dream of a scientific republic, whose only limitation was the supply of scientists.

Jesse Greenstein, a Caltech astronomer, provided more details about DuBridge's personality and accomplishments [Greenstein 1997]:

> In November 1940, under pressure from Lawrence and Loomis, Lee became the founding director of the Radiation Laboratory (RadLab) centered at the Massachusetts Institute of Technology. It did not disband until January 1946. His first helpers, recruited on a crash basis, included a dozen from the nuclear physics community, Alex Allen, Ken Bainbridge, Ed McMillan, I. I. Rabi, Norman Ramsey, Stan Van Voorhis, and Milton White; some of the staff later won Nobel Prizes. By 1945 the lab employed 4,000 scientists and engineers. Lee's style, one that he retained all his life, was one of showing leadership rather than exerting authority. He listened and understood the problems well, but he could be finally decisive. Their first project was to design and build a radar for air interception, which took three months plus a year to mount on the Northrup Black Widow airplanes.
>
> Also designed and built were radar to detect ships and submarines at sea, for night bombing, and to point guns. Over 100 types of microwave radar were created. For each there were training programs, service instructions, and manuals for field maintenance. Many prospective users were trained at MIT. RadLab personnel fanned out over the world to train users and improve field operations. The annual budget reached $50 million. The lab and its products (the theory of high-frequency circuits and the many uses of microwaves) were described in an unclassified twenty-seven-volume series published at the end of the war. [...]
>
> He was in many ways an ideal college president for the twenty-three years he held that office. He was soft-spoken, responsive, and persuasive. He somehow knew how to say "no" and still retain the friendship of a faculty member. He visited faculty offices to ask what was new in a member's field. As senior professor of astronomy I enjoyed Lee's questions as to what had been found recently at Palomar. His broad physical insight gave him quick understanding and he savored what remained puzzling. A further extraordinary ability was to repeat a story, with background and speculation about its future, to a meeting of the Board of Trustees or to the Associates. Sometimes the solution was only money, which he provided at once in small amounts and in large amounts after some effort. Lee spoke very well in public and was under constant pressure to explain Caltech science and education to organizations and the public.

Crawford Greenewalt (1902–1993), shown in Fig. 11.67, helped Du Pont build the plutonium-producing Hanford fission reactors during World War II, and he ran Du Pont 1948–1967 when it introduced its most innovative chemical products [Greenewalt 1959; Hounshell and Smith 1988; Zilg 1984]. In their landmark book on the history of R&D at Du Pont, historians David Hounshell and John Smith, Jr. described Greenewalt's approach [Hounshell and Smith 1988, pp. 358–361]:

> In the twentieth century history of the Du Pont Company, there was perhaps never a more perfect fit between corporate objectives and the career, style, and philosophy of the company's president than during the presidency of Crawford H. Greenewalt. [...]
>
> Starting from virtually no knowledge of fission in October 1942, he rapidly acquired a deep knowledge of reactor physics—deep enough to keep a check on Chicago physicists and not to be cowed by them. [...] Greenewalt so impressed Fermi and Compton that both offered him positions in their postwar research enterprises. [...]
>
> The Manhattan Project's success and the elder du Ponts' continued concerns about family management of the company quickly propelled Greenewalt to the top. [...]
>
> Not long after assuming the presidency, Greenewalt articulated what he believed to be the Du Pont Company's two fundamental principles of growth and development that had served in the past and would continue to govern in the future. Writing in his first annual report as president, Greenewalt noted, "The first of these has been to seek diversification in any chemical field to which it can make a substantial technical contribution." Such a principle meant that "research results have been applied over a wide commercial area." But Du Pont had not done research and development in just any area of the chemical industry. Rather, as Greenewalt stressed, "the second principle has been to direct the Company's research and manufacturing efforts primarily to the large and difficult tasks which inherently require great resources in technical ability and finances." Greenewalt's second principle was a corollary to the one laid down some forty years earlier by Pierre du Pont, who said that the company should always have a few really big, high-risk research projects going because the company stood to benefit both from potentially large payoffs and from keeping an expert force of researchers continually engaged by the company. Greenewalt, the chemical engineer turned executive, envisioned the company developing and managing large, integrated, continuous-process chemical plants that would be the embodiment of his principles. In the future, Du Pont would marshal its resources to do what most other companies could not. From these efforts, "new nylons" would emerge.
>
> The rapid and strong impact that nylon's success had on the Du Pont Company's strategy of growth and its concomitant R&D policies is perhaps best expressed in the phrase "new nylons." By 1945, these two words had become shorthand for the whole paradigmatic shift in Du Pont's research program whereby all the industrial departments, not just the Chemical Department, would undertake fundamental research at the expanded Experimental Station. From a policy level, Crawford Greenewalt's widely circulated report, "Fundamental Research: Definition and Justification," stated the matter succinctly: "We are interested primarily in fundamental research studies which are likely to produce new nylons." [...] Greenewalt often pondered the statistical basis of research and concluded that it was but a form of gambling where the odds were greatly improved through the conduct of fundamental research within a widely diversified company such as Du Pont.

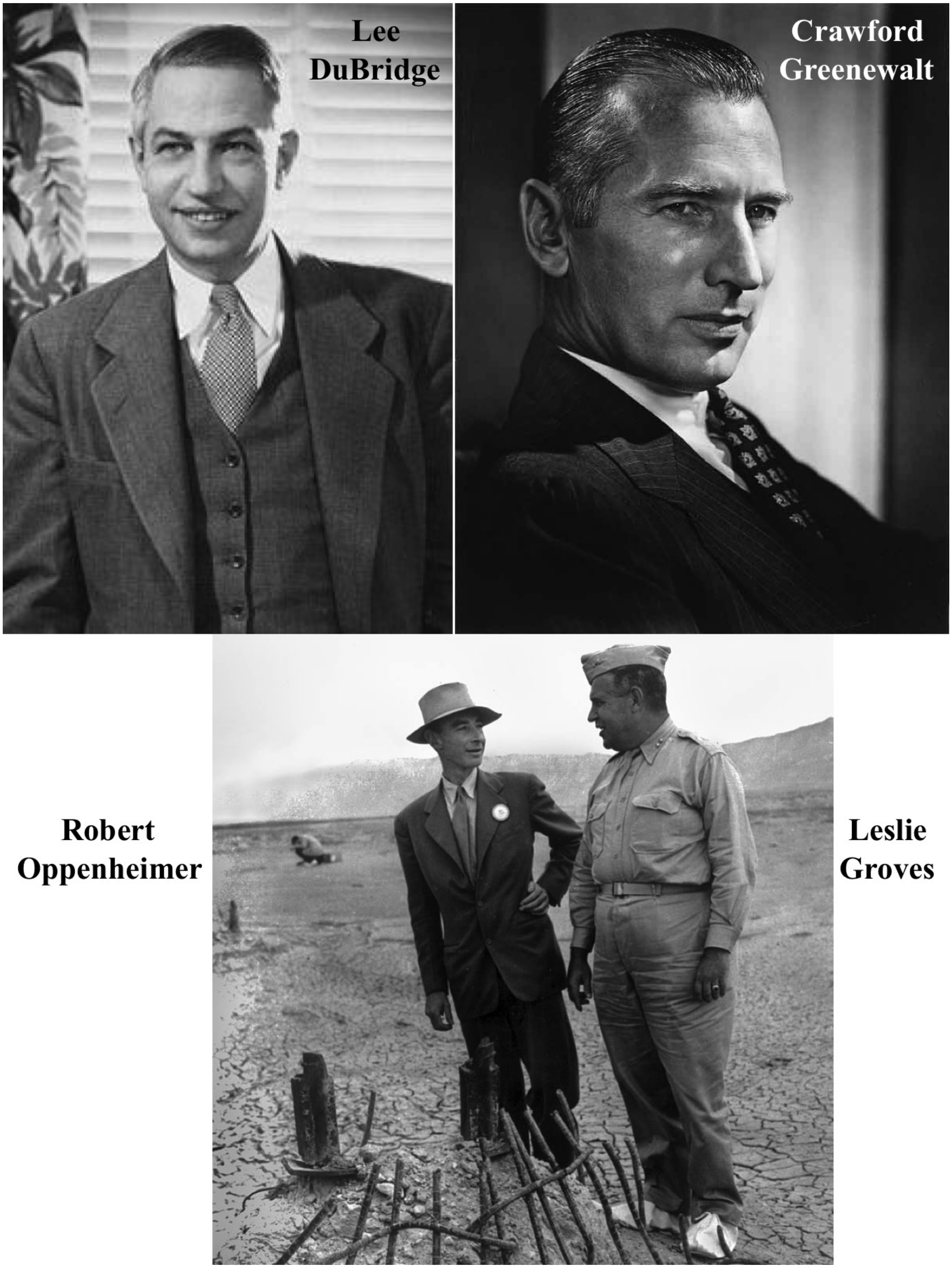
Lee DuBridge
Crawford Greenewalt
Robert Oppenheimer
Leslie Groves

Figure 11.67: More examples of U.S. scientific "enlightened despots": Lee DuBridge directed the MIT Radiation (radar) Laboratory 1940–1946 and the California Institute of Technology 1946–1969. Crawford Greenewalt oversaw the plutonium-producing Hanford fission reactors during World War II and ran Du Pont 1948–1967 when it introduced its most innovative chemical products. Army General Leslie Groves and J. Robert Oppenheimer were the military and scientific directors, respectively, for the WWII U.S. nuclear weapons program, and helped establish the postwar program.

Army General Leslie Groves (1896–1970) and J. Robert Oppenheimer (1904–1967), shown in Fig. 11.67, were the military and scientific directors, respectively, for the WWII U.S. nuclear weapons program, and helped to establish the postwar program.[11]

Colonel Kenneth Nichols, who oversaw the construction and operation of all Manhattan Project facilities under Groves, described Groves [Nichols 1987, p. 108]:

> First, General Groves is the biggest S.O.B. I have ever worked for. He is most demanding. He is most critical. He is always a driver, never a praiser. He is abrasive and sarcastic. He disregards all normal organizational channels. He is extremely intelligent. He has the guts to make timely, difficult decisions. He is the most egotistical man I know. He knows he is right and so sticks by his decision. He abounds with energy and expects everyone to work as hard, or even harder, than he does... if I had to do my part of the atomic bomb project over again and had the privilege of picking my boss, I would pick General Groves.

Nuclear historian and policy analyst Robert Norris described the working relationship between Groves and Oppenheimer [Norris 2002, pp. 242–243]:

> That Oppenheimer and Groves should have worked so well together is really no mystery. Groves saw in Oppenheimer an "overwhelming ambition" that drove him. He understood that Oppenheimer was frustrated and disappointed; that his contributions to theoretical physics had not brought him the recognition he believed he deserved. This project could be his route to immortality. Part of Groves's genius was to entwine other people's ambitions with his own. Groves and Oppenheimer got on so well because each saw in the other the skills and intelligence necessary to fulfill their common goal, the successful use of the bomb in World War II. The bomb in fact would be the route to immortality for both of them.
>
> They treated each other in special ways. Oppenheimer could at times be sarcastic with students or colleagues who could not keep up with his quick mind. Not so with Groves. He patiently answered whatever query the general asked. On Groves's part he treated Oppenheimer delicately, like a fine instrument that needed to be played just right. Groves's normal approach with most of his subordinates was to push them as hard as he could. The pressure was a test to see what they were made of. The more they took, the tougher they were. The good ones would make it through, and those who broke would be transferred, demoted, or replaced. The general saw that this approach would not work with Oppenheimer. Some men if pushed too hard will break.

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[11] Bird and Sherwin 2005; Jennet Conant 2005; Coster-Mullen 2012; Davis 1968; Groves 1962; Chuck Hansen 1988, 2007; Hawkins et al. 1983; Hoddeson et al. 1993; Jungk 1958; Kelly 2007; Nichols 1987; Norris 2002; Oppenheimer 1984; Bruce Cameron Reed 2015a, 2019; Rhodes 1986, 1995; Serber 1992; Smyth 1945; Sublette 2019.

Army Colonel Ernest Gruhn (1897–1994), shown in Fig. 11.68, the first director of the Joint Intelligence Objectives Agency, was a very strong supporter of developing revolutionary technologies during and after World War II. He played a vital role in getting the United States to import a large number of creators and creations from the German-speaking world and to harness those innovators and technologies for U.S. military applications. In his history of Operation Overcast/Paperclip, Tom Bower wrote [Bower 1987, pp. 137–138]:

> The detailed management of Overcast had by then been transferred from Bissell to Colonel Ernest Gruhn, who had been appointed director of the Joint Intelligence Objectives Agency. Operating from a few rooms in the Munitions Building in Washington, Gruhn and successive directors of JOIA would become passionate advocates of America's need to recruit the Germans and deny them to other powers. More sinisterly, they would deliberately conceal their irregular and unauthorized activities from civilian government departments.

Clarence "Kelly" Johnson (1910–1990), shown in Fig. 11.68, created and ran the Lockheed "Skunk Works" 1943–1975. His operation produced a large number of highly innovative aircraft, including the first U.S. jet fighters such as the P-80 and F-104, the U-2 high-altitude spy plane, the hypersonic SR-71 Blackbird spy plane, and stealth aircraft technology [Johnson and Smith 1989; Pace 2016; Rich 1994, 1995; Tirpak 2018; Yenne 2014]. Ben Rich, Johnson's right-hand man and successor, described Johnson's approach [Rich 1995]:

> Be quick, be quiet, be on time.
>
> That was the credo of Clarence L. (Kelly) Johnson, the aeronautical innovator who founded Lockheed's supersecret "Skunk Works" where he designed the world's fastest and highest-flying aircraft—the SR-71 Blackbird.
>
> Johnson played a leading role in the design of more than forty aircraft and set up a Skunk Works-type operation to develop a Lockheed satellite—the Agena-D—that became the nation's workhorse in space. His achievements over almost six decades captured every major aviation design award and the highest civilian honors of the U.S. government and made him an aerospace legend. [...]
>
> Johnson achieved international recognition for the highly successful Skunk Works operation—"a concentration of a few good people . . . applying the simplest, most straightforward methods possible to develop and produce new products" with minimum overhead and outside oversight—and for his unparalleled management style. [...]
>
> Johnson was known for his hard adherence to principles. On several occasions he turned back development contracts to the U.S. Department of Defense after initial work indicated the proposed aircraft would not be effective, no matter how much money the DoD was willing to provide. [...]
>
> The secret of Kelly Johnson's success was really no secret. He was not only one of the world's foremost designers, but he was an innovative manager who gave people who worked for him challenges to constantly create better products.

> Many of us in the Skunk Works turned down promotions to other Lockheed organizations to stay with Kelly. And uppermost for Kelly was to stay with the Skunk Works. He was offered a company presidency at Lockheed three times—and three times he declined it. "To me," said Kelly, "there was no better job within the corporation than head of Advanced Development Projects—the Skunk Works."
>
> Even when he retired from Lockheed as a corporate senior vice president in 1975, Johnson continued at the Skunk Works as a senior advisor. His influence continues in the Skunk Works. "Our aim," he said, "is to get results cheaper, sooner, and better through application of common sense to tough problems. If it works, don't fix it."
>
> "Reduce reports and other paperwork to a minimum."
>
> "Keep it simple, stupid—KISS—is our constant reminder."
>
> Johnson instinctively knew how to select people for his organization. He knew how to get the most out of the fewest people and how to get the job done—well. He let his managers run their programs with a minimum of interference. He not only gave you the authority but also the responsibility.

Ben Rich gave more information on Johnson and his Skunk Works approach [Rich 1994, p. 7]:

> Most Skunk Workers were handpicked by our just retired leader, Kelly Johnson, one of the reigning barons of American aviation, who first joined Lockheed in 1933 as a twenty-three-year-old fledgling engineer to help design and build the Electra twin-engine transport that helped put the young company and commercial aviation on the map. By the time he retired forty-two years later, Kelly Johnson was recognized as the preeminent aerodynamicist of his time, who had created the fastest and highest-flying military airplanes in history. Inside the Skunk Works, we were a small, intensely cohesive group consisting of about fifty veteran engineers and designers and a hundred or so expert machinists and shop workers. Our forte was building a small number of very technologically advanced airplanes for highly secret missions. What came off our drawing boards provided key strategic and technological advantages for the United States, since our enemies had no way to stop our overflights. Principal customers were the Central Intelligence Agency and the U.S. Air Force; for years we functioned as the CIA's unofficial "toy makers," building for it fabulously successful spy planes, while developing an intimate working partnership with the agency that was unique between government and private industry. Our relations with the Air Force blue-suiters were love-hate—depending on whose heads Kelly was knocking together at any given time to keep the Skunk Works as free as possible from bureaucratic interlopers or the imperious wills of overbearing generals. To his credit Kelly never wavered in his battle for our independence from outside interference, and although more than one Air Force chief of staff over the years had to act as peacemaker between Kelly and some generals of the Air Staff, the proof of our success was that the airplanes we built operated under tight secrecy for eight to ten years before the government even acknowledged their existence.

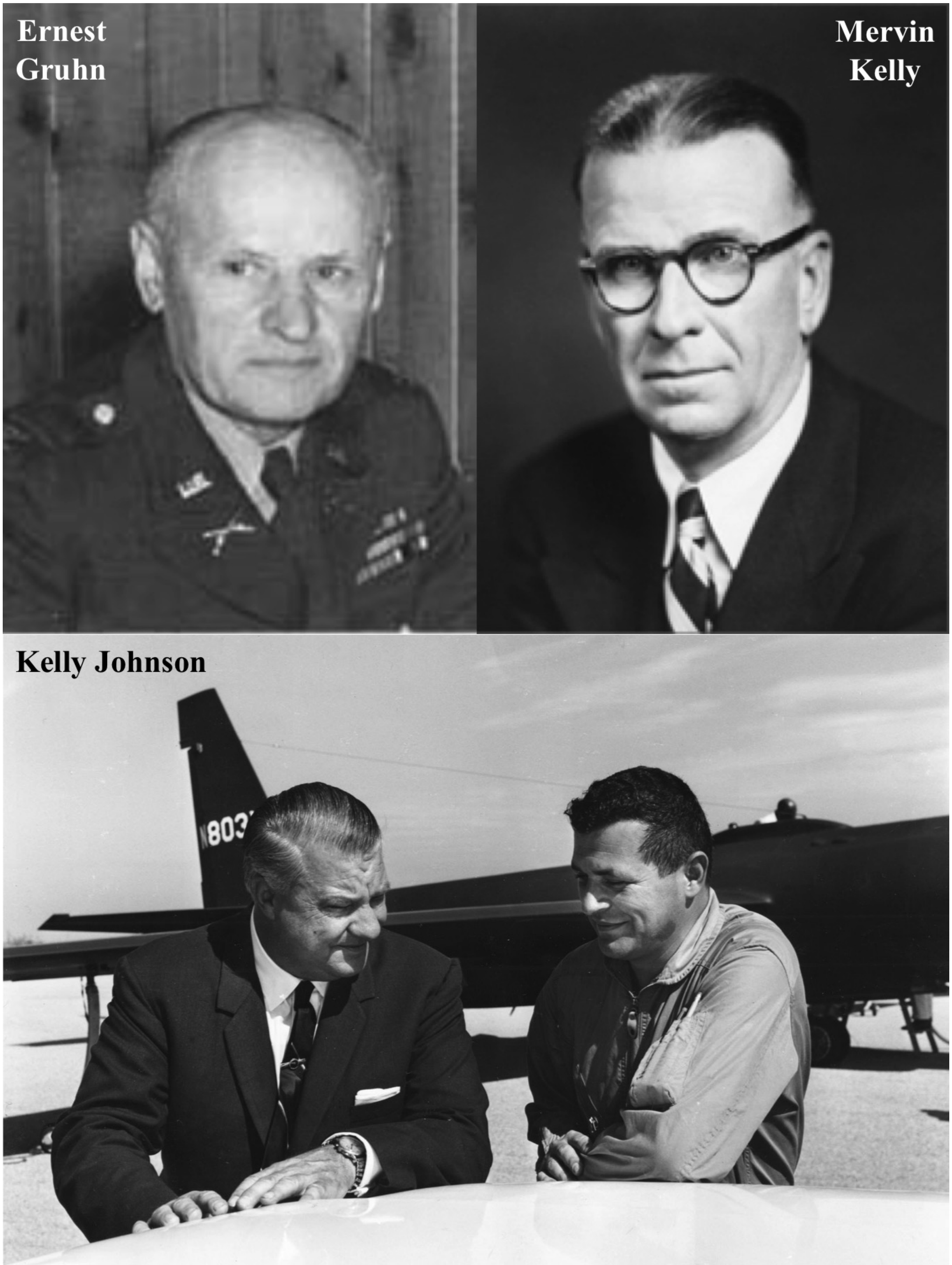

Figure 11.68: More examples of U.S. scientific "enlightened despots": Army Colonel Ernest Gruhn ran the Joint Intelligence Objectives Agency that transferred German scientists and technologies to the United States after World War II. Mervin Kelley created and led breakthrough research programs at AT&T Bell Laboratories 1936–1959. Kelly Johnson (left, with pilot Francis Gary Powers in front of a U-2 spy plane) created and ran the Lockheed "Skunk Works" 1943–1975.

Mervin Kelly (1895–1971), shown in Fig. 11.68, built and led the highly innovative research programs at AT&T Bell Laboratories during the period 1936–1959, occupying positions ranging from director of research to president.[12] John Pierce, a research manager under Kelly at Bell Laboratories, gave a detailed description of Kelly's personality [Pierce 1975]:

> [...] Kelly's greatest contribution lay in creative technical management. It is no more than just to say that Kelly made Bell Laboratories the foremost industrial laboratory in the world. He recognized and inspired good men and good work. He assessed and drove to completion important technical potentialities and opportunities. He shaped and managed a complex organization. And, he inspired the confidence and won the support of the management of AT&T and of the operating telephone companies of the Bell System. As Frederick R. Kappel, former board chairman of AT&T said after Kelly's death:
>
> "He was a great fellow for the Bell System. Mervin was always and forever pushing the operating management, and the heads of AT&T as well, to get on with new things. His aggressiveness got him in a lot of hot arguments, but I always sat back and said, 'Give it to them, Mervin, that's what we need.' Every place needs a fireball or sparkplug, and he was it."
>
> Kelly was not only a sparkplug; he combined determination and showmanship. Twice he submitted his resignation to the president of AT&T, stating that important work at Bell Laboratories was not being adequately funded. In each case, he got the funds. Surely, he was sincere, but he was dramatic as well. [...]
>
> Kelly's greatest accomplishments lay in the Bell Laboratories. He valued talent sincerely, as his warm biographical sketch of C. J. Davisson shows. He wanted, found, appreciated, and encouraged the sort of men who invented the transistor. [...]
>
> When the transistor had been invented, Kelly recognized its worth. As a foreign member of the Swedish Academy of Sciences, he pressed for the award of the Nobel Prize to Bardeen, Brattain, and Shockley. And, for years at Bell Laboratories nothing was any good unless it was "new art" (solid state).
>
> Kelly fostered or launched ambitious programs in nationwide dialing, in automation of maintenance and testing, in microwave communication, in coaxial cable transmission, in transoceanic cables, and in electronic switching. All were timely, and, in the end, all were successful. [...]
>
> After Kelly retired from Bell Laboratories, he acted as a consultant to a number of companies, but chiefly to International Business Machines Incorporated. In this capacity, his energy and enthusiasm were no less than in his leadership of Bell Laboratories, but he wisely realized that his role was that of counsellor to the management, including Thomas Watson, Jr., the chairman of the board, and not that of a boss. According to E. R. Piore, vice president and chief scientist of IBM:
>
> "He traveled to all technical locations in IBM that stretch across this country north and south and east and west and which are located in six countries in Europe. Once in the laboratory, he would [as he used to do at Bell Laboratories] spend time with the people at the bench, stimulating discussion and thinking, constantly evaluating the person and

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[12] Bernstein 1984; Gertner 2012; Kelly 1950; Pierce 1975; Rhoads 2005; Riordan and Hoddeson 1997; Wolff 1983.

> the program. Thus he acquired possibly more than any other person, a judgment of men, of programs, and the methods in use. This quality of conversing with the man at the bench, making the man feel at home with Kelly, in no way inhibited him with similar conversations with men up the ladder, including Tom Watson, Jr., and the rest of the group that had oversight over the whole IBM enterprise. Thus he would report to me after his trip and report to Tom Watson also. Mervin was not making a career for himself in IBM. Thus he never fought for his convictions but quietly gave his views—strong, moderate, or negative. This is one reason why his influence was great whether talking to me or to those above me. These conversations dealt with technology, people and management.
>
> "His evaluation and identification of people had a profound effect on their careers. He was after the best technical people, and recommended that they be placed in jobs of ever-increasing responsibility. I would judge that this was his greatest accomplishment in IBM." [...]
>
> Continually pressing for higher achievement, Kelly always prized and promoted ability wherever he found it. Conversely, he was uniformly impatient with mediocrity and almost ruthlessly intolerant of incompetence. [...]

Pierce also provided numerous examples of Mervin Kelly's views on how industrial research and development should be managed [Pierce 1975]:

> Kelly had no doubt as to the place of science and technology in man's life. He wrote: "So completely have they dominated the pattern of our growth that when the man in the street speaks of 'progress,' he usually means scientific and technological progress."
>
> Kelly was equally clear concerning the source of such progress: "Basic research is the foundation on which all technologic advances rest."
>
> What is the source, the generating force behind new ideas? Kelly said: "But with all the needed emphasis on leadership, organization and teamwork, the individual has remained supreme—of paramount importance. It is in the mind of a single person that creative ideas and concepts are born."
>
> Where should basic research be carried out? Kelly noted that " . . . the academic community has been the principal home of basic research for more than a century. . . ." However, he looked toward industry for substantial contributions to research: "The author believes that at least 10 per cent of most research and development budgets can be profitably employed in basic research. Any company that has 50 or more members of professional staff, that will dedicate 10 per cent of them to basic research, can build a strong, productive, and profitable effort." [...]
>
> Using the Bell Laboratories as an example of organized technology, Kelly delineated three areas that preceded the manufacture of complicated technological systems:
>
> "The first includes all of the research and fundamental development. This is our non-scheduled area of work. It provides the reservoir of completely new knowledge, principles, materials, methods, and art that are essential for the development of new communications systems and facilities.

> "The second we call 'systems engineering'. Its major responsibility is the determination of the new specific systems and facilities development projects—their operational and economic objectives and the broad technical plan to be followed. 'Systems engineering' controls and guides the use of the new knowledge obtained from the research and fundamental development programs in the creation of new telephone services and the improvement and lowering of cost of services already established.
>
> "The third encompasses all specific development and design of new systems and facilities. The work is most carefully programmed in conformity with the plan established by the systems engineering studies. Our research and fundamental development programs supply the new knowledge required in meeting the objectives of the new specific developments."
>
> In addition to these three technical areas, Kelly referred to another, the management of buildings, shops, and services:
>
> "The nonscientific duties of management should be minimized for all levels of the research supervision. Through proper organization, direct responsibility for people can be limited to scientists and their aides. Budget preparation, management of shops, services, secretaries and typists, for example, can be done by an intimately associated professional management staff of non-scientists. There should be the very minimum of diversion of the attention of the research leadership and the individual researchers from their scientific programs. This can be accomplished by organizational structures and operations fashioned to free all scientists from nonresearch supervisory duties which, at the same time, provide excellent and economical service in all areas that support the direct scientific endeavor." [...]
>
> Concerning the three functions into which he divided technological endeavor, Kelly made a number of observations. About research, he said:
>
> "Inspired and productive research in industry requires men of the same high quality as is required for distinguished pure research in our universities.
>
> "They must be given freedoms that are equivalent to those of the research man in the university." [...]

Pierce later summarized four aspects of the mid-twentieth-century Bell Laboratories management style that he thought could and should be implemented in other times and places in order to promote revolutionary innovation [Gertner 2012, p. 351]:

> A technically competent management all the way to the top.
>
> Researchers didn't have to raise funds.
>
> Research on a topic or system could be and was supported for years.
>
> Research [on a particular project] could be terminated without damning the researcher.

Before leaving the subject of early management at Bell Laboratories, one should also note (among other examples there) the earlier and partially overlapping contributions of Frank Jewett (1879–1949), who was the first president of Bell Laboratories 1925–1940, chairman of the Bell Laboratories Board of Directors 1940–1944, president of the U.S. National Academy of Sciences 1939–1947, and a member of the National Defense Research Committee during World War II [Buckley 1952].

George W. Merck (1894–1957), shown in Fig. 11.69, ran the U.S. company Merck 1925–1957. His father, Georg(e) Merck, had come to the United States in 1891 to found an American branch of the German pharmaceutical company Merck, but the U.S. government forced the American branch to become a fully independent U.S.-owned company during World War I. George W. Merck succeeded his father as the leader of the American company. During his tenure, he greatly expanded research in a wide variety of areas, and was known for focusing more on producing useful new products than pursuing the highest profits. *Fortune* magazine named him one of the "10 greatest CEOs of all time" [Collins 2003]:

> The Merck & Co. boss didn't worry about Wall Street—and grew profits 50-fold.
>
> Late one afternoon in 1978, Dr. William Campbell did what all great researchers do: He wondered at the data. While testing a new compound to battle parasites in animals, he was struck with the idea that it might be effective against another parasite—one that causes blindness and itching in humans so horrific that some victims have committed suicide. Campbell might have simply scribbled a note in the files and gone to lunch. After all, the potential "customers"—tribal people in remote tropical locations—would have no money to buy it. Undaunted, Campbell penned a memo to his employer, Merck & Co., urging pursuit of the idea. Today 30 million people a year receive Mectizan, the drug inspired by his observation, largely free of charge.
>
> The most exceptional part of the story is that it wasn't an exception. "Medicine is for people, not for the profits," George Merck II declared on the cover of Time in August 1952—a rule his company observed in dispensing streptomycin to Japanese children following World War II. Yet fuzzy-headed moralistic fervor wasn't George Merck. Austere and patrician, he simply believed that the purpose of a corporation is to do something useful, and to do it very well. "And if we have remembered that, the profits have never failed to appear," he explained. "The better we remembered, the larger they have been." It's the mirror image of CEOs whose unhealthy fixations with Wall Street have served neither people nor profits: Merck served shareholders so well precisely because he served others first.

(Army) Air Force General Donald Putt (1905–1988), shown in Fig. 11.69, was a very strong advocate for developing revolutionary technologies after World War II. He played an especially important role in helping the United States acquire a large number of creators and creations from the German-speaking world and employ them for U.S. military applications. For example, Wolfgang Samuel, a retired Air Force colonel and military historian, summarized the contributions of Donald Putt [Samuel 2004, pp. 7–8]:

> Putt determined to go after the intellectual capital of the former Third Reich, the scientists who had designed the jet and rocket planes and other advanced weapons never brought to bear against the Allies simply because the Nazis ran out of time. More than any of his peers, Putt clearly grasped the importance of the German scientist to the technological future of the United States and wanted as many of them as possible, and as soon as possible, brought to Wright Field, the research, development, and test center for the Army Air Forces. There, he thought, the scientists should resume work, making up the technological deficit America had allowed itself to accumulate in the prewar years. [...H]e persisted relentlessly, and in time his efforts were crowned with success.

George W. Merck
Donald Putt
Simon Ramo
Hyman Rickover

Figure 11.69: More examples of U.S. scientific “enlightened despots”: George W. Merck ran the U.S. company Merck 1925–1957. Air Force General Donald Putt recruited German and Austrian scientists at the end of World War II and funded their work in the United States after the war. Simon Ramo directed innovative corporate research for military applications at GE, Hughes Aircraft, and TRW from the 1940s to the 1970s. Navy Admiral Hyman Rickover shepherded the development of fission power for submarines and ships from 1945 onward.

Simon Ramo (1913–2016), shown in Fig. 11.69, ran a very innovative electronics program at General Electric (1936–1946), then created and ran the highly innovative research program at Hughes Aircraft (1946–1953), and then co-founded and managed research at TRW (Thompson Ramo Wooldridge, 1953–1978) [Dyer 1998; Ramo 1980a, 1980b, 1983, 1988, 2005]. Along the way, Ramo reported directly to U.S. presidents and led development of the first U.S. electron microscopes, long-range air defense systems, intercontinental ballistic missiles, interplanetary space probes, and other technologies. The *New York Times* obituary summarized Ramo's accomplishments [NYT 2016-06-30 p. A25]:

> Dr. Ramo, who advised a string of presidents, legislators and cabinet officials on science and technology, was a pioneering force in the aerospace and electronics industries throughout the postwar period.

Navy Admiral Hyman Rickover (1900–1986), shown in Fig. 11.69, shepherded the development of fission power for submarines and ships from 1945 onward [Allen and Polmar 2007; Kruse 2015; Oliver 2014; Rockwell 1995]. *Time* magazine featured Rickover on the cover of its 11 January 1954 issue and described his personality:

> Sharp-tongued Hyman Rickover spurred his men to exhaustion, ripped through red tape, drove contractors into rages. He went on making enemies, but by the end of the war he had won the rank of captain. He had also won a reputation as a man *who gets things done.*

Kevin Kruse described Rickover's methods [Kruse 2015]:

> Rickover was careful to assemble a staff that could build the Navy he envisioned, even though that staff did not always fit the Navy mold. He was the first Navy admiral to bring women on to a submarine (in the 1950s) not because he was a Civil Rights leader but because, as Oliver writes in the book, "we needed brains to make the submarine force successful ... and women possessed half of the available resource."
>
> Rickover went so far as to invent his own selection process, one that bucked Naval practice and policy but was more suited to his needs. Children of the influential were not selected as a matter of course, nor were people with political connections. The Bureau of Personnel did not control the process and the admiral interviewed every new recruit.
>
> Once selected, Rickover allowed his sailors the leeway to try new things and the power to change established practice if a new process was better. He encouraged his staff to do what worked, regardless of preconceived ideas.
>
> Rickover was, himself, an odd choice to change the Navy. He never saw combat, and did not wear the standard uniform at all if he could help it. He was small of stature, a Jewish refugee from Poland and, for all his work altering perceptions, was not the consummate politician top military leaders often are.
>
> He was also the longest-serving naval officer in U.S. history, with 63 years active duty. Which, by itself, says a lot.

Even shortly before the end of his life, Rickover was still creating new programs to nurture young scientists and engineers. In 1983–1984, he helped establish the Center for Excellence in Education and the Research Science Institute, which host 80 high school students at MIT for research mentoring each summer, invite middle- and high-school teachers to participate in research laboratories, and offer other programs to promote scientific innovation [https://www.cee.org/about-us/history/history].

Air Force General Bernard Schriever (1910–2005), shown in Fig. 11.70, was a protégé of General Henry Arnold. Following the path originally laid out by Arnold, Schriever was a strong champion for the development of missiles, rockets, and spacecraft in the U.S. Air Force from his initial appointment to that area in 1954 until his retirement in 1966 [Stephen Johnson 2002; Jacob Neufeld 2004; Sheehan 2009].

Air Force historian Jacob Neufeld gave an excellent overview of Schriever's career and impact [Jacob Neufeld 2004]:

> After the war, Schriever's leadership and accomplishments attracted the attention of senior officers, notably "Hap" Arnold, now the Commanding General of the Army Air Forces. Recognizing his protégé's rare combination of engineering training and operational experience, Arnold assigned Schriever the delicate job of maintaining the close ties forged during the war between the Air Force and nation's leading scientists. Working with the world famous Dr. Theodore von Kármán, chairman of the Scientific Advisory Board (SAB), and with RAND Corporation staffers, Schriever focused on long-range scientific planning. He helped to refine a methodology that matched long-range military requirements with ongoing research and development. Plans were drawn for all major elements of air power—strategic and tactical warfare, air defense, intelligence, and reconnaissance; RAND, the SAB, and university researchers performed the systems analysis studies. As a result, the Air Force did not have to wait for technological change to mature, but could lead and direct it. Put another way, Schriever's staff combined operational requirements with technologies, strategies, and objectives to establish objectives for future systems. "Technology push" thus prevailed over "requirements pull." [...]
>
> In its February 1954 report, the Teapot committee recommended that the Air Force initiate a crash program to produce an ICBM. In May, the Air Force made the Atlas ICBM its top priority and Gardner selected Brigadier General Schriever to head the program.
>
> Activated on 1 July 1954, in Inglewood, a suburb of Los Angeles, Schriever's Western Development Division (WDD), was housed in a former parochial school. It began with twelve officers and three enlisted men, and eventually grew to some 1,500 personnel. Schriever had to create an organization to manage extremely varied and novel science and technology, build facilities for testing and production, integrate the missile systems, fit together the nuclear weapons they would carry, and provide the launching sites, equipment, and ground support necessary to bring the missiles to operational status. Moreover, he had to accomplish all of this within six years and before the Soviets could themselves build, deploy, and target their missiles against the United States! It was a deadly serious, real-life contest of "beat the clock." [...]

Even as he was preoccupied with acquiring ICBMs and IRBMs, Schriever foresaw the potential of outer space systems and the need to extend the Air Force's interests into the "high frontier." While many of his achievements in the space field remain classified, we can acknowledge his pivotal role in developing the requirements for intelligence and reconnaissance satellites and manned space flight. Schriever's enthusiasm for space exploration tapped his fortitude in sometimes standing up alone to his superiors. Indeed, although some people tried to muzzle him, Schriever never shrank back from what he believed in. [...]

Promoted to four-star rank and head of AFSC General Schriever conceived and effected the consolidation of Air Force technical and logistical efforts into a single organization. More significantly, he transformed the concept of materiel development and acquisition from a functional to a systems approach—the focal point for virtually all-new weapons.

Schriever's role in this transformation was pivotal with respect to his insistence on technologically superior performance standards, adherence to pre-established production schedules, and reliance on cost-control measures. While AFSC commander, he fostered research and oversaw the acquisition of systems that provided strategic deterrence; early detection, warning, and air defense; advanced aircraft and spacecraft designs; command, control, and communication systems; and aerospace medicine. By 1963, AFSC organization employed some 27,000 military and 37,000 civilians, operated an annual budget of over $7 billion (about 40 percent of the USAF's total), and managed eighty major weapons systems. General Schriever defined and institutionalized the acquisition process by demonstrating the interrelationship between technology, strategy, organization, and politics. [...]

In 1963, in response to Air Force Secretary Eugene Zuckert's request for a futuristic study, Schriever launched Project Forecast—one of the most comprehensive long-range assessments ever undertaken of the nation's position in military science and technology. Participants included 40 government agencies, 26 colleges and universities, 70 corporations and 10 non-profit organizations. Published in 1964, this landmark report concluded that rather than leveling off, technology was only beginning its exponential growth. Project Forecast identified several promising areas of exploration that would lead to quantum improvements in air and space weapons: notably in the fields of advanced composite materials, computers, flight design, and propulsion.

For twenty years, from the end of World War II until his retirement in 1966, General Schriever was at the locus of events as the Air Force developed its organization and processes for complex technology. [...] In the Development Planning Office, he helped establish systems analysis as the procedure to set requirements for new technologies.

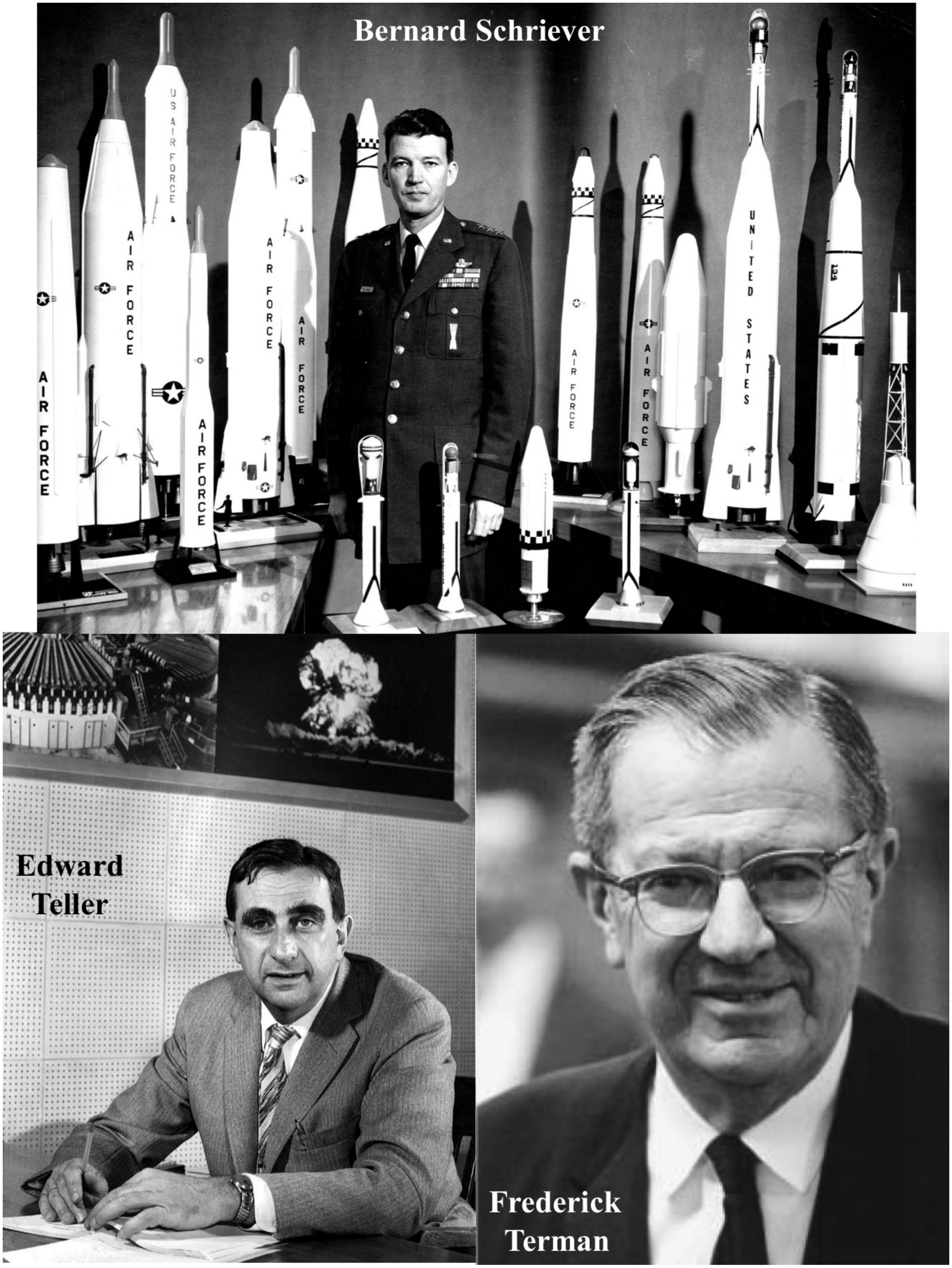

Bernard Schriever
US AIR FORCE
AIR FORCE
UNITED STATES
Edward Teller
Frederick Terman

Figure 11.70: More examples of U.S. scientific “enlightened despots”: Air Force General Bernard Schriever championed the development of missiles, rockets, and spacecraft 1954–1966. Edward Teller was the scientific head of the U.S. program to develop the hydrogen bomb, and founded and directed the Lawrence Livermore National Laboratory 1958–1975. Frederick Terman was instrumental in establishing Silicon Valley in California 1946–1965.

Edward Teller (1908–2003), shown in Fig. 11.70, one of the German-speaking creators who emigrated to the United States during the Third Reich, was the scientific head of the U.S. program to develop the hydrogen bomb, and founded and helped to direct the Lawrence Livermore National Laboratory 1952–1975 [Blumberg and Panos 1990; Broad 1985, 1992; Teller 1979, 1987, 2001]. While Teller's scientific contributions to the wartime Manhattan Project and postwar H-bomb program are described in Section 8.7, what is especially significant for this section is Teller's political position as an enlightened despot directing major parts of the U.S. research system.

Historian of science István Hargittai summed up Teller's personality [István Hargittai 2010, p. 456]:

> Edward Teller, who survived three exiles, contributed to the way the twentieth century played out on a worldwide stage, even if the extent of his influence is debatable. He had extraordinary willpower and triumphed over many obstacles, including his physical handicap. He waged struggles that many of his peers would have refrained from. He thrust himself into battles that often engulfed him as they would have engulfed anybody. He seemed at times invincible, and he was a dedicated fighter for the containment of communism to an extent few others were. His dedication often appeared as obsession and his schemes as irrational. While he was attempting to save the Free World, he was also trying to impose his will upon it. John A. Wheeler, who was friendly with him throughout his life, noted of him that "he fought obstinately for what he believed in. I may have disagreed with his tactics but never with his goals."

For over half a century and with enormous energy and success, Teller lobbied the government for political and financial support for revolutionary scientific research, while at the same time continually recruiting and mentoring countless young scientists to work on a variety of highly innovative projects. The Lawrence Livermore National Laboratory is the most visible result of those efforts, as described by biographers Stanley Blumberg and Louis Panos [Blumberg and Panos 1990, pp. 211–213]:

> The Lawrence Livermore National Laboratory sits in a valley an hour's drive east of San Francisco. [...]
>
> In 1952, Teller sold Washington on the need for a new weapons lab, and Ernest O. Lawrence sold Teller on Livermore as the place for it. [...]
>
> In time, the laboratory took on distinct signs of Teller's influence. He continued to champion its original purpose as a source of new weapons design and was instrumental in attracting talented young physicists to Livermore. [...]
>
> By 1988 the laboratory employed about 8,000 scientists and other employees on projects costing more than $1 billion a year. Official secrecy shrouds much of their work, inevitably arousing public curiosity concerning the tidbits occasionally dropped about such exotic projects as the X-ray laser, particle beams, kinetic energy, and the like. Lost in the fanfare over these is other, more fundamental work, such as environmental and biomedical research projects seeking answers to vital questions: How do plants respond to chronic low levels of pollutants in the atmosphere? How will chemicals discharged into oceans and streams affect fisheries? How do energy by-products and discharges work their way through the environment and the food chain to affect humans? In looking for the answers, scientists analyze damage to reproductive cells, develop bioassays to detect genetic injury, and do molecular studies on damage and repair of human genes.

Frederick Terman (1900–1982), shown in Fig. 11.70, received his Ph.D. under Vannevar Bush in 1924 and became an electrical engineering professor at Stanford. During World War II he led the Radio Research Laboratory at Harvard University in developing important radar techniques such as radar jammers and chaff countermeasures. After the war, he returned to Stanford as Dean of Engineering and then Provost. During that period (1946–1965), he focused on attracting and supporting talented individuals and new companies to that region, establishing Silicon Valley [Gillmor 2004; Lécuyer 2007; Lowen 1997; Villard 1998].

One of Terman's former students, Stanford electrical engineering professor O. G. Villard, Jr. described Terman's impact [Villard 1998]:

> Frederick Emmons Terman—author, teacher, mentor, university administrator and maker of policy par excellence—was beyond any reasonable doubt responsible for the concentration of economic accomplishment in what has come to be known as California's Silicon Valley, as well as for important innovations in engineering. [...]
>
> [Terman's father] was inventor and co-developer of the Stanford Binet intelligence (or IQ) test[...] This circumstance may well have had an influence in forming Fred Terman's personal philosophy concerning the importance to any organization of truly gifted individuals, who with their followers could be said to form "steeples of excellence."

Richard Atkinson, who taught at Stanford under Terman's leadership for nearly 25 years and ultimately became the president of the University of California, described Terman [Gillmor 2004, p. vii]:

> "Father of Silicon Valley": these words seem to leap from the page. Invariably this is the only description now applied to Fred Terman in newspaper and magazine articles. It is not an inaccurate title, but it hardly begins to do justice to the genius that was Frederick Emmons Terman. It is difficult to know where to begin when describing him. He was without doubt a brilliant electrical engineer, a learned scholar who authored groundbreaking textbooks on radio engineering and electronics, an inspiring teacher who kindled the spirit of discovery in his students, and an academic administrator whose devotion to excellence and visionary leadership firmly set a university on the path toward greatness. It was the latter, coupled with the extraordinary depth of his vision that I find the most compelling and enduring of Fred's many accomplishments.

Thomas J. Watson, Jr. (1914–1993), shown in Fig. 11.71, built the innovative research programs at IBM (International Business Machines) during the period 1946–1971, first as vice president and then as president of the company [Thomas Watson 1963, 2000]. The research programs he established greatly advanced computer technologies, microelectronics, and solid state physics applications.

Investors Business Daily wrote [Scott Smith 2016]:

> Watson is credited with moving IBM into the age of electronics at this time, taking it from a manufacturer of adding machines and typewriters to the forefront of the computer industry. In the 1950s, IBM not only invented the first electronic computer and the magnetic hard drive, but designed intercontinental missiles and developed the first artificial intelligence – a machine that could learn from its own experience.
>
> In 1957, IBM revolutionized programming with the FORTRAN language, and the next year it built the SAGE computer to run North American Air Defense. Watson also raised the company's investment in research and development from 3% of annual sales to 6%–9%.
>
> "He invested a lot of money on research and development," said Goldsby, "and it usually paid off."
>
> IBM continued to soar under Watson's leadership in the 1960s, creating the SABRE system for airline reservations, working with NASA on the lunar landing and launching the revolutionary System/360. This offered a range of commercial and scientific uses with the ability to upgrade without having to rewrite applications. Fortune magazine called it "IBM's $5 billion gamble," and it was massively profitable, the major contributor to the 500% increase in company revenue and earnings through the decade.
>
> In this era, IBM also changed its marketing approach from one that only sold hardware, services and software together as one package to one that offered them "unbundled" – a model for later tech companies.
>
> IBM was now the largest computer maker in the world, with 270,000 employees by 1970 and a corporate headquarters in Armonk, N.Y. But the next year, Watson had to step down because of a heart condition. [...]
>
> As the 1990s ended, *Time* magazine named Watson to its list of the "100 most influential people of the 20th century."

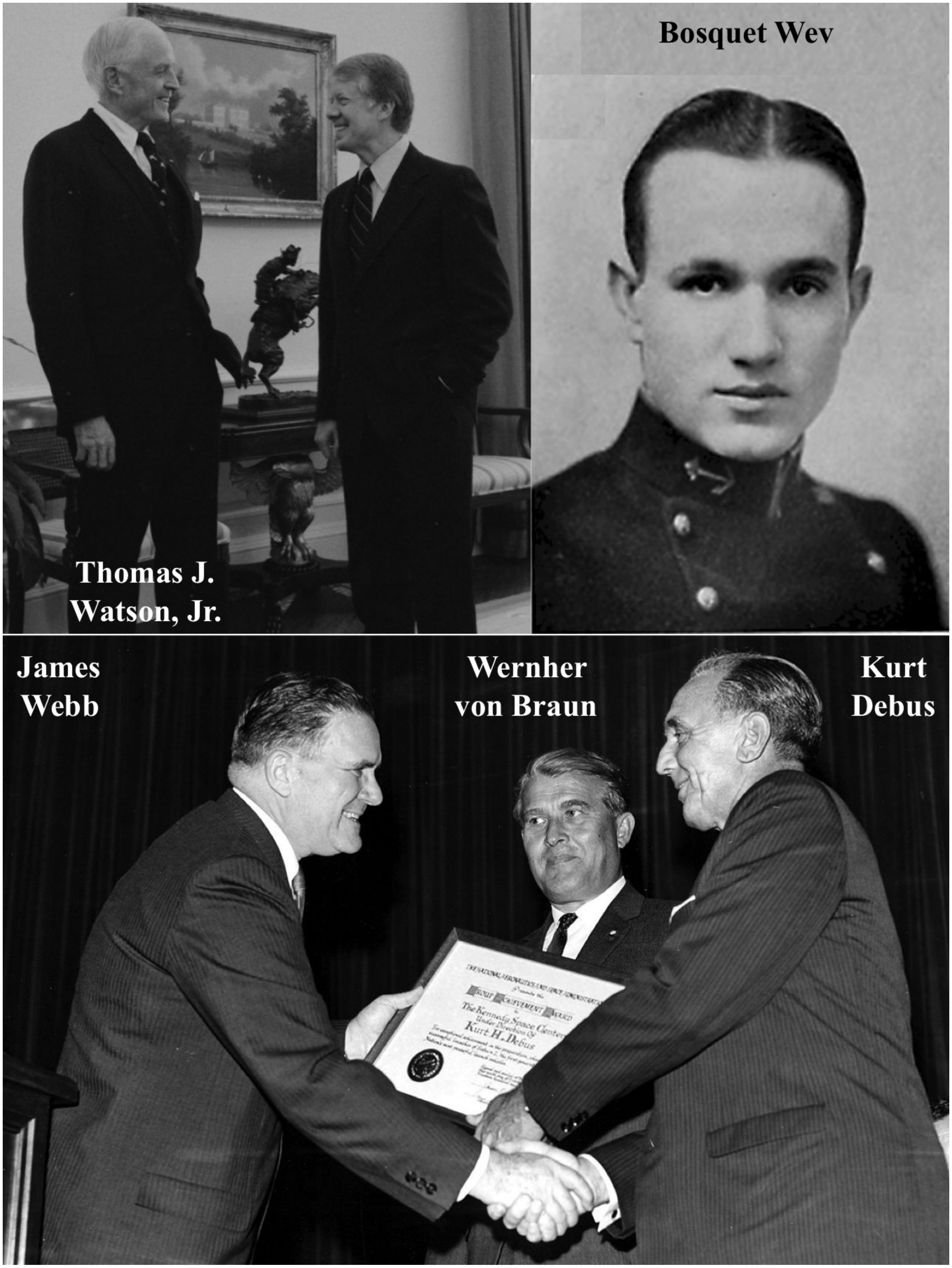

Thomas J.
Watson, Jr.
Bosquet Wev
James
Webb
Wernher
von Braun
Kurt
Debus

Figure 11.71: More examples of U.S. scientific "enlightened despots": Thomas J. Watson, Jr. (shown with President Jimmy Carter) built the innovative research programs at IBM during the period 1946–1971. Navy Captain Bosquet Wev (for whom only a very early photo is available) of the Joint Intelligence Objectives Agency strongly advocated for the acquisition of German and Austrian scientists and technologies after World War II. James Webb (lower left, shown with Wernher von Braun and Kurt Debus) ran NASA during its most productive period, 1961–1968.

James Webb (1906–1992), shown with Wernher von Braun and Kurt Debus in Fig. 11.71, ran NASA during its heyday of 1961–1968 [Bizony 2006; Lambright 1995]. He was responsible for all manned and unmanned missions during that time, as well as the Apollo-Saturn technology that had been perfected by the end of his tenure. Webb answered directly to the President, worked with von Braun, Debus, and other German-speaking rocket engineers, and coordinated the vast amount of U.S. industry required to produce all of the necessary hardware. W. Henry Lambright, a professor of political science and public administration at Syracuse University, described Webb's skills [Lambright 1995, pp. 216–217]:

> Management innovation was both a reality and public relations strategy for Webb. Above all, he understood the importance of power: its nurture, use, and loss. With this understanding he showed what a public executive with the right mix of energy, conviction, skill, wide-ranging contacts, and experience can do when conditions are ripe. He was cunning, guileful, manipulative, and hyperbolic—a lot like Lyndon Johnson. If he did not cross the line of administrative accountability, he surely edged up against it. But unlike Johnson, whose orientation was to legislation, Webb cared deeply about the effective administration of public affairs and was able to inspire those under him to new heights. He pushed a vast army of specialists in a common direction, at breakneck speed. A bold risk taker, he confronted pressures from astronauts, the president's science adviser, the air force, the defense secretary, other NASA executives, Congress, media, industry, universities, and many others, and did not flinch. Rather than break under political pressure, he used rhetorical and coalition-building techniques to impose pressures and coopt others. Organizing and reorganizing NASA as circumstances changed, using the resources at his disposal to reward and punish, he kept reign on his internal forces while orchestrating external support. Throughout, he focused on Apollo's goal and what it took to get there.

Space historian Piers Bizony [Bizony 2006, pp. ix–x] added:

> It was a smart operator from North Carolina, James E. Webb, who steered the expansion of NASA from a minor collection of research labs into one of the grandest enterprises the world has ever seen. Aided by a cadre of Southern-born businessmen and politicians, Webb established a colossal network of influence in the service of space. For all its recent setbacks, NASA still commands influence today because of the legacy he created. He knew how to persuade not one, but two presidents in succession to give him what he wanted. [...]
>
> We think of space administrators as dull, colourless bureaucrats. Webb was nothing of the kind. He was a powerful personality, combative, manipulative and driven. You underestimated him at your peril. He was a big, stocky bruiser of a man. When he walked into a room, people knew about it. His broad North Carolina accent and verbose way of speaking sometimes made him come across like a good ol' boy, a 'blabbermouth', as Bobby Kennedy once described him. Yet under all the down-home bluster, one of the sharpest and shrewdest political minds in American history was at work. He took hold of the space age and ran it just the way he wanted.
>
> Webb knew everyone in Washington, and pretty much everyone in the business world. He understood what they wanted, and where his interests and theirs might converge.

> During his leadership of the space efforts in the Kennedy and Lyndon Johnson years, he dispensed largesse, called in favours and occasionally strong-armed people who were foolish enough to oppose him. He was not a man to take 'no' for an answer. His enemies believed he was on a personal crusade to gain power and influence through his running of the space agency. And indeed he was. He was a visionary 'technocrat' whose ambitions stretched far beyond merely landing a man on the moon. By 1964 he held sway over 5 per cent of the entire US federal budget. The potential of that great wealth on the ground was just as important to him as the missions it could pay for in space. Here was a dyed-in-the-wool Democrat idealist who believed in personal honour, moral duty and national responsibility. He had come of age in the Depression years, and worked with Roosevelt during the New Deal era of national reconstruction. He believed passionately in the benefits of good government.

Navy Captain Bosquet Wev (1903–1979) of the Joint Intelligence Objectives Agency (JIOA) was a very strong supporter of developing revolutionary technologies after World War II. He played an especially important role in aiding the United States to acquire a large number of creators and creations from the German-speaking world and to support the employment of those innovators and technologies for U.S. military applications [Bower 1987; Crim 2018; Linda Hunt 1991]. Because Wev and his work were so secretive, the only available photo of him was taken very early in his Navy career and is shown in Fig. 11.71.

In his early book on the Paperclip program, Tom Bower gave a brief description of Wev [Bower 1987, p. 169]:

> Appropriately, with the new era the operation was given a new name: Overcast was replaced by Paperclip. [...]
>
> Equally appropriately, the new era began with the arrival of a new deputy director of JIOA. Captain Bosquet Wev, a conspiciously zealous naval officer, treated his responsibilities at the newly reconstituted JIOA with chauvinistic passion, unwavering obedience, and obsessive secrecy.

Historian Brian Crim described Wev's aims and methods in a much more recent book on Paperclip [Crim 2018, pp. 101–102]:

> Wev regarded the JIOA as a clearing house for intelligence, targeting, and document collection. Paperclip was vital to America's evolving national security concerns, and the more scientists the JIOA could identify, secure, and exfiltrate from Europe before the Soviet Union did the same, the better. Wev's intransigence and dismissive attitude toward rules and regulations reflected the War Department's privileged position, a point he reiterated frequently in meetings.

As shown in Section 10.2.6 and in this section, tremendous numbers of the revolutionary innovations both in the German-speaking research world and in the early decades ($\sim$1940s–1960s) of the U.S. research system can be linked to the enlightened despot scientific management style that was common in those places and times. It is difficult to imagine that all of those revolutionary innovations would have occurred in the modern research system, in which consensus-based bureaucratic competition for limited funding favors very short-term, very low-risk work and eschews new innovations and new innovators.

Indeed, most of the enlightened despots listed in this section retired in the late 1960s or early 1970s, right around the time that the U.S. research system appeared to shift from long-term work on revolutionary innovations to short-term work on incremental progress:

- William Allen retired from Boeing in 1972.
- Vannevar Bush was active on scientific advisory boards until the 1960s.
- James Conant was active on various fronts until the 1960s.
- Lee DuBridge stepped down from Caltech in 1969.
- Crawford Greenewalt left Du Pont in 1967.
- Leslie Groves and Robert Oppenheimer were both active in different ways into the 1960s.
- Kelly Johnson retired from the Lockheed Skunk Works in 1975.
- Mervin Kelly was active until he died in 1971.
- Donald Putt retired from the Air Force in 1957 and from United Technology Center in 1962.
- Simon Ramo stepped down from TRW in 1978.
- Hyman Rickover remained a formidable force through the 1970s.
- Bernard Schriever left the Air Force in 1966.
- Edward Teller retired from managing Lawrence Livermore National Laboratory in 1975.
- Frederick Terman retired from Stanford in 1965.
- Thomas Watson Jr. retired from IBM in 1971.
- James Webb and Wernher von Braun left NASA in 1968 and 1972, respectively.

It is difficult to find examples of enlightened scientific despots who were so numerous or so successful in the United States after that period of time.

This finding suggests that one way to increase the amount of revolutionary innovation in the modern research system would be to find enlightened despots with good judgment, strongly support them from a very high level, and allow them to allocate at least some fraction of the research budget over a sustained period of time to those they consider the most promising innovators and innovations. This approach has been advocated by people such as Pierre Azoulay [Azoulay et al. 2019], Sydney Brenner (p. 2248), and Donald Braben [Braben 2004, 2008, 2014], and is discussed in Chapter 12 .

It is also interesting to note that many enlightened despots who were not strong scientists themselves chose to lead jointly with a very talented scientist. These duos could operate very effectively for years, typically with the less scientific partner carrying most of the burden of advocating for the program “upward” with government officials who were above that program, and the more scientific partner primarily directing “downward” the research of scientists under that program. Examples of these upward/downward management duos included:

- General Henry Arnold and Theodore von Kármán in the U.S. Air Force.
- General Walter Dornberger and Wernher von Braun in Germany.
- James Webb and Wernher von Braun at NASA.
- General Leslie Groves and Robert Oppenheimer in the Manhattan Project.
- Dean Wooldridge and Simon Ramo at Hughes Aircraft and TRW.
- Various pairings of Edward Teller (in either role) over a forty-year period with others such as Ernest Lawrence, Herbert York, and Lowell Wood.

11.2.7 Systems Analysis

Just as systems analysis methods enabled scientists and sponsors in the earlier German-speaking world to explore all possible creations in a given area and identify the best ones, those same methods also guided research and development in the United States, especially during the 1940s–1960s. In fact, the United States directly appropriated the systems analysis methods from the German-speaking world via two routes:

- Importing a wide range of German creations (such as prototype missiles covering all possible categories, or jet engines covering all possible types), which had already been conceived, developed, and categorized by the systems analysis approach.
- Importing German-speaking creators who championed systems analysis methods and employed them in the service of the U.S. government, especially creators such as Theodore von Kármán, Fritz Zwicky, John von Neumann, and Leo Szilard.

A good example of the influence of systems analysis on early U.S. research and development is General Henry Arnold's 12 November 1945 *Third Report of the Commanding General of the Army Air Forces to the Secretary of War* (see p. 5456):

> [...] We must look at the future of aerial warfare in the light of the following considerations:
>
> 1. Aircraft, piloted or pilotless, will move at speeds far beyond the velocity of sound, well over 700 miles per hour.
>
> 2. Improvements in aerodynamics, propulsion, and electronic control will enable unmanned devices to transport means of destruction to targets at distances up to many thousands of miles. However, until such time as guided missiles are so developed that there is no further need for manned aircraft, research in the field of "conventional" aircraft of improved design must be vigorously pursued.
>
> 3. Small amounts of explosive materials, as in atomic bombs, will cause destruction of many square miles.
>
> 4. Defense against present day aircraft may be perfected by target-seeking missiles.
>
> 5. Only aircraft or missiles moving at extreme speeds will be able to penetrate enemy territory protected by such defenses.
>
> 6. A communications system between control center and each individual aircraft will be established.
>
> 7. Location and observation of targets, take-off, navigation and landing of aircraft, and communications will be independent of visibility or weather.
>
> 8. Fully equipped airborne task forces will be able to strike at far distant points and will be totally supplied by air.

> [...] Further, the great unit cost of the atomic bomb means that as nearly as possible every one must be delivered to its intended target. This can be done in one of several ways, all of which involve air power. For example, the following evolution may be suggested:
>
> a. Today, our Army Air Forces are the recognized masters of strategic bombing. Until others can match the present efficiency of our own antiaircraft defenses, we can run a large air operation for the sole purpose of delivering one or two atomic bombs. Our experience in the war suggests that the percentage of failures in an operation of this kind would be low.
>
> b. When improved antiaircraft defenses make this impracticable, we should be ready with a weapon of the general type of the German V-2 rocket, having greatly improved range and precision, and launched from great distances. V-2 is ideally suited to deliver atomic explosives, because effective defense against it would prove extremely difficult.
>
> c. If defenses which can cope even with such a 3,000-mile-per-hour projectile are developed, we must be ready to launch such projectiles nearer the target, to give them a shorter time of flight and make them harder to detect and destroy. We must be ready to launch them from unexpected directions. This can be done from true space ships, capable of operating outside the earth's atmosphere. The design of such a ship is all but practicable today; research will unquestionably bring it into being within the foreseeable future.
>
> [...] Complete dispersal of our cities and moving vital industries underground on a sufficiently large scale would be overwhelmingly expensive. [...]
>
> Although there now appear to be insurmountable difficulties in an active defense against future atomic projectiles similar to the German V-2 but armed with atomic explosives, this condition should only intensify our efforts to discover an effective means of defense. [...]
>
> Jet propulsion is in its infancy despite the fact that this war has evolved six distinct methods of utilizing atmospheric oxygen for propulsion, such as (1) *motorjet*—or reciprocating engine plus ducted fan, (2) *turboprop*—a gas turbine plus propeller, (3) *turbofan*—a gas turbine plus ducted fan, (4) *turbojet*—a gas turbine plus jet, (5) *ramjet*—a continuous jet with compression by aerodynamic ram, and (6) *pulsojet*—or intermittent jet. These new and strange sounding words will be familiar ones in our speech in the near future, and right now they carry more meaning for Americans than any other six words I know.

The above quote, which was clearly heavily influenced by Arnold's chief scientific advisor, Theodore von Kármán (see p. 5438), applied systems analysis first to aerial warfare, then to atomic bomb delivery methods, and finally to aircraft propulsion.

Under the guidance of Theodore von Kármán [Gorn 1992], John von Neumann [Macrae 1992], and others, the entire 1940s–1960s U.S. national defense system was based on systems analysis. All three parts of the nuclear triad (intercontinental jet bombers, land-based intercontinental ballistic missiles, and submarine-launched missiles) were borrowed directly from wartime German programs; see Appendix E for more information. Government-funded think tanks sprang up to apply systems analysis to the remaining details of the defense system; some prominent examples included:

- RAND Corporation (initiated in 1945, finalized in 1948) [Jardini 2013; Kaplan 1991].
- MIT Lincoln Laboratory (founded in 1951) [Grometstein 2011].
- Institute for Defense Analyses (IDA, founded in 1956) [Finkbeiner 2006].
- MITRE Corporation (founded in 1958) [Shearman 2008].
- JASON advisory group (founded in 1959) [Finkbeiner 2006].
- The Analytic Sciences Corporation (TASC, founded in 1966) [http://www.fundinguniverse.com/company-histories/analytic-sciences-corporation-history/].

However, that systems analysis methodology was primarily applied to the U.S. national defense system, not other areas of research and development. By around 1970, the Cold War had relaxed, the national defense system had assumed essentially the form that it still has, and there was little motivation to apply systems analysis to new problems. Moreover, the imported German creations that were steeped in systems analysis (missiles of all possible types, jets of all possible types, etc.) had been developed to a very mature state, and the imported German-speaking masters of systems analysis had mostly retired or died. Thus much of the research performed in the decades since around 1970 has been conducted without the insights that systems analysis could offer both to individual scientists and also to the sponsors of scientific research programs.

11.2.8 Limited Natural Resources

Whereas the earlier German-speaking world was very limited in the natural resources that it possessed on its own lands or that it could import, the United States had a wealth of natural resources on its own territory, and even more that it could import from willing suppliers around the world. As a result, the German-speaking world had a strong incentive to invent revolutionary new synthetic materials and processes, but the United States did not. With the assistance of the U.S. government, American companies commercialized synthetic innovations that had been developed in the German world, ranging from new plastics to food substitutes [Gimbel 1990a]. Unfortunately they do not appear to have made the same proportionally large investments that the German-speaking world had made in creating new generations of revolutionary synthetic products and processes.

Now that the United States and the rest of the world are more concerned about dwindling natural resources and accumulating amounts of greenhouse gases, pollution, and waste, these newfound concerns could potentially be used as strong forces to drive a large amount of fresh innovation for synthetic and/or recycled materials.

11.2.9 International Rivalry

Just as military and industrial competition with other countries was a strong driver of innovation in the German-speaking world throughout the entire period 1800–1945 (Fig. 10.15), international competition also strongly motivated innovation in the United States during the 1940s, 1950s, and 1960s (Fig. 11.72).

During World War II, political and military leaders in the United States were deeply concerned about German domination in Europe and German development of revolutionary new technologies such as nuclear weapons, long-range rockets, and jets that could entrench or further spread that domination. As a result, they strongly supported Vannevar Bush's new innovation system, as discussed in Section 11.2.6. Large numbers of immigrant German-speaking scientists and American scientists were rapidly mobilized in the United States to develop nuclear weapons, perfect radar systems, mass-produce penicillin, and accomplish other feats.

Before World War II had even ended, the United States had started to turn its attention to the coming Cold War with the Soviet Union. In 1945, the United States scrambled to extract as many creators, creations, and resources as possible from the former German Reich before those could fall into Soviet hands, although a large fraction did nonetheless. From 1945 onward, the United States was in a race to adopt and perfect as many German-created military technologies as possible, or to develop new ones, before the Soviet Union could do the same. Among the revolutionary technologies that were fielded were improved nuclear weapons, jet fighters and bombers, ground-to-air and air-to-air missiles and smart bombs, advanced air defense networks, nuclear submarines and nuclear aircraft carriers, intermediate range and intercontinental ballistic missiles, nerve gases, and biological warfare agents. Those technologies were arrayed against their Soviet counterparts throughout the Cold War standoff, and some of them were tested on the battlefield in proxy wars between the two superpowers such as those in Korea and Vietnam. In addition to direct military competition, the United States and the Soviet Union also engaged in the space race as an alternative way to display their prowess with closely military-related technologies to each other and to the rest of the world. Buttressing all of those Cold War programs (and heavily subsidized by them) were rapid industrial developments in aerospace technologies, microelectronics, nuclear power, chemical engineering, biomedical research, and other areas.

The journalist David Beers, who grew up surrounded by his father's Cold-War research at Lockheed, described the enormous impact on research and development [Beers 1996, pp. 29–31]:

> It was the government mobilizing and funding technology with a zeal that would burn even hotter once LBJ and John F. Kennedy rode their *Sputnik* scare strategy to the White House in 1960.
>
> It was the state commanding, in a sense, that not only technology but *places* come into being.
>
> Blue sky metropolises, nurtured by federal dollars, would be commanded to rise out of orange groves and scrublands and prairies and deserts and other former boondocks to industrial America. The money would flow to the Northwest of Boeing, to the Texas of Bell Aviation and Mission Control, to the Rocky Mountains of the North American

> Air Defense Command, to the Florida of Martin-Marietta and Cape Canaveral, to the Alabama of Wernher von Braun's U.S. Army Redstone rocket works. [...]
>
> The money would go, as well, to certain centers of technological innovation, the realms, for example, of Boston's MIT and Pasadena's CalTech, universities that made a specialty of military contracts. A basic rule of thumb is that the money flowed to where life could be made affordably good for the blue sky professional and family. [...]
>
> The biggest of them all, of course, was and is Southern California, home to Aerojet and Convair and Ford Aerospace and Hughes and Litton and Lear Siegler and McDonnell-Douglas and Northrop and Rockwell and RAND and TRW and the United States Air Force Space Division and all the hundreds of subcontractors that serve them as well as many key military bases and universities. The San Fernando Valley of Southern California is home as well to Lockheed, and a time came in the late 1950s when Lockheed was commanded to build an answer to *Sputnik*.

However, the Cold War competition dramatically slowed around 1970. After beating the United States to launch the first satellite and the first person in Earth orbit, the Soviet Union lost the moon race when the United States landed the first people on the moon on 20 July 1969; the Soviet Union then cancelled its own manned lunar program and chose not to continue the space race toward even grander goals. With no further competition, the United States discontinued its advanced space program after only six manned lunar landings and billions of dollars spent to develop those technologies, and has only sent astronauts to low Earth orbit with much less capable rockets in the many decades since then.

At almost the same time, the Strategic Arms Limitation Talks (SALT) between the United States and the Soviet Union began in November 1969, effectively marking the end of the fierce competition to develop ever more powerful weapons and delivery systems for them. In general, Soviet Premier Leonid Brezhnev and his successors were significantly less militarily aggressive than Joseph Stalin and Nikita Khrushchev had been. With greatly decreased competition from the Soviet Union, and no other serious rivals in sight, beginning around 1970 the U.S. government started to lose interest in rapid and revolutionary innovation, and its research and development system and industries tended to follow suit.[13]

David Beers wrote about the dramatic shift that he observed in 1970 [Beers 1996, pp. 132–133]:

> "This," President Nixon declared of the lunar landing, "is the greatest week since the beginning of the world, the creation." My tribe, certainly, assumed Apollo's success would secure our dominance. Having been placed in charge of the future, we had delivered as promised a man on the moon on television. As scripted by our tribe's father, Wernher von Braun, the moon shot was to be but a way station on the path to Mars, a warm-up for the building and launching of a "flotilla" of manned spaceships to the red planet.

---

[13] The United States did feel some sense of economic and technological rivalry with Japan during the 1980s, but that was nowhere near as strong or as sustained as the military rivalry with the Soviet Union had been, and therefore was much less motivational for the U.S. innovation system [LaFeber 1997].

> Yet almost at the moment *Eagle* landed, blue sky icons seemed to lose their mojo powers. Environmentalists, utterly unmoved by the sleek loveliness of the SST [supersonic transport], painted it loud and rude, shot it down. The B-70 superbomber program had already crashed in Congress as the antiwar movement challenged the notion that the Pentagon, NASA, or any state authority should be the revered and unchallenged steward of a people's imagination about the future. Few (except for my tribe) took seriously Vice President Agnew's call for a Mars mission. [...]
>
> One year after the greatest week since the beginning of the world, a slowing in weapons spending, coinciding with a slump in commercial jet sales, caused mass aerospace layoffs across the country. [...]
>
> That was a time when some of my father's peers went from designing satellites to perfecting alloy backpack frames (surely Dad hadn't been a compatriot of Neil Armstrong's only to make camping gear!) I remember, while watching the Jetsons suburbanize the Milky Way on TV, reading newspaper stories about out-of-work Lockheed men killing themselves.
>
> That was a time when the tribe clung to hubris nevertheless. One year after the greatest week in the history of the world, members of the blue sky tribe convened the West Coast's First Aerospace Congress to take up the issue of where next to apply the methods used to conquer the moon. Let us now turn aerospace engineers loose, speakers urged, on the problems of pollution, crime, urban blight, racism, poverty. Let us fix society with systems engineering. It fell to Vernon L. Grose, vice president of Tustin Institute of Technology in Santa Barbara, to counsel some caution.

Any remaining Cold War motivation that could drive revolutionary scientific innovation was lost when the Soviet Union disintegrated in 1991. By the time military or economic threats from Islamic terrorism, China, and a resurgent Russia became apparent in the 2000s, the U.S. government was too distracted by bitter internal political battles, and the U.S. research and development system had become too dysfunctional and calcified in the intervening several decades, to seriously rise up to properly deal with any new international innovation challenges.

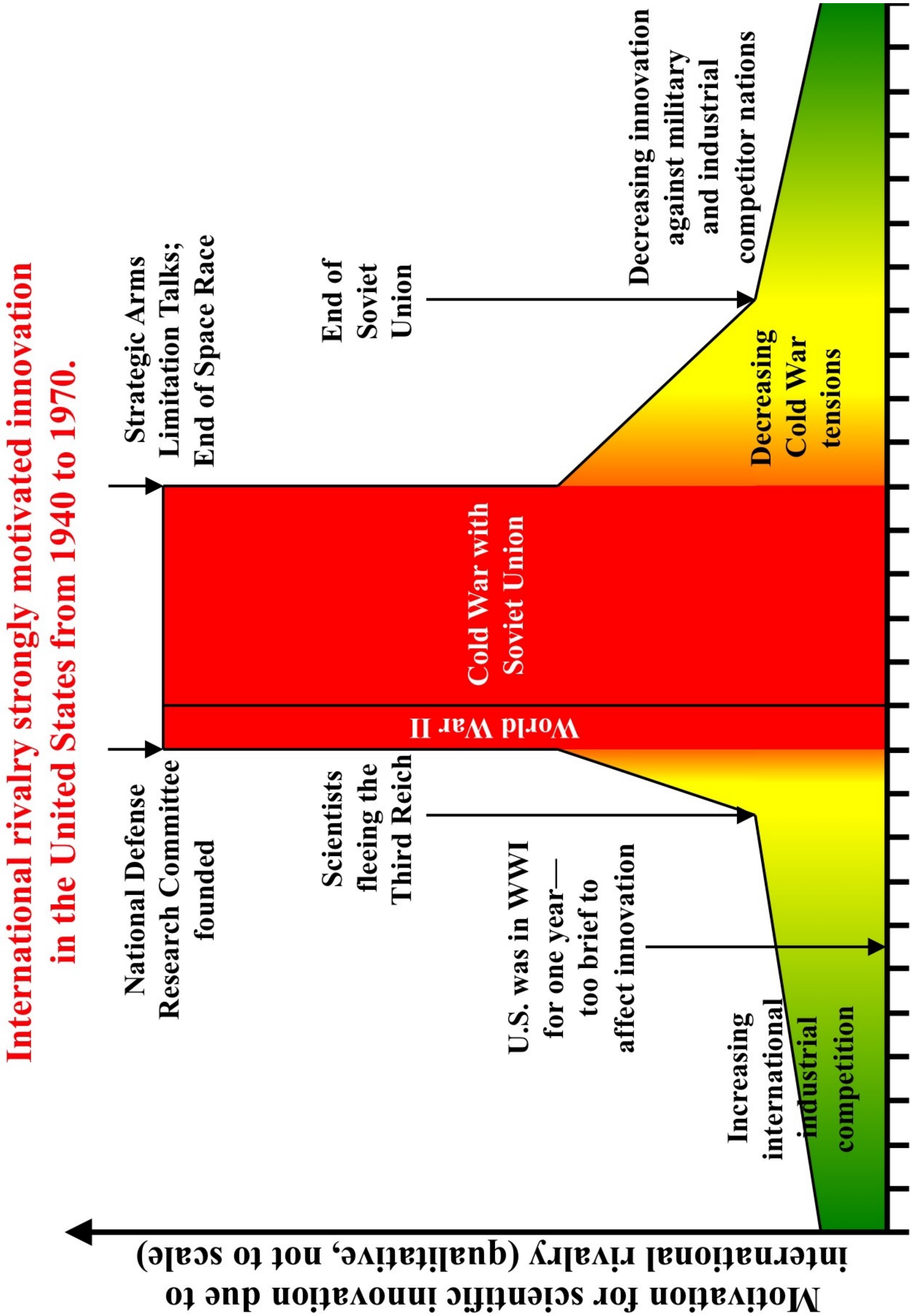


Figure 11.72: International rivalry strongly motivated innovation in the United States from 1940 to 1970.

11.2.10 Industrial Unity of Purpose

Paradoxically, competition between companies can decrease the incentive for innovation, rather than increase it, as shown in Fig. 11.73. Bell Laboratories developed transistors but other companies made fortunes based on that technology [Riordan and Hoddeson 1997]. Hughes Aircraft publicly announced the first laser yet it was other companies that profited by producing and selling lasers [Bromberg 1991]. IBM and Xerox PARC created versatile computers, but lost out when such computers were mass-produced by other companies like Apple and Dell [Isaacson 2014]. Apple developed the iPhone yet lost most of its market share to other companies that rapidly produced similar smart phones [Isaacson 2011]. Pharmaceutical companies have spent billions of dollars to develop new drugs, only to have their patents expire within just a few years after the lengthy drug development and approval process, allowing other companies to manufacture generic versions of those drugs [Alberts 2014; Begley 2009; Hsueh 2015; Mittra 2009; O'Neill 2012].

As a result of this historical pattern, modern companies have learned that it is much more lucrative not to innovate. It is much less profitable to invest a large amount of money in developing an innovative new product that is rapidly copied by competitors, and much more profitable not to invest in research and simply to copy innovations that are developed by someone else.

In the German-speaking world from around 1800 to 1945, these negative forces of competition among domestic companies were counteracted by the much greater sense of competition with foreign governments and industries (Section 10.2.10). The leaders of different German-speaking companies were united by a common sense of purpose, such as beating industrial competition from the United Kingdom or trying to win World Wars I and II. That industrial unity of purpose was cultivated and rewarded by the federal government.

Similarly, from the 1940s to the 1960s, U.S. companies received a much stronger positive incentive for innovation from foreign military competition, first with Germany and then with the Soviet Union, than any domestic negative incentive against innovation. As with the earlier German model, this industrial unity of purpose was nurtured and even dictated by the federal government. Throughout World War II, the Cold War, and the space race, the U.S. government invited bids from companies to develop revolutionary technologies, selectively funded those companies with the most attractive bids, and stipulated when and how companies would collaborate with each other when different parts of a system would be built by different companies (Fig. 11.74).

With the end of the space race and the easing of the Cold War around 1970, there was no longer strong incentive for this industrial unity of purpose, either from the U.S. government or from foreign competition. Companies were left to pursue their individual best economic interests using their own strategies. After a few very public examples (such as those cited above) that it was much more lucrative to take advantage of other companies' innovations than to invest in creating their own innovations, companies fell into a pattern that emphasized very short term, very low risk, very lucrative products. That pattern has continued to the present day.

**Without enough government protection,
companies that invested in developing innovative products
lost most of the market share to other companies
that simply copied those products.**

Transistors

Lasers

Pharmaceuticals

5 Ampoules 2 ml
Valium 10
ROCHE
10 mg
Valium – Trade Mark

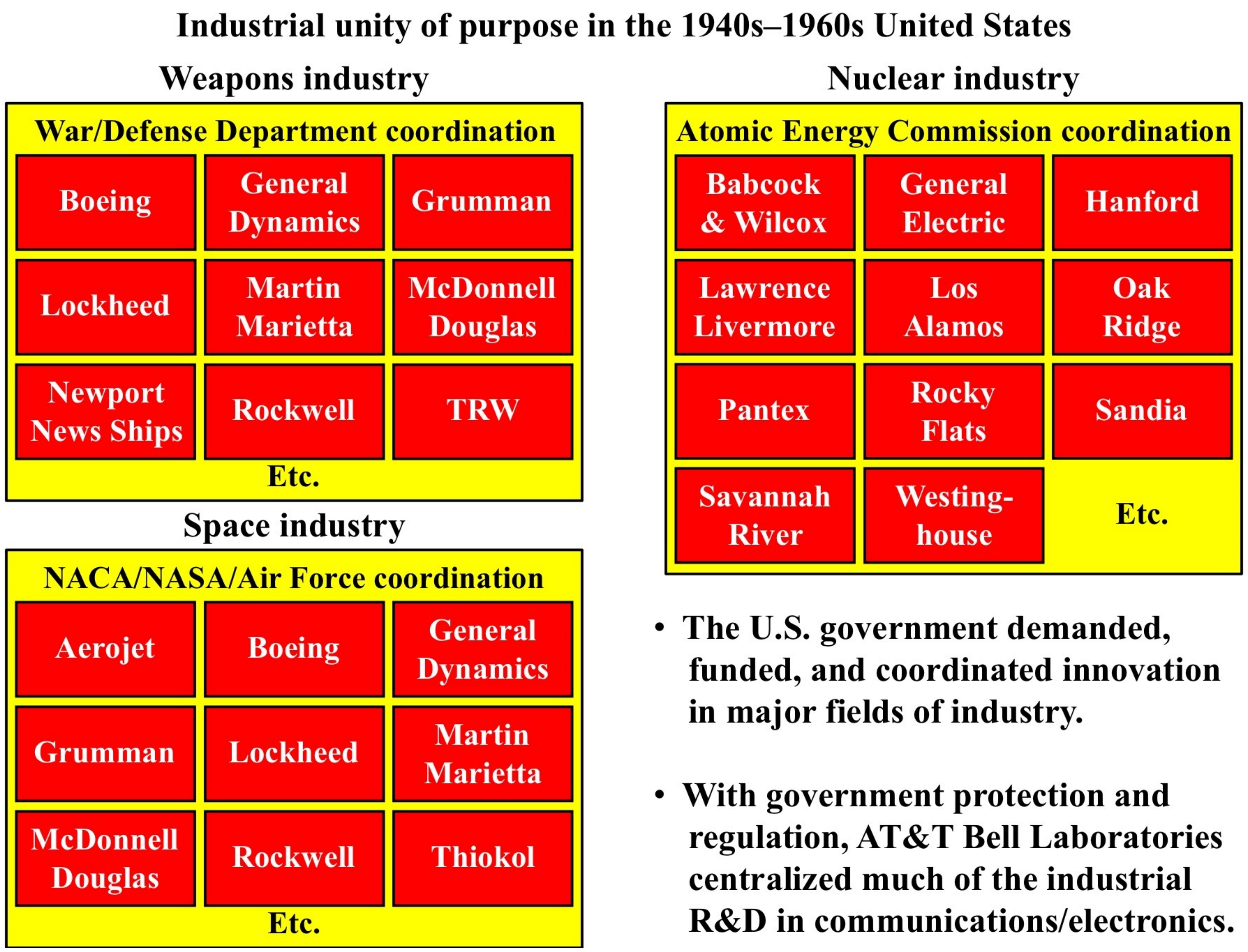
Personal computers

Smartphones

Companies should view very innovative, longer-term R&D as:

- **A worthwhile investment in staying ahead of competitors.**
- **Not a financial liability whose resulting products could be copied by competitors that did not fund their own R&D.**

Figure 11.73: Without enough government protection, companies that invested in developing innovative products lost most of the market share to other companies that simply copied those products, creating a strong disincentive for companies to fund R&D.



Industrial unity of purpose in the 1940s–1960s United States

Weapons industry

War/Defense Department coordination

Boeing
General Dynamics
Grumman
Lockheed
Martin Marietta
McDonnell Douglas
Newport News Ships
Rockwell
TRW
Etc.

Space industry

NACA/NASA/Air Force coordination

Aerojet
Boeing
General Dynamics
Grumman
Lockheed
Martin Marietta
McDonnell Douglas
Rockwell
Thiokol
Etc.

Nuclear industry

Atomic Energy Commission coordination

Babcock & Wilcox
General Electric
Hanford
Lawrence Livermore
Los Alamos
Oak Ridge
Pantex
Rocky Flats
Sandia
Savannah River
Westinghouse
Etc.

- The U.S. government demanded, funded, and coordinated innovation in major fields of industry.
- With government protection and regulation, AT&T Bell Laboratories centralized much of the industrial R&D in communications/electronics.

Figure 11.74: In the United States from 1940 to 1970, companies were less afraid of losing their innovations to each other than of losing to foreign countries, strongly motivating them to innovate (with strong support and coordination by government agencies).

Another strong incentive that the U.S. government could use to alter and unify corporate behavior is taxes. U.S. corporate tax rates were extremely low prior to 1940, high during the 1940s–1960s, and then lower from the 1970s onward, as shown in Fig. 11.75. The high corporate tax rates during the 1940s–1960s were a strong incentive for executives to reinvest most of their company's income in research and development, infrastructure, and employees instead of trying to remove it from the company as cash profits and lose much of it. When those tax rates began to seriously decline from the 1970s onward, the culture of U.S. companies altered dramatically. Research and development programs were downsized or eliminated, U.S.-based laboratories and manufacturing facilities were neglected or closed and outsourced overseas, employees were considered easily replaceable and treated poorly, and more and more of the income generated by large corporate organizations was channeled to fewer and fewer people in those organizations. After those trends have continued for over half a century, the United States has reached a point where many of the largest companies pay no taxes at all on billions of dollars in profit [NYT 2021-04-02] and there are disastrous effects on revolutionary scientific innovation (Sections 1.1 and 11.3.1) and society in general.

Simon Ramo, cofounder of TRW, described how U.S. companies began to view R&D as more of a burden than an opportunity beginning in the 1970s—see p. 52.

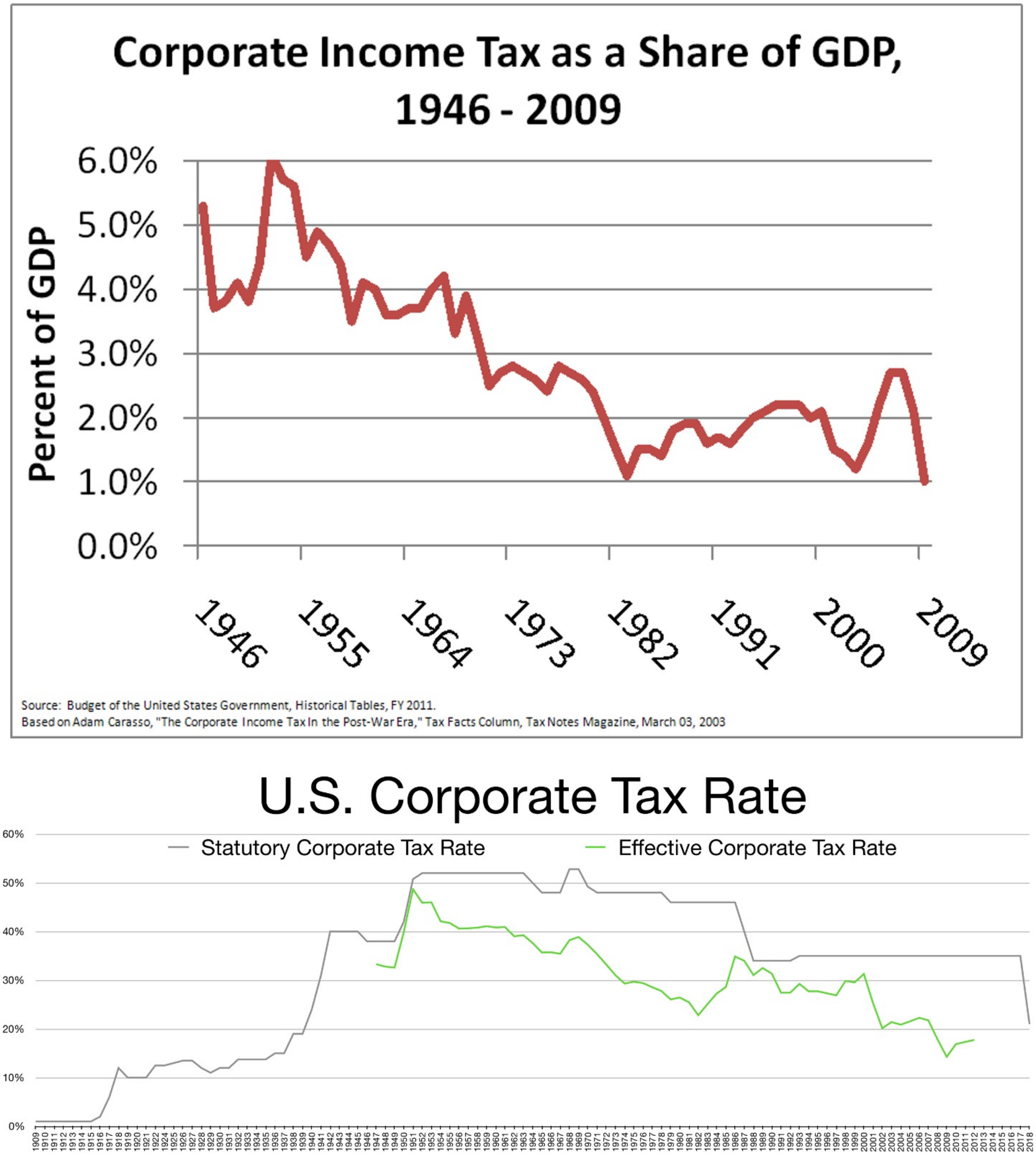
John Pierce, a research manager under Mervin Kelly at Bell Laboratories during its heyday, gave a very similar description of various external and internal forces that led Bell Laboratories to become less interested in innovative R&D after Kelly retired [Pierce 1975]:

> Kelly's concept of "organized creative technology," embracing research, fundamental (or exploratory) development, systems engineering, and final development for manufacture is persuasive. His concept of the place of basic research in industry is inspiring and appealing. What, however, are we to make of these in practice?
>
> There seems to be no avoiding Kelly's conclusion that industrial progress is based on the results of basic research. We can note that basic research is sometimes inspired by technological invention. Thermodynamics was inspired by the steam engine. But, whatever its inspiration, basic research lies behind the whole of modern technology. Kelly felt strongly that much basic research should be carried out in industrial laboratories.
>
> During Kelly's career at Bell Laboratories, he experienced (despite the years of the Depression) the relatively stable support derived from the provision of a service as opposed to the manufacture of products for the market place. The exception to this was defense work, but this was done during periods of close cooperation between government and industry in the national crises of World War II and the Korean War. These were circumstances far more favorable to research, or at least to the dedicated effort of first-rate men, than is work in a manufacturing industry where markets as well as revenues fluctuate.
>
> Further, in Kelly's time the effect on science of some government actions and attitudes was less clear than it is today. The consequences to science of antitrust actions that sever service from manufacture (in aircraft and airlines, for example), that render successful companies insecure in their operations and in cooperative relations with universities, and that prevent cooperative research toward common needs, were not yet clear. Further, in Kelly's time the attitude of government toward both science and industry was on the

> whole friendly and cooperative. Today, the attitude of government has, in many areas, become at once hostile, highly demanding, and minutely dictatorial through statutory and bureaucratic means.
>
> Thus, Kelly may have overestimated the amount and quality of research that could in the future be expected from industry, and perhaps from the nation.
>
> Some of Kelly's ideas concerning the organizational form most suitable for "organized creative technology" have hazards as well as power. The autonomy of research, the prerogatives of systems engineering, and the separation of the management of non-technological functions from the technological management depend for their success on inspired leadership.
>
> When leadership is uninspired or inadequate, it is easy for research to drift away from the overall purpose of an organization. It is easy for the rest of the organization to disregard research. It is easy for systems engineers to become stale and to lose their feel for the actual state of research on one hand and the current realities of development, manufacture, and operation on the other. It is easy for a large staff organization concerned with buildings, facilities, shops, libraries, and even computer services to put organizational order and budgetary neatness ahead of the real needs and problems of scientists and engineers.
>
> Above all, a technological organization must have the leadership to see and pursue real opportunities and real needs.

Thus beginning around 1970, U.S. companies became less and less supportive of innovative research and development, and that pattern continued for several decades. By the time another serious foreign competitor arose in China around 2000 or so, it became apparent that China could rapidly copy any U.S. innovation, mass-produce it, and sell it for less in U.S. and global markets. Therefore not only domestic but also foreign competition became a strong disincentive to invest in research and development of major new innovations.

High U.S. corporate tax rates during the 1940s–1960s were a strong incentive for executives to reinvest most of a company's income in research and development, infrastructure, and employees instead of trying to remove it from the company as cash profits and lose much of it.



Source: Budget of the United States Government, Historical Tables, FY 2011.
Based on Adam Carasso, "The Corporate Income Tax In the Post-War Era," Tax Facts Column, Tax Notes Magazine, March 03, 2003

Figure 11.75: High U.S. corporate tax rates during the 1940s–1960s were a strong incentive for executives to reinvest most of a company's income in research and development, infrastructure, and employees instead of trying to remove it from the company as cash profits and lose much of it.

11.2.11 Other Factors

Family backgrounds of creators

Just as a disproportionate percentage of innovators in the German-speaking world was Jewish, a disproportionate percentage in the U.S. system has also been Jewish. Currently approximately 2% of the U.S. population is Jewish or of Jewish background. Yet from 1901 through 2013, 25% of all U.S. Nobel Prize winners in science were Jewish and born in the Unites States. Including both those born in the United States and also those who immigrated to the United States from other countries of origin, 38% of all U.S. Nobel Prize winners in science were Jewish [Gerstl 2014, p. 87]. Those statistics may indicate that certain family backgrounds place more emphasis on intellectual education and careers, or even more specifically on science-related education and careers.

However, this factor is not sufficient for producing revolutionary scientific innovations. There are currently approximately six million Jewish people in the United States, as well as millions of people from all sorts of other backgrounds, yet the rate of revolutionary innovations per year (certainly the rate of revolutionary innovations per year per person) seems far lower than in earlier times. What appears to be lacking are the systemic approaches (such as those listed in previous sections) that fostered, supported, and rewarded revolutionary innovators and innovations in the German-speaking world and in the early U.S. system, but that have subsequently been largely abandoned.

Other possible factors

In addition to the factors already considered in this chapter, it is possible that other factors helped or hindered scientific innovation in the United States. In the future, scholars who examine this topic further should evaluate factors such as those listed on p. 2030, and determine how much if any effect each factor has had on innovation.

11.3 Failure to Sustain Approaches Transferred from the German-Speaking World

The U.S. research system was highly productive during its early decades in the 1940s–1960s, when it largely focused on perfecting creations it had imported from the earlier German-speaking world (Section 11.1), using thousands of creators (Section 11.1) and some systemic approaches (Section 11.2) that it had also imported from the German-speaking world. Unfortunately, productivity apparently declined after that period, as the original creations reached complete technological maturity, the original German-speaking creators retired or died, and the system drifted further from the approaches that had originally facilitated the successes of those creators and creations. In particular, research funding stagnated or declined (Figs. 11.62–11.64), far-sighted enlightened despots were replaced by consensus-based bureaucracies, and research shifted from longer-term development of revolutionary innovations to extremely low-risk production of immediately marketable commercial products or immediately publishable academic papers. This section quotes some first-hand observations of the apparent decline of the modern research system, then examines potential explanations for that decline.

11.3.1 Observations of Decline

The following are personal accounts from several discerning experts who observed these changes as they happened in all three sectors of the U.S. research system:

A. The university-based academic research system (p. 2245).

B. The corporate research system based in private company laboratories (p. 2254).

C. The government research system based in government-run and/or government-funded laboratories (p. 2256).

A. Observations of decline in the academic research system

Philip Anderson (1923–2020, 1977 Nobel Prize in Physics) was part of the U.S. research system from the 1940s onward and described its decline [Laurie Brown et al. 1995, pp. 2027–2029]:

> The gigantic growth... took place to a large extent because of a perception both in industry and in government that the products created were economically useful. The result was funding on a scale which absorbed essentially all new recruits. Through the first three postwar decades this was unquestionably the case; we hardly need to repeat the litany of practically useful materials and devices which came out during these years.
>
> [...] The result was an increasing overcrowding of research as a profession. One may question—and leaders of various kinds did—how much research is too much, or even whether there *could* be too much research, research being viewed as an absolute good. But conditions within the profession, viewed objectively, made it quite clear that aside from the inevitable funding crunch there were dysfunctions in the system.

> There was a very sharp change in the nature of a research career. The 'promising' young scientist's publication rate grew by factors of five to ten; the number of applications a young researcher might make for postdoctoral work or an entry-level position from two or three to 50. Senior scientists were overwhelmed with receiving and sending reams of letters of recommendation, which thereupon became meaningless. The numbers of meetings in a given specialized subject, and the number of subjects with a formal meeting list, both grew by factors of ten or more. In many subjects one could 'meet' nearly 52 weeks in the year, somewhere in the world, and leaders in the field were invited to all. Meetings almost inevitably led to publications. Most publications became tactical in this game of jockeying one's way to the top; publications in certain prestige journals were seen as essential entry tickets or score counters rather than as serious means of communication. Great numbers of these publications were about simulations of dubious realism or relevance. Essentially, in the early part of the postwar period the career was science-driven, motivated mostly by absorption with the great enterprise of discovery, and by genuine curiosity as to how nature operates. By the last decade of the century far too many, especially of the young people, were seeing science as a competitive interpersonal game, in which the winner was not the one who was objectively right as to the nature of scientific reality but the one who was successful at getting grants, publishing in PRL [*Physical Review Letters*], and being noticed in the news pages of *Nature*, *Science*, or *Physics Today.*
>
> In many subjects the great volume of publications, the fragmentation into self-referential so-called schools who met separately, and a general deterioration in quality which came primarily from excessive specialization and from careerist sociology, meant that quite literally more was worse.

Note that Anderson described all of these problems in 1995, and they have only become even more pronounced in the decades since then.

As early as 1972, Albert Szent-Györgyi (Hungarian, 1893–1986), the winner of the 1937 Nobel Prize in Physiology or Medicine, noticed similar problems in the American research system. In a letter to the journal *Science*, he complained about how the system had come to discriminate against funding revolutionary innovators who pioneered entirely new research directions (whom he labelled "Dionysians") in favor of only funding scientists who made evolutionary, incremental progress in already known directions ("Apollonians") [Szent-Györgyi 1972]:

> In science the Apollonian tends to develop established lines to perfection, while the Dionysian rather relies on intuition and is more likely to open new, unexpected alleys for research. [...]
>
> The future of mankind depends on the progress of science, and the progress of science depends on the support it can find. Support mostly takes the form of grants, and the present methods of distributing grants unduly favor the Apollonian. Applying for a grant begins with writing a project. The Apollonian clearly sees the future lines of his research and has no difficulty writing a clear project. Not so the Dionysian, who knows only the direction in which he wants to go out into the unknown; he has no idea what he is going to find there and how he is going to find it. [...]

> A discovery must be, by definition, at variance with existing knowledge. During my lifetime, I made two. Both were rejected offhand by the popes of the field. Had I predicted these discoveries in my applications, and had these authorities been my judges, it is evident what their decisions would have been. [...]
>
> The problem is a most important one, especially now, as science grapples with one of nature's mysteries, cancer, which may demand entirely new approaches.

Sydney Brenner (1927–2019), who won the Nobel Prize in Physiology or Medicine in 2002 for his work on molecular biology, described similar problems with the modern academic research system [Dzeng 2014]:

> In America you've got to have credits from a large number of courses before you can do a PhD. That's very good for training a very good average scientific work professional. But that training doesn't allow people the kind of room to expand their own creativity. But expanding your own creativity doesn't suit everybody. For the exceptional students, the ones who can and probably will make a mark, they will still need institutions free from regulation. [...]
>
> I strongly believe that the only way to encourage innovation is to give it to the young. The young have a great advantage in that they are ignorant. Because I think ignorance in science is very important. If you're like me and you know too much you can't try new things. I always work in fields of which I'm totally ignorant. [...]
>
> Today the Americans have developed a new culture in science based on the slavery of graduate students. Now graduate students of American institutions are afraid. He just performs. He's got to perform. The postdoc is an indentured labourer. We now have labs that don't work in the same way as the early labs where people were independent, where they could have their own ideas and could pursue them.
>
> The most important thing today is for young people to take responsibility, to actually know how to formulate an idea and how to work on it. Not to buy into the so-called apprenticeship. I think you can only foster that by having sort of deviant studies. That is, you go on and do something really different. Then I think you will be able to foster it.
>
> But today there is no way to do this without money. That's the difficulty. In order to do science you have to have it supported. The supporters now, the bureaucrats of science, do not wish to take any risks. So in order to get it supported, they want to know from the start that it will work. This means you have to have preliminary information, which means that you are bound to follow the straight and narrow.
>
> There's no exploration any more except in a very few places. You know like someone going off to study Neanderthal bones. Can you see this happening anywhere else? No, you see, because he would need to do something that's important to advance the aims of the people who fund science.
>
> I think I've often divided people into two classes: Catholics and Methodists. Catholics are people who sit on committees and devise huge schemes in order to try to change

things, but nothing's happened. Nothing happens because the committee is a regression to the mean, and the mean is mediocre. Now what you've got to do is good works in your own parish. That's a Methodist. [...]

I am fortunate enough to be able to do this because in Singapore I actually have started two labs and am about to start a third, which are only for young people. These are young Singaporeans who have all been sent abroad to get their PhDs at places like Cambridge, Stanford, and Berkeley. They return back and rather than work five years as a post-doc for some other person, I've got a lab where they can work for themselves. They're not working for me and I've told them that. [...]

They can have some money, and of course they've got to accept the responsibility of execution. I help them in the sense that I oblige them and help them find things, and I can also guide them and so on. We discuss things a lot because I've never believed in these group meetings, which seems to be the bane of American life; the head of the lab trying to find out what's going on in his lab. Instead, I work with people one on one, like the Cambridge tutorial. Now we just have seminars and group meetings and so on.

So I think you've got to try to do something like that for the young people and if you can then I think you will create. That's the way to change the future. Because if these people are successful then they will be running science in twenty years' time. [...]

Even God wouldn't get a grant today because somebody on the committee would say, oh those were very interesting experiments (creating the universe), but they've never been repeated. And then someone else would say, yes and he did it a long time ago, what's he done recently? And a third would say, to top it all, he published it all in an un-refereed journal (The Bible).

So you know we now have these performance criteria, which I think are just ridiculous in many ways. But of course this money has to be apportioned, and our administrators love having numbers like impact factors or scores. Singapore is full of them too. Everybody has what are called key performance indicators. But everybody has them. You have to justify them.

I think one of the big things we had in the old LMB [Laboratory of Molecular Biology], which I don't think is the case now, was that we never let the committee assess individuals. We never let them; the individuals were our responsibility. We asked them to review the work of the group as a whole. Because if they went down to individuals, they would say, this man is unproductive. He hasn't published anything for the last five years. So you've got to have institutions that can not only allow this, but also protect the people that are engaged on very long term, and to the funders, extremely risky work.

I have sometimes given a lecture in America called "The Casino Fund." In the Casino Fund, every organisation that gives money to science gives 1% of that to the Casino Fund and writes it off. So now who runs the Casino Fund? You give it to me. You give it to people like me, to successful gamblers. People who have done all this who can have different ideas about projects and people, and you let us allocate it.

> You should hear the uproar. No sooner did I sit down then all the business people stand up and say, how can we ensure payback on our investment? My answer was, okay make it 0.1%. But nobody wants to accept the risk. Of course we would love it if we were to put it to work. We'd love it for nothing. They won't even allow 1%. And of course all the academics say we've got to have peer review. But I don't believe in peer review because I think it's very distorted and as I've said, it's simply a regression to the mean.
>
> I think peer review is hindering science. In fact, I think it has become a completely corrupt system. It's corrupt in many ways, in that scientists and academics have handed over to the editors of these journals the ability to make judgment on science and scientists. There are universities in America, and I've heard from many committees, that we won't consider people's publications in low impact factor journals.
>
> Now I mean, people are trying to do something, but I think it's not publish or perish, it's publish in the okay places [or perish]. And this has assembled a most ridiculous group of people. I wrote a column for many years in the nineties, in a journal called *Current Biology*. In one article, "Hard Cases," I campaigned against this [culture] because I think it is not only bad, it's corrupt. In other words it puts the judgment in the hands of people who really have no reason to exercise judgment at all. And that's all been done in the aid of commerce, because they are now giant organisations making money out of it. [...]
>
> I think that this has now just become ridiculous and it's one of the contaminating things that young people in particular have to actually now contend with. I know of many places in which they say they need this paper in *Nature*, or I need my paper in *Science* because I've got to get a post-doc. But there is no judgment of its contribution as it is.

In an obituary for Frederick Sanger (1918–2013), the only person to ever win two Nobel Prizes in Chemistry (1958 and 1980), Sydney Brenner continued his analysis of how the research system has changed [Brenner 2014]:

> A Fred Sanger would not survive today's world of science. With continuous reporting and appraisals, some committee would note that he published little of import between insulin in 1952 and his first paper on RNA sequencing in 1967 with another long gap until DNA sequencing in 1977. He would be labelled as unproductive, and his modest personal support would be denied. We no longer have a culture that allows individuals to embark on long-term—and what would be considered today extremely risky—projects.

As another example of the change in academia over the last several decades, the British newspaper *The Guardian* wrote about Peter Higgs (1929–), who won a Nobel Prize in Physics in 2013 for having predicted the existence and properties of a fundamental particle, the "Higgs boson," 50 years before it was finally discovered [Aitkenhead 2013]:

> Peter Higgs, the British physicist who gave his name to the Higgs boson, believes no university would employ him in today's academic system because he would not be considered "productive" enough. [...]

> He doubts a similar breakthrough could be achieved in today's academic culture, because of the expectations on academics to collaborate and keep churning out papers. He said: "It's difficult to imagine how I would ever have enough peace and quiet in the present sort of climate to do what I did in 1964." [...]
>
> By the time he retired in 1996, he was uncomfortable with the new academic culture. "After I retired it was quite a long time before I went back to my department. I thought I was well out of it. It wasn't my way of doing things any more. Today I wouldn't get an academic job. It's as simple as that. I don't think I would be regarded as productive enough."

Even though the primary product of the academic research system is published papers, with their quantity considered far more important than their quality, even the content of those papers ends up largely unread, unknown, and unused. In part, that is because of (1) the completely overwhelming flood of papers and journals; (2) the fact that most academic researchers are too busy frantically writing their own papers to spend much time reading and applying other researchers' papers; and (3) the unnecessarily microspecialized vocabulary that academics keep creating, resulting in a "tower of Babel" effect that makes academics in even slightly different fields unintelligible to each other, let alone to their sponsors or the general public. [For the history of these trends, see for example: Buranyi 2017; Francis 2020.]

Another reason that published papers tend to have so little effect is that the large majority of scientific papers are inaccessible to most of the population due to exorbitant online journal paywalls or the cost or obscurity of the printed volumes in which they appear. Sarah Kendzior, who has a Ph.D. in anthropology, used the JSTOR (Journal Storage) electronic journal database as an example to illustrate this general problem [Kendzior 2015, pp. 124–129]:

> Universities that want to use JSTOR are charged as much as $50,000 in annual subscription fees.
>
> Individuals who want to use JSTOR must shell out an average of $19 per article. The academics who write the articles are not paid for their work, nor are the academics who review it. The only people who profit are the 211 employees of JSTOR. [...]
>
> Today, publishing in an academic journal all but ensures that your writing will go unread. [...] If I wanted to download my [own] articles, I would have to pay $183. That is the total cost of the six academic articles I published between 2006 and 2012[...]
>
> New professors are awarded tenure based on their publication output, but not on the impact of their research on the world—perhaps because, due to paywalls, it is usually minimal. [...]
>
> The academic publishing industry seems poised to collapse before it changes. But some scholars are writing about the current crisis. Last month, an article called "Public Intellectuals, Online Media and Public Spheres: Current Realignments" was published in the *International Journal of Politics, Culture and Society.*
>
> I would tell you what it says, but I do not know. It is behind a paywall.

In an article in *The New Yorker*, Ronan Farrow presented examples of how some modern universities appear to pursue money above all else [Farrow 2019]:

> New documents show that the M.I.T. Media Lab was aware of Epstein's status as a convicted sex offender, and that Epstein directed contributions to the lab far exceeding the amounts M.I.T. has publicly admitted.
>
> The M.I.T. Media Lab, which has been embroiled in a scandal over accepting donations from the financier and convicted sex offender Jeffrey Epstein, had a deeper fund-raising relationship with Epstein than it has previously acknowledged, and it attempted to conceal the extent of its contacts with him. Dozens of pages of e-mails and other documents obtained by *The New Yorker* reveal that, although Epstein was listed as "disqualified" in M.I.T.'s official donor database, the Media Lab continued to accept gifts from him, consulted him about the use of the funds, and, by marking his contributions as anonymous, avoided disclosing their full extent, both publicly and within the university. Perhaps most notably, Epstein appeared to serve as an intermediary between the lab and other wealthy donors, soliciting millions of dollars in donations from individuals and organizations, including the technologist and philanthropist Bill Gates and the investor Leon Black. According to the records obtained by *The New Yorker* and accounts from current and former faculty and staff of the media lab, Epstein was credited with securing at least $7.5 million in donations for the lab, including two million dollars from Gates and $5.5 million from Black, gifts the e-mails describe as "directed" by Epstein or made at his behest. The effort to conceal the lab's contact with Epstein was so widely known that some staff in the office of the lab's director, Joi Ito, referred to Epstein as Voldemort or "he who must not be named." [...]
>
> Questions about when to accept money from wealthy figures accused of misconduct have always been fraught. Before his conviction, Epstein donated to numerous philanthropic, academic, and political institutions, which responded in a variety of ways to the claims of abuse. When news of the allegations first broke, in 2006, a Harvard spokesperson said that the university, which had received a $6.5-million donation from him three years earlier, would not be returning the money. Following Epstein's second arrest, in 2019, the university reiterated its stance.

Further articles revealed the corrosive effect on research when universities value the immediate pursuit of huge amounts of money above everything else. For example, *Business Insider* reported on one project in "MIT's Media Lab Has an Ambitious Project That Purports to Revolutionize Agriculture. Insiders Say It's Mostly Smoke and Mirrors" [Brodwin 2019]:

> The "personal food computer," a device that MIT Media Lab senior researcher Caleb Harper presented as helping thousands of people across the globe grow custom, local food, simply doesn't work, according to two employees and multiple internal documents that Business Insider viewed. One person asked not to be identified for fear of retaliation.
>
> Harper is the director of MIT's Open Agriculture Initiative and leads a group of seven people who work on transforming the food system by studying better methods of growing crops.

> The food computers are plastic boxes outfitted with advanced sensors and LED lights and were designed to make it possible for anyone, anywhere to grow food, even without soil, Harper has said. Instead of soil, the boxes use hydroponics, or a system of farming that involves dissolving nutrients in water and feeding them to the plant that way. [...]
>
> Harper forwarded an email requesting comment on this story to an MIT spokesperson. The spokesperson didn't provide a comment.
>
> The aim was to make it look like the devices lived up to Harper's claims, the employees said. Those claims, which included assertions that the devices could grow foods like broccoli four times faster than traditional methods, landed Harper and his team articles in outlets ranging from the Wall Street Journal to Wired and National Geographic. [...]
>
> Paula Cerqueira, a researcher and dietitian who worked as a project manager at the Open Agriculture Initiative for two years, told Business Insider that the personal food computers are "glorified grow boxes."
>
> Cerqueira was part of a team that, on several occasions, delivered the personal food computers to schools. She also helped demonstrate the boxes to big-name MIT Media Lab investors.
>
> During the organization's "Members Weeks"—once-a-semester events that drew donors including Google, Salesforce, Citigroup, and 21st Century Fox—Cerqueira and her coworkers would show investors how the technology worked.
>
> On one occasion, Cerqueira said, her coworkers were told to fetch basil grown from a nearby location and place it into the personal food computers to make it look like it had been grown inside the boxes.
>
> "They wanted the best looking plants in there," Cerqueira told Business Insider. "They were always looking for funding."
>
> In another instance, Harper told Cerqueira to buy edible lavender plants from a nearby flower's market and place them in the boxes for a photoshoot, she said. Before any photos were taken, she carefully dusted off the tell-tale soil on the plants' roots.
>
> The central problem with the personal food computer was that it simply didn't work, Cerqueira and another person with knowledge of the matter told Business Insider.

The technology investor Peter Thiel summed up some of the problems with the modern academic research system in a 27 April 2023 speech [Thiel 2023]:

> Start with the university. It's easy to focus on all the insanity in the humanities. But if you remember what universities themselves believe—that all their serious work, their cutting- edge research, is done in the sciences—the focus on the humanities begins to resemble an attention redirect, stifling the hard questions about what is actually going on in the sciences. Are they progressing as advertised? Are we still living in an accelerating world in which science is fundamentally healthy and critical, with diversity

> of thought? It shouldn't have required covid to be able to ask these questions, to notice that "science" has somehow gotten to be a very, very diseased thing. Most imagine a scientist to be an independent researcher who thinks for himself, and this figure may still appear in children's books, but in practice the occupation mostly entails the enforcement of a fixed set of dogmas.
>
> A few years after *The Diversity Myth* came out, a Stanford physics professor, Bob Laughlin, got a Nobel Prize. And he began to suffer from the supreme delusion that, now that he had a Nobel Prize in physics, he also had academic freedom and could investigate anything he wanted. Now, there are a lot of controversial topics in science. You could have a heterodox view on stem-cell research, or you could be a skeptic of climate change or Darwinism. But Laughlin hit on a topic that was far more taboo than any of the above. He had the idea that most of the scientists were doing no work at all. They were actually stealing money from the government, just creating all these fraudulent grant applications. Laughlin had done a lot of work studying the physics of super-high temperatures (superconductivity and the like), and he once told me that, of the roughly fifty thousand papers written on the subject, maybe twenty-five of them were any good at all.
>
> Laughlin's team started with the biology department at Stanford, launching a sort of inquiry into what, exactly, it was doing. They didn't actually publish the results—they just had a public hearing and generally denounced all the professors as having stolen money from the government. The generous conclusion would be that the department wasn't fully fraudulent: just an incredibly incrementalist exercise in groupthink that wasn't really moving the dial forward. This was a line of thinking that was completely, completely taboo. I don't need to tell you how the story ends.
>
> This question of scientific and technological stagnation is in some sense the Achilles heel of the universities. It's hard to uncover. Right now the humanities are transparently ridiculous. You might think of the humanities as the Department of Motor Vehicles. And the physics department is sort of like the self-proclaimed rocket scientists at the National Security Agency. The crypsis makes their activities look more intelligent and more advanced. But my belief is that the DMV is probably better run than the NSA. The fact that you don't have a clue what's going on at the NSA gives you a hint as to which of the two is worse. Something like this is going on with the sciences more broadly.
>
> There are two basic debate techniques you can have when you're arguing with someone. You can go after the enemy at the weakest point, which in the college context is the humanities: it's ridiculous, and you're most likely to come away with a sort of tactical victory. But the other strategy is to go after the enemy's strongest point: to say there's no real science going on, that string theorists aren't making the fundamental breakthroughs that we're told, and that physicists have otherwise been twiddling their thumbs for fifty years. And if you can win that point, it's game, set, and match.

For related information on some of the corrosive factors affecting the academic research system, see pp. 49–51, 2262–2263, and the references cited therein [see also Buranyi 2017; Francis 2020; Preston 2021; Sarkowski 2001].

B. Observations of decline in the corporate research system

This book has already quoted Simon Ramo, cofounder of TRW, on how U.S. companies began to view R&D as more of a burden than an opportunity beginning in the 1970s (p. 52). On a similar note, Richard Rosenbloom (1933–2011, a professor at the Harvard Business School) and William Spencer (1931–, president of the SEMATECH semiconductor manufacturers' consortium) commented on the decline in industrial research in a 1993 conference paper [later published in Rosenbloom and Spencer 1996, pp. 1–2, 4–5]:

> Familiar exemplars of organizations devoted to industrial research include DuPont's Experimental Station in Wilmington, IBM's Watson Research Center in Yorktown Heights, AT&T's Bell Laboratories at Murray Hill, and the Xerox Palo Alto Research Center.
>
> The decades following World War II were a golden era for research organizations in American industry. Corporate leaders, persuaded by the dazzling achievements of wartime and such undisputed research successes as nylon and the transistor, funded rapid expansion of research staffs and facilities. DuPont, for example, increased its R&D staff by 150 percent in the first decade after the war and the greatest growth occurred at the Experimental Station, the center of its fundamental research in chemistry. Radio Corporation of America (RCA), a pioneer in electronics, formed the RCA Laboratories Division, with an expansive budget and a campus-like setting in Princeton, New Jersey. Implicit in the rationale for these investments was a simple model of innovation: Scientific research in industry would generate a stream of inventions and discoveries that engineering would then make practical and affordable so that commercial organizations could harvest new revenues and profits.
>
> The stream of industrial innovations that ensued from these investments fulfilled at least the first part of this ambitious corporate vision. Industrial laboratories proved to be wellsprings of important new technologies that then became staples of modern life, such as the integrated circuit, liquid crystals, and a multitude of new synthetic polymers, to name only a few. The interplay of university and corporate laboratories brought the development of lasers, techniques of recombinant DNA, and a host of computer technologies. [...]
>
> Unfortunately, technological fecundity and scientific distinction did not always carry through to the corporate bottom line. Although the new science and technology created in industry contributed substantially to economic growth and productivity, corporate sponsors of the research often failed to capture significant returns. At first, buoyant demand in the U.S. economy in the 1950s and 1960s and the strong international market positions of the leaders in industrial research made it easy for those firms to sustain substantial investments in research even without clear evidence of immediate payoffs. The more competitive business environment of the 1980s, however, led managers to make more careful assessments of the profits gleaned from research. [...]
>
> One after another, these firms are restructuring, redirecting, and resizing their research organizations as part of a corporatewide emphasis on the timely and profitable commercialization of inventions combined with the rapid and continuing improvement of technologies in use. A recent authoritative survey of the American situation by the Na-

> tional Science Board (NSB) has concluded that "In large corporations, effort is shifting away from central [R&D] laboratories toward division-level effort with greater emphasis on risk minimization to meet the needs of today's customers" (National Science Board 1992, iii).
>
> When the directors of Kodak decided to replace Kay Whitmore, the company's chief executive, they let reporters know that one of his most important failings was that he "spent too much on R&D without getting results." According to an article in the *Wall Street Journal*, investors applauded the move, urging Kodak to "become an 'aggressive follower' by capitalizing on rivals' inventions instead of mostly developing its own." Reporters did not record which rivals were expected to replace Kodak as the technological pioneers that the company would imitate. IBM also cut the annual budget of its research division from $650 million to $500 million and redirected its focus toward "Services, Applications, and Solutions" [SAS] and away from investments in basic physical sciences and technology. The company planned to increase the SAS budget from 5 percent to 20 percent of the division's total between 1992 and 1994 with correspondingly sharp reductions in funding for basic sciences.

In the decades since Rosenbloom and Spencer made those observations, corporate research has shifted even further away from innovative research, with top management and investors focused only on daily stock prices and very near-term, very low-risk (non-innovative) products.

More broadly, the changes in corporate culture are illustrated by public statements by the Business Roundtable, a group of U.S. CEOs [Archie Carroll et al. 2012; Pearlstein 2018]. The Business Roundtable's 1981 Statement on Corporate Responsibility reflected the traditional values that had been preached (if not always practiced) by U.S. businesses since the 1930s:

> Corporations have a responsibility, first of all, to make available to the public quality goods and services at fair prices, thereby earning a profit that attracts investment to continue and enhance the enterprise, provide jobs, and build the economy. [...] Responsibility to all these constituents in toto constitutes responsibility to society, making the corporation both an economically and socially viable entity. Business and society have a symbiotic relationship: The long-term viability of the corporation depends upon its responsibility to the society of which it is a part. And the well-being of society depends upon profitable and responsible business enterprises.

In stark contrast, the Business Roundtable's 1997 Statement on Corporate Responsibility revealed a focus on one thing, to the exclusion of all else:

> The principal objective of a business enterprise is to generate economic returns to its owners. If the CEO and the directors are not focused on shareholder value, it may be less likely the corporation will realize that value.

Thus companies such as those represented by the Business Roundtable not only chose to neglect research and other longer-term investments but explicitly eliminated any sense of responsibility to society or even to their own employees. Short-term profits for those individuals running the company or making money from the company became the only goal that mattered.

C. Observations of decline in the government research system

After the 1969 U.S. victory in the moon race, and the end of any serious further international space competition, U.S. government funding for space-related research and development began to decline. However, there were similar declines in other areas of government-funded research.

Beginning in fiscal year 1970, government funding for longer-term research was severely limited by a budget amendment introduced by Senate Majority Leader Mike Mansfield. He also introduced a second, further restrictive amendment in 1973. The U.S. Office of Technology Assessment briefly explained the first Mansfield Amendment [OTA 1991, p. 61]:

> The celebrated Mansfield amendment, passed as part of the fiscal year 1970 Military Authorization Act (Public Law 91-121), prohibited military funding of research that lacked a direct or apparent relationship to specific military function. Through subsequent modification the Mansfield amendment moved the Department of Defense toward the support of more short-term applied research in universities.

Soon after the first Mansfield Amendment in 1970, the chemist Herbert Laitinen published an accurate prediction of the long-term changes it would cause to the U.S. research system [Laitinen 1970]:

> Late in 1969, the Congress of the United States passed an authorization bill for expenditures of the Department of Defense for the fiscal year 1970. An amendment by Sen. Mansfield which passed with virtually no advance public notice has since caused apprehension, confusion, and secondary effects of a magnitude that still eludes estimation.
>
> The amendment, called section 203, states "None of the funds authorized by this Act may be used to carry out any research project or study unless such project or study has a direct and apparent relationship to a specific military function." [...]
>
> Now that the issue of "direct and apparent relationship to a specific military function" has been raised, a similar "Mansfield effect" appears to be emerging in mission-oriented civilian agencies, such as the National Institutes of Health and the Federal Water Pollution Control Agency, to require a closer and more obvious relationship between research and mission. [...] If it were simply a matter of transfer of funds to the one research agency that is not mission-oriented, the National Science Foundation, no serious harm would be done. Unfortunately, the NSF is not receiving additional support. On the contrary, it has been directed, through the Daddario bill, to expand its function to support applied as well as basic research [with its existing budget]. Thus, an already serious squeeze on pure research seems destined to intensify.
>
> Now to complete the circle, the emergence on the job market of a pool of postdoctorates that can no longer be supported on research grants, plus the new group of graduating Ph.D.'s to compete for a dwindling number of research positions in industry, government, and academic departments is being cited as evidence that we have an abundance of Ph.D.'s and that decreased graduate support is therefore justified. Clearly this is short-sighted policy. What is needed is a strong and continuing commitment to basic research in support of all mission-oriented technology, both in relation to research training at pre- and postdoctoral levels and in relation to research output. Anything less will

> waste the talents of a substantial group of skilled research workers and will compromise our technological future.

An old version of the history of DARPA (the Defense Advanced Research Projects Agency) archived on the internet explained the second Mansfield Amendment of 1973 [https://www.bibliotecapleyades.net/sociopolitica/sociopol_DARPA01.htm]:

> The Mansfield Amendment of 1973 expressly limited appropriations for defense research (through ARPA/DARPA) to projects with direct military application.
>
> Some contend that the amendment devastated American science, since ARPA/DARPA was a major funding source for basic science projects of the time; the National Science Foundation never made up the difference as expected. But the resulting "brain drain" is also credited with boosting the development of the fledgling personal computer industry.

While the decline in U.S. government-funded research began around 1970, it became even worse with the end of the Cold War in 1991. Lynn Gref (1941–2013), who spent his career conducting and managing research at Department of Defense (DOD) and NASA laboratories, described the decline of applied research or "Phase Two" research at government laboratories [Gref 2010, pp. 116–117]:

> It is in Phase Two research (device phase) that a decline in research activity of at least a decade duration can be detected. Now let us consider the indicators of a decline in Phase Two research. [...I]ndustry has become the dominant source of funds for R&D. Industry is even more dominant for R&D outside of the medical science arena. This is in itself not necessarily bad. However, it will become evident that industry has lost much of its ability or willingness to perform the Phase Two research that leads to the revolutionary devices of the future.
>
> Second, R&D performed at the Government's laboratories has declined more than 50% since 1970 based on funding received[...] Most of their work falls into Phase Two. After the end of the Cold War, funding for new weapons systems declined dramatically. (The Iraq War has brought an influx of orders for existing weapons systems and benefited much of the remaining defense industry, but it has had the devastating effect of further restricting R&D funding to efforts with an immediate application to the war.) The defense industry went through a major restructuring and consolidation between the end of the Cold War and the beginning of the Iraq War. During this period, industry went after all available funding from the DOD. The large companies turned to sources they previously shunned including Phase Two research. The companies employed massive lobbying efforts to achieve these objectives. Consequently, a goal of the DOD's laboratories became spending approximately 70% of their funding with industry. (The DOD originally established the laboratories to perform research needed by the services. Buying research from industry is a very recent occurrence.) This had two negative effects. First, it further reduced the funds retained by the laboratories to use for their in-house activities including research. The impact was that of a funding cut. Second, the technologists at the laboratories had to use their time to perform contracting functions—writing requests for proposals, evaluating proposals and monitoring the work of contractors—instead of performing their own research. The reduction of internal funding and the change in assignments has dramatically reduced research performed at the DOD laboratories. In addition, studies initiated by Congress have pointed to a

> perceived excess capacity in DOD laboratories and suggested restructuring the laboratories so that they would be Government owned and contractor operated. In this latter case, industry would perform all of DOD's research other than that done by universities. Recalling [...] the rich heritage of innovation of the Naval Research Laboratories and the other DOD service laboratories, the decline in technology development by DOD's laboratories is a tragedy for Phase Two of the development cycle.
>
> The "industrialization of Government research" has not been unique to the DOD. It has affected agencies such as NASA. NASA has terminated "block" funding of technology work at its center laboratories. It has replaced the technology development that its centers previously performed on an assigned basis with various competitions, most of which are open to all comers. With these competitions has come the pressure on NASA to award industry a greater proportion of the R&D dollars. The contraction and consolidation of the military industrial contractors that occurred after the end of the Cold War certainly had a part in this change at NASA as it did with the DOD laboratories. With the need to survive, NASA's research funds became fair game for these contractors. Unfortunately, when the researchers at the NASA centers fail to obtain funding for their efforts, then they must go elsewhere and their research ends. For example, JPL received from NASA approximately $100M on an assigned basis for Phase Two research in FY2000 and today it is less than $50M, mostly obtained on a competitive basis.
>
> Furthermore, competition for Phase Two funding does not foster risk taking and long-term efforts. No matter how one cuts it, the winners of funding are those who can demonstrate the best value for the Government. That is, winners are those that can identify measurable benefits of their research, demonstrate the risks of the proposed work are reasonable and manageable, prove the approach to the research is sound, and argue that success is likely. That just is not the real life situation for Phase Two research [...] where failure occurs more often than success.
>
> Competing for research funding is an environment in which research becomes incremental and unimaginative. In other words, the competitive environment turns the researchers into "surviving" financially. Improving the materials and processes used to build a device is much more likely to meet the requirements of a competition than some "wild new" idea that may take a decade or more to work out with few, if any, applications apparent[...] Similarly, proposing an enhancement to work that has already been funded and is in a proven interest area of the sponsor is more likely to be a successful bid than an "out of the box" or "off the wall" idea. Such a chilling environment for innovation is not conducive to funding research ideas that could really have an impact similar to those of NRL's radar developments of the past.

Summary of observations of decline

According to longtime first-hand observers such as those quoted above, the academic, corporate, and government research sectors of the U.S. innovation system were all very productive during the 1940s–1960s, all began to drift and steadily decline beginning around 1970 or so, experienced a further drop around the end of the Cold War ($\sim$1991), and have declined even more since 2000 due to priority shifts at the highest levels of government, industry, and academia. The end result is the problems discussed in Section 1.1.

11.3.2 Explanations for Decline

The contemporary observers quoted in the previous section ably described the decline in innovation that occurred from around 1970 onward, yet it is necessary to seek a better understanding of the fundamental reasons for that decline. A number of potential explanations have been offered:

A. Exhaustion of the supply of innovators and innovations that had been adopted from the earlier German-speaking world (p. 2259).

B. Abandonment of German-like systemic practices for promoting innovation (p. 2260).

C. The decline and end of Cold War competition that promoted innovation (p. 2260).

D. Darwinian selection of researchers for traits other than innovation (p. 2262).

E. Political divisions that undermine government support for innovation (p. 2264).

F. Loss of consumer demand for innovation (p. 2265).

G. A shift in the types of innovation that consumers demand (p. 2266).

In practice, all of these factors probably played a significant role in the decline, and indeed the various factors likely exacerbated each other.

A. Exhaustion of innovators and innovations adopted from the German-speaking world

As argued in Chapters 2–10 and Section 11.1, a huge number of innovators and innovations were produced by the German-speaking world prior to 1945. By around 1970, most of the thousands of German-speaking creators who had been recruited from that world had retired or died, and the enormous numbers of inventions and discoveries that had originated in that earlier world had already been copied, optimized, and utilized to their fullest potential in the United States and other countries.

B. Abandonment of German-like systemic practices for promoting innovation

As covered in Sections 11.2 and 11.3.1, especially during the 1940s–1960s, the United States (and presumably other countries) implemented many systemic practices that strongly promoted revolutionary scientific innovation, and that were highly similar to systemic practices from the earlier German-speaking world. Just as those practices had cultivated countless creators and creations in the German-speaking world, they also bred homegrown innovators and innovations in the United States. Unfortunately, around 1970, the United States began to abandon some of those systemic practices. That shift made it harder to cultivate as many brand new revolutionary innovators and innovations after that time, and it also made it harder for any innovators and innovations that had been developed in the earlier days of the system to continue to find sufficient financial and political support.

C. Decline and end of Cold War competition that promoted innovation

As argued in Section 11.2.9, just as the earlier German-speaking world was strongly driven throughout its existence by military and industrial competition with the United Kingdom, United States, and other countries, the U.S. system in the 1940s through 1960s was strongly driven first by World War II competition with Germany and then by Cold War competition with the Soviet Union. However, around 1970 (with the U.S. victory in the moon race and the beginning of the Strategic Arms Limitation Talks) that Cold War competition greatly relaxed, and in 1991 it collapsed entirely. Without a strong sense of urgent international competition, the U.S. innovation system fell victim to other priorities and forces.

In the afterword to his book *The Gift*, writing professor Lewis Kenyon described how the end of the Cold War impacted both scientists and artists, with funding decreasing and shifting from longer-term, more philanthropic objectives to very short-term, purely money-making aims [Hyde 2019]:

> Which brings me back to the fall of the Soviet Union, for it was the Cold War that energized much of the public funding devoted to art and science in the decades after World War II. [...]
>
> Of that context one could say, to put it positively, that the Soviet Union turned out to provide a useful counterforce to the harsher realities of capitalism. It goaded the West into provisioning those parts of social life not well served by market forces. To put it negatively, however, if Cold War rhetoric lay at the foundation, then the entire edifice was historically vulnerable. Thus when the Soviet Union fell in 1989 so did the bulk of public patronage in the West. In the U.S., for example, we almost immediately got the attacks on the National Endowment for the Arts and the loss of nearly all funding to individual artists. A similar if less publicized story played out in basic science. In a 1998 interview Leon Lederman, Nobel laureate in physics, said: "We always thought, naïvely, that here we are working in abstract, absolutely useless research and once the cold war ended, we wouldn't have to fight for resources. Instead, we found, we were the cold war. We'd been getting all this money for quark research because our leaders decided that science, even useless science, was a component of the cold war. As soon as it was over, they didn't need science."

> In short, around 1990 the third phase of this history began, an era of market triumphalism in which not only has public support of the arts and sciences begun to dry up but those who stilled their voices during the Cold War, those who have long believed in an unlimited market, have felt free to advance unselfconsciously.
>
> In instance after instance, public institutions have been encouraged to think of themselves as private businesses. The universities have set up "technology transfer offices" and tried to fund themselves by selling knowledge rather than simply disseminating it, as their old mission statements once asked them to do. Grammar schools have learned that they can sell exclusive rights to soft drink vendors intent on creating brand loyalty in the very young. Public radio and television are now cluttered with advertising. Even commercial television has become more so: in the U.S., the networks once limited their ads to nine minutes an hour; they gave that up in the last decade and ads now run eighteen minutes in prime time.
>
> Natural abundance has been similarly commercialized, everywhere subject to the grid of artificial scarcity. Ancient aquifers, by rights belonging to all who live above them, are now pumped and packaged. Drinking water, once an essence of life, has become a resource to be sold in little plastic bottles. Broadcast spectrum, one of nature's richest gifts, has been parceled out to industry and then sold back to the public.
>
> Our cultural abundance suffers the same fate. The ever-expanding reach of copyright has removed more and more art and ideas from the public domain. The Walt Disney Company happily built its film empire out of folk culture ("Snow White," "Pinocchio") but any folk who try to build on Disney can expect a "cease and desist" letter in the next mail. Patents are now used to create property rights in things once thought inalienable–seedlines, human genes, medicines long known to indigenous cultures. A company that makes jam recently got itself a patent on the crustless peanut butter-and-jelly sandwich.
>
> This period of market triumphalism has, in sum, seen a successful move to commercialize a long list of things once thought to have no price, and to enclose common holdings, both natural and cultural, that we used to assume no one was allowed to take private.

Broadening out the discussion beyond just scientific innovation, there appears to have been a sea change in the entire U.S. economy and society around the early 1970s. Economic analyses have shown that from the 1940s until around 1970, the United States experienced strong economic growth, and that growth was shared across all parts of the population. Those same economic analyses have demonstrated that from the 1970s onward, U.S. economic growth was often much weaker than in the preceding decades, and the rewards for what growth did occur were increasingly concentrated in the hands of the wealthiest individuals and companies [Carter Price and Edwards 2020; Saez and Zucman 2016].

It appears that as Cold War competition waned, the wealthiest individuals and their political allies no longer needed the broader population to help produce new innovations, share in their success and generated income, and mount a competition with the Soviet Union. Rather, they seem to have turned toward simply vacuuming up as much of the pre-existing innovations, resources, and wealth as possible, leaving the innovation system and the general populace to suffer a slow but steady decline from the 1970s onward.

D. Darwinian selection of researchers for traits other than innovation

As the United States began to abandon innovation-promoting practices like those from the earlier German-speaking world, from the 1970s onward the modern system came increasingly to value the sheer number of academic papers much more than their quality or significance. Since academic scientists were now rewarded with funding primarily based on their number of published papers rather than the scientific quality, originality, or importance of their work, labs that emphasized quantity over quality received more funding, trained more students, and graduated those students into the system to create their own labs that focused on quantity over quality. In a Darwinian fashion, within a few cycles of "reproduction," scientists who emphasized quantity over quality became vastly more numerous and much more powerful (as peer review committee members for research grant funding, hiring, and tenure decisions) than any remaining scientists who valued the quality, originality, and revolutionary importance of research.

Two scientists, Paul Smaldino and Richard McElreath, described the impact of Darwinian selection for traits other than revolutionary innovation, applied to generation after generation of professors and their students [Smaldino and McElreath 2016]:

> This paper argues that some of the most powerful incentives in contemporary science actively encourage, reward and propagate poor research methods and abuse of statistical procedures. We term this process the natural selection of bad science to indicate that it requires no conscious strategizing nor cheating on the part of researchers. Instead, it arises from the positive selection of methods and habits that lead to publication. How can natural selection operate on research methodology? There are no research 'genes'. But science is a cultural activity, and such activities change through evolutionary processes. Philosophers of science such as Campbell, Popper and Hull have discussed how scientific theories evolve by variation and selection retention. But scientific methods also develop in this way. Laboratory methods can propagate either directly, through the production of graduate students who go on to start their own labs, or indirectly, through prestige-biased adoption by researchers in other labs. Methods which are associated with greater success in academic careers will, other things being equal, tend to spread.
>
> The requirements for natural selection to produce design are easy to satisfy. Darwin outlined the logic of natural selection as requiring three conditions:
>
> (i) There must be variation.
>
> (ii) That variation must have consequences for survival or reproduction.
>
> (iii) Variation must be heritable.
>
> In this case, there are no biological traits being passed from scientific mentors to apprentices. However, research practices do vary. That variation has consequences—habits that lead to publication lead to obtaining highly competitive research positions. And variation in practice is partly heritable, in the sense that apprentices acquire research habits and statistical procedures from mentors and peers. Researchers also acquire research practice from successful role models in their fields, even if they do not personally know them. Therefore, when researchers are rewarded primarily for publishing, then habits which promote publication are naturally selected. Unfortunately, such habits can directly undermine scientific progress. [...]

> The rate at which new papers are added to the scientific literature has steadily increased in recent decades. This is partly due to more opportunities for collaboration, resulting in more multi-author papers. However, the increases in publication rate may also be driven by changing incentives. Recently, Brischoux & Angelier looked at the career statistics of junior researchers hired by the French CNRS in evolutionary biology between 2005 and 2013. They found persistent increases in the average number of publications at the time of hiring: newly hired biologists now have almost twice as many publications as they did 10 years ago (22 in 2013 versus 12.5 in 2005). These numbers reflect intense competition for academic research positions. The world's universities produce many more PhDs than there are permanent academic positions for them to fill, and while this problem has escalated in recent years, it has been present for at least two decades. Such competition is all the more challenging for researchers who graduate from any but the most prestigious universities, who face additional discrimination on the job market. Although there may be jobs available outside of academia— indeed, often better-paying jobs than university professorships—tenure-track faculty positions at major research universities come with considerable prestige, flexibility and creative freedom, and remain desirable. Among those who manage to get hired, there is continued competition for grants, promotions, prestige and placement of graduate students.
>
> Given this competition, there are incentives for scientists to stand out among their peers. Only the top graduate students can become tenure-track professors, and only the top assistant professors will receive tenure and high profile grants. [...]
>
> Incentives drive cultural evolution. In the scientific community, incentives for publication quantity can drive the evolution of poor methodological practices. We have provided some empirical evidence that this occurred, as well as a general model of the process. If we want to improve how our scientific culture functions, we must consider not only the individual behaviours we wish to change, but also the social forces that provide affordances and incentives for those behaviours. We are hardly the first to consider a need to alter the incentives for career success in science. However, we are the first to illustrate the evolutionary logic of how, in the absence of change, the existing incentives will necessarily lead to the degradation of scientific practices.
>
> An incentive structure that rewards publication quantity will, in the absence of countervailing forces, select for methods that produce the greatest number of publishable results. This, in turn, will lead to the natural selection of poor methods and increasingly high false discovery rates. Although we have focused on false discoveries, there are additional negative repercussions of this kind of incentive structure. Scrupulous research on difficult problems may require years of intense work before yielding coherent, publishable results. If shallower work generating more publications is favoured, then researchers interested in pursuing complex questions may find themselves without jobs, perhaps to the detriment of the scientific community more broadly. [...]
>
> Institutional change is difficult to accomplish, because it requires coordination on a large scale, which is often costly to early adopters. Yet such change is needed to ensure the integrity of science.

Other scholars have made very similar arguments about the perverse incentives warping academic research [Bhattacharya and Packalen 2020; Charlton 2009; Chu and Evans 2021; Ritchie 2020].

E. Political divisions that undermine government support for innovation

Severe political divisions in the United States arose by the late 1960s and have only worsened since then, undermining strong government understanding of, support for, and utilization of revolutionary innovation as had existed earlier. The science policy analysts Chris Mooney and Sheril Kirshenbaum described the impact on scientific innovation [Mooney and Kirshenbaum 2010, pp. 28–29]:

> Yet the heyday of science wouldn't last long. The trend of ever-rising federal investment in research reversed itself in the late 1960s; non-military science funding fell through much of the 1970s. The central involvement of the National Science Foundation in shaping high school educational curricula also gradually fell away—as did the prominence of the scientific elite in advising our leaders.
>
> All this occurred for a snarl of reasons that center on the collapse of political consensus in America over the same time period. The scientific community couldn't escape the conflicts of the day any more than any other major social group. The creation of new regulatory agencies, like the Environmental Protection Agency in 1970, repeatedly dragged scientific information into a contested decision-making process. And the growing antiwar and antinuclear movements flailed not only against the "military-industrial complex" but against those parts of the scientific establishment that worked with it or for it, especially on university campuses.
>
> Not only did the new mood of "questioning authority" include the questioning of science, but there was often good reason for skepticism. The environmental and consumer movements, spearheaded by the likes of Rachel Carson and Ralph Nader, brought home the realization that science wasn't always beneficial. Seemingly wonderful technologies—DDT, chlorofluorocarbons—could have nasty, unforeseen consequences. A narrative began to emerge about "corporate science": driven by greed, conducted without adequate safeguards, placing profits over people.
>
> Amid the backlash, the role of scientists in policy making also ebbed, as did the status of the presidential science advisor. Whereas the post had enjoyed a high level of recognition and influence under Eisenhower and Kennedy, the Vietnam War brought that cozy relationship to an end. In 1973, President Richard Nixon fired his science advisers outright over disagreements about the viability of the Supersonic Transport program and other matters.
>
> The emergence of the Religious Right onto the political stage in the 1970s—motivated in part by its adherents' resentment of the nation's intellectual and scientific elites—was also a major factor in curtailing the role of science in public policy. Soon battles between Christian conservatives and the science community over matters like the teaching of evolution and embryo-related research became an inescapable political reality. And so we entered the "culture wars": Secular, scientific, and pro-choice America clashed regularly with a "faith-based" (and very Republican) side of the country. A vast array of political issues could be cast in a pugilistic context that pitted "religion" against "reason." Science ceased to serve as a bulwark for common goals and purposes; instead, its findings came to divide us.

Other books have made similar arguments that increasing political divisions have fostered hostility toward scientists and the loss of innovation or even functionality within the scientific system [e.g., Gruber and Johnson 2019; Mooney 2006; Otto 2016]. By 2020, the consequences of these long-term trends in the United States were all too visible to the entire world.

F. Loss of consumer demand for innovation

Biologist Jan Vijg argued persuasively that the rate of revolutionary scientific innovation has greatly declined in recent decades, then offered his views on the causes of that decline. While the world at present may not be as nearly utopian as Vijg viewed it in 2011, his fundamental point seems sound: In contrast to circumstances that prompted revolutionary innovations in the past, currently there are not enough people with enough power who are sufficiently dissatisfied with the current state of technology to be strongly motivated to change it, and in fact many are strongly motivated to resist change [Vijg 2011, pp. 109–110]:

> The cold war is over and most current states profess support for democracy, the rule of law and a safety net for everyone. Almost all of us seem to have abandoned violence as a way to make progress. Representatives of the earth's states meet regularly and although we tend to think that nothing ever comes out of these meetings, the reality is that there are probably very few citizens who do not profit from the myriad of changes that slowly but surely transform us into a planet-wide commonwealth of states with almost unrealistically good credentials. Good governance, responsible industry leaders and better citizens slowly but irrepressibly take hold of society by creating a network of rules and regulations that make it all but impossible to run roughshod over others. People around the world are becoming healthier, wealthier, better educated, more peaceful, and increasingly connected, and they are living longer.
>
> Precisely because society is so successful, with technology maturing and all structures in place for optimally using it to the benefit of humankind, it has now become very difficult for new, breakthrough inventions to thrive. Investments are more likely in areas that have stabilized and proved their mettle, and regulatory constraints make it often very difficult for new inventions to get a fair chance at being implemented. This is especially true for medicine and biotechnology, two areas where scientific input should all but guarantee rapid progress. However, it also applies to the energy and transportation sectors where we witness a stalling of progress in strategic technologies. In spite of the hype in glossy magazines and the occasional newspaper article, to maintain the current fleet of passenger planes is simply too convenient and the days of Howard Hughes are definitely over. Surprisingly enough, this even applies to information technology where progress has helped us enormously to do the things we were already doing much quicker and in a much more convenient way than in the past. However, it does no longer break new ground and does not radically alter the way we live and work.
>
> In a sense, we have become a victim of our own success. The intricate net we have woven to protect each and every one of us from harm, to allow a maximum of input to everyone in decision making and to patiently listen to all arguments have turned us into the most successful society the world has ever seen. But paradoxically, this very success is now beginning to hold us back from making the further great strides to again transform human society, like the tremendous achievements of the 19^{th} and 20^{th} centuries did before.

G. Shift in the types of innovation that consumers demand

Both Nicholas Carr and Tyler Cowen proposed that the most financially lucrative demand for innovations has shifted from truly revolutionary technologies to mundane consumer products with annual cosmetic updates, "feel-good" products like Facebook and Prozac, and non-technological products for the very wealthy [Carr 2015; Cowen 2011].

Wall Street Journal writer and book author Nicholas Carr argued that the apparent slowdown in revolutionary innovations is largely driven by consumers who are more interested in "technologies of the self" than in more world-changing technologies [Carr 2012, 2015]. Carr's thesis has significant overlap with Jan Vijg's argument (modern society is sufficiently comfortable that innovation is no longer a priority). Carr explained his viewpoint with an essay [Carr 2015] and an accompanying diagram (redrawn in Fig. 11.76):

> Let me float an alternative explanation: There has been no decline in innovation; there has just been a shift in its focus. We're as creative as ever, but we've funneled our creativity into areas that produce smaller-scale, less far-reaching, less visible breakthroughs. And we've done that for entirely rational reasons. We're getting precisely the kind of innovation that we desire—and that we deserve.
>
> My idea—and it's a rough one—is that there's a hierarchy of innovation that runs in parallel with Abraham Maslow's famous hierarchy of needs. Maslow argued that human needs progress through five stages, with each new stage requiring the fulfillment of lower-level, or more basic, needs. So first we need to meet our most primitive Physiological needs, and that frees us to focus on our needs for Safety, and once our needs for Safety are met, we can attend to our needs for Belongingness, and then on to our needs for personal Esteem, and finally to our needs for Self-Actualization. If you look at Maslow's hierarchy as an inflexible structure, with clear boundaries between its levels, it falls apart. Our needs are messy, and the boundaries between them are porous. A caveman probably pursued self-esteem and self-actualization, to some degree, just as we today spend effort seeking to fulfill our physical needs. But if you look at the hierarchy as a map of human focus, or of emphasis, then it makes sense—and indeed seems to be born out by history. In short: The more comfortable you are, the more time you spend thinking about yourself.
>
> If progress is shaped by human needs, then general shifts in needs would also bring shifts in the nature of technological innovation. The tools we invent would move through the hierarchy of needs, from tools that help safeguard our bodies on up to tools that allow us to modify our internal states, from tools of survival to tools of the self. Here's my crack at what the hierarchy of innovation looks like [...]:
>
> The focus, or emphasis, of innovation moves up through five stages, propelled by shifts in the needs we seek to fulfill. In the beginning come Technologies of Survival (think fire), then Technologies of Social Organization (think cathedral), then Technologies of Prosperity (think steam engine), then technologies of leisure (think TV), and finally Technologies of the Self (think Facebook, or Prozac).

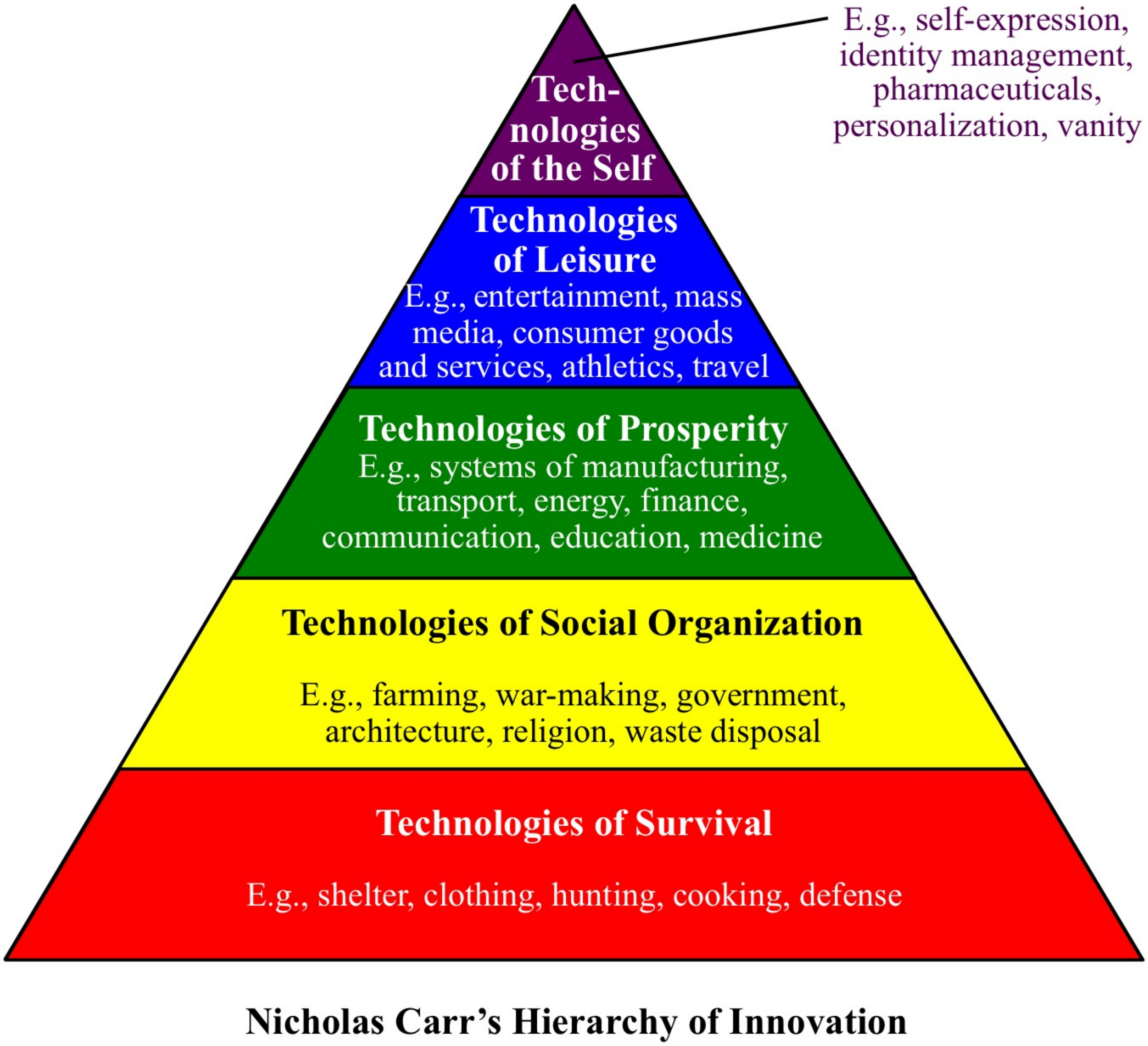

E.g., self-expression, identity management, pharmaceuticals, personalization, vanity
Technologies of the Self
Technologies of Leisure
E.g., entertainment, mass media, consumer goods and services, athletics, travel
Technologies of Prosperity
E.g., systems of manufacturing, transport, energy, finance, communication, education, medicine
Technologies of Social Organization
E.g., farming, war-making, government, architecture, religion, waste disposal
Technologies of Survival
E.g., shelter, clothing, hunting, cooking, defense
Nicholas Carr's Hierarchy of Innovation

Figure 11.76: Nicholas Carr's proposed "hierarchy of innovation" [redrawn based on Carr 2015].

> As with Maslow's hierarchy, you shouldn't look at my hierarchy as a rigid one. Innovation today continues at all five levels. But the rewards, both monetary and reputational, are greatest at the highest level (Technologies of the Self), which has the effect of shunting investment, attention, and activity in that direction. We're already physically comfortable, so getting a little more physically comfortable doesn't seem particularly pressing. We've become inward looking, and what we crave are more powerful tools for modifying our internal state or projecting that state outward. An entrepreneur has a greater prospect of fame and riches if he creates, say, a popular social-networking tool than if he creates a faster, more efficient system for mass transit. The arc of innovation, to put a dark spin on it, is toward decadence.

> One of the consequences is that, as we move to the top level of the innovation hierarchy, the inventions have less visible, less transformative effects. We're no longer changing the shape of the physical world or even of society, as it manifests itself in the physical world. We're altering internal states, transforming the invisible self. Not surprisingly, when you step back and take a broad view, it looks like stagnation—it looks like nothing is changing very much. That's particularly true when you compare what's happening today with what happened a hundred years ago, when our focus on Technologies of Prosperity was peaking and our focus on Technologies of Leisure was also rapidly increasing, bringing a highly visible transformation of our physical circumstances.

Economist Tyler Cowen noted the decline in innovation and attributed it to several factors [Cowen 2011]. Most prominently, he said that the United States had already consumed all of the low-hanging fruit of technologies that could be readily developed. When viewed from the perspective of the history of science, it would seem unlikely that Cowen's argument is truly correct, that there truly are no more potential new technologies within humanity's current reach. For example, the classical world overlooked Hero's steam engine and its revolutionary potential, the steam era overlooked both gasoline internal combustion engines and the electrical revolution, nineteenth century physics overlooked both relativity and quantum physics, and classical biology overlooked the mechanisms and potential applications of DNA. If the rate of revolutionary innovations has slowed, it seems far more probable that the slowdown is due much more to deficiencies in the current innovation system, rather than to the actual absence of potential new technologies within our grasp.

On the other hand, if a large fraction of our modern technologies originated from the earlier German-speaking research world (as described in this book), then a somewhat more narrow interpretation of Cowen's argument could be quite valid. The United States plucked the low-hanging fruit of inventions and discoveries made in the earlier German-speaking world, took those creations to their fullest potential, and greatly profited from them, but never invested sufficient money, time, and energy to grow large amounts of entirely new fruit for future harvests.

Cowen's other explanations are also enlightening: Innovation shifted first from truly revolutionary technologies to more easily developed, easily marketed consumer products, and then from widely useful (if mundane) products to dubious "innovations" that only benefit a chosen few, sometimes even at the expense of everyone else [Cowen 2011, pp. 7–10, 20–21]:

> In a figurative sense, the American economy has enjoyed lots of low-hanging fruit since at least the seventeenth century, whether it be free land, lots of immigrant labor, or powerful new technologies. Yet during the last forty years, that low-hanging fruit started disappearing, and we started pretending it was still there. We have failed to recognize that we are at a technological plateau and the trees are more bare than we would like to think. That's it. That is what has gone wrong. [...]
>
> Around the globe, the populous countries that have been wealthy for some time share one common feature: Their rates of economic growth have slowed down since about 1970. That's a sign that the pace of technological development has been slowing down. It's not that something specific caused the slowdown, but rather we started to exhaust the benefits of our previous momentum without renewing them. [...]
>
> The period from 1880 to 1940 brought numerous major technological advances into our lives. [...]

> Today, in contrast, apart from the seemingly magical internet, life in broad material terms isn't so different from what it was in 1953. [...] Life is better and we have more stuff, but the pace of change has slowed down compared to what people saw two or three generations ago.
>
> It would make my life a lot better to have a teleportation machine. It makes my life only slightly better to have a larger refrigerator that makes ice in cubed or crushed form. We all understand that difference from a personal point of view, yet somehow we are reluctant to apply it to the economy writ large. But that's the truth behind our crisis today—the low-hanging fruit has been mostly plucked, at least for the time being. [...]
>
> A fundamental way to put the point is this: *A lot of our recent innovations are "private goods" rather than "public goods."* Contemporary innovation often takes the form of expanding positions of economic and political privilege, extracting resources from the government by lobbying, seeking the sometimes extreme protections of intellectual property laws, and producing goods that are exclusive or status related rather than universal, private rather than public; think twenty-five seasons of new, fall season Gucci handbags.
>
> The dubious financial innovations connected to our recent financial crisis are another (perhaps less obvious) example of discoveries that benefit some individuals but are not public goods more generally. A lot of the gains from recent financial innovations are captured by a relatively small number of individuals.

Note that there is considerable overlap among the economics-based arguments of Tyler Cowen, Nicholas Carr, and Jan Vijg: the **supply** of truly revolutionary scientific innovations is much less now because there has been an insufficiently strong and insufficiently widespread **demand** for revolutionary scientific innovations.

Summary of decline

As a final perspective on how much the U.S. innovation system has changed, in 1940 MIT professor Vannevar Bush showed President Franklin Roosevelt a one-page proposal outlining his multi-year, multi-billion-dollar plan for a new federally funded R&D system that would include the Manhattan Project, radar, and all other defense-related research projects. Roosevelt heard and approved the proposal in less than 15 minutes [Zachary 1997a, p. 112].

In contrast, nowadays even a professor's $100,000 proposal to the National Institutes of Health for modest experiments by some graduate students involves writing a detailed grant application that may be over 100 pages long, consumes several person-months to assemble, requires submitting extensive data and references to prove that the proposed experiments will definitely produce the intended results before they are even officially begun, can take over a year to pass through NIH administrative offices and peer review committees, and might stand less than a 10% chance of being funded after all of that. (Moreover, the very low success rate of proposals means that a research group might have to write 10 or more such proposals each year in hopes of getting just one funded, and writing that many proposals every year is a truly massive and enormously expensive diversion of personnel away from doing any of the actual research described in the proposals.)

Chapter 12

Learning from the Creators

Ich habe auf eine geringe Vermuthung eine gefährliche Reise gewagt und erblicke schon die Vorgebürge neuer Länder. Diejenigen, welche die Herzhaftigkeit haben die Untersuchung fortzusetzen, werden sie betreten und das Vergnügen haben, selbige mit ihrem Namen zu bezeichnen.

Upon a small conjecture I have ventured on a dangerous journey and already behold the foothills of new lands. Those who have the courage to continue the quest will enter those lands and have the joy of putting their name on them.

Immanuel Kant. 1755.
Allgemeine Naturgeschichte und Theorie des Himmels, Vorrede
[*Natural History and Theory of the Heavens*, Foreword].

Section 12.1 summarizes the major findings of Chapters 1–11.

Section 12.2 then applies that information to offer suggestions for:

> 12.2.1. Whole state or national innovation systems that would like to increase their production of revolutionary research.
>
> 12.2.2. Individual companies, organizations, or laboratories that would like to pursue more innovative research.
>
> 12.2.3. Individuals now trying to pursue careers in innovative research in the existing state of the global system.
>
> 12.2.4. Scholars who would like to further study the past, present, and potential future of revolutionary creators and creations.

Finally, Section 12.3 presents an afterword to encapsulate the vision for this book.

12.1 Summary of the Creators, Their Creations, and Their Approaches

As covered in Chapter 1, the motivation for this study follows from a series of logical steps, with many accompanying assumptions and limitations that are freely acknowledged (see Section 1.2.3 for a much longer and more detailed list):

1. Based on data and analyses from authors cited in Section 1.1, compared to earlier times, the modern research system appears to have produced fewer revolutionary innovations per year, or at least fewer revolutionary innovations per year per person in the system, or fewer innovations per year per amount of money spent on the system. (This study does not argue that the modern research system has produced no revolutionary innovations.)

2. Having concluded that the modern innovation rate has declined, this study proceeds on the assumption that it is possible that the modern innovation rate **can** be increased, or in other words that we have not simply encountered physical limits on innovation.

3. Moreover, this study operates on the assumption that the modern innovation rate **should** be increased, or the belief that at least on balance, new innovations will improve people's lives and are morally and socially desirable.

4. Rather than trying to reinvent the wheel, this study focuses on examining already proven ways to promote innovation. It does not consider new, unproven methods to promote innovation, although other scholars certainly should propose and evaluate new methods as well.

5. Among those proven ways to promote innovation, this study specifically considers past innovation systems. (Nevertheless, other scholars should and are evaluating various current innovation systems worldwide, and there is much to learn from those studies.)

6. Out of all past innovation systems, this study focuses on the predominantly German-speaking world of the nineteenth and early twentieth centuries, which admittedly is a topic with very fuzzy spatial, temporal, and intellectual boundaries. Based on the evidence in Chapters 2–9 and the appendices, I believe that world was the most innovative; at the very least it was **one of** the most innovative systems and thus worthy of detailed examination. This study is not intended to make an argument for nationalist or ethnic bragging rights. I highly recommend that readers of this book seek out or even conduct their own studies of scientific innovations from other places and times.

7. This study assumes that we can identify useful methods that promoted innovation in the earlier German-speaking world, yet it is at best a concise overview of a vast field encompassing the actions of thousands of scientists and engineers across many countries during two centuries, as well as investigations into that time period by countless subsequent scholars. I do not mean to imply that innovation systems in the earlier German-speaking world were ever perfect or even unique, or that all of their innovation-promoting factors could or should be applied to the modern world. In no way is this study an argument that the Third Reich had inherently superior scientific research approaches. For reasons of length, this study cannot even begin to address the large number of related ethical questions that are already covered in detail

by many other authors; I highly recommend that all readers seek out those books and study them.[1]

8. The ultimate objective of this study is to make these methods of improving innovation available to the modern world. In order to maximize the potential audience, longevity, and impact of this study, I decided to make the final document freely available on the internet instead of publishing it as a printed book, which might be expensive and difficult to obtain and might rapidly go out of print, as so many of the cited references have.

9. Because the body of information on German-speaking innovators is both so large and so incomplete, this book cannot help but be incomplete and imperfect. I would welcome any suggestions for improvements to future editions. At the very least, hopefully this book will spur discussion, learning, and further work in the important areas that it covers.

Scientists and engineers who were trained in the German-speaking world of the nineteenth and early twentieth centuries produced a wide range of discoveries and inventions that have shaped our modern world, including:

- Biomedical advances from genetics to antibiotics (Chapter 2 and Appendix A)
- Chemical breakthroughs from color film to synthetic rubber (Chapter 3)
- Discoveries about the Earth and our universe from continental drift to stellar distances (Chapter 4)
- Revolutionary physics from relativity to quantum mechanics (Chapter 5)
- Electrical inventions from semiconductors to computers (Chapter 6 and Appendices B–C)
- Mechanical systems from automobiles to submarines (Chapter 7)
- Nuclear reactions and applications from fission to fusion (Chapter 8 and Appendix D)
- Aerospace vehicles from jet planes to moon rockets (Chapter 9 and Appendix E)

Although other authors have studied the history of some of those creations and creators in detail, and Chapters 2–9 and the appendices shed additional light on others, much more work is needed to elucidate the full range and details of the contributions made by the German-speaking research world.

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[1] E.g., Bar-Zohar 1967; Beyerchen 1977; Black 2012a, 2012b, 2017; Borkin 1978; Bower 1987; Campbell and Harsch 2013; Cornwell 2003; Crim 2018; Deichmann 1996; Joseph Fisher 2017; Friedrich et al. 2017; Geissler 1998a, 1998b, 1999; Gellermann 1986; Georg 2012; Gimbel 1986, 1990a, 1990b, 1990c; Gröhler 1989; Guillemin 2005; Friedrich Hansen 1993; István Hargittai 2006; Harris Paxman 2002; Haunschmied et al. 2007; Hayes 2001; Heim et al. 2009; Hentschel and Hentschel 1996; Linda Hunt 1991; Jacobsen 2014; Jeffreys 2008; Karlsch and Laufer 2002; Kaszeta 2020; Kater 1989; Keynes 2019; Klee 2001; Kurowski 1982; Lasby 1971; Leff 2019; Le Maner and Sellier 2001; Julian Lewis 2002; Lichtblau 2014; Macrakis 1993; Milton Mayer 2017; Medawar and Pyke 2000; Mick 2000; Nachmansohn 1979; Nash 2013; Michael Neufeld 1995, 2002, 2003, 2007; Plumpe 1990; Posner and Ware 2000; Pringle 2006; Renneberg and Walker 1993; Sasuly 1947; Schambach 2011; Sellier 2003; Simpson 1988; Spitz 2005; Stoltzenberg 1994, 2005; Sutton 1976; Szöllösi-Janze 2001, 2015; Tucker 2006; Wachsmann 2015; Bernd Wagner 2000; Jens-Christian Wagner 2011, 2015; Wallace 2004; Whitman 2018.

As discussed in Chapter 10, one may identify common factors within the German-speaking world that facilitated the success of those creators and creations. These factors promoted greater freedom to pursue longer-term and riskier potential innovations, and they included:

1. Science was socially glorified, from children's activities and amateur science clubs to prestigious jobs and government-lauded scientific heroes.
2. A century-long steady exponential increase in funding gave scientists, employers, and sponsors much more freedom to pursue higher-risk and/or longer-term research.
3. Many Ph.D. students were encouraged to propose their own research topics and to pursue them independently.
4. Scientists received their final degrees nearly a decade earlier in life, and independent research funding up to two decades earlier, than modern scientists do.
5. Scientists who made major contributions to multiple disciplines, and fraternization among scientists from different disciplines, were much more common than in the modern world.
6. Instead of peer review, an autocratic yet farsighted scientific management culture of "enlightened despots" granted stable jobs and funding to the most promising creators and creations.
7. Both scientists and sponsors used a systems analysis approach to focus on the most important problems and the most effective innovations to address those problems.
8. The lack of natural resources spurred the creation of a wide range of innovative alternatives.
9. International rivalry (both economic and military) was a powerful driving force for innovation.
10. German-speaking companies were less afraid of losing their own innovations to each other than of being outstripped by foreign countries, giving them a strong motivation to innovate.

From Chapter 11, the modern world eagerly adopted the creations of the earlier German-speaking world, yet ultimately largely forgot both the creators and the systemic approaches that had made such creations possible. Over the course of waves that occurred before, during, and after the Third Reich, all of the creations, most of the creators, and some of the systemic approaches were transferred from the German-speaking world to the United States and other countries in a German scientific diaspora. Those countries spent many decades fully perfecting and mass-producing the innovations that had been created by the earlier German-speaking world, resulting in our modern world of jet aircraft, electronics, and pharmaceuticals. Most of the creators who had already died or who remained in German-speaking areas were largely forgotten by the non-German-speaking world, which often mistakenly attributed their creations to whichever non-German-speaking individuals or organizations had acquired their technical information. Most of the creators who emigrated out of German-speaking areas led well-funded but quiet lives perfecting their creations and were also ultimately forgotten; only a few, such as Albert Einstein, Edward Teller, and Wernher von Braun, sought or received lasting fame. Especially during the 1940s–1960s, the United States and other countries practiced some of the general approaches that had made the earlier German-speaking world successful, thereby cultivating new innovators and innovations of their own.

By the 1970s, most of the German-speaking creators had retired or died, their creations had been refined to the point of diminishing incremental returns, and global research systems had abandoned most of the German-like practices they had adopted, significantly reducing their efficiency at producing entirely new innovators and innovations. The Cold War as a strong motivating force for innovation had also greatly relaxed around 1970, and most of the truly revolutionary new innovators (or innovations) that were produced by the global research system found it increasingly difficult to obtain proper support as time went by. From the 1990s onward, with the Cold War over and officials both public and private haggling over every research dollar while spending recklessly in other areas, the academic, corporate, and government research sectors each became increasingly dysfunctional in their own ways. As a result, even though the modern world has far more researchers, funding, and political stability than the earlier German-speaking world, it is difficult to identify as many revolutionary innovations that have been wholly developed by that modern system as those examples listed in Chapters 2–9 and Appendices A–E.

In 1946, the U.S. Department of Commerce wrote a press release that compared the German and U.S. approaches to research and explained what the United States could learn from the German model (see p. 5067). Most of those observations are still highly relevant three-quarters of a century later [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases, The Chemical Problem in Germany]:

> The picture in scientific and chemical fields of development has long been very competitive and often retarded by the lack of financial assistance. Many of the industries of the United States while progressive on the production line have been quite willing to accept the benefit of the research and development of others, but not bothering to maintain research units of their own.
>
> Many of the chemical achievements now in use are the result of the research and development accomplished in other countries. While the United States enjoys the privilege of a school system that can and does provide numbers of young scientists, well versed in their particular fields, few are employed by industry at salaries commensurate with their skill. Consequently, the young scientific mind resolves the problem as one of mis-selection [of a career], so therefore, seeks and obtains more remunerative positions outside of their field causing a complete dislocation of their academic achievements.
>
> The German government and German industry had an entirely different attitude toward their scientifically trained men. The research and development work accomplished in the past decade will attest the value of subsidizing the scientists in the form of annuities and awards, not only for completed work but generous support of an idea from its embryonic imaginary state, through the laboratories, pilot plant, to the final production stage.
>
> In an emergency such as this country has just passed through, the United States was very fortunate that it could and did regiment the outstanding scientific brains of the country to undertake the modernization of the materials and warfare. Production lines and basic raw materials plus natural resources played as important a part as did science, yet one without the other would and could have proved quite ineffectual.
>
> The German industry and their subsidized scientists early realized that their natural resources were insufficient and the raw materials that could be imported would not be depended upon, nor were they readily obtainable. The problem was placed before

the German scientist, with the result that synthetic materials were produced, such as the industries in the United States never considered feasible, profitable, probable or possible.

Research and development work in Germany was concentrated in the larger industries of the I. G. Farbenindustrie caliber by grants made to the teaching staffs of universities and scientists of independent laboratories. The larger industries in turn were subsidized or controlled by the government.

Many tens of millions of dollars were expended in the U.S., not lavishly nor extravagantly during the war years, but much of the monies thus expended could have been more advantageously used had the work of research and development been protracted rather than immediately required as a war expedient. [...]

The inherent German love of gadgets, these investigators found, has produced a nation of gadgeteers and inventors. This is fostered by broad thorough elementary education in the mechanical and manual arts and by their system of apprenticeship training and has largely been instrumental in bringing about German development. [...]

The investigators were deeply impressed by the large pool of skilled mechanics upon whom Germany could draw. Their system of training the youth in mechanics, and shop practice, and familiarizing them with all kinds of modern tools had much to do with Germany's ability to wage such a devastating war against so many powerful nations. The same abilities and skills could be used for the increased production of the civilian products needed in peaceful pursuits. [...]

The most striking feature of the work the Germans performed for the development of their war material is undoubtedly the extremely high scientific order of their researches. In many fields they were pioneering and the outstanding results they achieved may, beyond doubt, be attributed to the long range provisions and the scientific approach on which they based their programs and the wealth of refined solutions they investigated in their research laboratories with the well-known German thoroughness.

12.2 Lessons from the Creators

Based on the perspective accumulated in Chapters 1–11, this section will offer suggestions for state or national innovation systems that would like to increase their production of revolutionary research (Section 12.2.1), for individual organizations or laboratories that would like to pursue more innovative research (Section 12.2.2), for individuals now trying to pursue careers in innovative research in the existing state of the global system (Section 12.2.3), and for scholars who would like to further study the past, present, and potential future of revolutionary creators and creations (Section 12.2.4).

12.2.1 Lessons for State, National, and Global Innovation Systems

Just as the nations of the earlier German-speaking world, as well as the United States during the 1940s–1960s, adopted policies that bred, supported, and rewarded revolutionary innovators and innovations, a modern nation or the entire global system could implement some of those proven policies. Many of these methods could even be adopted by an individual state (such as California or Massachusetts) within a nation. Based on the analysis of the earlier systems in Sections 10.2 and 11.2, those policies that a modern state or nation could consider (suitably adapted for modern times) include:

1. Science, science teachers, and science researchers were idolized and well funded in the German world, and also during the 1940s–1960s in the U.S. system, from children's activities and amateur science clubs to prestigious jobs and government-lauded scientific heroes. The social and financial status of science, science teachers, and science researchers should be elevated greatly beyond where they currently are in the modern world:
   (a) Better quality and greater variety of educational science experiment kits for children should be produced and more widely advertised and used.
   (b) Student science competitions (especially ones like science fairs that emulate real scientific research) should be given much greater emphasis, and the winners of those competitions should be publicly praised and rewarded at least as much as student athletes.
   (c) The salaries and working conditions of science and other teachers should be improved in order to attract very talented people to those positions and to recognize and reward the most effective teachers.
   (d) Important new scientific discoveries and inventions should be given much more coverage (comparable to or greater than that of sports stars and popular culture celebrities) in television news programs, movies, online video and audio programs, newspapers, magazines, and popular internet sites.
2. The highly innovative German-speaking world experienced exponential growth of research funding throughout its entire history until 1945, and the very productive period of the U.S. system during the 1940s–1960s also had exponential funding growth. Much greater freedom from funding pressures during those periods promoted much greater freedom to support longer-term, higher-risk, and potentially revolutionary innovators and innovations.
   (a) Although exponential funding growth cannot continue indefinitely, many nations or states could certainly afford to invest much more of their money in advanced research

and development than they do currently. For example, U.S. federal funding for R&D as a percent of GDP in 2017 was only around one-third of what it had been in the 1960s, and is expected to continue to decline.

(b) Even without having permanent exponential funding growth, governments could implement policies that would emulate the most important effects of such growth. Specifically, the number of graduating students trained in science research should be very close to the number of available permanent job positions, as it has been during periods of exponential funding growth, not far larger than the number of available permanent job positions as it is now.

(c) Increasing the number of temporary positions such as postdoctoral positions and internships would only put more young scientists into a holding pattern without either solving the fundamental mismatch between the number of scientists and the number of permanent jobs, or allowing those scientists to be independently productive.

(d) If the number of permanent job positions cannot be increased due to national fiscal constraints, the number of graduating students seeking science and engineering research careers should be decreased by motivating some students to seek other majors and other jobs, while still strongly encouraging the most creative students to pursue majors and careers in science and engineering research.

(e) If the amount of available funding and permanent job positions better matched the number of graduating students and career researchers, scientists would be able to spend much more of their time and energy doing productive research, and much less of their time and energy pursuing elusive funding and positions.

(f) If the amount of available funding and permanent job positions were much closer to the number of graduating students and career researchers, it would be much more acceptable to sponsors, institutions, and the scientists themselves for researchers to pursue longer-term work without an immediately demonstrable payoff, as well as more innovative higher-risk work that would be less guaranteed to yield results than very incremental, low-risk work. It would be much easier for the system to gamble that some of the funded researchers and projects would ultimately pay off and some would not, and to deem those stakes acceptable.

(g) Just as the above steps would increase freedom for academic and government researchers to pursue longer-term and higher-risk research, government could take steps to promote more long-term and/or higher-risk research in companies as well. Improved tax, patent, regulatory, or other government incentives could make it much more advantageous for companies to spend more of their money on research, and much more lucrative for the first company that develops any given major innovation, thereby encouraging companies to invest more of their capital in research, and specifically to put a greater fraction of it into longer-term, more innovative R&D.

(h) To conclude this topic, increased funding can be helpful but is not sufficient by itself. Doubling the R&D spending would not do much good if that simply yielded twice as many esoteric and repetitious papers in publicly inaccessible journals from academia, twice as many smart phone apps and erectile dysfunction pills from industry, and twice as much bureaucracy at government laboratories. The most important factor is not just providing more money, but rather providing scientists more freedom from the burden of proposals, from career woes, from the present focus on short-term results, and from the current bias toward very low-risk work.

3. Many German-speaking students were trained from an early age to be very creative and self-reliant researchers and inventors. Once they reached the universities, many (though certainly not all) German-speaking students were actively encouraged to come up with their own original Ph.D. thesis topics and to pursue that research independently, with loose mentorship from their Ph.D. advisors. That seems to have been true to some extent in the early U.S. system as well. In contrast, most modern U.S. students come up through an assembly line of rote science classes, are finally assigned a specific thesis topic and methods by their Ph.D. advisor, and then spend multiple postdoc jobs doing specific assigned work as well. If and when those scientists finally obtain an independent position, they do not have any expertise proposing and conducting truly innovative research.

    (a) Olympic gymnasts and concert pianists train from a very early age for their ultimate goal. It would be ludicrous to expect young people to simply watch Olympic gymnasts or concert pianists from the sidelines for decades, then finally step on stage for the first time in their 40s and be successful Olympic gymnasts or concert pianists themselves. It is equally ludicrous for the modern scientific system to hope to train revolutionary scientific innovators in that same fashion.

    (b) Science students in the modern world should be trained from an early age to be very creative and self-reliant researchers, using methods such as science kits for younger children and science fairs for older children, as already mentioned.

    (c) For university theses, students should be allowed and in fact strongly encouraged to select their own research topic and methods.

    (d) Research advisors should provide as much advice and assistance as is necessary (but only what is necessary) to ensure that their students are pursuing productive research topics using suitable methods.

    (e) Research advisors at universities should not use students as unpaid or low-wage labor to benefit the advisors' own research grants or lists of publications. Rather, advisors should do their own research work themselves, or hire actual paid employees to help them do the work.

4. Scientists in the earlier German-speaking world received their final degrees approximately a decade earlier in life, and independent research funding up to two decades earlier, than modern scientists do. Scientists in the early U.S. research system also received their degrees and funding earlier than modern scientists, although not as early as those in the former German-speaking world.

    (a) The average age at which scientists receive their final degree and are able to work independently should be greatly reduced. Lowering that age back toward the early to mid-twenties now would increase the number of years during which scientists could be productive, and in particular it would greatly increase the number of youthful working years during which those scientists have the greatest creativity, the most energy, and the fewest non-research obligations.

   (b) The average age at which scientists receive their Ph.D. should be lowered by decreasing the redundancy between high school and undergraduate courses, streamlining graduate education, and making sure that graduate research is shorter and more focused on a Ph.D. thesis (not work by the graduate student on unrelated projects and papers that primarily benefit the thesis advisor or that simply pad the student's résumé for an overly competitive job market).

   (c) The average age at which Ph.D. scientists obtain their first real job position and their own research funding should be lowered by eliminating postdoctoral positions and internships. That change would allow new doctoral graduates to proceed directly to stable, well-paying jobs where they could be maximally creative and productive. Although institutions may claim that postdoctoral positions provide valuable mentoring to young scientists, in practice the postdoctoral positions are much more about providing a pool of highly skilled, low-wage labor to lab supervisors than any essential mentorship or further education.

5. Individuals who made major contributions to multiple disciplines, and routine fraternization among individuals from different disciplines, were rather common in the German-speaking world, and still occurred quite a bit in the early U.S. research system. In this modern era of microspecialization, the older interdisciplinary mindset should be revived and rewarded:

   (a) The modern world should train, support, and reward at least some percentage of multidisciplinary scientists who can make major contributions in multiple fields, apply knowledge and methods from one field to another, and use their broader view to guide fields of research away from less productive areas and toward more productive ones.

   (b) All scientists should be strongly encouraged to make their research comprehensible to people outside their field, and to interact with scientists in other fields in a variety of environments. Increased interactions among individuals from different disciplines would also help cross-pollinate ideas among different fields, and help scientists in different fields obtain greater perspective.

6. In the German-speaking world and the early U.S. research system, "enlightened despots" were able to spot potentially revolutionary innovators and innovations and grant them long-term financial and political support. While there is certainly a place for methodical peer review, entrusting virtually all funding and hiring decisions to peer review risks overlooking those creative new scientists and ideas that are so revolutionary that they cannot easily and immediately get broad consensus from the scientific status quo.

   (a) Rather than allotting all funding (and effectively most jobs) by peer review, the modern research system should set aside some percentage of research funding to be allocated by enlightened despots who are good at identifying potentially revolutionary innovators and innovations.

   (b) Such enlightened despots should have the clear authority to grant financial and political support to any people or projects they deem worthy, and to grant that support for many years without having to demonstrate that there is an immediate payoff, or even that all funded research will eventually pay off.

   (c) How enlightened despots with the best discernment would be selected is an unresolved question. In both the German-speaking world and the early U.S. research system, they either arrived at their positions by some combination of luck and force of will, or else they were hand-picked by previously established enlightened despots. Those methods are not perfect but could be tried now, or perhaps a better way to select the best enlightened despots could be found.

   (d) Wherever possible, any remaining peer review should be done by reviewers unaware of the researchers' names and affiliations, so that they can more fairly evaluate the actual research in question.

7. In the German-speaking world and in the early U.S. research system, a systems analysis approach was used to great effect in order to identify the most important problems and the most effective innovations to address those problems, and to help focus scientific personnel and funding in those directions. This systems analysis approach was employed by both scientists and sponsors. In contrast, the modern world appears to be too subject to the whims of vast numbers of self-interested individuals whose overriding priority is to maximize outputs other than innovation, such as their number of publications or their stock price. It would be beneficial to re-emphasize a systems analysis approach.

   (a) Systems analysis should be widely taught and practiced in schools and universities.

   (b) By using systems analysis, key decision makers in government, industry, and academia could help focus more resources on the most important problems and potential solutions.

   (c) If individual scientists were taught to practice systems analysis, they could use that method to guide their careers and their research projects in more promising directions, and to ensure that no potentially useful regions of the conceptual "phase space" had been overlooked.

8. The very limited availability of natural resources was a major factor in driving innovation in the German-speaking world. It was much less of a factor in the early U.S. research system, although the United States did adopt many of the synthetic products that had been developed in the earlier German-speaking world.

   (a) Now that the world is much more conscious of its dwindling natural resources and the rising long-term costs of climate change, pollution, and waste, government-funded programs and government regulations for industrial programs should prioritize the development of very innovative methods of reducing the consumption of natural resources and minimizing the creation of waste products.

   (b) Such policies would not only improve the environment in which we and future generations must live, but would also be a strong driver of a wide range of new and very beneficial innovations.

9. International rivalry, largely military but also economic, was the driving force behind the historical German-speaking world and the early U.S. research system. Without seeking a return to militarism and war, a healthy sense of competition among states or nations could be useful:

   (a) Peaceful economic rivalry and even regional pride (as in sports competitions) could be employed constructively to motivate states or nations to accelerate their research and development programs.

   (b) Existing high-tech innovation centers (small geographical areas in which R&D is concentrated) that support and promote interactions among programs they contain could be strengthened, and rival high-tech centers could be created to compete for the best scientists, projects, research funding, and economic income from resulting inventions and products. [See Gruber and Johnson 2019 for a strong and detailed argument for many regional high-tech innovation centers.]

10. For more than a century, German-speaking companies were much more afraid of being outstripped by foreign countries than of losing their own innovations to each other. Likewise, in the 1940s–1960s, U.S. companies were much more afraid of losing first to the Axis countries and then to the Soviet Union than to each other. In both cases, that mindset toward competition gave the companies a strong motivation to innovate.

    (a) Companies should view very innovative, longer-term R&D as a worthwhile investment in staying ahead of competitors, not a financial liability whose resulting products could be copied by competitors that did not have to spend any money on their own R&D.

    (b) Improved tax, patent, regulatory, or other government incentives could make it much more lucrative for the first company that develops any given major innovation, and/or less lucrative for copycats.

    (c) Suitably structured tax incentives could also provide strong inducements for companies to put much more of their capital and annual income into research and development (and other useful things, including infrastructure and employee salaries/benefits), instead of enormous cash and stock payouts that only benefit a small number of individuals.

12.2.2 Lessons for Individual Organizations and Laboratories

While it might be difficult to persuade an entire nation to reform its scientific system, individual universities, companies, government laboratories, or other organizations could readily adopt certain practices related to those that made the older German-speaking world so successful.

Many of the strategies already listed in Section 12.2.1 could be implemented in a scaled-down, much more local fashion:

1. An organization should do anything within its power to improve the social and financial status of science research. An organization should strongly encourage, support, recognize, and reward innovative research among its own members. It should also promote its scientific innovation and accomplishments to the outside world, and sponsor educational science programs and student competitions in the outside world. The costs of these internal and external promotional programs would be handsomely repaid by both the increased productivity of the organization's own members and the organization's enhanced prestige and desirability as viewed by the outside world.

2. Universities should better match the number of graduating students and career researchers with the amount of funding and permanent job positions, so that scientists do not waste much of their time and energy pursuing elusive funding and positions. With a better balance between people and jobs, and therefore reduced pressure for all job occupants to have maximum short-term productivity, each organization should make room for at least some of its members to spend at least some of their time pursuing longer-term work without an immediately demonstrable payoff, as well as more innovative higher-risk work that would be less guaranteed to yield results than very incremental, low-risk work. While some of those bets would not pay off, others could pay off with revolutionary results that could prove highly lucrative over the long run.

3. In individual organizations from K-12 programs and universities to companies and government laboratories, young scientists should be trained from the very beginning to be creative and self-reliant researchers. Such investments of time, resources, and institutional trust in the younger scientists could ultimately yield very large returns.

4. Individual universities should implement programs in which the average age at which scientists receive their doctoral degrees is in their early to mid-twenties; such programs would be so attractive to students that those universities would have their pick of the best applicants. Organizations should also implement programs to provide jobs and stable funding for extremely young but highly creative scientists. These steps would greatly increase the number of productive working years during which those scientists have the greatest creativity, the most energy, and the fewest non-research obligations. Again, the longer-term payoffs for organizations that take these steps could be tremendous.

5. An organization should train, recruit, and reward at least some percentage of multidisciplinary scientists who can make major contributions in multiple fields, apply knowledge and methods from one field to another, and use their broader view to guide work away from less productive areas and toward more productive ones. All scientists within an organization

should be strongly encouraged to make their research comprehensible to people outside their field, and to interact with scientists in other fields in a variety of environments, in order to cross-pollinate ideas among different fields.

6. An organization should set aside at least some percentage of research hiring and funding decisions to be determined by enlightened despots who are good at identifying potentially revolutionary innovators and innovations. Such enlightened despots should have the clear authority to grant financial and political support to any people or projects they deem worthy, and to grant that support for many years without having to demonstrate that there is an immediate payoff, or even that all funded research will eventually pay off.

7. By using systems analysis, the leadership of an organization could help focus more of the organization's resources on the most important problems and potential solutions. If individual members of the organization were taught to practice systems analysis, they could use that method to guide their careers and their research projects in more promising directions, and to ensure that no potentially useful regions of the conceptual "phase space" had been overlooked.

8. In the face of dwindling natural resources and the rising long-term costs of climate change, pollution, and waste, organizations should prioritize the development of very innovative methods of reducing the consumption of natural resources and minimizing the creation of waste products.

9. Organizational pride and rivalry with other organizations should be used constructively to motivate innovation within an organization, and to promote interactions among the scientists and projects within the organization in order to maximize the potential of each one.

10. Companies should view very innovative, longer-term R&D as a worthwhile investment in staying ahead of competitors, not a financial liability whose resulting products could be copied by competitors that did not fund their own R&D. They should lobby federal and state governments for improved tax, patent, regulatory, or other incentives that would make it much more lucrative for the first company that develops any given major innovation. They should also lobby for structured tax incentives that would reward companies that put more of their capital into research.

In addition to smaller-scale local versions of those strategies, additional steps could be taken by individual labs and organizations:

11. In the German-speaking world, the cost of a university education was very low and not an obstacle, and students were generally able to go straight through their university education without having to spend significant time and energy working other jobs to try to pay for it. With no student loan debt, after graduation those students could immediately use their degrees to earn a good income. A university education in the United States in the 1940s–1960s was also quite affordable. In contrast, nowadays a university education in the United States leaves a student and also the student's family with enormous debts (up to many hundreds of thousands of dollars) that can last for decades or even a lifetime. It is imperative to eliminate this financial obstacle and burden.

   (a) Universities with large endowments should use income from those endowments to make their educational programs tuition-free for any students they admit. By doing so, they would get their pick of the best students in the world.

   (b) Whatever factors have been driving U.S. tuition costs to astronomical levels (ever-multiplying armies of non-teaching administrators and staff, professors who are paid very highly yet leave most or all of the teaching to adjunct faculty or grad students, overpriced and overly showy buildings and athletic facilities, etc.) were never essential in the past. They can certainly be eliminated in these times when online students all around the world can watch videos of the world's best lecturer on a given topic, read an excellent electronic textbook on any subject, or complete automated assignments and exams on their computers at essentially negligible cost.

12. In the German-speaking world and in the early U.S. research system, many young scientists had already produced revolutionary inventions and discoveries by the time they were in their mid-twenties. Many modern students could do so too if they were given enough time, resources, and support.

    (a) For relatively very little money, individual laboratories or a philanthropic foundation could identify students who have done the most innovative, independent research in high school science fairs such as the International Science and Engineering Fair (ISEF) and Science Talent Search (STS), and offer them summer or part-time positions in college where they would be completely free to develop and pursue their own ideas (with appropriate supervision and assistance as needed).

    (b) Such students should be able to hone and exercise the innovative research talents they have already developed, instead of having to leave those behind to spend years of drudge work slowly working their way up the ladder (undergraduate students following instructions from graduate students following instructions from postdocs following instructions from a tenure-track assistant professor following instructions from the university department and from research sponsors).

    (c) Organizations offering temporary positions to such students should not impose any intellectual property agreements on their new ideas, in order to avoid creating legal and financial entanglements that could strangle the students' ideas in the crib as soon as the students leave their temporary positions.

13. Universities are places where students go to learn; therefore, universities should select and evaluate their professors largely on the basis of their teaching ability, and support and honor those who invest the most energy and talent in their teaching. In the earlier German-speaking world, research was important but never eclipsed, let alone eliminated, the responsibility of professors to be good teachers. If it is too difficult for modern professors to balance teaching and research, some professors' positions could be designated primarily for teaching, and some primarily for research. In that case, universities would need to avoid the pitfalls of giving higher status to research professors than to teaching professors, or of using student tuition to fund non-teaching research professors.

14. Employers, sponsors, and journals should evaluate scientists' research proposals and results on the basis of their true quality, innovation, and significance, not on the basis of the sheer

volume of a scientist's papers or name recognition of people or places involved in the work. In the German-speaking world, a lone and obscure patent clerk without a Ph.D. (Einstein) could submit a highly insightful paper, have it be promptly published and carefully listened to, and change the world as a result. How feasible would that be in the modern system?

   (a) Peer reviewers could evaluate papers and research grant proposals more fairly if the reviewers did not know the authors or institutions involved in the research. For that approach to work properly, it might also be necessary to avoid clues in the cited references, resource lists, or other sections that might give the reviewers too much information about the authors or institutions.

   (b) Scientists should be evaluated based on the actual scientific quality and importance of their work, as they generally were in the German-speaking world and in the early U.S. research system. Evaluating scientists primarily on the basis of the sheer quantity of their publications or where they appeared is a concept that arose in the modern system and that does not give priority to the types of work, scientists, or research projects that will actually have the greatest impact.

15. Scientists should strive to make their work more comprehensible and relevant to scientists in other fields, to government, and to the general public. Whereas scientists now seemingly seek to invent more and more unnecessarily specialized language and isolated subfields, scientists of all fields once rubbed shoulders in the coffeehouses and symposia of the German-speaking world.

16. Corporate leaders, managers, and workers should be rewarded on the basis of their contributions to the long-term potential and success of the company, not on the basis of tomorrow's stock price or next year's product. In the German-speaking world and in the United States of the 1940s–1960s, companies deliberately recruited, supported, rewarded, and profited from leaders and scientists with successful long-term visions for revolutionary products.

17. In the German-speaking world, government laboratories such as the Kaiser Wilhelm Institutes and the military labs were strong centers of innovation that could very effectively focus on revolutionary research because they were free of both the teaching obligations of universities and the product manufacturing obligations of companies. In the United States of the 1940s–1960s, government-run laboratories such as Los Alamos, NASA centers, and U.S. Air Force, Navy, and Army research labs enjoyed similar advantages and supported revolutionary innovators and innovations. Yet in the modern United States, many government-run and government-funded laboratories now struggle through 70+ years of accumulated red tape to continue working on technologies that have not been revolutionary for 70+ years.

   (a) Any remaining truly essential functions that government laboratories perform regarding those now extremely mature technologies should be transferred to much cheaper, simpler contractors. Current government laboratories should be drastically restructured or otherwise replaced with new government laboratories to eliminate their red tape and to refocus them on new potentially revolutionary technologies.

   (b) Modern government laboratories should make the most of their potential to combine the best qualities of academia and industry and to avoid the worst qualities of each, just as such laboratories did in the German-speaking world and in the early U.S. research system. In principle, government laboratories can avoid the teaching and constant paper-publishing obligations of academia while emulating its focus on longer-term research, and also avoid the obligations of industry to produce lucrative products in the short term while retaining industry's focus on applications instead of pure basic research.

18. Whereas many modern organizations view their employees as interchangeable and inexpensive components to be replaced frequently and at will, older German organizations viewed their employees as a valuable long-term resource to be cultivated (p. 1985). Modern organizations should adopt that same view, carefully hiring the best job applicants; paying and treating them very well; giving them the training, resources, time, freedom, and support they need to be as successful as possible; and recognizing and rewarding their accomplishments. Having the best employees with the best resources will help an organization be as innovative and productive as possible in the long term, and will also help it continue to hire and support new employees to maintain that tradition.

12.2.3 Lessons for Individual Scientists and Engineers

While individual scientists and engineers are very unlikely to be able to exert control over the whole research system or even part of it, they can control their own careers. Based on this study comparing the earlier innovation systems with the present system, options and suggestions for individuals are given below and summarized graphically in Fig. 12.1.

1. Everyone should be very cognizant that the modern innovation system is divided into academic, corporate, and government research sectors, and that in general each is currently suffering from deep-seated problems outlined in Sections 1.1 and 11.3. If someone is interested in science but would like to avoid those problems by pursuing a career not in scientific research and development, there are a large number of potentially fulfilling and potentially lucrative careers that involve science but not R&D. To give just a few examples, one might consider:
    (a) Becoming a medical doctor, nurse, veterinarian, or other healthcare worker.
    (b) Practicing law in science-related areas such as writing patent applications or negotiating technology licensing agreements.
    (c) Pursuing a business or finance career in science-related areas, for example by evaluating scientific ideas for venture capital firms, or by earning business or finance degrees to work in corresponding positions in science-related companies.
    (d) Teaching science or math subjects at K-12 grade levels or at a community college.
    (e) Producing and/or selling scientific or medical tools, equipment, or supplies, or even educational scientific kits and toys.
    (f) Writing or offering science advice for science fiction films, television shows, novels, comics, etc.
2. Because the problems in the modern innovation system are so pronounced, only someone who feels strongly personally compelled to pursue a career in scientific R&D should do so. After having studied the problems in the academic, corporate, and government research sectors, if someone finds one of those sectors preferable to the other two and is willing to endure its known difficulties for the duration of a career, that can be a clear and well-informed choice:
    (a) Some individuals will be most willing to live with the problems in academic research.
    (b) Some individuals will be most willing to live with the problems in corporate research.
    (c) Some individuals will be most willing to live with the problems in government research.
    (d) If someone feels personally compelled to pursue an innovative scientific career and yet is not satisfied with the current state of the academic, corporate, and government research sectors, the available options involve harder choices and murkier information.

3. One possibility for intrepid young innovators is to seek areas where R&D funding for new projects might be more readily available than is the case in the mainstream system:
    (a) Some corner of the existing research system may still be conducive to revolutionary innovation, especially if it is nurtured and protected by an enlightened despot like those of earlier times—perhaps a particularly farsighted corporate CEO/owner/investor/senior manager, philanthropist, university administrator, or defense or intelligence sponsor.
    (b) Some field that is so incredibly old, so new, such a novel combination of existing fields, or so offbeat that it is not filled to overflowing with peer-reviewed competitors may afford better opportunities.
    (c) There might be better funding prospects for new innovators and innovations in those few countries that still have steadily increasing investments in R&D.
4. Another possibility, though only for the very courageous individual, would be to try to improve some specific part of one of the existing research sectors (academic, corporate, or government). Several guidelines should be kept in mind:
    (a) Before proceeding down this path, one should very carefully select which specific part of which research sector to try to improve, and equally carefully plan exactly how that improvement could be realistically accomplished.
    (b) One should expect fierce resistance from the existing system at every step of the way.
    (c) One should recognize from the outset that there is a high probability any effort at reform or improvement will fail, no matter how well intentioned, carefully planned, and diligently executed it might be.
    (d) Anyone advocating for improvement should seek supportive allies at all levels from high government positions to physical plant maintenance. That is sound advice for any pursuit, but especially critical if a reformer is to have any hope of success.
5. If someone feels personally compelled to pursue innovative R&D and is not satisfied with (or cannot access) any of the options outlined above, the remaining possibility is to try to pursue a research career outside of the official sectors. Several keys are important to make this sort of career path possible:
    (a) In the absence of financial support from the academic, corporate, or government research sectors, it is necessary to seek and obtain alternative sources of financial support for independent scientific work. The nature of those alternative sources will depend upon an individual's specific circumstances, interests, and opportunities, but could range anywhere from taking a normal job that pays well but allows enough outside time for research (e.g., Swiss patent clerk), to marrying into wealth, to accepting internet donations or crowdfunding.

   (b) It is critical to identify and focus on projects that can be accomplished with limited labor (often only that of the individual, or even just some fraction of the individual's time) and very limited equipment, supplies, and other resources. Those considerations will likely limit any work to theoretical analyses or at best very small-scale experimental research.

   (c) Two or more individuals interested in the same or similar areas might pool their time and resources in order to accomplish more and to provide mutual encouragement. Among other possibilities, one might establish or join a "maker space," amateur science club, scientific co-op, or other organization.

   (d) No matter how high the quality of an unaffiliated individual's work might be, that person will likely have great difficulty getting proper consideration from scientific journals, government patent offices, or corporate technology licensing offices. Therefore, without necessarily giving up on those establishment methods for output, one should seriously consider alternative methods of output for any significant scientific results, including freely releasing results on the internet without any possibility of monetary gain in hopes of maximizing the ultimate impact of those results.

6. Based on the examples of successful creators from the earlier research systems, modern individuals should follow these practices both for finding/creating a suitable job (which requires innovative problem solving in its own right) and for conducting innovative research:

   (a) No matter how limited your time, resources, and options may be, practice innovation right now and every day after that, rather than hoping to start later on down the road. Brainstorm for new ideas for innovative research projects, make a list of the ideas, and add to that list every time you think of a new idea, day or night. Constantly consider various ways in which those ideas could be analyzed theoretically, computationally, or experimentally, or how they could be developed in part or in whole into models or prototypes. Seek outside input to correct or supplement your ideas, but do not simply copy what others say or do. To be as successful as possible at scientific innovation, you must practice it from as early an age as possible, and as much as possible (just like any other skill).

   (b) Constantly seek out resources and opportunities to test or develop any of the innovative ideas from your list, and keep your eyes open for opportunities that may arise spontaneously.

   (c) Employ a top-down systems analysis approach [Zwicky 1969] to identify first the most important problems to work on, and then the range of possible solutions for those problems, and finally out of those possibilities the best solutions for the best problems that one could pursue, all subject to the constraints of your own particular talents, resources, and opportunities.

   (d) Study multiple fields, and multiple areas within a field. Having multidisciplinary expertise can enable you to make contributions in different fields (as opportunities arise), achieve new results by applying knowledge and methods from one field to another, and use your broader view to guide your work away from less productive areas and toward more productive ones.

(e) Actively seek out people who are as close to being enlightened despots as you can find—individual people who (i) are most inclined to support the sort of innovative research you would like to do and (ii) are best able to offer you financial support, political support, and/or useful advice.

(f) Present your research in such a way that it will be comprehensible to scientists outside that particular field and also to non-scientists. Along the way, actively maximize your interactions with scientists in other fields in a variety of environments, in order to cross-pollinate ideas.

(g) Wherever and however possible, help inspire, train, support, and reward aspiring scientists who are younger than you. Although you may have few resources, a younger aspiring scientist will probably have even fewer than you do. You could be the closest thing to an enlightened despot that they will find.

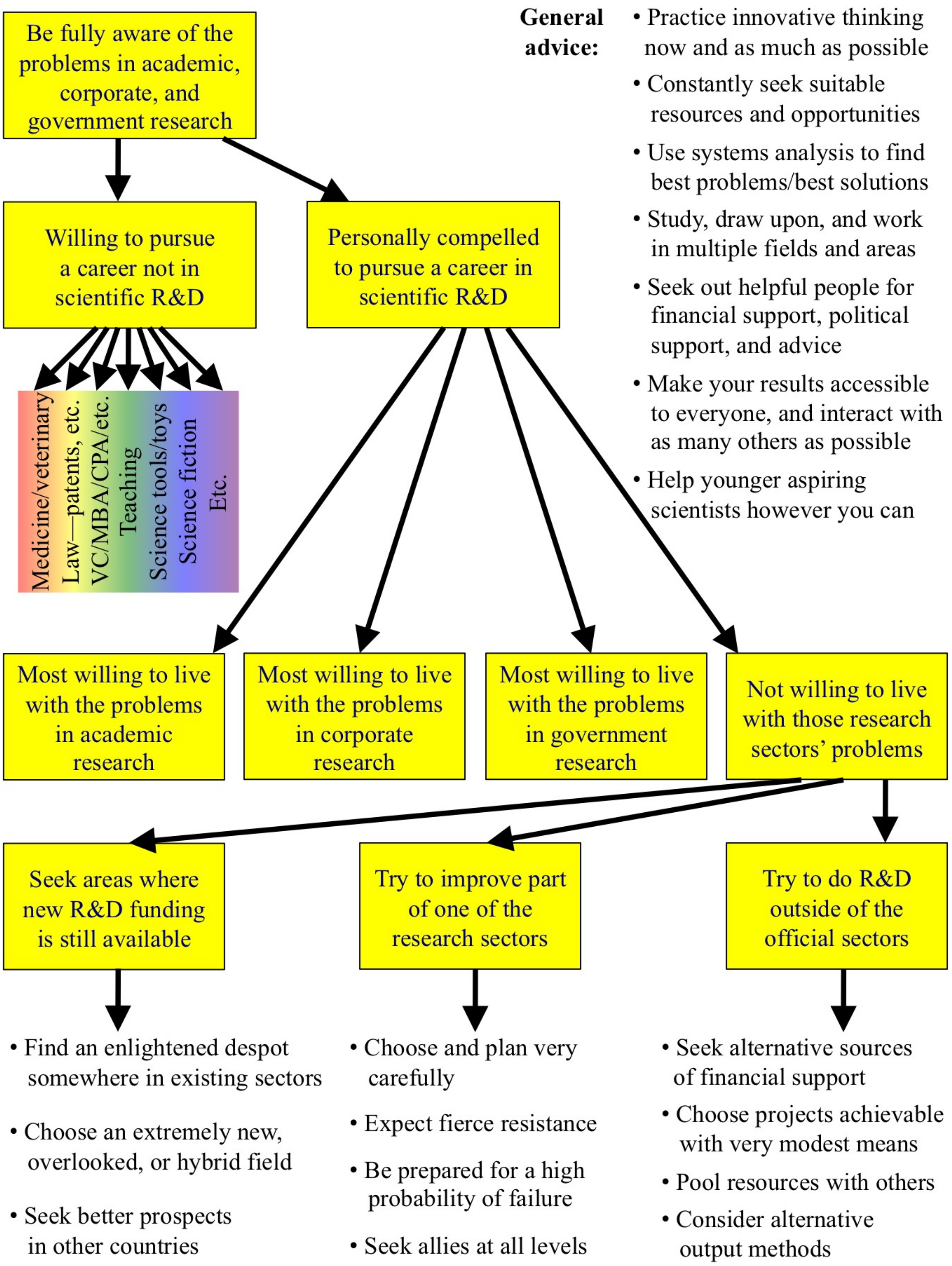
Be fully aware of the problems in academic, corporate, and government research
Willing to pursue a career not in scientific R&D
Personally compelled to pursue a career in scientific R&D
Medicine/veterinary
Law—patents, etc.
VC/MBA/CPA/etc.
Teaching
Science tools/toys
Science fiction
Etc.
General advice:
• Practice innovative thinking now and as much as possible
• Constantly seek suitable resources and opportunities
• Use systems analysis to find best problems/best solutions
• Study, draw upon, and work in multiple fields and areas
• Seek out helpful people for financial support, political support, and advice
• Make your results accessible to everyone, and interact with as many others as possible
• Help younger aspiring scientists however you can
Most willing to live with the problems in academic research
Most willing to live with the problems in corporate research
Most willing to live with the problems in government research
Not willing to live with those research sectors' problems
Seek areas where new R&D funding is still available
Try to improve part of one of the research sectors
Try to do R&D outside of the official sectors
• Find an enlightened despot somewhere in existing sectors
• Choose an extremely new, overlooked, or hybrid field
• Seek better prospects in other countries
• Choose and plan very carefully
• Expect fierce resistance
• Be prepared for a high probability of failure
• Seek allies at all levels
• Seek alternative sources of financial support
• Choose projects achievable with very modest means
• Pool resources with others
• Consider alternative output methods

Figure 12.1: Options for individual scientists and engineers.

12.2.4 Lessons for Scholars of Past, Present, & Potential Future Innovation Systems

Due to limitations of time, resources, and length, this study could only give an overview of some of the issues involved in revolutionary scientific innovation in the historical German-speaking world and in the United States. Issues that were briefly introduced in this study deserve to be investigated and written up in far more detail. Many related areas could not be addressed at all in this study, yet warrant thorough exploration in their own right. For convenience, all of these issues for further study may be categorized on the basis of whether they primarily focus on past, present, or potential future innovation systems.

Some questions that should be further investigated by scholars of past innovation systems include:

1. What factors helped or hindered revolutionary scientific innovation in the German-speaking world:
   (a) Prior to 1800?
   (b) From 1800 to 1945? Is there other evidence to support or refute the factors proposed in Chapter 10? Is there evidence for major factors that were not considered in Chapter 10? (See p. 2030 for some possibilities.)
   (c) After 1945 (on both sides of the Iron Curtain)?

   How could knowledge about those historical factors be applied to improve modern innovation systems?

2. What factors helped or hindered the U.S. innovation system:
   (a) Prior to the 1940s?
   (b) During the 1940s–1960s? Is there other evidence to support or refute the factors proposed in Chapter 11? Is there evidence for major factors that were not considered in Chapter 11? (See p. 2030 for some possibilities.)
   (c) After the 1960s? Is there other evidence to support or refute the factors proposed in Chapter 11? Is there evidence for major factors that were not considered in Chapter 11?

   How could knowledge about those historical factors be applied to improve modern innovation systems?

3. What factors helped or hindered the historical innovation systems in:
    - (a) United Kingdom?
    - (b) France?
    - (c) Russia/Soviet Union?
    - (d) Scandinavian countries?
    - (e) Italy?
    - (f) Japan?
    - (g) Other countries?

    How could knowledge about those historical factors be applied to improve modern innovation systems?

4. What were the major innovators, leaders, details, timeline, and maximum extent of the historical German-speaking world's contributions in:
    - (a) Molecular and cellular biology, including DNA, RNA, proteins, immunology, cancer, antibiotics, vaccines, fermentation, biotechnology, offensive and defensive biological warfare, etc.?
    - (b) Chemical weapons more advanced than tabun, sarin, and soman?
    - (c) Microelectronics, including diodes, transistors, laser diodes, other semiconductor devices, printed circuits, integrated circuits, computers, robotics, guidance systems, encryption systems, photocopiers, etc.?
    - (d) Directed energy technologies, including lasers, masers, ion beams, electron beams, neutron or other neutral particle beams, electromagnetic pulse, X-ray and gamma-ray beams, ultraviolet beams, infrared beams, microwave beams, acoustic beams, electric and/or magnetic railguns, etc.?
    - (e) Nuclear technologies, including fission reactors, fission weapons, fusion reactors, fusion weapons, nuclear aircraft propulsion, nuclear rocket propulsion, nuclear submarine propulsion, transuranic isotope production and characterization, etc.?
    - (f) Advanced aerospace technologies, including intercontinental jet aircraft, multistage rockets, intercontinental ballistic missiles, submarine-launched missiles, manned spacecraft, space planes and space shuttles, reentry systems, large liquid propellant rocket engines, solid propellant rockets, electric rocket propulsion technologies, and space stations?
    - (g) Other areas in biology and medicine?
    - (h) Other areas in chemistry and materials science?

   (i) Other areas in earth and space science?

   (j) Other areas in physics and applied mathematics?

   (k) Other areas in electrical and electromagnetic engineering?

   (l) Other areas in mechanical engineering?

   (m) Other areas in nuclear science and technology?

   (n) Other areas in aerospace engineering?

   Because Allied documentation (foreign scientist case files; Alsos, BIOS, CIOS, FIAT, JIOA, and NavTecMisEu reports; etc.) on German and Austrian research is so extensive yet only accessible as paper documents in a few national archives, it would be extremely helpful if the German and Austrian governments would fund scholars to photograph or digitize those documents and make them available on the internet. Such a step would greatly enhance the general understanding of all of the above areas.

5. How did family traditions, immigration status, and cultural backgrounds affect the production of creators?

   (a) What aspects of Jewish family life in the early German-speaking and U.S. systems, East Asian or South Asian family life in the modern U.S. system, or other family backgrounds resulted in a far larger percentage of creators having those backgrounds than was true for the entire population in those countries?

   (b) What aspects of being an immigrant, or the descendant of people who immigrated in a recent previous generation (for example, parents or grandparents), resulted in a far larger percentage of creators having that background than was true for the entire population in those countries?

   (c) What aspects of the general culture in various countries made it less likely that children of families that had been in those countries for many generations would become successful scientific innovators? What cultural aspects encouraged children to be less intellectually driven, or if intellectually driven less inclined toward a career in scientific research, or if scientists less creative or less successful?

6. For the most successful scientific enlightened despots in the German-speaking world, early U.S. system, or other research systems:

   (a) How did the system select the best despots and measure their success during their careers?

   (b) What criteria and methods did the best despots use to select the most promising new innovators and innovations?

   (c) What managerial, political, and financial methods did the despots use to ensure proper support for their own positions and for the scientists that they backed?

   (d) How did the system best support the despots and the scientists that they backed?

7. What were the major creators, creations, innovation methods, and transfer methods involved in transferring innovations from the German-speaking world to:

   (a) Other countries before the Third Reich?

   (b) Other countries during the Third Reich?

   (c) The United States after the Third Reich?

   (d) The Soviet Union after the Third Reich?

   (e) The United Kingdom after the Third Reich?

   (f) France after the Third Reich?

   (g) Other countries after the Third Reich?

Some questions that should be further investigated by scholars of present innovation systems include:

1. What factors help or hinder the current innovation systems in:
   (a) The United States?
   (b) China?
   (c) Japan?
   (d) Germany?
   (e) South Korea?
   (f) India?
   (g) France?
   (h) United Kingdom?
   (i) Russia?
   (j) Singapore?
   (k) Other countries?

   How could knowledge about those factors be applied to improve the innovation systems in other countries?

2. What fractions of modern corporate R&D funding are spent on:
   (a) Products for which some version and/or competitor is already on the market?
   (b) Products that reach the market within one, two, three, four, five, or more years?
   (c) Products that never reach the market?

   How do those figures compare to statistics from earlier times or from other countries? What do the results say about the current level of innovation, creative risk, and long-term planning in the modern corporate R&D system?

3. On average, how much time does a modern principal investigator at a government-funded and/or government-run laboratory spend on:
   (a) Actual research—designing and carrying out experimental or theoretical research?
   (b) Work that is not actual research—writing grant applications, writing up progress reports and papers, seeking bureaucratic approvals, attending meetings, etc.?

How do those results compare with statistics from earlier times or from other countries?

4. On average, how much time does a modern university professor spend on:
   (a) Actual teaching?
   (b) Actual research—designing and carrying out experimental or theoretical research?
   (c) Work that is not actual research or teaching—writing grant applications, meeting with sponsors or donors, writing up progress reports and papers, serving on peer review committees, attending other meetings, etc.?

   How do those results compare with statistics from earlier times or from other countries? What do the results say about the quality of education and research in the modern academic system?

5. What is the average age at which a modern principal investigator is truly free (in a position of long-term employment; provided with sufficient funding, equipment, labor, and time; etc.) to propose and pursue their own entirely original scientific research projects? How do those results compare with statistics from earlier times or from other countries?

6. Why has the average cost of university education (at least in the United States, and possibly in other countries) risen much faster than the inflation rate for several decades? What fractions of those increases went toward administrators, buildings, university endowments, direct improvements in teaching, direct improvements in research, direct improvements in student life, etc.?

7. Why has the average cost of K-12 and university textbooks (at least in the United States, and possibly in other countries) risen much faster than the inflation rate for several decades? If publishers can profitably sell much lower-priced “international editions” of those same books outside of the United States, why can or do they not profitably sell editions of those books within the United States for the same lower prices? Why are textbooks so much more expensive than other types of books, even other types of books that require the same level of detail and editing as textbooks?

8. What fraction of the scientific work published each year is freely available online without registrations, memberships, subscriptions, pay-per-article firewalls, conference costs, having to find or purchase a copy of a book or journal, etc.?

Some questions that should be further investigated by scholars of potential future innovation systems include:

1. In addition to lessons that can be learned from past or present innovation systems, what entirely new strategies can be devised for improving innovation systems? How could those strategies be tested at a smaller scale to measure and optimize their effectiveness and to minimize any negative consequences before implementing them at a large scale?

2. Given the capabilities of the internet and the desirability to minimize costs while maximizing the accessibility and quality of education, what is the best system for university-level education and degrees?

3. What are the most effective ways to inspire young students to want to become scientific innovators?

4. What are the best strategies for finding the most innovative students and giving them the skills, resources, support, and freedom to create revolutionary innovations?

5. Are there better alternatives for research funding decisions than peer review? If some fraction of research funding and hiring decisions were entrusted to scientific enlightened despots, what would be the best way to select despots with the greatest discernment and skill? Even letting successful despots select new despots could lead to a decline in quality, like the gradual decline of early Christian popes or the abrupt end of the “Five Good Emperors” of the Roman Empire.

6. Are there better alternatives for publication than the current system of peer review in (mostly) highly specialized journals? What are the best ways to disseminate researchers’ results while (a) enforcing standards for scientific quality, (b) making the results as widely and freely accessible as possible, and (c) reducing the glut of virtually unread and insignificant papers?

12.3 Afterword

I believe that the ability to create revolutionary scientific innovations is a noble and all-too-rare skill that has transformed the world (mostly for the better) over the past millennia, and that has the potential to further improve the world in the future. While a certain number of revolutionary scientific innovators can arise spontaneously in almost any environment and may sometimes find just the right opportunities to realize their creations, a far larger number of revolutionary innovators and innovations can be produced if there is a system that actively inspires and trains new revolutionary innovators, and then diligently supports and rewards them for developing revolutionary innovations. By researching, writing, and presenting this book, I have endeavored to offer what I hope is a new and useful perspective on the past, the present, and the possible future of systems for promoting revolutionary scientific innovation.

In science and engineering, it is helpful to represent complex signals or data as the sum of several different simple signals of steadily decreasing size and importance, with the simple individual signals sometimes interacting with each other in nonlinear and less easily predictable ways. Likewise, I believe it can be useful to view the complexities of history as the sum of many different simple forces and movements, from larger and more dominant ones to smaller and less significant ones; sometimes those simple individual historical forces interact with each other in nonlinear and less predictable ways.

The history of revolutionary scientific innovation covers the world, spans thousands of years, and includes countless individual larger and smaller forces as well as their nonlinear interactions. I have not even attempted to tackle that complete picture and that complete set of forces. Rather, I have endeavored to illuminate one of those individual forces, the predominantly German-speaking scientific world of the nineteenth and early twentieth centuries, which served as an engine for producing enormous numbers of revolutionary scientific innovators, who in turn produced huge numbers of revolutionary scientific innovations. I believe that most historians, scientists, and leaders have not had a proper understanding of the accomplishments, the methods, and the importance of that earlier German-speaking innovation engine.

Based upon data such as that summarized in this book, I would like to propose a theory, and to encourage others to consider it, modify it, prove it, disprove it, or offer alternatives to it:

> The German-speaking world of the nineteenth and early twentieth centuries was the strongest (though certainly not the only) engine for producing revolutionary scientific innovators during its time, and quite possibly even the strongest (but not only) such engine in all of history. That engine was carefully constructed and nurtured throughout the nineteenth and early twentieth centuries, but then was seriously damaged in 1933 and almost entirely dismantled in 1945.[2] Thus it ceased to produce many new revolutionary scientific innovators around

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[2] The Third Reich drove out, fired, imprisoned, and/or killed a large fraction of the scientific innovators. Most of the remaining ones were mistreated and misused, even if some of their creations did receive lavish funding. The Third Reich also caused huge numbers of its students (many of whom would have become future scientists) and some of its existing scientists to die fighting in the war, made the schools and universities highly ideological and dysfunctional, and made scientists focus their energies solely on developing military projects without also refilling the research pipeline by training the next generation of innovators and making new discoveries in fundamental science. Even if the Third Reich had won the war, the German-speaking scientific world that had been so carefully cultivated by earlier generations would have been destroyed. As it was, the Third Reich lost, and most of the remaining scientists

> 1933–1945. (Rebuilding the German-speaking research world after 1945 took decades, and one could debate whether the rebuilt German-speaking research world more closely resembles the earlier German-speaking world or the rest of the postwar scientific world.)
>
> Newly educated and empowered revolutionary scientific innovators tend to have rather specific visions of the revolutionary scientific innovations that they would like to create and perfect. Succeeding waves of innovators that were produced by the German-speaking world throughout the nineteenth and early twentieth centuries created and perfected succeeding waves of microbiology discoveries, applied chemistry methods, earth science discoveries, physics theories, electromagnetic devices, mechanical inventions, and early aircraft. The final wave of revolutionary innovators produced by the German-speaking engine before its 1933–1945 decline and demise immediately fixed their sights on antibiotics and biotechnology, synthetic drug molecules and polymers, high-energy physics and cosmology, microelectronics and computers, sophisticated automobiles and submarines, nuclear reactors and nuclear weapons, and jets and rockets. Beginning during the period 1933–1945 and continuing for the remaining decades of their careers, that final wave of German-speaking scientific innovators made those visions a reality, the fabric of the modern world in which we now live.

I would also like to suggest two corollaries to my theory for people to debate, and I believe that they too are supported by data such as that presented in this book:

1. If the German-speaking engine of the nineteenth and early twentieth centuries had never existed, most of the revolutionary innovators it produced would never have existed, and they would never have been able to create their revolutionary innovations. In that case, the state of science and engineering in the modern world might have been many years or even decades less advanced than it currently is. (Naturally, some revolutionary German-speaking innovators would have found a way to develop and to succeed even in the absence of a nurturing system, and the rest of the world would have continued to produce some revolutionary innovators and innovations, although I believe at a slower rate.)

2. The world's primary engine for producing revolutionary scientific innovators was one of the least recognized casualties of World War II, yet perhaps the one with the longest lasting and most widespread consequences. If the German-speaking engine had not been damaged and dismantled in 1933–1945, but rather had continued to function or even to grow, the state of science and engineering in the modern world might be decades more advanced than it currently is. What revolutionary scientific innovations would have been conceived and developed by the wave of new revolutionary innovators that the fully functional German-speaking engine might have produced by 1960? By 1980? By 2000? Today? What revolutionary medicines and materials might we have developed by now? What power sources and vehicles might we have had by now? How far might human settlements have ventured into the oceans and into space by now? (Of course, even after the end of the German-speaking engine in 1945, the world continued to produce some new revolutionary innovators and innovations, yet I would suggest not at the same rate as what the German-speaking engine had produced or what it might have continued to produce.)

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and all of their innovations were removed and divided among the Allied countries, which generally used them up for short-term gain instead of leveraging them as a long-term investment to help create and support large numbers of new revolutionary innovators.

Nevertheless, the ultimate purpose of this book is not to get lost pondering the possibilities of the past, but rather to contemplate potential strategies for the future. If the world previously constructed an effective engine for creating huge numbers of revolutionary scientific innovators and innovations, it can assemble another such engine, or maybe even a better engine, now. We need not debate whether it is possible to create such an engine of revolutionary innovation. We need not wonder how we might build such an engine. We just need to fully remember the Forgotten Creators, and to learn all that we can from them.

Appendices

Es läßt sich wohl behaupten, daß die Geschichte der Wissenschaften die Wissenschaft selbst sei. Man kann dasjenige, was man besitzt, nicht rein erkennen, bis man das, was andere vor uns besessen, zu erkennen weiß.

It can be argued that the history of science is science itself. One cannot recognize clearly what one has found until one knows what others found before us.

Johann Wolfgang von Goethe [Schwenk 2000, p. 7].

Appendix A: **Advanced Creations in Biology and Medicine** **p. 2305**

Appendix B: **Advanced Creations in Electrical Engineering** **p. 2653**

Appendix C: **Advanced Creations in Directed Energy** **p. 3019**

Appendix D: **Advanced Creations in Nuclear Engineering** **p. 3253**

Appendix E: **Advanced Creations in Aerospace Engineering** **p. 5185**

1. In order not to obscure the book's arguments by simply referring readers to numerous documents that may be difficult to obtain, relevant excerpts from a large number of key sources are presented in the appendices.

2. To make the contents computer-searchable for readers and internet search engines, most documents have been retyped (with annotations as appropriate) instead of being reproduced as photographs.

3. Where I have retyped documents, I have tried to preserve the formatting of the original documents (underlining, etc.) as much as possible.

4. To avoid variant spellings that would not come up in a computer text search, I have silently corrected some obvious typographical errors in some of the quoted source documents. U.S. and U.K. documents that were typed during and shortly after World War II were often careless in their spellings of the German names of people and places.

5. In order to avoid increasing the length of this already enormous book by a factor of several fold, I have abridged portions of the documents that seemed less relevant, as denoted by [...] in the quoted text.

6. Where I wanted to add emphasis to passages in quoted documents to draw the attention of readers, I have displayed those passages in red. Even passages not in red are relevant, though, which is why I have taken the time to type them up and include them too.

7. To add my own commentary regarding quoted documents yet clearly distinguish my commentary from the text of the source documents, [my commentary appears in blue text inside square brackets].

8. Key sources not in English are presented in both their original language and a parallel English translation.

9. Citations direct interested readers to the original sources of these documents in case readers would like to verify their authenticity and read them in full.

10. Each source quote has been placed in the most relevant section, but it may be germane to other sections as well, as indicated by cross-references.

Appendix A

Advanced Creations in Biology and Medicine

Was war also das Leben? Es war Wärme, das Wärmeprodukt formerhaltender Bestandlosigkeit, ein Fieber der Materie, von welchem der Prozeß unaufhörlicher Zersetzung und Wiederherstellung unhaltbar verwickelt, unhaltbar kunstreich aufgebauter Eiweissmolekel begleitet war.

What then was life? It was warmth, the warmth generated by a form-preserving instability, a fever of matter, which accompanied the process of ceaseless decay and repair of protein molecules that were too impossibly complicated, too impossibly ingenious in structure.

Thomas Mann. 1924. *Der Zauberberg* [*The Magic Mountain*]. Chapter 5.
English translation adapted from H. T. Lowe-Porter.

This appendix presents portions of archival documents from during and immediately after World War II. These documents suggest that Germany:

A.1. Had the largest and most advanced biotechnology programs in the world at that time.

A.2. Was developing neural interfaces to control prosthetic limbs and weapons systems.

A.3. Possessed a significant offensive program in biological warfare.

A.4. Discovered advanced V-series nerve agents during the war.

Much more archival research is needed to elucidate the complete history and accomplishments of these programs.

A.1 Biotechnology

[A commonly held view among historians of science is that biotechnology was a postwar U.S./U.K. invention and that the German-speaking world was very late and far behind in pursuing biotechnology. For example, historian of science Luitgard Marschall summarized this view of biotechnology in Germany [Szöllösi-Janze 2001, pp. 112–114]:

> Owing to their theoretical foundation in organic chemistry, the research and production methods of chemical synthesis were regarded already at the beginning of the twentieth century as extremely science-based and therefore as modern and innovative. Biotechnology, in contrast, was for a long time considered to be an empirical and backward production technique, just because of its lack of theory and science-based methods [...]
>
> [B]etween 1933 and 1945 biotechnological processes were used only to compensate the deficits of chemical syntheses. Biotechnology was thus relegated to special processing niches. However, this relegation of biotechnological processes in favour of chemical ones had already started prior to 1933 and, after 1945, it culminated in further retardation. This of course indicates a continuous process. Nevertheless, the development in the Third Reich demonstrated particular features which had a lasting influence on the further course of biotechnology. [...]
>
> The metaphor of technological trajectories provides a viable explanatory model for the development of industrial biotechnology in Germany. As is well known, the German chemical industry decided early on to follow the path of chemical synthesis [...] This decision proved to be extraordinarily successful and contributed to its gaining a leading position in synthetic organic chemistry. It had some opportunity costs, however: up to now the fact has been ignored that the early commitment to chemical synthesis and its intensive expansion was detrimental to the development of biotechnology. For a long period in the twentieth century biotechnology played the part of a 'loser technology'. Its academic and industrial development was neglected in Germany until the 1970s in favour of chemical synthesis.

As shown in this section and in Chapter 2, there is a large amount of evidence that biotechnology and molecular biology (including knowledge, tools, methods, and applications) were developed by the German-speaking world in the nineteenth and early twentieth centuries, then transferred to the United States, United Kingdom, and other countries:

1. German-speaking scientists invented and perfected instruments suitable for biotechnology:
    (a) Carl Zeiss (German, 1816–1888), Ernst Abbe (German, 1840–1905), and Otto Schott (German, 1851–1935) perfected diffraction-limited optical microscopes during the 1870s–1880s (p. 1270).
    (b) In 1902, Richard Zsigmondy (Austrian, 1865–1929) and Henry Siedentopf (German, 1872-1940) invented the ultramicroscope for determining particle sizes in colloids; see p. 1271.
    (c) August Köhler (German, 1866–1948) and Moritz von Rohr (German, 1868–1940) invented the ultraviolet microscope in 1904, as shown on p. 1272.

   (d) August Köhler and Henry Siedentopf invented the fluorescence microscope in 1908 (p. 1273). Fluorescence microscopes are now a widespread tool in biology laboratories because different cellular components can be labeled with different colors of fluorescent tags.

   (e) Karl Bratuschek (German?, 1865–1913) at the Zeiss company was apparently moving toward the development of phase contrast microscopy before his death [Wimmer 2017]. Frits Zernike (Dutch, 1888–1966) invented phase contrast microscopes in 1933, and they were mass produced by Zeiss (pp. 1274, 2474–2484).

   (f) In 1926, Hans Busch (German, 1884–1973) created the first electrostatic and magnetic lenses for electrons. From 1931 onward, four different groups, all in the greater Berlin area, built and demonstrated electron microscopes: Technische Hochschule Berlin, Siemens & Halske, Allgemeine Elektrizität Gesellschaft (AEG), and Manfred von Ardenne (German, 1907–1997). See pp. 1289–1295.

   (g) Fritz Pregl (Austrian, 1869–1930) developed micro-pipetting and micro-analysis tools and methods in the 1910s (pp. 473, 2320–2324).

   (h) Scientists from the German-speaking world invented and used centrifuges for a large range of applications from 1864 through World War II (pp. 2394–2399).

   (i) German-speaking scientists harnessed focused sound waves for a wide variety of applications, ranging from the first ultrasound imaging devices to ultrasonic sonicators to disrupt chemical solutions and molecules. Documents in Section C.4 demonstrate that those technologies were developed and successfully demonstrated in Germany and Austria during the 1930s and early 1940s, and then directly transferred to other countries in 1945, leading to modern acoustic and ultrasound devices.

   (j) Robert Havemann (German, 1910–1982) invented spectrophotometers no later than 1936 (pp. 2378–2388). He also conducted important research on colloids (p. 719).

   (k) P. H. Keck (German?, 19??–19??) invented luminometers no later than 1943 (pp. 2446–2447).

   (l) In 1940 or earlier, Andreas Lembke (German, 1911–2002), Hellmuth Bayha (German?, 19??–19??), Karl Krammer (German?, 19??–19??), Eugen Sauter (German?, 19??–19??), and other scientists developed and successfully implemented methods of using intense ultraviolet light to sterilize liquids and other materials (pp. 2367–2373).

2. German-speaking scientists discovered most of the major types of bacteria and developed antiseptics and antibiotics to prevent or treat bacterial infections:

   (a) With newly improved microscopes (Section 6.9), it became much easier to see organisms as small as bacteria. However, a remaining problem was that most bacteria are essentially clear, and surrounded by essentially clear liquid or other sample material. Therefore, scientists in the German-speaking world developed methods that stained bacteria different colors than the surrounding sample material, making it much easier to visualize their shapes and identify them under the microscope. Scientists who developed important early microscope staining techniques for bacteria included Karl Weigert (German, 1845–1904), Paul Ehrlich (German, 1854–1915), and Robert Koch (German, 1843–1910), as shown on p. 166.

   (b) In 1872, Ferdinand Cohn (German, 1828–1898, p. 167) created the modern classification system for bacterial shapes (spheres or cocci, rods or bacilli, spirals or spirochetes, etc.).

   (c) Based on the earlier stains, Hans Christian Gram (Danish but worked and made his discovery in Germany, 1853–1938, p. 166) developed the "Gram staining" method in Berlin in 1884 while working with Carl Friedländer (German, 1847–1887, p. 174). Gram staining is still widely used to distinguish between bacteria with two different types of cell walls, "Gram-positive" bacteria that turn purple with this technique and "Gram-negative" bacteria that turn red. The ability to distinguish between Gram-positive and Gram-negative bacteria, and among bacteria with different shapes, was and remains a powerful method to identify bacteria under the microscope (p. 163).

   (d) Robert Koch (German, 1843–1910) and many other German-speaking scientists discovered most of the common pathogenic types of bacteria (pp. 164–176).

   (e) In 1847 (approximately two decades before Joseph Lister), Ignaz Semmelweis (Austrian, 1818–1865) developed and demonstrated antiseptics to prevent bacterial infections (pp. 164–165).

   (f) Paul Ehrlich (German, 1854–1915) discovered Salvarsan, the first antibiotic, in 1909 and successfully used it to treat syphilis (p. 187).

   (g) Gerhard Domagk (German, 1895–1964) discovered and demonstrated sulfa antibiotics, the first broad-spectrum antibiotics, in 1932. The large sulfa family of antibiotics is still widely used today (p. 188).

   (h) Ernst Chain (German, 1906–1979) purified penicillin in 1940 (p. 189), taking penicillin from an effect that could only be demonstrated in Petri dishes to an effective antibiotic that could be mass-produced and administered to people.

   (i) Richard Kuhn (Austrian, 1900–1967) produced and tested synthetic antibiotics such as "3065" during World War II, using massively parallel chemical synthesis and testing to carry out very modern methods of structure-activity relationship (SAR) optimization of the drug molecules (pp. 190, 2325, 2352, 2389, 2406–2411).

3. German-speaking scientists developed methods of culturing and utilizing prokaryotic (bacteria) and eukaryotic (yeast, animal, and plant) cells:

   (a) Working together with Robert Koch, Julius Petri (German, 1852–1921) invented Petri dishes in 1881. In that same year, spouses Fanny Hesse (born of German parents in the United States, lived in Germany, 1850–1934) and Walther Hesse (German, 1846–1911) developed agar nutrient gel to fill those dishes [Brock 1999; Schlegel 2004]. The agar provides a solid surface that does not decay to a messy liquid as microorganisms grow on it. Agar-filled Petri dishes are now virtually ubiquitous in biology laboratories for culturing microorganisms.

   (b) By 1890, Carl Wehmer (1858–1935) was using yeast fermentation to produce citric acid, fumaric acid, and other substances [Benninga 1990]. See pp. 2315–2319.

   (c) Otto Röhm (German, 1876–1939) and his company Röhm and Haas developed industrial-scale culture of microorganisms to produce and purify enzymes (proteases, starch hydrolases, pectinases, lipases, etc.) for many different commercial applications during the period from 1906 through World War II (pp. 2448–2452).

   (d) Franz Schardinger (Austrian, 1853–1920) used bacterial fermentation to produce acetone (1903–1904). See p. 180 for some of his publications demonstrating his methods and results.

   (e) In 1910, Chaim Azriel Weizmann (Belarus, educated and worked in Germany and Switzerland, 1874–1952) began internationally popularizing Schardinger's methods of using bacterial fermentation to produce acetone (p. 183). (Sometimes international credit was given to Weizmann for popularizing these methods, but not to Schardinger for first inventing, demonstrating, and publishing these methods.)

   (f) In the early twentieth century, bioreactors for the continuous liquid culture of microorganisms were developed by scientists at Benkiser, Boehringer, I.G. Farben, Phrix, Röhm and Haas, and other German companies and laboratories (pp. 2326–2339, 2401–2404, 2412, 2448–2452).

   (g) In the 1940s, the use of bioreactors for the continuous liquid culture of microorganisms was internationally popularized by German-speaking refugees such as Ernst Chain (German, 1906–1979, working in the United Kingdom) and Leo Szilard (Hungarian, 1898–1964, working in the United States, p. 183), and also by Allied investigators who wrote numerous reports on the German biotechnology industry (pp. 2401–2404, 2412).

   (h) German-speaking scientists developed methods of isolating cells from larger organisms and using "tissue culture" methods to keep those cells alive and even get them to reproduce under laboratory conditions (p. 87). Wilhelm Roux (German, 1850–1924) conducted the first animal cell tissue culture experiments in 1885, removing medullary plate cells from a chicken embryo and keeping them alive in culture for 13 days. Paul Grawitz (German, 1850–1932) experimented with tissue culture of additional animal cell types in the 1890s. Gottlieb Haberlandt (Austrian, 1854–1945) developed plant cell tissue culture and also discovered totipotency, the ability of some "stem" cells to give rise to any type of specialized cell in an organism, in 1902.

4. German-speaking scientists made key discoveries regarding viruses:

   (a) Peter Plett (German states, 1766–1823) developed and successfully demonstrated a cowpox-based vaccine for smallpox virus beginning in the late 1780s, and first reported his results in 1790. Edward Jenner (English, 1749–1823) rediscovered the same thing several years later, and published his first results in 1798. Yet Jenner became famous as the discoverer of smallpox vaccine, and Plett has been virtually forgotten [Plett 2006]. See p. 194.

   (b) German-speaking scientists discovered and characterized tobacco mosaic virus from 1886 onward (pp. 195–196).

   (c) From 1897 onward, German-speaking scientists discovered and characterized foot-and-mouth disease virus, produced therapeutic antibodies for it, created vaccines for it, demonstrated a tissue culture model for it, and developed immunoassays for it (pp. 197–199).

   (d) German-speaking scientists discovered and characterized poliovirus from 1908 onward (pp. 200–201).

   (e) German-speaking scientists pioneered the study of bacteriophages, viruses that infect bacteria, and made numerous other contributions to virology (pp. 200–202).

5. German-speaking scientists discovered and analyzed nucleic acids (DNA and RNA):

   (a) Gregor Mendel (Austrian, 1822–1884) discovered the rules of genetics using plants he grew at his monastery (1864 or earlier), and meticulously documented his discoveries and explanations in a lengthy book. See p. 96.

   (b) In 1869, Johannes Friedrich Miescher (Swiss, 1844–1895) extracted and purified DNA (which he called nuclein) from human white blood cells and suggested that DNA is involved in heredity (p. 97).

   (c) Walther Flemming (German, 1843–1905) made detailed observations of chromosomes during mitotic cell division from 1873 onward (p. 98).

   (d) Beginning in the 1870s, Albrecht Kossel (German, 1853–1927) showed that DNA and RNA contain five different bases (adenine, cytosine, guanine, thymine, and uracil), demonstrated that those bases are connected via linkages of sugars and phosphates, and isolated and studied proteins that bind to nucleic acids in the nucleus (histones and other accessory proteins). See p. 99.

   (e) No later than 1907, Wilhelm Weinberg (German, 1862–1937) discovered the equilibrium distribution of alleles (different versions of a gene) within a population of a species (p. 100).

   (f) In 1933 or earlier, Ernst Caspari (German, 1909–1988), Alfred Kühn (German, 1885–1968), Adolf Butenandt (German, 1903–1995), and other researchers in Germany analyzed mutations in insects and discovered that individual genes encode individual proteins (pp. 101–102).

   (g) In a revolutionary 1935 paper, Max Delbrück (German, 1906–1981), Nikolai Timoféeff-Ressovsky (Russian but worked in Germany 1925–1945, lived 1900–1981), and Karl Günter Zimmer (German, 1911–1988) at the Kaiser Wilhelm Society in Berlin described and demonstrated the structure of chromosomal DNA, methods and consequences of inducing point mutations in DNA, and forced genetic recombination of different pieces of DNA (p. 103).

   (h) In or before 1940 (under wartime conditions and 13 years before the discovery by Rosalind Franklin, Francis Crick, and James Watson), Hans Friedrich-Freksa (German, 1906–1973) proposed that the structure of DNA is double-stranded with electrostatic attraction between complementary sequences on the two strands (p. 104).

   (i) By 1940–1942, and also despite the severe wartime hindrances, Gerhard Schramm (German, 1910–1969) identified the genome of the tobacco mosaic virus as RNA, showed that its protein subunits are identical, and mutated the RNA to create mutant proteins (p. 105).

   (j) Many other German-speaking scientists also made significant contributions to knowledge about DNA and RNA (pp. 106–112).

6. German-speaking scientists pioneered the study, diagnosis, prevention, and treatment of cancer:

(a) During the period 1889–1891, Erik Johan Widmark (Swedish but closely coupled to the German-speaking research world, 1850–1909) and Friedrich Hammer (German, 1860–1943) demonstrated via a series of experiments that ultraviolet light causes suntans and sunburns, and that those effects could be reduced by coating the skin with a protective layer of certain natural plant extracts (p. 125).

(b) Leopold Freund (Austrian, 1868–1943) and Eduard Schiff (Austrian, 1849–1913) developed and employed radiation therapy to kill tumors from 1896 onward (pp. 1509–1510). Freund wrote the first medical textbook on radiation therapy in 1902 and published it in 1903 [Leopold Freund 1903]. Translations of the book in English and other languages were published in 1904, so Freund truly founded and shaped the field of radiation therapy worldwide.

(c) Theodor Boveri (German, 1862–1915) realized in 1902 that cancer can be caused by pro-mitotic (cell-division-inducing) mutations from radiation, chemicals, or viruses (pp. 113–117).

(d) In 1922, Leopold Freund and Josef Maria Eder (Austrian, 1855–1944) invented the first chemical sunscreen, which was marketed as Antilux (p. 126).

(e) Fritz Lickint (German, 1898–1960) began medical studies of smokers vs. nonsmokers in the 1920s, published evidence that smoking causes cancer in 1929, and published a >1200 page medical book on the detailed pathology caused by smoking in 1939 (p. 118). His discoveries led to public health campaigns against smoking, first in Germany and much later worldwide [Haustein 2004].

(f) German-speaking scientists identified specific carcinogens from the 1870s through World War II and developed methods to control and prevent exposure (pp. 113–124, 2375–2374).

(g) By the early 1940s, German-speaking scientists developed therapeutic antibodies against cancer-related antigens (pp. 2354–2359). Such therapeutic antibodies are currently one of the most modern and most effective methods of treating cancers in patients.

(h) German-speaking scientists also made many other significant contributions to knowledge about cancer (pp. 119–124).

7. German-speaking scientists characterized and harnessed proteins and enzymes:

   (a) Wilhelm Kühne (German, 1837–1900) was one of the first scientists to study proteins in detail (p. 128). He discovered trypsin, a digestive enzyme or protease that degrades other proteins, studied proteins in muscle and rhodopsin in human photoreceptor cells, and in fact coined the word “enzyme” (p. 138).

   (b) Franz Hofmeister (Austrian, 1850–1922) established many methods of protein chemistry that are still used today (Fig. 2.42). He discovered the peptide bonds in proteins, the effect of various salts on proteins, differing protein solubilities, methods of protein purification, and methods of protein crystallization [Abernethy 1967].

   (c) Beginning in the 1870s, Albrecht Kossel (German, 1853–1927) showed that proteins are composed of amino acids, and isolated and characterized the individual amino acids (p. 140).

  (d) German-speaking scientists invented immunoassays (228). Max von Gruber (Austrian, 1853–1927) discovered the agglutination reaction, in which antibodies and pathogens clump together, in 1896. Rudolf Kraus (Austrian, 1868–1932) used the agglutination reaction to create an antibody assay for specific bacterial precipitins in 1897. August von Wasserman (German, 1866–1925) used similar methods to create a complement fixation test for syphilis bacteria in 1906.

  (e) In 1912, Leonor Michaelis (German, 1875–1949) and Maud Menten (Canadian, worked in Germany, 1879–1960) developed experimental and theoretical methods to analyze the chemical reaction rates of enzymes (p. 142).

  (f) Otto Röhm (German, 1876–1939) pioneered the industrial production, purification, and use of enzymes (proteases, starch hydrolases, pectinases, lipases, etc.) for applications such as leather production (1906), washing detergents (1914), pharmaceuticals (1920), and juice processing (1934). See pp. 2353, 2445, 2448–2452.

  (g) Starting in the 1910s, Max Bergmann (German, 1886–1944) created methods of determining the amino acid sequences of natural proteins and of artificially synthesizing proteins with specific amino acid sequences (p. 130).

  (h) German-speaking scientists played leading roles in discovering and understanding the enzymes involved in mitochondria, cellular respiration, and related metabolic reactions (pp. 156–159).

  (i) In the 1930s and early 1940s, German-speaking scientists developed several egg protein substitutes that consisted of protein extracted, purified, and processed on an industrial scale from cultured yeast, animal blood plasma (Plenora), fish (Eiweiss), and milk (Milei). See pp. 2326–2339, 2390–2393, 2400–2401.

  (j) Max Perutz (Austrian, 1914–2002) developed and demonstrated methods of determining detailed three-dimensional protein structures such as hemoglobin (p. 144).

  (k) German-speaking scientists also made many other contributions to knowledge about proteins and enzymes (pp. 135–137).

8. In addition to all of the above production, German-speaking scientists produced and purified a wide range of other biomolecules for many different applications:

  (a) In the 1930s and early 1940s, many German-speaking scientists developed artificial methods to produce lipids or fats for foods, soaps, fuels, and other products. Glycerin, sterols, fatty acids, and triglycerides were produced from chemical synthesis on an industrial scale and sold for food products and other applications [BIOS 86; BIOS 805; FIAT 213; FIAT 407]. See p. 518.

  (b) Fats were produced and purified from various strains of cultured algae and fungi using biotechnology methods [BIOS 236; BIOS 691; FIAT 371]. In addition to the food applications, this appears to have been the origin of algal and other microbial biofuel technologies. See pp. 2326–2339, 2361–2364, 2430–2444.

  (c) Artificially produced fats were used to make a variety of food products, including cooking oil, cooking fat (shortening), margarine, creamer, salad oil, chocolate [Clarke 1946], synthetic human milk (infant formula) [FIAT 107], etc.

(d) Both the natural science and the practical applications of steroid hormones were developed almost entirely by creators from the greater German-speaking world.[1] See pp. 358–367. The discoveries regarding these hormones had revolutionary, immediate, and long-lasting implications, making possible the creation of pregnancy tests (1927), oral contraceptives (1930), menopause treatments, anabolic steroids, anti-inflammatory steroid drugs, blood pressure medications, therapeutics for high cholesterol, etc.

(e) German-speaking scientists made virtually all of the key discoveries regarding the role of insulin in controlling and preventing diabetes.[2] See pp. 373–374.

(f) During World War II, German-speaking scientists developed freeze-dried human blood for transfusions (pp. 2354–2358).

(g) Also during the war, German-speaking scientists invented and widely used periston synthetic blood plasma (pp. 340–341, 2340–2351, 2418–2429). They created capain synthetic blood plasma too (p. 342).

(h) German-speaking scientists made most of the major discoveries regarding vitamins and their production.[3] See pp. 349–350.

(i) German-speaking scientists developed most of the major preservatives that are still widely used in foods, pharmaceuticals, and biotechnology reagents, such as: (1) Ascorbic acid (vitamin C), which was identified in 1930 by Albert Szent-Györgyi (Hungarian, 1893–1986) and mass-produced via chemical synthesis in 1933 by Tadeusz Reichstein (Polish, educated and worked in Switzerland, 1897–1996). (2) Benzoic acid, which was first analyzed in 1832 by Friedrich Wöhler (German, 1800–1882) and Justus von Liebig (German, 1803–1873). (3) Citric acid, which was first produced from fermentation in fungi in 1890 by Carl Wehmer (German, 1858–1935). (4) Sorbic acid, which was discovered in 1859 by August Wilhelm von Hofmann (German, 1818–1892). (5) Ethylenediaminetetraacetic acid (EDTA), which was synthesized and demonstrated in 1935 by Ferdinand Münz (Austrian, 1888–1969). See pp. 522–523.

(j) German-speaking chemists developed artificial methods of producing caffeine, including from direct chemical synthesis [FIAT 885] and from the conversion of uric acid harvested from snake urine [BIOS 449]. See pp. 514, 2354–2355.

(k) A wide variety of other biomolecules were also produced (for example, see p. 2366).

Thus the available evidence shows that most aspects of biotechnology and molecular biology were developed in the German-speaking world, and that the German-speaking world was the leader in those areas through World War II.

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[1] Butenandt 1931; Dominguez-Lacasa 2005; Gausemeier 2005; Jahn 2004; Junker 2004; Karlson 1990; Koesling and Schülke 2010; Kohler 2008; Magner 2002; Marks 2010; Possehl 1989; Raviña and Kubinyi 2011; Schieder and Trunk 2004; Schneider 1972; von Schwerin 2013; Sneader 2005; Stoff 2012; Taschwer 2016; Weatherall 1991.

[2] Bliss 2007, pp. 25–31; Meienhofer 1963; Mellinghoff 1971, 1972; von Schwerin et al. 2013, pp. 151–155; Sneader 2005, pp. 164–166.

[3] Jahn 2004; Junker 2004; Kohler 2008; Magner 2002; von Schwerin 2013; Sneader 2005; Stoff 2012; Weatherall 1991.

The evidence also shows that knowledge, methods, and materials for biotechnology and molecular biology were transferred to other countries:

- Before the Third Reich, in the form of published and patented information, German-speaking companies (e.g., Röhm and Haas) that transferred technologies to other countries, some scientists (e.g., Carl and Gerty Cori, Chaim Weizmann) who moved to other countries, and scientists from other countries who received part of their education in the German-speaking world.

- During the Third Reich, in the form of published and patented information and also many key scientists (Charlotte Auerbach, Max Bergmann, Ernst Chain, Erwin Chargaff, Max Delbrück, George Gamow, Richard Goldschmidt, Hans Krebs, Max Perutz, Albert Szent-Györgyi, Leo Szilard, etc.) who fled to other countries.

- After the Third Reich, in the form of huge numbers of scientists who moved to other countries, Allied seizures of German and Austrian plants and documents, and Allied reports (BIOS, CIOS, FIAT, etc.) on German and Austrian technologies.

Due to length constraints, this section and Chapter 2 can only briefly mention a limited number of examples. Hopefully other authors will more fully investigate and report the history and contributions of German-speaking scientists to the development of biotechnology and molecular biology.]

H. Benninga. 1990. *A History of Lactic Acid Making: A Chapter in the History of Biotechnology.* Dordrecht: Kluwer.

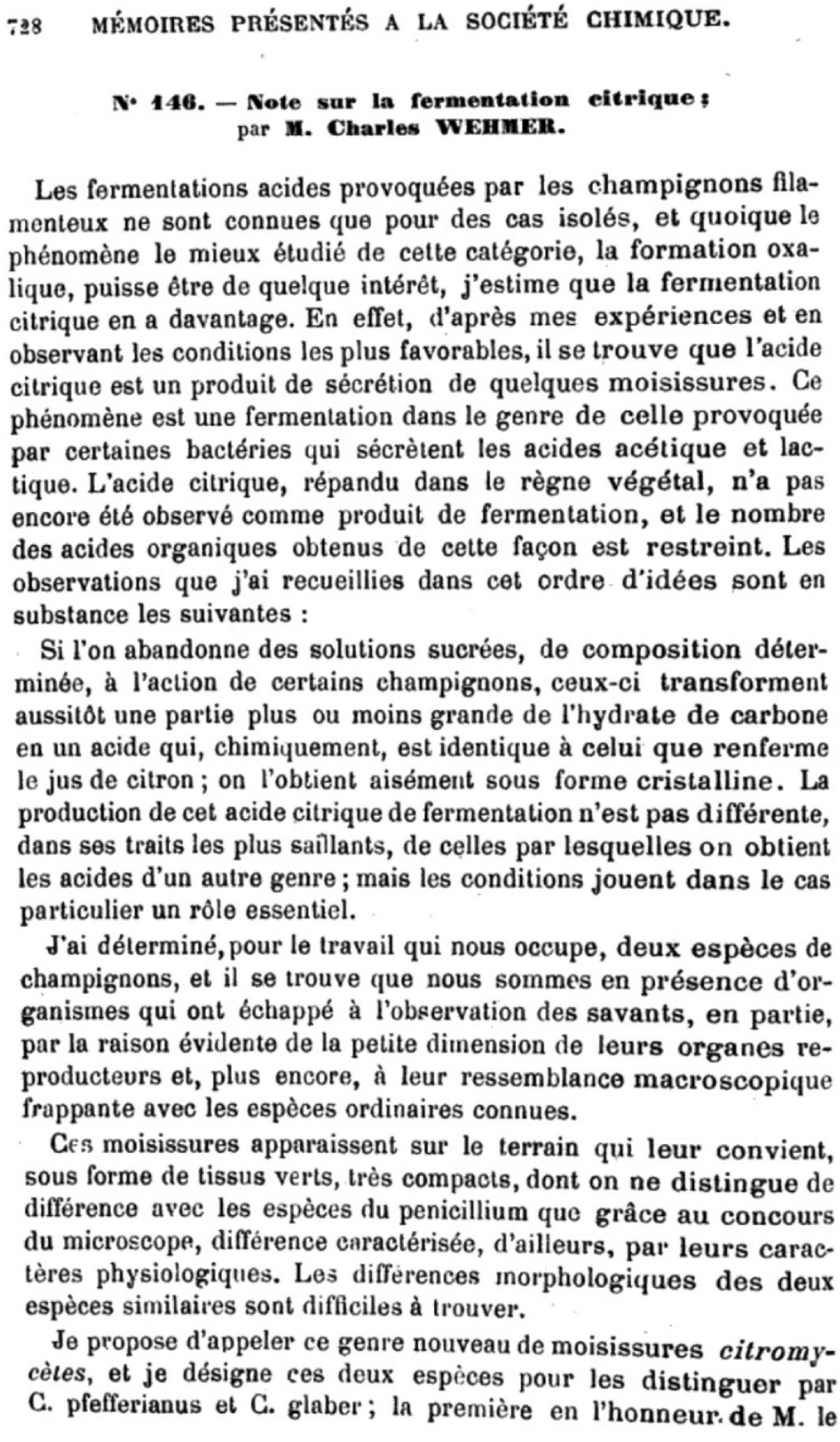
In 1893 a short communication from the hands of Carl Wehmer appeared about citric acid fermentation in the Bulletin de la Société Chimique de France[...] In the same year he applied for patents in Great Britain (British Patent 5620, granted in 1893) and in Germany (German Patent 72,957, granted in 1894); the "Fabriques de Produits Chimiques de Thann et de Mulhouse" was registered as the owner of both patents.

In the communication to the "Bulletin" Wehmer reported that he had already begun the experiments in 1890, and now was able to produce citric acid on a 10 kg scale. [...]

The first metabolic product obtained by Wehmer was oxalic acid. This acid is present in many plants and in molds as well, which sometimes produce it in appreciable quantities.

The next metabolic acid of importance he discovered was citric acid. Two species of fungi which he denominated *Citromyces*—but today are included in the genus *Penicillium*—were able to produce interesting quantities of citric acid when grown on 10% sugar solutions. Wehmer immediately recognized the practical importance of his findings and applied for patents.

[Wehmer also pioneered the use of cultured fungal cells to produce fumaric acid and possibly other substances as well. See pp. 2316–2319.]



728 MÉMOIRES PRÉSENTÉS A LA SOCIÉTÉ CHIMIQUE.

Nº 146. — Note sur la fermentation citrique ;

par M. Charles WEHMER.

Les fermentations acides provoquées par les champignons filamenteux ne sont connues que pour des cas isolés, et quoique le phénomène le mieux étudié de cette catégorie, la formation oxalique, puisse être de quelque intérêt, j'estime que la fermentation citrique en a davantage. En effet, d'après mes expériences et en observant les conditions les plus favorables, il se trouve que l'acide citrique est un produit de sécrétion de quelques moisissures. Ce phénomène est une fermentation dans le genre de celle provoquée par certaines bactéries qui sécrètent les acides acétique et lactique. L'acide citrique, répandu dans le règne végétal, n'a pas encore été observé comme produit de fermentation, et le nombre des acides organiques obtenus de cette façon est restreint. Les observations que j'ai recueillies dans cet ordre d'idées sont en substance les suivantes :

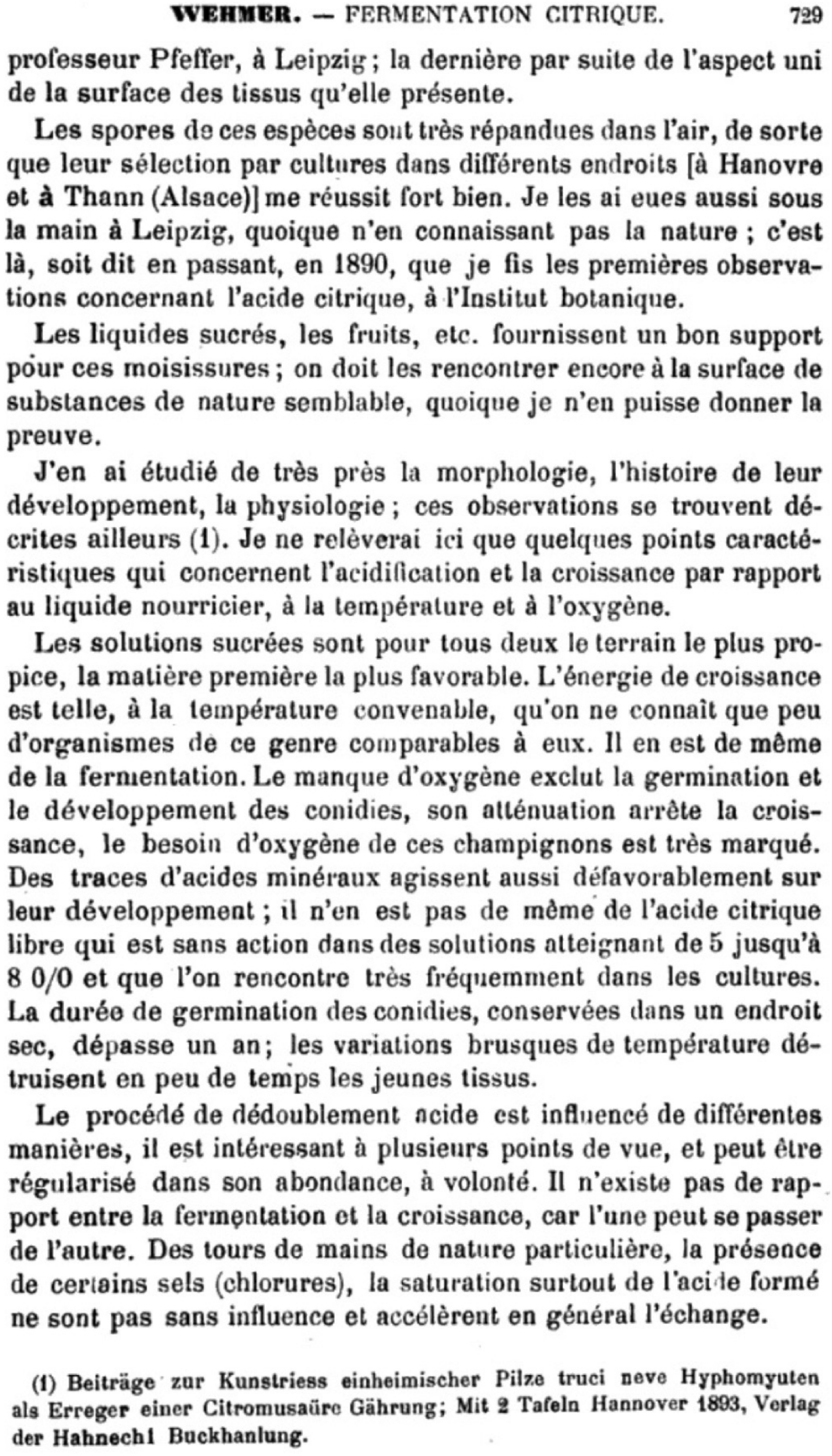
Si l'on abandonne des solutions sucrées, de composition déterminée, à l'action de certains champignons, ceux-ci transforment aussitôt une partie plus ou moins grande de l'hydrate de carbone en un acide qui, chimiquement, est identique à celui que renferme le jus de citron ; on l'obtient aisément sous forme cristalline. La production de cet acide citrique de fermentation n'est pas différente, dans ses traits les plus saillants, de celles par lesquelles on obtient les acides d'un autre genre ; mais les conditions jouent dans le cas particulier un rôle essentiel.

J'ai déterminé, pour le travail qui nous occupe, deux espèces de champignons, et il se trouve que nous sommes en présence d'organismes qui ont échappé à l'observation des savants, en partie, par la raison évidente de la petite dimension de leurs organes reproducteurs et, plus encore, à leur ressemblance macroscopique frappante avec les espèces ordinaires connues.

Ces moisissures apparaissent sur le terrain qui leur convient, sous forme de tissus verts, très compacts, dont on ne distingue de différence avec les espèces du penicillium que grâce au concours du microscope, différence caractérisée, d'ailleurs, par leurs caractères physiologiques. Les différences morphologiques des deux espèces similaires sont difficiles à trouver.

Je propose d'appeler ce genre nouveau de moisissures *citromycètes*, et je désigne ces deux espèces pour les distinguer par C. pfefferianus et C. glaber ; la première en l'honneur de M. le

Figure A.1: Carl Wehmer pioneered the use of cultured fungal cells to produce citric acid and other substances [*Bulletin de la Société Chimique de France* 9:728–730 (1893)].



WEHMER. — FERMENTATION CITRIQUE. 729

professeur Pfeffer, à Leipzig; la dernière par suite de l'aspect uni de la surface des tissus qu'elle présente.

Les spores de ces espèces sont très répandues dans l'air, de sorte que leur sélection par cultures dans différents endroits [à Hanovre et à Thann (Alsace)] me réussit fort bien. Je les ai eues aussi sous la main à Leipzig, quoique n'en connaissant pas la nature; c'est là, soit dit en passant, en 1890, que je fis les premières observations concernant l'acide citrique, à l'Institut botanique.

Les liquides sucrés, les fruits, etc. fournissent un bon support pour ces moisissures; on doit les rencontrer encore à la surface de substances de nature semblable, quoique je n'en puisse donner la preuve.

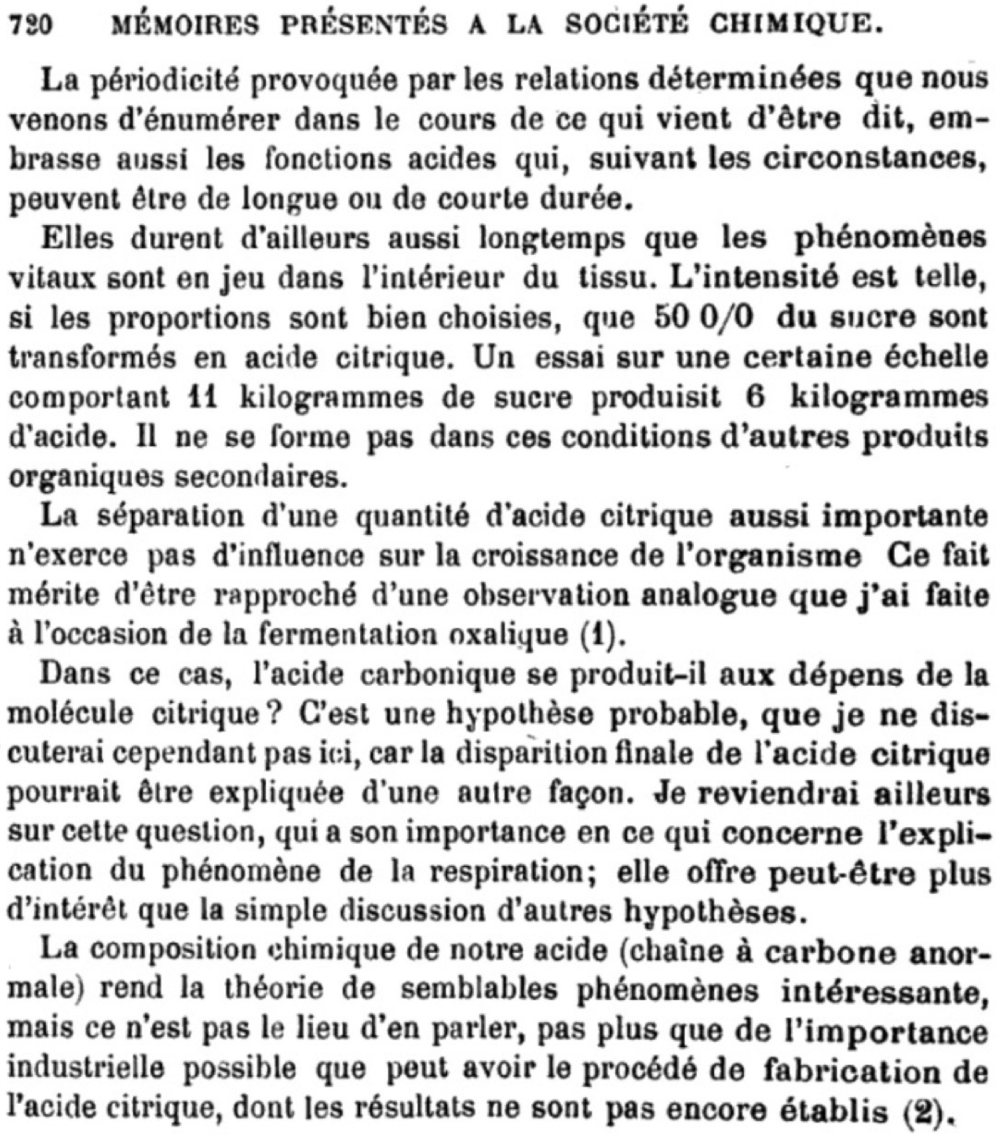
J'en ai étudié de très près la morphologie, l'histoire de leur développement, la physiologie; ces observations se trouvent décrites ailleurs (1). Je ne relèverai ici que quelques points caractéristiques qui concernent l'acidification et la croissance par rapport au liquide nourricier, à la température et à l'oxygène.

Les solutions sucrées sont pour tous deux le terrain le plus propice, la matière première la plus favorable. L'énergie de croissance est telle, à la température convenable, qu'on ne connaît que peu d'organismes de ce genre comparables à eux. Il en est de même de la fermentation. Le manque d'oxygène exclut la germination et le développement des conidies, son atténuation arrête la croissance, le besoin d'oxygène de ces champignons est très marqué. Des traces d'acides minéraux agissent aussi défavorablement sur leur développement; il n'en est pas de même de l'acide citrique libre qui est sans action dans des solutions atteignant de 5 jusqu'à 8 0/0 et que l'on rencontre très fréquemment dans les cultures. La durée de germination des conidies, conservées dans un endroit sec, dépasse un an; les variations brusques de température détruisent en peu de temps les jeunes tissus.

Le procédé de dédoublement acide est influencé de différentes manières, il est intéressant à plusieurs points de vue, et peut être régularisé dans son abondance, à volonté. Il n'existe pas de rapport entre la fermentation et la croissance, car l'une peut se passer de l'autre. Des tours de mains de nature particulière, la présence de certains sels (chlorures), la saturation surtout de l'acide formé ne sont pas sans influence et accélèrent en général l'échange.

(1) Beiträge zur Kunstriess einheimischer Pilze truci neve Hyphomyuten als Erreger einer Citromusaüre Gährung; Mit 2 Tafeln Hannover 1893, Verlag der Hahnech1 Buckhanlung.

Figure A.2: Carl Wehmer pioneered the use of cultured fungal cells to produce citric acid and other substances [*Bulletin de la Société Chimique de France* 9:728–730 (1893)].



720 MÉMOIRES PRÉSENTÉS A LA SOCIÉTÉ CHIMIQUE.

La périodicité provoquée par les relations déterminées que nous venons d'énumérer dans le cours de ce qui vient d'être dit, embrasse aussi les fonctions acides qui, suivant les circonstances, peuvent être de longue ou de courte durée.

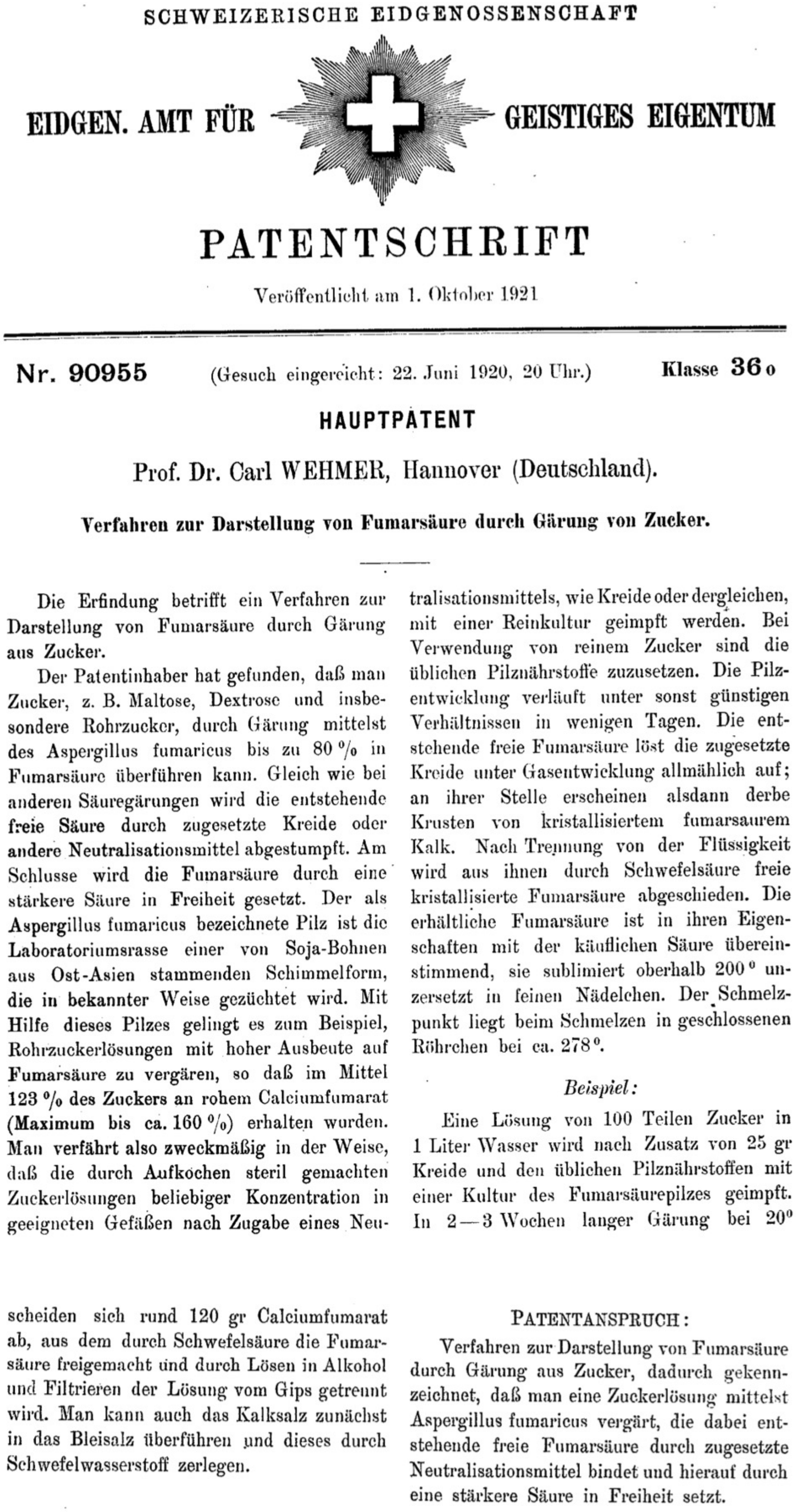
Elles durent d'ailleurs aussi longtemps que les phénomènes vitaux sont en jeu dans l'intérieur du tissu. L'intensité est telle, si les proportions sont bien choisies, que 50 0/0 du sucre sont transformés en acide citrique. Un essai sur une certaine échelle comportant 11 kilogrammes de sucre produisit 6 kilogrammes d'acide. Il ne se forme pas dans ces conditions d'autres produits organiques secondaires.

La séparation d'une quantité d'acide citrique aussi importante n'exerce pas d'influence sur la croissance de l'organisme Ce fait mérite d'être rapproché d'une observation analogue que j'ai faite à l'occasion de la fermentation oxalique (1).

Dans ce cas, l'acide carbonique se produit-il aux dépens de la molécule citrique ? C'est une hypothèse probable, que je ne discuterai cependant pas ici, car la disparition finale de l'acide citrique pourrait être expliquée d'une autre façon. Je reviendrai ailleurs sur cette question, qui a son importance en ce qui concerne l'explication du phénomène de la respiration; elle offre peut-être plus d'intérêt que la simple discussion d'autres hypothèses.

La composition chimique de notre acide (chaîne à carbone anormale) rend la théorie de semblables phénomènes intéressante, mais ce n'est pas le lieu d'en parler, pas plus que de l'importance industrielle possible que peut avoir le procédé de fabrication de l'acide citrique, dont les résultats ne sont pas encore établis (2).

Figure A.3: Carl Wehmer pioneered the use of cultured fungal cells to produce citric acid and other substances [*Bulletin de la Société Chimique de France* 9:728–730 (1893)].



SCHWEIZERISCHE EIDGENOSSENSCHAFT

EIDGEN. AMT FÜR GEISTIGES EIGENTUM

PATENTSCHRIFT

Veröffentlicht am 1. Oktober 1921

Nr. 90955 (Gesuch eingereicht: 22. Juni 1920, 20 Uhr.) **Klasse 36 o**

HAUPTPATENT

Prof. Dr. Carl WEHMER, Hannover (Deutschland).

Verfahren zur Darstellung von Fumarsäure durch Gärung von Zucker.

Die Erfindung betrifft ein Verfahren zur Darstellung von Fumarsäure durch Gärung aus Zucker.

Der Patentinhaber hat gefunden, daß man Zucker, z. B. Maltose, Dextrose und insbesondere Rohrzucker, durch Gärung mittelst des Aspergillus fumaricus bis zu 80 % in Fumarsäure überführen kann. Gleich wie bei anderen Säuregärungen wird die entstehende freie Säure durch zugesetzte Kreide oder andere Neutralisationsmittel abgestumpft. Am Schlusse wird die Fumarsäure durch eine stärkere Säure in Freiheit gesetzt. Der als Aspergillus fumaricus bezeichnete Pilz ist die Laboratoriumsrasse einer von Soja-Bohnen aus Ost-Asien stammenden Schimmelform, die in bekannter Weise gezüchtet wird. Mit Hilfe dieses Pilzes gelingt es zum Beispiel, Rohrzuckerlösungen mit hoher Ausbeute auf Fumarsäure zu vergären, so daß im Mittel 123 % des Zuckers an rohem Calciumfumarat (Maximum bis ca. 160 %) erhalten wurden. Man verfährt also zweckmäßig in der Weise, daß die durch Aufkochen steril gemachten Zuckerlösungen beliebiger Konzentration in geeigneten Gefäßen nach Zugabe eines Neutralisationsmittels, wie Kreide oder dergleichen, mit einer Reinkultur geimpft werden. Bei Verwendung von reinem Zucker sind die üblichen Pilznährstoffe zuzusetzen. Die Pilzentwicklung verläuft unter sonst günstigen Verhältnissen in wenigen Tagen. Die entstehende freie Fumarsäure löst die zugesetzte Kreide unter Gasentwicklung allmählich auf; an ihrer Stelle erscheinen alsdann derbe Krusten von kristallisiertem fumarsaurem Kalk. Nach Trennung von der Flüssigkeit wird aus ihnen durch Schwefelsäure freie kristallisierte Fumarsäure abgeschieden. Die erhältliche Fumarsäure ist in ihren Eigenschaften mit der käuflichen Säure übereinstimmend, sie sublimiert oberhalb 200° unzersetzt in feinen Nädelchen. Der Schmelzpunkt liegt beim Schmelzen in geschlossenen Röhrchen bei ca. 278°.

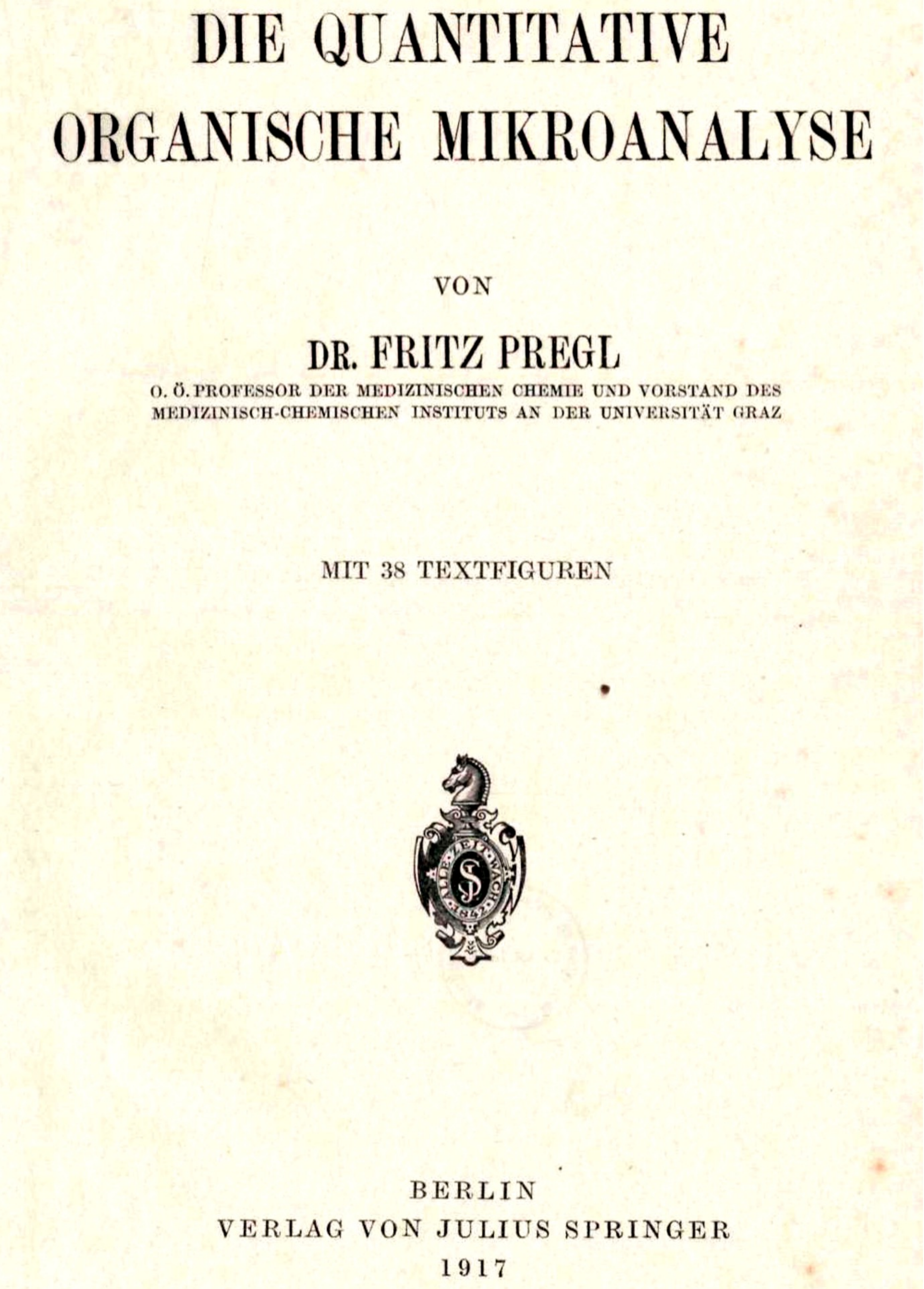
Beispiel:

Eine Lösung von 100 Teilen Zucker in 1 Liter Wasser wird nach Zusatz von 25 gr Kreide und den üblichen Pilznährstoffen mit einer Kultur des Fumarsäurepilzes geimpft. In 2—3 Wochen langer Gärung bei 20° scheiden sich rund 120 gr Calciumfumarat ab, aus dem durch Schwefelsäure die Fumarsäure freigemacht und durch Lösen in Alkohol und Filtrieren der Lösung vom Gips getrennt wird. Man kann auch das Kalksalz zunächst in das Bleisalz überführen und dieses durch Schwefelwasserstoff zerlegen.

PATENTANSPRUCH:

Verfahren zur Darstellung von Fumarsäure durch Gärung aus Zucker, dadurch gekennzeichnet, daß man eine Zuckerlösung mittelst Aspergillus fumaricus vergärt, die dabei entstehende freie Fumarsäure durch zugesetzte Neutralisationsmittel bindet und hierauf durch eine stärkere Säure in Freiheit setzt.

Figure A.4: Carl Wehmer pioneered the use of cultured fungal cells to produce fumaric acid and other substances [Swiss patent CH 90,955].



DIE QUANTITATIVE
ORGANISCHE MIKROANALYSE

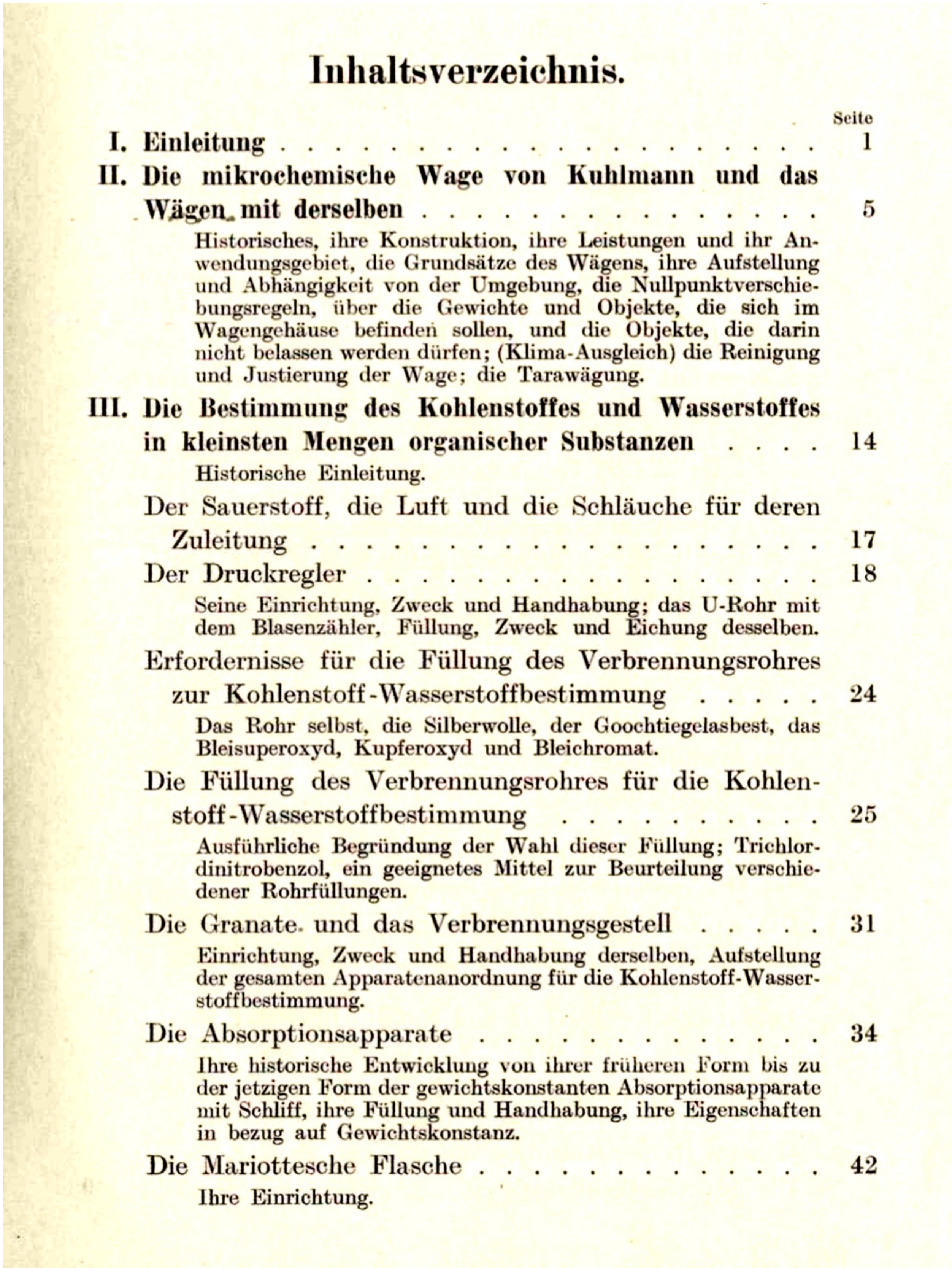
VON

DR. FRITZ PREGL
O. Ö. PROFESSOR DER MEDIZINISCHEN CHEMIE UND VORSTAND DES
MEDIZINISCH-CHEMISCHEN INSTITUTS AN DER UNIVERSITÄT GRAZ

MIT 38 TEXTFIGUREN

BERLIN
VERLAG VON JULIUS SPRINGER
1917

Figure A.5: In the 1910s, Fritz Pregl developed micro-pipetting and micro-analysis tools and methods that are now used in virtually all biology and chemistry laboratories [Pregl 1917].



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Ihre Einrichtung.

Figure A.6: In the 1910s, Fritz Pregl developed micro-pipetting and micro-analysis tools and methods that are now used in virtually all biology and chemistry laboratories [Pregl 1917].

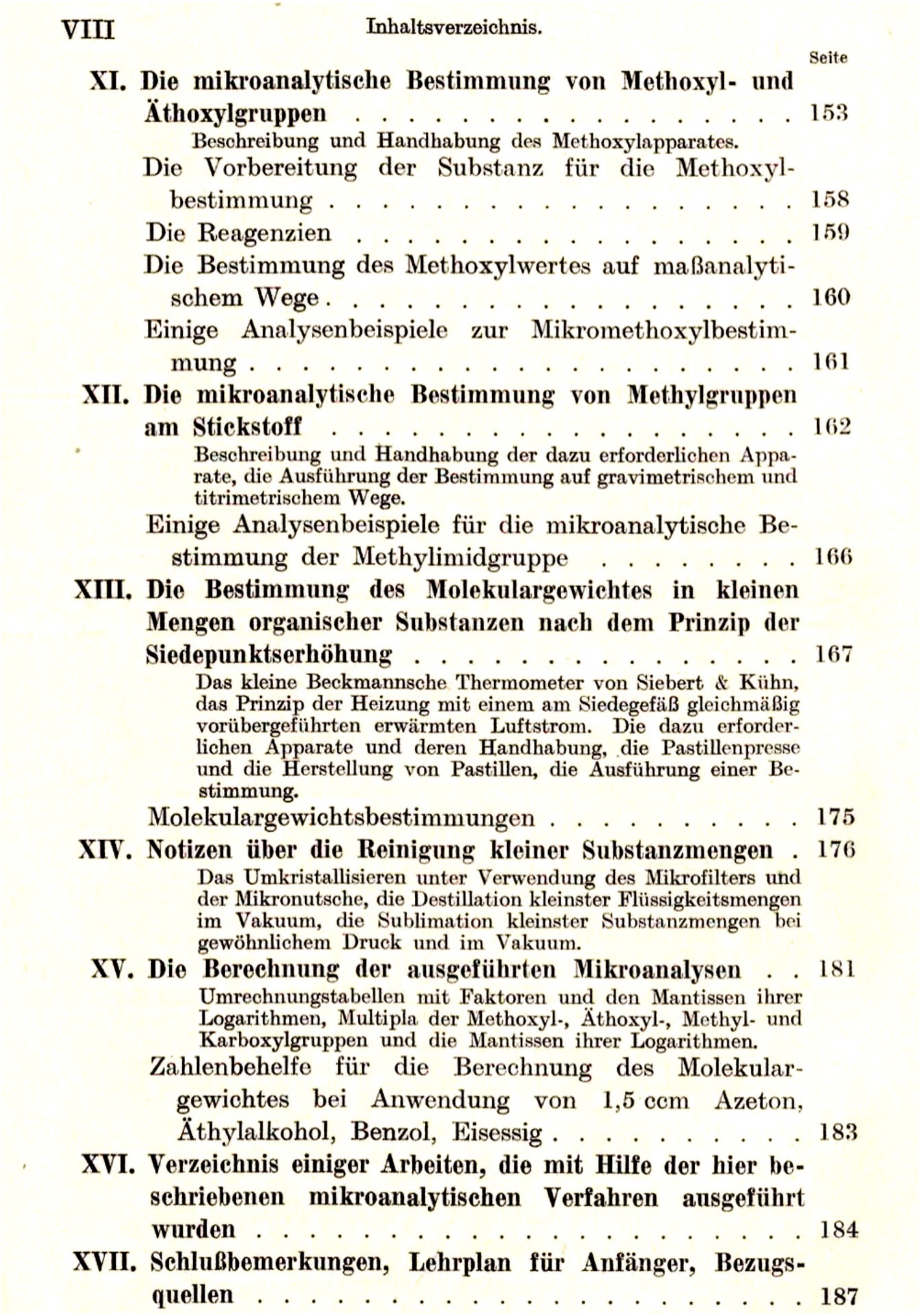

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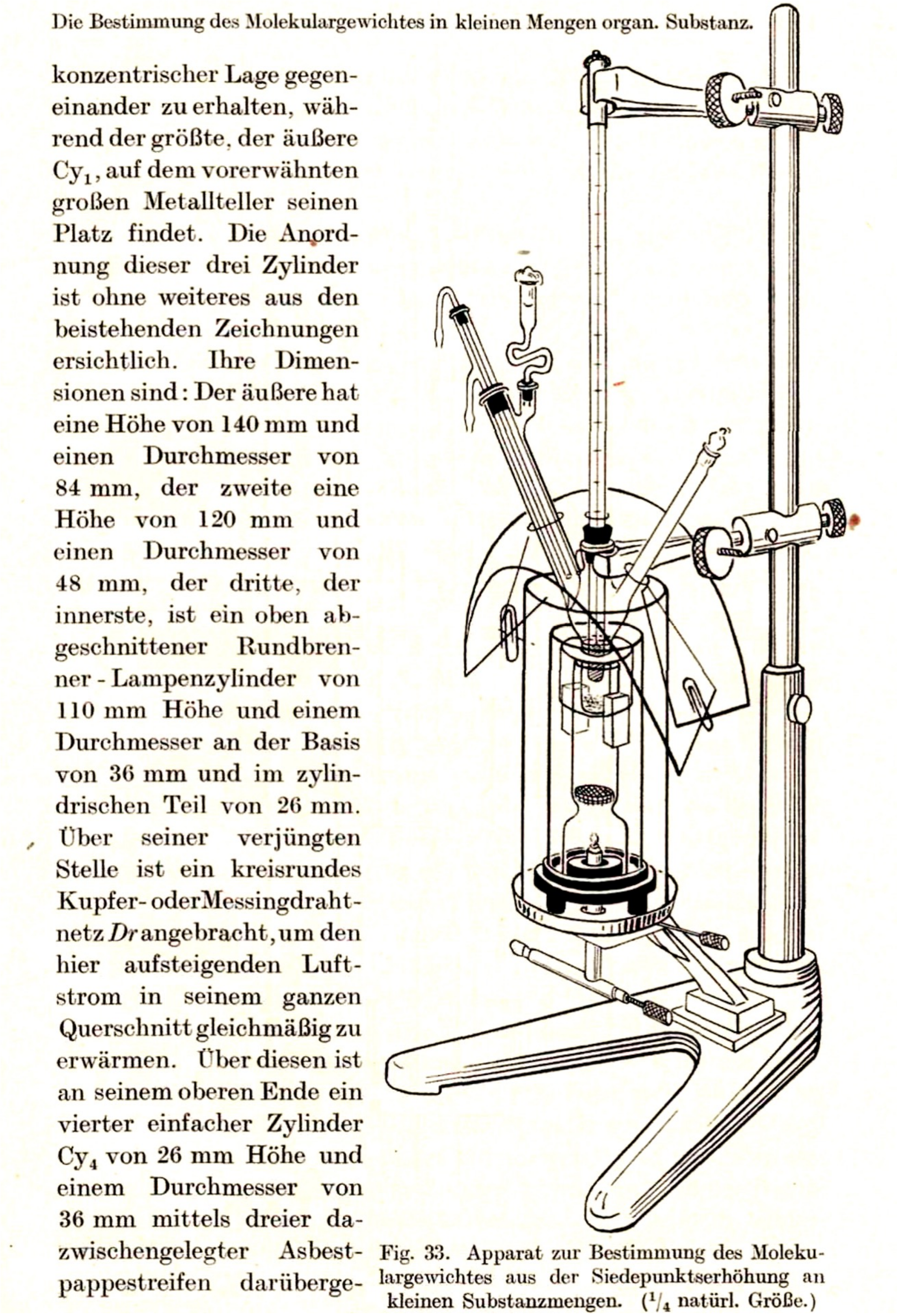
Figure A.7: In the 1910s, Fritz Pregl developed micro-pipetting and micro-analysis tools and methods that are now used in virtually all biology and chemistry laboratories [Pregl 1917].

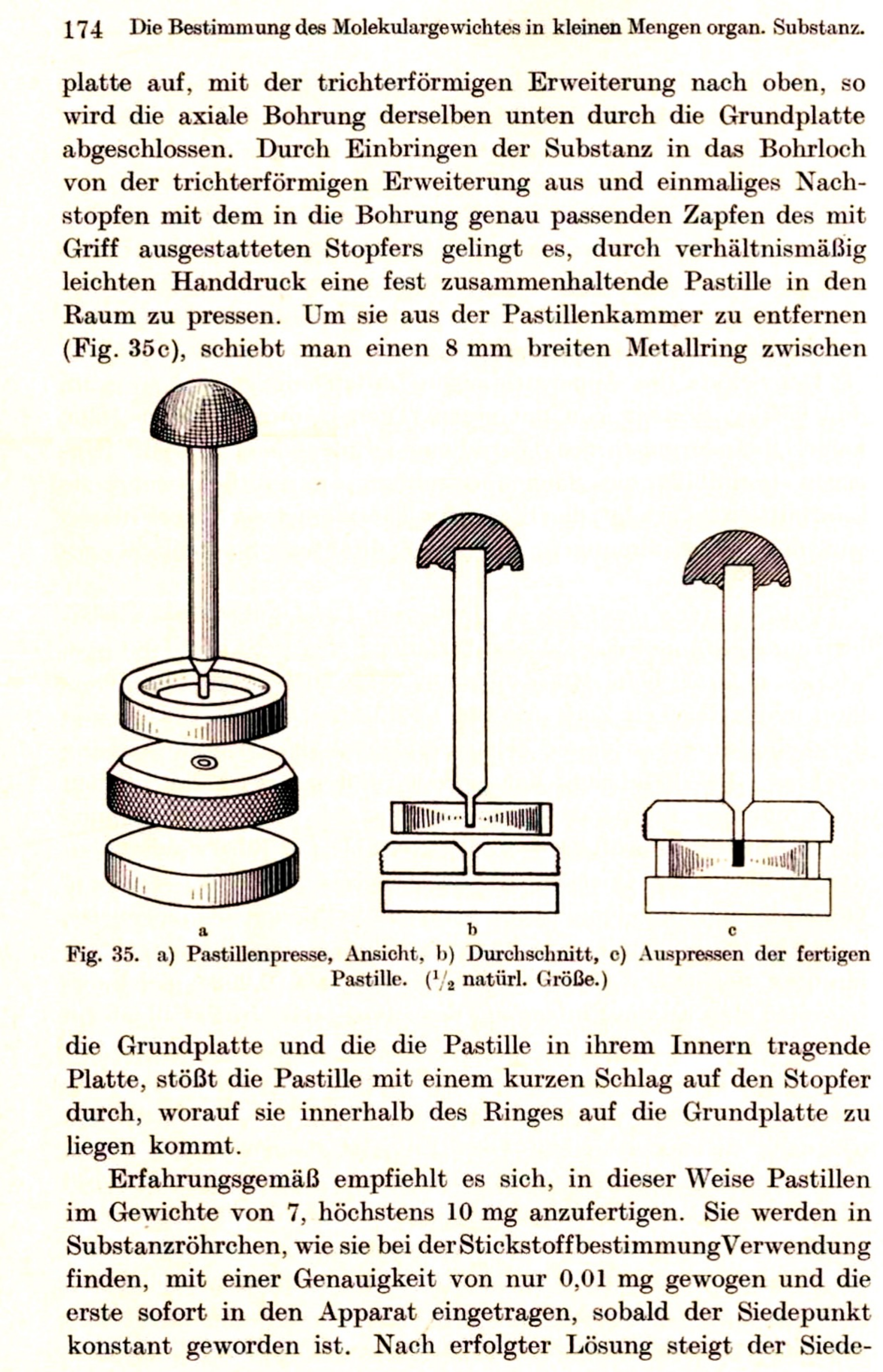


Die Bestimmung des Molekulargewichtes in kleinen Mengen organ. Substanz.

konzentrischer Lage gegeneinander zu erhalten, während der größte, der äußere Cy_1, auf dem vorerwähnten großen Metallteller seinen Platz findet. Die Anordnung dieser drei Zylinder ist ohne weiteres aus den beistehenden Zeichnungen ersichtlich. Ihre Dimensionen sind: Der äußere hat eine Höhe von 140 mm und einen Durchmesser von 84 mm, der zweite eine Höhe von 120 mm und einen Durchmesser von 48 mm, der dritte, der innerste, ist ein oben abgeschnittener Rundbrenner-Lampenzylinder von 110 mm Höhe und einem Durchmesser an der Basis von 36 mm und im zylindrischen Teil von 26 mm. Über seiner verjüngten Stelle ist ein kreisrundes Kupfer- oder Messingdrahtnetz *Dr* angebracht, um den hier aufsteigenden Luftstrom in seinem ganzen Querschnitt gleichmäßig zu erwärmen. Über diesen ist an seinem oberen Ende ein vierter einfacher Zylinder Cy_4 von 26 mm Höhe und einem Durchmesser von 36 mm mittels dreier dazwischengelegter Asbestpappestreifen darüberge-

Fig. 33. Apparat zur Bestimmung des Molekulargewichtes aus der Siedepunktserhöhung an kleinen Substanzmengen. ($^1/_4$ natürl. Größe.)

Figure A.8: In the 1910s, Fritz Pregl developed micro-pipetting and micro-analysis tools and methods that are now used in virtually all biology and chemistry laboratories [Pregl 1917].



174 Die Bestimmung des Molekulargewichtes in kleinen Mengen organ. Substanz.

platte auf, mit der trichterförmigen Erweiterung nach oben, so wird die axiale Bohrung derselben unten durch die Grundplatte abgeschlossen. Durch Einbringen der Substanz in das Bohrloch von der trichterförmigen Erweiterung aus und einmaliges Nachstopfen mit dem in die Bohrung genau passenden Zapfen des mit Griff ausgestatteten Stopfers gelingt es, durch verhältnismäßig leichten Handdruck eine fest zusammenhaltende Pastille in den Raum zu pressen. Um sie aus der Pastillenkammer zu entfernen (Fig. 35c), schiebt man einen 8 mm breiten Metallring zwischen die Grundplatte und die die Pastille in ihrem Innern tragende Platte, stößt die Pastille mit einem kurzen Schlag auf den Stopfer durch, worauf sie innerhalb des Ringes auf die Grundplatte zu liegen kommt.

Fig. 35. a) Pastillenpresse, Ansicht, b) Durchschnitt, c) Auspressen der fertigen Pastille. ($^1/_2$ natürl. Größe.)

Erfahrungsgemäß empfiehlt es sich, in dieser Weise Pastillen im Gewichte von 7, höchstens 10 mg anzufertigen. Sie werden in Substanzröhrchen, wie sie bei der Stickstoffbestimmung Verwendung finden, mit einer Genauigkeit von nur 0,01 mg gewogen und die erste sofort in den Apparat eingetragen, sobald der Siedepunkt konstant geworden ist. Nach erfolgter Lösung steigt der Siede-

Figure A.9: In the 1910s, Fritz Pregl developed micro-pipetting and micro-analysis tools and methods that are now used in virtually all biology and chemistry laboratories [Pregl 1917].

BIOS 219. ***Work on Synthesis and Production of Drugs 3065 (2:2^1-Dihydroxy-5:5^1-Dibrome Benzil) and 3214 (2:2^1-Dihydroxy-3:3^1-5:5^1-Tetrachlor Benzil).***

The M.L.D. of 3065 is one gram per kilogram which is almost the same as sulphapyridine.

[Richard Kuhn] stated that 3065 is the first compound found to be effective against Rickettsia virus and Influenza virus strain A. These experiments have been carried out at Marburg. In a typical experiment on mice infected with Influenza virus strain A, all the treated animals survived whereas all the control group were dead within 6–7 days.

A number of cases of Gonorrhea had responded to treatment with 3065 after being unsuccessfully treated with the sulphonamides.

The main clinical trials on 3065 have been on amputations, thoracoplastic work, and ruptured appendices. Summaries of some of these clinical trials are given in Appendix II.

Prof. Kuhn stated that the drug was first prepared at the end of 1943, and asked about cost he was of the opinion that it would be more expensive than the sulpha drugs.

After the discussion on the drug work inspection was made of the laboratories and the following three items of general interest noted.

1. Prof. Zimmerman, who was working at the I.G. Farben in Ludwigshafen, developed during the war an automatic micro-analysis apparatus which is capable of carrying out 16 micro-analyses per day. Details of this apparatus have not been published and Prof. Kuhn was of the opinion that it would be rather difficult to obtain the essential details of construction.

2. The attack on potatoes by the Colorado Beetle has been a severe problem during the war. The work carried out under the supervision of Kuhn has revealed that an alkaloid can be extracted from the leaves of resistant types of potatoes, bred at an agricultural station near Heidelberg, but there has been no evidence that this substance occurs in plants that are attacked.

3. Kapsenberg Caps. The caps have been developed and used as an alternative to cotton wool plugs in bacteriological tubes and according to Kuhn have entirely supplanted the use of cotton wool at the K.W.I. The caps are made from aluminium and the attached sketch gives some idea of their construction.

   [...] According to Ambros he was simply making 3065 as a personal favor for Kuhn since they are close friends. [...]

   In vitro experiments with 3065 and Burroughs-Wellcome penicillin which had been captured from the British Army showed that 3065 was 300 times more effective against staphylococcus aureus. Ambros pointed out, however, that they did not know the history of [the] penicillin so that it may have undergone some deterioration before they got it. Also the difference in solubility between the two compounds made comparison difficult. A clinical test carried out on a leg amputation wound has shown that 3065 was five to six times more effective than Marfinil.

   Naturally he was not able to give any figures on cost since the material had only been made in the laboratory, but he seemed to think that it would be produced for something like 10–20 Marks per kilogram.

BIOS 236. ***Developments in Pure and Applied Microbiology (American, British and French Zones) During World War II.***

SECTION "A"

DEVELOPMENTS IN PURE AND APPLIED MICROBIOLOGY IN GERMANY (AMERICAN, FRENCH & BRITISH ZONES) DURING WORLD WAR II

[...T]he study of industrial microbiology is really in its infancy, and developments are to a large extent dependent on the outcome of fundamental investigations in research laboratories. A considerable part of the work of the [BIOS] team was therefore concerned with the review of relevant investigations in agricultural experiment stations, universities and other research institutions. [...]

Prof. [F.] Rindel's interests cover a wide field. His earlier work was in the field of pure organic chemistry, and he had within recent years revised Richter's textbook on Organic Chemistry. From a study of the chemistry of various microbiological products, his interests had extended to many nutritional problems. A list of his publications during the war period is given below (5 to 10), but his contacts with microbiological research extended beyond the subjects of these papers.

On the subject of food yeast and other protein preparations of microbiological origin he gave the following information and opinions:

(a) Lactose-fermenting strains of yeast had been isolated which yielded 52 Kg of protein per 100 Kg lactose. These were of no use for bakery purposes, but other lactose-fermenting yeasts had been isolated which would give good gas-production when whey is incorporated in bread dough.

(b) Yeast protein is lacking in cysteine and when fed alone to rats, causes liver damage. The authority for this statement was given as Dr. Fink, who had been associated with the development of the fermentation of wood sugar by Torulopsis utilis and was now stated to be with the Irex Company at Fulbach. Later a similar view was expressed by Prof Lembke of Kiel (see report on protein production by micro-organisms issued separately).

(c) Food yeast grown on waste sulphite liquor from wood pulp had frequently been found to contain lead to the extent of 70 to 80 parts per million (determined by dithizone).

(d) Organisms other than Torulopsis utilis had been used to produce protein for food purposes, e.g. Oidium lactis at a factory at Lenzing, Austria (reference to our visit to this factory is included in our separate report), and Aspergillus sp. at a factory at Traunstein, between Salzburg and Munch. (It was not possible to devote time to locating this factory). Prof Reindel was dubious about using such protein preparations as food until it had been established that they are free from anti-biotic substances. [...]

From the industrial standpoint, the work of most significance appeared to be that on fat production by micro-organisms. An undeveloped observation was that yeasts of the genus Nectaromyces give high fat yields (10 to 15 g per 100 g. sugar utilized) when cultivated by the aeration procedure used for Torulopsis utilis and other yeasts used for food purposes or bread fermentation.

Prof Rippel had recently completed an advanced textbook on the physiology and morphology of micro-organisms which was to have been published by J. Springer of Berlin. [...]

Prof Dr. S. Strugger, however, had been transferred to this institute from the Botanical Institute of the University of Jena, where his work had been financed by the firm Carl Zeiss. He is a cytologist and one of the editors of the journal "Protoplasma". During the war he had been developing the technique of fluorescence microscopy, using Zeiss apparatus with quartz lenses [...], and had also studied methods of vital staining of bacterial cells and spermatozoa using acridine-orange[...] The technique was demonstrated to us and appear to be rapid and reliable for application to the control of certain industrial fermentations. [...]

SECTION "B"

PRODUCTION OF PROTEIN BY MICROBIOLOGICAL METHODS

[...] During the war the German food economy was particularly short of proteins and fat. An intensive effort was therefore made to overcome part of this deficiency through the production of micro-organisms which could be grown on carbohydrates present in whey or the waste liquors from pulp mills. In addition plants were erected to hydrolyse wood cellulose to sugars for this purpose and the necessary nitrogen was supplied in the form of inorganic ammonium salts. This report summarises the processes used in three industrial plants for the production of proteins and does not claim to be comprehensive. The first section deals with production of wood sugars by the Bergius process using concentrated hydrochloric acid. Following this is an account of the Scholler process in which dilute sulphuric acid is used to saccharify wood. On the medium obtained Torula utilis was grown to produce proteins. The third section describes a process used in a wood pulp plant whereby Oidium lactis was grown on waste sulphite liquor for the same purpose. The use of this product as human food had not met with approval and, although on industrial scale, the process was really still experimental.

The final report deals with some of the laboratory research leading up to the cultivation of moulds for their nutritive qualities. [...]

A short interview with Dr. [Andreas] Lembke in the Sanatorium indicated that he had carried on considerable research work on the question of cultivating mould for the production of protein. He stated that during the first World War, his predecessor, Professor Henneberg had begun the cultivation of yeasts for use in protein supplement while working in the Garungewerbe Institute of Berlin. He had also discovered that urea could be fed to cows with beneficial results as a source of nitrogen. After Prof. Henneberg's death in 1936 his work was continued by Prof. Lembke in Kiel.

Prof. Lembke's interest in this work centred around the nature of the amino acids produced by yeasts and moulds. He cultivated many different strains of moulds but found that only a few races were rich in cysteine, methionine and glutathione. Since most yeasts being grown for protein production were very low in cysteine he was anxious to select other organisms which were rich in this particular amino acid. He claims to have had success in obtaining cultures of several moulds which met these requirements.

Strains of Fusarium, Candida, Oidium, Endomyces and Rhizopus were cultured and both wet and dry powdered preparations were made for use in feeding experiments. Some of these products were smoked like bacon or sausages and he said they were quite edible. Being a doctor of medicine as well as a microbiologist, he conducted nutritional studies and claimed that feeding up to 60 grams per day for over 6 months had been beneficial. He stated that the general health of the group of people fed on these proteins was better than the controls.

In feeding experiments he said that it was very important that the moulds should be heated or autolysed before eating them, otherwise they caused diarrhoea.

Of the different moulds used in this work Prof. Lembke thought Fusarium was probably the most satisfactory. He said the East Munich Dairy Station was growing Fusarium on whey. It was also quite satisfactory when grown on waste sulphite liquor. [...]

SECTION “C”

PRODUCTION OF FATS BY MICROBIOLOGICAL METHODS

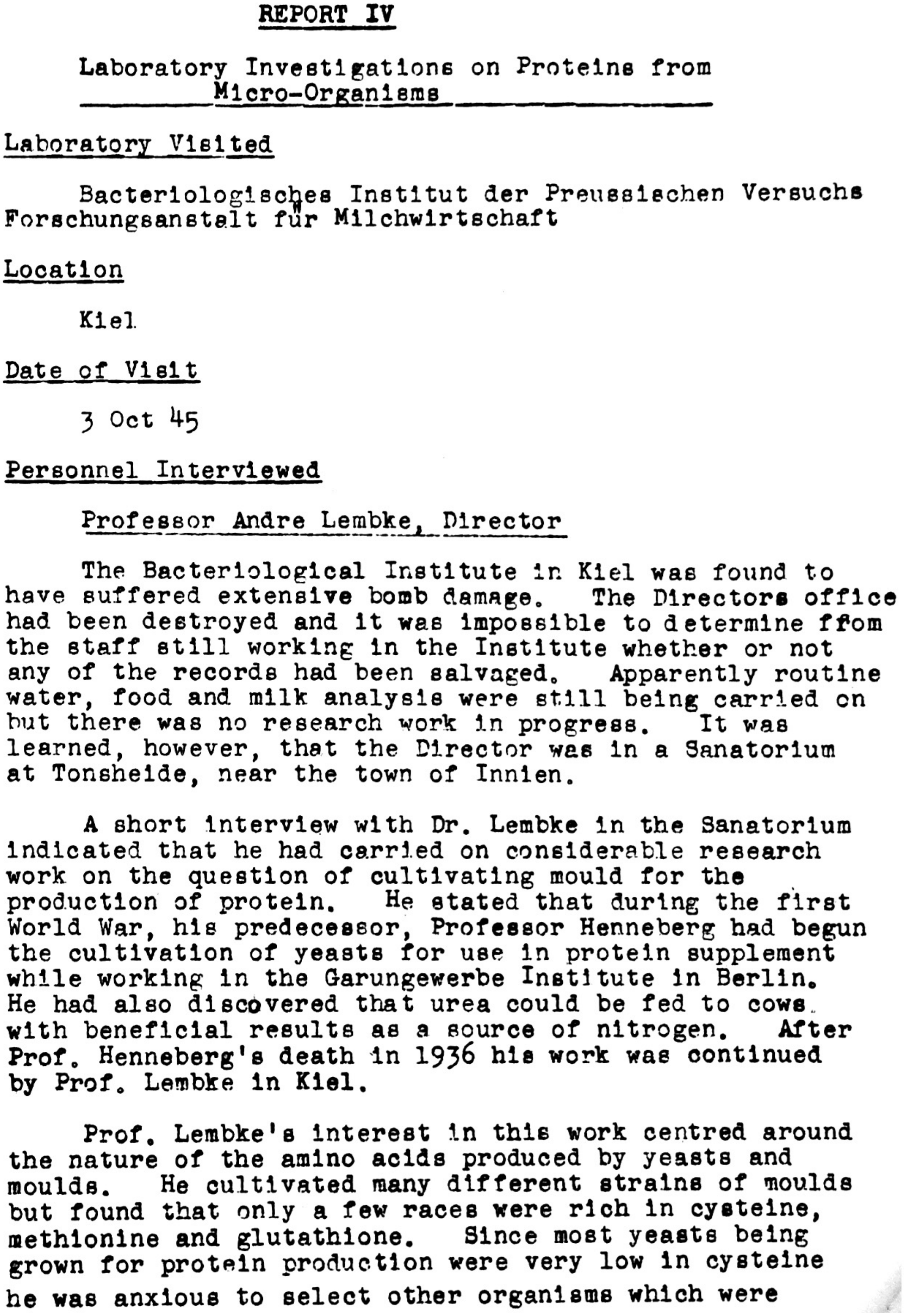
The process showed some novel feature with regard to the cultivation of a mould [Oidium lactis] for high fat production and with regard to the combination of different types of waste material used.

SECTION “D”

ORGANIC ACID MANUFACTURE BY MICROBIOLOGICAL METHODS IN GERMANY

[...] This firm was equipped for preparing lactic, gluconic and citric acids by microbiological methods, but was not producing these at the time of the inspection, owing to shortage of fuel. The plant had in each case been installed prior to the war, that for citric acid immediately prior to the war. [...]

The firm Boehringer was established in Wurtemberg over a century ago and was concerned originally with the manufacture of tartaric acid and tartrates from wine byproducts. A branch was established in Oberingelheim in 1885 to manufacture lactic acid by a fermentating process and the firm claims to be a pioneer in this field. Subsequently other fermentation processes were introduced, and a large section of the firm is now concerned with the manufacture of pharmaceutical preparations by chemical methods. This last aspect of the firm’s activities was outside the scope of our investigations.



REPORT IV

Laboratory Investigations on Proteins from Micro-Organisms

Laboratory Visited

Bacteriologisches Institut der Preussischen Versuchs Forschungsanstalt für Milchwirtschaft

Location

Kiel.

Date of Visit

3 Oct 45

Personnel Interviewed

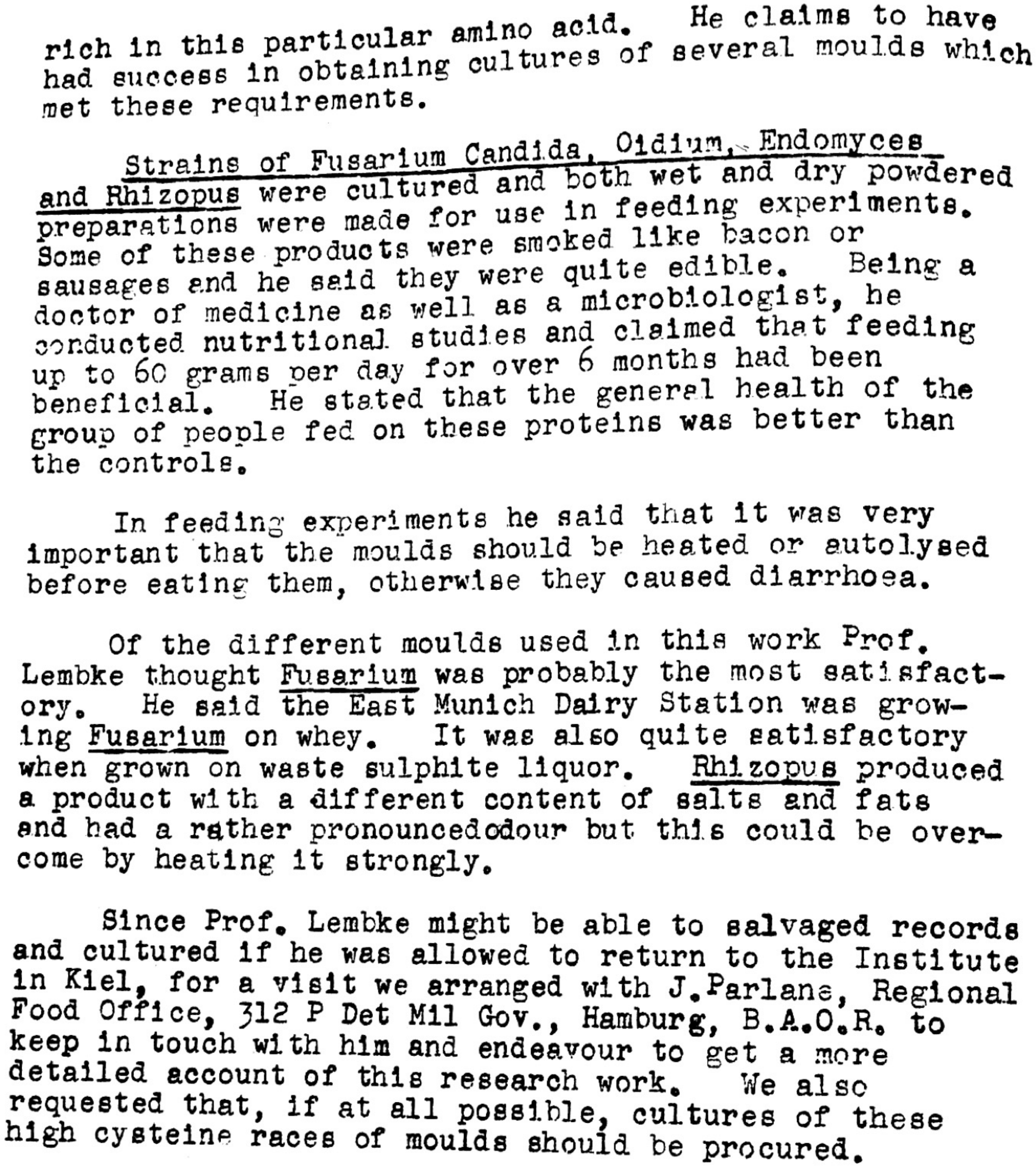
Professor Andre Lembke, Director

The Bacteriological Institute in Kiel was found to have suffered extensive bomb damage. The Directors office had been destroyed and it was impossible to determine ffom the staff still working in the Institute whether or not any of the records had been salvaged. Apparently routine water, food and milk analysis were still being carried on but there was no research work in progress. It was learned, however, that the Director was in a Sanatorium at Tonsheide, near the town of Innien.

A short interview with Dr. Lembke in the Sanatorium indicated that he had carried on considerable research work on the question of cultivating mould for the production of protein. He stated that during the first World War, his predecessor, Professor Henneberg had begun the cultivation of yeasts for use in protein supplement while working in the Garungewerbe Institute in Berlin. He had also discovered that urea could be fed to cows with beneficial results as a source of nitrogen. After Prof. Henneberg's death in 1936 his work was continued by Prof. Lembke in Kiel.

Prof. Lembke's interest in this work centred around the nature of the amino acids produced by yeasts and moulds. He cultivated many different strains of moulds but found that only a few races were rich in cysteine, methionine and glutathione. Since most yeasts being grown for protein production were very low in cysteine he was anxious to select other organisms which were

Figure A.10: Biotechnology methods for producing and purifying edible protein from cultured yeast [BIOS 236].



rich in this particular amino acid. He claims to have had success in obtaining cultures of several moulds which met these requirements.

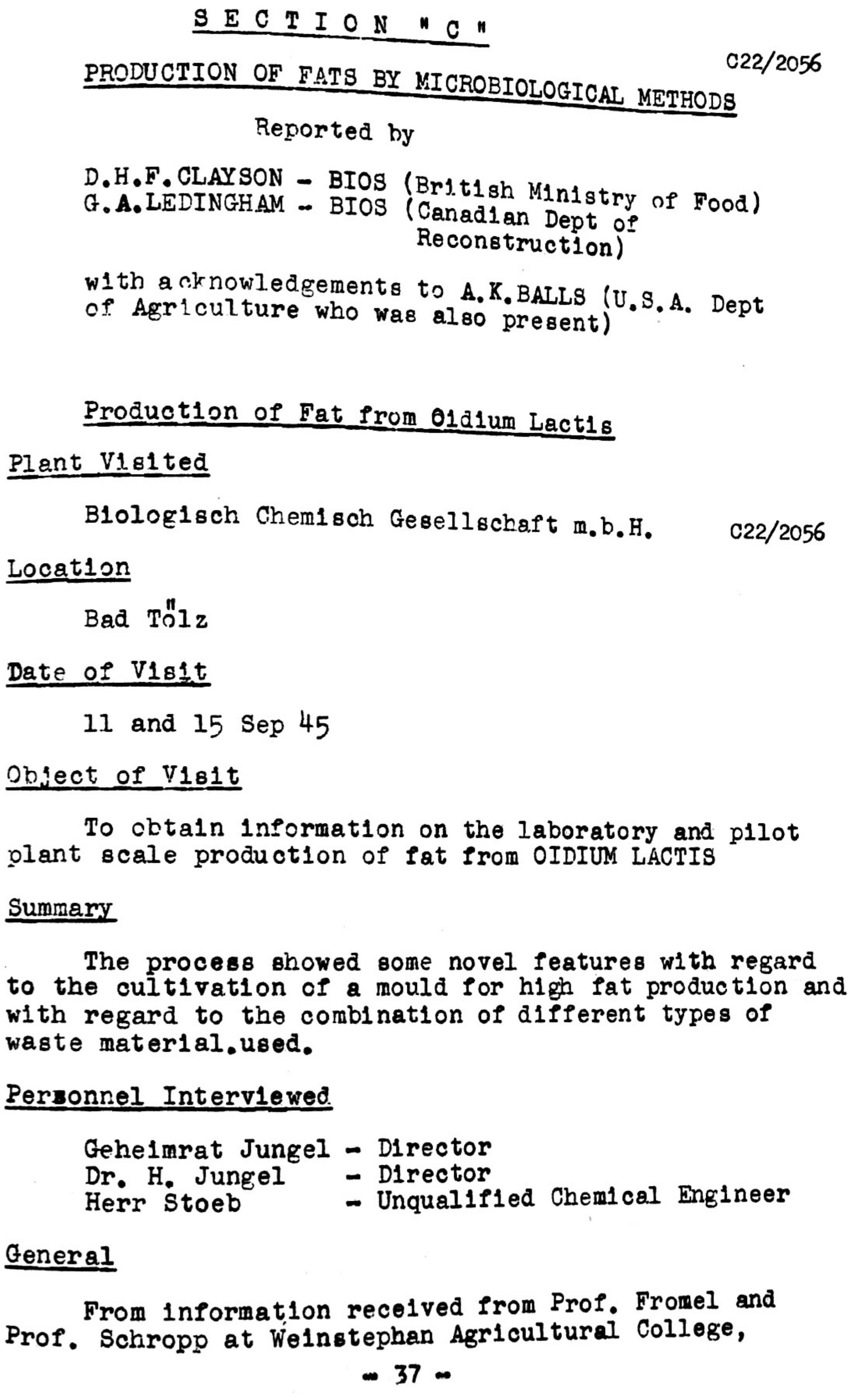
Strains of Fusarium Candida, Oidium, Endomyces and Rhizopus were cultured and both wet and dry powdered preparations were made for use in feeding experiments. Some of these products were smoked like bacon or sausages and he said they were quite edible. Being a doctor of medicine as well as a microbiologist, he conducted nutritional studies and claimed that feeding up to 60 grams per day for over 6 months had been beneficial. He stated that the general health of the group of people fed on these proteins was better than the controls.

In feeding experiments he said that it was very important that the moulds should be heated or autolysed before eating them, otherwise they caused diarrhoea.

Of the different moulds used in this work Prof. Lembke thought Fusarium was probably the most satisfactory. He said the East Munich Dairy Station was growing Fusarium on whey. It was also quite satisfactory when grown on waste sulphite liquor. Rhizopus produced a product with a different content of salts and fats and had a rather pronounced odour but this could be overcome by heating it strongly.

Since Prof. Lembke might be able to salvaged records and cultured if he was allowed to return to the Institute in Kiel, for a visit we arranged with J.Parlane, Regional Food Office, 312 P Det Mil Gov., Hamburg, B.A.O.R. to keep in touch with him and endeavour to get a more detailed account of this research work. We also requested that, if at all possible, cultures of these high cysteine races of moulds should be procured.

Figure A.11: Biotechnology methods for producing and purifying edible protein from cultured yeast [BIOS 236].



SECTION "C"

C22/2056

PRODUCTION OF FATS BY MICROBIOLOGICAL METHODS

Reported by

D.H.F.CLAYSON - BIOS (British Ministry of Food)
G.A.LEDINGHAM - BIOS (Canadian Dept of Reconstruction)

with acknowledgements to A.K.BALLS (U.S.A. Dept of Agriculture who was also present)

Production of Fat from Oidium Lactis

Plant Visited

Biologisch Chemisch Gesellschaft m.b.H. C22/2056

Location

Bad Tölz

Date of Visit

11 and 15 Sep 45

Object of Visit

To obtain information on the laboratory and pilot plant scale production of fat from OIDIUM LACTIS

Summary

The process showed some novel features with regard to the cultivation of a mould for high fat production and with regard to the combination of different types of waste material.used.

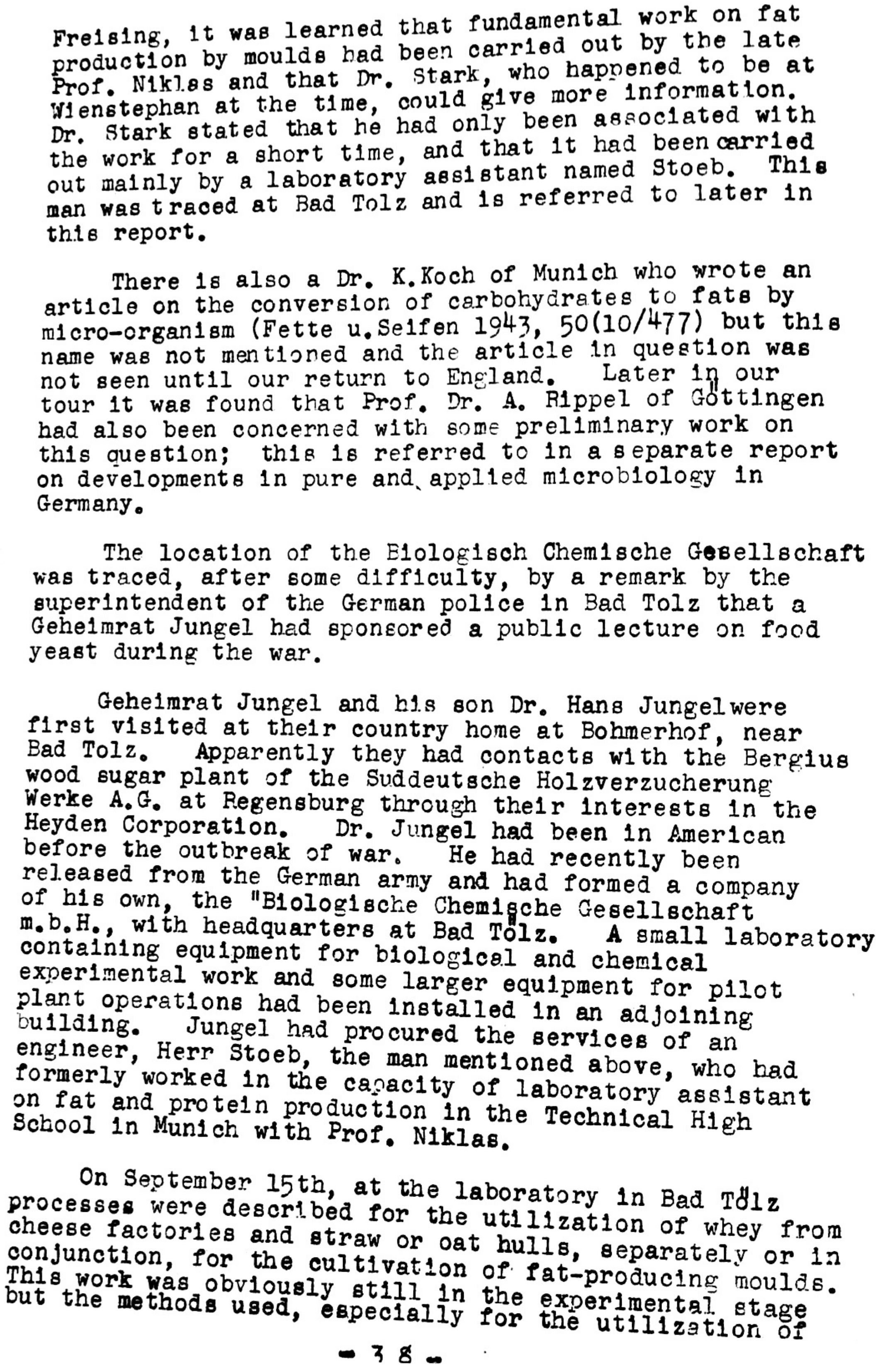
Personnel Interviewed

Geheimrat Jungel - Director
Dr. H. Jungel - Director
Herr Stoeb - Unqualified Chemical Engineer

General

From information received from Prof. Fromel and Prof. Schropp at Weinstephan Agricultural College,

Figure A.12: Biotechnology methods for producing and purifying lipids from cultured yeast [BIOS 236].



Freising, it was learned that fundamental work on fat production by moulds had been carried out by the late Prof. Niklas and that Dr. Stark, who happened to be at Wienstephan at the time, could give more information. Dr. Stark stated that he had only been associated with the work for a short time, and that it had been carried out mainly by a laboratory assistant named Stoeb. This man was traced at Bad Tolz and is referred to later in this report.

There is also a Dr. K.Koch of Munich who wrote an article on the conversion of carbohydrates to fats by micro-organism (Fette u.Seifen 1943, 50(10/477) but this name was not mentioned and the article in question was not seen until our return to England. Later in our tour it was found that Prof. Dr. A. Rippel of Göttingen had also been concerned with some preliminary work on this question; this is referred to in a separate report on developments in pure and applied microbiology in Germany.

The location of the Biologisch Chemische Gesellschaft was traced, after some difficulty, by a remark by the superintendent of the German police in Bad Tolz that a Geheimrat Jungel had sponsored a public lecture on food yeast during the war.

Geheimrat Jungel and his son Dr. Hans Jungel were first visited at their country home at Bohmerhof, near Bad Tolz. Apparently they had contacts with the Bergius wood sugar plant of the Suddeutsche Holzverzucherung Werke A.G. at Regensburg through their interests in the Heyden Corporation. Dr. Jungel had been in American before the outbreak of war. He had recently been released from the German army and had formed a company of his own, the "Biologische Chemische Gesellschaft m.b.H., with headquarters at Bad Tölz. A small laboratory containing equipment for biological and chemical experimental work and some larger equipment for pilot plant operations had been installed in an adjoining building. Jungel had procured the services of an engineer, Herr Stoeb, the man mentioned above, who had formerly worked in the capacity of laboratory assistant on fat and protein production in the Technical High School in Munich with Prof. Niklas.

On September 15th, at the laboratory in Bad Tölz processes were described for the utilization of whey from cheese factories and straw or oat hulls, separately or in conjunction, for the cultivation of fat-producing moulds. This work was obviously still in the experimental stage but the methods used, especially for the utilization of

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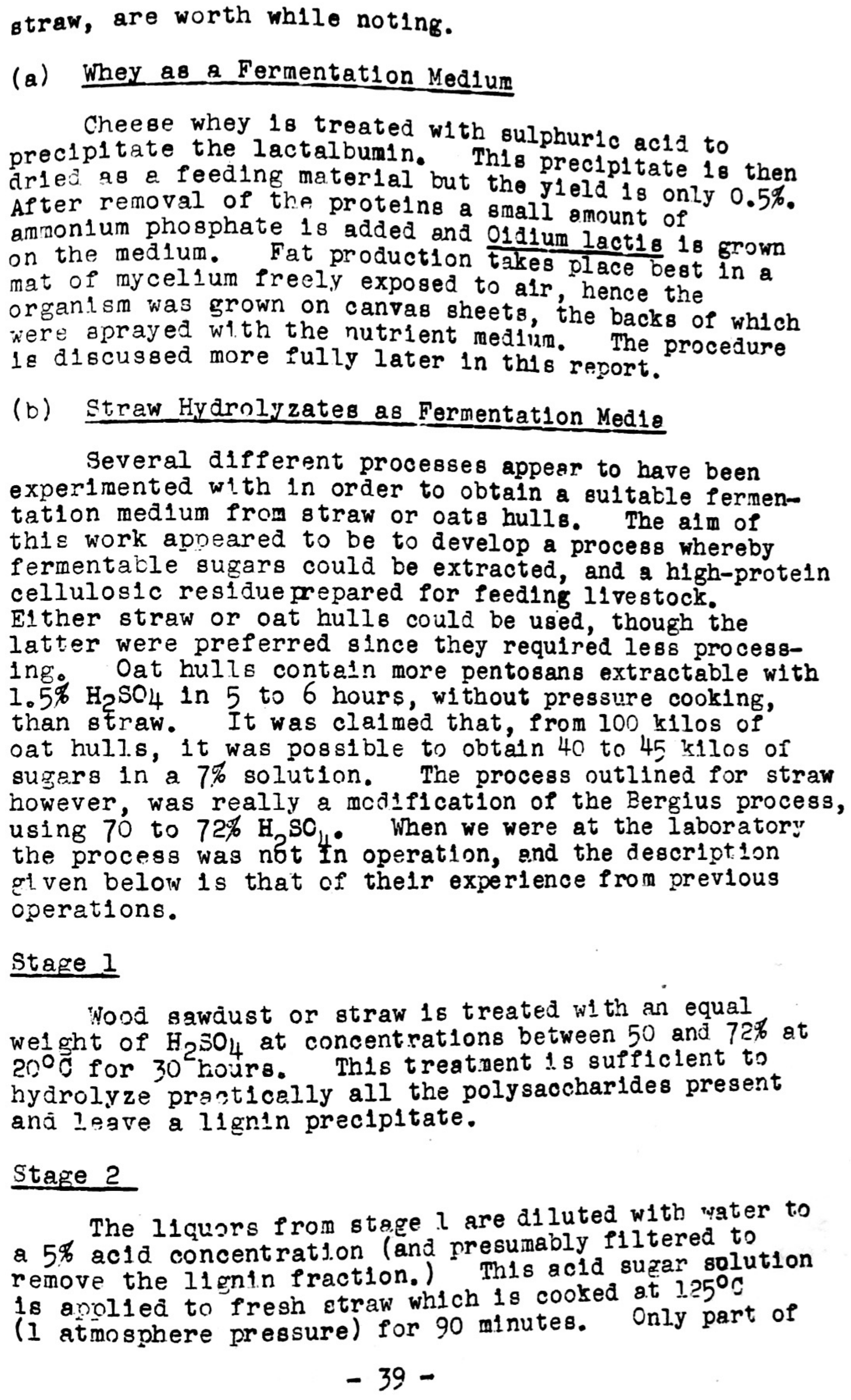
Figure A.13: Biotechnology methods for producing and purifying lipids from cultured yeast [BIOS 236].



straw, are worth while noting.

(a) Whey as a Fermentation Medium

Cheese whey is treated with sulphuric acid to precipitate the lactalbumin. This precipitate is then dried as a feeding material but the yield is only 0.5%. After removal of the proteins a small amount of ammonium phosphate is added and Oidium lactis is grown on the medium. Fat production takes place best in a mat of mycelium freely exposed to air, hence the organism was grown on canvas sheets, the backs of which were sprayed with the nutrient medium. The procedure is discussed more fully later in this report.

(b) Straw Hydrolyzates as Fermentation Media

Several different processes appear to have been experimented with in order to obtain a suitable fermentation medium from straw or oats hulls. The aim of this work appeared to be to develop a process whereby fermentable sugars could be extracted, and a high-protein cellulosic residue prepared for feeding livestock. Either straw or oat hulls could be used, though the latter were preferred since they required less processing. Oat hulls contain more pentosans extractable with 1.5% H_2SO_4 in 5 to 6 hours, without pressure cooking, than straw. It was claimed that, from 100 kilos of oat hulls, it was possible to obtain 40 to 45 kilos of sugars in a 7% solution. The process outlined for straw however, was really a modification of the Bergius process, using 70 to 72% H_2SO_4. When we were at the laboratory the process was not in operation, and the description given below is that of their experience from previous operations.

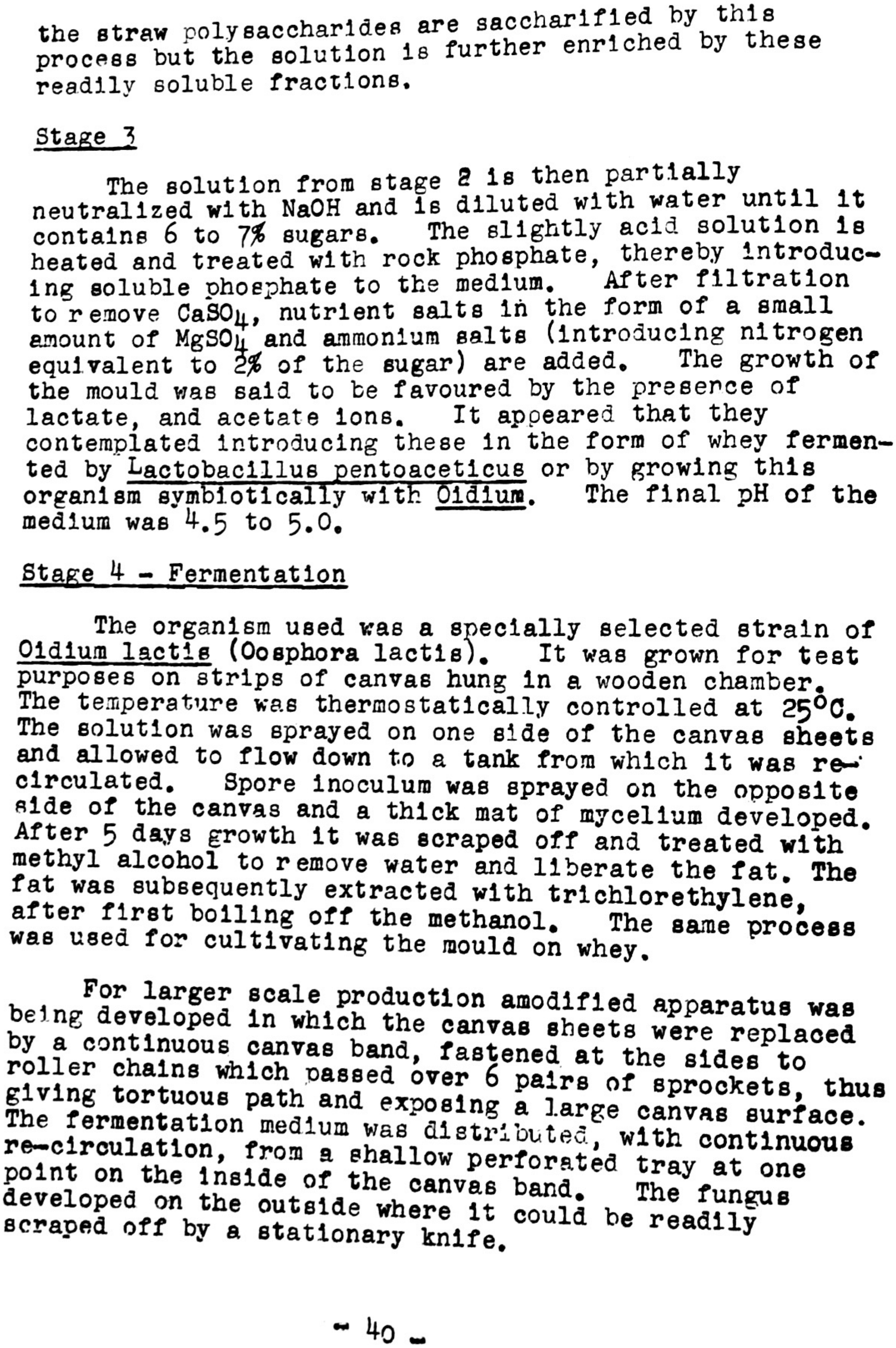
Stage 1

Wood sawdust or straw is treated with an equal weight of H_2SO_4 at concentrations between 50 and 72% at 20°C for 30 hours. This treatment is sufficient to hydrolyze practically all the polysaccharides present and leave a lignin precipitate.

Stage 2

The liquors from stage 1 are diluted with water to a 5% acid concentration (and presumably filtered to remove the lignin fraction.) This acid sugar solution is applied to fresh straw which is cooked at 125°C (1 atmosphere pressure) for 90 minutes. Only part of

Figure A.14: Biotechnology methods for producing and purifying lipids from cultured yeast [BIOS 236].



the straw polysaccharides are saccharified by this process but the solution is further enriched by these readily soluble fractions.

Stage 3

The solution from stage 2 is then partially neutralized with NaOH and is diluted with water until it contains 6 to 7% sugars. The slightly acid solution is heated and treated with rock phosphate, thereby introducing soluble phosphate to the medium. After filtration to remove $CaSO_4$, nutrient salts in the form of a small amount of $MgSO_4$ and ammonium salts (introducing nitrogen equivalent to 2% of the sugar) are added. The growth of the mould was said to be favoured by the presence of lactate, and acetate ions. It appeared that they contemplated introducing these in the form of whey fermented by *Lactobacillus pentoaceticus* or by growing this organism symbiotically with *Oidium*. The final pH of the medium was 4.5 to 5.0.

Stage 4 - Fermentation

The organism used was a specially selected strain of *Oidium lactis* (Oosphora lactis). It was grown for test purposes on strips of canvas hung in a wooden chamber. The temperature was thermostatically controlled at 25°C. The solution was sprayed on one side of the canvas sheets and allowed to flow down to a tank from which it was recirculated. Spore inoculum was sprayed on the opposite side of the canvas and a thick mat of mycelium developed. After 5 days growth it was scraped off and treated with methyl alcohol to remove water and liberate the fat. The fat was subsequently extracted with trichlorethylene, after first boiling off the methanol. The same process was used for cultivating the mould on whey.

For larger scale production amodified apparatus was being developed in which the canvas sheets were replaced by a continuous canvas band, fastened at the sides to roller chains which passed over 6 pairs of sprockets, thus giving tortuous path and exposing a large canvas surface. The fermentation medium was distributed, with continuous re-circulation, from a shallow perforated tray at one point on the inside of the canvas band. The fungus developed on the outside where it could be readily scraped off by a stationary knife.

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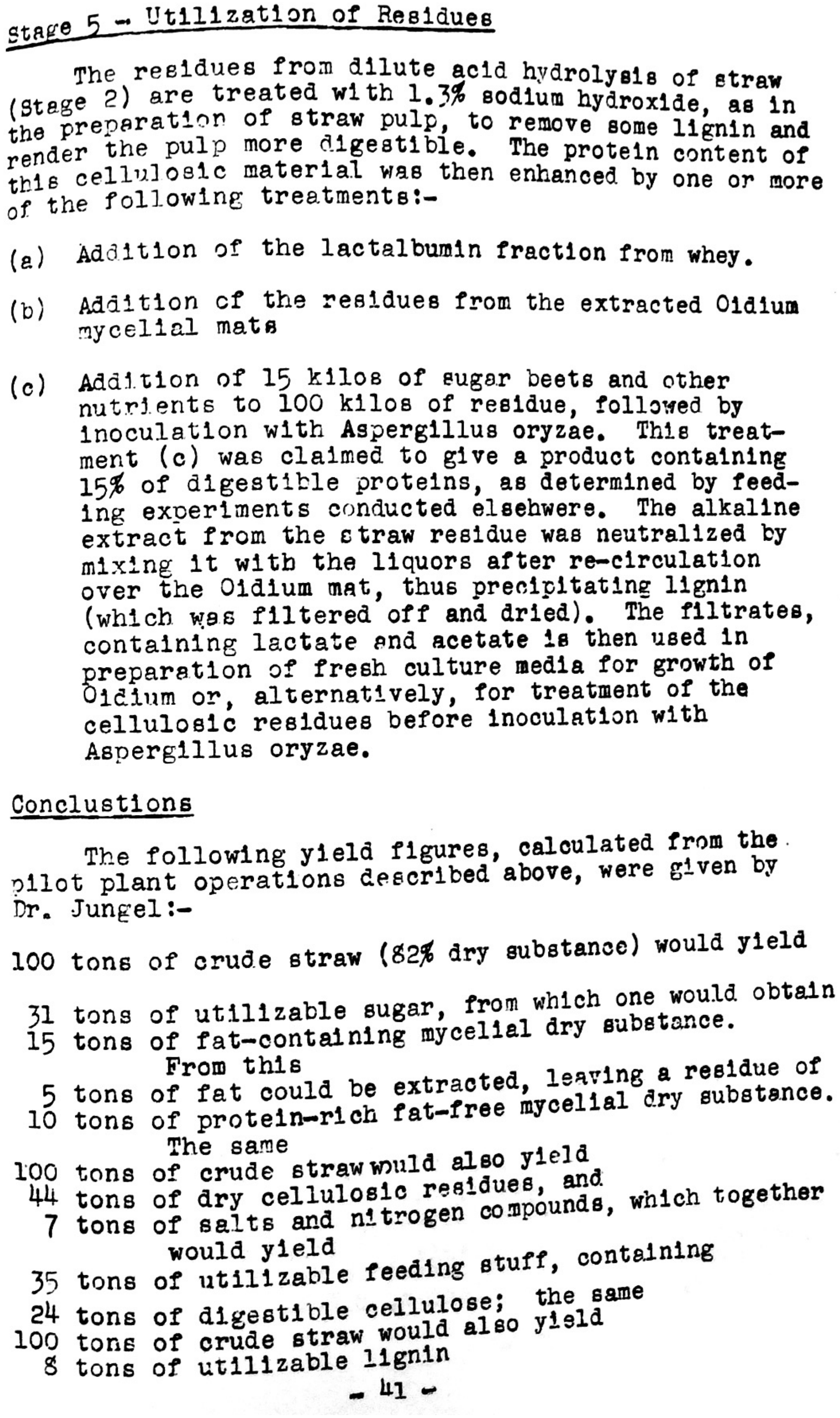
Figure A.15: Biotechnology methods for producing and purifying lipids from cultured yeast [BIOS 236].



Stage 5 - Utilization of Residues

The residues from dilute acid hydrolysis of straw (Stage 2) are treated with 1.3% sodium hydroxide, as in the preparation of straw pulp, to remove some lignin and render the pulp more digestible. The protein content of this cellulosic material was then enhanced by one or more of the following treatments:-

(a) Addition of the lactalbumin fraction from whey.

(b) Addition of the residues from the extracted Oidium mycelial mats

(c) Addition of 15 kilos of sugar beets and other nutrients to 100 kilos of residue, followed by inoculation with Aspergillus oryzae. This treatment (c) was claimed to give a product containing 15% of digestible proteins, as determined by feeding experiments conducted elsehwere. The alkaline extract from the straw residue was neutralized by mixing it with the liquors after re-circulation over the Oidium mat, thus precipitating lignin (which was filtered off and dried). The filtrates, containing lactate and acetate is then used in preparation of fresh culture media for growth of Oidium or, alternatively, for treatment of the cellulosic residues before inoculation with Aspergillus oryzae.

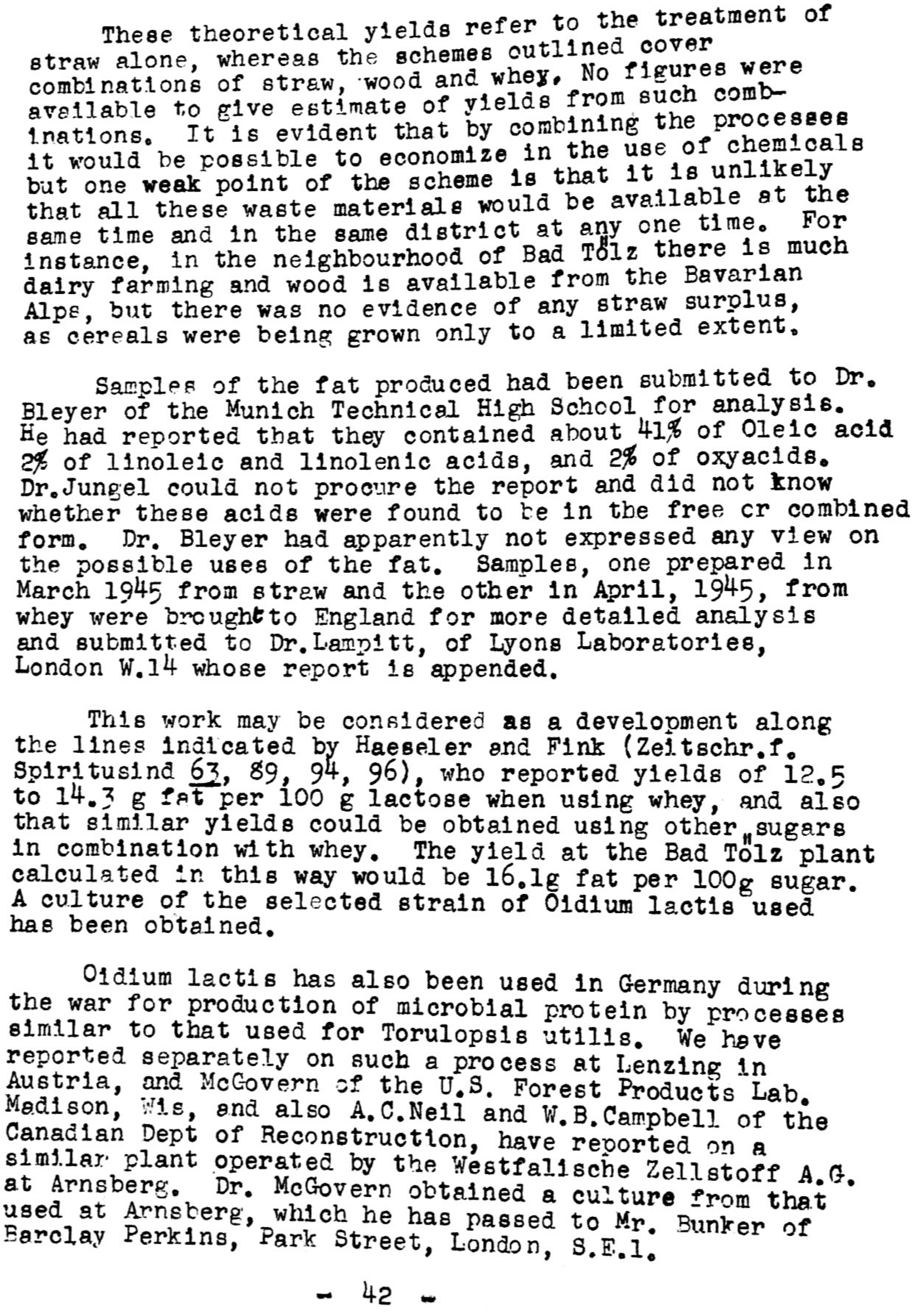
Conclusions

The following yield figures, calculated from the pilot plant operations described above, were given by Dr. Jungel:-

100 tons of crude straw (82% dry substance) would yield

31 tons of utilizable sugar, from which one would obtain
15 tons of fat-containing mycelial dry substance.
From this
5 tons of fat could be extracted, leaving a residue of
10 tons of protein-rich fat-free mycelial dry substance.
The same
100 tons of crude straw would also yield
44 tons of dry cellulosic residues, and
7 tons of salts and nitrogen compounds, which together
would yield
35 tons of utilizable feeding stuff, containing
24 tons of digestible cellulose; the same
100 tons of crude straw would also yield
8 tons of utilizable lignin

Figure A.16: Biotechnology methods for producing and purifying lipids from cultured yeast [BIOS 236].



These theoretical yields refer to the treatment of straw alone, whereas the schemes outlined cover combinations of straw, wood and whey. No figures were available to give estimate of yields from such combinations. It is evident that by combining the processes it would be possible to economize in the use of chemicals but one weak point of the scheme is that it is unlikely that all these waste materials would be available at the same time and in the same district at any one time. For instance, in the neighbourhood of Bad Tölz there is much dairy farming and wood is available from the Bavarian Alps, but there was no evidence of any straw surplus, as cereals were being grown only to a limited extent.

Samples of the fat produced had been submitted to Dr. Bleyer of the Munich Technical High School for analysis. He had reported that they contained about 41% of Oleic acid 2% of linoleic and linolenic acids, and 2% of oxyacids. Dr.Jungel could not procure the report and did not know whether these acids were found to be in the free or combined form. Dr. Bleyer had apparently not expressed any view on the possible uses of the fat. Samples, one prepared in March 1945 from straw and the other in April, 1945, from whey were brought to England for more detailed analysis and submitted to Dr.Lampitt, of Lyons Laboratories, London W.14 whose report is appended.

This work may be considered as a development along the lines indicated by Haeseler and Fink (Zeitschr.f. Spiritusind 63, 89, 94, 96), who reported yields of 12.5 to 14.3 g fat per 100 g lactose when using whey, and also that similar yields could be obtained using other sugars in combination with whey. The yield at the Bad Tölz plant calculated in this way would be 16.1g fat per 100g sugar. A culture of the selected strain of Oidium lactis used has been obtained.

Oidium lactis has also been used in Germany during the war for production of microbial protein by processes similar to that used for Torulopsis utilis. We have reported separately on such a process at Lenzing in Austria, and McGovern of the U.S. Forest Products Lab. Madison, Wis, and also A.C.Neil and W.B.Campbell of the Canadian Dept of Reconstruction, have reported on a similar plant operated by the Westfalische Zellstoff A.G. at Arnsberg. Dr. McGovern obtained a culture from that used at Arnsberg, which he has passed to Mr. Bunker of Barclay Perkins, Park Street, London, S.E.1.

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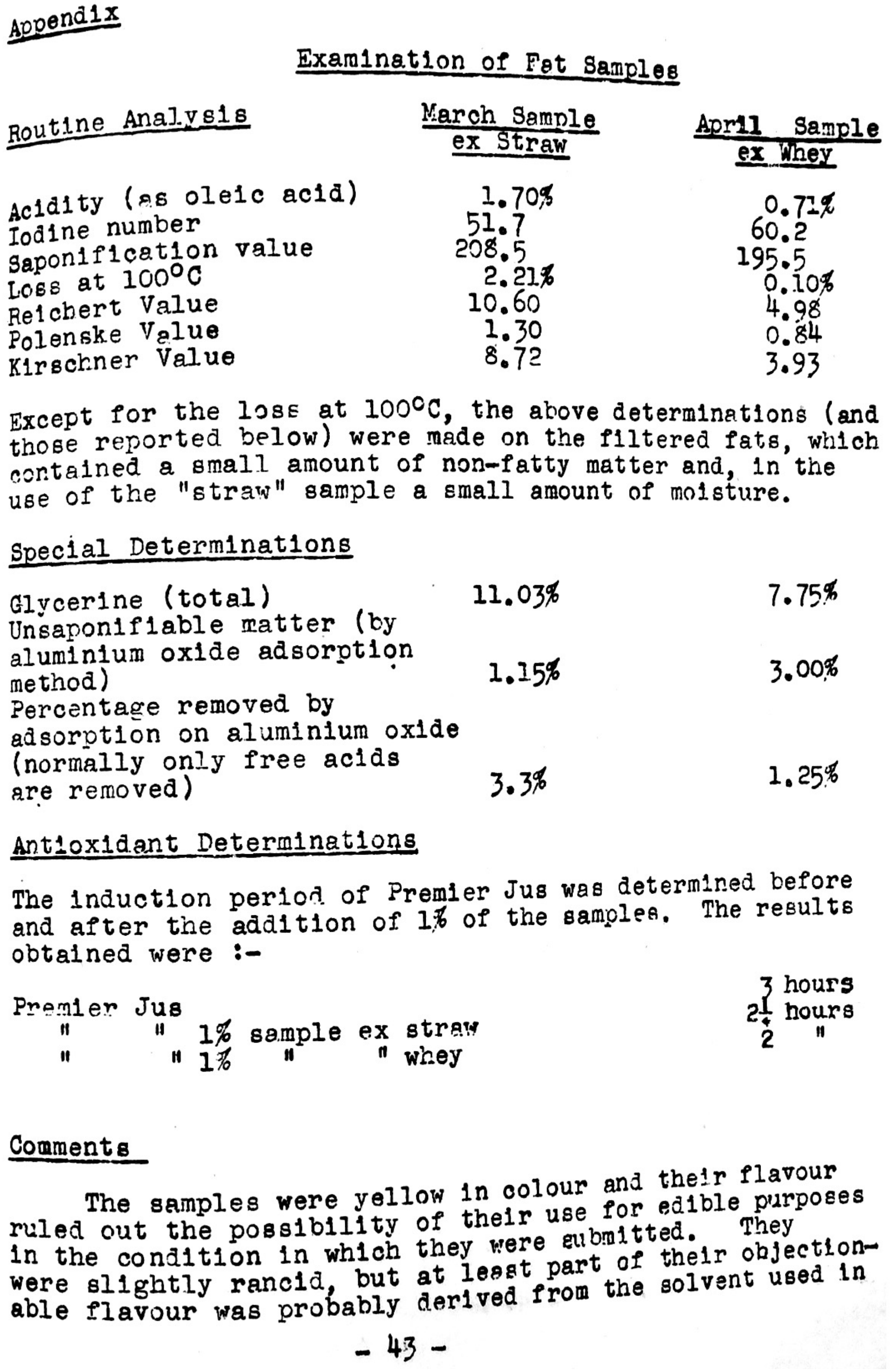
Figure A.17: Biotechnology methods for producing and purifying lipids from cultured yeast [BIOS 236].



Appendix

Examination of Fat Samples

Routine Analysis	March Sample ex Straw	April Sample ex Whey
Acidity (as oleic acid)	1.70%	0.71%
Iodine number	51.7	60.2
Saponification value	208.5	195.5
Loss at 100°C	2.21%	0.10%
Reichert Value	10.60	4.98
Polenske Value	1.30	0.84
Kirschner Value	8.72	3.93

Except for the loss at 100°C, the above determinations (and those reported below) were made on the filtered fats, which contained a small amount of non-fatty matter and, in the use of the "straw" sample a small amount of moisture.

Special Determinations

Glycerine (total)	11.03%	7.75%
Unsaponifiable matter (by aluminium oxide adsorption method)	1.15%	3.00%
Percentage removed by adsorption on aluminium oxide (normally only free acids are removed)	3.3%	1.25%

Antioxidant Determinations

The induction period of Premier Jus was determined before and after the addition of 1% of the samples. The results obtained were :-

Premier Jus	3 hours
" " 1% sample ex straw	2¼ hours
" " 1% " " whey	2 "

Comments

The samples were yellow in colour and their flavour ruled out the possibility of their use for edible purposes in the condition in which they were submitted. They were slightly rancid, but at least part of their objectionable flavour was probably derived from the solvent used in

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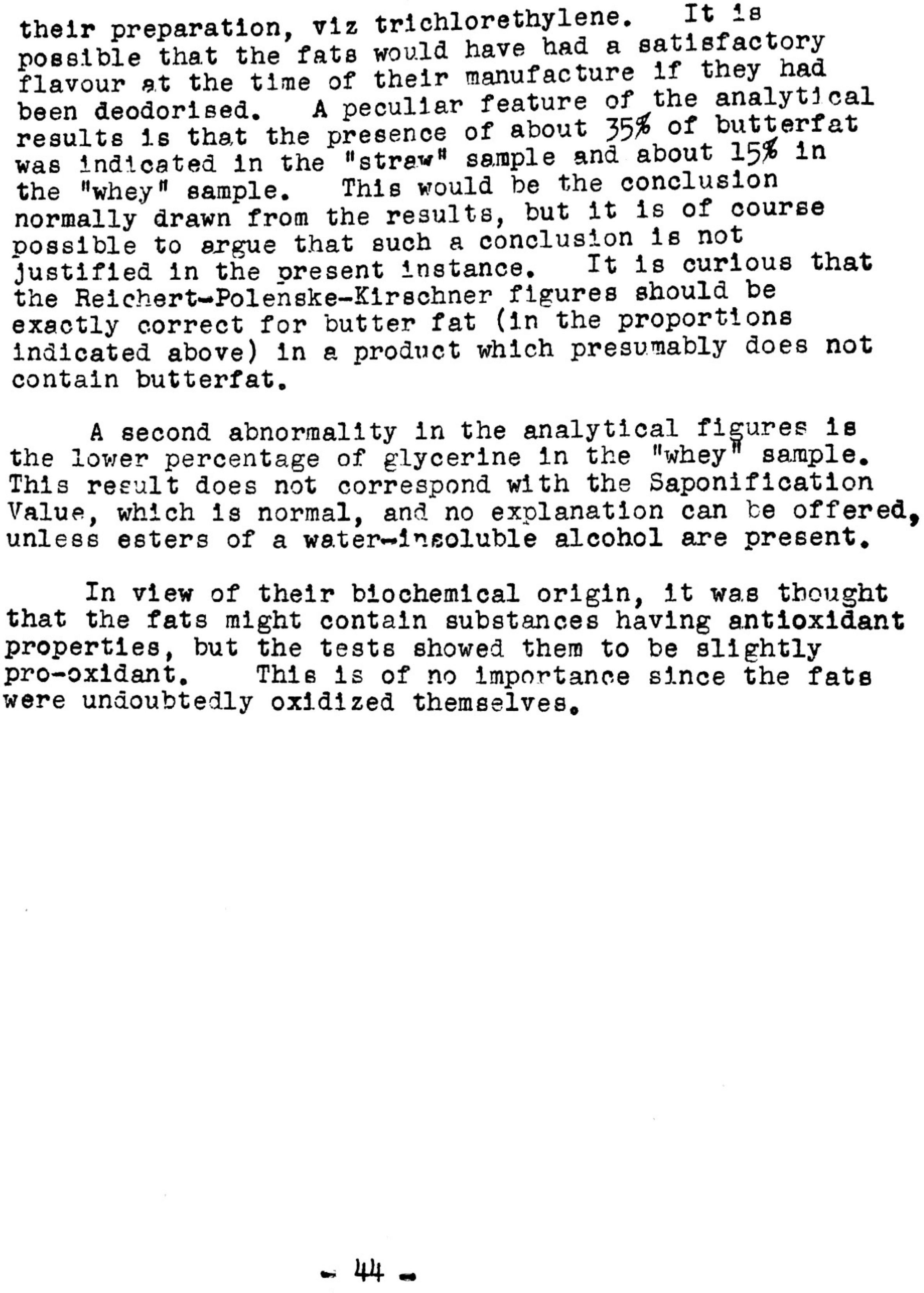
Figure A.18: Biotechnology methods for producing and purifying lipids from cultured yeast [BIOS 236].



their preparation, viz trichlorethylene. It is possible that the fats would have had a satisfactory flavour at the time of their manufacture if they had been deodorised. A peculiar feature of the analytical results is that the presence of about 35% of butterfat was indicated in the "straw" sample and about 15% in the "whey" sample. This would be the conclusion normally drawn from the results, but it is of course possible to argue that such a conclusion is not justified in the present instance. It is curious that the Reichert-Polenske-Kirschner figures should be exactly correct for butter fat (in the proportions indicated above) in a product which presumably does not contain butterfat.

A second abnormality in the analytical figures is the lower percentage of glycerine in the "whey" sample. This result does not correspond with the Saponification Value, which is normal, and no explanation can be offered, unless esters of a water-insoluble alcohol are present.

In view of their biochemical origin, it was thought that the fats might contain substances having antioxidant properties, but the tests showed them to be slightly pro-oxidant. This is of no importance since the fats were undoubtedly oxidized themselves.

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Figure A.19: Biotechnology methods for producing and purifying lipids from cultured yeast [BIOS 236].

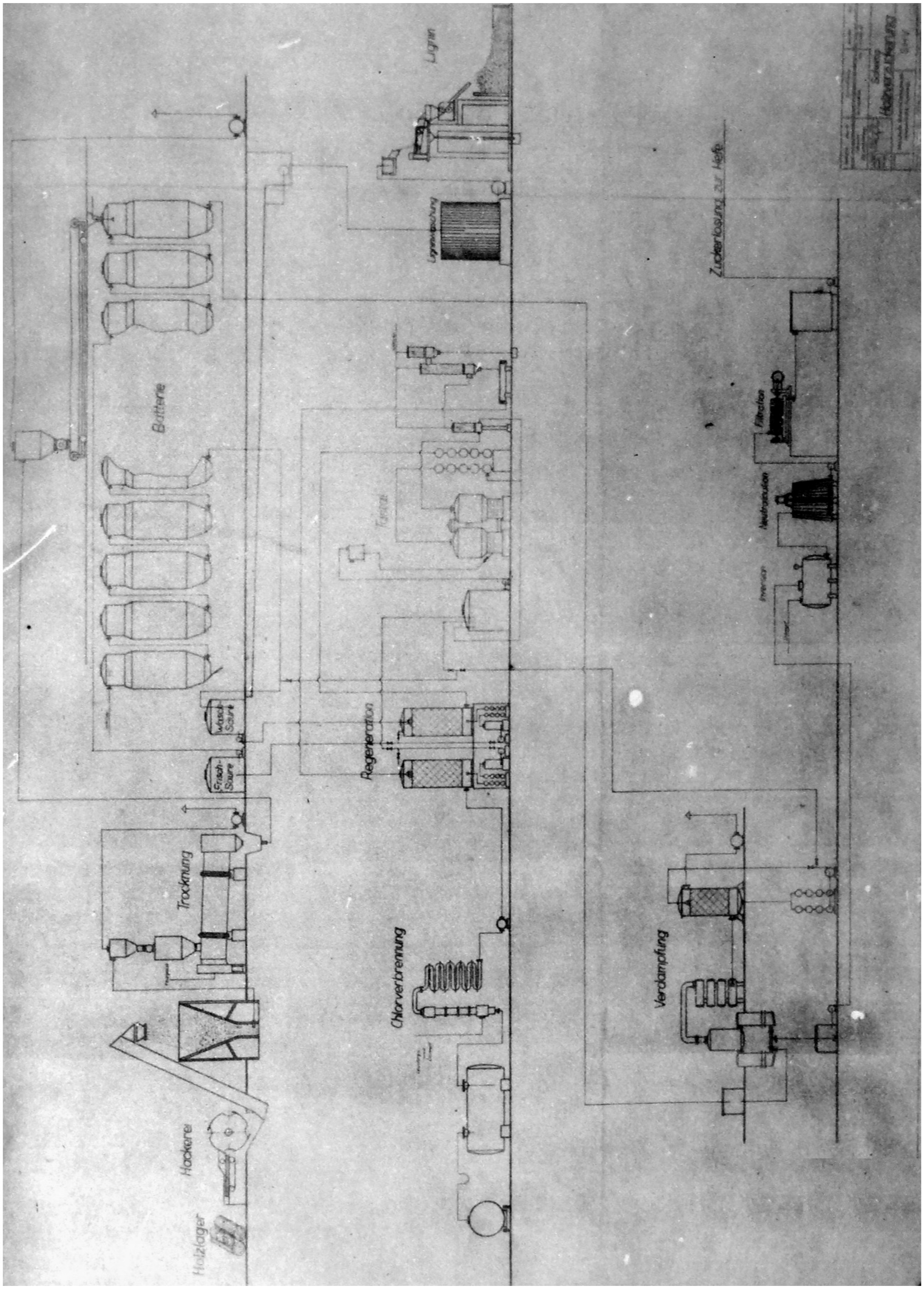

Lignin
Batterie
Wasch-Säure
Frisch-Säure
Trocknung
Regeneration
Chlorverbrennung
Zuckerlösung zur Hefe
Filtration
Neutralisation
Inversion
Verdampfung
Hackerei
Holzlager

Figure A.20: Schematic overview of bioreactors and processing pipeline [BIOS 236].

BIOS 266+Appendix. ***New Technical Applications of Acetylene.***

[This report was based on interrogations of Walter Reppe, and outlined the large-scale production of periston synthetic blood plasma and many other products from acetylene.

Please see tables from this report on pp. 2341–2343.]

BIOS 354. ***Polvinyl Pyrrolidones. Translation of a Report by Dr. Fikentscher and Dr. Herrle, Ludwigshafen, with an Addendum on Periston (Synthetic Blood Serum).***

[Please see part of this report on pp. 2344–2351.]

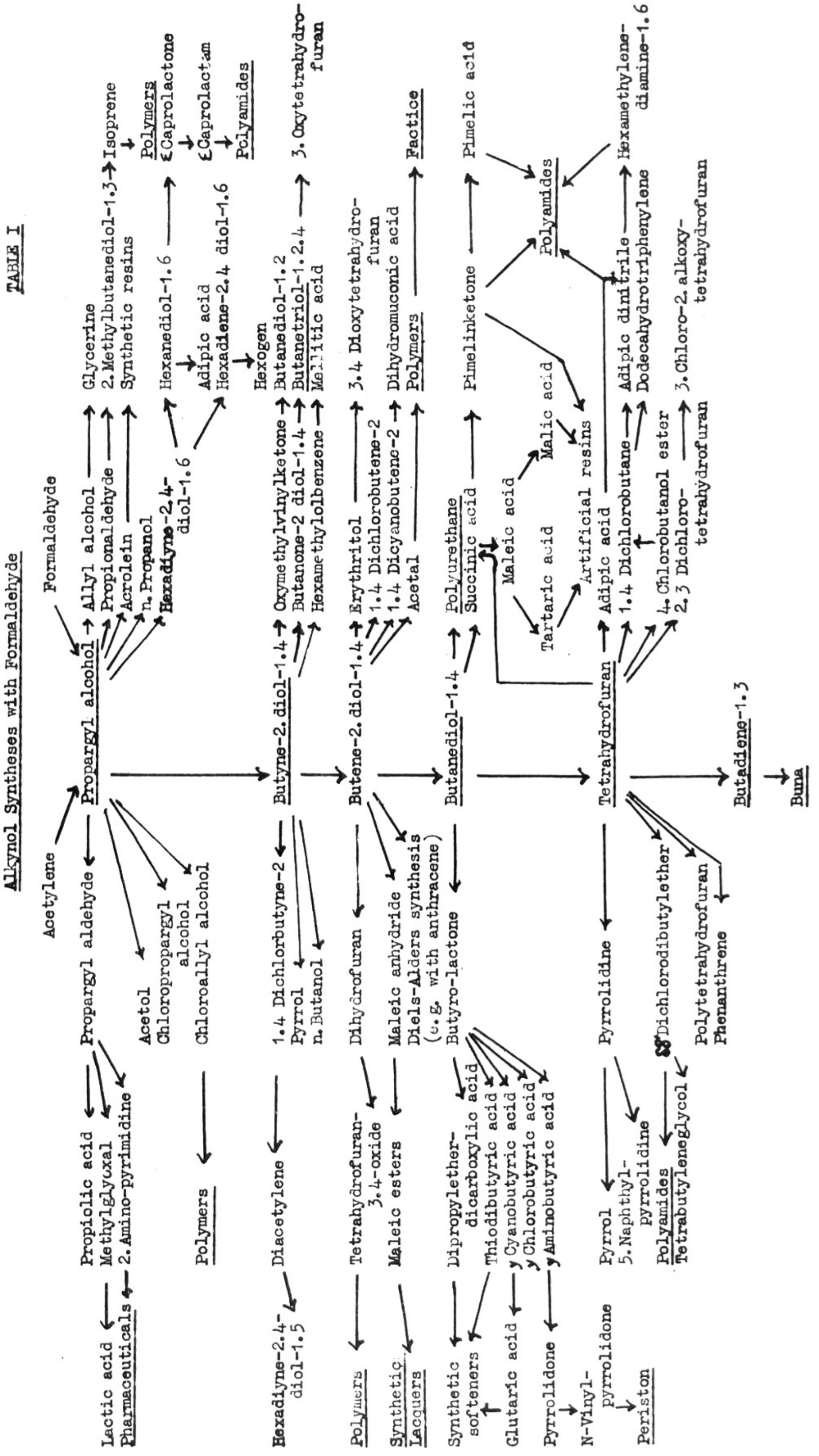


TABLE I
Alkynol Syntheses with Formaldehyde
Acetylene
Formaldehyde
Propargyl alcohol
Propargyl aldehyde
Propiolic acid
Methylglyoxal
2. Amino-pyrimidine
Lactic acid
Pharmaceuticals
Acetol
Chloropropargyl alcohol
Chloroallyl alcohol
Polymers
Allyl alcohol
Propionaldehyde
Acrolein
n. Propanol
Hexadiyne-2.4-diol-1.6
Glycerine
2. Methylbutanediol-1.3
Isoprene
Synthetic resins
Polymers
Hexanediol-1.6
ԑCaprolactone
Adipic acid
Hexadiene-2.4 diol-1.6
ԑCaprolactam
Polyamides
Hexogen
Butyne-2. diol-1.4
1.4 Dichlorbutyne-2
Pyrrol
n. Butanol
Diacetylene
Hexadiyne-2.4-diol-1.5
Oxymethylvinylketone
Butanone-2 diol-1.4
Hexamethylolbenzene
Butanediol-1.2
Butanetriol-1.2.4
Mellitic acid
3. Oxytetrahydrofuran
Butene-2. diol-1.4
Dihydrofuran
Tetrahydrofuran-3.4-oxide
Polymers
Maleic anhydride
Maleic esters
Synthetic Lacquers
Diels-Alders synthesis (e.g. with anthracene)
Erythritol
1.4 Dichlorobutene-2
1.4 Dicyanobutene-2
Acetal
3.4 Dioxytetrahydrofuran
Dihydromuconic acid
Polymers
Factice
Butanediol-1.4
Butyro-lactone
Dipropylether-dicarboxylic acid
Thiodibutyric acid
γ Cyanobutyric acid
γ Chlorobutyric acid
γ Aminobutyric acid
Synthetic softeners
Glutaric acid
Pyrrolidone
N-Vinyl-pyrrolidone
Periston
Polyurethane
Succinic acid
Maleic acid
Tartaric acid
Malic acid
Artificial resins
Pimelinketone
Pimelic acid
Polyamides
Tetrahydrofuran
Pyrrolidine
Pyrrol
5. Naphthyl-pyrrolidine
Polyamides
Tetrabutyleneglycol
SS'Dichlorodibutylether
Polytetrahydrofuran
Phenanthrene
Adipic acid
1.4 Dichlorobutane
4. Chlorobutanol ester
2.3 Dichloro-tetrahydrofuran
Adipic dinitrile
Dodecahydrotriphenylene
Hexamethylene-diamine-1.6
3. Chloro-2. alkoxy-tetrahydrofuran
Butadiene-1.3
Buna

Figure A.21: Large-scale production of periston synthetic blood plasma and many other products from acetylene [BIOS 266 Appendix].

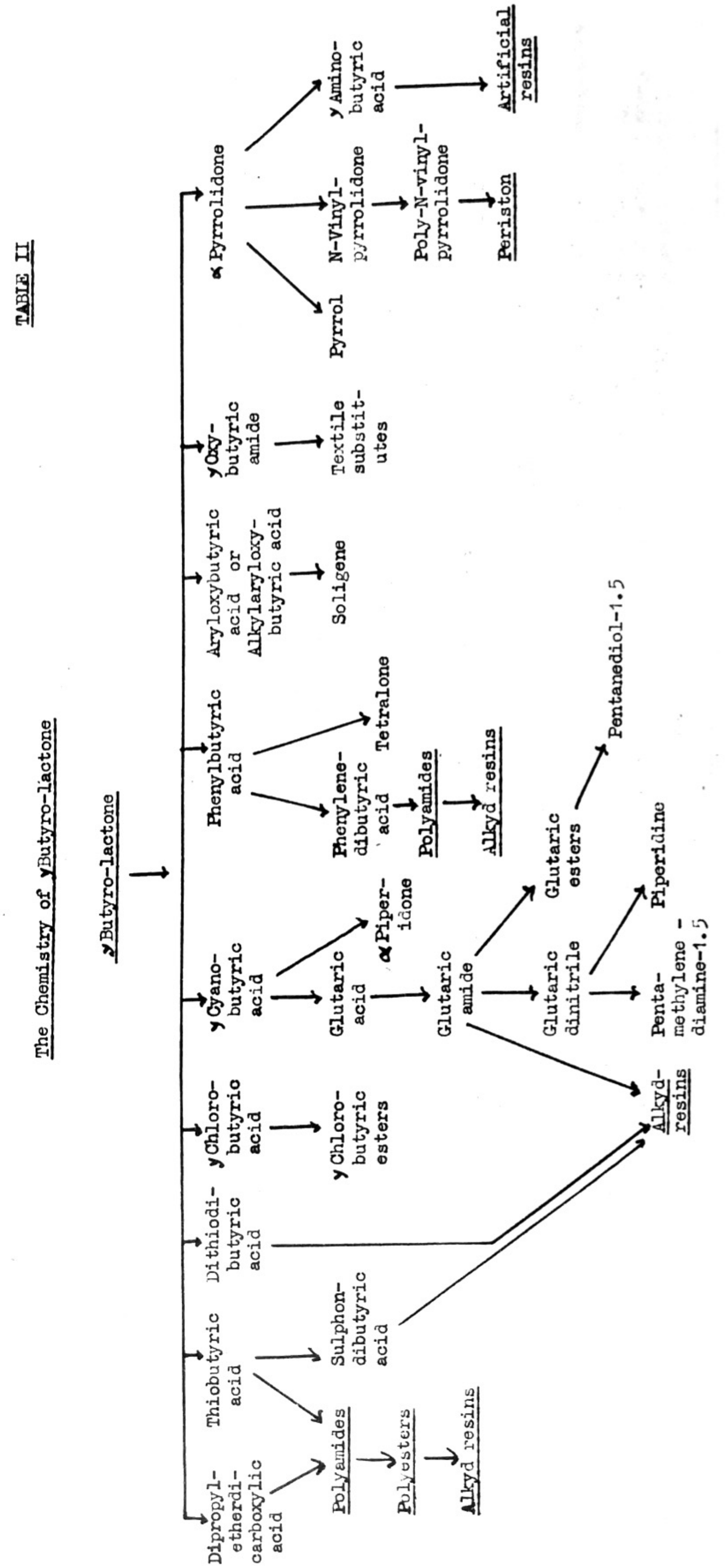


TABLE II
The Chemistry of γButyro-lactone
γButyro-lactone
Dipropyl-etherdi-carboxylic acid
Polyamides
Polyesters
Alkyd resins
Thiobutyric acid
Sulphon-dibutyric acid
Dithiodi-butyric acid
γChloro-butyric acid
γChloro-butyric esters
Alkyd-resins
γCyano-butyric acid
Glutaric acid
αPiper-idone
Glutaric amide
Glutaric dinitrile
Glutaric esters
Penta-methylene - diamine-1.5
Piperidine
Pentanediol-1.5
Phenylbutyric acid
Phenylene-dibutyric acid
Tetralone
Polyamides
Alkyd resins
Aryloxybutyric acid or Alkylaryloxy-butyric acid
Soligene
γOxy-butyric amide
Textile substit-utes
α Pyrrolidone
Pyrrol
N-Vinyl-pyrrolidone
Poly-N-vinyl-pyrrolidone
Periston
γAmino-butyric acid
Artificial resins

Figure A.22: Large-scale production of periston synthetic blood plasma and many other products from acetylene [BIOS 266 Appendix].

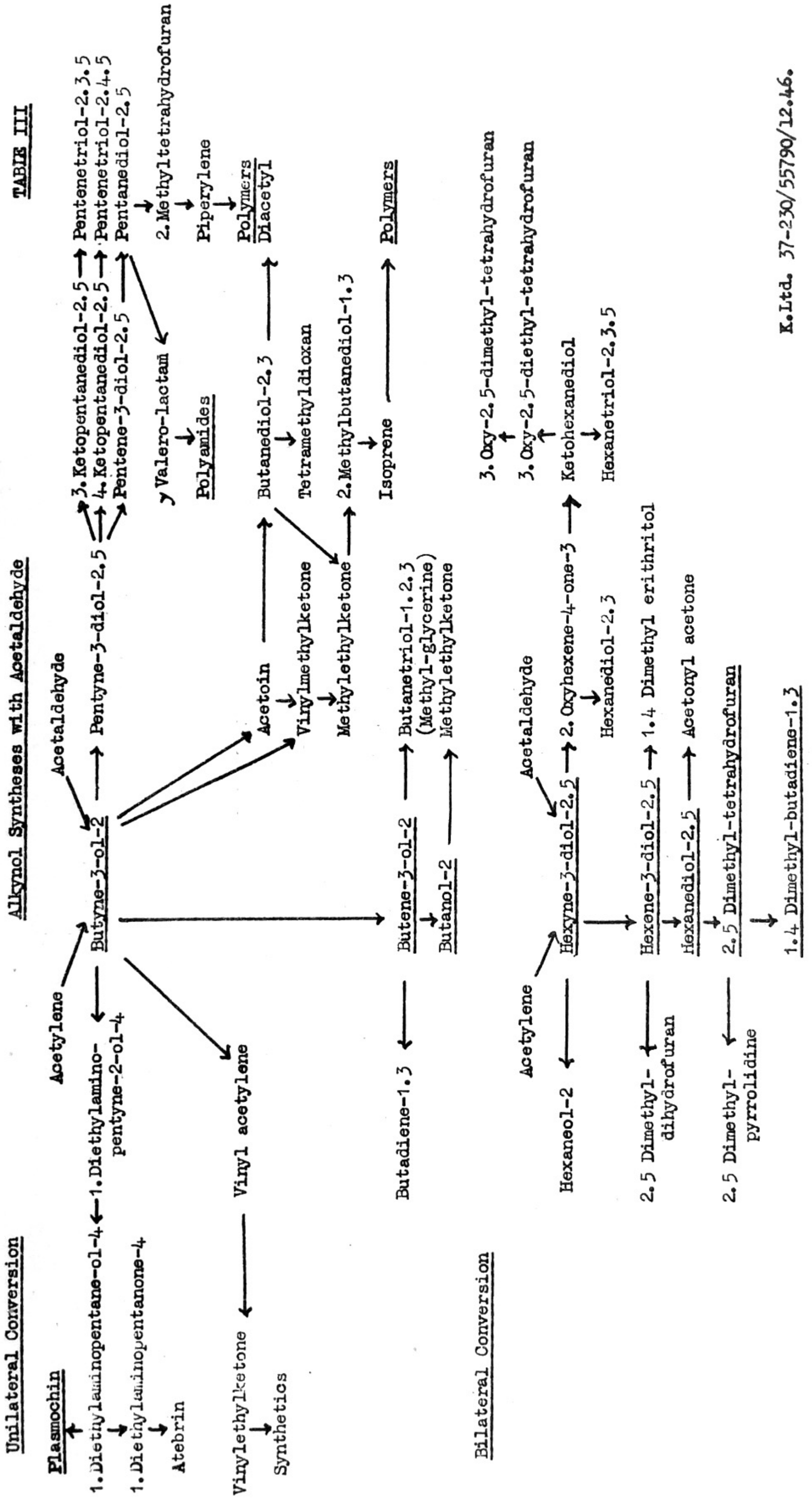
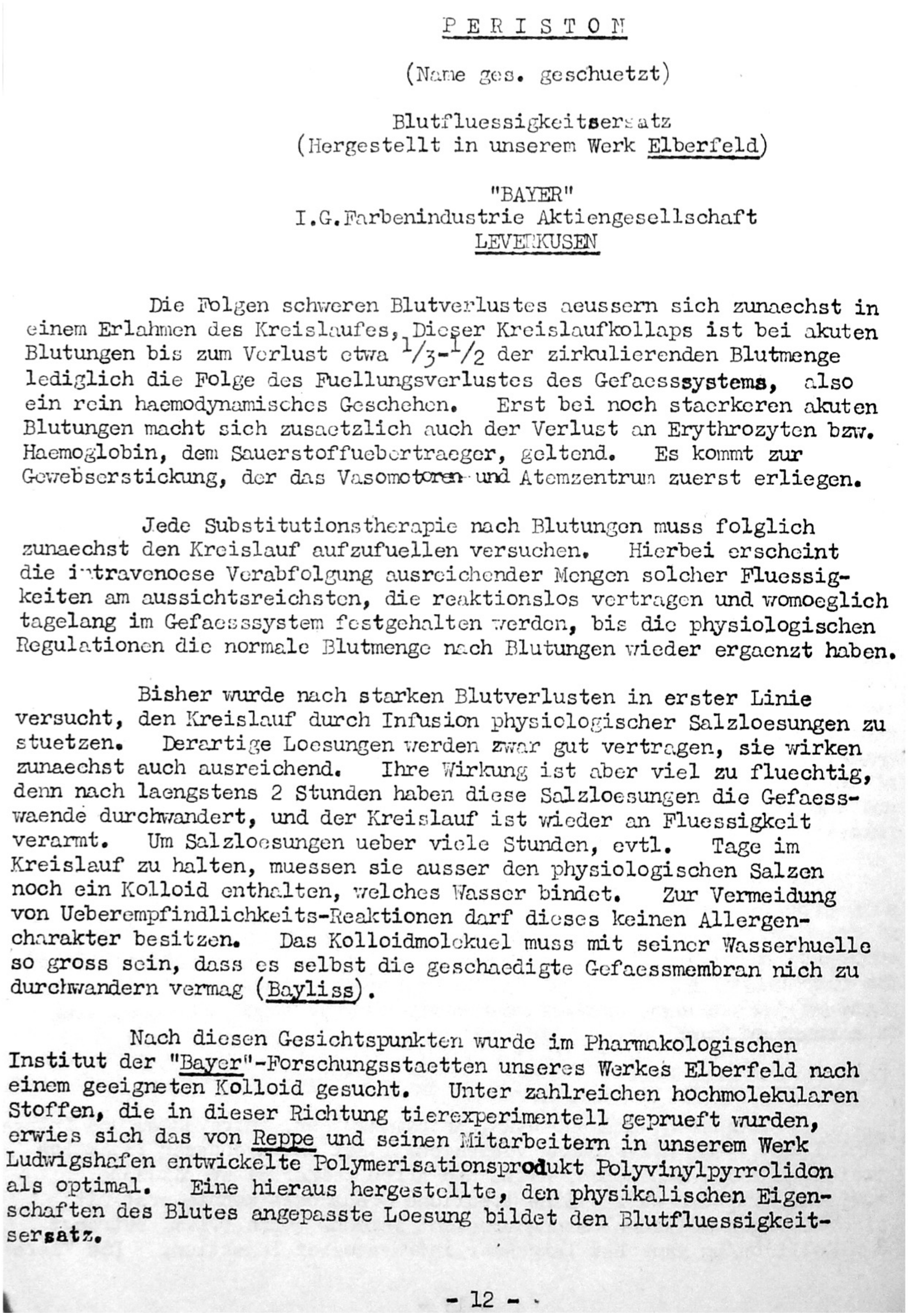


TABLE III
Unilateral Conversion
Alkynol Syntheses with Acetaldehyde
Plasmochin
1.Diethylaminopentane-ol-4
1.Diethylaminopentanone-4
Atebrin
1.Diethylamino-pentyne-2-ol-4
Acetylene
Butyne-3-ol-2
Acetaldehyde
Pentyne-3-diol-2.5
3.Ketopentanediol-2.5
4.Ketopentanediol-2.5
Pentene-3-diol-2.5
Pentenetriol-2.3.5
Pentenetriol-2.4.5
Pentanediol-2.5
2.Methyltetrahydrofuran
Piperylene
Polymers
γ Valero-lactam
Polyamides
Vinyl acetylene
Vinylethylketone
Synthetics
Acetoin
Vinylmethylketone
Methylethylketone
Butanediol-2.3
Tetramethyldioxan
2.Methylbutanediol-1.3
Diacetyl
Butadiene-1.3
Butene-3-ol-2
Butanol-2
Butanetriol-1.2.3 (Methyl-glycerine)
Methylethylketone
Isoprene
Polymers
Bilateral Conversion
Hexaneol-2
Acetylene
Hexyne-3-diol-2.5
Acetaldehyde
2.Oxyhexene-4-one-3
Hexanediol-2.3
Ketohexanediol
Hexanetriol-2.3.5
3.Oxy-2.5-dimethyl-tetrahydrofuran
3.Oxy-2.5-diethyl-tetrahydrofuran
2.5 Dimethyl-dihydrofuran
Hexene-3-diol-2.5
1.4 Dimethyl erithritol
Hexanediol-2.5
Acetonyl acetone
2.5 Dimethyl-pyrrolidine
2.5 Dimethyl-tetrahydrofuran
1.4 Dimethyl-butadiene-1.3
K.Ltd. 37-230/55790/12.46.

Figure A.23: Large-scale production of periston synthetic blood plasma and many other products from acetylene [BIOS 266 Appendix].



PERISTON

(Name ges. geschuetzt)

Blutfluessigkeitsersatz
(Hergestellt in unserem Werk Elberfeld)

"BAYER"
I.G.Farbenindustrie Aktiengesellschaft
LEVERKUSEN

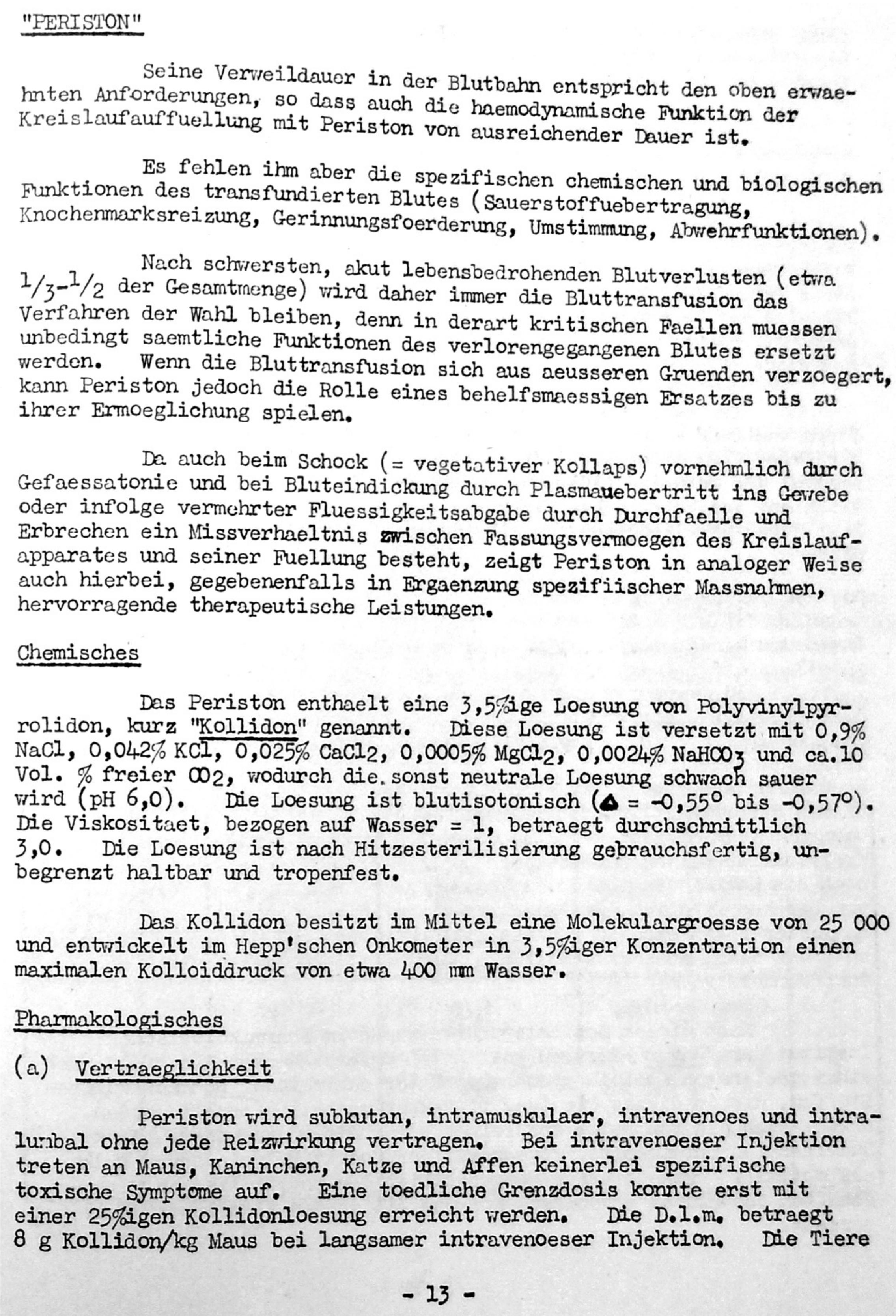
Die Folgen schweren Blutverlustes aeussern sich zunaechst in einem Erlahmen des Kreislaufes, Dieser Kreislaufkollaps ist bei akuten Blutungen bis zum Verlust etwa $^{1}/_{3}$-$^{1}/_{2}$ der zirkulierenden Blutmenge lediglich die Folge des Fuellungsverlustes des Gefaesssystems, also ein rein haemodynamisches Geschehen. Erst bei noch staerkeren akuten Blutungen macht sich zusaetzlich auch der Verlust an Erythrozyten bzw. Haemoglobin, dem Sauerstoffuebertraeger, geltend. Es kommt zur Gewebserstickung, der das Vasomotoren- und Atemzentrum zuerst erliegen.

Jede Substitutionstherapie nach Blutungen muss folglich zunaechst den Kreislauf aufzufuellen versuchen. Hierbei erscheint die intravenoese Verabfolgung ausreichender Mengen solcher Fluessigkeiten am aussichtsreichsten, die reaktionslos vertragen und womoeglich tagelang im Gefaesssystem festgehalten werden, bis die physiologischen Regulationen die normale Blutmenge nach Blutungen wieder ergaenzt haben.

Bisher wurde nach starken Blutverlusten in erster Linie versucht, den Kreislauf durch Infusion physiologischer Salzloesungen zu stuetzen. Derartige Loesungen werden zwar gut vertragen, sie wirken zunaechst auch ausreichend. Ihre Wirkung ist aber viel zu fluechtig, denn nach laengstens 2 Stunden haben diese Salzloesungen die Gefaesswaende durchwandert, und der Kreislauf ist wieder an Fluessigkeit verarmt. Um Salzloesungen ueber viele Stunden, evtl. Tage im Kreislauf zu halten, muessen sie ausser den physiologischen Salzen noch ein Kolloid enthalten, welches Wasser bindet. Zur Vermeidung von Ueberempfindlichkeits-Reaktionen darf dieses keinen Allergencharakter besitzen. Das Kolloidmolekuel muss mit seiner Wasserhuelle so gross sein, dass es selbst die geschaedigte Gefaessmembran nich zu durchwandern vermag (Bayliss).

Nach diesen Gesichtspunkten wurde im Pharmakologischen Institut der "Bayer"-Forschungsstaetten unseres Werkes Elberfeld nach einem geeigneten Kolloid gesucht. Unter zahlreichen hochmolekularen Stoffen, die in dieser Richtung tierexperimentell geprueft wurden, erwies sich das von Reppe und seinen Mitarbeitern in unserem Werk Ludwigshafen entwickelte Polymerisationsprodukt Polyvinylpyrrolidon als optimal. Eine hieraus hergestellte, den physikalischen Eigenschaften des Blutes angepasste Loesung bildet den Blutfluessigkeitsersatz.

Figure A.24: A report on periston synthetic blood plasma [BIOS 354].



"PERISTON"

Seine Verweildauer in der Blutbahn entspricht den oben erwaehnten Anforderungen, so dass auch die haemodynamische Funktion der Kreislaufauffuellung mit Periston von ausreichender Dauer ist.

Es fehlen ihm aber die spezifischen chemischen und biologischen Funktionen des transfundierten Blutes (Sauerstoffuebertragung, Knochenmarksreizung, Gerinnungsfoerderung, Umstimmung, Abwehrfunktionen).

Nach schwersten, akut lebensbedrohenden Blutverlusten (etwa $1/3$-$1/2$ der Gesamtmenge) wird daher immer die Bluttransfusion das Verfahren der Wahl bleiben, denn in derart kritischen Faellen muessen unbedingt saemtliche Funktionen des verlorengegangenen Blutes ersetzt werden. Wenn die Bluttransfusion sich aus aeusseren Gruenden verzoegert, kann Periston jedoch die Rolle eines behelfsmaessigen Ersatzes bis zu ihrer Ermoeglichung spielen.

Da auch beim Schock (= vegetativer Kollaps) vornehmlich durch Gefaessatonie und bei Bluteindickung durch Plasmauebertritt ins Gewebe oder infolge vermehrter Fluessigkeitsabgabe durch Durchfaelle und Erbrechen ein Missverhaeltnis zwischen Fassungsvermoegen des Kreislaufapparates und seiner Fuellung besteht, zeigt Periston in analoger Weise auch hierbei, gegebenenfalls in Ergaenzung spezifiischer Massnahmen, hervorragende therapeutische Leistungen.

Chemisches

Das Periston enthaelt eine 3,5%ige Loesung von Polyvinylpyrrolidon, kurz "Kollidon" genannt. Diese Loesung ist versetzt mit 0,9% NaCl, 0,042% KCl, 0,025% $CaCl_2$, 0,0005% $MgCl_2$, 0,0024% $NaHCO_3$ und ca. 10 Vol. % freier CO_2, wodurch die sonst neutrale Loesung schwach sauer wird (pH 6,0). Die Loesung ist blutisotonisch (Δ = -0,55° bis -0,57°). Die Viskositaet, bezogen auf Wasser = 1, betraegt durchschnittlich 3,0. Die Loesung ist nach Hitzesterilisierung gebrauchsfertig, unbegrenzt haltbar und tropenfest.

Das Kollidon besitzt im Mittel eine Molekulargroesse von 25 000 und entwickelt im Hepp'schen Onkometer in 3,5%iger Konzentration einen maximalen Kolloiddruck von etwa 400 mm Wasser.

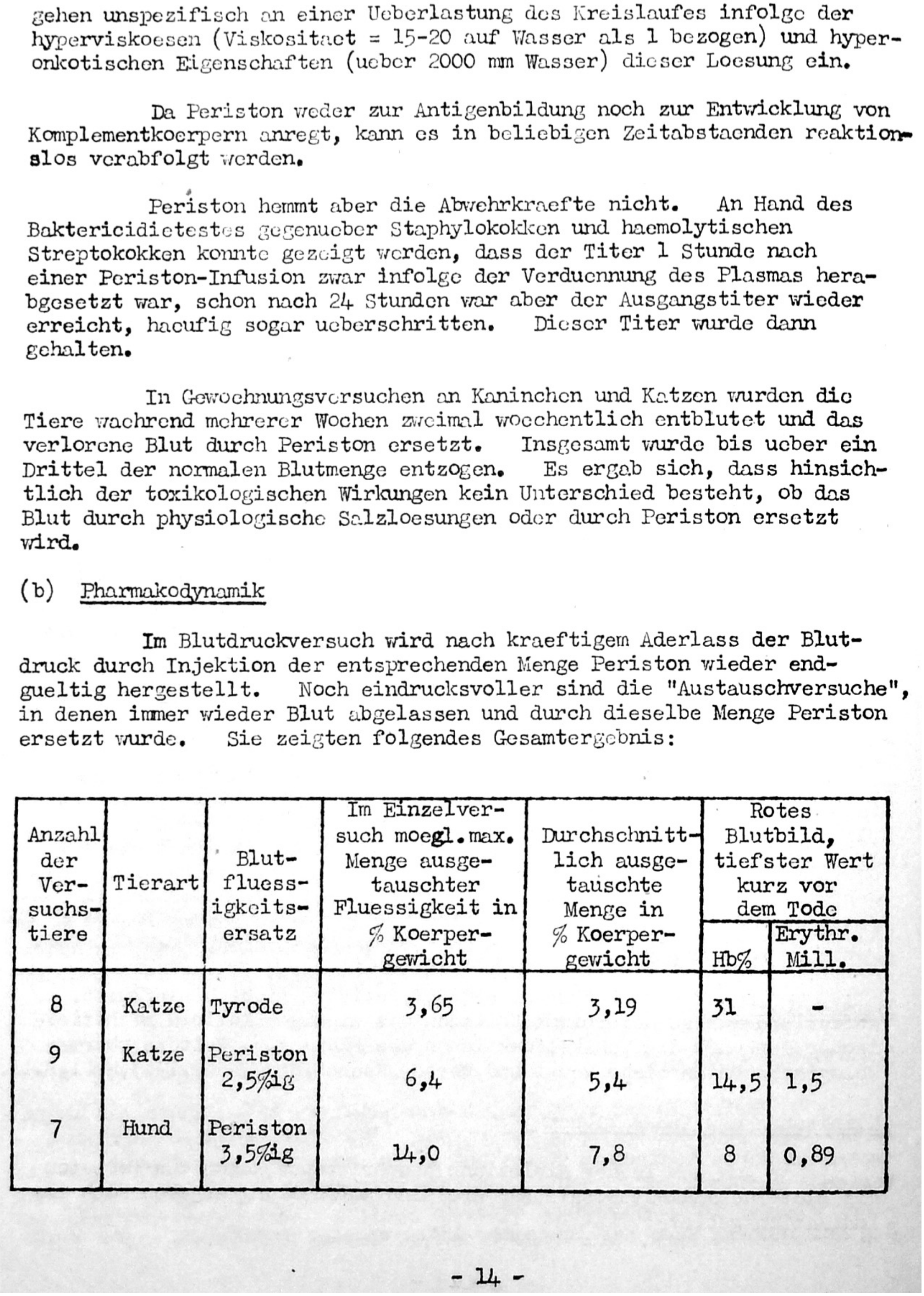
Pharmakologisches

(a) Vertraeglichkeit

Periston wird subkutan, intramuskulaer, intravenoes und intralumbal ohne jede Reizwirkung vertragen. Bei intravenoeser Injektion treten an Maus, Kaninchen, Katze und Affen keinerlei spezifische toxische Symptome auf. Eine toedliche Grenzdosis konnte erst mit einer 25%igen Kollidonloesung erreicht werden. Die D.l.m. betraegt 8 g Kollidon/kg Maus bei langsamer intravenoeser Injektion. Die Tiere

- 13 -

Figure A.25: A report on periston synthetic blood plasma [BIOS 354].



gehen unspezifisch an einer Ueberlastung des Kreislaufes infolge der hyperviskoesen (Viskositaet = 15-20 auf Wasser als 1 bezogen) und hyperonkotischen Eigenschaften (ueber 2000 mm Wasser) dieser Loesung ein.

Da Periston weder zur Antigenbildung noch zur Entwicklung von Komplementkoerpern anregt, kann es in beliebigen Zeitabstaenden reaktionslos verabfolgt werden.

Periston hemmt aber die Abwehrkraefte nicht. An Hand des Baktericidietestes gegenueber Staphylokokken und haemolytischen Streptokokken konnte gezeigt werden, dass der Titer 1 Stunde nach einer Periston-Infusion zwar infolge der Verduennung des Plasmas herabgesetzt war, schon nach 24 Stunden war aber der Ausgangstiter wieder erreicht, haeufig sogar ueberschritten. Dieser Titer wurde dann gehalten.

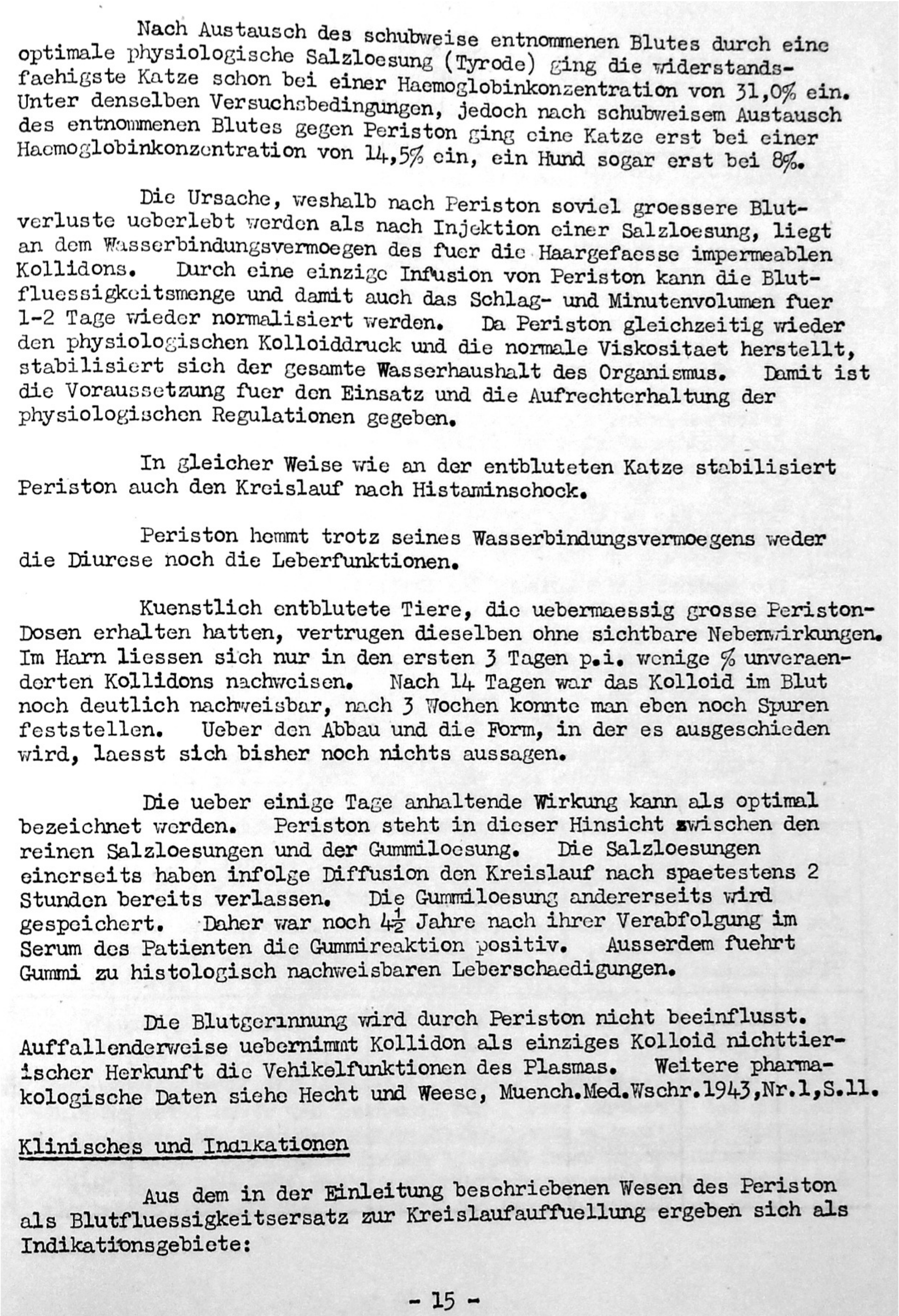
In Gewoehnungsversuchen an Kaninchen und Katzen wurden die Tiere waehrend mehrerer Wochen zweimal woechentlich entblutet und das verlorene Blut durch Periston ersetzt. Insgesamt wurde bis ueber ein Drittel der normalen Blutmenge entzogen. Es ergab sich, dass hinsichtlich der toxikologischen Wirkungen kein Unterschied besteht, ob das Blut durch physiologische Salzloesungen oder durch Periston ersetzt wird.

(b) Pharmakodynamik

Im Blutdruckversuch wird nach kraeftigem Aderlass der Blutdruck durch Injektion der entsprechenden Menge Periston wieder endgueltig hergestellt. Noch eindrucksvoller sind die "Austauschversuche", in denen immer wieder Blut abgelassen und durch dieselbe Menge Periston ersetzt wurde. Sie zeigten folgendes Gesamtergebnis:

Anzahl der Versuchstiere	Tierart	Blutfluessigkeitsersatz	Im Einzelversuch moegl. max. Menge ausgetauschter Fluessigkeit in % Koerpergewicht	Durchschnittlich ausgetauschte Menge in % Koerpergewicht	Rotes Blutbild, tiefster Wert kurz vor dem Tode	
					Hb%	Erythr. Mill.
8	Katze	Tyrode	3,65	3,19	31	-
9	Katze	Periston 2,5%ig	6,4	5,4	14,5	1,5
7	Hund	Periston 3,5%ig	14,0	7,8	8	0,89

Figure A.26: A report on periston synthetic blood plasma [BIOS 354].



Nach Austausch des schubweise entnommenen Blutes durch eine optimale physiologische Salzloesung (Tyrode) ging die widerstandsfaehigste Katze schon bei einer Haemoglobinkonzentration von 31,0% ein. Unter denselben Versuchsbedingungen, jedoch nach schubweisem Austausch des entnommenen Blutes gegen Periston ging eine Katze erst bei einer Haemoglobinkonzentration von 14,5% ein, ein Hund sogar erst bei 8%.

Die Ursache, weshalb nach Periston soviel groessere Blutverluste ueberlebt werden als nach Injektion einer Salzloesung, liegt an dem Wasserbindungsvermoegen des fuer die Haargefaesse impermeablen Kollidons. Durch eine einzige Infusion von Periston kann die Blutfluessigkeitsmenge und damit auch das Schlag- und Minutenvolumen fuer 1-2 Tage wieder normalisiert werden. Da Periston gleichzeitig wieder den physiologischen Kolloiddruck und die normale Viskositaet herstellt, stabilisiert sich der gesamte Wasserhaushalt des Organismus. Damit ist die Voraussetzung fuer den Einsatz und die Aufrechterhaltung der physiologischen Regulationen gegeben.

In gleicher Weise wie an der entbluteten Katze stabilisiert Periston auch den Kreislauf nach Histaminschock.

Periston hemmt trotz seines Wasserbindungsvermoegens weder die Diurese noch die Leberfunktionen.

Kuenstlich entblutete Tiere, die uebermaessig grosse Periston-Dosen erhalten hatten, vertrugen dieselben ohne sichtbare Nebenwirkungen. Im Harn liessen sich nur in den ersten 3 Tagen p.i. wenige % unveraenderten Kollidons nachweisen. Nach 14 Tagen war das Kolloid im Blut noch deutlich nachweisbar, nach 3 Wochen konnte man eben noch Spuren feststellen. Ueber den Abbau und die Form, in der es ausgeschieden wird, laesst sich bisher noch nichts aussagen.

Die ueber einige Tage anhaltende Wirkung kann als optimal bezeichnet werden. Periston steht in dieser Hinsicht zwischen den reinen Salzloesungen und der Gummiloesung. Die Salzloesungen einerseits haben infolge Diffusion den Kreislauf nach spaetestens 2 Stunden bereits verlassen. Die Gummiloesung andererseits wird gespeichert. Daher war noch 4½ Jahre nach ihrer Verabfolgung im Serum des Patienten die Gummireaktion positiv. Ausserdem fuehrt Gummi zu histologisch nachweisbaren Leberschaedigungen.

Die Blutgerinnung wird durch Periston nicht beeinflusst. Auffallenderweise uebernimmt Kollidon als einziges Kolloid nichttierischer Herkunft die Vehikelfunktionen des Plasmas. Weitere pharmakologische Daten siehe Hecht und Weese, Muench.Med.Wschr.1943,Nr.1,S.11.

Klinisches und Indikationen

Aus dem in der Einleitung beschriebenen Wesen des Periston als Blutfluessigkeitsersatz zur Kreislaufauffuellung ergeben sich als Indikationsgebiete:

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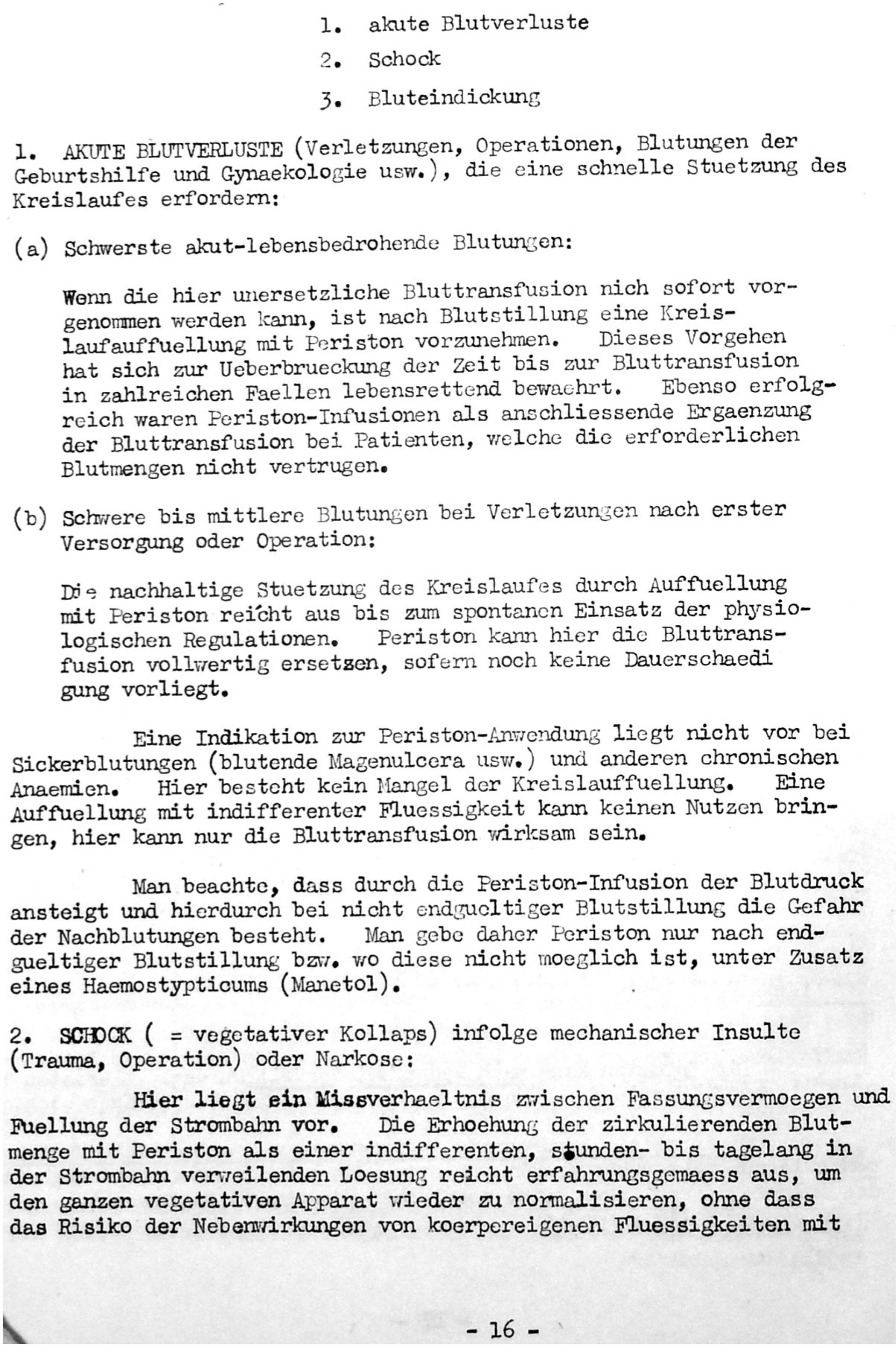
Figure A.27: A report on periston synthetic blood plasma [BIOS 354].



1. akute Blutverluste
2. Schock
3. Bluteindickung

1. AKUTE BLUTVERLUSTE (Verletzungen, Operationen, Blutungen der Geburtshilfe und Gynaekologie usw.), die eine schnelle Stuetzung des Kreislaufes erfordern:

(a) Schwerste akut-lebensbedrohende Blutungen:

Wenn die hier unersetzliche Bluttransfusion nich sofort vorgenommen werden kann, ist nach Blutstillung eine Kreislaufauffuellung mit Periston vorzunehmen. Dieses Vorgehen hat sich zur Ueberbrueckung der Zeit bis zur Bluttransfusion in zahlreichen Faellen lebensrettend bewaehrt. Ebenso erfolgreich waren Periston-Infusionen als anschliessende Ergaenzung der Bluttransfusion bei Patienten, welche die erforderlichen Blutmengen nicht vertrugen.

(b) Schwere bis mittlere Blutungen bei Verletzungen nach erster Versorgung oder Operation:

Die nachhaltige Stuetzung des Kreislaufes durch Auffuellung mit Periston reicht aus bis zum spontanen Einsatz der physiologischen Regulationen. Periston kann hier die Bluttransfusion vollwertig ersetzen, sofern noch keine Dauerschaedigung vorliegt.

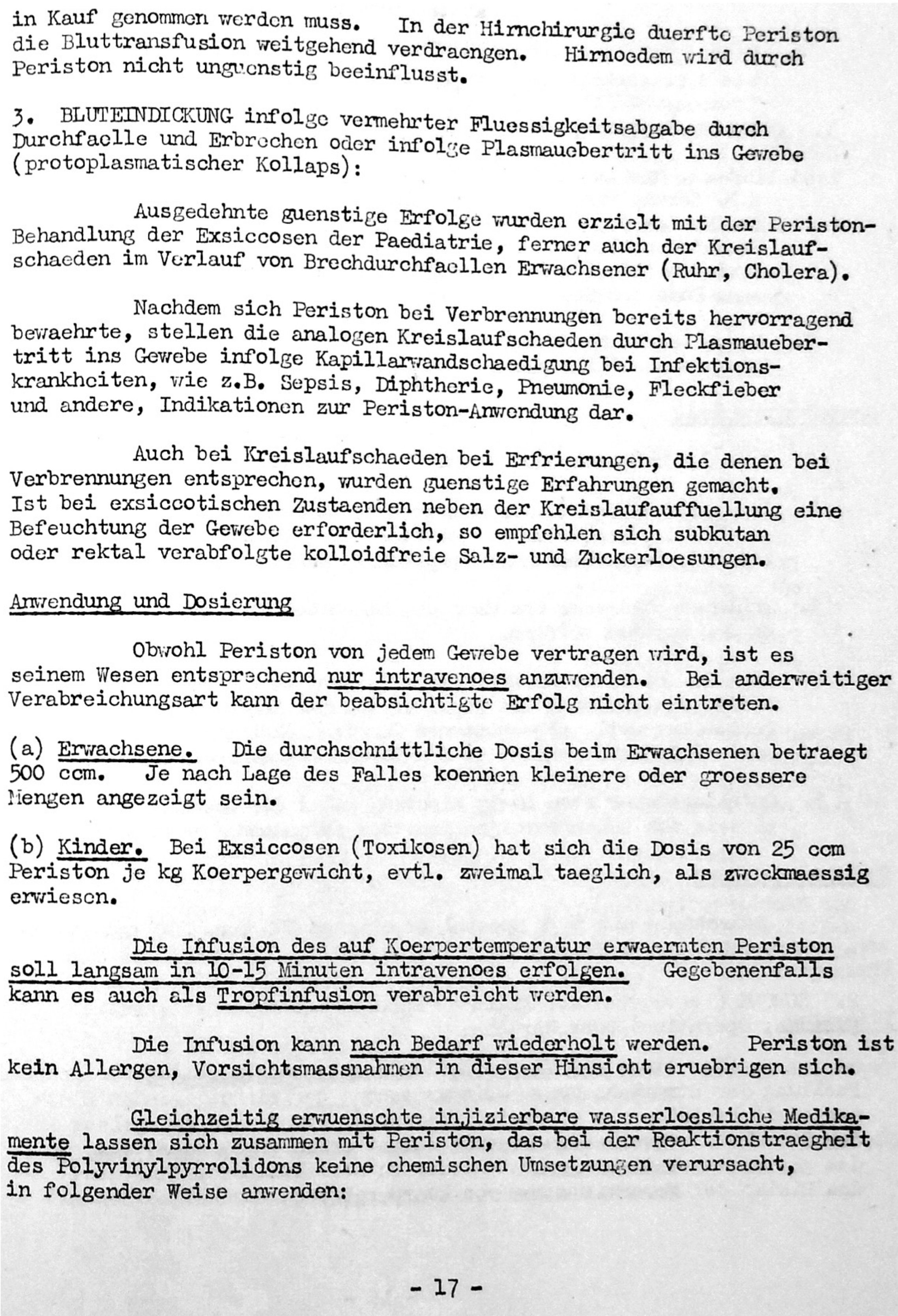
Eine Indikation zur Periston-Anwendung liegt nicht vor bei Sickerblutungen (blutende Magenulcera usw.) und anderen chronischen Anaemien. Hier besteht kein Mangel der Kreislaufauffuellung. Eine Auffuellung mit indifferenter Fluessigkeit kann keinen Nutzen bringen, hier kann nur die Bluttransfusion wirksam sein.

Man beachte, dass durch die Periston-Infusion der Blutdruck ansteigt und hierdurch bei nicht endgueltiger Blutstillung die Gefahr der Nachblutungen besteht. Man gebe daher Periston nur nach endgueltiger Blutstillung bzw. wo diese nicht moeglich ist, unter Zusatz eines Haemostypticums (Manetol).

2. SCHOCK (= vegetativer Kollaps) infolge mechanischer Insulte (Trauma, Operation) oder Narkose:

Hier liegt ein Missverhaeltnis zwischen Fassungsvermoegen und Fuellung der Strombahn vor. Die Erhoehung der zirkulierenden Blutmenge mit Periston als einer indifferenten, stunden- bis tagelang in der Strombahn verweilenden Loesung reicht erfahrungsgemaess aus, um den ganzen vegetativen Apparat wieder zu normalisieren, ohne dass das Risiko der Nebenwirkungen von koerpereigenen Fluessigkeiten mit

Figure A.28: A report on periston synthetic blood plasma [BIOS 354].



in Kauf genommen werden muss. In der Hirnchirurgie duerfte Periston die Bluttransfusion weitgehend verdraengen. Hirnoedem wird durch Periston nicht unguenstig beeinflusst.

3. BLUTEINDICKUNG infolge vermehrter Fluessigkeitsabgabe durch Durchfaelle und Erbrechen oder infolge Plasmauebertritt ins Gewebe (protoplasmatischer Kollaps):

Ausgedehnte guenstige Erfolge wurden erzielt mit der Periston-Behandlung der Exsiccosen der Paediatrie, ferner auch der Kreislaufschaeden im Verlauf von Brechdurchfaellen Erwachsener (Ruhr, Cholera).

Nachdem sich Periston bei Verbrennungen bereits hervorragend bewaehrte, stellen die analogen Kreislaufschaeden durch Plasmauebertritt ins Gewebe infolge Kapillarwandschaedigung bei Infektionskrankheiten, wie z.B. Sepsis, Diphtherie, Pneumonie, Fleckfieber und andere, Indikationen zur Periston-Anwendung dar.

Auch bei Kreislaufschaeden bei Erfrierungen, die denen bei Verbrennungen entsprechen, wurden guenstige Erfahrungen gemacht. Ist bei exsiccotischen Zustaenden neben der Kreislaufauffuellung eine Befeuchtung der Gewebe erforderlich, so empfehlen sich subkutan oder rektal verabfolgte kolloidfreie Salz- und Zuckerloesungen.

Anwendung und Dosierung

Obwohl Periston von jedem Gewebe vertragen wird, ist es seinem Wesen entsprechend nur intravenoes anzuwenden. Bei anderweitiger Verabreichungsart kann der beabsichtigte Erfolg nicht eintreten.

(a) Erwachsene. Die durchschnittliche Dosis beim Erwachsenen betraegt 500 ccm. Je nach Lage des Falles koennen kleinere oder groessere Mengen angezeigt sein.

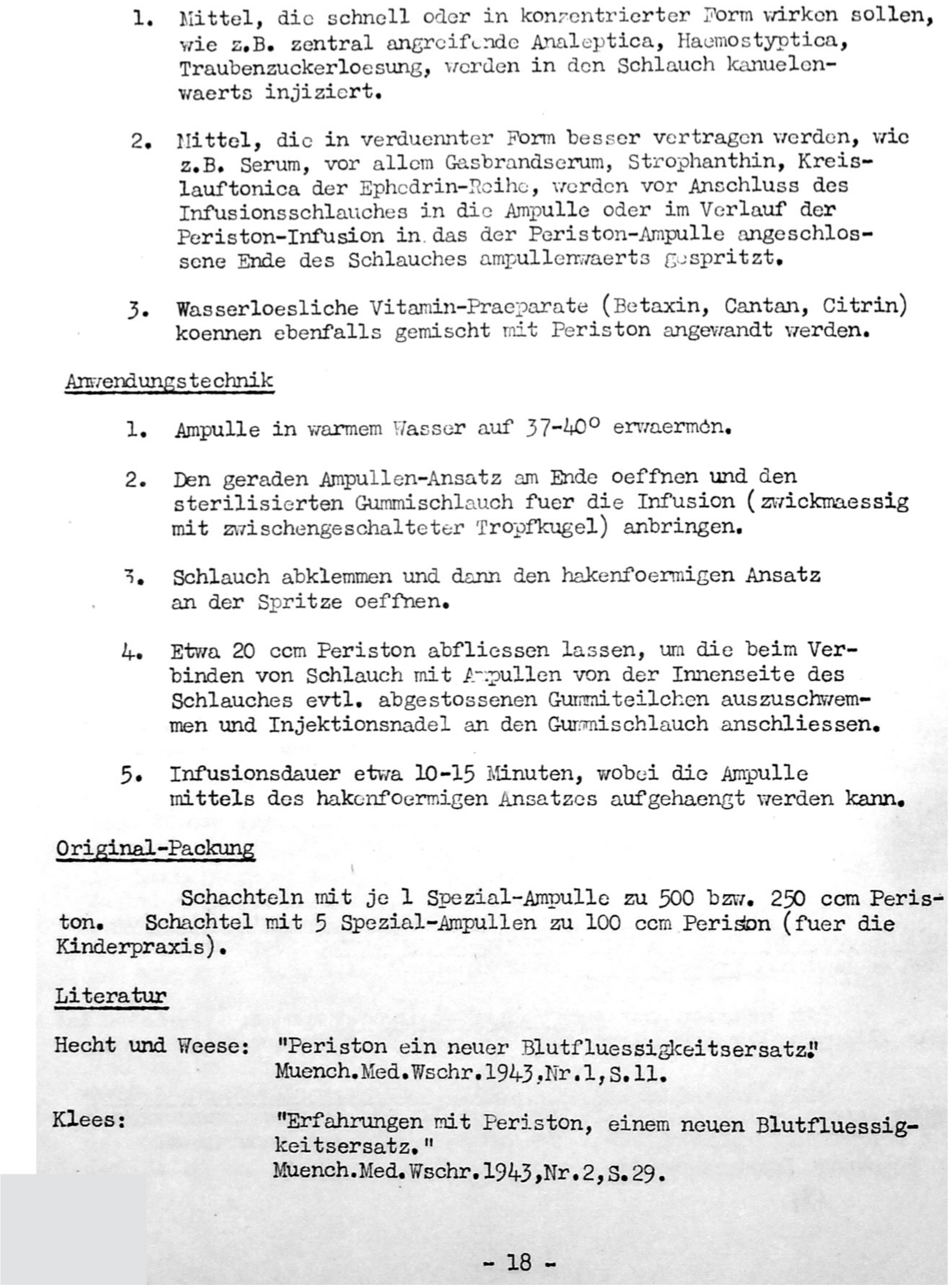
(b) Kinder. Bei Exsiccosen (Toxikosen) hat sich die Dosis von 25 ccm Periston je kg Koerpergewicht, evtl. zweimal taeglich, als zweckmaessig erwiesen.

Die Infusion des auf Koerpertemperatur erwaermten Periston soll langsam in 10-15 Minuten intravenoes erfolgen. Gegebenenfalls kann es auch als Tropfinfusion verabreicht werden.

Die Infusion kann nach Bedarf wiederholt werden. Periston ist kein Allergen, Vorsichtsmassnahmen in dieser Hinsicht eruebrigen sich.

Gleichzeitig erwuenschte injizierbare wasserloesliche Medikamente lassen sich zusammen mit Periston, das bei der Reaktionstraegheit des Polyvinylpyrrolidons keine chemischen Umsetzungen verursacht, in folgender Weise anwenden:

Figure A.29: A report on periston synthetic blood plasma [BIOS 354].



1. Mittel, die schnell oder in konzentrierter Form wirken sollen, wie z.B. zentral angreifende Analeptica, Haemostyptica, Traubenzuckerloesung, werden in den Schlauch kanuelenwaerts injiziert.

2. Mittel, die in verduennter Form besser vertragen werden, wie z.B. Serum, vor allem Gasbrandserum, Strophanthin, Kreislauftonica der Ephedrin-Reihe, werden vor Anschluss des Infusionsschlauches in die Ampulle oder im Verlauf der Periston-Infusion in das der Periston-Ampulle angeschlossene Ende des Schlauches ampullenwaerts gespritzt.

3. Wasserloesliche Vitamin-Praeparate (Betaxin, Cantan, Citrin) koennen ebenfalls gemischt mit Periston angewandt werden.

Anwendungstechnik

1. Ampulle in warmem Wasser auf 37-40° erwaermen.

2. Den geraden Ampullen-Ansatz am Ende oeffnen und den sterilisierten Gummischlauch fuer die Infusion (zwickmaessig mit zwischengeschalteter Tropfkugel) anbringen.

3. Schlauch abklemmen und dann den hakenfoermigen Ansatz an der Spritze oeffnen.

4. Etwa 20 ccm Periston abfliessen lassen, um die beim Verbinden von Schlauch mit Ampullen von der Innenseite des Schlauches evtl. abgestossenen Gummiteilchen auszuschwemmen und Injektionsnadel an den Gummischlauch anschliessen.

5. Infusionsdauer etwa 10-15 Minuten, wobei die Ampulle mittels des hakenfoermigen Ansatzes aufgehaengt werden kann.

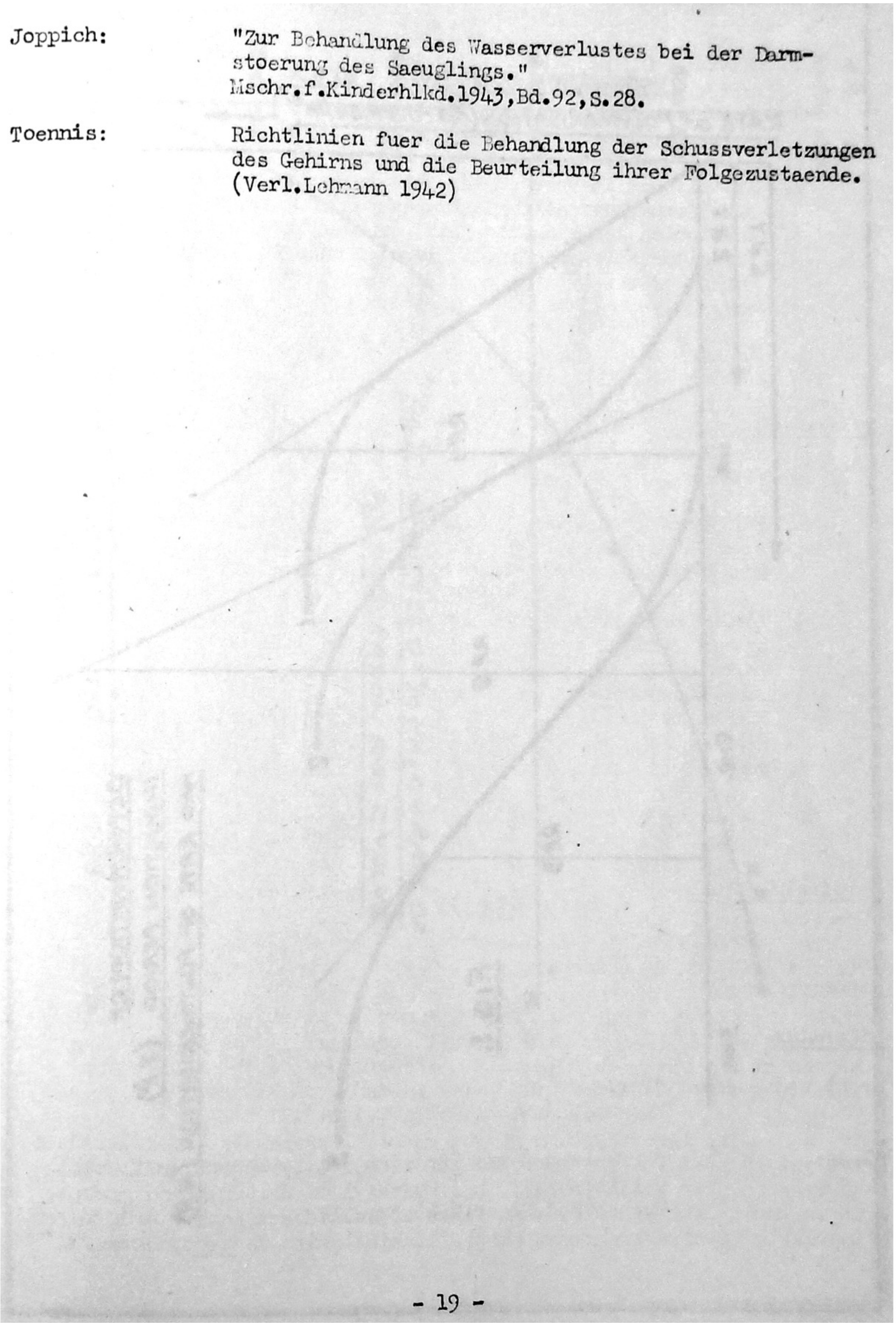
Original-Packung

Schachteln mit je 1 Spezial-Ampulle zu 500 bzw. 250 ccm Periston. Schachtel mit 5 Spezial-Ampullen zu 100 ccm Periston (fuer die Kinderpraxis).

Literatur

Hecht und Weese:	"Periston ein neuer Blutfluessigkeitsersatz." Muench.Med.Wschr.1943,Nr.1,S.11.
Klees:	"Erfahrungen mit Periston, einem neuen Blutfluessigkeitsersatz." Muench.Med.Wschr.1943,Nr.2,S.29.

Figure A.30: A report on periston synthetic blood plasma [BIOS 354].



Joppich: "Zur Behandlung des Wasserverlustes bei der Darmstoerung des Saeuglings."
Mschr.f.Kinderhlkd.1943,Bd.92,S.28.

Toennis: Richtlinien fuer die Behandlung der Schussverletzungen des Gehirns und die Beurteilung ihrer Folgezustaende.
(Verl.Lehmann 1942)

Figure A.31: A report on periston synthetic blood plasma [BIOS 354].

BIOS 395. *German Fluorescent Lamp Industry and Phosphor Chemical Manufacture.* pp. 1–2

Dr. Leonhard Birkofor was assistant to Prof. Richard Kuhn described as Director of the Institute for Chemistry and Administrative Head of the Kaiser Wilhelm Institute.

[...] Dr. Leonhard Birkofor was interviewed during the period the investigating team was awaiting Dr. Leibnitz. He volunteered the information that the work of Dr. Kuhn and himself was directed largely to biological and biochemical research. He stated that they had developed a substituted benzil compound of the following constitution:-

i.e., symmetrical 1.1. dihydroxy 4.4 dibrom benzil, which he stated had bacteriocidal properties similar to those of penicillin. The compound MP 213^{o}C consisted of yellow needles and a 5 gm. sample was obtained.

Dr. Birkofor stated that so far 500 gms. had been distributed and tests in various hospitals had shown positive reactions against streptococcus, staphylococcus, gonococcus and pneumococcus. The medical investigations at these hospitals were continuing.

BIOS 436. ***Enzyme Products and "Acrisin" Finishing Agents for Textiles: Rohm and Haas G.m.b.H., Darmstadt.*** [Enzymes for washing]

[...] Concentrated preparations of pancreatic tryptase and diastase were prepared from an aqueous extract by selective precipitation. The concentrated products were diluted with sodium carbonate or sodium chloride respectively before being sold. [...]

No research had been carried out recently on enzyme products although the production of bacterial enzymes had been considered. [...]

The rough powder is ground and laboratory tests are carried out to estimate the enzymatic activity. The products are diluted, if necessary, in order that the final mixture will meet the standard specification for rate of conversion of starch to sugar (diastase) or for rate of liquefaction of gelatine (tryptase).

Care was necessary in handling the concentrated tryptase preparation in view of its rapid attack of animal tissue. Gloves, goggles and dust masks were provided for the workers but it had not always been possible to compel workers to wear them.

These highly concentrated works products are diluted between 40 and 50 times before being marketed. The principle diluent for the diastase is sodium chloride and for tryptase, sodium carbonate with or without sodium sulphate. With the diastase preparation, however, 5% calcium formate and mono- and di-sodium phosphates are added. The calcium formate is used to avoid the effect of varying hardness of different waters and the phosphates buffer solutions of the product to pH 6.6 to 7. The diastase is marketed under the name "Degomma" for desizing cotton fabrics.

The tryptase products were used on a considerable scale for bating and de-hairing hides but a very large mount was used for soaking articles before washing.

In the soaking powder, the concentrated tryptase is diluted with approximately 98% sodium carbonate, and the product is called Burnus or Enzymolin. A ½% solution is used at 35^{o}C (not exceeding 40 ^{o}C) for 10–15 minutes in commercial laundries whilst for household use an overnight soak is given in a similar solution.

It is claimed that much of the soiling matter is attached to fabrics by means of protein, starch or fatty matter and that these cementing materials are attacked and rendered soluble by the enzymes thus simplifying the subsequent washing process.

The maximum production of Burnus has been about 170 metric tons per month.

BIOS 449. ***German Medical Targets.*** [Pharmaceuticals, hormones, antibiotics, cancer, DDT]

[pp. 2–12:]

Report on the Researches of the Scientific Laboratory of C. F. Boehringer & Soehne, Mannheim-Waldhof during the war 1939–1945

[...] The research on producing the thymus hormone was based on the studies of Bomskov, who ascertained that extracts of the thymus glands of guinea-pigs are able to mobilize glycogen stored in different organs such as heart, liver and muscles. [...] He found, that the thymus really is a gland of internal secretion. Tests were made to concentrate the active substance and to establish its constitution. Bomskov made acetone extracts and showed that the active substance, especially after saponifying can be extracted with ether. We used glacial acetic acid and hydrocarbon chlorides as extracting solvents, the latter proved especially advantageous, as shown by the following examples[...]

Together with Prof. Brederick we elaborate a procedure for the manufacture of caffeine from uric acid. The uric acid is to be added in a formamide-melt of about 200^o and so transformed to xanthine, which is easily converted to caffeine by methylating with dimethylsulphate [...]

The greatest obstacle in this process is to procure a sufficiently pure and cheap uric acid.

The process with serpents' excrement which contains more than 80% of uric acid, is very easy and needs no further purification. [...]

Manufacture of Malaria Remedies.

[...] The new compound designated "Amichin" is scarcely inferior to quinine, whilst in general variations in the quinine molecule result in diminishing the anti-malaria efficiency. Many azo-compounds of Amichin were prepare and tested. Of these "Amichinazokairolin" proved especially non toxic and about 30 times more active than quinine in the canary test. This exceedingly favourable result caused us to test this product on man in larger scale. [...] There it proved that the strong increase of efficiency shown in the canary test was not so marked in human experiments, whilst the good tolerableness was maintained. The augmentation of efficiency compared to quinine amounted to only about four fold in the same range of application (that is both compounds act against schizontes only and not against gametes). [...]

In general the yeast was subject to an exact investigation. We are manufacturing on a factory scale nucleic acid from yeast and the resulting protein products were worked up to an animal food. As in wartime there is a large deficit in protein, we tried to transform the protein by-products of the nucleic acid manufacture into products fit for human nourishment. We succeeded in extracting albumen which can be whipped and which could replace the albumen in cooking and baking. This chemical introduced in trade circles under the trade mark "Backalbin" was sold in many thousands of kilos until the shortage of yeast stopped the manufacture. [...]

Furthermore we were producing a preparation of capsaicin to replace pepper. [...]

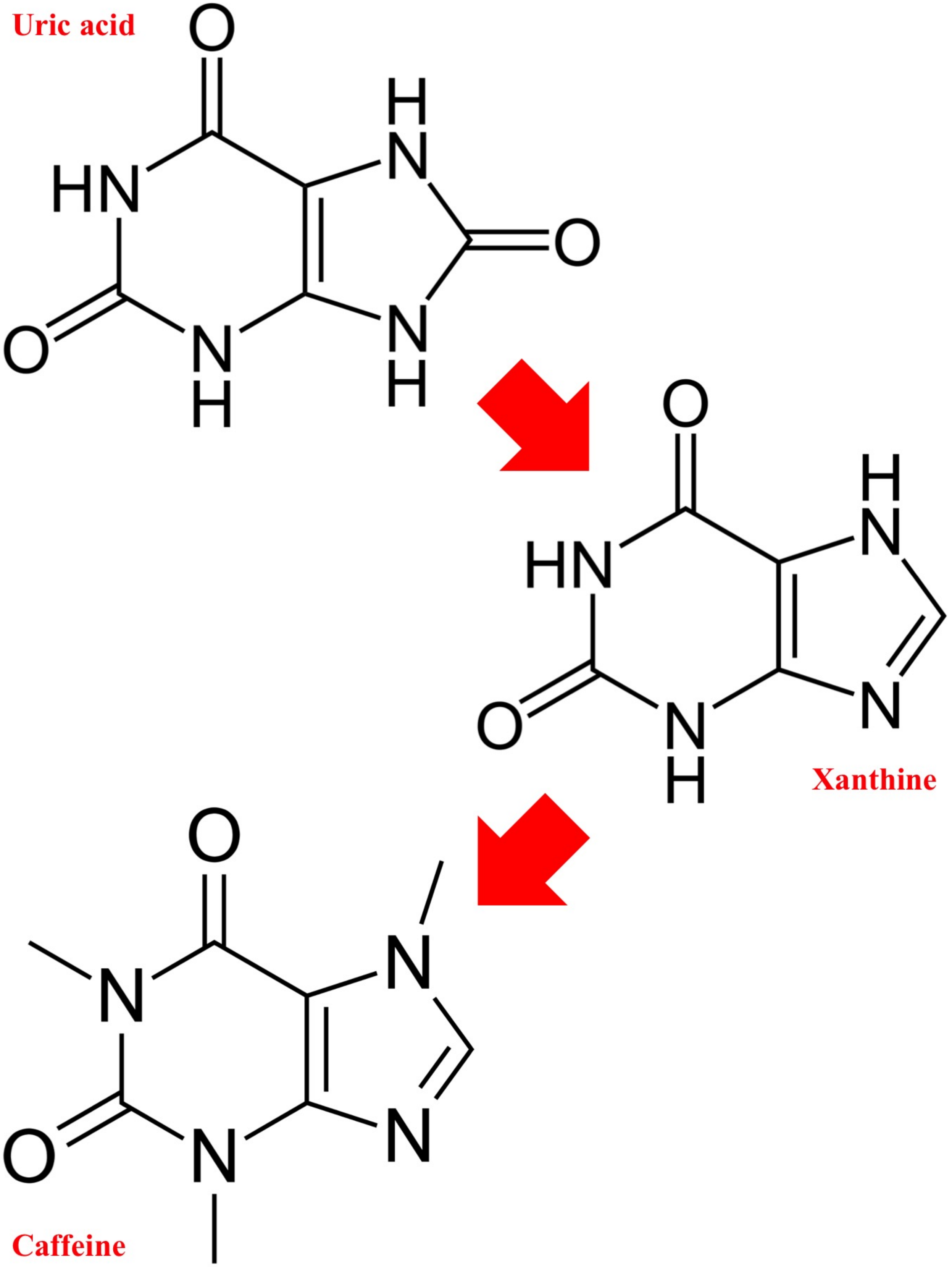

Uric acid
O
HN
H
N
O
O
N
H
N
H
O
H
N
HN
O
N
H
N
Xanthine
O
N
N
O
N
N
Caffeine

Figure A.32: BIOS 449 described the industrial farming of uric acid from snake urine and the conversion of the uric acid into caffeine.

[pp. 21–23]

Schering A.G., Berlin N 65 Werk Müllerstr. 170/72 [...]

Penicillin This had been mainly on a laboratory scale. The strain they had used was supplied by Prof. Rostock. It was suggested that he might have obtained it from Jena or perhaps Hanover. The unitage they obtained was 5–20 units/c.c. on the 13th and 14th days on a Czapek Dox medium with added lactose or glucose. Even though this was said to have been on a laboratory scale we found that the autoclave they had used was said to weigh 18 tons. The standard used was captured English penicillin and they used the inhibition of growth of Staph. aureus in 50 c.c. of medium. They had supplied some clinics in Berlin and Leipzig with material for trial but there had been little available for the chemical determination of the constitution of penicillin. (We think that this statement is not quite accurate but Dr. Clerc himself was not involved in the various procedures described.)

[p. 37]

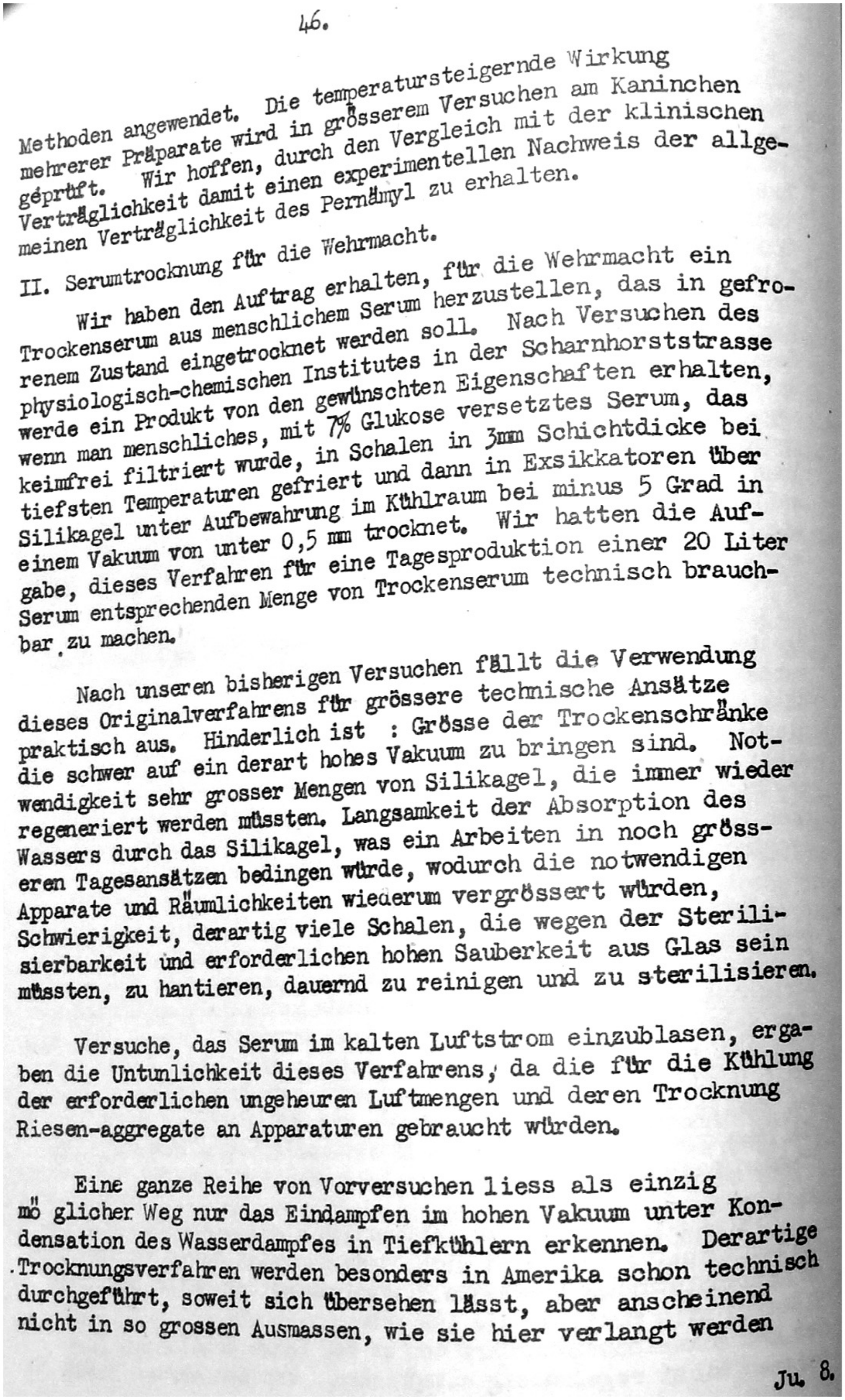
EXPERIMENTAL TUMOURS

Various experiments to uncover possible immunity mechanisms were carried out (e.g., immune sera (anti-Ehrlich carcinoma sera in rabbits, etc.) and attempts to breed tumour immune animals). The Ehrlich ascites tumour was fractioned and of the various portions used as antigens the mitochondrial fraction showed the most interesting results. The work ultimately had to be confined within very narrow limits.

DRYING OF SERUM FOR THE WEHRMACHT

Work on the freeze drying of human serum started early in 1941. They were alive to the possibilities for the use of this process not only for war purposes but also for various processes and products required in peace. They devised an apparatus capable of drying some 20 litres a day by the beginning of 1942. Finally in the first six months of 1943 they prepared 348 kg of dried serum and in 1944 607 kg. They planned to have a special serum drying plant at Luckenwalde. In the first three months of 1945 their output of dried serum dropped some 70%. The Military Medical Academy was interested in the amino acid content of blood hydrolysates for use in hunger oedema.

[Please see the following pages for more information from this report on producing freeze-dried human blood, therapeutic antibodies that target cancer cells, and other advanced medical therapeutics.]



Methoden angewendet. Die temperatursteigernde Wirkung mehrerer Präparate wird in grösserem Versuchen am Kaninchen geprüft. Wir hoffen, durch den Vergleich mit der klinischen Verträglichkeit damit einen experimentellen Nachweis der allgemeinen Verträglichkeit des Pernämyl zu erhalten.

II. Serumtrocknung für die Wehrmacht.

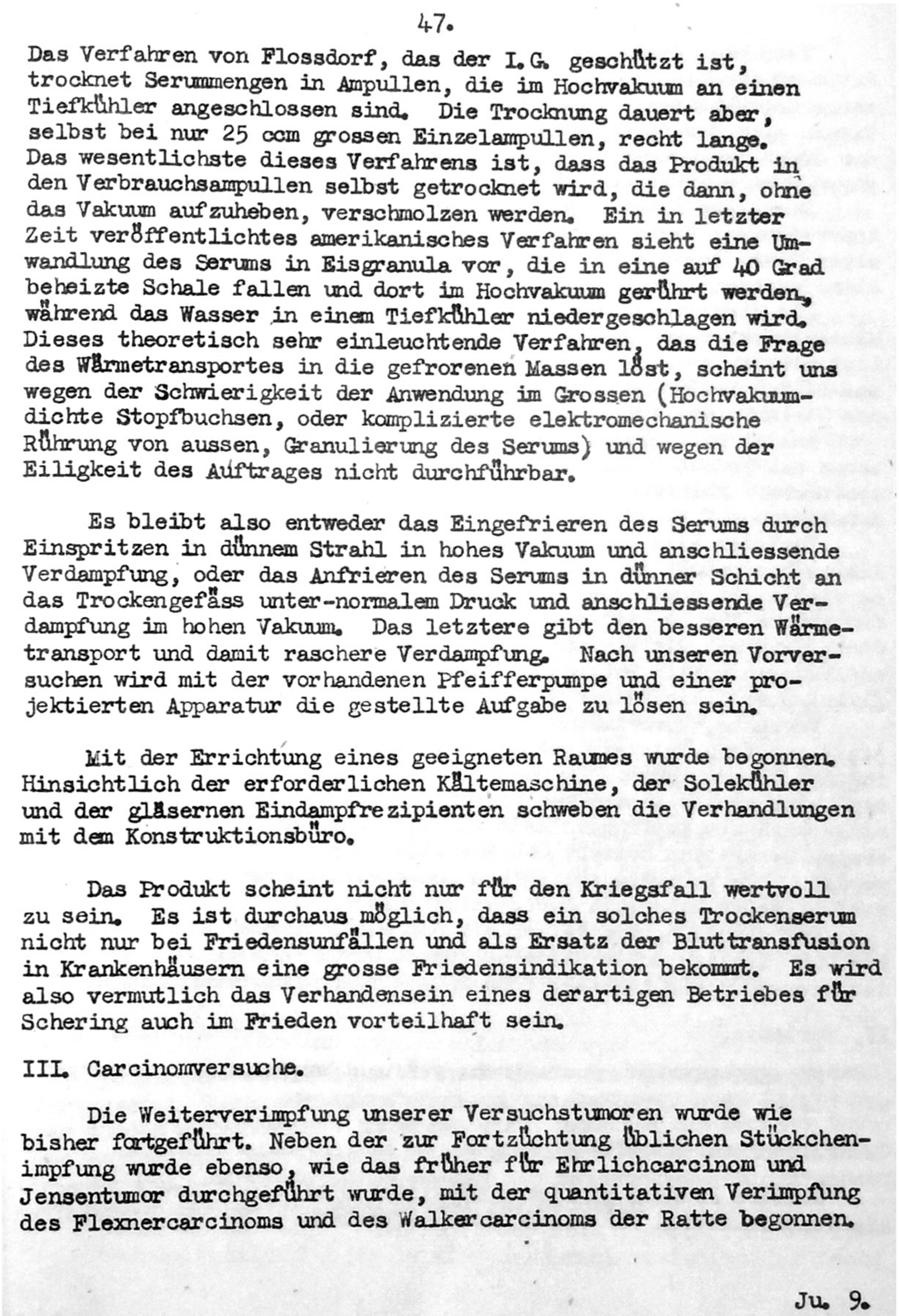
Wir haben den Auftrag erhalten, für die Wehrmacht ein Trockenserum aus menschlichem Serum herzustellen, das in gefrorenem Zustand eingetrocknet werden soll. Nach Versuchen des physiologisch-chemischen Institutes in der Scharnhorststrasse werde ein Produkt von den gewünschten Eigenschaften erhalten, wenn man menschliches, mit 7% Glukose versetztes Serum, das keimfrei filtriert wurde, in Schalen in 3mm Schichtdicke bei tiefsten Temperaturen gefriert und dann in Exsikkatoren über Silikagel unter Aufbewahrung im Kühlraum bei minus 5 Grad in einem Vakuum von unter 0,5 mm trocknet. Wir hatten die Aufgabe, dieses Verfahren für eine Tagesproduktion einer 20 Liter Serum entsprechenden Menge von Trockenserum technisch brauchbar zu machen.

Nach unseren bisherigen Versuchen fällt die Verwendung dieses Originalverfahrens für grössere technische Ansätze praktisch aus. Hinderlich ist : Grösse der Trockenschränke die schwer auf ein derart hohes Vakuum zu bringen sind. Notwendigkeit sehr grosser Mengen von Silikagel, die immer wieder regeneriert werden müssten. Langsamkeit der Absorption des Wassers durch das Silikagel, was ein Arbeiten in noch grösseren Tagesansätzen bedingen würde, wodurch die notwendigen Apparate und Räumlichkeiten wiederum vergrössert würden, Schwierigkeit, derartig viele Schalen, die wegen der Sterilisierbarkeit und erforderlichen hohen Sauberkeit aus Glas sein müssten, zu hantieren, dauernd zu reinigen und zu sterilisieren.

Versuche, das Serum im kalten Luftstrom einzublasen, ergaben die Untunlichkeit dieses Verfahrens, da die für die Kühlung der erforderlichen ungeheuren Luftmengen und deren Trocknung Riesen-aggregate an Apparaturen gebraucht würden.

Eine ganze Reihe von Vorversuchen liess als einzig möglicher Weg nur das Eindampfen im hohen Vakuum unter Kondensation des Wasserdampfes in Tiefkühlern erkennen. Derartige Trocknungsverfahren werden besonders in Amerika schon technisch durchgeführt, soweit sich übersehen lässt, aber anscheinend nicht in so grossen Ausmassen, wie sie hier verlangt werden

Figure A.33: A report on producing freeze-dried human blood, therapeutic antibodies that target cancer cells, and other advanced medical therapeutics [BIOS 449].



47.

Das Verfahren von Flossdorf, das der I.G. geschützt ist, trocknet Serummengen in Ampullen, die im Hochvakuum an einen Tiefkühler angeschlossen sind. Die Trocknung dauert aber, selbst bei nur 25 ccm grossen Einzelampullen, recht lange. Das wesentlichste dieses Verfahrens ist, dass das Produkt in den Verbrauchsampullen selbst getrocknet wird, die dann, ohne das Vakuum aufzuheben, verschmolzen werden. Ein in letzter Zeit veröffentlichtes amerikanisches Verfahren sieht eine Umwandlung des Serums in Eisgranula vor, die in eine auf 40 Grad beheizte Schale fallen und dort im Hochvakuum gerührt werden, während das Wasser in einem Tiefkühler niedergeschlagen wird. Dieses theoretisch sehr einleuchtende Verfahren, das die Frage des Wärmetransportes in die gefrorenen Massen löst, scheint uns wegen der Schwierigkeit der Anwendung im Grossen (Hochvakuumdichte Stopfbuchsen, oder komplizierte elektromechanische Rührung von aussen, Granulierung des Serums) und wegen der Eiligkeit des Auftrages nicht durchführbar.

Es bleibt also entweder das Eingefrieren des Serums durch Einspritzen in dünnem Strahl in hohes Vakuum und anschliessende Verdampfung, oder das Anfrieren des Serums in dünner Schicht an das Trockengefäss unter-normalem Druck und anschliessende Verdampfung im hohen Vakuum. Das letztere gibt den besseren Wärmetransport und damit raschere Verdampfung. Nach unseren Vorversuchen wird mit der vorhandenen Pfeifferpumpe und einer projektierten Apparatur die gestellte Aufgabe zu lösen sein.

Mit der Errichtung eines geeigneten Raumes wurde begonnen. Hinsichtlich der erforderlichen Kältemaschine, der Solekühler und der gläsernen Eindampfrezipienten schweben die Verhandlungen mit dem Konstruktionsbüro.

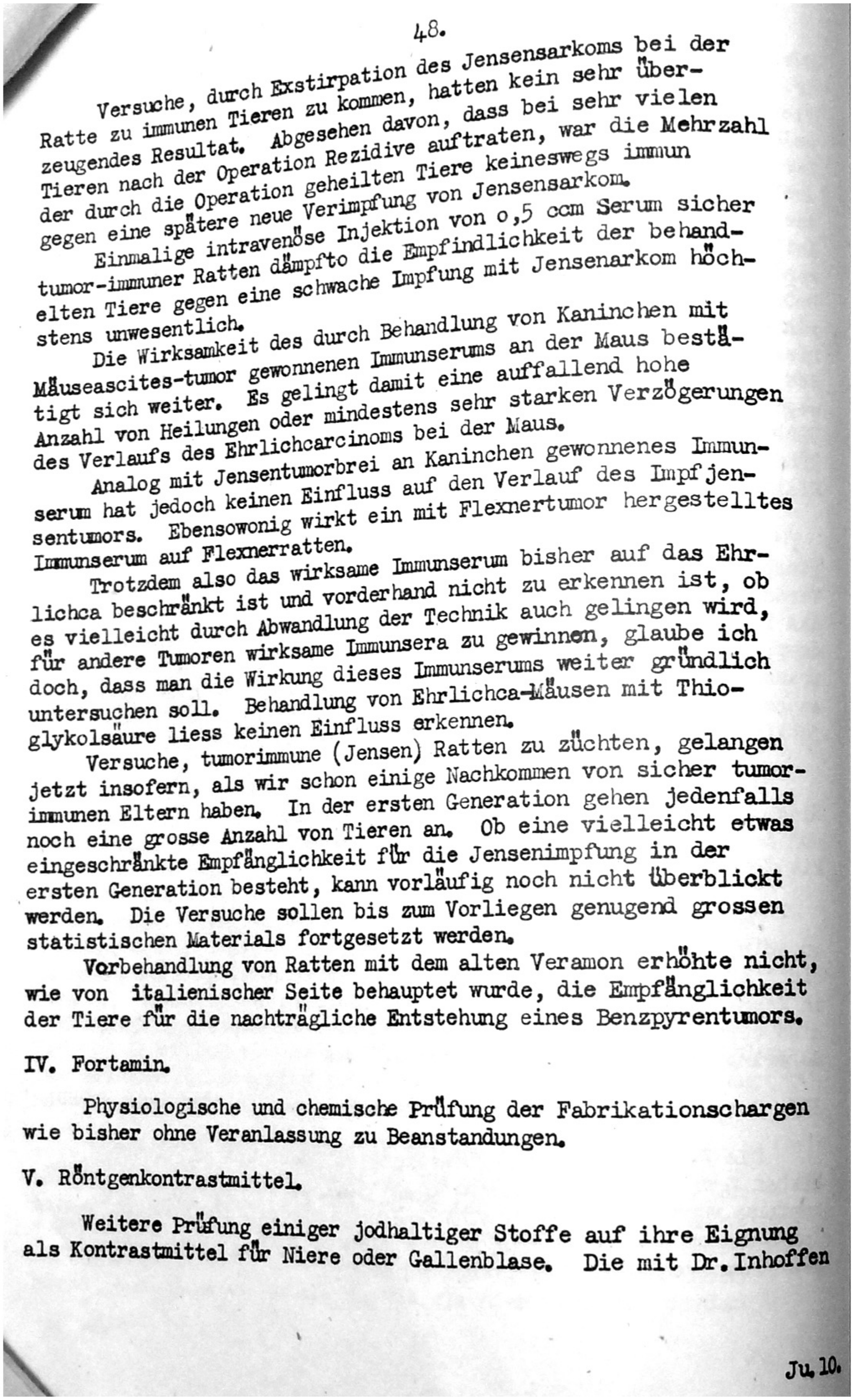
Das Produkt scheint nicht nur für den Kriegsfall wertvoll zu sein. Es ist durchaus möglich, dass ein solches Trockenserum nicht nur bei Friedensunfällen und als Ersatz der Bluttransfusion in Krankenhäusern eine grosse Friedensindikation bekommt. Es wird also vermutlich das Verhandensein eines derartigen Betriebes für Schering auch im Frieden vorteilhaft sein.

III. Carcinomversuche.

Die Weiterverimpfung unserer Versuchstumoren wurde wie bisher fortgeführt. Neben der zur Fortzüchtung üblichen Stückchenimpfung wurde ebenso, wie das früher für Ehrlichcarcinom und Jensentumor durchgeführt wurde, mit der quantitativen Verimpfung des Flexnercarcinoms und des Walkercarcinoms der Ratte begonnen.

Ju. 9.

Figure A.34: A report on producing freeze-dried human blood, therapeutic antibodies that target cancer cells, and other advanced medical therapeutics [BIOS 449].



48.

Versuche, durch Exstirpation des Jensensarkoms bei der Ratte zu immunen Tieren zu kommen, hatten kein sehr überzeugendes Resultat. Abgesehen davon, dass bei sehr vielen Tieren nach der Operation Rezidive auftraten, war die Mehrzahl der durch die Operation geheilten Tiere keineswegs immun gegen eine spätere neue Verimpfung von Jensensarkom.

Einmalige intravenöse Injektion von o,5 ccm Serum sicher tumor-immuner Ratten dämpfto die Empfindlichkeit der behandelten Tiere gegen eine schwache Impfung mit Jensenarkom höchstens unwesentlich.

Die Wirksamkeit des durch Behandlung von Kaninchen mit Mäuseascites-tumor gewonnenen Immunserums an der Maus bestätigt sich weiter. Es gelingt damit eine auffallend hohe Anzahl von Heilungen oder mindestens sehr starken Verzögerungen des Verlaufs des Ehrlichcarcinoms bei der Maus.

Analog mit Jensentumorbrei an Kaninchen gewonnenes Immunserum hat jedoch keinen Einfluss auf den Verlauf des Impfjensentumors. Ebensowonig wirkt ein mit Flexnertumor hergestelltes Immunserum auf Flexnerratten.

Trotzdem also das wirksame Immunserum bisher auf das Ehrlichca beschränkt ist und vorderhand nicht zu erkennen ist, ob es vielleicht durch Abwandlung der Technik auch gelingen wird, für andere Tumoren wirksame Immunsera zu gewinnen, glaube ich doch, dass man die Wirkung dieses Immunserums weiter gründlich untersuchen soll. Behandlung von Ehrlichca-Mäusen mit Thioglykolsäure liess keinen Einfluss erkennen.

Versuche, tumorimmune (Jensen) Ratten zu züchten, gelangen jetzt insofern, als wir schon einige Nachkommen von sicher tumorimmunen Eltern haben. In der ersten Generation gehen jedenfalls noch eine grosse Anzahl von Tieren an. Ob eine vielleicht etwas eingeschränkte Empfänglichkeit für die Jensenimpfung in der ersten Generation besteht, kann vorläufig noch nicht überblickt werden. Die Versuche sollen bis zum Vorliegen genugend grossen statistischen Materials fortgesetzt werden.

Vorbehandlung von Ratten mit dem alten Veramon erhöhte nicht, wie von italienischer Seite behauptet wurde, die Empfänglichkeit der Tiere für die nachträgliche Entstehung eines Benzpyrentumors.

IV. Fortamin.

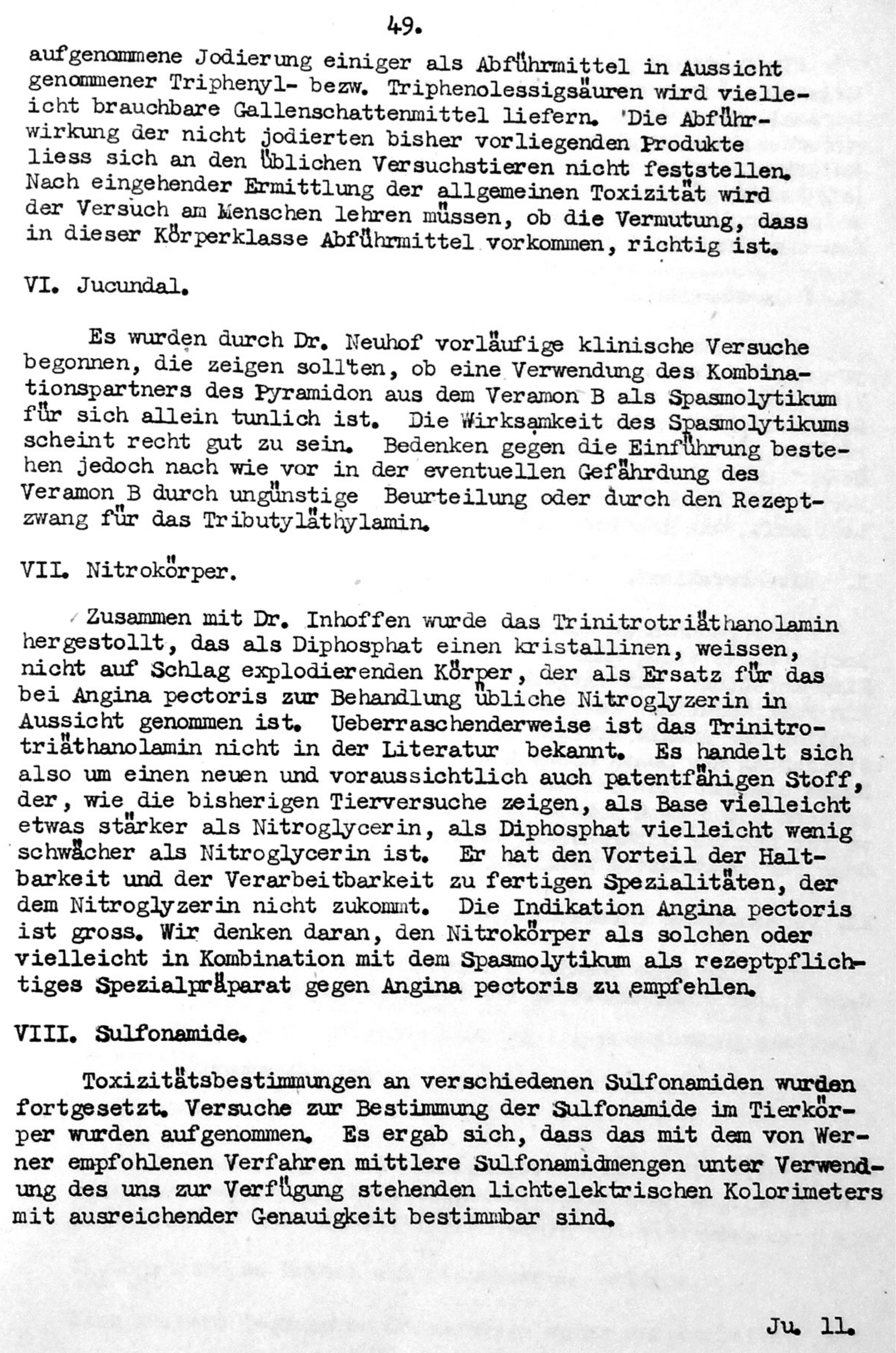
Physiologische und chemische Prüfung der Fabrikationschargen wie bisher ohne Veranlassung zu Beanstandungen.

V. Röntgenkontrastmittel.

Weitere Prüfung einiger jodhaltiger Stoffe auf ihre Eignung als Kontrastmittel für Niere oder Gallenblase. Die mit Dr. Inhoffen

Ju. 10.

Figure A.35: A report on producing freeze-dried human blood, therapeutic antibodies that target cancer cells, and other advanced medical therapeutics [BIOS 449].



49.

aufgenommene Jodierung einiger als Abführmittel in Aussicht genommener Triphenyl- bezw. Triphenolessigsäuren wird vielleicht brauchbare Gallenschattenmittel liefern. 'Die Abführwirkung der nicht jodierten bisher vorliegenden Produkte liess sich an den üblichen Versuchstieren nicht feststellen. Nach eingehender Ermittlung der allgemeinen Toxizität wird der Versuch am Menschen lehren müssen, ob die Vermutung, dass in dieser Körperklasse Abführmittel vorkommen, richtig ist.

VI. Jucundal.

Es wurden durch Dr. Neuhof vorläufige klinische Versuche begonnen, die zeigen sollten, ob eine Verwendung des Kombinationspartners des Pyramidon aus dem Veramon B als Spasmolytikum für sich allein tunlich ist. Die Wirksamkeit des Spasmolytikums scheint recht gut zu sein. Bedenken gegen die Einführung bestehen jedoch nach wie vor in der eventuellen Gefährdung des Veramon B durch ungünstige Beurteilung oder durch den Rezeptzwang für das Tributyläthylamin.

VII. Nitrokörper.

Zusammen mit Dr. Inhoffen wurde das Trinitrotriäthanolamin hergestollt, das als Diphosphat einen kristallinen, weissen, nicht auf Schlag explodierenden Körper, der als Ersatz für das bei Angina pectoris zur Behandlung übliche Nitroglyzerin in Aussicht genommen ist. Ueberraschenderweise ist das Trinitrotriäthanolamin nicht in der Literatur bekannt. Es handelt sich also um einen neuen und voraussichtlich auch patentfähigen Stoff, der, wie die bisherigen Tierversuche zeigen, als Base vielleicht etwas stärker als Nitroglycerin, als Diphosphat vielleicht wenig schwächer als Nitroglycerin ist. Er hat den Vorteil der Haltbarkeit und der Verarbeitbarkeit zu fertigen Spezialitäten, der dem Nitroglyzerin nicht zukommt. Die Indikation Angina pectoris ist gross. Wir denken daran, den Nitrokörper als solchen oder vielleicht in Kombination mit dem Spasmolytikum als rezeptpflichtiges Spezialpräparat gegen Angina pectoris zu empfehlen.

VIII. Sulfonamide.

Toxizitätsbestimmungen an verschiedenen Sulfonamiden wurden fortgesetzt. Versuche zur Bestimmung der Sulfonamide im Tierkörper wurden aufgenommen. Es ergab sich, dass das mit dem von Werner empfohlenen Verfahren mittlere Sulfonamidmengen unter Verwendung des uns zur Verfügung stehenden lichtelektrischen Kolorimeters mit ausreichender Genauigkeit bestimmbar sind.

Ju. 11.

Figure A.36: A report on producing freeze-dried human blood, therapeutic antibodies that target cancer cells, and other advanced medical therapeutics [BIOS 449].

BIOS 691. *Some Aspects of Microbiological Research in Germany.*

[pp. 1–2]

Professor Lembke, formerly director of the Bakteriologisches Institut, Preussische Versuchs- und Forschungsanstalt für Milchwirtschaft in Kiel, and now scientifically active again after a period of detention, was interviewed in Sielbeck to obtain a general picture of the work which had been carried out under his direction during the past six years. The Bakteriologisches Institut was totally destroyed by bombing during the war, but a good deal of work was carried on elsewhere, notably in Sielbeck at the temporary quarters of the Institut für Virusforschung of Kiel University. In the past few months new quarters for the Bakteriologisches Institut have been found in Kiel, and its work is gradually being reestablished there.

Professor Lembke and his associates have been active in a large number of fields, some of which have already been covered by previous reports (e.g. ultra-violet pasteurization of milk). However, two aspects of their investigations do not appear to have received detailed attention and seem worth study. These are (a) protein synthesis by yeasts and molds and (b) the production of antibiotics, notably of an alleged penicillin-like substance known as Mycoin C.

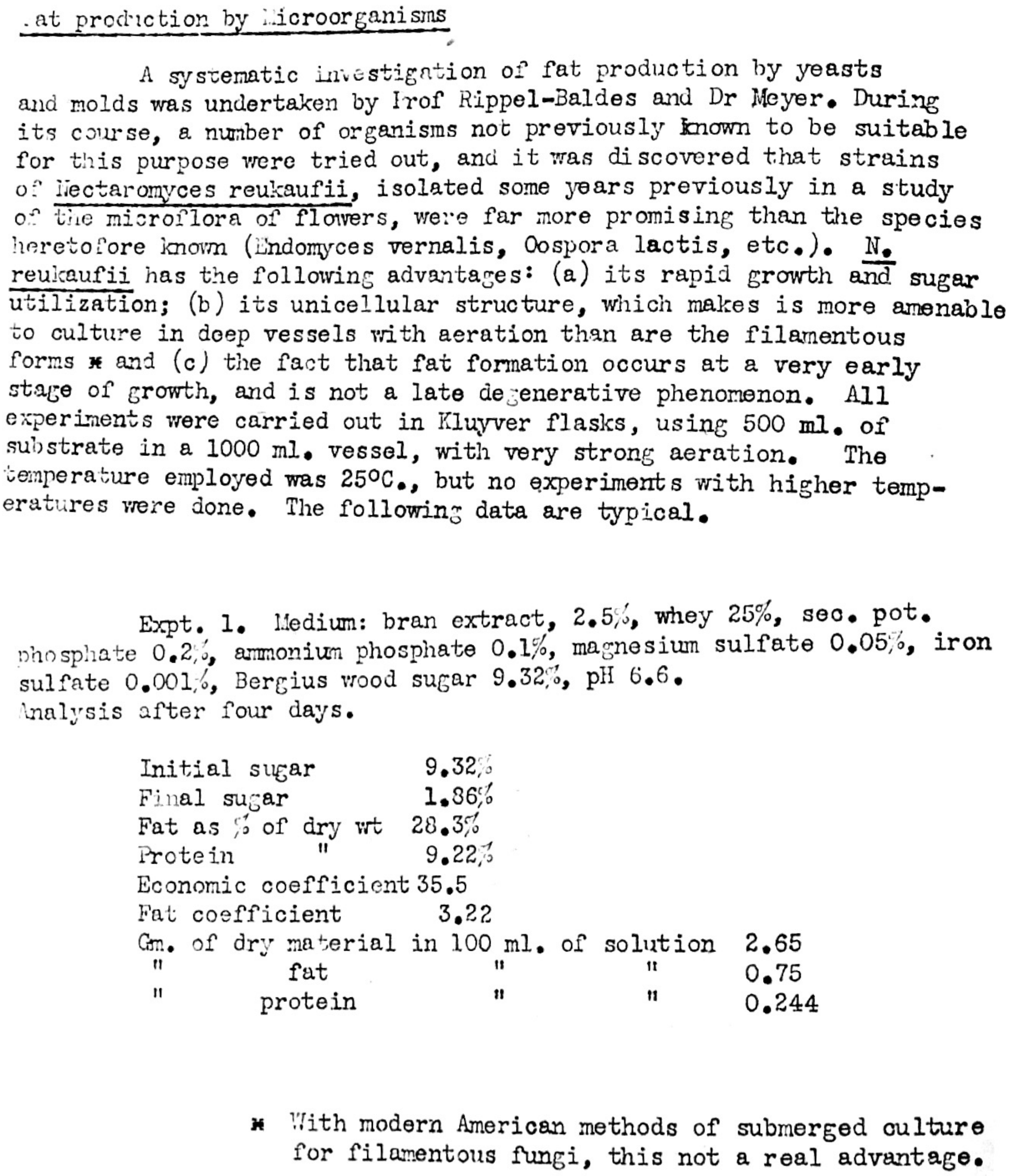
[...] The best organisms found for protein synthesis were Oospora lactis, Oospora amycelica, Saccharomyces lactis and Torulopsis sp.

[pp. 13–14]

A visit was also paid to Prof R. Harder at the Botanisches Institut. [...]

The basic concept underlying this approach to the problem of microbial fat production is a fairly obvious one. In the case of fat synthesis by non-photosynthetic microorganisms such as the yeasts, carbohydrates must be used as the raw material, and the process is highly wasteful from the overall standpoint, since a large part of the substrate is lost by respiration. Fat can undoubtedly be obtained, but only by using large amounts of carbohydrate otherwise utilizable as human or animal foodstuffs. On the other hand, if one could find good fat-producing photosynthetic microorganisms, fat could be obtained from them without any depletion of the carbohydrate supply.

Two good groups of fat-producing photosynthetic microorganisms were discovered: certain fresh-water diatoms, and strains of Chlamydomonas. [...] After various techniques of cultivation had been tried, the best proved to the use of tall glass cylinders, 5 cm in diameter and 80 cm high. They were filled almost completely with the culture medium and a slow current of air bubbled through during growth. [...] The algae grew luxuriantly and eventually underwent a “fatty degeneration”, the cells becoming packed with large fat globules. In the case of Chlamydomonas this occurred after 10–14 days’ growth. [...] With artificial illumination there is also the possibility of obtaining a crop in depth.



Fat production by Microorganisms

A systematic investigation of fat production by yeasts and molds was undertaken by Prof Rippel-Baldes and Dr Meyer. During its course, a number of organisms not previously known to be suitable for this purpose were tried out, and it was discovered that strains of Nectaromyces reukaufii, isolated some years previously in a study of the microflora of flowers, were far more promising than the species heretofore known (Endomyces vernalis, Oospora lactis, etc.). N. reukaufii has the following advantages: (a) its rapid growth and sugar utilization; (b) its unicellular structure, which makes is more amenable to culture in deep vessels with aeration than are the filamentous forms * and (c) the fact that fat formation occurs at a very early stage of growth, and is not a late degenerative phenomenon. All experiments were carried out in Kluyver flasks, using 500 ml. of substrate in a 1000 ml. vessel, with very strong aeration. The temperature employed was 25°C., but no experiments with higher temperatures were done. The following data are typical.

Expt. 1. Medium: bran extract, 2.5%, whey 25%, sec. pot. phosphate 0.2%, ammonium phosphate 0.1%, magnesium sulfate 0.05%, iron sulfate 0.001%, Bergius wood sugar 9.32%, pH 6.6.
Analysis after four days.

Initial sugar	9.32%
Final sugar	1.86%
Fat as % of dry wt	28.3%
Protein "	9.22%
Economic coefficient	35.5
Fat coefficient	3.22
Gm. of dry material in 100 ml. of solution	2.65
" fat " "	0.75
" protein " "	0.244

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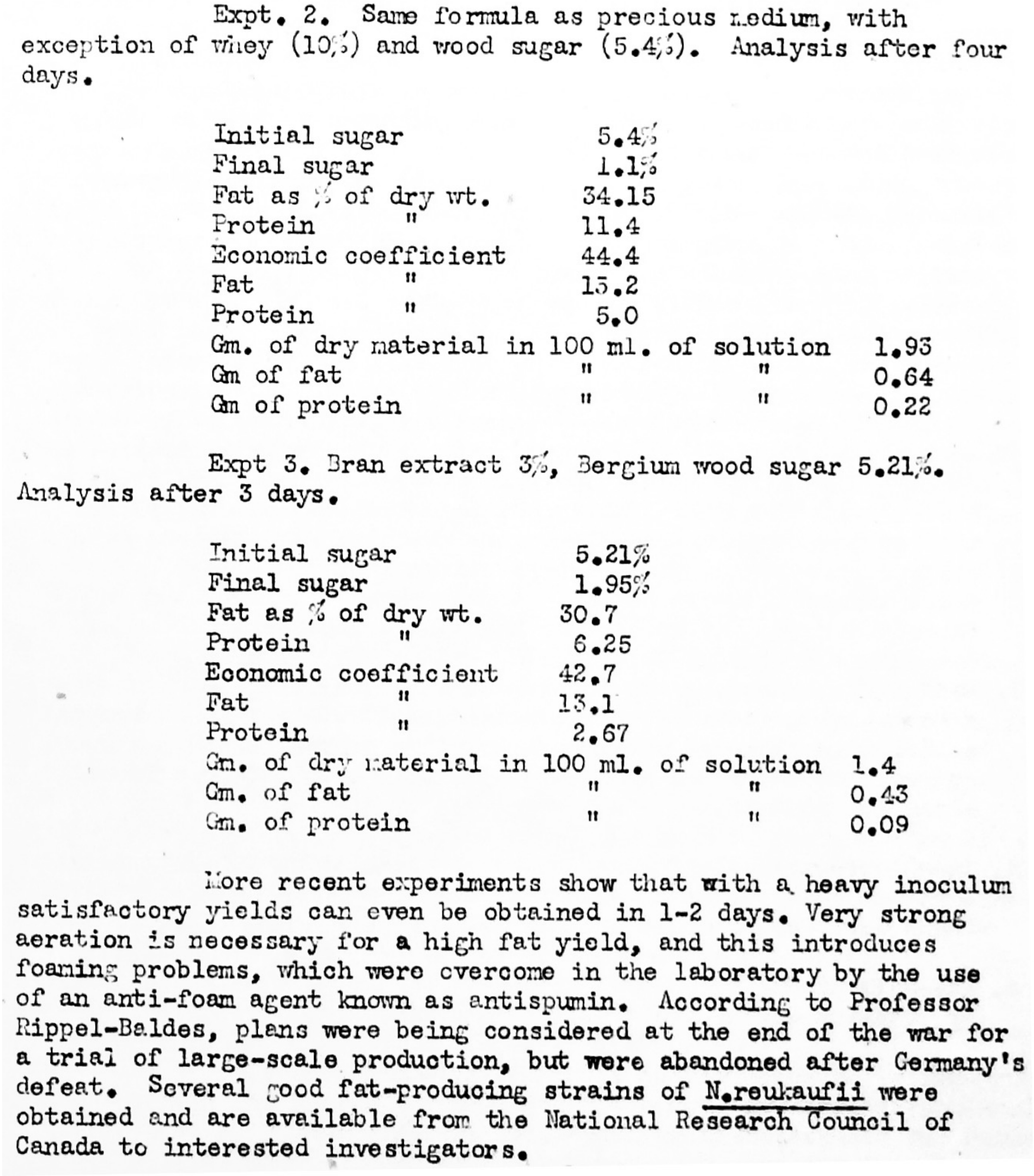
* With modern American methods of submerged culture for filamentous fungi, this not a real advantage.

Figure A.37: Fat production and extraction from yeast cultured in bioreactors [BIOS 691].



Expt. 2. Same formula as precious medium, with exception of whey (10%) and wood sugar (5.4%). Analysis after four days.

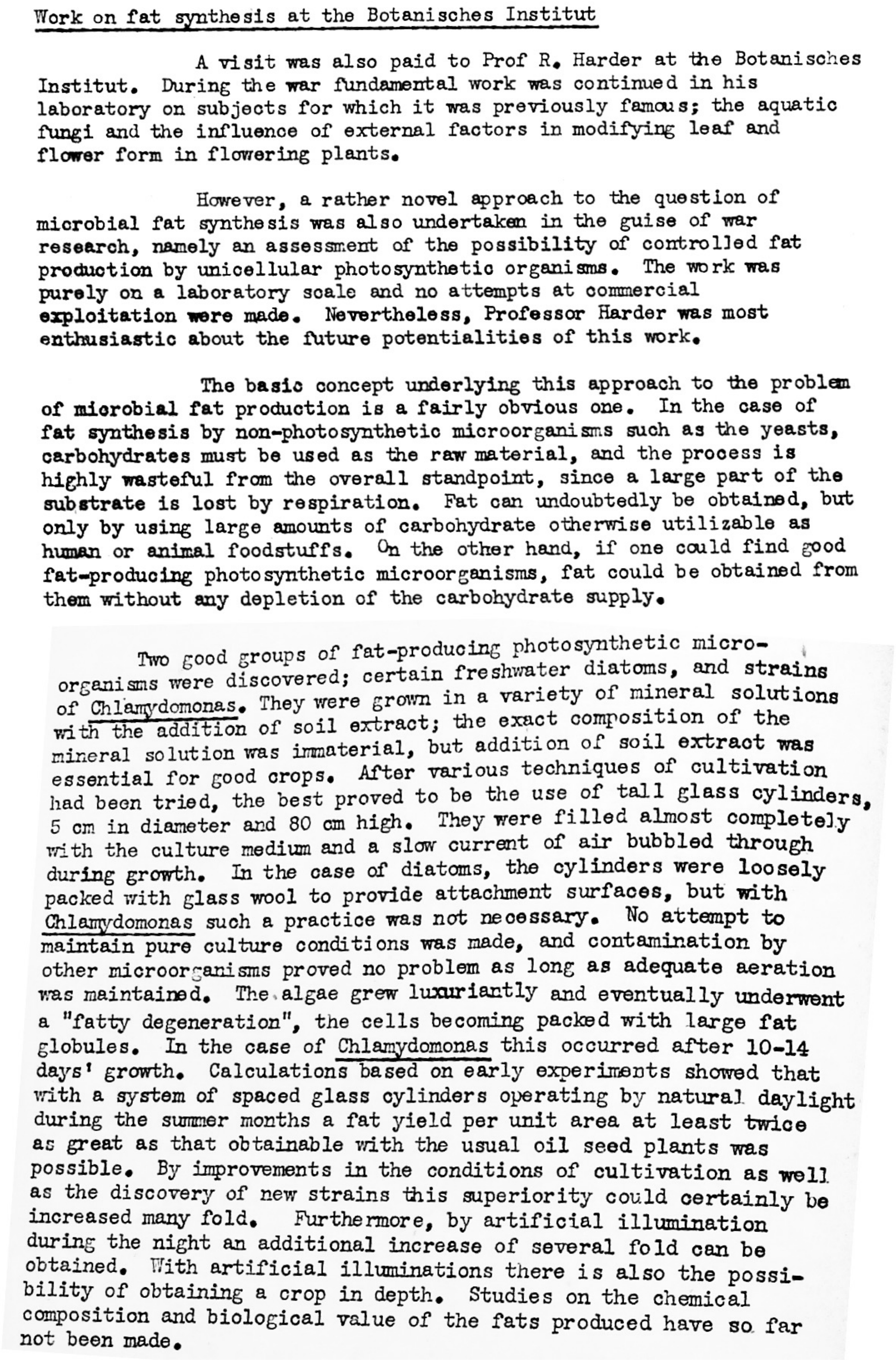
Initial sugar		5.4%	
Final sugar		1.1%	
Fat as % of dry wt.		34.15	
Protein	"	11.4	
Economic coefficient		44.4	
Fat	"	15.2	
Protein	"	5.0	
Gm. of dry material in 100 ml. of solution			1.93
Gm of fat	"	"	0.64
Gm of protein	"	"	0.22

Expt 3. Bran extract 3%, Bergium wood sugar 5.21%. Analysis after 3 days.

Initial sugar		5.21%	
Final sugar		1.95%	
Fat as % of dry wt.		30.7	
Protein	"	6.25	
Economic coefficient		42.7	
Fat	"	13.1	
Protein	"	2.67	
Gm. of dry material in 100 ml. of solution			1.4
Gm. of fat	"	"	0.43
Gm. of protein	"	"	0.09

More recent experiments show that with a heavy inoculum satisfactory yields can even be obtained in 1-2 days. Very strong aeration is necessary for a high fat yield, and this introduces foaming problems, which were overcome in the laboratory by the use of an anti-foam agent known as antispumin. According to Professor Rippel-Baldes, plans were being considered at the end of the war for a trial of large-scale production, but were abandoned after Germany's defeat. Several good fat-producing strains of N.reukaufii were obtained and are available from the National Research Council of Canada to interested investigators.

Figure A.38: Fat production and extraction from yeast cultured in bioreactors [BIOS 691].



Work on fat synthesis at the Botanisches Institut

A visit was also paid to Prof R. Harder at the Botanisches Institut. During the war fundamental work was continued in his laboratory on subjects for which it was previously famous; the aquatic fungi and the influence of external factors in modifying leaf and flower form in flowering plants.

However, a rather novel approach to the question of microbial fat synthesis was also undertaken in the guise of war research, namely an assessment of the possibility of controlled fat production by unicellular photosynthetic organisms. The work was purely on a laboratory scale and no attempts at commercial exploitation were made. Nevertheless, Professor Harder was most enthusiastic about the future potentialities of this work.

The basic concept underlying this approach to the problem of microbial fat production is a fairly obvious one. In the case of fat synthesis by non-photosynthetic microorganisms such as the yeasts, carbohydrates must be used as the raw material, and the process is highly wasteful from the overall standpoint, since a large part of the substrate is lost by respiration. Fat can undoubtedly be obtained, but only by using large amounts of carbohydrate otherwise utilizable as human or animal foodstuffs. On the other hand, if one could find good fat-producing photosynthetic microorganisms, fat could be obtained from them without any depletion of the carbohydrate supply.

Two good groups of fat-producing photosynthetic microorganisms were discovered; certain freshwater diatoms, and strains of Chlamydomonas. They were grown in a variety of mineral solutions with the addition of soil extract; the exact composition of the mineral solution was immaterial, but addition of soil extract was essential for good crops. After various techniques of cultivation had been tried, the best proved to be the use of tall glass cylinders, 5 cm in diameter and 80 cm high. They were filled almost completely with the culture medium and a slow current of air bubbled through during growth. In the case of diatoms, the cylinders were loosely packed with glass wool to provide attachment surfaces, but with Chlamydomonas such a practice was not necessary. No attempt to maintain pure culture conditions was made, and contamination by other microorganisms proved no problem as long as adequate aeration was maintained. The algae grew luxuriantly and eventually underwent a "fatty degeneration", the cells becoming packed with large fat globules. In the case of Chlamydomonas this occurred after 10-14 days' growth. Calculations based on early experiments showed that with a system of spaced glass cylinders operating by natural daylight during the summer months a fat yield per unit area at least twice as great as that obtainable with the usual oil seed plants was possible. By improvements in the conditions of cultivation as well as the discovery of new strains this superiority could certainly be increased many fold. Furthermore, by artificial illumination during the night an additional increase of several fold can be obtained. With artificial illuminations there is also the possibility of obtaining a crop in depth. Studies on the chemical composition and biological value of the fats produced have so far not been made.

Figure A.39: Fat production and extraction from algae cultured in bioreactors [BIOS 691].

BIOS 710. ***Manufacture of Biolase (Starch-Hydrolysing Enzyme) at Kalle & Co. (I. G. Farben A. G.) Wiesbaden, Biebrich.***

The manufacture of Biolase, a starch-hydrolysing enzyme, was carried out by Kalle & Co., Wiesbaden. A request has been made for details of their manufacturing process, and this report describes the information obtained as to the method used by Kalle & Co. as gained from an interrogation of a member of the staff, Dr. Altgelt. A brief description of the plant used is also given, but as this was not in operation when inspected in October 1945, it was not possible to check the statements made. [...]

The capacity of the plant was stated to be 30 tonnes per month, concentrated material, equivalent to 1350 tonnes per month of standard material.

In the building however, there were new plant items awaiting installation and the capacity of these was stated to be four times greater than that of the existing plant. Dr. Altgelt stated however, that the intention was to demolish the existing plant as soon as the new plant was in commission.

BIOS 766. ***The Manufacture of Pharmaceuticals and Fine Chemicals in the U.S. and French Zones of Germany.***

[Please see p. 2366 for the table of contents of this long report, which provides a good overview of the range of biological and chemical pharmaceuticals that were being produced in Germany by the end of the war.]

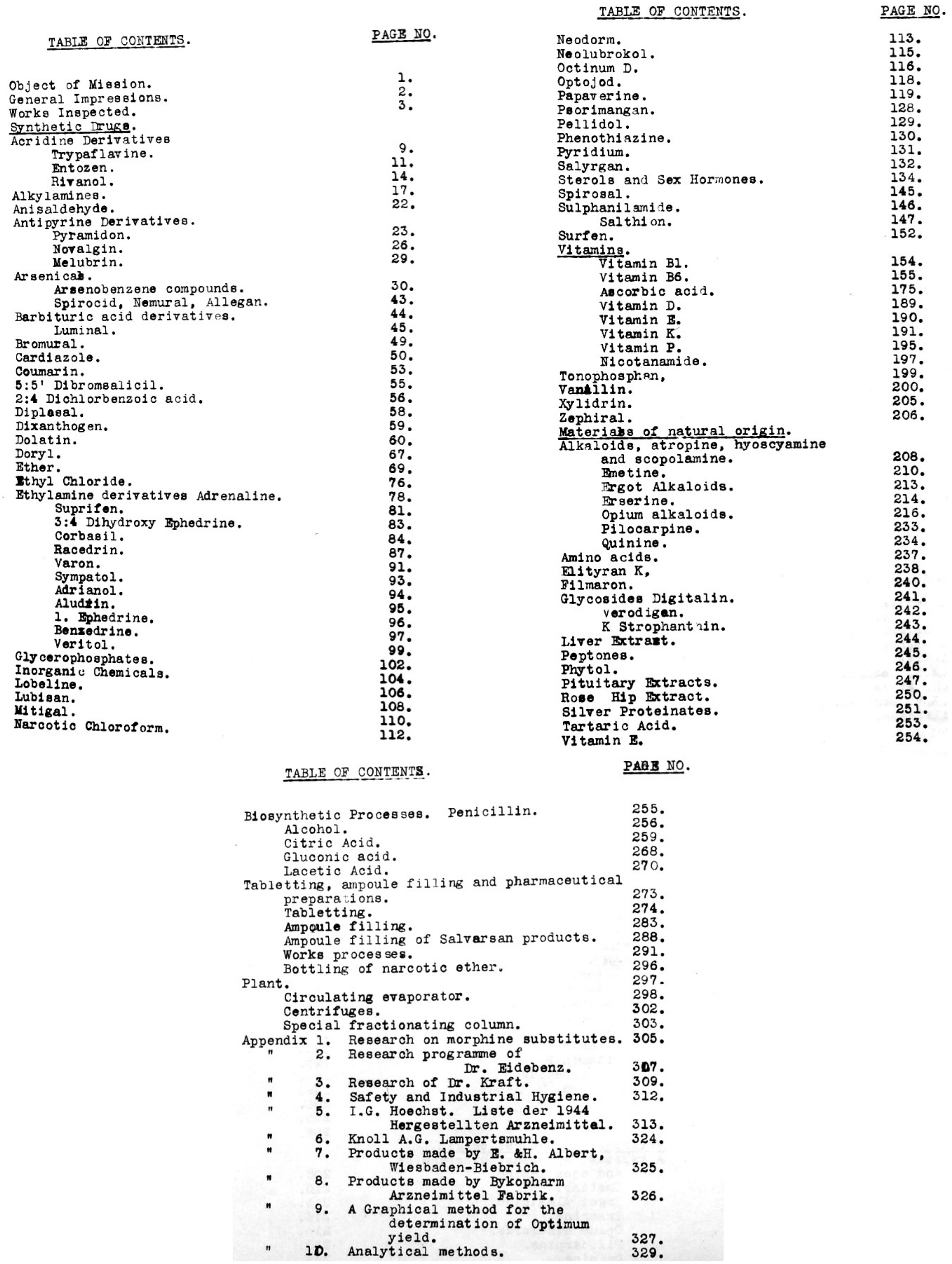


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Figure A.40: Table of contents listing many biopharmaceuticals being produced in Germany by the end of the war [BIOS 766].

BIOS 770. *Further Developments in Dairying in Germany.*

[In 1940, German-speaking scientists developed and successfully implemented the use of intense ultraviolet light to sterilize liquids and other materials [BIOS 770; FIAT 50; FIAT 107; FIAT 257].

Some of the most important scientists in the project were Andreas Lembke (German, 1911–2002), Hellmuth Bayha (German?, 19??–19??), Karl Krammer (German?, 19??–19??), and Eugen Sauter (German?, 19??–19??).

See figures on pp. 2368–2373.

This approach is now widely used in modern biology laboratories to sterilize water, the interiors of biosafety cabinets, safety goggles, and other materials.]

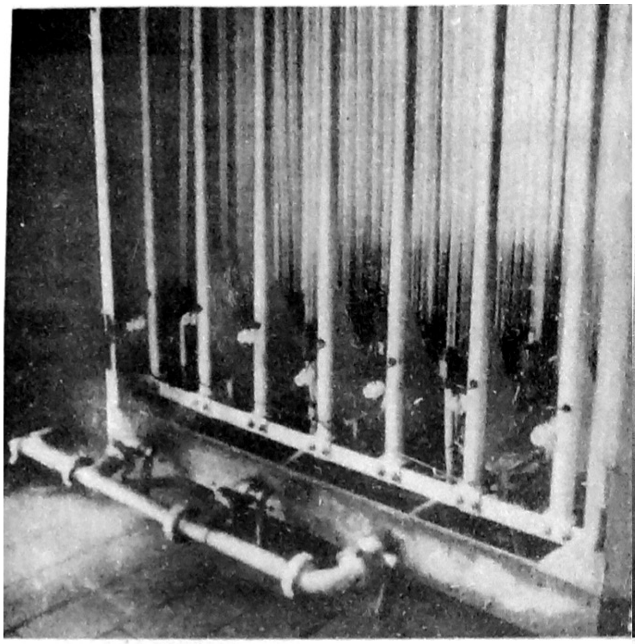


PLATE 1.
ULTRA VIOLET RAY PLANT
INLET SIDE

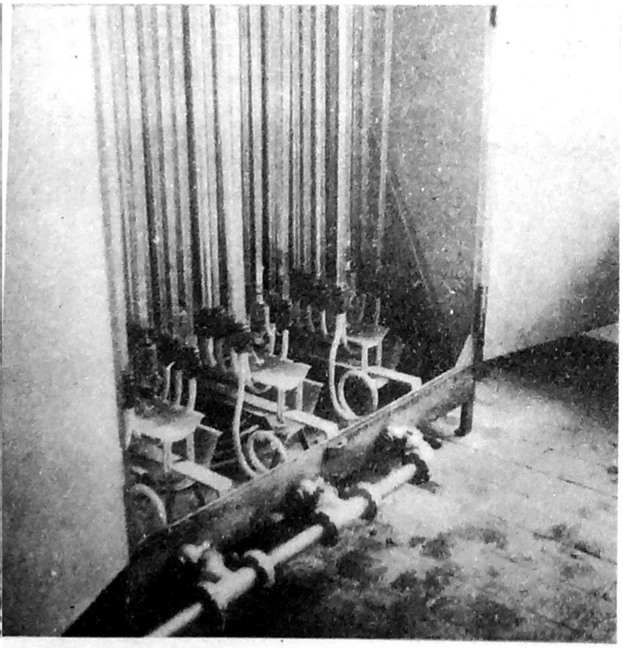


PLATE 2.
ULTRA VIOLET RAY PLANT
OUTLET SIDE

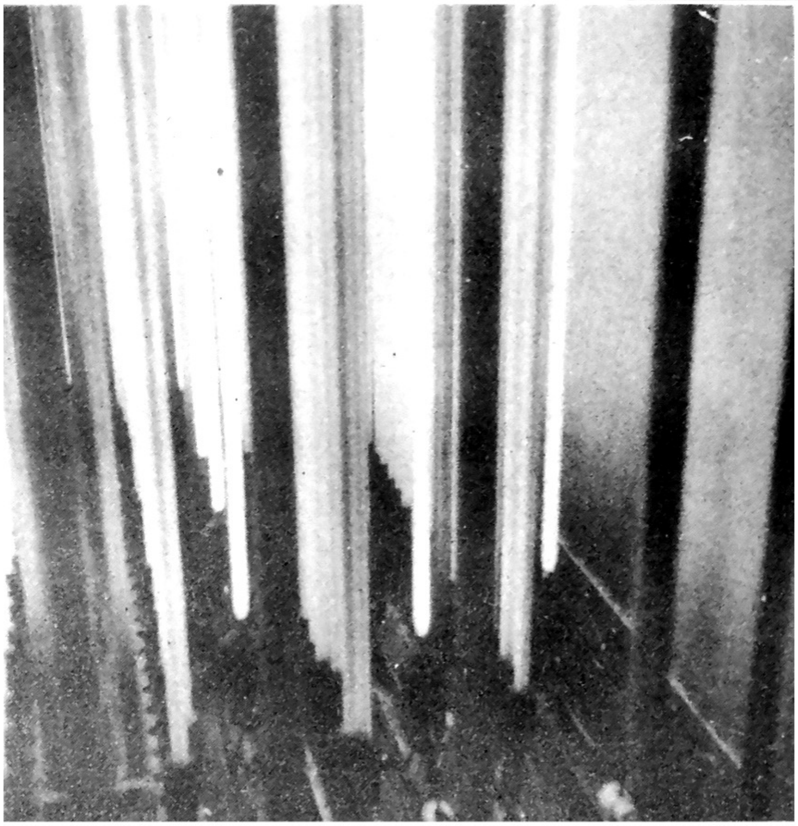


PLATE 3.
ULTRA VIOLET RAY PLANT
(IN OPERATION)

Sterilization of milk or other materials using ultraviolet light (1940)

Andreas Lembke
(1911–2002)

Hellmuth Bayha
(19??–19??)

Karl Krammer
(19??–19??)

Eugen Sauter
(19??–19??)

Figure A.41: Andreas Lembke, Hellmuth Bayha, Karl Krammer, Eugen Sauter, and other scientists developed and successfully implemented methods of using intense ultraviolet light to sterilize liquids and other materials [BIOS 770].

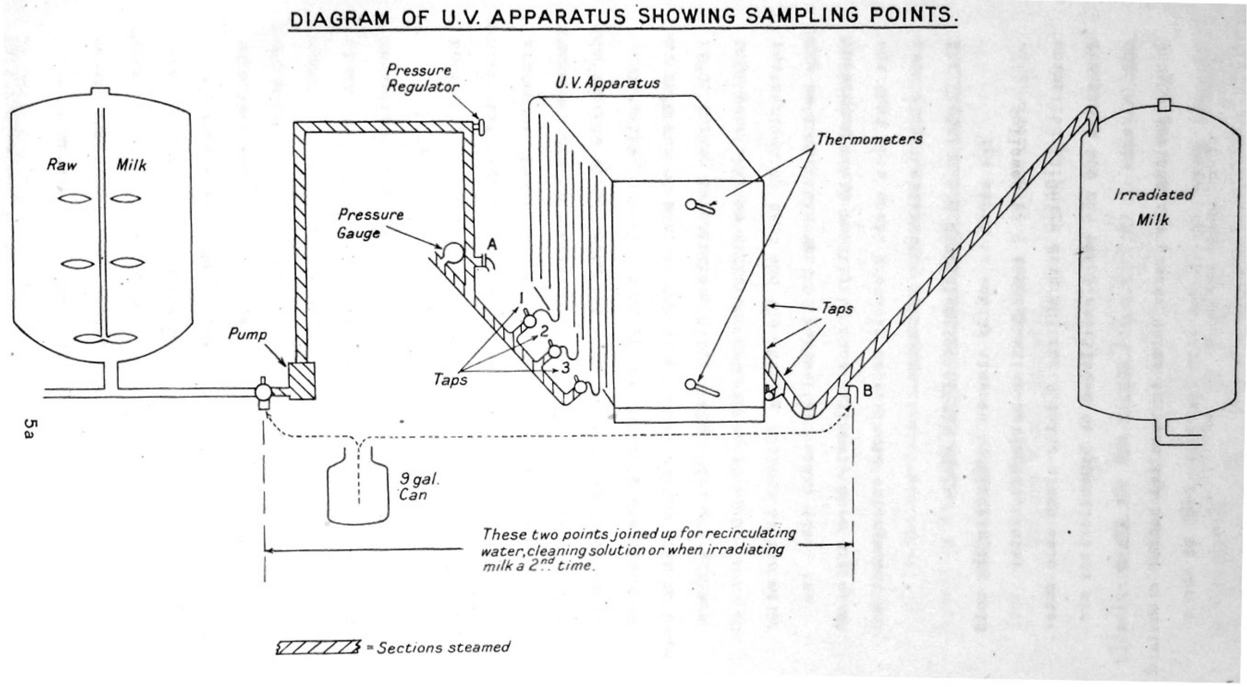


DIAGRAM OF U.V. APPARATUS SHOWING SAMPLING POINTS.

Raw Milk
Pressure Regulator
U.V. Apparatus
Thermometers
Irradiated Milk
Pressure Gauge
A
1
2
3
Taps
Taps
Pump
B
5a
9 gal. Can
These two points joined up for recirculating water, cleaning solution or when irradiating milk a 2nd time.
= Sections steamed

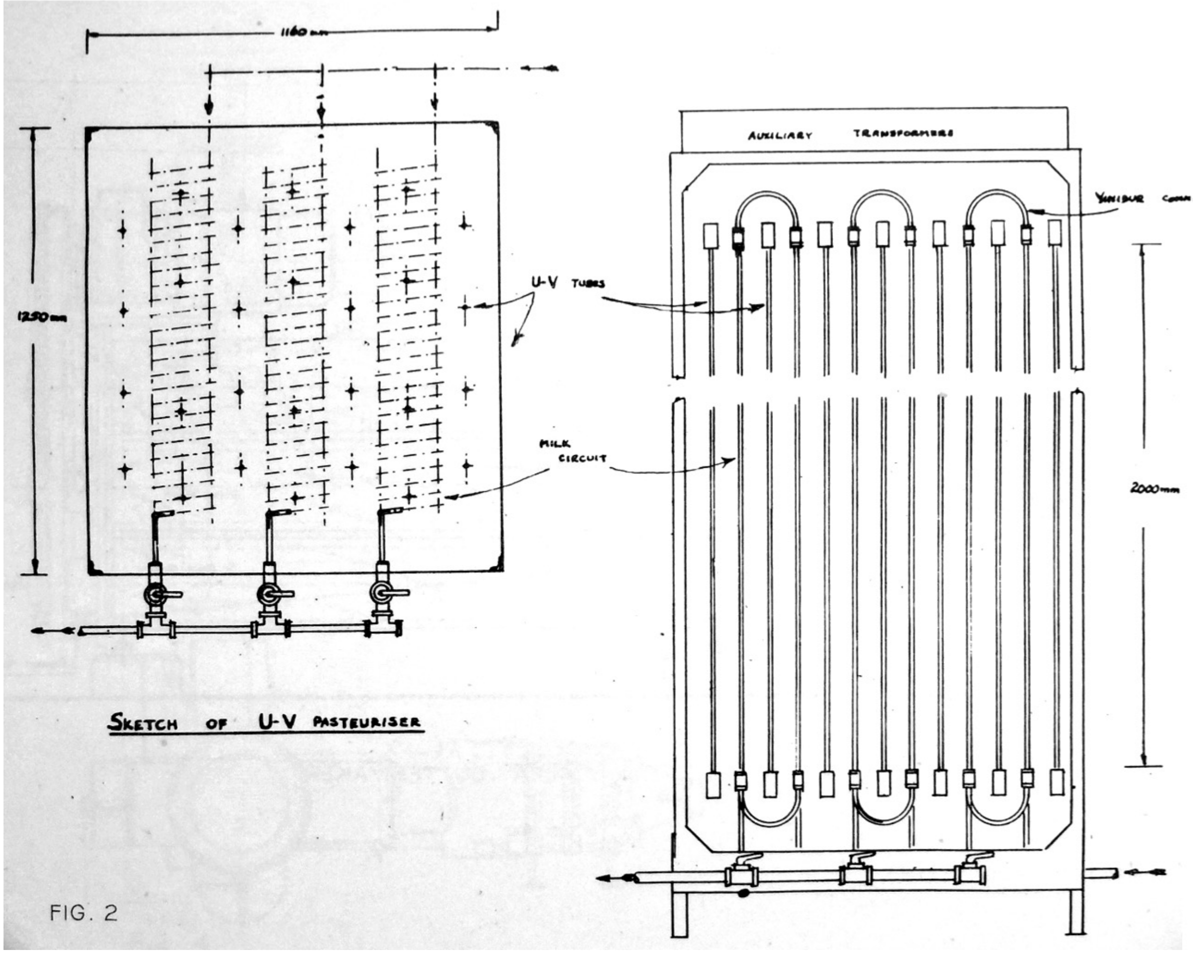
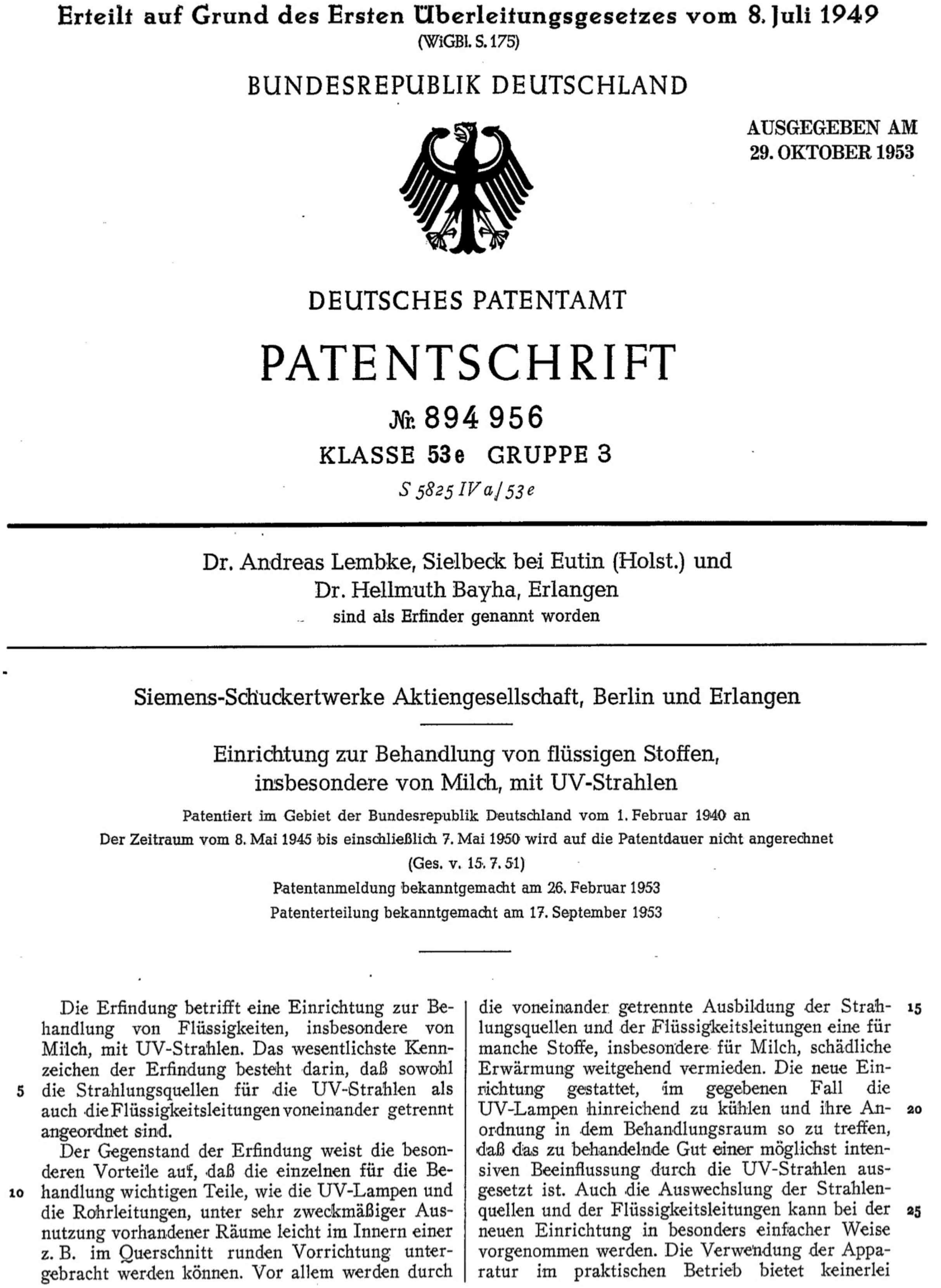

1160 mm
1250 mm
U-V TUBES
MILK CIRCUIT
SKETCH OF U-V PASTEURISER
AUXILIARY TRANSFORMERS
UNIBUR CONNECTIONS
2000 mm

FIG. 2

Figure A.42: Andreas Lembke, Hellmuth Bayha, Karl Krammer, Eugen Sauter, and other scientists developed and successfully implemented methods of using intense ultraviolet light to sterilize liquids and other materials [BIOS 770].



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
29. OKTOBER 1953

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 894 956

KLASSE 53e GRUPPE 3

S 5825 IVa/53e

Dr. Andreas Lembke, Sielbeck bei Eutin (Holst.) und
Dr. Hellmuth Bayha, Erlangen
sind als Erfinder genannt worden

Siemens-Schuckertwerke Aktiengesellschaft, Berlin und Erlangen

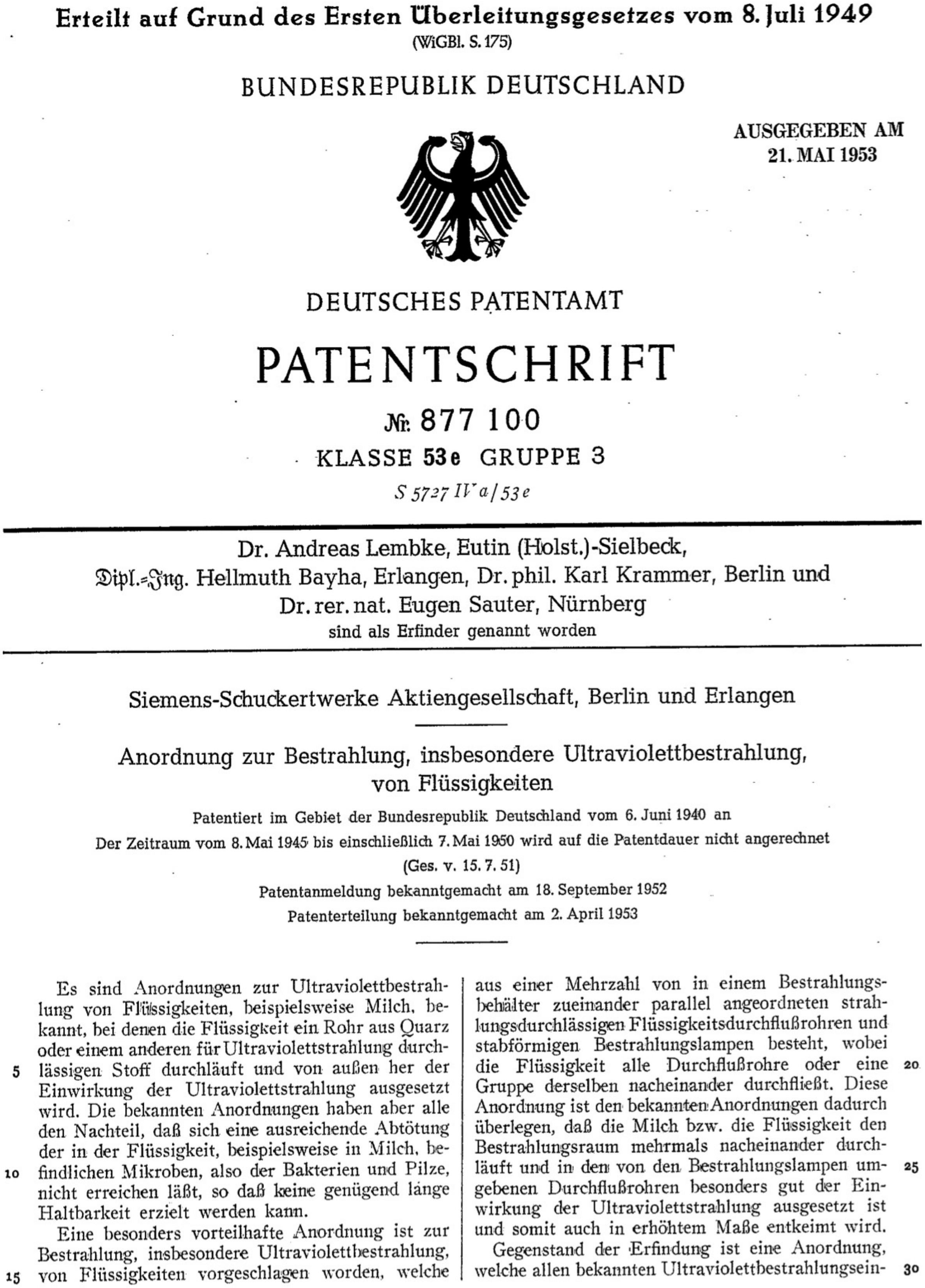
Einrichtung zur Behandlung von flüssigen Stoffen, insbesondere von Milch, mit UV-Strahlen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 1. Februar 1940 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
(Ges. v. 15. 7. 51)
Patentanmeldung bekanntgemacht am 26. Februar 1953
Patenterteilung bekanntgemacht am 17. September 1953

Die Erfindung betrifft eine Einrichtung zur Behandlung von Flüssigkeiten, insbesondere von Milch, mit UV-Strahlen. Das wesentlichste Kennzeichen der Erfindung besteht darin, daß sowohl die Strahlungsquellen für die UV-Strahlen als auch die Flüssigkeitsleitungen voneinander getrennt angeordnet sind.

Der Gegenstand der Erfindung weist die besonderen Vorteile auf, daß die einzelnen für die Behandlung wichtigen Teile, wie die UV-Lampen und die Rohrleitungen, unter sehr zweckmäßiger Ausnutzung vorhandener Räume leicht im Innern einer z. B. im Querschnitt runden Vorrichtung untergebracht werden können. Vor allem werden durch die voneinander getrennte Ausbildung der Strahlungsquellen und der Flüssigkeitsleitungen eine für manche Stoffe, insbesondere für Milch, schädliche Erwärmung weitgehend vermieden. Die neue Einrichtung gestattet, im gegebenen Fall die UV-Lampen hinreichend zu kühlen und ihre Anordnung in dem Behandlungsraum so zu treffen, daß das zu behandelnde Gut einer möglichst intensiven Beeinflussung durch die UV-Strahlen ausgesetzt ist. Auch die Auswechslung der Strahlenquellen und der Flüssigkeitsleitungen kann bei der neuen Einrichtung in besonders einfacher Weise vorgenommen werden. Die Verwendung der Apparatur im praktischen Betrieb bietet keinerlei

Figure A.43: Andreas Lembke, Hellmuth Bayha, Karl Krammer, Eugen Sauter, and other scientists developed and successfully implemented methods of using intense ultraviolet light to sterilize liquids and other materials [German patent DE 894,956, filed in 1940].



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
21. MAI 1953

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 877 100

KLASSE **53e** GRUPPE 3

S 5727 IVa/53e

Dr. Andreas Lembke, Eutin (Holst.)-Sielbeck,
Dipl.-Ing. Hellmuth Bayha, Erlangen, Dr. phil. Karl Krammer, Berlin und
Dr. rer. nat. Eugen Sauter, Nürnberg
sind als Erfinder genannt worden

Siemens-Schuckertwerke Aktiengesellschaft, Berlin und Erlangen

Anordnung zur Bestrahlung, insbesondere Ultraviolettbestrahlung, von Flüssigkeiten

Patentiert im Gebiet der Bundesrepublik Deutschland vom 6. Juni 1940 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
(Ges. v. 15. 7. 51)
Patentanmeldung bekanntgemacht am 18. September 1952
Patenterteilung bekanntgemacht am 2. April 1953

Es sind Anordnungen zur Ultraviolettbestrahlung von Flüssigkeiten, beispielsweise Milch, bekannt, bei denen die Flüssigkeit ein Rohr aus Quarz oder einem anderen für Ultraviolettstrahlung durchlässigen Stoff durchläuft und von außen her der Einwirkung der Ultraviolettstrahlung ausgesetzt wird. Die bekannten Anordnungen haben aber alle den Nachteil, daß sich eine ausreichende Abtötung der in der Flüssigkeit, beispielsweise in Milch, befindlichen Mikroben, also der Bakterien und Pilze, nicht erreichen läßt, so daß keine genügend lange Haltbarkeit erzielt werden kann.

Eine besonders vorteilhafte Anordnung ist zur Bestrahlung, insbesondere Ultraviolettbestrahlung, von Flüssigkeiten vorgeschlagen worden, welche aus einer Mehrzahl von in einem Bestrahlungsbehälter zueinander parallel angeordneten strahlungsdurchlässigen Flüssigkeitsdurchflußrohren und stabförmigen Bestrahlungslampen besteht, wobei die Flüssigkeit alle Durchflußrohre oder eine Gruppe derselben nacheinander durchfließt. Diese Anordnung ist den bekannten Anordnungen dadurch überlegen, daß die Milch bzw. die Flüssigkeit den Bestrahlungsraum mehrmals nacheinander durchläuft und in den von den Bestrahlungslampen umgebenen Durchflußrohren besonders gut der Einwirkung der Ultraviolettstrahlung ausgesetzt ist und somit auch in erhöhtem Maße entkeimt wird.

Gegenstand der Erfindung ist eine Anordnung, welche allen bekannten Ultraviolettbestrahlungsein-

Figure A.44: Andreas Lembke, Hellmuth Bayha, Karl Krammer, Eugen Sauter, and other scientists developed and successfully implemented methods of using intense ultraviolet light to sterilize liquids and other materials [German patent DE 877,100, filed in 1940].

Zu der Patentschrift 877 100
Kl. 53e Gr. 3

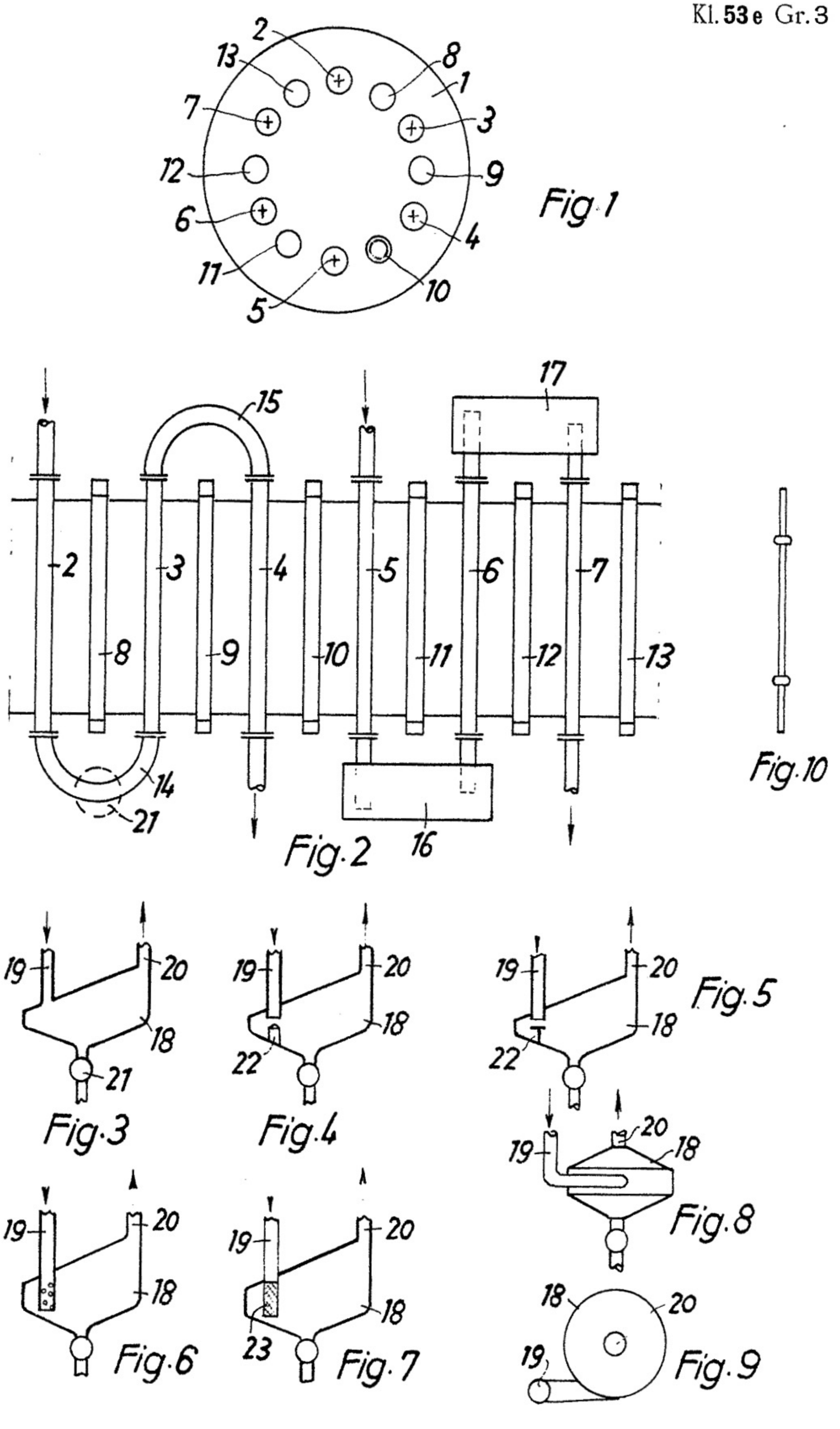


Fig. 1
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Fig. 2
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Fig. 3
Fig. 4
Fig. 5
Fig. 6
Fig. 7
Fig. 8
Fig. 9
Fig. 10
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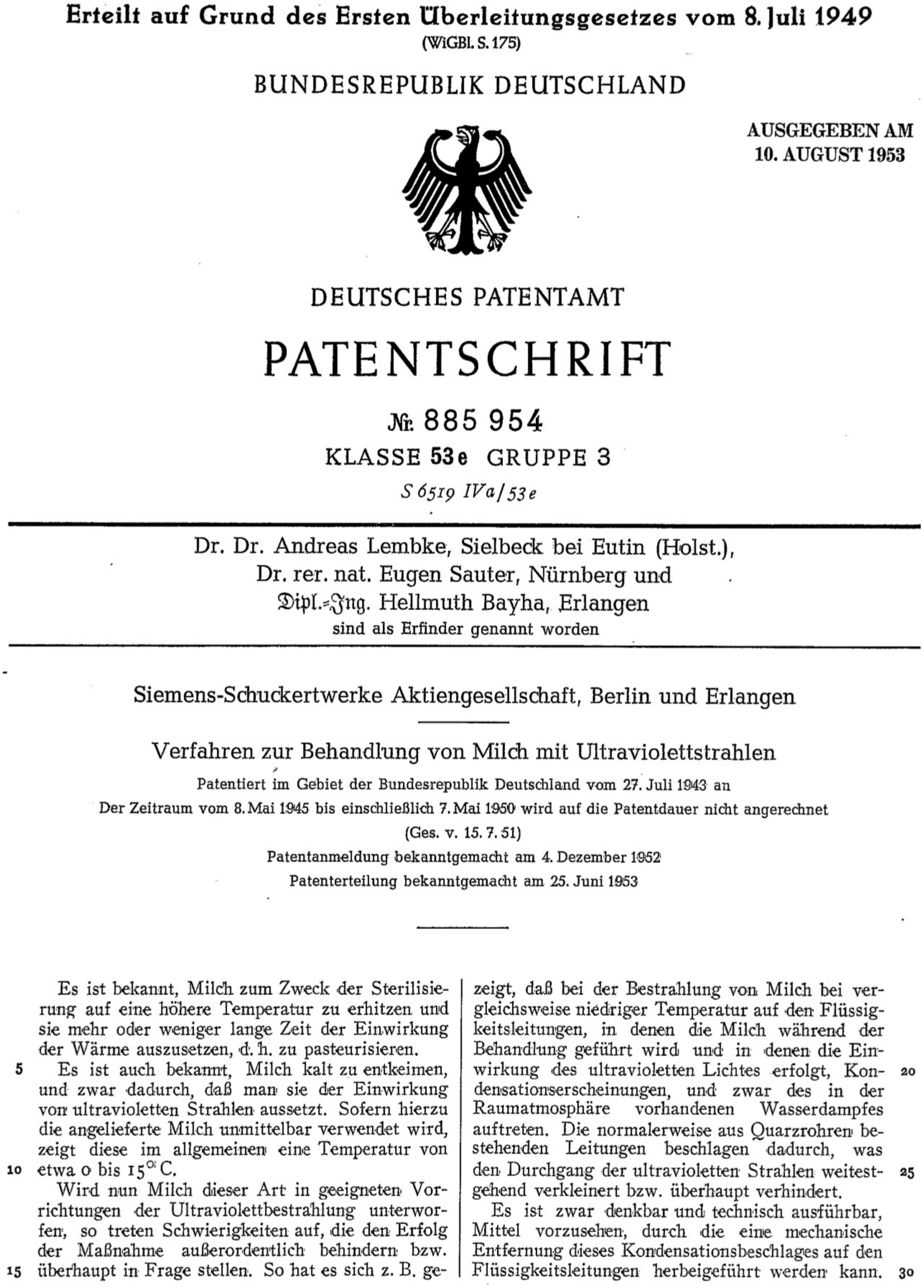
22
23

Figure A.45: Andreas Lembke, Hellmuth Bayha, Karl Krammer, Eugen Sauter, and other scientists developed and successfully implemented methods of using intense ultraviolet light to sterilize liquids and other materials [German patent DE 877,100, filed in 1940].



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
10. AUGUST 1953

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 885 954

KLASSE **53e** GRUPPE 3

S 6519 IVa/53e

Dr. Dr. Andreas Lembke, Sielbeck bei Eutin (Holst.),
Dr. rer. nat. Eugen Sauter, Nürnberg und
Dipl.-Ing. Hellmuth Bayha, Erlangen
sind als Erfinder genannt worden

Siemens-Schuckertwerke Aktiengesellschaft, Berlin und Erlangen

Verfahren zur Behandlung von Milch mit Ultraviolettstrahlen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 27. Juli 1943 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
(Ges. v. 15. 7. 51)
Patentanmeldung bekanntgemacht am 4. Dezember 1952
Patenterteilung bekanntgemacht am 25. Juni 1953

Es ist bekannt, Milch zum Zweck der Sterilisierung auf eine höhere Temperatur zu erhitzen und sie mehr oder weniger lange Zeit der Einwirkung der Wärme auszusetzen, d. h. zu pasteurisieren.

Es ist auch bekannt, Milch kalt zu entkeimen, und zwar dadurch, daß man sie der Einwirkung von ultravioletten Strahlen aussetzt. Sofern hierzu die angelieferte Milch unmittelbar verwendet wird, zeigt diese im allgemeinen eine Temperatur von etwa 0 bis 15° C.

Wird nun Milch dieser Art in geeigneten Vorrichtungen der Ultraviolettbestrahlung unterworfen, so treten Schwierigkeiten auf, die den Erfolg der Maßnahme außerordentlich behindern bzw. überhaupt in Frage stellen. So hat es sich z. B. gezeigt, daß bei der Bestrahlung von Milch bei vergleichsweise niedriger Temperatur auf den Flüssigkeitsleitungen, in denen die Milch während der Behandlung geführt wird und in denen die Einwirkung des ultravioletten Lichtes erfolgt, Kondensationserscheinungen, und zwar des in der Raumatmosphäre vorhandenen Wasserdampfes auftreten. Die normalerweise aus Quarzrohren bestehenden Leitungen beschlagen dadurch, was den Durchgang der ultravioletten Strahlen weitestgehend verkleinert bzw. überhaupt verhindert.

Es ist zwar denkbar und technisch ausführbar, Mittel vorzusehen, durch die eine mechanische Entfernung dieses Kondensationsbeschlages auf den Flüssigkeitsleitungen herbeigeführt werden kann.

Figure A.46: Andreas Lembke, Hellmuth Bayha, Karl Krammer, Eugen Sauter, and other scientists developed and successfully implemented methods of using intense ultraviolet light to sterilize liquids and other materials [German patent DE 885,954, filed in 1943].

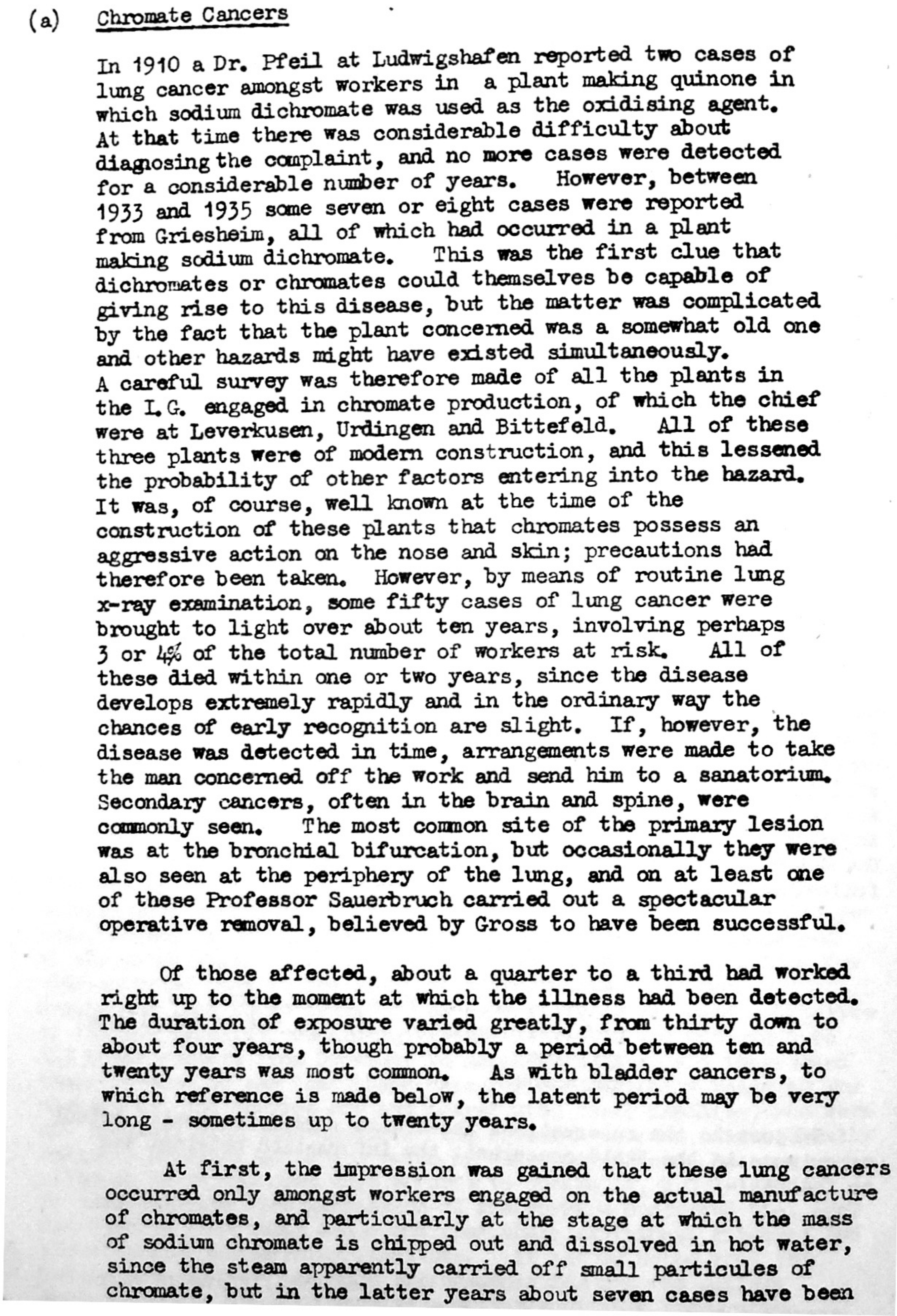
BIOS 784. *Interrogation of Dr. Gross, Prof. Flury and Dr. Wirth on Industrial Hygiene and Toxicology.*

[This report includes examples of studies of cancers due to workplace chemical exposure; see pp. 2375–2377.]

BIOS 1229. *Wool—Its Chemistry & Modification by Chemical Treatment in Germany.* pp. 6–7.

Schöberl has been interested in the chemistry and enzymatic activity of papain as well as its reaction on wool. In connection with the latter effect, the activation of papain by bodies containing mercapto and disulphide groups appears to be of interest. Natural, i.e., unpurified, papain contains its own activators in the form of mercapto bodies. Removal of these, results in a purified papain of increased sulphur content as sulphate and organically bound as cystine and to a less extent as methionine. Studying the activation of the purified papain on the liquefaction of gelatin, Schöberl observed that a mercaptan such as thioglycollic acid was a strong activator of papain and so also was the disulphide dithioglycollic acid. [...]

This work is described in a paper by Schöberl and Fisch ‘Über Schwefelgehalt und Aktivierbarkeit von Papain’—Biochemische Zeitschrift, 1939, 302, 310.



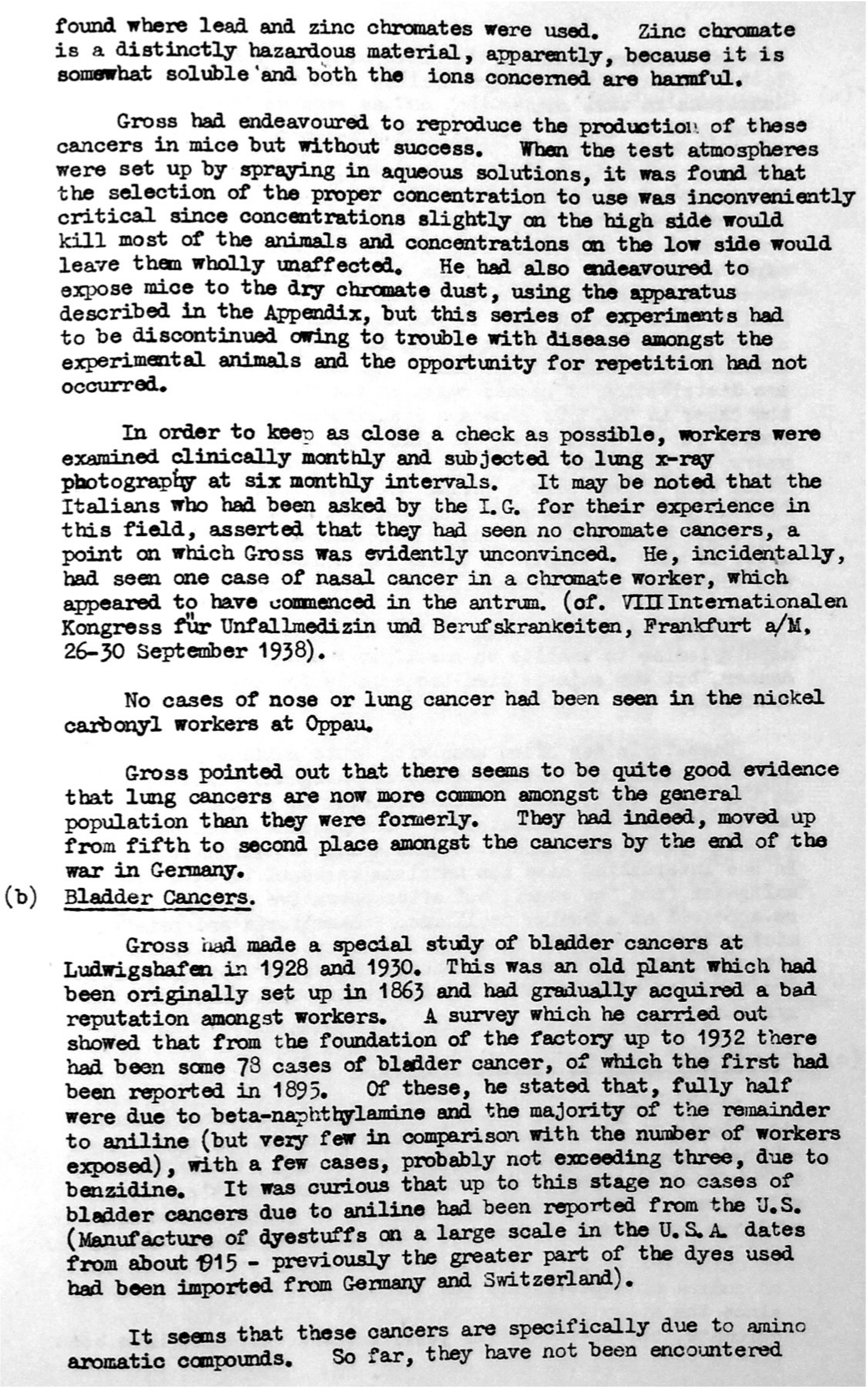
(a) Chromate Cancers

In 1910 a Dr. Pfeil at Ludwigshafen reported two cases of lung cancer amongst workers in a plant making quinone in which sodium dichromate was used as the oxidising agent. At that time there was considerable difficulty about diagnosing the complaint, and no more cases were detected for a considerable number of years. However, between 1933 and 1935 some seven or eight cases were reported from Griesheim, all of which had occurred in a plant making sodium dichromate. This was the first clue that dichromates or chromates could themselves be capable of giving rise to this disease, but the matter was complicated by the fact that the plant concerned was a somewhat old one and other hazards might have existed simultaneously. A careful survey was therefore made of all the plants in the I.G. engaged in chromate production, of which the chief were at Leverkusen, Urdingen and Bittefeld. All of these three plants were of modern construction, and this lessened the probability of other factors entering into the hazard. It was, of course, well known at the time of the construction of these plants that chromates possess an aggressive action on the nose and skin; precautions had therefore been taken. However, by means of routine lung x-ray examination, some fifty cases of lung cancer were brought to light over about ten years, involving perhaps 3 or 4% of the total number of workers at risk. All of these died within one or two years, since the disease develops extremely rapidly and in the ordinary way the chances of early recognition are slight. If, however, the disease was detected in time, arrangements were made to take the man concerned off the work and send him to a sanatorium. Secondary cancers, often in the brain and spine, were commonly seen. The most common site of the primary lesion was at the bronchial bifurcation, but occasionally they were also seen at the periphery of the lung, and on at least one of these Professor Sauerbruch carried out a spectacular operative removal, believed by Gross to have been successful.

Of those affected, about a quarter to a third had worked right up to the moment at which the illness had been detected. The duration of exposure varied greatly, from thirty down to about four years, though probably a period between ten and twenty years was most common. As with bladder cancers, to which reference is made below, the latent period may be very long - sometimes up to twenty years.

At first, the impression was gained that these lung cancers occurred only amongst workers engaged on the actual manufacture of chromates, and particularly at the stage at which the mass of sodium chromate is chipped out and dissolved in hot water, since the steam apparently carried off small particules of chromate, but in the latter years about seven cases have been

Figure A.47: Examples of studies of cancers due to workplace chemical exposure [BIOS 784].



found where lead and zinc chromates were used. Zinc chromate is a distinctly hazardous material, apparently, because it is somewhat soluble and both the ions concerned are harmful.

Gross had endeavoured to reproduce the production of these cancers in mice but without success. When the test atmospheres were set up by spraying in aqueous solutions, it was found that the selection of the proper concentration to use was inconveniently critical since concentrations slightly on the high side would kill most of the animals and concentrations on the low side would leave them wholly unaffected. He had also endeavoured to expose mice to the dry chromate dust, using the apparatus described in the Appendix, but this series of experiments had to be discontinued owing to trouble with disease amongst the experimental animals and the opportunity for repetition had not occurred.

In order to keep as close a check as possible, workers were examined clinically monthly and subjected to lung x-ray photography at six monthly intervals. It may be noted that the Italians who had been asked by the I.G. for their experience in this field, asserted that they had seen no chromate cancers, a point on which Gross was evidently unconvinced. He, incidentally, had seen one case of nasal cancer in a chromate worker, which appeared to have commenced in the antrum. (of. VIII Internationalen Kongress für Unfallmedizin und Berufskrankeiten, Frankfurt a/M, 26-30 September 1938).

No cases of nose or lung cancer had been seen in the nickel carbonyl workers at Oppau.

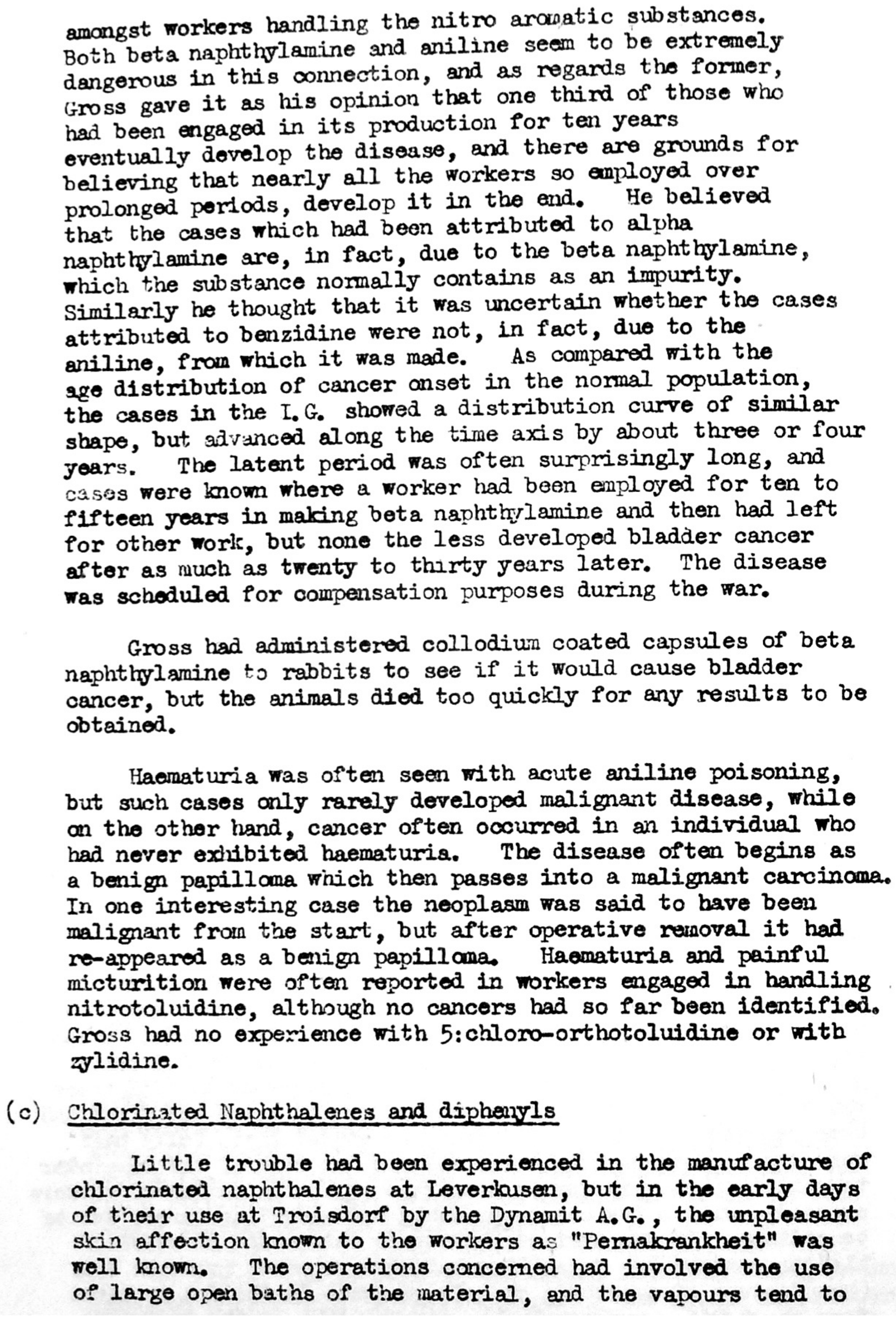
Gross pointed out that there seems to be quite good evidence that lung cancers are now more common amongst the general population than they were formerly. They had indeed, moved up from fifth to second place amongst the cancers by the end of the war in Germany.

(b) Bladder Cancers.

Gross had made a special study of bladder cancers at Ludwigshafen in 1928 and 1930. This was an old plant which had been originally set up in 1863 and had gradually acquired a bad reputation amongst workers. A survey which he carried out showed that from the foundation of the factory up to 1932 there had been some 78 cases of bladder cancer, of which the first had been reported in 1895. Of these, he stated that, fully half were due to beta-naphthylamine and the majority of the remainder to aniline (but very few in comparison with the number of workers exposed), with a few cases, probably not exceeding three, due to benzidine. It was curious that up to this stage no cases of bladder cancers due to aniline had been reported from the U.S. (Manufacture of dyestuffs on a large scale in the U.S.A. dates from about 1915 - previously the greater part of the dyes used had been imported from Germany and Switzerland).

It seems that these cancers are specifically due to amino aromatic compounds. So far, they have not been encountered

Figure A.48: Examples of studies of cancers due to workplace chemical exposure [BIOS 784].



amongst workers handling the nitro aromatic substances. Both beta naphthylamine and aniline seem to be extremely dangerous in this connection, and as regards the former, Gross gave it as his opinion that one third of those who had been engaged in its production for ten years eventually develop the disease, and there are grounds for believing that nearly all the workers so employed over prolonged periods, develop it in the end. He believed that the cases which had been attributed to alpha naphthylamine are, in fact, due to the beta naphthylamine, which the substance normally contains as an impurity. Similarly he thought that it was uncertain whether the cases attributed to benzidine were not, in fact, due to the aniline, from which it was made. As compared with the age distribution of cancer onset in the normal population, the cases in the I.G. showed a distribution curve of similar shape, but advanced along the time axis by about three or four years. The latent period was often surprisingly long, and cases were known where a worker had been employed for ten to fifteen years in making beta naphthylamine and then had left for other work, but none the less developed bladder cancer after as much as twenty to thirty years later. The disease was scheduled for compensation purposes during the war.

Gross had administered collodium coated capsules of beta naphthylamine to rabbits to see if it would cause bladder cancer, but the animals died too quickly for any results to be obtained.

Haematuria was often seen with acute aniline poisoning, but such cases only rarely developed malignant disease, while on the other hand, cancer often occurred in an individual who had never exhibited haematuria. The disease often begins as a benign papilloma which then passes into a malignant carcinoma. In one interesting case the neoplasm was said to have been malignant from the start, but after operative removal it had re-appeared as a benign papilloma. Haematuria and painful micturition were often reported in workers engaged in handling nitrotoluidine, although no cancers had so far been identified. Gross had no experience with 5:chloro-orthotoluidine or with xylidine.

(c) Chlorinated Naphthalenes and diphenyls

Little trouble had been experienced in the manufacture of chlorinated naphthalenes at Leverkusen, but in the early days of their use at Troisdorf by the Dynamit A.G., the unpleasant skin affection known to the workers as "Pernakrankheit" was well known. The operations concerned had involved the use of large open baths of the material, and the vapours tend to

Figure A.49: Examples of studies of cancers due to workplace chemical exposure [BIOS 784].

BIOS 1253. ***A Photoelectric Colorimeter (Photoelectric Absorptiometer) Designed by Professor R. Havemann, Produced by W. Kauhausen in Berlin-Dahlem.***

1. GENERAL.

When visiting the Materialprüfungsanstalt, Unter den Eichen 86 Berlin-Dahlem, we found that the firm W. Kauhausen, laboratory furnishers, has an office in one of the many rooms of that building not used any more for its original purpose.

This firm is producing a photoelectric Colorimeter (photoelectric absorptiometer), designed by Professor R. Havemann, director of the Kaiser Wilhelm Institut für Elektrophysik.

The instrument was seen in the store rooms of the firm and, in operation, in the pharmacological Institute of the University Berlin, the director of which, Professor W. Heubner, has been using it on a large scale for many years and confirmed its excellent performance.

The writer things the instrument presents several interesting features worth reporting. [...]

3. PUBLICATIONS ABOUT THE INSTRUMENT.

The instrument is described in detail and illustrated in Kauhausen's catalogue. Havemann has published papers about it in Biochemische Zeitschrift, vol. 301, 1939, p. 105; vol. 306, 1940, p. 224; 310, 1942, p. 378; Angew. Chemie 54, 1941, p. 105; Zschr. f. physikal. Chemie A vol. 188, 1941, p. 182, Beiheft 48 zur Zeitschrift des Vereins deutscher Chemiker.

4. DESCRIPTION OF THE INSTRUMENT.

The instrument has the form of a horizontal cylinder mounted on short legs. As can be seen in the diagram reproduced at the end as figure 1, the light source is in the left third; it is either a 100 Watt filament lamp, or a mercury, sodium or cadmium vapour lamp (Osram Spectral Lamps). These lamps are easily interchangeable.

Monochromatic light of the following wavelengths (mu) [nanometers] becomes thus available: 326 (Cd); 365 (Hg); 435–6 (Hg); 509 (Cd); 546 (Hg); 577–9 (Hg); 589–95 (Na); 644 (Cd).

Two photocells of the barrier layer type are arranged on either side of the lamp. The left hand one—the compensating cell—is permanently fixed and has an iris diaphragm. The other one, however, on the side of the liquid under test, is mounted on a revolving spindle, the rotation of which varies the distance of the cell from the light source. This is the measuring cell. [...]

Additional equipment for fluorescence measurements can also easily be fitted.

Light-absorbing filters can be inserted on either side, producing more or less monochromatic light according to the light source chosen.

A shunt is provided for varying the sensitivity of the galvo. [...]

7. CELLS FOR THE LIQUID TO BE TESTED.

The cells taking the coloured liquid are kept in position by a spring-loaded ring, enabling a quick interchange of cells of various sizes and guaranteeing exact location of the cell position.

In addition to simple cells with depths of 5, 10, 20, 30 and 40 mm, several cells of special design are available, as shown in figures 2 to 5.

Figure 2 shows a flow through cell with very wide inflow funnel; the side tube on the right is an air outlet. The wide tubes and the absence of bends make the operations of filling and emptying rapid and simple.

Figure 3 shows a cell with a jacket in which liquid from a thermostat fitted with a pump can be circulated, so as to keep the liquid under test at a constant temperature, which is particularly useful for physico-chemical measurements.

Figure 4 shows a cell specially constructed for photometric titrations. It is fitted with a stirring device which is shewn more fully in figure 5.

The side of the cell is joined tangentially at point A and the stirrer thus acts as a centrifugal pump. The contents of the cell are mixed very rapidly and this makes the photometric titration with this apparatus much more speedy than a potentiometric or amperometric titration.

The photometric titration enables colour changes too indefinite or too delicate to be followed by simple observation to be followed with ease and great accuracy. This allows very dilute solutions to be used and the use of indicators becomes unnecessary in some cases, e.g. with iodometric and bromometric methods. [...]

9. FLUORESCENCE MEASUREMENTS.

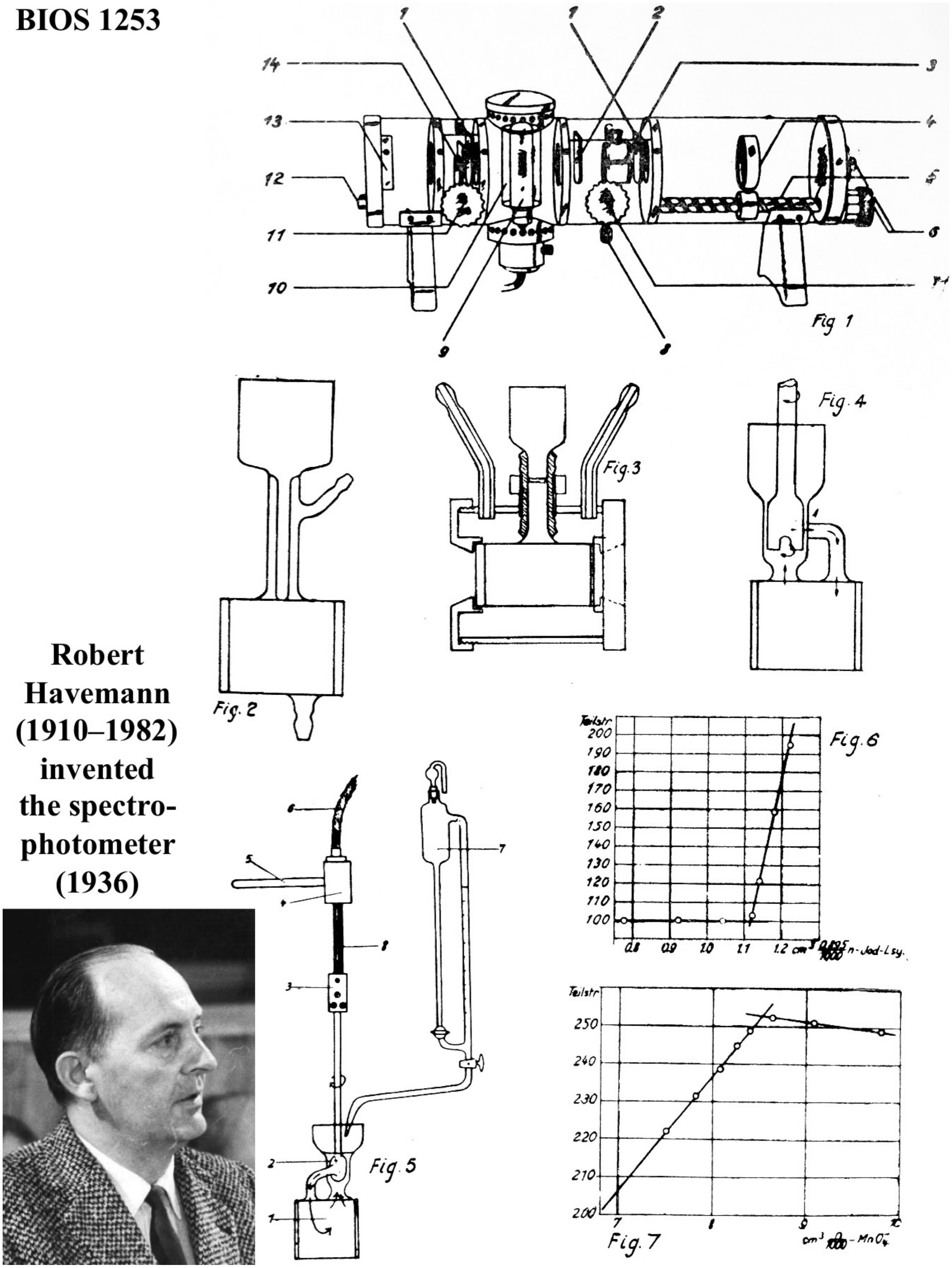
The light from the mercury lamp first passes the filter UG2, transmitting the UV line 365 mu and some infra-red rays only. The transmitted light then passes the cell with the liquid under test and then impinges upon a filter GG8 which absorbs the UV light but transmits the infra-red and any visible fluorescent light produced in the solution. The infra-red light is then retained by a further filter BG23, so that only the light produced in consequence of fluorescent material being present impinges upon the photocell. [...]

Quartz cells are available for this type of work but it appears from the description, that glass cells can also be used, although the fluorescence of the glass interferes to some extent.

10. ACCURACY CLAIMED.

An overall accuracy of 0.2 to 0.3% is claimed. [...]

[This instrument appears to be the first true spectrophotometer, and it has all of the essential features of modern spectrophotometers. Robert Havemann (German, 1910–1982) invented spectrophotometers no later than 1936, as shown by the patents on pp. 2381–2388. This BIOS report made clear that Havemann's spectrophotometers had been extensively used in Germany for many years before Allied investigators discovered them and sent detailed documentation (and perhaps whole instruments) to the United Kingdom and United States, which presumably copied the technology. Such spectrophotometers are now used worldwide for a wide variety of biochemical and chemical measurements.]



BIOS 1253

Robert Havemann (1910–1982) invented the spectrophotometer (1936)

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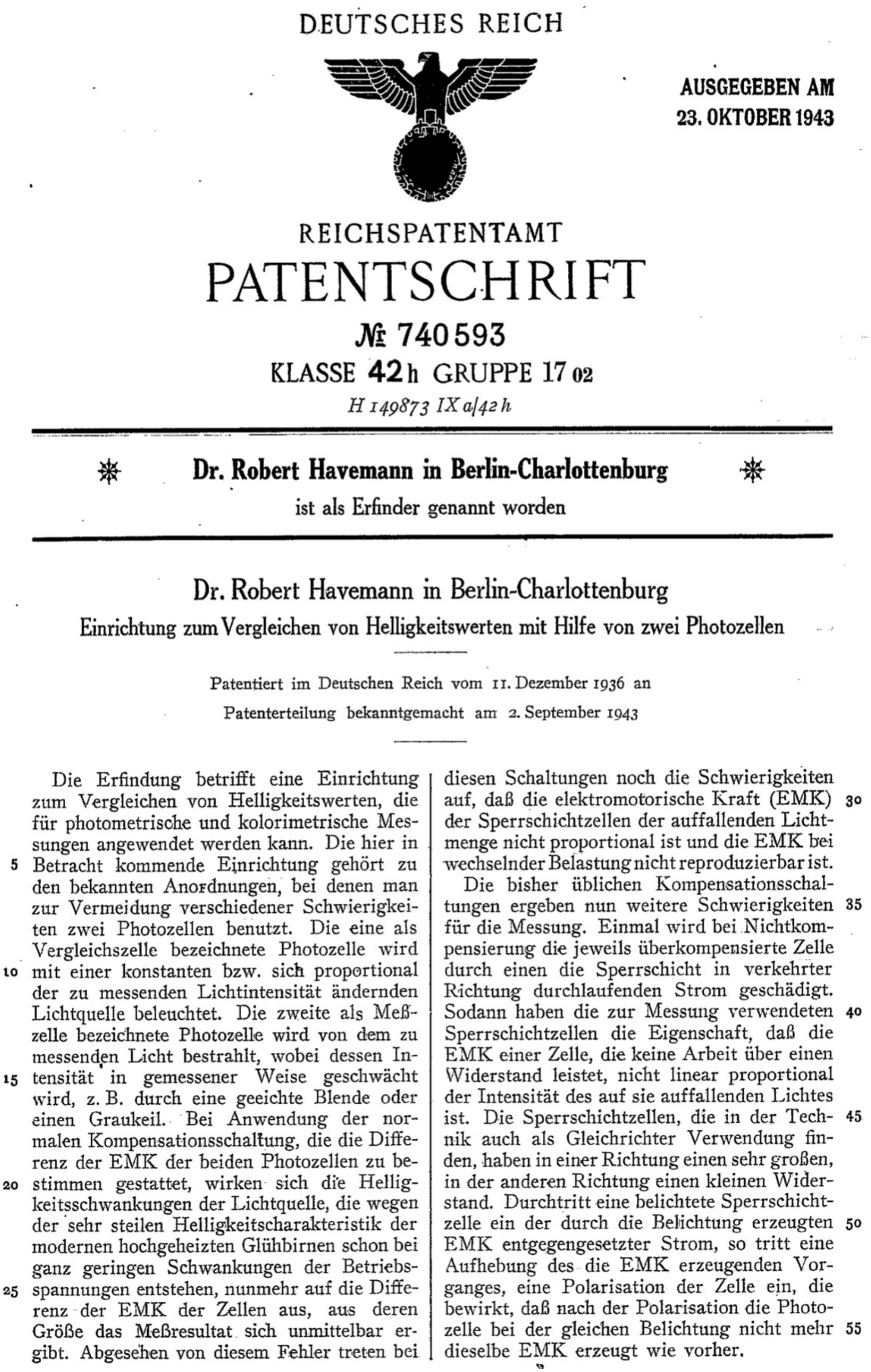
Fig 1
Fig. 2
Fig. 3
Fig. 4
1
6
5
4
8
3
7
2
1
Fig. 5
Teilstr.
200
190
180
170
160
150
140
130
120
110
100
0.8
0.9
1.0
1.1
1.2 cm³
n-Jod-Lsg.
Fig. 6
Teilstr.
250
240
230
220
210
200
7
8
9
10
cm³
-MnO₄
Fig. 7

Figure A.50: Robert Havemann invented the spectrophotometer in 1936 [BIOS 1253].



DEUTSCHES REICH

AUSGEGEBEN AM
23. OKTOBER 1943

REICHSPATENTAMT

PATENTSCHRIFT

№ 740593

KLASSE 42h GRUPPE 17 02

H 149873 IX a/42 h

Dr. Robert Havemann in Berlin-Charlottenburg
ist als Erfinder genannt worden

Dr. Robert Havemann in Berlin-Charlottenburg

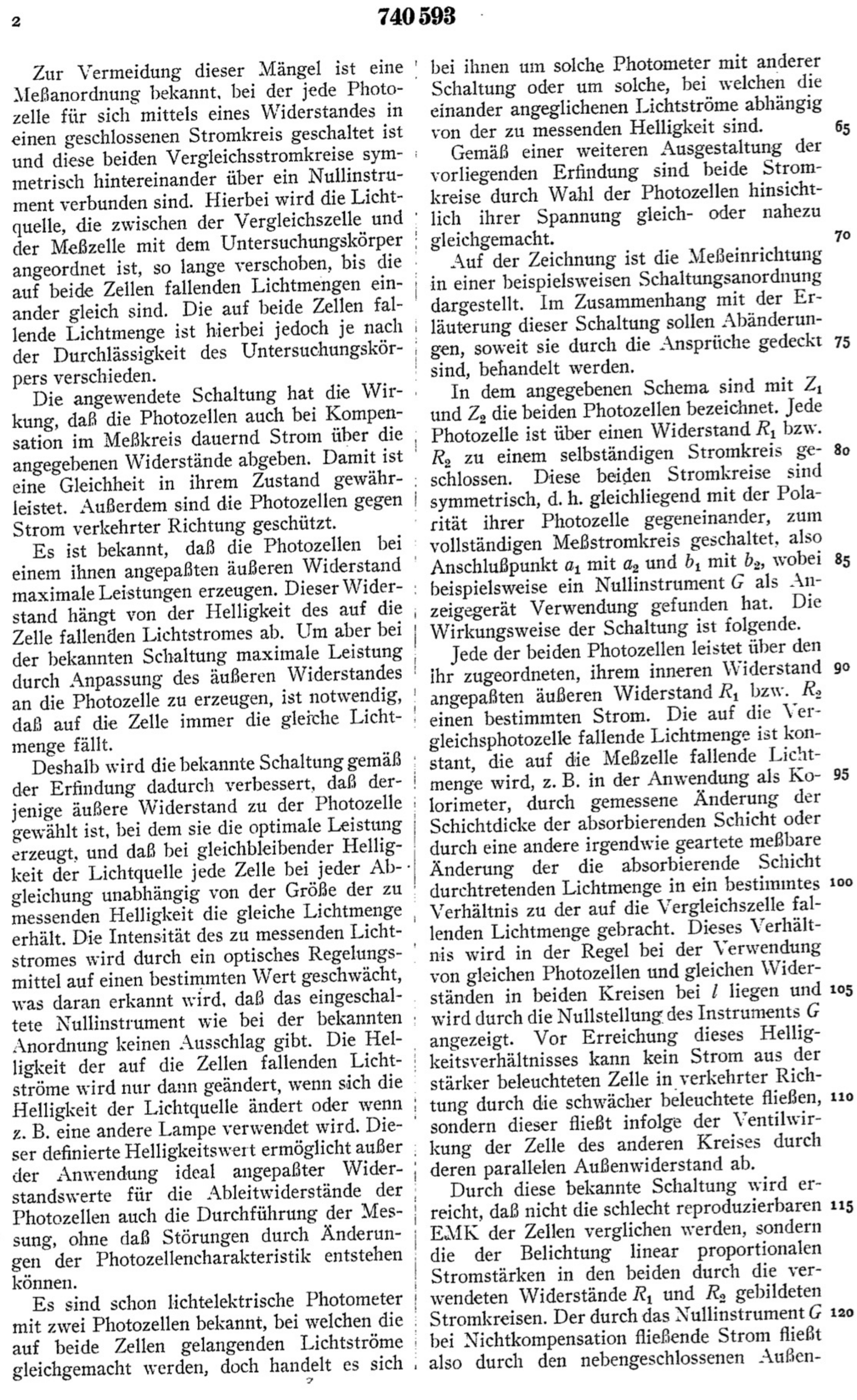
Einrichtung zum Vergleichen von Helligkeitswerten mit Hilfe von zwei Photozellen

Patentiert im Deutschen Reich vom 11. Dezember 1936 an
Patenterteilung bekanntgemacht am 2. September 1943

Die Erfindung betrifft eine Einrichtung zum Vergleichen von Helligkeitswerten, die für photometrische und kolorimetrische Messungen angewendet werden kann. Die hier in Betracht kommende Einrichtung gehört zu den bekannten Anordnungen, bei denen man zur Vermeidung verschiedener Schwierigkeiten zwei Photozellen benutzt. Die eine als Vergleichszelle bezeichnete Photozelle wird mit einer konstanten bzw. sich proportional der zu messenden Lichtintensität ändernden Lichtquelle beleuchtet. Die zweite als Meßzelle bezeichnete Photozelle wird von dem zu messenden Licht bestrahlt, wobei dessen Intensität in gemessener Weise geschwächt wird, z. B. durch eine geeichte Blende oder einen Graukeil. Bei Anwendung der normalen Kompensationsschaltung, die die Differenz der EMK der beiden Photozellen zu bestimmen gestattet, wirken sich die Helligkeitsschwankungen der Lichtquelle, die wegen der sehr steilen Helligkeitscharakteristik der modernen hochgeheizten Glühbirnen schon bei ganz geringen Schwankungen der Betriebsspannungen entstehen, nunmehr auf die Differenz der EMK der Zellen aus, aus deren Größe das Meßresultat sich unmittelbar ergibt. Abgesehen von diesem Fehler treten bei diesen Schaltungen noch die Schwierigkeiten auf, daß die elektromotorische Kraft (EMK) der Sperrschichtzellen der auffallenden Lichtmenge nicht proportional ist und die EMK bei wechselnder Belastung nicht reproduzierbar ist.

Die bisher üblichen Kompensationsschaltungen ergeben nun weitere Schwierigkeiten für die Messung. Einmal wird bei Nichtkompensierung die jeweils überkompensierte Zelle durch einen die Sperrschicht in verkehrter Richtung durchlaufenden Strom geschädigt. Sodann haben die zur Messung verwendeten Sperrschichtzellen die Eigenschaft, daß die EMK einer Zelle, die keine Arbeit über einen Widerstand leistet, nicht linear proportional der Intensität des auf sie auffallenden Lichtes ist. Die Sperrschichtzellen, die in der Technik auch als Gleichrichter Verwendung finden, haben in einer Richtung einen sehr großen, in der anderen Richtung einen kleinen Widerstand. Durchtritt eine belichtete Sperrschichtzelle ein der durch die Belichtung erzeugten EMK entgegengesetzter Strom, so tritt eine Aufhebung des die EMK erzeugenden Vorganges, eine Polarisation der Zelle ein, die bewirkt, daß nach der Polarisation die Photozelle bei der gleichen Belichtung nicht mehr dieselbe EMK erzeugt wie vorher.

Figure A.51: Robert Havemann invented the spectrophotometer in 1936.



Zur Vermeidung dieser Mängel ist eine Meßanordnung bekannt, bei der jede Photozelle für sich mittels eines Widerstandes in einen geschlossenen Stromkreis geschaltet ist und diese beiden Vergleichsstromkreise symmetrisch hintereinander über ein Nullinstrument verbunden sind. Hierbei wird die Lichtquelle, die zwischen der Vergleichszelle und der Meßzelle mit dem Untersuchungskörper angeordnet ist, so lange verschoben, bis die auf beide Zellen fallenden Lichtmengen einander gleich sind. Die auf beide Zellen fallende Lichtmenge ist hierbei jedoch je nach der Durchlässigkeit des Untersuchungskörpers verschieden.

Die angewendete Schaltung hat die Wirkung, daß die Photozellen auch bei Kompensation im Meßkreis dauernd Strom über die angegebenen Widerstände abgeben. Damit ist eine Gleichheit in ihrem Zustand gewährleistet. Außerdem sind die Photozellen gegen Strom verkehrter Richtung geschützt.

Es ist bekannt, daß die Photozellen bei einem ihnen angepaßten äußeren Widerstand maximale Leistungen erzeugen. Dieser Widerstand hängt von der Helligkeit des auf die Zelle fallenden Lichtstromes ab. Um aber bei der bekannten Schaltung maximale Leistung durch Anpassung des äußeren Widerstandes an die Photozelle zu erzeugen, ist notwendig, daß auf die Zelle immer die gleiche Lichtmenge fällt.

Deshalb wird die bekannte Schaltung gemäß der Erfindung dadurch verbessert, daß derjenige äußere Widerstand zu der Photozelle gewählt ist, bei dem sie die optimale Leistung erzeugt, und daß bei gleichbleibender Helligkeit der Lichtquelle jede Zelle bei jeder Abgleichung unabhängig von der Größe der zu messenden Helligkeit die gleiche Lichtmenge erhält. Die Intensität des zu messenden Lichtstromes wird durch ein optisches Regelungsmittel auf einen bestimmten Wert geschwächt, was daran erkannt wird, daß das eingeschaltete Nullinstrument wie bei der bekannten Anordnung keinen Ausschlag gibt. Die Helligkeit der auf die Zellen fallenden Lichtströme wird nur dann geändert, wenn sich die Helligkeit der Lichtquelle ändert oder wenn z. B. eine andere Lampe verwendet wird. Dieser definierte Helligkeitswert ermöglicht außer der Anwendung ideal angepaßter Widerstandswerte für die Ableitwiderstände der Photozellen auch die Durchführung der Messung, ohne daß Störungen durch Änderungen der Photozellencharakteristik entstehen können.

Es sind schon lichtelektrische Photometer mit zwei Photozellen bekannt, bei welchen die auf beide Zellen gelangenden Lichtströme gleichgemacht werden, doch handelt es sich bei ihnen um solche Photometer mit anderer Schaltung oder um solche, bei welchen die einander angeglichenen Lichtströme abhängig von der zu messenden Helligkeit sind.

Gemäß einer weiteren Ausgestaltung der vorliegenden Erfindung sind beide Stromkreise durch Wahl der Photozellen hinsichtlich ihrer Spannung gleich- oder nahezu gleichgemacht.

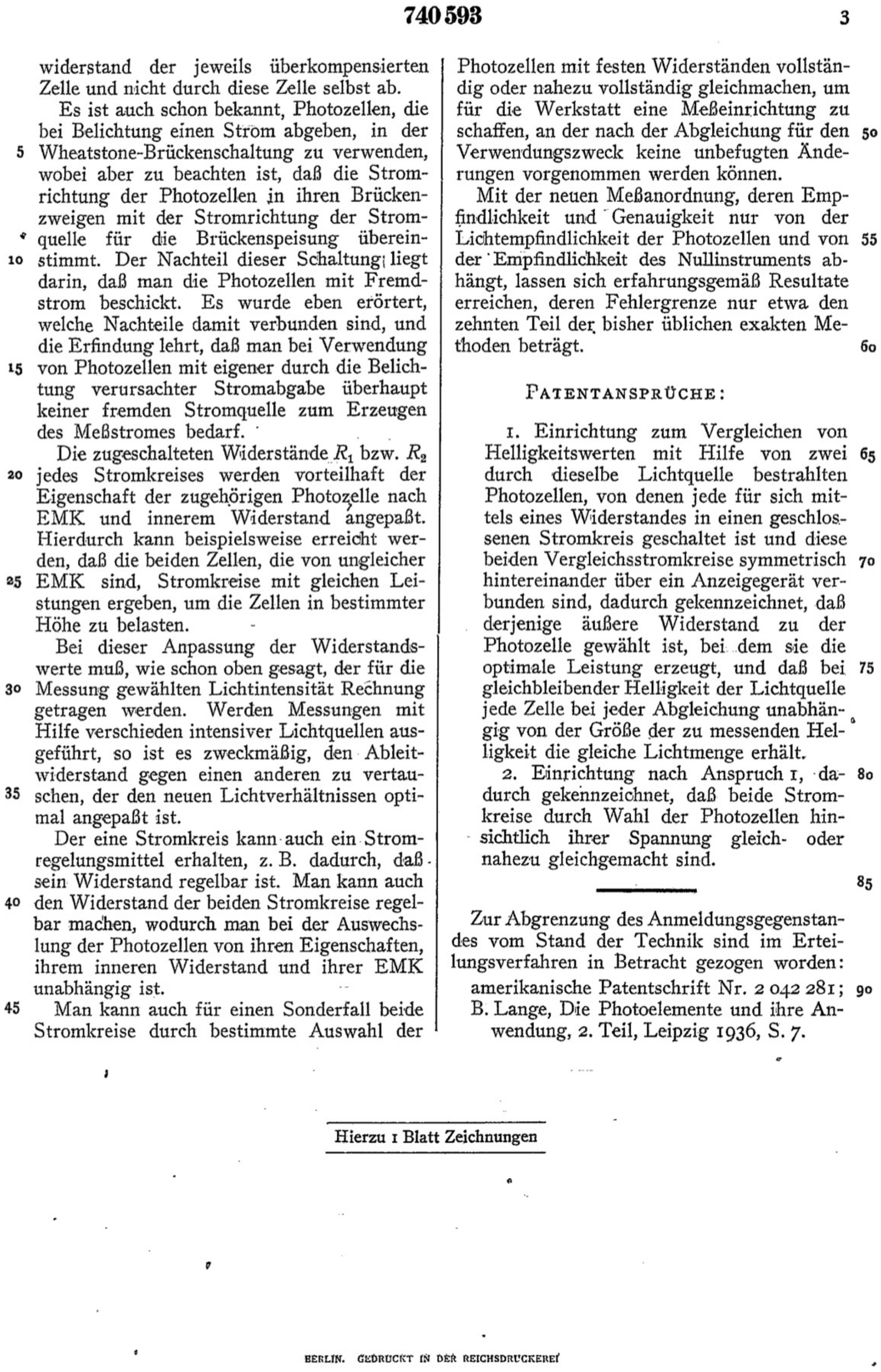
Auf der Zeichnung ist die Meßeinrichtung in einer beispielsweisen Schaltungsanordnung dargestellt. Im Zusammenhang mit der Erläuterung dieser Schaltung sollen Abänderungen, soweit sie durch die Ansprüche gedeckt sind, behandelt werden.

In dem angegebenen Schema sind mit Z_1 und Z_2 die beiden Photozellen bezeichnet. Jede Photozelle ist über einen Widerstand R_1 bzw. R_2 zu einem selbständigen Stromkreis geschlossen. Diese beiden Stromkreise sind symmetrisch, d. h. gleichliegend mit der Polarität ihrer Photozelle gegeneinander, zum vollständigen Meßstromkreis geschaltet, also Anschlußpunkt a_1 mit a_2 und b_1 mit b_2, wobei beispielsweise ein Nullinstrument G als Anzeigegerät Verwendung gefunden hat. Die Wirkungsweise der Schaltung ist folgende.

Jede der beiden Photozellen leistet über den ihr zugeordneten, ihrem inneren Widerstand angepaßten äußeren Widerstand R_1 bzw. R_2 einen bestimmten Strom. Die auf die Vergleichsphotozelle fallende Lichtmenge ist konstant, die auf die Meßzelle fallende Lichtmenge wird, z. B. in der Anwendung als Kolorimeter, durch gemessene Änderung der Schichtdicke der absorbierenden Schicht oder durch eine andere irgendwie geartete meßbare Änderung der die absorbierende Schicht durchtretenden Lichtmenge in ein bestimmtes Verhältnis zu der auf die Vergleichszelle fallenden Lichtmenge gebracht. Dieses Verhältnis wird in der Regel bei der Verwendung von gleichen Photozellen und gleichen Widerständen in beiden Kreisen bei l liegen und wird durch die Nullstellung des Instruments G angezeigt. Vor Erreichung dieses Helligkeitsverhältnisses kann kein Strom aus der stärker beleuchteten Zelle in verkehrter Richtung durch die schwächer beleuchtete fließen, sondern dieser fließt infolge der Ventilwirkung der Zelle des anderen Kreises durch deren parallelen Außenwiderstand ab.

Durch diese bekannte Schaltung wird erreicht, daß nicht die schlecht reproduzierbaren EMK der Zellen verglichen werden, sondern die der Belichtung linear proportionalen Stromstärken in den beiden durch die verwendeten Widerstände R_1 und R_2 gebildeten Stromkreisen. Der durch das Nullinstrument G bei Nichtkompensation fließende Strom fließt also durch den nebengeschlossenen Außen-

Figure A.52: Robert Havemann invented the spectrophotometer in 1936.



widerstand der jeweils überkompensierten Zelle und nicht durch diese Zelle selbst ab.

Es ist auch schon bekannt, Photozellen, die bei Belichtung einen Strom abgeben, in der Wheatstone-Brückenschaltung zu verwenden, wobei aber zu beachten ist, daß die Stromrichtung der Photozellen in ihren Brückenzweigen mit der Stromrichtung der Stromquelle für die Brückenspeisung übereinstimmt. Der Nachteil dieser Schaltung liegt darin, daß man die Photozellen mit Fremdstrom beschickt. Es wurde eben erörtert, welche Nachteile damit verbunden sind, und die Erfindung lehrt, daß man bei Verwendung von Photozellen mit eigener durch die Belichtung verursachter Stromabgabe überhaupt keiner fremden Stromquelle zum Erzeugen des Meßstromes bedarf.

Die zugeschalteten Widerstände R_1 bzw. R_2 jedes Stromkreises werden vorteilhaft der Eigenschaft der zugehörigen Photozelle nach EMK und innerem Widerstand angepaßt. Hierdurch kann beispielsweise erreicht werden, daß die beiden Zellen, die von ungleicher EMK sind, Stromkreise mit gleichen Leistungen ergeben, um die Zellen in bestimmter Höhe zu belasten.

Bei dieser Anpassung der Widerstandswerte muß, wie schon oben gesagt, der für die Messung gewählten Lichtintensität Rechnung getragen werden. Werden Messungen mit Hilfe verschieden intensiver Lichtquellen ausgeführt, so ist es zweckmäßig, den Ableitwiderstand gegen einen anderen zu vertauschen, der den neuen Lichtverhältnissen optimal angepaßt ist.

Der eine Stromkreis kann auch ein Stromregelungsmittel erhalten, z. B. dadurch, daß sein Widerstand regelbar ist. Man kann auch den Widerstand der beiden Stromkreise regelbar machen, wodurch man bei der Auswechslung der Photozellen von ihren Eigenschaften, ihrem inneren Widerstand und ihrer EMK unabhängig ist.

Man kann auch für einen Sonderfall beide Stromkreise durch bestimmte Auswahl der Photozellen mit festen Widerständen vollständig oder nahezu vollständig gleichmachen, um für die Werkstatt eine Meßeinrichtung zu schaffen, an der nach der Abgleichung für den Verwendungszweck keine unbefugten Änderungen vorgenommen werden können.

Mit der neuen Meßanordnung, deren Empfindlichkeit und Genauigkeit nur von der Lichtempfindlichkeit der Photozellen und von der Empfindlichkeit des Nullinstruments abhängt, lassen sich erfahrungsgemäß Resultate erreichen, deren Fehlergrenze nur etwa den zehnten Teil der bisher üblichen exakten Methoden beträgt.

PATENTANSPRÜCHE:

1. Einrichtung zum Vergleichen von Helligkeitswerten mit Hilfe von zwei durch dieselbe Lichtquelle bestrahlten Photozellen, von denen jede für sich mittels eines Widerstandes in einen geschlossenen Stromkreis geschaltet ist und diese beiden Vergleichsstromkreise symmetrisch hintereinander über ein Anzeigegerät verbunden sind, dadurch gekennzeichnet, daß derjenige äußere Widerstand zu der Photozelle gewählt ist, bei dem sie die optimale Leistung erzeugt, und daß bei gleichbleibender Helligkeit der Lichtquelle jede Zelle bei jeder Abgleichung unabhängig von der Größe der zu messenden Helligkeit die gleiche Lichtmenge erhält.

2. Einrichtung nach Anspruch 1, dadurch gekennzeichnet, daß beide Stromkreise durch Wahl der Photozellen hinsichtlich ihrer Spannung gleich- oder nahezu gleichgemacht sind.

Zur Abgrenzung des Anmeldungsgegenstandes vom Stand der Technik sind im Erteilungsverfahren in Betracht gezogen worden:

amerikanische Patentschrift Nr. 2 042 281;
B. Lange, Die Photoelemente und ihre Anwendung, 2. Teil, Leipzig 1936, S. 7.

Hierzu 1 Blatt Zeichnungen

BERLIN. GEDRUCKT IN DER REICHSDRUCKEREI

Figure A.53: Robert Havemann invented the spectrophotometer in 1936.

Zu der Patentschrift **740593**
Kl. 42h Gr. 17 02

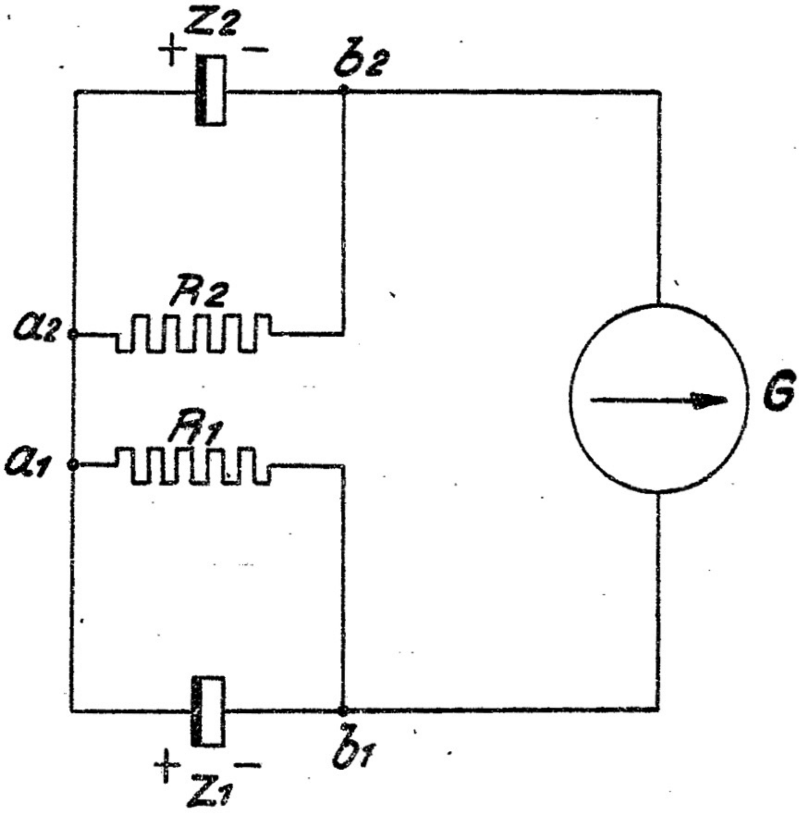
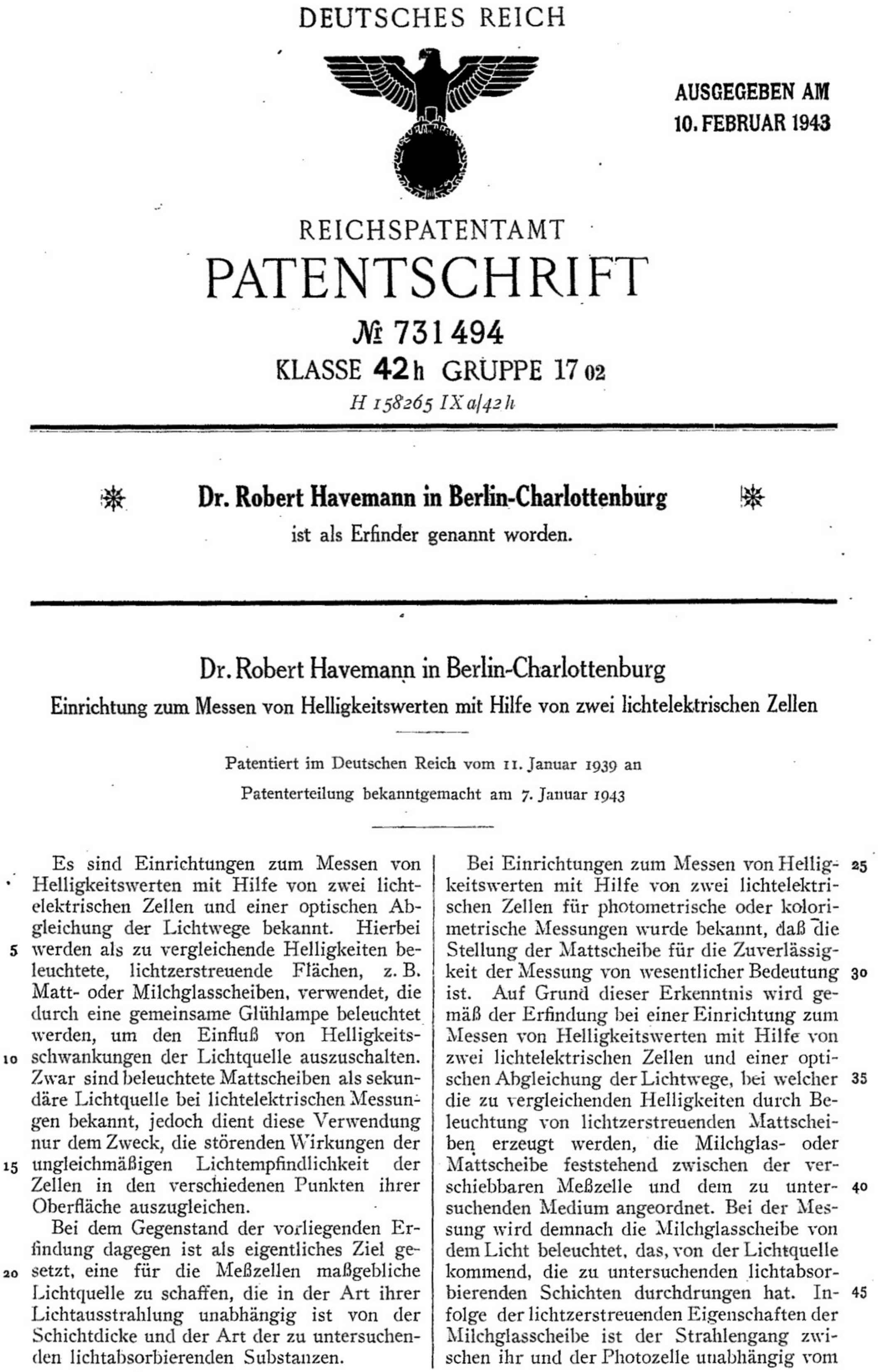

+ Z2 −
b2
R2
a2
R1
a1
G
b1
+ Z1 −

Figure A.54: Robert Havemann invented the spectrophotometer in 1936.



DEUTSCHES REICH

AUSGEGEBEN AM 10. FEBRUAR 1943

REICHSPATENTAMT

PATENTSCHRIFT

№ 731 494

KLASSE **42** h GRUPPE 17$_{02}$

H 158265 IX a/42 h

Dr. Robert Havemann in Berlin-Charlottenburg

ist als Erfinder genannt worden.

Dr. Robert Havemann in Berlin-Charlottenburg

Einrichtung zum Messen von Helligkeitswerten mit Hilfe von zwei lichtelektrischen Zellen

Patentiert im Deutschen Reich vom 11. Januar 1939 an

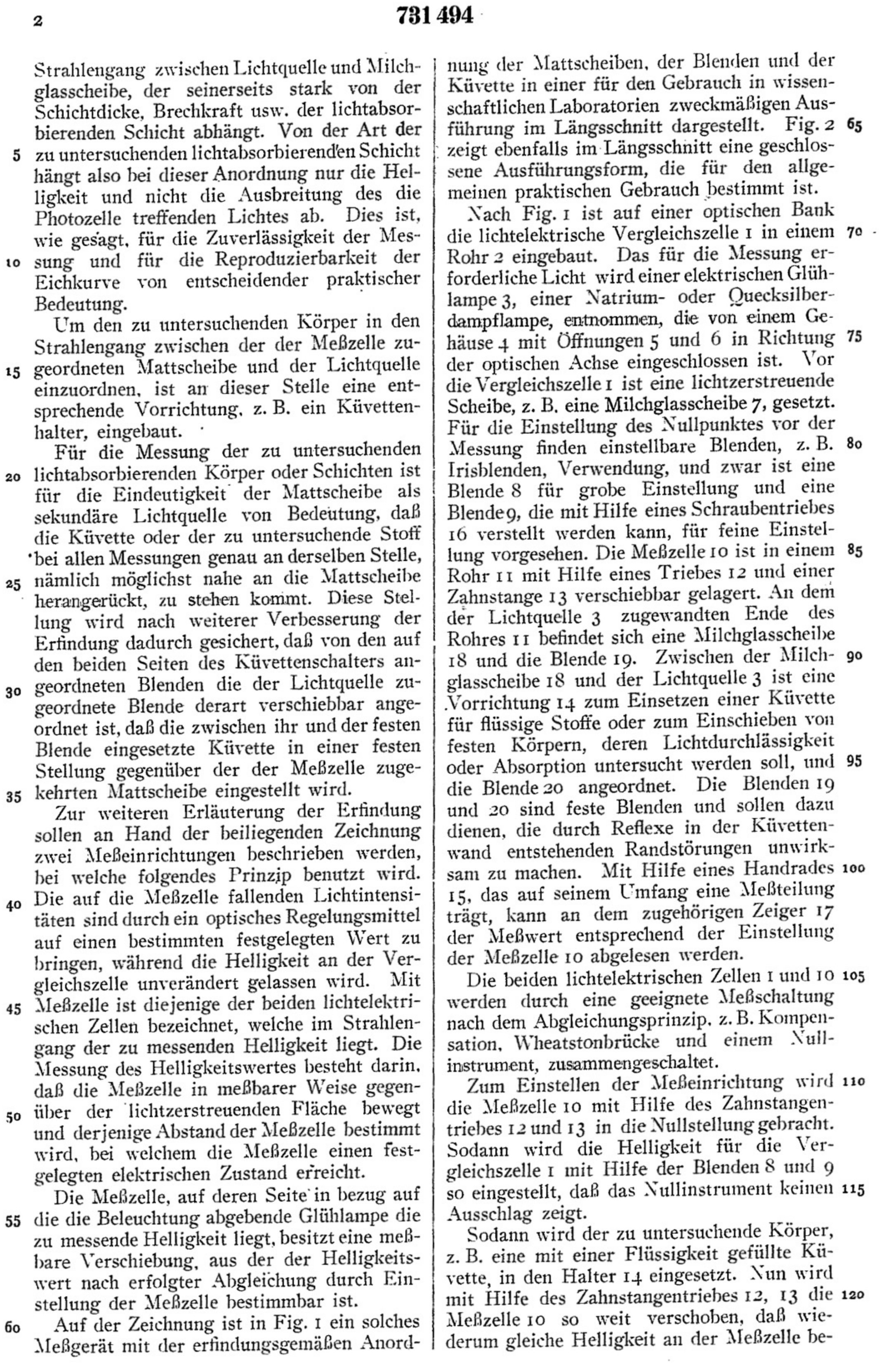
Patenterteilung bekanntgemacht am 7. Januar 1943

Es sind Einrichtungen zum Messen von Helligkeitswerten mit Hilfe von zwei lichtelektrischen Zellen und einer optischen Abgleichung der Lichtwege bekannt. Hierbei werden als zu vergleichende Helligkeiten beleuchtete, lichtzerstreuende Flächen, z. B. Matt- oder Milchglasscheiben, verwendet, die durch eine gemeinsame Glühlampe beleuchtet werden, um den Einfluß von Helligkeitsschwankungen der Lichtquelle auszuschalten. Zwar sind beleuchtete Mattscheiben als sekundäre Lichtquelle bei lichtelektrischen Messungen bekannt, jedoch dient diese Verwendung nur dem Zweck, die störenden Wirkungen der ungleichmäßigen Lichtempfindlichkeit der Zellen in den verschiedenen Punkten ihrer Oberfläche auszugleichen.

Bei dem Gegenstand der vorliegenden Erfindung dagegen ist als eigentliches Ziel gesetzt, eine für die Meßzellen maßgebliche Lichtquelle zu schaffen, die in der Art ihrer Lichtausstrahlung unabhängig ist von der Schichtdicke und der Art der zu untersuchenden lichtabsorbierenden Substanzen.

Bei Einrichtungen zum Messen von Helligkeitswerten mit Hilfe von zwei lichtelektrischen Zellen für photometrische oder kolorimetrische Messungen wurde bekannt, daß die Stellung der Mattscheibe für die Zuverlässigkeit der Messung von wesentlicher Bedeutung ist. Auf Grund dieser Erkenntnis wird gemäß der Erfindung bei einer Einrichtung zum Messen von Helligkeitswerten mit Hilfe von zwei lichtelektrischen Zellen und einer optischen Abgleichung der Lichtwege, bei welcher die zu vergleichenden Helligkeiten durch Beleuchtung von lichtzerstreuenden Mattscheiben erzeugt werden, die Milchglas- oder Mattscheibe feststehend zwischen der verschiebbaren Meßzelle und dem zu untersuchenden Medium angeordnet. Bei der Messung wird demnach die Milchglasscheibe von dem Licht beleuchtet, das, von der Lichtquelle kommend, die zu untersuchenden lichtabsorbierenden Schichten durchdrungen hat. Infolge der lichtzerstreuenden Eigenschaften der Milchglasscheibe ist der Strahlengang zwischen ihr und der Photozelle unabhängig vom

Figure A.55: Robert Havemann invented the spectrophotometer in 1936.



2

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Strahlengang zwischen Lichtquelle und Milchglasscheibe, der seinerseits stark von der Schichtdicke, Brechkraft usw. der lichtabsorbierenden Schicht abhängt. Von der Art der zu untersuchenden lichtabsorbierenden Schicht hängt also bei dieser Anordnung nur die Helligkeit und nicht die Ausbreitung des die Photozelle treffenden Lichtes ab. Dies ist, wie gesagt, für die Zuverlässigkeit der Messung und für die Reproduzierbarkeit der Eichkurve von entscheidender praktischer Bedeutung.

Um den zu untersuchenden Körper in den Strahlengang zwischen der der Meßzelle zugeordneten Mattscheibe und der Lichtquelle einzuordnen, ist an dieser Stelle eine entsprechende Vorrichtung, z. B. ein Küvettenhalter, eingebaut.

Für die Messung der zu untersuchenden lichtabsorbierenden Körper oder Schichten ist für die Eindeutigkeit der Mattscheibe als sekundäre Lichtquelle von Bedeutung, daß die Küvette oder der zu untersuchende Stoff bei allen Messungen genau an derselben Stelle, nämlich möglichst nahe an die Mattscheibe herangerückt, zu stehen kommt. Diese Stellung wird nach weiterer Verbesserung der Erfindung dadurch gesichert, daß von den auf den beiden Seiten des Küvettenschalters angeordneten Blenden die der Lichtquelle zugeordnete Blende derart verschiebbar angeordnet ist, daß die zwischen ihr und der festen Blende eingesetzte Küvette in einer festen Stellung gegenüber der der Meßzelle zugekehrten Mattscheibe eingestellt wird.

Zur weiteren Erläuterung der Erfindung sollen an Hand der beiliegenden Zeichnung zwei Meßeinrichtungen beschrieben werden, bei welche folgendes Prinzip benutzt wird. Die auf die Meßzelle fallenden Lichtintensitäten sind durch ein optisches Regelungsmittel auf einen bestimmten festgelegten Wert zu bringen, während die Helligkeit an der Vergleichszelle unverändert gelassen wird. Mit Meßzelle ist diejenige der beiden lichtelektrischen Zellen bezeichnet, welche im Strahlengang der zu messenden Helligkeit liegt. Die Messung des Helligkeitswertes besteht darin, daß die Meßzelle in meßbarer Weise gegenüber der lichtzerstreuenden Fläche bewegt und derjenige Abstand der Meßzelle bestimmt wird, bei welchem die Meßzelle einen festgelegten elektrischen Zustand erreicht.

Die Meßzelle, auf deren Seite in bezug auf die die Beleuchtung abgebende Glühlampe die zu messende Helligkeit liegt, besitzt eine meßbare Verschiebung, aus der der Helligkeitswert nach erfolgter Abgleichung durch Einstellung der Meßzelle bestimmbar ist.

Auf der Zeichnung ist in Fig. 1 ein solches Meßgerät mit der erfindungsgemäßen Anordnung der Mattscheiben, der Blenden und der Küvette in einer für den Gebrauch in wissenschaftlichen Laboratorien zweckmäßigen Ausführung im Längsschnitt dargestellt. Fig. 2 zeigt ebenfalls im Längsschnitt eine geschlossene Ausführungsform, die für den allgemeinen praktischen Gebrauch bestimmt ist.

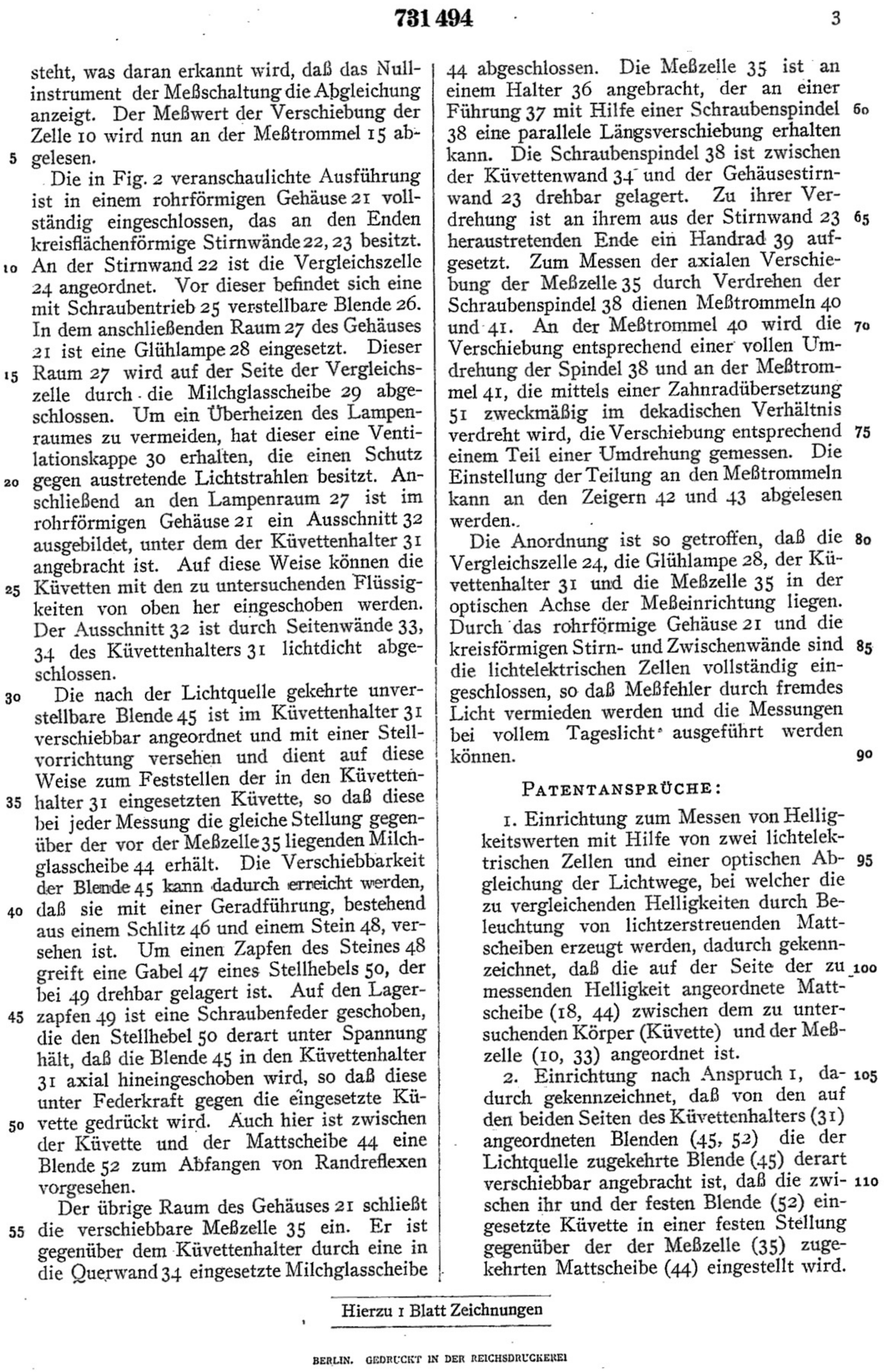
Nach Fig. 1 ist auf einer optischen Bank die lichtelektrische Vergleichszelle 1 in einem Rohr 2 eingebaut. Das für die Messung erforderliche Licht wird einer elektrischen Glühlampe 3, einer Natrium- oder Quecksilberdampflampe, entnommen, die von einem Gehäuse 4 mit Öffnungen 5 und 6 in Richtung der optischen Achse eingeschlossen ist. Vor die Vergleichszelle 1 ist eine lichtzerstreuende Scheibe, z. B. eine Milchglasscheibe 7, gesetzt. Für die Einstellung des Nullpunktes vor der Messung finden einstellbare Blenden, z. B. Irisblenden, Verwendung, und zwar ist eine Blende 8 für grobe Einstellung und eine Blende 9, die mit Hilfe eines Schraubentriebes 16 verstellt werden kann, für feine Einstellung vorgesehen. Die Meßzelle 10 ist in einem Rohr 11 mit Hilfe eines Triebes 12 und einer Zahnstange 13 verschiebbar gelagert. An dem der Lichtquelle 3 zugewandten Ende des Rohres 11 befindet sich eine Milchglasscheibe 18 und die Blende 19. Zwischen der Milchglasscheibe 18 und der Lichtquelle 3 ist eine Vorrichtung 14 zum Einsetzen einer Küvette für flüssige Stoffe oder zum Einschieben von festen Körpern, deren Lichtdurchlässigkeit oder Absorption untersucht werden soll, und die Blende 20 angeordnet. Die Blenden 19 und 20 sind feste Blenden und sollen dazu dienen, die durch Reflexe in der Küvettenwand entstehenden Randstörungen unwirksam zu machen. Mit Hilfe eines Handrades 15, das auf seinem Umfang eine Meßteilung trägt, kann an dem zugehörigen Zeiger 17 der Meßwert entsprechend der Einstellung der Meßzelle 10 abgelesen werden.

Die beiden lichtelektrischen Zellen 1 und 10 werden durch eine geeignete Meßschaltung nach dem Abgleichungsprinzip, z. B. Kompensation, Wheatstonbrücke und einem Nullinstrument, zusammengeschaltet.

Zum Einstellen der Meßeinrichtung wird die Meßzelle 10 mit Hilfe des Zahnstangentriebes 12 und 13 in die Nullstellung gebracht. Sodann wird die Helligkeit für die Vergleichszelle 1 mit Hilfe der Blenden 8 und 9 so eingestellt, daß das Nullinstrument keinen Ausschlag zeigt.

Sodann wird der zu untersuchende Körper, z. B. eine mit einer Flüssigkeit gefüllte Küvette, in den Halter 14 eingesetzt. Nun wird mit Hilfe des Zahnstangentriebes 12, 13 die Meßzelle 10 so weit verschoben, daß wiederum gleiche Helligkeit an der Meßzelle be-

Figure A.56: Robert Havemann invented the spectrophotometer in 1936.



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steht, was daran erkannt wird, daß das Nullinstrument der Meßschaltung die Abgleichung anzeigt. Der Meßwert der Verschiebung der Zelle 10 wird nun an der Meßtrommel 15 abgelesen.

Die in Fig. 2 veranschaulichte Ausführung ist in einem rohrförmigen Gehäuse 21 vollständig eingeschlossen, das an den Enden kreisflächenförmige Stirnwände 22, 23 besitzt. An der Stirnwand 22 ist die Vergleichszelle 24 angeordnet. Vor dieser befindet sich eine mit Schraubentrieb 25 verstellbare Blende 26. In dem anschließenden Raum 27 des Gehäuses 21 ist eine Glühlampe 28 eingesetzt. Dieser Raum 27 wird auf der Seite der Vergleichszelle durch die Milchglasscheibe 29 abgeschlossen. Um ein Überheizen des Lampenraumes zu vermeiden, hat dieser eine Ventilationskappe 30 erhalten, die einen Schutz gegen austretende Lichtstrahlen besitzt. Anschließend an den Lampenraum 27 ist im rohrförmigen Gehäuse 21 ein Ausschnitt 32 ausgebildet, unter dem der Küvettenhalter 31 angebracht ist. Auf diese Weise können die Küvetten mit den zu untersuchenden Flüssigkeiten von oben her eingeschoben werden. Der Ausschnitt 32 ist durch Seitenwände 33, 34 des Küvettenhalters 31 lichtdicht abgeschlossen.

Die nach der Lichtquelle gekehrte unverstellbare Blende 45 ist im Küvettenhalter 31 verschiebbar angeordnet und mit einer Stellvorrichtung versehen und dient auf diese Weise zum Feststellen der in den Küvettenhalter 31 eingesetzten Küvette, so daß diese bei jeder Messung die gleiche Stellung gegenüber der vor der Meßzelle 35 liegenden Milchglasscheibe 44 erhält. Die Verschiebbarkeit der Blende 45 kann dadurch erreicht werden, daß sie mit einer Geradführung, bestehend aus einem Schlitz 46 und einem Stein 48, versehen ist. Um einen Zapfen des Steines 48 greift eine Gabel 47 eines Stellhebels 50, der bei 49 drehbar gelagert ist. Auf den Lagerzapfen 49 ist eine Schraubenfeder geschoben, die den Stellhebel 50 derart unter Spannung hält, daß die Blende 45 in den Küvettenhalter 31 axial hineingeschoben wird, so daß diese unter Federkraft gegen die eingesetzte Küvette gedrückt wird. Auch hier ist zwischen der Küvette und der Mattscheibe 44 eine Blende 52 zum Abfangen von Randreflexen vorgesehen.

Der übrige Raum des Gehäuses 21 schließt die verschiebbare Meßzelle 35 ein. Er ist gegenüber dem Küvettenhalter durch eine in die Querwand 34 eingesetzte Milchglasscheibe 44 abgeschlossen. Die Meßzelle 35 ist an einem Halter 36 angebracht, der an einer Führung 37 mit Hilfe einer Schraubenspindel 38 eine parallele Längsverschiebung erhalten kann. Die Schraubenspindel 38 ist zwischen der Küvettenwand 34 und der Gehäusestirnwand 23 drehbar gelagert. Zu ihrer Verdrehung ist an ihrem aus der Stirnwand 23 heraustretenden Ende ein Handrad 39 aufgesetzt. Zum Messen der axialen Verschiebung der Meßzelle 35 durch Verdrehen der Schraubenspindel 38 dienen Meßtrommeln 40 und 41. An der Meßtrommel 40 wird die Verschiebung entsprechend einer vollen Umdrehung der Spindel 38 und an der Meßtrommel 41, die mittels einer Zahnradübersetzung 51 zweckmäßig im dekadischen Verhältnis verdreht wird, die Verschiebung entsprechend einem Teil einer Umdrehung gemessen. Die Einstellung der Teilung an den Meßtrommeln kann an den Zeigern 42 und 43 abgelesen werden.

Die Anordnung ist so getroffen, daß die Vergleichszelle 24, die Glühlampe 28, der Küvettenhalter 31 und die Meßzelle 35 in der optischen Achse der Meßeinrichtung liegen. Durch das rohrförmige Gehäuse 21 und die kreisförmigen Stirn- und Zwischenwände sind die lichtelektrischen Zellen vollständig eingeschlossen, so daß Meßfehler durch fremdes Licht vermieden werden und die Messungen bei vollem Tageslicht ausgeführt werden können.

PATENTANSPRÜCHE:

1. Einrichtung zum Messen von Helligkeitswerten mit Hilfe von zwei lichtelektrischen Zellen und einer optischen Abgleichung der Lichtwege, bei welcher die zu vergleichenden Helligkeiten durch Beleuchtung von lichtzerstreuenden Mattscheiben erzeugt werden, dadurch gekennzeichnet, daß die auf der Seite der zu messenden Helligkeit angeordnete Mattscheibe (18, 44) zwischen dem zu untersuchenden Körper (Küvette) und der Meßzelle (10, 33) angeordnet ist.

2. Einrichtung nach Anspruch 1, dadurch gekennzeichnet, daß von den auf den beiden Seiten des Küvettenhalters (31) angeordneten Blenden (45, 52) die der Lichtquelle zugekehrte Blende (45) derart verschiebbar angebracht ist, daß die zwischen ihr und der festen Blende (52) eingesetzte Küvette in einer festen Stellung gegenüber der der Meßzelle (35) zugekehrten Mattscheibe (44) eingestellt wird.

Hierzu 1 Blatt Zeichnungen

BERLIN. GEDRUCKT IN DER REICHSDRUCKEREI

Figure A.57: Robert Havemann invented the spectrophotometer in 1936.

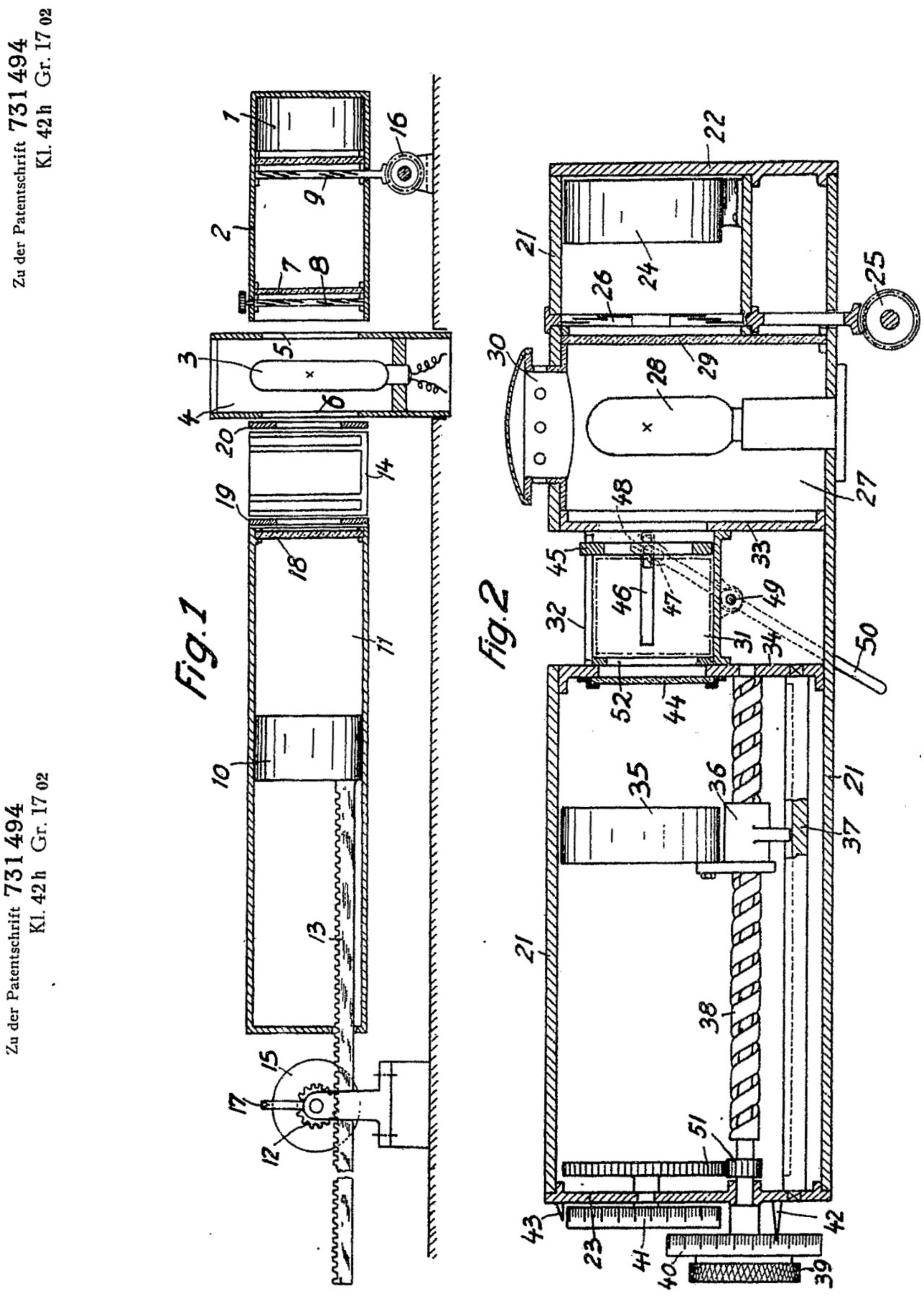
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Fig. 1
Fig. 2
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Figure A.58: Robert Havemann invented the spectrophotometer in 1936.

BIOS 1320. ***Preparation of Biological Products at Selected Targets in Germany.*** [Lots of vaccines, hormones extracted from organs, serums, etc.]

[pp. 81–82:]

Professor Kuhn was interviewed at FIAT Main-Hoechst[...]

3065 (i) Kuhn maintained that he at no stage proposed the oral administration of this drug. The substance is inactivated by protein (e.g. broth) with which it combines, and must be tested in a synthetic medium. It has been used effectively in local applications particularly in combination with sulpha drugs (for burns) as it is not inactivated by p-amino benzoic acid. Recent clinical reports are very favourable and Kuhn promised to have a summary of these prepared.

(ii) For intestinal infections experimental work and clinical trials have been carried out with the colourless diacetyl derivative of di-bromsalicil. This substance has a very low toxicity so that large doses can be given. It is however, very rapidly hydrolysed in the gut and thus a high local concentration of the hydrolysed drug can be achieved in amount above that rendered inactive by protein combination. A clinical trial on children with intestinal infections is being carried out under the supervision of Fr. Dr. Knöwenagel. Both drugs are, according to Kuhn, more expensive to produce than the usual sulpha drugs.

Other Investigations:

(i) The alkaloid claimed by Kuhn and co-workers to be present in Colorado beetle resistant strains of the potato plant and to be responsible for the protection of the plant has been isolated in a crystalline condition. It appears to be of the solanine type. The pure alkaloid has been shown to be markedly toxic to larvae of the Colorado beetle.

(ii) Work is being continued on the biochemistry of differential growth control but this was not discussed in detail. [...]

[pp. 85–86:]

Experimental work on the production of penicillin had been going on for at least 3 years at Elberfeld under the direction of Dr. Auhagen. During this time little progress appears to have been made, probably due to concentration by this firm on Marfanil [a sulfonamide antibiotic] and related compounds. In previous reports Auhagen had claimed to have produced penicillin assaying 200 units per mg. and to have obtained 50 units per ml. in broth with surface cultures. [...]

The strain he was using had been locally isolated and had been identified in England as Penicillium bruneo rubrum. [...]

It was intended to freeze dry the purified penicillin in bulk and weigh out into ampoules aseptically.

BIOS 1417. ***Food Preservation with Special Reference to Its Domestic Application.***

2. Plenora-Werke, Neuekampstrasse, Hamburg.

Herr Speck, the Manager, took us round and explained the process very thoroughly. We also spoke to several heads of departments, the laboratory director, and bakery manager. The firm was concerned entirely with the manufacture of a dried egg substitute from blood plasma. The process was started on an experimental scale in 1934, and went into production on a large scale on the outbreak of war in 1939. The factory was almost completely destroyed by bombs but was largely rebuilt in 1943. This was said to be the only factory in the world making this product from blood.

The blood came in from the slaughterhouses, some of which were close by, but a good deal also came from Denmark in casks (aluminium or lacquered) and preserved with ammonia. Every animal was vetted before slaughtering. The blood was first mixed with sodium phosphate or citrate to prevent coagulation, strained, then separated by centrifuging into the red and white fractions. Both parts were then cooled at a temperature of 2^oC. to 4^oC. in a refrigerator. It must not reach freezing point. The blood was stored at this temperature until required. Blood received from any distance was separated into red and white fractions and cooled before transport.

The two fractions were heated separately in an open steam-jacketed pan to remove about 50% of the water. Each part was then dehydrated in a spray-dryer of the type generally used for drying eggs or milk. The dried red fraction was sold for sausage-making[...]

The factory had been producing 5,000 Kg. of "Plenora" per day but could produce ten times that quantity if sufficient raw materials were available.

This process certainly produces a very useful and nutritious substitute for egg from slaughterhouse blood, which is wasted in this country [U.K.] in large quantities.

BIOS 1481. ***Albumen Substitutes from Fish: Further Report on Deutschen Eiweiss Gesellschaft.***

For the production of first grade high protein Eiweiss for medical and culinary purposes fresh skinned fillets of cod and haddock are used. This raw material gives a final product of little taste or smell and of high grade quality and solubility and is said to be better than egg albumen for most purposes where this material was formerly used. [...]

The whole process can be separated into the following stages:

(i) Preparation of raw material

(ii) Initial cooking and washing

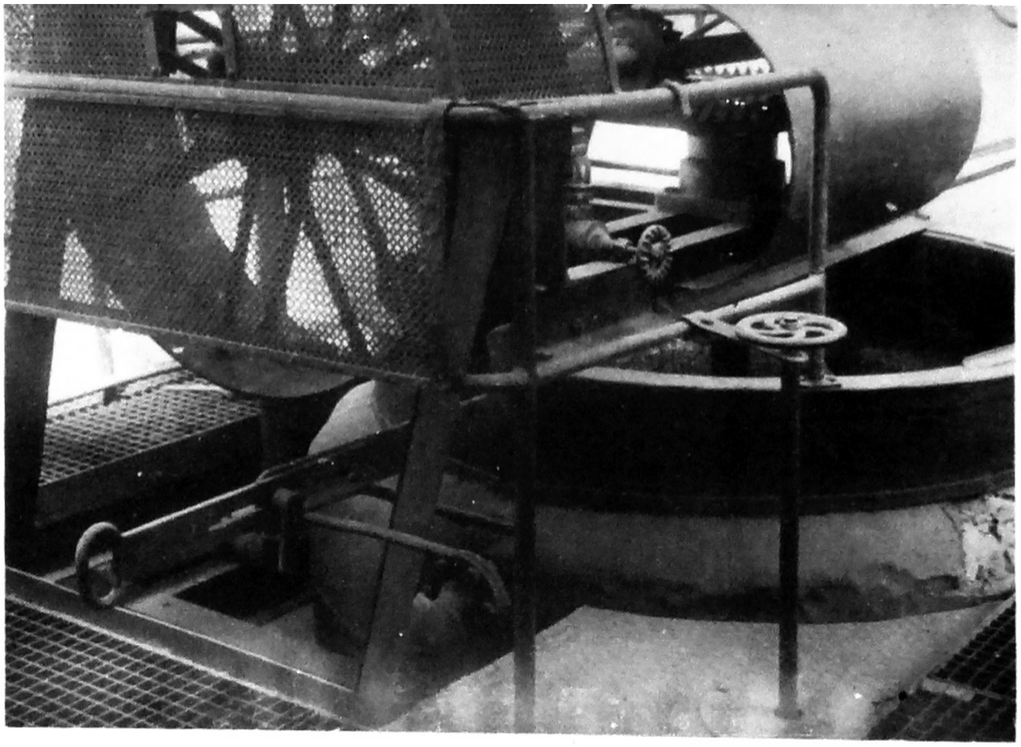
(iii) Pressing

(iv) Solvent extraction

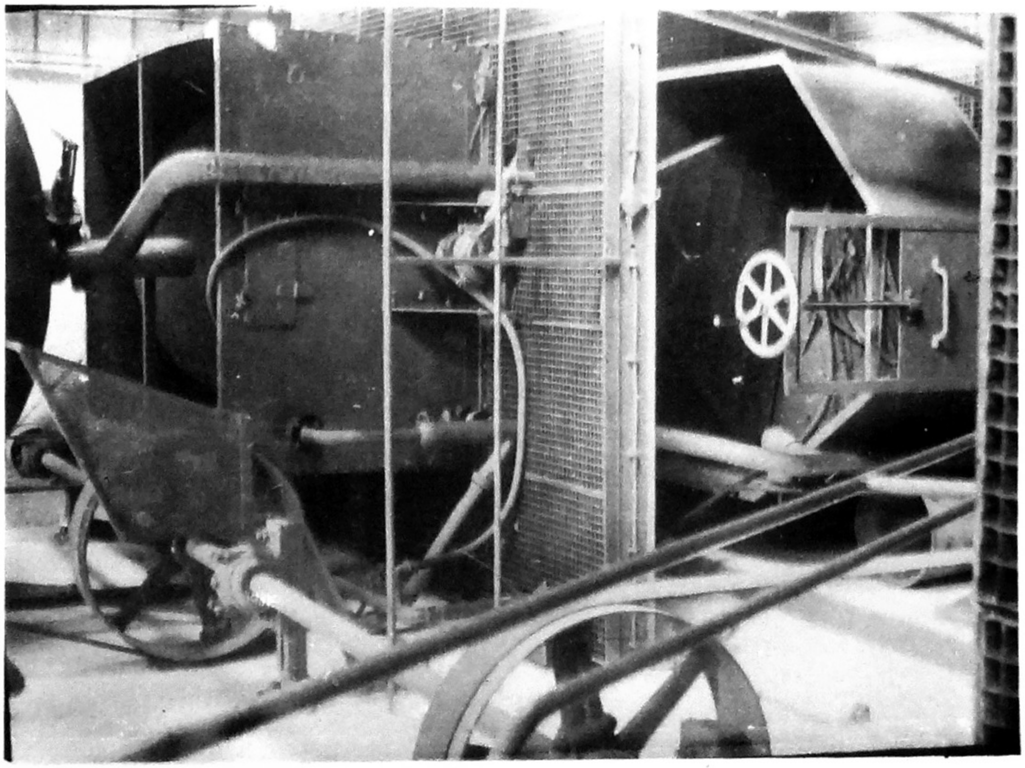
(v) Solvent recovery

(vi) Hydrolization (i.e. conversion of insoluble protein into soluble Eiweiss)

and it is therefore proposed to deal with these stages in their respective order. [...]



Steam Jacketted Acid Treatment Tank.



Perforated Reel Washer above, draining tank below.

Figure A.59: Protein purification and processing equipment for industrial manufacturing of artificial albumen products for medical and culinary applications [BIOS 1481].

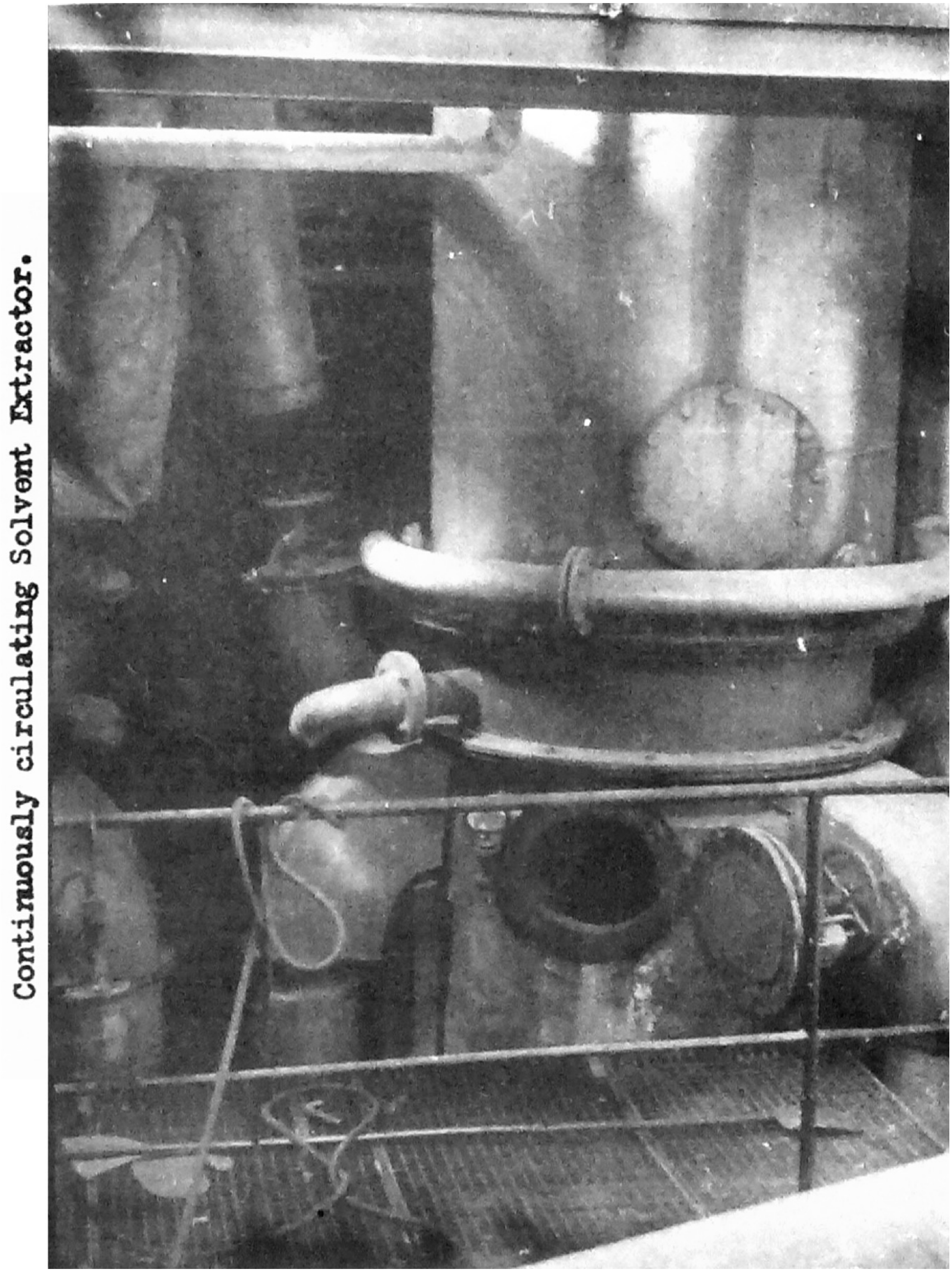
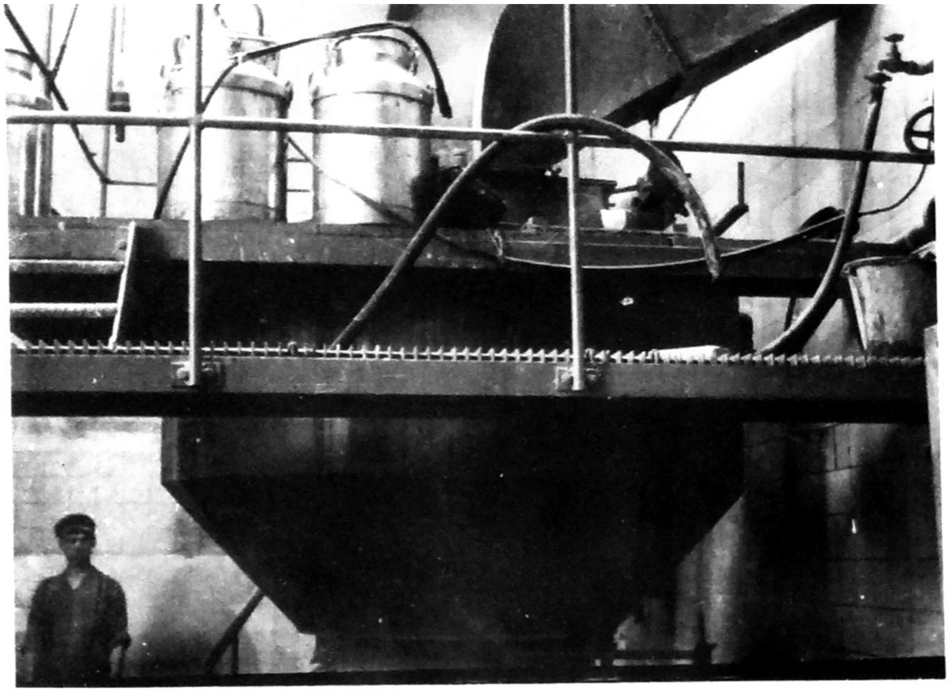
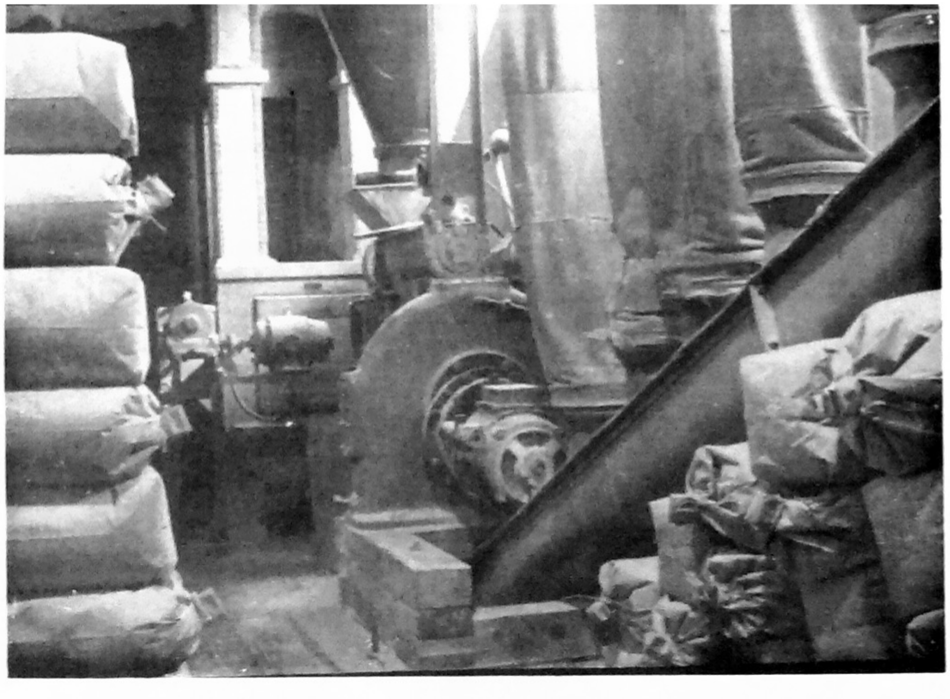

Continuously circulating Solvent Extractor.

Figure A.60: Protein purification and processing equipment for industrial manufacturing of artificial albumen products for medical and culinary applications [BIOS 1481].



Steam Jacketted conical Petzholdt Mixer or Digestion Tank.



Alpine Collople Mill 14,000 r.p.m.

Figure A.61: Protein purification and processing equipment for industrial manufacturing of artificial albumen products for medical and culinary applications [BIOS 1481].

Johanna Vogel-Prandtl. 2014. *Ludwig Prandtl: A Personal Biography Drawn from Memories and Correspondence.* Göttingen: Universitätsverlag Göttingen. pp. 3–4. http://library.oapen.org/handle/20.500.12657/31848

In the merchant's house in Hauptstraße, Alexander Prandtl [father of Ludwig Prandtl] rented a room from the widow Maria Ostermann as, at the age of 29, he started to work as a university teacher at the central agricultural school in Weihenstephan in Freising. He came from Munich, where he had been to school and then studied. After attending the polytechnic school, he gained the qualification of cultural engineer and obtained an appointment in this capacity with the federal state in Lower Bavaria. He subsequently received an appointment as professor of applied mathematics and amelioration2. In Weihenstephan, the following subjects were also taught: agricultural chemistry, agricultural equipment drawing and botanical drawing, the anatomy and physiology of domestic animals, forestry, meteorology, as well as other subjects. A brewery for study purposes was attached to the institution. Alexander carried out scientific work in the laboratory of the dairy research station. In the period between 1870 and 1875, he mostly worked on the construction of a continuously operating milk centrifuge. The idea of studying the separation of cream from milk using centrifugal force came from his brother Antonin, who had published a work on this subject eleven years previously in the polytechnic journal. He initially approached the practical task of making it possible to concentrate milk using his knowledge of chemistry. Alexander was successful in adding some significant improvements to his brother's discovery and, in 1875, he demonstrated his cream separator at the World's Fair in Frankfurt am Main, Germany. This machine, which was the first continuously operating milk centrifuge in the world, attracted great attention and provided the impulse for further developments. The same model was later exhibited in the *Deutsches Museum* (German Museum), in the Department of Dairy Farming. In the next few years, he developed a new piece of equipment: a milk separator that could be used to produce milk in parts without it creaming. In addition, Alexander published a number of scientific papers in the Weihenstephan Milk Journal, whose themes I would like to mention here for reasons of completeness. In 1877 the article "On the theoretically expected effect of creaming caused by centrifugal forces" and, in 1879, "The effect of currents caused by heating or cooling milk" were published.

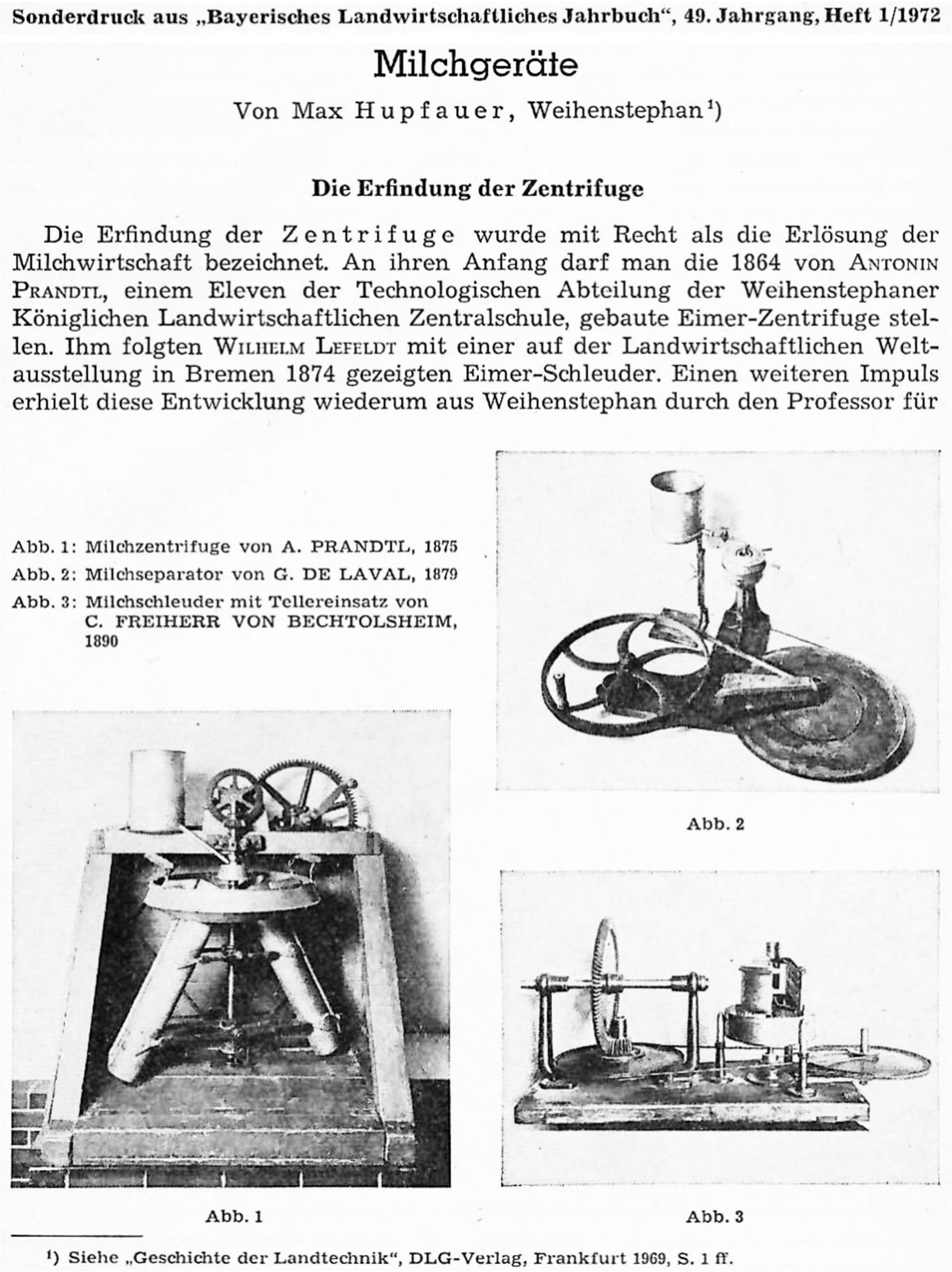
Max Hupfauer. 1972. Milchgeräte. *Bayerisches Landwirtschaftliches Jahrbuch* 49:1: 105–124. https://mediatum.ub.tum.de/1554376

Die Erfindung der Zentrifuge wurde mit Recht als die Erlösung der Milchwirtschaft bezeichnet. An ihren Anfang darf man die 1864 von ANTONIN PRANDTL, einem Eleven der Technologischen Abteilung der Weihenstephaner Königlichen Landwirtschaftlichen Zentralschule, gebaute Eimer-Zentrifuge stellen. Ihm folgten WILHELM LEFELDT mit einer auf der Landwirtschaftlichen Weltausstellung in Bremen 1874 gezeigten Eimer-Schleuder. Einen weiteren Impuls erhielt diese Entwicklung wiederum aus Weihenstephan durch den Professor für Landwirtschaft, Dr. ALEXANDER PRANDTL, einem Bruder des vorhin erwähnten, der 1875 eine Milchschleuder konstruiert hatte, welche bereits den Gedanken der ununterbrochenen Entrahmung verwirklichen sollte (Abb. 1). Dieses Ziel erreichte jedoch erst 1878 der schwedische Ingenieur Dr. GUSTAV PATRlK DE LAVAL, welcher durch Veröffentlichungen über LEFELDT's Milchschleuder zu seiner bahnbrechenden Erfindung angeregt worden war (Abb. 2).

Absatzgebiete waren aber nur größere Molkereien, bis es DE LAVAL 1886 gelang, eine Ausführung für Handbetrieb herzustellen. Ausschlaggebend für die weitere Verbreitung wurde 1890 die Erfindung des Münchener Ingenieurs CARL FREIHERR VON BECHTOLSHEIM (Abb. 3), mit deren Hilfe störende Strömungen in der umlaufenden Zentrifugentrommel beseitigt und damit die Stundenleistung, die Entrahmungsschärfe sowie die Ausbeute wesentlich erhöht werden. DE LAVAL erkennt die weittragende Bedeutung dieser Erfindung und kauft das Deutsche Reichspatent Nr. 48 615 für die von ihm inzwischen gegründete Separatorenfabrik in Stockholm auf. Um die Jahrhundertwende hatten bereits mehr als 150 000 Maschinen das Werk verlassen und erst, als am 14. Juli 1903 das ALFA-LAVAL-Patent erlosch, konnten auch andere Fabrikanten gleichwertige Geräte liefern. Über die stürmische Entwicklung der Milchverarbeitung mit Hilfe von Zentrifugen gibt Professor MARTINYS Bericht Auskunft, wonach im Jahre 1907 bei einer Gesamtzahl von 347 649 landwirtschaftlichen Betrieben 336 906 Milchschleudern benutzten und in gewerblichen Betrieben außerdem 10 743 Molkerei-Zentrifugen gezählt wurden. Diese Mechanisierung der Rahmgewinnung war die Grundlage der weithin verbreiteten bäuerlichen Butterherstellung.

The invention of the centrifuge was rightly described as the salvation of the dairy industry. It began with the bucket centrifuge built in 1864 by ANTONIN PRANDTL, a student in the technology department of the Royal Agricultural College in Weihenstephan. He was followed by WILHELM LEFELDT with a bucket centrifuge exhibited at the World Agricultural Exhibition in Bremen in 1874. This development received further impetus from Weihenstephan through the Professor of Agriculture, Dr. ALEXANDER PRANDTL, a brother of the aforementioned, who had constructed a milk centrifuge in 1875, which was already intended to realize the idea of continuous operation (Fig. 1). However, this goal was not achieved until 1878 by the Swedish engineer Dr. GUSTAV PATRlK DE LAVAL, who had been inspired by publications on LEFELDT's milk extractor to make his groundbreaking invention (Fig. 2).

However, only larger dairies sold them until DE LAVAL succeeded in producing a version for manual operation in 1886. In 1890, the invention of the Munich engineer CARL FREIHERR VON BECHTOLSHEIM (Fig. 3) eliminated the disturbing currents in the rotating centrifuge drum, thus significantly increasing the hourly output, the skimming sharpness, and the yield, which was decisive for further distribution. DE LAVAL recognized the far-reaching significance of this invention and bought the German Imperial Patent No. 48,615 for the separator factory he had since founded in Stockholm. By the turn of the century, more than 150,000 machines had already left the factory and it was only when the ALFA-LAVAL patent expired on 14 July 1903 that other manufacturers were able to supply equivalent devices. Professor MARTINY's report provides information on the rapid development of milk processing with the aid of centrifuges, according to which in 1907 336,906 milk centrifuges were used on a total of 347,649 farms and 10,743 dairy centrifuges were also counted on commercial farms. This mechanization of cream production was the basis of widespread farm butter production.



Sonderdruck aus „Bayerisches Landwirtschaftliches Jahrbuch", 49. Jahrgang, Heft 1/1972

Milchgeräte

Von Max Hupfauer, Weihenstephan[1])

Die Erfindung der Zentrifuge

Die Erfindung der Zentrifuge wurde mit Recht als die Erlösung der Milchwirtschaft bezeichnet. An ihren Anfang darf man die 1864 von Antonin Prandtl, einem Eleven der Technologischen Abteilung der Weihenstephaner Königlichen Landwirtschaftlichen Zentralschule, gebaute Eimer-Zentrifuge stellen. Ihm folgten Wilhelm Lefeldt mit einer auf der Landwirtschaftlichen Weltausstellung in Bremen 1874 gezeigten Eimer-Schleuder. Einen weiteren Impuls erhielt diese Entwicklung wiederum aus Weihenstephan durch den Professor für

Abb. 1: Milchzentrifuge von A. PRANDTL, 1875
Abb. 2: Milchseparator von G. DE LAVAL, 1879
Abb. 3: Milchschleuder mit Tellereinsatz von C. FREIHERR VON BECHTOLSHEIM, 1890

Abb. 2

Abb. 1

Abb. 3

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[1]) Siehe „Geschichte der Landtechnik", DLG-Verlag, Frankfurt 1969, S. 1 ff.

Figure A.62: Centrifuges for milk separation and other applications were first developed in the German-speaking world, beginning no later than 1864 [https://mediatum.ub.tum.de/1554376].

BIOS 1487. *Chemical Laboratory Instrumentation in Germany.* pp. 101–109.

APPENDIX 2

TRANSLATION

THE PHYWE Ultracentrifuge

Physikalische Werkstatten A.G. Göttingen (Hann.)

Development of the Ultracentrifuge

In 1923, The Svedberg and J. B. Nichols built a centrifuge in which optical observation of the sedimentation of dissolved particles was possible during the rotation. [...]

Characteristics of the PHYWE Ultracentrifuge

Phywe A.G., Göttingen, and G. Schramm (Kaiser Wilhelm Institut für Biochemie, Berlin-Dahlem) developed jointly an ultracentrifuge, with air drive, which is simple to operate and within the means of every laboratory, but which, nevertheless, possesses a sufficiently high separating power. The choice of an air drive, in conjunction with a special damping device, ensured smooth running of the centrifuge. In its simplest form, the Phywe ultracentrifuge is suitable for preparative work. It can, however, also be fitted with a second rotor for optical observation and hence for analytical work. The optical method adopted is the "schlieren" method, but the apparatus is constructed so that the scale method can also be used. [...]

General Considerations on Measurements with the Ultracentrifuge

The ultracentrifuge is one of the most important instruments for the investigation of high molecular or colloidal substances. The field of application lies in the region where most chemical and physical methods of separation and characterisation of the substances fail. The ultracentrifuge serves for the determination of the size and the homogeneity of a molecular species. For this purpose two methods are used: (1) Determination of the sedimentation velocity, (2) the sedimentation equilibrium. [...]

Applications of the Ultracentrifuge

The ultracentrifuge can be used for the investigation of the most varied range of substances. Doubtless the greatest successes have been obtained in the field of the proteins, but promising work has also been done in the case of the carbohydrates, polystyrols, and similar organic products, inorganic colloids and inorganic salts.

The work on the proteins has shown that the naturally occurring proteins are, in respect of molecular weight, always homogeneous substances. Even complex systems such as serum (References 9 and 10) or milk proteins (Reference 11) can be analysed with the aid of the ultracentrifuge. They are always resolved into a limited number of homogeneous components. Systematic investigations of the proteins from different species have led to interesting genetical relations. In the examination of enzymes, sera and antibodies, snake venom and other physiologically active proteins, the ultracentrifuge has strikingly proved its value (Reference 3). The newer developments in the field of virus proteins and bacteriophages would be inconceivable without the ultracentrifuge. (For the application of the ultracentrifuge in virus research see Reference 12). [...]

References: [...]

3. T. Svedberg, Koll. Zeit., 1938, 85, 119.

9. P. von Matzenbecher, Biochem Z, 1933, 266, 226.

10. A. S. McFarlane, Biochem. J., 1935, 29, 660.

11. K. O. Pedersen, Biochem. J., 1936, 30, 948.

12. Handbuch der Virusforschung, R. Doerr u C. Hallauer, Julius Springer (1938).

[Centrifuges for milk separation and other applications were first developed in the German-speaking world, beginning no later than 1864 (pp. 2394–2396).

The ultracentrifuge described in BIOS 1487 was one of several that were developed by Gerhard Schramm for his groundbreaking research on viruses and proteins.

Ultracentrifuges are now extensively used in biology and chemistry laboratories worldwide.

The next page shows a diagram of the ultracentrifuge from BIOS 1487.]

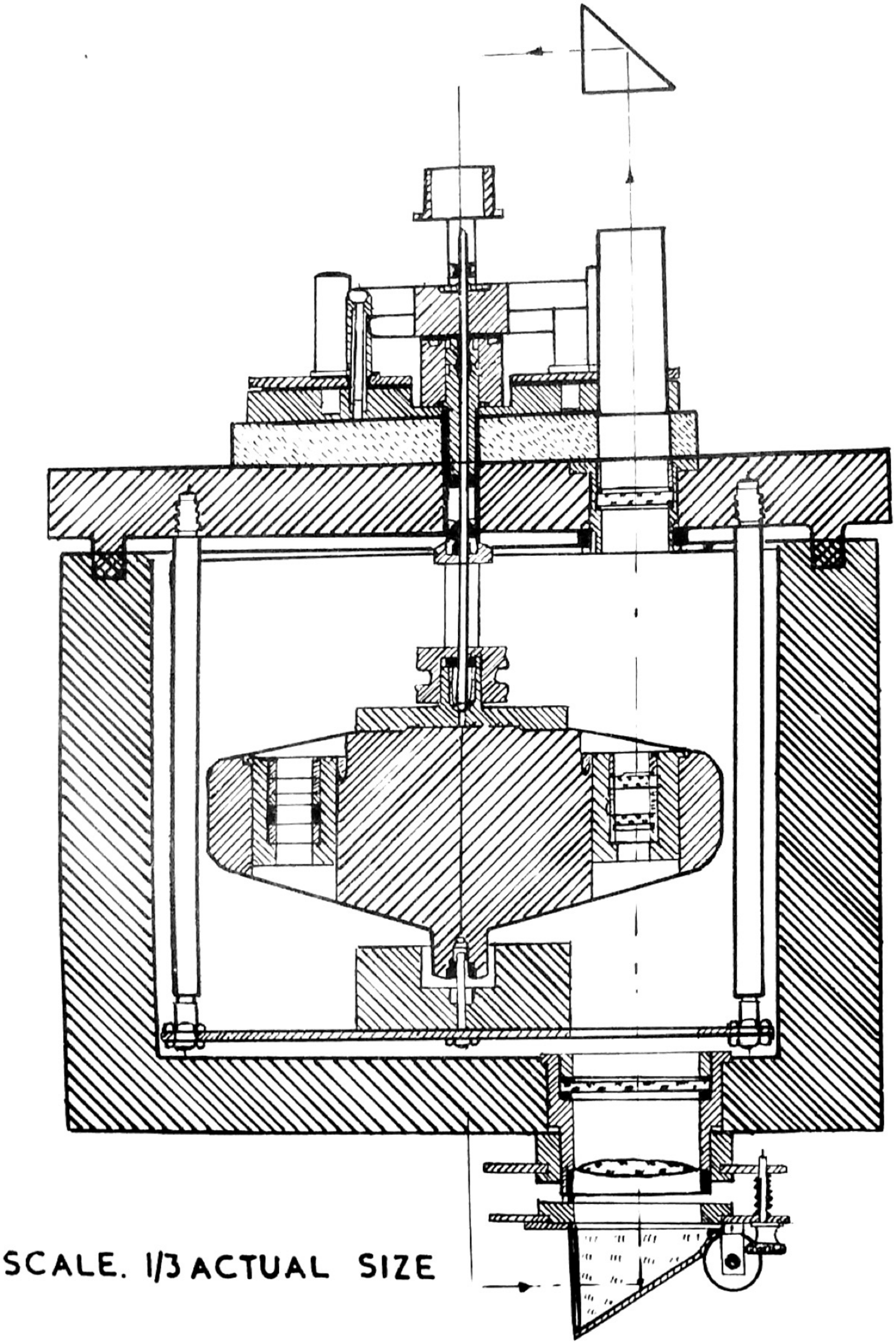

SCALE. 1/3 ACTUAL SIZE

Figure A.63: Ultracentrifuge developed by Gerhard Schramm and collaborators beginning in the 1930s [BIOS 1487].

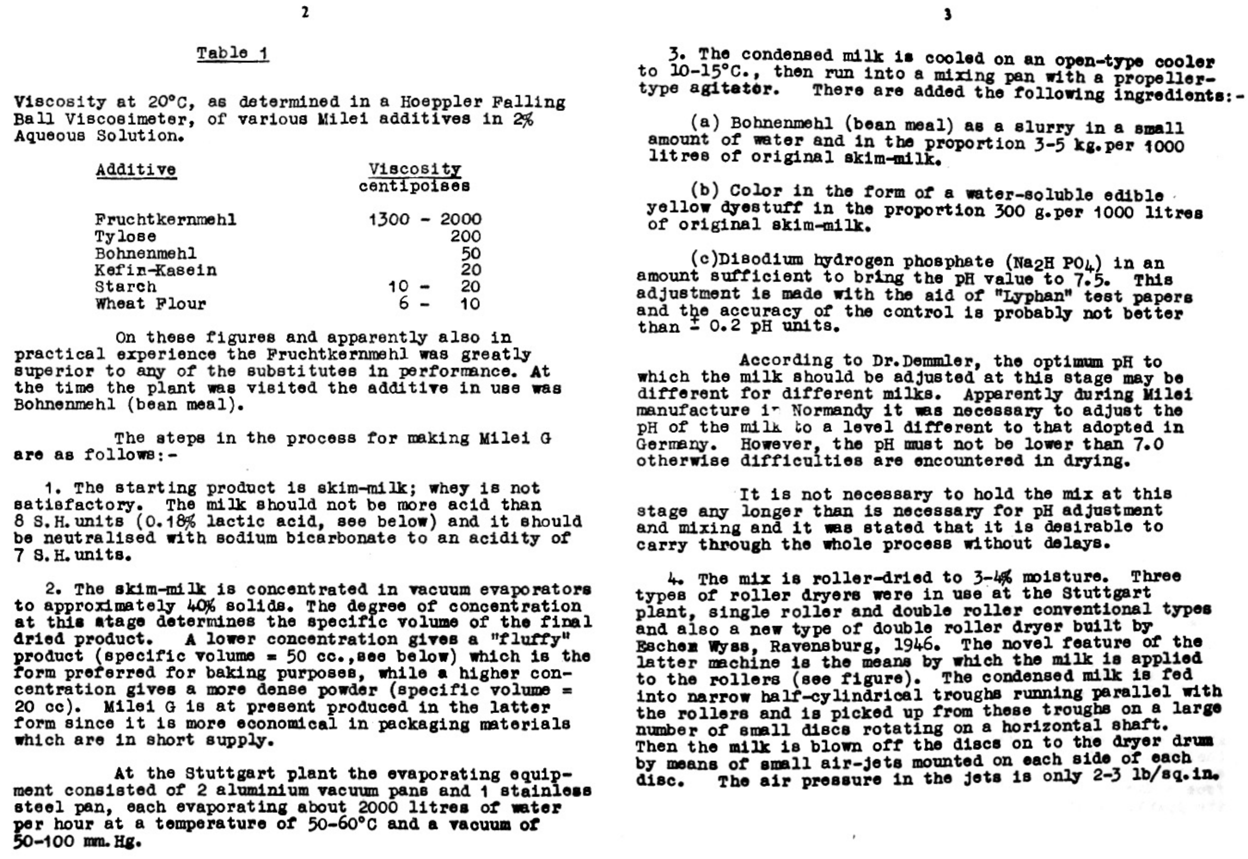


Table 1

Viscosity at 20°C, as determined in a Hoeppler Falling Ball Viscosimeter, of various Milei additives in 2% Aqueous Solution.

Additive	Viscosity centipoises
Fruchtkernmehl	1300 - 2000
Tylose	200
Bohnenmehl	50
Kefin-Kasein	20
Starch	10 - 20
Wheat Flour	6 - 10

On these figures and apparently also in practical experience the Fruchtkernmehl was greatly superior to any of the substitutes in performance. At the time the plant was visited the additive in use was Bohnenmehl (bean meal).

The steps in the process for making Milei G are as follows:-

1. The starting product is skim-milk; whey is not satisfactory. The milk should not be more acid than 8 S.H. units (0.18% lactic acid, see below) and it should be neutralised with sodium bicarbonate to an acidity of 7 S.H. units.

2. The skim-milk is concentrated in vacuum evaporators to approximately 40% solids. The degree of concentration at this stage determines the specific volume of the final dried product. A lower concentration gives a "fluffy" product (specific volume = 50 cc., see below) which is the form preferred for baking purposes, while a higher concentration gives a more dense powder (specific volume = 20 cc). Milei G is at present produced in the latter form since it is more economical in packaging materials which are in short supply.

At the Stuttgart plant the evaporating equipment consisted of 2 aluminium vacuum pans and 1 stainless steel pan, each evaporating about 2000 litres of water per hour at a temperature of 50-60°C and a vacuum of 50-100 mm. Hg.

3. The condensed milk is cooled on an open-type cooler to 10-15°C., then run into a mixing pan with a propeller-type agitator. There are added the following ingredients:-

(a) Bohnenmehl (bean meal) as a slurry in a small amount of water and in the proportion 3-5 kg. per 1000 litres of original skim-milk.

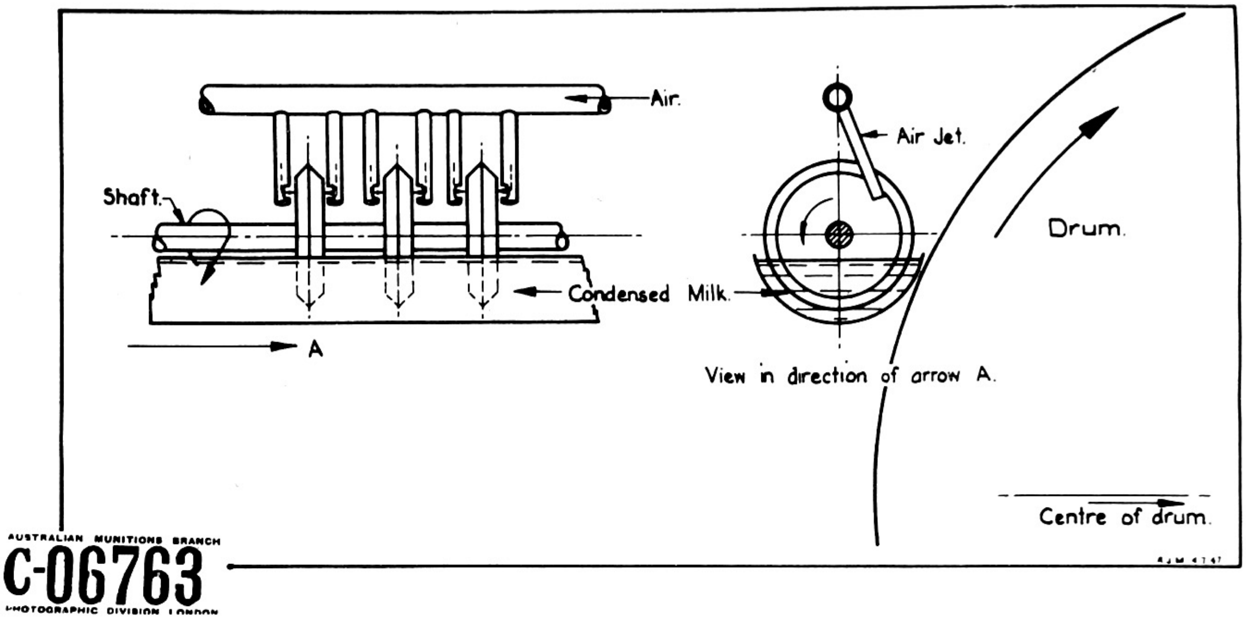
(b) Color in the form of a water-soluble edible yellow dyestuff in the proportion 300 g. per 1000 litres of original skim-milk.

(c) Disodium hydrogen phosphate ($Na_2H\ PO_4$) in an amount sufficient to bring the pH value to 7.5. This adjustment is made with the aid of "Lyphan" test papers and the accuracy of the control is probably not better than ± 0.2 pH units.

According to Dr. Demmler, the optimum pH to which the milk should be adjusted at this stage may be different for different milks. Apparently during Milei manufacture in Normandy it was necessary to adjust the pH of the milk to a level different to that adopted in Germany. However, the pH must not be lower than 7.0 otherwise difficulties are encountered in drying.

It is not necessary to hold the mix at this stage any longer than is necessary for pH adjustment and mixing and it was stated that it is desirable to carry through the whole process without delays.

4. The mix is roller-dried to 3-4% moisture. Three types of roller dryers were in use at the Stuttgart plant, single roller and double roller conventional types and also a new type of double roller dryer built by Escher Wyss, Ravensburg, 1946. The novel feature of the latter machine is the means by which the milk is applied to the rollers (see figure). The condensed milk is fed into narrow half-cylindrical troughs running parallel with the rollers and is picked up from these troughs on a large number of small discs rotating on a horizontal shaft. Then the milk is blown off the discs on to the dryer drum by means of small air-jets mounted on each side of each disc. The air pressure in the jets is only 2-3 lb/sq.in.



AUSTRALIAN MUNITIONS BRANCH
C-06763
PHOTOGRAPHIC DIVISION LONDON

Figure A.64: Protein purification and processing for industrial manufacturing of Milei artificial albumen products [BIOS 1513].

BIOS 1513. ***The Manufacture of "Milei" Egg Substitutes.***

Milei G (gelb) is an egg-yolk or whole-egg substitute which is described as having the binding properties of egg in bakery products and household cooking. To some extent these binding properties are due to a vegetable constituent which is added. [...]

Milei W (Weiss) is an egg-white substitute which has the whipping properties of egg-white and is used mainly for meringue-type bakery products. [...]

[See the figure from this report on the preceding page.]

BIOS 1776. ***Yeast and Citric Acid Production from Sugar Beet Molasses in Germany.***

The following report deals with only two aspects of the industrial utilization of beet molasses, namely the manufacture of yeast and citric acid. Yeast production is a relatively old and well-established industry, hence only the processes used by one of the largest German firms in the field were examined. In contrast to the yeast industry, fermentation citric acid production is of more recent origin and only became established in Germany during the war. The first plant operated by C. H. Boehringer Sohn, Ingelheim on the Rhine, started production in 1938–1939. Another entirely independent company, the Chemische Fabrik J. A. Benkiser at Ladenburg, near Heidelberg, planned erection of a new fermentation citric acid plant in the same year. This plant was built during the war but did not get into production until January, 1945. Both companies had been familiar with the chemical manufacture of citric acid for many years, importing calcium citrate as the raw material. Research was carried out on the fermentation process and its results, combined with industrial experience from Czechoslovakia, enabled each company to develop its own process. Contrary to the history of most citric acid producers in other countries, both of the German plants were built for the use of sugar beet molasses as a raw material and neither have operated with sugar in various stages of refining.

[Please see figures from this report on the following pages.]

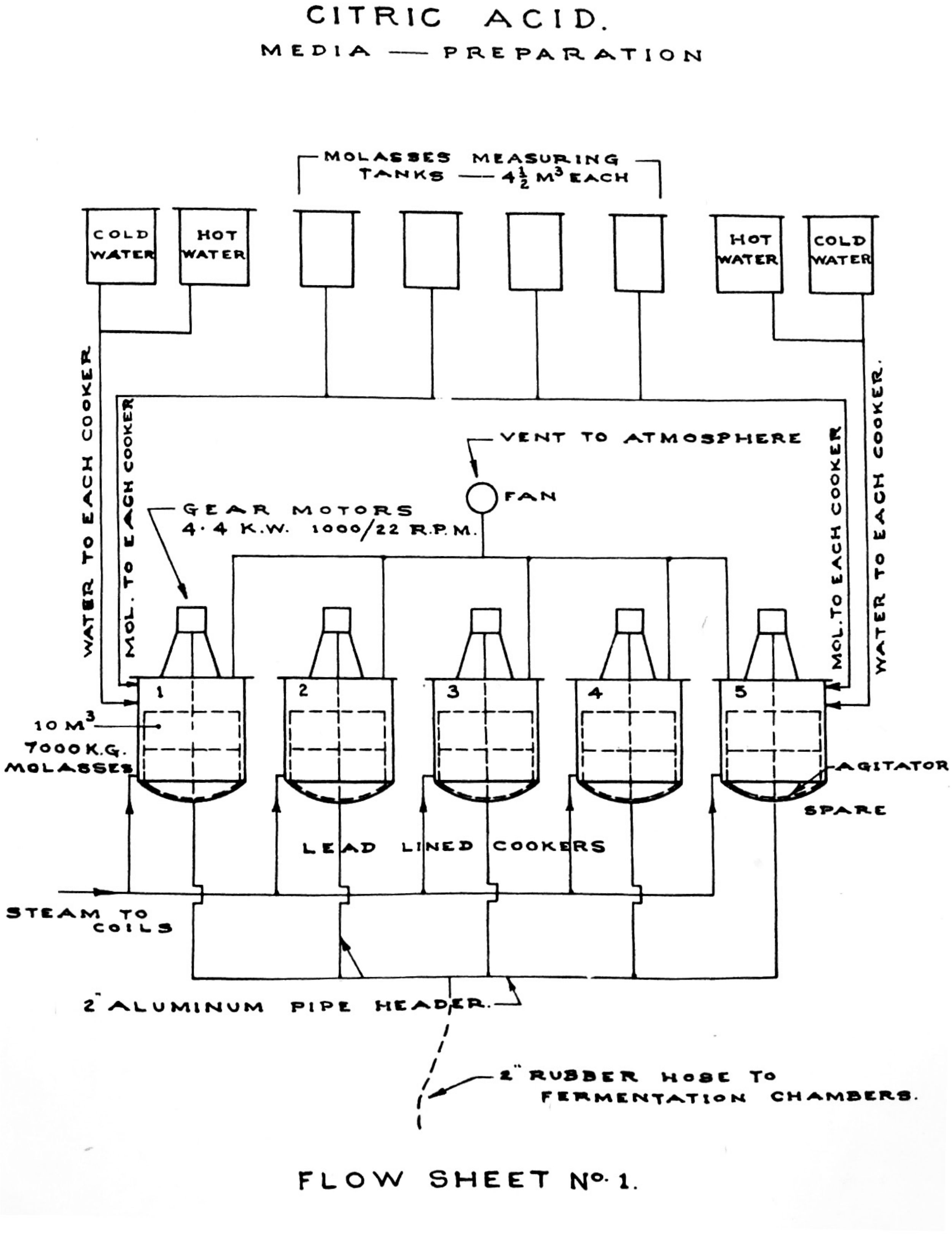

CITRIC ACID.
MEDIA — PREPARATION
MOLASSES MEASURING TANKS — 4½ M³ EACH
COLD WATER
HOT WATER
HOT WATER
COLD WATER
WATER TO EACH COOKER
MOL. TO EACH COOKER
MOL. TO EACH COOKER
WATER TO EACH COOKER.
VENT TO ATMOSPHERE
FAN
GEAR MOTORS
4·4 K.W. 1000/22 R.P.M.
1
2
3
4
5
10 M³
7000 K.G. MOLASSES
AGITATOR
SPARE
LEAD LINED COOKERS
STEAM TO COILS
2" ALUMINUM PIPE HEADER.
2" RUBBER HOSE TO FERMENTATION CHAMBERS.
FLOW SHEET No. 1.

Figure A.65: Large-scale production and purification of citric acid from yeast fermenters [BIOS 1776].

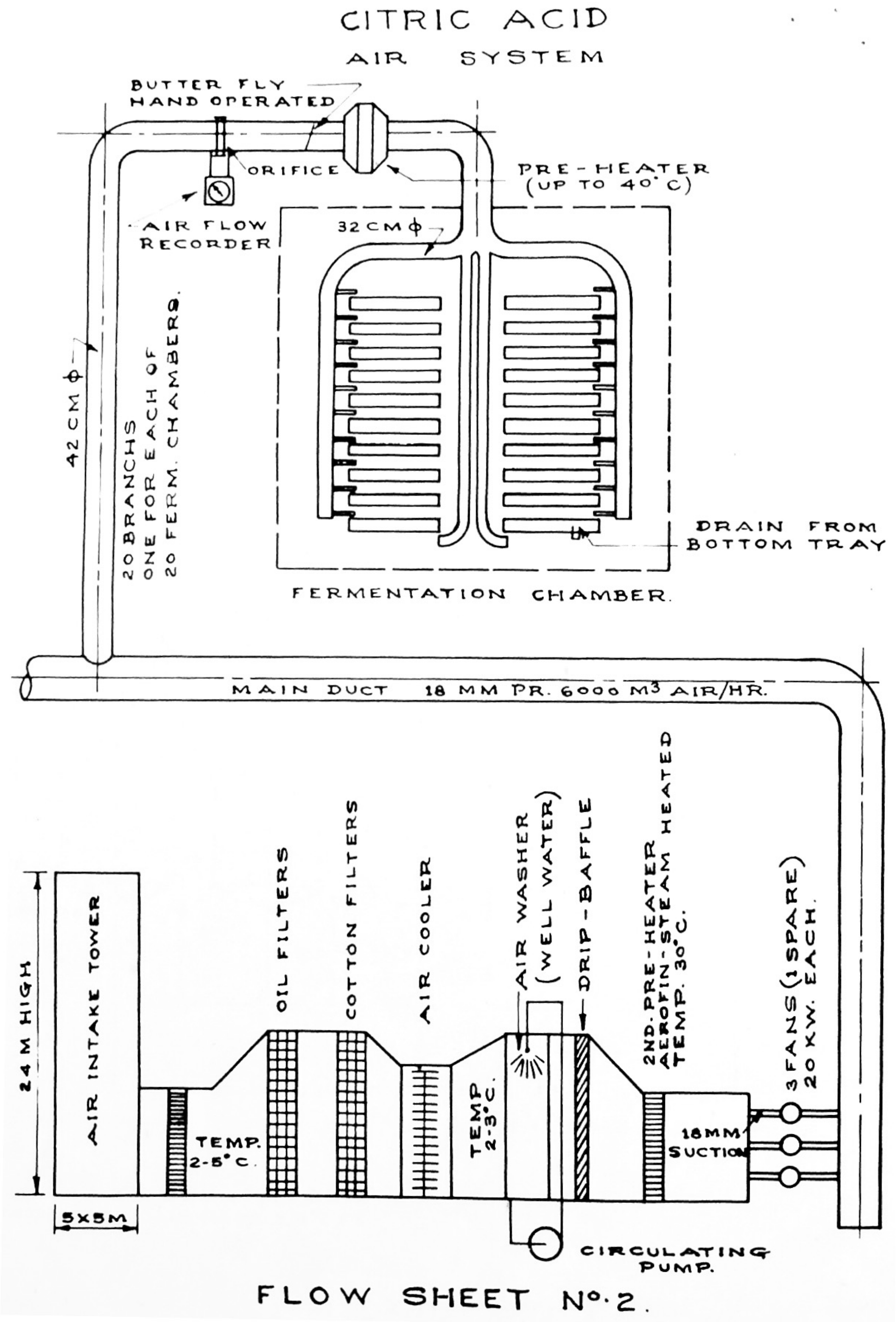

CITRIC ACID
AIR SYSTEM
BUTTER FLY HAND OPERATED
ORIFICE
PRE-HEATER (UP TO 40°C)
AIR FLOW RECORDER
32 CM φ
42 CM φ
20 BRANCHS ONE FOR EACH OF 20 FERM. CHAMBERS.
DRAIN FROM BOTTOM TRAY
FERMENTATION CHAMBER.
MAIN DUCT 18 MM PR. 6000 M3 AIR/HR.
24 M HIGH
AIR INTAKE TOWER
5X5M
TEMP. 2-5°C.
OIL FILTERS
COTTON FILTERS
AIR COOLER
TEMP. 2-3°C.
AIR WASHER (WELL WATER)
DRIP-BAFFLE
2ND. PRE-HEATER AEROFIN-STEAM HEATED TEMP. 30°C.
3 FANS (1 SPARE) 20 KW. EACH.
18MM SUCTION
CIRCULATING PUMP.
FLOW SHEET No. 2.

Figure A.66: Large-scale production and purification of citric acid from yeast fermenters [BIOS 1776].

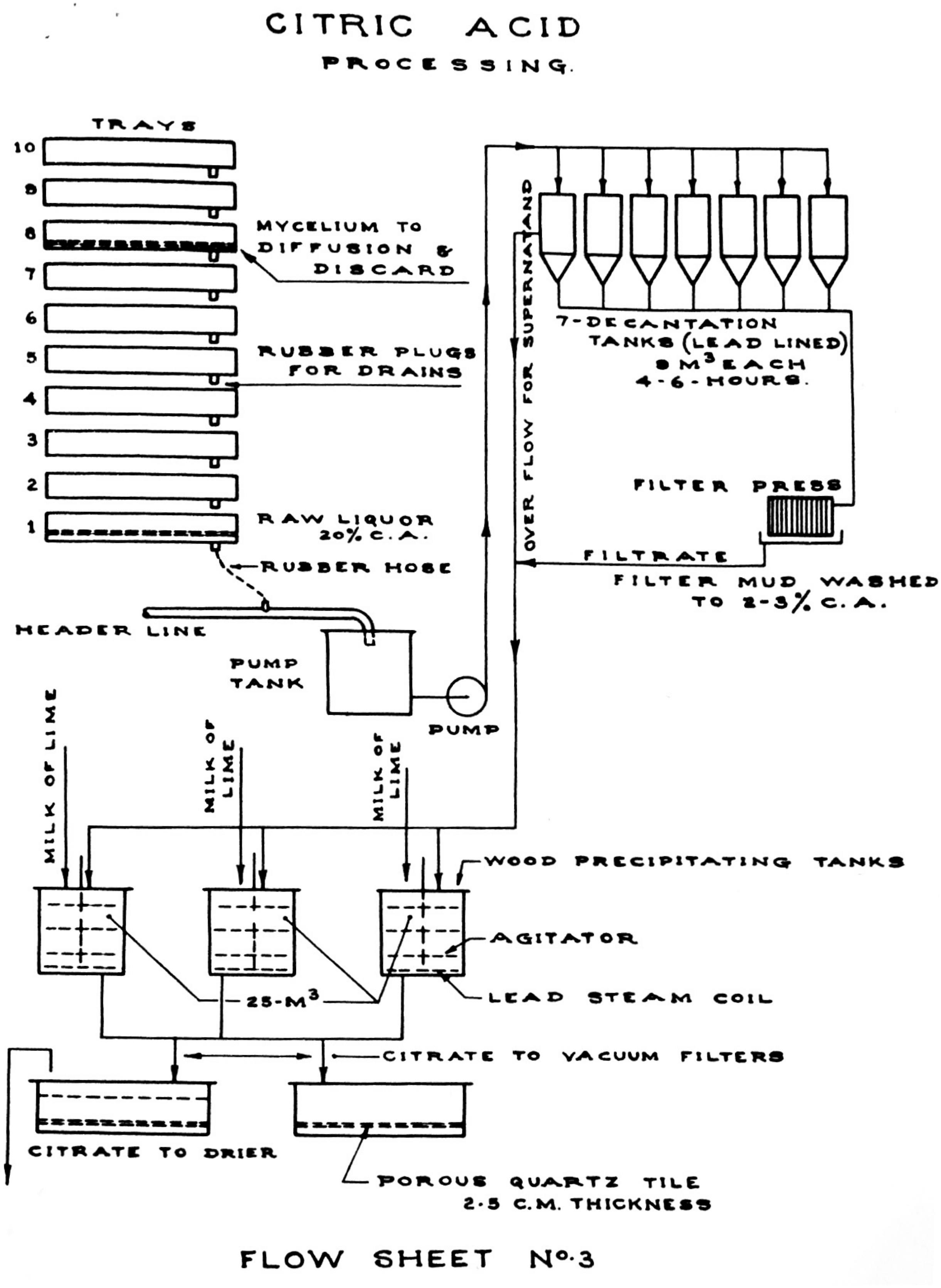

CITRIC ACID
PROCESSING.
TRAYS
10
9
8
7
6
5
4
3
2
1
MYCELIUM TO DIFFUSION & DISCARD
RUBBER PLUGS FOR DRAINS
RAW LIQUOR 20% C.A.
RUBBER HOSE
HEADER LINE
PUMP TANK
PUMP
OVER FLOW FOR SUPERNATAND
7-DECANTATION TANKS (LEAD LINED) 9 M3 EACH 4-6-HOURS.
FILTER PRESS
FILTRATE
FILTER MUD WASHED TO 2-3% C.A.
MILK OF LIME
MILK OF LIME
MILK OF LIME
WOOD PRECIPITATING TANKS
AGITATOR
25-M3
LEAD STEAM COIL
CITRATE TO VACUUM FILTERS
CITRATE TO DRIER
POROUS QUARTZ TILE 2.5 C.M. THICKNESS
FLOW SHEET No.3

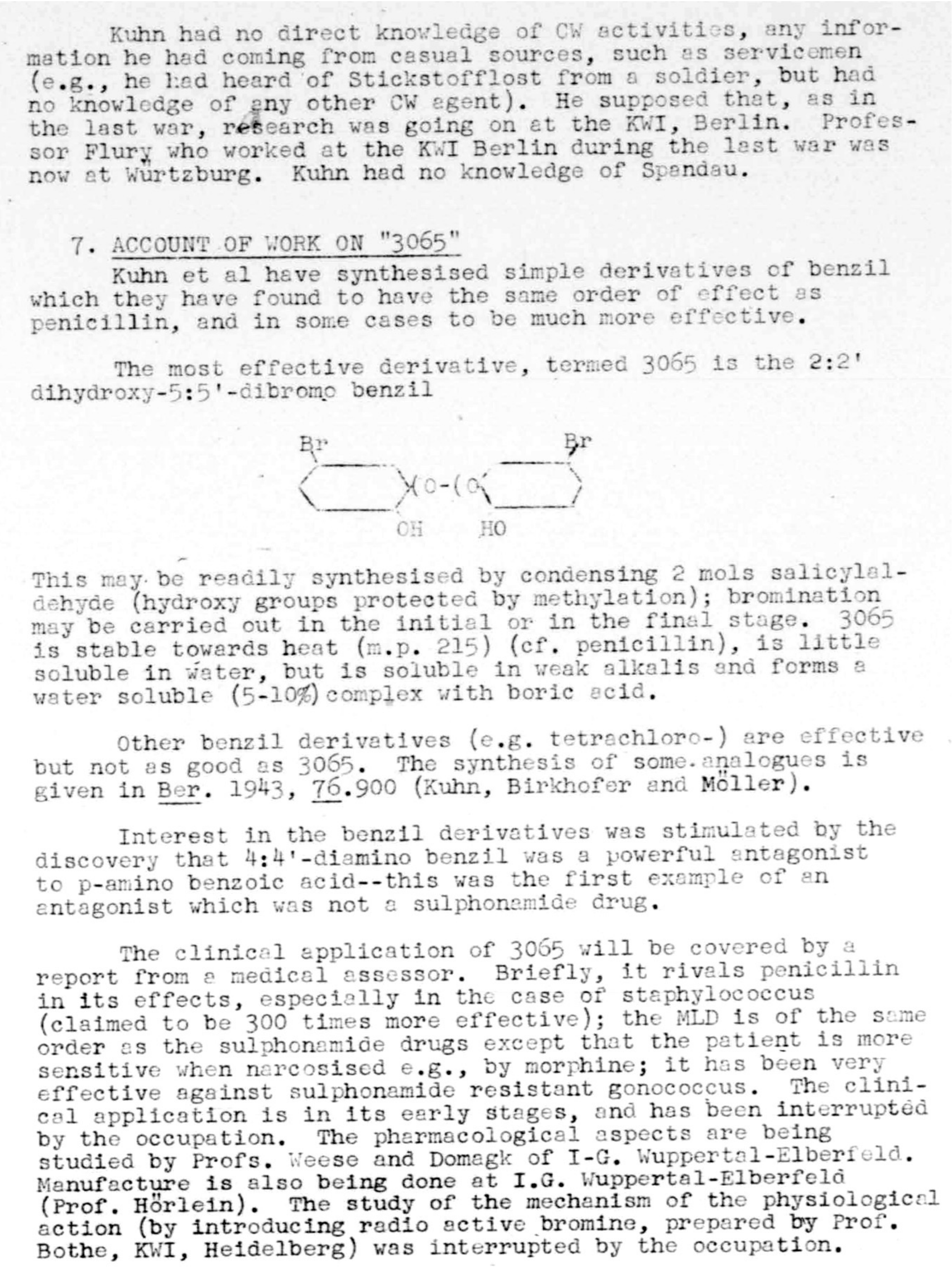
Figure A.67: Large-scale production and purification of citric acid from yeast fermenters [BIOS 1776].

CIOS ER 1. ***Professor R. Kuhn at the KWI, Heidelberg.***

[Please see p. 2406.]

CIOS ER 10. ***K.W.I. für Medizinische Forschung, Heidelberg.***

[Please see pp. 2407–2411.]



Kuhn had no direct knowledge of CW activities, any information he had coming from casual sources, such as servicemen (e.g., he had heard of Stickstofflost from a soldier, but had no knowledge of any other CW agent). He supposed that, as in the last war, research was going on at the KWI, Berlin. Professor Flury who worked at the KWI Berlin during the last war was now at Würtzburg. Kuhn had no knowledge of Spandau.

7. ACCOUNT OF WORK ON "3065"

Kuhn et al have synthesised simple derivatives of benzil which they have found to have the same order of effect as penicillin, and in some cases to be much more effective.

The most effective derivative, termed 3065 is the 2:2' dihydroxy-5:5'-dibromo benzil

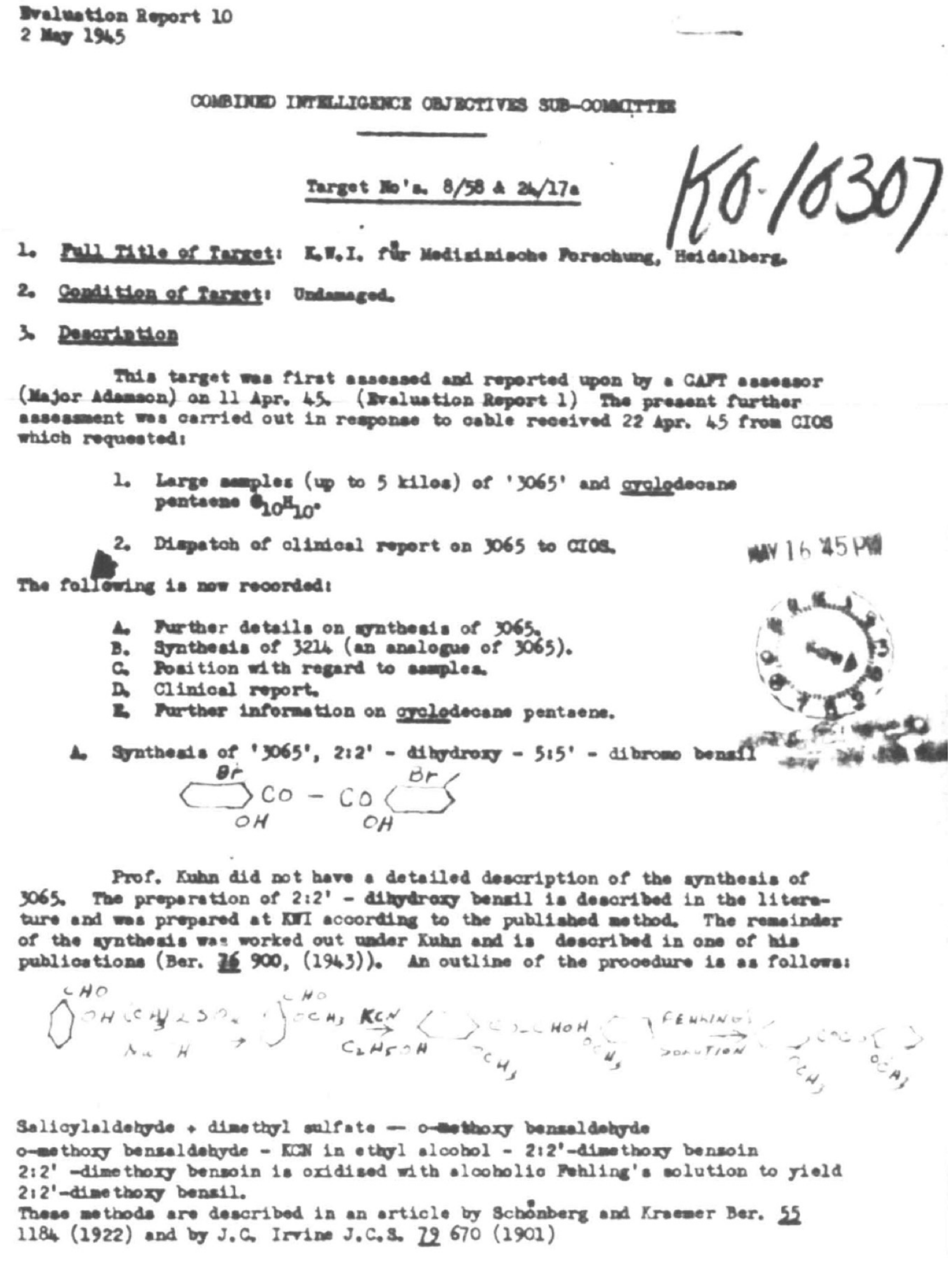
This may be readily synthesised by condensing 2 mols salicylaldehyde (hydroxy groups protected by methylation); bromination may be carried out in the initial or in the final stage. 3065 is stable towards heat (m.p. 215) (cf. penicillin), is little soluble in water, but is soluble in weak alkalis and forms a water soluble (5-10%) complex with boric acid.

Other benzil derivatives (e.g. tetrachloro-) are effective but not as good as 3065. The synthesis of some analogues is given in Ber. 1943, 76.900 (Kuhn, Birkhofer and Möller).

Interest in the benzil derivatives was stimulated by the discovery that 4:4'-diamino benzil was a powerful antagonist to p-amino benzoic acid--this was the first example of an antagonist which was not a sulphonamide drug.

The clinical application of 3065 will be covered by a report from a medical assessor. Briefly, it rivals penicillin in its effects, especially in the case of staphylococcus (claimed to be 300 times more effective); the MLD is of the same order as the sulphonamide drugs except that the patient is more sensitive when narcosised e.g., by morphine; it has been very effective against sulphonamide resistant gonococcus. The clinical application is in its early stages, and has been interrupted by the occupation. The pharmacological aspects are being studied by Profs. Weese and Domagk of I-G. Wuppertal-Elberfeld. Manufacture is also being done at I.G. Wuppertal-Elberfeld (Prof. Hörlein). The study of the mechanism of the physiological action (by introducing radio active bromine, prepared by Prof. Bothe, KWI, Heidelberg) was interrupted by the occupation.

Figure A.68: Richard Kuhn developed a synthetic antibiotic dubbed “3065” [CIOS ER 1].


Br
CO – CO
Br
OH
OH
CHO
OH (CH3)2SO4
NaOH
CHO
OCH3
KCN
C2H5OH
CO–CHOH
OCH3
OCH3
FEHLING'S
SOLUTION
COCO
OCH3
OCH3

Evaluation Report 10
2 May 1945

COMBINED INTELLIGENCE OBJECTIVES SUB-COMMITTEE

Target No's. 8/58 & 24/17a

KO-10307

1. Full Title of Target: K.W.I. für Medizinische Forschung, Heidelberg.

2. Condition of Target: Undamaged.

3. Description

This target was first assessed and reported upon by a CAFT assessor (Major Adamson) on 11 Apr. 45. (Evaluation Report 1) The present further assessment was carried out in response to cable received 22 Apr. 45 from CIOS which requested:

1. Large samples (up to 5 kilos) of '3065' and cyclodecane pentaene $C_{10}H_{10}$.

2. Dispatch of clinical report on 3065 to CIOS.

MAY 16 '45 PM

The following is now recorded:

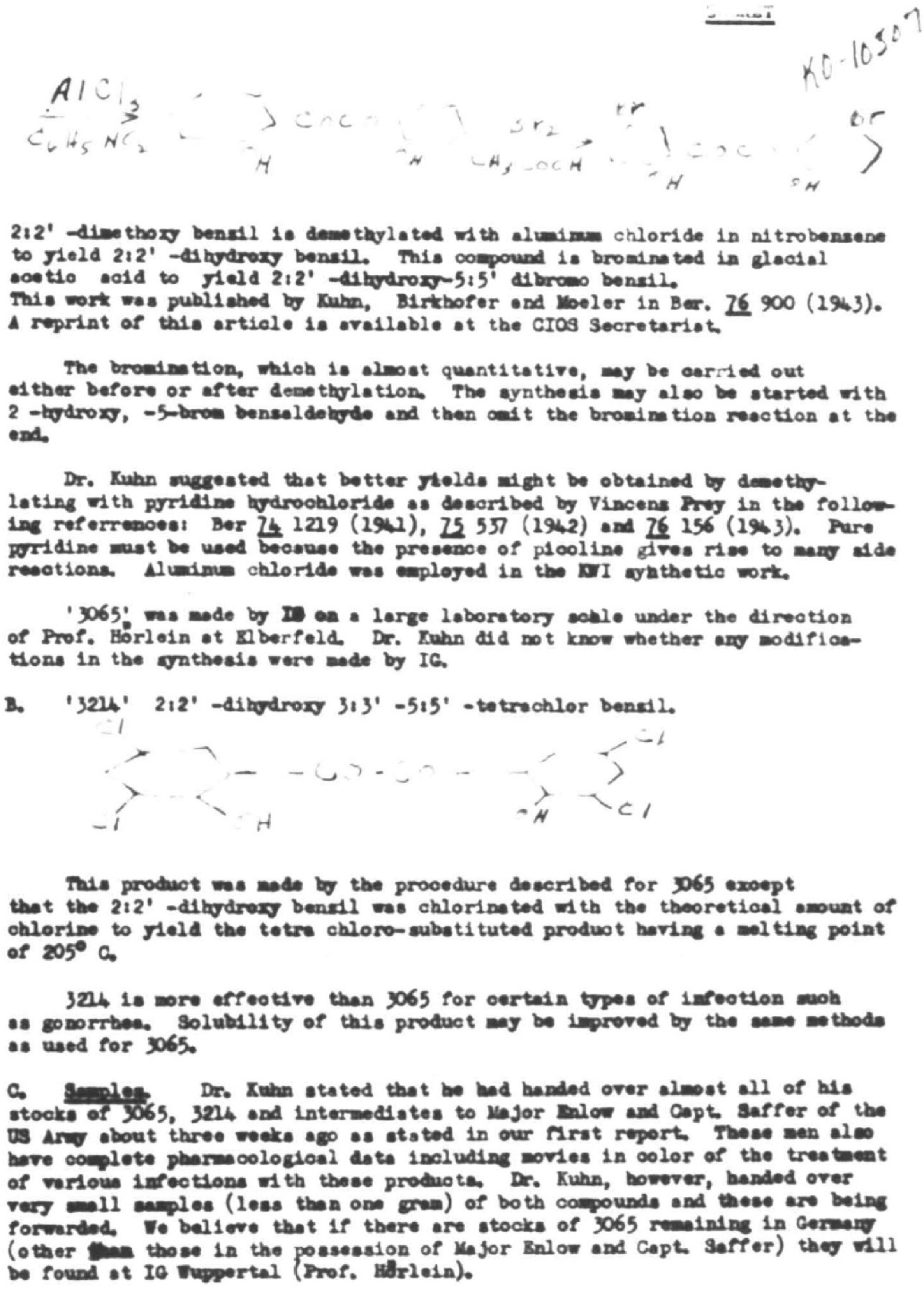
A. Further details on synthesis of 3065.
B. Synthesis of 3214 (an analogue of 3065).
C. Position with regard to samples.
D. Clinical report.
E. Further information on cyclodecane pentaene.

A. Synthesis of '3065', 2:2' - dihydroxy - 5:5' - dibromo benzil

Prof. Kuhn did not have a detailed description of the synthesis of 3065. The preparation of 2:2' - dihydroxy benzil is described in the literature and was prepared at KWI according to the published method. The remainder of the synthesis was worked out under Kuhn and is described in one of his publications (Ber. 76 900, (1943)). An outline of the procedure is as follows:

Salicylaldehyde + dimethyl sulfate — o-methoxy benzaldehyde
o-methoxy benzaldehyde - KCN in ethyl alcohol - 2:2'-dimethoxy benzoin
2:2' -dimethoxy benzoin is oxidised with alcoholic Fehling's solution to yield 2:2'-dimethoxy benzil.
These methods are described in an article by Schönberg and Kraemer Ber. 55 1184 (1922) and by J.C. Irvine J.C.S. 79 670 (1901)

Figure A.69: Richard Kuhn developed a synthetic antibiotic dubbed “3065” [CIOS ER 10].



KO-10507

AlCl3
C6H5NO2
Br2
CH3COOH

2:2' -dimethoxy benzil is demethylated with aluminum chloride in nitrobenzene to yield 2:2' -dihydroxy benzil. This compound is brominated in glacial acetic acid to yield 2:2' -dihydroxy-5:5' dibromo benzil. This work was published by Kuhn, Birkhofer and Moeler in Ber. 76 900 (1943). A reprint of this article is available at the CIOS Secretariat.

The bromination, which is almost quantitative, may be carried out either before or after demethylation. The synthesis may also be started with 2 -hydroxy, -5-brom benzaldehyde and then omit the bromination reaction at the end.

Dr. Kuhn suggested that better yields might be obtained by demethylating with pyridine hydrochloride as described by Vincenz Prey in the following referrences: Ber 74 1219 (1941), 75 537 (1942) and 76 156 (1943). Pure pyridine must be used because the presence of picoline gives rise to many side reactions. Aluminum chloride was employed in the KWI synthetic work.

'3065' was made by IG on a large laboratory scale under the direction of Prof. Hörlein at Elberfeld. Dr. Kuhn did not know whether any modifications in the synthesis were made by IG.

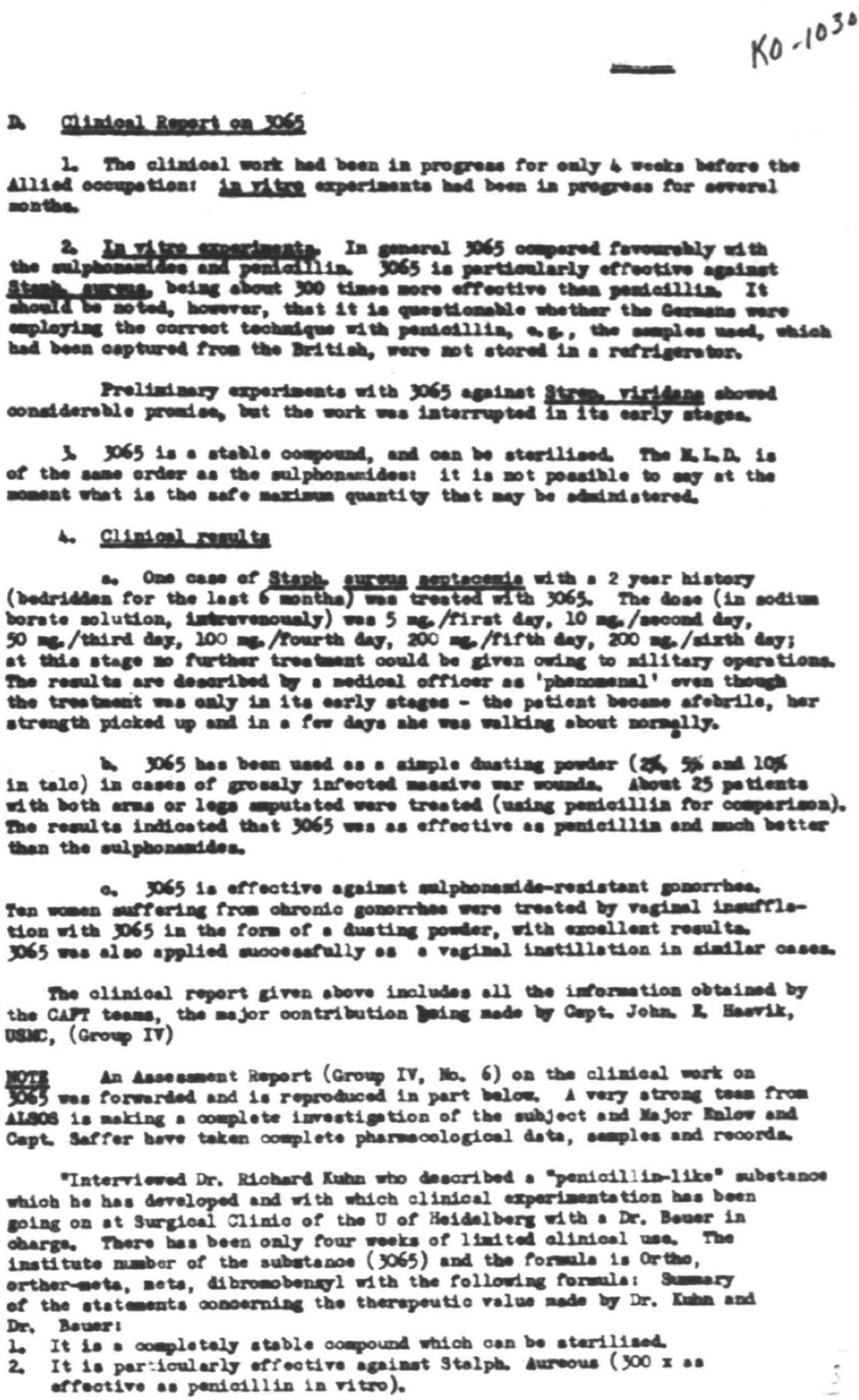
B. '3214' 2:2' -dihydroxy 3:3' -5:5' -tetrachlor benzil.

This product was made by the procedure described for 3065 except that the 2:2' -dihydroxy benzil was chlorinated with the theoretical amount of chlorine to yield the tetra chloro-substituted product having a melting point of 205° C.

3214 is more effective than 3065 for certain types of infection such as gonorrhea. Solubility of this product may be improved by the same methods as used for 3065.

C. Samples. Dr. Kuhn stated that he had handed over almost all of his stocks of 3065, 3214 and intermediates to Major Enlow and Capt. Saffer of the US Army about three weeks ago as stated in our first report. These men also have complete pharmacological data including movies in color of the treatment of various infections with these products. Dr. Kuhn, however, handed over very small samples (less than one gram) of both compounds and these are being forwarded. We believe that if there are stocks of 3065 remaining in Germany (other than those in the possession of Major Enlow and Capt. Saffer) they will be found at IG Wuppertal (Prof. Hörlein).

Figure A.70: Richard Kuhn developed a synthetic antibiotic dubbed “3065” [CIOS ER 10].



KO-10307

D. Clinical Report on 3065

1. The clinical work had been in progress for only 4 weeks before the Allied occupation: in vitro experiments had been in progress for several months.

2. In vitro experiments. In general 3065 compared favourably with the sulphonamides and penicillin. 3065 is particularly effective against Staph. aureus, being about 300 times more effective than penicillin. It should be noted, however, that it is questionable whether the Germans were employing the correct technique with penicillin, e.g., the samples used, which had been captured from the British, were not stored in a refrigerator.

Preliminary experiments with 3065 against Strep. viridans showed considerable promise, but the work was interrupted in its early stages.

3. 3065 is a stable compound, and can be sterilised. The M.L.D. is of the same order as the sulphonamides: it is not possible to say at the moment what is the safe maximum quantity that may be administered.

4. Clinical results

a. One case of Staph. aureus septacemia with a 2 year history (bedridden for the last 6 months) was treated with 3065. The dose (in sodium borate solution, intravenously) was 5 mg./first day, 10 mg./second day, 50 mg./third day, 100 mg./fourth day, 200 mg./fifth day, 200 mg./sixth day; at this stage no further treatment could be given owing to military operations. The results are described by a medical officer as 'phenomenal' even though the treatment was only in its early stages - the patient became afebrile, her strength picked up and in a few days she was walking about normally.

b. 3065 has been used as a simple dusting powder (2%, 5% and 10% in talc) in cases of grossly infected massive war wounds. About 25 patients with both arms or legs amputated were treated (using penicillin for comparison). The results indicated that 3065 was as effective as penicillin and much better than the sulphonamides.

c. 3065 is effective against sulphonamide-resistant gonorrhea. Ten women suffering from chronic gonorrhea were treated by vaginal insufflation with 3065 in the form of a dusting powder, with excellent results. 3065 was also applied successfully as a vaginal instillation in similar cases.

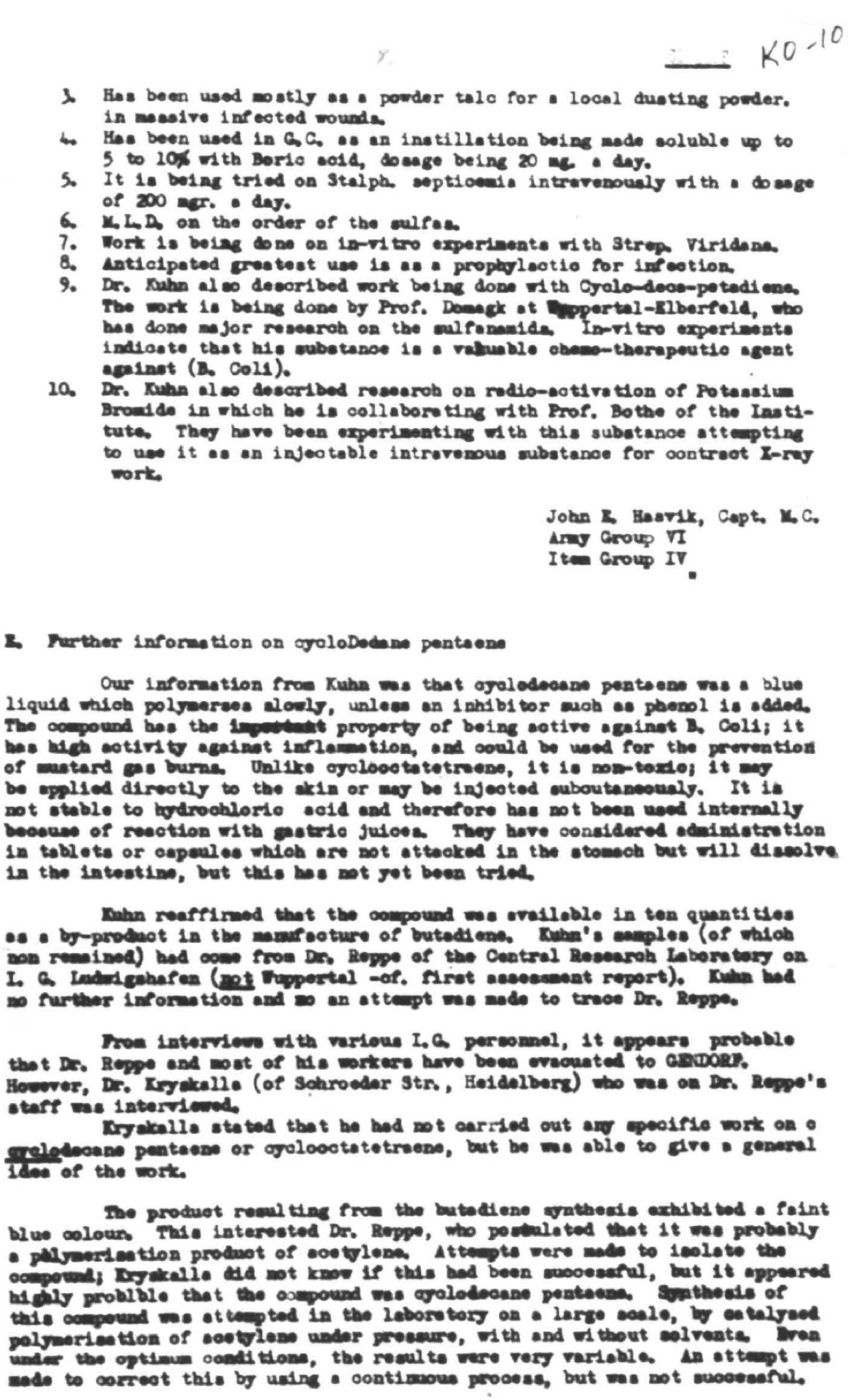
The clinical report given above includes all the information obtained by the CAFT teams, the major contribution being made by Capt. John. R. Haavik, USMC, (Group IV)

NOTE An Assessment Report (Group IV, No. 6) on the clinical work on 3065 was forwarded and is reproduced in part below. A very strong team from ALSOS is making a complete investigation of the subject and Major Enlow and Capt. Saffer have taken complete pharmacological data, samples and records.

"Interviewed Dr. Richard Kuhn who described a "penicillin-like" substance which he has developed and with which clinical experimentation has been going on at Surgical Clinic of the U of Heidelberg with a Dr. Bauer in charge. There has been only four weeks of limited clinical use. The institute number of the substance (3065) and the formula is Ortho, orther-meta, meta, dibromobenzyl with the following formula: Summary of the statements concerning the therapeutic value made by Dr. Kuhn and Dr. Bauer:

1. It is a completely stable compound which can be sterilised.
2. It is particularly effective against Stalph. Aureous (300 x as effective as penicillin in vitro).

Figure A.71: Richard Kuhn developed a synthetic antibiotic dubbed "3065" [CIOS ER 10].



KO-10307

3. Has been used mostly as a powder talc for a local dusting powder. in massive infected wounds.
4. Has been used in G.C. as an instillation being made soluble up to 5 to 10% with Boric acid, dosage being 20 mg. a day.
5. It is being tried on Stalph. septicemia intravenously with a dosage of 200 mgr. a day.
6. M.L.D. on the order of the sulfas.
7. Work is being done on in-vitro experiments with Strep. Viridans.
8. Anticipated greatest use is as a prophylactic for infection.
9. Dr. Kuhn also described work being done with Cyclo-deca-petadiene. The work is being done by Prof. Domagk at Wuppertal-Elberfeld, who has done major research on the sulfanamida. In-vitro experiments indicate that his substance is a valuable chemo-therapeutic agent against (B. Coli).
10. Dr. Kuhn also described research on radio-activation of Potassium Bromide in which he is collaborating with Prof. Bothe of the Institute. They have been experimenting with this substance attempting to use it as an injectable intravenous substance for contrast X-ray work.

John E. Haavik, Capt. M.C.
Army Group VI
Item Group IV

E. Further information on cycloDedane pentaene

Our information from Kuhn was that cyclodecane pentaene was a blue liquid which polymerses slowly, unless an inhibitor such as phenol is added. The compound has the important property of being active against B. Coli; it has high activity against inflammation, and could be used for the prevention of mustard gas burns. Unlike cyclooctatetraene, it is non-toxic; it may be applied directly to the skin or may be injected subcutaneously. It is not stable to hydrochloric acid and therefore has not been used internally because of reaction with gastric juices. They have considered administration in tablets or capsules which are not attacked in the stomach but will dissolve in the intestine, but this has not yet been tried.

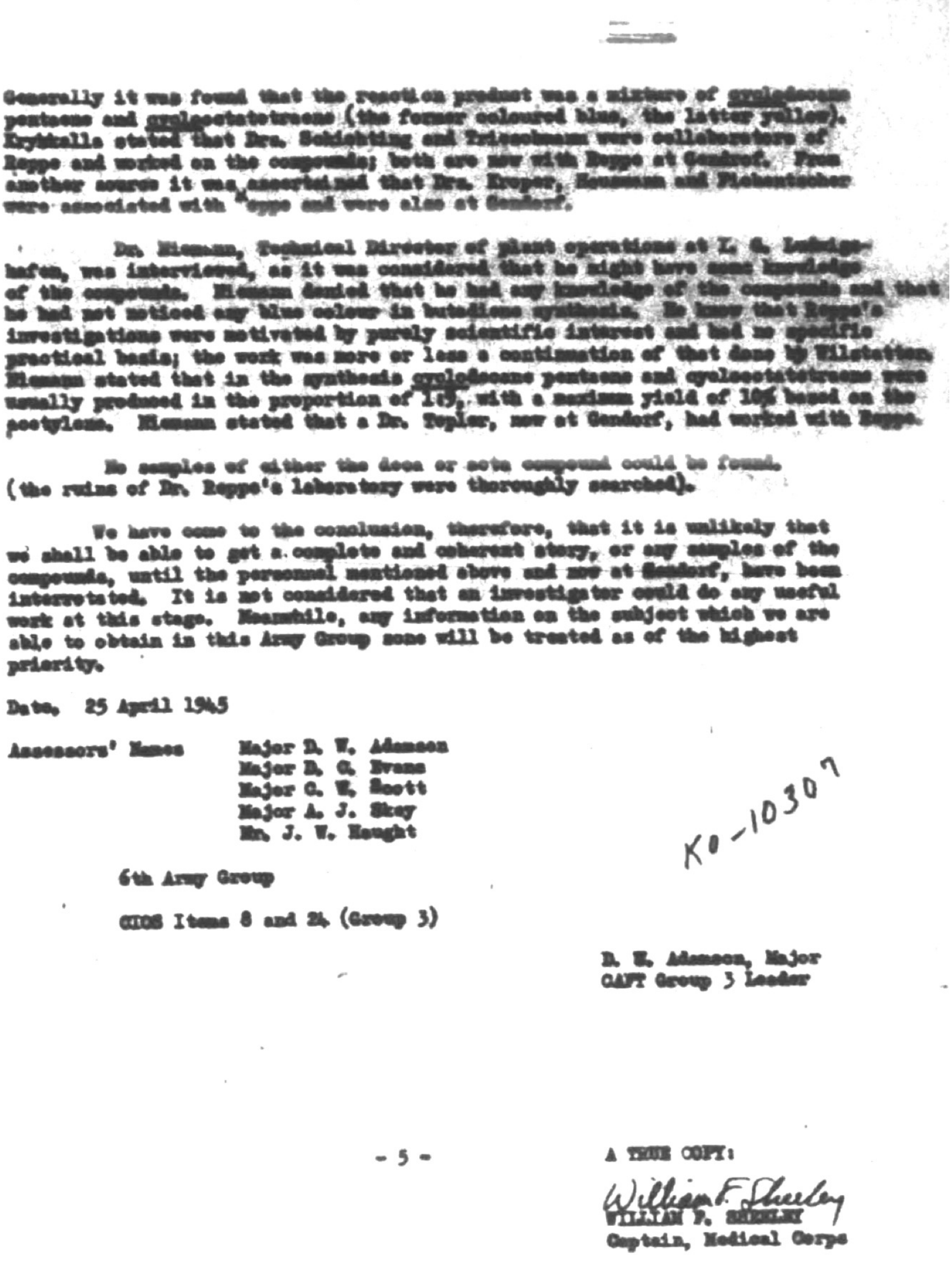
Kuhn reaffirmed that the compound was available in ten quantities as a by-product in the manufacture of butadiene. Kuhn's samples (of which non remained) had come from Dr. Reppe of the Central Research Laboratory on I. G. Ludwigshafen (not Wuppertal -cf. first assessment report). Kuhn had no further information and so an attempt was made to trace Dr. Reppe.

From interviews with various I.G. personnel, it appears probable that Dr. Reppe and most of his workers have been evacuated to GENDORF. However, Dr. Kryskalle (of Schroeder Str., Heidelberg) who was on Dr. Reppe's staff was interviewed.

Kryskalle stated that he had not carried out any specific work on c cyclodecane pentaene or cyclooctatetraene, but he was able to give a general idea of the work.

The product resulting from the butadiene synthesis exhibited a faint blue colour. This interested Dr. Reppe, who postulated that it was probably a polymerisation product of acetylene. Attempts were made to isolate the compound; Kryskalle did not know if this had been successful, but it appeared highly problble that the compound was cyclodecane pentaene. Synthesis of this compound was attempted in the laboratory on a large scale, by catalysed polymerisation of acetylene under pressure, with and without solvents. Even under the optimum conditions, the results were very variable. An attempt was made to correct this by using a continuous process, but was not successful.

Figure A.72: Richard Kuhn developed a synthetic antibiotic dubbed “3065” [CIOS ER 10].



Generally it was found that the reaction product was a mixture of cyclodecane pentaene and cyclooctatetraene (the former coloured blue, the latter yellow). Krybkalla stated that Drs. Schlichting and Triesohmann were collaborators of Reppe and worked on the compounds; both are now with Reppe at Gendorf. From another source it was ascertained that Drs. Kroper, Neumann and Pichentscher were associated with Reppe and were also at Gendorf.

Dr. Niemann, Technical Director of plant operations at I. G. Ludwigshafen, was interviewed, as it was considered that he might have some knowledge of the compounds. Niemann denied that he had any knowledge of the compounds and that he had not noticed any blue colour in butadiene synthesis. He knew that Reppe's investigations were motivated by purely scientific interest and had no specific practical basis; the work was more or less a continuation of that done by Willstatter. Niemann stated that in the synthesis cyclodecane pentaene and cyclooctatetraene were usually produced in the proportion of 1:3, with a maximum yield of 10% based on the acetylene. Niemann stated that a Dr. Topler, now at Gendorf, had worked with Reppe.

No samples of either the deca or octa compound could be found. (the ruins of Dr. Reppe's laboratory were thoroughly searched).

We have come to the conclusion, therefore, that it is unlikely that we shall be able to get a complete and coherent story, or any samples of the compounds, until the personnel mentioned above and now at Gendorf, have been interrotated. It is not considered that an investigator could do any useful work at this stage. Meanwhile, any information on the subject which we are able to obtain in this Army Group zone will be treated as of the highest priority.

Date, 25 April 1945

Assessors' Names
Major D. W. Adamson
Major D. G. Evans
Major C. W. Scott
Major A. J. Skey
Mr. J. W. Haught

6th Army Group

CIOS Items 8 and 24 (Group 3)

KO-10307

D. W. Adamson, Major
CAFT Group 3 Leader

- 5 -

A TRUE COPY:
William F. Sheeley
WILLIAM F. SHEELEY
Captain, Medical Corps

Figure A.73: Richard Kuhn developed a synthetic antibiotic dubbed "3065" [CIOS ER 10].

CIOS XXIV-16. *Pharmaceutical Targets in Southern Germany.*

[See Fig. A.74.]

CIOS XXV-54. *Pharmaceuticals at I.G. Farbenindustrie Plant Elberfeld*

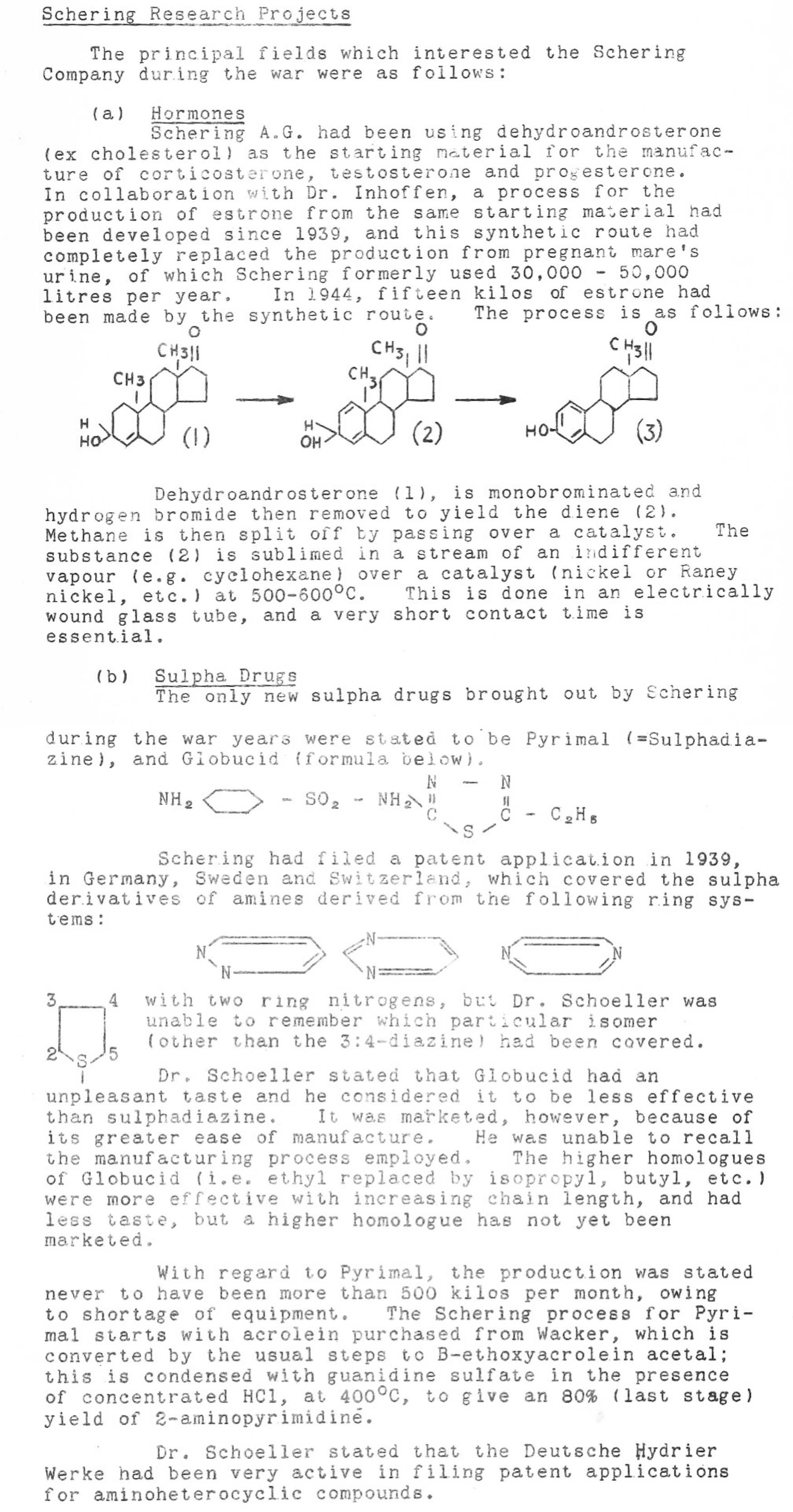
[This report contains great examples of structure-activity relationship (SAR) testing and optimization with drug molecules such as antibiotics and antimalarials. It also provides a good description of periston. See Figs. A.75–A.90.]

FIAT 195. *Yeast and Nutrition Targets in Germany.* pp. 2, 4.

The targets concerned with growth of food yeast on wood sugars were those visited at the I.G. Farbenindustrie (Bitterfeld), the I.G. Farbenindustrie Film Fabrik (Wolfen) and the Phrix, A.G. (Hamburg). The first mentioned plant contained novel circulating aeration columns for keeping down foaming which was of paramount importance when sulfite waste liquors were used. The latter two plans also employed a foam-minimizing fermentation tank design. The large centrifugal basket-type centrifuges use by the Wolfen plant for separation and washing of the yeast may have application in the U.S. if larger production is anticipated. Most of the wood sugar yeast plants plasmolyzed the cells by heating the pressed yeast with steam. This operation contributed somewhat to an improvement in flavor as well as assured a non-viable product. The I.G. Farbenindustrie plants used a strain of Candidia arborea and the Phrix plant claimed to use Torula utilis. Both types ferment pentoses as well as hexoses. [...]

The research institutes visited included the Universities of Leipzig, Halle, Tübingen, and Kaiser Wilhelm Institute (Heidelberg and Dortmund). The writer was impressed with the freedom the research workers were given. Pure research studies were allowed to proceed practically unmolested. During the first few years of the war some of the younger men were drafted for Army service, but even in the last months of the war many of these were being returned to their laboratories.

[...] The German scientists, such as Kuhn, Butenandt, Aberhalden, Scheunert, certainly reflect the vigorous scientific training characteristic of the German universities and serve to emphasize the high level of achievement in their respective fields. It is noteworthy that the Army research program left such men unmolested to continue their respective peace-time researches.



CH3
CH3
H
HO
(1)
CH3
CH3
H
OH
(2)
HO
(3)
NH2
SO2
NH2
N
N
C
S
C
C2H5
N
N
N
N
N
N
3
4
2
S
5

Schering Research Projects

The principal fields which interested the Schering Company during the war were as follows:

(a) Hormones

Schering A.G. had been using dehydroandrosterone (ex cholesterol) as the starting material for the manufacture of corticosterone, testosterone and progesterone. In collaboration with Dr. Inhoffen, a process for the production of estrone from the same starting material had been developed since 1939, and this synthetic route had completely replaced the production from pregnant mare's urine, of which Schering formerly used 30,000 - 50,000 litres per year. In 1944, fifteen kilos of estrone had been made by the synthetic route. The process is as follows:

Dehydroandrosterone (1), is monobrominated and hydrogen bromide then removed to yield the diene (2). Methane is then split off by passing over a catalyst. The substance (2) is sublimed in a stream of an indifferent vapour (e.g. cyclohexane) over a catalyst (nickel or Raney nickel, etc.) at 500-600°C. This is done in an electrically wound glass tube, and a very short contact time is essential.

(b) Sulpha Drugs

The only new sulpha drugs brought out by Schering during the war years were stated to be Pyrimal (=Sulphadiazine), and Globucid (formula below).

Schering had filed a patent application in 1939, in Germany, Sweden and Switzerland, which covered the sulpha derivatives of amines derived from the following ring systems:

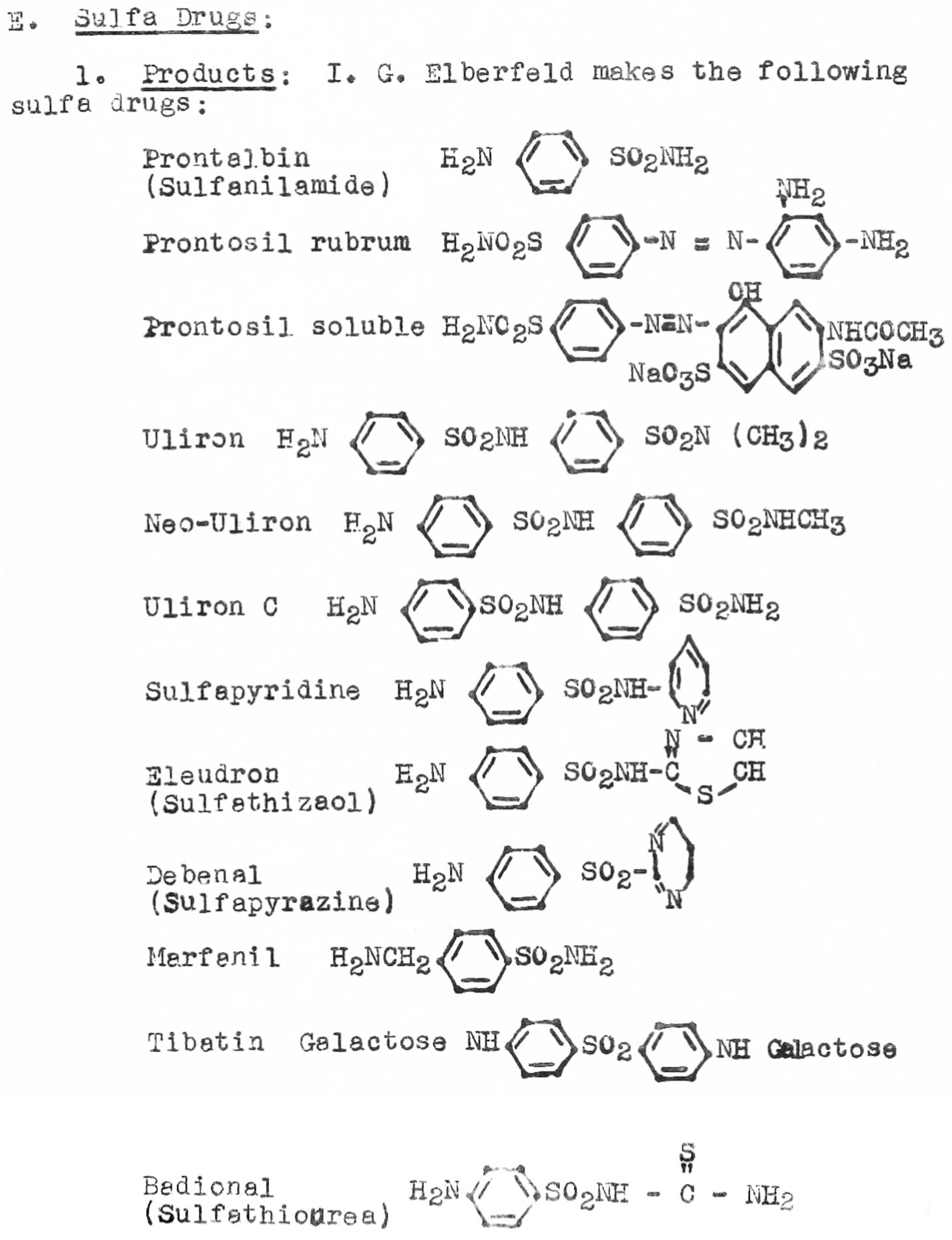
with two ring nitrogens, but Dr. Schoeller was unable to remember which particular isomer (other than the 3:4-diazine) had been covered.

Dr. Schoeller stated that Globucid had an unpleasant taste and he considered it to be less effective than sulphadiazine. It was marketed, however, because of its greater ease of manufacture. He was unable to recall the manufacturing process employed. The higher homologues of Globucid (i.e. ethyl replaced by isopropyl, butyl, etc.) were more effective with increasing chain length, and had less taste, but a higher homologue has not yet been marketed.

With regard to Pyrimal, the production was stated never to have been more than 500 kilos per month, owing to shortage of equipment. The Schering process for Pyrimal starts with acrolein purchased from Wacker, which is converted by the usual steps to B-ethoxyacrolein acetal; this is condensed with guanidine sulfate in the presence of concentrated HCl, at 400°C, to give an 80% (last stage) yield of 2-aminopyrimidine.

Dr. Schoeller stated that the Deutsche Hydrier Werke had been very active in filing patent applications for aminoheterocyclic compounds.

Figure A.74: Production of synthetic hormones and multiple sulfa antibiotics by Schering [CIOS XXIV-16].



E. Sulfa Drugs:

1. Products: I. G. Elberfeld makes the following sulfa drugs:

Prontalbin (Sulfanilamide)

Prontosil rubrum

Prontosil soluble

Uliron

Neo-Uliron

Uliron C

Sulfapyridine

Eleudron (Sulfethizaol)

Debenal (Sulfapyrazine)

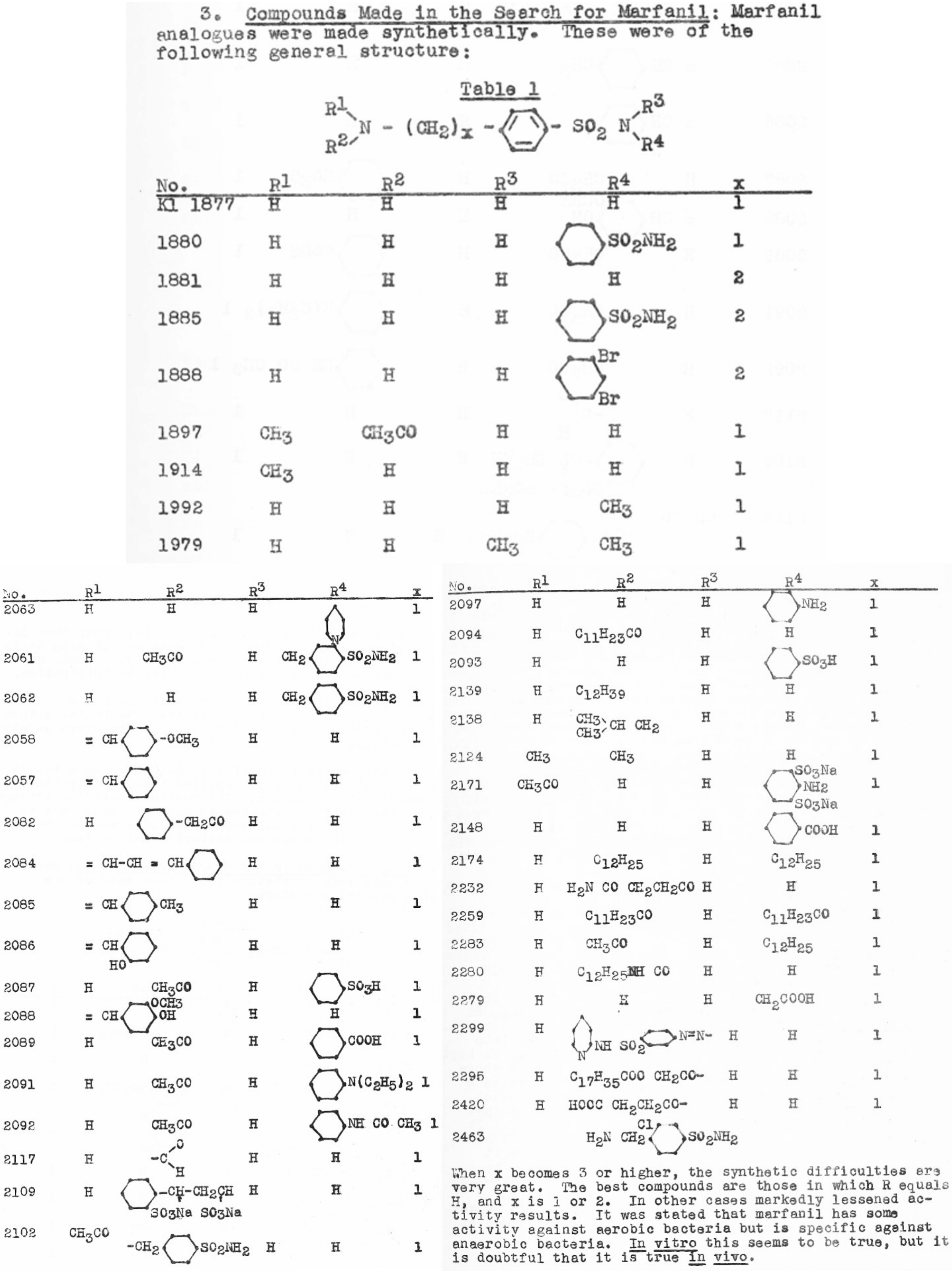
Marfenil

Tibatin

Bedional (Sulfethiourea)

H2N SO2NH2
H2NO2S -N = N- NH2 -NH2
H2NO2S -N=N- OH NHCOCH3 SO3Na NaO3S
H2N SO2NH SO2N (CH3)2
H2N SO2NH SO2NHCH3
H2N SO2NH SO2NH2
H2N SO2NH- N
H2N SO2NH-C N CH CH S
H2N SO2- N N
H2NCH2 SO2NH2
Galactose NH SO2 NH Galactose
H2N SO2NH - C - NH2 S

Figure A.75: Examples of the variety of sulfa antibiotics that were mass-produced and used clinically [CIOS XXV-54].



3. Compounds Made in the Search for Marfanil: Marfanil analogues were made synthetically. These were of the following general structure:

Table 1

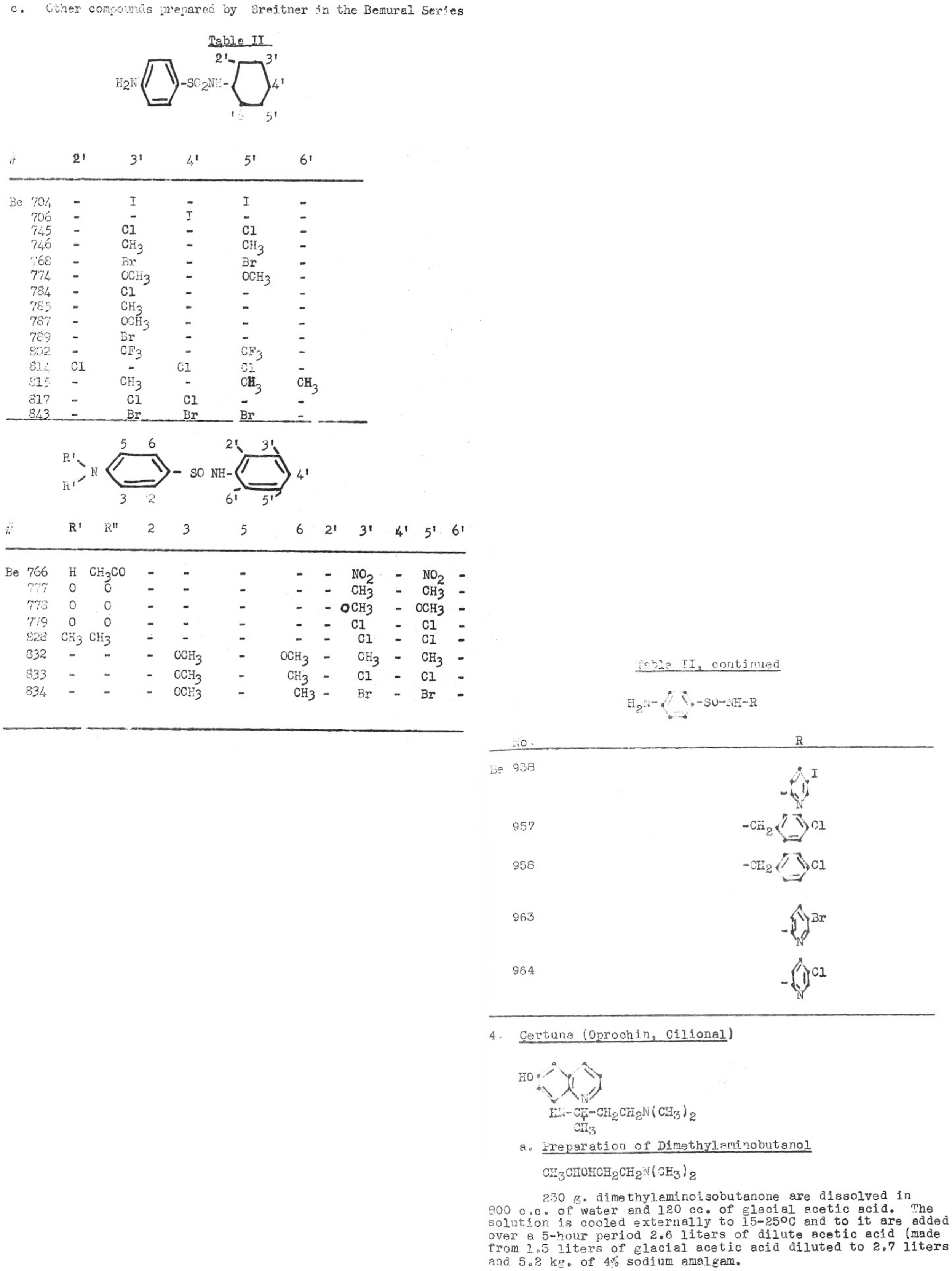
$R^1R^2N - (CH_2)_x - ⌬ - SO_2 N R^3R^4$

No.	R^1	R^2	R^3	R^4	x
Kl 1877	H	H	H	H	1
1880	H	H	H	⌬SO_2NH_2	1
1881	H	H	H	H	2
1885	H	H	H	⌬SO_2NH_2	2
1888	H	H	H	⌬ Br Br	2
1897	CH_3	CH_3CO	H	H	1
1914	CH_3	H	H	H	1
1992	H	H	H	CH_3	1
1979	H	H	CH_3	CH_3	1
2063	H	H	H	⌬ N	1
2061	H	CH_3CO	H	CH_2⌬SO_2NH_2	1
2062	H	H	H	CH_2⌬SO_2NH_2	1
2058	= CH⌬$-OCH_3$		H	H	1
2057	= CH⌬		H	H	1
2082	H	⌬$-CH_2CO$	H	H	1
2084	= CH-CH = CH⌬		H	H	1
2085	= CH⌬CH_3		H	H	1
2086	= CH⌬ HO		H	H	1
2087	H	CH_3CO	H	⌬SO_3H	1
2088	= CH⌬ OCH3 OH		H	H	1
2089	H	CH_3CO	H	⌬COOH	1
2091	H	CH_3CO	H	⌬$N(C_2H_5)_2$	1
2092	H	CH_3CO	H	⌬NH CO CH_3	1
2117	H	$-C\genfrac{}{}{0pt}{}{O}{H}$	H	H	1
2109	H	⌬$-CH-CH_2CH$ SO3Na SO3Na	H	H	1
2102	CH_3CO	$-CH_2$⌬SO_2NH_2	H	H	1

No.	R^1	R^2	R^3	R^4	x
2097	H	H	H	⌬NH_2	1
2094	H	$C_{11}H_{23}CO$	H	H	1
2093	H	H	H	⌬SO_3H	1
2139	H	$C_{12}H_{39}$	H	H	1
2138	H	$\genfrac{}{}{0pt}{}{CH3}{CH3}$ CH CH_2	H	H	1
2124	CH3	CH_3	H	H	1
2171	CH_3CO	H	H	⌬ SO_3Na NH2 SO3Na	1
2148	H	H	H	⌬ COOH	1
2174	H	$C_{12}H_{25}$	H	$C_{12}H_{25}$	1
2232	H	H_2N CO CH_2CH_2CO	H	H	1
2259	H	$C_{11}H_{23}CO$	H	$C_{11}H_{23}CO$	1
2283	H	CH_3CO	H	$C_{12}H_{25}$	1
2280	H	$C_{12}H_{25}$NH CO	H	H	1
2279	H	H	H	CH_2COOH	1
2299	H	⌬ N NH SO_2⌬N=N-	H	H	1
2295	H	$C_{17}H_{35}COO$ CH_2CO-	H	H	1
2420	H	HOCC CH_2CH_2CO-	H	H	1
2463		H_2N CH_2⌬ Cl SO_2NH_2			

When x becomes 3 or higher, the synthetic difficulties are very great. The best compounds are those in which R equals H, and x is 1 or 2. In other cases markedly lessened activity results. It was stated that marfanil has some activity against aerobic bacteria but is specific against anaerobic bacteria. In vitro this seems to be true, but it is doubtful that it is true in vivo.

Figure A.76: Structure-activity relationship (SAR) optimization of antibiotic molecules [CIOS XXV-54].



c. Other compounds prepared by Breitner in the Bemural Series

Table II

H_2N
$-SO_2NH-$
2'
3'
4'
5'
6'

#	2'	3'	4'	5'	6'
Be 704	-	I	-	I	-
706	-	-	I	-	-
745	-	Cl	-	Cl	-
746	-	CH_3	-	CH_3	-
768	-	Br	-	Br	-
774	-	OCH_3	-	OCH_3	-
784	-	Cl	-	-	-
785	-	CH_3	-	-	-
787	-	OCH_3	-	-	-
789	-	Br	-	-	-
802	-	CF_3	-	CF_3	-
814	Cl	-	Cl	Cl	-
815	-	CH_3	-	CH_3	CH_3
817	-	Cl	Cl	-	-
843	-	Br	Br	Br	-

R'
R'
N
5
6
3
2
- SO NH-
2'
3'
4'
5'
6'

#	R'	R"	2	3	5	6	2'	3'	4'	5'	6'
Be 766	H	CH_3CO	-	-	-	-	-	NO_2	-	NO_2	-
777	O	O	-	-	-	-	-	CH_3	-	CH_3	-
778	O	O	-	-	-	-	-	OCH_3	-	OCH_3	-
779	O	O	-	-	-	-	-	Cl	-	Cl	-
828	CH_3	CH_3	-	-	-	-	-	Cl	-	Cl	-
832	-	-	-	OCH_3	-	OCH_3	-	CH_3	-	CH_3	-
833	-	-	-	OCH_3	-	CH_3	-	Cl	-	Cl	-
834	-	-	-	OCH_3	-	CH_3	-	Br	-	Br	-

Table II, continued

$H_2N-C_6H_4-SO-NH-R$

No.	R
Be 938	I N
957	$-CH_2$ Cl
958	$-CH_2$ Cl
963	Br N
964	Cl N

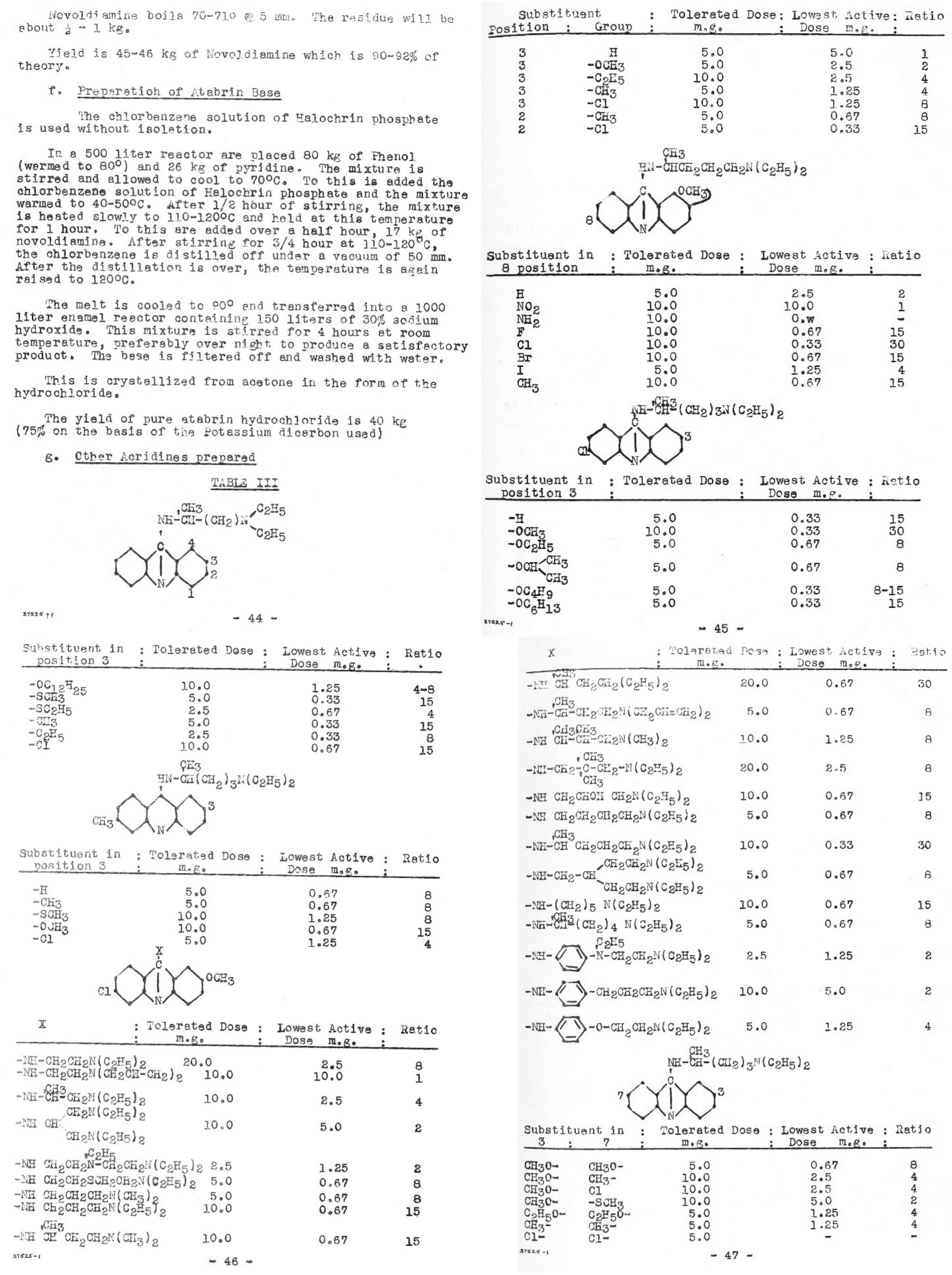
4. Certuna (Oprochin, Cilional)

a. Preparation of Dimethylaminobutanol

$CH_3CHOHCH_2CH_2N(CH_3)_2$

230 g. dimethylaminoisobutanone are dissolved in 800 c.c. of water and 120 cc. of glacial acetic acid. The solution is cooled externally to 15-25°C and to it are added over a 5-hour period 2.6 liters of dilute acetic acid (made from 1.5 liters of glacial acetic acid diluted to 2.7 liters and 5.2 kg. of 4% sodium amalgam.

Figure A.77: Structure-activity relationship (SAR) optimization of antimalarial molecules [CIOS XXV-54].



Novoldiamine boils 70-71o @ 5 mm. The residue will be about ½ - 1 kg.

Yield is 45-46 kg of Novoldiamine which is 90-92% of theory.

f. Preparation of Atabrin Base

The chlorbenzene solution of Halochrin phosphate is used without isolation.

In a 500 liter reactor are placed 80 kg of Phenol (warmed to 80°) and 26 kg of pyridine. The mixture is stirred and allowed to cool to 70°C. To this is added the chlorbenzene solution of Halochrin phosphate and the mixture warmed to 40-50°C. After 1/2 hour of stirring, the mixture is heated slowly to 110-120°C and held at this temperature for 1 hour. To this are added over a half hour, 17 kg of novoldiamine. After stirring for 3/4 hour at 110-120°C, the chlorbenzene is distilled off under a vacuum of 50 mm. After the distillation is over, the temperature is again raised to 120°C.

The melt is cooled to 90° and transferred into a 1000 liter enamel reactor containing 150 liters of 30% sodium hydroxide. This mixture is stirred for 4 hours at room temperature, preferably over night to produce a satisfactory product. The base is filtered off and washed with water.

This is crystallized from acetone in the form of the hydrochloride.

The yield of pure atabrin hydrochloride is 40 kg (75% on the basis of the Potassium dicarbon used)

g. Other Acridines prepared

TABLE III

37525-1

- 44 -

Substituent Position	Substituent Group	Tolerated Dose m.g.	Lowest Active Dose m.g.	Ratio
3	H	5.0	5.0	1
3	$-OCH_3$	5.0	2.5	2
3	$-C_2H_5$	10.0	2.5	4
3	$-CH_3$	5.0	1.25	4
3	$-Cl$	10.0	1.25	8
2	$-CH_3$	5.0	0.67	8
2	$-Cl$	5.0	0.33	15

Substituent in 8 position	Tolerated Dose m.g.	Lowest Active Dose m.g.	Ratio
H	5.0	2.5	2
NO_2	10.0	10.0	1
NH_2	10.0	0.w	-
F	10.0	0.67	15
Cl	10.0	0.33	30
Br	10.0	0.67	15
I	5.0	1.25	4
CH_3	10.0	0.67	15

Substituent in position 3	Tolerated Dose	Lowest Active Dose m.g.	Ratio
$-H$	5.0	0.33	15
$-OCH_3$	10.0	0.33	30
$-OC_2H_5$	5.0	0.67	8
$-OCH(CH_3)_2$	5.0	0.67	8
$-OC_4H_9$	5.0	0.33	8-15
$-OC_6H_{13}$	5.0	0.33	15

37525-1

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Substituent in position 3	Tolerated Dose	Lowest Active Dose m.g.	Ratio
$-OC_{12}H_{25}$	10.0	1.25	4-8
$-SCH_3$	5.0	0.33	15
$-SC_2H_5$	2.5	0.67	4
$-CH_3$	5.0	0.33	15
$-C_2H_5$	2.5	0.33	8
$-Cl$	10.0	0.67	15

Substituent in position 3	Tolerated Dose m.g.	Lowest Active Dose m.g.	Ratio
$-H$	5.0	0.67	8
$-CH_3$	5.0	0.67	8
$-SCH_3$	10.0	1.25	8
$-OCH_3$	10.0	0.67	15
$-Cl$	5.0	1.25	4

X	Tolerated Dose m.g.	Lowest Active Dose m.g.	Ratio
$-NH-CH_2CH_2N(C_2H_5)_2$	20.0	2.5	8
$-NH-CH_2CH_2N(CH_2CH-CH_2)_2$	10.0	10.0	1
$-NH-\overset{CH_3}{CH}-CH_2N(C_2H_5)_2$	10.0	2.5	4
$-NH\ CH(CH_2N(C_2H_5)_2)_2$	10.0	5.0	2
$-NH\ CH_2CH_2\overset{C_2H_5}{N}-CH_2CH_2N(C_2H_5)_2$	2.5	1.25	2
$-NH\ CH_2CH_2SCH_2CH_2N(C_2H_5)_2$	5.0	0.67	8
$-NH\ CH_2CH_2CH_2N(CH_3)_2$	5.0	0.67	8
$-NH\ CH_2CH_2CH_2N(C_2H_5)_2$	10.0	0.67	15
$-NH\ \overset{CH_3}{CH}\ CH_2CH_2N(CH_3)_2$	10.0	0.67	15

37525-1

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X	Tolerated Dose m.g.	Lowest Active Dose m.g.	Ratio
$-NH\ \overset{CH_3}{CH}\ CH_2CH_2(C_2H_5)_2$	20.0	0.67	30
$-NH-\overset{CH_3}{CH}-CH_2CH_2N(CH_2CH=CH_2)_2$	5.0	0.67	8
$-NH\ \overset{CH_3}{CH}-\overset{CH_3}{CH}-CH_2N(CH_3)_2$	10.0	1.25	8
$-NH-CH_2-C(CH_3)_2-CH_2-N(C_2H_5)_2$	20.0	2.5	8
$-NH\ CH_2CHOH\ CH_2N(C_2H_5)_2$	10.0	0.67	15
$-NH\ CH_2CH_2CH_2CH_2N(C_2H_5)_2$	5.0	0.67	8
$-NH-\overset{CH_3}{CH}\ CH_2CH_2CH_2N(C_2H_5)_2$	10.0	0.33	30
$-NH-CH_2-CH(CH_2CH_2N(C_2H_5)_2)_2$	5.0	0.67	8
$-NH-(CH_2)_5\ N(C_2H_5)_2$	10.0	0.67	15
$-NH-\overset{CH_3}{CH}-(CH_2)_4\ N(C_2H_5)_2$	5.0	0.67	8
$-NH-C_6H_4-\overset{C_2H_5}{N}-CH_2CH_2N(C_2H_5)_2$	2.5	1.25	2
$-NH-C_6H_4-CH_2CH_2CH_2N(C_2H_5)_2$	10.0	5.0	2
$-NH-C_6H_4-O-CH_2CH_2N(C_2H_5)_2$	5.0	1.25	4

Substituent in 3	Substituent in 7	Tolerated Dose m.g.	Lowest Active Dose m.g.	Ratio
CH_3O-	CH_3O-	5.0	0.67	8
CH_3O-	CH_3-	10.0	2.5	4
CH_3O-	Cl	10.0	2.5	4
CH_3O-	$-SCH_3$	10.0	5.0	2
C_2H_5O-	C_2H_5O-	5.0	1.25	4
CH_3-	CH_3-	5.0	1.25	4
$Cl-$	$Cl-$	5.0	-	-

37525-1

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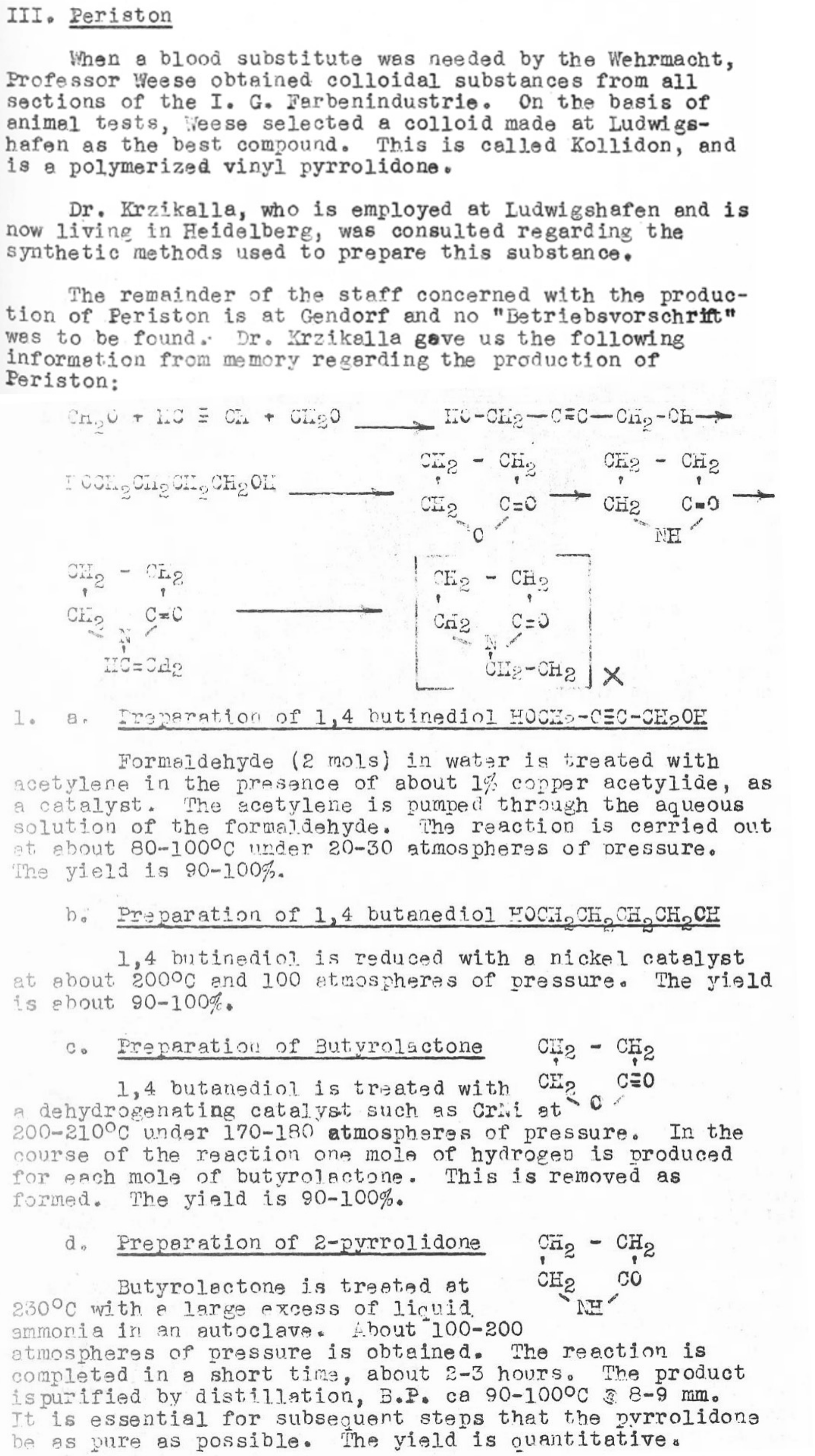
Figure A.78: Structure-activity relationship (SAR) optimization of antimalarial molecules [CIOS XXV-54].



III. Periston

When a blood substitute was needed by the Wehrmacht, Professor Weese obtained colloidal substances from all sections of the I. G. Farbenindustrie. On the basis of animal tests, Weese selected a colloid made at Ludwigshafen as the best compound. This is called Kollidon, and is a polymerized vinyl pyrrolidone.

Dr. Krzikalla, who is employed at Ludwigshafen and is now living in Heidelberg, was consulted regarding the synthetic methods used to prepare this substance.

The remainder of the staff concerned with the production of Periston is at Gendorf and no "Betriebsvorschrift" was to be found. Dr. Krzikalla gave us the following information from memory regarding the production of Periston:

$CH_2O + HC \equiv CH + CH_2O \longrightarrow HO-CH_2-C\equiv C-CH_2-OH \rightarrow$

$HOCH_2CH_2CH_2CH_2OH \longrightarrow$

1. a. Preparation of 1,4 butinediol $HOCH_2-C\equiv C-CH_2OH$

Formaldehyde (2 mols) in water is treated with acetylene in the presence of about 1% copper acetylide, as a catalyst. The acetylene is pumped through the aqueous solution of the formaldehyde. The reaction is carried out at about 80-100°C under 20-30 atmospheres of pressure. The yield is 90-100%.

b. Preparation of 1,4 butanediol $HOCH_2CH_2CH_2CH_2OH$

1,4 butinediol is reduced with a nickel catalyst at about 200°C and 100 atmospheres of pressure. The yield is about 90-100%.

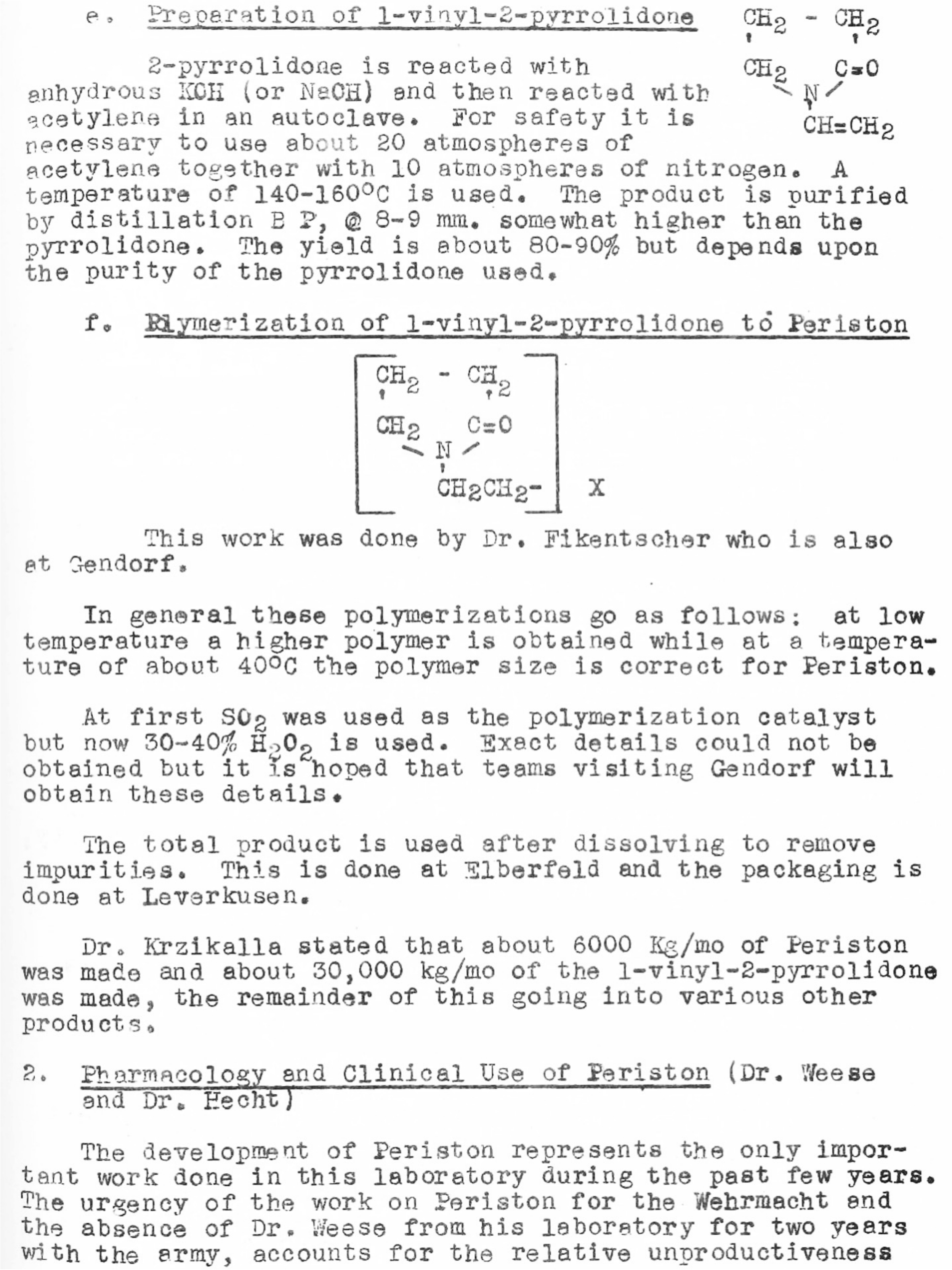
c. Preparation of Butyrolactone

1,4 butanediol is treated with a dehydrogenating catalyst such as CrNi at 200-210°C under 170-180 atmospheres of pressure. In the course of the reaction one mole of hydrogen is produced for each mole of butyrolactone. This is removed as formed. The yield is 90-100%.

d. Preparation of 2-pyrrolidone

Butyrolactone is treated at 230°C with a large excess of liquid ammonia in an autoclave. About 100-200 atmospheres of pressure is obtained. The reaction is completed in a short time, about 2-3 hours. The product is purified by distillation, B.P. ca 90-100°C @ 8-9 mm. It is essential for subsequent steps that the pyrrolidone be as pure as possible. The yield is quantitative.

Figure A.79: Information on periston [CIOS XXV-54].



e. Preparation of 1-vinyl-2-pyrrolidone

CH2 - CH2
CH2 C=O
N
CH=CH2

2-pyrrolidone is reacted with anhydrous KOH (or NaOH) and then reacted with acetylene in an autoclave. For safety it is necessary to use about 20 atmospheres of acetylene together with 10 atmospheres of nitrogen. A temperature of 140-160°C is used. The product is purified by distillation B P, @ 8-9 mm. somewhat higher than the pyrrolidone. The yield is about 80-90% but depends upon the purity of the pyrrolidone used.

f. Polymerization of 1-vinyl-2-pyrrolidone to Periston

This work was done by Dr. Fikentscher who is also at Gendorf.

In general these polymerizations go as follows: at low temperature a higher polymer is obtained while at a temperature of about 40°C the polymer size is correct for Periston.

At first SO_2 was used as the polymerization catalyst but now 30-40% H_2O_2 is used. Exact details could not be obtained but it is hoped that teams visiting Gendorf will obtain these details.

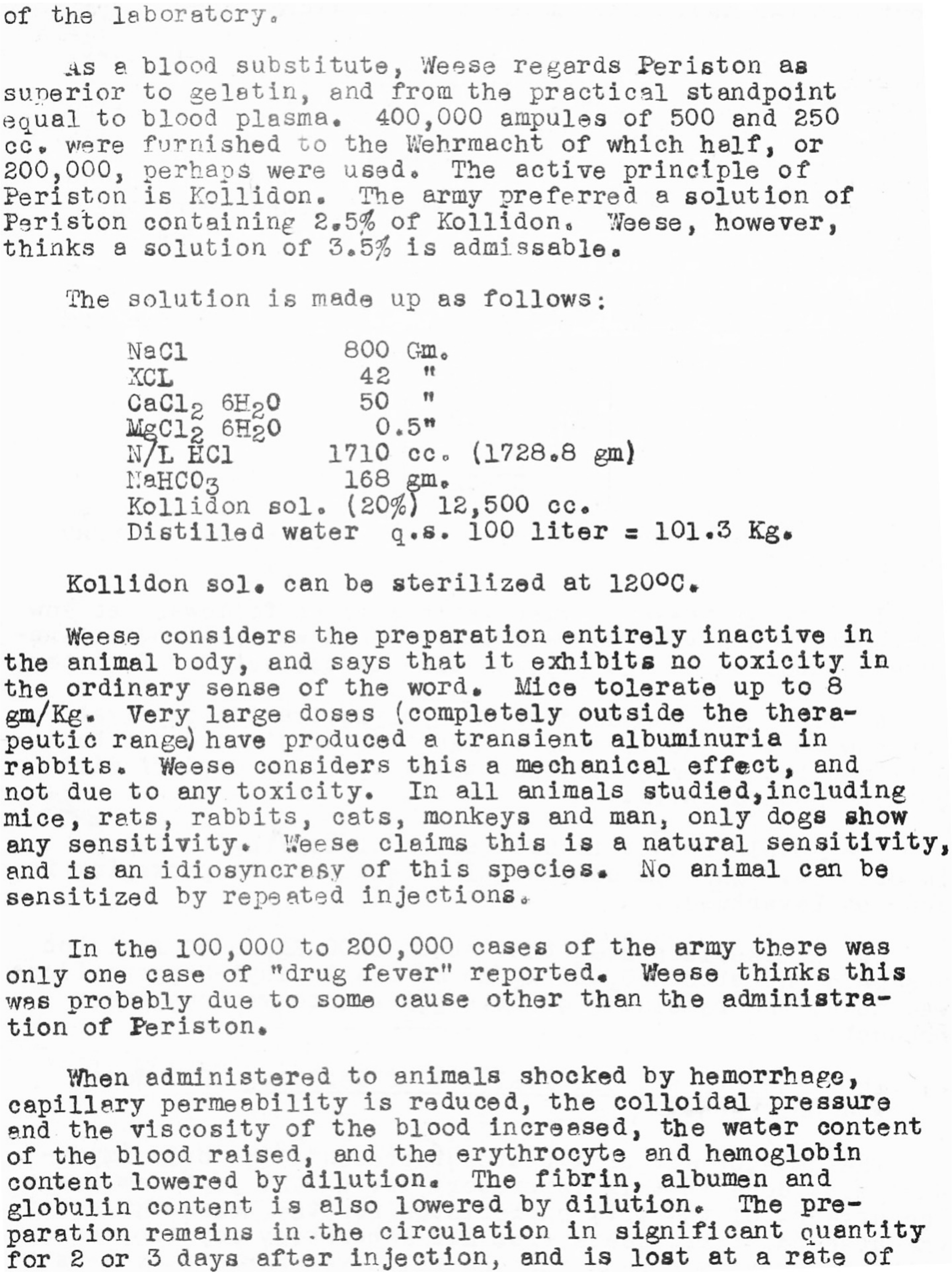
The total product is used after dissolving to remove impurities. This is done at Elberfeld and the packaging is done at Leverkusen.

Dr. Krzikalla stated that about 6000 Kg/mo of Periston was made and about 30,000 kg/mo of the 1-vinyl-2-pyrrolidone was made, the remainder of this going into various other products.

2. Pharmacology and Clinical Use of Periston (Dr. Weese and Dr. Hecht)

The development of Periston represents the only important work done in this laboratory during the past few years. The urgency of the work on Periston for the Wehrmacht and the absence of Dr. Weese from his laboratory for two years with the army, accounts for the relative unproductiveness

Figure A.80: Information on periston [CIOS XXV-54].



of the laboratory.

As a blood substitute, Weese regards Periston as superior to gelatin, and from the practical standpoint equal to blood plasma. 400,000 ampules of 500 and 250 cc. were furnished to the Wehrmacht of which half, or 200,000, perhaps were used. The active principle of Periston is Kollidon. The army preferred a solution of Periston containing 2.5% of Kollidon. Weese, however, thinks a solution of 3.5% is admissable.

The solution is made up as follows:

NaCl	800 Gm.
XCL	42 "
$CaCl_2$ $6H_2O$	50 "
$MgCl_2$ $6H_2O$	0.5"
N/L HCl	1710 cc. (1728.8 gm)
$NaHCO_3$	168 gm.
Kollidon sol. (20%)	12,500 cc.
Distilled water	q.s. 100 liter = 101.3 Kg.

Kollidon sol. can be sterilized at 120°C.

Weese considers the preparation entirely inactive in the animal body, and says that it exhibits no toxicity in the ordinary sense of the word. Mice tolerate up to 8 gm/Kg. Very large doses (completely outside the therapeutic range) have produced a transient albuminuria in rabbits. Weese considers this a mechanical effect, and not due to any toxicity. In all animals studied, including mice, rats, rabbits, cats, monkeys and man, only dogs show any sensitivity. Weese claims this is a natural sensitivity, and is an idiosyncrasy of this species. No animal can be sensitized by repeated injections.

In the 100,000 to 200,000 cases of the army there was only one case of "drug fever" reported. Weese thinks this was probably due to some cause other than the administration of Periston.

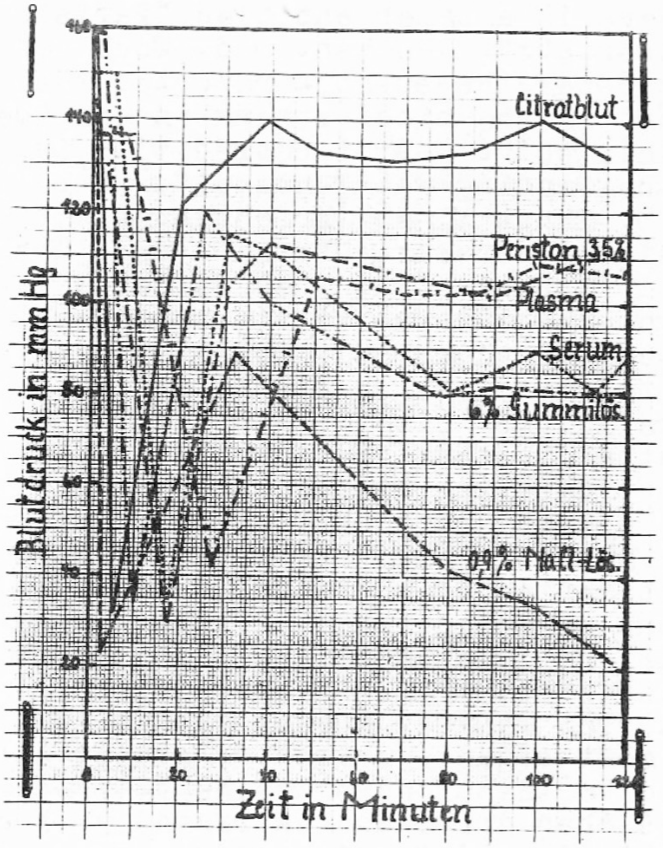
When administered to animals shocked by hemorrhage, capillary permeability is reduced, the colloidal pressure and the viscosity of the blood increased, the water content of the blood raised, and the erythrocyte and hemoglobin content lowered by dilution. The fibrin, albumen and globulin content is also lowered by dilution. The preparation remains in the circulation in significant quantity for 2 or 3 days after injection, and is lost at a rate of

Figure A.81: Information on periston [CIOS XXV-54].

about 50% per day. The preparation is excreted by the kidney for two or three days, but thereafter cannot be found again in the urine. Not more than 50% can be accounted for by urinary excretion. Hecht believes that only the smaller molecules, possibly up to mol. wt. 10,000 are excreted, the rest being changed in some unknown manner in the body. The doses recommended are up to 500 cc. for adults and 25 cc/kg. body weight for infants.

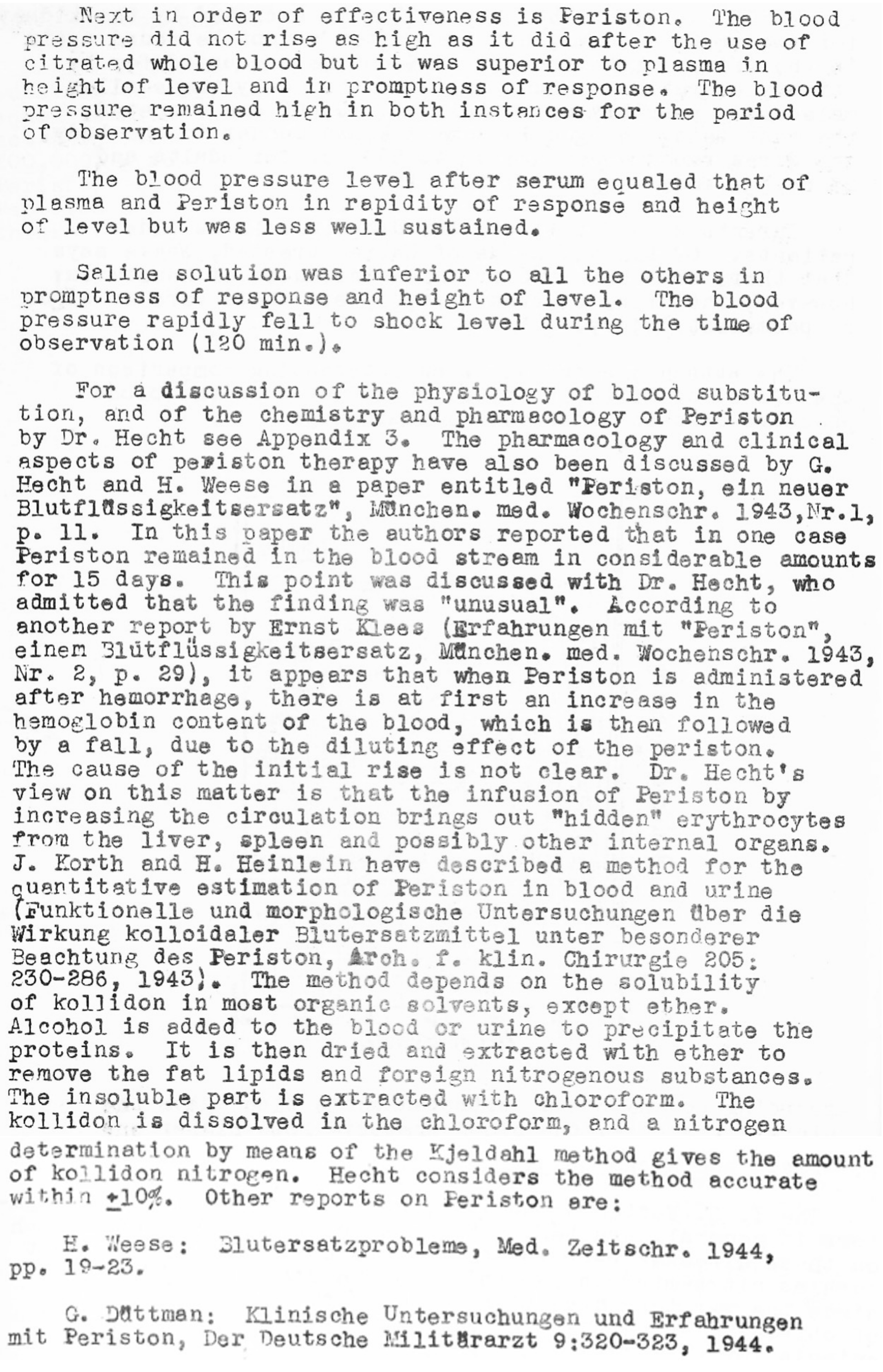
Infants do not tolerate the drug as well as older patients. Of the thousands of babies treated, Weese says that there have been two or three instances of hematuria; however, the urine cleared promptly and there were no signs of permanent injury.

The attached chart shows an interesting comparison of the effect of different blood substitutes on the blood pressure of cats after severe hemorrhage.



According to the chart, citrated whole blood gave the quickest response; the blood pressure rose higher and remained high for the duration of observation.

Figure A.82: Information on periston [CIOS XXV-54].



Next in order of effectiveness is Periston. The blood pressure did not rise as high as it did after the use of citrated whole blood but it was superior to plasma in height of level and in promptness of response. The blood pressure remained high in both instances for the period of observation.

The blood pressure level after serum equaled that of plasma and Periston in rapidity of response and height of level but was less well sustained.

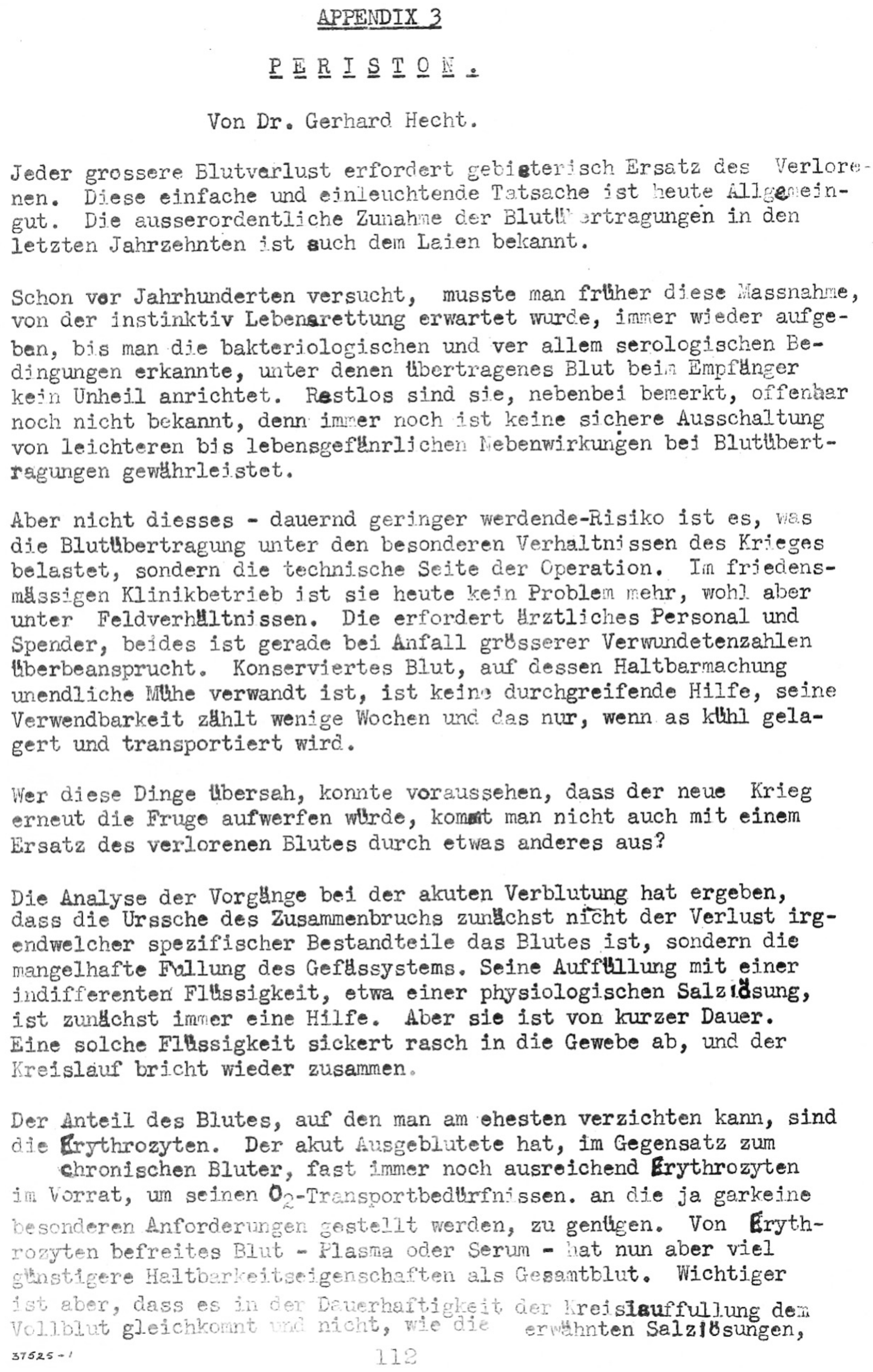
Saline solution was inferior to all the others in promptness of response and height of level. The blood pressure rapidly fell to shock level during the time of observation (120 min.).

For a discussion of the physiology of blood substitution, and of the chemistry and pharmacology of Periston by Dr. Hecht see Appendix 3. The pharmacology and clinical aspects of periston therapy have also been discussed by G. Hecht and H. Weese in a paper entitled "Periston, ein neuer Blutflüssigkeitsersatz", München. med. Wochenschr. 1943, Nr. 1, p. 11. In this paper the authors reported that in one case Periston remained in the blood stream in considerable amounts for 15 days. This point was discussed with Dr. Hecht, who admitted that the finding was "unusual". According to another report by Ernst Klees (Erfahrungen mit "Periston", einem Blütflüssigkeitsersatz, München. med. Wochenschr. 1943, Nr. 2, p. 29), it appears that when Periston is administered after hemorrhage, there is at first an increase in the hemoglobin content of the blood, which is then followed by a fall, due to the diluting effect of the periston. The cause of the initial rise is not clear. Dr. Hecht's view on this matter is that the infusion of Periston by increasing the circulation brings out "hidden" erythrocytes from the liver, spleen and possibly other internal organs. J. Korth and H. Heinlein have described a method for the quantitative estimation of Periston in blood and urine (Funktionelle und morphologische Untersuchungen über die Wirkung kolloidaler Blutersatzmittel unter besonderer Beachtung des Periston, Arch. f. klin. Chirurgie 205: 230-286, 1943). The method depends on the solubility of kollidon in most organic solvents, except ether. Alcohol is added to the blood or urine to precipitate the proteins. It is then dried and extracted with ether to remove the fat lipids and foreign nitrogenous substances. The insoluble part is extracted with chloroform. The kollidon is dissolved in the chloroform, and a nitrogen determination by means of the Kjeldahl method gives the amount of kollidon nitrogen. Hecht considers the method accurate within ±10%. Other reports on Periston are:

H. Weese: Blutersatzprobleme, Med. Zeitschr. 1944, pp. 19-23.

G. Düttman: Klinische Untersuchungen und Erfahrungen mit Periston, Der Deutsche Militärarzt 9:320-323, 1944.

Figure A.83: Information on periston [CIOS XXV-54].



APPENDIX 3

PERISTON.

Von Dr. Gerhard Hecht.

Jeder grossere Blutverlust erfordert gebieterisch Ersatz des Verlorenen. Diese einfache und einleuchtende Tatsache ist heute Allgemeingut. Die ausserordentliche Zunahme der Blutübertragungen in den letzten Jahrzehnten ist auch dem Laien bekannt.

Schon vor Jahrhunderten versucht, musste man früher diese Massnahme, von der instinktiv Lebensrettung erwartet wurde, immer wieder aufgeben, bis man die bakteriologischen und ver allem serologischen Bedingungen erkannte, unter denen übertragenes Blut beim Empfänger kein Unheil anrichtet. Restlos sind sie, nebenbei bemerkt, offenbar noch nicht bekannt, denn immer noch ist keine sichere Ausschaltung von leichteren bis lebensgefährlichen Nebenwirkungen bei Blutübertragungen gewährleistet.

Aber nicht diesses - dauernd geringer werdende-Risiko ist es, was die Blutübertragung unter den besonderen Verhaltnissen des Krieges belastet, sondern die technische Seite der Operation. Im friedensmässigen Klinikbetrieb ist sie heute kein Problem mehr, wohl aber unter Feldverhältnissen. Die erfordert ärztliches Personal und Spender, beides ist gerade bei Anfall grösserer Verwundetenzahlen überbeansprucht. Konserviertes Blut, auf dessen Haltbarmachung unendliche Mühe verwandt ist, ist keine durchgreifende Hilfe, seine Verwendbarkeit zählt wenige Wochen und das nur, wenn as kühl gelagert und transportiert wird.

Wer diese Dinge übersah, konnte voraussehen, dass der neue Krieg erneut die Fruge aufwerfen würde, kommt man nicht auch mit einem Ersatz des verlorenen Blutes durch etwas anderes aus?

Die Analyse der Vorgänge bei der akuten Verblutung hat ergeben, dass die Urssche des Zusammenbruchs zunächst nicht der Verlust irgendwelcher spezifischer Bestandteile das Blutes ist, sondern die mangelhafte Füllung des Gefässystems. Seine Auffüllung mit einer indifferenten Flüssigkeit, etwa einer physiologischen Salzlösung, ist zunächst immer eine Hilfe. Aber sie ist von kurzer Dauer. Eine solche Flüssigkeit sickert rasch in die Gewebe ab, und der Kreislauf bricht wieder zusammen.

Der Anteil des Blutes, auf den man am ehesten verzichten kann, sind die Erythrozyten. Der akut Ausgeblutete hat, im Gegensatz zum chronischen Bluter, fast immer noch ausreichend Erythrozyten im Vorrat, um seinen O_2-Transportbedürfnissen. an die ja garkeine besonderen Anforderungen gestellt werden, zu genügen. Von Erythrozyten befreites Blut - Plasma oder Serum - hat nun aber viel günstigere Haltbarkeitseigenschaften als Gesamtblut. Wichtiger ist aber, dass es in der Dauerhaftigkeit der Kreislauffullung dem Vollblut gleichkomnt und nicht, wie die erwähnten Salzlösungen,

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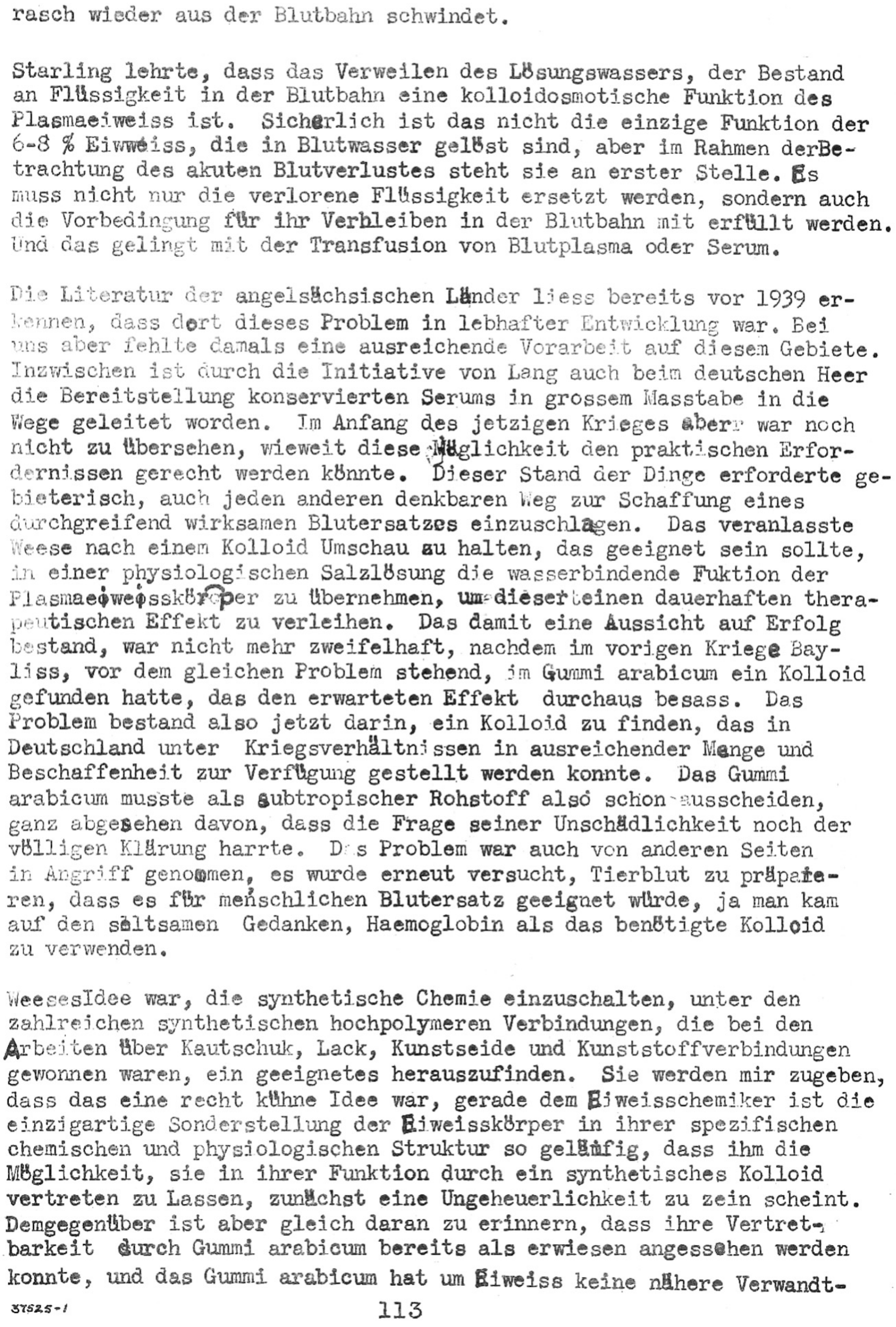
Figure A.84: Information on periston [CIOS XXV-54].



rasch wieder aus der Blutbahn schwindet.

Starling lehrte, dass das Verweilen des Lösungswassers, der Bestand an Flüssigkeit in der Blutbahn eine kolloidosmotische Funktion des Plasmaeiweiss ist. Sicherlich ist das nicht die einzige Funktion der 6-8 % Eiwweiss, die in Blutwasser gelöst sind, aber im Rahmen derBetrachtung des akuten Blutverlustes steht sie an erster Stelle. Es muss nicht nur die verlorene Flüssigkeit ersetzt werden, sondern auch die Vorbedingung für ihr Verbleiben in der Blutbahn mit erfüllt werden. Und das gelingt mit der Transfusion von Blutplasma oder Serum.

Die Literatur der angelsächsischen Länder liess bereits vor 1939 erkennen, dass dort dieses Problem in lebhafter Entwicklung war. Bei uns aber fehlte damals eine ausreichende Vorarbeit auf diesem Gebiete. Inzwischen ist durch die Initiative von Lang auch beim deutschen Heer die Bereitstellung konservierten Serums in grossem Masstabe in die Wege geleitet worden. Im Anfang des jetzigen Krieges aber war noch nicht zu übersehen, wieweit diese Möglichkeit den praktischen Erfordernissen gerecht werden könnte. Dieser Stand der Dinge erforderte gebieterisch, auch jeden anderen denkbaren Weg zur Schaffung eines durchgreifend wirksamen Blutersatzes einzuschlagen. Das veranlasste Weese nach einem Kolloid Umschau zu halten, das geeignet sein sollte, in einer physiologischen Salzlösung die wasserbindende Fuktion der Plasmaeiweisskörper zu übernehmen, um dieser einen dauerhaften therapeutischen Effekt zu verleihen. Das damit eine Aussicht auf Erfolg bestand, war nicht mehr zweifelhaft, nachdem im vorigen Kriege Bayliss, vor dem gleichen Problem stehend, im Gummi arabicum ein Kolloid gefunden hatte, das den erwarteten Effekt durchaus besass. Das Problem bestand also jetzt darin, ein Kolloid zu finden, das in Deutschland unter Kriegsverhältnissen in ausreichender Menge und Beschaffenheit zur Verfügung gestellt werden konnte. Das Gummi arabicum musste als subtropischer Rohstoff also schon ausscheiden, ganz abgesehen davon, dass die Frage seiner Unschädlichkeit noch der völligen Klärung harrte. Das Problem war auch von anderen Seiten in Angriff genommen, es wurde erneut versucht, Tierblut zu präparieren, dass es für menschlichen Blutersatz geeignet würde, ja man kam auf den seltsamen Gedanken, Haemoglobin als das benötigte Kolloid zu verwenden.

WeesesIdee war, die synthetische Chemie einzuschalten, unter den zahlreichen synthetischen hochpolymeren Verbindungen, die bei den Arbeiten über Kautschuk, Lack, Kunstseide und Kunststoffverbindungen gewonnen waren, ein geeignetes herauszufinden. Sie werden mir zugeben, dass das eine recht kühne Idee war, gerade dem Eiweisschemiker ist die einzigartige Sonderstellung der Eiweisskörper in ihrer spezifischen chemischen und physiologischen Struktur so geläufig, dass ihm die Möglichkeit, sie in ihrer Funktion durch ein synthetisches Kolloid vertreten zu Lassen, zunächst eine Ungeheuerlichkeit zu zein scheint. Demgegenüber ist aber gleich daran zu erinnern, dass ihre Vertretbarkeit durch Gummi arabicum bereits als erwiesen angessehen werden konnte, und das Gummi arabicum hat um Eiweiss keine nähere Verwandt-

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Figure A.85: Information on periston [CIOS XXV-54].

schaft, als ein synthetischer Körper, ich werde noch zeigen, dass das Umgekehrte gilt.

Ich möchte nun übergehen, welche Verbindungen wir damals alle auf ihre Eignung geprüft haben und nur kurz andeuten, wie die Prüfung der zur Auswahl gestandenen Körper durchgeführt wurde. Natürlich mussten sie wasserlöslich sein. Da es im allgemeinen nicht das Ziel der auf einschlägigen Gebieten tätigen Synthetiker war, wasserlösliche Verbindungen zu gewinnen, war die Auswahl unter den bereits hergestellten Verbindungen nicht übermässwig gross, und engte sich noch weiter ein, als sie auf ihre Wechselwirkungen mit den in physiologischen Lösungen notwendig enthaltenen Salzen geprüft wurden: viele von ihnen bildeten u.B. unlösliche Kalksalze. Dann kam die wichtigste Forderung in Sinne des primus non nocere: ihre anstandslos Verträglichkeit bei intravenöser Injektion grösster Dosen. Dann erst kam die kolloidchemische Seite: Der kolloidosmotische Druck musste grössenordnungsmässig zu dem des Plassweiweissen passen und schliesslich der Tierversuch mit einem grösseren Blutverlust des Leben retten, als es die kolloidfreie Salzlösung es tut.

In dieser Weise kamen wir zur Auswahl eines bestimaten Kolloides, des "Kollidons", das in geeigneter Salzlösung gelöst unter der Bezeichnung "Periston" dann klinisch geprüft und seit 3 Jahren in nunmehr hunderttausenden von Fällen beim Heer praktisch benutzt worden ist. Über den klinischen Erfolg nur einige ganz kurze Angaben: Zunächst ist die Verträglichkeit über allem Zweifel erhaben, ausser ganz vereinzeltn Fallen von Fieberreaktion - unendliche viel seltener als nach Blut- oder Serumtransfusionen - sind uns keine für das Präparat spezifischen Nebenwirkungen gemeldet worden. Und über den Effekt liegen neben kühlen und reservierten, in der Mehrzahl absolut positive Berichte von kriegschirurgischer Seite vor. Daneben wird in heimischen Kliniken, selbst dort also, wo die Bluttransfusion mölich wäre, viel Periston benutzt, sicherlich wäre es noch viel mehr, wenn die Produktion nicht von der Seite der Glasampullen her hinter den Anforderungen zurückbliebe.

An dieser Stelle möchte ich es als meine Auggabe-ansehen, Sie mit einigen Eigenachaften dieses Kolloides bekannt zu machen. Es ist in dem von Herrn Dr. Reppe geleiteten I.G. Laboratorium in Ludwigshafen erfunden worden. Nach einer von Reppe entwickelten Synthese wird N-Vinylpyrrolidon

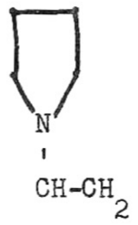
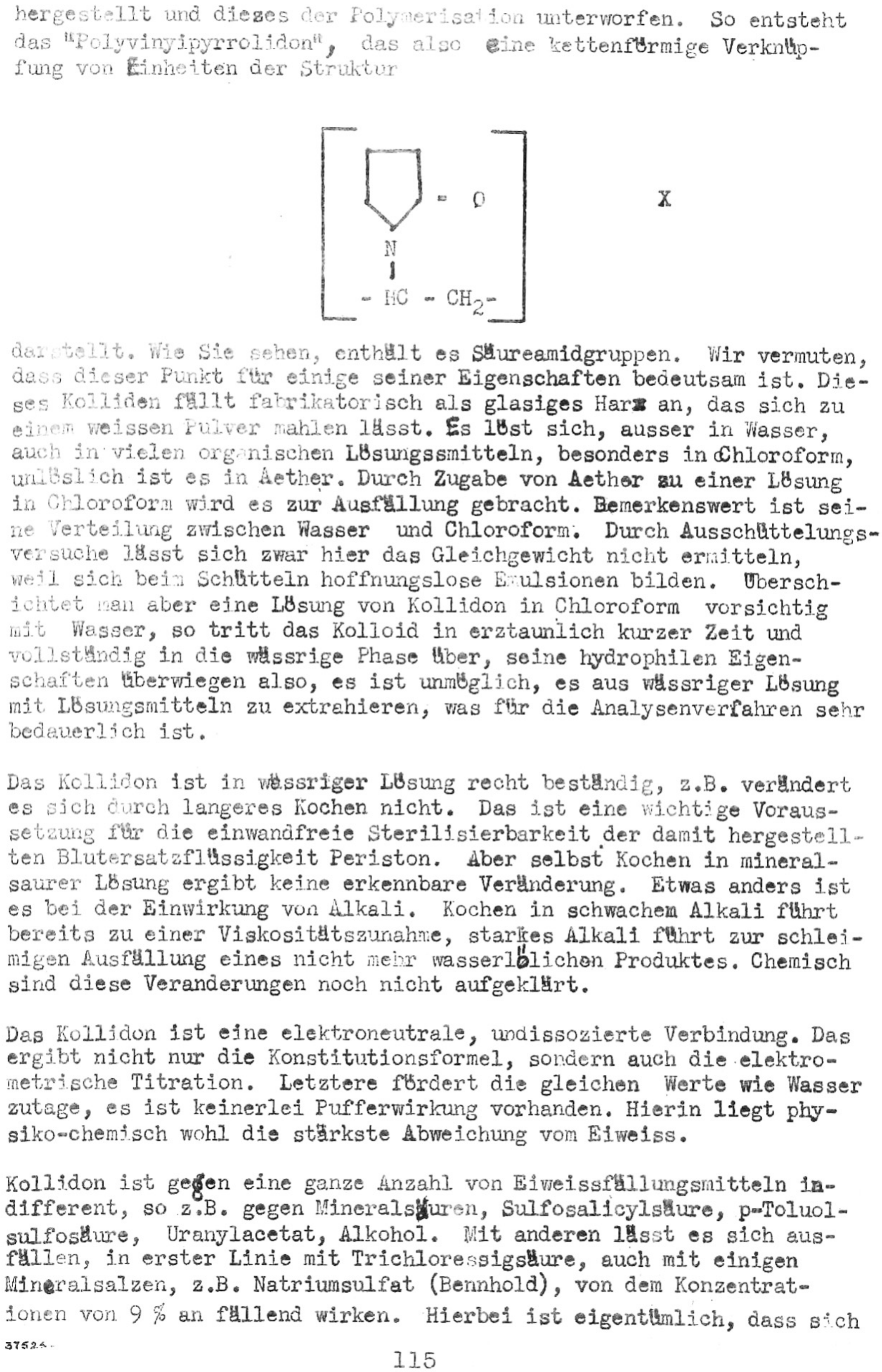


Figure A.86: Information on periston [CIOS XXV-54].



hergestellt und dieses der Polymerisation unterworfen. So entsteht das "Polyvinyipyrrolidon", das also eine kettenförmige Verknüpfung von Einheiten der Struktur

darstellt. Wie Sie sehen, enthält es Säureamidgruppen. Wir vermuten, dass dieser Punkt für einige seiner Eigenschaften bedeutsam ist. Dieses Kolliden fällt fabrikatorisch als glasiges Harz an, das sich zu einem weissen Pulver mahlen lässt. Es löst sich, ausser in Wasser, auch in vielen organischen Lösungssmitteln, besonders in Chloroform, unlöslich ist es in Aether. Durch Zugabe von Aether zu einer Lösung in Chloroform wird es zur Ausfällung gebracht. Bemerkenswert ist seine Verteilung zwischen Wasser und Chloroform. Durch Ausschüttelungsversuche lässt sich zwar hier das Gleichgewicht nicht ermitteln, weil sich beim Schütteln hoffnungslose Emulsionen bilden. Überschichtet man aber eine Lösung von Kollidon in Chloroform vorsichtig mit Wasser, so tritt das Kolloid in erztaunlich kurzer Zeit und vollständig in die wässrige Phase über, seine hydrophilen Eigenschaften überwiegen also, es ist unmöglich, es aus wässriger Lösung mit Lösungsmitteln zu extrahieren, was für die Analysenverfahren sehr bedauerlich ist.

Das Kollidon ist in wässriger Lösung recht beständig, z.B. verändert es sich durch langeres Kochen nicht. Das ist eine wichtige Voraussetzung für die einwandfreie Sterilisierbarkeit der damit hergestellten Blutersatzflüssigkeit Periston. Aber selbst Kochen in mineralsaurer Lösung ergibt keine erkennbare Veränderung. Etwas anders ist es bei der Einwirkung von Alkali. Kochen in schwachem Alkali führt bereits zu einer Viskositätszunahme, starkes Alkali führt zur schleimigen Ausfällung eines nicht mehr wasserlöslichen Produktes. Chemisch sind diese Veranderungen noch nicht aufgeklärt.

Das Kollidon ist eine elektroneutrale, undissozierte Verbindung. Das ergibt nicht nur die Konstitutionsformel, sondern auch die elektrometrische Titration. Letztere fördert die gleichen Werte wie Wasser zutage, es ist keinerlei Pufferwirkung vorhanden. Hierin liegt physiko-chemisch wohl die stärkste Abweichung vom Eiweiss.

Kollidon ist gegen eine ganze Anzahl von Eiweissfällungsmitteln indifferent, so z.B. gegen Mineralsäuren, Sulfosalicylsäure, p-Toluolsulfosäure, Uranylacetat, Alkohol. Mit anderen lässt es sich ausfällen, in erster Linie mit Trichloressigsäure, auch mit einigen Mineralsalzen, z.B. Natriumsulfat (Bennhold), von dem Konzentrationen von 9 % an fällend wirken. Hierbei ist eigentümlich, dass sich

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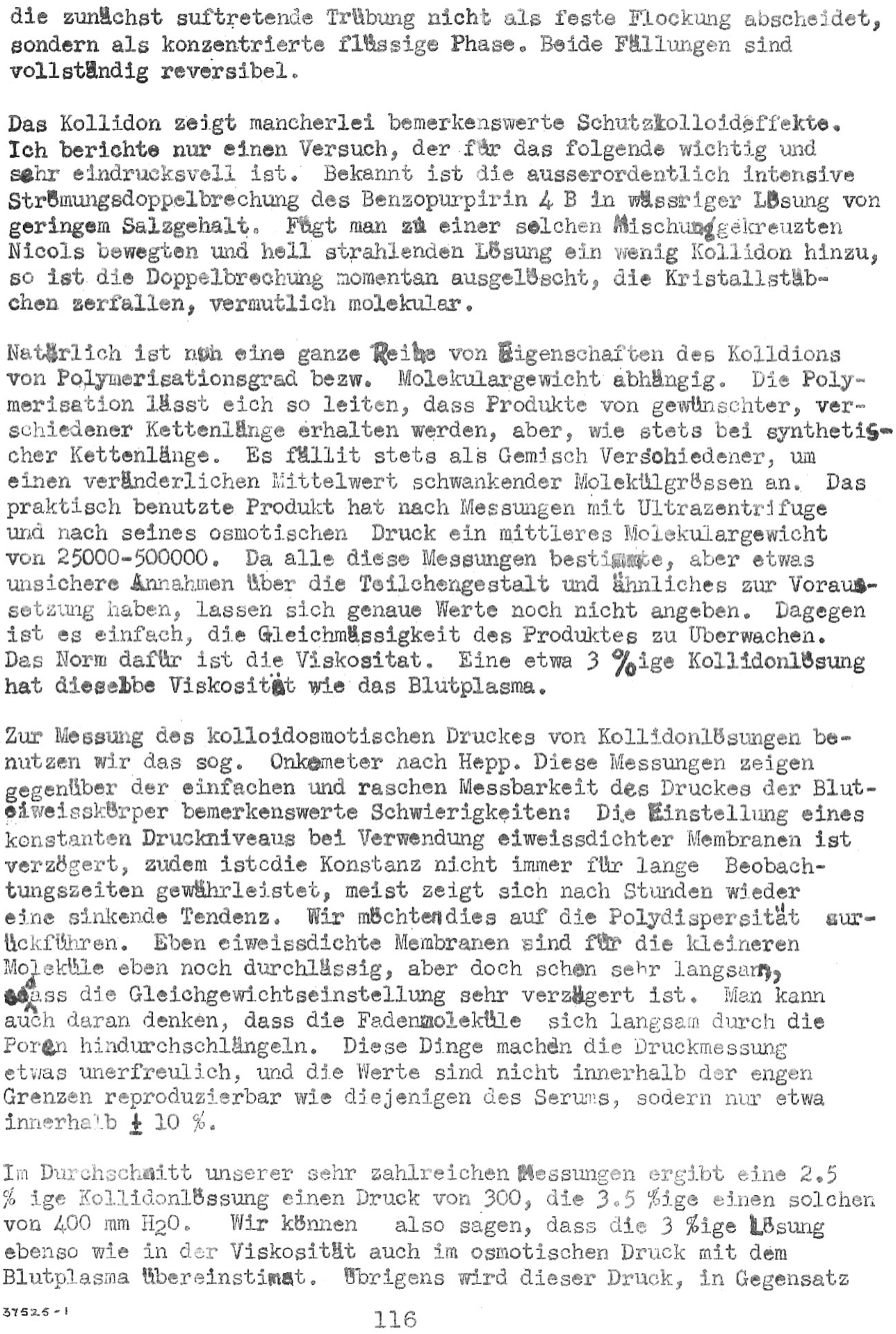
Figure A.87: Information on periston [CIOS XXV-54].



die zunächst auftretende Trübung nicht als feste Flockung abscheidet, sondern als konzentrierte flüssige Phase. Beide Fällungen sind vollständig reversibel.

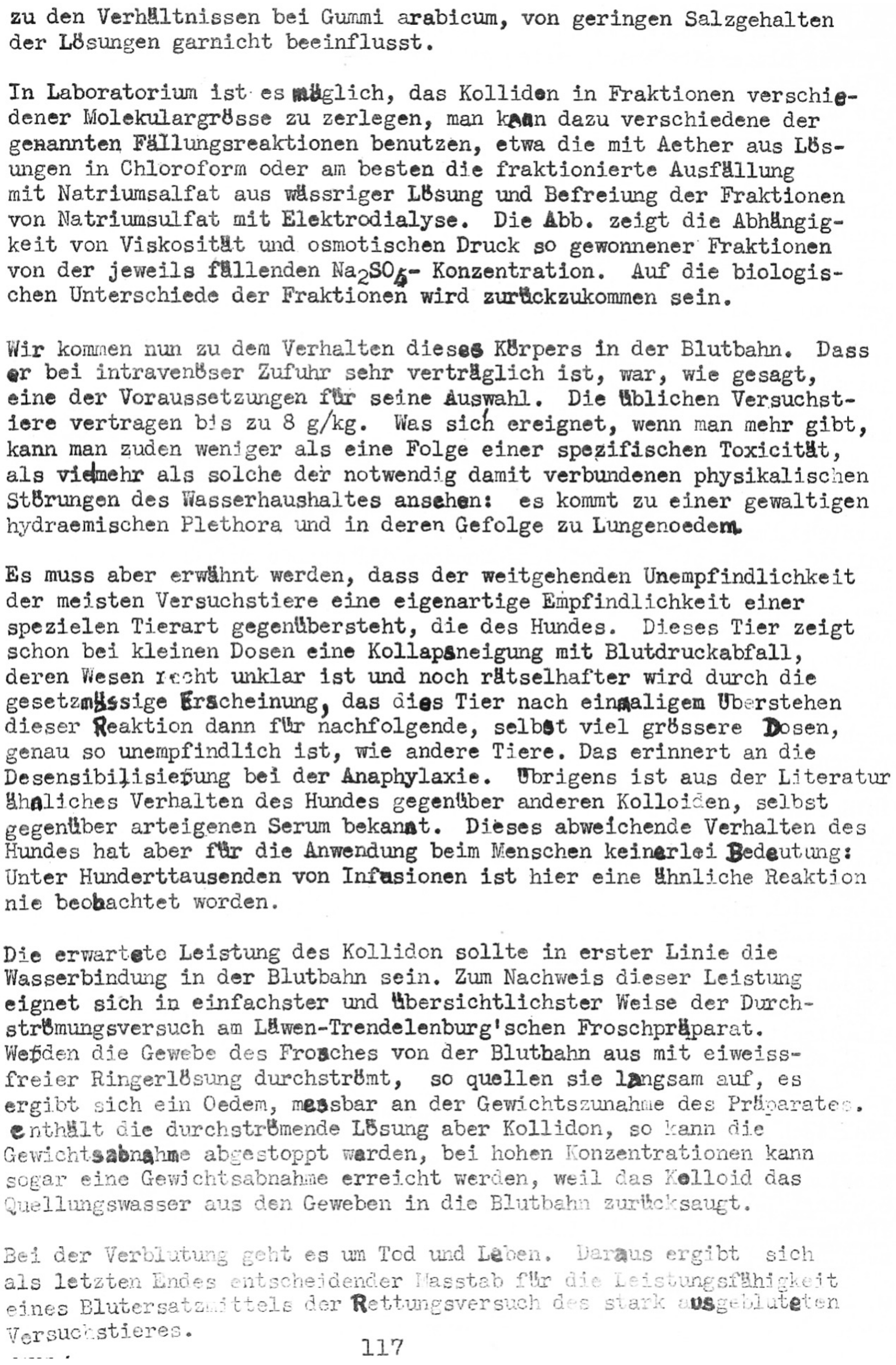
Das Kollidon zeigt mancherlei bemerkenswerte Schutzkolloideffekte. Ich berichte nur einen Versuch, der für das folgende wichtig und sehr eindrucksvell ist. Bekannt ist die ausserordentlich intensive Strömungsdoppelbrechung des Benzopurpirin 4 B in wässriger Lösung von geringem Salzgehalt. Fügt man zu einer solchen Mischung gekreuzten Nicols bewegten und hell strahlenden Lösung ein wenig Kollidon hinzu, so ist die Doppelbrechung momentan ausgelöscht, die Kristallstäbchen zerfallen, vermutlich molekular.

Natürlich ist noch eine ganze Reihe von Eigenschaften des Kolldions von Polymerisationsgrad bezw. Molekulargewicht abhängig. Die Polymerisation lässt eich so leiten, dass Produkte von gewünschter, verschiedener Kettenlänge erhalten werden, aber, wie stets bei synthetischer Kettenlänge. Es fällit stets als Gemisch Verschiedener, um einen veränderlichen Mittelwert schwankender Molekülgrössen an. Das praktisch benutzte Produkt hat nach Messungen mit Ultrazentrifuge und nach seines osmotischen Druck ein mittleres Molekulargewicht von 25000-500000. Da alle diese Messungen bestimmte, aber etwas unsichere Annahmen über die Teilchengestalt und ähnliches zur Voraussetzung haben, lassen sich genaue Werte noch nicht angeben. Dagegen ist es einfach, die Gleichmässigkeit des Produktes zu Überwachen. Das Norm dafür ist die Viskositat. Eine etwa 3 %ige Kollidonlösung hat dieselbe Viskosität wie das Blutplasma.

Zur Messung des kolloidosmotischen Druckes von Kollidonlösungen benutzen wir das sog. Onkometer nach Hepp. Diese Messungen zeigen gegenüber der einfachen und raschen Messbarkeit des Druckes der Bluteiweisskörper bemerkenswerte Schwierigkeiten: Die Einstellung eines konstanten Druckniveaus bei Verwendung eiweissdichter Membranen ist verzögert, zudem istcdie Konstanz nicht immer für lange Beobachtungszeiten gewährleistet, meist zeigt sich nach Stunden wieder eine sinkende Tendenz. Wir möchten dies auf die Polydispersität zurückführen. Eben eiweissdichte Membranen sind für die kleineren Moleküle eben noch durchlässig, aber doch schon sehr langsam, dass die Gleichgewichtseinstellung sehr verzögert ist. Man kann auch daran denken, dass die Fadenmoleküle sich langsam durch die Poren hindurchschlängeln. Diese Dinge machen die Druckmessung etwas unerfreulich, und die Werte sind nicht innerhalb der engen Grenzen reproduzierbar wie diejenigen des Serums, sodern nur etwa innerhalb ± 10 %.

Im Durchschnitt unserer sehr zahlreichen Messungen ergibt eine 2.5 % ige Kollidonlössung einen Druck von 300, die 3.5 %ige einen solchen von 400 mm H_2O. Wir können also sagen, dass die 3 %ige Lösung ebenso wie in der Viskosität auch im osmotischen Druck mit dem Blutplasma übereinstimmt. Übrigens wird dieser Druck, in Gegensatz

Figure A.88: Information on periston [CIOS XXV-54].



zu den Verhältnissen bei Gummi arabicum, von geringen Salzgehalten der Lösungen garnicht beeinflusst.

In Laboratorium ist es möglich, das Kolliden in Fraktionen verschiedener Molekulargrösse zu zerlegen, man kann dazu verschiedene der genannten Fällungsreaktionen benutzen, etwa die mit Aether aus Lösungen in Chloroform oder am besten die fraktionierte Ausfällung mit Natriumsalfat aus wässriger Lösung und Befreiung der Fraktionen von Natriumsulfat mit Elektrodialyse. Die Abb. zeigt die Abhängigkeit von Viskosität und osmotischen Druck so gewonnener Fraktionen von der jeweils fällenden Na_2SO_4- Konzentration. Auf die biologischen Unterschiede der Fraktionen wird zurückzukommen sein.

Wir kommen nun zu dem Verhalten dieses Körpers in der Blutbahn. Dass er bei intravenöser Zufuhr sehr verträglich ist, war, wie gesagt, eine der Voraussetzungen für seine Auswahl. Die üblichen Versuchstiere vertragen bis zu 8 g/kg. Was sich ereignet, wenn man mehr gibt, kann man zuden weniger als eine Folge einer spezifischen Toxicität, als vielmehr als solche der notwendig damit verbundenen physikalischen Störungen des Wasserhaushaltes ansehen: es kommt zu einer gewaltigen hydraemischen Plethora und in deren Gefolge zu Lungenoedem.

Es muss aber erwähnt werden, dass der weitgehenden Unempfindlichkeit der meisten Versuchstiere eine eigenartige Empfindlichkeit einer spezielen Tierart gegenübersteht, die des Hundes. Dieses Tier zeigt schon bei kleinen Dosen eine Kollapsneigung mit Blutdruckabfall, deren Wesen recht unklar ist und noch rätselhafter wird durch die gesetzmässige Erscheinung, das dies Tier nach einmaligem Überstehen dieser Reaktion dann für nachfolgende, selbst viel grössere Dosen, genau so unempfindlich ist, wie andere Tiere. Das erinnert an die Desensibilisierung bei der Anaphylaxie. Übrigens ist aus der Literatur ähnliches Verhalten des Hundes gegenüber anderen Kolloiden, selbst gegenüber arteigenen Serum bekannt. Dieses abweichende Verhalten des Hundes hat aber für die Anwendung beim Menschen keinerlei Bedeutung: Unter Hunderttausenden von Infusionen ist hier eine ähnliche Reaktion nie beobachtet worden.

Die erwartete Leistung des Kollidon sollte in erster Linie die Wasserbindung in der Blutbahn sein. Zum Nachweis dieser Leistung eignet sich in einfachster und übersichtlichster Weise der Durchströmungsversuch am Läwen-Trendelenburg'schen Froschpräparat. Werden die Gewebe des Frosches von der Blutbahn aus mit eiweissfreier Ringerlösung durchströmt, so quellen sie langsam auf, es ergibt sich ein Oedem, messbar an der Gewichtszunahme des Präparates. enthält die durchströmende Lösung aber Kollidon, so kann die Gewichtsabnahme abgestoppt warden, bei hohen Konzentrationen kann sogar eine Gewichtsabnahme erreicht werden, weil das Kolloid das Quellungswasser aus den Geweben in die Blutbahn zurücksaugt.

Bei der Verblutung geht es um Tod und Leben. Daraus ergibt sich als letzten Endes entscheidender Masstab für die Leistungsfähigkeit eines Blutersatzmittels der Rettungsversuch des stark ausgebluteten Versuchstieres.

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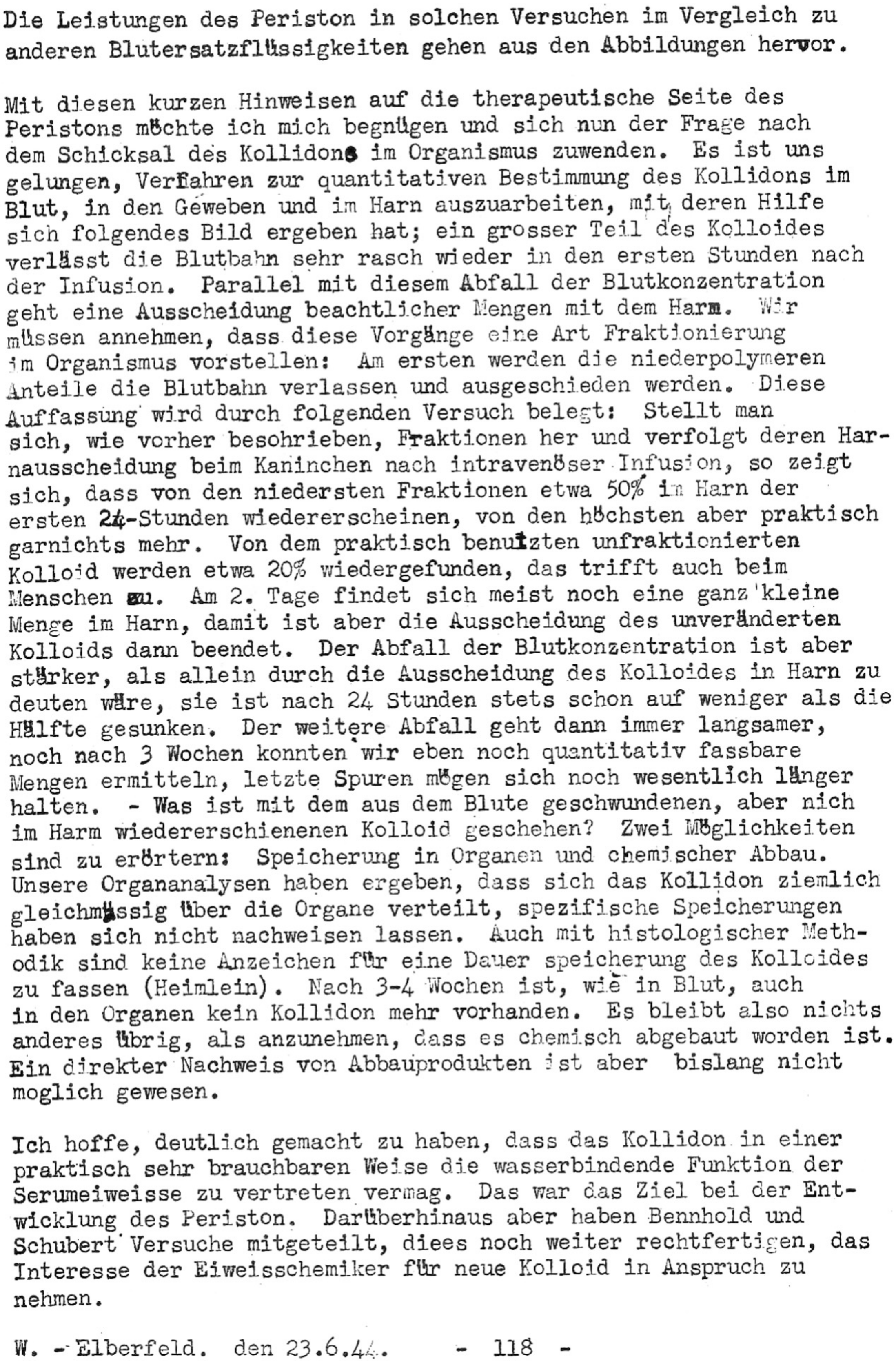
Figure A.89: Information on periston [CIOS XXV-54].



Die Leistungen des Periston in solchen Versuchen im Vergleich zu anderen Blutersatzflüssigkeiten gehen aus den Abbildungen hervor.

Mit diesen kurzen Hinweisen auf die therapeutische Seite des Peristons möchte ich mich begnügen und sich nun der Frage nach dem Schicksal des Kollidons im Organismus zuwenden. Es ist uns gelungen, Verfahren zur quantitativen Bestimmung des Kollidons im Blut, in den Geweben und im Harn auszuarbeiten, mit deren Hilfe sich folgendes Bild ergeben hat; ein grosser Teil des Kolloides verlässt die Blutbahn sehr rasch wieder in den ersten Stunden nach der Infusion. Parallel mit diesem Abfall der Blutkonzentration geht eine Ausscheidung beachtlicher Mengen mit dem Harm. Wir müssen annehmen, dass diese Vorgänge eine Art Fraktionierung im Organismus vorstellen: Am ersten werden die niederpolymeren Anteile die Blutbahn verlassen und ausgeschieden werden. Diese Auffassung wird durch folgenden Versuch belegt: Stellt man sich, wie vorher beschrieben, Fraktionen her und verfolgt deren Harnausscheidung beim Kaninchen nach intravenöser Infusion, so zeigt sich, dass von den niedersten Fraktionen etwa 50% im Harn der ersten 24-Stunden wiedererscheinen, von den höchsten aber praktisch garnichts mehr. Von dem praktisch benutzten unfraktionierten Kolloid werden etwa 20% wiedergefunden, das trifft auch beim Menschen zu. Am 2. Tage findet sich meist noch eine ganz kleine Menge im Harn, damit ist aber die Ausscheidung des unveränderten Kolloids dann beendet. Der Abfall der Blutkonzentration ist aber stärker, als allein durch die Ausscheidung des Kolloides in Harn zu deuten wäre, sie ist nach 24 Stunden stets schon auf weniger als die Hälfte gesunken. Der weitere Abfall geht dann immer langsamer, noch nach 3 Wochen konnten wir eben noch quantitativ fassbare Mengen ermitteln, letzte Spuren mögen sich noch wesentlich länger halten. - Was ist mit dem aus dem Blute geschwundenen, aber nich im Harm wiedererschienenen Kolloid geschehen? Zwei Möglichkeiten sind zu erörtern: Speicherung in Organen und chemischer Abbau. Unsere Organanalysen haben ergeben, dass sich das Kollidon ziemlich gleichmässig über die Organe verteilt, spezifische Speicherungen haben sich nicht nachweisen lassen. Auch mit histologischer Methodik sind keine Anzeichen für eine Dauer speicherung des Kolloides zu fassen (Heimlein). Nach 3-4 Wochen ist, wie in Blut, auch in den Organen kein Kollidon mehr vorhanden. Es bleibt also nichts anderes übrig, als anzunehmen, dass es chemisch abgebaut worden ist. Ein direkter Nachweis von Abbauprodukten ist aber bislang nicht moglich gewesen.

Ich hoffe, deutlich gemacht zu haben, dass das Kollidon in einer praktisch sehr brauchbaren Weise die wasserbindende Funktion der Serumeiweisse zu vertreten vermag. Das war das Ziel bei der Entwicklung des Periston. Darüberhinaus aber haben Bennhold und Schubert Versuche mitgeteilt, diees noch weiter rechtfertigen, das Interesse der Eiweisschemiker für neue Kolloid in Anspruch zu nehmen.

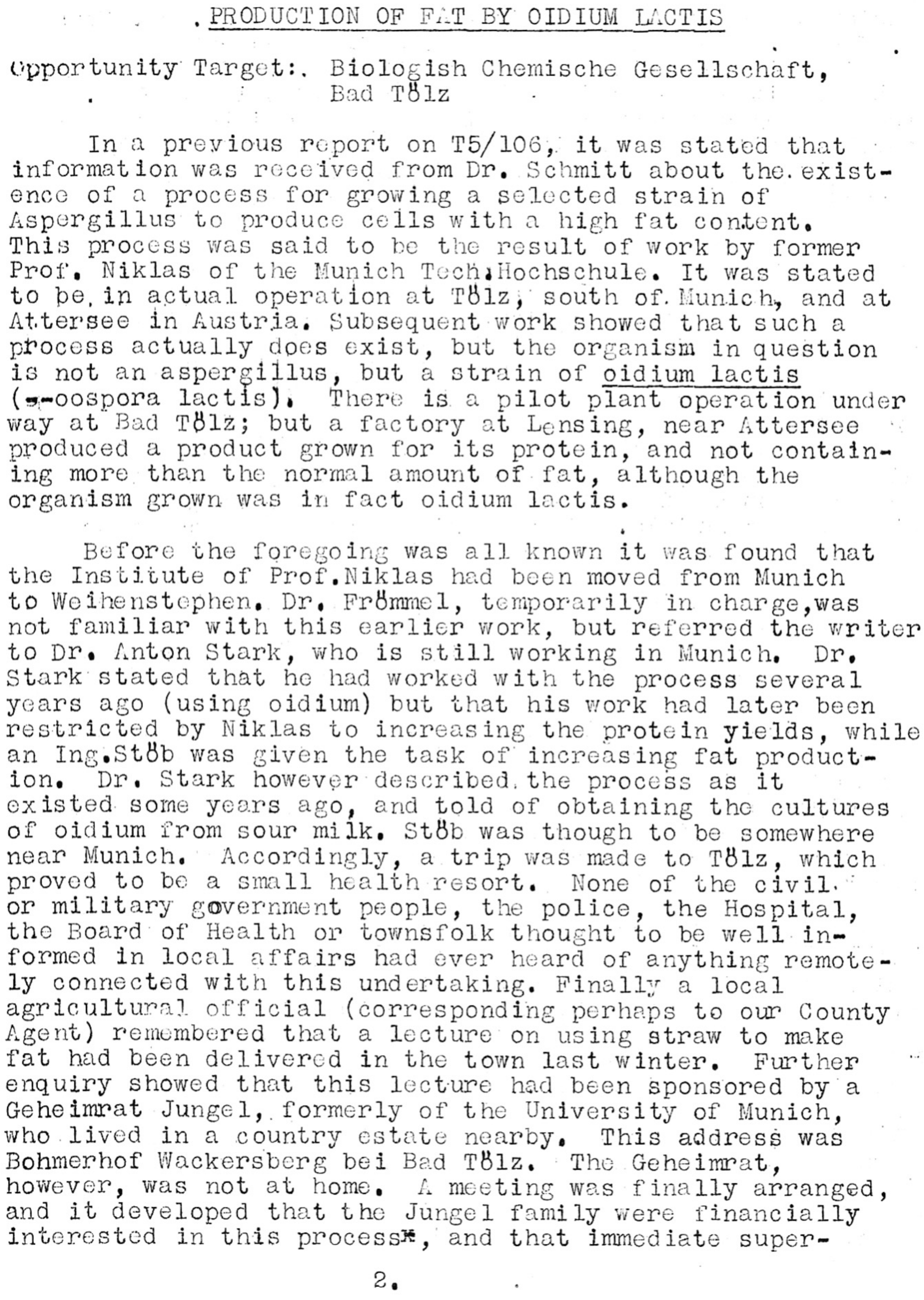
W. - Elberfeld. den 23.6.44. - 118 -

Figure A.90: Information on periston [CIOS XXV-54].

FIAT 371. ***Production of Fat by Oidium lactis.***

[See pp. 2431–2438 for some of the pages from this report.

See pp. 2439–2444 for examples of related patents by Hans Stöb.]



PRODUCTION OF FAT BY OIDIUM LACTIS

Opportunity Target:. Biologish Chemische Gesellschaft,
Bad Tölz

In a previous report on T5/106, it was stated that information was received from Dr. Schmitt about the existence of a process for growing a selected strain of Aspergillus to produce cells with a high fat content. This process was said to be the result of work by former Prof. Niklas of the Munich Tech.Hochschule. It was stated to be in actual operation at Tölz, south of Munich, and at Attersee in Austria. Subsequent work showed that such a process actually does exist, but the organism in question is not an aspergillus, but a strain of oidium lactis (=oospora lactis). There is a pilot plant operation under way at Bad Tölz; but a factory at Lensing, near Attersee produced a product grown for its protein, and not containing more than the normal amount of fat, although the organism grown was in fact oidium lactis.

Before the foregoing was all known it was found that the Institute of Prof.Niklas had been moved from Munich to Weihenstephen. Dr. Frömmel, temporarily in charge,was not familiar with this earlier work, but referred the writer to Dr. Anton Stark, who is still working in Munich. Dr. Stark stated that he had worked with the process several years ago (using oidium) but that his work had later been restricted by Niklas to increasing the protein yields, while an Ing.Stöb was given the task of increasing fat production. Dr. Stark however described the process as it existed some years ago, and told of obtaining the cultures of oidium from sour milk. Stöb was though to be somewhere near Munich. Accordingly, a trip was made to Tölz, which proved to be a small health resort. None of the civil or military government people, the police, the Hospital, the Board of Health or townsfolk thought to be well informed in local affairs had ever heard of anything remotely connected with this undertaking. Finally a local agricultural official (corresponding perhaps to our County Agent) remembered that a lecture on using straw to make fat had been delivered in the town last winter. Further enquiry showed that this lecture had been sponsored by a Geheimrat Jungel, formerly of the University of Munich, who lived in a country estate nearby. This address was Bohmerhof Wackersberg bei Bad Tölz. The Geheimrat, however, was not at home. A meeting was finally arranged, and it developed that the Jungel family were financially interested in this process*, and that immediate super-

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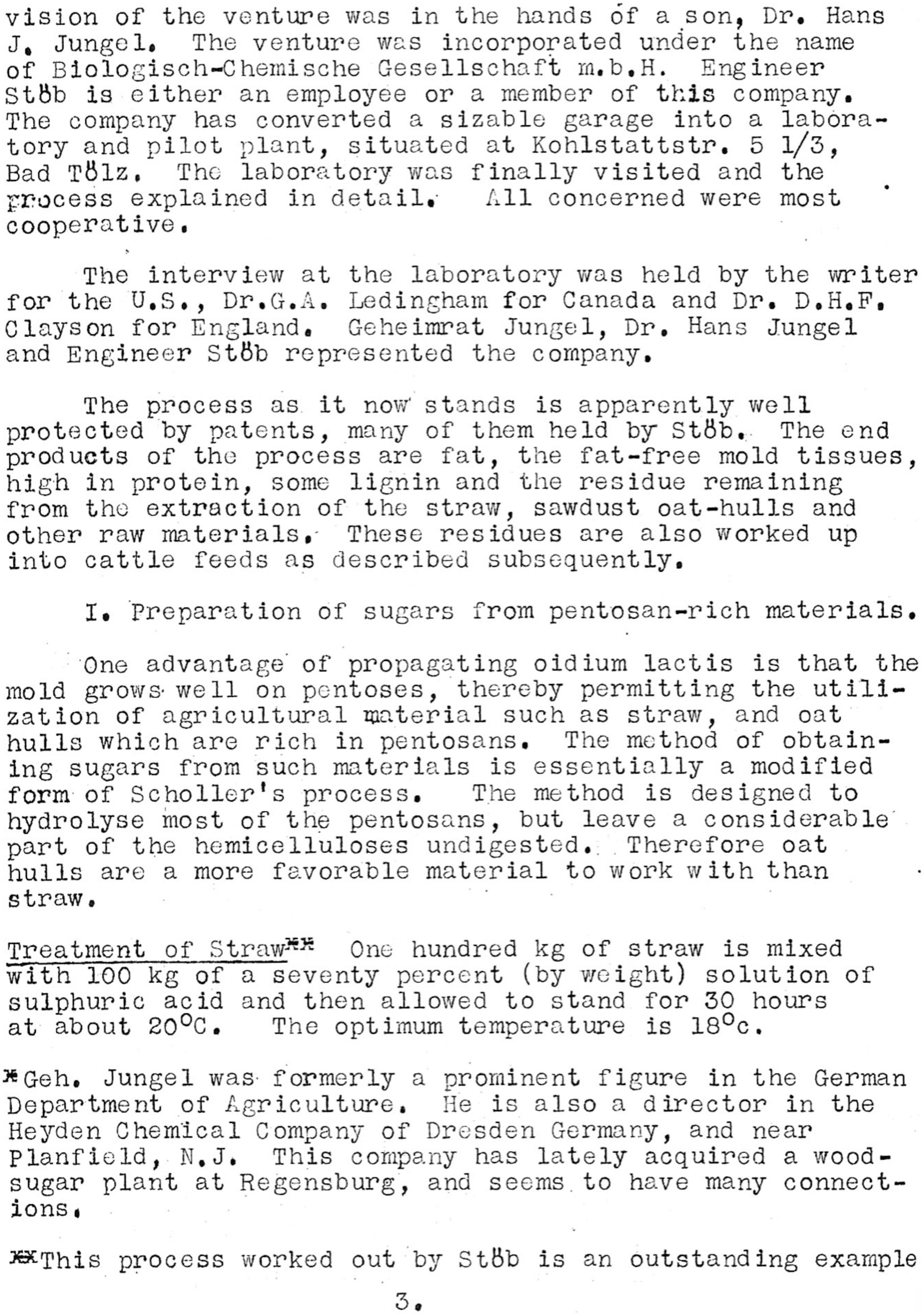
Figure A.91: Production of fat by *Oidium lactis* [FIAT 371].



vision of the venture was in the hands of a son, Dr. Hans J. Jungel. The venture was incorporated under the name of Biologisch-Chemische Gesellschaft m.b.H. Engineer Stöb is either an employee or a member of this company. The company has converted a sizable garage into a laboratory and pilot plant, situated at Kohlstattstr. 5 1/3, Bad Tölz. The laboratory was finally visited and the process explained in detail. All concerned were most cooperative.

The interview at the laboratory was held by the writer for the U.S., Dr.G.A. Ledingham for Canada and Dr. D.H.F. Clayson for England. Geheimrat Jungel, Dr. Hans Jungel and Engineer Stöb represented the company.

The process as it now stands is apparently well protected by patents, many of them held by Stöb. The end products of the process are fat, the fat-free mold tissues, high in protein, some lignin and the residue remaining from the extraction of the straw, sawdust oat-hulls and other raw materials. These residues are also worked up into cattle feeds as described subsequently.

I. Preparation of sugars from pentosan-rich materials.

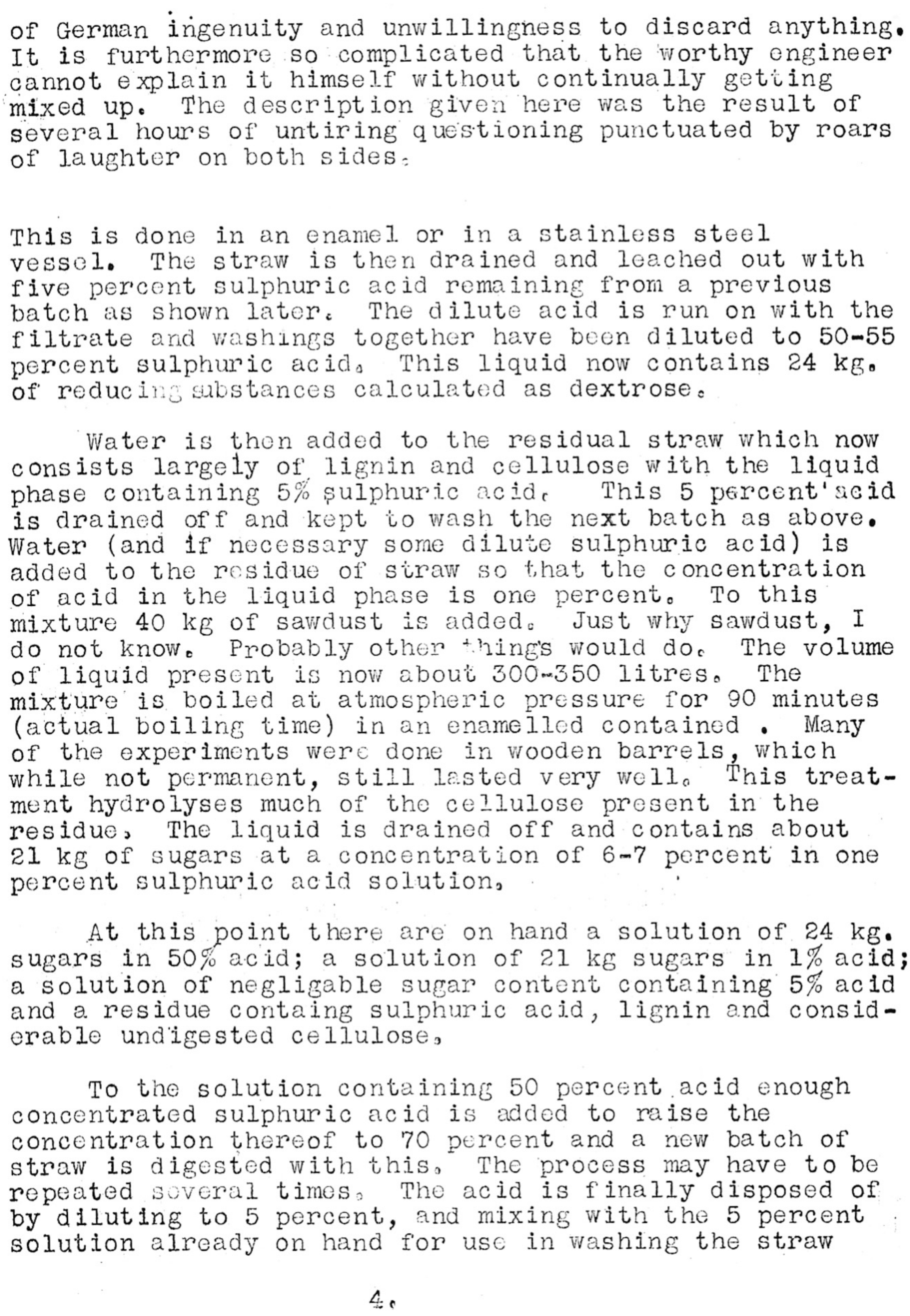
One advantage of propagating oidium lactis is that the mold grows well on pentoses, thereby permitting the utilization of agricultural material such as straw, and oat hulls which are rich in pentosans. The method of obtaining sugars from such materials is essentially a modified form of Scholler's process. The method is designed to hydrolyse most of the pentosans, but leave a considerable part of the hemicelluloses undigested. Therefore oat hulls are a more favorable material to work with than straw.

Treatment of Straw** One hundred kg of straw is mixed with 100 kg of a seventy percent (by weight) solution of sulphuric acid and then allowed to stand for 30 hours at about 20°C. The optimum temperature is 18°c.

*Geh. Jungel was formerly a prominent figure in the German Department of Agriculture. He is also a director in the Heyden Chemical Company of Dresden Germany, and near Planfield, N.J. This company has lately acquired a wood-sugar plant at Regensburg, and seems to have many connections.

**This process worked out by Stöb is an outstanding example

Figure A.92: Production of fat by *Oidium lactis* [FIAT 371].



of German ingenuity and unwillingness to discard anything. It is furthermore so complicated that the worthy engineer cannot explain it himself without continually getting mixed up. The description given here was the result of several hours of untiring questioning punctuated by roars of laughter on both sides.

This is done in an enamel or in a stainless steel vessel. The straw is then drained and leached out with five percent sulphuric acid remaining from a previous batch as shown later. The dilute acid is run on with the filtrate and washings together have been diluted to 50-55 percent sulphuric acid. This liquid now contains 24 kg. of reducing substances calculated as dextrose.

Water is then added to the residual straw which now consists largely of lignin and cellulose with the liquid phase containing 5% sulphuric acid. This 5 percent acid is drained off and kept to wash the next batch as above. Water (and if necessary some dilute sulphuric acid) is added to the residue of straw so that the concentration of acid in the liquid phase is one percent. To this mixture 40 kg of sawdust is added. Just why sawdust, I do not know. Probably other things would do. The volume of liquid present is now about 300-350 litres. The mixture is boiled at atmospheric pressure for 90 minutes (actual boiling time) in an enamelled contained . Many of the experiments were done in wooden barrels, which while not permanent, still lasted very well. This treatment hydrolyses much of the cellulose present in the residue. The liquid is drained off and contains about 21 kg of sugars at a concentration of 6-7 percent in one percent sulphuric acid solution.

At this point there are on hand a solution of 24 kg. sugars in 50% acid; a solution of 21 kg sugars in 1% acid; a solution of negligable sugar content containing 5% acid and a residue containg sulphuric acid, lignin and considerable undigested cellulose.

To the solution containing 50 percent acid enough concentrated sulphuric acid is added to raise the concentration thereof to 70 percent and a new batch of straw is digested with this. The process may have to be repeated several times. The acid is finally disposed of by diluting to 5 percent, and mixing with the 5 percent solution already on hand for use in washing the straw

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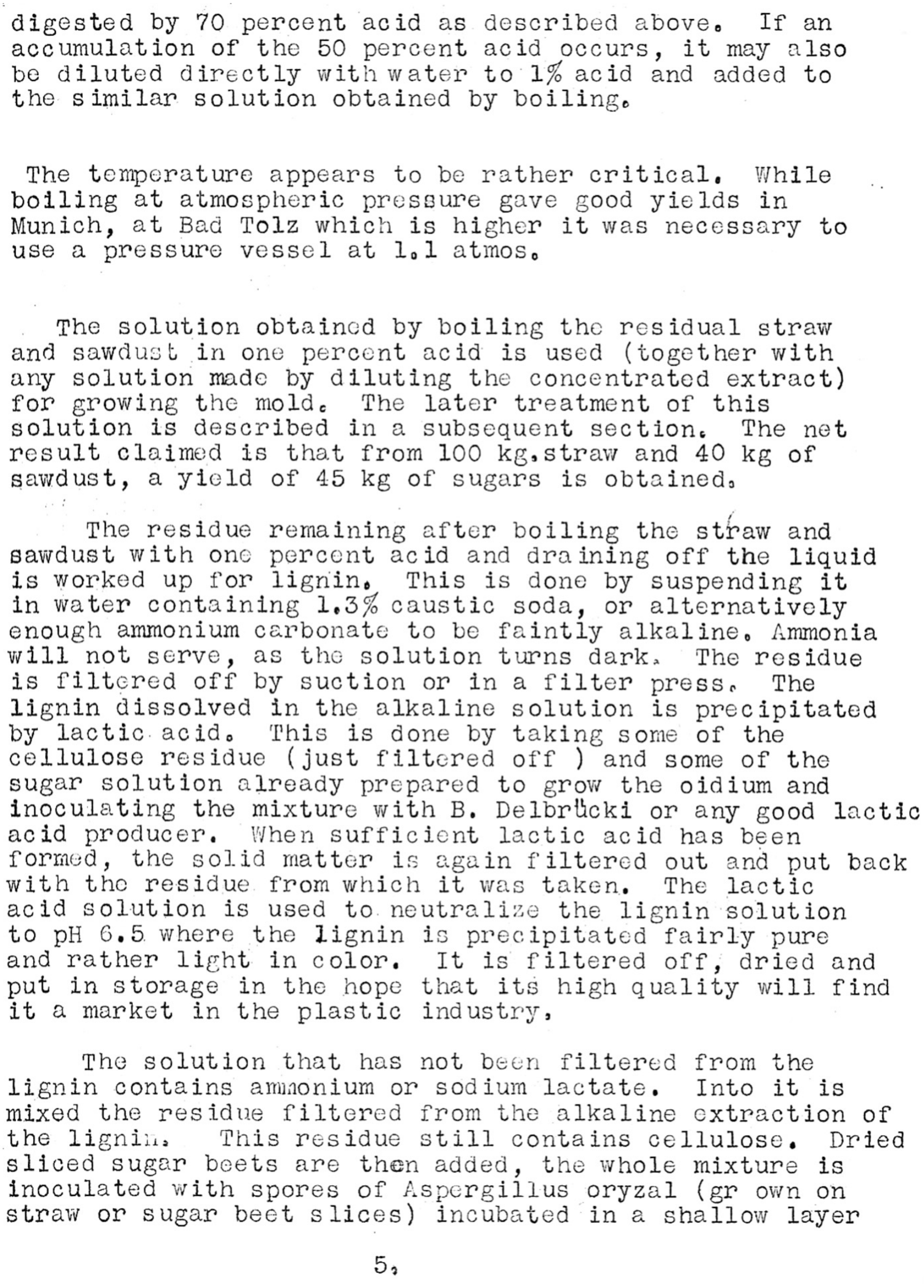
Figure A.93: Production of fat by *Oidium lactis* [FIAT 371].



digested by 70 percent acid as described above. If an accumulation of the 50 percent acid occurs, it may also be diluted directly with water to 1% acid and added to the similar solution obtained by boiling.

The temperature appears to be rather critical. While boiling at atmospheric pressure gave good yields in Munich, at Bad Tolz which is higher it was necessary to use a pressure vessel at 1.1 atmos.

The solution obtained by boiling the residual straw and sawdust in one percent acid is used (together with any solution made by diluting the concentrated extract) for growing the mold. The later treatment of this solution is described in a subsequent section. The net result claimed is that from 100 kg, straw and 40 kg of sawdust, a yield of 45 kg of sugars is obtained.

The residue remaining after boiling the straw and sawdust with one percent acid and draining off the liquid is worked up for lignin. This is done by suspending it in water containing 1.3% caustic soda, or alternatively enough ammonium carbonate to be faintly alkaline. Ammonia will not serve, as the solution turns dark. The residue is filtered off by suction or in a filter press. The lignin dissolved in the alkaline solution is precipitated by lactic acid. This is done by taking some of the cellulose residue (just filtered off) and some of the sugar solution already prepared to grow the oidium and inoculating the mixture with B. Delbrücki or any good lactic acid producer. When sufficient lactic acid has been formed, the solid matter is again filtered out and put back with the residue from which it was taken. The lactic acid solution is used to neutralize the lignin solution to pH 6.5 where the lignin is precipitated fairly pure and rather light in color. It is filtered off, dried and put in storage in the hope that its high quality will find it a market in the plastic industry.

The solution that has not been filtered from the lignin contains ammonium or sodium lactate. Into it is mixed the residue filtered from the alkaline extraction of the lignin. This residue still contains cellulose. Dried sliced sugar beets are then added, the whole mixture is inoculated with spores of Aspergillus oryzal (gr own on straw or sugar beet slices) incubated in a shallow layer

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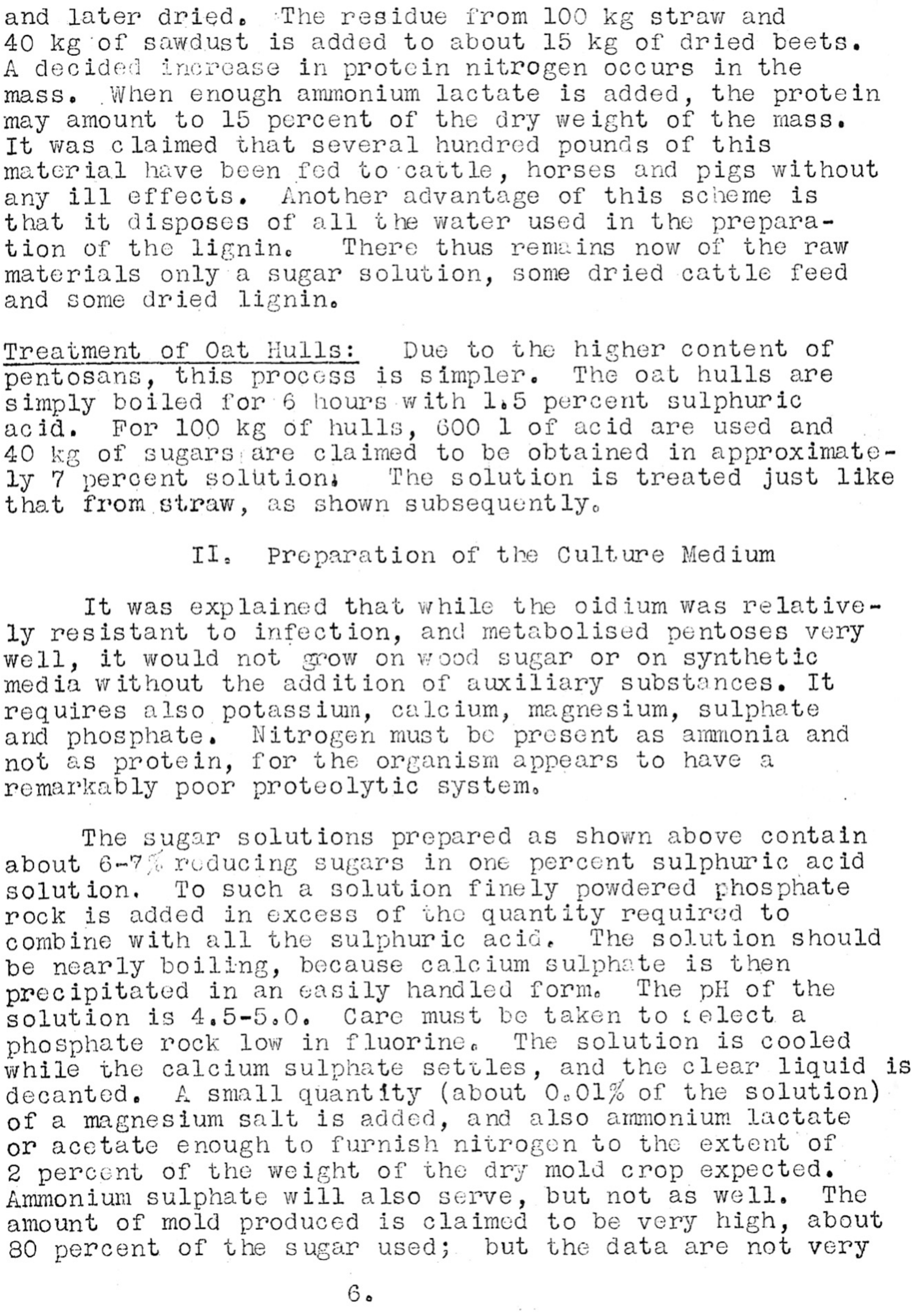
Figure A.94: Production of fat by *Oidium lactis* [FIAT 371].



and later dried. The residue from 100 kg straw and 40 kg of sawdust is added to about 15 kg of dried beets. A decided increase in protein nitrogen occurs in the mass. When enough ammonium lactate is added, the protein may amount to 15 percent of the dry weight of the mass. It was claimed that several hundred pounds of this material have been fed to cattle, horses and pigs without any ill effects. Another advantage of this scheme is that it disposes of all the water used in the preparation of the lignin. There thus remains now of the raw materials only a sugar solution, some dried cattle feed and some dried lignin.

Treatment of Oat Hulls: Due to the higher content of pentosans, this process is simpler. The oat hulls are simply boiled for 6 hours with 1.5 percent sulphuric acid. For 100 kg of hulls, 600 l of acid are used and 40 kg of sugars are claimed to be obtained in approximately 7 percent solution. The solution is treated just like that from straw, as shown subsequently.

II. Preparation of the Culture Medium

It was explained that while the oidium was relatively resistant to infection, and metabolised pentoses very well, it would not grow on wood sugar or on synthetic media without the addition of auxiliary substances. It requires also potassium, calcium, magnesium, sulphate and phosphate. Nitrogen must be present as ammonia and not as protein, for the organism appears to have a remarkably poor proteolytic system.

The sugar solutions prepared as shown above contain about 6-7% reducing sugars in one percent sulphuric acid solution. To such a solution finely powdered phosphate rock is added in excess of the quantity required to combine with all the sulphuric acid. The solution should be nearly boiling, because calcium sulphate is then precipitated in an easily handled form. The pH of the solution is 4.5-5.0. Care must be taken to select a phosphate rock low in fluorine. The solution is cooled while the calcium sulphate settles, and the clear liquid is decanted. A small quantity (about 0.01% of the solution) of a magnesium salt is added, and also ammonium lactate or acetate enough to furnish nitrogen to the extent of 2 percent of the weight of the dry mold crop expected. Ammonium sulphate will also serve, but not as well. The amount of mold produced is claimed to be very high, about 80 percent of the sugar used; but the data are not very

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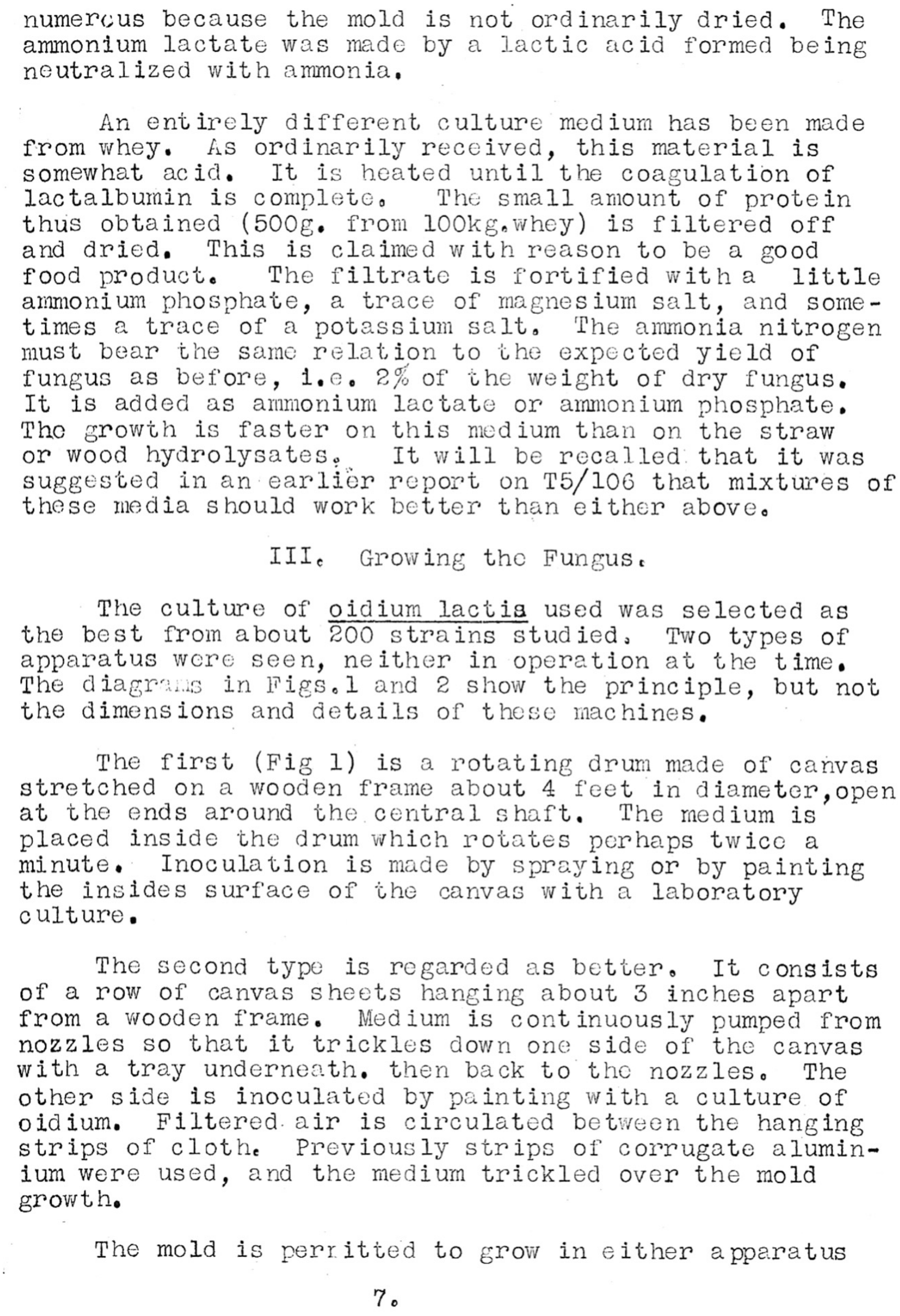
Figure A.95: Production of fat by *Oidium lactis* [FIAT 371].



numerous because the mold is not ordinarily dried. The ammonium lactate was made by a lactic acid formed being neutralized with ammonia.

An entirely different culture medium has been made from whey. As ordinarily received, this material is somewhat acid. It is heated until the coagulation of lactalbumin is complete. The small amount of protein thus obtained (500g. from 100kg.whey) is filtered off and dried. This is claimed with reason to be a good food product. The filtrate is fortified with a little ammonium phosphate, a trace of magnesium salt, and sometimes a trace of a potassium salt. The ammonia nitrogen must bear the same relation to the expected yield of fungus as before, i.e. 2% of the weight of dry fungus. It is added as ammonium lactate or ammonium phosphate. The growth is faster on this medium than on the straw or wood hydrolysates. It will be recalled that it was suggested in an earlier report on T5/106 that mixtures of these media should work better than either above.

III. Growing the Fungus.

The culture of oidium lactis used was selected as the best from about 200 strains studied. Two types of apparatus were seen, neither in operation at the time. The diagrams in Figs.1 and 2 show the principle, but not the dimensions and details of these machines.

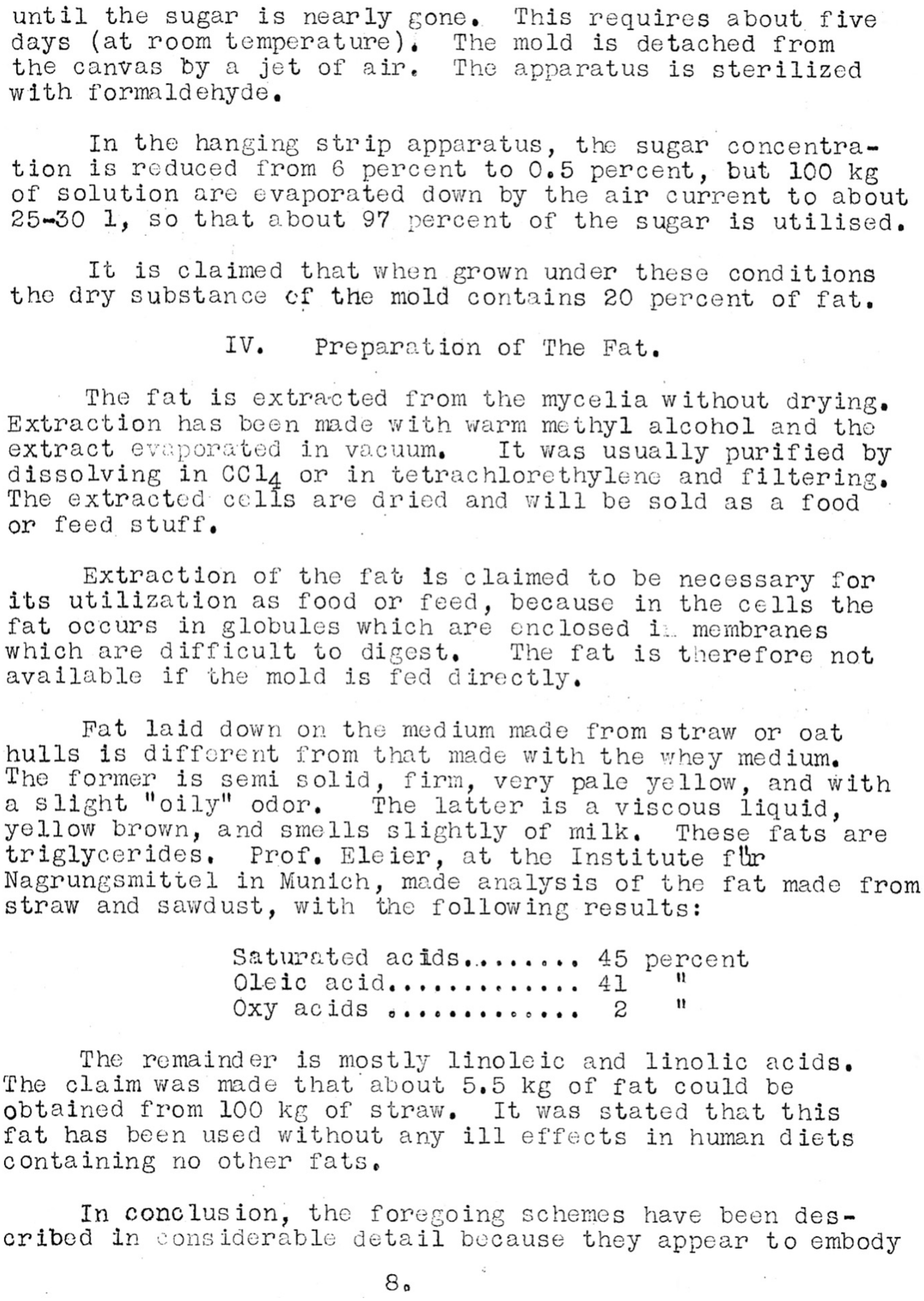
The first (Fig 1) is a rotating drum made of canvas stretched on a wooden frame about 4 feet in diameter,open at the ends around the central shaft. The medium is placed inside the drum which rotates perhaps twice a minute. Inoculation is made by spraying or by painting the insides surface of the canvas with a laboratory culture.

The second type is regarded as better. It consists of a row of canvas sheets hanging about 3 inches apart from a wooden frame. Medium is continuously pumped from nozzles so that it trickles down one side of the canvas with a tray underneath. then back to the nozzles. The other side is inoculated by painting with a culture of oidium. Filtered air is circulated between the hanging strips of cloth. Previously strips of corrugate aluminium were used, and the medium trickled over the mold growth.

The mold is permitted to grow in either apparatus

7.

Figure A.96: Production of fat by *Oidium lactis* [FIAT 371].



until the sugar is nearly gone. This requires about five days (at room temperature). The mold is detached from the canvas by a jet of air. The apparatus is sterilized with formaldehyde.

In the hanging strip apparatus, the sugar concentration is reduced from 6 percent to 0.5 percent, but 100 kg of solution are evaporated down by the air current to about 25-30 l, so that about 97 percent of the sugar is utilised.

It is claimed that when grown under these conditions the dry substance of the mold contains 20 percent of fat.

IV. Preparation of The Fat.

The fat is extracted from the mycelia without drying. Extraction has been made with warm methyl alcohol and the extract evaporated in vacuum. It was usually purified by dissolving in CCl_4 or in tetrachlorethylene and filtering. The extracted cells are dried and will be sold as a food or feed stuff.

Extraction of the fat is claimed to be necessary for its utilization as food or feed, because in the cells the fat occurs in globules which are enclosed in membranes which are difficult to digest. The fat is therefore not available if the mold is fed directly.

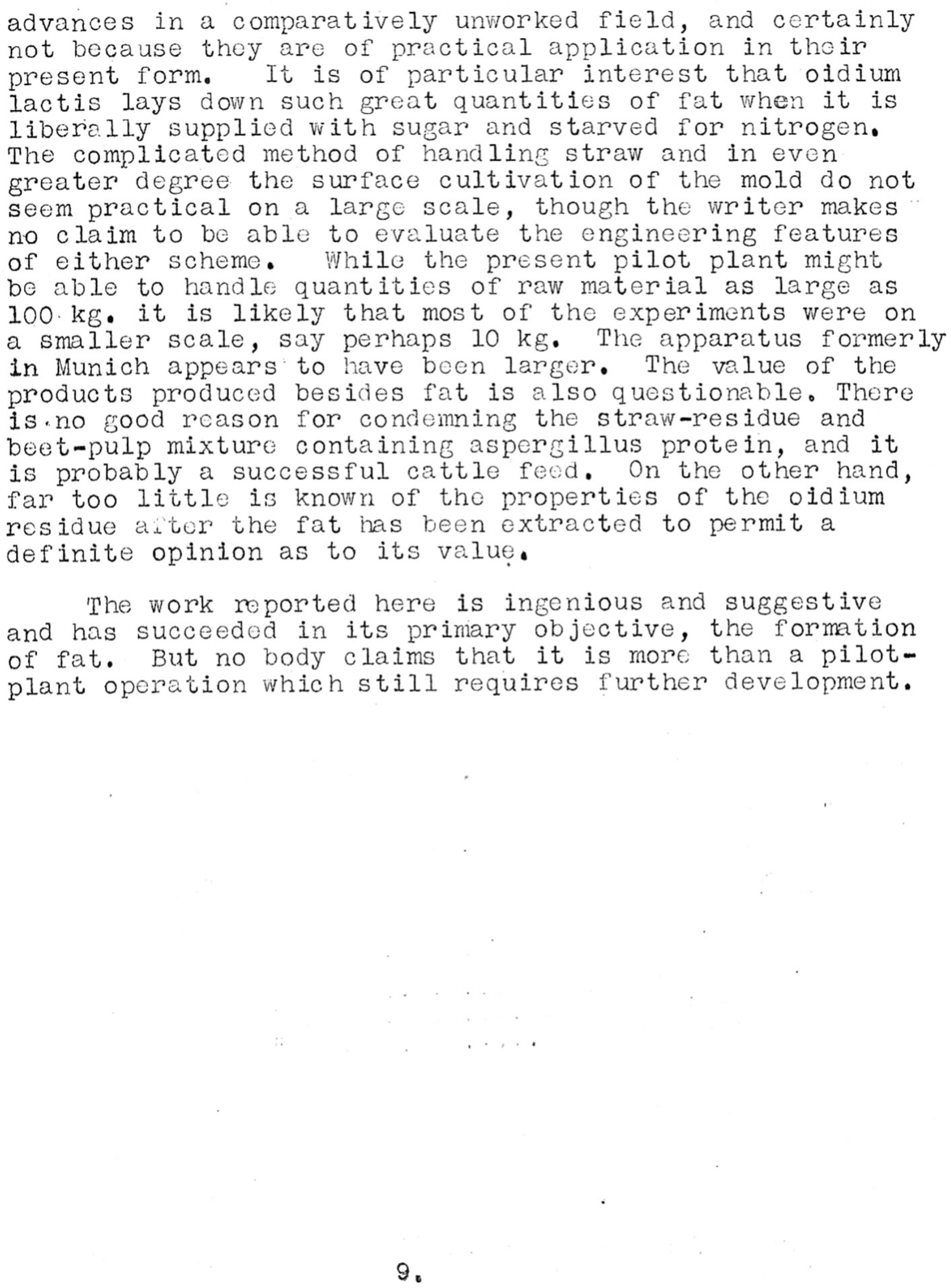
Fat laid down on the medium made from straw or oat hulls is different from that made with the whey medium. The former is semi solid, firm, very pale yellow, and with a slight "oily" odor. The latter is a viscous liquid, yellow brown, and smells slightly of milk. These fats are triglycerides. Prof. Eleier, at the Institute für Nagrungsmittel in Munich, made analysis of the fat made from straw and sawdust, with the following results:

Saturated acids.........	45 percent
Oleic acid.............	41 "
Oxy acids	2 "

The remainder is mostly linoleic and linolic acids. The claim was made that about 5.5 kg of fat could be obtained from 100 kg of straw. It was stated that this fat has been used without any ill effects in human diets containing no other fats.

In conclusion, the foregoing schemes have been described in considerable detail because they appear to embody

Figure A.97: Production of fat by *Oidium lactis* [FIAT 371].

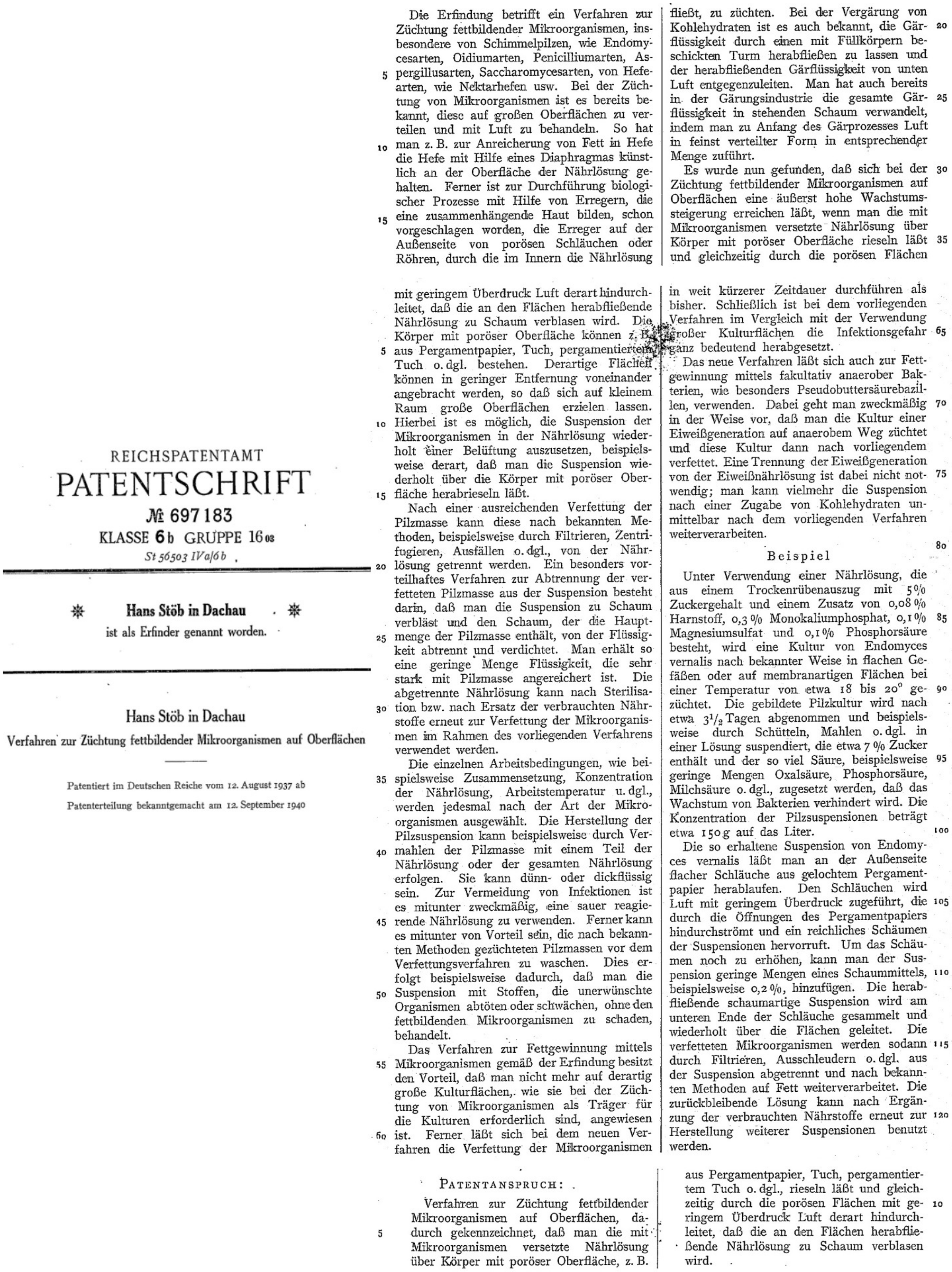


advances in a comparatively unworked field, and certainly not because they are of practical application in their present form. It is of particular interest that oidium lactis lays down such great quantities of fat when it is liberally supplied with sugar and starved for nitrogen. The complicated method of handling straw and in even greater degree the surface cultivation of the mold do not seem practical on a large scale, though the writer makes no claim to be able to evaluate the engineering features of either scheme. While the present pilot plant might be able to handle quantities of raw material as large as 100 kg. it is likely that most of the experiments were on a smaller scale, say perhaps 10 kg. The apparatus formerly in Munich appears to have been larger. The value of the products produced besides fat is also questionable. There is no good reason for condemning the straw-residue and beet-pulp mixture containing aspergillus protein, and it is probably a successful cattle feed. On the other hand, far too little is known of the properties of the oidium residue after the fat has been extracted to permit a definite opinion as to its value.

The work reported here is ingenious and suggestive and has succeeded in its primary objective, the formation of fat. But no body claims that it is more than a pilot-plant operation which still requires further development.

9.

Figure A.98: Production of fat by *Oidium lactis* [FIAT 371].



REICHSPATENTAMT
PATENTSCHRIFT
№ 697 183
KLASSE 6b GRUPPE 16_{03}
St 56503 IVa/6b

Hans Stöb in Dachau
ist als Erfinder genannt worden.

Hans Stöb in Dachau
Verfahren zur Züchtung fettbildender Mikroorganismen auf Oberflächen

Patentiert im Deutschen Reiche vom 12. August 1937 ab
Patenterteilung bekanntgemacht am 12. September 1940

Die Erfindung betrifft ein Verfahren zur Züchtung fettbildender Mikroorganismen, insbesondere von Schimmelpilzen, wie Endomycesarten, Oidiumarten, Penicilliumarten, Aspergillusarten, Saccharomycesarten, von Hefearten, wie Nektarhefen usw. Bei der Züchtung von Mikroorganismen ist es bereits bekannt, diese auf großen Oberflächen zu verteilen und mit Luft zu behandeln. So hat man z. B. zur Anreicherung von Fett in Hefe die Hefe mit Hilfe eines Diaphragmas künstlich an der Oberfläche der Nährlösung gehalten. Ferner ist zur Durchführung biologischer Prozesse mit Hilfe von Erregern, die eine zusammenhängende Haut bilden, schon vorgeschlagen worden, die Erreger auf der Außenseite von porösen Schläuchen oder Röhren, durch die im Innern die Nährlösung fließt, zu züchten. Bei der Vergärung von Kohlehydraten ist es auch bekannt, die Gärflüssigkeit durch einen mit Füllkörpern beschickten Turm herabfließen zu lassen und der herabfließenden Gärflüssigkeit von unten Luft entgegenzuleiten. Man hat auch bereits in der Gärungsindustrie die gesamte Gärflüssigkeit in stehenden Schaum verwandelt, indem man zu Anfang des Gärprozesses Luft in feinst verteilter Form in entsprechender Menge zuführt.

Es wurde nun gefunden, daß sich bei der Züchtung fettbildender Mikroorganismen auf Oberflächen eine äußerst hohe Wachstumssteigerung erreichen läßt, wenn man die mit Mikroorganismen versetzte Nährlösung über Körper mit poröser Oberfläche rieseln läßt und gleichzeitig durch die porösen Flächen mit geringem Überdruck Luft derart hindurchleitet, daß die an den Flächen herabfließende Nährlösung zu Schaum verblasen wird. Die Körper mit poröser Oberfläche können z. B. aus Pergamentpapier, Tuch, pergamentiertem Tuch o. dgl. bestehen. Derartige Flächen können in geringer Entfernung voneinander angebracht werden, so daß sich auf kleinem Raum große Oberflächen erzielen lassen. Hierbei ist es möglich, die Suspension der Mikroorganismen in der Nährlösung wiederholt einer Belüftung auszusetzen, beispielsweise derart, daß man die Suspension wiederholt über die Körper mit poröser Oberfläche herabrieseln läßt.

Nach einer ausreichenden Verfettung der Pilzmasse kann diese nach bekannten Methoden, beispielsweise durch Filtrieren, Zentrifugieren, Ausfällen o. dgl., von der Nährlösung getrennt werden. Ein besonders vorteilhaftes Verfahren zur Abtrennung der verfetteten Pilzmasse aus der Suspension besteht darin, daß man die Suspension zu Schaum verbläst und den Schaum, der die Hauptmenge der Pilzmasse enthält, von der Flüssigkeit abtrennt und verdichtet. Man erhält so eine geringe Menge Flüssigkeit, die sehr stark mit Pilzmasse angereichert ist. Die abgetrennte Nährlösung kann nach Sterilisation bzw. nach Ersatz der verbrauchten Nährstoffe erneut zur Verfettung der Mikroorganismen im Rahmen des vorliegenden Verfahrens verwendet werden.

Die einzelnen Arbeitsbedingungen, wie beispielsweise Zusammensetzung, Konzentration der Nährlösung, Arbeitstemperatur u. dgl., werden jedesmal nach der Art der Mikroorganismen ausgewählt. Die Herstellung der Pilzsuspension kann beispielsweise durch Vermahlen der Pilzmasse mit einem Teil der Nährlösung oder der gesamten Nährlösung erfolgen. Sie kann dünn- oder dickflüssig sein. Zur Vermeidung von Infektionen ist es mitunter zweckmäßig, eine sauer reagierende Nährlösung zu verwenden. Ferner kann es mitunter von Vorteil sein, die nach bekannten Methoden gezüchteten Pilzmassen vor dem Verfettungsverfahren zu waschen. Dies erfolgt beispielsweise dadurch, daß man die Suspension mit Stoffen, die unerwünschte Organismen abtöten oder schwächen, ohne den fettbildenden Mikroorganismen zu schaden, behandelt.

Das Verfahren zur Fettgewinnung mittels Mikroorganismen gemäß der Erfindung besitzt den Vorteil, daß man nicht mehr auf derartig große Kulturflächen, wie sie bei der Züchtung von Mikroorganismen als Träger für die Kulturen erforderlich sind, angewiesen ist. Ferner läßt sich bei dem neuen Verfahren die Verfettung der Mikroorganismen in weit kürzerer Zeitdauer durchführen als bisher. Schließlich ist bei dem vorliegenden Verfahren im Vergleich mit der Verwendung großer Kulturflächen die Infektionsgefahr ganz bedeutend herabgesetzt.

Das neue Verfahren läßt sich auch zur Fettgewinnung mittels fakultativ anaerober Bakterien, wie besonders Pseudobuttersäurebazillen, verwenden. Dabei geht man zweckmäßig in der Weise vor, daß man die Kultur einer Eiweißgeneration auf anaerobem Weg züchtet und diese Kultur dann nach vorliegendem verfettet. Eine Trennung der Eiweißgeneration von der Eiweißnährlösung ist dabei nicht notwendig; man kann vielmehr die Suspension nach einer Zugabe von Kohlehydraten unmittelbar nach dem vorliegenden Verfahren weiterverarbeiten.

Beispiel

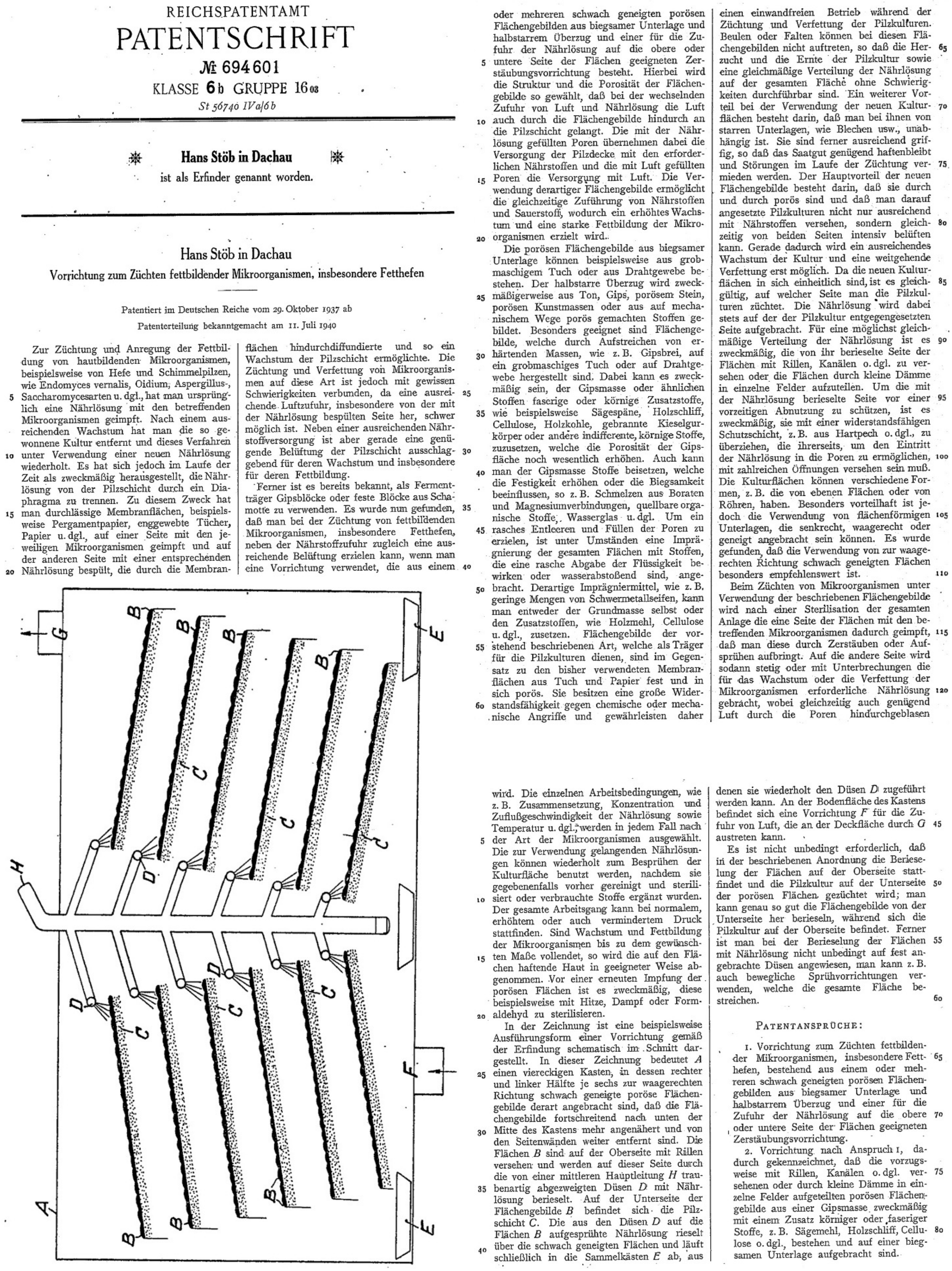
Unter Verwendung einer Nährlösung, die aus einem Trockenrübenauszug mit 5% Zuckergehalt und einem Zusatz von 0,08% Harnstoff, 0,3% Monokaliumphosphat, 0,1% Magnesiumsulfat und 0,1% Phosphorsäure besteht, wird eine Kultur von Endomyces vernalis nach bekannter Weise in flachen Gefäßen oder auf membranartigen Flächen bei einer Temperatur von etwa 18 bis 20° gezüchtet. Die gebildete Pilzkultur wird nach etwa $3^1/_2$ Tagen abgenommen und beispielsweise durch Schütteln, Mahlen o. dgl. in einer Lösung suspendiert, die etwa 7% Zucker enthält und der so viel Säure, beispielsweise geringe Mengen Oxalsäure, Phosphorsäure, Milchsäure o. dgl., zugesetzt werden, daß das Wachstum von Bakterien verhindert wird. Die Konzentration der Pilzsuspensionen beträgt etwa 150 g auf das Liter.

Die so erhaltene Suspension von Endomyces vernalis läßt man an der Außenseite flacher Schläuche aus gelochtem Pergamentpapier herablaufen. Den Schläuchen wird Luft mit geringem Überdruck zugeführt, die durch die Öffnungen des Pergamentpapiers hindurchströmt und ein reichliches Schäumen der Suspensionen hervorruft. Um das Schäumen noch zu erhöhen, kann man der Suspension geringe Mengen eines Schaummittels, beispielsweise 0,2%, hinzufügen. Die herabfließende schaumartige Suspension wird am unteren Ende der Schläuche gesammelt und wiederholt über die Flächen geleitet. Die verfetteten Mikroorganismen werden sodann durch Filtrieren, Ausschleudern o. dgl. aus der Suspension abgetrennt und nach bekannten Methoden auf Fett weiterverarbeitet. Die zurückbleibende Lösung kann nach Ergänzung der verbrauchten Nährstoffe erneut zur Herstellung weiterer Suspensionen benutzt werden.

Patentanspruch:

Verfahren zur Züchtung fettbildender Mikroorganismen auf Oberflächen, dadurch gekennzeichnet, daß man die mit Mikroorganismen versetzte Nährlösung über Körper mit poröser Oberfläche, z. B. aus Pergamentpapier, Tuch, pergamentiertem Tuch o. dgl., rieseln läßt und gleichzeitig durch die porösen Flächen mit geringem Überdruck Luft derart hindurchleitet, daß die an den Flächen herabfließende Nährlösung zu Schaum verblasen wird.

Figure A.99: Examples of Hans Stöb's patents on production of fat by *Oidium lactis* and other biotechnology methods.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REICHSPATENTAMT

PATENTSCHRIFT

№ 694601

KLASSE 6b GRUPPE 16 03

St 56740 IVa/6b

Hans Stöb in Dachau

ist als Erfinder genannt worden.

Hans Stöb in Dachau

Vorrichtung zum Züchten fettbildender Mikroorganismen, insbesondere Fetthefen

Patentiert im Deutschen Reiche vom 29. Oktober 1937 ab

Patenterteilung bekanntgemacht am 11. Juli 1940

Zur Züchtung und Anregung der Fettbildung von hautbildenden Mikroorganismen, beispielsweise von Hefe und Schimmelpilzen, wie Endomyces vernalis, Oidium, Aspergillus-, Saccharomycesarten u. dgl., hat man ursprünglich eine Nährlösung mit den betreffenden Mikroorganismen geimpft. Nach einem ausreichenden Wachstum hat man die so gewonnene Kultur entfernt und dieses Verfahren unter Verwendung einer neuen Nährlösung wiederholt. Es hat sich jedoch im Laufe der Zeit als zweckmäßig herausgestellt, die Nährlösung von der Pilzschicht durch ein Diaphragma zu trennen. Zu diesem Zweck hat man durchlässige Membranflächen, beispielsweise Pergamentpapier, enggewebte Tücher, Papier u. dgl., auf einer Seite mit den jeweiligen Mikroorganismen geimpft und auf der anderen Seite mit einer entsprechenden Nährlösung bespült, die durch die Membranflächen hindurchdiffundierte und so ein Wachstum der Pilzschicht ermöglichte. Die Züchtung und Verfettung von Mikroorganismen auf diese Art ist jedoch mit gewissen Schwierigkeiten verbunden, da eine ausreichende Luftzufuhr, insbesondere von der mit der Nährlösung bespülten Seite her, schwer möglich ist. Neben einer ausreichenden Nährstoffversorgung ist aber gerade eine genügende Belüftung der Pilzschicht ausschlaggebend für deren Wachstum und insbesondere für deren Fettbildung.

Ferner ist es bereits bekannt, als Fermentträger Gipsblöcke oder feste Blöcke aus Schamotte zu verwenden. Es wurde nun gefunden, daß man bei der Züchtung von fettbildenden Mikroorganismen, insbesondere Fetthefen, neben der Nährstoffzufuhr zugleich eine ausreichende Belüftung erzielen kann, wenn man eine Vorrichtung verwendet, die aus einem oder mehreren schwach geneigten porösen Flächengebilden aus biegsamer Unterlage und halbstarrem Überzug und einer für die Zufuhr der Nährlösung auf die obere oder untere Seite der Flächen geeigneten Zerstäubungsvorrichtung besteht. Hierbei wird die Struktur und die Porosität der Flächengebilde so gewählt, daß bei der wechselnden Zufuhr von Luft und Nährlösung die Luft auch durch die Flächengebilde hindurch an die Pilzschicht gelangt. Die mit der Nährlösung gefüllten Poren übernehmen dabei die Versorgung der Pilzdecke mit den erforderlichen Nährstoffen und die mit Luft gefüllten Poren die Versorgung mit Luft. Die Verwendung derartiger Flächengebilde ermöglicht die gleichzeitige Zuführung von Nährstoffen und Sauerstoff, wodurch ein erhöhtes Wachstum und eine starke Fettbildung der Mikroorganismen erzielt wird.

Die porösen Flächengebilde aus biegsamer Unterlage können beispielsweise aus grobmaschigem Tuch oder aus Drahtgewebe bestehen. Der halbstarre Überzug wird zweckmäßigerweise aus Ton, Gips, porösem Stein, porösen Kunstmassen oder aus auf mechanischem Wege porös gemachten Stoffen gebildet. Besonders geeignet sind Flächengebilde, welche durch Aufstreichen von erhärtenden Massen, wie z. B. Gipsbrei, auf ein grobmaschiges Tuch oder auf Drahtgewebe hergestellt sind. Dabei kann es zweckmäßig sein, der Gipsmasse oder ähnlichen Stoffen faserige oder körnige Zusatzstoffe, wie beispielsweise Sägespäne, Holzschliff, Cellulose, Holzkohle, gebrannte Kieselgurkörper oder andere indifferente, körnige Stoffe, zuzusetzen, welche die Porosität der Gipsfläche noch wesentlich erhöhen. Auch kann man der Gipsmasse Stoffe beisetzen, welche die Festigkeit erhöhen oder die Biegsamkeit beeinflussen, so z. B. Schmelzen aus Boraten und Magnesiumverbindungen, quellbare organische Stoffe, Wasserglas u. dgl. Um ein rasches Entleeren und Füllen der Poren zu erzielen, ist unter Umständen eine Imprägnierung der gesamten Flächen mit Stoffen, die eine rasche Abgabe der Flüssigkeit bewirken oder wasserabstoßend sind, angebracht. Derartige Imprägniermittel, wie z. B. geringe Mengen von Schwermetallseifen, kann man entweder der Grundmasse selbst oder den Zusatzstoffen, wie Holzmehl, Cellulose u. dgl., zusetzen. Flächengebilde der vorstehend beschriebenen Art, welche als Träger für die Pilzkulturen dienen, sind im Gegensatz zu den bisher verwendeten Membranflächen aus Tuch und Papier fest und in sich porös. Sie besitzen eine große Widerstandsfähigkeit gegen chemische oder mechanische Angriffe und gewährleisten daher einen einwandfreien Betrieb während der Züchtung und Verfettung der Pilzkulturen. Beulen oder Falten können bei diesen Flächengebilden nicht auftreten, so daß die Herzucht und die Ernte der Pilzkultur sowie eine gleichmäßige Verteilung der Nährlösung auf der gesamten Fläche ohne Schwierigkeiten durchführbar sind. Ein weiterer Vorteil bei der Verwendung der neuen Kulturflächen besteht darin, daß man bei ihnen von starren Unterlagen, wie Blechen usw., unabhängig ist. Sie sind ferner ausreichend griffig, so daß das Saatgut genügend haftenbleibt und Störungen im Laufe der Züchtung vermieden werden. Der Hauptvorteil der neuen Flächengebilde besteht darin, daß sie durch und durch porös sind und daß man darauf angesetzte Pilzkulturen nicht nur ausreichend mit Nährstoffen versehen, sondern gleichzeitig von beiden Seiten intensiv belüften kann. Gerade dadurch wird ein ausreichendes Wachstum der Kultur und eine weitgehende Verfettung erst möglich. Da die neuen Kulturflächen in sich einheitlich sind, ist es gleichgültig, auf welcher Seite man die Pilzkulturen züchtet. Die Nährlösung wird dabei stets auf der der Pilzkultur entgegengesetzten Seite aufgebracht. Für eine möglichst gleichmäßige Verteilung der Nährlösung ist es zweckmäßig, die von ihr berieselte Seite der Flächen mit Rillen, Kanälen o. dgl. zu versehen oder die Flächen durch kleine Dämme in einzelne Felder aufzuteilen. Um die mit der Nährlösung berieselte Seite vor einer vorzeitigen Abnutzung zu schützen, ist es zweckmäßig, sie mit einer widerstandsfähigen Schutzschicht, z. B. aus Hartpech o. dgl., zu überziehen, die ihrerseits, um den Eintritt der Nährlösung in die Poren zu ermöglichen, mit zahlreichen Öffnungen versehen sein muß. Die Kulturflächen können verschiedene Formen, z. B. die von ebenen Flächen oder von Röhren, haben. Besonders vorteilhaft ist jedoch die Verwendung von flächenförmigen Unterlagen, die senkrecht, waagerecht oder geneigt angebracht sein können. Es wurde gefunden, daß die Verwendung von zur waagerechten Richtung schwach geneigten Flächen besonders empfehlenswert ist.

Beim Züchten von Mikroorganismen unter Verwendung der beschriebenen Flächengebilde wird nach einer Sterilisation der gesamten Anlage die eine Seite der Flächen mit den betreffenden Mikroorganismen dadurch geimpft, daß man diese durch Zerstäuben oder Aufsprühen aufbringt. Auf die andere Seite wird sodann stetig oder mit Unterbrechungen die für das Wachstum oder die Verfettung der Mikroorganismen erforderliche Nährlösung gebracht, wobei gleichzeitig auch genügend Luft durch die Poren hindurchgeblasen wird. Die einzelnen Arbeitsbedingungen, wie z. B. Zusammensetzung, Konzentration und Zuflußgeschwindigkeit der Nährlösung sowie Temperatur u. dgl., werden in jedem Fall nach der Art der Mikroorganismen ausgewählt. Die zur Verwendung gelangenden Nährlösungen können wiederholt zum Besprühen der Kulturfläche benutzt werden, nachdem sie gegebenenfalls vorher gereinigt und sterilisiert oder verbrauchte Stoffe ergänzt wurden. Der gesamte Arbeitsgang kann bei normalem, erhöhtem oder auch vermindertem Druck stattfinden. Sind Wachstum und Fettbildung der Mikroorganismen bis zu dem gewünschten Maße vollendet, so wird die auf den Flächen haftende Haut in geeigneter Weise abgenommen. Vor einer erneuten Impfung der porösen Flächen ist es zweckmäßig, diese beispielsweise mit Hitze, Dampf oder Formaldehyd zu sterilisieren.

In der Zeichnung ist eine beispielsweise Ausführungsform einer Vorrichtung gemäß der Erfindung schematisch im Schnitt dargestellt. In dieser Zeichnung bedeutet *A* einen viereckigen Kasten, in dessen rechter und linker Hälfte je sechs zur waagerechten Richtung schwach geneigte poröse Flächengebilde derart angebracht sind, daß die Flächengebilde fortschreitend nach unten der Mitte des Kastens mehr angenähert und von den Seitenwänden weiter entfernt sind. Die Flächen *B* sind auf der Oberseite mit Rillen versehen und werden auf dieser Seite durch die von einer mittleren Hauptleitung *H* traubenartig abgezweigten Düsen *D* mit Nährlösung berieselt. Auf der Unterseite der Flächengebilde *B* befindet sich die Pilzschicht *C*. Die aus den Düsen *D* auf die Flächen *B* aufgesprühte Nährlösung rieselt über die schwach geneigten Flächen und läuft schließlich in die Sammelkästen *E* ab, aus denen sie wiederholt den Düsen *D* zugeführt werden kann. An der Bodenfläche des Kastens befindet sich eine Vorrichtung *F* für die Zufuhr von Luft, die an der Deckfläche durch *G* austreten kann.

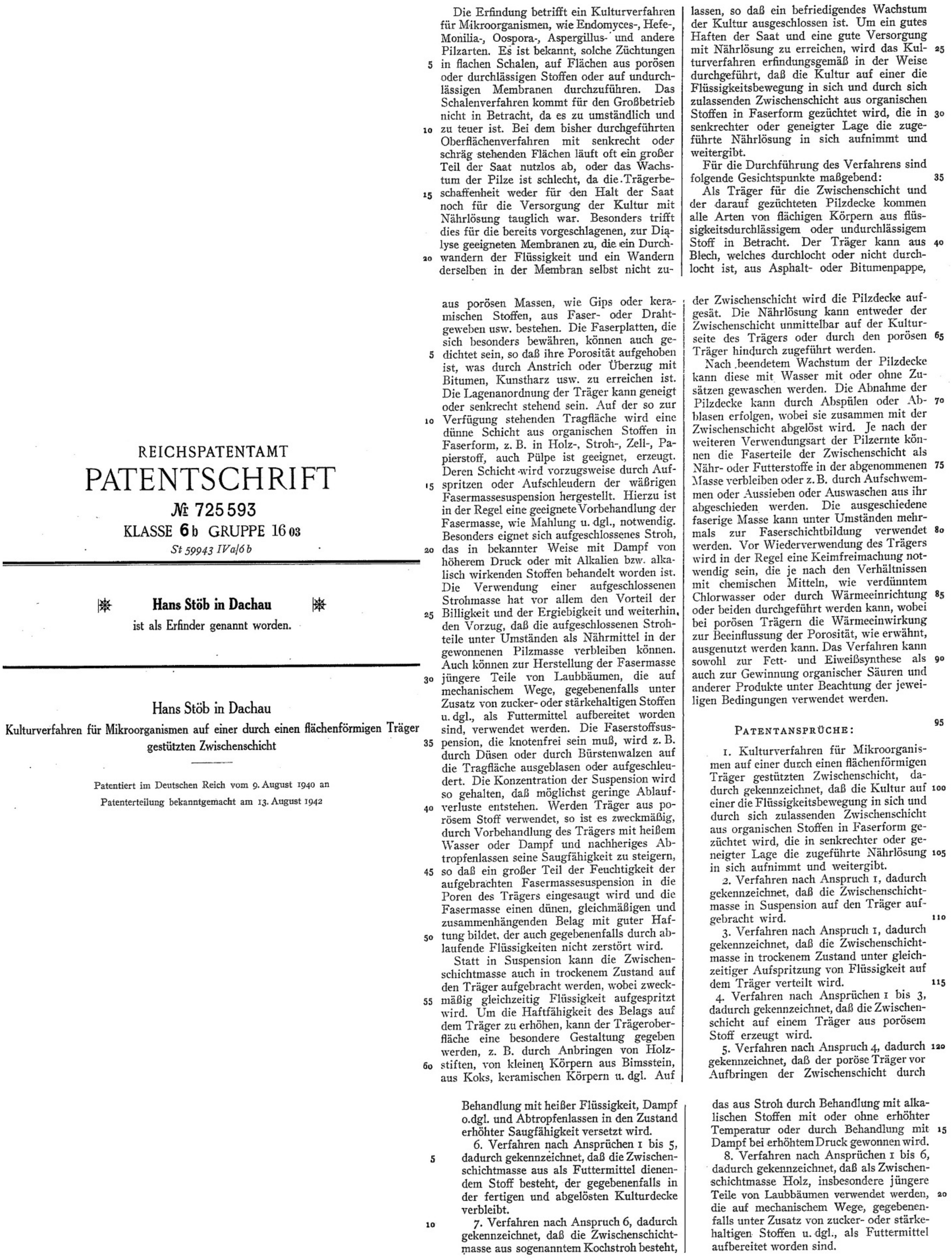
Es ist nicht unbedingt erforderlich, daß in der beschriebenen Anordnung die Berieselung der Flächen auf der Oberseite stattfindet und die Pilzkultur auf der Unterseite der porösen Flächen gezüchtet wird; man kann genau so gut die Flächengebilde von der Unterseite her berieseln, während sich die Pilzkultur auf der Oberseite befindet. Ferner ist man bei der Berieselung der Flächen mit Nährlösung nicht unbedingt auf fest angebrachte Düsen angewiesen, man kann z. B. auch bewegliche Sprühvorrichtungen verwenden, welche die gesamte Fläche bestreichen.

PATENTANSPRÜCHE:

1. Vorrichtung zum Züchten fettbildender Mikroorganismen, insbesondere Fetthefen, bestehend aus einem oder mehreren schwach geneigten porösen Flächengebilden aus biegsamer Unterlage und halbstarrem Überzug und einer für die Zufuhr der Nährlösung auf die obere oder untere Seite der Flächen geeigneten Zerstäubungsvorrichtung.

2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die vorzugsweise mit Rillen, Kanälen o. dgl. versehenen oder durch kleine Dämme in einzelne Felder aufgeteilten porösen Flächengebilde aus einer Gipsmasse zweckmäßig mit einem Zusatz körniger oder faseriger Stoffe, z. B. Sägemehl, Holzschliff, Cellulose o. dgl., bestehen und auf einer biegsamen Unterlage aufgebracht sind.

Figure A.100: Examples of Hans Stöb's patents on production of fat by *Oidium lactis* and other biotechnology methods.



REICHSPATENTAMT

PATENTSCHRIFT

№ 725593
KLASSE **6**b GRUPPE 16 03
St 59943 IVa/6b

Hans Stöb in Dachau
ist als Erfinder genannt worden.

Hans Stöb in Dachau
Kulturverfahren für Mikroorganismen auf einer durch einen flächenförmigen Träger gestützten Zwischenschicht

Patentiert im Deutschen Reich vom 9. August 1940 an
Patenterteilung bekanntgemacht am 13. August 1942

Die Erfindung betrifft ein Kulturverfahren für Mikroorganismen, wie Endomyces-, Hefe-, Monilia-, Oospora-, Aspergillus- und andere Pilzarten. Es ist bekannt, solche Züchtungen in flachen Schalen, auf Flächen aus porösen oder durchlässigen Stoffen oder auf undurchlässigen Membranen durchzuführen. Das Schalenverfahren kommt für den Großbetrieb nicht in Betracht, da es zu umständlich und zu teuer ist. Bei dem bisher durchgeführten Oberflächenverfahren mit senkrecht oder schräg stehenden Flächen läuft oft ein großer Teil der Saat nutzlos ab, oder das Wachstum der Pilze ist schlecht, da die Trägerbeschaffenheit weder für den Halt der Saat noch für die Versorgung der Kultur mit Nährlösung tauglich war. Besonders trifft dies für die bereits vorgeschlagenen, zur Dialyse geeigneten Membranen zu, die ein Durchwandern der Flüssigkeit und ein Wandern derselben in der Membran selbst nicht zulassen, so daß ein befriedigendes Wachstum der Kultur ausgeschlossen ist. Um ein gutes Haften der Saat und eine gute Versorgung mit Nährlösung zu erreichen, wird das Kulturverfahren erfindungsgemäß in der Weise durchgeführt, daß die Kultur auf einer die Flüssigkeitsbewegung in sich und durch sich zulassenden Zwischenschicht aus organischen Stoffen in Faserform gezüchtet wird, die in senkrechter oder geneigter Lage die zugeführte Nährlösung in sich aufnimmt und weitergibt.

Für die Durchführung des Verfahrens sind folgende Gesichtspunkte maßgebend:

Als Träger für die Zwischenschicht und der darauf gezüchteten Pilzdecke kommen alle Arten von flächigen Körpern aus flüssigkeitsdurchlässigem oder undurchlässigem Stoff in Betracht. Der Träger kann aus Blech, welches durchlocht oder nicht durchlocht ist, aus Asphalt- oder Bitumenpappe, aus porösen Massen, wie Gips oder keramischen Stoffen, aus Faser- oder Drahtgeweben usw. bestehen. Die Faserplatten, die sich besonders bewähren, können auch gedichtet sein, so daß ihre Porosität aufgehoben ist, was durch Anstrich oder Überzug mit Bitumen, Kunstharz usw. zu erreichen ist. Die Lagenanordnung der Träger kann geneigt oder senkrecht stehend sein. Auf der so zur Verfügung stehenden Tragfläche wird eine dünne Schicht aus organischen Stoffen in Faserform, z. B. in Holz-, Stroh-, Zell-, Papierstoff, auch Pülpe ist geeignet, erzeugt. Deren Schicht wird vorzugsweise durch Aufspritzen oder Aufschleudern der wäßrigen Fasermassesuspension hergestellt. Hierzu ist in der Regel eine geeignete Vorbehandlung der Fasermasse, wie Mahlung u. dgl., notwendig. Besonders eignet sich aufgeschlossenes Stroh, das in bekannter Weise mit Dampf von höherem Druck oder mit Alkalien bzw. alkalisch wirkenden Stoffen behandelt worden ist. Die Verwendung einer aufgeschlossenen Strohmasse hat vor allem den Vorteil der Billigkeit und der Ergiebigkeit und weiterhin, den Vorzug, daß die aufgeschlossenen Strohteile unter Umständen als Nährmittel in der gewonnenen Pilzmasse verbleiben können. Auch können zur Herstellung der Fasermasse jüngere Teile von Laubbäumen, die auf mechanischem Wege, gegebenenfalls unter Zusatz von zucker- oder stärkehaltigen Stoffen u. dgl., als Futtermittel aufbereitet worden sind, verwendet werden. Die Faserstoffsuspension, die knotenfrei sein muß, wird z. B. durch Düsen oder durch Bürstenwalzen auf die Tragfläche ausgeblasen oder aufgeschleudert. Die Konzentration der Suspension wird so gehalten, daß möglichst geringe Ablaufverluste entstehen. Werden Träger aus porösem Stoff verwendet, so ist es zweckmäßig, durch Vorbehandlung des Trägers mit heißem Wasser oder Dampf und nachheriges Abtropfenlassen seine Saugfähigkeit zu steigern, so daß ein großer Teil der Feuchtigkeit der aufgebrachten Fasermassesuspension in die Poren des Trägers eingesaugt wird und die Fasermasse einen dünen, gleichmäßigen und zusammenhängenden Belag mit guter Haftung bildet, der auch gegebenenfalls durch ablaufende Flüssigkeiten nicht zerstört wird.

Statt in Suspension kann die Zwischenschichtmasse auch in trockenem Zustand auf den Träger aufgebracht werden, wobei zweckmäßig gleichzeitig Flüssigkeit aufgespritzt wird. Um die Haftfähigkeit des Belags auf dem Träger zu erhöhen, kann der Trägeroberfläche eine besondere Gestaltung gegeben werden, z. B. durch Anbringen von Holzstiften, von kleinen Körpern aus Bimsstein, aus Koks, keramischen Körpern u. dgl. Auf der Zwischenschicht wird die Pilzdecke aufgesät. Die Nährlösung kann entweder der Zwischenschicht unmittelbar auf der Kulturseite des Trägers oder durch den porösen Träger hindurch zugeführt werden.

Nach beendetem Wachstum der Pilzdecke kann diese mit Wasser mit oder ohne Zusätzen gewaschen werden. Die Abnahme der Pilzdecke kann durch Abspülen oder Abblasen erfolgen, wobei sie zusammen mit der Zwischenschicht abgelöst wird. Je nach der weiteren Verwendungsart der Pilzernte können die Faserteile der Zwischenschicht als Nähr- oder Futterstoffe in der abgenommenen Masse verbleiben oder z. B. durch Aufschwemmen oder Aussieben oder Auswaschen aus ihr abgeschieden werden. Die ausgeschiedene faserige Masse kann unter Umständen mehrmals zur Faserschichtbildung verwendet werden. Vor Wiederverwendung des Trägers wird in der Regel eine Keimfreimachung notwendig sein, die je nach den Verhältnissen mit chemischen Mitteln, wie verdünntem Chlorwasser oder durch Wärmeeinrichtung oder beiden durchgeführt werden kann, wobei bei porösen Trägern die Wärmeeinwirkung zur Beeinflussung der Porosität, wie erwähnt, ausgenutzt werden kann. Das Verfahren kann sowohl zur Fett- und Eiweißsynthese als auch zur Gewinnung organischer Säuren und anderer Produkte unter Beachtung der jeweiligen Bedingungen verwendet werden.

PATENTANSPRÜCHE:

1. Kulturverfahren für Mikroorganismen auf einer durch einen flächenförmigen Träger gestützten Zwischenschicht, dadurch gekennzeichnet, daß die Kultur auf einer die Flüssigkeitsbewegung in sich und durch sich zulassenden Zwischenschicht aus organischen Stoffen in Faserform gezüchtet wird, die in senkrechter oder geneigter Lage die zugeführte Nährlösung in sich aufnimmt und weitergibt.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die Zwischenschichtmasse in Suspension auf den Träger aufgebracht wird.

3. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die Zwischenschichtmasse in trockenem Zustand unter gleichzeitiger Aufspritzung von Flüssigkeit auf dem Träger verteilt wird.

4. Verfahren nach Ansprüchen 1 bis 3, dadurch gekennzeichnet, daß die Zwischenschicht auf einem Träger aus porösem Stoff erzeugt wird.

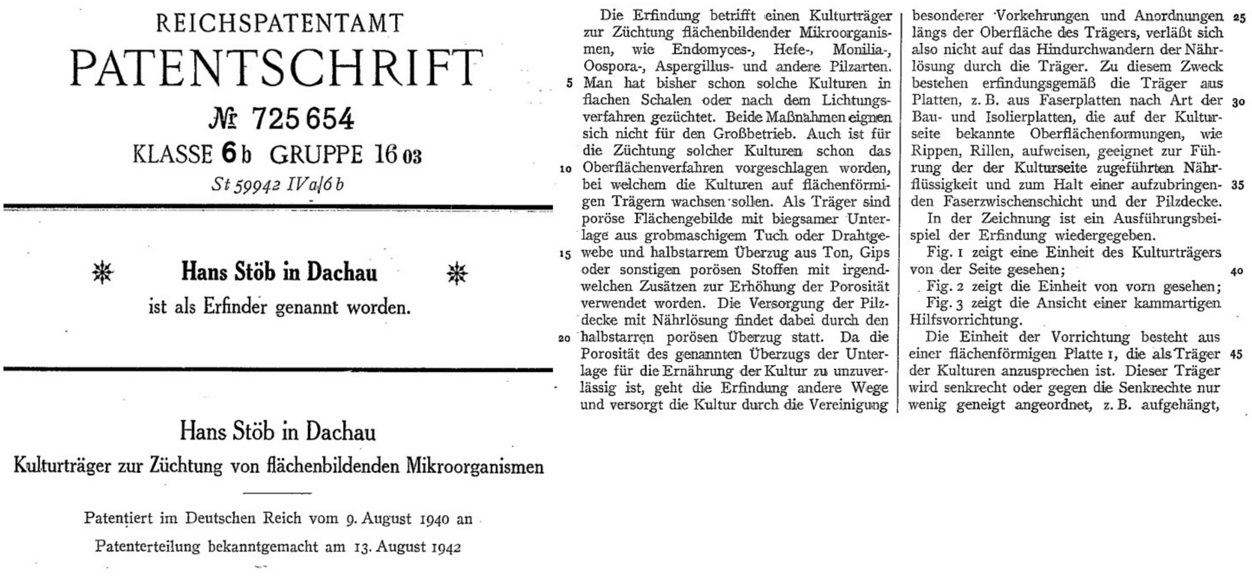
5. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß der poröse Träger vor Aufbringen der Zwischenschicht durch Behandlung mit heißer Flüssigkeit, Dampf o.dgl. und Abtropfenlassen in den Zustand erhöhter Saugfähigkeit versetzt wird.

6. Verfahren nach Ansprüchen 1 bis 5, dadurch gekennzeichnet, daß die Zwischenschichtmasse aus als Futtermittel dienendem Stoff besteht, der gegebenenfalls in der fertigen und abgelösten Kulturdecke verbleibt.

7. Verfahren nach Anspruch 6, dadurch gekennzeichnet, daß die Zwischenschichtmasse aus sogenanntem Kochstroh besteht, das aus Stroh durch Behandlung mit alkalischen Stoffen mit oder ohne erhöhter Temperatur oder durch Behandlung mit Dampf bei erhöhtem Druck gewonnen wird.

8. Verfahren nach Ansprüchen 1 bis 6, dadurch gekennzeichnet, daß als Zwischenschichtmasse Holz, insbesondere jüngere Teile von Laubbäumen verwendet werden, die auf mechanischem Wege, gegebenenfalls unter Zusatz von zucker- oder stärkehaltigen Stoffen u. dgl., als Futtermittel aufbereitet worden sind.

Figure A.101: Examples of Hans Stöb's patents on production of fat by *Oidium lactis* and other biotechnology methods.



REICHSPATENTAMT

PATENTSCHRIFT

№ 725 654

KLASSE **6b** GRUPPE 16 03

St 59942 IVa/6b

Hans Stöb in Dachau

ist als Erfinder genannt worden.

Hans Stöb in Dachau

Kulturträger zur Züchtung von flächenbildenden Mikroorganismen

Patentiert im Deutschen Reich vom 9. August 1940 an

Patenterteilung bekanntgemacht am 13. August 1942

Die Erfindung betrifft einen Kulturträger zur Züchtung flächenbildender Mikroorganismen, wie Endomyces-, Hefe-, Monilia-, Oospora-, Aspergillus- und andere Pilzarten. Man hat bisher schon solche Kulturen in flachen Schalen oder nach dem Lichtungsverfahren gezüchtet. Beide Maßnahmen eignen sich nicht für den Großbetrieb. Auch ist für die Züchtung solcher Kulturen schon das Oberflächenverfahren vorgeschlagen worden, bei welchem die Kulturen auf flächenförmigen Trägern wachsen sollen. Als Träger sind poröse Flächengebilde mit biegsamer Unterlage aus grobmaschigem Tuch oder Drahtgewebe und halbstarrem Überzug aus Ton, Gips oder sonstigen porösen Stoffen mit irgendwelchen Zusätzen zur Erhöhung der Porosität verwendet worden. Die Versorgung der Pilzdecke mit Nährlösung findet dabei durch den halbstarren porösen Überzug statt. Da die Porosität des genannten Überzugs der Unterlage für die Ernährung der Kultur zu unzuverlässig ist, geht die Erfindung andere Wege und versorgt die Kultur durch die Vereinigung besonderer Vorkehrungen und Anordnungen längs der Oberfläche des Trägers, verläßt sich also nicht auf das Hindurchwandern der Nährlösung durch die Träger. Zu diesem Zweck bestehen erfindungsgemäß die Träger aus Platten, z. B. aus Faserplatten nach Art der Bau- und Isolierplatten, die auf der Kulturseite bekannte Oberflächenformungen, wie Rippen, Rillen, aufweisen, geeignet zur Führung der der Kulturseite zugeführten Nährflüssigkeit und zum Halt einer aufzubringenden Faserzwischenschicht und der Pilzdecke.

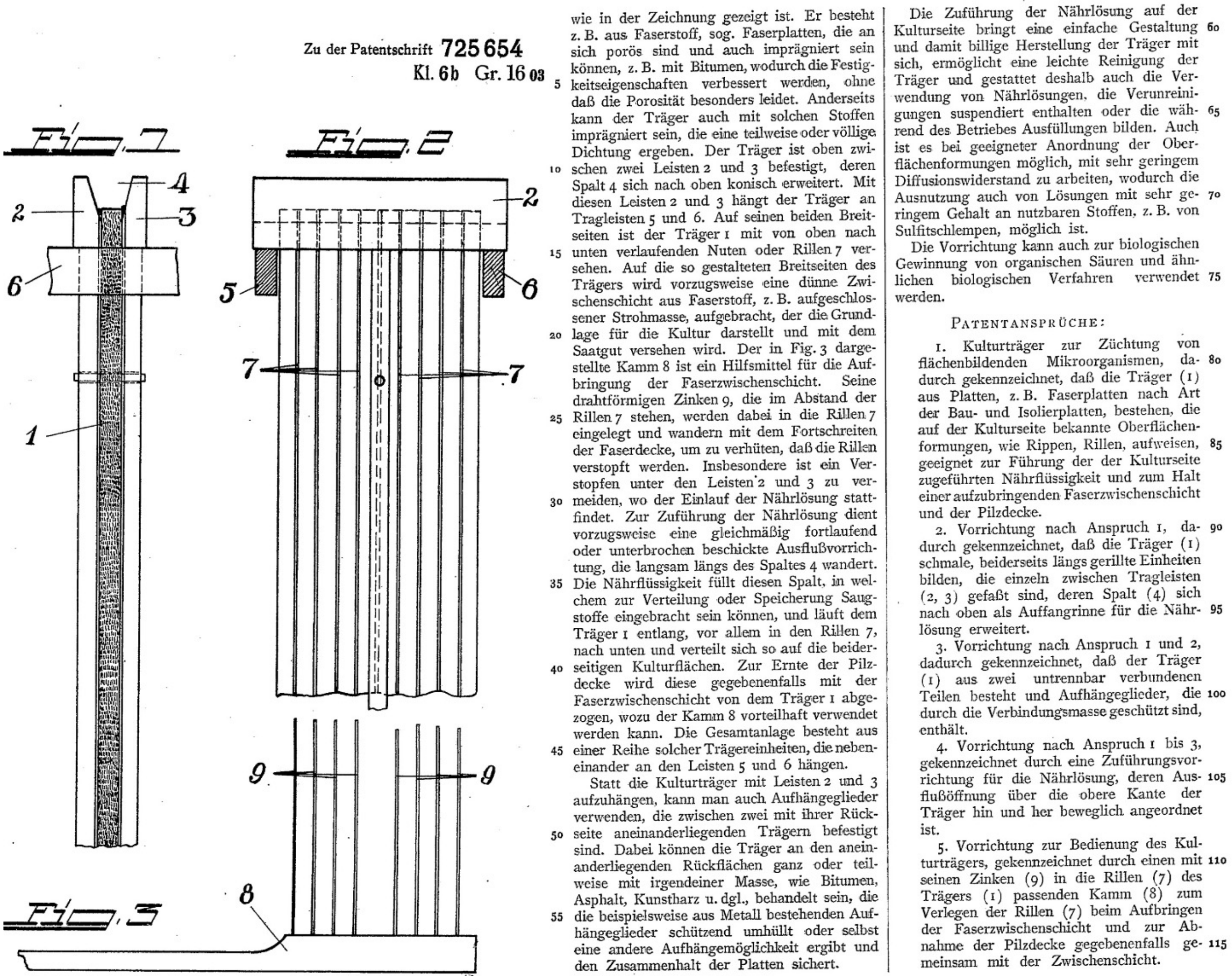
In der Zeichnung ist ein Ausführungsbeispiel der Erfindung wiedergegeben.

Fig. 1 zeigt eine Einheit des Kulturträgers von der Seite gesehen;

Fig. 2 zeigt die Einheit von vorn gesehen;

Fig. 3 zeigt die Ansicht einer kammartigen Hilfsvorrichtung.

Die Einheit der Vorrichtung besteht aus einer flächenförmigen Platte 1, die als Träger der Kulturen anzusprechen ist. Dieser Träger wird senkrecht oder gegen die Senkrechte nur wenig geneigt angeordnet, z. B. aufgehängt,



Zu der Patentschrift **725 654**

Kl. 6b Gr. 16 03

Fig. 1
4
2
3
6
1
Fig. 2
2
5
6
7
7
Fig. 3
8
9
9

wie in der Zeichnung gezeigt ist. Er besteht z. B. aus Faserstoff, sog. Faserplatten, die an sich porös sind und auch imprägniert sein können, z. B. mit Bitumen, wodurch die Festigkeitseigenschaften verbessert werden, ohne daß die Porosität besonders leidet. Anderseits kann der Träger auch mit solchen Stoffen imprägniert sein, die eine teilweise oder völlige Dichtung ergeben. Der Träger ist oben zwischen zwei Leisten 2 und 3 befestigt, deren Spalt 4 sich nach oben konisch erweitert. Mit diesen Leisten 2 und 3 hängt der Träger an Tragleisten 5 und 6. Auf seinen beiden Breitseiten ist der Träger 1 mit von oben nach unten verlaufenden Nuten oder Rillen 7 versehen. Auf die so gestalteten Breitseiten des Trägers wird vorzugsweise eine dünne Zwischenschicht aus Faserstoff, z. B. aufgeschlossener Strohmasse, aufgebracht, der die Grundlage für die Kultur darstellt und mit dem Saatgut versehen wird. Der in Fig. 3 dargestellte Kamm 8 ist ein Hilfsmittel für die Aufbringung der Faserzwischenschicht. Seine drahtförmigen Zinken 9, die im Abstand der Rillen 7 stehen, werden dabei in die Rillen 7 eingelegt und wandern mit dem Fortschreiten der Faserdecke, um zu verhüten, daß die Rillen verstopft werden. Insbesondere ist ein Verstopfen unter den Leisten 2 und 3 zu vermeiden, wo der Einlauf der Nährlösung stattfindet. Zur Zuführung der Nährlösung dient vorzugsweise eine gleichmäßig fortlaufend oder unterbrochen beschickte Ausflußvorrichtung, die langsam längs des Spaltes 4 wandert. Die Nährflüssigkeit füllt diesen Spalt, in welchem zur Verteilung oder Speicherung Saugstoffe eingebracht sein können, und läuft dem Träger 1 entlang, vor allem in den Rillen 7, nach unten und verteilt sich so auf die beiderseitigen Kulturflächen. Zur Ernte der Pilzdecke wird diese gegebenenfalls mit der Faserzwischenschicht von dem Träger 1 abgezogen, wozu der Kamm 8 vorteilhaft verwendet werden kann. Die Gesamtanlage besteht aus einer Reihe solcher Trägereinheiten, die nebeneinander an den Leisten 5 und 6 hängen.

Statt die Kulturträger mit Leisten 2 und 3 aufzuhängen, kann man auch Aufhängeglieder verwenden, die zwischen zwei mit ihrer Rückseite aneinanderliegenden Trägern befestigt sind. Dabei können die Träger an den aneinanderliegenden Rückflächen ganz oder teilweise mit irgendeiner Masse, wie Bitumen, Asphalt, Kunstharz u. dgl., behandelt sein, die die beispielsweise aus Metall bestehenden Aufhängeglieder schützend umhüllt oder selbst eine andere Aufhängemöglichkeit ergibt und den Zusammenhalt der Platten sichert.

Die Zuführung der Nährlösung auf der Kulturseite bringt eine einfache Gestaltung und damit billige Herstellung der Träger mit sich, ermöglicht eine leichte Reinigung der Träger und gestattet deshalb auch die Verwendung von Nährlösungen, die Verunreinigungen suspendiert enthalten oder die während des Betriebes Ausfüllungen bilden. Auch ist es bei geeigneter Anordnung der Oberflächenformungen möglich, mit sehr geringem Diffusionswiderstand zu arbeiten, wodurch die Ausnutzung auch von Lösungen mit sehr geringem Gehalt an nutzbaren Stoffen, z. B. von Sulfitschlempen, möglich ist.

Die Vorrichtung kann auch zur biologischen Gewinnung von organischen Säuren und ähnlichen biologischen Verfahren verwendet werden.

PATENTANSPRÜCHE:

1. Kulturträger zur Züchtung von flächenbildenden Mikroorganismen, dadurch gekennzeichnet, daß die Träger (1) aus Platten, z. B. Faserplatten nach Art der Bau- und Isolierplatten, bestehen, die auf der Kulturseite bekannte Oberflächenformungen, wie Rippen, Rillen, aufweisen, geeignet zur Führung der der Kulturseite zugeführten Nährflüssigkeit und zum Halt einer aufzubringenden Faserzwischenschicht und der Pilzdecke.

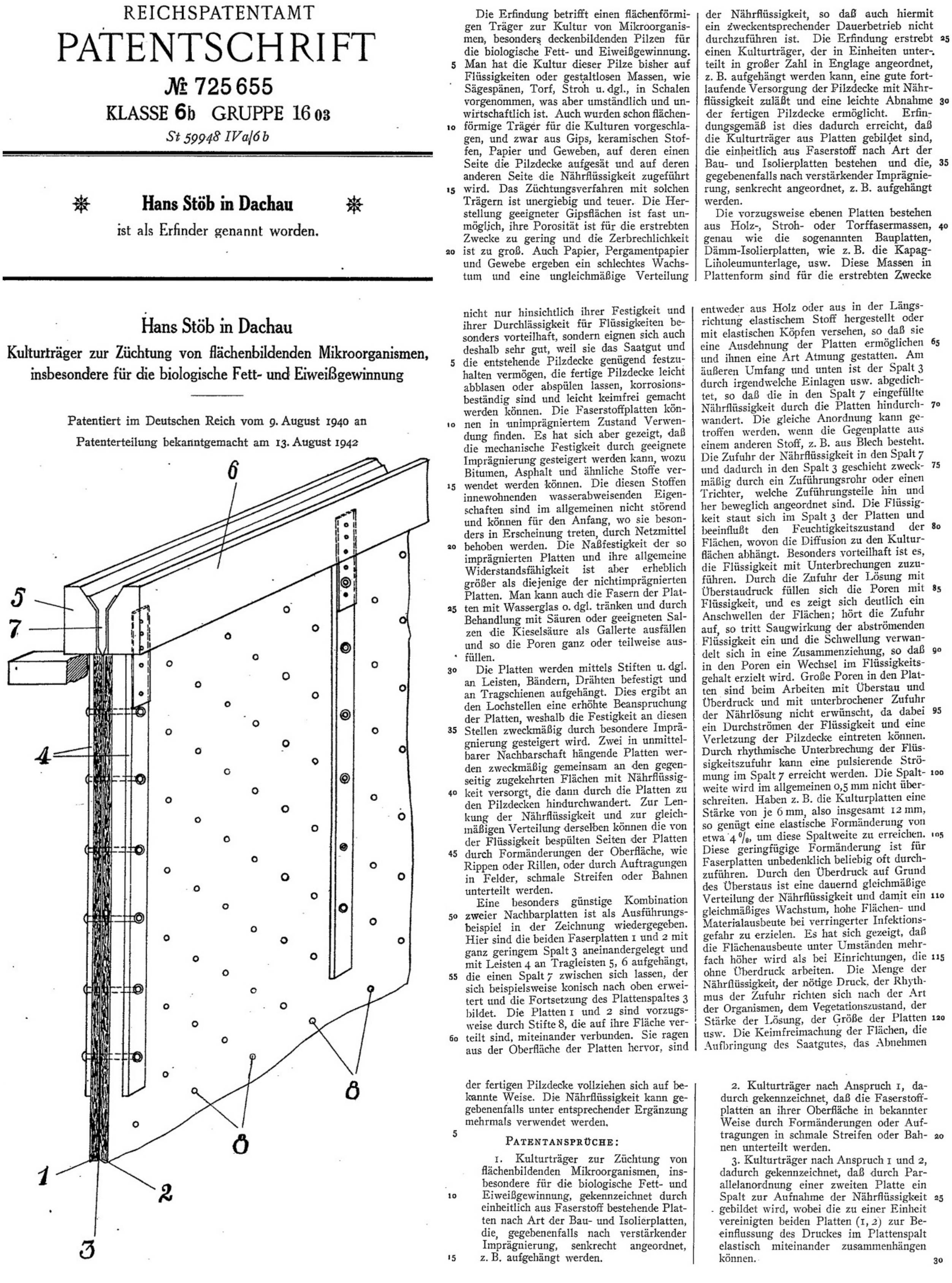
2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Träger (1) schmale, beiderseits längs gerillte Einheiten bilden, die einzeln zwischen Tragleisten (2, 3) gefaßt sind, deren Spalt (4) sich nach oben als Auffangrinne für die Nährlösung erweitert.

3. Vorrichtung nach Anspruch 1 und 2, dadurch gekennzeichnet, daß der Träger (1) aus zwei untrennbar verbundenen Teilen besteht und Aufhängeglieder, die durch die Verbindungsmasse geschützt sind, enthält.

4. Vorrichtung nach Anspruch 1 bis 3, gekennzeichnet durch eine Zuführungsvorrichtung für die Nährlösung, deren Ausflußöffnung über die obere Kante der Träger hin und her beweglich angeordnet ist.

5. Vorrichtung zur Bedienung des Kulturträgers, gekennzeichnet durch einen mit seinen Zinken (9) in die Rillen (7) des Trägers (1) passenden Kamm (8) zum Verlegen der Rillen (7) beim Aufbringen der Faserzwischenschicht und zur Abnahme der Pilzdecke gegebenenfalls gemeinsam mit der Zwischenschicht.

Figure A.102: Examples of Hans Stöb's patents on production of fat by *Oidium lactis* and other biotechnology methods.



REICHSPATENTAMT

PATENTSCHRIFT

№ 725 655

KLASSE 6b GRUPPE 16 03

St 59948 IVa/6b

Hans Stöb in Dachau

ist als Erfinder genannt worden.

Hans Stöb in Dachau

Kulturträger zur Züchtung von flächenbildenden Mikroorganismen, insbesondere für die biologische Fett- und Eiweißgewinnung

Patentiert im Deutschen Reich vom 9. August 1940 an

Patenterteilung bekanntgemacht am 13. August 1942

Die Erfindung betrifft einen flächenförmigen Träger zur Kultur von Mikroorganismen, besonders deckenbildenden Pilzen für die biologische Fett- und Eiweißgewinnung. Man hat die Kultur dieser Pilze bisher auf Flüssigkeiten oder gestaltlosen Massen, wie Sägespänen, Torf, Stroh u. dgl., in Schalen vorgenommen, was aber umständlich und unwirtschaftlich ist. Auch wurden schon flächenförmige Träger für die Kulturen vorgeschlagen, und zwar aus Gips, keramischen Stoffen, Papier und Geweben, auf deren einen Seite die Pilzdecke aufgesät und auf deren anderen Seite die Nährflüssigkeit zugeführt wird. Das Züchtungsverfahren mit solchen Trägern ist unergiebig und teuer. Die Herstellung geeigneter Gipsflächen ist fast unmöglich, ihre Porosität ist für die erstrebten Zwecke zu gering und die Zerbrechlichkeit ist zu groß. Auch Papier, Pergamentpapier und Gewebe ergeben ein schlechtes Wachstum und eine ungleichmäßige Verteilung der Nährflüssigkeit, so daß auch hiermit ein zweckentsprechender Dauerbetrieb nicht durchzuführen ist. Die Erfindung erstrebt einen Kulturträger, der in Einheiten unterteilt in großer Zahl in Englage angeordnet, z. B. aufgehängt werden kann, eine gute fortlaufende Versorgung der Pilzdecke mit Nährflüssigkeit zuläßt und eine leichte Abnahme der fertigen Pilzdecke ermöglicht. Erfindungsgemäß ist dies dadurch erreicht, daß die Kulturträger aus Platten gebildet sind, die einheitlich aus Faserstoff nach Art der Bau- und Isolierplatten bestehen und die, gegebenenfalls nach verstärkender Imprägnierung, senkrecht angeordnet, z. B. aufgehängt werden.

Die vorzugsweise ebenen Platten bestehen aus Holz-, Stroh- oder Torffasermassen, genau wie die sogenannten Bauplatten, Dämm-Isolierplatten, wie z. B. die Kapag-Linoleumunterlage, usw. Diese Massen in Plattenform sind für die erstrebten Zwecke nicht nur hinsichtlich ihrer Festigkeit und ihrer Durchlässigkeit für Flüssigkeiten besonders vorteilhaft, sondern eignen sich auch deshalb sehr gut, weil sie das Saatgut und die entstehende Pilzdecke genügend festzuhalten vermögen, die fertige Pilzdecke leicht abblasen oder abspülen lassen, korrosionsbeständig sind und leicht keimfrei gemacht werden können. Die Faserstoffplatten können in unimprägniertem Zustand Verwendung finden. Es hat sich aber gezeigt, daß die mechanische Festigkeit durch geeignete Imprägnierung gesteigert werden kann, wozu Bitumen, Asphalt und ähnliche Stoffe verwendet werden können. Die diesen Stoffen innewohnenden wasserabweisenden Eigenschaften sind im allgemeinen nicht störend und können für den Anfang, wo sie besonders in Erscheinung treten, durch Netzmittel behoben werden. Die Naßfestigkeit der so imprägnierten Platten und ihre allgemeine Widerstandsfähigkeit ist aber erheblich größer als diejenige der nichtimprägnierten Platten. Man kann auch die Fasern der Platten mit Wasserglas o. dgl. tränken und durch Behandlung mit Säuren oder geeigneten Salzen die Kieselsäure als Gallerte ausfällen und so die Poren ganz oder teilweise ausfüllen.

Die Platten werden mittels Stiften u. dgl. an Leisten, Bändern, Drähten befestigt und an Tragschienen aufgehängt. Dies ergibt an den Lochstellen eine erhöhte Beanspruchung der Platten, weshalb die Festigkeit an diesen Stellen zweckmäßig durch besondere Imprägnierung gesteigert wird. Zwei in unmittelbarer Nachbarschaft hängende Platten werden zweckmäßig gemeinsam an den gegenseitig zugekehrten Flächen mit Nährflüssigkeit versorgt, die dann durch die Platten zu den Pilzdecken hindurchwandert. Zur Lenkung der Nährflüssigkeit und zur gleichmäßigen Verteilung derselben können die von der Flüssigkeit bespülten Seiten der Platten durch Formänderungen der Oberfläche, wie Rippen oder Rillen, oder durch Auftragungen in Felder, schmale Streifen oder Bahnen unterteilt werden.

Eine besonders günstige Kombination zweier Nachbarplatten ist als Ausführungsbeispiel in der Zeichnung wiedergegeben. Hier sind die beiden Faserplatten 1 und 2 mit ganz geringem Spalt 3 aneinandergelegt und mit Leisten 4 an Tragleisten 5, 6 aufgehängt, die einen Spalt 7 zwischen sich lassen, der sich beispielsweise konisch nach oben erweitert und die Fortsetzung des Plattenspaltes 3 bildet. Die Platten 1 und 2 sind vorzugsweise durch Stifte 8, die auf ihre Fläche verteilt sind, miteinander verbunden. Sie ragen aus der Oberfläche der Platten hervor, sind entweder aus Holz oder aus in der Längsrichtung elastischem Stoff hergestellt oder mit elastischen Köpfen versehen, so daß sie eine Ausdehnung der Platten ermöglichen und ihnen eine Art Atmung gestatten. Am äußeren Umfang und unten ist der Spalt 3 durch irgendwelche Einlagen usw. abgedichtet, so daß die in den Spalt 7 eingefüllte Nährflüssigkeit durch die Platten hindurchwandert. Die gleiche Anordnung kann getroffen werden, wenn die Gegenplatte aus einem anderen Stoff, z. B. aus Blech besteht. Die Zufuhr der Nährflüssigkeit in den Spalt 7 und dadurch in den Spalt 3 geschieht zweckmäßig durch ein Zuführungsrohr oder einen Trichter, welche Zuführungsteile hin und her beweglich angeordnet sind. Die Flüssigkeit staut sich im Spalt 3 der Platten und beeinflußt den Feuchtigkeitszustand der Flächen, wovon die Diffusion zu den Kulturflächen abhängt. Besonders vorteilhaft ist es, die Flüssigkeit mit Unterbrechungen zuzuführen. Durch die Zufuhr der Lösung mit Überstaudruck füllen sich die Poren mit Flüssigkeit, und es zeigt sich deutlich ein Anschwellen der Flächen; hört die Zufuhr auf, so tritt Saugwirkung der abströmenden Flüssigkeit ein und die Schwellung verwandelt sich in eine Zusammenziehung, so daß in den Poren ein Wechsel im Flüssigkeitsgehalt erzielt wird. Große Poren in den Platten sind beim Arbeiten mit Überstau und Überdruck und mit unterbrochener Zufuhr der Nährlösung nicht erwünscht, da dabei ein Durchströmen der Flüssigkeit und eine Verletzung der Pilzdecke eintreten können. Durch rhythmische Unterbrechung der Flüssigkeitszufuhr kann eine pulsierende Strömung im Spalt 7 erreicht werden. Die Spaltweite wird im allgemeinen 0,5 mm nicht überschreiten. Haben z. B. die Kulturplatten eine Stärke von je 6 mm, also insgesamt 12 mm, so genügt eine elastische Formänderung von etwa 4 %, um diese Spaltweite zu erreichen. Diese geringfügige Formänderung ist für Faserplatten unbedenklich beliebig oft durchzuführen. Durch den Überdruck auf Grund des Überstaus ist eine dauernd gleichmäßige Verteilung der Nährflüssigkeit und damit ein gleichmäßiges Wachstum, hohe Flächen- und Materialausbeute bei verringerter Infektionsgefahr zu erzielen. Es hat sich gezeigt, daß die Flächenausbeute unter Umständen mehrfach höher wird als bei Einrichtungen, die ohne Überdruck arbeiten. Die Menge der Nährflüssigkeit, der nötige Druck, der Rhythmus der Zufuhr richten sich nach der Art der Organismen, dem Vegetationszustand, der Stärke der Lösung, der Größe der Platten usw. Die Keimfreimachung der Flächen, die Aufbringung des Saatgutes, das Abnehmen der fertigen Pilzdecke vollziehen sich auf bekannte Weise. Die Nährflüssigkeit kann gegebenenfalls unter entsprechender Ergänzung mehrmals verwendet werden.

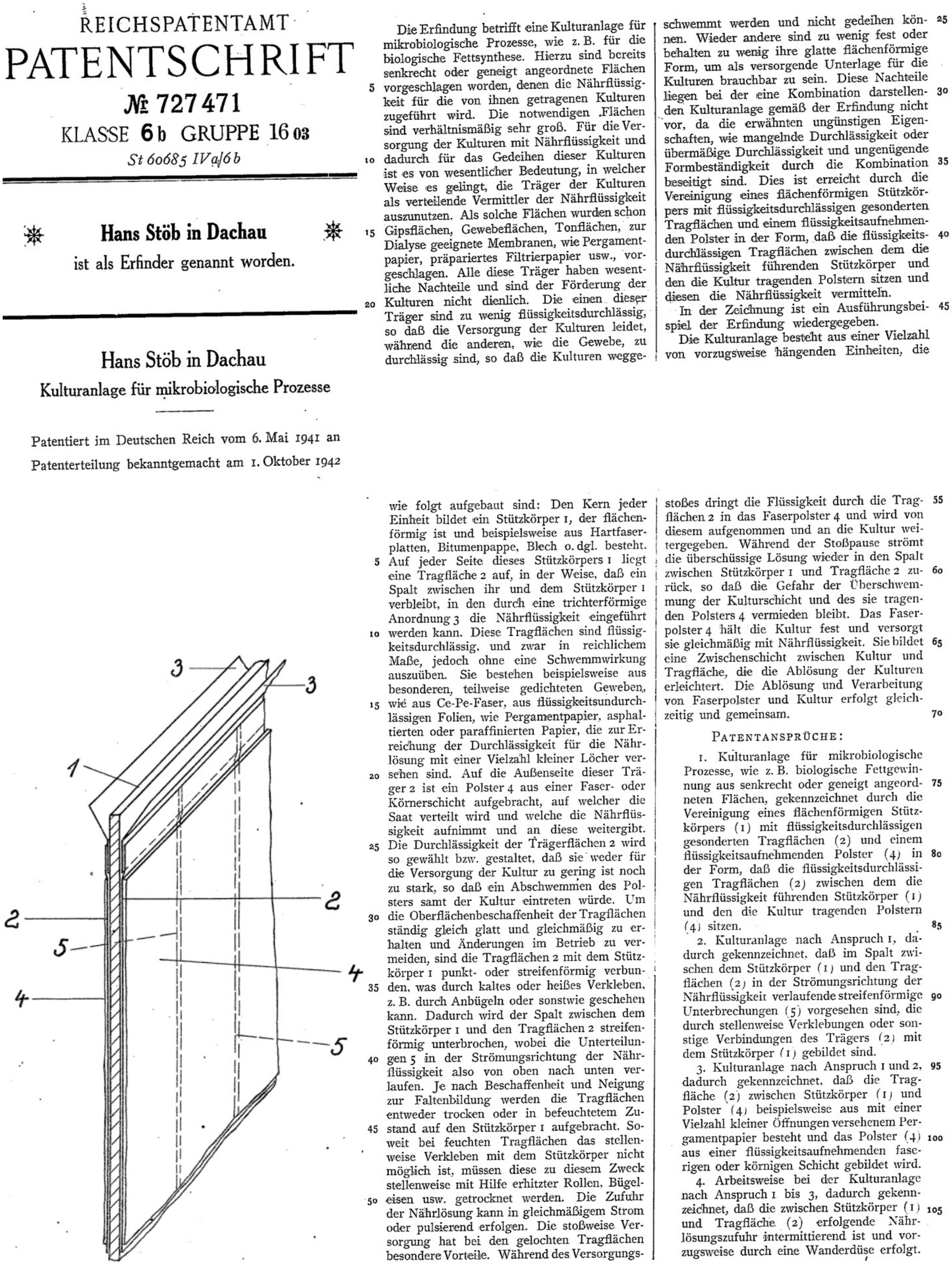
PATENTANSPRÜCHE:

1. Kulturträger zur Züchtung von flächenbildenden Mikroorganismen, insbesondere für die biologische Fett- und Eiweißgewinnung, gekennzeichnet durch einheitlich aus Faserstoff bestehende Platten nach Art der Bau- und Isolierplatten, die, gegebenenfalls nach verstärkender Imprägnierung, senkrecht angeordnet, z. B. aufgehängt werden.

2. Kulturträger nach Anspruch 1, dadurch gekennzeichnet, daß die Faserstoffplatten an ihrer Oberfläche in bekannter Weise durch Formänderungen oder Auftragungen in schmale Streifen oder Bahnen unterteilt werden.

3. Kulturträger nach Anspruch 1 und 2, dadurch gekennzeichnet, daß durch Parallelanordnung einer zweiten Platte ein Spalt zur Aufnahme der Nährflüssigkeit gebildet wird, wobei die zu einer Einheit vereinigten beiden Platten (1, 2) zur Beeinflussung des Druckes im Plattenspalt elastisch miteinander zusammenhängen können.

Figure A.103: Examples of Hans Stöb's patents on production of fat by *Oidium lactis* and other biotechnology methods.



REICHSPATENTAMT

PATENTSCHRIFT

№ 727 471

KLASSE **6 b** GRUPPE 16 03

St 60685 IVa/6 b

Hans Stöb in Dachau
ist als Erfinder genannt worden.

Hans Stöb in Dachau

Kulturanlage für mikrobiologische Prozesse

Patentiert im Deutschen Reich vom 6. Mai 1941 an
Patenterteilung bekanntgemacht am 1. Oktober 1942

Die Erfindung betrifft eine Kulturanlage für mikrobiologische Prozesse, wie z. B. für die biologische Fettsynthese. Hierzu sind bereits senkrecht oder geneigt angeordnete Flächen vorgeschlagen worden, denen die Nährflüssigkeit für die von ihnen getragenen Kulturen zugeführt wird. Die notwendigen Flächen sind verhältnismäßig sehr groß. Für die Versorgung der Kulturen mit Nährflüssigkeit und dadurch für das Gedeihen dieser Kulturen ist es von wesentlicher Bedeutung, in welcher Weise es gelingt, die Träger der Kulturen als verteilende Vermittler der Nährflüssigkeit auszunutzen. Als solche Flächen wurden schon Gipsflächen, Gewebeflächen, Tonflächen, zur Dialyse geeignete Membranen, wie Pergamentpapier, präpariertes Filtrierpapier usw., vorgeschlagen. Alle diese Träger haben wesentliche Nachteile und sind der Förderung der Kulturen nicht dienlich. Die einen dieser Träger sind zu wenig flüssigkeitsdurchlässig, so daß die Versorgung der Kulturen leidet, während die anderen, wie die Gewebe, zu durchlässig sind, so daß die Kulturen weggeschwemmt werden und nicht gedeihen können. Wieder andere sind zu wenig fest oder behalten zu wenig ihre glatte flächenförmige Form, um als versorgende Unterlage für die Kulturen brauchbar zu sein. Diese Nachteile liegen bei der eine Kombination darstellenden Kulturanlage gemäß der Erfindung nicht vor, da die erwähnten ungünstigen Eigenschaften, wie mangelnde Durchlässigkeit oder übermäßige Durchlässigkeit und ungenügende Formbeständigkeit durch die Kombination beseitigt sind. Dies ist erreicht durch die Vereinigung eines flächenförmigen Stützkörpers mit flüssigkeitsdurchlässigen gesonderten Tragflächen und einem flüssigkeitsaufnehmenden Polster in der Form, daß die flüssigkeitsdurchlässigen Tragflächen zwischen dem die Nährflüssigkeit führenden Stützkörper und den die Kultur tragenden Polstern sitzen und diesen die Nährflüssigkeit vermitteln.

In der Zeichnung ist ein Ausführungsbeispiel der Erfindung wiedergegeben.

Die Kulturanlage besteht aus einer Vielzahl von vorzugsweise hängenden Einheiten, die wie folgt aufgebaut sind: Den Kern jeder Einheit bildet ein Stützkörper 1, der flächenförmig ist und beispielsweise aus Hartfaserplatten, Bitumenpappe, Blech o. dgl. besteht. Auf jeder Seite dieses Stützkörpers 1 liegt eine Tragfläche 2 auf, in der Weise, daß ein Spalt zwischen ihr und dem Stützkörper 1 verbleibt, in den durch eine trichterförmige Anordnung 3 die Nährflüssigkeit eingeführt werden kann. Diese Tragflächen sind flüssigkeitsdurchlässig, und zwar in reichlichem Maße, jedoch ohne eine Schwemmwirkung auszuüben. Sie bestehen beispielsweise aus besonderen, teilweise gedichteten Geweben, wie aus Ce-Pe-Faser, aus flüssigkeitsundurchlässigen Folien, wie Pergamentpapier, asphaltierten oder paraffinierten Papier, die zur Erreichung der Durchlässigkeit für die Nährlösung mit einer Vielzahl kleiner Löcher versehen sind. Auf die Außenseite dieser Träger 2 ist ein Polster 4 aus einer Faser- oder Körnerschicht aufgebracht, auf welcher die Saat verteilt wird und welche die Nährflüssigkeit aufnimmt und an diese weitergibt. Die Durchlässigkeit der Trägerflächen 2 wird so gewählt bzw. gestaltet, daß sie weder für die Versorgung der Kultur zu gering ist noch zu stark, so daß ein Abschwemmen des Polsters samt der Kultur eintreten würde. Um die Oberflächenbeschaffenheit der Tragflächen ständig gleich glatt und gleichmäßig zu erhalten und Änderungen im Betrieb zu vermeiden, sind die Tragflächen 2 mit dem Stützkörper 1 punkt- oder streifenförmig verbunden, was durch kaltes oder heißes Verkleben, z. B. durch Anbügeln oder sonstwie geschehen kann. Dadurch wird der Spalt zwischen dem Stützkörper 1 und den Tragflächen 2 streifenförmig unterbrochen, wobei die Unterteilungen 5 in der Strömungsrichtung der Nährflüssigkeit also von oben nach unten verlaufen. Je nach Beschaffenheit und Neigung zur Faltenbildung werden die Tragflächen entweder trocken oder in befeuchtetem Zustand auf den Stützkörper 1 aufgebracht. Soweit bei feuchten Tragflächen das stellenweise Verkleben mit dem Stützkörper nicht möglich ist, müssen diese zu diesem Zweck stellenweise mit Hilfe erhitzter Rollen, Bügeleisen usw. getrocknet werden. Die Zufuhr der Nährlösung kann in gleichmäßigem Strom oder pulsierend erfolgen. Die stoßweise Versorgung hat bei den gelochten Tragflächen besondere Vorteile. Während des Versorgungsstoßes dringt die Flüssigkeit durch die Tragflächen 2 in das Faserpolster 4 und wird von diesem aufgenommen und an die Kultur weitergegeben. Während der Stoßpause strömt die überschüssige Lösung wieder in den Spalt zwischen Stützkörper 1 und Tragfläche 2 zurück, so daß die Gefahr der Überschwemmung der Kulturschicht und des sie tragenden Polsters 4 vermieden bleibt. Das Faserpolster 4 hält die Kultur fest und versorgt sie gleichmäßig mit Nährflüssigkeit. Sie bildet eine Zwischenschicht zwischen Kultur und Tragfläche, die die Ablösung der Kulturen erleichtert. Die Ablösung und Verarbeitung von Faserpolster und Kultur erfolgt gleichzeitig und gemeinsam.

PATENTANSPRÜCHE:

1. Kulturanlage für mikrobiologische Prozesse, wie z. B. biologische Fettgewinnung aus senkrecht oder geneigt angeordneten Flächen, gekennzeichnet durch die Vereinigung eines flächenförmigen Stützkörpers (1) mit flüssigkeitsdurchlässigen gesonderten Tragflächen (2) und einem flüssigkeitsaufnehmenden Polster (4) in der Form, daß die flüssigkeitsdurchlässigen Tragflächen (2) zwischen dem die Nährflüssigkeit führenden Stützkörper (1) und den die Kultur tragenden Polstern (4) sitzen.

2. Kulturanlage nach Anspruch 1, dadurch gekennzeichnet, daß im Spalt zwischen dem Stützkörper (1) und den Tragflächen (2) in der Strömungsrichtung der Nährflüssigkeit verlaufende streifenförmige Unterbrechungen (5) vorgesehen sind, die durch stellenweise Verklebungen oder sonstige Verbindungen des Trägers (2) mit dem Stützkörper (1) gebildet sind.

3. Kulturanlage nach Anspruch 1 und 2, dadurch gekennzeichnet, daß die Tragfläche (2) zwischen Stützkörper (1) und Polster (4) beispielsweise aus mit einer Vielzahl kleiner Öffnungen versehenem Pergamentpapier besteht und das Polster (4) aus einer flüssigkeitsaufnehmenden faserigen oder körnigen Schicht gebildet wird.

4. Arbeitsweise bei der Kulturanlage nach Anspruch 1 bis 3, dadurch gekennzeichnet, daß die zwischen Stützkörper (1) und Tragfläche (2) erfolgende Nährlösungszufuhr intermittierend ist und vorzugsweise durch eine Wanderdüse erfolgt.

Figure A.104: Examples of Hans Stöb's patents on production of fat by *Oidium lactis* and other biotechnology methods.

FIAT 545. ***Pulling Wool by the Use of Enzymes.***

PURPOSE

To remove wool from pelts without detriment to the wool fibers nor to the hides.

SUMMARY

By the use of an enzymatic product called Arazym NSL, the above purpose appears to have been accomplished with excellent results.

ARAZYM NSL

This process of pulling wool from sheep skins was developed by the Röhm and Haas Company of Darmstadt who are the manufacturers of the enzyme product named Arazym NSL.

The process was explained by Dr. C. T. Kaulter, Technical Director of Röhm and Haas and is a development of research carried on during the past five or six years.

Manufacture

Originally the enzyme used was produced from animal pancreas imported frozen from American packing houses. When the war interrupted these importations, they began producing enzymes from cultures in bran. Protease is the active principle. Production has been terminated at present due to the destruction of the factory, but it is now being reconstructed and they expect to be in production again by spring.

The mould, Aspergil paraciticus, is produced in pure strains in the laboratory. Trays of bran seeded with the mould are cultured for five days at 20^oC. to 22^oC. The temperature must not be allowed to rise above 28^oC. Temperature is kept down by cold water which is circulated through the shelves on which the shallow trays of bran rest.

No particular attention is paid to pH control but it normally runs around 6.8.

The mould culture is then extracted with water and precipitated with ammonium sulphate or sodium sulphate or a mixture of both. It also may be precipitated with ethyl alcohol. The salts used for precipitation are in 35% solution.

After the proteinic matter is precipitated out, it is put through a filter press and then dried under vacuum at 30^oC. A protease of high concentration which contains 40,000 enzymatic units is thus obtained. [...]

COMPARISONS BETWEEN OLD AND NEW PULLING PROCESSES

The old lime process took only about 12 hours instead of 24 hours and could be used on cold skins. Also the old methods with lime and sulfide were very cheap.

However, the resulting pulled wool by the enzyme process is much superior in handle and contains no bothersome chemicals. The additional cost of the enzyme over the cheaper chemicals is more than made up in the increased value and higher selling price of the wool as well as an estimated increase in wool yield of approximately 10%.

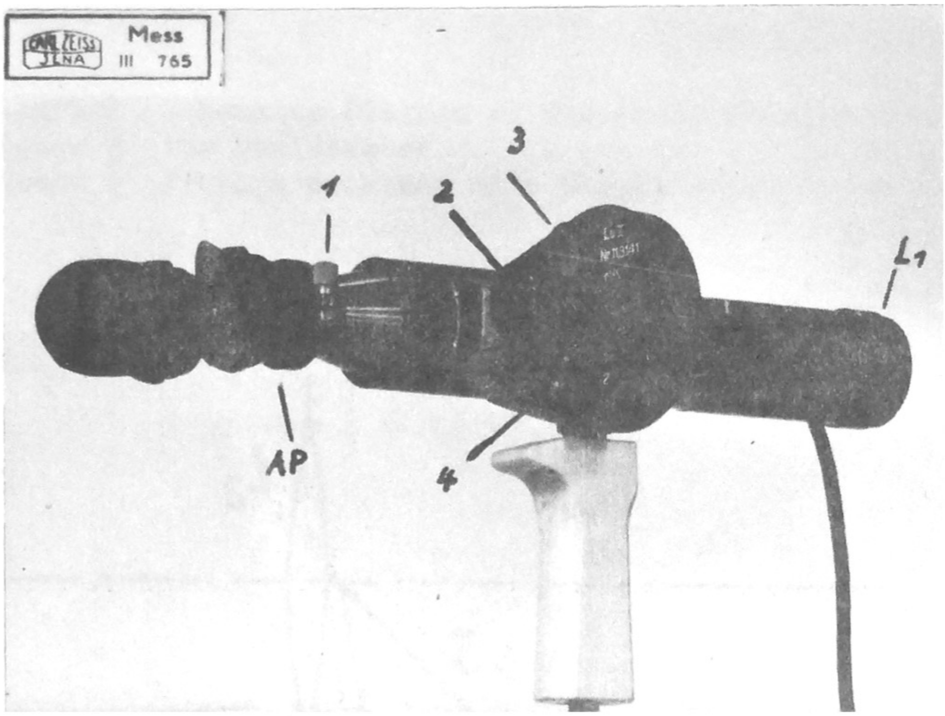
FIAT 570. ***Inoculation of Food Plant Seeds with Specific Strains of Microorganisms.***

FIAT 871. ***The Luminometer.***

ABSTRACT

A new visual photometer, called the Luminometer, was developed in 1943 by Carl Zeiss to measure very faint brightnesses. In contrast to ordinary photometers it has a field of view of 30^o and an exit pupil 9 mm. in diameter. The measuring range covered by the Luminometer is 10^{-2} to 10^{-6} millilambert. At a brightness of 10^{-5} millilambert, for instance, the average error of matching brightnesses in one operation is about 15 percent. The accuracy as compared with that of ordinary photometers is about three times greater. [...]

P. H. Keck "Ueber die Genauigkeit visueller Photometer bei geringen Leuchtdichten". Zeiss, Nachtrichten Vol. 5, pp. 173–182, 1944.


CARL ZEISS JENA
Mess
III 765
1
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3
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L1
AP

P. H. Keck
(19??–19??)
invented
luminometer (1943)

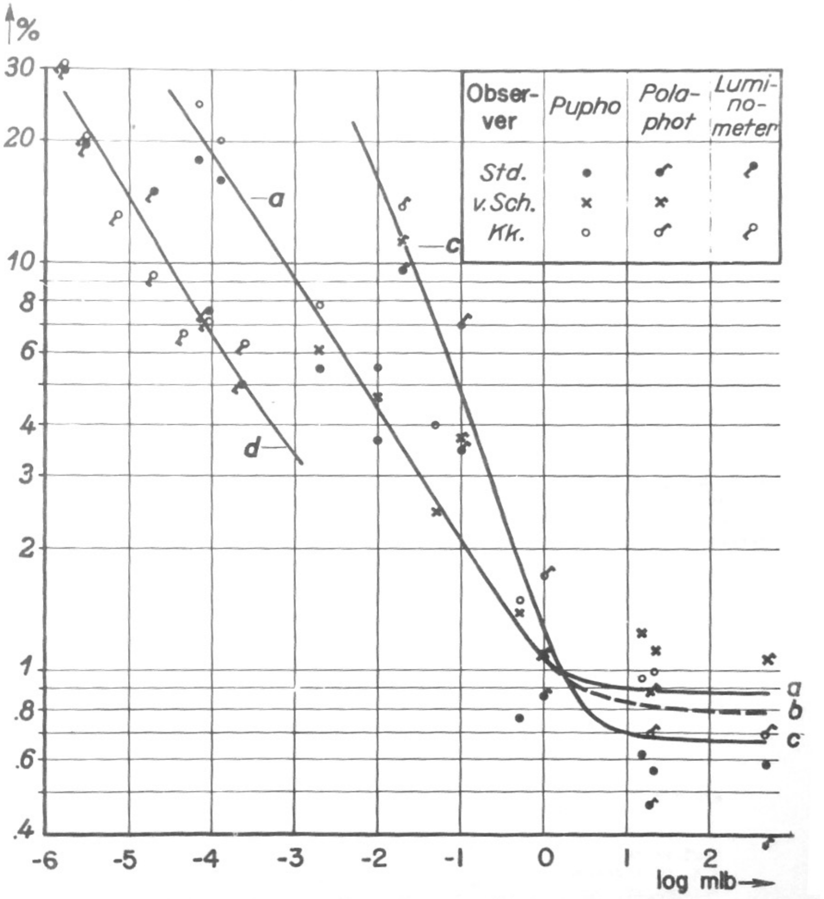


Fig 3 : Average accuracy of a single match versus brightness.
a) Pulfrichphotometer; b) Polaphot; c) Luminometer.

Figure A.105: Luminometer invented by P. H. Keck in 1943 [FIAT 871].

FIAT 910. ***Production of Pharmaceutical and Industrial Enzymes in Southern Germany.***

ABSTRACT

In this report the processing methods are described for the manufacture of a number of enzymes.

Protease. The protein digestive enzyme was produced from special strains of Aspergillus parasiticus for use, in varying proportions, in commercial preparations for the leather industry.

Pectinase was produced from Aspergillus wentii for use in the fruit industries in clearing juices, prevention of jellying, etc.

Pancreatic amylase, called "Degomma", was prepared before the war from beef pancreas and used in the textile trade for destarching.

"Clauden" a styptic substance from beef lung tissue was a popular item for the pharmaceutical trade for the control of hemorrhage.

Sanarthrit a cartilaginous extract was used pharmaceutically as an anti-arthritic injectable substance (non proteinaceous).

"Telatuten" another injectable substance was on the pharmaceutical market for the treatment of arteriosclerosis.

"Luizyme" an enzyme mixture was a mixture of cellulases, amylases, proteases and esterases obtained from Aspergillus uryceae and widely used in the treatment of digestive disorders.

The preparation of these enzymatic substances is recorded in detail. [...]

Evaluation:

Manufacturing processes of enzymes for pharmaceutical and industrial operation have been obtained. Many of these agents are comparatively new, all of them are valuable assets in this particular field of chemistry. The source of some of them is unique and the whole field warrants the attention of the American industry.

ENZYMATIC PRODUCTS OF RÖHM AND HAAS, DARMSTADT

General

Röhm and Haas at Darmstadt originally went into the enzyme field with the assumption of developing a pharmaceutical market. After some initial pharmaceutical enzyme production, it was discovered that the scope of protease application in the industrial field was much greater, and further production gradually turned entirely towards this field.

For the production of protease, special strains of Aspergillus parasiticus were utilized. Wheat bran substances served as a medium. The filtrates of autolyzed cultures contain the active principles which can be precipitated with ammonium sulphate. The precipitates are dried and serve in standardized solutions or powder mixes of varying percentages as the active agents in commercial preparations. Some of these are sold under the trade names of Burnus, Oropon and Arazym.

THE PRODUCTION OF PROTEASE

Fundamentally the production of protease consists of five steps:

Pure culture of Aspergillus parasiticus.

Production of initial spore yield for protease.

Production of technical spore seed for protease.

Volume culture of Aspergillus parasiticus and processing to liquid enzyme concentrates.

Production of dry protease, (enzyme-carrier) mixture and storage. [...]

[This report describes and shows large, advanced, industrial biotechnology installations for producing and purifying a variety of different enzymes. Please see pp. 2450–2452 for some of the illustrations from this report.]

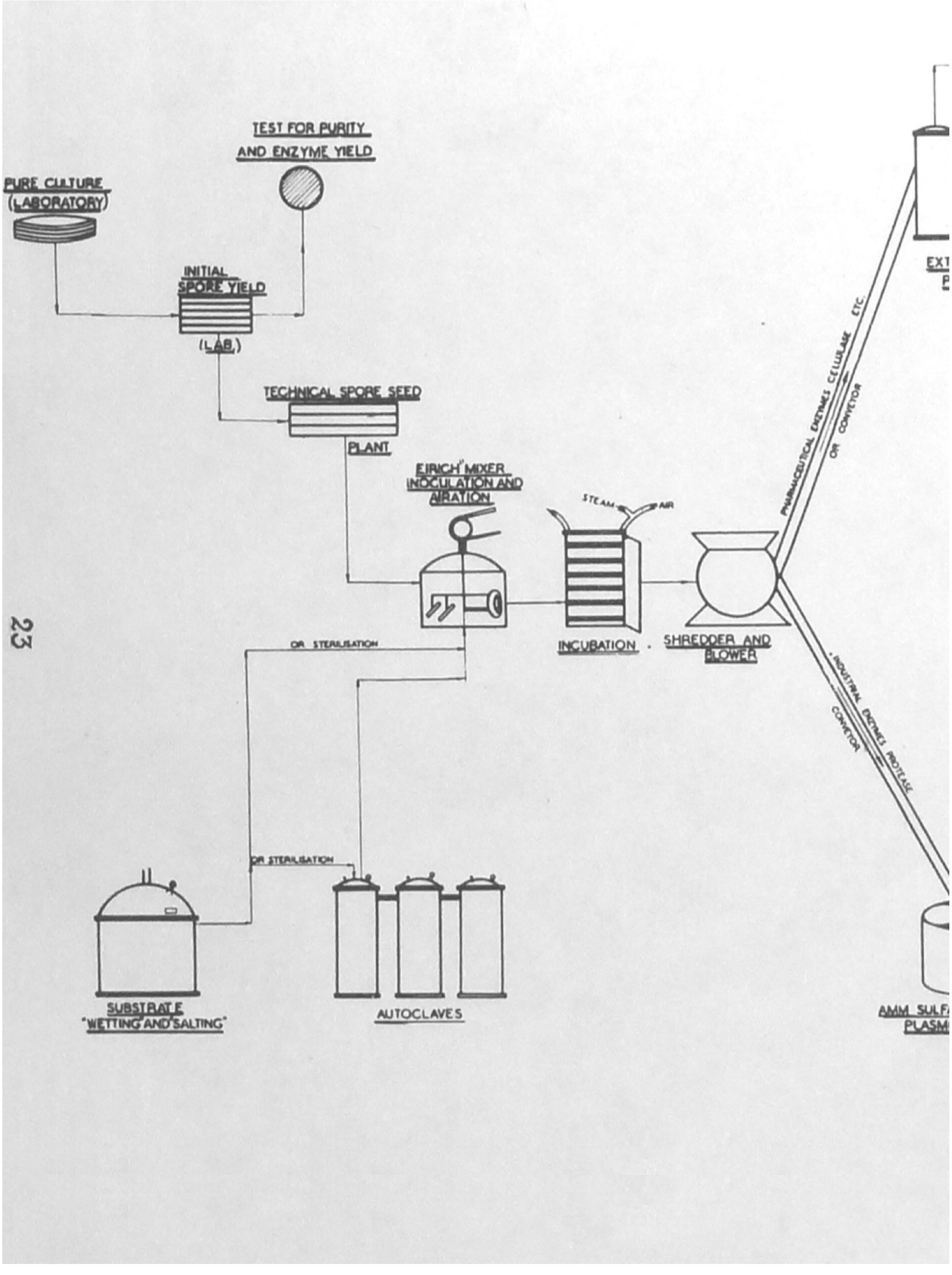

TEST FOR PURITY
AND ENZYME YIELD
PURE CULTURE
(LABORATORY)
INITIAL
SPORE YIELD
(LAB.)
TECHNICAL SPORE SEED
PLANT
EIRICH" MIXER
INOCULATION AND
AIRATION
STEAM
AIR
INCUBATION
SHREDDER AND
BLOWER
PHARMACEUTICAL ENZYMES CELLULASE ETC.
OR CONVEYOR
INDUSTRIAL ENZYMES PROTEASE
CONVEYOR
EXT
P
23
OR STERILISATION
OR STERILISATION
SUBSTRATE
"WETTING AND SALTING"
AUTOCLAVES
AMM. SULF
PLASM

Figure A.106: Production and purification of enzymes from industrial fermentation [FIAT 910].

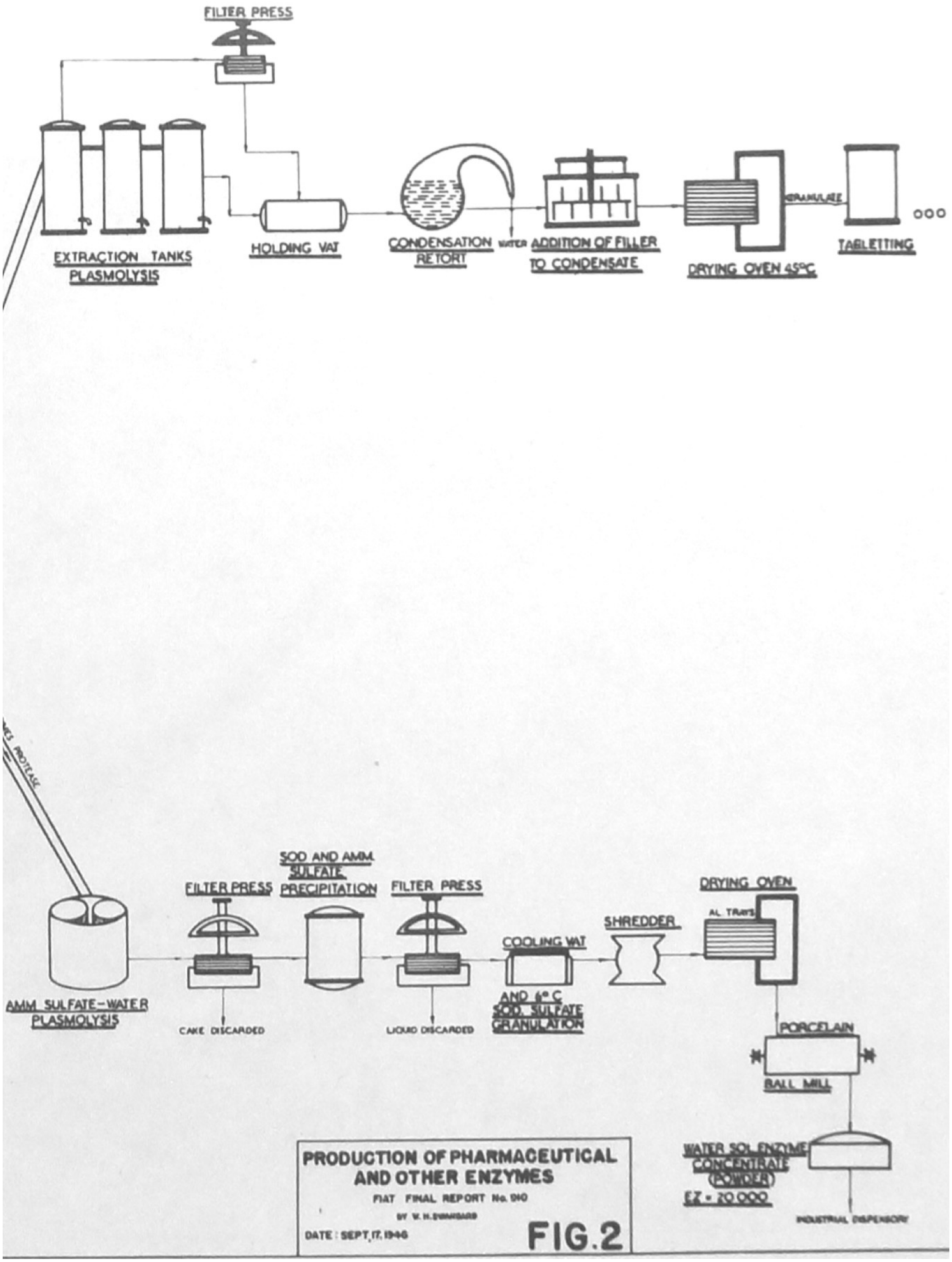
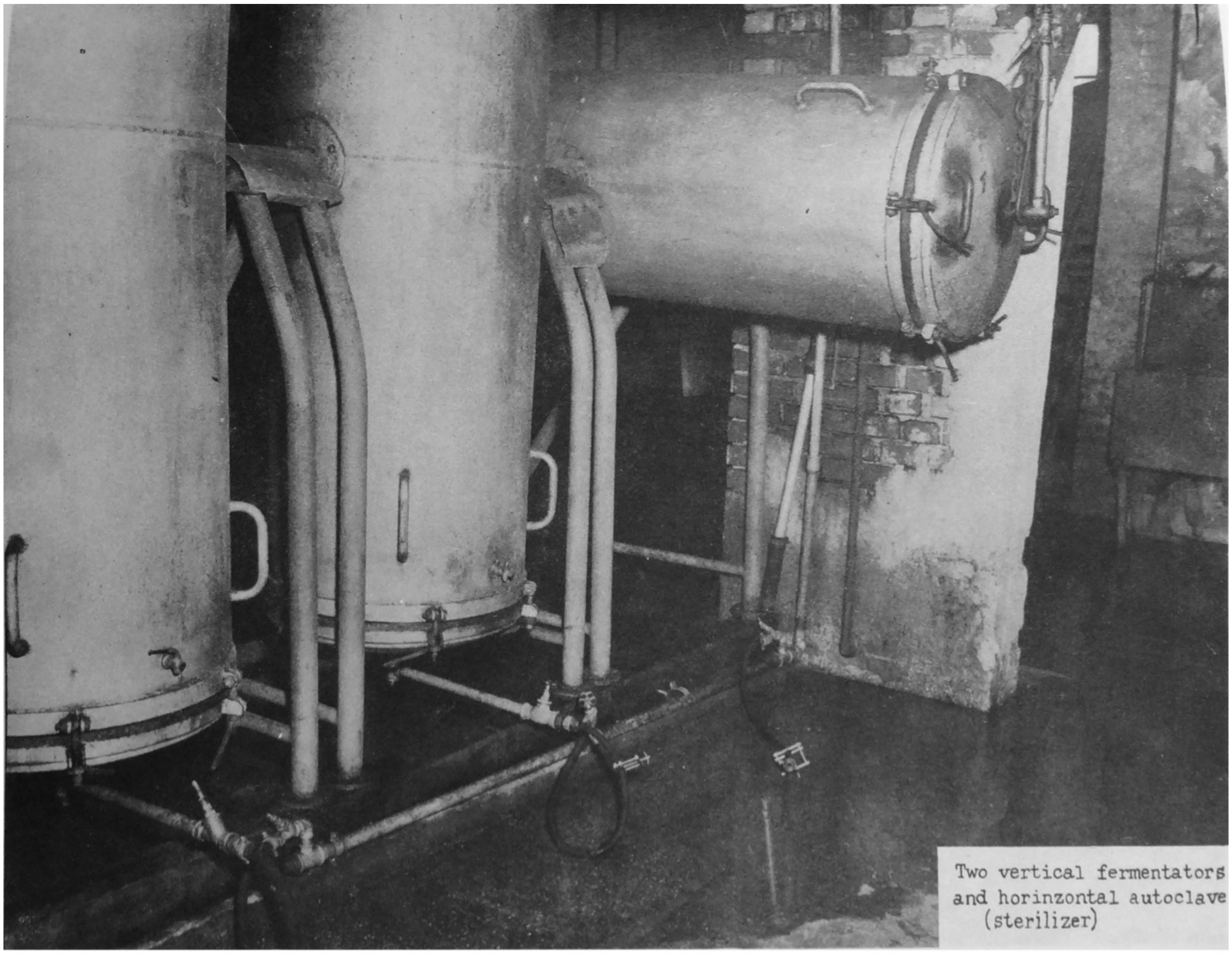

FILTER PRESS
EXTRACTION TANKS
PLASMOLYSIS
HOLDING VAT
CONDENSATION
RETORT
WATER
ADDITION OF FILLER
TO CONDENSATE
DRYING OVEN 45°C
GRANULATE
TABLETTING
PROTEASE
AMM. SULFATE-WATER
PLASMOLYSIS
FILTER PRESS
CAKE DISCARDED
SOD AND AMM.
SULFATE
PRECIPITATION
FILTER PRESS
LIQUID DISCARDED
COOLING VAT
AND 6° C
SOD. SULFATE
GRANULATION
SHREDDER
DRYING OVEN
AL. TRAYS
PORCELAIN
BALL MILL
WATER SOL. ENZYME
CONCENTRATE
(POWDER)
EZ = 20 000
INDUSTRIAL DISPENSORY
PRODUCTION OF PHARMACEUTICAL
AND OTHER ENZYMES
FIAT FINAL REPORT No. 910
BY W. H. SWANGARD
DATE : SEPT. 17. 1946
FIG.2

Figure A.107: Production and purification of enzymes from industrial fermentation [FIAT 910].



Two vertical fermentators
and horinzontal autoclave
(sterilizer)

Figure A.108: Production and purification of enzymes from industrial fermentation [FIAT 910].

FIAT 964. ***Regarding the Resistance to Temperature Variations of Zygotes of Chlamydomonas.***

ABSTRACT

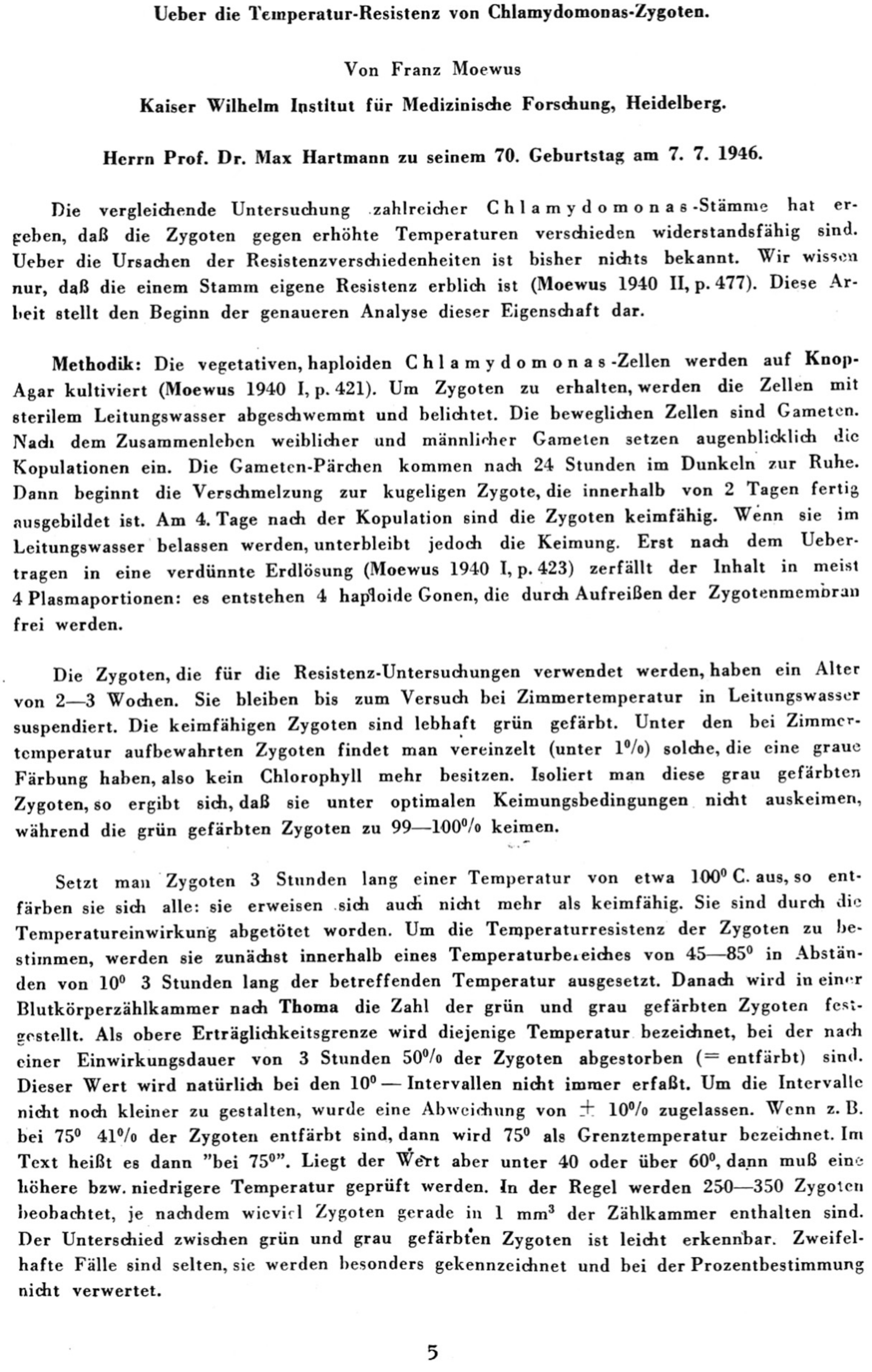
Complete details of the technique used in experimenting with the zygotes are given. Two strains of Chlamydomonas eugametos were tested at temperatures varying from 45–85^{o}C. Resistance paralleled the osmotic properties of the zygotes, the cells with greater osmotic properties being more resistant. Two genes condition the zygote resistance. The gene "zyte" rules the osmotic valves while the gene "zyme" modifies the strength of the osmotic membranes of the zygotes.

BIOGRAPHICAL NOTE

Dr. Franz Moewus, professorial lecturer for botany at Heidelberg University, is a pupil of Dr. Max Hartmann with whom he worked in the Kaiser Wilhelm Institute for Biology in Berlin-Dahlem. For the past 10 years he has been engaged at the Kaiser Wilhelm Institute for Medical Research in Heidelberg on research in the field of fertility agents, sex determining substances, blastocholines, and genetic investigations.

[This report covers culture methods and genetic analysis of *Chlamydomonas* algae to engineer robust microorganisms for biotechnology applications. Since *Chlamydomonas* is photosynthetic, it was probably being studied for applications such as photosynthetic biofuel or food production.

See pp. 2454–2460 for some of the pages from this report.]



Ueber die Temperatur-Resistenz von Chlamydomonas-Zygoten.

Von Franz Moewus

Kaiser Wilhelm Institut für Medizinische Forschung, Heidelberg.

Herrn Prof. Dr. Max Hartmann zu seinem 70. Geburtstag am 7. 7. 1946.

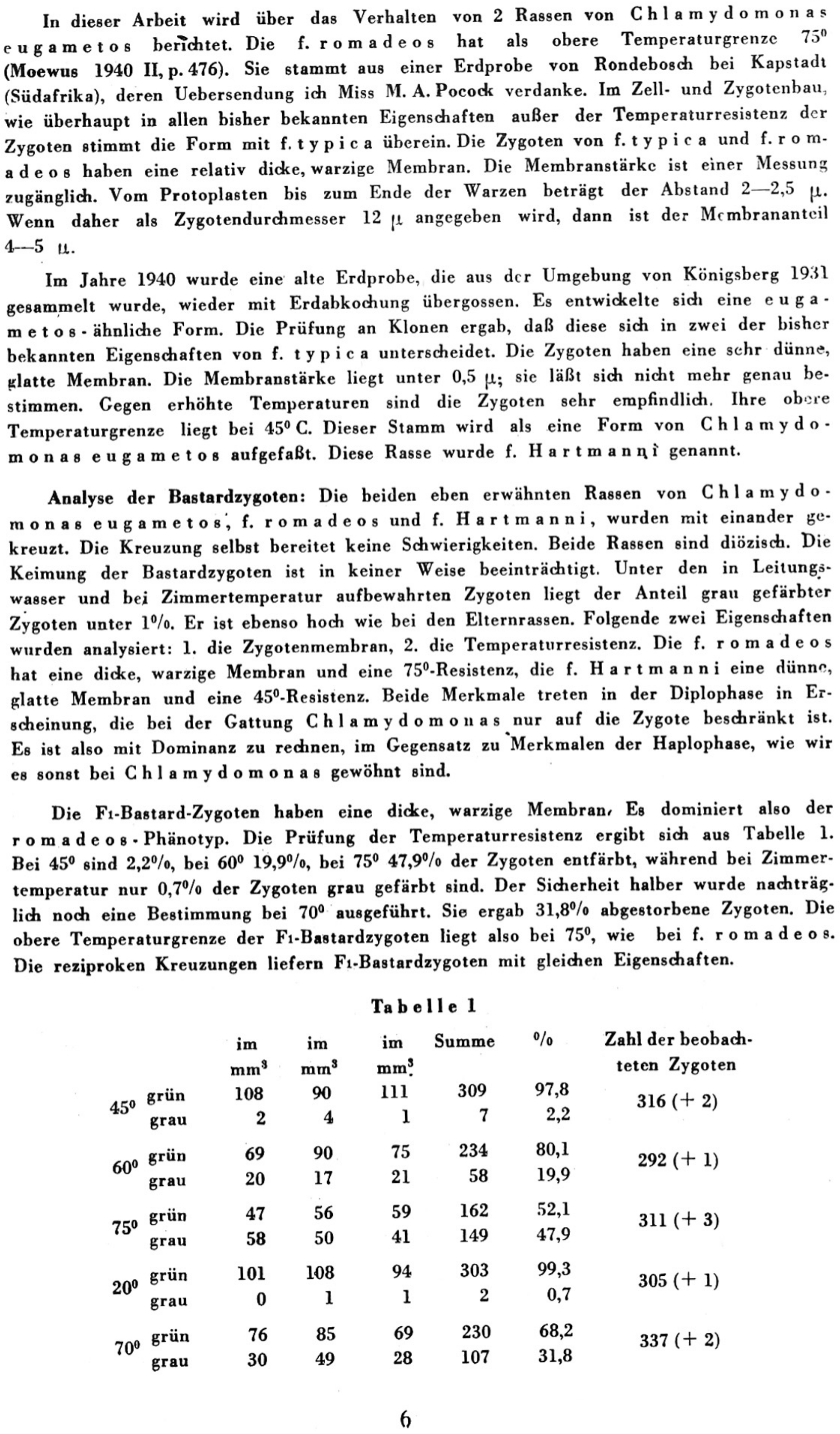
Die vergleichende Untersuchung zahlreicher Chlamydomonas-Stämme hat ergeben, daß die Zygoten gegen erhöhte Temperaturen verschieden widerstandsfähig sind. Ueber die Ursachen der Resistenzverschiedenheiten ist bisher nichts bekannt. Wir wissen nur, daß die einem Stamm eigene Resistenz erblich ist (**Moewus** 1940 II, p. 477). Diese Arbeit stellt den Beginn der genaueren Analyse dieser Eigenschaft dar.

Methodik: Die vegetativen, haploiden Chlamydomonas-Zellen werden auf **Knop**-Agar kultiviert (**Moewus** 1940 I, p. 421). Um Zygoten zu erhalten, werden die Zellen mit sterilem Leitungswasser abgeschwemmt und belichtet. Die beweglichen Zellen sind Gameten. Nach dem Zusammenleben weiblicher und männlicher Gameten setzen augenblicklich die Kopulationen ein. Die Gameten-Pärchen kommen nach 24 Stunden im Dunkeln zur Ruhe. Dann beginnt die Verschmelzung zur kugeligen Zygote, die innerhalb von 2 Tagen fertig ausgebildet ist. Am 4. Tage nach der Kopulation sind die Zygoten keimfähig. Wenn sie im Leitungswasser belassen werden, unterbleibt jedoch die Keimung. Erst nach dem Uebertragen in eine verdünnte Erdlösung (**Moewus** 1940 I, p. 423) zerfällt der Inhalt in meist 4 Plasmaportionen: es entstehen 4 haploide Gonen, die durch Aufreißen der Zygotenmembran frei werden.

Die Zygoten, die für die Resistenz-Untersuchungen verwendet werden, haben ein Alter von 2—3 Wochen. Sie bleiben bis zum Versuch bei Zimmertemperatur in Leitungswasser suspendiert. Die keimfähigen Zygoten sind lebhaft grün gefärbt. Unter den bei Zimmertemperatur aufbewahrten Zygoten findet man vereinzelt (unter 1%) solche, die eine graue Färbung haben, also kein Chlorophyll mehr besitzen. Isoliert man diese grau gefärbten Zygoten, so ergibt sich, daß sie unter optimalen Keimungsbedingungen nicht auskeimen, während die grün gefärbten Zygoten zu 99—100% keimen.

Setzt man Zygoten 3 Stunden lang einer Temperatur von etwa 100° C. aus, so entfärben sie sich alle: sie erweisen sich auch nicht mehr als keimfähig. Sie sind durch die Temperatureinwirkung abgetötet worden. Um die Temperaturresistenz der Zygoten zu bestimmen, werden sie zunächst innerhalb eines Temperaturbereiches von 45—85° in Abständen von 10° 3 Stunden lang der betreffenden Temperatur ausgesetzt. Danach wird in einer Blutkörperzählkammer nach **Thoma** die Zahl der grün und grau gefärbten Zygoten festgestellt. Als obere Erträglichkeitsgrenze wird diejenige Temperatur bezeichnet, bei der nach einer Einwirkungsdauer von 3 Stunden 50% der Zygoten abgestorben (= entfärbt) sind. Dieser Wert wird natürlich bei den 10° — Intervallen nicht immer erfaßt. Um die Intervalle nicht noch kleiner zu gestalten, wurde eine Abweichung von ± 10% zugelassen. Wenn z. B. bei 75° 41% der Zygoten entfärbt sind, dann wird 75° als Grenztemperatur bezeichnet. Im Text heißt es dann "bei 75°". Liegt der Wert aber unter 40 oder über 60%, dann muß eine höhere bzw. niedrigere Temperatur geprüft werden. In der Regel werden 250—350 Zygoten beobachtet, je nachdem wieviel Zygoten gerade in 1 mm³ der Zählkammer enthalten sind. Der Unterschied zwischen grün und grau gefärbten Zygoten ist leicht erkennbar. Zweifelhafte Fälle sind selten, sie werden besonders gekennzeichnet und bei der Prozentbestimmung nicht verwertet.

Figure A.109: Culture methods and genetic analysis of *Chlamydomonas* algae to engineer robust microorganisms for biotechnology applications [FIAT 964].



In dieser Arbeit wird über das Verhalten von 2 Rassen von Chlamydomonas eugametos berichtet. Die f. romadeos hat als obere Temperaturgrenze 75° (Moewus 1940 II, p. 476). Sie stammt aus einer Erdprobe von Rondebosch bei Kapstadt (Südafrika), deren Uebersendung ich Miss M. A. Pocock verdanke. Im Zell- und Zygotenbau, wie überhaupt in allen bisher bekannten Eigenschaften außer der Temperaturresistenz der Zygoten stimmt die Form mit f. typica überein. Die Zygoten von f. typica und f. romadeos haben eine relativ dicke, warzige Membran. Die Membranstärke ist einer Messung zugänglich. Vom Protoplasten bis zum Ende der Warzen beträgt der Abstand 2—2,5 μ. Wenn daher als Zygotendurchmesser 12 μ angegeben wird, dann ist der Membrananteil 4—5 μ.

Im Jahre 1940 wurde eine alte Erdprobe, die aus der Umgebung von Königsberg 1931 gesammelt wurde, wieder mit Erdabkochung übergossen. Es entwickelte sich eine eugametos-ähnliche Form. Die Prüfung an Klonen ergab, daß diese sich in zwei der bisher bekannten Eigenschaften von f. typica unterscheidet. Die Zygoten haben eine sehr dünne, glatte Membran. Die Membranstärke liegt unter 0,5 μ; sie läßt sich nicht mehr genau bestimmen. Gegen erhöhte Temperaturen sind die Zygoten sehr empfindlich. Ihre obere Temperaturgrenze liegt bei 45° C. Dieser Stamm wird als eine Form von Chlamydomonas eugametos aufgefaßt. Diese Rasse wurde f. Hartmanni genannt.

Analyse der Bastardzygoten: Die beiden eben erwähnten Rassen von Chlamydomonas eugametos, f. romadeos und f. Hartmanni, wurden mit einander gekreuzt. Die Kreuzung selbst bereitet keine Schwierigkeiten. Beide Rassen sind diözisch. Die Keimung der Bastardzygoten ist in keiner Weise beeinträchtigt. Unter den in Leitungswasser und bei Zimmertemperatur aufbewahrten Zygoten liegt der Anteil grau gefärbter Zygoten unter 1%. Er ist ebenso hoch wie bei den Elternrassen. Folgende zwei Eigenschaften wurden analysiert: 1. die Zygotenmembran, 2. die Temperaturresistenz. Die f. romadeos hat eine dicke, warzige Membran und eine 75°-Resistenz, die f. Hartmanni eine dünne, glatte Membran und eine 45°-Resistenz. Beide Merkmale treten in der Diplophase in Erscheinung, die bei der Gattung Chlamydomonas nur auf die Zygote beschränkt ist. Es ist also mit Dominanz zu rechnen, im Gegensatz zu Merkmalen der Haplophase, wie wir es sonst bei Chlamydomonas gewöhnt sind.

Die F$_1$-Bastard-Zygoten haben eine dicke, warzige Membran. Es dominiert also der romadeos-Phänotyp. Die Prüfung der Temperaturresistenz ergibt sich aus Tabelle 1. Bei 45° sind 2,2%, bei 60° 19,9%, bei 75° 47,9% der Zygoten entfärbt, während bei Zimmertemperatur nur 0,7% der Zygoten grau gefärbt sind. Der Sicherheit halber wurde nachträglich noch eine Bestimmung bei 70° ausgeführt. Sie ergab 31,8% abgestorbene Zygoten. Die obere Temperaturgrenze der F$_1$-Bastardzygoten liegt also bei 75°, wie bei f. romadeos. Die reziproken Kreuzungen liefern F$_1$-Bastardzygoten mit gleichen Eigenschaften.

Tabelle 1

		im mm^3	im mm^3	im mm^3	Summe	%	Zahl der beobachteten Zygoten
45°	grün	108	90	111	309	97,8	316 (+ 2)
	grau	2	4	1	7	2,2	
60°	grün	69	90	75	234	80,1	292 (+ 1)
	grau	20	17	21	58	19,9	
75°	grün	47	56	59	162	52,1	311 (+ 3)
	grau	58	50	41	149	47,9	
20°	grün	101	108	94	303	99,3	305 (+ 1)
	grau	0	1	1	2	0,7	
70°	grün	76	85	69	230	68,2	337 (+ 2)
	grau	30	49	28	107	31,8	

6

Figure A.110: Culture methods and genetic analysis of *Chlamydomonas* algae to engineer robust microorganisms for biotechnology applications [FIAT 964].

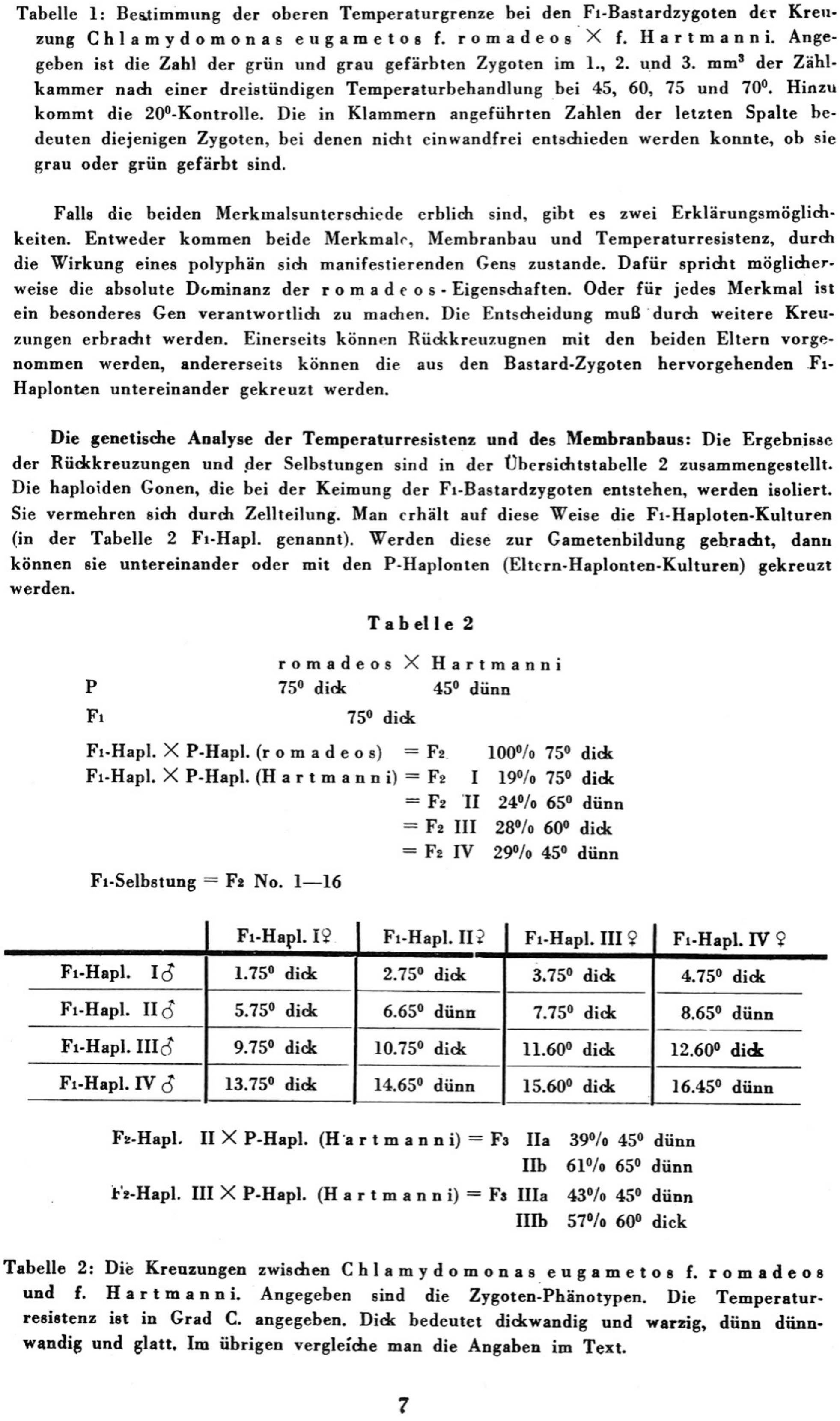


Tabelle 1: Bestimmung der oberen Temperaturgrenze bei den F_1-Bastardzygoten der Kreuzung Chlamydomonas eugametos f. romadeos × f. Hartmanni. Angegeben ist die Zahl der grün und grau gefärbten Zygoten im 1., 2. und 3. mm^3 der Zählkammer nach einer dreistündigen Temperaturbehandlung bei 45, 60, 75 und 70°. Hinzu kommt die 20°-Kontrolle. Die in Klammern angeführten Zahlen der letzten Spalte bedeuten diejenigen Zygoten, bei denen nicht einwandfrei entschieden werden konnte, ob sie grau oder grün gefärbt sind.

Falls die beiden Merkmalsunterschiede erblich sind, gibt es zwei Erklärungsmöglichkeiten. Entweder kommen beide Merkmale, Membranbau und Temperaturresistenz, durch die Wirkung eines polyphän sich manifestierenden Gens zustande. Dafür spricht möglicherweise die absolute Dominanz der romadeos-Eigenschaften. Oder für jedes Merkmal ist ein besonderes Gen verantwortlich zu machen. Die Entscheidung muß durch weitere Kreuzungen erbracht werden. Einerseits können Rückkreuzugnen mit den beiden Eltern vorgenommen werden, andererseits können die aus den Bastard-Zygoten hervorgehenden F_1-Haplonten untereinander gekreuzt werden.

Die genetische Analyse der Temperaturresistenz und des Membranbaus: Die Ergebnisse der Rückkreuzungen und der Selbstungen sind in der Übersichtstabelle 2 zusammengestellt. Die haploiden Gonen, die bei der Keimung der F_1-Bastardzygoten entstehen, werden isoliert. Sie vermehren sich durch Zellteilung. Man erhält auf diese Weise die F_1-Haploten-Kulturen (in der Tabelle 2 F_1-Hapl. genannt). Werden diese zur Gametenbildung gebracht, dann können sie untereinander oder mit den P-Haplonten (Eltern-Haplonten-Kulturen) gekreuzt werden.

Tabelle 2

romadeos × Hartmanni
P 75° dick 45° dünn
F_1 75° dick

F_1-Hapl. × P-Hapl. (romadeos) = F_2 100% 75° dick
F_1-Hapl. × P-Hapl. (Hartmanni) = F_2 I 19% 75° dick
= F_2 II 24% 65° dünn
= F_2 III 28% 60° dick
= F_2 IV 29% 45° dünn

F_1-Selbstung = F_2 No. 1—16

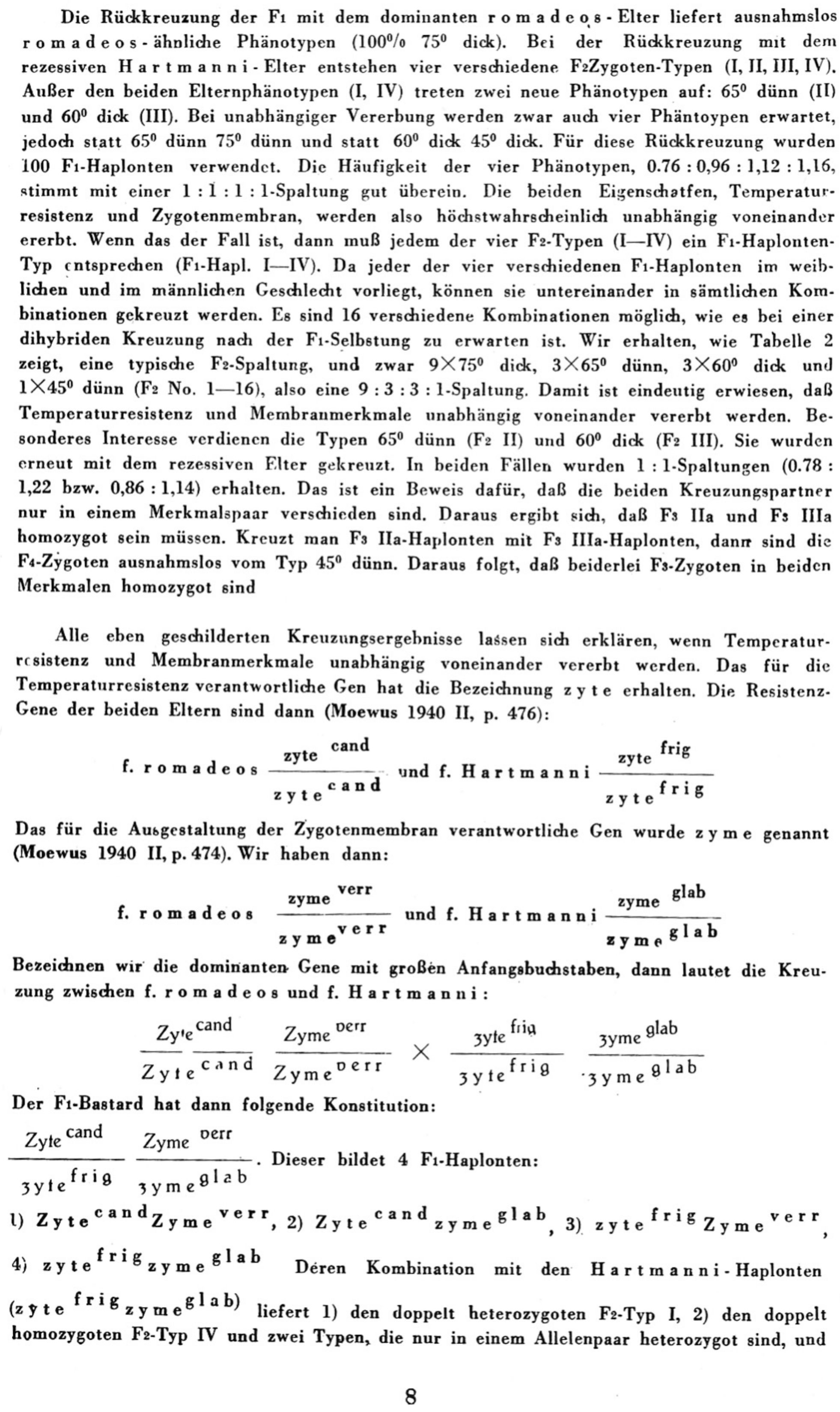
	F_1-Hapl. I♀	F_1-Hapl. II♀	F_1-Hapl. III♀	F_1-Hapl. IV♀
F_1-Hapl. I♂	1.75° dick	2.75° dick	3.75° dick	4.75° dick
F_1-Hapl. II♂	5.75° dick	6.65° dünn	7.75° dick	8.65° dünn
F_1-Hapl. III♂	9.75° dick	10.75° dick	11.60° dick	12.60° dick
F_1-Hapl. IV♂	13.75° dick	14.65° dünn	15.60° dick	16.45° dünn

F_2-Hapl. II × P-Hapl. (Hartmanni) = F_3 IIa 39% 45° dünn
IIb 61% 65° dünn
F_2-Hapl. III × P-Hapl. (Hartmanni) = F_3 IIIa 43% 45° dünn
IIIb 57% 60° dick

Tabelle 2: Die Kreuzungen zwischen Chlamydomonas eugametos f. romadeos und f. Hartmanni. Angegeben sind die Zygoten-Phänotypen. Die Temperaturresistenz ist in Grad C. angegeben. Dick bedeutet dickwandig und warzig, dünn dünnwandig und glatt. Im übrigen vergleiche man die Angaben im Text.

7

Figure A.111: Culture methods and genetic analysis of *Chlamydomonas* algae to engineer robust microorganisms for biotechnology applications [FIAT 964].



Die Rückkreuzung der F_1 mit dem dominanten romadeos-Elter liefert ausnahmslos romadeos-ähnliche Phänotypen (100% 75° dick). Bei der Rückkreuzung mit dem rezessiven Hartmanni-Elter entstehen vier verschiedene F_2Zygoten-Typen (I, II, III, IV). Außer den beiden Elternphänotypen (I, IV) treten zwei neue Phänotypen auf: 65° dünn (II) und 60° dick (III). Bei unabhängiger Vererbung werden zwar auch vier Phäntoypen erwartet, jedoch statt 65° dünn 75° dünn und statt 60° dick 45° dick. Für diese Rückkreuzung wurden 100 F_1-Haplonten verwendet. Die Häufigkeit der vier Phänotypen, 0.76 : 0,96 : 1,12 : 1,16, stimmt mit einer 1 : 1 : 1 : 1-Spaltung gut überein. Die beiden Eigenschatfen, Temperaturresistenz und Zygotenmembran, werden also höchstwahrscheinlich unabhängig voneinander ererbt. Wenn das der Fall ist, dann muß jedem der vier F_2-Typen (I—IV) ein F_1-Haplonten-Typ entsprechen (F_1-Hapl. I—IV). Da jeder der vier verschiedenen F_1-Haplonten im weiblichen und im männlichen Geschlecht vorliegt, können sie untereinander in sämtlichen Kombinationen gekreuzt werden. Es sind 16 verschiedene Kombinationen möglich, wie es bei einer dihybriden Kreuzung nach der F_1-Selbstung zu erwarten ist. Wir erhalten, wie Tabelle 2 zeigt, eine typische F_2-Spaltung, und zwar 9×75° dick, 3×65° dünn, 3×60° dick und 1×45° dünn (F_2 No. 1—16), also eine 9 : 3 : 3 : 1-Spaltung. Damit ist eindeutig erwiesen, daß Temperaturresistenz und Membranmerkmale unabhängig voneinander vererbt werden. Besonderes Interesse verdienen die Typen 65° dünn (F_2 II) und 60° dick (F_2 III). Sie wurden erneut mit dem rezessiven Elter gekreuzt. In beiden Fällen wurden 1 : 1-Spaltungen (0.78 : 1,22 bzw. 0,86 : 1,14) erhalten. Das ist ein Beweis dafür, daß die beiden Kreuzungspartner nur in einem Merkmalspaar verschieden sind. Daraus ergibt sich, daß F_3 IIa und F_3 IIIa homozygot sein müssen. Kreuzt man F_3 IIa-Haplonten mit F_3 IIIa-Haplonten, dann sind die F_4-Zygoten ausnahmslos vom Typ 45° dünn. Daraus folgt, daß beiderlei F_3-Zygoten in beiden Merkmalen homozygot sind

Alle eben geschilderten Kreuzungsergebnisse lassen sich erklären, wenn Temperaturresistenz und Membranmerkmale unabhängig voneinander vererbt werden. Das für die Temperaturresistenz verantwortliche Gen hat die Bezeichnung zyte erhalten. Die Resistenz-Gene der beiden Eltern sind dann (Moewus 1940 II, p. 476):

$$\text{f. romadeos}\ \frac{\text{zyte}^{\text{cand}}}{\text{zyte}^{\text{cand}}}\ \text{und f. Hartmanni}\ \frac{\text{zyte}^{\text{frig}}}{\text{zyte}^{\text{frig}}}$$

Das für die Ausgestaltung der Zygotenmembran verantwortliche Gen wurde zyme genannt (Moewus 1940 II, p. 474). Wir haben dann:

$$\text{f. romadeos}\ \frac{\text{zyme}^{\text{verr}}}{\text{zyme}^{\text{verr}}}\ \text{und f. Hartmanni}\ \frac{\text{zyme}^{\text{glab}}}{\text{zyme}^{\text{glab}}}$$

Bezeichnen wir die dominanten Gene mit großen Anfangsbuchstaben, dann lautet die Kreuzung zwischen f. romadeos und f. Hartmanni:

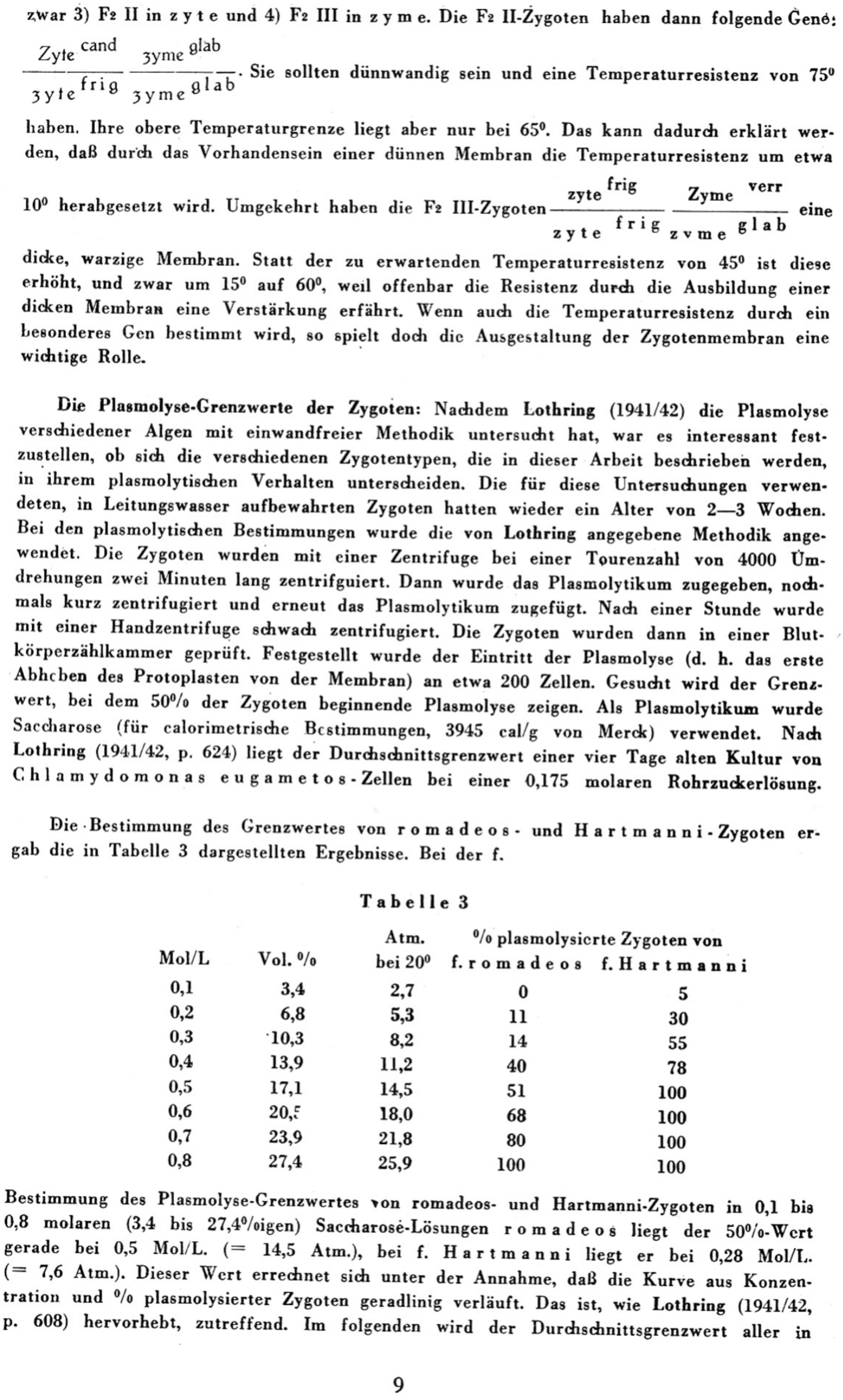
$$\frac{\text{Zyte}^{\text{cand}}}{\text{Zyte}^{\text{cand}}}\ \frac{\text{Zyme}^{\text{verr}}}{\text{Zyme}^{\text{verr}}} \times \frac{\text{zyte}^{\text{frig}}}{\text{zyte}^{\text{frig}}}\ \frac{\text{zyme}^{\text{glab}}}{\text{zyme}^{\text{glab}}}$$

Der F_1-Bastard hat dann folgende Konstitution:

$\dfrac{\text{Zyte}^{\text{cand}}}{\text{zyte}^{\text{frig}}}\ \dfrac{\text{Zyme}^{\text{verr}}}{\text{zyme}^{\text{glab}}}$. Dieser bildet 4 F_1-Haplonten:

1) $\text{Zyte}^{\text{cand}}\text{Zyme}^{\text{verr}}$, 2) $\text{Zyte}^{\text{cand}}\text{zyme}^{\text{glab}}$, 3) $\text{zyte}^{\text{frig}}\text{Zyme}^{\text{verr}}$, 4) $\text{zyte}^{\text{frig}}\text{zyme}^{\text{glab}}$ Deren Kombination mit den Hartmanni-Haplonten ($\text{zyte}^{\text{frig}}\text{zyme}^{\text{glab}}$) liefert 1) den doppelt heterozygoten F_2-Typ I, 2) den doppelt homozygoten F_2-Typ IV und zwei Typen, die nur in einem Allelenpaar heterozygot sind, und

Figure A.112: Culture methods and genetic analysis of *Chlamydomonas* algae to engineer robust microorganisms for biotechnology applications [FIAT 964].



zwar 3) F_2 II in zyte und 4) F_2 III in zyme. Die F_2 II-Zygoten haben dann folgende Gene: $\frac{\text{Zyte}^{\text{cand}}}{\text{ʒyte}^{\text{frig}}}\ \frac{\text{ʒyme}^{\text{glab}}}{\text{ʒyme}^{\text{glab}}}$. Sie sollten dünnwandig sein und eine Temperaturresistenz von 75° haben. Ihre obere Temperaturgrenze liegt aber nur bei 65°. Das kann dadurch erklärt werden, daß durch das Vorhandensein einer dünnen Membran die Temperaturresistenz um etwa 10° herabgesetzt wird. Umgekehrt haben die F_2 III-Zygoten $\frac{\text{zyte}^{\text{frig}}}{\text{zyte}^{\text{frig}}}\ \frac{\text{Zyme}^{\text{verr}}}{\text{zyme}^{\text{glab}}}$ eine dicke, warzige Membran. Statt der zu erwartenden Temperaturresistenz von 45° ist diese erhöht, und zwar um 15° auf 60°, weil offenbar die Resistenz durch die Ausbildung einer dicken Membran eine Verstärkung erfährt. Wenn auch die Temperaturresistenz durch ein besonderes Gen bestimmt wird, so spielt doch die Ausgestaltung der Zygotenmembran eine wichtige Rolle.

Die Plasmolyse-Grenzwerte der Zygoten: Nachdem **Lothring** (1941/42) die Plasmolyse verschiedener Algen mit einwandfreier Methodik untersucht hat, war es interessant festzustellen, ob sich die verschiedenen Zygotentypen, die in dieser Arbeit beschrieben werden, in ihrem plasmolytischen Verhalten unterscheiden. Die für diese Untersuchungen verwendeten, in Leitungswasser aufbewahrten Zygoten hatten wieder ein Alter von 2—3 Wochen. Bei den plasmolytischen Bestimmungen wurde die von **Lothring** angegebene Methodik angewendet. Die Zygoten wurden mit einer Zentrifuge bei einer Tourenzahl von 4000 Umdrehungen zwei Minuten lang zentrifguiert. Dann wurde das Plasmolytikum zugegeben, nochmals kurz zentrifugiert und erneut das Plasmolytikum zugefügt. Nach einer Stunde wurde mit einer Handzentrifuge schwach zentrifugiert. Die Zygoten wurden dann in einer Blutkörperzählkammer geprüft. Festgestellt wurde der Eintritt der Plasmolyse (d. h. das erste Abheben des Protoplasten von der Membran) an etwa 200 Zellen. Gesucht wird der Grenzwert, bei dem 50% der Zygoten beginnende Plasmolyse zeigen. Als Plasmolytikum wurde Saccharose (für calorimetrische Bestimmungen, 3945 cal/g von Merck) verwendet. Nach **Lothring** (1941/42, p. 624) liegt der Durchschnittsgrenzwert einer vier Tage alten Kultur von Chlamydomonas eugametos-Zellen bei einer 0,175 molaren Rohrzuckerlösung.

Die Bestimmung des Grenzwertes von romadeos- und Hartmanni-Zygoten ergab die in Tabelle 3 dargestellten Ergebnisse. Bei der f.

Tabelle 3

Mol/L	Vol. %	Atm. bei 20°	% plasmolysierte Zygoten von f. romadeos	f. Hartmanni
0,1	3,4	2,7	0	5
0,2	6,8	5,3	11	30
0,3	10,3	8,2	14	55
0,4	13,9	11,2	40	78
0,5	17,1	14,5	51	100
0,6	20,5	18,0	68	100
0,7	23,9	21,8	80	100
0,8	27,4	25,9	100	100

Bestimmung des Plasmolyse-Grenzwertes von romadeos- und Hartmanni-Zygoten in 0,1 bis 0,8 molaren (3,4 bis 27,4%igen) Saccharose-Lösungen romadeos liegt der 50%-Wert gerade bei 0,5 Mol/L. (= 14,5 Atm.), bei f. Hartmanni liegt er bei 0,28 Mol/L. (= 7,6 Atm.). Dieser Wert errechnet sich unter der Annahme, daß die Kurve aus Konzentration und % plasmolysierter Zygoten geradlinig verläuft. Das ist, wie **Lothring** (1941/42, p. 608) hervorhebt, zutreffend. Im folgenden wird der Durchschnittsgrenzwert aller in

Figure A.113: Culture methods and genetic analysis of *Chlamydomonas* algae to engineer robust microorganisms for biotechnology applications [FIAT 964].

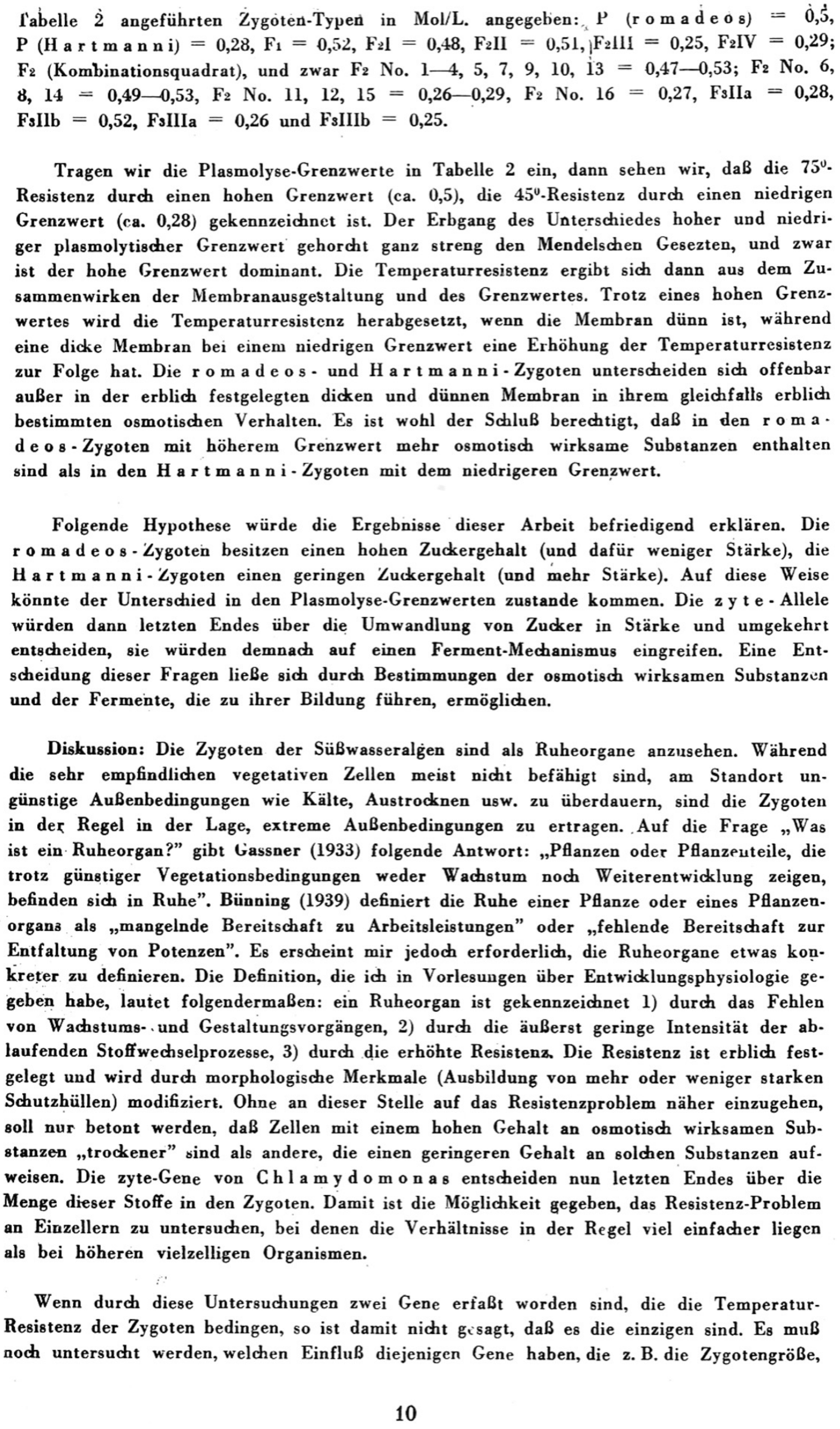


Tabelle 2 angeführten Zygoten-Typen in Mol/L. angegeben: P (romadeos) = 0,5, P (Hartmanni) = 0,28, F_1 = 0,52, F_2I = 0,48, F_2II = 0,51, F_2III = 0,25, F_2IV = 0,29; F_2 (Kombinationsquadrat), und zwar F_2 No. 1—4, 5, 7, 9, 10, 13 = 0,47—0,53; F_2 No. 6, 8, 14 = 0,49—0,53, F_2 No. 11, 12, 15 = 0,26—0,29, F_2 No. 16 = 0,27, F_3IIa = 0,28, F_3IIb = 0,52, F_3IIIa = 0,26 und F_3IIIb = 0,25.

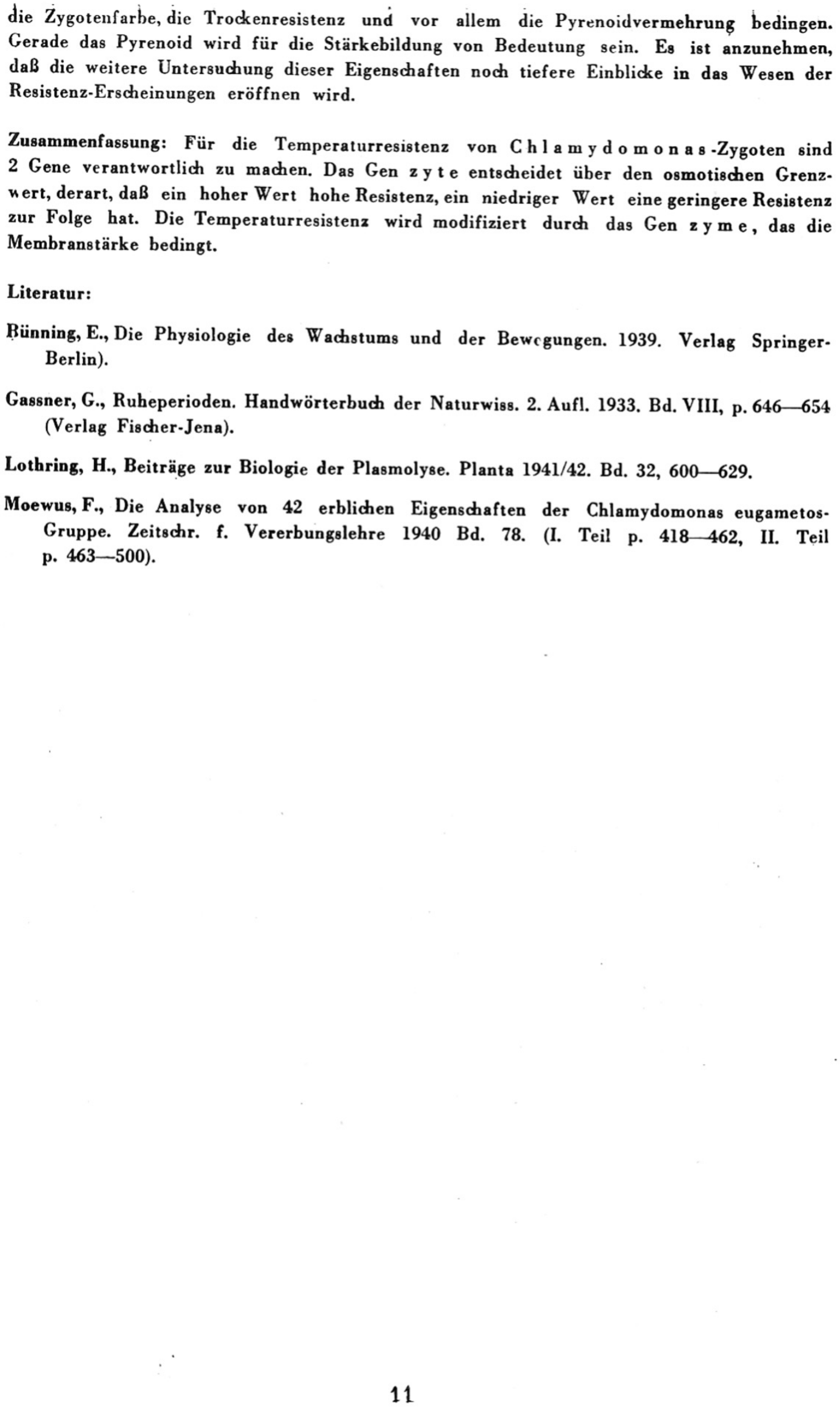
Tragen wir die Plasmolyse-Grenzwerte in Tabelle 2 ein, dann sehen wir, daß die 75°-Resistenz durch einen hohen Grenzwert (ca. 0,5), die 45°-Resistenz durch einen niedrigen Grenzwert (ca. 0,28) gekennzeichnet ist. Der Erbgang des Unterschiedes hoher und niedriger plasmolytischer Grenzwert gehorcht ganz streng den Mendelschen Gesezten, und zwar ist der hohe Grenzwert dominant. Die Temperaturresistenz ergibt sich dann aus dem Zusammenwirken der Membranausgestaltung und des Grenzwertes. Trotz eines hohen Grenzwertes wird die Temperaturresistenz herabgesetzt, wenn die Membran dünn ist, während eine dicke Membran bei einem niedrigen Grenzwert eine Erhöhung der Temperaturresistenz zur Folge hat. Die romadeos- und Hartmanni-Zygoten unterscheiden sich offenbar außer in der erblich festgelegten dicken und dünnen Membran in ihrem gleichfalls erblich bestimmten osmotischen Verhalten. Es ist wohl der Schluß berechtigt, daß in den romadeos-Zygoten mit höherem Grenzwert mehr osmotisch wirksame Substanzen enthalten sind als in den Hartmanni-Zygoten mit dem niedrigeren Grenzwert.

Folgende Hypothese würde die Ergebnisse dieser Arbeit befriedigend erklären. Die romadeos-Zygoten besitzen einen hohen Zuckergehalt (und dafür weniger Stärke), die Hartmanni-Zygoten einen geringen Zuckergehalt (und mehr Stärke). Auf diese Weise könnte der Unterschied in den Plasmolyse-Grenzwerten zustande kommen. Die zyte-Allele würden dann letzten Endes über die Umwandlung von Zucker in Stärke und umgekehrt entscheiden, sie würden demnach auf einen Ferment-Mechanismus eingreifen. Eine Entscheidung dieser Fragen ließe sich durch Bestimmungen der osmotisch wirksamen Substanzen und der Fermente, die zu ihrer Bildung führen, ermöglichen.

Diskussion: Die Zygoten der Süßwasseralgen sind als Ruheorgane anzusehen. Während die sehr empfindlichen vegetativen Zellen meist nicht befähigt sind, am Standort ungünstige Außenbedingungen wie Kälte, Austrocknen usw. zu überdauern, sind die Zygoten in der Regel in der Lage, extreme Außenbedingungen zu ertragen. Auf die Frage „Was ist ein Ruheorgan?" gibt Gassner (1933) folgende Antwort: „Pflanzen oder Pflanzenteile, die trotz günstiger Vegetationsbedingungen weder Wachstum noch Weiterentwicklung zeigen, befinden sich in Ruhe". Bünning (1939) definiert die Ruhe einer Pflanze oder eines Pflanzenorgans als „mangelnde Bereitschaft zu Arbeitsleistungen" oder „fehlende Bereitschaft zur Entfaltung von Potenzen". Es erscheint mir jedoch erforderlich, die Ruheorgane etwas konkreter zu definieren. Die Definition, die ich in Vorlesungen über Entwicklungsphysiologie gegeben habe, lautet folgendermaßen: ein Ruheorgan ist gekennzeichnet 1) durch das Fehlen von Wachstums- und Gestaltungsvorgängen, 2) durch die äußerst geringe Intensität der ablaufenden Stoffwechselprozesse, 3) durch die erhöhte Resistenz. Die Resistenz ist erblich festgelegt und wird durch morphologische Merkmale (Ausbildung von mehr oder weniger starken Schutzhüllen) modifiziert. Ohne an dieser Stelle auf das Resistenzproblem näher einzugehen, soll nur betont werden, daß Zellen mit einem hohen Gehalt an osmotisch wirksamen Substanzen „trockener" sind als andere, die einen geringeren Gehalt an solchen Substanzen aufweisen. Die zyte-Gene von Chlamydomonas entscheiden nun letzten Endes über die Menge dieser Stoffe in den Zygoten. Damit ist die Möglichkeit gegeben, das Resistenz-Problem an Einzellern zu untersuchen, bei denen die Verhältnisse in der Regel viel einfacher liegen als bei höheren vielzelligen Organismen.

Wenn durch diese Untersuchungen zwei Gene erfaßt worden sind, die die Temperatur-Resistenz der Zygoten bedingen, so ist damit nicht gesagt, daß es die einzigen sind. Es muß noch untersucht werden, welchen Einfluß diejenigen Gene haben, die z. B. die Zygotengröße,

Figure A.114: Culture methods and genetic analysis of *Chlamydomonas* algae to engineer robust microorganisms for biotechnology applications [FIAT 964].



die Zygotenfarbe, die Trockenresistenz und vor allem die Pyrenoidvermehrung bedingen. Gerade das Pyrenoid wird für die Stärkebildung von Bedeutung sein. Es ist anzunehmen, daß die weitere Untersuchung dieser Eigenschaften noch tiefere Einblicke in das Wesen der Resistenz-Erscheinungen eröffnen wird.

Zusammenfassung: Für die Temperaturresistenz von Chlamydomonas-Zygoten sind 2 Gene verantwortlich zu machen. Das Gen zyte entscheidet über den osmotischen Grenzwert, derart, daß ein hoher Wert hohe Resistenz, ein niedriger Wert eine geringere Resistenz zur Folge hat. Die Temperaturresistenz wird modifiziert durch das Gen zyme, das die Membranstärke bedingt.

Literatur:

Bünning, E., Die Physiologie des Wachstums und der Bewegungen. 1939. Verlag Springer-Berlin).

Gassner, G., Ruheperioden. Handwörterbuch der Naturwiss. 2. Aufl. 1933. Bd. VIII, p. 646—654 (Verlag Fischer-Jena).

Lothring, H., Beiträge zur Biologie der Plasmolyse. Planta 1941/42. Bd. 32, 600—629.

Moewus, F., Die Analyse von 42 erblichen Eigenschaften der Chlamydomonas eugametos-Gruppe. Zeitschr. f. Vererbungslehre 1940 Bd. 78. (I. Teil p. 418—462, II. Teil p. 463—500).

Figure A.115: Culture methods and genetic analysis of *Chlamydomonas* algae to engineer robust microorganisms for biotechnology applications [FIAT 964].

FIAT 996. ***The Commercial Development and Manufacture of Synthetic Hormones in Germany.***

The technical development of the synthesis of the estrogenic, androgenic, and adrenal cortical hormones and of the manufacturing processes employed in Germany for their commercial production from cholesterol and stigmasterol are reviewed. Procedures for the preparation of testosterone and progesterone from dehydroandrosterone, for the conversion of hydroxyetiocholenic acid to desoxycorticosterone, for the transformation of acetoxybisnorcholenic acid to progesterone and desoxycorticosterone, and for the reduction of estrone to estriol are described and charted. Full manufacturing details of the Schering A.G. processes for the synthesis of hormones from cholesterol and of the Schering and I.G. Farbenindustrie processes for the synthesis of progesterone from phytosterol are discussed. The original German processes are collected in an appendix. A further appendix gives a transcript of a patent application for the preparation of estradiol and other related compounds of the cyclopentanopolyhydrophenanthrene series.

[This very long report describes many of the details of the commercial synthesis of a variety of steroid hormones. Please see pp. 2462–2470 for some of the pages from this report.

CIOS XXV-54, *Pharmaceuticals at I.G. Farbenindustrie Plant Elberfeld*, also covers some related work.]

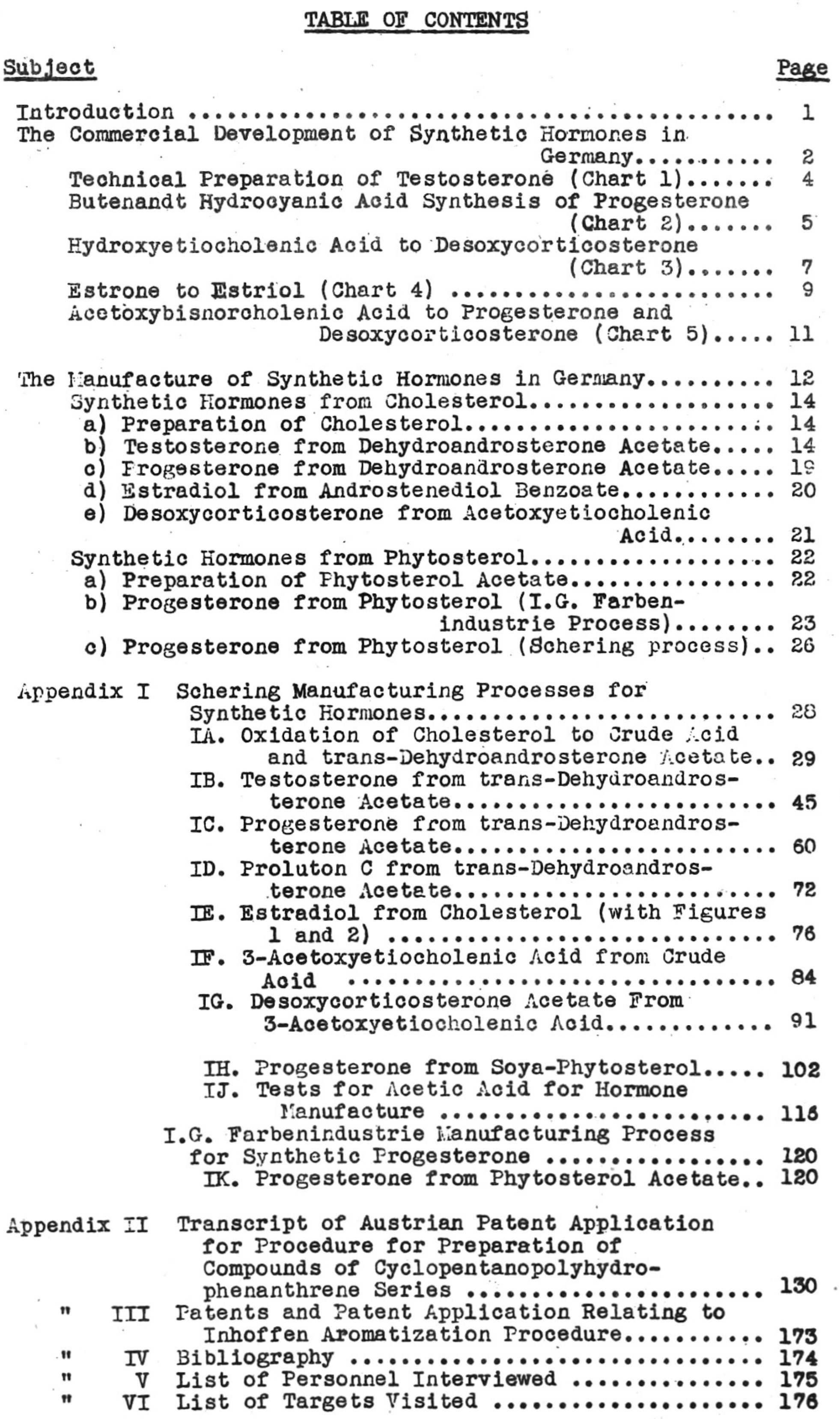


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Figure A.116: Commercial synthesis of a variety of steroid hormones [FIAT 996].

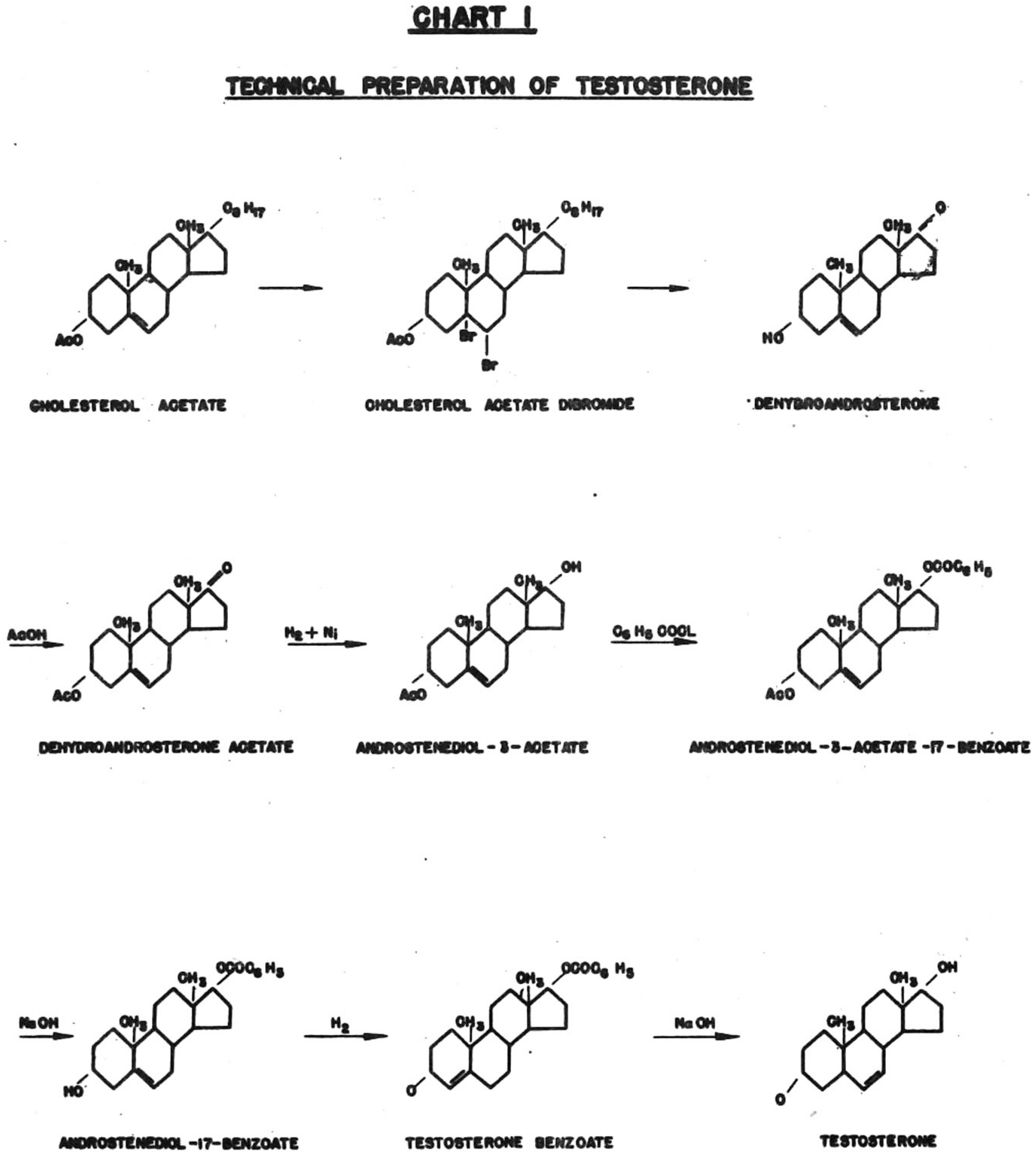


CHART I
TECHNICAL PREPARATION OF TESTOSTERONE
C8H17
CH3
CH3
AcO
CHOLESTEROL ACETATE
C8H17
CH3
CH3
AcO
Br
Br
CHOLESTEROL ACETATE DIBROMIDE
O
CH3
CH3
HO
DEHYDROANDROSTERONE
AcOH
O
CH3
CH3
AcO
DEHYDROANDROSTERONE ACETATE
H2 + Ni
OH
CH3
CH3
AcO
ANDROSTENEDIOL - 3 - ACETATE
C6 H5 COCL
OCOC6 H5
CH3
CH3
AcO
ANDROSTENEDIOL - 3 - ACETATE - 17 - BENZOATE
NaOH
OCOC6 H5
CH3
CH3
HO
ANDROSTENEDIOL - 17 - BENZOATE
H2
OCOC6 H5
CH3
CH3
O
TESTOSTERONE BENZOATE
NaOH
OH
CH3
CH3
O
TESTOSTERONE

Figure A.117: Commercial synthesis of a variety of steroid hormones [FIAT 996].

CHART 2

BUTENANDT HCN SYNTHESIS OF PROGESTERONE

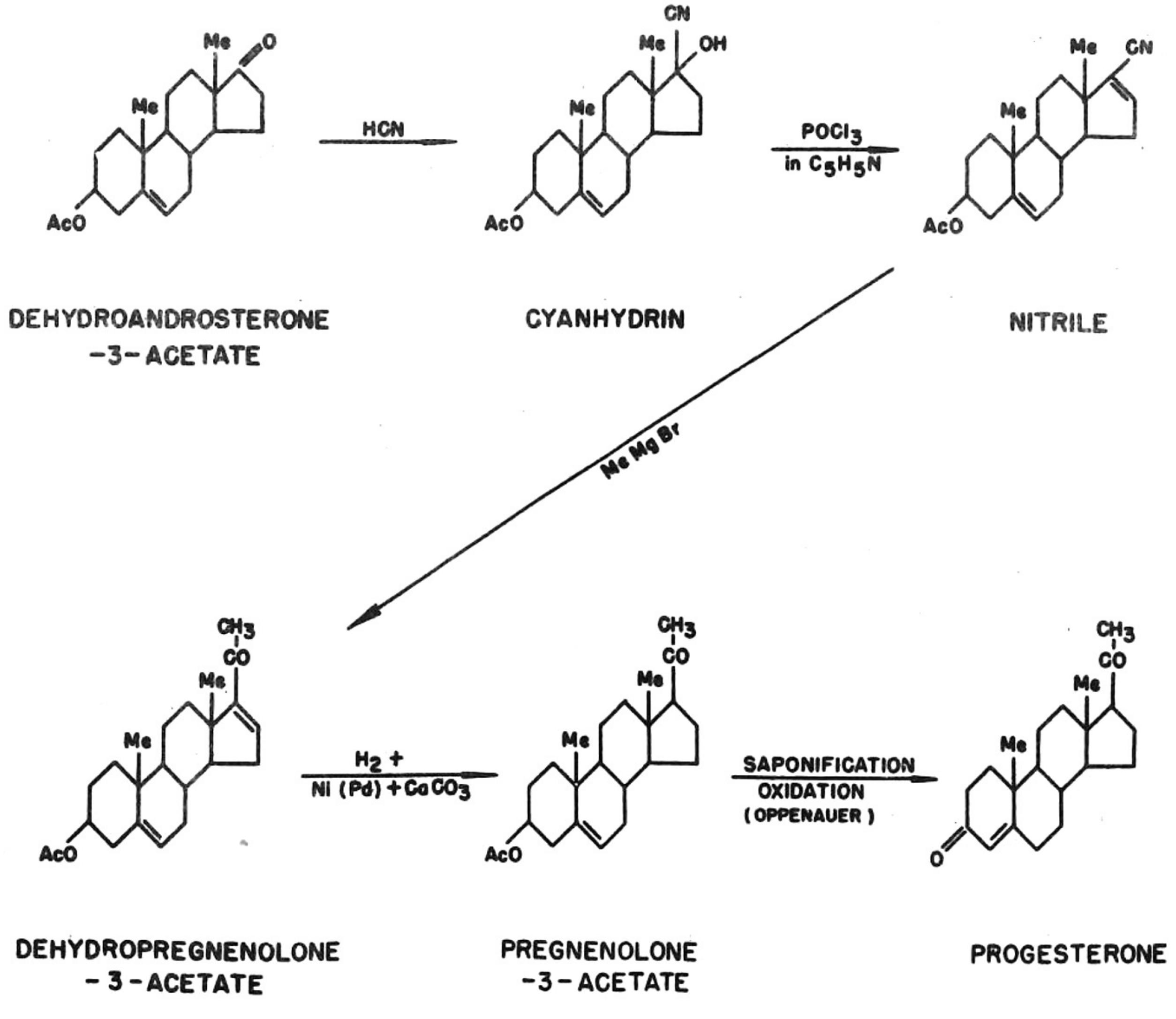

Me
O
Me
AcO
HCN
CN
Me
OH
Me
AcO
$POCl_3$
in C_5H_5N
Me
CN
Me
AcO
DEHYDROANDROSTERONE -3-ACETATE
CYANHYDRIN
NITRILE
Me Mg Br
CH_3
CO
Me
Me
AcO
H_2 +
Ni (Pd) + $CaCO_3$
CH_3
CO
Me
Me
AcO
SAPONIFICATION
OXIDATION
(OPPENAUER)
CH_3
CO
Me
Me
O
DEHYDROPREGNENOLONE - 3 - ACETATE
PREGNENOLONE -3 - ACETATE
PROGESTERONE

Figure A.118: Commercial synthesis of a variety of steroid hormones [FIAT 996].

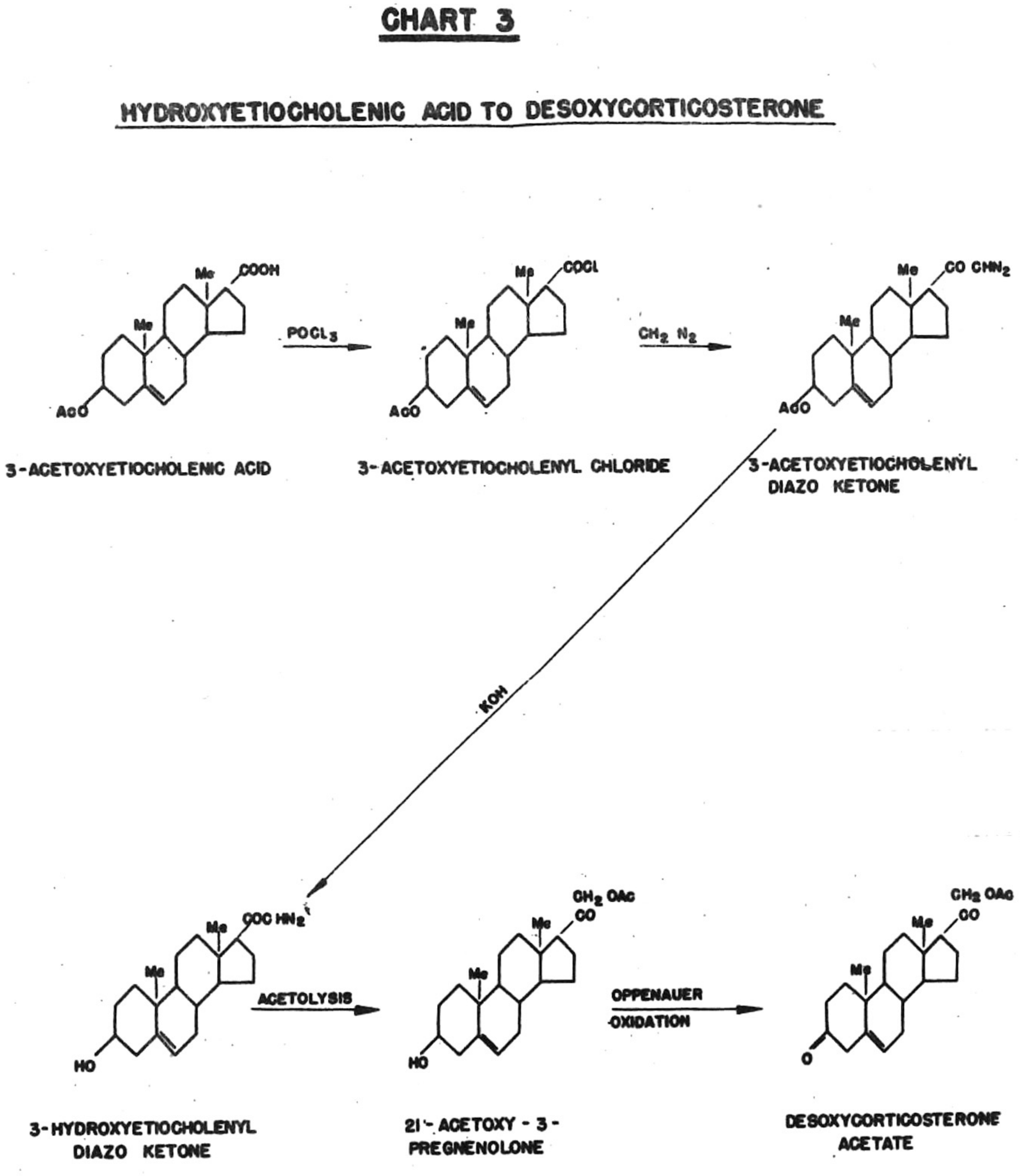


CHART 3
HYDROXYETIOCHOLENIC ACID TO DESOXYCORTICOSTERONE
Me
COOH
AcO
POCl3
COCl
CH2 N2
CO CHN2
3-ACETOXYETIOCHOLENIC ACID
3-ACETOXYETIOCHOLENYL CHLORIDE
3-ACETOXYETIOCHOLENYL DIAZO KETONE
KOH
COC HN2
HO
ACETOLYSIS
CH2 OAc
CO
OPPENAUER OXIDATION
O
3-HYDROXYETIOCHOLENYL DIAZO KETONE
21-ACETOXY-3-PREGNENOLONE
DESOXYCORTICOSTERONE ACETATE

Figure A.119: Commercial synthesis of a variety of steroid hormones [FIAT 996].

CHART 4

ESTRONE TO ESTRIOL

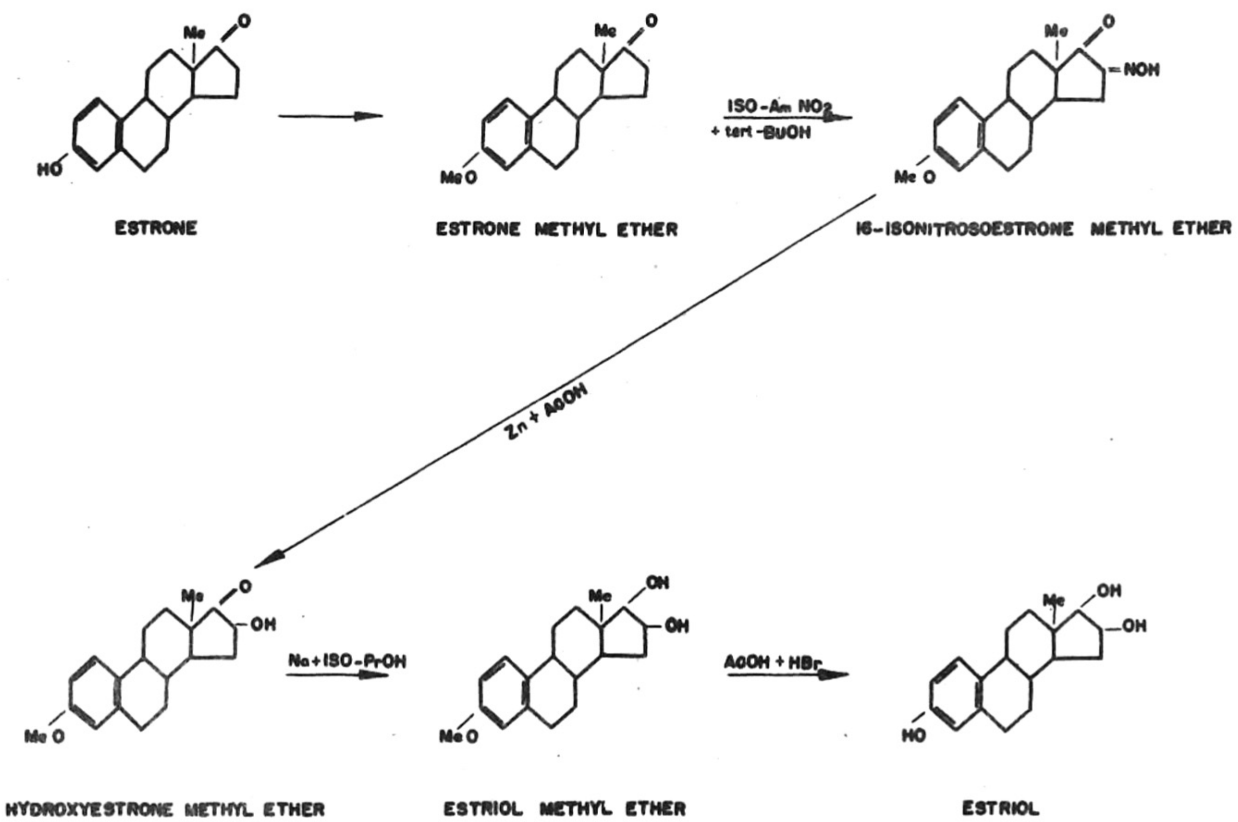

Me
O
HO
ESTRONE
Me
O
MeO
ESTRONE METHYL ETHER
ISO-Am NO2
+ tert-BuOH
Me
O
=NOH
Me O
16-ISONITROSOESTRONE METHYL ETHER
Zn + AcOH
Me
O
OH
Me O
HYDROXYESTRONE METHYL ETHER
Na+ISO-PrOH
Me
OH
OH
MeO
ESTRIOL METHYL ETHER
AcOH + HBr
Me
OH
OH
HO
ESTRIOL

Figure A.120: Commercial synthesis of a variety of steroid hormones [FIAT 996].

CHART 5

ACETOXYBISNORCHOLENIC ACID TO PROGESTERONE AND DESOXYCORTICOSTERONE

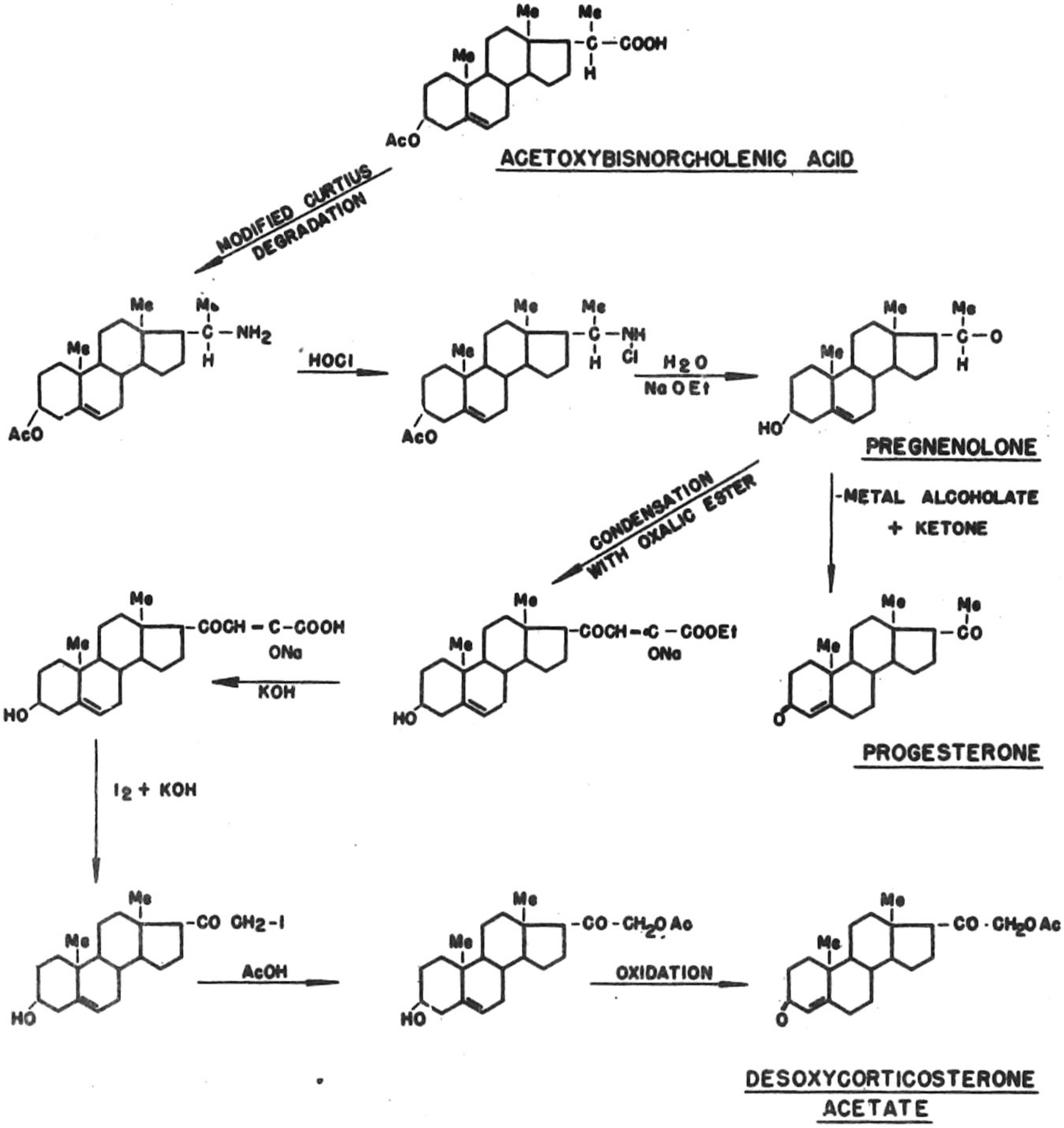
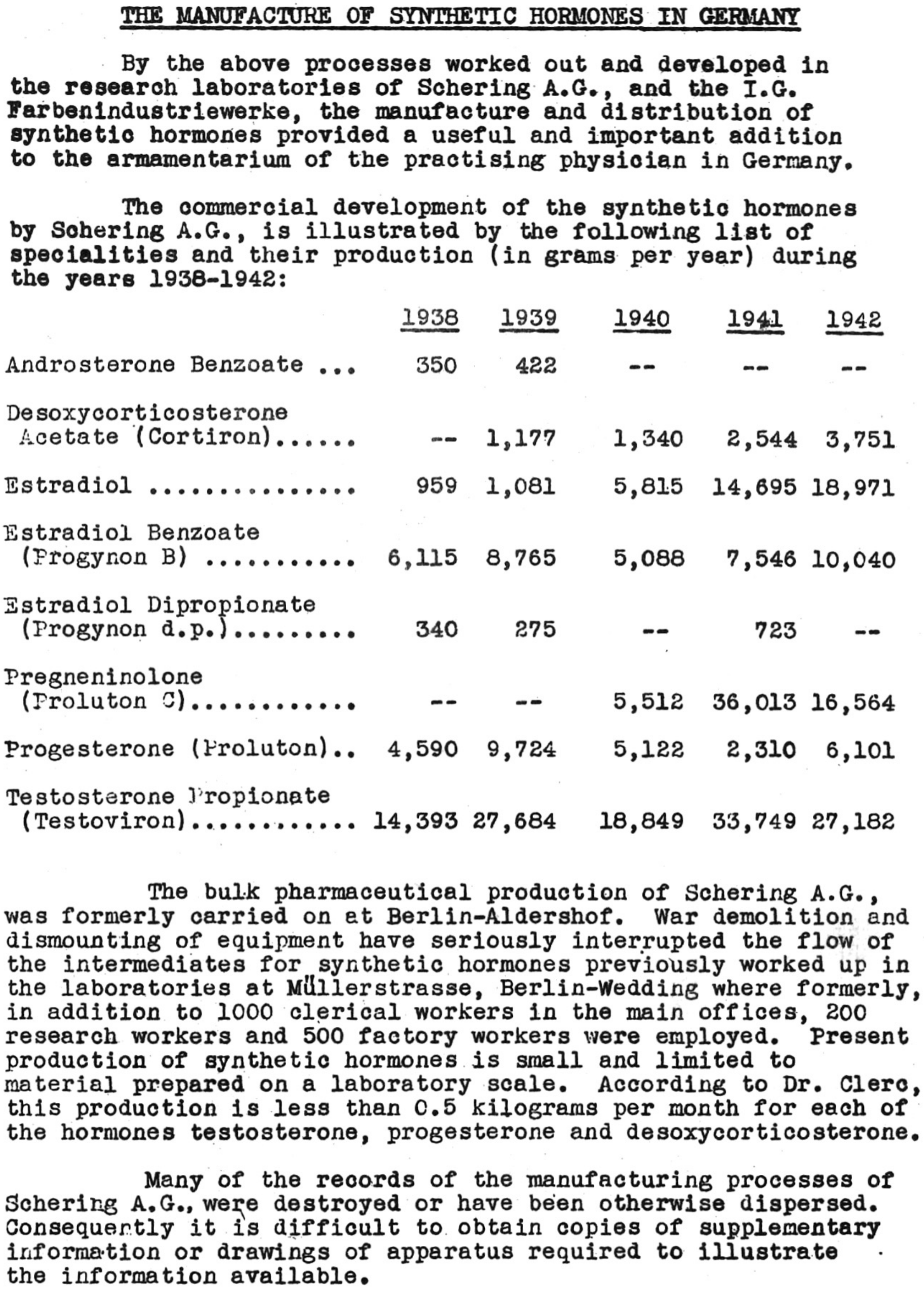

ACETOXYBISNORCHOLENIC ACID
MODIFIED CURTIUS DEGRADATION
HOCl
H2O
NaOEt
PREGNENOLONE
CONDENSATION WITH OXALIC ESTER
-METAL ALCOHOLATE
+ KETONE
KOH
PROGESTERONE
I2 + KOH
AcOH
OXIDATION
DESOXYCORTICOSTERONE ACETATE
Me
AcO
HO
-C-COOH
-C-NH2
-C-NH
Cl
-C-O
-COCH-C-COOH
ONa
-COCH-C-COOEt
-CO
-CO CH2-I
-CO-CH2OAc

Figure A.121: Commercial synthesis of a variety of steroid hormones [FIAT 996].



THE MANUFACTURE OF SYNTHETIC HORMONES IN GERMANY

By the above processes worked out and developed in the research laboratories of Schering A.G., and the I.G. Farbenindustriewerke, the manufacture and distribution of synthetic hormones provided a useful and important addition to the armamentarium of the practising physician in Germany.

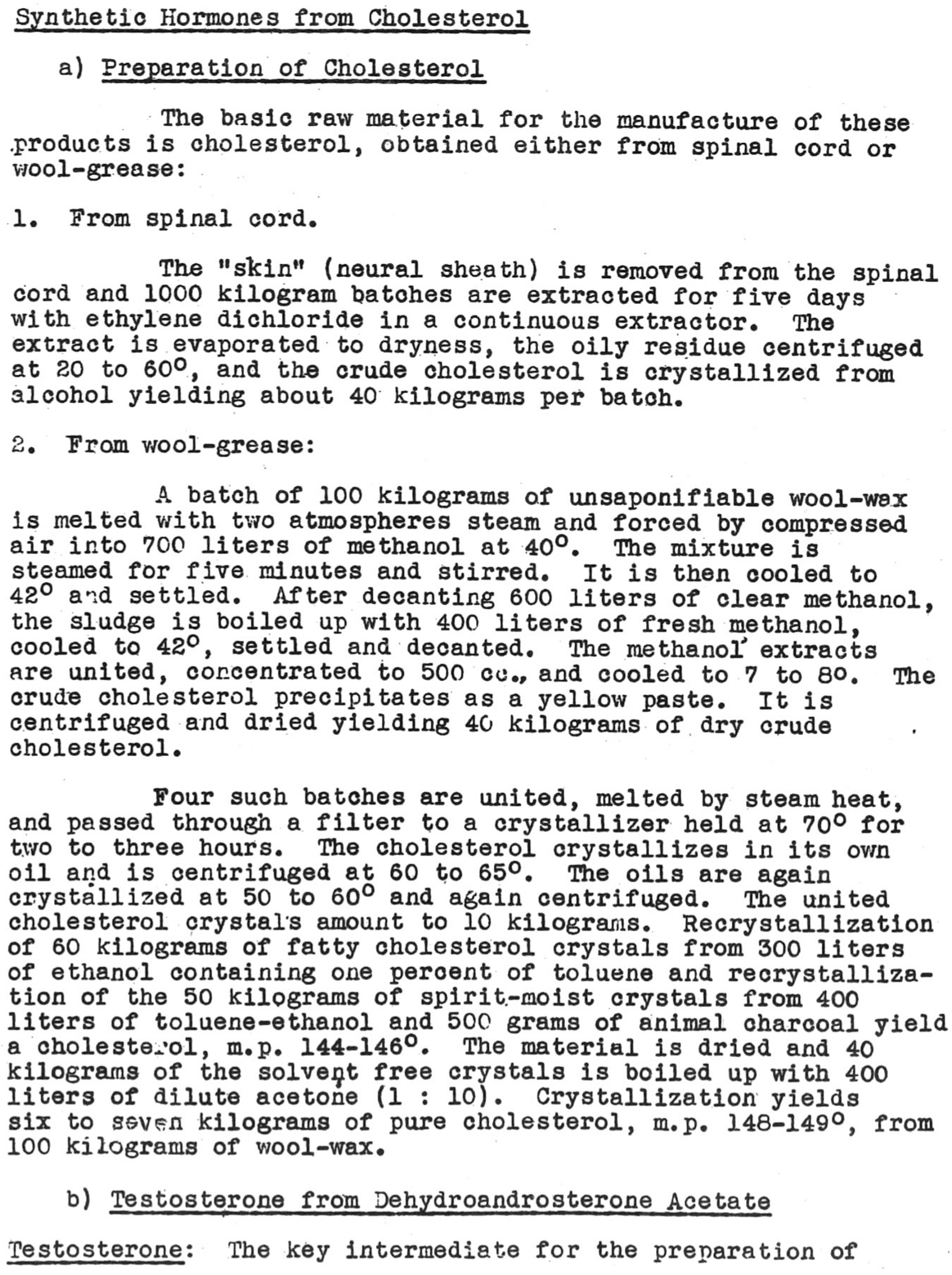
The commercial development of the synthetic hormones by Schering A.G., is illustrated by the following list of specialities and their production (in grams per year) during the years 1938-1942:

	1938	1939	1940	1941	1942
Androsterone Benzoate ...	350	422	--	--	--
Desoxycorticosterone Acetate (Cortiron)......	--	1,177	1,340	2,544	3,751
Estradiol	959	1,081	5,815	14,695	18,971
Estradiol Benzoate (Progynon B)	6,115	8,765	5,088	7,546	10,040
Estradiol Dipropionate (Progynon d.p.).........	340	275	--	723	--
Pregneninolone (Proluton C)............	--	--	5,512	36,013	16,564
Progesterone (Proluton)..	4,590	9,724	5,122	2,310	6,101
Testosterone Propionate (Testoviron)............	14,393	27,684	18,849	33,749	27,182

The bulk pharmaceutical production of Schering A.G., was formerly carried on at Berlin-Aldershof. War demolition and dismounting of equipment have seriously interrupted the flow of the intermediates for synthetic hormones previously worked up in the laboratories at Müllerstrasse, Berlin-Wedding where formerly, in addition to 1000 clerical workers in the main offices, 200 research workers and 500 factory workers were employed. Present production of synthetic hormones is small and limited to material prepared on a laboratory scale. According to Dr. Clerc, this production is less than 0.5 kilograms per month for each of the hormones testosterone, progesterone and desoxycorticosterone.

Many of the records of the manufacturing processes of Schering A.G., were destroyed or have been otherwise dispersed. Consequently it is difficult to obtain copies of supplementary information or drawings of apparatus required to illustrate the information available.

Figure A.122: Commercial synthesis of a variety of steroid hormones [FIAT 996].



Synthetic Hormones from Cholesterol

a) Preparation of Cholesterol

The basic raw material for the manufacture of these products is cholesterol, obtained either from spinal cord or wool-grease:

1. From spinal cord.

The "skin" (neural sheath) is removed from the spinal cord and 1000 kilogram batches are extracted for five days with ethylene dichloride in a continuous extractor. The extract is evaporated to dryness, the oily residue centrifuged at 20 to 60°, and the crude cholesterol is crystallized from alcohol yielding about 40 kilograms per batch.

2. From wool-grease:

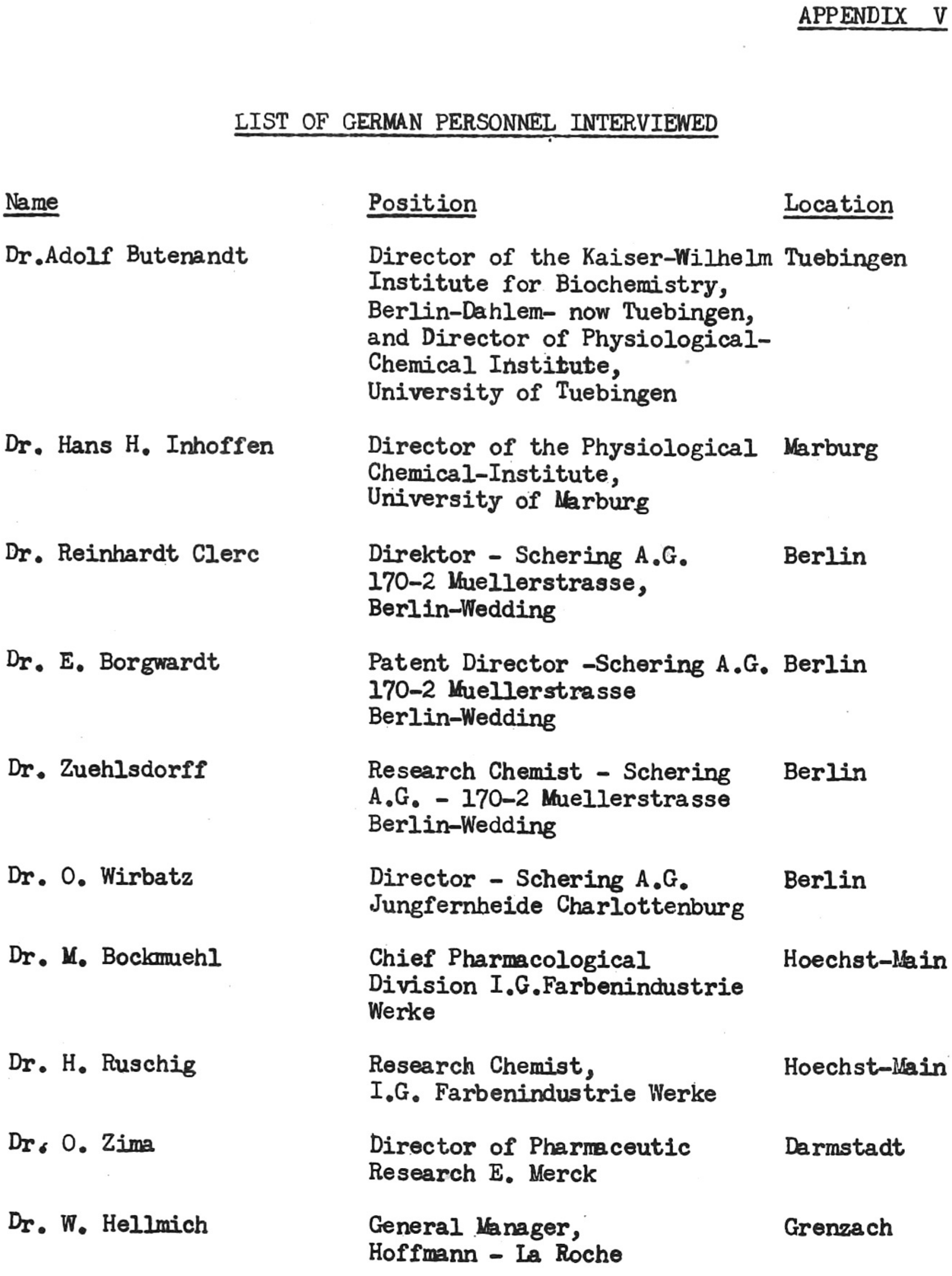
A batch of 100 kilograms of unsaponifiable wool-wax is melted with two atmospheres steam and forced by compressed air into 700 liters of methanol at 40°. The mixture is steamed for five minutes and stirred. It is then cooled to 42° and settled. After decanting 600 liters of clear methanol, the sludge is boiled up with 400 liters of fresh methanol, cooled to 42°, settled and decanted. The methanol extracts are united, concentrated to 500 cc., and cooled to 7 to 8°. The crude cholesterol precipitates as a yellow paste. It is centrifuged and dried yielding 40 kilograms of dry crude cholesterol.

Four such batches are united, melted by steam heat, and passed through a filter to a crystallizer held at 70° for two to three hours. The cholesterol crystallizes in its own oil and is centrifuged at 60 to 65°. The oils are again crystallized at 50 to 60° and again centrifuged. The united cholesterol crystals amount to 10 kilograms. Recrystallization of 60 kilograms of fatty cholesterol crystals from 300 liters of ethanol containing one percent of toluene and recrystallization of the 50 kilograms of spirit-moist crystals from 400 liters of toluene-ethanol and 500 grams of animal charcoal yield a cholesterol, m.p. 144-146°. The material is dried and 40 kilograms of the solvent free crystals is boiled up with 400 liters of dilute acetone (1 : 10). Crystallization yields six to seven kilograms of pure cholesterol, m.p. 148-149°, from 100 kilograms of wool-wax.

b) Testosterone from Dehydroandrosterone Acetate

Testosterone: The key intermediate for the preparation of

Figure A.123: Commercial synthesis of a variety of steroid hormones [FIAT 996].

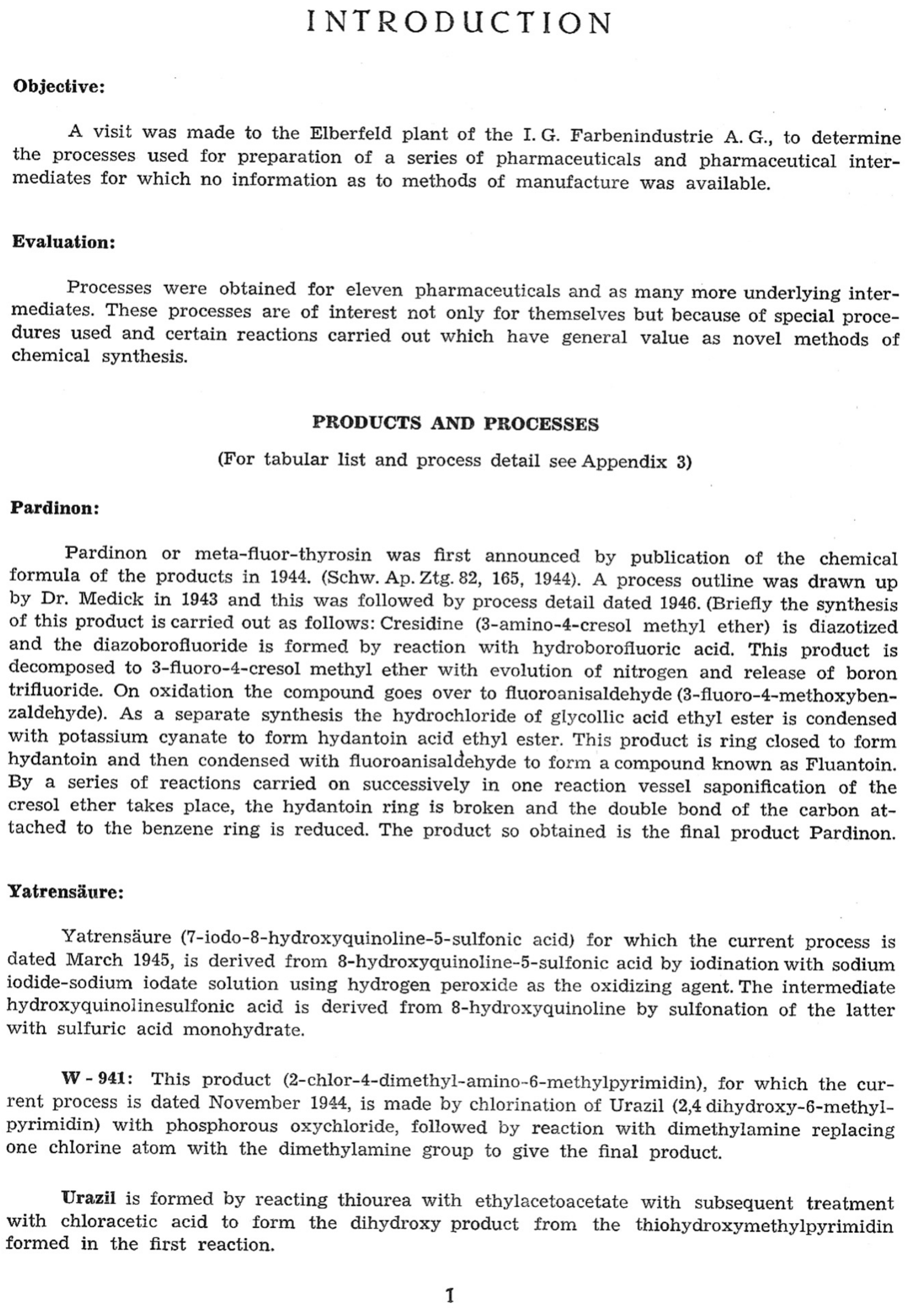


APPENDIX V

LIST OF GERMAN PERSONNEL INTERVIEWED

Name	Position	Location
Dr.Adolf Butenandt	Director of the Kaiser-Wilhelm Institute for Biochemistry, Berlin-Dahlem- now Tuebingen, and Director of Physiological-Chemical Institute, University of Tuebingen	Tuebingen
Dr. Hans H. Inhoffen	Director of the Physiological Chemical-Institute, University of Marburg	Marburg
Dr. Reinhardt Clerc	Direktor - Schering A.G. 170-2 Muellerstrasse, Berlin-Wedding	Berlin
Dr. E. Borgwardt	Patent Director -Schering A.G. 170-2 Muellerstrasse Berlin-Wedding	Berlin
Dr. Zuehlsdorff	Research Chemist - Schering A.G. - 170-2 Muellerstrasse Berlin-Wedding	Berlin
Dr. O. Wirbatz	Director - Schering A.G. Jungfernheide Charlottenburg	Berlin
Dr. M. Bockmuehl	Chief Pharmacological Division I.G.Farbenindustrie Werke	Hoechst-Main
Dr. H. Ruschig	Research Chemist, I.G. Farbenindustrie Werke	Hoechst-Main
Dr. O. Zima	Director of Pharmaceutic Research E. Merck	Darmstadt
Dr. W. Hellmich	General Manager, Hoffmann - La Roche	Grenzach

Figure A.124: Commercial synthesis of a variety of steroid hormones [FIAT 996].



INTRODUCTION

Objective:

A visit was made to the Elberfeld plant of the I. G. Farbenindustrie A. G., to determine the processes used for preparation of a series of pharmaceuticals and pharmaceutical intermediates for which no information as to methods of manufacture was available.

Evaluation:

Processes were obtained for eleven pharmaceuticals and as many more underlying intermediates. These processes are of interest not only for themselves but because of special procedures used and certain reactions carried out which have general value as novel methods of chemical synthesis.

PRODUCTS AND PROCESSES

(For tabular list and process detail see Appendix 3)

Pardinon:

Pardinon or meta-fluor-thyrosin was first announced by publication of the chemical formula of the products in 1944. (Schw. Ap. Ztg. 82, 165, 1944). A process outline was drawn up by Dr. Medick in 1943 and this was followed by process detail dated 1946. (Briefly the synthesis of this product is carried out as follows: Cresidine (3-amino-4-cresol methyl ether) is diazotized and the diazoborofluoride is formed by reaction with hydroborofluoric acid. This product is decomposed to 3-fluoro-4-cresol methyl ether with evolution of nitrogen and release of boron trifluoride. On oxidation the compound goes over to fluoroanisaldehyde (3-fluoro-4-methoxybenzaldehyde). As a separate synthesis the hydrochloride of glycollic acid ethyl ester is condensed with potassium cyanate to form hydantoin acid ethyl ester. This product is ring closed to form hydantoin and then condensed with fluoroanisaldehyde to form a compound known as Fluantoin. By a series of reactions carried on successively in one reaction vessel saponification of the cresol ether takes place, the hydantoin ring is broken and the double bond of the carbon attached to the benzene ring is reduced. The product so obtained is the final product Pardinon.

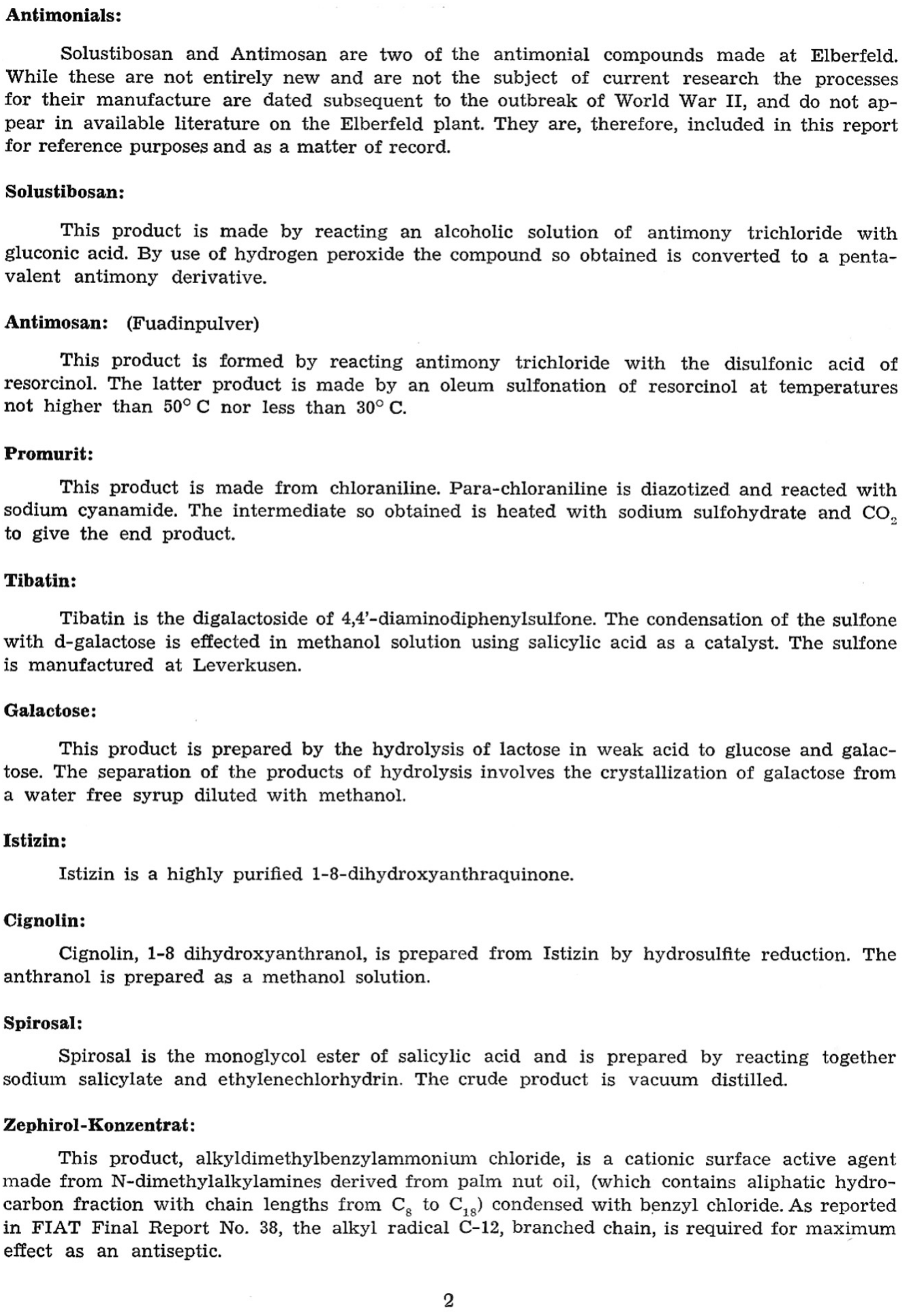
Yatrensäure:

Yatrensäure (7-iodo-8-hydroxyquinoline-5-sulfonic acid) for which the current process is dated March 1945, is derived from 8-hydroxyquinoline-5-sulfonic acid by iodination with sodium iodide-sodium iodate solution using hydrogen peroxide as the oxidizing agent. The intermediate hydroxyquinolinesulfonic acid is derived from 8-hydroxyquinoline by sulfonation of the latter with sulfuric acid monohydrate.

W - 941: This product (2-chlor-4-dimethyl-amino-6-methylpyrimidin), for which the current process is dated November 1944, is made by chlorination of Urazil (2,4 dihydroxy-6-methylpyrimidin) with phosphorous oxychloride, followed by reaction with dimethylamine replacing one chlorine atom with the dimethylamine group to give the final product.

Urazil is formed by reacting thiourea with ethylacetoacetate with subsequent treatment with chloracetic acid to form the dihydroxy product from the thiohydroxymethylpyrimidin formed in the first reaction.

Figure A.125: Commercial synthesis of a variety of pharmaceuticals [FIAT 1014].



Antimonials:

Solustibosan and Antimosan are two of the antimonial compounds made at Elberfeld. While these are not entirely new and are not the subject of current research the processes for their manufacture are dated subsequent to the outbreak of World War II, and do not appear in available literature on the Elberfeld plant. They are, therefore, included in this report for reference purposes and as a matter of record.

Solustibosan:

This product is made by reacting an alcoholic solution of antimony trichloride with gluconic acid. By use of hydrogen peroxide the compound so obtained is converted to a pentavalent antimony derivative.

Antimosan: (Fuadinpulver)

This product is formed by reacting antimony trichloride with the disulfonic acid of resorcinol. The latter product is made by an oleum sulfonation of resorcinol at temperatures not higher than 50° C nor less than 30° C.

Promurit:

This product is made from chloraniline. Para-chloraniline is diazotized and reacted with sodium cyanamide. The intermediate so obtained is heated with sodium sulfohydrate and CO_2 to give the end product.

Tibatin:

Tibatin is the digalactoside of 4,4'-diaminodiphenylsulfone. The condensation of the sulfone with d-galactose is effected in methanol solution using salicylic acid as a catalyst. The sulfone is manufactured at Leverkusen.

Galactose:

This product is prepared by the hydrolysis of lactose in weak acid to glucose and galactose. The separation of the products of hydrolysis involves the crystallization of galactose from a water free syrup diluted with methanol.

Istizin:

Istizin is a highly purified 1-8-dihydroxyanthraquinone.

Cignolin:

Cignolin, 1-8 dihydroxyanthranol, is prepared from Istizin by hydrosulfite reduction. The anthranol is prepared as a methanol solution.

Spirosal:

Spirosal is the monoglycol ester of salicylic acid and is prepared by reacting together sodium salicylate and ethylenechlorhydrin. The crude product is vacuum distilled.

Zephirol-Konzentrat:

This product, alkyldimethylbenzylammonium chloride, is a cationic surface active agent made from N-dimethylalkylamines derived from palm nut oil, (which contains aliphatic hydrocarbon fraction with chain lengths from C_8 to C_{18}) condensed with benzyl chloride. As reported in FIAT Final Report No. 38, the alkyl radical C-12, branched chain, is required for maximum effect as an antiseptic.

Figure A.126: Commercial synthesis of a variety of pharmaceuticals [FIAT 1014].

FIAT 1014. ***Miscellaneous Pharmaceuticals and Pharmaceutical Intermediates Manufactured at I. G. Farbenindustrie A. G., Elberfeld.*** [See pp. 2471–2472 for a summary. This is a very long report, mostly in German, on the commercial synthesis of various pharmaceuticals based on the work of Gerhard Domagk, Gerhard Schrader, and other top I.G. Farben biochemists. See also FIAT 1042.]

FIAT 1046. ***Production of Crude Citric Acid by Fermentation in Germany.***

Charging of the Fermentation Room:

Each fermentation room contains 80 pans supported on a steel framework. The treated molasses is run from the cooking tanks into the individual pans by means of rubber hose until a liquor depth of about eight centimeters is reached. After the pans are charged the contents are allowed to cool until the temperature reaches about 40^{o}C. At this point, spores of the mold, Aspergillus niger, which have been grown in Kolle bottles in the laboratory, are introduced into the air stream entering the room and blown over the surface of the pans.

Fermentation Cycle:

The spores germinate on the molasses solution and in about 48 hours the entire surface is covered by the mycelia of the mold. During the early growth phase the air temperature is maintained close to 30^{o}C and the air is slowly circulated. When the growth is established, the conversion of the sugar to citric acid takes place rapidly with the liberation of considerable heat. A large proportion of the heat is held as latent heat in the water vapor given off through the respiration of the mold. As a consequence the relative humidity in the room tends to increase, but this increase is held well below the saturation point by the constant introduction of low humidity fresh air from the air conditioning equipment. After seven days, the rate of fermentation decreases and by the tenth day the room contents are ready for harvesting. [...]

Clarification and Extraction:

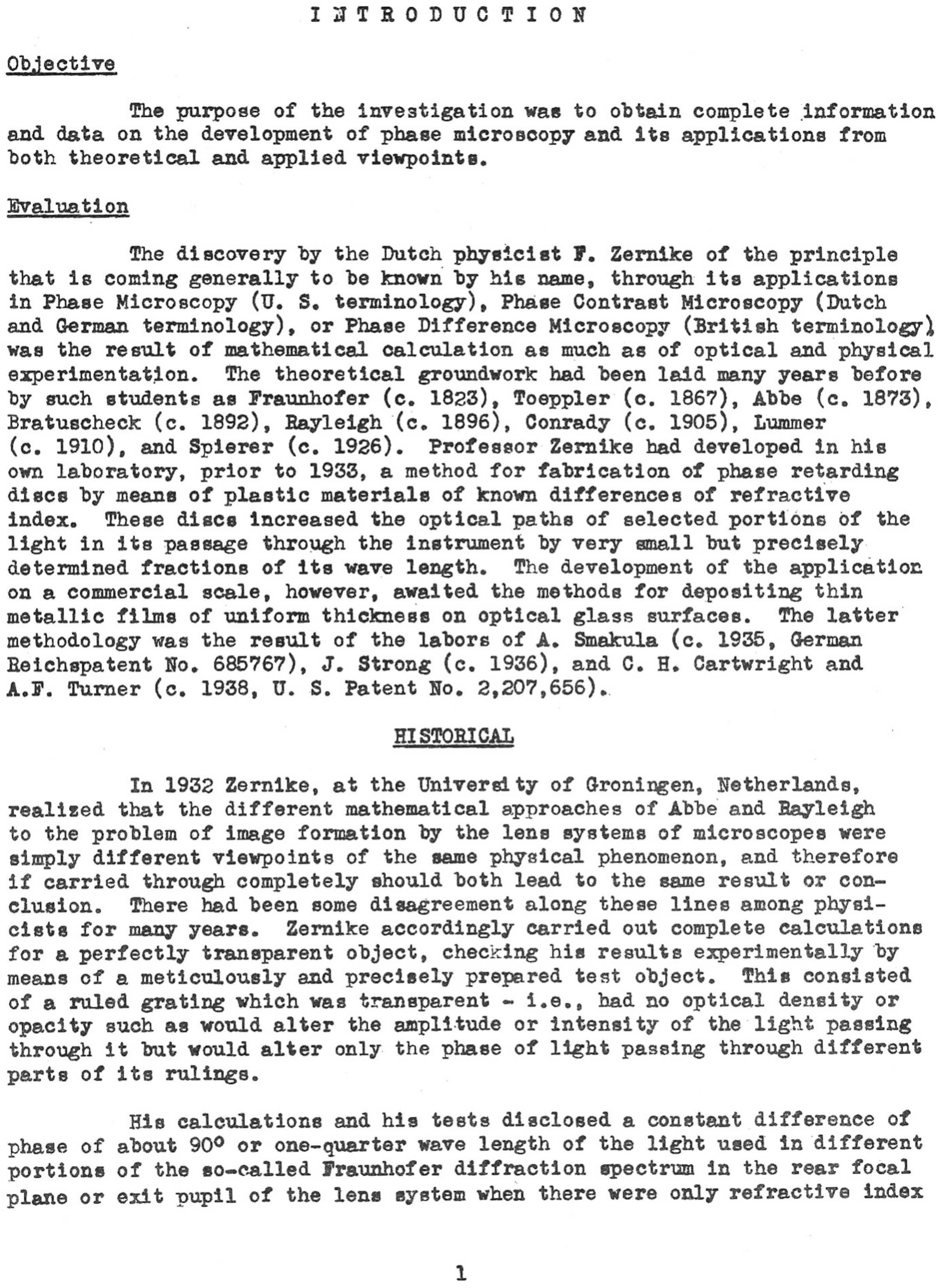
The fermented liquor is freed from insoluble material, which forms during the fermentation, by settling and decantation. The mycelia are dumped from the cars into tanks where the citric acid adhering to the wrinkled surfaces of the mold is extracted by counter-current washing. The extract joins the main body of the fermentation liquor.

Recovery of the Citric Acid:

The clarified fermentation liquor is sent to the precipitation tanks and heated to 90^{o}C. Slaked lime is added until pH 8.0 to 8.2 is reached. The tank contents are then brought to the boiling point. The mixture is stirred and the calcium citrate is quickly precipitated. The calcium citrate is separated by filtration, washed, dried and sacked.

The calcium citrate is converted to citric acid by a process of refining which is very similar to the manufacture of tartaric acid.

FIAT 1059. ***The Phase Principle in Microscopy.*** **With supplement.**
[See pp. 2474–2484 for some key pages from this long report documenting the invention, demonstration, and technology transfer of phase-contrast microscopy.]



INTRODUCTION

Objective

The purpose of the investigation was to obtain complete information and data on the development of phase microscopy and its applications from both theoretical and applied viewpoints.

Evaluation

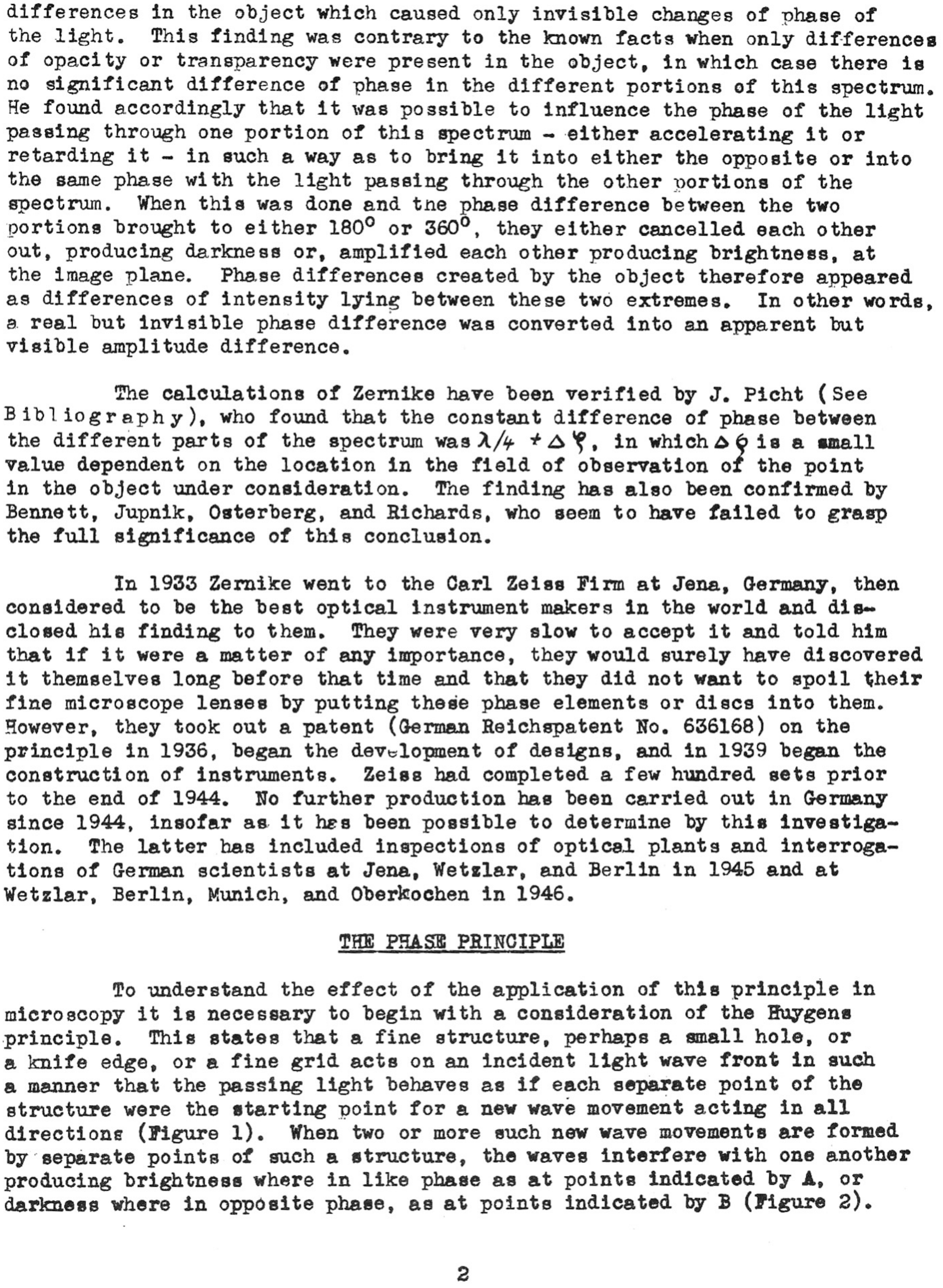
The discovery by the Dutch physicist F. Zernike of the principle that is coming generally to be known by his name, through its applications in Phase Microscopy (U. S. terminology), Phase Contrast Microscopy (Dutch and German terminology), or Phase Difference Microscopy (British terminology) was the result of mathematical calculation as much as of optical and physical experimentation. The theoretical groundwork had been laid many years before by such students as Fraunhofer (c. 1823), Toeppler (c. 1867), Abbe (c. 1873), Bratuscheck (c. 1892), Rayleigh (c. 1896), Conrady (c. 1905), Lummer (c. 1910), and Spierer (c. 1926). Professor Zernike had developed in his own laboratory, prior to 1933, a method for fabrication of phase retarding discs by means of plastic materials of known differences of refractive index. These discs increased the optical paths of selected portions of the light in its passage through the instrument by very small but precisely determined fractions of its wave length. The development of the application on a commercial scale, however, awaited the methods for depositing thin metallic films of uniform thickness on optical glass surfaces. The latter methodology was the result of the labors of A. Smakula (c. 1935, German Reichspatent No. 685767), J. Strong (c. 1936), and C. H. Cartwright and A.F. Turner (c. 1938, U. S. Patent No. 2,207,656).

HISTORICAL

In 1932 Zernike, at the University of Groningen, Netherlands, realized that the different mathematical approaches of Abbe and Rayleigh to the problem of image formation by the lens systems of microscopes were simply different viewpoints of the same physical phenomenon, and therefore if carried through completely should both lead to the same result or conclusion. There had been some disagreement along these lines among physicists for many years. Zernike accordingly carried out complete calculations for a perfectly transparent object, checking his results experimentally by means of a meticulously and precisely prepared test object. This consisted of a ruled grating which was transparent - i.e., had no optical density or opacity such as would alter the amplitude or intensity of the light passing through it but would alter only the phase of light passing through different parts of its rulings.

His calculations and his tests disclosed a constant difference of phase of about 90° or one-quarter wave length of the light used in different portions of the so-called Fraunhofer diffraction spectrum in the rear focal plane or exit pupil of the lens system when there were only refractive index

Figure A.127: Invention, demonstration, and technology transfer of phase-contrast microscopy [FIAT 1059].



differences in the object which caused only invisible changes of phase of the light. This finding was contrary to the known facts when only differences of opacity or transparency were present in the object, in which case there is no significant difference of phase in the different portions of this spectrum. He found accordingly that it was possible to influence the phase of the light passing through one portion of this spectrum - either accelerating it or retarding it - in such a way as to bring it into either the opposite or into the same phase with the light passing through the other portions of the spectrum. When this was done and the phase difference between the two portions brought to either 180° or 360°, they either cancelled each other out, producing darkness or, amplified each other producing brightness, at the image plane. Phase differences created by the object therefore appeared as differences of intensity lying between these two extremes. In other words, a real but invisible phase difference was converted into an apparent but visible amplitude difference.

The calculations of Zernike have been verified by J. Picht (See Bibliography), who found that the constant difference of phase between the different parts of the spectrum was $\lambda/4 + \Delta\varphi$, in which $\Delta\varphi$ is a small value dependent on the location in the field of observation of the point in the object under consideration. The finding has also been confirmed by Bennett, Jupnik, Osterberg, and Richards, who seem to have failed to grasp the full significance of this conclusion.

In 1933 Zernike went to the Carl Zeiss Firm at Jena, Germany, then considered to be the best optical instrument makers in the world and disclosed his finding to them. They were very slow to accept it and told him that if it were a matter of any importance, they would surely have discovered it themselves long before that time and that they did not want to spoil their fine microscope lenses by putting these phase elements or discs into them. However, they took out a patent (German Reichspatent No. 636168) on the principle in 1936, began the development of designs, and in 1939 began the construction of instruments. Zeiss had completed a few hundred sets prior to the end of 1944. No further production has been carried out in Germany since 1944, insofar as it has been possible to determine by this investigation. The latter has included inspections of optical plants and interrogations of German scientists at Jena, Wetzlar, and Berlin in 1945 and at Wetzlar, Berlin, Munich, and Oberkochen in 1946.

THE PHASE PRINCIPLE

To understand the effect of the application of this principle in microscopy it is necessary to begin with a consideration of the Huygens principle. This states that a fine structure, perhaps a small hole, or a knife edge, or a fine grid acts on an incident light wave front in such a manner that the passing light behaves as if each separate point of the structure were the starting point for a new wave movement acting in all directions (Figure 1). When two or more such new wave movements are formed by separate points of such a structure, the waves interfere with one another producing brightness where in like phase as at points indicated by A, or darkness where in opposite phase, as at points indicated by B (Figure 2).

Figure A.128: Invention, demonstration, and technology transfer of phase-contrast microscopy [FIAT 1059].

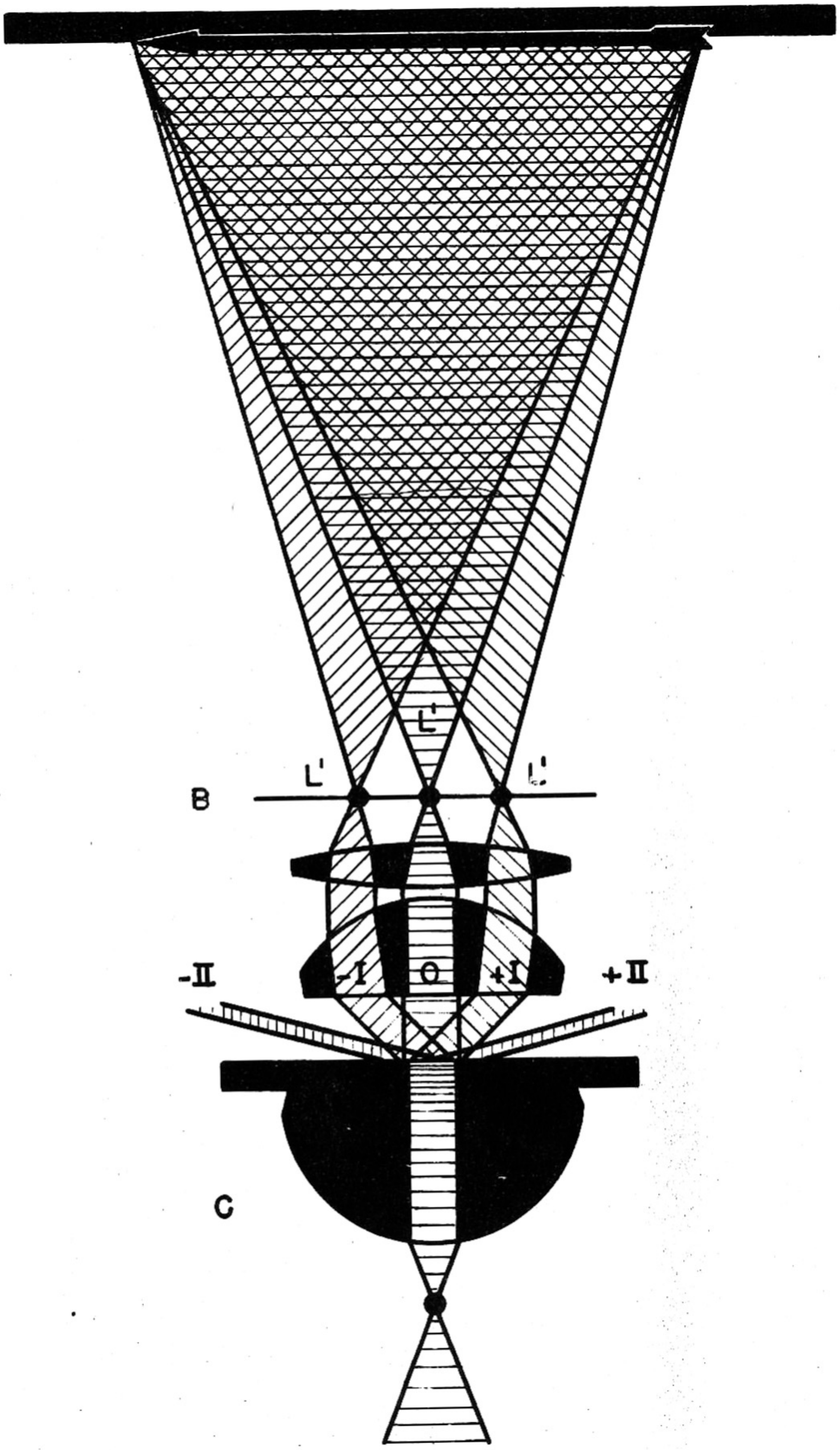


FIGURE 4. ILLUSTRATING FORMATION OF THE FRAUNHOFER DIFFRACTION SPECTRUM IN THE LENS SYSTEM OF A MICROSCOPE.

Figure A.129: Invention, demonstration, and technology transfer of phase-contrast microscopy [FIAT 1059].

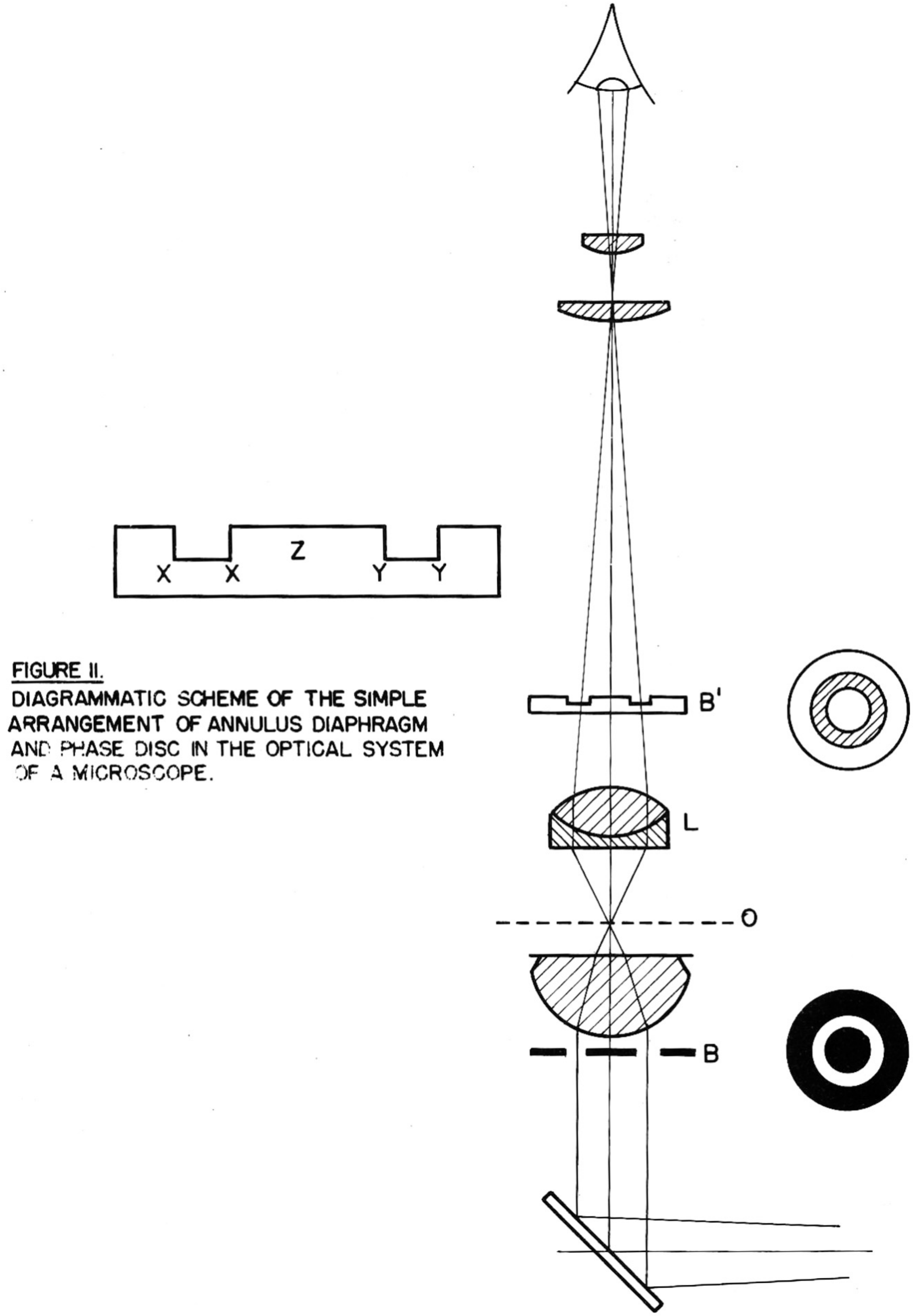
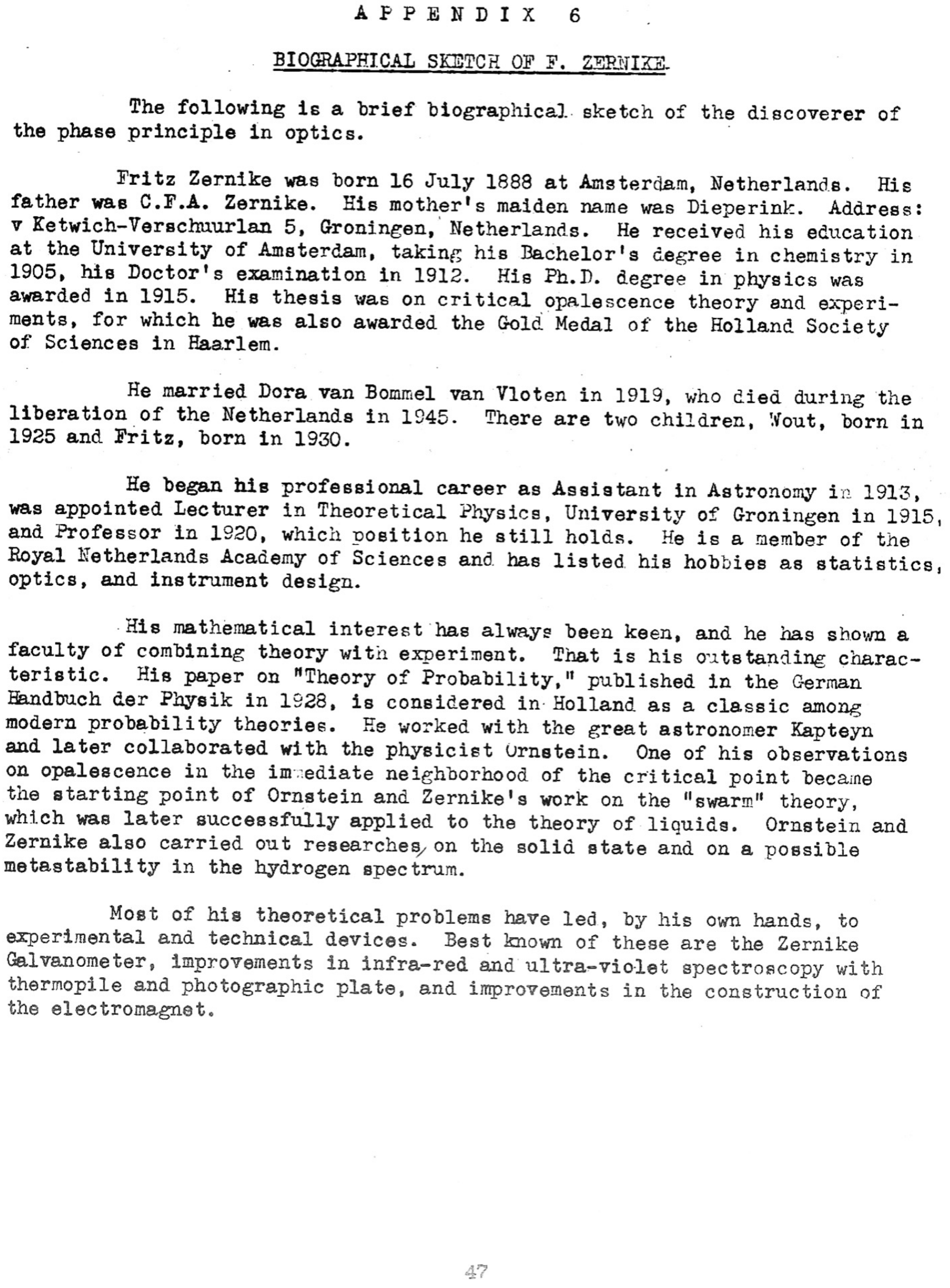


FIGURE II.

DIAGRAMMATIC SCHEME OF THE SIMPLE ARRANGEMENT OF ANNULUS DIAPHRAGM AND PHASE DISC IN THE OPTICAL SYSTEM OF A MICROSCOPE.

Figure A.130: Invention, demonstration, and technology transfer of phase-contrast microscopy [FIAT 1059].



APPENDIX 6

BIOGRAPHICAL SKETCH OF F. ZERNIKE.

The following is a brief biographical sketch of the discoverer of the phase principle in optics.

Fritz Zernike was born 16 July 1888 at Amsterdam, Netherlands. His father was C.F.A. Zernike. His mother's maiden name was Dieperink. Address: v Ketwich-Verschuurlan 5, Groningen, Netherlands. He received his education at the University of Amsterdam, taking his Bachelor's degree in chemistry in 1905, his Doctor's examination in 1912. His Ph.D. degree in physics was awarded in 1915. His thesis was on critical opalescence theory and experiments, for which he was also awarded the Gold Medal of the Holland Society of Sciences in Haarlem.

He married Dora van Bommel van Vloten in 1919, who died during the liberation of the Netherlands in 1945. There are two children, Wout, born in 1925 and Fritz, born in 1930.

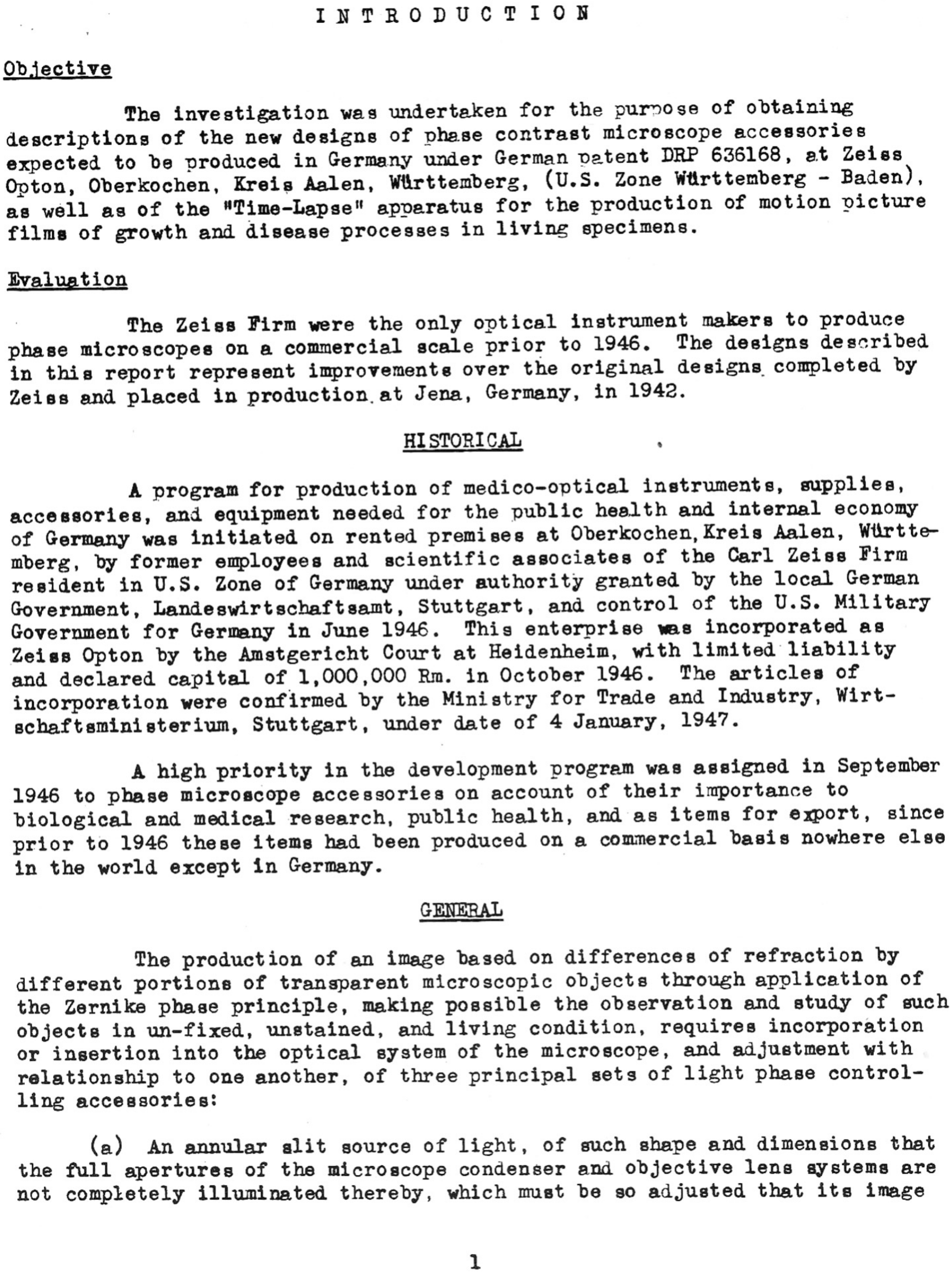
He began his professional career as Assistant in Astronomy in 1913, was appointed Lecturer in Theoretical Physics, University of Groningen in 1915, and Professor in 1920, which position he still holds. He is a member of the Royal Netherlands Academy of Sciences and has listed his hobbies as statistics, optics, and instrument design.

His mathematical interest has always been keen, and he has shown a faculty of combining theory with experiment. That is his outstanding characteristic. His paper on "Theory of Probability," published in the German Handbuch der Physik in 1928, is considered in Holland as a classic among modern probability theories. He worked with the great astronomer Kapteyn and later collaborated with the physicist Ornstein. One of his observations on opalescence in the immediate neighborhood of the critical point became the starting point of Ornstein and Zernike's work on the "swarm" theory, which was later successfully applied to the theory of liquids. Ornstein and Zernike also carried out researches, on the solid state and on a possible metastability in the hydrogen spectrum.

Most of his theoretical problems have led, by his own hands, to experimental and technical devices. Best known of these are the Zernike Galvanometer, improvements in infra-red and ultra-violet spectroscopy with thermopile and photographic plate, and improvements in the construction of the electromagnet.

47

Figure A.131: Invention, demonstration, and technology transfer of phase-contrast microscopy [FIAT 1059].



INTRODUCTION

Objective

The investigation was undertaken for the purpose of obtaining descriptions of the new designs of phase contrast microscope accessories expected to be produced in Germany under German patent DRP 636168, at Zeiss Opton, Oberkochen, Kreis Aalen, Württemberg, (U.S. Zone Württemberg - Baden), as well as of the "Time-Lapse" apparatus for the production of motion picture films of growth and disease processes in living specimens.

Evaluation

The Zeiss Firm were the only optical instrument makers to produce phase microscopes on a commercial scale prior to 1946. The designs described in this report represent improvements over the original designs completed by Zeiss and placed in production at Jena, Germany, in 1942.

HISTORICAL

A program for production of medico-optical instruments, supplies, accessories, and equipment needed for the public health and internal economy of Germany was initiated on rented premises at Oberkochen, Kreis Aalen, Württemberg, by former employees and scientific associates of the Carl Zeiss Firm resident in U.S. Zone of Germany under authority granted by the local German Government, Landeswirtschaftsamt, Stuttgart, and control of the U.S. Military Government for Germany in June 1946. This enterprise was incorporated as Zeiss Opton by the Amstgericht Court at Heidenheim, with limited liability and declared capital of 1,000,000 Rm. in October 1946. The articles of incorporation were confirmed by the Ministry for Trade and Industry, Wirtschaftsministerium, Stuttgart, under date of 4 January, 1947.

A high priority in the development program was assigned in September 1946 to phase microscope accessories on account of their importance to biological and medical research, public health, and as items for export, since prior to 1946 these items had been produced on a commercial basis nowhere else in the world except in Germany.

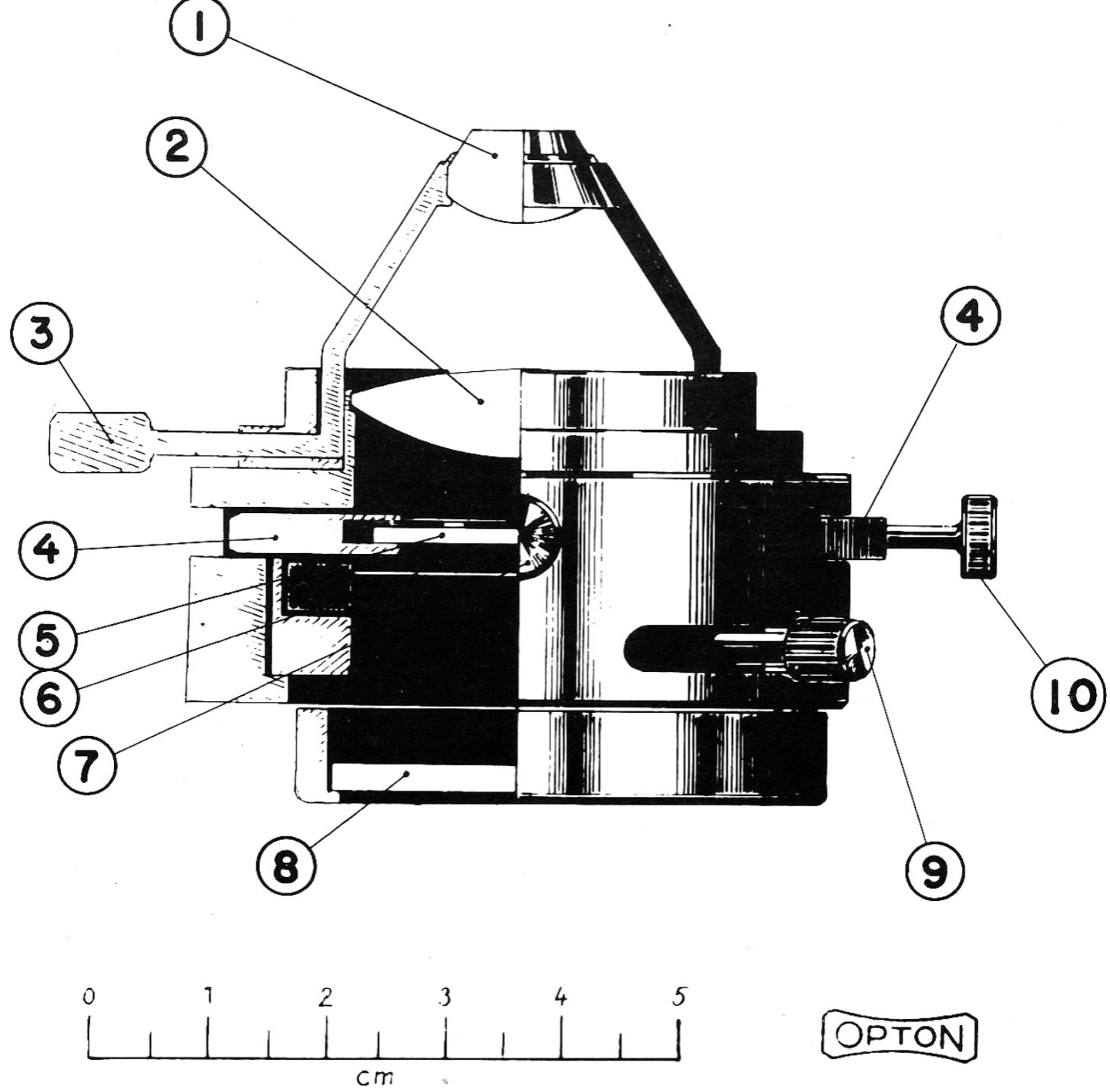
GENERAL

The production of an image based on differences of refraction by different portions of transparent microscopic objects through application of the Zernike phase principle, making possible the observation and study of such objects in un-fixed, unstained, and living condition, requires incorporation or insertion into the optical system of the microscope, and adjustment with relationship to one another, of three principal sets of light phase controlling accessories:

(a) An annular slit source of light, of such shape and dimensions that the full apertures of the microscope condenser and objective lens systems are not completely illuminated thereby, which must be so adjusted that its image

Figure A.132: Invention, demonstration, and technology transfer of phase-contrast microscopy [FIAT 1059 Supplement].

Figure 1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OPTON

Microscope condenser incorporating interchangeable phase diaphragms.

Figure A.133: Invention, demonstration, and technology transfer of phase-contrast microscopy [FIAT 1059 Supplement].

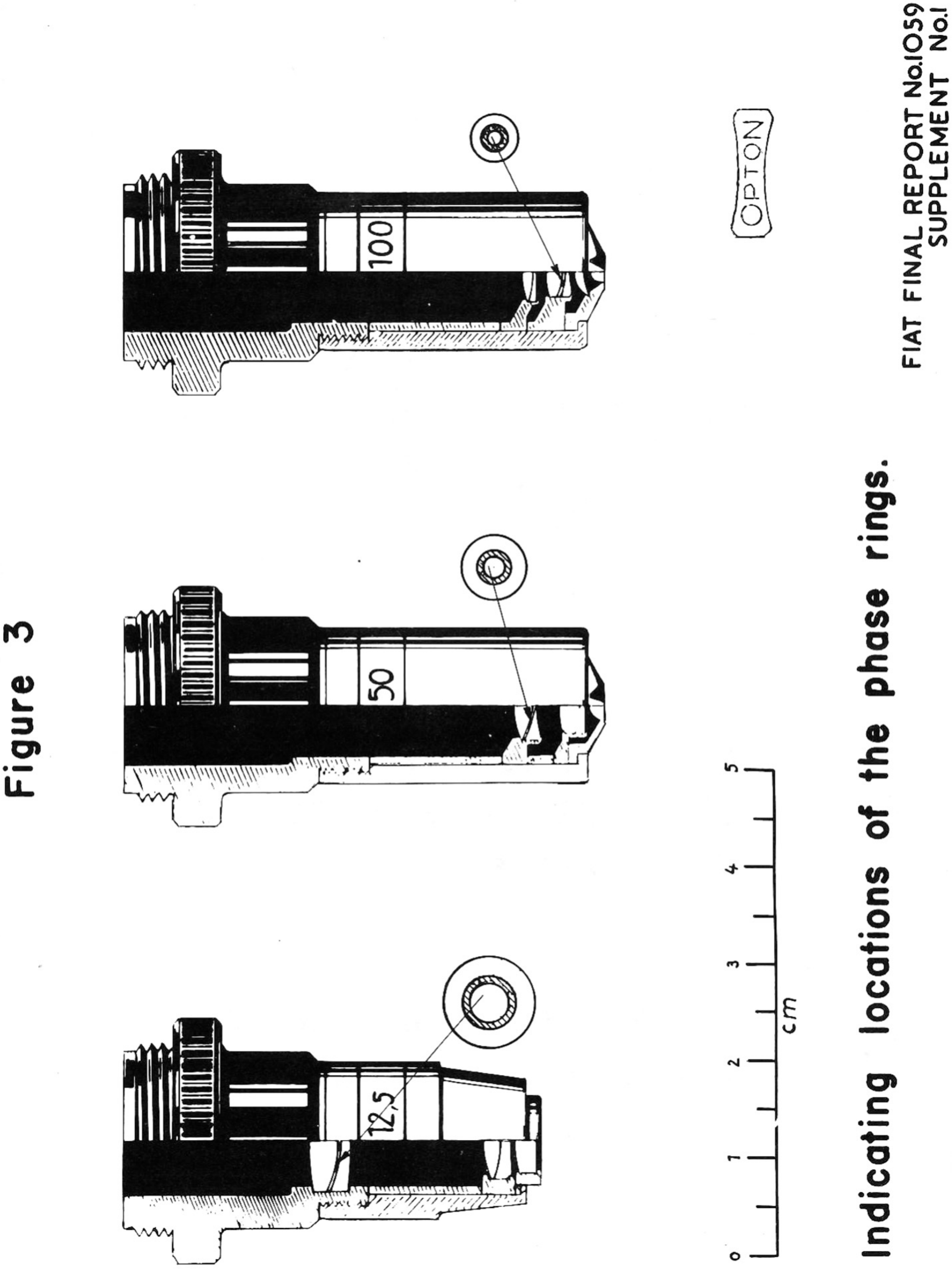
Figure 3
FIAT FINAL REPORT No.1059
SUPPLEMENT No.1
OPTON
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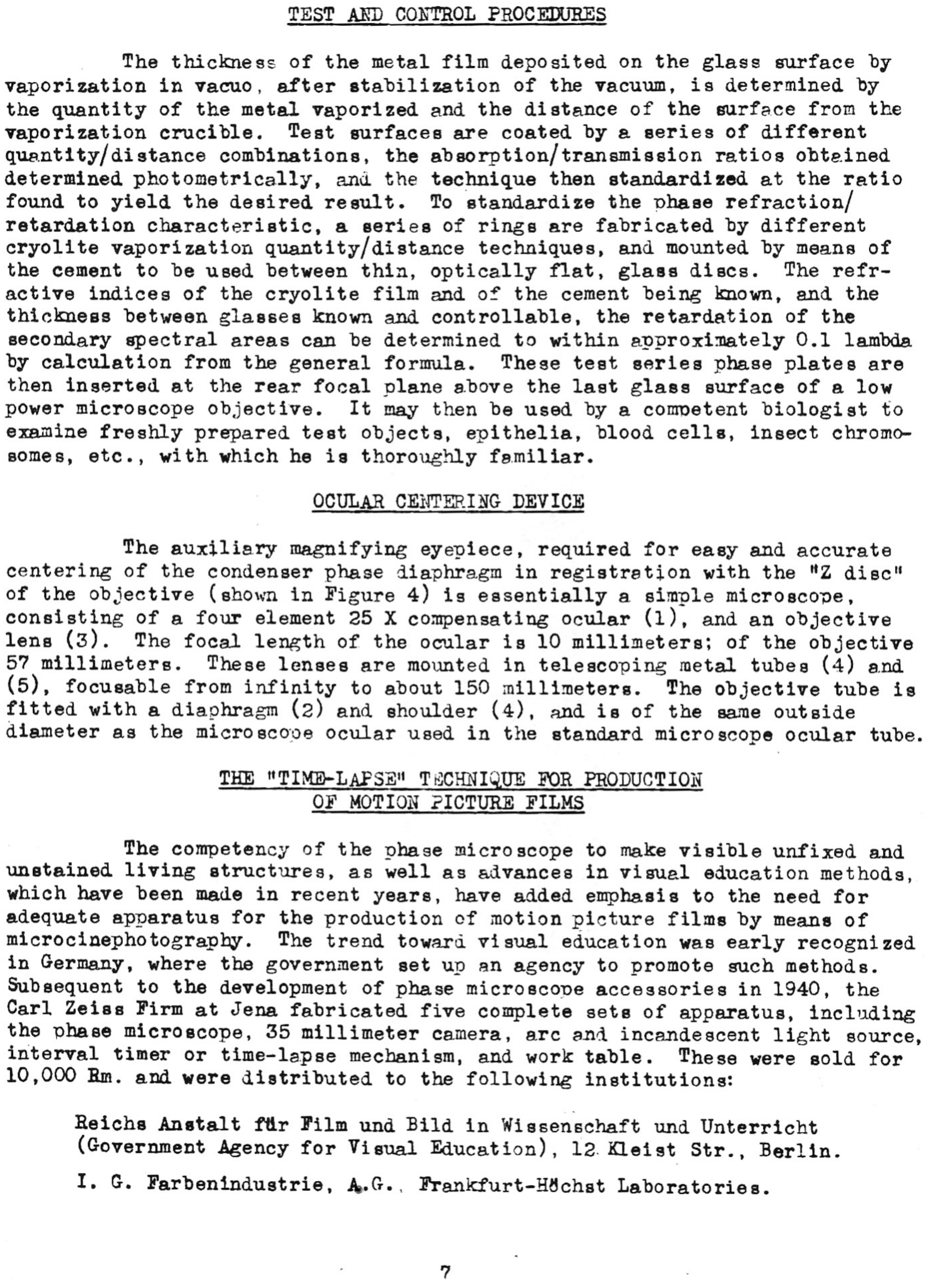
cm
Indicating locations of the phase rings.

Figure A.134: Invention, demonstration, and technology transfer of phase-contrast microscopy [FIAT 1059 Supplement].



TEST AND CONTROL PROCEDURES

The thickness of the metal film deposited on the glass surface by vaporization in vacuo, after stabilization of the vacuum, is determined by the quantity of the metal vaporized and the distance of the surface from the vaporization crucible. Test surfaces are coated by a series of different quantity/distance combinations, the absorption/transmission ratios obtained determined photometrically, and the technique then standardized at the ratio found to yield the desired result. To standardize the phase refraction/retardation characteristic, a series of rings are fabricated by different cryolite vaporization quantity/distance techniques, and mounted by means of the cement to be used between thin, optically flat, glass discs. The refractive indices of the cryolite film and of the cement being known, and the thickness between glasses known and controllable, the retardation of the secondary spectral areas can be determined to within approximately 0.1 lambda by calculation from the general formula. These test series phase plates are then inserted at the rear focal plane above the last glass surface of a low power microscope objective. It may then be used by a competent biologist to examine freshly prepared test objects, epithelia, blood cells, insect chromosomes, etc., with which he is thoroughly familiar.

OCULAR CENTERING DEVICE

The auxiliary magnifying eyepiece, required for easy and accurate centering of the condenser phase diaphragm in registration with the "Z disc" of the objective (shown in Figure 4) is essentially a simple microscope, consisting of a four element 25 X compensating ocular (1), and an objective lens (3). The focal length of the ocular is 10 millimeters; of the objective 57 millimeters. These lenses are mounted in telescoping metal tubes (4) and (5), focusable from infinity to about 150 millimeters. The objective tube is fitted with a diaphragm (2) and shoulder (4), and is of the same outside diameter as the microscope ocular used in the standard microscope ocular tube.

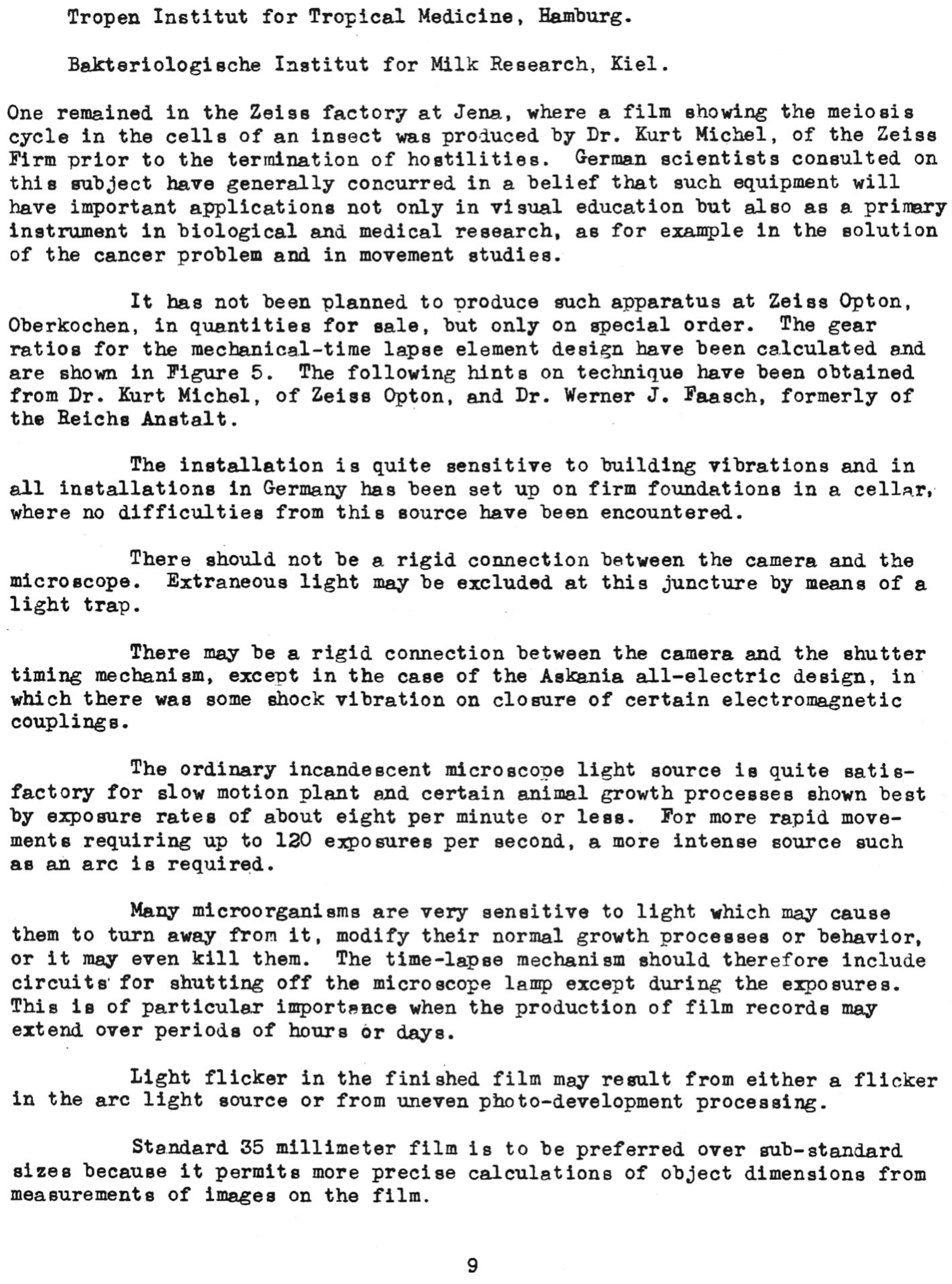
THE "TIME-LAPSE" TECHNIQUE FOR PRODUCTION OF MOTION PICTURE FILMS

The competency of the phase microscope to make visible unfixed and unstained living structures, as well as advances in visual education methods, which have been made in recent years, have added emphasis to the need for adequate apparatus for the production of motion picture films by means of microcinephotography. The trend toward visual education was early recognized in Germany, where the government set up an agency to promote such methods. Subsequent to the development of phase microscope accessories in 1940, the Carl Zeiss Firm at Jena fabricated five complete sets of apparatus, including the phase microscope, 35 millimeter camera, arc and incandescent light source, interval timer or time-lapse mechanism, and work table. These were sold for 10,000 Rm. and were distributed to the following institutions:

Reichs Anstalt für Film und Bild in Wissenschaft und Unterricht
(Government Agency for Visual Education), 12 Kleist Str., Berlin.

I. G. Farbenindustrie, A.G., Frankfurt-Höchst Laboratories.

Figure A.135: Invention, demonstration, and technology transfer of phase-contrast microscopy [FIAT 1059 Supplement].



Tropen Institut for Tropical Medicine, Hamburg.

Bakteriologische Institut for Milk Research, Kiel.

One remained in the Zeiss factory at Jena, where a film showing the meiosis cycle in the cells of an insect was produced by Dr. Kurt Michel, of the Zeiss Firm prior to the termination of hostilities. German scientists consulted on this subject have generally concurred in a belief that such equipment will have important applications not only in visual education but also as a primary instrument in biological and medical research, as for example in the solution of the cancer problem and in movement studies.

It has not been planned to produce such apparatus at Zeiss Opton, Oberkochen, in quantities for sale, but only on special order. The gear ratios for the mechanical-time lapse element design have been calculated and are shown in Figure 5. The following hints on technique have been obtained from Dr. Kurt Michel, of Zeiss Opton, and Dr. Werner J. Faasch, formerly of the Reichs Anstalt.

The installation is quite sensitive to building vibrations and in all installations in Germany has been set up on firm foundations in a cellar, where no difficulties from this source have been encountered.

There should not be a rigid connection between the camera and the microscope. Extraneous light may be excluded at this juncture by means of a light trap.

There may be a rigid connection between the camera and the shutter timing mechanism, except in the case of the Askania all-electric design, in which there was some shock vibration on closure of certain electromagnetic couplings.

The ordinary incandescent microscope light source is quite satisfactory for slow motion plant and certain animal growth processes shown best by exposure rates of about eight per minute or less. For more rapid movements requiring up to 120 exposures per second, a more intense source such as an arc is required.

Many microorganisms are very sensitive to light which may cause them to turn away from it, modify their normal growth processes or behavior, or it may even kill them. The time-lapse mechanism should therefore include circuits for shutting off the microscope lamp except during the exposures. This is of particular importance when the production of film records may extend over periods of hours or days.

Light flicker in the finished film may result from either a flicker in the arc light source or from uneven photo-development processing.

Standard 35 millimeter film is to be preferred over sub-standard sizes because it permits more precise calculations of object dimensions from measurements of images on the film.

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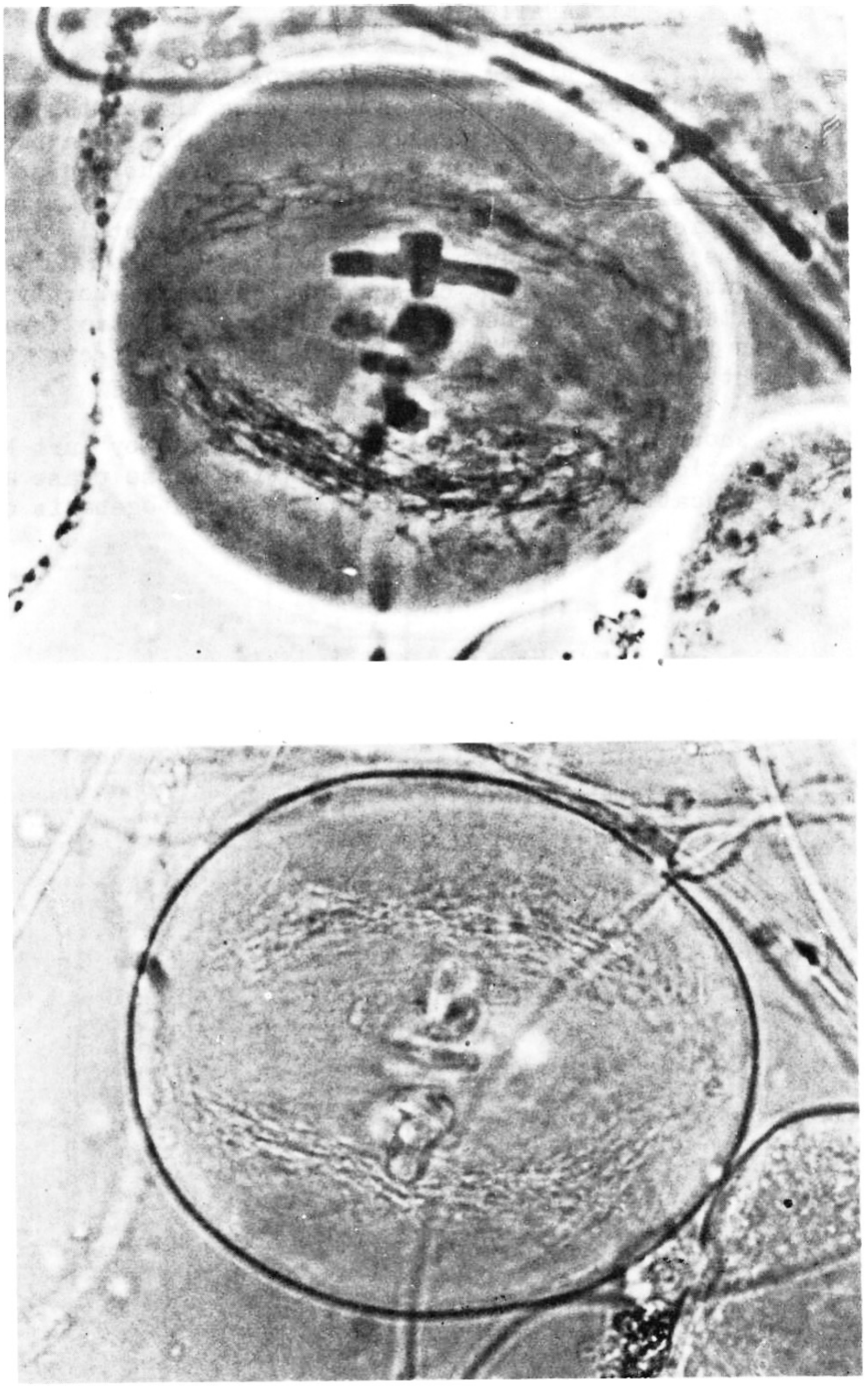
Figure A.136: Invention, demonstration, and technology transfer of phase-contrast microscopy [FIAT 1059 Supplement].

Figure 6



Chromosomes and mitochondria in sperm cell of an insect.
Above: phase contrast photograph.
Below: bright-field photograph of the same cell.

Figure A.137: Invention, demonstration, and technology transfer of phase-contrast microscopy [FIAT 1059 Supplement].

A.2 Prostheses and Neural Interfaces (Bionics)

[Due to the combination of strong support for scientific innovation and the large numbers of people with war injuries, the German-speaking world led the development of prosthetic limbs. The development of prostheses also overlapped with the development of methods for interfacing electrical or electromechanical systems with the human nervous system.

In 1808, Albrecht Ludwig Berblinger (German states, 1770–1829) developed the first prosthetic legs with movable joints, which made the legs much more practical to use. See p. 398. (Berblinger also made early attempts at developing manned gliders.)

Jakob Riedinger (German, 1861–1917) developed a prosthetic arm with movable joints, the "Würzburg working arm." See p. 399. He also established national programs to treat and to assist the disabled.

During World War I, Ferdinand Sauerbruch (German, 1875–1951) invented the first prosthetic arms that could be controlled by residual arm stump muscles, a design that became known as the "Sauerbruch arm." See p. 399. In 1904, Sauerbruch also invented a pressurized chamber (the "Sauerbruch chamber") for much more safely opening the thorax of a patient to conduct operations on the heart or lungs.

Georg Schlesinger (German, 1874–1949) worked with Jakob Riedinger and Ferdinand Sauerbruch to design and build improved prosthetic arms and legs during and after World War I. See p. 399. Schlesinger also spent much of his career improving the standardization, testing, and calibration of machine tools.

From the nineteenth century onward, numerous scientists from the German-speaking world experimented with electrodes to carry signals to or from the brains of animals or humans (pp. 232 ff). Those scientists included Gustav Fritsch (German, 1838–1927), Eduard Hitzig (German, 1838–1907), Jacques Loeb (German, 1859–1924), Oskar Vogt (German, 1870–1959), Cécile Vogt-Mugnier (French but worked in Germany, 1875–1962), and Walter Rudolf Hess (Swiss, 1881–1973).

In 1924, Hans Berger (German, 1873–1941) invented electroencephalography (EEG), the method of detecting, measuring, and recording human brain waves. Napoleon Cybulski (Polish, 1854–1919) and Adolf Beck (Polish/Austrian, 1863–1942) also carried out early experiments in electroencephalography. See p. 259.

During and after World War II, Ulrich Henschke (German, 1914–1980) and Hans Mauch (German, 1906–1984) further advanced those two lines of research—prostheses and electrical interfaces with the human nervous system. They also combined those two areas of research by trying to develop prosthetic limbs or prosthetic sensory systems that could interface with the human nervous system, creating a new field that later became known as "bionics." (The term bionics was coined in 1958 at the U.S. Air Force laboratory where Henschke and Mauch worked—see p. 2493—and was subsequently popularized by Martin Caidin's 1972 novel *Cyborg* and the 1970s television series based on it, *The Six Million Dollar Man* and *The Bionic Woman*).

Also during the war, Ulrich Henschke and Hans Mauch headed an aviation medicine research institute that aimed to improve the efficiency of human-operated weapons systems. [There are brief mentions of Henschke and Mauch and a group photo in Campbell and Harsch 2013.] It appears that they explored neural interfaces for those applications as well, since such interfaces could improve the response times for pilots and weapons operators and give them an advantage over their opponents who had to physically move controls with their hands and feet, or help pilots respond more rapidly in controlling high-speed jets, rocket planes, or rockets.

As an example of how pilot response times were considered a major factor and a research priority at the highest levels, Heinrich Himmler's adjutant, Werner Grothmann, reported that Himmler had concerns about piloted long-range rockets (p. 5359):

> Either someone pilots the rocket into the target, or it must go fully automatic. Himmler was skeptical as to whether a pilot could react at that speed. I mean, the rocket was supposed to fly several thousand kilometers.

(For fictional examples of how a neural interface system might be advantageous for a pilot's reaction times, see the 1977 Craig Thomas novel *Firefox* and its 1982 film adaptation.)

Some of the more advanced work of Henschke and Mauch was mentioned in the documents quoted in this section, but detailed reports by Henschke and Mauch or detailed reports by others assessing that work have never been publicly released. Can those reports be located in archives and declassified? Just how far did their work progress, both during and after the war? What direct or indirect effects did it have on later work in this field?

Categories of users that were or likely would have been considered for the neural interface work would have included:

- Handicapped or injured people (pp. 2488–2491).
- Pilots of manned airplanes, jets, rocket planes, and rockets (pp. 2488, 2492, 2506–2508, 2513).
- Operators of remotely guided missiles or other weapons systems (pp. 2488, 2492, 2506–2508, 2513) [NavTecMisEu 229-45].
- Operators of teleoperated robots (Section 6.7.4).

Interface methods that were or likely would have been considered for the neural interface work would have included:

- Signals in peripheral nerves (pp. 239–243, 336, 2488–2491).
- Brain waves or other signals in the central nervous system (pp. 259, 2489).
- Eye motions (pp. 2506–2508).

Interfaced devices that were or likely would have been considered would have included:

- Prosthetic legs (pp. 2488–2491).
- Prosthetic arms (pp. 2488–2491).
- Visual prostheses (pp. 2488–2489, 2491, 2509–2513).
- Aircraft or other vehicle controls (pp. 2492, 2506–2508, 2513).
- Remotely guided missiles or other weapons system controls (pp. 2492, 2506–2508, 2513) [NavTecMisEu 229-45].

Other work by Henschke and Mauch was better documented in publicly available sources:

- Henschke and Mauch developed what ultimately became known as the Swing-aNd-Stance (S-N-S) hydraulically controlled prosthetic leg, which has been used worldwide for decades since then. See pp. 2494–2504 and 2509–2513.
- Henschke and Mauch developed and patented a tachistoscope that could present high-speed visual information to a user and monitor the person's reactions (pp. 2506–2508). It seems likely that the tachistoscope was part of a larger program to test and improve the reaction times of pilots and weapons systems operators using neural interfaces as compared to manual controls.
- During the war, Henschke also developed simulators for training operators of remotely guided missiles [NavTecMisEu 229-45].
- Henschke and Mauch designed a variety of aviation control systems (pp. 2492, 2513).
- Henschke developed brachytherapy methods for treating cancer (p. 2514).
- Mauch played a key role in the early development of jet engines and jet aircraft (p. 1764).
- Mauch designed space suits (p. 2513).
- Henschke and Mauch conducted other work in aviation medicine (pp. 2488–2489, 2513) [Campbell and Harsch 2013].

Was similar work on neural interfaces for prostheses and/or weapons systems conducted by other German-speaking scientists? It seems likely, since the German-speaking world pioneered the relevant fields, and there would have been strong demand for such applications.

Much more archival research needs to be conducted in order to investigate the hypotheses I have outlined above and to elucidate the true and complete history of German-speaking work in these areas.]

Charles A. Lindbergh. 1970. *The Wartime Journals of Charles A. Lindbergh.* New York: Harcourt Brace Jovanovich. pp. 977–978.

From Oberammergau Lieutenant Uellendahl and I drove to Garmisch-Partenkirchen to see the Medical Research Institute operated by Dr. [Ulrich] Henschke, located on the slope of a mountain—a small institute, simply built and simply but very intelligently run. Dr. Henschke, a man in his mid thirties, turned out to be a great admirer of Dr. Carrel—had studied *Man the Unknown* with care and understood it as no one else I have talked to. He had a copy of *The Culture of Organs* on his shelves, and the Swiss edition of *Listen! the Wind*. He says his greatest ambition is to have an institute such as Carrel wrote of.

We discuss a number of Dr. Henschke's projects: gunnery sights, artificial limbs, hearing for the blind, cellular emanations, etc. He shows us through his laboratories—small buildings like mountain cabins—views of Alps and valleys through the windows—ideal places for creative work. In one he is testing new methods of controlling guns in aircraft. "It is best to use only one group of muscles." He has a stick (pilot's) with a bar on top which acts as a rudder, "so it is not necessary to use the feet at all in aiming a fighter." I protest, saying that I think we are getting too far away from monkeys anyhow, and that I do not see why we should not also use our feet. He asks me to try it out for myself—a rather crude affair made quickly out of plank and wire. I get down in the seat while the apparatus is adjusted.

At one end of the room is a rotating stick, at the end of which a photoelectric cell is fastened. A spotlight is fastened to the stick, and one is supposed to keep the light beam on the photoelectric cell. As long as the beam covers half or more of the cell, a counter, set to the rate of fire of a machine gun, is in operation. When the beam covers less than half the cell, the counter stops operating. By means of a stop watch the number of hits per minute are counted.

I found that I made a much better score when using the stick alone, which I have never done before, than when the spotlight was hooked up to the rudder and stick as in a normal fighter. The difference was several hundred per cent in favor of the former method! However, in fairness, it must be said that the rudder hookup was cramped and jerky. But this is not enough to account for the great difference in the number of hits I made. I tried removing my heavy G.I. boots and doubled my previous score with the conventional controls—one has a much better "feel" with his shoes off. But the advantage of controlling everything with the arms, "one group of muscles alone," was still apparently great.

At another small building Dr. Henschke showed us where he was developing artificial limbs which would be actuated by the nerves and muscles of the stump. He demonstrated with two German soldiers, one of whom had lost an arm and the other a leg.

Joyce Milton. 1993. *Loss of Eden: A Biography of Charles and Anne Morrow Lindbergh.* New York: HarperCollins. pp. 415–416.

Charles worked for United Aircraft in Connecticut until May of 1945, and shortly after V-E day, he joined a Naval Technical Mission in Europe as a civilian representative of the corporation. [...]

Joining the Technical Mission in Munich, Lindbergh became part of a team of observers who drove their jeeps into territory where the Wehrmacht, defeated but not yet demobilized, was still in effective control. [...] Lindbergh's group located Professor Willy Messerschmitt, who was living in a barn; Dr. Felix Kracht, the inventor of the rocket glider; Dr. Helmut Schelp, assistant head of development of the jet and rocket propulsion program; Dr. Franz Josef Neugebauer, who was working on a design for a nuclear-propelled aircraft; Dr. August Lichte, a developer of the Junker JU 004 turbojet engine; and Dr. Ulrich Henschke, who was working on artificial limbs capable of being controlled by neurological impulses.

CIOS ER 97. *Luftfahrt-Forschungsanstalt München Medizinisches Institut Garmisch-Partenkirchen.* 14 June 1945. [This report is filled with spelling, capitalization, and grammatical errors that have been silently corrected here to make it more readable. The Germans who carried out this scientific work were conducting research decades ahead of their time. The Americans who reported on this scientific work could not even spell.]

In 1942 a "Research Order" was given to Dr. U. Henschke to form a new Aviation Medical Research Institute. It worked at first in connection with the Radiology Institute of the University of Berlin, and in June 1943 it was designated as an aeronautical research institute of Munich and called "Work-group Henschke." It was evacuated in 1944 to Garmisch-Partenkirchen to devote full time to aviation medicine. The institute now has departments in all major branches of aviation medicine, but some department heads were away to their respective universities and private homes at the time of German collapse and have been unable to return. The following research problems are among those on which the institute had been working with a brief summary of the type of work: [...]

J. Research on Prostheses.

For the past few months this institute had devoted most of its time to work on "eye prostheses" and extremity prostheses. Briefly, apparatuses have been constructed using selenium cells and photoelectric cells which convert visual stimuli into auditory sense. In the problem of limb prostheses the approach has been that of using the impulses of the amputated nerve to direct electro-mechanical prostheses which will be controlled mentally. This problem is in the beginning stages but work on it is going on at present. Beginning work on measurement of brain waves with apparatus capable of focusing on certain parts of the brain has also started.

Germans Tried to Develop Controlled Artificial Leg. *St. Joseph Gazette* (St. Joseph, Missouri), 19 September 1946, p. 7 [https://news.google.com/newspapers?id=zypaAAAAIBAJ&sjid=HkwNAAAAIBAJ&hl=es&pg=1168%2C1131947].

WRIGHT FIELD, Ohio, Sept. 18.—(INS)—An American intelligence team was reported tonight to have learned that German scientists experimented during the war on an artificial leg activated by impulses from the human brain.

According to information gained by an air materiel command technical intelligence team, the leg used electro-mechanical devices wired to the severed nerve endings.

Tonight's announcement from the Wright Field public relations office added:

"The Germans believed that galvanic electricity flowing along the nerves would supply the power impulses and that these could be controlled mentally, manipulating the leg according to the wishes of the wearer.

"Investigators believe that varying degrees of concentration were to be employed by the amputee on the theory that mental intensity would act like a rheostat, controlling the amount of nervous electricity and moving the leg in the manner desired. The Germans were as much interested in proving the disputed point of the existence of nervous electricity as they were in perfecting a fool-proof artificial leg.

Moved to Mountain Haven

"Originally located in Munich, the Aeronautical Research Institute was moved in August, 1944 to Garmisch-Partenkirchen, a mountain retreat where each scientist was given a combined house and laboratory of his own.

"These units were located 300 feet apart so that the occupants could work undisturbed. The mountain site was selected because its beauty lent itself to new ideas." Physicians, technicians, physicists, chemists, and psychologists were employed there. The institute was supported principally by the University of Munich and the German air force.

"While the electrical leg was still in the experimental stage when the war ended, the institute had completed work on an artificial limb, considered superior to any prosthetic device previously used. This was a hydraulic leg depending on a hand-operated valve and a piston-like arrangement in the calf.

Knee Controlled by Valve

"This artificial limb owes its success largely to the valve controlling the knee action. For standing, walking, or ascending and descending inclines, the knee joint must be maintained at various angles. The hydraulic system used in this leg does this with the voluntary control valve.

"A slight pull at the valve allows a slow knee flexion. A medium pull provides knee fixation, and a strong pull permits its extension. The last is essential in climbing stairs or inclines and makes it possible for the amputee to do this in a natural manner.

"Another interesting institute development was an artificial arm in which the hand was moved by a magnet and controlled by the stump muscles. Magnets also were used in another type of knee which was controlled in the same manner."

Ambitious Experiment: Brain-Controlled Artificial Leg was Goal of Nazi Scientists. *Press and Sun-Bulletin* (Binghamton, New York), 19 September 1946, p. 1.

When V-E Day ended their work, German scientists were attempting to perfect an artificial leg that could be controlled by impulses from the human brain. [...]

The scientists had also developed an artificial arm moved by magnets, and photo-electric and selenium cells to convert visual stimuli into auditory channels for the blind.

[Versions of this story also appeared in many other newspapers, such as:

Austin American-Statesman (Austin, Texas), 19 September 1946, p. 21.

Muncie Evening Press (Muncie, Indiana), 19 September 1946, p. 6.

The Tipton Daily Tribune (Tipton, Indiana), 20 September 1946, p. 7.

Journal Gazette (Mattoon, Illinois), 19 September 1946, p. 1.

Press and Sun-Bulletin (Binghamton, New York), 19 September 1946, p. 1.

Journal and Courier (Lafayette, Indiana), 25 September 1946 p. 15.

The Dayton Herald (Dayton, Ohio), 19 September 1946, p. 24.

The Knoxville News-Sentinel (Knoxville, Tennessee), 22 September 1946, p. 36.

The Knoxville Journal (Knoxville, Tennessee), 2 December 1946, p. 14.

Dayton Daily News (Dayton, Ohio), 19 September 1946, p. 10.

Clarion-Ledger (Jackson, Mississippi), 1 December 1946, p. 15.

El Paso Herald-Post (El Paso, Texas), 20 September 1946, p. 12.

The Times Recorder (Zanesville, Ohio), 19 September 1946, p. 1.

The Billings Gazette (Billings, Montana), 20 September 1946, p. 5.

The Vancouver Sun (Vancouver, British Columbia, Canada), 20 September 1946, p. 14.

The Ogden Standard-Examiner (Ogden, Utah), 20 September 1946, p. 2.

Nashville Banner (Nashville, Tennessee), 19 September 1946, p. 1.

Tucson Daily Citizen (Tucson, Arizona), 20 September 1946, p. 3.

Fort Worth Star-Telegram (Fort Worth, Texas), 19 September 1946, pp. 7, 39.

Fort Worth Star-Telegram (Fort Worth, Texas), 20 September 1946, p. 11.

The Evening Review (East Liverpool, Ohio), 19 September 1946, p. 12.

The Evening Independent (Massillon, Ohio), 19 September 1946, p. 14.

The Zanesville Signal (Zanesville, Ohio), 19 September 1946, p. 15.

The Newark Advocate (Newark, Ohio), 19 September 1946, p. 2.

Bucyrus Telegraph-Forum (Bucyrus, Ohio), 19 September 1946, p. 8.

Lancaster Eagle-Gazette (Lancaster, Ohio), 19 September 1946, p. 13.

The Marion Star (Marion, Ohio), 19 September 1946, p. 5.]

Ulrich K. Henschke and Hans A. Mauch. How Man Controls. In: Strughold, Hubertus, ed. 1950. *German Aviation Medicine, World War II.* 2 vols. Washington, D.C.: U.S. Government Printing Office. Vol. 1, pp. 83–91.

Starting from the need for better adaptation of aircraft controls to man, a new field of aviation medicine, the study of human control, was established.

The best approach was found to be the investigation and description of the behavior of man, while he controls, by the same experimental and mathematical methods as are used in regulator mechanics.

From this viewpoint, the following was found concerning the behavior of man in control cycles:

1. The transition function of man in simple control cycles corresponds in principle to that of an astatic transmission system with a delay time of about 0.2 second. It resembles in some respects the transition function of a so-called sampling transmission system operating in a stepwise manner.

2. In other control cycles with more complicated mechanical elements, man can perform other transition functions. The process of learning how to control can be interpreted by saying that man tends toward a transition function which is best adapted to the other parts of the control cycle.

3. Optimal regulation by man is reached, if the other parts of the regulation cycle are designed to make possible working of man with the same transition function as in simple control cycles consisting of a man as regulator and of a lever system as regulation section.

4. The use of man in control cycles is more desirable than that of an automatic regulator only if determination of the measuring value by the human eye and by the human brain takes an essential part in the regulation process.

R. R. Roth. 1983. The Foundation of Bionics. *Perspectives in Biology and Medicine* 26:2:229–242 [https://muse.jhu.edu/article/403622/pdf].

The word "bionics," as it appears today, originated with Maj. (later Col.) Jack E. Steele of the Aerospace Division of the U.S. Air Force, from the Greek word for life and suffix "ic," meaning "having the nature of". According to Steele, he coined the term in August 1958 to promote bionics as a new science. The research program, which was to receive the name "bionics" in the spring of 1959, was inaugurated at the Wright-Patterson Center of the U.S. Air Force. Bionics was under discussion, for the first time, at the Twelfth Annual Aeronautical Electronics Conference, held in May 1960. One session of the meeting, under the chairmanship of Dr. John E. Keto of the U.S. Air Force, was devoted to bionics. Four papers on bionics were read, including one by Major Steele. They were published in August 1960 in *Waveguide, Dayton Section of the Institute of Radio Engineers*. However, the official launching of the new science took place in September 1960 when 700 engineers, physicists, mathematicians, psychologists, psychiatrists, biologists, and biophysicists were invited to a congress in Dayton, Ohio. About 30 participants spoke about bionics, and a 500-page volume provides the record of the occasion.

[It is probably not a coincidence that the field of bionics was named and publicly inaugurated at the Air Force labs at Wright Patterson where Henschke and Mauch worked or had worked. Could future archival researchers investigate the possible connections between the work of Henschke and Mauch beginning there in 1946 and the public launch of the bionics program in the late 1950s?]

Sept. 6, 1949. U. K. HENSCHKE ET AL **2,480,856**

LEG PROSTHESES

Filed July 9, 1948 3 Sheets-Sheet 1

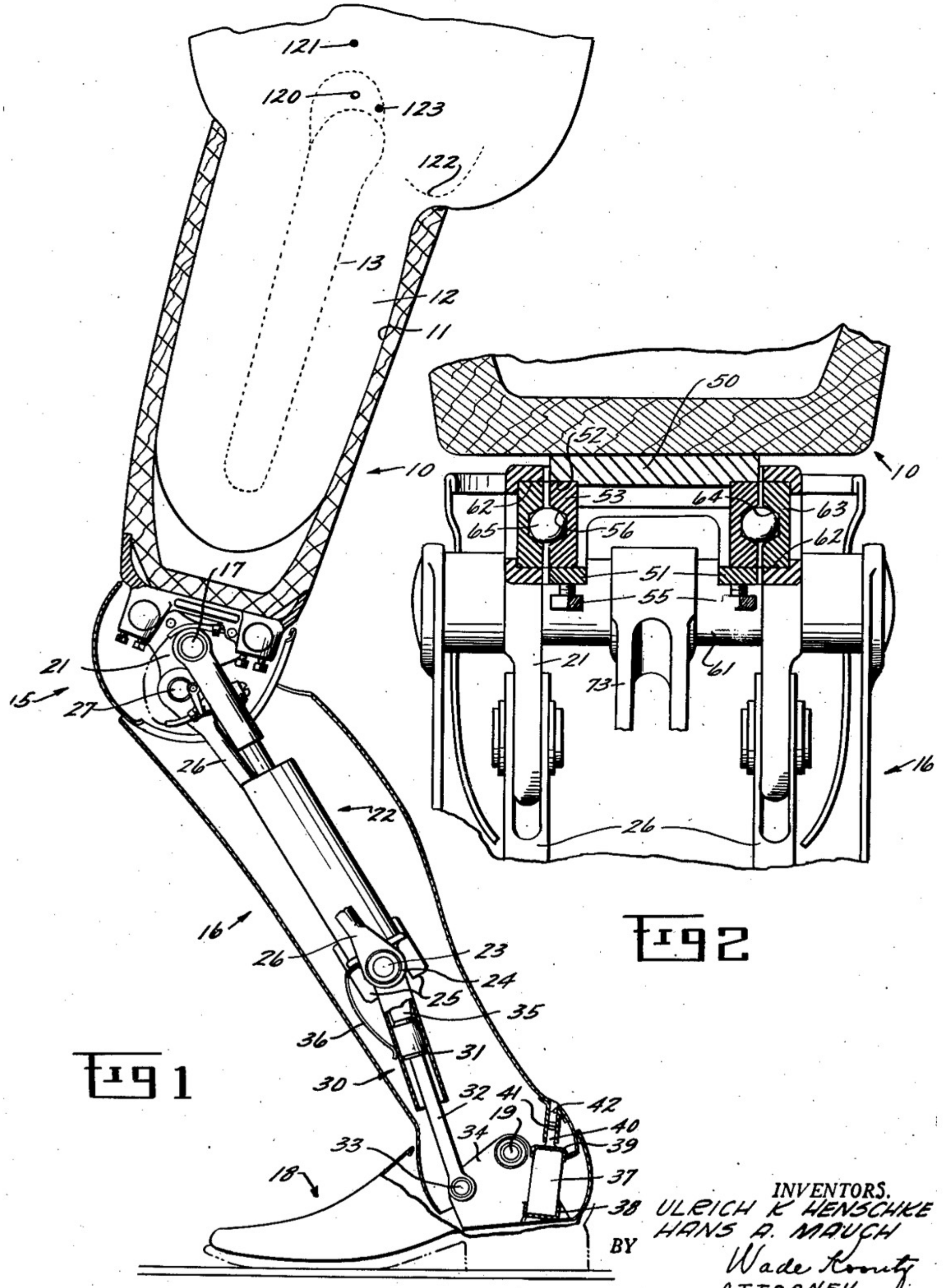

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Fig 2

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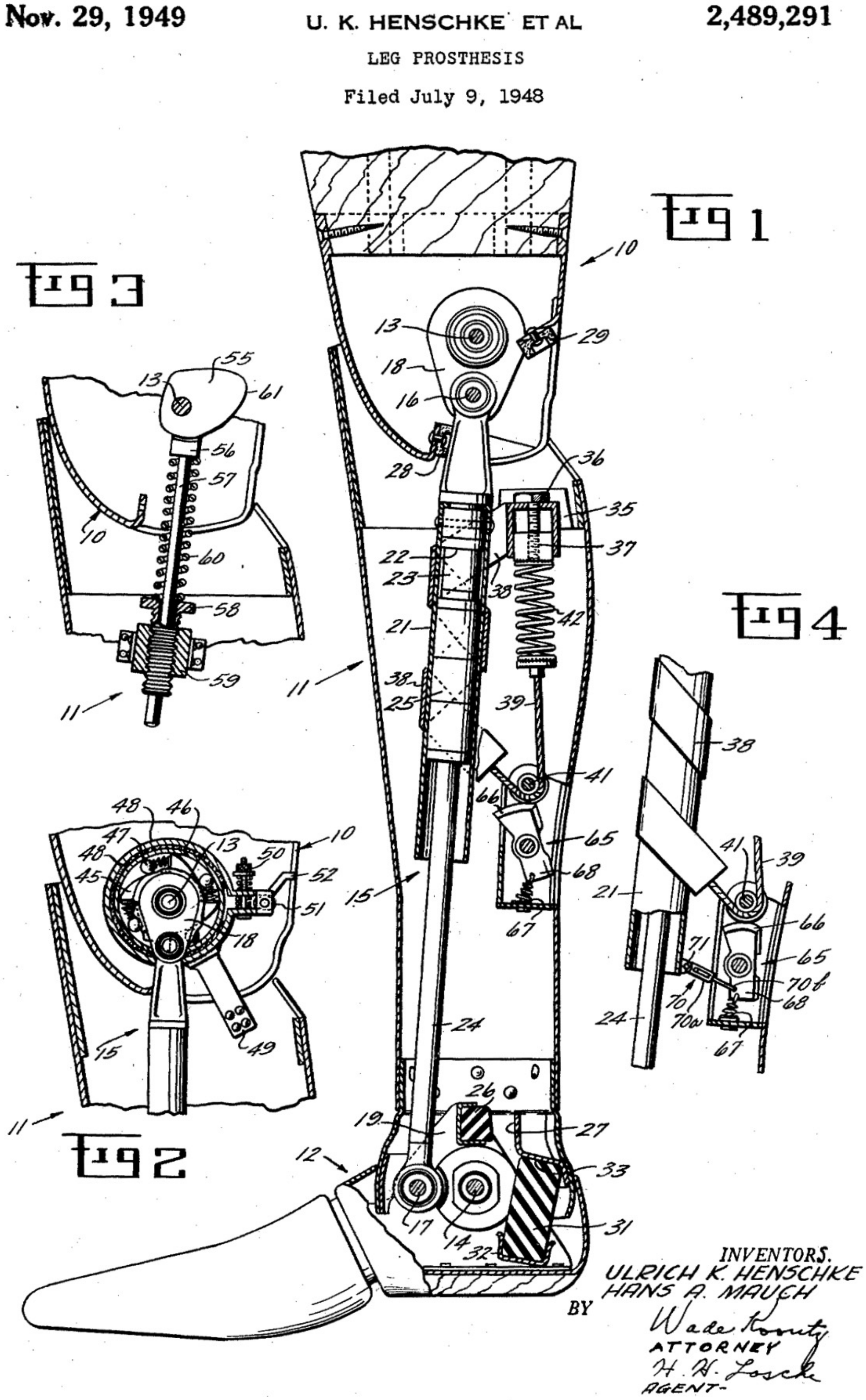
BY Wade Koontz
ATTORNEY
H. H. Losche
AGENT—

Figure A.138: Examples of patents by Ulrich Henschke and Hans Mauch on sophisticated prosthetic legs.



Nov. 29, 1949 U. K. HENSCHKE ET AL 2,489,291

LEG PROSTHESIS

Filed July 9, 1948

INVENTORS.
ULRICH K. HENSCHKE
HANS A. MAUCH
BY
Wade Koontz
ATTORNEY
H. H. Losche
AGENT-

Fig 1
Fig 2
Fig 3
Fig 4
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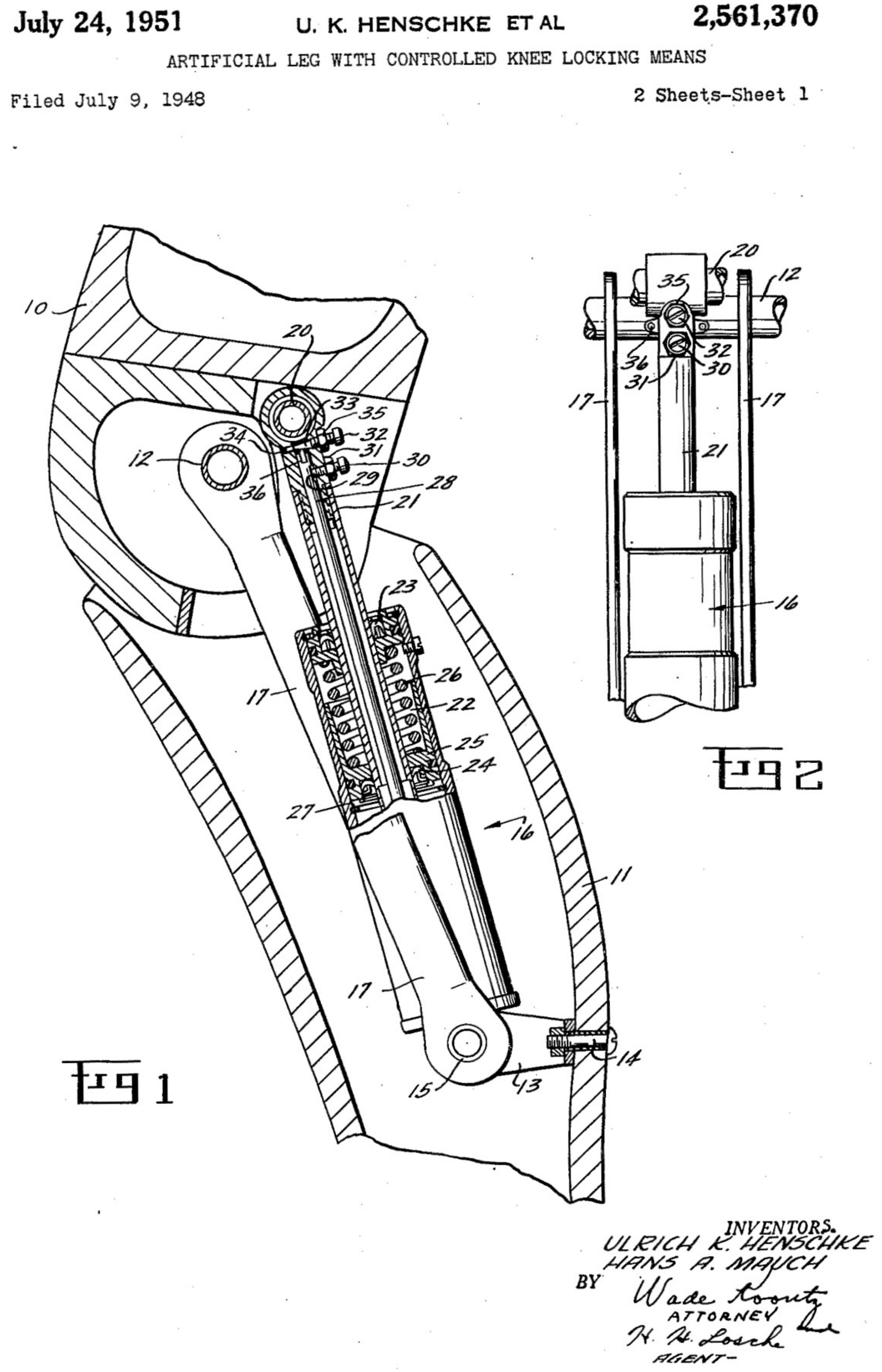
Figure A.139: Examples of patents by Ulrich Henschke and Hans Mauch on sophisticated prosthetic legs.



July 24, 1951 U. K. HENSCHKE ET AL 2,561,370

ARTIFICIAL LEG WITH CONTROLLED KNEE LOCKING MEANS

Filed July 9, 1948 2 Sheets-Sheet 1

INVENTORS.
ULRICH K. HENSCHKE
HANS A. MAUCH
BY Wade Koontz
ATTORNEY
H. H. Losche
AGENT-

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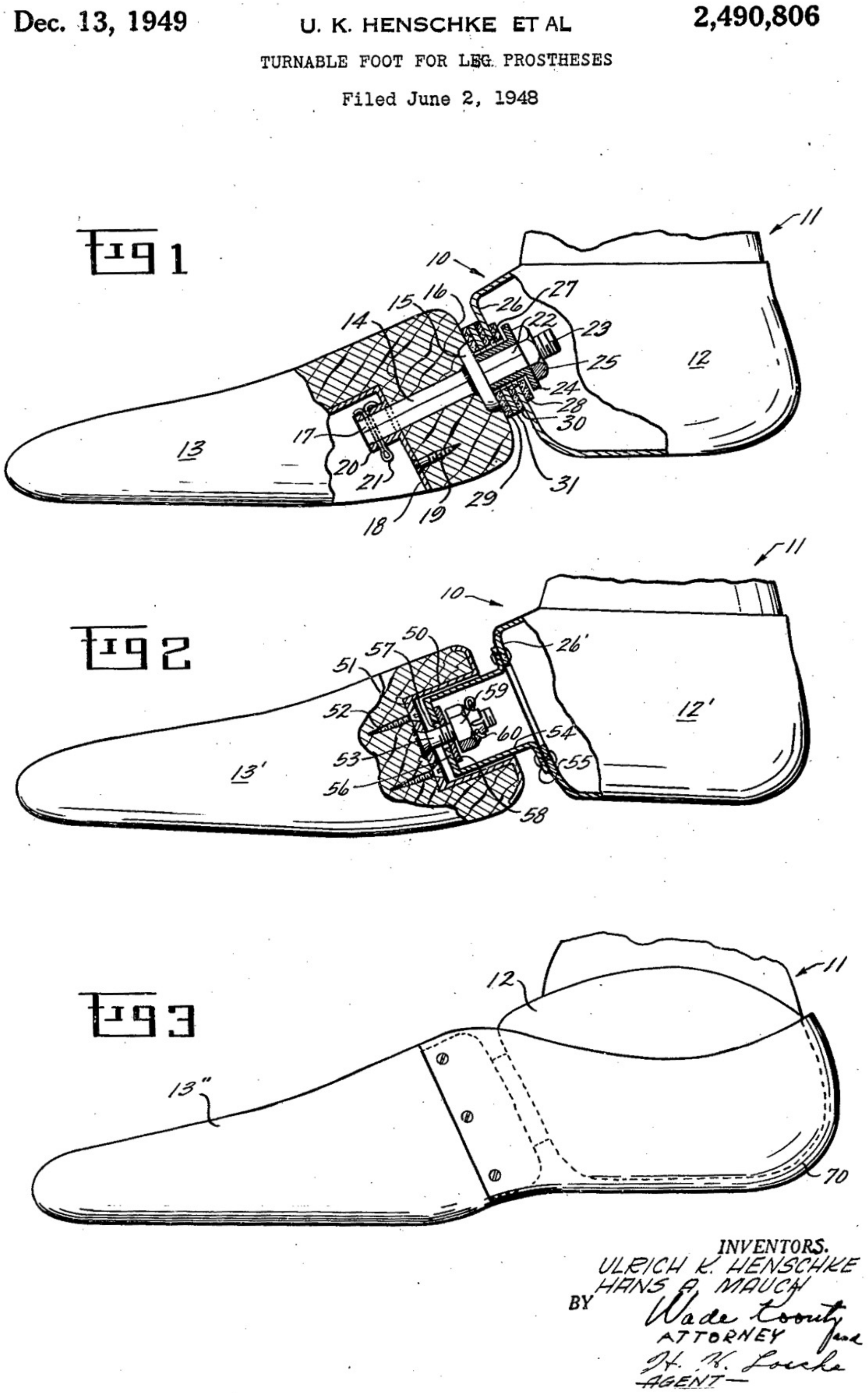
Fig 2

Figure A.140: Examples of patents by Ulrich Henschke and Hans Mauch on sophisticated prosthetic legs.



Dec. 13, 1949 U. K. HENSCHKE ET AL **2,490,806**

TURNABLE FOOT FOR LEG PROSTHESES

Filed June 2, 1948

INVENTORS.
ULRICH K. HENSCHKE
HANS A. MAUCH
BY Wade Koontz
ATTORNEY and
H. K. Loesche
AGENT

Fig 1
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Figure A.141: Examples of patents by Ulrich Henschke and Hans Mauch on sophisticated prosthetic legs.

***Report from Heidelberg: The Story of the Army Air Forces Aero Medical Center in Germany 1945–1947.* 28 February 1947 [http://resource.nlm.nih.gov/14130150R].**

Though of no immediate aero medical significance, one of the most interesting and valuable contributions made by scientists working at the Aero Medical Center was the development of an artificial leg with a hydraulic knee joint which could be controlled by the wearer [p. 2499]. This new type of leg prosthesis, which was devised by Dr. Ulrich Henschke and Ing. Hans Mauch, was turned over by the Air Surgeon, in the summer of 1946, to the Surgeon General for further development and refinement in the United States. A 30-minute sound motion picture entitled "New Principles in Lower Extremity Prosthesis" was produced in Heidelberg by the 8th Combat Crew Camera Unit under the supervision of Major Sebon R. Wallace, former professor of psychology at Tulane University. This movie was presented to leading AAF flight surgeons at a conference in the Pentagon Building in May 1946, and thereafter was made available to the Surgeon General. The hydraulic type of artificial leg developed at the Aero Medical Center attracted considerable attention in the U.S. press [p. 2500] and also was the subject of an article by General Grow in the AAF Review [p. 2504].

[For examples of additional reports on the Henschke-Mauch hydraulic leg, see:

New Artificial Leg Is Made in Germany. *New York Times*, 23 April 1946, p. 3.

Artificial Leg Explained. *New York Times*, 28 April 1946, p. 16.

Artificial Legs. *Maryborough Chronicle, Wide Bay and Burnett Advertiser* (Queensland, Australia), 6 July 1946, p. 5.

New Hope for the Limbless. *Cairns Post* (Queensland, Australia), 9 July 1946, p. 3.

Abdominal Muscles Used to Work New Artificial Leg. *Morning Bulletin* (Rockhampton, Queensland, Australia), 30 July 1946, p. 8.

Ad Hoc Committee on Fluid-Controlled Legs. 1960. *Final Summary Report: Henschke-Mauch "Hydraulik" System, Model B (Swing-Phase Control) for Above-Knee Prostheses.* Washington, D.C.: National Research Council.]

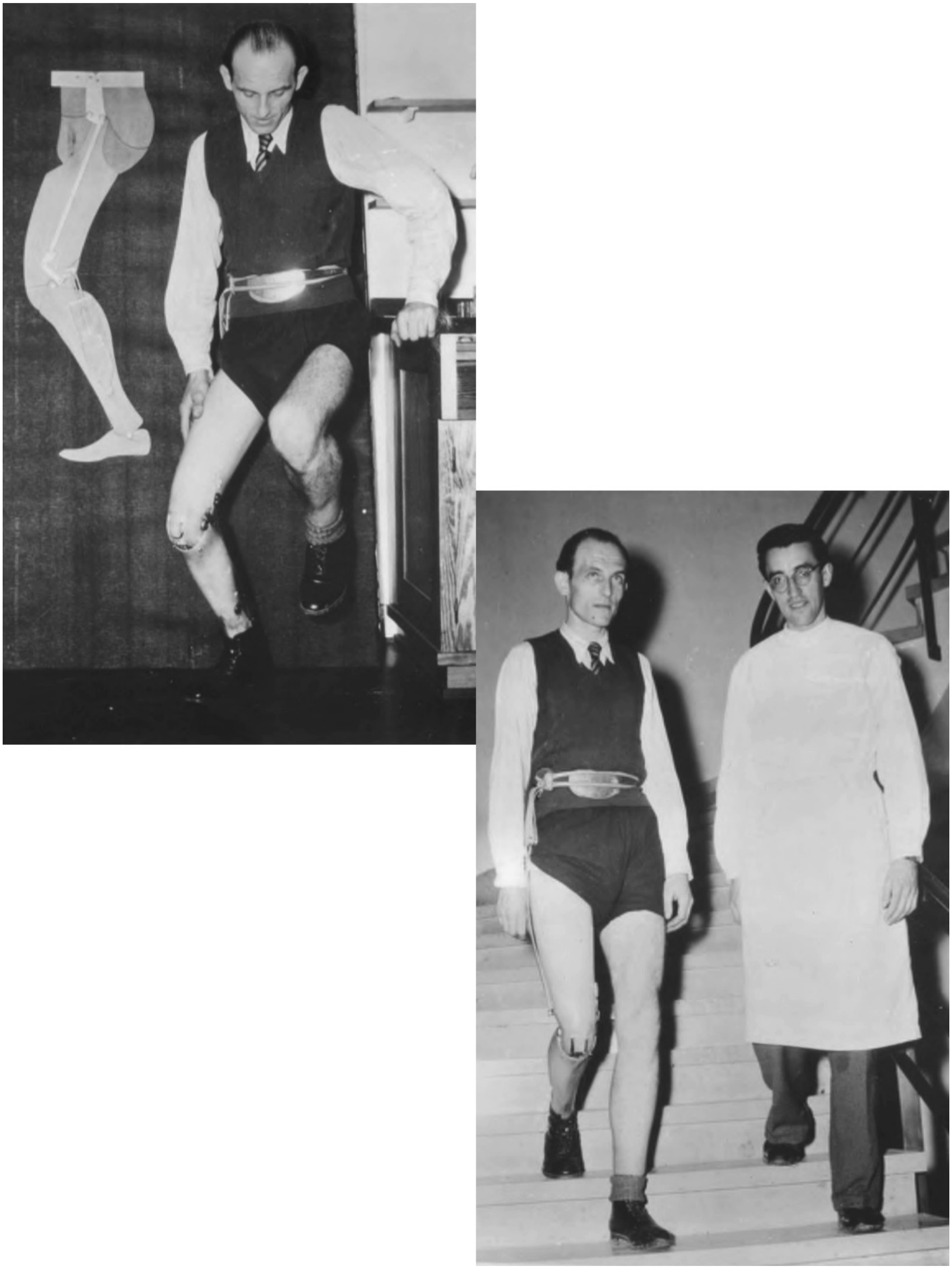
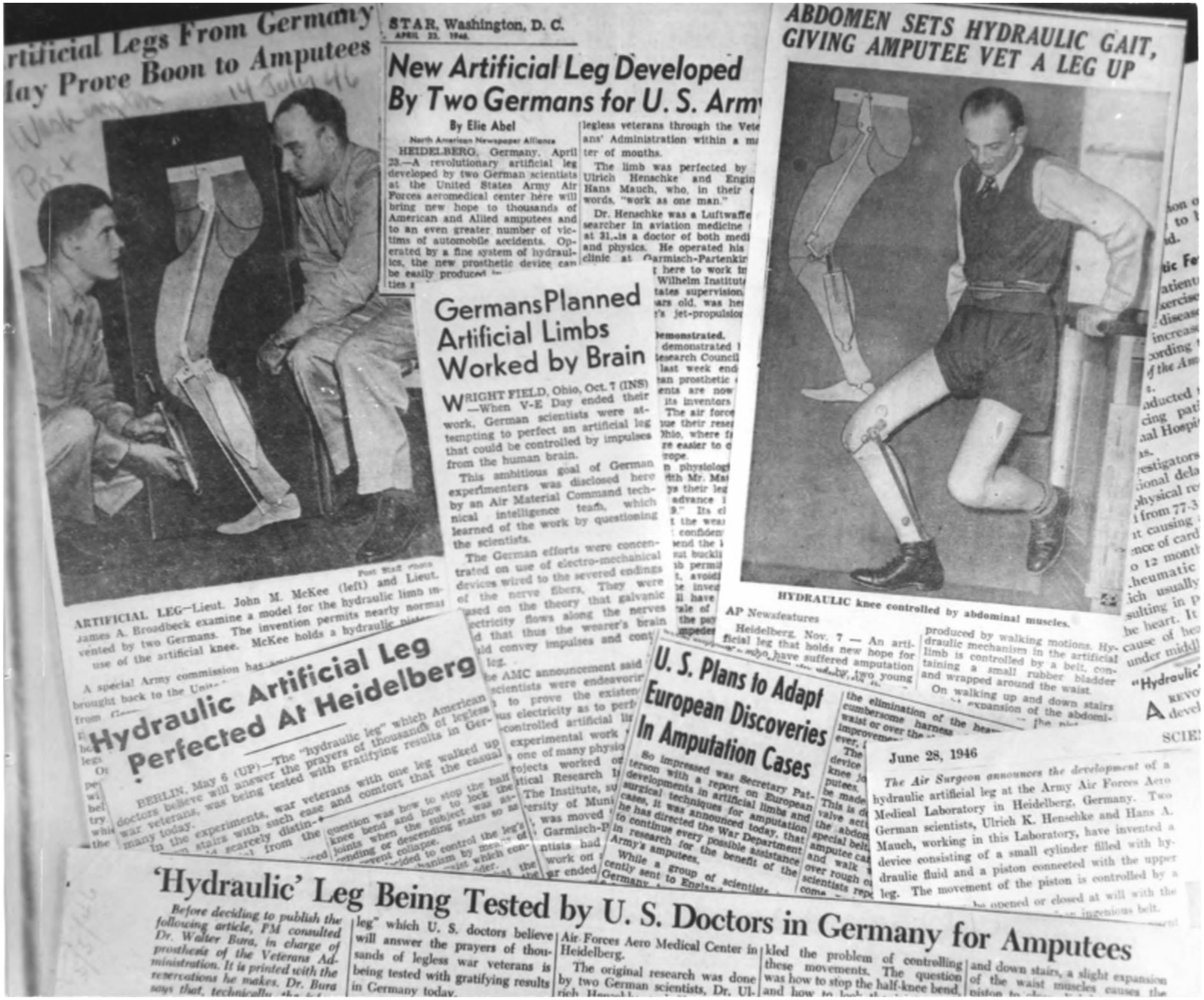


Figure A.142: Ulrich Henschke (in the white lab coat) with an amputee demonstrating that the prosthetic leg made it possible to jump or to walk down stairs without difficulty.



rtificial Legs From Germany
lay Prove Boon to Amputees

Washington Post × 14 July 46

ARTIFICIAL LEG—Lieut. John M. McKee (left) and Lieut. James A. Broadbeck examine a model for the hydraulic limb invented by two Germans. The invention permits nearly normal use of the artificial knee. McKee holds a hydraulic

Post Staff Photo

A special Army commission has
brought back to the Unit

STAR, Washington, D. C.
APRIL 23, 1946.

New Artificial Leg Developed By Two Germans for U. S. Army

By Elie Abel

North American Newspaper Alliance

HEIDELBERG, Germany, April 23.—A revolutionary artificial leg developed by two German scientists at the United States Army Air Forces aeromedical center here will bring new hope to thousands of American and Allied amputees and to an even greater number of victims of automobile accidents. Operated by a fine system of hydraulics, the new prosthetic device can be easily produced

legless veterans through the Veterans' Administration within a matter of months.

The limb was perfected by Ulrich Henschke and Engin Hans Mauch, who, in their words, "work as one man."

Dr. Henschke was a Luftwaffe searcher in aviation medicine at 31, is a doctor of both medi and physics. He operated his clinic at Garmisch-Partenkir

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Germans Planned Artificial Limbs Worked by Brain

WRIGHT FIELD, Ohio, Oct. 7 (INS) —When V-E Day ended their work, German scientists were attempting to perfect an artificial leg that could be controlled by impulses from the human brain.

This ambitious goal of German experimenters was disclosed here by an Air Material Command technical intelligence team, which learned of the work by questioning the scientists.

The German efforts were concentrated on use of electro-mechanical devices wired to the severed endings of the nerve fibers. They were based on the theory that galvanic electricity flows along the nerves and that thus the wearer's brain could convey impulses and cont leg.

The AMC announcement said scientists were endeavoring to prove the existence electricity as to perf controlled artificial li experimental work one of many physio projects worked o tical Research I The Institute, s ersity of Muni was moved Garmisch-P ntists had work on ar ended

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ABDOMEN SETS HYDRAULIC GAIT, GIVING AMPUTEE VET A LEG UP

HYDRAULIC knee controlled by abdominal muscles.

AP Newsfeatures

Heidelberg, Nov. 7 — An artificial leg that holds new hope for who have suffered amputation two young

produced by walking motions. Hydraulic mechanism in the artificial limb is controlled by a belt, containing a small rubber bladder and wrapped around the waist.

On walking up and down stairs expansion of the abdomi-

Hydraulic Artificial Leg Perfected At Heidelberg

BERLIN, May 6 (UP)—The "hydraulic leg" which American doctors believe will answer the prayers of thousands of legless war veterans, was being tested with gratifying results in Germany today.

In the experiments, war veterans with one leg walked up stairs with such ease and comfort that the casual scarcely distin- from the

question was how to stop the half knee bend and how to lock the joints when the subject was ascending or descending stairs so as prevent collapse. decided to control the leg's by means of

---

U. S. Plans to Adapt European Discoveries In Amputation Cases

So impressed was Secretary Patterson with a report on European developments in artificial limbs and surgical techniques for amputation cases, it was announced today, that he has directed the War Department to continue every possible assistance in research for the benefit of the Army's amputees.

While a group of scientists recently sent to England Germany

the elimination of the cumbersome harness waist or over the improvement ever, The device knee puteess be made This is valve act the abdom special belt amputee ca and walk over rough scientists rep come

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June 28, 1946

The Air Surgeon announces the development of a hydraulic artificial leg at the Army Air Forces Aero Medical Laboratory in Heidelberg, Germany. Two German scientists, Ulrich K. Henschke and Hans A. Mauch, working in this Laboratory, have invented a device consisting of a small cylinder filled with hydraulic fluid and a piston connected with the upper leg. The movement of the piston is controlled by a be opened or closed at will with the ingenious belt.

'Hydraulic' Leg Being Tested by U. S. Doctors in Germany for Amputees

Before deciding to publish the following article, PM consulted Dr. Walter Bura, in charge of prosthesis of the Veterans Administration. It is printed with the reservations he makes. Dr. Bura says that, technically

leg" which U. S. doctors believe will answer the prayers of thousands of legless war veterans is being tested with gratifying results in Germany today.

Air Forces Aero Medical Center in Heidelberg.

The original research was done by two German scientists, Dr. Ul-

kled the problem of controlling these movements. The question was how to stop the half-knee bend, and how

and down stairs, a slight expansion of the waist muscles causes the

Figure A.143: Examples of 1946 newspaper articles on the prosthetic and neural interface work of Ulrich Henschke and Hans Mauch.

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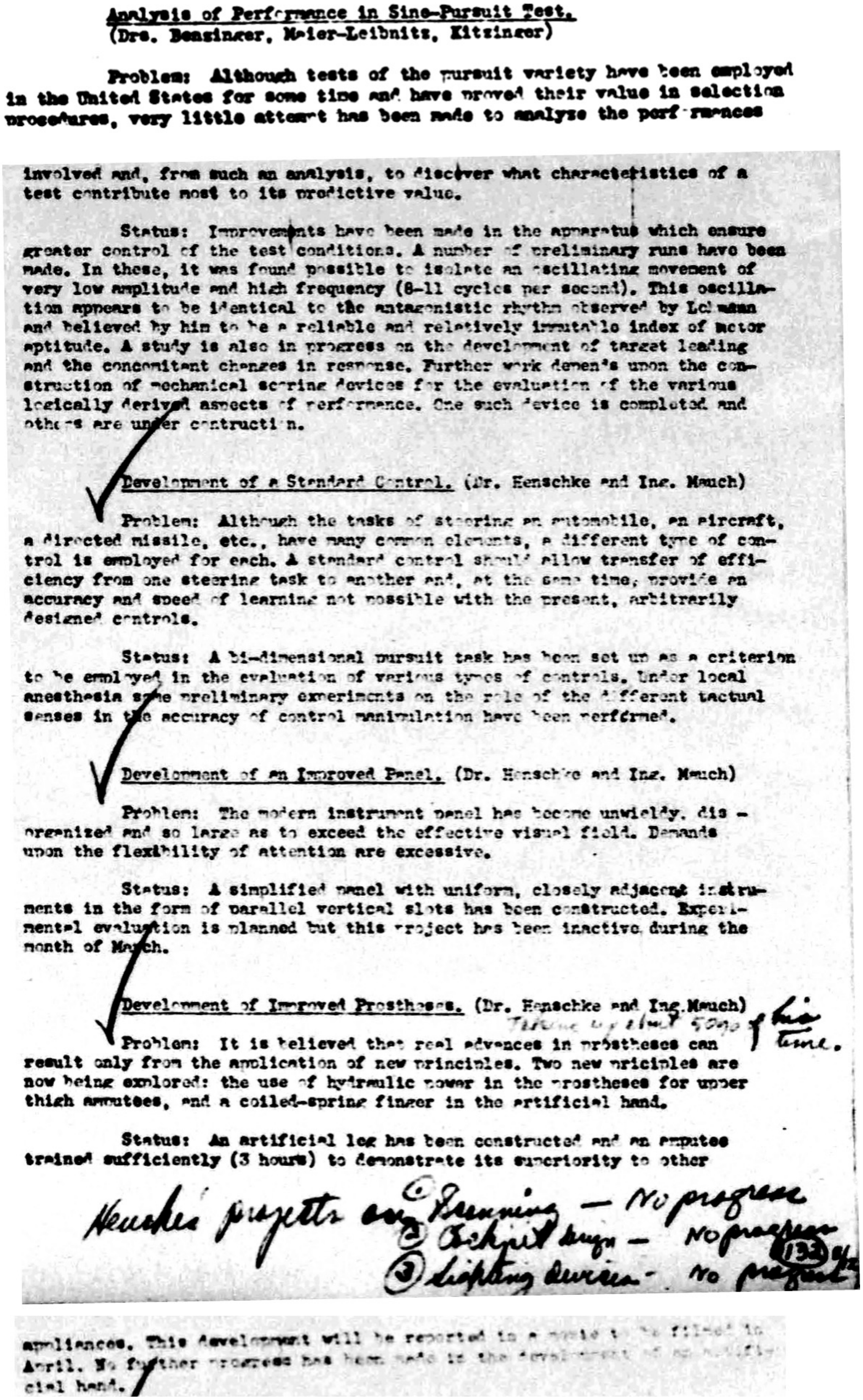

Analysis of Performance in Sine-Pursuit Test.
(Drs. Bensinger, Meier-Leibnitz, Kitzinger)

Problem: Although tests of the pursuit variety have been employed in the United States for some time and have proved their value in selection procedures, very little attempt has been made to analyse the performances involved and, from such an analysis, to discover what characteristics of a test contribute most to its predictive value.

Status: Improvements have been made in the apparatus which ensure greater control of the test conditions. A number of preliminary runs have been made. In these, it was found possible to isolate an oscillating movement of very low amplitude and high frequency (8-11 cycles per second). This oscillation appears to be identical to the antagonistic rhythm observed by Lehmann and believed by him to be a reliable and relatively immutable index of motor aptitude. A study is also in progress on the development of target leading and the concomitant changes in response. Further work depends upon the construction of mechanical scoring devices for the evaluation of the various logically derived aspects of performance. One such device is completed and others are under contruction.

✓ **Development of a Standard Control.** (Dr. Henschke and Ing. Mauch)

Problem: Although the tasks of steering an automobile, an aircraft, a directed missile, etc., have many common elements, a different type of control is employed for each. A standard control should allow transfer of efficiency from one steering task to another and, at the same time, provide an accuracy and speed of learning not possible with the present, arbitrarily designed controls.

Status: A bi-dimensional pursuit task has been set up as a criterion to be employed in the evaluation of various types of controls. Under local anesthesia some preliminary experiments on the role of the different tactual senses in the accuracy of control manipulation have been performed.

✓ **Development of an Improved Panel.** (Dr. Henschke and Ing. Mauch)

Problem: The modern instrument panel has become unwieldy, disorganized and so large as to exceed the effective visual field. Demands upon the flexibility of attention are excessive.

Status: A simplified panel with uniform, closely adjacent instruments in the form of parallel vertical slots has been constructed. Experimental evaluation is planned but this project has been inactive during the month of March.

✓ **Development of Improved Prostheses.** (Dr. Henschke and Ing. Mauch)

Taking up about 50% of his time.

Problem: It is believed that real advances in prostheses can result only from the application of new principles. Two new priciples are now being explored: the use of hydraulic power in the prostheses for upper thigh amputees, and a coiled-spring finger in the artificial hand.

Status: An artificial leg has been constructed and an amputee trained sufficiently (3 hours) to demonstrate its superiority to other

Henschke's projects are ① Training — No progress
② Cockpit design — No progress
③ Lifting devices — No progress

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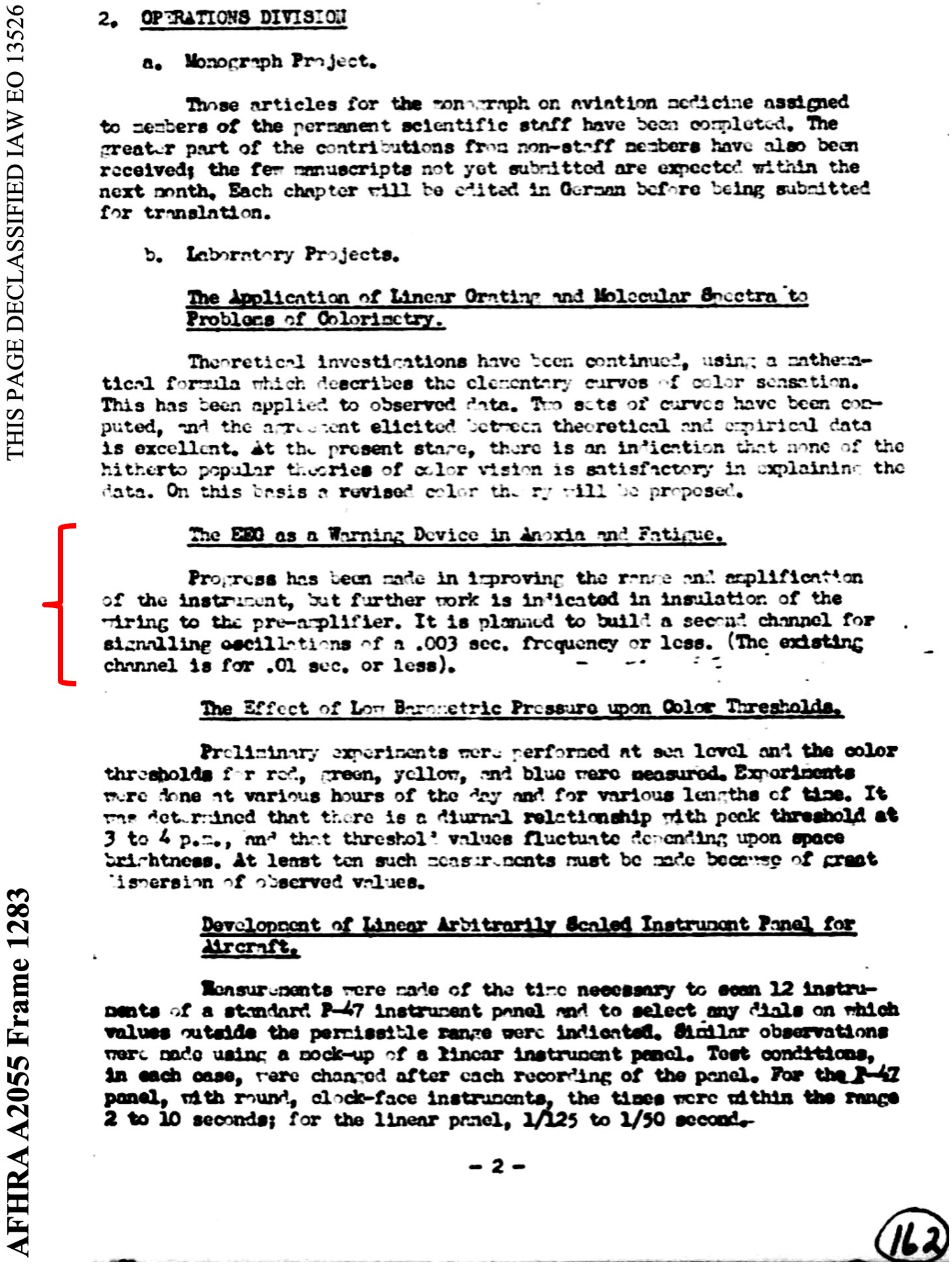
appliances. This development will be reported in a movie to be filmed in April. No further progress has been made in the development of an artificial hand.

AFHRA A2055 Frames 1214-1216

Figure A.144: Examples of prosthetic and neural interface work by Ulrich Henschke, Hans Mauch, and other German experts at Wright Field. Francis J. Nied. 31 March 1946. AAF Aero Medical Center Monthly Status Report No. 6 [AFHRA A2055 Frames 1214-1216].



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2. **OPERATIONS DIVISION**

a. **Monograph Project.**

Those articles for the monograph on aviation medicine assigned to members of the permanent scientific staff have been completed. The greater part of the contributions from non-staff members have also been received; the few manuscripts not yet submitted are expected within the next month. Each chapter will be edited in German before being submitted for translation.

b. **Laboratory Projects.**

The Application of Linear Grating and Molecular Spectra to Problems of Colorimetry.

Theoretical investigations have been continued, using a mathematical formula which describes the elementary curves of color sensation. This has been applied to observed data. Two sets of curves have been computed, and the agreement elicited between theoretical and empirical data is excellent. At the present stage, there is an indication that none of the hitherto popular theories of color vision is satisfactory in explaining the data. On this basis a revised color theory will be proposed.

The EEG as a Warning Device in Anoxia and Fatigue.

Progress has been made in improving the range and amplification of the instrument, but further work is indicated in insulation of the wiring to the pre-amplifier. It is planned to build a second channel for signalling oscillations of a .003 sec. frequency or less. (The existing channel is for .01 sec. or less).

The Effect of Low Barometric Pressure upon Color Thresholds.

Preliminary experiments were performed at sea level and the color thresholds for red, green, yellow, and blue were measured. Experiments were done at various hours of the day and for various lengths of time. It was determined that there is a diurnal relationship with peak threshold at 3 to 4 p.m., and that threshold values fluctuate depending upon space brightness. At least ten such measurements must be made because of great dispersion of observed values.

Development of Linear Arbitrarily Scaled Instrument Panel for Aircraft.

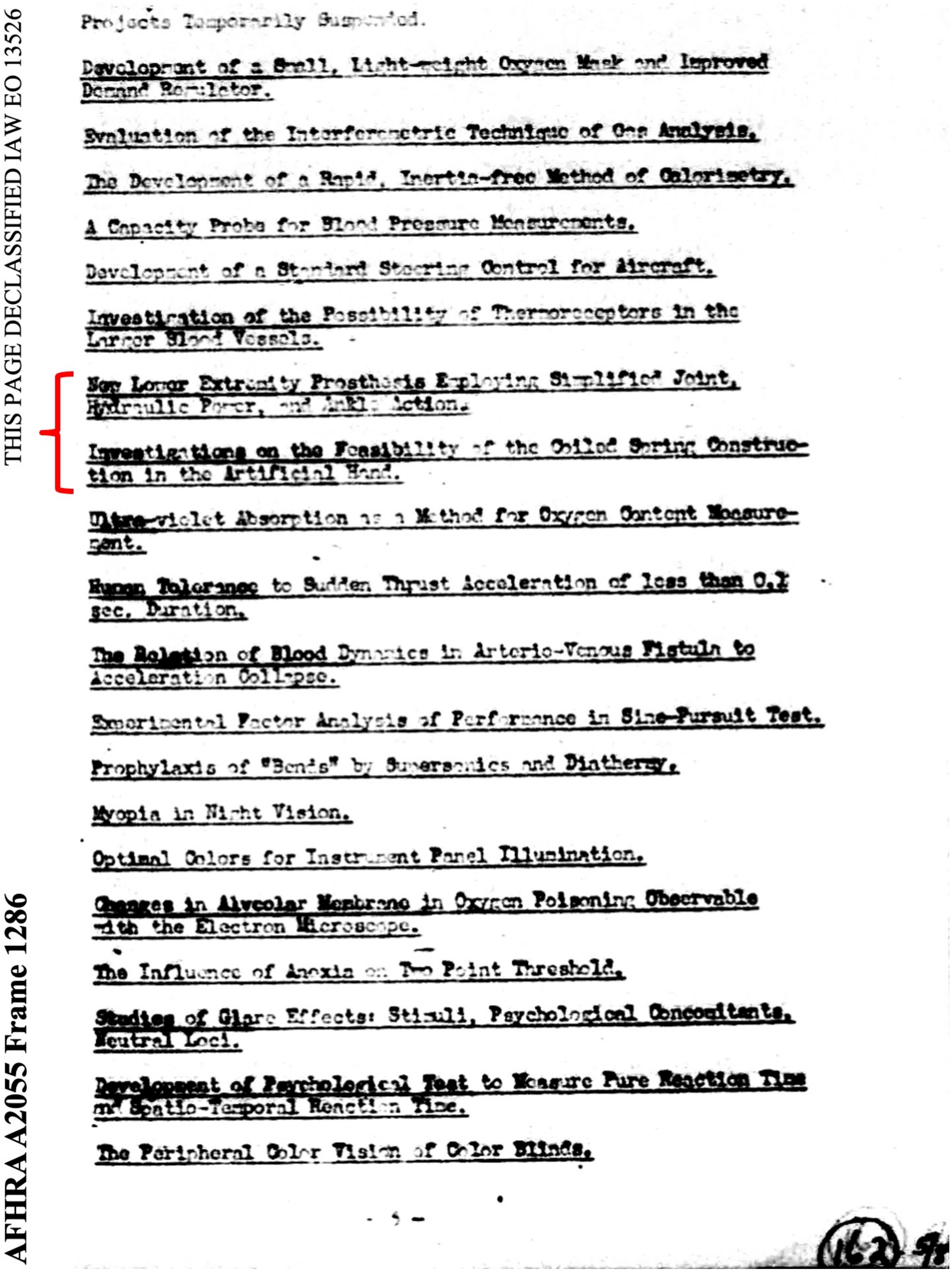
Measurements were made of the time necessary to scan 12 instruments of a standard P-47 instrument panel and to select any dials on which values outside the permissible range were indicated. Similar observations were made using a mock-up of a linear instrument panel. Test conditions, in each case, were changed after each recording of the panel. For the P-47 panel, with round, clock-face instruments, the times were within the range 2 to 10 seconds; for the linear panel, 1/125 to 1/50 second.

- 2 -

(162)

AFHRA A2055 Frame 1283

Figure A.145: Examples of prosthetic and neural interface work by Ulrich Henschke, Hans Mauch, and other German experts at Wright Field. Francis J. Nied. 30 September 1946. AAF Aero Medical Center Monthly Status Report No. 12 [AFHRA A2055 Frame 1283].



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Projects Temporarily Suspended.

Development of a Small, Light-weight Oxygen Mask and Improved Demand Regulator.

Evaluation of the Interferometric Technique of Gas Analysis.

The Development of a Rapid, Inertia-free Method of Calorimetry.

A Capacity Probe for Blood Pressure Measurements.

Development of a Standard Steering Control for Aircraft.

Investigation of the Possibility of Thermoreceptors in the Larger Blood Vessels.

New Lower Extremity Prosthesis Employing Simplified Joint, Hydraulic Power, and Ankle Action.

Investigations on the Feasibility of the Coiled Spring Construction in the Artificial Hand.

Ultra-violet Absorption as a Method for Oxygen Content Measurement.

Human Tolerance to Sudden Thrust Acceleration of less than 0.1 sec. Duration.

The Relation of Blood Dynamics in Arterio-Venous Fistula to Acceleration Collapse.

Experimental Factor Analysis of Performance in Sine-Pursuit Test.

Prophylaxis of "Bends" by Supersonics and Diathermy.

Myopia in Night Vision.

Optimal Colors for Instrument Panel Illumination.

Changes in Alveolar Membrane in Oxygen Poisoning Observable with the Electron Microscope.

The Influence of Anoxia on Two Point Threshold.

Studies of Glare Effects: Stimuli, Psychological Concomitants, Neutral Loci.

Development of Psychological Test to Measure Pure Reaction Time and Spatio-Temporal Reaction Time.

The Peripheral Color Vision of Color Blinds.

- 5 -

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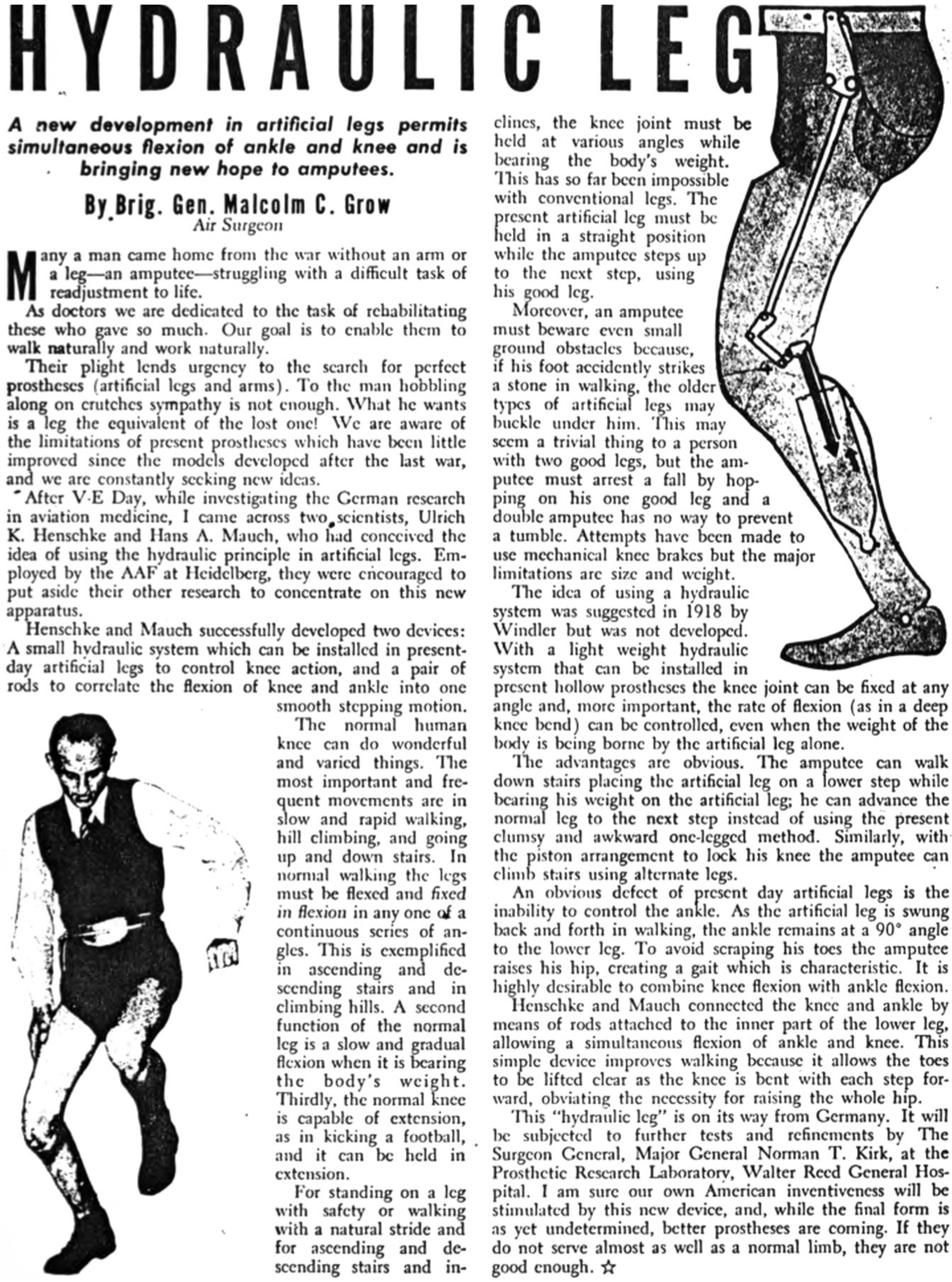
AFHRA A2055 Frame 1286

Figure A.146: Examples of prosthetic and neural interface work by Ulrich Henschke, Hans Mauch, and other German experts at Wright Field. Francis J. Nied. 30 September 1946. AAF Aero Medical Center Monthly Status Report No. 12 [AFHRA A2055 Frame 1286].



HYDRAULIC LEG

A new development in artificial legs permits simultaneous flexion of ankle and knee and is bringing new hope to amputees.

By Brig. Gen. Malcolm C. Grow

Air Surgeon

Many a man came home from the war without an arm or a leg—an amputee—struggling with a difficult task of readjustment to life.

As doctors we are dedicated to the task of rehabilitating these who gave so much. Our goal is to enable them to walk naturally and work naturally.

Their plight lends urgency to the search for perfect prostheses (artificial legs and arms). To the man hobbling along on crutches sympathy is not enough. What he wants is a leg the equivalent of the lost one! We are aware of the limitations of present prostheses which have been little improved since the models developed after the last war, and we are constantly seeking new ideas.

After V-E Day, while investigating the German research in aviation medicine, I came across two scientists, Ulrich K. Henschke and Hans A. Mauch, who had conceived the idea of using the hydraulic principle in artificial legs. Employed by the AAF at Heidelberg, they were encouraged to put aside their other research to concentrate on this new apparatus.

Henschke and Mauch successfully developed two devices: A small hydraulic system which can be installed in present-day artificial legs to control knee action, and a pair of rods to correlate the flexion of knee and ankle into one smooth stepping motion.

The normal human knee can do wonderful and varied things. The most important and frequent movements are in slow and rapid walking, hill climbing, and going up and down stairs. In normal walking the legs must be flexed and *fixed in flexion* in any one of a continuous series of angles. This is exemplified in ascending and descending stairs and in climbing hills. A second function of the normal leg is a slow and gradual flexion when it is bearing the body's weight. Thirdly, the normal knee is capable of extension, as in kicking a football, and it can be held in extension.

For standing on a leg with safety or walking with a natural stride and for ascending and descending stairs and inclines, the knee joint must be held at various angles while bearing the body's weight. This has so far been impossible with conventional legs. The present artificial leg must be held in a straight position while the amputee steps up to the next step, using his good leg.

Moreover, an amputee must beware even small ground obstacles because, if his foot accidently strikes a stone in walking, the older types of artificial legs may buckle under him. This may seem a trivial thing to a person with two good legs, but the amputee must arrest a fall by hopping on his one good leg and a double amputee has no way to prevent a tumble. Attempts have been made to use mechanical knee brakes but the major limitations are size and weight.

The idea of using a hydraulic system was suggested in 1918 by Windler but was not developed. With a light weight hydraulic system that can be installed in present hollow prostheses the knee joint can be fixed at any angle and, more important, the rate of flexion (as in a deep knee bend) can be controlled, even when the weight of the body is being borne by the artificial leg alone.

The advantages are obvious. The amputee can walk down stairs placing the artificial leg on a lower step while bearing his weight on the artificial leg; he can advance the normal leg to the next step instead of using the present clumsy and awkward one-legged method. Similarly, with the piston arrangement to lock his knee the amputee can climb stairs using alternate legs.

An obvious defect of present day artificial legs is the inability to control the ankle. As the artificial leg is swung back and forth in walking, the ankle remains at a 90° angle to the lower leg. To avoid scraping his toes the amputee raises his hip, creating a gait which is characteristic. It is highly desirable to combine knee flexion with ankle flexion.

Henschke and Mauch connected the knee and ankle by means of rods attached to the inner part of the lower leg, allowing a simultaneous flexion of ankle and knee. This simple device improves walking because it allows the toes to be lifted clear as the knee is bent with each step forward, obviating the necessity for raising the whole hip.

This "hydraulic leg" is on its way from Germany. It will be subjected to further tests and refinements by The Surgeon General, Major General Norman T. Kirk, at the Prosthetic Research Laboratory, Walter Reed General Hospital. I am sure our own American inventiveness will be stimulated by this new device, and, while the final form is as yet undetermined, better prostheses are coming. If they do not serve almost as well as a normal limb, they are not good enough. ☆

Figure A.147: Malcolm C. Grow. Hydraulic Leg. *AAF Review* July 1946, p. 8.

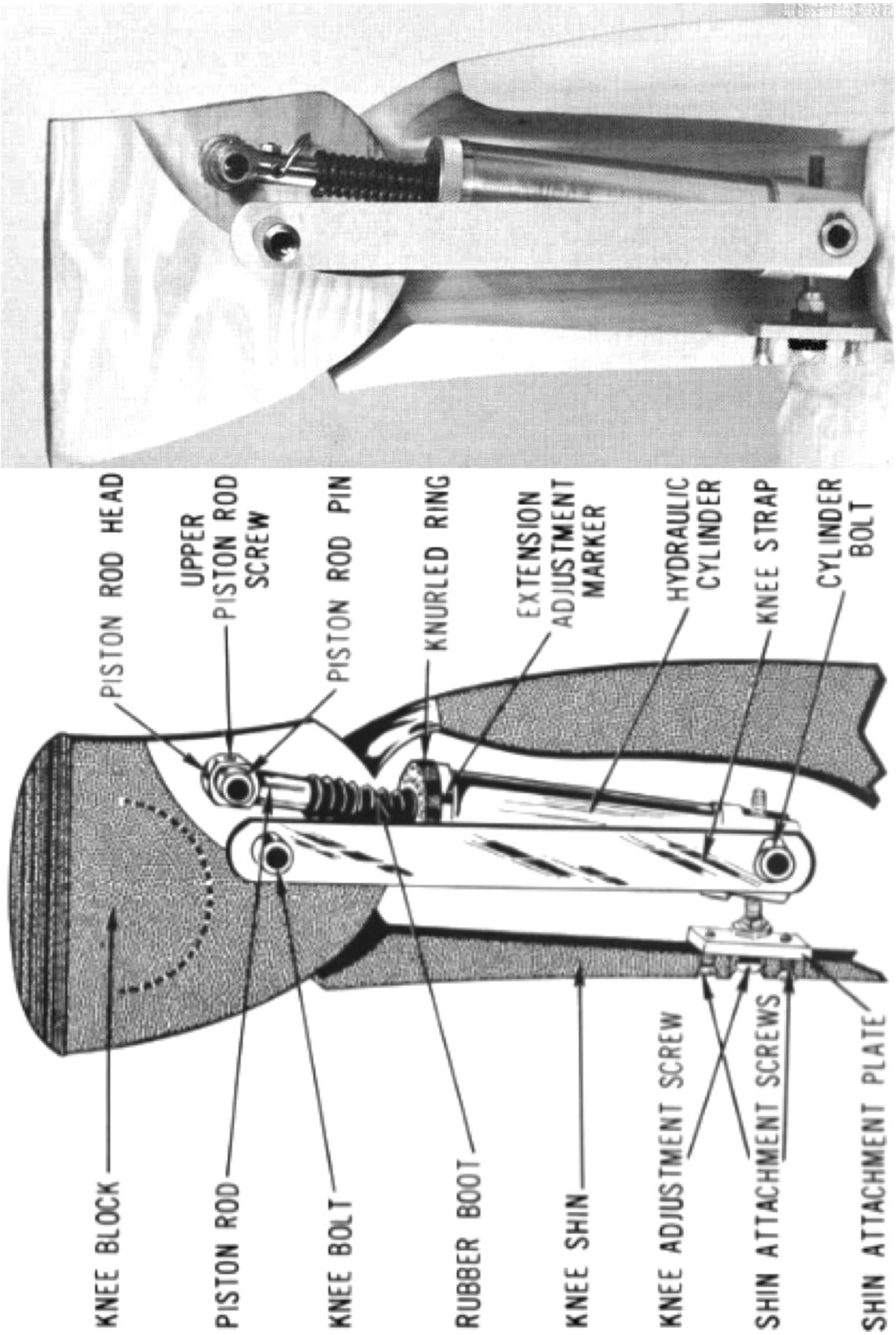

PISTON ROD HEAD
UPPER PISTON ROD SCREW
PISTON ROD PIN
KNURLED RING
EXTENSION ADJUSTMENT MARKER
HYDRAULIC CYLINDER
KNEE STRAP
CYLINDER BOLT
KNEE BLOCK
PISTON ROD
KNEE BOLT
RUBBER BOOT
KNEE SHIN
KNEE ADJUSTMENT SCREW
SHIN ATTACHMENT SCREWS
SHIN ATTACHMENT PLATE

Figure A.148: Details of the hydraulic knee mechanism in the prosthetic leg.

March 25, 1952 U. K. HENSCHKE ET AL **2,590,101**

TACHISTOSCOPE

Filed April 18, 1949 3 Sheets-Sheet 1

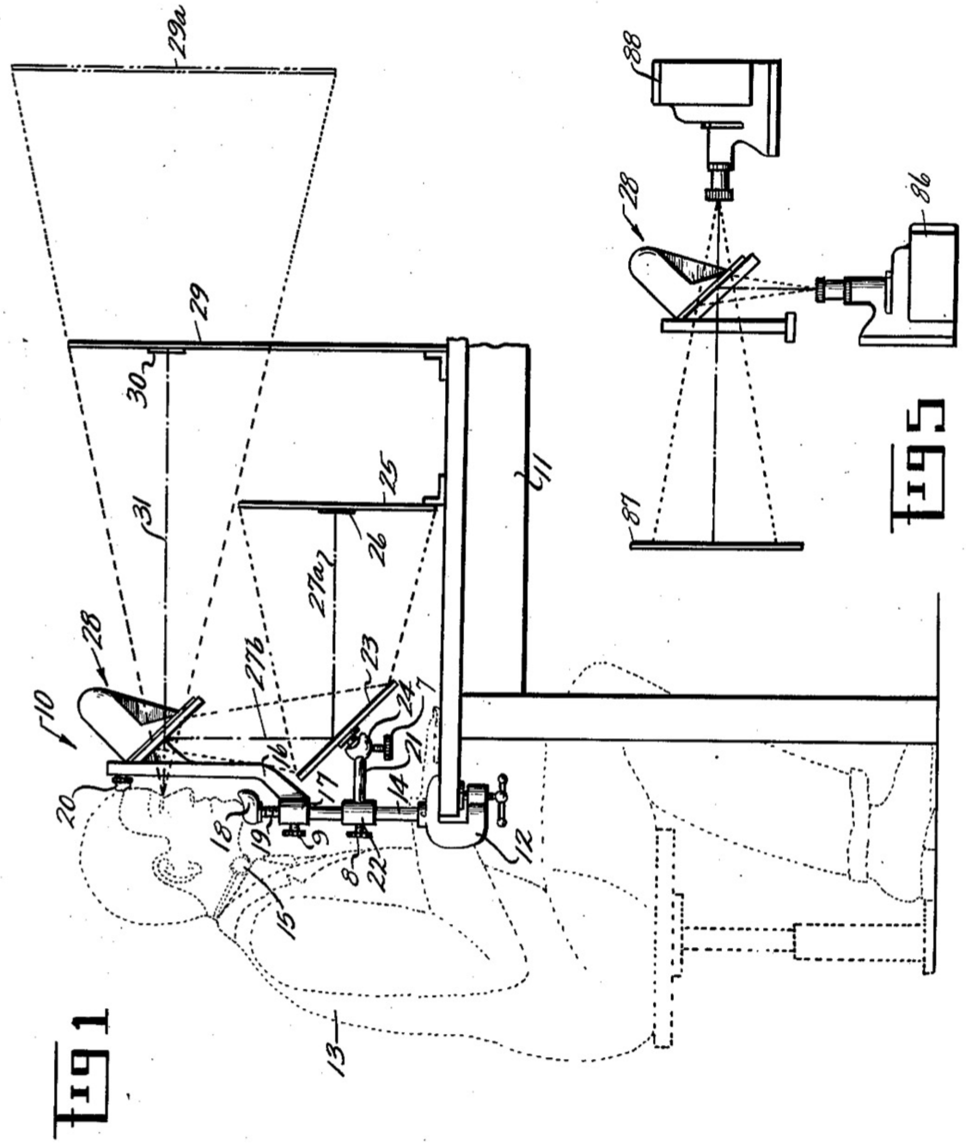

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Fig 1
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INVENTORS
ULRICH K HENSCHKE
HANS A. MAUCH
BY Wade Koontz and
Chester Tietig
ATTORNEYS –

Figure A.149: Patent by Ulrich Henschke and Hans Mauch on a tachistoscope that could present high-speed visual information to a user and monitor the person's reactions.

March 25, 1952 U. K. HENSCHKE ET AL **2,590,101**

TACHISTOSCOPE

Filed April 18, 1949 3 Sheets-Sheet 2

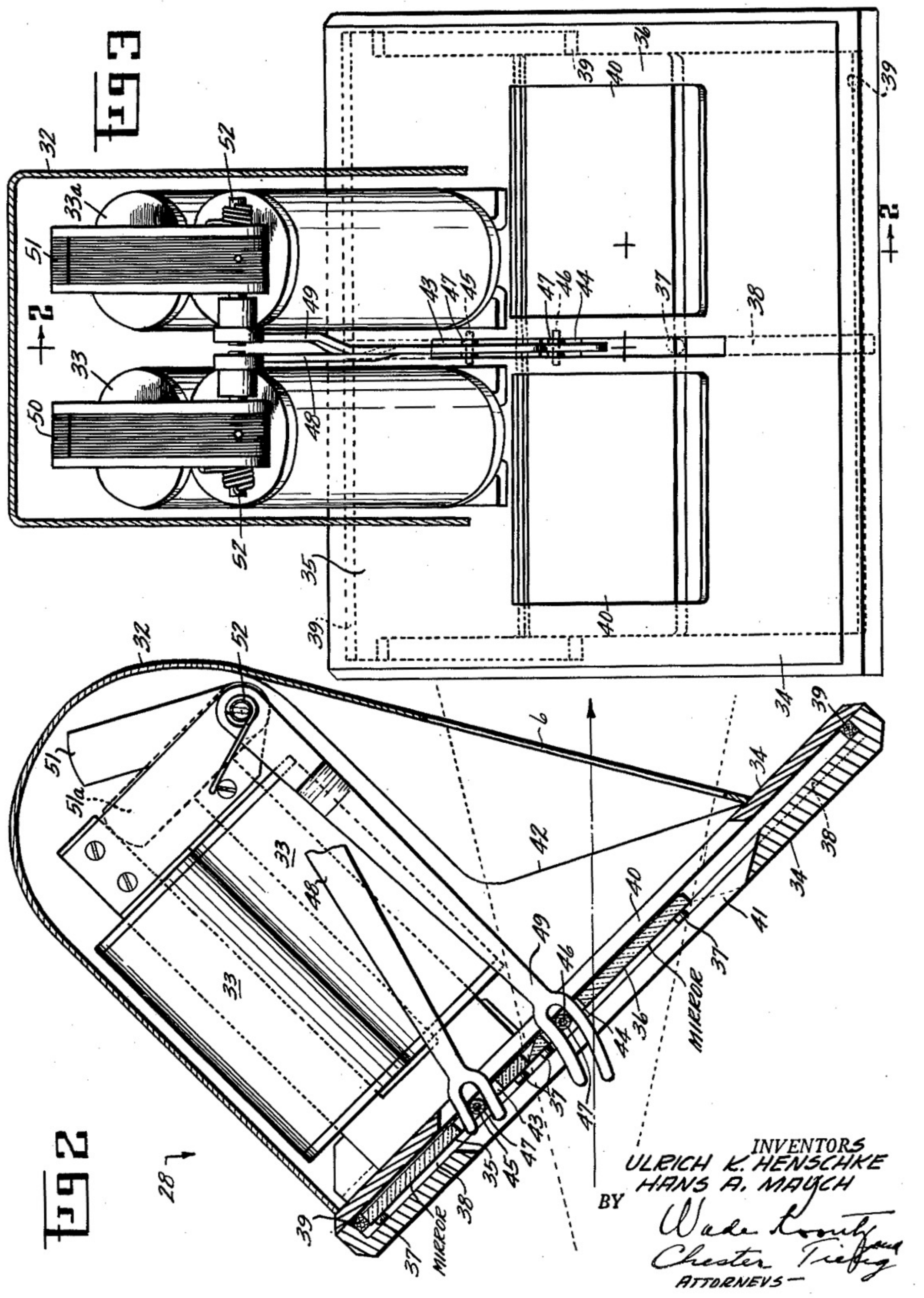
Fig 3
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MIRROR
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INVENTORS
ULRICH K. HENSCHKE
HANS A. MAUCH
BY
Wade Koontz and
Chester Tietig
ATTORNEYS

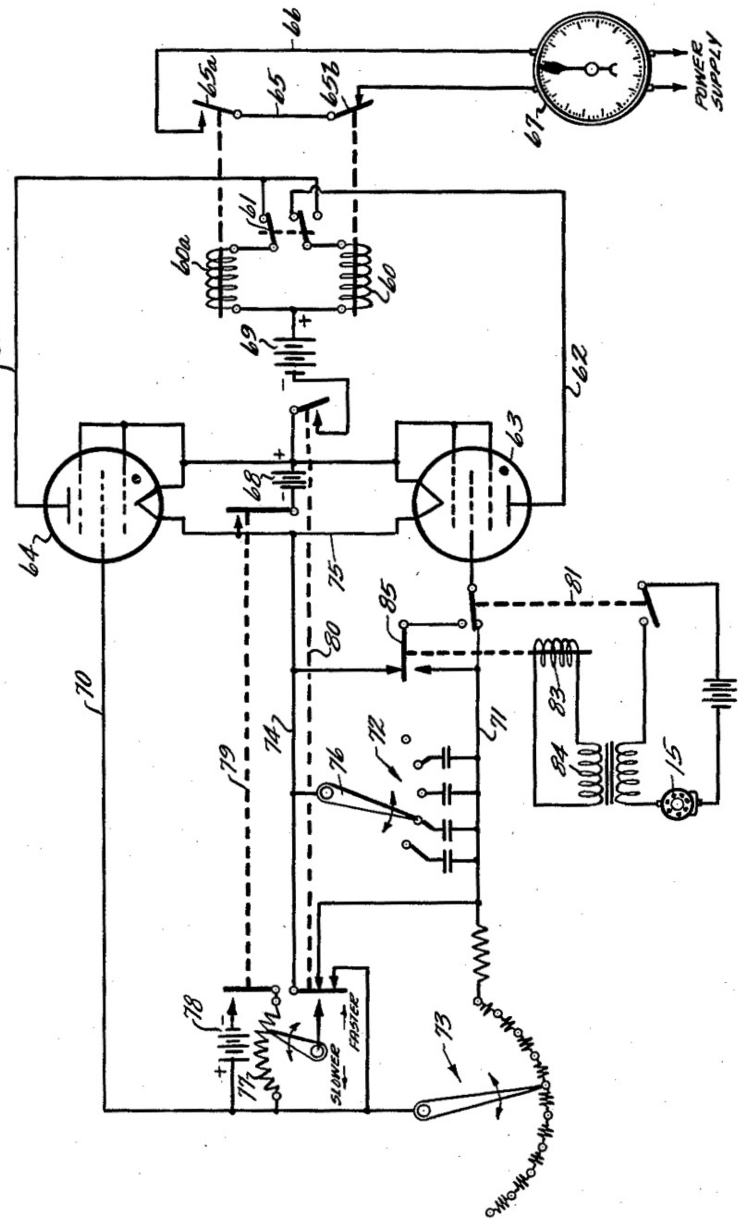
Figure A.150: Patent by Ulrich Henschke and Hans Mauch on a tachistoscope that could present high-speed visual information to a user and monitor the person's reactions.

March 25, 1952 U. K. HENSCHKE ET AL **2,590,101**

TACHISTOSCOPE

Filed April 18, 1949 3 Sheets-Sheet 3

Fig 4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POWER SUPPLY
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SLOWER
FASTER

INVENTORS
ULRICH K. HENSCHKE
HANS A. MAUCH
BY Wade Koontz and
Chester Tietig
ATTORNEYS

Figure A.151: Patent by Ulrich Henschke and Hans Mauch on a tachistoscope that could present high-speed visual information to a user and monitor the person's reactions.

Bess Furman. 1962. *Progress in Prosthetics.* Washington, D.C.: U.S. Government Printing Office. pp. 105–109 [http://www.oandplibrary.org/assets/pdf/ProgressInProsthetics.pdf].

As World War II drew to its close, the United States Army conducted a highly secret operation which went by the code name "Paperclip." [...]

One of the "Paperclip" scientists, Hans A. Mauch, head of the development of the V-l rocket used in the bombardment of England, also happened to be an expert in technical medicine, particularly prosthetic devices. His rocketry achievement won for him the highest decoration of the German Government.

Indeed, War Department records show that Mr. Mauch was an expert in many things. As a youth, he studied at the Institute of Technology, Stuttgart and Berlin, becoming a Diploma Engineer in Electrical and Mechanical Engineering. From 1930 to 1935, he was chief engineer for technical development at the Zwietusch Works, Berlin. From 1935 to 1939 he was with the German Air Ministry where he first directed the development of testing installations for propulsion systems, then of airfield equipment, and finally of rocket and jet engines. His initiative in the jet-engine field is considered a major reason for the head start Germany had in this field during World War II.

From 1939 to 1945, he was an independent engineer for developments in half a dozen important fields. These were: (1) Hydraulic, pneumatic, mechanical and electrical equipment used in aircraft and motor vehicles, hydraulic-energy transmitting devices, pneumatic-energy-distribution systems, high-performance mechanical-energy transmissions, electric controls and measuring devices; (2) filters for liquid and gaseous substances; (3) airfield cranes, movable ladders and platforms; (4) high-efficiency heat exchangers having low air resistance; (5) the V-l , the ME 262 jet-propelled fighter, and remote-controlled missiles; (6) technical medicine, especially prostheses.

The Army officer who drew these publishable facts from the still-secret files of Operation Paperclip was moved to remark as he read them off: "This man seems to be able to do almost anything he puts his mind on."

When Mauch came to this country in December 1946, the Air Force claimed him for its experimental work at Wright Field, Dayton, Ohio. He developed protective equipment for extending human endurance at high temperatures. One such article of equipment was the United States Air Force "Air Conditioned Suit" which he invented and which was the subject of an article in Life Magazine. At that time, Hans Mauch firmly refused to permit his name to be used. For Hans Mauch is a philosopher as well as an inventor, and his philosophy, given at that time, was: "Although I admit it gives me great professional satisfaction to make contributions to the society I live in, I don't think it is essential for my work as a scientist to be known to a great many people. Much rather than to be famous at the end of my days, I would like to be able to state that I have had one or two dozen really good friends."

While the work at Wright Field claimed all of Mauch's regular employment time, the Air Force encouraged him to continue his prosthetic research and development work in his spare time. This he did in the basement workshop of his Dayton home. In this country, he had married an Austrian woman "Paperclip" scientist, Tatjana Schmid.

For some years, Mr. Mauch did his prosthetic research in collaboration with another "Paperclip" scientist, Ulrich K. Henschke, now a cancer research specialist at Cornell University. The main results of this work so far are two hydraulic systems for above-knee amputees, the "Henschke-Mauch Hydraulic Swing-Control System" and the "Henschke-Mauch Hydraulic Swing-and-Stance Control System." These hydraulic legs, developed under contract with the Veterans' Administration, were accorded by New York University the full-scale testing reserved for highly important developments.

After eleven years of work as a civilian scientist at Wright Field, Hans Mauch resigned. Given as his reason was the fact that private enterprise required his full-time duty. The Air Force immediately appointed him a consultant to enable continuation of his work on the development of a highly advanced environmental test chamber for the simulation of cockpit conditions in supersonic and space vehicles.

The private enterprise to which he could at last devote his energies was the production of hydraulic legs and other scientific inventions in the field of rehabilitative medicine and human-factors engineering. The laboratory building he now has under construction at 3035 Dryden Road, Dayton, will initially have 5,000 square feet of space on two floors and is so planned that it can be expanded to 26,000 square feet.

In the prosthetics field Mauch is also working on a hydraulic ankle and on a chemical power source for upper-extremity prostheses. He conducted the original investigation in Germany on hydrogen peroxide as a possible energy source for artificial limbs. Other activities of his include the development of a reading machine and of guiding devices for the blind, and work on a personal type of air conditioning, an offshoot of his former Wright Field activities. Both the limb prosthetics researches and the aids to the blind are sponsored by the Veterans' Administration.

A visit with Hans Mauch was included in my trip through the Midwest. As pictured by his fellow scientists all over the country, he turned out to be a rare raconteur who, however, abhors seeing his own words in print between quotation marks.

Mauch sees a prosthesis as a device by which man regains lost abilities or provides himself with abilities nature denied him. In this sense, an airplane is a flight prosthesis, a telescope is a vision prosthesis, and an electronic computer is a brain prosthesis.

He calls the swing-and-stance control a "hydraulic brain" located in the artificial leg. He says that throughout the twelve years of its development the initial plans remained unchanged—"just making refinements so it will do everything the amputee wants it to do and nothing he doesn't want it to do."

What the amputee wants the leg to do, he notes, amounts to quite a list: He wants the leg to support him—even in its flexed position—when he stumbles. He wants the leg to yield slowly under his weight when he walks downstairs or downhill. He would like the leg to have swing characteristics of the good leg. He would appreciate it if the leg could be locked at any knee angle. He would like it if all the control functions so far listed could be easily adjusted to match his particular gait and his walking habits.

The list of the things the amputee doesn't want the leg to do, Mauch has found out in his researches, is about as long. He doesn't want the leg to make any noises. He doesn't want it to be significantly heavier than a conventional prosthesis or to have an inferior cosmetic appearance. He would prefer it if the leg needed a minimum of maintenance and repair work. Its price should not be too high, and its life expectancy should not be too short.

The list of what an amputee wants has been included in the new hydraulic leg. The list of what he doesn't want has been ruled out. That all this is nearing accomplishment in twelve years of mostly spare-time activity makes the time period appear relatively short, after all.

Mauch says his World War II work on a rocket which hits the target without a man to guide it is akin in its way to the hydraulic leg—both are simulations of the controls of the human brain, a subject which so fascinated him from earliest youth that it has led him to make numerous inventions in the control field.

In an amputation, he points out, the communication system from brain to leg or arm has been cut off. The ideal thing, the path of the future, he says, is to catch the impulses of the nerve ends and channel them into the prosthesis; and to put pressure and position sensors into the prosthesis and channel their signals through the nerve ends back to the brain.

Eugene Murphy. 1989. Hans Adolph Mauch 1906–1984. *Memorial Tributes: Volume 3*, pp. 258–264. National Academy of Engineering [https://www.nae.edu/189294/HANS-ADOLPH-MAUCH-19061984]**.**

[...] Fortunately, the S-N-S, his well-known hydraulic artificial knee designed to control both swing and stance phases of walking for above-knee amputees, was a well-established product here and abroad (more than 12,000 had been sold). Voluntarily, Mauch had progressively lengthened the warranty period to two years on this ingenious, complex, yet dependable mechanism. [...]

Mauch's third major consulting activity was original research and development in the fields of aviation medicine and prosthetic devices. In this bioengineering sector, Hans Mauch cooperated closely with Ulrich K. Henschke, a radiologist with a Ph.D. in physics. Head of the Aeromedical Institute in Munich, Dr. Henschke worked on a variety of physiological problems.

After World War II, the U.S. Air Force assembled many top German scientists and engineers at Heidelberg. There, Henschke and Mauch collaborated on an important chapter, "How Man Controls," of a two-volume work, *German Aviation Medicine—World War II.* This chapter was a pioneering effort in what later became known as the fields of cybernetics and human factors engineering. Henschke and Mauch also assembled an extensive bibliography of German work on artificial limbs, designed a metal artificial leg that was intended for mass production of components and easy assembly to an individually fitted socket, and constructed a series of models illustrating various concepts for stabilizing the knee joint of an above-knee prosthesis.

In March 1946 the U.S. Army surgeon general sent a team to Europe to survey artificial limbs. In addition to important information on various devices and procedures including the suction socket leg and cineplastic surgery to control arms, the team brought back the Henschke-Mauch bibliography and the concepts they developed involving knee control. Subsequently, Henschke and Mauch went to Dayton, Ohio, late in 1946, to work as civilian employees at the Aeromedical Laboratory of the Wright Air Force Development Center. Yet, they were able to devote only a small portion of their efforts to prosthetics. Later, Mauch and several others worked evenings and weekends in the basement of his small home with support by the Veterans Administration through its National Academy of Sciences' contract.

Hans Mauch became a naturalized U.S. citizen in June 1955. He left the Aeromedical Laboratory in 1957 to set up his own organization, which was incorporated in 1959 as Mauch Laboratories, Inc. The company engaged in research, development, and manufacturing in the biomedical engineering field. [...]

Except for a classified project to develop a novel space suit for the Air Force and NASA, which the company performed from 1959 to 1964, all of Mauch's work until the mid-1970s was devoted to rehabilitation projects sponsored by the Veterans Administration in coordination, through various National Research Council committees, with projects of other agencies. In recent years, after termination of his VA contracts, further improvements in the company's devices were made by Mauch as proprietary developments.

After exhaustive development and evaluation efforts that culminated in a nationwide clinical trial, the original Henschke-Mauch Model A semivoluntary stance-and-swing hydraulic leg for above-knee amputees was shortened, refined, and renamed the S-N-S. A simpler Model B to control only the swing phase was produced briefly in 1963; it has been refined and is currently sold as Model S. Several other companies produced swing-phase units under the Mauch patent, which was assigned to the VA and licensed to others without royalties after training at Mauch Laboratories.

The Mauch swing control provides programmed resistance that automatically varies with knee angle and walking speed, plus the possibility of independent adjustment of resistances to flexion and extension. The stance phase control always allows extension, but automatically imposes a high (but adjustable) resistance to knee flexion except after a brief application of a hyperextension moment, normally after the heel leaves the ground.

The rigid locking of the device is normally undesirable (the residual limb could be injured after stumbling), but it can be obtained voluntarily if desired— for example, for prolonged standing or for driving an automobile with flexed knee. Conversely, very low resistance to flexion can also be ensured for bicycling. These knee control features are superior to other brakes and locks that have been disclosed in literature and patent applications here and abroad for well over a century.

The S-N-S is the sole survivor of many years of effort by numerous capable engineers and interdisciplinary teams supported by substantial government projects. The genius, persistence, and vision of Hans Mauch are demonstrated by his eventual success with the S-N-S, the recent acceptance of the hydraulic ankle, and his yearning to attain a truly voluntary yet subconscious control of swing-and-stance phase movement.

Although this memoir focuses on Mauch's contributions to hydraulic lower limb prostheses, he made thoughtful, ingenious contributions in many fields, including aviation and aviation medicine, space suits, and the human factors aspects of displays and controls. Mauch was the inventor or coinventor of more than eighty patented inventions in nine countries and the author or coauthor of numerous papers and reports. Under VA contract, he developed several types of personal reading machines for the blind, another area he and Dr. Henschke had explored in Heidelberg. His audible-output Stereotoner direct-translation reading aid, which was smaller, lighter, and lower in price than the widely known tactile-output Optacon, reached limited commercial production.

Otha Linton. 2006. Ulrich Henschke. ***Journal of the American College of Radiology*** **3:8:639 [https://doi.org/10.1016/j.jacr.2006.03.016].**

For most of his career in cancer treatment, Ulrich Henschke was noted for mechanical efforts to put exact amounts of ionizing radiation into the tumors of his patients. Notable to those who saw his demonstrations of brachytherapy in the 1960s were afterloading devices to insert radon or artificial isotopes into cervical or uterine cancers. The concept was to position applicators without the radiation sources. Then, using air pressure or hydraulics, the sources would be forced into place and then withdrawn after the intended doses were delivered. The combination of metal fittings, pumps, and rubber tubes leading from radiation safes to the applicators in patients added an unusual touch to a very serious solution to a difficult problem.

Later on, Dr Henschke developed the Janus machine, using low-energy ^{60}Co sources for treatment facilities in rural areas and underdeveloped countries. The approach involved placing the cobalt in a holder in the wall between 2 treatment rooms. The lead shielding could be revolved to treat a patient in either room or to protect against exposures while people were working in both rooms. The machines were installed in Nigeria, Liberia, Jamaica, Haiti, Tanganyika, India, and several states in the United States. [...]

He donated Janus therapy machines for use in African countries, where the resources for modern, high-technology treatment centers were not available. He managed to establish 10 centers in 9 countries.

It was on a trip to Africa in June 1980 that Dr Henschke was killed in a small-plane crash. He was 66.

[For more information on Henschke's radioactive therapeutics for cancer, see for example:

New Device Tried in Breast Cancer. *New York Times*, 19 November 1961, p. 81.

Breast Cancer Work Is Cited at Parley. *New York Times*, 25 July 1962, p. 29.

Rise in Cancer Cures Shown in Iodine Use. *New York Times*, 11 April 1968, p. 26.

Dr. Ulrich K. Henschke, Noted for Cancer Work. *New York Times*, 1 July 1980, p. 31 [obituary].

Jesse N. Aronowitz. 2012. Whitmore, Henschke, and Hilaris: The Reorientation of Prostate Brachytherapy (1970–1987). *Brachytherapy* 11:2:157–162 [https://doi.org/10.1016/j.brachy.2011.03.003].]

A.3 Biological Warfare

[According to official histories, the Third Reich did not conduct any significant work on offensive biological weapons research. Officially, what little work was conducted was merely defensive research, aimed at finding methods of protecting against biological weapons in case they were developed and employed by other countries.[4]

The conclusion that wartime Germany did not pursue offensive biological weapons research is based on two sources of information:

- German documents that were discovered and made public by the U.S. Alsos Mission, which was tasked with finding out everything about any German weapons of mass destruction (biological, chemical, or nuclear) during and immediately after the war. Considering that Alsos (a) completely failed to discover Germany's massive chemical nerve agent program during the war, and (b) failed to investigate most of Germany's nuclear program (Appendix D), historians should not put much faith in Alsos's discoveries or conclusions regarding Germany's biological weapons program. At best the information from Alsos can serve as a starting point for far more extensive historical investigations of the biological weapons program.

- Postwar claims by German scientists and officers that they were conducting only defensive, not offensive, biological weapons research. Whatever the true nature of the wartime programs, historians should not put much stock in the scientists' and officers' postwar denials, in view of the fact that those individuals were on trial or in danger of being put on trial for war crimes.

There are a number of reasons to suspect that wartime Germany did actually have a large and advanced offensive biological warfare program:

1. German-speaking scientists had pioneered the whole fields of microbiology and immunology from the nineteenth century through World War II (Section 2.2). Thus they would have been well positioned to lead the world in developing biological weapons if they were so inclined.

2. Germany systematically harnessed scientific innovations to develop a wide variety of advanced weapons during the war—rockets, missiles, jets, infrared night vision, nerve agents, directed energy weapons (Appendix C), etc. It would have been inconsistent not to harness scientific innovations in microbiology for weapons.

3. Germany aided and worked closely with Japan, which is well known to have possessed and employed biological weapons during the war.

4. A number of wartime intelligence reports described the research, production, and even stockpiling of biological weapons. For some examples, see pp. 2518–2557.

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[4] See for example: Barenblatt 2004; Blome 1941; Michael Carroll 2004; Deichmann 1996; Geißler 1998a, 1998b; Gold 1997; Guillemin 2005; Haagen 1941; Friedrich Hansen 1993; Sheldon Harris 2002; Kater 1989; Keremidis 2013; Klee 2001; Leitenberg and Zilinskas 2012; Posner and Ware 2000; Regis 1999; Reinhardt 2013; Vivien Spitz 2005; Tokyo War Crimes Trial 1950; U.S. Army 1956.

5. Alsos found many groups and individuals that were part of an (allegedly only defensive) biological warfare research program called Blitzarbeiter (Lightning Worker) in some documents and Blitzableiter (Lightning Rod) in other documents. Much of their work could have also been used for offensive purposes, or Alsos might easily have missed groups, locations, or scientists doing offensive work. See pp. 2559–2569. Among the scientists mentioned by Alsos:

   (a) Kurt Blome (German, 1894–1969) seems to have managed offensive biological warfare programs during the Third Reich, provided information and materials to build up the wartime Japanese biological warfare program (e.g., Unit 100 and Unit 731[5]), and worked for the U.S. Army to transfer related technologies after the war.

   (b) Eugen Haagen (German, 1898–1972) was one of the preeminent virologists in the world before the war, apparently tested biological warfare agents and novel vaccines on human subjects during the war, and continued to conduct research after the war.

   (c) Heinrich Kliewe (German, 1892–1969) seems to have played critical roles during the Third Reich in developing greatly improved methods of growing and disseminating biological agents, revolutionary technologies that formed the core of postwar biological warfare agent work in the United States, United Kingdom, Soviet Union, and other countries.

   (d) Walter Schreiber (German, 1893–1970) apparently managed defensive biological warfare programs during the Third Reich (although that involved forced experimentation on humans), then worked for the U.S. Air Force School of Medicine after the war.

   (e) Erich Traub (German, 1906–1985) evidently developed and tested bacterial and viral agents for military use against farm animals during the war, then after the war helped to build up related programs at the U.S. Plum Island Animal Disease Center, Army Biological Laboratories, and Naval Medical Research Institute.

   (f) A number of other German-speaking biological warfare experts (e.g., Anna Bürger) were identified and recruited by Allied countries after the war.

6. Some surviving and declassified documents show equipment for working with biological agents and disseminating airborne biological agents with nebulizers and other aerosol sprayers. They also show wind speed and animal information for field trials of biological warfare agents, and test results for trials with at least seven biological warfare agents: a *Staphylococcus* species, a *Shigella* species, typhus (*Rickettsia prowazekii*), cholera (*Vibrio cholerae*), plague (*Yersinia pestis*), anthrax (*Bacillus anthracis*), and anthrax spores. See Figs. A.200–A.204.

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[5] Barenblatt 2004; Gold 1997; Guillemin 2005; Sheldon Harris 2002; Regis 1999; Tokyo War Crimes Trial 1950;
https://www.pacificatrocities.org/books.html
https://english.almayadeen.net/news/politics/china-demands-japan-to-get-rid-of-wwii-chemical-weapons
https://www.japantimes.co.jp/news/2022/10/06/national/wwii-poison-gas/
https://www.dontow.com/2009/04/japans-biological-and-chemical-warfare-in-china-during-wwii/
https://www.latimes.com/archives/la-xpm-1988-09-18-mn-3410-story.html

7. The Reichsinstitut für Krebsforschung (Reich Institute for Cancer Research in Poznan, Poland) was a specially built secure biological research facility that operated from 1942 until it was taken over by the Soviet army in 1945. Virtually all documentation about the institute and its work were destroyed by the Third Reich or captured by the Soviets. Officially it was a cancer research institute, but the facility's design suggests that it was a biological warfare research laboratory, arguably the most advanced facility of that type in the world at that time (Fig. A.205).

8. The Reichsinstitut für Grenzbereiche der Medizin in Geraberg (Reich Institute for Frontiers of Medicine in Geraberg, Thuringia) was under construction and at least partially operational from 1944 to the end of the war (Figs. A.206–A.208). It received many of the scientists and supplies that had been evacuated from the Poznan laboratory.

9. Many other locations throughout territory controlled by the Third Reich may also have been used to develop, produce, and/or test biological weapons—university laboratories, industrial sites, government laboratories, military installations, and underground facilities. After the war, much of that territory was occupied by Soviet forces and not open to investigations by other countries.

10. Germany destroyed a large amount of documents and material at the end of the war in order to preserve its secrets. It would be far easier to destroy biological weapons than chemical or nuclear weapons—bleach or heat would kill bacteria or viruses to prevent postwar discovery by Allied forces.

11. There were postwar reports about knowledge and/or agents surviving from the wartime biological weapons program. See p. 2576 for an example.

12. If Allied countries did discover evidence for wartime German biological weapons, they would have had strong incentives not to make that evidence public, both to arm themselves against rival nations and to claim that their own scientific prowess was greater than that of Germany or other countries. In fact, a U.S. intelligence card catalog shows that there were a number of wartime and postwar reports detailing German production of biological warfare agents, but those reports are still classified and unavailable to the public (Figs. A.210–A.209).

Thus there is currently some evidence that Germany may have actually made major advances in biological warfare research and development during the war, and that German-speaking scientists may have subsequently transferred those methods and materials to postwar biological warfare programs in the United States, United Kingdom, Soviet Union, and other countries. Much more research should be conducted in archives and even at some of the suspected physical sites involved in order to determine the true extent and history of biological warfare work in wartime Germany. While bioweapon development may not be viewed as an honorable field of research (harnessing microbiological knowledge to cause diseases instead of to cure them), the revolutionary nature of the actual science is noteworthy, and the long-term impact on Cold War military programs, modern concerns about bioterrorism, and even research on clinical pathogens and therapeutics has been profound.]

Robert Harris and Jeremy Paxman. 2002. *A Higher Form of Killing: The Secret History of Chemical and Biological Warfare.* 2nd ed. NY: Random House. p. 91.

Both Polish and Russian partisans used biological weapons in sabotage operations against the Germans. In December 1942, for example, the Gestapo discovered a germ warfare arsenal in a four-room Warsaw house used by the Polish underground. They reported to Himmler the discovery of "three flasks of typhus bacilli, seventeen sealed rubber tubes presumably containing bacteria, and one fountain pen with instructions for use for spreading bacteria." Twenty pounds of arsenic had also passed through the house. A few days later, Himmler showed Hitler a captured NKVD order instructing Russian partisans to use arsenic to poison German troops. The raid on the Warsaw house apparently failed to prevent the Poles from continuing to use germ weapons. The Combined Chiefs of Staff learned from the Polish liaison officer in Washington, Colonel Mitkiewicz, that in the first four months of 1943, 426 Germans had been poisoned by the Polish underground; that seventy-seven "poisoned parcels" had been sent to Germany; and that "a few hundred" Nazis had been assassinated by means of "typhoid [typhus] fever microbes and typhoid [typhus] fever lice."

W. Seth Carus 2001. *Bioterrorism and Biocrimes: The Illicit Use of Biological Agents Since 1900.* Revised ed. Washington, D.C.: National Defense University. p. 88. [https://wmdcenter.ndu.edu/Portals/97/Documents/Publications/Articles/Bioterrorism-and-Biocrimes.pdf]

Another source, a member of the Polish underground during the Second World War, claims that the State Institute of Hygiene, apparently located in Warsaw, Poland, was used by the Polish resistance, then known as the Union for Armed Resistance (ZWZ). According to this account, the German Gestapo received anonymous letters denouncing people for various purposes. In many cases, the letters were written to settle grudges, but the fake charges were sufficient to get the victims arrested by the Germans. To put a halt to this practice, the staff of the Institute of Hygiene prepared anthrax cultures, and infected fake anonymous letters that were sent to the Gestapo. When Gestapo agents began to suffer from the symptoms of cutaneous anthrax, they started throwing away anonymous letters without opening them.

[Although the two sources above concern the resistance, they do illustrate that the knowledge, resources, and willingness to make biological weapons were all available in wartime Europe.]

Concern for German Bacteriological Warfare [AFHRA 43811 electronic p. 1075]

Start Record EE L/C Box 43 7.84

Concern for German Bacteriological Warfare

Memo from BG Tom White, AC/S Intelligence to [Henry] Arnold, Feb 8, 1944 quoting from a special report on German secret weapons which indicated that Germany was capable of using BW and had at least two suitable agents "X" and "N," and that either could be dispersed from pilotless planes. White said there were no methods of detection known and decontamination methods were not known.

White reported that a special outlet valve filter for standard US gas masks would be available in quantity to equip all US troops in the UK by May 1, 1944. Also that anti-toxin for up to 400,000 US troops against "X" would be available by May 1, 1944.

White also reported that officers specially trained in BW were being sent to various theater commanders within the next month.

From Bern, Switzerland to Shepardson, OSS. IN-8398. 25 April 1944 [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

#3152-3. TOLEDO. In reference to our #2481 and #2750.

Through a trustworthy middleman we have received an additional short item from Briault indicating that the information given earlier is still in effect and that "when dogs are inoculated with serum from Leporides infected with Tularemia, a dry bacillus is produced which is extremely poisonous and contagious, and which causes terrific congestion." We are also advised that in Paris dogs are being requisitioned in large numbers, and that Tularemia is being studied by Japanese scientific groups. The same informant declares that a bombing attack should be launched against St. Gobain at Chauny where containers are produced. However, we are also advised that prior to the bombing photographs should be made of the place so that new works buildings may be identified.

From Bern to Shepardson, OSS. IN-8654. 28 April 1944 [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

#3215. TOLEDO.

We have additional information on Doctor Briault to the effect that he was placed under arrest at the close of 1942, with the 2nd Bureau of Marine at Vichy, and was released in April of the following year. We have heard that the Director of the Pasteur Institute at Tunis knows him, and that perhaps he is known at the Pasteur Institute in Algiers as well.

The following information was supplied by an untried source: 6 months ago, the Germans took over the brewery located in Weimar, at #9 Schuetsengasse, to convert it for bacteriological warfare purposes.

From Shepardson, OSS to Ustravic, London. OUT-7967. 29 April 1944 [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

#40034. TOLEDO. From 154 to Cecil.

Data compiled from 2 accounts indicates the following: The Nazis have commenced the propagation of rats on a big scale at the Kastrup Airdrome. All the bigger airdromes in Denmark are equipped with similar propagating stations. It appears that the Nazi plan to drop diseased rats on enemy countries. These accounts are SL/67, from a trustworthy Polish source in London and dated the 25th of February and #1411/44 from Polish Intelligence and dated the 8th of January.

Is is possible to obtain an estimate of the rat population now at Kastrup and other airdromes at present engaged in propagation?

Are these rodents gray, white or black in coloring? What shade is the most numerous and what color is the second most prevalent? Do they treat the rats? Has the rodent population in these various localities been allowed to increase; do they slaughter them and burn them; have the rats been let loose in enemy territory?

From Bern to Shepardson, OSS. IN-9714. 12 May 1944 [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

#3418-22. TOLEDO. To Jackpost and Cecil, London, Action: Washington
Information: London   In reference to your #1576 and #1591.

Further information on Dr. B. has been secured by 401 through an envoy who has just come from France. This information will have to be checked, since it originated with Dr. B. himself. The doctor is a personal friend of Labarthe, who is now in London, as well as of Louis Marin, who is in Algiers at present. He was an assistant to Professor Wurmser and also worked under Professor Laugier who are now in Rio and Algiers, respectively. He maintained contact with Bobschow (sic) at Vichy until November 1942.

According to the notes which are not entirely clear, Dr. B seems to have been Laboratory Chief at the Rothschild Foundation; he maintains that he was a "Fellow" of the Rockefeller Foundation as well.

Concerning the bacteria: German war laboratories are experimenting with 5 elements as follows: Melitococci, Typhus exanthematique, Bacillus tularensis, Morve and Peste pulmonaire. The chances of these bacilli being used eventually are as follows: 3 out of 10 for the Melitococci, 6 out of 10 for the Typhus, and 1 out of 10 for the other 3.

Mediocre success accompanied experiments with torpedoes and bacteria shells in Russia, temperature conditions being a disadvantage there. Although a plan for large scale bombardment of embarkation camps on the English coast has been considered it has not been put into effect because "the receptacle to hold the bacteria is being re-examined and ought to be modified. The germs are preserved by drying and freezing. They should undergo an important change the moment they are discharged because experiments with these toxic powders in Russia have been disappointing. They catch on fire at the moment of deflagration (sic)".

The St. Gobain factory has just been enlarged and receptacles are being manufactured in the newly built additions. This factory seems to be the only one to manufacture these receptacles in an unbreakable material.

A good many dogs were collected in Paris by the Germans for the purpose of experimentation in bacteriology. German laboratories are actively engaged in the production of anti-typhus vaccine and French professors who were deported to Germany are working on problems involving typhus and the tissues. These professors are working in the laboratories at the Buchenwald Camp, which is located near Weimar.

According to Dr. B., the Scientific Research Service of the German Army is the source of the above information. Note from 110: I am sorry that I have no way of determining the dependability of Dr. B.

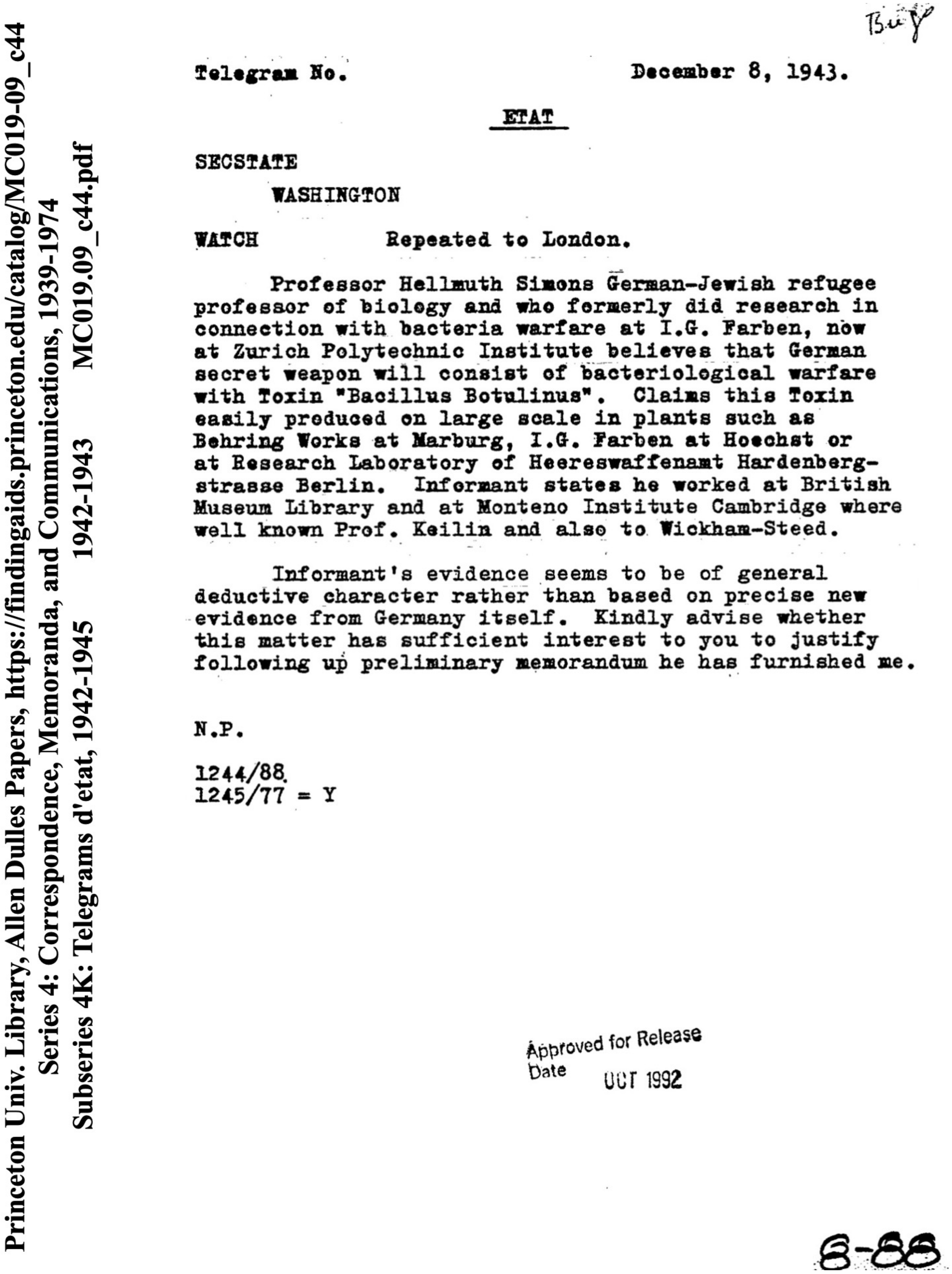
From Exdet, Algiers to Shepardson, OSS. IN-17824. 20 August 1944 [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

#48364. Green and Mitchell to Washington, information Rome and Caserta. Relay of Bari #433.

We have received a report from English sources dated August 12 says that 1,000,000 bottles of disease-producing germs, mainly cholera and plague, have been prepared in Osijek by the Nazis for use against regions held by large forces.

Klaus Reinhardt. 2013. The Entomological Institute of the Waffen-SS: Evidence for Offensive Biological Warfare Research in the Third Reich. *Endeavour* 37:4:220–227.

In January 1942, Heinrich Himmler, head of the Schutzstaffel (SS) and police in Nazi Germany, ordered the creation of an entomological institute to study the physiology and control of insects that inflict harm to humans. Founded in the grounds of the concentration camp at Dachau, it has been the focus of previous research, notably into the question of whether it was involved in biological warfare research. This article examines research protocols by the appointed leader Eduard May, presented here for the first time, which confirm the existence of an offensive biological warfare research programme in Nazi Germany.



Princeton Univ. Library, Allen Dulles Papers, https://findingaids.princeton.edu/catalog/MC019-09_c44
Series 4: Correspondence, Memoranda, and Communications, 1939-1974
Subseries 4K: Telegrams d'etat, 1942-1945 1942-1943 MC019.09_c44.pdf

Bu y

Telegram No. December 8, 1943.

ETAT

SECSTATE
WASHINGTON

WATCH Repeated to London.

Professor Hellmuth Simons German-Jewish refugee professor of biology and who formerly did research in connection with bacteria warfare at I.G. Farben, now at Zurich Polytechnic Institute believes that German secret weapon will consist of bacteriological warfare with Toxin "Bacillus Botulinus". Claims this Toxin easily produced on large scale in plants such as Behring Works at Marburg, I.G. Farben at Hoechst or at Research Laboratory of Heereswaffenamt Hardenbergstrasse Berlin. Informant states he worked at British Museum Library and at Monteno Institute Cambridge where well known Prof. Keilin and also to Wickham-Steed.

Informant's evidence seems to be of general deductive character rather than based on precise new evidence from Germany itself. Kindly advise whether this matter has sufficient interest to you to justify following up preliminary memorandum he has furnished me.

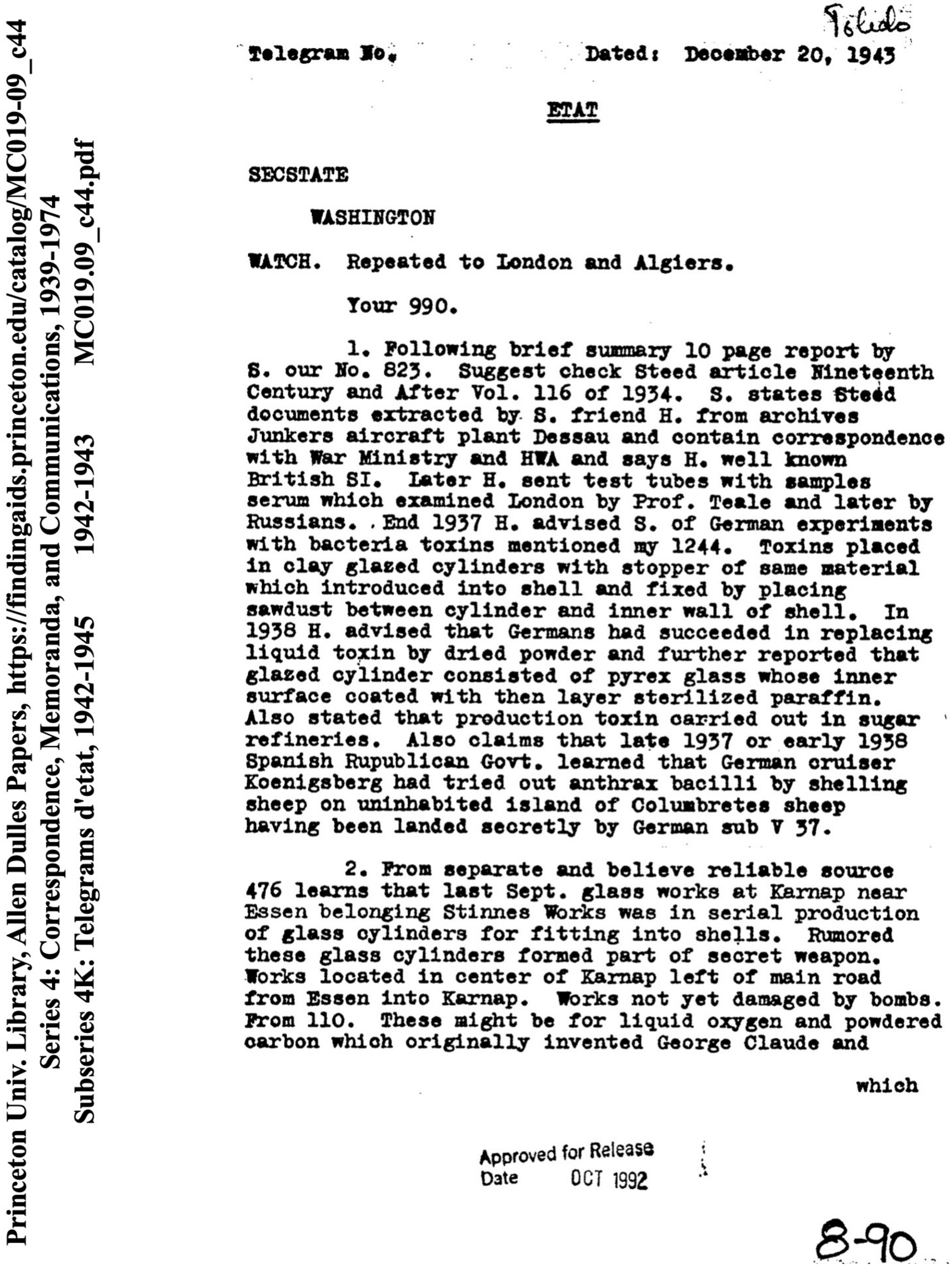
N.P.

1244/88
1245/77 = Y

Approved for Release
Date OCT 1992

8-88

Figure A.152: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44].



Princeton Univ. Library, Allen Dulles Papers, https://findingaids.princeton.edu/catalog/MC019-09_c44
Series 4: Correspondence, Memoranda, and Communications, 1939-1974
Subseries 4K: Telegrams d'etat, 1942-1945 1942-1943 MC019.09_c44.pdf

Toledo

Telegram No. Dated: December 20, 1943

ETAT

SECSTATE

WASHINGTON

WATCH. Repeated to London and Algiers.

Your 990.

1. Following brief summary 10 page report by S. our No. 823. Suggest check Steed article Nineteenth Century and After Vol. 116 of 1934. S. states Steed documents extracted by S. friend H. from archives Junkers aircraft plant Dessau and contain correspondence with War Ministry and HWA and says H. well known British SI. Later H. sent test tubes with samples serum which examined London by Prof. Teale and later by Russians. End 1937 H. advised S. of German experiments with bacteria toxins mentioned my 1244. Toxins placed in clay glazed cylinders with stopper of same material which introduced into shell and fixed by placing sawdust between cylinder and inner wall of shell. In 1938 H. advised that Germans had succeeded in replacing liquid toxin by dried powder and further reported that glazed cylinder consisted of pyrex glass whose inner surface coated with then layer sterilized paraffin. Also stated that production toxin carried out in sugar refineries. Also claims that late 1937 or early 1938 Spanish Rupublican Govt. learned that German cruiser Koenigsberg had tried out anthrax bacilli by shelling sheep on uninhabited island of Columbretes sheep having been landed secretly by German sub V 37.

2. From separate and believe reliable source 476 learns that last Sept. glass works at Karnap near Essen belonging Stinnes Works was in serial production of glass cylinders for fitting into shells. Rumored these glass cylinders formed part of secret weapon. Works located in center of Karnap left of main road from Essen into Karnap. Works not yet damaged by bombs. From 110. These might be for liquid oxygen and powdered carbon which originally invented George Claude and

which

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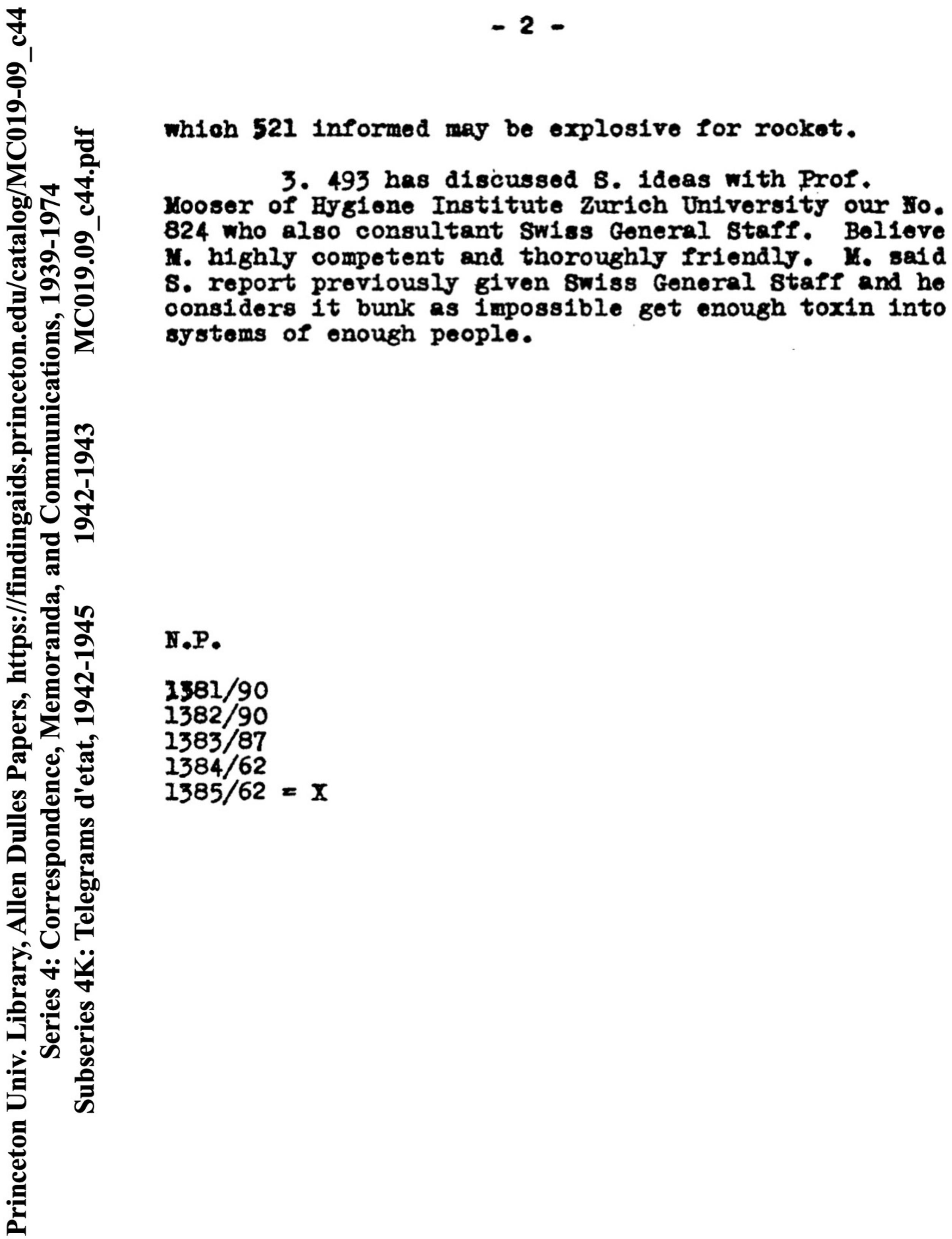
Date OCT 1992

8-90

Figure A.153: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44].



Princeton Univ. Library, Allen Dulles Papers, https://findingaids.princeton.edu/catalog/MC019-09_c44
Series 4: Correspondence, Memoranda, and Communications, 1939-1974
Subseries 4K: Telegrams d'etat, 1942-1945 1942-1943 MC019.09_c44.pdf

- 2 -

which 521 informed may be explosive for rocket.

3. 493 has discussed S. ideas with Prof. Mooser of Hygiene Institute Zurich University our No. 824 who also consultant Swiss General Staff. Believe M. highly competent and thoroughly friendly. M. said S. report previously given Swiss General Staff and he considers it bunk as impossible get enough toxin into systems of enough people.

N.P.

1381/90
1382/90
1383/87
1384/62
1385/62 = X

Figure A.154: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44].

**NARA RG 226, Entry A1-134,
Box 216, Folder 1360 OUT TOLEDO**

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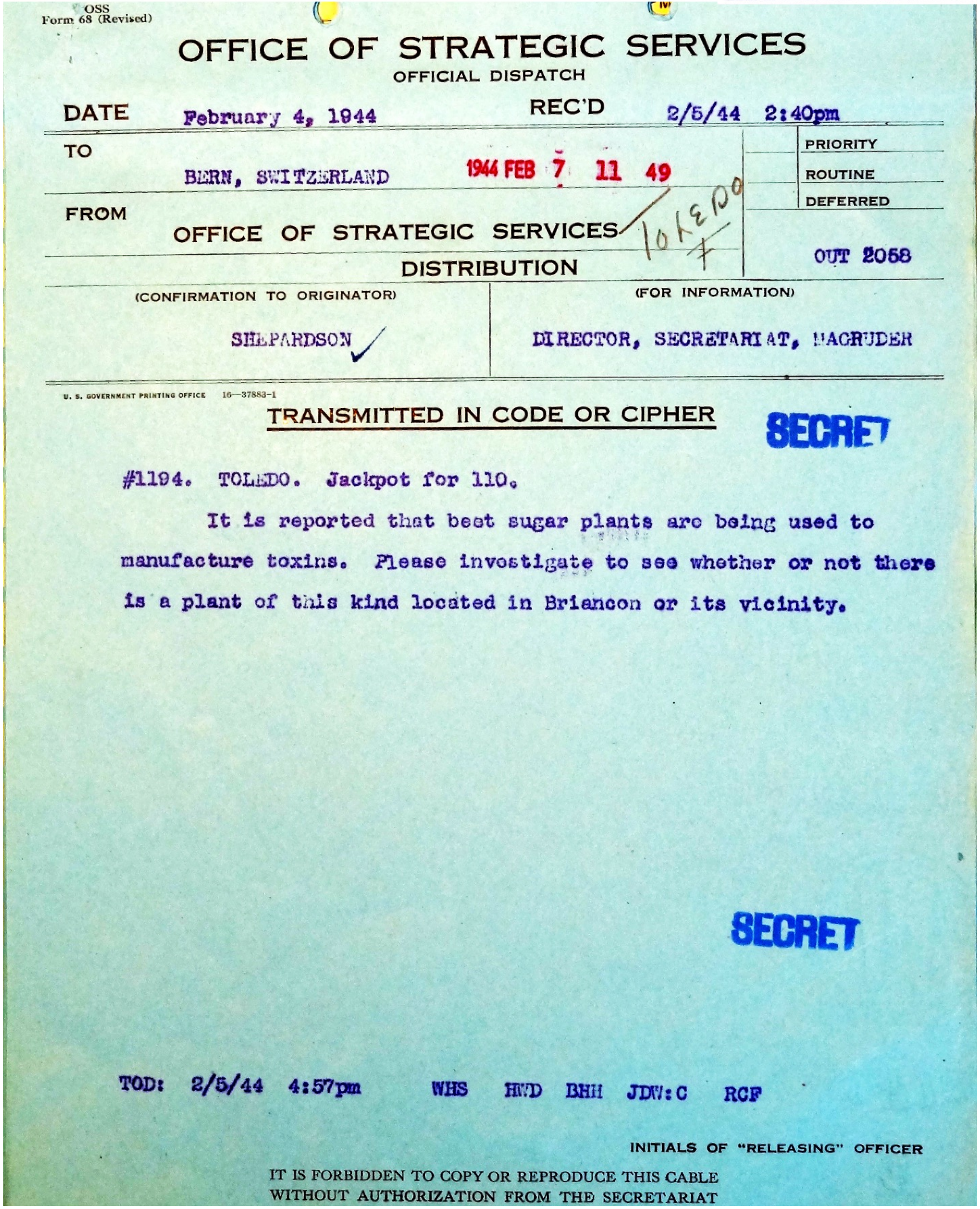
Authority NND857134



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Form 68 (Revised)

OFFICE OF STRATEGIC SERVICES

OFFICIAL DISPATCH

DATE February 4, 1944 REC'D 2/5/44 2:40pm

TO BERN, SWITZERLAND 1944 FEB 7 11 49

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SECRET

#1194. TOLEDO. Jackpot for 110.

It is reported that beet sugar plants are being used to manufacture toxins. Please investigate to see whether or not there is a plant of this kind located in Briancon or its vicinity.

SECRET

TOD: 2/5/44 4:57pm WHS HWD BHH JDW:C RCF

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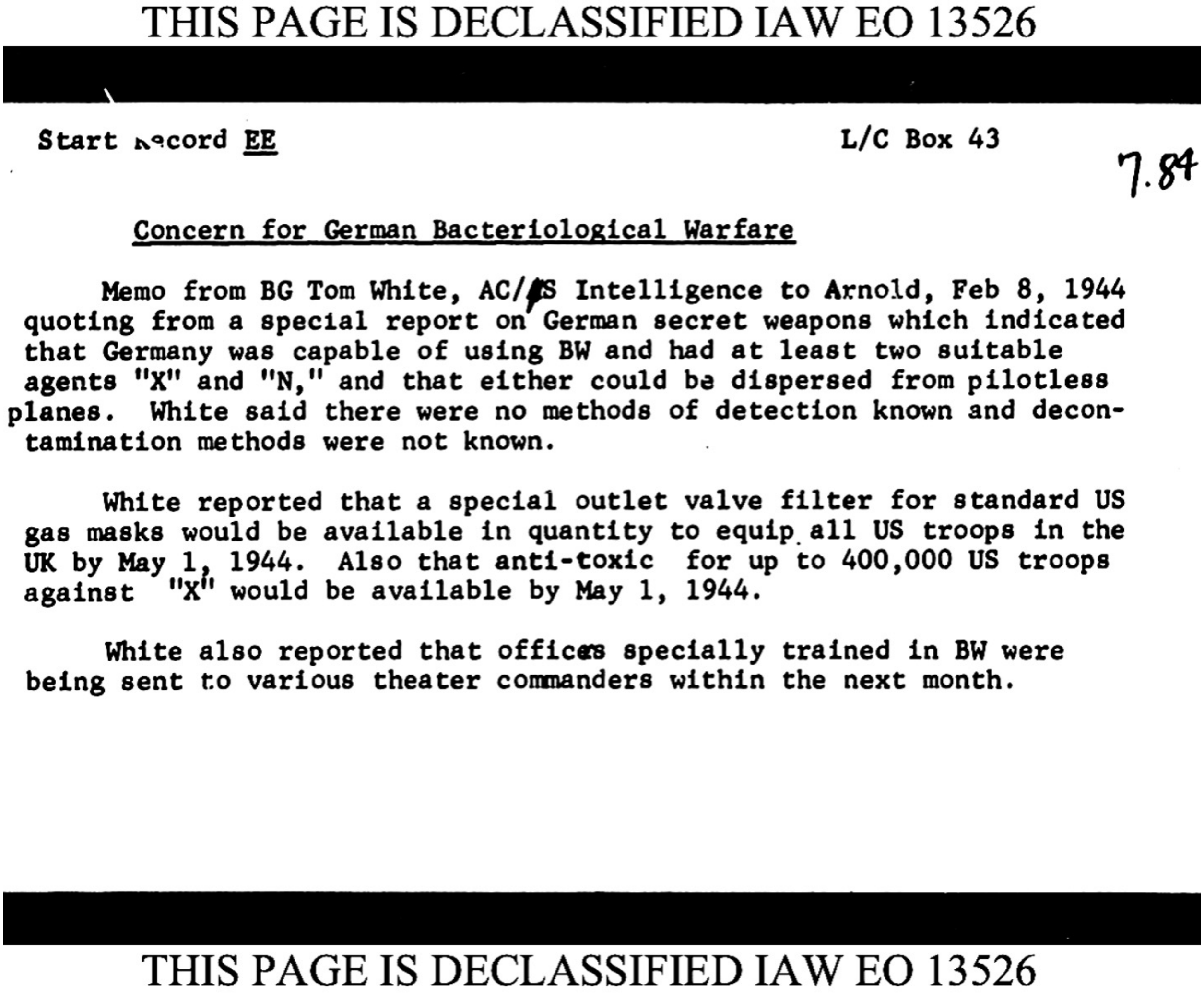
Figure A.155: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

AFHRA 43811 p. 1075



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[redacted]

Start Record EE **L/C Box 43**

7.84

Concern for German Bacteriological Warfare

Memo from BG Tom White, AC/AS Intelligence to Arnold, Feb 8, 1944 quoting from a special report on German secret weapons which indicated that Germany was capable of using BW and had at least two suitable agents "X" and "N," and that either could be dispersed from pilotless planes. White said there were no methods of detection known and decontamination methods were not known.

White reported that a special outlet valve filter for standard US gas masks would be available in quantity to equip all US troops in the UK by May 1, 1944. Also that anti-toxic for up to 400,000 US troops against "X" would be available by May 1, 1944.

White also reported that officers specially trained in BW were being sent to various theater commanders within the next month.

[redacted]

THIS PAGE IS DECLASSIFIED IAW EO 13526

Figure A.156: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [AFHRA 43811 electronic p. 1075].

**NARA RG 226, Entry A1-134,
Box 216, Folder 1359 IN TOLEDO**

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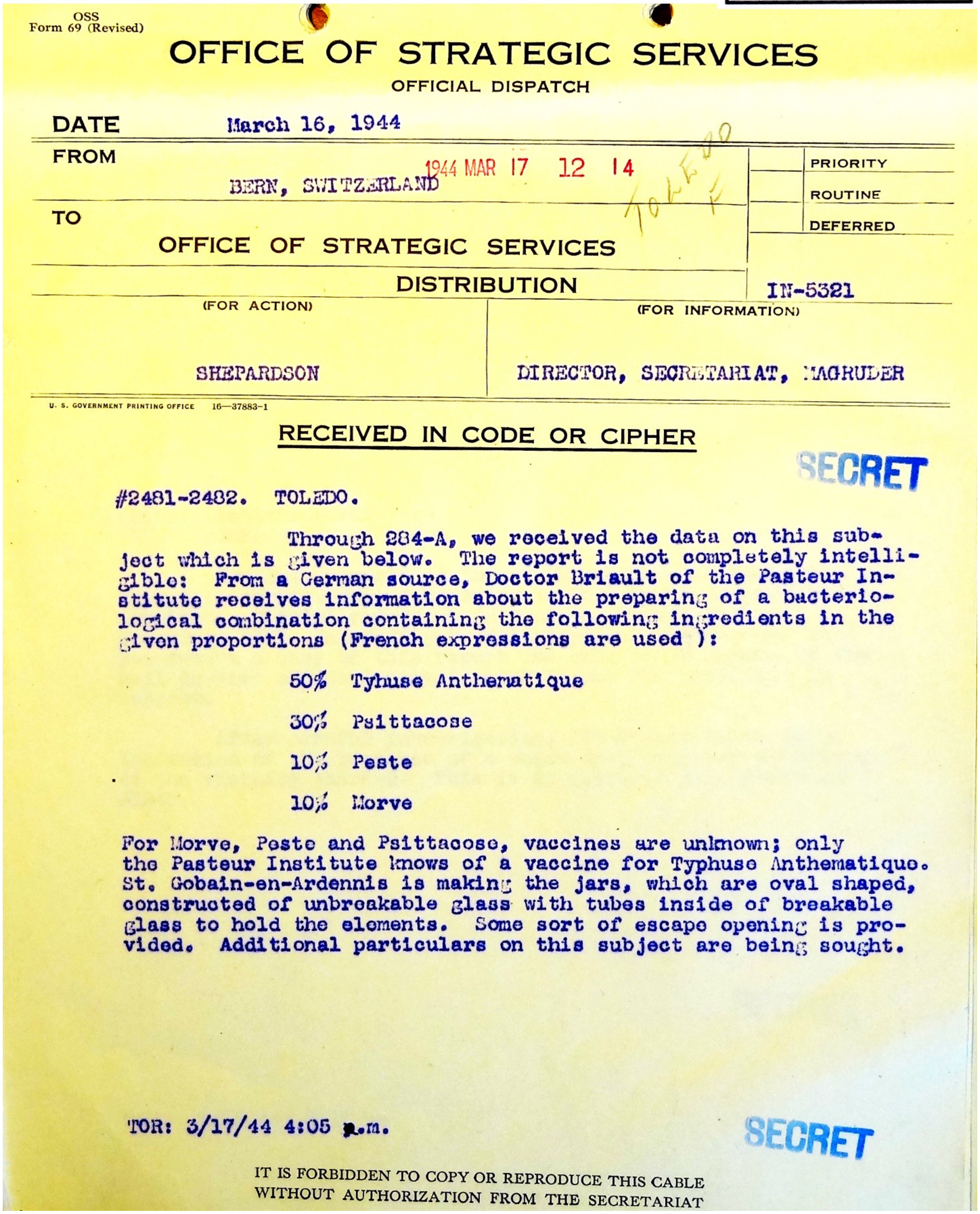

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OFFICE OF STRATEGIC SERVICES
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DATE March 16, 1944

FROM BERN, SWITZERLAND 1944 MAR 17 12 14

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#2481-2482. TOLEDO.

Through 284-A, we received the data on this subject which is given below. The report is not completely intelligible: From a German source, Doctor Briault of the Pasteur Institute receives information about the preparing of a bacteriological combination containing the following ingredients in the given proportions (French expressions are used):

50%	Tyhuse Anthematique
30%	Psittacose
10%	Peste
10%	Morve

For Morve, Peste and Psittacose, vaccines are unknown; only the Pasteur Institute knows of a vaccine for Typhuse Anthematique. St. Gobain-en-Ardennis is making the jars, which are oval shaped, constructed of unbreakable glass with tubes inside of breakable glass to hold the elements. Some sort of escape opening is provided. Additional particulars on this subject are being sought.

TOR: 3/17/44 4:05 p.m.

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Figure A.157: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

NARA RG 226, Entry A1-134,
Box 216, Folder 1360 OUT TOLEDO

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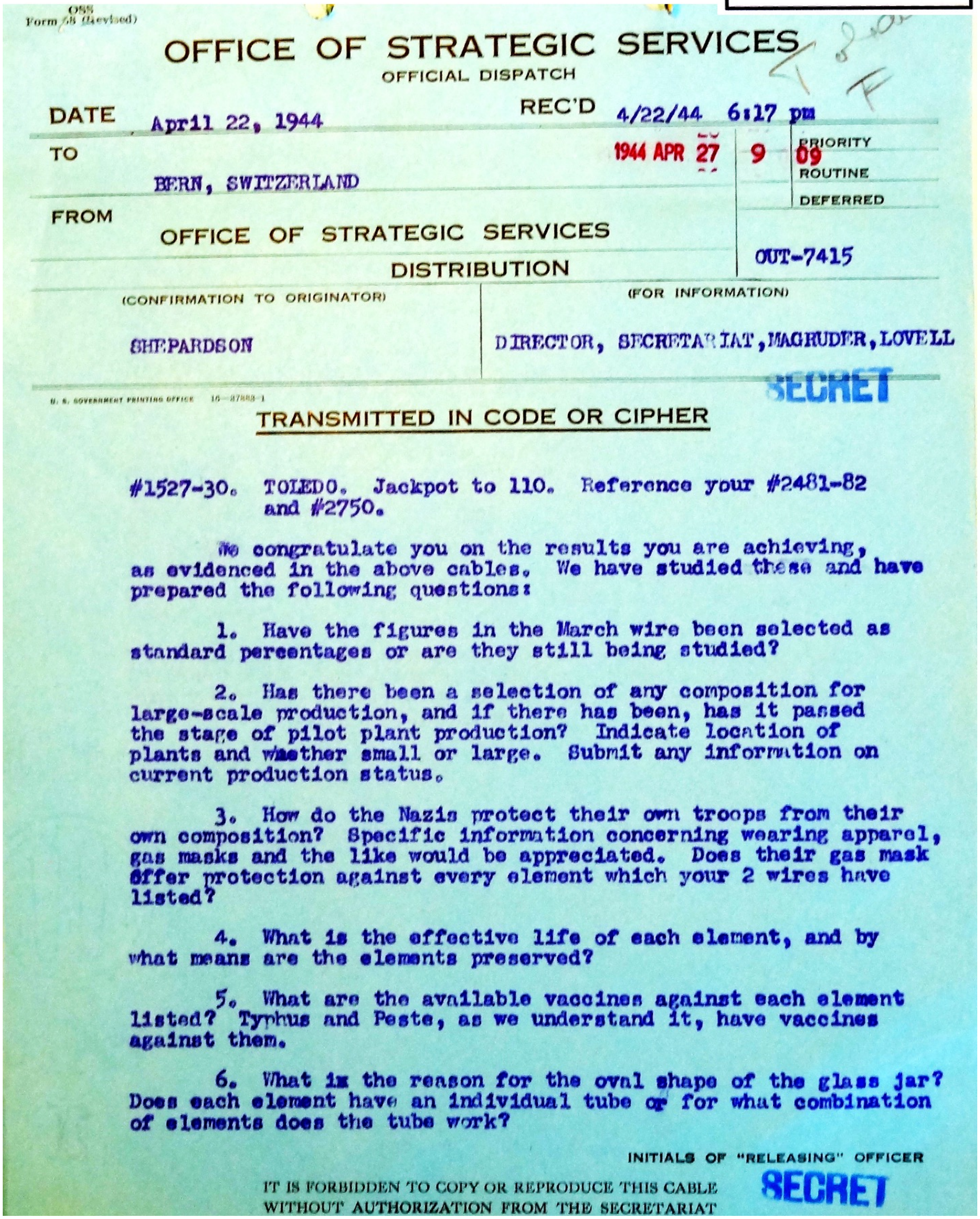

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OFFICE OF STRATEGIC SERVICES
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DATE April 22, 1944
REC'D 4/22/44 6:17 pm
1944 APR 27 9 09

TO BERN, SWITZERLAND

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#1527-30. TOLEDO. Jackpot to 110. Reference your #2481-82 and #2750.

We congratulate you on the results you are achieving, as evidenced in the above cables. We have studied these and have prepared the following questions:

1. Have the figures in the March wire been selected as standard percentages or are they still being studied?

2. Has there been a selection of any composition for large-scale production, and if there has been, has it passed the stage of pilot plant production? Indicate location of plants and whether small or large. Submit any information on current production status.

3. How do the Nazis protect their own troops from their own composition? Specific information concerning wearing apparel, gas masks and the like would be appreciated. Does their gas mask offer protection against every element which your 2 wires have listed?

4. What is the effective life of each element, and by what means are the elements preserved?

5. What are the available vaccines against each element listed? Typhus and Peste, as we understand it, have vaccines against them.

6. What ix the reason for the oval shape of the glass jar? Does each element have an individual tube or for what combination of elements does the tube work?

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Figure A.158: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

**NARA RG 226, Entry A1-134,
Box 216, Folder 1360 OUT TOLEDO**

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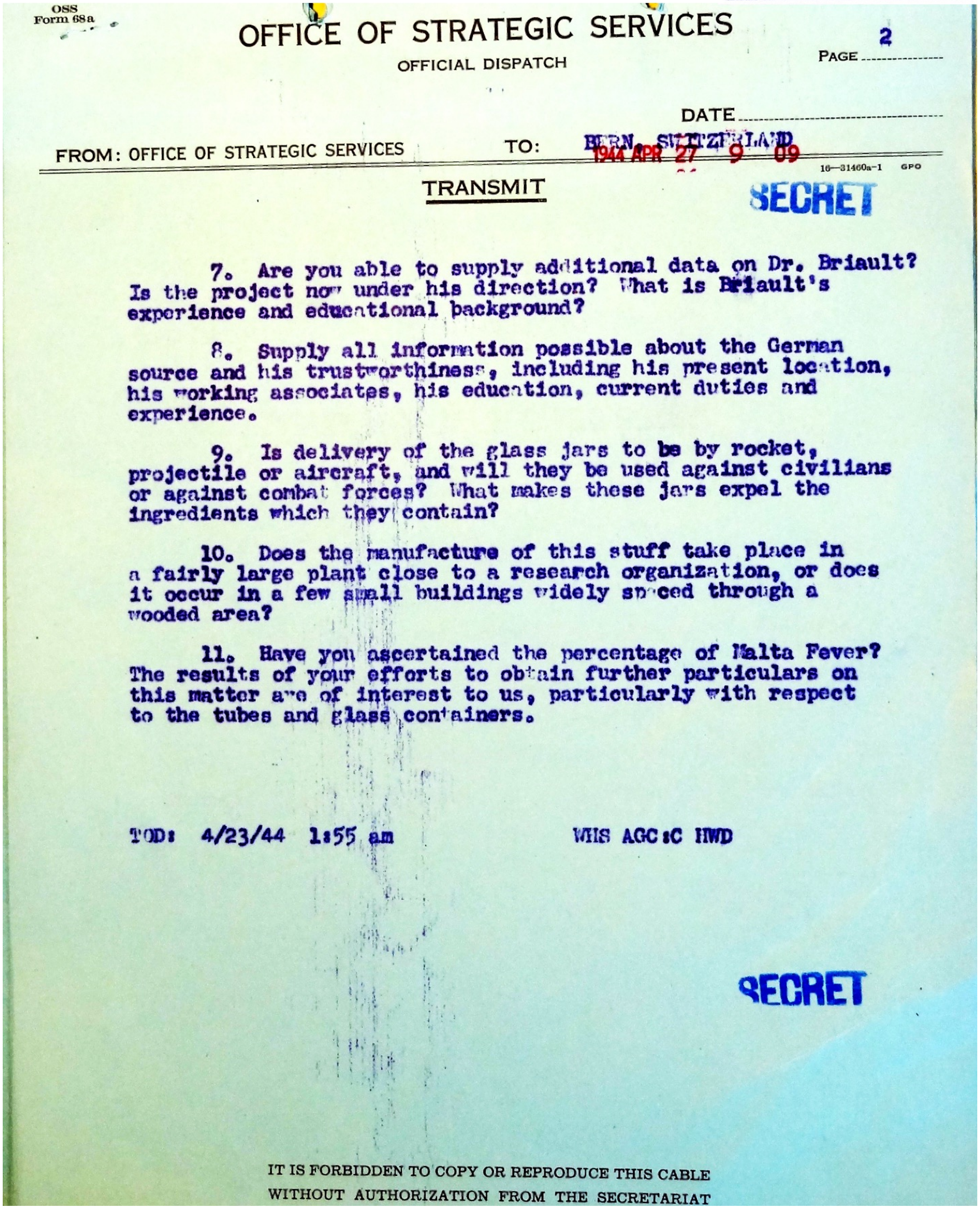

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Form 68a

OFFICE OF STRATEGIC SERVICES

OFFICIAL DISPATCH

PAGE 2

DATE

FROM: OFFICE OF STRATEGIC SERVICES TO: BERN, SWITZERLAND

1944 APR 27 9 09

16—31460a-1 GPO

TRANSMIT

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7. Are you able to supply additional data on Dr. Briault? Is the project now under his direction? What is Briault's experience and educational background?

8. Supply all information possible about the German source and his trustworthiness, including his present location, his working associates, his education, current duties and experience.

9. Is delivery of the glass jars to be by rocket, projectile or aircraft, and will they be used against civilians or against combat forces? What makes these jars expel the ingredients which they contain?

10. Does the manufacture of this stuff take place in a fairly large plant close to a research organization, or does it occur in a few small buildings widely spaced through a wooded area?

11. Have you ascertained the percentage of Malta Fever? The results of your efforts to obtain further particulars on this matter are of interest to us, particularly with respect to the tubes and glass containers.

TOD: 4/23/44 1:55 am WIIS AGC:C HWD

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Figure A.159: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

NARA RG 226, Entry A1-134,
Box 216, Folder 1359 IN TOLEDO

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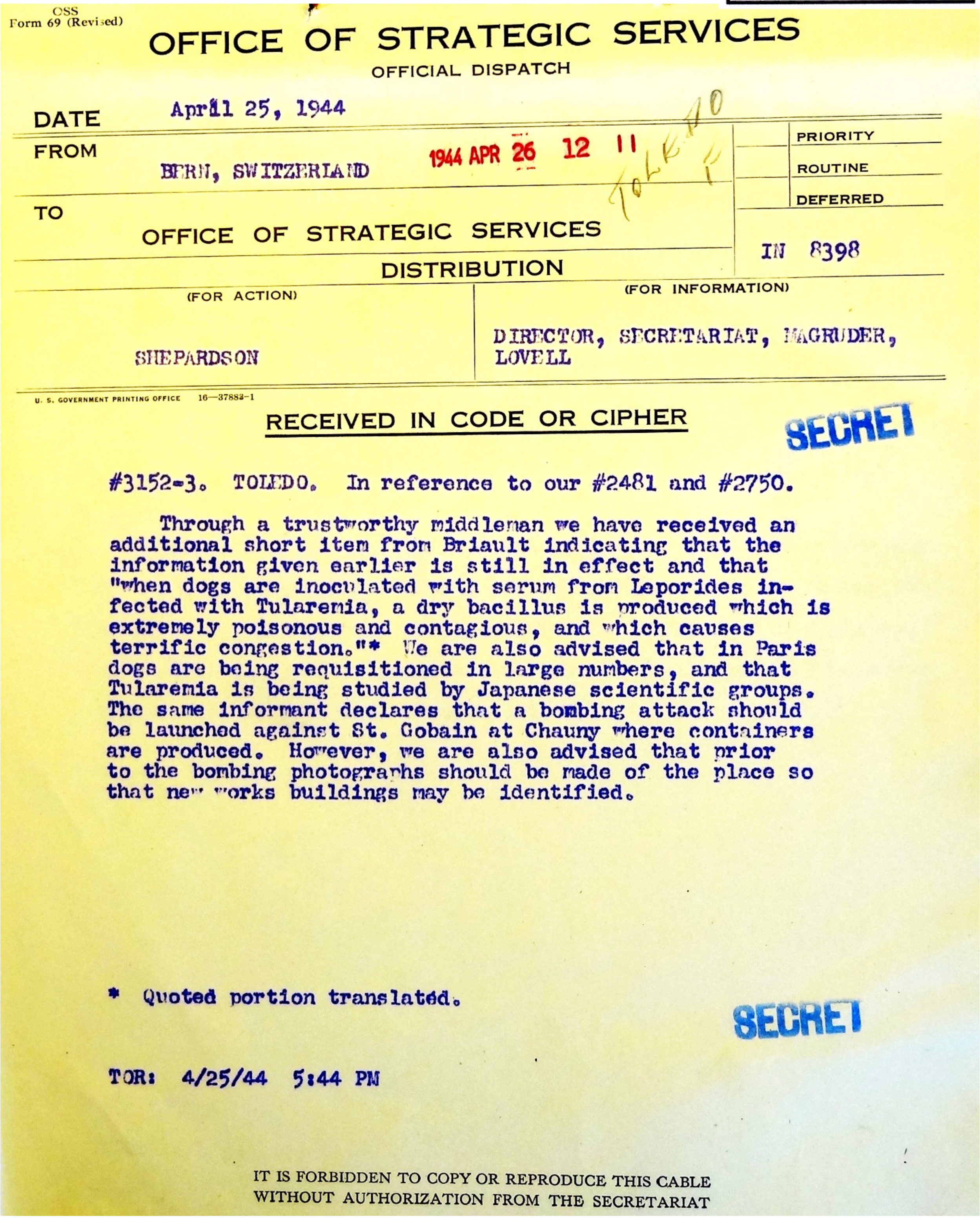

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OFFICE OF STRATEGIC SERVICES
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DATE April 25, 1944

FROM BERN, SWITZERLAND 1944 APR 26 12 11 TOLEDO F

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#3152-3. TOLEDO. In reference to our #2481 and #2750.

Through a trustworthy middleman we have received an additional short item from Briault indicating that the information given earlier is still in effect and that "when dogs are inoculated with serum from Leporides infected with Tularemia, a dry bacillus is produced which is extremely poisonous and contagious, and which causes terrific congestion."* We are also advised that in Paris dogs are being requisitioned in large numbers, and that Tularemia is being studied by Japanese scientific groups. The same informant declares that a bombing attack should be launched against St. Gobain at Chauny where containers are produced. However, we are also advised that prior to the bombing photographs should be made of the place so that new works buildings may be identified.

* Quoted portion translated.

SECRET

TOR: 4/25/44 5:44 PM

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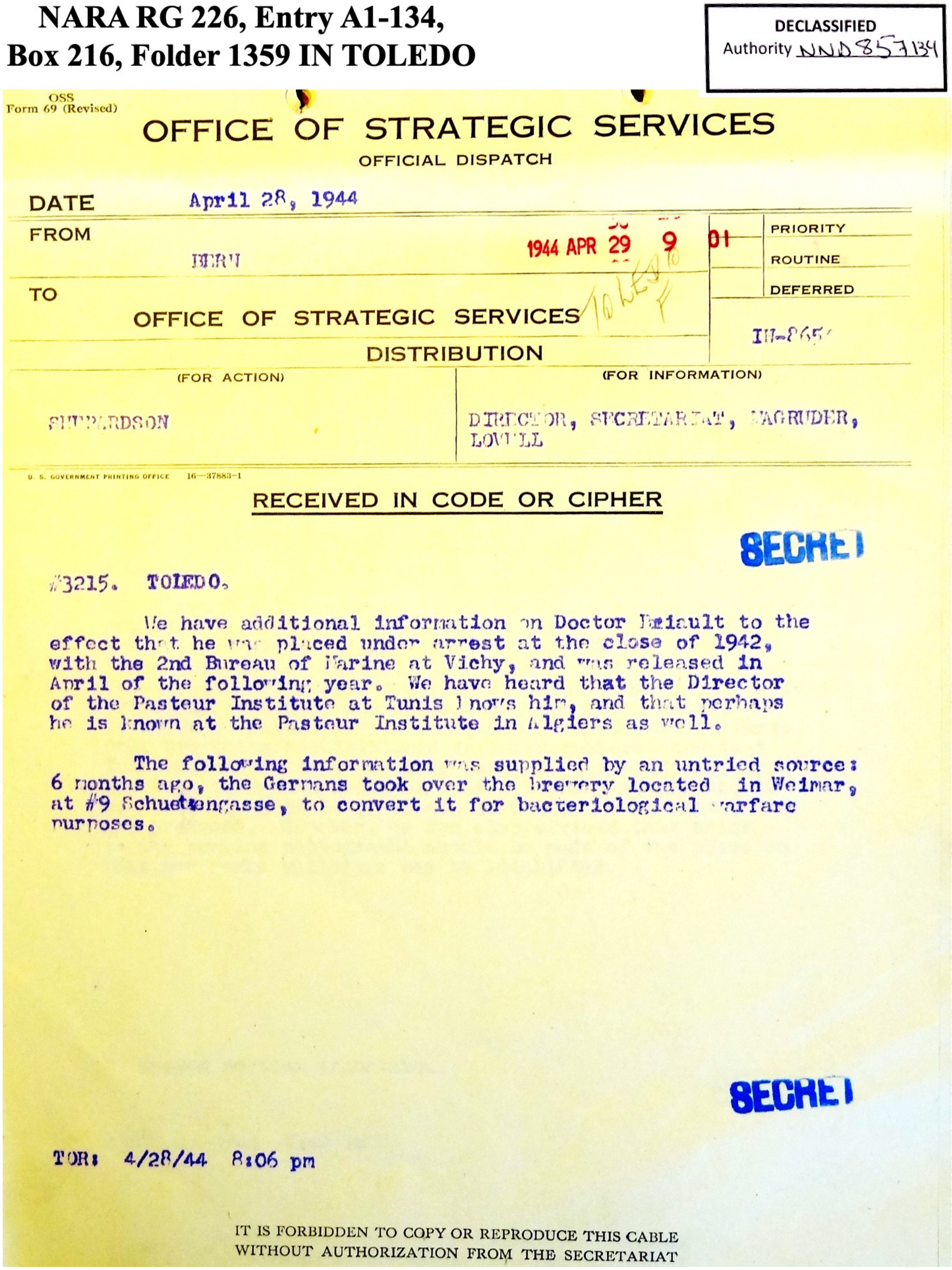
Figure A.160: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].



NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO

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#3215. TOLEDO.

We have additional information on Doctor Briault to the effect that he was placed under arrest at the close of 1942, with the 2nd Bureau of Marine at Vichy, and was released in April of the following year. We have heard that the Director of the Pasteur Institute at Tunis knows him, and that perhaps he is known at the Pasteur Institute in Algiers as well.

The following information was supplied by an untried source: 6 months ago, the Germans took over the brewery located in Weimar, at #9 Schuetzengasse, to convert it for bacteriological warfare purposes.

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TOR: 4/28/44 8:06 pm

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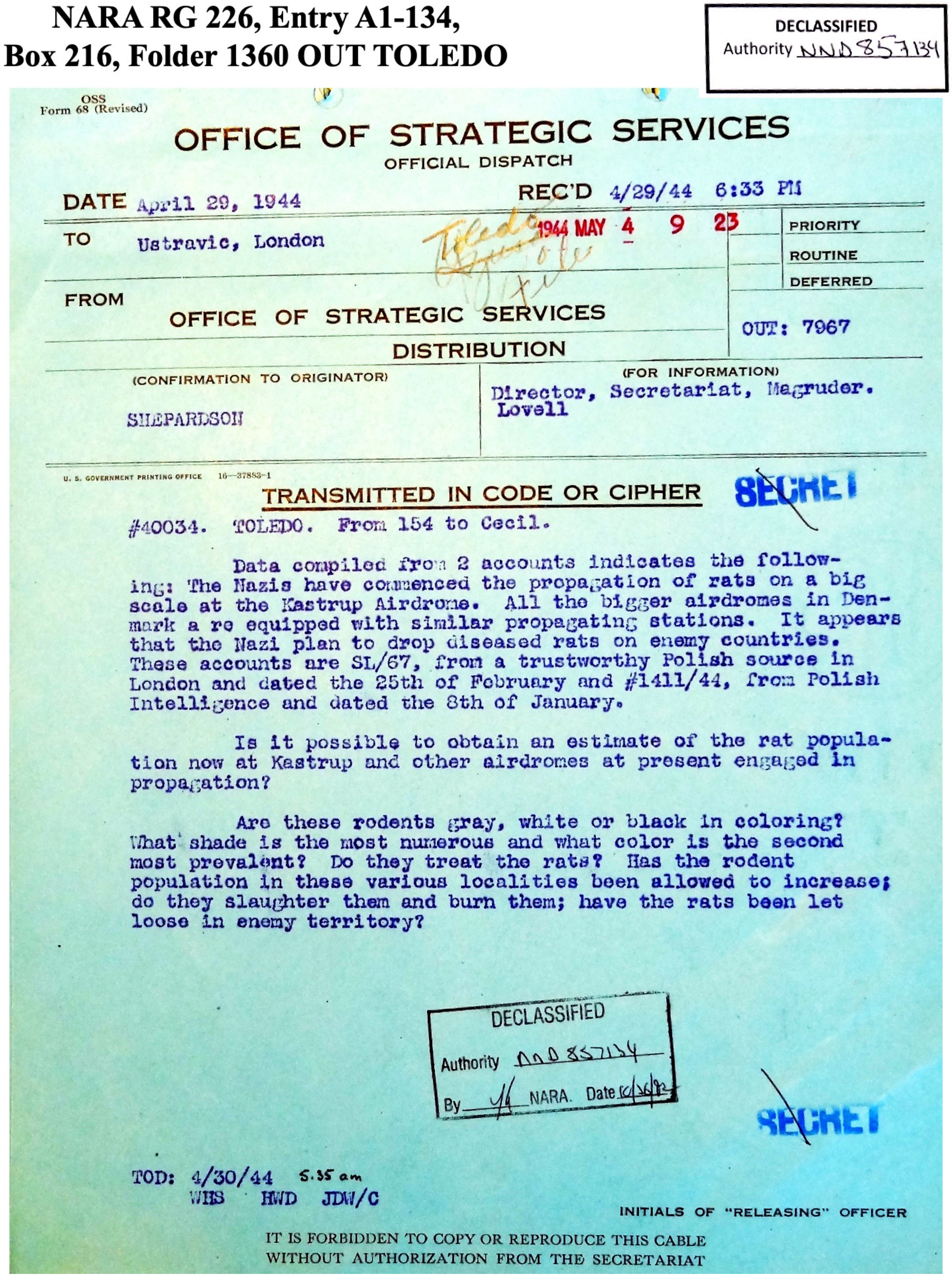
Figure A.161: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].



NARA RG 226, Entry A1-134,
Box 216, Folder 1360 OUT TOLEDO

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DATE April 29, 1944
REC'D 4/29/44 6:33 PM

TO Ustravic, London

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[illegible]
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#40034. TOLEDO. From 154 to Cecil.

Data compiled from 2 accounts indicates the following: The Nazis have commenced the propagation of rats on a big scale at the Kastrup Airdrome. All the bigger airdromes in Denmark a re equipped with similar propagating stations. It appears that the Nazi plan to drop diseased rats on enemy countries. These accounts are SL/67, from a trustworthy Polish source in London and dated the 25th of February and #1411/44, from Polish Intelligence and dated the 8th of January.

Is it possible to obtain an estimate of the rat population now at Kastrup and other airdromes at present engaged in propagation?

Are these rodents gray, white or black in coloring? What shade is the most numerous and what color is the second most prevalent? Do they treat the rats? Has the rodent population in these various localities been allowed to increase; do they slaughter them and burn them; have the rats been let loose in enemy territory?

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Authority NND 857134
By NARA. Date 10/26/92

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TOD: 4/30/44 5.35 am
WHS HWD JDW/C

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Figure A.162: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

NARA RG 226, Entry A1-134,
Box 216, Folder 1360 OUT TOLEDO

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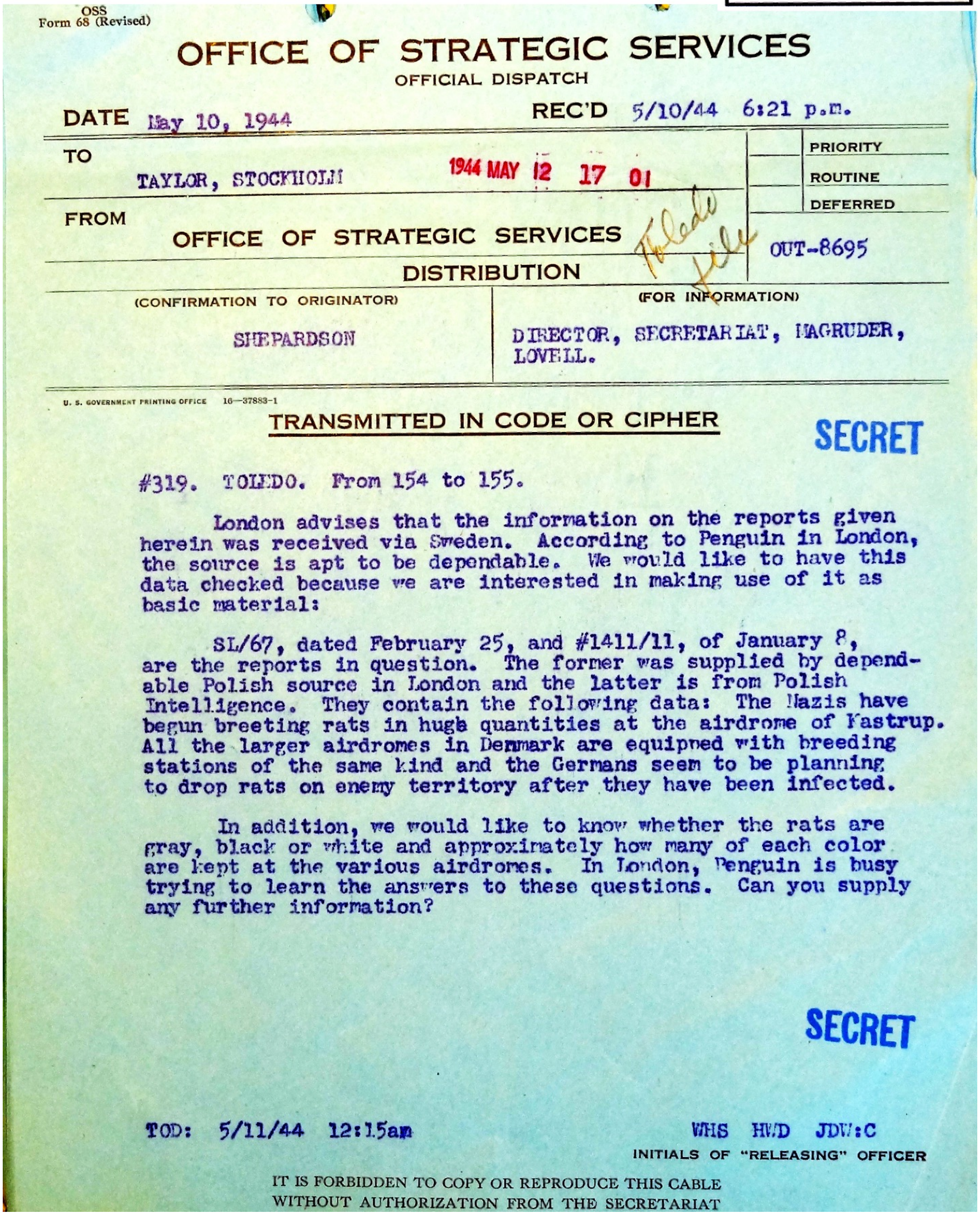

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OFFICE OF STRATEGIC SERVICES

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DATE May 10, 1944 REC'D 5/10/44 6:21 p.m.

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TAYLOR, STOCKHOLM 1944 MAY 12 17 01

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#319. TOLEDO. From 154 to 155.

London advises that the information on the reports given herein was received via Sweden. According to Penguin in London, the source is apt to be dependable. We would like to have this data checked because we are interested in making use of it as basic material:

SL/67, dated February 25, and #1411/11, of January 8, are the reports in question. The former was supplied by dependable Polish source in London and the latter is from Polish Intelligence. They contain the following data: The Nazis have begun breeting rats in hugh quantities at the airdrome of Kastrup. All the larger airdromes in Denmark are equipped with breeding stations of the same kind and the Germans seem to be planning to drop rats on enemy territory after they have been infected.

In addition, we would like to know whether the rats are gray, black or white and approximately how many of each color are kept at the various airdromes. In London, Penguin is busy trying to learn the answers to these questions. Can you supply any further information?

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TOD: 5/11/44 12:15am

WHS HWD JDW:C
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Figure A.163: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

NARA RG 226, Entry A1-134,
Box 216, Folder 1359 IN TOLEDO

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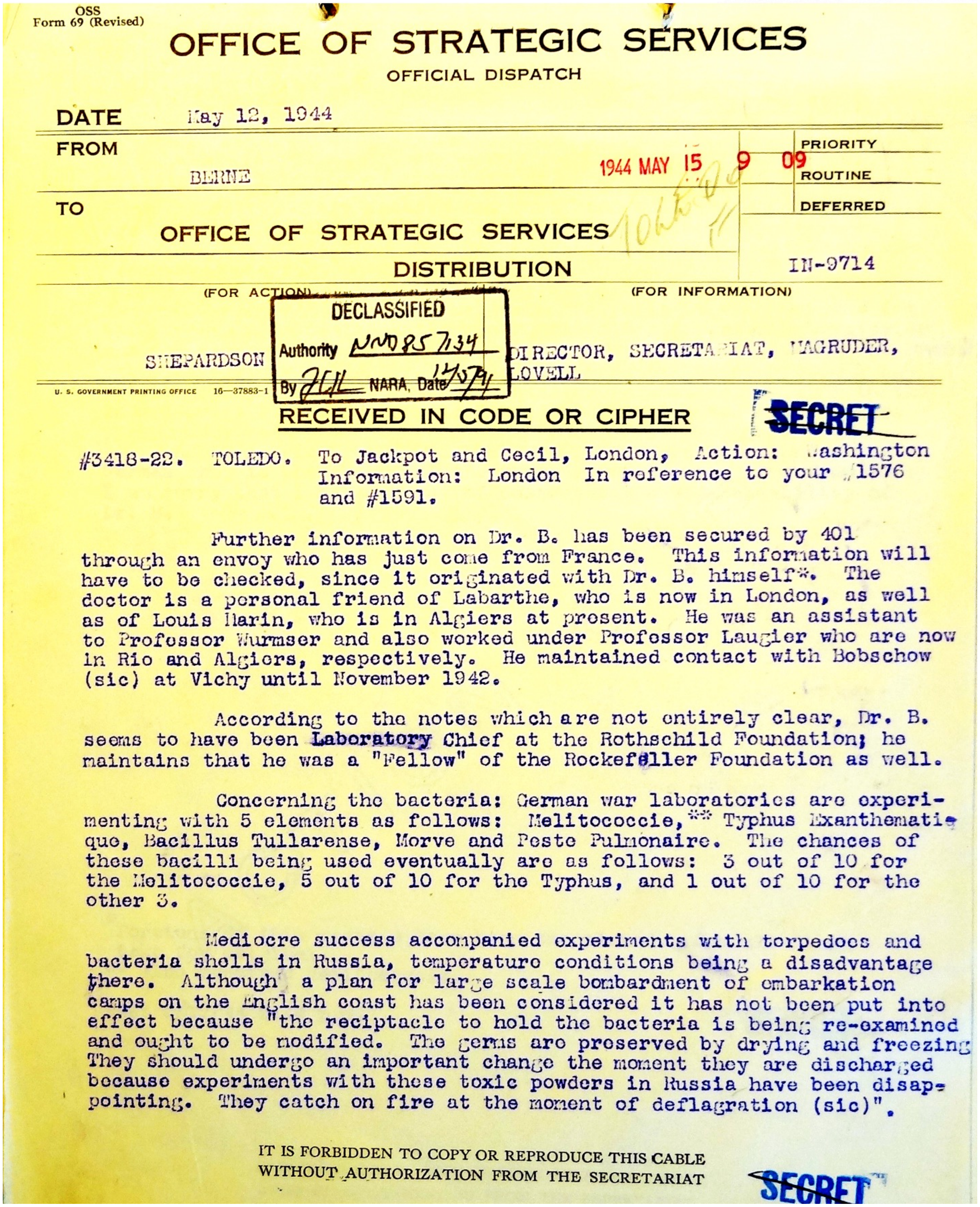

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DATE May 12, 1944

FROM BERNE

1944 MAY 15 9 09

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#3418-22. TOLEDO. To Jackpot and Cecil, London, Action: Washington
Information: London In reference to your #1576
and #1591.

Further information on Dr. B. has been secured by 401 through an envoy who has just come from France. This information will have to be checked, since it originated with Dr. B. himself*. The doctor is a personal friend of Labarthe, who is now in London, as well as of Louis Marin, who is in Algiers at present. He was an assistant to Professor Wurmser and also worked under Professor Laugier who are now in Rio and Algiers, respectively. He maintained contact with Bobschow (sic) at Vichy until November 1942.

According to the notes which are not entirely clear, Dr. B. seems to have been Laboratory Chief at the Rothschild Foundation; he maintains that he was a "Fellow" of the Rockefeller Foundation as well.

Concerning the bacteria: German war laboratories are experimenting with 5 elements as follows: Melitococcie,** Typhus Exanthematique, Bacillus Tullarense, Morve and Peste Pulmonaire. The chances of these bacilli being used eventually are as follows: 3 out of 10 for the Melitococcie, 5 out of 10 for the Typhus, and 1 out of 10 for the other 3.

Mediocre success accompanied experiments with torpedoes and bacteria shells in Russia, temperature conditions being a disadvantage there. Although a plan for large scale bombardment of embarkation camps on the English coast has been considered it has not been put into effect because "the reciptacle to hold the bacteria is being re-examined and ought to be modified. The germs are preserved by drying and freezing They should undergo an important change the moment they are discharged because experiments with these toxic powders in Russia have been disappointing. They catch on fire at the moment of deflagration (sic)".

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Figure A.164: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

**NARA RG 226, Entry A1-134,
Box 216, Folder 1359 IN TOLEDO**

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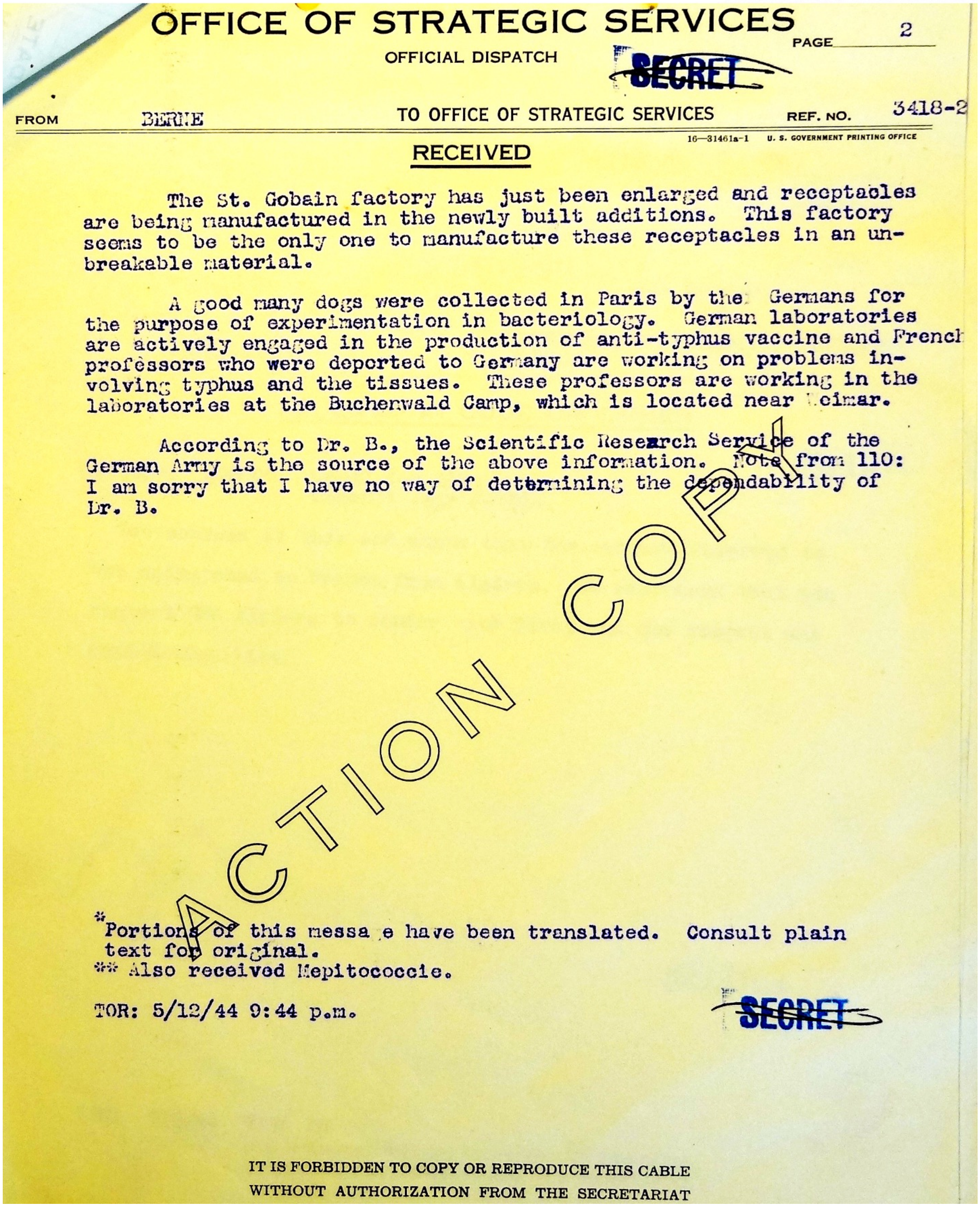

OFFICE OF STRATEGIC SERVICES
PAGE 2
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FROM BERNE TO OFFICE OF STRATEGIC SERVICES REF. NO. 3418-2

16—31461a-1 U. S. GOVERNMENT PRINTING OFFICE

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The St. Gobain factory has just been enlarged and receptacles are being manufactured in the newly built additions. This factory seems to be the only one to manufacture these receptacles in an unbreakable material.

A good many dogs were collected in Paris by the Germans for the purpose of experimentation in bacteriology. German laboratories are actively engaged in the production of anti-typhus vaccine and French professors who were deported to Germany are working on problems involving typhus and the tissues. These professors are working in the laboratories at the Buchenwald Camp, which is located near Weimar.

According to Dr. B., the Scientific Research Service of the German Army is the source of the above information. Note from 110: I am sorry that I have no way of determining the dependability of Dr. B.

ACTION COPY

*Portions of this message have been translated. Consult plain text for original.
** Also received Mepitococcie.

TOR: 5/12/44 9:44 p.m.

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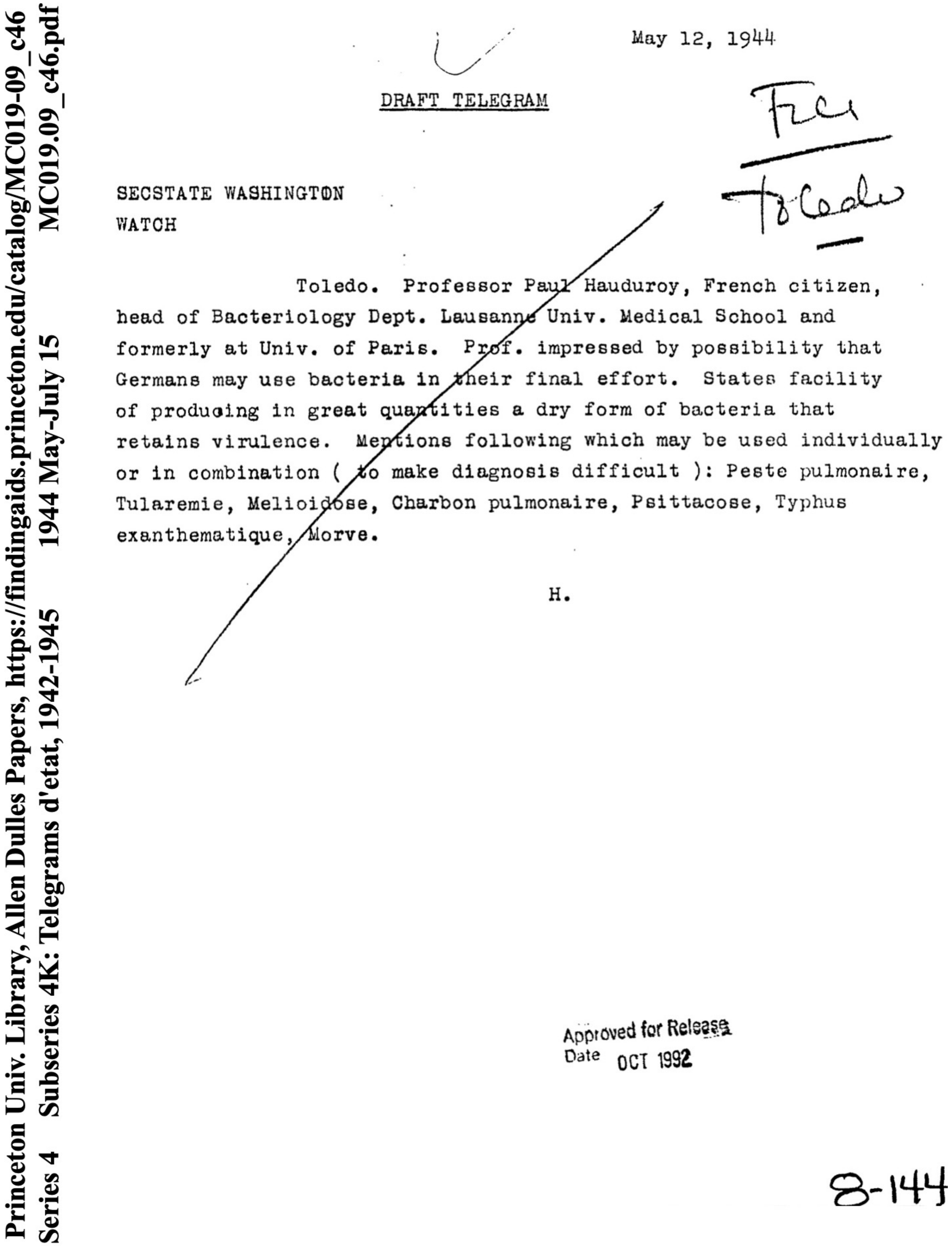
Figure A.165: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].



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May 12, 1944

DRAFT TELEGRAM

Fra

To Code

SECSTATE WASHINGTON
WATCH

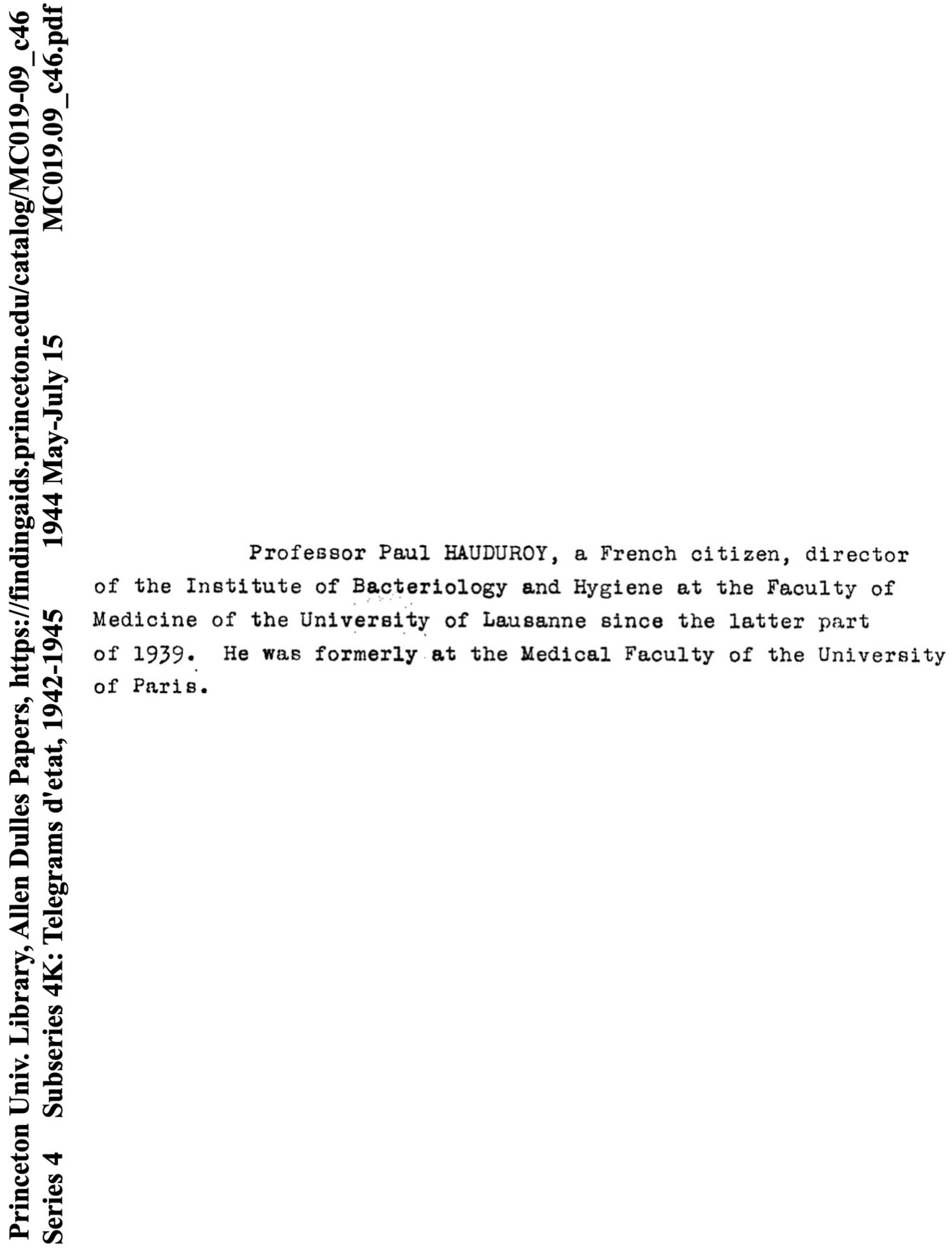
Toledo. Professor Paul Hauduroy, French citizen, head of Bacteriology Dept. Lausanne Univ. Medical School and formerly at Univ. of Paris. Prof. impressed by possibility that Germans may use bacteria in their final effort. States facility of producing in great quantities a dry form of bacteria that retains virulence. Mentions following which may be used individually or in combination (to make diagnosis difficult): Peste pulmonaire, Tularemie, Melioidose, Charbon pulmonaire, Psittacose, Typhus exanthematique, Morve.

H.

Approved for Release
Date OCT 1992

8-144

Figure A.166: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].



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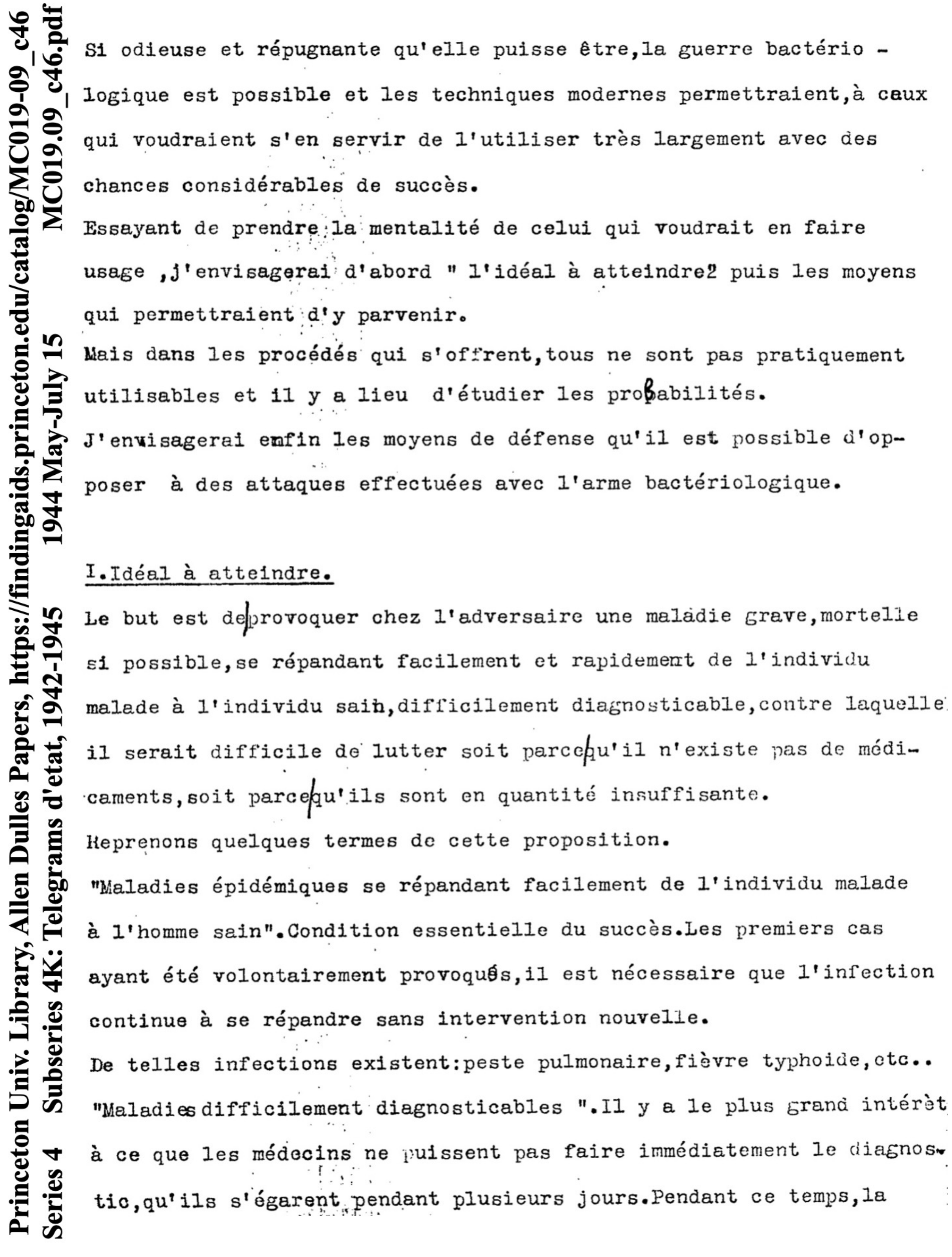
Professor Paul HAUDUROY, a French citizen, director of the Institute of Bacteriology and Hygiene at the Faculty of Medicine of the University of Lausanne since the latter part of 1939. He was formerly at the Medical Faculty of the University of Paris.

Figure A.167: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].



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Si odieuse et répugnante qu'elle puisse être, la guerre bactériologique est possible et les techniques modernes permettraient, à ceux qui voudraient s'en servir de l'utiliser très largement avec des chances considérables de succès.

Essayant de prendre la mentalité de celui qui voudrait en faire usage, j'envisagerai d'abord " l'idéal à atteindre" puis les moyens qui permettraient d'y parvenir.

Mais dans les procédés qui s'offrent, tous ne sont pas pratiquement utilisables et il y a lieu d'étudier les probabilités.

J'envisagerai enfin les moyens de défense qu'il est possible d'opposer à des attaques effectuées avec l'arme bactériologique.

I. Idéal à atteindre.

Le but est de provoquer chez l'adversaire une maladie grave, mortelle si possible, se répandant facilement et rapidement de l'individu malade à l'individu sain, difficilement diagnosticable, contre laquelle il serait difficile de lutter soit parce qu'il n'existe pas de médicaments, soit parce qu'ils sont en quantité insuffisante.

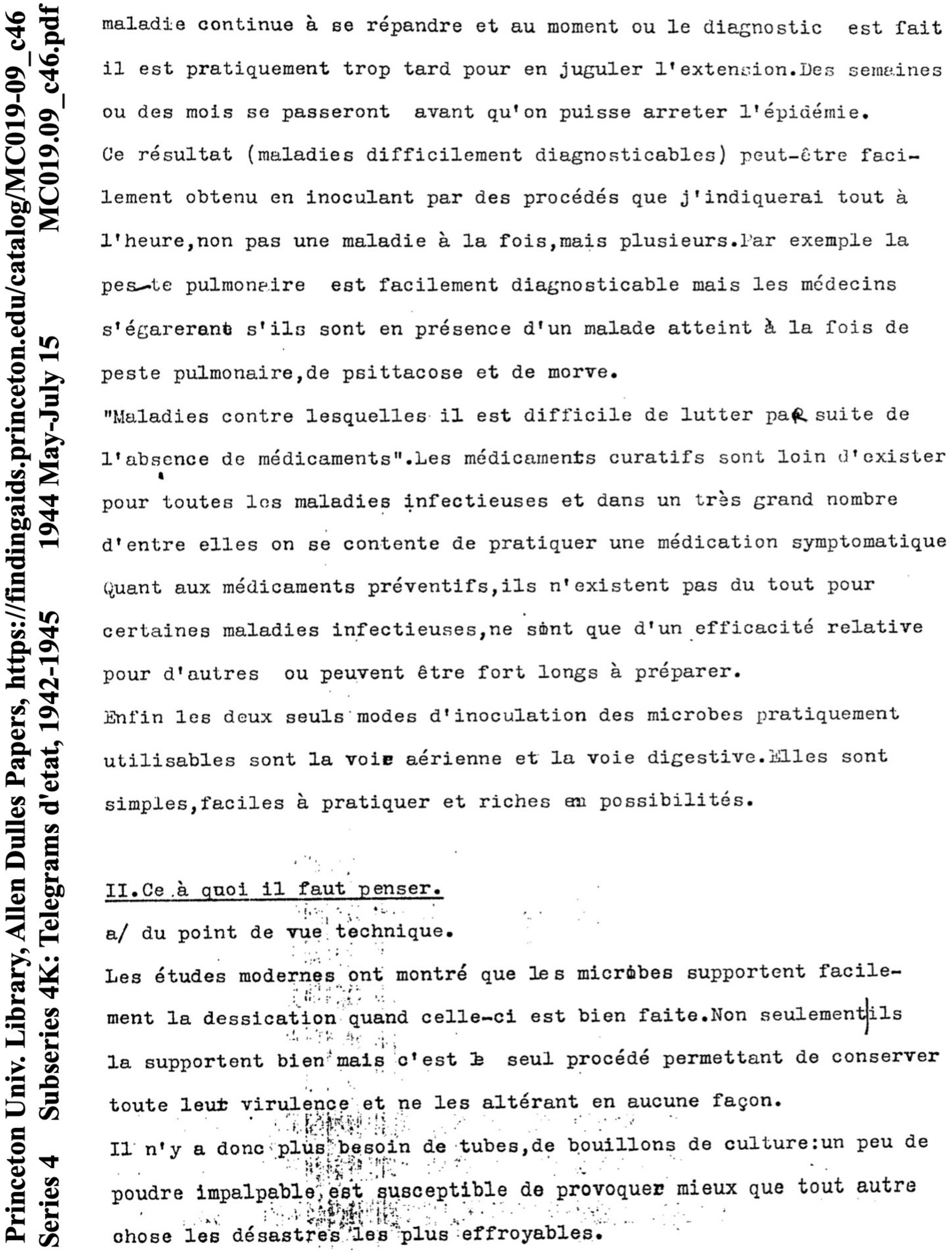
Reprenons quelques termes de cette proposition.

"Maladies épidémiques se répandant facilement de l'individu malade à l'homme sain". Condition essentielle du succès. Les premiers cas ayant été volontairement provoqués, il est nécessaire que l'infection continue à se répandre sans intervention nouvelle.

De telles infections existent: peste pulmonaire, fièvre typhoide, etc..

"Maladies difficilement diagnosticables ". Il y a le plus grand intérêt à ce que les médecins ne puissent pas faire immédiatement le diagnostic, qu'ils s'égarent pendant plusieurs jours. Pendant ce temps, la

Figure A.168: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].



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maladie continue à se répandre et au moment ou le diagnostic est fait il est pratiquement trop tard pour en juguler l'extension. Des semaines ou des mois se passeront avant qu'on puisse arreter l'épidémie.

Ce résultat (maladies difficilement diagnosticables) peut-être facilement obtenu en inoculant par des procédés que j'indiquerai tout à l'heure, non pas une maladie à la fois, mais plusieurs. Par exemple la peste pulmonaire est facilement diagnosticable mais les médecins s'égareront s'ils sont en présence d'un malade atteint à la fois de peste pulmonaire, de psittacose et de morve.

"Maladies contre lesquelles il est difficile de lutter par suite de l'absence de médicaments". Les médicaments curatifs sont loin d'exister pour toutes les maladies infectieuses et dans un très grand nombre d'entre elles on se contente de pratiquer une médication symptomatique Quant aux médicaments préventifs, ils n'existent pas du tout pour certaines maladies infectieuses, ne sont que d'un efficacité relative pour d'autres ou peuvent être fort longs à préparer.

Enfin les deux seuls modes d'inoculation des microbes pratiquement utilisables sont la voie aérienne et la voie digestive. Elles sont simples, faciles à pratiquer et riches en possibilités.

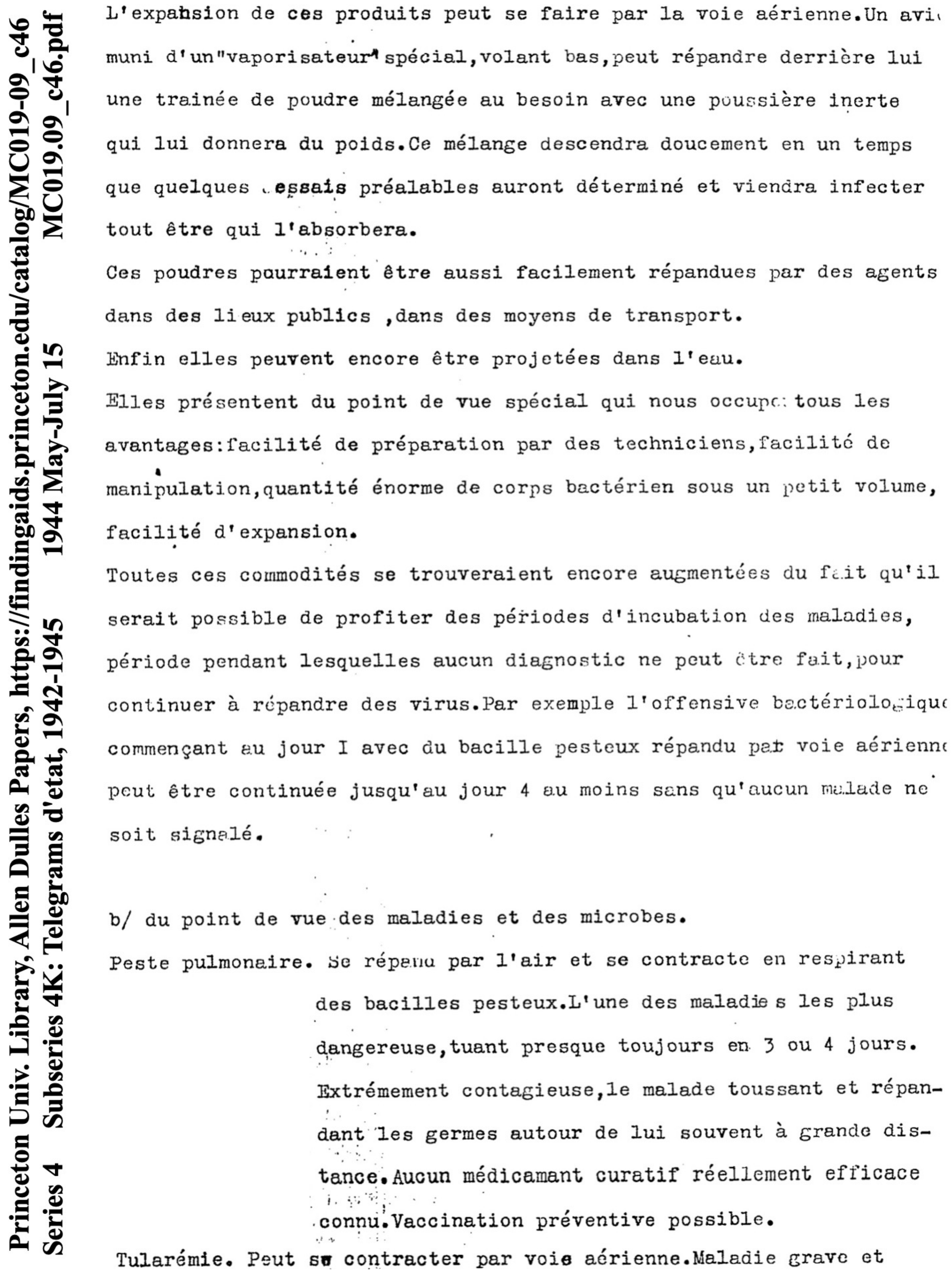
II. Ce à quoi il faut penser.

a/ du point de vue technique.

Les études modernes ont montré que les microbes supportent facilement la dessication quand celle-ci est bien faite. Non seulement ils la supportent bien mais c'est le seul procédé permettant de conserver toute leur virulence et ne les altérant en aucune façon.

Il n'y a donc plus besoin de tubes, de bouillons de culture: un peu de poudre impalpable, est susceptible de provoquer mieux que tout autre chose les désastres les plus effroyables.

Figure A.169: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].



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L'expahsion de ces produits peut se faire par la voie aérienne.Un avi muni d'un"vaporisateur"spécial,volant bas,peut répandre derrière lui une trainée de poudre mélangée au besoin avec une poussière inerte qui lui donnera du poids.Ce mélange descendra doucement en un temps que quelques essais préalables auront déterminé et viendra infecter tout être qui l'absorbera.

Ces poudres pourraient être aussi facilement répandues par des agents dans des lieux publics ,dans des moyens de transport.

Enfin elles peuvent encore être projetées dans l'eau.

Elles présentent du point de vue spécial qui nous occupe tous les avantages:facilité de préparation par des techniciens,facilité de manipulation,quantité énorme de corps bactérien sous un petit volume, facilité d'expansion.

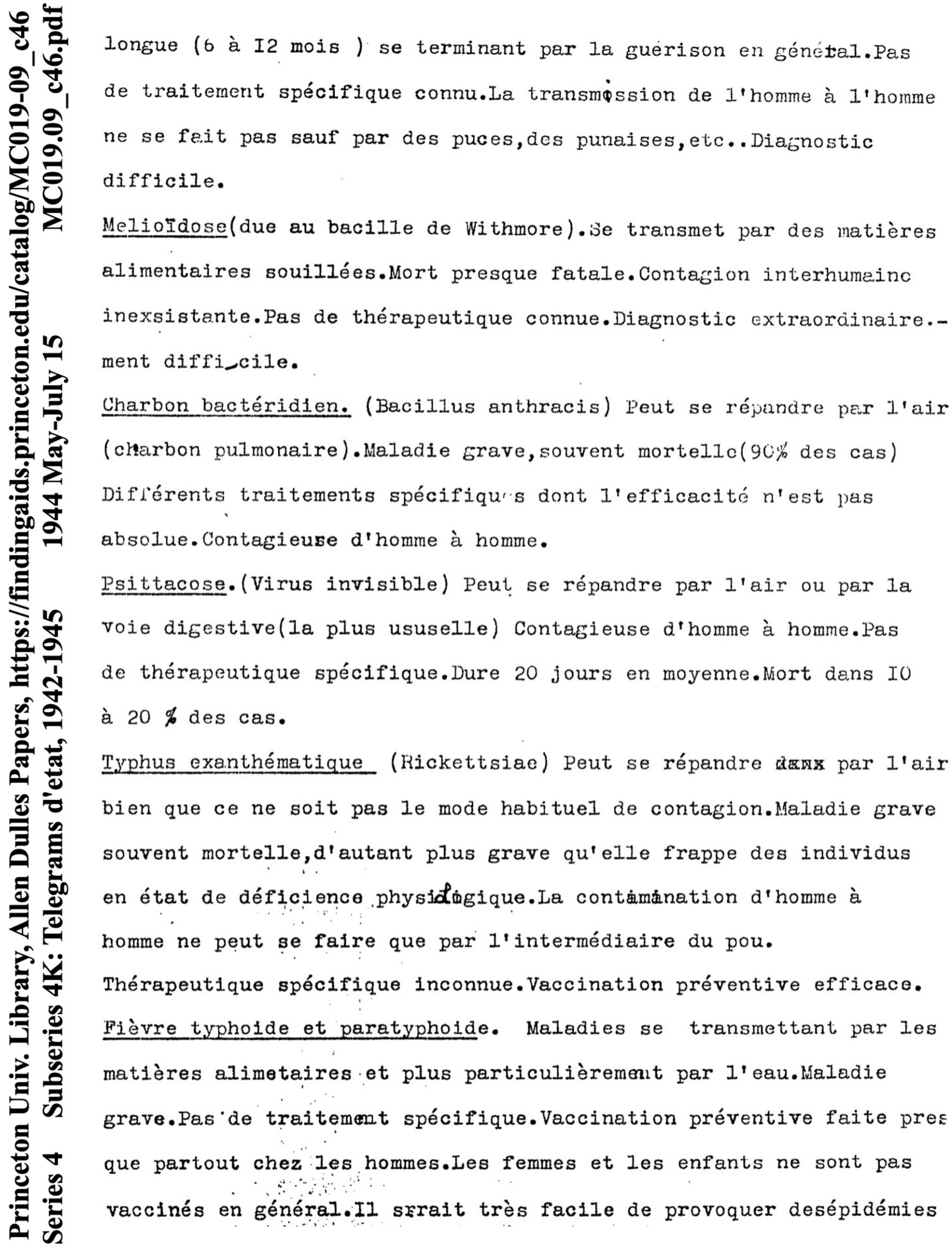
Toutes ces commodités se trouveraient encore augmentées du fait qu'il serait possible de profiter des périodes d'incubation des maladies, période pendant lesquelles aucun diagnostic ne peut être fait,pour continuer à répandre des virus.Par exemple l'offensive bactériologiqu commençant au jour I avec du bacille pesteux répandu par voie aérienn peut être continuée jusqu'au jour 4 au moins sans qu'aucun malade ne soit signalé.

b/ du point de vue des maladies et des microbes.

Peste pulmonaire. Se répand par l'air et se contracte en respirant des bacilles pesteux.L'une des maladies les plus dangereuse,tuant presque toujours en 3 ou 4 jours. Extrémement contagieuse,le malade toussant et répandant les germes autour de lui souvent à grande distance.Aucun médicamant curatif réellement efficace connu.Vaccination préventive possible.

Tularémie. Peut se contracter par voie aérienne.Maladie grave et

Figure A.170: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].



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longue (6 à I2 mois) se terminant par la guérison en général.Pas de traitement spécifique connu.La transmission de l'homme à l'homme ne se fait pas sauf par des puces,des punaises,etc..Diagnostic difficile.

Melioïdose(due au bacille de Withmore).Se transmet par des matières alimentaires souillées.Mort presque fatale.Contagion interhumaine inexsistante.Pas de thérapeutique connue.Diagnostic extraordinairement difficile.

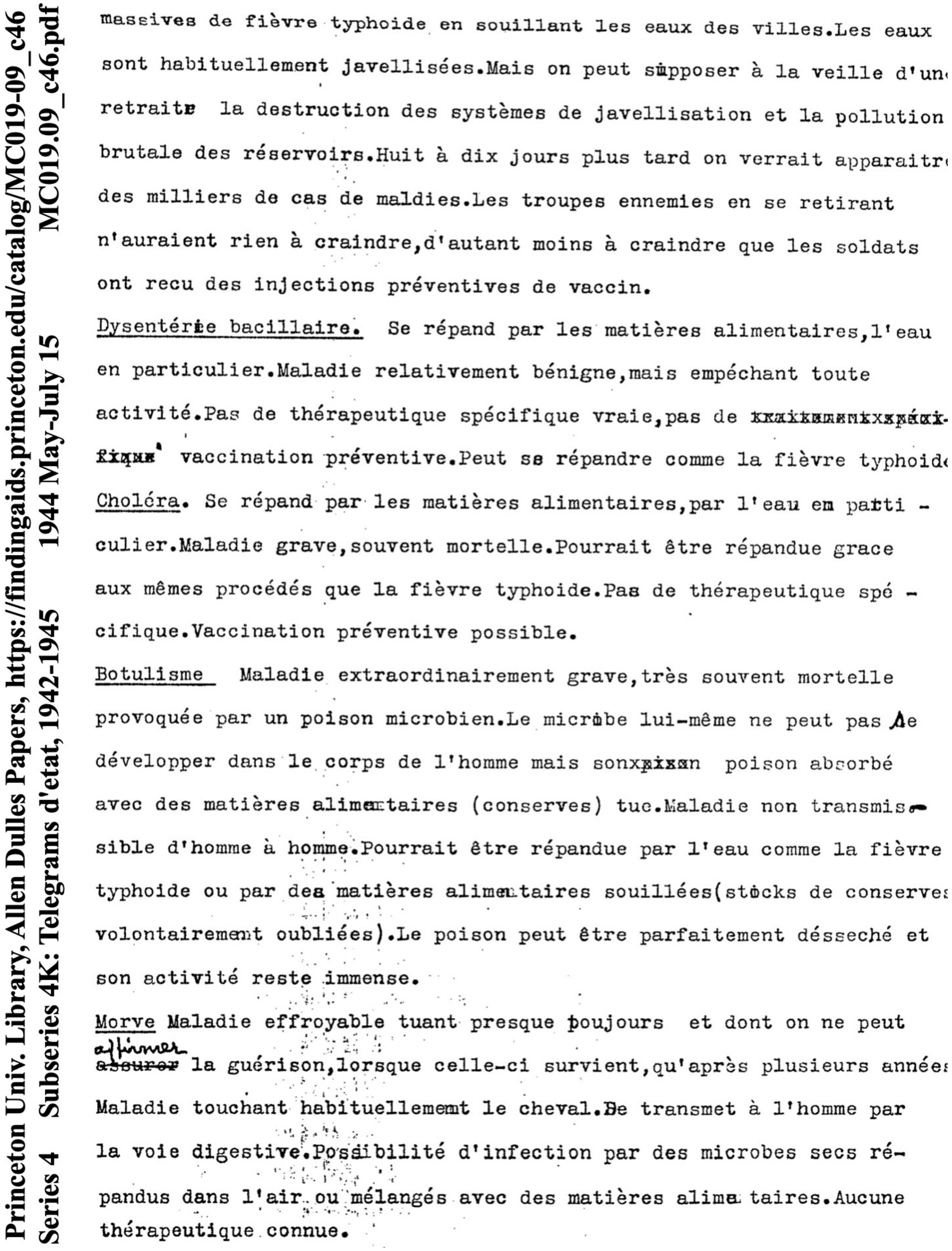
Charbon bactéridien. (Bacillus anthracis) Peut se répandre par l'air (charbon pulmonaire).Maladie grave,souvent mortelle(90% des cas) Différents traitements spécifiques dont l'efficacité n'est pas absolue.Contagieuse d'homme à homme.

Psittacose.(Virus invisible) Peut se répandre par l'air ou par la voie digestive(la plus ususelle) Contagieuse d'homme à homme.Pas de thérapeutique spécifique.Dure 20 jours en moyenne.Mort dans I0 à 20 % des cas.

Typhus exanthématique (Rickettsiae) Peut se répandre ~~dans~~ par l'air bien que ce ne soit pas le mode habituel de contagion.Maladie grave souvent mortelle,d'autant plus grave qu'elle frappe des individus en état de déficience physiologique.La contamination d'homme à homme ne peut se faire que par l'intermédiaire du pou. Thérapeutique spécifique inconnue.Vaccination préventive efficace.

Fièvre typhoide et paratyphoide. Maladies se transmettant par les matières alimetaires et plus particulièrement par l'eau.Maladie grave.Pas de traitement spécifique.Vaccination préventive faite presque partout chez les hommes.Les femmes et les enfants ne sont pas vaccinés en général.Il serait très facile de provoquer desépidémies

Figure A.171: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].



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massives de fièvre typhoide en souillant les eaux des villes.Les eaux sont habituellement javellisées.Mais on peut supposer à la veille d'un retraite la destruction des systèmes de javellisation et la pollution brutale des réservoirs.Huit à dix jours plus tard on verrait apparaitr des milliers de cas de maldies.Les troupes ennemies en se retirant n'auraient rien à craindre,d'autant moins à craindre que les soldats ont recu des injections préventives de vaccin.

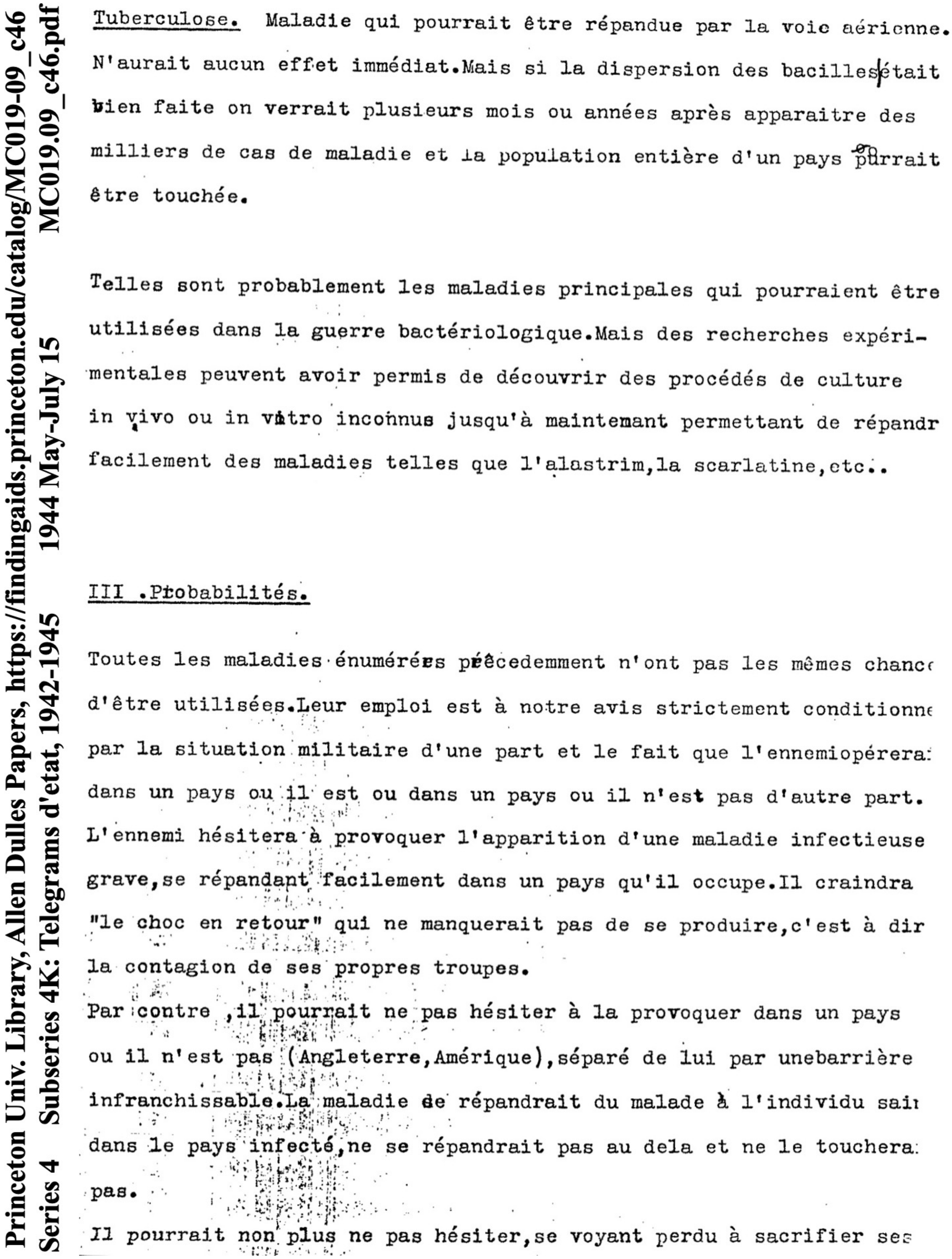
Dysentérie bacillaire. Se répand par les matières alimentaires,l'eau en particulier.Maladie relativement bénigne,mais empéchant toute activité.Pas de thérapeutique spécifique vraie,pas de ~~traitement spécifique~~ vaccination préventive.Peut se répandre comme la fièvre typhoid

Choléra. Se répand par les matières alimentaires,par l'eau en particulier.Maladie grave,souvent mortelle.Pourrait être répandue grace aux mêmes procédés que la fièvre typhoide.Pas de thérapeutique spécifique.Vaccination préventive possible.

Botulisme Maladie extraordinairement grave,très souvent mortelle provoquée par un poison microbien.Le microbe lui-même ne peut pas se développer dans le corps de l'homme mais son ~~poison~~ poison absorbé avec des matières alimentaires (conserves) tue.Maladie non transmissible d'homme à homme.Pourrait être répandue par l'eau comme la fièvre typhoide ou par des matières alimentaires souillées(stocks de conserve volontairement oubliées).Le poison peut être parfaitement désseché et son activité reste immense.

Morve Maladie effroyable tuant presque toujours et dont on ne peut ~~assurer~~ affirmer la guérison,lorsque celle-ci survient,qu'après plusieurs année Maladie touchant habituellement le cheval.Se transmet à l'homme par la voie digestive.Possibilité d'infection par des microbes secs répandus dans l'air ou mélangés avec des matières alimentaires.Aucune thérapeutique connue.

Figure A.172: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].



Tuberculose. Maladie qui pourrait être répandue par la voie aérienne. N'aurait aucun effet immédiat.Mais si la dispersion des bacilles était bien faite on verrait plusieurs mois ou années après apparaitre des milliers de cas de maladie et la population entière d'un pays pourrait être touchée.

Telles sont probablement les maladies principales qui pourraient être utilisées dans la guerre bactériologique.Mais des recherches expérimentales peuvent avoir permis de découvrir des procédés de culture in vivo ou in vitro inconnus jusqu'à maintemant permettant de répandr facilement des maladies telles que l'alastrim,la scarlatine,etc..

III .Probabilités.

Toutes les maladies énumérées précedemment n'ont pas les mêmes chanc d'être utilisées.Leur emploi est à notre avis strictement conditionn par la situation militaire d'une part et le fait que l'ennemiopérera dans un pays ou il est ou dans un pays ou il n'est pas d'autre part. L'ennemi hésitera à provoquer l'apparition d'une maladie infectieuse grave,se répandant facilement dans un pays qu'il occupe.Il craindra "le choc en retour" qui ne manquerait pas de se produire,c'est à dir la contagion de ses propres troupes.

Par contre ,il pourrait ne pas hésiter à la provoquer dans un pays ou il n'est pas (Angleterre,Amérique),séparé de lui par unebarrière infranchissable.La maladie se répandrait du malade à l'individu sai dans le pays infecté,ne se répandrait pas au dela et ne le touchera pas.

Il pourrait non plus ne pas hésiter,se voyant perdu à sacrifier ses

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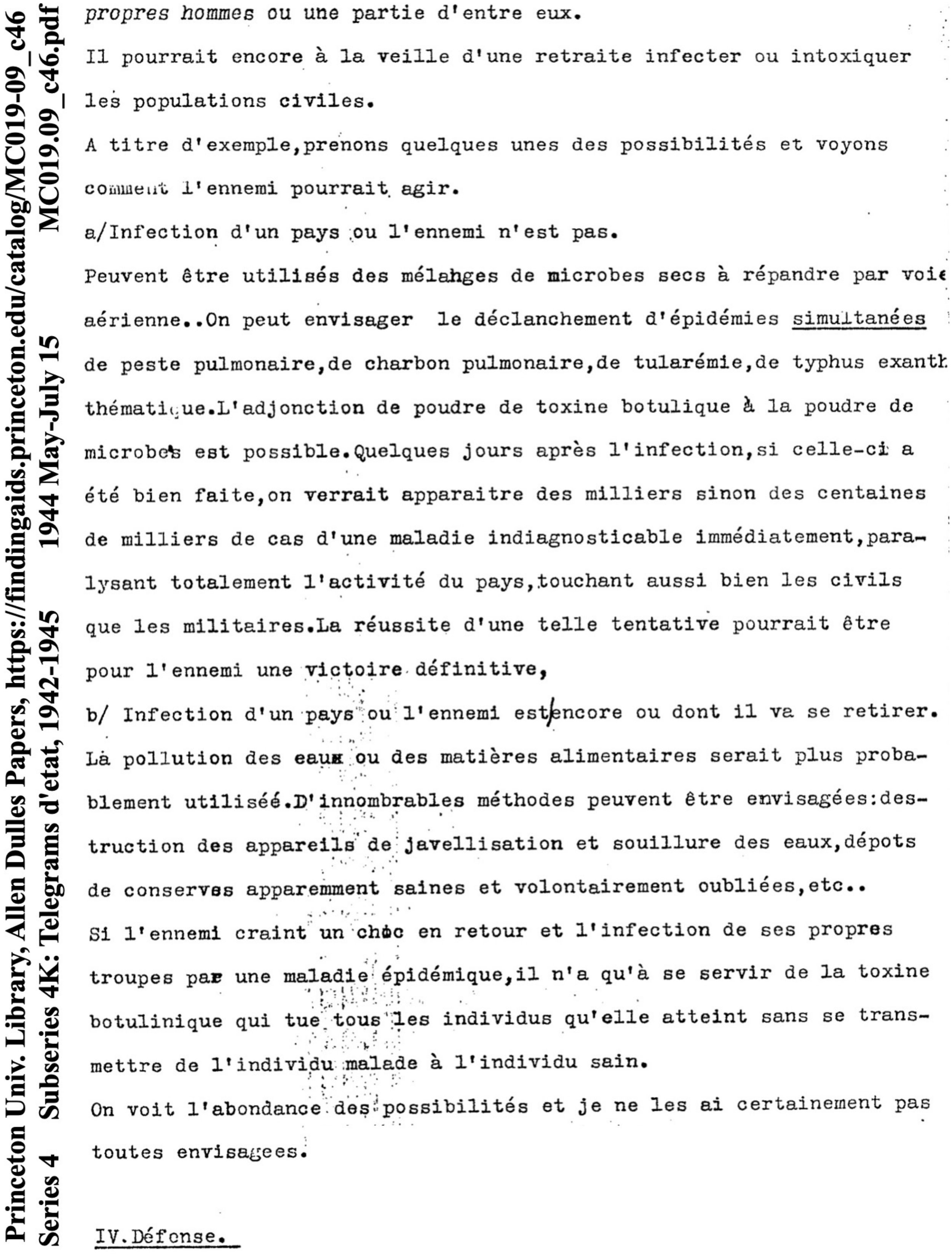
Figure A.173: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].



propres hommes ou une partie d'entre eux.

Il pourrait encore à la veille d'une retraite infecter ou intoxiquer les populations civiles.

A titre d'exemple,prenons quelques unes des possibilités et voyons comment l'ennemi pourrait agir.

a/Infection d'un pays ou l'ennemi n'est pas.

Peuvent être utilisés des mélahges de microbes secs à répandre par voie aérienne..On peut envisager le déclanchement d'épidémies simultanées de peste pulmonaire,de charbon pulmonaire,de tularémie,de typhus exanthématique.L'adjonction de poudre de toxine botulique à la poudre de microbes est possible.Quelques jours après l'infection,si celle-ci a été bien faite,on verrait apparaitre des milliers sinon des centaines de milliers de cas d'une maladie indiagnosticable immédiatement,paralysant totalement l'activité du pays,touchant aussi bien les civils que les militaires.La réussite d'une telle tentative pourrait être pour l'ennemi une victoire définitive,

b/ Infection d'un pays ou l'ennemi est/encore ou dont il va se retirer.

La pollution des eaux ou des matières alimentaires serait plus probablement utiliséé.D'innombrables méthodes peuvent être envisagées:destruction des appareils de javellisation et souillure des eaux,dépots de conserves apparemment saines et volontairement oubliées,etc..

Si l'ennemi craint un choc en retour et l'infection de ses propres troupes par une maladie épidémique,il n'a qu'à se servir de la toxine botulinique qui tue tous les individus qu'elle atteint sans se transmettre de l'individu malade à l'individu sain.

On voit l'abondance des possibilités et je ne les ai certainement pas toutes envisagees.

IV.Défense.

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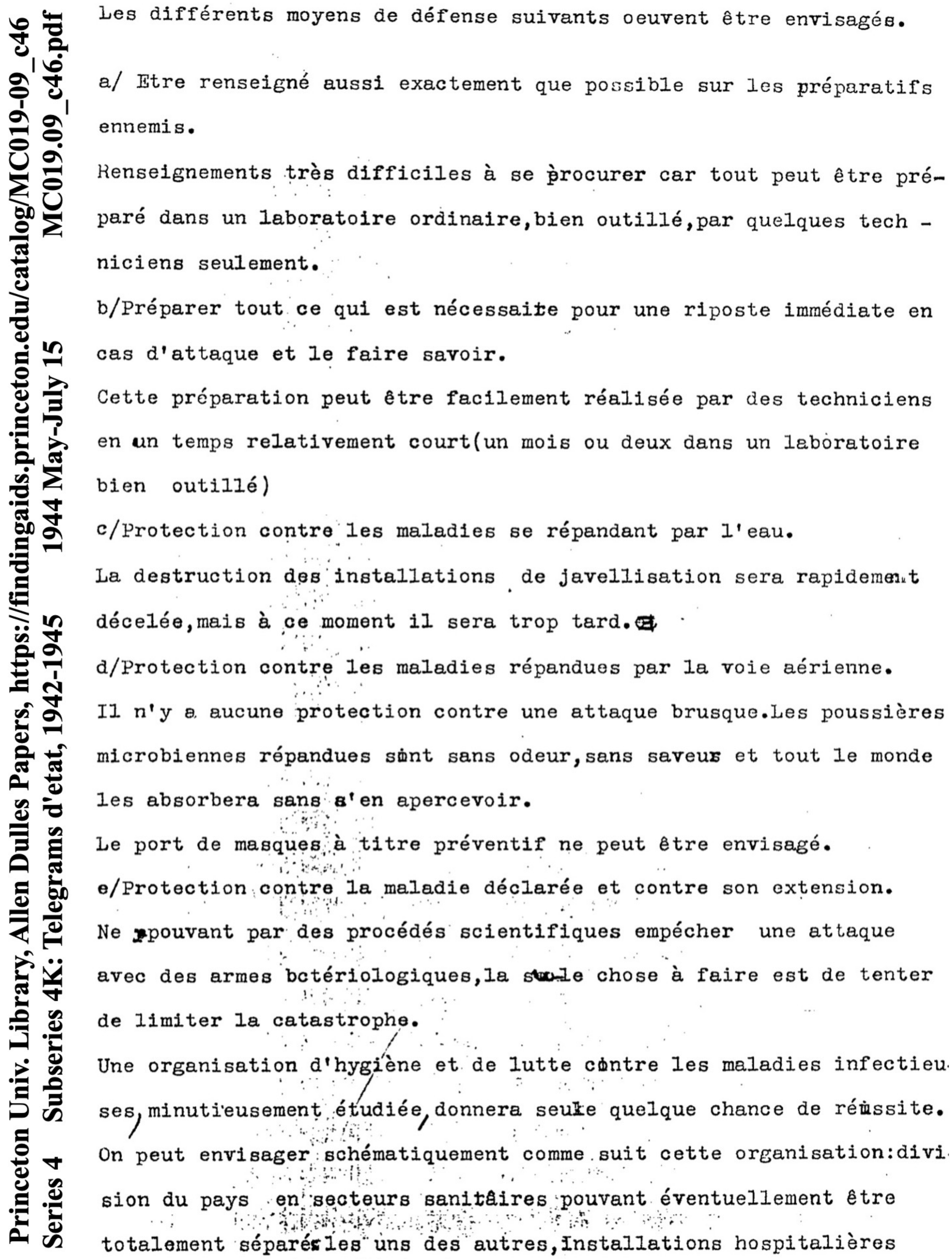
Figure A.174: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].



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Les différents moyens de défense suivants oeuvent être envisagés.

a/ Etre renseigné aussi exactement que possible sur les préparatifs ennemis.

Renseignements très difficiles à se procurer car tout peut être préparé dans un laboratoire ordinaire, bien outillé, par quelques techniciens seulement.

b/Préparer tout ce qui est nécessaite pour une riposte immédiate en cas d'attaque et le faire savoir.

Cette préparation peut être facilement réalisée par des techniciens en un temps relativement court(un mois ou deux dans un laboratoire bien outillé)

c/Protection contre les maladies se répandant par l'eau.

La destruction des installations de javellisation sera rapidement décelée, mais à ce moment il sera trop tard.

d/Protection contre les maladies répandues par la voie aérienne.

Il n'y a aucune protection contre une attaque brusque. Les poussières microbiennes répandues sont sans odeur, sans saveur et tout le monde les absorbera sans s'en apercevoir.

Le port de masques à titre préventif ne peut être envisagé.

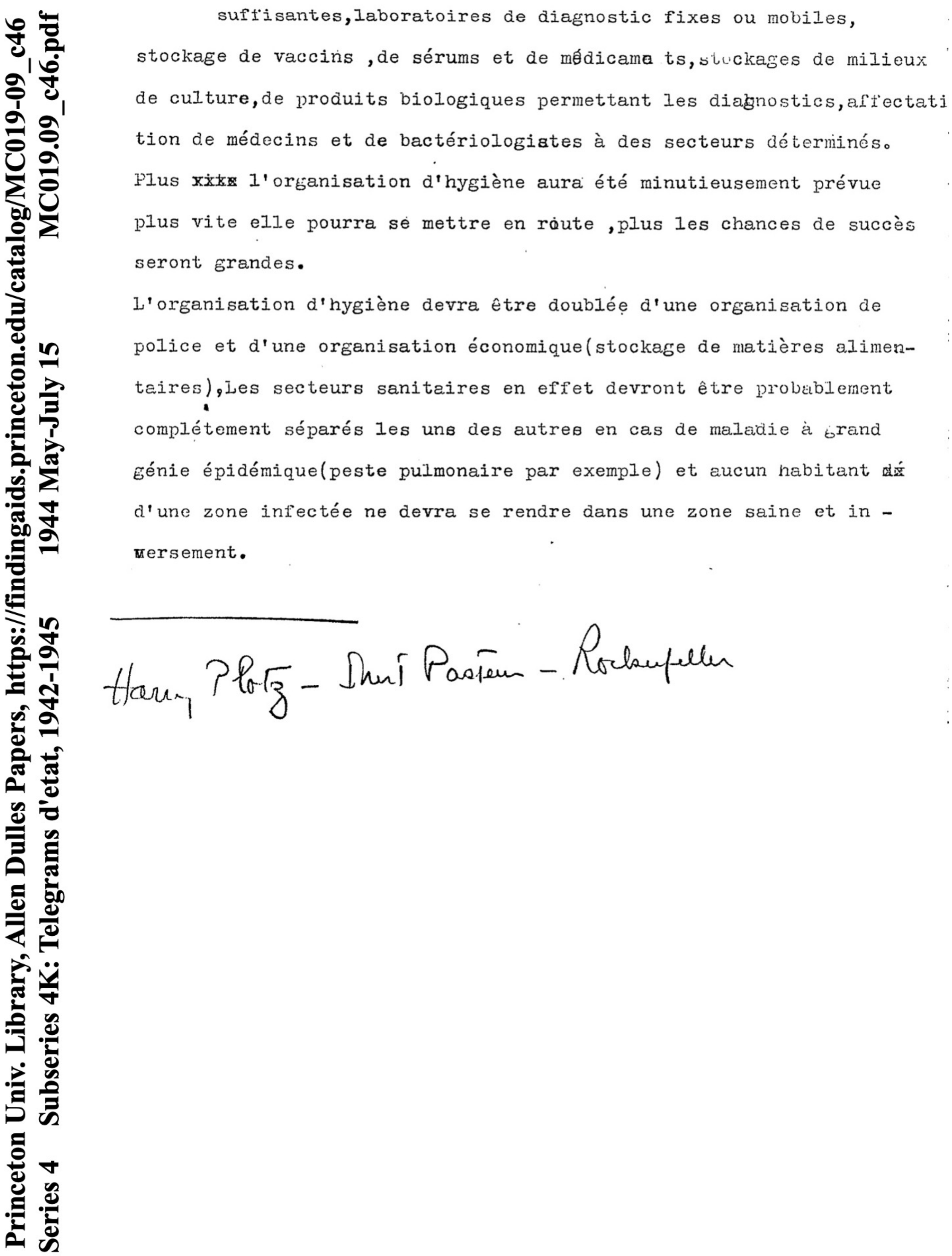
e/Protection contre la maladie déclarée et contre son extension.

Ne pouvant par des procédés scientifiques empécher une attaque avec des armes bctériologiques, la seule chose à faire est de tenter de limiter la catastrophe.

Une organisation d'hygiène et de lutte contre les maladies infectieuses, minutieusement étudiée, donnera seule quelque chance de réussite.

On peut envisager schématiquement comme suit cette organisation: division du pays en secteurs sanitaires pouvant éventuellement être totalement séparés les uns des autres, Installations hospitalières

Figure A.175: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].



suffisantes,laboratoires de diagnostic fixes ou mobiles, stockage de vaccins ,de sérums et de médicaments,stockages de milieux de culture,de produits biologiques permettant les diagnostics,affectatition de médecins et de bactériologistes à des secteurs déterminés.
Plus ~~xxxx~~ l'organisation d'hygiène aura été minutieusement prévue plus vite elle pourra se mettre en route ,plus les chances de succès seront grandes.

L'organisation d'hygiène devra être doublée d'une organisation de police et d'une organisation économique(stockage de matières alimentaires),Les secteurs sanitaires en effet devront être probablement complétement séparés les uns des autres en cas de maladie à grand génie épidémique(peste pulmonaire par exemple) et aucun habitant ~~dx~~ d'une zone infectée ne devra se rendre dans une zone saine et inversement.

Harry Plotz – Inst Pasteur – Rockefeller

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Figure A.176: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].

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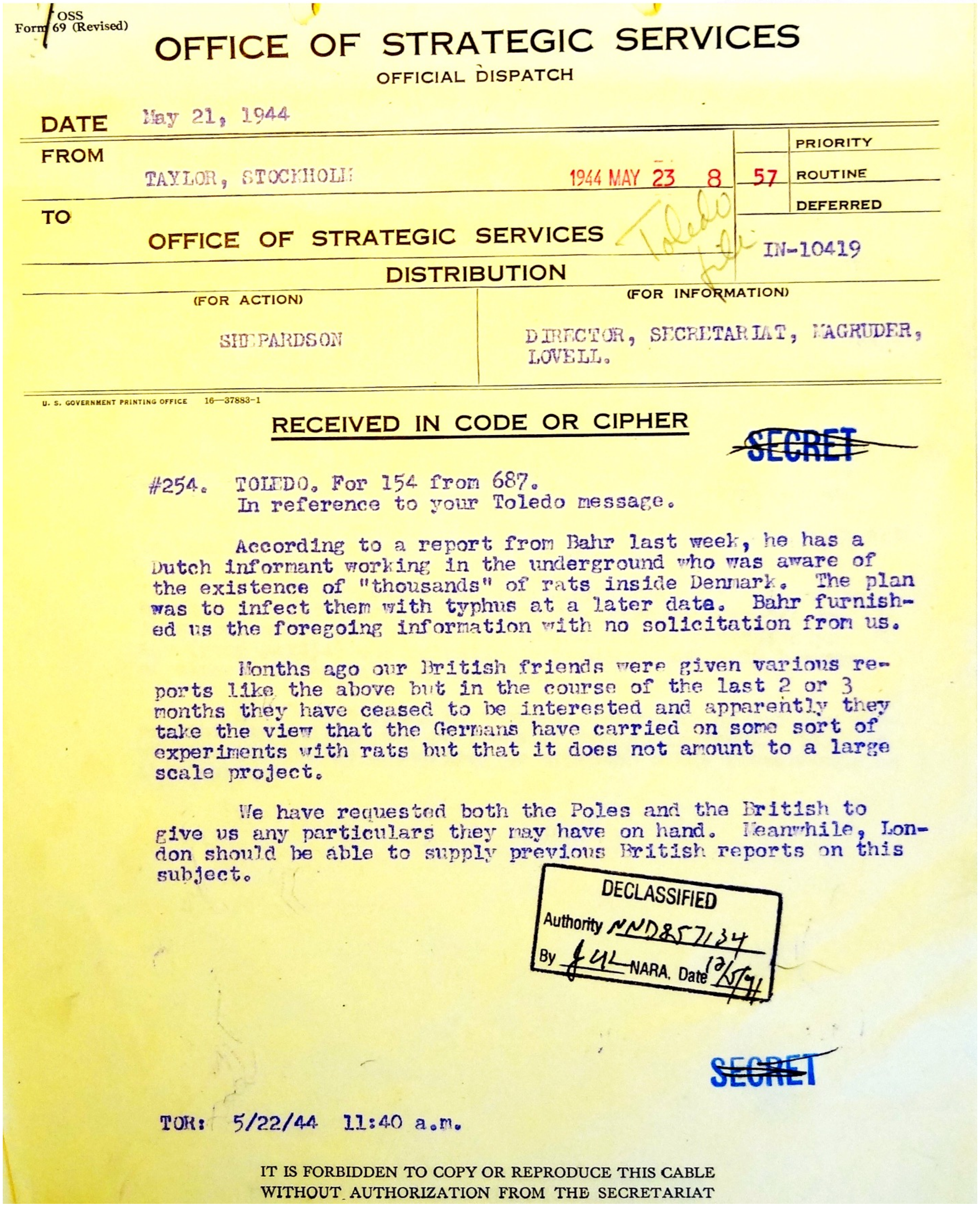

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#254. TOLEDO. For 154 from 687.
In reference to your Toledo message.

According to a report from Bahr last week, he has a Dutch informant working in the underground who was aware of the existence of "thousands" of rats inside Denmark. The plan was to infect them with typhus at a later date. Bahr furnished us the foregoing information with no solicitation from us.

Months ago our British friends were given various reports like the above but in the course of the last 2 or 3 months they have ceased to be interested and apparently they take the view that the Germans have carried on some sort of experiments with rats but that it does not amount to a large scale project.

We have requested both the Poles and the British to give us any particulars they may have on hand. Meanwhile, London should be able to supply previous British reports on this subject.

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Figure A.177: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

NARA RG 226, Entry A1-134,
Box 216, Folder 1359 IN TOLEDO

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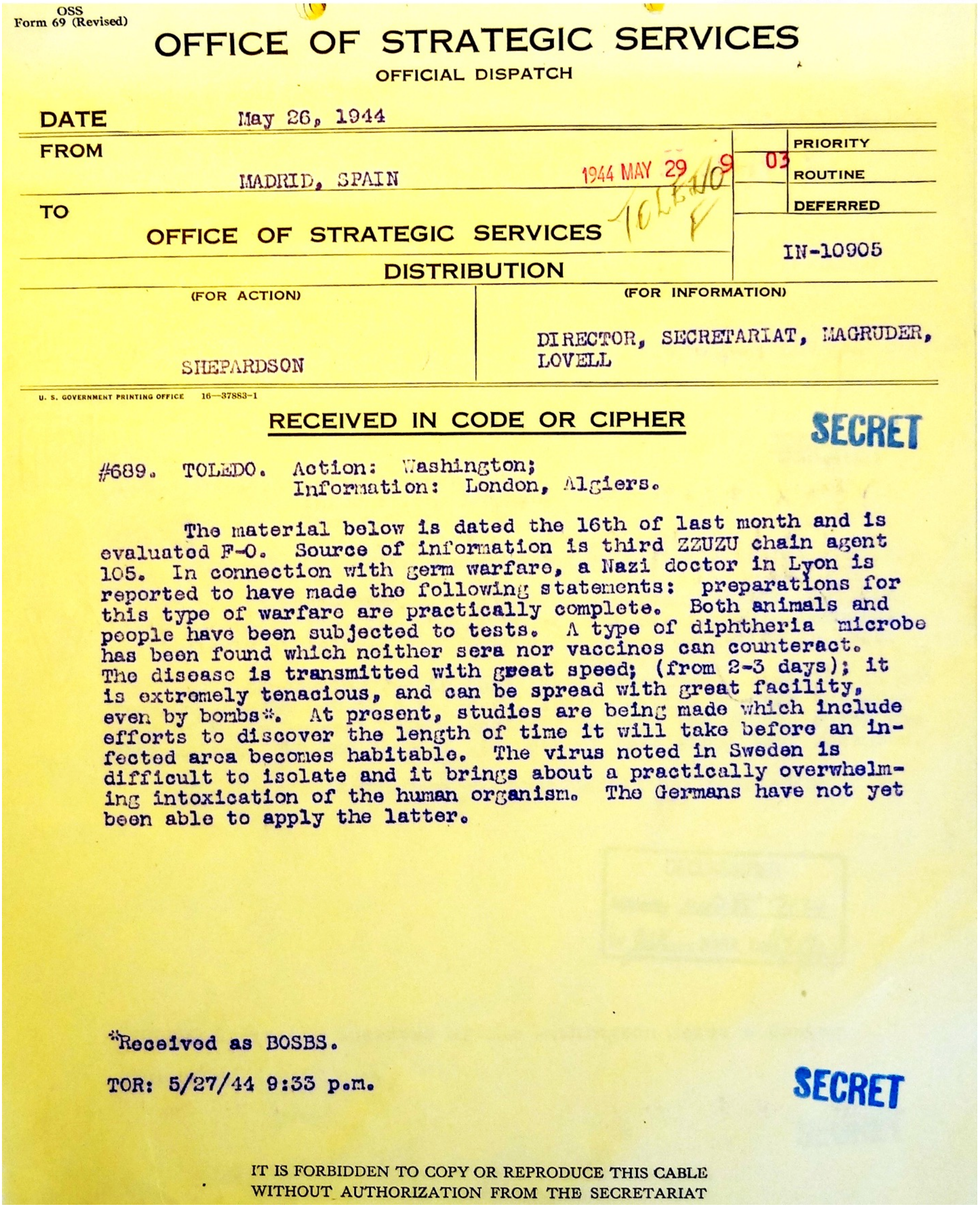
Authority NND857134



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Form 69 (Revised)

OFFICE OF STRATEGIC SERVICES

OFFICIAL DISPATCH

DATE	May 26, 1944
FROM	MADRID, SPAIN
TO	OFFICE OF STRATEGIC SERVICES

1944 MAY 29 9 03

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#689. TOLEDO. Action: Washington;
Information: London, Algiers.

The material below is dated the 16th of last month and is evaluated F-0. Source of information is third ZZUZU chain agent 105. In connection with germ warfare, a Nazi doctor in Lyon is reported to have made the following statements: preparations for this type of warfare are practically complete. Both animals and people have been subjected to tests. A type of diphtheria microbe has been found which neither sera nor vaccines can counteract. The disease is transmitted with great speed; (from 2-3 days); it is extremely tenacious, and can be spread with great facility, even by bombs*. At present, studies are being made which include efforts to discover the length of time it will take before an infected area becomes habitable. The virus noted in Sweden is difficult to isolate and it brings about a practically overwhelming intoxication of the human organism. The Germans have not yet been able to apply the latter.

*Received as BOSBS.

TOR: 5/27/44 9:33 p.m.

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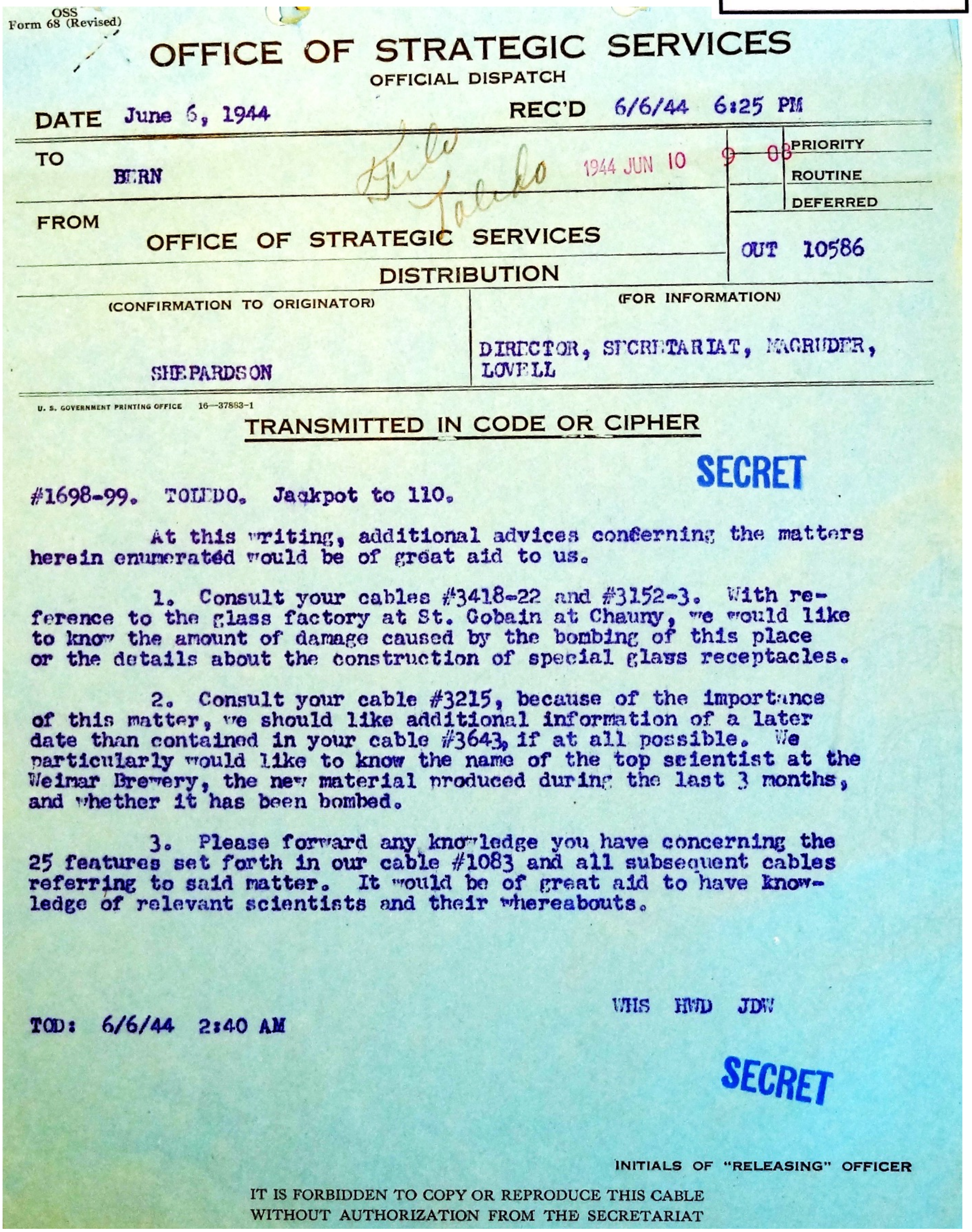
Figure A.178: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

NARA RG 226, Entry A1-134,
Box 216, Folder 1360 OUT TOLEDO

DECLASSIFIED
Authority NND857134



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OFFICE OF STRATEGIC SERVICES
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DATE June 6, 1944 REC'D 6/6/44 6:25 PM

TO BERN

File Toledo

1944 JUN 10 9 08

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FROM OFFICE OF STRATEGIC SERVICES

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#1698-99. TOLEDO. Jackpot to 110.

At this writing, additional advices concerning the matters herein enumerated would be of great aid to us.

1. Consult your cables #3418-22 and #3152-3. With reference to the glass factory at St. Gobain at Chauny, we would like to know the amount of damage caused by the bombing of this place or the details about the construction of special glass receptacles.

2. Consult your cable #3215, because of the importance of this matter, we should like additional information of a later date than contained in your cable #3643, if at all possible. We particularly would like to know the name of the top scientist at the Weimar Brewery, the new material produced during the last 3 months, and whether it has been bombed.

3. Please forward any knowledge you have concerning the 25 features set forth in our cable #1083 and all subsequent cables referring to said matter. It would be of great aid to have knowledge of relevant scientists and their whereabouts.

WHS HWD JDW

TOD: 6/6/44 2:40 AM

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Figure A.179: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

NARA RG 226, Entry A1-134,
Box 216, Folder 1359 IN TOLEDO

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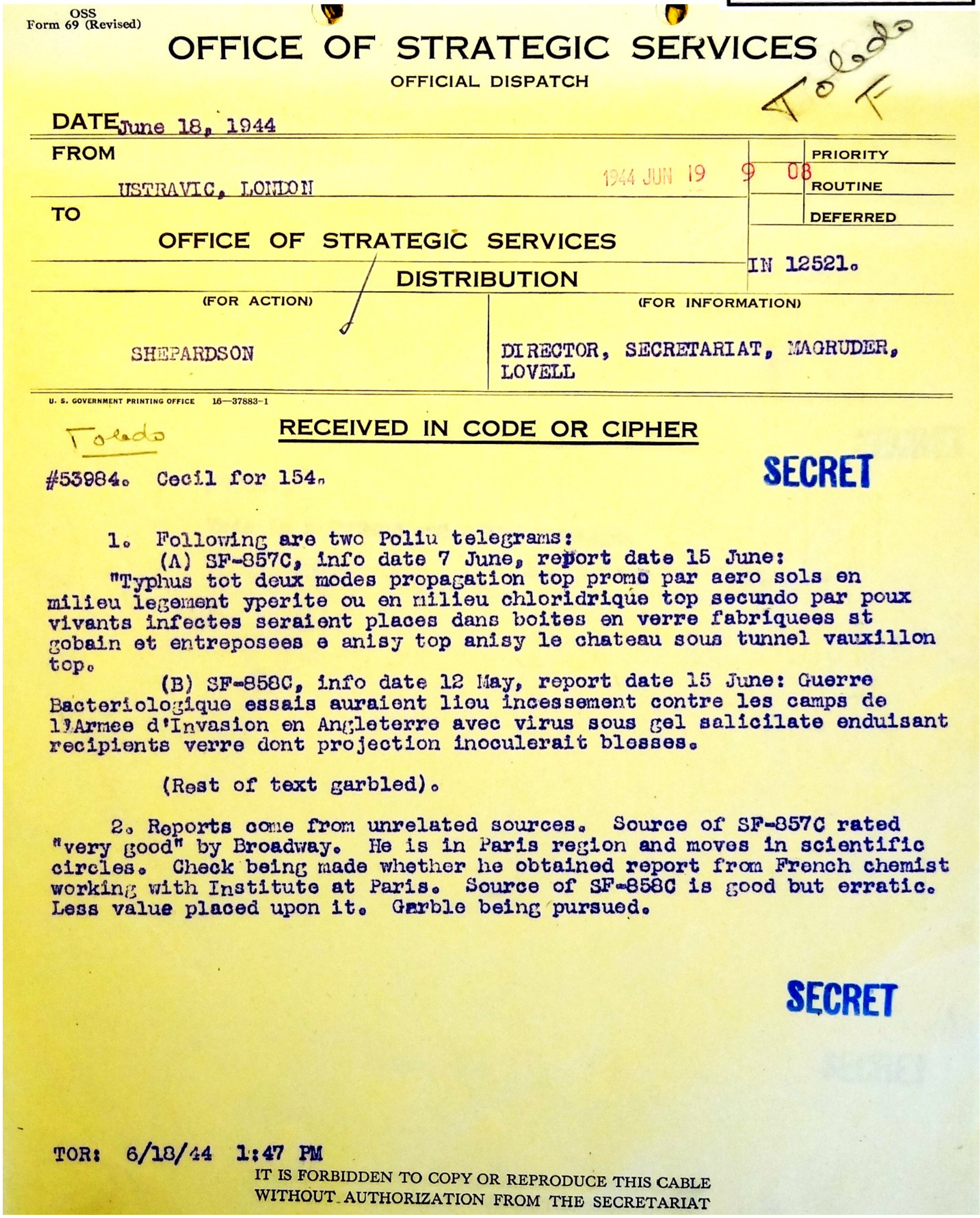
Authority NND857134



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OFFICE OF STRATEGIC SERVICES
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Toledo
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DATE June 18, 1944

FROM
USTRAVIC, LONDON

1944 JUN 19 9 08

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Toledo

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#53984. Cecil for 154.

1. Following are two Poliu telegrams:

(A) SF-857C, info date 7 June, report date 15 June: "Typhus tot deux modes propagation top promo par aero sols en milieu legement yperite ou en milieu chloridrique top secundo par poux vivants infectes seraient places dans boites en verre fabriquees st gobain et entreposees e anisy top anisy le chateau sous tunnel vauxillon top.

(B) SF-858C, info date 12 May, report date 15 June: Guerre Bacteriologique essais auraient lieu incessement contre les camps de l'Armee d'Invasion en Angleterre avec virus sous gel salicilate enduisant recipients verre dont projection inoculerait blesses.

(Rest of text garbled).

2. Reports come from unrelated sources. Source of SF-857C rated "very good" by Broadway. He is in Paris region and moves in scientific circles. Check being made whether he obtained report from French chemist working with Institute at Paris. Source of SF-858C is good but erratic. Less value placed upon it. Garble being pursued.

SECRET

TOR: 6/18/44 1:47 PM

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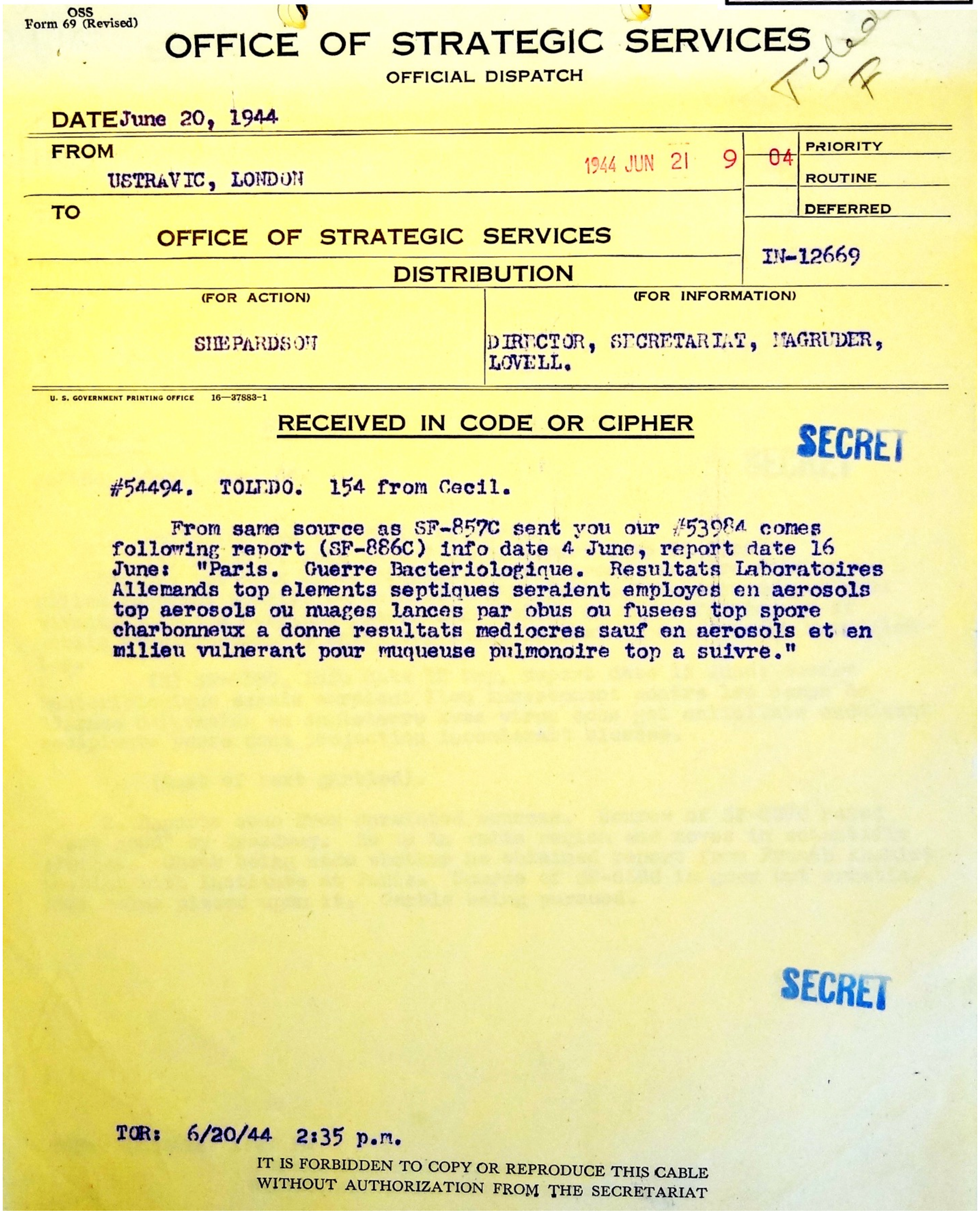
Figure A.180: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

NARA RG 226, Entry A1-134,
Box 216, Folder 1359 IN TOLEDO

DECLASSIFIED
Authority NND857134



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Form 69 (Revised)

OFFICE OF STRATEGIC SERVICES

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Toledo F

DATE June 20, 1944

FROM
USTRAVIC, LONDON

1944 JUN 21 9 04

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#54494. TOLEDO. 154 from Cecil.

From same source as SF-857C sent you our #53984 comes following report (SF-886C) info date 4 June, report date 16 June: "Paris. Guerre Bacteriologique. Resultats Laboratoires Allemands top elements septiques seraient employes en aerosols top aerosols ou nuages lances par obus ou fusees top spore charbonneux a donne resultats mediocres sauf en aerosols et en milieu vulnerant pour muqueuse pulmonoire top a suivre."

SECRET

TOR: 6/20/44 2:35 p.m.

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Figure A.181: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

NARA RG 226, Entry A1-134,
Box 216, Folder 1359 IN TOLEDO

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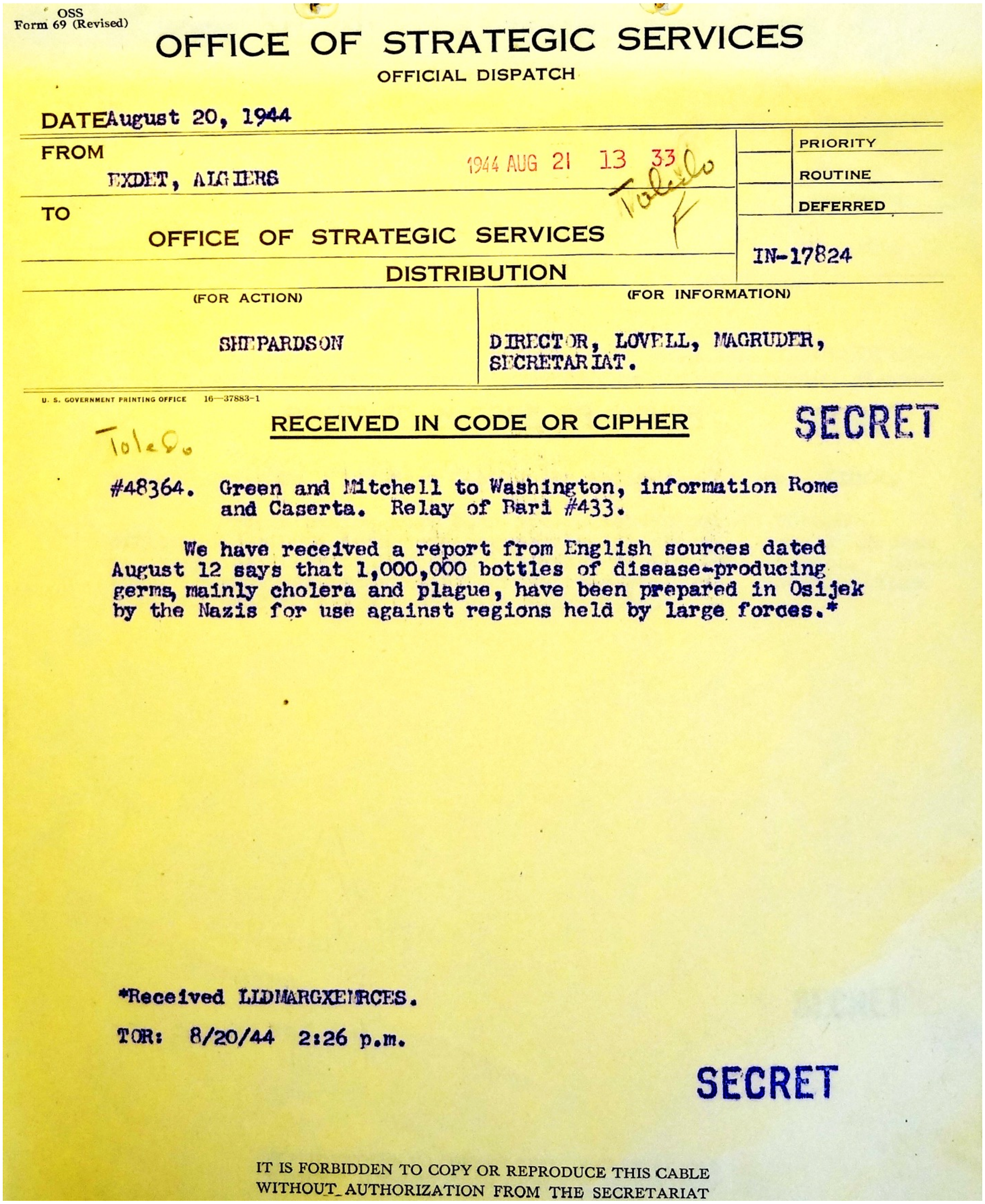
Authority NND857134



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Form 69 (Revised)

OFFICE OF STRATEGIC SERVICES
OFFICIAL DISPATCH

DATE August 20, 1944

FROM
EXDET, ALGIERS

1944 AUG 21 13 33

Toledo

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Toledo

#48364. Green and Mitchell to Washington, information Rome and Caserta. Relay of Bari #433.

We have received a report from English sources dated August 12 says that 1,000,000 bottles of disease-producing germs, mainly cholera and plague, have been prepared in Osijek by the Nazis for use against regions held by large forces.*

*Received LLDMARGXEMRCES.

TOR: 8/20/44 2:26 p.m.

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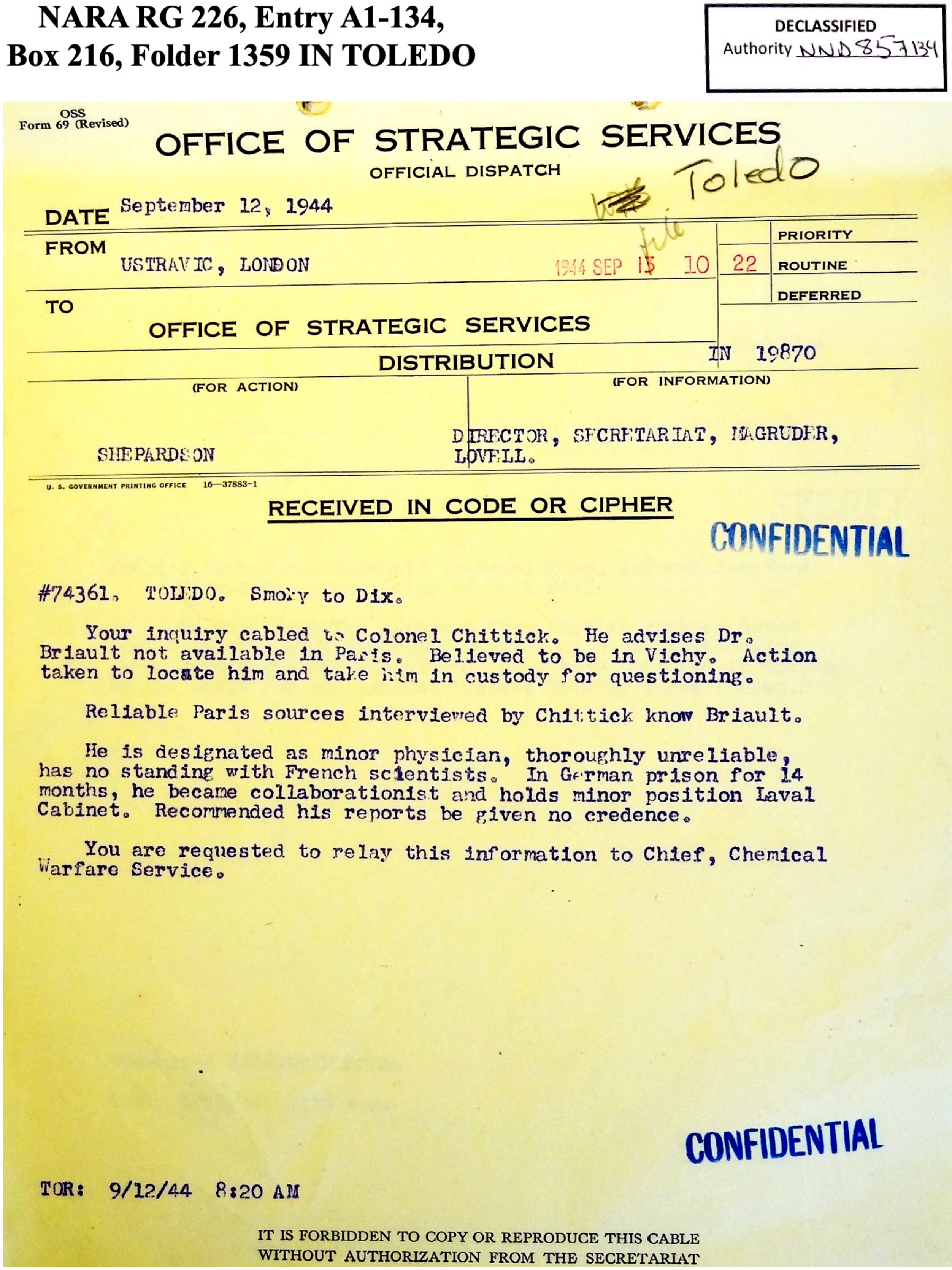
Figure A.182: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].



NARA RG 226, Entry A1-134,
Box 216, Folder 1359 IN TOLEDO

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Authority NND857134

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OFFICE OF STRATEGIC SERVICES
OFFICIAL DISPATCH

Toledo
file

DATE	September 12, 1944	PRIORITY
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TO	OFFICE OF STRATEGIC SERVICES	

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#74361. TOLEDO. Smoky to Dix.

Your inquiry cabled to Colonel Chittick. He advises Dr. Briault not available in Paris. Believed to be in Vichy. Action taken to locate him and take him in custody for questioning.

Reliable Paris sources interviewed by Chittick know Briault.

He is designated as minor physician, thoroughly unreliable, has no standing with French scientists. In German prison for 14 months, he became collaborationist and holds minor position Laval Cabinet. Recommended his reports be given no credence.

You are requested to relay this information to Chief, Chemical Warfare Service.

CONFIDENTIAL

TOR: 9/12/44 8:20 AM

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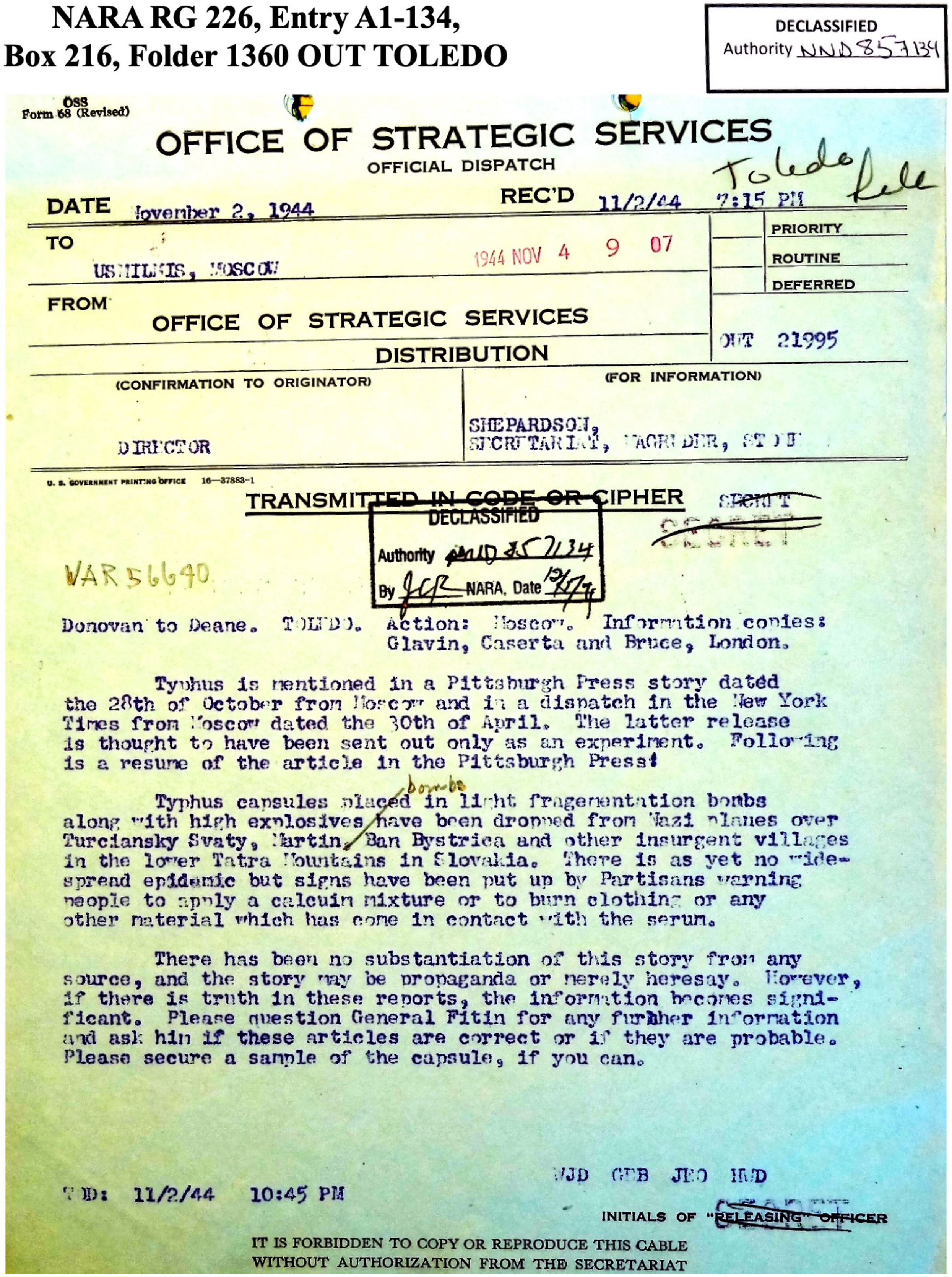
Figure A.183: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].



NARA RG 226, Entry A1-134,
Box 216, Folder 1360 OUT TOLEDO

DECLASSIFIED
Authority NND857134

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Form 68 (Revised)

OFFICE OF STRATEGIC SERVICES
OFFICIAL DISPATCH

Toledo file

DATE November 2, 1944 REC'D 11/2/44 7:15 PM

TO
USMILMIS, MOSCOW

1944 NOV 4 9 07

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Authority NND 857134
By JCR NARA, Date 12/7/

WAR 56640

Donovan to Deane. TOLEDO. Action: Moscow. Information copies:
Glavin, Caserta and Bruce, London.

Typhus is mentioned in a Pittsburgh Press story dated the 28th of October from Moscow and in a dispatch in the New York Times from Moscow dated the 30th of April. The latter release is thought to have been sent out only as an experiment. Following is a resume of the article in the Pittsburgh Press:

bombs

Typhus capsules placed in light fragementation bombs along with high explosives have been dropped from Nazi planes over Turciansky Svaty, Martin, Ban Bystrica and other insurgent villages in the lower Tatra Mountains in Slovakia. There is as yet no widespread epidemic but signs have been put up by Partisans warning people to apply a calcuim mixture or to burn clothing or any other material which has come in contact with the serum.

There has been no substantiation of this story from any source, and the story may be propaganda or merely heresay. However, if there is truth in these reports, the information becomes significant. Please question General Fitin for any further information and ask him if these articles are correct or if they are probable. Please secure a sample of the capsule, if you can.

WJD GEB JEO HMD

TOD: 11/2/44 10:45 PM

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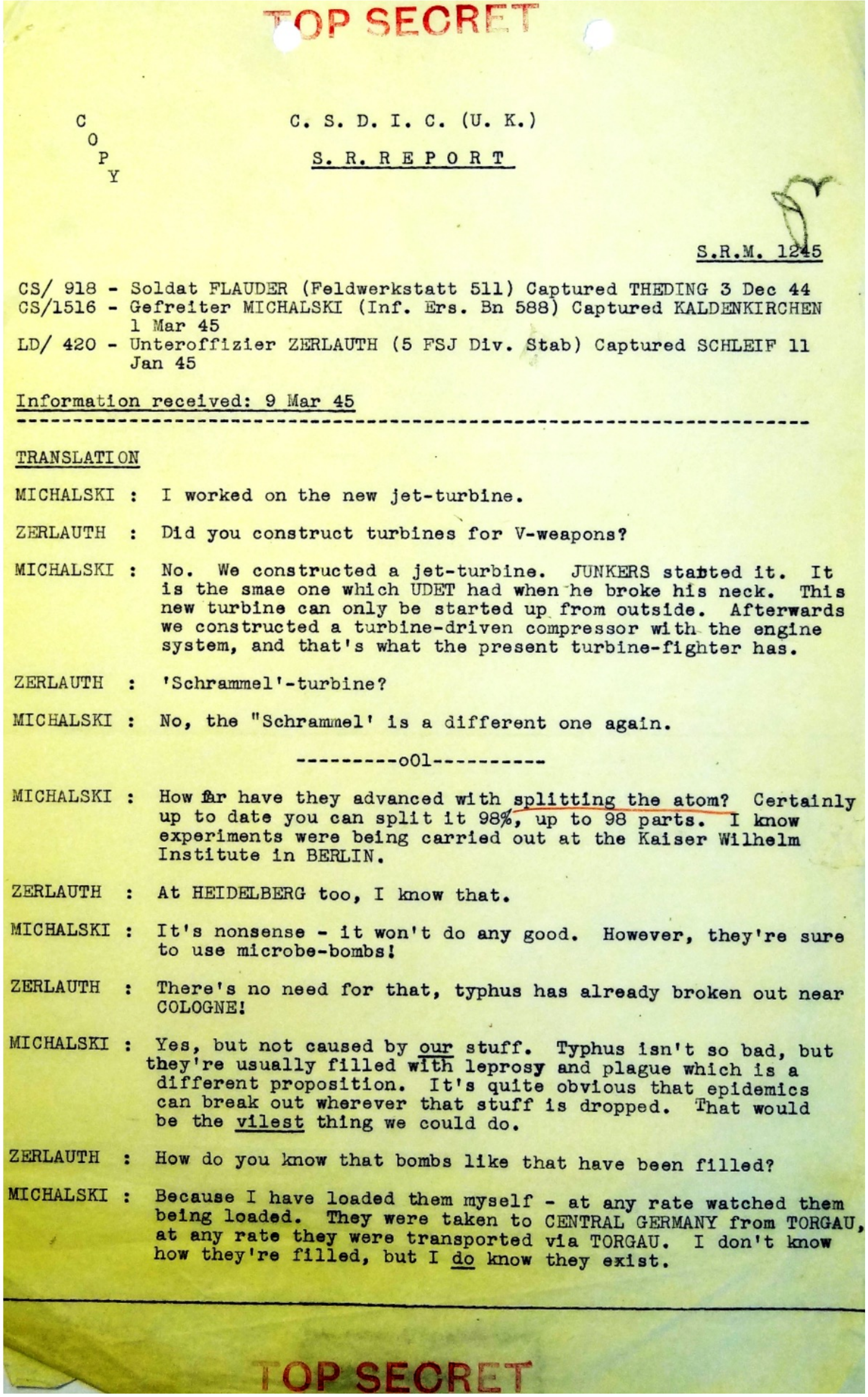
Figure A.184: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL



TOP SECRET

C
O
P
Y

C. S. D. I. C. (U. K.)

S. R. REPORT

S.R.M. 1245

CS/ 918 - Soldat FLAUDER (Feldwerkstatt 511) Captured THEDING 3 Dec 44
CS/1516 - Gefreiter MICHALSKI (Inf. Ers. Bn 588) Captured KALDENKIRCHEN 1 Mar 45
LD/ 420 - Unteroffizier ZERLAUTH (5 FSJ Div. Stab) Captured SCHLEIF 11 Jan 45

Information received: 9 Mar 45

TRANSLATION

MICHALSKI : I worked on the new jet-turbine.

ZERLAUTH : Did you construct turbines for V-weapons?

MICHALSKI : No. We constructed a jet-turbine. JUNKERS stabted it. It is the smae one which UDET had when he broke his neck. This new turbine can only be started up from outside. Afterwards we constructed a turbine-driven compressor with the engine system, and that's what the present turbine-fighter has.

ZERLAUTH : 'Schrammel'-turbine?

MICHALSKI : No, the "Schrammel' is a different one again.

---------oOl----------

MICHALSKI : How far have they advanced with splitting the atom? Certainly up to date you can split it 98%, up to 98 parts. I know experiments were being carried out at the Kaiser Wilhelm Institute in BERLIN.

ZERLAUTH : At HEIDELBERG too, I know that.

MICHALSKI : It's nonsense - it won't do any good. However, they're sure to use microbe-bombs!

ZERLAUTH : There's no need for that, typhus has already broken out near COLOGNE!

MICHALSKI : Yes, but not caused by our stuff. Typhus isn't so bad, but they're usually filled with leprosy and plague which is a different proposition. It's quite obvious that epidemics can break out wherever that stuff is dropped. That would be the vilest thing we could do.

ZERLAUTH : How do you know that bombs like that have been filled?

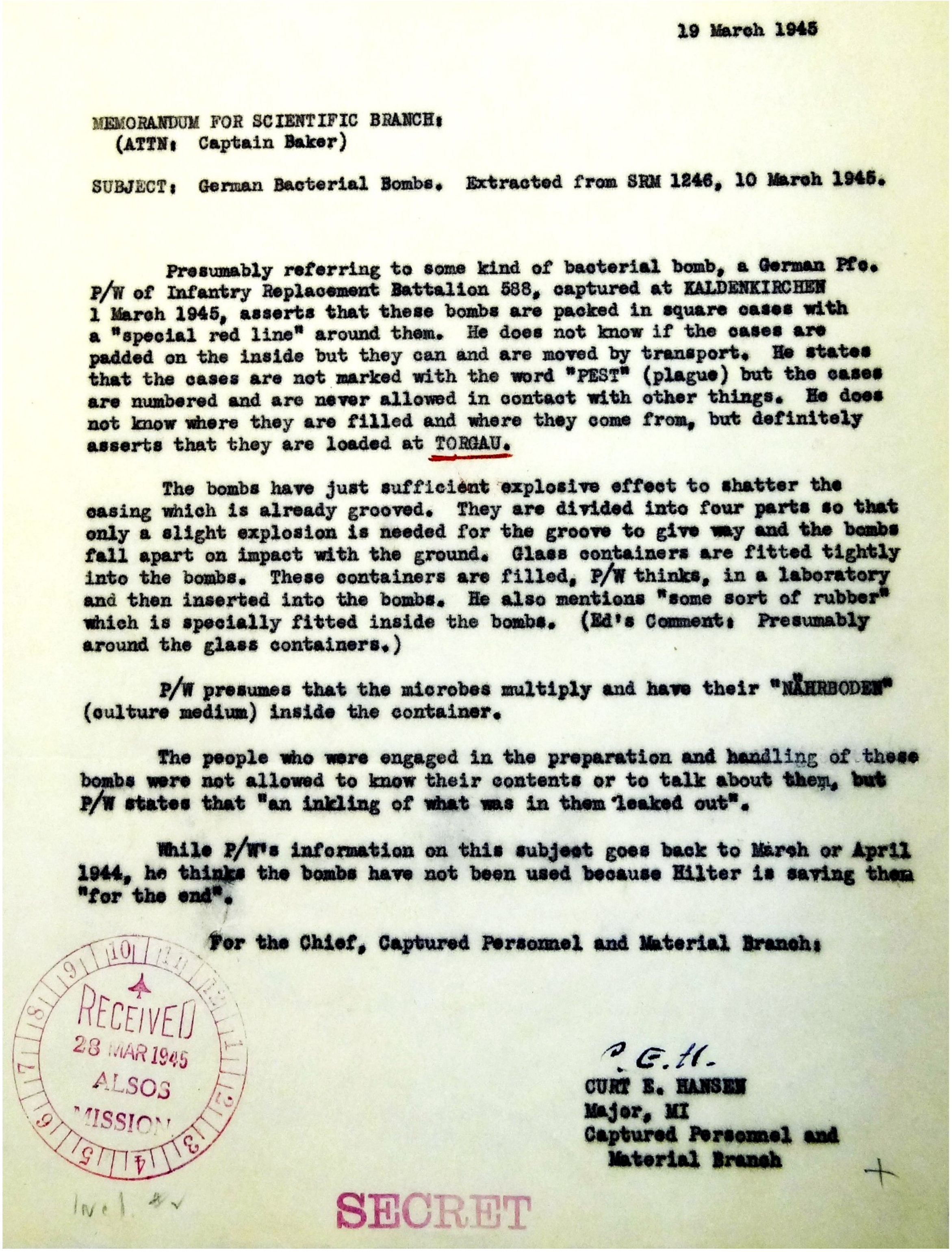
MICHALSKI : Because I have loaded them myself - at any rate watched them being loaded. They were taken to CENTRAL GERMANY from TORGAU, at any rate they were transported via TORGAU. I don't know how they're filled, but I do know they exist.

TOP SECRET

Figure A.185: U.K. intelligence report on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

DECLASSIFIED
Authority NND 750122

NARA RG 165, Entry NM84-187,
Box 137, Folder BW 55



19 March 1945

MEMORANDUM FOR SCIENTIFIC BRANCH:
(ATTN: Captain Baker)

SUBJECT: German Bacterial Bombs. Extracted from SRM 1246, 10 March 1945.

Presumably referring to some kind of bacterial bomb, a German Pfc. P/W of Infantry Replacement Battalion 588, captured at KALDENKIRCHEN 1 March 1945, asserts that these bombs are packed in square cases with a "special red line" around them. He does not know if the cases are padded on the inside but they can and are moved by transport. He states that the cases are not marked with the word "PEST" (plague) but the cases are numbered and are never allowed in contact with other things. He does not know where they are filled and where they come from, but definitely asserts that they are loaded at TORGAU.

The bombs have just sufficient explosive effect to shatter the casing which is already grooved. They are divided into four parts so that only a slight explosion is needed for the groove to give way and the bombs fall apart on impact with the ground. Glass containers are fitted tightly into the bombs. These containers are filled, P/W thinks, in a laboratory and then inserted into the bombs. He also mentions "some sort of rubber" which is specially fitted inside the bombs. (Ed's Comment: Presumably around the glass containers.)

P/W presumes that the microbes multiply and have their "NÄHRBODEN" (culture medium) inside the container.

The people who were engaged in the preparation and handling of these bombs were not allowed to know their contents or to talk about them, but P/W states that "an inkling of what was in them leaked out".

While P/W's information on this subject goes back to March or April 1944, he thinks the bombs have not been used because Hilter is saving them "for the end".

For the Chief, Captured Personnel and Material Branch:

RECEIVED
28 MAR 1945
ALSOS
MISSION

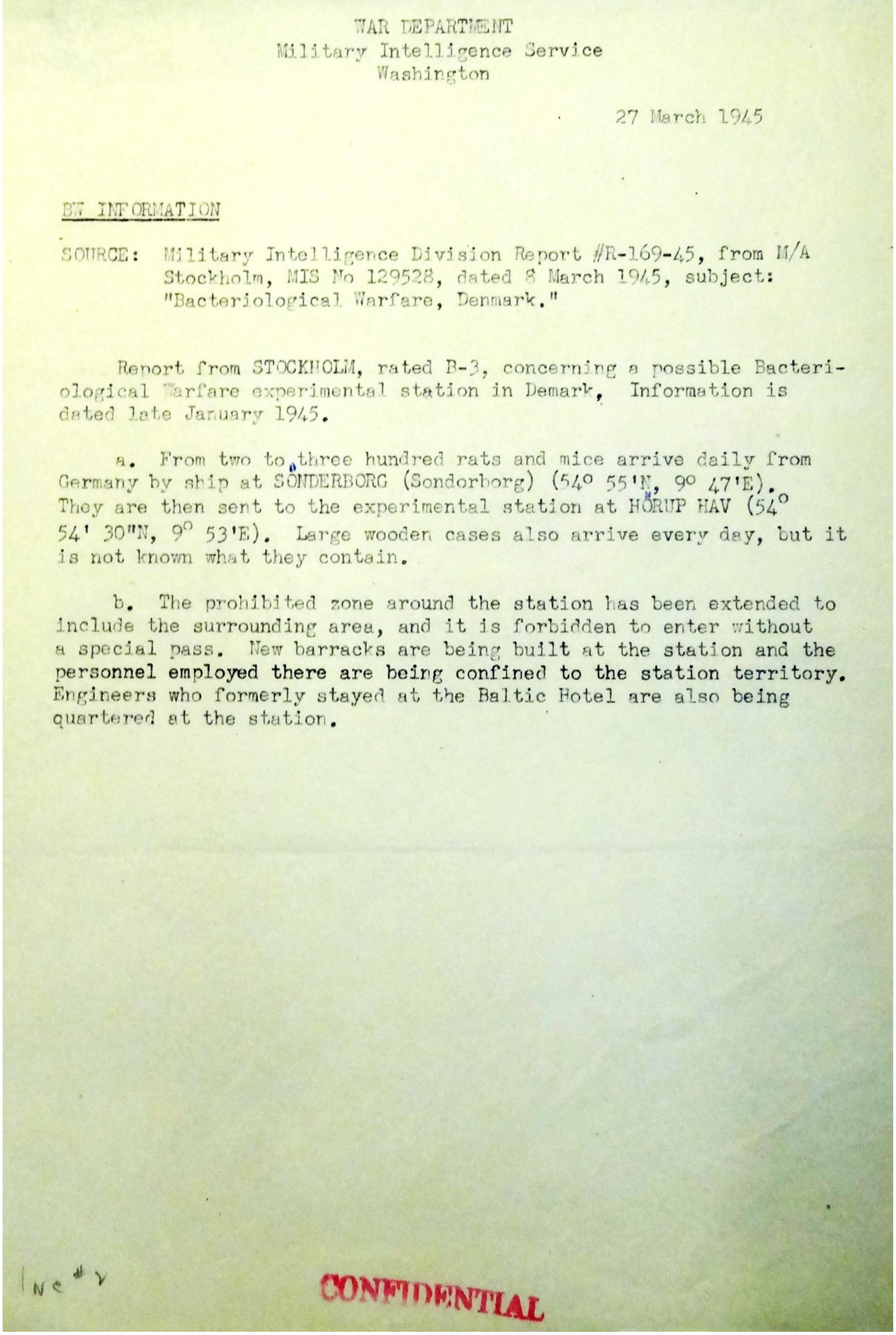
C.E.H.
CURT E. HANSEN
Major, MI
Captured Personnel and
Material Branch

Incl. #

SECRET

Figure A.186: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 165, Entry NM84-187, Box 137, Folder BW 55].

DECLASSIFIED
Authority NND 750122



WAR DEPARTMENT
Military Intelligence Service
Washington

27 March 1945

BW INFORMATION

SOURCE: Military Intelligence Division Report #R-169-45, from M/A Stockholm, MIS No 129528, dated 8 March 1945, subject: "Bacteriological Warfare, Denmark."

Report from STOCKHOLM, rated B-3, concerning a possible Bacteriological Warfare experimental station in Demark. Information is dated late January 1945.

a. From two to three hundred rats and mice arrive daily from Germany by ship at SÖNDERBORG (Sondorborg) (54° 55'N, 9° 47'E). They are then sent to the experimental station at HÖRUP HAV (54° 54' 30"N, 9° 53'E). Large wooden cases also arrive every day, but it is not known what they contain.

b. The prohibited zone around the station has been extended to include the surrounding area, and it is forbidden to enter without a special pass. New barracks are being built at the station and the personnel employed there are being confined to the station territory. Engineers who formerly stayed at the Baltic Hotel are also being quartered at the station.

Nc #2

CONFIDENTIAL

NARA RG 165, Entry NM84-187, Box 137, Folder BW 55

Figure A.187: U.S. intelligence reports on apparent large-scale offensive biological warfare preparations in Germany [NARA RG 165, Entry NM84-187, Box 137, Folder BW 55].

DECLASSIFIED
Authority NND 917017

**NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1
GERMANY: Summary Reports (1944). Bacteriological/Chemical
Warfare in Axis Europe, Supplementary Report #2, 11 March 1944**

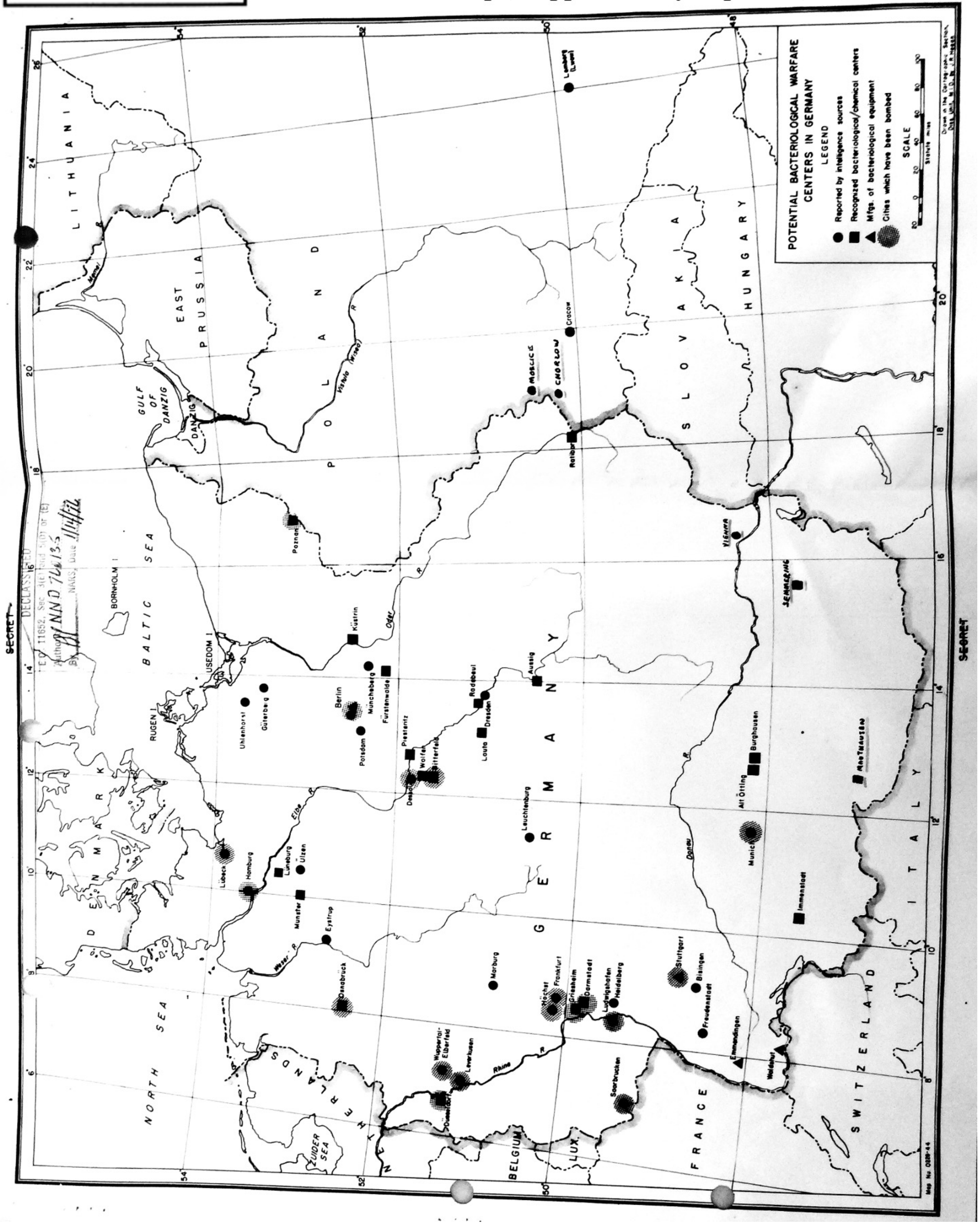

POTENTIAL BACTERIOLOGICAL WARFARE CENTERS IN GERMANY
LEGEND
● Reported by intelligence sources
■ Recognized bacteriological/chemical centers
▲ Mfgs. of bacteriological equipment
Cities which have been bombed
SCALE
Statute miles
SECRET
DECLASSIFIED
E.O. 11652, Sec. 3(E) and 5(D) or (E)
Authority NND 746135
NARS, Date 1/14/72
LITHUANIA
EAST PRUSSIA
GULF OF DANZIG
DANZIG
POLAND
Vistula (Wisla) R.
Lemberg (Lwow)
Cracow
MOSCICE
CHORZOW
Ratibor
SLOVAKIA
HUNGARY
Poznan
VIENNA
SEMMERING
BALTIC SEA
BORNHOLM I.
USEDOM I.
RUGEN I.
Oder R.
Küstrin
Fürstenwalde
Müncheberg
Berlin
Potsdam
Uhlenhorst
Güterberg
Radebeul
Dresden
Aussig
Lauta
Priestertz
Dessau
Wolfen
Bitterfeld
Leuchtenburg
GERMANY
Elbe R.
Lübeck
Hamburg
Lüneburg
Ülzen
Munster
Eystrup
Weser R.
Osnabruck
Marburg
Hochst
Frankfurt
Griesheim
Darmstadt
Ludwigshafen
Heidelberg
Stuttgart
Bissingen
Freudenstadt
Emmendingen
Waldshut
Wuppertal-Elberfeld
Leverkusen
Dusseldorf
Rhine R.
Saarbrucken
Danau
Alt Ötting
Burghausen
Munich
Immenstadt
DENMARK
NORTH SEA
NETHERLANDS
ZUIDER SEA
BELGIUM
LUX.
FRANCE
SWITZERLAND
ITALY
Map No. 0281-44

Figure A.188: Bacteriological/Chemical Warfare in Axis Europe, Supplementary Report #2, 11 March 1944 [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

DECLASSIFIED
Authority NW54481

NARA RG 38, Entry P5, Box 8, Folder
ALSOS Intelligence Report B-C-H-H/305

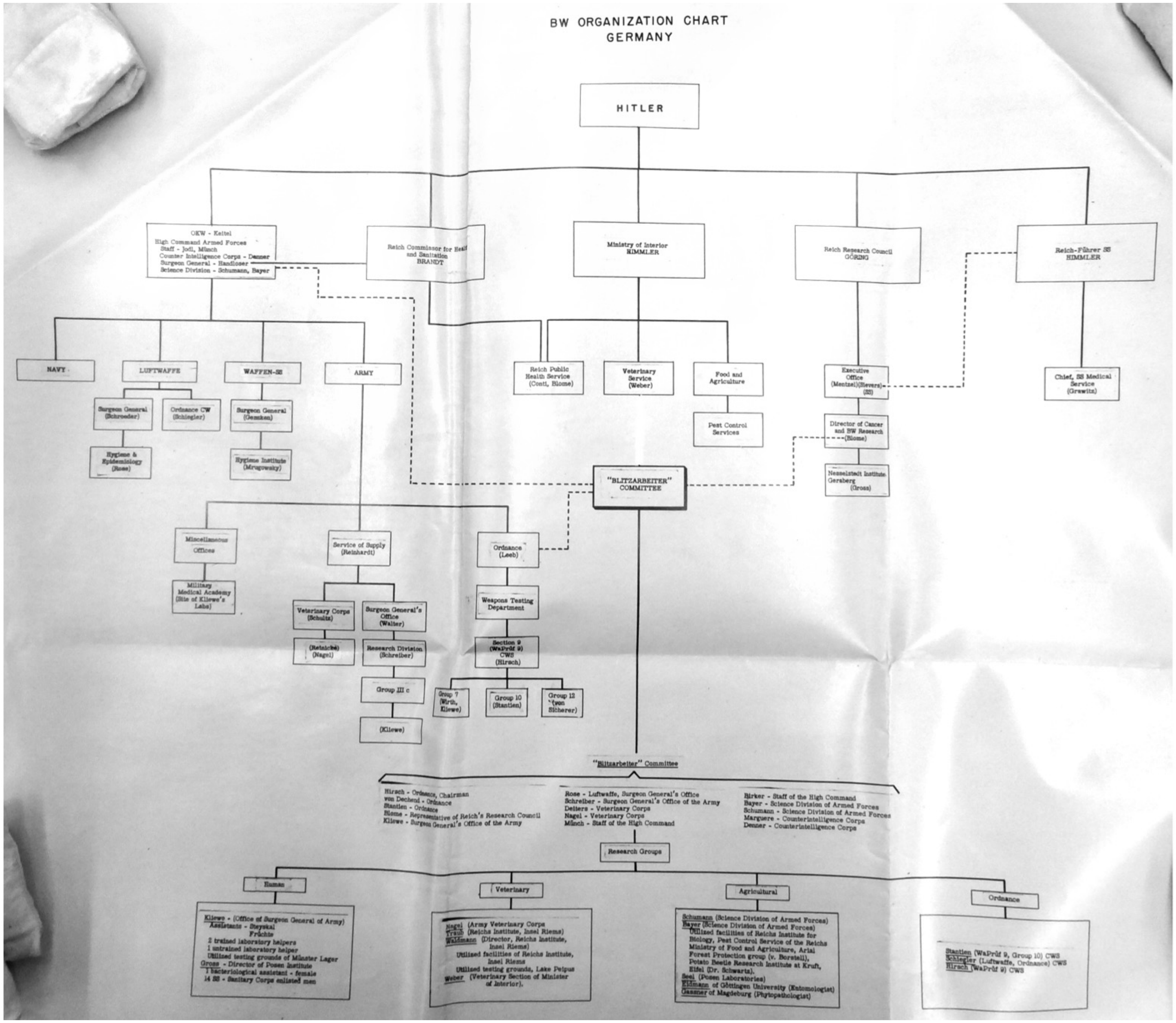

BW ORGANIZATION CHART
GERMANY
HITLER
OKW - Keitel
High Command Armed Forces
Staff - Jodl, Münch
Counter Intelligence Corps - Denner
Surgeon General - Handloser
Science Division - Schumann, Bayer
Reich Commissioner for Heal and Sanitation BRANDT
Ministry of Interior HIMMLER
Reich Research Council GÖRING
Reich-Führer SS HIMMLER
NAVY
LUFTWAFFE
WAFFEN-SS
ARMY
Surgeon General (Schroeder)
Ordnance CW (Schiegler)
Hygiene & Epidemiology (Rose)
Surgeon General (Genzken)
Hygiene Institute (Mrugowsky)
Reich Public Health Service (Conti, Blome)
Veterinary Service (Weber)
Food and Agriculture
Pest Control Services
Executive Office (Mentzel)(Sievers) (SS)
Director of Cancer and BW Research (Blome)
Nesselstedt Institute Gerabterg (Gross)
Chief, SS Medical Service (Grawitz)
"BLITZARBEITER" COMMITTEE
Miscellaneous Offices
Military Medical Academy (Site of Kliewe's Labs)
Service of Supply (Reinhardt)
Veterinary Corps (Schultz)
(Reinické) (Nagel)
Surgeon General's Office (Walter)
Research Division (Schreiber)
Group III c
(Kliewe)
Ordnance (Leeb)
Weapons Testing Department
Section 9 (WaPrüf 9) CWS (Hirsch)
Group 7 (Wirth, Kliewe)
Group 10 (Stantien)
Group 12 (von Sicherer)
"Blitzarbeiter" Committee
Hirsch - Ordnance, Chairman
von Dechend - Ordnance
Stantien - Ordnance
Blome - Representative of Reich's Research Council
Kliewe - Surgeon General's Office of the Army
Rose - Luftwaffe, Surgeon General's Office
Schreiber - Surgeon General's Office of the Army
Deiters - Veterinary Corps
Nagel - Veterinary Corps
Münch - Staff of the High Command
Birker - Staff of the High Command
Bayer - Science Division of Armed Forces
Schumann - Science Division of Armed Forces
Marguere - Counterintelligence Corps
Denner - Counterintelligence Corps
Research Groups
Human
Veterinary
Agricultural
Ordnance
Kliewe - (Office of Surgeon General of Army)
Assistants - Steyskal
Früchte
2 trained laboratory helpers
1 untrained laboratory helper
Utilized testing grounds of Münster Lager
Gross - Director of Posen Institute
1 bacteriological assistant - female
14 SS - Sanitary Corps enlisted men
Nagel (Army Veterinary Corps
Traub (Reichs Institute, Insel Riems)
Waldmann (Director, Reichs Institute, Insel Riems)
Utilized facilities of Reichs Institute, Insel Riems
Utilized testing grounds, Lake Peipus
Weber (Veterinary Section of Minister of Interior).
Schumann (Science Division of Armed Forces)
Bayer (Science Division of Armed Forces)
Utilized facilities of Reichs Institute for Biology, Pest Control Service of the Reichs Ministry of Food and Agriculture, Arial Forest Protection group (v. Borstell), Potato Beetle Research Institute at Kruft, Eifel (Dr. Schwartz).
Seel (Posen Laboratories)
Eidmann of Göttingen University (Entomologist)
Gassner of Magdeburg (Phytopathologist)
Stantien (WaPrüf 9, Group 10) CWS
Schlegler (Luftwaffe, Ordnance) CWS
Hirsch (WaPrüf 9) CWS

Figure A.189: Organization chart for the World War II German biological warfare program, according to the U.S. Alsos Mission [NARA RG 38, Entry P5, Box 8, Folder ALSOS Intelligence Report B-C-H-H/305]. This chart may be highly incomplete, but it makes a good starting point for studying the program.

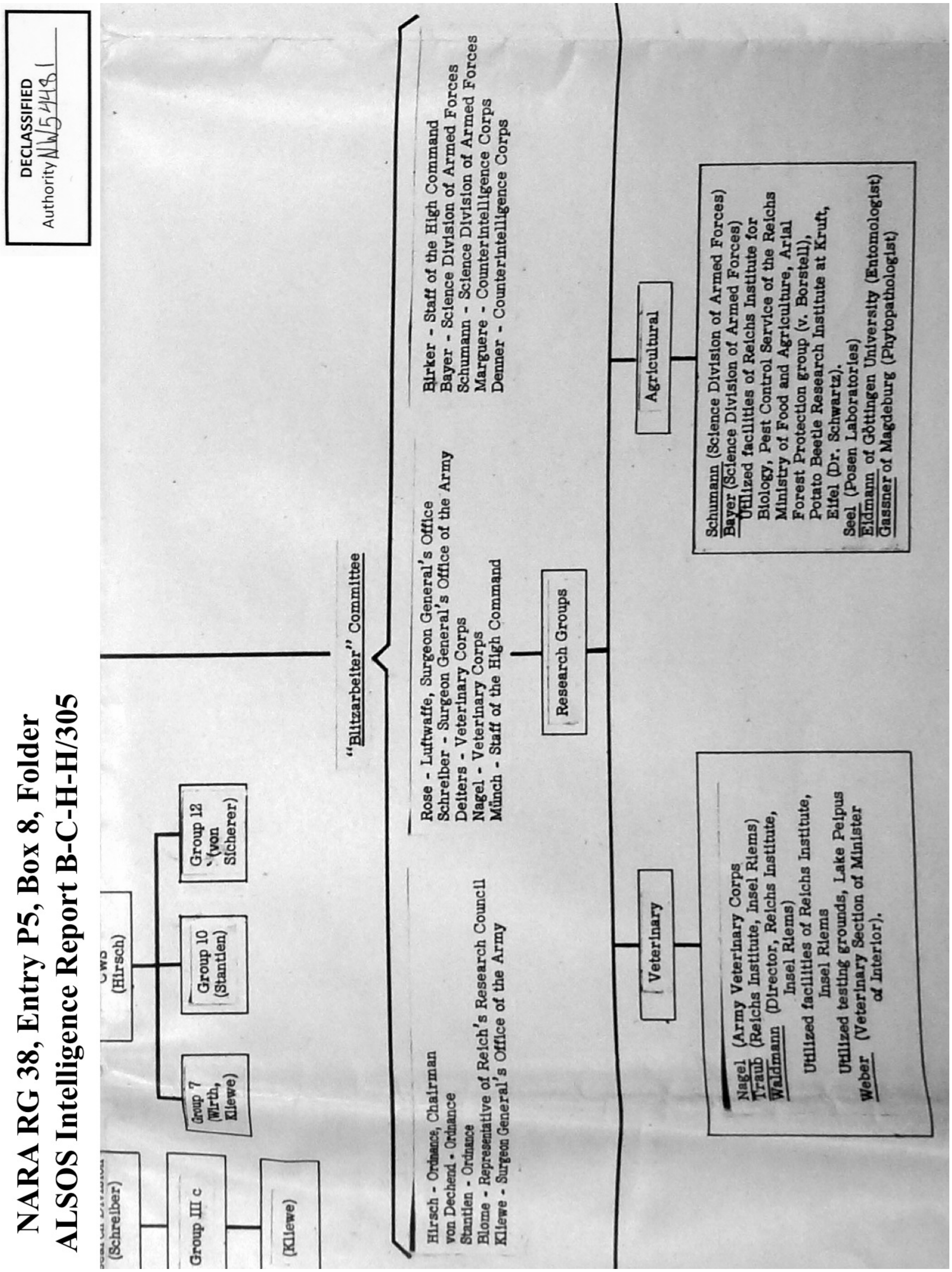
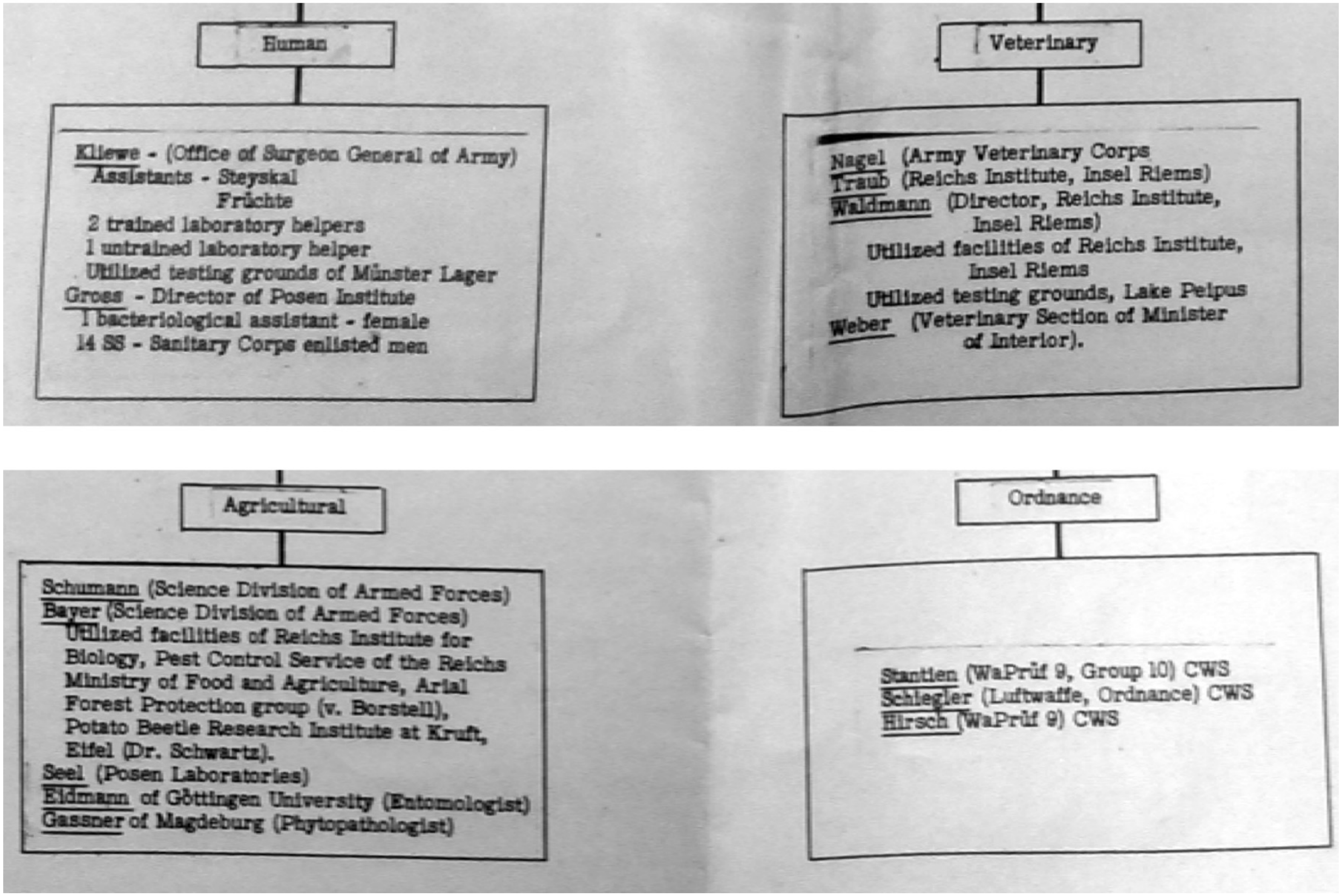

NARA RG 38, Entry P5, Box 8, Folder
ALSOS Intelligence Report B-C-H-H/305
DECLASSIFIED
Authority NW54481
(Schreiber)
Group III c
(Kliewe)
CWB (Hirsch)
Group 7 (Wirth, Kliewe)
Group 10 (Stantien)
Group 12 (von Sicherer)
"Blitzarbeiter" Committee
Hirsch - Ordnance, Chairman
von Dechend - Ordnance
Stantien - Ordnance
Blome - Representative of Reich's Research Council
Kliewe - Surgeon General's Office of the Army
Rose - Luftwaffe, Surgeon General's Office
Schreiber - Surgeon General's Office of the Army
Deiters - Veterinary Corps
Nagel - Veterinary Corps
Münch - Staff of the High Command
Birker - Staff of the High Command
Bayer - Science Division of Armed Forces
Schumann - Science Division of Armed Forces
Marguere - Counterintelligence Corps
Denner - Counterintelligence Corps
Research Groups
Veterinary
Agricultural
Nagel (Army Veterinary Corps
Traub (Reichs Institute, Insel Riems)
Waldmann (Director, Reichs Institute, Insel Riems)
Utilized facilities of Reichs Institute, Insel Riems
Utilized testing grounds, Lake Peipus
Weber (Veterinary Section of Minister of Interior).
Schumann (Science Division of Armed Forces)
Bayer (Science Division of Armed Forces)
Utilized facilities of Reichs Institute for Biology, Pest Control Service of the Reichs Ministry of Food and Agriculture, Arial Forest Protection group (v. Borstell), Potato Beetle Research Institute at Kruft, Eifel (Dr. Schwartz).
Seel (Posen Laboratories)
Eidmann of Göttingen University (Entomologist)
Gassner of Magdeburg (Phytopathologist)

Figure A.190: Organization chart for the World War II German biological warfare program, according to the U.S. Alsos Mission [NARA RG 38, Entry P5, Box 8, Folder ALSOS Intelligence Report B-C-H-H/305]. This chart may be highly incomplete, but it makes a good starting point for studying the program.

DECLASSIFIED
Authority NW54481

NARA RG 38, Entry P5, Box 8, Folder ALSOS Intelligence Report B-C-H-H/305



Human

Kliewe - (Office of Surgeon General of Army)
Assistants - Steyskal
Früchte
2 trained laboratory helpers
1 untrained laboratory helper
Utilized testing grounds of Münster Lager
Gross - Director of Posen Institute
1 bacteriological assistant - female
14 SS - Sanitary Corps enlisted men

Veterinary

Nagel (Army Veterinary Corps
Traub (Reichs Institute, Insel Riems)
Waldmann (Director, Reichs Institute, Insel Riems)
Utilized facilities of Reichs Institute, Insel Riems
Utilized testing grounds, Lake Peipus
Weber (Veterinary Section of Minister of Interior).

Agricultural

Schumann (Science Division of Armed Forces)
Bayer (Science Division of Armed Forces)
Utilized facilities of Reichs Institute for Biology, Pest Control Service of the Reichs Ministry of Food and Agriculture, Arial Forest Protection group (v. Borstell), Potato Beetle Research Institute at Kruft, Eifel (Dr. Schwartz).
Seel (Posen Laboratories)
Eidmann of Göttingen University (Entomologist)
Gassner of Magdeburg (Phytopathologist)

Ordnance

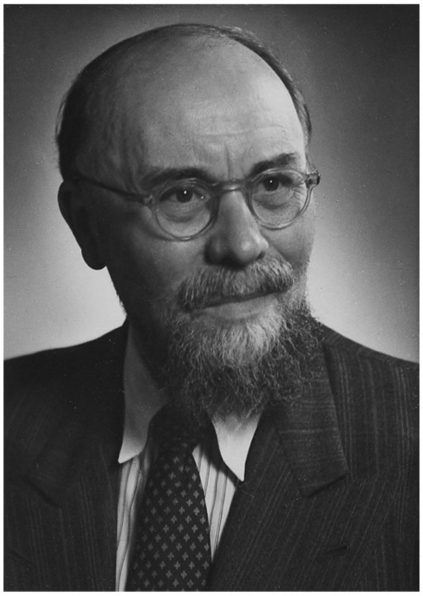
Stantien (WaPrüf 9, Group 10) CWS
Schlegler (Luftwaffe, Ordnance) CWS
Hirsch (WaPrüf 9) CWS

Figure A.191: Organization chart for the World War II German biological warfare program, according to the U.S. Alsos Mission [NARA RG 38, Entry P5, Box 8, Folder ALSOS Intelligence Report B-C-H-H/305]. This chart may be highly incomplete, but it makes a good starting point for studying the program.

Biological warfare agents

?? Bayer
(19??–19??)

Richard Bieling
(1888–1967)



?? Birker
(19??–19??)

Kurt Blome
(1894–1969)

?? von Borstell
(19??–19??)

Henning Brandis
(1916–2004)

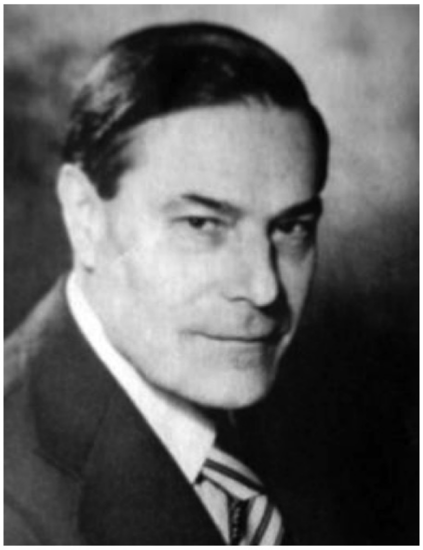


Figure A.192: Examples of German-speaking scientists involved in developing and testing biological warfare agents.

Biological warfare agents

Anna Bürger
(19??–19??)

?? von Dechend
(19??–19??)

?? Deiters
(19??–19??)

?? Denner
(19??–19??)

?? Dennitz
(19??–19??)

?? Eidmann
(19??–19??)

Figure A.193: More examples of German-speaking scientists involved in developing and testing biological warfare agents.

Biological warfare agents

?? Früchte
(19??–19??)

?? Gassner
(19??–19??)

E. Gildemeister
(19??–19??)

Eberhard Gross
(19??–19??)

Martin Gumpert
(1897–1955)

Eugen Haagen
(1898–1972)

Figure A.194: More examples of German-speaking scientists involved in developing and testing biological warfare agents.

Biological warfare agents

Walter Hirsch
(19??–19??)

Gustav Kausche
(19??–19??)

J. Kemper
(19??–19??)

Heinrich Kliewe
(1892–1969)

Edmund Lesser
(1852–1918)

?? Marguere
(19??–19??)

Figure A.195: More examples of German-speaking scientists involved in developing and testing biological warfare agents.

Biological warfare agents

Hubert Möhlmann
(19??–19??)

?? Münch
(19??–19??)

Heinz-Christoph Nagel
(19??–19??)

?? Riehm
(19??–19??)

Heinz Rohrer
(19??–19??)

?? Rose
(19??–19??)

Figure A.196: More examples of German-speaking scientists involved in developing and testing biological warfare agents.

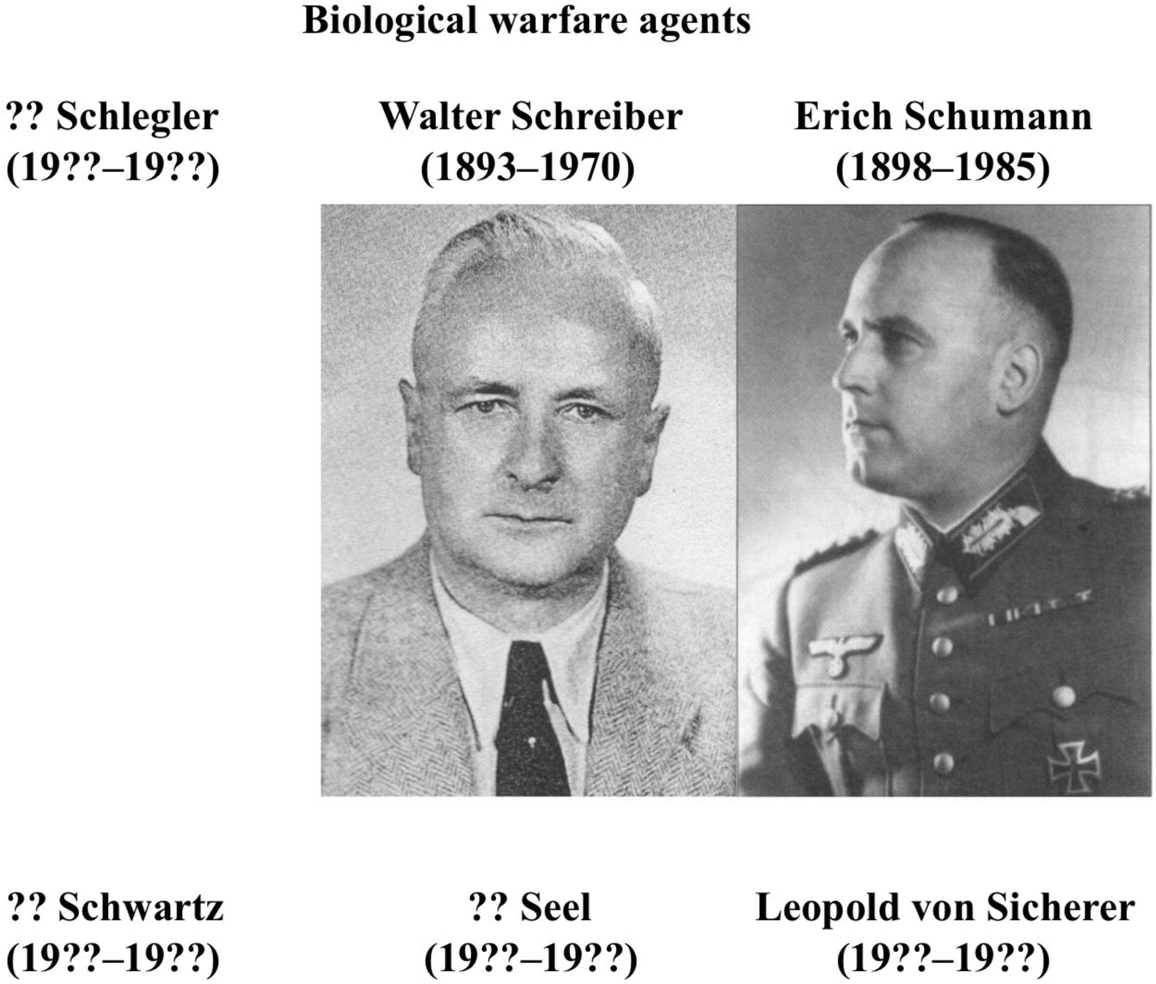

Biological warfare agents
?? Schlegler
(19??–19??)
Walter Schreiber
(1893–1970)
Erich Schumann
(1898–1985)
?? Schwartz
(19??–19??)
?? Seel
(19??–19??)
Leopold von Sicherer
(19??–19??)

Figure A.197: More examples of German-speaking scientists involved in developing and testing biological warfare agents.

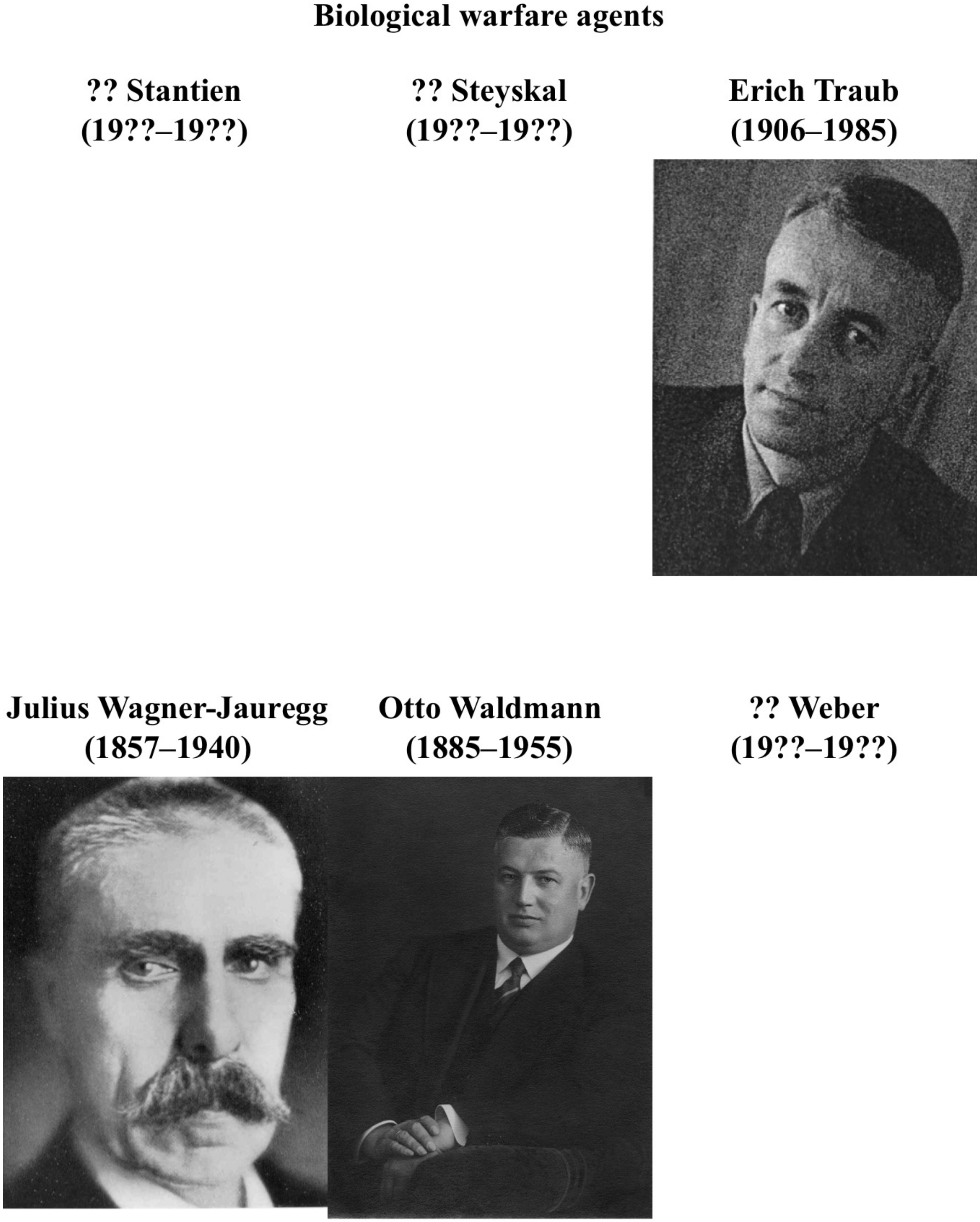

Biological warfare agents
?? Stantien
(19??–19??)
?? Steyskal
(19??–19??)
Erich Traub
(1906–1985)
Julius Wagner-Jauregg
(1857–1940)
Otto Waldmann
(1885–1955)
?? Weber
(19??–19??)

Figure A.198: More examples of German-speaking scientists involved in developing and testing biological warfare agents.

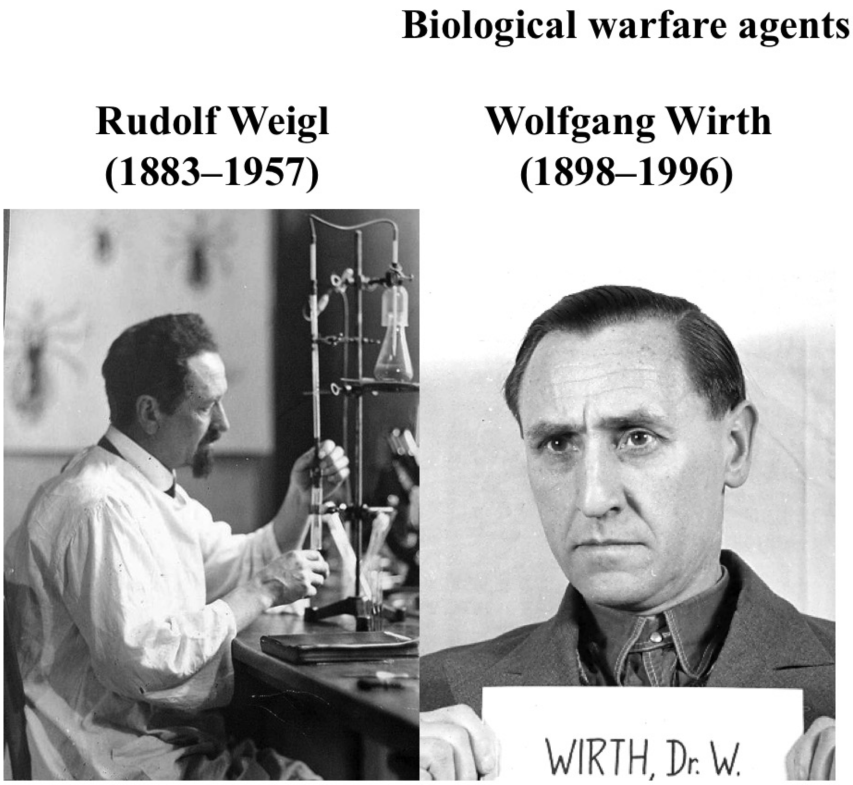

Biological warfare agents
Rudolf Weigl
(1883–1957)
Wolfgang Wirth
(1898–1996)
WIRTH, Dr. W.

Figure A.199: More examples of German-speaking scientists involved in developing and testing biological warfare agents.

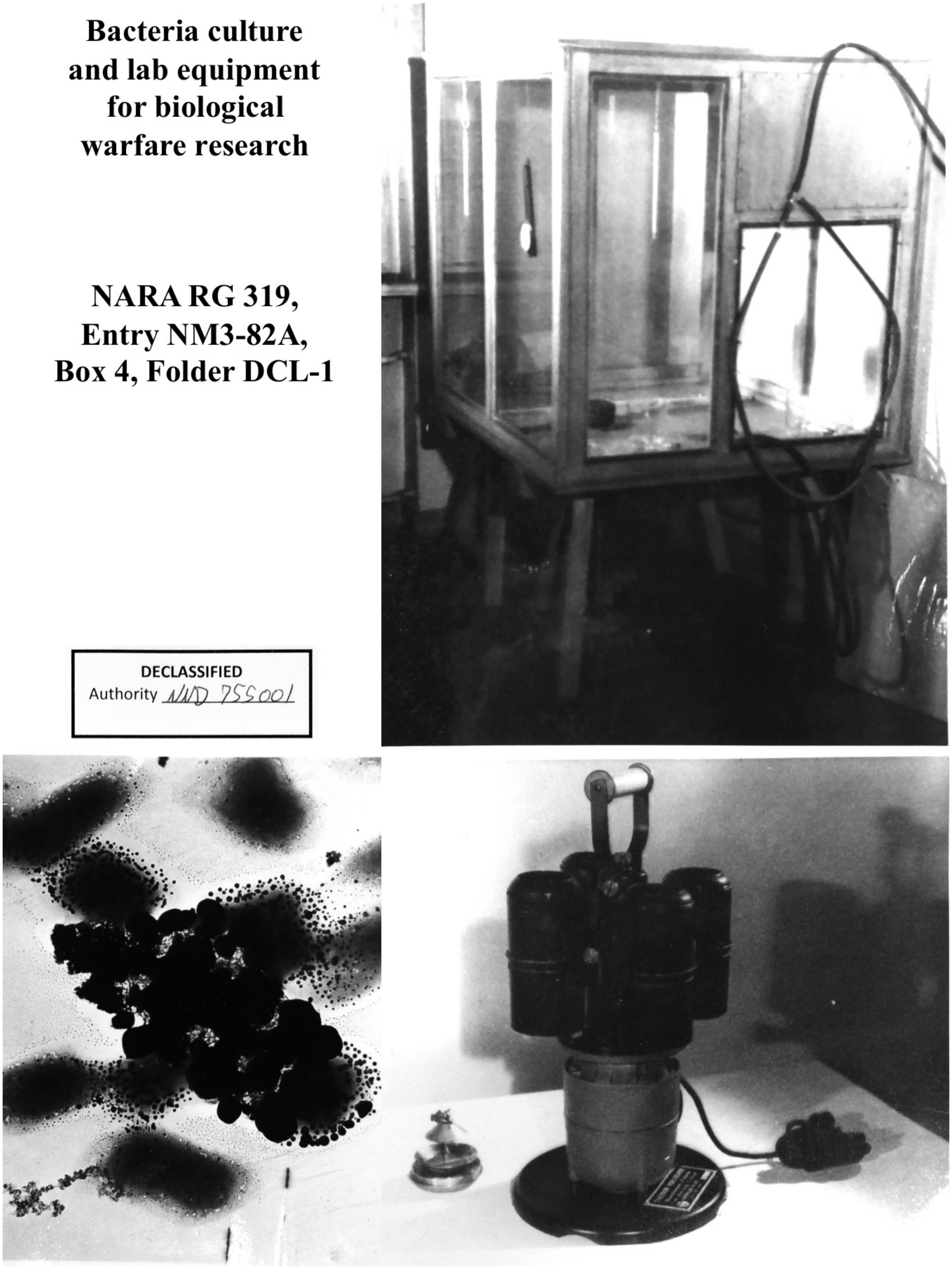

Bacteria culture and lab equipment for biological warfare research
NARA RG 319, Entry NM3-82A, Box 4, Folder DCL-1
DECLASSIFIED
Authority NND 755001

Figure A.200: Bacteria culture and laboratory equipment for biological warfare research [NARA RG 319, Entry NM3-82A, Box 4, Folder DCL-1].

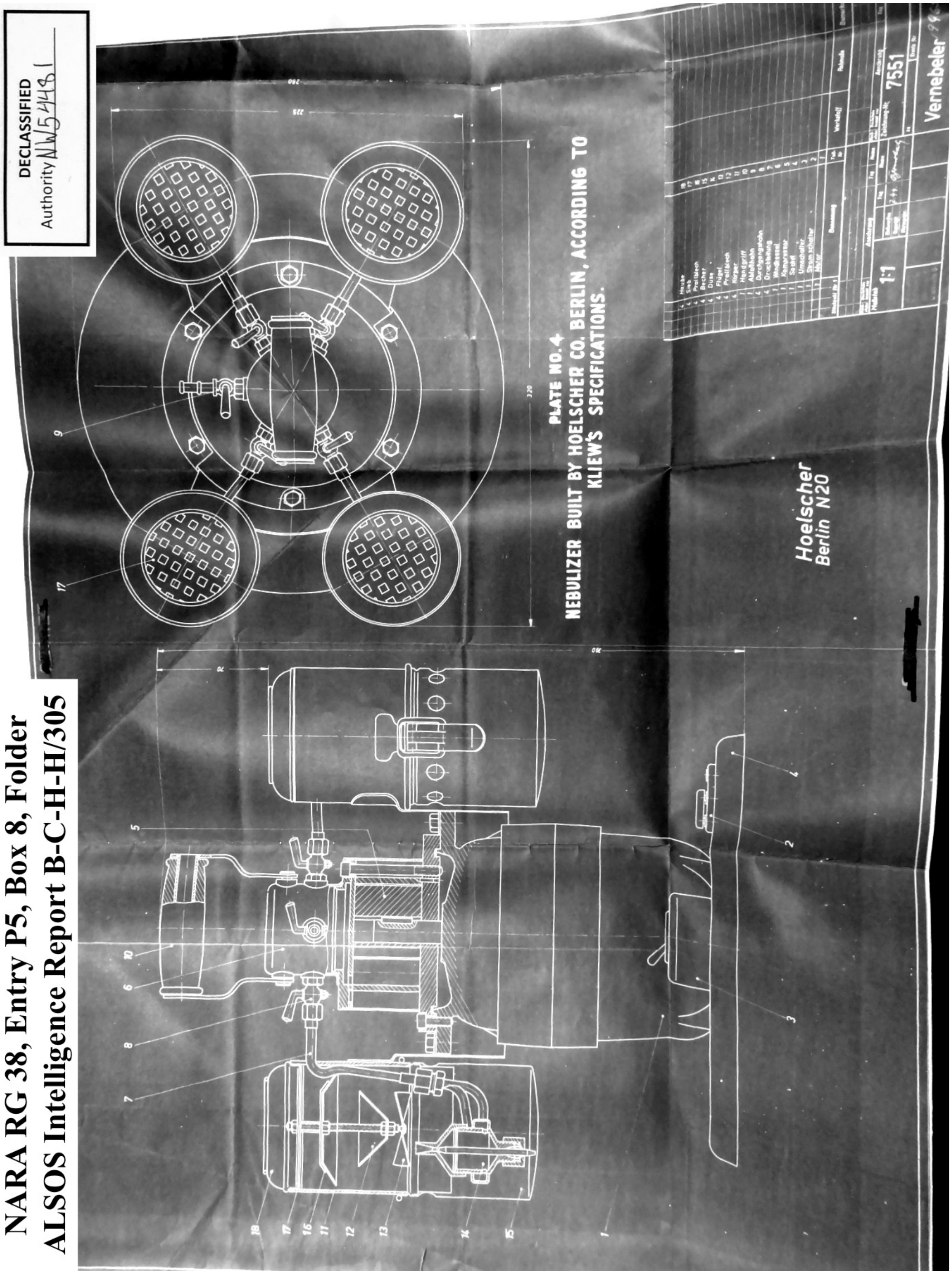

DECLASSIFIED
Authority NW54491
NARA RG 38, Entry P5, Box 8, Folder
ALSOS Intelligence Report B-C-H-H/305
PLATE NO. 4
NEBULIZER BUILT BY HOELSCHER CO. BERLIN, ACCORDING TO
KLIEW'S SPECIFICATIONS.
Hoelscher
Berlin N20
7551
1:1
Vernebeler

Figure A.201: Nebulizer (aerosol sprayer) designed and built for Heinrich Kliewe [NARA RG 38, Entry P5, Box 8, Folder ALSOS Intelligence Report B-C-H-H/305]. Compare with lower right photo of Fig. A.200.

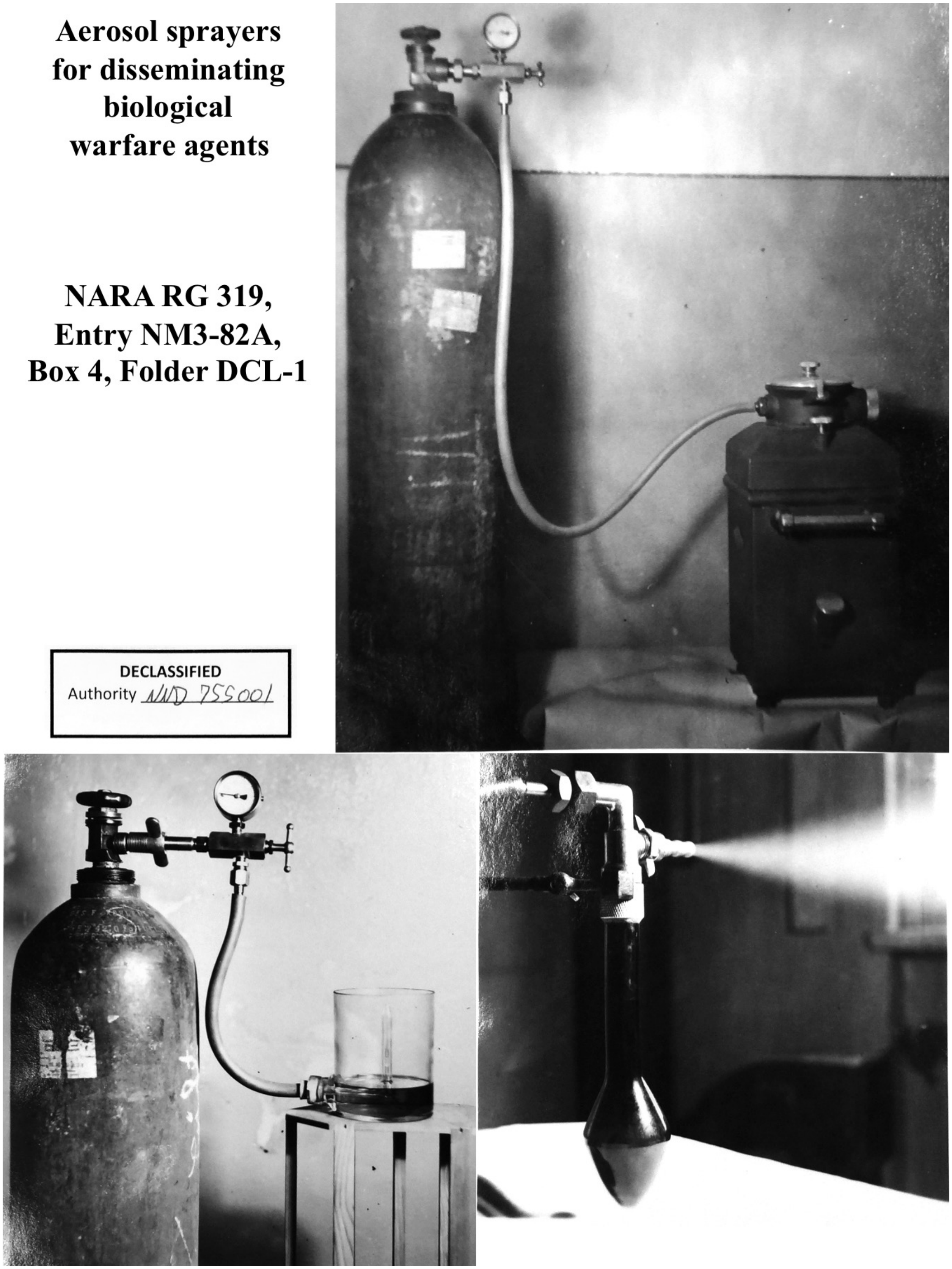

Aerosol sprayers for disseminating biological warfare agents
NARA RG 319, Entry NM3-82A, Box 4, Folder DCL-1
DECLASSIFIED
Authority NND 755001

Figure A.202: Aerosol sprayers for disseminating biological warfare agents [NARA RG 319, Entry NM3-82A, Box 4, Folder DCL-1].

DECLASSIFIED
Authority NND 755001

Wind speed & animal information for field tests NARA RG 319, Entry NM3-82A, Box 4, Folder Biological Warfare/BW # 25

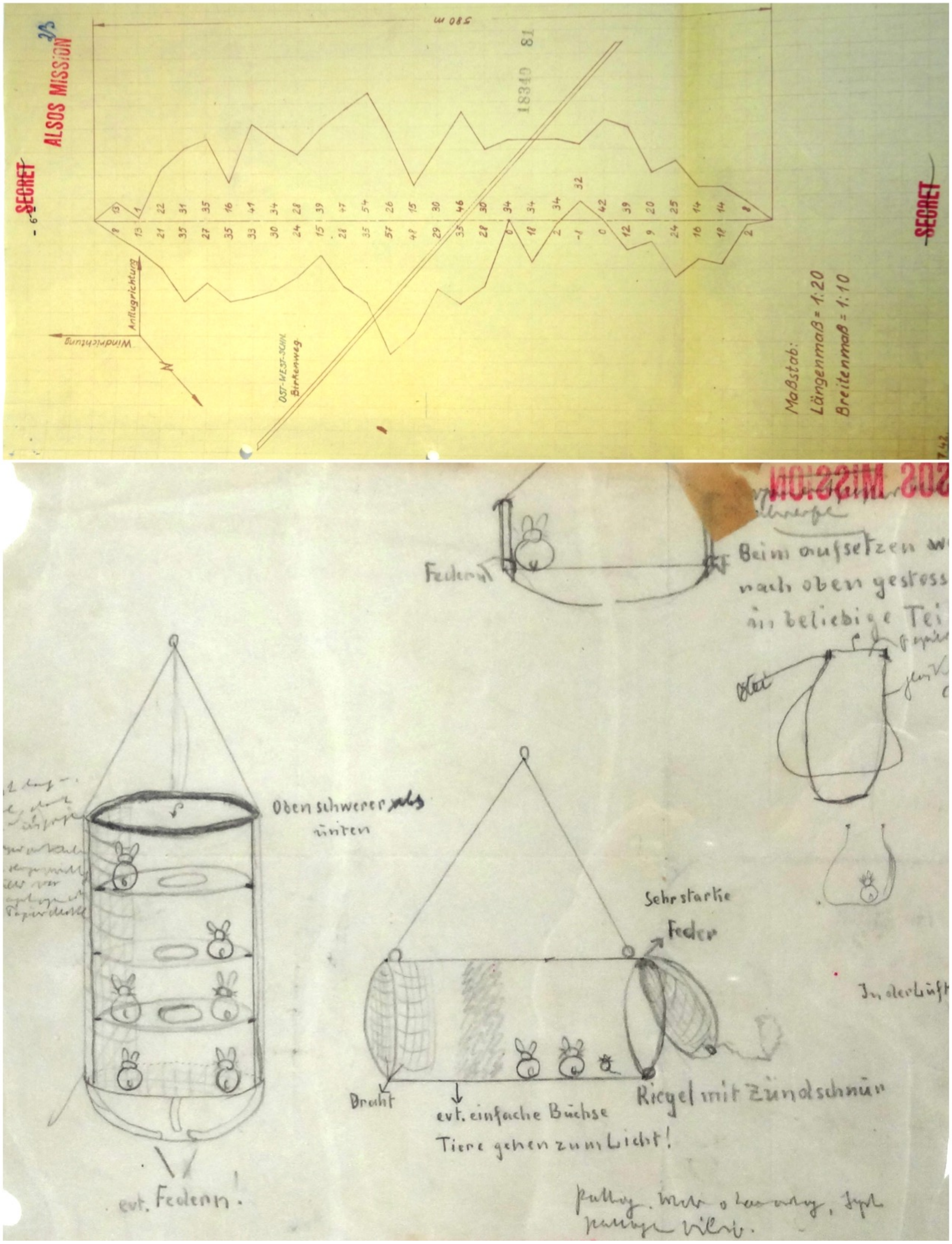
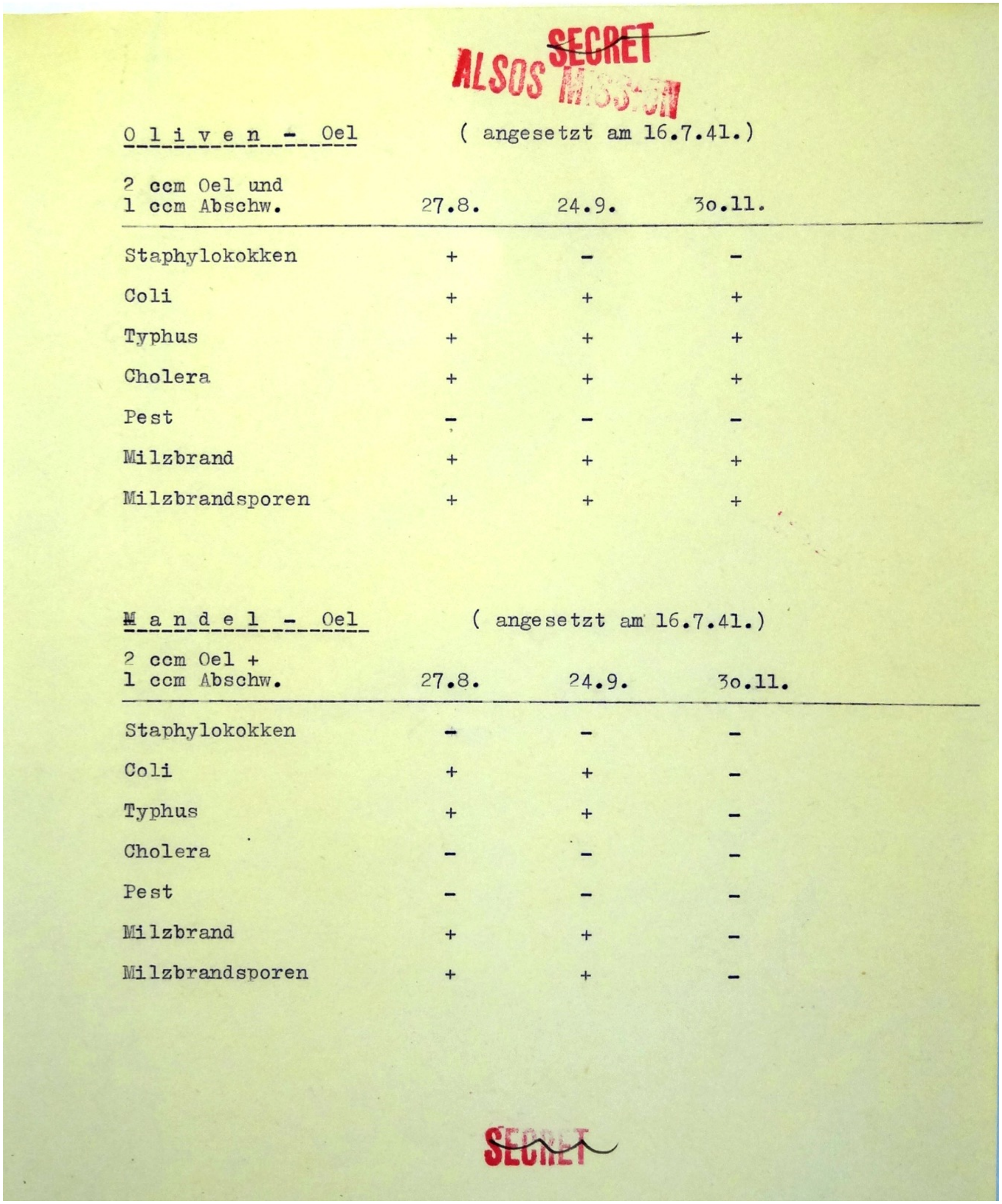

580 m
ALSOS MISSION
2/3
SECRET
- 6 -
18340 81
13 1 22 31 35 16 41 34 28 39 47 54 26 15 30 46 30 34 34 34 32 42 39 20 25 14 14 8
9 13 21 35 27 35 33 30 24 15 28 35 57 48 29 35 28 0 18 2 -1 0 12 9 24 16 18 2
Anflugrichtung
Windrichtung
N
OST-WEST-SCHN.
Birkenweg
Maßstab:
Längenmaß = 1:20
Breitenmaß = 1:10
SECRET
SOS MISSION
Federn
Beim aufsetzen w
nach oben gestoss
in beliebige Tei
Oben schwerer als
unten
Sehr starke
Feder
In der Luft
Draht
evt. einfache Büchse
Riegel mit Zündschnur
Tiere gehen zum Licht!
evt. Federn!

Figure A.203: Wind speed and animal information for field trials of biological warfare agents [NARA RG 319, Entry NM3-82A, Box 4, Folder Biological Warfare/BW # 25].

DECLASSIFIED
Authority NND 755001

Test results for seven biological warfare agents NARA RG 319, Entry NM3-82A, Box 4, Folder Data/DCC-2



ALSOS ~~SECRET~~ MISSION

Oliven - Oel (angesetzt am 16.7.41.)

2 ccm Oel und 1 ccm Abschw.	27.8.	24.9.	3o.11.
Staphylokokken	+	-	-
Coli	+	+	+
Typhus	+	+	+
Cholera	+	+	+
Pest	-	-	-
Milzbrand	+	+	+
Milzbrandsporen	+	+	+

Mandel - Oel (angesetzt am 16.7.41.)

2 ccm Oel + 1 ccm Abschw.	27.8.	24.9.	3o.11.
Staphylokokken	-	-	-
Coli	+	+	-
Typhus	+	+	-
Cholera	-	-	-
Pest	-	-	-
Milzbrand	+	+	-
Milzbrandsporen	+	+	-

~~SECRET~~

Figure A.204: Test results for trials with seven biological warfare agents: a *Staphylococcus* species, a *Shigella* species, typhus (*Rickettsia prowazekii*), cholera (*Vibrio cholerae*), plague (*Yersinia pestis*), anthrax (*Bacillus anthracis*), and anthrax spores [NARA RG 319, Entry NM3-82A, Box 4, Folder Data/DCC-2].

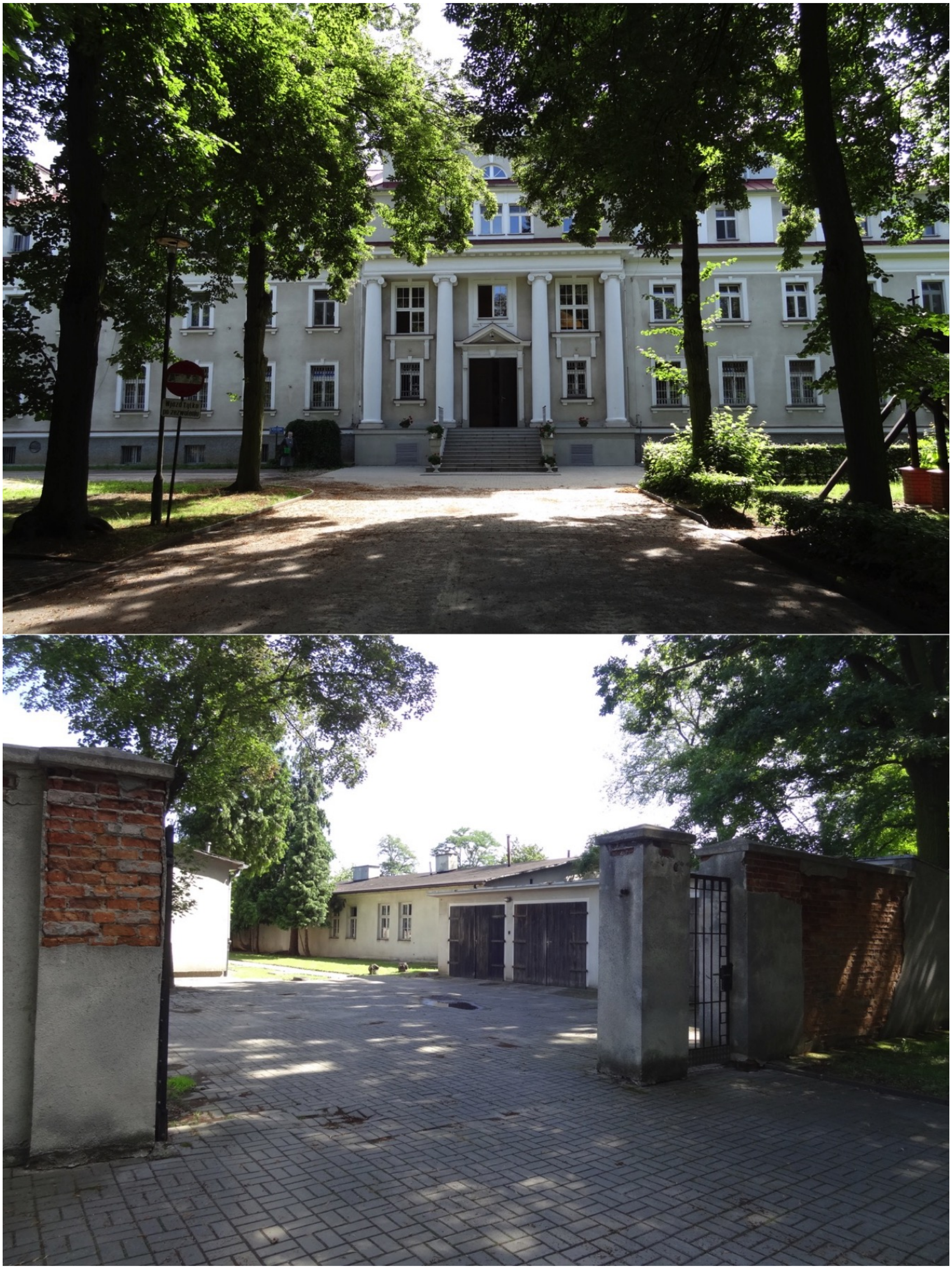


Figure A.205: The former Reichsinstitut für Krebsforschung (Poznan, Poland), which was a major laboratory for biological warfare research during the Third Reich, as it appears now.

Nazi Underground Leaders Captured. ***San Bernardino Sun.*** **24 February 1947 p. 1 [https://cdnc.ucr.edu/cgi-bin/cdnc?a=d&d=SBS19470224.1.1]**

Nazi Underground Leaders Captured

Bacteria Weapon Reported Found in Group's Hands

BERLIN, Feb. 23 (AP) American and British troops cracked down today on a widespread Nazi underground movement which claimed possession of a secret bacteriological weapon to turn against the occupying powers. A former colonel in the German army section that worked on war-with-germs projects was among the "hundreds" seized.

It was the biggest push against the underground since the war ended, and the first on a bizonal scale.

Authorities said they had not learned definitely whether the group actually possessed a bacteriological weapon. Lt. Gen. Lucius D. Clay reported American authorities did not consider the movement "particularly dangerous," while a British spokesman said it was "silly and pretentious" but could not be allowed to spread.

Moving swiftly over ice-glazed roads and in a snowstorm, soldiers and intelligence agents picked up a number of former high ranking officers in the SS (elite guard) and other Nazi organizations. The Americans reported the arrest of about 30 suspects in their zone but said most of the raids were in British Germany. There authorities said hundreds of persons were seized by "thousands" of allied troops in what was described as "Operation Selection Board." With arrests continuing, they disclosed no specific totals.

'WAR' IN RUSSIA

British officials said the movement had tentacles in the Soviet and French zones, and that its aims included restoration of German militarism and a Nazi dictatorship "in order to lead the nations of Europe against Russia." The Russians and French were kept informed of the progress of the raids.

Among those arrested in the American zone were former SS Major Gen. Kurt Ellerick, Hitler Youth Col. Walter Shimmelpfeng, Army Major Felix Buck, SS Major Martin Zinzt, SA (Storm Troops) Major Fridolin Becker, SS Capts. Ernst Berndt, Siegfried Bettke and Werner Roepke, and SS Lts. Hans Pavel and Hans Becker. Some were connected with other military men seized on similar charges in the past three months, officials said.

GERM EXPERT CAUGHT

The British nabbed Col. Hans Eismann, former officer of the bacteriological warfare division, who had been living under an assumed name; Col. Heinz Kling, former SS officer who headed a tank regiment at the end of the war; Dr. Rolf Wilkenning, SS officer described as an important member of the former German intelligence service and founder of the Koelner Kreis, prewar group used by German intelligence for pre-invasion penetration of the Low countries.

DECLASSIFIED
Authority NW54481

Plans for Geraberg biological warfare laboratory
NARA RG 38, Entry P5, Box 8, Folder
ALSOS Intelligence Report B-C-H-H/305

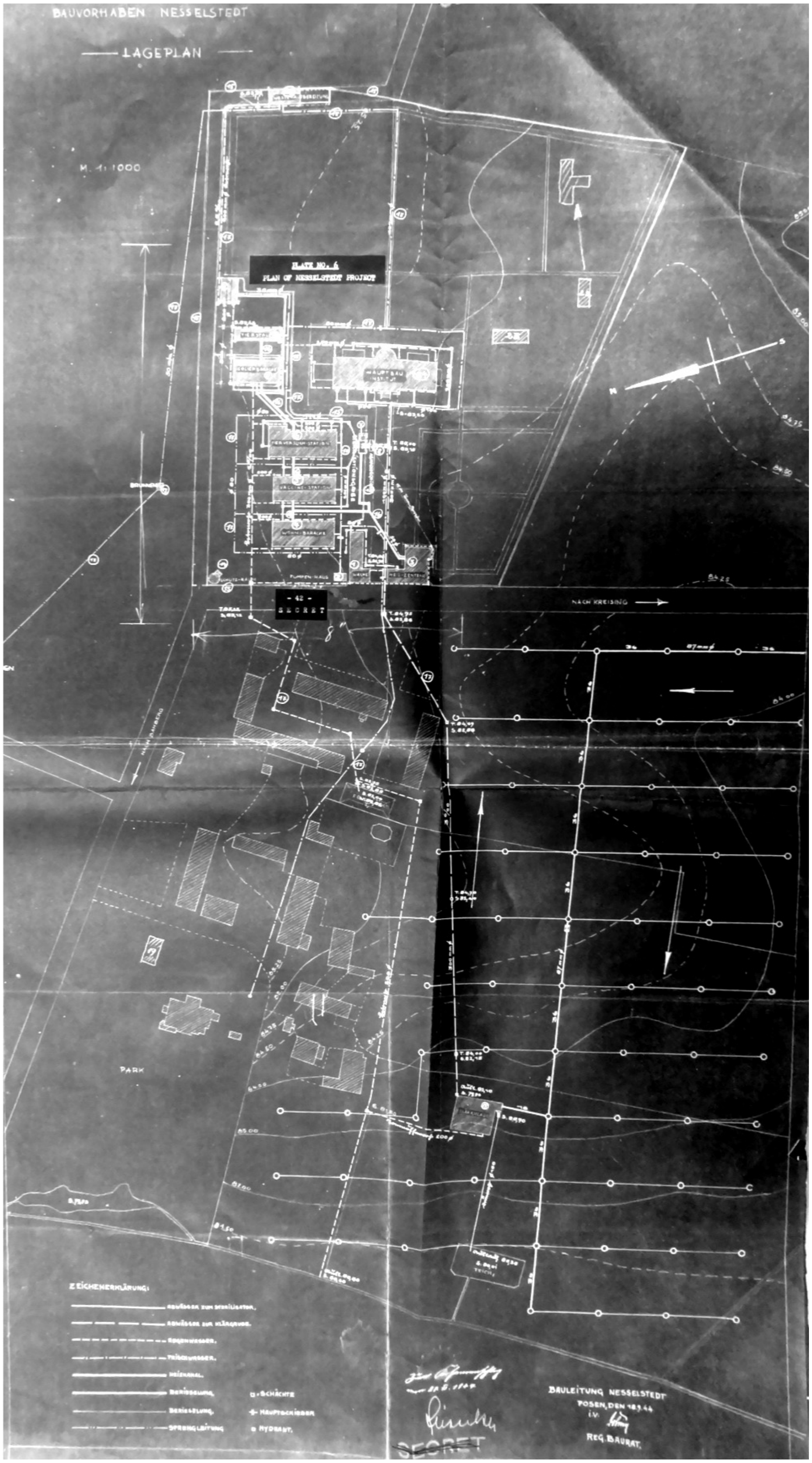

BAUVORHABEN NESSELSTEDT
LAGEPLAN
M. 1:1000
PLATE NO. 6
PLAN OF NESSELSTEDT PROJECT
HAUPTBAU INSTITUT
- 42 -
SECRET
NACH KREISING
PARK
ZEICHENERKLÄRUNG:
ABWÄSSER ZUM STERILISATOR.
ABWÄSSER ZUR KLÄRGRUBE.
REGENWASSER.
TRINKWASSER.
HEIZKANAL.
BERIESELUNG.
BERIESELUNG.
SPRENGLEITUNG.
□ SCHÄCHTE
HAUPTSCHIEBER
○ HYDRANT.
BAULEITUNG NESSELSTEDT
POSEN, DEN 18.3.44
I.V.
REG. BAURAT.
SECRET

Figure A.206: Plans for the Reichsinstitut für Grenzbereiche der Medizin (Geraberg) biological warfare laboratory [NARA RG 38, Entry P5, Box 8, Folder ALSOS Intelligence Report B-C-H-H/305].

DECLASSIFIED
Authority NND 755001

Plans for Geraberg biological warfare laboratory
NARA RG 319, Entry NM3-82A, Box 4,
Folder DCL-1

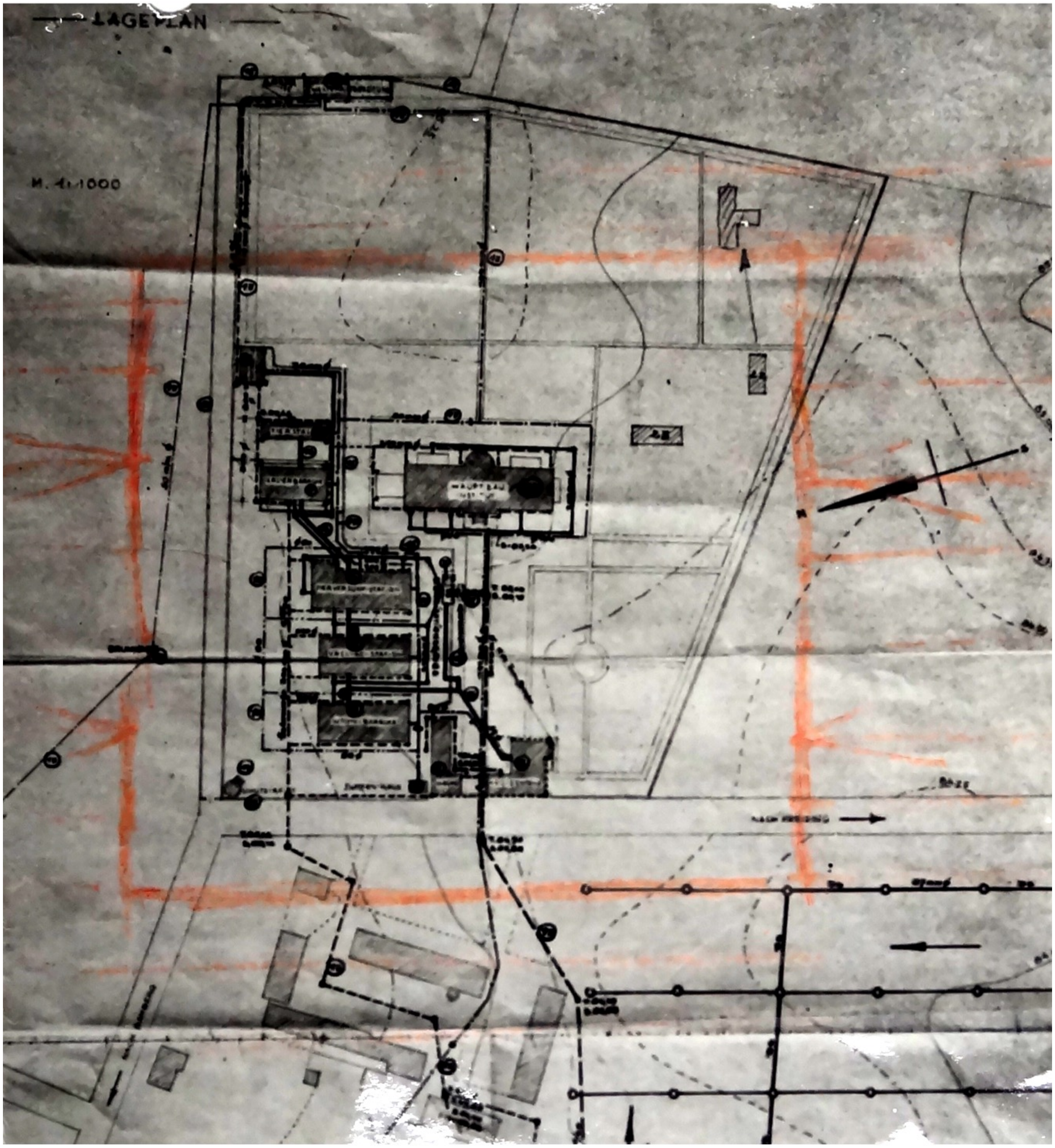


Figure A.207: Plans for the Reichsinstitut für Grenzbereiche der Medizin (Geraberg) biological warfare laboratory [NARA RG 319, Entry NM3-82A, Box 4, Folder DCL-1].

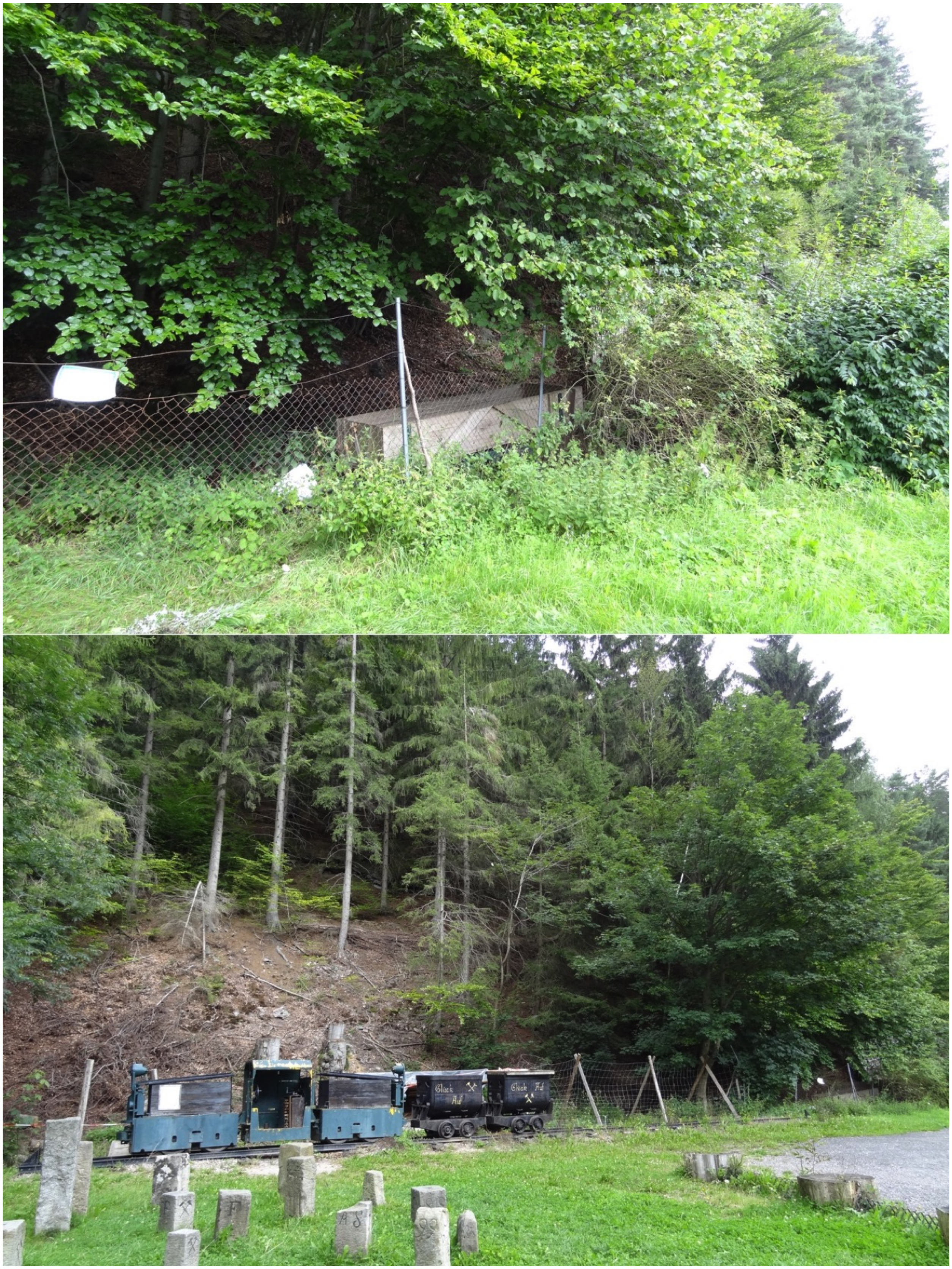
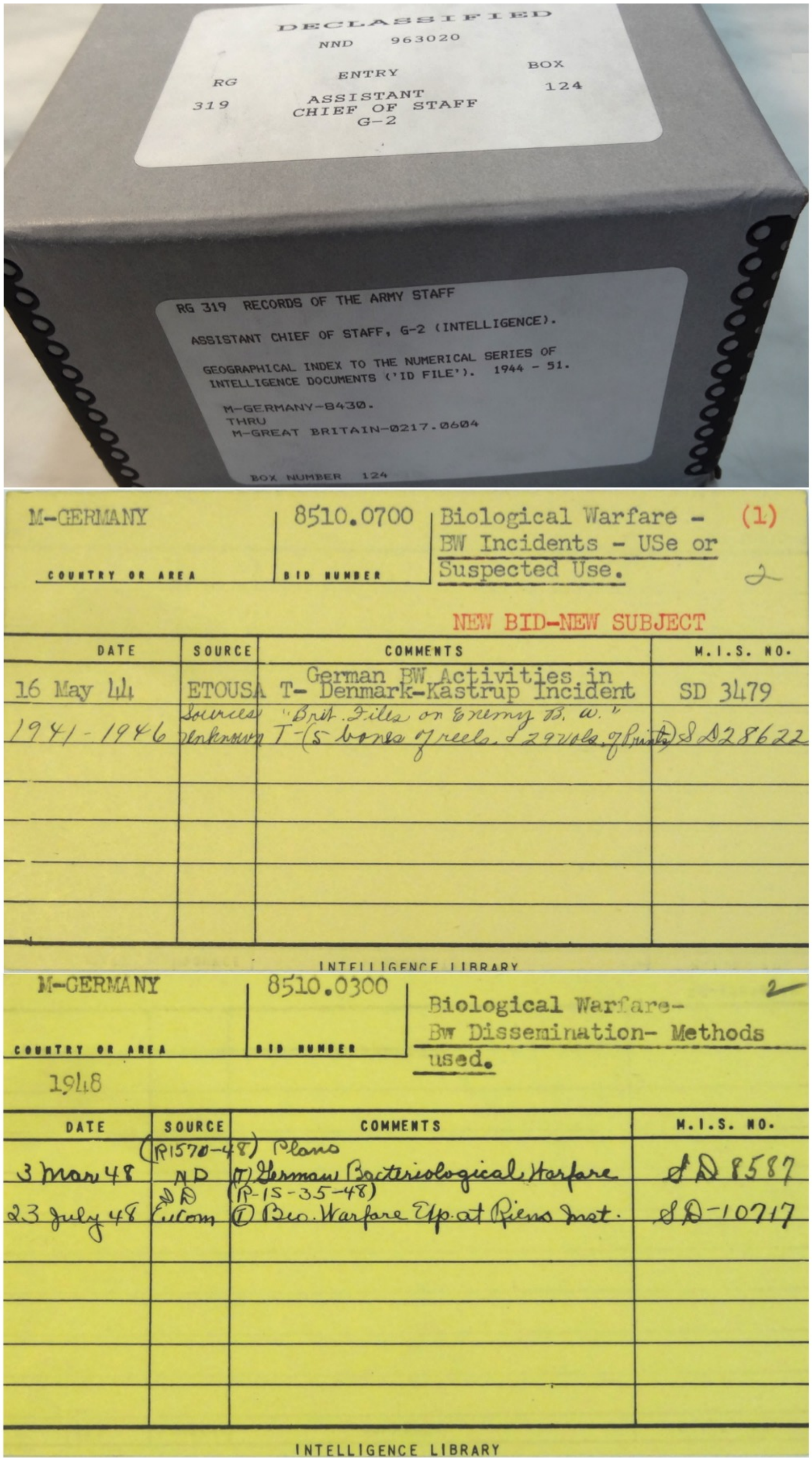


Figure A.208: The location of the former Reichsinstitut für Grenzbereiche der Medizin (Geraberg), which was intended to be a major laboratory for biological warfare research during the Third Reich, as it appears now.

DECLASSIFIED
Authority NND 963020



DECLASSIFIED
NND 963020
RG 319
ENTRY
ASSISTANT CHIEF OF STAFF G-2
BOX 124

RG 319 RECORDS OF THE ARMY STAFF

ASSISTANT CHIEF OF STAFF, G-2 (INTELLIGENCE).

GEOGRAPHICAL INDEX TO THE NUMERICAL SERIES OF INTELLIGENCE DOCUMENTS ('ID FILE'). 1944 - 51.

M-GERMANY-8430.
THRU
M-GREAT BRITAIN-0217.0604

BOX NUMBER 124

M-GERMANY
COUNTRY OR AREA
8510.0700
BID NUMBER
Biological Warfare - BW Incidents - USe or Suspected Use.
(1)
2

NEW BID-NEW SUBJECT

DATE	SOURCE	COMMENTS	M.I.S. NO.
16 May 44	ETOUSA	T- German BW Activities in Denmark-Kastrup Incident	SD 3479
1941-1946	Sources unknown	"Brit. Files on Enemy B. W." T-(5 boxes of reels & 29 vols. of Prints)	SD 28622

INTELLIGENCE LIBRARY

M-GERMANY
COUNTRY OR AREA
8510.0300
BID NUMBER
Biological Warfare- Bw Dissemination- Methods used.
2

1948

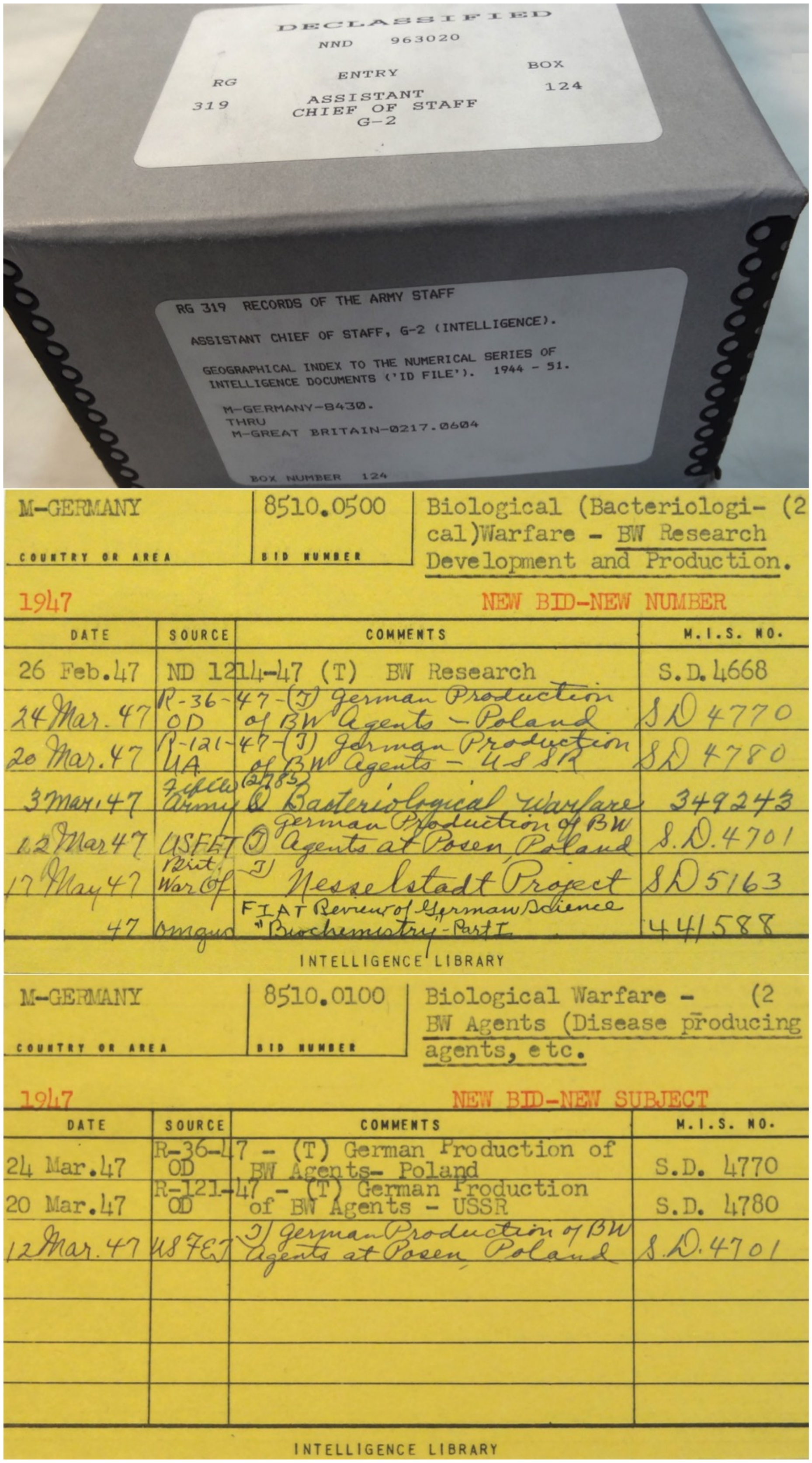
DATE	SOURCE	COMMENTS	M.I.S. NO.
3 Mar 48	ND	(R1570-48) Plans (T) German Bacteriological Warfare	SD 8587
23 July 48	SD Eucom	(R-15-35-48) ① Bio. Warfare Exp. at Riems Inst.	SD-10717

INTELLIGENCE LIBRARY

NARA RG 319,
Entry A1-84E, Box 124

Figure A.209: A U.S. intelligence card catalog shows that there were a number of reports detailing German production of biological warfare agents, but those reports are still classified and unavailable to the public [NARA RG 319, Entry A1-84E, Box 124].

DECLASSIFIED
Authority NND 963020


DECLASSIFIED
NND 963020
RG 319
ENTRY ASSISTANT CHIEF OF STAFF G-2
BOX 124
RG 319 RECORDS OF THE ARMY STAFF
ASSISTANT CHIEF OF STAFF, G-2 (INTELLIGENCE).
GEOGRAPHICAL INDEX TO THE NUMERICAL SERIES OF INTELLIGENCE DOCUMENTS ('ID FILE'). 1944 - 51.
M-GERMANY-8430.
THRU
M-GREAT BRITAIN-0217.0604
BOX NUMBER 124

COUNTRY OR AREA	BID NUMBER	
M-GERMANY	8510.0500	Biological (Bacteriological)Warfare - BW Research Development and Production. (2

1947 NEW BID-NEW NUMBER

DATE	SOURCE	COMMENTS	M.I.S. NO.
26 Feb.47	ND 1214-47	(T) BW Research	S.D.4668
24 Mar.47	R-36-47-OD	(T) German Production of BW Agents - Poland	SD 4770
20 Mar.47	R-121-47-UA	(T) German Production of BW Agents - USSR	SD 4780
3 Mar.47	Fifth Army	(2785) (C) Bacteriological Warfare	349243
12 Mar 47	USFET	(T) German Production of BW Agents at Posen, Poland	S.D.4701
17 May 47	Brit. War Of	(T) Nesselstadt Project	SD 5163
47	Omgus	FIAT Review of German Science "Biochemistry"-Part I	441588

INTELLIGENCE LIBRARY

COUNTRY OR AREA	BID NUMBER	
M-GERMANY	8510.0100	Biological Warfare - BW Agents (Disease producing agents, etc. (2

1947 NEW BID-NEW SUBJECT

DATE	SOURCE	COMMENTS	M.I.S. NO.
24 Mar.47	R-36-47 OD	- (T) German Production of BW Agents- Poland	S.D. 4770
20 Mar.47	R-121-47 OD	- (T) German Production of BW Agents - USSR	S.D. 4780
12 Mar.47	USFET	(T) German Production of BW Agents at Posen, Poland	S.D.4701

INTELLIGENCE LIBRARY

NARA RG 319,
Entry A1-84E, Box 124

Figure A.210: A U.S. intelligence card catalog shows that there were a number of reports detailing German production of biological warfare agents, but those reports are still classified and unavailable to the public, except for the last one [NARA RG 319, Entry A1-84E, Box 124]. For S.D. 4701, see the next page.

S.D. 4701/MIS-926445 [NARA RG 319, Entry NM3-85M, Box 62, Folder 926445].

U.S. War Department General Staff, Intelligence Division. 29 January 1947. German Production of Biological Warfare Agents.

1. The Intelligence Division has a specific requirement for the following:

Reference is made to a broadcast in German from Moscow to Europe, 15 January 1947, 9:00 a.m. EST., commentary by Kubanin, "The Nuremberg Trial of Nazi Doctors." The following is quoted from a summary of this broadcast:

"Their (German) experiments had been designed to promote the scientific development of the methods for killing people by the million. Thus the liberating Red Army had found at Poznan a German factory manufacturing lethal bacteria on a mass scale."

Latest information in I.D. indicates that the German project at Posen, Poland, had not begun operations for the production of biological warfare agents although construction had been completed.

The following information is requested:

a. Who's Who information concerning Kubanin.

b. Any information available on Russian knowledge of German BW with particular reference to the installation at Posen, Poland.

c. What is the present condition of the installation at Posen and for what purposes is it being used, if any?

d. Is there any other evidence concerning the manufacture of bacteria at the Posen installation by the Germans?

2. To assist in satisfying this requirement, the following collection guidance is submitted for consideration.

The installation at Posen, Poland, is referred to in German intelligence documents as the "Nesselstedt Project."

3. As complete an answer to the requirement, as may be procurable, must be received in the Intelligence Division on or before 1 Apr. '47. [...]

4. Specific reference should be made to Control No. S-629 in all replies to this requirement. [...]

Office of the Assistant Chief of Staff, G-2, Headquarters, United States Forces, European Theatre, to Director of Intelligence, War Department General Staff. 12 March 1947.

No information is available in this headquarters at the present time pertaining to the request made in basic communication, Control No. S-629. Any subsequent information will be forwarded. [...]

A.4 Chemical Warfare

A.4.1 German Chemical Weapons

[Scientists in the Third Reich produced and tested a wide variety of organophosphate nerve agents, and created several especially potent ones (which were given postwar codenames beginning with G for German): tabun (GA), sarin (GB), soman (GD), ethylsarin (GE), cyclosarin (GF), and isopentylsarin (GH). (The code name GC was not used, to avoid confusion with the U.S. code name for phosgene, CG [Tucker 2006, p. 105]. GG was likely skipped because of the double letters.) These agents were exclusively possessed by the Third Reich and were stockpiled but never used, due to fear that Allied nations would retaliate with much cruder but still effective first-generation chemical weapons such as mustard gas (which had also originally been created by German scientists). The G-series nerve agents and information on how to produce them was removed from Germany at the end of the war, and G-series agents have been mass-produced by a wide range of nations ever since.]

BIOS 542. *Interrogation of Certain German Personalities Connected with Chemical Warfare.*

PROFESSOR DR. RICHARD KUHN

(interrogated on 1–2 April 1946, at the K.W.I, Heidelberg)

[...] Pinacolyl alcohol gave compound 25075, SOMAN, which proved to be even more potent and which has not, in fact, been surpassed so far. It was first prepared in the early spring of 1944.

To assist in the evaluation of these compounds as they were prepared, KUHN's team used a test based on the relative inhibition of choline esterase by the candidate agent, compared to that caused by a standard agent in the methane-phosphonic ester series; in the later stages of the work compound 15146, SARIN, was used as the reference standard. Wa Prüf 9 were in the habit of sending to KUHN compounds prepared in other laboratories for screening in this fashion; of these compounds sent in from the outside, the SARIN-SOMAN analogue prepared with diethyl carbinol by HÜCKEL was the most active, being but little less active than SOMAN itself.

Meanwhile, the general problem of the mechanism of action and pharmacological properties of the TABUN (15083)–SARIN–SOMAN series was being tackled by the various members of the KUHN team[...]

x Code numbers commencing with 25001 represent substances prepared by KUHN; 21001 by HÜCKEL, and 14001 and 15001 by I.G.

KUHN's work in this field was abruptly terminated by the HWA in September 1944, when they carried off all relevant documents and demanded the destruction of all laboratory notebooks, etc. The complete set of these documents was stated by KUHN to have been buried in a mine shaft at RÜDESDORF, ten miles east of BERLIN, either in the same shaft as that used for burying the library of the German Chemical Society from the HOFFMANHAUS, or in one adjacent to it. Some months ago, KUHN was informed by Dr. PFLÜCKE of KASTANIEN ALLE 35, POTSDAM, that the entire contents of these shafts, presumably including the KUHN reports, were carried off by Prof. Col. KARGIN to the KARPOV INSTITUTE in MOSCOW. [...]

KUHN also stated that, in accordance with the usual German practice, he was not in contact with any other workers in the C.W. field, that he did not know the names of any such workers, and that in particular he knew nothing of SCHRADER's work. The last of these statements is almost certainly true, for it was clear from one of his last remarks that he believed that iso propyl fluorophosphate had never been prepared (he recommended its examination) whereas in fact SCHRADER has described several ways of making it. [...]

[The above report, BIOS 542, stated that "the usual German practice" for secret military programs such as nerve agent development was for individual scientists to know only their part of the program, not other parts of the program or even other scientists who were working in those other parts. That highly compartmentalized approach would also have been employed in the German nuclear program (Appendix D).

BIOS 542 also showed that at least three different groups—Richard Kuhn's group, Gerhard Schrader's group at I.G. Farben Leverkusen, and Erich Hückel's group—were independently synthesizing large numbers of novel nerve agents.

Finally, BIOS 542 revealed that all of Kuhn's information on nerve agent synthesis, and perhaps all of the information for the entire German nerve agent program, was captured and utilized by the Soviet Union.]

[A significant innovation in nerve agents first became publicly known after the war (see molecular diagrams on p. 569). Although G-series agents were relatively small molecules that dispersed fairly rapidly, if they were coupled to an oily hydrocarbon chain, they could persist on surfaces for long periods of time and also readily penetrate through human skin. These improved nerve agents became known as the V-series (for venomous); VX was the favorite in the United States and United Kingdom, and the similarly acting VR was the favorite in the Soviet Union.

There are a number of reasons to suspect that the key innovation for the V-series may have been a wartime German creation:

- Nearly three decades earlier, German scientists pioneered the method of linking a toxic agent to an oily hydrocarbon chain in order to make the agent persist much longer in the environment and to make the agent readily penetrate through human skin. That was the key to mustard agent, by far their most successful previous chemical weapon.

- Beginning in 1943, the slow but inexorable Soviet push westward led Germany to further accelerate its already well-funded and advanced scientific research and development programs, in order to find military methods of countering the Soviet forces. Making the most toxic German chemical agents persist much longer in the environment, so that they could be used to contaminate areas and block a Soviet advance (see p. 2633 for such plans), would be a very obvious and very high-priority goal.

- After the war, Gerhard Schrader, Ernst Schegk, and Hanshelmut Schlör of Bayer in Leverkusen (part of I.G. Farben during the war) filed patents on linking an oily hydrocarbon chain to a toxic organophosphate molecular structure (see Figs. A.211–A.214 for examples), although postwar restrictions both delayed public acknowledgement of that work and compelled them to focus on insecticide applications instead of chemical warfare applications.

- After the war, V-series agents were not invented by one clearly defined Allied scientist or group. Rather, they appeared almost simultaneously from several apparently independent groups, making it seem more likely that they were based on wartime German work that had been disseminated to all of those groups. In 1952, Ranajit Ghosh and J. F. Newman at the UK Imperial Chemical Industries (ICI) Plant Protection Laboratory produced a potent V-series agent, Amiton, that had been intended as an insecticide. Almost simultaneously, Lars-Erik Tammelin of the Swedish Institute of Chemical Defense produced similar compounds that came to be known as Tammelin esters. The United States began producing VX, and the Soviet Union began producing VR.

- German experts such as Friedrich Wilhelm Hoffmann were employed after the war to mass produce V-series agents. Hoffmann was also deeply involved in the postwar U.S. development (or perhaps the postwar transfer/recapitulation of wartime German work) of the Agent Orange defoliant, dioxin, various other toxins, attempts to harness LSD, and other chemical agents.[6]

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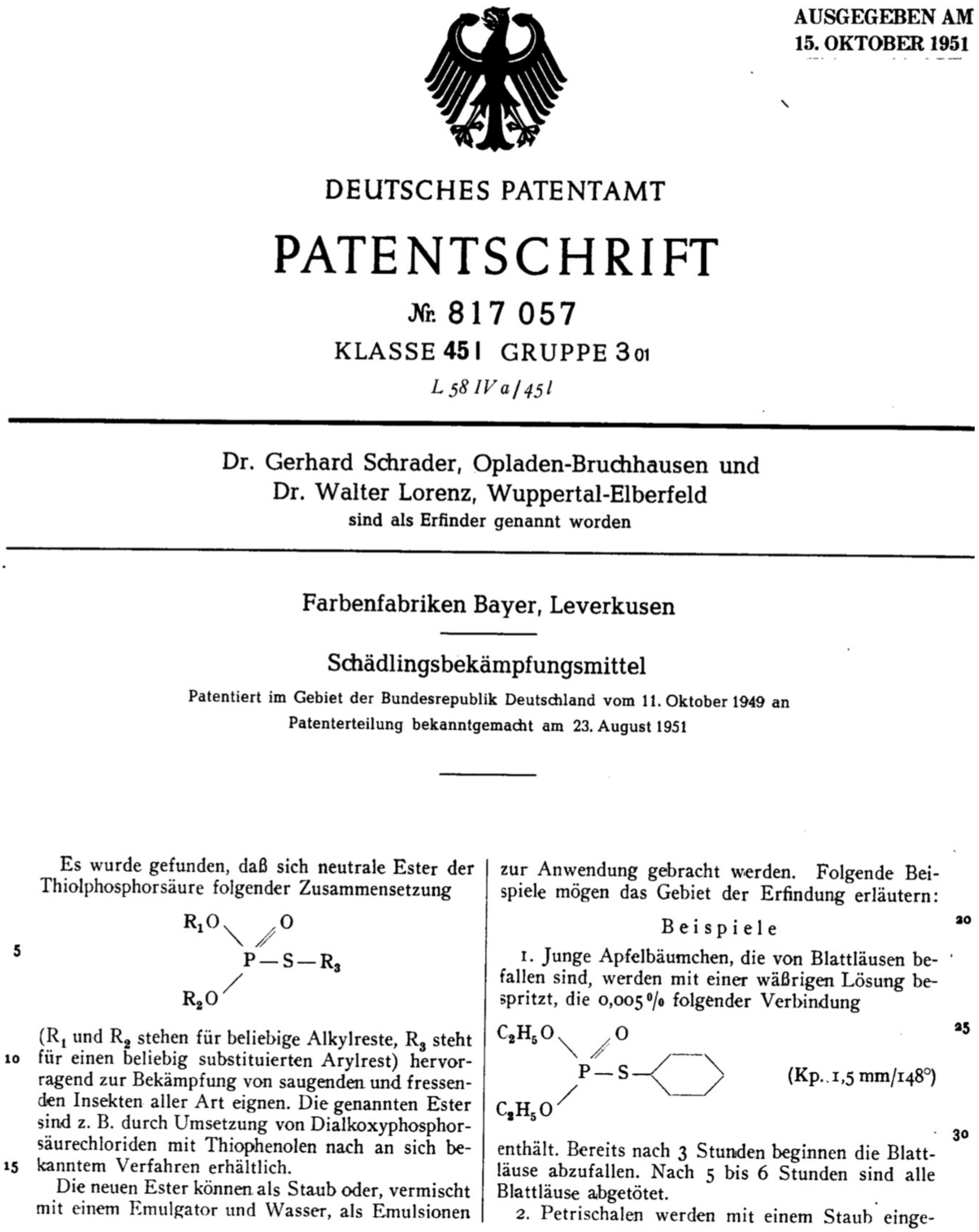
[6] Albarelli 2009; Jacobsen 2014, pp. 384–389; Lindemann 2016; Möller et al. 2014; Sandermann 1984; Sorge 2017.



AUSGEGEBEN AM
15. OKTOBER 1951

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 817 057

KLASSE 45l GRUPPE 3 01

L 58 IVa/45l

Dr. Gerhard Schrader, Opladen-Bruchhausen und
Dr. Walter Lorenz, Wuppertal-Elberfeld
sind als Erfinder genannt worden

Farbenfabriken Bayer, Leverkusen

Schädlingsbekämpfungsmittel

Patentiert im Gebiet der Bundesrepublik Deutschland vom 11. Oktober 1949 an
Patenterteilung bekanntgemacht am 23. August 1951

Es wurde gefunden, daß sich neutrale Ester der Thiolphosphorsäure folgender Zusammensetzung

(R_1 und R_2 stehen für beliebige Alkylreste, R_3 steht für einen beliebig substituierten Arylrest) hervorragend zur Bekämpfung von saugenden und fressenden Insekten aller Art eignen. Die genannten Ester sind z. B. durch Umsetzung von Dialkoxyphosphorsäurechloriden mit Thiophenolen nach an sich bekanntem Verfahren erhältlich.

Die neuen Ester können als Staub oder, vermischt mit einem Emulgator und Wasser, als Emulsionen zur Anwendung gebracht werden. Folgende Beispiele mögen das Gebiet der Erfindung erläutern:

Beispiele

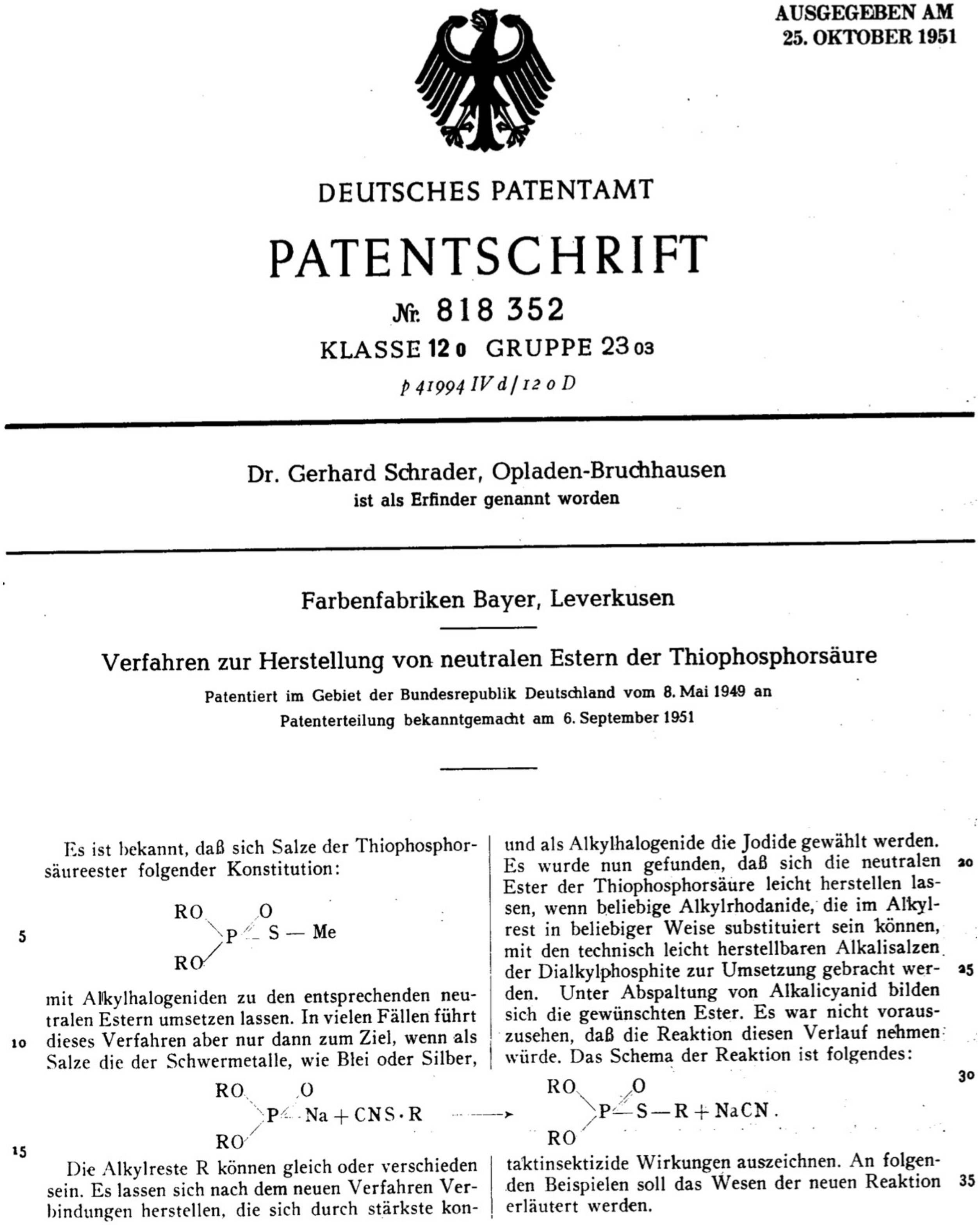
1. Junge Apfelbäumchen, die von Blattläusen befallen sind, werden mit einer wäßrigen Lösung bespritzt, die 0,005% folgender Verbindung

(Kp. 1,5 mm/148°)

enthält. Bereits nach 3 Stunden beginnen die Blattläuse abzufallen. Nach 5 bis 6 Stunden sind alle Blattläuse abgetötet.

2. Petrischalen werden mit einem Staub einge-

Figure A.211: Example from Gerhard Schrader's postwar patents on V-series nerve agents, based on wartime work.



AUSGEGEBEN AM
25. OKTOBER 1951

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 818 352

KLASSE 12 o GRUPPE 23 03

p 41994 IV d / 12 o D

Dr. Gerhard Schrader, Opladen-Bruchhausen
ist als Erfinder genannt worden

Farbenfabriken Bayer, Leverkusen

Verfahren zur Herstellung von neutralen Estern der Thiophosphorsäure

Patentiert im Gebiet der Bundesrepublik Deutschland vom 8. Mai 1949 an
Patenterteilung bekanntgemacht am 6. September 1951

Es ist bekannt, daß sich Salze der Thiophosphorsäureester folgender Konstitution:

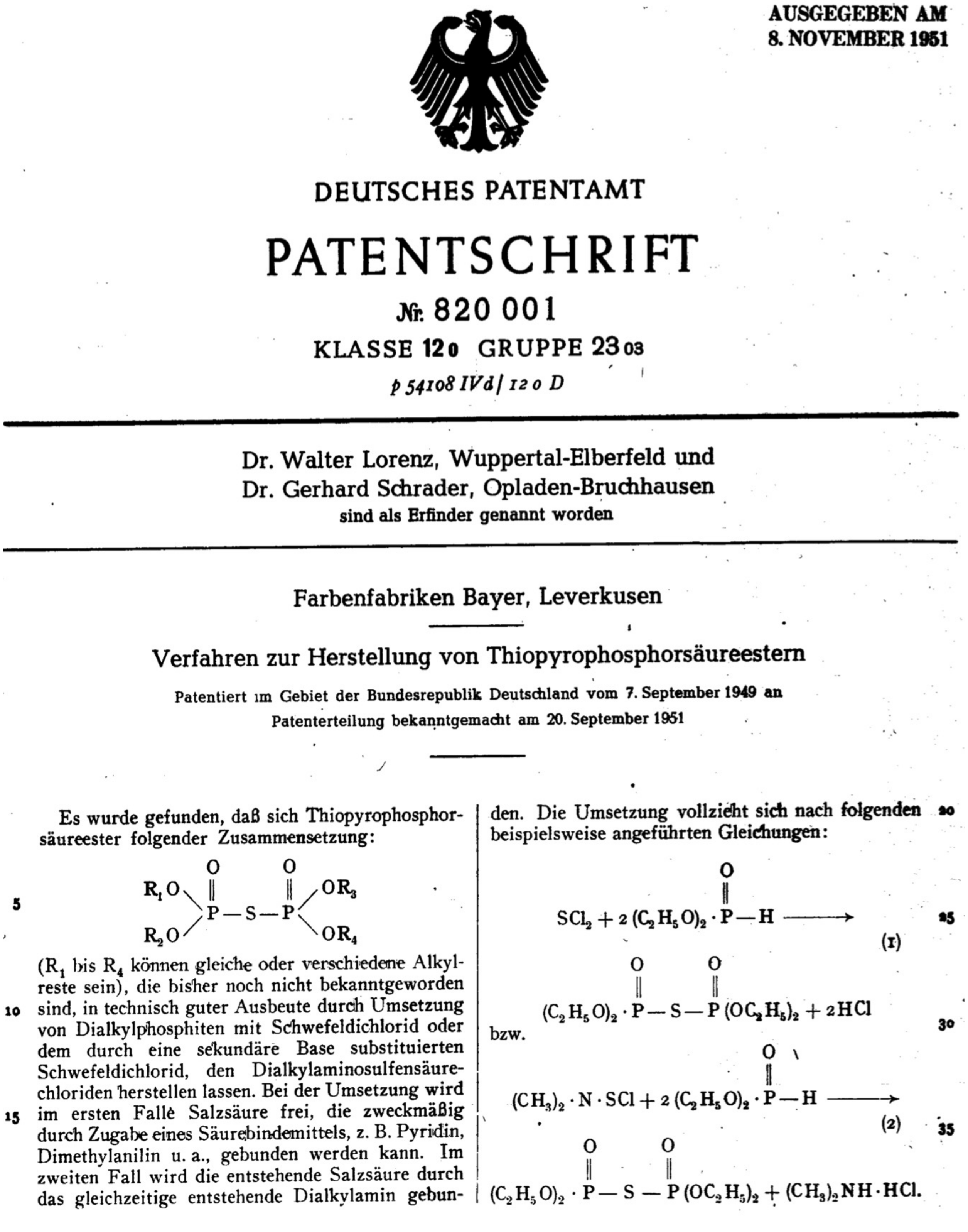
$$\begin{matrix} RO & & O \\ & P & \!\!-\, S - Me \\ RO & & \end{matrix}$$

mit Alkylhalogeniden zu den entsprechenden neutralen Estern umsetzen lassen. In vielen Fällen führt dieses Verfahren aber nur dann zum Ziel, wenn als Salze die der Schwermetalle, wie Blei oder Silber, und als Alkylhalogenide die Jodide gewählt werden. Es wurde nun gefunden, daß sich die neutralen Ester der Thiophosphorsäure leicht herstellen lassen, wenn beliebige Alkylrhodanide, die im Alkylrest in beliebiger Weise substituiert sein können, mit den technisch leicht herstellbaren Alkalisalzen der Dialkylphosphite zur Umsetzung gebracht werden. Unter Abspaltung von Alkalicyanid bilden sich die gewünschten Ester. Es war nicht vorauszusehen, daß die Reaktion diesen Verlauf nehmen würde. Das Schema der Reaktion ist folgendes:

$$\begin{matrix} RO & & O \\ & P & \!\!-\, Na + CNS \cdot R \\ RO & & \end{matrix} \longrightarrow \begin{matrix} RO & & O \\ & P & \!\!-\, S - R + NaCN\,. \\ RO & & \end{matrix}$$

Die Alkylreste R können gleich oder verschieden sein. Es lassen sich nach dem neuen Verfahren Verbindungen herstellen, die sich durch stärkste kontaktinsektizide Wirkungen auszeichnen. An folgenden Beispielen soll das Wesen der neuen Reaktion erläutert werden.

Figure A.212: Example from Gerhard Schrader's postwar patents on V-series nerve agents, based on wartime work.



AUSGEGEBEN AM
8. NOVEMBER 1951

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 820 001

KLASSE 12o GRUPPE 23 03

p 54108 IVd / 12 o D

Dr. Walter Lorenz, Wuppertal-Elberfeld und
Dr. Gerhard Schrader, Opladen-Bruchhausen
sind als Erfinder genannt worden

Farbenfabriken Bayer, Leverkusen

Verfahren zur Herstellung von Thiopyrophosphorsäureestern

Patentiert im Gebiet der Bundesrepublik Deutschland vom 7. September 1949 an
Patenterteilung bekanntgemacht am 20. September 1951

Es wurde gefunden, daß sich Thiopyrophosphorsäureester folgender Zusammensetzung:

$$\begin{matrix}R_1O\\R_2O\end{matrix}\!>\!\overset{\overset{O}{\|}}{P}-S-\overset{\overset{O}{\|}}{P}\!<\!\begin{matrix}OR_3\\OR_4\end{matrix}$$

(R_1 bis R_4 können gleiche oder verschiedene Alkylreste sein), die bisher noch nicht bekanntgeworden sind, in technisch guter Ausbeute durch Umsetzung von Dialkylphosphiten mit Schwefeldichlorid oder dem durch eine sekundäre Base substituierten Schwefeldichlorid, den Dialkylaminosulfensäurechloriden herstellen lassen. Bei der Umsetzung wird im ersten Falle Salzsäure frei, die zweckmäßig durch Zugabe eines Säurebindemittels, z. B. Pyridin, Dimethylanilin u. a., gebunden werden kann. Im zweiten Fall wird die entstehende Salzsäure durch das gleichzeitige entstehende Dialkylamin gebunden. Die Umsetzung vollzieht sich nach folgenden beispielsweise angeführten Gleichungen:

$$SCl_2 + 2\,(C_2H_5O)_2\cdot\overset{\overset{O}{\|}}{P}-H \longrightarrow \quad (1)$$

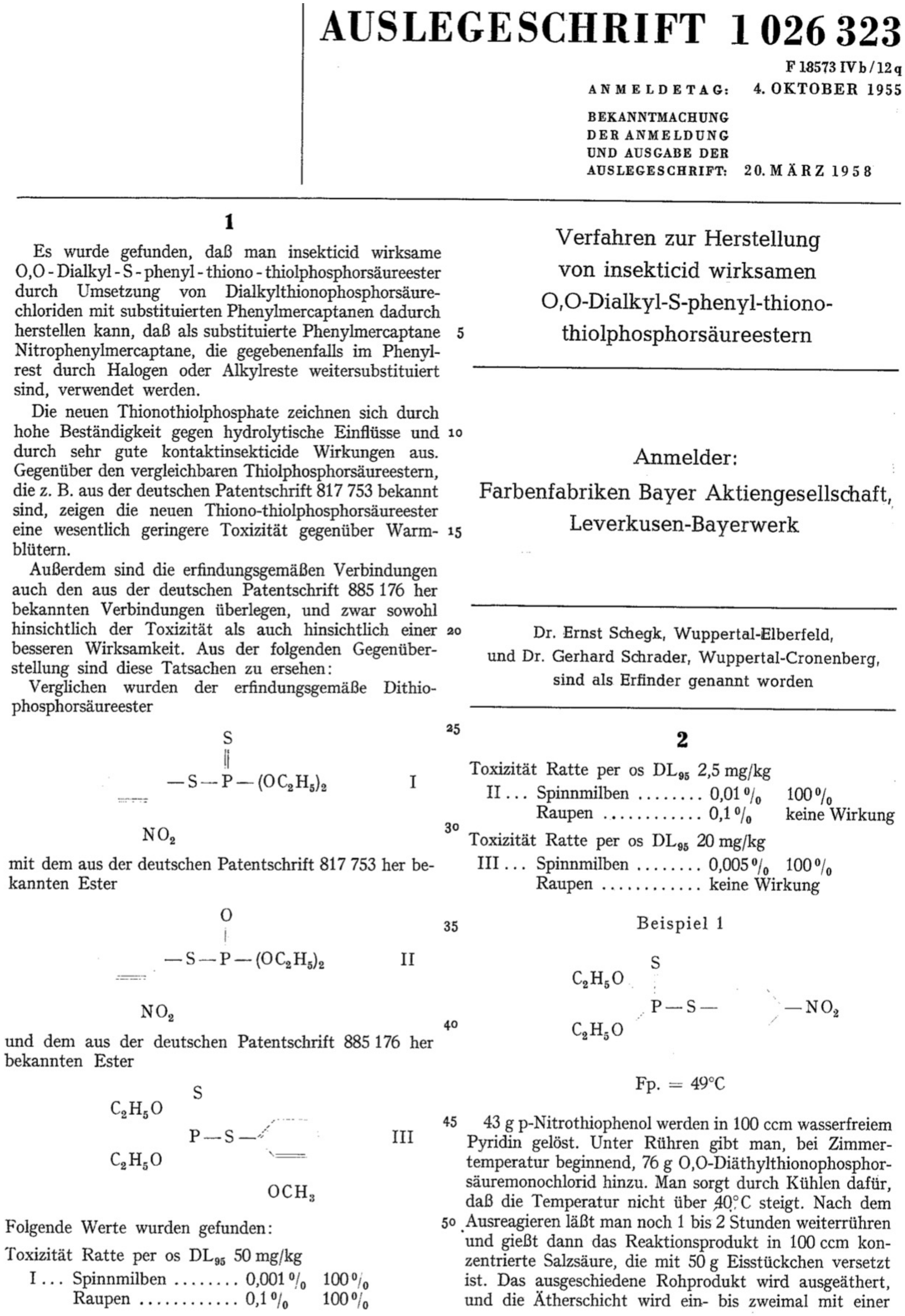
$$(C_2H_5O)_2\cdot\overset{\overset{O}{\|}}{P}-S-\overset{\overset{O}{\|}}{P}(OC_2H_5)_2 + 2\,HCl$$

bzw.

$$(CH_3)_2\cdot N\cdot SCl + 2\,(C_2H_5O)_2\cdot\overset{\overset{O}{\|}}{P}-H \longrightarrow \quad (2)$$

$$(C_2H_5O)_2\cdot\overset{\overset{O}{\|}}{P}-S-\overset{\overset{O}{\|}}{P}(OC_2H_5)_2 + (CH_3)_2NH\cdot HCl.$$

Figure A.213: Example from Gerhard Schrader's postwar patents on V-series nerve agents, based on wartime work.



AUSLEGESCHRIFT 1 026 323

F 18573 IVb/12q

ANMELDETAG: 4. OKTOBER 1955

BEKANNTMACHUNG
DER ANMELDUNG
UND AUSGABE DER
AUSLEGESCHRIFT: 20. MÄRZ 1958

Verfahren zur Herstellung von insekticid wirksamen O,O-Dialkyl-S-phenyl-thiono-thiolphosphorsäureestern

Anmelder:
Farbenfabriken Bayer Aktiengesellschaft,
Leverkusen-Bayerwerk

Dr. Ernst Schegk, Wuppertal-Elberfeld,
und Dr. Gerhard Schrader, Wuppertal-Cronenberg,
sind als Erfinder genannt worden

1

Es wurde gefunden, daß man insekticid wirksame O,O-Dialkyl-S-phenyl-thiono-thiolphosphorsäureester durch Umsetzung von Dialkylthionophosphorsäurechloriden mit substituierten Phenylmercaptanen dadurch herstellen kann, daß als substituierte Phenylmercaptane Nitrophenylmercaptane, die gegebenenfalls im Phenylrest durch Halogen oder Alkylreste weitersubstituiert sind, verwendet werden.

Die neuen Thionothiolphosphate zeichnen sich durch hohe Beständigkeit gegen hydrolytische Einflüsse und durch sehr gute kontaktinsekticide Wirkungen aus. Gegenüber den vergleichbaren Thiolphosphorsäureestern, die z. B. aus der deutschen Patentschrift 817 753 bekannt sind, zeigen die neuen Thiono-thiolphosphorsäureester eine wesentlich geringere Toxizität gegenüber Warmblütern.

Außerdem sind die erfindungsgemäßen Verbindungen auch den aus der deutschen Patentschrift 885 176 her bekannten Verbindungen überlegen, und zwar sowohl hinsichtlich der Toxizität als auch hinsichtlich einer besseren Wirksamkeit. Aus der folgenden Gegenüberstellung sind diese Tatsachen zu ersehen:

Verglichen wurden der erfindungsgemäße Dithiophosphorsäureester

I

mit dem aus der deutschen Patentschrift 817 753 her bekannten Ester

II

und dem aus der deutschen Patentschrift 885 176 her bekannten Ester

III

Folgende Werte wurden gefunden:

Toxizität Ratte per os DL_{95} 50 mg/kg

I ...	Spinnmilben	0,001 %	100 %
	Raupen	0,1 %	100 %

2

Toxizität Ratte per os DL_{95} 2,5 mg/kg

II ...	Spinnmilben	0,01 %	100 %
	Raupen	0,1 %	keine Wirkung

Toxizität Ratte per os DL_{95} 20 mg/kg

III ...	Spinnmilben	0,005 %	100 %
	Raupen	keine Wirkung	

Beispiel 1

Fp. = 49°C

43 g p-Nitrothiophenol werden in 100 ccm wasserfreiem Pyridin gelöst. Unter Rühren gibt man, bei Zimmertemperatur beginnend, 76 g O,O-Diäthylthionophosphorsäuremonochlorid hinzu. Man sorgt durch Kühlen dafür, daß die Temperatur nicht über 40°C steigt. Nach dem Ausreagieren läßt man noch 1 bis 2 Stunden weiterrühren und gießt dann das Reaktionsprodukt in 100 ccm konzentrierte Salzsäure, die mit 50 g Eisstückchen versetzt ist. Das ausgeschiedene Rohprodukt wird ausgeäthert, und die Ätherschicht wird ein- bis zweimal mit einer

Figure A.214: Example from Gerhard Schrader's postwar patents on V-series nerve agents, based on wartime work.

BIOS 714. *The Development of New Insecticides and Chemical Warfare Agents*

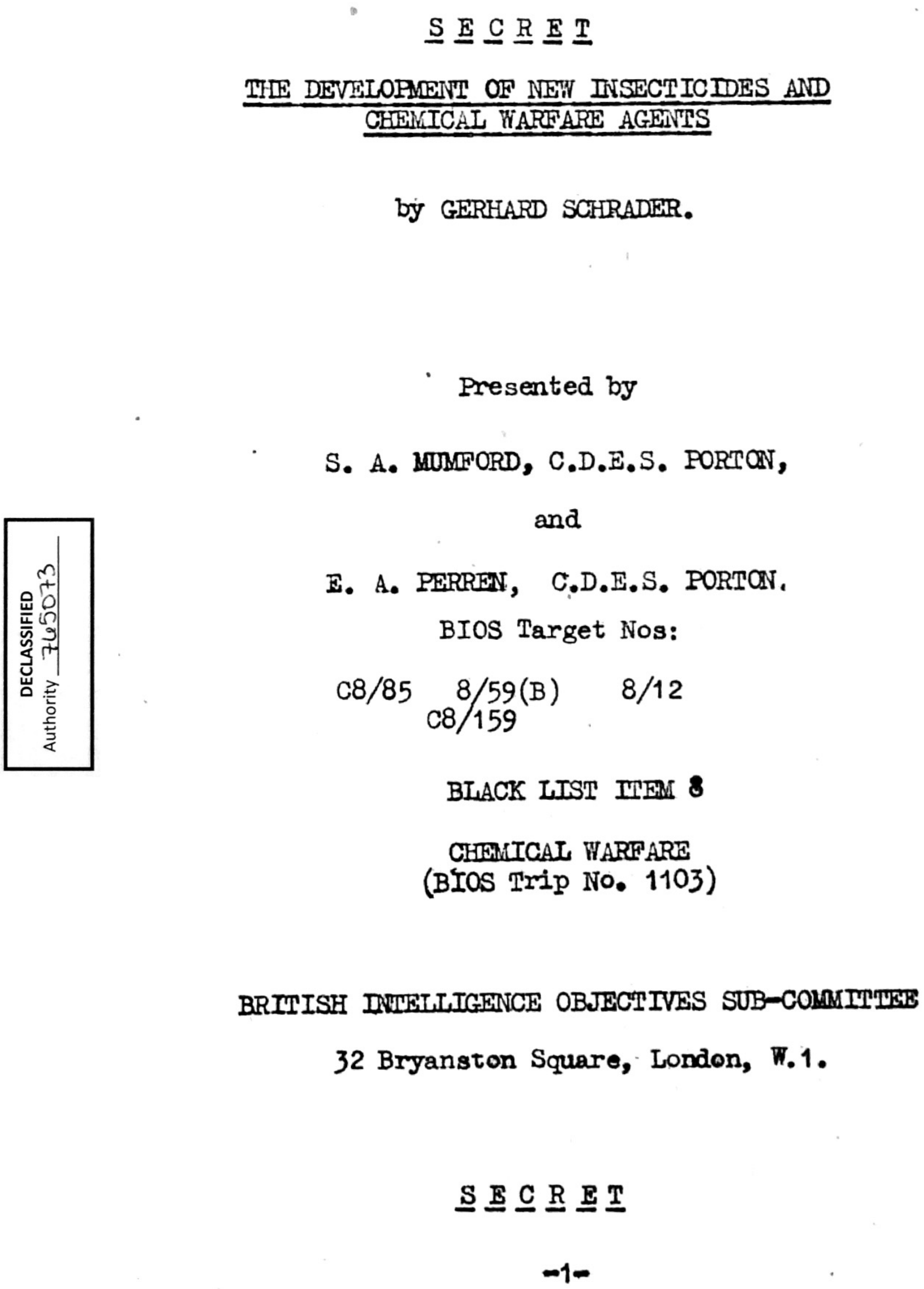
[Please see photographs of selected pages of this report in Figs. A.215–A.238.

This report demonstrates that Gerhard Schrader did in fact develop and test a wide variety of V-series nerve agents during the war. While being imprisoned and interrogated by Allied forces at Dustbin (see p. 2126) after the war, Schrader wrote several reports such as this that recounted his wartime experiments and results. Many of Schrader's agents listed in BIOS 714 possessed the same key molecular features as VX and VR, such as using a nitrogen atom to attach two branches of hydrocarbons to the toxic part of the molecule. Very unusually for this report series, the BIOS 714 report was issued in two versions, an original edition and a heavily censored "revised" edition that omitted all of the V-series agents and was less than half as long.

It seems likely that there are other important reports about these V-series agents from Schrader, or perhaps even reports about additional V-series agents that Schrader may have invented and tested. It is also quite possible that other scientists such as Richard Kuhn, Erich Hückel, Friedrich Wilhelm Hoffmann, or Otto Ambros developed further V-series agents in Germany during the war.

The personal interrogations of Schrader and other German-speaking scientists by Allied chemists, reports such as the uncensored original edition of BIOS 714, and other German information captured by the Allies most likely led to the postwar production of V-series agents in the United States and other countries. Much more archival research is needed to clarify the history of the development and dissemination of knowledge about V-series agents.

For Gerhard Schrader's original German manuscript of this report, as well as other related information, see NARA RG 319, Entry A1-134B, Box 693, Folders XE171240 Gerhard Schrader (six folders).]



SECRET

THE DEVELOPMENT OF NEW INSECTICIDES AND CHEMICAL WARFARE AGENTS

by GERHARD SCHRADER.

Presented by

S. A. MUMFORD, C.D.E.S. PORTON,

and

E. A. PERREN, C.D.E.S. PORTON.

BIOS Target Nos:

C8/85 8/59(B) 8/12
C8/159

DECLASSIFIED
Authority 765073

BLACK LIST ITEM 8

CHEMICAL WARFARE
(BIOS Trip No. 1103)

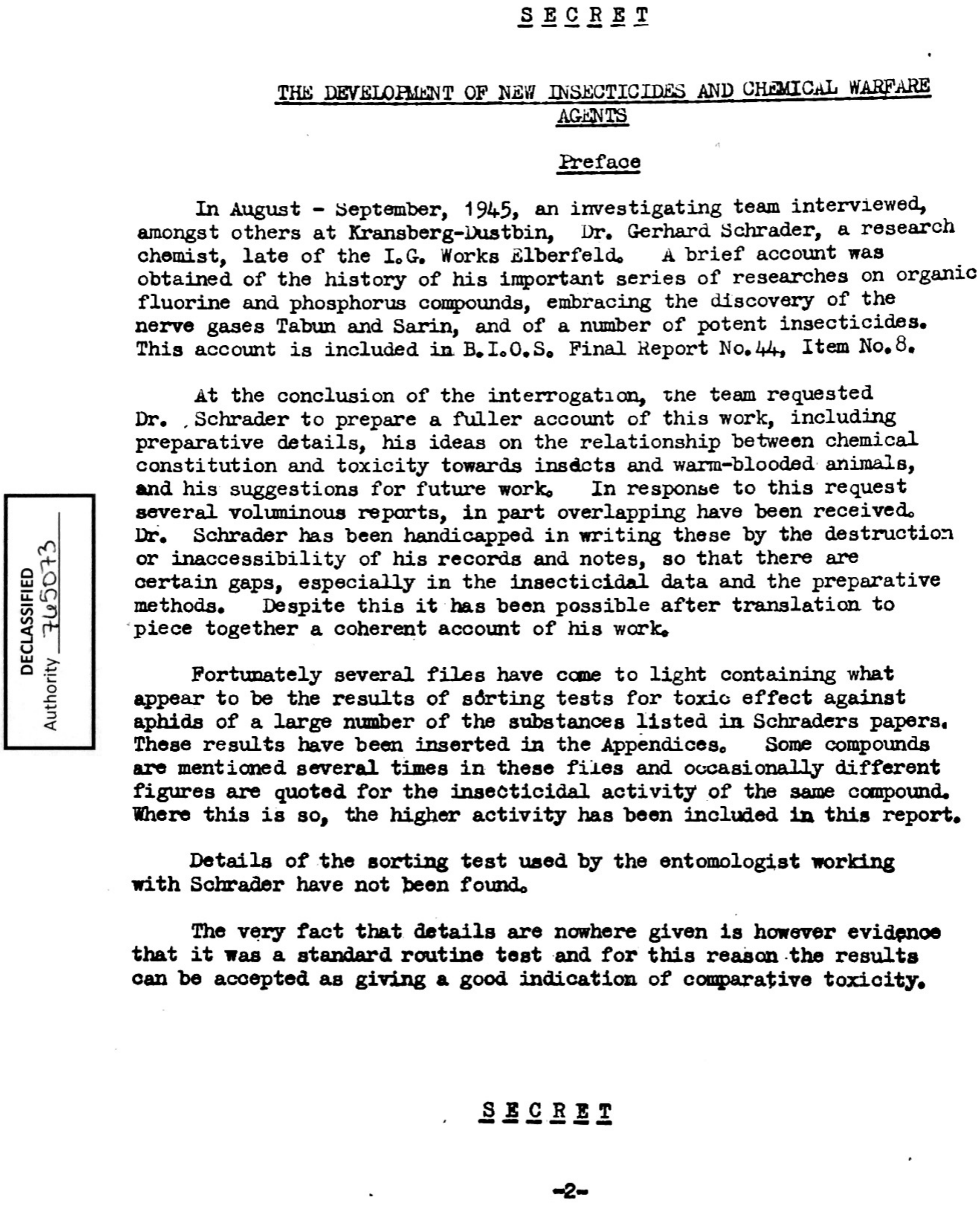
BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE

32 Bryanston Square, London, W.1.

SECRET

-1-

Figure A.215: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



SECRET

THE DEVELOPMENT OF NEW INSECTICIDES AND CHEMICAL WARFARE AGENTS

Preface

In August - September, 1945, an investigating team interviewed, amongst others at Kransberg-Dustbin, Dr. Gerhard Schrader, a research chemist, late of the I.G. Works Elberfeld. A brief account was obtained of the history of his important series of researches on organic fluorine and phosphorus compounds, embracing the discovery of the nerve gases Tabun and Sarin, and of a number of potent insecticides. This account is included in B.I.O.S. Final Report No.44, Item No.8.

At the conclusion of the interrogation, the team requested Dr. Schrader to prepare a fuller account of this work, including preparative details, his ideas on the relationship between chemical constitution and toxicity towards insdcts and warm-blooded animals, and his suggestions for future work. In response to this request several voluminous reports, in part overlapping have been received. Dr. Schrader has been handicapped in writing these by the destruction or inaccessibility of his records and notes, so that there are certain gaps, especially in the insecticidal data and the preparative methods. Despite this it has been possible after translation to piece together a coherent account of his work.

Fortunately several files have come to light containing what appear to be the results of sorting tests for toxic effect against aphids of a large number of the substances listed in Schraders papers. These results have been inserted in the Appendices. Some compounds are mentioned several times in these files and occasionally different figures are quoted for the insecticidal activity of the same compound. Where this is so, the higher activity has been included in this report.

Details of the sorting test used by the entomologist working with Schrader have not been found.

The very fact that details are nowhere given is however evidence that it was a standard routine test and for this reason the results can be accepted as giving a good indication of comparative toxicity.

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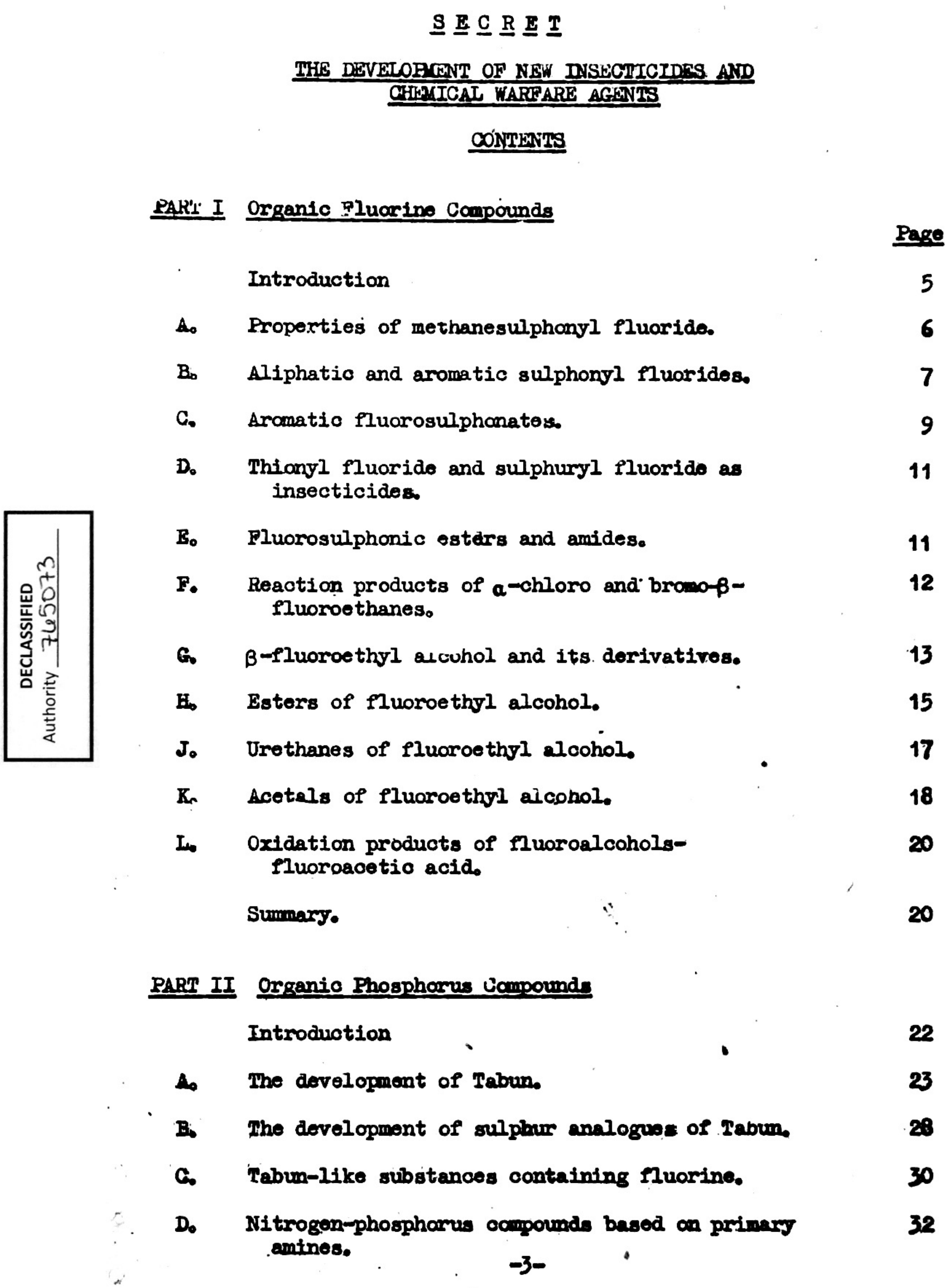
Figure A.216: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



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THE DEVELOPMENT OF NEW INSECTICIDES AND CHEMICAL WARFARE AGENTS

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Figure A.217: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].

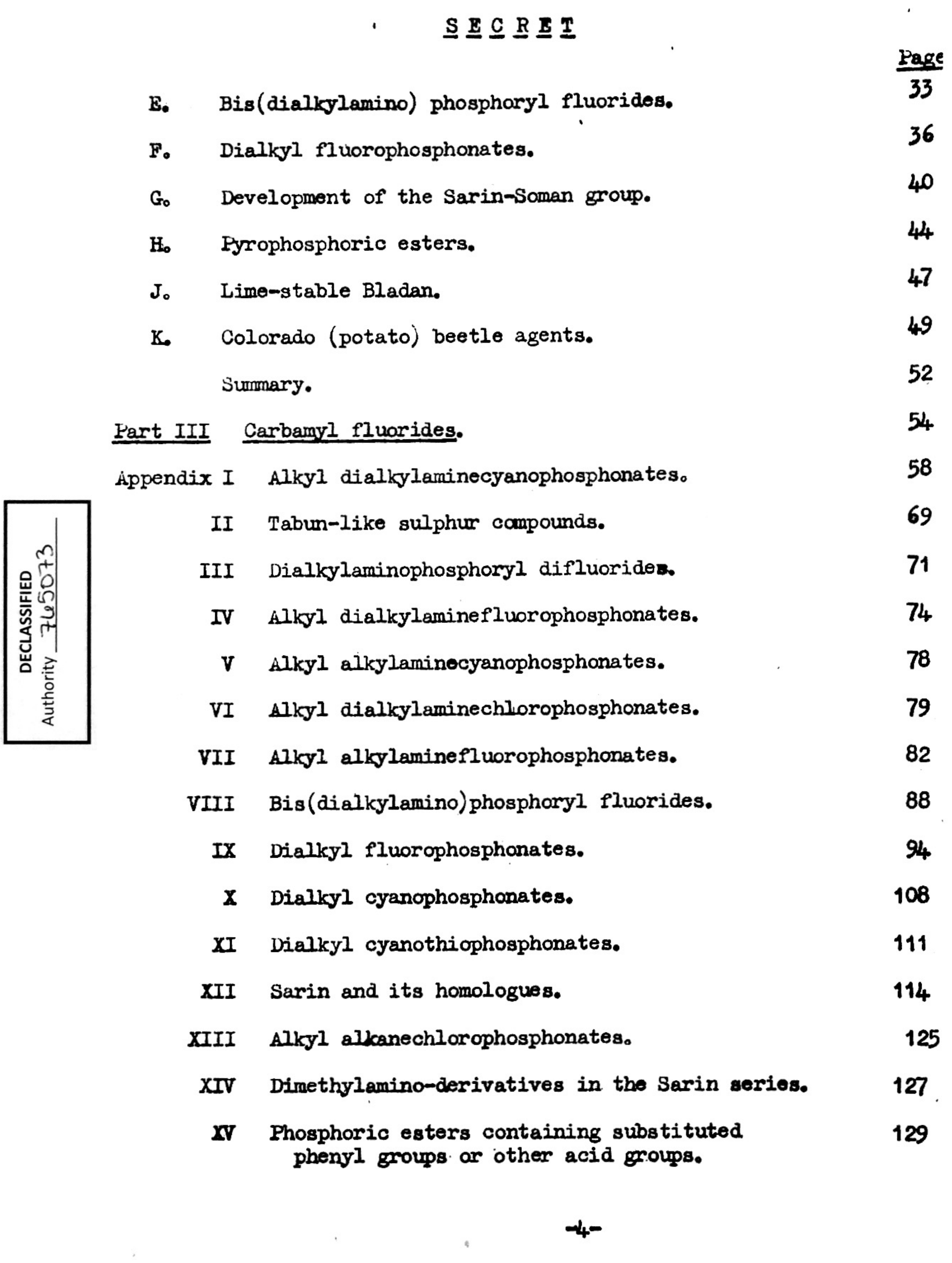

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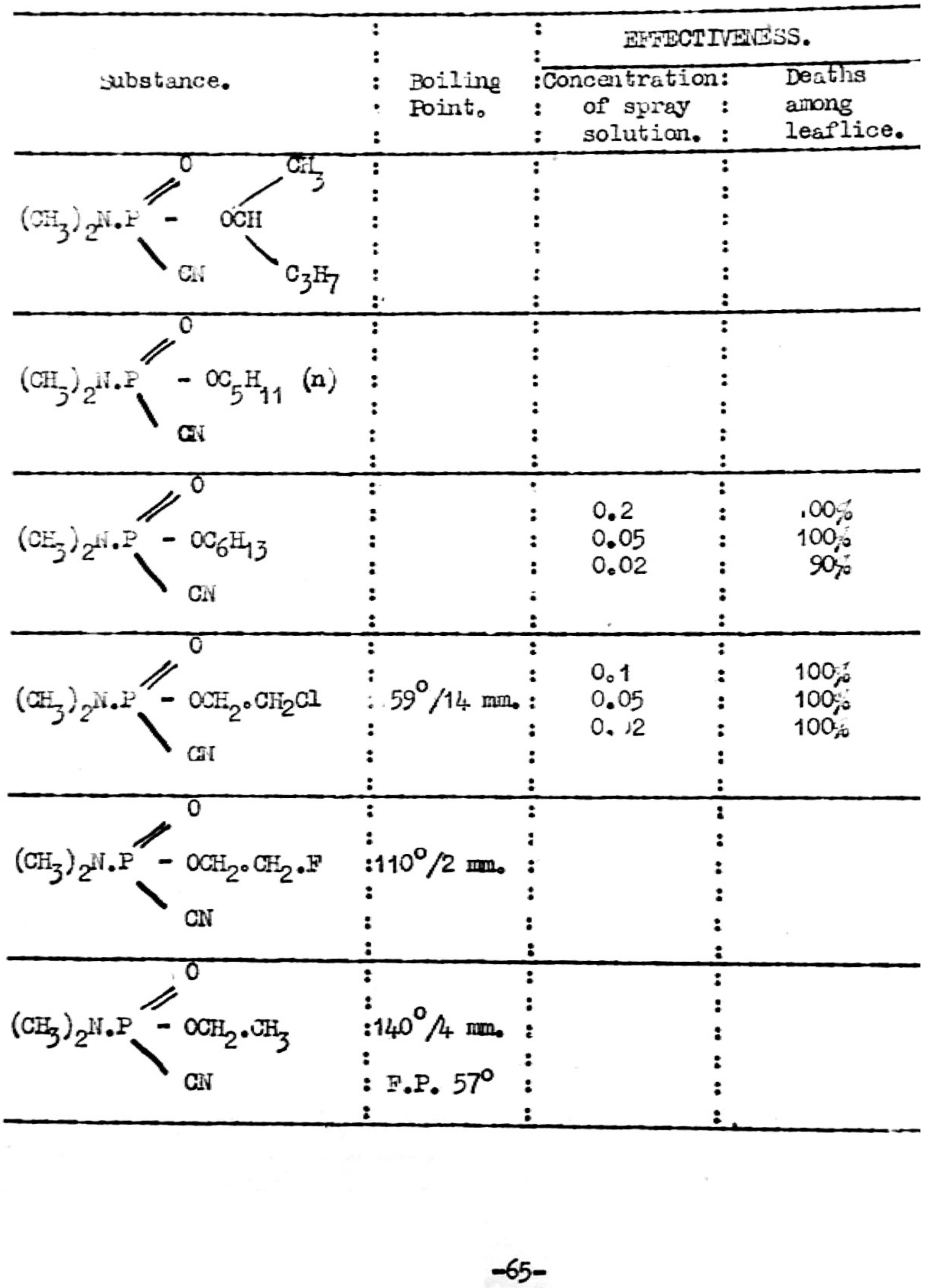
Figure A.218: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].

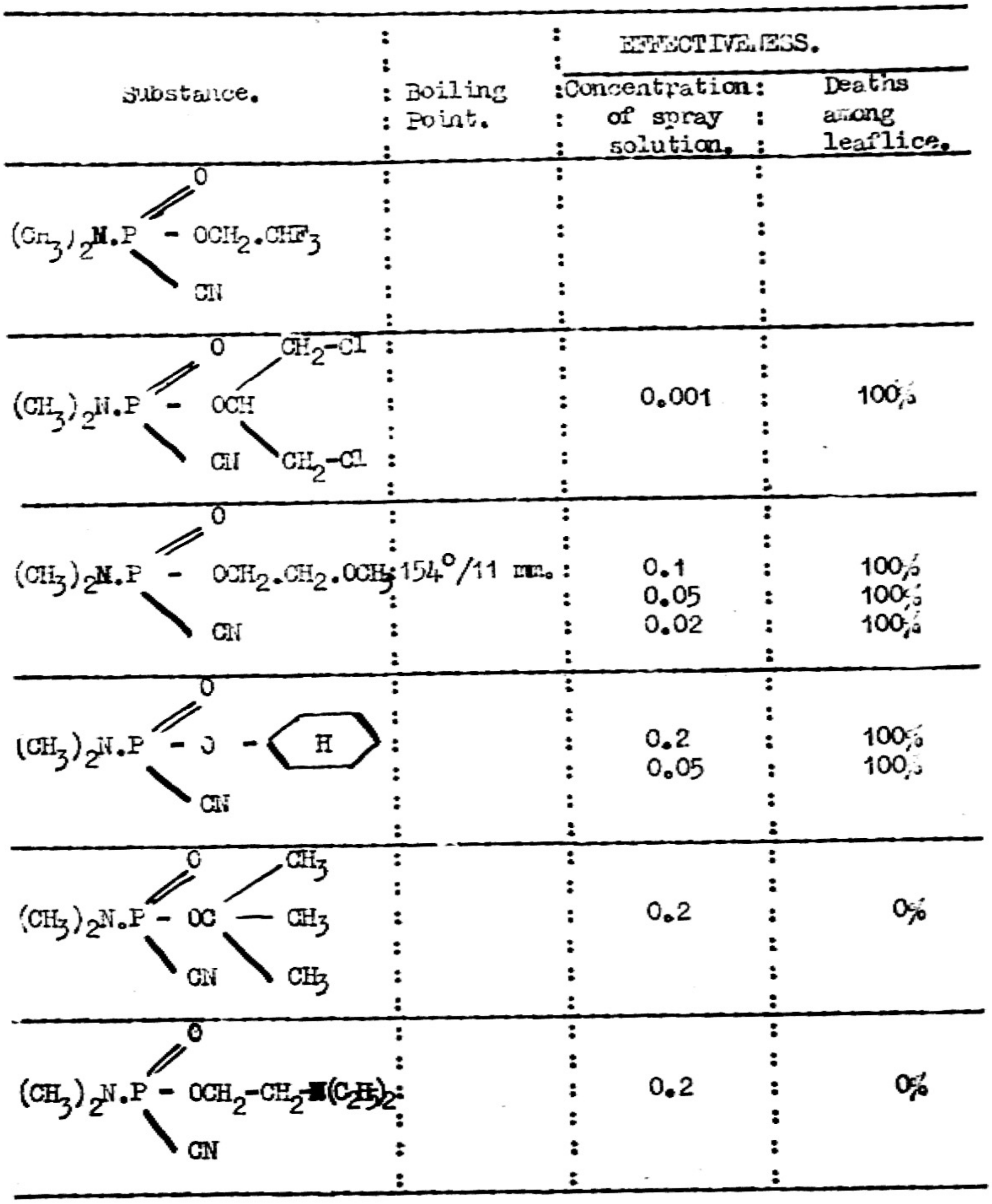


Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
$(CH_3)_2N.P(=O)(CN) - OCH(CH_3)C_3H_7$			
$(CH_3)_2N.P(=O)(CN) - OC_5H_{11}$ (n)			
$(CH_3)_2N.P(=O)(CN) - OC_6H_{13}$		0.2 0.05 0.02	.00% 100% 90%
$(CH_3)_2N.P(=O)(CN) - OCH_2.CH_2Cl$	59°/14 mm.	0.1 0.05 0.02	100% 100% 100%
$(CH_3)_2N.P(=O)(CN) - OCH_2.CH_2.F$	110°/2 mm.		
$(CH_3)_2N.P(=O)(CN) - OCH_2.CH_3$	140°/4 mm. F.P. 57°		

-65-

DECLASSIFIED
Authority 765073

Figure A.219: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
$(CH_3)_2N.P(=O)(CN)-OCH_2.CHF_3$			
$(CH_3)_2N.P(=O)(CN)-OCH(CH_2-Cl)_2$		0.001	100%
$(CH_3)_2N.P(=O)(CN)-OCH_2.CH_2.OCH_3$	154°/11 mm.	0.1 0.05 0.02	100% 100% 100%
$(CH_3)_2N.P(=O)(CN)-O-C_6H_{11}$ (H)		0.2 0.05	100% 100%
$(CH_3)_2N.P(=O)(CN)-OC(CH_3)_3$		0.2	0%
$(CH_3)_2N.P(=O)(CN)-OCH_2-CH_2-N(C_2H_5)_2$		0.2	0%

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Figure A.220: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].

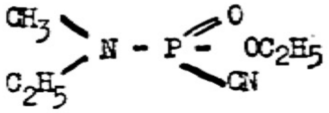
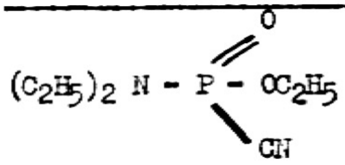
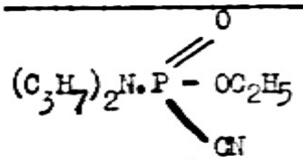
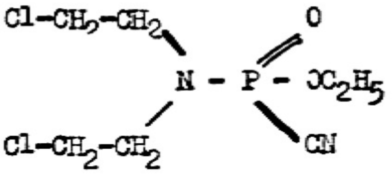
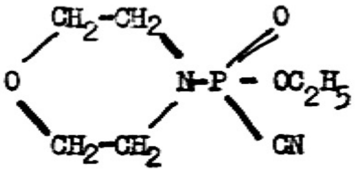
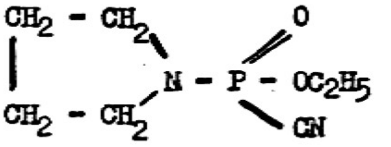
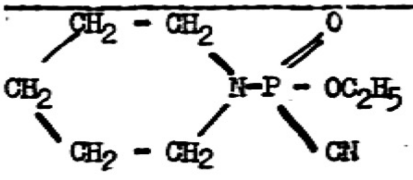
Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution,	Deaths among leaflice.
	117°/10 mm.		
	124°/17 mm.	0.2 0.02	100% 0%
	143°/12 mm.		
		0.05	0%
		0.2	100%
	118°/3 mm.	0.05 0.02	100% 95%
	140°/9 mm.	0.05 0.025	100% 100%

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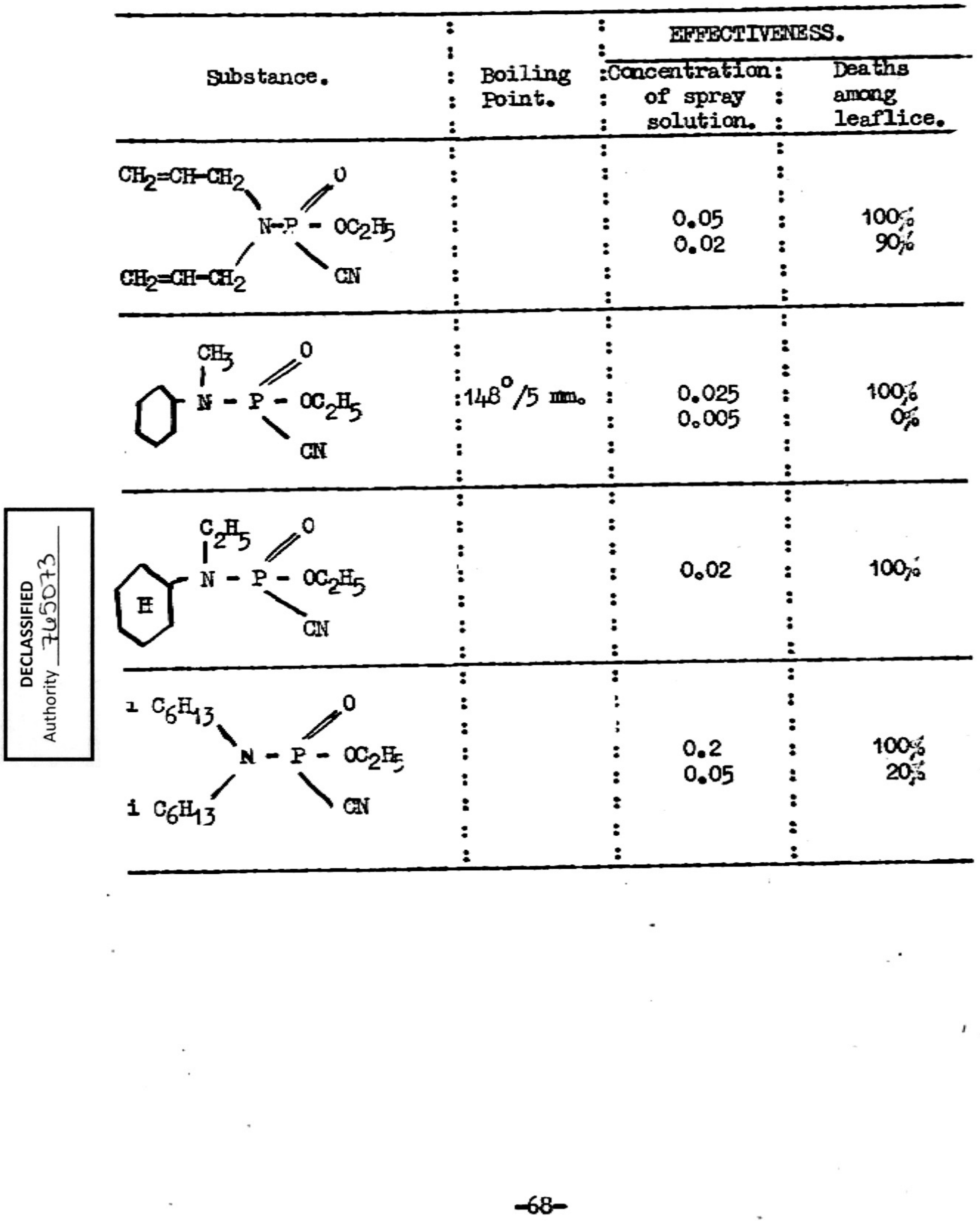
Figure A.221: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



CH2=CH-CH2
N-P - OC2H5
O
CN
CH2=CH-CH2
CH3
N - P - OC2H5
O
CN
C2H5
H
N - P - OC2H5
O
CN
i C6H13
N - P - OC2H5
O
CN
i C6H13

Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
		0.05 0.02	100% 90%
	148°/5 mm.	0.025 0.005	100% 0%
		0.02	100%
		0.2 0.05	100% 20%

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Figure A.222: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].

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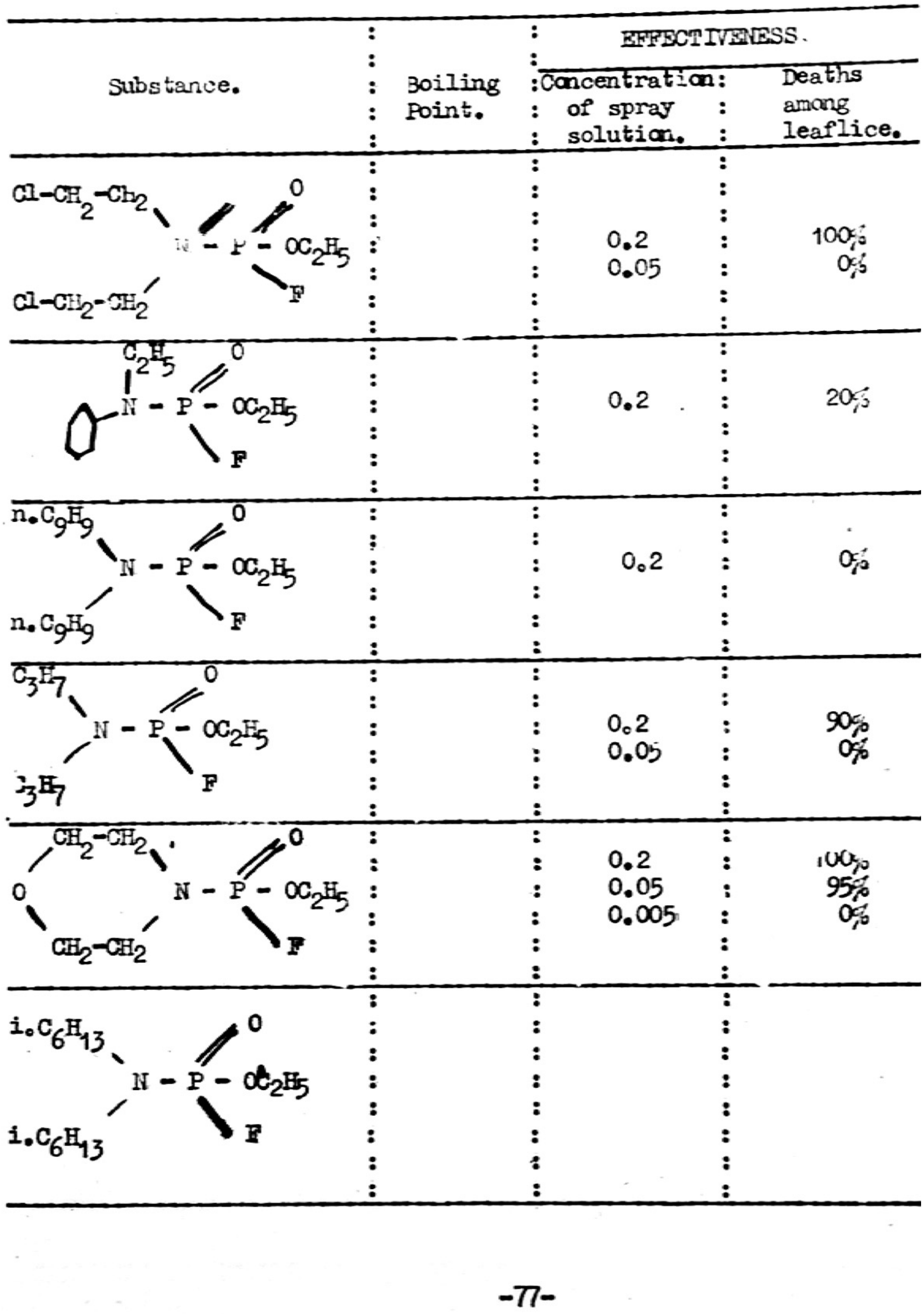

Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
$Cl-CH_2-Ch_2$ $Cl-CH_2-CH_2$ $N-P(=O)-OC_2H_5$ F		0.2 0.05	100% 0%
C_2H_5 $N-P(=O)-OC_2H_5$ F		0.2	20%
$n.C_9H_9$ $n.C_9H_9$ $N-P(=O)-OC_2H_5$ F		0.2	0%
C_3H_7 C_3H_7 $N-P(=O)-OC_2H_5$ F		0.2 0.05	90% 0%
CH_2-CH_2 O CH_2-CH_2 $N-P(=O)-OC_2H_5$ F		0.2 0.05 0.005	100% 95% 0%
$i.C_6H_{13}$ $i.C_6H_{13}$ $N-P(=O)-OC_2H_5$ F			

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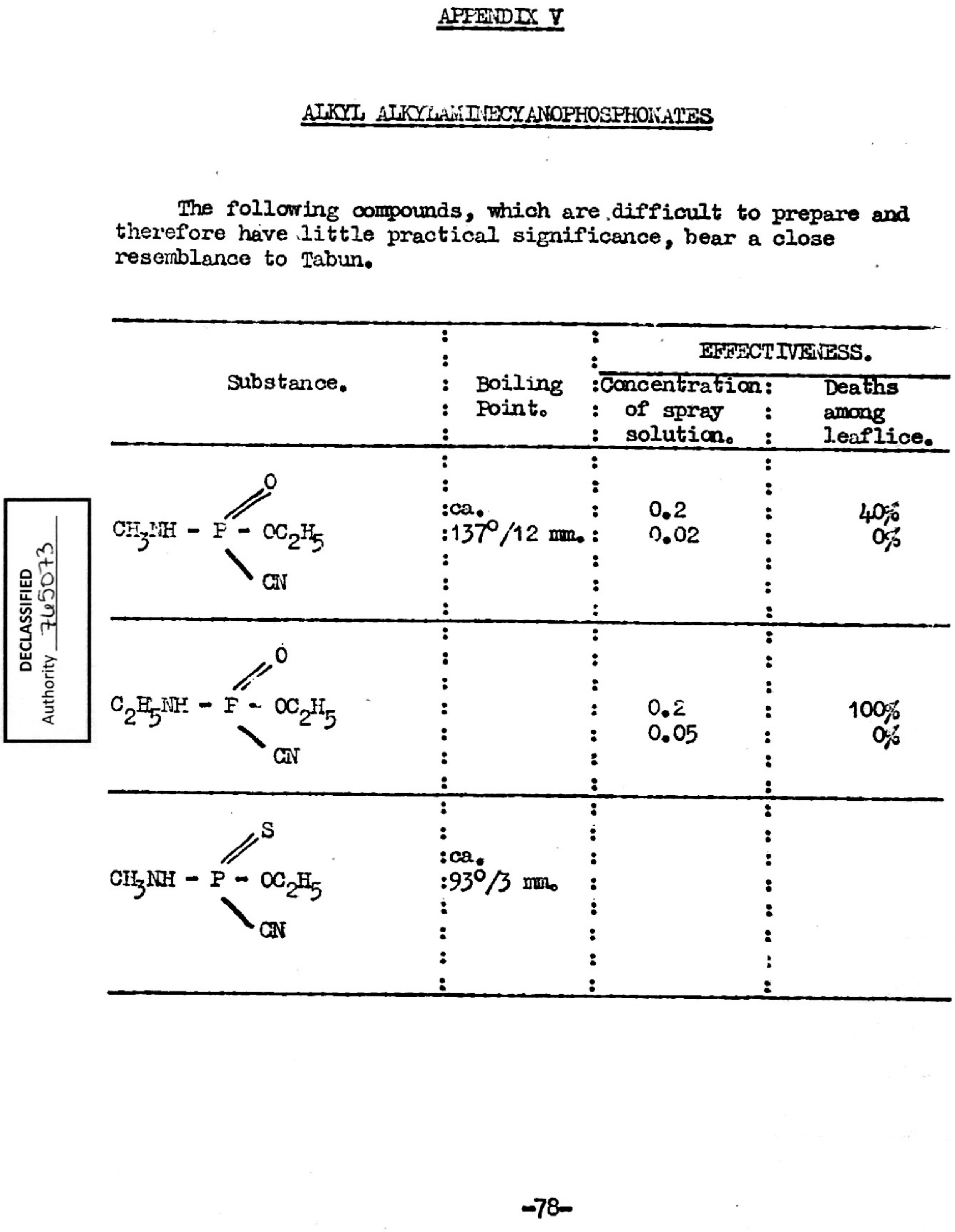
Figure A.223: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



APPENDIX V

ALKYL ALKYLAMINECYANOPHOSPHONATES

The following compounds, which are difficult to prepare and therefore have little practical significance, bear a close resemblance to Tabun.

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Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
$CH_3NH-\overset{O}{\underset{CN}{P}}-OC_2H_5$	ca. 137°/12 mm.	0.2 0.02	40% 0%
$C_2H_5NH-\overset{O}{\underset{CN}{P}}-OC_2H_5$		0.2 0.05	100% 0%
$CH_3NH-\overset{S}{\underset{CN}{P}}-OC_2H_5$	ca. 93°/3 mm.		

Figure A.224: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].

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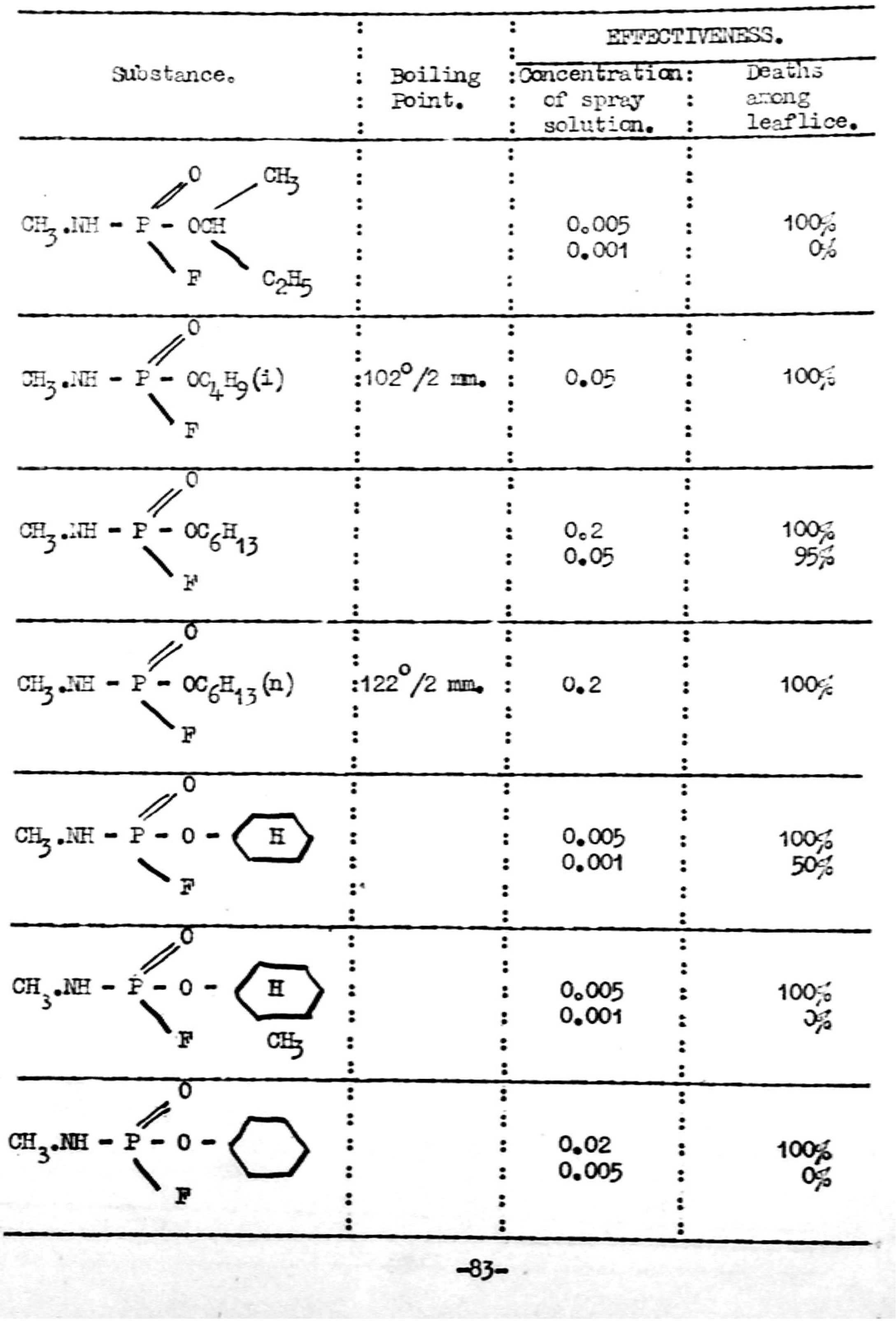
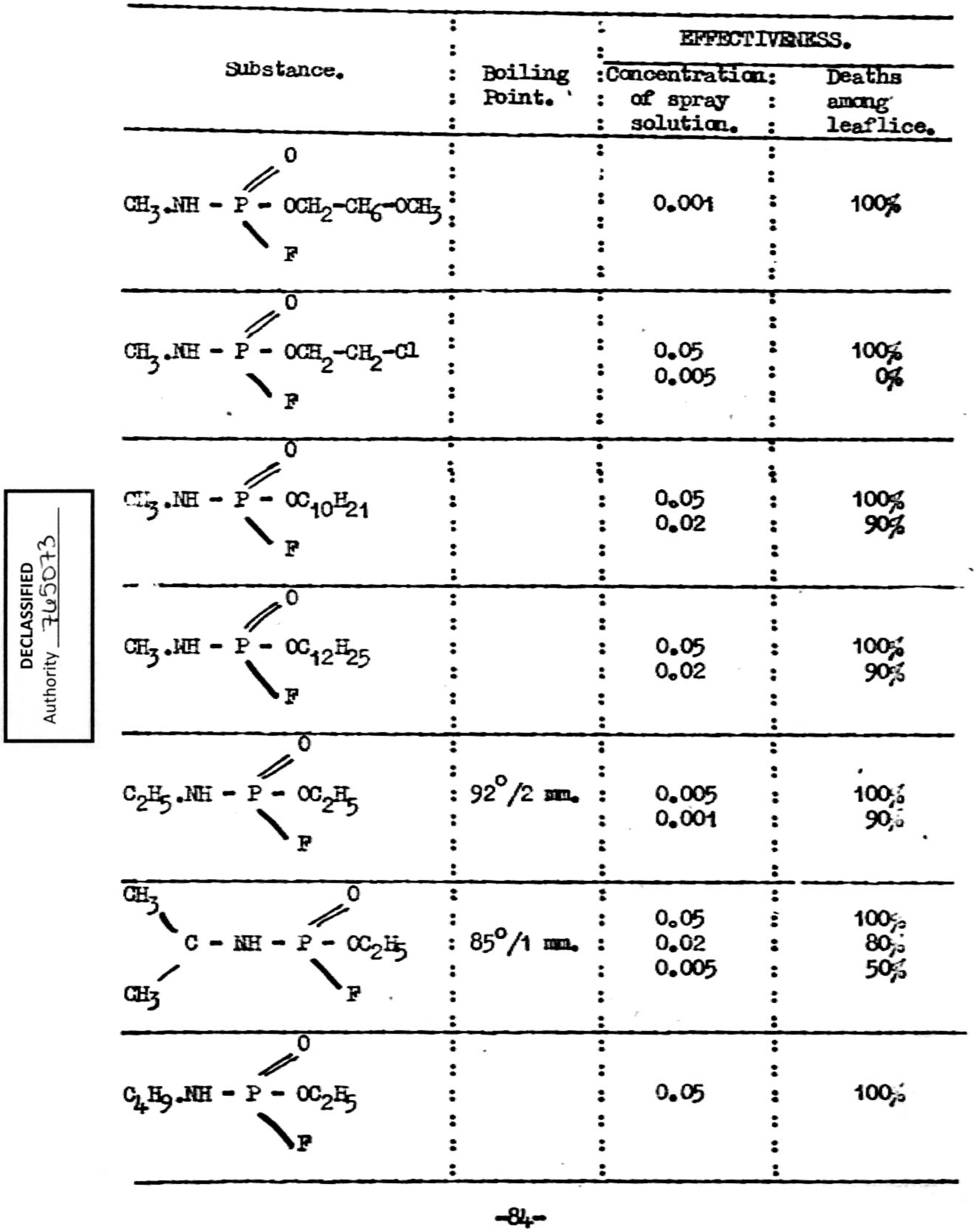


Substance.	Boiling Point.	EFFECTIVENESS. Concentration of spray solution.	Deaths among leaflice.
$CH_3.NH - P(=O)(F) - OCH(CH_3)(C_2H_5)$		0.005 0.001	100% 0%
$CH_3.NH - P(=O)(F) - OC_4H_9$(i)	102°/2 mm.	0.05	100%
$CH_3.NH - P(=O)(F) - OC_6H_{13}$		0.2 0.05	100% 95%
$CH_3.NH - P(=O)(F) - OC_6H_{13}$(n)	122°/2 mm.	0.2	100%
$CH_3.NH - P(=O)(F) - O -$ H		0.005 0.001	100% 50%
$CH_3.NH - P(=O)(F) - O -$ H, CH_3		0.005 0.001	100% 0%
$CH_3.NH - P(=O)(F) - O -$		0.02 0.005	100% 0%

Figure A.225: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
$CH_3.NH-\overset{O}{\underset{F}{P}}-OCH_2-CH_6-OCH_3$		0.001	100%
$CH_3.NH-\overset{O}{\underset{F}{P}}-OCH_2-CH_2-Cl$		0.05 0.005	100% 0%
$CH_3.NH-\overset{O}{\underset{F}{P}}-OC_{10}H_{21}$		0.05 0.02	100% 90%
$CH_3.NH-\overset{O}{\underset{F}{P}}-OC_{12}H_{25}$		0.05 0.02	100% 90%
$C_2H_5.NH-\overset{O}{\underset{F}{P}}-OC_2H_5$	92°/2 mm.	0.005 0.001	100% 90%
$\overset{CH_3}{\underset{CH_3}{C}}-NH-\overset{O}{\underset{F}{P}}-OC_2H_5$	85°/1 mm.	0.05 0.02 0.005	100% 80% 50%
$C_4H_9.NH-\overset{O}{\underset{F}{P}}-OC_2H_5$		0.05	100%

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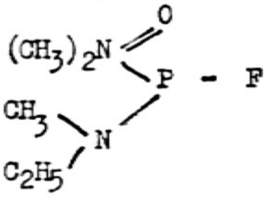
Figure A.226: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].

by rolling for 24 hours, the grain then being dried at room temperature until the original weight of 100 g. was regained. 1 such grain was sufficient to kill a mouse. When another compound of this series was tested in the same way, 2 to 3 grains were necessary to cause death.



C. Other members of the series

Other members of this series are listed below.

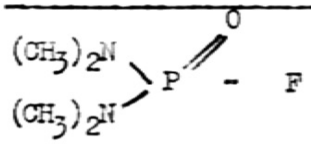
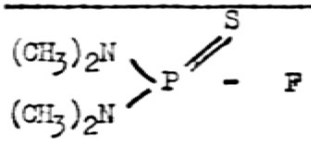
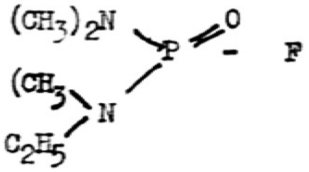
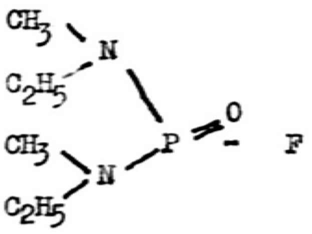
Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
	67°/4 mm.	0.05 0.02	100% 95%
	58°/1.5 mm.	0.05 0.02 0.005	100% 95% 0%
	90°/11 mm.	0.05 0.02	100% 50%
	105°/9 mm.	0.05 0.02	100% 95%

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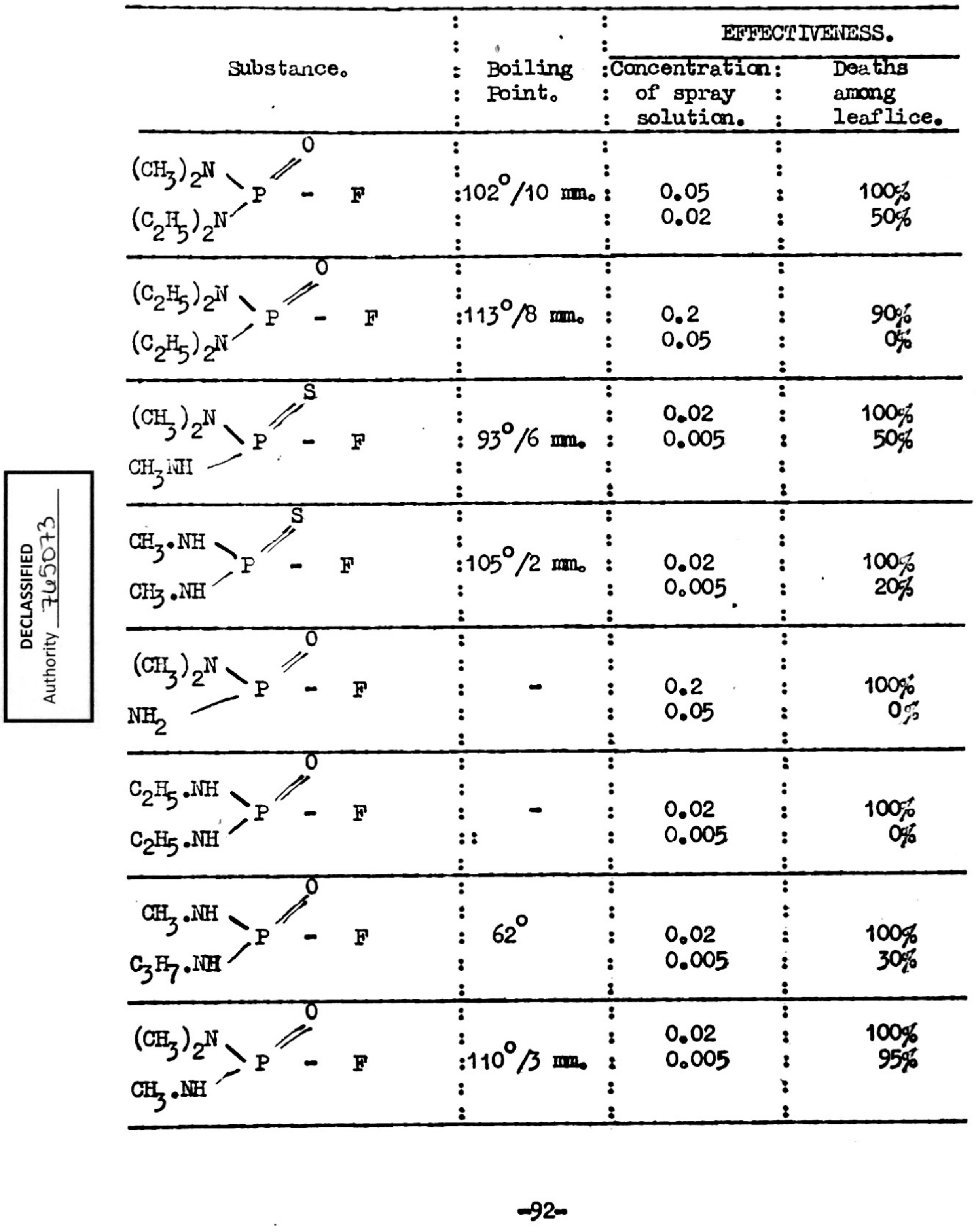
Figure A.227: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
O $(CH_3)_2N$ P – F $(C_2H_5)_2N$	102°/10 mm.	0.05 0.02	100% 50%
O $(C_2H_5)_2N$ P – F $(C_2H_5)_2N$	113°/8 mm.	0.2 0.05	90% 0%
S $(CH_3)_2N$ P – F CH_3NH	93°/6 mm.	0.02 0.005	100% 50%
S $CH_3.NH$ P – F $CH_3.NH$	105°/2 mm.	0.02 0.005	100% 20%
O $(CH_3)_2N$ P – F NH_2	-	0.2 0.05	100% 0%
O $C_2H_5.NH$ P – F $C_2H_5.NH$	-	0.02 0.005	100% 0%
O $CH_3.NH$ P – F $C_3H_7.NH$	62°	0.02 0.005	100% 30%
O $(CH_3)_2N$ P – F $CH_3.NH$	110°/3 mm.	0.02 0.005	100% 95%

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Figure A.228: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].

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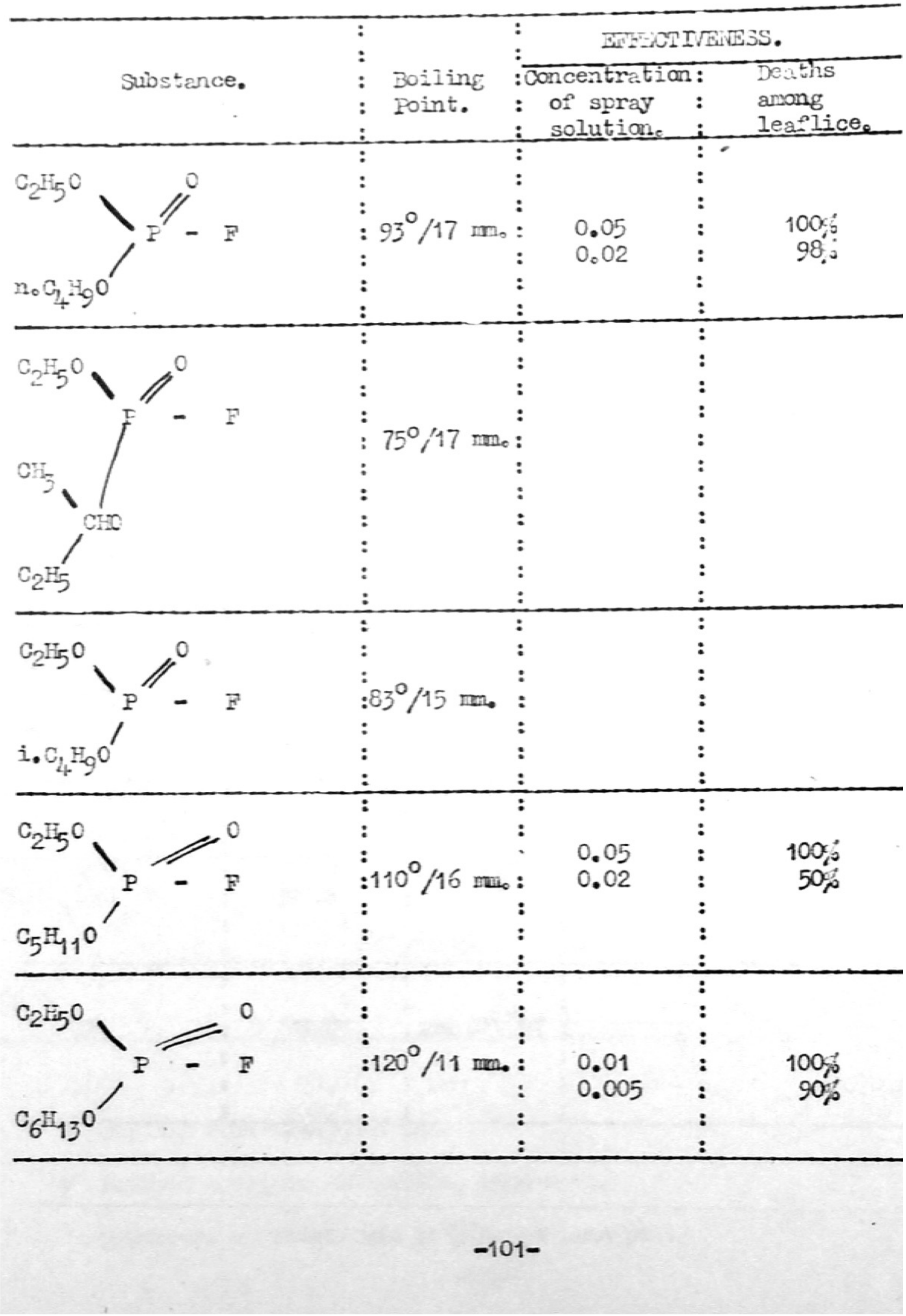

Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
C_2H_5O O P - F $n.C_4H_9O$	93°/17 mm.	0.05 0.02	100% 98%
C_2H_5O O P - F CH_3 CHO C_2H_5	75°/17 mm.		
C_2H_5O O P - F $i.C_4H_9O$	83°/15 mm.		
C_2H_5O O P - F $C_5H_{11}O$	110°/16 mm.	0.05 0.02	100% 50%
C_2H_5O O P - F $C_6H_{13}O$	120°/11 mm.	0.01 0.005	100% 90%

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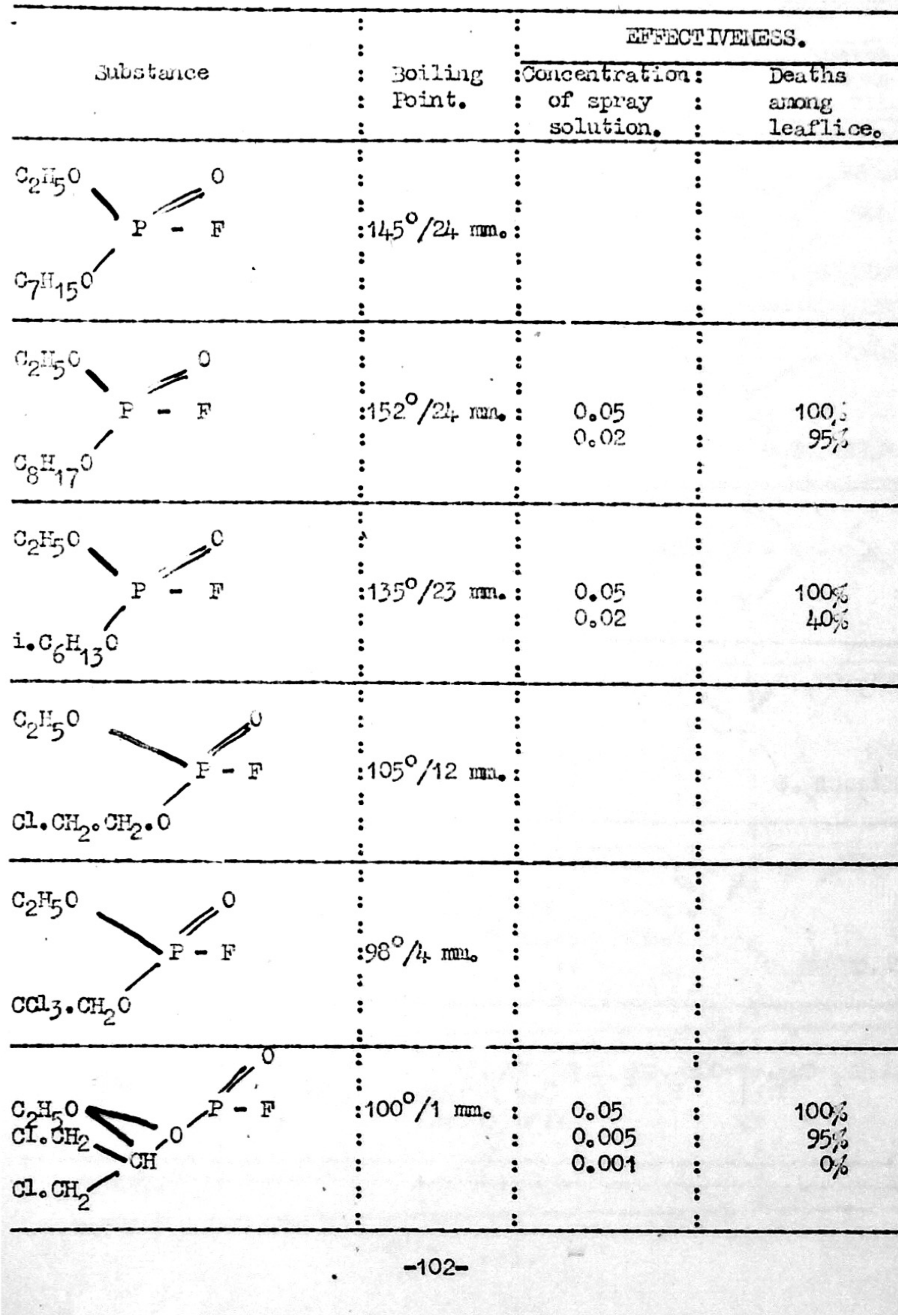
Figure A.229: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



Substance	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
C_2H_5O O P - F $C_7H_{15}O$	145°/24 mm.		
C_2H_5O O P - F $C_8H_{17}O$	152°/24 mm.	0.05 0.02	100% 95%
C_2H_5O O P - F $i.C_6H_{13}O$	135°/23 mm.	0.05 0.02	100% 40%
C_2H_5O O P - F $Cl.CH_2.CH_2.O$	105°/12 mm.		
C_2H_5O O P - F $CCl_3.CH_2O$	98°/4 mm.		
O C_2H_5O P - F $Cl.CH_2$ O CH $Cl.CH_2$	100°/1 mm.	0.05 0.005 0.001	100% 95% 0%

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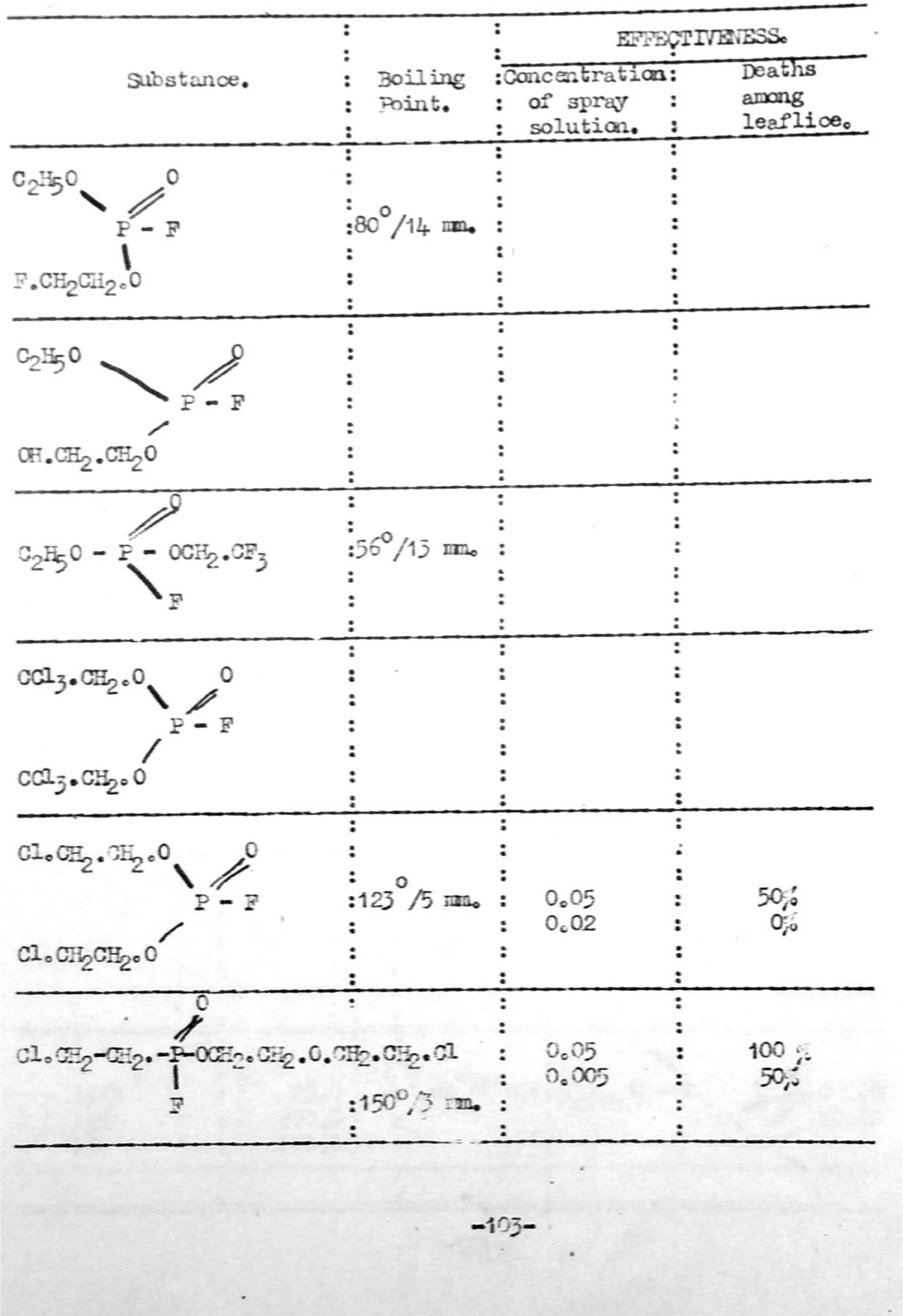
Figure A.230: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
C_2H_5O O P - F $F.CH_2CH_2.O$	$80^\circ/14$ mm.		
C_2H_5O O P - F $OH.CH_2.CH_2O$			
O $C_2H_5O - P - OCH_2.CF_3$ F	$56^\circ/13$ mm.		
$CCl_3.CH_2.O$ O P - F $CCl_3.CH_2.O$			
$Cl.CH_2.CH_2.O$ O P - F $Cl.CH_2CH_2.O$	$123^\circ/5$ mm.	0.05 0.02	50% 0%
O $Cl.CH_2-CH_2.-P-OCH_2.CH_2.O.CH_2.CH_2.Cl$ F	$150^\circ/3$ mm.	0.05 0.005	100% 50%

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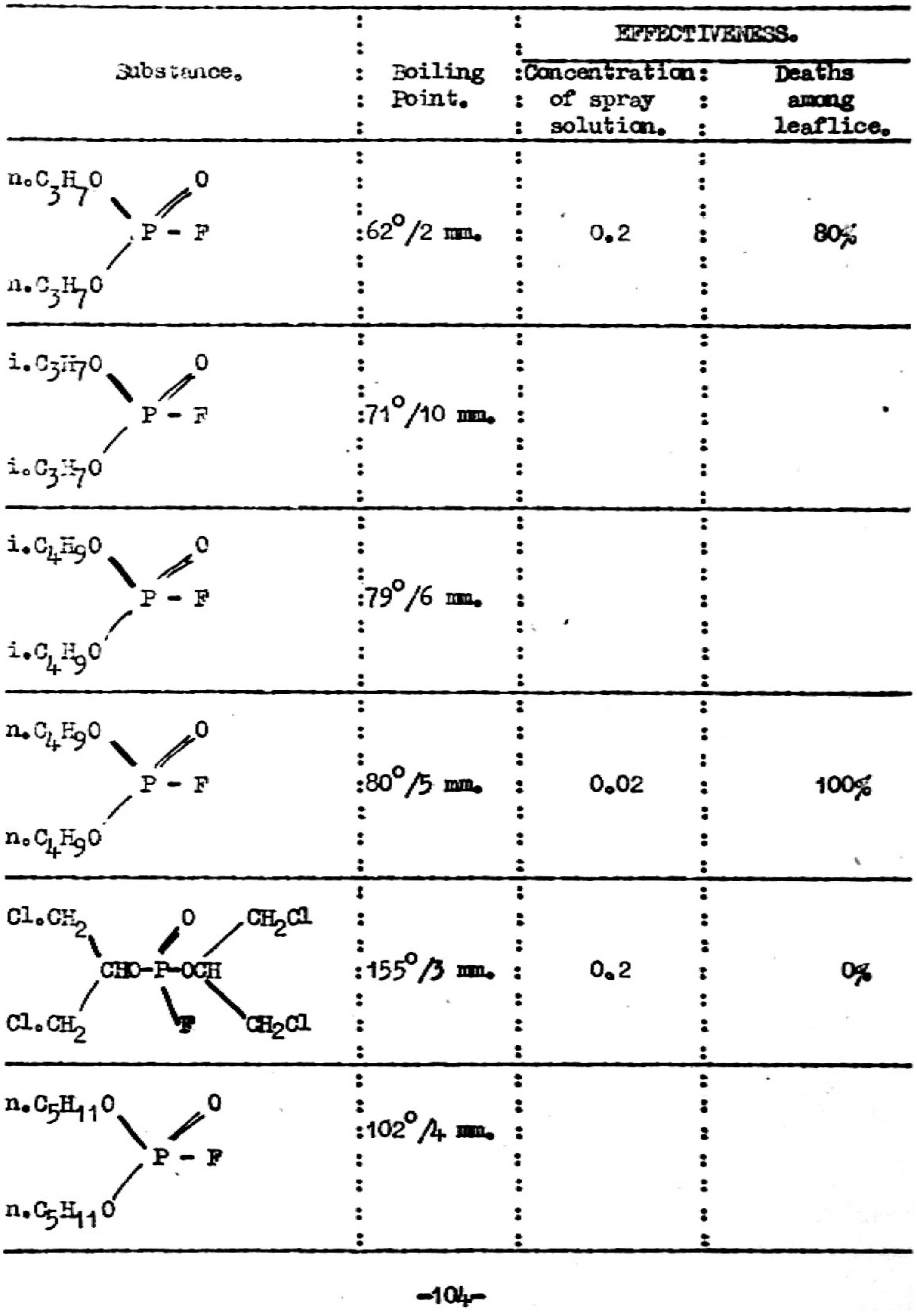
Figure A.231: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
$n.C_3H_7O$ O P - F $n.C_3H_7O$	62°/2 mm.	0.2	80%
$i.C_3H_7O$ O P - F $i.C_3H_7O$	71°/10 mm.		
$i.C_4H_9O$ O P - F $i.C_4H_9O$	79°/6 mm.		
$n.C_4H_9O$ O P - F $n.C_4H_9O$	80°/5 mm.	0.02	100%
$Cl.CH_2$ O CH_2Cl CHO-P-OCH $Cl.CH_2$ F CH_2Cl	155°/3 mm.	0.2	0%
$n.C_5H_{11}O$ O P - F $n.C_5H_{11}O$	102°/4 mm.		

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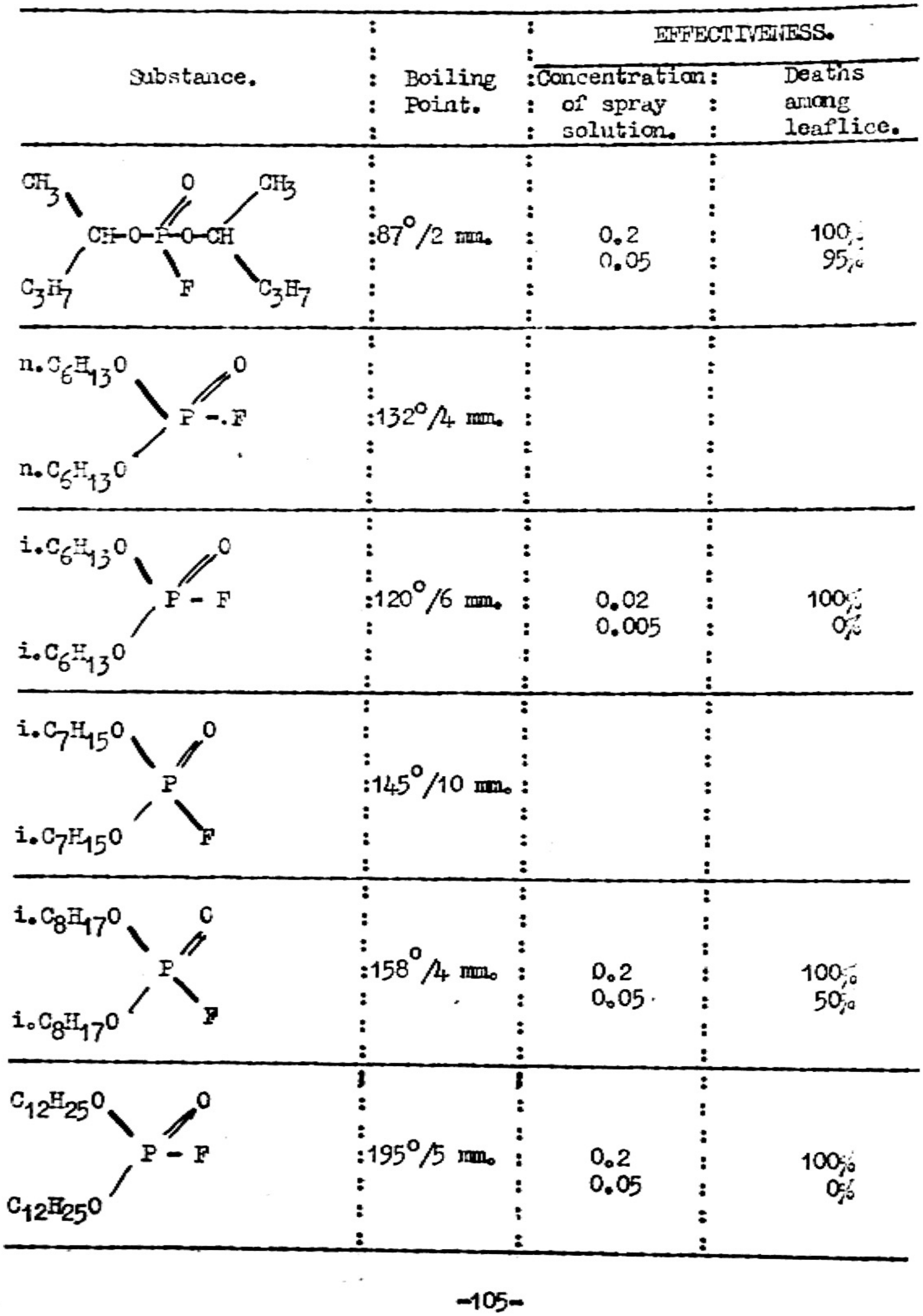
Figure A.232: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
$CH_3(C_3H_7)CH\text{-}O\text{-}P(O)(F)\text{-}O\text{-}CH(CH_3)C_3H_7$	87°/2 mm.	0.2 0.05	100% 95%
$(n.C_6H_{13}O)_2P(O)\text{-}F$	132°/4 mm.		
$(i.C_6H_{13}O)_2P(O)\text{-}F$	120°/6 mm.	0.02 0.005	100% 0%
$(i.C_7H_{15}O)_2P(O)F$	145°/10 mm.		
$(i.C_8H_{17}O)_2P(O)F$	158°/4 mm.	0.2 0.05	100% 50%
$(C_{12}H_{25}O)_2P(O)\text{-}F$	195°/5 mm.	0.2 0.05	100% 0%

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Figure A.233: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].

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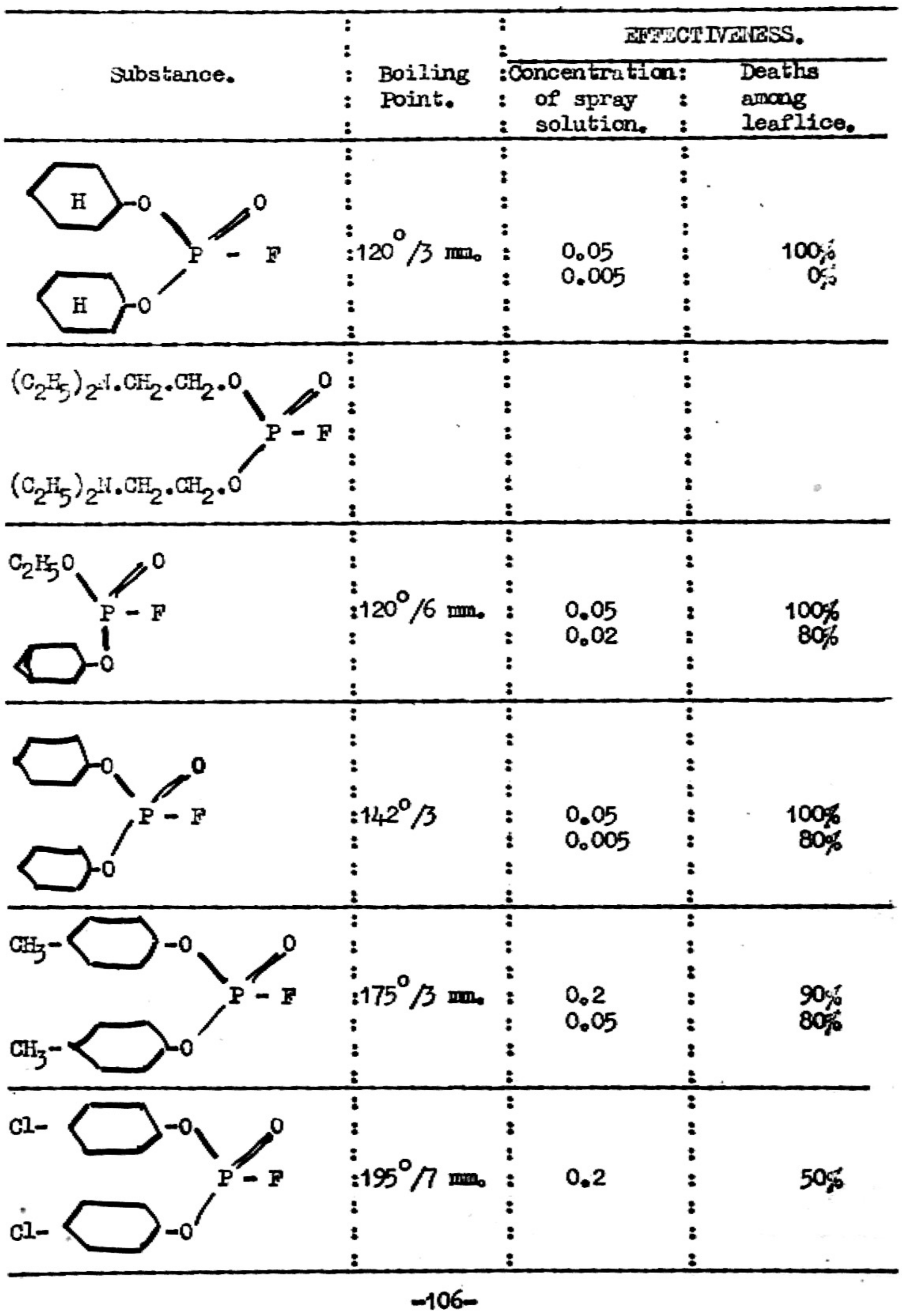

Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
	120°/3 mm.	0.05 0.005	100% 0%
$(C_2H_5)_2N.CH_2.CH_2.O$ / $(C_2H_5)_2N.CH_2.CH_2.O$ P(=O)–F			
	120°/6 mm.	0.05 0.02	100% 80%
	142°/3	0.05 0.005	100% 80%
	175°/3 mm.	0.2 0.05	90% 80%
	195°/7 mm.	0.2	50%

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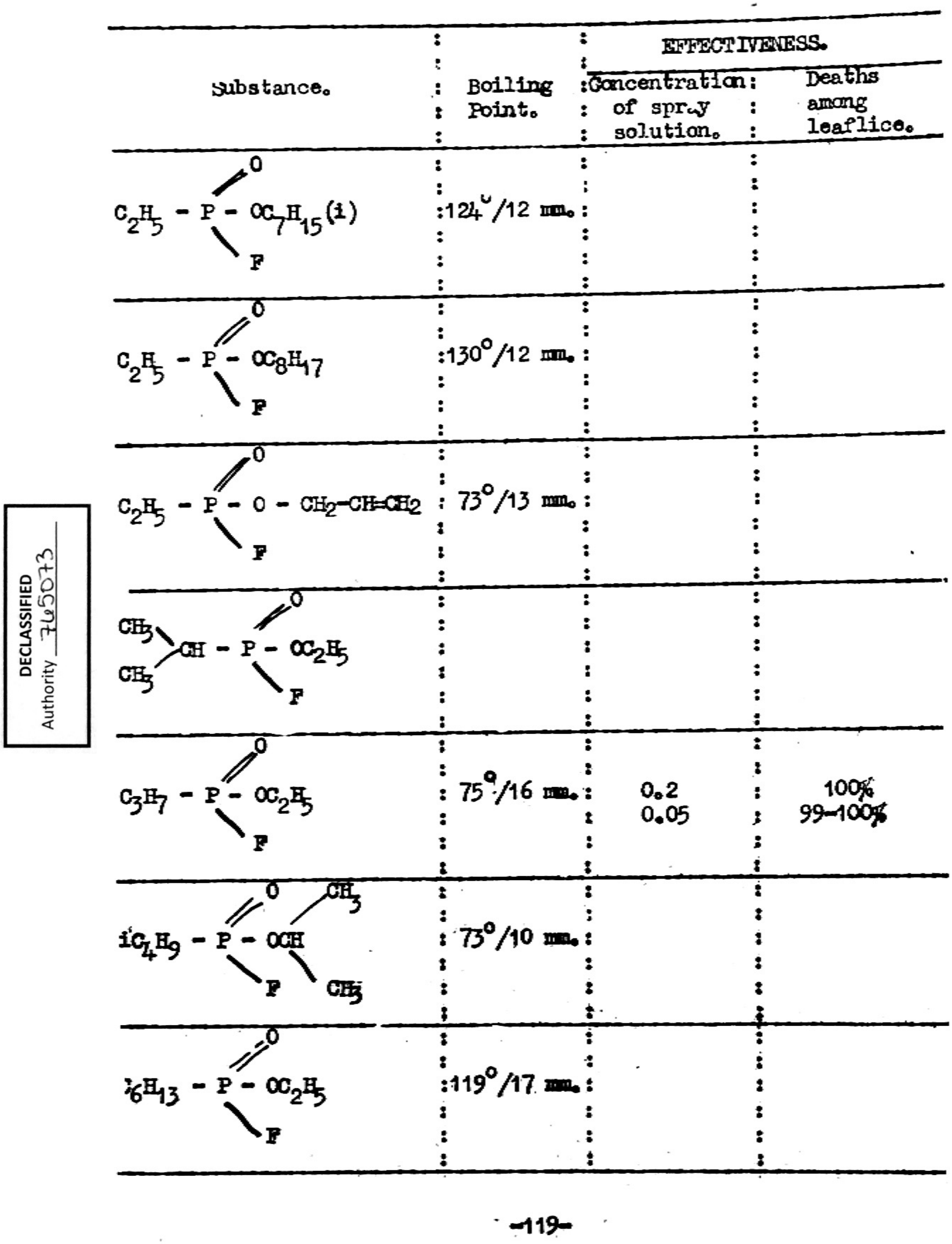
Figure A.234: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
$C_2H_5-P(=O)(-F)-OC_7H_{15}(i)$	124°/12 mm.		
$C_2H_5-P(=O)(-F)-OC_8H_{17}$	130°/12 mm.		
$C_2H_5-P(=O)(-F)-O-CH_2-CH=CH_2$	73°/13 mm.		
$(CH_3)_2CH-P(=O)(-F)-OC_2H_5$			
$C_3H_7-P(=O)(-F)-OC_2H_5$	75°/16 mm.	0.2 0.05	100% 99-100%
$iC_4H_9-P(=O)(-F)-OCH(CH_3)_2$	73°/10 mm.		
$C_6H_{13}-P(=O)(-F)-OC_2H_5$	119°/17 mm.		

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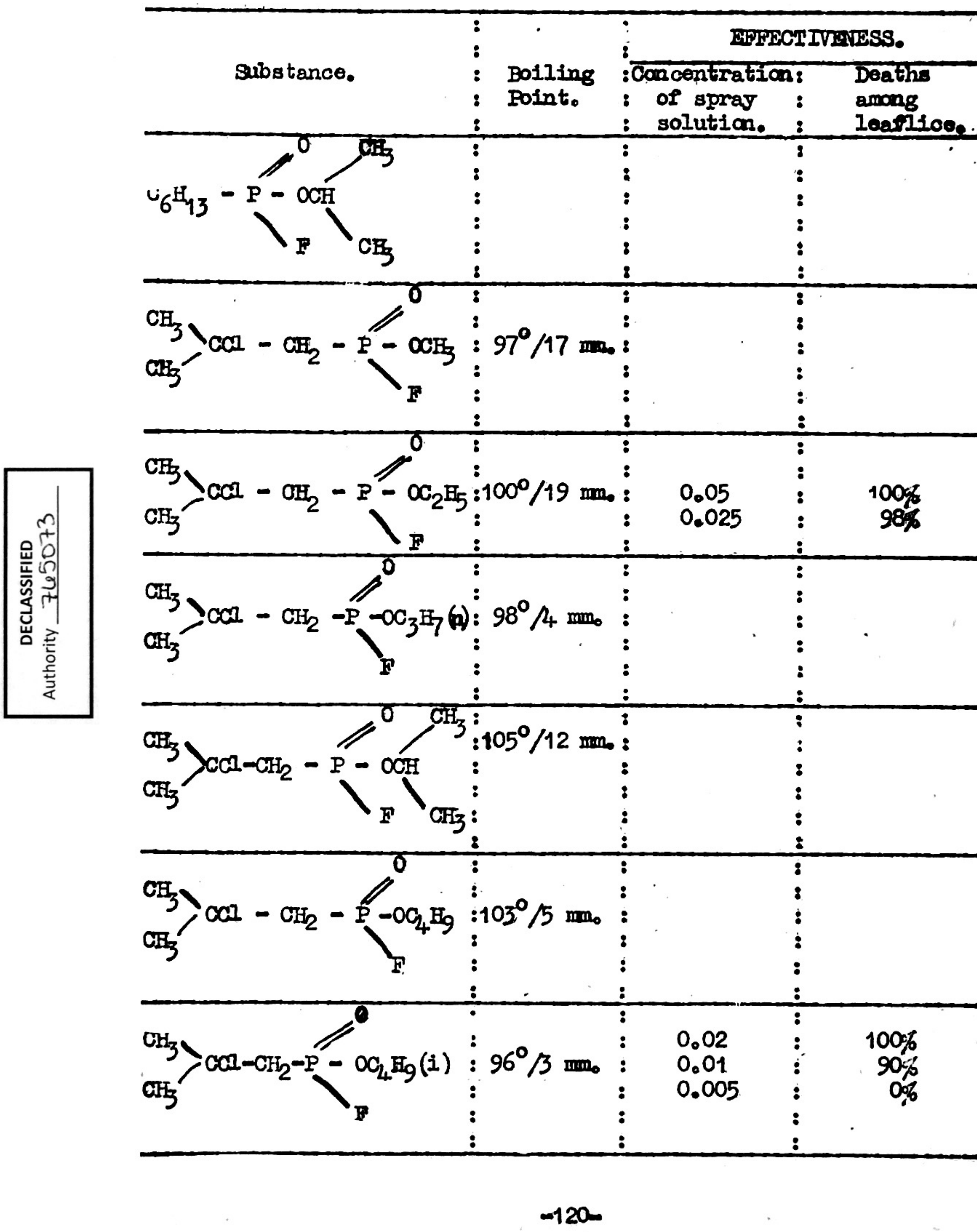
Figure A.235: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
O CH_3 C_6H_{13} - P - OCH F CH_3			
O CH_3 CCl - CH_2 - P - OCH_3 CH_3 F	97°/17 mm.		
O CH_3 CCl - CH_2 - P - OC_2H_5 CH_3 F	100°/19 mm.	0.05 0.025	100% 98%
O CH_3 CCl - CH_2 -P -OC_3H_7(n) CH_3 F	98°/4 mm.		
O CH_3 CH_3 CCl-CH_2 - P - OCH CH_3 F CH_3	105°/12 mm.		
O CH_3 CCl - CH_2 - P -OC_4H_9 CH_3 F	103°/5 mm.		
O CH_3 CCl-CH_2-P - OC_4H_9(i) CH_3 F	96°/3 mm.	0.02 0.01 0.005	100% 90% 0%

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Figure A.236: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].

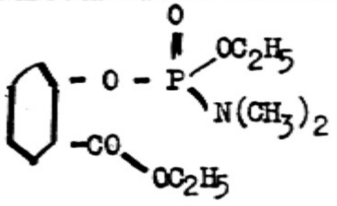
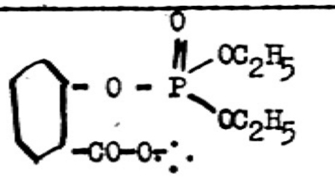
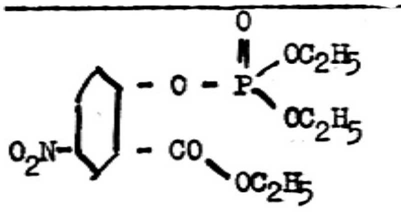
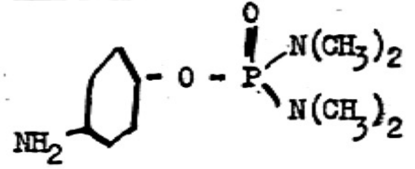
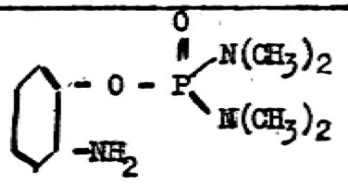
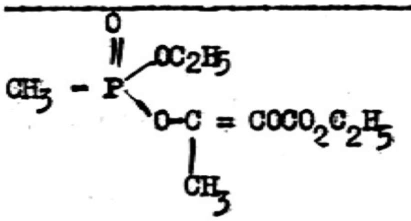
Substance.	Boiling Point.	EFFECTIVENESS.	
		Concentration of spray solution.	Deaths among leaflice.
	160°/2 mm.	0.2	0%
	180°/2 mm.		
	190°/4 mm.		
	M.p. 136°.	0.2	10%
	-	0.2	30%
	130°/1 mm.		

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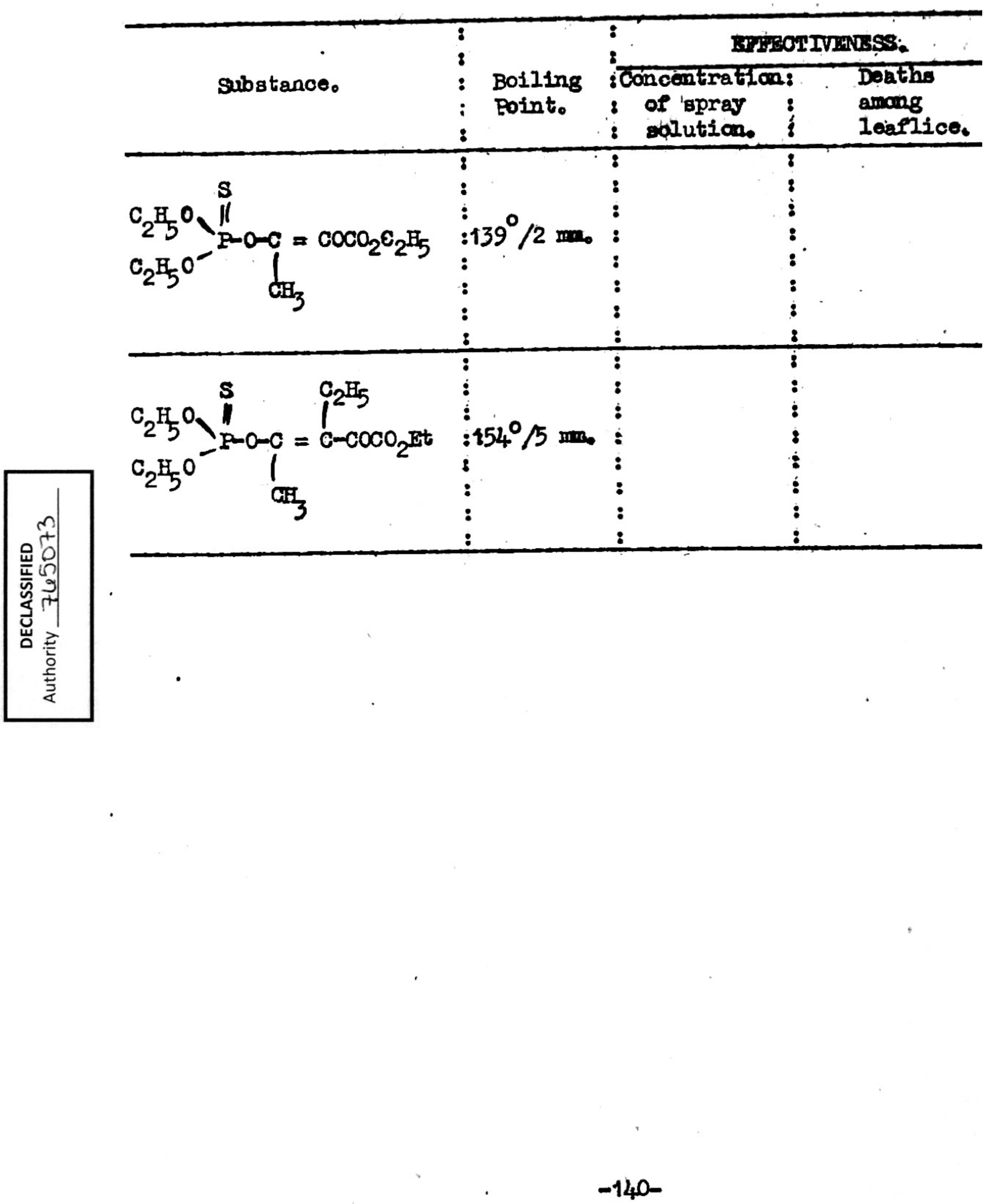
Figure A.237: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



		EFFECTIVENESS.	
Substance.	Boiling Point.	Concentration of spray solution.	Deaths among leaflice.
$(C_2H_5O)_2P(S)\text{-}O\text{-}C(CH_3) = COCO_2C_2H_5$	139°/2 mm.		
$(C_2H_5O)_2P(S)\text{-}O\text{-}C(CH_3) = C(C_2H_5)\text{-}COCO_2Et$	154°/5 mm.		

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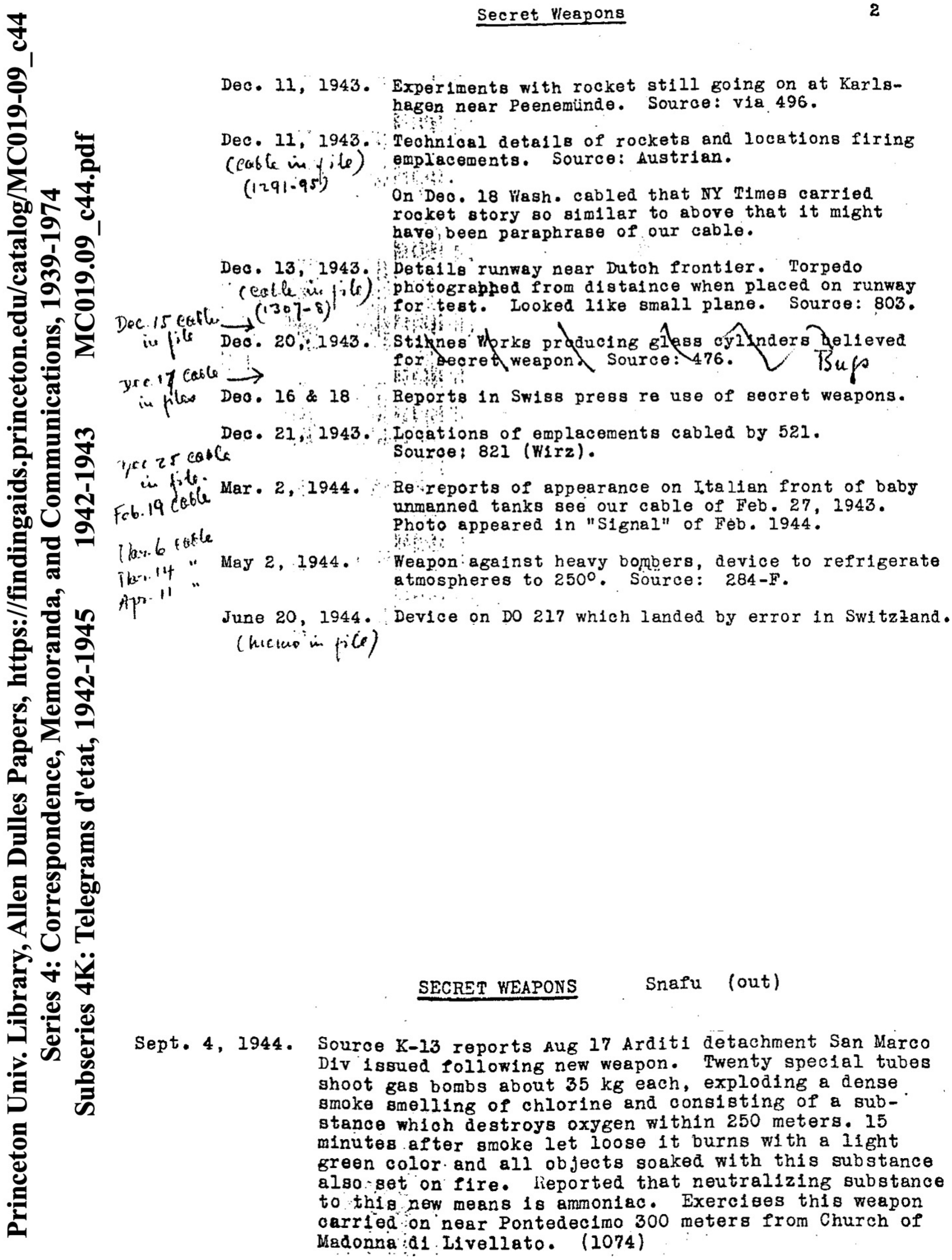
Figure A.238: Excerpt from Gerhard Schrader's description of the wartime development and testing of V-series nerve agents [BIOS 714].



Princeton Univ. Library, Allen Dulles Papers, https://findingaids.princeton.edu/catalog/MC019-09_c44
Series 4: Correspondence, Memoranda, and Communications, 1939-1974
Subseries 4K: Telegrams d'etat, 1942-1945 1942-1943 MC019.09_c44.pdf

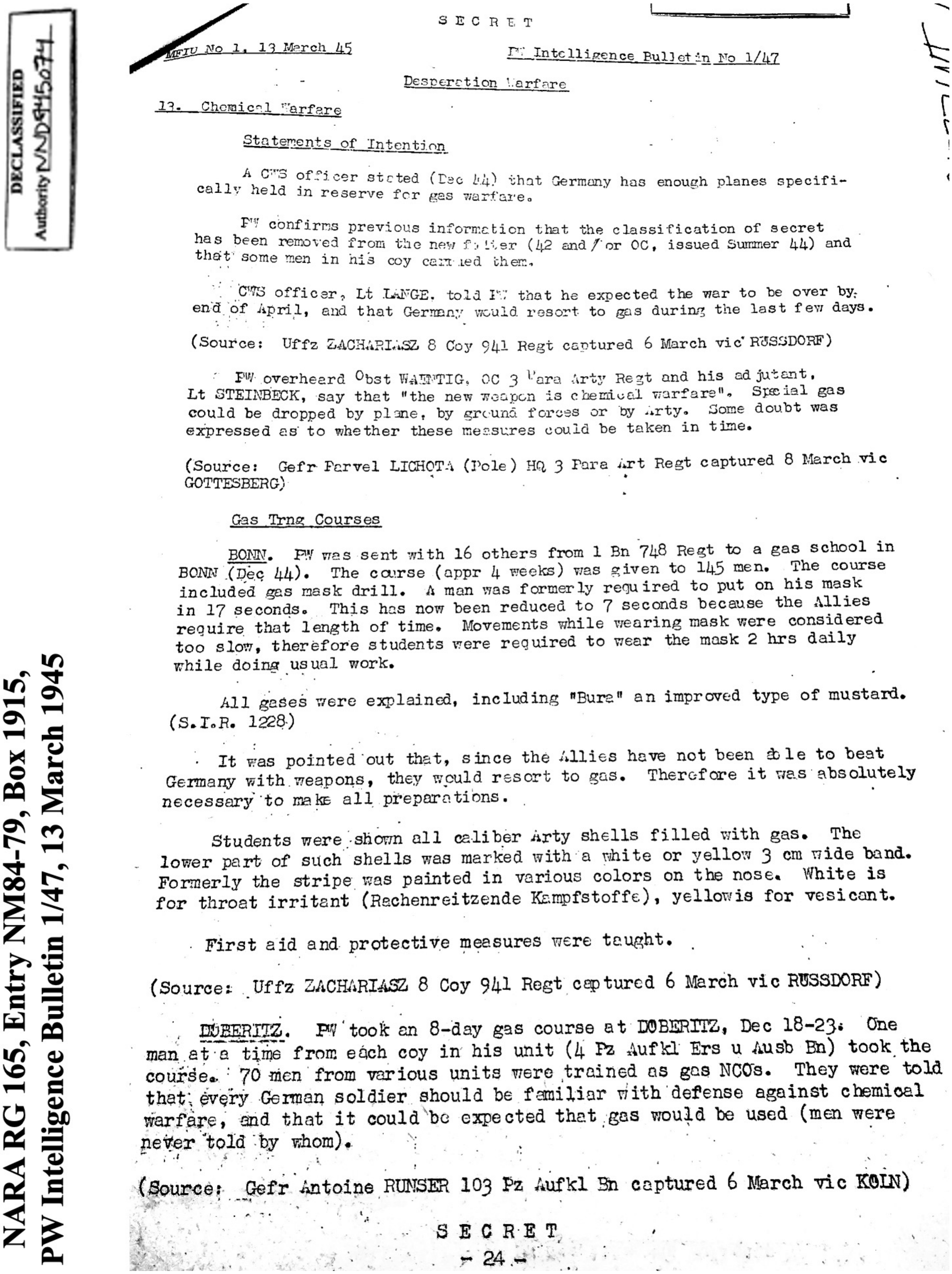
Secret Weapons 2

Dec. 11, 1943.	Experiments with rocket still going on at Karlshagen near Peenemünde. Source: via 496.
Dec. 11, 1943. (cable in file) (1291-95)	Technical details of rockets and locations firing emplacements. Source: Austrian. On Dec. 18 Wash. cabled that NY Times carried rocket story so similar to above that it might have been paraphrase of our cable.
Dec. 13, 1943. (cable in file) (1307-8)	Details runway near Dutch frontier. Torpedo photographed from distaince when placed on runway for test. Looked like small plane. Source: 803.
Dec 15 cable in file → Dec. 20, 1943.	Stinnes Works producing glass cylinders believed for secret weapon. Source: 476. Bufs
Dec 17 cable in files → Dec. 16 & 18	Reports in Swiss press re use of secret weapons.
Dec. 21, 1943.	Locations of emplacements cabled by 521. Source: 821 (Wirz).
Dec 25 cable in file. Feb. 19 cable Mar. 2, 1944.	Re-reports of appearance on Italian front of baby unmanned tanks see our cable of Feb. 27, 1943. Photo appeared in "Signal" of Feb. 1944.
Mar. 6 cable Mar. 14 " Apr. 11 " May 2, 1944.	Weapon against heavy bombers, device to refrigerate atmospheres to 250°. Source: 284-F.
June 20, 1944. (memo in file)	Device on DO 217 which landed by error in Switzland.

SECRET WEAPONS Snafu (out)

Sept. 4, 1944.	Source K-13 reports Aug 17 Arditi detachment San Marco Div issued following new weapon. Twenty special tubes shoot gas bombs about 35 kg each, exploding a dense smoke smelling of chlorine and consisting of a substance which destroys oxygen within 250 meters. 15 minutes after smoke let loose it burns with a light green color and all objects soaked with this substance also set on fire. Reported that neutralizing substance to this new means is ammoniac. Exercises this weapon carried on near Pontedecimo 300 meters from Church of Madonna di Livellato. (1074)

Figure A.239: Allen Dulles. Messages mentioning an endothermic weapon (May 2, 1944) and chlorine trifluoride or a similar chemical weapon (Sept. 4, 1944). [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44].



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MFIU No 1, 13 March 45

PW Intelligence Bulletin No 1/47

Desperation Warfare

13. Chemical Warfare

Statements of Intention

A CWS officer stated (Dec 44) that Germany has enough planes specifically held in reserve for gas warfare.

PW confirms previous information that the classification of secret has been removed from the new filter (42 and/or OC, issued Summer 44) and that some men in his coy carried them.

CWS officer, Lt LANGE, told PW that he expected the war to be over by end of April, and that Germany would resort to gas during the last few days.

(Source: Uffz ZACHARIASZ 8 Coy 941 Regt captured 6 March vic RUSSDORF)

PW overheard Obst WAENTIG, OC 3 Para Arty Regt and his adjutant, Lt STEINBECK, say that "the new weapon is chemical warfare". Special gas could be dropped by plane, by ground forces or by Arty. Some doubt was expressed as to whether these measures could be taken in time.

(Source: Gefr Parvel LICHOTA (Pole) HQ 3 Para Art Regt captured 8 March vic GOTTESBERG)

Gas Trng Courses

BONN. PW was sent with 16 others from 1 Bn 748 Regt to a gas school in BONN (Dec 44). The course (appr 4 weeks) was given to 145 men. The course included gas mask drill. A man was formerly required to put on his mask in 17 seconds. This has now been reduced to 7 seconds because the Allies require that length of time. Movements while wearing mask were considered too slow, therefore students were required to wear the mask 2 hrs daily while doing usual work.

All gases were explained, including "Bura" an improved type of mustard. (S.I.R. 1228)

It was pointed out that, since the Allies have not been able to beat Germany with weapons, they would resort to gas. Therefore it was absolutely necessary to make all preparations.

Students were shown all caliber Arty shells filled with gas. The lower part of such shells was marked with a white or yellow 3 cm wide band. Formerly the stripe was painted in various colors on the nose. White is for throat irritant (Rachenreitzende Kampfstoffe), yellow is for vesicant.

First aid and protective measures were taught.

(Source: Uffz ZACHARIASZ 8 Coy 941 Regt captured 6 March vic RUSSDORF)

DOBERITZ. PW took an 8-day gas course at DOBERITZ, Dec 18-23. One man at a time from each coy in his unit (4 Pz Aufkl Ers u Ausb Bn) took the course. 70 men from various units were trained as gas NCOs. They were told that every German soldier should be familiar with defense against chemical warfare, and that it could be expected that gas would be used (men were never told by whom).

(Source: Gefr Antoine RUNSER 103 Pz Aufkl Bn captured 6 March vic KOLN)

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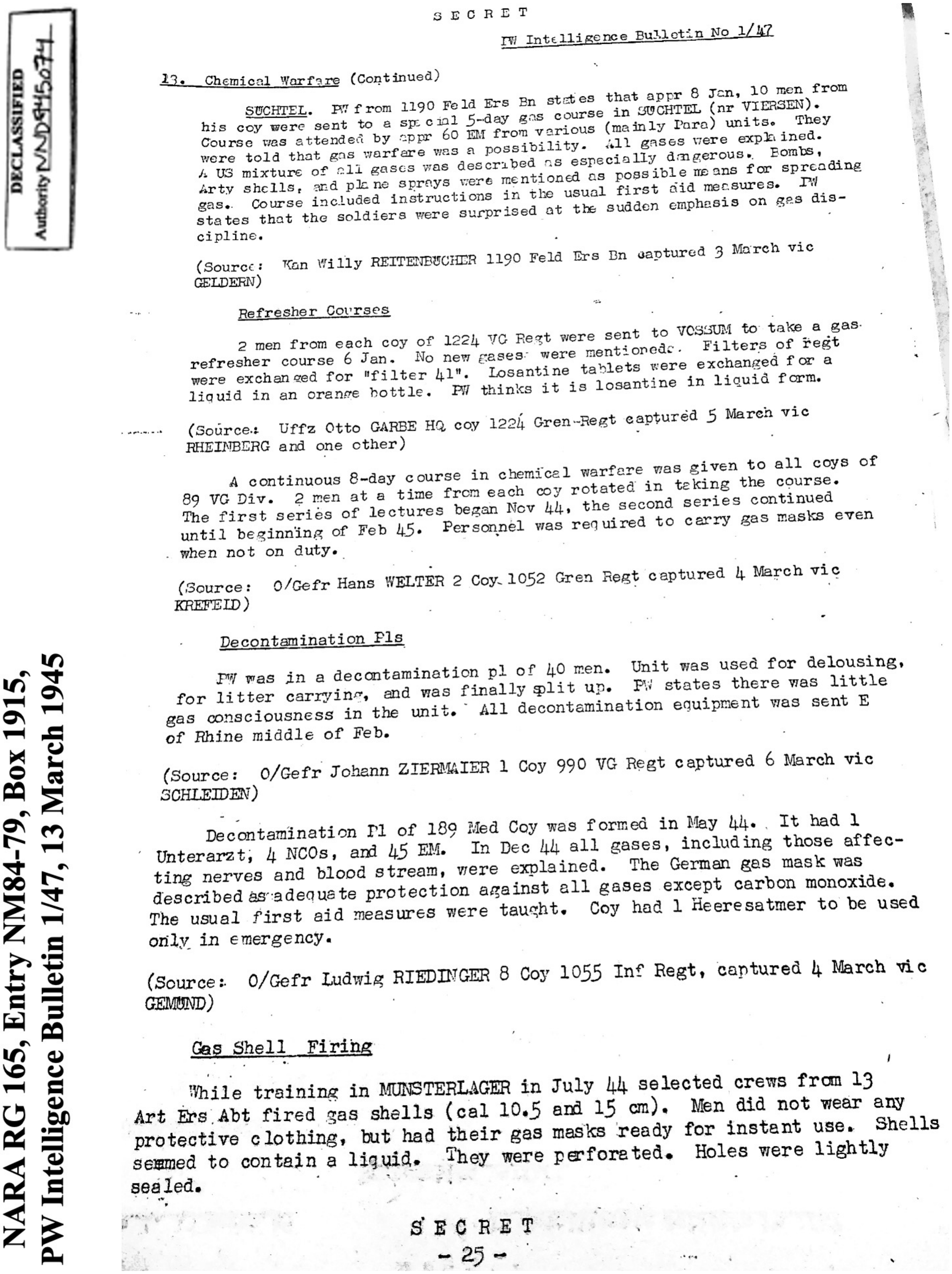
Figure A.240: PW Intelligence Bulletin 1/47, 13 March 1945 [NARA RG 165, Entry NM84-79, Box 1915].



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13. Chemical Warfare (Continued)

SUCHTEL. PW from 1190 Feld Ers Bn states that appr 8 Jan, 10 men from his coy were sent to a special 5-day gas course in SUCHTEL (nr VIERSEN). Course was attended by appr 60 EM from various (mainly Para) units. They were told that gas warfare was a possibility. All gases were explained. A US mixture of all gases was described as especially dangerous. Bombs, Arty shells, and plane sprays were mentioned as possible means for spreading gas. Course included instructions in the usual first aid measures. PW states that the soldiers were surprised at the sudden emphasis on gas discipline.

(Source: Kan Willy REITENBUCHER 1190 Feld Ers Bn captured 3 March vic GELDERN)

Refresher Courses

2 men from each coy of 1224 VG Regt were sent to VOSSUM to take a gas refresher course 6 Jan. No new gases were mentioned. Filters of regt were exchanged for "filter 41". Losantine tablets were exchanged for a liquid in an orange bottle. PW thinks it is losantine in liquid form.

(Source: Uffz Otto GARBE HQ coy 1224 Gren-Regt captured 5 March vic RHEINBERG and one other)

A continuous 8-day course in chemical warfare was given to all coys of 89 VG Div. 2 men at a time from each coy rotated in taking the course. The first series of lectures began Nov 44, the second series continued until beginning of Feb 45. Personnel was required to carry gas masks even when not on duty.

(Source: O/Gefr Hans WELTER 2 Coy 1052 Gren Regt captured 4 March vic KREFELD)

Decontamination Pls

PW was in a decontamination pl of 40 men. Unit was used for delousing, for litter carrying, and was finally split up. PW states there was little gas consciousness in the unit. All decontamination equipment was sent E of Rhine middle of Feb.

(Source: O/Gefr Johann ZIERMAIER 1 Coy 990 VG Regt captured 6 March vic SCHLEIDEN)

Decontamination Pl of 189 Med Coy was formed in May 44. It had 1 Unterarzt, 4 NCOs, and 45 EM. In Dec 44 all gases, including those affecting nerves and blood stream, were explained. The German gas mask was described as adequate protection against all gases except carbon monoxide. The usual first aid measures were taught. Coy had 1 Heeresatmer to be used only in emergency.

(Source: O/Gefr Ludwig RIEDINGER 8 Coy 1055 Inf Regt, captured 4 March vic GEMUND)

Gas Shell Firing

While training in MUNSTERLAGER in July 44 selected crews from 13 Art Ers Abt fired gas shells (cal 10.5 and 15 cm). Men did not wear any protective clothing, but had their gas masks ready for instant use. Shells semmed to contain a liquid. They were perforated. Holes were lightly sealed.

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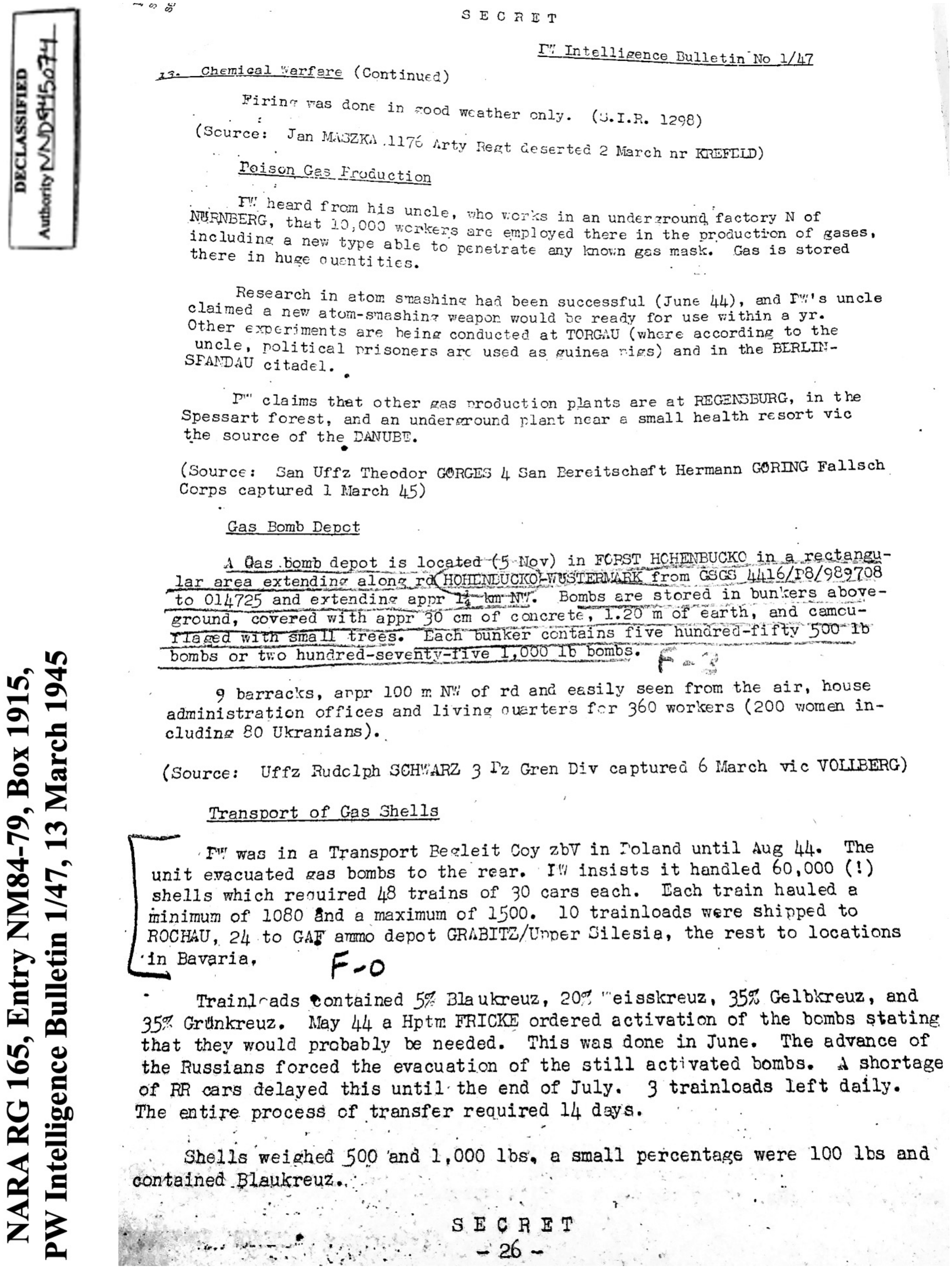
Figure A.241: PW Intelligence Bulletin 1/47, 13 March 1945 [NARA RG 165, Entry NM84-79, Box 1915].



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13. Chemical Warfare (Continued)

Firing was done in good weather only. (S.I.R. 1298)

(Source: Jan MASZKA 1176 Arty Regt deserted 2 March nr KREFELD)

Poison Gas Production

PW heard from his uncle, who works in an underground factory N of NURNBERG, that 10,000 workers are employed there in the production of gases, including a new type able to penetrate any known gas mask. Gas is stored there in huge quantities.

Research in atom smashing had been successful (June 44), and PW's uncle claimed a new atom-smashing weapon would be ready for use within a yr. Other experiments are being conducted at TORGAU (where according to the uncle, political prisoners are used as guinea pigs) and in the BERLIN-SPANDAU citadel.

PW claims that other gas production plants are at REGENSBURG, in the Spessart forest, and an underground plant near a small health resort vic the source of the DANUBE.

(Source: San Uffz Theodor GORGES 4 San Bereitschaft Hermann GORING Fallsch Corps captured 1 March 45)

Gas Bomb Depot

A Gas bomb depot is located (5 Nov) in FORST HOHENBUCKO in a rectangular area extending along rd HOHENBUCKO-WUSTERMARK from GSGS 4416/P8/989708 to 014725 and extending appr 1¼ km NW. Bombs are stored in bunkers aboveground, covered with appr 30 cm of concrete, 1.20 m of earth, and camouflaged with small trees. Each bunker contains five hundred-fifty 500 lb bombs or two hundred-seventy-five 1,000 lb bombs. F-3

9 barracks, appr 100 m NW of rd and easily seen from the air, house administration offices and living quarters for 360 workers (200 women including 80 Ukranians).

(Source: Uffz Rudolph SCHWARZ 3 Pz Gren Div captured 6 March vic VOLLBERG)

Transport of Gas Shells

PW was in a Transport Begleit Coy zbV in Poland until Aug 44. The unit evacuated gas bombs to the rear. PW insists it handled 60,000 (!) shells which required 48 trains of 30 cars each. Each train hauled a minimum of 1080 and a maximum of 1500. 10 trainloads were shipped to ROCHAU, 24 to GAF ammo depot GRABITZ/Upper Silesia, the rest to locations in Bavaria. F-0

Trainloads contained 5% Blaukreuz, 20% Weisskreuz, 35% Gelbkreuz, and 35% Grünkreuz. May 44 a Hptm FRICKE ordered activation of the bombs stating that they would probably be needed. This was done in June. The advance of the Russians forced the evacuation of the still activated bombs. A shortage of RR cars delayed this until the end of July. 3 trainloads left daily. The entire process of transfer required 14 days.

Shells weighed 500 and 1,000 lbs, a small percentage were 100 lbs and contained Blaukreuz.

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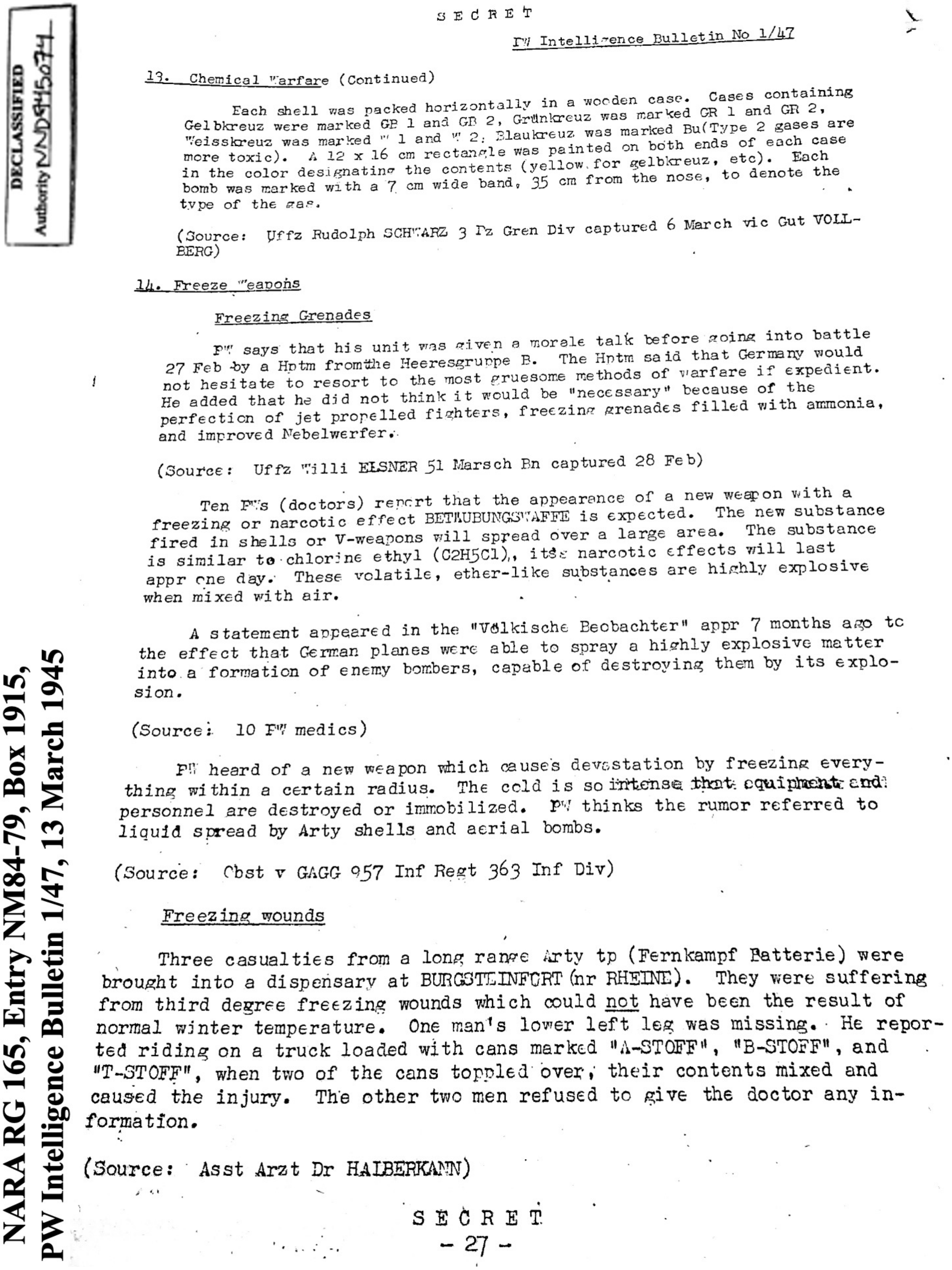
Figure A.242: PW Intelligence Bulletin 1/47, 13 March 1945 [NARA RG 165, Entry NM84-79, Box 1915].



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13. Chemical Warfare (Continued)

Each shell was packed horizontally in a wooden case. Cases containing Gelbkreuz were marked GB 1 and GB 2, Grünkreuz was marked GR 1 and GR 2, Weisskreuz was marked W 1 and W 2; Blaukreuz was marked Bu(Type 2 gases are more toxic). A 12 x 16 cm rectangle was painted on both ends of each case in the color designating the contents (yellow for gelbkreuz, etc). Each bomb was marked with a 7 cm wide band, 35 cm from the nose, to denote the type of the gas.

(Source: Uffz Rudolph SCHWARZ 3 Pz Gren Div captured 6 March vic Gut VOLLBERG)

14. Freeze Weapons

Freezing Grenades

PW says that his unit was given a morale talk before going into battle 27 Feb by a Hptm from the Heeresgruppe B. The Hptm said that Germany would not hesitate to resort to the most gruesome methods of warfare if expedient. He added that he did not think it would be "necessary" because of the perfection of jet propelled fighters, freezing grenades filled with ammonia, and improved Nebelwerfer.

(Source: Uffz Willi ELSNER 51 Marsch Bn captured 28 Feb)

Ten PWs (doctors) report that the appearance of a new weapon with a freezing or narcotic effect BETAUBUNGSWAFFE is expected. The new substance fired in shells or V-weapons will spread over a large area. The substance is similar to chlorine ethyl (C_2H_5Cl), its narcotic effects will last appr one day. These volatile, ether-like substances are highly explosive when mixed with air.

A statement appeared in the "Völkische Beobachter" appr 7 months ago to the effect that German planes were able to spray a highly explosive matter into a formation of enemy bombers, capable of destroying them by its explosion.

(Source: 10 PW medics)

PW heard of a new weapon which causes devastation by freezing everything within a certain radius. The cold is so intense that equipment and personnel are destroyed or immobilized. PW thinks the rumor referred to liquid spread by Arty shells and aerial bombs.

(Source: Obst v GAGG 957 Inf Regt 363 Inf Div)

Freezing wounds

Three casualties from a long range Arty tp (Fernkampf Batterie) were brought into a dispensary at BURGSTEINFORT (nr RHEINE). They were suffering from third degree freezing wounds which could not have been the result of normal winter temperature. One man's lower left leg was missing. He reported riding on a truck loaded with cans marked "A-STOFF", "B-STOFF", and "T-STOFF", when two of the cans toppled over, their contents mixed and caused the injury. The other two men refused to give the doctor any information.

(Source: Asst Arzt Dr HALBERKANN)

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Figure A.243: PW Intelligence Bulletin 1/47, 13 March 1945 [NARA RG 165, Entry NM84-79, Box 1915].

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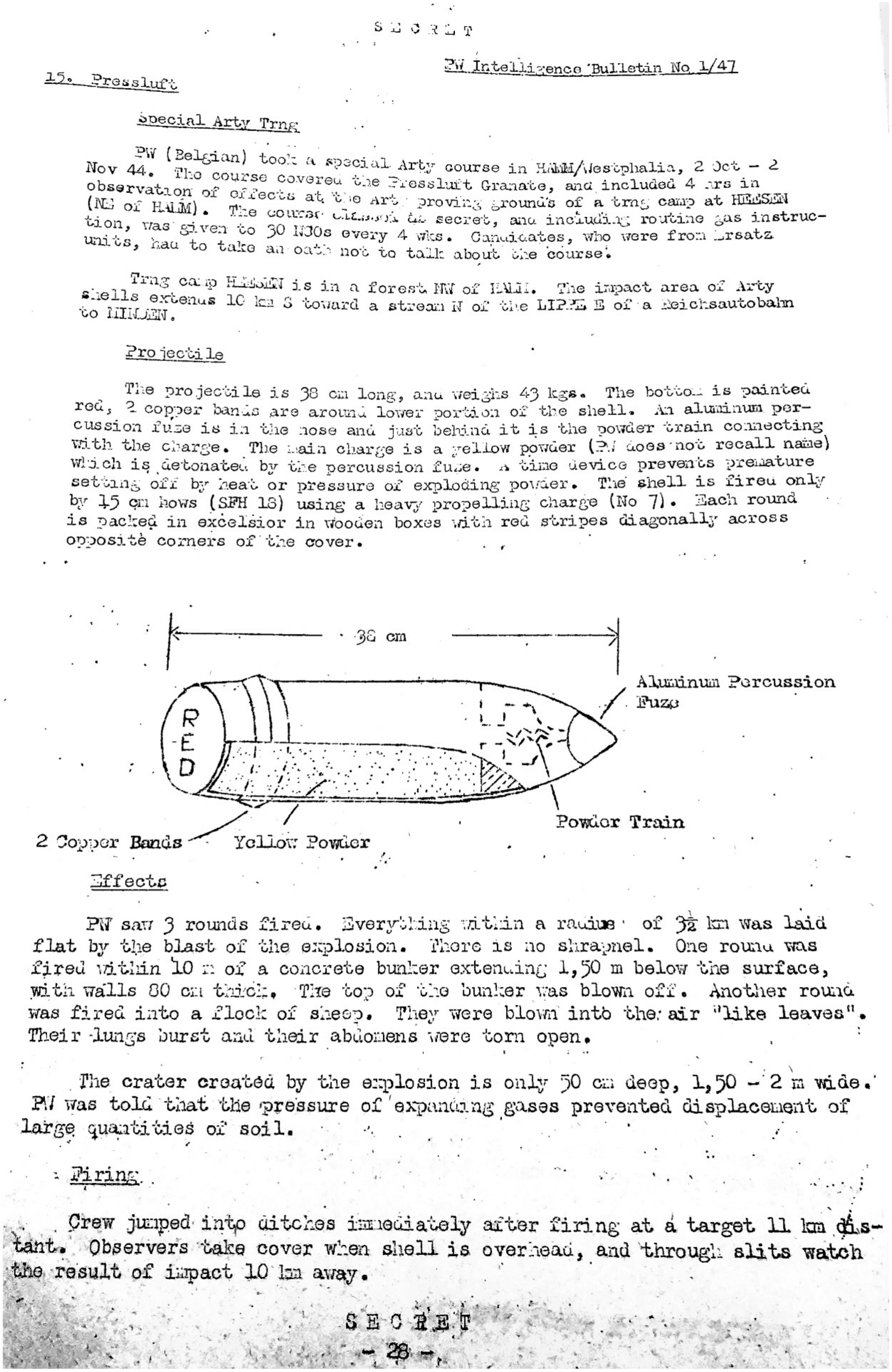

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15. Pressluft

Special Arty Trng

PW (Belgian) took a special Arty course in HAMM/Westphalia, 2 Oct – 2 Nov 44. The course covered the Pressluft Granate, and included 4 hrs in observation of effects at the Arty proving grounds of a trng camp at HEESEN (NE of HAMM). The course classed as secret, and including routine gas instruction, was given to 30 NCOs every 4 wks. Candidates, who were from Ersatz units, had to take an oath not to talk about the course.

Trng camp HEESEN is in a forest NW of HAMM. The impact area of Arty shells extends 10 km S toward a stream N of the LIPPE E of a Reichsautobahn to MINDEN.

Projectile

The projectile is 38 cm long, and weighs 43 kgs. The bottom is painted red, 2 copper bands are around lower portion of the shell. An aluminum percussion fuze is in the nose and just behind it is the powder train connecting with the charge. The main charge is a yellow powder (PW does not recall name) which is detonated by the percussion fuze. A time device prevents premature setting off by heat or pressure of exploding powder. The shell is fired only by 15 cm hows (SFH 18) using a heavy propelling charge (No 7). Each round is packed in excelsior in wooden boxes with red stripes diagonally across opposite corners of the cover.

Effects

PW saw 3 rounds fired. Everything within a radius of $3\frac{1}{2}$ km was laid flat by the blast of the explosion. There is no shrapnel. One round was fired within 10 m of a concrete bunker extending 1,50 m below the surface, with walls 80 cm thick. The top of the bunker was blown off. Another round was fired into a flock of sheep. They were blown into the air "like leaves". Their lungs burst and their abdomens were torn open.

The crater created by the explosion is only 50 cm deep, 1,50 – 2 m wide. PW was told that the pressure of expanding gases prevented displacement of large quantities of soil.

Firing

Crew jumped into ditches immediately after firing at a target 11 km distant. Observers take cover when shell is overhead, and through slits watch the result of impact 10 km away.

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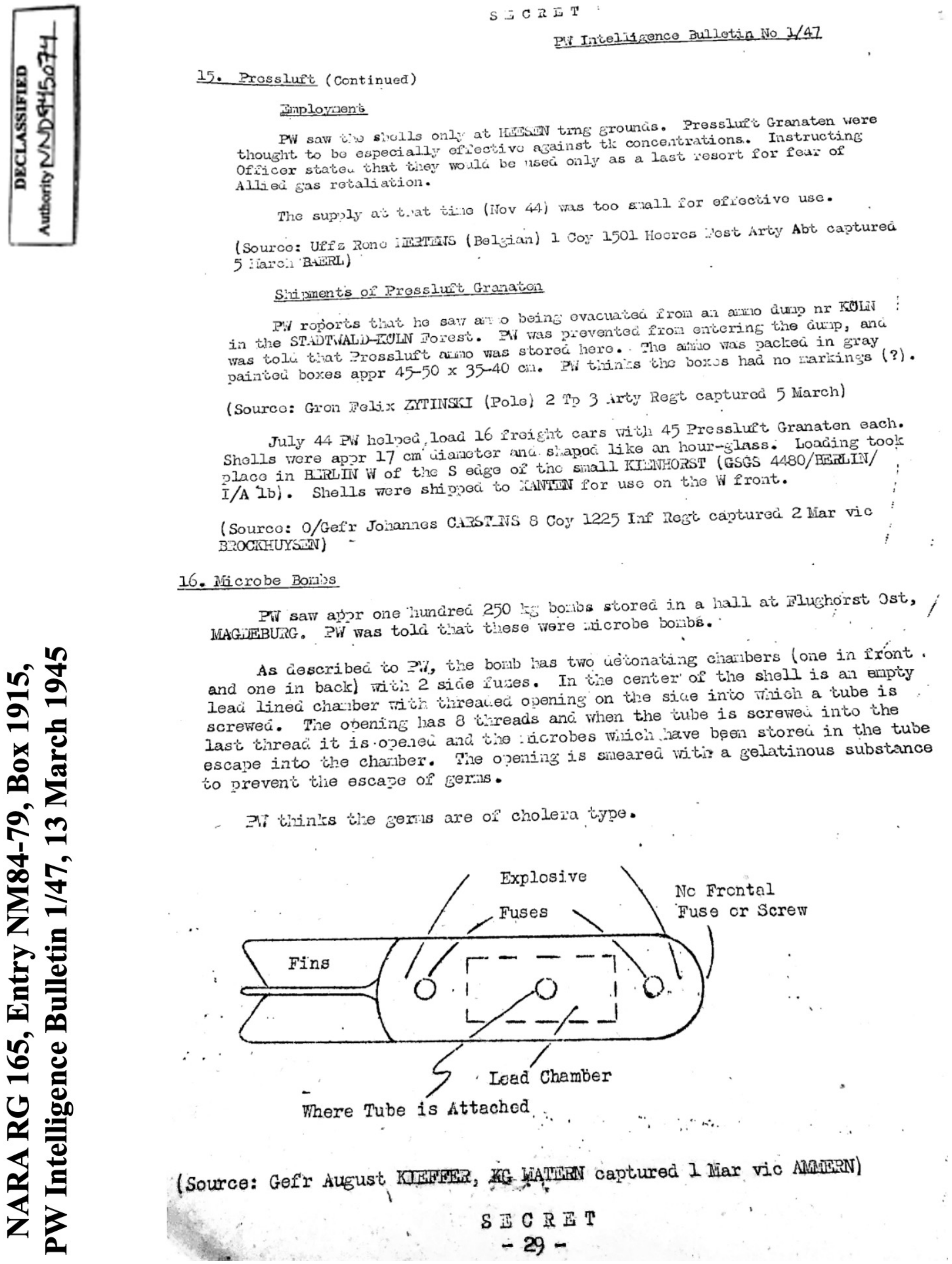
Figure A.244: PW Intelligence Bulletin 1/47, 13 March 1945 [NARA RG 165, Entry NM84-79, Box 1915].



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15. Pressluft (Continued)

Employment

PW saw the shells only at HEESEN trng grounds. Pressluft Granaten were thought to be especially effective against tk concentrations. Instructing Officer stated that they would be used only as a last resort for fear of Allied gas retaliation.

The supply at that time (Nov 44) was too small for effective use.

(Source: Uffz Rene MERTENS (Belgian) 1 Coy 1501 Heeres West Arty Abt captured 5 March BAERL)

Shipments of Pressluft Granaten

PW reports that he saw ammo being evacuated from an ammo dump nr KÖLN in the STADTWALD-KÖLN Forest. PW was prevented from entering the dump, and was told that Pressluft ammo was stored here. The ammo was packed in gray painted boxes appr 45-50 x 35-40 cm. PW thinks the boxes had no markings (?).

(Source: Gren Felix ZYTINSKI (Pole) 2 Tp 3 Arty Regt captured 5 March)

July 44 PW helped load 16 freight cars with 45 Pressluft Granaten each. Shells were appr 17 cm diameter and shaped like an hour-glass. Loading took place in BERLIN W of the S edge of the small KIENHORST (GSGS 4480/BERLIN/I/A 1b). Shells were shipped to XANTEN for use on the W front.

(Source: O/Gefr Johannes CARSTENS 8 Coy 1225 Inf Regt captured 2 Mar vic BROCKHUYSEN)

16. Microbe Bombs

PW saw appr one hundred 250 kg bombs stored in a hall at Flughorst Ost, MAGDEBURG. PW was told that these were microbe bombs.

As described to PW, the bomb has two detonating chambers (one in front and one in back) with 2 side fuses. In the center of the shell is an empty lead lined chamber with threaded opening on the side into which a tube is screwed. The opening has 8 threads and when the tube is screwed into the last thread it is opened and the microbes which have been stored in the tube escape into the chamber. The opening is smeared with a gelatinous substance to prevent the escape of germs.

PW thinks the germs are of cholera type.

(Source: Gefr August KIEFFER, KG MATERN captured 1 Mar vic AMMERN)

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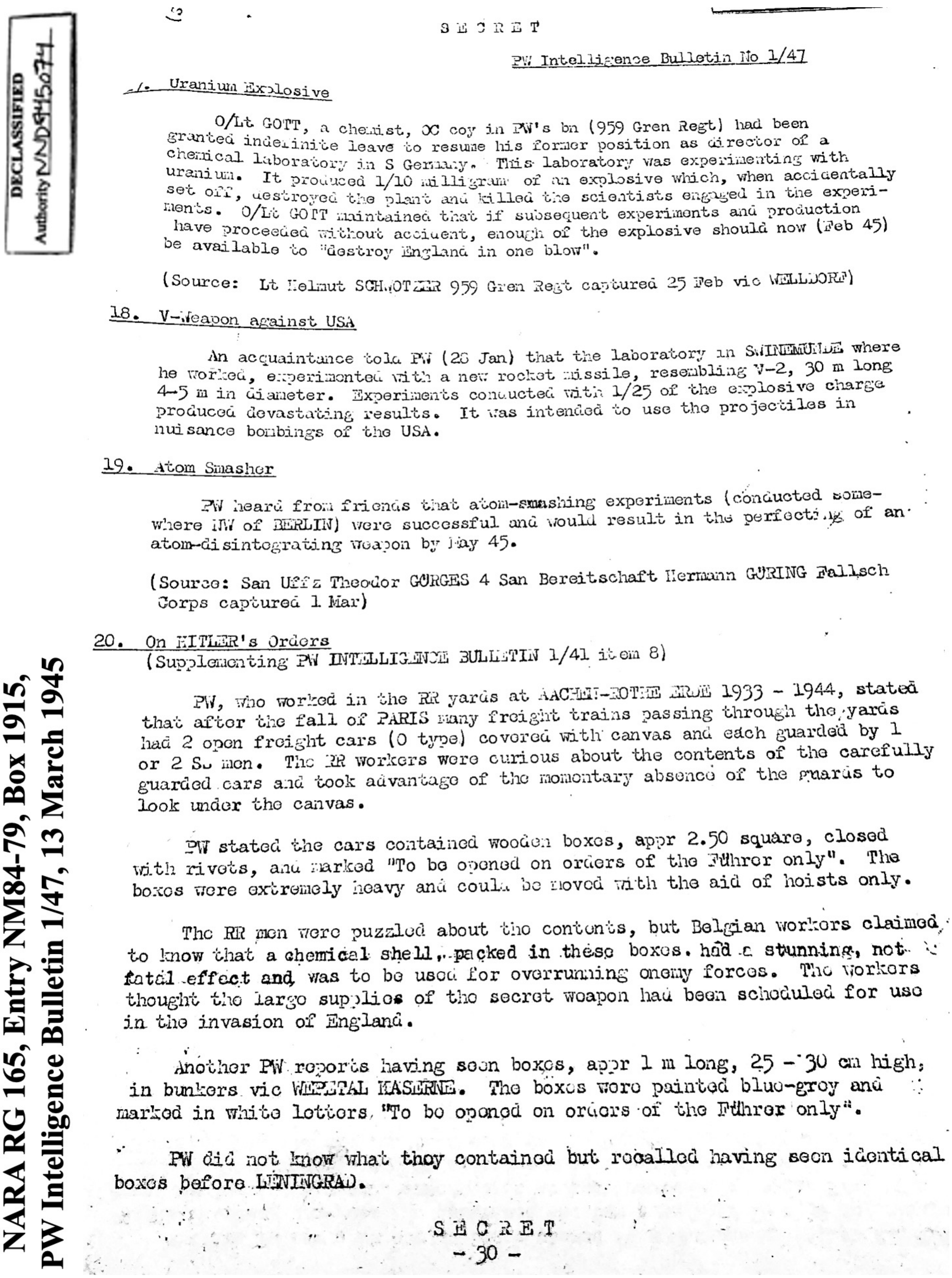
Figure A.245: PW Intelligence Bulletin 1/47, 13 March 1945 [NARA RG 165, Entry NM84-79, Box 1915].



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PW Intelligence Bulletin No 1/47

17. Uranium Explosive

O/Lt GOTT, a chemist, OC coy in PW's bn (959 Gren Regt) had been granted indefinite leave to resume his former position as director of a chemical laboratory in S Germany. This laboratory was experimenting with uranium. It produced 1/10 milligram of an explosive which, when accidentally set off, destroyed the plant and killed the scientists engaged in the experiments. O/Lt GOTT maintained that if subsequent experiments and production have proceeded without accident, enough of the explosive should now (Feb 45) be available to "destroy England in one blow".

(Source: Lt Helmut SCHWOTZER 959 Gren Regt captured 25 Feb vic WELLDORF)

18. V-Weapon against USA

An acquaintance told PW (28 Jan) that the laboratory in SWINEMUNDE where he worked, experimented with a new rocket missile, resembling V-2, 30 m long 4-5 m in diameter. Experiments conducted with 1/25 of the explosive charge produced devastating results. It was intended to use the projectiles in nuisance bombings of the USA.

19. Atom Smasher

PW heard from friends that atom-smashing experiments (conducted somewhere NW of BERLIN) were successful and would result in the perfecting of an atom-disintegrating weapon by May 45.

(Source: San Uffz Theodor GÖRGES 4 San Bereitschaft Hermann GÖRING Fallsch Corps captured 1 Mar)

20. On HITLER's Orders
(Supplementing PW INTELLIGENCE BULLETIN 1/41 item 8)

PW, who worked in the RR yards at AACHEN-ROTHE ERDE 1933 - 1944, stated that after the fall of PARIS many freight trains passing through the yards had 2 open freight cars (O type) covered with canvas and each guarded by 1 or 2 SS men. The RR workers were curious about the contents of the carefully guarded cars and took advantage of the momentary absence of the guards to look under the canvas.

PW stated the cars contained wooden boxes, appr 2.50 square, closed with rivets, and marked "To be opened on orders of the Führer only". The boxes were extremely heavy and could be moved with the aid of hoists only.

The RR men were puzzled about the contents, but Belgian workers claimed to know that a chemical shell, packed in these boxes. had a stunning, not fatal effect and was to be used for overrunning enemy forces. The workers thought the large supplies of the secret weapon had been scheduled for use in the invasion of England.

Another PW reports having seen boxes, appr 1 m long, 25 - 30 cm high, in bunkers vic WEPETAL KASERNE. The boxes were painted blue-grey and marked in white letters "To be opened on orders of the Führer only".

PW did not know what they contained but recalled having seen identical boxes before LENINGRAD.

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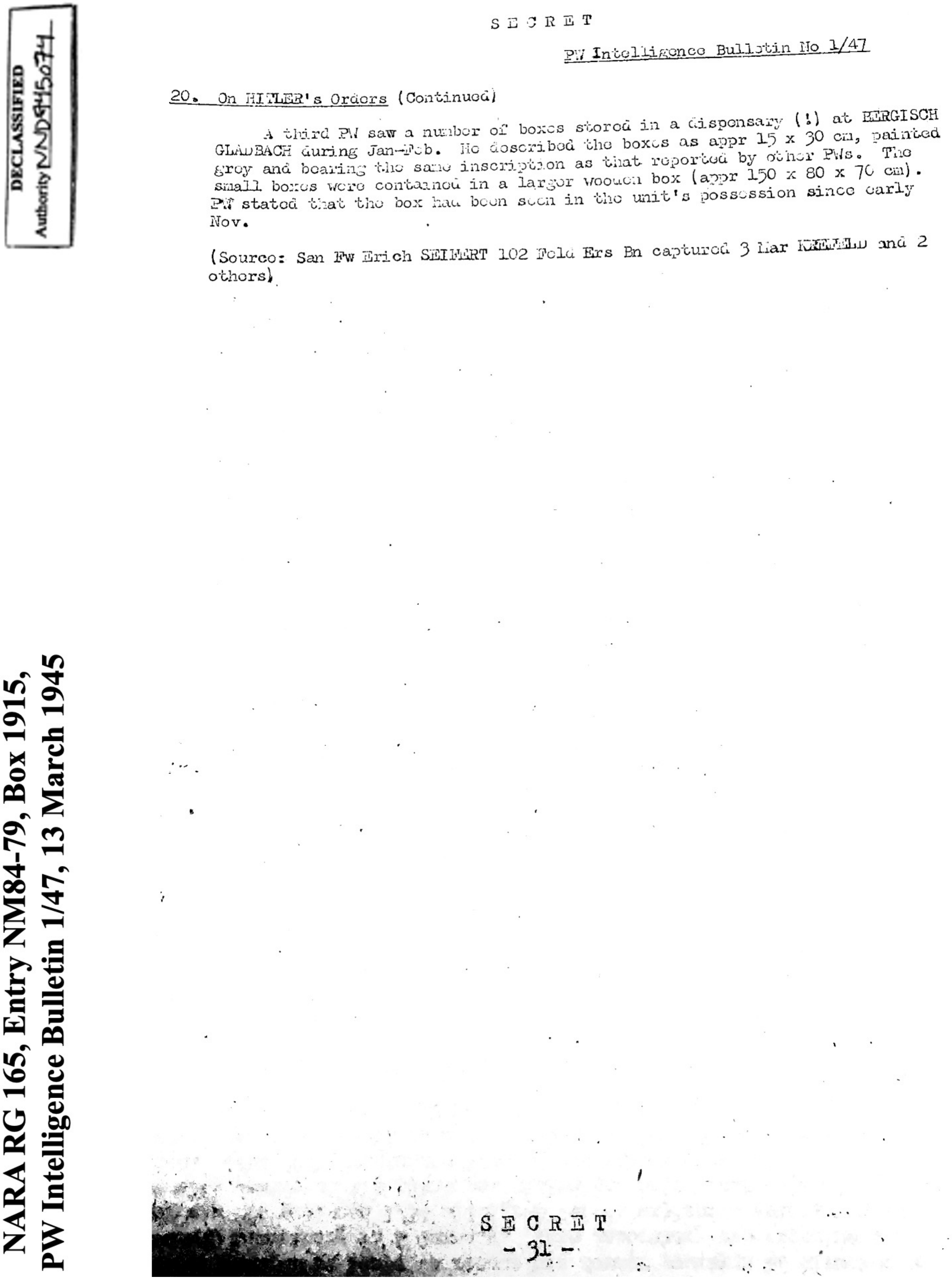
Figure A.246: PW Intelligence Bulletin 1/47, 13 March 1945 [NARA RG 165, Entry NM84-79, Box 1915].



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20. On HITLER's Orders (Continued)

A third PW saw a number of boxes stored in a dispensary (!) at BERGISCH GLADBACH during Jan-Feb. He described the boxes as appr 15 x 30 cm, painted grey and bearing the same inscription as that reported by other PWs. The small boxes were contained in a larger wooden box (appr 150 x 80 x 70 cm). PW stated that the box had been seen in the unit's possession since early Nov.

(Source: San Fw Erich SEIFERT 102 Feld Ers Bn captured 3 Mar KREFELD and 2 others)

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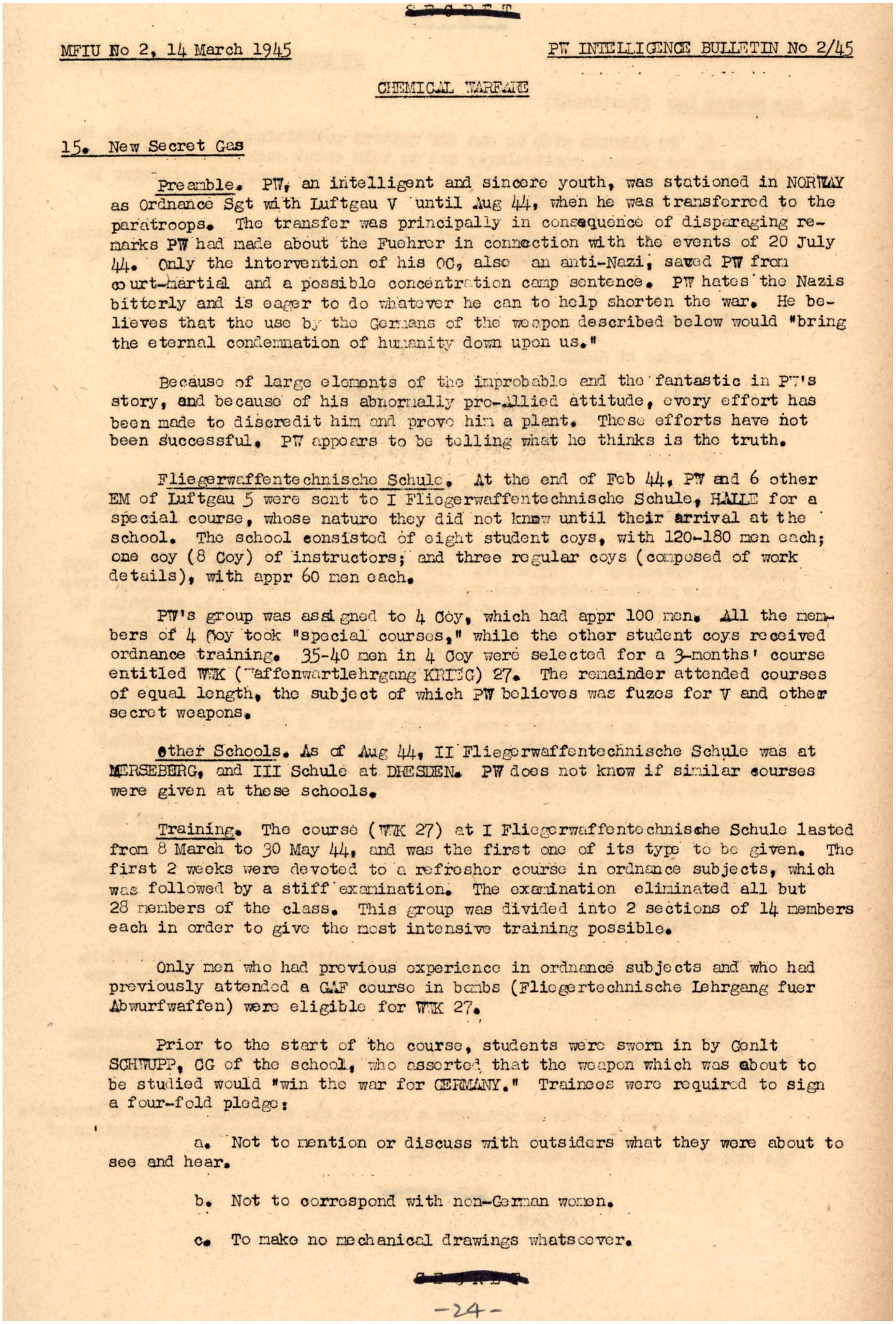
PW Intelligence Bulletin 1/47, 13 March 1945

Figure A.247: PW Intelligence Bulletin 1/47, 13 March 1945 [NARA RG 165, Entry NM84-79, Box 1915].

PW Intelligence Bulletin No 2/45, AFHRA folder 506.61952 Nos. 2/41--2/50 6 Mar--1 Apr 1945, IRIS 207533 THIS PAGE IS DECLASSIFIED IAW EO 13526



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MFIU No 2, 14 March 1945 PW INTELLIGENCE BULLETIN No 2/45

CHEMICAL WARFARE

15. New Secret Gas

Preamble. PW, an intelligent and sincere youth, was stationed in NORWAY as Ordnance Sgt with Luftgau V until Aug 44, when he was transferred to the paratroops. The transfer was principally in consequence of disparaging remarks PW had made about the Fuehrer in connection with the events of 20 July 44. Only the intervention of his OC, also an anti-Nazi, saved PW from court-martial and a possible concentration camp sentence. PW hates the Nazis bitterly and is eager to do whatever he can to help shorten the war. He believes that the use by the Germans of the weapon described below would "bring the eternal condemnation of humanity down upon us."

Because of large elements of the improbable and the fantastic in PW's story, and because of his abnormally pro-Allied attitude, every effort has been made to discredit him and prove him a plant. These efforts have not been successful. PW appears to be telling what he thinks is the truth.

Fliegerwaffentechnische Schule. At the end of Feb 44, PW and 6 other EM of Luftgau 5 were sent to I Fliegerwaffentechnische Schule, HALLE for a special course, whose nature they did not know until their arrival at the school. The school consisted of eight student coys, with 120-180 men each; one coy (8 Coy) of instructors; and three regular coys (composed of work details), with appr 60 men each.

PW's group was assigned to 4 Coy, which had appr 100 men. All the members of 4 Coy took "special courses," while the other student coys received ordnance training. 35-40 men in 4 Coy were selected for a 3-months' course entitled WWK (Waffenwartlehrgang KRIEG) 27. The remainder attended courses of equal length, the subject of which PW believes was fuzes for V and other secret weapons.

Other Schools. As of Aug 44, II Fliegerwaffentechnische Schule was at MERSEBERG, and III Schule at DRESDEN. PW does not know if similar courses were given at these schools.

Training. The course (WWK 27) at I Fliegerwaffentechnische Schule lasted from 8 March to 30 May 44, and was the first one of its type to be given. The first 2 weeks were devoted to a refresher course in ordnance subjects, which was followed by a stiff examination. The examination eliminated all but 28 members of the class. This group was divided into 2 sections of 14 members each in order to give the most intensive training possible.

Only men who had previous experience in ordnance subjects and who had previously attended a GAF course in bombs (Fliegertechnische Lehrgang fuer Abwurfwaffen) were eligible for WWK 27.

Prior to the start of the course, students were sworn in by Genlt SCHWUPP, CG of the school, who asserted that the weapon which was about to be studied would "win the war for GERMANY." Trainees were required to sign a four-fold pledge:

a. Not to mention or discuss with outsiders what they were about to see and hear.

b. Not to correspond with non-German women.

c. To make no mechanical drawings whatsoever.

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Figure A.248: PW Intelligence Bulletin 2/45, 14 March 1945 [AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533; AFHRA A5186, frames 0482–0489; also available at NARA RG 165, Entry NM84-79, Box 1917].

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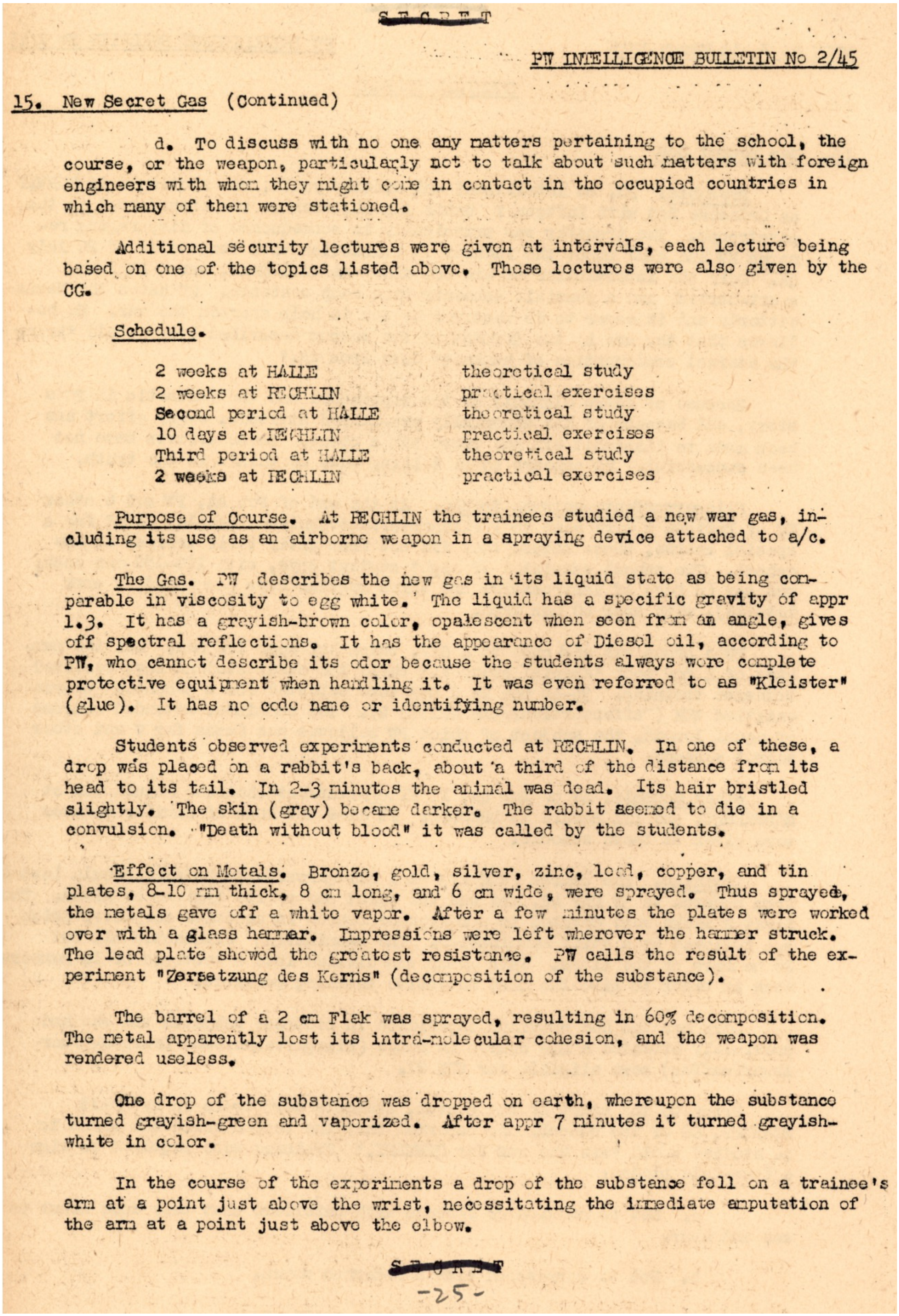

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PW INTELLIGENCE BULLETIN No 2/45

15. New Secret Gas (Continued)

d. To discuss with no one any matters pertaining to the school, the course, or the weapon, particularly not to talk about such matters with foreign engineers with whom they might come in contact in the occupied countries in which many of them were stationed.

Additional security lectures were given at intervals, each lecture being based on one of the topics listed above. These lectures were also given by the CG.

Schedule.

2 weeks at HALLE	theoretical study
2 weeks at RECHLIN	practical exercises
Second period at HALLE	theoretical study
10 days at RECHLIN	practical exercises
Third period at HALLE	theoretical study
2 weeks at RECHLIN	practical exercises

Purpose of Course. At RECHLIN the trainees studied a new war gas, including its use as an airborne weapon in a spraying device attached to a/c.

The Gas. PW describes the new gas in its liquid state as being comparable in viscosity to egg white. The liquid has a specific gravity of appr 1.3. It has a grayish-brown color, opalescent when seen from an angle, gives off spectral reflections. It has the appearance of Diesel oil, according to PW, who cannot describe its odor because the students always wore complete protective equipment when handling it. It was even referred to as "Kleister" (glue). It has no code name or identifying number.

Students observed experiments conducted at RECHLIN. In one of these, a drop was placed on a rabbit's back, about a third of the distance from its head to its tail. In 2-3 minutes the animal was dead. Its hair bristled slightly. The skin (gray) became darker. The rabbit seemed to die in a convulsion. "Death without blood" it was called by the students.

Effect on Metals. Bronze, gold, silver, zinc, lead, copper, and tin plates, 8-10 mm thick, 8 cm long, and 6 cm wide, were sprayed. Thus sprayed, the metals gave off a white vapor. After a few minutes the plates were worked over with a glass hammer. Impressions were left wherever the hammer struck. The lead plate showed the greatest resistance. PW calls the result of the experiment "Zersetzung des Kerns" (decomposition of the substance).

The barrel of a 2 cm Flak was sprayed, resulting in 60% decomposition. The metal apparently lost its intra-molecular cohesion, and the weapon was rendered useless.

One drop of the substance was dropped on earth, whereupon the substance turned grayish-green and vaporized. After appr 7 minutes it turned grayish-white in color.

In the course of the experiments a drop of the substance fell on a trainee's arm at a point just above the wrist, necessitating the immediate amputation of the arm at a point just above the elbow.

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Figure A.249: PW Intelligence Bulletin 2/45, 14 March 1945 [AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533; AFHRA A5186, frames 0482–0489; also available at NARA RG 165, Entry NM84-79, Box 1917].

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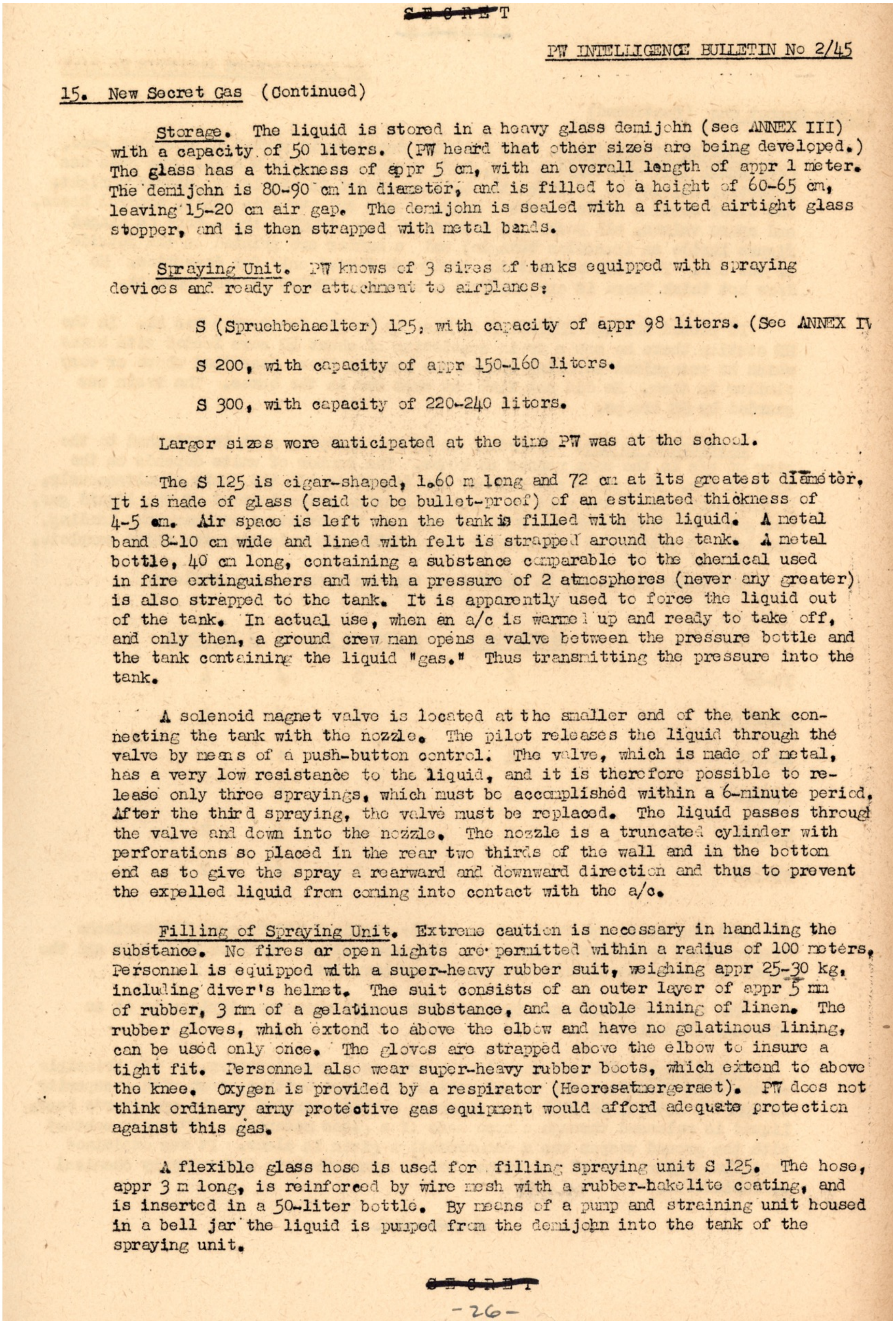

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PW INTELLIGENCE BULLETIN No 2/45

15. New Secret Gas (Continued)

Storage. The liquid is stored in a heavy glass demijohn (see ANNEX III) with a capacity of 50 liters. (PW heard that other sizes are being developed.) The glass has a thickness of appr 5 cm, with an overall length of appr 1 meter. The demijohn is 80-90 cm in diameter, and is filled to a height of 60-65 cm, leaving 15-20 cm air gap. The demijohn is sealed with a fitted airtight glass stopper, and is then strapped with metal bands.

Spraying Unit. PW knows of 3 sires of tanks equipped with spraying devices and ready for attachment to airplanes:

S (Spruchbehaelter) 125, with capacity of appr 98 liters. (See ANNEX IV

S 200, with capacity of appr 150-160 liters.

S 300, with capacity of 220-240 liters.

Larger sizes were anticipated at the time PW was at the school.

The S 125 is cigar-shaped, 1.60 m long and 72 cm at its greatest diameter. It is made of glass (said to be bullet-proof) of an estimated thickness of 4-5 cm. Air space is left when the tank is filled with the liquid. A metal band 8-10 cm wide and lined with felt is strapped around the tank. A metal bottle, 40 cm long, containing a substance comparable to the chemical used in fire extinguishers and with a pressure of 2 atmospheres (never any greater) is also strapped to the tank. It is apparently used to force the liquid out of the tank. In actual use, when an a/c is warmed up and ready to take off, and only then, a ground crew man opens a valve between the pressure bottle and the tank containing the liquid "gas." Thus transmitting the pressure into the tank.

A solenoid magnet valve is located at the smaller end of the tank connecting the tank with the nozzle. The pilot releases the liquid through the valve by means of a push-button control. The valve, which is made of metal, has a very low resistance to the liquid, and it is therefore possible to release only three sprayings, which must be accomplished within a 6-minute period. After the third spraying, the valve must be replaced. The liquid passes through the valve and down into the nozzle. The nozzle is a truncated cylinder with perforations so placed in the rear two thirds of the wall and in the bottom end as to give the spray a rearward and downward direction and thus to prevent the expelled liquid from coming into contact with the a/c.

Filling of Spraying Unit. Extreme caution is necessary in handling the substance. No fires or open lights are permitted within a radius of 100 meters. Personnel is equipped with a super-heavy rubber suit, weighing appr 25-30 kg, including diver's helmet. The suit consists of an outer layer of appr 5 mm of rubber, 3 mm of a gelatinous substance, and a double lining of linen. The rubber gloves, which extend to above the elbow and have no gelatinous lining, can be used only once. The gloves are strapped above the elbow to insure a tight fit. Personnel also wear super-heavy rubber boots, which extend to above the knee. Oxygen is provided by a respirator (Heeresatmergeraet). PW does not think ordinary army protective gas equipment would afford adequate protection against this gas.

A flexible glass hose is used for filling spraying unit S 125. The hose, appr 3 m long, is reinforced by wire mesh with a rubber-bakelite coating, and is inserted in a 50-liter bottle. By means of a pump and straining unit housed in a bell jar the liquid is pumped from the demijohn into the tank of the spraying unit.

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Figure A.250: PW Intelligence Bulletin 2/45, 14 March 1945 [AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533; AFHRA A5186, frames 0482–0489; also available at NARA RG 165, Entry NM84-79, Box 1917].

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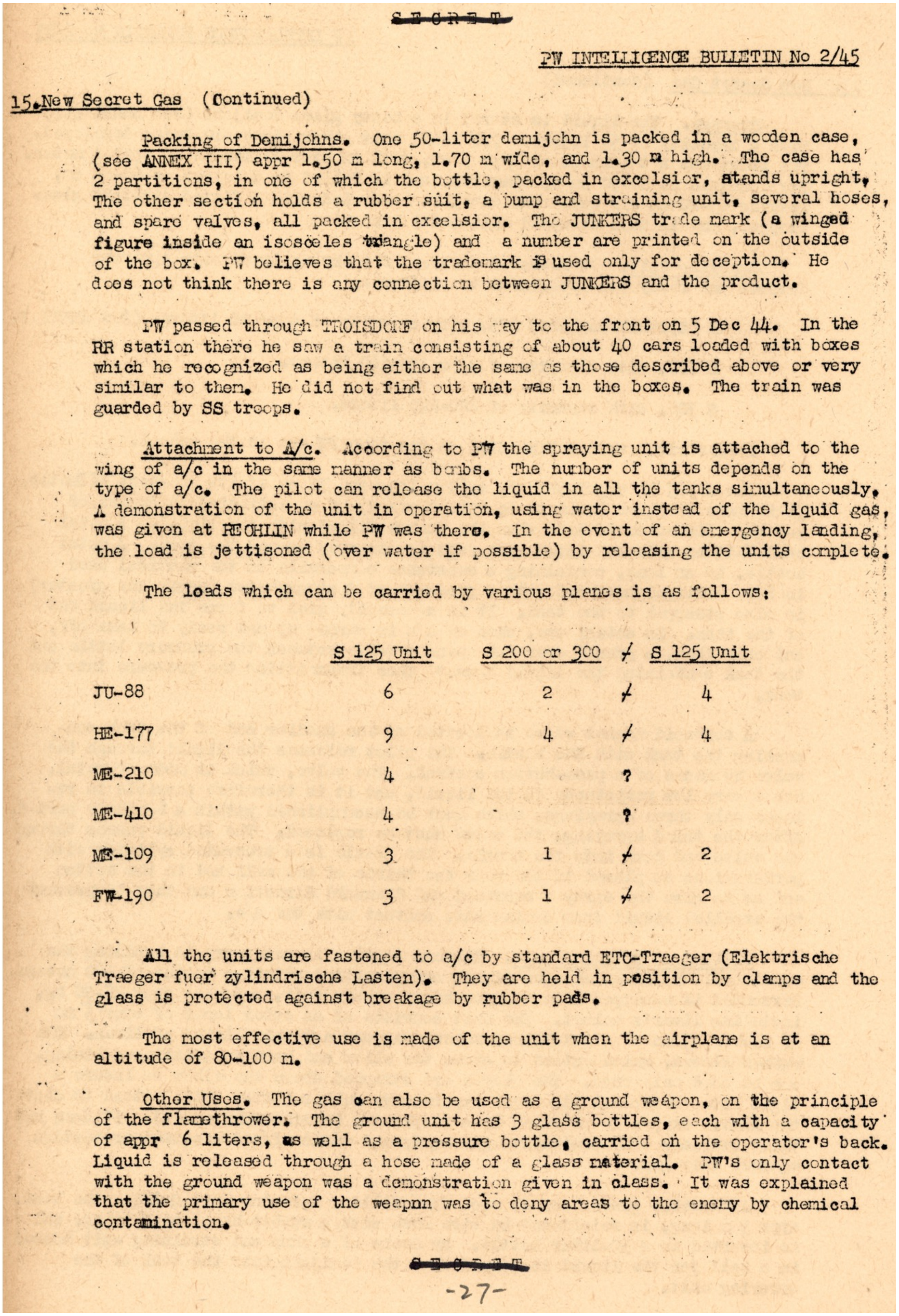

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PW INTELLIGENCE BULLETIN No 2/45

15. New Secret Gas (Continued)

Packing of Demijohns. One 50-liter demijohn is packed in a wooden case, (see ANNEX III) appr 1.50 m long, 1.70 m wide, and 1.30 m high. The case has 2 partitions, in one of which the bottle, packed in excelsior, stands upright. The other section holds a rubber suit, a pump and straining unit, several hoses, and spare valves, all packed in excelsior. The JUNKERS trade mark (a winged figure inside an isosceles triangle) and a number are printed on the outside of the box. PW believes that the trademark is used only for deception. He does not think there is any connection between JUNKERS and the product.

PW passed through TROISDORF on his way to the front on 5 Dec 44. In the RR station there he saw a train consisting of about 40 cars loaded with boxes which he recognized as being either the same as those described above or very similar to them. He did not find out what was in the boxes. The train was guarded by SS troops.

Attachment to A/c. According to PW the spraying unit is attached to the wing of a/c in the same manner as bombs. The number of units depends on the type of a/c. The pilot can release the liquid in all the tanks simultaneously. A demonstration of the unit in operation, using water instead of the liquid gas, was given at RECHLIN while PW was there. In the event of an emergency landing, the load is jettisoned (over water if possible) by releasing the units complete.

The loads which can be carried by various planes is as follows;

	S 125 Unit	S 200 or 300	+	S 125 Unit
JU-88	6	2	+	4
HE-177	9	4	+	4
ME-210	4		?	
ME-410	4		?	
ME-109	3	1	+	2
FW-190	3	1	+	2

All the units are fastened to a/c by standard ETC-Traeger (Elektrische Traeger fuer zylindrische Lasten). They are held in position by clamps and the glass is protected against breakage by rubber pads.

The most effective use is made of the unit when the airplane is at an altitude of 80-100 m.

Other Uses. The gas can also be used as a ground weapon, on the principle of the flamethrower. The ground unit has 3 glass bottles, each with a capacity of appr 6 liters, as well as a pressure bottle, carried on the operator's back. Liquid is released through a hose made of a glass material. PW's only contact with the ground weapon was a demonstration given in class. It was explained that the primary use of the weapnn was to deny areas to the enemy by chemical contamination.

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Figure A.251: PW Intelligence Bulletin 2/45, 14 March 1945 [AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533; AFHRA A5186, frames 0482–0489; also available at NARA RG 165, Entry NM84-79, Box 1917].

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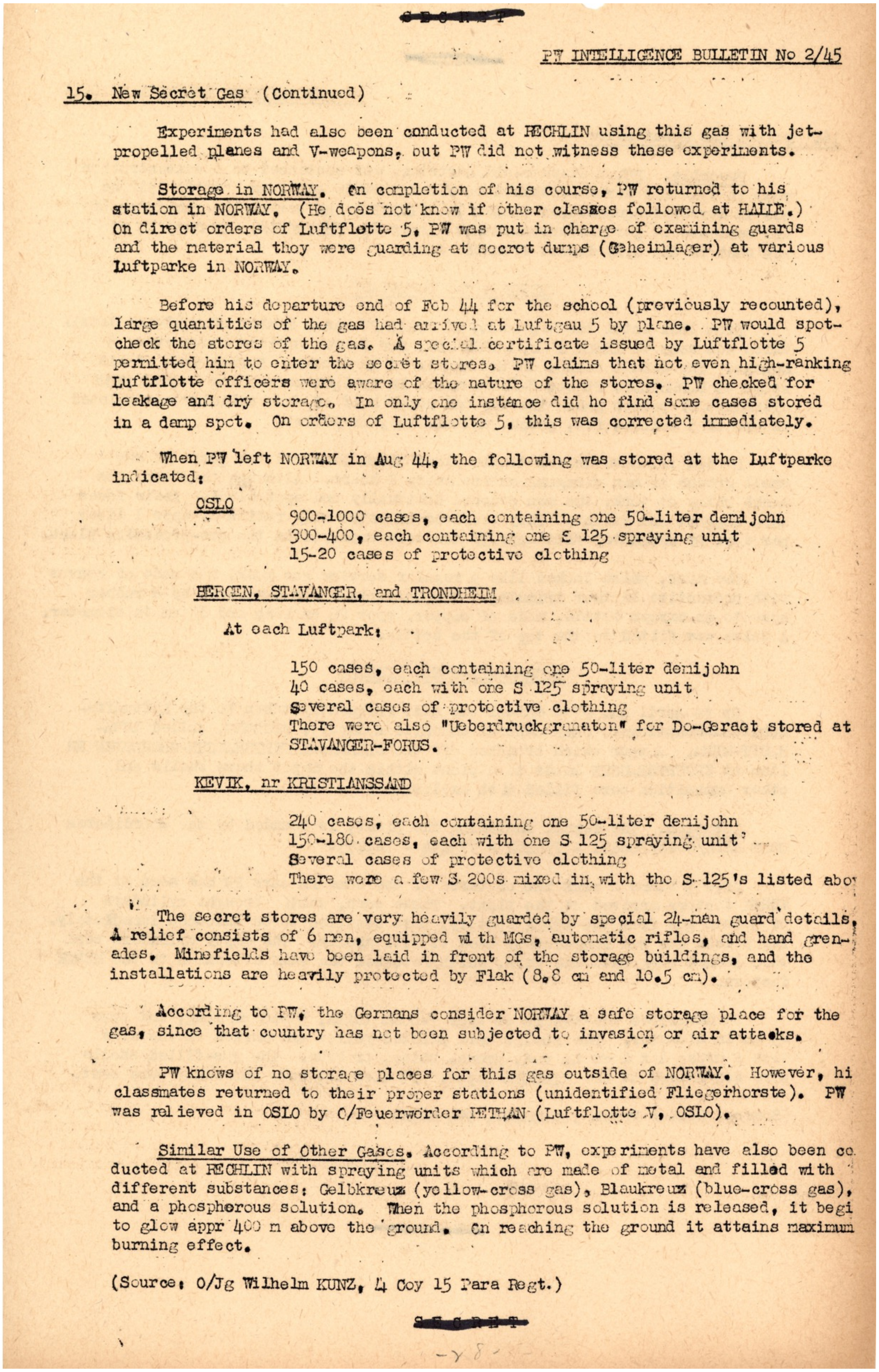

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PW INTELLIGENCE BULLETIN No 2/45

15. New Secret Gas (Continued)

Experiments had also been conducted at RECHLIN using this gas with jet-propelled planes and V-weapons, but PW did not witness these experiments.

Storage in NORWAY. On completion of his course, PW returned to his station in NORWAY. (He does not know if other classes followed at HALLE.) On direct orders of Luftflotte 5, PW was put in charge of examining guards and the material they were guarding at secret dumps (Geheimlager) at various Luftparke in NORWAY.

Before his departure end of Feb 44 for the school (previously recounted), large quantities of the gas had arrived at Luftgau 5 by plane. PW would spot-check the stores of the gas. A special certificate issued by Luftflotte 5 permitted him to enter the secret stores. PW claims that not even high-ranking Luftflotte officers were aware of the nature of the stores. PW checked for leakage and dry storage. In only one instance did he find some cases stored in a damp spot. On orders of Luftflotte 5, this was corrected immediately.

When PW left NORWAY in Aug 44, the following was stored at the Luftparke indicated:

OSLO

900-1000 cases, each containing one 50-liter demijohn
300-400, each containing one S 125 spraying unit
15-20 cases of protective clothing

BERGEN, STAVANGER, and TRONDHEIM

At each Luftpark:

150 cases, each containing one 50-liter demijohn
40 cases, each with one S 125 spraying unit
Several cases of protective clothing
There were also "Ueberdruckgranaten" for Do-Geraet stored at STAVANGER-FORUS.

KEVIK, nr KRISTIANSSAND

240 cases, each containing one 50-liter demijohn
150-180 cases, each with one S 125 spraying unit
Several cases of protective clothing
There were a few S 200s mixed in with the S-125's listed abo

The secret stores are very heavily guarded by special 24-man guard details. A relief consists of 6 men, equipped with MGs, automatic rifles, and hand grenades. Minefields have been laid in front of the storage buildings, and the installations are heavily protected by Flak (8.8 cm and 10.5 cm).

According to PW, the Germans consider NORWAY a safe storage place for the gas, since that country has not been subjected to invasion or air attacks.

PW knows of no storage places for this gas outside of NORWAY. However, hi classmates returned to their proper stations (unidentified Fliegerhorste). PW was relieved in OSLO by O/Feuerwerker PETHAN (Luftflotte V, OSLO).

Similar Use of Other Gases. According to PW, experiments have also been co ducted at RECHLIN with spraying units which are made of metal and filled with different substances: Gelbkreuz (yellow-cross gas), Blaukreuz (blue-cross gas), and a phosphorous solution. When the phosphorous solution is released, it begi to glow appr 400 m above the ground. On reaching the ground it attains maximum burning effect.

(Source: O/Jg Wilhelm KUNZ, 4 Coy 15 Para Regt.)

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Figure A.252: PW Intelligence Bulletin 2/45, 14 March 1945 [AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533; AFHRA A5186, frames 0482–0489; also available at NARA RG 165, Entry NM84-79, Box 1917].

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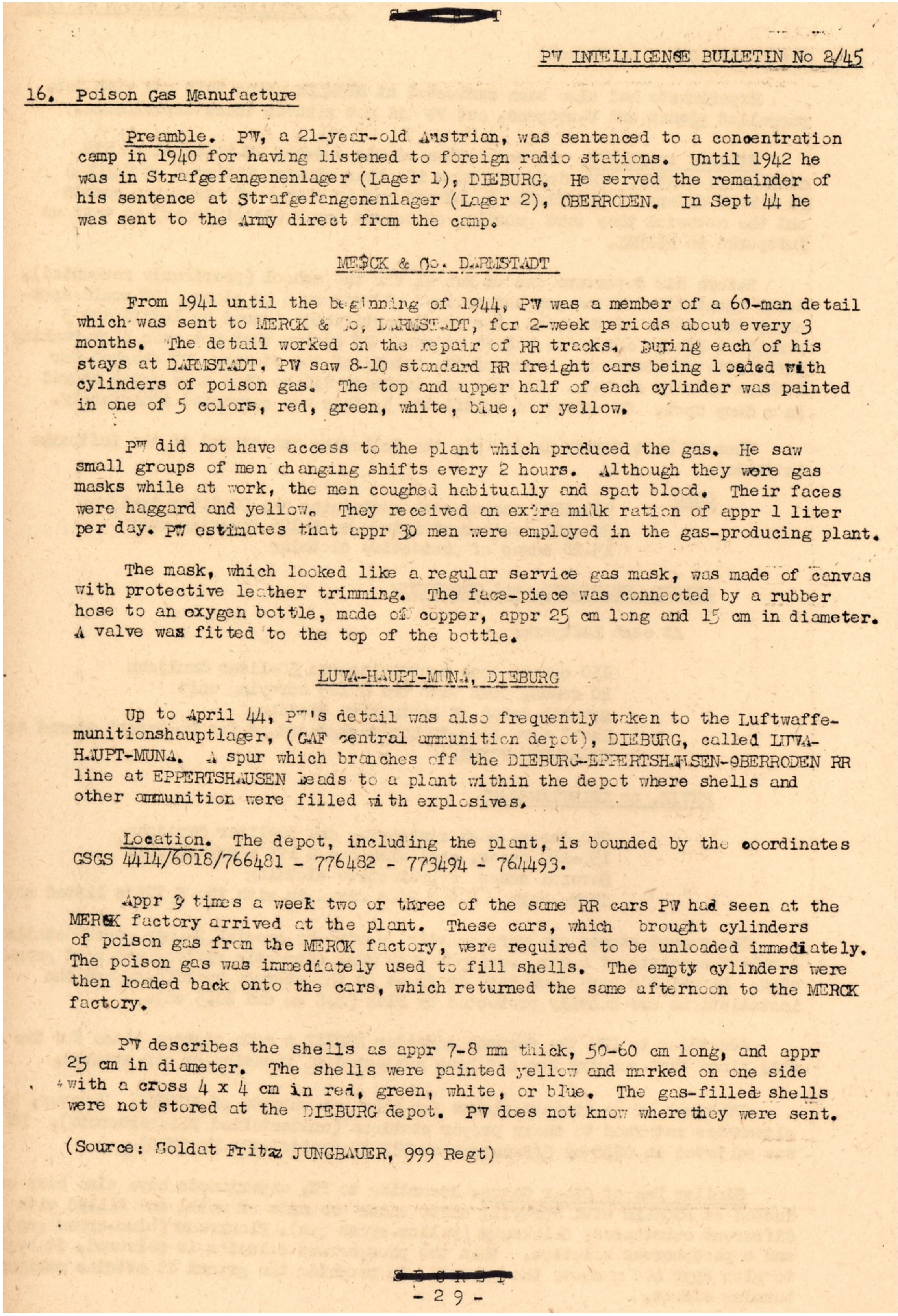

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PW INTELLIGENCE BULLETIN No 2/45

16. Poison Gas Manufacture

Preamble. PW, a 21-year-old Austrian, was sentenced to a concentration camp in 1940 for having listened to foreign radio stations. Until 1942 he was in Strafgefangenenlager (Lager 1), DIEBURG. He served the remainder of his sentence at Strafgefangenenlager (Lager 2), OBERRODEN. In Sept 44 he was sent to the Army direct from the camp.

MERCK & Co. DARMSTADT

From 1941 until the beginning of 1944, PW was a member of a 60-man detail which was sent to MERCK & Co, DARMSTADT, for 2-week periods about every 3 months. The detail worked on the repair of RR tracks. During each of his stays at DARMSTADT, PW saw 8-10 standard RR freight cars being loaded with cylinders of poison gas. The top and upper half of each cylinder was painted in one of 5 colors, red, green, white, blue, or yellow.

PW did not have access to the plant which produced the gas. He saw small groups of men changing shifts every 2 hours. Although they wore gas masks while at work, the men coughed habitually and spat blood. Their faces were haggard and yellow. They received an extra milk ration of appr 1 liter per day. PW estimates that appr 30 men were employed in the gas-producing plant.

The mask, which looked like a regular service gas mask, was made of canvas with protective leather trimming. The face-piece was connected by a rubber hose to an oxygen bottle, made of copper, appr 25 cm long and 15 cm in diameter. A valve was fitted to the top of the bottle.

LUVA-HAUPT-MUNA, DIEBURG

Up to April 44, PW's detail was also frequently taken to the Luftwaffe-munitionshauptlager, (GAF central ammunition depot), DIEBURG, called LUVA-HAUPT-MUNA. A spur which branches off the DIEBURG-EPPERTSHAUSEN-OBERRODEN RR line at EPPERTSHAUSEN leads to a plant within the depot where shells and other ammunition were filled with explosives.

Location. The depot, including the plant, is bounded by the coordinates GSGS 4414/6018/766481 - 776482 - 773494 - 764493.

Appr 3 times a week two or three of the same RR cars PW had seen at the MERCK factory arrived at the plant. These cars, which brought cylinders of poison gas from the MERCK factory, were required to be unloaded immediately. The poison gas was immediately used to fill shells. The empty cylinders were then loaded back onto the cars, which returned the same afternoon to the MERCK factory.

PW describes the shells as appr 7-8 mm thick, 50-60 cm long, and appr 25 cm in diameter. The shells were painted yellow and marked on one side with a cross 4 x 4 cm in red, green, white, or blue. The gas-filled shells were not stored at the DIEBURG depot. PW does not know where they were sent.

(Source: Soldat Fritz JUNGBAUER, 999 Regt)

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Figure A.253: PW Intelligence Bulletin 2/45, 14 March 1945 [AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533; AFHRA A5186, frames 0482–0489; also available at NARA RG 165, Entry NM84-79, Box 1917].

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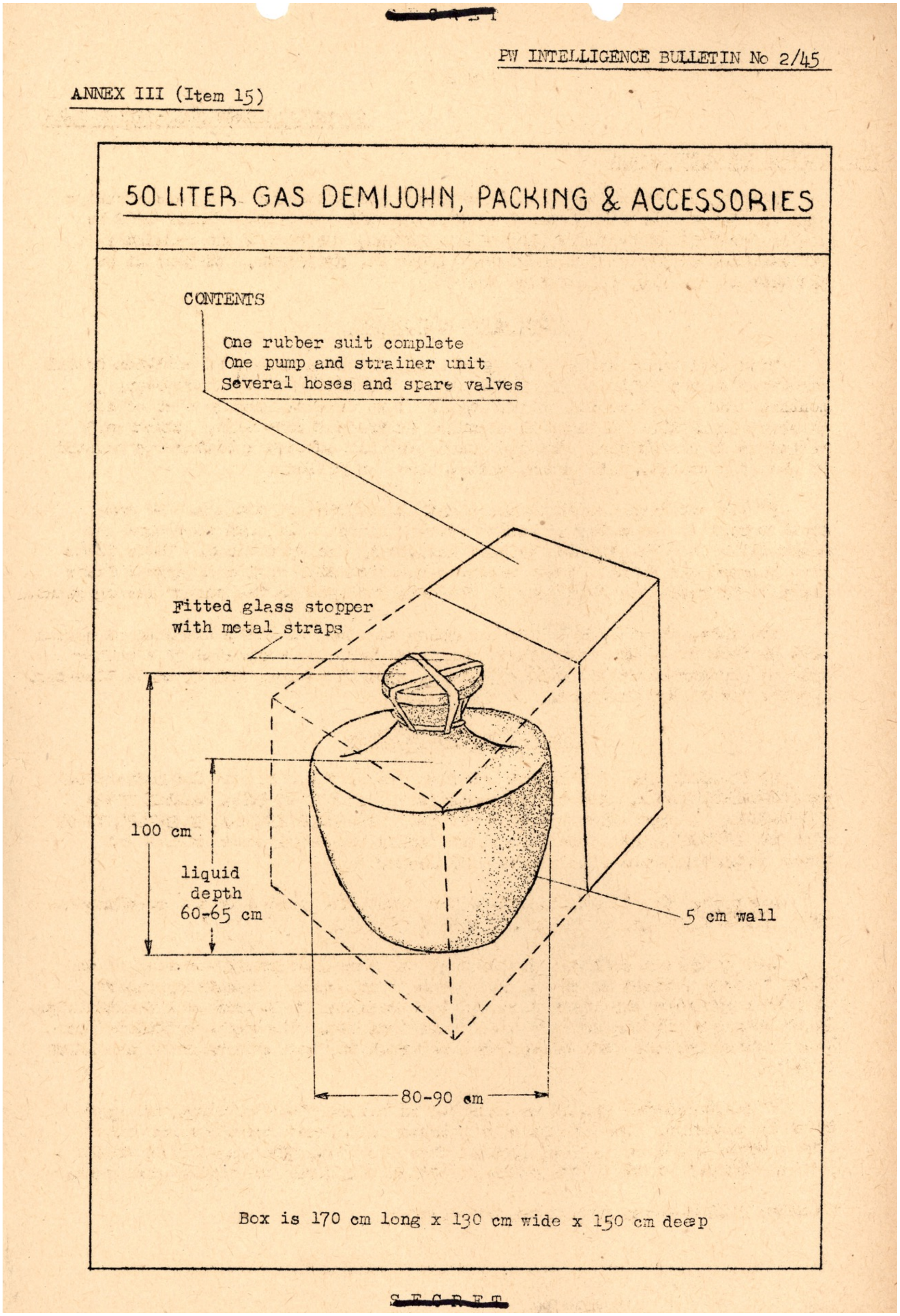

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PW INTELLIGENCE BULLETIN No 2/45

ANNEX III (Item 15)

50 LITER GAS DEMIJOHN, PACKING & ACCESSORIES

CONTENTS

One rubber suit complete
One pump and strainer unit
Several hoses and spare valves

Fitted glass stopper with metal straps
100 cm
liquid depth 60-65 cm
5 cm wall
80-90 cm

Box is 170 cm long x 130 cm wide x 150 cm deep

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Figure A.254: PW Intelligence Bulletin 2/45, 14 March 1945 [AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533; AFHRA A5186, frames 0482–0489; also available at NARA RG 165, Entry NM84-79, Box 1917].

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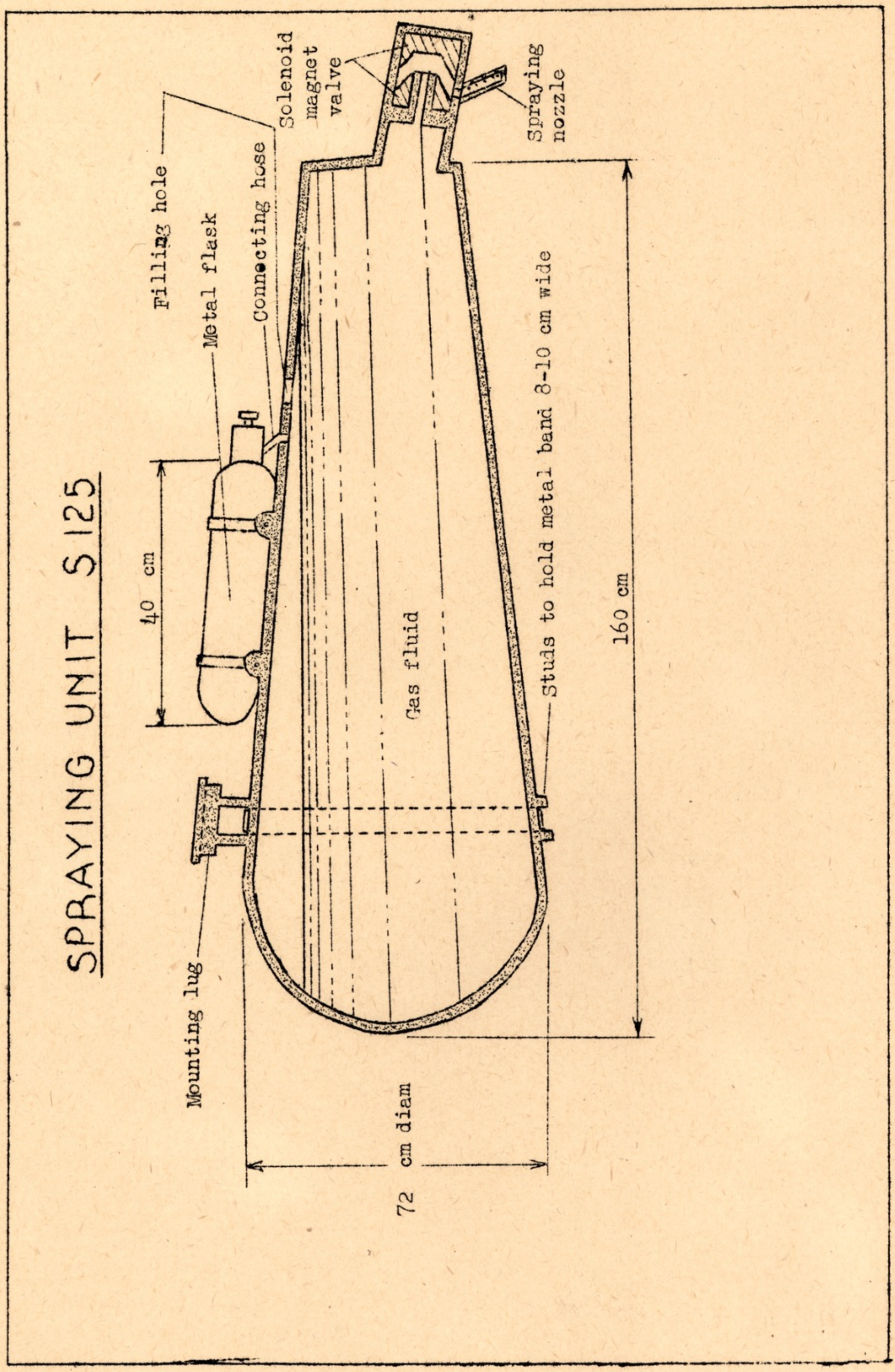
PW INTELLIGENCE BULLETIN No 2/45

ANNEX IV (Item 15)


SPRAYING UNIT S 125
Filling hole
Metal flask
Connecting hose
Solenoid magnet valve
Spraying nozzle
40 cm
Gas fluid
Studs to hold metal band 8-10 cm wide
160 cm
Mounting lug
72 cm diam

[redacted]

Figure A.255: PW Intelligence Bulletin 2/45, 14 March 1945 [AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533; AFHRA A5186, frames 0482–0489; also available at NARA RG 165, Entry NM84-79, Box 1917].

A.4.2 Allied/Axis Threats of Mutual Assured Destruction

[Unlike the view in conventional history books, the following documents demonstrate that both Axis and Allied forces very nearly used chemical weapons and other weapons of mass destruction (WMDs) in World War II, and that the threats by both sides to use chemical and other WMDs played an enormously important role in how and why the war was waged as it actually was.

Germany stockpiled and very seriously considered using its chemical weapons (both the newer ones like nerve agents and the older ones like mustard agent) against Allied targets, especially to halt Russian advances on the Eastern Front. It also appears to have had fuel-air explosives (p. 557), biological weapons (Section A.3), and nuclear weapons (Appendix D; see especially Section D.13).

The United States and United Kingdom stockpiled and very seriously considered using their own copies of the chemical weapons that Germany had invented in the previous war (mustard and phosgene) with the explicit goal of killing millions of civilians in German cities. In addition, the U.K. had a stockpile of anthrax-infected cattle feed that could be dropped on German farms, and the U.S. had fission products from its recently built breeder reactors that could be dropped on German cities as a radiological weapon.

These documents show that the Allies considered using their chemical and other WMDs not only in response to any use of German chemical weapons, but also in response to the use of other novel German weapons, such as V-2 rockets carrying conventional explosives. Thus the Allies almost certainly would have launched a massive attack on German civilian populations if Germany had used any form of WMDs, including nuclear or biological weapons. This was confirmed by the German general Heinrich Kittel in a secret recording in January 1945 (pp. 3786–3791). See also pp. 2645–2646.

These documents are also a clear example of how Allied countries covered up important wartime events and decisions, kept information about them classified for decades, and are known to still be keeping relevant archival documents classified and unavailable to the public and to historians.

Thus behind the conventional warfare history of World War II that the public knows, there was a far less visible yet likely even more important game of deterrence and brinksmanship between the Allied and Axis forces involving weapons of mass destruction. On the Allied side were massive numbers of crude but effective weapons. On the Axis side were massive numbers of far more sophisticated chemical weapons, as well as currently unclear but apparently quite real numbers of nuclear weapons, biological weapons, and other novel weapons such as fuel-air explosives. Each side appears to have been well aware of the threats posed by the other side, and that shaped their strategic choices in how the war played out.

[For additional information and archival references, see Gellermann 1986.]

The details of these Axis and Allied programs should be clarified, and this aspect of the war should be given the treatment it deserves in books on the history of World War II.]

Henry Picker. 2009. *Hitlers Tischgespräche im Führerhauptquartier.* 2nd ed. Berlin: Propyläen-Taschenbuch bei Ullstein. p. 668.

Aus diesem Grunde recherchierte Hitler Okt./Nov. 1944 noch einmal bei der britischen Regierung bezüglich eines Minimalagreements, das den Briten die Erhaltung ihres Empire und Deutschland die Stabilisierung der Ostfront auf der Linie Memel—Kaschau [Klaipeda—Kosice] unter enger Anlehnung an die Flüsse Narew und Weichsel tolerieren sollte. Auf Leys Vorschlag wollte Hitler auf dieser etwa 750 km langen Front zwischen die deutschen und die russischen Truppen einen Giftgas-Vorhang legen. Zur Vorbereitung hatte er bereits für die deutsche Wehrmacht Millionen von Gasmasken produzieren und Gaskriegvorbereitungen befehlen lassen. Für die Giftgaswand wollte Hitler die Kampfstoffe Lost und Tabun verwenden. Seit 1939 hatte er monatlich im Schnitt 3100 t Lost und 1000 t Tabun herstellen lassen. Lost machte mit ihm verseuchte Gebiete längerfristig unbetretbar, da es Nervenstörungen, Sehbehinderungen, Atembeschwerden und Hautverätzungen herbeiführte. Tabun war tödlich selbst bei kleinsten Dosen. Die Gasmasken der Roten Armee waren für beide Gifte in der deutschen Zusammensetzung kein ausreichender Schutz. Churchill liess Hitler Vorschläge jedoch zurückweisen. Ja, er drohte, Grossbritannien werde als Gegenmassnahme sofort seine gesamten Giftgasvorräte von 32000 t Gelbkreuz und Phosgengas über Deutschlands Großstätde “abregnen” lassen und damit 2500 qkm deutschen Großstadtraums total lebensvernichtend zerstören. Hitler entnahm daraus, dass Churchill selbst ein Deutschland in den Vorkriegsgrenzen nicht überleben lassen wollte.

For this reason, in Oct./Nov. 1944, Hitler again made inquiries of the British government concerning a minimum agreement that would tolerate the British maintaining their Empire and Germany stabilizing the Eastern Front on the Memel-Kaschau [Klaipeda—Kosice] line, closely following the Narew and Vistula Rivers. At Ley’s suggestion, Hitler wanted to place a poison gas curtain between the German and Russian troops on this front, which was about 750 km long. In preparation, he had already had millions of gas masks produced for the German Wehrmacht and gas war preparations ordered. For the poison gas wall Hitler wanted to use the warfare agents mustard and tabun. Since 1939, he had an average of 3,100 tons of mustard and 1,000 tons of tabun produced every month. Mustard made areas contaminated with it inaccessible for a longer period of time, since it caused nerve disorders, impaired vision, respiratory problems and skin burns. Tabun was lethal even at the smallest doses. Red Army gas masks were inadequate protection for either poison in the German composition. Churchill, however, made Hitler reject the suggestions. Yes, he threatened that Britain would immediately “rain” its entire poison gas stockpile of 32,000 tons of mustard and phosgene gas over Germany’s major cities as a countermeasure, totally destroying 2,500 sq. km. of German urban space. Hitler took from this that Churchill did not want to let Germany survive even within its prewar borders.

Rochus Misch. 2014. *Hitler’s Last Witness: The Memoirs of Hitler’s Bodyguard.* Barnsley, U.K.: Frontline Books. p. 60.

I remember seeing a report about the development of the atom bomb. It stated that the American research was at least nine months behind the German. [...] The Western Allies had threatened that, if Germany used the atom bomb, they would assemble 15,000 aircraft in North Africa and use them to drench all of Germany with poison gas.

[See also p. 4667 and the other sources quoted throughout Section D.13.]

Winston Churchill. 10 May 1942. Broadcast Report on the War. British Library of Information. [https://www.ibiblio.org/pha/policy/1942/1942-05-10a.html]

We send our salutations to the Russian armies and we hope that the thousands of tanks and aeroplanes which have been carried to their aid from Britain and America will be a useful contribution to their own magnificently developed and reorganized munitions resources.

There is, however, one serious matter which I must mention to you. The Soviet Government have expressed to us the view that the Germans in the desperation of their assault may make use of poison gas against the armies and people of Russia. We are, ourselves, firmly resolved not to use this odious weapon unless it is used first by the Germans. Knowing our Hun, however, we have not neglected to make preparations on a formidable scale.

I wish now to make it plain that we shall treat the unprovoked use of poison gas against our Russian ally exactly as if it were used against ourselves and if we are satisfied that this new outrage has been committed by Hitler we will use our great and growing air superiority in the West to carry gas warfare on the largest possible scale far and wide against military objectives in Germany.

It is thus for Hitler to choose whether he wishes to add this additional horror to aerial warfare.

We have for some time past been bringing our defensive and precautionary arrangements up to date and I now give public warning so that there may be no carelessness or neglect. Of one thing I am sure: that the British people who have entered into the full comradeship of war with our Russian ally will not shrink from any sacrifice or trial which that comradeship may require.

Meanwhile, our deliveries of tanks, aircraft and munitions to Russia from Britain and from the United States continue upon the full scale. We have the duty of escorting the northern convoys to their destination.

[In addition to being broadcast on radio stations, Churchill's speech was printed and reported in many newspapers around the world. See for example:

Text of Churchill Speech. *Evening Star* (Washington, DC) 11 May 1942, p. A-13.
https://chroniclingamerica.loc.gov/lccn/sn83045462/1942-05-11/ed-1/seq-15/

Churchill Optimistic In War Report, Warns Nazis on Poison Gas. *Evening Star* (Washington, DC) 11 May 1942, p. A-2. https://chroniclingamerica.loc.gov/lccn/sn83045462/1942-05-11/ed-1/seq-4/

It was surely noticed by German officials, as Churchill intended.]

Urgency of Gas Warning. *The Courier-Mail* (Brisbane, Queensland, Australia) 1943-04-24 p. 2.

LONDON, April 23 (Special—A.A.P.).—Mr. Churchill's warning that the Germans might soon use gas against the Russians is regarded as grave.

Without the customary notice to the Press, and at the unusual hour of 1 a.m., the statement was issued from No. 10 Downing Street as follows:—

> "Reports have been received from several sources that Hitler is preparing to use poison gas on the Russian front.
>
> "Accordingly the Government will take early occasion to renew the Prime Minister's warning of last year that any use of poison gas against our Russian allies by the Nazis or their satellites will immediately be followed by the fullest possible use of this process of war upon German munition centres, sea ports, and other military objectives in Germany.
>
> "British resources and the scale of delivery have greatly increased since last year.
>
> "Necessary precautionary measures against reprisals already have been enjoined by competent authorities in the United Kingdom."

Fresh Advice

Issue of the statement so suddenly and at 1 a.m. is taken to mean that Mr. Churchill received further information on Germany's gas intentions of such a nature that he did not hesitate, despite the late hour, to issue it to the newspapers immediately.

Soon after issue of the statement, the B.B.C. broadcast it fully to the German people. The announcer read the statement without any preliminaries, and repeated it after the news bulletin.

Mr. Churchill's earlier warning was given in a broadcast on May 10, 1942. After 24 hours' silence the German radio then said that Germany would abide by the pledge given at the outbreak, namely, that Germany would not use poison gas unless her enemies used it first.

Hitler in Rage?

An official of the Soviet Embassy told the Daily Mail: "We passed on to the British Foreign Office information that supplies of poison gas recently reached the German armies on the Russian Front."

Reports have long been current that Germany's setbacks, particularly the tremendous effect of the R.A.F.'s bombing, have sent Hitler into a rage.

It is felt in London that Hitler's relative inaction in Europe is not because his resources are so strained, and may prove very deceptive.

[See also:

Britain Warns Nazis on Gas; Hears They Plan to Use It; ‘Several Sources’ Report Hitler Is Ready to Employ Lethal Fumes in Russia—Instant Reprisals Promised. *New York Times* 22 April 1943 p. 1. https://www.nytimes.com/1943/04/22/archives/britain-warns-nazis-on-gas-hears-they-plan-to-use-it-several.html

Churchill Promises Immediate Reprisals If Nazis Use Gas. *Evening Star* (Washington, DC) 22 April 1943 p. B-18. https://chroniclingamerica.loc.gov/lccn/sn83045462/1943-04-22/ed-1/seq-34/

Britain Warns Nazis on Gas. *Daily News* (Los Angeles) 22 April 1943 p. 17. https://cdnc.ucr.edu/?a=d&d=DNLA19430422.1.17

The story was also printed in many other newspapers around the world.]

Leaflets such as this one (Fig. A.256) were dropped on Germany by Allied planes in 1943 [Gellermann 1986, p. 245].

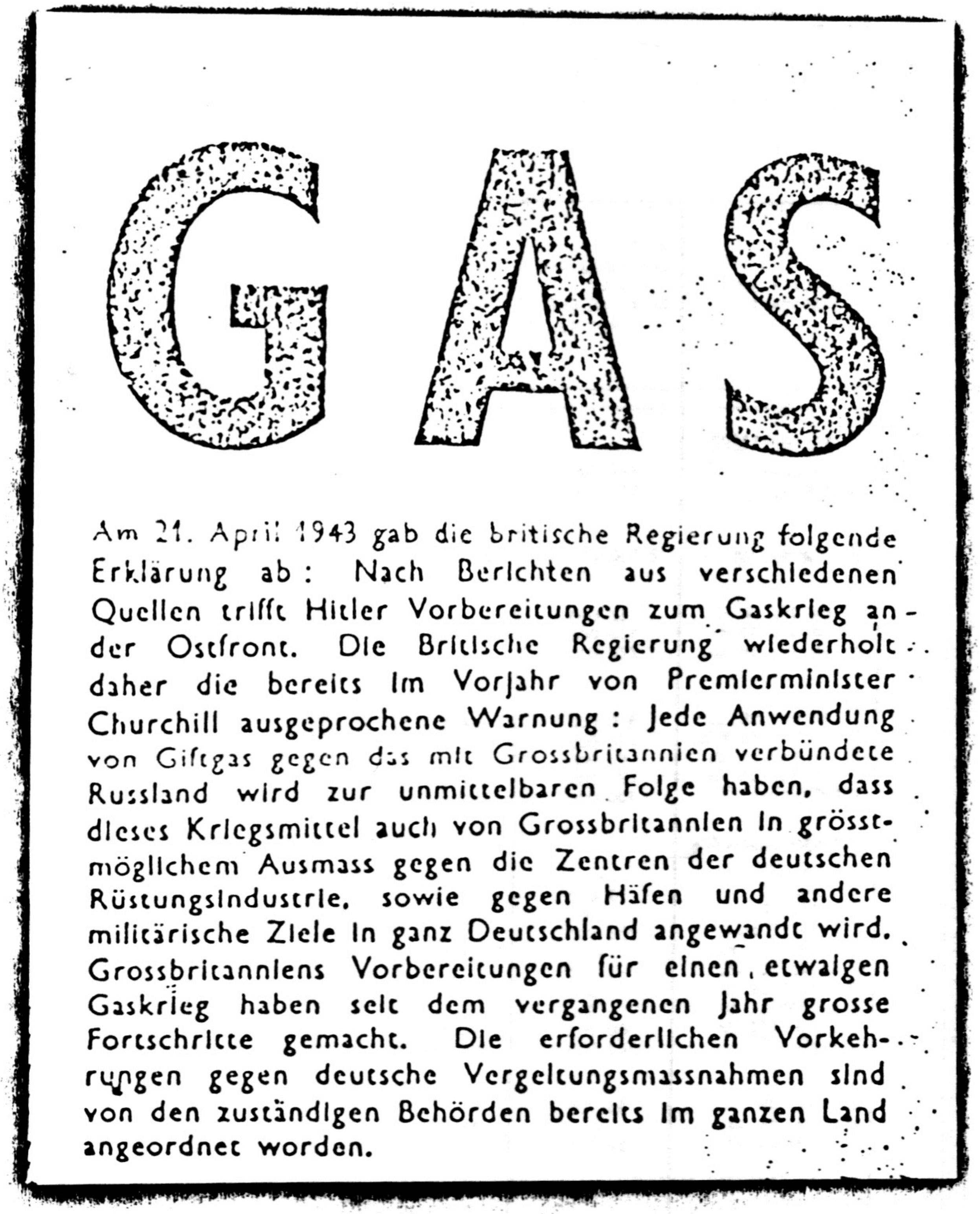
GAS

Am 21. April 1943 gab die britische Regierung folgende Erklärung ab: Nach Berichten aus verschiedenen Quellen trifft Hitler Vorbereitungen zum Gaskrieg an der Ostfront. Die Britische Regierung wiederholt daher die bereits im Vorjahr von Premierminister Churchill ausgesprochene Warnung: Jede Anwendung von Giftgas gegen das mit Grossbritannien verbündete Russland wird zur unmittelbaren Folge haben, dass dieses Kriegsmittel auch von Grossbritannien in grösstmöglichem Ausmass gegen die Zentren der deutschen Rüstungsindustrie, sowie gegen Häfen und andere militärische Ziele in ganz Deutschland angewandt wird. Grossbritanniens Vorbereitungen für einen etwaigen Gaskrieg haben seit dem vergangenen Jahr grosse Fortschritte gemacht. Die erforderlichen Vorkehrungen gegen deutsche Vergeltungsmassnahmen sind von den zuständigen Behörden bereits im ganzen Land angeordnet worden.

GAS

On 21 April 1943, the British government issued the following statement: According to reports from various sources, Hitler is making preparations for gas warfare on the Eastern Front. The British Government therefore repeats the warning already issued the previous year by Prime Minister Churchill: Any use of poison gas against Russia, which is an ally of Great Britain, will have the immediate consequence that this means of war will also be used by Great Britain to the greatest possible extent against the centers of the German armaments industry, as well as against ports and other military targets throughout Germany. Britain’s preparations for a possible gas war have made great strides since last year. The necessary precautions against German retaliatory measures have already been ordered by the relevant authorities throughout the country.

[Note that this warning translated into German is essentially the same as the statement that the U.K. government issued to international media (p. 2635). Rushed distribution of this warning in both forms suggests that Allied intelligence was convinced that Germany was highly likely to launch chemical attacks on the Eastern Front within a matter of days or weeks, and that the United Kingdom wanted to do everything possible to deter that.]



GAS

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Figure A.256: Leaflets such as this one were dropped on Germany by Allied planes in 1943 [Gellermann 1986, p. 245]. See the translation on p. 2636.

Franklin D. Roosevelt. 8 June 1943. Statement Warning the Axis Against Using Poison Gas. [Online by Gerhard Peters and John T. Woolley, The American Presidency Project. https://www.presidency.ucsb.edu/documents/statement-warning-the-axis-against-using-poison-gas]

From time to time since the present war began there have been reports that one or more of the Axis powers were seriously contemplating use of poisonous or noxious gases or other inhumane devices of warfare.

I have been loath to believe that any Nation, even our present enemies, could or would be willing to loose upon mankind such terrible and inhumane weapons. However, evidence that the Axis powers are making significant preparations indicative of such an intention is being reported with increasing frequency from a variety of sources.

Use of such weapons has been outlawed by the general opinion of civilized mankind. This country has not used them, and I hope that we never will be compelled to use them. I state categorically that we shall under no circumstances resort to the use of such weapons unless they are first used by our enemies.

As President of the United States and as Commander in Chief of the American armed forces, I want to make clear beyond all doubt to any of our enemies contemplating a resort to such desperate and barbarous methods that acts of this nature committed against any one of the United Nations will be regarded as having been committed against the United States itself and will be treated accordingly. We promise to any perpetrators of such crimes full and swift retaliation in kind and I feel obliged now to warn the Axis armies and the Axis peoples, in Europe and in Asia, that the terrible consequences of any use of these inhumane methods on their part will be brought down swiftly and surely upon their own heads. Any use of gas by any Axis power, therefore, will immediately be followed by the fullest possible retaliation upon munition centers, seaports, and other military objectives throughout the whole extent of the territory of such Axis country.

[Roosevelt's statement was published around the world as a clear message to the Axis powers that the United States was prepared to use chemical weapons if the Axis used anything other than conventional weapons.

See for example:

U.S. Will Retaliate Against Use of Gas, President Declares. *Evening Star* (Washington, DC) 1943-06-09 p. A-4. https://chroniclingamerica.loc.gov/lccn/sn83045462/1943-06-09/ed-1/seq-4/

British Surprised by Warning on Gas. London Speculates Roosevelt Had Japan in Mind When He Cautioned Axis. *New York Times* 1943-06-10 p. 2. https://www.nytimes.com/1943/06/10/archives/british-surprised-by-warning-on-gas-london-speculates-roosevelt-had.html

Axis Powers Warned Not to Use Gas. Retaliatory Action Planned. *The Canberra Times* (Australia) 1943-06-10 p. 1.

Axis Warned Not to Use Gas. *Examiner* (Launceston, Tasmania, Australia) 1943-06-10 p. 1.

For more information, see:

https://nhd.org/wp-content/files/The%20Bari%20Incident%20-%20Lesson%20Plan.pdf

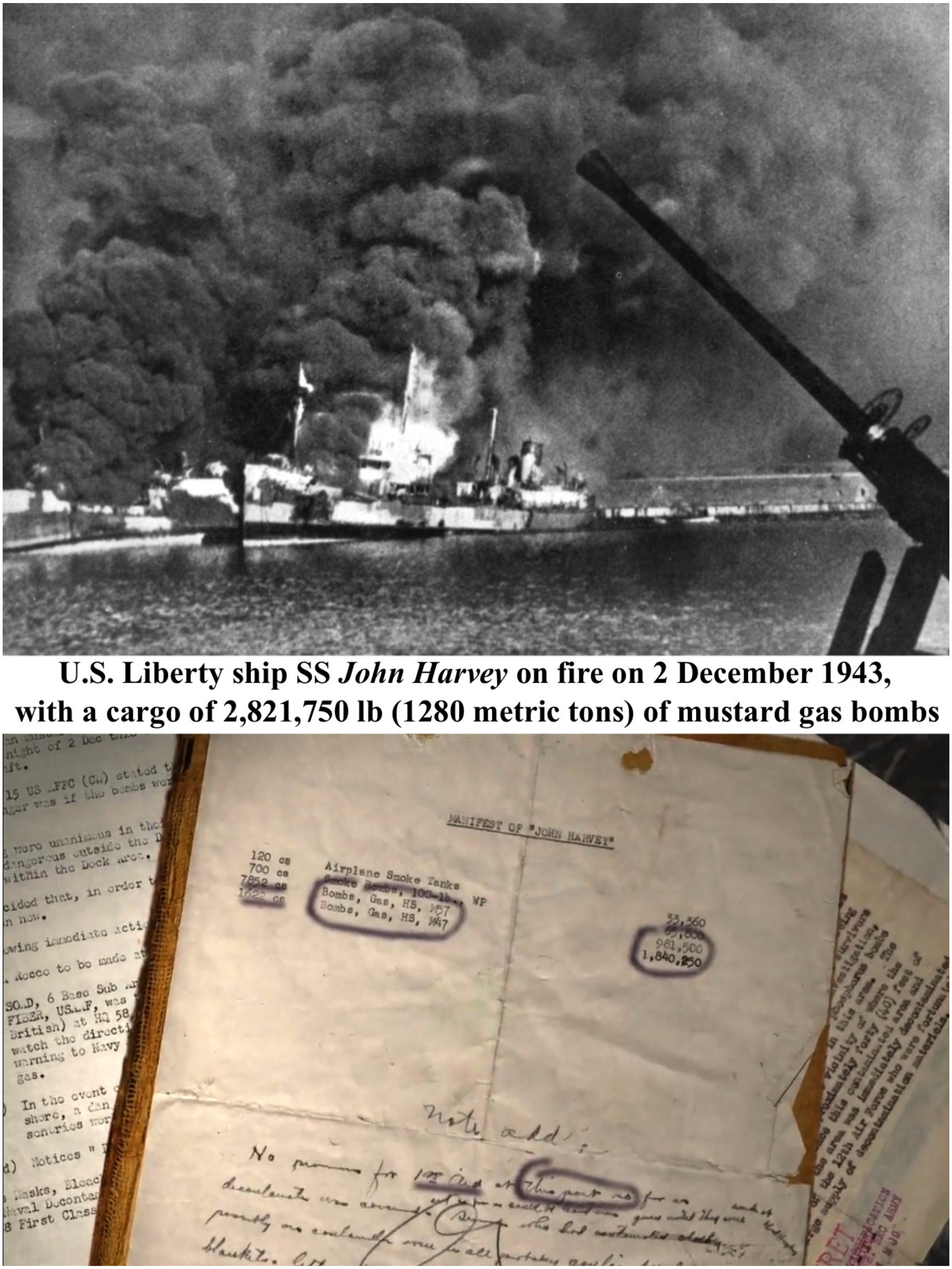
https://abmceducation.org/sites/default/files/Statement-Warning-Axis.pdf]

Dwight D. Eisenhower. 1948. *Crusade in Europe.* New York: Doubleday. Ch. 12.

On December 2, 1943, a most regrettable and disturbing incident took place at the port of Bari. We were using that port to assist in the support of the Eighth Army and the large air forces we were rapidly building up in Italy. It was constantly crowded with ships and the port itself was located uncomfortably close to some of the enemy air bases just across the narrow Adriatic.

One night the port was subjected to a raid and we suffered the greatest single loss from air action inflicted upon us during the entire period of Allied campaigning in the Mediterranean and in Europe. We lost sixteen vessels, some of them loaded with extremely valuable cargo. The greatest damage arose from the fact that a fuel ship was struck and the escaping oil carried fiery catastrophe to many of the neighboring vessels. One circumstance connected with the affair could have had the most unfortunate repercussions. One of the ships was loaded with a quantity of mustard gas, which we were always forced to carry with us because of uncertainty of German intentions in the use of this weapon. Fortunately the wind was offshore and the escaping gas caused no casualties. Had the wind been in the opposite direction, however, great disaster could well have resulted. It would have been indeed difficult to explain, even though we manufactured and carried this material only for reprisal purposes in case of surprise action on the part of the enemy.

[Eisenhower's postwar statement that there were no casualties from the U.S. mustard agent at Bari was a knowing and blatant falsehood, as shown on p. 2643. However, this case serves as an excellent example of an important wartime incident that was deliberately denied and suppressed by the United States and United Kingdom for decades after the war. What other factual wartime events and programs were also denied even decades after the war?]

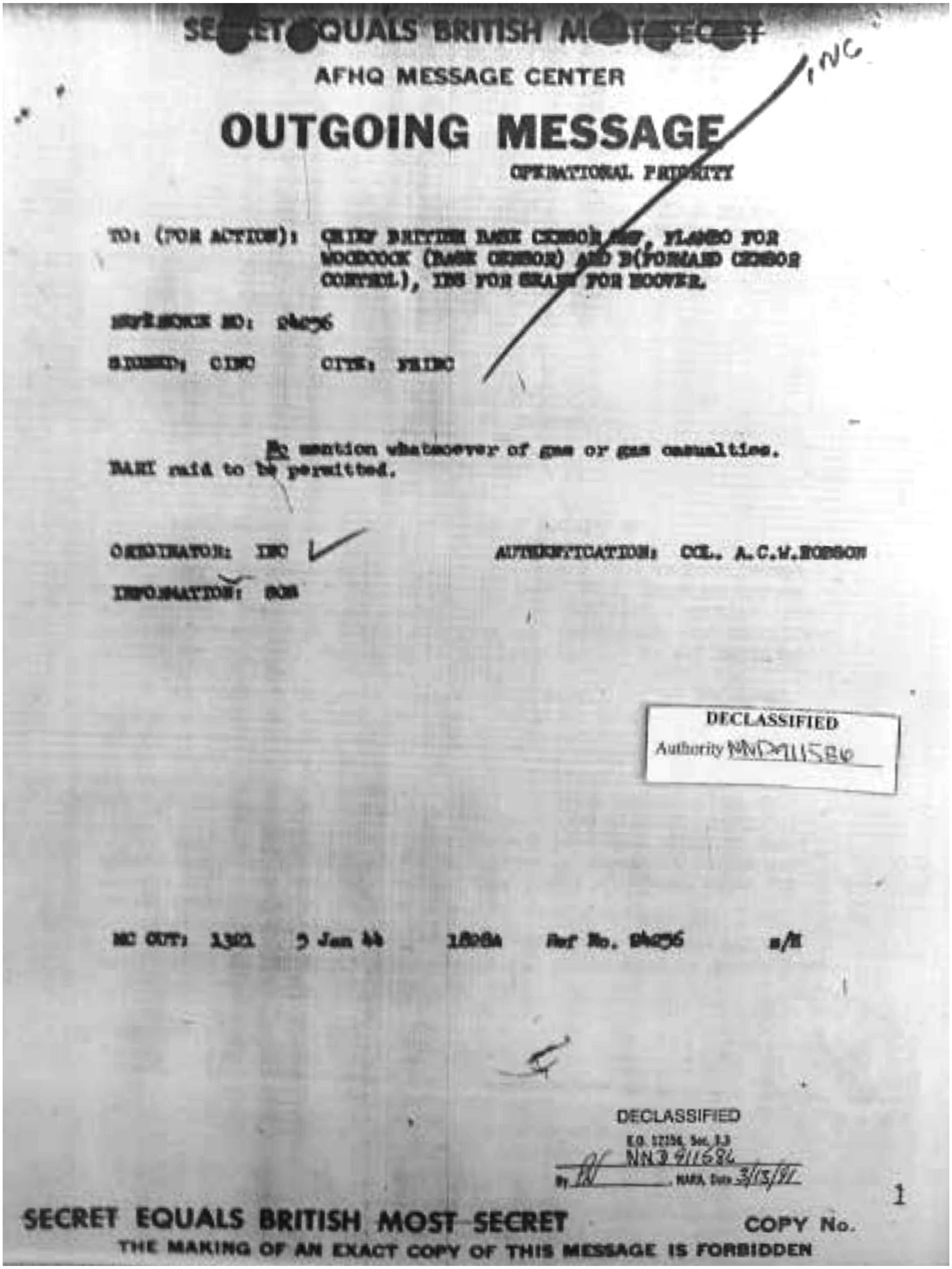

U.S. Liberty ship SS *John Harvey* on fire on 2 December 1943,
with a cargo of 2,821,750 lb (1280 metric tons) of mustard gas bombs

MANIFEST OF "JOHN HARVEY"

120 cs	Airplane Smoke Tanks	33,360
700 cs	Smoke Bombs, 100-lb., WP	[illegible]
7852 cs	Bombs, Gas, HS, M57	981,500
1622 cs	Bombs, Gas, HS, M47	1,840,250

Note add:

Figure A.257: U.S. Liberty ship SS *John Harvey* on fire on 2 December 1943 at Bari, Italy, with a cargo of 2,821,750 lb (1280 metric tons) of mustard gas bombs.



SECRET EQUALS BRITISH MOST SECRET

INC

AFHQ MESSAGE CENTER

OUTGOING MESSAGE

OPERATIONAL PRIORITY

TO: (FOR ACTION): CHIEF BRITISH BASE CENSOR AAF, FLAMBO FOR WOODCOCK (BASE CENSOR) AND B(FORWARD CENSOR CONTROL), INS FOR GRANT FOR HOOVER.

REFERENCE NO: 94056

SIGNED: CINC CITE: FHINC

No mention whatsoever of gas or gas casualties. BARI raid to be permitted.

ORIGINATOR: INC

AUTHENTICATION: COL. A.C.W.ROBSON

INFORMATION: SGS

DECLASSIFIED
Authority NND911586

MC OUT: 1321 5 Jan 44 1808A Ref No. 94056 s/H

DECLASSIFIED
E.O. 12356, Sec. 3.3
NND 911586
By NARA, Date 3/13/91

SECRET EQUALS BRITISH MOST SECRET COPY No. 1

THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN

Figure A.258: Top Secret Allied order from 5 January 1944, stating: "No mention whatsoever of gas or gas casualties BARI raid to be permitted."
[https://nhd.org/wp-content/files/The%20Bari%20Incident%20-%20Lesson%20Plan.pdf]

Jennet Conant. 2020. *The Great Secret: The Classified World War II Disaster that Launched the War on Cancer.* New York: W.W. Norton. pp. 293–295, 318–319.

Lt. Col. Alphonsus d'Abreu, the officer in charge of the surgical division of the 98th British General Hospital in Bari, did not approve of the deletions or the whitewashing of history. "I hope you will forgive me when I deny the accuracy of your statement that the escaping gas caused no casualties," he wrote Eisenhower, his former commanding officer in Italy, on January 26, 1949. "I was stationed there at the time and was responsible for the management of some 1,280 casualties of all nationalities," he continued, adding that he still had his notes, "and I am afraid the death toll was very high." Most of the casualties were caused by the mixture of mustard gas and oil in the harbor and "were in fact very severely contaminated and many of them died later of the well known lung complications of this fearful chemical." [...]

Eisenhower [...] was already mulling a run for the presidency[....] "While I have not yet had an opportunity to check back through official records, I shall do so," he assured d'Abreu, "and a correction will be made in future printings." No correction was ever made.

In the fifth installment of his voluminous memoirs of World War II, *Closing the Ring*, published in 1951, Churchill continued to cling obstinately to his position that there was no mustard gas in Bari. [...]

On October 9, 1987, the *American Medical News* reported, "Thus, 44 years after Bari, and 22 years since Churchill's death, the division is delving into musty, old, never released records and into the role of Stewart Alexander, MD, then a brash young lieutenant colonel and chemical warfare expert, who made what was one of the most politically sensitive diagnoses ever made." [...]

On Friday, May 20, 1988, at a small ceremony in the Capitol, a white-haired Alexander [...] received the long-overdue military honor. [...]

In the press conference afterward, Captain Mark Yow, assistant executive officer to the surgeon general, explained that the US Army could not have honored Alexander until recently, when the British declassified the documents relating to the incident. (The British are the masters of the slow reveal: The bulk of the Bari incident files were declassified in 1971, a group of Air Ministry papers a decade later, but some were not opened until 2008. Still others will not be released until 2044.) It was noted that the British government had no plans for any official UK honor for the doctor's work at Bari.

[In addition to the at least 1,280 military casualties noted by d'Abreu, there were probably even more casualties among civilians who were in the harbor or on the shore. Those civilian casualties were never properly investigated and tallied. Of those who were not killed outright by the mustard agent, many developed cancer or other long-term health problems, as discussed in Conant's book.

If a wartime event such as this could be classified, denied, and buried for so long (with some files on the Bari incident that still will not be released until at least 2044), what other wartime secrets remained buried just as deeply, or even more deeply?]

Winston S. Churchill to General Hastings Ismay. 6 July 1944. [https://www.heraldscotland.com/news/12251410.memo-from-winston-churchill-to-general-ismay-date-july-6-1944-it-may-be-several-weeks-before-i-ask-you-to-drench-germany-with-poison-gas-and-if-we-do-it-let-us-do-it-one-hundred-per-cent/ and https://nhd.org/wp-content/files/The%20Bari%20Incident%20-%20Lesson%20Plan.pdf]

1. I WANT you to think very seriously over this question of poison gas. I would not use it unless it could be shown either that (a) it was life or death for us, or (b) that it would shorten the war by a year.

2. It is absurd to consider morality on this topic when everybody used it in the last war without a word of complaint from the moralists or the Church. On the other hand, in the last war the bombing of open cities was regarded as forbidden. Now everybody does it as a matter of course. It is simply a question of fashion changing as she does between long and short skirts for women.

3. I want a cold-blooded calculation made as to how it would pay us to use poison gas, by which I mean principally mustard. We will want to gain more ground in Normandy so as not to be cooped up in a small area. We could probably deliver 20 tons to their one and for the sake of the one they would bring their bomber aircraft into the area against our superiority, thus paying a heavy toll.

4. Why have the Germans not used it? Not certainly out of moral scruples or affection for us. They have not used it because it does not pay them. The greatest temptation ever offered to them was the beaches of Normandy. This they could have drenched with gas greatly to the hindrance of our troops. That they thought about it is certain and that they prepared against our use of gas is also certain. But the only reason they have not used it against us is that they fear the retaliation. What is to their detriment is to our advantage.

5. Although one sees how unpleasant it is to receive poison gas attacks, from which nearly everyone recovers, it is useless to protest that an equal amount of HE will not inflict greater cruelties and sufferings on troops or civilians. One really must not be bound within silly conventions of the mind whether they be those that ruled in the last war or those in reverse which rule in this.

6. If the bombardment of London really became a serious nuisance and great rockets with far-reaching and devastating effect fell on many centres of Government and labour, I should be prepared to do anything that would hit the enemy in a murderous place. I may certainly have to ask you to support me in using poison gas. We could drench the cities of the Ruhr and many other cities in Germany in such a way that most of the population would be requiring constant medical attention. I do not see why we would always have all the disadvantages of being the gentleman while they have all the advantages of being the cad. There are times when this may be so but not now.

7. I quite agree it may be several weeks or even months before I shall ask you to drench Germany with poison gas, and if we do it, let us do it 100%. In the meanwhile, I want the matter studied in cold blood by sensible people and not by that particular set of psalm-singing uniformed defeatists which one runs across now here now there. Pray address yourself to this. It is a big thing and can only be discarded for a big reason. I shall of course have to square Uncle Joe and the President; but you need not bring this into your calculations at the present time. Just try to find out what it is like on its merits.

WS
6. 7. 44.

Vom Himmel hoch: Ein geheimer Plan enthüllt, daß die Amerikaner gegen Kriegsende bereit waren, einen großen Teil der deutschen Bevölkerung mit Giftgas zu vernichten. [From high in the sky: A secret plan reveals that toward the end of the war the Americans were prepared to exterminate a large part of the German population with poison gas.] *Der Spiegel* 23 October 1988.

Erst ein Zufallsfund des württembergischen Privatforschers und Fachautors Fritz Hahn, 66, in einem Washingtoner Archiv enthüllt die Dramatik eines Planes, den die US-Kriegführung unmittelbar nach dem "Ersteinsatz von Gas durch die Achsenmächte" ("G-Day") verwirklichen wollte. Danach sollten, von Italien und England aus, Tausende Flugzeuge "in einer 15-Tage-Operation"...

– 30 deutsche Großstädte mit Senfgas und/oder dem noch giftigeren Phosgen einnebeln.

– Alle wichtigen Industrie- und Fabrikationsanlagen zerbomben und so den Zweiten Weltkrieg in Europa mit einem Schlag beenden.

Unter Punkt 4 des Plans ("Mögliche Ergebnisse des Angriffs") errechneten US-Spezialisten der Abteilung für Chemiekriegführung, wie viele Menschen "direkt beeinträchtigt", also getötet würden—"5600000". Weitere zwölf Millionen "würden dem vorgeschlagenen Angriff indirekt ausgesetzt" sein. [...]

Für alle 30 Städte, vom US-Verteidigungsministerium und von Geheimdienstlern als "Schlüsselziele" ausgesucht, gab es präzise Beschreibungen jener Viertel, die als Angriffsobjekt "empfehlenswert" seien—in Hamburg, beispielsweise, waren es drei:

I. Dieses Ziel umfaßt die Innenstadt mit einer Fläche "von einer Quadratmeile ... annähernd 200000 Personen (nächtliche Bevölkerung um 100000), das Geschäfts- und Speicherzentrum. Angrenzend im Süden der Hafen längs der Elbe, eingeschlossen sind die U-Boot-Werften."

Only a chance find by Fritz Hahn, 66, a private researcher and specialist author from Württemberg, in a Washington archive reveals the drama of a plan that the U.S. war leadership wanted to implement immediately after the "first use of gas by the Axis powers" ("G-Day"). According to this plan, from Italy and England, thousands of planes were to "in a 15-day operation":

– Fog 30 major German cities with mustard gas and/or the even more poisonous phosgene.

– Bomb all major industrial and manufacturing plants, ending World War II in Europe in one fell swoop.

Under point 4 of the plan ("Possible Results of the Attack"), U.S. specialists in the Chemical Warfare Division calculated how many people would be "directly affected," i.e., killed—"5,600,000." Another twelve million "would be indirectly exposed" to the proposed attack. [...]

For all 30 cities, selected by the U.S. Department of War and intelligence officials as "key targets," there were precise descriptions of those neighborhoods that were "recommendable" as targets for attack—in Hamburg, for example, there were three:

I. This target comprises the inner city with an area "of one square mile . . . approximately 200,000 persons (nightly population around 100,000), the business and warehouse center. Adjacent to the south the port along the Elbe, enclosed are the submarine yards."

II. Dieses Ziel umfaßt das dichtbevölkerte Wohngebiet ”östlich des Altonaer Bahnhofs, nördlich der Elbe und des Parkgürtels um die Innenstadt, südlich von Eimsbüttel, des dichtbesiedeltsten Stadtteils. In diesem anderthalb Quadratmeilen großen Zielgebiet leben 190000 Menschen.”

III. Dieses Ziel umfaßt die dichtbesiedelten “Wohngebiete im Nordosten der Stadt. In diesem anderthalb Quadratmeilen großen Zielgebiet leben 140000 Menschen.”

Fünf Städte—München, Augsburg, Nürnberg, Stuttgart und Karlsruhe—sollten vom italienischen US-Stützpunkt Foggia, rund 100 Kilometer nördlich von Bari, angeflogen werden. Alle anderen—unter ihnen Berlin, Köln, Düsseldorf, Leipzig und Dresden—von London aus.

Je nach den klimatischen Bedingungen wären das leicht flüchtige Phosgen oder der schwerere Lost abgeworfen worden. Dabei kalkulierten die Planer zur Vergiftung “einer Quadratmeile” den Einsatz von mindestens “100 Flugzeugen mit 4000 Bomben a 100 Pfund (Lost)” oder “600 Bomben a 1000 Pfund (Phosgen)” ein.

Amerikas Chemiefabriken hatten genügend Kampfstoff produziert, gegen Ende des Krieges lagerten in den Arsenalen 140000 Tonnen. Aber es standen zum damaligen Zeitpunkt nicht genügend Bomber bereit.

Bei einem Angriff im März 1944 hätte die amerikanische Luftwaffe jedoch 63 Prozent des “Zielprogramms” erledigen können, im Juni schon 76 Prozent. Möglich scheint, daß die Briten im Bedarfsfall mitgeflogen wären, am 1. April 1944 standen bei der Royal Air Force 5630 Bomber parat, 45 mehr als bei den amerikanischen Verbündeten.

II. This objective includes the densely populated residential area “east of the Altona train station, north of the Elbe and the park belt around the city center, south of Eimsbüttel, the most densely populated district. This one-and-a-half square mile target area is home to 190,000 people.”

III. This target includes the densely populated “residential areas in the northeastern part of the city. 140,000 people live in this one and one-half square mile target area.”

Five cities—Munich, Augsburg, Nuremberg, Stuttgart, and Karlsruhe—were to be approached from the Italian U.S. base at Foggia, about 100 kilometers north of Bari. All others—including Berlin, Cologne, Düsseldorf, Leipzig, and Dresden—from London.

Depending on climatic conditions, the more volatile phosgene or the heavier mustard would have been dropped. In the process, planners calculated the use of at least “100 planes with 4000 bombs of 100 pounds (mustard)” or “600 bombs of 1000 pounds (phosgene)” to poison “one square mile.”

America’s chemical factories had produced enough warfare agent; by the end of the war, 140,000 tons were stored in the arsenals. But there were not enough bombers ready at the time.

In a March 1944 attack, however, the American Air Forces could have completed 63 percent of the “target program,” and by June it could have completed 76 percent. It seems possible that the British would have flown along if necessary; on 1 April 1944, the Royal Air Force had 5630 bombers on standby, 45 more than their American allies.

[In a secret January 1945 recording, the German general Heinrich Kittel stated that the threat of Allied chemical weapons was to deter Germany from using the atomic bomb that it possessed (pp. 3786–3791).]

Stephen L. McFarland. 1997. *Battles Not Fought: The Creation of an Independent Air Force.* [https://www.usafa.edu/app/uploads/Harmon40.pdf]

The Joint Chiefs of Staff assigned the Army Air Forces to prepare for this battle that never took place. While B-17s and B-24s battled their way to Schweinfurt, Regensburg, Gotha, Heiterblick, Leipzig, and Berlin, hundreds of thousands of gas bombs were being stockpiled in England for what many thought was their inevitable use once the V-1s and V-2s began dropping out of the sky with a hiss, not a bang. The Allies would not strike first; Churchill and Roosevelt had already declared this. But if Germany did initiate chemical or biological warfare, the Allies would be ready to raise the ante. The Army Air Forces retaliatory plan, in conjunction with the Royal Air Force, identified Germany's thirty-eight largest cities for destruction with anticipation of killing upwards of twenty million people, making over one-half of Germany's urban area uninhabitable, and reducing industrial production by 60 percent. Ready in time for the Normandy invasion, 4,600 American heavy bombers then in the Eighth and Fifteenth Air Forces would launch a fifteen-day all-out blitz, each carrying a 75 percent mustard gas bomb load mixed with a 25 percent high explosive bomb load to help spread the gas. German civilians did not receive gas masks until late 1944 and then only for Nazi Party officials. Germany had no penicillin to fight the bacterial infections that would accompany the blistering effects of mustard gas. An average gas persistence of thirty days guaranteed a holocaust of unprecedented proportions.

R. V. Jones and J. M. Lewis. 1987. Churchill's Anthrax Bombs—A Debate. *Bulletin of the Atomic Scientists* 43:9:42–45. [https://www.julianlewis.net/essays-and-topics/2938:churchills-anthrax-bombs-a-debate-9]

In May 1981, a British television report by Robert Harris of the BBC made international headlines for alleging—wrongly, as it transpired—that Winston Churchill had advocated using anthrax against Nazi Germany in response to the 1944 V-weapon offensives. The truth was that he had pressed for consideration of the use of poison gas, but had reluctantly accepted the advice of his military advisers (the British Chiefs of Staff and their subordinate Joint Planning Staff) not to take such a step under the circumstances. He had not asked for the use of biological warfare to be considered, but, in reporting back to him negatively on the gas question, the Chiefs of Staff had added a brief examination of the biological warfare situation. As Bernstein rightly notes, this report pointed out that no use of anthrax would in any case be practicable as anthrax bombs were, as yet, unavailable. [...]

One of us (R.V. Jones) was present when Churchill put to the War Cabinet's Crossbow Committee, on 18 July 1944, his suggestion that Britain should attempt to deter the onset of the V.2 campaign by threatening the Germans with gas should they launch their rockets. Some of those present spoke firmly against it, and none spoke in favour.

[This article is important because R. V. Jones admitted that Churchill strongly advocated going ahead and dropping chemical weapons on Germany, even though Germany had not used weapons of mass destruction, which would have killed millions of civilians. However, this article appears to be incorrect about the anthrax. Please see the following pages for documentation on Churchill's plan to also drop five million anthrax "cakes" on German civilian targets.]

George Rosie. UK Planned to Wipe Out Germany with Anthrax: Allies' World War Two Shame. *Sunday Herald* (Glasgow) 14 October 2001, p. 2.

As the world recoils at the horrific possibility of al-Qaeda terrorists waging anthrax war against United States citizens, the *Sunday Herald* can reveal that Britain manufactured five million anthrax cattle cakes during the second world war and planned to drop them on Germany in 1944.

The aim of Operation Vegetarian was to wipe out the German beef and dairy herds and then see the bacterium spread to the human population. With people then having no access to antibiotics, this would have caused many thousands—perhaps even millions—of German men, women and children to suffer awful deaths.

The anthrax cakes were tested on Gruinard Island, off Wester Ross, which was finally cleared of contamination in 1990. Operation VEGETARIAN was planned for the summer of 1944 but, in the event, it was abandoned as the Allies' Normandy invasion progressed successfully.

Details of the wartime secret operation are contained in a series of War Office files (WO 188) at the Public Record Office in Kew. Some of the files are still classified. The man whose task was to carry out Operation Vegetarian was Dr Paul Fildes, director of the biology department at Porton Down near Salisbury in Wiltshire. Fildes had previously been in charge of the Medical Research Council's bacterial chemistry unit at Middlesex Hospital.

In early 1942, Fildes began searching Britain for suppliers and manufacturers of linseed-oil cattle cake to make five million small cakes. Large quantities of the bacillus itself had to be produced, while special containers to carry the cattle cakes had to be designed and made. Some RAF bombers had to be modified to deliver the anthrax-infected payload. And all of it had to be done as cheaply as possible.

The raw material for the cake was provided by the Olympia Oil and Cake Company in Blackburn. The contract to cut the cattle cake into small pieces went to J & E Atkinson of Bond Street in London, perfumers and toilet-soap manufacturers and suppliers to the royal family. The Atkinsons calculated that they could produce 180,000 to 250,000 cakes, each 2.5cm in diameter and 10 grammes in weight, in a 44-hour week. The price was to be between 12 and 15 shillings per thousand. The firm pledged to deliver 5,273,400 cakes by April 1943. By the middle of July 1942, the Atkinsons informed Fildes that 'we are now producing at the rate of 40,000 per day'.

The anthrax was manufactured by the Ministry of Agriculture and Fisheries at its veterinary laboratory in Surrey. An Oxford academic named Dr E Schuster was set to work devising the pump to inject the bacilli into the cattle cakes. The Porton Down scientists settled on cube-shaped cardboard containers, 18 cm square, to carry the infected foodstuff.

Each held 400 cakes. They would be fitted with a steel handle 'of a size which enables the operator to grasp the handle without difficulty when wearing thick leather or moleskin gloves...' Thirteen women were then recruited from various soap-making firms, sworn to secrecy and given the job of injecting the cattle cakes with anthrax spores.

At the same time, Fildes and his team were working on the best way to deliver the diseased cattle feed to the German herds.

The RAF's research unit came up with a simple solution—easily made wooden trays that fitted on to aircraft flare chutes. Their Bomber Command Lancasters, Halifaxes and Stirlings were chosen for the job.

By the beginning of 1944, Operation VEGETARIAN was ready to go. It was crucial to mount any attack in the summer months. Fildes said: 'The cattle must be caught in the open grazing fields when lush spring grass is on the wane.' 'Trials have shown that these tablets ... are found and consumed by the cattle in a very short time.' 'Cattle are concentrated in the northern half of Oldenburg and northwest Hanover. Aircraft flying to and from Berlin will fly over 60 miles of grazing land.'

Fildes calculated that, at an average ground speed of 300mph, the distance would be covered in 18 minutes. 'If one box of tablets is dispersed every two minutes, then each aircraft will be required to carry and disperse nine, or say 10, boxes.'

One Lancaster bomber returning from a raid on Berlin would be able to scatter 4000 anthrax-infected cakes over a 60-mile swathe in less than 20 minutes. A dozen aircraft would have been enough to litter most of the north German countryside with anthrax spores. Operation VEGETARIAN was a seriously deadly project.

But, by the time Fildes's operation was ready to go in the summer of 1944, the Normandy invasion had taken place and Allied armies were crashing through northern France and up through Italy. The war against Nazi Germany was instead being won by conventional means. At the end of 1945, five million anthrax-infected cattle cakes were incinerated in one of Porton Down's furnaces.

[See also:

Jeanne Guillemin. 2005. *Biological Weapons: From the Invention of State-Sponsored Programs to Contemporary Bioterrorism.* New York: Columbia University Press. pp. 50–56.

Robert Harris and Jeremy Paxman. 2002. *A Higher Form of Killing: The Secret History of Chemical and Biological Warfare.* 2nd ed. New York: Random House. pp. 88–90.

Julian Lewis. 2002. *Changing Direction: British Military Planning for Post-war Strategic Defence, 1942–47.* 2nd ed. London: Taylor & Francis.]

Werner Heisenberg, 6 August 1945. Quoted in: Farm Hall Report 4 [Bernstein 2001; Frank 1993; Hoffmann 2023].

About a year ago, I heard from SEGNER (?) from the Foreign Office that the Americans had threatened to drop a uranium bomb on Dresden if we didn't surrender soon. At that time I was asked whether I thought it possible, and, with complete conviction, I replied: "No."

Werner Heisenberg. 31 October 1963 letter to Ernst Brüche. Quoted in: Ernst Brüche. 1964. Was wußte man 1943/44 in Deutschland von der Atombombe? *Physikalische Blätter* 20:5:220–225. https://doi.org/10.1002/phbl.19640200504

Im Sommer 1944 (wahrscheinlich Anfang Juli) kam einmal der Adjutant von Göring zu mir mit der Mitteilung, es sei über die deutsche Vertretung in Lissabon eine amerikanische Drohung gegen die deutsche Regierung ausgesprochen worden, es werde innerhalb der nächsten sechs Wochen eine Atombombe über Dresden abgeworfen werden, wenn die Regierung nicht in irgendeiner Art um Frieden bäte. Über den genauen Inhalt der Bedingungen wurde mir nichts mitgeteilt. Ich wurde von dem Adjutanten Görings gefragt, ob ich es für möglich hielte, daß die Amerikaner bereits über eine Atombombe verfügten. Mir war diese Frage begreiflicherweise sehr unangenehm, weil mit der Antwort auf jeden Fall eine große Verantwortung verbunden war. Ich habe dann gesagt, daß ich es zwar für außerordentlich unwahrscheinlich, aber nicht für völlig unmöglich hielte, daß die Amerikaner zu diesem Zeitpunkt über eine solche Waffe verfügten, und habe versucht zu erklären, daß die Herstellung der Waffe auf jeden Fall einen enormen industriellen Aufwand erfordern müßte, von dem ich mir nicht denken könnte, daß die Amerikaner ihn schon geleistet hätten.

In the summer of 1944 (probably at the beginning of July) the adjutant of Goering once came to me with the information that an American threat had been made against the German government via the German representation in Lisbon that an atomic bomb would be dropped on Dresden within the next six weeks if the government did not ask for peace in some way. I was told nothing about the exact content of the conditions. I was asked by Goering's aide whether I thought it possible that the Americans already had an atomic bomb. I was understandably very uncomfortable with this question, because the answer was in any case connected with a great responsibility. I then said that I thought it extraordinarily improbable, but not entirely impossible, that the Americans had such a weapon at that time, and tried to explain that the production of the weapon would in any case require an enormous industrial effort which I could not imagine that the Americans had already made.

[Heisenberg's story is puzzling, since in July 1944 the U.S. was still a year away from its first completed atomic bomb.

The U.S. X-10 breeder reactor at Oak Ridge began operation in November 1943, and the first Hanford breeder reactor began operation in September 1944. Perhaps the information reported by Heisenberg was a U.S. threat to collect the fission products from those reactors and drop those on Dresden or other German cities as a radiological weapon. The reason for naming Dresden might be that it had been largely beyond the range of earlier Allied bombing, so it had been spared much damage to that date; thus the effects of a radiological attack on an otherwise relatively healthy city might be more obvious.

Heisenberg mentioned an Allied attack on Dresden that was threatened to occur around September 1944. A few months after that time, in February 1945, Allied bombers did indeed attack Dresden, but with conventional firebombs, killing over 20,000 German civilians.

If Heisenberg's report is accurate, it is interesting that the United States would threaten to attack a German city with a hastily constructed radiological weapon and call it a full-fledged atomic bomb, rather than threaten Germany with the very real Allied stockpiles of mustard and phosgene chemical weapons. The highly specific nature of this U.S. threat suggests that it was intended to counter an equally specific German threat: the use of German atomic bombs against one or more Allied targets. See Section D.13 for much more information.

Thus the German and Allied threats and counter-threats with chemical, biological, and nuclear weapons of mass destruction all appear to have been interrelated. This specter of mutual assured destruction (MAD) seems to have continually loomed over the final years of World War II. History books on the war should do a far better job of exploring and explaining this important aspect of the war, as well as how this threat profoundly influenced how all of the more visible aspects of the war played out.

See also: Alex Wellerstein. 11 October 2013. Heisenberg's Dresden Story: A Wartime Atomic Mystery. *Restricted Data: The Nuclear Secrecy Blog.*
https://blog.nuclearsecrecy.com/2013/10/11/heisenbergs-dresden-story/]

Appendix B

Advanced Creations in Electrical Engineering

Die polnischen Juden machen nach gewissen gesprochen Gebeten und gehaltenen Fasttägen, die Gestalt eines Menschen aus Thon oder Leimen, und wenn sie das wunderkräftige Schemhamphoras darüber sprechen, so muß er lebendig werden. Reden kann er zwar nicht, versteht aber ziemlich was man spricht und befiehlt. Sie heißen ihn Golem, und brauchen ihn zu einem Aufwärter, allerley Hausarbeit zu verrichten, allein er darf nimmer aus dem Hause gehen. An seiner Stirn steht geschrieben *aemaeth* (Wahrheit, Gott) er nimmt aber täglich zu, und wird leicht größer und stärker denn alle Hausgenossen, so klein er anfangs gewesen ist. Daher sie aus Furcht vor ihm den ersten Buchstaben auslöschen, so daß nichts bleibt als *maeth* (er ist todt) worauf er zusammenfällt und wiederum in Ton aufgelöst wird.

The Polish Jews, after speaking certain prayers and observing fast days, made the figure of a man out of clay or loam, and when they speak the miracle-working Schemhamphoras over it, the figure comes alive. It is true that he cannot speak, but he understands reasonably well what anyone says to him and commands him to do. They call him Golem and use him as a servant to do all sorts of housework, but he may never leave the house alone. On his forehead is written *Aemaeth* (Truth, God). However, he increases in size daily and easily becomes larger and stronger than all his housemates, regardless of how small he was at first. Therefore, fearing him, they rub out the first letter, so that nothing remains but *Maeth* (he is dead), whereupon he collapses and is dissolved again into clay.

Jakob Grimm. 1808. *Zeitung für Einsiedler* [*Journal for Hermits*] No. 7, 23 April.
English translation by Edan Dekel and David Gantt Gurley.

German-speaking research groups designed and developed revolutionary microelectronics technologies years before those technologies were officially "invented" at Bell Laboratories and other non-German firms.

This appendix presents documentary evidence for:

B.1. The invention of transistors by German-speaking creators.

B.2. The invention of printed circuits/multi-pin connectors by German-speaking creators.

B.3. The invention of integrated circuits by German-speaking creators.

B.4. The invention of light emitting diodes (LEDs) by German-speaking creators.

B.5. The transfer of those technologies to other countries and companies.

Much more archival research is needed to clarify the historical details for the development and transfer of microelectronics technologies.

B.1 Transistors

[According to official histories, the first transistor was invented in the United States at AT&T Bell Telephone Laboratories in late 1947 and early 1948 by John Bardeen (American, 1908–1991), Walter Brattain (American, 1902–1987), and William Shockley (American, 1910–1989).

However, there is evidence that transistors were actually developed (or under development) earlier by at least 12 independent groups in the predominantly German-speaking research world that were led by the following scientists (Fig. B.1):

1. Julius Edgar Lilienfeld (Austrian, 1882–1963)
2. Oskar Heil (German, 1908–1994)
3. Gilles Holst (Dutch, 1886–1968) and Willem Christiaan van Geel (Dutch, 1895–1967)
4. Rudolf Hilsch (German, 1903–1972) and Robert Pohl (German, 1884–1976)
5. Erich Habann (German, 1892–1968)
6. Walter Schottky (Swiss/German, 1886–1976)
7. Heinrich Welker (German, 1912–1981) and Herbert Mataré (German, 1912–2011)
8. Erwin Weise (German?, 19??–19??)
9. Frank Rose (German?, 19??–19??), Eberhard Spenke (German, 1905–1992), and Erich Waldkötter (German?, 19??–19??)
10. Karl Seiler (German, 1910–1991) and Paul Ludwig Günther (German, 1892–1969)
11. Helmar Frank (Moravian, 1919–2015) and Jan Tauc (Bohemian, 1922–2010)
12. Bernhard Gudden (German, 1892–1945) and Kurt Lehovec (Bohemian/Austrian/Czech, 1918–2012)

In addition to these 12 groups, were there any other German-speaking groups developing transistors, for example at laboratories run by AEG, Askania, Blaupunkt, Fernseh, Loewe Radio, C. Lorenz, Philips, the Reichspost, Siemens, the SS, Telefunken, various universities, or other laboratories in Germany, Austria, Czech territory, Polish territory, or elsewhere? Much more archival research is needed in this area.]

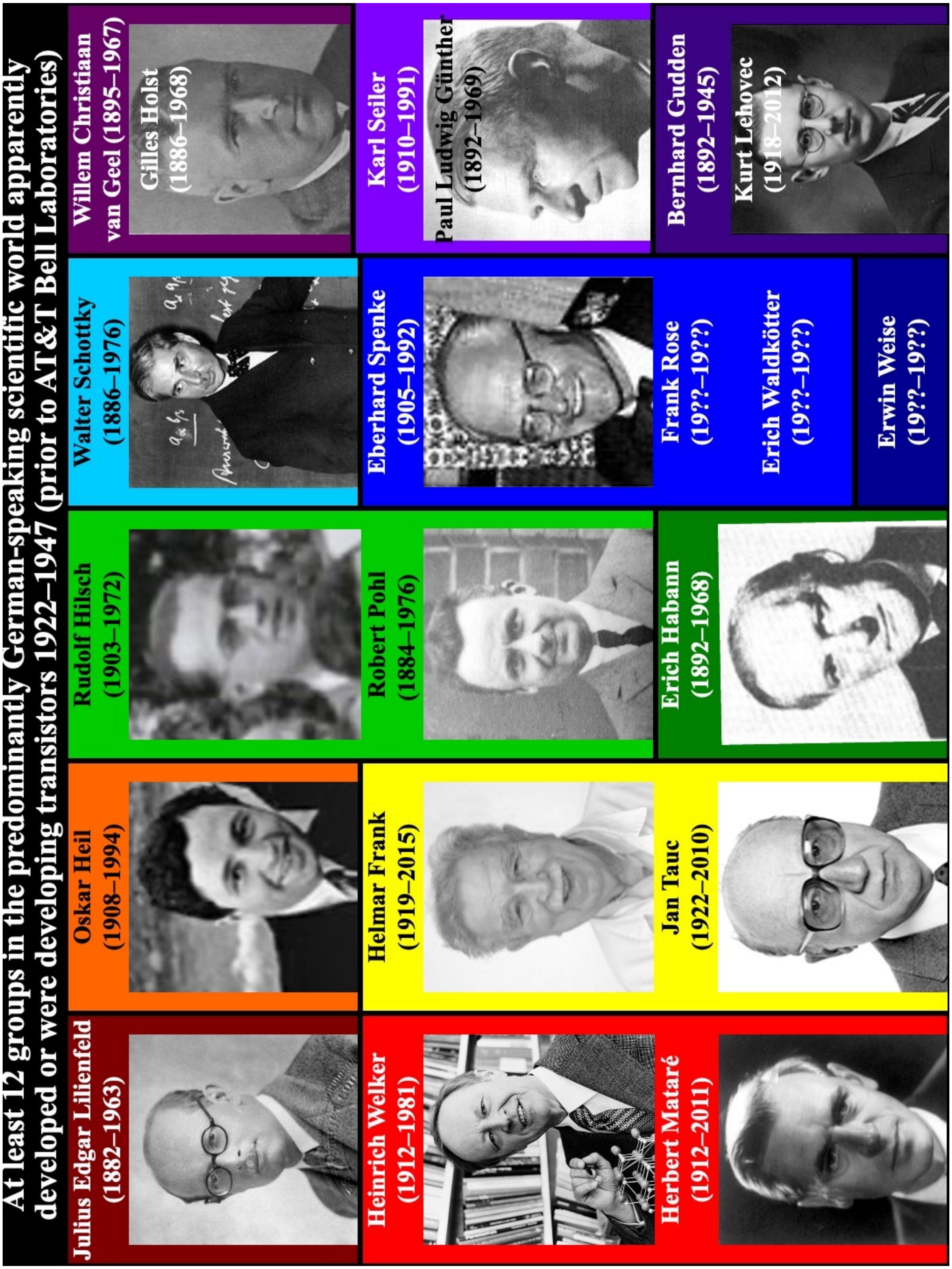

At least 12 groups in the predominantly German-speaking scientific world apparently developed or were developing transistors 1922–1947 (prior to AT&T Bell Laboratories)
Julius Edgar Lilienfeld (1882–1963)
Oskar Heil (1908–1994)
Rudolf Hilsch (1903–1972)
Walter Schottky (1886–1976)
Willem Christiaan van Geel (1895–1967)
Gilles Holst (1886–1968)
Heinrich Welker (1912–1981)
Helmar Frank (1919–2015)
Robert Pohl (1884–1976)
Eberhard Spenke (1905–1992)
Karl Seiler (1910–1991)
Paul Ludwig Günther (1892–1969)
Herbert Mataré (1912–2011)
Jan Tauc (1922–2010)
Erich Habann (1892–1968)
Frank Rose (19??–19??)
Erich Waldkötter (19??–19??)
Erwin Weise (19??–19??)
Bernhard Gudden (1892–1945)
Kurt Lehovec (1918–2012)

Figure B.1: At least 12 groups in the predominantly German-speaking scientific world apparently developed or were developing transistors 1922–1947 (prior to AT&T Bell Laboratories).

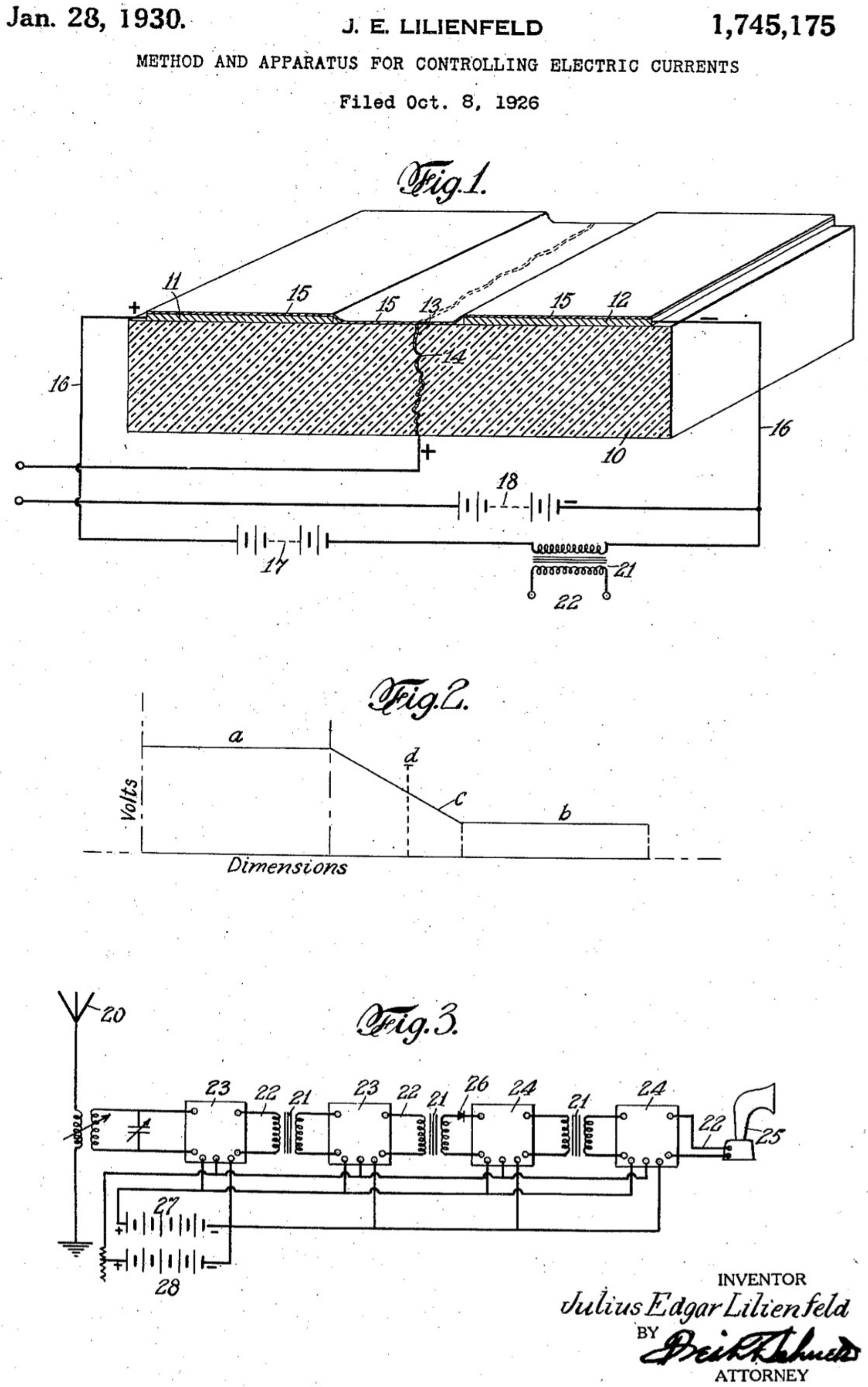
[**1. Julius Edgar Lilienfeld (Austrian, 1882–1963)** filed several patent applications on a field effect transistor during the period 1925–1928, including:

> Julius Edgar Lilienfeld. Filed in 1925 in Canada and in 1926 in the United States. U.S. Patent 1,745,175. Method and Apparatus for Controlling Electric Currents. (pp. 2657–2660)
>
> Julius Edgar Lilienfeld. Filed in 1928. U.S. Patent 1,900,018. Device for Controlling Electric Current. (pp. 2661–2670)
>
> Julius Edgar Lilienfeld. Filed in 1928. U.S. Patent 1,877,140. Amplifier for Electric Currents. (pp. 2671–2677)

The great level of detail in those applications regarding the production and performance of such transistors strongly suggests that he built and tested them [Arns 1998; Crawford 1991], although exactly what results he achieved are not clear from currently available documents.

Much later, Bell Laboratories secretly built fully functioning devices based directly on Lilienfeld's patents, lending further support to the view that the patents were based on Lilienfeld's own successful experimentation [Arns 1998; Shockley and Pearson 1948].

In the 1920s, Lilienfeld moved to the United States, where he married an American woman. It appears that he was unsuccessful in finding sufficient financial and political support for his transistor approach in the United States. In the 1930s, Lilienfeld and his wife moved to the island of Saint Thomas in the Caribbean, where they lived the rest of their lives.]



Jan. 28, 1930. J. E. LILIENFELD 1,745,175

METHOD AND APPARATUS FOR CONTROLLING ELECTRIC CURRENTS

Filed Oct. 8, 1926

Fig.1.
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Fig.2.
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Dimensions
Fig.3.
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+
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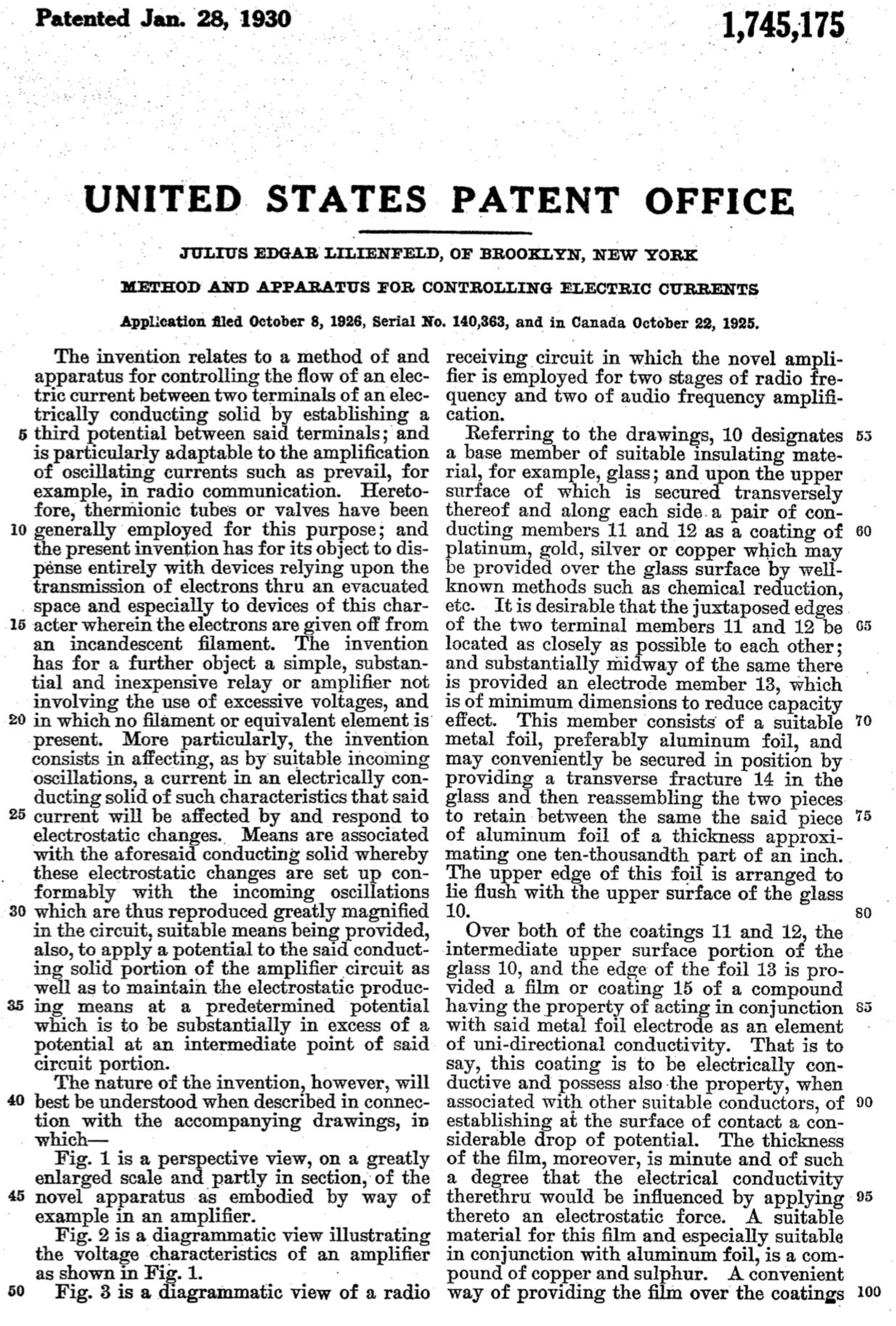
INVENTOR
Julius Edgar Lilienfeld
BY
ATTORNEY

Figure B.2: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,745,175 (originally filed in 1925 in Canada).



Patented Jan. 28, 1930 **1,745,175**

UNITED STATES PATENT OFFICE

JULIUS EDGAR LILIENFELD, OF BROOKLYN, NEW YORK

METHOD AND APPARATUS FOR CONTROLLING ELECTRIC CURRENTS

Application filed October 8, 1926, Serial No. 140,363, and in Canada October 22, 1925.

The invention relates to a method of and apparatus for controlling the flow of an electric current between two terminals of an electrically conducting solid by establishing a third potential between said terminals; and is particularly adaptable to the amplification of oscillating currents such as prevail, for example, in radio communication. Heretofore, thermionic tubes or valves have been generally employed for this purpose; and the present invention has for its object to dispense entirely with devices relying upon the transmission of electrons thru an evacuated space and especially to devices of this character wherein the electrons are given off from an incandescent filament. The invention has for a further object a simple, substantial and inexpensive relay or amplifier not involving the use of excessive voltages, and in which no filament or equivalent element is present. More particularly, the invention consists in affecting, as by suitable incoming oscillations, a current in an electrically conducting solid of such characteristics that said current will be affected by and respond to electrostatic changes. Means are associated with the aforesaid conducting solid whereby these electrostatic changes are set up conformably with the incoming oscillations which are thus reproduced greatly magnified in the circuit, suitable means being provided, also, to apply a potential to the said conducting solid portion of the amplifier circuit as well as to maintain the electrostatic producing means at a predetermined potential which is to be substantially in excess of a potential at an intermediate point of said circuit portion.

The nature of the invention, however, will best be understood when described in connection with the accompanying drawings, in which—

Fig. 1 is a perspective view, on a greatly enlarged scale and partly in section, of the novel apparatus as embodied by way of example in an amplifier.

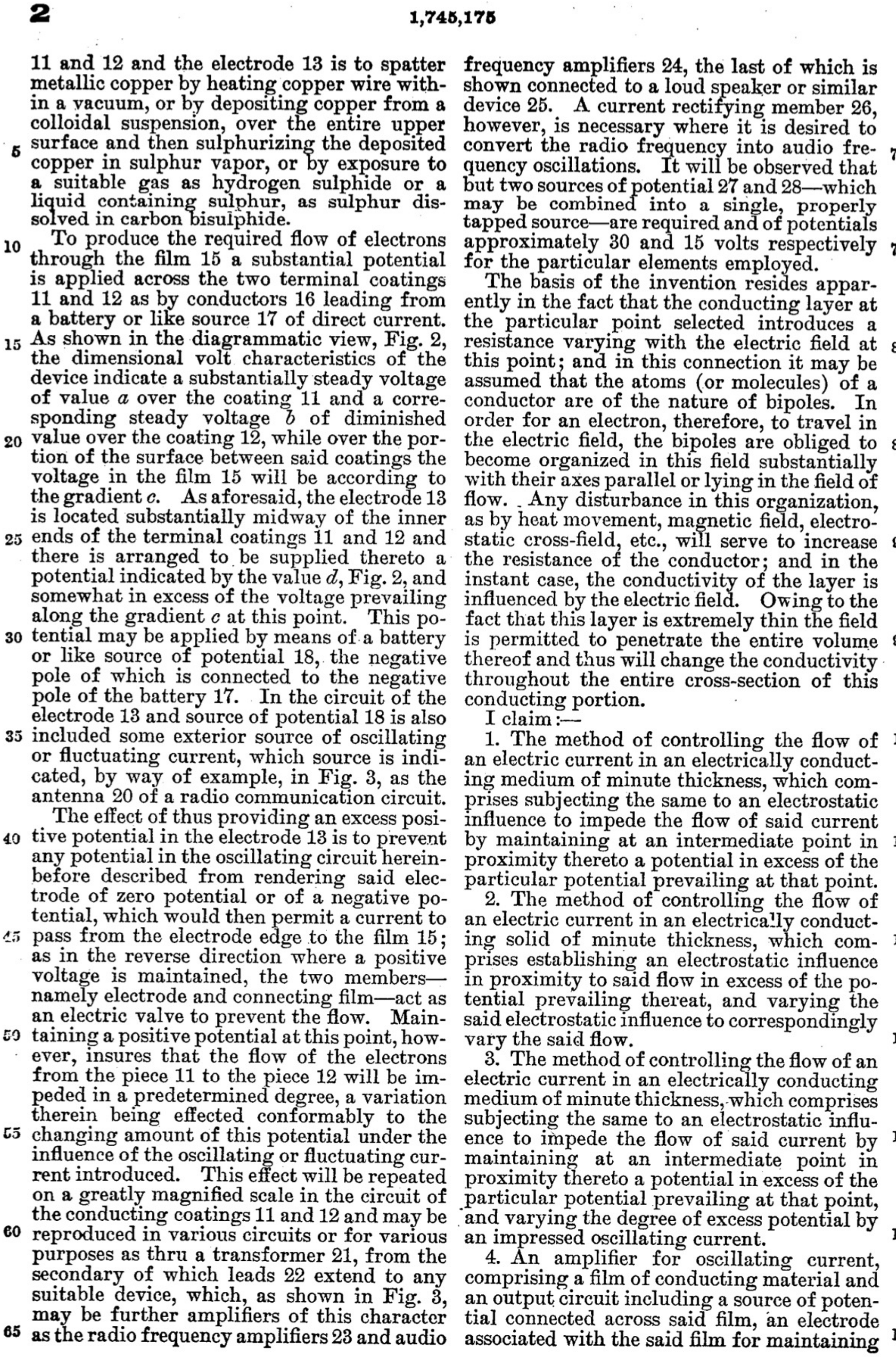
Fig. 2 is a diagrammatic view illustrating the voltage characteristics of an amplifier as shown in Fig. 1.

Fig. 3 is a diagrammatic view of a radio receiving circuit in which the novel amplifier is employed for two stages of radio frequency and two of audio frequency amplification.

Referring to the drawings, 10 designates a base member of suitable insulating material, for example, glass; and upon the upper surface of which is secured transversely thereof and along each side a pair of conducting members 11 and 12 as a coating of platinum, gold, silver or copper which may be provided over the glass surface by well-known methods such as chemical reduction, etc. It is desirable that the juxtaposed edges of the two terminal members 11 and 12 be located as closely as possible to each other; and substantially midway of the same there is provided an electrode member 13, which is of minimum dimensions to reduce capacity effect. This member consists of a suitable metal foil, preferably aluminum foil, and may conveniently be secured in position by providing a transverse fracture 14 in the glass and then reassembling the two pieces to retain between the same the said piece of aluminum foil of a thickness approximating one ten-thousandth part of an inch. The upper edge of this foil is arranged to lie flush with the upper surface of the glass 10.

Over both of the coatings 11 and 12, the intermediate upper surface portion of the glass 10, and the edge of the foil 13 is provided a film or coating 15 of a compound having the property of acting in conjunction with said metal foil electrode as an element of uni-directional conductivity. That is to say, this coating is to be electrically conductive and possess also the property, when associated with other suitable conductors, of establishing at the surface of contact a considerable drop of potential. The thickness of the film, moreover, is minute and of such a degree that the electrical conductivity therethru would be influenced by applying thereto an electrostatic force. A suitable material for this film and especially suitable in conjunction with aluminum foil, is a compound of copper and sulphur. A convenient way of providing the film over the coatings

Figure B.3: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,745,175 (originally filed in 1925 in Canada).



2 1,745,175

11 and 12 and the electrode 13 is to spatter metallic copper by heating copper wire within a vacuum, or by depositing copper from a colloidal suspension, over the entire upper surface and then sulphurizing the deposited copper in sulphur vapor, or by exposure to a suitable gas as hydrogen sulphide or a liquid containing sulphur, as sulphur dissolved in carbon bisulphide.

To produce the required flow of electrons through the film 15 a substantial potential is applied across the two terminal coatings 11 and 12 as by conductors 16 leading from a battery or like source 17 of direct current. As shown in the diagrammatic view, Fig. 2, the dimensional volt characteristics of the device indicate a substantially steady voltage of value *a* over the coating 11 and a corresponding steady voltage *b* of diminished value over the coating 12, while over the portion of the surface between said coatings the voltage in the film 15 will be according to the gradient *c*. As aforesaid, the electrode 13 is located substantially midway of the inner ends of the terminal coatings 11 and 12 and there is arranged to be supplied thereto a potential indicated by the value *d*, Fig. 2, and somewhat in excess of the voltage prevailing along the gradient *c* at this point. This potential may be applied by means of a battery or like source of potential 18, the negative pole of which is connected to the negative pole of the battery 17. In the circuit of the electrode 13 and source of potential 18 is also included some exterior source of oscillating or fluctuating current, which source is indicated, by way of example, in Fig. 3, as the antenna 20 of a radio communication circuit.

The effect of thus providing an excess positive potential in the electrode 13 is to prevent any potential in the oscillating circuit hereinbefore described from rendering said electrode of zero potential or of a negative potential, which would then permit a current to pass from the electrode edge to the film 15; as in the reverse direction where a positive voltage is maintained, the two members—namely electrode and connecting film—act as an electric valve to prevent the flow. Maintaining a positive potential at this point, however, insures that the flow of the electrons from the piece 11 to the piece 12 will be impeded in a predetermined degree, a variation therein being effected conformably to the changing amount of this potential under the influence of the oscillating or fluctuating current introduced. This effect will be repeated on a greatly magnified scale in the circuit of the conducting coatings 11 and 12 and may be reproduced in various circuits or for various purposes as thru a transformer 21, from the secondary of which leads 22 extend to any suitable device, which, as shown in Fig. 3, may be further amplifiers of this character as the radio frequency amplifiers 23 and audio frequency amplifiers 24, the last of which is shown connected to a loud speaker or similar device 25. A current rectifying member 26, however, is necessary where it is desired to convert the radio frequency into audio frequency oscillations. It will be observed that but two sources of potential 27 and 28—which may be combined into a single, properly tapped source—are required and of potentials approximately 30 and 15 volts respectively for the particular elements employed.

The basis of the invention resides apparently in the fact that the conducting layer at the particular point selected introduces a resistance varying with the electric field at this point; and in this connection it may be assumed that the atoms (or molecules) of a conductor are of the nature of bipoles. In order for an electron, therefore, to travel in the electric field, the bipoles are obliged to become organized in this field substantially with their axes parallel or lying in the field of flow. Any disturbance in this organization, as by heat movement, magnetic field, electrostatic cross-field, etc., will serve to increase the resistance of the conductor; and in the instant case, the conductivity of the layer is influenced by the electric field. Owing to the fact that this layer is extremely thin the field is permitted to penetrate the entire volume thereof and thus will change the conductivity throughout the entire cross-section of this conducting portion.

I claim:—

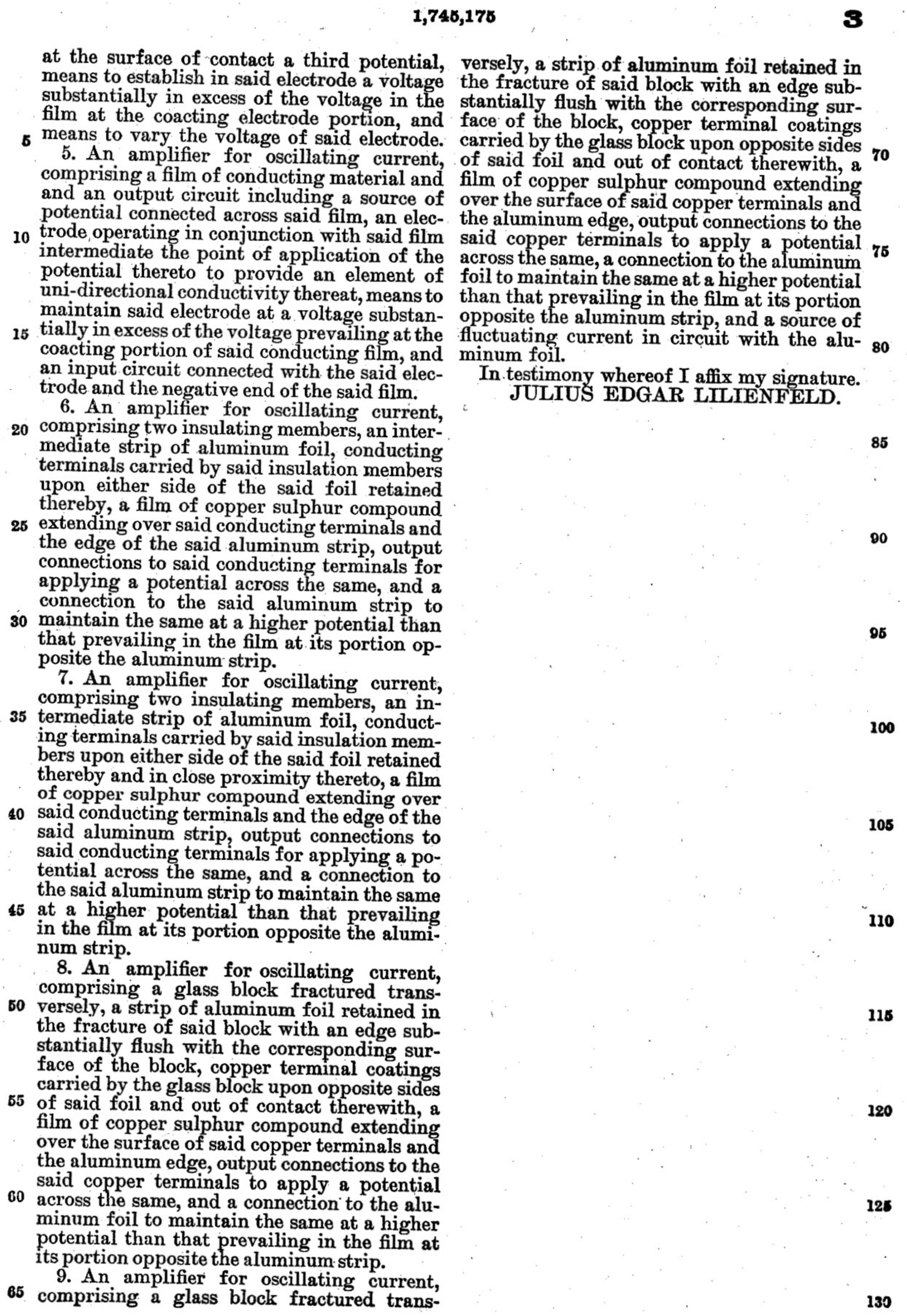
1. The method of controlling the flow of an electric current in an electrically conducting medium of minute thickness, which comprises subjecting the same to an electrostatic influence to impede the flow of said current by maintaining at an intermediate point in proximity thereto a potential in excess of the particular potential prevailing at that point.

2. The method of controlling the flow of an electric current in an electrically conducting solid of minute thickness, which comprises establishing an electrostatic influence in proximity to said flow in excess of the potential prevailing thereat, and varying the said electrostatic influence to correspondingly vary the said flow.

3. The method of controlling the flow of an electric current in an electrically conducting medium of minute thickness, which comprises subjecting the same to an electrostatic influence to impede the flow of said current by maintaining at an intermediate point in proximity thereto a potential in excess of the particular potential prevailing at that point, and varying the degree of excess potential by an impressed oscillating current.

4. An amplifier for oscillating current, comprising a film of conducting material and an output circuit including a source of potential connected across said film, an electrode associated with the said film for maintaining

Figure B.4: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,745,175 (originally filed in 1925 in Canada).



1,745,175 **3**

at the surface of contact a third potential, means to establish in said electrode a voltage substantially in excess of the voltage in the film at the coacting electrode portion, and means to vary the voltage of said electrode.

5. An amplifier for oscillating current, comprising a film of conducting material and and an output circuit including a source of potential connected across said film, an electrode operating in conjunction with said film intermediate the point of application of the potential thereto to provide an element of uni-directional conductivity thereat, means to maintain said electrode at a voltage substantially in excess of the voltage prevailing at the coacting portion of said conducting film, and an input circuit connected with the said electrode and the negative end of the said film.

6. An amplifier for oscillating current, comprising two insulating members, an intermediate strip of aluminum foil, conducting terminals carried by said insulation members upon either side of the said foil retained thereby, a film of copper sulphur compound extending over said conducting terminals and the edge of the said aluminum strip, output connections to said conducting terminals for applying a potential across the same, and a connection to the said aluminum strip to maintain the same at a higher potential than that prevailing in the film at its portion opposite the aluminum strip.

7. An amplifier for oscillating current, comprising two insulating members, an intermediate strip of aluminum foil, conducting terminals carried by said insulation members upon either side of the said foil retained thereby and in close proximity thereto, a film of copper sulphur compound extending over said conducting terminals and the edge of the said aluminum strip, output connections to said conducting terminals for applying a potential across the same, and a connection to the said aluminum strip to maintain the same at a higher potential than that prevailing in the film at its portion opposite the aluminum strip.

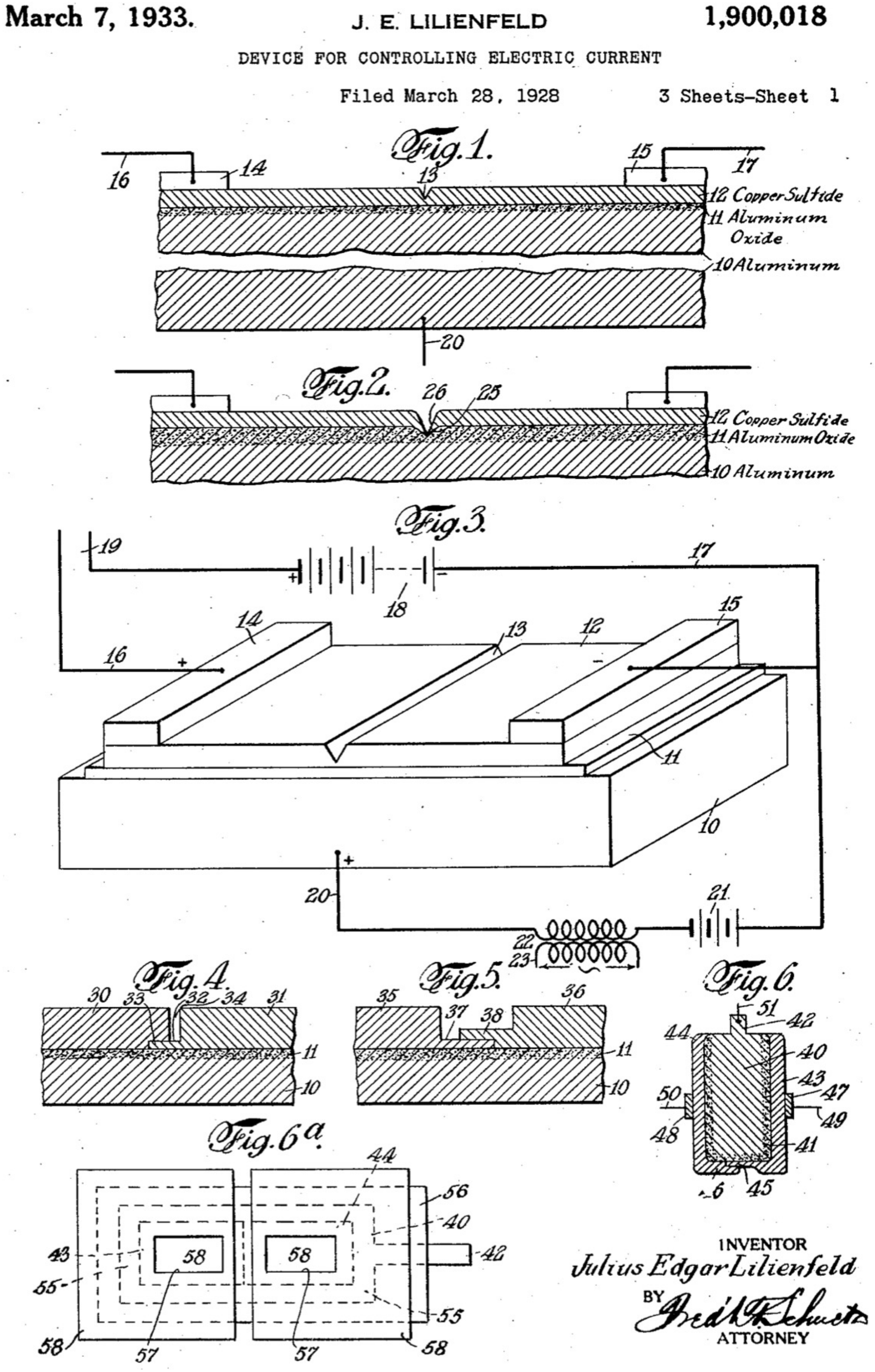
8. An amplifier for oscillating current, comprising a glass block fractured transversely, a strip of aluminum foil retained in the fracture of said block with an edge substantially flush with the corresponding surface of the block, copper terminal coatings carried by the glass block upon opposite sides of said foil and out of contact therewith, a film of copper sulphur compound extending over the surface of said copper terminals and the aluminum edge, output connections to the said copper terminals to apply a potential across the same, and a connection to the aluminum foil to maintain the same at a higher potential than that prevailing in the film at its portion opposite the aluminum strip.

9. An amplifier for oscillating current, comprising a glass block fractured transversely, a strip of aluminum foil retained in the fracture of said block with an edge substantially flush with the corresponding surface of the block, copper terminal coatings carried by the glass block upon opposite sides of said foil and out of contact therewith, a film of copper sulphur compound extending over the surface of said copper terminals and the aluminum edge, output connections to the said copper terminals to apply a potential across the same, a connection to the aluminum foil to maintain the same at a higher potential than that prevailing in the film at its portion opposite the aluminum strip, and a source of fluctuating current in circuit with the aluminum foil.

In testimony whereof I affix my signature.

JULIUS EDGAR LILIENFELD.

Figure B.5: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,745,175 (originally filed in 1925 in Canada).



March 7, 1933. J. E. LILIENFELD **1,900,018**

DEVICE FOR CONTROLLING ELECTRIC CURRENT

Filed March 28, 1928 3 Sheets-Sheet 1

INVENTOR
Julius Edgar Lilienfeld
BY
ATTORNEY

Fig. 1.
16
14
13
15
17
12 Copper Sulfide
11 Aluminum Oxide
10 Aluminum
20
Fig. 2.
26
25
12 Copper Sulfide
11 Aluminum Oxide
10 Aluminum
Fig. 3.
19
+
18
-
17
14
13
12
15
16
+
-
11
10
+
20
21
22
23
Fig. 4.
30
33
32
34
31
11
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Fig. 5.
35
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38
36
11
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Fig. 6.
51
42
44
40
43
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48
41
6
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Fig. 6a.
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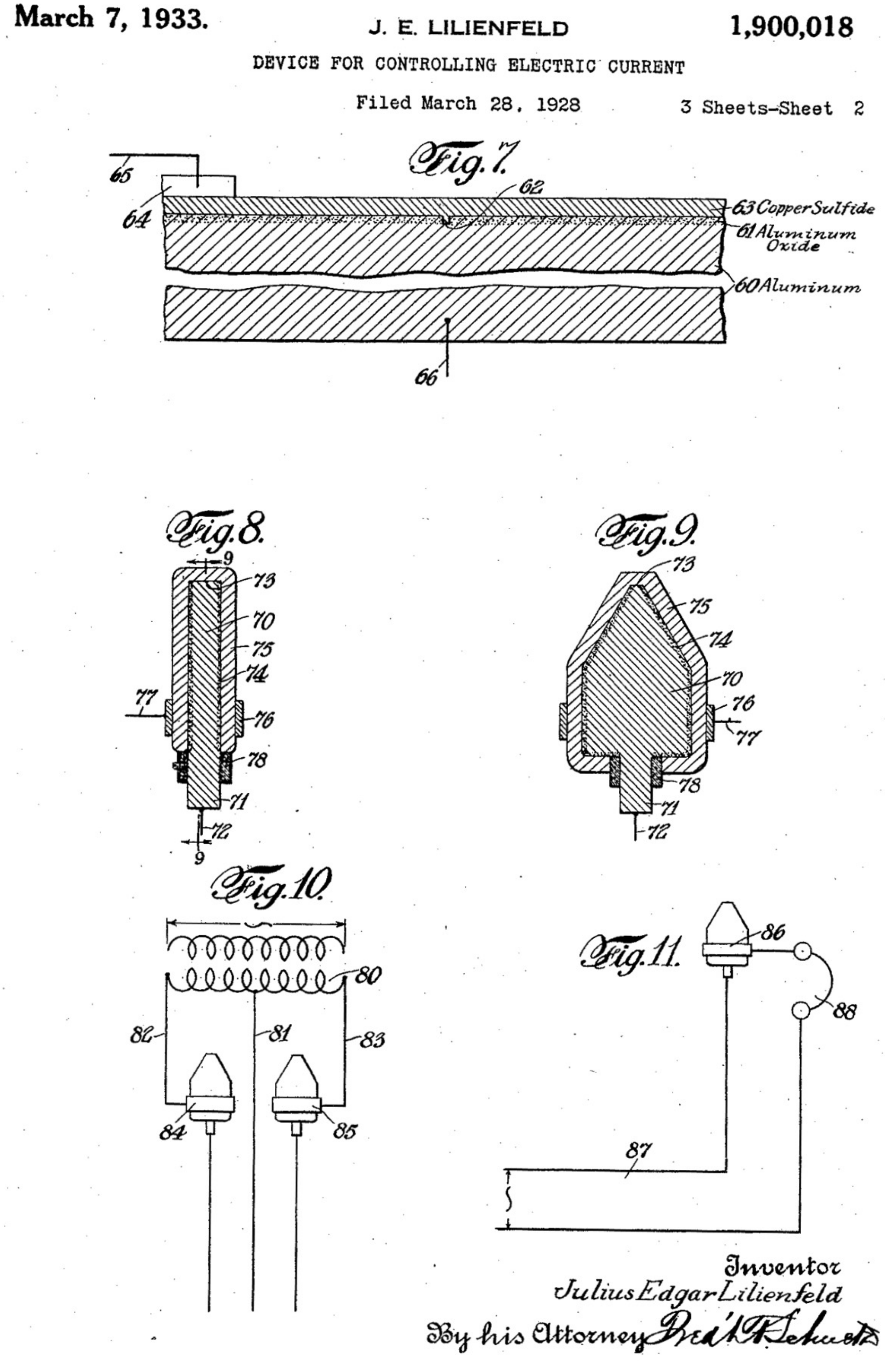
Figure B.6: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,900,018 (filed in 1928).



March 7, 1933. J. E. LILIENFELD **1,900,018**

DEVICE FOR CONTROLLING ELECTRIC CURRENT

Filed March 28, 1928 3 Sheets-Sheet 2

Fig. 7.
65
64
62
63 Copper Sulfide
61 Aluminum Oxide
60 Aluminum
66
Fig. 8.
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73
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75
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76
78
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72
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Fig. 9.
73
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71
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Fig. 10.
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Fig. 11.
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Inventor
Julius Edgar Lilienfeld
By his Attorney

Figure B.7: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,900,018 (filed in 1928).

March 7, 1933. J. E. LILIENFELD **1,900,018**

DEVICE FOR CONTROLLING ELECTRIC CURRENT

Filed March 28, 1928 3 Sheets-Sheet 3

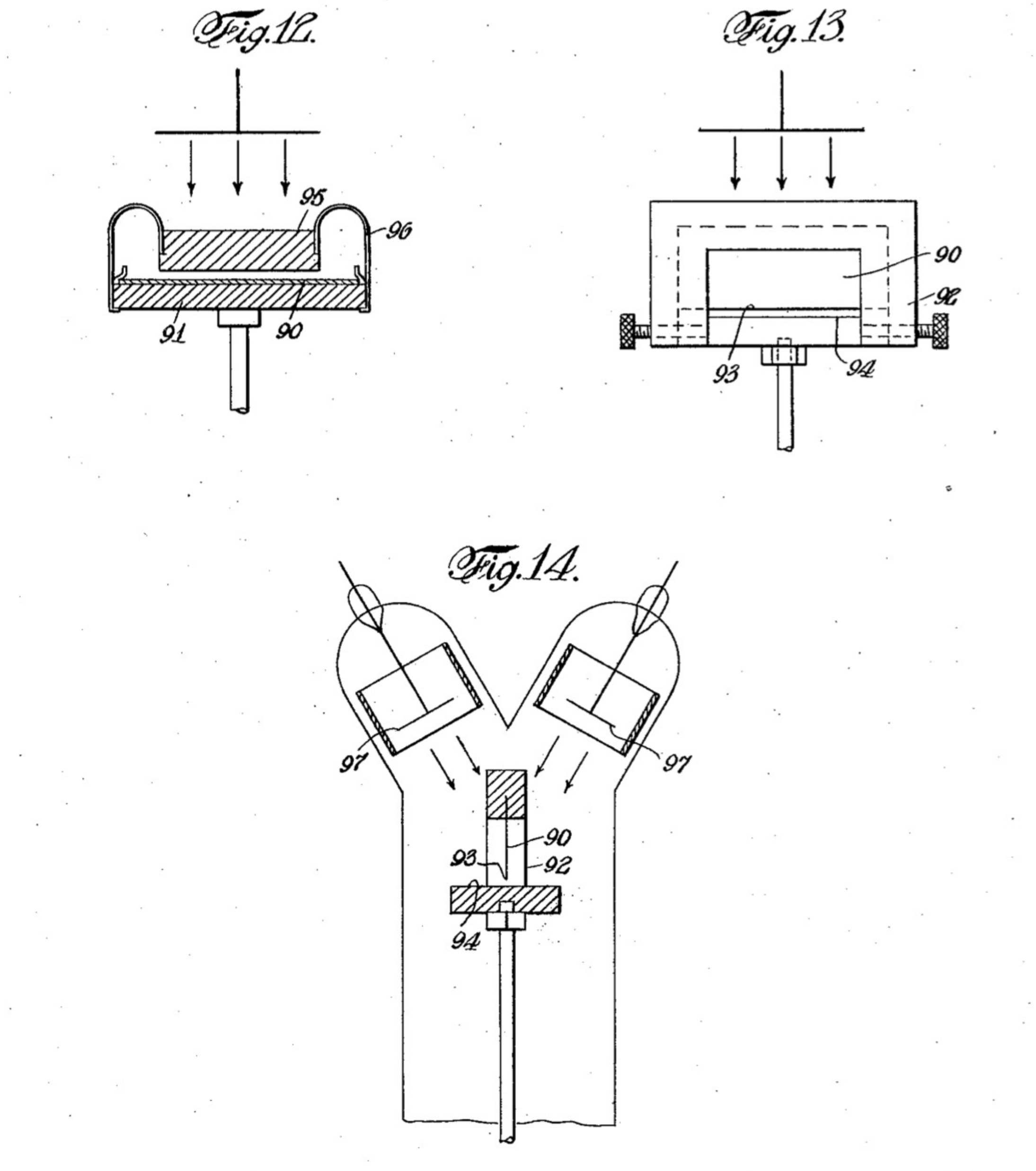
Fig.12.
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Fig.13.
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Fig.14.
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93
92
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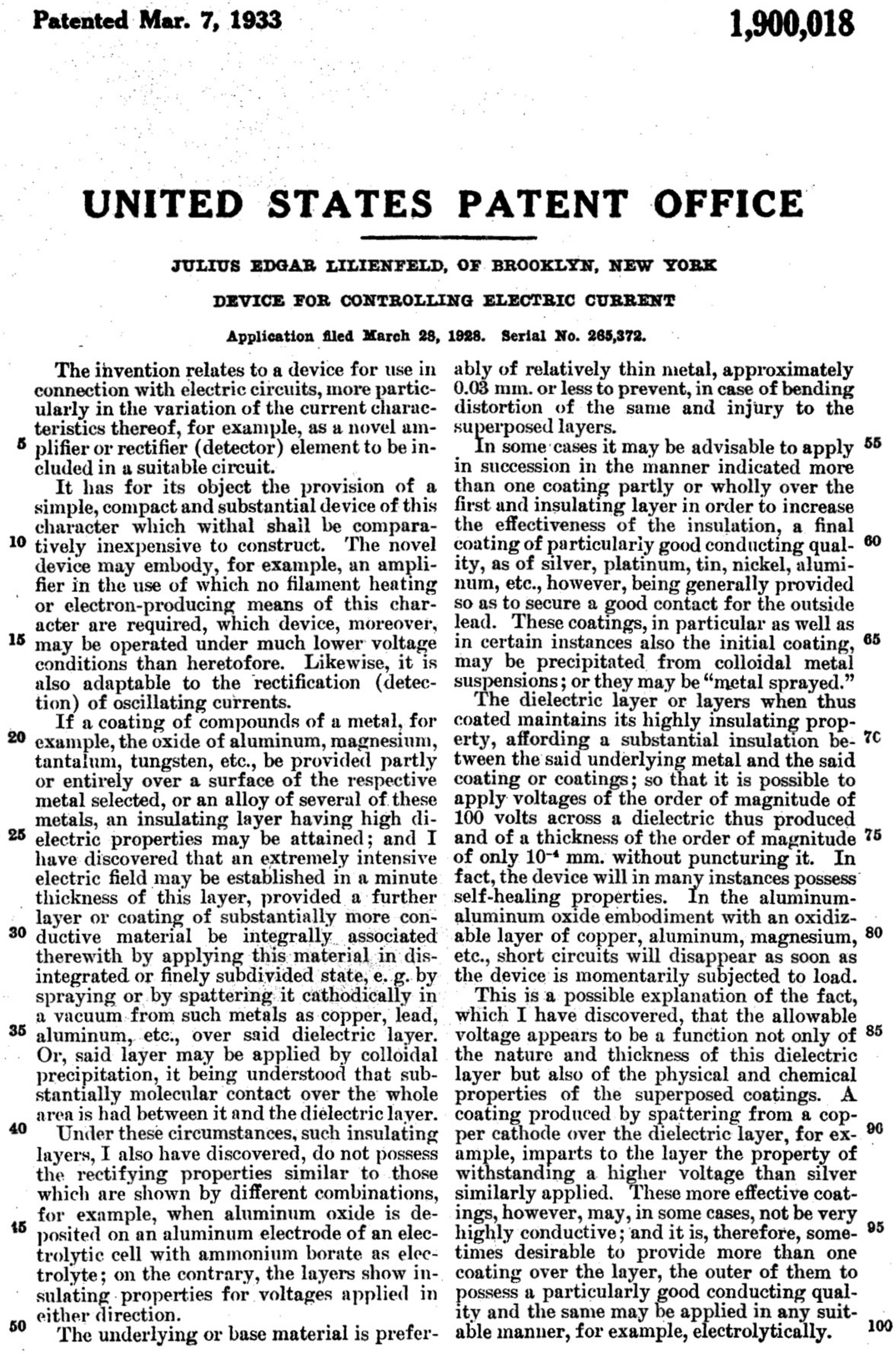
Inventor
Julius Edgar Lilienfeld
By his Attorney

Figure B.8: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,900,018 (filed in 1928).



Patented Mar. 7, 1933 **1,900,018**

UNITED STATES PATENT OFFICE

JULIUS EDGAR LILIENFELD, OF BROOKLYN, NEW YORK

DEVICE FOR CONTROLLING ELECTRIC CURRENT

Application filed March 28, 1928. Serial No. 265,372.

The invention relates to a device for use in connection with electric circuits, more particularly in the variation of the current characteristics thereof, for example, as a novel amplifier or rectifier (detector) element to be included in a suitable circuit.

It has for its object the provision of a simple, compact and substantial device of this character which withal shall be comparatively inexpensive to construct. The novel device may embody, for example, an amplifier in the use of which no filament heating or electron-producing means of this character are required, which device, moreover, may be operated under much lower voltage conditions than heretofore. Likewise, it is also adaptable to the rectification (detection) of oscillating currents.

If a coating of compounds of a metal, for example, the oxide of aluminum, magnesium, tantalum, tungsten, etc., be provided partly or entirely over a surface of the respective metal selected, or an alloy of several of these metals, an insulating layer having high dielectric properties may be attained; and I have discovered that an extremely intensive electric field may be established in a minute thickness of this layer, provided a further layer or coating of substantially more conductive material be integrally associated therewith by applying this material in disintegrated or finely subdivided state, e. g. by spraying or by spattering it cathodically in a vacuum from such metals as copper, lead, aluminum, etc., over said dielectric layer. Or, said layer may be applied by colloidal precipitation, it being understood that substantially molecular contact over the whole area is had between it and the dielectric layer.

Under these circumstances, such insulating layers, I also have discovered, do not possess the rectifying properties similar to those which are shown by different combinations, for example, when aluminum oxide is deposited on an aluminum electrode of an electrolytic cell with ammonium borate as electrolyte; on the contrary, the layers show insulating properties for voltages applied in either direction.

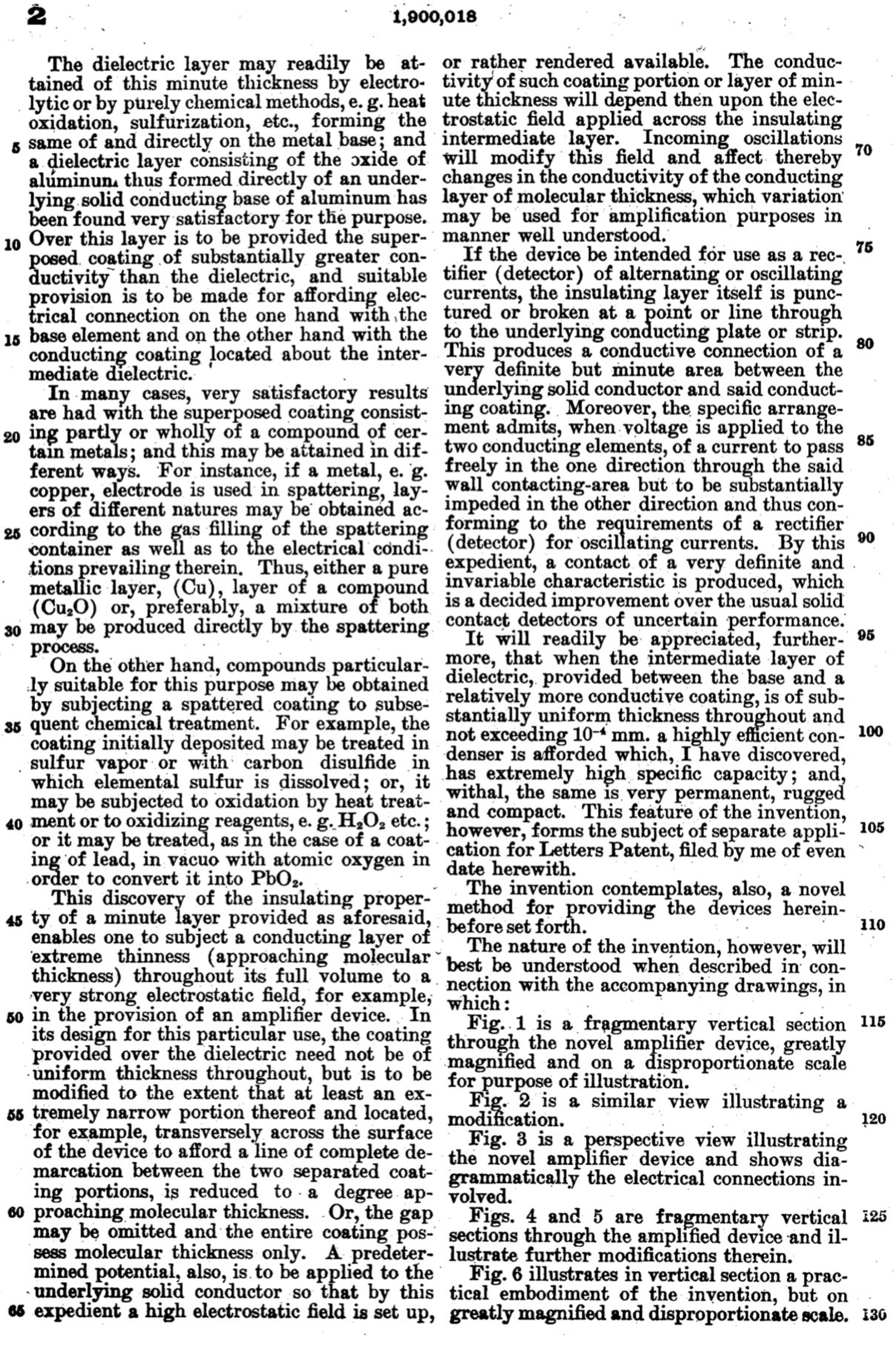
The underlying or base material is preferably of relatively thin metal, approximately 0.03 mm. or less to prevent, in case of bending distortion of the same and injury to the superposed layers.

In some cases it may be advisable to apply in succession in the manner indicated more than one coating partly or wholly over the first and insulating layer in order to increase the effectiveness of the insulation, a final coating of particularly good conducting quality, as of silver, platinum, tin, nickel, aluminum, etc., however, being generally provided so as to secure a good contact for the outside lead. These coatings, in particular as well as in certain instances also the initial coating, may be precipitated from colloidal metal suspensions; or they may be "metal sprayed."

The dielectric layer or layers when thus coated maintains its highly insulating property, affording a substantial insulation between the said underlying metal and the said coating or coatings; so that it is possible to apply voltages of the order of magnitude of 100 volts across a dielectric thus produced and of a thickness of the order of magnitude of only 10^{-4} mm. without puncturing it. In fact, the device will in many instances possess self-healing properties. In the aluminum-aluminum oxide embodiment with an oxidizable layer of copper, aluminum, magnesium, etc., short circuits will disappear as soon as the device is momentarily subjected to load.

This is a possible explanation of the fact, which I have discovered, that the allowable voltage appears to be a function not only of the nature and thickness of this dielectric layer but also of the physical and chemical properties of the superposed coatings. A coating produced by spattering from a copper cathode over the dielectric layer, for example, imparts to the layer the property of withstanding a higher voltage than silver similarly applied. These more effective coatings, however, may, in some cases, not be very highly conductive; and it is, therefore, sometimes desirable to provide more than one coating over the layer, the outer of them to possess a particularly good conducting quality and the same may be applied in any suitable manner, for example, electrolytically.

Figure B.9: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,900,018 (filed in 1928).



2 1,900,018

The dielectric layer may readily be attained of this minute thickness by electrolytic or by purely chemical methods, e. g. heat oxidation, sulfurization, etc., forming the same of and directly on the metal base; and a dielectric layer consisting of the oxide of aluminum thus formed directly of an underlying solid conducting base of aluminum has been found very satisfactory for the purpose. Over this layer is to be provided the superposed coating of substantially greater conductivity than the dielectric, and suitable provision is to be made for affording electrical connection on the one hand with the base element and on the other hand with the conducting coating located about the intermediate dielectric.

In many cases, very satisfactory results are had with the superposed coating consisting partly or wholly of a compound of certain metals; and this may be attained in different ways. For instance, if a metal, e. g. copper, electrode is used in spattering, layers of different natures may be obtained according to the gas filling of the spattering container as well as to the electrical conditions prevailing therein. Thus, either a pure metallic layer, (Cu), layer of a compound (Cu_2O) or, preferably, a mixture of both may be produced directly by the spattering process.

On the other hand, compounds particularly suitable for this purpose may be obtained by subjecting a spattered coating to subsequent chemical treatment. For example, the coating initially deposited may be treated in sulfur vapor or with carbon disulfide in which elemental sulfur is dissolved; or, it may be subjected to oxidation by heat treatment or to oxidizing reagents, e. g. H_2O_2 etc.; or it may be treated, as in the case of a coating of lead, in vacuo with atomic oxygen in order to convert it into PbO_2.

This discovery of the insulating property of a minute layer provided as aforesaid, enables one to subject a conducting layer of extreme thinness (approaching molecular thickness) throughout its full volume to a very strong electrostatic field, for example, in the provision of an amplifier device. In its design for this particular use, the coating provided over the dielectric need not be of uniform thickness throughout, but is to be modified to the extent that at least an extremely narrow portion thereof and located, for example, transversely across the surface of the device to afford a line of complete demarcation between the two separated coating portions, is reduced to a degree approaching molecular thickness. Or, the gap may be omitted and the entire coating possess molecular thickness only. A predetermined potential, also, is to be applied to the underlying solid conductor so that by this expedient a high electrostatic field is set up, or rather rendered available. The conductivity of such coating portion or layer of minute thickness will depend then upon the electrostatic field applied across the insulating intermediate layer. Incoming oscillations will modify this field and affect thereby changes in the conductivity of the conducting layer of molecular thickness, which variation may be used for amplification purposes in manner well understood.

If the device be intended for use as a rectifier (detector) of alternating or oscillating currents, the insulating layer itself is punctured or broken at a point or line through to the underlying conducting plate or strip. This produces a conductive connection of a very definite but minute area between the underlying solid conductor and said conducting coating. Moreover, the specific arrangement admits, when voltage is applied to the two conducting elements, of a current to pass freely in the one direction through the said wall contacting-area but to be substantially impeded in the other direction and thus conforming to the requirements of a rectifier (detector) for oscillating currents. By this expedient, a contact of a very definite and invariable characteristic is produced, which is a decided improvement over the usual solid contact detectors of uncertain performance.

It will readily be appreciated, furthermore, that when the intermediate layer of dielectric, provided between the base and a relatively more conductive coating, is of substantially uniform thickness throughout and not exceeding 10^{-4} mm. a highly efficient condenser is afforded which, I have discovered, has extremely high specific capacity; and, withal, the same is very permanent, rugged and compact. This feature of the invention, however, forms the subject of separate application for Letters Patent, filed by me of even date herewith.

The invention contemplates, also, a novel method for providing the devices hereinbefore set forth.

The nature of the invention, however, will best be understood when described in connection with the accompanying drawings, in which:

Fig. 1 is a fragmentary vertical section through the novel amplifier device, greatly magnified and on a disproportionate scale for purpose of illustration.

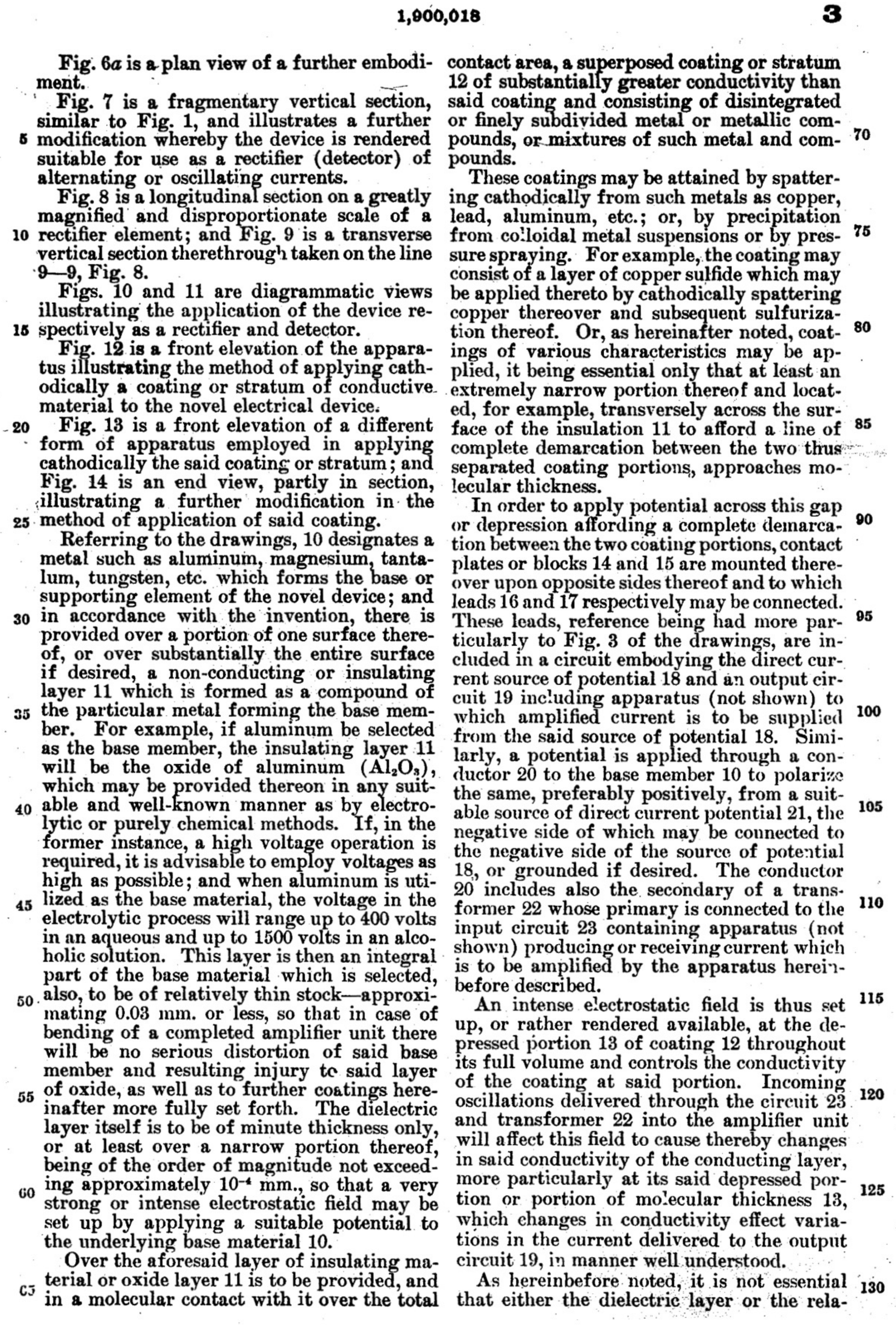
Fig. 2 is a similar view illustrating a modification.

Fig. 3 is a perspective view illustrating the novel amplifier device and shows diagrammatically the electrical connections involved.

Figs. 4 and 5 are fragmentary vertical sections through the amplified device and illustrate further modifications therein.

Fig. 6 illustrates in vertical section a practical embodiment of the invention, but on greatly magnified and disproportionate scale.

Figure B.10: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,900,018 (filed in 1928).



1,900,018 **3**

Fig. 6*a* is a plan view of a further embodiment.

Fig. 7 is a fragmentary vertical section, similar to Fig. 1, and illustrates a further modification whereby the device is rendered suitable for use as a rectifier (detector) of alternating or oscillating currents.

Fig. 8 is a longitudinal section on a greatly magnified and disproportionate scale of a rectifier element; and Fig. 9 is a transverse vertical section therethrough taken on the line 9—9, Fig. 8.

Figs. 10 and 11 are diagrammatic views illustrating the application of the device respectively as a rectifier and detector.

Fig. 12 is a front elevation of the apparatus illustrating the method of applying cathodically a coating or stratum of conductive material to the novel electrical device.

Fig. 13 is a front elevation of a different form of apparatus employed in applying cathodically the said coating or stratum; and Fig. 14 is an end view, partly in section, illustrating a further modification in the method of application of said coating.

Referring to the drawings, 10 designates a metal such as aluminum, magnesium, tantalum, tungsten, etc. which forms the base or supporting element of the novel device; and in accordance with the invention, there is provided over a portion of one surface thereof, or over substantially the entire surface if desired, a non-conducting or insulating layer 11 which is formed as a compound of the particular metal forming the base member. For example, if aluminum be selected as the base member, the insulating layer 11 will be the oxide of aluminum (Al_2O_3), which may be provided thereon in any suitable and well-known manner as by electrolytic or purely chemical methods. If, in the former instance, a high voltage operation is required, it is advisable to employ voltages as high as possible; and when aluminum is utilized as the base material, the voltage in the electrolytic process will range up to 400 volts in an aqueous and up to 1500 volts in an alcoholic solution. This layer is then an integral part of the base material which is selected, also, to be of relatively thin stock—approximating 0.03 mm. or less, so that in case of bending of a completed amplifier unit there will be no serious distortion of said base member and resulting injury to said layer of oxide, as well as to further coatings hereinafter more fully set forth. The dielectric layer itself is to be of minute thickness only, or at least over a narrow portion thereof, being of the order of magnitude not exceeding approximately 10^{-4} mm., so that a very strong or intense electrostatic field may be set up by applying a suitable potential to the underlying base material 10.

Over the aforesaid layer of insulating material or oxide layer 11 is to be provided, and in a molecular contact with it over the total contact area, a superposed coating or stratum 12 of substantially greater conductivity than said coating and consisting of disintegrated or finely subdivided metal or metallic compounds, or mixtures of such metal and compounds.

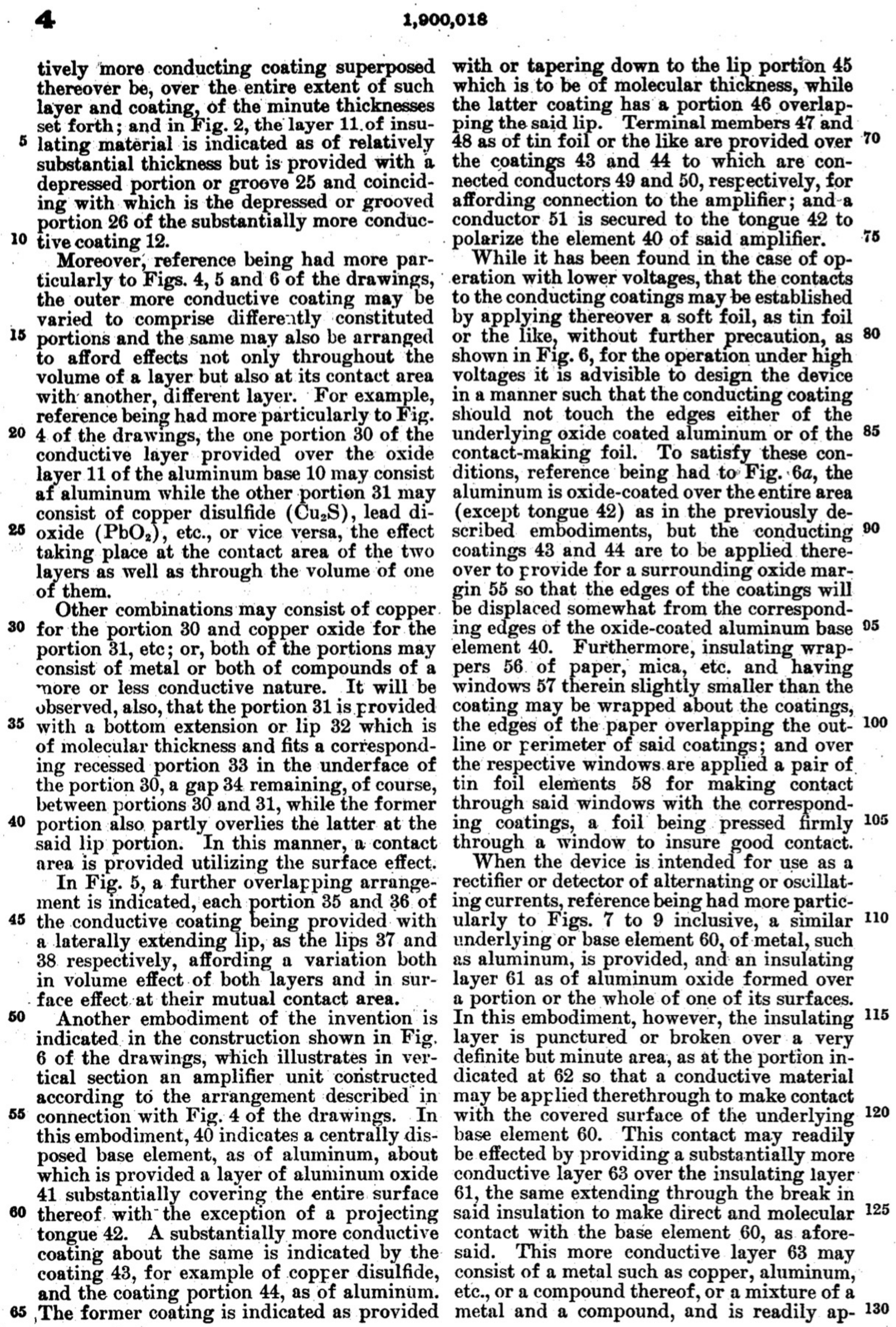
These coatings may be attained by spattering cathodically from such metals as copper, lead, aluminum, etc.; or, by precipitation from colloidal metal suspensions or by pressure spraying. For example, the coating may consist of a layer of copper sulfide which may be applied thereto by cathodically spattering copper thereover and subsequent sulfurization thereof. Or, as hereinafter noted, coatings of various characteristics may be applied, it being essential only that at least an extremely narrow portion thereof and located, for example, transversely across the surface of the insulation 11 to afford a line of complete demarcation between the two thus separated coating portions, approaches molecular thickness.

In order to apply potential across this gap or depression affording a complete demarcation between the two coating portions, contact plates or blocks 14 and 15 are mounted thereover upon opposite sides thereof and to which leads 16 and 17 respectively may be connected. These leads, reference being had more particularly to Fig. 3 of the drawings, are included in a circuit embodying the direct current source of potential 18 and an output circuit 19 including apparatus (not shown) to which amplified current is to be supplied from the said source of potential 18. Similarly, a potential is applied through a conductor 20 to the base member 10 to polarize the same, preferably positively, from a suitable source of direct current potential 21, the negative side of which may be connected to the negative side of the source of potential 18, or grounded if desired. The conductor 20 includes also the secondary of a transformer 22 whose primary is connected to the input circuit 23 containing apparatus (not shown) producing or receiving current which is to be amplified by the apparatus hereinbefore described.

An intense electrostatic field is thus set up, or rather rendered available, at the depressed portion 13 of coating 12 throughout its full volume and controls the conductivity of the coating at said portion. Incoming oscillations delivered through the circuit 23 and transformer 22 into the amplifier unit will affect this field to cause thereby changes in said conductivity of the conducting layer, more particularly at its said depressed portion or portion of molecular thickness 13, which changes in conductivity effect variations in the current delivered to the output circuit 19, in manner well understood.

As hereinbefore noted, it is not essential that either the dielectric layer or the rela-

Figure B.11: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,900,018 (filed in 1928).



4 **1,900,018**

tively more conducting coating superposed thereover be, over the entire extent of such layer and coating, of the minute thicknesses set forth; and in Fig. 2, the layer 11 of insulating material is indicated as of relatively substantial thickness but is provided with a depressed portion or groove 25 and coinciding with which is the depressed or grooved portion 26 of the substantially more conductive coating 12.

Moreover, reference being had more particularly to Figs. 4, 5 and 6 of the drawings, the outer more conductive coating may be varied to comprise differently constituted portions and the same may also be arranged to afford effects not only throughout the volume of a layer but also at its contact area with another, different layer. For example, reference being had more particularly to Fig. 4 of the drawings, the one portion 30 of the conductive layer provided over the oxide layer 11 of the aluminum base 10 may consist af aluminum while the other portion 31 may consist of copper disulfide (Cu_2S), lead dioxide (PbO_2), etc., or vice versa, the effect taking place at the contact area of the two layers as well as through the volume of one of them.

Other combinations may consist of copper for the portion 30 and copper oxide for the portion 31, etc; or, both of the portions may consist of metal or both of compounds of a more or less conductive nature. It will be observed, also, that the portion 31 is provided with a bottom extension or lip 32 which is of molecular thickness and fits a corresponding recessed portion 33 in the underface of the portion 30, a gap 34 remaining, of course, between portions 30 and 31, while the former portion also partly overlies the latter at the said lip portion. In this manner, a contact area is provided utilizing the surface effect.

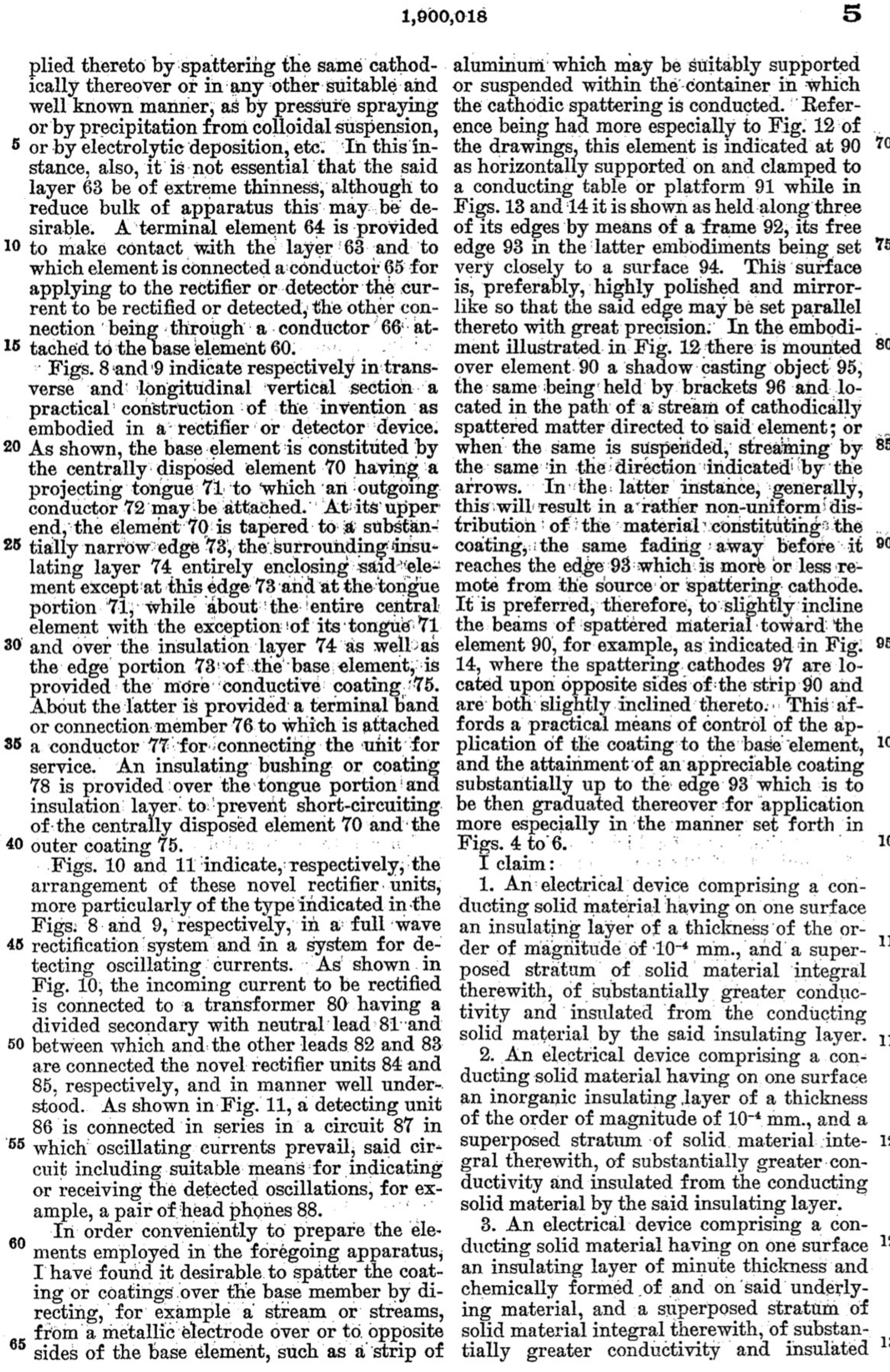
In Fig. 5, a further overlapping arrangement is indicated, each portion 35 and 36 of the conductive coating being provided with a laterally extending lip, as the lips 37 and 38 respectively, affording a variation both in volume effect of both layers and in surface effect at their mutual contact area.

Another embodiment of the invention is indicated in the construction shown in Fig. 6 of the drawings, which illustrates in vertical section an amplifier unit constructed according to the arrangement described in connection with Fig. 4 of the drawings. In this embodiment, 40 indicates a centrally disposed base element, as of aluminum, about which is provided a layer of aluminum oxide 41 substantially covering the entire surface thereof with the exception of a projecting tongue 42. A substantially more conductive coating about the same is indicated by the coating 43, for example of copper disulfide, and the coating portion 44, as of aluminum. The former coating is indicated as provided with or tapering down to the lip portion 45 which is to be of molecular thickness, while the latter coating has a portion 46 overlapping the said lip. Terminal members 47 and 48 as of tin foil or the like are provided over the coatings 43 and 44 to which are connected conductors 49 and 50, respectively, for affording connection to the amplifier; and a conductor 51 is secured to the tongue 42 to polarize the element 40 of said amplifier.

While it has been found in the case of operation with lower voltages, that the contacts to the conducting coatings may be established by applying thereover a soft foil, as tin foil or the like, without further precaution, as shown in Fig. 6, for the operation under high voltages it is advisible to design the device in a manner such that the conducting coating should not touch the edges either of the underlying oxide coated aluminum or of the contact-making foil. To satisfy these conditions, reference being had to Fig. 6*a*, the aluminum is oxide-coated over the entire area (except tongue 42) as in the previously described embodiments, but the conducting coatings 43 and 44 are to be applied thereover to provide for a surrounding oxide margin 55 so that the edges of the coatings will be displaced somewhat from the corresponding edges of the oxide-coated aluminum base element 40. Furthermore, insulating wrappers 56 of paper, mica, etc. and having windows 57 therein slightly smaller than the coating may be wrapped about the coatings, the edges of the paper overlapping the outline or perimeter of said coatings; and over the respective windows are applied a pair of tin foil elements 58 for making contact through said windows with the corresponding coatings, a foil being pressed firmly through a window to insure good contact.

When the device is intended for use as a rectifier or detector of alternating or oscillating currents, reference being had more particularly to Figs. 7 to 9 inclusive, a similar underlying or base element 60, of metal, such as aluminum, is provided, and an insulating layer 61 as of aluminum oxide formed over a portion or the whole of one of its surfaces. In this embodiment, however, the insulating layer is punctured or broken over a very definite but minute area, as at the portion indicated at 62 so that a conductive material may be applied therethrough to make contact with the covered surface of the underlying base element 60. This contact may readily be effected by providing a substantially more conductive layer 63 over the insulating layer 61, the same extending through the break in said insulation to make direct and molecular contact with the base element 60, as aforesaid. This more conductive layer 63 may consist of a metal such as copper, aluminum, etc., or a compound thereof, or a mixture of a metal and a compound, and is readily ap-

Figure B.12: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,900,018 (filed in 1928).



1,900,018 5

plied thereto by spattering the same cathodically thereover or in any other suitable and well known manner, as by pressure spraying or by precipitation from colloidal suspension, or by electrolytic deposition, etc. In this instance, also, it is not essential that the said layer 63 be of extreme thinness, although to reduce bulk of apparatus this may be desirable. A terminal element 64 is provided to make contact with the layer 63 and to which element is connected a conductor 65 for applying to the rectifier or detector the current to be rectified or detected, the other connection being through a conductor 66 attached to the base element 60.

Figs. 8 and 9 indicate respectively in transverse and longitudinal vertical section a practical construction of the invention as embodied in a rectifier or detector device. As shown, the base element is constituted by the centrally disposed element 70 having a projecting tongue 71 to which an outgoing conductor 72 may be attached. At its upper end, the element 70 is tapered to a substantially narrow edge 73, the surrounding insulating layer 74 entirely enclosing said element except at this edge 73 and at the tongue portion 71, while about the entire central element with the exception of its tongue 71 and over the insulation layer 74 as well as the edge portion 73 of the base element, is provided the more conductive coating 75. About the latter is provided a terminal band or connection member 76 to which is attached a conductor 77 for connecting the unit for service. An insulating bushing or coating 78 is provided over the tongue portion and insulation layer to prevent short-circuiting of the centrally disposed element 70 and the outer coating 75.

Figs. 10 and 11 indicate, respectively, the arrangement of these novel rectifier units, more particularly of the type indicated in the Figs. 8 and 9, respectively, in a full wave rectification system and in a system for detecting oscillating currents. As shown in Fig. 10, the incoming current to be rectified is connected to a transformer 80 having a divided secondary with neutral lead 81 and between which and the other leads 82 and 83 are connected the novel rectifier units 84 and 85, respectively, and in manner well understood. As shown in Fig. 11, a detecting unit 86 is connected in series in a circuit 87 in which oscillating currents prevail, said circuit including suitable means for indicating or receiving the detected oscillations, for example, a pair of head phones 88.

In order conveniently to prepare the elements employed in the foregoing apparatus, I have found it desirable to spatter the coating or coatings over the base member by directing, for example a stream or streams, from a metallic electrode over or to opposite sides of the base element, such as a strip of aluminum which may be suitably supported or suspended within the container in which the cathodic spattering is conducted. Reference being had more especially to Fig. 12 of the drawings, this element is indicated at 90 as horizontally supported on and clamped to a conducting table or platform 91 while in Figs. 13 and 14 it is shown as held along three of its edges by means of a frame 92, its free edge 93 in the latter embodiments being set very closely to a surface 94. This surface is, preferably, highly polished and mirror-like so that the said edge may be set parallel thereto with great precision. In the embodiment illustrated in Fig. 12 there is mounted over element 90 a shadow casting object 95, the same being held by brackets 96 and located in the path of a stream of cathodically spattered matter directed to said element; or when the same is suspended, streaming by the same in the direction indicated by the arrows. In the latter instance, generally, this will result in a rather non-uniform distribution of the material constituting the coating, the same fading away before it reaches the edge 93 which is more or less remote from the source or spattering cathode. It is preferred, therefore, to slightly incline the beams of spattered material toward the element 90, for example, as indicated in Fig. 14, where the spattering cathodes 97 are located upon opposite sides of the strip 90 and are both slightly inclined thereto. This affords a practical means of control of the application of the coating to the base element, and the attainment of an appreciable coating substantially up to the edge 93 which is to be then graduated thereover for application more especially in the manner set forth in Figs. 4 to 6.

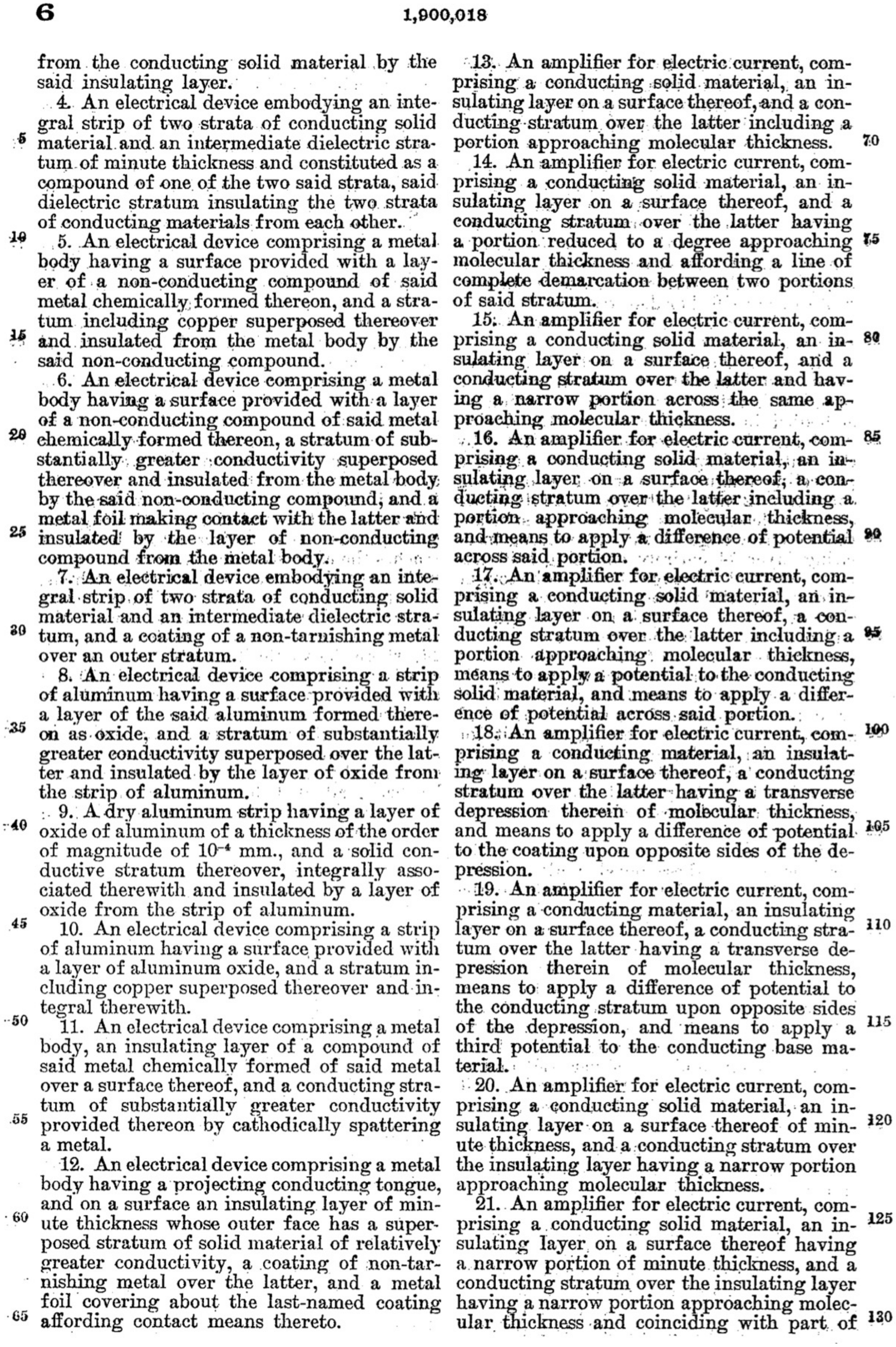
I claim:

1. An electrical device comprising a conducting solid material having on one surface an insulating layer of a thickness of the order of magnitude of 10^{-4} mm., and a superposed stratum of solid material integral therewith, of substantially greater conductivity and insulated from the conducting solid material by the said insulating layer.

2. An electrical device comprising a conducting solid material having on one surface an inorganic insulating layer of a thickness of the order of magnitude of 10^{-4} mm., and a superposed stratum of solid material integral therewith, of substantially greater conductivity and insulated from the conducting solid material by the said insulating layer.

3. An electrical device comprising a conducting solid material having on one surface an insulating layer of minute thickness and chemically formed of and on said underlying material, and a superposed stratum of solid material integral therewith, of substantially greater conductivity and insulated

Figure B.13: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,900,018 (filed in 1928).



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from the conducting solid material by the said insulating layer.

4. An electrical device embodying an integral strip of two strata of conducting solid material and an intermediate dielectric stratum of minute thickness and constituted as a compound of one of the two said strata, said dielectric stratum insulating the two strata of conducting materials from each other.

5. An electrical device comprising a metal body having a surface provided with a layer of a non-conducting compound of said metal chemically formed thereon, and a stratum including copper superposed thereover and insulated from the metal body by the said non-conducting compound.

6. An electrical device comprising a metal body having a surface provided with a layer of a non-conducting compound of said metal chemically formed thereon, a stratum of substantially greater conductivity superposed thereover and insulated from the metal body by the said non-conducting compound, and a metal foil making contact with the latter and insulated by the layer of non-conducting compound from the metal body.

7. An electrical device embodying an integral strip of two strata of conducting solid material and an intermediate dielectric stratum, and a coating of a non-tarnishing metal over an outer stratum.

8. An electrical device comprising a strip of aluminum having a surface provided with a layer of the said aluminum formed thereon as oxide, and a stratum of substantially greater conductivity superposed over the latter and insulated by the layer of oxide from the strip of aluminum.

9. A dry aluminum strip having a layer of oxide of aluminum of a thickness of the order of magnitude of 10^{-4} mm., and a solid conductive stratum thereover, integrally associated therewith and insulated by a layer of oxide from the strip of aluminum.

10. An electrical device comprising a strip of aluminum having a surface provided with a layer of aluminum oxide, and a stratum including copper superposed thereover and integral therewith.

11. An electrical device comprising a metal body, an insulating layer of a compound of said metal chemically formed of said metal over a surface thereof, and a conducting stratum of substantially greater conductivity provided thereon by cathodically spattering a metal.

12. An electrical device comprising a metal body having a projecting conducting tongue, and on a surface an insulating layer of minute thickness whose outer face has a superposed stratum of solid material of relatively greater conductivity, a coating of non-tarnishing metal over the latter, and a metal foil covering about the last-named coating affording contact means thereto.

13. An amplifier for electric current, comprising a conducting solid material, an insulating layer on a surface thereof, and a conducting stratum over the latter including a portion approaching molecular thickness.

14. An amplifier for electric current, comprising a conducting solid material, an insulating layer on a surface thereof, and a conducting stratum over the latter having a portion reduced to a degree approaching molecular thickness and affording a line of complete demarcation between two portions of said stratum.

15. An amplifier for electric current, comprising a conducting solid material, an insulating layer on a surface thereof, and a conducting stratum over the latter and having a narrow portion across the same approaching molecular thickness.

16. An amplifier for electric current, comprising a conducting solid material, an insulating layer on a surface thereof, a conducting stratum over the latter including a portion approaching molecular thickness, and means to apply a difference of potential across said portion.

17. An amplifier for electric current, comprising a conducting solid material, an insulating layer on a surface thereof, a conducting stratum over the latter including a portion approaching molecular thickness, means to apply a potential to the conducting solid material, and means to apply a difference of potential across said portion.

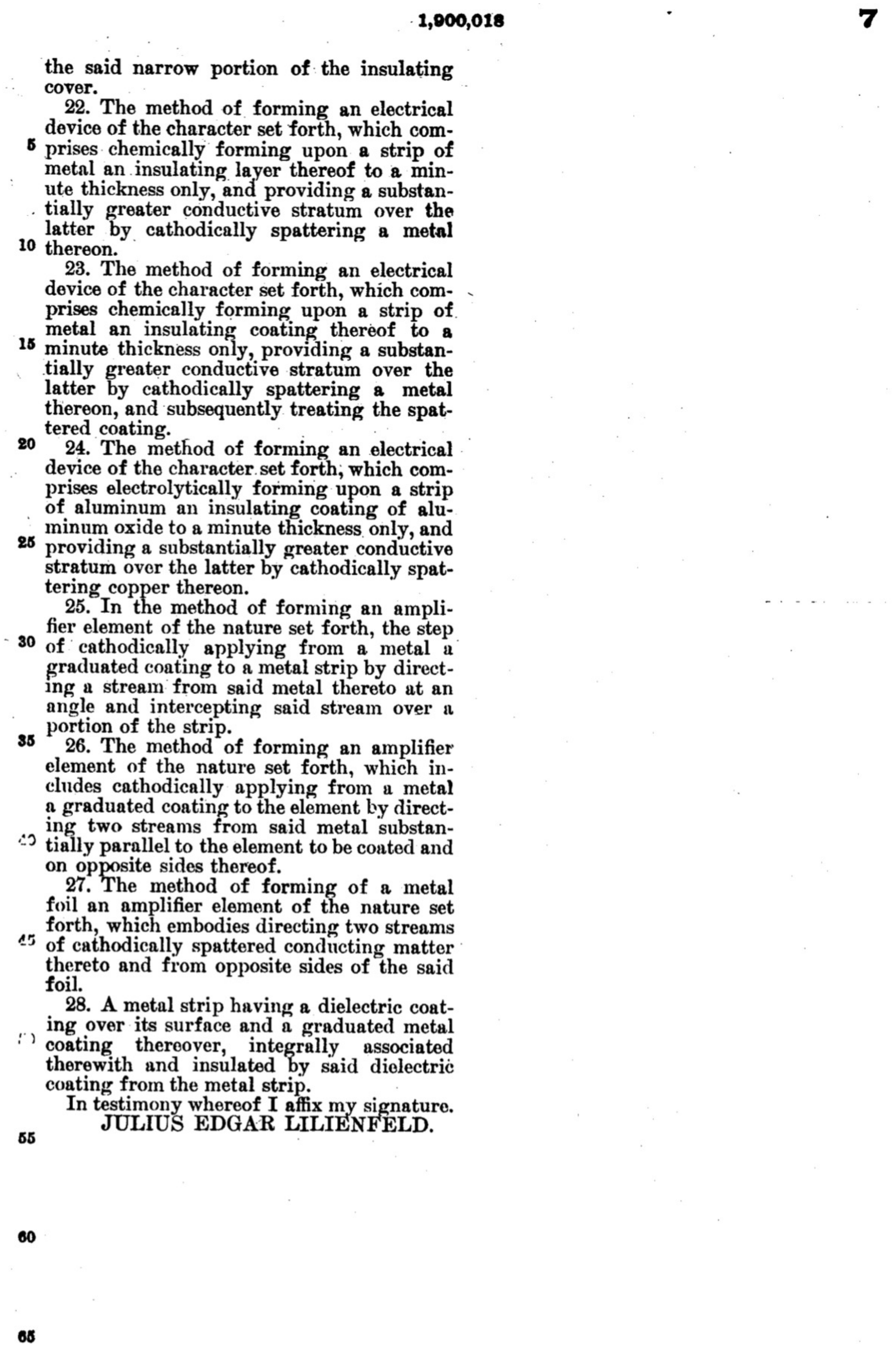
18. An amplifier for electric current, comprising a conducting material, an insulating layer on a surface thereof, a conducting stratum over the latter having a transverse depression therein of molecular thickness, and means to apply a difference of potential to the coating upon opposite sides of the depression.

19. An amplifier for electric current, comprising a conducting material, an insulating layer on a surface thereof, a conducting stratum over the latter having a transverse depression therein of molecular thickness, means to apply a difference of potential to the conducting stratum upon opposite sides of the depression, and means to apply a third potential to the conducting base material.

20. An amplifier for electric current, comprising a conducting solid material, an insulating layer on a surface thereof of minute thickness, and a conducting stratum over the insulating layer having a narrow portion approaching molecular thickness.

21. An amplifier for electric current, comprising a conducting solid material, an insulating layer on a surface thereof having a narrow portion of minute thickness, and a conducting stratum over the insulating layer having a narrow portion approaching molecular thickness and coinciding with part of

Figure B.14: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,900,018 (filed in 1928).



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the said narrow portion of the insulating cover.

22. The method of forming an electrical device of the character set forth, which comprises chemically forming upon a strip of metal an insulating layer thereof to a minute thickness only, and providing a substantially greater conductive stratum over the latter by cathodically spattering a metal thereon.

23. The method of forming an electrical device of the character set forth, which comprises chemically forming upon a strip of metal an insulating coating thereof to a minute thickness only, providing a substantially greater conductive stratum over the latter by cathodically spattering a metal thereon, and subsequently treating the spattered coating.

24. The method of forming an electrical device of the character set forth, which comprises electrolytically forming upon a strip of aluminum an insulating coating of aluminum oxide to a minute thickness only, and providing a substantially greater conductive stratum over the latter by cathodically spattering copper thereon.

25. In the method of forming an amplifier element of the nature set forth, the step of cathodically applying from a metal a graduated coating to a metal strip by directing a stream from said metal thereto at an angle and intercepting said stream over a portion of the strip.

26. The method of forming an amplifier element of the nature set forth, which includes cathodically applying from a metal a graduated coating to the element by directing two streams from said metal substantially parallel to the element to be coated and on opposite sides thereof.

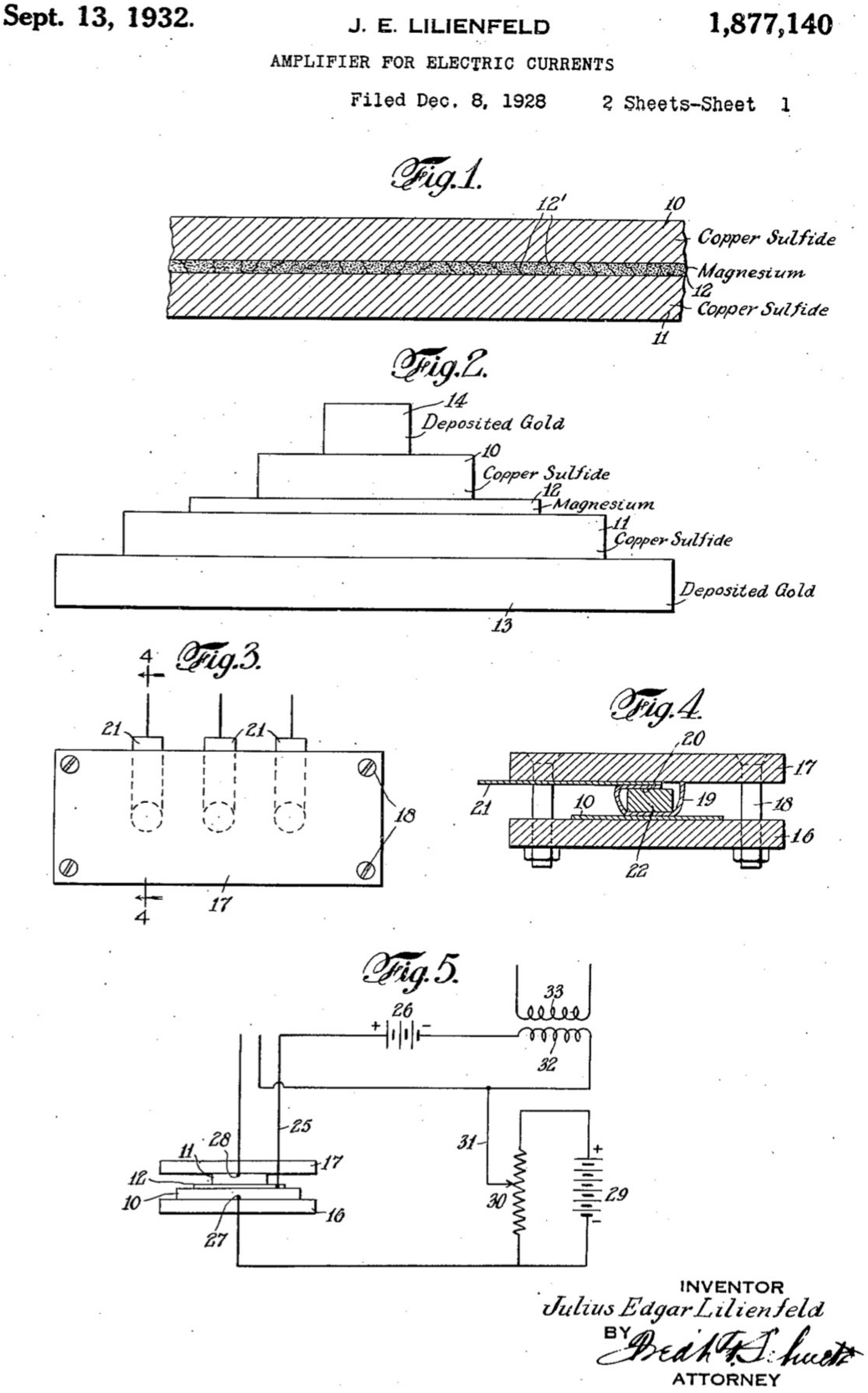
27. The method of forming of a metal foil an amplifier element of the nature set forth, which embodies directing two streams of cathodically spattered conducting matter thereto and from opposite sides of the said foil.

28. A metal strip having a dielectric coating over its surface and a graduated metal coating thereover, integrally associated therewith and insulated by said dielectric coating from the metal strip.

In testimony whereof I affix my signature.

JULIUS EDGAR LILIENFELD.

Figure B.15: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,900,018 (filed in 1928).



Sept. 13, 1932. J. E. LILIENFELD **1,877,140**

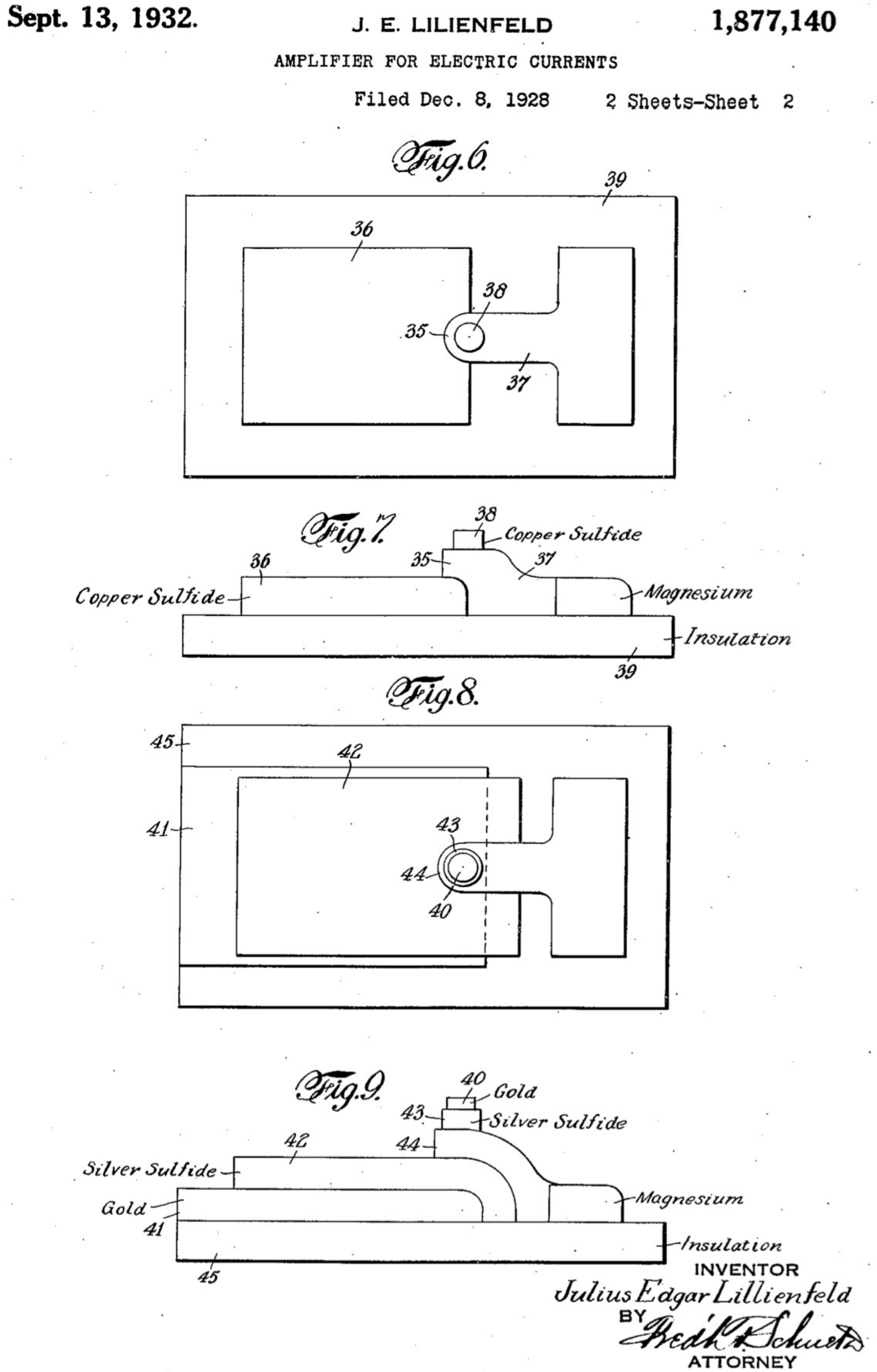
AMPLIFIER FOR ELECTRIC CURRENTS

Filed Dec. 8, 1928 2 Sheets-Sheet 1

INVENTOR
Julius Edgar Lilienfeld
BY
ATTORNEY

Fig.1.
12'
10
Copper Sulfide
Magnesium
12
Copper Sulfide
11
Fig.2.
14
Deposited Gold
10
Copper Sulfide
12
Magnesium
11
Copper Sulfide
Deposited Gold
13
Fig.3.
4
21
21
18
17
4
Fig.4.
20
17
21
10
19
18
16
22
Fig.5.
33
26
+
-
32
25
31
28
11
17
12
10
16
27
30
+
29
-

Figure B.16: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,877,140 (filed in 1928).



Sept. 13, 1932. J. E. LILIENFELD **1,877,140**

AMPLIFIER FOR ELECTRIC CURRENTS

Filed Dec. 8, 1928 2 Sheets-Sheet 2

INVENTOR

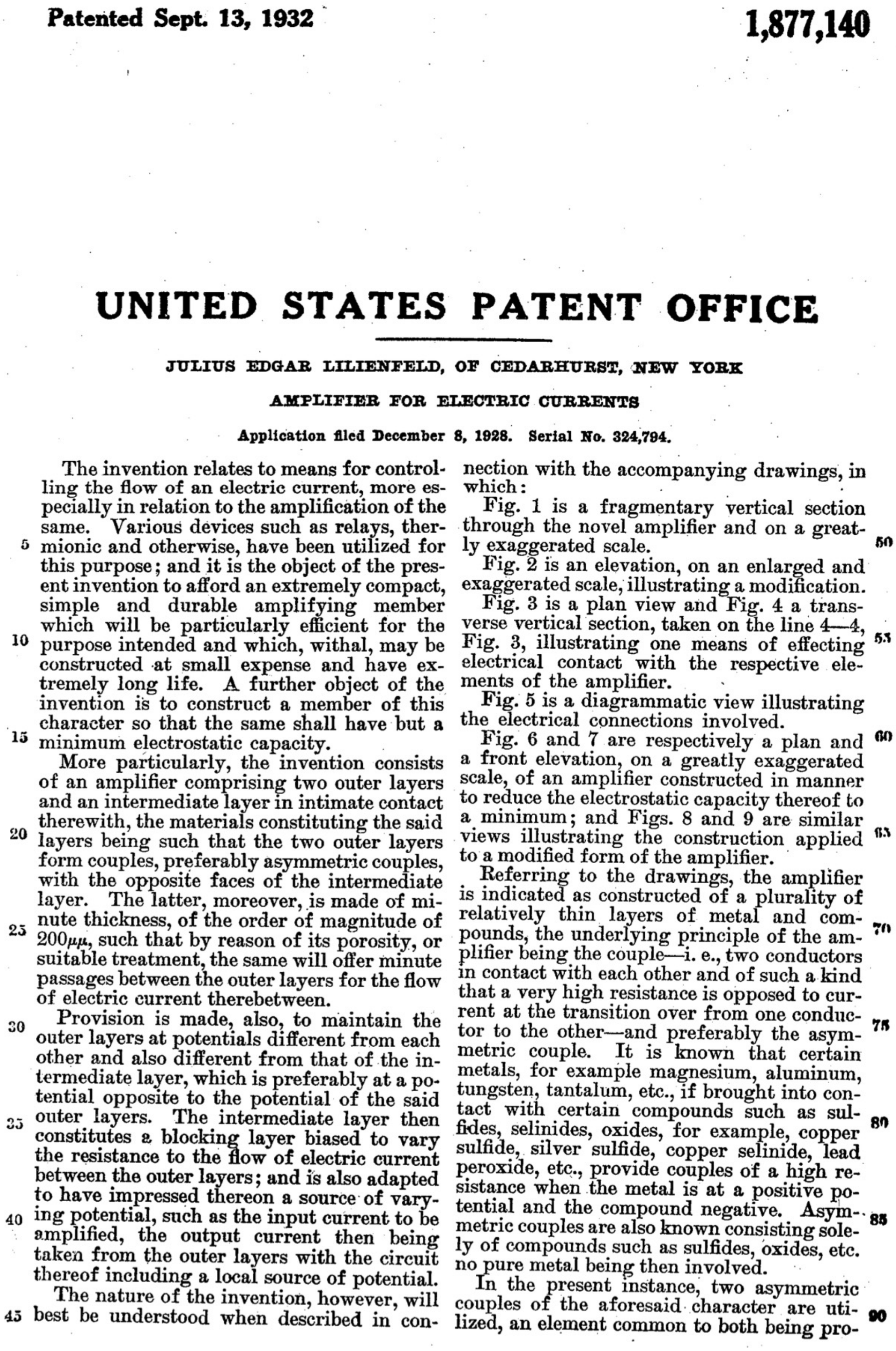
Julius Edgar Lillienfeld

BY

ATTORNEY

Fig. 6.
39
36
38
35
37
Fig. 7.
38
Copper Sulfide
35
37
36
Copper Sulfide
Magnesium
Insulation
39
Fig. 8.
45
42
41
43
44
40
Fig. 9.
40
Gold
43
Silver Sulfide
42
44
Silver Sulfide
Magnesium
Gold
41
Insulation
45

Figure B.17: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,877,140 (filed in 1928).



Patented Sept. 13, 1932 **1,877,140**

UNITED STATES PATENT OFFICE

JULIUS EDGAR LILIENFELD, OF CEDARHURST, NEW YORK

AMPLIFIER FOR ELECTRIC CURRENTS

Application filed December 8, 1928. Serial No. 324,794.

The invention relates to means for controlling the flow of an electric current, more especially in relation to the amplification of the same. Various devices such as relays, thermionic and otherwise, have been utilized for this purpose; and it is the object of the present invention to afford an extremely compact, simple and durable amplifying member which will be particularly efficient for the purpose intended and which, withal, may be constructed at small expense and have extremely long life. A further object of the invention is to construct a member of this character so that the same shall have but a minimum electrostatic capacity.

More particularly, the invention consists of an amplifier comprising two outer layers and an intermediate layer in intimate contact therewith, the materials constituting the said layers being such that the two outer layers form couples, preferably asymmetric couples, with the opposite faces of the intermediate layer. The latter, moreover, is made of minute thickness, of the order of magnitude of 200$\mu\mu$, such that by reason of its porosity, or suitable treatment, the same will offer minute passages between the outer layers for the flow of electric current therebetween.

Provision is made, also, to maintain the outer layers at potentials different from each other and also different from that of the intermediate layer, which is preferably at a potential opposite to the potential of the said outer layers. The intermediate layer then constitutes a blocking layer biased to vary the resistance to the flow of electric current between the outer layers; and is also adapted to have impressed thereon a source of varying potential, such as the input current to be amplified, the output current then being taken from the outer layers with the circuit thereof including a local source of potential.

The nature of the invention, however, will best be understood when described in connection with the accompanying drawings, in which:

Fig. 1 is a fragmentary vertical section through the novel amplifier and on a greatly exaggerated scale.

Fig. 2 is an elevation, on an enlarged and exaggerated scale, illustrating a modification.

Fig. 3 is a plan view and Fig. 4 a transverse vertical section, taken on the line 4—4, Fig. 3, illustrating one means of effecting electrical contact with the respective elements of the amplifier.

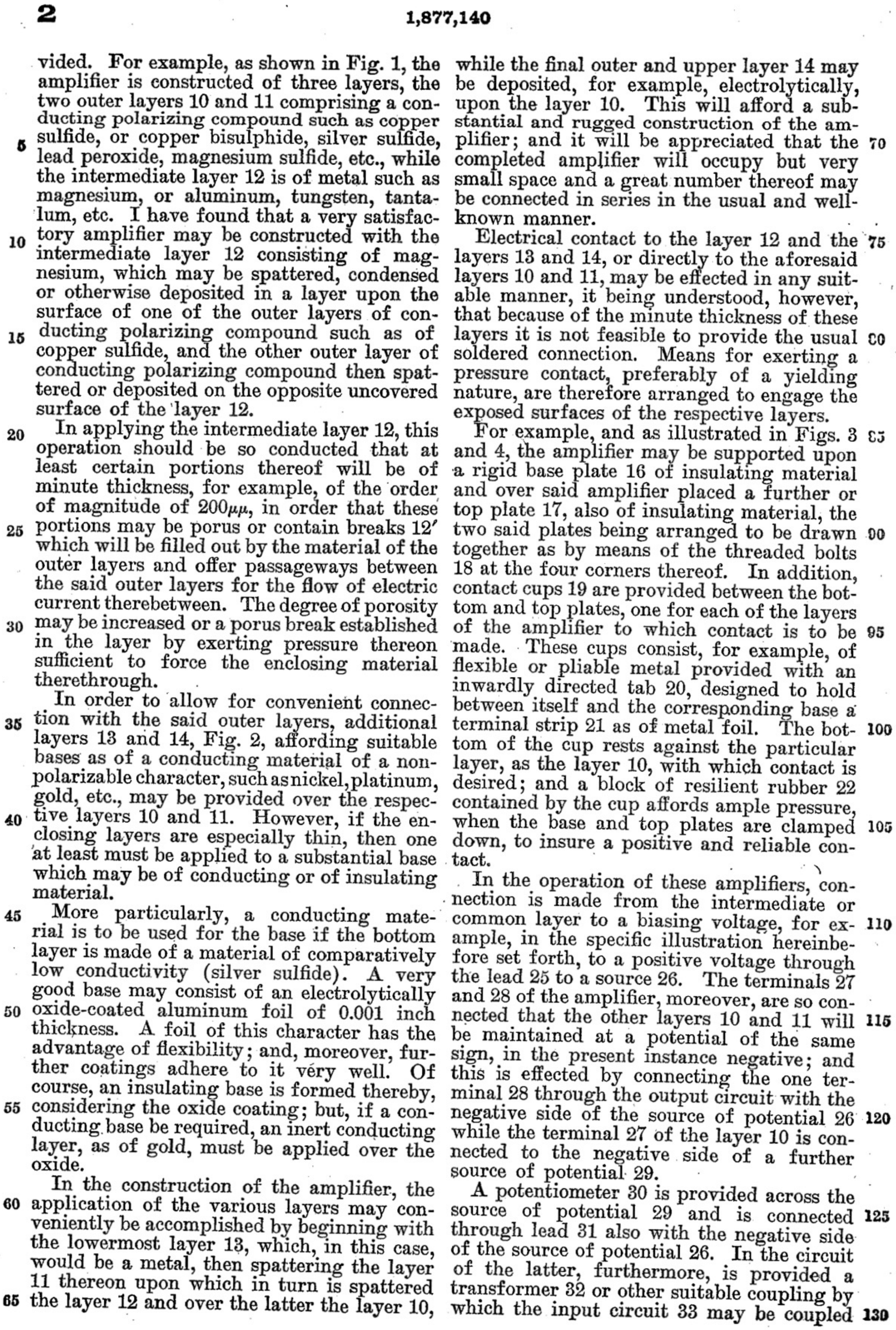
Fig. 5 is a diagrammatic view illustrating the electrical connections involved.

Fig. 6 and 7 are respectively a plan and a front elevation, on a greatly exaggerated scale, of an amplifier constructed in manner to reduce the electrostatic capacity thereof to a minimum; and Figs. 8 and 9 are similar views illustrating the construction applied to a modified form of the amplifier.

Referring to the drawings, the amplifier is indicated as constructed of a plurality of relatively thin layers of metal and compounds, the underlying principle of the amplifier being the couple—i. e., two conductors in contact with each other and of such a kind that a very high resistance is opposed to current at the transition over from one conductor to the other—and preferably the asymmetric couple. It is known that certain metals, for example magnesium, aluminum, tungsten, tantalum, etc., if brought into contact with certain compounds such as sulfides, selinides, oxides, for example, copper sulfide, silver sulfide, copper selinide, lead peroxide, etc., provide couples of a high resistance when the metal is at a positive potential and the compound negative. Asymmetric couples are also known consisting solely of compounds such as sulfides, oxides, etc. no pure metal being then involved.

In the present instance, two asymmetric couples of the aforesaid character are utilized, an element common to both being pro-

Figure B.18: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,877,140 (filed in 1928).



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vided. For example, as shown in Fig. 1, the amplifier is constructed of three layers, the two outer layers 10 and 11 comprising a conducting polarizing compound such as copper sulfide, or copper bisulphide, silver sulfide, lead peroxide, magnesium sulfide, etc., while the intermediate layer 12 is of metal such as magnesium, or aluminum, tungsten, tantalum, etc. I have found that a very satisfactory amplifier may be constructed with the intermediate layer 12 consisting of magnesium, which may be spattered, condensed or otherwise deposited in a layer upon the surface of one of the outer layers of conducting polarizing compound such as of copper sulfide, and the other outer layer of conducting polarizing compound then spattered or deposited on the opposite uncovered surface of the layer 12.

In applying the intermediate layer 12, this operation should be so conducted that at least certain portions thereof will be of minute thickness, for example, of the order of magnitude of $200\mu\mu$, in order that these portions may be porus or contain breaks $12'$ which will be filled out by the material of the outer layers and offer passageways between the said outer layers for the flow of electric current therebetween. The degree of porosity may be increased or a porus break established in the layer by exerting pressure thereon sufficient to force the enclosing material therethrough.

In order to allow for convenient connection with the said outer layers, additional layers 13 and 14, Fig. 2, affording suitable bases as of a conducting material of a non-polarizable character, such as nickel, platinum, gold, etc., may be provided over the respective layers 10 and 11. However, if the enclosing layers are especially thin, then one at least must be applied to a substantial base which may be of conducting or of insulating material.

More particularly, a conducting material is to be used for the base if the bottom layer is made of a material of comparatively low conductivity (silver sulfide). A very good base may consist of an electrolytically oxide-coated aluminum foil of 0.001 inch thickness. A foil of this character has the advantage of flexibility; and, moreover, further coatings adhere to it very well. Of course, an insulating base is formed thereby, considering the oxide coating; but, if a conducting base be required, an inert conducting layer, as of gold, must be applied over the oxide.

In the construction of the amplifier, the application of the various layers may conveniently be accomplished by beginning with the lowermost layer 13, which, in this case, would be a metal, then spattering the layer 11 thereon upon which in turn is spattered the layer 12 and over the latter the layer 10, while the final outer and upper layer 14 may be deposited, for example, electrolytically, upon the layer 10. This will afford a substantial and rugged construction of the amplifier; and it will be appreciated that the completed amplifier will occupy but very small space and a great number thereof may be connected in series in the usual and well-known manner.

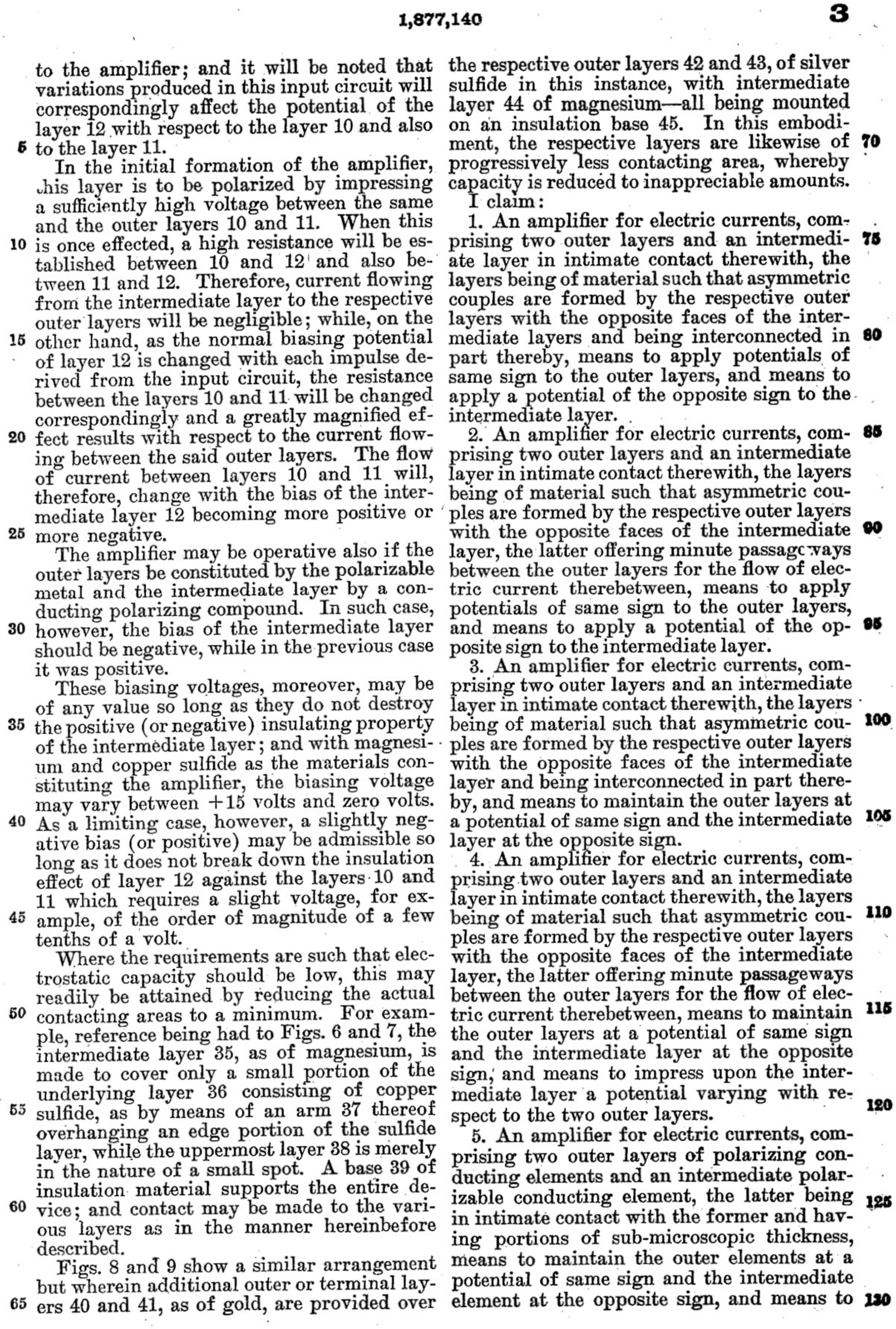
Electrical contact to the layer 12 and the layers 13 and 14, or directly to the aforesaid layers 10 and 11, may be effected in any suitable manner, it being understood, however, that because of the minute thickness of these layers it is not feasible to provide the usual soldered connection. Means for exerting a pressure contact, preferably of a yielding nature, are therefore arranged to engage the exposed surfaces of the respective layers.

For example, and as illustrated in Figs. 3 and 4, the amplifier may be supported upon a rigid base plate 16 of insulating material and over said amplifier placed a further or top plate 17, also of insulating material, the two said plates being arranged to be drawn together as by means of the threaded bolts 18 at the four corners thereof. In addition, contact cups 19 are provided between the bottom and top plates, one for each of the layers of the amplifier to which contact is to be made. These cups consist, for example, of flexible or pliable metal provided with an inwardly directed tab 20, designed to hold between itself and the corresponding base a terminal strip 21 as of metal foil. The bottom of the cup rests against the particular layer, as the layer 10, with which contact is desired; and a block of resilient rubber 22 contained by the cup affords ample pressure, when the base and top plates are clamped down, to insure a positive and reliable contact.

In the operation of these amplifiers, connection is made from the intermediate or common layer to a biasing voltage, for example, in the specific illustration hereinbefore set forth, to a positive voltage through the lead 25 to a source 26. The terminals 27 and 28 of the amplifier, moreover, are so connected that the other layers 10 and 11 will be maintained at a potential of the same sign, in the present instance negative; and this is effected by connecting the one terminal 28 through the output circuit with the negative side of the source of potential 26 while the terminal 27 of the layer 10 is connected to the negative side of a further source of potential 29.

A potentiometer 30 is provided across the source of potential 29 and is connected through lead 31 also with the negative side of the source of potential 26. In the circuit of the latter, furthermore, is provided a transformer 32 or other suitable coupling by which the input circuit 33 may be coupled

Figure B.19: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,877,140 (filed in 1928).



1,877,140 3

to the amplifier; and it will be noted that variations produced in this input circuit will correspondingly affect the potential of the layer 12 with respect to the layer 10 and also to the layer 11.

In the initial formation of the amplifier, this layer is to be polarized by impressing a sufficiently high voltage between the same and the outer layers 10 and 11. When this is once effected, a high resistance will be established between 10 and 12 and also between 11 and 12. Therefore, current flowing from the intermediate layer to the respective outer layers will be negligible; while, on the other hand, as the normal biasing potential of layer 12 is changed with each impulse derived from the input circuit, the resistance between the layers 10 and 11 will be changed correspondingly and a greatly magnified effect results with respect to the current flowing between the said outer layers. The flow of current between layers 10 and 11 will, therefore, change with the bias of the intermediate layer 12 becoming more positive or more negative.

The amplifier may be operative also if the outer layers be constituted by the polarizable metal and the intermediate layer by a conducting polarizing compound. In such case, however, the bias of the intermediate layer should be negative, while in the previous case it was positive.

These biasing voltages, moreover, may be of any value so long as they do not destroy the positive (or negative) insulating property of the intermediate layer; and with magnesium and copper sulfide as the materials constituting the amplifier, the biasing voltage may vary between +15 volts and zero volts. As a limiting case, however, a slightly negative bias (or positive) may be admissible so long as it does not break down the insulation effect of layer 12 against the layers 10 and 11 which requires a slight voltage, for example, of the order of magnitude of a few tenths of a volt.

Where the requirements are such that electrostatic capacity should be low, this may readily be attained by reducing the actual contacting areas to a minimum. For example, reference being had to Figs. 6 and 7, the intermediate layer 35, as of magnesium, is made to cover only a small portion of the underlying layer 36 consisting of copper sulfide, as by means of an arm 37 thereof overhanging an edge portion of the sulfide layer, while the uppermost layer 38 is merely in the nature of a small spot. A base 39 of insulation material supports the entire device; and contact may be made to the various layers as in the manner hereinbefore described.

Figs. 8 and 9 show a similar arrangement but wherein additional outer or terminal layers 40 and 41, as of gold, are provided over the respective outer layers 42 and 43, of silver sulfide in this instance, with intermediate layer 44 of magnesium—all being mounted on an insulation base 45. In this embodiment, the respective layers are likewise of progressively less contacting area, whereby capacity is reduced to inappreciable amounts.

I claim:

1. An amplifier for electric currents, comprising two outer layers and an intermediate layer in intimate contact therewith, the layers being of material such that asymmetric couples are formed by the respective outer layers with the opposite faces of the intermediate layers and being interconnected in part thereby, means to apply potentials of same sign to the outer layers, and means to apply a potential of the opposite sign to the intermediate layer.

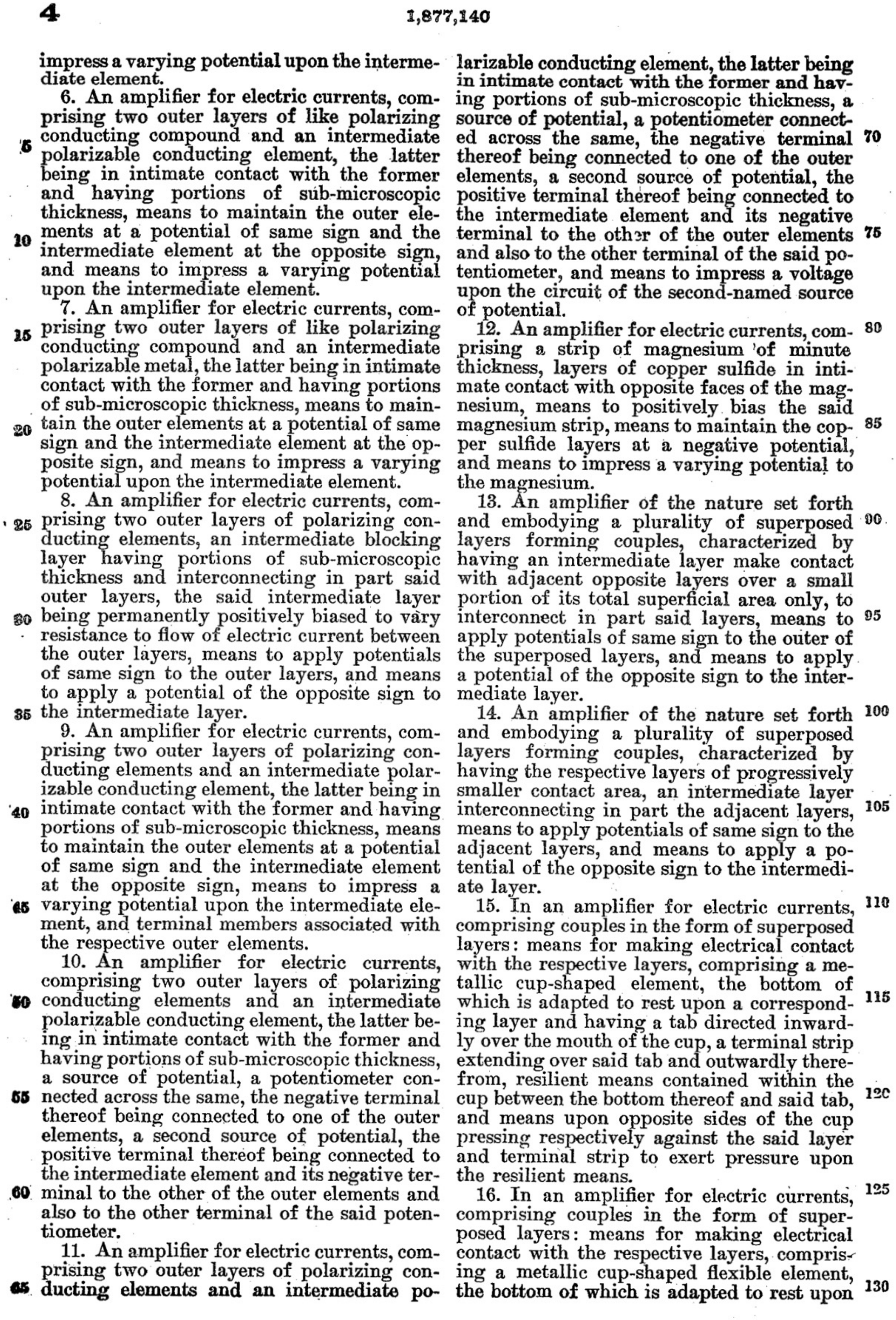
2. An amplifier for electric currents, comprising two outer layers and an intermediate layer in intimate contact therewith, the layers being of material such that asymmetric couples are formed by the respective outer layers with the opposite faces of the intermediate layer, the latter offering minute passageways between the outer layers for the flow of electric current therebetween, means to apply potentials of same sign to the outer layers, and means to apply a potential of the opposite sign to the intermediate layer.

3. An amplifier for electric currents, comprising two outer layers and an intermediate layer in intimate contact therewith, the layers being of material such that asymmetric couples are formed by the respective outer layers with the opposite faces of the intermediate layer and being interconnected in part thereby, and means to maintain the outer layers at a potential of same sign and the intermediate layer at the opposite sign.

4. An amplifier for electric currents, comprising two outer layers and an intermediate layer in intimate contact therewith, the layers being of material such that asymmetric couples are formed by the respective outer layers with the opposite faces of the intermediate layer, the latter offering minute passageways between the outer layers for the flow of electric current therebetween, means to maintain the outer layers at a potential of same sign and the intermediate layer at the opposite sign, and means to impress upon the intermediate layer a potential varying with respect to the two outer layers.

5. An amplifier for electric currents, comprising two outer layers of polarizing conducting elements and an intermediate polarizable conducting element, the latter being in intimate contact with the former and having portions of sub-microscopic thickness, means to maintain the outer elements at a potential of same sign and the intermediate element at the opposite sign, and means to

Figure B.20: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,877,140 (filed in 1928).



4

1,877,140

impress a varying potential upon the intermediate element.

6. An amplifier for electric currents, comprising two outer layers of like polarizing conducting compound and an intermediate polarizable conducting element, the latter being in intimate contact with the former and having portions of sub-microscopic thickness, means to maintain the outer elements at a potential of same sign and the intermediate element at the opposite sign, and means to impress a varying potential upon the intermediate element.

7. An amplifier for electric currents, comprising two outer layers of like polarizing conducting compound and an intermediate polarizable metal, the latter being in intimate contact with the former and having portions of sub-microscopic thickness, means to maintain the outer elements at a potential of same sign and the intermediate element at the opposite sign, and means to impress a varying potential upon the intermediate element.

8. An amplifier for electric currents, comprising two outer layers of polarizing conducting elements, an intermediate blocking layer having portions of sub-microscopic thickness and interconnecting in part said outer layers, the said intermediate layer being permanently positively biased to vary resistance to flow of electric current between the outer layers, means to apply potentials of same sign to the outer layers, and means to apply a potential of the opposite sign to the intermediate layer.

9. An amplifier for electric currents, comprising two outer layers of polarizing conducting elements and an intermediate polarizable conducting element, the latter being in intimate contact with the former and having portions of sub-microscopic thickness, means to maintain the outer elements at a potential of same sign and the intermediate element at the opposite sign, means to impress a varying potential upon the intermediate element, and terminal members associated with the respective outer elements.

10. An amplifier for electric currents, comprising two outer layers of polarizing conducting elements and an intermediate polarizable conducting element, the latter being in intimate contact with the former and having portions of sub-microscopic thickness, a source of potential, a potentiometer connected across the same, the negative terminal thereof being connected to one of the outer elements, a second source of potential, the positive terminal thereof being connected to the intermediate element and its negative terminal to the other of the outer elements and also to the other terminal of the said potentiometer.

11. An amplifier for electric currents, comprising two outer layers of polarizing conducting elements and an intermediate polarizable conducting element, the latter being in intimate contact with the former and having portions of sub-microscopic thickness, a source of potential, a potentiometer connected across the same, the negative terminal thereof being connected to one of the outer elements, a second source of potential, the positive terminal thereof being connected to the intermediate element and its negative terminal to the other of the outer elements and also to the other terminal of the said potentiometer, and means to impress a voltage upon the circuit of the second-named source of potential.

12. An amplifier for electric currents, comprising a strip of magnesium of minute thickness, layers of copper sulfide in intimate contact with opposite faces of the magnesium, means to positively bias the said magnesium strip, means to maintain the copper sulfide layers at a negative potential, and means to impress a varying potential to the magnesium.

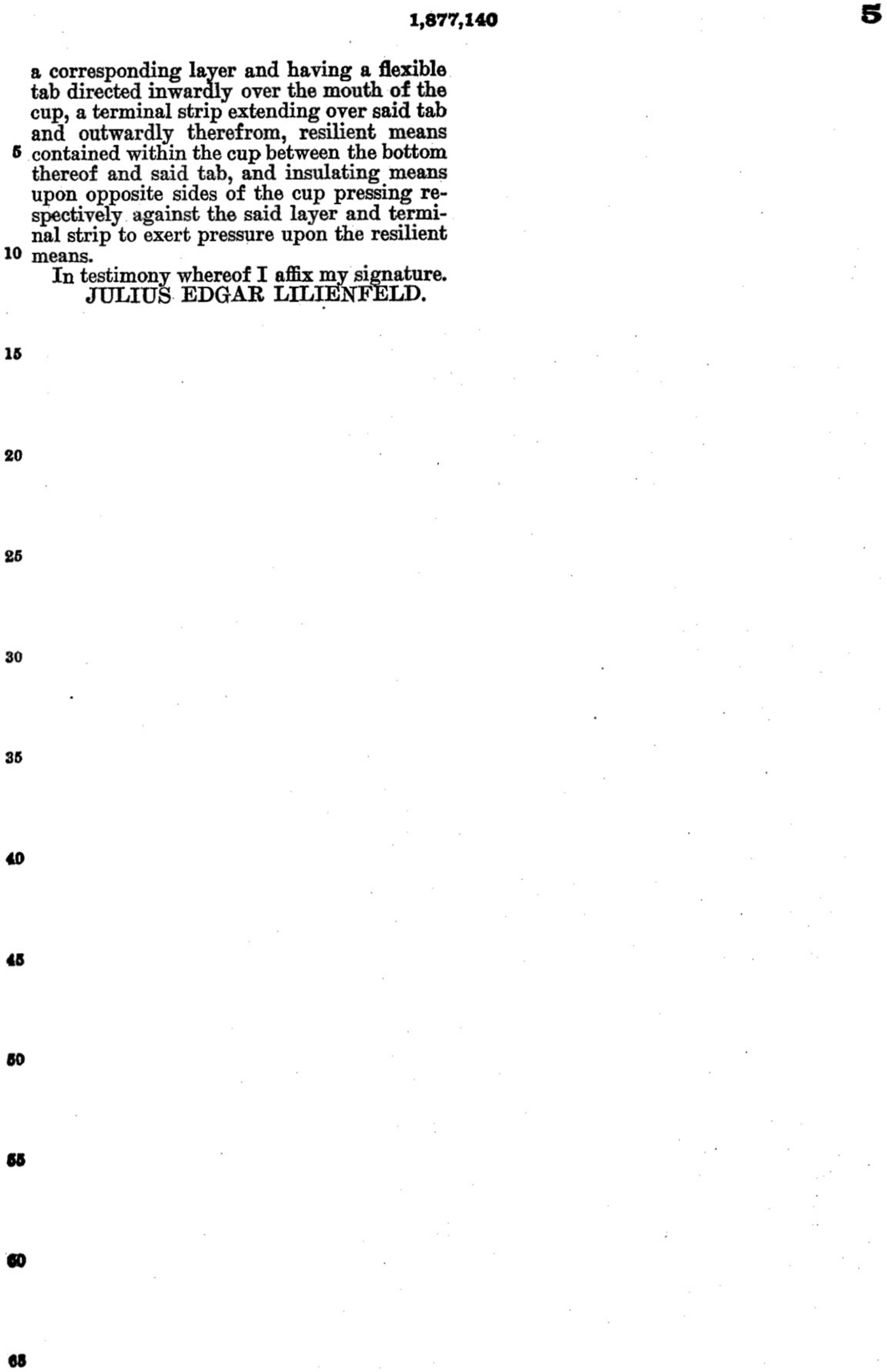
13. An amplifier of the nature set forth and embodying a plurality of superposed layers forming couples, characterized by having an intermediate layer make contact with adjacent opposite layers over a small portion of its total superficial area only, to interconnect in part said layers, means to apply potentials of same sign to the outer of the superposed layers, and means to apply a potential of the opposite sign to the intermediate layer.

14. An amplifier of the nature set forth and embodying a plurality of superposed layers forming couples, characterized by having the respective layers of progressively smaller contact area, an intermediate layer interconnecting in part the adjacent layers, means to apply potentials of same sign to the adjacent layers, and means to apply a potential of the opposite sign to the intermediate layer.

15. In an amplifier for electric currents, comprising couples in the form of superposed layers: means for making electrical contact with the respective layers, comprising a metallic cup-shaped element, the bottom of which is adapted to rest upon a corresponding layer and having a tab directed inwardly over the mouth of the cup, a terminal strip extending over said tab and outwardly therefrom, resilient means contained within the cup between the bottom thereof and said tab, and means upon opposite sides of the cup pressing respectively against the said layer and terminal strip to exert pressure upon the resilient means.

16. In an amplifier for electric currents, comprising couples in the form of superposed layers: means for making electrical contact with the respective layers, comprising a metallic cup-shaped flexible element, the bottom of which is adapted to rest upon

Figure B.21: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,877,140 (filed in 1928).



1,877,140 5

a corresponding layer and having a flexible tab directed inwardly over the mouth of the cup, a terminal strip extending over said tab and outwardly therefrom, resilient means contained within the cup between the bottom thereof and said tab, and insulating means upon opposite sides of the cup pressing respectively against the said layer and terminal strip to exert pressure upon the resilient means.

In testimony whereof I affix my signature.
JULIUS EDGAR LILIENFELD.

Figure B.22: Julius Edgar Lilienfeld filed a number of highly detailed patent applications on field effect transistors, including U.S. Patent 1,877,140 (filed in 1928).

[**2. Oskar Heil (German, 1908–1994)** filed detailed patent applications on field effect transistors in 1934 in several countries, such as:

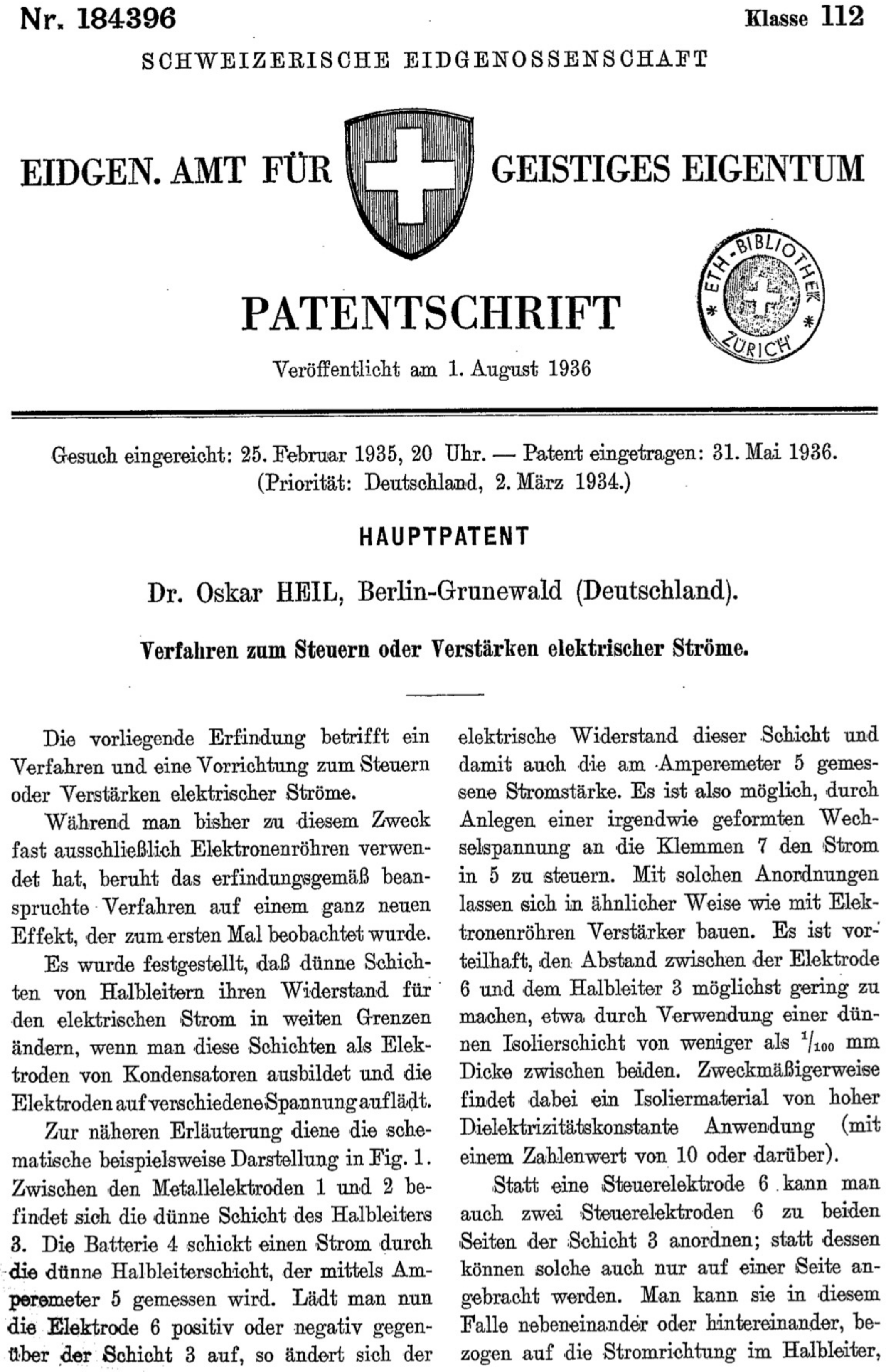
> Oskar Heil. Filed 1934. Swiss patent CH184,396. Verfahren zum Steuern oder Verstärken elektrischer Ströme. [Method for Controlling or Amplifying Electrical Currents.]
>
> Oskar Heil. Filed 1934. U.K. patent GB439,457. Improvements in or Relating to Electrical Amplifiers and Other Control Arrangements and Devices.

See pp. 2679–2685.

Currently it is unclear just what experimental work Heil may have done on the concept either before or after filing the patent application, or whether other German-speaking scientists may have taken up the ideas proposed in the application.

During World War II, Heil conducted electronics and physics research at C. Lorenz AG in Germany. After the war, he moved to the United States, where he continued his research for several decades, working for the U.S. government as well as several electronics companies.

Much more archival research should be conducted to elucidate the history and impact of Heil's ideas and projects both in Europe and in the United States.



Nr. 184396 **Klasse 112**

SCHWEIZERISCHE EIDGENOSSENSCHAFT

EIDGEN. AMT FÜR GEISTIGES EIGENTUM

ETH-BIBLIOTHEK ZÜRICH

PATENTSCHRIFT

Veröffentlicht am 1. August 1936

Gesuch eingereicht: 25. Februar 1935, 20 Uhr. — Patent eingetragen: 31. Mai 1936.
(Priorität: Deutschland, 2. März 1934.)

HAUPTPATENT

Dr. Oskar HEIL, Berlin-Grunewald (Deutschland).

Verfahren zum Steuern oder Verstärken elektrischer Ströme.

Die vorliegende Erfindung betrifft ein Verfahren und eine Vorrichtung zum Steuern oder Verstärken elektrischer Ströme.

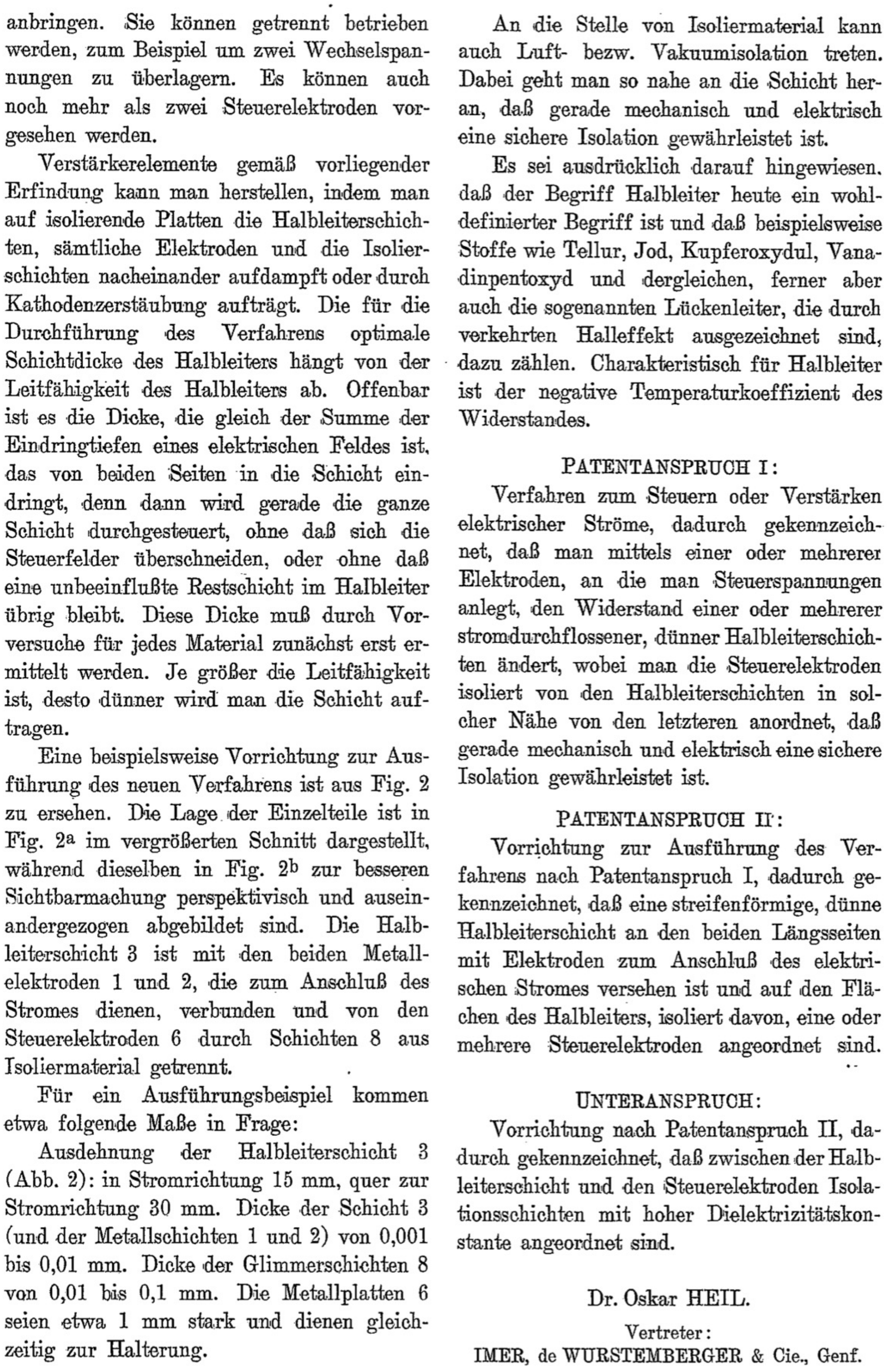
Während man bisher zu diesem Zweck fast ausschließlich Elektronenröhren verwendet hat, beruht das erfindungsgemäß beanspruchte Verfahren auf einem ganz neuen Effekt, der zum ersten Mal beobachtet wurde.

Es wurde festgestellt, daß dünne Schichten von Halbleitern ihren Widerstand für den elektrischen Strom in weiten Grenzen ändern, wenn man diese Schichten als Elektroden von Kondensatoren ausbildet und die Elektroden auf verschiedene Spannung auflädt.

Zur näheren Erläuterung diene die schematische beispielsweise Darstellung in Fig. 1. Zwischen den Metallelektroden 1 und 2 befindet sich die dünne Schicht des Halbleiters 3. Die Batterie 4 schickt einen Strom durch die dünne Halbleiterschicht, der mittels Amperemeter 5 gemessen wird. Lädt man nun die Elektrode 6 positiv oder negativ gegenüber der Schicht 3 auf, so ändert sich der elektrische Widerstand dieser Schicht und damit auch die am Amperemeter 5 gemessene Stromstärke. Es ist also möglich, durch Anlegen einer irgendwie geformten Wechselspannung an die Klemmen 7 den Strom in 5 zu steuern. Mit solchen Anordnungen lassen sich in ähnlicher Weise wie mit Elektronenröhren Verstärker bauen. Es ist vorteilhaft, den Abstand zwischen der Elektrode 6 und dem Halbleiter 3 möglichst gering zu machen, etwa durch Verwendung einer dünnen Isolierschicht von weniger als $^1/_{100}$ mm Dicke zwischen beiden. Zweckmäßigerweise findet dabei ein Isoliermaterial von hoher Dielektrizitätskonstante Anwendung (mit einem Zahlenwert von 10 oder darüber).

Statt eine Steuerelektrode 6 kann man auch zwei Steuerelektroden 6 zu beiden Seiten der Schicht 3 anordnen; statt dessen können solche auch nur auf einer Seite angebracht werden. Man kann sie in diesem Falle nebeneinander oder hintereinander, bezogen auf die Stromrichtung im Halbleiter,

Figure B.23: Oskar Heil filed patent applications on field effect transistors in Germany and other countries in 1934.



anbringen. Sie können getrennt betrieben werden, zum Beispiel um zwei Wechselspannungen zu überlagern. Es können auch noch mehr als zwei Steuerelektroden vorgesehen werden.

Verstärkerelemente gemäß vorliegender Erfindung kann man herstellen, indem man auf isolierende Platten die Halbleiterschichten, sämtliche Elektroden und die Isolierschichten nacheinander aufdampft oder durch Kathodenzerstäubung aufträgt. Die für die Durchführung des Verfahrens optimale Schichtdicke des Halbleiters hängt von der Leitfähigkeit des Halbleiters ab. Offenbar ist es die Dicke, die gleich der Summe der Eindringtiefen eines elektrischen Feldes ist, das von beiden Seiten in die Schicht eindringt, denn dann wird gerade die ganze Schicht durchgesteuert, ohne daß sich die Steuerfelder überschneiden, oder ohne daß eine unbeeinflußte Restschicht im Halbleiter übrig bleibt. Diese Dicke muß durch Vorversuche für jedes Material zunächst erst ermittelt werden. Je größer die Leitfähigkeit ist, desto dünner wird man die Schicht auftragen.

Eine beispielsweise Vorrichtung zur Ausführung des neuen Verfahrens ist aus Fig. 2 zu ersehen. Die Lage der Einzelteile ist in Fig. 2^a im vergrößerten Schnitt dargestellt, während dieselben in Fig. 2^b zur besseren Sichtbarmachung perspektivisch und auseinandergezogen abgebildet sind. Die Halbleiterschicht 3 ist mit den beiden Metallelektroden 1 und 2, die zum Anschluß des Stromes dienen, verbunden und von den Steuerelektroden 6 durch Schichten 8 aus Isoliermaterial getrennt.

Für ein Ausführungsbeispiel kommen etwa folgende Maße in Frage:

Ausdehnung der Halbleiterschicht 3 (Abb. 2): in Stromrichtung 15 mm, quer zur Stromrichtung 30 mm. Dicke der Schicht 3 (und der Metallschichten 1 und 2) von 0,001 bis 0,01 mm. Dicke der Glimmerschichten 8 von 0,01 bis 0,1 mm. Die Metallplatten 6 seien etwa 1 mm stark und dienen gleichzeitig zur Halterung.

An die Stelle von Isoliermaterial kann auch Luft- bezw. Vakuumisolation treten. Dabei geht man so nahe an die Schicht heran, daß gerade mechanisch und elektrisch eine sichere Isolation gewährleistet ist.

Es sei ausdrücklich darauf hingewiesen, daß der Begriff Halbleiter heute ein wohldefinierter Begriff ist und daß beispielsweise Stoffe wie Tellur, Jod, Kupferoxydul, Vanadinpentoxyd und dergleichen, ferner aber auch die sogenannten Lückenleiter, die durch verkehrten Halleffekt ausgezeichnet sind, dazu zählen. Charakteristisch für Halbleiter ist der negative Temperaturkoeffizient des Widerstandes.

PATENTANSPRUCH I:

Verfahren zum Steuern oder Verstärken elektrischer Ströme, dadurch gekennzeichnet, daß man mittels einer oder mehrerer Elektroden, an die man Steuerspannungen anlegt, den Widerstand einer oder mehrerer stromdurchflossener, dünner Halbleiterschichten ändert, wobei man die Steuerelektroden isoliert von den Halbleiterschichten in solcher Nähe von den letzteren anordnet, daß gerade mechanisch und elektrisch eine sichere Isolation gewährleistet ist.

PATENTANSPRUCH II:

Vorrichtung zur Ausführung des Verfahrens nach Patentanspruch I, dadurch gekennzeichnet, daß eine streifenförmige, dünne Halbleiterschicht an den beiden Längsseiten mit Elektroden zum Anschluß des elektrischen Stromes versehen ist und auf den Flächen des Halbleiters, isoliert davon, eine oder mehrere Steuerelektroden angeordnet sind.

UNTERANSPRUCH:

Vorrichtung nach Patentanspruch II, dadurch gekennzeichnet, daß zwischen der Halbleiterschicht und den Steuerelektroden Isolationsschichten mit hoher Dielektrizitätskonstante angeordnet sind.

Dr. Oskar HEIL.

Vertreter:
IMER, de WURSTEMBERGER & Cie., Genf.

Figure B.24: Oskar Heil filed patent applications on field effect transistors in Germany and other countries in 1934.

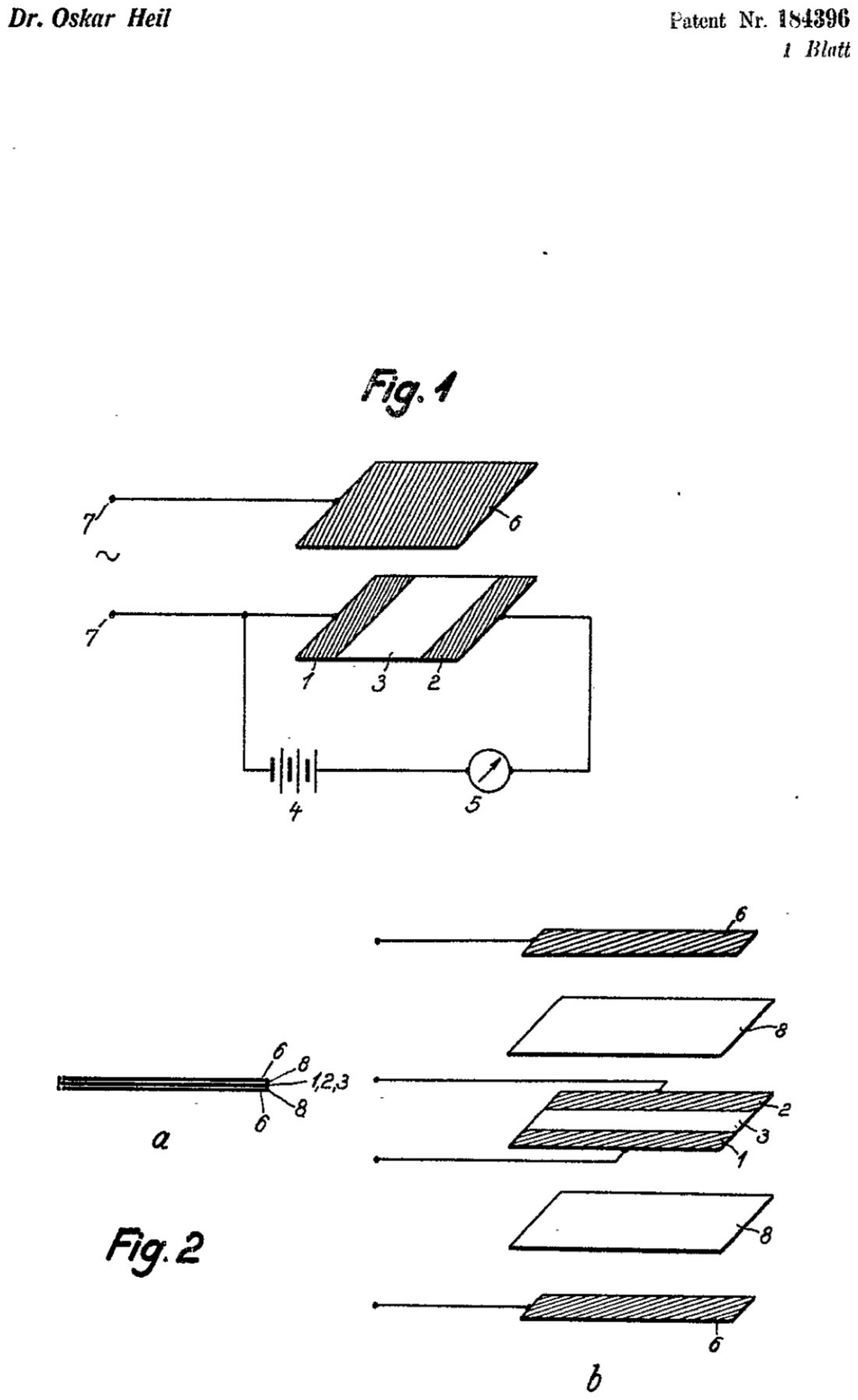
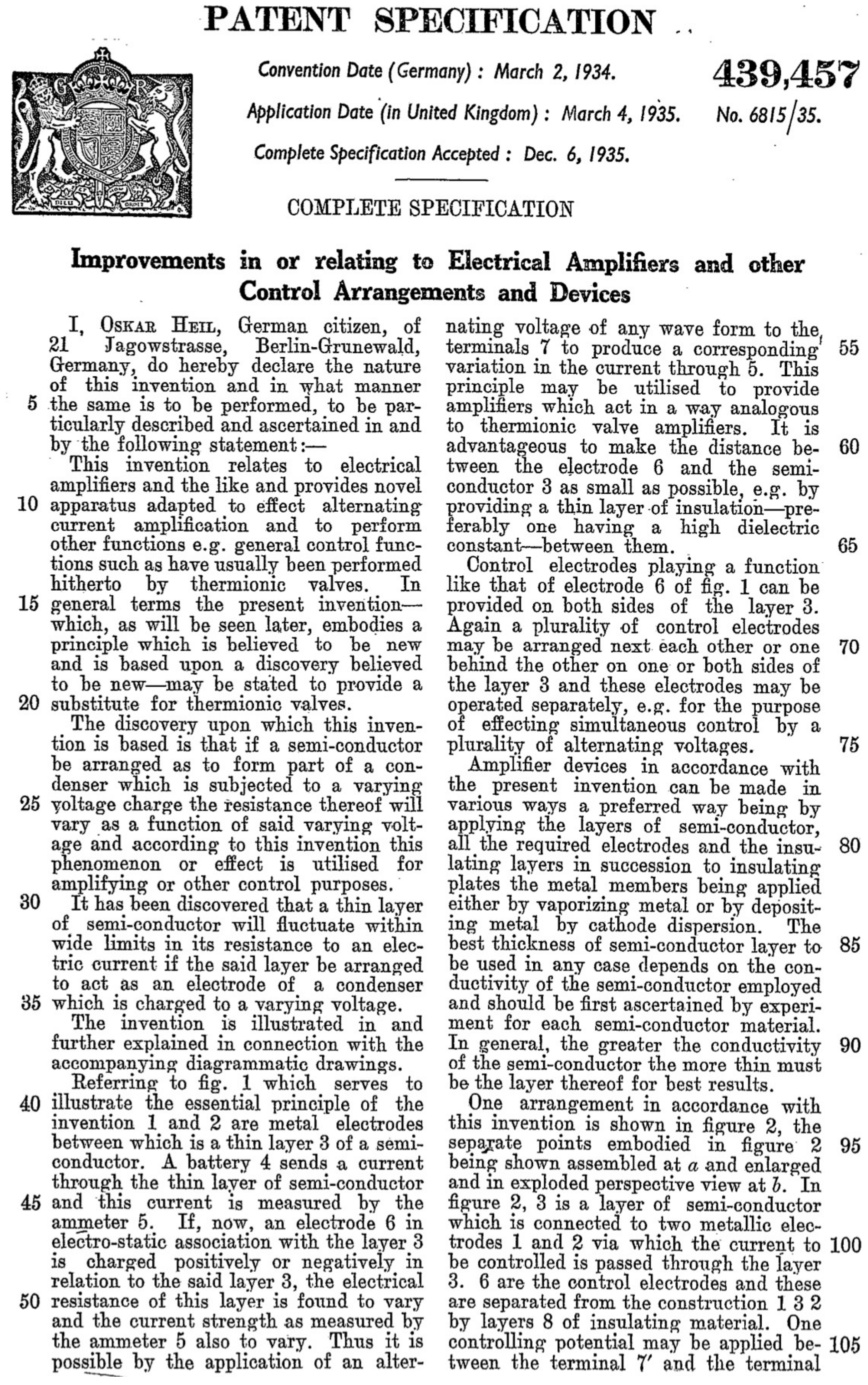

Dr. Oskar Heil
Patent Nr. 184396
1 Blatt
Fig. 1
7
~
7
6
1
3
2
4
5
6
8
1,2,3
8
6
a
Fig. 2
6
8
2
3
1
8
6
b

Figure B.25: Oskar Heil filed patent applications on field effect transistors in Germany and other countries in 1934.



PATENT SPECIFICATION

Convention Date (Germany): March 2, 1934.

Application Date (in United Kingdom): March 4, 1935. No. 6815/35.

Complete Specification Accepted: Dec. 6, 1935.

439,457

COMPLETE SPECIFICATION

Improvements in or relating to Electrical Amplifiers and other Control Arrangements and Devices

I, Oskar Heil, German citizen, of 21 Jagowstrasse, Berlin-Grunewald, Germany, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to electrical amplifiers and the like and provides novel apparatus adapted to effect alternating current amplification and to perform other functions e.g. general control functions such as have usually been performed hitherto by thermionic valves. In general terms the present invention—which, as will be seen later, embodies a principle which is believed to be new and is based upon a discovery believed to be new—may be stated to provide a substitute for thermionic valves.

The discovery upon which this invention is based is that if a semi-conductor be arranged as to form part of a condenser which is subjected to a varying voltage charge the resistance thereof will vary as a function of said varying voltage and according to this invention this phenomenon or effect is utilised for amplifying or other control purposes.

It has been discovered that a thin layer of semi-conductor will fluctuate within wide limits in its resistance to an electric current if the said layer be arranged to act as an electrode of a condenser which is charged to a varying voltage.

The invention is illustrated in and further explained in connection with the accompanying diagrammatic drawings.

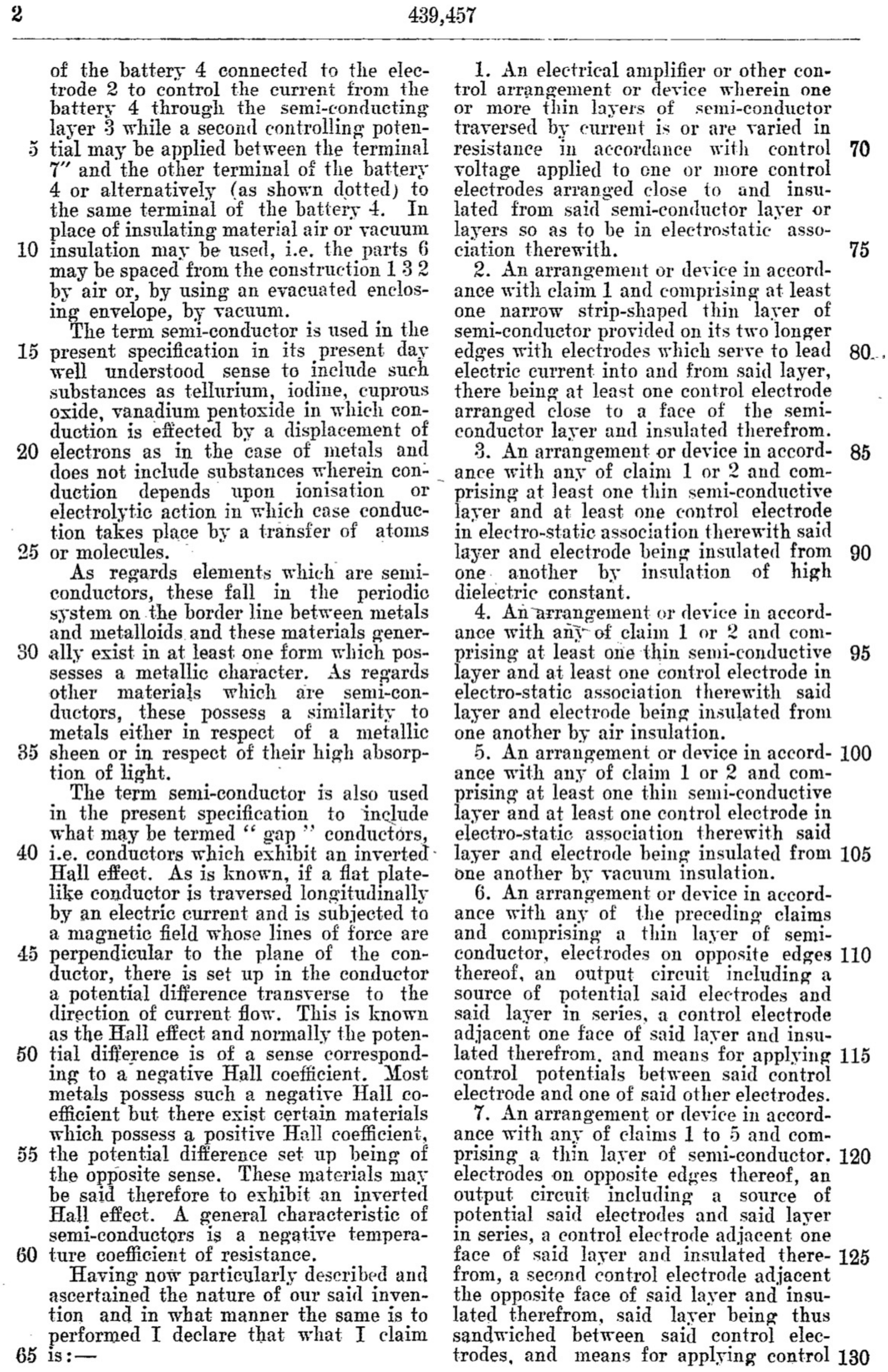
Referring to fig. 1 which serves to illustrate the essential principle of the invention 1 and 2 are metal electrodes between which is a thin layer 3 of a semiconductor. A battery 4 sends a current through the thin layer of semi-conductor and this current is measured by the ammeter 5. If, now, an electrode 6 in electro-static association with the layer 3 is charged positively or negatively in relation to the said layer 3, the electrical resistance of this layer is found to vary and the current strength as measured by the ammeter 5 also to vary. Thus it is possible by the application of an alternating voltage of any wave form to the terminals 7 to produce a corresponding variation in the current through 5. This principle may be utilised to provide amplifiers which act in a way analogous to thermionic valve amplifiers. It is advantageous to make the distance between the electrode 6 and the semiconductor 3 as small as possible, e.g. by providing a thin layer of insulation—preferably one having a high dielectric constant—between them.

Control electrodes playing a function like that of electrode 6 of fig. 1 can be provided on both sides of the layer 3. Again a plurality of control electrodes may be arranged next each other or one behind the other on one or both sides of the layer 3 and these electrodes may be operated separately, e.g. for the purpose of effecting simultaneous control by a plurality of alternating voltages.

Amplifier devices in accordance with the present invention can be made in various ways a preferred way being by applying the layers of semi-conductor, all the required electrodes and the insulating layers in succession to insulating plates the metal members being applied either by vaporizing metal or by depositing metal by cathode dispersion. The best thickness of semi-conductor layer to be used in any case depends on the conductivity of the semi-conductor employed and should be first ascertained by experiment for each semi-conductor material. In general, the greater the conductivity of the semi-conductor the more thin must be the layer thereof for best results.

One arrangement in accordance with this invention is shown in figure 2, the separate points embodied in figure 2 being shown assembled at *a* and enlarged and in exploded perspective view at *b*. In figure 2, 3 is a layer of semi-conductor which is connected to two metallic electrodes 1 and 2 via which the current to be controlled is passed through the layer 3. 6 are the control electrodes and these are separated from the construction 1 3 2 by layers 8 of insulating material. One controlling potential may be applied between the terminal 7′ and the terminal

Figure B.26: Oskar Heil filed patent applications on field effect transistors in Germany and other countries in 1934.



of the battery 4 connected to the electrode 2 to control the current from the battery 4 through the semi-conducting layer 3 while a second controlling potential may be applied between the terminal 7″ and the other terminal of the battery 4 or alternatively (as shown dotted) to the same terminal of the battery 4. In place of insulating material air or vacuum insulation may be used, i.e. the parts 6 may be spaced from the construction 1 3 2 by air or, by using an evacuated enclosing envelope, by vacuum.

The term semi-conductor is used in the present specification in its present day well understood sense to include such substances as tellurium, iodine, cuprous oxide, vanadium pentoxide in which conduction is effected by a displacement of electrons as in the case of metals and does not include substances wherein conduction depends upon ionisation or electrolytic action in which case conduction takes place by a transfer of atoms or molecules.

As regards elements which are semi-conductors, these fall in the periodic system on the border line between metals and metalloids and these materials generally exist in at least one form which possesses a metallic character. As regards other materials which are semi-conductors, these possess a similarity to metals either in respect of a metallic sheen or in respect of their high absorption of light.

The term semi-conductor is also used in the present specification to include what may be termed " gap " conductors, i.e. conductors which exhibit an inverted Hall effect. As is known, if a flat plate-like conductor is traversed longitudinally by an electric current and is subjected to a magnetic field whose lines of force are perpendicular to the plane of the conductor, there is set up in the conductor a potential difference transverse to the direction of current flow. This is known as the Hall effect and normally the potential difference is of a sense corresponding to a negative Hall coefficient. Most metals possess such a negative Hall coefficient but there exist certain materials which possess a positive Hall coefficient, the potential difference set up being of the opposite sense. These materials may be said therefore to exhibit an inverted Hall effect. A general characteristic of semi-conductors is a negative temperature coefficient of resistance.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to performed I declare that what I claim is:—

1. An electrical amplifier or other control arrangement or device wherein one or more thin layers of semi-conductor traversed by current is or are varied in resistance in accordance with control voltage applied to one or more control electrodes arranged close to and insulated from said semi-conductor layer or layers so as to be in electrostatic association therewith.

2. An arrangement or device in accordance with claim 1 and comprising at least one narrow strip-shaped thin layer of semi-conductor provided on its two longer edges with electrodes which serve to lead electric current into and from said layer, there being at least one control electrode arranged close to a face of the semi-conductor layer and insulated therefrom.

3. An arrangement or device in accordance with any of claim 1 or 2 and comprising at least one thin semi-conductive layer and at least one control electrode in electro-static association therewith said layer and electrode being insulated from one another by insulation of high dielectric constant.

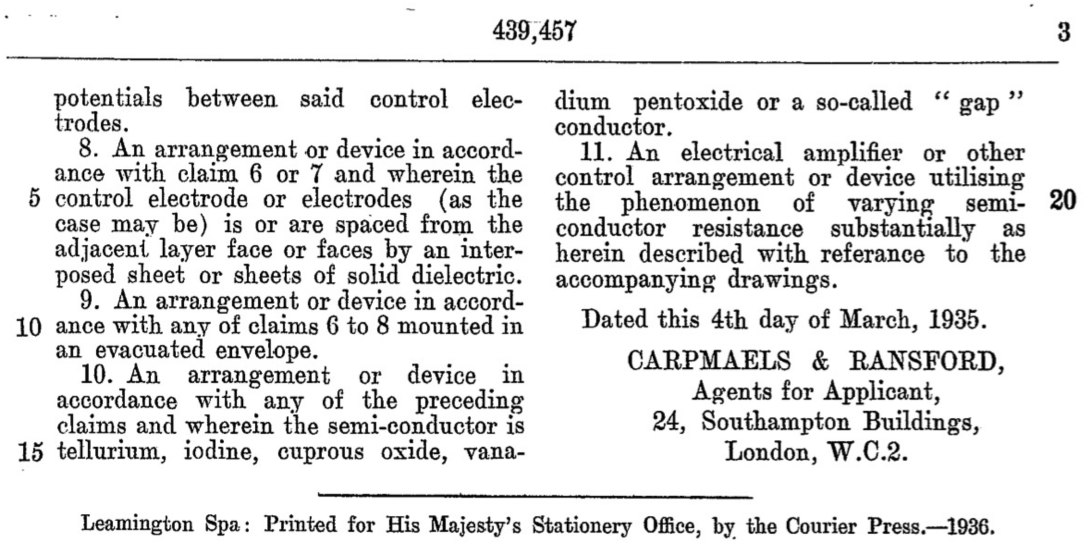
4. An arrangement or device in accordance with any of claim 1 or 2 and comprising at least one thin semi-conductive layer and at least one control electrode in electro-static association therewith said layer and electrode being insulated from one another by air insulation.

5. An arrangement or device in accordance with any of claim 1 or 2 and comprising at least one thin semi-conductive layer and at least one control electrode in electro-static association therewith said layer and electrode being insulated from one another by vacuum insulation.

6. An arrangement or device in accordance with any of the preceding claims and comprising a thin layer of semi-conductor, electrodes on opposite edges thereof, an output circuit including a source of potential said electrodes and said layer in series, a control electrode adjacent one face of said layer and insulated therefrom. and means for applying control potentials between said control electrode and one of said other electrodes.

7. An arrangement or device in accordance with any of claims 1 to 5 and comprising a thin layer of semi-conductor. electrodes on opposite edges thereof, an output circuit including a source of potential said electrodes and said layer in series, a control electrode adjacent one face of said layer and insulated therefrom, a second control electrode adjacent the opposite face of said layer and insulated therefrom, said layer being thus sandwiched between said control electrodes, and means for applying control

Figure B.27: Oskar Heil filed patent applications on field effect transistors in Germany and other countries in 1934.



potentials between said control electrodes.

8. An arrangement or device in accordance with claim 6 or 7 and wherein the control electrode or electrodes (as the case may be) is or are spaced from the adjacent layer face or faces by an interposed sheet or sheets of solid dielectric.

9. An arrangement or device in accordance with any of claims 6 to 8 mounted in an evacuated envelope.

10. An arrangement or device in accordance with any of the preceding claims and wherein the semi-conductor is tellurium, iodine, cuprous oxide, vanadium pentoxide or a so-called "gap" conductor.

11. An electrical amplifier or other control arrangement or device utilising the phenomenon of varying semi-conductor resistance substantially as herein described with referance to the accompanying drawings.

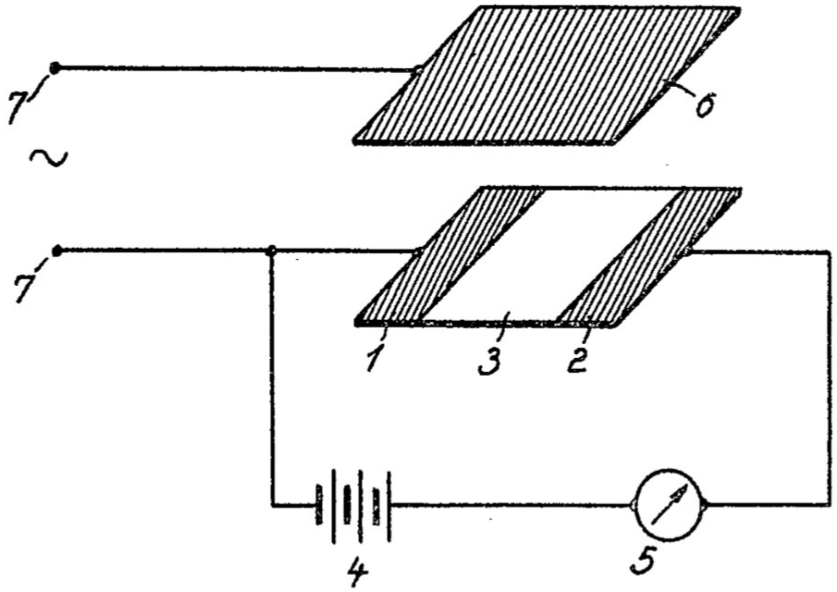
Dated this 4th day of March, 1935.

CARPMAELS & RANSFORD,
Agents for Applicant,
24, Southampton Buildings,
London, W.C.2.

Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1936.

Figure B.28: Oskar Heil filed patent applications on field effect transistors in Germany and other countries in 1934.

Fig. 1



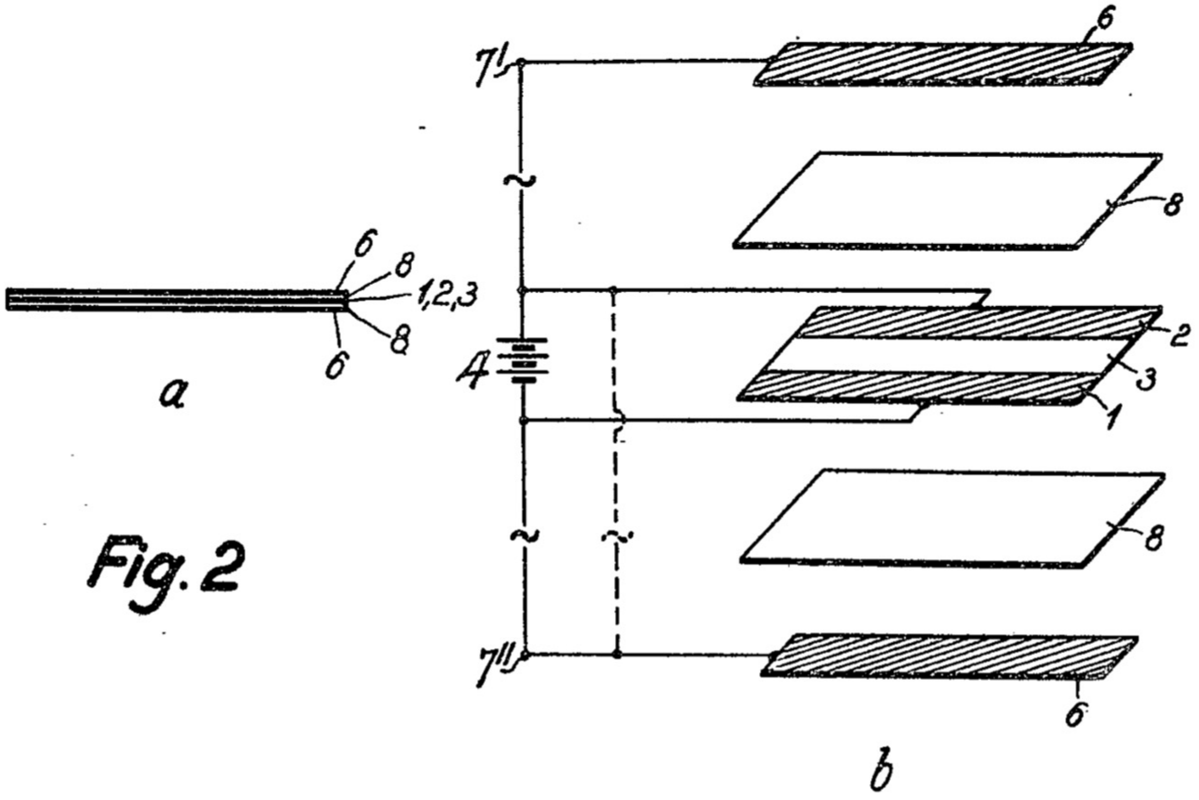

6
8
1,2,3
8
6
a
7'
~
6
8
A
2
3
1
~
8
7''
6
b

Fig. 2

Figure B.29: Oskar Heil filed patent applications on field effect transistors in Germany and other countries in 1934.

3. Gilles Holst (Dutch, 1886–1968) and Willem Christiaan van Geel (Dutch, 1895–1967) filed a patent application on transistors in 1935 [Van Delft 2014]:

> Gilles Holst and Willem Christiaan van Geel. Filed in Germany in 1935 and subsequently in other countries. U.S. patent 2,173,904. Electrode System of Unsymmetrical Conductivity.

See pp. 2687–2689.

Holst was the research director at the Philips Eindhoven laboratory, and van Geel was an expert there on metal and semiconductor materials. Both were nominated for the Nobel Prize in Physics but never won.[1]

Holst was also one of the inventors of the sodium vapor lamp in 1932 (p. 971).

Philips Eindhoven was closely tied to the rest of the predominantly German-speaking research world from the late nineteenth century through World War II, including work on electronics, communications, and directed energy beams.[2]

To what extent was the work by Holst and van Geel based on the earlier patents of Julius Lilienfeld and Oscar Heil?

How much did they interact with other groups in the greater German-speaking world that were trying to develop transistors in the 1930s and early 1940s?

How far did the transistor-related work of Holst and van Geel get by 1945?

Did their work influence postwar projects at Bell Laboratories?

Much more archival research is needed.]

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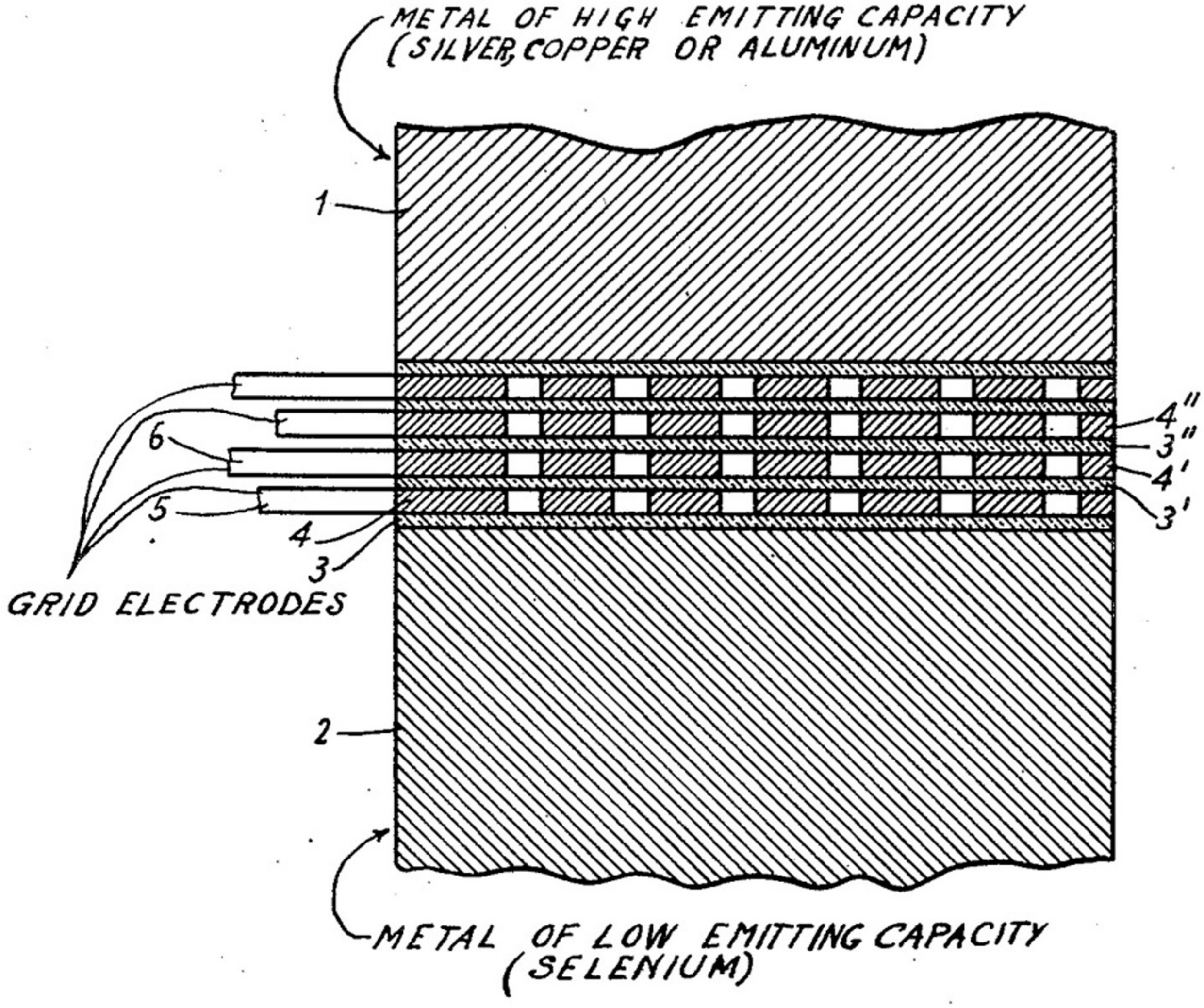
[1] https://www.nobelprize.org/nomination/archive/show.php?id=4874
https://www.nobelprize.org/nomination/archive/show.php?id=4936

[2] See for example: CIOS III-1; CIOS VI-26, 27; CIOS X-13; CIOS XI-10; CIOS XII-22.

Sept. 26, 1939. **G. HOLST ET AL** **2,173,904**

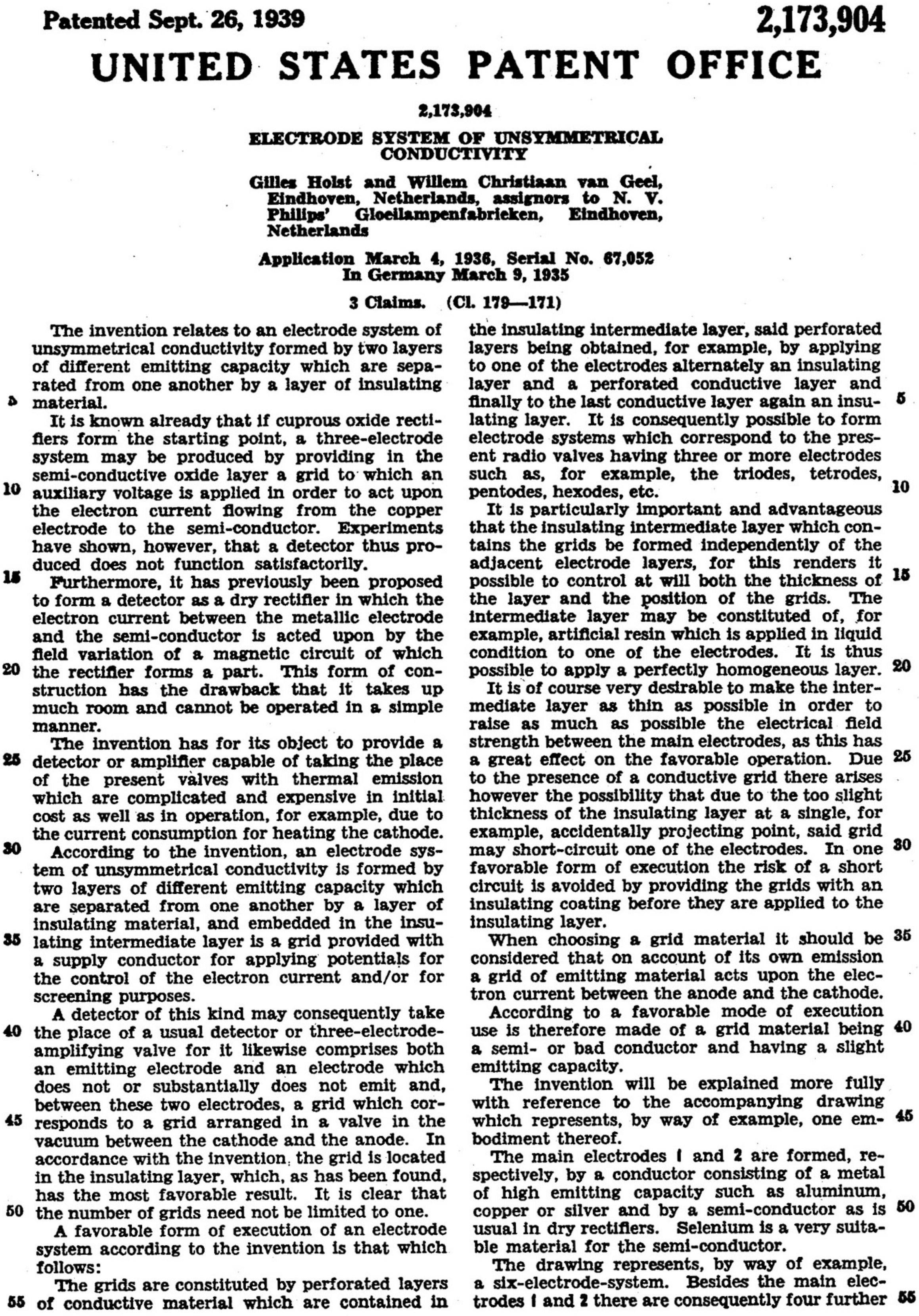
ELECTRODE SYSTEM OF UNSYMMETRICAL CONDUCTIVITY

Filed March 4, 1936


METAL OF HIGH EMITTING CAPACITY
(SILVER, COPPER OR ALUMINUM)
1
6
5
4
3
GRID ELECTRODES
4''
3''
4'
3'
2
METAL OF LOW EMITTING CAPACITY
(SELENIUM)

INVENTORS
GILLES HOLST
W. C. VAN GEEL
BY
ATTORNEY

Figure B.30: Gilles Holst and Willem Christiaan van Geel filed a patent application on transistors in 1935.



Patented Sept. 26, 1939 **2,173,904**

UNITED STATES PATENT OFFICE

2,173,904

ELECTRODE SYSTEM OF UNSYMMETRICAL CONDUCTIVITY

Gilles Holst and Willem Christiaan van Geel, Eindhoven, Netherlands, assignors to N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands

Application March 4, 1936, Serial No. 67,052
In Germany March 9, 1935

3 Claims. (Cl. 179—171)

The invention relates to an electrode system of unsymmetrical conductivity formed by two layers of different emitting capacity which are separated from one another by a layer of insulating material.

It is known already that if cuprous oxide rectifiers form the starting point, a three-electrode system may be produced by providing in the semi-conductive oxide layer a grid to which an auxiliary voltage is applied in order to act upon the electron current flowing from the copper electrode to the semi-conductor. Experiments have shown, however, that a detector thus produced does not function satisfactorily.

Furthermore, it has previously been proposed to form a detector as a dry rectifier in which the electron current between the metallic electrode and the semi-conductor is acted upon by the field variation of a magnetic circuit of which the rectifier forms a part. This form of construction has the drawback that it takes up much room and cannot be operated in a simple manner.

The invention has for its object to provide a detector or amplifier capable of taking the place of the present valves with thermal emission which are complicated and expensive in initial cost as well as in operation, for example, due to the current consumption for heating the cathode.

According to the invention, an electrode system of unsymmetrical conductivity is formed by two layers of different emitting capacity which are separated from one another by a layer of insulating material, and embedded in the insulating intermediate layer is a grid provided with a supply conductor for applying potentials for the control of the electron current and/or for screening purposes.

A detector of this kind may consequently take the place of a usual detector or three-electrode-amplifying valve for it likewise comprises both an emitting electrode and an electrode which does not or substantially does not emit and, between these two electrodes, a grid which corresponds to a grid arranged in a valve in the vacuum between the cathode and the anode. In accordance with the invention, the grid is located in the insulating layer, which, as has been found, has the most favorable result. It is clear that the number of grids need not be limited to one.

A favorable form of execution of an electrode system according to the invention is that which follows:

The grids are constituted by perforated layers of conductive material which are contained in the insulating intermediate layer, said perforated layers being obtained, for example, by applying to one of the electrodes alternately an insulating layer and a perforated conductive layer and finally to the last conductive layer again an insulating layer. It is consequently possible to form electrode systems which correspond to the present radio valves having three or more electrodes such as, for example, the triodes, tetrodes, pentodes, hexodes, etc.

It is particularly important and advantageous that the insulating intermediate layer which contains the grids be formed independently of the adjacent electrode layers, for this renders it possible to control at will both the thickness of the layer and the position of the grids. The intermediate layer may be constituted of, for example, artificial resin which is applied in liquid condition to one of the electrodes. It is thus possible to apply a perfectly homogeneous layer.

It is of course very desirable to make the intermediate layer as thin as possible in order to raise as much as possible the electrical field strength between the main electrodes, as this has a great effect on the favorable operation. Due to the presence of a conductive grid there arises however the possibility that due to the too slight thickness of the insulating layer at a single, for example, accidentally projecting point, said grid may short-circuit one of the electrodes. In one favorable form of execution the risk of a short circuit is avoided by providing the grids with an insulating coating before they are applied to the insulating layer.

When choosing a grid material it should be considered that on account of its own emission a grid of emitting material acts upon the electron current between the anode and the cathode.

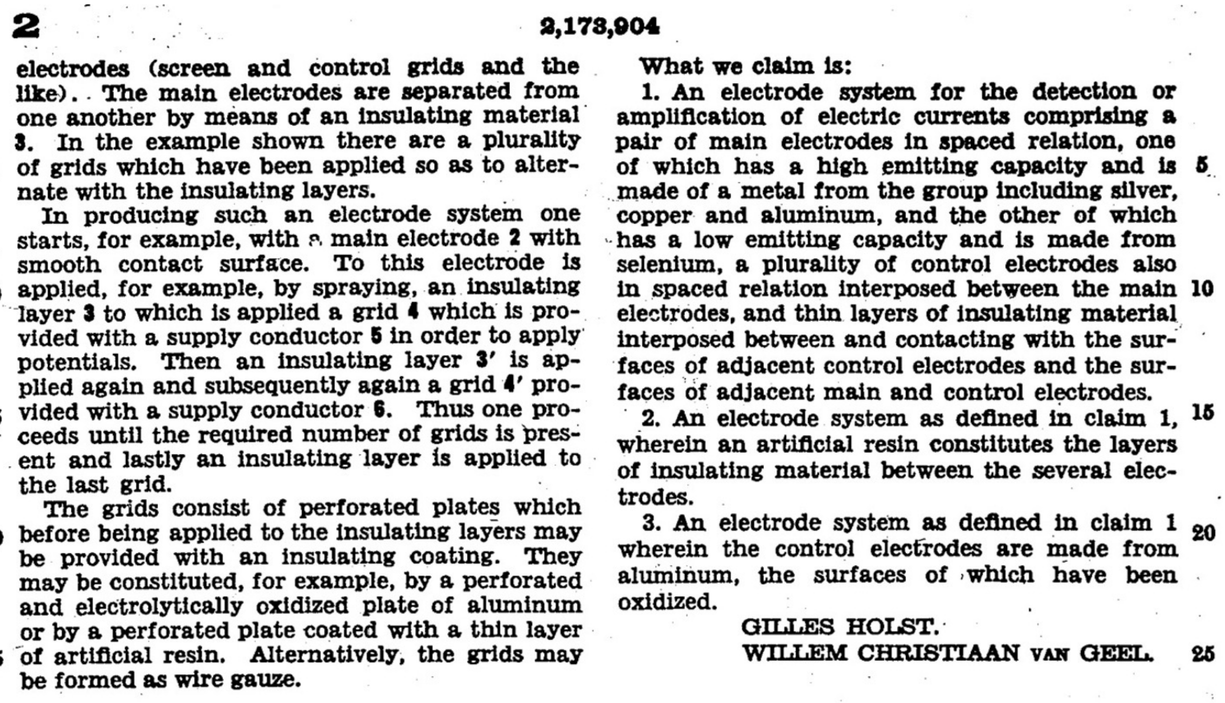
According to a favorable mode of execution use is therefore made of a grid material being a semi- or bad conductor and having a slight emitting capacity.

The invention will be explained more fully with reference to the accompanying drawing which represents, by way of example, one embodiment thereof.

The main electrodes 1 and 2 are formed, respectively, by a conductor consisting of a metal of high emitting capacity such as aluminum, copper or silver and by a semi-conductor as is usual in dry rectifiers. Selenium is a very suitable material for the semi-conductor.

The drawing represents, by way of example, a six-electrode-system. Besides the main electrodes 1 and 2 there are consequently four further

Figure B.31: Gilles Holst and Willem Christiaan van Geel filed a patent application on transistors in 1935.



2 2,173,904

electrodes (screen and control grids and the like). The main electrodes are separated from one another by means of an insulating material 3. In the example shown there are a plurality of grids which have been applied so as to alternate with the insulating layers.

In producing such an electrode system one starts, for example, with a main electrode 2 with smooth contact surface. To this electrode is applied, for example, by spraying, an insulating layer 3 to which is applied a grid 4 which is provided with a supply conductor 5 in order to apply potentials. Then an insulating layer 3' is applied again and subsequently again a grid 4' provided with a supply conductor 6. Thus one proceeds until the required number of grids is present and lastly an insulating layer is applied to the last grid.

The grids consist of perforated plates which before being applied to the insulating layers may be provided with an insulating coating. They may be constituted, for example, by a perforated and electrolytically oxidized plate of aluminum or by a perforated plate coated with a thin layer of artificial resin. Alternatively, the grids may be formed as wire gauze.

What we claim is:

1. An electrode system for the detection or amplification of electric currents comprising a pair of main electrodes in spaced relation, one of which has a high emitting capacity and is made of a metal from the group including silver, copper and aluminum, and the other of which has a low emitting capacity and is made from selenium, a plurality of control electrodes also in spaced relation interposed between the main electrodes, and thin layers of insulating material interposed between and contacting with the surfaces of adjacent control electrodes and the surfaces of adjacent main and control electrodes.

2. An electrode system as defined in claim 1, wherein an artificial resin constitutes the layers of insulating material between the several electrodes.

3. An electrode system as defined in claim 1 wherein the control electrodes are made from aluminum, the surfaces of which have been oxidized.

GILLES HOLST.
WILLEM CHRISTIAAN VAN GEEL.

Figure B.32: Gilles Holst and Willem Christiaan van Geel filed a patent application on transistors in 1935.

[**4. Rudolf Hilsch (German, 1903–1972) and Robert Pohl (German, 1884–1976)** demonstrated a proof-of-concept point-contact transistor in 1938:

> Rudolf Hilsch and Robert Pohl. 1938. Steuerung von Elektronenströmen mit einem Dreielektrodenkristall und ein Modell einer Sperrschicht. *Zeitschrift für Physik* 111:399–408.

Like a modern transistor, this solid-state semiconductor device had three electrodes, with the current flow into the middle electrode (the base, in modern terminology) controlling and greatly amplified by the much larger current flow between the other two electrodes (see pp. 2691–2692). For the 1938 experiments, that signal amplification was approximately a factor of 20. These results were extremely impressive, but the reason they are best described as "proof of concept" is that they were obtained in a material (a potassium bromide crystal) that became a good semiconductor only at a very high temperature (490^oC) and high voltages (100–150 Volts), which would not be practical for use in normal electronic circuits.

Hilsch recognized those limitations and promptly proposed that the results be replicated by modifying existing room-temperature semiconductor diodes to add a third electrode for the base (see below and p. 2693):

> Rudolf Hilsch. 1939. Elektronenleitung in Kristallen. *Die Naturwissenschaften* 27:489–492.

From available documentation, it is unclear exactly what projects Hilsch worked on between 1939 and the postwar period. Given his determination to replicate the transistor amplifier results in a more practical semiconductor device, and given the extensive wartime work on new and improved semiconductor devices, it seems likely that he would have carried his transistor work further, or collaborated with other scientists to do so.

In any event, the 1938 Hilsch and Pohl paper and the 1939 Hilsch paper were published in physics journals that were highly regarded and widely read in the German-speaking world, so they would have encouraged many other scientists (such as those mentioned in this appendix) to try to replicate, extend, and apply that work.

At the end of World War II, both Hilsch and Pohl were extensively interrogated by scientists and officials from Allied countries in order to aid postwar electronics programs in those countries (see for example pp. 2997 and 3005).]

Rudolf Hilsch. 1939. Elektronenleitung in Kristallen. *Die Naturwissenschaften* 27:489–492.

Durch diese Messung ist zum erstenmal gezeigt worden, daß man auch in festen Körpern Ströme steuern kann. Die Trägheit der Ströme in diesem "großen" Modell ist naturgemäß groß. Es ist jetzt nur eine Aufgabe der Technik, auch in den dünnen Sperrschichten der technischen Gleichrichter das Steuergitter unterzubringen. Wenn die Lösung dieser Aufgabe gelingt, kann der Dreielektroden-Kristall auch technisch neben dem Dreielektroden-Rohr seine Bedeutung erhalten.	This measurement has shown for the first time that it is also possible to control currents in solid bodies. The inertia of the currents in this "large" model is naturally large. It is now only a technical task to add the control grid in the thin barrier layers of engineering rectifiers. If the solution to this problem is successful, the three-electrode crystal can also gain technical significance alongside the three-electrode tube.

Rudolf Hilsch
(1903–1972)
and
Robert Pohl
(1884–1976)
demonstrated
a prototype
point-contact
transistor (1938)

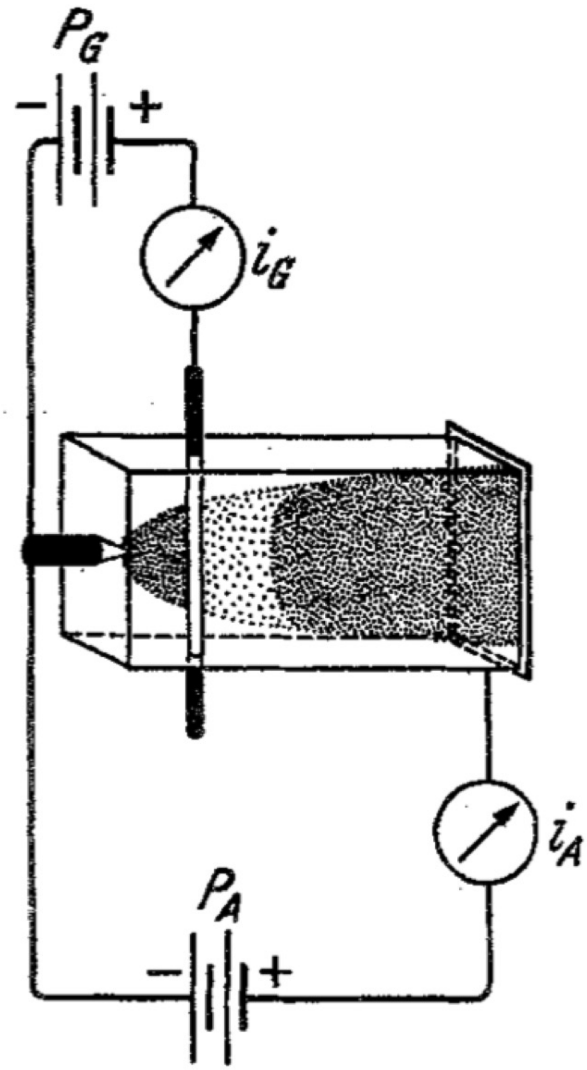


Fig. 6. Schema und Schaltung eines Dreielektrodenkristalles. Gezeichnet ist die durch Farbzentren sichtbar gemachte Elektronenverteilung während einer Abnahme des Anodenstromes. Die negative Aufladung des Gitters ist vergrößert worden, der Anodenstrom hat aber noch nicht seinen stationären Wert erreicht. (Kristallabmessungen 2 × 5 × 10 mm).

Rudolf Hilsch and
Robert Pohl. 1938.
Steuerung von
Elektronenströmen
mit einem
Dreielektrodenkristall
und ein Modell
einer Sperrschicht.
Zeitschrift für Physik
111:399.

Figure B.33: Rudolf Hilsch and Robert Pohl demonstrated a prototype point-contact transistor in 1938.

Rudolf Hilsch
(1903–1972)
and
Robert Pohl
(1884–1976)
demonstrated
a prototype
point-contact
transistor (1938)

Fig. 7.

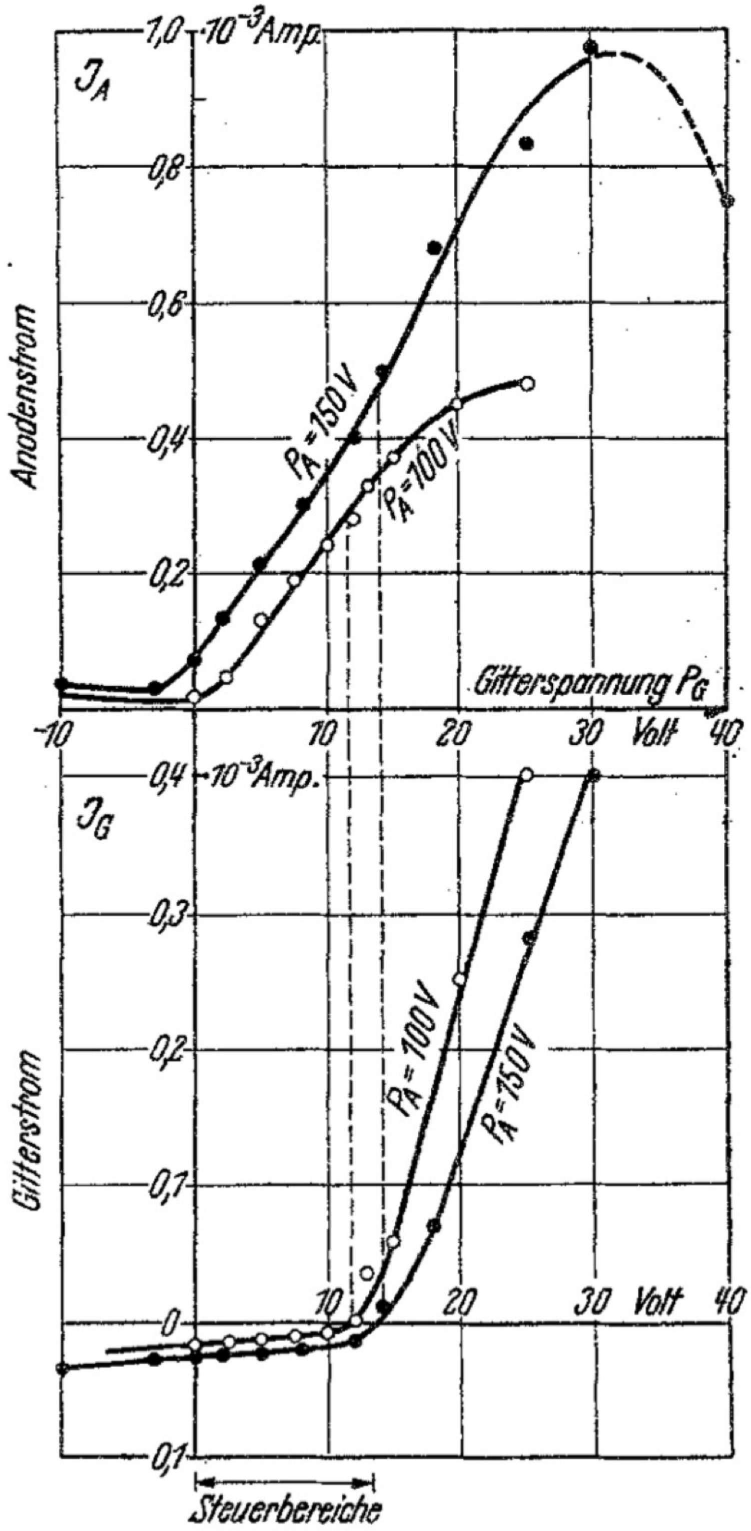


Fig. 8.

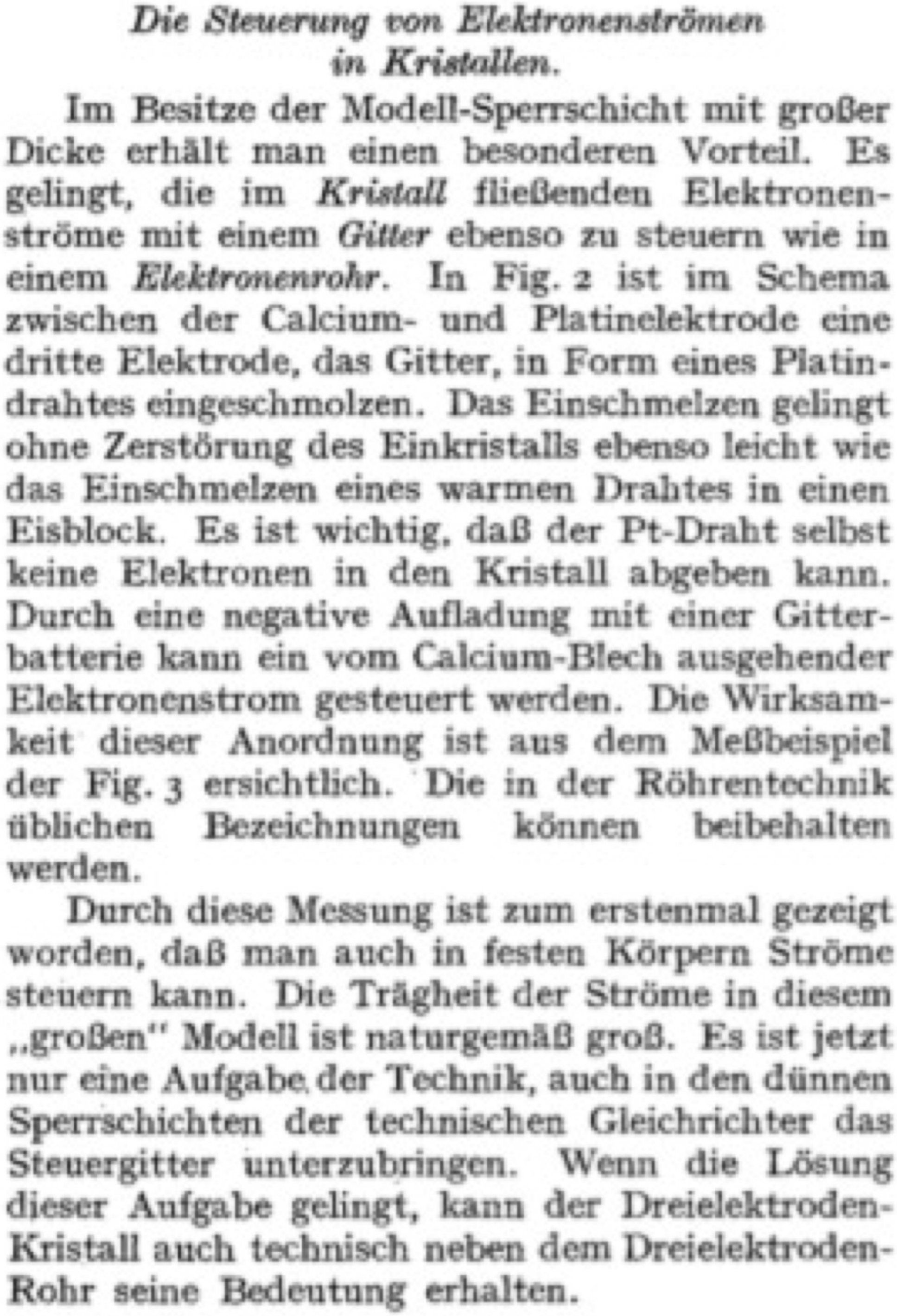
Fig. 7 und 8. Die beiden Kennlinien eines Dreielektrodenkristalles mit 20 facher Verstärkung. $T = 490^0$ C.

Rudolf Hilsch and
Robert Pohl. 1938.
Steuerung von
Elektronenströmen
mit einem
Dreielektrodenkristall
und ein Modell
einer Sperrschicht.
Zeitschrift für Physik
111:399.

Figure B.34: Rudolf Hilsch and Robert Pohl demonstrated a prototype point-contact transistor in 1938.

Rudolf Hilsch (1903–1972) and Robert Pohl (1884–1976) demonstrated a prototype point-contact transistor (1938)

Rudolf Hilsch. 1939. Elektronenleitung in Kristallen. *Die Naturwissenschaften* 27:489–492.



Die Steuerung von Elektronenströmen in Kristallen.

Im Besitze der Modell-Sperrschicht mit großer Dicke erhält man einen besonderen Vorteil. Es gelingt, die im *Kristall* fließenden Elektronenströme mit einem *Gitter* ebenso zu steuern wie in einem *Elektronenrohr*. In Fig. 2 ist im Schema zwischen der Calcium- und Platinelektrode eine dritte Elektrode, das Gitter, in Form eines Platindrahtes eingeschmolzen. Das Einschmelzen gelingt ohne Zerstörung des Einkristalls ebenso leicht wie das Einschmelzen eines warmen Drahtes in einen Eisblock. Es ist wichtig, daß der Pt-Draht selbst keine Elektronen in den Kristall abgeben kann. Durch eine negative Aufladung mit einer Gitterbatterie kann ein vom Calcium-Blech ausgehender Elektronenstrom gesteuert werden. Die Wirksamkeit dieser Anordnung ist aus dem Meßbeispiel der Fig. 3 ersichtlich. Die in der Röhrentechnik üblichen Bezeichnungen können beibehalten werden.

Durch diese Messung ist zum erstenmal gezeigt worden, daß man auch in festen Körpern Ströme steuern kann. Die Trägheit der Ströme in diesem „großen" Modell ist naturgemäß groß. Es ist jetzt nur eine Aufgabe der Technik, auch in den dünnen Sperrschichten der technischen Gleichrichter das Steuergitter unterzubringen. Wenn die Lösung dieser Aufgabe gelingt, kann der Dreielektroden-Kristall auch technisch neben dem Dreielektroden-Rohr seine Bedeutung erhalten.

Figure B.35: Rudolf Hilsch and Robert Pohl demonstrated a prototype point-contact transistor in 1938.

[**5. Erich Habann (German, 1892–1968)** filed a very detailed patent application on point-contact transistors, their fabrication, and use:

> Erich Habann. Filed in 1942. German patent DE 971,775. Einrichtung zur Verstärkung elektrischer Ströme und Spannungen. [Device for Amplifying Electrical Currents and Voltages.] (pp. 2695–2698)

The level of detail in the patent application suggests that by 1942, Habann may well have already produced and demonstrated such transistors at his Hessenwinkel laboratory (p. 2699).

Although documentation on his transistor results is not currently available, it is known that Habann worked on a number of secretive research projects involving electronics, rockets, and nuclear physics during the war, and that he was well funded by the German military. After the war, he continued his research for the Soviet Union.

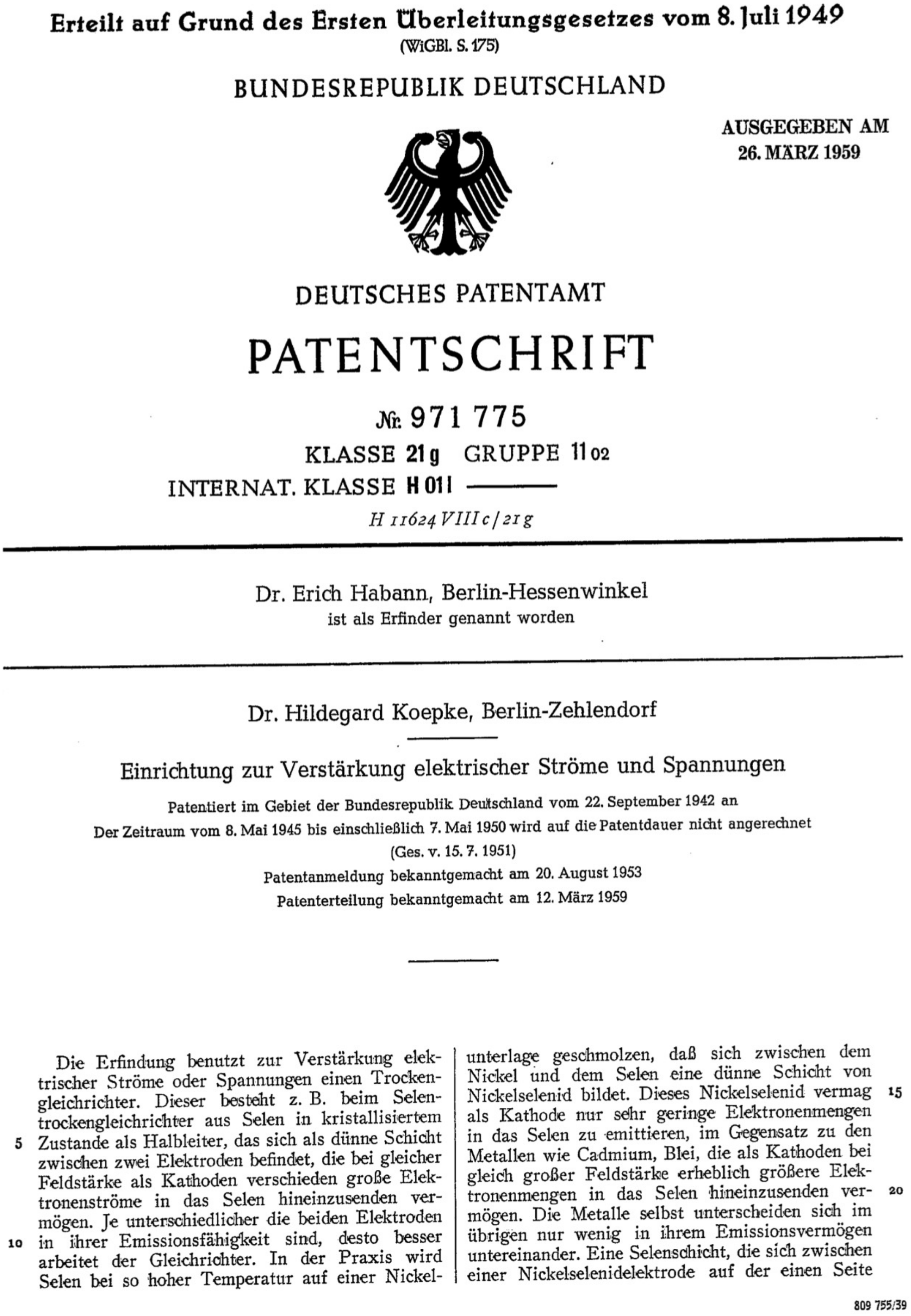
If Habann indeed had a working prototype transistor by 1942, it is possible that such transistors may have been mass-produced for use in rocket guidance systems or other applications before the end of the war.

It is also quite possible that Habann, his hardware, and his information directly or indirectly aided the development of microelectronics technologies in Allied countries after the war.

It appears that thus far only the German historian Günter Nagel has investigated and briefly written about Erich Habann and his inventions:

> Günter Nagel. 2006. Pionier der Funktechnik. *Brandenburger Blätter.* 15 December 2006 p. 9.
>
> Günter Nagel. 2011. *Himmlers Waffenforscher: Physiker, Chemiker, Mathematiker und Techniker im Dienste der SS.* Aachen: Helios.
>
> Günter Nagel. 2012a. *Wissenschaft für den Krieg: Die geheimen Arbeiten der Abteilung Forschung des Heereswaffenamtes.* Stuttgart: Franz Steiner.

Much more archival research should be conducted to investigate Habann's technical accomplishments, as well as their direct and indirect impacts on other research programs.]



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
26. MÄRZ 1959

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 971 775

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Dr. Erich Habann, Berlin-Hessenwinkel
ist als Erfinder genannt worden

Dr. Hildegard Koepke, Berlin-Zehlendorf

Einrichtung zur Verstärkung elektrischer Ströme und Spannungen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 22. September 1942 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
(Ges. v. 15. 7. 1951)
Patentanmeldung bekanntgemacht am 20. August 1953
Patenterteilung bekanntgemacht am 12. März 1959

Die Erfindung benutzt zur Verstärkung elektrischer Ströme oder Spannungen einen Trockengleichrichter. Dieser besteht z. B. beim Selentrockengleichrichter aus Selen in kristallisiertem Zustande als Halbleiter, das sich als dünne Schicht zwischen zwei Elektroden befindet, die bei gleicher Feldstärke als Kathoden verschieden große Elektronenströme in das Selen hineinzusenden vermögen. Je unterschiedlicher die beiden Elektroden in ihrer Emissionsfähigkeit sind, desto besser arbeitet der Gleichrichter. In der Praxis wird Selen bei so hoher Temperatur auf einer Nickelunterlage geschmolzen, daß sich zwischen dem Nickel und dem Selen eine dünne Schicht von Nickelselenid bildet. Dieses Nickelselenid vermag als Kathode nur sehr geringe Elektronenmengen in das Selen zu emittieren, im Gegensatz zu den Metallen wie Cadmium, Blei, die als Kathoden bei gleich großer Feldstärke erheblich größere Elektronenmengen in das Selen hineinzusenden vermögen. Die Metalle selbst unterscheiden sich im übrigen nur wenig in ihrem Emissionsvermögen untereinander. Eine Selenschicht, die sich zwischen einer Nickelselenidelektrode auf der einen Seite

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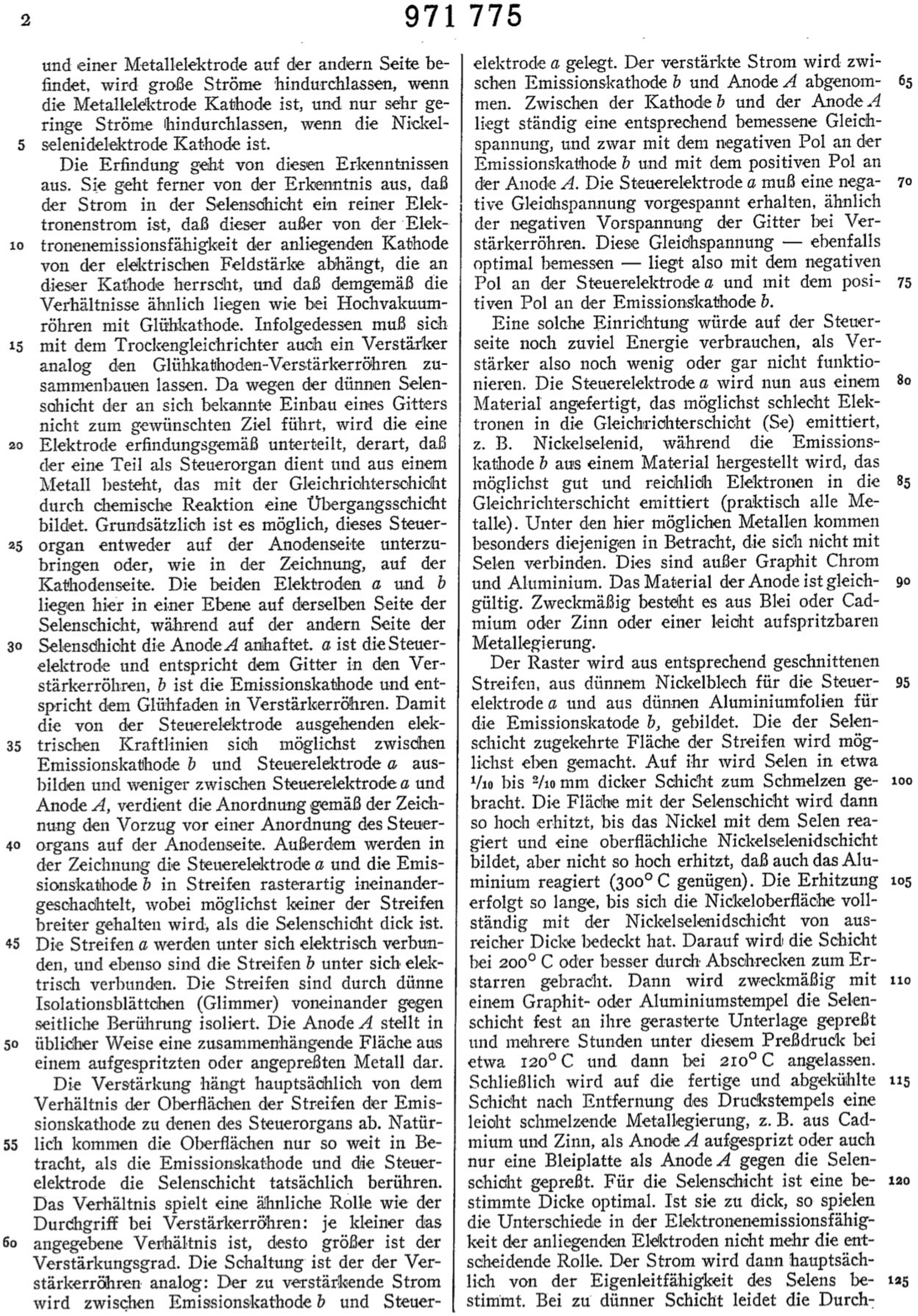
Figure B.36: In 1942, Erich Habann filed a detailed patent application on point-contact transistors, their fabrication, and use.



und einer Metallelektrode auf der andern Seite befindet, wird große Ströme hindurchlassen, wenn die Metallelektrode Kathode ist, und nur sehr geringe Ströme hindurchlassen, wenn die Nickelselenidelektrode Kathode ist.

Die Erfindung geht von diesen Erkenntnissen aus. Sie geht ferner von der Erkenntnis aus, daß der Strom in der Selenschicht ein reiner Elektronenstrom ist, daß dieser außer von der Elektronenemissionsfähigkeit der anliegenden Kathode von der elektrischen Feldstärke abhängt, die an dieser Kathode herrscht, und daß demgemäß die Verhältnisse ähnlich liegen wie bei Hochvakuumröhren mit Glühkathode. Infolgedessen muß sich mit dem Trockengleichrichter auch ein Verstärker analog den Glühkathoden-Verstärkerröhren zusammenbauen lassen. Da wegen der dünnen Selenschicht der an sich bekannte Einbau eines Gitters nicht zum gewünschten Ziel führt, wird die eine Elektrode erfindungsgemäß unterteilt, derart, daß der eine Teil als Steuerorgan dient und aus einem Metall besteht, das mit der Gleichrichterschicht durch chemische Reaktion eine Übergangsschicht bildet. Grundsätzlich ist es möglich, dieses Steuerorgan entweder auf der Anodenseite unterzubringen oder, wie in der Zeichnung, auf der Kathodenseite. Die beiden Elektroden *a* und *b* liegen hier in einer Ebene auf derselben Seite der Selenschicht, während auf der andern Seite der Selenschicht die Anode *A* anhaftet. *a* ist die Steuerelektrode und entspricht dem Gitter in den Verstärkerröhren, *b* ist die Emissionskathode und entspricht dem Glühfaden in Verstärkerröhren. Damit die von der Steuerelektrode ausgehenden elektrischen Kraftlinien sich möglichst zwischen Emissionskathode *b* und Steuerelektrode *a* ausbilden und weniger zwischen Steuerelektrode *a* und Anode *A*, verdient die Anordnung gemäß der Zeichnung den Vorzug vor einer Anordnung des Steuerorgans auf der Anodenseite. Außerdem werden in der Zeichnung die Steuerelektrode *a* und die Emissionskathode *b* in Streifen rasterartig ineinandergeschachtelt, wobei möglichst keiner der Streifen breiter gehalten wird, als die Selenschicht dick ist. Die Streifen *a* werden unter sich elektrisch verbunden, und ebenso sind die Streifen *b* unter sich elektrisch verbunden. Die Streifen sind durch dünne Isolationsblättchen (Glimmer) voneinander gegen seitliche Berührung isoliert. Die Anode *A* stellt in üblicher Weise eine zusammenhängende Fläche aus einem aufgespritzten oder angepreßten Metall dar.

Die Verstärkung hängt hauptsächlich von dem Verhältnis der Oberflächen der Streifen der Emissionskathode zu denen des Steuerorgans ab. Natürlich kommen die Oberflächen nur so weit in Betracht, als die Emissionskathode und die Steuerelektrode die Selenschicht tatsächlich berühren. Das Verhältnis spielt eine ähnliche Rolle wie der Durchgriff bei Verstärkerröhren: je kleiner das angegebene Verhältnis ist, desto größer ist der Verstärkungsgrad. Die Schaltung ist der der Verstärkerröhren analog: Der zu verstärkende Strom wird zwischen Emissionskathode *b* und Steuerelektrode *a* gelegt. Der verstärkte Strom wird zwischen Emissionskathode *b* und Anode *A* abgenommen. Zwischen der Kathode *b* und der Anode *A* liegt ständig eine entsprechend bemessene Gleichspannung, und zwar mit dem negativen Pol an der Emissionskathode *b* und mit dem positiven Pol an der Anode *A*. Die Steuerelektrode *a* muß eine negative Gleichspannung vorgespannt erhalten, ähnlich der negativen Vorspannung der Gitter bei Verstärkerröhren. Diese Gleichspannung — ebenfalls optimal bemessen — liegt also mit dem negativen Pol an der Steuerelektrode *a* und mit dem positiven Pol an der Emissionskathode *b*.

Eine solche Einrichtung würde auf der Steuerseite noch zuviel Energie verbrauchen, als Verstärker also noch wenig oder gar nicht funktionieren. Die Steuerelektrode *a* wird nun aus einem Material angefertigt, das möglichst schlecht Elektronen in die Gleichrichterschicht (Se) emittiert, z. B. Nickelselenid, während die Emissionskathode *b* aus einem Material hergestellt wird, das möglichst gut und reichlich Elektronen in die Gleichrichterschicht emittiert (praktisch alle Metalle). Unter den hier möglichen Metallen kommen besonders diejenigen in Betracht, die sich nicht mit Selen verbinden. Dies sind außer Graphit Chrom und Aluminium. Das Material der Anode ist gleichgültig. Zweckmäßig besteht es aus Blei oder Cadmium oder Zinn oder einer leicht aufspritzbaren Metallegierung.

Der Raster wird aus entsprechend geschnittenen Streifen, aus dünnem Nickelblech für die Steuerelektrode *a* und aus dünnen Aluminiumfolien für die Emissionskatode *b*, gebildet. Die der Selenschicht zugekehrte Fläche der Streifen wird möglichst eben gemacht. Auf ihr wird Selen in etwa $^{1}/_{10}$ bis $^{2}/_{10}$ mm dicker Schicht zum Schmelzen gebracht. Die Fläche mit der Selenschicht wird dann so hoch erhitzt, bis das Nickel mit dem Selen reagiert und eine oberflächliche Nickelselenidschicht bildet, aber nicht so hoch erhitzt, daß auch das Aluminium reagiert (300° C genügen). Die Erhitzung erfolgt so lange, bis sich die Nickeloberfläche vollständig mit der Nickelselenidschicht von ausreicher Dicke bedeckt hat. Darauf wird die Schicht bei 200° C oder besser durch Abschrecken zum Erstarren gebracht. Dann wird zweckmäßig mit einem Graphit- oder Aluminiumstempel die Selenschicht fest an ihre gerasterte Unterlage gepreßt und mehrere Stunden unter diesem Preßdruck bei etwa 120° C und dann bei 210° C angelassen. Schließlich wird auf die fertige und abgekühlte Schicht nach Entfernung des Druckstempels eine leicht schmelzende Metallegierung, z. B. aus Cadmium und Zinn, als Anode *A* aufgesprizt oder auch nur eine Bleiplatte als Anode *A* gegen die Selenschicht gepreßt. Für die Selenschicht ist eine bestimmte Dicke optimal. Ist sie zu dick, so spielen die Unterschiede in der Elektronenemissionsfähigkeit der anliegenden Elektroden nicht mehr die entscheidende Rolle. Der Strom wird dann hauptsächlich von der Eigenleitfähigkeit des Selens bestimmt. Bei zu dünner Schicht leidet die Durch-

Figure B.37: In 1942, Erich Habann filed a detailed patent application on point-contact transistors, their fabrication, and use.

schlagsfestigkeit, und die konstruktiven Schwierigkeiten werden zu groß. Die optimale Schichtdicke liegt beim Selen zwischen 1/10 und 2/10 mm.

Es besteht ein Interesse, zur Verringerung ihrer Kapazität die Streifen *a* und *b* möglichst klein zu machen. An Stelle der Streifen werden besser dünne Drähte aus Nickel und Aluminium verwendet, die gemeinsam über eine Porzellanunterlage, die entsprechende Rillen hat, gewickelt werden, und zwar derart, daß die Drähte einlagig und abwechselnd, lediglich durch die Porzellanrillen isoliert, dicht nebeneinander auf der Porzellanfläche liegen.

Der Verstärker arbeitet trägheitslos. Er kann, wenn der Anodenkreis mit dem Steuerkreis rückgekoppelt wird, als Generator dienen, oder er kann mit weiteren Verstärkern in Reihe geschaltet werden, indem der aus dem Anodenkreis des ersten Verstärkers resultierende Strom über einen Transformator oder ein sonstiges geeignetes Kopplungsglied dem Steuerkreis des zweiten Verstärkers zugeleitet wird usw. Es können so hohe Verstärkungen erzielt werden. Andererseits können mehrere Verstärker auch parallel geschaltet und so der Aufnahme und der verstärkten Wiedergabe auch größerer Leistungen angepaßt werden. Es besteht die Möglichkeit, diese Anpassung von vornherein durch Bemessung der gesamten Selenfläche vorzunehmen.

Eine höhere Anodenspannung liefert ohne weiteres eine größere Leistung. Die positive Anodenspannung wird aber dadurch begrenzt, daß von der Steuerelektrode *a*, die ja gegenüber allen andern Elektroden, insbesondere gegenüber der Anode *A* negativ ist, nicht nur kein größerer Strom zur Emissionskathode *b*, sondern auch nicht zur Anode *A* hinüberfließen darf. Insofern müssen Anodenspannung und Vorspannung des Steuergitters einander optimal angepaßt sein. Die Leistung des Verstärkers kann weiterhin durch Kühlflächen, welche die Temperatur der Selenschicht beim Betriebe niedrig halten, gesteigert werden.

Die Erfindung ist nicht auf den Selengleichrichter beschränkt. In gleicher Weise können andere Gleichrichtertypen verwendet werden. Beim Kupferoxydulgleichrichter beispielsweise entspricht das Kupferoxydul der Selenschicht und das Kupferoxyd der Nickelselenidschicht. Die Steuerelektrode wird daher hier einen dünnen Überzug von Kupferoxyd erhalten müssen und erst mit diesem die Kupferoxydulschicht berühren dürfen. Das Material der Anode ist auch hier gleichgültig, während die Emissionskathode zweckmäßig aus reinem Kupfer besteht.

PATENTANSPRÜCHE:

1. Einrichtung zur Verstärkung elektrischer Ströme und Spannungen mittels einer von drei Elektroden oberflächlich berührten Gleichrichterschicht, bei der eine Elektrode als Steuerelektrode dient, dadurch gekennzeichnet, daß auf der einen Seite der Gleichrichterschicht eine zusammenhängende Elektrode anliegt, während die auf der anderen Seite liegende Elektrode unterteilt ist, derart, daß der eine Teil als Steuerelektrode dient und aus einem Metall besteht, das mit der Gleichrichterschicht durch chemische Reaktion eine Übergangsschicht bildet.

2. Einrichtung nach Anspruch 1, dadurch gekennzeichnet, daß bei einer aus einer Verbindung bestehenden Gleichrichterschicht, wie Kupferoxydul, die Übergangsschicht statt durch Reaktion des Metalls der Steuerelektrode mit der Gleichrichterschicht durch Reaktion eines Metalloides (Sauerstoff) mit der Gleichrichterschicht gebildet ist.

3. Einrichtung nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die beiden auf derselben Seite der Gleichrichterschicht benachbarten Elektroden rasterartig oder rostartig ineinander verschachtelt sind, derart, daß die ineinandergreifenden Teile eng nebeneinander liegen und eine Breite besitzen, die vorzugsweise kleiner als die Stärke der Gleichrichterschicht ist.

4. Einrichtung nach den Ansprüchen 1 bis 3, dadurch gekennzeichnet, daß die Steuerelektrode von größerer Flächenausdehnung als die neben ihr angeordnete Elektrode ist.

5. Einrichtung nach den Ansprüchen 1 bis 4, dadurch gekennzeichnet, daß die Veränderung der von der Steuerelektrode beaufschlagten Flächenteile der Gleichrichterschicht als kontinuierlicher Übergang durch thermische Behandlung erzielt ist.

6. Einrichtung nach Anspruch 5, dadurch gekennzeichnet, daß die optimale Stärke der Übergangsschicht durch die Höhe der angewandten Temperatur und die Dauer der Erhitzung bestimmt ist.

7. Einrichtung nach den Ansprüchen 1 bis 7, dadurch gekennzeichnet, daß die anderen Elektroden aus einem Material bestehen, das sich nicht mit der Gleichrichterschicht verbindet.

8. Einrichtung nach den Ansprüchen 1 bis 7, dadurch gekennzeichnet, daß die der Steuerelektrode benachbarte Elektrode die Anode darstellt.

9. Einrichtung nach den Ansprüchen 1 bis 7, dadurch gekennzeichnet, daß die der Steuerelektrode benachbarte Elektrode die Kathode darstellt.

10. Einrichtung nach den Ansprüchen 1 bis 9, dadurch gekennzeichnet, daß Mittel zur Kühlung (Kühlflächen) vorgesehen sind.

In Betracht gezogene Druckschriften:

Deutsche Patentschriften Nr. 450 091, 519 161, 684 522;

österreichische Patentschrift Nr. 130 102;

Figure B.38: In 1942, Erich Habann filed a detailed patent application on point-contact transistors, their fabrication, and use.

schweizerische Patentschriften Nr. 184 396, 215 504;
französische Patentschrift Nr. 786 454;
britische Patentschriften Nr. 349 584, 500 342, 500 344, 529 754;
USA.-Patentschriften Nr. 1 745 175, 1 900 018, 2 160 383, 2 173 904;
Zeitschrift für Physik, 111 (1938/39), S. 399, 406 bis 408;
Zeitschrift für Elektrochemie und angewandte physikalische Chemie, 1943, S. 274ff., 284;
Physikalisches Taschenbuch von Hermann Ebert, Braunschweig, 1951, S. 346;
D'Ans-Lax: »Taschenbuch für Chemiker und Physiker«, Springer-Verlag, 1949, S. 1218;
Berichte der Sächsischen Akademie der Wissenschaften, Leipzig, Bd. 82, 1930, S. 133;
Gmelin: »Handbuch für anorganische Chemie«, Bd. 10, »Selen«, S. 417;
Proc. I.R.E., Bd. 40, S. 1512ff. (1952);
Transact. Electrochem. Soc., 79 (1941), S. 359/360.

Hierzu 1 Blatt Zeichnungen

Zu der Patentschrift **971 775**
Kl. **21g** Gr. 11 02
Internat. Kl. **H 01 l** ——

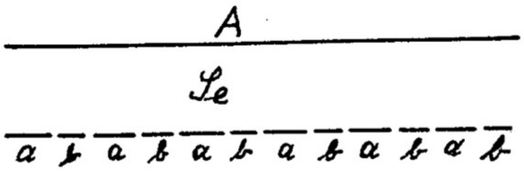
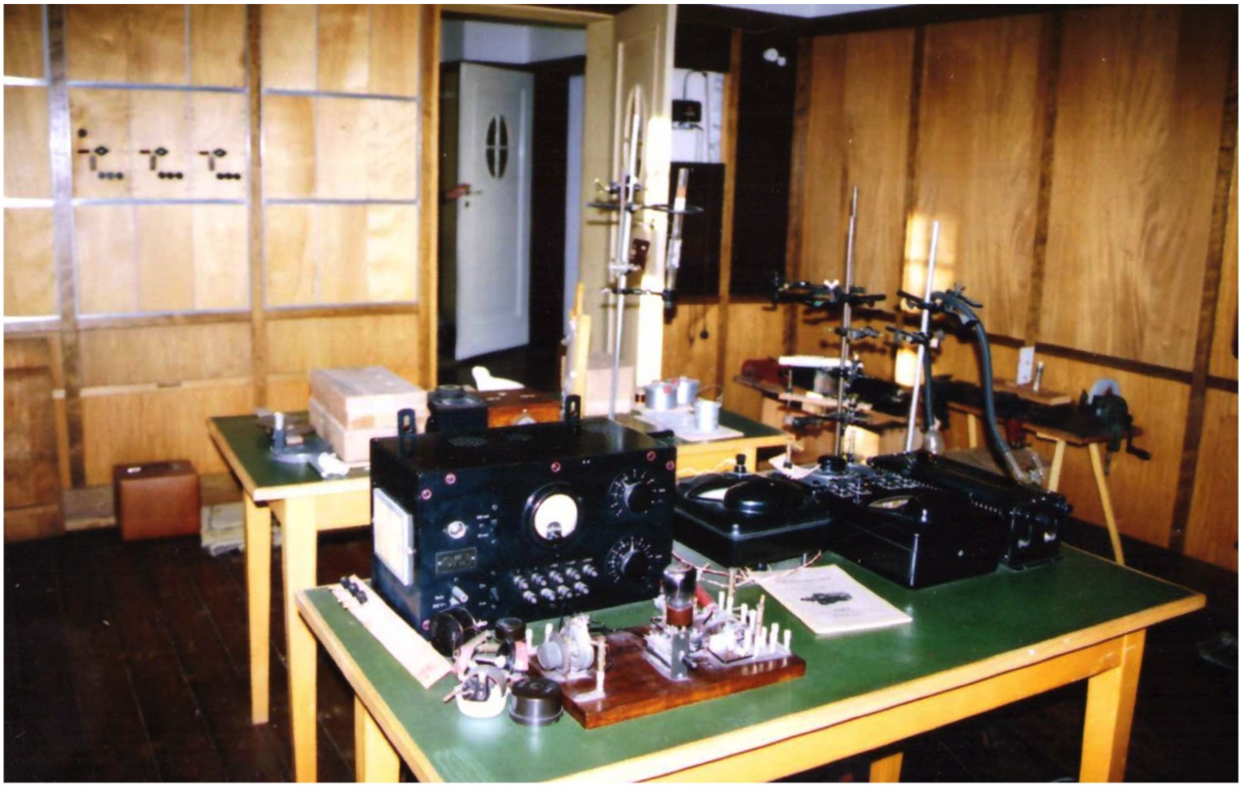


Figure B.39: In 1942, Erich Habann filed a detailed patent application on point-contact transistors, their fabrication, and use.



Hessenwinkel laboratory of Erich Habann (1892–1968), who filed a very detailed patent application on point-contact transistors, their fabrication, and use (1942)

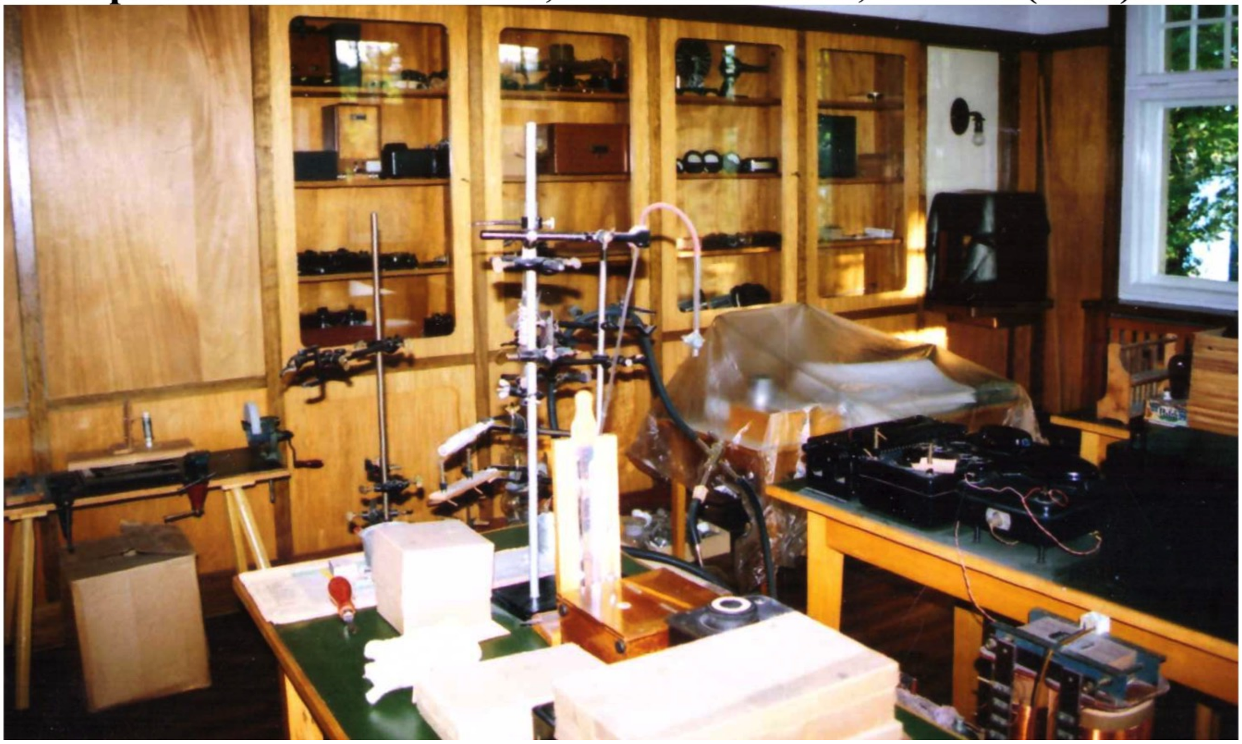


Figure B.40: The Hessenwinkel laboratory of Erich Habann, who filed a very detailed patent application on point-contact transistors, their fabrication, and use in 1942 [courtesy of Günter Nagel].

[**6. Walter Schottky (Swiss/German, 1886–1976)** conducted detailed analyses of semiconductor properties necessary for transistors during World War II [Handel 1999]. See for example:

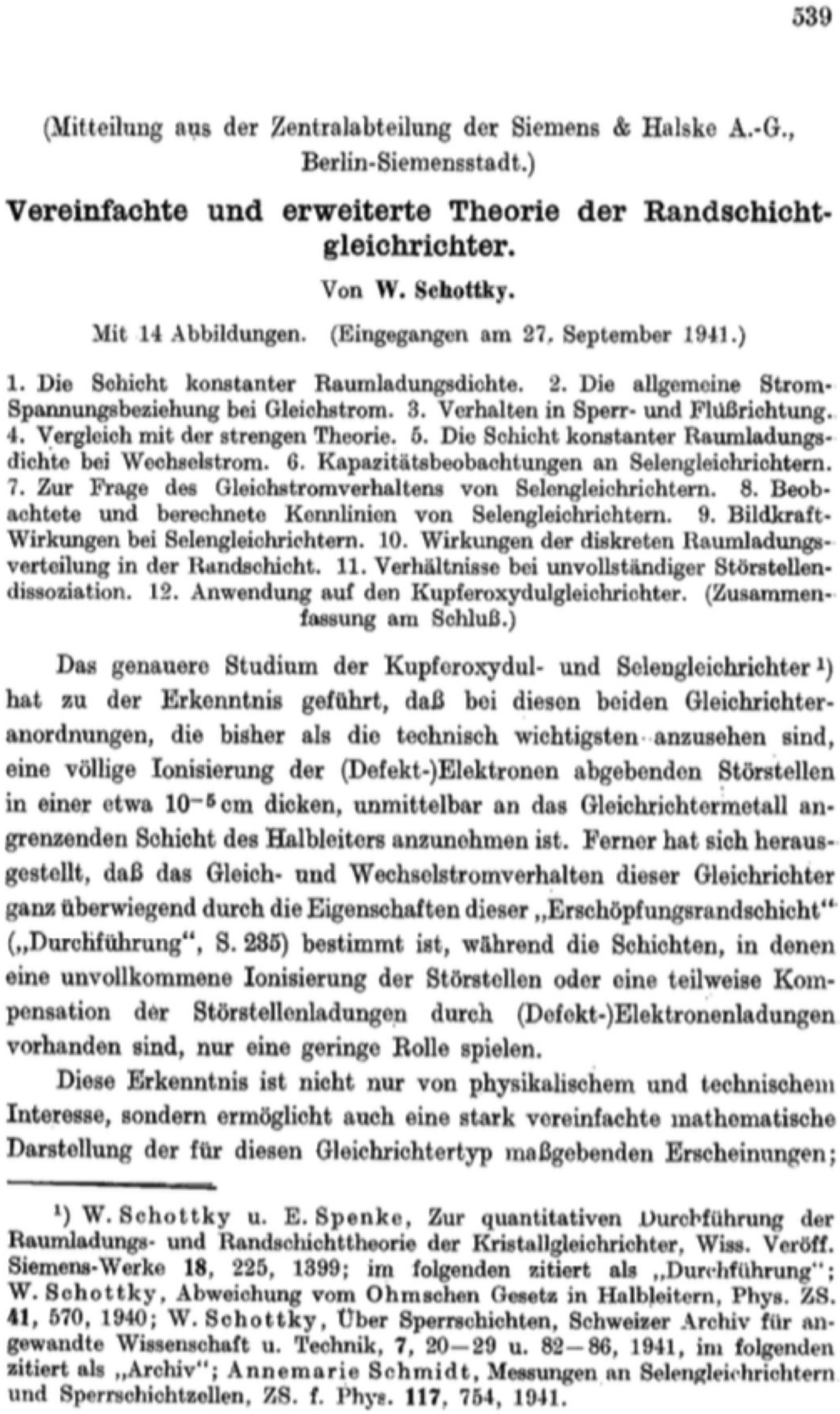
> Walter Schottky. 1942. Vereinfachte und erweiterte Theorie der Randschichtgleichrichter. [Simplified and Extended Theory of Boundary Layer Rectifiers.] *Zeitschrift für Physik* 118:539–592. (p. 2701)

> Walter Schottky. Filed in 1948 but based on wartime work. German patent DE 841,174. Halbleiteranordnung. [Semiconductor Device.] (pp. 2702–2707)

All of Schottky's research papers were seized by the United States in 1945 and never returned to him or publicly disclosed:

> NARA RG 40, Entry UD-75, Box 24, Folder Selenium Rectifier Machinery. (pp. 2708–2709)

Did Schottky's work lead to functional transistors in wartime Germany and/or the postwar United States? Historians should carry out much more research on this topic.]



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(Mitteilung aus der Zentralabteilung der Siemens & Halske A.-G., Berlin-Siemensstadt.)

Vereinfachte und erweiterte Theorie der Randschichtgleichrichter.

Von **W. Schottky.**

Mit 14 Abbildungen. (Eingegangen am 27. September 1941.)

1. Die Schicht konstanter Raumladungsdichte. 2. Die allgemeine Strom-Spannungsbeziehung bei Gleichstrom. 3. Verhalten in Sperr- und Flußrichtung. 4. Vergleich mit der strengen Theorie. 5. Die Schicht konstanter Raumladungsdichte bei Wechselstrom. 6. Kapazitätsbeobachtungen an Selengleichrichtern. 7. Zur Frage des Gleichstromverhaltens von Selengleichrichtern. 8. Beobachtete und berechnete Kennlinien von Selengleichrichtern. 9. Bildkraft-Wirkungen bei Selengleichrichtern. 10. Wirkungen der diskreten Raumladungsverteilung in der Randschicht. 11. Verhältnisse bei unvollständiger Störstellendissoziation. 12. Anwendung auf den Kupferoxydulgleichrichter. (Zusammenfassung am Schluß.)

Das genauere Studium der Kupferoxydul- und Selengleichrichter 1) hat zu der Erkenntnis geführt, daß bei diesen beiden Gleichrichteranordnungen, die bisher als die technisch wichtigsten anzusehen sind, eine völlige Ionisierung der (Defekt-)Elektronen abgebenden Störstellen in einer etwa 10^{-5} cm dicken, unmittelbar an das Gleichrichtermetall angrenzenden Schicht des Halbleiters anzunehmen ist. Ferner hat sich herausgestellt, daß das Gleich- und Wechselstromverhalten dieser Gleichrichter ganz überwiegend durch die Eigenschaften dieser „Erschöpfungsrandschicht" („Durchführung", S. 235) bestimmt ist, während die Schichten, in denen eine unvollkommene Ionisierung der Störstellen oder eine teilweise Kompensation der Störstellenladungen durch (Defekt-)Elektronenladungen vorhanden sind, nur eine geringe Rolle spielen.

Diese Erkenntnis ist nicht nur von physikalischem und technischem Interesse, sondern ermöglicht auch eine stark vereinfachte mathematische Darstellung der für diesen Gleichrichtertyp maßgebenden Erscheinungen;

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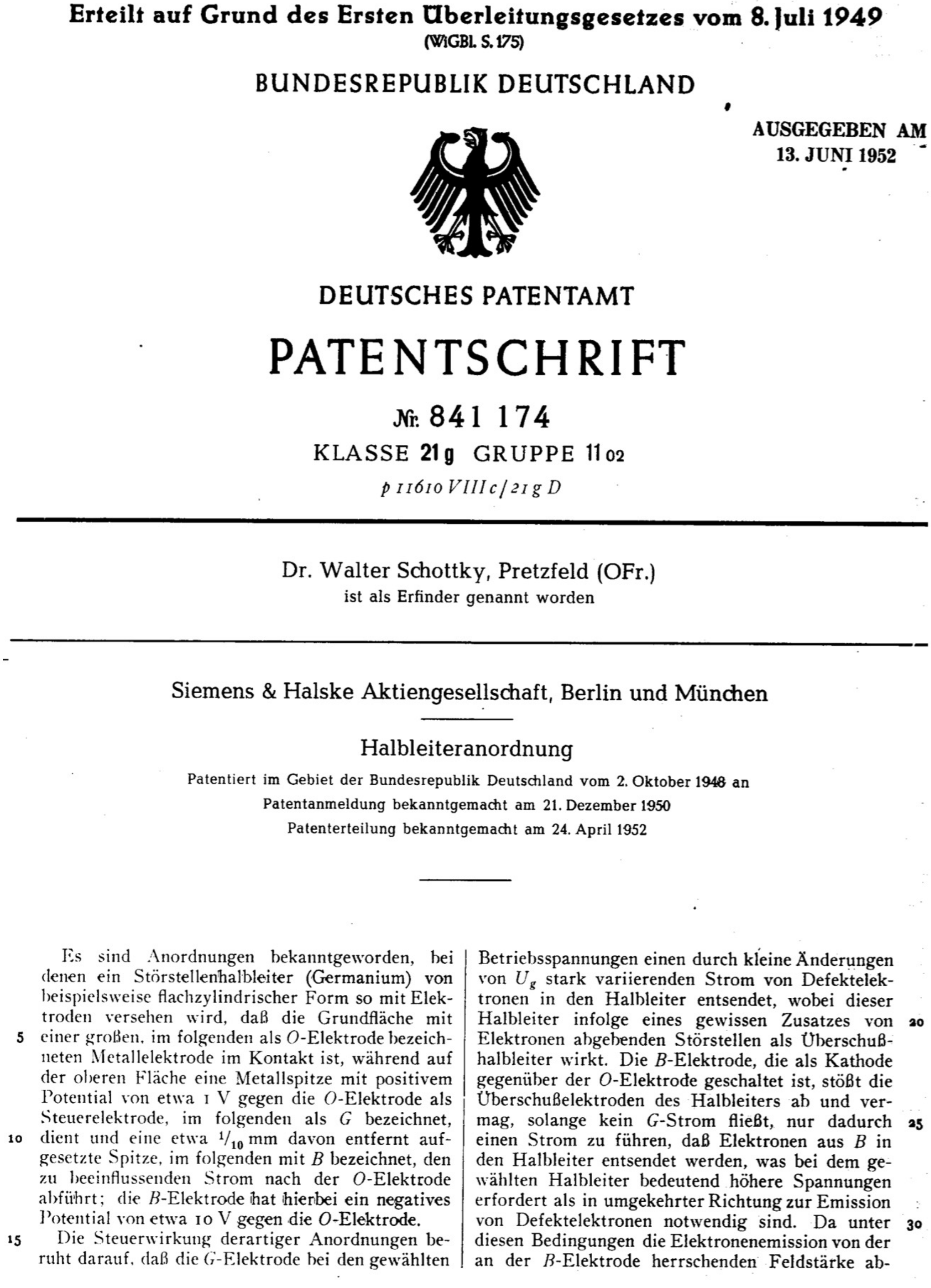
1) W. Schottky u. E. Spenke, Zur quantitativen Durchführung der Raumladungs- und Randschichttheorie der Kristallgleichrichter, Wiss. Veröff. Siemens-Werke **18**, 225, 1399; im folgenden zitiert als „Durchführung"; W. Schottky, Abweichung vom Ohmschen Gesetz in Halbleitern, Phys. ZS. **41**, 570, 1940; W. Schottky, Über Sperrschichten, Schweizer Archiv für angewandte Wissenschaft u. Technik, **7**, 20—29 u. 82—86, 1941, im folgenden zitiert als „Archiv"; Annemarie Schmidt, Messungen an Selengleichrichtern und Sperrschichtzellen, ZS. f. Phys. **117**, 754, 1941.

Figure B.41: Walter Schottky published detailed analyses of semiconductor properties necessary for transistors in 1942 [*Zeitschrift für Physik* (1942) 118:539–592].



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
13. JUNI 1952

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 841 174

KLASSE 21g GRUPPE 11 02

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Dr. Walter Schottky, Pretzfeld (OFr.)
ist als Erfinder genannt worden

Siemens & Halske Aktiengesellschaft, Berlin und München

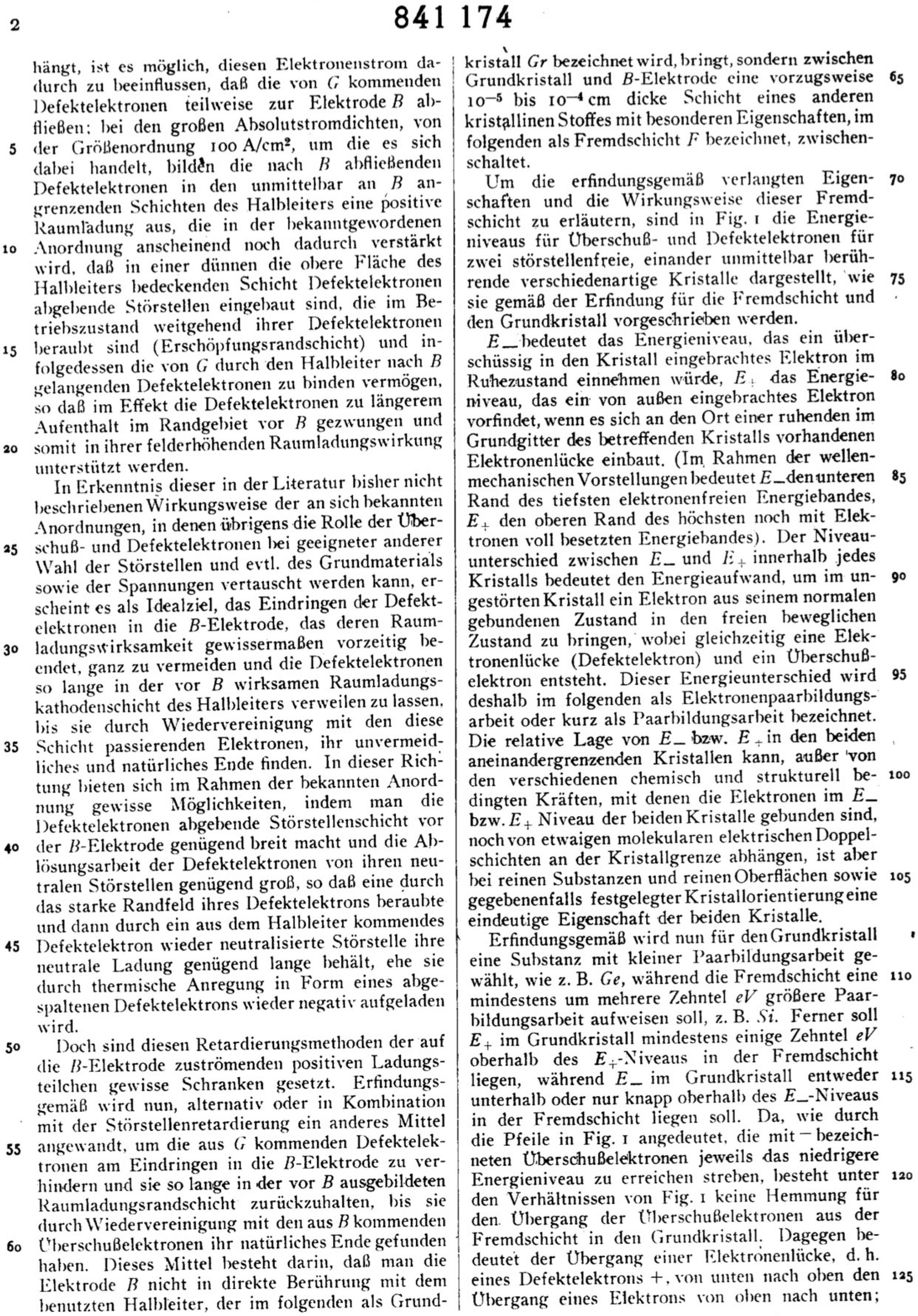
Halbleiteranordnung

Patentiert im Gebiet der Bundesrepublik Deutschland vom 2. Oktober 1948 an
Patentanmeldung bekanntgemacht am 21. Dezember 1950
Patenterteilung bekanntgemacht am 24. April 1952

Es sind Anordnungen bekanntgeworden, bei denen ein Störstellenhalbleiter (Germanium) von beispielsweise flachzylindrischer Form so mit Elektroden versehen wird, daß die Grundfläche mit einer großen, im folgenden als *O*-Elektrode bezeichneten Metallelektrode im Kontakt ist, während auf der oberen Fläche eine Metallspitze mit positivem Potential von etwa 1 V gegen die *O*-Elektrode als Steuerelektrode, im folgenden als *G* bezeichnet, dient und eine etwa $^1/_{10}$ mm davon entfernt aufgesetzte Spitze, im folgenden mit *B* bezeichnet, den zu beeinflussenden Strom nach der *O*-Elektrode abführt; die *B*-Elektrode hat hierbei ein negatives Potential von etwa 10 V gegen die *O*-Elektrode.

Die Steuerwirkung derartiger Anordnungen beruht darauf, daß die *G*-Elektrode bei den gewählten Betriebsspannungen einen durch kleine Änderungen von U_g stark variierenden Strom von Defektelektronen in den Halbleiter entsendet, wobei dieser Halbleiter infolge eines gewissen Zusatzes von Elektronen abgebenden Störstellen als Überschußhalbleiter wirkt. Die *B*-Elektrode, die als Kathode gegenüber der *O*-Elektrode geschaltet ist, stößt die Überschußelektroden des Halbleiters ab und vermag, solange kein *G*-Strom fließt, nur dadurch einen Strom zu führen, daß Elektronen aus *B* in den Halbleiter entsendet werden, was bei dem gewählten Halbleiter bedeutend höhere Spannungen erfordert als in umgekehrter Richtung zur Emission von Defektelektronen notwendig sind. Da unter diesen Bedingungen die Elektronenemission von der an der *B*-Elektrode herrschenden Feldstärke ab-

Figure B.42: Walter Schottky published detailed analyses of semiconductor properties necessary for transistors in 1942.



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hängt, ist es möglich, diesen Elektronenstrom dadurch zu beeinflussen, daß die von *G* kommenden Defektelektronen teilweise zur Elektrode *B* abfließen; bei den großen Absolutstromdichten, von der Größenordnung 100 A/cm², um die es sich dabei handelt, bilden die nach *B* abfließenden Defektelektronen in den unmittelbar an *B* angrenzenden Schichten des Halbleiters eine positive Raumladung aus, die in der bekanntgewordenen Anordnung anscheinend noch dadurch verstärkt wird, daß in einer dünnen die obere Fläche des Halbleiters bedeckenden Schicht Defektelektronen abgebende Störstellen eingebaut sind, die im Betriebszustand weitgehend ihrer Defektelektronen beraubt sind (Erschöpfungsrandschicht) und infolgedessen die von *G* durch den Halbleiter nach *B* gelangenden Defektelektronen zu binden vermögen, so daß im Effekt die Defektelektronen zu längerem Aufenthalt im Randgebiet vor *B* gezwungen und somit in ihrer felderhöhenden Raumladungswirkung unterstützt werden.

In Erkenntnis dieser in der Literatur bisher nicht beschriebenen Wirkungsweise der an sich bekannten Anordnungen, in denen übrigens die Rolle der Überschuß- und Defektelektronen bei geeigneter anderer Wahl der Störstellen und evtl. des Grundmaterials sowie der Spannungen vertauscht werden kann, erscheint es als Idealziel, das Eindringen der Defektelektronen in die *B*-Elektrode, das deren Raumladungswirksamkeit gewissermaßen vorzeitig beendet, ganz zu vermeiden und die Defektelektronen so lange in der vor *B* wirksamen Raumladungskathodenschicht des Halbleiters verweilen zu lassen, bis sie durch Wiedervereinigung mit den diese Schicht passierenden Elektronen, ihr unvermeidliches und natürliches Ende finden. In dieser Richtung bieten sich im Rahmen der bekannten Anordnung gewisse Möglichkeiten, indem man die Defektelektronen abgebende Störstellenschicht vor der *B*-Elektrode genügend breit macht und die Ablösungsarbeit der Defektelektronen von ihren neutralen Störstellen genügend groß, so daß eine durch das starke Randfeld ihres Defektelektrons beraubte und dann durch ein aus dem Halbleiter kommendes Defektelektron wieder neutralisierte Störstelle ihre neutrale Ladung genügend lange behält, ehe sie durch thermische Anregung in Form eines abgespaltenen Defektelektrons wieder negativ aufgeladen wird.

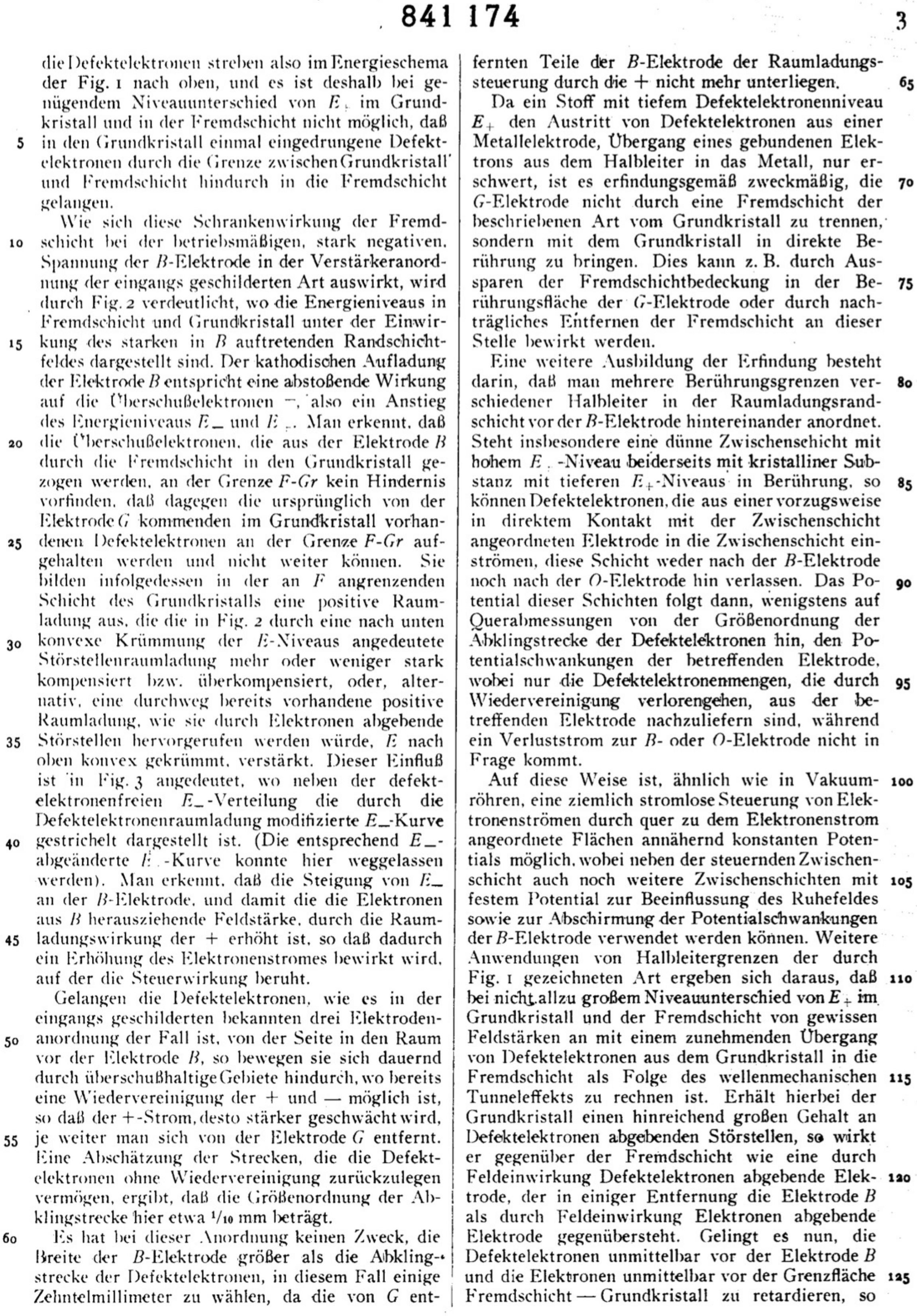
Doch sind diesen Retardierungsmethoden der auf die *B*-Elektrode zuströmenden positiven Ladungsteilchen gewisse Schranken gesetzt. Erfindungsgemäß wird nun, alternativ oder in Kombination mit der Störstellenretardierung ein anderes Mittel angewandt, um die aus *G* kommenden Defektelektronen am Eindringen in die *B*-Elektrode zu verhindern und sie so lange in der vor *B* ausgebildeten Raumladungsrandschicht zurückzuhalten, bis sie durch Wiedervereinigung mit den aus *B* kommenden Überschußelektronen ihr natürliches Ende gefunden haben. Dieses Mittel besteht darin, daß man die Elektrode *B* nicht in direkte Berührung mit dem benutzten Halbleiter, der im folgenden als Grundkristall *Gr* bezeichnet wird, bringt, sondern zwischen Grundkristall und *B*-Elektrode eine vorzugsweise 10^{-5} bis 10^{-4} cm dicke Schicht eines anderen kristallinen Stoffes mit besonderen Eigenschaften, im folgenden als Fremdschicht *F* bezeichnet, zwischenschaltet.

Um die erfindungsgemäß verlangten Eigenschaften und die Wirkungsweise dieser Fremdschicht zu erläutern, sind in Fig. 1 die Energieniveaus für Überschuß- und Defektelektronen für zwei störstellenfreie, einander unmittelbar berührende verschiedenartige Kristalle dargestellt, wie sie gemäß der Erfindung für die Fremdschicht und den Grundkristall vorgeschrieben werden.

E_- bedeutet das Energieniveau, das ein überschüssig in den Kristall eingebrachtes Elektron im Ruhezustand einnehmen würde, E_+ das Energieniveau, das ein von außen eingebrachtes Elektron vorfindet, wenn es sich an den Ort einer ruhenden im Grundgitter des betreffenden Kristalls vorhandenen Elektronenlücke einbaut. (Im Rahmen der wellenmechanischen Vorstellungen bedeutet E_- den unteren Rand des tiefsten elektronenfreien Energiebandes, E_+ den oberen Rand des höchsten noch mit Elektronen voll besetzten Energiebandes). Der Niveauunterschied zwischen E_- und E_+ innerhalb jedes Kristalls bedeutet den Energieaufwand, um im ungestörten Kristall ein Elektron aus seinem normalen gebundenen Zustand in den freien beweglichen Zustand zu bringen, wobei gleichzeitig eine Elektronenlücke (Defektelektron) und ein Überschußelektron entsteht. Dieser Energieunterschied wird deshalb im folgenden als Elektronenpaarbildungsarbeit oder kurz als Paarbildungsarbeit bezeichnet. Die relative Lage von E_- bzw. E_+ in den beiden aneinandergrenzenden Kristallen kann, außer von den verschiedenen chemisch und strukturell bedingten Kräften, mit denen die Elektronen im E_- bzw. E_+ Niveau der beiden Kristalle gebunden sind, noch von etwaigen molekularen elektrischen Doppelschichten an der Kristallgrenze abhängen, ist aber bei reinen Substanzen und reinen Oberflächen sowie gegebenenfalls festgelegter Kristallorientierung eine eindeutige Eigenschaft der beiden Kristalle.

Erfindungsgemäß wird nun für den Grundkristall eine Substanz mit kleiner Paarbildungsarbeit gewählt, wie z. B. *Ge*, während die Fremdschicht eine mindestens um mehrere Zehntel *eV* größere Paarbildungsarbeit aufweisen soll, z. B. *Si*. Ferner soll E_+ im Grundkristall mindestens einige Zehntel *eV* oberhalb des E_+-Niveaus in der Fremdschicht liegen, während E_- im Grundkristall entweder unterhalb oder nur knapp oberhalb des E_--Niveaus in der Fremdschicht liegen soll. Da, wie durch die Pfeile in Fig. 1 angedeutet, die mit $-$ bezeichneten Überschußelektronen jeweils das niedrigere Energieniveau zu erreichen streben, besteht unter den Verhältnissen von Fig. 1 keine Hemmung für den Übergang der Überschußelektronen aus der Fremdschicht in den Grundkristall. Dagegen bedeutet der Übergang einer Elektronenlücke, d. h. eines Defektelektrons +, von unten nach oben den Übergang eines Elektrons von oben nach unten;

Figure B.43: Walter Schottky published detailed analyses of semiconductor properties necessary for transistors in 1942.



die Defektelektronen streben also im Energieschema der Fig. 1 nach oben, und es ist deshalb bei genügendem Niveauunterschied von E_+ im Grundkristall und in der Fremdschicht nicht möglich, daß in den Grundkristall einmal eingedrungene Defektelektronen durch die Grenze zwischen Grundkristall und Fremdschicht hindurch in die Fremdschicht gelangen.

Wie sich diese Schrankenwirkung der Fremdschicht bei der betriebsmäßigen, stark negativen. Spannung der *B*-Elektrode in der Verstärkeranordnung der eingangs geschilderten Art auswirkt, wird durch Fig. 2 verdeutlicht, wo die Energieniveaus in Fremdschicht und Grundkristall unter der Einwirkung des starken in *B* auftretenden Randschichtfeldes dargestellt sind. Der kathodischen Aufladung der Elektrode *B* entspricht eine abstoßende Wirkung auf die Überschußelektronen −, also ein Anstieg des Energieniveaus E_- und E_+. Man erkennt, daß die Überschußelektronen, die aus der Elektrode *B* durch die Fremdschicht in den Grundkristall gezogen werden, an der Grenze *F-Gr* kein Hindernis vorfinden, daß dagegen die ursprünglich von der Elektrode *G* kommenden im Grundkristall vorhandenen Defektelektronen an der Grenze *F-Gr* aufgehalten werden und nicht weiter können. Sie bilden infolgedessen in der an *F* angrenzenden Schicht des Grundkristalls eine positive Raumladung aus, die die in Fig. 2 durch eine nach unten konvexe Krümmung der *E*-Niveaus angedeutete Störstellenraumladung mehr oder weniger stark kompensiert bzw. überkompensiert, oder, alternativ, eine durchweg bereits vorhandene positive Raumladung, wie sie durch Elektronen abgebende Störstellen hervorgerufen werden würde, *E* nach oben konvex gekrümmt, verstärkt. Dieser Einfluß ist in Fig. 3 angedeutet, wo neben der defektelektronenfreien E_--Verteilung die durch die Defektelektronenraumladung modifizierte E_--Kurve gestrichelt dargestellt ist. (Die entsprechend E_--abgeänderte E_+-Kurve konnte hier weggelassen werden). Man erkennt, daß die Steigung von E_- an der *B*-Elektrode, und damit die die Elektronen aus *B* herausziehende Feldstärke, durch die Raumladungswirkung der + erhöht ist, so daß dadurch ein Erhöhung des Elektronenstromes bewirkt wird, auf der die Steuerwirkung beruht.

Gelangen die Defektelektronen, wie es in der eingangs geschilderten bekannten drei Elektrodenanordnung der Fall ist, von der Seite in den Raum vor der Elektrode *B*, so bewegen sie sich dauernd durch überschußhaltige Gebiete hindurch, wo bereits eine Wiedervereinigung der + und — möglich ist, so daß der +-Strom, desto stärker geschwächt wird, je weiter man sich von der Elektrode *G* entfernt. Eine Abschätzung der Strecken, die die Defektelektronen ohne Wiedervereinigung zurückzulegen vermögen, ergibt, daß die Größenordnung der Abklingstrecke hier etwa 1/10 mm beträgt.

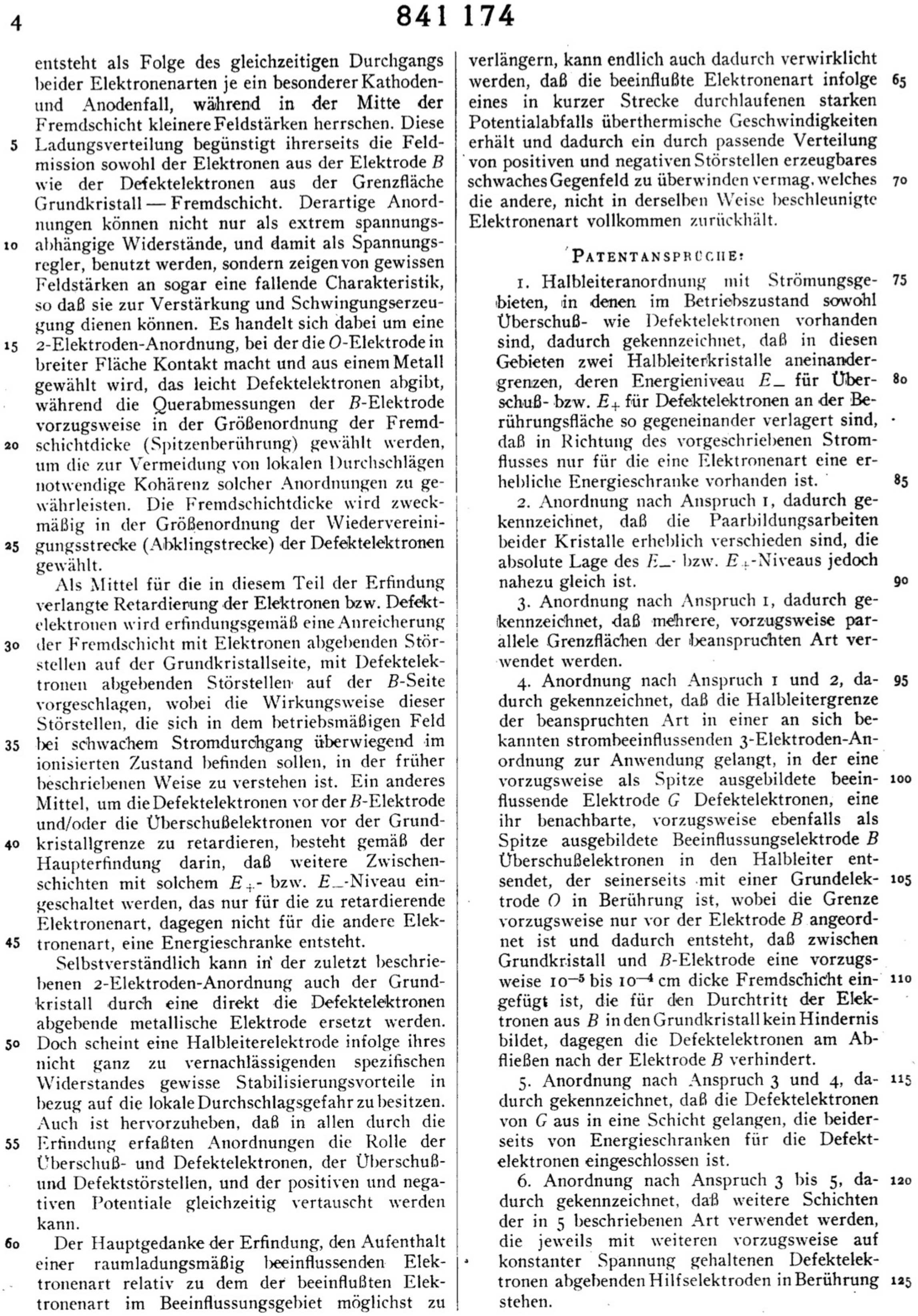
Es hat bei dieser Anordnung keinen Zweck, die Breite der *B*-Elektrode größer als die Abklingstrecke der Defektelektronen, in diesem Fall einige Zehntelmillimeter zu wählen, da die von *G* entfernten Teile der *B*-Elektrode der Raumladungssteuerung durch die + nicht mehr unterliegen.

Da ein Stoff mit tiefem Defektelektronenniveau E_+ den Austritt von Defektelektronen aus einer Metallelektrode, Übergang eines gebundenen Elektrons aus dem Halbleiter in das Metall, nur erschwert, ist es erfindungsgemäß zweckmäßig, die *G*-Elektrode nicht durch eine Fremdschicht der beschriebenen Art vom Grundkristall zu trennen, sondern mit dem Grundkristall in direkte Berührung zu bringen. Dies kann z. B. durch Aussparen der Fremdschichtbedeckung in der Berührungsfläche der *G*-Elektrode oder durch nachträgliches Entfernen der Fremdschicht an dieser Stelle bewirkt werden.

Eine weitere Ausbildung der Erfindung besteht darin, daß man mehrere Berührungsgrenzen verschiedener Halbleiter in der Raumladungsrandschicht vor der *B*-Elektrode hintereinander anordnet. Steht insbesondere eine dünne Zwischenschicht mit hohem E_+-Niveau beiderseits mit kristalliner Substanz mit tieferen E_+-Niveaus in Berührung, so können Defektelektronen, die aus einer vorzugsweise in direktem Kontakt mit der Zwischenschicht angeordneten Elektrode in die Zwischenschicht einströmen, diese Schicht weder nach der *B*-Elektrode noch nach der *O*-Elektrode hin verlassen. Das Potential dieser Schichten folgt dann, wenigstens auf Querabmessungen von der Größenordnung der Abklingstrecke der Defektelektronen hin, den Potentialschwankungen der betreffenden Elektrode, wobei nur die Defektelektronenmengen, die durch Wiedervereinigung verlorengehen, aus der betreffenden Elektrode nachzuliefern sind, während ein Verluststrom zur *B*- oder *O*-Elektrode nicht in Frage kommt.

Auf diese Weise ist, ähnlich wie in Vakuumröhren, eine ziemlich stromlose Steuerung von Elektronenströmen durch quer zu dem Elektronenstrom angeordnete Flächen annähernd konstanten Potentials möglich, wobei neben der steuernden Zwischenschicht auch noch weitere Zwischenschichten mit festem Potential zur Beeinflussung des Ruhefeldes sowie zur Abschirmung der Potentialschwankungen der *B*-Elektrode verwendet werden können. Weitere Anwendungen von Halbleitergrenzen der durch Fig. 1 gezeichneten Art ergeben sich daraus, daß bei nicht allzu großem Niveauunterschied von E_+ im Grundkristall und der Fremdschicht von gewissen Feldstärken an mit einem zunehmenden Übergang von Defektelektronen aus dem Grundkristall in die Fremdschicht als Folge des wellenmechanischen Tunneleffekts zu rechnen ist. Erhält hierbei der Grundkristall einen hinreichend großen Gehalt an Defektelektronen abgebenden Störstellen, so wirkt er gegenüber der Fremdschicht wie eine durch Feldeinwirkung Defektelektronen abgebende Elektrode, der in einiger Entfernung die Elektrode *B* als durch Feldeinwirkung Elektronen abgebende Elektrode gegenübersteht. Gelingt es nun, die Defektelektronen unmittelbar vor der Elektrode *B* und die Elektronen unmittelbar vor der Grenzfläche Fremdschicht — Grundkristall zu retardieren, so

Figure B.44: Walter Schottky published detailed analyses of semiconductor properties necessary for transistors in 1942.



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entsteht als Folge des gleichzeitigen Durchgangs beider Elektronenarten je ein besonderer Kathoden- und Anodenfall, während in der Mitte der Fremdschicht kleinere Feldstärken herrschen. Diese Ladungsverteilung begünstigt ihrerseits die Feldmission sowohl der Elektronen aus der Elektrode *B* wie der Defektelektronen aus der Grenzfläche Grundkristall — Fremdschicht. Derartige Anordnungen können nicht nur als extrem spannungsabhängige Widerstände, und damit als Spannungsregler, benutzt werden, sondern zeigen von gewissen Feldstärken an sogar eine fallende Charakteristik, so daß sie zur Verstärkung und Schwingungserzeugung dienen können. Es handelt sich dabei um eine 2-Elektroden-Anordnung, bei der die *O*-Elektrode in breiter Fläche Kontakt macht und aus einem Metall gewählt wird, das leicht Defektelektronen abgibt, während die Querabmessungen der *B*-Elektrode vorzugsweise in der Größenordnung der Fremdschichtdicke (Spitzenberührung) gewählt werden, um die zur Vermeidung von lokalen Durchschlägen notwendige Kohärenz solcher Anordnungen zu gewährleisten. Die Fremdschichtdicke wird zweckmäßig in der Größenordnung der Wiedervereinigungsstrecke (Abklingstrecke) der Defektelektronen gewählt.

Als Mittel für die in diesem Teil der Erfindung verlangte Retardierung der Elektronen bzw. Defektelektronen wird erfindungsgemäß eine Anreicherung der Fremdschicht mit Elektronen abgebenden Störstellen auf der Grundkristallseite, mit Defektelektronen abgebenden Störstellen auf der *B*-Seite vorgeschlagen, wobei die Wirkungsweise dieser Störstellen, die sich in dem betriebsmäßigen Feld bei schwachem Stromdurchgang überwiegend im ionisierten Zustand befinden sollen, in der früher beschriebenen Weise zu verstehen ist. Ein anderes Mittel, um die Defektelektronen vor der *B*-Elektrode und/oder die Überschußelektronen vor der Grundkristallgrenze zu retardieren, besteht gemäß der Haupterfindung darin, daß weitere Zwischenschichten mit solchem E_+- bzw. E_--Niveau eingeschaltet werden, das nur für die zu retardierende Elektronenart, dagegen nicht für die andere Elektronenart, eine Energieschranke entsteht.

Selbstverständlich kann in der zuletzt beschriebenen 2-Elektroden-Anordnung auch der Grundkristall durch eine direkt die Defektelektronen abgebende metallische Elektrode ersetzt werden. Doch scheint eine Halbleiterelektrode infolge ihres nicht ganz zu vernachlässigenden spezifischen Widerstandes gewisse Stabilisierungsvorteile in bezug auf die lokale Durchschlagsgefahr zu besitzen. Auch ist hervorzuheben, daß in allen durch die Erfindung erfaßten Anordnungen die Rolle der Überschuß- und Defektelektronen, der Überschuß- und Defektstörstellen, und der positiven und negativen Potentiale gleichzeitig vertauscht werden kann.

Der Hauptgedanke der Erfindung, den Aufenthalt einer raumladungsmäßig beeinflussenden Elektronenart relativ zu dem der beeinflußten Elektronenart im Beeinflussungsgebiet möglichst zu verlängern, kann endlich auch dadurch verwirklicht werden, daß die beeinflußte Elektronenart infolge eines in kurzer Strecke durchlaufenen starken Potentialabfalls überthermische Geschwindigkeiten erhält und dadurch ein durch passende Verteilung von positiven und negativen Störstellen erzeugbares schwaches Gegenfeld zu überwinden vermag, welches die andere, nicht in derselben Weise beschleunigte Elektronenart vollkommen zurückhält.

PATENTANSPRÜCHE:

1. Halbleiteranordnung mit Strömungsgebieten, in denen im Betriebszustand sowohl Überschuß- wie Defektelektronen vorhanden sind, dadurch gekennzeichnet, daß in diesen Gebieten zwei Halbleiterkristalle aneinandergrenzen, deren Energieniveau E_- für Überschuß- bzw. E_+ für Defektelektronen an der Berührungsfläche so gegeneinander verlagert sind, daß in Richtung des vorgeschriebenen Stromflusses nur für die eine Elektronenart eine erhebliche Energieschranke vorhanden ist.

2. Anordnung nach Anspruch 1, dadurch gekennzeichnet, daß die Paarbildungsarbeiten beider Kristalle erheblich verschieden sind, die absolute Lage des E_-- bzw. E_+-Niveaus jedoch nahezu gleich ist.

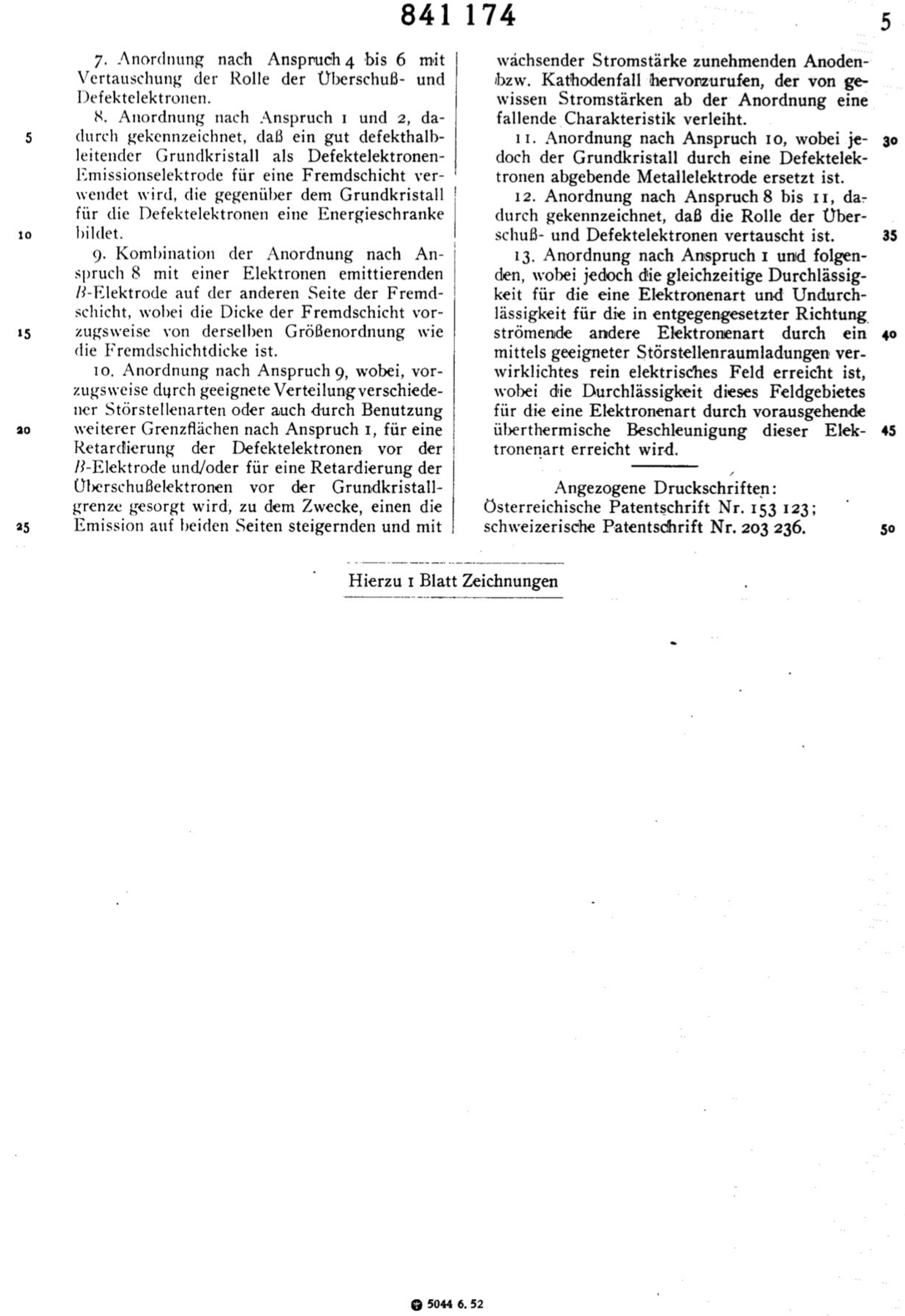
3. Anordnung nach Anspruch 1, dadurch gekennzeichnet, daß mehrere, vorzugsweise parallele Grenzflächen der beanspruchten Art verwendet werden.

4. Anordnung nach Anspruch 1 und 2, dadurch gekennzeichnet, daß die Halbleitergrenze der beanspruchten Art in einer an sich bekannten strombeeinflussenden 3-Elektroden-Anordnung zur Anwendung gelangt, in der eine vorzugsweise als Spitze ausgebildete beeinflussende Elektrode *G* Defektelektronen, eine ihr benachbarte, vorzugsweise ebenfalls als Spitze ausgebildete Beeinflussungselektrode *B* Überschußelektronen in den Halbleiter entsendet, der seinerseits mit einer Grundelektrode *O* in Berührung ist, wobei die Grenze vorzugsweise nur vor der Elektrode *B* angeordnet ist und dadurch entsteht, daß zwischen Grundkristall und *B*-Elektrode eine vorzugsweise 10^{-5} bis 10^{-4} cm dicke Fremdschicht eingefügt ist, die für den Durchtritt der Elektronen aus *B* in den Grundkristall kein Hindernis bildet, dagegen die Defektelektronen am Abfließen nach der Elektrode *B* verhindert.

5. Anordnung nach Anspruch 3 und 4, dadurch gekennzeichnet, daß die Defektelektronen von *G* aus in eine Schicht gelangen, die beiderseits von Energieschranken für die Defektelektronen eingeschlossen ist.

6. Anordnung nach Anspruch 3 bis 5, dadurch gekennzeichnet, daß weitere Schichten der in 5 beschriebenen Art verwendet werden, die jeweils mit weiteren vorzugsweise auf konstanter Spannung gehaltenen Defektelektronen abgebenden Hilfselektroden in Berührung stehen.

Figure B.45: Walter Schottky published detailed analyses of semiconductor properties necessary for transistors in 1942.



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7. Anordnung nach Anspruch 4 bis 6 mit Vertauschung der Rolle der Überschuß- und Defektelektronen.

8. Anordnung nach Anspruch 1 und 2, dadurch gekennzeichnet, daß ein gut defekthalbleitender Grundkristall als Defektelektronen-Emissionselektrode für eine Fremdschicht verwendet wird, die gegenüber dem Grundkristall für die Defektelektronen eine Energieschranke bildet.

9. Kombination der Anordnung nach Anspruch 8 mit einer Elektronen emittierenden *B*-Elektrode auf der anderen Seite der Fremdschicht, wobei die Dicke der Fremdschicht vorzugsweise von derselben Größenordnung wie die Fremdschichtdicke ist.

10. Anordnung nach Anspruch 9, wobei, vorzugsweise durch geeignete Verteilung verschiedener Störstellenarten oder auch durch Benutzung weiterer Grenzflächen nach Anspruch 1, für eine Retardierung der Defektelektronen vor der *B*-Elektrode und/oder für eine Retardierung der Überschußelektronen vor der Grundkristallgrenze gesorgt wird, zu dem Zwecke, einen die Emission auf beiden Seiten steigernden und mit wachsender Stromstärke zunehmenden Anoden- bzw. Kathodenfall hervorzurufen, der von gewissen Stromstärken ab der Anordnung eine fallende Charakteristik verleiht.

11. Anordnung nach Anspruch 10, wobei jedoch der Grundkristall durch eine Defektelektronen abgebende Metallelektrode ersetzt ist.

12. Anordnung nach Anspruch 8 bis 11, dadurch gekennzeichnet, daß die Rolle der Überschuß- und Defektelektronen vertauscht ist.

13. Anordnung nach Anspruch 1 und folgenden, wobei jedoch die gleichzeitige Durchlässigkeit für die eine Elektronenart und Undurchlässigkeit für die in entgegengesetzter Richtung strömende andere Elektronenart durch ein mittels geeigneter Störstellenraumladungen verwirklichtes rein elektrisches Feld erreicht ist, wobei die Durchlässigkeit dieses Feldgebietes für die eine Elektronenart durch vorausgehende überthermische Beschleunigung dieser Elektronenart erreicht wird.

Angezogene Druckschriften:
Österreichische Patentschrift Nr. 153 123;
schweizerische Patentschrift Nr. 203 236.

Hierzu 1 Blatt Zeichnungen

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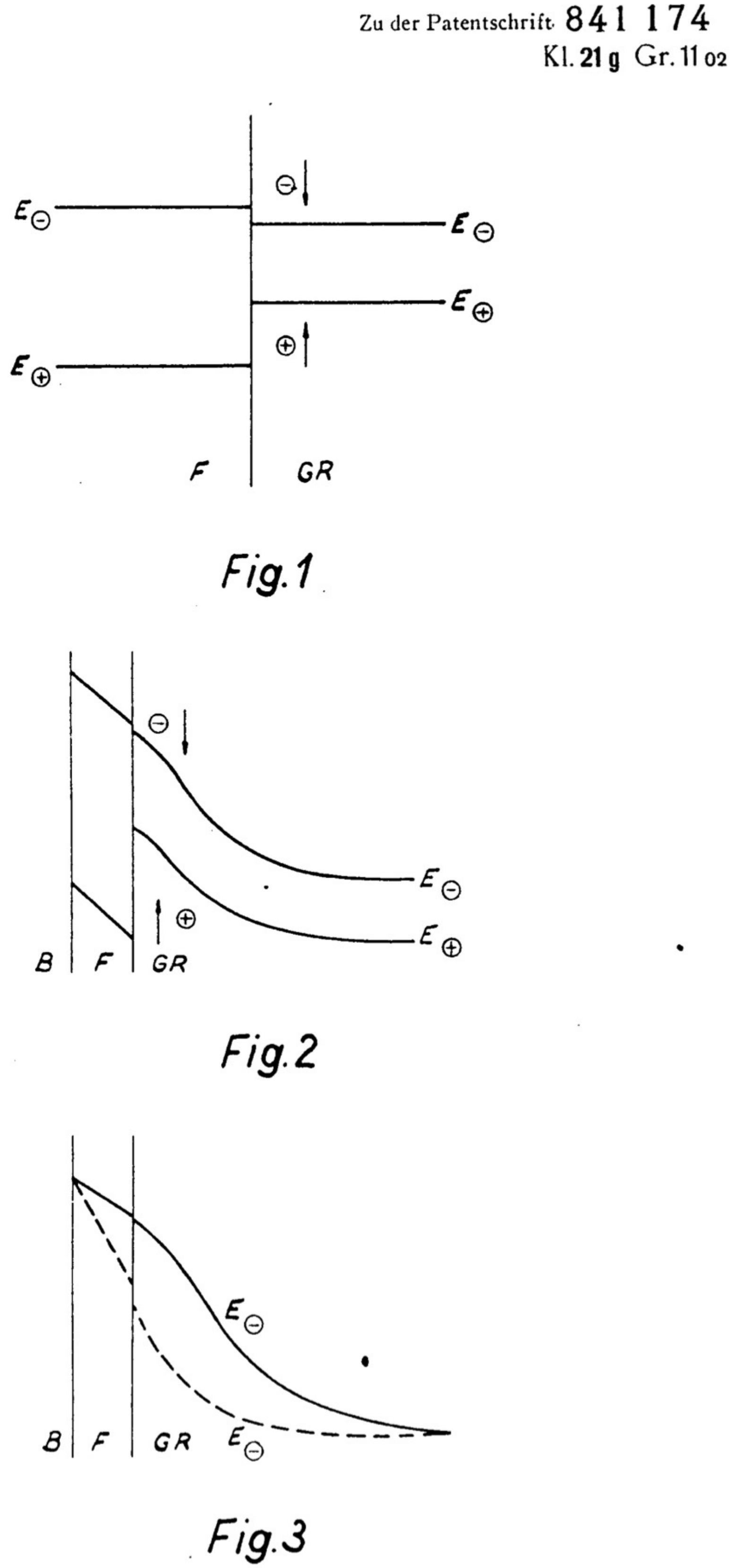
Figure B.46: Walter Schottky published detailed analyses of semiconductor properties necessary for transistors in 1942.



Zu der Patentschrift 841 174
Kl. 21g Gr. 11 02

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Fig.3

Figure B.47: Walter Schottky published detailed analyses of semiconductor properties necessary for transistors in 1942.

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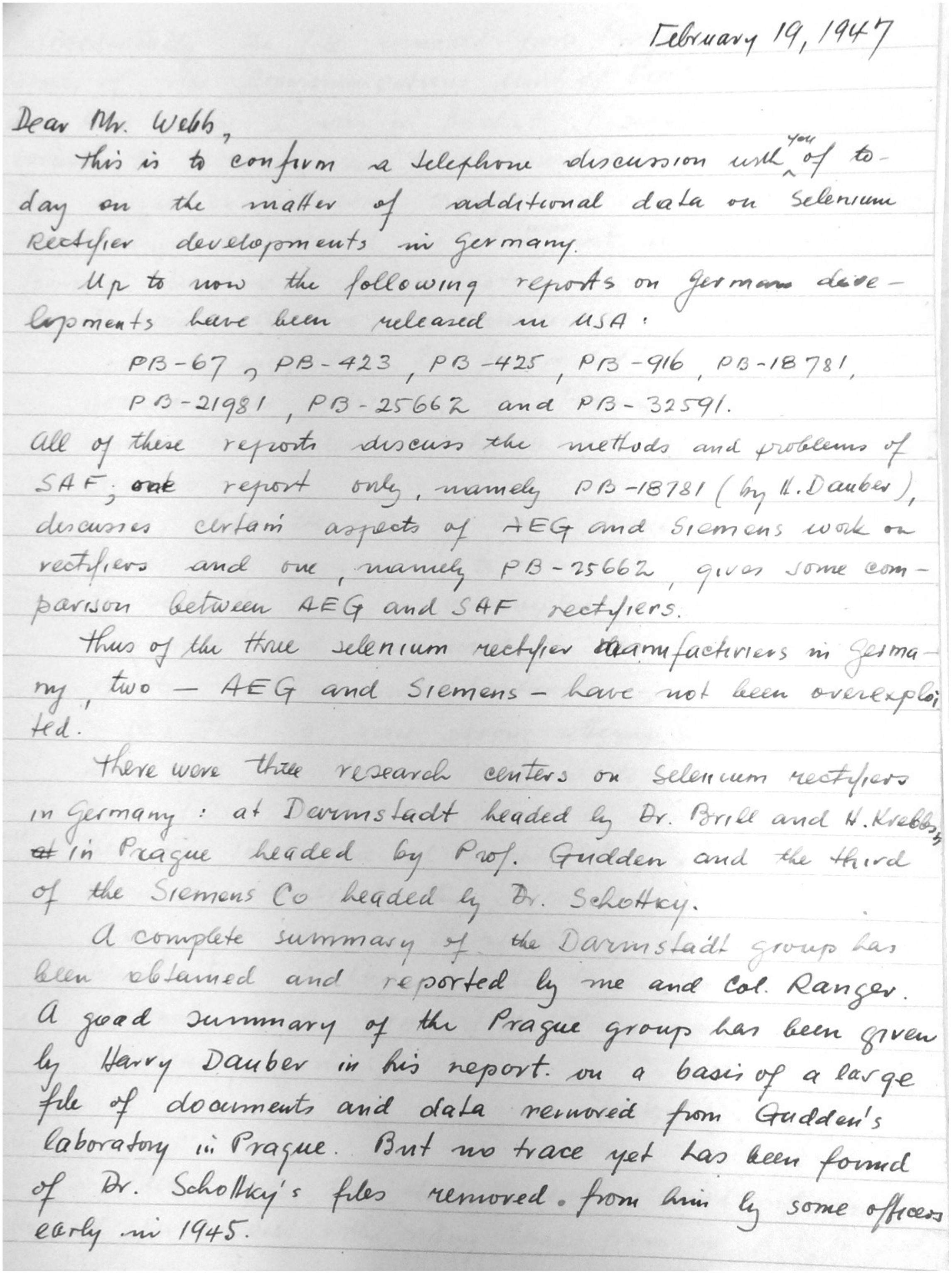
Folder Selenium Rectifier Machinery



February 19, 1947

Dear Mr. Webb,

this is to confirm a telephone discussion with you of today on the matter of additional data on Selenium Rectifier developments in Germany.

Up to now the following reports on German developments have been released in USA:

PB-67, PB-423, PB-425, PB-916, PB-18781,
PB-21981, PB-25662 and PB-32591.

All of these reports discuss the methods and problems of SAF; one report only, namely PB-18781 (by H. Dauber), discusses certain aspects of AEG and Siemens work on rectifiers and one, namely PB-25662, gives some comparison between AEG and SAF rectifiers.

thus of the three selenium rectifier manufactiriers in Germany, two — AEG and Siemens — have not been overexploited.

there were three research centers on Selenium rectifiers in Germany: at Darmstadt headed by Dr. Brill and H. Krebbs, ~~at~~ in Prague headed by Prof. Gudden and the third of the Siemens Co headed by Dr. Schottky.

A complete summary of the Darmstadt group has been obtained and reported by me and Col. Ranger. A good summary of the Prague group has been given by Harry Dauber in his report. on a basis of a large file of documents and data removed from Gudden's laboratory in Prague. But no trace yet has been found of Dr. Schottky's files removed. from him by some officers early in 1945.

Figure B.48: Walter Schottky published detailed analyses of semiconductor properties necessary for transistors in 1942. All of his papers were seized by the United States in 1945 and never returned [NARA RG 40, Entry UD-75, Box 24, Folder Selenium Rectifier Machinery].

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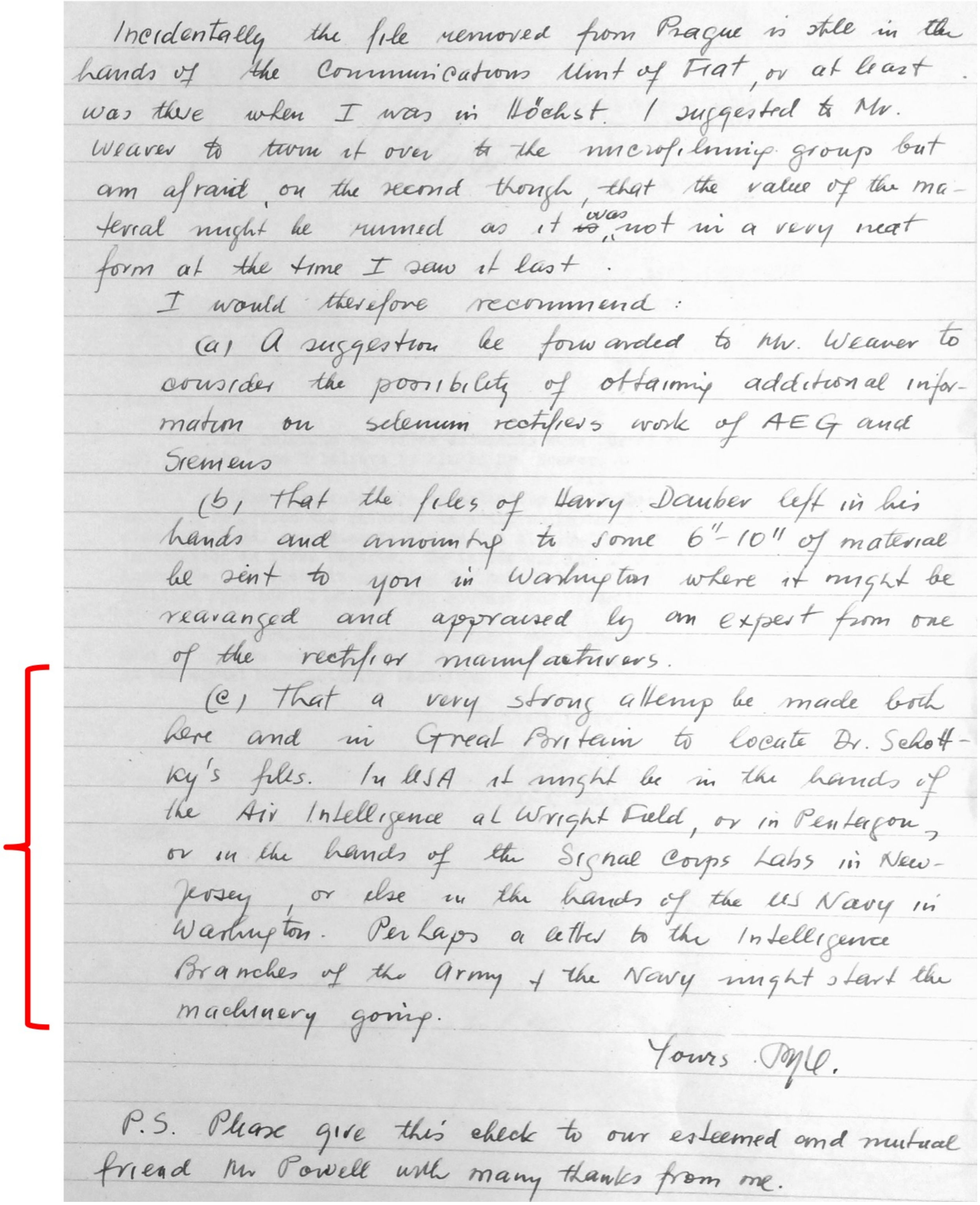
NARA RG 40, Entry UD-75, Box 24,
Folder Selenium Rectifier Machinery



Incidentally the file removed from Prague is still in the hands of the Communications Unit of Fiat, or at least was there when I was in Höchst. I suggested to Mr. Weaver to turn it over to the microfilming group but am afraid, on the second thought, that the value of the material might be ruined as it ~~is~~ was not in a very neat form at the time I saw it last.

I would therefore recommend:

(a) a suggestion be forwarded to Mr. Weaver to consider the possibility of obtaining additional information on selenium rectifiers work of AEG and Siemens

(b) that the files of Harry Dauber left in his hands and amounting to some 6"-10" of material be sent to you in Washington where it might be rearanged and appraised by an expert from one of the rectifier manufacturers.

(c) That a very strong attemp be made both here and in Great Britain to locate Dr. Schottky's files. In USA it might be in the hands of the Air Intelligence at Wright Field, or in Pentagon, or in the hands of the Signal Corps Labs in New-Jersey, or else in the hands of the US Navy in Washington. Perhaps a letter to the Intelligence Branches of the Army + the Navy might start the machinery going.

Yours

P.S. Please give this check to our esteemed and mutual friend Mr Powell with many thanks from me.

Figure B.49: Walter Schottky published detailed analyses of semiconductor properties necessary for transistors in 1942. All of his papers were seized by the United States in 1945 and never returned [NARA RG 40, Entry UD-75, Box 24, Folder Selenium Rectifier Machinery].

[**7. Heinrich Welker (German, 1912–1981) and Herbert Mataré (German, 1912–2011)** began developing a point-contact transistor in Germany during the war. Welker filed a detailed patent application based on that wartime work on 6 April 1945.

After the war, Welker and Mataré continued their work in France. In 1948, they publicly announced their transistor (p. 2711) and filed further patent applications.[3]

For more information, see:

> Heinrich Welker. Filed in 1945. German patent DE 980,084. Halbleiteranordnung zur kapazitiven Steuerung von Strömen in einem Halbleiterkristall. [Semiconductor Device for Capacitively Controlling Currents in a Semiconductor Crystal.] (pp. 2712–2716)
>
> Herbert Mataré and Heinrich Welker. Filed in 1948 but based on wartime work. U.S. patent 2,673,948. Crystal Device for Controlling Electric Currents by Means of a Solid Semiconductor. (pp. 2717–2720)

The postwar work by Welker and Mataré in France is relatively well known, but much more archival research needs to be conducted to investigate the history and accomplishments of their German projects during the war. Among many other questions, was their postwar French work an improvement upon their wartime German work, or was it rather a reconstruction of their wartime German work?]

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[3] Handel 1999; Ringer and Welker 1948; Riordan 2005; Van Dormael 2004, 2009, 2012.

Heinrich Welker (1912–1981) and Herbert Mataré (1912–2011):

- **Filed a detailed patent application in Germany on 6 April 1945 based on wartime work**
- **Filed additional patent applications in many countries in 1948**
- **Publicly announced a working point-contact transistor in 1948 in France**

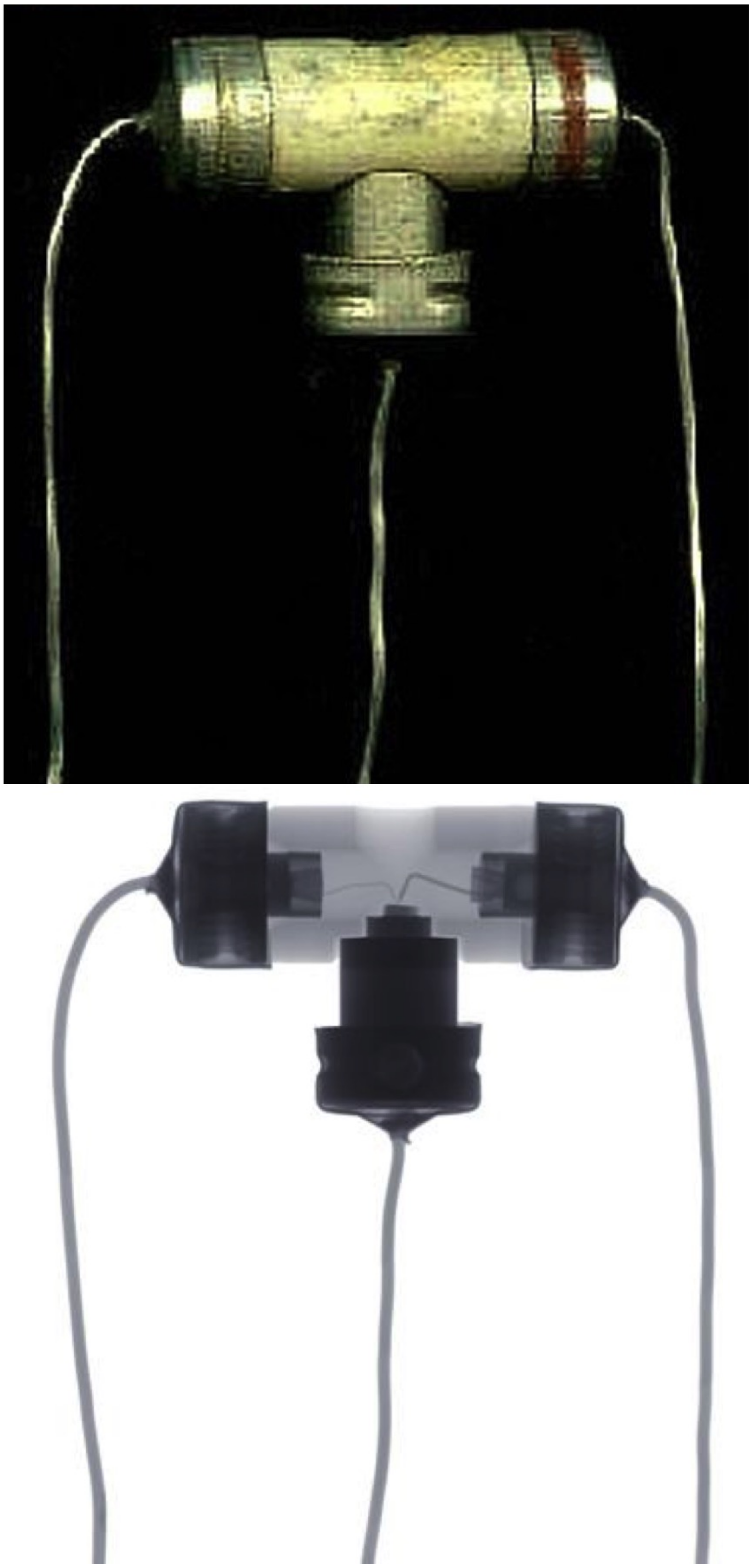
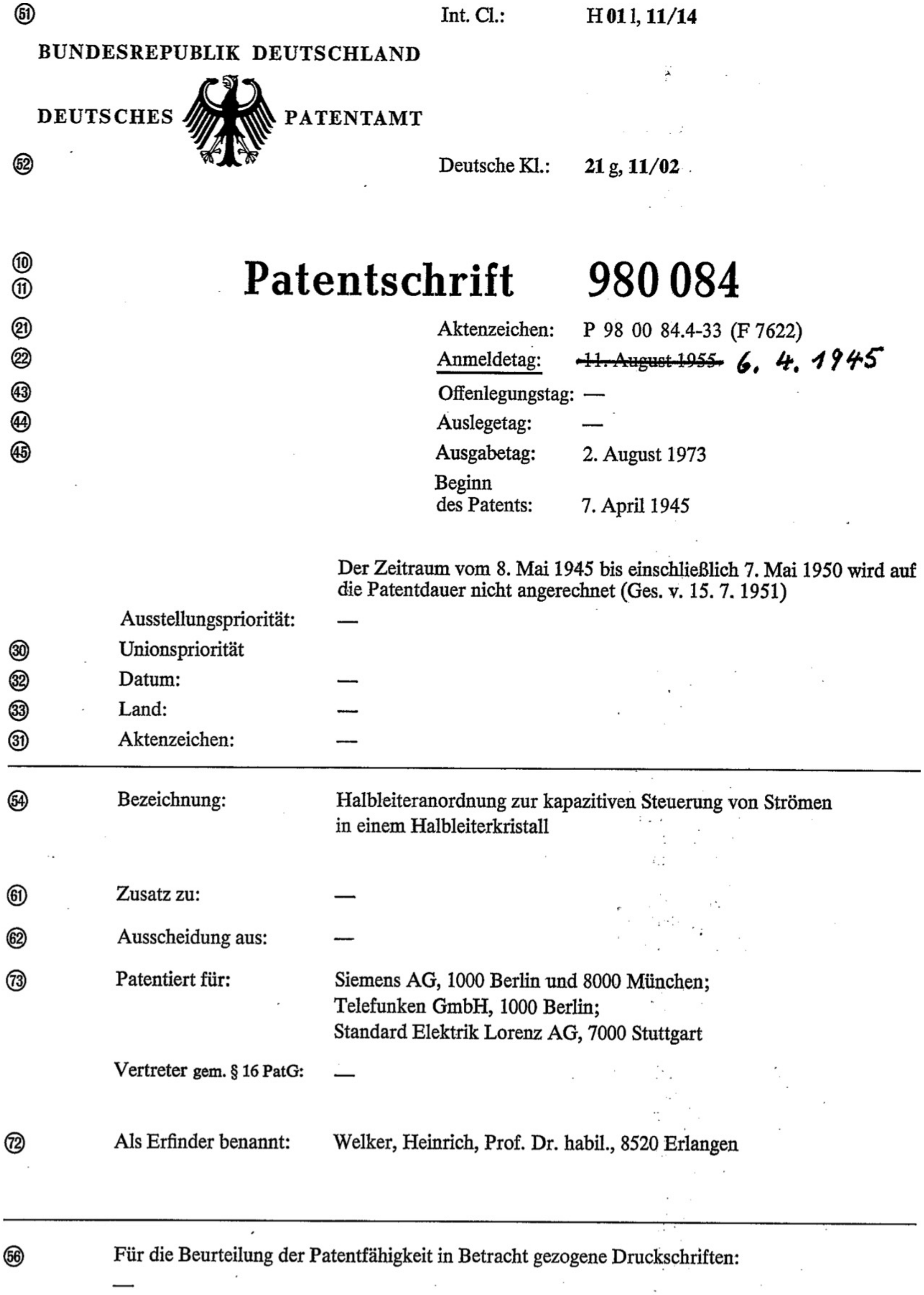


Figure B.50: Heinrich Welker and Herbert Mataré began developing a point-contact transistor in Germany during the war, filed a detailed patent application based on that wartime work on 6 April 1945, and publicly announced their transistor in 1948 in France.



(51) Int. Cl.: **H 01 l, 11/14**

BUNDESREPUBLIK DEUTSCHLAND

DEUTSCHES PATENTAMT

(52) Deutsche Kl.: **21 g, 11/02**

⑩ ⑪ **Patentschrift 980 084**

㉑ Aktenzeichen: P 98 00 84.4-33 (F 7622)
㉒ Anmeldetag: ~~11. August 1955~~ 6. 4. 1945
㊸ Offenlegungstag: —
㊹ Auslegetag: —
㊺ Ausgabetag: 2. August 1973
Beginn des Patents: 7. April 1945

Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet (Ges. v. 15. 7. 1951)

Ausstellungspriorität: —
㉚ Unionspriorität
㉜ Datum: —
㉝ Land: —
㉛ Aktenzeichen: —

(54) Bezeichnung: Halbleiteranordnung zur kapazitiven Steuerung von Strömen in einem Halbleiterkristall

(61) Zusatz zu: —

(62) Ausscheidung aus: —

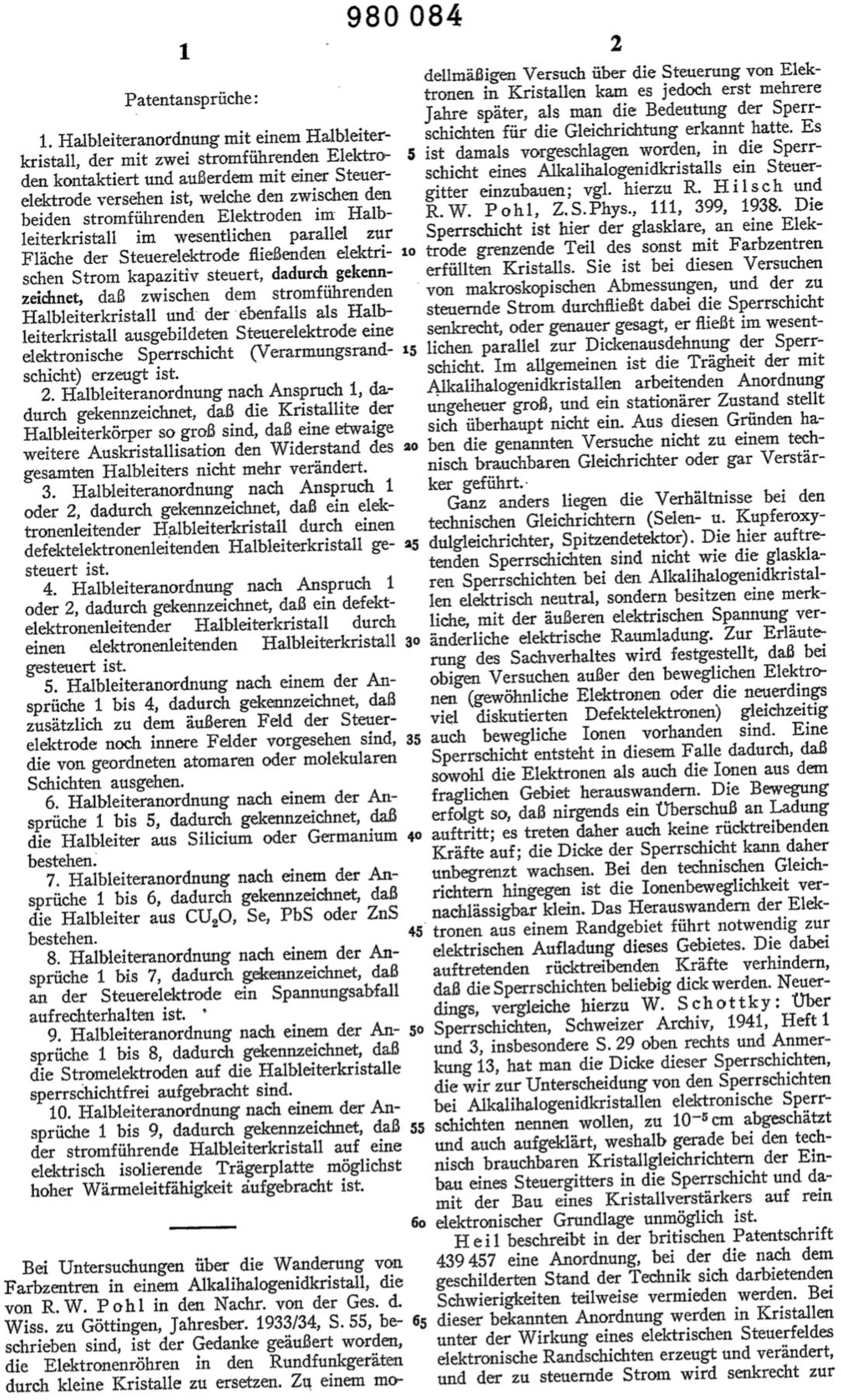
(73) Patentiert für: Siemens AG, 1000 Berlin und 8000 München;
Telefunken GmbH, 1000 Berlin;
Standard Elektrik Lorenz AG, 7000 Stuttgart

Vertreter gem. § 16 PatG: —

(72) Als Erfinder benannt: Welker, Heinrich, Prof. Dr. habil., 8520 Erlangen

(56) Für die Beurteilung der Patentfähigkeit in Betracht gezogene Druckschriften:
—

Figure B.51: Heinrich Welker and Herbert Mataré began developing a point-contact transistor in Germany during the war, filed a detailed patent application based on that wartime work on 6 April 1945, and publicly announced their transistor in 1948 in France.



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Patentansprüche:

1. Halbleiteranordnung mit einem Halbleiterkristall, der mit zwei stromführenden Elektroden kontaktiert und außerdem mit einer Steuerelektrode versehen ist, welche den zwischen den beiden stromführenden Elektroden im Halbleiterkristall im wesentlichen parallel zur Fläche der Steuerelektrode fließenden elektrischen Strom kapazitiv steuert, **dadurch gekennzeichnet,** daß zwischen dem stromführenden Halbleiterkristall und der ebenfalls als Halbleiterkristall ausgebildeten Steuerelektrode eine elektronische Sperrschicht (Verarmungsrandschicht) erzeugt ist.

2. Halbleiteranordnung nach Anspruch 1, dadurch gekennzeichnet, daß die Kristallite der Halbleiterkörper so groß sind, daß eine etwaige weitere Auskristallisation den Widerstand des gesamten Halbleiters nicht mehr verändert.

3. Halbleiteranordnung nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß ein elektronenleitender Halbleiterkristall durch einen defektelektronenleitenden Halbleiterkristall gesteuert ist.

4. Halbleiteranordnung nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß ein defektelektronenleitender Halbleiterkristall durch einen elektronenleitenden Halbleiterkristall gesteuert ist.

5. Halbleiteranordnung nach einem der Ansprüche 1 bis 4, dadurch gekennzeichnet, daß zusätzlich zu dem äußeren Feld der Steuerelektrode noch innere Felder vorgesehen sind, die von geordneten atomaren oder molekularen Schichten ausgehen.

6. Halbleiteranordnung nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß die Halbleiter aus Silicium oder Germanium bestehen.

7. Halbleiteranordnung nach einem der Ansprüche 1 bis 6, dadurch gekennzeichnet, daß die Halbleiter aus CU_2O, Se, PbS oder ZnS bestehen.

8. Halbleiteranordnung nach einem der Ansprüche 1 bis 7, dadurch gekennzeichnet, daß an der Steuerelektrode ein Spannungsabfall aufrechterhalten ist.

9. Halbleiteranordnung nach einem der Ansprüche 1 bis 8, dadurch gekennzeichnet, daß die Stromelektroden auf die Halbleiterkristalle sperrschichtfrei aufgebracht sind.

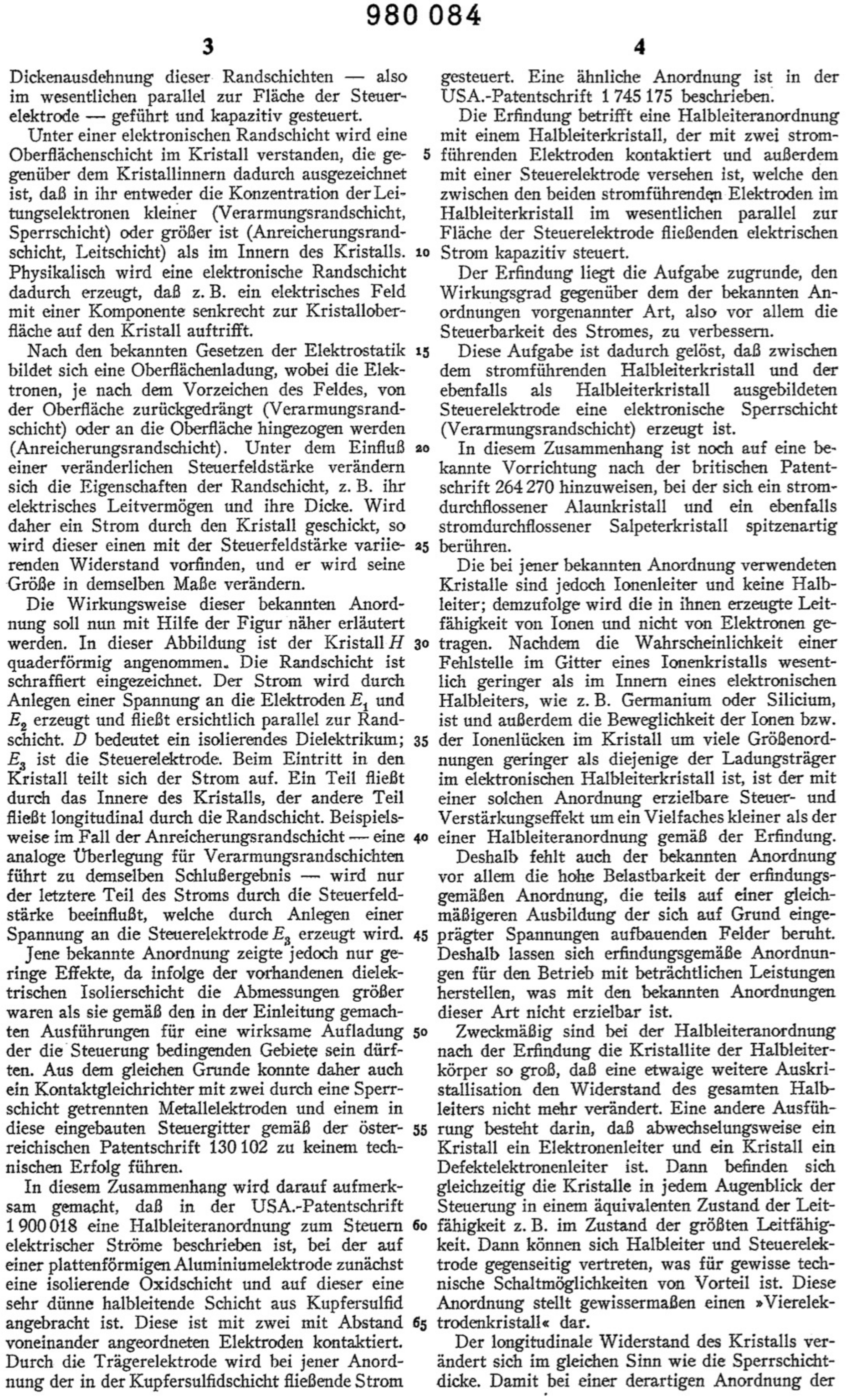
10. Halbleiteranordnung nach einem der Ansprüche 1 bis 9, dadurch gekennzeichnet, daß der stromführende Halbleiterkristall auf eine elektrisch isolierende Trägerplatte möglichst hoher Wärmeleitfähigkeit aufgebracht ist.

Bei Untersuchungen über die Wanderung von Farbzentren in einem Alkalihalogenidkristall, die von R. W. Pohl in den Nachr. von der Ges. d. Wiss. zu Göttingen, Jahresber. 1933/34, S. 55, beschrieben sind, ist der Gedanke geäußert worden, die Elektronenröhren in den Rundfunkgeräten durch kleine Kristalle zu ersetzen. Zu einem modellmäßigen Versuch über die Steuerung von Elektronen in Kristallen kam es jedoch erst mehrere Jahre später, als man die Bedeutung der Sperrschichten für die Gleichrichtung erkannt hatte. Es ist damals vorgeschlagen worden, in die Sperrschicht eines Alkalihalogenidkristalls ein Steuergitter einzubauen; vgl. hierzu R. Hilsch und R. W. Pohl, Z.S.Phys., 111, 399, 1938. Die Sperrschicht ist hier der glasklare, an eine Elektrode grenzende Teil des sonst mit Farbzentren erfüllten Kristalls. Sie ist bei diesen Versuchen von makroskopischen Abmessungen, und der zu steuernde Strom durchfließt dabei die Sperrschicht senkrecht, oder genauer gesagt, er fließt im wesentlichen parallel zur Dickenausdehnung der Sperrschicht. Im allgemeinen ist die Trägheit der mit Alkalihalogenidkristallen arbeitenden Anordnung ungeheuer groß, und ein stationärer Zustand stellt sich überhaupt nicht ein. Aus diesen Gründen haben die genannten Versuche nicht zu einem technisch brauchbaren Gleichrichter oder gar Verstärker geführt.

Ganz anders liegen die Verhältnisse bei den technischen Gleichrichtern (Selen- u. Kupferoxydulgleichrichter, Spitzendetektor). Die hier auftretenden Sperrschichten sind nicht wie die glasklaren Sperrschichten bei den Alkalihalogenidkristallen elektrisch neutral, sondern besitzen eine merkliche, mit der äußeren elektrischen Spannung veränderliche elektrische Raumladung. Zur Erläuterung des Sachverhaltes wird festgestellt, daß bei obigen Versuchen außer den beweglichen Elektronen (gewöhnliche Elektronen oder die neuerdings viel diskutierten Defektelektronen) gleichzeitig auch bewegliche Ionen vorhanden sind. Eine Sperrschicht entsteht in diesem Falle dadurch, daß sowohl die Elektronen als auch die Ionen aus dem fraglichen Gebiet herauswandern. Die Bewegung erfolgt so, daß nirgends ein Überschuß an Ladung auftritt; es treten daher auch keine rücktreibenden Kräfte auf; die Dicke der Sperrschicht kann daher unbegrenzt wachsen. Bei den technischen Gleichrichtern hingegen ist die Ionenbeweglichkeit vernachlässigbar klein. Das Herauswandern der Elektronen aus einem Randgebiet führt notwendig zur elektrischen Aufladung dieses Gebietes. Die dabei auftretenden rücktreibenden Kräfte verhindern, daß die Sperrschichten beliebig dick werden. Neuerdings, vergleiche hierzu W. Schottky: Über Sperrschichten, Schweizer Archiv, 1941, Heft 1 und 3, insbesondere S. 29 oben rechts und Anmerkung 13, hat man die Dicke dieser Sperrschichten, die wir zur Unterscheidung von den Sperrschichten bei Alkalihalogenidkristallen elektronische Sperrschichten nennen wollen, zu 10^{-5} cm abgeschätzt und auch aufgeklärt, weshalb gerade bei den technisch brauchbaren Kristallgleichrichtern der Einbau eines Steuergitters in die Sperrschicht und damit der Bau eines Kristallverstärkers auf rein elektronischer Grundlage unmöglich ist.

Heil beschreibt in der britischen Patentschrift 439 457 eine Anordnung, bei der die nach dem geschilderten Stand der Technik sich darbietenden Schwierigkeiten teilweise vermieden werden. Bei dieser bekannten Anordnung werden in Kristallen unter der Wirkung eines elektrischen Steuerfeldes elektronische Randschichten erzeugt und verändert, und der zu steuernde Strom wird senkrecht zur

Figure B.52: Heinrich Welker and Herbert Mataré began developing a point-contact transistor in Germany during the war, filed a detailed patent application based on that wartime work on 6 April 1945, and publicly announced their transistor in 1948 in France.



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Dickenausdehnung dieser Randschichten — also im wesentlichen parallel zur Fläche der Steuerelektrode — geführt und kapazitiv gesteuert.

Unter einer elektronischen Randschicht wird eine Oberflächenschicht im Kristall verstanden, die gegenüber dem Kristallinnern dadurch ausgezeichnet ist, daß in ihr entweder die Konzentration der Leitungselektronen kleiner (Verarmungsrandschicht, Sperrschicht) oder größer ist (Anreicherungsrandschicht, Leitschicht) als im Innern des Kristalls. Physikalisch wird eine elektronische Randschicht dadurch erzeugt, daß z. B. ein elektrisches Feld mit einer Komponente senkrecht zur Kristalloberfläche auf den Kristall auftrifft.

Nach den bekannten Gesetzen der Elektrostatik bildet sich eine Oberflächenladung, wobei die Elektronen, je nach dem Vorzeichen des Feldes, von der Oberfläche zurückgedrängt (Verarmungsrandschicht) oder an die Oberfläche hingezogen werden (Anreicherungsrandschicht). Unter dem Einfluß einer veränderlichen Steuerfeldstärke verändern sich die Eigenschaften der Randschicht, z. B. ihr elektrisches Leitvermögen und ihre Dicke. Wird daher ein Strom durch den Kristall geschickt, so wird dieser einen mit der Steuerfeldstärke variierenden Widerstand vorfinden, und er wird seine Größe in demselben Maße verändern.

Die Wirkungsweise dieser bekannten Anordnung soll nun mit Hilfe der Figur näher erläutert werden. In dieser Abbildung ist der Kristall *H* quaderförmig angenommen. Die Randschicht ist schraffiert eingezeichnet. Der Strom wird durch Anlegen einer Spannung an die Elektroden E_1 und E_2 erzeugt und fließt ersichtlich parallel zur Randschicht. *D* bedeutet ein isolierendes Dielektrikum; E_3 ist die Steuerelektrode. Beim Eintritt in den Kristall teilt sich der Strom auf. Ein Teil fließt durch das Innere des Kristalls, der andere Teil fließt longitudinal durch die Randschicht. Beispielsweise im Fall der Anreicherungsrandschicht — eine analoge Überlegung für Verarmungsrandschichten führt zu demselben Schlußergebnis — wird nur der letztere Teil des Stroms durch die Steuerfeldstärke beeinflußt, welche durch Anlegen einer Spannung an die Steuerelektrode E_3 erzeugt wird.

Jene bekannte Anordnung zeigte jedoch nur geringe Effekte, da infolge der vorhandenen dielektrischen Isolierschicht die Abmessungen größer waren als sie gemäß den in der Einleitung gemachten Ausführungen für eine wirksame Aufladung der die Steuerung bedingenden Gebiete sein dürften. Aus dem gleichen Grunde konnte daher auch ein Kontaktgleichrichter mit zwei durch eine Sperrschicht getrennten Metallelektroden und einem in diese eingebauten Steuergitter gemäß der österreichischen Patentschrift 130 102 zu keinem technischen Erfolg führen.

In diesem Zusammenhang wird darauf aufmerksam gemacht, daß in der USA.-Patentschrift 1 900 018 eine Halbleiteranordnung zum Steuern elektrischer Ströme beschrieben ist, bei der auf einer plattenförmigen Aluminiumelektrode zunächst eine isolierende Oxidschicht und auf dieser eine sehr dünne halbleitende Schicht aus Kupfersulfid angebracht ist. Diese ist mit zwei mit Abstand voneinander angeordneten Elektroden kontaktiert. Durch die Trägerelektrode wird bei jener Anordnung der in der Kupfersulfidschicht fließende Strom gesteuert. Eine ähnliche Anordnung ist in der USA.-Patentschrift 1 745 175 beschrieben.

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Die Erfindung betrifft eine Halbleiteranordnung mit einem Halbleiterkristall, der mit zwei stromführenden Elektroden kontaktiert und außerdem mit einer Steuerelektrode versehen ist, welche den zwischen den beiden stromführenden Elektroden im Halbleiterkristall im wesentlichen parallel zur Fläche der Steuerelektrode fließenden elektrischen Strom kapazitiv steuert.

Der Erfindung liegt die Aufgabe zugrunde, den Wirkungsgrad gegenüber dem der bekannten Anordnungen vorgenannter Art, also vor allem die Steuerbarkeit des Stromes, zu verbessern.

Diese Aufgabe ist dadurch gelöst, daß zwischen dem stromführenden Halbleiterkristall und der ebenfalls als Halbleiterkristall ausgebildeten Steuerelektrode eine elektronische Sperrschicht (Verarmungsrandschicht) erzeugt ist.

In diesem Zusammenhang ist noch auf eine bekannte Vorrichtung nach der britischen Patentschrift 264 270 hinzuweisen, bei der sich ein stromdurchflossener Alaunkristall und ein ebenfalls stromdurchflossener Salpeterkristall spitzenartig berühren.

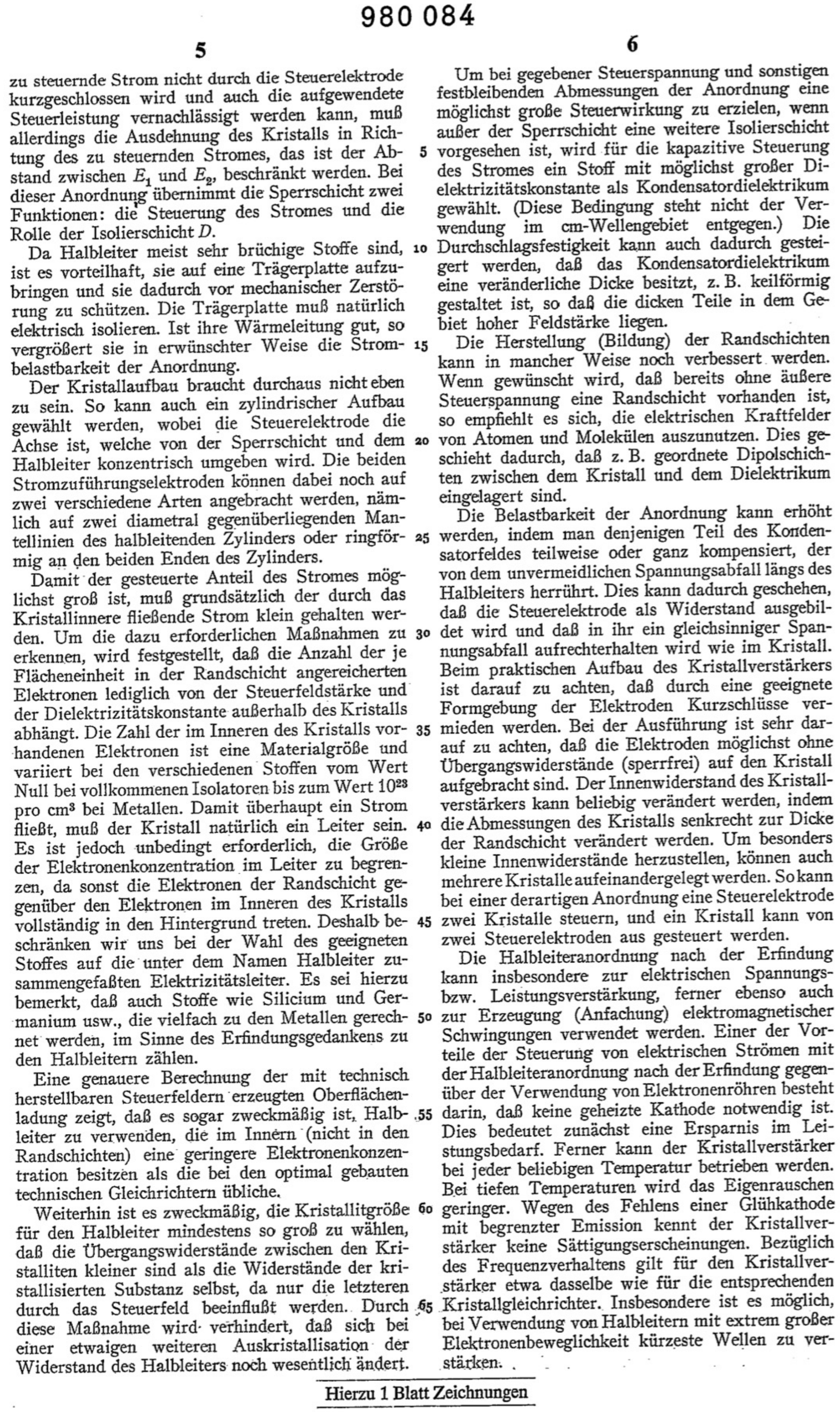
Die bei jener bekannten Anordnung verwendeten Kristalle sind jedoch Ionenleiter und keine Halbleiter; demzufolge wird die in ihnen erzeugte Leitfähigkeit von Ionen und nicht von Elektronen getragen. Nachdem die Wahrscheinlichkeit einer Fehlstelle im Gitter eines Ionenkristalls wesentlich geringer als im Innern eines elektronischen Halbleiters, wie z. B. Germanium oder Silicium, ist und außerdem die Beweglichkeit der Ionen bzw. der Ionenlücken im Kristall um viele Größenordnungen geringer als diejenige der Ladungsträger im elektronischen Halbleiterkristall ist, ist der mit einer solchen Anordnung erzielbare Steuer- und Verstärkungseffekt um ein Vielfaches kleiner als der einer Halbleiteranordnung gemäß der Erfindung.

Deshalb fehlt auch der bekannten Anordnung vor allem die hohe Belastbarkeit der erfindungsgemäßen Anordnung, die teils auf einer gleichmäßigeren Ausbildung der sich auf Grund eingeprägter Spannungen aufbauenden Felder beruht. Deshalb lassen sich erfindungsgemäße Anordnungen für den Betrieb mit beträchtlichen Leistungen herstellen, was mit den bekannten Anordnungen dieser Art nicht erzielbar ist.

Zweckmäßig sind bei der Halbleiteranordnung nach der Erfindung die Kristallite der Halbleiterkörper so groß, daß eine etwaige weitere Auskristallisation den Widerstand des gesamten Halbleiters nicht mehr verändert. Eine andere Ausführung besteht darin, daß abwechselungsweise ein Kristall ein Elektronenleiter und ein Kristall ein Defektelektronenleiter ist. Dann befinden sich gleichzeitig die Kristalle in jedem Augenblick der Steuerung in einem äquivalenten Zustand der Leitfähigkeit z. B. im Zustand der größten Leitfähigkeit. Dann können sich Halbleiter und Steuerelektrode gegenseitig vertreten, was für gewisse technische Schaltmöglichkeiten von Vorteil ist. Diese Anordnung stellt gewissermaßen einen »Vierelektrodenkristall« dar.

Der longitudinale Widerstand des Kristalls verändert sich im gleichen Sinn wie die Sperrschichtdicke. Damit bei einer derartigen Anordnung der

Figure B.53: Heinrich Welker and Herbert Mataré began developing a point-contact transistor in Germany during the war, filed a detailed patent application based on that wartime work on 6 April 1945, and publicly announced their transistor in 1948 in France.



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zu steuernde Strom nicht durch die Steuerelektrode kurzgeschlossen wird und auch die aufgewendete Steuerleistung vernachlässigt werden kann, muß allerdings die Ausdehnung des Kristalls in Richtung des zu steuernden Stromes, das ist der Abstand zwischen E_1 und E_2, beschränkt werden. Bei dieser Anordnung übernimmt die Sperrschicht zwei Funktionen: die Steuerung des Stromes und die Rolle der Isolierschicht *D*.

Da Halbleiter meist sehr brüchige Stoffe sind, ist es vorteilhaft, sie auf eine Trägerplatte aufzubringen und sie dadurch vor mechanischer Zerstörung zu schützen. Die Trägerplatte muß natürlich elektrisch isolieren. Ist ihre Wärmeleitung gut, so vergrößert sie in erwünschter Weise die Strombelastbarkeit der Anordnung.

Der Kristallaufbau braucht durchaus nicht eben zu sein. So kann auch ein zylindrischer Aufbau gewählt werden, wobei die Steuerelektrode die Achse ist, welche von der Sperrschicht und dem Halbleiter konzentrisch umgeben wird. Die beiden Stromzuführungselektroden können dabei noch auf zwei verschiedene Arten angebracht werden, nämlich auf zwei diametral gegenüberliegenden Mantellinien des halbleitenden Zylinders oder ringförmig an den beiden Enden des Zylinders.

Damit der gesteuerte Anteil des Stromes möglichst groß ist, muß grundsätzlich der durch das Kristallinnere fließende Strom klein gehalten werden. Um die dazu erforderlichen Maßnahmen zu erkennen, wird festgestellt, daß die Anzahl der je Flächeneinheit in der Randschicht angereicherten Elektronen lediglich von der Steuerfeldstärke und der Dielektrizitätskonstante außerhalb des Kristalls abhängt. Die Zahl der im Inneren des Kristalls vorhandenen Elektronen ist eine Materialgröße und variiert bei den verschiedenen Stoffen vom Wert Null bei vollkommenen Isolatoren bis zum Wert 10^{23} pro cm^3 bei Metallen. Damit überhaupt ein Strom fließt, muß der Kristall natürlich ein Leiter sein. Es ist jedoch unbedingt erforderlich, die Größe der Elektronenkonzentration im Leiter zu begrenzen, da sonst die Elektronen der Randschicht gegenüber den Elektronen im Inneren des Kristalls vollständig in den Hintergrund treten. Deshalb beschränken wir uns bei der Wahl des geeigneten Stoffes auf die unter dem Namen Halbleiter zusammengefaßten Elektrizitätsleiter. Es sei hierzu bemerkt, daß auch Stoffe wie Silicium und Germanium usw., die vielfach zu den Metallen gerechnet werden, im Sinne des Erfindungsgedankens zu den Halbleitern zählen.

Eine genauere Berechnung der mit technisch herstellbaren Steuerfeldern erzeugten Oberflächenladung zeigt, daß es sogar zweckmäßig ist, Halbleiter zu verwenden, die im Innern (nicht in den Randschichten) eine geringere Elektronenkonzentration besitzen als die bei den optimal gebauten technischen Gleichrichtern übliche.

Weiterhin ist es zweckmäßig, die Kristallitgröße für den Halbleiter mindestens so groß zu wählen, daß die Übergangswiderstände zwischen den Kristalliten kleiner sind als die Widerstände der kristallisierten Substanz selbst, da nur die letzteren durch das Steuerfeld beeinflußt werden. Durch diese Maßnahme wird verhindert, daß sich bei einer etwaigen weiteren Auskristallisation der Widerstand des Halbleiters noch wesentlich ändert.

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Um bei gegebener Steuerspannung und sonstigen festbleibenden Abmessungen der Anordnung eine möglichst große Steuerwirkung zu erzielen, wenn außer der Sperrschicht eine weitere Isolierschicht vorgesehen ist, wird für die kapazitive Steuerung des Stromes ein Stoff mit möglichst großer Dielektrizitätskonstante als Kondensatordielektrikum gewählt. (Diese Bedingung steht nicht der Verwendung im cm-Wellengebiet entgegen.) Die Durchschlagsfestigkeit kann auch dadurch gesteigert werden, daß das Kondensatordielektrikum eine veränderliche Dicke besitzt, z. B. keilförmig gestaltet ist, so daß die dicken Teile in dem Gebiet hoher Feldstärke liegen.

Die Herstellung (Bildung) der Randschichten kann in mancher Weise noch verbessert werden. Wenn gewünscht wird, daß bereits ohne äußere Steuerspannung eine Randschicht vorhanden ist, so empfiehlt es sich, die elektrischen Kraftfelder von Atomen und Molekülen auszunutzen. Dies geschieht dadurch, daß z. B. geordnete Dipolschichten zwischen dem Kristall und dem Dielektrikum eingelagert sind.

Die Belastbarkeit der Anordnung kann erhöht werden, indem man denjenigen Teil des Kondensatorfeldes teilweise oder ganz kompensiert, der von dem unvermeidlichen Spannungsabfall längs des Halbleiters herrührt. Dies kann dadurch geschehen, daß die Steuerelektrode als Widerstand ausgebildet wird und daß in ihr ein gleichsinniger Spannungsabfall aufrechterhalten wird wie im Kristall. Beim praktischen Aufbau des Kristallverstärkers ist darauf zu achten, daß durch eine geeignete Formgebung der Elektroden Kurzschlüsse vermieden werden. Bei der Ausführung ist sehr darauf zu achten, daß die Elektroden möglichst ohne Übergangswiderstände (sperrfrei) auf den Kristall aufgebracht sind. Der Innenwiderstand des Kristallverstärkers kann beliebig verändert werden, indem die Abmessungen des Kristalls senkrecht zur Dicke der Randschicht verändert werden. Um besonders kleine Innenwiderstände herzustellen, können auch mehrere Kristalle aufeinandergelegt werden. So kann bei einer derartigen Anordnung eine Steuerelektrode zwei Kristalle steuern, und ein Kristall kann von zwei Steuerelektroden aus gesteuert werden.

Die Halbleiteranordnung nach der Erfindung kann insbesondere zur elektrischen Spannungs- bzw. Leistungsverstärkung, ferner ebenso auch zur Erzeugung (Anfachung) elektromagnetischer Schwingungen verwendet werden. Einer der Vorteile der Steuerung von elektrischen Strömen mit der Halbleiteranordnung nach der Erfindung gegenüber der Verwendung von Elektronenröhren besteht darin, daß keine geheizte Kathode notwendig ist. Dies bedeutet zunächst eine Ersparnis im Leistungsbedarf. Ferner kann der Kristallverstärker bei jeder beliebigen Temperatur betrieben werden. Bei tiefen Temperaturen wird das Eigenrauschen geringer. Wegen des Fehlens einer Glühkathode mit begrenzter Emission kennt der Kristallverstärker keine Sättigungserscheinungen. Bezüglich des Frequenzverhaltens gilt für den Kristallverstärker etwa dasselbe wie für die entsprechenden Kristallgleichrichter. Insbesondere ist es möglich, bei Verwendung von Halbleitern mit extrem großer Elektronenbeweglichkeit kürzeste Wellen zu verstärken.

Hierzu 1 Blatt Zeichnungen

Figure B.54: Heinrich Welker and Herbert Mataré began developing a point-contact transistor in Germany during the war, filed a detailed patent application based on that wartime work on 6 April 1945, and publicly announced their transistor in 1948 in France.

ZEICHNUNGEN BLATT 1

Nummer:	**980 084**
Int. Cl.:	**H 01 l, 11/14**
Deutsche Kl.:	**21 g, 11/02**
Auslegetag:	2. August 1973

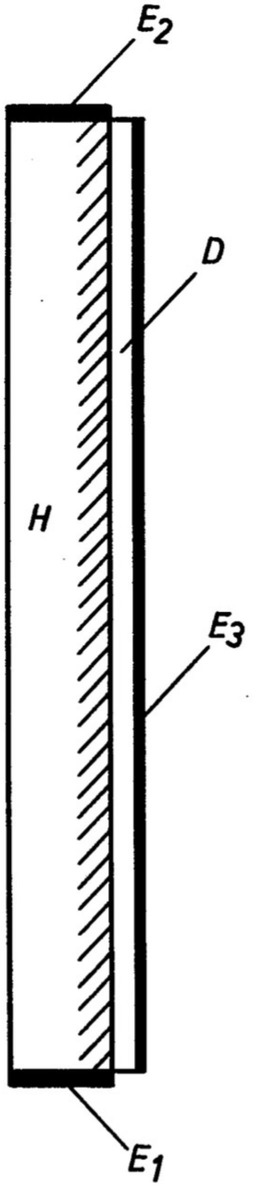

Figure B.55: Heinrich Welker and Herbert Mataré began developing a point-contact transistor in Germany during the war, filed a detailed patent application based on that wartime work on 6 April 1945, and publicly announced their transistor in 1948 in France.

March 30, 1954 H. F. MATARÉ ET AL **2,673,948**
CRYSTAL DEVICE FOR CONTROLLING ELECTRIC CURRENTS
BY MEANS OF A SOLID SEMICONDUCTOR
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FIG. 1

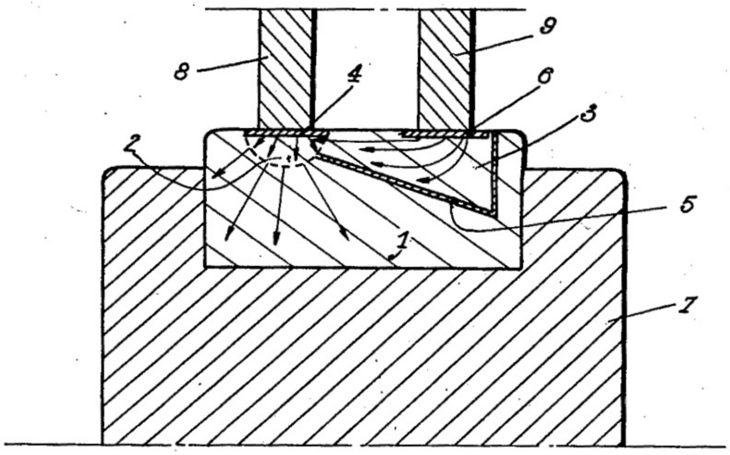
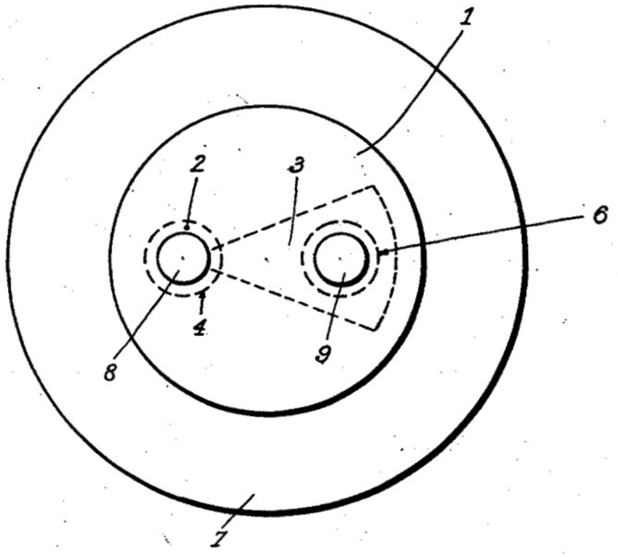


FIG. 2



INVENTORS
HERBERT FRANÇOIS MATARÉ & HEINRICH WELKER
BY
ATTORNEY

Figure B.56: Heinrich Welker and Herbert Mataré began developing a point-contact transistor in Germany during the war, filed a detailed patent application based on that wartime work on 6 April 1945, and publicly announced their transistor in 1948 in France.

March 30, 1954 H. F. MATARÉ ET AL **2,673,948**

CRYSTAL DEVICE FOR CONTROLLING ELECTRIC CURRENTS
BY MEANS OF A SOLID SEMICONDUCTOR

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Fig. 3

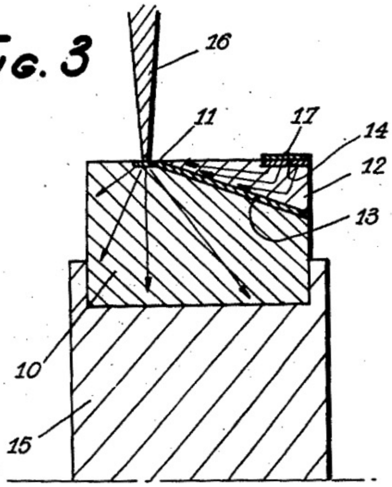


Fig. 6

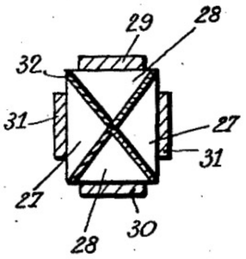


Fig. 4

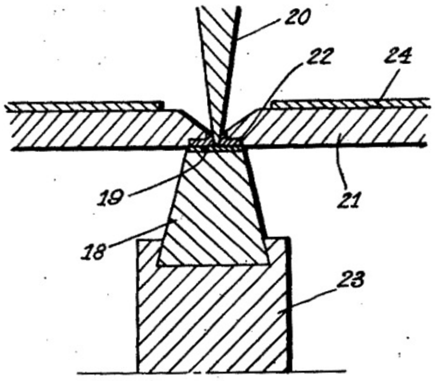
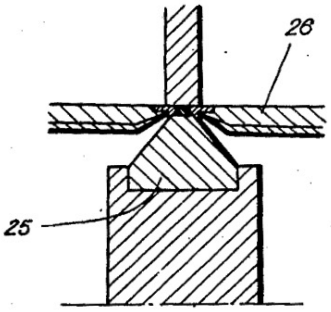


Fig. 5



INVENTORS
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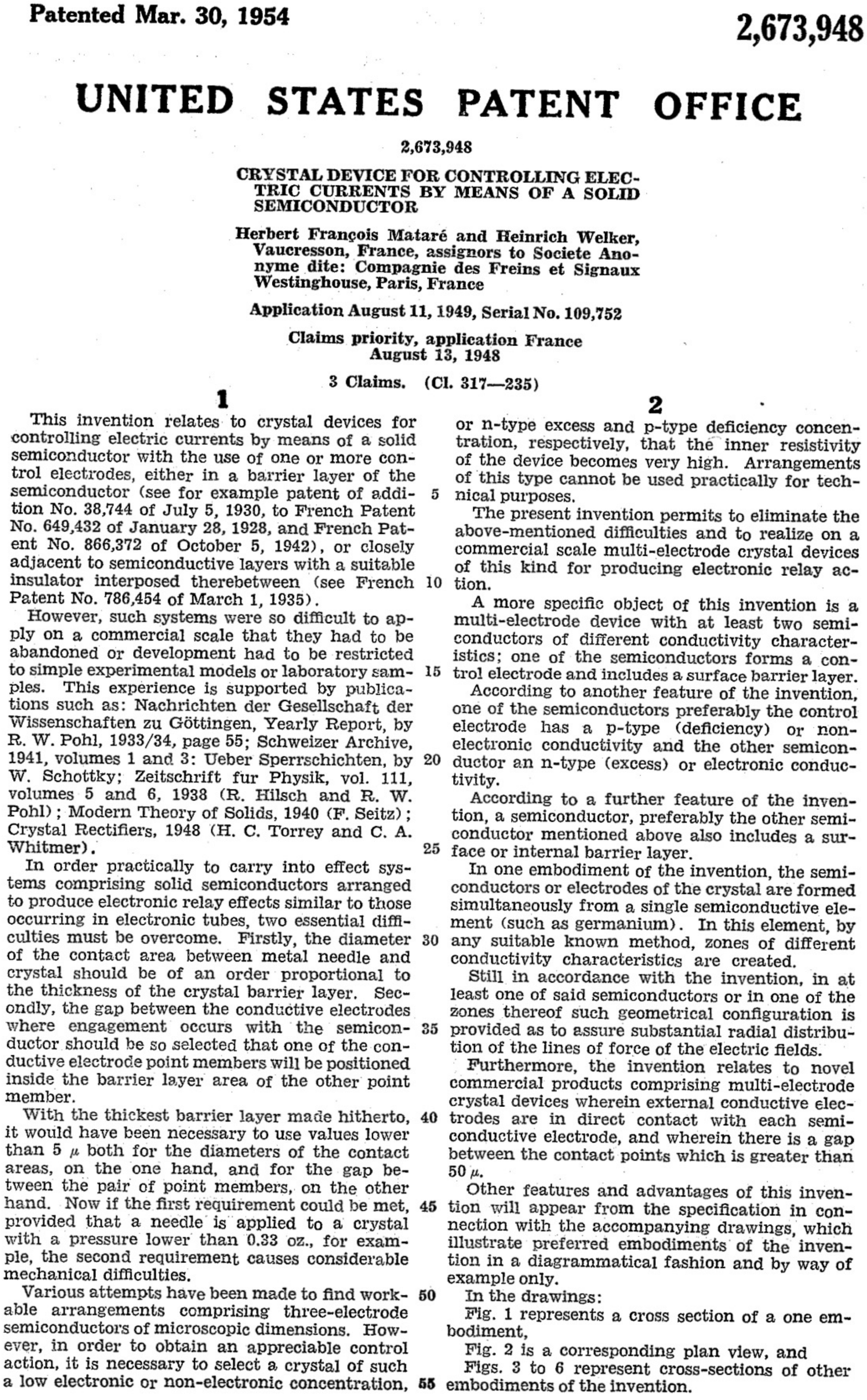
ATTORNEY

Figure B.57: Heinrich Welker and Herbert Mataré began developing a point-contact transistor in Germany during the war, filed a detailed patent application based on that wartime work on 6 April 1945, and publicly announced their transistor in 1948 in France.



Patented Mar. 30, 1954 **2,673,948**

UNITED STATES PATENT OFFICE

2,673,948

CRYSTAL DEVICE FOR CONTROLLING ELECTRIC CURRENTS BY MEANS OF A SOLID SEMICONDUCTOR

Herbert François Mataré and Heinrich Welker, Vaucresson, France, assignors to Societe Anonyme dite: Compagnie des Freins et Signaux Westinghouse, Paris, France

Application August 11, 1949, Serial No. 109,752

Claims priority, application France August 13, 1948

3 Claims. (Cl. 317—235)

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This invention relates to crystal devices for controlling electric currents by means of a solid semiconductor with the use of one or more control electrodes, either in a barrier layer of the semiconductor (see for example patent of addition No. 38,744 of July 5, 1930, to French Patent No. 649,432 of January 28, 1928, and French Patent No. 866,372 of October 5, 1942), or closely adjacent to semiconductive layers with a suitable insulator interposed therebetween (see French Patent No. 786,454 of March 1, 1935).

However, such systems were so difficult to apply on a commercial scale that they had to be abandoned or development had to be restricted to simple experimental models or laboratory samples. This experience is supported by publications such as: Nachrichten der Gesellschaft der Wissenschaften zu Göttingen, Yearly Report, by R. W. Pohl, 1933/34, page 55; Schweizer Archive, 1941, volumes 1 and 3: Ueber Sperrschichten, by W. Schottky; Zeitschrift fur Physik, vol. 111, volumes 5 and 6, 1938 (R. Hilsch and R. W. Pohl); Modern Theory of Solids, 1940 (F. Seitz); Crystal Rectifiers, 1948 (H. C. Torrey and C. A. Whitmer).

In order practically to carry into effect systems comprising solid semiconductors arranged to produce electronic relay effects similar to those occurring in electronic tubes, two essential difficulties must be overcome. Firstly, the diameter of the contact area between metal needle and crystal should be of an order proportional to the thickness of the crystal barrier layer. Secondly, the gap between the conductive electrodes where engagement occurs with the semiconductor should be so selected that one of the conductive electrode point members will be positioned inside the barrier layer area of the other point member.

With the thickest barrier layer made hitherto, it would have been necessary to use values lower than 5 μ both for the diameters of the contact areas, on the one hand, and for the gap between the pair of point members, on the other hand. Now if the first requirement could be met, provided that a needle is applied to a crystal with a pressure lower than 0.33 oz., for example, the second requirement causes considerable mechanical difficulties.

Various attempts have been made to find workable arrangements comprising three-electrode semiconductors of microscopic dimensions. However, in order to obtain an appreciable control action, it is necessary to select a crystal of such a low electronic or non-electronic concentration,

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or n-type excess and p-type deficiency concentration, respectively, that the inner resistivity of the device becomes very high. Arrangements of this type cannot be used practically for technical purposes.

The present invention permits to eliminate the above-mentioned difficulties and to realize on a commercial scale multi-electrode crystal devices of this kind for producing electronic relay action.

A more specific object of this invention is a multi-electrode device with at least two semiconductors of different conductivity characteristics; one of the semiconductors forms a control electrode and includes a surface barrier layer.

According to another feature of the invention, one of the semiconductors preferably the control electrode has a p-type (deficiency) or non-electronic conductivity and the other semiconductor an n-type (excess) or electronic conductivity.

According to a further feature of the invention, a semiconductor, preferably the other semiconductor mentioned above also includes a surface or internal barrier layer.

In one embodiment of the invention, the semiconductors or electrodes of the crystal are formed simultaneously from a single semiconductive element (such as germanium). In this element, by any suitable known method, zones of different conductivity characteristics are created.

Still in accordance with the invention, in at least one of said semiconductors or in one of the zones thereof such geometrical configuration is provided as to assure substantial radial distribution of the lines of force of the electric fields.

Furthermore, the invention relates to novel commercial products comprising multi-electrode crystal devices wherein external conductive electrodes are in direct contact with each semiconductive electrode, and wherein there is a gap between the contact points which is greater than 50 μ.

Other features and advantages of this invention will appear from the specification in connection with the accompanying drawings, which illustrate preferred embodiments of the invention in a diagrammatical fashion and by way of example only.

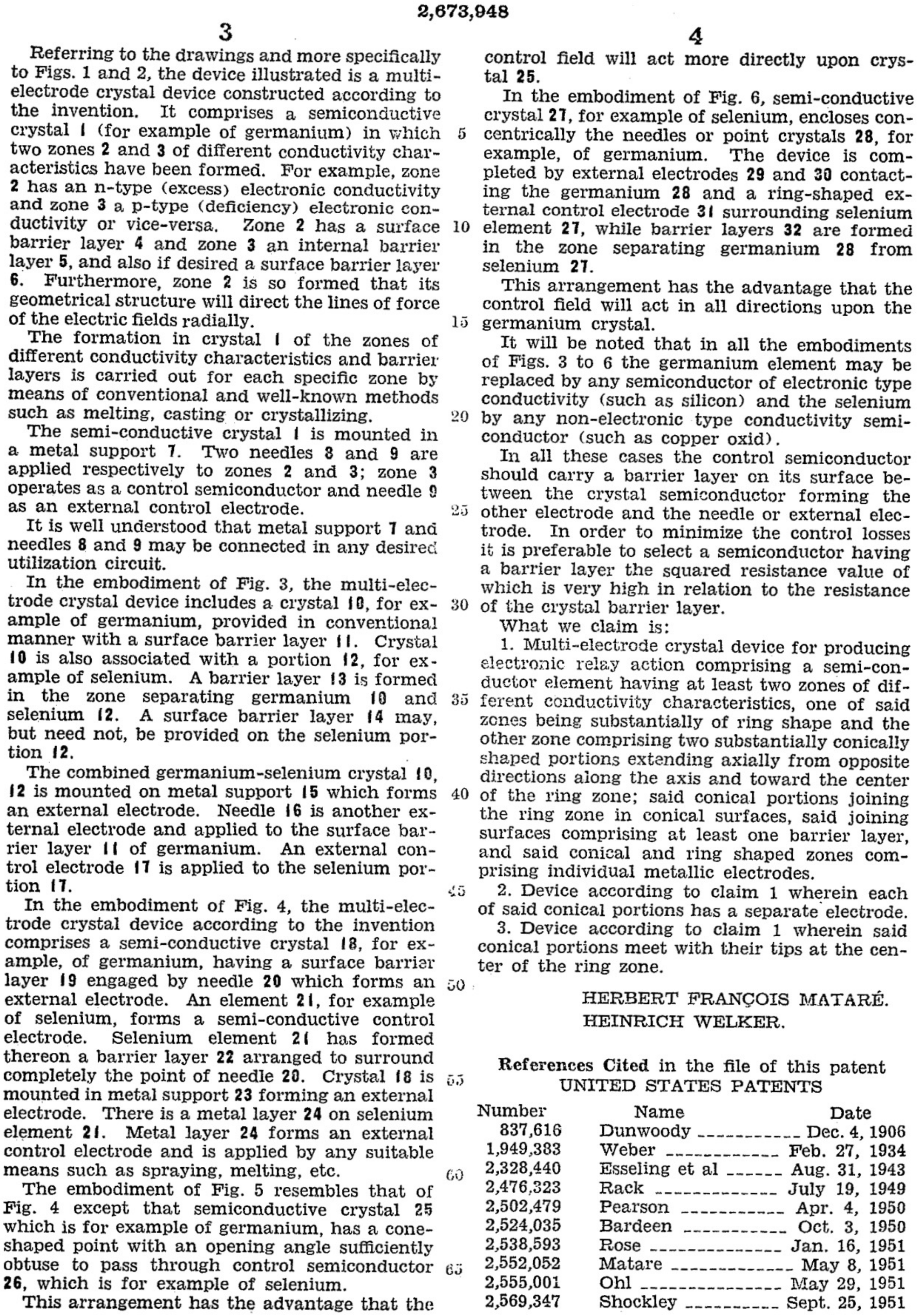
In the drawings:

Fig. 1 represents a cross section of a one embodiment,

Fig. 2 is a corresponding plan view, and

Figs. 3 to 6 represent cross-sections of other embodiments of the invention.

Figure B.58: Heinrich Welker and Herbert Mataré began developing a point-contact transistor in Germany during the war, filed a detailed patent application based on that wartime work on 6 April 1945, and publicly announced their transistor in 1948 in France.



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Referring to the drawings and more specifically to Figs. 1 and 2, the device illustrated is a multi-electrode crystal device constructed according to the invention. It comprises a semiconductive crystal **1** (for example of germanium) in which two zones **2** and **3** of different conductivity characteristics have been formed. For example, zone **2** has an n-type (excess) electronic conductivity and zone **3** a p-type (deficiency) electronic conductivity or vice-versa. Zone **2** has a surface barrier layer **4** and zone **3** an internal barrier layer **5**, and also if desired a surface barrier layer **6**. Furthermore, zone **2** is so formed that its geometrical structure will direct the lines of force of the electric fields radially.

The formation in crystal **1** of the zones of different conductivity characteristics and barrier layers is carried out for each specific zone by means of conventional and well-known methods such as melting, casting or crystallizing.

The semi-conductive crystal **1** is mounted in a metal support **7**. Two needles **8** and **9** are applied respectively to zones **2** and **3**; zone **3** operates as a control semiconductor and needle **9** as an external control electrode.

It is well understood that metal support **7** and needles **8** and **9** may be connected in any desired utilization circuit.

In the embodiment of Fig. 3, the multi-electrode crystal device includes a crystal **10**, for example of germanium, provided in conventional manner with a surface barrier layer **11**. Crystal **10** is also associated with a portion **12**, for example of selenium. A barrier layer **13** is formed in the zone separating germanium **10** and selenium **12**. A surface barrier layer **14** may, but need not, be provided on the selenium portion **12**.

The combined germanium-selenium crystal **10**, **12** is mounted on metal support **15** which forms an external electrode. Needle **16** is another external electrode and applied to the surface barrier layer **11** of germanium. An external control electrode **17** is applied to the selenium portion **17**.

In the embodiment of Fig. 4, the multi-electrode crystal device according to the invention comprises a semi-conductive crystal **18**, for example, of germanium, having a surface barrier layer **19** engaged by needle **20** which forms an external electrode. An element **21**, for example of selenium, forms a semi-conductive control electrode. Selenium element **21** has formed thereon a barrier layer **22** arranged to surround completely the point of needle **20**. Crystal **18** is mounted in metal support **23** forming an external electrode. There is a metal layer **24** on selenium element **21**. Metal layer **24** forms an external control electrode and is applied by any suitable means such as spraying, melting, etc.

The embodiment of Fig. 5 resembles that of Fig. 4 except that semiconductive crystal **25** which is for example of germanium, has a cone-shaped point with an opening angle sufficiently obtuse to pass through control semiconductor **26**, which is for example of selenium.

This arrangement has the advantage that the

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control field will act more directly upon crystal **25**.

In the embodiment of Fig. 6, semi-conductive crystal **27**, for example of selenium, encloses concentrically the needles or point crystals **28**, for example, of germanium. The device is completed by external electrodes **29** and **30** contacting the germanium **28** and a ring-shaped external control electrode **31** surrounding selenium element **27**, while barrier layers **32** are formed in the zone separating germanium **28** from selenium **27**.

This arrangement has the advantage that the control field will act in all directions upon the germanium crystal.

It will be noted that in all the embodiments of Figs. 3 to 6 the germanium element may be replaced by any semiconductor of electronic type conductivity (such as silicon) and the selenium by any non-electronic type conductivity semiconductor (such as copper oxid).

In all these cases the control semiconductor should carry a barrier layer on its surface between the crystal semiconductor forming the other electrode and the needle or external electrode. In order to minimize the control losses it is preferable to select a semiconductor having a barrier layer the squared resistance value of which is very high in relation to the resistance of the crystal barrier layer.

What we claim is:

1. Multi-electrode crystal device for producing electronic relay action comprising a semi-conductor element having at least two zones of different conductivity characteristics, one of said zones being substantially of ring shape and the other zone comprising two substantially conically shaped portions extending axially from opposite directions along the axis and toward the center of the ring zone; said conical portions joining the ring zone in conical surfaces, said joining surfaces comprising at least one barrier layer, and said conical and ring shaped zones comprising individual metallic electrodes.

2. Device according to claim 1 wherein each of said conical portions has a separate electrode.

3. Device according to claim 1 wherein said conical portions meet with their tips at the center of the ring zone.

HERBERT FRANÇOIS MATARÉ.
HEINRICH WELKER.

References Cited in the file of this patent
UNITED STATES PATENTS

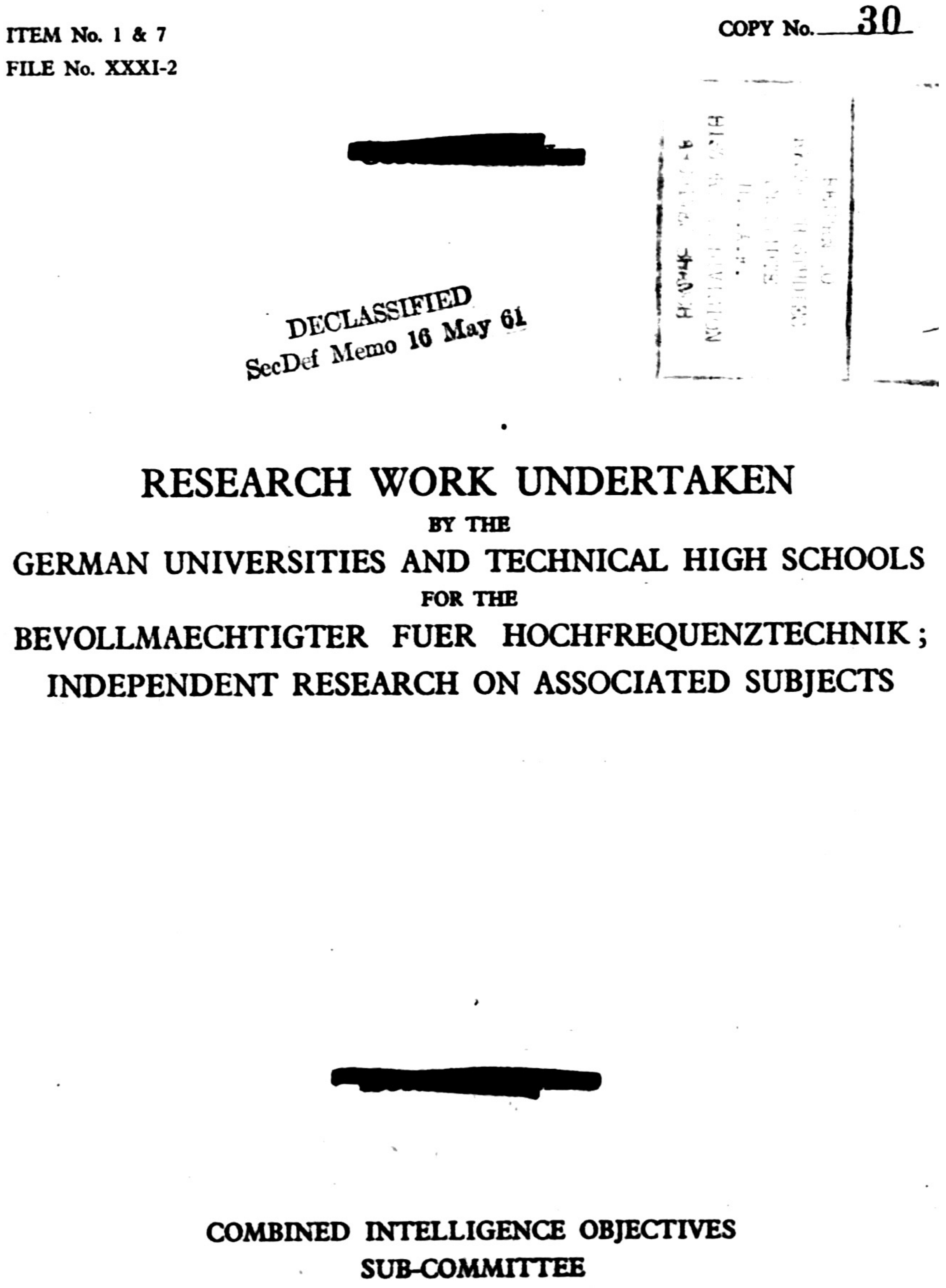
Number	Name	Date
837,616	Dunwoody	Dec. 4, 1906
1,949,383	Weber	Feb. 27, 1934
2,328,440	Esseling et al	Aug. 31, 1943
2,476,323	Rack	July 19, 1949
2,502,479	Pearson	Apr. 4, 1950
2,524,035	Bardeen	Oct. 3, 1950
2,538,593	Rose	Jan. 16, 1951
2,552,052	Matare	May 8, 1951
2,555,001	Ohl	May 29, 1951
2,569,347	Shockley	Sept. 25, 1951

Figure B.59: Heinrich Welker and Herbert Mataré began developing a point-contact transistor in Germany during the war, filed a detailed patent application based on that wartime work on 6 April 1945, and publicly announced their transistor in 1948 in France.

[**8. Erwin Weise (German?, 19??–19??)** admitted to Allied investigators that he "had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes" to create "electronic amplifiers without vacuum" (p. 2724).

For more information, see:

> CIOS XXXI-2. *Research Work Undertaken by the German Universities and Technical High Schools for the Bevollmaechtigter fuer Hochfrequenztechnik; Independent Research on Associated Subjects.* (pp. 2722–2724)
>
> BIOS 1658. *Interrogation of Erwin Weise. Research and Development of Semi-Conducting Materials. Practical Applications for Ultra-Sensitive Temperature Measuring Equipment and Automatic Control and Stabilizing Problems.*(pp. 2725–2729)
>
> Erwin Weise. Filed 1940. German patent DE 721,677. Einrichtung zur Entnahme gleichbleibender Gleich- oder Wechselspannung aus Netzen mit schwankender Spannung. [Device for Drawing Constant Direct or Alternating Voltage from Networks with Fluctuating Voltage.] (pp. 2730–2733)]



ITEM No. 1 & 7
FILE No. XXXI-2

COPY No. 30

[redacted]

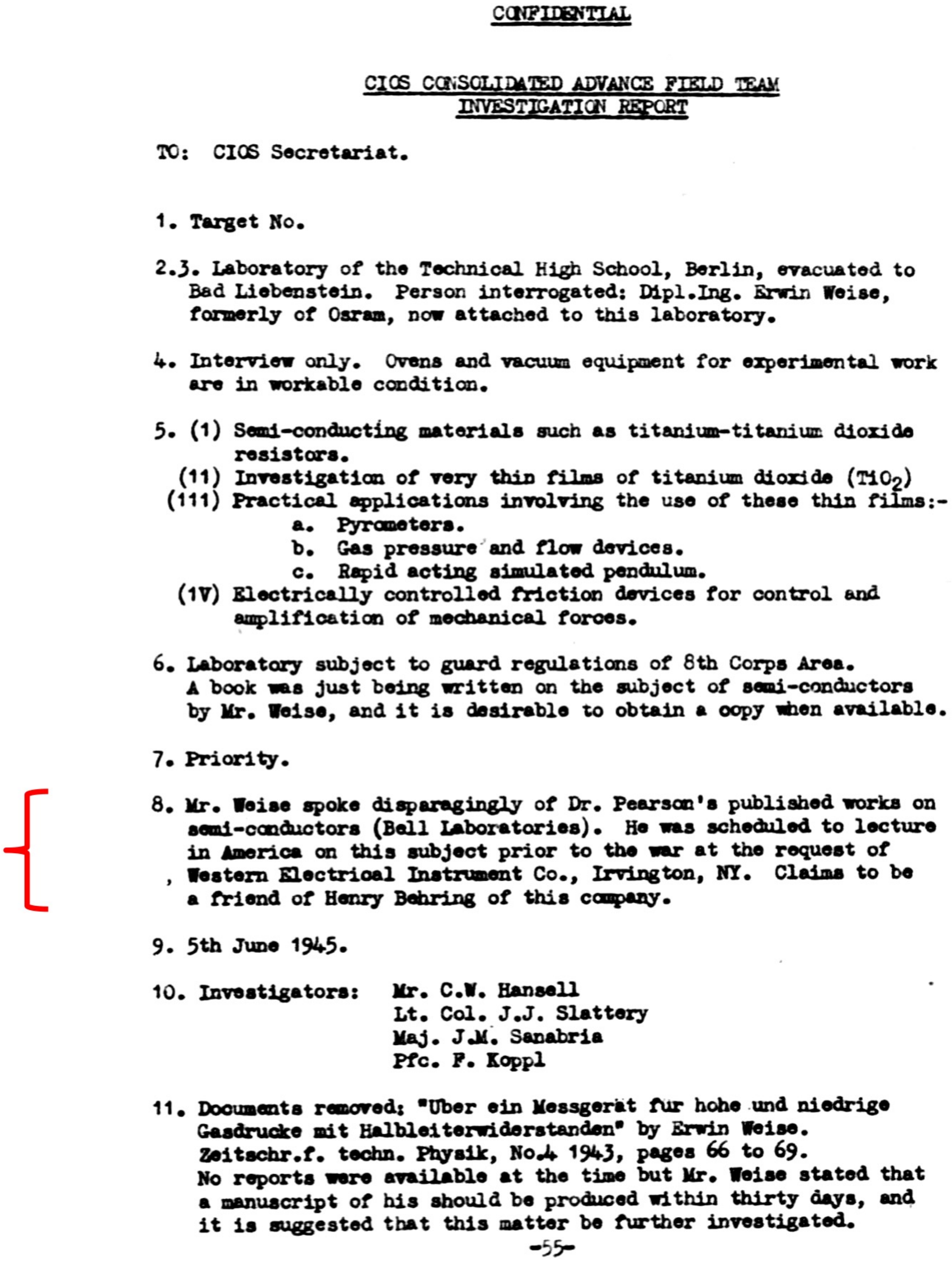
DECLASSIFIED
SecDef Memo 16 May 61

RESEARCH WORK UNDERTAKEN
BY THE
GERMAN UNIVERSITIES AND TECHNICAL HIGH SCHOOLS
FOR THE
BEVOLLMAECHTIGTER FUER HOCHFREQUENZTECHNIK;
INDEPENDENT RESEARCH ON ASSOCIATED SUBJECTS

[redacted]

COMBINED INTELLIGENCE OBJECTIVES
SUB-COMMITTEE

Figure B.60: Erwin Weise told Allied investigators that he “had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes” to create “electronic amplifiers without vacuum.”



CONFIDENTIAL

CIOS CONSOLIDATED ADVANCE FIELD TEAM
INVESTIGATION REPORT

TO: CIOS Secretariat.

1. Target No.

2.3. Laboratory of the Technical High School, Berlin, evacuated to Bad Liebenstein. Person interrogated: Dipl.Ing. Erwin Weise, formerly of Osram, now attached to this laboratory.

4. Interview only. Ovens and vacuum equipment for experimental work are in workable condition.

5. (1) Semi-conducting materials such as titanium-titanium dioxide resistors.
(11) Investigation of very thin films of titanium dioxide (TiO_2)
(111) Practical applications involving the use of these thin films:-
    a. Pyrometers.
    b. Gas pressure and flow devices.
    c. Rapid acting simulated pendulum.
(1V) Electrically controlled friction devices for control and amplification of mechanical forces.

6. Laboratory subject to guard regulations of 8th Corps Area. A book was just being written on the subject of semi-conductors by Mr. Weise, and it is desirable to obtain a copy when available.

7. Priority.

8. Mr. Weise spoke disparagingly of Dr. Pearson's published works on semi-conductors (Bell Laboratories). He was scheduled to lecture in America on this subject prior to the war at the request of Western Electrical Instrument Co., Irvington, NY. Claims to be a friend of Henry Behring of this company.

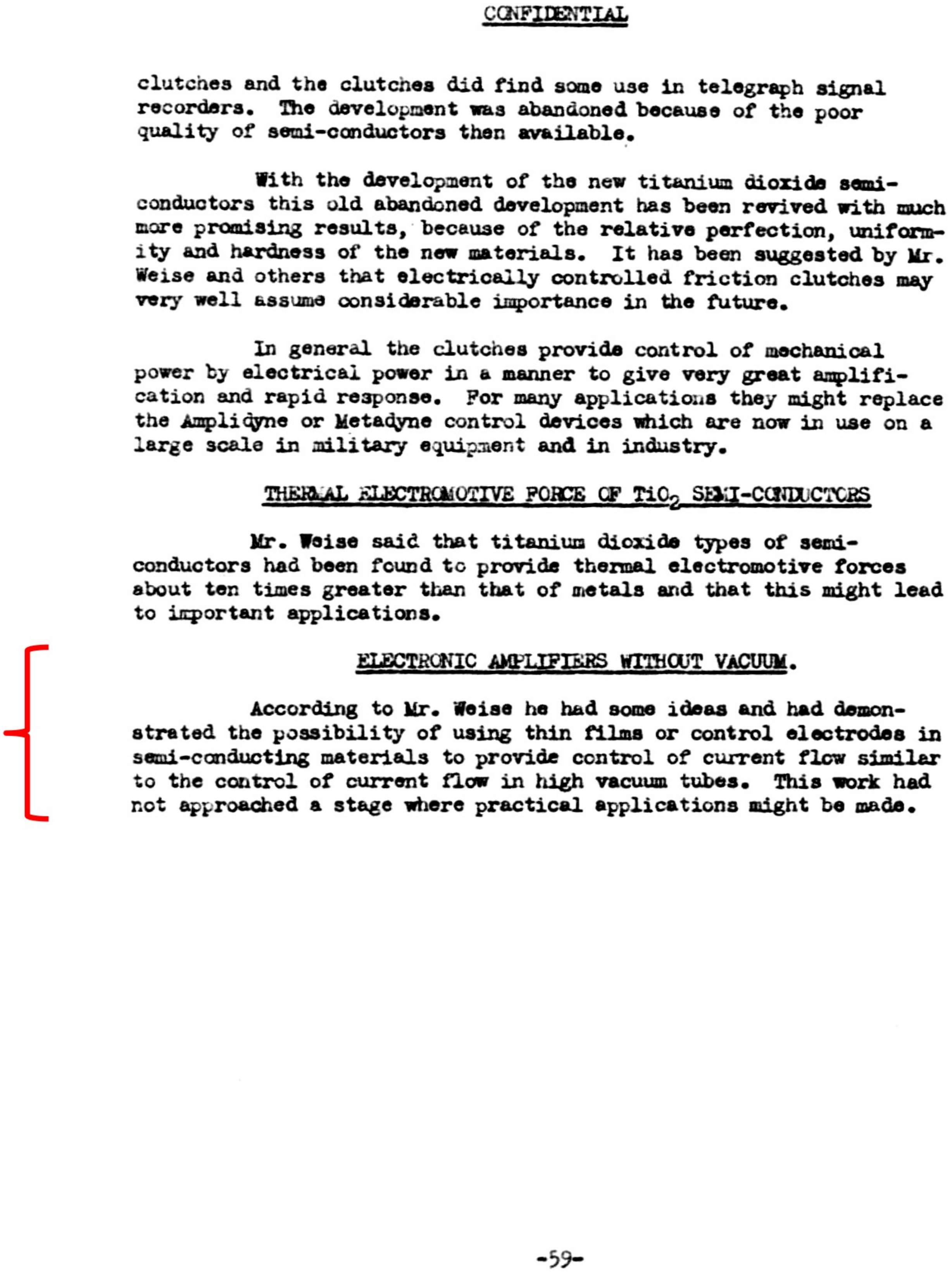
9. 5th June 1945.

10. Investigators: Mr. C.W. Hansell
Lt. Col. J.J. Slattery
Maj. J.M. Sanabria
Pfc. F. Koppl

11. Documents removed: "Uber ein Messgerat fur hohe und niedrige Gasdrucke mit Halbleiterwiderstanden" by Erwin Weise. Zeitschr.f. techn. Physik, No.4 1943, pages 66 to 69. No reports were available at the time but Mr. Weise stated that a manuscript of his should be produced within thirty days, and it is suggested that this matter be further investigated.

-55-

Figure B.61: Erwin Weise told Allied investigators that he "had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes" to create "electronic amplifiers without vacuum."



CONFIDENTIAL

clutches and the clutches did find some use in telegraph signal recorders. The development was abandoned because of the poor quality of semi-conductors then available.

With the development of the new titanium dioxide semi-conductors this old abandoned development has been revived with much more promising results, because of the relative perfection, uniformity and hardness of the new materials. It has been suggested by Mr. Weise and others that electrically controlled friction clutches may very well assume considerable importance in the future.

In general the clutches provide control of mechanical power by electrical power in a manner to give very great amplification and rapid response. For many applications they might replace the Amplidyne or Metadyne control devices which are now in use on a large scale in military equipment and in industry.

THERMAL ELECTROMOTIVE FORCE OF TiO_2 SEMI-CONDUCTORS

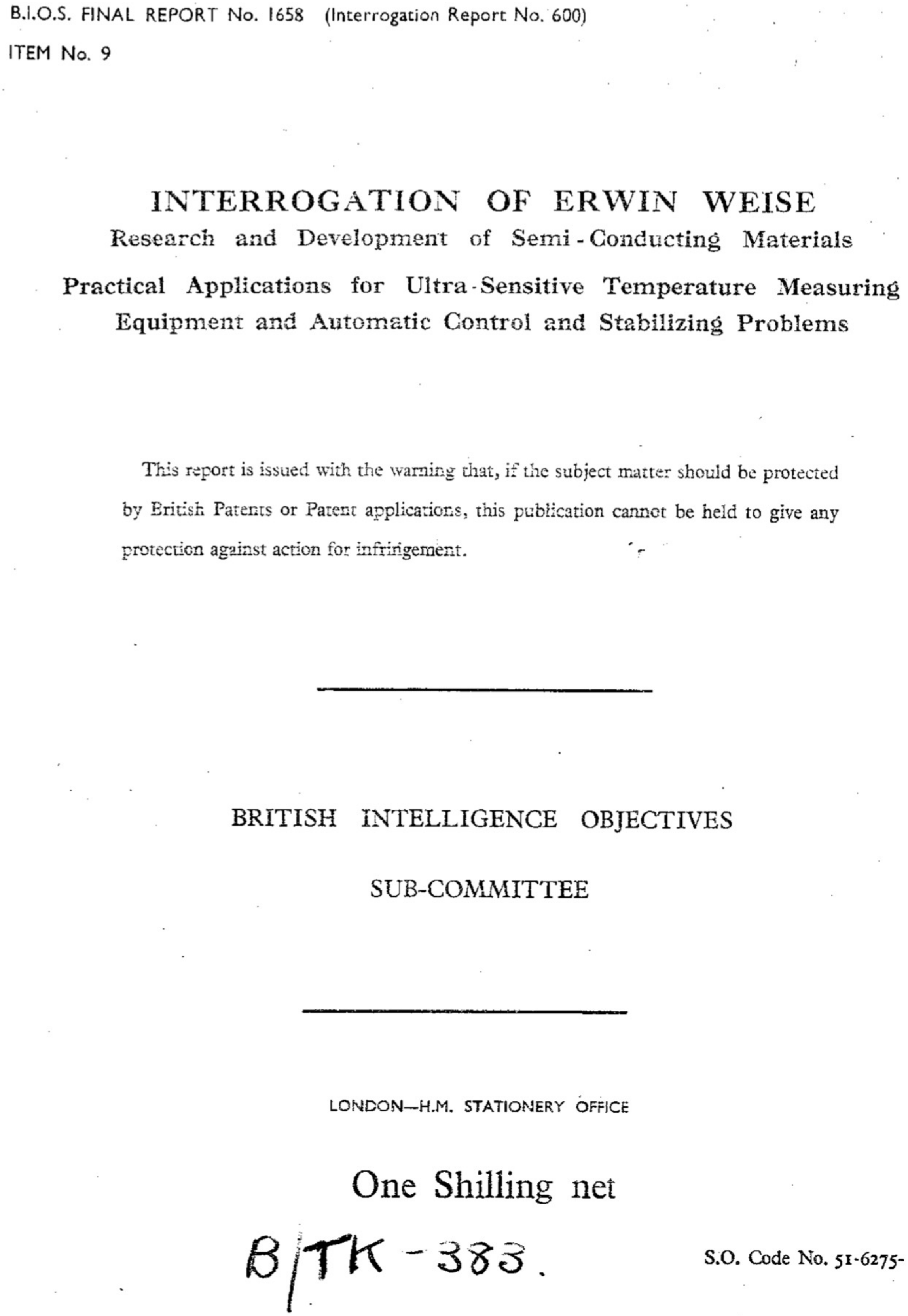
Mr. Weise said that titanium dioxide types of semi-conductors had been found to provide thermal electromotive forces about ten times greater than that of metals and that this might lead to important applications.

ELECTRONIC AMPLIFIERS WITHOUT VACUUM.

According to Mr. Weise he had some ideas and had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes. This work had not approached a stage where practical applications might be made.

-59-

Figure B.62: Erwin Weise told Allied investigators that he “had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes” to create “electronic amplifiers without vacuum.”



B.I.O.S. FINAL REPORT No. 1658 (Interrogation Report No. 600)

ITEM No. 9

INTERROGATION OF ERWIN WEISE

Research and Development of Semi-Conducting Materials

Practical Applications for Ultra-Sensitive Temperature Measuring Equipment and Automatic Control and Stabilizing Problems

This report is issued with the warning that, if the subject matter should be protected by British Patents or Patent applications, this publication cannot be held to give any protection against action for infringement.

BRITISH INTELLIGENCE OBJECTIVES

SUB-COMMITTEE

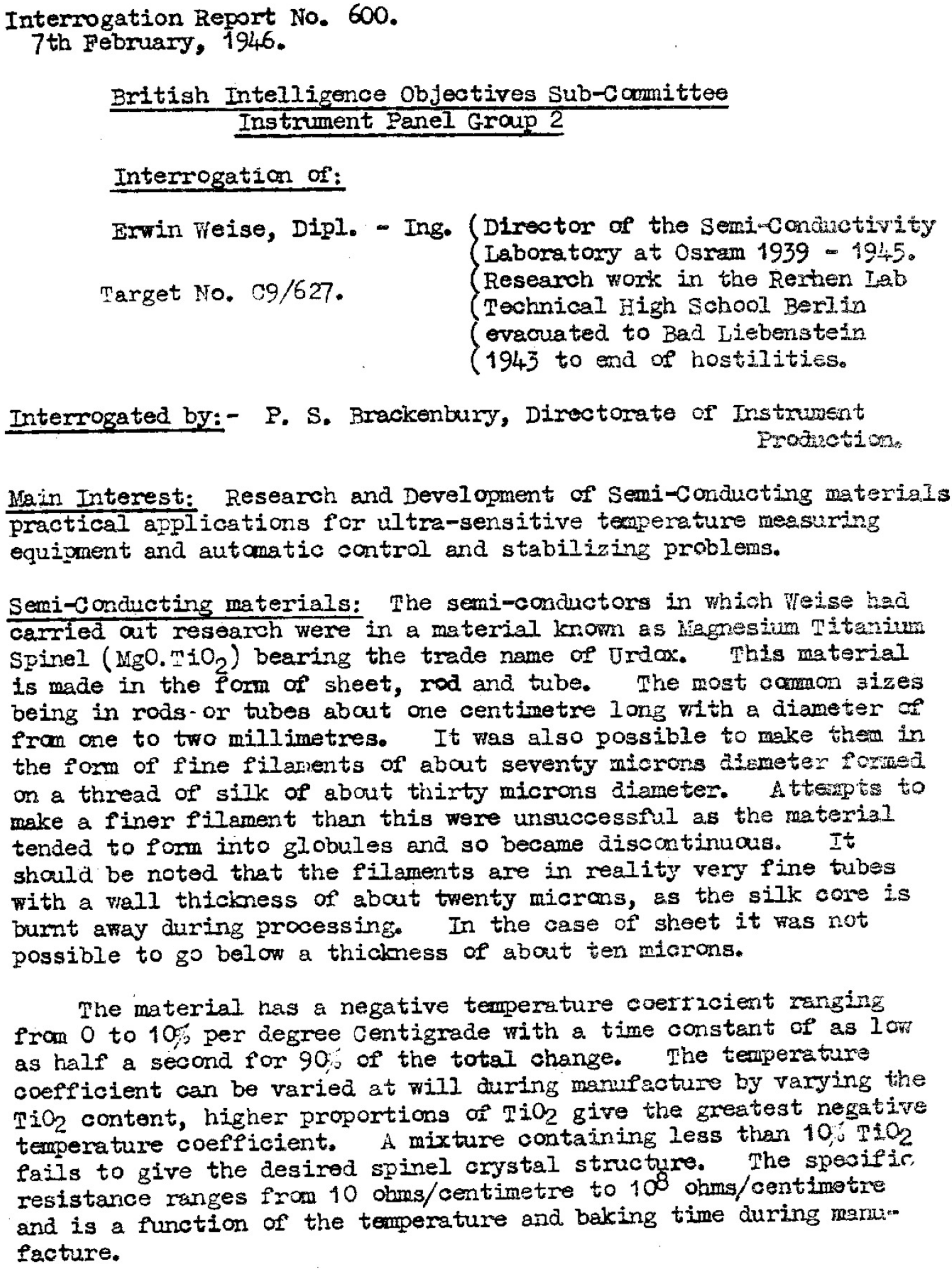
LONDON—H.M. STATIONERY OFFICE

One Shilling net

B/TK - 383.

S.O. Code No. 51-6275-

Figure B.63: Erwin Weise told Allied investigators that he “had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes” to create “electronic amplifiers without vacuum.”



Interrogation Report No. 600.
7th February, 1946.

British Intelligence Objectives Sub-Committee
Instrument Panel Group 2

Interrogation of:

Erwin Weise, Dipl. - Ing. (Director of the Semi-Conductivity
(Laboratory at Osram 1939 - 1945.
(Research work in the Rerhen Lab
(Technical High School Berlin
(evacuated to Bad Liebenstein
(1943 to end of hostilities.

Target No. C9/627.

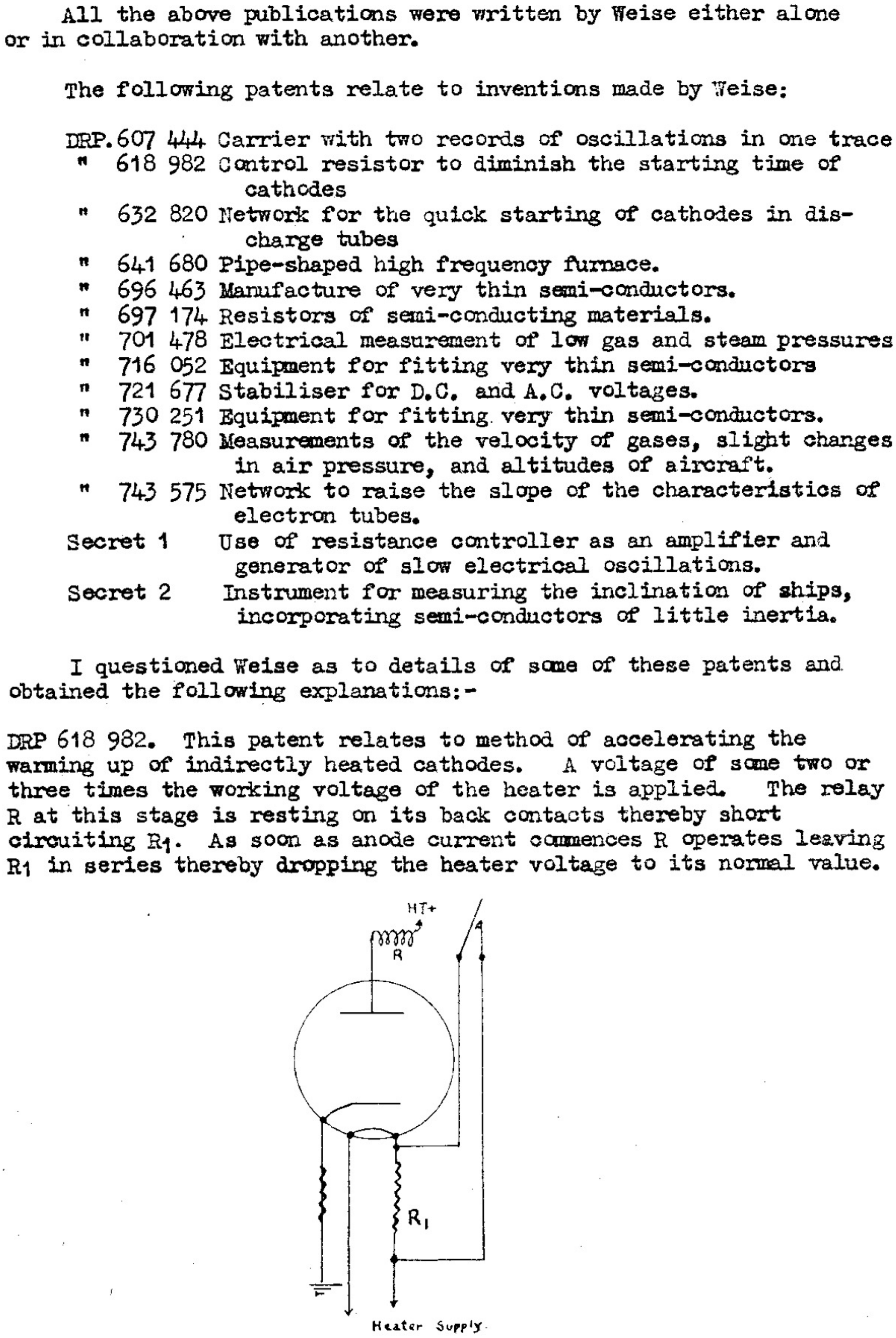
Interrogated by:- P. S. Brackenbury, Directorate of Instrument Production.

Main Interest: Research and Development of Semi-Conducting materials, practical applications for ultra-sensitive temperature measuring equipment and automatic control and stabilizing problems.

Semi-Conducting materials: The semi-conductors in which Weise had carried out research were in a material known as Magnesium Titanium Spinel ($MgO.TiO_2$) bearing the trade name of Urdox. This material is made in the form of sheet, rod and tube. The most common sizes being in rods or tubes about one centimetre long with a diameter of from one to two millimetres. It was also possible to make them in the form of fine filaments of about seventy microns diameter formed on a thread of silk of about thirty microns diameter. Attempts to make a finer filament than this were unsuccessful as the material tended to form into globules and so became discontinuous. It should be noted that the filaments are in reality very fine tubes with a wall thickness of about twenty microns, as the silk core is burnt away during processing. In the case of sheet it was not possible to go below a thickness of about ten microns.

The material has a negative temperature coefficient ranging from 0 to 10% per degree Centigrade with a time constant of as low as half a second for 90% of the total change. The temperature coefficient can be varied at will during manufacture by varying the TiO_2 content, higher proportions of TiO_2 give the greatest negative temperature coefficient. A mixture containing less than 10% TiO_2 fails to give the desired spinel crystal structure. The specific resistance ranges from 10 ohms/centimetre to 10^8 ohms/centimetre and is a function of the temperature and baking time during manufacture.

Figure B.64: Erwin Weise told Allied investigators that he “had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes” to create “electronic amplifiers without vacuum.”



All the above publications were written by Weise either alone or in collaboration with another.

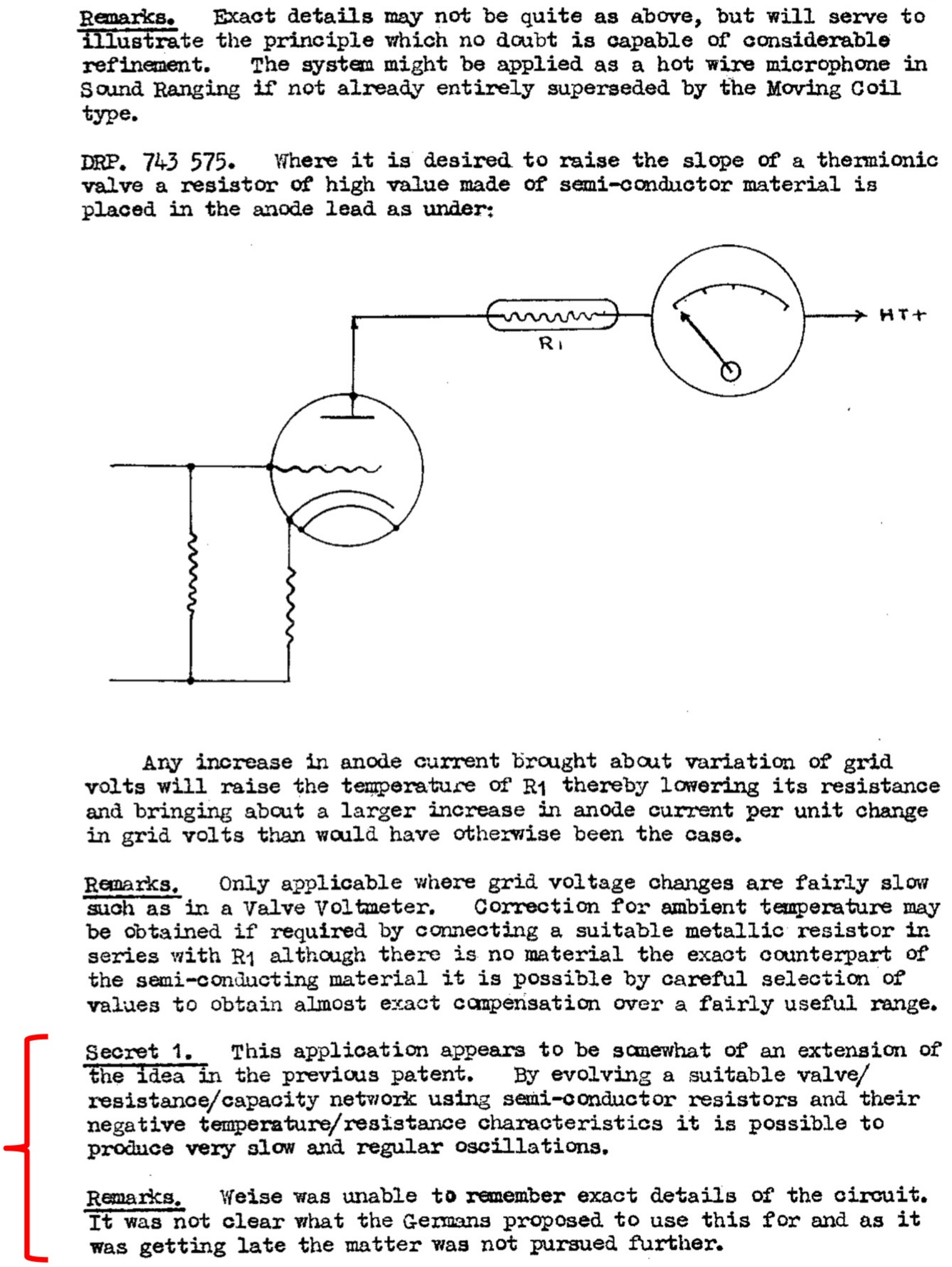
The following patents relate to inventions made by Weise:

DRP.	607 444	Carrier with two records of oscillations in one trace
"	618 982	Control resistor to diminish the starting time of cathodes
"	632 820	Network for the quick starting of cathodes in discharge tubes
"	641 680	Pipe-shaped high frequency furnace.
"	696 463	Manufacture of very thin semi-conductors.
"	697 174	Resistors of semi-conducting materials.
"	701 478	Electrical measurement of low gas and steam pressures
"	716 052	Equipment for fitting very thin semi-conductors
"	721 677	Stabiliser for D.C. and A.C. voltages.
"	730 251	Equipment for fitting very thin semi-conductors.
"	743 780	Measurements of the velocity of gases, slight changes in air pressure, and altitudes of aircraft.
"	743 575	Network to raise the slope of the characteristics of electron tubes.
Secret 1		Use of resistance controller as an amplifier and generator of slow electrical oscillations.
Secret 2		Instrument for measuring the inclination of ships, incorporating semi-conductors of little inertia.

I questioned Weise as to details of some of these patents and obtained the following explanations:-

DRP 618 982. This patent relates to method of accelerating the warming up of indirectly heated cathodes. A voltage of some two or three times the working voltage of the heater is applied. The relay R at this stage is resting on its back contacts thereby short circuiting R_1. As soon as anode current commences R operates leaving R_1 in series thereby dropping the heater voltage to its normal value.

Figure B.65: Erwin Weise told Allied investigators that he “had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes” to create “electronic amplifiers without vacuum.”



Remarks. Exact details may not be quite as above, but will serve to illustrate the principle which no doubt is capable of considerable refinement. The system might be applied as a hot wire microphone in Sound Ranging if not already entirely superseded by the Moving Coil type.

DRP. 743 575. Where it is desired to raise the slope of a thermionic valve a resistor of high value made of semi-conductor material is placed in the anode lead as under:

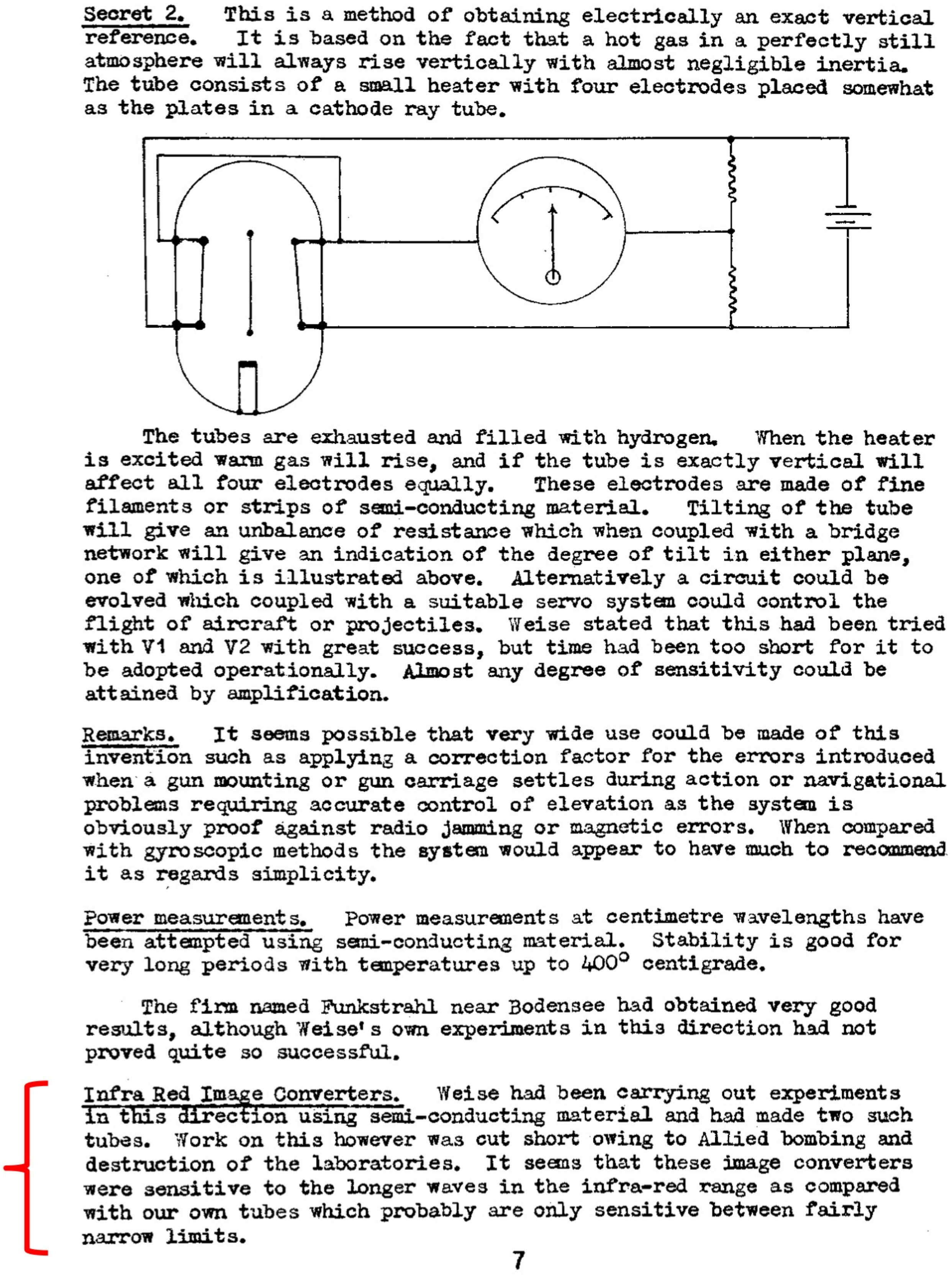
Any increase in anode current brought about variation of grid volts will raise the temperature of R1 thereby lowering its resistance and bringing about a larger increase in anode current per unit change in grid volts than would have otherwise been the case.

Remarks. Only applicable where grid voltage changes are fairly slow such as in a Valve Voltmeter. Correction for ambient temperature may be obtained if required by connecting a suitable metallic resistor in series with R1 although there is no material the exact counterpart of the semi-conducting material it is possible by careful selection of values to obtain almost exact compensation over a fairly useful range.

Secret 1. This application appears to be somewhat of an extension of the idea in the previous patent. By evolving a suitable valve/resistance/capacity network using semi-conductor resistors and their negative temperature/resistance characteristics it is possible to produce very slow and regular oscillations.

Remarks. Weise was unable to remember exact details of the circuit. It was not clear what the Germans proposed to use this for and as it was getting late the matter was not pursued further.

Figure B.66: Erwin Weise told Allied investigators that he "had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes" to create "electronic amplifiers without vacuum."



Secret 2. This is a method of obtaining electrically an exact vertical reference. It is based on the fact that a hot gas in a perfectly still atmosphere will always rise vertically with almost negligible inertia. The tube consists of a small heater with four electrodes placed somewhat as the plates in a cathode ray tube.

The tubes are exhausted and filled with hydrogen. When the heater is excited warm gas will rise, and if the tube is exactly vertical will affect all four electrodes equally. These electrodes are made of fine filaments or strips of semi-conducting material. Tilting of the tube will give an unbalance of resistance which when coupled with a bridge network will give an indication of the degree of tilt in either plane, one of which is illustrated above. Alternatively a circuit could be evolved which coupled with a suitable servo system could control the flight of aircraft or projectiles. Weise stated that this had been tried with V1 and V2 with great success, but time had been too short for it to be adopted operationally. Almost any degree of sensitivity could be attained by amplification.

Remarks. It seems possible that very wide use could be made of this invention such as applying a correction factor for the errors introduced when a gun mounting or gun carriage settles during action or navigational problems requiring accurate control of elevation as the system is obviously proof against radio jamming or magnetic errors. When compared with gyroscopic methods the system would appear to have much to recommend it as regards simplicity.

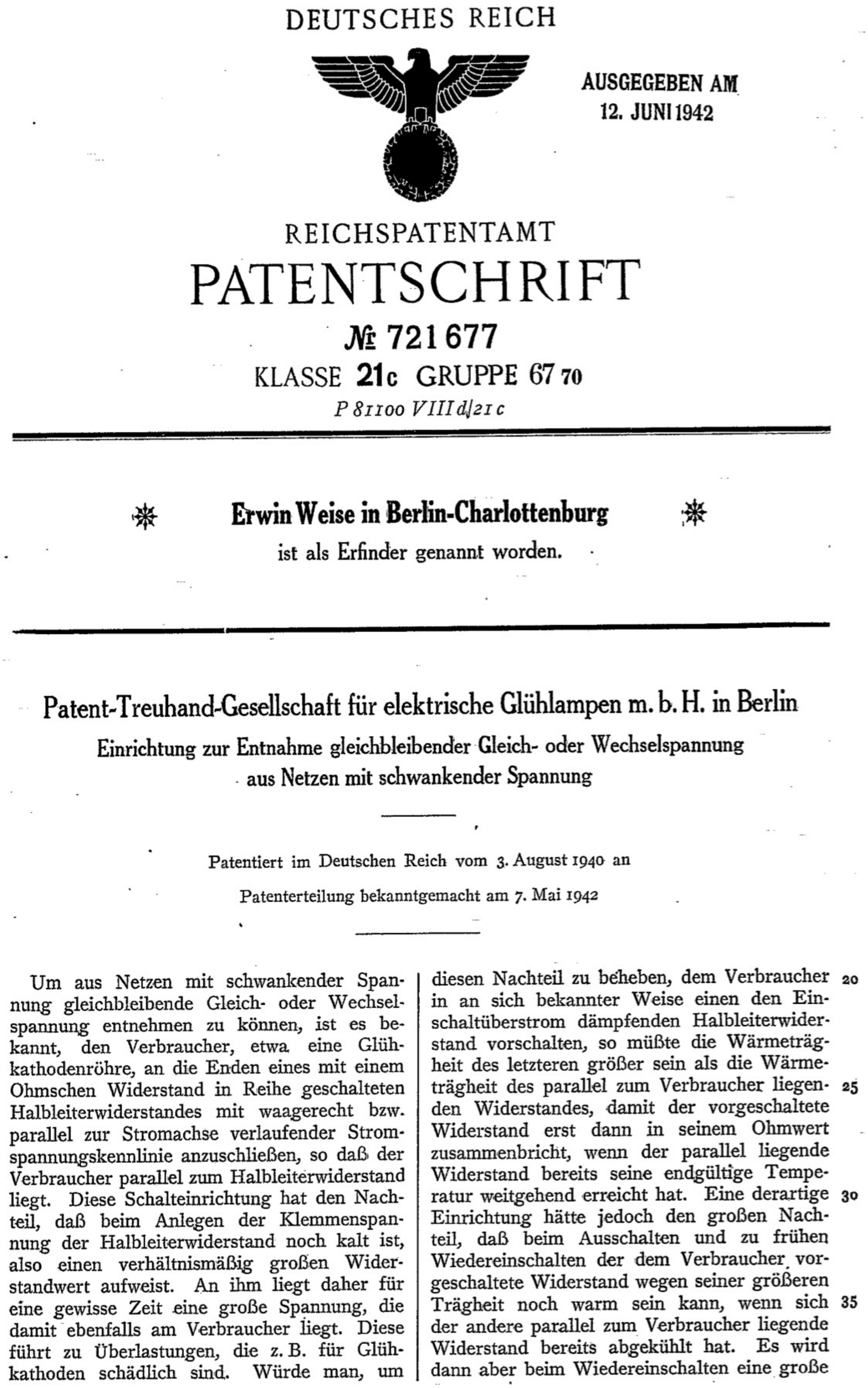
Power measurements. Power measurements at centimetre wavelengths have been attempted using semi-conducting material. Stability is good for very long periods with temperatures up to 400° centigrade.

The firm named Funkstrahl near Bodensee had obtained very good results, although Weise's own experiments in this direction had not proved quite so successful.

Infra Red Image Converters. Weise had been carrying out experiments in this direction using semi-conducting material and had made two such tubes. Work on this however was cut short owing to Allied bombing and destruction of the laboratories. It seems that these image converters were sensitive to the longer waves in the infra-red range as compared with our own tubes which probably are only sensitive between fairly narrow limits.

7

Figure B.67: Erwin Weise told Allied investigators that he “had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes” to create “electronic amplifiers without vacuum.”



DEUTSCHES REICH

AUSGEGEBEN AM
12. JUNI 1942

REICHSPATENTAMT

PATENTSCHRIFT

№ 721 677

KLASSE **21c** GRUPPE 67 70

P 81100 VIIId/21c

Erwin Weise in Berlin-Charlottenburg

ist als Erfinder genannt worden.

Patent-Treuhand-Gesellschaft für elektrische Glühlampen m. b. H. in Berlin

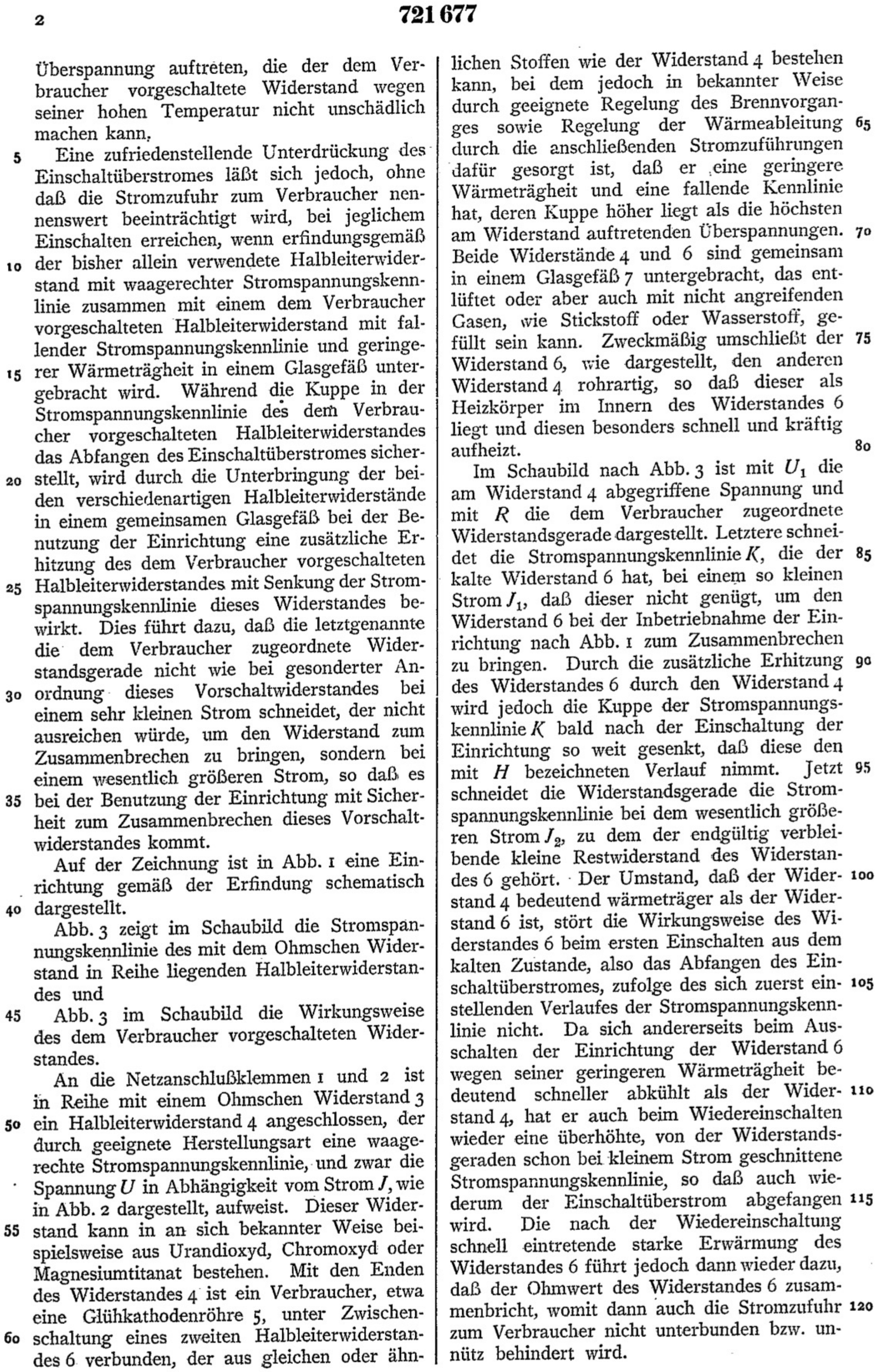
Einrichtung zur Entnahme gleichbleibender Gleich- oder Wechselspannung aus Netzen mit schwankender Spannung

Patentiert im Deutschen Reich vom 3. August 1940 an

Patenterteilung bekanntgemacht am 7. Mai 1942

Um aus Netzen mit schwankender Spannung gleichbleibende Gleich- oder Wechselspannung entnehmen zu können, ist es bekannt, den Verbraucher, etwa eine Glühkathodenröhre, an die Enden eines mit einem Ohmschen Widerstand in Reihe geschalteten Halbleiterwiderstandes mit waagerecht bzw. parallel zur Stromachse verlaufender Stromspannungskennlinie anzuschließen, so daß der Verbraucher parallel zum Halbleiterwiderstand liegt. Diese Schalteinrichtung hat den Nachteil, daß beim Anlegen der Klemmenspannung der Halbleiterwiderstand noch kalt ist, also einen verhältnismäßig großen Widerstandwert aufweist. An ihm liegt daher für eine gewisse Zeit eine große Spannung, die damit ebenfalls am Verbraucher liegt. Diese führt zu Überlastungen, die z. B. für Glühkathoden schädlich sind. Würde man, um diesen Nachteil zu beheben, dem Verbraucher in an sich bekannter Weise einen den Einschaltüberstrom dämpfenden Halbleiterwiderstand vorschalten, so müßte die Wärmeträgheit des letzteren größer sein als die Wärmeträgheit des parallel zum Verbraucher liegenden Widerstandes, damit der vorgeschaltete Widerstand erst dann in seinem Ohmwert zusammenbricht, wenn der parallel liegende Widerstand bereits seine endgültige Temperatur weitgehend erreicht hat. Eine derartige Einrichtung hätte jedoch den großen Nachteil, daß beim Ausschalten und zu frühen Wiedereinschalten der dem Verbraucher vorgeschaltete Widerstand wegen seiner größeren Trägheit noch warm sein kann, wenn sich der andere parallel zum Verbraucher liegende Widerstand bereits abgekühlt hat. Es wird dann aber beim Wiedereinschalten eine große

Figure B.68: Erwin Weise told Allied investigators that he “had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes” to create “electronic amplifiers without vacuum.”



2 **721 677**

Überspannung auftreten, die der dem Verbraucher vorgeschaltete Widerstand wegen seiner hohen Temperatur nicht unschädlich machen kann.

Eine zufriedenstellende Unterdrückung des Einschaltüberstromes läßt sich jedoch, ohne daß die Stromzufuhr zum Verbraucher nennenswert beeinträchtigt wird, bei jeglichem Einschalten erreichen, wenn erfindungsgemäß der bisher allein verwendete Halbleiterwiderstand mit waagerechter Stromspannungskennlinie zusammen mit einem dem Verbraucher vorgeschalteten Halbleiterwiderstand mit fallender Stromspannungskennlinie und geringerer Wärmeträgheit in einem Glasgefäß untergebracht wird. Während die Kuppe in der Stromspannungskennlinie des dem Verbraucher vorgeschalteten Halbleiterwiderstandes das Abfangen des Einschaltüberstromes sicherstellt, wird durch die Unterbringung der beiden verschiedenartigen Halbleiterwiderstände in einem gemeinsamen Glasgefäß bei der Benutzung der Einrichtung eine zusätzliche Erhitzung des dem Verbraucher vorgeschalteten Halbleiterwiderstandes mit Senkung der Stromspannungskennlinie dieses Widerstandes bewirkt. Dies führt dazu, daß die letztgenannte die dem Verbraucher zugeordnete Widerstandsgerade nicht wie bei gesonderter Anordnung dieses Vorschaltwiderstandes bei einem sehr kleinen Strom schneidet, der nicht ausreichen würde, um den Widerstand zum Zusammenbrechen zu bringen, sondern bei einem wesentlich größeren Strom, so daß es bei der Benutzung der Einrichtung mit Sicherheit zum Zusammenbrechen dieses Vorschaltwiderstandes kommt.

Auf der Zeichnung ist in Abb. 1 eine Einrichtung gemäß der Erfindung schematisch dargestellt.

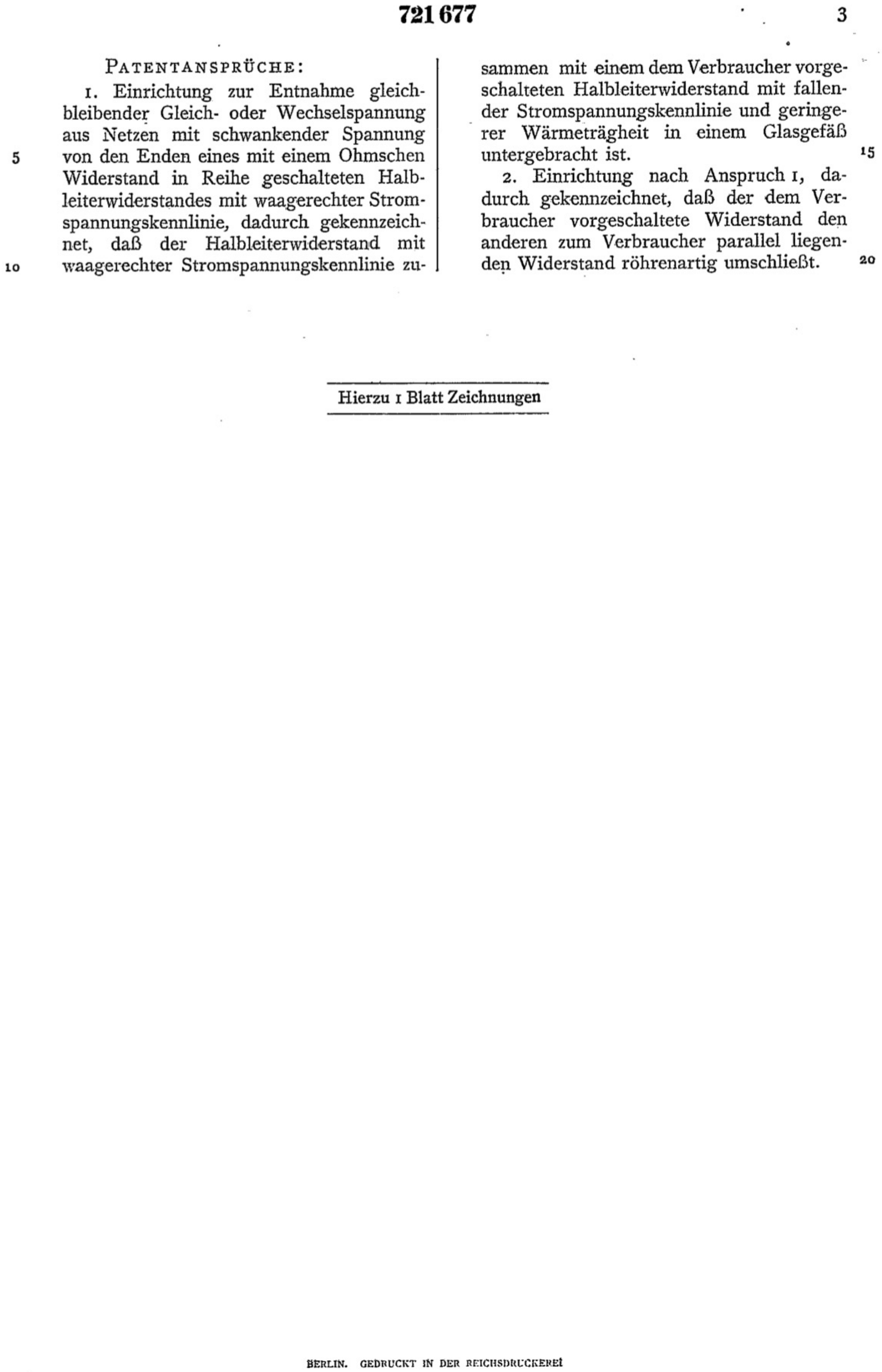
Abb. 3 zeigt im Schaubild die Stromspannungskennlinie des mit dem Ohmschen Widerstand in Reihe liegenden Halbleiterwiderstandes und

Abb. 3 im Schaubild die Wirkungsweise des dem Verbraucher vorgeschalteten Widerstandes.

An die Netzanschlußklemmen 1 und 2 ist in Reihe mit einem Ohmschen Widerstand 3 ein Halbleiterwiderstand 4 angeschlossen, der durch geeignete Herstellungsart eine waagerechte Stromspannungskennlinie, und zwar die Spannung U in Abhängigkeit vom Strom J, wie in Abb. 2 dargestellt, aufweist. Dieser Widerstand kann in an sich bekannter Weise beispielsweise aus Urandioxyd, Chromoxyd oder Magnesiumtitanat bestehen. Mit den Enden des Widerstandes 4 ist ein Verbraucher, etwa eine Glühkathodenröhre 5, unter Zwischenschaltung eines zweiten Halbleiterwiderstandes 6 verbunden, der aus gleichen oder ähnlichen Stoffen wie der Widerstand 4 bestehen kann, bei dem jedoch in bekannter Weise durch geeignete Regelung des Brennvorganges sowie Regelung der Wärmeableitung durch die anschließenden Stromzuführungen dafür gesorgt ist, daß er eine geringere Wärmeträgheit und eine fallende Kennlinie hat, deren Kuppe höher liegt als die höchsten am Widerstand auftretenden Überspannungen. Beide Widerstände 4 und 6 sind gemeinsam in einem Glasgefäß 7 untergebracht, das entlüftet oder aber auch mit nicht angreifenden Gasen, wie Stickstoff oder Wasserstoff, gefüllt sein kann. Zweckmäßig umschließt der Widerstand 6, wie dargestellt, den anderen Widerstand 4 rohrartig, so daß dieser als Heizkörper im Innern des Widerstandes 6 liegt und diesen besonders schnell und kräftig aufheizt.

Im Schaubild nach Abb. 3 ist mit U_1 die am Widerstand 4 abgegriffene Spannung und mit R die dem Verbraucher zugeordnete Widerstandsgerade dargestellt. Letztere schneidet die Stromspannungskennlinie K, die der kalte Widerstand 6 hat, bei einem so kleinen Strom J_1, daß dieser nicht genügt, um den Widerstand 6 bei der Inbetriebnahme der Einrichtung nach Abb. 1 zum Zusammenbrechen zu bringen. Durch die zusätzliche Erhitzung des Widerstandes 6 durch den Widerstand 4 wird jedoch die Kuppe der Stromspannungskennlinie K bald nach der Einschaltung der Einrichtung so weit gesenkt, daß diese den mit H bezeichneten Verlauf nimmt. Jetzt schneidet die Widerstandsgerade die Stromspannungskennlinie bei dem wesentlich größeren Strom J_2, zu dem der endgültig verbleibende kleine Restwiderstand des Widerstandes 6 gehört. Der Umstand, daß der Widerstand 4 bedeutend wärmeträger als der Widerstand 6 ist, stört die Wirkungsweise des Widerstandes 6 beim ersten Einschalten aus dem kalten Zustande, also das Abfangen des Einschaltüberstromes, zufolge des sich zuerst einstellenden Verlaufes der Stromspannungskennlinie nicht. Da sich andererseits beim Ausschalten der Einrichtung der Widerstand 6 wegen seiner geringeren Wärmeträgheit bedeutend schneller abkühlt als der Widerstand 4, hat er auch beim Wiedereinschalten wieder eine überhöhte, von der Widerstandsgeraden schon bei kleinem Strom geschnittene Stromspannungskennlinie, so daß auch wiederum der Einschaltüberstrom abgefangen wird. Die nach der Wiedereinschaltung schnell eintretende starke Erwärmung des Widerstandes 6 führt jedoch dann wieder dazu, daß der Ohmwert des Widerstandes 6 zusammenbricht, womit dann auch die Stromzufuhr zum Verbraucher nicht unterbunden bzw. unnütz behindert wird.

Figure B.69: Erwin Weise told Allied investigators that he "had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes" to create "electronic amplifiers without vacuum."



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PATENTANSPRÜCHE:

1. Einrichtung zur Entnahme gleichbleibender Gleich- oder Wechselspannung aus Netzen mit schwankender Spannung von den Enden eines mit einem Ohmschen Widerstand in Reihe geschalteten Halbleiterwiderstandes mit waagerechter Stromspannungskennlinie, dadurch gekennzeichnet, daß der Halbleiterwiderstand mit waagerechter Stromspannungskennlinie zusammen mit einem dem Verbraucher vorgeschalteten Halbleiterwiderstand mit fallender Stromspannungskennlinie und geringerer Wärmeträgheit in einem Glasgefäß untergebracht ist.

2. Einrichtung nach Anspruch 1, dadurch gekennzeichnet, daß der dem Verbraucher vorgeschaltete Widerstand den anderen zum Verbraucher parallel liegenden Widerstand röhrenartig umschließt.

Hierzu 1 Blatt Zeichnungen

BERLIN. GEDRUCKT IN DER REICHSDRUCKEREI

Figure B.70: Erwin Weise told Allied investigators that he "had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes" to create "electronic amplifiers without vacuum."

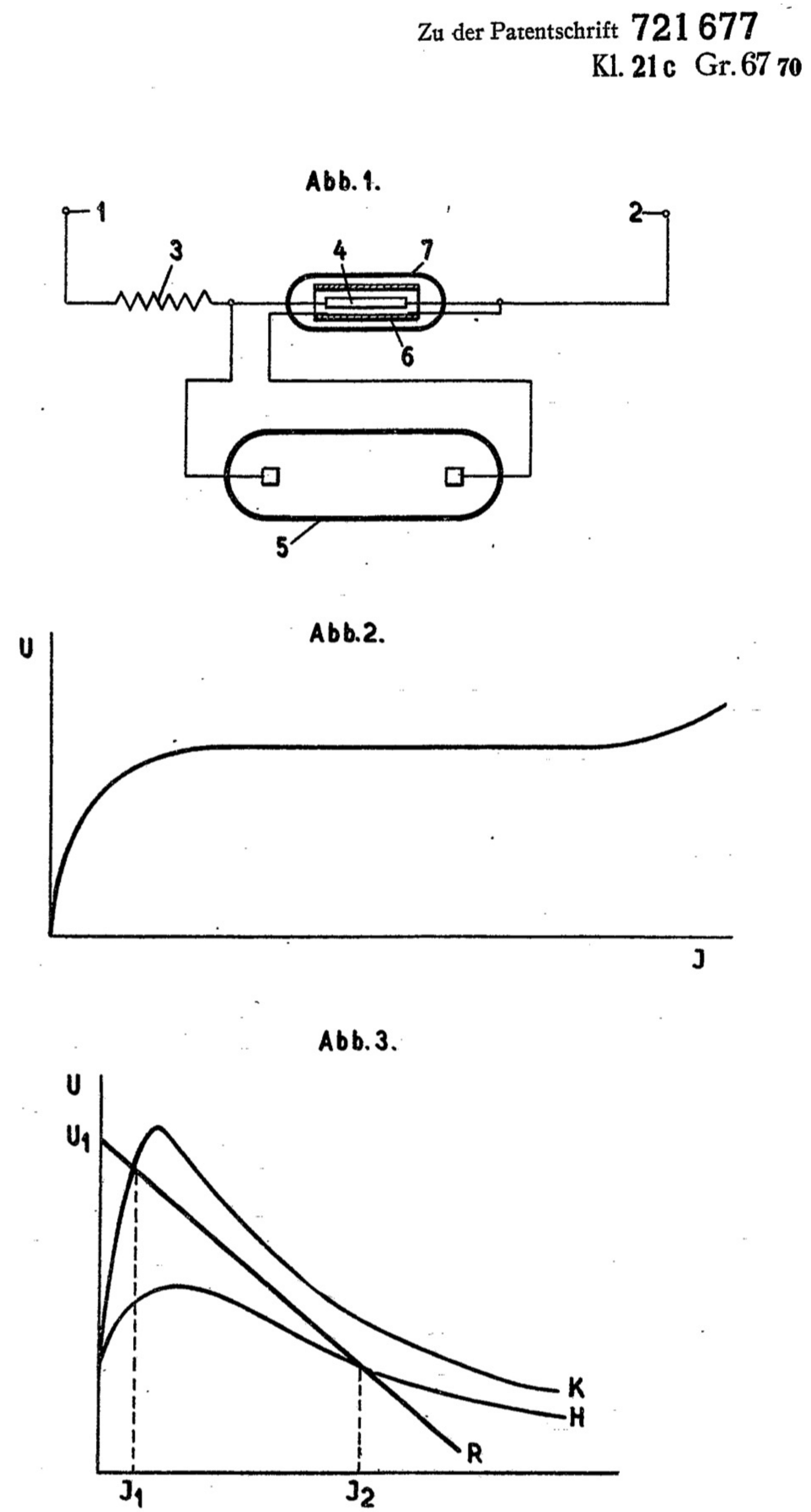
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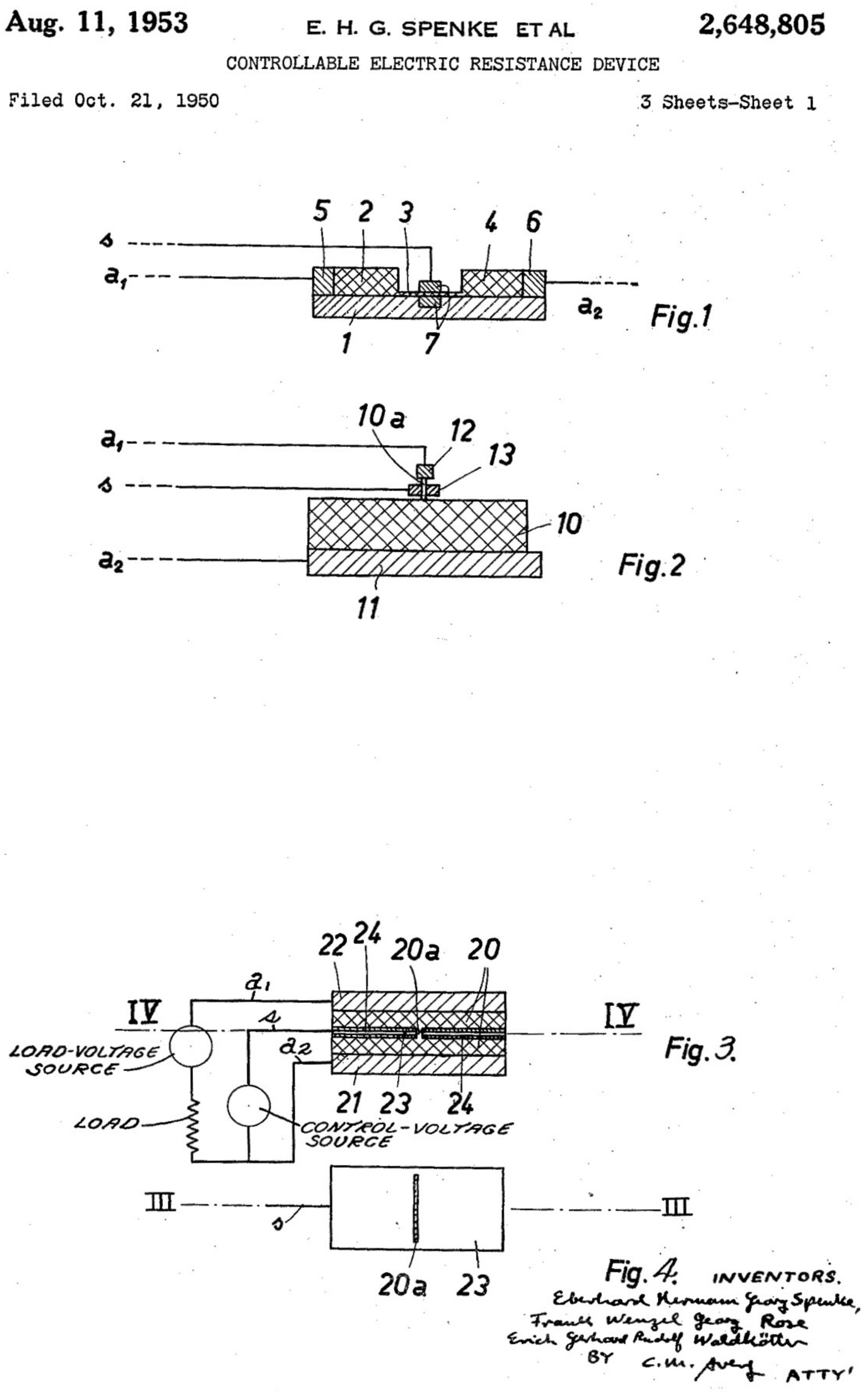
Figure B.71: Erwin Weise told Allied investigators that he "had demonstrated the possibility of using thin films or control electrodes in semi-conducting materials to provide control of current flow similar to the control of current flow in high vacuum tubes" to create "electronic amplifiers without vacuum."

[**9. Frank Rose (German?, 19??–19??), Eberhard Spenke (German, 1905–1992), and Erich Waldkötter (German?, 19??–19??)** filed detailed patent applications on transistors [Handel 1999]. See for example:

> Eberhard Spenke, Frank Rose, and Erich Waldkötter. Filed in 1949 but likely based on wartime work. U.S. patent 2,648,805. Controllable Electric Resistance Device. (pp. 2735–2744)

Because of the extreme political and financial restrictions on conducting research in Germany after the war, it seems likely that their patent applications were based on wartime work. Indeed, large numbers of patent applications on wartime inventions were filed in 1949 when the West German patent office opened.]



Aug. 11, 1953 E. H. G. SPENKE ET AL **2,648,805**

CONTROLLABLE ELECTRIC RESISTANCE DEVICE

Filed Oct. 21, 1950 3 Sheets-Sheet 1

5
2
3
4
6
s
a1
a2
1
7
Fig.1
10a
12
13
a1
s
10
a2
11
Fig.2
22
24
20a
20
a1
IV
IV
s
a2
LOAD-VOLTAGE SOURCE
LOAD
CONTROL-VOLTAGE SOURCE
21
23
24
Fig.3.
III
III
s
20a
23
Fig.4.

INVENTORS.
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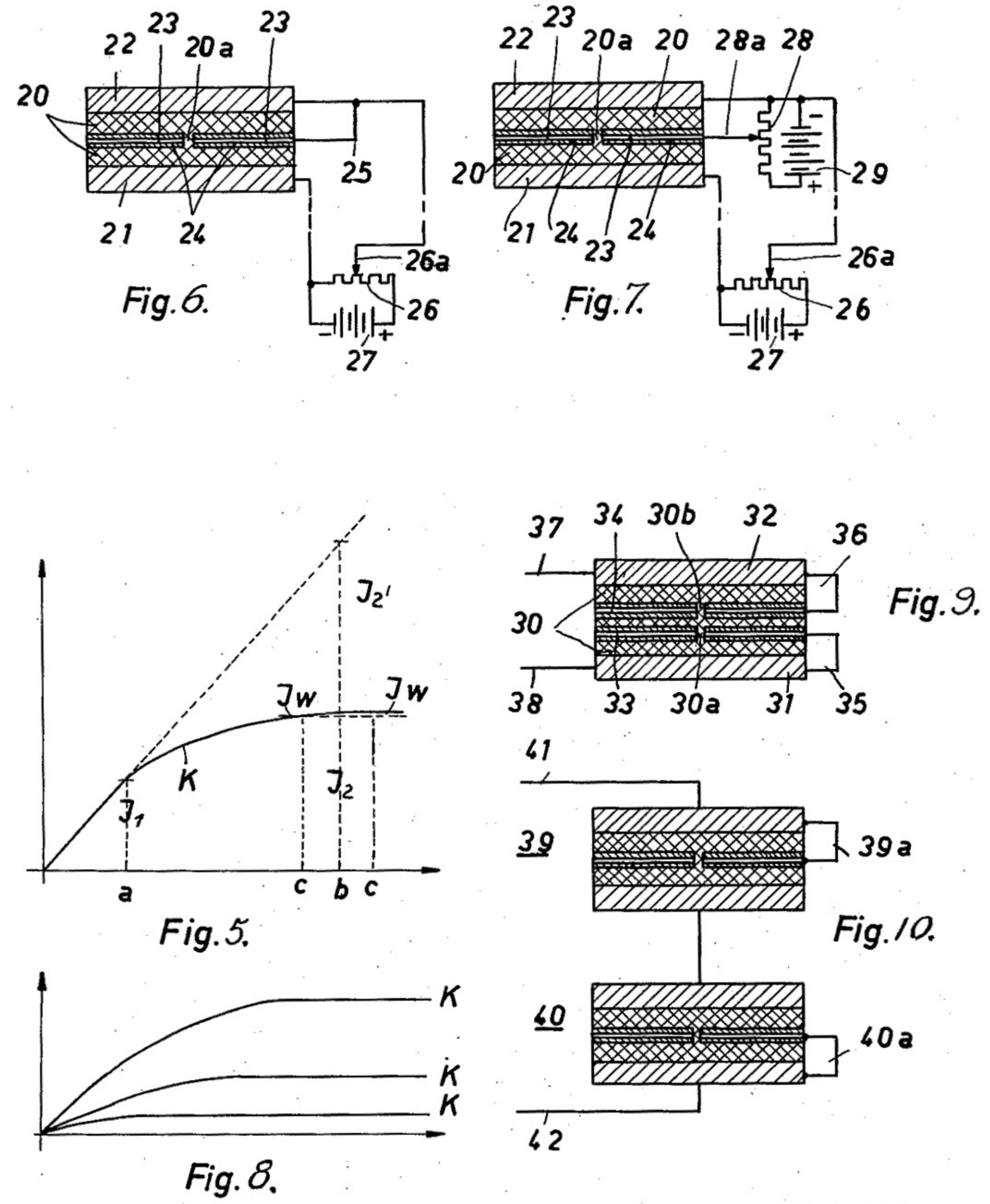
BY C.M. Avery ATTY'

Figure B.72: Frank Rose, Eberhard Spenke, and Erich Waldkötter filed detailed patent applications on transistors in 1949, likely based on wartime work.

Aug. 11, 1953 E. H. G. SPENKE ET AL **2,648,805**

CONTROLLABLE ELECTRIC RESISTANCE DEVICE

Filed Oct. 21, 1950 3 Sheets-Sheet 2


22
23
20a
23
20
25
21
24
26a
26
27
Fig. 6.
22
23
20a
20
28a
28
29
20
21
24
23
24
26a
26
27
Fig. 7.
J2'
Jw
Jw
K
J1
J2
a
c
b
c
Fig. 5.
K
K
K
Fig. 8.
37
34
30b
32
36
30
38
33
30a
31
35
Fig. 9.
41
39
39a
Fig. 10.
40
40a
42

INVENTORS:
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Figure B.73: Frank Rose, Eberhard Spenke, and Erich Waldkötter filed detailed patent applications on transistors in 1949, likely based on wartime work.

Aug. 11, 1953 E. H. G. SPENKE ET AL **2,648,805**

CONTROLLABLE ELECTRIC RESISTANCE DEVICE

Filed Oct. 21, 1950 3 Sheets-Sheet 3

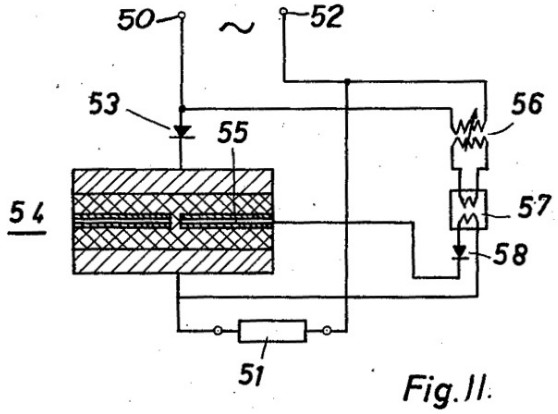
50
~
52
53
55
56
54
57
58
51

Fig. 11.

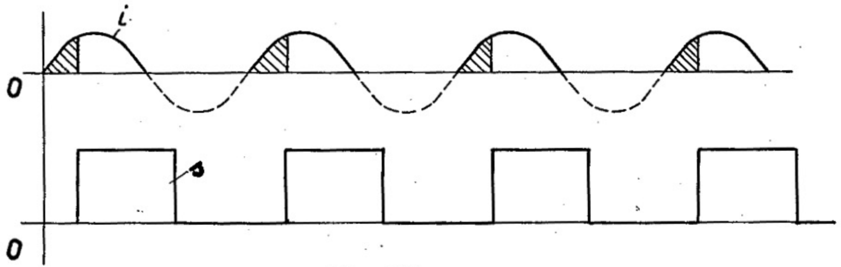

Fig. 12.

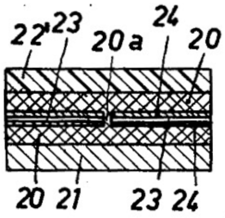
22
23
20a
24
20
20
21
23
24

Fig. 13.

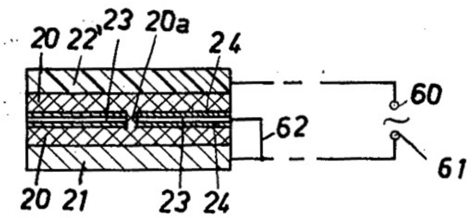
20
22
23
20a
24
60
62
~
61
20
21
23
24

Fig. 14.

INVENTORS:
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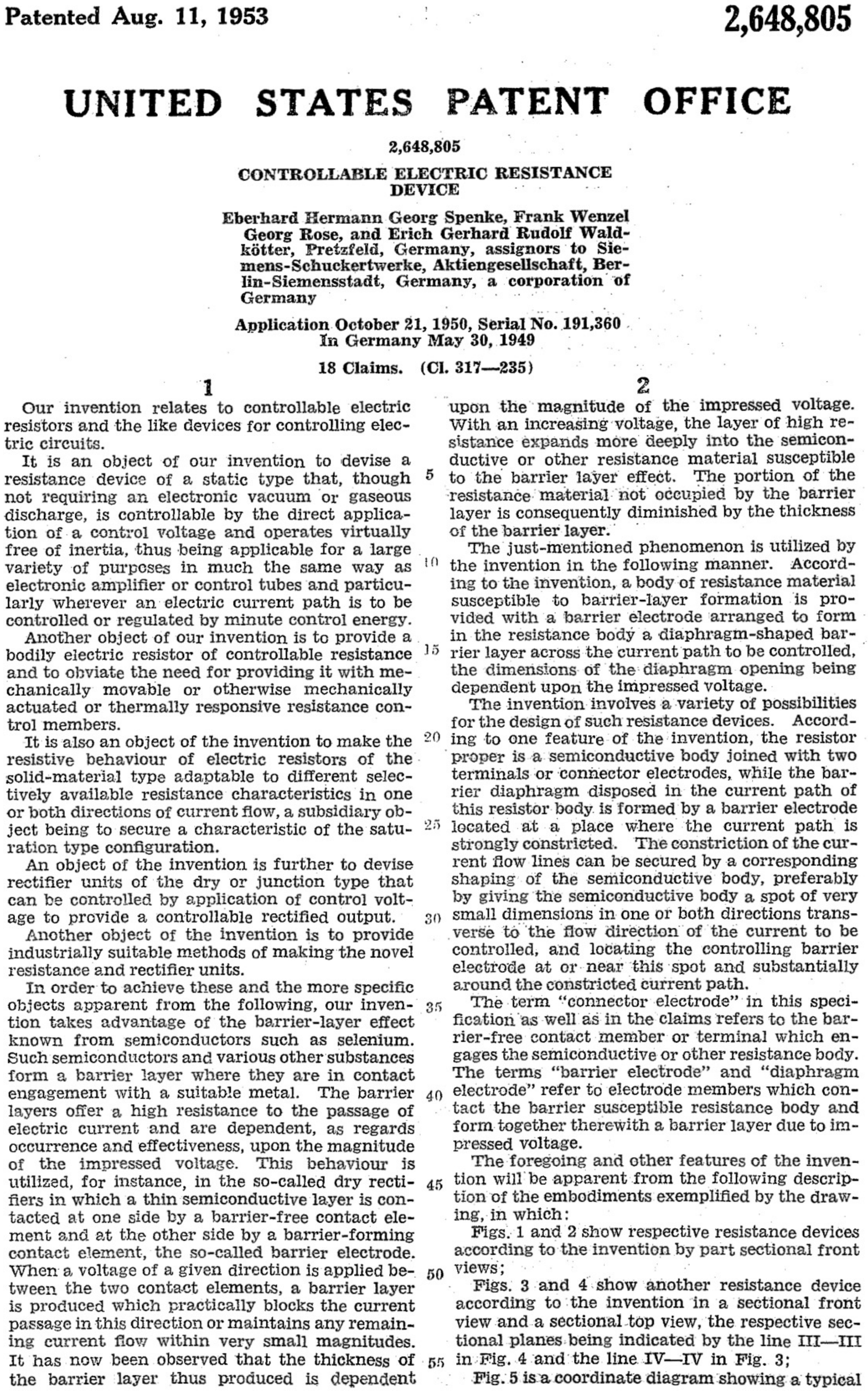
Erich Gerhard Rudolf Waldkötter
BY C. M. Avery ATTY

Figure B.74: Frank Rose, Eberhard Spenke, and Erich Waldkötter filed detailed patent applications on transistors in 1949, likely based on wartime work.



Patented Aug. 11, 1953 **2,648,805**

UNITED STATES PATENT OFFICE

2,648,805

CONTROLLABLE ELECTRIC RESISTANCE DEVICE

Eberhard Hermann Georg Spenke, Frank Wenzel Georg Rose, and Erich Gerhard Rudolf Waldkötter, Pretzfeld, Germany, assignors to Siemens-Schuckertwerke, Aktiengesellschaft, Berlin-Siemensstadt, Germany, a corporation of Germany

Application October 21, 1950, Serial No. 191,360
In Germany May 30, 1949

18 Claims. (Cl. 317—235)

Our invention relates to controllable electric resistors and the like devices for controlling electric circuits.

It is an object of our invention to devise a resistance device of a static type that, though not requiring an electronic vacuum or gaseous discharge, is controllable by the direct application of a control voltage and operates virtually free of inertia, thus being applicable for a large variety of purposes in much the same way as electronic amplifier or control tubes and particularly wherever an electric current path is to be controlled or regulated by minute control energy.

Another object of our invention is to provide a bodily electric resistor of controllable resistance and to obviate the need for providing it with mechanically movable or otherwise mechanically actuated or thermally responsive resistance control members.

It is also an object of the invention to make the resistive behaviour of electric resistors of the solid-material type adaptable to different selectively available resistance characteristics in one or both directions of current flow, a subsidiary object being to secure a characteristic of the saturation type configuration.

An object of the invention is further to devise rectifier units of the dry or junction type that can be controlled by application of control voltage to provide a controllable rectified output.

Another object of the invention is to provide industrially suitable methods of making the novel resistance and rectifier units.

In order to achieve these and the more specific objects apparent from the following, our invention takes advantage of the barrier-layer effect known from semiconductors such as selenium. Such semiconductors and various other substances form a barrier layer where they are in contact engagement with a suitable metal. The barrier layers offer a high resistance to the passage of electric current and are dependent, as regards occurrence and effectiveness, upon the magnitude of the impressed voltage. This behaviour is utilized, for instance, in the so-called dry rectifiers in which a thin semiconductive layer is contacted at one side by a barrier-free contact element and at the other side by a barrier-forming contact element, the so-called barrier electrode. When a voltage of a given direction is applied between the two contact elements, a barrier layer is produced which practically blocks the current passage in this direction or maintains any remaining current flow within very small magnitudes. It has now been observed that the thickness of the barrier layer thus produced is dependent upon the magnitude of the impressed voltage. With an increasing voltage, the layer of high resistance expands more deeply into the semiconductive or other resistance material susceptible to the barrier layer effect. The portion of the resistance material not occupied by the barrier layer is consequently diminished by the thickness of the barrier layer.

The just-mentioned phenomenon is utilized by the invention in the following manner. According to the invention, a body of resistance material susceptible to barrier-layer formation is provided with a barrier electrode arranged to form in the resistance body a diaphragm-shaped barrier layer across the current path to be controlled, the dimensions of the diaphragm opening being dependent upon the impressed voltage.

The invention involves a variety of possibilities for the design of such resistance devices. According to one feature of the invention, the resistor proper is a semiconductive body joined with two terminals or connector electrodes, while the barrier diaphragm disposed in the current path of this resistor body is formed by a barrier electrode located at a place where the current path is strongly constricted. The constriction of the current flow lines can be secured by a corresponding shaping of the semiconductive body, preferably by giving the semiconductive body a spot of very small dimensions in one or both directions transverse to the flow direction of the current to be controlled, and locating the controlling barrier electrode at or near this spot and substantially around the constricted current path.

The term "connector electrode" in this specification as well as in the claims refers to the barrier-free contact member or terminal which engages the semiconductive or other resistance body. The terms "barrier electrode" and "diaphragm electrode" refer to electrode members which contact the barrier susceptible resistance body and form together therewith a barrier layer due to impressed voltage.

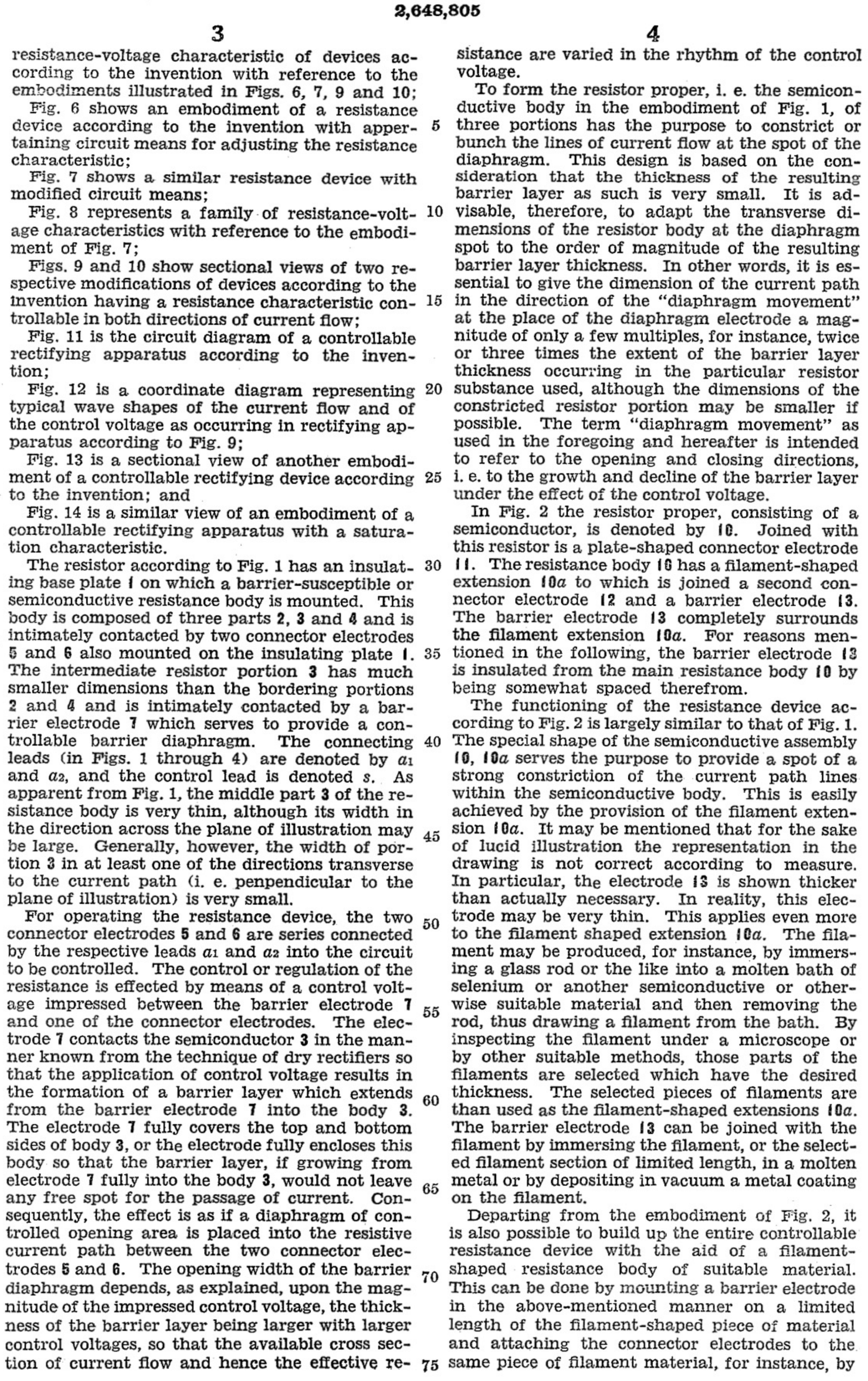
The foregoing and other features of the invention will be apparent from the following description of the embodiments exemplified by the drawing, in which:

Figs. 1 and 2 show respective resistance devices according to the invention by part sectional front views;

Figs. 3 and 4 show another resistance device according to the invention in a sectional front view and a sectional top view, the respective sectional planes being indicated by the line III—III in Fig. 4 and the line IV—IV in Fig. 3;

Fig. 5 is a coordinate diagram showing a typical

Figure B.75: Frank Rose, Eberhard Spenke, and Erich Waldkötter filed detailed patent applications on transistors in 1949, likely based on wartime work.



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3

resistance-voltage characteristic of devices according to the invention with reference to the embodiments illustrated in Figs. 6, 7, 9 and 10;

Fig. 6 shows an embodiment of a resistance device according to the invention with appertaining circuit means for adjusting the resistance characteristic;

Fig. 7 shows a similar resistance device with modified circuit means;

Fig. 8 represents a family of resistance-voltage characteristics with reference to the embodiment of Fig. 7;

Figs. 9 and 10 show sectional views of two respective modifications of devices according to the invention having a resistance characteristic controllable in both directions of current flow;

Fig. 11 is the circuit diagram of a controllable rectifying apparatus according to the invention;

Fig. 12 is a coordinate diagram representing typical wave shapes of the current flow and of the control voltage as occurring in rectifying apparatus according to Fig. 9;

Fig. 13 is a sectional view of another embodiment of a controllable rectifying device according to the invention; and

Fig. 14 is a similar view of an embodiment of a controllable rectifying apparatus with a saturation characteristic.

The resistor according to Fig. 1 has an insulating base plate **1** on which a barrier-susceptible or semiconductive resistance body is mounted. This body is composed of three parts **2**, **3** and **4** and is intimately contacted by two connector electrodes **5** and **6** also mounted on the insulating plate **1**. The intermediate resistor portion **3** has much smaller dimensions than the bordering portions **2** and **4** and is intimately contacted by a barrier electrode **7** which serves to provide a controllable barrier diaphragm. The connecting leads (in Figs. 1 through 4) are denoted by a_1 and a_2, and the control lead is denoted *s*. As apparent from Fig. 1, the middle part **3** of the resistance body is very thin, although its width in the direction across the plane of illustration may be large. Generally, however, the width of portion **3** in at least one of the directions transverse to the current path (i. e. penpendicular to the plane of illustration) is very small.

For operating the resistance device, the two connector electrodes **5** and **6** are series connected by the respective leads a_1 and a_2 into the circuit to be controlled. The control or regulation of the resistance is effected by means of a control voltage impressed between the barrier electrode **7** and one of the connector electrodes. The electrode **7** contacts the semiconductor **3** in the manner known from the technique of dry rectifiers so that the application of control voltage results in the formation of a barrier layer which extends from the barrier electrode **7** into the body **3**. The electrode **7** fully covers the top and bottom sides of body **3**, or the electrode fully encloses this body so that the barrier layer, if growing from electrode **7** fully into the body **3**, would not leave any free spot for the passage of current. Consequently, the effect is as if a diaphragm of controlled opening area is placed into the resistive current path between the two connector electrodes **5** and **6**. The opening width of the barrier diaphragm depends, as explained, upon the magnitude of the impressed control voltage, the thickness of the barrier layer being larger with larger control voltages, so that the available cross section of current flow and hence the effective resistance are varied in the rhythm of the control voltage.

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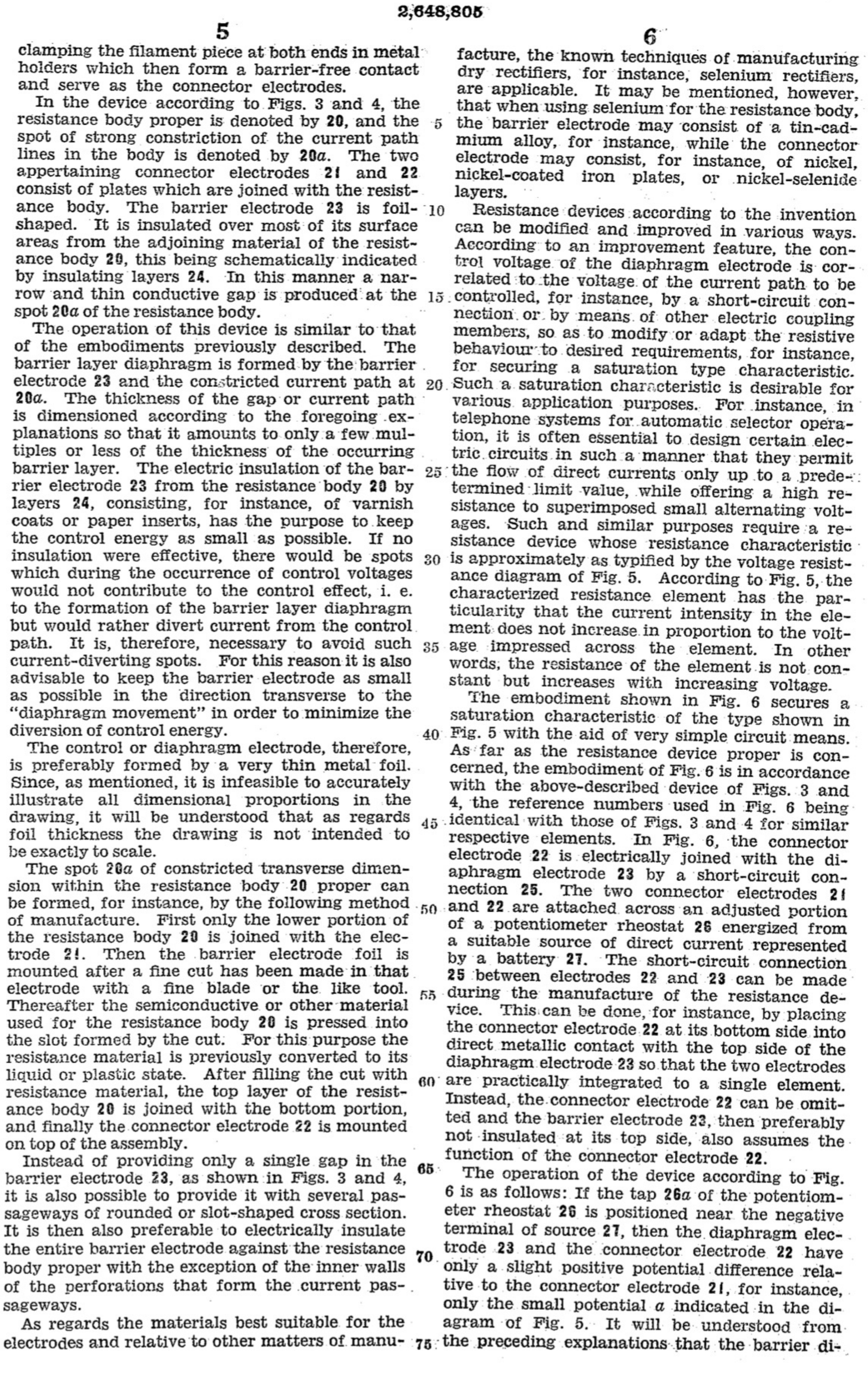
To form the resistor proper, i. e. the semiconductive body in the embodiment of Fig. 1, of three portions has the purpose to constrict or bunch the lines of current flow at the spot of the diaphragm. This design is based on the consideration that the thickness of the resulting barrier layer as such is very small. It is advisable, therefore, to adapt the transverse dimensions of the resistor body at the diaphragm spot to the order of magnitude of the resulting barrier layer thickness. In other words, it is essential to give the dimension of the current path in the direction of the "diaphragm movement" at the place of the diaphragm electrode a magnitude of only a few multiples, for instance, twice or three times the extent of the barrier layer thickness occurring in the particular resistor substance used, although the dimensions of the constricted resistor portion may be smaller if possible. The term "diaphragm movement" as used in the foregoing and hereafter is intended to refer to the opening and closing directions, i. e. to the growth and decline of the barrier layer under the effect of the control voltage.

In Fig. 2 the resistor proper, consisting of a semiconductor, is denoted by **10**. Joined with this resistor is a plate-shaped connector electrode **11**. The resistance body **10** has a filament-shaped extension **10*a*** to which is joined a second connector electrode **12** and a barrier electrode **13**. The barrier electrode **13** completely surrounds the filament extension **10*a***. For reasons mentioned in the following, the barrier electrode **13** is insulated from the main resistance body **10** by being somewhat spaced therefrom.

The functioning of the resistance device according to Fig. 2 is largely similar to that of Fig. 1. The special shape of the semiconductive assembly **10**, **10*a*** serves the purpose to provide a spot of a strong constriction of the current path lines within the semiconductive body. This is easily achieved by the provision of the filament extension **10*a***. It may be mentioned that for the sake of lucid illustration the representation in the drawing is not correct according to measure. In particular, the electrode **13** is shown thicker than actually necessary. In reality, this electrode may be very thin. This applies even more to the filament shaped extension **10*a***. The filament may be produced, for instance, by immersing a glass rod or the like into a molten bath of selenium or another semiconductive or otherwise suitable material and then removing the rod, thus drawing a filament from the bath. By inspecting the filament under a microscope or by other suitable methods, those parts of the filaments are selected which have the desired thickness. The selected pieces of filaments are than used as the filament-shaped extensions **10*a***. The barrier electrode **13** can be joined with the filament by immersing the filament, or the selected filament section of limited length, in a molten metal or by depositing in vacuum a metal coating on the filament.

Departing from the embodiment of Fig. 2, it is also possible to build up the entire controllable resistance device with the aid of a filament-shaped resistance body of suitable material. This can be done by mounting a barrier electrode in the above-mentioned manner on a limited length of the filament-shaped piece of material and attaching the connector electrodes to the same piece of filament material, for instance, by

Figure B.76: Frank Rose, Eberhard Spenke, and Erich Waldkötter filed detailed patent applications on transistors in 1949, likely based on wartime work.



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clamping the filament piece at both ends in metal holders which then form a barrier-free contact and serve as the connector electrodes.

In the device according to Figs. 3 and 4, the resistance body proper is denoted by **20**, and the spot of strong constriction of the current path lines in the body is denoted by **20a**. The two appertaining connector electrodes **21** and **22** consist of plates which are joined with the resistance body. The barrier electrode **23** is foil-shaped. It is insulated over most of its surface areas from the adjoining material of the resistance body **20**, this being schematically indicated by insulating layers **24**. In this manner a narrow and thin conductive gap is produced at the spot **20a** of the resistance body.

The operation of this device is similar to that of the embodiments previously described. The barrier layer diaphragm is formed by the barrier electrode **23** and the constricted current path at **20a**. The thickness of the gap or current path is dimensioned according to the foregoing explanations so that it amounts to only a few multiples or less of the thickness of the occurring barrier layer. The electric insulation of the barrier electrode **23** from the resistance body **20** by layers **24**, consisting, for instance, of varnish coats or paper inserts, has the purpose to keep the control energy as small as possible. If no insulation were effective, there would be spots which during the occurrence of control voltages would not contribute to the control effect, i. e. to the formation of the barrier layer diaphragm but would rather divert current from the control path. It is, therefore, necessary to avoid such current-diverting spots. For this reason it is also advisable to keep the barrier electrode as small as possible in the direction transverse to the "diaphragm movement" in order to minimize the diversion of control energy.

The control or diaphragm electrode, therefore, is preferably formed by a very thin metal foil. Since, as mentioned, it is infeasible to accurately illustrate all dimensional proportions in the drawing, it will be understood that as regards foil thickness the drawing is not intended to be exactly to scale.

The spot **20a** of constricted transverse dimension within the resistance body **20** proper can be formed, for instance, by the following method of manufacture. First only the lower portion of the resistance body **20** is joined with the electrode **21**. Then the barrier electrode foil is mounted after a fine cut has been made in that electrode with a fine blade or the like tool. Thereafter the semiconductive or other material used for the resistance body **20** is pressed into the slot formed by the cut. For this purpose the resistance material is previously converted to its liquid or plastic state. After filling the cut with resistance material, the top layer of the resistance body **20** is joined with the bottom portion, and finally the connector electrode **22** is mounted on top of the assembly.

Instead of providing only a single gap in the barrier electrode **23**, as shown in Figs. 3 and 4, it is also possible to provide it with several passageways of rounded or slot-shaped cross section. It is then also preferable to electrically insulate the entire barrier electrode against the resistance body proper with the exception of the inner walls of the perforations that form the current passageways.

As regards the materials best suitable for the electrodes and relative to other matters of manufacture, the known techniques of manufacturing dry rectifiers, for instance, selenium rectifiers, are applicable. It may be mentioned, however, that when using selenium for the resistance body, the barrier electrode may consist of a tin-cadmium alloy, for instance, while the connector electrode may consist, for instance, of nickel, nickel-coated iron plates, or nickel-selenide layers.

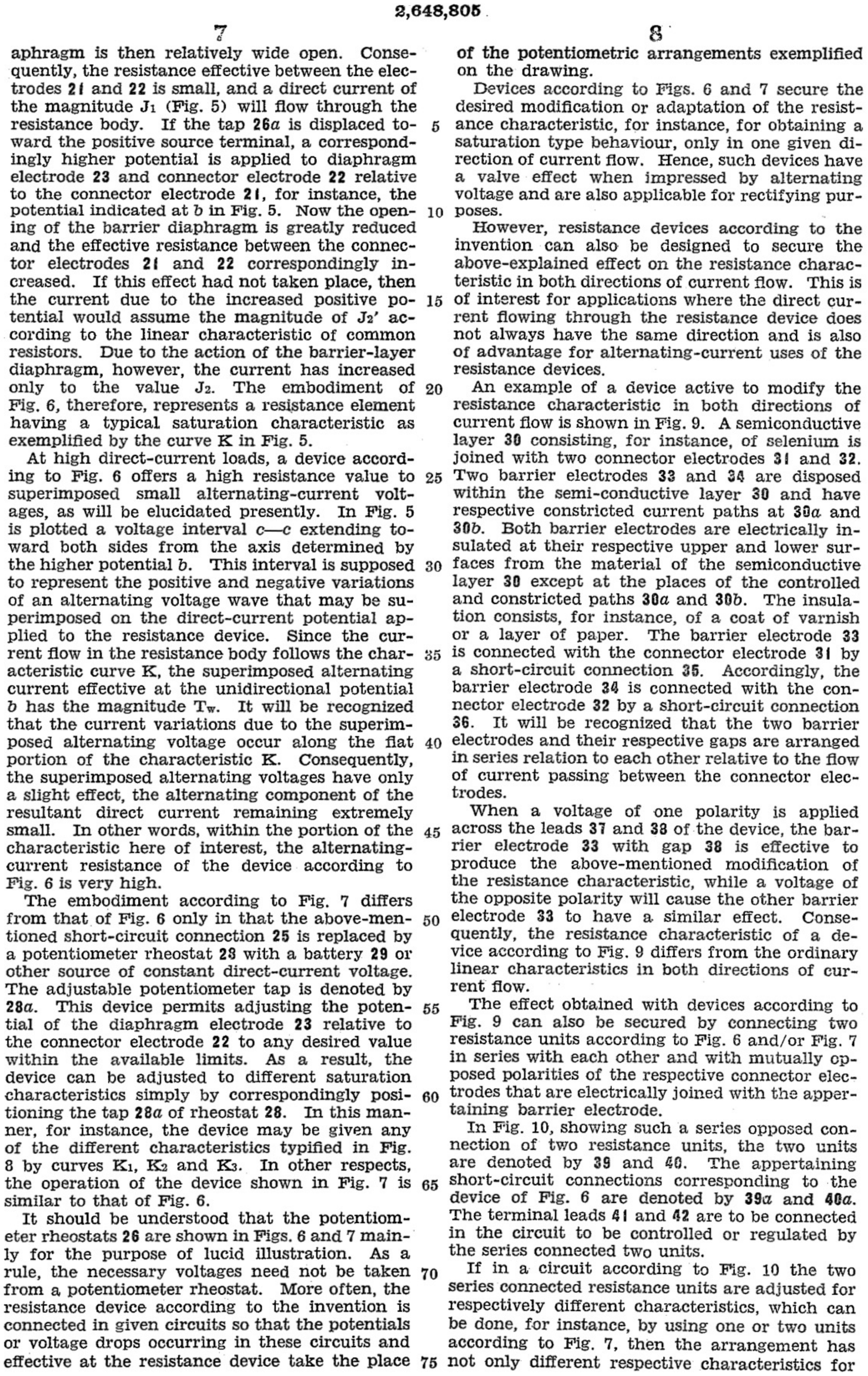
6

Resistance devices according to the invention can be modified and improved in various ways. According to an improvement feature, the control voltage of the diaphragm electrode is correlated to the voltage of the current path to be controlled, for instance, by a short-circuit connection or by means of other electric coupling members, so as to modify or adapt the resistive behaviour to desired requirements, for instance, for securing a saturation type characteristic. Such a saturation characteristic is desirable for various application purposes. For instance, in telephone systems for automatic selector operation, it is often essential to design certain electric circuits in such a manner that they permit the flow of direct currents only up to a predetermined limit value, while offering a high resistance to superimposed small alternating voltages. Such and similar purposes require a resistance device whose resistance characteristic is approximately as typified by the voltage resistance diagram of Fig. 5. According to Fig. 5, the characterized resistance element has the particularity that the current intensity in the element does not increase in proportion to the voltage impressed across the element. In other words, the resistance of the element is not constant but increases with increasing voltage.

The embodiment shown in Fig. 6 secures a saturation characteristic of the type shown in Fig. 5 with the aid of very simple circuit means. As far as the resistance device proper is concerned, the embodiment of Fig. 6 is in accordance with the above-described device of Figs. 3 and 4, the reference numbers used in Fig. 6 being identical with those of Figs. 3 and 4 for similar respective elements. In Fig. 6, the connector electrode **22** is electrically joined with the diaphragm electrode **23** by a short-circuit connection **25**. The two connector electrodes **21** and **22** are attached across an adjusted portion of a potentiometer rheostat **26** energized from a suitable source of direct current represented by a battery **27**. The short-circuit connection **25** between electrodes **22** and **23** can be made during the manufacture of the resistance device. This can be done, for instance, by placing the connector electrode **22** at its bottom side into direct metallic contact with the top side of the diaphragm electrode **23** so that the two electrodes are practically integrated to a single element. Instead, the connector electrode **22** can be omitted and the barrier electrode **23**, then preferably not insulated at its top side, also assumes the function of the connector electrode **22**.

The operation of the device according to Fig. 6 is as follows: If the tap **26a** of the potentiometer rheostat **26** is positioned near the negative terminal of source **27**, then the diaphragm electrode **23** and the connector electrode **22** have only a slight positive potential difference relative to the connector electrode **21**, for instance, only the small potential *a* indicated in the diagram of Fig. 5. It will be understood from the preceding explanations that the barrier di-

Figure B.77: Frank Rose, Eberhard Spenke, and Erich Waldkötter filed detailed patent applications on transistors in 1949, likely based on wartime work.



aphragm is then relatively wide open. Consequently, the resistance effective between the electrodes **21** and **22** is small, and a direct current of the magnitude J_1 (Fig. 5) will flow through the resistance body. If the tap **26***a* is displaced toward the positive source terminal, a correspondingly higher potential is applied to diaphragm electrode **23** and connector electrode **22** relative to the connector electrode **21**, for instance, the potential indicated at *b* in Fig. 5. Now the opening of the barrier diaphragm is greatly reduced and the effective resistance between the connector electrodes **21** and **22** correspondingly increased. If this effect had not taken place, then the current due to the increased positive potential would assume the magnitude of J_2' according to the linear characteristic of common resistors. Due to the action of the barrier-layer diaphragm, however, the current has increased only to the value J_2. The embodiment of Fig. 6, therefore, represents a resistance element having a typical saturation characteristic as exemplified by the curve K in Fig. 5.

At high direct-current loads, a device according to Fig. 6 offers a high resistance value to superimposed small alternating-current voltages, as will be elucidated presently. In Fig. 5 is plotted a voltage interval *c*—*c* extending toward both sides from the axis determined by the higher potential *b*. This interval is supposed to represent the positive and negative variations of an alternating voltage wave that may be superimposed on the direct-current potential applied to the resistance device. Since the current flow in the resistance body follows the characteristic curve K, the superimposed alternating current effective at the unidirectional potential *b* has the magnitude T_w. It will be recognized that the current variations due to the superimposed alternating voltage occur along the flat portion of the characteristic K. Consequently, the superimposed alternating voltages have only a slight effect, the alternating component of the resultant direct current remaining extremely small. In other words, within the portion of the characteristic here of interest, the alternating-current resistance of the device according to Fig. 6 is very high.

The embodiment according to Fig. 7 differs from that of Fig. 6 only in that the above-mentioned short-circuit connection **25** is replaced by a potentiometer rheostat **28** with a battery **29** or other source of constant direct-current voltage. The adjustable potentiometer tap is denoted by **28***a*. This device permits adjusting the potential of the diaphragm electrode **23** relative to the connector electrode **22** to any desired value within the available limits. As a result, the device can be adjusted to different saturation characteristics simply by correspondingly positioning the tap **28***a* of rheostat **28**. In this manner, for instance, the device may be given any of the different characteristics typified in Fig. 8 by curves K_1, K_2 and K_3. In other respects, the operation of the device shown in Fig. 7 is similar to that of Fig. 6.

It should be understood that the potentiometer rheostats **26** are shown in Figs. 6 and 7 mainly for the purpose of lucid illustration. As a rule, the necessary voltages need not be taken from a potentiometer rheostat. More often, the resistance device according to the invention is connected in given circuits so that the potentials or voltage drops occurring in these circuits and effective at the resistance device take the place of the potentiometric arrangements exemplified on the drawing.

Devices according to Figs. 6 and 7 secure the desired modification or adaptation of the resistance characteristic, for instance, for obtaining a saturation type behaviour, only in one given direction of current flow. Hence, such devices have a valve effect when impressed by alternating voltage and are also applicable for rectifying purposes.

However, resistance devices according to the invention can also be designed to secure the above-explained effect on the resistance characteristic in both directions of current flow. This is of interest for applications where the direct current flowing through the resistance device does not always have the same direction and is also of advantage for alternating-current uses of the resistance devices.

An example of a device active to modify the resistance characteristic in both directions of current flow is shown in Fig. 9. A semiconductive layer **30** consisting, for instance, of selenium is joined with two connector electrodes **31** and **32**. Two barrier electrodes **33** and **34** are disposed within the semi-conductive layer **30** and have respective constricted current paths at **30***a* and **30***b*. Both barrier electrodes are electrically insulated at their respective upper and lower surfaces from the material of the semiconductive layer **30** except at the places of the controlled and constricted paths **30***a* and **30***b*. The insulation consists, for instance, of a coat of varnish or a layer of paper. The barrier electrode **33** is connected with the connector electrode **31** by a short-circuit connection **35**. Accordingly, the barrier electrode **34** is connected with the connector electrode **32** by a short-circuit connection **36**. It will be recognized that the two barrier electrodes and their respective gaps are arranged in series relation to each other relative to the flow of current passing between the connector electrodes.

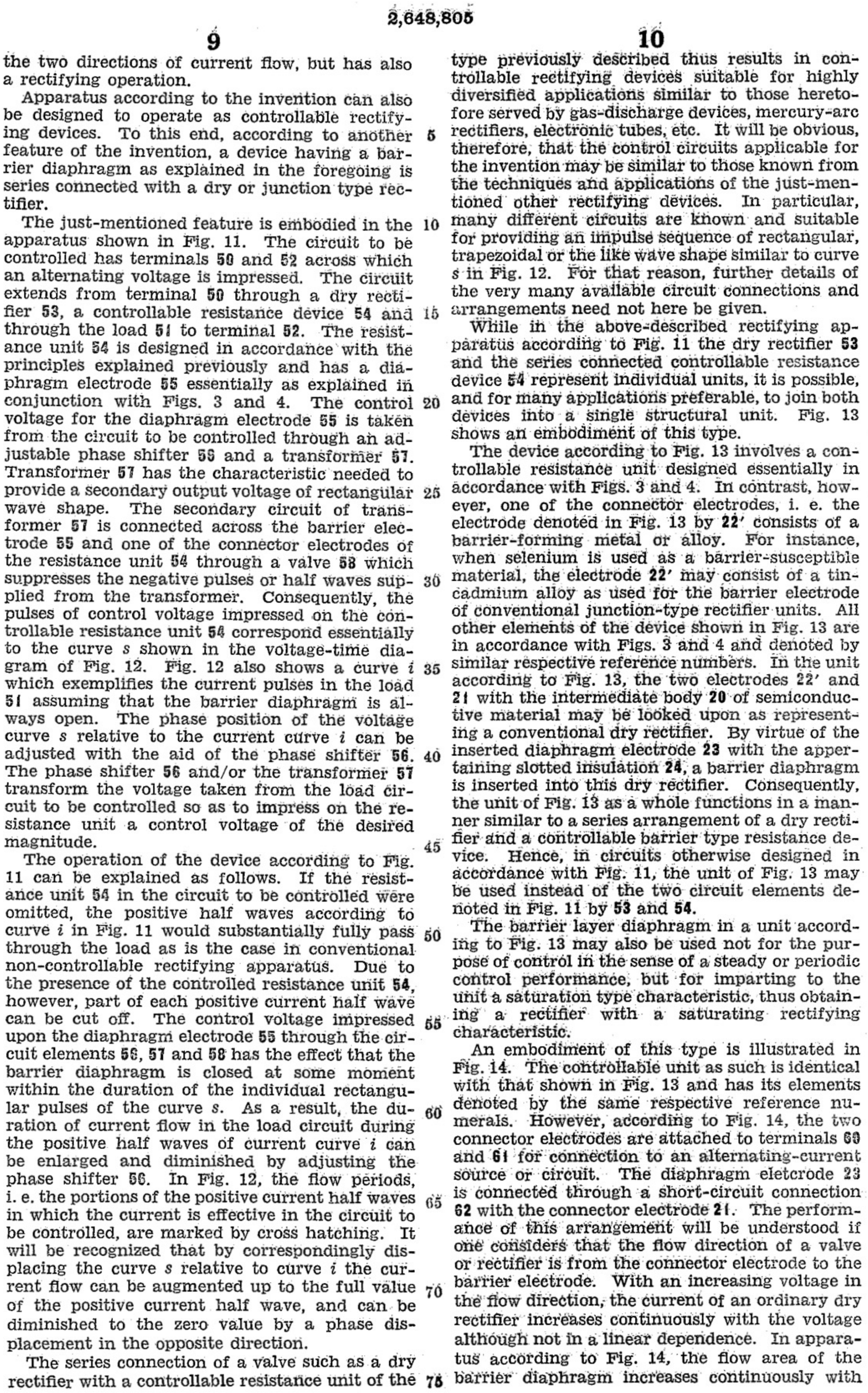
When a voltage of one polarity is applied across the leads **37** and **38** of the device, the barrier electrode **33** with gap **38** is effective to produce the above-mentioned modification of the resistance characteristic, while a voltage of the opposite polarity will cause the other barrier electrode **33** to have a similar effect. Consequently, the resistance characteristic of a device according to Fig. 9 differs from the ordinary linear characteristics in both directions of current flow.

The effect obtained with devices according to Fig. 9 can also be secured by connecting two resistance units according to Fig. 6 and/or Fig. 7 in series with each other and with mutually opposed polarities of the respective connector electrodes that are electrically joined with the appertaining barrier electrode.

In Fig. 10, showing such a series opposed connection of two resistance units, the two units are denoted by **39** and **40**. The appertaining short-circuit connections corresponding to the device of Fig. 6 are denoted by **39***a* and **40***a*. The terminal leads **41** and **42** are to be connected in the circuit to be controlled or regulated by the series connected two units.

If in a circuit according to Fig. 10 the two series connected resistance units are adjusted for respectively different characteristics, which can be done, for instance, by using one or two units according to Fig. 7, then the arrangement has not only different respective characteristics for

Figure B.78: Frank Rose, Eberhard Spenke, and Erich Waldkötter filed detailed patent applications on transistors in 1949, likely based on wartime work.



the two directions of current flow, but has also a rectifying operation.

Apparatus according to the invention can also be designed to operate as controllable rectifying devices. To this end, according to another feature of the invention, a device having a barrier diaphragm as explained in the foregoing is series connected with a dry or junction type rectifier.

The just-mentioned feature is embodied in the apparatus shown in Fig. 11. The circuit to be controlled has terminals **50** and **52** across which an alternating voltage is impressed. The circuit extends from terminal **50** through a dry rectifier **53**, a controllable resistance device **54** and through the load **51** to terminal **52**. The resistance unit **54** is designed in accordance with the principles explained previously and has a diaphragm electrode **55** essentially as explained in conjunction with Figs. 3 and 4. The control voltage for the diaphragm electrode **55** is taken from the circuit to be controlled through an adjustable phase shifter **56** and a transformer **57**. Transformer **57** has the characteristic needed to provide a secondary output voltage of rectangular wave shape. The secondary circuit of transformer **57** is connected across the barrier electrode **55** and one of the connector electrodes of the resistance unit **54** through a valve **58** which suppresses the negative pulses or half waves supplied from the transformer. Consequently, the pulses of control voltage impressed on the controllable resistance unit **54** correspond essentially to the curve s shown in the voltage-time diagram of Fig. 12. Fig. 12 also shows a curve i which exemplifies the current pulses in the load **51** assuming that the barrier diaphragm is always open. The phase position of the voltage curve s relative to the current curve i can be adjusted with the aid of the phase shifter **56**. The phase shifter **56** and/or the transformer **57** transform the voltage taken from the load circuit to be controlled so as to impress on the resistance unit a control voltage of the desired magnitude.

The operation of the device according to Fig. 11 can be explained as follows. If the resistance unit 54 in the circuit to be controlled were omitted, the positive half waves according to curve i in Fig. 11 would substantially fully pass through the load as is the case in conventional non-controllable rectifying apparatus. Due to the presence of the controlled resistance unit **54**, however, part of each positive current half wave can be cut off. The control voltage impressed upon the diaphragm electrode **55** through the circuit elements **56**, **57** and **58** has the effect that the barrier diaphragm is closed at some moment within the duration of the individual rectangular pulses of the curve s. As a result, the duration of current flow in the load circuit during the positive half waves of current curve i can be enlarged and diminished by adjusting the phase shifter **56**. In Fig. 12, the flow periods, i. e. the portions of the positive current half waves in which the current is effective in the circuit to be controlled, are marked by cross hatching. It will be recognized that by correspondingly displacing the curve s relative to curve i the current flow can be augmented up to the full value of the positive current half wave, and can be diminished to the zero value by a phase displacement in the opposite direction.

The series connection of a valve such as a dry rectifier with a controllable resistance unit of the type previously described thus results in controllable rectifying devices suitable for highly diversified applications similar to those heretofore served by gas-discharge devices, mercury-arc rectifiers, electronic tubes, etc. It will be obvious, therefore, that the control circuits applicable for the invention may be similar to those known from the techniques and applications of the just-mentioned other rectifying devices. In particular, many different circuits are known and suitable for providing an impulse sequence of rectangular, trapezoidal or the like wave shape similar to curve s in Fig. 12. For that reason, further details of the very many available circuit connections and arrangements need not here be given.

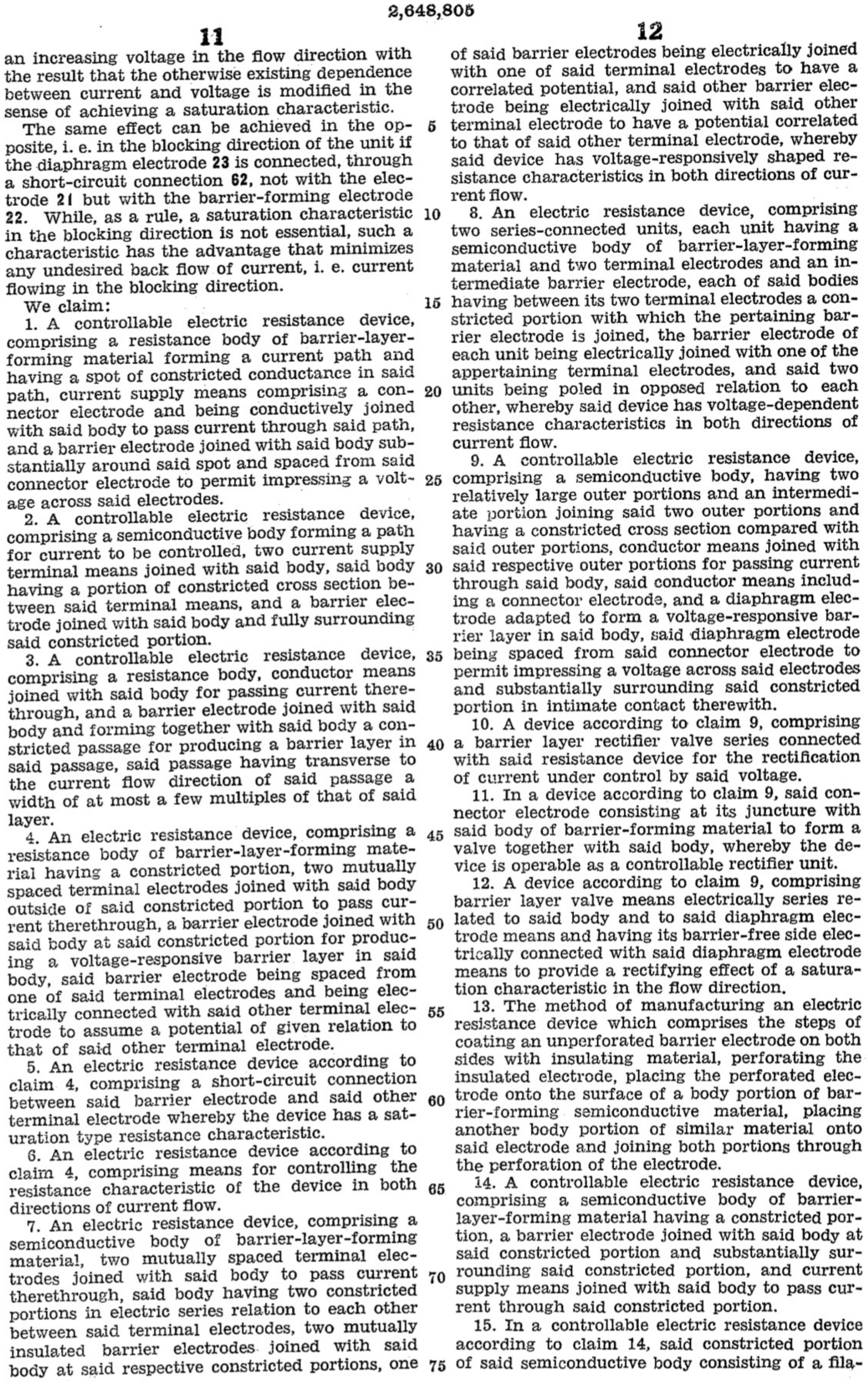
While in the above-described rectifying apparatus according to Fig. 11 the dry rectifier **53** and the series connected controllable resistance device **54** represent individual units, it is possible, and for many applications preferable, to join both devices into a single structural unit. Fig. 13 shows an embodiment of this type.

The device according to Fig. 13 involves a controllable resistance unit designed essentially in accordance with Figs. 3 and 4. In contrast, however, one of the connector electrodes, i. e. the electrode denoted in Fig. 13 by **22′** consists of a barrier-forming metal or alloy. For instance, when selenium is used as a barrier-susceptible material, the electrode **22′** may consist of a tin-cadmium alloy as used for the barrier electrode of conventional junction-type rectifier units. All other elements of the device shown in Fig. 13 are in accordance with Figs. 3 and 4 and denoted by similar respective reference numbers. In the unit according to Fig. 13, the two electrodes 22′ and **21** with the intermediate body **20** of semiconductive material may be looked upon as representing a conventional dry rectifier. By virtue of the inserted diaphragm electrode **23** with the appertaining slotted insulation **24**, a barrier diaphragm is inserted into this dry rectifier. Consequently, the unit of Fig. 13 as a whole functions in a manner similar to a series arrangement of a dry rectifier and a controllable barrier type resistance device. Hence, in circuits otherwise designed in accordance with Fig. 11, the unit of Fig. 13 may be used instead of the two circuit elements denoted in Fig. 11 by **53** and **54**.

The barrier layer diaphragm in a unit according to Fig. 13 may also be used not for the purpose of control in the sense of a steady or periodic control performance, but for imparting to the unit a saturation type characteristic, thus obtaining a rectifier with a saturating rectifying characteristic.

An embodiment of this type is illustrated in Fig. 14. The controllable unit as such is identical with that shown in Fig. 13 and has its elements denoted by the same respective reference numerals. However, according to Fig. 14, the two connector electrodes are attached to terminals **60** and **61** for connection to an alternating-current source or circuit. The diaphragm eletcrode 23 is connected through a short-circuit connection **62** with the connector electrode **21**. The performance of this arrangement will be understood if one considers that the flow direction of a valve or rectifier is from the connector electrode to the barrier electrode. With an increasing voltage in the flow direction, the current of an ordinary dry rectifier increases continuously with the voltage although not in a linear dependence. In apparatus according to Fig. 14, the flow area of the barrier diaphragm increases continuously with

Figure B.79: Frank Rose, Eberhard Spenke, and Erich Waldkötter filed detailed patent applications on transistors in 1949, likely based on wartime work.



an increasing voltage in the flow direction with the result that the otherwise existing dependence between current and voltage is modified in the sense of achieving a saturation characteristic.

The same effect can be achieved in the opposite, i. e. in the blocking direction of the unit if the diaphragm electrode **23** is connected, through a short-circuit connection **62**, not with the electrode **21** but with the barrier-forming electrode **22**. While, as a rule, a saturation characteristic in the blocking direction is not essential, such a characteristic has the advantage that minimizes any undesired back flow of current, i. e. current flowing in the blocking direction.

We claim:

1. A controllable electric resistance device, comprising a resistance body of barrier-layer-forming material forming a current path and having a spot of constricted conductance in said path, current supply means comprising a connector electrode and being conductively joined with said body to pass current through said path, and a barrier electrode joined with said body substantially around said spot and spaced from said connector electrode to permit impressing a voltage across said electrodes.

2. A controllable electric resistance device, comprising a semiconductive body forming a path for current to be controlled, two current supply terminal means joined with said body, said body having a portion of constricted cross section between said terminal means, and a barrier electrode joined with said body and fully surrounding said constricted portion.

3. A controllable electric resistance device, comprising a resistance body, conductor means joined with said body for passing current therethrough, and a barrier electrode joined with said body and forming together with said body a constricted passage for producing a barrier layer in said passage, said passage having transverse to the current flow direction of said passage a width of at most a few multiples of that of said layer.

4. An electric resistance device, comprising a resistance body of barrier-layer-forming material having a constricted portion, two mutually spaced terminal electrodes joined with said body outside of said constricted portion to pass current therethrough, a barrier electrode joined with said body at said constricted portion for producing a voltage-responsive barrier layer in said body, said barrier electrode being spaced from one of said terminal electrodes and being electrically connected with said other terminal electrode to assume a potential of given relation to that of said other terminal electrode.

5. An electric resistance device according to claim 4, comprising a short-circuit connection between said barrier electrode and said other terminal electrode whereby the device has a saturation type resistance characteristic.

6. An electric resistance device according to claim 4, comprising means for controlling the resistance characteristic of the device in both directions of current flow.

7. An electric resistance device, comprising a semiconductive body of barrier-layer-forming material, two mutually spaced terminal electrodes joined with said body to pass current therethrough, said body having two constricted portions in electric series relation to each other between said terminal electrodes, two mutually insulated barrier electrodes joined with said body at said respective constricted portions, one of said barrier electrodes being electrically joined with one of said terminal electrodes to have a correlated potential, and said other barrier electrode being electrically joined with said other terminal electrode to have a potential correlated to that of said other terminal electrode, whereby said device has voltage-responsively shaped resistance characteristics in both directions of current flow.

8. An electric resistance device, comprising two series-connected units, each unit having a semiconductive body of barrier-layer-forming material and two terminal electrodes and an intermediate barrier electrode, each of said bodies having between its two terminal electrodes a constricted portion with which the pertaining barrier electrode is joined, the barrier electrode of each unit being electrically joined with one of the appertaining terminal electrodes, and said two units being poled in opposed relation to each other, whereby said device has voltage-dependent resistance characteristics in both directions of current flow.

9. A controllable electric resistance device, comprising a semiconductive body, having two relatively large outer portions and an intermediate portion joining said two outer portions and having a constricted cross section compared with said outer portions, conductor means joined with said respective outer portions for passing current through said body, said conductor means including a connector electrode, and a diaphragm electrode adapted to form a voltage-responsive barrier layer in said body, said diaphragm electrode being spaced from said connector electrode to permit impressing a voltage across said electrodes and substantially surrounding said constricted portion in intimate contact therewith.

10. A device according to claim 9, comprising a barrier layer rectifier valve series connected with said resistance device for the rectification of current under control by said voltage.

11. In a device according to claim 9, said connector electrode consisting at its juncture with said body of barrier-forming material to form a valve together with said body, whereby the device is operable as a controllable rectifier unit.

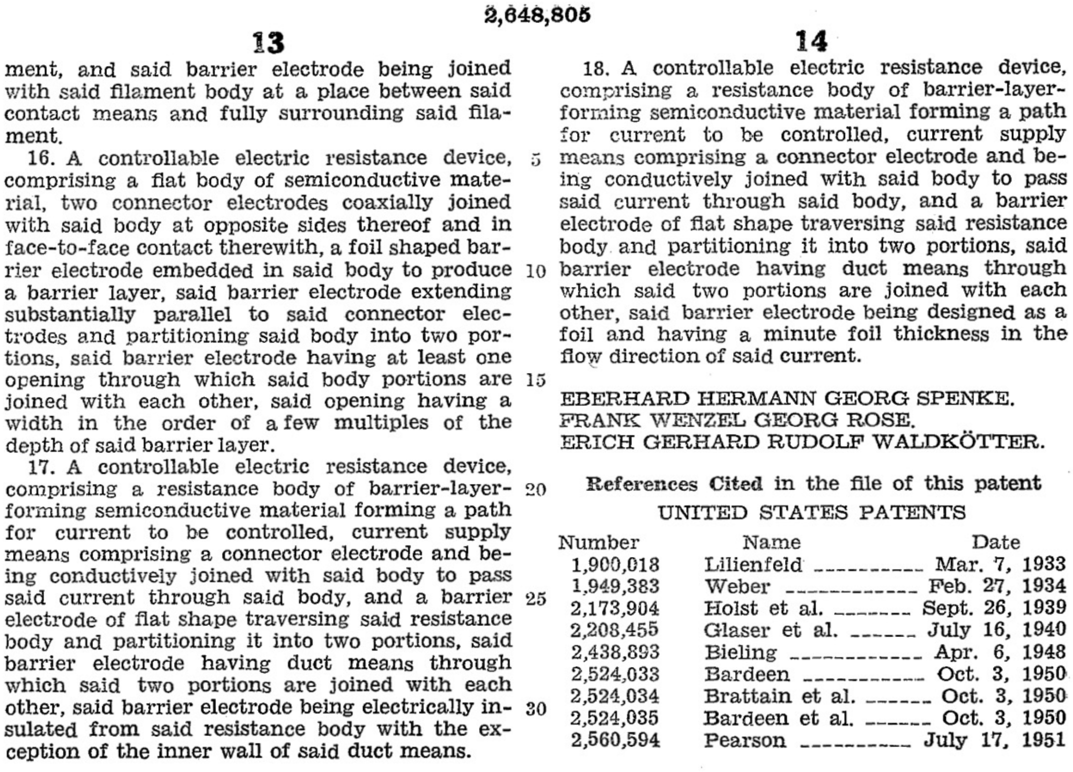
12. A device according to claim 9, comprising barrier layer valve means electrically series related to said body and to said diaphragm electrode means and having its barrier-free side electrically connected with said diaphragm electrode means to provide a rectifying effect of a saturation characteristic in the flow direction.

13. The method of manufacturing an electric resistance device which comprises the steps of coating an unperforated barrier electrode on both sides with insulating material, perforating the insulated electrode, placing the perforated electrode onto the surface of a body portion of barrier-forming semiconductive material, placing another body portion of similar material onto said electrode and joining both portions through the perforation of the electrode.

14. A controllable electric resistance device, comprising a semiconductive body of barrier-layer-forming material having a constricted portion, a barrier electrode joined with said body at said constricted portion and substantially surrounding said constricted portion, and current supply means joined with said body to pass current through said constricted portion.

15. In a controllable electric resistance device according to claim 14, said constricted portion of said semiconductive body consisting of a fila-

Figure B.80: Frank Rose, Eberhard Spenke, and Erich Waldkötter filed detailed patent applications on transistors in 1949, likely based on wartime work.



2,648,805

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ment, and said barrier electrode being joined with said filament body at a place between said contact means and fully surrounding said filament.

16. A controllable electric resistance device, comprising a flat body of semiconductive material, two connector electrodes coaxially joined with said body at opposite sides thereof and in face-to-face contact therewith, a foil shaped barrier electrode embedded in said body to produce a barrier layer, said barrier electrode extending substantially parallel to said connector electrodes and partitioning said body into two portions, said barrier electrode having at least one opening through which said body portions are joined with each other, said opening having a width in the order of a few multiples of the depth of said barrier layer.

17. A controllable electric resistance device, comprising a resistance body of barrier-layer-forming semiconductive material forming a path for current to be controlled, current supply means comprising a connector electrode and being conductively joined with said body to pass said current through said body, and a barrier electrode of flat shape traversing said resistance body and partitioning it into two portions, said barrier electrode having duct means through which said two portions are joined with each other, said barrier electrode being electrically insulated from said resistance body with the exception of the inner wall of said duct means.

14

18. A controllable electric resistance device, comprising a resistance body of barrier-layer-forming semiconductive material forming a path for current to be controlled, current supply means comprising a connector electrode and being conductively joined with said body to pass said current through said body, and a barrier electrode of flat shape traversing said resistance body and partitioning it into two portions, said barrier electrode having duct means through which said two portions are joined with each other, said barrier electrode being designed as a foil and having a minute foil thickness in the flow direction of said current.

EBERHARD HERMANN GEORG SPENKE.
FRANK WENZEL GEORG ROSE.
ERICH GERHARD RUDOLF WALDKÖTTER.

References Cited in the file of this patent

UNITED STATES PATENTS

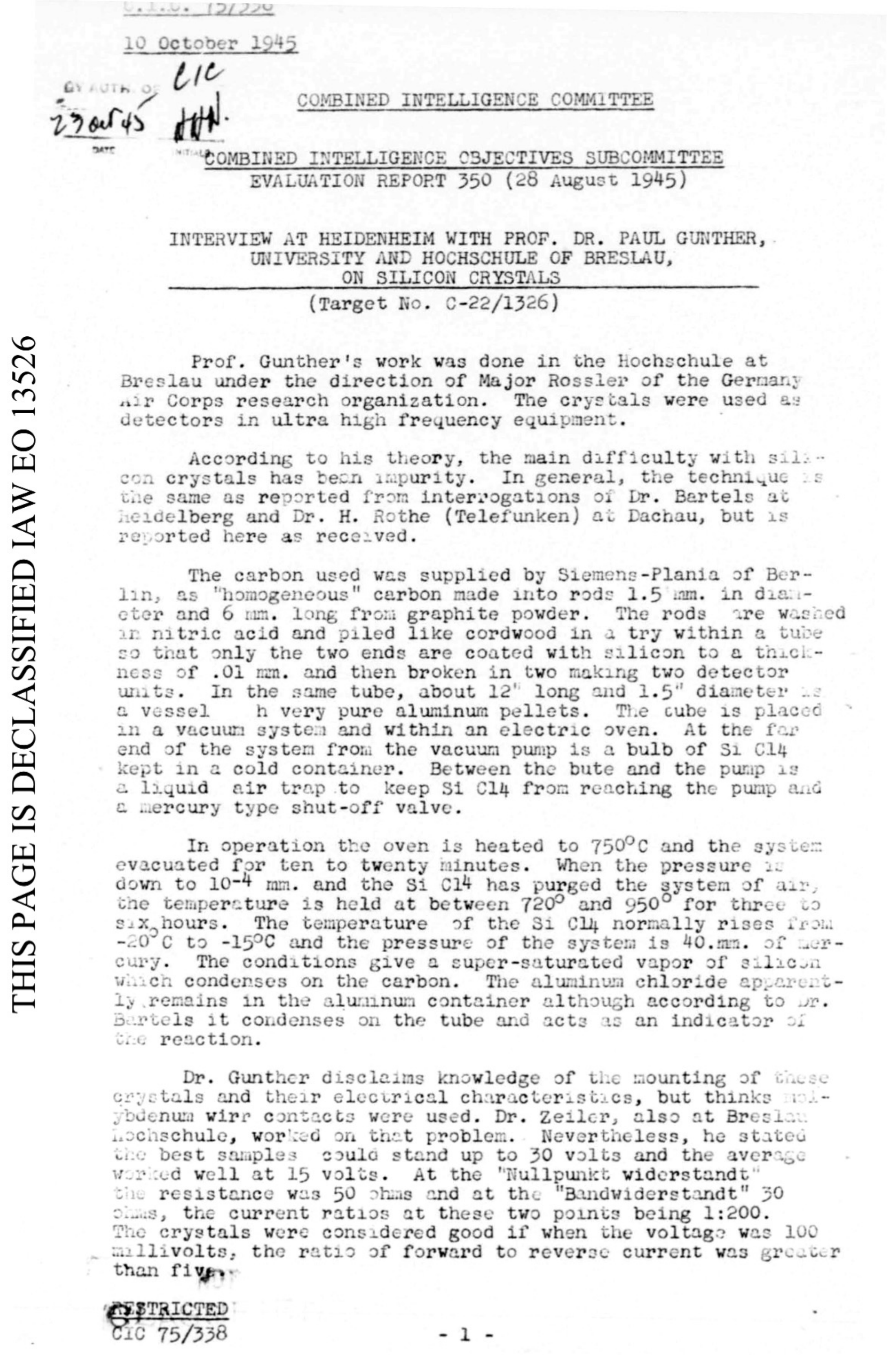
Number	Name	Date
1,900,018	Lilienfeld	Mar. 7, 1933
1,949,383	Weber	Feb. 27, 1934
2,173,904	Holst et al.	Sept. 26, 1939
2,208,455	Glaser et al.	July 16, 1940
2,438,893	Bieling	Apr. 6, 1948
2,524,033	Bardeen	Oct. 3, 1950
2,524,034	Brattain et al.	Oct. 3, 1950
2,524,035	Bardeen et al.	Oct. 3, 1950
2,560,594	Pearson	July 17, 1951

Figure B.81: Frank Rose, Eberhard Spenke, and Erich Waldkötter filed detailed patent applications on transistors in 1949, likely based on wartime work.

[**10. Karl Seiler (German, 1910–1991), Paul Ludwig Günther (German, 1892–1969), and others** developed methods for designing and fabricating silicon semiconductor devices throughout the war and into the postwar period [Handel 1999]. Their work was applied to transistors after the war, and it may have been used for that purpose during the war.

See for example:

> CIOS ER 350. *Interview at Heidenheim with Prof. Dr. Paul Günther, University and Hochschule of Breslau, on Silicon Crystals.* (pp. 2746–2747)
>
> Karl Seiler. Filed in 1950 (but apparently based on wartime work). U.S. patent 2,701,216. Method of Making Surface-Type and Point-Type Rectifiers and Crystal-Amplifier Layers from Elements. (pp. 2748–2751)
>
> Paul Ludwig Günther and Franz Kerkhoff. Filed in 1954 (but apparently based on wartime work). U.S. patent 2,876,400. Composite Electrodes for Directional Crystal Devices. (pp. 2752–2754)]



C.I.C. 75/338

10 October 1945

BY AUTH. OF CIC
23 Oct 45
DATE INITIALS

COMBINED INTELLIGENCE COMMITTEE

COMBINED INTELLIGENCE OBJECTIVES SUBCOMMITTEE
EVALUATION REPORT 350 (28 August 1945)

INTERVIEW AT HEIDENHEIM WITH PROF. DR. PAUL GUNTHER,
UNIVERSITY AND HOCHSCHULE OF BRESLAU,
ON SILICON CRYSTALS

(Target No. C-22/1326)

THIS PAGE IS DECLASSIFIED IAW EO 13526

Prof. Gunther's work was done in the Hochschule at Breslau under the direction of Major Rossler of the Germany Air Corps research organization. The crystals were used as detectors in ultra high frequency equipment.

According to his theory, the main difficulty with silicon crystals has been impurity. In general, the technique is the same as reported from interrogations of Dr. Bartels at Heidelberg and Dr. H. Rothe (Telefunken) at Dachau, but is reported here as received.

The carbon used was supplied by Siemens-Plania of Berlin, as "homogeneous" carbon made into rods 1.5 mm. in diameter and 6 mm. long from graphite powder. The rods are washed in nitric acid and piled like cordwood in a try within a tube so that only the two ends are coated with silicon to a thickness of .01 mm. and then broken in two making two detector units. In the same tube, about 12" long and 1.5" diameter is a vessel h very pure aluminum pellets. The cube is placed in a vacuum system and within an electric oven. At the far end of the system from the vacuum pump is a bulb of Si Cl4 kept in a cold container. Between the bute and the pump is a liquid air trap to keep Si Cl4 from reaching the pump and a mercury type shut-off valve.

In operation the oven is heated to 750°C and the system evacuated for ten to twenty minutes. When the pressure is down to 10^{-4} mm. and the Si Cl^{4} has purged the system of air, the temperature is held at between 720° and 950° for three to six hours. The temperature of the Si Cl4 normally rises from -20°C to -15°C and the pressure of the system is 40.mm. of mercury. The conditions give a super-saturated vapor of silicon which condenses on the carbon. The aluminum chloride apparently remains in the aluminum container although according to Dr. Bartels it condenses on the tube and acts as an indicator of the reaction.

Dr. Gunther disclaims knowledge of the mounting of these crystals and their electrical characteristics, but thinks molybdenum wirr contacts were used. Dr. Zeiler, also at Breslau Hochschule, worked on that problem. Nevertheless, he stated the best samples could stand up to 30 volts and the average worked well at 15 volts. At the "Nullpunkt widerstandt" the resistance was 50 ohms and at the "Bandwiderstandt" 30 ohms, the current ratios at these two points being 1:200. The crystals were considered good if when the voltage was 100 millivolts, the ratio of forward to reverse current was greater than five.

RESTRICTED
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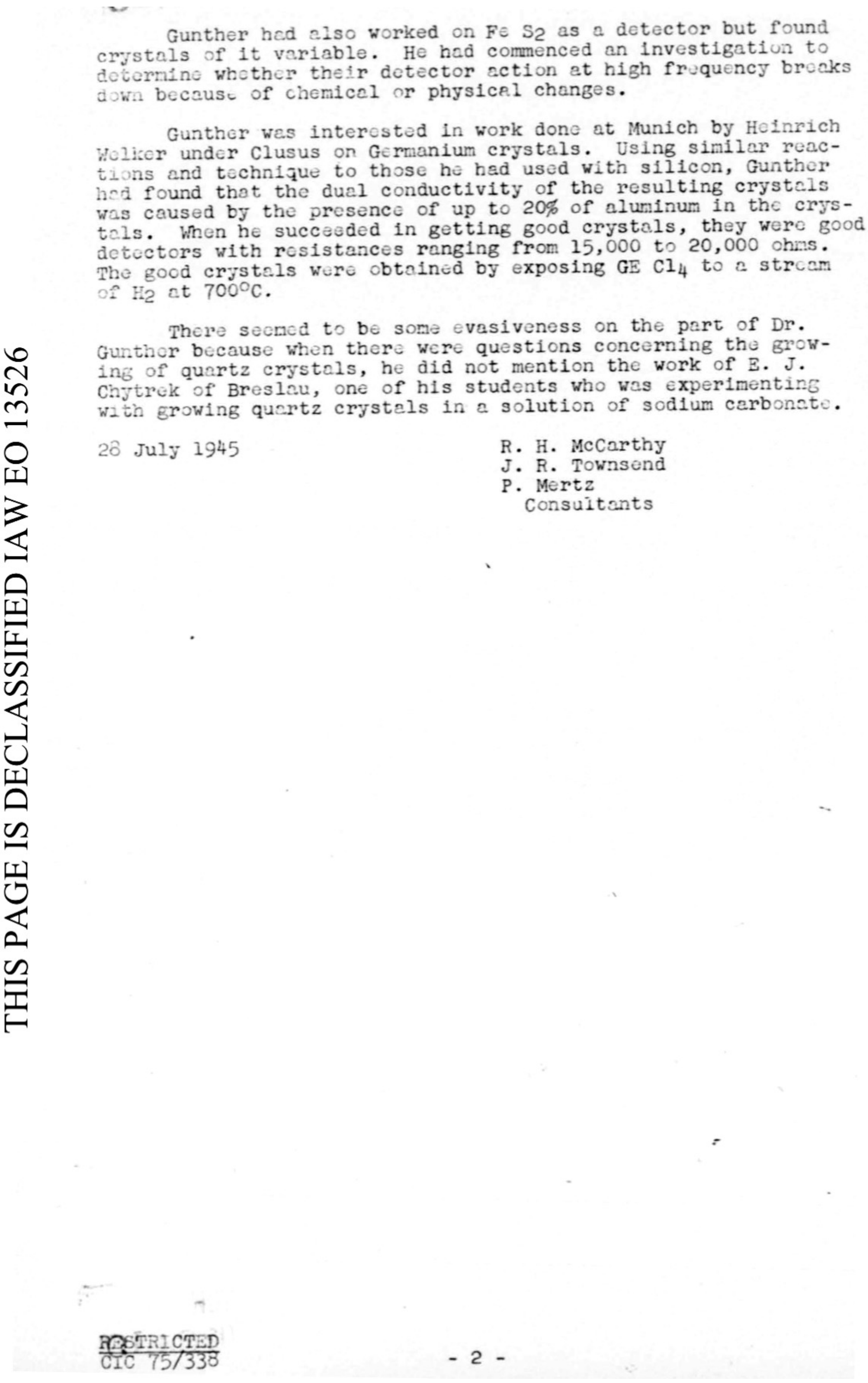
Figure B.82: Karl Seiler and Paul Ludwig Günther designed and fabricated silicon electronic devices during the war, and filed patents on silicon transistors after the war (likely based on wartime work) [CIOS ER 350].



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Gunther had also worked on Fe S_2 as a detector but found crystals of it variable. He had commenced an investigation to determine whether their detector action at high frequency breaks down because of chemical or physical changes.

Gunther was interested in work done at Munich by Heinrich Welker under Clusus on Germanium crystals. Using similar reactions and technique to those he had used with silicon, Gunther had found that the dual conductivity of the resulting crystals was caused by the presence of up to 20% of aluminum in the crystals. When he succeeded in getting good crystals, they were good detectors with resistances ranging from 15,000 to 20,000 ohms. The good crystals were obtained by exposing GE Cl_4 to a stream of H_2 at 700°C.

There seemed to be some evasiveness on the part of Dr. Gunther because when there were questions concerning the growing of quartz crystals, he did not mention the work of E. J. Chytrek of Breslau, one of his students who was experimenting with growing quartz crystals in a solution of sodium carbonate.

28 July 1945

R. H. McCarthy
J. R. Townsend
P. Mertz
Consultants

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Figure B.83: Karl Seiler and Paul Ludwig Günther designed and fabricated silicon electronic devices during the war, and filed patents on silicon transistors after the war (likely based on wartime work) [CIOS ER 350].

Feb. 1, 1955 K. SEILER **2,701,216**

METHOD OF MAKING SURFACE-TYPE AND POINT-TYPE RECTIFIERS
AND CRYSTAL-AMPLIFIER LAYERS FROM ELEMENTS
Filed April 5, 1950

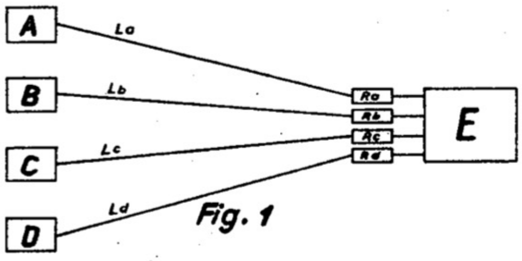

A
B
C
D
La
Lb
Lc
Ld
Ra
Rb
Rc
Rd
E

Fig. 1

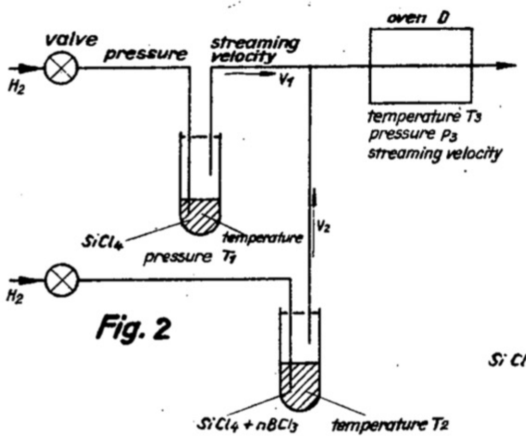

valve
pressure
streaming velocity
V1
oven D
temperature T3
pressure P3
streaming velocity
H2
SiCl4
pressure T1
temperature
V2
H2
SiCl4 + nBCl3
temperature T2

Fig. 2

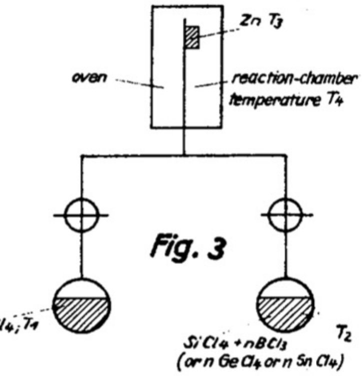

Zn T3
oven
reaction-chamber temperature T4
Si Cl4; T1
SiCl4 + nBCl3 (or n GeCl4 or n Sn Cl4)
T2

Fig. 3

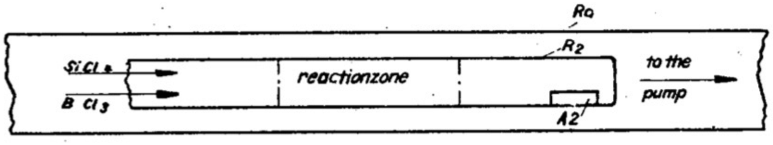

Ra
R2
SiCl4
B Cl3
reactionzone
to the pump
A2

Fig. 4

Fig. 5

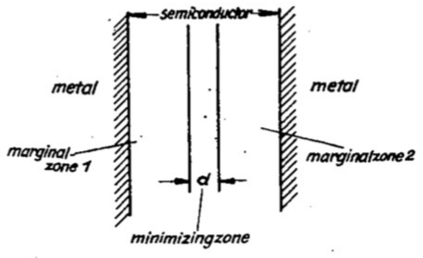
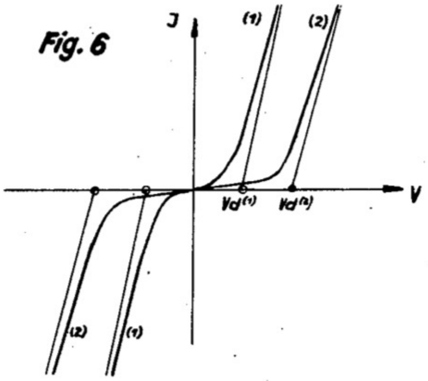
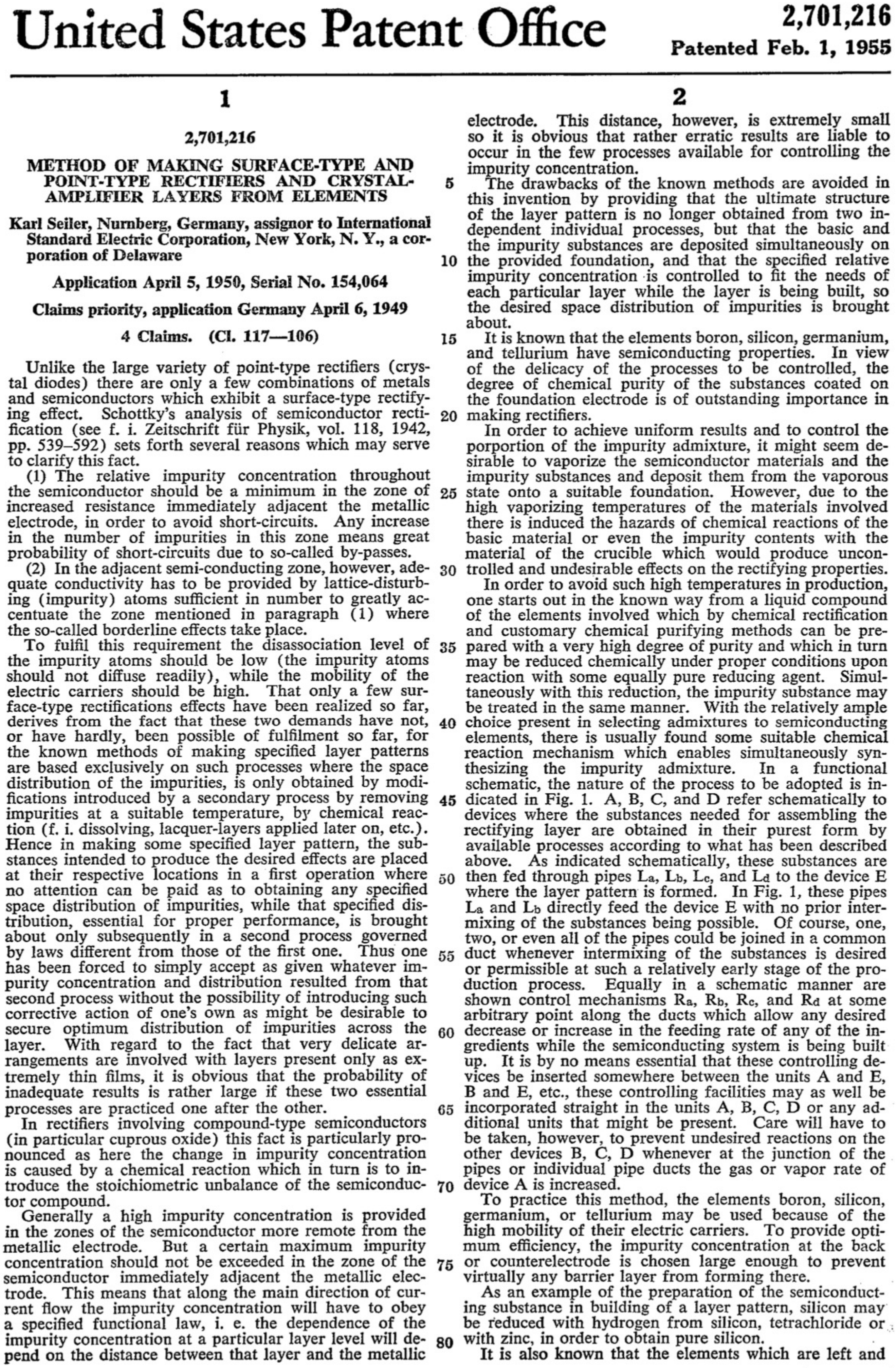

semiconductor
metal
metal
marginal-zone 1
marginalzone 2
d
minimizingzone

Fig. 6



Dr. Karl Seiler
Nürnberg, Platenstr. 66.

Figure B.84: Karl Seiler and Paul Ludwig Günther designed and fabricated silicon electronic devices during the war, and filed patents on silicon transistors after the war (likely based on wartime work).



United States Patent Office

2,701,216
Patented Feb. 1, 1955

2,701,216

METHOD OF MAKING SURFACE-TYPE AND POINT-TYPE RECTIFIERS AND CRYSTAL-AMPLIFIER LAYERS FROM ELEMENTS

Karl Seiler, Nurnberg, Germany, assignor to International Standard Electric Corporation, New York, N. Y., a corporation of Delaware

Application April 5, 1950, Serial No. 154,064

Claims priority, application Germany April 6, 1949

4 Claims. (Cl. 117—106)

Unlike the large variety of point-type rectifiers (crystal diodes) there are only a few combinations of metals and semiconductors which exhibit a surface-type rectifying effect. Schottky's analysis of semiconductor rectification (see f. i. Zeitschrift für Physik, vol. 118, 1942, pp. 539–592) sets forth several reasons which may serve to clarify this fact.

(1) The relative impurity concentration throughout the semiconductor should be a minimum in the zone of increased resistance immediately adjacent the metallic electrode, in order to avoid short-circuits. Any increase in the number of impurities in this zone means great probability of short-circuits due to so-called by-passes.

(2) In the adjacent semi-conducting zone, however, adequate conductivity has to be provided by lattice-disturbing (impurity) atoms sufficient in number to greatly accentuate the zone mentioned in paragraph (1) where the so-called borderline effects take place.

To fulfil this requirement the disassociation level of the impurity atoms should be low (the impurity atoms should not diffuse readily), while the mobility of the electric carriers should be high. That only a few surface-type rectifications effects have been realized so far, derives from the fact that these two demands have not, or have hardly, been possible of fulfilment so far, for the known methods of making specified layer patterns are based exclusively on such processes where the space distribution of the impurities, is only obtained by modifications introduced by a secondary process by removing impurities at a suitable temperature, by chemical reaction (f. i. dissolving, lacquer-layers applied later on, etc.). Hence in making some specified layer pattern, the substances intended to produce the desired effects are placed at their respective locations in a first operation where no attention can be paid as to obtaining any specified space distribution of impurities, while that specified distribution, essential for proper performance, is brought about only subsequently in a second process governed by laws different from those of the first one. Thus one has been forced to simply accept as given whatever impurity concentration and distribution resulted from that second process without the possibility of introducing such corrective action of one's own as might be desirable to secure optimum distribution of impurities across the layer. With regard to the fact that very delicate arrangements are involved with layers present only as extremely thin films, it is obvious that the probability of inadequate results is rather large if these two essential processes are practiced one after the other.

In rectifiers involving compound-type semiconductors (in particular cuprous oxide) this fact is particularly pronounced as here the change in impurity concentration is caused by a chemical reaction which in turn is to introduce the stoichiometric unbalance of the semiconductor compound.

Generally a high impurity concentration is provided in the zones of the semiconductor more remote from the metallic electrode. But a certain maximum impurity concentration should not be exceeded in the zone of the semiconductor immediately adjacent the metallic electrode. This means that along the main direction of current flow the impurity concentration will have to obey a specified functional law, i. e. the dependence of the impurity concentration at a particular layer level will depend on the distance between that layer and the metallic electrode. This distance, however, is extremely small so it is obvious that rather erratic results are liable to occur in the few processes available for controlling the impurity concentration.

The drawbacks of the known methods are avoided in this invention by providing that the ultimate structure of the layer pattern is no longer obtained from two independent individual processes, but that the basic and the impurity substances are deposited simultaneously on the provided foundation, and that the specified relative impurity concentration is controlled to fit the needs of each particular layer while the layer is being built, so the desired space distribution of impurities is brought about.

It is known that the elements boron, silicon, germanium, and tellurium have semiconducting properties. In view of the delicacy of the processes to be controlled, the degree of chemical purity of the substances coated on the foundation electrode is of outstanding importance in making rectifiers.

In order to achieve uniform results and to control the porportion of the impurity admixture, it might seem desirable to vaporize the semiconductor materials and the impurity substances and deposit them from the vaporous state onto a suitable foundation. However, due to the high vaporizing temperatures of the materials involved there is induced the hazards of chemical reactions of the basic material or even the impurity contents with the material of the crucible which would produce uncontrolled and undesirable effects on the rectifying properties.

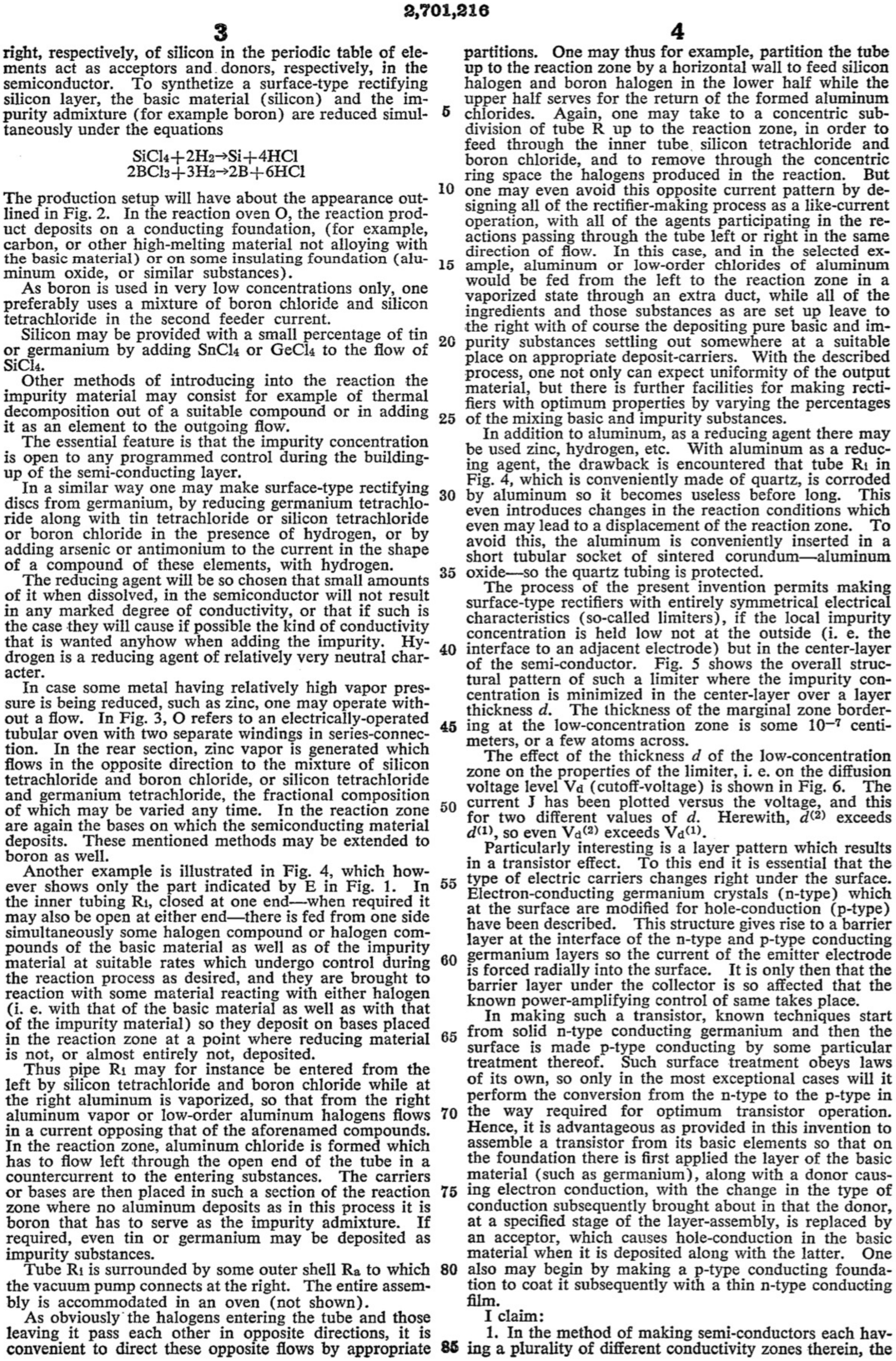
In order to avoid such high temperatures in production, one starts out in the known way from a liquid compound of the elements involved which by chemical rectification and customary chemical purifying methods can be prepared with a very high degree of purity and which in turn may be reduced chemically under proper conditions upon reaction with some equally pure reducing agent. Simultaneously with this reduction, the impurity substance may be treated in the same manner. With the relatively ample choice present in selecting admixtures to semiconducting elements, there is usually found some suitable chemical reaction mechanism which enables simultaneously synthesizing the impurity admixture. In a functional schematic, the nature of the process to be adopted is indicated in Fig. 1. A, B, C, and D refer schematically to devices where the substances needed for assembling the rectifying layer are obtained in their purest form by available processes according to what has been described above. As indicated schematically, these substances are then fed through pipes L_a, L_b, L_c, and L_d to the device E where the layer pattern is formed. In Fig. 1, these pipes L_a and L_b directly feed the device E with no prior intermixing of the substances being possible. Of course, one, two, or even all of the pipes could be joined in a common duct whenever intermixing of the substances is desired or permissible at such a relatively early stage of the production process. Equally in a schematic manner are shown control mechanisms R_a, R_b, R_c, and R_d at some arbitrary point along the ducts which allow any desired decrease or increase in the feeding rate of any of the ingredients while the semiconducting system is being built up. It is by no means essential that these controlling devices be inserted somewhere between the units A and E, B and E, etc., these controlling facilities may as well be incorporated straight in the units A, B, C, D or any additional units that might be present. Care will have to be taken, however, to prevent undesired reactions on the other devices B, C, D whenever at the junction of the pipes or individual pipe ducts the gas or vapor rate of device A is increased.

To practice this method, the elements boron, silicon, germanium, or tellurium may be used because of the high mobility of their electric carriers. To provide optimum efficiency, the impurity concentration at the back or counterelectrode is chosen large enough to prevent virtually any barrier layer from forming there.

As an example of the preparation of the semiconducting substance in building of a layer pattern, silicon may be reduced with hydrogen from silicon, tetrachloride or with zinc, in order to obtain pure silicon.

It is also known that the elements which are left and

Figure B.85: Karl Seiler and Paul Ludwig Günther designed and fabricated silicon electronic devices during the war, and filed patents on silicon transistors after the war (likely based on wartime work).



right, respectively, of silicon in the periodic table of elements act as acceptors and donors, respectively, in the semiconductor. To synthetize a surface-type rectifying silicon layer, the basic material (silicon) and the impurity admixture (for example boron) are reduced simultaneously under the equations

$$SiCl_4+2H_2\rightarrow Si+4HCl$$
$$2BCl_3+3H_2\rightarrow 2B+6HCl$$

The production setup will have about the appearance outlined in Fig. 2. In the reaction oven O, the reaction product deposits on a conducting foundation, (for example, carbon, or other high-melting material not alloying with the basic material) or on some insulating foundation (aluminum oxide, or similar substances).

As boron is used in very low concentrations only, one preferably uses a mixture of boron chloride and silicon tetrachloride in the second feeder current.

Silicon may be provided with a small percentage of tin or germanium by adding $SnCl_4$ or $GeCl_4$ to the flow of $SiCl_4$.

Other methods of introducing into the reaction the impurity material may consist for example of thermal decomposition out of a suitable compound or in adding it as an element to the outgoing flow.

The essential feature is that the impurity concentration is open to any programmed control during the building-up of the semi-conducting layer.

In a similar way one may make surface-type rectifying discs from germanium, by reducing germanium tetrachloride along with tin tetrachloride or silicon tetrachloride or boron chloride in the presence of hydrogen, or by adding arsenic or antimonium to the current in the shape of a compound of these elements, with hydrogen.

The reducing agent will be so chosen that small amounts of it when dissolved, in the semiconductor will not result in any marked degree of conductivity, or that if such is the case they will cause if possible the kind of conductivity that is wanted anyhow when adding the impurity. Hydrogen is a reducing agent of relatively very neutral character.

In case some metal having relatively high vapor pressure is being reduced, such as zinc, one may operate without a flow. In Fig. 3, O refers to an electrically-operated tubular oven with two separate windings in series-connection. In the rear section, zinc vapor is generated which flows in the opposite direction to the mixture of silicon tetrachloride and boron chloride, or silicon tetrachloride and germanium tetrachloride, the fractional composition of which may be varied any time. In the reaction zone are again the bases on which the semiconducting material deposits. These mentioned methods may be extended to boron as well.

Another example is illustrated in Fig. 4, which however shows only the part indicated by E in Fig. 1. In the inner tubing R_1, closed at one end—when required it may also be open at either end—there is fed from one side simultaneously some halogen compound or halogen compounds of the basic material as well as of the impurity material at suitable rates which undergo control during the reaction process as desired, and they are brought to reaction with some material reacting with either halogen (i. e. with that of the basic material as well as with that of the impurity material) so they deposit on bases placed in the reaction zone at a point where reducing material is not, or almost entirely not, deposited.

Thus pipe R_1 may for instance be entered from the left by silicon tetrachloride and boron chloride while at the right aluminum is vaporized, so that from the right aluminum vapor or low-order aluminum halogens flows in a current opposing that of the aforenamed compounds. In the reaction zone, aluminum chloride is formed which has to flow left through the open end of the tube in a countercurrent to the entering substances. The carriers or bases are then placed in such a section of the reaction zone where no aluminum deposits as in this process it is boron that has to serve as the impurity admixture. If required, even tin or germanium may be deposited as impurity substances.

Tube R_1 is surrounded by some outer shell R_a to which the vacuum pump connects at the right. The entire assembly is accommodated in an oven (not shown).

As obviously the halogens entering the tube and those leaving it pass each other in opposite directions, it is convenient to direct these opposite flows by appropriate partitions. One may thus for example, partition the tube up to the reaction zone by a horizontal wall to feed silicon halogen and boron halogen in the lower half while the upper half serves for the return of the formed aluminum chlorides. Again, one may take to a concentric subdivision of tube R up to the reaction zone, in order to feed through the inner tube silicon tetrachloride and boron chloride, and to remove through the concentric ring space the halogens produced in the reaction. But one may even avoid this opposite current pattern by designing all of the rectifier-making process as a like-current operation, with all of the agents participating in the reactions passing through the tube left or right in the same direction of flow. In this case, and in the selected example, aluminum or low-order chlorides of aluminum would be fed from the left to the reaction zone in a vaporized state through an extra duct, while all of the ingredients and those substances as are set up leave to the right with of course the depositing pure basic and impurity substances settling out somewhere at a suitable place on appropriate deposit-carriers. With the described process, one not only can expect uniformity of the output material, but there is further facilities for making rectifiers with optimum properties by varying the percentages of the mixing basic and impurity substances.

In addition to aluminum, as a reducing agent there may be used zinc, hydrogen, etc. With aluminum as a reducing agent, the drawback is encountered that tube R_1 in Fig. 4, which is conveniently made of quartz, is corroded by aluminum so it becomes useless before long. This even introduces changes in the reaction conditions which even may lead to a displacement of the reaction zone. To avoid this, the aluminum is conveniently inserted in a short tubular socket of sintered corundum—aluminum oxide—so the quartz tubing is protected.

The process of the present invention permits making surface-type rectifiers with entirely symmetrical electrical characteristics (so-called limiters), if the local impurity concentration is held low not at the outside (i. e. the interface to an adjacent electrode) but in the center-layer of the semi-conductor. Fig. 5 shows the overall structural pattern of such a limiter where the impurity concentration is minimized in the center-layer over a layer thickness *d*. The thickness of the marginal zone bordering at the low-concentration zone is some 10^{-7} centimeters, or a few atoms across.

The effect of the thickness *d* of the low-concentration zone on the properties of the limiter, i. e. on the diffusion voltage level V_d (cutoff-voltage) is shown in Fig. 6. The current J has been plotted versus the voltage, and this for two different values of *d*. Herewith, $d^{(2)}$ exceeds $d^{(1)}$, so even $V_d^{(2)}$ exceeds $V_d^{(1)}$.

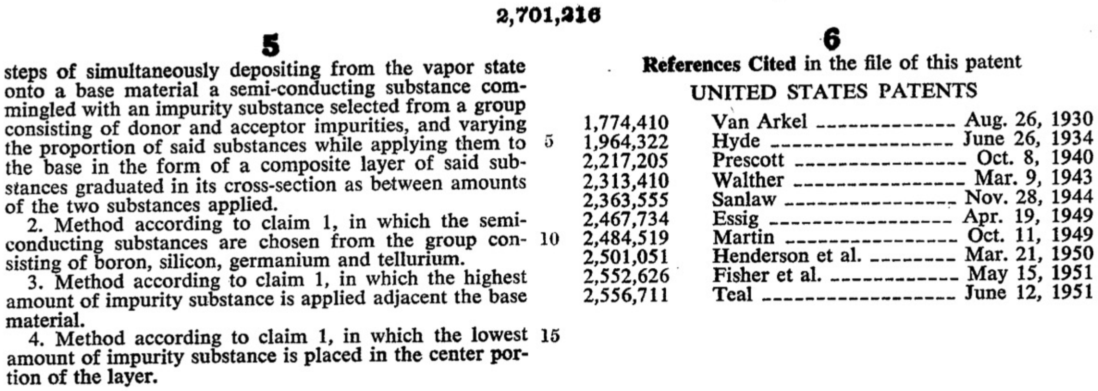
Particularly interesting is a layer pattern which results in a transistor effect. To this end it is essential that the type of electric carriers changes right under the surface. Electron-conducting germanium crystals (n-type) which at the surface are modified for hole-conduction (p-type) have been described. This structure gives rise to a barrier layer at the interface of the n-type and p-type conducting germanium layers so the current of the emitter electrode is forced radially into the surface. It is only then that the barrier layer under the collector is so affected that the known power-amplifying control of same takes place.

In making such a transistor, known techniques start from solid n-type conducting germanium and then the surface is made p-type conducting by some particular treatment thereof. Such surface treatment obeys laws of its own, so only in the most exceptional cases will it perform the conversion from the n-type to the p-type in the way required for optimum transistor operation. Hence, it is advantageous as provided in this invention to assemble a transistor from its basic elements so that on the foundation there is first applied the layer of the basic material (such as germanium), along with a donor causing electron conduction, with the change in the type of conduction subsequently brought about in that the donor, at a specified stage of the layer-assembly, is replaced by an acceptor, which causes hole-conduction in the basic material when it is deposited along with the latter. One also may begin by making a p-type conducting foundation to coat it subsequently with a thin n-type conducting film.

I claim:

1. In the method of making semi-conductors each having a plurality of different conductivity zones therein, the

Figure B.86: Karl Seiler and Paul Ludwig Günther designed and fabricated silicon electronic devices during the war, and filed patents on silicon transistors after the war (likely based on wartime work).



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steps of simultaneously depositing from the vapor state onto a base material a semi-conducting substance commingled with an impurity substance selected from a group consisting of donor and acceptor impurities, and varying the proportion of said substances while applying them to the base in the form of a composite layer of said substances graduated in its cross-section as between amounts of the two substances applied.

2. Method according to claim 1, in which the semi-conducting substances are chosen from the group consisting of boron, silicon, germanium and tellurium.

3. Method according to claim 1, in which the highest amount of impurity substance is applied adjacent the base material.

4. Method according to claim 1, in which the lowest amount of impurity substance is placed in the center portion of the layer.

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References Cited in the file of this patent

UNITED STATES PATENTS

1,774,410	Van Arkel	Aug. 26, 1930
1,964,322	Hyde	June 26, 1934
2,217,205	Prescott	Oct. 8, 1940
2,313,410	Walther	Mar. 9, 1943
2,363,555	Sanlaw	Nov. 28, 1944
2,467,734	Essig	Apr. 19, 1949
2,484,519	Martin	Oct. 11, 1949
2,501,051	Henderson et al.	Mar. 21, 1950
2,552,626	Fisher et al.	May 15, 1951
2,556,711	Teal	June 12, 1951

Figure B.87: Karl Seiler and Paul Ludwig Günther designed and fabricated silicon electronic devices during the war, and filed patents on silicon transistors after the war (likely based on wartime work).

March 3, 1959 P. GÜNTHER ET AL 2,876,400

COMPOSITE ELECTRODES FOR DIRECTIONAL CRYSTAL DEVICES

Filed Feb. 1, 1954

Fig. 1.

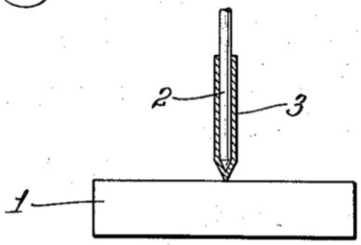
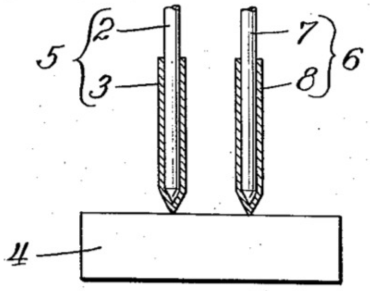
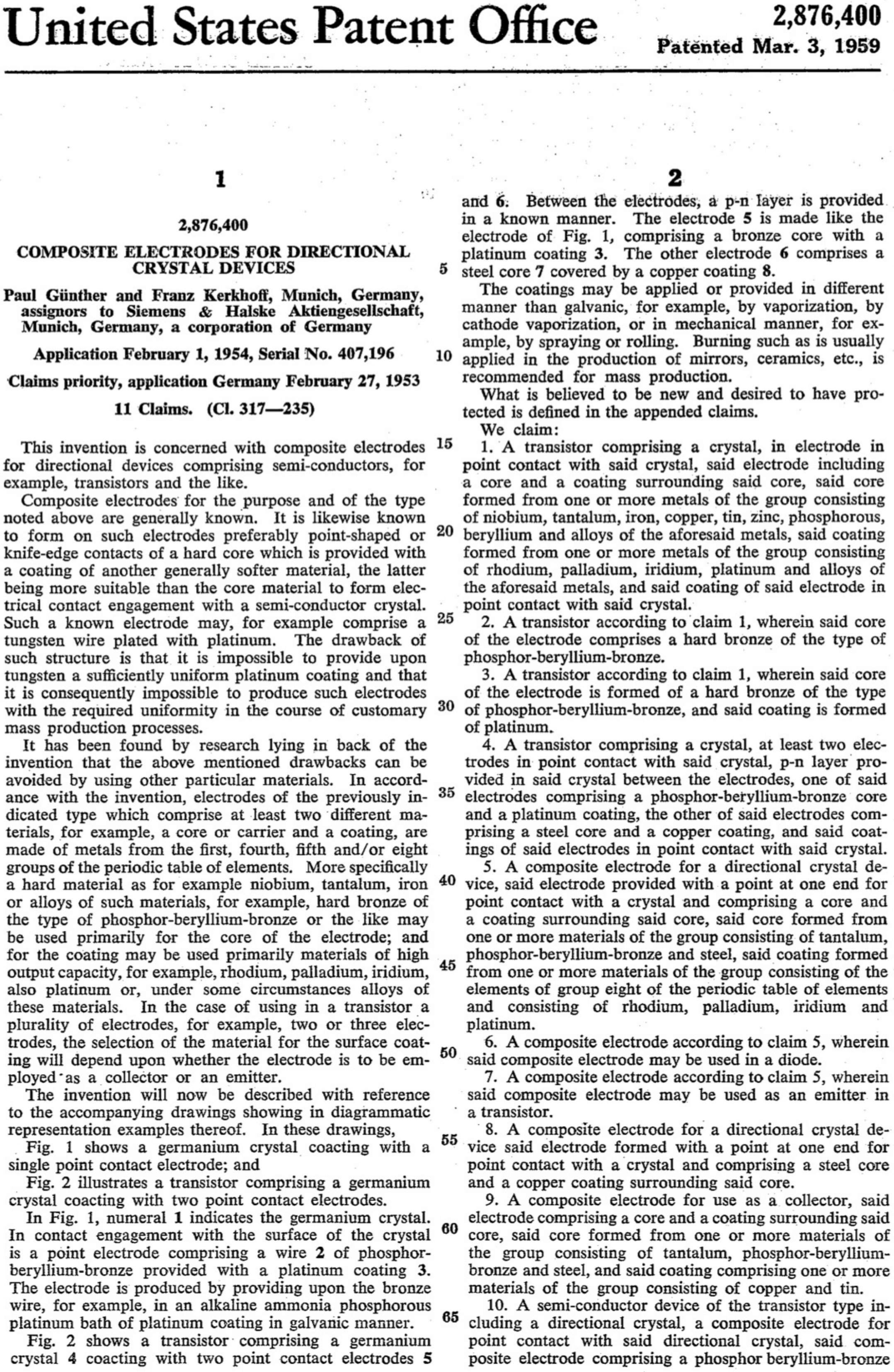


Fig. 2.



INVENTORS
Paul Günther and
Franz Kerkhoff
By
atty.

Figure B.88: Karl Seiler and Paul Ludwig Günther designed and fabricated silicon electronic devices during the war, and filed patents on silicon transistors after the war (likely based on wartime work).



United States Patent Office

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Patented Mar. 3, 1959

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COMPOSITE ELECTRODES FOR DIRECTIONAL CRYSTAL DEVICES

Paul Günther and Franz Kerkhoff, Munich, Germany, assignors to Siemens & Halske Aktiengesellschaft, Munich, Germany, a corporation of Germany

Application February 1, 1954, Serial No. 407,196

Claims priority, application Germany February 27, 1953

11 Claims. (Cl. 317—235)

This invention is concerned with composite electrodes for directional devices comprising semi-conductors, for example, transistors and the like.

Composite electrodes for the purpose and of the type noted above are generally known. It is likewise known to form on such electrodes preferably point-shaped or knife-edge contacts of a hard core which is provided with a coating of another generally softer material, the latter being more suitable than the core material to form electrical contact engagement with a semi-conductor crystal. Such a known electrode may, for example comprise a tungsten wire plated with platinum. The drawback of such structure is that it is impossible to provide upon tungsten a sufficiently uniform platinum coating and that it is consequently impossible to produce such electrodes with the required uniformity in the course of customary mass production processes.

It has been found by research lying in back of the invention that the above mentioned drawbacks can be avoided by using other particular materials. In accordance with the invention, electrodes of the previously indicated type which comprise at least two different materials, for example, a core or carrier and a coating, are made of metals from the first, fourth, fifth and/or eight groups of the periodic table of elements. More specifically a hard material as for example niobium, tantalum, iron or alloys of such materials, for example, hard bronze of the type of phosphor-beryllium-bronze or the like may be used primarily for the core of the electrode; and for the coating may be used primarily materials of high output capacity, for example, rhodium, palladium, iridium, also platinum or, under some circumstances alloys of these materials. In the case of using in a transistor a plurality of electrodes, for example, two or three electrodes, the selection of the material for the surface coating will depend upon whether the electrode is to be employed as a collector or an emitter.

The invention will now be described with reference to the accompanying drawings showing in diagrammatic representation examples thereof. In these drawings,

Fig. 1 shows a germanium crystal coacting with a single point contact electrode; and

Fig. 2 illustrates a transistor comprising a germanium crystal coacting with two point contact electrodes.

In Fig. 1, numeral **1** indicates the germanium crystal. In contact engagement with the surface of the crystal is a point electrode comprising a wire **2** of phosphor-beryllium-bronze provided with a platinum coating **3**. The electrode is produced by providing upon the bronze wire, for example, in an alkaline ammonia phosphorous platinum bath of platinum coating in galvanic manner.

Fig. 2 shows a transistor comprising a germanium crystal **4** coacting with two point contact electrodes **5**

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and **6**. Between the electrodes, a p-n layer is provided in a known manner. The electrode **5** is made like the electrode of Fig. 1, comprising a bronze core with a platinum coating **3**. The other electrode **6** comprises a steel core **7** covered by a copper coating **8**.

The coatings may be applied or provided in different manner than galvanic, for example, by vaporization, by cathode vaporization, or in mechanical manner, for example, by spraying or rolling. Burning such as is usually applied in the production of mirrors, ceramics, etc., is recommended for mass production.

What is believed to be new and desired to have protected is defined in the appended claims.

We claim:

1. A transistor comprising a crystal, in electrode in point contact with said crystal, said electrode including a core and a coating surrounding said core, said core formed from one or more metals of the group consisting of niobium, tantalum, iron, copper, tin, zinc, phosphorous, beryllium and alloys of the aforesaid metals, said coating formed from one or more metals of the group consisting of rhodium, palladium, iridium, platinum and alloys of the aforesaid metals, and said coating of said electrode in point contact with said crystal.

2. A transistor according to claim 1, wherein said core of the electrode comprises a hard bronze of the type of phosphor-beryllium-bronze.

3. A transistor according to claim 1, wherein said core of the electrode is formed of a hard bronze of the type of phosphor-beryllium-bronze, and said coating is formed of platinum.

4. A transistor comprising a crystal, at least two electrodes in point contact with said crystal, p-n layer provided in said crystal between the electrodes, one of said electrodes comprising a phosphor-beryllium-bronze core and a platinum coating, the other of said electrodes comprising a steel core and a copper coating, and said coatings of said electrodes in point contact with said crystal.

5. A composite electrode for a directional crystal device, said electrode provided with a point at one end for point contact with a crystal and comprising a core and a coating surrounding said core, said core formed from one or more materials of the group consisting of tantalum, phosphor-beryllium-bronze and steel, said coating formed from one or more materials of the group consisting of the elements of group eight of the periodic table of elements and consisting of rhodium, palladium, iridium and platinum.

6. A composite electrode according to claim 5, wherein said composite electrode may be used in a diode.

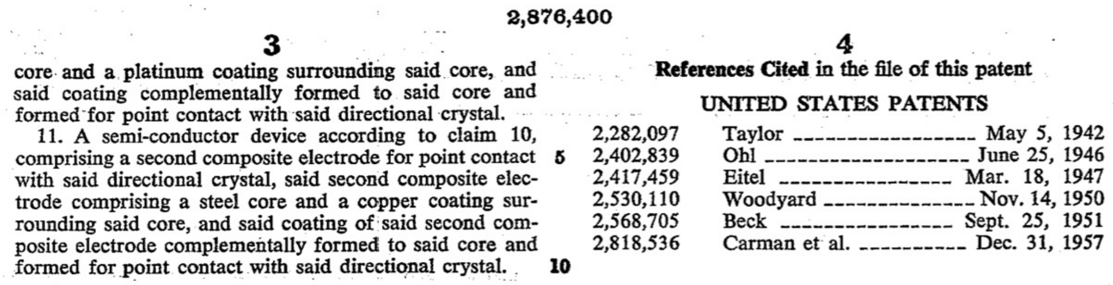
7. A composite electrode according to claim 5, wherein said composite electrode may be used as an emitter in a transistor.

8. A composite electrode for a directional crystal device said electrode formed with a point at one end for point contact with a crystal and comprising a steel core and a copper coating surrounding said core.

9. A composite electrode for use as a collector, said electrode comprising a core and a coating surrounding said core, said core formed from one or more materials of the group consisting of tantalum, phosphor-beryllium-bronze and steel, and said coating comprising one or more materials of the group consisting of copper and tin.

10. A semi-conductor device of the transistor type including a directional crystal, a composite electrode for point contact with said directional crystal, said composite electrode comprising a phosphor beryllium-bronze

Figure B.89: Karl Seiler and Paul Ludwig Günther designed and fabricated silicon electronic devices during the war, and filed patents on silicon transistors after the war (likely based on wartime work).



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core and a platinum coating surrounding said core, and said coating complementally formed to said core and formed for point contact with said directional crystal.

11. A semi-conductor device according to claim 10, comprising a second composite electrode for point contact with said directional crystal, said second composite electrode comprising a steel core and a copper coating surrounding said core, and said coating of said second composite electrode complementally formed to said core and formed for point contact with said directional crystal.

4

References Cited in the file of this patent

UNITED STATES PATENTS

2,282,097	Taylor	May 5, 1942
2,402,839	Ohl	June 25, 1946
2,417,459	Eitel	Mar. 18, 1947
2,530,110	Woodyard	Nov. 14, 1950
2,568,705	Beck	Sept. 25, 1951
2,818,536	Carman et al.	Dec. 31, 1957

Figure B.90: Karl Seiler and Paul Ludwig Günther designed and fabricated silicon electronic devices during the war, and filed patents on silicon transistors after the war (likely based on wartime work).

[**11. Helmar Frank (Moravian, 1919–2015) and Jan Tauc (Bohemian, 1922–2010)** worked in very large, highly secret, German-run laboratories in Tannwald (now Tanvald, Czech Republic) during the war [Lojek 2007]. When Czechoslovakia salvaged what was left of those laboratories and restarted them after the war, one of the first actions that Frank and Tauc carried out was to produce and demonstrate transistors. Those postwar Czech transistors were based at least in part, and quite possibly entirely, on wartime German work. See for example:

pp. 1050–1072

pp. 2756–2757

p. 3983

p. 5503

p. 5513

p. 5549

Both Frank and Tauc continued to develop semiconductor and microelectronics technologies in Czechoslovakia for many years. Frank was interrogated by the United States in 1945 regarding his knowledge of advanced electronics technologies. Tauc eventually moved to the United States.

12. Bernhard Gudden (German, 1892–1945) and Kurt Lehovec (Bohemian/Austrian/Czech, 1918–2012) ran a secretive and well-funded group that was developing advanced semiconductor devices at Charles University in Prague during the war [Lojek 2007]. After the war, Gudden refused to assist Russian or Russian-backed forces and died in a Czech prison. Lehovec was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits. His first U.S. patent application on transistors covered a design that had several advantages over the transistors from Bell Laboratories, and that may well have been based on wartime work that he and Gudden had been conducting. See for example:

p. 1074

p. 1097

pp. 2757–2763

pp. 2818–2832

pp. 2895–2910

Historians should conduct much more archival research on the history and accomplishments of the wartime microelectronics programs at Bohemian/Moravian/Czech laboratories such as those where Helmar Frank, Jan Tauc, Bernhard Gudden, and Kurt Lehovec worked. Historians should also investigate the many ways that numerous countries benefitted after the war from scientists, information, and materials from those wartime programs.]

Czech National Library of Technology. Professor Helmar Frank. English translation. [https://www.techlib.cz/cs/84002-profesor-helmar-frank]

Helmar Frank was a Czechoslovak physicist of German nationality. He graduated in the Czechoslovak Republic and the Protectorate of Bohemia und Moravia, worked at the German University in Prague, the Institute of Physics of Charles University in Prague, the Research Institute of Communication Technology in Prague and since 1968 he worked as associate professor and later professor at the Faculty of Nuclear and Physical Engineering Technical University in Prague.

He created the first Czechoslovak semiconductor amplifying component—the point-contact germanium transistor—and developed, initiated and helped to introduce production of semiconductor materials and components in many Czechoslovak factories. [...]

1940–1942 scientific assistant at the Institute of Physics of the German University in Prague

1942–1945 lecturer Prof. Gudden at the Institute of Physics of the German University in Prague

1945–1947 detained by the Czechoslovak army in the framework of reparations

1947–1950 employed as a civil contract employee of the Military Technical Institute with a workplace in the Institute of Physics of Charles University

1950–1968 employed as an independent researcher at the Research Institute for Electro (tech) Physics. (VÚPEF, later VÚST)

1968–1983 Associate Professor, Department of Solid State Engineering, Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague (KIPL FJFI ČVUT)

1972–1981 Head of the Department of Solid State Engineering

1973 appointed Chairman of the Board for the Defense of Candidate Dissertations, Chairman of the State Examination Board for the State Final Examinations, elected Vice-Dean for Science and Foreign Relations;

1983–2008 professor at FNSPE CTU

1950–2009 lectures and cooperation Faculty of Mathematics and Physics, Charles University in Prague, Technical University of Dresden, University of Regensburg, GSF Munich, Slovak Technical University in Bratislava, cooperation with CKD Semiconductors Prague, Tesla Vrchlabi, Prumet Sumperk, Tesla Roznov, Tesla Piestany

***Jan Tauc 1922–2010.* National Academy of Sciences 2011 [https://nas.nasonline.org/site/DocServer/Tauc_Jan.pdf]**

Jan's first job after graduation was at a government-supported research institute with a mission to develop electronic technologies (such as television and microwaves), using equipment and documentation left behind by the German army and declassified information from the West that became available after the war. The institute was located first in Tanvald, a mountainous region of northern Bohemia, which was the location of the former German army center. There Jan became involved in microwave detectors that the Germans had developed for the 10 cm wavelength band, using germanium. When the news of the invention of the transistor reached Prague, he used the germanium of those detectors to build the first point-contact transistor in Czechoslovakia and decided to stay in that field.

Bo Lojek. 2007. *History of Semiconductor Engineering.* Berlin: Springer. pp. 195–204.

Czech-born Kurt Lehovec started his career during World War II at Charles University in Prague as a Ph.D. student of Prof. B. Gudden (B. Gudden graduated and worked under Prof. Pohl). Kurt's Ph.D. study focused on lead-selenide as an infrared detector. During the course of this research, he noticed that Thallium diffused into Selenium very rapidly and the "blocking effect" of the rectifier was significantly improved. Süddeutsche Apparate Fabrik in Nüremberg supported Lehovec's study. This association let Lehovec attend a secret scientific conference about "Material X" in 1942 in Munich. The code name, Material X, was used for Germanium, and Lehovec did not know what Material X was.

German military research maintained two research groups working on semiconductors in occupied Czechoslovakian "Böhmen und Mähren" territory: The Prague group headed by Prof. B. Gudden worked on the rectifying diode; a second and larger group worked in the small town of Tanvald in the North of Bohemia on microwave point contact diode and radar research. Many members of the German research groups, including Prof. Gudden, were killed in May 1945 during the liberation of Czechoslovakia by the Red Army. A major part of the Tanvald research facility was confiscated by the Soviet army and transferred to the Soviet Union; the rest of the inventory was set on fire and destroyed.

Several kilograms of Germanium survived the fire and were used by Jan Tauc and Helmar Frank to build the first European [sic—actually the first Czech] transistors in 1949. Jan Tauc later immigrated to the United States. Helmar Frank, who was also a student of Prof. Gudden at Charles University, directed post-war semiconductor research sponsored by the Czechoslovakian Army at the former Philips Laboratories in Prague.

During the war the British Intelligence Assault Unit 30AU identified prominent scientists involved in German research. [...] At the end of the war, the CIA and KGB quickly joined the British effort and transferred several researchers from the Prague and Tanvald research groups to their respective countries. The CIA with U.S. Joint Intelligence Objectives Agency (JIOA) executed the Project Paperclip, and picked up Kurt Lehovec. Under very dramatic circumstances, when the Red Army began the liberation of Prague, and when hours not days made a difference, Lehovec peddled on a bicycle with his tennis racquet from Prague to the American occupied zone. Later, he was deported as a Paperclip item in a U.S. Navy ship to the Squier Laboratory at U.S. Signal Corps in Fort Monmouth in New Jersey.

The thinking behind project Paperclip was exemplified in a letter Major General Hugh Knerr, Deputy Commanding General for Administration of U.S. Strategic Forces in Europe, wrote to Lieutenant General Carl Spatz in [June] 1945: "*Occupation of German scientific and industrial establishments has revealed the fact that we have been alarmingly backward in many fields of research, if we do not take this opportunity to seize apparatus and the brains that developed it and put this combination back to work promptly, we will remain several years behind while we attempt to cover a field already exploited.*"

[...] Lehovec arrived at the U.S. Signal Corps with physical chemists, Dr. Rudolf Brill and Ernst Baers, physicists; Horst Kedesti, Georg Hass, Georg Goubau, Günter Guttwein, and electrical engineers; Hans Ziegler, Eduard Gerber, and Richard Guenther. From 210 Paperclip scientists the Signal Corps utilized 24 scientists, all involved in radar and communication research. The rocket scientists ended up in White Sands.

[...] In 1959, Ziegler became the Chief Scientist of U.S. Army Signal Corps' Laboratories at Fort Monmouth, N.J. After the Army's re-organization, he was appointed in 1963 to Deputy for Science and Chief Scientist of the US Army Electronics Command and in 1971 to Director of the U.S. Army Electronics Technology & Devices Laboratory. Dr. Ziegler was also a Fellow of the IEEE and the American Academy of Science. The Army recognized his achievements with two Meritorious—and the coveted Exceptional—Civil Service Awards. [...]

Lehovec asked the chief scientist of Squier Laboratory, Dr. Golay, what his research project should be, and he received the answer: "*you can do whatever you want, we need everything.*" Lehovec was one of the youngest members of the Paperclip team, and he worked very hard from day one. His group was assigned to the "Institute of Advanced Study" and had about 10 members. In 1948, Lehovec was sent to Purdue University to visit Prof. Lark-Horovitz's group to discuss ongoing research with the Signal Corps. With Dr. Harold A. Zahl, the Chief Scientist of the Signal Corps, Lehovec visited Bell Laboratories and started the Army's research on silicon and germanium devices, primarily on the problems of light emission from solids.

From his Prague studies he was familiar with the work of Russian scientist O. Lossew on "cold" light emission, first observed in silicon carbide in 1907. This effect, which was manifested by passing current through selected crystals of silicon carbide, showed a type of light emission which remained unexplained. Dr. Carl A. Accardo remembered when he was approached by Lehovec with an inquiry "*if I would be interested in studying the effects with him and his co-worker Edward Jamgochian.*" Their research indicated that the produced light was due to the recombination of electrons and holes across a so-called p-n junction. The two articles authored by Lehovec, Accardo and Jamgochian appeared in Physical Review and were presented at the American Physical Society in New York. The articles provided the theoretical background and an explanation of what later become known as LED's, or light emitting diodes.

Lehovec was a principal and reviewer of Semiconductor Research Contract DA36-0390SC 71131 between the U.S. Signal Corps and Prof. Karl Lark-Horovitz's group at Purdue University. During 1949–1950 Lark-Horovitz and R. Bray investigated the effect of strong electric fields on the observed spreading resistance of metal-germanium point-contact rectifiers. Some of these experiments closely resembled the work carried out simultaneously at Bell Telephone Laboratories by Bardeen, Brattain, and Shockley. [...]

Lehovec set up laboratory production in record time and he was on a mission. His goal was not to duplicate Bell Telephone Laboratories devices. He wanted to be an innovator, not a follower. He noticed already at the Signal Corps that the only drawback of the silicon devices was lower mobility of free carriers, which would make the devices somewhat slower compared to the germanium devices. Kurt Lehovec realized that the only way to overcome this disadvantage was to make the device smaller. However, to manufacture small devices in the beginning of the nineteen fifties was not an easy task. In addition, Sprague's management philosophy was, "*if this is any good, Bell would have done it already.*"

Lehovec found two basic problems with the Bell point contact transistor which the Sprague Company licensed:

1) Tedious labor to manipulate under a microscope two tiny wires to the correct position.

2) The possibility of sliding of the wires during the handling the device.

Lehovec came up with an ingenious solution to these problems which Armen Fermenian put into practice, a narrow sheet of beryllium copper was guided over a ceramic frame and glued to it. Two metal chisels cut the sheet within the frame providing the triangular shapes with sharp points facing to each other. A plunger then bent the tips of the triangles into vertical position at the desired spacing of the point contacts.

Lehovec visited Bell Labs and showed a transistor to Jack Morton. Morton was very impressed with Sprague technology and considered an order of a large number of devices for Western Electric. The deal was, however, aborted by Sprague management. The next major improvement of transistor technology was the introduction of new “capillary alloying” for junction transistor. This method allowed to calculate the amount of germanium dissolved in the indium from the germanium-indium phase diagram at the given temperature, and thus to control the junction depth. In addition, the surface-melt technique enabled the production of multiple junctions in a single slice of semiconductor. The method was superior to the BTL and TI grown-junction transistor process, which could produce only PNP or NPN structures. [...]

Another of Lehovec’s major inventions, junction isolation, had a very interesting background. Lehovec attended a workshop at Princeton University in the end of 1958. Torkel Wallmark of RCA presented in this workshop a visionary presentation about the next generation of electronics. Wallmark listed problems that needed to be solved before integrated circuits could be designed. One of these limitations was device isolation. Lehovec, educated from his work on the surface-melt multiple-junction devices found a solution while driving his red Corvette—PN junction isolation.

The engineering problem was solved; the bigger problem remained to be overcome. At that time nobody had heard anything about integrated circuits, so only visionaries could have appreciated the importance of Lehovec’s invention. The Sprague Company did not have visionaries and they did not want to file a patent application. Sprague’s patent attorney, Hillary Sweeney, explained at great length to Lehovec, that a patent needed to have a docket number and must be in sequence with previous disclosures, and that he was too busy to do it. Lehovec wrote the patent application himself and mailed it to the Patent Office. After months, a persistent Lehovec finally prevailed. His patent was approved and issued by the Patent Office without a major objection. Immediately after the patent 3,029,3662 was issued, Al Bower, of the patent firm Connolly & Hutz that handled the Sprague patents, called Lehovec that Texas Instruments is suing Sprague for patent interference. [...]

Texas Instruments set up the interference proceeding hearing in a large conference room and equipped Kilby with double digits of TI’s attorneys. Sprague Company was represented by Attorney at Law, Mr. Hutz, and Kurt Lehovec. [...]

The whole Texas Instruments séance ended as a complete debacle, and attorney Hutz was asked to deliver a written summary of arguments presented at the hearing. Three weeks later the U.S. Patent Office decided that Lehovec was entitled to all patent claims and was awarded patent priority.

Harold Zahl, a retired Director of the U.S. Army's Fort Monmouth laboratory [Zahl 1968, pp. 108–109]

On "Project Paperclip" it was not pieces of equipment or missiles which were brought over from Germany, it was people—scientists, engineers, and families. In the cruel years immediately following the war there were many very able scientists and engineers who wished to leave Western Europe and make a new home in the United States.

"Screening" offices were accordingly set up in Europe, and applications studied very carefully as to ability and previous political interests. Simultaneously military laboratories in this country were asked whether they wished any of these people, and their dossiers were made available for decision purposes.

As most elsewhere, at Monmouth we had two problems: First, the war still remained very fresh in the memories of our people; and second, we were still releasing relatively unskilled American citizens. But the superb talent available through "Paperclip" suggested once-in-a-lifetime opportunities, and much of the top American talent was straining to get out of the military environment back to their teaching jobs or to industry.

Demonstrative of the type of talent we were dealing with, on each request the requester had to sign a statement to the effect that the equivalent to the person he was asking for was not available in the U.S. The problem of asking for this type of talent, or rather the decision as to whether we should, was put squarely up to me as director of research. I recommended "Yes, let's try it with 25 people," and we were in business. This was probably one of the most important decisions I have ever made.

The men and their families then started coming over, most of them with all their worldly possessions and hardly any money. The title of "Doctor" soon grew commonplace at Monmouth. In coming over, they were signed for a two-year contract, with our option to return them in six months if we for any reason found them unsatisfactory. After the contract expired, Civil Service regulations allowed them to change to what was called Schedule-A, a form of Civil Service which would be finalized once citizenship had been achieved.

I have in my office a photo of the first 16 which came over, hands up, swearing allegiance to the United States, as they moved into Schedule-A. Of these 16, now twenty years later, 11 still remain at the Monmouth laboratory, all in very high positions, and one in the very highest. It was a wonderful experience to see the old "Melting Pot" in action.

In retrospect, throughout the country we see thousands of our best citizens, able engineers, scientists, and administrators, with a byproduct of tens of thousands of brilliant children in our schools . . . the results of "Paperclip." Surely this country is better and stronger because of that decision, made by a few men more than two decades ago.

Dec. 4, 1956 K. LEHOVEC **2,773,224**

TRANSISTOR POINT CONTACT ARRANGEMENT

Filed Dec. 31, 1952

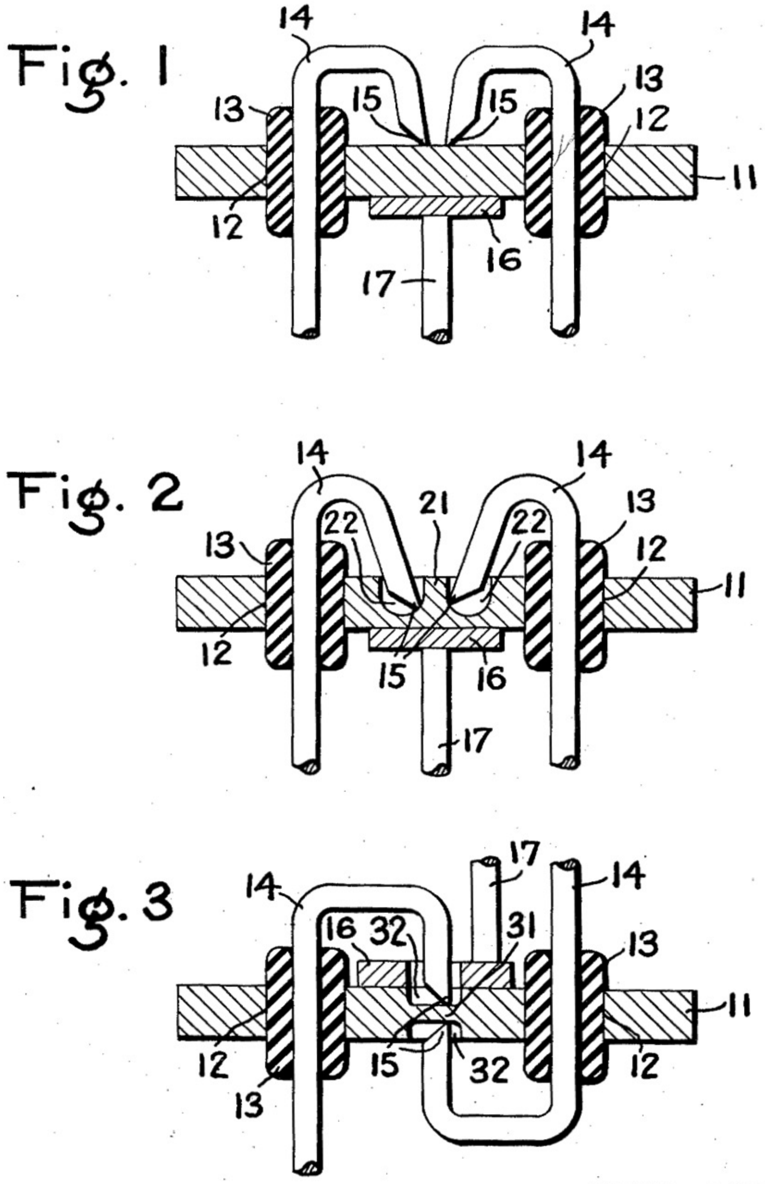
Fig. 1
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Fig. 2
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Fig. 3
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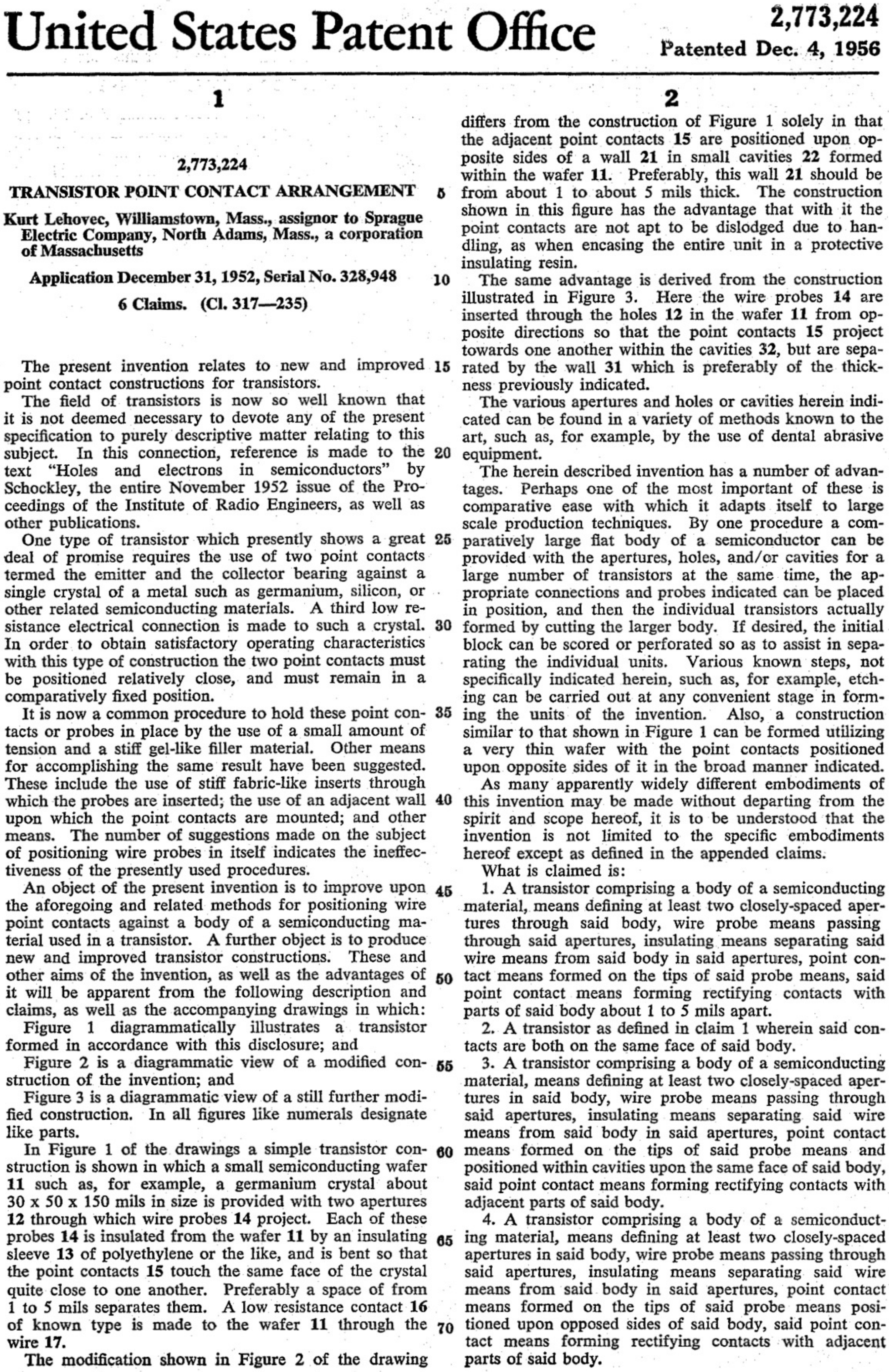
INVENTOR.
KURT LEHOVEC
BY
Connolly and Hutz
HIS ATTORNEYS

Figure B.91: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits. In 1952, he filed a patent application on a transistor design that had several advantages over the transistors from Bell Laboratories.



United States Patent Office

2,773,224
Patented Dec. 4, 1956

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2,773,224

TRANSISTOR POINT CONTACT ARRANGEMENT

Kurt Lehovec, Williamstown, Mass., assignor to Sprague Electric Company, North Adams, Mass., a corporation of Massachusetts

Application December 31, 1952, Serial No. 328,948

6 Claims. (Cl. 317—235)

The present invention relates to new and improved point contact constructions for transistors.

The field of transistors is now so well known that it is not deemed necessary to devote any of the present specification to purely descriptive matter relating to this subject. In this connection, reference is made to the text "Holes and electrons in semiconductors" by Schockley, the entire November 1952 issue of the Proceedings of the Institute of Radio Engineers, as well as other publications.

One type of transistor which presently shows a great deal of promise requires the use of two point contacts termed the emitter and the collector bearing against a single crystal of a metal such as germanium, silicon, or other related semiconducting materials. A third low resistance electrical connection is made to such a crystal. In order to obtain satisfactory operating characteristics with this type of construction the two point contacts must be positioned relatively close, and must remain in a comparatively fixed position.

It is now a common procedure to hold these point contacts or probes in place by the use of a small amount of tension and a stiff gel-like filler material. Other means for accomplishing the same result have been suggested. These include the use of stiff fabric-like inserts through which the probes are inserted; the use of an adjacent wall upon which the point contacts are mounted; and other means. The number of suggestions made on the subject of positioning wire probes in itself indicates the ineffectiveness of the presently used procedures.

An object of the present invention is to improve upon the aforegoing and related methods for positioning wire point contacts against a body of a semiconducting material used in a transistor. A further object is to produce new and improved transistor constructions. These and other aims of the invention, as well as the advantages of it will be apparent from the following description and claims, as well as the accompanying drawings in which:

Figure 1 diagrammatically illustrates a transistor formed in accordance with this disclosure; and

Figure 2 is a diagrammatic view of a modified construction of the invention; and

Figure 3 is a diagrammatic view of a still further modified construction. In all figures like numerals designate like parts.

In Figure 1 of the drawings a simple transistor construction is shown in which a small semiconducting wafer **11** such as, for example, a germanium crystal about 30 x 50 x 150 mils in size is provided with two apertures **12** through which wire probes **14** project. Each of these probes **14** is insulated from the wafer **11** by an insulating sleeve **13** of polyethylene or the like, and is bent so that the point contacts **15** touch the same face of the crystal quite close to one another. Preferably a space of from 1 to 5 mils separates them. A low resistance contact **16** of known type is made to the wafer **11** through the wire **17**.

The modification shown in Figure 2 of the drawing

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differs from the construction of Figure 1 solely in that the adjacent point contacts **15** are positioned upon opposite sides of a wall **21** in small cavities **22** formed within the wafer **11**. Preferably, this wall **21** should be from about 1 to about 5 mils thick. The construction shown in this figure has the advantage that with it the point contacts are not apt to be dislodged due to handling, as when encasing the entire unit in a protective insulating resin.

The same advantage is derived from the construction illustrated in Figure 3. Here the wire probes **14** are inserted through the holes **12** in the wafer **11** from opposite directions so that the point contacts **15** project towards one another within the cavities **32**, but are separated by the wall **31** which is preferably of the thickness previously indicated.

The various apertures and holes or cavities herein indicated can be found in a variety of methods known to the art, such as, for example, by the use of dental abrasive equipment.

The herein described invention has a number of advantages. Perhaps one of the most important of these is comparative ease with which it adapts itself to large scale production techniques. By one procedure a comparatively large flat body of a semiconductor can be provided with the apertures, holes, and/or cavities for a large number of transistors at the same time, the appropriate connections and probes indicated can be placed in position, and then the individual transistors actually formed by cutting the larger body. If desired, the initial block can be scored or perforated so as to assist in separating the individual units. Various known steps, not specifically indicated herein, such as, for example, etching can be carried out at any convenient stage in forming the units of the invention. Also, a construction similar to that shown in Figure 1 can be formed utilizing a very thin wafer with the point contacts positioned upon opposite sides of it in the broad manner indicated.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope hereof, it is to be understood that the invention is not limited to the specific embodiments hereof except as defined in the appended claims.

What is claimed is:

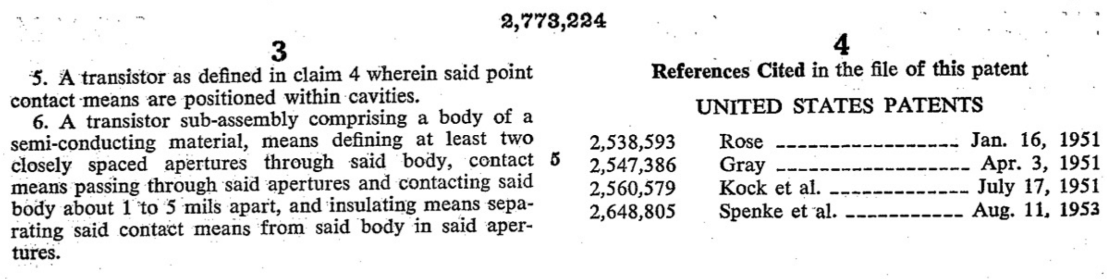
1. A transistor comprising a body of a semiconducting material, means defining at least two closely-spaced apertures through said body, wire probe means passing through said apertures, insulating means separating said wire means from said body in said apertures, point contact means formed on the tips of said probe means, said point contact means forming rectifying contacts with parts of said body about 1 to 5 mils apart.

2. A transistor as defined in claim 1 wherein said contacts are both on the same face of said body.

3. A transistor comprising a body of a semiconducting material, means defining at least two closely-spaced apertures in said body, wire probe means passing through said apertures, insulating means separating said wire means from said body in said apertures, point contact means formed on the tips of said probe means and positioned within cavities upon the same face of said body, said point contact means forming rectifying contacts with adjacent parts of said body.

4. A transistor comprising a body of a semiconducting material, means defining at least two closely-spaced apertures in said body, wire probe means passing through said apertures, insulating means separating said wire means from said body in said apertures, point contact means formed on the tips of said probe means positioned upon opposed sides of said body, said point contact means forming rectifying contacts with adjacent parts of said body.

Figure B.92: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits. In 1952, he filed a patent application on a transistor design that had several advantages over the transistors from Bell Laboratories.



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5. A transistor as defined in claim 4 wherein said point contact means are positioned within cavities.

6. A transistor sub-assembly comprising a body of a semi-conducting material, means defining at least two closely spaced apertures through said body, contact means passing through said apertures and contacting said body about 1 to 5 mils apart, and insulating means separating said contact means from said body in said apertures.

4

References Cited in the file of this patent

UNITED STATES PATENTS

2,538,593	Rose	Jan. 16, 1951
2,547,386	Gray	Apr. 3, 1951
2,560,579	Kock et al.	July 17, 1951
2,648,805	Spenke et al.	Aug. 11, 1953

Figure B.93: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits. In 1952, he filed a patent application on a transistor design that had several advantages over the transistors from Bell Laboratories.

B.2 Printed Circuits and Multi-Pin Connectors

[While moving from large vacuum tubes to small transistors greatly helped to miniaturize and simplify electronics, the development of printed circuit boards was another major step in microelectronics. In printed circuits, electronic components are attached to an insulating board that is covered with etched metal lines for wires, avoiding the labor and bulkiness involved in connecting separate physical wires to each component. A closely related technological development was multipin connectors, which could be used without printed circuits but became even more advantageous when used together with printed circuits.

As shown on pp. 2766–2777, Albert Hanson (German, 18??–19??) filed patent applications on printed circuits and multi-pin connectors in 1902 and 1903. From the available documentation, it is not clear how far he got in implementing his designs, although the highly detailed nature of the patents suggests that he may well have built and tested printed circuits and multi-pin connectors.

Mathias Nowottnick, an engineering professor at the University of Rostock, noted that printed circuit technology, apparently based on Hanson's patents, was being used by at least three German companies by 1927–1932 [Nowottnick 2014, p. 4]:

1927 Telefunken, Verdrahtung von Bauteilen mittels Messingstreifen.	1927 Telefunken, wiring of components using brass strips.
1930 Hescho-Werke in Hermsdorf Aufdrucken von Leiterzügen auf Keramiksubstrat mittels Siebdrucktechnik (stellt heute noch die Grundlage für die Dickschichttechnik dar!)—"Gedruckte Schaltung".	1930 Hescho Works in Hermsdorf Imprinting of conductors on ceramic substrate using screen printing technology (still the basis for thick-film technology today!)—"printed circuits."
1932 erste Leiterplatte mit genieteten Metallstreifen, Sachsenwerk Licht und Kraft AG [Fig. B.106]	1932 first printed circuit board with riveted metal strips, Sachsenwerk Light and Power AG [Fig. B.106]

Wolfgang Scheel, a longtime department head of the Fraunhofer Institute, named additional German companies that were among the first to use printed circuits [Manfred Frank 2003, p. 2]:

Lassen Sie mich zunächst feststellen, dass die Leiterplatte in diesem Jahr [2003] ihren 100. Geburtstag feiert. Der Berliner Hanson hat dafür das Patent 1903 angemeldet. Ferner möchte ich anmerken, dass als Pionierfirmen auf dem Gebiet der Leiterplattenentwicklung in Deutschland die Sachsenwerk Licht und Kraft AG Niedersedlitz, die Ruwelwerke Geldern, die Lackwerke Peters in Kempen und die Isola AG in Düren zu nennen sind.	Let me first note that the printed circuit board celebrates its 100th birthday this year [2003]. Hanson from Berlin filed the patent for it in 1903. I would also like to note that the pioneering companies in the field of printed circuit board development in Germany are Sachsenwerk Licht und Kraft AG Niedersedlitz, Ruwelwerke Geldern, Lackwerke Peters in Kempen and Isola AG in Düren.

Paul Eisler (Austrian, 1907–1992) studied engineering at the University of Vienna, graduated in

1930, and worked in electrical engineering, during which time he apparently became familiar with then-current German and Austrian printed circuit technologies that were based on Hanson's original patents. In 1936 Eisler fled to the United Kingdom, taking his knowledge of printed circuit technologies with him, and he immediately began building printed circuits upon his arrival there [Eisler 1989; Medawar and Pyke 2000].[4]

Eisler brought printed circuit technology to the attention of the British government during World War II and filed patent applications on it in 1944 (pp. 2779–2795). Some U.S. officials discovered Eisler's work and incorporated simple printed circuits into proximity fuses for artillery shells that were used in late 1944 and 1945, but otherwise Allied countries do not seem to have harnessed the potential of printed circuits during the war.

In contrast, as shown on pp. 2796–2799, printed circuits were in "wide use" in wartime Germany (apparently having grown far beyond just Telefunken, Hescho-Werke, and Sachsenwerk since ~1930), and all of that printed circuit technology was transferred to the United States on a large scale after the war by people such as longtime Bell Telephone Laboratories engineer Todos Odarenko.

The final step in the development of printed circuits came when Rudolf Strauss (German, 1913–2001) developed the wave soldering method for the fully automated manufacturing of printed circuits, or surface mount technology (SMT), from 1951 to 1955; see pp. 2800–2806 [rondinax.wordpress.com/2014/01/31/rudolf-strauss-1913-2001-a-key-player-in-the-rondinax-and-rondix-story/]. (Was Strauss truly the original creator of wave soldering, or did he bring that method with him from the German-speaking world, just as Eisler apparently brought printed circuits?)

Boris Chertok, who led some of the Soviet missions removing German technologies after World War II, mentioned the widespread German use of sophisticated multi-pin connectors. Those likely went along with printed circuits, since printed circuits were in wide use and both multi-pin connectors and printed circuits traced back to Albert Hanson's inventions. Chertok also described the transfer of many other advanced electronics technologies to the Soviet Union (pp. 2807–2812).

The figure on p. 2813 shows a panel of multi-pin connectors from an A-4 (V-2) rocket produced during the war [Peenemünde Archive, Folder ARK 41].

Much more archival research is needed to reconstruct the detailed history and extent of research and development of printed circuits in the German-speaking world, as well as how that work was transferred to other countries during and after the Third Reich.]

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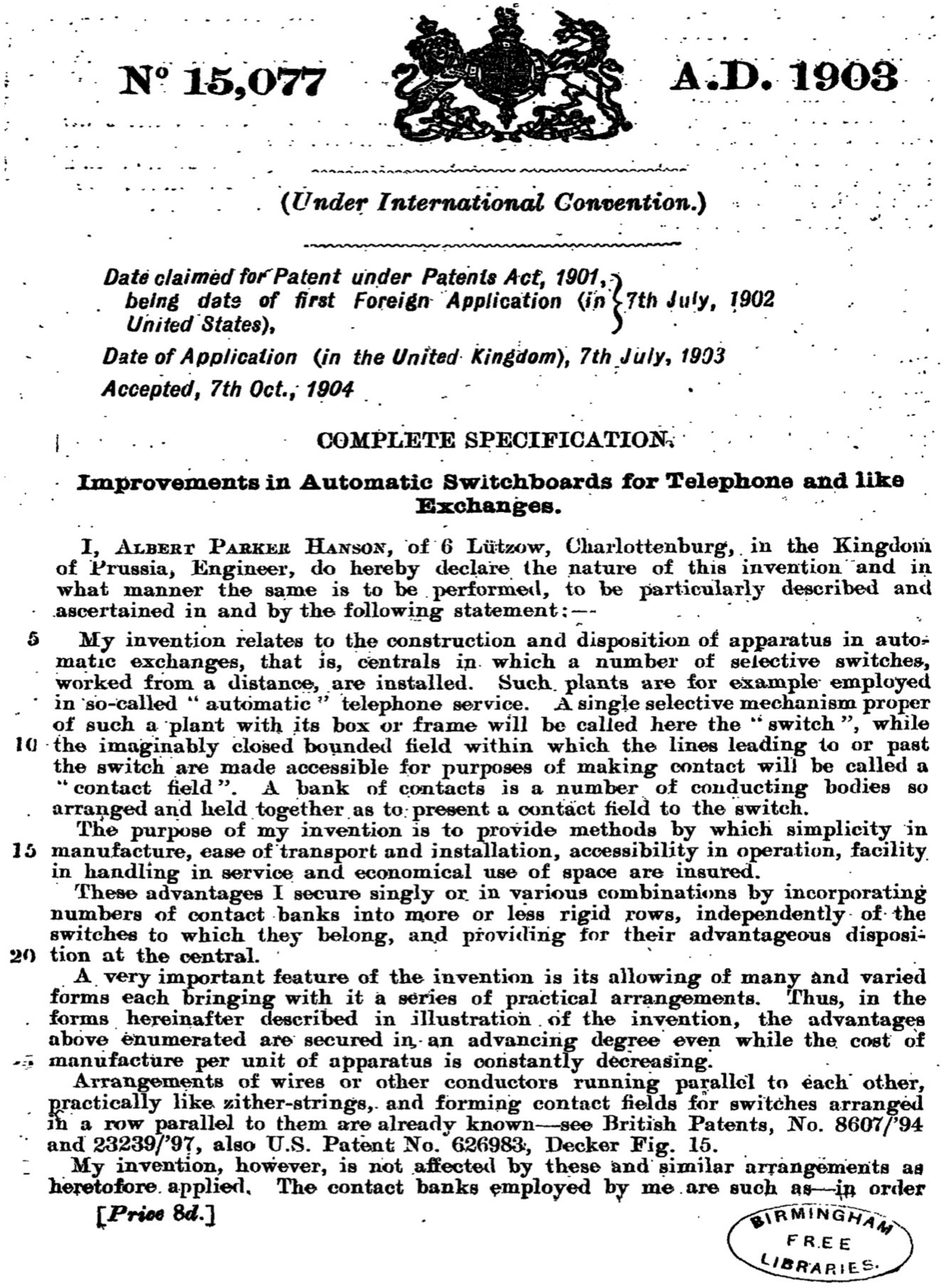
[4] Note that many historians have described Eisler as the inventor of printed circuits. While Eisler played a critical role in transferring printed circuit technology out of the German-speaking world and producing the first printed circuits in Allied countries, it seems clear from the historical record that Albert Hanson was the original inventor in 1902, and that multiple companies in the German-speaking world were building and selling printed circuits several years before Eisler ever built his first printed circuit board. From both his studies and his work as an electrical engineer, presumably he would have been familiar with those technologies before he left the German-speaking world.



Nº 15,077 **A.D. 1903**

(*Under International Convention.*)

Date claimed for Patent under Patents Act, 1901, being date of first Foreign Application (in United States), *7th July, 1902*

Date of Application (in the United Kingdom), 7th July, 1903

Accepted, 7th Oct., 1904

COMPLETE SPECIFICATION.

Improvements in Automatic Switchboards for Telephone and like Exchanges.

I, ALBERT PARKER HANSON, of 6 Lützow, Charlottenburg, in the Kingdom of Prussia, Engineer, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

My invention relates to the construction and disposition of apparatus in automatic exchanges, that is, centrals in which a number of selective switches, worked from a distance, are installed. Such plants are for example employed in so-called "automatic" telephone service. A single selective mechanism proper of such a plant with its box or frame will be called here the "switch", while the imaginably closed bounded field within which the lines leading to or past the switch are made accessible for purposes of making contact will be called a "contact field". A bank of contacts is a number of conducting bodies so arranged and held together as to present a contact field to the switch.

The purpose of my invention is to provide methods by which simplicity in manufacture, ease of transport and installation, accessibility in operation, facility in handling in service and economical use of space are insured.

These advantages I secure singly or in various combinations by incorporating numbers of contact banks into more or less rigid rows, independently of the switches to which they belong, and providing for their advantageous disposition at the central.

A very important feature of the invention is its allowing of many and varied forms each bringing with it a series of practical arrangements. Thus, in the forms hereinafter described in illustration of the invention, the advantages above enumerated are secured in an advancing degree even while the cost of manufacture per unit of apparatus is constantly decreasing.

Arrangements of wires or other conductors running parallel to each other, practically like zither-strings, and forming contact fields for switches arranged in a row parallel to them are already known—see British Patents, No. 8607/'94 and 23239/'97, also U.S. Patent No. 626983, Decker Fig. 15.

My invention, however, is not affected by these and similar arrangements as heretofore applied. The contact banks employed by me are such as—in order

[*Price 8d.*]

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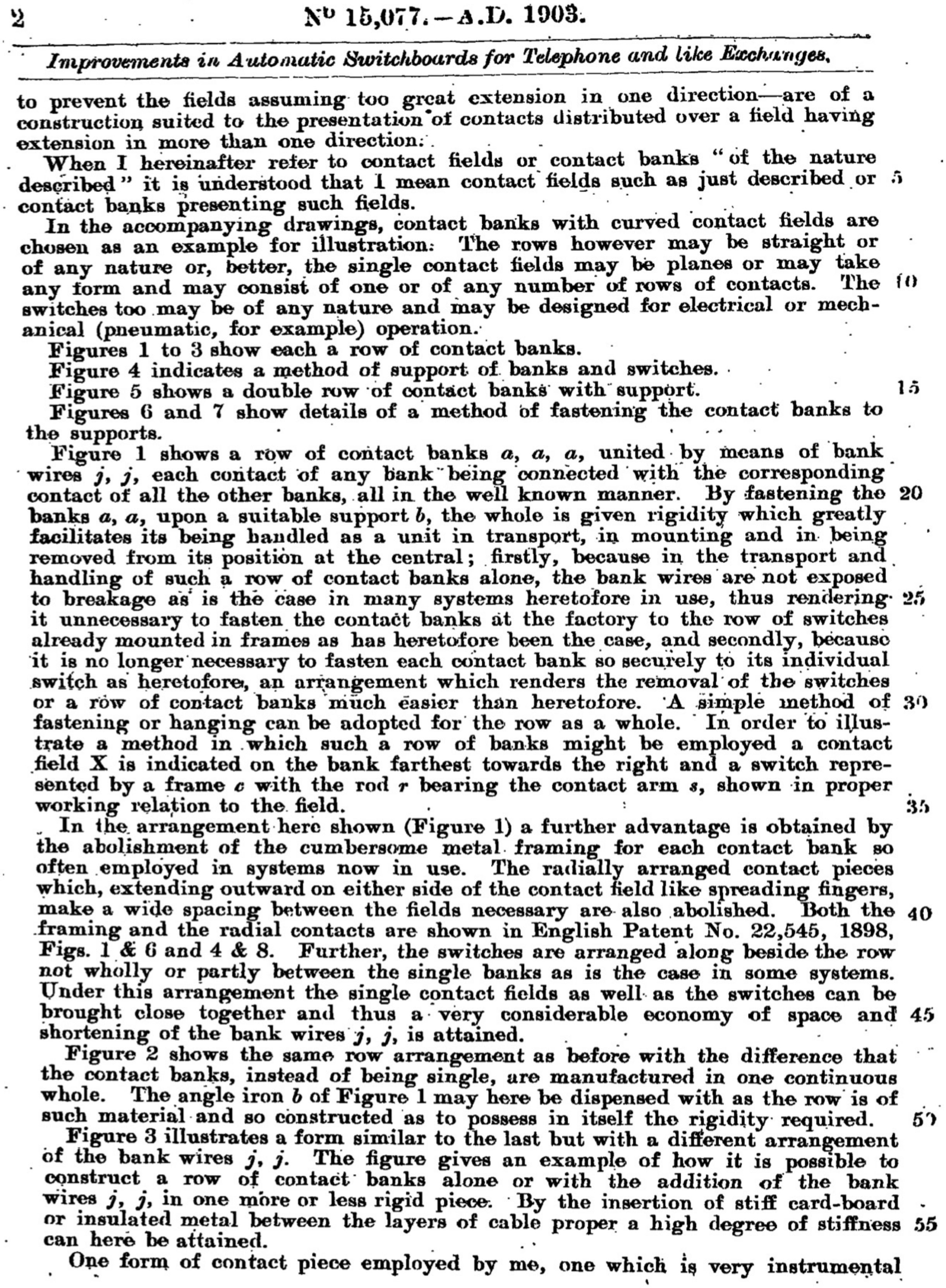
Figure B.94: Albert Hanson filed detailed patent applications on printed circuits and multi-pin connectors in 1902–1903.



2 Nº 15,077.—A.D. 1903.

Improvements in Automatic Switchboards for Telephone and like Exchanges.

to prevent the fields assuming too great extension in one direction—are of a construction suited to the presentation of contacts distributed over a field having extension in more than one direction.

When I hereinafter refer to contact fields or contact banks "of the nature described" it is understood that I mean contact fields such as just described or contact banks presenting such fields.

In the accompanying drawings, contact banks with curved contact fields are chosen as an example for illustration. The rows however may be straight or of any nature or, better, the single contact fields may be planes or may take any form and may consist of one or of any number of rows of contacts. The switches too may be of any nature and may be designed for electrical or mechanical (pneumatic, for example) operation.

Figures 1 to 3 show each a row of contact banks.

Figure 4 indicates a method of support of banks and switches.

Figure 5 shows a double row of contact banks with support.

Figures 6 and 7 show details of a method of fastening the contact banks to the supports.

Figure 1 shows a row of contact banks *a*, *a*, *a*, united by means of bank wires *j*, *j*, each contact of any bank being connected with the corresponding contact of all the other banks, all in the well known manner. By fastening the banks *a*, *a*, upon a suitable support *b*, the whole is given rigidity which greatly facilitates its being handled as a unit in transport, in mounting and in being removed from its position at the central; firstly, because in the transport and handling of such a row of contact banks alone, the bank wires are not exposed to breakage as is the case in many systems heretofore in use, thus rendering it unnecessary to fasten the contact banks at the factory to the row of switches already mounted in frames as has heretofore been the case, and secondly, because it is no longer necessary to fasten each contact bank so securely to its individual switch as heretofore, an arrangement which renders the removal of the switches or a row of contact banks much easier than heretofore. A simple method of fastening or hanging can be adopted for the row as a whole. In order to illustrate a method in which such a row of banks might be employed a contact field X is indicated on the bank farthest towards the right and a switch represented by a frame *c* with the rod *r* bearing the contact arm *s*, shown in proper working relation to the field.

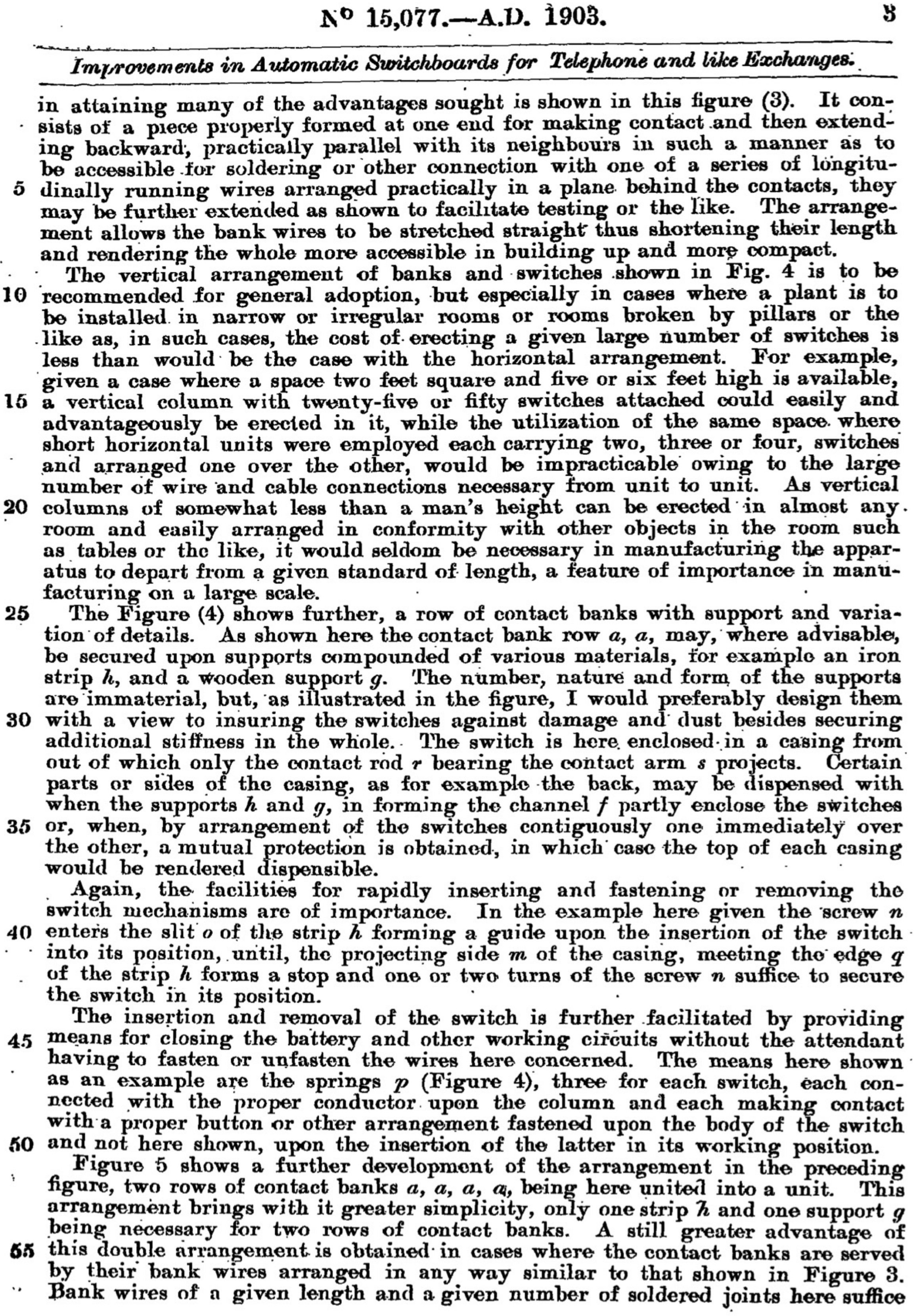
In the arrangement here shown (Figure 1) a further advantage is obtained by the abolishment of the cumbersome metal framing for each contact bank so often employed in systems now in use. The radially arranged contact pieces which, extending outward on either side of the contact field like spreading fingers, make a wide spacing between the fields necessary are also abolished. Both the framing and the radial contacts are shown in English Patent No. 22,545, 1898, Figs. 1 & 6 and 4 & 8. Further, the switches are arranged along beside the row not wholly or partly between the single banks as is the case in some systems. Under this arrangement the single contact fields as well as the switches can be brought close together and thus a very considerable economy of space and shortening of the bank wires *j*, *j*, is attained.

Figure 2 shows the same row arrangement as before with the difference that the contact banks, instead of being single, are manufactured in one continuous whole. The angle iron *b* of Figure 1 may here be dispensed with as the row is of such material and so constructed as to possess in itself the rigidity required.

Figure 3 illustrates a form similar to the last but with a different arrangement of the bank wires *j*, *j*. The figure gives an example of how it is possible to construct a row of contact banks alone or with the addition of the bank wires *j*, *j*, in one more or less rigid piece. By the insertion of stiff card-board or insulated metal between the layers of cable proper a high degree of stiffness can here be attained.

One form of contact piece employed by me, one which is very instrumental

Figure B.95: Albert Hanson filed detailed patent applications on printed circuits and multi-pin connectors in 1902–1903.



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Improvements in Automatic Switchboards for Telephone and like Exchanges.

in attaining many of the advantages sought is shown in this figure (3). It consists of a piece properly formed at one end for making contact and then extending backward, practically parallel with its neighbours in such a manner as to be accessible for soldering or other connection with one of a series of longitudinally running wires arranged practically in a plane behind the contacts, they may be further extended as shown to facilitate testing or the like. The arrangement allows the bank wires to be stretched straight thus shortening their length and rendering the whole more accessible in building up and more compact.

The vertical arrangement of banks and switches shown in Fig. 4 is to be recommended for general adoption, but especially in cases where a plant is to be installed in narrow or irregular rooms or rooms broken by pillars or the like as, in such cases, the cost of erecting a given large number of switches is less than would be the case with the horizontal arrangement. For example, given a case where a space two feet square and five or six feet high is available, a vertical column with twenty-five or fifty switches attached could easily and advantageously be erected in it, while the utilization of the same space where short horizontal units were employed each carrying two, three or four, switches and arranged one over the other, would be impracticable owing to the large number of wire and cable connections necessary from unit to unit. As vertical columns of somewhat less than a man's height can be erected in almost any room and easily arranged in conformity with other objects in the room such as tables or the like, it would seldom be necessary in manufacturing the apparatus to depart from a given standard of length, a feature of importance in manufacturing on a large scale.

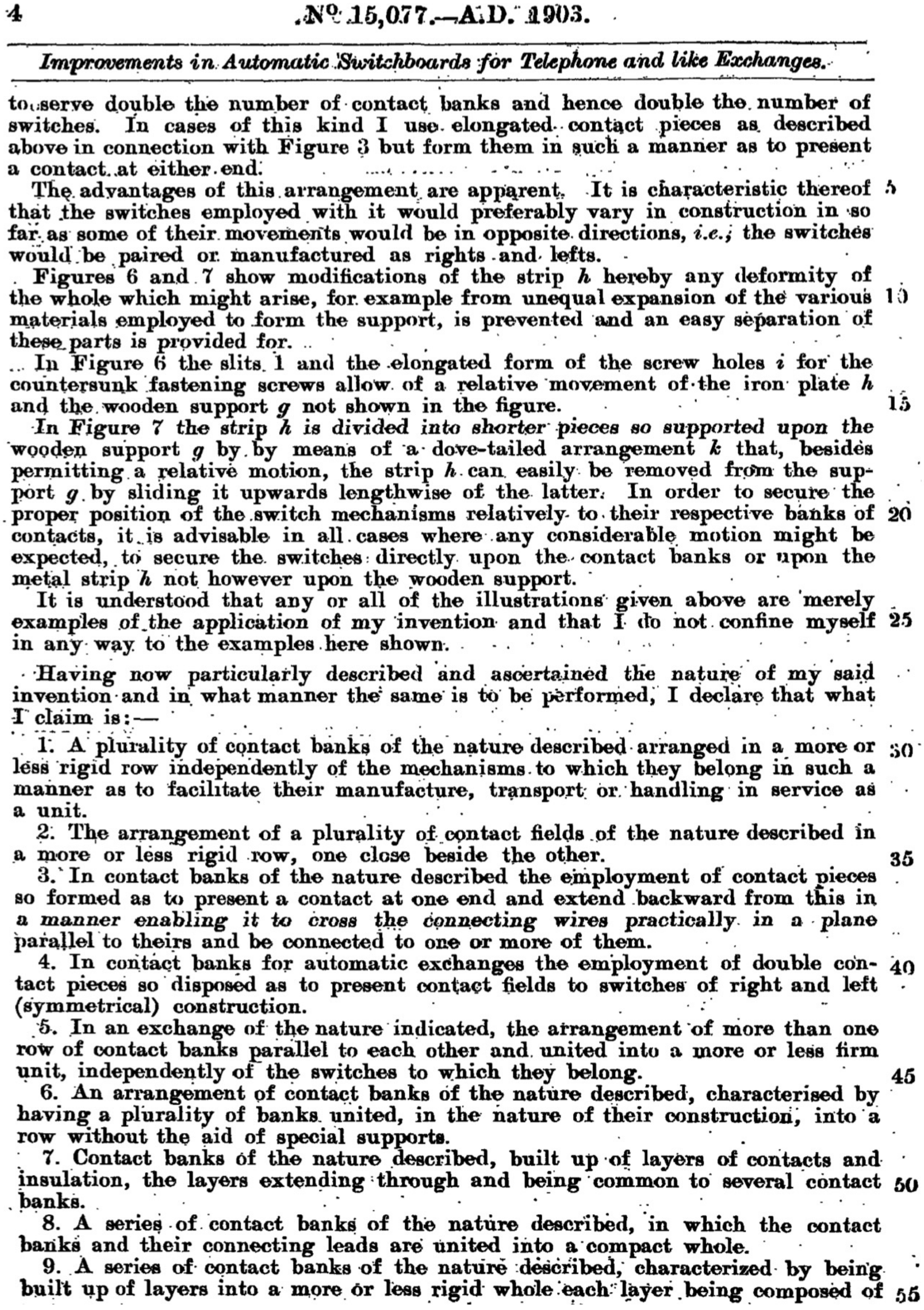
The Figure (4) shows further, a row of contact banks with support and variation of details. As shown here the contact bank row *a*, *a*, may, where advisable, be secured upon supports compounded of various materials, for example an iron strip *h*, and a wooden support *g*. The number, nature and form of the supports are immaterial, but, as illustrated in the figure, I would preferably design them with a view to insuring the switches against damage and dust besides securing additional stiffness in the whole. The switch is here enclosed in a casing from out of which only the contact rod *r* bearing the contact arm *s* projects. Certain parts or sides of the casing, as for example the back, may be dispensed with when the supports *h* and *g*, in forming the channel *f* partly enclose the switches or, when, by arrangement of the switches contiguously one immediately over the other, a mutual protection is obtained, in which case the top of each casing would be rendered dispensible.

Again, the facilities for rapidly inserting and fastening or removing the switch mechanisms are of importance. In the example here given the screw *n* enters the slit *o* of the strip *h* forming a guide upon the insertion of the switch into its position, until, the projecting side *m* of the casing, meeting the edge *q* of the strip *h* forms a stop and one or two turns of the screw *n* suffice to secure the switch in its position.

The insertion and removal of the switch is further facilitated by providing means for closing the battery and other working circuits without the attendant having to fasten or unfasten the wires here concerned. The means here shown as an example are the springs *p* (Figure 4), three for each switch, each connected with the proper conductor upon the column and each making contact with a proper button or other arrangement fastened upon the body of the switch and not here shown, upon the insertion of the latter in its working position.

Figure 5 shows a further development of the arrangement in the preceding figure, two rows of contact banks *a*, *a*, *a*, *a*, being here united into a unit. This arrangement brings with it greater simplicity, only one strip *h* and one support *g* being necessary for two rows of contact banks. A still greater advantage of this double arrangement is obtained in cases where the contact banks are served by their bank wires arranged in any way similar to that shown in Figure 3. Bank wires of a given length and a given number of soldered joints here suffice

Figure B.96: Albert Hanson filed detailed patent applications on printed circuits and multi-pin connectors in 1902–1903.



4 No. 15,077.—A.D. 1903.

Improvements in Automatic Switchboards for Telephone and like Exchanges.

to serve double the number of contact banks and hence double the number of switches. In cases of this kind I use elongated contact pieces as described above in connection with Figure 3 but form them in such a manner as to present a contact at either end.

The advantages of this arrangement are apparent. It is characteristic thereof that the switches employed with it would preferably vary in construction in so far as some of their movements would be in opposite directions, *i.e.*; the switches would be paired or manufactured as rights and lefts.

Figures 6 and 7 show modifications of the strip *h* hereby any deformity of the whole which might arise, for example from unequal expansion of the various materials employed to form the support, is prevented and an easy separation of these parts is provided for.

In Figure 6 the slits 1 and the elongated form of the screw holes *i* for the countersunk fastening screws allow of a relative movement of the iron plate *h* and the wooden support *g* not shown in the figure.

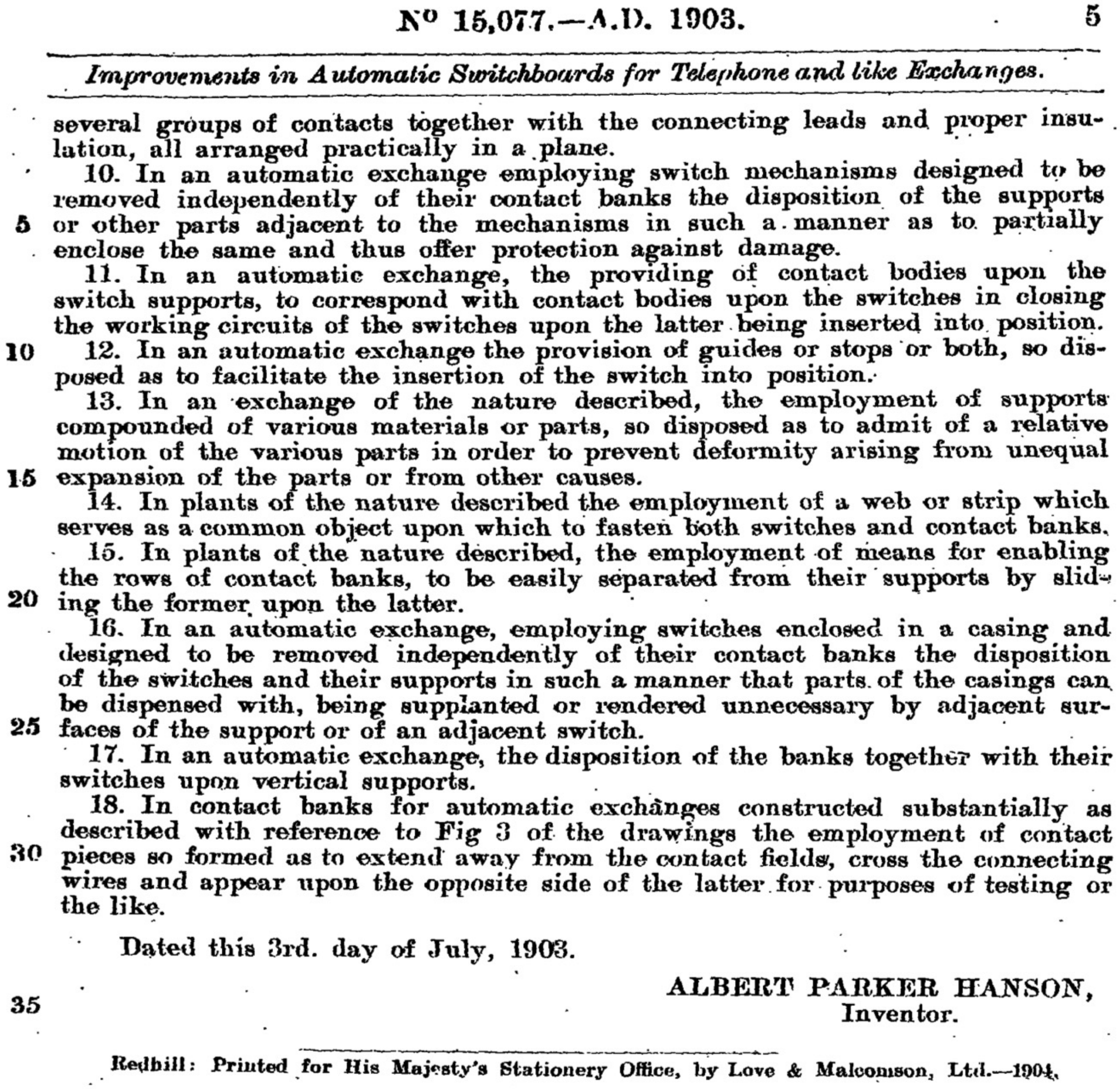
In Figure 7 the strip h is divided into shorter pieces so supported upon the wooden support *g* by by means of a dove-tailed arrangement *k* that, besides permitting a relative motion, the strip *h* can easily be removed from the support *g* by sliding it upwards lengthwise of the latter. In order to secure the proper position of the switch mechanisms relatively to their respective banks of contacts, it is advisable in all cases where any considerable motion might be expected, to secure the switches directly upon the contact banks or upon the metal strip *h* not however upon the wooden support.

It is understood that any or all of the illustrations given above are merely examples of the application of my invention and that I do not confine myself in any way to the examples here shown.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. A plurality of contact banks of the nature described arranged in a more or less rigid row independently of the mechanisms to which they belong in such a manner as to facilitate their manufacture, transport or handling in service as a unit.
2. The arrangement of a plurality of contact fields of the nature described in a more or less rigid row, one close beside the other.
3. In contact banks of the nature described the employment of contact pieces so formed as to present a contact at one end and extend backward from this in *a manner enabling it to cross the connecting wires practically* in a plane parallel to theirs and be connected to one or more of them.
4. In contact banks for automatic exchanges the employment of double contact pieces so disposed as to present contact fields to switches of right and left (symmetrical) construction.
5. In an exchange of the nature indicated, the arrangement of more than one row of contact banks parallel to each other and united into a more or less firm unit, independently of the switches to which they belong.
6. An arrangement of contact banks of the nature described, characterised by having a plurality of banks united, in the nature of their construction, into a row without the aid of special supports.
7. Contact banks of the nature described, built up of layers of contacts and insulation, the layers extending through and being common to several contact banks.
8. A series of contact banks of the nature described, in which the contact banks and their connecting leads are united into a compact whole.
9. A series of contact banks of the nature described, characterized by being built up of layers into a more or less rigid whole each layer being composed of

Figure B.97: Albert Hanson filed detailed patent applications on printed circuits and multi-pin connectors in 1902–1903.



Improvements in Automatic Switchboards for Telephone and like Exchanges.

several groups of contacts together with the connecting leads and proper insulation, all arranged practically in a plane.

10. In an automatic exchange employing switch mechanisms designed to be removed independently of their contact banks the disposition of the supports or other parts adjacent to the mechanisms in such a manner as to partially enclose the same and thus offer protection against damage.

11. In an automatic exchange, the providing of contact bodies upon the switch supports, to correspond with contact bodies upon the switches in closing the working circuits of the switches upon the latter being inserted into position.

12. In an automatic exchange the provision of guides or stops or both, so disposed as to facilitate the insertion of the switch into position.

13. In an exchange of the nature described, the employment of supports compounded of various materials or parts, so disposed as to admit of a relative motion of the various parts in order to prevent deformity arising from unequal expansion of the parts or from other causes.

14. In plants of the nature described the employment of a web or strip which serves as a common object upon which to fasten both switches and contact banks.

15. In plants of the nature described, the employment of means for enabling the rows of contact banks, to be easily separated from their supports by sliding the former upon the latter.

16. In an automatic exchange, employing switches enclosed in a casing and designed to be removed independently of their contact banks the disposition of the switches and their supports in such a manner that parts of the casings can be dispensed with, being supplanted or rendered unnecessary by adjacent surfaces of the support or of an adjacent switch.

17. In an automatic exchange, the disposition of the banks together with their switches upon vertical supports.

18. In contact banks for automatic exchanges constructed substantially as described with reference to Fig 3 of the drawings the employment of contact pieces so formed as to extend away from the contact fields, cross the connecting wires and appear upon the opposite side of the latter for purposes of testing or the like.

Dated this 3rd. day of July, 1903.

ALBERT PARKER HANSON,
Inventor.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1904.

Figure B.98: Albert Hanson filed detailed patent applications on printed circuits and multi-pin connectors in 1902–1903.

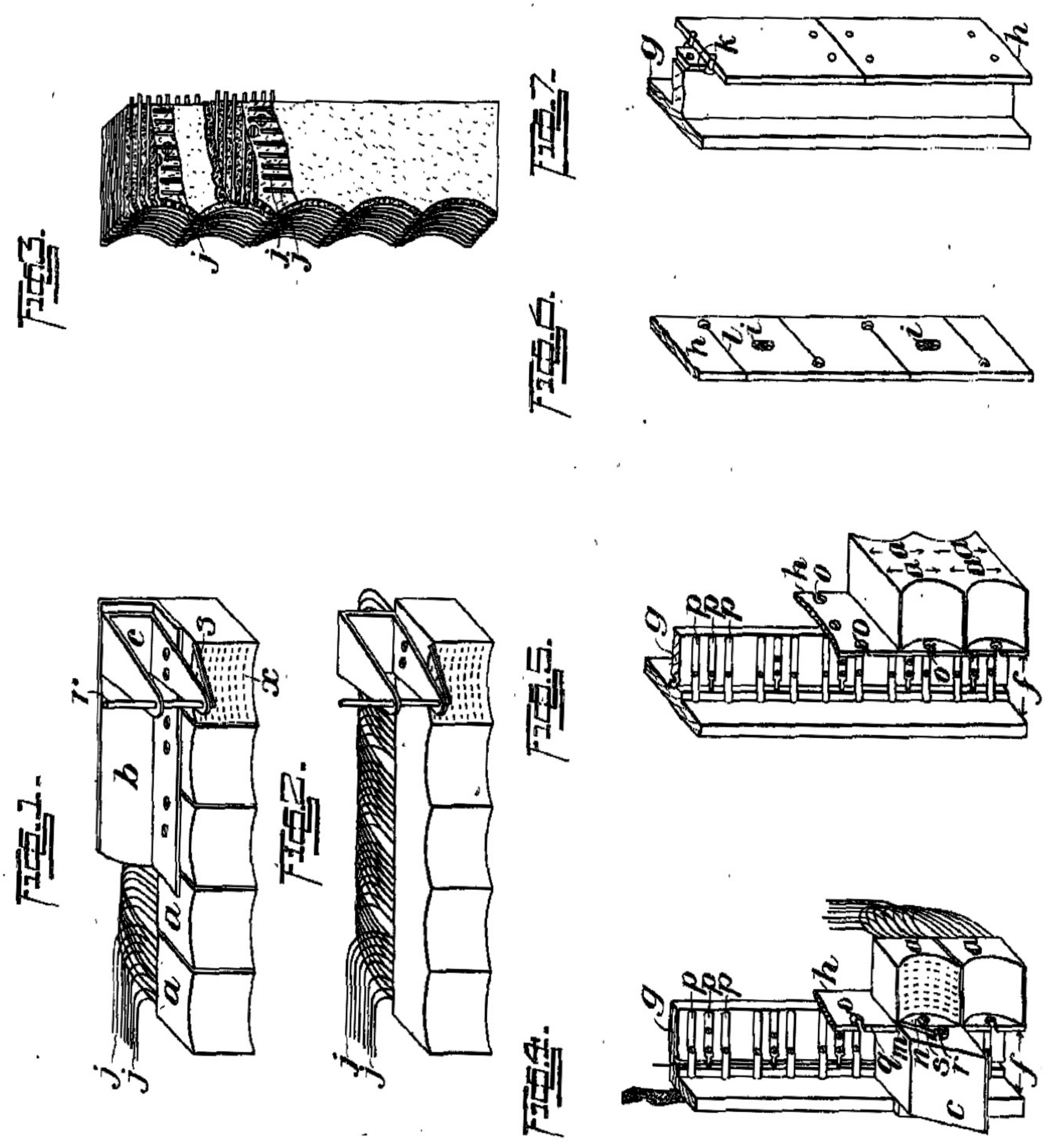
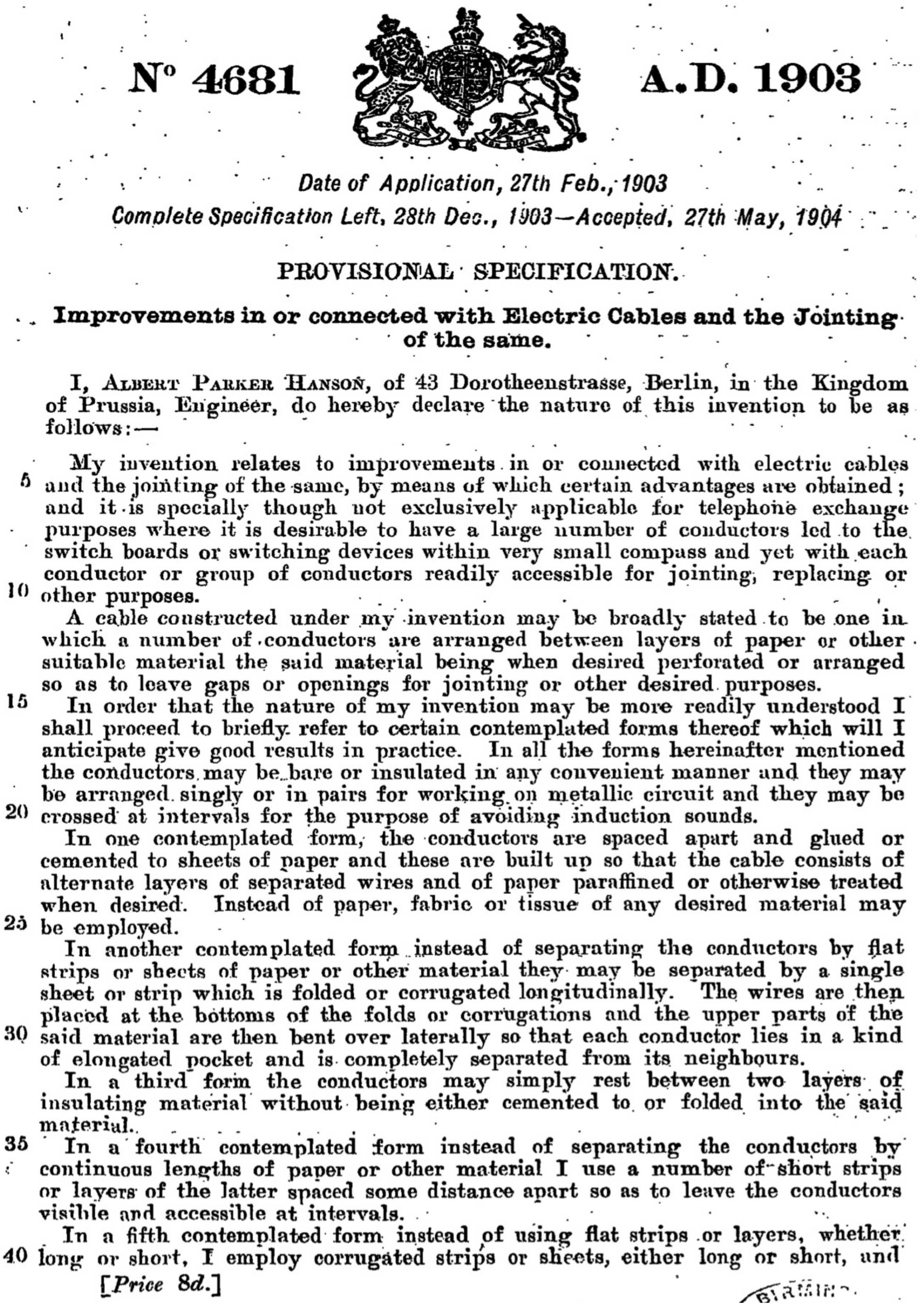


FIG. 1.
j
j
a
a
b
c
r
s
x
FIG. 2.
j
j
FIG. 3.
j
j
j
FIG. 4.
g
p
p
p
h
o
q
m
n
s
r
c
f
a
a
FIG. 5.
g
p
p
p
h
o
o
o
f
a
a
FIG. 6.
h
i
g
i
g
i
FIG. 7.
g
k
h

Figure B.99: Albert Hanson filed detailed patent applications on printed circuits and multi-pin connectors in 1902–1903.



Nº 4681 **A.D. 1903**

Date of Application, 27th Feb., 1903

Complete Specification Left, 28th Dec., 1903—Accepted, 27th May, 1904

PROVISIONAL SPECIFICATION.

Improvements in or connected with Electric Cables and the Jointing of the same.

I, Albert Parker Hanson, of 43 Dorotheenstrasse, Berlin, in the Kingdom of Prussia, Engineer, do hereby declare the nature of this invention to be as follows:—

My invention relates to improvements in or connected with electric cables and the jointing of the same, by means of which certain advantages are obtained; and it is specially though not exclusively applicable for telephone exchange purposes where it is desirable to have a large number of conductors led to the switch boards or switching devices within very small compass and yet with each conductor or group of conductors readily accessible for jointing, replacing or other purposes.

A cable constructed under my invention may be broadly stated to be one in which a number of conductors are arranged between layers of paper or other suitable material the said material being when desired perforated or arranged so as to leave gaps or openings for jointing or other desired purposes.

In order that the nature of my invention may be more readily understood I shall proceed to briefly refer to certain contemplated forms thereof which will I anticipate give good results in practice. In all the forms hereinafter mentioned the conductors may be bare or insulated in any convenient manner and they may be arranged singly or in pairs for working on metallic circuit and they may be crossed at intervals for the purpose of avoiding induction sounds.

In one contemplated form, the conductors are spaced apart and glued or cemented to sheets of paper and these are built up so that the cable consists of alternate layers of separated wires and of paper paraffined or otherwise treated when desired. Instead of paper, fabric or tissue of any desired material may be employed.

In another contemplated form instead of separating the conductors by flat strips or sheets of paper or other material they may be separated by a single sheet or strip which is folded or corrugated longitudinally. The wires are then placed at the bottoms of the folds or corrugations and the upper parts of the said material are then bent over laterally so that each conductor lies in a kind of elongated pocket and is completely separated from its neighbours.

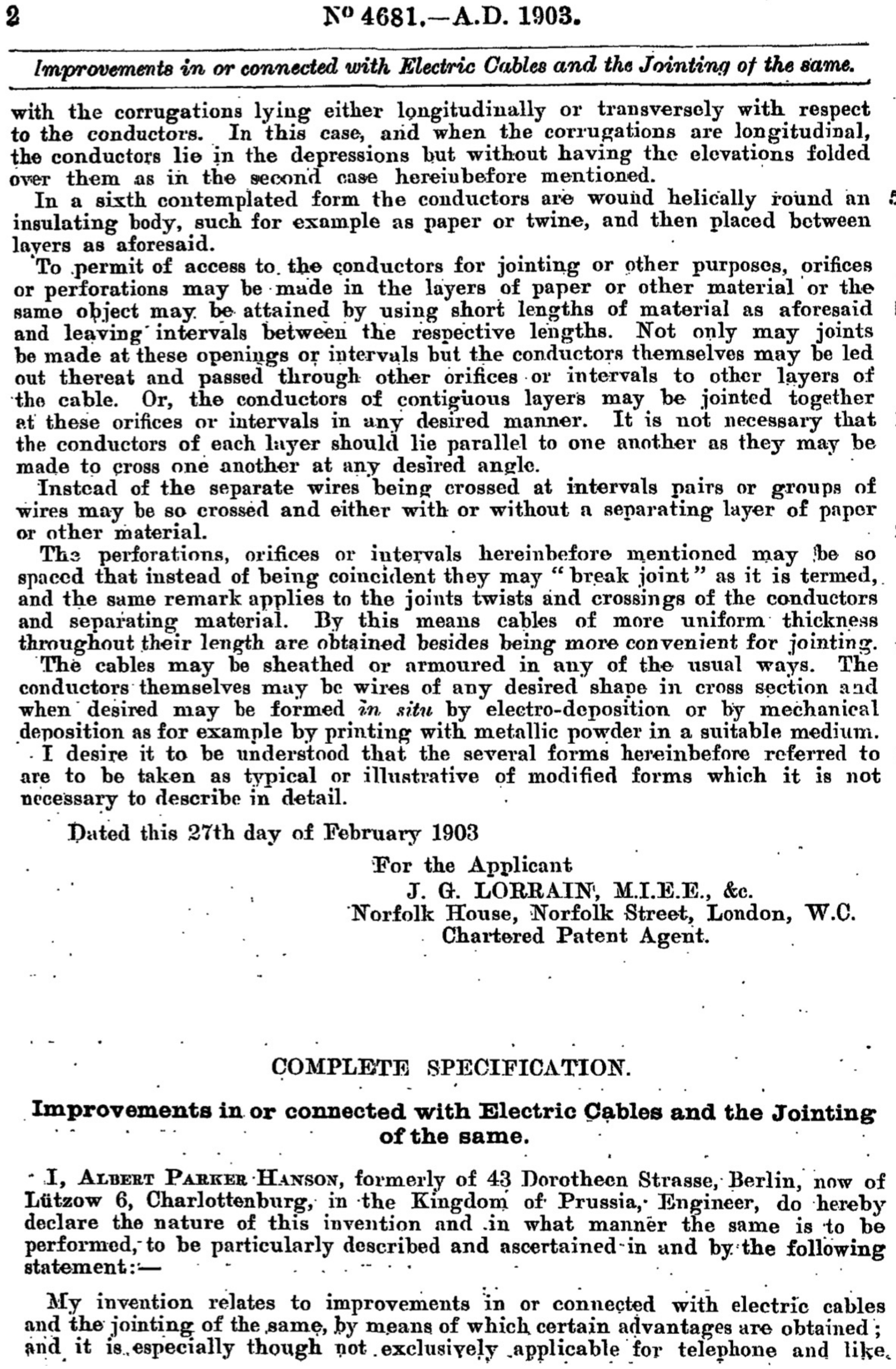
In a third form the conductors may simply rest between two layers of insulating material without being either cemented to or folded into the said material.

In a fourth contemplated form instead of separating the conductors by continuous lengths of paper or other material I use a number of short strips or layers of the latter spaced some distance apart so as to leave the conductors visible and accessible at intervals.

In a fifth contemplated form instead of using flat strips or layers, whether long or short, I employ corrugated strips or sheets, either long or short, and

[*Price* 8*d*.]

Figure B.100: Albert Hanson filed detailed patent applications on printed circuits and multi-pin connectors in 1902–1903.



2 No 4681.—A.D. 1903.

Improvements in or connected with Electric Cables and the Jointing of the same.

with the corrugations lying either longitudinally or transversely with respect to the conductors. In this case, and when the corrugations are longitudinal, the conductors lie in the depressions but without having the elevations folded over them as in the second case hereinbefore mentioned.

In a sixth contemplated form the conductors are wound helically round an insulating body, such for example as paper or twine, and then placed between layers as aforesaid.

To permit of access to the conductors for jointing or other purposes, orifices or perforations may be made in the layers of paper or other material or the same object may be attained by using short lengths of material as aforesaid and leaving intervals between the respective lengths. Not only may joints be made at these openings or intervals but the conductors themselves may be led out thereat and passed through other orifices or intervals to other layers of the cable. Or, the conductors of contiguous layers may be jointed together at these orifices or intervals in any desired manner. It is not necessary that the conductors of each layer should lie parallel to one another as they may be made to cross one another at any desired angle.

Instead of the separate wires being crossed at intervals pairs or groups of wires may be so crossed and either with or without a separating layer of paper or other material.

The perforations, orifices or intervals hereinbefore mentioned may be so spaced that instead of being coincident they may "break joint" as it is termed, and the same remark applies to the joints twists and crossings of the conductors and separating material. By this means cables of more uniform thickness throughout their length are obtained besides being more convenient for jointing.

The cables may be sheathed or armoured in any of the usual ways. The conductors themselves may be wires of any desired shape in cross section and when desired may be formed *in situ* by electro-deposition or by mechanical deposition as for example by printing with metallic powder in a suitable medium.

I desire it to be understood that the several forms hereinbefore referred to are to be taken as typical or illustrative of modified forms which it is not necessary to describe in detail.

Dated this 27th day of February 1903

For the Applicant
J. G. LORRAIN, M.I.E.E., &c.
Norfolk House, Norfolk Street, London, W.C.
Chartered Patent Agent.

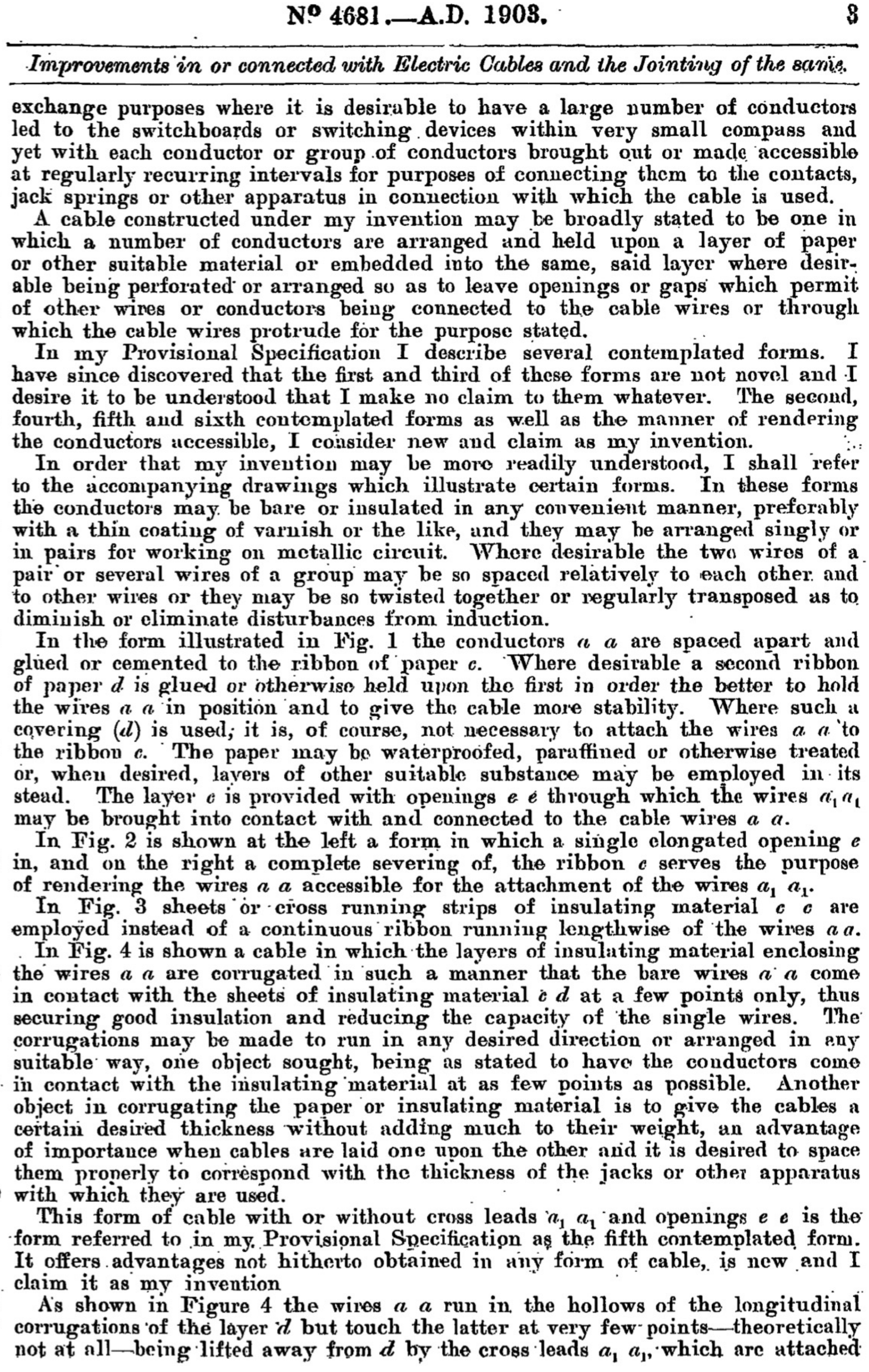
COMPLETE SPECIFICATION.

Improvements in or connected with Electric Cables and the Jointing of the same.

I, Albert Parker Hanson, formerly of 43 Dorotheen Strasse, Berlin, now of Lützow 6, Charlottenburg, in the Kingdom of Prussia, Engineer, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

My invention relates to improvements in or connected with electric cables and the jointing of the same, by means of which certain advantages are obtained; and it is especially though not exclusively applicable for telephone and like

Figure B.101: Albert Hanson filed detailed patent applications on printed circuits and multi-pin connectors in 1902–1903.



Nº 4681.—A.D. 1903. 3

Improvements in or connected with Electric Cables and the Jointing of the same.

exchange purposes where it is desirable to have a large number of conductors led to the switchboards or switching devices within very small compass and yet with each conductor or group of conductors brought out or made accessible at regularly recurring intervals for purposes of connecting them to the contacts, jack springs or other apparatus in connection with which the cable is used.

A cable constructed under my invention may be broadly stated to be one in which a number of conductors are arranged and held upon a layer of paper or other suitable material or embedded into the same, said layer where desirable being perforated or arranged so as to leave openings or gaps which permit of other wires or conductors being connected to the cable wires or through which the cable wires protrude for the purpose stated.

In my Provisional Specification I describe several contemplated forms. I have since discovered that the first and third of these forms are not novel and I desire it to be understood that I make no claim to them whatever. The second, fourth, fifth and sixth contemplated forms as well as the manner of rendering the conductors accessible, I consider new and claim as my invention.

In order that my invention may be more readily understood, I shall refer to the accompanying drawings which illustrate certain forms. In these forms the conductors may be bare or insulated in any convenient manner, preferably with a thin coating of varnish or the like, and they may be arranged singly or in pairs for working on metallic circuit. Where desirable the two wires of a pair or several wires of a group may be so spaced relatively to each other and to other wires or they may be so twisted together or regularly transposed as to diminish or eliminate disturbances from induction.

In the form illustrated in Fig. 1 the conductors a a are spaced apart and glued or cemented to the ribbon of paper c. Where desirable a second ribbon of paper d is glued or otherwise held upon the first in order the better to hold the wires a a in position and to give the cable more stability. Where such a covering (d) is used, it is, of course, not necessary to attach the wires a a to the ribbon c. The paper may be waterproofed, paraffined or otherwise treated or, when desired, layers of other suitable substance may be employed in its stead. The layer c is provided with openings e e through which the wires a_1 a_1 may be brought into contact with and connected to the cable wires a a.

In Fig. 2 is shown at the left a form in which a single elongated opening e in, and on the right a complete severing of, the ribbon c serves the purpose of rendering the wires a a accessible for the attachment of the wires a_1 a_1.

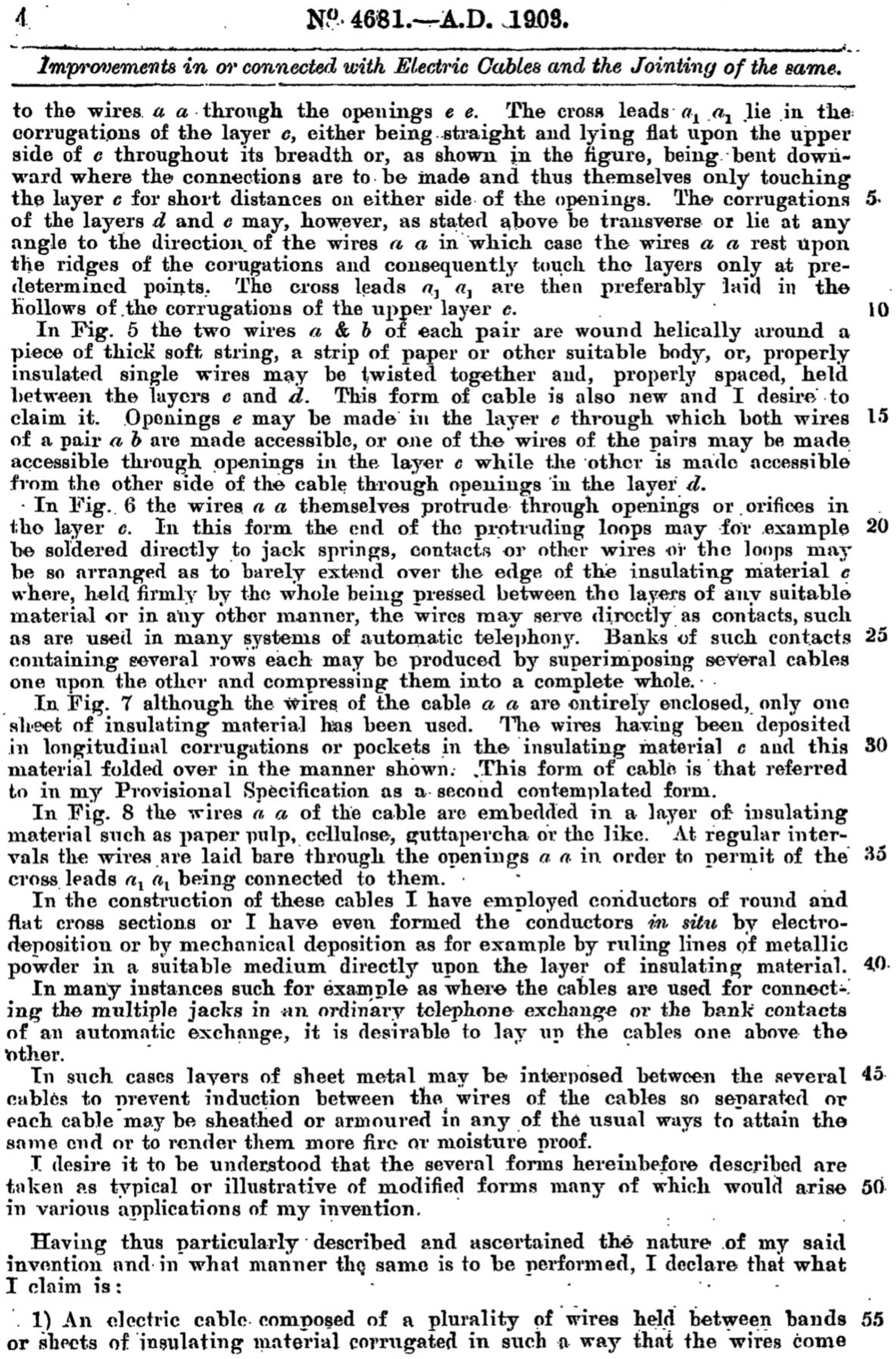
In Fig. 3 sheets or cross running strips of insulating material c c are employed instead of a continuous ribbon running lengthwise of the wires a a.

In Fig. 4 is shown a cable in which the layers of insulating material enclosing the wires a a are corrugated in such a manner that the bare wires a a come in contact with the sheets of insulating material c d at a few points only, thus securing good insulation and reducing the capacity of the single wires. The corrugations may be made to run in any desired direction or arranged in any suitable way, one object sought, being as stated to have the conductors come in contact with the insulating material at as few points as possible. Another object in corrugating the paper or insulating material is to give the cables a certain desired thickness without adding much to their weight, an advantage of importance when cables are laid one upon the other and it is desired to space them properly to correspond with the thickness of the jacks or other apparatus with which they are used.

This form of cable with or without cross leads a_1 a_1 and openings e e is the form referred to in my Provisional Specification as the fifth contemplated form. It offers advantages not hitherto obtained in any form of cable, is new and I claim it as my invention

As shown in Figure 4 the wires a a run in the hollows of the longitudinal corrugations of the layer d but touch the latter at very few points—theoretically not at all—being lifted away from d by the cross leads a_1 a_1, which are attached

Figure B.102: Albert Hanson filed detailed patent applications on printed circuits and multi-pin connectors in 1902–1903.



4 **Nº. 4681.—A.D. 1903.**

Improvements in or connected with Electric Cables and the Jointing of the same.

to the wires *a a* through the openings *e e*. The cross leads a_1 a_1 lie in the corrugations of the layer *c*, either being straight and lying flat upon the upper side of *c* throughout its breadth or, as shown in the figure, being bent downward where the connections are to be made and thus themselves only touching the layer *c* for short distances on either side of the openings. The corrugations of the layers *d* and *c* may, however, as stated above be transverse or lie at any angle to the direction of the wires *a a* in which case the wires *a a* rest upon the ridges of the corugations and consequently touch the layers only at predetermined points. The cross leads a_1 a_1 are then preferably laid in the hollows of the corrugations of the upper layer *c*.

In Fig. 5 the two wires *a* & *b* of each pair are wound helically around a piece of thick soft string, a strip of paper or other suitable body, or, properly insulated single wires may be twisted together and, properly spaced, held between the layers *c* and *d*. This form of cable is also new and I desire to claim it. Openings *e* may be made in the layer *c* through which both wires of a pair *a b* are made accessible, or one of the wires of the pairs may be made accessible through openings in the layer *c* while the other is made accessible from the other side of the cable through openings in the layer *d*.

In Fig. 6 the wires *a a* themselves protrude through openings or orifices in the layer *c*. In this form the end of the protruding loops may for example be soldered directly to jack springs, contacts or other wires or the loops may be so arranged as to barely extend over the edge of the insulating material *c* where, held firmly by the whole being pressed between the layers of any suitable material or in any other manner, the wires may serve directly as contacts, such as are used in many systems of automatic telephony. Banks of such contacts containing several rows each may be produced by superimposing several cables one upon the other and compressing them into a complete whole.

In Fig. 7 although the wires of the cable *a a* are entirely enclosed, only one sheet of insulating material has been used. The wires having been deposited in longitudinal corrugations or pockets in the insulating material *c* and this material folded over in the manner shown. This form of cable is that referred to in my Provisional Specification as a second contemplated form.

In Fig. 8 the wires *a a* of the cable are embedded in a layer of insulating material such as paper pulp, cellulose, guttapercha or the like. At regular intervals the wires are laid bare through the openings *a a* in order to permit of the cross leads a_1 a_1 being connected to them.

In the construction of these cables I have employed conductors of round and flat cross sections or I have even formed the conductors *in situ* by electrodeposition or by mechanical deposition as for example by ruling lines of metallic powder in a suitable medium directly upon the layer of insulating material.

In many instances such for example as where the cables are used for connecting the multiple jacks in an ordinary telephone exchange or the bank contacts of an automatic exchange, it is desirable to lay up the cables one above the other.

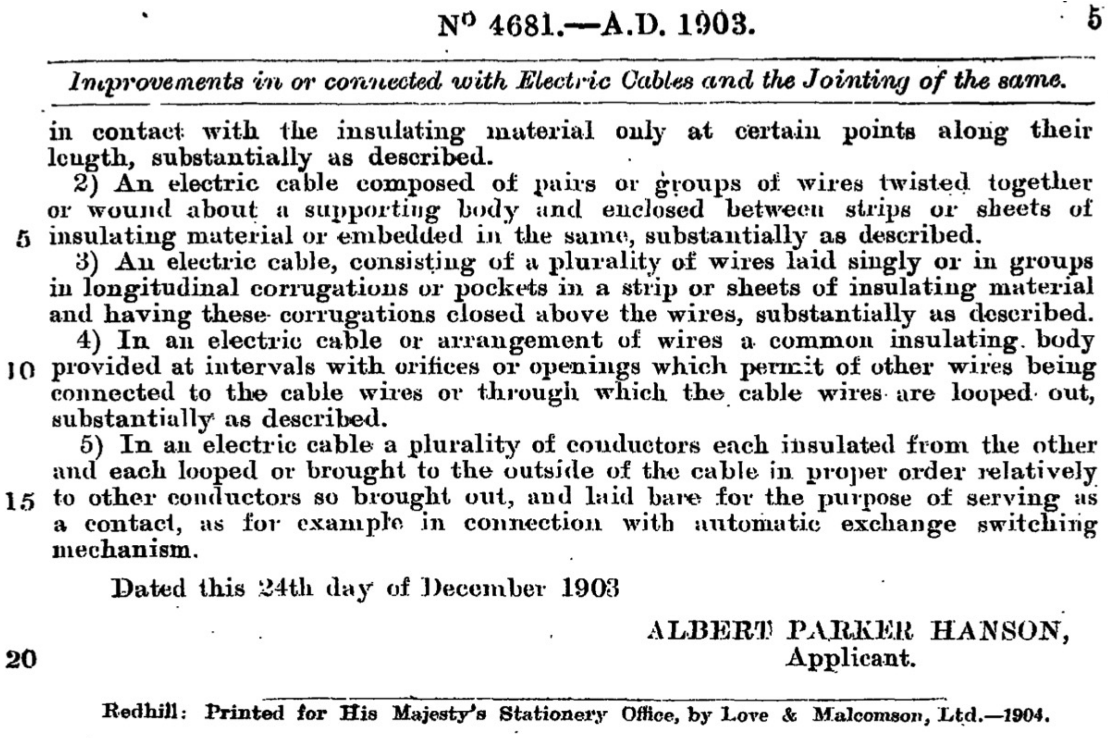
In such cases layers of sheet metal may be interposed between the several cables to prevent induction between the wires of the cables so separated or each cable may be sheathed or armoured in any of the usual ways to attain the same end or to render them more fire or moisture proof.

I desire it to be understood that the several forms hereinbefore described are taken as typical or illustrative of modified forms many of which would arise in various applications of my invention.

Having thus particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:

1) An electric cable composed of a plurality of wires held between bands or sheets of insulating material corrugated in such a way that the wires come

Figure B.103: Albert Hanson filed detailed patent applications on printed circuits and multi-pin connectors in 1902–1903.



Nº 4681.—A.D. 1903. 5

Improvements in or connected with Electric Cables and the Jointing of the same.

in contact with the insulating material only at certain points along their length, substantially as described.

2) An electric cable composed of pairs or groups of wires twisted together or wound about a supporting body and enclosed between strips or sheets of insulating material or embedded in the same, substantially as described.

3) An electric cable, consisting of a plurality of wires laid singly or in groups in longitudinal corrugations or pockets in a strip or sheets of insulating material and having these corrugations closed above the wires, substantially as described.

4) In an electric cable or arrangement of wires a common insulating body provided at intervals with orifices or openings which permit of other wires being connected to the cable wires or through which the cable wires are looped out, substantially as described.

5) In an electric cable a plurality of conductors each insulated from the other and each looped or brought to the outside of the cable in proper order relatively to other conductors so brought out, and laid bare for the purpose of serving as a contact, as for example in connection with automatic exchange switching mechanism.

Dated this 24th day of December 1903

ALBERT PARKER HANSON,
Applicant.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1904.

Figure B.104: Albert Hanson filed detailed patent applications on printed circuits and multi-pin connectors in 1902–1903.

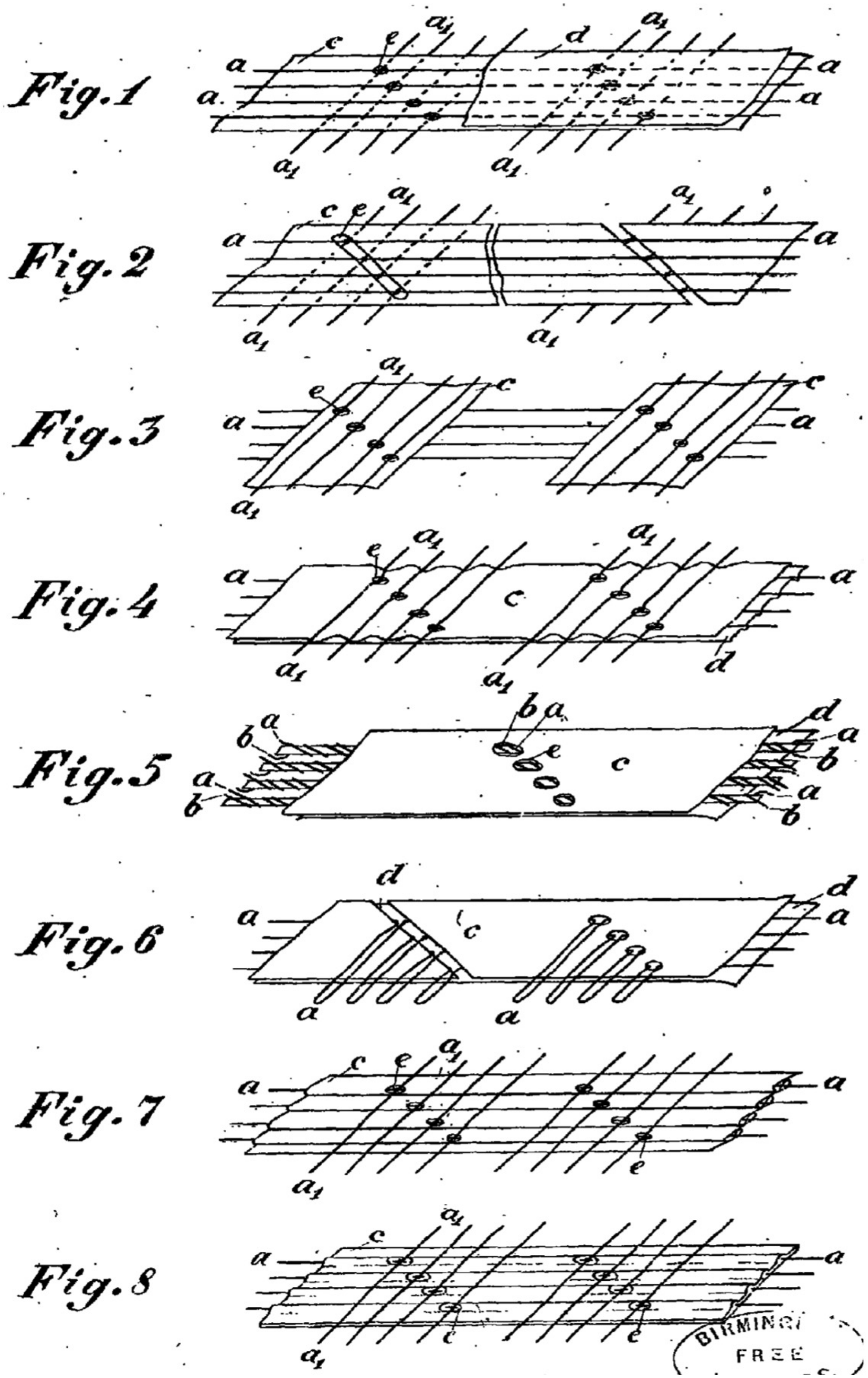


Fig.1
a
a
c
e
a_1
d
a_1
a
a
a_1
a_1
Fig.2
c
e
a_1
a_1
a
a
a_1
a_1
Fig.3
e
a_1
c
c
a
a
a_1
Fig.4
e
a_1
a_1
a
a
c
a_1
a_1
d
Fig.5
a
b
a
b
b
a
e
c
d
a
b
a
b
Fig.6
d
d
a
c
a
a
a
Fig.7
c
e
a_1
a
a
e
a_1
Fig.8
a_1
c
a
a
c
e
a_1

BIRMING
FREE

Figure B.105: Albert Hanson filed detailed patent applications on printed circuits and multi-pin connectors in 1902–1903.

Printed circuit board with riveted metal strips

Sachsenwerk Licht und Kraft AG

1932

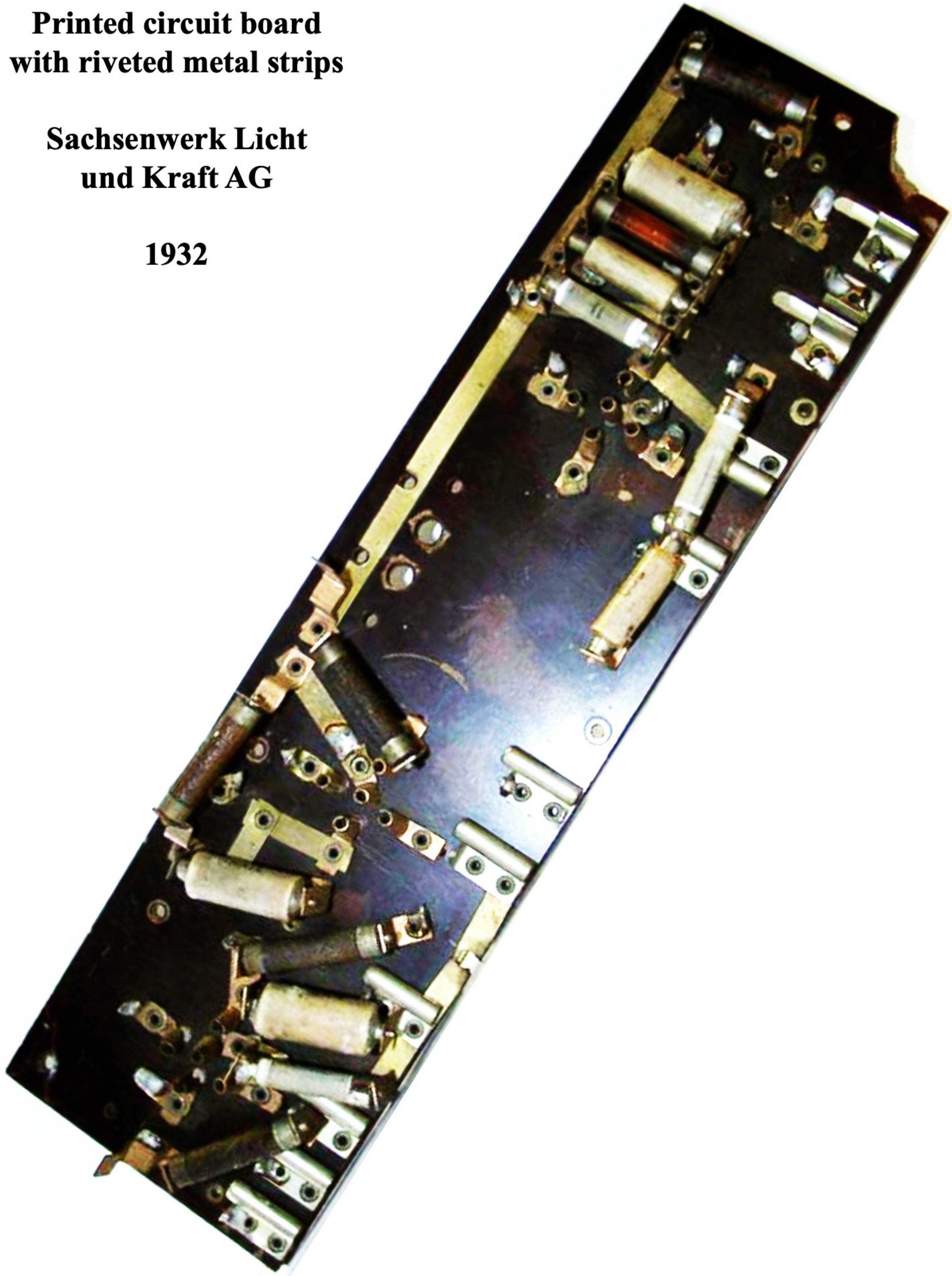


Figure B.106: Printed circuit board with riveted metal strips, Sachsenwerk Licht und Kraft AG, 1932.

Paul Eisler (1907–1992) produced printed circuits (1936) and filed a detailed patent application (1944)

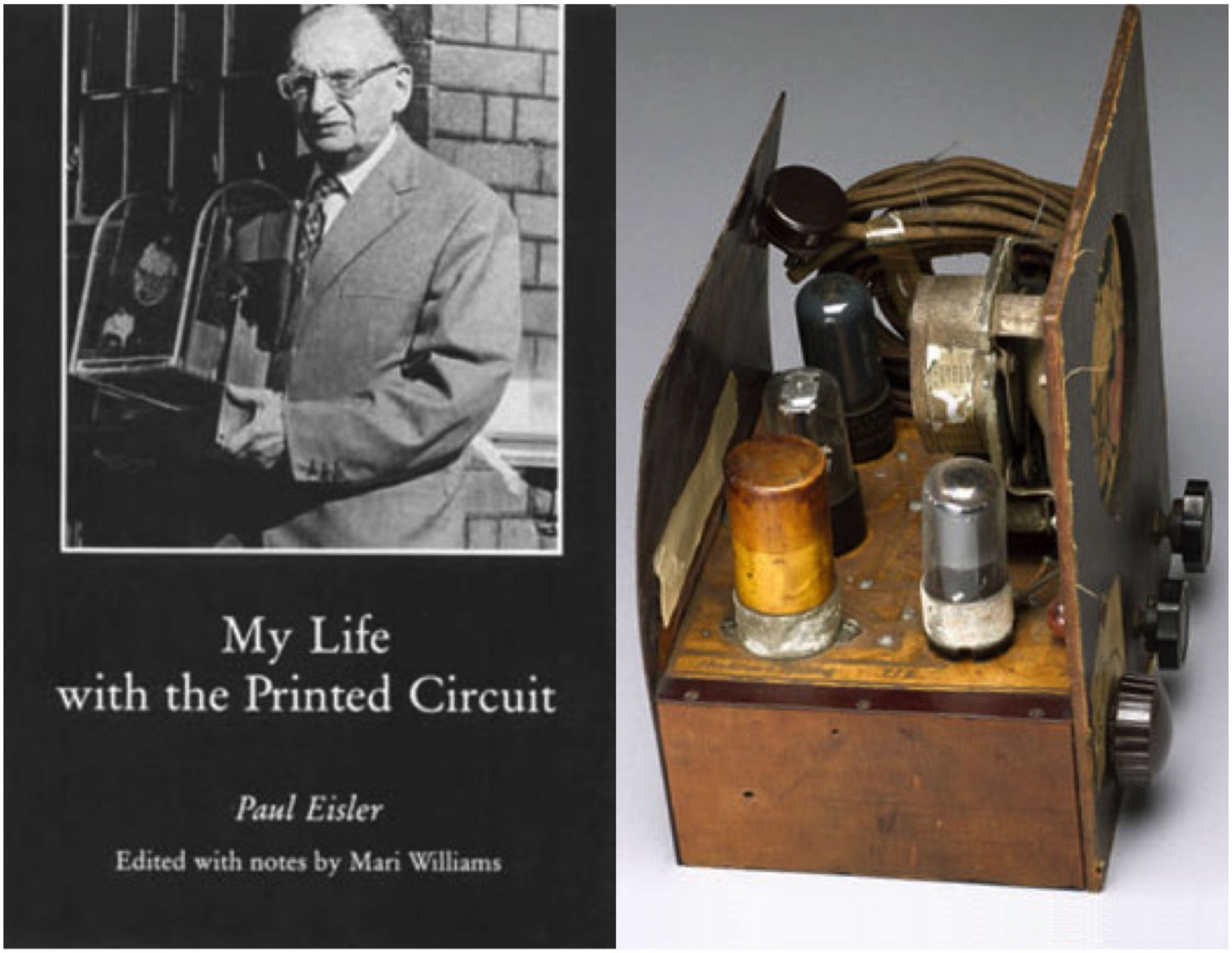

My Life
with the Printed Circuit
Paul Eisler
Edited with notes by Mari Williams

Figure B.107: Paul Eisler produced printed circuits in 1936 and filed a patent application on them in 1944. At least three German companies produced printed circuits several years before Eisler, and he was presumably familiar with their technology from his studies and work as an electrical engineer in the German-speaking world.

May 25, 1948. **P. EISLER** **2,441,960**

MANUFACTURE OF ELECTRIC CIRCUIT COMPONENTS

Filed Feb. 3, 1944 8 Sheets-Sheet 1

FIG. 1.

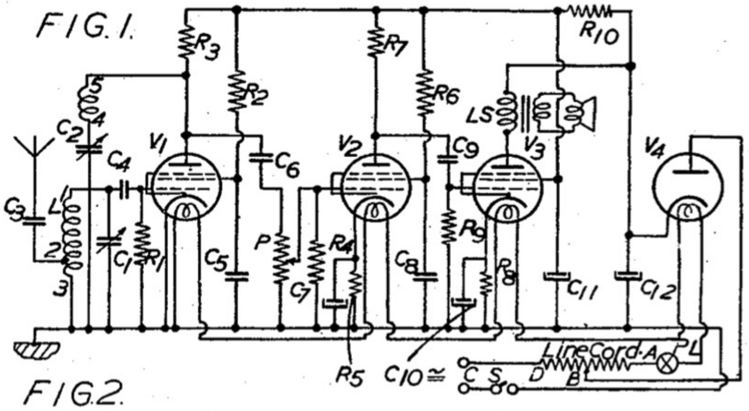
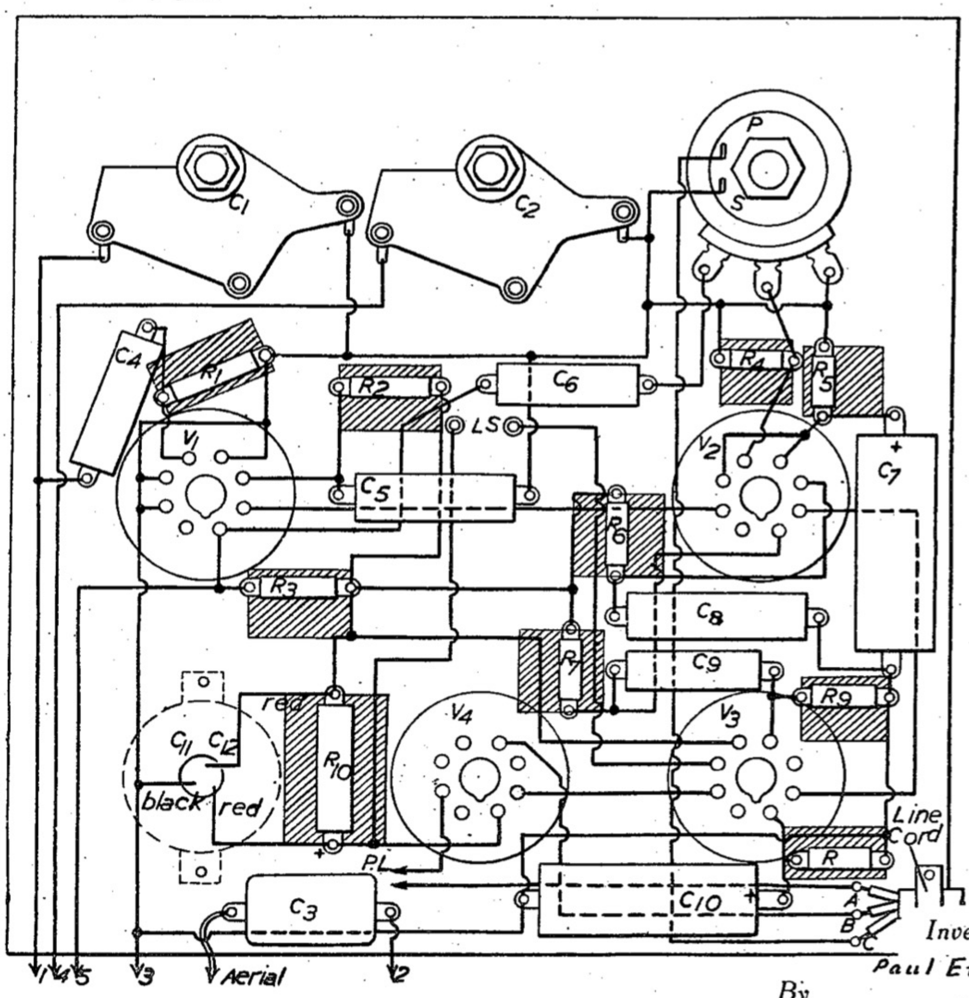

R3
R2
R7
R6
R10
5
4
C2
C4
V1
C6
V2
C9
LS
V3
V4
C3
L1
2
3
C1
R1
C5
P
C7
R4
C8
R9
R8
C11
C12
R5
C10
C
S
D
B
Line Cord A
PL

FIG. 2.


C1
C2
P
S
C4
R1
R2
C6
R4
R5
LS
V1
V2
C7
C5
R6
R3
C8
C9
R7
R9
red
C11
C12
R10
V4
V3
black
red
Line Cord
R
PL
C3
C10
A
B
C
1
4
5
3
Aerial
2

Inventor
Paul Eisler
By
A. E. O'dell
Attorney

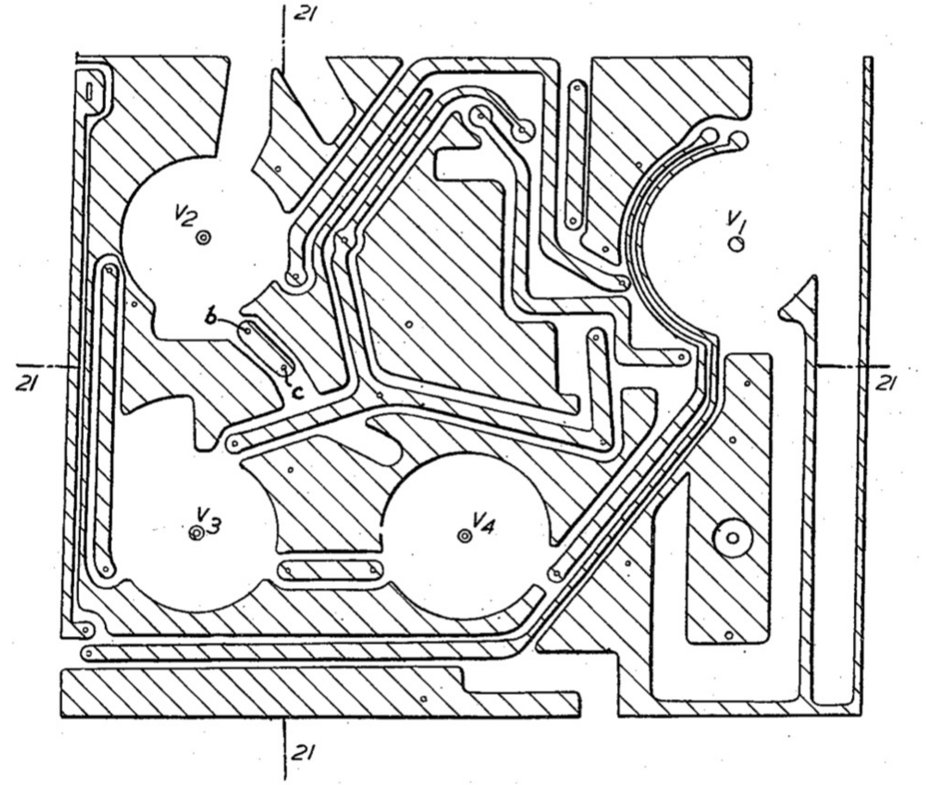
Figure B.108: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.

May 25, 1948. **P. EISLER** **2,441,960**

MANUFACTURE OF ELECTRIC CIRCUIT COMPONENTS

Filed Feb. 3, 1944 8 Sheets-Sheet 2

FIG.3.



Inventor
Paul Eisler
By
A. E. Odell
Attorney

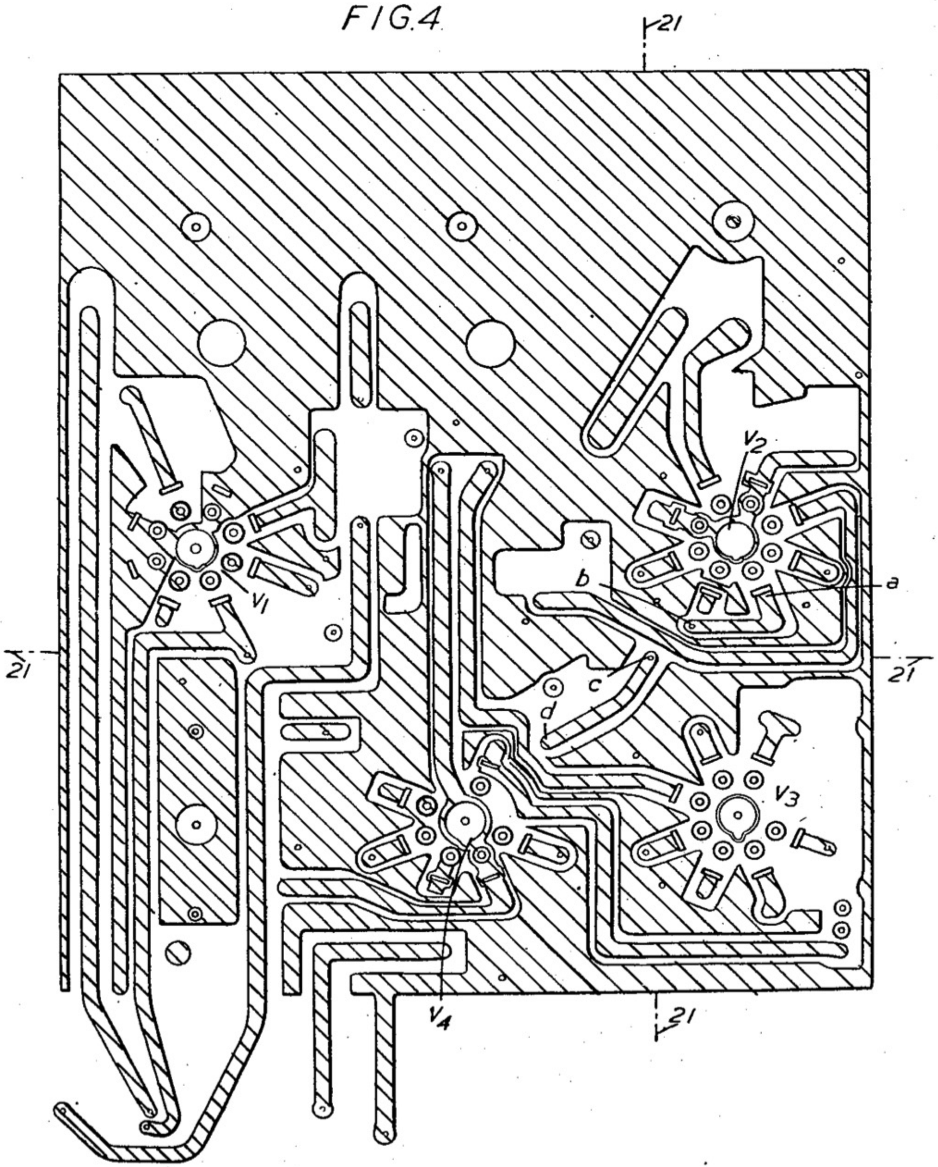
Figure B.109: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.

May 25, 1948. **P. EISLER** **2,441,960**

MANUFACTURE OF ELECTRIC CIRCUIT COMPONENTS

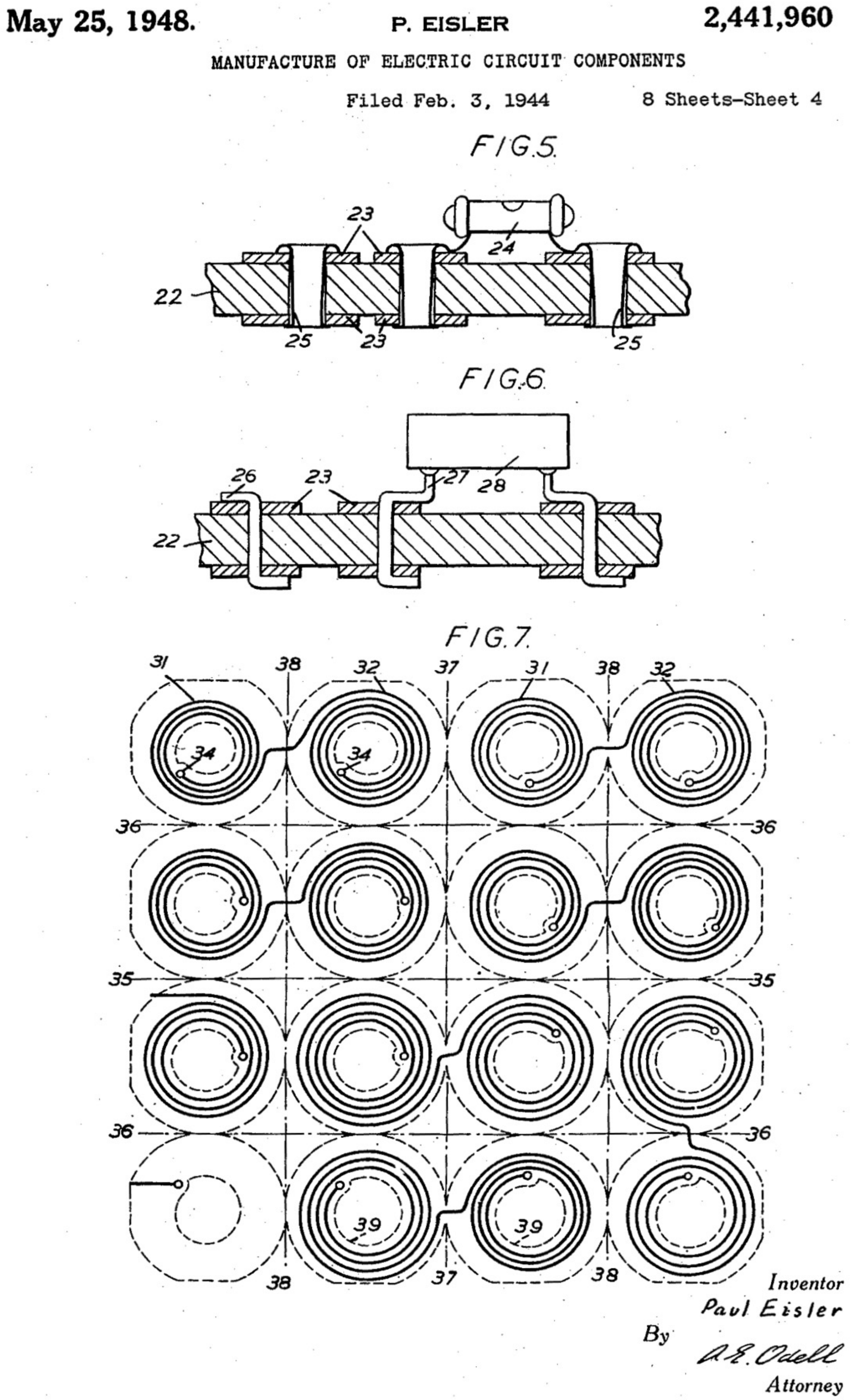
Filed Feb. 3, 1944 8 Sheets–Sheet 3

FIG.4



Inventor
Paul Eisler
By
A. J. O'dell
Attorney

Figure B.110: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.



May 25, 1948. **P. EISLER** **2,441,960**

MANUFACTURE OF ELECTRIC CIRCUIT COMPONENTS

Filed Feb. 3, 1944 8 Sheets-Sheet 4

FIG.5.
23
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FIG.6.
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FIG.7.
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Inventor
Paul Eisler
By
A.E. Odell
Attorney

Figure B.111: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.

May 25, 1948. **P. EISLER** **2,441,960**

MANUFACTURE OF ELECTRIC CIRCUIT COMPONENTS

Filed Feb. 3, 1944 8 Sheets-Sheet 5

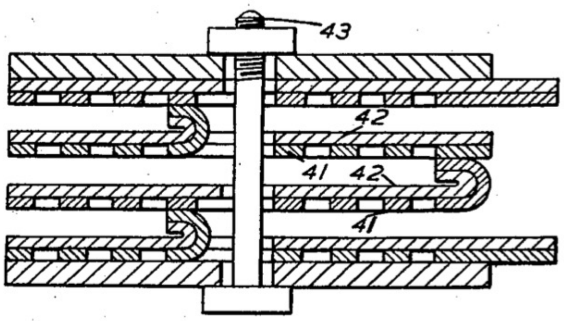
43
42
41
42
41

FIG.8.

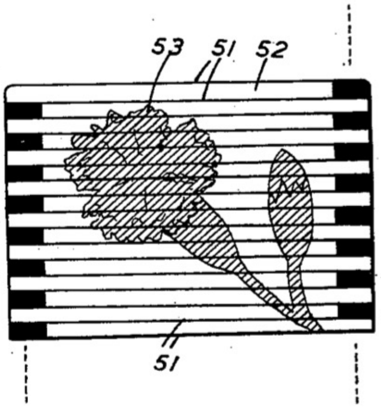

FIG.9.

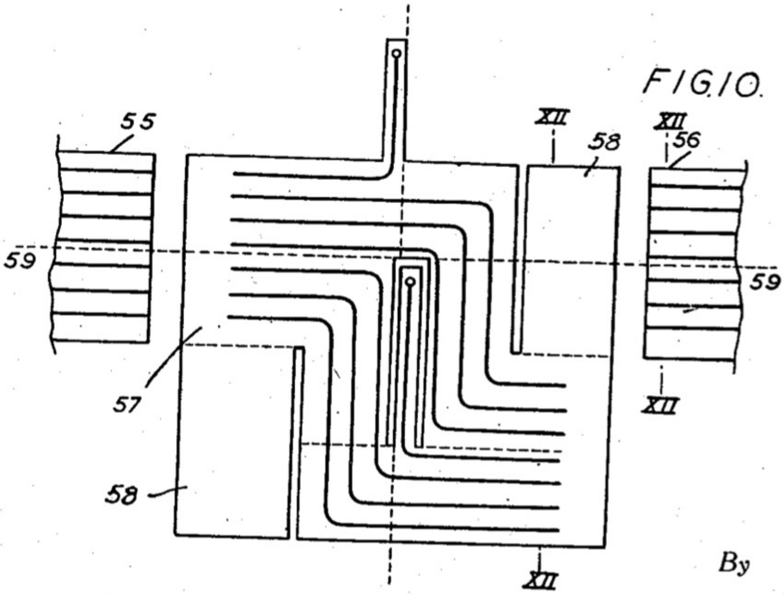
55
59
57
58
XII
58
XII
56
59
XII
XII

FIG.10.

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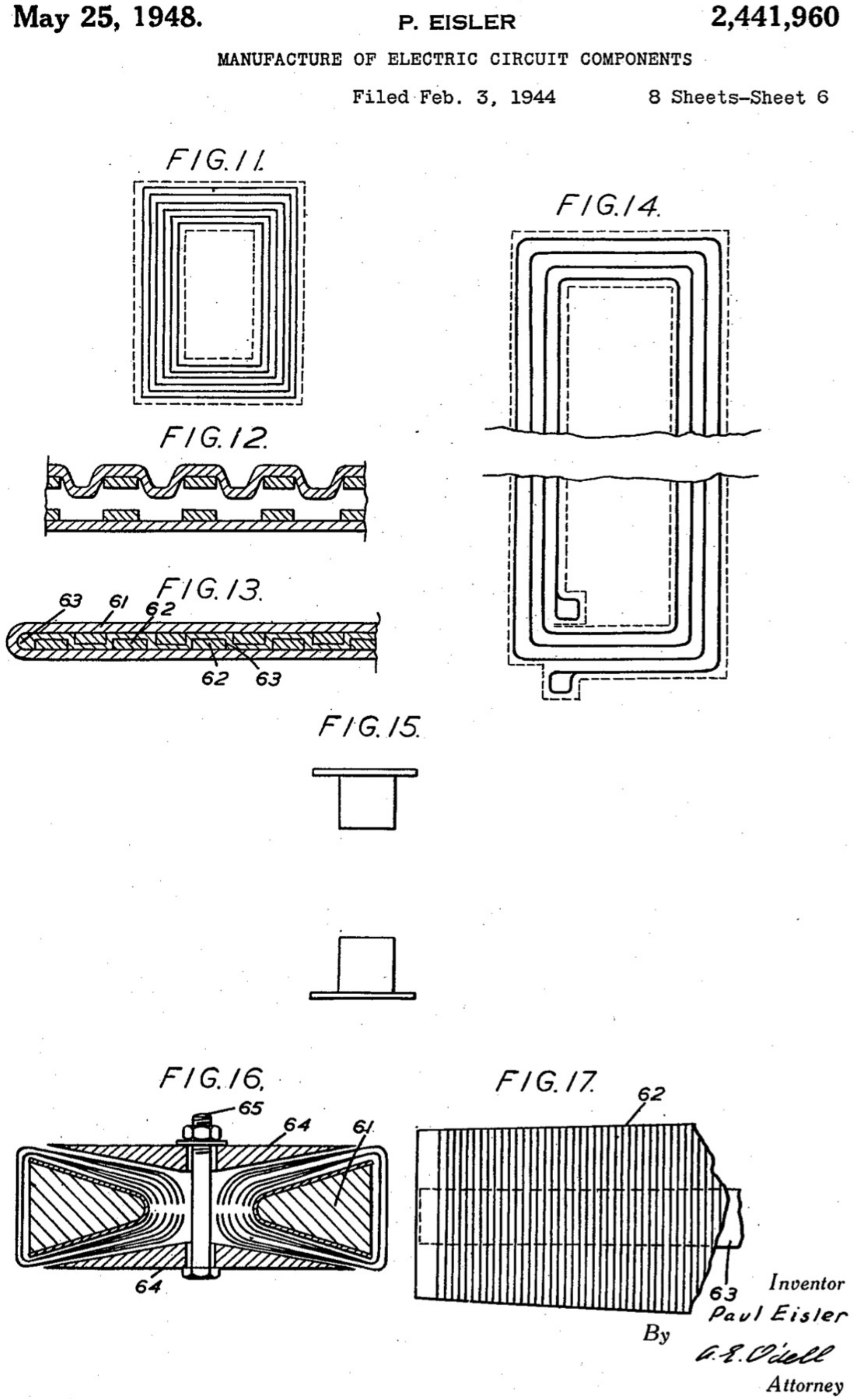
Figure B.112: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.



May 25, 1948. **P. EISLER** **2,441,960**

MANUFACTURE OF ELECTRIC CIRCUIT COMPONENTS

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FIG. 11.
FIG. 12.
FIG. 13.
63
61
62
62
63
FIG. 14.
FIG. 15.
FIG. 16.
65
64
61
64
FIG. 17.
62
63

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Figure B.113: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.

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MANUFACTURE OF ELECTRIC CIRCUIT COMPONENTS

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FIG. 18.

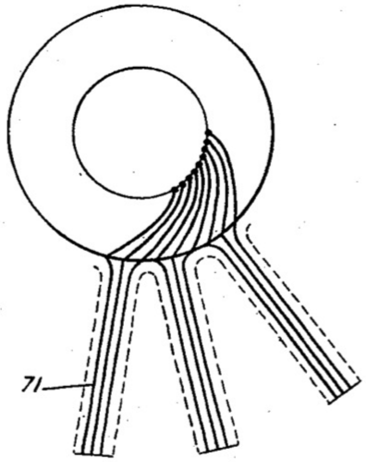

FIG. 19.

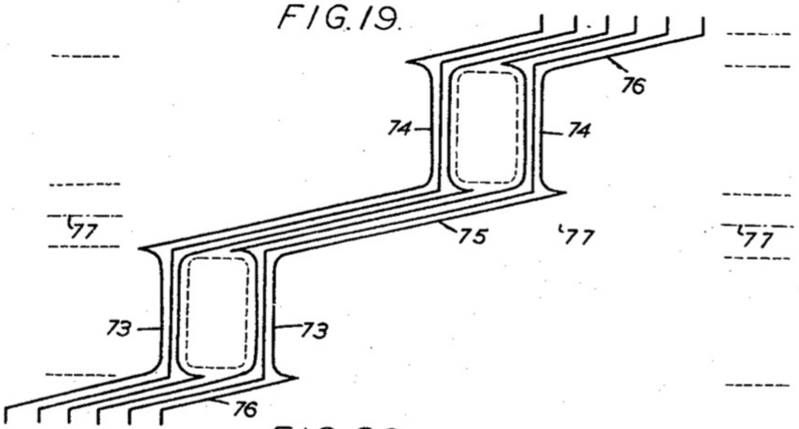

FIG. 20.

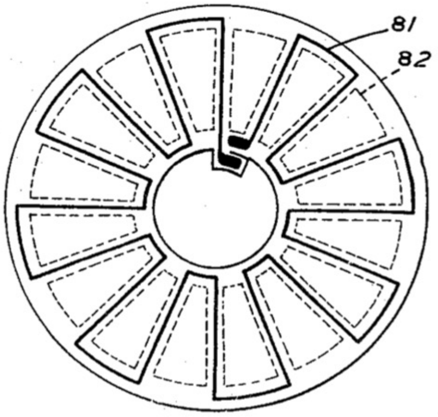

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Figure B.114: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.

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MANUFACTURE OF ELECTRIC CIRCUIT COMPONENTS

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FIG. 21.

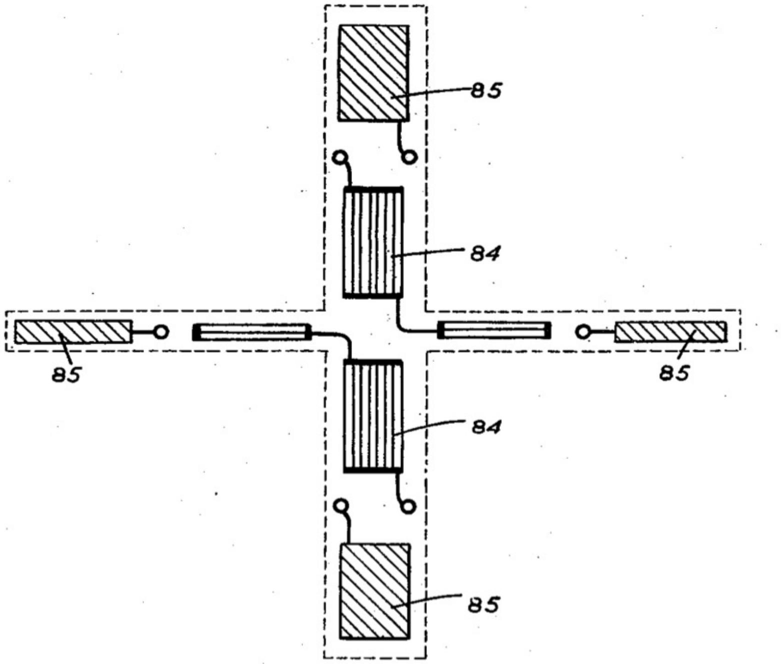
85
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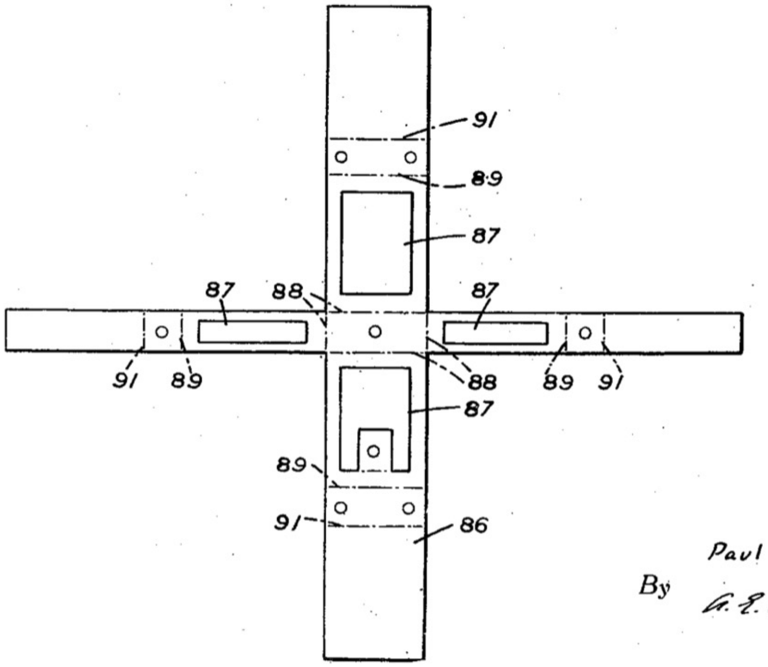
FIG. 22.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Inventor
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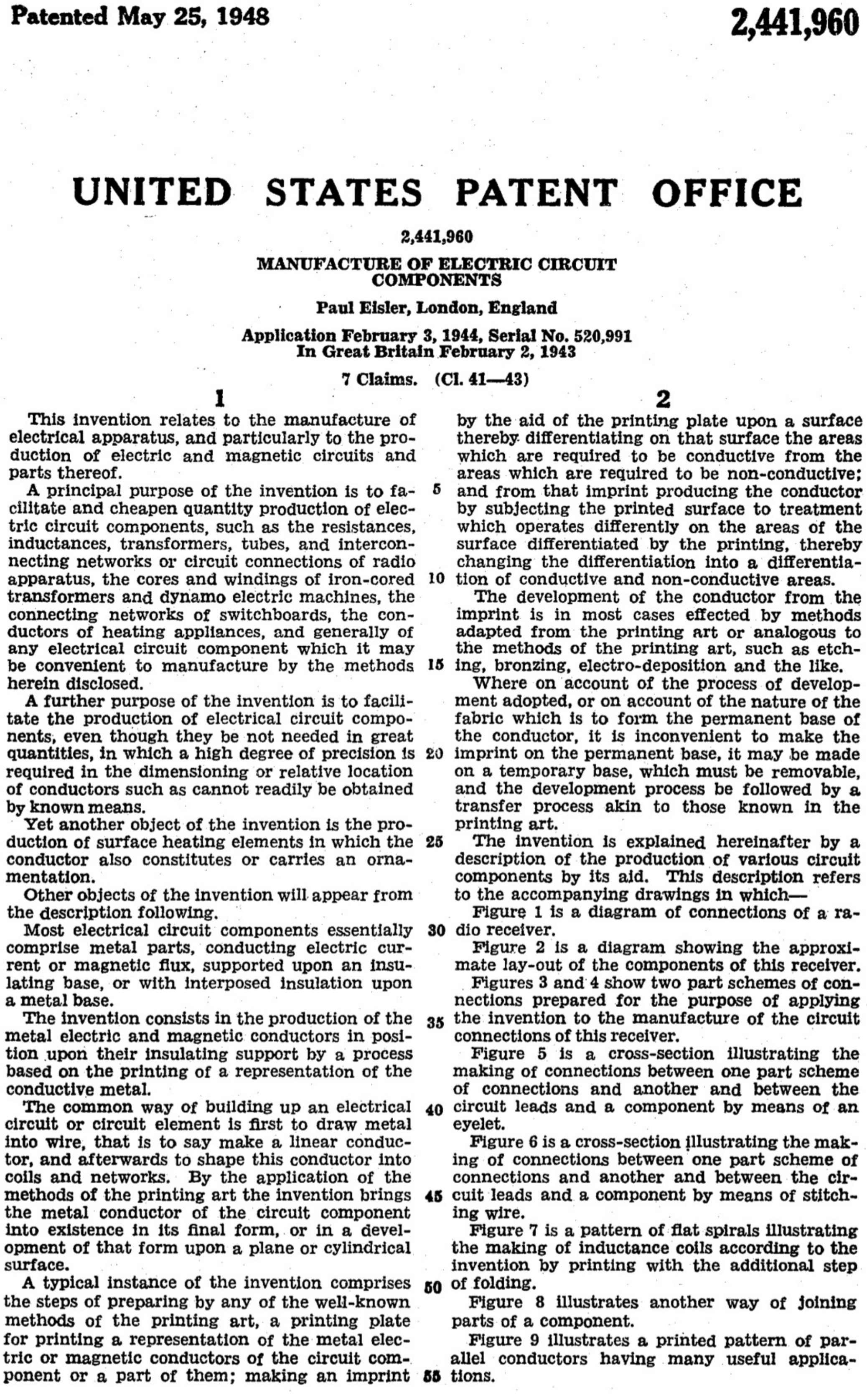
By A. E. Odell
Attorney

Figure B.115: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.



Patented May 25, 1948 **2,441,960**

UNITED STATES PATENT OFFICE

2,441,960

MANUFACTURE OF ELECTRIC CIRCUIT COMPONENTS

Paul Eisler, London, England

Application February 3, 1944, Serial No. 520,991
In Great Britain February 2, 1943

7 Claims. (Cl. 41—43)

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This invention relates to the manufacture of electrical apparatus, and particularly to the production of electric and magnetic circuits and parts thereof.

A principal purpose of the invention is to facilitate and cheapen quantity production of electric circuit components, such as the resistances, inductances, transformers, tubes, and interconnecting networks or circuit connections of radio apparatus, the cores and windings of iron-cored transformers and dynamo electric machines, the connecting networks of switchboards, the conductors of heating appliances, and generally of any electrical circuit component which it may be convenient to manufacture by the methods herein disclosed.

A further purpose of the invention is to facilitate the production of electrical circuit components, even though they be not needed in great quantities, in which a high degree of precision is required in the dimensioning or relative location of conductors such as cannot readily be obtained by known means.

Yet another object of the invention is the production of surface heating elements in which the conductor also constitutes or carries an ornamentation.

Other objects of the invention will appear from the description following.

Most electrical circuit components essentially comprise metal parts, conducting electric current or magnetic flux, supported upon an insulating base, or with interposed insulation upon a metal base.

The invention consists in the production of the metal electric and magnetic conductors in position upon their insulating support by a process based on the printing of a representation of the conductive metal.

The common way of building up an electrical circuit or circuit element is first to draw metal into wire, that is to say make a linear conductor, and afterwards to shape this conductor into coils and networks. By the application of the methods of the printing art the invention brings the metal conductor of the circuit component into existence in its final form, or in a development of that form upon a plane or cylindrical surface.

A typical instance of the invention comprises the steps of preparing by any of the well-known methods of the printing art, a printing plate for printing a representation of the metal electric or magnetic conductors of the circuit component or a part of them; making an imprint

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by the aid of the printing plate upon a surface thereby differentiating on that surface the areas which are required to be conductive from the areas which are required to be non-conductive; and from that imprint producing the conductor by subjecting the printed surface to treatment which operates differently on the areas of the surface differentiated by the printing, thereby changing the differentiation into a differentiation of conductive and non-conductive areas.

The development of the conductor from the imprint is in most cases effected by methods adapted from the printing art or analogous to the methods of the printing art, such as etching, bronzing, electro-deposition and the like.

Where on account of the process of development adopted, or on account of the nature of the fabric which is to form the permanent base of the conductor, it is inconvenient to make the imprint on the permanent base, it may be made on a temporary base, which must be removable, and the development process be followed by a transfer process akin to those known in the printing art.

The invention is explained hereinafter by a description of the production of various circuit components by its aid. This description refers to the accompanying drawings in which—

Figure 1 is a diagram of connections of a radio receiver.

Figure 2 is a diagram showing the approximate lay-out of the components of this receiver.

Figures 3 and 4 show two part schemes of connections prepared for the purpose of applying the invention to the manufacture of the circuit connections of this receiver.

Figure 5 is a cross-section illustrating the making of connections between one part scheme of connections and another and between the circuit leads and a component by means of an eyelet.

Figure 6 is a cross-section illustrating the making of connections between one part scheme of connections and another and between the circuit leads and a component by means of stitching wire.

Figure 7 is a pattern of flat spirals illustrating the making of inductance coils according to the invention by printing with the additional step of folding.

Figure 8 illustrates another way of joining parts of a component.

Figure 9 illustrates a printed pattern of parallel conductors having many useful applications.

Figure B.116: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.

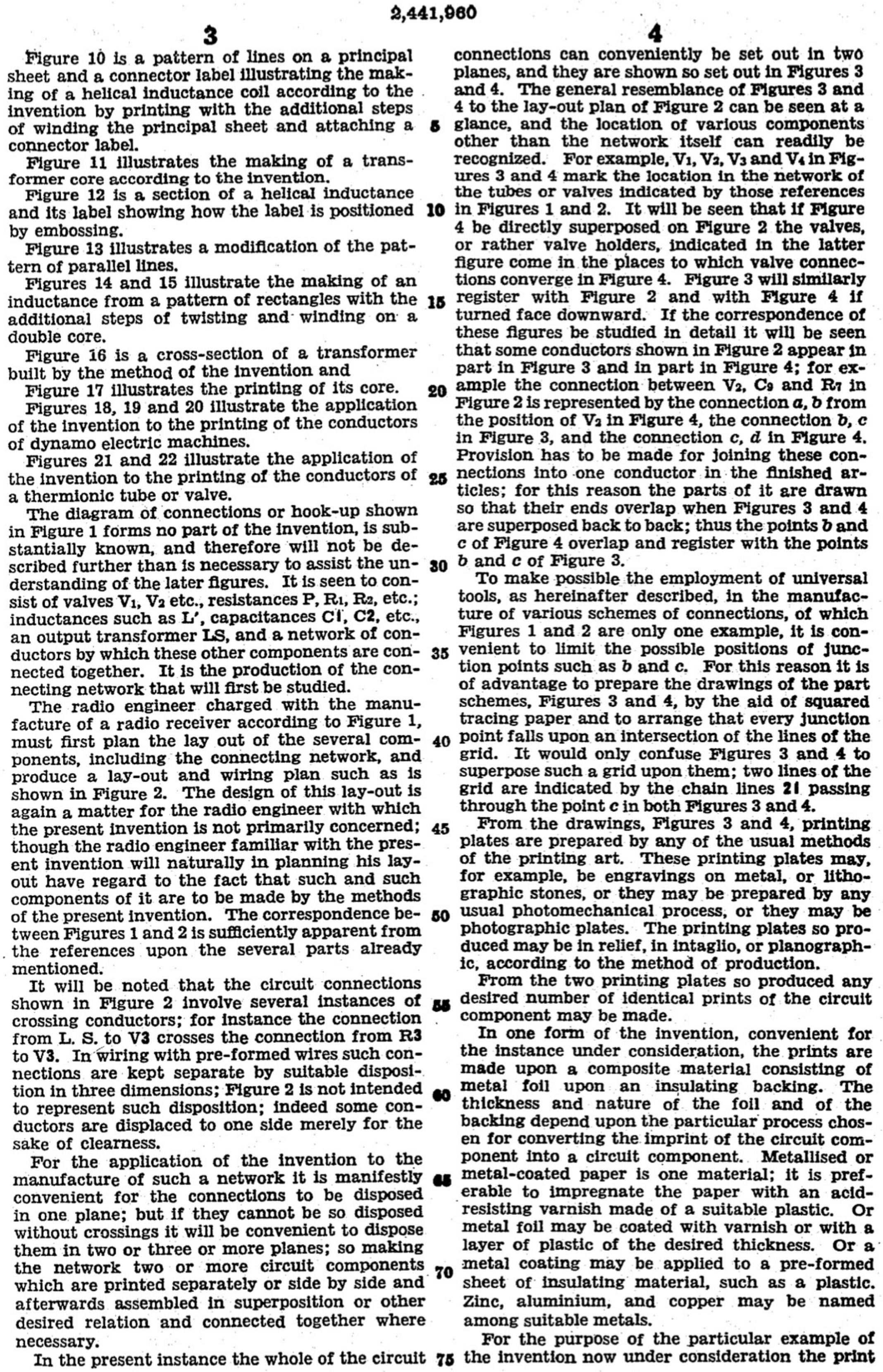


Figure 10 is a pattern of lines on a principal sheet and a connector label illustrating the making of a helical inductance coil according to the invention by printing with the additional steps of winding the principal sheet and attaching a connector label.

Figure 11 illustrates the making of a transformer core according to the invention.

Figure 12 is a section of a helical inductance and its label showing how the label is positioned by embossing.

Figure 13 illustrates a modification of the pattern of parallel lines.

Figures 14 and 15 illustrate the making of an inductance from a pattern of rectangles with the additional steps of twisting and winding on a double core.

Figure 16 is a cross-section of a transformer built by the method of the invention and

Figure 17 illustrates the printing of its core.

Figures 18, 19 and 20 illustrate the application of the invention to the printing of the conductors of dynamo electric machines.

Figures 21 and 22 illustrate the application of the invention to the printing of the conductors of a thermionic tube or valve.

The diagram of connections or hook-up shown in Figure 1 forms no part of the invention, is substantially known, and therefore will not be described further than is necessary to assist the understanding of the later figures. It is seen to consist of valves V_1, V_2 etc., resistances P, R_1, R_2, etc.; inductances such as L′, capacitances C1, C2, etc., an output transformer LS, and a network of conductors by which these other components are connected together. It is the production of the connecting network that will first be studied.

The radio engineer charged with the manufacture of a radio receiver according to Figure 1, must first plan the lay out of the several components, including the connecting network, and produce a lay-out and wiring plan such as is shown in Figure 2. The design of this lay-out is again a matter for the radio engineer with which the present invention is not primarily concerned; though the radio engineer familiar with the present invention will naturally in planning his layout have regard to the fact that such and such components of it are to be made by the methods of the present invention. The correspondence between Figures 1 and 2 is sufficiently apparent from the references upon the several parts already mentioned.

It will be noted that the circuit connections shown in Figure 2 involve several instances of crossing conductors; for instance the connection from L. S. to V3 crosses the connection from R3 to V3. In wiring with pre-formed wires such connections are kept separate by suitable disposition in three dimensions; Figure 2 is not intended to represent such disposition; indeed some conductors are displaced to one side merely for the sake of clearness.

For the application of the invention to the manufacture of such a network it is manifestly convenient for the connections to be disposed in one plane; but if they cannot be so disposed without crossings it will be convenient to dispose them in two or three or more planes; so making the network two or more circuit components which are printed separately or side by side and afterwards assembled in superposition or other desired relation and connected together where necessary.

In the present instance the whole of the circuit connections can conveniently be set out in two planes, and they are shown so set out in Figures 3 and 4. The general resemblance of Figures 3 and 4 to the lay-out plan of Figure 2 can be seen at a glance, and the location of various components other than the network itself can readily be recognized. For example, V_1, V_2, V_3 and V_4 in Figures 3 and 4 mark the location in the network of the tubes or valves indicated by those references in Figures 1 and 2. It will be seen that if Figure 4 be directly superposed on Figure 2 the valves, or rather valve holders, indicated in the latter figure come in the places to which valve connections converge in Figure 4. Figure 3 will similarly register with Figure 2 and with Figure 4 if turned face downward. If the correspondence of these figures be studied in detail it will be seen that some conductors shown in Figure 2 appear in part in Figure 3 and in part in Figure 4; for example the connection between V_2, C_9 and R_7 in Figure 2 is represented by the connection *a*, *b* from the position of V_2 in Figure 4, the connection *b*, *c* in Figure 3, and the connection *c*, *d* in Figure 4. Provision has to be made for joining these connections into one conductor in the finished articles; for this reason the parts of it are drawn so that their ends overlap when Figures 3 and 4 are superposed back to back; thus the points *b* and *c* of Figure 4 overlap and register with the points *b* and *c* of Figure 3.

To make possible the employment of universal tools, as hereinafter described, in the manufacture of various schemes of connections, of which Figures 1 and 2 are only one example, it is convenient to limit the possible positions of junction points such as *b* and *c*. For this reason it is of advantage to prepare the drawings of the part schemes, Figures 3 and 4, by the aid of squared tracing paper and to arrange that every junction point falls upon an intersection of the lines of the grid. It would only confuse Figures 3 and 4 to superpose such a grid upon them; two lines of the grid are indicated by the chain lines **21** passing through the point *c* in both Figures 3 and 4.

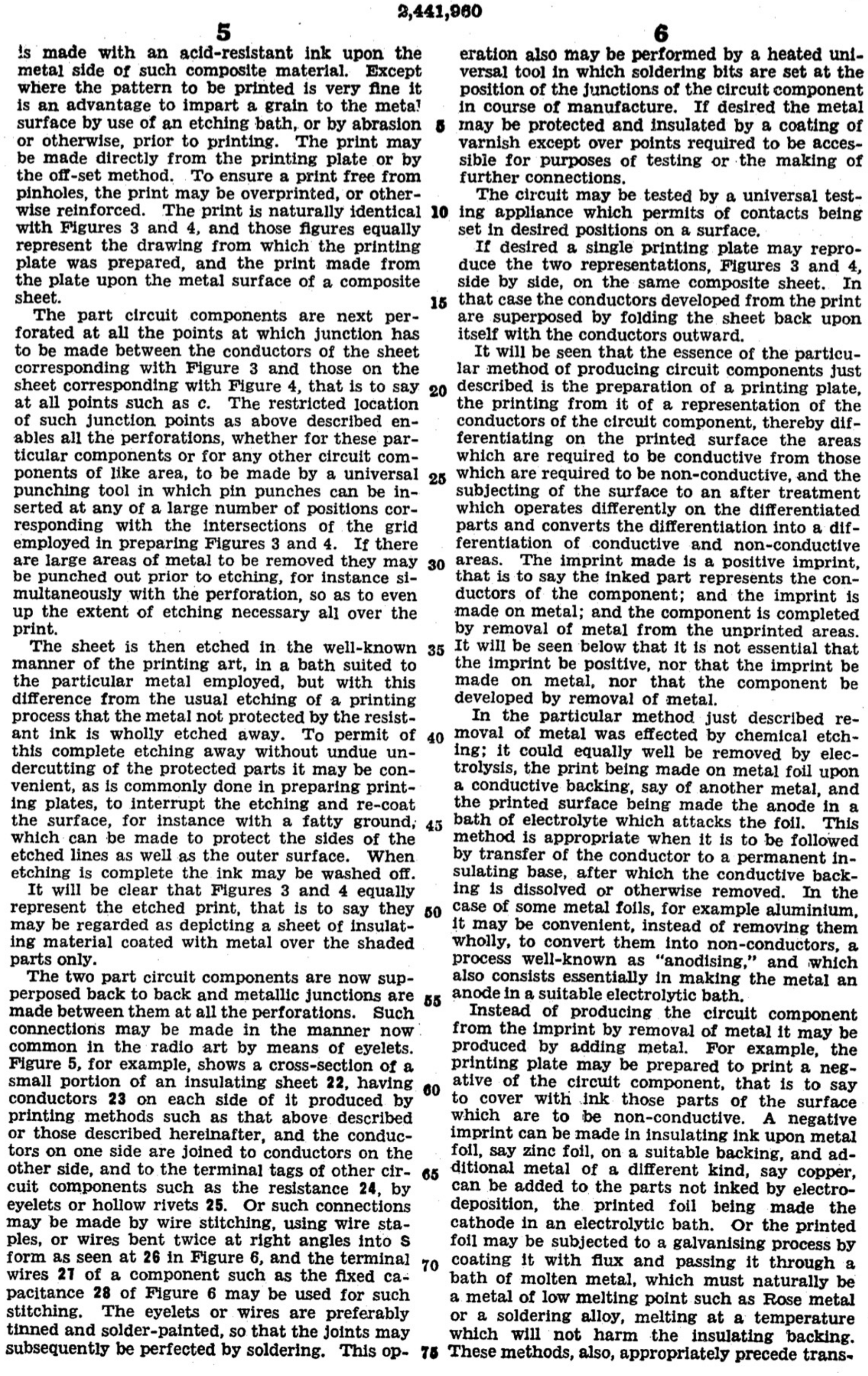
From the drawings, Figures 3 and 4, printing plates are prepared by any of the usual methods of the printing art. These printing plates may, for example, be engravings on metal, or lithographic stones, or they may be prepared by any usual photomechanical process, or they may be photographic plates. The printing plates so produced may be in relief, in intaglio, or planographic, according to the method of production.

From the two printing plates so produced any desired number of identical prints of the circuit component may be made.

In one form of the invention, convenient for the instance under consideration, the prints are made upon a composite material consisting of metal foil upon an insulating backing. The thickness and nature of the foil and of the backing depend upon the particular process chosen for converting the imprint of the circuit component into a circuit component. Metallised or metal-coated paper is one material; it is preferable to impregnate the paper with an acid-resisting varnish made of a suitable plastic. Or metal foil may be coated with varnish or with a layer of plastic of the desired thickness. Or a metal coating may be applied to a pre-formed sheet of insulating material, such as a plastic. Zinc, aluminium, and copper may be named among suitable metals.

For the purpose of the particular example of the invention now under consideration the print

Figure B.117: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.



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is made with an acid-resistant ink upon the metal side of such composite material. Except where the pattern to be printed is very fine it is an advantage to impart a grain to the metal surface by use of an etching bath, or by abrasion or otherwise, prior to printing. The print may be made directly from the printing plate or by the off-set method. To ensure a print free from pinholes, the print may be overprinted, or otherwise reinforced. The print is naturally identical with Figures 3 and 4, and those figures equally represent the drawing from which the printing plate was prepared, and the print made from the plate upon the metal surface of a composite sheet.

The part circuit components are next perforated at all the points at which junction has to be made between the conductors of the sheet corresponding with Figure 3 and those on the sheet corresponding with Figure 4, that is to say at all points such as *c*. The restricted location of such junction points as above described enables all the perforations, whether for these particular components or for any other circuit components of like area, to be made by a universal punching tool in which pin punches can be inserted at any of a large number of positions corresponding with the intersections of the grid employed in preparing Figures 3 and 4. If there are large areas of metal to be removed they may be punched out prior to etching, for instance simultaneously with the perforation, so as to even up the extent of etching necessary all over the print.

The sheet is then etched in the well-known manner of the printing art, in a bath suited to the particular metal employed, but with this difference from the usual etching of a printing process that the metal not protected by the resistant ink is wholly etched away. To permit of this complete etching away without undue undercutting of the protected parts it may be convenient, as is commonly done in preparing printing plates, to interrupt the etching and re-coat the surface, for instance with a fatty ground, which can be made to protect the sides of the etched lines as well as the outer surface. When etching is complete the ink may be washed off.

It will be clear that Figures 3 and 4 equally represent the etched print, that is to say they may be regarded as depicting a sheet of insulating material coated with metal over the shaded parts only.

The two part circuit components are now superposed back to back and metallic junctions are made between them at all the perforations. Such connections may be made in the manner now common in the radio art by means of eyelets. Figure 5, for example, shows a cross-section of a small portion of an insulating sheet **22**, having conductors **23** on each side of it produced by printing methods such as that above described or those described hereinafter, and the conductors on one side are joined to conductors on the other side, and to the terminal tags of other circuit components such as the resistance **24**, by eyelets or hollow rivets **25**. Or such connections may be made by wire stitching, using wire staples, or wires bent twice at right angles into S form as seen at **26** in Figure 6, and the terminal wires **27** of a component such as the fixed capacitance **28** of Figure 6 may be used for such stitching. The eyelets or wires are preferably tinned and solder-painted, so that the joints may subsequently be perfected by soldering. This operation also may be performed by a heated universal tool in which soldering bits are set at the position of the junctions of the circuit component in course of manufacture. If desired the metal may be protected and insulated by a coating of varnish except over points required to be accessible for purposes of testing or the making of further connections.

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The circuit may be tested by a universal testing appliance which permits of contacts being set in desired positions on a surface.

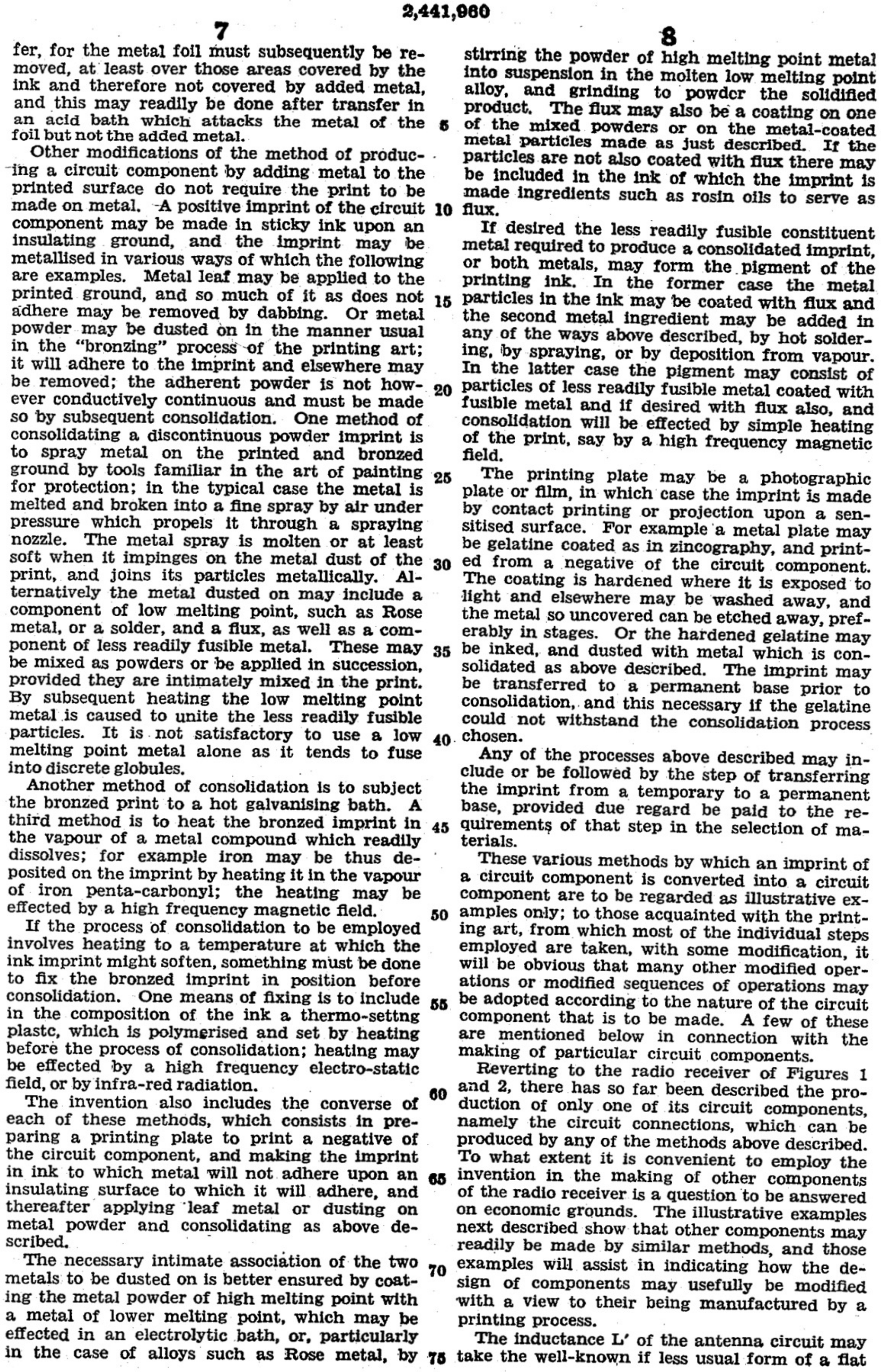
If desired a single printing plate may reproduce the two representations, Figures 3 and 4, side by side, on the same composite sheet. In that case the conductors developed from the print are superposed by folding the sheet back upon itself with the conductors outward.

It will be seen that the essence of the particular method of producing circuit components just described is the preparation of a printing plate, the printing from it of a representation of the conductors of the circuit component, thereby differentiating on the printed surface the areas which are required to be conductive from those which are required to be non-conductive, and the subjecting of the surface to an after treatment which operates differently on the differentiated parts and converts the differentiation into a differentiation of conductive and non-conductive areas. The imprint made is a positive imprint, that is to say the inked part represents the conductors of the component; and the imprint is made on metal; and the component is completed by removal of metal from the unprinted areas. It will be seen below that it is not essential that the imprint be positive, nor that the imprint be made on metal, nor that the component be developed by removal of metal.

In the particular method just described removal of metal was effected by chemical etching; it could equally well be removed by electrolysis, the print being made on metal foil upon a conductive backing, say of another metal, and the printed surface being made the anode in a bath of electrolyte which attacks the foil. This method is appropriate when it is to be followed by transfer of the conductor to a permanent insulating base, after which the conductive backing is dissolved or otherwise removed. In the case of some metal foils, for example aluminium, it may be convenient, instead of removing them wholly, to convert them into non-conductors, a process well-known as "anodising," and which also consists essentially in making the metal an anode in a suitable electrolytic bath.

Instead of producing the circuit component from the imprint by removal of metal it may be produced by adding metal. For example, the printing plate may be prepared to print a negative of the circuit component, that is to say to cover with ink those parts of the surface which are to be non-conductive. A negative imprint can be made in insulating ink upon metal foil, say zinc foil, on a suitable backing, and additional metal of a different kind, say copper, can be added to the parts not inked by electrodeposition, the printed foil being made the cathode in an electrolytic bath. Or the printed foil may be subjected to a galvanising process by coating it with flux and passing it through a bath of molten metal, which must naturally be a metal of low melting point such as Rose metal or a soldering alloy, melting at a temperature which will not harm the insulating backing. These methods, also, appropriately precede trans-

Figure B.118: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.



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fer, for the metal foil must subsequently be removed, at least over those areas covered by the ink and therefore not covered by added metal, and this may readily be done after transfer in an acid bath which attacks the metal of the foil but not the added metal.

Other modifications of the method of producing a circuit component by adding metal to the printed surface do not require the print to be made on metal. A positive imprint of the circuit component may be made in sticky ink upon an insulating ground, and the imprint may be metallised in various ways of which the following are examples. Metal leaf may be applied to the printed ground, and so much of it as does not adhere may be removed by dabbing. Or metal powder may be dusted on in the manner usual in the "bronzing" process of the printing art; it will adhere to the imprint and elsewhere may be removed; the adherent powder is not however conductively continuous and must be made so by subsequent consolidation. One method of consolidating a discontinuous powder imprint is to spray metal on the printed and bronzed ground by tools familiar in the art of painting for protection; in the typical case the metal is melted and broken into a fine spray by air under pressure which propels it through a spraying nozzle. The metal spray is molten or at least soft when it impinges on the metal dust of the print, and joins its particles metallically. Alternatively the metal dusted on may include a component of low melting point, such as Rose metal, or a solder, and a flux, as well as a component of less readily fusible metal. These may be mixed as powders or be applied in succession, provided they are intimately mixed in the print. By subsequent heating the low melting point metal is caused to unite the less readily fusible particles. It is not satisfactory to use a low melting point metal alone as it tends to fuse into discrete globules.

Another method of consolidation is to subject the bronzed print to a hot galvanising bath. A third method is to heat the bronzed imprint in the vapour of a metal compound which readily dissolves; for example iron may be thus deposited on the imprint by heating it in the vapour of iron penta-carbonyl; the heating may be effected by a high frequency magnetic field.

If the process of consolidation to be employed involves heating to a temperature at which the ink imprint might soften, something must be done to fix the bronzed imprint in position before consolidation. One means of fixing is to include in the composition of the ink a thermo-settng plastc, which is polymerised and set by heating before the process of consolidation; heating may be effected by a high frequency electro-static field, or by infra-red radiation.

The invention also includes the converse of each of these methods, which consists in preparing a printing plate to print a negative of the circuit component, and making the imprint in ink to which metal will not adhere upon an insulating surface to which it will adhere, and thereafter applying leaf metal or dusting on metal powder and consolidating as above described.

The necessary intimate association of the two metals to be dusted on is better ensured by coating the metal powder of high melting point with a metal of lower melting point, which may be effected in an electrolytic bath, or, particularly in the case of alloys such as Rose metal, by

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stirring the powder of high melting point metal into suspension in the molten low melting point alloy, and grinding to powder the solidified product. The flux may also be a coating on one of the mixed powders or on the metal-coated metal particles made as just described. If the particles are not also coated with flux there may be included in the ink of which the imprint is made ingredients such as rosin oils to serve as flux.

If desired the less readily fusible constituent metal required to produce a consolidated imprint, or both metals, may form the pigment of the printing ink. In the former case the metal particles in the ink may be coated with flux and the second metal ingredient may be added in any of the ways above described, by hot soldering, by spraying, or by deposition from vapour. In the latter case the pigment may consist of particles of less readily fusible metal coated with fusible metal and if desired with flux also, and consolidation will be effected by simple heating of the print, say by a high frequency magnetic field.

The printing plate may be a photographic plate or film, in which case the imprint is made by contact printing or projection upon a sensitised surface. For example a metal plate may be gelatine coated as in zincography, and printed from a negative of the circuit component. The coating is hardened where it is exposed to light and elsewhere may be washed away, and the metal so uncovered can be etched away, preferably in stages. Or the hardened gelatine may be inked, and dusted with metal which is consolidated as above described. The imprint may be transferred to a permanent base prior to consolidation, and this necessary if the gelatine could not withstand the consolidation process chosen.

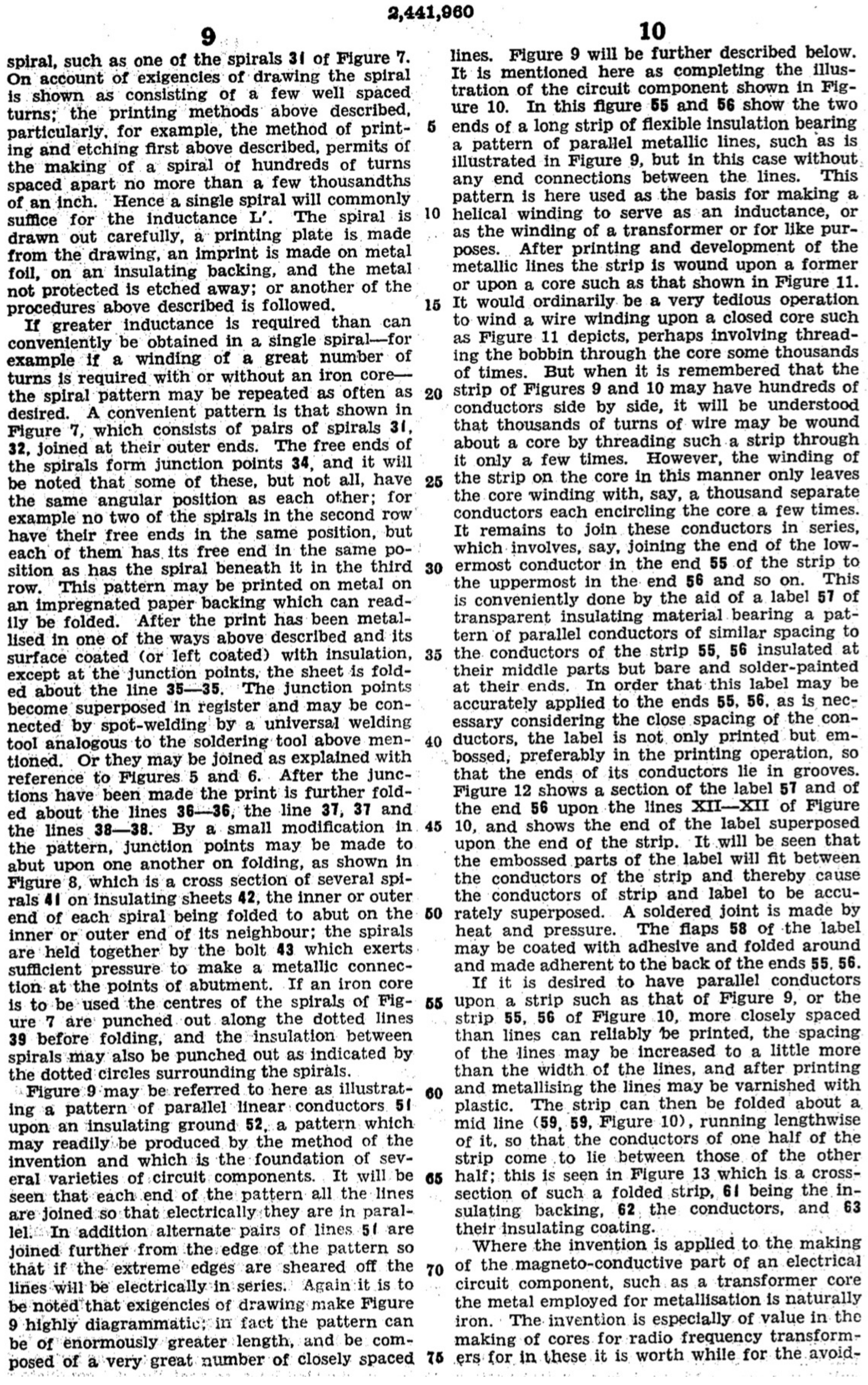
Any of the processes above described may include or be followed by the step of transferring the imprint from a temporary to a permanent base, provided due regard be paid to the requirements of that step in the selection of materials.

These various methods by which an imprint of a circuit component is converted into a circuit component are to be regarded as illustrative examples only; to those acquainted with the printing art, from which most of the individual steps employed are taken, with some modification, it will be obvious that many other modified operations or modified sequences of operations may be adopted according to the nature of the circuit component that is to be made. A few of these are mentioned below in connection with the making of particular circuit components.

Reverting to the radio receiver of Figures 1 and 2, there has so far been described the production of only one of its circuit components, namely the circuit connections, which can be produced by any of the methods above described. To what extent it is convenient to employ the invention in the making of other components of the radio receiver is a question to be answered on economic grounds. The illustrative examples next described show that other components may readily be made by similar methods, and those examples will assist in indicating how the design of components may usefully be modified with a view to their being manufactured by a printing process.

The inductance L' of the antenna circuit may take the well-known if less usual form of a flat

Figure B.119: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.



spiral, such as one of the spirals 31 of Figure 7. On account of exigencies of drawing the spiral is shown as consisting of a few well spaced turns; the printing methods above described, particularly, for example, the method of printing and etching first above described, permits of the making of a spiral of hundreds of turns spaced apart no more than a few thousandths of an inch. Hence a single spiral will commonly suffice for the inductance L'. The spiral is drawn out carefully, a printing plate is made from the drawing, an imprint is made on metal foil, on an insulating backing, and the metal not protected is etched away; or another of the procedures above described is followed.

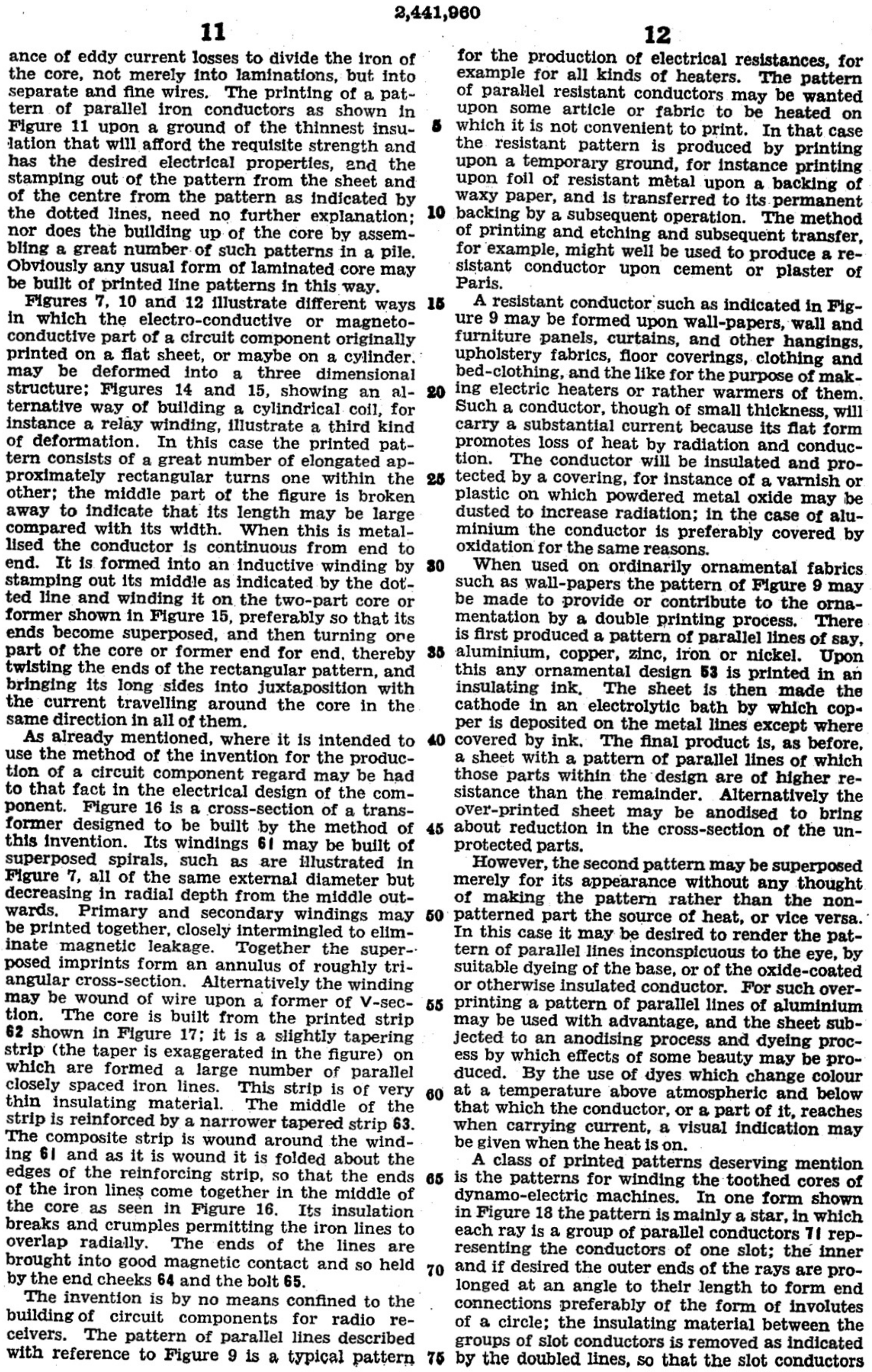
If greater inductance is required than can conveniently be obtained in a single spiral—for example if a winding of a great number of turns is required with or without an iron core—the spiral pattern may be repeated as often as desired. A convenient pattern is that shown in Figure 7, which consists of pairs of spirals 31, 32, joined at their outer ends. The free ends of the spirals form junction points 34, and it will be noted that some of these, but not all, have the same angular position as each other; for example no two of the spirals in the second row have their free ends in the same position, but each of them has its free end in the same position as has the spiral beneath it in the third row. This pattern may be printed on metal on an impregnated paper backing which can readily be folded. After the print has been metallised in one of the ways above described and its surface coated (or left coated) with insulation, except at the junction points, the sheet is folded about the line 35—35. The junction points become superposed in register and may be connected by spot-welding by a universal welding tool analogous to the soldering tool above mentioned. Or they may be joined as explained with reference to Figures 5 and 6. After the junctions have been made the print is further folded about the lines 36—36, the line 37, 37 and the lines 38—38. By a small modification in the pattern, junction points may be made to abut upon one another on folding, as shown in Figure 8, which is a cross section of several spirals 41 on insulating sheets 42, the inner or outer end of each spiral being folded to abut on the inner or outer end of its neighbour; the spirals are held together by the bolt 43 which exerts sufficient pressure to make a metallic connection at the points of abutment. If an iron core is to be used the centres of the spirals of Figure 7 are punched out along the dotted lines 39 before folding, and the insulation between spirals may also be punched out as indicated by the dotted circles surrounding the spirals.

Figure 9 may be referred to here as illustrating a pattern of parallel linear conductors 51 upon an insulating ground 52, a pattern which may readily be produced by the method of the invention and which is the foundation of several varieties of circuit components. It will be seen that each end of the pattern all the lines are joined so that electrically they are in parallel. In addition alternate pairs of lines 51 are joined further from the edge of the pattern so that if the extreme edges are sheared off the lines will be electrically in series. Again it is to be noted that exigencies of drawing make Figure 9 highly diagrammatic; in fact the pattern can be of enormously greater length, and be composed of a very great number of closely spaced lines. Figure 9 will be further described below. It is mentioned here as completing the illustration of the circuit component shown in Figure 10. In this figure 55 and 56 show the two ends of a long strip of flexible insulation bearing a pattern of parallel metallic lines, such as is illustrated in Figure 9, but in this case without any end connections between the lines. This pattern is here used as the basis for making a helical winding to serve as an inductance, or as the winding of a transformer or for like purposes. After printing and development of the metallic lines the strip is wound upon a former or upon a core such as that shown in Figure 11. It would ordinarily be a very tedious operation to wind a wire winding upon a closed core such as Figure 11 depicts, perhaps involving threading the bobbin through the core some thousands of times. But when it is remembered that the strip of Figures 9 and 10 may have hundreds of conductors side by side, it will be understood that thousands of turns of wire may be wound about a core by threading such a strip through it only a few times. However, the winding of the strip on the core in this manner only leaves the core winding with, say, a thousand separate conductors each encircling the core a few times. It remains to join these conductors in series, which involves, say, joining the end of the lowermost conductor in the end 55 of the strip to the uppermost in the end 56 and so on. This is conveniently done by the aid of a label 57 of transparent insulating material bearing a pattern of parallel conductors of similar spacing to the conductors of the strip 55, 56 insulated at their middle parts but bare and solder-painted at their ends. In order that this label may be accurately applied to the ends 55, 56, as is necessary considering the close spacing of the conductors, the label is not only printed but embossed, preferably in the printing operation, so that the ends of its conductors lie in grooves. Figure 12 shows a section of the label 57 and of the end 56 upon the lines XII—XII of Figure 10, and shows the end of the label superposed upon the end of the strip. It will be seen that the embossed parts of the label will fit between the conductors of the strip and thereby cause the conductors of strip and label to be accurately superposed. A soldered joint is made by heat and pressure. The flaps 58 of the label may be coated with adhesive and folded around and made adherent to the back of the ends 55, 56.

If it is desired to have parallel conductors upon a strip such as that of Figure 9, or the strip 55, 56 of Figure 10, more closely spaced than lines can reliably be printed, the spacing of the lines may be increased to a little more than the width of the lines, and after printing and metallising the lines may be varnished with plastic. The strip can then be folded about a mid line (59, 59, Figure 10), running lengthwise of it, so that the conductors of one half of the strip come to lie between those of the other half; this is seen in Figure 13 which is a cross-section of such a folded strip, 61 being the insulating backing, 62 the conductors, and 63 their insulating coating.

Where the invention is applied to the making of the magneto-conductive part of an electrical circuit component, such as a transformer core the metal employed for metallisation is naturally iron. The invention is especially of value in the making of cores for radio frequency transformers for in these it is worth while for the avoid-

Figure B.120: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.



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ance of eddy current losses to divide the iron of the core, not merely into laminations, but into separate and fine wires. The printing of a pattern of parallel iron conductors as shown in Figure 11 upon a ground of the thinnest insulation that will afford the requisite strength and has the desired electrical properties, and the stamping out of the pattern from the sheet and of the centre from the pattern as indicated by the dotted lines, need no further explanation; nor does the building up of the core by assembling a great number of such patterns in a pile. Obviously any usual form of laminated core may be built of printed line patterns in this way.

Figures 7, 10 and 12 illustrate different ways in which the electro-conductive or magneto-conductive part of a circuit component originally printed on a flat sheet, or maybe on a cylinder, may be deformed into a three dimensional structure; Figures 14 and 15, showing an alternative way of building a cylindrical coil, for instance a relay winding, illustrate a third kind of deformation. In this case the printed pattern consists of a great number of elongated approximately rectangular turns one within the other; the middle part of the figure is broken away to indicate that its length may be large compared with its width. When this is metallised the conductor is continuous from end to end. It is formed into an inductive winding by stamping out its middle as indicated by the dotted line and winding it on the two-part core or former shown in Figure 15, preferably so that its ends become superposed, and then turning one part of the core or former end for end, thereby twisting the ends of the rectangular pattern, and bringing its long sides into juxtaposition with the current travelling around the core in the same direction in all of them.

As already mentioned, where it is intended to use the method of the invention for the production of a circuit component regard may be had to that fact in the electrical design of the component. Figure 16 is a cross-section of a transformer designed to be built by the method of this invention. Its windings 61 may be built of superposed spirals, such as are illustrated in Figure 7, all of the same external diameter but decreasing in radial depth from the middle outwards. Primary and secondary windings may be printed together, closely intermingled to eliminate magnetic leakage. Together the superposed imprints form an annulus of roughly triangular cross-section. Alternatively the winding may be wound of wire upon a former of V-section. The core is built from the printed strip 62 shown in Figure 17; it is a slightly tapering strip (the taper is exaggerated in the figure) on which are formed a large number of parallel closely spaced iron lines. This strip is of very thin insulating material. The middle of the strip is reinforced by a narrower tapered strip 63. The composite strip is wound around the winding 61 and as it is wound it is folded about the edges of the reinforcing strip, so that the ends of the iron lines come together in the middle of the core as seen in Figure 16. Its insulation breaks and crumples permitting the iron lines to overlap radially. The ends of the lines are brought into good magnetic contact and so held by the end cheeks 64 and the bolt 65.

The invention is by no means confined to the building of circuit components for radio receivers. The pattern of parallel lines described with reference to Figure 9 is a typical pattern

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for the production of electrical resistances, for example for all kinds of heaters. The pattern of parallel resistant conductors may be wanted upon some article or fabric to be heated on which it is not convenient to print. In that case the resistant pattern is produced by printing upon a temporary ground, for instance printing upon foil of resistant metal upon a backing of waxy paper, and is transferred to its permanent backing by a subsequent operation. The method of printing and etching and subsequent transfer, for example, might well be used to produce a resistant conductor upon cement or plaster of Paris.

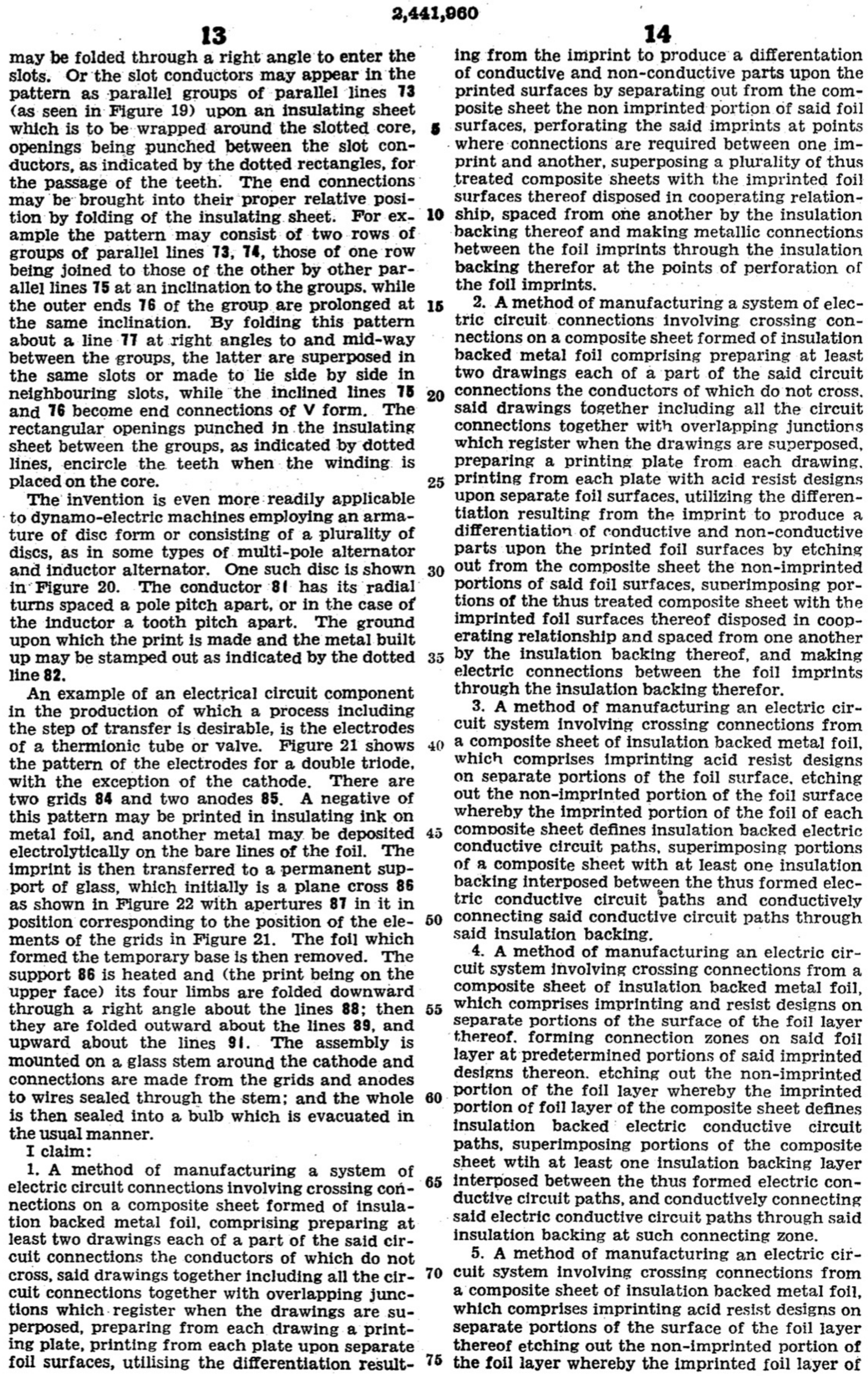
A resistant conductor such as indicated in Figure 9 may be formed upon wall-papers, wall and furniture panels, curtains, and other hangings, upholstery fabrics, floor coverings, clothing and bed-clothing, and the like for the purpose of making electric heaters or rather warmers of them. Such a conductor, though of small thickness, will carry a substantial current because its flat form promotes loss of heat by radiation and conduction. The conductor will be insulated and protected by a covering, for instance of a varnish or plastic on which powdered metal oxide may be dusted to increase radiation; in the case of aluminium the conductor is preferably covered by oxidation for the same reasons.

When used on ordinarily ornamental fabrics such as wall-papers the pattern of Figure 9 may be made to provide or contribute to the ornamentation by a double printing process. There is first produced a pattern of parallel lines of say, aluminium, copper, zinc, iron or nickel. Upon this any ornamental design 53 is printed in an insulating ink. The sheet is then made the cathode in an electrolytic bath by which copper is deposited on the metal lines except where covered by ink. The final product is, as before, a sheet with a pattern of parallel lines of which those parts within the design are of higher resistance than the remainder. Alternatively the over-printed sheet may be anodised to bring about reduction in the cross-section of the unprotected parts.

However, the second pattern may be superposed merely for its appearance without any thought of making the pattern rather than the non-patterned part the source of heat, or vice versa. In this case it may be desired to render the pattern of parallel lines inconspicuous to the eye, by suitable dyeing of the base, or of the oxide-coated or otherwise insulated conductor. For such overprinting a pattern of parallel lines of aluminium may be used with advantage, and the sheet subjected to an anodising process and dyeing process by which effects of some beauty may be produced. By the use of dyes which change colour at a temperature above atmospheric and below that which the conductor, or a part of it, reaches when carrying current, a visual indication may be given when the heat is on.

A class of printed patterns deserving mention is the patterns for winding the toothed cores of dynamo-electric machines. In one form shown in Figure 18 the pattern is mainly a star, in which each ray is a group of parallel conductors 71 representing the conductors of one slot; the inner and if desired the outer ends of the rays are prolonged at an angle to their length to form end connections preferably of the form of involutes of a circle; the insulating material between the groups of slot conductors is removed as indicated by the doubled lines, so that the slot conductors

Figure B.121: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.



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may be folded through a right angle to enter the slots. Or the slot conductors may appear in the pattern as parallel groups of parallel lines **73** (as seen in Figure 19) upon an insulating sheet which is to be wrapped around the slotted core, openings being punched between the slot conductors, as indicated by the dotted rectangles, for the passage of the teeth. The end connections may be brought into their proper relative position by folding of the insulating sheet. For example the pattern may consist of two rows of groups of parallel lines **73**, **74**, those of one row being joined to those of the other by other parallel lines **75** at an inclination to the groups, while the outer ends **76** of the group are prolonged at the same inclination. By folding this pattern about a line **77** at right angles to and mid-way between the groups, the latter are superposed in the same slots or made to lie side by side in neighbouring slots, while the inclined lines **75** and **76** become end connections of V form. The rectangular openings punched in the insulating sheet between the groups, as indicated by dotted lines, encircle the teeth when the winding is placed on the core.

The invention is even more readily applicable to dynamo-electric machines employing an armature of disc form or consisting of a plurality of discs, as in some types of multi-pole alternator and inductor alternator. One such disc is shown in Figure 20. The conductor **81** has its radial turns spaced a pole pitch apart, or in the case of the inductor a tooth pitch apart. The ground upon which the print is made and the metal built up may be stamped out as indicated by the dotted line **82**.

An example of an electrical circuit component in the production of which a process including the step of transfer is desirable, is the electrodes of a thermionic tube or valve. Figure 21 shows the pattern of the electrodes for a double triode, with the exception of the cathode. There are two grids **84** and two anodes **85**. A negative of this pattern may be printed in insulating ink on metal foil, and another metal may be deposited electrolytically on the bare lines of the foil. The imprint is then transferred to a permanent support of glass, which initially is a plane cross **86** as shown in Figure 22 with apertures **87** in it in position corresponding to the position of the elements of the grids in Figure 21. The foil which formed the temporary base is then removed. The support **86** is heated and (the print being on the upper face) its four limbs are folded downward through a right angle about the lines **88**; then they are folded outward about the lines **89**, and upward about the lines **91**. The assembly is mounted on a glass stem around the cathode and connections are made from the grids and anodes to wires sealed through the stem; and the whole is then sealed into a bulb which is evacuated in the usual manner.

I claim:

1. A method of manufacturing a system of electric circuit connections involving crossing connections on a composite sheet formed of insulation backed metal foil, comprising preparing at least two drawings each of a part of the said circuit connections the conductors of which do not cross, said drawings together including all the circuit connections together with overlapping junctions which register when the drawings are superposed, preparing from each drawing a printing plate, printing from each plate upon separate foil surfaces, utilising the differentiation resulting from the imprint to produce a differentation of conductive and non-conductive parts upon the printed surfaces by separating out from the composite sheet the non imprinted portion of said foil surfaces, perforating the said imprints at points where connections are required between one imprint and another, superposing a plurality of thus treated composite sheets with the imprinted foil surfaces thereof disposed in cooperating relationship, spaced from one another by the insulation backing thereof and making metallic connections between the foil imprints through the insulation backing therefor at the points of perforation of the foil imprints.

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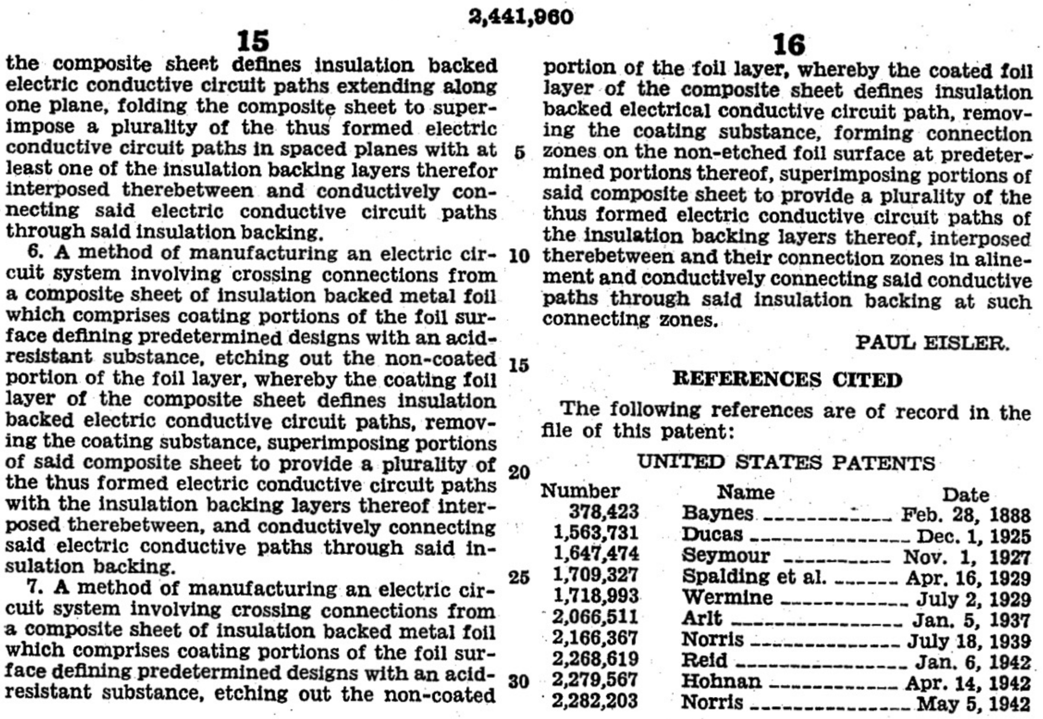
2. A method of manufacturing a system of electric circuit connections involving crossing connections on a composite sheet formed of insulation backed metal foil comprising preparing at least two drawings each of a part of the said circuit connections the conductors of which do not cross, said drawings together including all the circuit connections together with overlapping junctions which register when the drawings are superposed, preparing a printing plate from each drawing, printing from each plate with acid resist designs upon separate foil surfaces, utilizing the differentiation resulting from the imprint to produce a differentiation of conductive and non-conductive parts upon the printed foil surfaces by etching out from the composite sheet the non-imprinted portions of said foil surfaces, superimposing portions of the thus treated composite sheet with the imprinted foil surfaces thereof disposed in cooperating relationship and spaced from one another by the insulation backing thereof, and making electric connections between the foil imprints through the insulation backing therefor.

3. A method of manufacturing an electric circuit system involving crossing connections from a composite sheet of insulation backed metal foil, which comprises imprinting acid resist designs on separate portions of the foil surface, etching out the non-imprinted portion of the foil surface whereby the imprinted portion of the foil of each composite sheet defines insulation backed electric conductive circuit paths, superimposing portions of a composite sheet with at least one insulation backing interposed between the thus formed electric conductive circuit paths and conductively connecting said conductive circuit paths through said insulation backing.

4. A method of manufacturing an electric circuit system involving crossing connections from a composite sheet of insulation backed metal foil, which comprises imprinting and resist designs on separate portions of the surface of the foil layer thereof, forming connection zones on said foil layer at predetermined portions of said imprinted designs thereon, etching out the non-imprinted portion of the foil layer whereby the imprinted portion of foil layer of the composite sheet defines insulation backed electric conductive circuit paths, superimposing portions of the composite sheet wtih at least one insulation backing layer interposed between the thus formed electric conductive circuit paths, and conductively connecting said electric conductive circuit paths through said insulation backing at such connecting zone.

5. A method of manufacturing an electric circuit system involving crossing connections from a composite sheet of insulation backed metal foil, which comprises imprinting acid resist designs on separate portions of the surface of the foil layer thereof etching out the non-imprinted portion of the foil layer whereby the imprinted foil layer of

Figure B.122: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.



the composite sheet defines insulation backed electric conductive circuit paths extending along one plane, folding the composite sheet to superimpose a plurality of the thus formed electric conductive circuit paths in spaced planes with at least one of the insulation backing layers therefor interposed therebetween and conductively connecting said electric conductive circuit paths through said insulation backing.

6. A method of manufacturing an electric circuit system involving crossing connections from a composite sheet of insulation backed metal foil which comprises coating portions of the foil surface defining predetermined designs with an acid-resistant substance, etching out the non-coated portion of the foil layer, whereby the coating foil layer of the composite sheet defines insulation backed electric conductive circuit paths, removing the coating substance, superimposing portions of said composite sheet to provide a plurality of the thus formed electric conductive circuit paths with the insulation backing layers thereof interposed therebetween, and conductively connecting said electric conductive paths through said insulation backing.

7. A method of manufacturing an electric circuit system involving crossing connections from a composite sheet of insulation backed metal foil which comprises coating portions of the foil surface defining predetermined designs with an acid-resistant substance, etching out the non-coated portion of the foil layer, whereby the coated foil layer of the composite sheet defines insulation backed electrical conductive circuit path, removing the coating substance, forming connection zones on the non-etched foil surface at predetermined portions thereof, superimposing portions of said composite sheet to provide a plurality of the thus formed electric conductive circuit paths of the insulation backing layers thereof, interposed therebetween and their connection zones in alinement and conductively connecting said conductive paths through said insulation backing at such connecting zones.

PAUL EISLER.

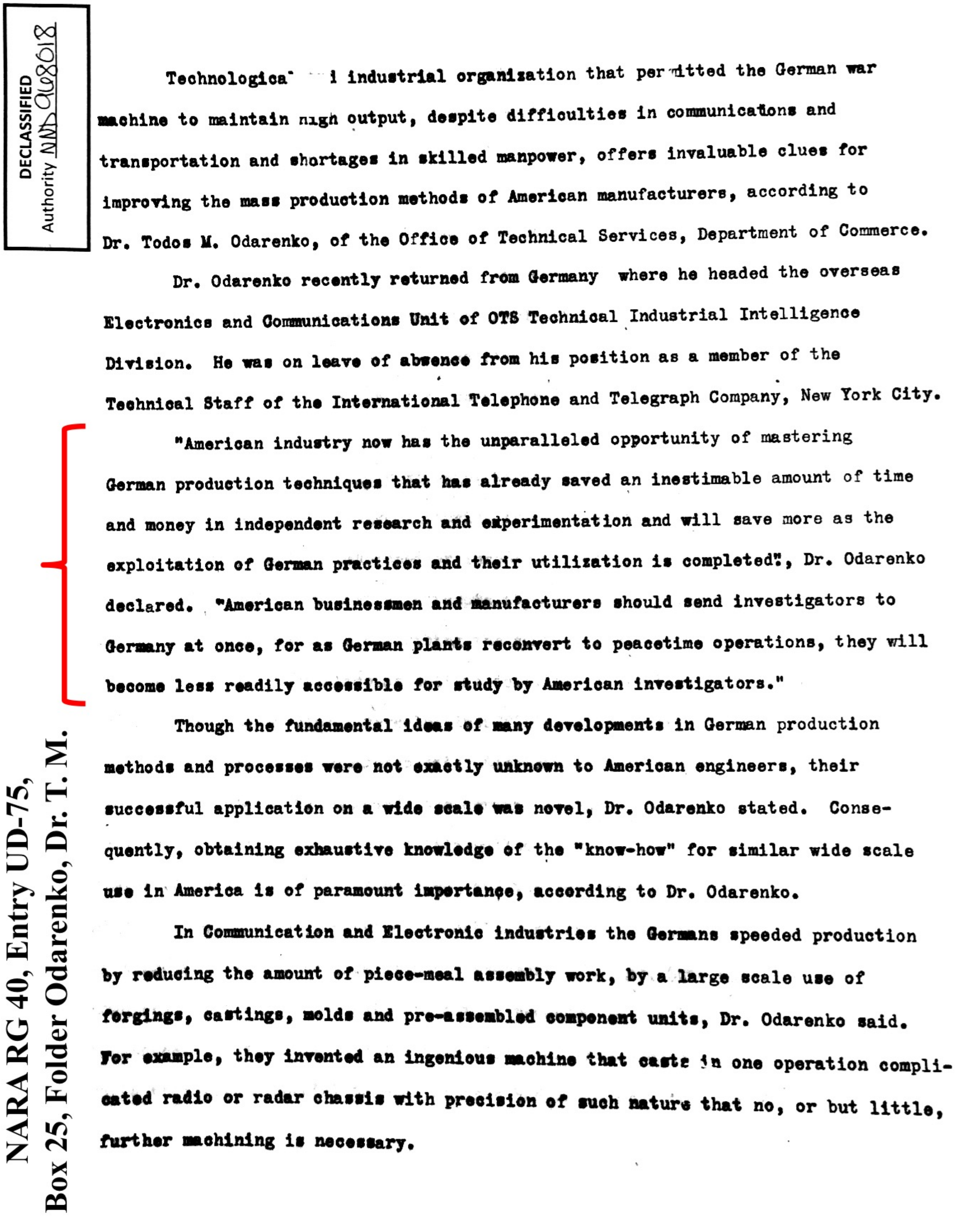
REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
378,423	Baynes	Feb. 28, 1888
1,563,731	Ducas	Dec. 1, 1925
1,647,474	Seymour	Nov. 1, 1927
1,709,327	Spalding et al.	Apr. 16, 1929
1,718,993	Wermine	July 2, 1929
2,066,511	Arlt	Jan. 5, 1937
2,166,367	Norris	July 18, 1939
2,268,619	Reid	Jan. 6, 1942
2,279,567	Hohnan	Apr. 14, 1942
2,282,203	Norris	May 5, 1942

Figure B.123: Paul Eisler produced printed circuits in 1936 and filed a detailed patent application in 1944.



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Technologica[illegible] industrial organization that permitted the German war machine to maintain high output, despite difficulties in communications and transportation and shortages in skilled manpower, offers invaluable clues for improving the mass production methods of American manufacturers, according to Dr. Todos M. Odarenko, of the Office of Technical Services, Department of Commerce.

Dr. Odarenko recently returned from Germany where he headed the overseas Electronics and Communications Unit of OTS Technical Industrial Intelligence Division. He was on leave of absence from his position as a member of the Technical Staff of the International Telephone and Telegraph Company, New York City.

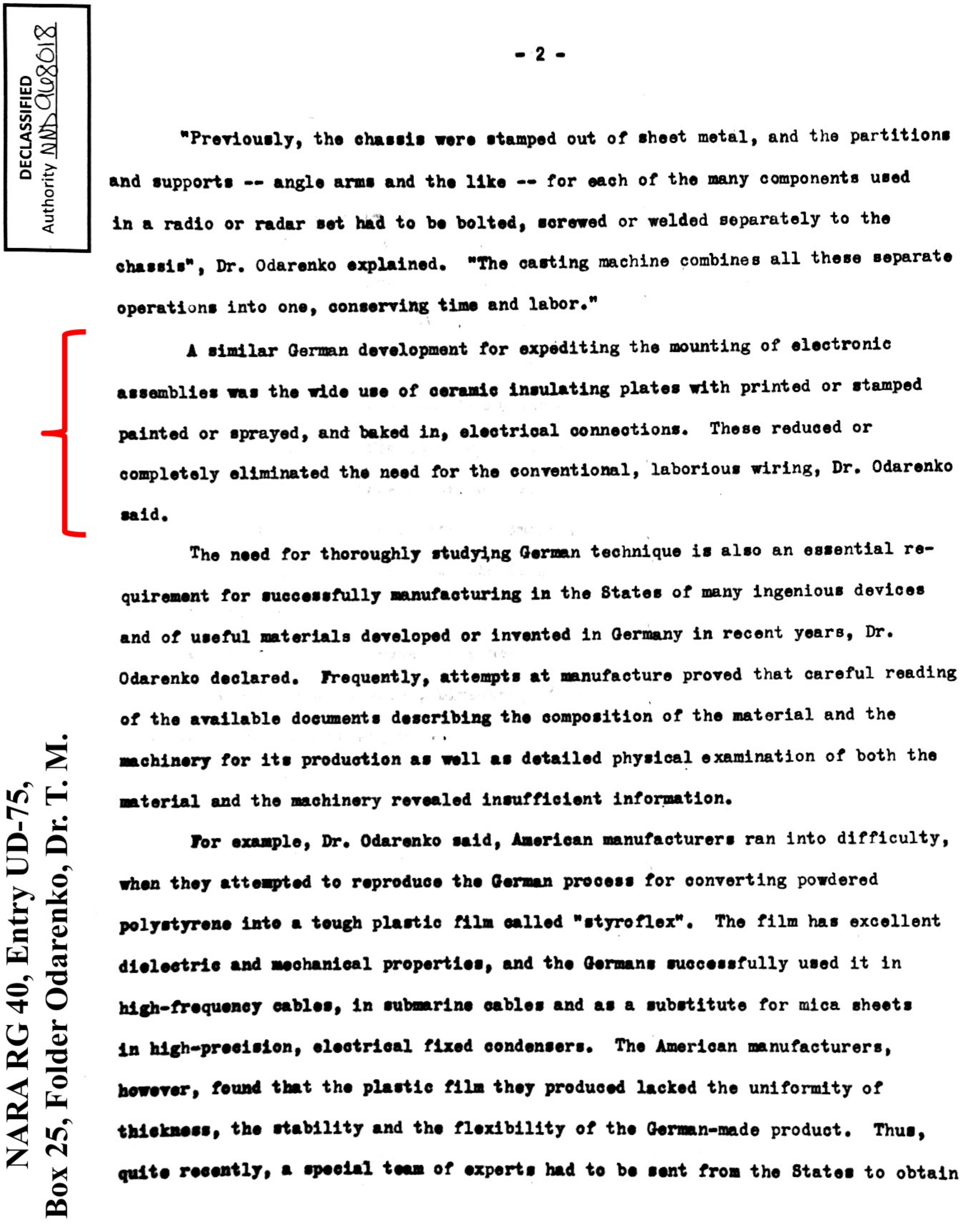
"American industry now has the unparalleled opportunity of mastering German production techniques that has already saved an inestimable amount of time and money in independent research and experimentation and will save more as the exploitation of German practices and their utilization is completed", Dr. Odarenko declared. "American businessmen and manufacturers should send investigators to Germany at once, for as German plants reconvert to peacetime operations, they will become less readily accessible for study by American investigators."

Though the fundamental ideas of many developments in German production methods and processes were not exactly unknown to American engineers, their successful application on a wide scale was novel, Dr. Odarenko stated. Consequently, obtaining exhaustive knowledge of the "know-how" for similar wide scale use in America is of paramount importance, according to Dr. Odarenko.

In Communication and Electronic industries the Germans speeded production by reducing the amount of piece-meal assembly work, by a large scale use of forgings, castings, molds and pre-assembled component units, Dr. Odarenko said. For example, they invented an ingenious machine that casts in one operation complicated radio or radar chassis with precision of such nature that no, or but little, further machining is necessary.

NARA RG 40, Entry UD-75,
Box 25, Folder Odarenko, Dr. T. M.

Figure B.124: Printed circuits were in "wide use" in wartime Germany and the technology was transferred to the United States after the war by people such as longtime Bell Telephone Laboratories engineer Todos Odarenko [NARA RG 40, Entry UD-75, Box 25, Folder Odarenko, Dr. T. M., undated press release (probably late 1946)].



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"Previously, the chassis were stamped out of sheet metal, and the partitions and supports -- angle arms and the like -- for each of the many components used in a radio or radar set had to be bolted, screwed or welded separately to the chassis", Dr. Odarenko explained. "The casting machine combines all these separate operations into one, conserving time and labor."

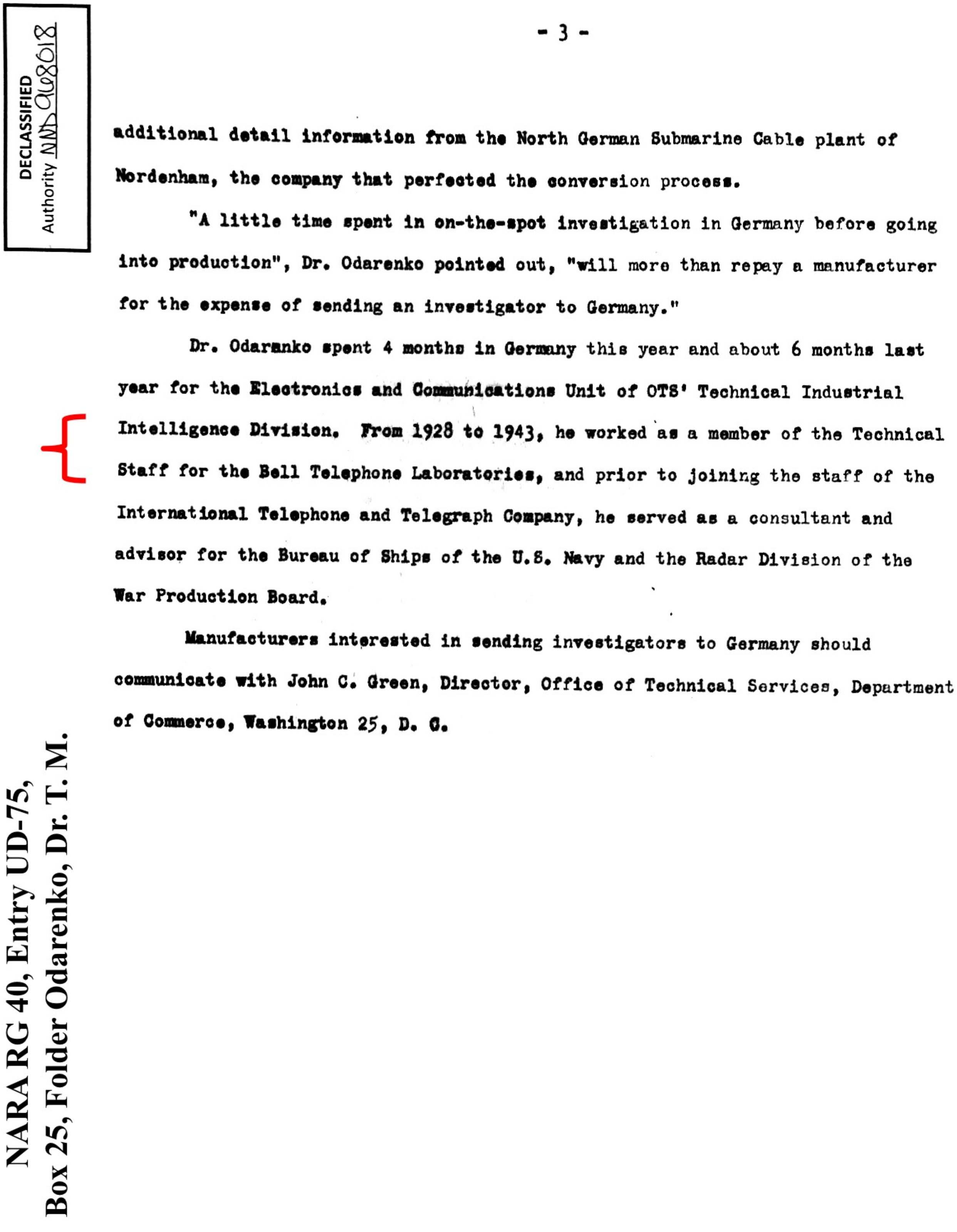
A similar German development for expediting the mounting of electronic assemblies was the wide use of ceramic insulating plates with printed or stamped painted or sprayed, and baked in, electrical connections. These reduced or completely eliminated the need for the conventional, laborious wiring, Dr. Odarenko said.

The need for thoroughly studying German technique is also an essential requirement for successfully manufacturing in the States of many ingenious devices and of useful materials developed or invented in Germany in recent years, Dr. Odarenko declared. Frequently, attempts at manufacture proved that careful reading of the available documents describing the composition of the material and the machinery for its production as well as detailed physical examination of both the material and the machinery revealed insufficient information.

For example, Dr. Odarenko said, American manufacturers ran into difficulty, when they attempted to reproduce the German process for converting powdered polystyrene into a tough plastic film called "styroflex". The film has excellent dielectric and mechanical properties, and the Germans successfully used it in high-frequency cables, in submarine cables and as a substitute for mica sheets in high-precision, electrical fixed condensers. The American manufacturers, however, found that the plastic film they produced lacked the uniformity of thickness, the stability and the flexibility of the German-made product. Thus, quite recently, a special team of experts had to be sent from the States to obtain

NARA RG 40, Entry UD-75,
Box 25, Folder Odarenko, Dr. T. M.

Figure B.125: Printed circuits were in "wide use" in wartime Germany and the technology was transferred to the United States after the war by people such as longtime Bell Telephone Laboratories engineer Todos Odarenko [NARA RG 40, Entry UD-75, Box 25, Folder Odarenko, Dr. T. M., undated press release (probably late 1946)].



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additional detail information from the North German Submarine Cable plant of Nordenham, the company that perfected the conversion process.

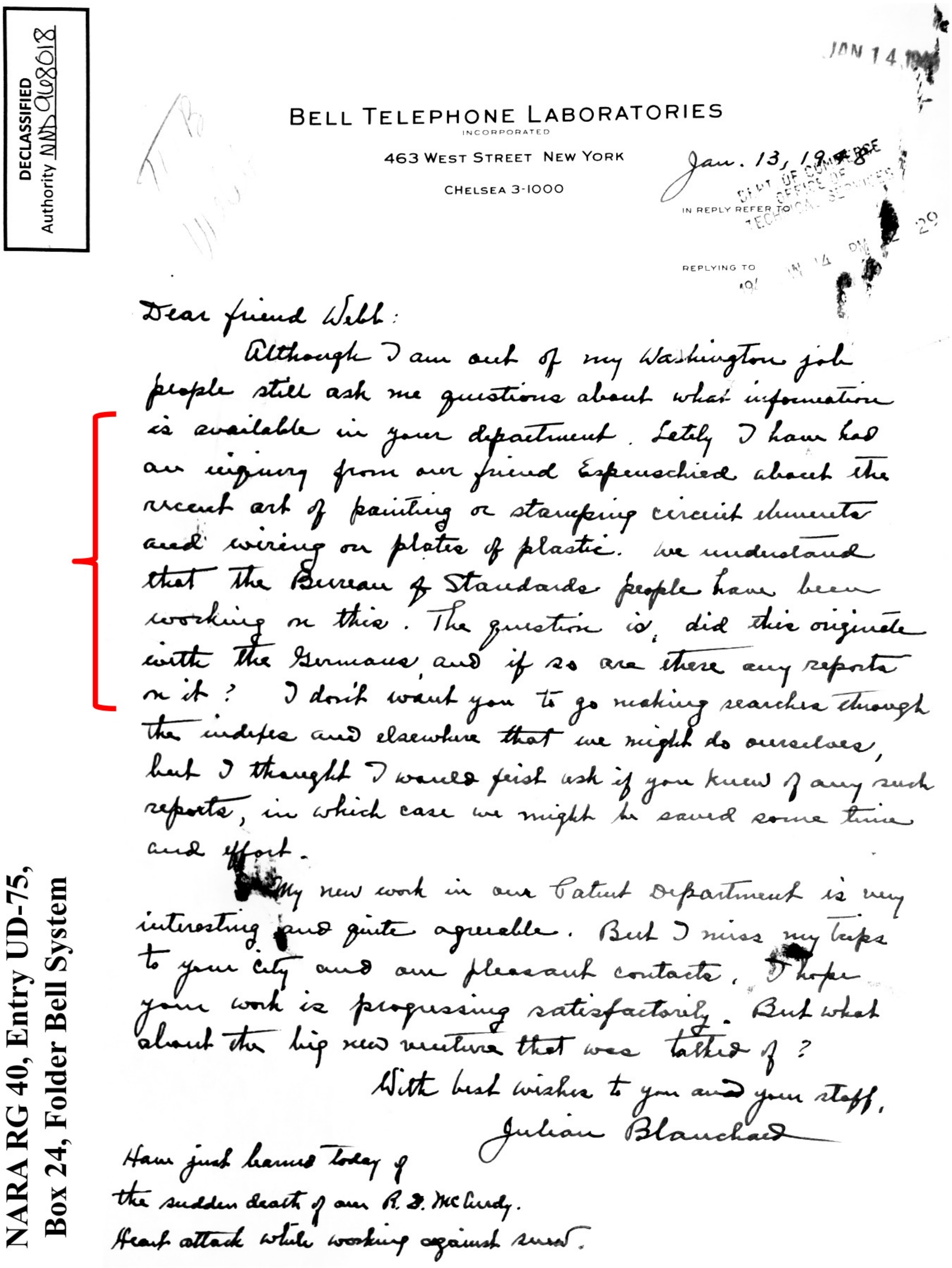
"A little time spent in on-the-spot investigation in Germany before going into production", Dr. Odarenko pointed out, "will more than repay a manufacturer for the expense of sending an investigator to Germany."

Dr. Odaranko spent 4 months in Germany this year and about 6 months last year for the Electronics and Communications Unit of OTS' Technical Industrial Intelligence Division. From 1928 to 1943, he worked as a member of the Technical Staff for the Bell Telephone Laboratories, and prior to joining the staff of the International Telephone and Telegraph Company, he served as a consultant and advisor for the Bureau of Ships of the U.S. Navy and the Radar Division of the War Production Board.

Manufacturers interested in sending investigators to Germany should communicate with John C. Green, Director, Office of Technical Services, Department of Commerce, Washington 25, D. C.

NARA RG 40, Entry UD-75,
Box 25, Folder Odarenko, Dr. T. M.

Figure B.126: Printed circuits were in "wide use" in wartime Germany and the technology was transferred to the United States after the war by people such as longtime Bell Telephone Laboratories engineer Todos Odarenko [NARA RG 40, Entry UD-75, Box 25, Folder Odarenko, Dr. T. M., undated press release (probably late 1946)].



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Jan. 13, 1948

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REPLYING TO
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Dear friend Webb:

Although I am out of my Washington job people still ask me questions about what information is available in your department. Lately I have had an inquiry from our friend Espenschied about the recent art of painting or stamping circuit elements and wiring on plates of plastic. We understand that the Bureau of Standards people have been working on this. The question is, did this originate with the Germans, and if so are there any reports on it? I don't want you to go making searches through the indexes and elsewhere that we might do ourselves, but I thought I would first ask if you knew of any such reports, in which case we might be saved some time and effort.

My new work in our Patent Department is very interesting and quite agreeable. But I miss my trips to your city and our pleasant contacts. I hope your work is progressing satisfactorily. But what about the big new venture that was talked of?

With best wishes to you and your staff,

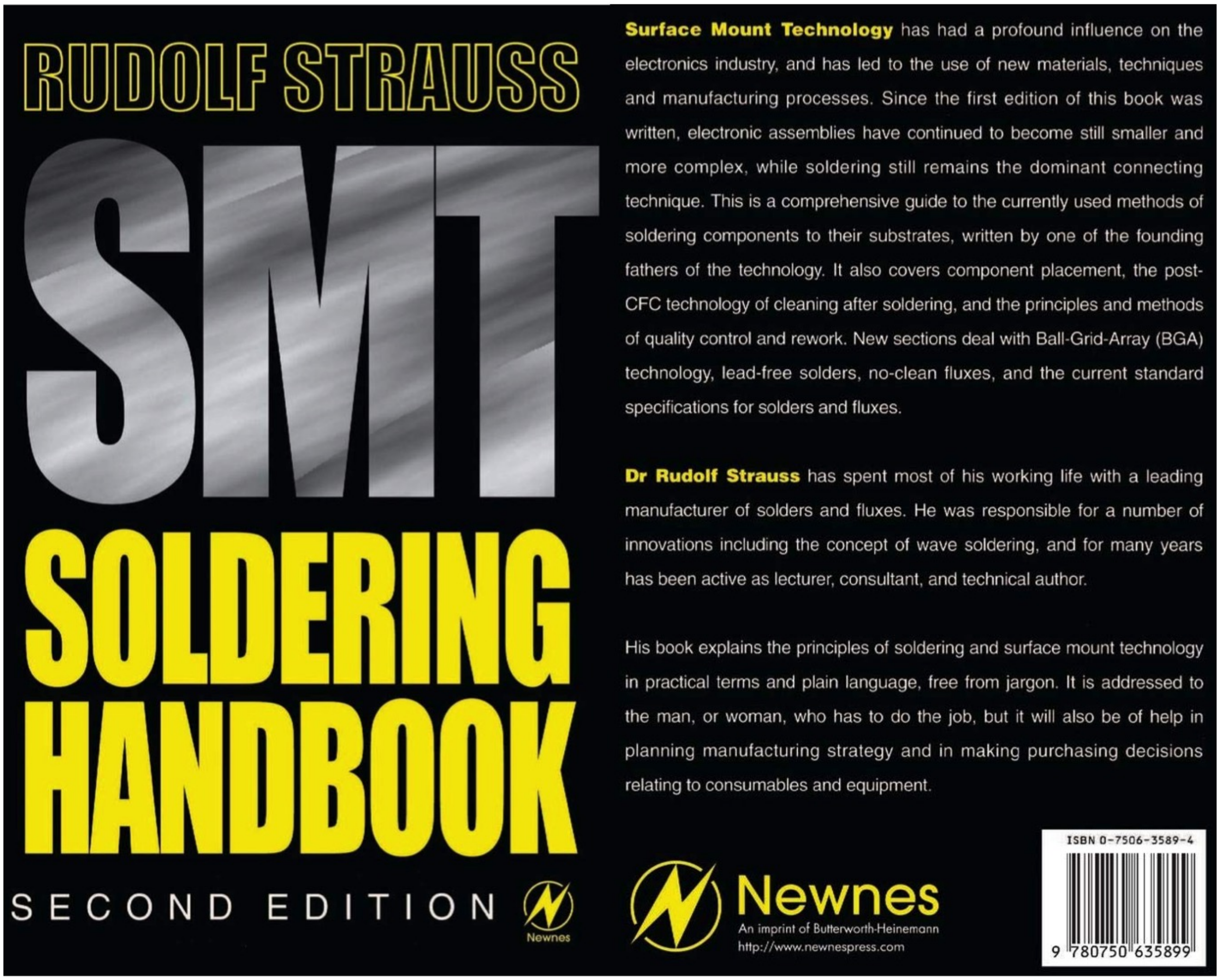
Julian Blanchard

Have just learned today of
the sudden death of our R. D. McCurdy.
Heart attack while working against snow.

NARA RG 40, Entry UD-75,
Box 24, Folder Bell System

Figure B.127: Printed circuit technology was transferred from Germany to U.S. companies such as Bell Telephone Laboratories after the war [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Rudolf Strauss (1913–2001) invented wave soldering for printed circuits, or surface mount technology (1951–1955)



RUDOLF STRAUSS

SMT SOLDERING HANDBOOK

SECOND EDITION

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Surface Mount Technology has had a profound influence on the electronics industry, and has led to the use of new materials, techniques and manufacturing processes. Since the first edition of this book was written, electronic assemblies have continued to become still smaller and more complex, while soldering still remains the dominant connecting technique. This is a comprehensive guide to the currently used methods of soldering components to their substrates, written by one of the founding fathers of the technology. It also covers component placement, the post-CFC technology of cleaning after soldering, and the principles and methods of quality control and rework. New sections deal with Ball-Grid-Array (BGA) technology, lead-free solders, no-clean fluxes, and the current standard specifications for solders and fluxes.

Dr Rudolf Strauss has spent most of his working life with a leading manufacturer of solders and fluxes. He was responsible for a number of innovations including the concept of wave soldering, and for many years has been active as lecturer, consultant, and technical author.

His book explains the principles of soldering and surface mount technology in practical terms and plain language, free from jargon. It is addressed to the man, or woman, who has to do the job, but it will also be of help in planning manufacturing strategy and in making purchasing decisions relating to consumables and equipment.

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Figure B.128: Rudolf Strauss invented wave soldering for printed circuits, or surface mount technology.

Oct. 2, 1962 **A. F. C. BARNES ETAL** **3,056,370**

APPARATUS FOR SOLDERING

Filed Oct. 9, 1956 2 Sheets-Sheet 1

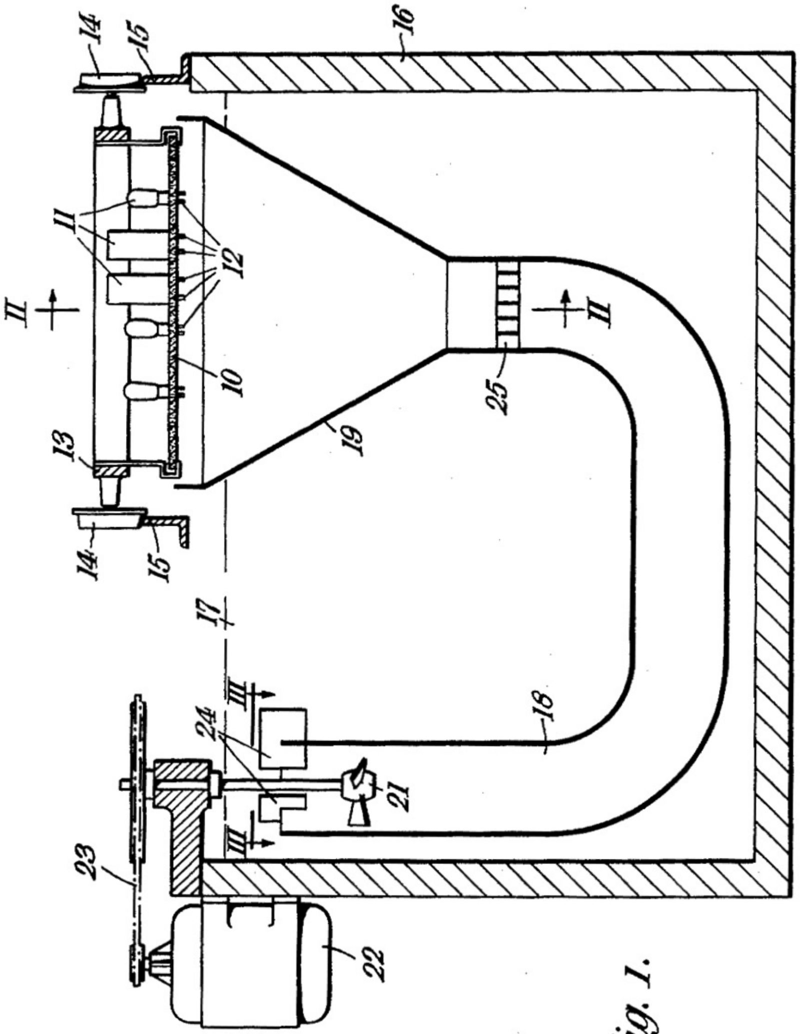
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Fig. 1.

INVENTORS

ALLAN F.C. BARNES
VICTOR B. ELLIOTT
RUDOLF S. STRAUSS

By
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ATTORNEYS

Figure B.129: Rudolf Strauss invented wave soldering for printed circuits, or surface mount technology.

Oct. 2, 1962 A. F. C. BARNES ETAL **3,056,370**

APPARATUS FOR SOLDERING

Filed Oct. 9, 1956 2 Sheets-Sheet 2

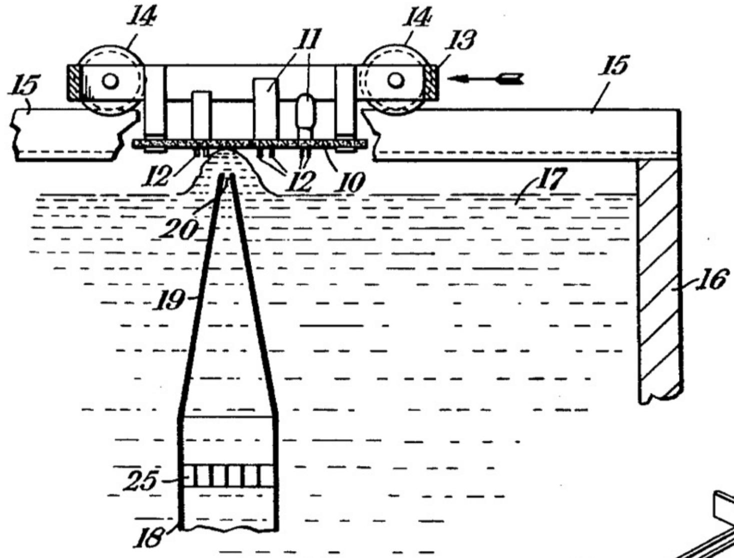
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Fig. 2.

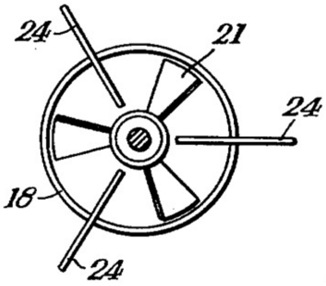
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Fig. 3.

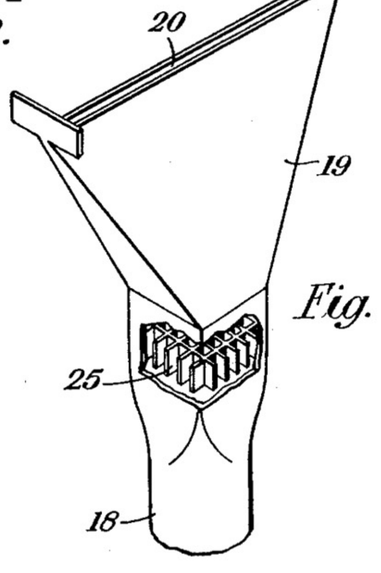

Fig. 4.

INVENTORS

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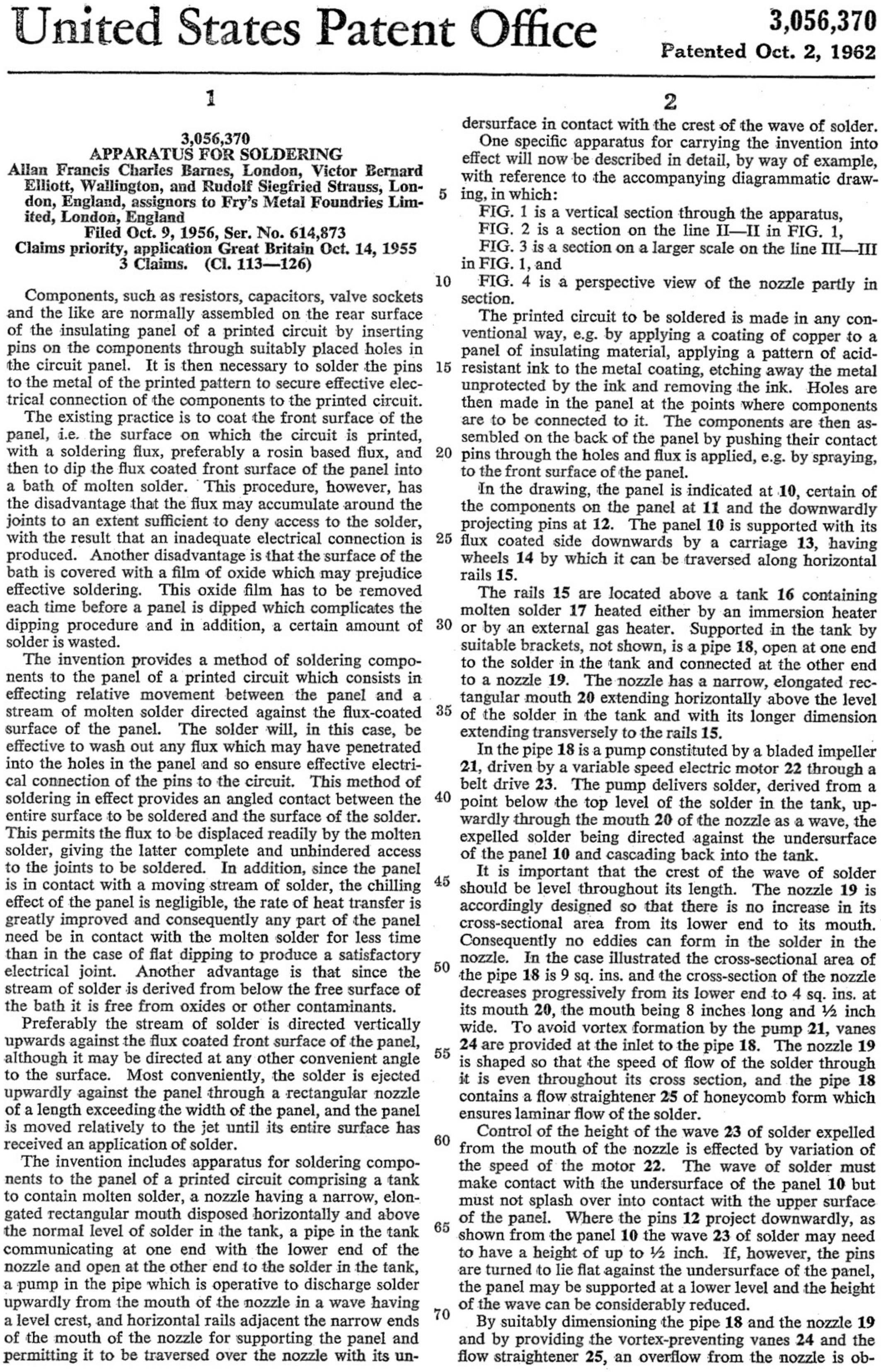
Figure B.130: Rudolf Strauss invented wave soldering for printed circuits, or surface mount technology.



United States Patent Office

3,056,370
Patented Oct. 2, 1962

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3,056,370

APPARATUS FOR SOLDERING

Allan Francis Charles Barnes, London, Victor Bernard Elliott, Wallington, and Rudolf Siegfried Strauss, London, England, assignors to Fry's Metal Foundries Limited, London, England
Filed Oct. 9, 1956, Ser. No. 614,873
Claims priority, application Great Britain Oct. 14, 1955
3 Claims. (Cl. 113—126)

Components, such as resistors, capacitors, valve sockets and the like are normally assembled on the rear surface of the insulating panel of a printed circuit by inserting pins on the components through suitably placed holes in the circuit panel. It is then necessary to solder the pins to the metal of the printed pattern to secure effective electrical connection of the components to the printed circuit.

The existing practice is to coat the front surface of the panel, i.e. the surface on which the circuit is printed, with a soldering flux, preferably a rosin based flux, and then to dip the flux coated front surface of the panel into a bath of molten solder. This procedure, however, has the disadvantage that the flux may accumulate around the joints to an extent sufficient to deny access to the solder, with the result that an inadequate electrical connection is produced. Another disadvantage is that the surface of the bath is covered with a film of oxide which may prejudice effective soldering. This oxide film has to be removed each time before a panel is dipped which complicates the dipping procedure and in addition, a certain amount of solder is wasted.

The invention provides a method of soldering components to the panel of a printed circuit which consists in effecting relative movement between the panel and a stream of molten solder directed against the flux-coated surface of the panel. The solder will, in this case, be effective to wash out any flux which may have penetrated into the holes in the panel and so ensure effective electrical connection of the pins to the circuit. This method of soldering in effect provides an angled contact between the entire surface to be soldered and the surface of the solder. This permits the flux to be displaced readily by the molten solder, giving the latter complete and unhindered access to the joints to be soldered. In addition, since the panel is in contact with a moving stream of solder, the chilling effect of the panel is negligible, the rate of heat transfer is greatly improved and consequently any part of the panel need be in contact with the molten solder for less time than in the case of flat dipping to produce a satisfactory electrical joint. Another advantage is that since the stream of solder is derived from below the free surface of the bath it is free from oxides or other contaminants.

Preferably the stream of solder is directed vertically upwards against the flux coated front surface of the panel, although it may be directed at any other convenient angle to the surface. Most conveniently, the solder is ejected upwardly against the panel through a rectangular nozzle of a length exceeding the width of the panel, and the panel is moved relatively to the jet until its entire surface has received an application of solder.

The invention includes apparatus for soldering components to the panel of a printed circuit comprising a tank to contain molten solder, a nozzle having a narrow, elongated rectangular mouth disposed horizontally and above the normal level of solder in the tank, a pipe in the tank communicating at one end with the lower end of the nozzle and open at the other end to the solder in the tank, a pump in the pipe which is operative to discharge solder upwardly from the mouth of the nozzle in a wave having a level crest, and horizontal rails adjacent the narrow ends of the mouth of the nozzle for supporting the panel and permitting it to be traversed over the nozzle with its undersurface in contact with the crest of the wave of solder.

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One specific apparatus for carrying the invention into effect will now be described in detail, by way of example, with reference to the accompanying diagrammatic drawing, in which:

FIG. 1 is a vertical section through the apparatus,

FIG. 2 is a section on the line II—II in FIG. 1,

FIG. 3 is a section on a larger scale on the line III—III in FIG. 1, and

FIG. 4 is a perspective view of the nozzle partly in section.

The printed circuit to be soldered is made in any conventional way, e.g. by applying a coating of copper to a panel of insulating material, applying a pattern of acid-resistant ink to the metal coating, etching away the metal unprotected by the ink and removing the ink. Holes are then made in the panel at the points where components are to be connected to it. The components are then assembled on the back of the panel by pushing their contact pins through the holes and flux is applied, e.g. by spraying, to the front surface of the panel.

In the drawing, the panel is indicated at **10**, certain of the components on the panel at **11** and the downwardly projecting pins at **12**. The panel **10** is supported with its flux coated side downwards by a carriage **13**, having wheels **14** by which it can be traversed along horizontal rails **15**.

The rails **15** are located above a tank **16** containing molten solder **17** heated either by an immersion heater or by an external gas heater. Supported in the tank by suitable brackets, not shown, is a pipe **18**, open at one end to the solder in the tank and connected at the other end to a nozzle **19**. The nozzle has a narrow, elongated rectangular mouth **20** extending horizontally above the level of the solder in the tank and with its longer dimension extending transversely to the rails **15**.

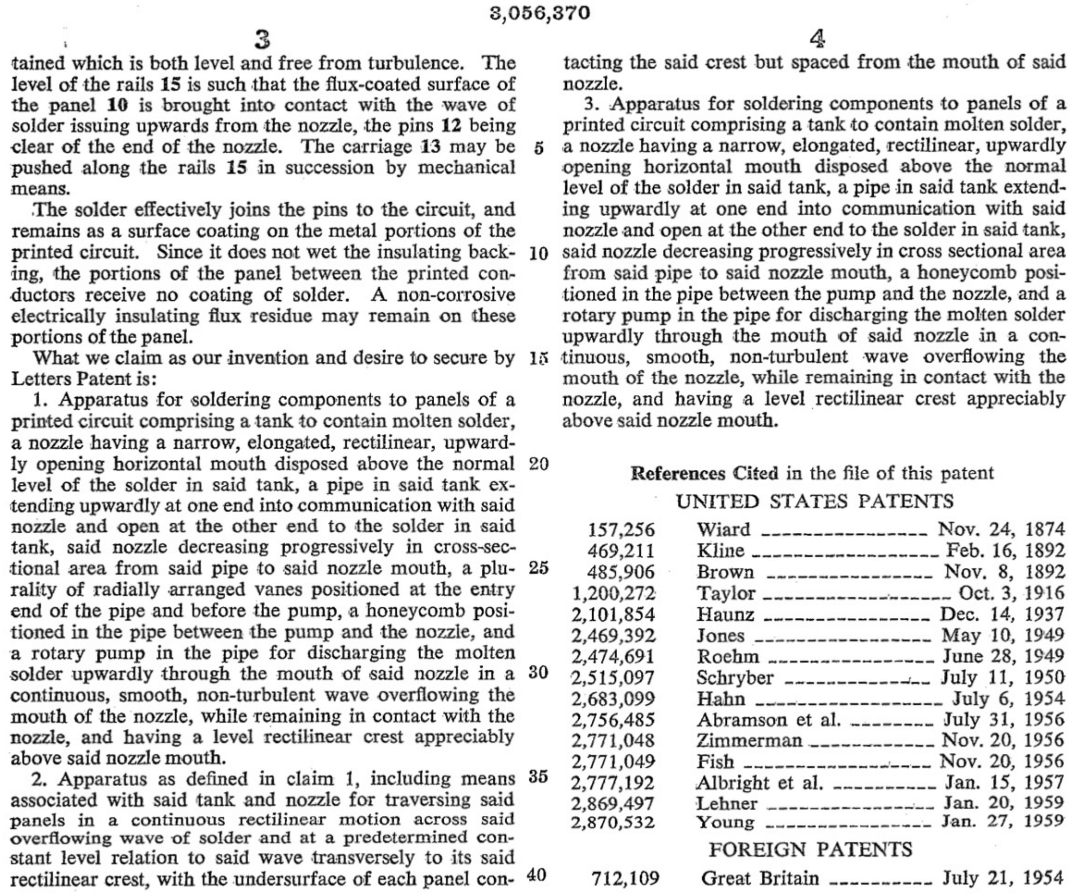
In the pipe **18** is a pump constituted by a bladed impeller **21**, driven by a variable speed electric motor **22** through a belt drive **23**. The pump delivers solder, derived from a point below the top level of the solder in the tank, upwardly through the mouth **20** of the nozzle as a wave, the expelled solder being directed against the undersurface of the panel **10** and cascading back into the tank.

It is important that the crest of the wave of solder should be level throughout its length. The nozzle **19** is accordingly designed so that there is no increase in its cross-sectional area from its lower end to its mouth. Consequently no eddies can form in the solder in the nozzle. In the case illustrated the cross-sectional area of the pipe **18** is 9 sq. ins. and the cross-section of the nozzle decreases progressively from its lower end to 4 sq. ins. at its mouth **20**, the mouth being 8 inches long and ½ inch wide. To avoid vortex formation by the pump **21**, vanes **24** are provided at the inlet to the pipe **18**. The nozzle **19** is shaped so that the speed of flow of the solder through it is even throughout its cross section, and the pipe **18** contains a flow straightener **25** of honeycomb form which ensures laminar flow of the solder.

Control of the height of the wave **23** of solder expelled from the mouth of the nozzle is effected by variation of the speed of the motor **22**. The wave of solder must make contact with the undersurface of the panel **10** but must not splash over into contact with the upper surface of the panel. Where the pins **12** project downwardly, as shown from the panel **10** the wave **23** of solder may need to have a height of up to ½ inch. If, however, the pins are turned to lie flat against the undersurface of the panel, the panel may be supported at a lower level and the height of the wave can be considerably reduced.

By suitably dimensioning the pipe **18** and the nozzle **19** and by providing the vortex-preventing vanes **24** and the flow straightener **25**, an overflow from the nozzle is ob-

Figure B.131: Rudolf Strauss invented wave soldering for printed circuits, or surface mount technology.



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tained which is both level and free from turbulence. The level of the rails **15** is such that the flux-coated surface of the panel **10** is brought into contact with the wave of solder issuing upwards from the nozzle, the pins **12** being clear of the end of the nozzle. The carriage **13** may be pushed along the rails **15** in succession by mechanical means.

The solder effectively joins the pins to the circuit, and remains as a surface coating on the metal portions of the printed circuit. Since it does not wet the insulating backing, the portions of the panel between the printed conductors receive no coating of solder. A non-corrosive electrically insulating flux residue may remain on these portions of the panel.

What we claim as our invention and desire to secure by Letters Patent is:

1. Apparatus for soldering components to panels of a printed circuit comprising a tank to contain molten solder, a nozzle having a narrow, elongated, rectilinear, upwardly opening horizontal mouth disposed above the normal level of the solder in said tank, a pipe in said tank extending upwardly at one end into communication with said nozzle and open at the other end to the solder in said tank, said nozzle decreasing progressively in cross-sectional area from said pipe to said nozzle mouth, a plurality of radially arranged vanes positioned at the entry end of the pipe and before the pump, a honeycomb positioned in the pipe between the pump and the nozzle, and a rotary pump in the pipe for discharging the molten solder upwardly through the mouth of said nozzle in a continuous, smooth, non-turbulent wave overflowing the mouth of the nozzle, while remaining in contact with the nozzle, and having a level rectilinear crest appreciably above said nozzle mouth.

2. Apparatus as defined in claim 1, including means associated with said tank and nozzle for traversing said panels in a continuous rectilinear motion across said overflowing wave of solder and at a predetermined constant level relation to said wave transversely to its said rectilinear crest, with the undersurface of each panel contacting the said crest but spaced from the mouth of said nozzle.

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3. Apparatus for soldering components to panels of a printed circuit comprising a tank to contain molten solder, a nozzle having a narrow, elongated, rectilinear, upwardly opening horizontal mouth disposed above the normal level of the solder in said tank, a pipe in said tank extending upwardly at one end into communication with said nozzle and open at the other end to the solder in said tank, said nozzle decreasing progressively in cross sectional area from said pipe to said nozzle mouth, a honeycomb positioned in the pipe between the pump and the nozzle, and a rotary pump in the pipe for discharging the molten solder upwardly through the mouth of said nozzle in a continuous, smooth, non-turbulent wave overflowing the mouth of the nozzle, while remaining in contact with the nozzle, and having a level rectilinear crest appreciably above said nozzle mouth.

References Cited in the file of this patent

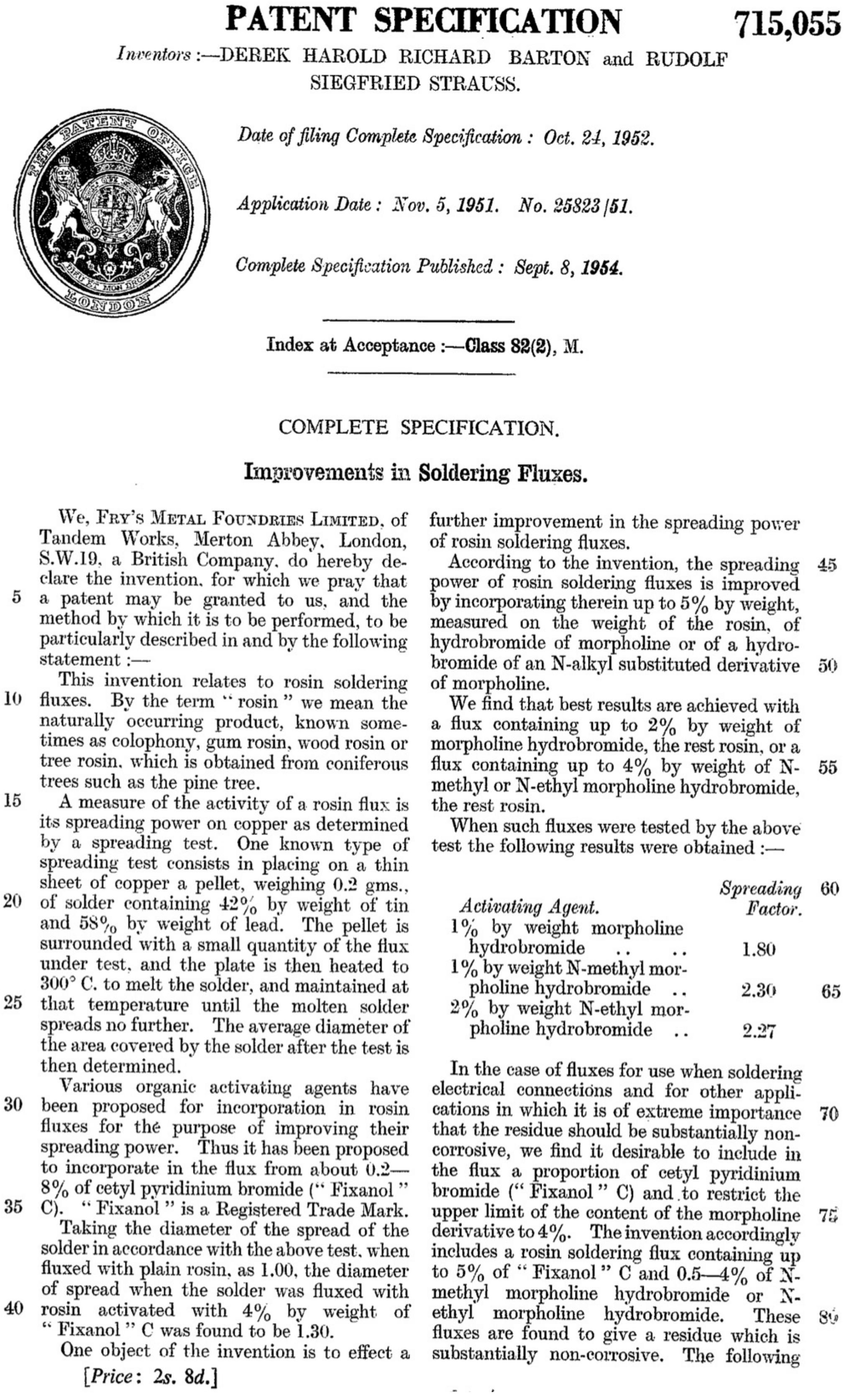
UNITED STATES PATENTS

157,256	Wiard	Nov. 24, 1874
469,211	Kline	Feb. 16, 1892
485,906	Brown	Nov. 8, 1892
1,200,272	Taylor	Oct. 3, 1916
2,101,854	Haunz	Dec. 14, 1937
2,469,392	Jones	May 10, 1949
2,474,691	Roehm	June 28, 1949
2,515,097	Schryber	July 11, 1950
2,683,099	Hahn	July 6, 1954
2,756,485	Abramson et al.	July 31, 1956
2,771,048	Zimmerman	Nov. 20, 1956
2,771,049	Fish	Nov. 20, 1956
2,777,192	Albright et al.	Jan. 15, 1957
2,869,497	Lehner	Jan. 20, 1959
2,870,532	Young	Jan. 27, 1959

FOREIGN PATENTS

712,109	Great Britain	July 21, 1954

Figure B.132: Rudolf Strauss invented wave soldering for printed circuits, or surface mount technology.



PATENT SPECIFICATION 715,055

Inventors :—DEREK HAROLD RICHARD BARTON and RUDOLF SIEGFRIED STRAUSS.

THE PATENT OFFICE LONDON

Date of filing Complete Specification : *Oct. 24, 1952.*

Application Date : *Nov. 5, 1951.* *No. 25823/51.*

Complete Specification Published : *Sept. 8, 1954.*

Index at Acceptance :—**Class 82(2)**, M.

COMPLETE SPECIFICATION.

Improvements in Soldering Fluxes.

We, FRY'S METAL FOUNDRIES LIMITED, of Tandem Works, Merton Abbey, London, S.W.19, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement :—

This invention relates to rosin soldering fluxes. By the term " rosin " we mean the naturally occurring product, known sometimes as colophony, gum rosin, wood rosin or tree rosin, which is obtained from coniferous trees such as the pine tree.

A measure of the activity of a rosin flux is its spreading power on copper as determined by a spreading test. One known type of spreading test consists in placing on a thin sheet of copper a pellet, weighing 0.2 gms., of solder containing 42% by weight of tin and 58% by weight of lead. The pellet is surrounded with a small quantity of the flux under test, and the plate is then heated to 300° C. to melt the solder, and maintained at that temperature until the molten solder spreads no further. The average diameter of the area covered by the solder after the test is then determined.

Various organic activating agents have been proposed for incorporation in rosin fluxes for the purpose of improving their spreading power. Thus it has been proposed to incorporate in the flux from about 0.2—8% of cetyl pyridinium bromide (" Fixanol " C). " Fixanol " is a Registered Trade Mark.

Taking the diameter of the spread of the solder in accordance with the above test, when fluxed with plain rosin, as 1.00, the diameter of spread when the solder was fluxed with rosin activated with 4% by weight of " Fixanol " C was found to be 1.30.

One object of the invention is to effect a further improvement in the spreading power of rosin soldering fluxes.

According to the invention, the spreading power of rosin soldering fluxes is improved by incorporating therein up to 5% by weight, measured on the weight of the rosin, of hydrobromide of morpholine or of a hydrobromide of an N-alkyl substituted derivative of morpholine.

We find that best results are achieved with a flux containing up to 2% by weight of morpholine hydrobromide, the rest rosin, or a flux containing up to 4% by weight of N-methyl or N-ethyl morpholine hydrobromide, the rest rosin.

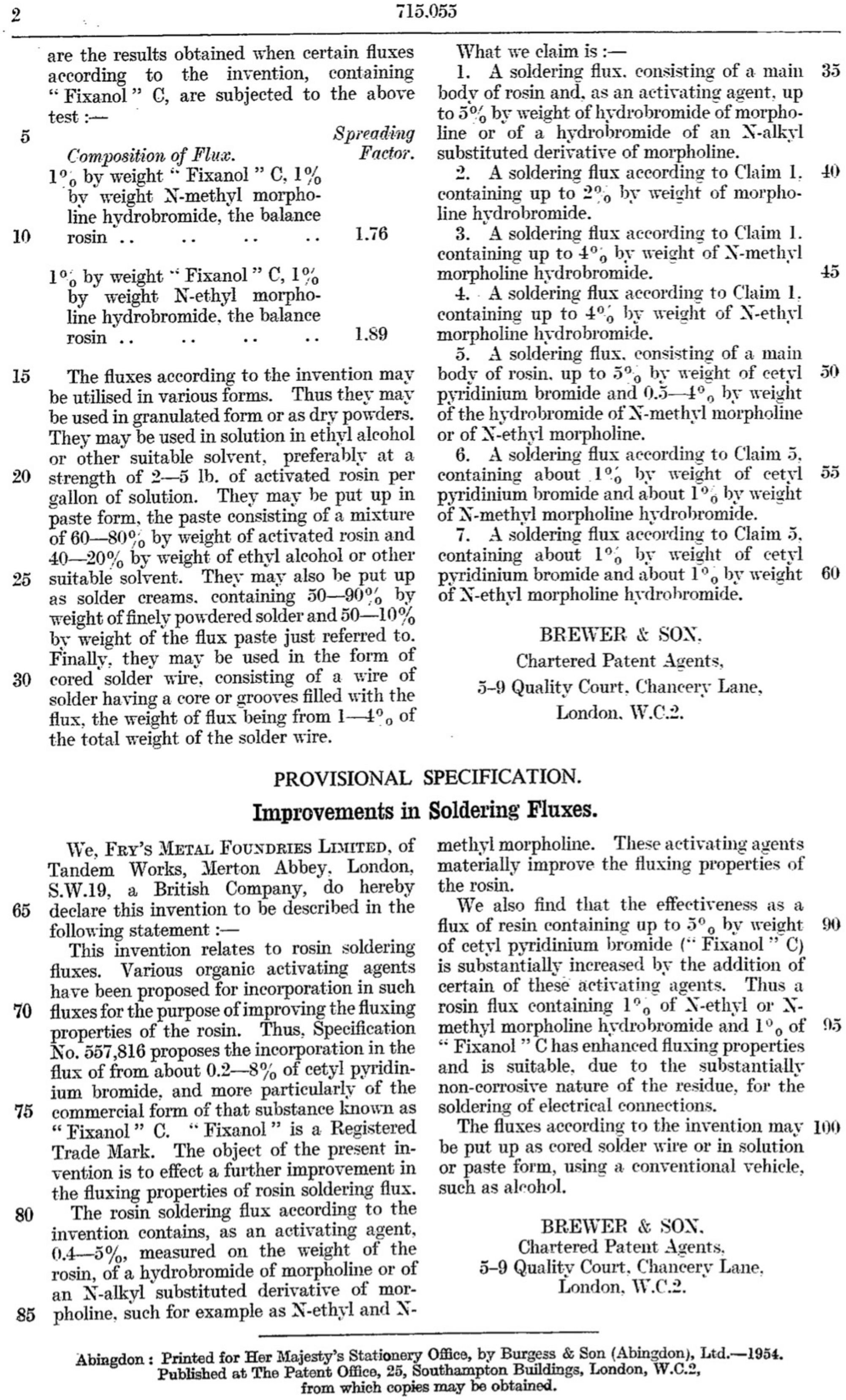
When such fluxes were tested by the above test the following results were obtained :—

Activating Agent.	*Spreading Factor.*
1% by weight morpholine hydrobromide	1.80
1% by weight N-methyl morpholine hydrobromide . .	2.30
2% by weight N-ethyl morpholine hydrobromide . .	2.27

In the case of fluxes for use when soldering electrical connections and for other applications in which it is of extreme importance that the residue should be substantially non-corrosive, we find it desirable to include in the flux a proportion of cetyl pyridinium bromide (" Fixanol " C) and to restrict the upper limit of the content of the morpholine derivative to 4%. The invention accordingly includes a rosin soldering flux containing up to 5% of " Fixanol " C and 0.5—4% of N-methyl morpholine hydrobromide or N-ethyl morpholine hydrobromide. These fluxes are found to give a residue which is substantially non-corrosive. The following

[*Price* : 2*s*. 8*d*.]

Figure B.133: Rudolf Strauss invented wave soldering for printed circuits, or surface mount technology.



are the results obtained when certain fluxes according to the invention, containing "Fixanol" C, are subjected to the above test:—

Composition of Flux.	*Spreading Factor.*
1% by weight "Fixanol" C, 1% by weight N-methyl morpholine hydrobromide, the balance rosin	1.76
1% by weight "Fixanol" C, 1% by weight N-ethyl morpholine hydrobromide, the balance rosin	1.89

The fluxes according to the invention may be utilised in various forms. Thus they may be used in granulated form or as dry powders. They may be used in solution in ethyl alcohol or other suitable solvent, preferably at a strength of 2—5 lb. of activated rosin per gallon of solution. They may be put up in paste form, the paste consisting of a mixture of 60—80% by weight of activated rosin and 40—20% by weight of ethyl alcohol or other suitable solvent. They may also be put up as solder creams, containing 50—90% by weight of finely powdered solder and 50—10% by weight of the flux paste just referred to. Finally, they may be used in the form of cored solder wire, consisting of a wire of solder having a core or grooves filled with the flux, the weight of flux being from 1—4% of the total weight of the solder wire.

What we claim is:—

1. A soldering flux, consisting of a main body of rosin and, as an activating agent, up to 5% by weight of hydrobromide of morpholine or of a hydrobromide of an N-alkyl substituted derivative of morpholine.
2. A soldering flux according to Claim 1, containing up to 2% by weight of morpholine hydrobromide.
3. A soldering flux according to Claim 1, containing up to 4% by weight of N-methyl morpholine hydrobromide.
4. A soldering flux according to Claim 1, containing up to 4% by weight of N-ethyl morpholine hydrobromide.
5. A soldering flux, consisting of a main body of rosin, up to 5% by weight of cetyl pyridinium bromide and 0.5—4% by weight of the hydrobromide of N-methyl morpholine or of N-ethyl morpholine.
6. A soldering flux according to Claim 5, containing about 1% by weight of cetyl pyridinium bromide and about 1% by weight of N-methyl morpholine hydrobromide.
7. A soldering flux according to Claim 5, containing about 1% by weight of cetyl pyridinium bromide and about 1% by weight of N-ethyl morpholine hydrobromide.

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PROVISIONAL SPECIFICATION.

Improvements in Soldering Fluxes.

We, FRY'S METAL FOUNDRIES LIMITED, of Tandem Works, Merton Abbey, London, S.W.19, a British Company, do hereby declare this invention to be described in the following statement:—

This invention relates to rosin soldering fluxes. Various organic activating agents have been proposed for incorporation in such fluxes for the purpose of improving the fluxing properties of the rosin. Thus, Specification No. 557,816 proposes the incorporation in the flux of from about 0.2—8% of cetyl pyridinium bromide, and more particularly of the commercial form of that substance known as "Fixanol" C. "Fixanol" is a Registered Trade Mark. The object of the present invention is to effect a further improvement in the fluxing properties of rosin soldering flux.

The rosin soldering flux according to the invention contains, as an activating agent, 0.4—5%, measured on the weight of the rosin, of a hydrobromide of morpholine or of an N-alkyl substituted derivative of morpholine, such for example as N-ethyl and N-methyl morpholine. These activating agents materially improve the fluxing properties of the rosin.

We also find that the effectiveness as a flux of resin containing up to 5% by weight of cetyl pyridinium bromide ("Fixanol" C) is substantially increased by the addition of certain of these activating agents. Thus a rosin flux containing 1% of N-ethyl or N-methyl morpholine hydrobromide and 1% of "Fixanol" C has enhanced fluxing properties and is suitable, due to the substantially non-corrosive nature of the residue, for the soldering of electrical connections.

The fluxes according to the invention may be put up as cored solder wire or in solution or paste form, using a conventional vehicle, such as alcohol.

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Abingdon: Printed for Her Majesty's Stationery Office, by Burgess & Son (Abingdon), Ltd.—1954.
Published at The Patent Office, 25, Southampton Buildings, London, W.C.2,
from which copies may be obtained.

Figure B.134: Rudolf Strauss invented wave soldering for printed circuits, or surface mount technology.

Jean Medawar and David Pyke. 2000. *Hitler's Gift: The True Story of the Scientists Expelled by the Nazi Regime.* New York: Arcade. p. 93.

Rudolf Strauss [...] met and became friends with Paul Eisler, a refugee from Austria, who had invented the printed electrical circuit board, which revolutionized the electronics industry. Strauss invented a technique for soldering thousands of electric connections in one operation. His 'wave soldering' machine, built in 1958, is still being made in a sophisticated form all over the industrial world. [...]

Recognition of Eisler's work took years. In late 1957 Lord Hailsham told the Royal Society that he rated the printed electric circuit as important an invention as penicillin or atomic fission.

Boris Chertok. 2005–2012. *Rockets and People.* 4 vols. Washington, DC: U.S. Government Printing Office. [https://www.nasa.gov/history/history-publications-and-resources/nasa-history-series/rockets-and-people/]

[Vol. 1, pp. 217–218:] We received "directives" and instructions thought up by God knows who, such as: "While inspecting German factories and laboratories, don't get carried away with intellectual achievements, but first and foremost compile a list of the types and number of machine tools, industrial engineering equipment, and instruments. As far as documentation and specialists are concerned, that is a matter of our judgement, and initiative will not be prohibited."

[Vol. 1, pp. 220–222:] DIARY ENTRY. 29–30 April 1945.

We are inspecting DVL [Deutsche Versuchsanstalt für Luftfahrt, or German Aviation Research Institute]. Administrative building. Archives, papers, personal documents—in safes. How do you open a safe? The sergeant and soldier detailed to us from the BAO already have experience. The soldier holds a large chisel against the safe doors. The sergeant, a "non-combatant" well over forty, delivers a precise, powerful blow with a heavy sledgehammer. Usually it opens the first time. Sometimes if the safe is especially "difficult," it takes three or four blows.The safes are full of reports with a red stripe,"Geheim!" (Secret) or "Streng Geheim!" (Top Secret). We leaf through the pages— reports, reports about all kinds of tests.

"DVL"—this is, after all, the equivalent of our TsAGI, LII, and Air Force NII all rolled into one. There is neither the time, nor the physical capability to read and study them.

The general has ordered us to list everything, load it into boxes, and send it by plane to Moscow. But where are we going to get as many boxes as we need? It turns out that the rear services and BAO do have them, and can organize everything! But there isn't even time to make a list of the reports.

Laboratory building. The aeronavigation laboratory is filled with benches for testing onboard instruments. The photochemical laboratory, the laboratory where materials are tested for strength and fatigue, vibration benches. A bombing and firing sights laboratory, accelerometer calibration units. And what magnificent drafting and designing equipment! I am envious of the German designers' workstations. Aside from the nice Kuhlman drafting unit, the swivel chair, and comfortable desk with lots of drawers, it is full of details, and everything has its place. Oh, this German love for details and this exactness, which has engrained such top-notch work into the culture.

The thing that every laboratory needs the most and that is in the shortest supply is the Siemens four-mirror oscillograph. There we found various models: two-, four-, and six-mirror models. Without them, conducting research on rapidly occurring dynamic processes is impossible. This is a new epoch in the technology of measurements and engineering research. In Moscow, at NII-1 we had only one six-mirror oscillograph for the entire institute. And these Germans had so many! No,we no longer felt the hatred or the thirst for vengeance that had boiled in each of us earlier. Now it was even a pity to break open these high quality steel laboratory doors and to entrust these diligent but not very careful soldiers with packing priceless precision instruments into boxes.

But faster, faster—all of Berlin is waiting for us! [...]

The electric instrument laboratory was fantastic! There were so many unique (for us) instruments of all types and ranges from the world-renowned German firms Siemens, Siemens und Halske, Rohde & Schwarz, and the Dutch firms Philips, Hartmann-Braun, and Lorentz! And again— photographic enlargers, slide projectors, movie projectors, chemicals, bulky stationary cameras, cine-theodolites, phototheodolites, and optics of incomprehensible purpose...

We christened a separate building the electrophysics building because of its contents. Electronic low- and high-frequency frequency meters, wave meters, precision noise meters, octave filters, harmonic analyzers, nonlinear distortion factor meters, motor generators and dynamotors for various voltages, even the scarce cathode ray (now called electronic) oscillographs. The richest building of all was the one containing radio and acoustical measurement equipment.

We are writing the addresses of our firms on the boxes:“P.O. Box” so-and-so. But what will really happen to this stuff? Who will meet the airplanes in Moscow?”

[Comments added by Chertok in the 1990s:] After much time had passed, I indeed never found a single report from that mass of secret and top-secret reports that I had sent from Adlershof. They were dispersed over LII, TsAGI, NISO, and other aircraft industry institutions. Only about one-tenth of the instruments that we had sent ended up at NII-1, provoking a justifiable reaction from my immediate chief. At NII-1 in Likhobory, they began preparing the next, independent expedition to Germany. This time, on their own airplane.

[Vol. 1, p. 230:] In the ensuing days, we continued to investigate the Askania facility. The factory had a broad spectrum of interesting items and competed with Siemens for our interest. We discovered another large factory and design bureau in Mariendorf. Here I finally found intact actuators for the V-2, as well as similar actuators for aircraft autopilots. Sets of autopilot equipment intended for delivery were assembled on the test stands. With astonishment, we discovered shops with submarine periscopes, periscope range finders, bombsights, and anti-aircraft fire control equipment (PUAZO). There were special cockpits equipped for crew training and testing where blind flight conditions were simulated. There was a rather large shop that was involved with purely optical production. Optical glass polishing machines stood next to the finished products—virtual mountains of lenses of various diameters up to 50 centimeters! The test laboratories were excellently equipped. They contained pressure chambers, thermal vacuum chambers, vibration stands, and rainfall simulators. Every area was equipped with all-purpose and special-purpose measurement instruments and also with our dream instrument: the Siemens multi-mirror oscillograph!

[Vol. 1, pp. 231–233:] DIARY ENTRY. 9 May 1945.

Our visit to the Telefunken factory in Zehlendorf was very interesting.

Originally it was a radio tube factory, but in the last few years it has switched almost completely to radar. In contrast to many other enterprises here we found almost all of the personnel, including chief engineer Wilki and his immediate staff. Chistyakov and I already spoke German rather briskly. For that reason we did not need an interpreter. Wilki and the production chief showed us the factory and laboratory. Wilki directed research in the field of centimetric waves. His laboratory, which is not located within this factory, has been conducting a thorough study of American and British radar installed on aircraft as well as radar sights for bombing and reconnaissance.

According to the assessments of the German specialists, the Americans and Brits have been very successful in the field of radar—especially in submarine warfare. Their aircraft detect periscopes from tens of kilometers away. In this regard, they have also worked a great deal on instruments to alert submarine crews that they have been illuminated by aircraft radar.

At the factory, they were involved in the series production of aircraft radar using American and British experience. The radar manufacturing shops were well equipped with electronic monitoring instruments.The factory turned out to be relatively new. They finished building it in 1939. In all, counting the Ostarbeiter, some 6,000–7,000 people worked there. Of that number, 3,000 were engineers and technicians. They experienced no shortage of materials or supplies.

The Lorenz and Blaupunkt companies provided large television screens for the radar and receivers.“But you didn’t study Soviet radar?”

According to information from our military, they did not find radar on a single one of your airplanes. And among the captured materials that they were able to provide us during our troops’ offensive, there was also nothing of interest.We decided that the Russians had safeguarded this technology so well that it did not fall into the hands of our military.”

I think that he spoke of “safeguarding” to be polite. In actual fact, they had surmised that during the war we had virtually no aircraft radar and radar sights. [...]

We wore them out with questions about other firms and studies. Like all radio and electronics specialists, they were well informed about related firms and developments and told us that Telefunken and Lorentz were involved primarily in radar technology for air defense purposes, while Askania and Siemens were involved in remote control. Over the past six months, many directors along with staff and laboratories had been moved to Thuringia and Westphalia.They knew that the secret weapon, the “vengeance rocket,” was being made in Peenemünde. None of them had ever been there—it was very secret. But other divisions of Telefunken were building ground-based radars and stations for the radio control of rockets.

The tube shops were excellently equipped. Here they were making magnetron tubes with a pulse power of up to 100 kilowatts!

That is how we first heard about the Kaiser Wilhelm Institute in Dahlem. Later, while exchanging impressions about everything that we had seen at Telefunken and then at Lorentz, we mused how, in spite of the strictest secrecy, scientific knowledge and its progress are ultimately shared between countries.Thoughts are transmitted between scientists over some sort of telepathic channel. Not only did we all toil separately, but we believed, and quite rightly, that the Germans were our mortal enemies. Our allies, out of consideration for secrecy, hardly shared their work with us. Nevertheless, with the exception of small lapses, parallel developments were taking place in the scientific fields of radar, nuclear energy, and rocket technology.

[Vol. 1, pp. 234–235:] DIARY ENTRY. 10 May 1945.

We barely managed to make our way to the Lorentz company in Tempelhof. [...]

Even before our visit, the factory itself had been taken over by the "trade union" officers of Moscow's radio factories.They had also appropriated from the basement, but did not interfere with our inspection. We talked with the German specialists for about two hours.They showed us transmitters for 3- and 9-centimeter range radars. It was interesting that the laboratory, which specialized in the development of television receivers, was quickly reoriented for instruments with large radar observation cathode ray tubes.

The factory produced ground-based radio stations with large rotating antennas for guiding aircraft to their airfields. We ascertained that in practice these radar stations were also used to control air battles in the direct coverage zone. We were surprised by the number of circular scanning stations with large screens that made it possible to see hostile aircraft and distinguish them from one's own. The Germans claimed that they had already produced around one hundred of these stations. It was hard to believe, considering the exceptional complexity and labor intensity of the system. Development of the Freya radar began as early as 1938. It enabled the detection of an aircraft at a distance of up to 120 kilometers. The Würzburg radar with a spherical antenna was developed to control anti- aircraft fire. Night fighters homed in on the target using the powerful "Würzburg Giant" radar station. At the beginning of the war, all of the German radar technology was in the decimeter range. The German engineers advised us, "Our war with the Brits was fought not only on the battlefield and in the air, but also in laboratories.They had already achieved great success as early as 1942 thanks to their daring switch to the centimeter range. At that time we did not have the same tube technology."

[Vol. 1, p. 235–238] He was Aleksandr Ivanovich Shokin, representing the GKO Council on Radar. At that time I had no way of knowing that I had met with the future deputy minister of the radio engineering industry, who would become the minister of the electronic industry. I would have the occasion to meet with him more than once in the latter period of his hypostases, almost up until his demise in 1986.

At that time in Berlin he said bitterly that, in spite of serious scientific achievements, our radio engineering and electronics industry was undoubtedly poorly developed compared with what we were seeing here. On this visit, as during all of our visits to German factories and laboratories, we were stunned by the abundance of instruments—both universal and special-purpose, especially in comparison to their scarcity at home. Vacuum-tube voltmeters, oscillographs, audio-signal generators, filters of all kinds, standard amplifiers, wave meters, frequency meters, etc., etc.—and all of it was high quality. Instrument models that we had considered precious before the war were continually showing up here. Not one of our institutes, factories, or laboratories could even imagine such abundance.

But indeed the war of the laboratories was not only a war of pure intellects. Each "intellect" had to be armed with the most advanced instruments for scientific research. This required a well-developed instrumentation industry.

Alas, even today, fifty years after the war, we do not fully appreciate the strength of the research scientist's laboratory weaponry, much less that of the engineer. Incidentally, one of the burning topics for the past ten years, our scandalous lag behind in the field of personal computers, has not only economic but also ideological roots: indifference to the specific needs of the human being as an individual, since, in the opinion of the country's senior leadership, above all, we had to be ahead of the "entire planet" in the smelting of steel and iron, in coal mining, oil production, and in the number of tractors and machine tools produced.

These garish indicators got through to the dullest bureaucrats at the highest levels of the Party-State hierarchy, but for the longest time they did not comprehend why it was necessary to lead or at least be on the level of an average capitalistic country in terms of providing measurement technology, not to mention expensive computers. And when it suddenly occurred to us,it turned out that we were one of the most backward countries in the world in that field.

Well, these are modern issues, but back then in Berlin and its surrounding areas we continued to collect worthwhile literature and send it to Moscow. I also insisted that we send back a wide variety of measurement technology.

Measurement equipment was my weakness during our collection of "spoils." I carefully prepared the cases containing instruments that had been retrieved by Red Army soldiers from the aerodrome maintenance battalion, then and waited for "my" airplane to deliver them to "my" institute.

By the middle of May, our *troika*—reinforced by several more specialists from NISO and LII, including Professor Sergey Nikolayevich Losyakov, had already put together a more or less clear picture of the instrument and radio industry in Greater Berlin. Our list contained more than thirty enterprises, each of which surpassed our own in terms of technology and production. The most interesting were the laboratories and factories of Askania, Telefunken, Lorenz, Siemens, AEG, Blaupunkt, and Loewe Radio.

For us it was a novelty that the company List, which specialized only in the development and mass-production of multi-pin plug connectors, existed and flourished among the Germans. They had produced hundreds of thousands of connectors for German aircraft and rockets.The concept was very simple, but the engineering and production involved were fundamentally new to us. This innovation developed in response to the extreme complexity of the electrical circuits used in flying vehicles. The connectors enhanced rapid assembly and allowed electrical components to be connected and disconnected reliably during the repair and testing of individual compartments.

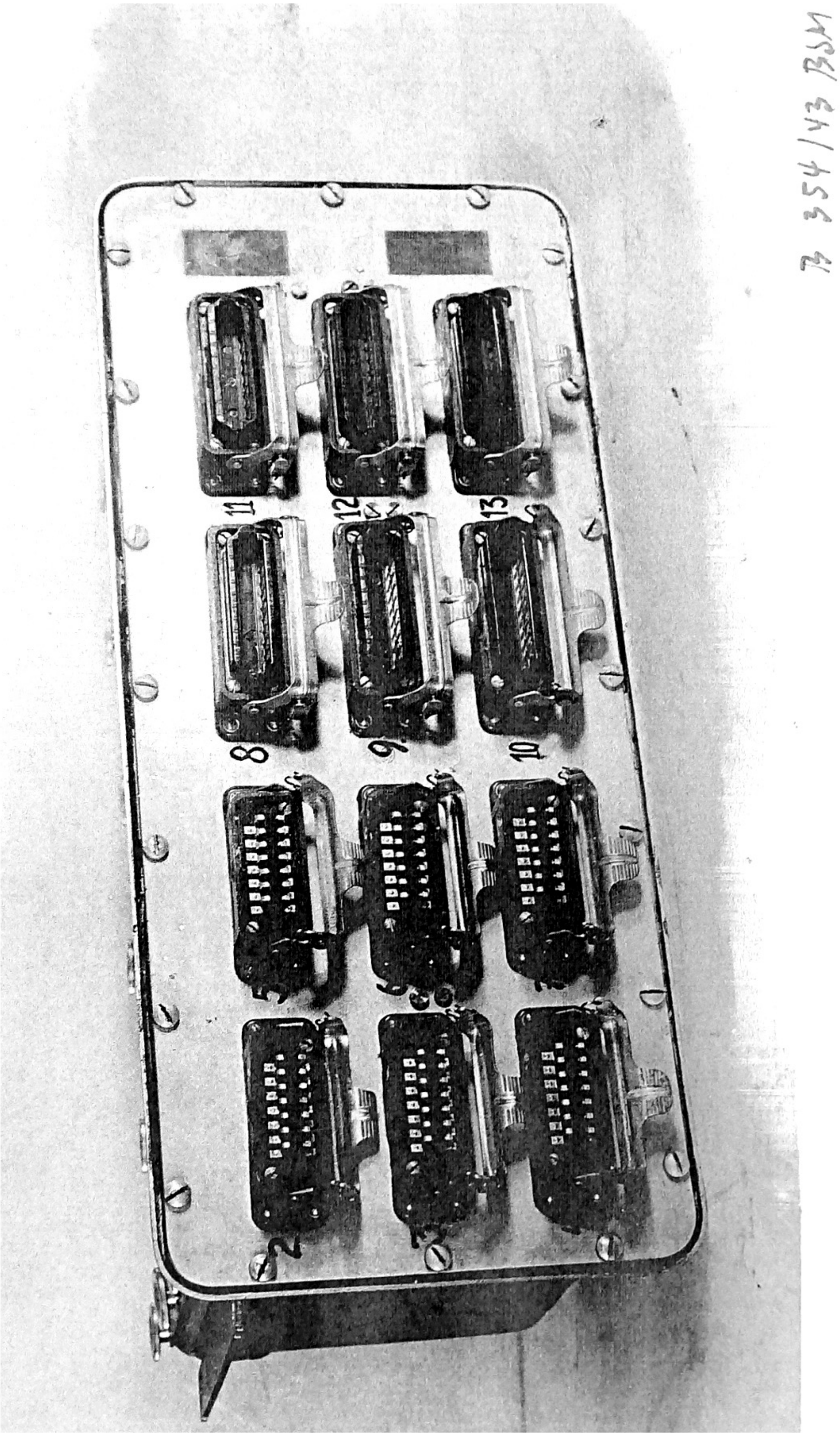
The very term *shteker*, or plug connector, made its way into the Russian language from the Germans after the war. Throughout history much has been transferred to the victors from the vanquished. Only after the war did we come to appreciate what a tremendous technical role such a seemingly simple device as the plug and socket connector was destined to play in aircraft and rocket technology! The Germans spent years developing reliable connectors, and introduced into aircraft and rocket technology the standard List *shteker*, which had from two to thirty pins. We needed three years to reproduce connectors that were as reliable. However, during our first years of mastering rocket technology they gave us a lot of trouble.

Now our industry produces connectors—both tiny and enormous, airtight, onboard and ground-based—to connect and remotely disconnect more than one hundred electric circuits. Despite all of these achievements, the problem of connector technology remains one of the most complex in the entire world. This is why there are booths at every international aerospace exhibition advertising hundreds of modifications of quick and reliable cable connectors. Dozens of powerful companies in many countries produce them by the millions.

We were interested not only in individual factories, but also in the organization and structure of the instrument and radar industry. German companies worked on a lot of technical problems on their own initiative, without waiting for instructions "from the top." They did not need the decisions of the Gosplan or People's Commissariats, without which not a single factory of ours could produce anything. Before the war, the electric measuring technology, instrument, and radio industries had developed rapidly to conquer the entire European market, and their products had successfully competed with those of the United States. The companies Hartmann-Braun, Telefunken, Anschütz, Siemens, Lorentz, AEG, Rohde & Schwarz, Askania, and Karl Zeiss enjoyed worldwide fame long before World War II. This created a solid technological base, which we simply did not have in these industries on the required scale at the beginning of the war.

Our general-purpose electrical instrument industry, our aircraft industry, and also our nautical instrumentation industry were all housed in just a few buildings in Moscow and Leningrad (Elektropribor, Teplopribor, and Svetlana in Leningrad; Aviapribor, the Lepse Factory, Elektrozavod, and Manometr in Moscow).

It is revealing that when we began to reproduce technology for the V-2 rocket after the war and develop our own new rockets, we found out that in our country there was only one factory, Krasnaya Zarya in Leningrad, that was able to manufacture such a mundane device as the multi-contact electrical relay. In Germany, Telefunken had three such factories and Siemens had at least two. This is one of the reasons that German weapons production did not drop, but continuously increased until mid-1944, despite the continuous bombing that Allied aviation inflicted on German cities.


B 354/43 BSM
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12
13
8
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10
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Figure B.135: Panel of multi-pin connectors from an A-4 (V-2) rocket produced during the war [Peenemünde Archive, Folder ARK 41].

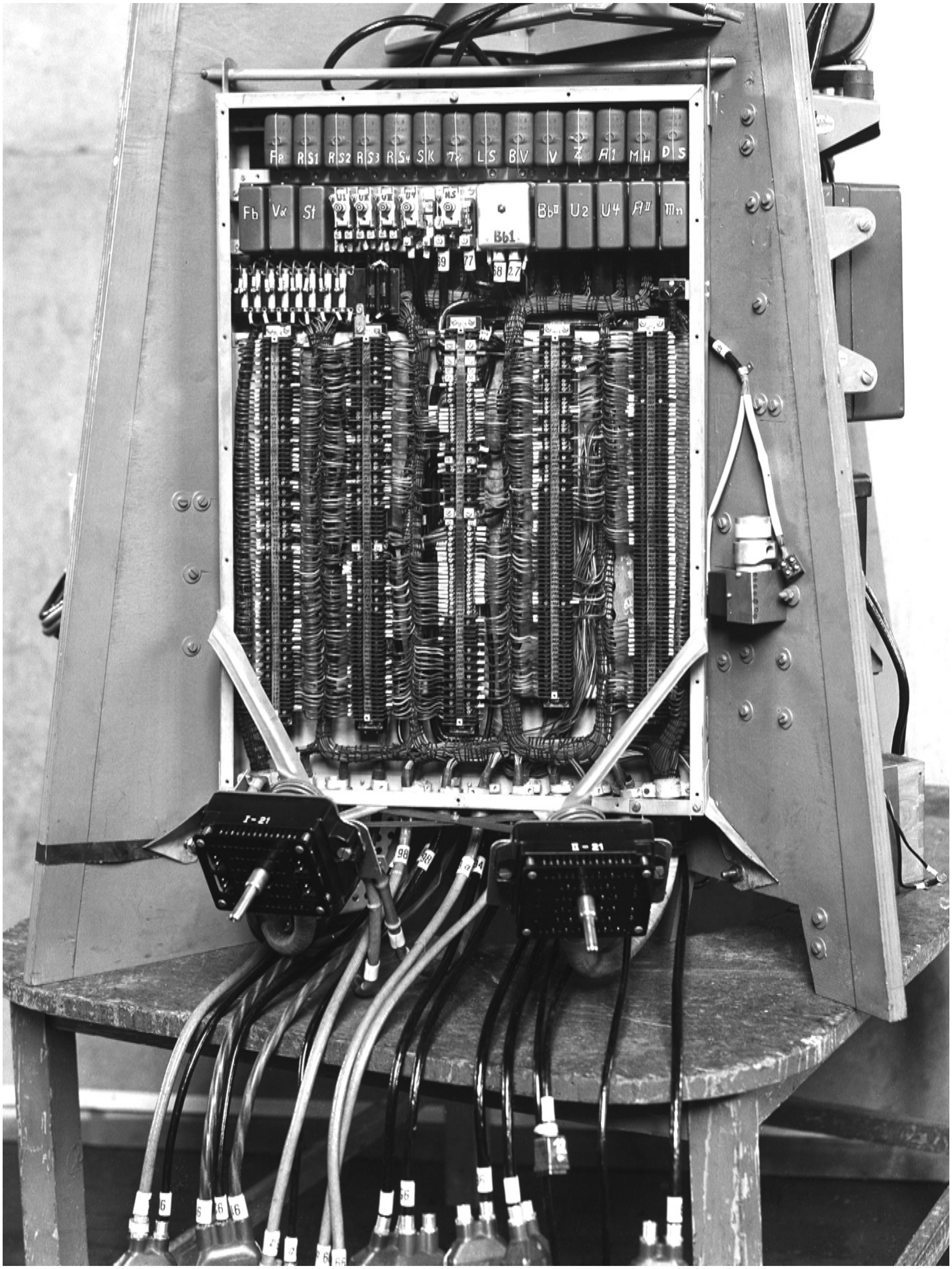

Fp
RS1
RS2
RS3
RS4
SK
LS
BV
V
Z
A1
MH
DS
Fb
Vα
St
Bb1
BbII
U2
U4
AII
Mn
I-21
II-21

Figure B.136: Part of the guidance system for an A-4 (V-2) rocket (1943) [Deutsches Museum Archive, photo 10890].

B.3 Integrated Circuits

[Even further miniaturization of electronics required moving from individual electronic components to integrated circuit chips that could contain large numbers of components on the same semiconductor substrate.

In 1949, Werner Jacobi (German, 1904–1985) filed a West German patent application on integrated circuits on behalf of Siemens & Halske. Since there were a large number of German inventors who filed patents on their wartime work when the (West) German patent office reopened in 1949, it is quite likely that Jacobi's patent application was based on experimental work that he had conducted at Siemens & Halske during the war (pp. 2816–2817).

Kurt Lehovec (Bohemian/Austrian/Czech, 1918–2012) developed advanced semiconductor devices for Germany in Prague during the war. After the war he was extensively interrogated by the United States and then moved to the United States (as part of Operation Paperclip), where he filed patents on transistors, integrated circuits, and light emitting diodes. See pp. 2757–2763, 2818–2832, and 2895–2910. Lehovec's integrated circuit designs may well have been based on wartime work, but even if they were early postwar ideas, they preceded the claims of American engineers who later worked on integrated circuits.

Other German-speaking scientists developed transistor fabrication methods that made integrated circuits practical:

- Herbert Kroemer (German, 1928–) invented the drift transistor in 1953, the double-heterostructure laser diode in 1963, and III-V semiconductor heterostructures in 1966. (See pp. 1111, 2833–2845, and 2917–2922.) He won the Nobel Prize in Physics in 2000 (p. 1104).

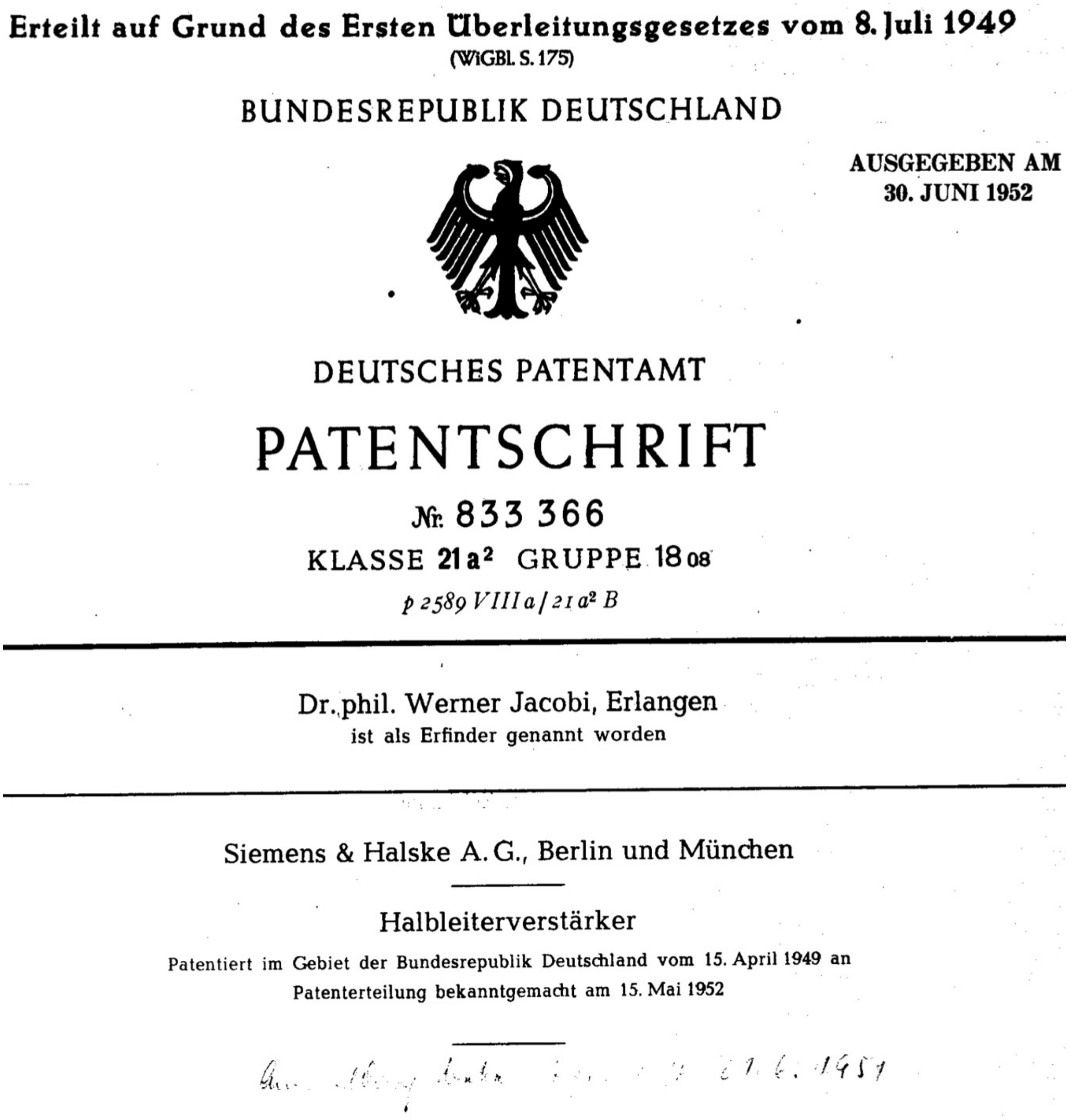
- Jean Hoerni (Swiss, 1924–1997) and Eugene Kleiner (Austrian, 1923–2003) devised methods of manufacturing silicon transistors at Fairchild Semiconductor; see pp. 1101 and 2846–2861. Through Fairchild and their later companies and investments, they also helped to develop Silicon Valley.

- Karl Heinz Zaininger (German, 1929–) developed modern methods for fabricating field effect transistors (pp. 1102 and 2862–2876).

As shown on pp. 2877–2887, Helmut Gröttrup (German, 1916–1981) and Jürgen Dethloff (German, 1924–2002) invented the smart card, or chip card, in 1966. Earlier, Gröttrup developed avionics systems in Germany during the war and led the German-speaking contributions to the postwar Soviet ballistic missile program (pp. 1874–1881).

As with transistors and printed circuits, much more research should be conducted to determine how much work on integrated circuits was conducted in the German-speaking world during the war, and how much impact German-speaking scientists and knowledge had on the postwar development of integrated circuits in other countries.]

Werner Jacobi (1904–1985) filed a patent application on integrated circuits in 1949 (based on wartime work?)



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
30. JUNI 1952

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 833 366

KLASSE **21a²** GRUPPE 18₀₈

p 2589 VIIIa/21a² B

Dr. phil. Werner Jacobi, Erlangen
ist als Erfinder genannt worden

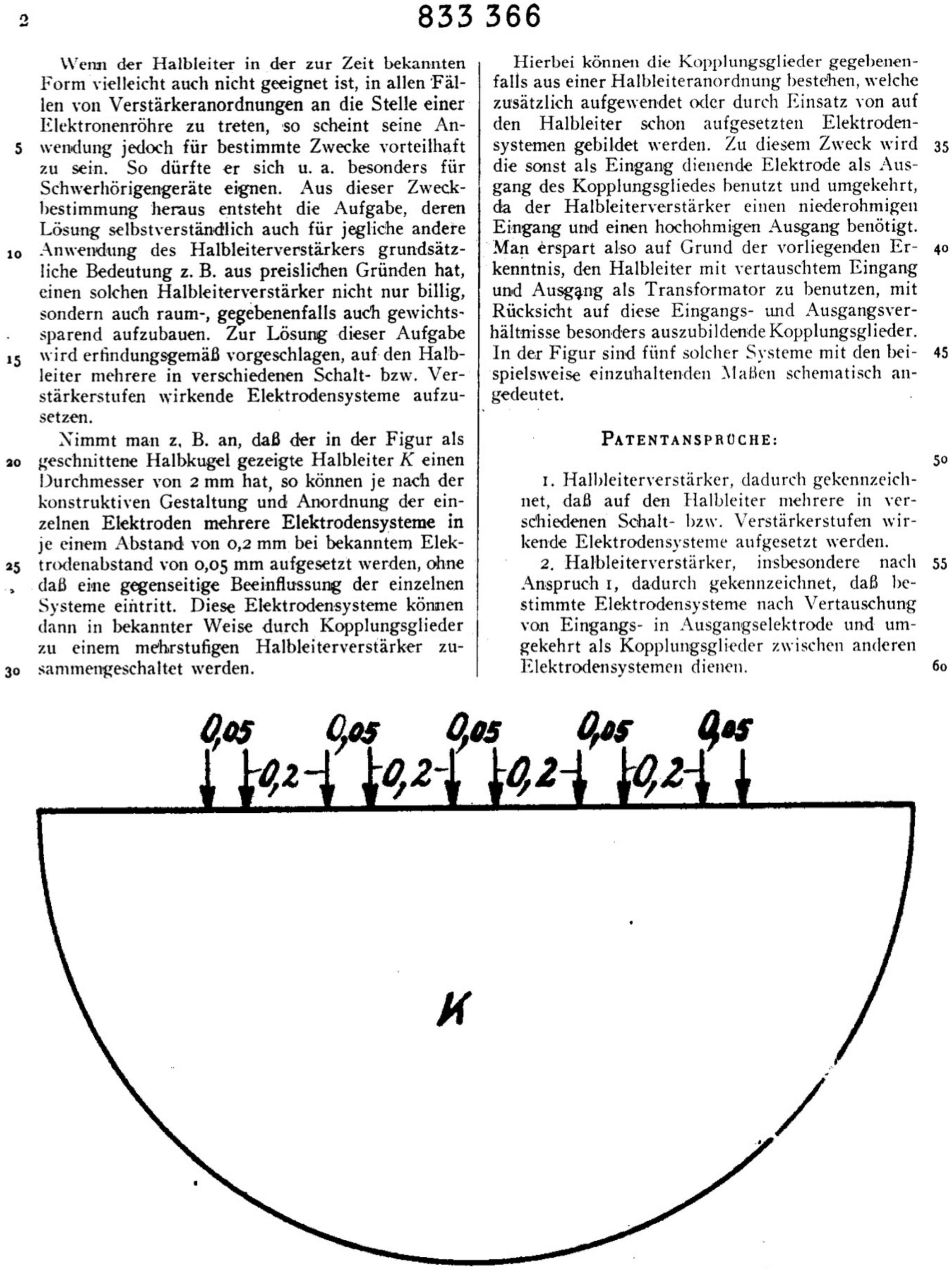
Siemens & Halske A. G., Berlin und München

Halbleiterverstärker

Patentiert im Gebiet der Bundesrepublik Deutschland vom 15. April 1949 an
Patenterteilung bekanntgemacht am 15. Mai 1952

[illegible] 21. 6. 1951

Figure B.137: Werner Jacobi filed a patent application on integrated circuits in 1949, which was quite likely based on experimental work that he had conducted during the war.



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833 366

Wenn der Halbleiter in der zur Zeit bekannten Form vielleicht auch nicht geeignet ist, in allen Fällen von Verstärkeranordnungen an die Stelle einer Elektronenröhre zu treten, so scheint seine Anwendung jedoch für bestimmte Zwecke vorteilhaft zu sein. So dürfte er sich u. a. besonders für Schwerhörigengeräte eignen. Aus dieser Zweckbestimmung heraus entsteht die Aufgabe, deren Lösung selbstverständlich auch für jegliche andere Anwendung des Halbleiterverstärkers grundsätzliche Bedeutung z. B. aus preislichen Gründen hat, einen solchen Halbleiterverstärker nicht nur billig, sondern auch raum-, gegebenenfalls auch gewichtssparend aufzubauen. Zur Lösung dieser Aufgabe wird erfindungsgemäß vorgeschlagen, auf den Halbleiter mehrere in verschiedenen Schalt- bzw. Verstärkerstufen wirkende Elektrodensysteme aufzusetzen.

Nimmt man z. B. an, daß der in der Figur als geschnittene Halbkugel gezeigte Halbleiter *K* einen Durchmesser von 2 mm hat, so können je nach der konstruktiven Gestaltung und Anordnung der einzelnen Elektroden mehrere Elektrodensysteme in je einem Abstand von 0,2 mm bei bekanntem Elektrodenabstand von 0,05 mm aufgesetzt werden, ohne daß eine gegenseitige Beeinflussung der einzelnen Systeme eintritt. Diese Elektrodensysteme können dann in bekannter Weise durch Kopplungsglieder zu einem mehrstufigen Halbleiterverstärker zusammengeschaltet werden.

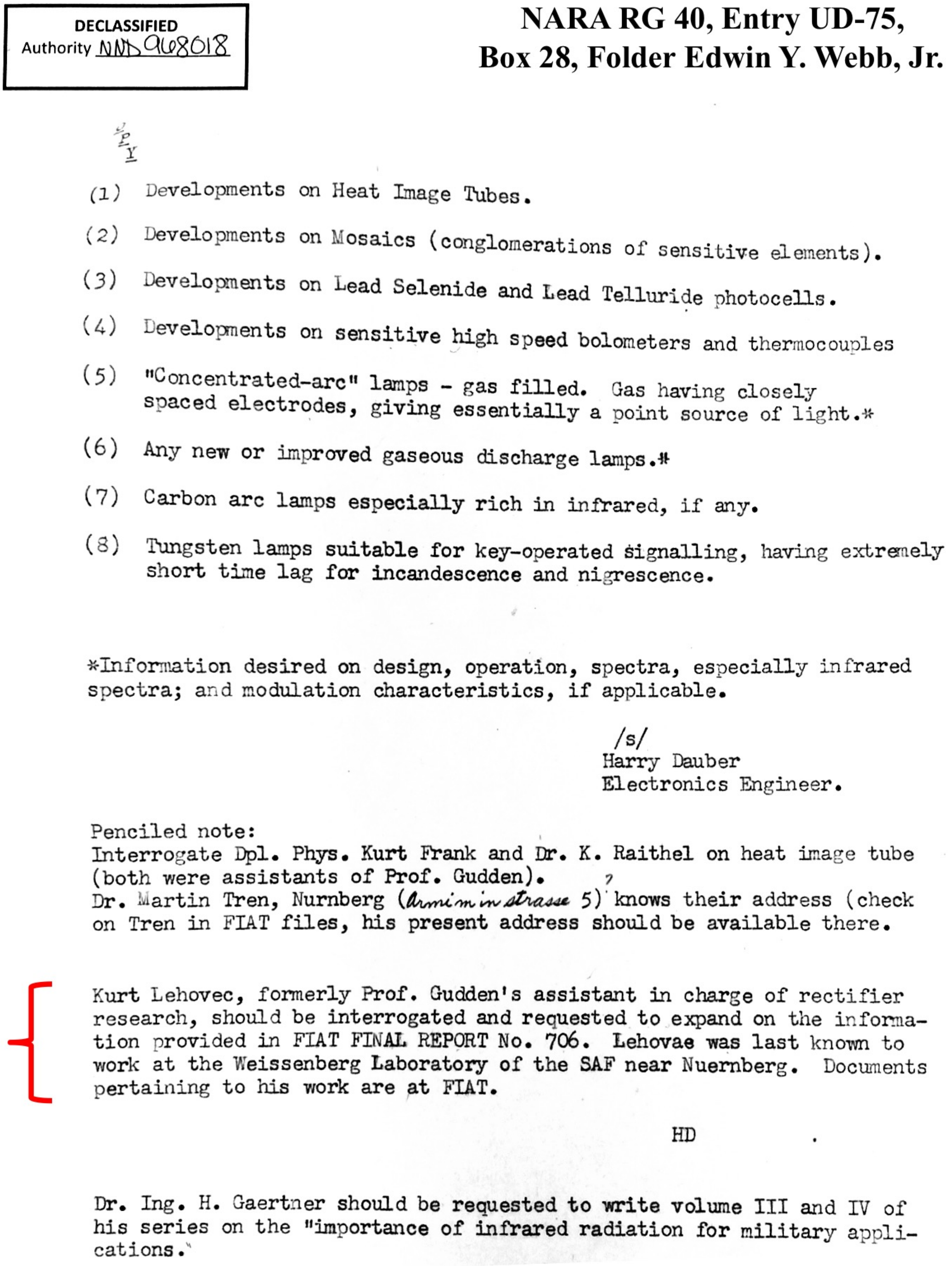
Hierbei können die Kopplungsglieder gegebenenfalls aus einer Halbleiteranordnung bestehen, welche zusätzlich aufgewendet oder durch Einsatz von auf den Halbleiter schon aufgesetzten Elektrodensystemen gebildet werden. Zu diesem Zweck wird die sonst als Eingang dienende Elektrode als Ausgang des Kopplungsgliedes benutzt und umgekehrt, da der Halbleiterverstärker einen niederohmigen Eingang und einen hochohmigen Ausgang benötigt. Man erspart also auf Grund der vorliegenden Erkenntnis, den Halbleiter mit vertauschtem Eingang und Ausgang als Transformator zu benutzen, mit Rücksicht auf diese Eingangs- und Ausgangsverhältnisse besonders auszubildende Kopplungsglieder. In der Figur sind fünf solcher Systeme mit den beispielsweise einzuhaltenden Maßen schematisch angedeutet.

PATENTANSPRÜCHE:

1. Halbleiterverstärker, dadurch gekennzeichnet, daß auf den Halbleiter mehrere in verschiedenen Schalt- bzw. Verstärkerstufen wirkende Elektrodensysteme aufgesetzt werden.

2. Halbleiterverstärker, insbesondere nach Anspruch 1, dadurch gekennzeichnet, daß bestimmte Elektrodensysteme nach Vertauschung von Eingangs- in Ausgangselektrode und umgekehrt als Kopplungsglieder zwischen anderen Elektrodensystemen dienen.

Figure B.138: Werner Jacobi filed a patent application on integrated circuits in 1949, which was quite likely based on experimental work that he had conducted during the war.



DECLASSIFIED
Authority NND968018

**NARA RG 40, Entry UD-75,
Box 28, Folder Edwin Y. Webb, Jr.**

(1) Developments on Heat Image Tubes.

(2) Developments on Mosaics (conglomerations of sensitive elements).

(3) Developments on Lead Selenide and Lead Telluride photocells.

(4) Developments on sensitive high speed bolometers and thermocouples

(5) "Concentrated-arc" lamps - gas filled. Gas having closely spaced electrodes, giving essentially a point source of light.*

(6) Any new or improved gaseous discharge lamps.*

(7) Carbon arc lamps especially rich in infrared, if any.

(8) Tungsten lamps suitable for key-operated signalling, having extremely short time lag for incandescence and nigrescence.

*Information desired on design, operation, spectra, especially infrared spectra; and modulation characteristics, if applicable.

/s/
Harry Dauber
Electronics Engineer.

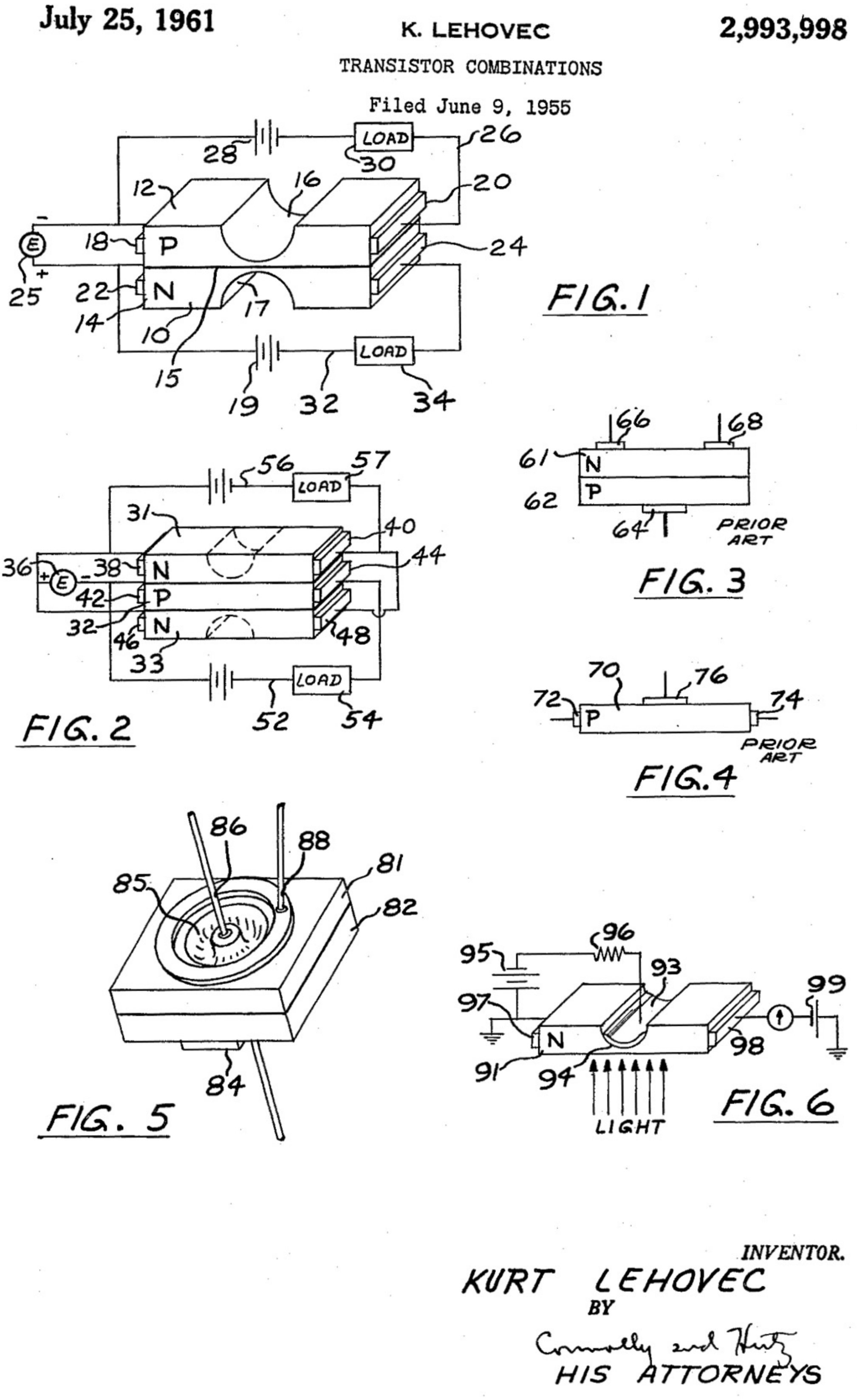
Penciled note:
Interrogate Dpl. Phys. Kurt Frank and Dr. K. Raithel on heat image tube (both were assistants of Prof. Gudden). ?
Dr. Martin Tren, Nurnberg (Arnimin strasse 5) knows their address (check on Tren in FIAT files, his present address should be available there.

Kurt Lehovec, formerly Prof. Gudden's assistant in charge of rectifier research, should be interrogated and requested to expand on the information provided in FIAT FINAL REPORT No. 706. Lehovae was last known to work at the Weissenberg Laboratory of the SAF near Nuernberg. Documents pertaining to his work are at FIAT.

HD

Dr. Ing. H. Gaertner should be requested to write volume III and IV of his series on the "importance of infrared radiation for military applications."

Figure B.139: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits [NARA RG 40, Entry UD-75, Box 28, Folder Edwin Y. Webb, Jr.].



July 25, 1961 **K. LEHOVEC** **2,993,998**

TRANSISTOR COMBINATIONS

Filed June 9, 1955

INVENTOR.

KURT LEHOVEC

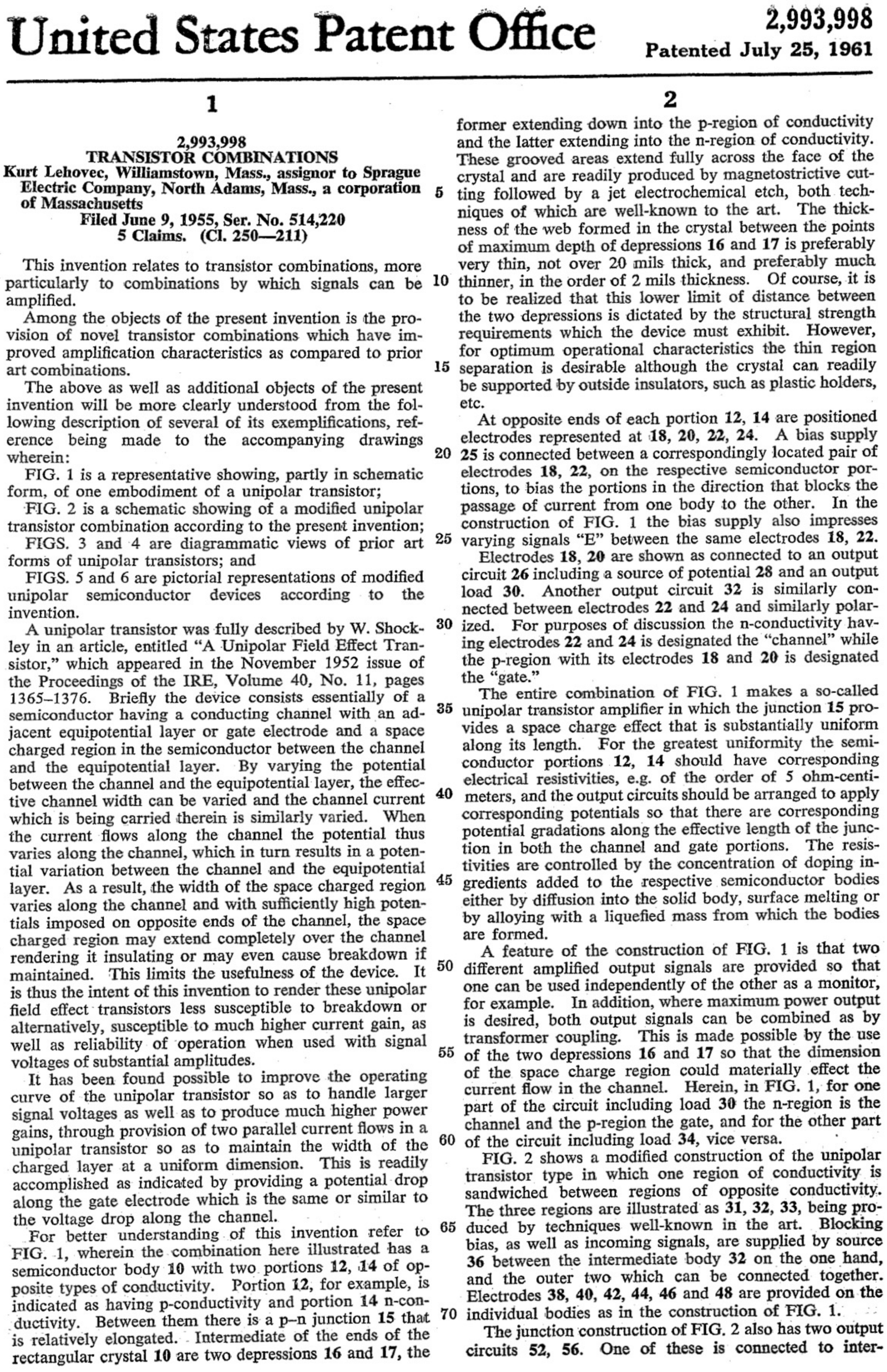
BY

Connolly and Hutz

HIS ATTORNEYS

FIG. 1
LOAD
LOAD
P
N
E
-
+
12
14
15
16
17
18
19
20
22
24
25
26
28
30
32
34
10
FIG. 2
LOAD
LOAD
N
P
N
E
+
-
31
32
33
36
38
40
42
44
46
48
52
54
56
57
FIG. 3
N
P
61
62
64
66
68
PRIOR ART
FIG. 4
P
70
72
74
76
PRIOR ART
FIG. 5
81
82
84
85
86
88
FIG. 6
N
91
93
94
95
96
97
98
99
LIGHT

Figure B.140: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits.



United States Patent Office

2,993,998
Patented July 25, 1961

1

2,993,998
TRANSISTOR COMBINATIONS
Kurt Lehovec, Williamstown, Mass., assignor to Sprague Electric Company, North Adams, Mass., a corporation of Massachusetts
Filed June 9, 1955, Ser. No. 514,220
5 Claims. (Cl. 250—211)

This invention relates to transistor combinations, more particularly to combinations by which signals can be amplified.

Among the objects of the present invention is the provision of novel transistor combinations which have improved amplification characteristics as compared to prior art combinations.

The above as well as additional objects of the present invention will be more clearly understood from the following description of several of its exemplifications, reference being made to the accompanying drawings wherein:

FIG. 1 is a representative showing, partly in schematic form, of one embodiment of a unipolar transistor;

FIG. 2 is a schematic showing of a modified unipolar transistor combination according to the present invention;

FIGS. 3 and 4 are diagrammatic views of prior art forms of unipolar transistors; and

FIGS. 5 and 6 are pictorial representations of modified unipolar semiconductor devices according to the invention.

A unipolar transistor was fully described by W. Shockley in an article, entitled "A Unipolar Field Effect Transistor," which appeared in the November 1952 issue of the Proceedings of the IRE, Volume 40, No. 11, pages 1365–1376. Briefly the device consists essentially of a semiconductor having a conducting channel with an adjacent equipotential layer or gate electrode and a space charged region in the semiconductor between the channel and the equipotential layer. By varying the potential between the channel and the equipotential layer, the effective channel width can be varied and the channel current which is being carried therein is similarly varied. When the current flows along the channel the potential thus varies along the channel, which in turn results in a potential variation between the channel and the equipotential layer. As a result, the width of the space charged region varies along the channel and with sufficiently high potentials imposed on opposite ends of the channel, the space charged region may extend completely over the channel rendering it insulating or may even cause breakdown if maintained. This limits the usefulness of the device. It is thus the intent of this invention to render these unipolar field effect transistors less susceptible to breakdown or alternatively, susceptible to much higher current gain, as well as reliability of operation when used with signal voltages of substantial amplitudes.

It has been found possible to improve the operating curve of the unipolar transistor so as to handle larger signal voltages as well as to produce much higher power gains, through provision of two parallel current flows in a unipolar transistor so as to maintain the width of the charged layer at a uniform dimension. This is readily accomplished as indicated by providing a potential drop along the gate electrode which is the same or similar to the voltage drop along the channel.

For better understanding of this invention refer to FIG. 1, wherein the combination here illustrated has a semiconductor body **10** with two portions **12**, **14** of opposite types of conductivity. Portion **12**, for example, is indicated as having p-conductivity and portion **14** n-conductivity. Between them there is a p–n junction **15** that is relatively elongated. Intermediate of the ends of the rectangular crystal **10** are two depressions **16** and **17**, the

2

former extending down into the p-region of conductivity and the latter extending into the n-region of conductivity. These grooved areas extend fully across the face of the crystal and are readily produced by magnetostrictive cutting followed by a jet electrochemical etch, both techniques of which are well-known to the art. The thickness of the web formed in the crystal between the points of maximum depth of depressions **16** and **17** is preferably very thin, not over 20 mils thick, and preferably much thinner, in the order of 2 mils thickness. Of course, it is to be realized that this lower limit of distance between the two depressions is dictated by the structural strength requirements which the device must exhibit. However, for optimum operational characteristics the thin region separation is desirable although the crystal can readily be supported by outside insulators, such as plastic holders, etc.

At opposite ends of each portion **12**, **14** are positioned electrodes represented at **18**, **20**, **22**, **24**. A bias supply **25** is connected between a correspondingly located pair of electrodes **18**, **22**, on the respective semiconductor portions, to bias the portions in the direction that blocks the passage of current from one body to the other. In the construction of FIG. 1 the bias supply also impresses varying signals "E" between the same electrodes **18**, **22**.

Electrodes **18**, **20** are shown as connected to an output circuit **26** including a source of potential **28** and an output load **30**. Another output circuit **32** is similarly connected between electrodes **22** and **24** and similarly polarized. For purposes of discussion the n-conductivity having electrodes **22** and **24** is designated the "channel" while the p-region with its electrodes **18** and **20** is designated the "gate."

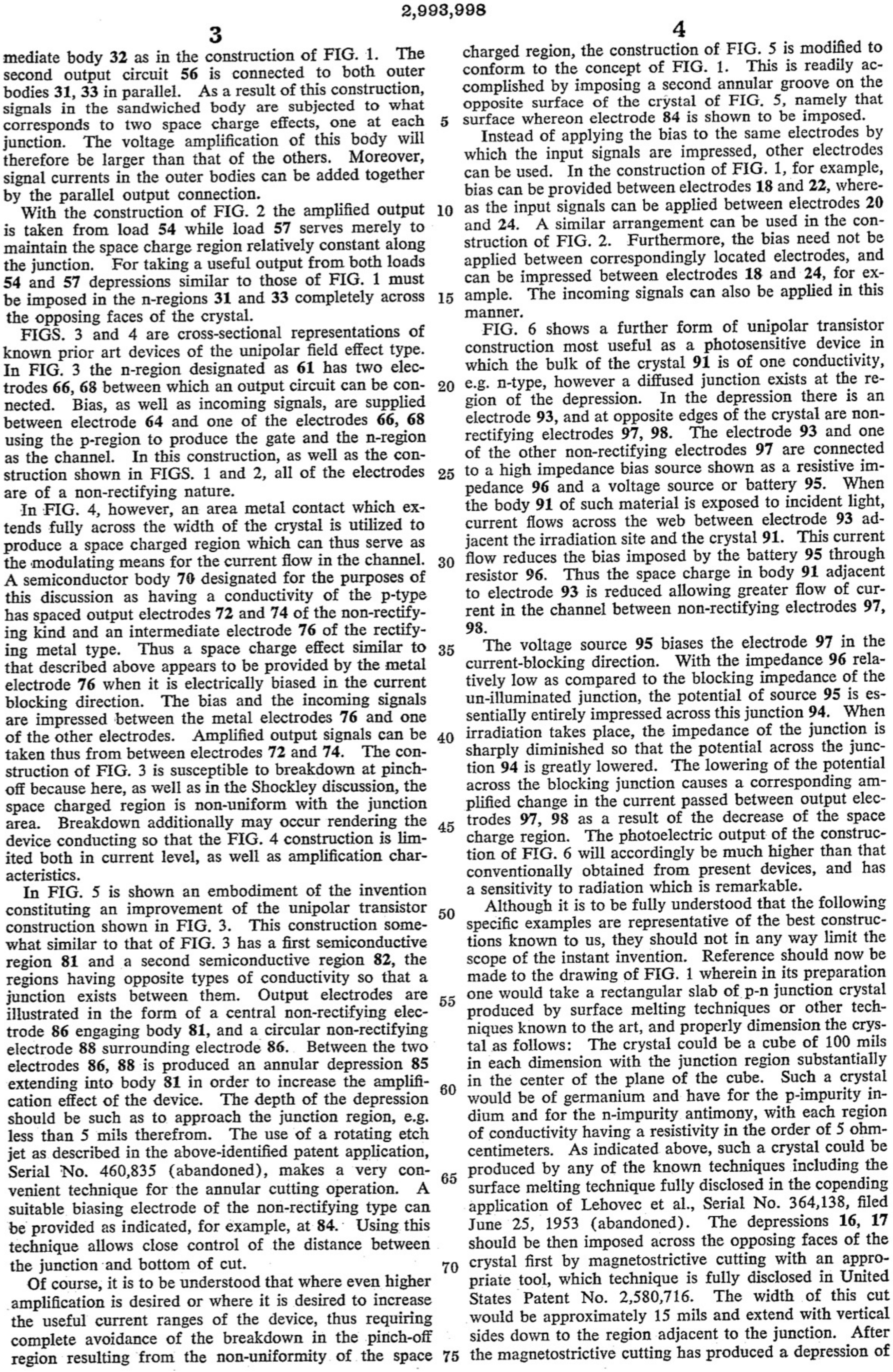
The entire combination of FIG. 1 makes a so-called unipolar transistor amplifier in which the junction **15** provides a space charge effect that is substantially uniform along its length. For the greatest uniformity the semiconductor portions **12**, **14** should have corresponding electrical resistivities, e.g. of the order of 5 ohm-centimeters, and the output circuits should be arranged to apply corresponding potentials so that there are corresponding potential gradations along the effective length of the junction in both the channel and gate portions. The resistivities are controlled by the concentration of doping ingredients added to the respective semiconductor bodies either by diffusion into the solid body, surface melting or by alloying with a liquefied mass from which the bodies are formed.

A feature of the construction of FIG. 1 is that two different amplified output signals are provided so that one can be used independently of the other as a monitor, for example. In addition, where maximum power output is desired, both output signals can be combined as by transformer coupling. This is made possible by the use of the two depressions **16** and **17** so that the dimension of the space charge region could materially effect the current flow in the channel. Herein, in FIG. 1, for one part of the circuit including load **30** the n-region is the channel and the p-region the gate, and for the other part of the circuit including load **34**, vice versa.

FIG. 2 shows a modified construction of the unipolar transistor type in which one region of conductivity is sandwiched between regions of opposite conductivity. The three regions are illustrated as **31**, **32**, **33**, being produced by techniques well-known in the art. Blocking bias, as well as incoming signals, are supplied by source **36** between the intermediate body **32** on the one hand, and the outer two which can be connected together. Electrodes **38**, **40**, **42**, **44**, **46** and **48** are provided on the individual bodies as in the construction of FIG. 1.

The junction construction of FIG. 2 also has two output circuits **52**, **56**. One of these is connected to inter-

Figure B.141: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits.



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mediate body **32** as in the construction of FIG. 1. The second output circuit **56** is connected to both outer bodies **31, 33** in parallel. As a result of this construction, signals in the sandwiched body are subjected to what corresponds to two space charge effects, one at each junction. The voltage amplification of this body will therefore be larger than that of the others. Moreover, signal currents in the outer bodies can be added together by the parallel output connection.

With the construction of FIG. 2 the amplified output is taken from load **54** while load **57** serves merely to maintain the space charge region relatively constant along the junction. For taking a useful output from both loads **54** and **57** depressions similar to those of FIG. 1 must be imposed in the n-regions **31** and **33** completely across the opposing faces of the crystal.

FIGS. 3 and 4 are cross-sectional representations of known prior art devices of the unipolar field effect type. In FIG. 3 the n-region designated as **61** has two electrodes **66, 68** between which an output circuit can be connected. Bias, as well as incoming signals, are supplied between electrode **64** and one of the electrodes **66, 68** using the p-region to produce the gate and the n-region as the channel. In this construction, as well as the construction shown in FIGS. 1 and 2, all of the electrodes are of a non-rectifying nature.

In FIG. 4, however, an area metal contact which extends fully across the width of the crystal is utilized to produce a space charged region which can thus serve as the modulating means for the current flow in the channel. A semiconductor body **70** designated for the purposes of this discussion as having a conductivity of the p-type has spaced output electrodes **72** and **74** of the non-rectifying kind and an intermediate electrode **76** of the rectifying metal type. Thus a space charge effect similar to that described above appears to be provided by the metal electrode **76** when it is electrically biased in the current blocking direction. The bias and the incoming signals are impressed between the metal electrodes **76** and one of the other electrodes. Amplified output signals can be taken thus from between electrodes **72** and **74**. The construction of FIG. 3 is susceptible to breakdown at pinch-off because here, as well as in the Shockley discussion, the space charged region is non-uniform with the junction area. Breakdown additionally may occur rendering the device conducting so that the FIG. 4 construction is limited both in current level, as well as amplification characteristics.

In FIG. 5 is shown an embodiment of the invention constituting an improvement of the unipolar transistor construction shown in FIG. 3. This construction somewhat similar to that of FIG. 3 has a first semiconductive region **81** and a second semiconductive region **82**, the regions having opposite types of conductivity so that a junction exists between them. Output electrodes are illustrated in the form of a central non-rectifying electrode **86** engaging body **81**, and a circular non-rectifying electrode **88** surrounding electrode **86**. Between the two electrodes **86, 88** is produced an annular depression **85** extending into body **81** in order to increase the amplification effect of the device. The depth of the depression should be such as to approach the junction region, e.g. less than 5 mils therefrom. The use of a rotating etch jet as described in the above-identified patent application, Serial No. 460,835 (abandoned), makes a very convenient technique for the annular cutting operation. A suitable biasing electrode of the non-rectifying type can be provided as indicated, for example, at **84**. Using this technique allows close control of the distance between the junction and bottom of cut.

Of course, it is to be understood that where even higher amplification is desired or where it is desired to increase the useful current ranges of the device, thus requiring complete avoidance of the breakdown in the pinch-off region resulting from the non-uniformity of the space charged region, the construction of FIG. 5 is modified to conform to the concept of FIG. 1. This is readily accomplished by imposing a second annular groove on the opposite surface of the crystal of FIG. 5, namely that surface whereon electrode **84** is shown to be imposed.

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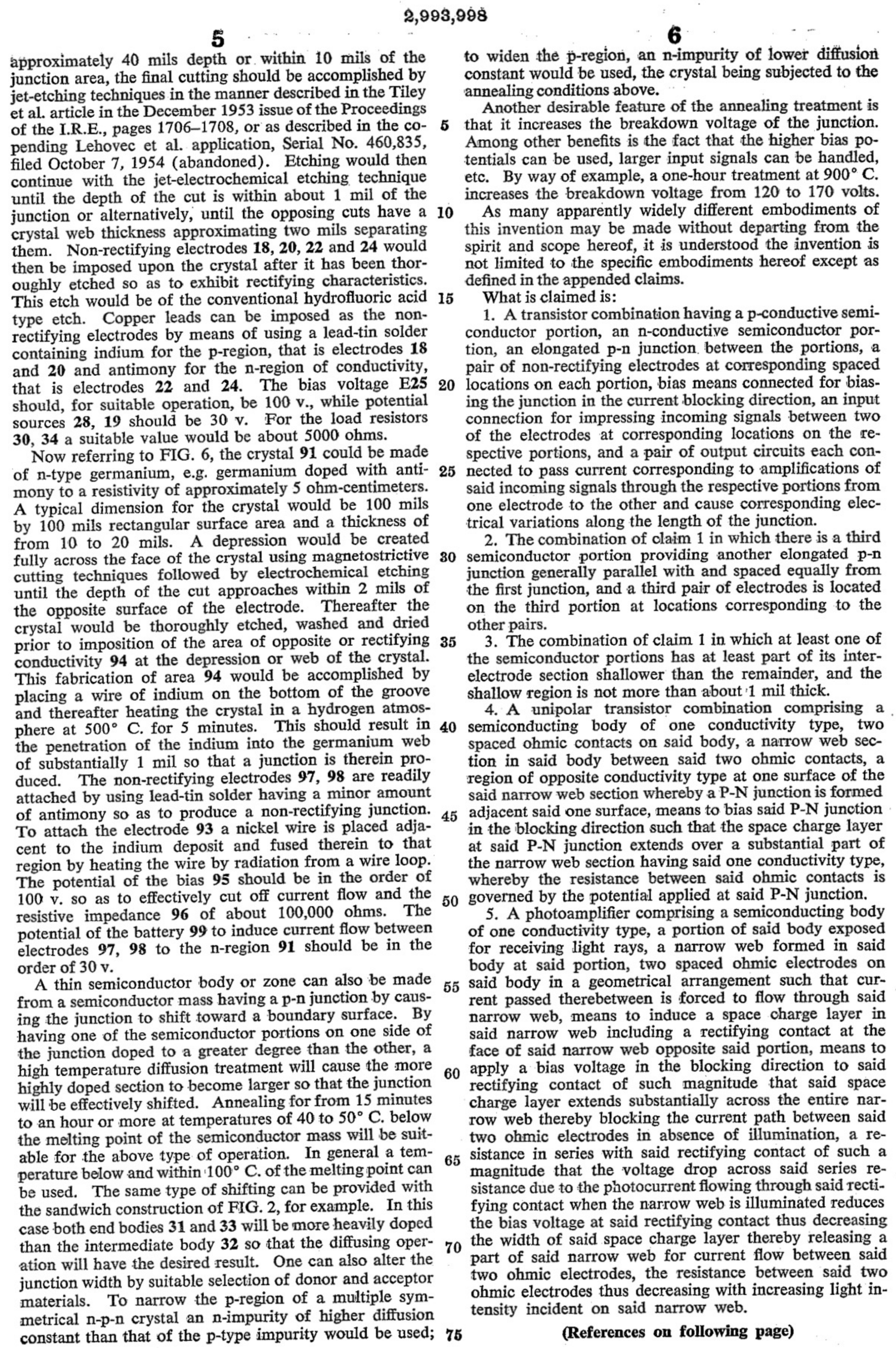
Instead of applying the bias to the same electrodes by which the input signals are impressed, other electrodes can be used. In the construction of FIG. 1, for example, bias can be provided between electrodes **18** and **22**, whereas the input signals can be applied between electrodes **20** and **24**. A similar arrangement can be used in the construction of FIG. 2. Furthermore, the bias need not be applied between correspondingly located electrodes, and can be impressed between electrodes **18** and **24**, for example. The incoming signals can also be applied in this manner.

FIG. 6 shows a further form of unipolar transistor construction most useful as a photosensitive device in which the bulk of the crystal **91** is of one conductivity, e.g. n-type, however a diffused junction exists at the region of the depression. In the depression there is an electrode **93**, and at opposite edges of the crystal are non-rectifying electrodes **97, 98**. The electrode **93** and one of the other non-rectifying electrodes **97** are connected to a high impedance bias source shown as a resistive impedance **96** and a voltage source or battery **95**. When the body **91** of such material is exposed to incident light, current flows across the web between electrode **93** adjacent the irradiation site and the crystal **91**. This current flow reduces the bias imposed by the battery **95** through resistor **96**. Thus the space charge in body **91** adjacent to electrode **93** is reduced allowing greater flow of current in the channel between non-rectifying electrodes **97, 98**.

The voltage source **95** biases the electrode **97** in the current-blocking direction. With the impedance **96** relatively low as compared to the blocking impedance of the un-illuminated junction, the potential of source **95** is essentially entirely impressed across this junction **94**. When irradiation takes place, the impedance of the junction is sharply diminished so that the potential across the junction **94** is greatly lowered. The lowering of the potential across the blocking junction causes a corresponding amplified change in the current passed between output electrodes **97, 98** as a result of the decrease of the space charge region. The photoelectric output of the construction of FIG. 6 will accordingly be much higher than that conventionally obtained from present devices, and has a sensitivity to radiation which is remarkable.

Although it is to be fully understood that the following specific examples are representative of the best constructions known to us, they should not in any way limit the scope of the instant invention. Reference should now be made to the drawing of FIG. 1 wherein in its preparation one would take a rectangular slab of p-n junction crystal produced by surface melting techniques or other techniques known to the art, and properly dimension the crystal as follows: The crystal could be a cube of 100 mils in each dimension with the junction region substantially in the center of the plane of the cube. Such a crystal would be of germanium and have for the p-impurity indium and for the n-impurity antimony, with each region of conductivity having a resistivity in the order of 5 ohm-centimeters. As indicated above, such a crystal could be produced by any of the known techniques including the surface melting technique fully disclosed in the copending application of Lehovec et al., Serial No. 364,138, filed June 25, 1953 (abandoned). The depressions **16, 17** should be then imposed across the opposing faces of the crystal first by magnetostrictive cutting with an appropriate tool, which technique is fully disclosed in United States Patent No. 2,580,716. The width of this cut would be approximately 15 mils and extend with vertical sides down to the region adjacent to the junction. After the magnetostrictive cutting has produced a depression of

Figure B.142: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits.



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approximately 40 mils depth or within 10 mils of the junction area, the final cutting should be accomplished by jet-etching techniques in the manner described in the Tiley et al. article in the December 1953 issue of the Proceedings of the I.R.E., pages 1706–1708, or as described in the copending Lehovec et al. application, Serial No. 460,835, filed October 7, 1954 (abandoned). Etching would then continue with the jet-electrochemical etching technique until the depth of the cut is within about 1 mil of the junction or alternatively, until the opposing cuts have a crystal web thickness approximating two mils separating them. Non-rectifying electrodes **18**, **20**, **22** and **24** would then be imposed upon the crystal after it has been thoroughly etched so as to exhibit rectifying characteristics. This etch would be of the conventional hydrofluoric acid type etch. Copper leads can be imposed as the non-rectifying electrodes by means of using a lead-tin solder containing indium for the p-region, that is electrodes **18** and **20** and antimony for the n-region of conductivity, that is electrodes **22** and **24**. The bias voltage E**25** should, for suitable operation, be 100 v., while potential sources **28**, **19** should be 30 v. For the load resistors **30**, **34** a suitable value would be about 5000 ohms.

Now referring to FIG. 6, the crystal **91** could be made of n-type germanium, e.g. germanium doped with antimony to a resistivity of approximately 5 ohm-centimeters. A typical dimension for the crystal would be 100 mils by 100 mils rectangular surface area and a thickness of from 10 to 20 mils. A depression would be created fully across the face of the crystal using magnetostrictive cutting techniques followed by electrochemical etching until the depth of the cut approaches within 2 mils of the opposite surface of the electrode. Thereafter the crystal would be thoroughly etched, washed and dried prior to imposition of the area of opposite or rectifying conductivity **94** at the depression or web of the crystal. This fabrication of area **94** would be accomplished by placing a wire of indium on the bottom of the groove and thereafter heating the crystal in a hydrogen atmosphere at 500° C. for 5 minutes. This should result in the penetration of the indium into the germanium web of substantially 1 mil so that a junction is therein produced. The non-rectifying electrodes **97**, **98** are readily attached by using lead-tin solder having a minor amount of antimony so as to produce a non-rectifying junction. To attach the electrode **93** a nickel wire is placed adjacent to the indium deposit and fused therein to that region by heating the wire by radiation from a wire loop. The potential of the bias **95** should be in the order of 100 v. so as to effectively cut off current flow and the resistive impedance **96** of about 100,000 ohms. The potential of the battery **99** to induce current flow between electrodes **97**, **98** to the n-region **91** should be in the order of 30 v.

A thin semiconductor body or zone can also be made from a semiconductor mass having a p-n junction by causing the junction to shift toward a boundary surface. By having one of the semiconductor portions on one side of the junction doped to a greater degree than the other, a high temperature diffusion treatment will cause the more highly doped section to become larger so that the junction will be effectively shifted. Annealing for from 15 minutes to an hour or more at temperatures of 40 to 50° C. below the melting point of the semiconductor mass will be suitable for the above type of operation. In general a temperature below and within 100° C. of the melting point can be used. The same type of shifting can be provided with the sandwich construction of FIG. 2, for example. In this case both end bodies **31** and **33** will be more heavily doped than the intermediate body **32** so that the diffusing operation will have the desired result. One can also alter the junction width by suitable selection of donor and acceptor materials. To narrow the p-region of a multiple symmetrical n-p-n crystal an n-impurity of higher diffusion constant than that of the p-type impurity would be used;

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to widen the p-region, an n-impurity of lower diffusion constant would be used, the crystal being subjected to the annealing conditions above.

Another desirable feature of the annealing treatment is that it increases the breakdown voltage of the junction. Among other benefits is the fact that the higher bias potentials can be used, larger input signals can be handled, etc. By way of example, a one-hour treatment at 900° C. increases the breakdown voltage from 120 to 170 volts.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope hereof, it is understood the invention is not limited to the specific embodiments hereof except as defined in the appended claims.

What is claimed is:

1. A transistor combination having a p-conductive semiconductor portion, an n-conductive semiconductor portion, an elongated p-n junction between the portions, a pair of non-rectifying electrodes at corresponding spaced locations on each portion, bias means connected for biasing the junction in the current blocking direction, an input connection for impressing incoming signals between two of the electrodes at corresponding locations on the respective portions, and a pair of output circuits each connected to pass current corresponding to amplifications of said incoming signals through the respective portions from one electrode to the other and cause corresponding electrical variations along the length of the junction.

2. The combination of claim 1 in which there is a third semiconductor portion providing another elongated p-n junction generally parallel with and spaced equally from the first junction, and a third pair of electrodes is located on the third portion at locations corresponding to the other pairs.

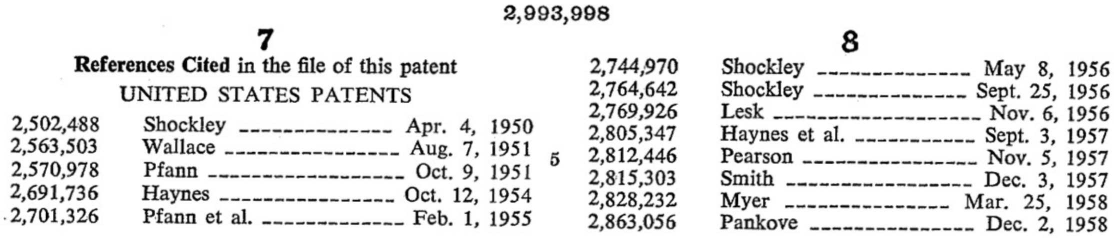
3. The combination of claim 1 in which at least one of the semiconductor portions has at least part of its inter-electrode section shallower than the remainder, and the shallow region is not more than about 1 mil thick.

4. A unipolar transistor combination comprising a semiconducting body of one conductivity type, two spaced ohmic contacts on said body, a narrow web section in said body between said two ohmic contacts, a region of opposite conductivity type at one surface of the said narrow web section whereby a P-N junction is formed adjacent said one surface, means to bias said P-N junction in the blocking direction such that the space charge layer at said P-N junction extends over a substantial part of the narrow web section having said one conductivity type, whereby the resistance between said ohmic contacts is governed by the potential applied at said P-N junction.

5. A photoamplifier comprising a semiconducting body of one conductivity type, a portion of said body exposed for receiving light rays, a narrow web formed in said body at said portion, two spaced ohmic electrodes on said body in a geometrical arrangement such that current passed therebetween is forced to flow through said narrow web, means to induce a space charge layer in said narrow web including a rectifying contact at the face of said narrow web opposite said portion, means to apply a bias voltage in the blocking direction to said rectifying contact of such magnitude that said space charge layer extends substantially across the entire narrow web thereby blocking the current path between said two ohmic electrodes in absence of illumination, a resistance in series with said rectifying contact of such a magnitude that the voltage drop across said series resistance due to the photocurrent flowing through said rectifying contact when the narrow web is illuminated reduces the bias voltage at said rectifying contact thus decreasing the width of said space charge layer thereby releasing a part of said narrow web for current flow between said two ohmic electrodes, the resistance between said two ohmic electrodes thus decreasing with increasing light intensity incident on said narrow web.

(References on following page)

Figure B.143: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits.



2,993,998

7

References Cited in the file of this patent

UNITED STATES PATENTS

2,502,488	Shockley	Apr. 4, 1950
2,563,503	Wallace	Aug. 7, 1951
2,570,978	Pfann	Oct. 9, 1951
2,691,736	Haynes	Oct. 12, 1954
2,701,326	Pfann et al.	Feb. 1, 1955

8

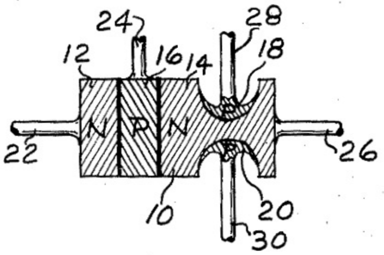
2,744,970	Shockley	May 8, 1956
2,764,642	Shockley	Sept. 25, 1956
2,769,926	Lesk	Nov. 6, 1956
2,805,347	Haynes et al.	Sept. 3, 1957
2,812,446	Pearson	Nov. 5, 1957
2,815,303	Smith	Dec. 3, 1957
2,828,232	Myer	Mar. 25, 1958
2,863,056	Pankove	Dec. 2, 1958

Figure B.144: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits.

Jan. 29, 1957 K. LEHOVEC **2,779,877**

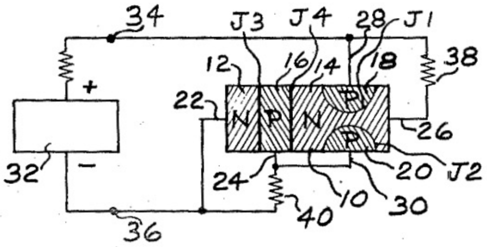
MULTIPLE JUNCTION TRANSISTOR UNIT

Filed June 17, 1955



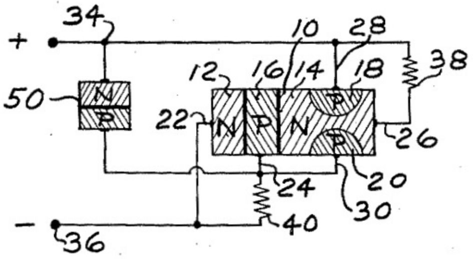
24
28
12
16
14
18
N
P
N
P
P
22
26
10
20
30

FIG. 1



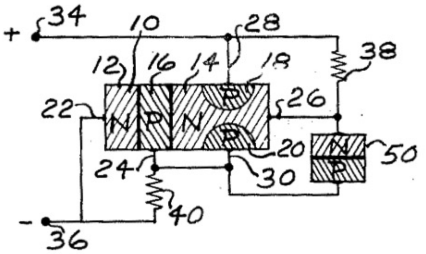
34
J3
J4
28
J1
38
12
16
14
18
+
22
N
P
N
P
P
26
32
−
24
20
J2
10
30
40
36

FIG. 2



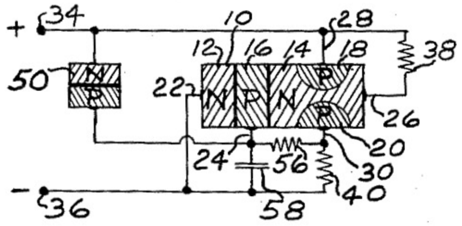
+
34
10
28
38
12
16
14
18
50
N
P
22
N
P
N
P
P
26
24
20
30
−
40
36

FIG. 3



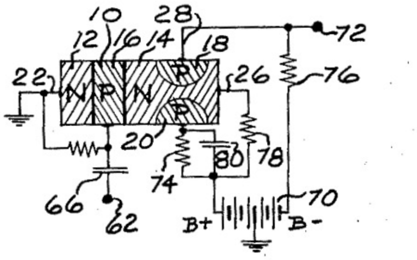
+
34
10
28
38
12
16
14
18
22
N
P
N
P
P
26
N
P
50
20
24
30
40
−
36

FIG. 4



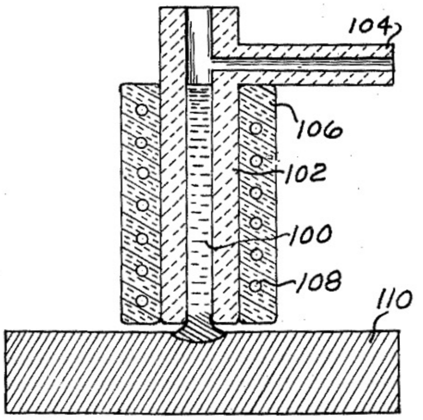
+
34
10
28
38
12
16
14
18
50
N
P
22
N
P
N
P
P
26
20
24
56
30
58
40
−
36

FIG. 5



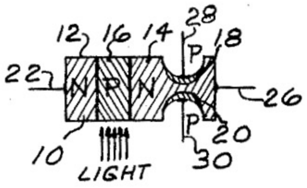
10
28
72
12
16
14
18
22
N
P
N
P
P
26
76
20
78
80
74
66
62
70
B+
B-

FIG. 6



104
106
102
100
108
110

FIG. 8

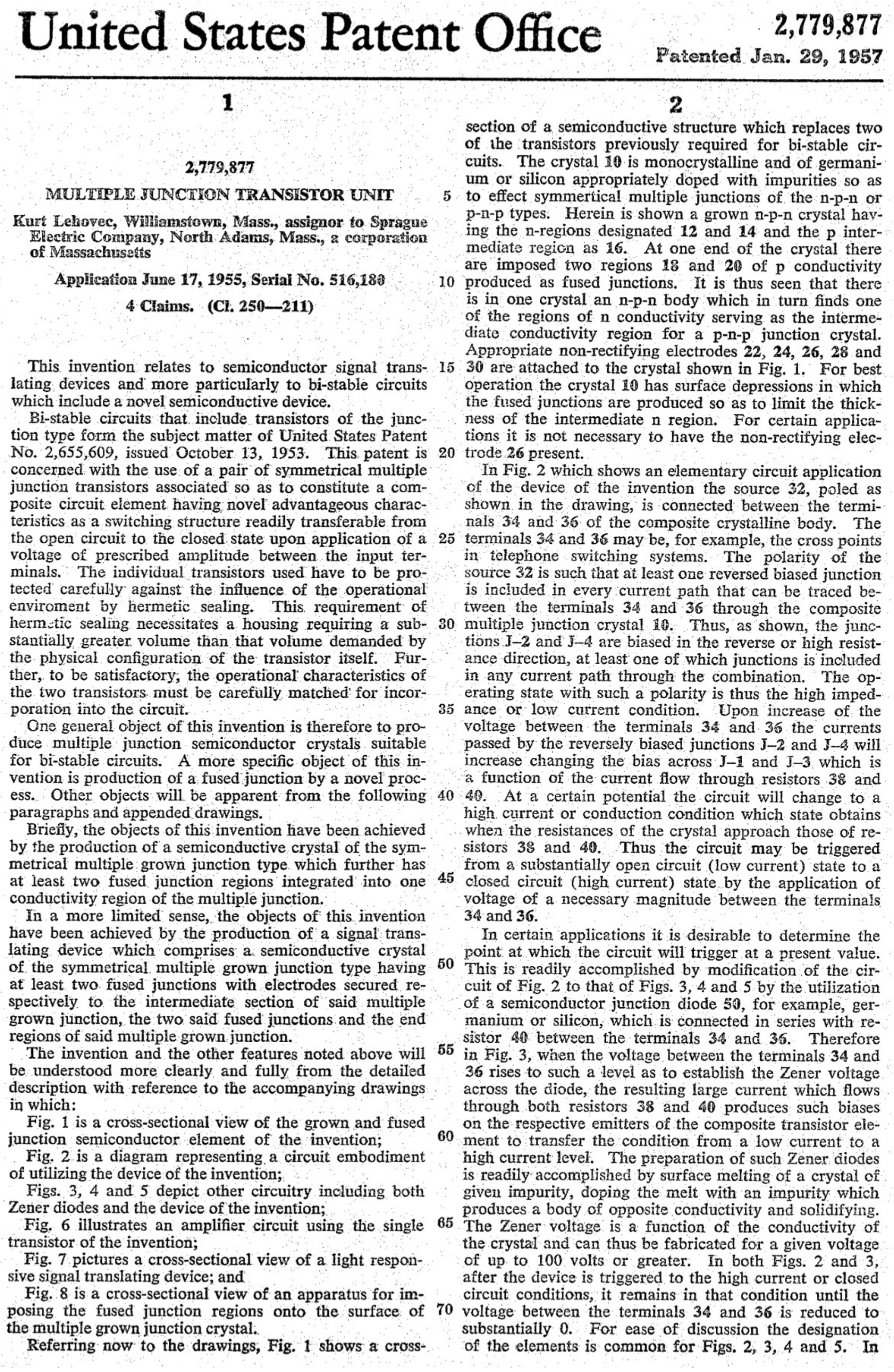


12
16
14
28
P
18
22
N
P
N
26
P
20
10
30
LIGHT

FIG. 7

INVENTOR.
KURT LEHOVEC
BY
Roland Dexter
HIS ATTORNEY

Figure B.145: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits.



United States Patent Office

2,779,877
Patented Jan. 29, 1957

2,779,877

MULTIPLE JUNCTION TRANSISTOR UNIT

Kurt Lehovec, Williamstown, Mass., assignor to Sprague Electric Company, North Adams, Mass., a corporation of Massachusetts

Application June 17, 1955, Serial No. 516,180

4 Claims. (Cl. 250—211)

This invention relates to semiconductor signal translating devices and more particularly to bi-stable circuits which include a novel semiconductive device.

Bi-stable circuits that include transistors of the junction type form the subject matter of United States Patent No. 2,655,609, issued October 13, 1953. This patent is concerned with the use of a pair of symmetrical multiple junction transistors associated so as to constitute a composite circuit element having novel advantageous characteristics as a switching structure readily transferable from the open circuit to the closed state upon application of a voltage of prescribed amplitude between the input terminals. The individual transistors used have to be protected carefully against the influence of the operational enviroment by hermetic sealing. This requirement of hermetic sealing necessitates a housing requiring a substantially greater volume than that volume demanded by the physical configuration of the transistor itself. Further, to be satisfactory, the operational characteristics of the two transistors must be carefully matched for incorporation into the circuit.

One general object of this invention is therefore to produce multiple junction semiconductor crystals suitable for bi-stable circuits. A more specific object of this invention is production of a fused junction by a novel process. Other objects will be apparent from the following paragraphs and appended drawings.

Briefly, the objects of this invention have been achieved by the production of a semiconductive crystal of the symmetrical multiple grown junction type which further has at least two fused junction regions integrated into one conductivity region of the multiple junction.

In a more limited sense, the objects of this invention have been achieved by the production of a signal translating device which comprises a semiconductive crystal of the symmetrical multiple grown junction type having at least two fused junctions with electrodes secured respectively to the intermediate section of said multiple grown junction, the two said fused junctions and the end regions of said multiple grown junction.

The invention and the other features noted above will be understood more clearly and fully from the detailed description with reference to the accompanying drawings in which:

Fig. 1 is a cross-sectional view of the grown and fused junction semiconductor element of the invention;

Fig. 2 is a diagram representing a circuit embodiment of utilizing the device of the invention;

Figs. 3, 4 and 5 depict other circuitry including both Zener diodes and the device of the invention;

Fig. 6 illustrates an amplifier circuit using the single transistor of the invention;

Fig. 7 pictures a cross-sectional view of a light responsive signal translating device; and

Fig. 8 is a cross-sectional view of an apparatus for imposing the fused junction regions onto the surface of the multiple grown junction crystal.

Referring now to the drawings, Fig. 1 shows a cross-section of a semiconductive structure which replaces two of the transistors previously required for bi-stable circuits. The crystal 10 is monocrystalline and of germanium or silicon appropriately doped with impurities so as to effect symmertical multiple junctions of the n-p-n or p-n-p types. Herein is shown a grown n-p-n crystal having the n-regions designated 12 and 14 and the p intermediate region as 16. At one end of the crystal there are imposed two regions 18 and 20 of p conductivity produced as fused junctions. It is thus seen that there is in one crystal an n-p-n body which in turn finds one of the regions of n conductivity serving as the intermediate conductivity region for a p-n-p junction crystal. Appropriate non-rectifying electrodes 22, 24, 26, 28 and 30 are attached to the crystal shown in Fig. 1. For best operation the crystal 10 has surface depressions in which the fused junctions are produced so as to limit the thickness of the intermediate n region. For certain applications it is not necessary to have the non-rectifying electrode 26 present.

In Fig. 2 which shows an elementary circuit application of the device of the invention the source 32, poled as shown in the drawing, is connected between the terminals 34 and 36 of the composite crystalline body. The terminals 34 and 36 may be, for example, the cross points in telephone switching systems. The polarity of the source 32 is such that at least one reversed biased junction is included in every current path that can be traced between the terminals 34 and 36 through the composite multiple junction crystal 10. Thus, as shown, the junctions J–2 and J–4 are biased in the reverse or high resistance direction, at least one of which junctions is included in any current path through the combination. The operating state with such a polarity is thus the high impedance or low current condition. Upon increase of the voltage between the terminals 34 and 36 the currents passed by the reversely biased junctions J–2 and J–4 will increase changing the bias across J–1 and J–3 which is a function of the current flow through resistors 38 and 40. At a certain potential the circuit will change to a high current or conduction condition which state obtains when the resistances of the crystal approach those of resistors 38 and 40. Thus the circuit may be triggered from a substantially open circuit (low current) state to a closed circuit (high current) state by the application of voltage of a necessary magnitude between the terminals 34 and 36.

In certain applications it is desirable to determine the point at which the circuit will trigger at a present value. This is readily accomplished by modification of the circuit of Fig. 2 to that of Figs. 3, 4 and 5 by the utilization of a semiconductor junction diode 50, for example, germanium or silicon, which is connected in series with resistor 40 between the terminals 34 and 36. Therefore in Fig. 3, when the voltage between the terminals 34 and 36 rises to such a level as to establish the Zener voltage across the diode, the resulting large current which flows through both resistors 38 and 40 produces such biases on the respective emitters of the composite transistor element to transfer the condition from a low current to a high current level. The preparation of such Zener diodes is readily accomplished by surface melting of a crystal of given impurity, doping the melt with an impurity which produces a body of opposite conductivity and solidifying. The Zener voltage is a function of the conductivity of the crystal and can thus be fabricated for a given voltage of up to 100 volts or greater. In both Figs. 2 and 3, after the device is triggered to the high current or closed circuit conditions, it remains in that condition until the voltage between the terminals 34 and 36 is reduced to substantially 0. For ease of discussion the designation of the elements is common for Figs. 2, 3, 4 and 5. In

Figure B.146: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits.

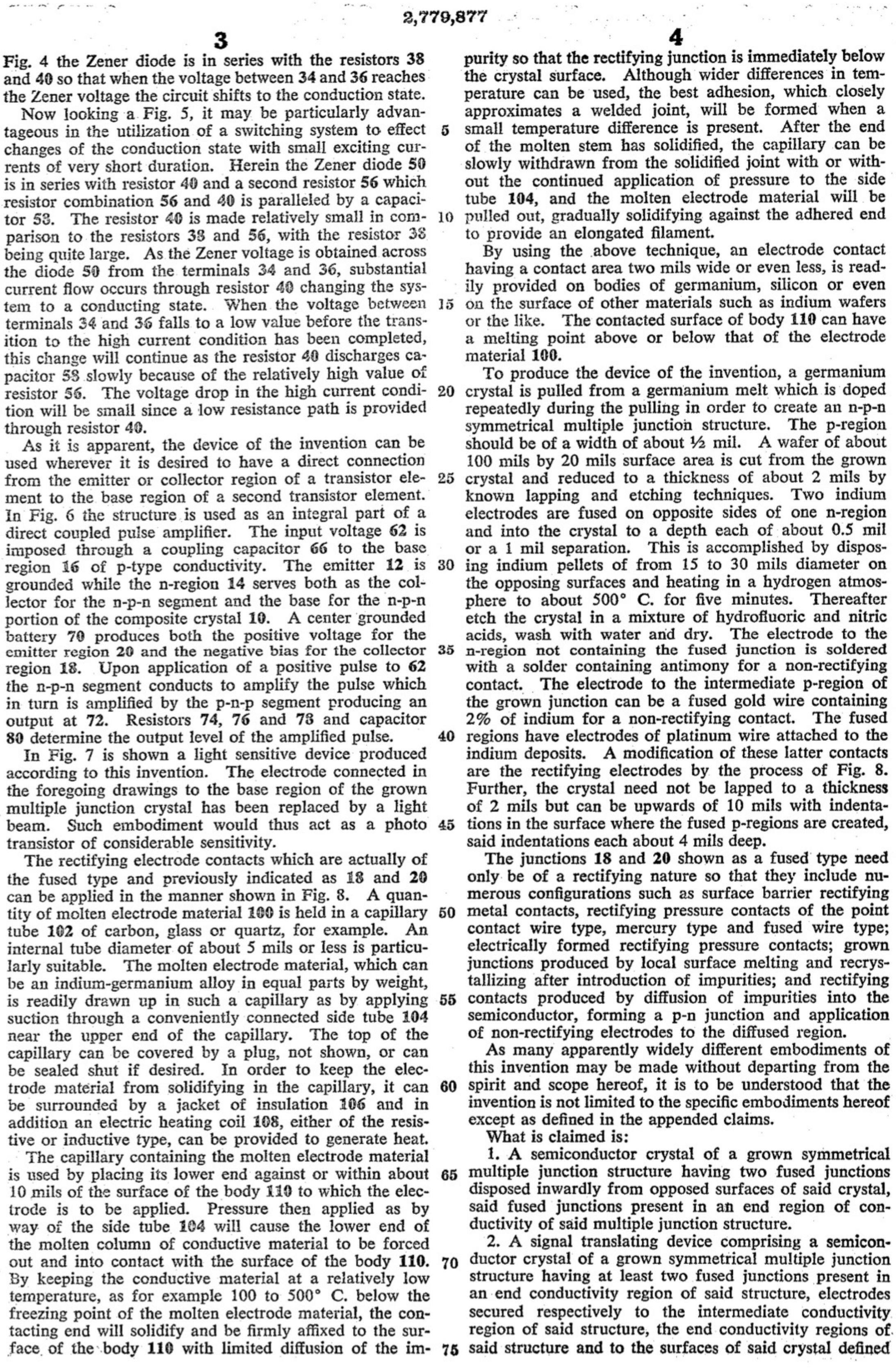


Fig. 4 the Zener diode is in series with the resistors **38** and **40** so that when the voltage between **34** and **36** reaches the Zener voltage the circuit shifts to the conduction state.

Now looking a Fig. 5, it may be particularly advantageous in the utilization of a switching system to effect changes of the conduction state with small exciting currents of very short duration. Herein the Zener diode **50** is in series with resistor **40** and a second resistor **56** which resistor combination **56** and **40** is paralleled by a capacitor **58**. The resistor **40** is made relatively small in comparison to the resistors **38** and **56**, with the resistor **38** being quite large. As the Zener voltage is obtained across the diode **50** from the terminals **34** and **36**, substantial current flow occurs through resistor **40** changing the system to a conducting state. When the voltage between terminals **34** and **36** falls to a low value before the transition to the high current condition has been completed, this change will continue as the resistor **40** discharges capacitor **58** slowly because of the relatively high value of resistor **56**. The voltage drop in the high current condition will be small since a low resistance path is provided through resistor **40**.

As it is apparent, the device of the invention can be used wherever it is desired to have a direct connection from the emitter or collector region of a transistor element to the base region of a second transistor element. In Fig. 6 the structure is used as an integral part of a direct coupled pulse amplifier. The input voltage **62** is imposed through a coupling capacitor **66** to the base region **16** of p-type conductivity. The emitter **12** is grounded while the n-region **14** serves both as the collector for the n-p-n segment and the base for the n-p-n portion of the composite crystal **10**. A center grounded battery **70** produces both the positive voltage for the emitter region **20** and the negative bias for the collector region **18**. Upon application of a positive pulse to **62** the n-p-n segment conducts to amplify the pulse which in turn is amplified by the p-n-p segment producing an output at **72**. Resistors **74**, **76** and **78** and capacitor **80** determine the output level of the amplified pulse.

In Fig. 7 is shown a light sensitive device produced according to this invention. The electrode connected in the foregoing drawings to the base region of the grown multiple junction crystal has been replaced by a light beam. Such embodiment would thus act as a photo transistor of considerable sensitivity.

The rectifying electrode contacts which are actually of the fused type and previously indicated as **18** and **20** can be applied in the manner shown in Fig. 8. A quantity of molten electrode material **100** is held in a capillary tube **102** of carbon, glass or quartz, for example. An internal tube diameter of about 5 mils or less is particularly suitable. The molten electrode material, which can be an indium-germanium alloy in equal parts by weight, is readily drawn up in such a capillary as by applying suction through a conveniently connected side tube **104** near the upper end of the capillary. The top of the capillary can be covered by a plug, not shown, or can be sealed shut if desired. In order to keep the electrode material from solidifying in the capillary, it can be surrounded by a jacket of insulation **106** and in addition an electric heating coil **108**, either of the resistive or inductive type, can be provided to generate heat.

The capillary containing the molten electrode material is used by placing its lower end against or within about 10 mils of the surface of the body **110** to which the electrode is to be applied. Pressure then applied as by way of the side tube **104** will cause the lower end of the molten column of conductive material to be forced out and into contact with the surface of the body **110**. By keeping the conductive material at a relatively low temperature, as for example 100 to 500° C. below the freezing point of the molten electrode material, the contacting end will solidify and be firmly affixed to the surface of the body **110** with limited diffusion of the impurity so that the rectifying junction is immediately below the crystal surface. Although wider differences in temperature can be used, the best adhesion, which closely approximates a welded joint, will be formed when a small temperature difference is present. After the end of the molten stem has solidified, the capillary can be slowly withdrawn from the solidified joint with or without the continued application of pressure to the side tube **104**, and the molten electrode material will be pulled out, gradually solidifying against the adhered end to provide an elongated filament.

By using the above technique, an electrode contact having a contact area two mils wide or even less, is readily provided on bodies of germanium, silicon or even on the surface of other materials such as indium wafers or the like. The contacted surface of body **110** can have a melting point above or below that of the electrode material **100**.

To produce the device of the invention, a germanium crystal is pulled from a germanium melt which is doped repeatedly during the pulling in order to create an n-p-n symmetrical multiple junction structure. The p-region should be of a width of about ½ mil. A wafer of about 100 mils by 20 mils surface area is cut from the grown crystal and reduced to a thickness of about 2 mils by known lapping and etching techniques. Two indium electrodes are fused on opposite sides of one n-region and into the crystal to a depth each of about 0.5 mil or a 1 mil separation. This is accomplished by disposing indium pellets of from 15 to 30 mils diameter on the opposing surfaces and heating in a hydrogen atmosphere to about 500° C. for five minutes. Thereafter etch the crystal in a mixture of hydrofluoric and nitric acids, wash with water and dry. The electrode to the n-region not containing the fused junction is soldered with a solder containing antimony for a non-rectifying contact. The electrode to the intermediate p-region of the grown junction can be a fused gold wire containing 2% of indium for a non-rectifying contact. The fused regions have electrodes of platinum wire attached to the indium deposits. A modification of these latter contacts are the rectifying electrodes by the process of Fig. 8. Further, the crystal need not be lapped to a thickness of 2 mils but can be upwards of 10 mils with indentations in the surface where the fused p-regions are created, said indentations each about 4 mils deep.

The junctions **18** and **20** shown as a fused type need only be of a rectifying nature so that they include numerous configurations such as surface barrier rectifying metal contacts, rectifying pressure contacts of the point contact wire type, mercury type and fused wire type; electrically formed rectifying pressure contacts; grown junctions produced by local surface melting and recrystallizing after introduction of impurities; and rectifying contacts produced by diffusion of impurities into the semiconductor, forming a p-n junction and application of non-rectifying electrodes to the diffused region.

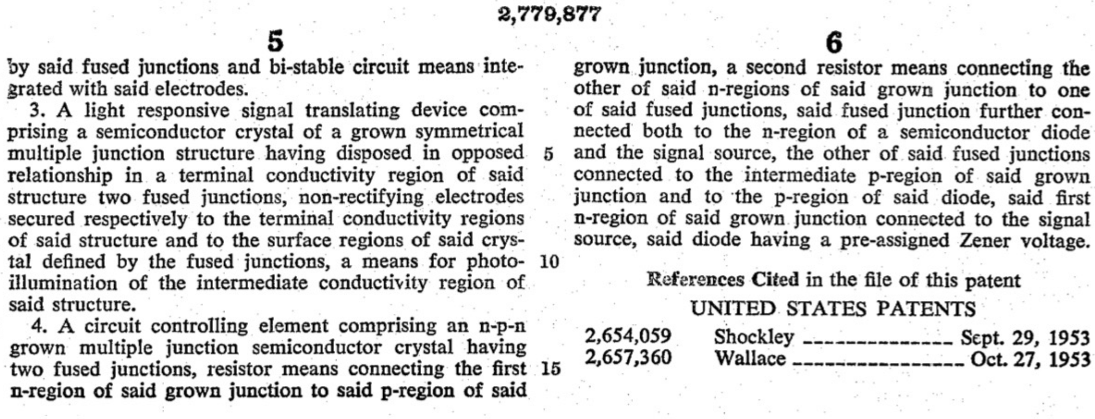
As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope hereof, it is to be understood that the invention is not limited to the specific embodiments hereof except as defined in the appended claims.

What is claimed is:

1. A semiconductor crystal of a grown symmetrical multiple junction structure having two fused junctions disposed inwardly from opposed surfaces of said crystal, said fused junctions present in an end region of conductivity of said multiple junction structure.

2. A signal translating device comprising a semiconductor crystal of a grown symmetrical multiple junction structure having at least two fused junctions present in an end conductivity region of said structure, electrodes secured respectively to the intermediate conductivity region of said structure, the end conductivity regions of said structure and to the surfaces of said crystal defined

Figure B.147: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits.



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by said fused junctions and bi-stable circuit means integrated with said electrodes.

3. A light responsive signal translating device comprising a semiconductor crystal of a grown symmetrical multiple junction structure having disposed in opposed relationship in a terminal conductivity region of said structure two fused junctions, non-rectifying electrodes secured respectively to the terminal conductivity regions of said structure and to the surface regions of said crystal defined by the fused junctions, a means for photo-illumination of the intermediate conductivity region of said structure.

4. A circuit controlling element comprising an n-p-n grown multiple junction semiconductor crystal having two fused junctions, resistor means connecting the first n-region of said grown junction to said p-region of said grown junction, a second resistor means connecting the other of said n-regions of said grown junction to one of said fused junctions, said fused junction further connected both to the n-region of a semiconductor diode and the signal source, the other of said fused junctions connected to the intermediate p-region of said grown junction and to the p-region of said diode, said first n-region of said grown junction connected to the signal source, said diode having a pre-assigned Zener voltage.

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References Cited in the file of this patent

UNITED STATES PATENTS

2,654,059	Shockley	Sept. 29, 1953
2,657,360	Wallace	Oct. 27, 1953

Figure B.148: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits.

April 10, 1962 **K. LEHOVEC** **3,029,366**

MULTIPLE SEMICONDUCTOR ASSEMBLY

Filed April 22, 1959

Fig.1.

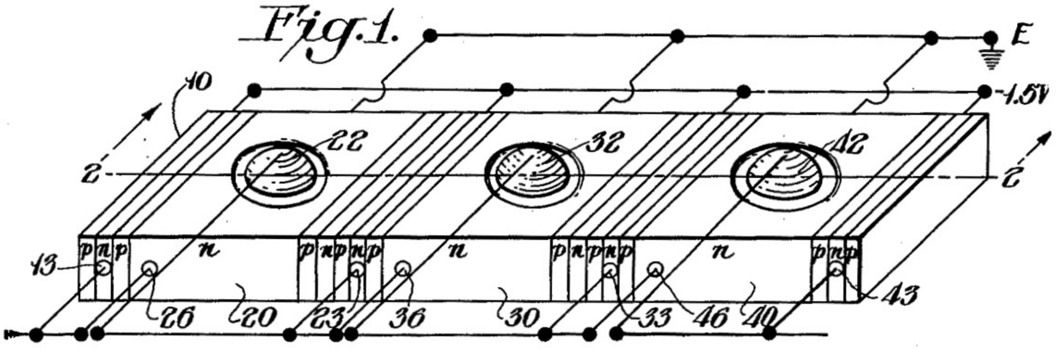
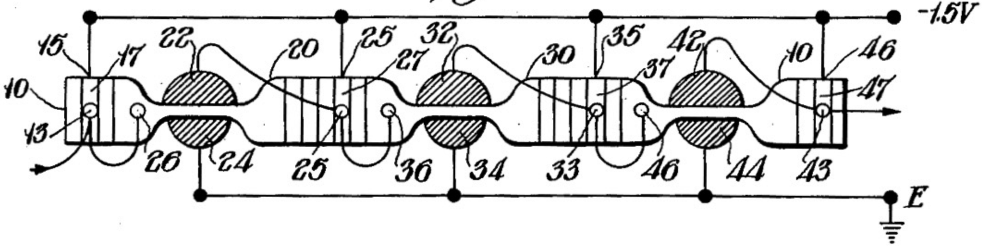

E
-1.5V
40
22
32
42
2
2
13
p n p
n
p n p n p
n
p n p n p
n
p n p
43
26
20
23
36
30
33
46
40

Fig.2.


-1.5V
45
17
22
20
25
32
27
30
35
37
42
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40
13
26
24
25
36
34
33
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43
E

Fig.3.

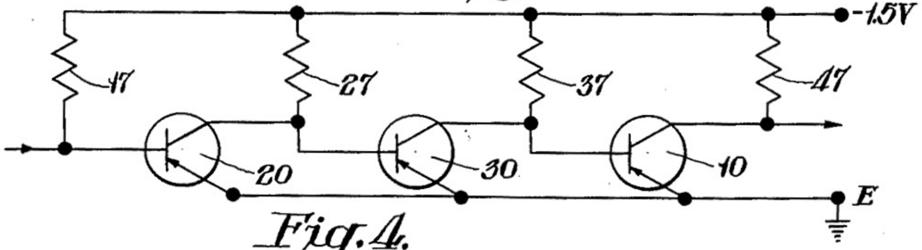

-1.5V
17
27
37
47
20
30
40
E

Fig.4.

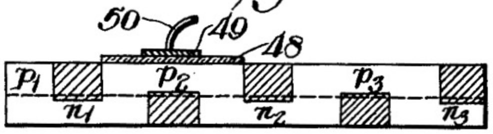
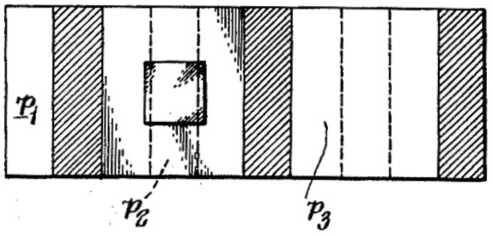

50
49
48
P1
P2
P3
n1
n2
n3

Fig.5.



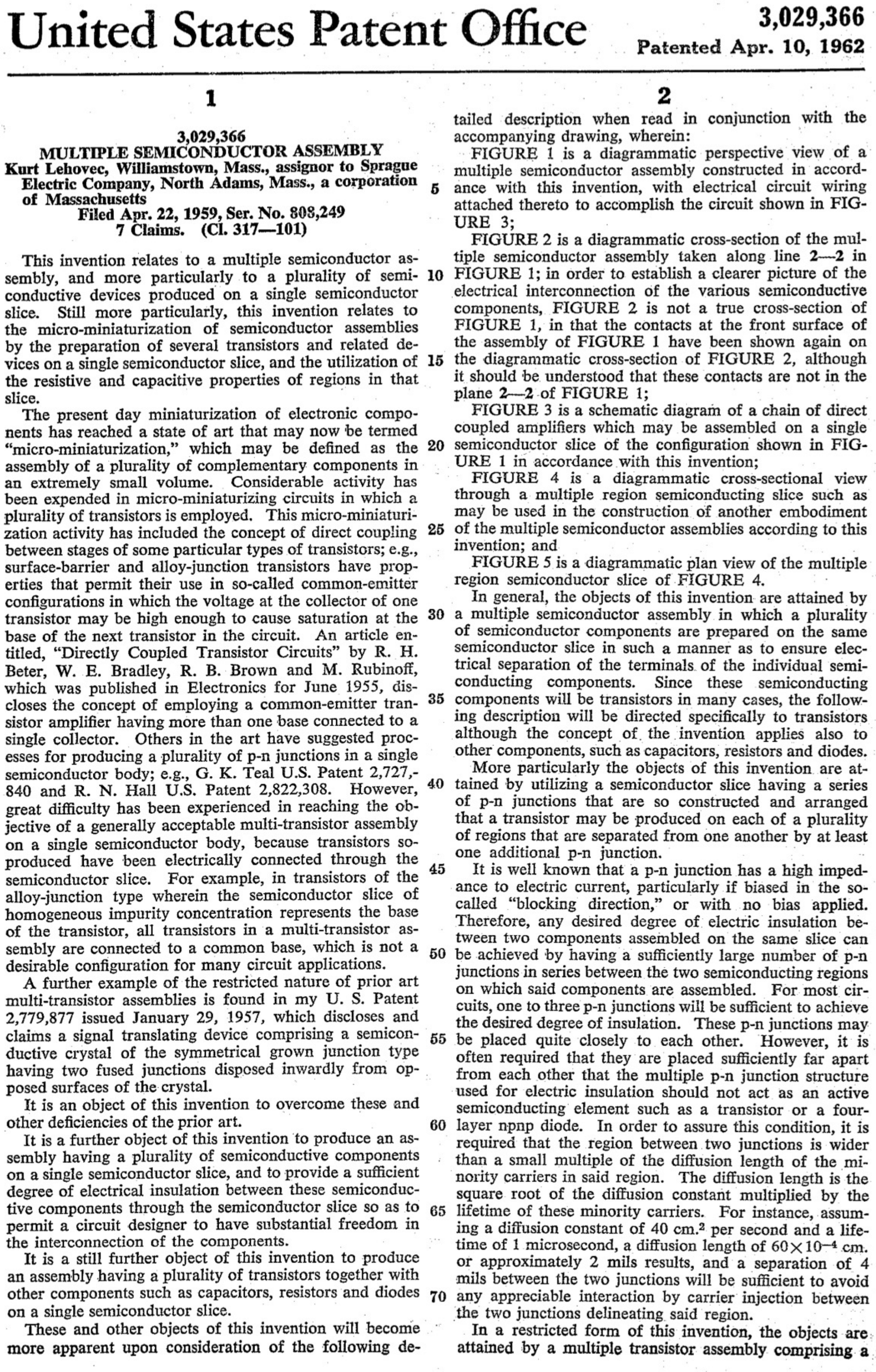
INVENTOR

Kurt Lehovec

BY Connolly and Hutz

ATTORNEYS

Figure B.149: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits.



United States Patent Office

3,029,366
Patented Apr. 10, 1962

3,029,366

MULTIPLE SEMICONDUCTOR ASSEMBLY

Kurt Lehovec, Williamstown, Mass., assignor to Sprague Electric Company, North Adams, Mass., a corporation of Massachusetts
Filed Apr. 22, 1959, Ser. No. 808,249
7 Claims. (Cl. 317—101)

This invention relates to a multiple semiconductor assembly, and more particularly to a plurality of semiconductive devices produced on a single semiconductor slice. Still more particularly, this invention relates to the micro-miniaturization of semiconductor assemblies by the preparation of several transistors and related devices on a single semiconductor slice, and the utilization of the resistive and capacitive properties of regions in that slice.

The present day miniaturization of electronic components has reached a state of art that may now be termed "micro-miniaturization," which may be defined as the assembly of a plurality of complementary components in an extremely small volume. Considerable activity has been expended in micro-miniaturizing circuits in which a plurality of transistors is employed. This micro-miniaturization activity has included the concept of direct coupling between stages of some particular types of transistors; e.g., surface-barrier and alloy-junction transistors have properties that permit their use in so-called common-emitter configurations in which the voltage at the collector of one transistor may be high enough to cause saturation at the base of the next transistor in the circuit. An article entitled, "Directly Coupled Transistor Circuits" by R. H. Beter, W. E. Bradley, R. B. Brown and M. Rubinoff, which was published in Electronics for June 1955, discloses the concept of employing a common-emitter transistor amplifier having more than one base connected to a single collector. Others in the art have suggested processes for producing a plurality of p-n junctions in a single semiconductor body; e.g., G. K. Teal U.S. Patent 2,727,840 and R. N. Hall U.S. Patent 2,822,308. However, great difficulty has been experienced in reaching the objective of a generally acceptable multi-transistor assembly on a single semiconductor body, because transistors so-produced have been electrically connected through the semiconductor slice. For example, in transistors of the alloy-junction type wherein the semiconductor slice of homogeneous impurity concentration represents the base of the transistor, all transistors in a multi-transistor assembly are connected to a common base, which is not a desirable configuration for many circuit applications.

A further example of the restricted nature of prior art multi-transistor assemblies is found in my U. S. Patent 2,779,877 issued January 29, 1957, which discloses and claims a signal translating device comprising a semiconductive crystal of the symmetrical grown junction type having two fused junctions disposed inwardly from opposed surfaces of the crystal.

It is an object of this invention to overcome these and other deficiencies of the prior art.

It is a further object of this invention to produce an assembly having a plurality of semiconductive components on a single semiconductor slice, and to provide a sufficient degree of electrical insulation between these semiconductive components through the semiconductor slice so as to permit a circuit designer to have substantial freedom in the interconnection of the components.

It is a still further object of this invention to produce an assembly having a plurality of transistors together with other components such as capacitors, resistors and diodes on a single semiconductor slice.

These and other objects of this invention will become more apparent upon consideration of the following detailed description when read in conjunction with the accompanying drawing, wherein:

FIGURE 1 is a diagrammatic perspective view of a multiple semiconductor assembly constructed in accordance with this invention, with electrical circuit wiring attached thereto to accomplish the circuit shown in FIGURE 3;

FIGURE 2 is a diagrammatic cross-section of the multiple semiconductor assembly taken along line 2—2 in FIGURE 1; in order to establish a clearer picture of the electrical interconnection of the various semiconductive components, FIGURE 2 is not a true cross-section of FIGURE 1, in that the contacts at the front surface of the assembly of FIGURE 1 have been shown again on the diagrammatic cross-section of FIGURE 2, although it should be understood that these contacts are not in the plane 2—2 of FIGURE 1;

FIGURE 3 is a schematic diagram of a chain of direct coupled amplifiers which may be assembled on a single semiconductor slice of the configuration shown in FIGURE 1 in accordance with this invention;

FIGURE 4 is a diagrammatic cross-sectional view through a multiple region semiconducting slice such as may be used in the construction of another embodiment of the multiple semiconductor assemblies according to this invention; and

FIGURE 5 is a diagrammatic plan view of the multiple region semiconductor slice of FIGURE 4.

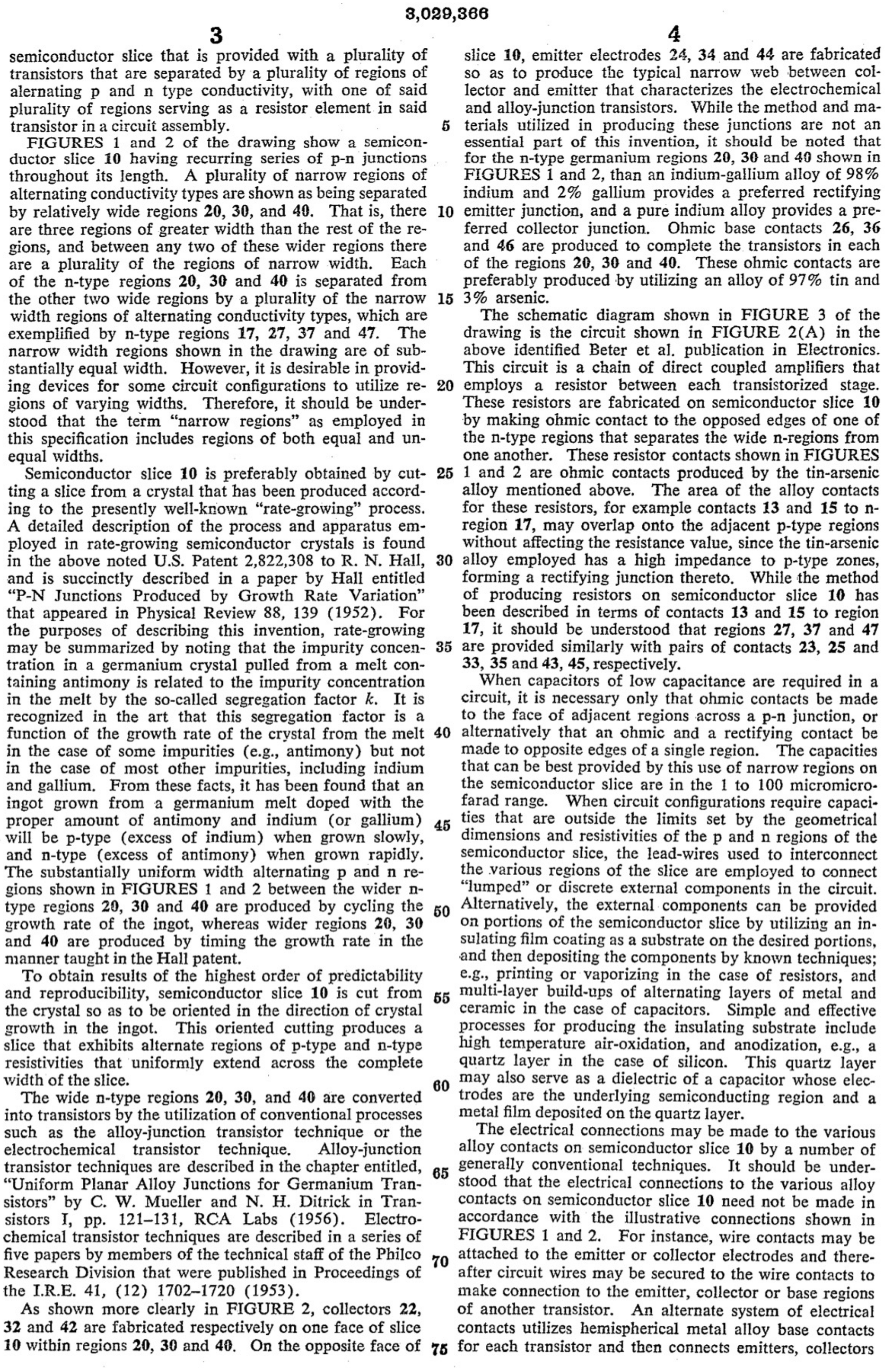
In general, the objects of this invention are attained by a multiple semiconductor assembly in which a plurality of semiconductor components are prepared on the same semiconductor slice in such a manner as to ensure electrical separation of the terminals of the individual semiconducting components. Since these semiconducting components will be transistors in many cases, the following description will be directed specifically to transistors although the concept of the invention applies also to other components, such as capacitors, resistors and diodes.

More particularly the objects of this invention are attained by utilizing a semiconductor slice having a series of p-n junctions that are so constructed and arranged that a transistor may be produced on each of a plurality of regions that are separated from one another by at least one additional p-n junction.

It is well known that a p-n junction has a high impedance to electric current, particularly if biased in the so-called "blocking direction," or with no bias applied. Therefore, any desired degree of electric insulation between two components assembled on the same slice can be achieved by having a sufficiently large number of p-n junctions in series between the two semiconducting regions on which said components are assembled. For most circuits, one to three p-n junctions will be sufficient to achieve the desired degree of insulation. These p-n junctions may be placed quite closely to each other. However, it is often required that they are placed sufficiently far apart from each other that the multiple p-n junction structure used for electric insulation should not act as an active semiconducting element such as a transistor or a four-layer npnp diode. In order to assure this condition, it is required that the region between two junctions is wider than a small multiple of the diffusion length of the minority carriers in said region. The diffusion length is the square root of the diffusion constant multiplied by the lifetime of these minority carriers. For instance, assuming a diffusion constant of 40 cm.^{2} per second and a lifetime of 1 microsecond, a diffusion length of 60×10^{-4} cm. or approximately 2 mils results, and a separation of 4 mils between the two junctions will be sufficient to avoid any appreciable interaction by carrier injection between the two junctions delineating said region.

In a restricted form of this invention, the objects are attained by a multiple transistor assembly comprising a

Figure B.150: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits.



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semiconductor slice that is provided with a plurality of transistors that are separated by a plurality of regions of alternating p and n type conductivity, with one of said plurality of regions serving as a resistor element in said transistor in a circuit assembly.

FIGURES 1 and 2 of the drawing show a semiconductor slice **10** having recurring series of p-n junctions throughout its length. A plurality of narrow regions of alternating conductivity types are shown as being separated by relatively wide regions **20, 30,** and **40.** That is, there are three regions of greater width than the rest of the regions, and between any two of these wider regions there are a plurality of the regions of narrow width. Each of the n-type regions **20, 30** and **40** is separated from the other two wide regions by a plurality of the narrow width regions of alternating conductivity types, which are exemplified by n-type regions **17, 27, 37** and **47.** The narrow width regions shown in the drawing are of substantially equal width. However, it is desirable in providing devices for some circuit configurations to utilize regions of varying widths. Therefore, it should be understood that the term "narrow regions" as employed in this specification includes regions of both equal and unequal widths.

Semiconductor slice **10** is preferably obtained by cutting a slice from a crystal that has been produced according to the presently well-known "rate-growing" process. A detailed description of the process and apparatus employed in rate-growing semiconductor crystals is found in the above noted U.S. Patent 2,822,308 to R. N. Hall, and is succinctly described in a paper by Hall entitled "P-N Junctions Produced by Growth Rate Variation" that appeared in Physical Review 88, 139 (1952). For the purposes of describing this invention, rate-growing may be summarized by noting that the impurity concentration in a germanium crystal pulled from a melt containing antimony is related to the impurity concentration in the melt by the so-called segregation factor *k*. It is recognized in the art that this segregation factor is a function of the growth rate of the crystal from the melt in the case of some impurities (e.g., antimony) but not in the case of most other impurities, including indium and gallium. From these facts, it has been found that an ingot grown from a germanium melt doped with the proper amount of antimony and indium (or gallium) will be p-type (excess of indium) when grown slowly, and n-type (excess of antimony) when grown rapidly. The substantially uniform width alternating p and n regions shown in FIGURES 1 and 2 between the wider n-type regions **20, 30** and **40** are produced by cycling the growth rate of the ingot, whereas wider regions **20, 30** and **40** are produced by timing the growth rate in the manner taught in the Hall patent.

To obtain results of the highest order of predictability and reproducibility, semiconductor slice **10** is cut from the crystal so as to be oriented in the direction of crystal growth in the ingot. This oriented cutting produces a slice that exhibits alternate regions of p-type and n-type resistivities that uniformly extend across the complete width of the slice.

The wide n-type regions **20, 30,** and **40** are converted into transistors by the utilization of conventional processes such as the alloy-junction transistor technique or the electrochemical transistor technique. Alloy-junction transistor techniques are described in the chapter entitled, "Uniform Planar Alloy Junctions for Germanium Transistors" by C. W. Mueller and N. H. Ditrick in Transistors I, pp. 121–131, RCA Labs (1956). Electrochemical transistor techniques are described in a series of five papers by members of the technical staff of the Philco Research Division that were published in Proceedings of the I.R.E. 41, (12) 1702–1720 (1953).

As shown more clearly in FIGURE 2, collectors **22, 32** and **42** are fabricated respectively on one face of slice **10** within regions **20, 30** and **40.** On the opposite face of

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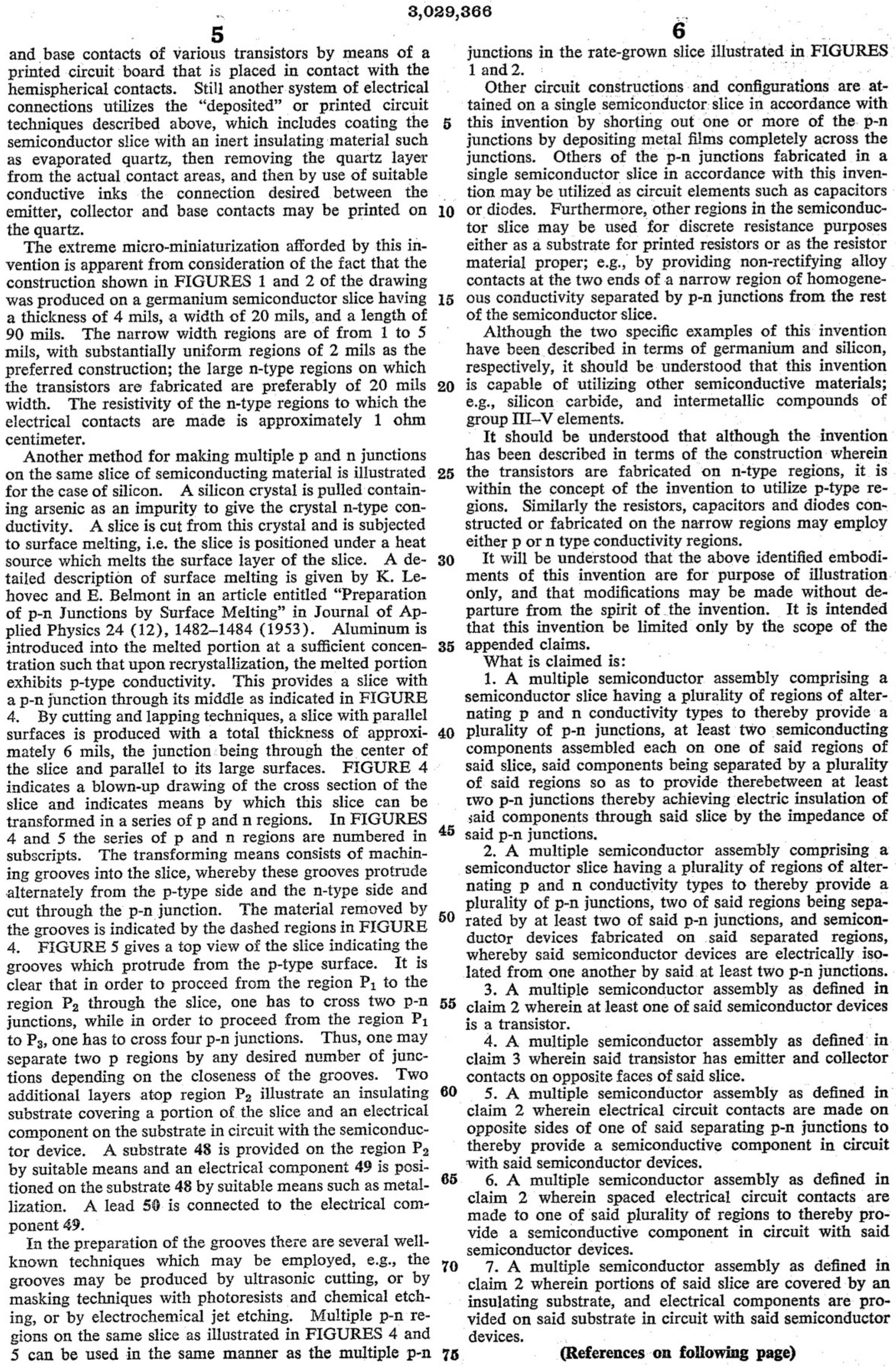
slice **10,** emitter electrodes **24, 34** and **44** are fabricated so as to produce the typical narrow web between collector and emitter that characterizes the electrochemical and alloy-junction transistors. While the method and materials utilized in producing these junctions are not an essential part of this invention, it should be noted that for the n-type germanium regions **20, 30** and **40** shown in FIGURES 1 and 2, than an indium-gallium alloy of 98% indium and 2% gallium provides a preferred rectifying emitter junction, and a pure indium alloy provides a preferred collector junction. Ohmic base contacts **26, 36** and **46** are produced to complete the transistors in each of the regions **20, 30** and **40.** These ohmic contacts are preferably produced by utilizing an alloy of 97% tin and 3% arsenic.

The schematic diagram shown in FIGURE 3 of the drawing is the circuit shown in FIGURE 2(A) in the above identified Beter et al. publication in Electronics. This circuit is a chain of direct coupled amplifiers that employs a resistor between each transistorized stage. These resistors are fabricated on semiconductor slice **10** by making ohmic contact to the opposed edges of one of the n-type regions that separates the wide n-regions from one another. These resistor contacts shown in FIGURES 1 and 2 are ohmic contacts produced by the tin-arsenic alloy mentioned above. The area of the alloy contacts for these resistors, for example contacts **13** and **15** to n-region **17,** may overlap onto the adjacent p-type regions without affecting the resistance value, since the tin-arsenic alloy employed has a high impedance to p-type zones, forming a rectifying junction thereto. While the method of producing resistors on semiconductor slice **10** has been described in terms of contacts **13** and **15** to region **17,** it should be understood that regions **27, 37** and **47** are provided similarly with pairs of contacts **23, 25** and **33, 35** and **43, 45,** respectively.

When capacitors of low capacitance are required in a circuit, it is necessary only that ohmic contacts be made to the face of adjacent regions across a p-n junction, or alternatively that an ohmic and a rectifying contact be made to opposite edges of a single region. The capacities that can be best provided by this use of narrow regions on the semiconductor slice are in the 1 to 100 micromicrofarad range. When circuit configurations require capacities that are outside the limits set by the geometrical dimensions and resistivities of the p and n regions of the semiconductor slice, the lead-wires used to interconnect the various regions of the slice are employed to connect "lumped" or discrete external components in the circuit. Alternatively, the external components can be provided on portions of the semiconductor slice by utilizing an insulating film coating as a substrate on the desired portions, and then depositing the components by known techniques; e.g., printing or vaporizing in the case of resistors, and multi-layer build-ups of alternating layers of metal and ceramic in the case of capacitors. Simple and effective processes for producing the insulating substrate include high temperature air-oxidation, and anodization, e.g., a quartz layer in the case of silicon. This quartz layer may also serve as a dielectric of a capacitor whose electrodes are the underlying semiconducting region and a metal film deposited on the quartz layer.

The electrical connections may be made to the various alloy contacts on semiconductor slice **10** by a number of generally conventional techniques. It should be understood that the electrical connections to the various alloy contacts on semiconductor slice **10** need not be made in accordance with the illustrative connections shown in FIGURES 1 and 2. For instance, wire contacts may be attached to the emitter or collector electrodes and thereafter circuit wires may be secured to the wire contacts to make connection to the emitter, collector or base regions of another transistor. An alternate system of electrical contacts utilizes hemispherical metal alloy base contacts for each transistor and then connects emitters, collectors

Figure B.151: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits.



and base contacts of various transistors by means of a printed circuit board that is placed in contact with the hemispherical contacts. Still another system of electrical connections utilizes the "deposited" or printed circuit techniques described above, which includes coating the semiconductor slice with an inert insulating material such as evaporated quartz, then removing the quartz layer from the actual contact areas, and then by use of suitable conductive inks the connection desired between the emitter, collector and base contacts may be printed on the quartz.

The extreme micro-miniaturization afforded by this invention is apparent from consideration of the fact that the construction shown in FIGURES 1 and 2 of the drawing was produced on a germanium semiconductor slice having a thickness of 4 mils, a width of 20 mils, and a length of 90 mils. The narrow width regions are of from 1 to 5 mils, with substantially uniform regions of 2 mils as the preferred construction; the large n-type regions on which the transistors are fabricated are preferably of 20 mils width. The resistivity of the n-type regions to which the electrical contacts are made is approximately 1 ohm centimeter.

Another method for making multiple p and n junctions on the same slice of semiconducting material is illustrated for the case of silicon. A silicon crystal is pulled containing arsenic as an impurity to give the crystal n-type conductivity. A slice is cut from this crystal and is subjected to surface melting, i.e. the slice is positioned under a heat source which melts the surface layer of the slice. A detailed description of surface melting is given by K. Lehovec and E. Belmont in an article entitled "Preparation of p-n Junctions by Surface Melting" in Journal of Applied Physics 24 (12), 1482–1484 (1953). Aluminum is introduced into the melted portion at a sufficient concentration such that upon recrystallization, the melted portion exhibits p-type conductivity. This provides a slice with a p-n junction through its middle as indicated in FIGURE 4. By cutting and lapping techniques, a slice with parallel surfaces is produced with a total thickness of approximately 6 mils, the junction being through the center of the slice and parallel to its large surfaces. FIGURE 4 indicates a blown-up drawing of the cross section of the slice and indicates means by which this slice can be transformed in a series of p and n regions. In FIGURES 4 and 5 the series of p and n regions are numbered in subscripts. The transforming means consists of machining grooves into the slice, whereby these grooves protrude alternately from the p-type side and the n-type side and cut through the p-n junction. The material removed by the grooves is indicated by the dashed regions in FIGURE 4. FIGURE 5 gives a top view of the slice indicating the grooves which protrude from the p-type surface. It is clear that in order to proceed from the region P_1 to the region P_2 through the slice, one has to cross two p-n junctions, while in order to proceed from the region P_1 to P_3, one has to cross four p-n junctions. Thus, one may separate two p regions by any desired number of junctions depending on the closeness of the grooves. Two additional layers atop region P_2 illustrate an insulating substrate covering a portion of the slice and an electrical component on the substrate in circuit with the semiconductor device. A substrate **48** is provided on the region P_2 by suitable means and an electrical component **49** is positioned on the substrate **48** by suitable means such as metallization. A lead **50** is connected to the electrical component **49**.

In the preparation of the grooves there are several well-known techniques which may be employed, e.g., the grooves may be produced by ultrasonic cutting, or by masking techniques with photoresists and chemical etching, or by electrochemical jet etching. Multiple p-n regions on the same slice as illustrated in FIGURES 4 and 5 can be used in the same manner as the multiple p-n junctions in the rate-grown slice illustrated in FIGURES 1 and 2.

Other circuit constructions and configurations are attained on a single semiconductor slice in accordance with this invention by shorting out one or more of the p-n junctions by depositing metal films completely across the junctions. Others of the p-n junctions fabricated in a single semiconductor slice in accordance with this invention may be utilized as circuit elements such as capacitors or diodes. Furthermore, other regions in the semiconductor slice may be used for discrete resistance purposes either as a substrate for printed resistors or as the resistor material proper; e.g., by providing non-rectifying alloy contacts at the two ends of a narrow region of homogeneous conductivity separated by p-n junctions from the rest of the semiconductor slice.

Although the two specific examples of this invention have been described in terms of germanium and silicon, respectively, it should be understood that this invention is capable of utilizing other semiconductive materials; e.g., silicon carbide, and intermetallic compounds of group III–V elements.

It should be understood that although the invention has been described in terms of the construction wherein the transistors are fabricated on n-type regions, it is within the concept of the invention to utilize p-type regions. Similarly the resistors, capacitors and diodes constructed or fabricated on the narrow regions may employ either p or n type conductivity regions.

It will be understood that the above identified embodiments of this invention are for purpose of illustration only, and that modifications may be made without departure from the spirit of the invention. It is intended that this invention be limited only by the scope of the appended claims.

What is claimed is:

1. A multiple semiconductor assembly comprising a semiconductor slice having a plurality of regions of alternating p and n conductivity types to thereby provide a plurality of p-n junctions, at least two semiconducting components assembled each on one of said regions of said slice, said components being separated by a plurality of said regions so as to provide therebetween at least two p-n junctions thereby achieving electric insulation of said components through said slice by the impedance of said p-n junctions.

2. A multiple semiconductor assembly comprising a semiconductor slice having a plurality of regions of alternating p and n conductivity types to thereby provide a plurality of p-n junctions, two of said regions being separated by at least two of said p-n junctions, and semiconductor devices fabricated on said separated regions, whereby said semiconductor devices are electrically isolated from one another by said at least two p-n junctions.

3. A multiple semiconductor assembly as defined in claim 2 wherein at least one of said semiconductor devices is a transistor.

4. A multiple semiconductor assembly as defined in claim 3 wherein said transistor has emitter and collector contacts on opposite faces of said slice.

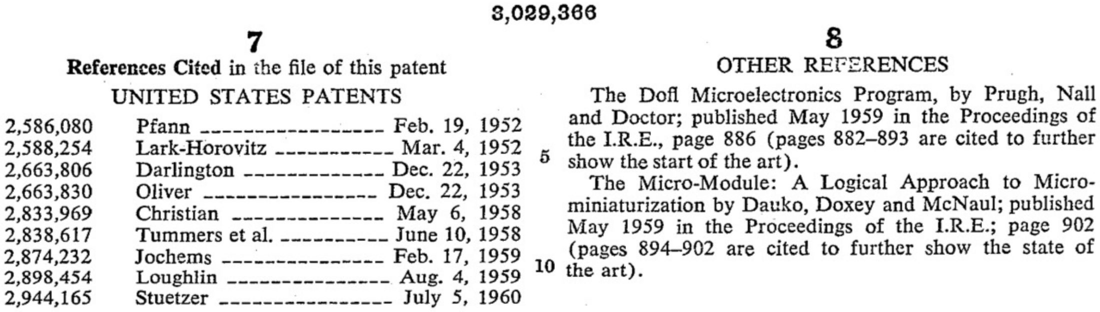
5. A multiple semiconductor assembly as defined in claim 2 wherein electrical circuit contacts are made on opposite sides of one of said separating p-n junctions to thereby provide a semiconductive component in circuit with said semiconductor devices.

6. A multiple semiconductor assembly as defined in claim 2 wherein spaced electrical circuit contacts are made to one of said plurality of regions to thereby provide a semiconductive component in circuit with said semiconductor devices.

7. A multiple semiconductor assembly as defined in claim 2 wherein portions of said slice are covered by an insulating substrate, and electrical components are provided on said substrate in circuit with said semiconductor devices.

(References on following page)

Figure B.152: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits.



3,029,366

7

References Cited in the file of this patent

UNITED STATES PATENTS

2,586,080	Pfann	Feb. 19, 1952
2,588,254	Lark-Horovitz	Mar. 4, 1952
2,663,806	Darlington	Dec. 22, 1953
2,663,830	Oliver	Dec. 22, 1953
2,833,969	Christian	May 6, 1958
2,838,617	Tummers et al.	June 10, 1958
2,874,232	Jochems	Feb. 17, 1959
2,898,454	Loughlin	Aug. 4, 1959
2,944,165	Stuetzer	July 5, 1960

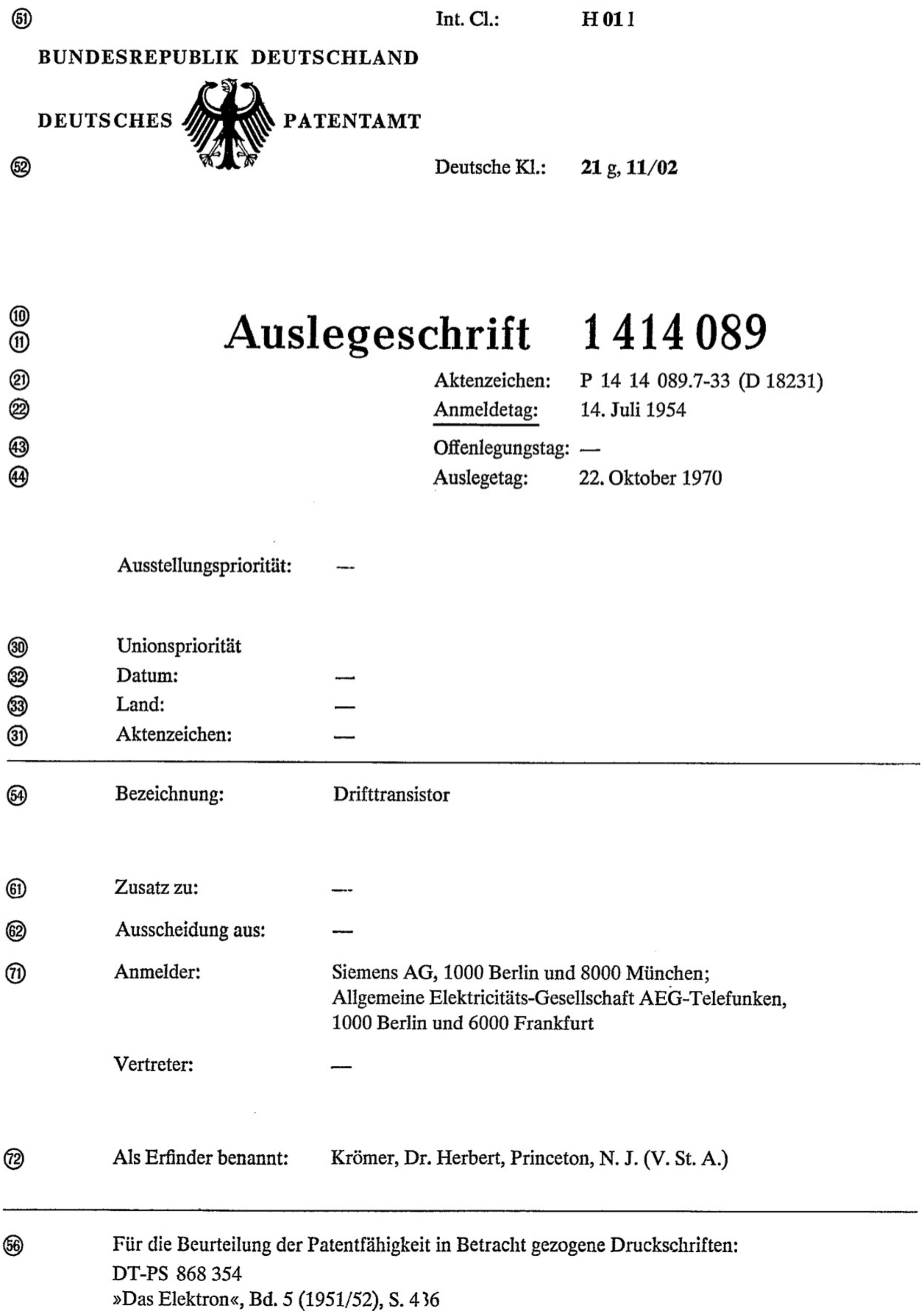
8

OTHER REFERENCES

The Dofl Microelectronics Program, by Prugh, Nall and Doctor; published May 1959 in the Proceedings of the I.R.E., page 886 (pages 882–893 are cited to further show the start of the art).

The Micro-Module: A Logical Approach to Microminiaturization by Dauko, Doxey and McNaul; published May 1959 in the Proceedings of the I.R.E.; page 902 (pages 894–902 are cited to further show the state of the art).

Figure B.153: Kurt Lehovec developed semiconductor devices for Germany during the war. After the war he was extensively interrogated by the United States and then moved to the United States, where he filed patents on light emitting diodes, transistors, and integrated circuits.



(51) Int. Cl.: **H 01 l**

BUNDESREPUBLIK DEUTSCHLAND

DEUTSCHES PATENTAMT

(52) Deutsche Kl.: **21 g, 11/02**

⑩
⑪ **Auslegeschrift 1 414 089**

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㉒ Anmeldetag: 14. Juli 1954

㊸ Offenlegungstag: —
㊹ Auslegetag: 22. Oktober 1970

Ausstellungspriorität: —

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㉜ Datum: —
㉝ Land: —
㉛ Aktenzeichen: —

(54) Bezeichnung: Drifttransistor

(61) Zusatz zu: —

(62) Ausscheidung aus: —

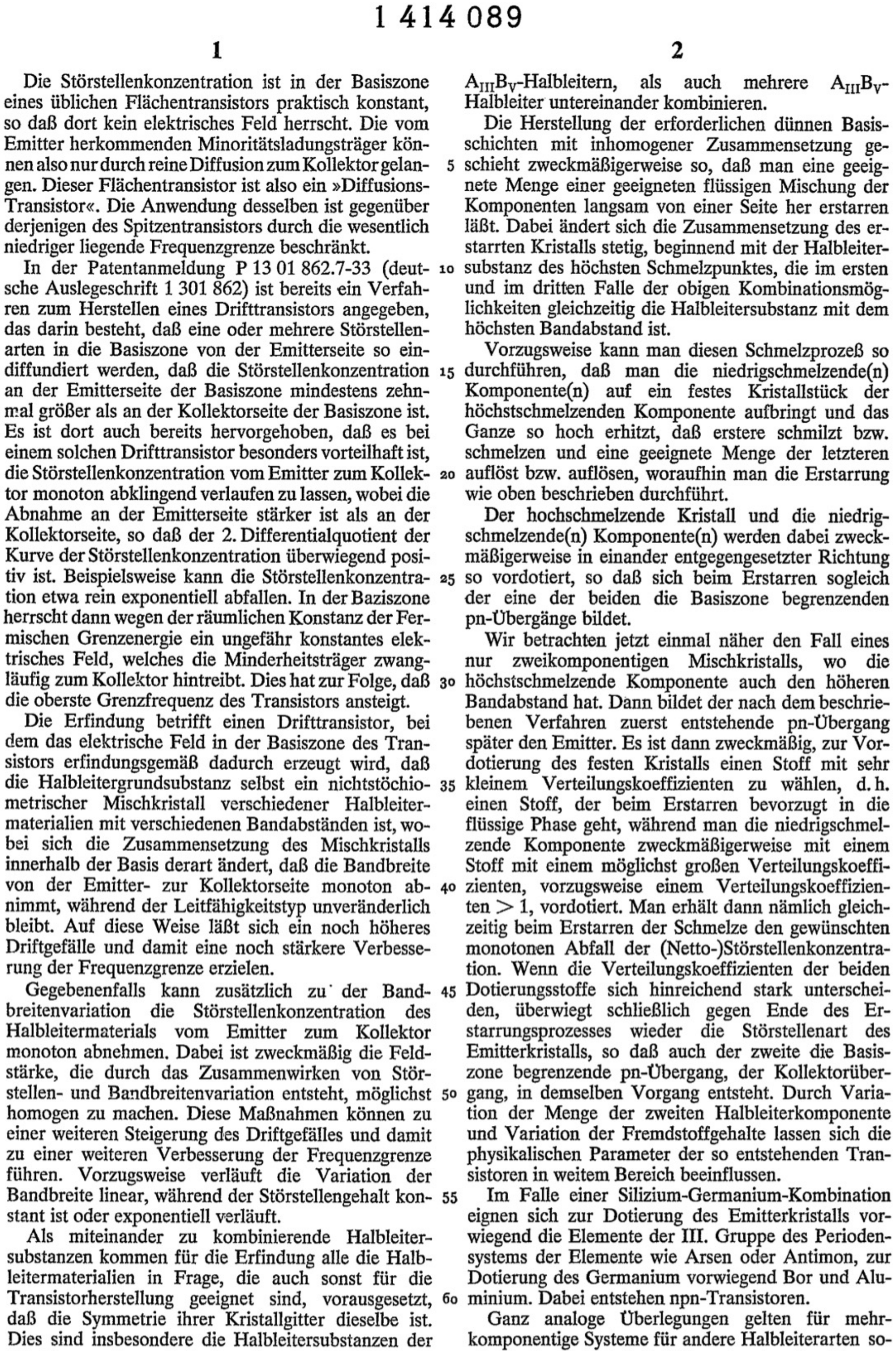
(71) Anmelder: Siemens AG, 1000 Berlin und 8000 München;
Allgemeine Elektricitäts-Gesellschaft AEG-Telefunken,
1000 Berlin und 6000 Frankfurt

Vertreter: —

(72) Als Erfinder benannt: Krömer, Dr. Herbert, Princeton, N. J. (V. St. A.)

(56) Für die Beurteilung der Patentfähigkeit in Betracht gezogene Druckschriften:
DT-PS 868 354
»Das Elektron«, Bd. 5 (1951/52), S. 436

Figure B.154: Herbert Kroemer invented the drift transistor in 1953.



1 414 089

Die Störstellenkonzentration ist in der Basiszone eines üblichen Flächentransistors praktisch konstant, so daß dort kein elektrisches Feld herrscht. Die vom Emitter herkommenden Minoritätsladungsträger können also nur durch reine Diffusion zum Kollektor gelangen. Dieser Flächentransistor ist also ein »Diffusions-Transistor«. Die Anwendung desselben ist gegenüber derjenigen des Spitzentransistors durch die wesentlich niedriger liegende Frequenzgrenze beschränkt.

In der Patentanmeldung P 13 01 862.7-33 (deutsche Auslegeschrift 1 301 862) ist bereits ein Verfahren zum Herstellen eines Drifttransistors angegeben, das darin besteht, daß eine oder mehrere Störstellenarten in die Basiszone von der Emitterseite so eindiffundiert werden, daß die Störstellenkonzentration an der Emitterseite der Basiszone mindestens zehnmal größer als an der Kollektorseite der Basiszone ist. Es ist dort auch bereits hervorgehoben, daß es bei einem solchen Drifttransistor besonders vorteilhaft ist, die Störstellenkonzentration vom Emitter zum Kollektor monoton abklingend verlaufen zu lassen, wobei die Abnahme an der Emitterseite stärker ist als an der Kollektorseite, so daß der 2. Differentialquotient der Kurve der Störstellenkonzentration überwiegend positiv ist. Beispielsweise kann die Störstellenkonzentration etwa rein exponentiell abfallen. In der Baziszone herrscht dann wegen der räumlichen Konstanz der Fermischen Grenzenergie ein ungefähr konstantes elektrisches Feld, welches die Minderheitsträger zwangläufig zum Kollektor hintreibt. Dies hat zur Folge, daß die oberste Grenzfrequenz des Transistors ansteigt.

Die Erfindung betrifft einen Drifttransistor, bei dem das elektrische Feld in der Basiszone des Transistors erfindungsgemäß dadurch erzeugt wird, daß die Halbleitergrundsubstanz selbst ein nichtstöchiometrischer Mischkristall verschiedener Halbleitermaterialien mit verschiedenen Bandabständen ist, wobei sich die Zusammensetzung des Mischkristalls innerhalb der Basis derart ändert, daß die Bandbreite von der Emitter- zur Kollektorseite monoton abnimmt, während der Leitfähigkeitstyp unveränderlich bleibt. Auf diese Weise läßt sich ein noch höheres Driftgefälle und damit eine noch stärkere Verbesserung der Frequenzgrenze erzielen.

Gegebenenfalls kann zusätzlich zu der Bandbreitenvariation die Störstellenkonzentration des Halbleitermaterials vom Emitter zum Kollektor monoton abnehmen. Dabei ist zweckmäßig die Feldstärke, die durch das Zusammenwirken von Störstellen- und Bandbreitenvariation entsteht, möglichst homogen zu machen. Diese Maßnahmen können zu einer weiteren Steigerung des Driftgefälles und damit zu einer weiteren Verbesserung der Frequenzgrenze führen. Vorzugsweise verläuft die Variation der Bandbreite linear, während der Störstellengehalt konstant ist oder exponentiell verläuft.

Als miteinander zu kombinierende Halbleitersubstanzen kommen für die Erfindung alle die Halbleitermaterialien in Frage, die auch sonst für die Transistorherstellung geeignet sind, vorausgesetzt, daß die Symmetrie ihrer Kristallgitter dieselbe ist. Dies sind insbesondere die Halbleitersubstanzen der IV. Gruppe des periodischen Systems der Elemente, wie Germanium und Silizium, sowie die gemischten Halbleiter vom Typ $A_{III}B_{V}$. Und zwar kann man sowohl Halbleitermaterialien der IV. Gruppe untereinander, als auch einen oder mehrere Halbleitermaterialien der IV. Gruppe mit einem oder mehreren $A_{III}B_{V}$-Halbleitern, als auch mehrere $A_{III}B_{V}$-Halbleiter untereinander kombinieren.

Die Herstellung der erforderlichen dünnen Basisschichten mit inhomogener Zusammensetzung geschieht zweckmäßigerweise so, daß man eine geeignete Menge einer geeigneten flüssigen Mischung der Komponenten langsam von einer Seite her erstarren läßt. Dabei ändert sich die Zusammensetzung des erstarrten Kristalls stetig, beginnend mit der Halbleitersubstanz des höchsten Schmelzpunktes, die im ersten und im dritten Falle der obigen Kombinationsmöglichkeiten gleichzeitig die Halbleitersubstanz mit dem höchsten Bandabstand ist.

Vorzugsweise kann man diesen Schmelzprozeß so durchführen, daß man die niedrigschmelzende(n) Komponente(n) auf ein festes Kristallstück der höchstschmelzenden Komponente aufbringt und das Ganze so hoch erhitzt, daß erstere schmilzt bzw. schmelzen und eine geeignete Menge der letzteren auflöst bzw. auflösen, woraufhin man die Erstarrung wie oben beschrieben durchführt.

Der hochschmelzende Kristall und die niedrigschmelzende(n) Komponente(n) werden dabei zweckmäßigerweise in einander entgegengesetzter Richtung so vordotiert, so daß sich beim Erstarren sogleich der eine der beiden die Basiszone begrenzenden pn-Übergänge bildet.

Wir betrachten jetzt einmal näher den Fall eines nur zweikomponentigen Mischkristalls, wo die höchstschmelzende Komponente auch den höheren Bandabstand hat. Dann bildet der nach dem beschriebenen Verfahren zuerst entstehende pn-Übergang später den Emitter. Es ist dann zweckmäßig, zur Vordotierung des festen Kristalls einen Stoff mit sehr kleinem Verteilungskoeffizienten zu wählen, d. h. einen Stoff, der beim Erstarren bevorzugt in die flüssige Phase geht, während man die niedrigschmelzende Komponente zweckmäßigerweise mit einem Stoff mit einem möglichst großen Verteilungskoeffizienten, vorzugsweise einem Verteilungskoeffizienten > 1, vordotiert. Man erhält dann nämlich gleichzeitig beim Erstarren der Schmelze den gewünschten monotonen Abfall der (Netto-)Störstellenkonzentration. Wenn die Verteilungskoeffizienten der beiden Dotierungsstoffe sich hinreichend stark unterscheiden, überwiegt schließlich gegen Ende des Erstarrungsprozesses wieder die Störstellenart des Emitterkristalls, so daß auch der zweite die Basiszone begrenzende pn-Übergang, der Kollektorübergang, in demselben Vorgang entsteht. Durch Variation der Menge der zweiten Halbleiterkomponente und Variation der Fremdstoffgehalte lassen sich die physikalischen Parameter der so entstehenden Transistoren in weitem Bereich beeinflussen.

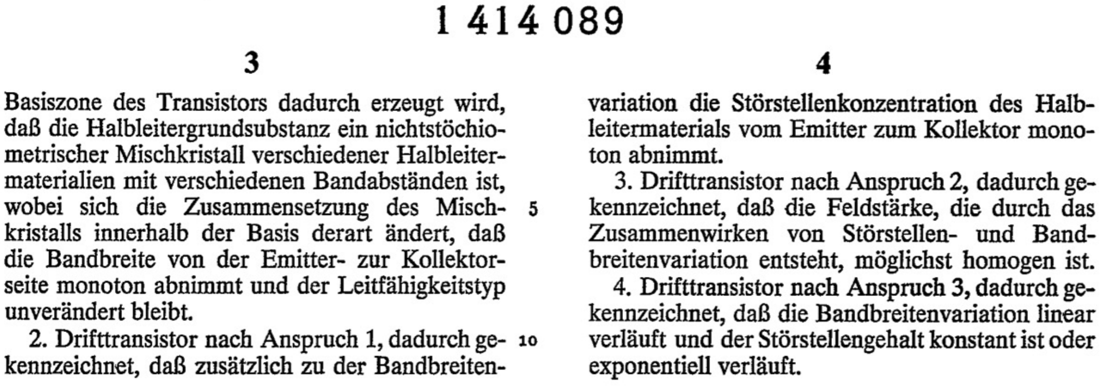
Im Falle einer Silizium-Germanium-Kombination eignen sich zur Dotierung des Emitterkristalls vorwiegend die Elemente der III. Gruppe des Periodensystems der Elemente wie Arsen oder Antimon, zur Dotierung des Germanium vorwiegend Bor und Aluminium. Dabei entstehen npn-Transistoren.

Ganz analoge Überlegungen gelten für mehrkomponentige Systeme für andere Halbleiterarten sowie für den Fall, daß die höherschmelzenden Komponenten den niedrigeren Bandabstand haben.

Patentansprüche:

1. Drifttransistor, dadurch gekennzeichnet, daß ein elektrisches Feld in der

Figure B.155: Herbert Kroemer invented the drift transistor in 1953.



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3

Basiszone des Transistors dadurch erzeugt wird, daß die Halbleitergrundsubstanz ein nichtstöchiometrischer Mischkristall verschiedener Halbleitermaterialien mit verschiedenen Bandabständen ist, wobei sich die Zusammensetzung des Mischkristalls innerhalb der Basis derart ändert, daß die Bandbreite von der Emitter- zur Kollektorseite monoton abnimmt und der Leitfähigkeitstyp unverändert bleibt.

2. Drifttransistor nach Anspruch 1, dadurch gekennzeichnet, daß zusätzlich zu der Bandbreitenvariation die Störstellenkonzentration des Halbleitermaterials vom Emitter zum Kollektor monoton abnimmt.

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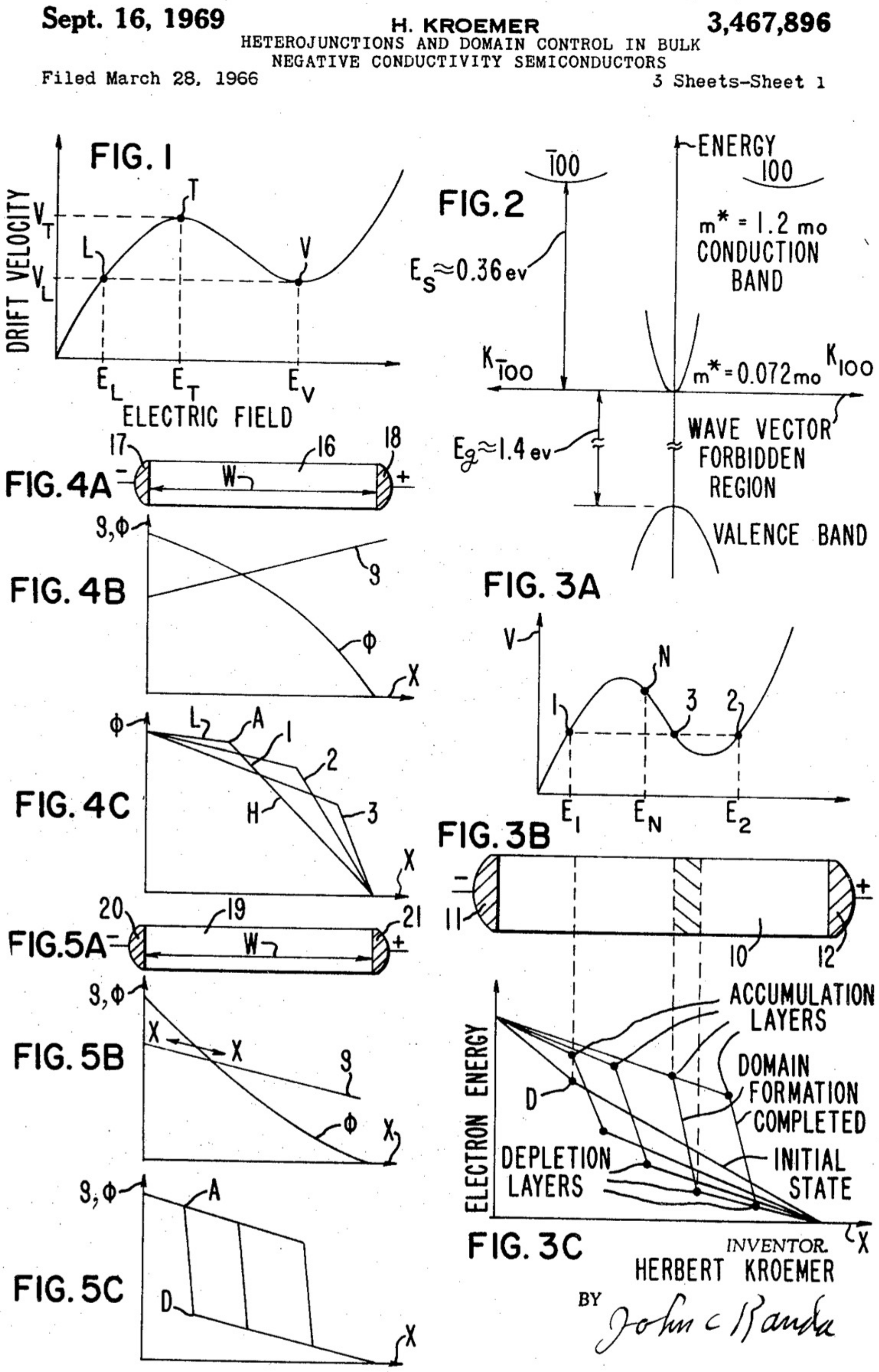
3. Drifttransistor nach Anspruch 2, dadurch gekennzeichnet, daß die Feldstärke, die durch das Zusammenwirken von Störstellen- und Bandbreitenvariation entsteht, möglichst homogen ist.

4. Drifttransistor nach Anspruch 3, dadurch gekennzeichnet, daß die Bandbreitenvariation linear verläuft und der Störstellengehalt konstant ist oder exponentiell verläuft.

Figure B.156: Herbert Kroemer invented the drift transistor in 1953.



Sept. 16, 1969 **H. KROEMER** **3,467,896**

HETEROJUNCTIONS AND DOMAIN CONTROL IN BULK
NEGATIVE CONDUCTIVITY SEMICONDUCTORS

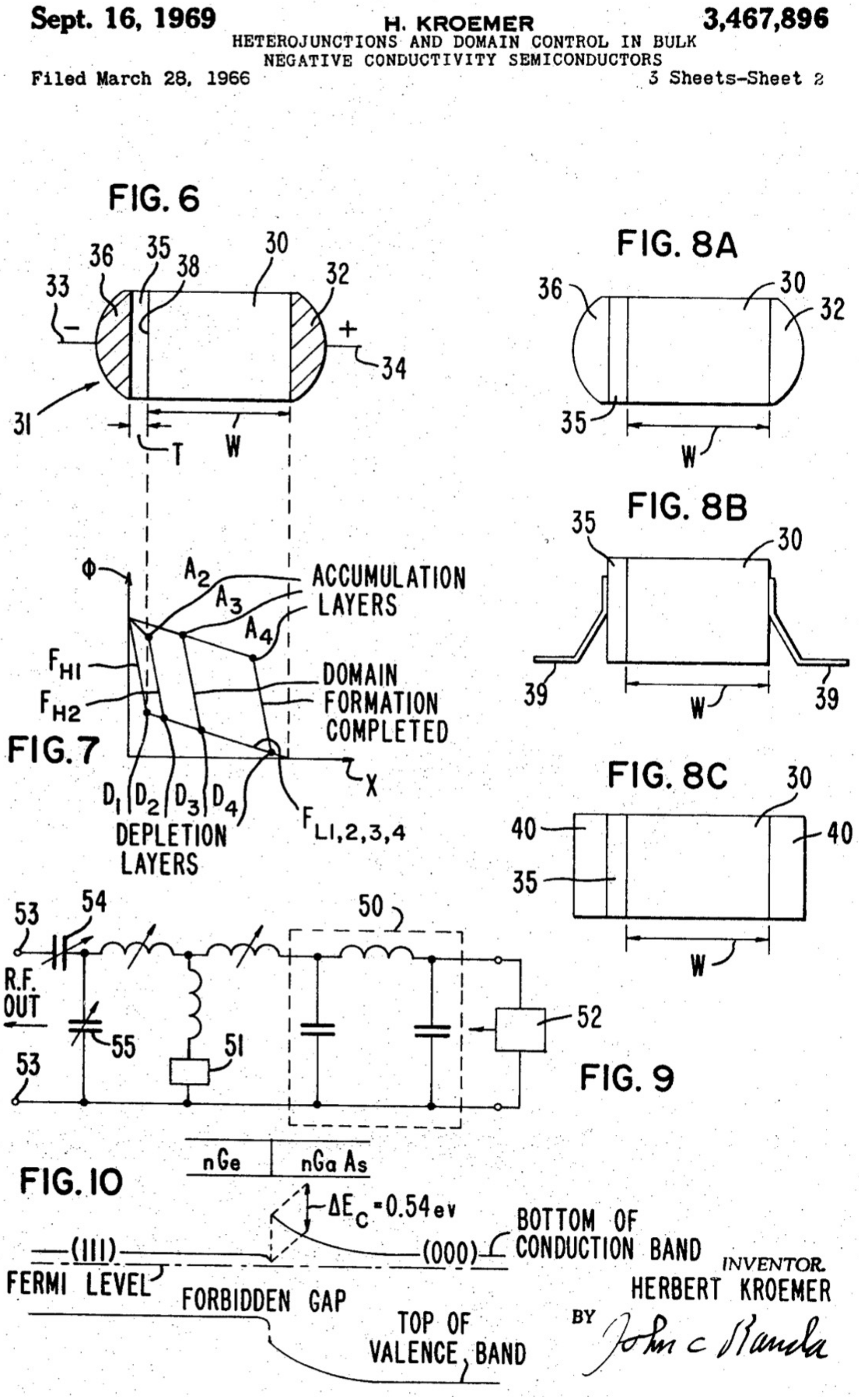
Filed March 28, 1966 3 Sheets-Sheet 1

FIG. 1
DRIFT VELOCITY
V_T
V_L
T
L
V
E_L
E_T
E_V
ELECTRIC FIELD
FIG. 2
ENERGY
$\bar{1}00$
100
$m^* = 1.2\ mo$
CONDUCTION BAND
$E_S \approx 0.36\ ev$
$K_{\bar{1}00}$
K_{100}
$m^* = 0.072\ mo$
WAVE VECTOR
FORBIDDEN REGION
$E_g \approx 1.4\ ev$
VALENCE BAND
FIG. 3A
V
1
N
3
2
E_1
E_N
E_2
FIG. 3B
11
10
12
FIG. 3C
ELECTRON ENERGY
ACCUMULATION LAYERS
DOMAIN FORMATION COMPLETED
D
DEPLETION LAYERS
INITIAL STATE
X
FIG. 4A
17
16
18
W
FIG. 4B
ρ, ϕ
ρ
ϕ
X
FIG. 4C
ϕ
L
A
1
2
H
3
X
FIG. 5A
20
19
21
W
FIG. 5B
ρ, ϕ
X
X
ρ
ϕ
X
FIG. 5C
ρ, ϕ
A
D
X

INVENTOR.
HERBERT KROEMER

BY John C Banda

Figure B.157: Herbert Kroemer invented III-V semiconductor heterostructures in 1966.



Sept. 16, 1969 **H. KROEMER** **3,467,896**

HETEROJUNCTIONS AND DOMAIN CONTROL IN BULK
NEGATIVE CONDUCTIVITY SEMICONDUCTORS

Filed March 28, 1966 3 Sheets-Sheet 2

FIG. 6
36
35
38
30
33
32
−
+
34
31
T
W
FIG. 8A
36
30
32
35
W
FIG. 8B
35
30
39
W
39
Φ
A_2
A_3
A_4
ACCUMULATION LAYERS
F_{H1}
F_{H2}
DOMAIN FORMATION COMPLETED
FIG. 7
X
D_1 D_2 D_3 D_4
DEPLETION LAYERS
$F_{L1,2,3,4}$
FIG. 8C
30
40
40
35
W
53
54
50
R.F. OUT
55
51
52
53
FIG. 9
nGe
nGa As
FIG. 10
$\Delta E_C = 0.54$ ev
BOTTOM OF CONDUCTION BAND
(111)
(000)
FERMI LEVEL
FORBIDDEN GAP
TOP OF VALENCE BAND

INVENTOR.
HERBERT KROEMER

BY John c Banda

Figure B.158: Herbert Kroemer invented III-V semiconductor heterostructures in 1966.

Sept. 16, 1969 **H. KROEMER** **3,467,896**

HETEROJUNCTIONS AND DOMAIN CONTROL IN BULK
NEGATIVE CONDUCTIVITY SEMICONDUCTORS

Filed March 28, 1966 3 Sheets-Sheet 3

FIG. 11

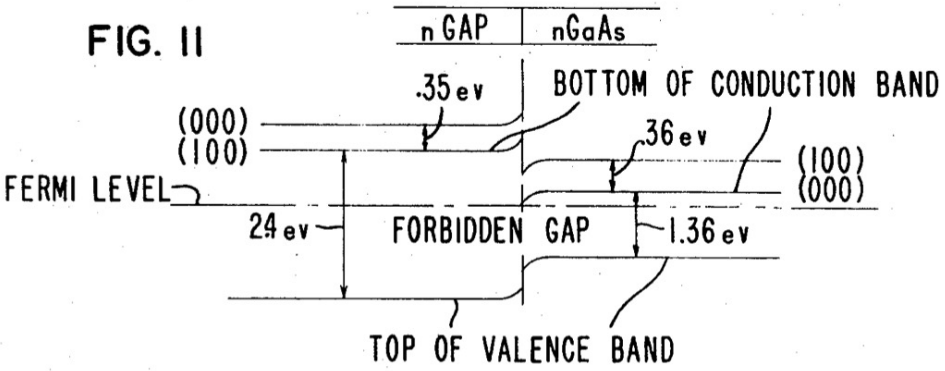

n GAP
nGaAs
.35 ev
BOTTOM OF CONDUCTION BAND
(000)
(100)
36 ev
(100)
(000)
FERMI LEVEL
24 ev
FORBIDDEN GAP
1.36 ev
TOP OF VALENCE BAND

FIG. 12 A

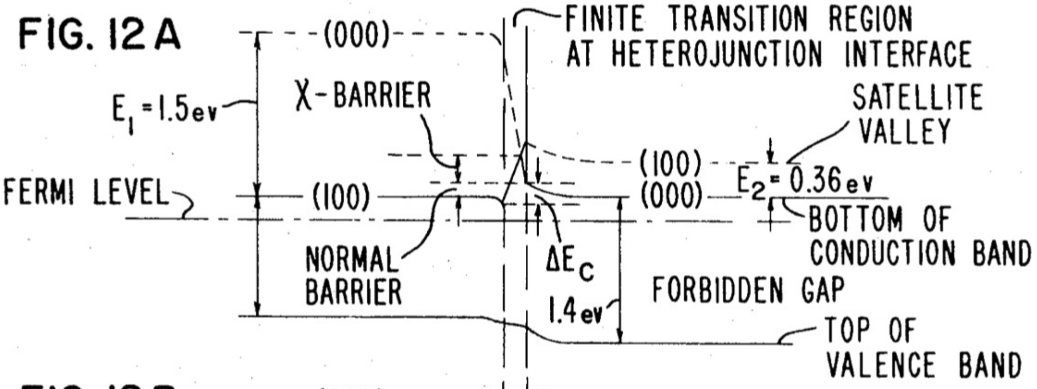

(000)
FINITE TRANSITION REGION AT HETEROJUNCTION INTERFACE
$E_1 = 1.5$ ev
X-BARRIER
SATELLITE VALLEY
(100)
$E_2 = 0.36$ ev
FERMI LEVEL
(100)
(000)
BOTTOM OF CONDUCTION BAND
NORMAL BARRIER
ΔE_C
FORBIDDEN GAP
1.4 ev
TOP OF VALENCE BAND

FIG. 12 B

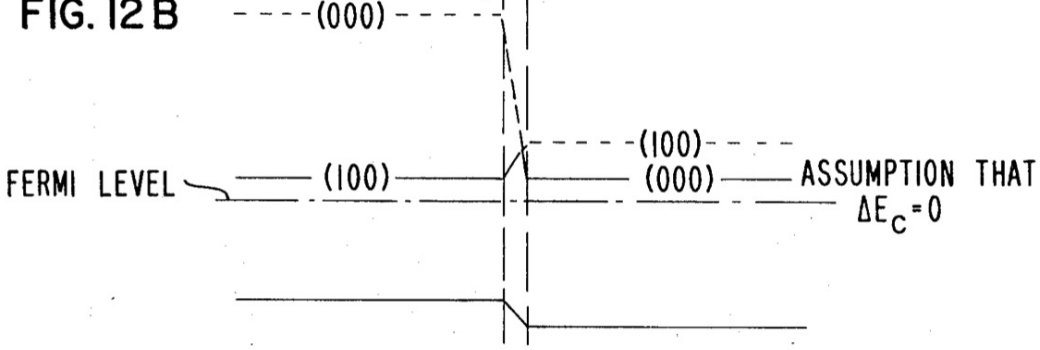
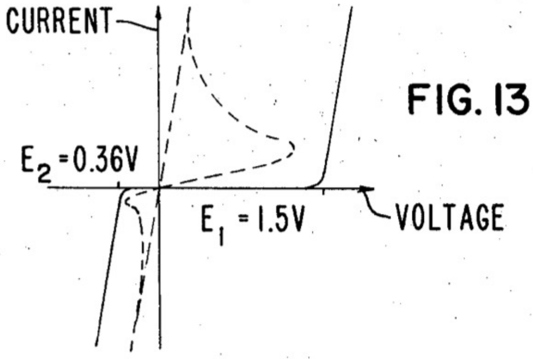
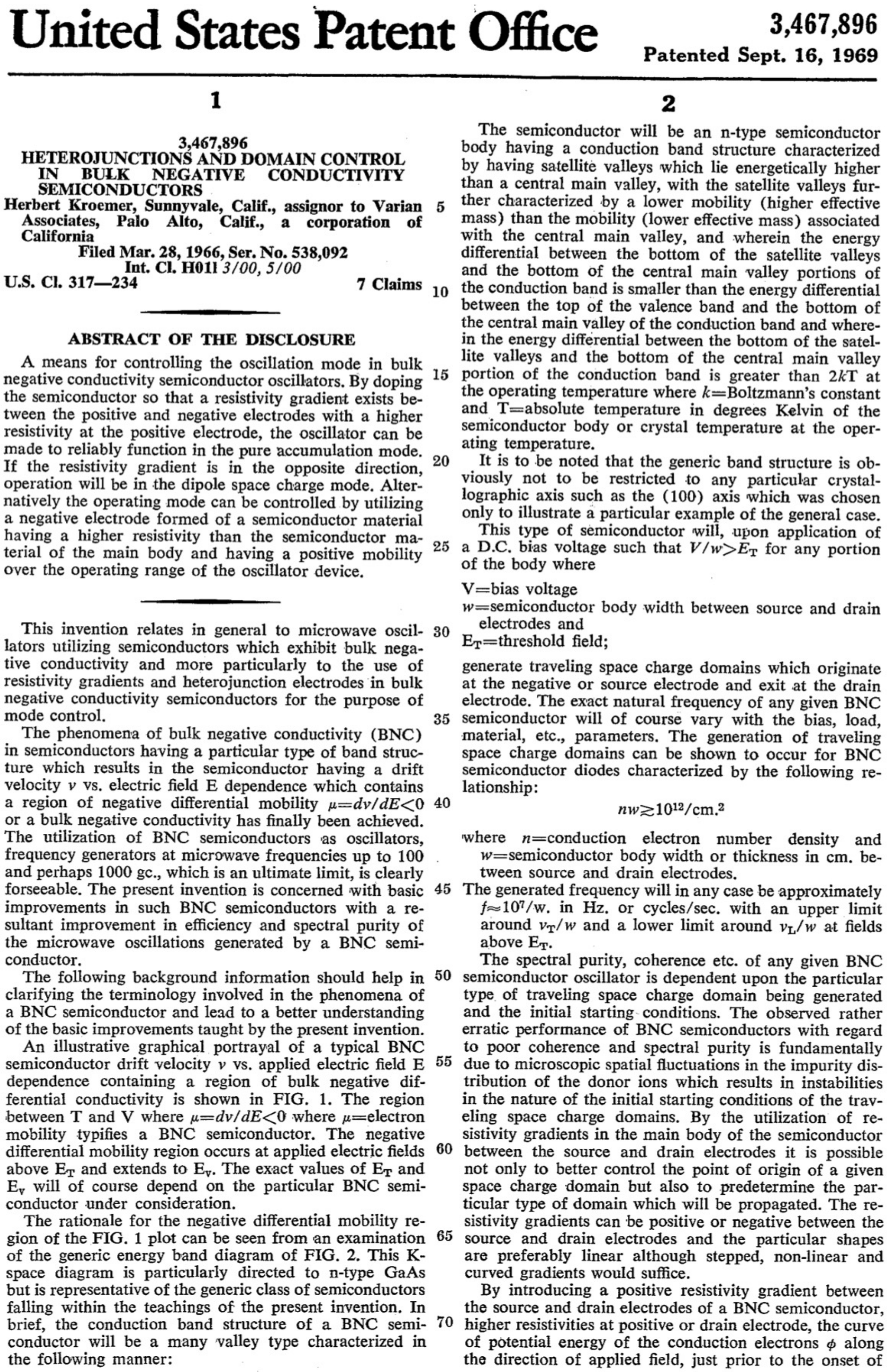

(000)
(100)
FERMI LEVEL
(100)
(000)
ASSUMPTION THAT $\Delta E_C = 0$

FIG. 13



INVENTOR.
HERBERT KROEMER
BY John c Randa

Figure B.159: Herbert Kroemer invented III-V semiconductor heterostructures in 1966.



United States Patent Office

3,467,896
Patented Sept. 16, 1969

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3,467,896
HETEROJUNCTIONS AND DOMAIN CONTROL IN BULK NEGATIVE CONDUCTIVITY SEMICONDUCTORS
Herbert Kroemer, Sunnyvale, Calif., assignor to Varian Associates, Palo Alto, Calif., a corporation of California
Filed Mar. 28, 1966, Ser. No. 538,092
Int. Cl. H01l 3/00, 5/00
U.S. Cl. 317—234 **7 Claims**

ABSTRACT OF THE DISCLOSURE

A means for controlling the oscillation mode in bulk negative conductivity semiconductor oscillators. By doping the semiconductor so that a resistivity gradient exists between the positive and negative electrodes with a higher resistivity at the positive electrode, the oscillator can be made to reliably function in the pure accumulation mode. If the resistivity gradient is in the opposite direction, operation will be in the dipole space charge mode. Alternatively the operating mode can be controlled by utilizing a negative electrode formed of a semiconductor material having a higher resistivity than the semiconductor material of the main body and having a positive mobility over the operating range of the oscillator device.

This invention relates in general to microwave oscillators utilizing semiconductors which exhibit bulk negative conductivity and more particularly to the use of resistivity gradients and heterojunction electrodes in bulk negative conductivity semiconductors for the purpose of mode control.

The phenomena of bulk negative conductivity (BNC) in semiconductors having a particular type of band structure which results in the semiconductor having a drift velocity v vs. electric field E dependence which contains a region of negative differential mobility $\mu=dv/dE<0$ or a bulk negative conductivity has finally been achieved. The utilization of BNC semiconductors as oscillators, frequency generators at microwave frequencies up to 100 and perhaps 1000 gc., which is an ultimate limit, is clearly forseeable. The present invention is concerned with basic improvements in such BNC semiconductors with a resultant improvement in efficiency and spectral purity of the microwave oscillations generated by a BNC semiconductor.

The following background information should help in clarifying the terminology involved in the phenomena of a BNC semiconductor and lead to a better understanding of the basic improvements taught by the present invention.

An illustrative graphical portrayal of a typical BNC semiconductor drift velocity v vs. applied electric field E dependence containing a region of bulk negative differential conductivity is shown in FIG. 1. The region between T and V where $\mu=dv/dE<0$ where μ=electron mobility typifies a BNC semiconductor. The negative differential mobility region occurs at applied electric fields above E_T and extends to E_V. The exact values of E_T and E_V will of course depend on the particular BNC semiconductor under consideration.

The rationale for the negative differential mobility region of the FIG. 1 plot can be seen from an examination of the generic energy band diagram of FIG. 2. This K-space diagram is particularly directed to n-type GaAs but is representative of the generic class of semiconductors falling within the teachings of the present invention. In brief, the conduction band structure of a BNC semiconductor will be a many valley type characterized in the following manner:

2

The semiconductor will be an n-type semiconductor body having a conduction band structure characterized by having satellite valleys which lie energetically higher than a central main valley, with the satellite valleys further characterized by a lower mobility (higher effective mass) than the mobility (lower effective mass) associated with the central main valley, and wherein the energy differential between the bottom of the satellite valleys and the bottom of the central main valley portions of the conduction band is smaller than the energy differential between the top of the valence band and the bottom of the central main valley of the conduction band and wherein the energy differential between the bottom of the satellite valleys and the bottom of the central main valley portion of the conduction band is greater than $2kT$ at the operating temperature where k=Boltzmann's constant and T=absolute temperature in degrees Kelvin of the semiconductor body or crystal temperature at the operating temperature.

It is to be noted that the generic band structure is obviously not to be restricted to any particular crystallographic axis such as the (100) axis which was chosen only to illustrate a particular example of the general case.

This type of semiconductor will, upon application of a D.C. bias voltage such that $V/w>E_T$ for any portion of the body where

V=bias voltage
w=semiconductor body width between source and drain electrodes and
E_T=threshold field;

generate traveling space charge domains which originate at the negative or source electrode and exit at the drain electrode. The exact natural frequency of any given BNC semiconductor will of course vary with the bias, load, material, etc., parameters. The generation of traveling space charge domains can be shown to occur for BNC semiconductor diodes characterized by the following relationship:

$$nw\gtrsim10^{12}/\text{cm.}^2$$

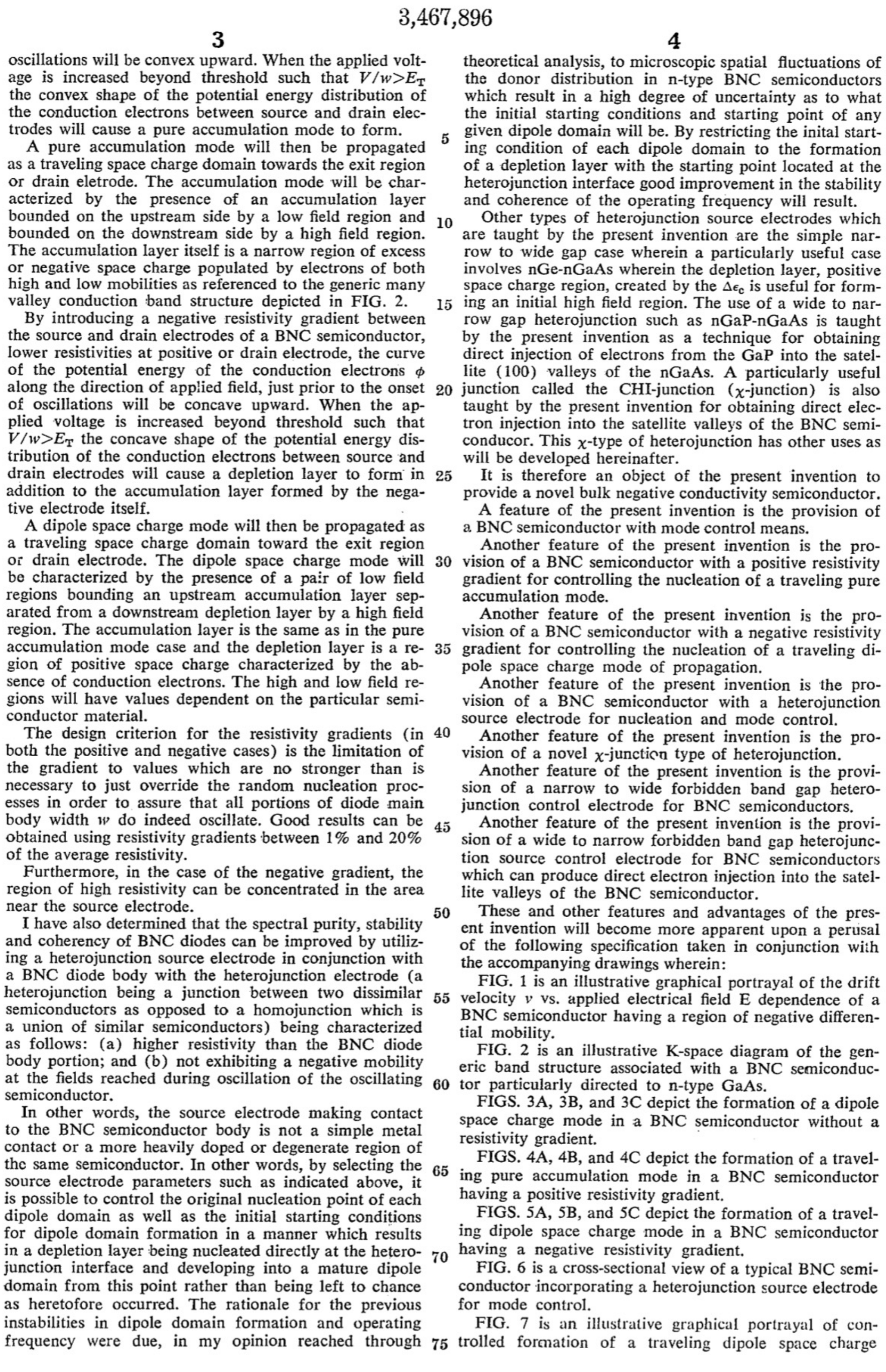
where n=conduction electron number density and
w=semiconductor body width or thickness in cm. between source and drain electrodes.

The generated frequency will in any case be approximately $f\approx10^7/w$. in Hz. or cycles/sec. with an upper limit around v_T/w and a lower limit around v_L/w at fields above E_T.

The spectral purity, coherence etc. of any given BNC semiconductor oscillator is dependent upon the particular type of traveling space charge domain being generated and the initial starting conditions. The observed rather erratic performance of BNC semiconductors with regard to poor coherence and spectral purity is fundamentally due to microscopic spatial fluctuations in the impurity distribution of the donor ions which results in instabilities in the nature of the initial starting conditions of the traveling space charge domains. By the utilization of resistivity gradients in the main body of the semiconductor between the source and drain electrodes it is possible not only to better control the point of origin of a given space charge domain but also to predetermine the particular type of domain which will be propagated. The resistivity gradients can be positive or negative between the source and drain electrodes and the particular shapes are preferably linear although stepped, non-linear and curved gradients would suffice.

By introducing a positive resistivity gradient between the source and drain electrodes of a BNC semiconductor, higher resistivities at positive or drain electrode, the curve of potential energy of the conduction electrons ϕ along the direction of applied field, just prior to the onset of

Figure B.160: Herbert Kroemer invented III-V semiconductor heterostructures in 1966.



oscillations will be convex upward. When the applied voltage is increased beyond threshold such that $V/w>E_T$ the convex shape of the potential energy distribution of the conduction electrons between source and drain electrodes will cause a pure accumulation mode to form.

A pure accumulation mode will then be propagated as a traveling space charge domain towards the exit region or drain eletrode. The accumulation mode will be characterized by the presence of an accumulation layer bounded on the upstream side by a low field region and bounded on the downstream side by a high field region. The accumulation layer itself is a narrow region of excess or negative space charge populated by electrons of both high and low mobilities as referenced to the generic many valley conduction band structure depicted in FIG. 2.

By introducing a negative resistivity gradient between the source and drain electrodes of a BNC semiconductor, lower resistivities at positive or drain electrode, the curve of the potential energy of the conduction electrons ϕ along the direction of applied field, just prior to the onset of oscillations will be concave upward. When the applied voltage is increased beyond threshold such that $V/w>E_T$ the concave shape of the potential energy distribution of the conduction electrons between source and drain electrodes will cause a depletion layer to form in addition to the accumulation layer formed by the negative electrode itself.

A dipole space charge mode will then be propagated as a traveling space charge domain toward the exit region or drain electrode. The dipole space charge mode will be characterized by the presence of a pair of low field regions bounding an upstream accumulation layer separated from a downstream depletion layer by a high field region. The accumulation layer is the same as in the pure accumulation mode case and the depletion layer is a region of positive space charge characterized by the absence of conduction electrons. The high and low field regions will have values dependent on the particular semiconductor material.

The design criterion for the resistivity gradients (in both the positive and negative cases) is the limitation of the gradient to values which are no stronger than is necessary to just override the random nucleation processes in order to assure that all portions of diode main body width w do indeed oscillate. Good results can be obtained using resistivity gradients between 1% and 20% of the average resistivity.

Furthermore, in the case of the negative gradient, the region of high resistivity can be concentrated in the area near the source electrode.

I have also determined that the spectral purity, stability and coherency of BNC diodes can be improved by utilizing a heterojunction source electrode in conjunction with a BNC diode body with the heterojunction electrode (a heterojunction being a junction between two dissimilar semiconductors as opposed to a homojunction which is a union of similar semiconductors) being characterized as follows: (a) higher resistivity than the BNC diode body portion; and (b) not exhibiting a negative mobility at the fields reached during oscillation of the oscillating semiconductor.

In other words, the source electrode making contact to the BNC semiconductor body is not a simple metal contact or a more heavily doped or degenerate region of the same semiconductor. In other words, by selecting the source electrode parameters such as indicated above, it is possible to control the original nucleation point of each dipole domain as well as the initial starting conditions for dipole domain formation in a manner which results in a depletion layer being nucleated directly at the heterojunction interface and developing into a mature dipole domain from this point rather than being left to chance as heretofore occurred. The rationale for the previous instabilities in dipole domain formation and operating frequency were due, in my opinion reached through theoretical analysis, to microscopic spatial fluctuations of the donor distribution in n-type BNC semiconductors which result in a high degree of uncertainty as to what the initial starting conditions and starting point of any given dipole domain will be. By restricting the inital starting condition of each dipole domain to the formation of a depletion layer with the starting point located at the heterojunction interface good improvement in the stability and coherence of the operating frequency will result.

Other types of heterojunction source electrodes which are taught by the present invention are the simple narrow to wide gap case wherein a particularly useful case involves nGe-nGaAs wherein the depletion layer, positive space charge region, created by the $\Delta\epsilon_c$ is useful for forming an initial high field region. The use of a wide to narrow gap heterojunction such as nGaP-nGaAs is taught by the present invention as a technique for obtaining direct injection of electrons from the GaP into the satellite (100) valleys of the nGaAs. A particularly useful junction called the CHI-junction (χ-junction) is also taught by the present invention for obtaining direct electron injection into the satellite valleys of the BNC semiconducor. This χ-type of heterojunction has other uses as will be developed hereinafter.

It is therefore an object of the present invention to provide a novel bulk negative conductivity semiconductor.

A feature of the present invention is the provision of a BNC semiconductor with mode control means.

Another feature of the present invention is the provision of a BNC semiconductor with a positive resistivity gradient for controlling the nucleation of a traveling pure accumulation mode.

Another feature of the present invention is the provision of a BNC semiconductor with a negative resistivity gradient for controlling the nucleation of a traveling dipole space charge mode of propagation.

Another feature of the present invention is the provision of a BNC semiconductor with a heterojunction source electrode for nucleation and mode control.

Another feature of the present invention is the provision of a novel χ-junction type of heterojunction.

Another feature of the present invention is the provision of a narrow to wide forbidden band gap heterojunction control electrode for BNC semiconductors.

Another feature of the present invention is the provision of a wide to narrow forbidden band gap heterojunction source control electrode for BNC semiconductors which can produce direct electron injection into the satellite valleys of the BNC semiconductor.

These and other features and advantages of the present invention will become more apparent upon a perusal of the following specification taken in conjunction with the accompanying drawings wherein:

FIG. 1 is an illustrative graphical portrayal of the drift velocity v vs. applied electrical field E dependence of a BNC semiconductor having a region of negative differential mobility.

FIG. 2 is an illustrative K-space diagram of the generic band structure associated with a BNC semiconductor particularly directed to n-type GaAs.

FIGS. 3A, 3B, and 3C depict the formation of a dipole space charge mode in a BNC semiconductor without a resistivity gradient.

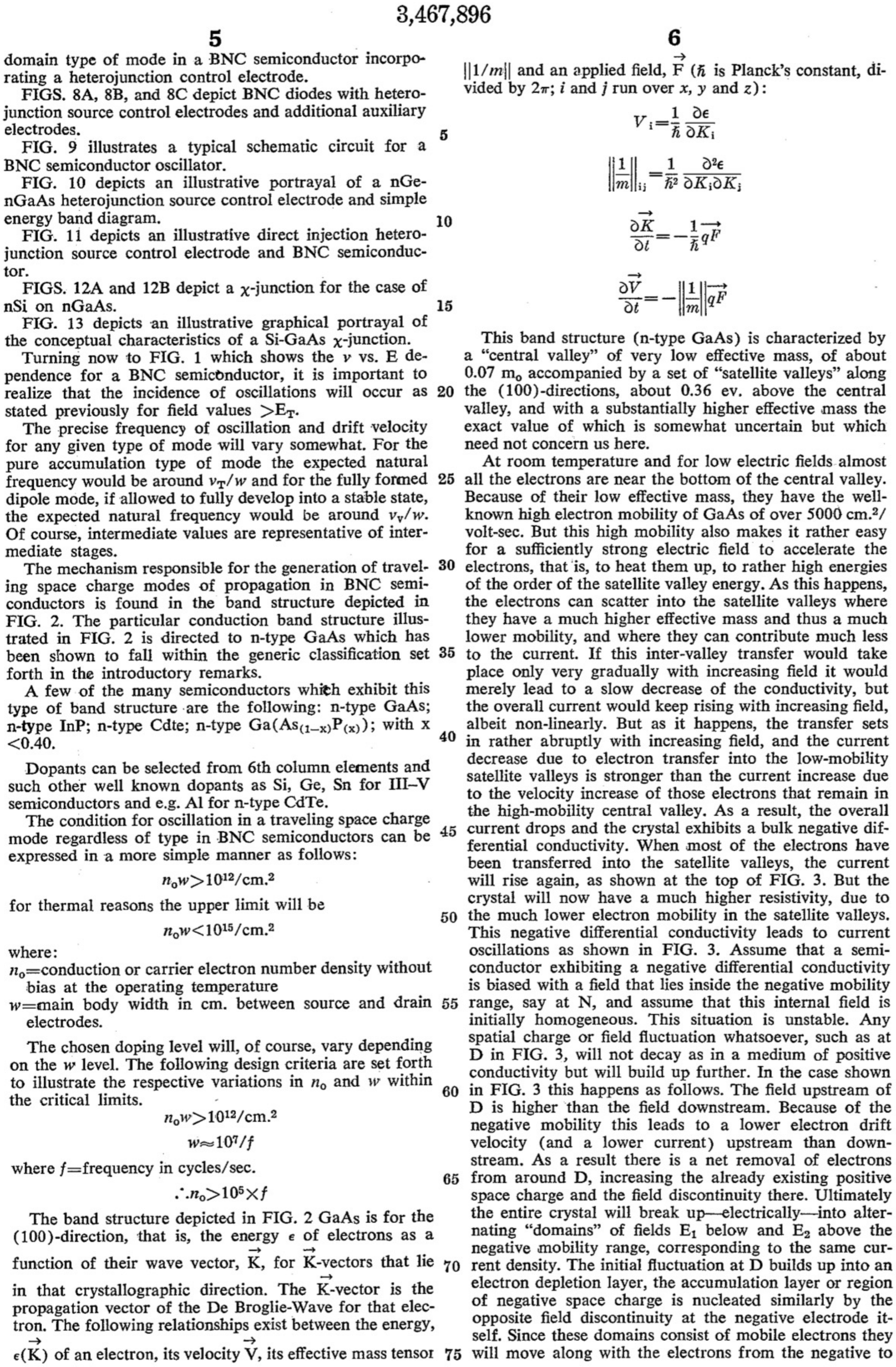
FIGS. 4A, 4B, and 4C depict the formation of a traveling pure accumulation mode in a BNC semiconductor having a positive resistivity gradient.

FIGS. 5A, 5B, and 5C depict the formation of a traveling dipole space charge mode in a BNC semiconductor having a negative resistivity gradient.

FIG. 6 is a cross-sectional view of a typical BNC semiconductor incorporating a heterojunction source electrode for mode control.

FIG. 7 is an illustrative graphical portrayal of controlled formation of a traveling dipole space charge

Figure B.161: Herbert Kroemer invented III-V semiconductor heterostructures in 1966.



domain type of mode in a BNC semiconductor incorporating a heterojunction control electrode.

FIGS. 8A, 8B, and 8C depict BNC diodes with heterojunction source control electrodes and additional auxiliary electrodes.

FIG. 9 illustrates a typical schematic circuit for a BNC semiconductor oscillator.

FIG. 10 depicts an illustrative portrayal of a nGe-nGaAs heterojunction source control electrode and simple energy band diagram.

FIG. 11 depicts an illustrative direct injection heterojunction source control electrode and BNC semiconductor.

FIGS. 12A and 12B depict a χ-junction for the case of nSi on nGaAs.

FIG. 13 depicts an illustrative graphical portrayal of the conceptual characteristics of a Si-GaAs χ-junction.

Turning now to FIG. 1 which shows the ν vs. E dependence for a BNC semiconductor, it is important to realize that the incidence of oscillations will occur as stated previously for field values $>E_T$.

The precise frequency of oscillation and drift velocity for any given type of mode will vary somewhat. For the pure accumulation type of mode the expected natural frequency would be around ν_T/w and for the fully formed dipole mode, if allowed to fully develop into a stable state, the expected natural frequency would be around ν_v/w. Of course, intermediate values are representative of intermediate stages.

The mechanism responsible for the generation of traveling space charge modes of propagation in BNC semiconductors is found in the band structure depicted in FIG. 2. The particular conduction band structure illustrated in FIG. 2 is directed to n-type GaAs which has been shown to fall within the generic classification set forth in the introductory remarks.

A few of the many semiconductors which exhibit this type of band structure are the following: n-type GaAs; n-type InP; n-type Cdte; n-type $Ga(As_{(1-x)}P_{(x)})$; with x <0.40.

Dopants can be selected from 6th column elements and such other well known dopants as Si, Ge, Sn for III–V semiconductors and e.g. Al for n-type CdTe.

The condition for oscillation in a traveling space charge mode regardless of type in BNC semiconductors can be expressed in a more simple manner as follows:

$$n_o w > 10^{12}/\text{cm.}^2$$

for thermal reasons the upper limit will be

$$n_o w < 10^{15}/\text{cm.}^2$$

where:

n_o=conduction or carrier electron number density without bias at the operating temperature

w=main body width in cm. between source and drain electrodes.

The chosen doping level will, of course, vary depending on the w level. The following design criteria are set forth to illustrate the respective variations in n_o and w within the critical limits.

$$n_o w > 10^{12}/\text{cm.}^2$$

$$w \approx 10^7/f$$

where f=frequency in cycles/sec.

$$\therefore n_o > 10^5 \times f$$

The band structure depicted in FIG. 2 GaAs is for the (100)-direction, that is, the energy ϵ of electrons as a function of their wave vector, $\vec{K}$, for $\vec{K}$-vectors that lie in that crystallographic direction. The $\vec{K}$-vector is the propagation vector of the De Broglie-Wave for that electron. The following relationships exist between the energy, $\epsilon(\vec{K})$ of an electron, its velocity $\vec{V}$, its effective mass tensor $\|1/m\|$ and an applied field, $\vec{F}$ ($\hbar$ is Planck's constant, divided by 2π; i and j run over x, y and z):

$$V_i = \frac{1}{\hbar}\frac{\partial\epsilon}{\partial K_i}$$

$$\left\|\frac{1}{m}\right\|_{ij} = \frac{1}{\hbar^2}\frac{\partial^2\epsilon}{\partial K_i \partial K_j}$$

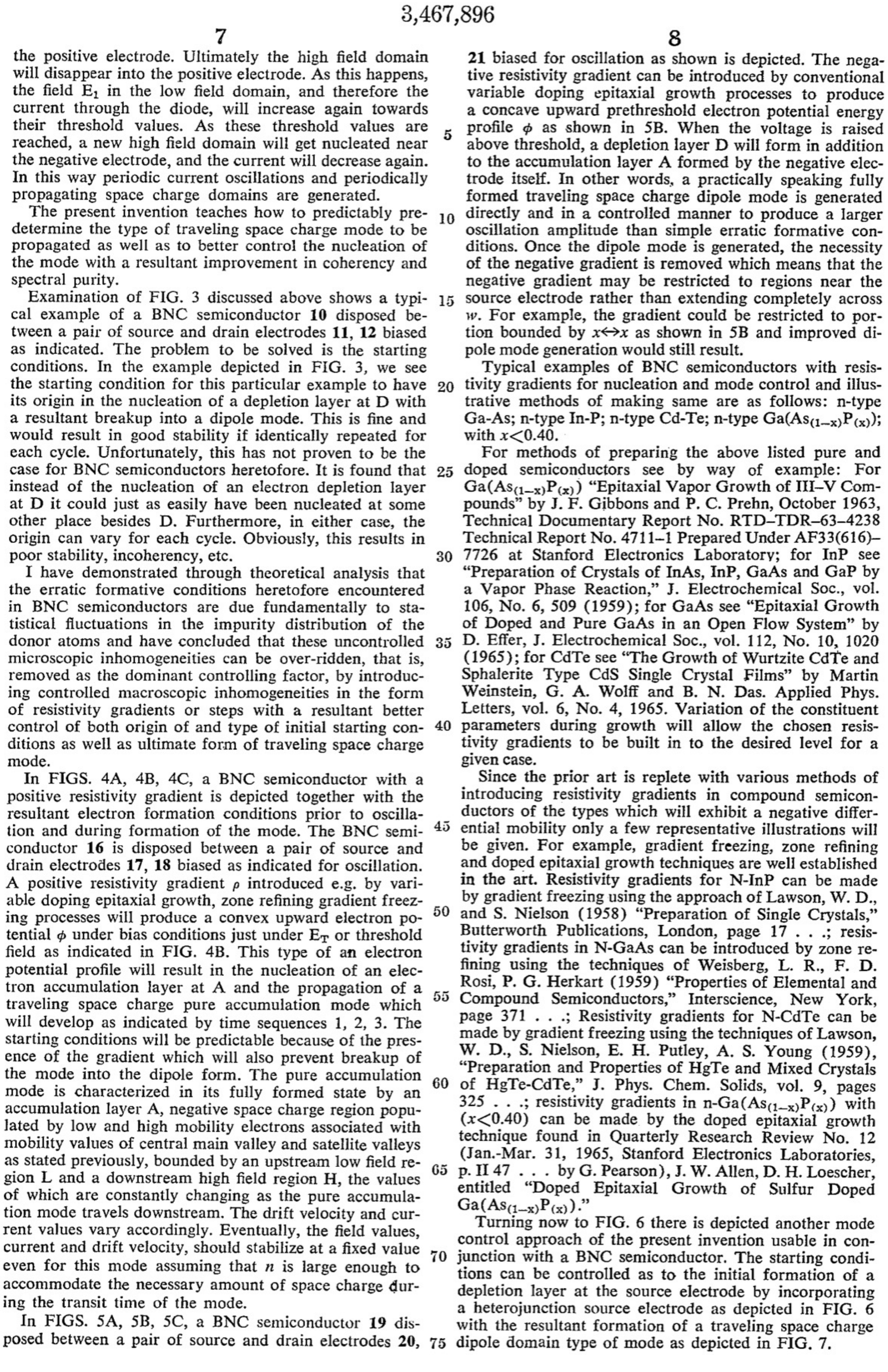
$$\frac{\partial\vec{K}}{\partial t} = -\frac{1}{\hbar}q\vec{F}$$

$$\frac{\partial\vec{V}}{\partial t} = -\left\|\frac{1}{m}\right\|\overrightarrow{qF}$$

This band structure (n-type GaAs) is characterized by a "central valley" of very low effective mass, of about 0.07 m_o accompanied by a set of "satellite valleys" along the (100)-directions, about 0.36 ev. above the central valley, and with a substantially higher effective mass the exact value of which is somewhat uncertain but which need not concern us here.

At room temperature and for low electric fields almost all the electrons are near the bottom of the central valley. Because of their low effective mass, they have the well-known high electron mobility of GaAs of over 5000 cm.^{2}/volt-sec. But this high mobility also makes it rather easy for a sufficiently strong electric field to accelerate the electrons, that is, to heat them up, to rather high energies of the order of the satellite valley energy. As this happens, the electrons can scatter into the satellite valleys where they have a much higher effective mass and thus a much lower mobility, and where they can contribute much less to the current. If this inter-valley transfer would take place only very gradually with increasing field it would merely lead to a slow decrease of the conductivity, but the overall current would keep rising with increasing field, albeit non-linearly. But as it happens, the transfer sets in rather abruptly with increasing field, and the current decrease due to electron transfer into the low-mobility satellite valleys is stronger than the current increase due to the velocity increase of those electrons that remain in the high-mobility central valley. As a result, the overall current drops and the crystal exhibits a bulk negative differential conductivity. When most of the electrons have been transferred into the satellite valleys, the current will rise again, as shown at the top of FIG. 3. But the crystal will now have a much higher resistivity, due to the much lower electron mobility in the satellite valleys. This negative differential conductivity leads to current oscillations as shown in FIG. 3. Assume that a semiconductor exhibiting a negative differential conductivity is biased with a field that lies inside the negative mobility range, say at N, and assume that this internal field is initially homogeneous. This situation is unstable. Any spatial charge or field fluctuation whatsoever, such as at D in FIG. 3, will not decay as in a medium of positive conductivity but will build up further. In the case shown in FIG. 3 this happens as follows. The field upstream of D is higher than the field downstream. Because of the negative mobility this leads to a lower electron drift velocity (and a lower current) upstream than downstream. As a result there is a net removal of electrons from around D, increasing the already existing positive space charge and the field discontinuity there. Ultimately the entire crystal will break up—electrically—into alternating "domains" of fields E_1 below and E_2 above the negative mobility range, corresponding to the same current density. The initial fluctuation at D builds up into an electron depletion layer, the accumulation layer or region of negative space charge is nucleated similarly by the opposite field discontinuity at the negative electrode itself. Since these domains consist of mobile electrons they will move along with the electrons from the negative to

Figure B.162: Herbert Kroemer invented III-V semiconductor heterostructures in 1966.



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the positive electrode. Ultimately the high field domain will disappear into the positive electrode. As this happens, the field E_1 in the low field domain, and therefore the current through the diode, will increase again towards their threshold values. As these threshold values are reached, a new high field domain will get nucleated near the negative electrode, and the current will decrease again. In this way periodic current oscillations and periodically propagating space charge domains are generated.

The present invention teaches how to predictably predetermine the type of traveling space charge mode to be propagated as well as to better control the nucleation of the mode with a resultant improvement in coherency and spectral purity.

Examination of FIG. 3 discussed above shows a typical example of a BNC semiconductor **10** disposed between a pair of source and drain electrodes **11**, **12** biased as indicated. The problem to be solved is the starting conditions. In the example depicted in FIG. 3, we see the starting condition for this particular example to have its origin in the nucleation of a depletion layer at D with a resultant breakup into a dipole mode. This is fine and would result in good stability if identically repeated for each cycle. Unfortunately, this has not proven to be the case for BNC semiconductors heretofore. It is found that instead of the nucleation of an electron depletion layer at D it could just as easily have been nucleated at some other place besides D. Furthermore, in either case, the origin can vary for each cycle. Obviously, this results in poor stability, incoherency, etc.

I have demonstrated through theoretical analysis that the erratic formative conditions heretofore encountered in BNC semiconductors are due fundamentally to statistical fluctuations in the impurity distribution of the donor atoms and have concluded that these uncontrolled microscopic inhomogeneities can be over-ridden, that is, removed as the dominant controlling factor, by introducing controlled macroscopic inhomogeneities in the form of resistivity gradients or steps with a resultant better control of both origin of and type of initial starting conditions as well as ultimate form of traveling space charge mode.

In FIGS. 4A, 4B, 4C, a BNC semiconductor with a positive resistivity gradient is depicted together with the resultant electron formation conditions prior to oscillation and during formation of the mode. The BNC semiconductor **16** is disposed between a pair of source and drain electrodes **17**, **18** biased as indicated for oscillation. A positive resistivity gradient ρ introduced e.g. by variable doping epitaxial growth, zone refining gradient freezing processes will produce a convex upward electron potential ϕ under bias conditions just under E_T or threshold field as indicated in FIG. 4B. This type of an electron potential profile will result in the nucleation of an electron accumulation layer at A and the propagation of a traveling space charge pure accumulation mode which will develop as indicated by time sequences 1, 2, 3. The starting conditions will be predictable because of the presence of the gradient which will also prevent breakup of the mode into the dipole form. The pure accumulation mode is characterized in its fully formed state by an accumulation layer A, negative space charge region populated by low and high mobility electrons associated with mobility values of central main valley and satellite valleys as stated previously, bounded by an upstream low field region L and a downstream high field region H, the values of which are constantly changing as the pure accumulation mode travels downstream. The drift velocity and current values vary accordingly. Eventually, the field values, current and drift velocity, should stabilize at a fixed value even for this mode assuming that n is large enough to accommodate the necessary amount of space charge during the transit time of the mode.

In FIGS. 5A, 5B, 5C, a BNC semiconductor **19** disposed between a pair of source and drain electrodes **20**,

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21 biased for oscillation as shown is depicted. The negative resistivity gradient can be introduced by conventional variable doping epitaxial growth processes to produce a concave upward prethreshold electron potential energy profile ϕ as shown in 5B. When the voltage is raised above threshold, a depletion layer D will form in addition to the accumulation layer A formed by the negative electrode itself. In other words, a practically speaking fully formed traveling space charge dipole mode is generated directly and in a controlled manner to produce a larger oscillation amplitude than simple erratic formative conditions. Once the dipole mode is generated, the necessity of the negative gradient is removed which means that the negative gradient may be restricted to regions near the source electrode rather than extending completely across w. For example, the gradient could be restricted to portion bounded by $x \leftrightarrow x$ as shown in 5B and improved dipole mode generation would still result.

Typical examples of BNC semiconductors with resistivity gradients for nucleation and mode control and illustrative methods of making same are as follows: n-type Ga-As; n-type In-P; n-type Cd-Te; n-type $Ga(As_{(1-x)}P_{(x)})$; with $x<0.40$.

For methods of preparing the above listed pure and doped semiconductors see by way of example: For $Ga(As_{(1-x)}P_{(x)})$ "Epitaxial Vapor Growth of III–V Compounds" by J. F. Gibbons and P. C. Prehn, October 1963, Technical Documentary Report No. RTD–TDR–63–4238 Technical Report No. 4711–1 Prepared Under AF33(616)–7726 at Stanford Electronics Laboratory; for InP see "Preparation of Crystals of InAs, InP, GaAs and GaP by a Vapor Phase Reaction," J. Electrochemical Soc., vol. 106, No. 6, 509 (1959); for GaAs see "Epitaxial Growth of Doped and Pure GaAs in an Open Flow System" by D. Effer, J. Electrochemical Soc., vol. 112, No. 10, 1020 (1965); for CdTe see "The Growth of Wurtzite CdTe and Sphalerite Type CdS Single Crystal Films" by Martin Weinstein, G. A. Wolff and B. N. Das. Applied Phys. Letters, vol. 6, No. 4, 1965. Variation of the constituent parameters during growth will allow the chosen resistivity gradients to be built in to the desired level for a given case.

Since the prior art is replete with various methods of introducing resistivity gradients in compound semiconductors of the types which will exhibit a negative differential mobility only a few representative illustrations will be given. For example, gradient freezing, zone refining and doped epitaxial growth techniques are well established in the art. Resistivity gradients for N-InP can be made by gradient freezing using the approach of Lawson, W. D., and S. Nielson (1958) "Preparation of Single Crystals," Butterworth Publications, London, page 17 . . .; resistivity gradients in N-GaAs can be introduced by zone refining using the techniques of Weisberg, L. R., F. D. Rosi, P. G. Herkart (1959) "Properties of Elemental and Compound Semiconductors," Interscience, New York, page 371 . . .; Resistivity gradients for N-CdTe can be made by gradient freezing using the techniques of Lawson, W. D., S. Nielson, E. H. Putley, A. S. Young (1959), "Preparation and Properties of HgTe and Mixed Crystals of HgTe-CdTe," J. Phys. Chem. Solids, vol. 9, pages 325 . . .; resistivity gradients in n-$Ga(As_{(1-x)}P_{(x)})$ with ($x<0.40$) can be made by the doped epitaxial growth technique found in Quarterly Research Review No. 12 (Jan.-Mar. 31, 1965, Stanford Electronics Laboratories, p. II 47 . . . by G. Pearson), J. W. Allen, D. H. Loescher, entitled "Doped Epitaxial Growth of Sulfur Doped $Ga(As_{(1-x)}P_{(x)})$."

Turning now to FIG. 6 there is depicted another mode control approach of the present invention usable in conjunction with a BNC semiconductor. The starting conditions can be controlled as to the initial formation of a depletion layer at the source electrode by incorporating a heterojunction source electrode as depicted in FIG. 6 with the resultant formation of a traveling space charge dipole domain type of mode as depicted in FIG. 7.

Figure B.163: Herbert Kroemer invented III-V semiconductor heterostructures in 1966.

The BNC semiconductor main body **30** depicted in FIG. 6 has a width w disposed between a pair of source and drain electrodes with a pair of leads **33, 34** if desired.

The source electrode in the case of n-type BNC diodes is the origin of the traveling space charge instability and the drain electrode is the exit for the traveling space charge instability. According to the further teachings of this invention by making the source electrode **31** include a heterojunction electrode **35** with the following characteristics,

(a) Higher resistivity than the oscillating body portion w
(b) Not exhibiting a negative conductivity at the electric fields reached during oscillation of the oscillating semiconductor,

improved frequency stability will result. The remaining portion, if any, of the source electrode can be a simple alloyed metal contact **36** such as tin or any other high conductivity contact electrode such as a heavily doped (degenerate) n^+ semiconductor of the same material to facilitate integration into integrated circuits. The drain electrode **32** is also preferably a high conductivity type of electrode such as for example, an ohmic metal electrode of tin. Alternatively, as mentioned above for facilitation of incorporation of the BNC semiconductors of the present invention in integrated circuit environments the metal electrode portions **36, 32** can be replaced with epitaxially grown layers of the same semiconductor as they are grown on only more heavily doped such that $n_c w > nw$ where n_c in this case is the electron conduction or carrier number density of the n-type semiconductor electrode portions **36, 32**. In other words, the important aspect of this type of mode control is the utilization of a heterojunction source electrode **35**. If desired, the heterojunction source electrode **35** can include a metal, or n^+ (degenerate) portion or metal pressure contact or other type of high conductivity electrode.

With the above indicated type of hetrojunction source electrode incorporated in a BNC semiconductor oscillator controlled dipole domain formation will result as indicated in FIG. 7. Initially, a depletion layer D will be nucleated directly at the heterojunction interface **38** bounded on the upstream side by a high field region F_{H1} and on the downstream side by a low field region F_{L1}. This space charge instability will commence propagation toward the drain electrode and will, practically speaking, immediately begin breakup of the high field region to cause nucleation of an accumulation layer A_2 upstream from the depletion layer at the next illustrative time interval represented by depletion layer D_2. From this point on the dipole domain continues development into its fully mature form such as indicated at time interval **3**, and ultimately propagates out the drain electrode at which point the cycle will repeat itself ad infinitum under stable bias and load conditions with $f \approx v_L/w$.

A suitable material for the hetrojunction control electrode **35** will obey the aforementioned criteria of:

$$\rho_h > \rho_B$$

where:

ρ_h=resistivity of the heterojunction control electrode,
ρ_B=resistivity of the BNC semiconductor body and σ_h is positive over the operating range of the device where σ_h=conductivity of the heterojunction control electrode.

Suitable relative ratios between ρ_h and ρ_B are that ρ_h exceed ρ_B by 10% or more as computed at the operating temperature and zero bias.

The techniques for measuring conductivity and resistivity are well known in the art. For example, see an article by L. J. Van der Pauw, "A Method of Measuring Specific Resistivity and Hall Effect of Discs of Arbitrary Shape," Philips Research Reports, vol. 13, p. 1 (1958).

A few specific examples of suitable heterojunction control electrode semiconductors utilizable in conjunction with a BNC body made of n-type GaAs are as follows:

n-GaP
n-GaAs-GaP mixture with more than 50% GaP

$$\mathrm{Ga}(\mathrm{As}_{(1-x)}-\mathrm{P}_{(x)})$$

with $x > .5$
n-Ge

and any other semiconductors not exhibiting a negative conductivity.

The thickness dimension t of the heterojunction control electrode will be less than w (preferably as thin as feasible) to facilitate formation of the high field region in a short time span for efficiency considerations. A typical illustrative example is 1 micron.

As mentioned previously, other types of BNC semiconductors are known beside n-type GaAs such as listed in the introduction. In each case the heterojunction control electrode material is easily selected from any known semiconductors with the restriction that $\rho_h > \rho_B$ and σ_h be positive.

Good practice would be to select III–V semiconductors as heterojunction control electrodes when the BNC main body is a III–V compound and II–VI semiconductors as heterojunction control electrodes when the BNC main body is a II–VI semiconductor. Ge can be used with both III–V main body semiconductors and II–VI main body semiconductors. The heterojunction control electrodes are preferably epitaxially deposited in manners well known in the art.

The following articles are cited to provide representative techniques for building heterojunction control electrodes having the above set forth properties.

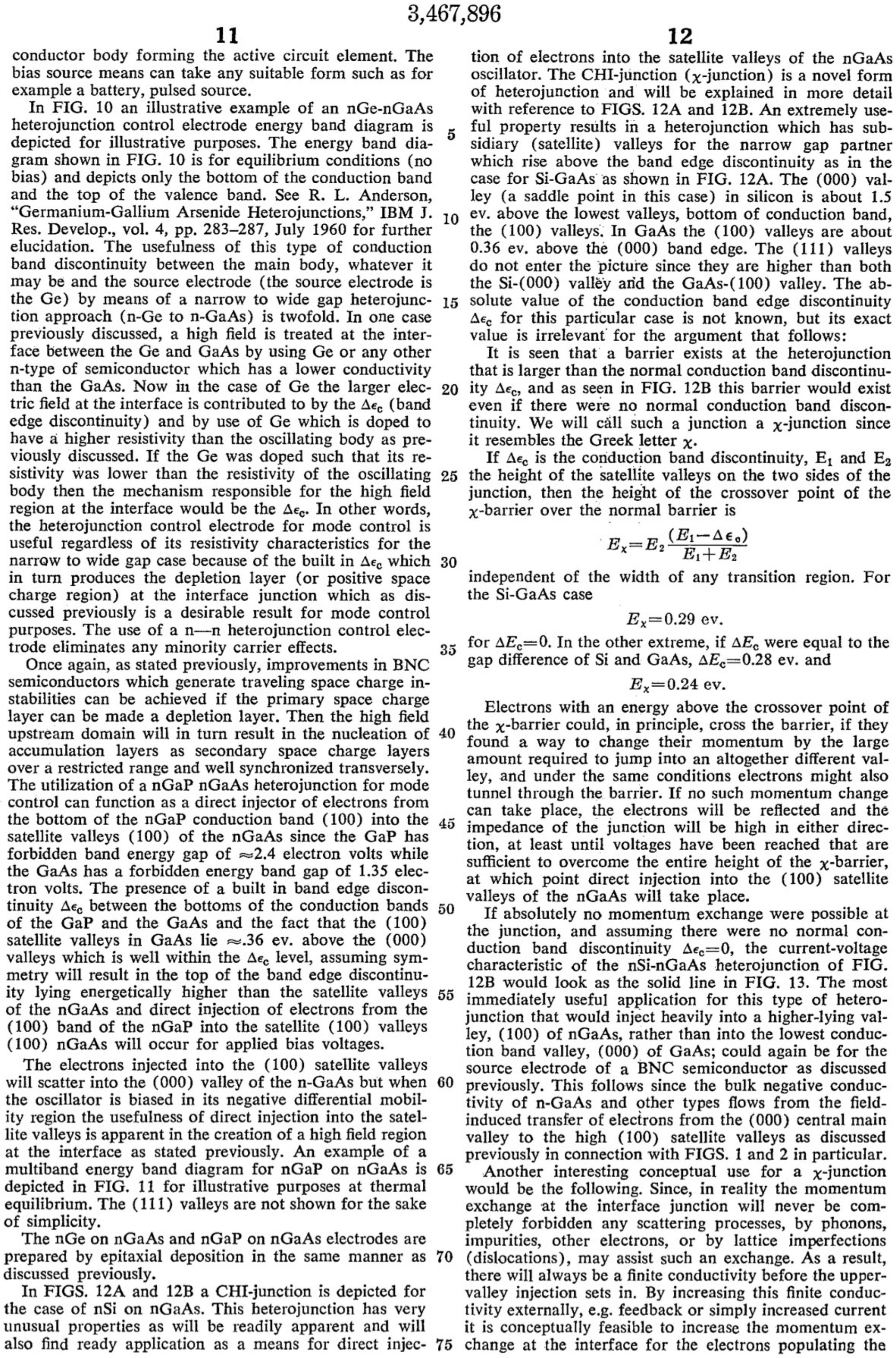
The deposition of n-Ge on -nGaAs is taught in an article by J. C. Marinace "Tunnel Diodes by Vapor Growth of Ge on Ge and on GaAs," IBM Journal of Res. and Dev., Vol. 4, No. 3, July 1960. The deposition of n-Ge on n-InP is set forth in an article entitled "Growth of Germanium Epitaxial Layers by the Pyrolysis of Germane" RCA Review, December 1963, No. 4, p. 499. This deposition technique can also be used for the deposition of n-Ge on n-CdTe and n-$\mathrm{Ga}(\mathrm{As}_{(1-x)}\mathrm{P}_{(x)})$ with $x < 0.40$. The deposition of n-GaP on n-GaAs and n-$\mathrm{Ga}(\mathrm{As}_{(1-x)}\mathrm{P}_{(x)})$ with $x > .5$ on n-GaAs is taught in NASA Research Grant No. NSG-555 Tech. Report No. 5108–1 by Yen-sun Chen, October 1965.

As discussed previously, the heterojunction control electrode will of necessity be the source electrode for mode control. The source electrode can also include a high conductivity portion such as alloyed tin portion **36** metal pressure contact or n^+ similar semiconductor as illustrated in FIGS. 8A, 8B, and 8C. The drain electrode will preferably be similar. In FIG. 8A the BNC diode with heterojunction control electrode is the same as in FIG. 6.

In FIG. 8B the tin electrode portions are replaced with metal pressure contacts **39** and in FIG. 8C the n^+ electrode scheme is used.

In FIG. 9 a typical schematic circuit of a microwave generator employing the bulk negative conductivity semiconductor with built in mode control means as the active element is depicted. The circuit includes a low pass filter section **50**, active element **51**, bias source means **52** and output terminals **53** for extracting the microwave energy. The circuit includes series and shunt capacitors **54, 55** for varying the coupling to the load and blocking the bias voltage from the load and for tuning the operating frequency of the generator. The particular oscillator depicted in FIG. 9 is merely an illustrative example of one of many possible forms which can be implemented by suitable microwave circuitry. For example, see an article by P. N. Robson and S. M. Mahrous in The Radio and Electronic Engineer, December 1965, pages 345–352, for a typical coaxial version of a microwave oscillator using the internal oscillations generated in a bulk negative conductivity semi-

Figure B.164: Herbert Kroemer invented III-V semiconductor heterostructures in 1966.



conductor body forming the active circuit element. The bias source means can take any suitable form such as for example a battery, pulsed source.

In FIG. 10 an illustrative example of an nGe-nGaAs heterojunction control electrode energy band diagram is depicted for illustrative purposes. The energy band diagram shown in FIG. 10 is for equilibrium conditions (no bias) and depicts only the bottom of the conduction band and the top of the valence band. See R. L. Anderson, "Germanium-Gallium Arsenide Heterojunctions," IBM J. Res. Develop., vol. 4, pp. 283–287, July 1960 for further elucidation. The usefulness of this type of conduction band discontinuity between the main body, whatever it may be and the source electrode (the source electrode is the Ge) by means of a narrow to wide gap heterojunction approach (n-Ge to n-GaAs) is twofold. In one case previously discussed, a high field is treated at the interface between the Ge and GaAs by using Ge or any other n-type of semiconductor which has a lower conductivity than the GaAs. Now in the case of Ge the larger electric field at the interface is contributed to by the $\Delta\epsilon_c$ (band edge discontinuity) and by use of Ge which is doped to have a higher resistivity than the oscillating body as previously discussed. If the Ge was doped such that its resistivity was lower than the resistivity of the oscillating body then the mechanism responsible for the high field region at the interface would be the $\Delta\epsilon_c$. In other words, the heterojunction control electrode for mode control is useful regardless of its resistivity characteristics for the narrow to wide gap case because of the built in $\Delta\epsilon_c$ which in turn produces the depletion layer (or positive space charge region) at the interface junction which as discussed previously is a desirable result for mode control purposes. The use of a n—n heterojunction control electrode eliminates any minority carrier effects.

Once again, as stated previously, improvements in BNC semiconductors which generate traveling space charge instabilities can be achieved if the primary space charge layer can be made a depletion layer. Then the high field upstream domain will in turn result in the nucleation of accumulation layers as secondary space charge layers over a restricted range and well synchronized transversely. The utilization of a nGaP nGaAs heterojunction for mode control can function as a direct injector of electrons from the bottom of the nGaP conduction band (100) into the satellite valleys (100) of the nGaAs since the GaP has forbidden band energy gap of ≈2.4 electron volts while the GaAs has a forbidden energy band gap of 1.35 electron volts. The presence of a built in band edge discontinuity $\Delta\epsilon_c$ between the bottoms of the conduction bands of the GaP and the GaAs and the fact that the (100) satellite valleys in GaAs lie ≈.36 ev. above the (000) valleys which is well within the $\Delta\epsilon_c$ level, assuming symmetry will result in the top of the band edge discontinuity lying energetically higher than the satellite valleys of the nGaAs and direct injection of electrons from the (100) band of the nGaP into the satellite (100) valleys (100) nGaAs will occur for applied bias voltages.

The electrons injected into the (100) satellite valleys will scatter into the (000) valley of the n-GaAs but when the oscillator is biased in its negative differential mobility region the usefulness of direct injection into the satellite valleys is apparent in the creation of a high field region at the interface as stated previously. An example of a multiband energy band diagram for nGaP on nGaAs is depicted in FIG. 11 for illustrative purposes at thermal equilibrium. The (111) valleys are not shown for the sake of simplicity.

The nGe on nGaAs and nGaP on nGaAs electrodes are prepared by epitaxial deposition in the same manner as discussed previously.

In FIGS. 12A and 12B a CHI-junction is depicted for the case of nSi on nGaAs. This heterojunction has very unusual properties as will be readily apparent and will also find ready application as a means for direct injection of electrons into the satellite valleys of the nGaAs oscillator. The CHI-junction (χ-junction) is a novel form of heterojunction and will be explained in more detail with reference to FIGS. 12A and 12B. An extremely useful property results in a heterojunction which has subsidiary (satellite) valleys for the narrow gap partner which rise above the band edge discontinuity as in the case for Si-GaAs as shown in FIG. 12A. The (000) valley (a saddle point in this case) in silicon is about 1.5 ev. above the lowest valleys, bottom of conduction band, the (100) valleys. In GaAs the (100) valleys are about 0.36 ev. above the (000) band edge. The (111) valleys do not enter the picture since they are higher than both the Si-(000) valley and the GaAs-(100) valley. The absolute value of the conduction band edge discontinuity $\Delta\epsilon_c$ for this particular case is not known, but its exact value is irrelevant for the argument that follows:

It is seen that a barrier exists at the heterojunction that is larger than the normal conduction band discontinuity $\Delta\epsilon_c$, and as seen in FIG. 12B this barrier would exist even if there were no normal conduction band discontinuity. We will call such a junction a χ-junction since it resembles the Greek letter χ.

If $\Delta\epsilon_c$ is the conduction band discontinuity, E_1 and E_2 the height of the satellite valleys on the two sides of the junction, then the height of the crossover point of the χ-barrier over the normal barrier is

$$E_x = E_2 \frac{(E_1 - \Delta\epsilon_c)}{E_1 + E_2}$$

independent of the width of any transition region. For the Si-GaAs case

$$E_x = 0.29 \text{ ev.}$$

for $\Delta E_c = 0$. In the other extreme, if ΔE_c were equal to the gap difference of Si and GaAs, $\Delta E_c = 0.28$ ev. and

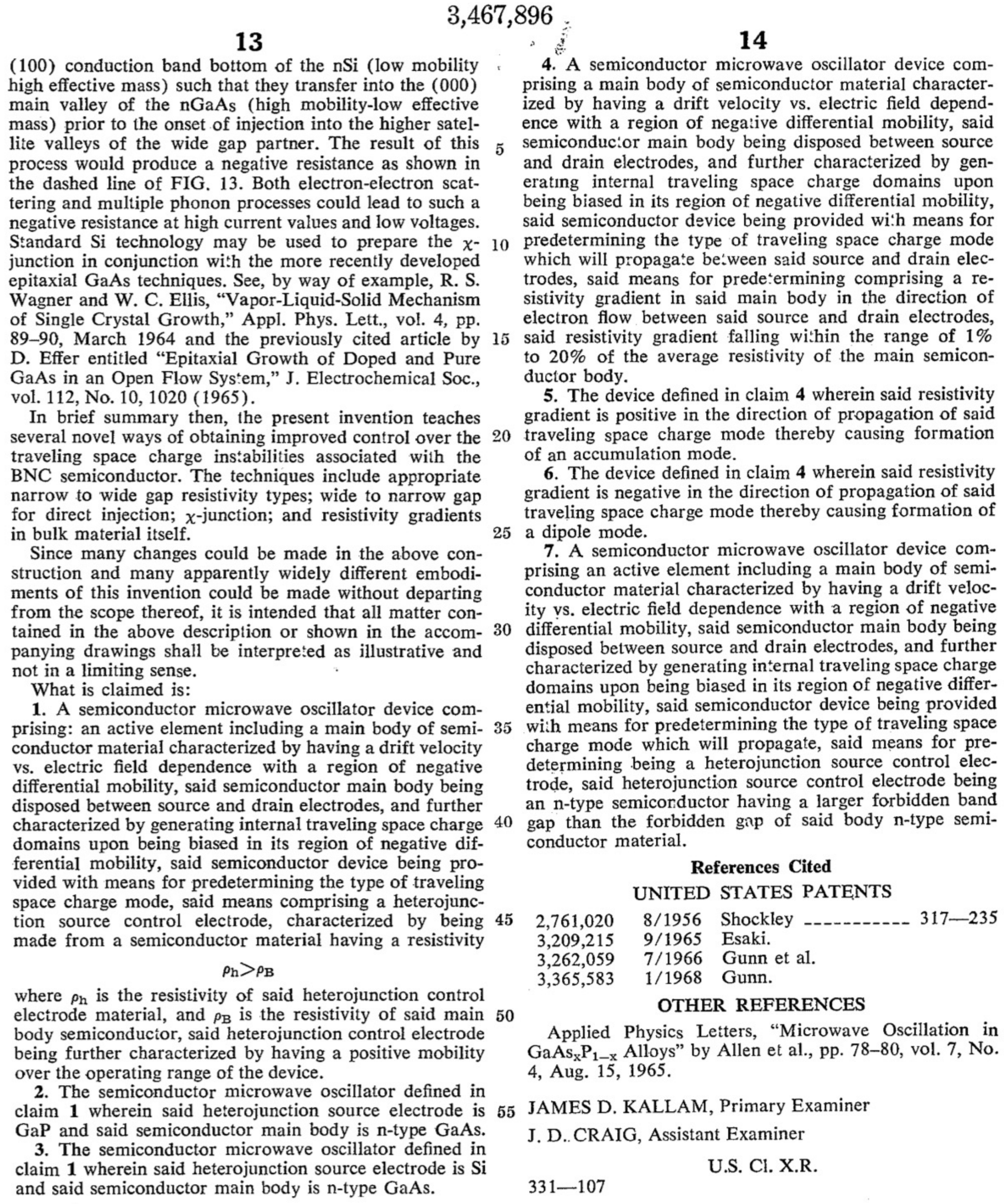
$$E_x = 0.24 \text{ ev.}$$

Electrons with an energy above the crossover point of the χ-barrier could, in principle, cross the barrier, if they found a way to change their momentum by the large amount required to jump into an altogether different valley, and under the same conditions electrons might also tunnel through the barrier. If no such momentum change can take place, the electrons will be reflected and the impedance of the junction will be high in either direction, at least until voltages have been reached that are sufficient to overcome the entire height of the χ-barrier, at which point direct injection into the (100) satellite valleys of the nGaAs will take place.

If absolutely no momentum exchange were possible at the junction, and assuming there were no normal conduction band discontinuity $\Delta\epsilon_c = 0$, the current-voltage characteristic of the nSi-nGaAs heterojunction of FIG. 12B would look as the solid line in FIG. 13. The most immediately useful application for this type of heterojunction that would inject heavily into a higher-lying valley, (100) of nGaAs, rather than into the lowest conduction band valley, (000) of GaAs; could again be for the source electrode of a BNC semiconductor as discussed previously. This follows since the bulk negative conductivity of n-GaAs and other types flows from the field-induced transfer of electrons from the (000) central main valley to the high (100) satellite valleys as discussed previously in connection with FIGS. 1 and 2 in particular.

Another interesting conceptual use for a χ-junction would be the following. Since, in reality the momentum exchange at the interface junction will never be completely forbidden any scattering processes, by phonons, impurities, other electrons, or by lattice imperfections (dislocations), may assist such an exchange. As a result, there will always be a finite conductivity before the upper-valley injection sets in. By increasing this finite conductivity externally, e.g. feedback or simply increased current it is conceptually feasible to increase the momentum exchange at the interface for the electrons populating the

Figure B.165: Herbert Kroemer invented III-V semiconductor heterostructures in 1966.



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(100) conduction band bottom of the nSi (low mobility high effective mass) such that they transfer into the (000) main valley of the nGaAs (high mobility-low effective mass) prior to the onset of injection into the higher satellite valleys of the wide gap partner. The result of this process would produce a negative resistance as shown in the dashed line of FIG. 13. Both electron-electron scattering and multiple phonon processes could lead to such a negative resistance at high current values and low voltages. Standard Si technology may be used to prepare the χ-junction in conjunction with the more recently developed epitaxial GaAs techniques. See, by way of example, R. S. Wagner and W. C. Ellis, "Vapor-Liquid-Solid Mechanism of Single Crystal Growth," Appl. Phys. Lett., vol. 4, pp. 89–90, March 1964 and the previously cited article by D. Effer entitled "Epitaxial Growth of Doped and Pure GaAs in an Open Flow System," J. Electrochemical Soc., vol. 112, No. 10, 1020 (1965).

In brief summary then, the present invention teaches several novel ways of obtaining improved control over the traveling space charge instabilities associated with the BNC semiconductor. The techniques include appropriate narrow to wide gap resistivity types; wide to narrow gap for direct injection; χ-junction; and resistivity gradients in bulk material itself.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A semiconductor microwave oscillator device comprising: an active element including a main body of semiconductor material characterized by having a drift velocity vs. electric field dependence with a region of negative differential mobility, said semiconductor main body being disposed between source and drain electrodes, and further characterized by generating internal traveling space charge domains upon being biased in its region of negative differential mobility, said semiconductor device being provided with means for predetermining the type of traveling space charge mode, said means comprising a heterojunction source control electrode, characterized by being made from a semiconductor material having a resistivity

$$\rho_h > \rho_B$$

where ρ_h is the resistivity of said heterojunction control electrode material, and ρ_B is the resistivity of said main body semiconductor, said heterojunction control electrode being further characterized by having a positive mobility over the operating range of the device.

2. The semiconductor microwave oscillator defined in claim **1** wherein said heterojunction source electrode is GaP and said semiconductor main body is n-type GaAs.

3. The semiconductor microwave oscillator defined in claim **1** wherein said heterojunction source electrode is Si and said semiconductor main body is n-type GaAs.

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4. A semiconductor microwave oscillator device comprising a main body of semiconductor material characterized by having a drift velocity vs. electric field dependence with a region of negative differential mobility, said semiconductor main body being disposed between source and drain electrodes, and further characterized by generating internal traveling space charge domains upon being biased in its region of negative differential mobility, said semiconductor device being provided with means for predetermining the type of traveling space charge mode which will propagate between said source and drain electrodes, said means for predetermining comprising a resistivity gradient in said main body in the direction of electron flow between said source and drain electrodes, said resistivity gradient falling within the range of 1% to 20% of the average resistivity of the main semiconductor body.

5. The device defined in claim **4** wherein said resistivity gradient is positive in the direction of propagation of said traveling space charge mode thereby causing formation of an accumulation mode.

6. The device defined in claim **4** wherein said resistivity gradient is negative in the direction of propagation of said traveling space charge mode thereby causing formation of a dipole mode.

7. A semiconductor microwave oscillator device comprising an active element including a main body of semiconductor material characterized by having a drift velocity vs. electric field dependence with a region of negative differential mobility, said semiconductor main body being disposed between source and drain electrodes, and further characterized by generating internal traveling space charge domains upon being biased in its region of negative differential mobility, said semiconductor device being provided with means for predetermining the type of traveling space charge mode which will propagate, said means for predetermining being a heterojunction source control electrode, said heterojunction source control electrode being an n-type semiconductor having a larger forbidden band gap than the forbidden gap of said body n-type semiconductor material.

References Cited

UNITED STATES PATENTS

2,761,020	8/1956	Shockley	317—235
3,209,215	9/1965	Esaki.	
3,262,059	7/1966	Gunn et al.	
3,365,583	1/1968	Gunn.	

OTHER REFERENCES

Applied Physics Letters, "Microwave Oscillation in $GaAs_xP_{1-x}$ Alloys" by Allen et al., pp. 78–80, vol. 7, No. 4, Aug. 15, 1965.

JAMES D. KALLAM, Primary Examiner

J. D. CRAIG, Assistant Examiner

U.S. Cl. X.R.

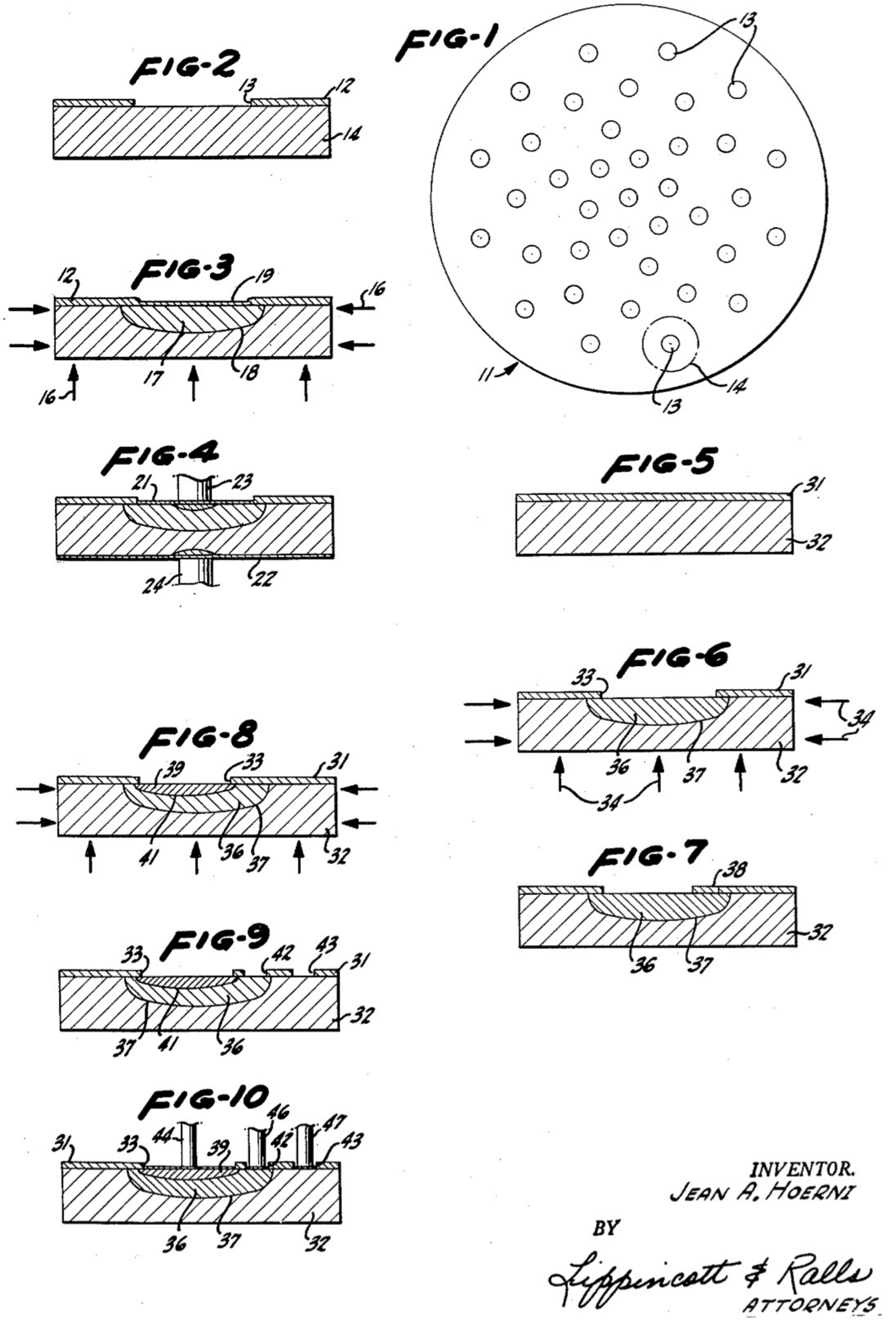
331—107

Figure B.166: Herbert Kroemer invented III-V semiconductor heterostructures in 1966.

March 20, 1962 J. A. HOERNI **3,025,589**

METHOD OF MANUFACTURING SEMICONDUCTOR DEVICES

Filed May 1, 1959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INVENTOR.
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Lippincott & Ralls
ATTORNEYS

Figure B.167: Jean Hoerni invented methods of manufacturing silicon transistors.

United States Patent Office

3,025,589

Patented Mar. 20, 1962

3,025,589
METHOD OF MANUFACTURING SEMICONDUCTOR DEVICES

Jean A. Hoerni, Los Altos, Calif., assignor, by mesne assignments, to Fairchild Camera and Instrument Corporation, Syosset, N.Y., a corporation of Delaware

Filed May 1, 1959, Ser. No. 810,388
11 Claims. (Cl. 29—25.3)

The present invention relates to an improvement in the manufacture of semiconductor devices including transistors and to an improved transistor structure. More particularly, the invention relates, as to the method thereof, to the control of semiconductor diffusing and masking to the end of producing an improved diffusion transistor having fully protected junctions and maximized exposed surfaces for ohmic contact attachment.

Advancements in transistor technology have in part been directed to the production of very small sized transistor structures, inasmuch as minute semiconductor geometries are required for high frequency applications of transistors. While the well known point-contact transistor is adapted for high frequency work, yet certain limitations attach to this type of transistor and consequently junction transistors have been developed for use in the high frequency range. One type of junction transistor which is particularly well adapted for high frequency applications is the double-diffused silicon transistor, and although the present invention is adapted for use with other types of transistors it is with respect to double-diffused silicon transistors that the following description is referenced.

As regards the manufacture of double-diffused silicon transistors, and in fact any minute transistor structure, difficulty is encountered in providing a sufficient exposed area of the base material for attachment of an ohmic contact thereto. By maintaining the extremely small element dimensions required of the transistor, there results only a minute thickness of base material exposed between the base-collector junction and the emitter-base junction on a transistor surface. Conventional transistor utility requires the provision of electrical contacts to the individual transistor elements or portions, and thus it is necessary for the dimensions of the base portion to be made sufficient to attach such contacts. In certain instances this limitation upon the size of the base portion is highly undesirable, inasmuch as conventional manufacturing practices produce a base thickness in proportion to the exposed base width.

Another difficulty arising from the limited size necessary for transistors to suitably operate at very high frequencies is encountered in the difficulty of protecting the transistor junction. This is particularly noted in the attachment of electrical contacts to the transistor portions inasmuch as very minute variations in the placement of electrical conductors or ohmic contacts to the transistor may well result in electrically shorting of the transistor junction, whereby the transistor structure is unsuited for use and must be rejected. This latter problem is compounded by the necessity in high-frequency transistors of employing an ohmic contact which substantially entirely covers the exposed surface of each of the elements in order to minimize the spreading resistance thereof. Conventional plating methods are unsuited for the provision of such ohmic contacts to within fractions of a millimeter from the transistor junction, as is normally required for transistor structures capable of operating at very high frequencies. Not only is the problem of providing suitable ohmic contacts to the transistor portions a major one, but also the possible damage or other types of inadvertent electrical shorting of the transistor junctions during manufacturing processes is of major importance in limiting the number of rejects in any manufacturing process. Additionally, long range contamination of transistor junctions may be a cause of drifting and deteriorization of transistor characteristics.

There have been developed for high frequency applications transistors of the "mesa" design wherein undesirable lateral extensions of the base-collector junction are removed by etching to produce transistors of very small dimensions. Although mesa transistors have found wide acceptance in the art, the junction exposed by the etching, as well as the other junction, is particularly vulnerable to contamination or degradation during subsequent portions of the manufacturing process. In accordance with the present invention there is produced a transistor having the minute dimensions of the mesa type, but with the unit at all times completely embedded in the semiconductor. In the process hereof, the transistor junctions are at all times fully protected by an oxide layer or coating formed simultaneously with the junction during diffusion at high temperatures so that no contamination of the transistor junctions during or after manufacture is possible. In this manner one of the major causes of transistor failure is entirely precluded.

The present invention provides a method of transistor manufacture overcoming the above-noted problems as well as others prevalent in the art. In the manufacture of transistors it is not uncommon for the semiconducting material to become oxidized on the exterior surfaces thereof, and it is conventional during manufacture to remove this outside coating as by etching, although it has been proposed ot leave a certain portion of this coating upon the transistor surface as a protection for portions thereof. The present invention provides, as integral steps in the manufacture of transistors, the control of the extent and position of semiconductor coating which serves the purpose of thereby delineating the exact lateral configuration of materials diffused into the semiconducting material and furthermore to provide a subsequent protection for the transistor surface. In accordance with the present invention it is possible not only to limit the extent of impurities diffusion in a semiconductor during the formation of different types of semiconductor, but furthermore, by the addition and subtraction of a masking layer or coating upon exposed transistor surfaces, it is herein possible to provide a precisely controlled area of any particular transistor material upon a common transistor surface. In addition, and in accordance with the present invention, there is herein provided, by the retention of a protective coating upon exposed transistor surfaces, means for preventing electrical shorting of transistor junctions and/or damage thereto during fabrication and manufacture of the transistor devices.

It is an object of the present invention to provide an improved method of manufacturing semiconductor devices wherein maximum surface protection of a device is afforded.

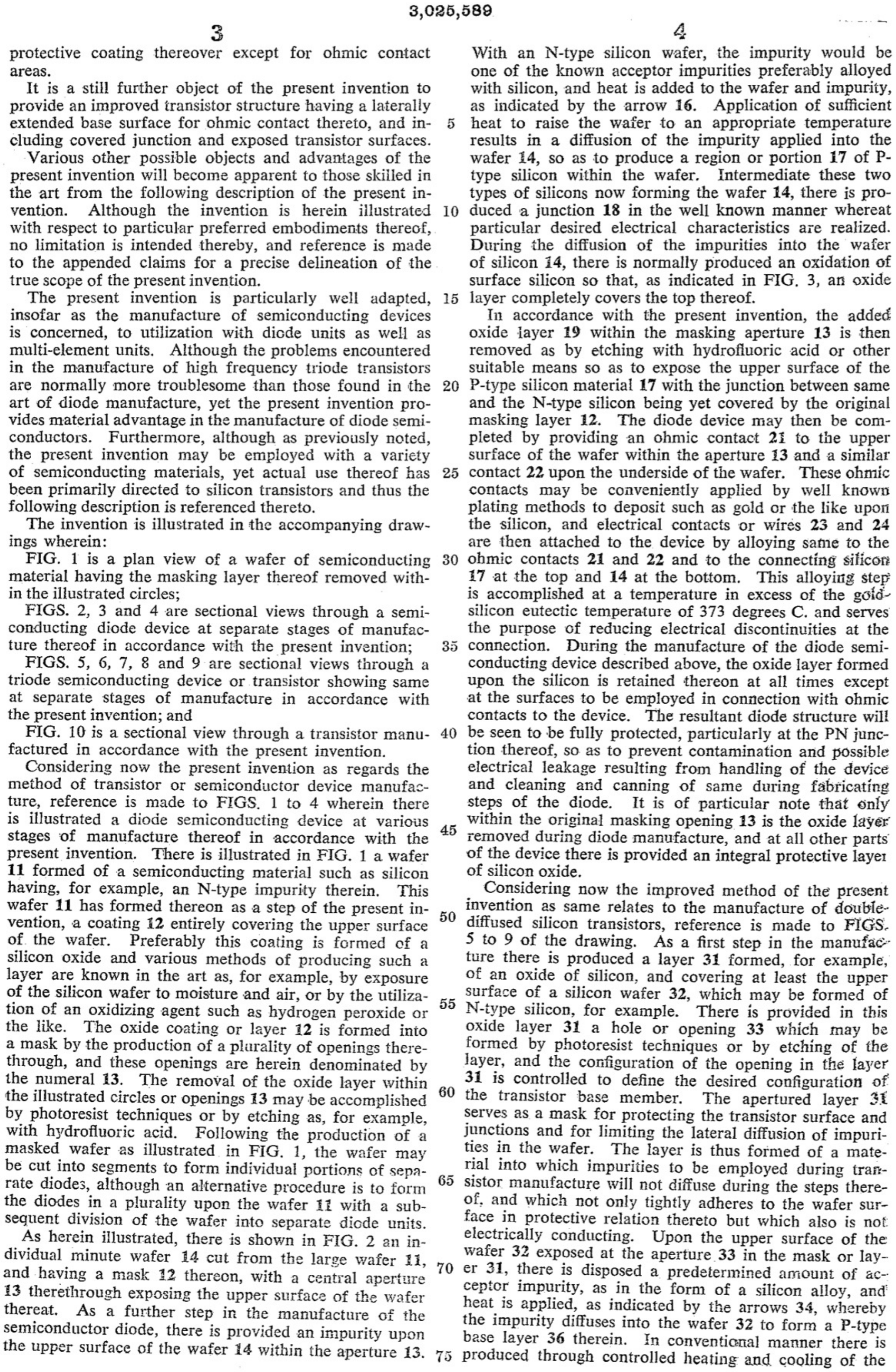
It is another object of the present invention to provide an improved method of manufacturing semiconductor devices wherein precise control is attained over lateral extent of diffused impurities therein.

It is a further object of the present invention to provide an improved method of transistor manufacture employing masking for controlling the extent of base surface area of minute double-diffused transistors.

It is yet another object of the present invention to provide a method of transistor manufacture including the addition of further masking to limit the diffusion of a second impurity in double-diffused transistors for maximizing the base surface area available for ohmic contacts, and additionally protecting transistor surfaces.

It is still another object of the present invention to provide an improved semiconducting device having a

Figure B.168: Jean Hoerni invented methods of manufacturing silicon transistors.



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protective coating thereover except for ohmic contact areas.

It is a still further object of the present invention to provide an improved transistor structure having a laterally extended base surface for ohmic contact thereto, and including covered junction and exposed transistor surfaces.

Various other possible objects and advantages of the present invention will become apparent to those skilled in the art from the following description of the present invention. Although the invention is herein illustrated with respect to particular preferred embodiments thereof, no limitation is intended thereby, and reference is made to the appended claims for a precise delineation of the true scope of the present invention.

The present invention is particularly well adapted, insofar as the manufacture of semiconducting devices is concerned, to utilization with diode units as well as multi-element units. Although the problems encountered in the manufacture of high frequency triode transistors are normally more troublesome than those found in the art of diode manufacture, yet the present invention provides material advantage in the manufacture of diode semiconductors. Furthermore, although as previously noted, the present invention may be employed with a variety of semiconducting materials, yet actual use thereof has been primarily directed to silicon transistors and thus the following description is referenced thereto.

The invention is illustrated in the accompanying drawings wherein:

FIG. 1 is a plan view of a wafer of semiconducting material having the masking layer thereof removed within the illustrated circles;

FIGS. 2, 3 and 4 are sectional views through a semiconducting diode device at separate stages of manufacture thereof in accordance with the present invention;

FIGS. 5, 6, 7, 8 and 9 are sectional views through a triode semiconducting device or transistor showing same at separate stages of manufacture in accordance with the present invention; and

FIG. 10 is a sectional view through a transistor manufactured in accordance with the present invention.

Considering now the present invention as regards the method of transistor or semiconductor device manufacture, reference is made to FIGS. 1 to 4 wherein there is illustrated a diode semiconducting device at various stages of manufacture thereof in accordance with the present invention. There is illustrated in FIG. 1 a wafer **11** formed of a semiconducting material such as silicon having, for example, an N-type impurity therein. This wafer **11** has formed thereon as a step of the present invention, a coating **12** entirely covering the upper surface of the wafer. Preferably this coating is formed of a silicon oxide and various methods of producing such a layer are known in the art as, for example, by exposure of the silicon wafer to moisture and air, or by the utilization of an oxidizing agent such as hydrogen peroxide or the like. The oxide coating or layer **12** is formed into a mask by the production of a plurality of openings therethrough, and these openings are herein denominated by the numeral **13**. The removal of the oxide layer within the illustrated circles or openings **13** may be accomplished by photoresist techniques or by etching as, for example, with hydrofluoric acid. Following the production of a masked wafer as illustrated in FIG. 1, the wafer may be cut into segments to form individual portions of separate diodes, although an alternative procedure is to form the diodes in a plurality upon the wafer **11** with a subsequent division of the wafer into separate diode units.

As herein illustrated, there is shown in FIG. 2 an individual minute wafer **14** cut from the large wafer **11**, and having a mask **12** thereon, with a central aperture **13** therethrough exposing the upper surface of the wafer thereat. As a further step in the manufacture of the semiconductor diode, there is provided an impurity upon the upper surface of the wafer **14** within the aperture **13**.

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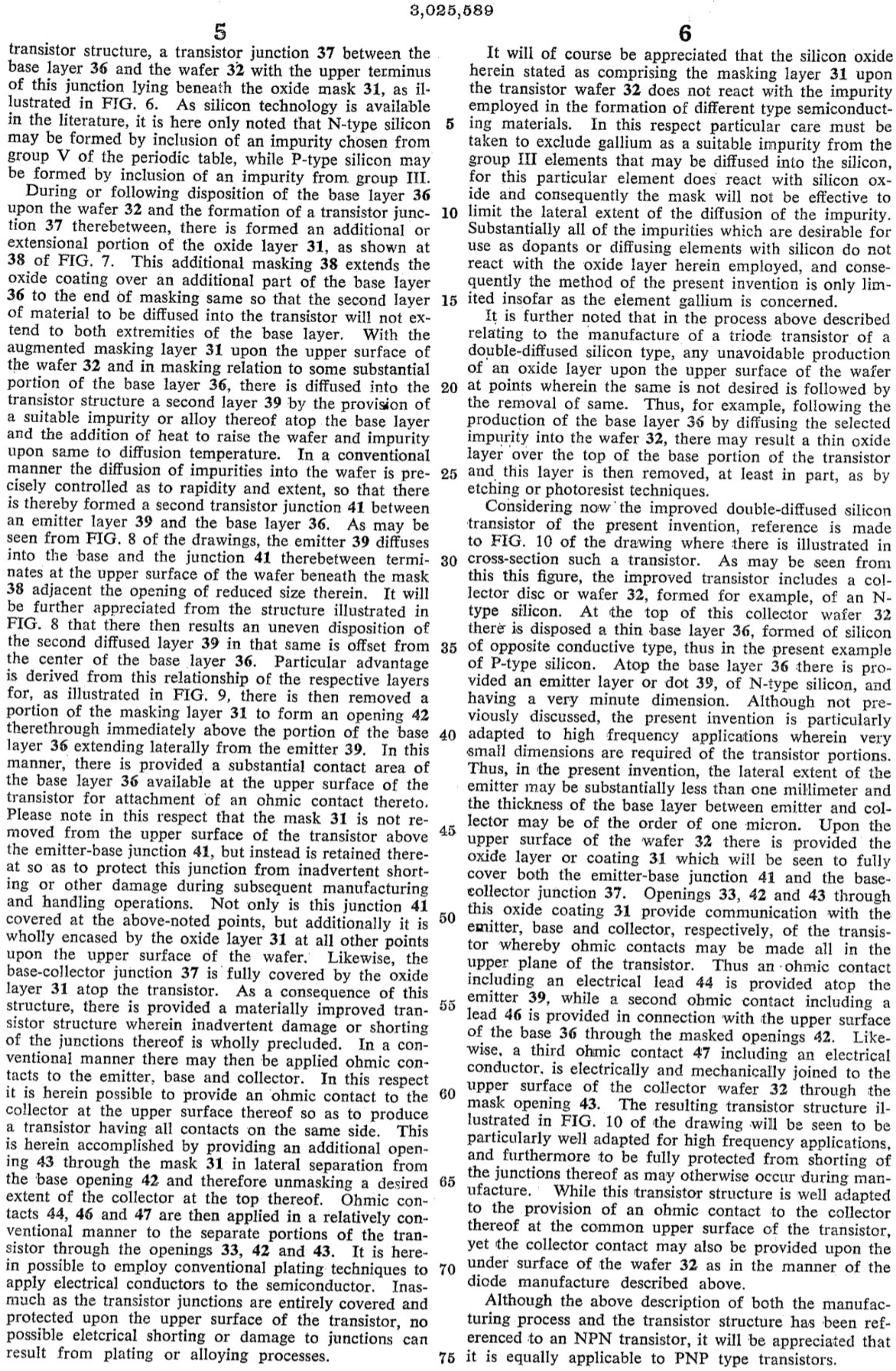
With an N-type silicon wafer, the impurity would be one of the known acceptor impurities preferably alloyed with silicon, and heat is added to the wafer and impurity, as indicated by the arrow **16**. Application of sufficient heat to raise the wafer to an appropriate temperature results in a diffusion of the impurity applied into the wafer **14**, so as to produce a region or portion **17** of P-type silicon within the wafer. Intermediate these two types of silicons now forming the wafer **14**, there is produced a junction **18** in the well known manner whereat particular desired electrical characteristics are realized. During the diffusion of the impurities into the wafer of silicon **14**, there is normally produced an oxidation of surface silicon so that, as indicated in FIG. 3, an oxide layer completely covers the top thereof.

In accordance with the present invention, the added oxide layer **19** within the masking aperture **13** is then removed as by etching with hydrofluoric acid or other suitable means so as to expose the upper surface of the P-type silicon material **17** with the junction between same and the N-type silicon being yet covered by the original masking layer **12**. The diode device may then be completed by providing an ohmic contact **21** to the upper surface of the wafer within the aperture **13** and a similar contact **22** upon the underside of the wafer. These ohmic contacts may be conveniently applied by well known plating methods to deposit such as gold or the like upon the silicon, and electrical contacts or wires **23** and **24** are then attached to the device by alloying same to the ohmic contacts **21** and **22** and to the connecting silicon **17** at the top and **14** at the bottom. This alloying step is accomplished at a temperature in excess of the gold-silicon eutectic temperature of 373 degrees C. and serves the purpose of reducing electrical discontinuities at the connection. During the manufacture of the diode semiconducting device described above, the oxide layer formed upon the silicon is retained thereon at all times except at the surfaces to be employed in connection with ohmic contacts to the device. The resultant diode structure will be seen to be fully protected, particularly at the PN junction thereof, so as to prevent contamination and possible electrical leakage resulting from handling of the device and cleaning and canning of same during fabricating steps of the diode. It is of particular note that only within the original masking opening **13** is the oxide layer removed during diode manufacture, and at all other parts of the device there is provided an integral protective layer of silicon oxide.

Considering now the improved method of the present invention as same relates to the manufacture of double-diffused silicon transistors, reference is made to FIGS. 5 to 9 of the drawing. As a first step in the manufacture there is produced a layer **31** formed, for example, of an oxide of silicon, and covering at least the upper surface of a silicon wafer **32**, which may be formed of N-type silicon, for example. There is provided in this oxide layer **31** a hole or opening **33** which may be formed by photoresist techniques or by etching of the layer, and the configuration of the opening in the layer **31** is controlled to define the desired configuration of the transistor base member. The apertured layer **31** serves as a mask for protecting the transistor surface and junctions and for limiting the lateral diffusion of impurities in the wafer. The layer is thus formed of a material into which impurities to be employed during transistor manufacture will not diffuse during the steps thereof, and which not only tightly adheres to the wafer surface in protective relation thereto but which also is not electrically conducting. Upon the upper surface of the wafer **32** exposed at the aperture **33** in the mask or layer **31**, there is disposed a predetermined amount of acceptor impurity, as in the form of a silicon alloy, and heat is applied, as indicated by the arrows **34**, whereby the impurity diffuses into the wafer **32** to form a P-type base layer **36** therein. In conventional manner there is produced through controlled heating and cooling of the

Figure B.169: Jean Hoerni invented methods of manufacturing silicon transistors.



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transistor structure, a transistor junction **37** between the base layer **36** and the wafer **32** with the upper terminus of this junction lying beneath the oxide mask **31**, as illustrated in FIG. 6. As silicon technology is available in the literature, it is here only noted that N-type silicon may be formed by inclusion of an impurity chosen from group V of the periodic table, while P-type silicon may be formed by inclusion of an impurity from group III.

During or following disposition of the base layer **36** upon the wafer **32** and the formation of a transistor junction **37** therebetween, there is formed an additional or extensional portion of the oxide layer **31**, as shown at **38** of FIG. 7. This additional masking **38** extends the oxide coating over an additional part of the base layer **36** to the end of masking same so that the second layer of material to be diffused into the transistor will not extend to both extremities of the base layer. With the augmented masking layer **31** upon the upper surface of the wafer **32** and in masking relation to some substantial portion of the base layer **36**, there is diffused into the transistor structure a second layer **39** by the provision of a suitable impurity or alloy thereof atop the base layer and the addition of heat to raise the wafer and impurity upon same to diffusion temperature. In a conventional manner the diffusion of impurities into the wafer is precisely controlled as to rapidity and extent, so that there is thereby formed a second transistor junction **41** between an emitter layer **39** and the base layer **36**. As may be seen from FIG. 8 of the drawings, the emitter **39** diffuses into the base and the junction **41** therebetween terminates at the upper surface of the wafer beneath the mask **38** adjacent the opening of reduced size therein. It will be further appreciated from the structure illustrated in FIG. 8 that there then results an uneven disposition of the second diffused layer **39** in that same is offset from the center of the base layer **36**. Particular advantage is derived from this relationship of the respective layers for, as illustrated in FIG. 9, there is then removed a portion of the masking layer **31** to form an opening **42** therethrough immediately above the portion of the base layer **36** extending laterally from the emitter **39**. In this manner, there is provided a substantial contact area of the base layer **36** available at the upper surface of the transistor for attachment of an ohmic contact thereto. Please note in this respect that the mask **31** is not removed from the upper surface of the transistor above the emitter-base junction **41**, but instead is retained thereat so as to protect this junction from inadvertent shorting or other damage during subsequent manufacturing and handling operations. Not only is this junction **41** covered at the above-noted points, but additionally it is wholly encased by the oxide layer **31** at all other points upon the upper surface of the wafer. Likewise, the base-collector junction **37** is fully covered by the oxide layer **31** atop the transistor. As a consequence of this structure, there is provided a materially improved transistor structure wherein inadvertent damage or shorting of the junctions thereof is wholly precluded. In a conventional manner there may then be applied ohmic contacts to the emitter, base and collector. In this respect it is herein possible to provide an ohmic contact to the collector at the upper surface thereof so as to produce a transistor having all contacts on the same side. This is herein accomplished by providing an additional opening **43** through the mask **31** in lateral separation from the base opening **42** and therefore unmasking a desired extent of the collector at the top thereof. Ohmic contacts **44**, **46** and **47** are then applied in a relatively conventional manner to the separate portions of the transistor through the openings **33**, **42** and **43**. It is herein possible to employ conventional plating techniques to apply electrical conductors to the semiconductor. Inasmuch as the transistor junctions are entirely covered and protected upon the upper surface of the transistor, no possible eletcrical shorting or damage to junctions can result from plating or alloying processes.

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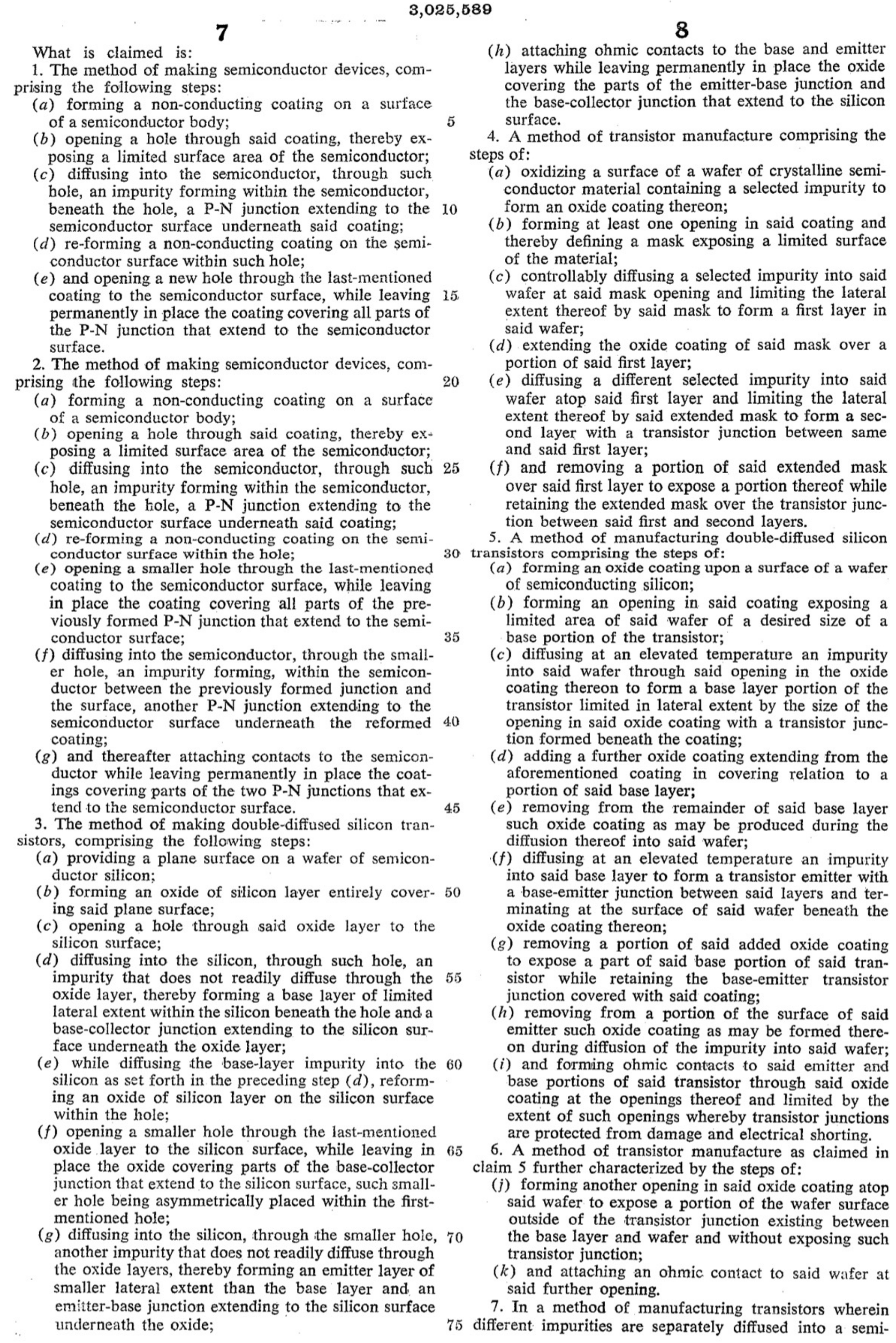
It will of course be appreciated that the silicon oxide herein stated as comprising the masking layer **31** upon the transistor wafer **32** does not react with the impurity employed in the formation of different type semiconducting materials. In this respect particular care must be taken to exclude gallium as a suitable impurity from the group III elements that may be diffused into the silicon, for this particular element does react with silicon oxide and consequently the mask will not be effective to limit the lateral extent of the diffusion of the impurity. Substantially all of the impurities which are desirable for use as dopants or diffusing elements with silicon do not react with the oxide layer herein employed, and consequently the method of the present invention is only limited insofar as the element gallium is concerned.

It is further noted that in the process above described relating to the manufacture of a triode transistor of a double-diffused silicon type, any unavoidable production of an oxide layer upon the upper surface of the wafer at points wherein the same is not desired is followed by the removal of same. Thus, for example, following the production of the base layer **36** by diffusing the selected impurity into the wafer **32**, there may result a thin oxide layer over the top of the base portion of the transistor and this layer is then removed, at least in part, as by etching or photoresist techniques.

Considering now the improved double-diffused silicon transistor of the present invention, reference is made to FIG. 10 of the drawing where there is illustrated in cross-section such a transistor. As may be seen from this this figure, the improved transistor includes a collector disc or wafer **32**, formed for example, of an N-type silicon. At the top of this collector wafer **32** there is disposed a thin base layer **36**, formed of silicon of opposite conductive type, thus in the present example of P-type silicon. Atop the base layer **36** there is provided an emitter layer or dot **39**, of N-type silicon, and having a very minute dimension. Although not previously discussed, the present invention is particularly adapted to high frequency applications wherein very small dimensions are required of the transistor portions. Thus, in the present invention, the lateral extent of the emitter may be substantially less than one millimeter and the thickness of the base layer between emitter and collector may be of the order of one micron. Upon the upper surface of the wafer **32** there is provided the oxide layer or coating **31** which will be seen to fully cover both the emitter-base junction **41** and the base-collector junction **37**. Openings **33**, **42** and **43** through this oxide coating **31** provide communication with the emitter, base and collector, respectively, of the transistor whereby ohmic contacts may be made all in the upper plane of the transistor. Thus an ohmic contact including an electrical lead **44** is provided atop the emitter **39**, while a second ohmic contact including a lead **46** is provided in connection with the upper surface of the base **36** through the masked openings **42**. Likewise, a third ohmic contact **47** including an electrical conductor, is electrically and mechanically joined to the upper surface of the collector wafer **32** through the mask opening **43**. The resulting transistor structure illustrated in FIG. 10 of the drawing will be seen to be particularly well adapted for high frequency applications, and furthermore to be fully protected from shorting of the junctions thereof as may otherwise occur during manufacture. While this transistor structure is well adapted to the provision of an ohmic contact to the collector thereof at the common upper surface of the transistor, yet the collector contact may also be provided upon the under surface of the wafer **32** as in the manner of the diode manufacture described above.

Although the above description of both the manufacturing process and the transistor structure has been referenced to an NPN transistor, it will be appreciated that it is equally applicable to PNP type transistors.

Figure B.170: Jean Hoerni invented methods of manufacturing silicon transistors.



What is claimed is:

1. The method of making semiconductor devices, comprising the following steps:
(*a*) forming a non-conducting coating on a surface of a semiconductor body;
(*b*) opening a hole through said coating, thereby exposing a limited surface area of the semiconductor;
(*c*) diffusing into the semiconductor, through such hole, an impurity forming within the semiconductor, beneath the hole, a P-N junction extending to the semiconductor surface underneath said coating;
(*d*) re-forming a non-conducting coating on the semiconductor surface within such hole;
(*e*) and opening a new hole through the last-mentioned coating to the semiconductor surface, while leaving permanently in place the coating covering all parts of the P-N junction that extend to the semiconductor surface.

2. The method of making semiconductor devices, comprising the following steps:
(*a*) forming a non-conducting coating on a surface of a semiconductor body;
(*b*) opening a hole through said coating, thereby exposing a limited surface area of the semiconductor;
(*c*) diffusing into the semiconductor, through such hole, an impurity forming within the semiconductor, beneath the hole, a P-N junction extending to the semiconductor surface underneath said coating;
(*d*) re-forming a non-conducting coating on the semiconductor surface within the hole;
(*e*) opening a smaller hole through the last-mentioned coating to the semiconductor surface, while leaving in place the coating covering all parts of the previously formed P-N junction that extend to the semiconductor surface;
(*f*) diffusing into the semiconductor, through the smaller hole, an impurity forming, within the semiconductor between the previously formed junction and the surface, another P-N junction extending to the semiconductor surface underneath the reformed coating;
(*g*) and thereafter attaching contacts to the semiconductor while leaving permanently in place the coatings covering parts of the two P-N junctions that extend to the semiconductor surface.

3. The method of making double-diffused silicon transistors, comprising the following steps:
(*a*) providing a plane surface on a wafer of semiconductor silicon;
(*b*) forming an oxide of silicon layer entirely covering said plane surface;
(*c*) opening a hole through said oxide layer to the silicon surface;
(*d*) diffusing into the silicon, through such hole, an impurity that does not readily diffuse through the oxide layer, thereby forming a base layer of limited lateral extent within the silicon beneath the hole and a base-collector junction extending to the silicon surface underneath the oxide layer;
(*e*) while diffusing the base-layer impurity into the silicon as set forth in the preceding step (*d*), reforming an oxide of silicon layer on the silicon surface within the hole;
(*f*) opening a smaller hole through the last-mentioned oxide layer to the silicon surface, while leaving in place the oxide covering parts of the base-collector junction that extend to the silicon surface, such smaller hole being asymmetrically placed within the first-mentioned hole;
(*g*) diffusing into the silicon, through the smaller hole, another impurity that does not readily diffuse through the oxide layers, thereby forming an emitter layer of smaller lateral extent than the base layer and an emitter-base junction extending to the silicon surface underneath the oxide;
(*h*) attaching ohmic contacts to the base and emitter layers while leaving permanently in place the oxide covering the parts of the emitter-base junction and the base-collector junction that extend to the silicon surface.

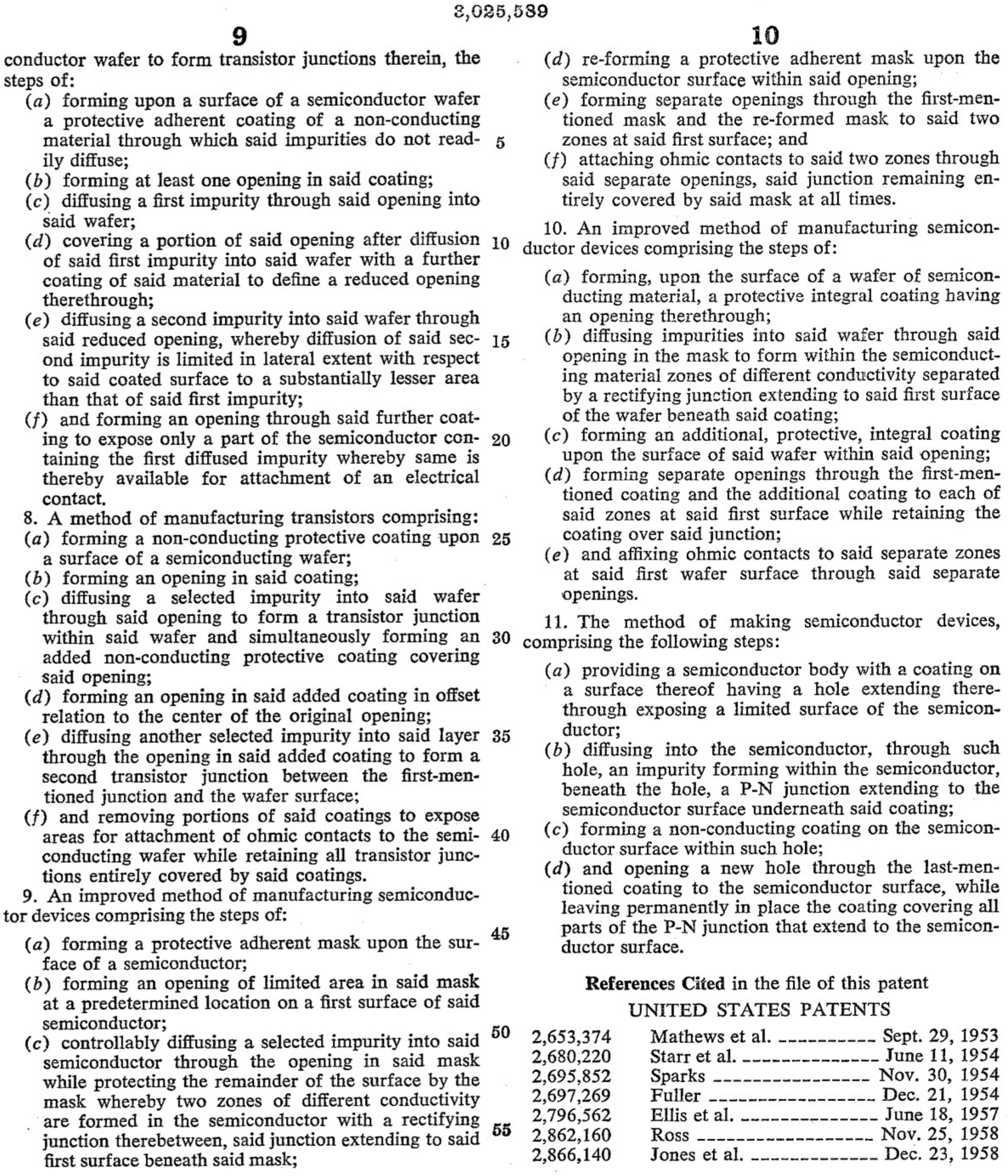
4. A method of transistor manufacture comprising the steps of:
(*a*) oxidizing a surface of a wafer of crystalline semiconductor material containing a selected impurity to form an oxide coating thereon;
(*b*) forming at least one opening in said coating and thereby defining a mask exposing a limited surface of the material;
(*c*) controllably diffusing a selected impurity into said wafer at said mask opening and limiting the lateral extent thereof by said mask to form a first layer in said wafer;
(*d*) extending the oxide coating of said mask over a portion of said first layer;
(*e*) diffusing a different selected impurity into said wafer atop said first layer and limiting the lateral extent thereof by said extended mask to form a second layer with a transistor junction between same and said first layer;
(*f*) and removing a portion of said extended mask over said first layer to expose a portion thereof while retaining the extended mask over the transistor junction between said first and second layers.

5. A method of manufacturing double-diffused silicon transistors comprising the steps of:
(*a*) forming an oxide coating upon a surface of a wafer of semiconducting silicon;
(*b*) forming an opening in said coating exposing a limited area of said wafer of a desired size of a base portion of the transistor;
(*c*) diffusing at an elevated temperature an impurity into said wafer through said opening in the oxide coating thereon to form a base layer portion of the transistor limited in lateral extent by the size of the opening in said oxide coating with a transistor junction formed beneath the coating;
(*d*) adding a further oxide coating extending from the aforementioned coating in covering relation to a portion of said base layer;
(*e*) removing from the remainder of said base layer such oxide coating as may be produced during the diffusion thereof into said wafer;
(*f*) diffusing at an elevated temperature an impurity into said base layer to form a transistor emitter with a base-emitter junction between said layers and terminating at the surface of said wafer beneath the oxide coating thereon;
(*g*) removing a portion of said added oxide coating to expose a part of said base portion of said transistor while retaining the base-emitter transistor junction covered with said coating;
(*h*) removing from a portion of the surface of said emitter such oxide coating as may be formed thereon during diffusion of the impurity into said wafer;
(*i*) and forming ohmic contacts to said emitter and base portions of said transistor through said oxide coating at the openings thereof and limited by the extent of such openings whereby transistor junctions are protected from damage and electrical shorting.

6. A method of transistor manufacture as claimed in claim 5 further characterized by the steps of:
(*j*) forming another opening in said oxide coating atop said wafer to expose a portion of the wafer surface outside of the transistor junction existing between the base layer and wafer and without exposing such transistor junction;
(*k*) and attaching an ohmic contact to said wafer at said further opening.

7. In a method of manufacturing transistors wherein different impurities are separately diffused into a semi-

Figure B.171: Jean Hoerni invented methods of manufacturing silicon transistors.



3,025,589

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conductor wafer to form transistor junctions therein, the steps of:

(*a*) forming upon a surface of a semiconductor wafer a protective adherent coating of a non-conducting material through which said impurities do not readily diffuse;
(*b*) forming at least one opening in said coating;
(*c*) diffusing a first impurity through said opening into said wafer;
(*d*) covering a portion of said opening after diffusion of said first impurity into said wafer with a further coating of said material to define a reduced opening therethrough;
(*e*) diffusing a second impurity into said wafer through said reduced opening, whereby diffusion of said second impurity is limited in lateral extent with respect to said coated surface to a substantially lesser area than that of said first impurity;
(*f*) and forming an opening through said further coating to expose only a part of the semiconductor containing the first diffused impurity whereby same is thereby available for attachment of an electrical contact.

8. A method of manufacturing transistors comprising:

(*a*) forming a non-conducting protective coating upon a surface of a semiconducting wafer;
(*b*) forming an opening in said coating;
(*c*) diffusing a selected impurity into said wafer through said opening to form a transistor junction within said wafer and simultaneously forming an added non-conducting protective coating covering said opening;
(*d*) forming an opening in said added coating in offset relation to the center of the original opening;
(*e*) diffusing another selected impurity into said layer through the opening in said added coating to form a second transistor junction between the first-mentioned junction and the wafer surface;
(*f*) and removing portions of said coatings to expose areas for attachment of ohmic contacts to the semiconducting wafer while retaining all transistor junctions entirely covered by said coatings.

9. An improved method of manufacturing semiconductor devices comprising the steps of:

(*a*) forming a protective adherent mask upon the surface of a semiconductor;
(*b*) forming an opening of limited area in said mask at a predetermined location on a first surface of said semiconductor;
(*c*) controllably diffusing a selected impurity into said semiconductor through the opening in said mask while protecting the remainder of the surface by the mask whereby two zones of different conductivity are formed in the semiconductor with a rectifying junction therebetween, said junction extending to said first surface beneath said mask;

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(*d*) re-forming a protective adherent mask upon the semiconductor surface within said opening;
(*e*) forming separate openings through the first-mentioned mask and the re-formed mask to said two zones at said first surface; and
(*f*) attaching ohmic contacts to said two zones through said separate openings, said junction remaining entirely covered by said mask at all times.

10. An improved method of manufacturing semiconductor devices comprising the steps of:

(*a*) forming, upon the surface of a wafer of semiconducting material, a protective integral coating having an opening therethrough;
(*b*) diffusing impurities into said wafer through said opening in the mask to form within the semiconducting material zones of different conductivity separated by a rectifying junction extending to said first surface of the wafer beneath said coating;
(*c*) forming an additional, protective, integral coating upon the surface of said wafer within said opening;
(*d*) forming separate openings through the first-mentioned coating and the additional coating to each of said zones at said first surface while retaining the coating over said junction;
(*e*) and affixing ohmic contacts to said separate zones at said first wafer surface through said separate openings.

11. The method of making semiconductor devices, comprising the following steps:

(*a*) providing a semiconductor body with a coating on a surface thereof having a hole extending therethrough exposing a limited surface of the semiconductor;
(*b*) diffusing into the semiconductor, through such hole, an impurity forming within the semiconductor, beneath the hole, a P-N junction extending to the semiconductor surface underneath said coating;
(*c*) forming a non-conducting coating on the semiconductor surface within such hole;
(*d*) and opening a new hole through the last-mentioned coating to the semiconductor surface, while leaving permanently in place the coating covering all parts of the P-N junction that extend to the semiconductor surface.

References Cited in the file of this patent

UNITED STATES PATENTS

2,653,374	Mathews et al.	Sept. 29, 1953
2,680,220	Starr et al.	June 11, 1954
2,695,852	Sparks	Nov. 30, 1954
2,697,269	Fuller	Dec. 21, 1954
2,796,562	Ellis et al.	June 18, 1957
2,862,160	Ross	Nov. 25, 1958
2,866,140	Jones et al.	Dec. 23, 1958

Figure B.172: Jean Hoerni invented methods of manufacturing silicon transistors.

Nov. 13, 1962 J. A. HOERNI **3,064,167**

SEMICONDUCTOR DEVICE

Original Filed May 1, 1959

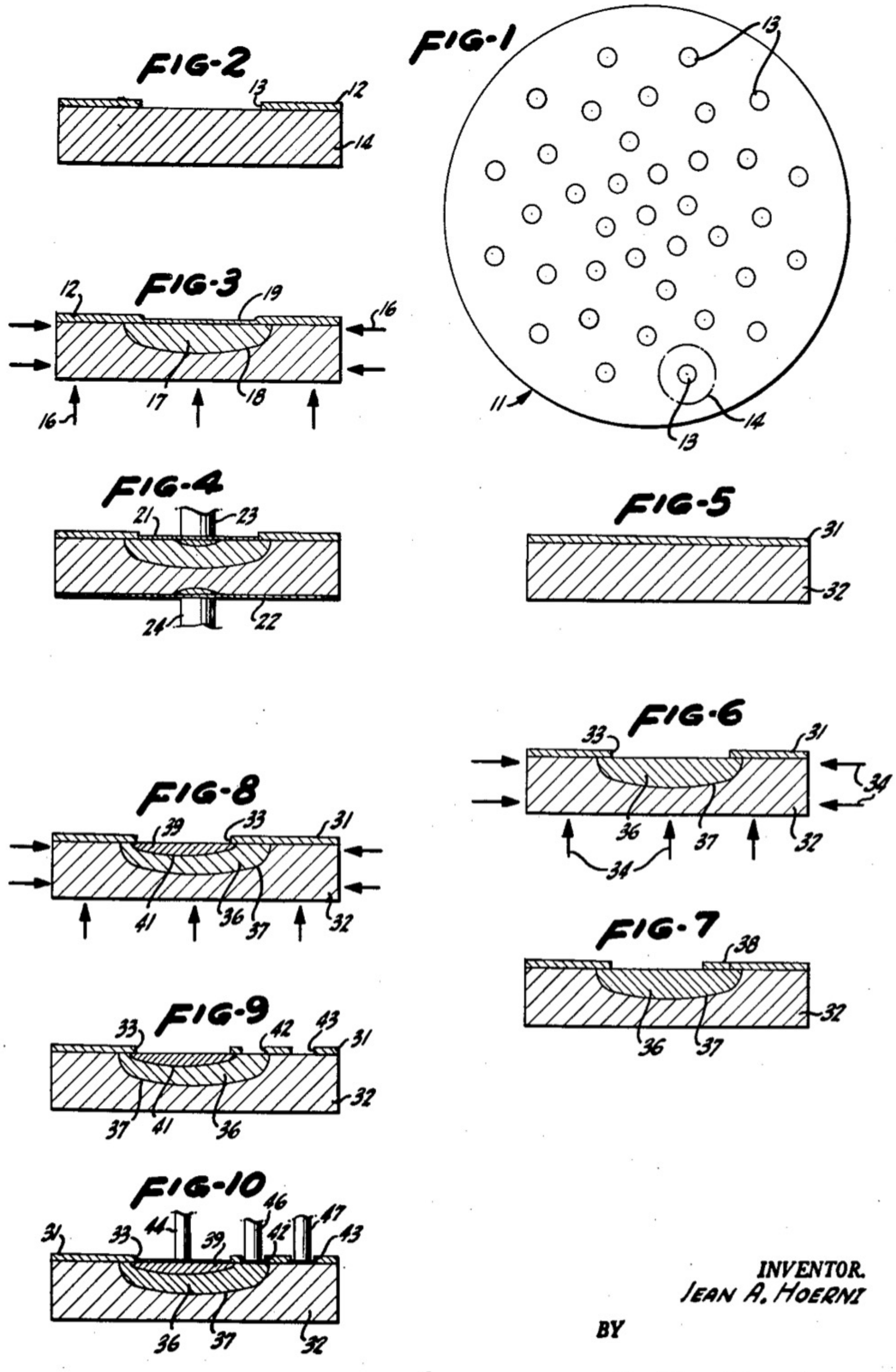
FIG-1
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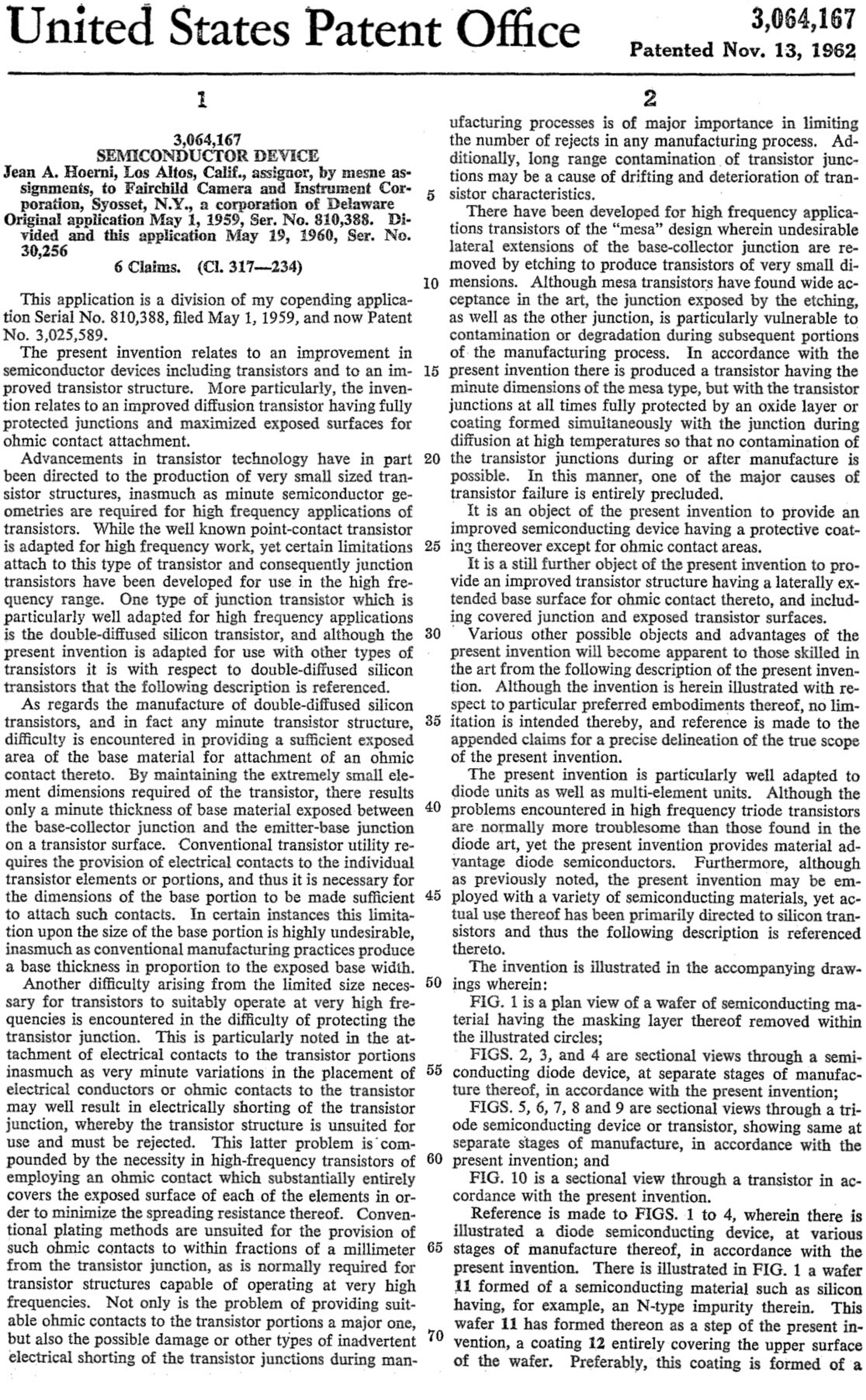
INVENTOR.
JEAN A. HOERNI

BY

Lippincott, Ralls & Hendricson
ATTORNEYS

Figure B.173: Jean Hoerni invented methods of manufacturing silicon transistors.



United States Patent Office

3,064,167
Patented Nov. 13, 1962

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3,064,167
SEMICONDUCTOR DEVICE

Jean A. Hoerni, Los Altos, Calif., assignor, by mesne assignments, to Fairchild Camera and Instrument Corporation, Syosset, N.Y., a corporation of Delaware
Original application May 1, 1959, Ser. No. 810,388. Divided and this application May 19, 1960, Ser. No. 30,256
6 Claims. (Cl. 317—234)

This application is a division of my copending application Serial No. 810,388, filed May 1, 1959, and now Patent No. 3,025,589.

The present invention relates to an improvement in semiconductor devices including transistors and to an improved transistor structure. More particularly, the invention relates to an improved diffusion transistor having fully protected junctions and maximized exposed surfaces for ohmic contact attachment.

Advancements in transistor technology have in part been directed to the production of very small sized transistor structures, inasmuch as minute semiconductor geometries are required for high frequency applications of transistors. While the well known point-contact transistor is adapted for high frequency work, yet certain limitations attach to this type of transistor and consequently junction transistors have been developed for use in the high frequency range. One type of junction transistor which is particularly well adapted for high frequency applications is the double-diffused silicon transistor, and although the present invention is adapted for use with other types of transistors it is with respect to double-diffused silicon transistors that the following description is referenced.

As regards the manufacture of double-diffused silicon transistors, and in fact any minute transistor structure, difficulty is encountered in providing a sufficient exposed area of the base material for attachment of an ohmic contact thereto. By maintaining the extremely small element dimensions required of the transistor, there results only a minute thickness of base material exposed between the base-collector junction and the emitter-base junction on a transistor surface. Conventional transistor utility requires the provision of electrical contacts to the individual transistor elements or portions, and thus it is necessary for the dimensions of the base portion to be made sufficient to attach such contacts. In certain instances this limitation upon the size of the base portion is highly undesirable, inasmuch as conventional manufacturing practices produce a base thickness in proportion to the exposed base width.

Another difficulty arising from the limited size necessary for transistors to suitably operate at very high frequencies is encountered in the difficulty of protecting the transistor junction. This is particularly noted in the attachment of electrical contacts to the transistor portions inasmuch as very minute variations in the placement of electrical conductors or ohmic contacts to the transistor may well result in electrically shorting of the transistor junction, whereby the transistor structure is unsuited for use and must be rejected. This latter problem is compounded by the necessity in high-frequency transistors of employing an ohmic contact which substantially entirely covers the exposed surface of each of the elements in order to minimize the spreading resistance thereof. Conventional plating methods are unsuited for the provision of such ohmic contacts to within fractions of a millimeter from the transistor junction, as is normally required for transistor structures capable of operating at very high frequencies. Not only is the problem of providing suitable ohmic contacts to the transistor portions a major one, but also the possible damage or other types of inadvertent electrical shorting of the transistor junctions during manufacturing processes is of major importance in limiting the number of rejects in any manufacturing process. Additionally, long range contamination of transistor junctions may be a cause of drifting and deterioration of transistor characteristics.

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There have been developed for high frequency applications transistors of the "mesa" design wherein undesirable lateral extensions of the base-collector junction are removed by etching to produce transistors of very small dimensions. Although mesa transistors have found wide acceptance in the art, the junction exposed by the etching, as well as the other junction, is particularly vulnerable to contamination or degradation during subsequent portions of the manufacturing process. In accordance with the present invention there is produced a transistor having the minute dimensions of the mesa type, but with the transistor junctions at all times fully protected by an oxide layer or coating formed simultaneously with the junction during diffusion at high temperatures so that no contamination of the transistor junctions during or after manufacture is possible. In this manner, one of the major causes of transistor failure is entirely precluded.

It is an object of the present invention to provide an improved semiconducting device having a protective coating thereover except for ohmic contact areas.

It is a still further object of the present invention to provide an improved transistor structure having a laterally extended base surface for ohmic contact thereto, and including covered junction and exposed transistor surfaces.

Various other possible objects and advantages of the present invention will become apparent to those skilled in the art from the following description of the present invention. Although the invention is herein illustrated with respect to particular preferred embodiments thereof, no limitation is intended thereby, and reference is made to the appended claims for a precise delineation of the true scope of the present invention.

The present invention is particularly well adapted to diode units as well as multi-element units. Although the problems encountered in high frequency triode transistors are normally more troublesome than those found in the diode art, yet the present invention provides material advantage diode semiconductors. Furthermore, although as previously noted, the present invention may be employed with a variety of semiconducting materials, yet actual use thereof has been primarily directed to silicon transistors and thus the following description is referenced thereto.

The invention is illustrated in the accompanying drawings wherein:

FIG. 1 is a plan view of a wafer of semiconducting material having the masking layer thereof removed within the illustrated circles;

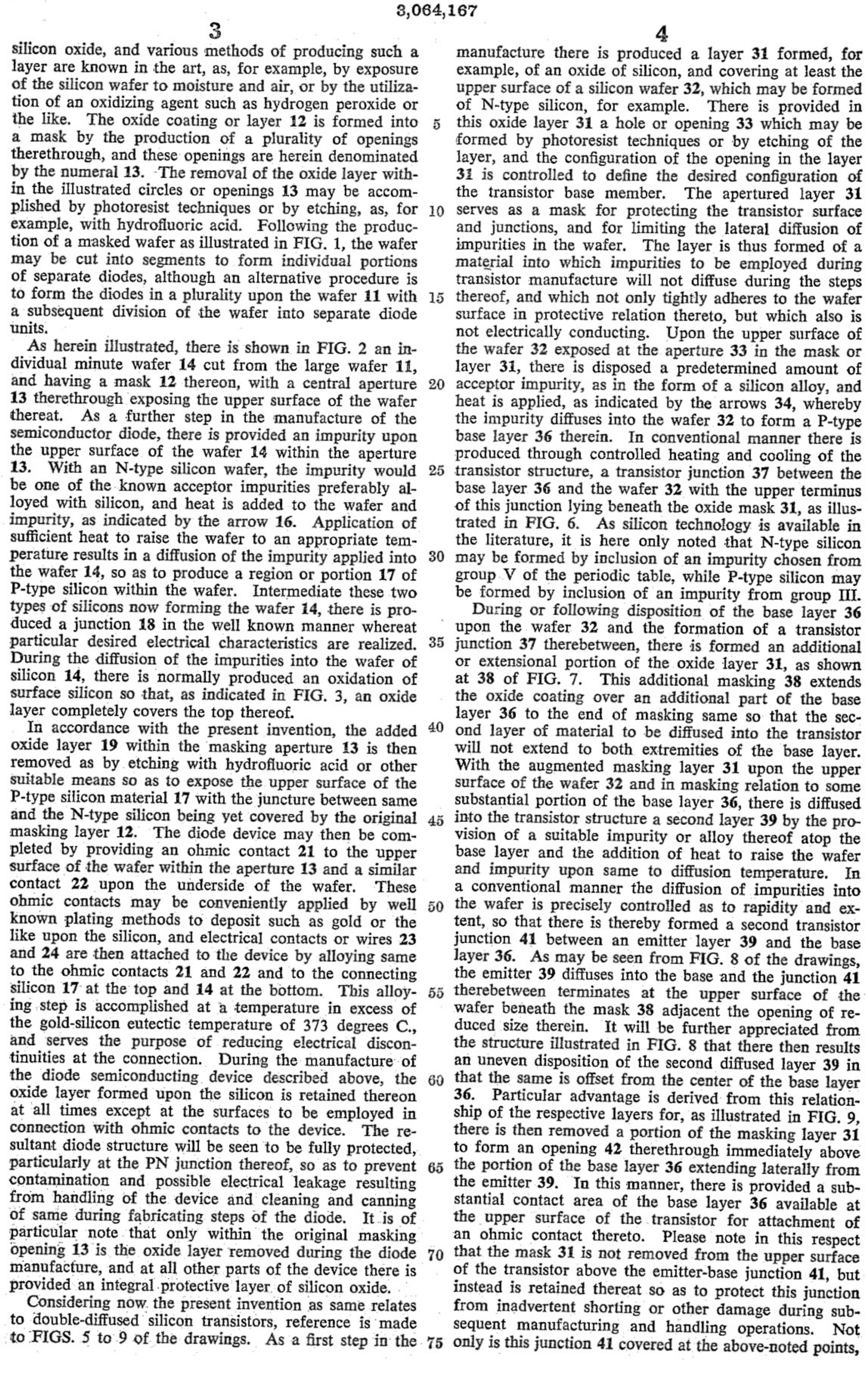
FIGS. 2, 3, and 4 are sectional views through a semiconducting diode device, at separate stages of manufacture thereof, in accordance with the present invention;

FIGS. 5, 6, 7, 8 and 9 are sectional views through a triode semiconducting device or transistor, showing same at separate stages of manufacture, in accordance with the present invention; and

FIG. 10 is a sectional view through a transistor in accordance with the present invention.

Reference is made to FIGS. 1 to 4, wherein there is illustrated a diode semiconducting device, at various stages of manufacture thereof, in accordance with the present invention. There is illustrated in FIG. 1 a wafer **11** formed of a semiconducting material such as silicon having, for example, an N-type impurity therein. This wafer **11** has formed thereon as a step of the present invention, a coating **12** entirely covering the upper surface of the wafer. Preferably, this coating is formed of a

Figure B.174: Jean Hoerni invented methods of manufacturing silicon transistors.



silicon oxide, and various methods of producing such a layer are known in the art, as, for example, by exposure of the silicon wafer to moisture and air, or by the utilization of an oxidizing agent such as hydrogen peroxide or the like. The oxide coating or layer **12** is formed into a mask by the production of a plurality of openings therethrough, and these openings are herein denominated by the numeral **13**. The removal of the oxide layer within the illustrated circles or openings **13** may be accomplished by photoresist techniques or by etching, as, for example, with hydrofluoric acid. Following the production of a masked wafer as illustrated in FIG. 1, the wafer may be cut into segments to form individual portions of separate diodes, although an alternative procedure is to form the diodes in a plurality upon the wafer **11** with a subsequent division of the wafer into separate diode units.

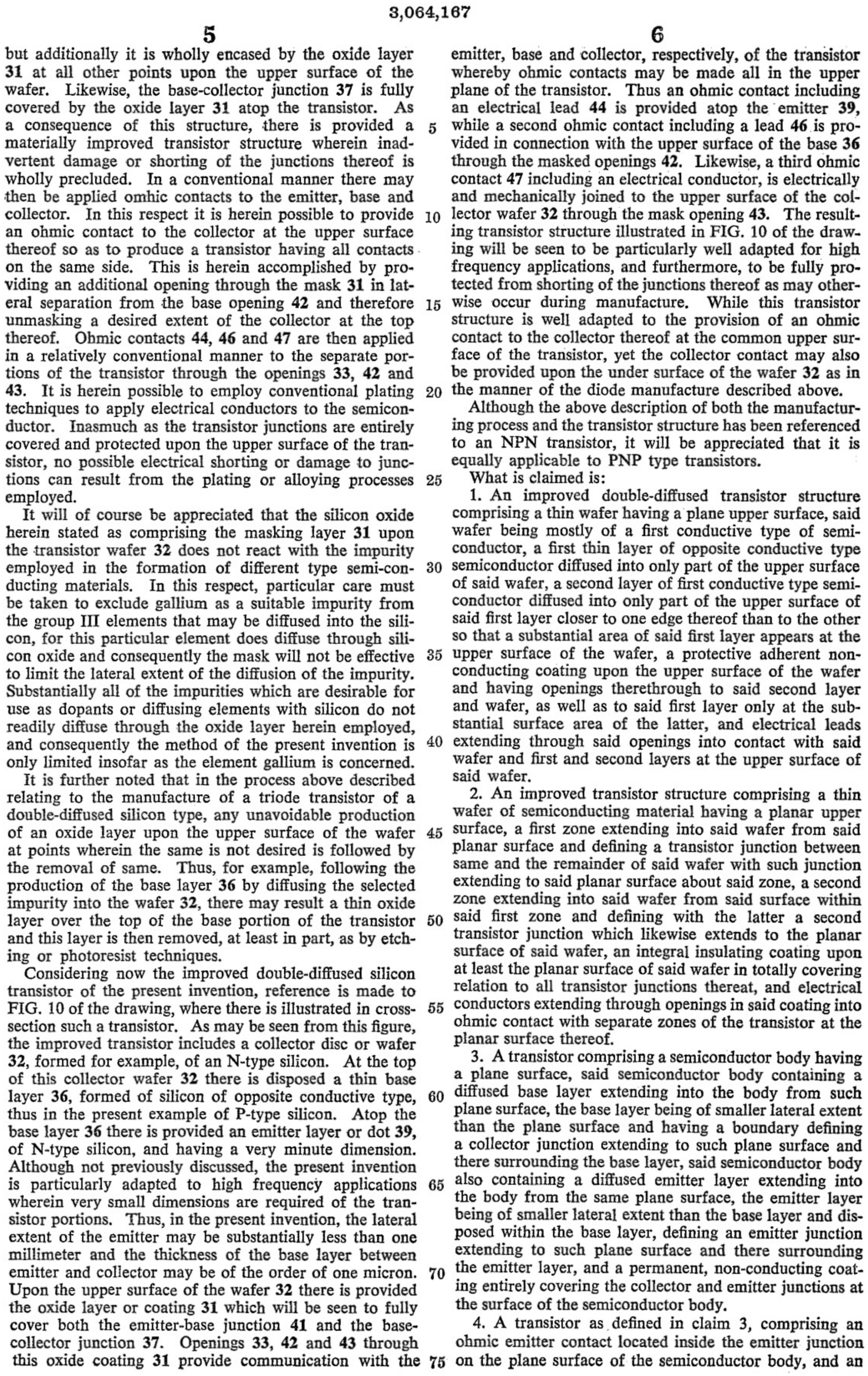
As herein illustrated, there is shown in FIG. 2 an individual minute wafer **14** cut from the large wafer **11**, and having a mask **12** thereon, with a central aperture **13** therethrough exposing the upper surface of the wafer thereat. As a further step in the manufacture of the semiconductor diode, there is provided an impurity upon the upper surface of the wafer **14** within the aperture **13**. With an N-type silicon wafer, the impurity would be one of the known acceptor impurities preferably alloyed with silicon, and heat is added to the wafer and impurity, as indicated by the arrow **16**. Application of sufficient heat to raise the wafer to an appropriate temperature results in a diffusion of the impurity applied into the wafer **14**, so as to produce a region or portion **17** of P-type silicon within the wafer. Intermediate these two types of silicons now forming the wafer **14**, there is produced a junction **18** in the well known manner whereat particular desired electrical characteristics are realized. During the diffusion of the impurities into the wafer of silicon **14**, there is normally produced an oxidation of surface silicon so that, as indicated in FIG. 3, an oxide layer completely covers the top thereof.

In accordance with the present invention, the added oxide layer **19** within the masking aperture **13** is then removed as by etching with hydrofluoric acid or other suitable means so as to expose the upper surface of the P-type silicon material **17** with the juncture between same and the N-type silicon being yet covered by the original masking layer **12**. The diode device may then be completed by providing an ohmic contact **21** to the upper surface of the wafer within the aperture **13** and a similar contact **22** upon the underside of the wafer. These ohmic contacts may be conveniently applied by well known plating methods to deposit such as gold or the like upon the silicon, and electrical contacts or wires **23** and **24** are then attached to the device by alloying same to the ohmic contacts **21** and **22** and to the connecting silicon **17** at the top and **14** at the bottom. This alloying step is accomplished at a temperature in excess of the gold-silicon eutectic temperature of 373 degrees C., and serves the purpose of reducing electrical discontinuities at the connection. During the manufacture of the diode semiconducting device described above, the oxide layer formed upon the silicon is retained thereon at all times except at the surfaces to be employed in connection with ohmic contacts to the device. The resultant diode structure will be seen to be fully protected, particularly at the PN junction thereof, so as to prevent contamination and possible electrical leakage resulting from handling of the device and cleaning and canning of same during fabricating steps of the diode. It is of particular note that only within the original masking opening **13** is the oxide layer removed during the diode manufacture, and at all other parts of the device there is provided an integral protective layer of silicon oxide.

Considering now the present invention as same relates to double-diffused silicon transistors, reference is made to FIGS. 5 to 9 of the drawings. As a first step in the manufacture there is produced a layer **31** formed, for example, of an oxide of silicon, and covering at least the upper surface of a silicon wafer **32**, which may be formed of N-type silicon, for example. There is provided in this oxide layer **31** a hole or opening **33** which may be formed by photoresist techniques or by etching of the layer, and the configuration of the opening in the layer **31** is controlled to define the desired configuration of the transistor base member. The apertured layer **31** serves as a mask for protecting the transistor surface and junctions, and for limiting the lateral diffusion of impurities in the wafer. The layer is thus formed of a material into which impurities to be employed during transistor manufacture will not diffuse during the steps thereof, and which not only tightly adheres to the wafer surface in protective relation thereto, but which also is not electrically conducting. Upon the upper surface of the wafer **32** exposed at the aperture **33** in the mask or layer **31**, there is disposed a predetermined amount of acceptor impurity, as in the form of a silicon alloy, and heat is applied, as indicated by the arrows **34**, whereby the impurity diffuses into the wafer **32** to form a P-type base layer **36** therein. In conventional manner there is produced through controlled heating and cooling of the transistor structure, a transistor junction **37** between the base layer **36** and the wafer **32** with the upper terminus of this junction lying beneath the oxide mask **31**, as illustrated in FIG. 6. As silicon technology is available in the literature, it is here only noted that N-type silicon may be formed by inclusion of an impurity chosen from group V of the periodic table, while P-type silicon may be formed by inclusion of an impurity from group III.

During or following disposition of the base layer **36** upon the wafer **32** and the formation of a transistor junction **37** therebetween, there is formed an additional or extensional portion of the oxide layer **31**, as shown at **38** of FIG. 7. This additional masking **38** extends the oxide coating over an additional part of the base layer **36** to the end of masking same so that the second layer of material to be diffused into the transistor will not extend to both extremities of the base layer. With the augmented masking layer **31** upon the upper surface of the wafer **32** and in masking relation to some substantial portion of the base layer **36**, there is diffused into the transistor structure a second layer **39** by the provision of a suitable impurity or alloy thereof atop the base layer and the addition of heat to raise the wafer and impurity upon same to diffusion temperature. In a conventional manner the diffusion of impurities into the wafer is precisely controlled as to rapidity and extent, so that there is thereby formed a second transistor junction **41** between an emitter layer **39** and the base layer **36**. As may be seen from FIG. 8 of the drawings, the emitter **39** diffuses into the base and the junction **41** therebetween terminates at the upper surface of the wafer beneath the mask **38** adjacent the opening of reduced size therein. It will be further appreciated from the structure illustrated in FIG. 8 that there then results an uneven disposition of the second diffused layer **39** in that the same is offset from the center of the base layer **36**. Particular advantage is derived from this relationship of the respective layers for, as illustrated in FIG. 9, there is then removed a portion of the masking layer **31** to form an opening **42** therethrough immediately above the portion of the base layer **36** extending laterally from the emitter **39**. In this manner, there is provided a substantial contact area of the base layer **36** available at the upper surface of the transistor for attachment of an ohmic contact thereto. Please note in this respect that the mask **31** is not removed from the upper surface of the transistor above the emitter-base junction **41**, but instead is retained thereat so as to protect this junction from inadvertent shorting or other damage during subsequent manufacturing and handling operations. Not only is this junction **41** covered at the above-noted points,

Figure B.175: Jean Hoerni invented methods of manufacturing silicon transistors.



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but additionally it is wholly encased by the oxide layer **31** at all other points upon the upper surface of the wafer. Likewise, the base-collector junction **37** is fully covered by the oxide layer **31** atop the transistor. As a consequence of this structure, there is provided a materially improved transistor structure wherein inadvertent damage or shorting of the junctions thereof is wholly precluded. In a conventional manner there may then be applied omhic contacts to the emitter, base and collector. In this respect it is herein possible to provide an ohmic contact to the collector at the upper surface thereof so as to produce a transistor having all contacts on the same side. This is herein accomplished by providing an additional opening through the mask **31** in lateral separation from the base opening **42** and therefore unmasking a desired extent of the collector at the top thereof. Ohmic contacts **44**, **46** and **47** are then applied in a relatively conventional manner to the separate portions of the transistor through the openings **33**, **42** and **43**. It is herein possible to employ conventional plating techniques to apply electrical conductors to the semiconductor. Inasmuch as the transistor junctions are entirely covered and protected upon the upper surface of the transistor, no possible electrical shorting or damage to junctions can result from the plating or alloying processes employed.

It will of course be appreciated that the silicon oxide herein stated as comprising the masking layer **31** upon the transistor wafer **32** does not react with the impurity employed in the formation of different type semi-conducting materials. In this respect, particular care must be taken to exclude gallium as a suitable impurity from the group III elements that may be diffused into the silicon, for this particular element does diffuse through silicon oxide and consequently the mask will not be effective to limit the lateral extent of the diffusion of the impurity. Substantially all of the impurities which are desirable for use as dopants or diffusing elements with silicon do not readily diffuse through the oxide layer herein employed, and consequently the method of the present invention is only limited insofar as the element gallium is concerned.

It is further noted that in the process above described relating to the manufacture of a triode transistor of a double-diffused silicon type, any unavoidable production of an oxide layer upon the upper surface of the wafer at points wherein the same is not desired is followed by the removal of same. Thus, for example, following the production of the base layer **36** by diffusing the selected impurity into the wafer **32**, there may result a thin oxide layer over the top of the base portion of the transistor and this layer is then removed, at least in part, as by etching or photoresist techniques.

Considering now the improved double-diffused silicon transistor of the present invention, reference is made to FIG. 10 of the drawing, where there is illustrated in cross-section such a transistor. As may be seen from this figure, the improved transistor includes a collector disc or wafer **32**, formed for example, of an N-type silicon. At the top of this collector wafer **32** there is disposed a thin base layer **36**, formed of silicon of opposite conductive type, thus in the present example of P-type silicon. Atop the base layer **36** there is provided an emitter layer or dot **39**, of N-type silicon, and having a very minute dimension. Although not previously discussed, the present invention is particularly adapted to high frequency applications wherein very small dimensions are required of the transistor portions. Thus, in the present invention, the lateral extent of the emitter may be substantially less than one millimeter and the thickness of the base layer between emitter and collector may be of the order of one micron. Upon the upper surface of the wafer **32** there is provided the oxide layer or coating **31** which will be seen to fully cover both the emitter-base junction **41** and the base-collector junction **37**. Openings **33**, **42** and **43** through this oxide coating **31** provide communication with the

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emitter, base and collector, respectively, of the transistor whereby ohmic contacts may be made all in the upper plane of the transistor. Thus an ohmic contact including an electrical lead **44** is provided atop the emitter **39**, while a second ohmic contact including a lead **46** is provided in connection with the upper surface of the base **36** through the masked openings **42**. Likewise, a third ohmic contact **47** including an electrical conductor, is electrically and mechanically joined to the upper surface of the collector wafer **32** through the mask opening **43**. The resulting transistor structure illustrated in FIG. 10 of the drawing will be seen to be particularly well adapted for high frequency applications, and furthermore, to be fully protected from shorting of the junctions thereof as may otherwise occur during manufacture. While this transistor structure is well adapted to the provision of an ohmic contact to the collector thereof at the common upper surface of the transistor, yet the collector contact may also be provided upon the under surface of the wafer **32** as in the manner of the diode manufacture described above.

Although the above description of both the manufacturing process and the transistor structure has been referenced to an NPN transistor, it will be appreciated that it is equally applicable to PNP type transistors.

What is claimed is:

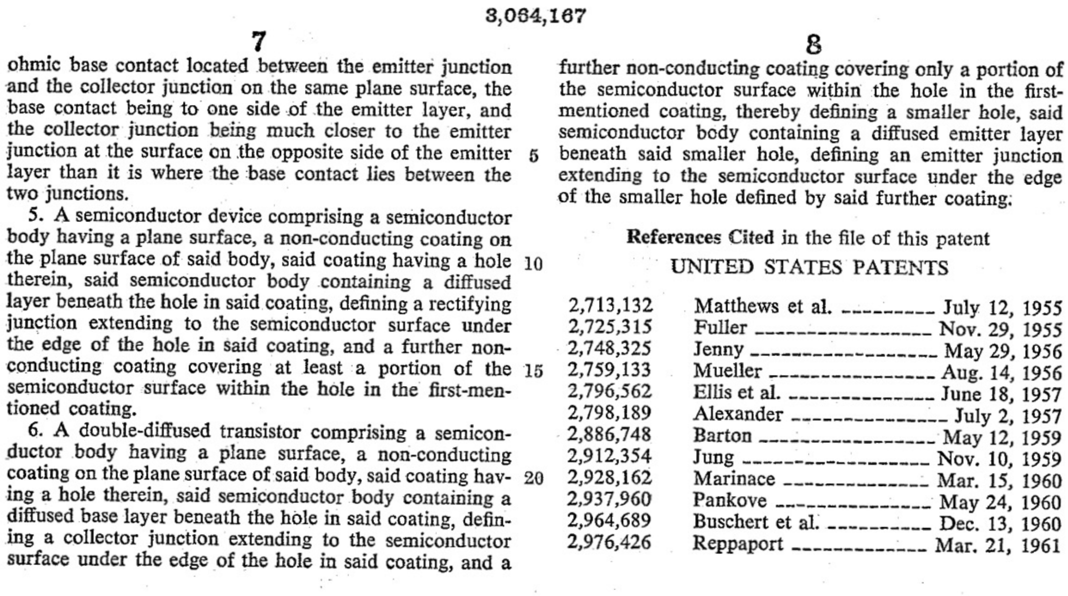
1. An improved double-diffused transistor structure comprising a thin wafer having a plane upper surface, said wafer being mostly of a first conductive type of semiconductor, a first thin layer of opposite conductive type semiconductor diffused into only part of the upper surface of said wafer, a second layer of first conductive type semiconductor diffused into only part of the upper surface of said first layer closer to one edge thereof than to the other so that a substantial area of said first layer appears at the upper surface of the wafer, a protective adherent nonconducting coating upon the upper surface of the wafer and having openings therethrough to said second layer and wafer, as well as to said first layer only at the substantial surface area of the latter, and electrical leads extending through said openings into contact with said wafer and first and second layers at the upper surface of said wafer.

2. An improved transistor structure comprising a thin wafer of semiconducting material having a planar upper surface, a first zone extending into said wafer from said planar surface and defining a transistor junction between same and the remainder of said wafer with such junction extending to said planar surface about said zone, a second zone extending into said wafer from said surface within said first zone and defining with the latter a second transistor junction which likewise extends to the planar surface of said wafer, an integral insulating coating upon at least the planar surface of said wafer in totally covering relation to all transistor junctions thereat, and electrical conductors extending through openings in said coating into ohmic contact with separate zones of the transistor at the planar surface thereof.

3. A transistor comprising a semiconductor body having a plane surface, said semiconductor body containing a diffused base layer extending into the body from such plane surface, the base layer being of smaller lateral extent than the plane surface and having a boundary defining a collector junction extending to such plane surface and there surrounding the base layer, said semiconductor body also containing a diffused emitter layer extending into the body from the same plane surface, the emitter layer being of smaller lateral extent than the base layer and disposed within the base layer, defining an emitter junction extending to such plane surface and there surrounding the emitter layer, and a permanent, non-conducting coating entirely covering the collector and emitter junctions at the surface of the semiconductor body.

4. A transistor as defined in claim 3, comprising an ohmic emitter contact located inside the emitter junction on the plane surface of the semiconductor body, and an

Figure B.176: Jean Hoerni invented methods of manufacturing silicon transistors.



ohmic base contact located between the emitter junction and the collector junction on the same plane surface, the base contact being to one side of the emitter layer, and the collector junction being much closer to the emitter junction at the surface on the opposite side of the emitter layer than it is where the base contact lies between the two junctions.

5. A semiconductor device comprising a semiconductor body having a plane surface, a non-conducting coating on the plane surface of said body, said coating having a hole therein, said semiconductor body containing a diffused layer beneath the hole in said coating, defining a rectifying junction extending to the semiconductor surface under the edge of the hole in said coating, and a further non-conducting coating covering at least a portion of the semiconductor surface within the hole in the first-mentioned coating.

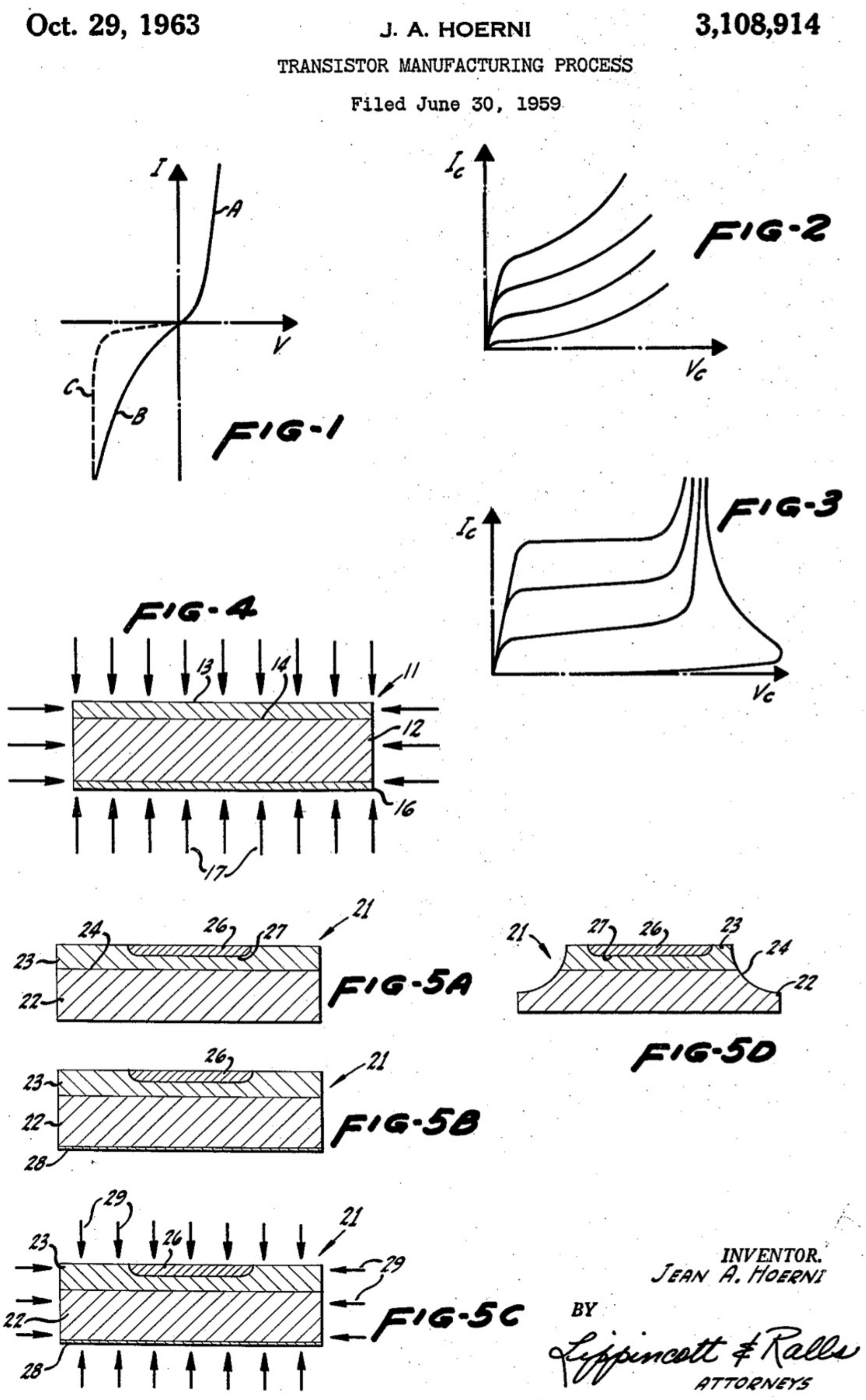
6. A double-diffused transistor comprising a semiconductor body having a plane surface, a non-conducting coating on the plane surface of said body, said coating having a hole therein, said semiconductor body containing a diffused base layer beneath the hole in said coating, defining a collector junction extending to the semiconductor surface under the edge of the hole in said coating, and a further non-conducting coating covering only a portion of the semiconductor surface within the hole in the first-mentioned coating, thereby defining a smaller hole, said semiconductor body containing a diffused emitter layer beneath said smaller hole, defining an emitter junction extending to the semiconductor surface under the edge of the smaller hole defined by said further coating.

References Cited in the file of this patent

UNITED STATES PATENTS

2,713,132	Matthews et al.	July 12, 1955
2,725,315	Fuller	Nov. 29, 1955
2,748,325	Jenny	May 29, 1956
2,759,133	Mueller	Aug. 14, 1956
2,796,562	Ellis et al.	June 18, 1957
2,798,189	Alexander	July 2, 1957
2,886,748	Barton	May 12, 1959
2,912,354	Jung	Nov. 10, 1959
2,928,162	Marinace	Mar. 15, 1960
2,937,960	Pankove	May 24, 1960
2,964,689	Buschert et al.	Dec. 13, 1960
2,976,426	Reppaport	Mar. 21, 1961

Figure B.177: Jean Hoerni invented methods of manufacturing silicon transistors.



Oct. 29, 1963 **J. A. HOERNI** **3,108,914**

TRANSISTOR MANUFACTURING PROCESS

Filed June 30, 1959

INVENTOR.
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BY
Lippincott & Ralls
ATTORNEYS

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FIG-5D
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FIG-5B
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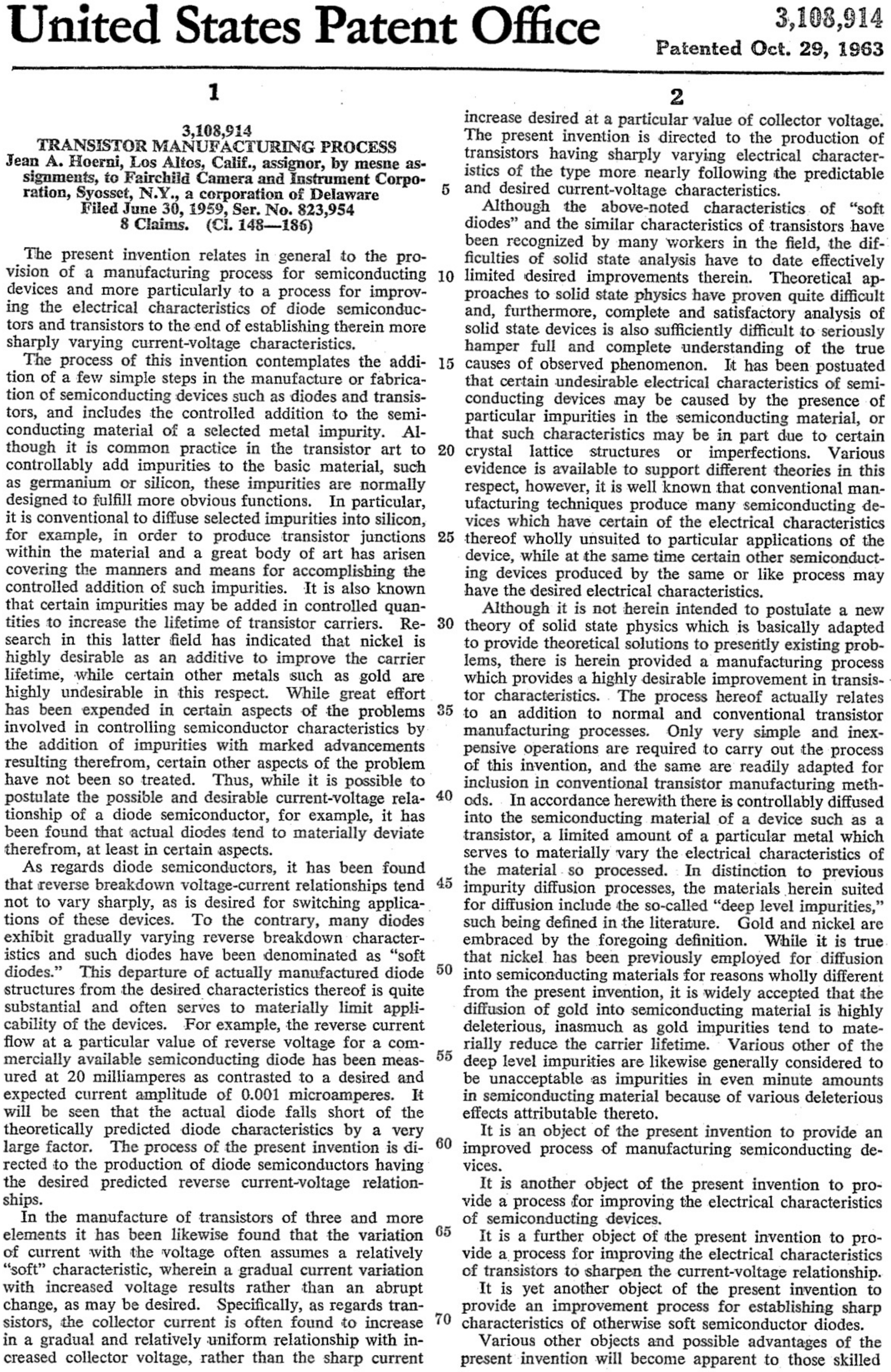
Figure B.178: Jean Hoerni invented methods of manufacturing silicon transistors.



United States Patent Office

3,108,914
Patented Oct. 29, 1963

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3,108,914
TRANSISTOR MANUFACTURING PROCESS
Jean A. Hoerni, Los Altos, Calif., assignor, by mesne assignments, to Fairchild Camera and Instrument Corporation, Syosset, N.Y., a corporation of Delaware
Filed June 30, 1959, Ser. No. 823,954
8 Claims. (Cl. 148—186)

The present invention relates in general to the provision of a manufacturing process for semiconducting devices and more particularly to a process for improving the electrical characteristics of diode semiconductors and transistors to the end of establishing therein more sharply varying current-voltage characteristics.

The process of this invention contemplates the addition of a few simple steps in the manufacture or fabrication of semiconducting devices such as diodes and transistors, and includes the controlled addition to the semiconducting material of a selected metal impurity. Although it is common practice in the transistor art to controllably add impurities to the basic material, such as germanium or silicon, these impurities are normally designed to fulfill more obvious functions. In particular, it is conventional to diffuse selected impurities into silicon, for example, in order to produce transistor junctions within the material and a great body of art has arisen covering the manners and means for accomplishing the controlled addition of such impurities. It is also known that certain impurities may be added in controlled quantities to increase the lifetime of transistor carriers. Research in this latter field has indicated that nickel is highly desirable as an additive to improve the carrier lifetime, while certain other metals such as gold are highly undesirable in this respect. While great effort has been expended in certain aspects of the problems involved in controlling semiconductor characteristics by the addition of impurities with marked advancements resulting therefrom, certain other aspects of the problem have not been so treated. Thus, while it is possible to postulate the possible and desirable current-voltage relationship of a diode semiconductor, for example, it has been found that actual diodes tend to materially deviate therefrom, at least in certain aspects.

As regards diode semiconductors, it has been found that reverse breakdown voltage-current relationships tend not to vary sharply, as is desired for switching applications of these devices. To the contrary, many diodes exhibit gradually varying reverse breakdown characteristics and such diodes have been denominated as "soft diodes." This departure of actually manufactured diode structures from the desired characteristics thereof is quite substantial and often serves to materially limit applicability of the devices. For example, the reverse current flow at a particular value of reverse voltage for a commercially available semiconducting diode has been measured at 20 milliamperes as contrasted to a desired and expected current amplitude of 0.001 microamperes. It will be seen that the actual diode falls short of the theoretically predicted diode characteristics by a very large factor. The process of the present invention is directed to the production of diode semiconductors having the desired predicted reverse current-voltage relationships.

In the manufacture of transistors of three and more elements it has been likewise found that the variation of current with the voltage often assumes a relatively "soft" characteristic, wherein a gradual current variation with increased voltage results rather than an abrupt change, as may be desired. Specifically, as regards transistors, the collector current is often found to increase in a gradual and relatively uniform relationship with increased collector voltage, rather than the sharp current

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increase desired at a particular value of collector voltage. The present invention is directed to the production of transistors having sharply varying electrical characteristics of the type more nearly following the predictable and desired current-voltage characteristics.

Although the above-noted characteristics of "soft diodes" and the similar characteristics of transistors have been recognized by many workers in the field, the difficulties of solid state analysis have to date effectively limited desired improvements therein. Theoretical approaches to solid state physics have proven quite difficult and, furthermore, complete and satisfactory analysis of solid state devices is also sufficiently difficult to seriously hamper full and complete understanding of the true causes of observed phenomenon. It has been postuated that certain undesirable electrical characteristics of semiconducting devices may be caused by the presence of particular impurities in the semiconducting material, or that such characteristics may be in part due to certain crystal lattice structures or imperfections. Various evidence is available to support different theories in this respect, however, it is well known that conventional manufacturing techniques produce many semiconducting devices which have certain of the electrical characteristics thereof wholly unsuited to particular applications of the device, while at the same time certain other semiconducting devices produced by the same or like process may have the desired electrical characteristics.

Although it is not herein intended to postulate a new theory of solid state physics which is basically adapted to provide theoretical solutions to presently existing problems, there is herein provided a manufacturing process which provides a highly desirable improvement in transistor characteristics. The process hereof actually relates to an addition to normal and conventional transistor manufacturing processes. Only very simple and inexpensive operations are required to carry out the process of this invention, and the same are readily adapted for inclusion in conventional transistor manufacturing methods. In accordance herewith there is controllably diffused into the semiconducting material of a device such as a transistor, a limited amount of a particular metal which serves to materially vary the electrical characteristics of the material so processed. In distinction to previous impurity diffusion processes, the materials herein suited for diffusion include the so-called "deep level impurities," such being defined in the literature. Gold and nickel are embraced by the foregoing definition. While it is true that nickel has been previously employed for diffusion into semiconducting materials for reasons wholly different from the present invention, it is widely accepted that the diffusion of gold into semiconducting material is highly deleterious, inasmuch as gold impurities tend to materially reduce the carrier lifetime. Various other of the deep level impurities are likewise generally considered to be unacceptable as impurities in even minute amounts in semiconducting material because of various deleterious effects attributable thereto.

It is an object of the present invention to provide an improved process of manufacturing semiconducting devices.

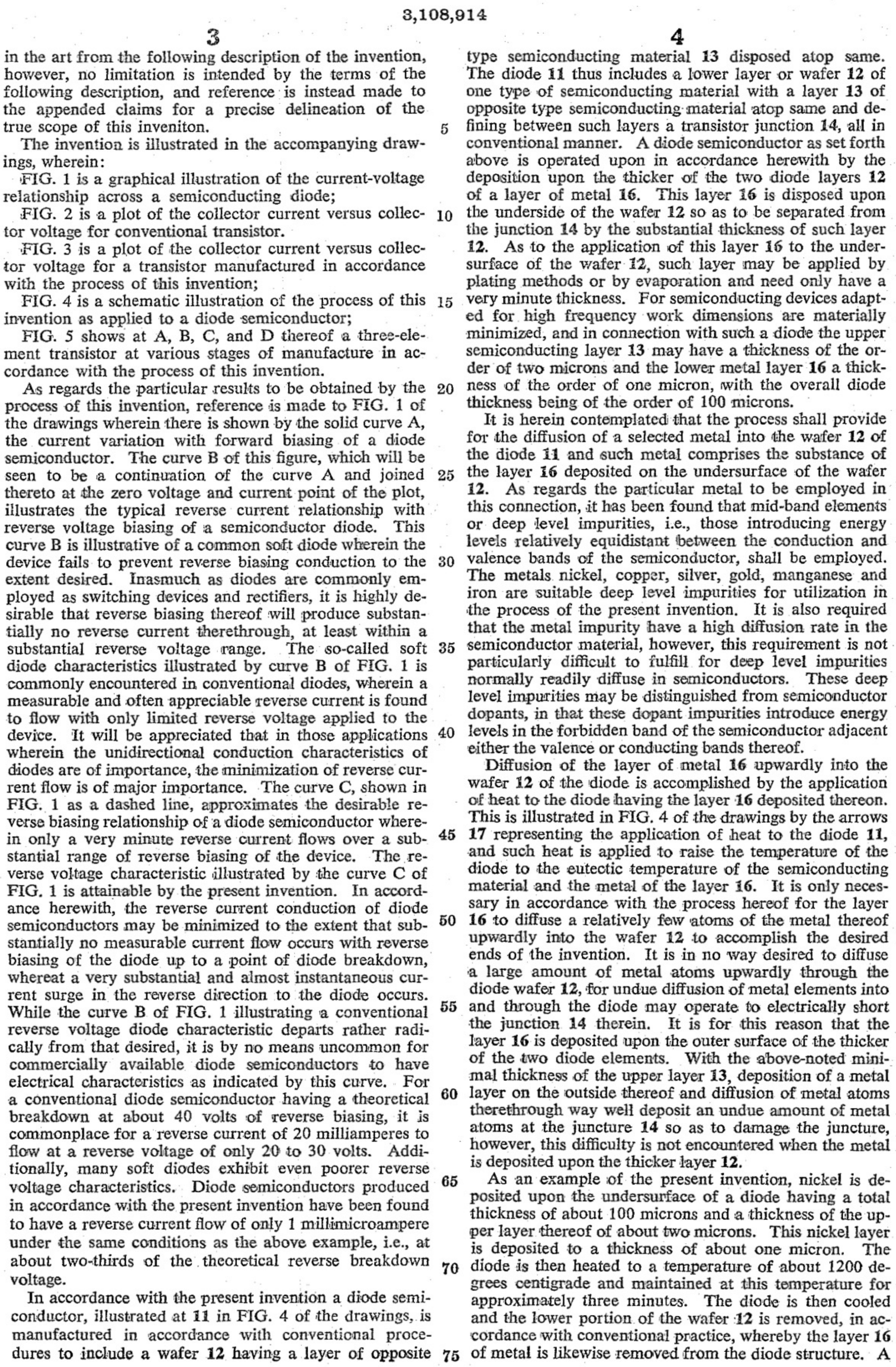
It is another object of the present invention to provide a process for improving the electrical characteristics of semiconducting devices.

It is a further object of the present invention to provide a process for improving the electrical characteristics of transistors to sharpen the current-voltage relationship.

It is yet another object of the present invention to provide an improvement process for establishing sharp characteristics of otherwise soft semiconductor diodes.

Various other objects and possible advantages of the present invention will become apparent to those skilled

Figure B.179: Jean Hoerni invented methods of manufacturing silicon transistors.



in the art from the following description of the invention, however, no limitation is intended by the terms of the following description, and reference is instead made to the appended claims for a precise delineation of the true scope of this inveniton.

The invention is illustrated in the accompanying drawings, wherein:

FIG. 1 is a graphical illustration of the current-voltage relationship across a semiconducting diode;

FIG. 2 is a plot of the collector current versus collector voltage for conventional transistor.

FIG. 3 is a plot of the collector current versus collector voltage for a transistor manufactured in accordance with the process of this invention;

FIG. 4 is a schematic illustration of the process of this invention as applied to a diode semiconductor;

FIG. 5 shows at A, B, C, and D thereof a three-element transistor at various stages of manufacture in accordance with the process of this invention.

As regards the particular results to be obtained by the process of this invention, reference is made to FIG. 1 of the drawings wherein there is shown by the solid curve A, the current variation with forward biasing of a diode semiconductor. The curve B of this figure, which will be seen to be a continuation of the curve A and joined thereto at the zero voltage and current point of the plot, illustrates the typical reverse current relationship with reverse voltage biasing of a semiconductor diode. This curve B is illustrative of a common soft diode wherein the device fails to prevent reverse biasing conduction to the extent desired. Inasmuch as diodes are commonly employed as switching devices and rectifiers, it is highly desirable that reverse biasing thereof will produce substantially no reverse current therethrough, at least within a substantial reverse voltage range. The so-called soft diode characteristics illustrated by curve B of FIG. 1 is commonly encountered in conventional diodes, wherein a measurable and often appreciable reverse current is found to flow with only limited reverse voltage applied to the device. It will be appreciated that in those applications wherein the unidirectional conduction characteristics of diodes are of importance, the minimization of reverse current flow is of major importance. The curve C, shown in FIG. 1 as a dashed line, approximates the desirable reverse biasing relationship of a diode semiconductor wherein only a very minute reverse current flows over a substantial range of reverse biasing of the device. The reverse voltage characteristic illustrated by the curve C of FIG. 1 is attainable by the present invention. In accordance herewith, the reverse current conduction of diode semiconductors may be minimized to the extent that substantially no measurable current flow occurs with reverse biasing of the diode up to a point of diode breakdown, whereat a very substantial and almost instantaneous current surge in the reverse direction to the diode occurs. While the curve B of FIG. 1 illustrating a conventional reverse voltage diode characteristic departs rather radically from that desired, it is by no means uncommon for commercially available diode semiconductors to have electrical characteristics as indicated by this curve. For a conventional diode semiconductor having a theoretical breakdown at about 40 volts of reverse biasing, it is commonplace for a reverse current of 20 milliamperes to flow at a reverse voltage of only 20 to 30 volts. Additionally, many soft diodes exhibit even poorer reverse voltage characteristics. Diode semiconductors produced in accordance with the present invention have been found to have a reverse current flow of only 1 millimicroampere under the same conditions as the above example, i.e., at about two-thirds of the theoretical reverse breakdown voltage.

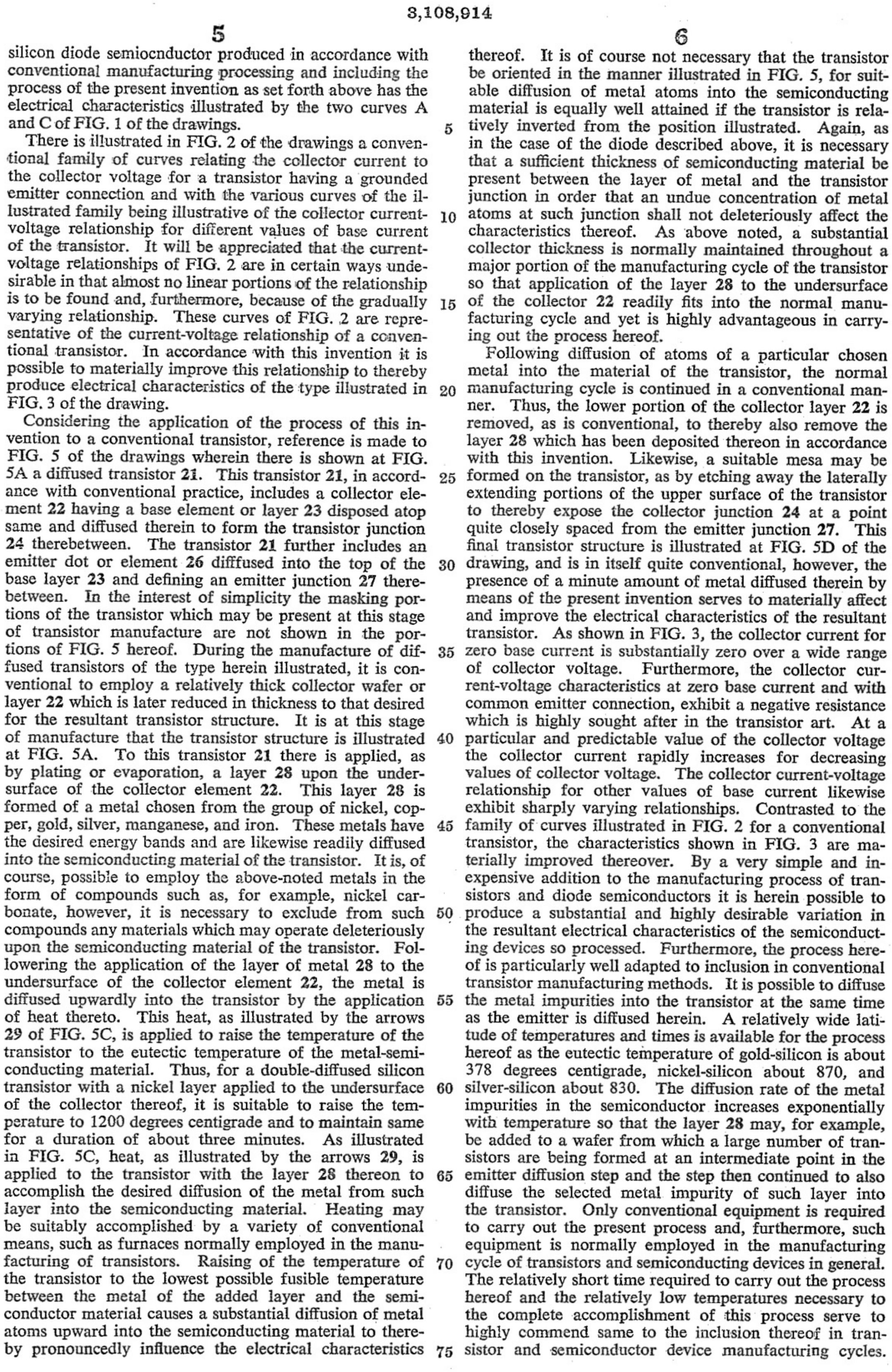
In accordance with the present invention a diode semiconductor, illustrated at **11** in FIG. 4 of the drawings, is manufactured in accordance with conventional procedures to include a wafer **12** having a layer of opposite type semiconducting material **13** disposed atop same. The diode **11** thus includes a lower layer or wafer **12** of one type of semiconducting material with a layer **13** of opposite type semiconducting material atop same and defining between such layers a transistor junction **14**, all in conventional manner. A diode semiconductor as set forth above is operated upon in accordance herewith by the deposition upon the thicker of the two diode layers **12** of a layer of metal **16**. This layer **16** is disposed upon the underside of the wafer **12** so as to be separated from the junction **14** by the substantial thickness of such layer **12**. As to the application of this layer **16** to the undersurface of the wafer **12**, such layer may be applied by plating methods or by evaporation and need only have a very minute thickness. For semiconducting devices adapted for high frequency work dimensions are materially minimized, and in connection with such a diode the upper semiconducting layer **13** may have a thickness of the order of two microns and the lower metal layer **16** a thickness of the order of one micron, with the overall diode thickness being of the order of 100 microns.

It is herein contemplated that the process shall provide for the diffusion of a selected metal into the wafer **12** of the diode **11** and such metal comprises the substance of the layer **16** deposited on the undersurface of the wafer **12**. As regards the particular metal to be employed in this connection, it has been found that mid-band elements or deep level impurities, i.e., those introducing energy levels relatively equidistant between the conduction and valence bands of the semiconductor, shall be employed. The metals nickel, copper, silver, gold, manganese and iron are suitable deep level impurities for utilization in the process of the present invention. It is also required that the metal impurity have a high diffusion rate in the semiconductor material, however, this requirement is not particularly difficult to fulfill for deep level impurities normally readily diffuse in semiconductors. These deep level impurities may be distinguished from semiconductor dopants, in that these dopant impurities introduce energy levels in the forbidden band of the semiconductor adjacent either the valence or conducting bands thereof.

Diffusion of the layer of metal **16** upwardly into the wafer **12** of the diode is accomplished by the application of heat to the diode having the layer **16** deposited thereon. This is illustrated in FIG. 4 of the drawings by the arrows **17** representing the application of heat to the diode **11**, and such heat is applied to raise the temperature of the diode to the eutectic temperature of the semiconducting material and the metal of the layer **16**. It is only necessary in accordance with the process hereof for the layer **16** to diffuse a relatively few atoms of the metal thereof upwardly into the wafer **12** to accomplish the desired ends of the invention. It is in no way desired to diffuse a large amount of metal atoms upwardly through the diode wafer **12**, for undue diffusion of metal elements into and through the diode may operate to electrically short the junction **14** therein. It is for this reason that the layer **16** is deposited upon the outer surface of the thicker of the two diode elements. With the above-noted minimal thickness of the upper layer **13**, deposition of a metal layer on the outside thereof and diffusion of metal atoms therethrough way well deposit an undue amount of metal atoms at the juncture **14** so as to damage the juncture, however, this difficulty is not encountered when the metal is deposited upon the thicker layer **12**.

As an example of the present invention, nickel is deposited upon the undersurface of a diode having a total thickness of about 100 microns and a thickness of the upper layer thereof of about two microns. This nickel layer is deposited to a thickness of about one micron. The diode is then heated to a temperature of about 1200 degrees centigrade and maintained at this temperature for approximately three minutes. The diode is then cooled and the lower portion of the wafer **12** is removed, in accordance with conventional practice, whereby the layer **16** of metal is likewise removed from the diode structure. A

Figure B.180: Jean Hoerni invented methods of manufacturing silicon transistors.



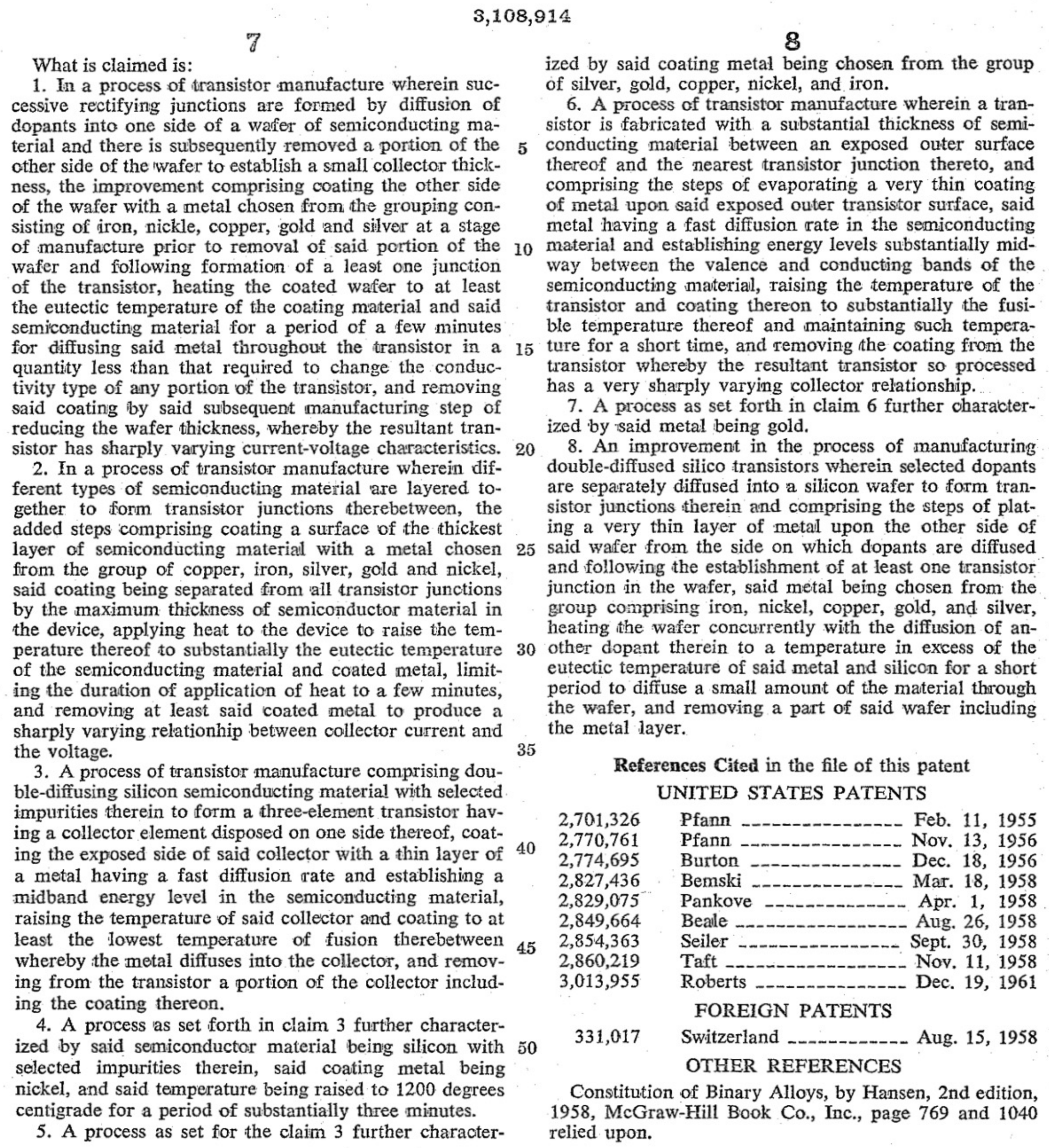
silicon diode semiocnductor produced in accordance with conventional manufacturing processing and including the process of the present invention as set forth above has the electrical characteristics illustrated by the two curves A and C of FIG. 1 of the drawings.

There is illustrated in FIG. 2 of the drawings a conventional family of curves relating the collector current to the collector voltage for a transistor having a grounded emitter connection and with the various curves of the illustrated family being illustrative of the collector current-voltage relationship for different values of base current of the transistor. It will be appreciated that the current-voltage relationships of FIG. 2 are in certain ways undesirable in that almost no linear portions of the relationship is to be found and, furthermore, because of the gradually varying relationship. These curves of FIG. 2 are representative of the current-voltage relationship of a conventional transistor. In accordance with this invention it is possible to materially improve this relationship to thereby produce electrical characteristics of the type illustrated in FIG. 3 of the drawing.

Considering the application of the process of this invention to a conventional transistor, reference is made to FIG. 5 of the drawings wherein there is shown at FIG. 5A a diffused transistor **21**. This transistor **21**, in accordance with conventional practice, includes a collector element **22** having a base element or layer **23** disposed atop same and diffused therein to form the transistor junction **24** therebetween. The transistor **21** further includes an emitter dot or element **26** difffused into the top of the base layer **23** and defining an emitter junction **27** therebetween. In the interest of simplicity the masking portions of the transistor which may be present at this stage of transistor manufacture are not shown in the portions of FIG. 5 hereof. During the manufacture of diffused transistors of the type herein illustrated, it is conventional to employ a relatively thick collector wafer or layer **22** which is later reduced in thickness to that desired for the resultant transistor structure. It is at this stage of manufacture that the transistor structure is illustrated at FIG. 5A. To this transistor **21** there is applied, as by plating or evaporation, a layer **28** upon the undersurface of the collector element **22**. This layer **28** is formed of a metal chosen from the group of nickel, copper, gold, silver, manganese, and iron. These metals have the desired energy bands and are likewise readily diffused into the semiconducting material of the transistor. It is, of course, possible to employ the above-noted metals in the form of compounds such as, for example, nickel carbonate, however, it is necessary to exclude from such compounds any materials which may operate deleteriously upon the semiconducting material of the transistor. Followering the application of the layer of metal **28** to the undersurface of the collector element **22**, the metal is diffused upwardly into the transistor by the application of heat thereto. This heat, as illustrated by the arrows **29** of FIG. 5C, is applied to raise the temperature of the transistor to the eutectic temperature of the metal-semiconducting material. Thus, for a double-diffused silicon transistor with a nickel layer applied to the undersurface of the collector thereof, it is suitable to raise the temperature to 1200 degrees centigrade and to maintain same for a duration of about three minutes. As illustrated in FIG. 5C, heat, as illustrated by the arrows **29**, is applied to the transistor with the layer **28** thereon to accomplish the desired diffusion of the metal from such layer into the semiconducting material. Heating may be suitably accomplished by a variety of conventional means, such as furnaces normally employed in the manufacturing of transistors. Raising of the temperature of the transistor to the lowest possible fusible temperature between the metal of the added layer and the semiconductor material causes a substantial diffusion of metal atoms upward into the semiconducting material to thereby pronouncedly influence the electrical characteristics thereof. It is of course not necessary that the transistor be oriented in the manner illustrated in FIG. 5, for suitable diffusion of metal atoms into the semiconducting material is equally well attained if the transistor is relatively inverted from the position illustrated. Again, as in the case of the diode described above, it is necessary that a sufficient thickness of semiconducting material be present between the layer of metal and the transistor junction in order that an undue concentration of metal atoms at such junction shall not deleteriously affect the characteristics thereof. As above noted, a substantial collector thickness is normally maintained throughout a major portion of the manufacturing cycle of the transistor so that application of the layer **28** to the undersurface of the collector **22** readily fits into the normal manufacturing cycle and yet is highly advantageous in carrying out the process hereof.

Following diffusion of atoms of a particular chosen metal into the material of the transistor, the normal manufacturing cycle is continued in a conventional manner. Thus, the lower portion of the collector layer **22** is removed, as is conventional, to thereby also remove the layer **28** which has been deposited thereon in accordance with this invention. Likewise, a suitable mesa may be formed on the transistor, as by etching away the laterally extending portions of the upper surface of the transistor to thereby expose the collector junction **24** at a point quite closely spaced from the emitter junction **27**. This final transistor structure is illustrated at FIG. 5D of the drawing, and is in itself quite conventional, however, the presence of a minute amount of metal diffused therein by means of the present invention serves to materially affect and improve the electrical characteristics of the resultant transistor. As shown in FIG. 3, the collector current for zero base current is substantially zero over a wide range of collector voltage. Furthermore, the collector current-voltage characteristics at zero base current and with common emitter connection, exhibit a negative resistance which is highly sought after in the transistor art. At a particular and predictable value of the collector voltage the collector current rapidly increases for decreasing values of collector voltage. The collector current-voltage relationship for other values of base current likewise exhibit sharply varying relationships. Contrasted to the family of curves illustrated in FIG. 2 for a conventional transistor, the characteristics shown in FIG. 3 are materially improved thereover. By a very simple and inexpensive addition to the manufacturing process of transistors and diode semiconductors it is herein possible to produce a substantial and highly desirable variation in the resultant electrical characteristics of the semiconducting devices so processed. Furthermore, the process hereof is particularly well adapted to inclusion in conventional transistor manufacturing methods. It is possible to diffuse the metal impurities into the transistor at the same time as the emitter is diffused herein. A relatively wide latitude of temperatures and times is available for the process hereof as the eutectic temperature of gold-silicon is about 378 degrees centigrade, nickel-silicon about 870, and silver-silicon about 830. The diffusion rate of the metal impurities in the semiconductor increases exponentially with temperature so that the layer **28** may, for example, be added to a wafer from which a large number of transistors are being formed at an intermediate point in the emitter diffusion step and the step then continued to also diffuse the selected metal impurity of such layer into the transistor. Only conventional equipment is required to carry out the present process and, furthermore, such equipment is normally employed in the manufacturing cycle of transistors and semiconducting devices in general. The relatively short time required to carry out the process hereof and the relatively low temperatures necessary to the complete accomplishment of this process serve to highly commend same to the inclusion thereof in transistor and semiconductor device manufacturing cycles.

Figure B.181: Jean Hoerni invented methods of manufacturing silicon transistors.



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What is claimed is:

1. In a process of transistor manufacture wherein successive rectifying junctions are formed by diffusion of dopants into one side of a wafer of semiconducting material and there is subsequently removed a portion of the other side of the wafer to establish a small collector thickness, the improvement comprising coating the other side of the wafer with a metal chosen from the grouping consisting of iron, nickle, copper, gold and silver at a stage of manufacture prior to removal of said portion of the wafer and following formation of a least one junction of the transistor, heating the coated wafer to at least the eutectic temperature of the coating material and said semiconducting material for a period of a few minutes for diffusing said metal throughout the transistor in a quantity less than that required to change the conductivity type of any portion of the transistor, and removing said coating by said subsequent manufacturing step of reducing the wafer thickness, whereby the resultant transistor has sharply varying current-voltage characteristics.

2. In a process of transistor manufacture wherein different types of semiconducting material are layered together to form transistor junctions therebetween, the added steps comprising coating a surface of the thickest layer of semiconducting material with a metal chosen from the group of copper, iron, silver, gold and nickel, said coating being separated from all transistor junctions by the maximum thickness of semiconductor material in the device, applying heat to the device to raise the temperature thereof to substantially the eutectic temperature of the semiconducting material and coated metal, limiting the duration of application of heat to a few minutes, and removing at least said coated metal to produce a sharply varying relationhip between collector current and the voltage.

3. A process of transistor manufacture comprising double-diffusing silicon semiconducting material with selected impurities therein to form a three-element transistor having a collector element disposed on one side thereof, coating the exposed side of said collector with a thin layer of a metal having a fast diffusion rate and establishing a midband energy level in the semiconducting material, raising the temperature of said collector and coating to at least the lowest temperature of fusion therebetween whereby the metal diffuses into the collector, and removing from the transistor a portion of the collector including the coating thereon.

4. A process as set forth in claim 3 further characterized by said semiconductor material being silicon with selected impurities therein, said coating metal being nickel, and said temperature being raised to 1200 degrees centigrade for a period of substantially three minutes.

5. A process as set for the claim 3 further characterized by said coating metal being chosen from the group of silver, gold, copper, nickel, and iron.

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6. A process of transistor manufacture wherein a transistor is fabricated with a substantial thickness of semiconducting material between an exposed outer surface thereof and the nearest transistor junction thereto, and comprising the steps of evaporating a very thin coating of metal upon said exposed outer transistor surface, said metal having a fast diffusion rate in the semiconducting material and establishing energy levels substantially midway between the valence and conducting bands of the semiconducting material, raising the temperature of the transistor and coating thereon to substantially the fusible temperature thereof and maintaining such temperature for a short time, and removing the coating from the transistor whereby the resultant transistor so processed has a very sharply varying collector relationship.

7. A process as set forth in claim 6 further characterized by said metal being gold.

8. An improvement in the process of manufacturing double-diffused silico transistors wherein selected dopants are separately diffused into a silicon wafer to form transistor junctions therein and comprising the steps of plating a very thin layer of metal upon the other side of said wafer from the side on which dopants are diffused and following the establishment of at least one transistor junction in the wafer, said metal being chosen from the group comprising iron, nickel, copper, gold, and silver, heating the wafer concurrently with the diffusion of another dopant therein to a temperature in excess of the eutectic temperature of said metal and silicon for a short period to diffuse a small amount of the material through the wafer, and removing a part of said wafer including the metal layer.

References Cited in the file of this patent

UNITED STATES PATENTS

2,701,326	Pfann	Feb. 11, 1955
2,770,761	Pfann	Nov. 13, 1956
2,774,695	Burton	Dec. 18, 1956
2,827,436	Bemski	Mar. 18, 1958
2,829,075	Pankove	Apr. 1, 1958
2,849,664	Beale	Aug. 26, 1958
2,854,363	Seiler	Sept. 30, 1958
2,860,219	Taft	Nov. 11, 1958
3,013,955	Roberts	Dec. 19, 1961

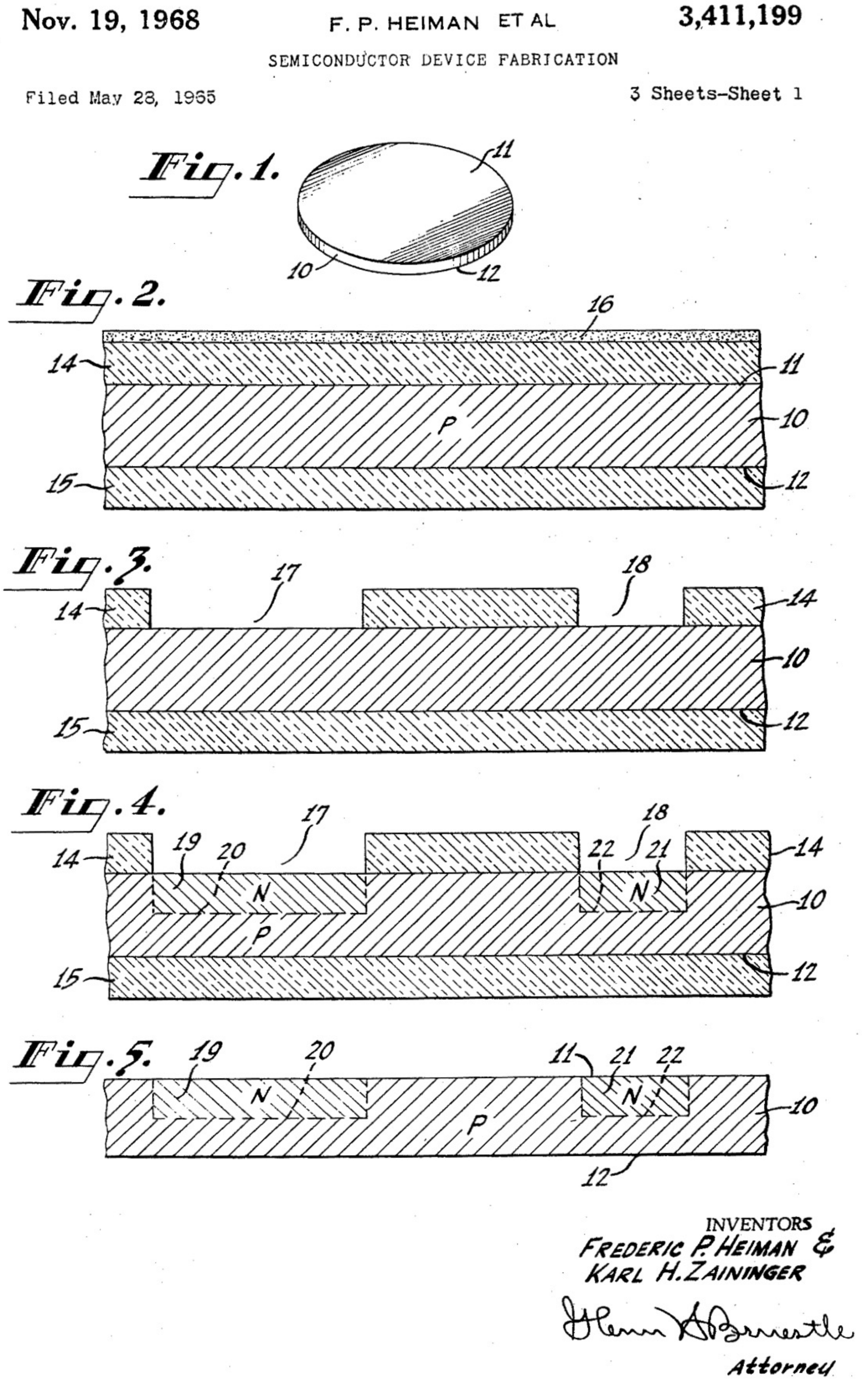
FOREIGN PATENTS

331,017	Switzerland	Aug. 15, 1958

OTHER REFERENCES

Constitution of Binary Alloys, by Hansen, 2nd edition, 1958, McGraw-Hill Book Co., Inc., page 769 and 1040 relied upon.

Figure B.182: Jean Hoerni invented methods of manufacturing silicon transistors.



Nov. 19, 1968 F. P. HEIMAN ET AL 3,411,199

SEMICONDUCTOR DEVICE FABRICATION

Filed May 28, 1965 3 Sheets-Sheet 1

Fig. 1.
11
10
12
Fig. 2.
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Fig. 3.
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Fig. 4.
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Fig. 5.
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11
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22
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P
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KARL H. ZAININGER

Attorney

Figure B.183: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.

Nov. 19, 1968 F. P. HEIMAN ET AL **3,411,199**

SEMICONDUCTOR DEVICE FABRICATION

Filed May 28, 1965 3 Sheets-Sheet 2

Fig. 6.

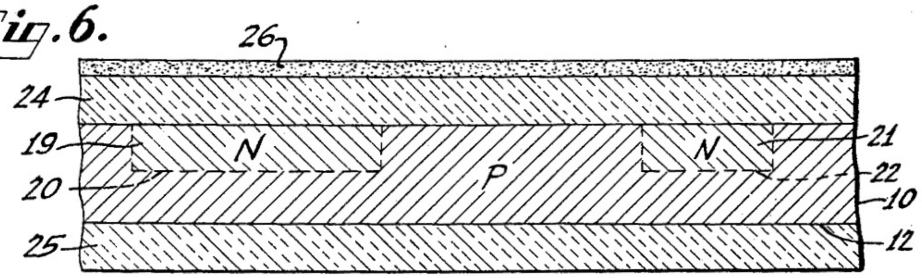
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Fig. 7.

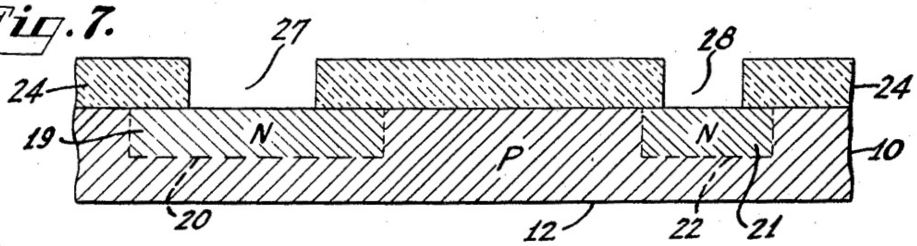
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Fig. 8.

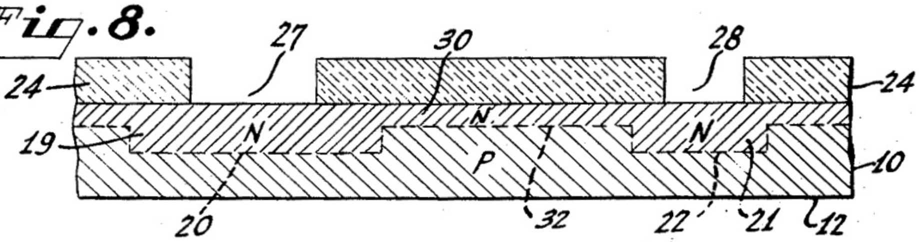
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Fig. 9.

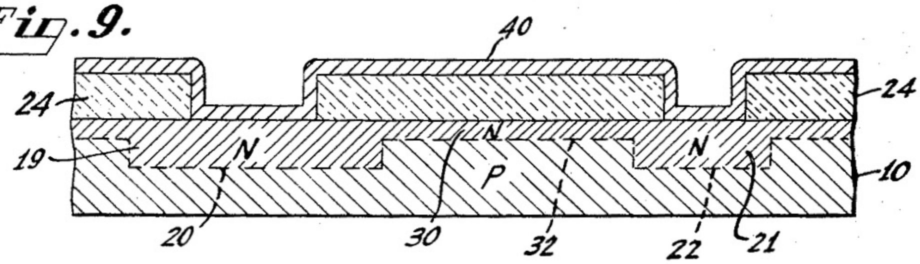
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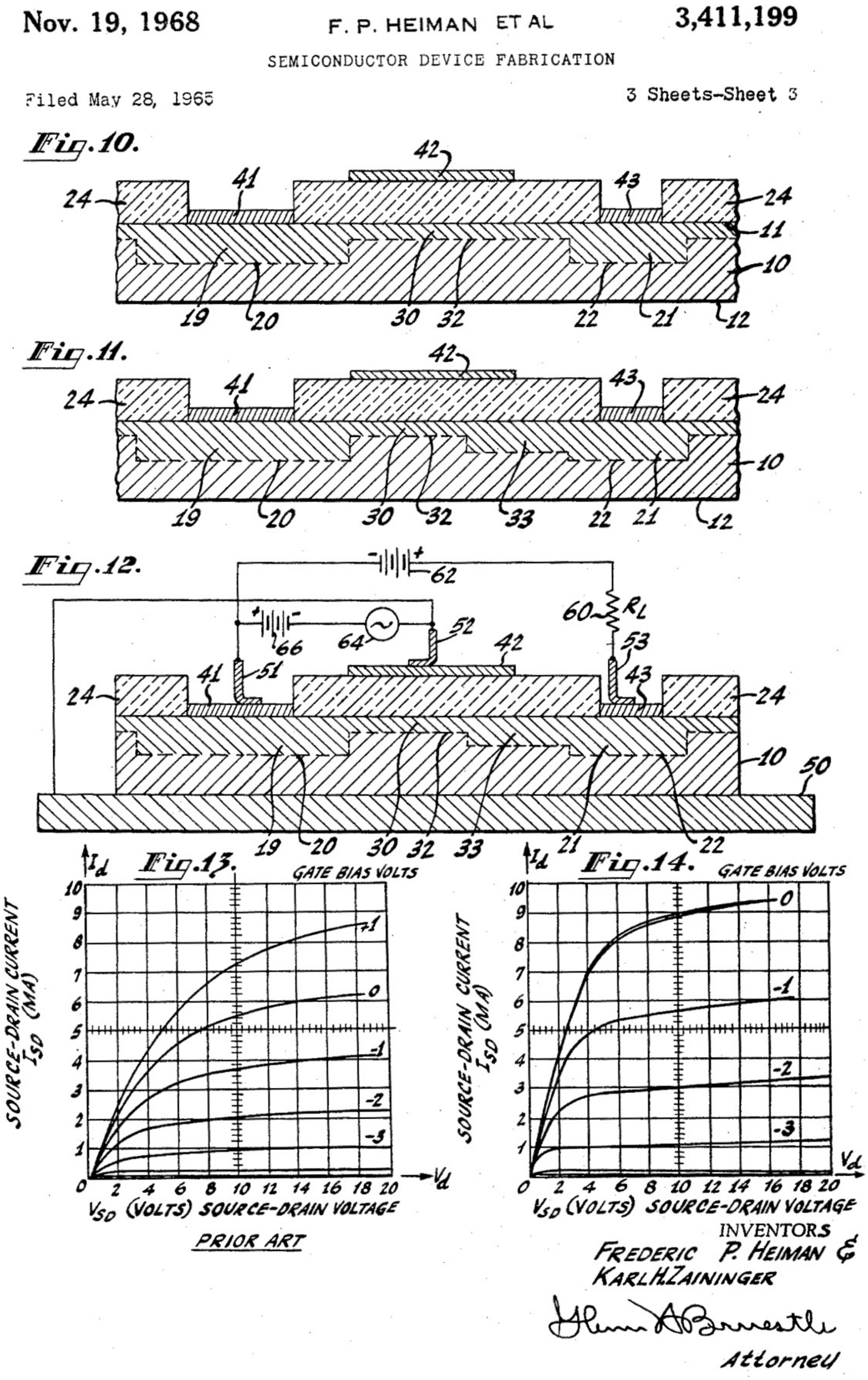
Figure B.184: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.



Nov. 19, 1968 F. P. HEIMAN ET AL 3,411,199

SEMICONDUCTOR DEVICE FABRICATION

Filed May 28, 1965 3 Sheets-Sheet 3

Fig. 10.
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Fig. 11.
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32
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22
21
12
Fig. 12.
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62
60
R_L
+
66
64
52
42
53
41
51
43
24
24
10
50
19
20
30
32
33
21
22
I_d
Fig. 13.
GATE BIAS VOLTS
+1
0
-1
-2
-3
SOURCE-DRAIN CURRENT I_{SD} (MA)
0 1 2 3 4 5 6 7 8 9 10
0 2 4 6 8 10 12 14 16 18 20
V_d
V_{SD} (VOLTS) SOURCE-DRAIN VOLTAGE
PRIOR ART
I_d
Fig. 14.
GATE BIAS VOLTS
0
-1
-2
-3
SOURCE-DRAIN CURRENT I_{SD} (MA)
0 1 2 3 4 5 6 7 8 9 10
0 2 4 6 8 10 12 14 16 18 20
V_d
V_{SD} (VOLTS) SOURCE-DRAIN VOLTAGE

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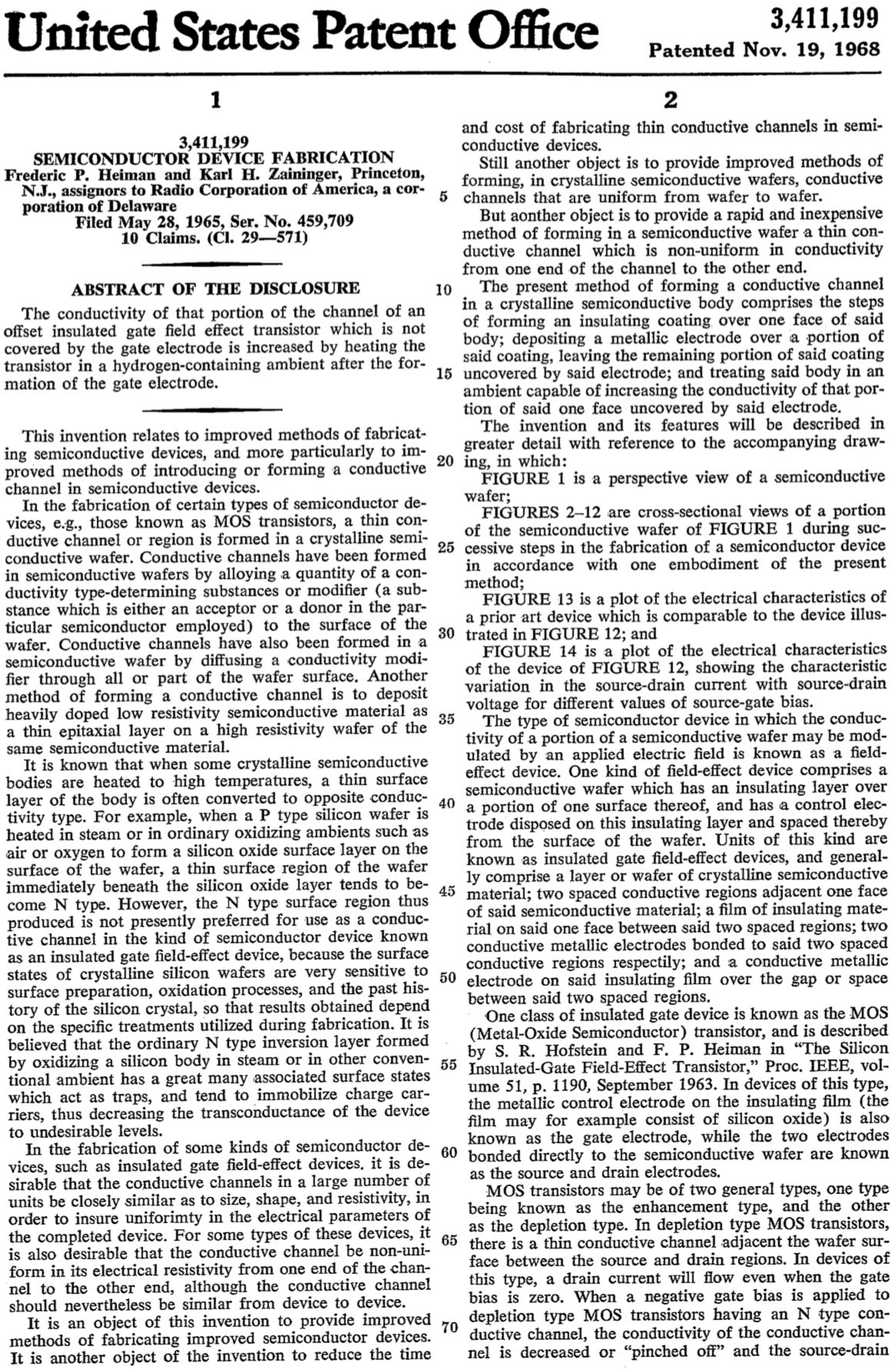
Figure B.185: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.



United States Patent Office

3,411,199
Patented Nov. 19, 1968

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3,411,199
SEMICONDUCTOR DEVICE FABRICATION

Frederic P. Heiman and Karl H. Zaininger, Princeton, N.J., assignors to Radio Corporation of America, a corporation of Delaware

Filed May 28, 1965, Ser. No. 459,709
10 Claims. (Cl. 29—571)

ABSTRACT OF THE DISCLOSURE

The conductivity of that portion of the channel of an offset insulated gate field effect transistor which is not covered by the gate electrode is increased by heating the transistor in a hydrogen-containing ambient after the formation of the gate electrode.

This invention relates to improved methods of fabricating semiconductive devices, and more particularly to improved methods of introducing or forming a conductive channel in semiconductive devices.

In the fabrication of certain types of semiconductor devices, e.g., those known as MOS transistors, a thin conductive channel or region is formed in a crystalline semiconductive wafer. Conductive channels have been formed in semiconductive wafers by alloying a quantity of a conductivity type-determining substances or modifier (a substance which is either an acceptor or a donor in the particular semiconductor employed) to the surface of the wafer. Conductive channels have also been formed in a semiconductive wafer by diffusing a conductivity modifier through all or part of the wafer surface. Another method of forming a conductive channel is to deposit heavily doped low resistivity semiconductive material as a thin epitaxial layer on a high resistivity wafer of the same semiconductive material.

It is known that when some crystalline semiconductive bodies are heated to high temperatures, a thin surface layer of the body is often converted to opposite conductivity type. For example, when a P type silicon wafer is heated in steam or in ordinary oxidizing ambients such as air or oxygen to form a silicon oxide surface layer on the surface of the wafer, a thin surface region of the wafer immediately beneath the silicon oxide layer tends to become N type. However, the N type surface region thus produced is not presently preferred for use as a conductive channel in the kind of semiconductor device known as an insulated gate field-effect device, because the surface states of crystalline silicon wafers are very sensitive to surface preparation, oxidation processes, and the past history of the silicon crystal, so that results obtained depend on the specific treatments utilized during fabrication. It is believed that the ordinary N type inversion layer formed by oxidizing a silicon body in steam or in other conventional ambient has a great many associated surface states which act as traps, and tend to immobilize charge carriers, thus decreasing the transconductance of the device to undesirable levels.

In the fabrication of some kinds of semiconductor devices, such as insulated gate field-effect devices. it is desirable that the conductive channels in a large number of units be closely similar as to size, shape, and resistivity, in order to insure uniforimty in the electrical parameters of the completed device. For some types of these devices, it is also desirable that the conductive channel be non-uniform in its electrical resistivity from one end of the channel to the other end, although the conductive channel should nevertheless be similar from device to device.

It is an object of this invention to provide improved methods of fabricating improved semiconductor devices. It is another object of the invention to reduce the time

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and cost of fabricating thin conductive channels in semiconductive devices.

Still another object is to provide improved methods of forming, in crystalline semiconductive wafers, conductive channels that are uniform from wafer to wafer.

But aonther object is to provide a rapid and inexpensive method of forming in a semiconductive wafer a thin conductive channel which is non-uniform in conductivity from one end of the channel to the other end.

The present method of forming a conductive channel in a crystalline semiconductive body comprises the steps of forming an insulating coating over one face of said body; depositing a metallic electrode over a portion of said coating, leaving the remaining portion of said coating uncovered by said electrode; and treating said body in an ambient capable of increasing the conductivity of that portion of said one face uncovered by said electrode.

The invention and its features will be described in greater detail with reference to the accompanying drawing, in which:

FIGURE 1 is a perspective view of a semiconductive wafer;

FIGURES 2–12 are cross-sectional views of a portion of the semiconductive wafer of FIGURE 1 during successive steps in the fabrication of a semiconductor device in accordance with one embodiment of the present method;

FIGURE 13 is a plot of the electrical characteristics of a prior art device which is comparable to the device illustrated in FIGURE 12; and

FIGURE 14 is a plot of the electrical characteristics of the device of FIGURE 12, showing the characteristic variation in the source-drain current with source-drain voltage for different values of source-gate bias.

The type of semiconductor device in which the conductivity of a portion of a semiconductive wafer may be modulated by an applied electric field is known as a field-effect device. One kind of field-effect device comprises a semiconductive wafer which has an insulating layer over a portion of one surface thereof, and has a control electrode disposed on this insulating layer and spaced thereby from the surface of the wafer. Units of this kind are known as insulated gate field-effect devices, and generally comprise a layer or wafer of crystalline semiconductive material; two spaced conductive regions adjacent one face of said semiconductive material; a film of insulating material on said one face between said two spaced regions; two conductive metallic electrodes bonded to said two spaced conductive regions respectily; and a conductive metallic electrode on said insulating film over the gap or space between said two spaced regions.

One class of insulated gate device is known as the MOS (Metal-Oxide Semiconductor) transistor, and is described by S. R. Hofstein and F. P. Heiman in "The Silicon Insulated-Gate Field-Effect Transistor," Proc. IEEE, volume 51, p. 1190, September 1963. In devices of this type, the metallic control electrode on the insulating film (the film may for example consist of silicon oxide) is also known as the gate electrode, while the two electrodes bonded directly to the semiconductive wafer are known as the source and drain electrodes.

MOS transistors may be of two general types, one type being known as the enhancement type, and the other as the depletion type. In depletion type MOS transistors, there is a thin conductive channel adjacent the wafer surface between the source and drain regions. In devices of this type, a drain current will flow even when the gate bias is zero. When a negative gate bias is applied to depletion type MOS transistors having an N type conductive channel, the conductivity of the conductive channel is decreased or "pinched off" and the source-drain

Figure B.186: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.

current is decreased. When a positive gate bias is applied to these devices, the conductivity of the channel increases, and the source-drain current increases. In depletion type MOS transistors having a P type conductive channel, the applied gate bias must be reversed in polarity to produce the same effect. Thus both positive and negative gate biases are effective in modulating the drain current of depletion type MOS transistors.

In one class of MOS transistors known as offset gate units, the control or gate electrode lies over only a portion of the conductive channel between the source and drain regions of the device. For a description of this type of device, see F. P. Heiman and S. R. Hofstein, "Metal-Oxide-Semiconductor Field-Effect Transistors," Electronics, Nov. 30, 1964, pp. 50–61.

Although the present method will be described in terms of an offset gate depletion type MOS transistor as a specific example, the method may also be applied to the fabrication of other types of semiconductor devices in which it is desired to fabricate a conductive channel in a crystalline semiconductive wafer beneath an insulating layer.

Example I

A crystalline silicon wafer **10** (FIGURE 1) is prepared with two opposing major faces **11** and **12**. The precise size, shape, conductivity type and resistivity of the wafer **10** is not critical. The wafer **10** may be of P type conductivity, or intrinsic, or of N type conductivity. In this example, the wafer **10** is a disc-shaped transverse slice of a monocrystalline P type ingot, and has a resistivity of about 1 to 100 ohm-cm. Suitably, the wafer **10** is about ¾ of an inch in diameter and 6 mils thick. It will be understood that a large number of units are simultaneously fabricated from a wafer of this size. In FIGURES 2–12, only a small portion of the entire semiconductive wafer **10**, and only small portions of the two opposing major faces **11** and **12**, are shown for greater clarity.

A silicon oxide coating is deposited over the surface of the wafer **10** by any convenient method. Since this coating is subsequently removed, its exact thickness is not critical. When the wafer **10** consists of silicon, as in this example, the silicon oxide layer may be formed by heating the wafer in steam for about 30 minutes at about 1050° C. Silicon oxide coatings **14** and **15** (FIGURE 2) are thus grown on major faces **11** and **12** respectively of the wafer. A thin layer **16** of a photoresist is deposited on one oxide coating **14**. The photoresist **16** may, for example, be a bichromated protein such as bichromated gum arabic, or may be a commercially available photoresist.

The photoresist layer **16** is exposed to a suitable light pattern, and developed. Those portions of the photoresist not exposed to light are removed by means of a suitable solvent, thereby exposing portions of silicon oxide layer **14**. The hardened, polymerized portions of the photoresist which remain on silicon oxide layer **14** serve as a mask during the subsequent etching step. The exposed portions of the silicon oxide layer **14** are removed by means of an etchant such as a hydrofluoric acid solution. The polymerized portions of the photoresist are then removed by means of a suitable stripper such as methylene chloride, leaving wafer **10** as in FIGURE 3, with a pair of openings **17** and **18** formed in the silicon oxide layer **14** on the wafer **10**.

The exact size and shape of openings **17** and **18** are not critical; they may be regular shapes such as polygons or circles, or may be irregular in shape. When the source and drain regions of an MOS transistor have the same size and shape, the device is symmetrical, that is, source and drain regions may be interchanged without affecting electrical characteristics of the device. In this example, the openings **17** and **18** are rectangular, but the area of one opening **18** is made very small, for example, about 30 square mils, and is smaller than the area of the other opening **17**. It has been found that improved operation at elevated frequencies is obtained by making the drain area of an MOS transistor very small. The area of the source region does not appreciably affect the high frequency performance of the device, and hence may be made relatively large for greater ease in bonding lead wires.

Wafer **10** is next heated in an ambient containing phosphorus pentoxide vapors for about 10 to 20 minutes at about 1000° C. Phosphorus diffuses into the exposed portions of wafer face **11** to form two phosphorus diffused regions **19** and **21** (FIGURE 4) immediately beneath openings **17** and **18** respectively. Since phosphorus is a donor in silicon, and the wafer **10** is originally of P type conductivity, rectifying barriers or p-n junctions **20** and **22** are formed at the boundaries between the N type phosphorus-diffused regions **19** and **21** respectively and the P type bulk of wafer **10**. Under these conditions, the N type phosphorus-diffused regions **19** and **21** may be about 5000 to 20,000 Angstroms thick, depending on the period of heating and the concentration of the phosphorus pentoxide vapors. In this example, the exposed surface area of region **21** is less than the exposed surface area of region **19**, as the area of opening **18** was less than the area of opening **17**.

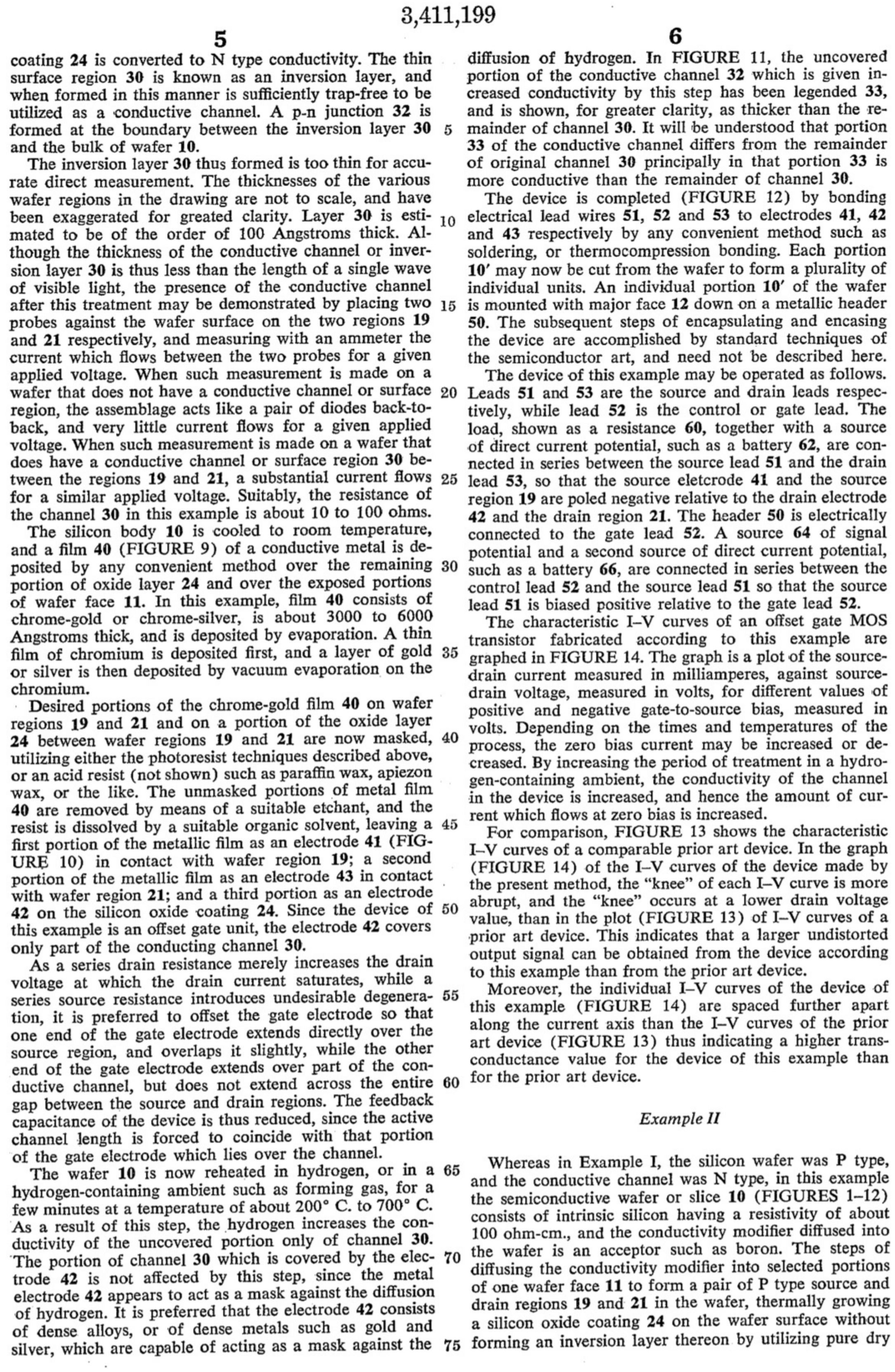
Wafer **10** is now treated in an etchant containing hydrofluoric acid so as to completely remove the oxide layer **15** and the remaining portions of the oxide layer **14**, leaving the wafer as in FIGURE 5.

Wafer **10** is reheated in an ambient of pure dry oxygen for a time and at a temperature sufficient to form a silicon oxide coating or layer thereon. The exact time and temperature of this heating step is not critical. At higher temperatures, a shorter heating time may be utilized. At low temperatures, a longer heating time is required to produce the same coating thickness. In this example, wafer **10** is heated at about 1000° C. for about 3 to 4 hours. Clean new silicon oxide coatings **24** and **25** (FIGURE 6) about 1000 to 3000 Angstroms thick are thus formed on wafer faces **11** and **12** respectively. It has been found that when oxide coatings are formed on silicon wafers in this manner, in the absence of moisture or impurities, the tendency for silicon wafers to develop surface inversion layers is minimized.

A thin layer **26** (FIGURE 6) of photoresist is deposited on silicon oxide coating **24**. The photoresist layer **26** is exposed to a suitable light pattern. Unexposed portions of the photoresist are then removed by any suitable solvent, thereby exposing portions of silicon oxide layer **24**. The exposed portions of silicon oxide layer **24**, as well as all of silicon oxide layer **25**, are then removed by means of a hydrofluoric acid solution. The remaining portions of the photoresist are then removed with a suitable stripper, leaving the wafer as in FIGURE 7, with contact openings **27** and **28** extending through the oxide coating **24** to the face **11** of wafer **10**. The exact size and shape of contact openings **27** and **28** is not critical, but openings **27** and **28** are entirely within the surface boundary of the phosphorus-diffused N type regions **19** and **21** respectively.

Wafer **10** is now heated in a reducing ambient such as hydrogen or a mixture of hydrogen and a non-oxidizing gas such as argon, nitrogen, or the like. Mixtures of nitrogen and a few volume percent hydrogen are useful for this purpose, and are known as forming gas. A suitable forming gas consists of 90 volumes of nitrogen and 10 volumes of hydrogen. The heating step is preferably conducted at temperatures of about 200° C. to 700° C. At about 700° C., heating for less than a minute is sufficient. If the heating temperature is decreased, the time of heating is increased. During this step, a thin surface region **30** (FIGURE 8) of wafer **10** beneath the silicon oxide

Figure B.187: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.



coating **24** is converted to N type conductivity. The thin surface region **30** is known as an inversion layer, and when formed in this manner is sufficiently trap-free to be utilized as a conductive channel. A p-n junction **32** is formed at the boundary between the inversion layer **30** and the bulk of wafer **10**.

The inversion layer **30** thus formed is too thin for accurate direct measurement. The thicknesses of the various wafer regions in the drawing are not to scale, and have been exaggerated for greated clarity. Layer **30** is estimated to be of the order of 100 Angstroms thick. Although the thickness of the conductive channel or inversion layer **30** is thus less than the length of a single wave of visible light, the presence of the conductive channel after this treatment may be demonstrated by placing two probes against the wafer surface on the two regions **19** and **21** respectively, and measuring with an ammeter the current which flows between the two probes for a given applied voltage. When such measurement is made on a wafer that does not have a conductive channel or surface region, the assemblage acts like a pair of diodes back-to-back, and very little current flows for a given applied voltage. When such measurement is made on a wafer that does have a conductive channel or surface region **30** between the regions **19** and **21**, a substantial current flows for a similar applied voltage. Suitably, the resistance of the channel **30** in this example is about 10 to 100 ohms.

The silicon body **10** is cooled to room temperature, and a film **40** (FIGURE 9) of a conductive metal is deposited by any convenient method over the remaining portion of oxide layer **24** and over the exposed portions of wafer face **11**. In this example, film **40** consists of chrome-gold or chrome-silver, is about 3000 to 6000 Angstroms thick, and is deposited by evaporation. A thin film of chromium is deposited first, and a layer of gold or silver is then deposited by vacuum evaporation on the chromium.

Desired portions of the chrome-gold film **40** on wafer regions **19** and **21** and on a portion of the oxide layer **24** between wafer regions **19** and **21** are now masked, utilizing either the photoresist techniques described above, or an acid resist (not shown) such as paraffin wax, apiezon wax, or the like. The unmasked portions of metal film **40** are removed by means of a suitable etchant, and the resist is dissolved by a suitable organic solvent, leaving a first portion of the metallic film as an electrode **41** (FIGURE 10) in contact with wafer region **19**; a second portion of the metallic film as an electrode **43** in contact with wafer region **21**; and a third portion as an electrode **42** on the silicon oxide coating **24**. Since the device of this example is an offset gate unit, the electrode **42** covers only part of the conducting channel **30**.

As a series drain resistance merely increases the drain voltage at which the drain current saturates, while a series source resistance introduces undesirable degeneration, it is preferred to offset the gate electrode so that one end of the gate electrode extends directly over the source region, and overlaps it slightly, while the other end of the gate electrode extends over part of the conductive channel, but does not extend across the entire gap between the source and drain regions. The feedback capacitance of the device is thus reduced, since the active channel length is forced to coincide with that portion of the gate electrode which lies over the channel.

The wafer **10** is now reheated in hydrogen, or in a hydrogen-containing ambient such as forming gas, for a few minutes at a temperature of about 200° C. to 700° C. As a result of this step, the hydrogen increases the conductivity of the uncovered portion only of channel **30**. The portion of channel **30** which is covered by the electrode **42** is not affected by this step, since the metal electrode **42** appears to act as a mask against the diffusion of hydrogen. It is preferred that the electrode **42** consists of dense alloys, or of dense metals such as gold and silver, which are capable of acting as a mask against the diffusion of hydrogen. In FIGURE 11, the uncovered portion of the conductive channel **32** which is given increased conductivity by this step has been legended **33**, and is shown, for greater clarity, as thicker than the remainder of channel **30**. It will be understood that portion **33** of the conductive channel differs from the remainder of original channel **30** principally in that portion **33** is more conductive than the remainder of channel **30**.

The device is completed (FIGURE 12) by bonding electrical lead wires **51**, **52** and **53** to electrodes **41**, **42** and **43** respectively by any convenient method such as soldering, or thermocompression bonding. Each portion **10′** may now be cut from the wafer to form a plurality of individual units. An individual portion **10′** of the wafer is mounted with major face **12** down on a metallic header **50**. The subsequent steps of encapsulating and encasing the device are accomplished by standard techniques of the semiconductor art, and need not be described here.

The device of this example may be operated as follows. Leads **51** and **53** are the source and drain leads respectively, while lead **52** is the control or gate lead. The load, shown as a resistance **60**, together with a source of direct current potential, such as a battery **62**, are connected in series between the source lead **51** and the drain lead **53**, so that the source eletcrode **41** and the source region **19** are poled negative relative to the drain electrode **42** and the drain region **21**. The header **50** is electrically connected to the gate lead **52**. A source **64** of signal potential and a second source of direct current potential, such as a battery **66**, are connected in series between the control lead **52** and the source lead **51** so that the source lead **51** is biased positive relative to the gate lead **52**.

The characteristic I–V curves of an offset gate MOS transistor fabricated according to this example are graphed in FIGURE 14. The graph is a plot of the source-drain current measured in milliamperes, against source-drain voltage, measured in volts, for different values of positive and negative gate-to-source bias, measured in volts. Depending on the times and temperatures of the process, the zero bias current may be increased or decreased. By increasing the period of treatment in a hydrogen-containing ambient, the conductivity of the channel in the device is increased, and hence the amount of current which flows at zero bias is increased.

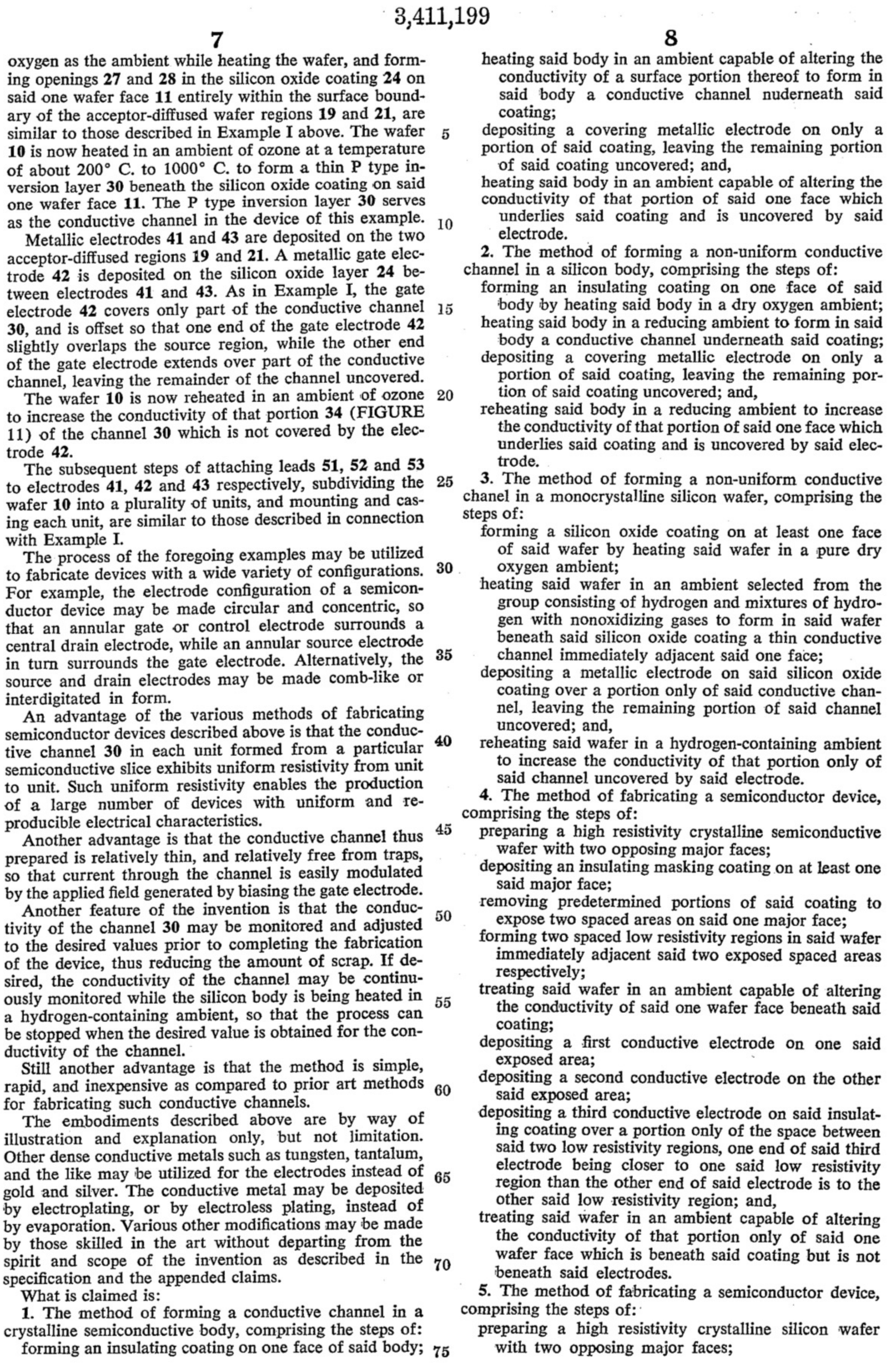
For comparison, FIGURE 13 shows the characteristic I–V curves of a comparable prior art device. In the graph (FIGURE 14) of the I–V curves of the device made by the present method, the "knee" of each I–V curve is more abrupt, and the "knee" occurs at a lower drain voltage value, than in the plot (FIGURE 13) of I–V curves of a prior art device. This indicates that a larger undistorted output signal can be obtained from the device according to this example than from the prior art device.

Moreover, the individual I–V curves of the device of this example (FIGURE 14) are spaced further apart along the current axis than the I–V curves of the prior art device (FIGURE 13) thus indicating a higher transconductance value for the device of this example than for the prior art device.

Example II

Whereas in Example I, the silicon wafer was P type, and the conductive channel was N type, in this example the semiconductive wafer or slice **10** (FIGURES 1–12) consists of intrinsic silicon having a resistivity of about 100 ohm-cm., and the conductivity modifier diffused into the wafer is an acceptor such as boron. The steps of diffusing the conductivity modifier into selected portions of one wafer face **11** to form a pair of P type source and drain regions **19** and **21** in the wafer, thermally growing a silicon oxide coating **24** on the wafer surface without forming an inversion layer thereon by utilizing pure dry

Figure B.188: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.



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oxygen as the ambient while heating the wafer, and forming openings **27** and **28** in the silicon oxide coating **24** on said one wafer face **11** entirely within the surface boundary of the acceptor-diffused wafer regions **19** and **21**, are similar to those described in Example I above. The wafer **10** is now heated in an ambient of ozone at a temperature of about 200° C. to 1000° C. to form a thin P type inversion layer **30** beneath the silicon oxide coating on said one wafer face **11**. The P type inversion layer **30** serves as the conductive channel in the device of this example.

Metallic electrodes **41** and **43** are deposited on the two acceptor-diffused regions **19** and **21**. A metallic gate electrode **42** is deposited on the silicon oxide layer **24** between electrodes **41** and **43**. As in Example I, the gate electrode **42** covers only part of the conductive channel **30**, and is offset so that one end of the gate electrode **42** slightly overlaps the source region, while the other end of the gate electrode extends over part of the conductive channel, leaving the remainder of the channel uncovered.

The wafer **10** is now reheated in an ambient of ozone to increase the conductivity of that portion **34** (FIGURE 11) of the channel **30** which is not covered by the electrode **42**.

The subsequent steps of attaching leads **51, 52** and **53** to electrodes **41, 42** and **43** respectively, subdividing the wafer **10** into a plurality of units, and mounting and casing each unit, are similar to those described in connection with Example I.

The process of the foregoing examples may be utilized to fabricate devices with a wide variety of configurations. For example, the electrode configuration of a semiconductor device may be made circular and concentric, so that an annular gate or control electrode surrounds a central drain electrode, while an annular source electrode in turn surrounds the gate electrode. Alternatively, the source and drain electrodes may be made comb-like or interdigitated in form.

An advantage of the various methods of fabricating semiconductor devices described above is that the conductive channel **30** in each unit formed from a particular semiconductive slice exhibits uniform resistivity from unit to unit. Such uniform resistivity enables the production of a large number of devices with uniform and reproducible electrical characteristics.

Another advantage is that the conductive channel thus prepared is relatively thin, and relatively free from traps, so that current through the channel is easily modulated by the applied field generated by biasing the gate electrode.

Another feature of the invention is that the conductivity of the channel **30** may be monitored and adjusted to the desired values prior to completing the fabrication of the device, thus reducing the amount of scrap. If desired, the conductivity of the channel may be continuously monitored while the silicon body is being heated in a hydrogen-containing ambient, so that the process can be stopped when the desired value is obtained for the conductivity of the channel.

Still another advantage is that the method is simple, rapid, and inexpensive as compared to prior art methods for fabricating such conductive channels.

The embodiments described above are by way of illustration and explanation only, but not limitation. Other dense conductive metals such as tungsten, tantalum, and the like may be utilized for the electrodes instead of gold and silver. The conductive metal may be deposited by electroplating, or by electroless plating, instead of by evaporation. Various other modifications may be made by those skilled in the art without departing from the spirit and scope of the invention as described in the specification and the appended claims.

What is claimed is:

1. The method of forming a conductive channel in a crystalline semiconductive body, comprising the steps of:

forming an insulating coating on one face of said body;

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heating said body in an ambient capable of altering the conductivity of a surface portion thereof to form in said body a conductive channel nuderneath said coating;

depositing a covering metallic electrode on only a portion of said coating, leaving the remaining portion of said coating uncovered; and,

heating said body in an ambient capable of altering the conductivity of that portion of said one face which underlies said coating and is uncovered by said electrode.

2. The method of forming a non-uniform conductive channel in a silicon body, comprising the steps of:

forming an insulating coating on one face of said body by heating said body in a dry oxygen ambient;

heating said body in a reducing ambient to form in said body a conductive channel underneath said coating;

depositing a covering metallic electrode on only a portion of said coating, leaving the remaining portion of said coating uncovered; and,

reheating said body in a reducing ambient to increase the conductivity of that portion of said one face which underlies said coating and is uncovered by said electrode.

3. The method of forming a non-uniform conductive chanel in a monocrystalline silicon wafer, comprising the steps of:

forming a silicon oxide coating on at least one face of said wafer by heating said wafer in a pure dry oxygen ambient;

heating said wafer in an ambient selected from the group consisting of hydrogen and mixtures of hydrogen with nonoxidizing gases to form in said wafer beneath said silicon oxide coating a thin conductive channel immediately adjacent said one face;

depositing a metallic electrode on said silicon oxide coating over a portion only of said conductive channel, leaving the remaining portion of said channel uncovered; and,

reheating said wafer in a hydrogen-containing ambient to increase the conductivity of that portion only of said channel uncovered by said electrode.

4. The method of fabricating a semiconductor device, comprising the steps of:

preparing a high resistivity crystalline semiconductive wafer with two opposing major faces;

depositing an insulating masking coating on at least one said major face;

removing predetermined portions of said coating to expose two spaced areas on said one major face;

forming two spaced low resistivity regions in said wafer immediately adjacent said two exposed spaced areas respectively;

treating said wafer in an ambient capable of altering the conductivity of said one wafer face beneath said coating;

depositing a first conductive electrode on one said exposed area;

depositing a second conductive electrode on the other said exposed area;

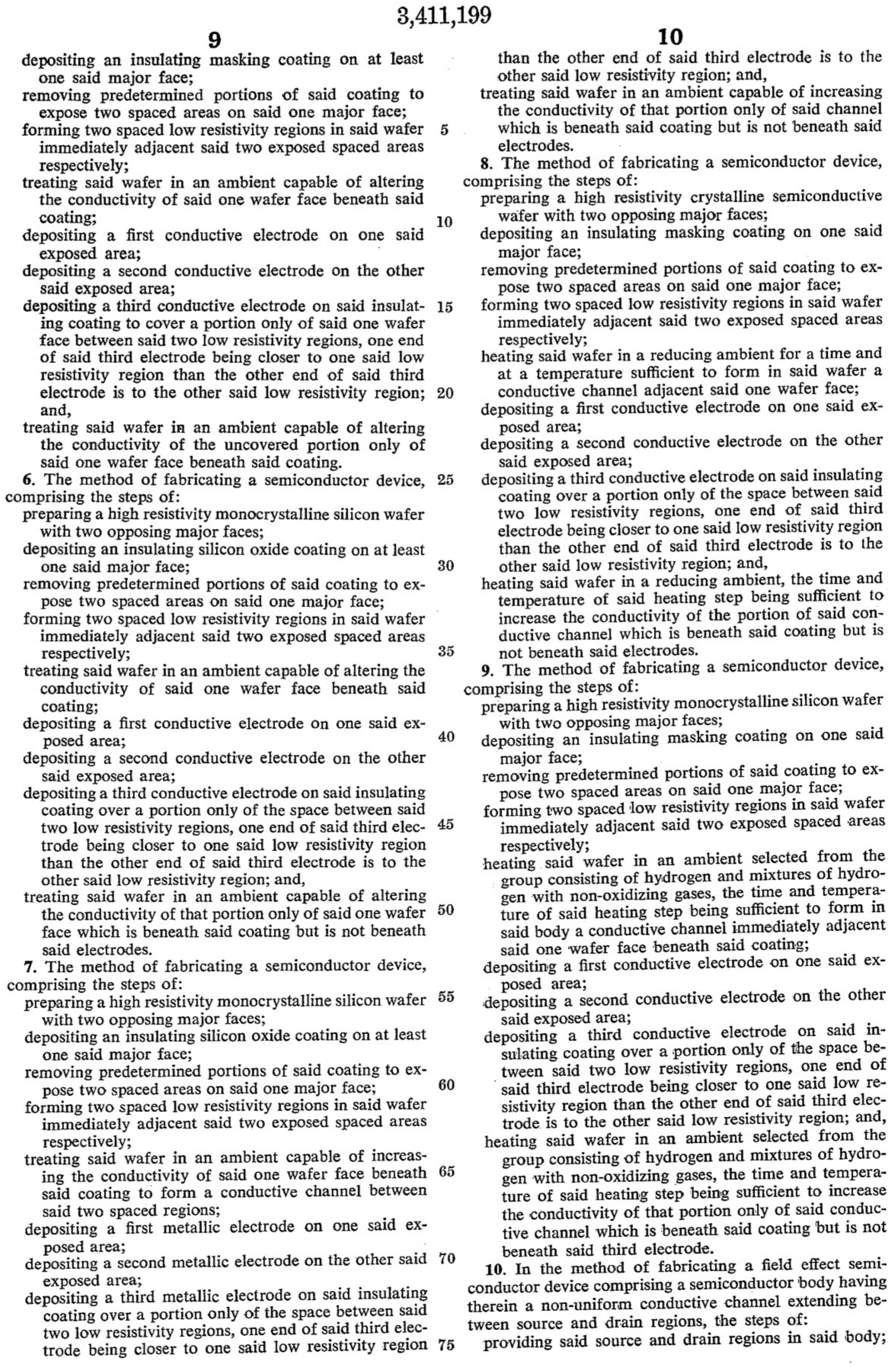
depositing a third conductive electrode on said insulating coating over a portion only of the space between said two low resistivity regions, one end of said third electrode being closer to one said low resistivity region than the other end of said electrode is to the other said low resistivity region; and,

treating said wafer in an ambient capable of altering the conductivity of that portion only of said one wafer face which is beneath said coating but is not beneath said electrodes.

5. The method of fabricating a semiconductor device, comprising the steps of:

preparing a high resistivity crystalline silicon wafer with two opposing major faces;

Figure B.189: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.



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depositing an insulating masking coating on at least one said major face;

removing predetermined portions of said coating to expose two spaced areas on said one major face;

forming two spaced low resistivity regions in said wafer immediately adjacent said two exposed spaced areas respectively;

treating said wafer in an ambient capable of altering the conductivity of said one wafer face beneath said coating;

depositing a first conductive electrode on one said exposed area;

depositing a second conductive electrode on the other said exposed area;

depositing a third conductive electrode on said insulating coating to cover a portion only of said one wafer face between said two low resistivity regions, one end of said third electrode being closer to one said low resistivity region than the other end of said third electrode is to the other said low resistivity region; and,

treating said wafer in an ambient capable of altering the conductivity of the uncovered portion only of said one wafer face beneath said coating.

6. The method of fabricating a semiconductor device, comprising the steps of:

preparing a high resistivity monocrystalline silicon wafer with two opposing major faces;

depositing an insulating silicon oxide coating on at least one said major face;

removing predetermined portions of said coating to expose two spaced areas on said one major face;

forming two spaced low resistivity regions in said wafer immediately adjacent said two exposed spaced areas respectively;

treating said wafer in an ambient capable of altering the conductivity of said one wafer face beneath said coating;

depositing a first conductive electrode on one said exposed area;

depositing a second conductive electrode on the other said exposed area;

depositing a third conductive electrode on said insulating coating over a portion only of the space between said two low resistivity regions, one end of said third electrode being closer to one said low resistivity region than the other end of said third electrode is to the other said low resistivity region; and,

treating said wafer in an ambient capable of altering the conductivity of that portion only of said one wafer face which is beneath said coating but is not beneath said electrodes.

7. The method of fabricating a semiconductor device, comprising the steps of:

preparing a high resistivity monocrystalline silicon wafer with two opposing major faces;

depositing an insulating silicon oxide coating on at least one said major face;

removing predetermined portions of said coating to expose two spaced areas on said one major face;

forming two spaced low resistivity regions in said wafer immediately adjacent said two exposed spaced areas respectively;

treating said wafer in an ambient capable of increasing the conductivity of said one wafer face beneath said coating to form a conductive channel between said two spaced regions;

depositing a first metallic electrode on one said exposed area;

depositing a second metallic electrode on the other said exposed area;

depositing a third metallic electrode on said insulating coating over a portion only of the space between said two low resistivity regions, one end of said third electrode being closer to one said low resistivity region

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than the other end of said third electrode is to the other said low resistivity region; and,

treating said wafer in an ambient capable of increasing the conductivity of that portion only of said channel which is beneath said coating but is not beneath said electrodes.

8. The method of fabricating a semiconductor device, comprising the steps of:

preparing a high resistivity crystalline semiconductive wafer with two opposing major faces;

depositing an insulating masking coating on one said major face;

removing predetermined portions of said coating to expose two spaced areas on said one major face;

forming two spaced low resistivity regions in said wafer immediately adjacent said two exposed spaced areas respectively;

heating said wafer in a reducing ambient for a time and at a temperature sufficient to form in said wafer a conductive channel adjacent said one wafer face;

depositing a first conductive electrode on one said exposed area;

depositing a second conductive electrode on the other said exposed area;

depositing a third conductive electrode on said insulating coating over a portion only of the space between said two low resistivity regions, one end of said third electrode being closer to one said low resistivity region than the other end of said third electrode is to the other said low resistivity region; and,

heating said wafer in a reducing ambient, the time and temperature of said heating step being sufficient to increase the conductivity of the portion of said conductive channel which is beneath said coating but is not beneath said electrodes.

9. The method of fabricating a semiconductor device, comprising the steps of:

preparing a high resistivity monocrystalline silicon wafer with two opposing major faces;

depositing an insulating masking coating on one said major face;

removing predetermined portions of said coating to expose two spaced areas on said one major face;

forming two spaced low resistivity regions in said wafer immediately adjacent said two exposed spaced areas respectively;

heating said wafer in an ambient selected from the group consisting of hydrogen and mixtures of hydrogen with non-oxidizing gases, the time and temperature of said heating step being sufficient to form in said body a conductive channel immediately adjacent said one wafer face beneath said coating;

depositing a first conductive electrode on one said exposed area;

depositing a second conductive electrode on the other said exposed area;

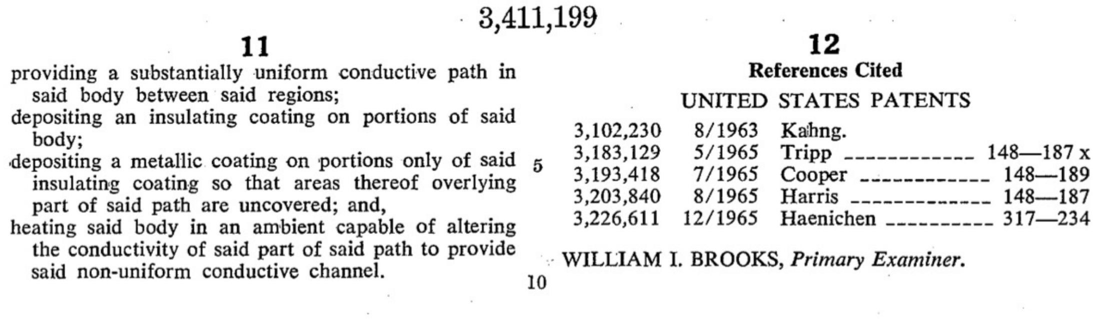
depositing a third conductive electrode on said insulating coating over a portion only of the space between said two low resistivity regions, one end of said third electrode being closer to one said low resistivity region than the other end of said third electrode is to the other said low resistivity region; and,

heating said wafer in an ambient selected from the group consisting of hydrogen and mixtures of hydrogen with non-oxidizing gases, the time and temperature of said heating step being sufficient to increase the conductivity of that portion only of said conductive channel which is beneath said coating but is not beneath said third electrode.

10. In the method of fabricating a field effect semiconductor device comprising a semiconductor body having therein a non-uniform conductive channel extending between source and drain regions, the steps of:

providing said source and drain regions in said body;

Figure B.190: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.



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providing a substantially uniform conductive path in said body between said regions;

depositing an insulating coating on portions of said body;

depositing a metallic coating on portions only of said insulating coating so that areas thereof overlying part of said path are uncovered; and,

heating said body in an ambient capable of altering the conductivity of said part of said path to provide said non-uniform conductive channel.

12

References Cited

UNITED STATES PATENTS

3,102,230	8/1963	Kahng.	
3,183,129	5/1965	Tripp	148—187 x
3,193,418	7/1965	Cooper	148—189
3,203,840	8/1965	Harris	148—187
3,226,611	12/1965	Haenichen	317—234

WILLIAM I. BROOKS, *Primary Examiner.*

Figure B.191: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.

Jan. 19, 1971 A. WAXMAN ET AL **3,556,966**

PLASMA ANODIZING ALUMINUM COATINGS ON A SEMICONDUCTOR

Filed Jan. 19, 1968 3 Sheets-Sheet 1

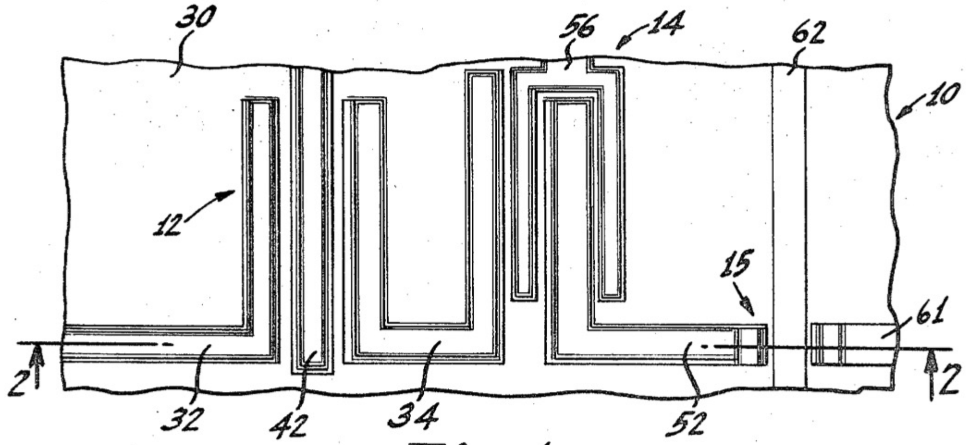
30
56
14
62
10
12
15
61
2
2
32
42
34
52

Fig. 1.

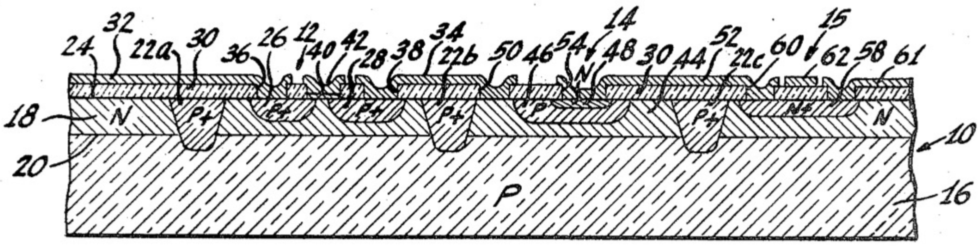
24
32
22a
30
36
26
12
40
42
28
38
34
22b
50
46
54
14
48
30
44
52
22c
60
15
62
58
61
18
N
P+
P+
P+
P+
P
N
P+
N+
N
10
20
P
16

Fig. 2.

Inventors:
ALBERT WAXMAN &
KARL H. ZAININGER

BY Robert V. Williams
Attorney

Figure B.192: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.

Jan. 19, 1971 A. WAXMAN ET AL **3,556,966**

PLASMA ANODIZING ALUMINUM COATINGS ON A SEMICONDUCTOR

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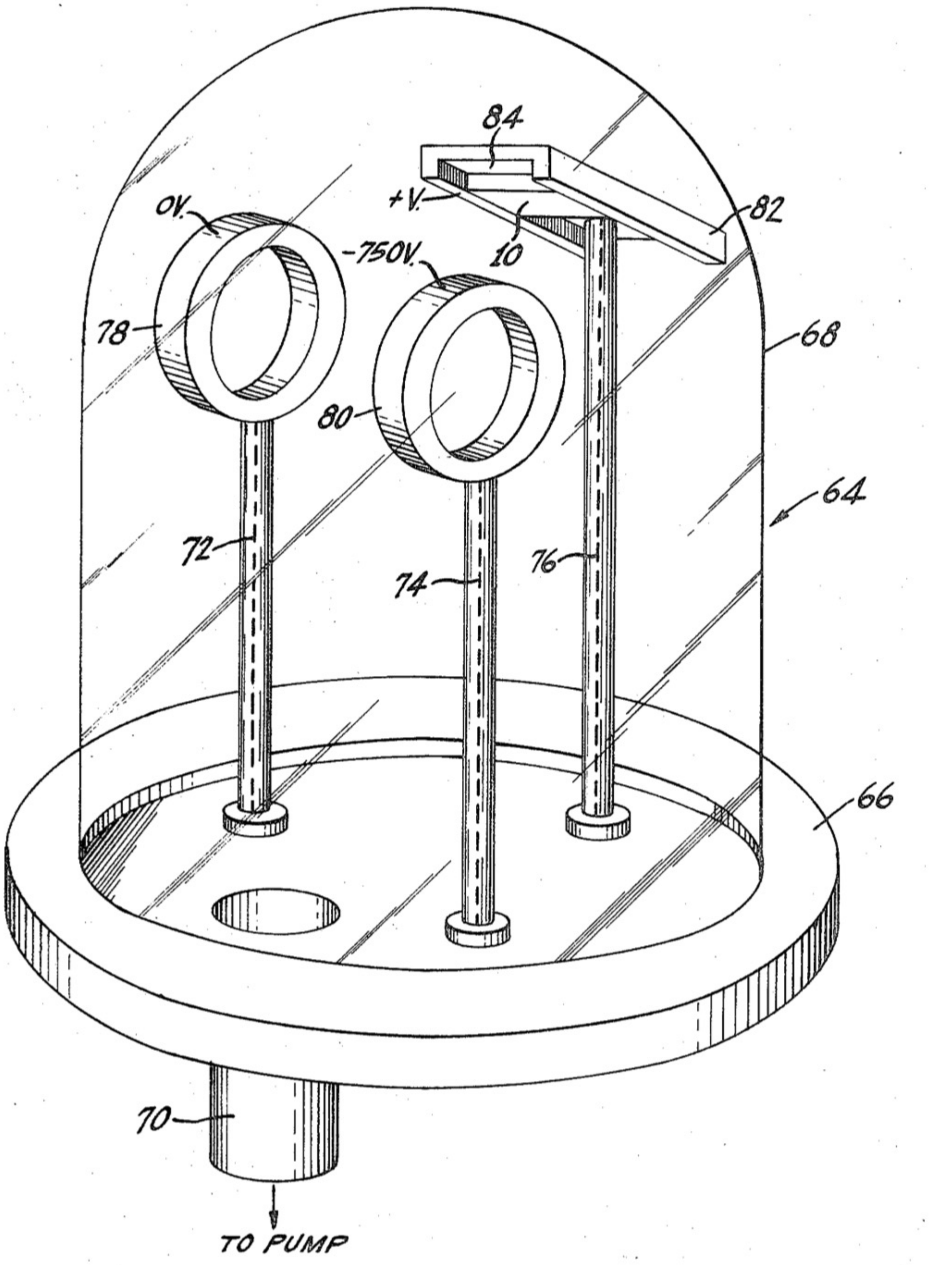
84
+V.
82
0V.
-750V.
10
78
68
80
64
72
74
76
66
70
TO PUMP

Fig. 3.

Inventors:
ALBERT WAXMAN &
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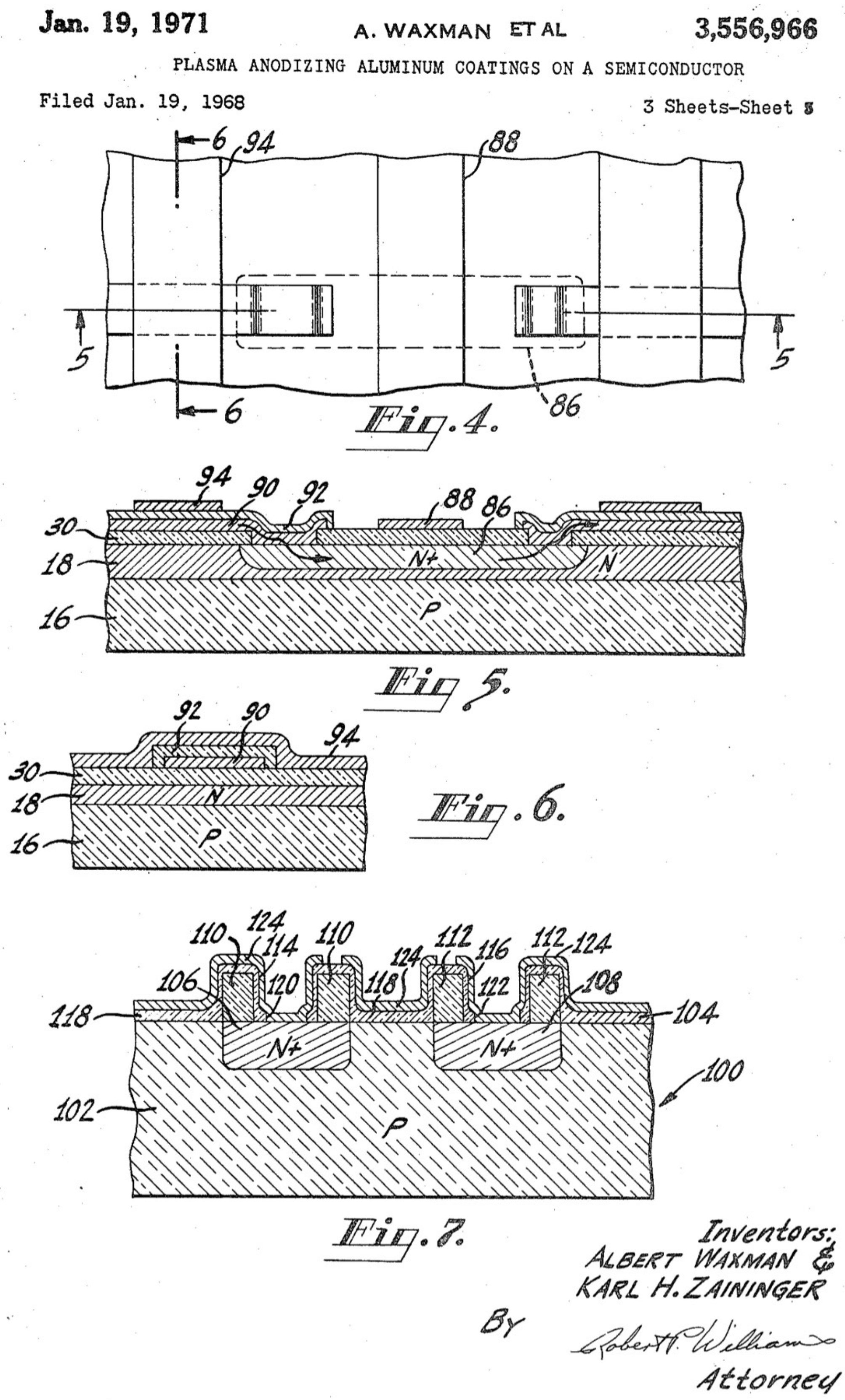
By Robert H. Williams
Attorney

Figure B.193: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.



Jan. 19, 1971 A. WAXMAN ET AL 3,556,966

PLASMA ANODIZING ALUMINUM COATINGS ON A SEMICONDUCTOR

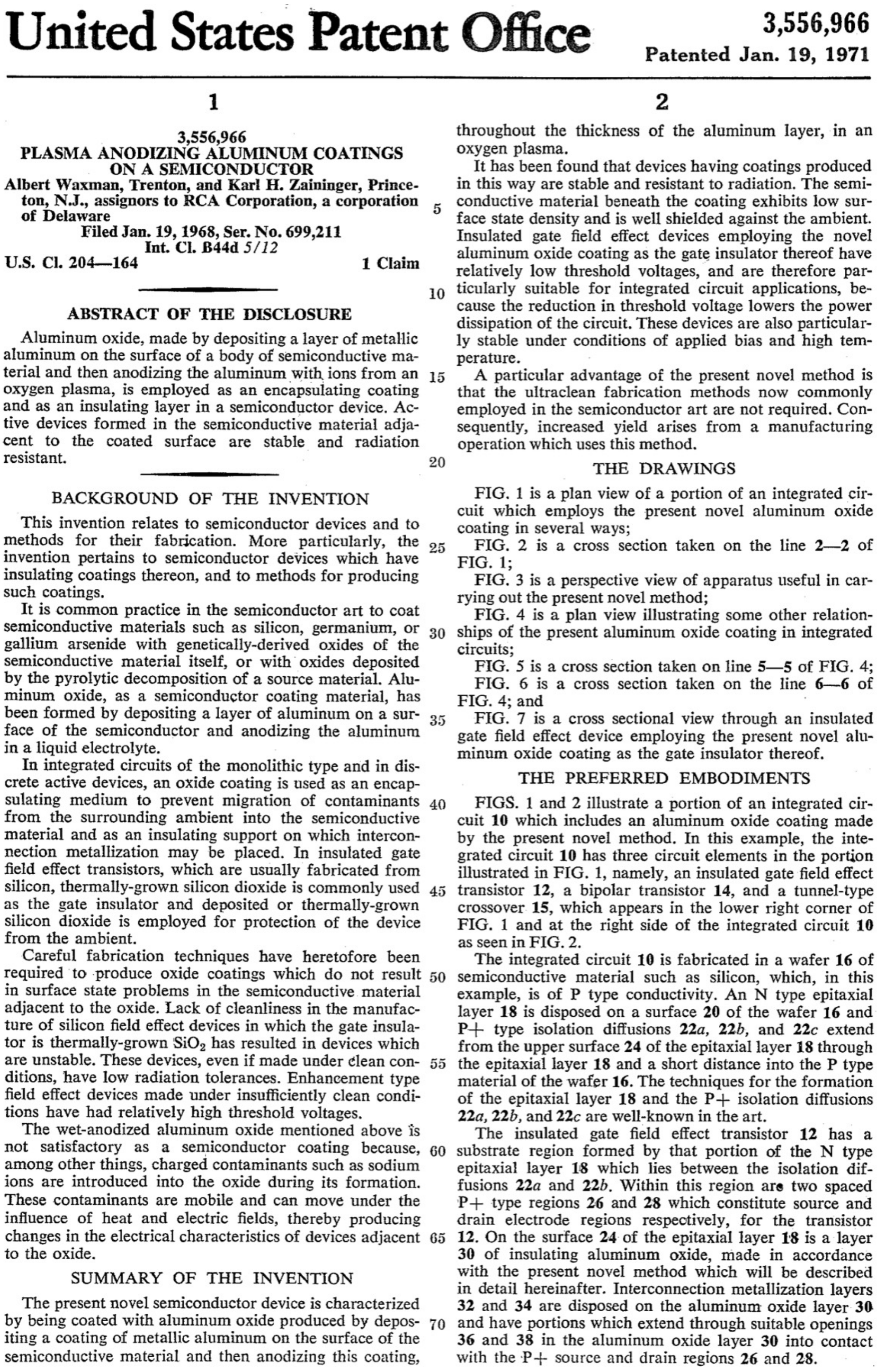
Filed Jan. 19, 1968 3 Sheets-Sheet 3

6
94
88
5
5
6
86
Fig. 4.
94
90
92
88
86
30
18
N+
N
16
P
Fig. 5.
92
90
94
30
18
N
16
P
Fig. 6.
110
124
114
110
124
112
116
112
124
106
120
118
122
108
118
104
N+
N+
100
102
P
Fig. 7.

Inventors:
ALBERT WAXMAN &
KARL H. ZAININGER

By Robert P. Williams
Attorney

Figure B.194: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.



United States Patent Office

3,556,966
Patented Jan. 19, 1971

3,556,966

PLASMA ANODIZING ALUMINUM COATINGS ON A SEMICONDUCTOR

Albert Waxman, Trenton, and Karl H. Zaininger, Princeton, N.J., assignors to RCA Corporation, a corporation of Delaware

Filed Jan. 19, 1968, Ser. No. 699,211
Int. Cl. B44d *5/12*
U.S. Cl. 204—164 **1 Claim**

ABSTRACT OF THE DISCLOSURE

Aluminum oxide, made by depositing a layer of metallic aluminum on the surface of a body of semiconductive material and then anodizing the aluminum with ions from an oxygen plasma, is employed as an encapsulating coating and as an insulating layer in a semiconductor device. Active devices formed in the semiconductive material adjacent to the coated surface are stable and radiation resistant.

BACKGROUND OF THE INVENTION

This invention relates to semiconductor devices and to methods for their fabrication. More particularly, the invention pertains to semiconductor devices which have insulating coatings thereon, and to methods for producing such coatings.

It is common practice in the semiconductor art to coat semiconductive materials such as silicon, germanium, or gallium arsenide with genetically-derived oxides of the semiconductive material itself, or with oxides deposited by the pyrolytic decomposition of a source material. Aluminum oxide, as a semiconductor coating material, has been formed by depositing a layer of aluminum on a surface of the semiconductor and anodizing the aluminum in a liquid electrolyte.

In integrated circuits of the monolithic type and in discrete active devices, an oxide coating is used as an encapsulating medium to prevent migration of contaminants from the surrounding ambient into the semiconductive material and as an insulating support on which interconnection metallization may be placed. In insulated gate field effect transistors, which are usually fabricated from silicon, thermally-grown silicon dioxide is commonly used as the gate insulator and deposited or thermally-grown silicon dioxide is employed for protection of the device from the ambient.

Careful fabrication techniques have heretofore been required to produce oxide coatings which do not result in surface state problems in the semiconductive material adjacent to the oxide. Lack of cleanliness in the manufacture of silicon field effect devices in which the gate insulator is thermally-grown SiO_2 has resulted in devices which are unstable. These devices, even if made under clean conditions, have low radiation tolerances. Enhancement type field effect devices made under insufficiently clean conditions have had relatively high threshold voltages.

The wet-anodized aluminum oxide mentioned above is not satisfactory as a semiconductor coating because, among other things, charged contaminants such as sodium ions are introduced into the oxide during its formation. These contaminants are mobile and can move under the influence of heat and electric fields, thereby producing changes in the electrical characteristics of devices adjacent to the oxide.

SUMMARY OF THE INVENTION

The present novel semiconductor device is characterized by being coated with aluminum oxide produced by depositing a coating of metallic aluminum on the surface of the semiconductive material and then anodizing this coating, throughout the thickness of the aluminum layer, in an oxygen plasma.

It has been found that devices having coatings produced in this way are stable and resistant to radiation. The semiconductive material beneath the coating exhibits low surface state density and is well shielded against the ambient. Insulated gate field effect devices employing the novel aluminum oxide coating as the gate insulator thereof have relatively low threshold voltages, and are therefore particularly suitable for integrated circuit applications, because the reduction in threshold voltage lowers the power dissipation of the circuit. These devices are also particularly stable under conditions of applied bias and high temperature.

A particular advantage of the present novel method is that the ultraclean fabrication methods now commonly employed in the semiconductor art are not required. Consequently, increased yield arises from a manufacturing operation which uses this method.

THE DRAWINGS

FIG. 1 is a plan view of a portion of an integrated circuit which employs the present novel aluminum oxide coating in several ways;

FIG. 2 is a cross section taken on the line **2—2** of FIG. 1;

FIG. 3 is a perspective view of apparatus useful in carrying out the present novel method;

FIG. 4 is a plan view illustrating some other relationships of the present aluminum oxide coating in integrated circuits;

FIG. 5 is a cross section taken on line **5—5** of FIG. 4;

FIG. 6 is a cross section taken on the line **6—6** of FIG. 4; and

FIG. 7 is a cross sectional view through an insulated gate field effect device employing the present novel aluminum oxide coating as the gate insulator thereof.

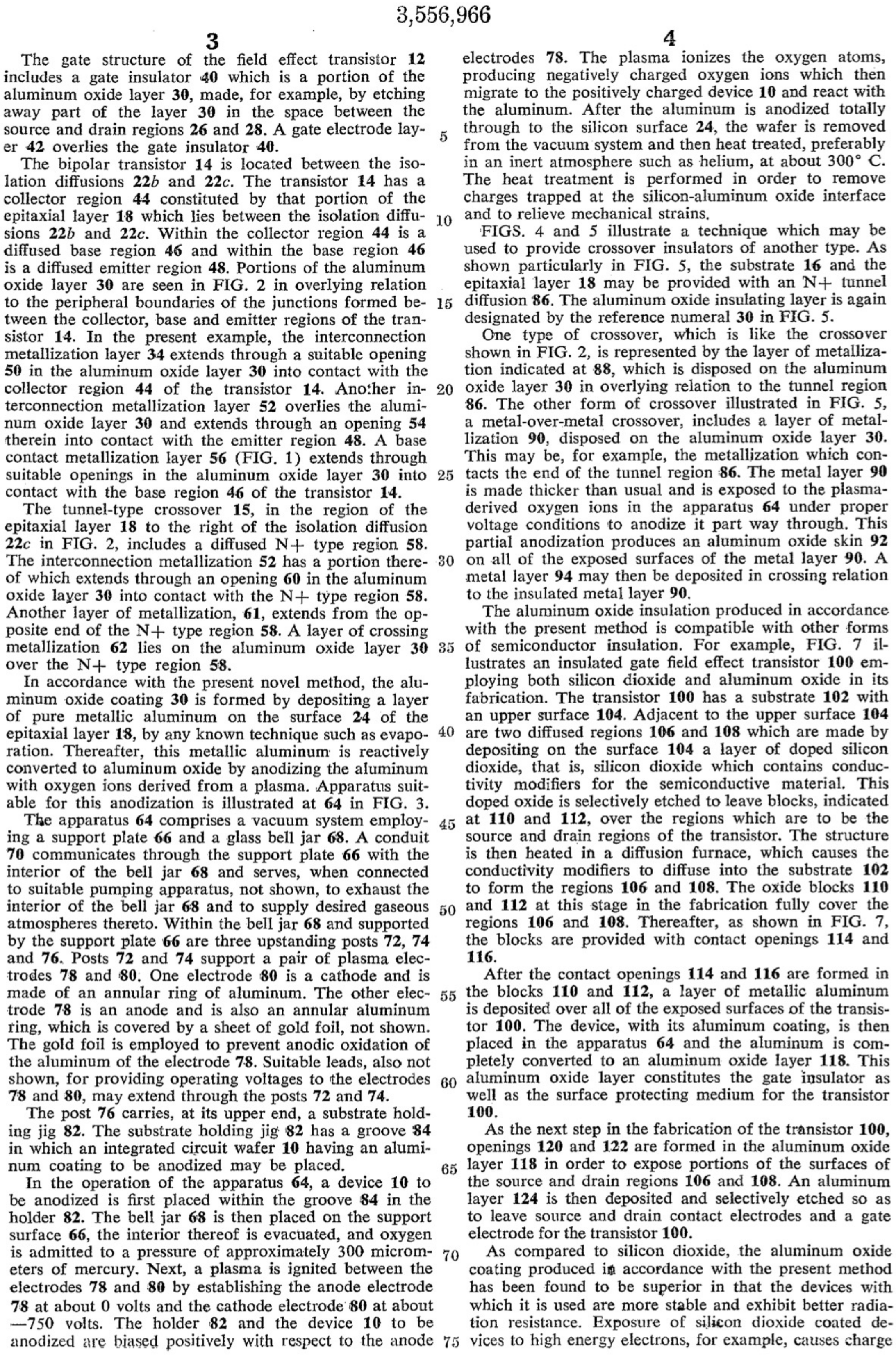
THE PREFERRED EMBODIMENTS

FIGS. 1 and 2 illustrate a portion of an integrated circuit **10** which includes an aluminum oxide coating made by the present novel method. In this example, the integrated circuit **10** has three circuit elements in the portion illustrated in FIG. 1, namely, an insulated gate field effect transistor **12**, a bipolar transistor **14**, and a tunnel-type crossover **15**, which appears in the lower right corner of FIG. 1 and at the right side of the integrated circuit **10** as seen in FIG. 2.

The integrated circuit **10** is fabricated in a wafer **16** of semiconductive material such as silicon, which, in this example, is of P type conductivity. An N type epitaxial layer **18** is disposed on a surface **20** of the wafer **16** and P+ type isolation diffusions **22*a*, 22*b*,** and **22*c*** extend from the upper surface **24** of the epitaxial layer **18** through the epitaxial layer **18** and a short distance into the P type material of the wafer **16.** The techniques for the formation of the epitaxial layer **18** and the P+ isolation diffusions **22*a*, 22*b*,** and **22*c*** are well-known in the art.

The insulated gate field effect transistor **12** has a substrate region formed by that portion of the N type epitaxial layer **18** which lies between the isolation diffusions **22*a*** and **22*b*.** Within this region are two spaced P+ type regions **26** and **28** which constitute source and drain electrode regions respectively, for the transistor **12.** On the surface **24** of the epitaxial layer **18** is a layer **30** of insulating aluminum oxide, made in accordance with the present novel method which will be described in detail hereinafter. Interconnection metallization layers **32** and **34** are disposed on the aluminum oxide layer **30** and have portions which extend through suitable openings **36** and **38** in the aluminum oxide layer **30** into contact with the P+ source and drain regions **26** and **28.**

Figure B.195: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.



The gate structure of the field effect transistor **12** includes a gate insulator **40** which is a portion of the aluminum oxide layer **30**, made, for example, by etching away part of the layer **30** in the space between the source and drain regions **26** and **28**. A gate electrode layer **42** overlies the gate insulator **40**.

The bipolar transistor **14** is located between the isolation diffusions **22*b*** and **22*c***. The transistor **14** has a collector region **44** constituted by that portion of the epitaxial layer **18** which lies between the isolation diffusions **22*b*** and **22*c***. Within the collector region **44** is a diffused base region **46** and within the base region **46** is a diffused emitter region **48**. Portions of the aluminum oxide layer **30** are seen in FIG. 2 in overlying relation to the peripheral boundaries of the junctions formed between the collector, base and emitter regions of the transistor **14**. In the present example, the interconnection metallization layer **34** extends through a suitable opening **50** in the aluminum oxide layer **30** into contact with the collector region **44** of the transistor **14**. Another interconnection metallization layer **52** overlies the aluminum oxide layer **30** and extends through an opening **54** therein into contact with the emitter region **48**. A base contact metallization layer **56** (FIG. 1) extends through suitable openings in the aluminum oxide layer **30** into contact with the base region **46** of the transistor **14**.

The tunnel-type crossover **15**, in the region of the epitaxial layer **18** to the right of the isolation diffusion **22*c*** in FIG. 2, includes a diffused N+ type region **58**. The interconnection metallization **52** has a portion thereof which extends through an opening **60** in the aluminum oxide layer **30** into contact with the N+ type region **58**. Another layer of metallization, **61**, extends from the opposite end of the N+ type region **58**. A layer of crossing metallization **62** lies on the aluminum oxide layer **30** over the N+ type region **58**.

In accordance with the present novel method, the aluminum oxide coating **30** is formed by depositing a layer of pure metallic aluminum on the surface **24** of the epitaxial layer **18**, by any known technique such as evaporation. Thereafter, this metallic aluminum is reactively converted to aluminum oxide by anodizing the aluminum with oxygen ions derived from a plasma. Apparatus suitable for this anodization is illustrated at **64** in FIG. 3.

The apparatus **64** comprises a vacuum system employing a support plate **66** and a glass bell jar **68**. A conduit **70** communicates through the support plate **66** with the interior of the bell jar **68** and serves, when connected to suitable pumping apparatus, not shown, to exhaust the interior of the bell jar **68** and to supply desired gaseous atmospheres thereto. Within the bell jar **68** and supported by the support plate **66** are three upstanding posts **72**, **74** and **76**. Posts **72** and **74** support a pair of plasma electrodes **78** and **80**. One electrode **80** is a cathode and is made of an annular ring of aluminum. The other electrode **78** is an anode and is also an annular aluminum ring, which is covered by a sheet of gold foil, not shown. The gold foil is employed to prevent anodic oxidation of the aluminum of the electrode **78**. Suitable leads, also not shown, for providing operating voltages to the electrodes **78** and **80**, may extend through the posts **72** and **74**.

The post **76** carries, at its upper end, a substrate holding jig **82**. The substrate holding jig **82** has a groove **84** in which an integrated circuit wafer **10** having an aluminum coating to be anodized may be placed.

In the operation of the apparatus **64**, a device **10** to be anodized is first placed within the groove **84** in the holder **82**. The bell jar **68** is then placed on the support surface **66**, the interior thereof is evacuated, and oxygen is admitted to a pressure of approximately 300 micrometers of mercury. Next, a plasma is ignited between the electrodes **78** and **80** by establishing the anode electrode **78** at about 0 volts and the cathode electrode **80** at about —750 volts. The holder **82** and the device **10** to be anodized are biased positively with respect to the anode electrodes **78**. The plasma ionizes the oxygen atoms, producing negatively charged oxygen ions which then migrate to the positively charged device **10** and react with the aluminum. After the aluminum is anodized totally through to the silicon surface **24**, the wafer is removed from the vacuum system and then heat treated, preferably in an inert atmosphere such as helium, at about 300° C. The heat treatment is performed in order to remove charges trapped at the silicon-aluminum oxide interface and to relieve mechanical strains.

FIGS. 4 and 5 illustrate a technique which may be used to provide crossover insulators of another type. As shown particularly in FIG. 5, the substrate **16** and the epitaxial layer **18** may be provided with an N+ tunnel diffusion **86**. The aluminum oxide insulating layer is again designated by the reference numeral **30** in FIG. 5.

One type of crossover, which is like the crossover shown in FIG. 2, is represented by the layer of metallization indicated at **88**, which is disposed on the aluminum oxide layer **30** in overlying relation to the tunnel region **86**. The other form of crossover illustrated in FIG. 5, a metal-over-metal crossover, includes a layer of metallization **90**, disposed on the aluminum oxide layer **30**. This may be, for example, the metallization which contacts the end of the tunnel region **86**. The metal layer **90** is made thicker than usual and is exposed to the plasma-derived oxygen ions in the apparatus **64** under proper voltage conditions to anodize it part way through. This partial anodization produces an aluminum oxide skin **92** on all of the exposed surfaces of the metal layer **90**. A metal layer **94** may then be deposited in crossing relation to the insulated metal layer **90**.

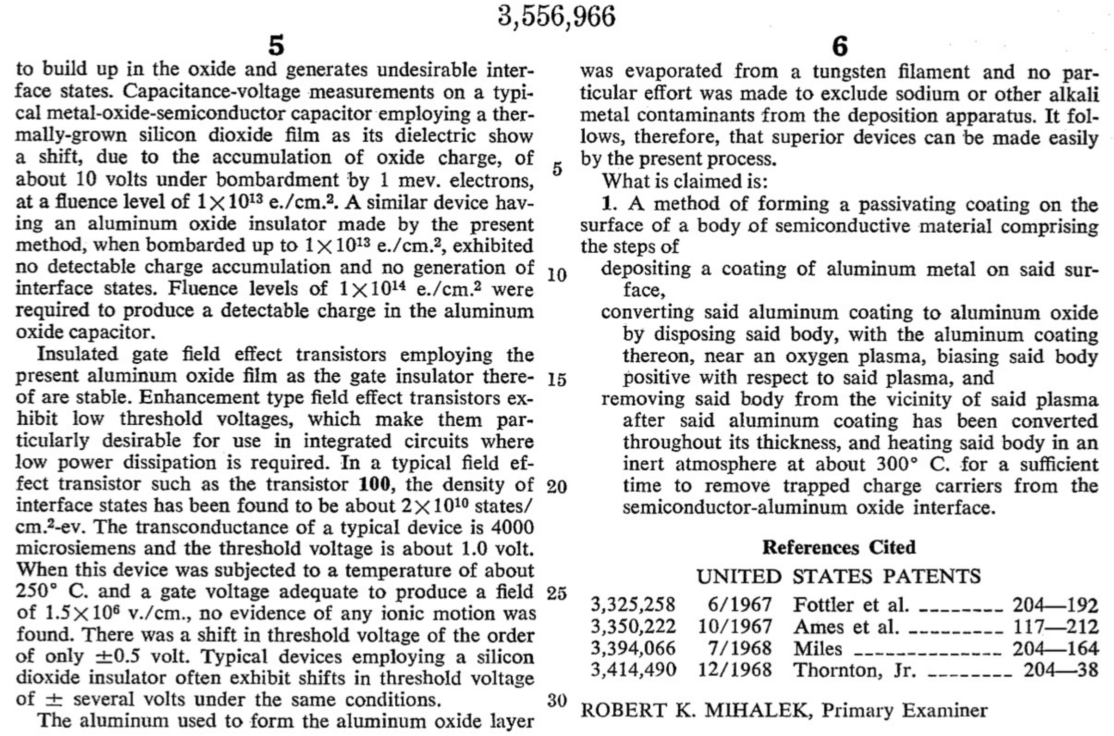
The aluminum oxide insulation produced in accordance with the present method is compatible with other forms of semiconductor insulation. For example, FIG. 7 illustrates an insulated gate field effect transistor **100** employing both silicon dioxide and aluminum oxide in its fabrication. The transistor **100** has a substrate **102** with an upper surface **104**. Adjacent to the upper surface **104** are two diffused regions **106** and **108** which are made by depositing on the surface **104** a layer of doped silicon dioxide, that is, silicon dioxide which contains conductivity modifiers for the semiconductive material. This doped oxide is selectively etched to leave blocks, indicated at **110** and **112**, over the regions which are to be the source and drain regions of the transistor. The structure is then heated in a diffusion furnace, which causes the conductivity modifiers to diffuse into the substrate **102** to form the regions **106** and **108**. The oxide blocks **110** and **112** at this stage in the fabrication fully cover the regions **106** and **108**. Thereafter, as shown in FIG. 7, the blocks are provided with contact openings **114** and **116**.

After the contact openings **114** and **116** are formed in the blocks **110** and **112**, a layer of metallic aluminum is deposited over all of the exposed surfaces of the transistor **100**. The device, with its aluminum coating, is then placed in the apparatus **64** and the aluminum is completely converted to an aluminum oxide layer **118**. This aluminum oxide layer constitutes the gate insulator as well as the surface protecting medium for the transistor **100**.

As the next step in the fabrication of the transistor **100**, openings **120** and **122** are formed in the aluminum oxide layer **118** in order to expose portions of the surfaces of the source and drain regions **106** and **108**. An aluminum layer **124** is then deposited and selectively etched so as to leave source and drain contact electrodes and a gate electrode for the transistor **100**.

As compared to silicon dioxide, the aluminum oxide coating produced in accordance with the present method has been found to be superior in that the devices with which it is used are more stable and exhibit better radiation resistance. Exposure of silicon dioxide coated devices to high energy electrons, for example, causes charge

Figure B.196: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.



to build up in the oxide and generates undesirable interface states. Capacitance-voltage measurements on a typical metal-oxide-semiconductor capacitor employing a thermally-grown silicon dioxide film as its dielectric show a shift, due to the accumulation of oxide charge, of about 10 volts under bombardment by 1 mev. electrons, at a fluence level of 1×10^{13} e./cm.^{2}. A similar device having an aluminum oxide insulator made by the present method, when bombarded up to 1×10^{13} e./cm.^{2}, exhibited no detectable charge accumulation and no generation of interface states. Fluence levels of 1×10^{14} e./cm.^{2} were required to produce a detectable charge in the aluminum oxide capacitor.

Insulated gate field effect transistors employing the present aluminum oxide film as the gate insulator thereof are stable. Enhancement type field effect transistors exhibit low threshold voltages, which make them particularly desirable for use in integrated circuits where low power dissipation is required. In a typical field effect transistor such as the transistor **100**, the density of interface states has been found to be about 2×10^{10} states/cm.^{2}-ev. The transconductance of a typical device is 4000 microsiemens and the threshold voltage is about 1.0 volt. When this device was subjected to a temperature of about 250° C. and a gate voltage adequate to produce a field of 1.5×10^6 v./cm., no evidence of any ionic motion was found. There was a shift in threshold voltage of the order of only ±0.5 volt. Typical devices employing a silicon dioxide insulator often exhibit shifts in threshold voltage of ± several volts under the same conditions.

The aluminum used to form the aluminum oxide layer was evaporated from a tungsten filament and no particular effort was made to exclude sodium or other alkali metal contaminants from the deposition apparatus. It follows, therefore, that superior devices can be made easily by the present process.

What is claimed is:

1. A method of forming a passivating coating on the surface of a body of semiconductive material comprising the steps of

depositing a coating of aluminum metal on said surface,

converting said aluminum coating to aluminum oxide by disposing said body, with the aluminum coating thereon, near an oxygen plasma, biasing said body positive with respect to said plasma, and

removing said body from the vicinity of said plasma after said aluminum coating has been converted throughout its thickness, and heating said body in an inert atmosphere at about 300° C. for a sufficient time to remove trapped charge carriers from the semiconductor-aluminum oxide interface.

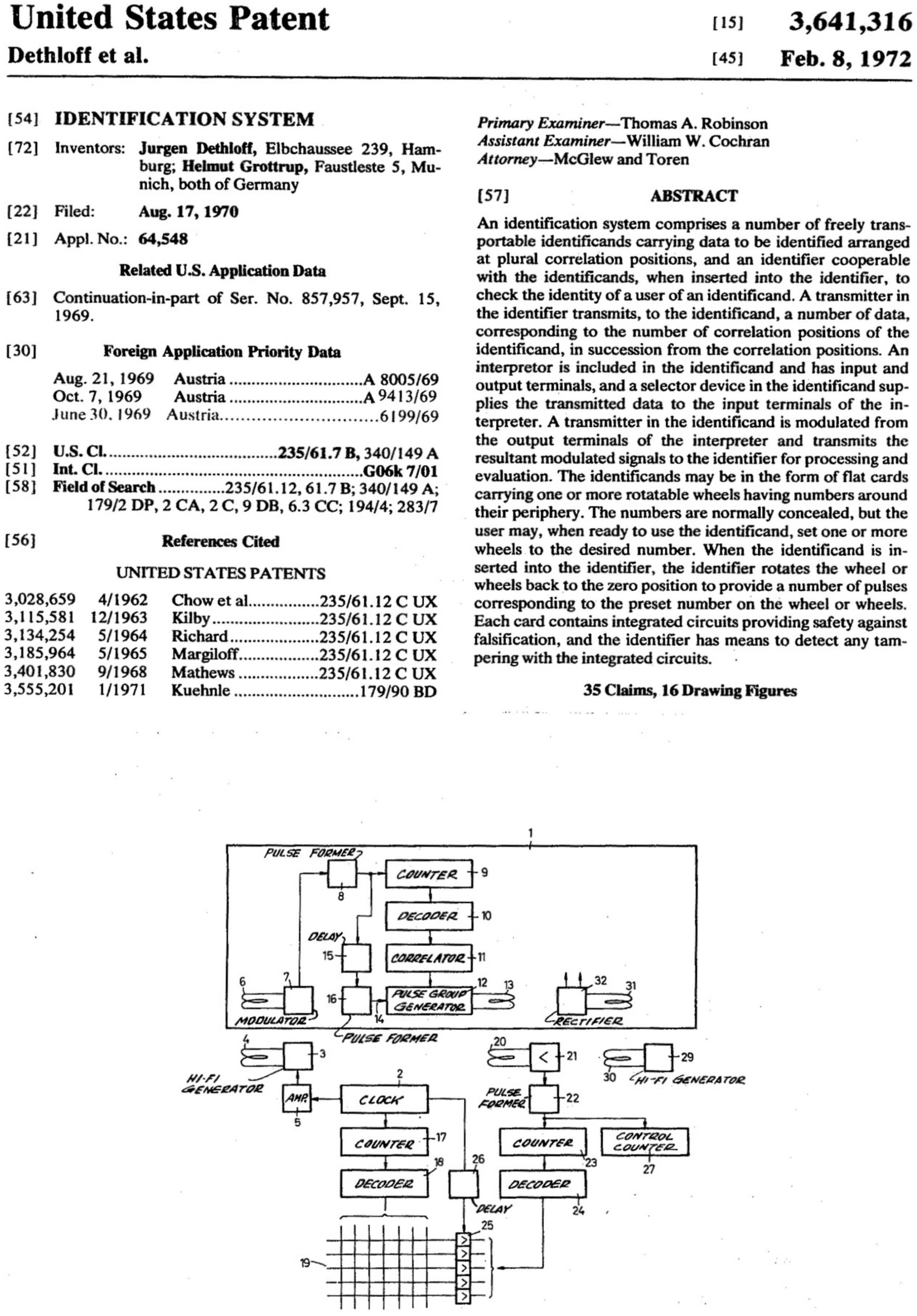
References Cited

UNITED STATES PATENTS

3,325,258	6/1967	Fottler et al.	204—192
3,350,222	10/1967	Ames et al.	117—212
3,394,066	7/1968	Miles	204—164
3,414,490	12/1968	Thornton, Jr.	204—38

ROBERT K. MIHALEK, Primary Examiner

Figure B.197: Karl Heinz Zaininger invented methods of manufacturing field effect transistors.



United States Patent

Dethloff et al.

[15] **3,641,316**

[45] **Feb. 8, 1972**

[54] **IDENTIFICATION SYSTEM**

[72] Inventors: **Jurgen Dethloff,** Elbchaussee 239, Hamburg; **Helmut Grottrup,** Faustleste 5, Munich, both of Germany

[22] Filed: **Aug. 17, 1970**

[21] Appl. No.: **64,548**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 857,957, Sept. 15, 1969.

[30] **Foreign Application Priority Data**

Aug. 21, 1969	Austria	A 8005/69
Oct. 7, 1969	Austria	A 9413/69
June 30, 1969	Austria	6199/69

[52] **U.S. Cl.** ....**235/61.7 B,** 340/149 A

[51] **Int. Cl.** **G06k 7/01**

[58] **Field of Search** ....235/61.12, 61.7 B; 340/149 A; 179/2 DP, 2 CA, 2 C, 9 DB, 6.3 CC; 194/4; 283/7

[56] **References Cited**

UNITED STATES PATENTS

3,028,659	4/1962	Chow et al.	235/61.12 C UX
3,115,581	12/1963	Kilby	235/61.12 C UX
3,134,254	5/1964	Richard	235/61.12 C UX
3,185,964	5/1965	Margiloff	235/61.12 C UX
3,401,830	9/1968	Mathews	235/61.12 C UX
3,555,201	1/1971	Kuehnle	179/90 BD

Primary Examiner—Thomas A. Robinson
Assistant Examiner—William W. Cochran
Attorney—McGlew and Toren

[57] **ABSTRACT**

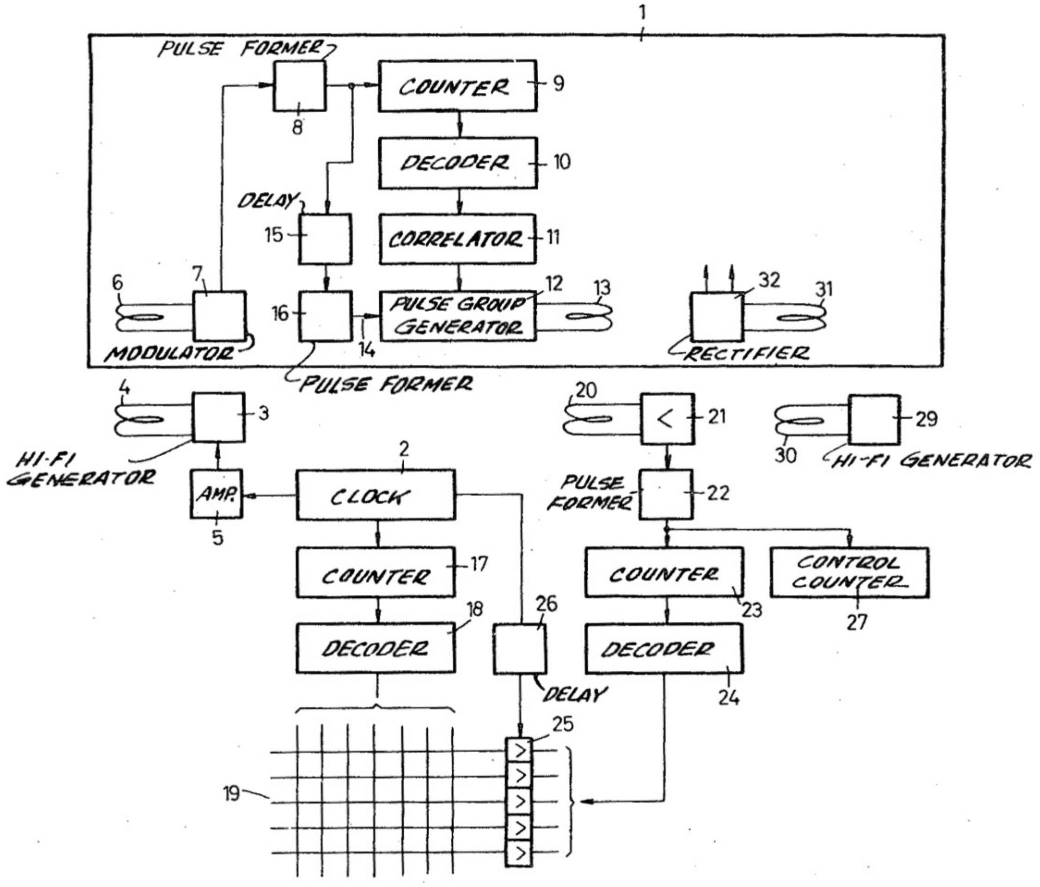
An identification system comprises a number of freely transportable identificands carrying data to be identified arranged at plural correlation positions, and an identifier cooperable with the identificands, when inserted into the identifier, to check the identity of a user of an identificand. A transmitter in the identifier transmits, to the identificand, a number of data, corresponding to the number of correlation positions of the identificand, in succession from the correlation positions. An interpretor is included in the identificand and has input and output terminals, and a selector device in the identificand supplies the transmitted data to the input terminals of the interpreter. A transmitter in the identificand is modulated from the output terminals of the interpreter and transmits the resultant modulated signals to the identifier for processing and evaluation. The identificands may be in the form of flat cards carrying one or more rotatable wheels having numbers around their periphery. The numbers are normally concealed, but the user may, when ready to use the identificand, set one or more wheels to the desired number. When the identificand is inserted into the identifier, the identifier rotates the wheel or wheels back to the zero position to provide a number of pulses corresponding to the preset number on the wheel or wheels. Each card contains integrated circuits providing safety against falsification, and the identifier has means to detect any tampering with the integrated circuits.

35 Claims, 16 Drawing Figures

Figure B.198: Helmut Gröttrup and Jürgen Dethloff invented the smart card, or chip card, in 1966. Earlier, Gröttrup developed avionics systems in Germany during the war and led the German-speaking contributions to the postwar Soviet ballistic missile program.

PATENTED FEB 8 1972 3,641,316

SHEET 1 OF 4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PULSE GROUP GENERATOR
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Fig.1

INVENTORS
JÜRGEN DETHLOFF
HELMUT GRÖTTRUP

BY

McGlew & Toren
ATTORNEYS

Figure B.199: Helmut Gröttrup and Jürgen Dethloff invented the smart card, or chip card, in 1966. Earlier, Gröttrup developed avionics systems in Germany during the war and led the German-speaking contributions to the postwar Soviet ballistic missile program.

PATENTED FEB 8 1972 3,641,316

SHEET 2 OF 4

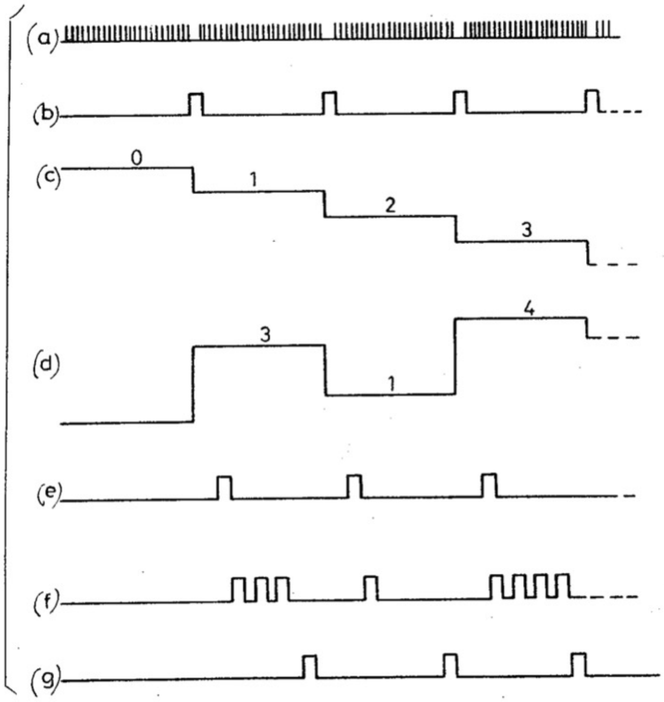

Fig.2

INVENTORS
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HELMUT GRÖTTRUP

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McGlew & Toren
ATTORNEYS

Figure B.200: Helmut Gröttrup and Jürgen Dethloff invented the smart card, or chip card, in 1966. Earlier, Gröttrup developed avionics systems in Germany during the war and led the German-speaking contributions to the postwar Soviet ballistic missile program.

PATENTED FEB 8 1972 3,641,316

SHEET 3 OF 4

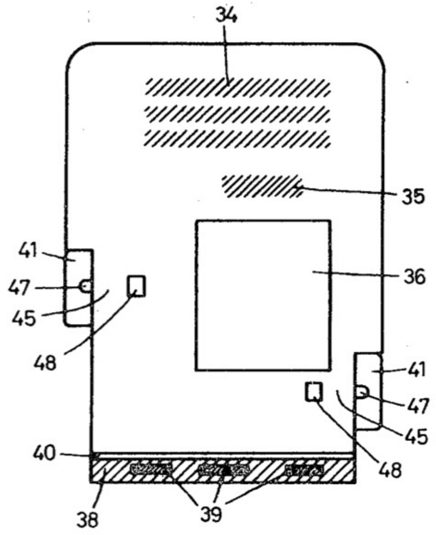
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Fig.3

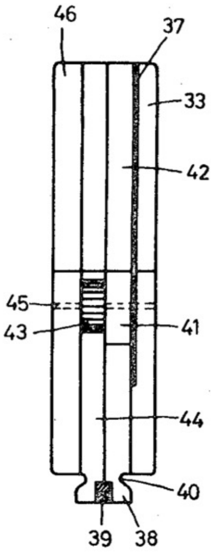
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Fig.4

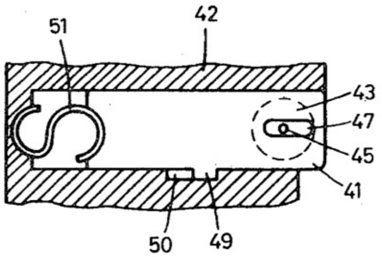
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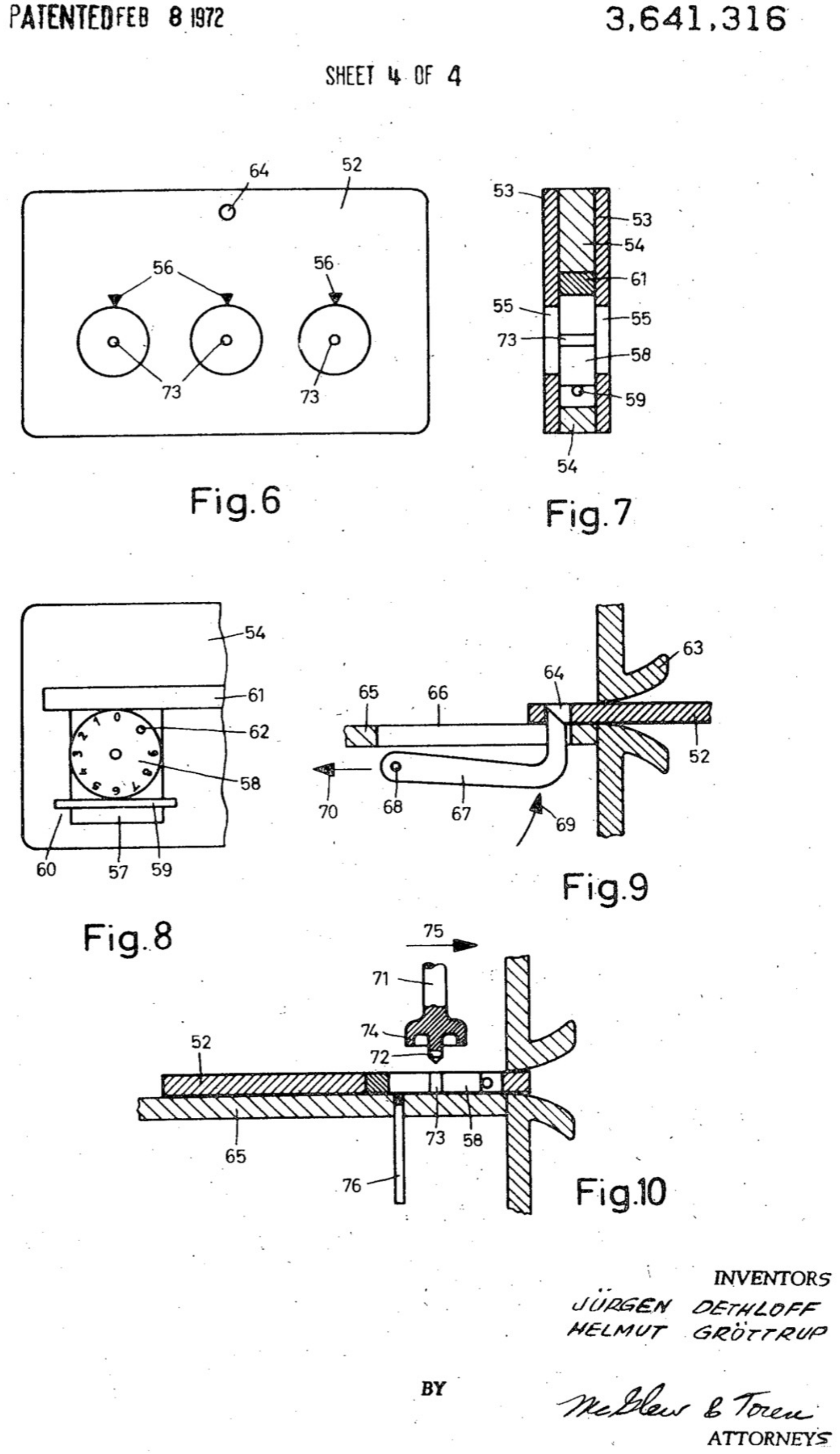
Fig.5

INVENTORS
JÜRGEN DETHLOFF
HELMUT GRÖTTRUP

BY

McGlew & Toren
ATTORNEYS

Figure B.201: Helmut Gröttrup and Jürgen Dethloff invented the smart card, or chip card, in 1966. Earlier, Gröttrup developed avionics systems in Germany during the war and led the German-speaking contributions to the postwar Soviet ballistic missile program.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SHEET 4 OF 4
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Fig.6
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Fig.7
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Fig.8
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Fig.9
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58
76
Fig.10
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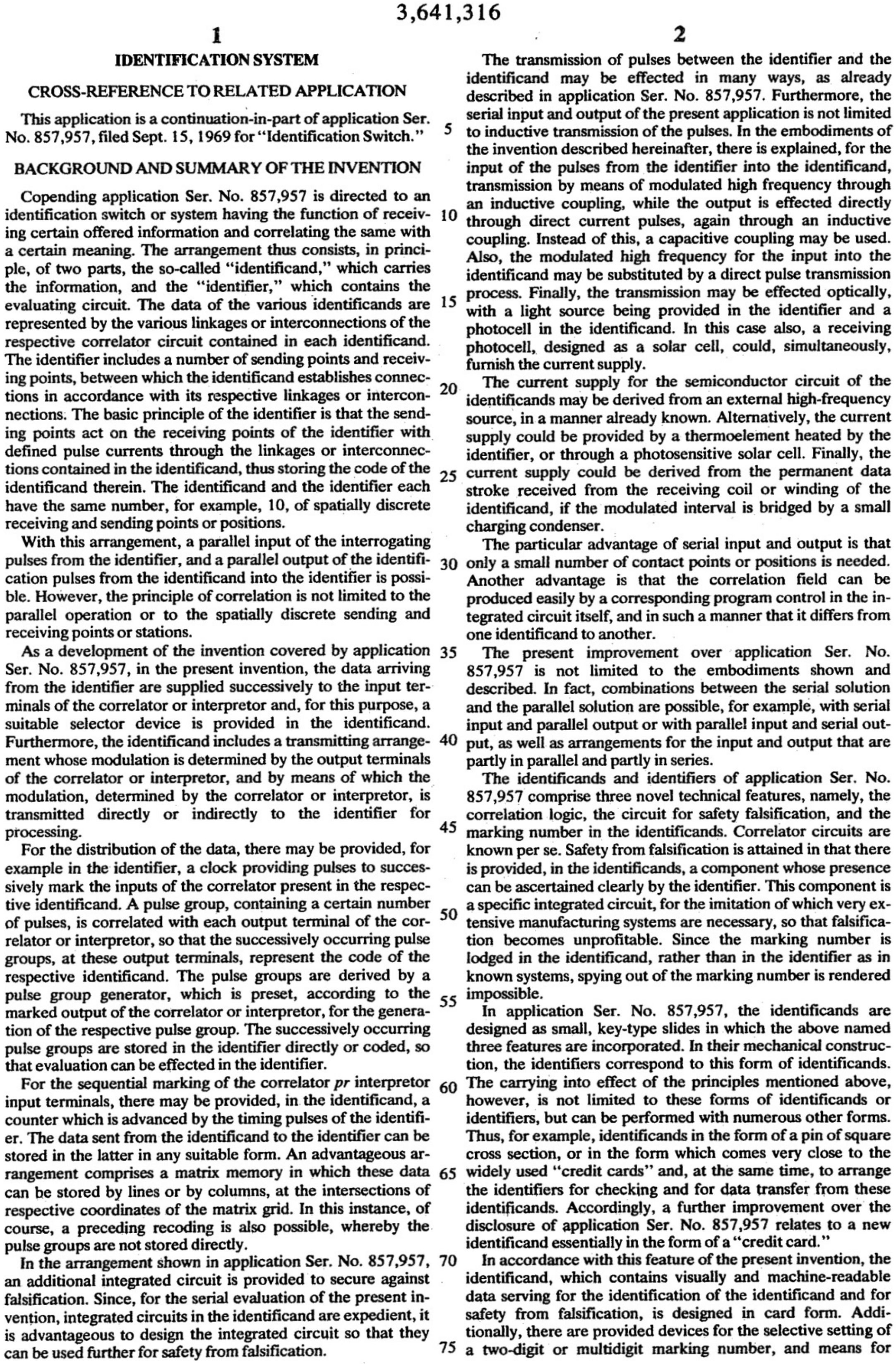
ATTORNEYS

Figure B.202: Helmut Gröttrup and Jürgen Dethloff invented the smart card, or chip card, in 1966. Earlier, Gröttrup developed avionics systems in Germany during the war and led the German-speaking contributions to the postwar Soviet ballistic missile program.



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IDENTIFICATION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of application Ser. No. 857,957, filed Sept. 15, 1969 for "Identification Switch."

BACKGROUND AND SUMMARY OF THE INVENTION

Copending application Ser. No. 857,957 is directed to an identification switch or system having the function of receiving certain offered information and correlating the same with a certain meaning. The arrangement thus consists, in principle, of two parts, the so-called "identificand," which carries the information, and the "identifier," which contains the evaluating circuit. The data of the various identificands are represented by the various linkages or interconnections of the respective correlator circuit contained in each identificand. The identifier includes a number of sending points and receiving points, between which the identificand establishes connections in accordance with its respective linkages or interconnections. The basic principle of the identifier is that the sending points act on the receiving points of the identifier with defined pulse currents through the linkages or interconnections contained in the identificand, thus storing the code of the identificand therein. The identificand and the identifier each have the same number, for example, 10, of spatially discrete receiving and sending points or positions.

With this arrangement, a parallel input of the interrogating pulses from the identifier, and a parallel output of the identification pulses from the identificand into the identifier is possible. However, the principle of correlation is not limited to the parallel operation or to the spatially discrete sending and receiving points or stations.

As a development of the invention covered by application Ser. No. 857,957, in the present invention, the data arriving from the identifier are supplied successively to the input terminals of the correlator or interpretor and, for this purpose, a suitable selector device is provided in the identificand. Furthermore, the identificand includes a transmitting arrangement whose modulation is determined by the output terminals of the correlator or interpretor, and by means of which the modulation, determined by the correlator or interpretor, is transmitted directly or indirectly to the identifier for processing.

For the distribution of the data, there may be provided, for example in the identifier, a clock providing pulses to successively mark the inputs of the correlator present in the respective identificand. A pulse group, containing a certain number of pulses, is correlated with each output terminal of the correlator or interpretor, so that the successively occurring pulse groups, at these output terminals, represent the code of the respective identificand. The pulse groups are derived by a pulse group generator, which is preset, according to the marked output of the correlator or interpretor, for the generation of the respective pulse group. The successively occurring pulse groups are stored in the identifier directly or coded, so that evaluation can be effected in the identifier.

For the sequential marking of the correlator *pr* interpretor input terminals, there may be provided, in the identificand, a counter which is advanced by the timing pulses of the identifier. The data sent from the identificand to the identifier can be stored in the latter in any suitable form. An advantageous arrangement comprises a matrix memory in which these data can be stored by lines or by columns, at the intersections of respective coordinates of the matrix grid. In this instance, of course, a preceding recoding is also possible, whereby the pulse groups are not stored directly.

In the arrangement shown in application Ser. No. 857,957, an additional integrated circuit is provided to secure against falsification. Since, for the serial evaluation of the present invention, integrated circuits in the identificand are expedient, it is advantageous to design the integrated circuit so that they can be used further for safety from falsification.

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The transmission of pulses between the identifier and the identificand may be effected in many ways, as already described in application Ser. No. 857,957. Furthermore, the serial input and output of the present application is not limited to inductive transmission of the pulses. In the embodiments of the invention described hereinafter, there is explained, for the input of the pulses from the identifier into the identificand, transmission by means of modulated high frequency through an inductive coupling, while the output is effected directly through direct current pulses, again through an inductive coupling. Instead of this, a capacitive coupling may be used. Also, the modulated high frequency for the input into the identificand may be substituted by a direct pulse transmission process. Finally, the transmission may be effected optically, with a light source being provided in the identifier and a photocell in the identificand. In this case also, a receiving photocell, designed as a solar cell, could, simultaneously, furnish the current supply.

The current supply for the semiconductor circuit of the identificands may be derived from an external high-frequency source, in a manner already known. Alternatively, the current supply could be provided by a thermoelement heated by the identifier, or through a photosensitive solar cell. Finally, the current supply could be derived from the permanent data stroke received from the receiving coil or winding of the identificand, if the modulated interval is bridged by a small charging condenser.

The particular advantage of serial input and output is that only a small number of contact points or positions is needed. Another advantage is that the correlation field can be produced easily by a corresponding program control in the integrated circuit itself, and in such a manner that it differs from one identificand to another.

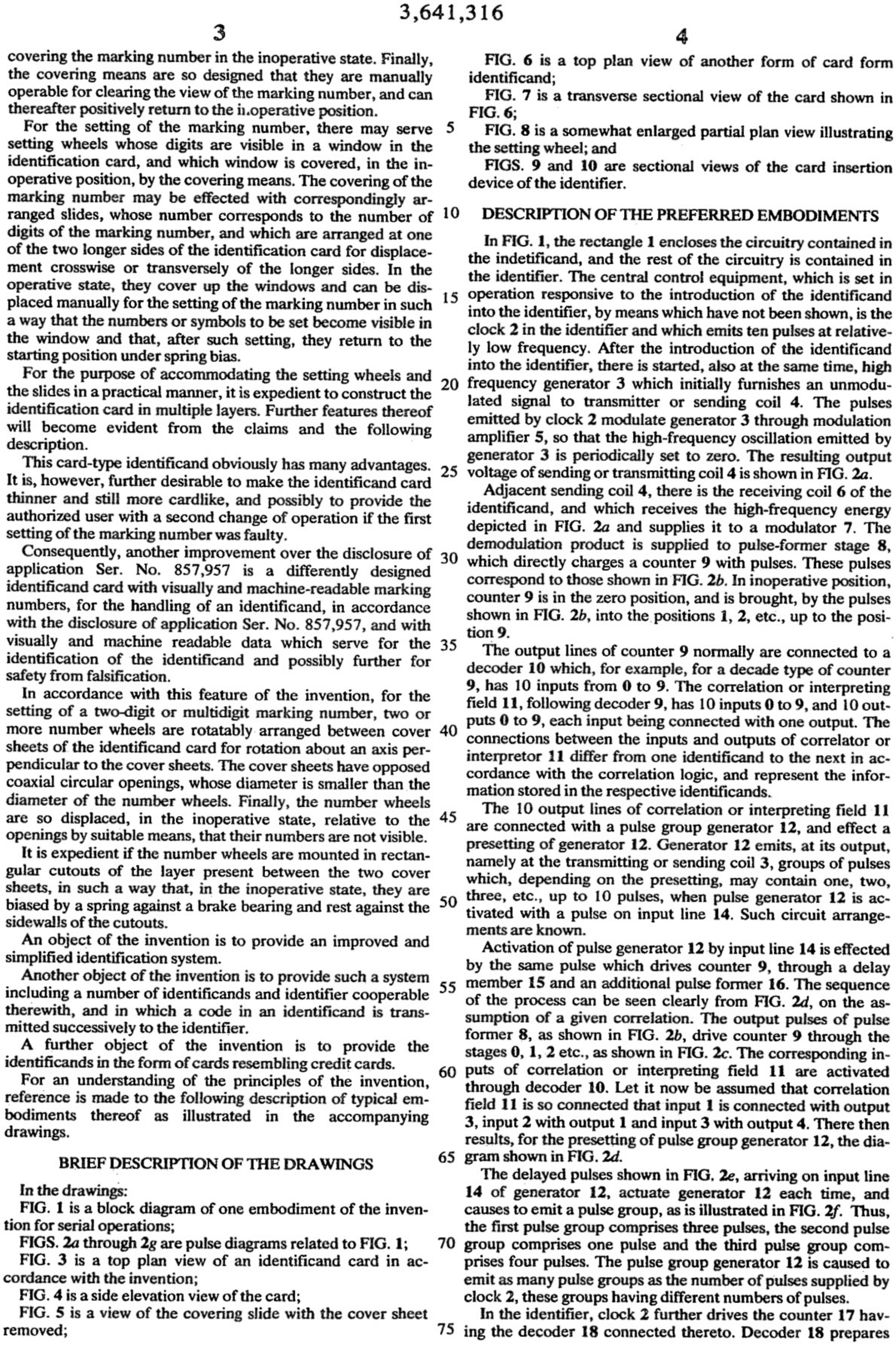
The present improvement over application Ser. No. 857,957 is not limited to the embodiments shown and described. In fact, combinations between the serial solution and the parallel solution are possible, for example, with serial input and parallel output or with parallel input and serial output, as well as arrangements for the input and output that are partly in parallel and partly in series.

The identificands and identifiers of application Ser. No. 857,957 comprise three novel technical features, namely, the correlation logic, the circuit for safety falsification, and the marking number in the identificands. Correlator circuits are known per se. Safety from falsification is attained in that there is provided, in the identificands, a component whose presence can be ascertained clearly by the identifier. This component is a specific integrated circuit, for the imitation of which very extensive manufacturing systems are necessary, so that falsification becomes unprofitable. Since the marking number is lodged in the identificand, rather than in the identifier as in known systems, spying out of the marking number is rendered impossible.

In application Ser. No. 857,957, the identificands are designed as small, key-type slides in which the above named three features are incorporated. In their mechanical construction, the identifiers correspond to this form of identificands. The carrying into effect of the principles mentioned above, however, is not limited to these forms of identificands or identifiers, but can be performed with numerous other forms. Thus, for example, identificands in the form of a pin of square cross section, or in the form which comes very close to the widely used "credit cards" and, at the same time, to arrange the identifiers for checking and for data transfer from these identificands. Accordingly, a further improvement over the disclosure of application Ser. No. 857,957 relates to a new identificand essentially in the form of a "credit card."

In accordance with this feature of the present invention, the identificand, which contains visually and machine-readable data serving for the identification of the identificand and for safety from falsification, is designed in card form. Additionally, there are provided devices for the selective setting of a two-digit or multidigit marking number, and means for

Figure B.203: Helmut Gröttrup and Jürgen Dethloff invented the smart card, or chip card, in 1966. Earlier, Gröttrup developed avionics systems in Germany during the war and led the German-speaking contributions to the postwar Soviet ballistic missile program.



covering the marking number in the inoperative state. Finally, the covering means are so designed that they are manually operable for clearing the view of the marking number, and can thereafter positively return to the inoperative position.

For the setting of the marking number, there may serve setting wheels whose digits are visible in a window in the identification card, and which window is covered, in the inoperative position, by the covering means. The covering of the marking number may be effected with correspondingly arranged slides, whose number corresponds to the number of digits of the marking number, and which are arranged at one of the two longer sides of the identification card for displacement crosswise or transversely of the longer sides. In the operative state, they cover up the windows and can be displaced manually for the setting of the marking number in such a way that the numbers or symbols to be set become visible in the window and that, after such setting, they return to the starting position under spring bias.

For the purpose of accommodating the setting wheels and the slides in a practical manner, it is expedient to construct the identification card in multiple layers. Further features thereof will become evident from the claims and the following description.

This card-type identificand obviously has many advantages. It is, however, further desirable to make the identificand card thinner and still more cardlike, and possibly to provide the authorized user with a second change of operation if the first setting of the marking number was faulty.

Consequently, another improvement over the disclosure of application Ser. No. 857,957 is a differently designed identificand card with visually and machine-readable marking numbers, for the handling of an identificand, in accordance with the disclosure of application Ser. No. 857,957, and with visually and machine readable data which serve for the identification of the identificand and possibly further for safety from falsification.

In accordance with this feature of the invention, for the setting of a two-digit or multidigit marking number, two or more number wheels are rotatably arranged between cover sheets of the identificand card for rotation about an axis perpendicular to the cover sheets. The cover sheets have opposed coaxial circular openings, whose diameter is smaller than the diameter of the number wheels. Finally, the number wheels are so displaced, in the inoperative state, relative to the openings by suitable means, that their numbers are not visible.

It is expedient if the number wheels are mounted in rectangular cutouts of the layer present between the two cover sheets, in such a way that, in the inoperative state, they are biased by a spring against a brake bearing and rest against the sidewalls of the cutouts.

An object of the invention is to provide an improved and simplified identification system.

Another object of the invention is to provide such a system including a number of identificands and identifier cooperable therewith, and in which a code in an identificand is transmitted successively to the identifier.

A further object of the invention is to provide the identificands in the form of cards resembling credit cards.

For an understanding of the principles of the invention, reference is made to the following description of typical embodiments thereof as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a block diagram of one embodiment of the invention for serial operations;

FIGS. **2***a* through **2***g* are pulse diagrams related to FIG. **1**;

FIG. **3** is a top plan view of an identificand card in accordance with the invention;

FIG. **4** is a side elevation view of the card;

FIG. **5** is a view of the covering slide with the cover sheet removed;

FIG. **6** is a top plan view of another form of card form identificand;

FIG. **7** is a transverse sectional view of the card shown in FIG. **6**;

FIG. **8** is a somewhat enlarged partial plan view illustrating the setting wheel; and

FIGS. **9** and **10** are sectional views of the card insertion device of the identifier.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. **1**, the rectangle **1** encloses the circuitry contained in the indetificand, and the rest of the circuitry is contained in the identifier. The central control equipment, which is set in operation responsive to the introduction of the identificand into the identifier, by means which have not been shown, is the clock **2** in the identifier and which emits ten pulses at relatively low frequency. After the introduction of the identificand into the identifier, there is started, also at the same time, high frequency generator **3** which initially furnishes an unmodulated signal to transmitter or sending coil **4**. The pulses emitted by clock **2** modulate generator **3** through modulation amplifier **5**, so that the high-frequency oscillation emitted by generator **3** is periodically set to zero. The resulting output voltage of sending or transmitting coil **4** is shown in FIG. **2***a*.

Adjacent sending coil **4**, there is the receiving coil **6** of the identificand, and which receives the high-frequency energy depicted in FIG. **2***a* and supplies it to a modulator **7**. The demodulation product is supplied to pulse-former stage **8**, which directly charges a counter **9** with pulses. These pulses correspond to those shown in FIG. **2***b*. In inoperative position, counter **9** is in the zero position, and is brought, by the pulses shown in FIG. **2***b*, into the positions **1**, **2**, etc., up to the position **9**.

The output lines of counter **9** normally are connected to a decoder **10** which, for example, for a decade type of counter **9**, has 10 inputs from **0** to **9**. The correlation or interpreting field **11**, following decoder **9**, has 10 inputs **0** to **9**, and 10 outputs **0** to **9**, each input being connected with one output. The connections between the inputs and outputs of correlator or interpretor **11** differ from one identificand to the next in accordance with the correlation logic, and represent the information stored in the respective identificands.

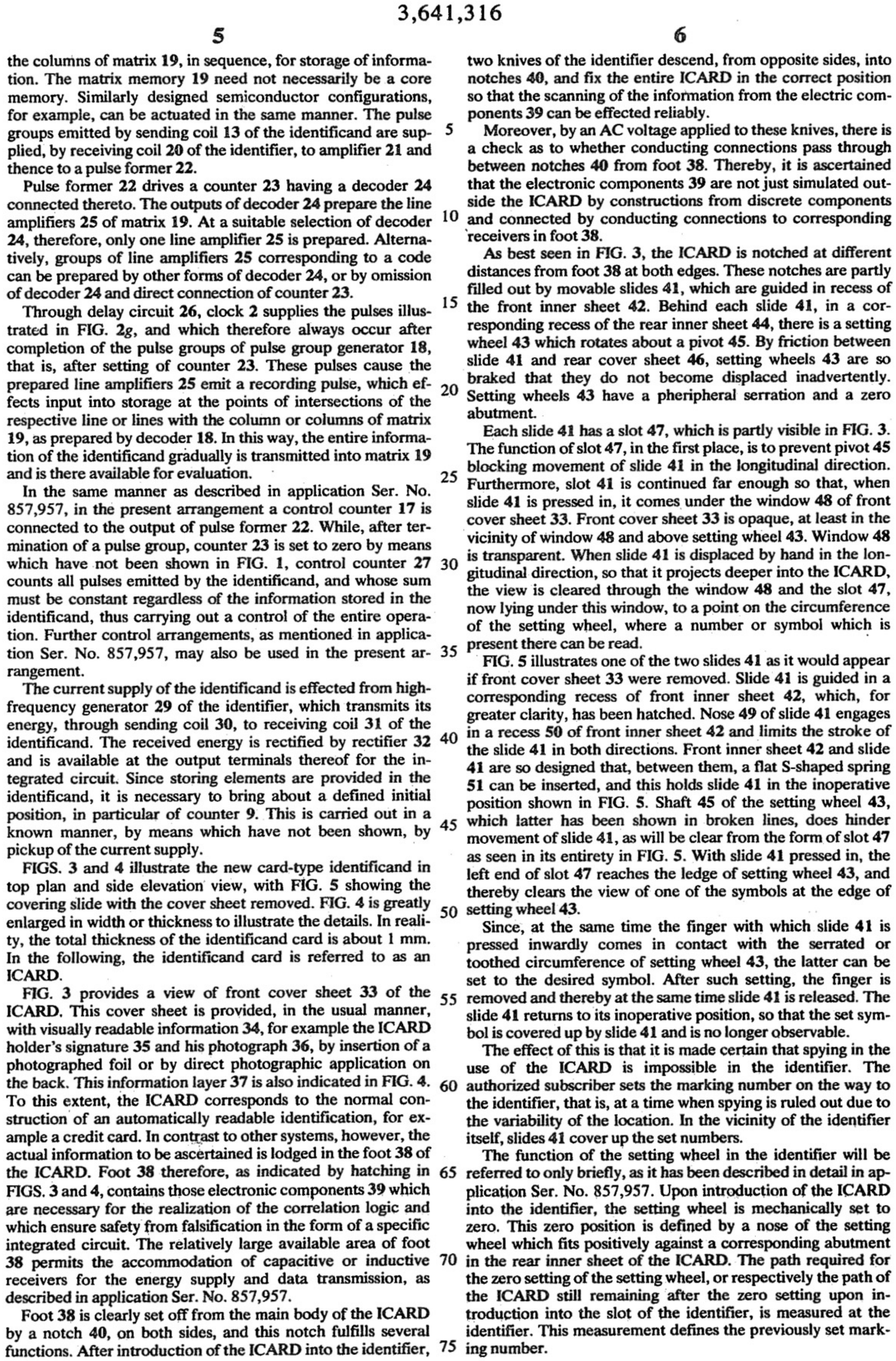
The 10 output lines of correlation or interpreting field **11** are connected with a pulse group generator **12**, and effect a presetting of generator **12**. Generator **12** emits, at its output, namely at the transmitting or sending coil **3**, groups of pulses which, depending on the presetting, may contain one, two, three, etc., up to 10 pulses, when pulse generator **12** is activated with a pulse on input line **14**. Such circuit arrangements are known.

Activation of pulse generator **12** by input line **14** is effected by the same pulse which drives counter **9**, through a delay member **15** and an additional pulse former **16**. The sequence of the process can be seen clearly from FIG. **2***d*, on the assumption of a given correlation. The output pulses of pulse former **8**, as shown in FIG. **2***b*, drive counter **9** through the stages **0**, **1**, **2** etc., as shown in FIG. **2***c*. The corresponding inputs of correlation or interpreting field **11** are activated through decoder **10**. Let it now be assumed that correlation field **11** is so connected that input **1** is connected with output **3**, input **2** with output **1** and input **3** with output **4**. There then results, for the presetting of pulse group generator **12**, the diagram shown in FIG. **2***d*.

The delayed pulses shown in FIG. **2***e*, arriving on input line **14** of generator **12**, actuate generator **12** each time, and causes to emit a pulse group, as is illustrated in FIG. **2***f*. Thus, the first pulse group comprises three pulses, the second pulse group comprises one pulse and the third pulse group comprises four pulses. The pulse group generator **12** is caused to emit as many pulse groups as the number of pulses supplied by clock **2**, these groups having different numbers of pulses.

In the identifier, clock **2** further drives the counter **17** having the decoder **18** connected thereto. Decoder **18** prepares

Figure B.204: Helmut Gröttrup and Jürgen Dethloff invented the smart card, or chip card, in 1966. Earlier, Gröttrup developed avionics systems in Germany during the war and led the German-speaking contributions to the postwar Soviet ballistic missile program.



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the columns of matrix **19**, in sequence, for storage of information. The matrix memory **19** need not necessarily be a core memory. Similarly designed semiconductor configurations, for example, can be actuated in the same manner. The pulse groups emitted by sending coil **13** of the identificand are supplied, by receiving coil **20** of the identifier, to amplifier **21** and thence to a pulse former **22**.

Pulse former **22** drives a counter **23** having a decoder **24** connected thereto. The outputs of decoder **24** prepare the line amplifiers **25** of matrix **19**. At a suitable selection of decoder **24**, therefore, only one line amplifier **25** is prepared. Alternatively, groups of line amplifiers **25** corresponding to a code can be prepared by other forms of decoder **24**, or by omission of decoder **24** and direct connection of counter **23**.

Through delay circuit **26**, clock **2** supplies the pulses illustrated in FIG. **2g**, and which therefore always occur after completion of the pulse groups of pulse group generator **18**, that is, after setting of counter **23**. These pulses cause the prepared line amplifiers **25** emit a recording pulse, which effects input into storage at the points of intersections of the respective line or lines with the column or columns of matrix **19**, as prepared by decoder **18**. In this way, the entire information of the identificand gradually is transmitted into matrix **19** and is there available for evaluation.

In the same manner as described in application Ser. No. 857,957, in the present arrangement a control counter **17** is connected to the output of pulse former **22**. While, after termination of a pulse group, counter **23** is set to zero by means which have not been shown in FIG. **1**, control counter **27** counts all pulses emitted by the identificand, and whose sum must be constant regardless of the information stored in the identificand, thus carrying out a control of the entire operation. Further control arrangements, as mentioned in application Ser. No. 857,957, may also be used in the present arrangement.

The current supply of the identificand is effected from high-frequency generator **29** of the identifier, which transmits its energy, through sending coil **30**, to receiving coil **31** of the identificand. The received energy is rectified by rectifier **32** and is available at the output terminals thereof for the integrated circuit. Since storing elements are provided in the identificand, it is necessary to bring about a defined initial position, in particular of counter **9**. This is carried out in a known manner, by means which have not been shown, by pickup of the current supply.

FIGS. **3** and **4** illustrate the new card-type identificand in top plan and side elevation view, with FIG. **5** showing the covering slide with the cover sheet removed. FIG. **4** is greatly enlarged in width or thickness to illustrate the details. In reality, the total thickness of the identificand card is about 1 mm. In the following, the identificand card is referred to as an ICARD.

FIG. **3** provides a view of front cover sheet **33** of the ICARD. This cover sheet is provided, in the usual manner, with visually readable information **34**, for example the ICARD holder's signature **35** and his photograph **36**, by insertion of a photographed foil or by direct photographic application on the back. This information layer **37** is also indicated in FIG. **4**. To this extent, the ICARD corresponds to the normal construction of an automatically readable identification, for example a credit card. In contrast to other systems, however, the actual information to be ascertained is lodged in the foot **38** of the ICARD. Foot **38** therefore, as indicated by hatching in FIGS. **3** and **4**, contains those electronic components **39** which are necessary for the realization of the correlation logic and which ensure safety from falsification in the form of a specific integrated circuit. The relatively large available area of foot **38** permits the accommodation of capacitive or inductive receivers for the energy supply and data transmission, as described in application Ser. No. 857,957.

Foot **38** is clearly set off from the main body of the ICARD by a notch **40**, on both sides, and this notch fulfills several functions. After introduction of the ICARD into the identifier, two knives of the identifier descend, from opposite sides, into notches **40**, and fix the entire ICARD in the correct position so that the scanning of the information from the electric components **39** can be effected reliably.

Moreover, by an AC voltage applied to these knives, there is a check as to whether conducting connections pass through between notches **40** from foot **38**. Thereby, it is ascertained that the electronic components **39** are not just simulated outside the ICARD by constructions from discrete components and connected by conducting connections to corresponding receivers in foot **38**.

As best seen in FIG. **3**, the ICARD is notched at different distances from foot **38** at both edges. These notches are partly filled out by movable slides **41**, which are guided in recess of the front inner sheet **42**. Behind each slide **41**, in a corresponding recess of the rear inner sheet **44**, there is a setting wheel **43** which rotates about a pivot **45**. By friction between slide **41** and rear cover sheet **46**, setting wheels **43** are so braked that they do not become displaced inadvertently. Setting wheels **43** have a pheripheral serration and a zero abutment.

Each slide **41** has a slot **47**, which is partly visible in FIG. **3**. The function of slot **47**, in the first place, is to prevent pivot **45** blocking movement of slide **41** in the longitudinal direction. Furthermore, slot **41** is continued far enough so that, when slide **41** is pressed in, it comes under the window **48** of front cover sheet **33**. Front cover sheet **33** is opaque, at least in the vicinity of window **48** and above setting wheel **43**. Window **48** is transparent. When slide **41** is displaced by hand in the longitudinal direction, so that it projects deeper into the ICARD, the view is cleared through the window **48** and the slot **47**, now lying under this window, to a point on the circumference of the setting wheel, where a number or symbol which is present there can be read.

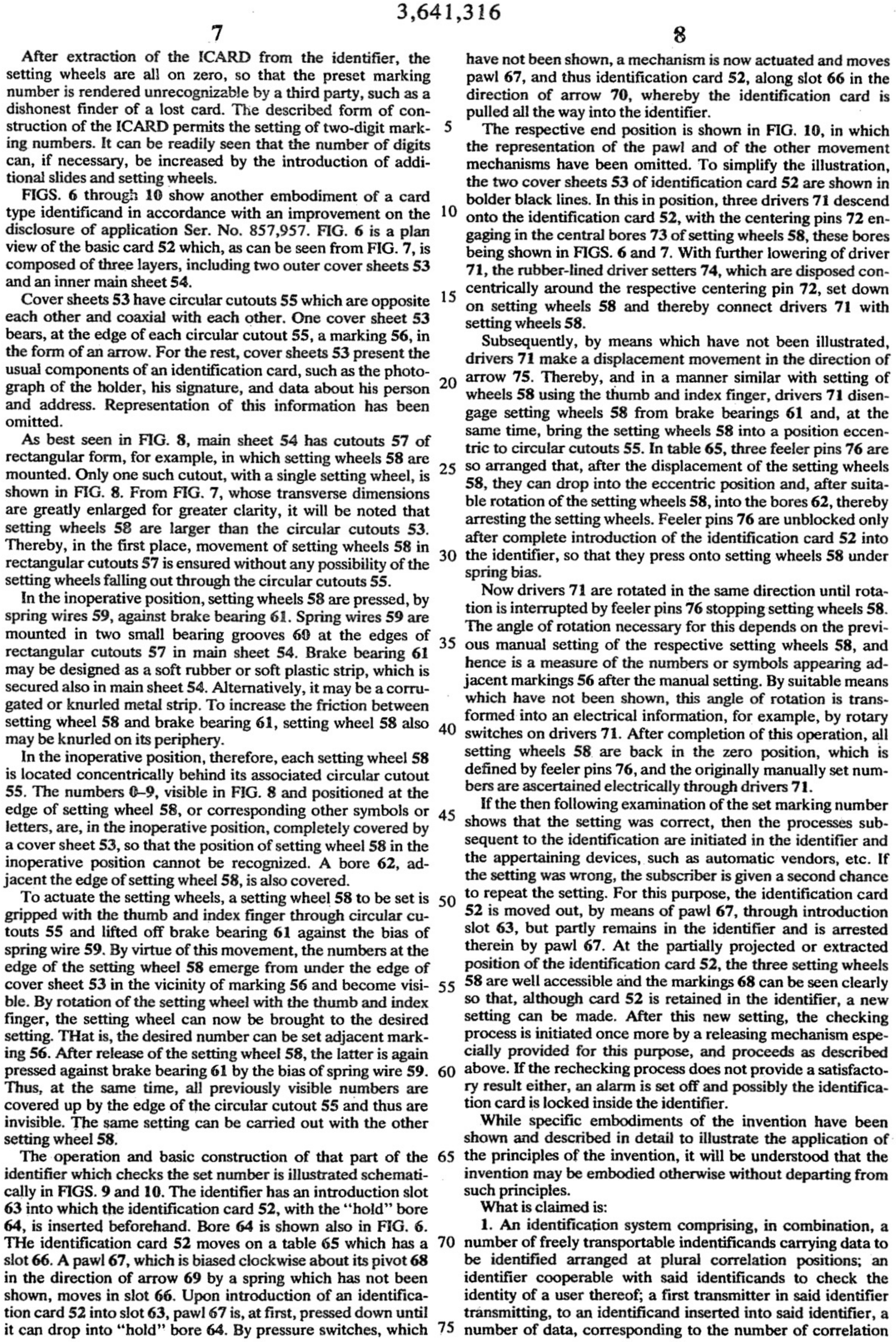
FIG. **5** illustrates one of the two slides **41** as it would appear if front cover sheet **33** were removed. Slide **41** is guided in a corresponding recess of front inner sheet **42**, which, for greater clarity, has been hatched. Nose **49** of slide **41** engages in a recess **50** of front inner sheet **42** and limits the stroke of the slide **41** in both directions. Front inner sheet **42** and slide **41** are so designed that, between them, a flat S-shaped spring **51** can be inserted, and this holds slide **41** in the inoperative position shown in FIG. **5**. Shaft **45** of the setting wheel **43**, which latter has been shown in broken lines, does hinder movement of slide **41**, as will be clear from the form of slot **47** as seen in its entirety in FIG. **5**. With slide **41** pressed in, the left end of slot **47** reaches the ledge of setting wheel **43**, and thereby clears the view of one of the symbols at the edge of setting wheel **43**.

Since, at the same time the finger with which slide **41** is pressed inwardly comes in contact with the serrated or toothed circumference of setting wheel **43**, the latter can be set to the desired symbol. After such setting, the finger is removed and thereby at the same time slide **41** is released. The slide **41** returns to its inoperative position, so that the set symbol is covered up by slide **41** and is no longer observable.

The effect of this is that it is made certain that spying in the use of the ICARD is impossible in the identifier. The authorized subscriber sets the marking number on the way to the identifier, that is, at a time when spying is ruled out due to the variability of the location. In the vicinity of the identifier itself, slides **41** cover up the set numbers.

The function of the setting wheel in the identifier will be referred to only briefly, as it has been described in detail in application Ser. No. 857,957. Upon introduction of the ICARD into the identifier, the setting wheel is mechanically set to zero. This zero position is defined by a nose of the setting wheel which fits positively against a corresponding abutment in the rear inner sheet of the ICARD. The path required for the zero setting of the setting wheel, or respectively the path of the ICARD still remaining after the zero setting upon introduction into the slot of the identifier, is measured at the identifier. This measurement defines the previously set marking number.

Figure B.205: Helmut Gröttrup and Jürgen Dethloff invented the smart card, or chip card, in 1966. Earlier, Gröttrup developed avionics systems in Germany during the war and led the German-speaking contributions to the postwar Soviet ballistic missile program.



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After extraction of the ICARD from the identifier, the setting wheels are all on zero, so that the preset marking number is rendered unrecognizable by a third party, such as a dishonest finder of a lost card. The described form of construction of the ICARD permits the setting of two-digit marking numbers. It can be readily seen that the number of digits can, if necessary, be increased by the introduction of additional slides and setting wheels.

FIGS. **6** through **10** show another embodiment of a card type identificand in accordance with an improvement on the disclosure of application Ser. No. 857,957. FIG. **6** is a plan view of the basic card **52** which, as can be seen from FIG. **7**, is composed of three layers, including two outer cover sheets **53** and an inner main sheet **54**.

Cover sheets **53** have circular cutouts **55** which are opposite each other and coaxial with each other. One cover sheet **53** bears, at the edge of each circular cutout **55**, a marking **56**, in the form of an arrow. For the rest, cover sheets **53** present the usual components of an identification card, such as the photograph of the holder, his signature, and data about his person and address. Representation of this information has been omitted.

As best seen in FIG. **8**, main sheet **54** has cutouts **57** of rectangular form, for example, in which setting wheels **58** are mounted. Only one such cutout, with a single setting wheel, is shown in FIG. **8**. From FIG. **7**, whose transverse dimensions are greatly enlarged for greater clarity, it will be noted that setting wheels **58** are larger than the circular cutouts **53**. Thereby, in the first place, movement of setting wheels **58** in rectangular cutouts **57** is ensured without any possibility of the setting wheels falling out through the circular cutouts **55**.

In the inoperative position, setting wheels **58** are pressed, by spring wires **59**, against brake bearing **61**. Spring wires **59** are mounted in two small bearing grooves **60** at the edges of rectangular cutouts **57** in main sheet **54**. Brake bearing **61** may be designed as a soft rubber or soft plastic strip, which is secured also in main sheet **54**. Alternatively, it may be a corrugated or knurled metal strip. To increase the friction between setting wheel **58** and brake bearing **61**, setting wheel **58** also may be knurled on its periphery.

In the inoperative position, therefore, each setting wheel **58** is located concentrically behind its associated circular cutout **55**. The numbers **0–9**, visible in FIG. **8** and positioned at the edge of setting wheel **58**, or corresponding other symbols or letters, are, in the inoperative position, completely covered by a cover sheet **53**, so that the position of setting wheel **58** in the inoperative position cannot be recognized. A bore **62**, adjacent the edge of setting wheel **58**, is also covered.

To actuate the setting wheels, a setting wheel **58** to be set is gripped with the thumb and index finger through circular cutouts **55** and lifted off brake bearing **61** against the bias of spring wire **59**. By virtue of this movement, the numbers at the edge of the setting wheel **58** emerge from under the edge of cover sheet **53** in the vicinity of marking **56** and become visible. By rotation of the setting wheel with the thumb and index finger, the setting wheel can now be brought to the desired setting. THat is, the desired number can be set adjacent marking **56**. After release of the setting wheel **58**, the latter is again pressed against brake bearing **61** by the bias of spring wire **59**. Thus, at the same time, all previously visible numbers are covered up by the edge of the circular cutout **55** and thus are invisible. The same setting can be carried out with the other setting wheel **58**.

The operation and basic construction of that part of the identifier which checks the set number is illustrated schematically in FIGS. **9** and **10**. The identifier has an introduction slot **63** into which the identification card **52**, with the "hold" bore **64**, is inserted beforehand. Bore **64** is shown also in FIG. **6**. THe identification card **52** moves on a table **65** which has a slot **66**. A pawl **67**, which is biased clockwise about its pivot **68** in the direction of arrow **69** by a spring which has not been shown, moves in slot **66**. Upon introduction of an identification card **52** into slot **63**, pawl **67** is, at first, pressed down until it can drop into "hold" bore **64**. By pressure switches, which have not been shown, a mechanism is now actuated and moves pawl **67**, and thus identification card **52**, along slot **66** in the direction of arrow **70**, whereby the identification card is pulled all the way into the identifier.

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The respective end position is shown in FIG. **10**, in which the representation of the pawl and of the other movement mechanisms have been omitted. To simplify the illustration, the two cover sheets **53** of identification card **52** are shown in bolder black lines. In this in position, three drivers **71** descend onto the identification card **52**, with the centering pins **72** engaging in the central bores **73** of setting wheels **58**, these bores being shown in FIGS. **6** and **7**. With further lowering of driver **71**, the rubber-lined driver setters **74**, which are disposed concentrically around the respective centering pin **72**, set down on setting wheels **58** and thereby connect drivers **71** with setting wheels **58**.

Subsequently, by means which have not been illustrated, drivers **71** make a displacement movement in the direction of arrow **75**. Thereby, and in a manner similar with setting of wheels **58** using the thumb and index finger, drivers **71** disengage setting wheels **58** from brake bearings **61** and, at the same time, bring the setting wheels **58** into a position eccentric to circular cutouts **55**. In table **65**, three feeler pins **76** are so arranged that, after the displacement of the setting wheels **58**, they can drop into the eccentric position and, after suitable rotation of the setting wheels **58**, into the bores **62**, thereby arresting the setting wheels. Feeler pins **76** are unblocked only after complete introduction of the identification card **52** into the identifier, so that they press onto setting wheels **58** under spring bias.

Now drivers **71** are rotated in the same direction until rotation is interrupted by feeler pins **76** stopping setting wheels **58**. The angle of rotation necessary for this depends on the previous manual setting of the respective setting wheels **58**, and hence is a measure of the numbers or symbols appearing adjacent markings **56** after the manual setting. By suitable means which have not been shown, this angle of rotation is transformed into an electrical information, for example, by rotary switches on drivers **71**. After completion of this operation, all setting wheels **58** are back in the zero position, which is defined by feeler pins **76**, and the originally manually set numbers are ascertained electrically through drivers **71**.

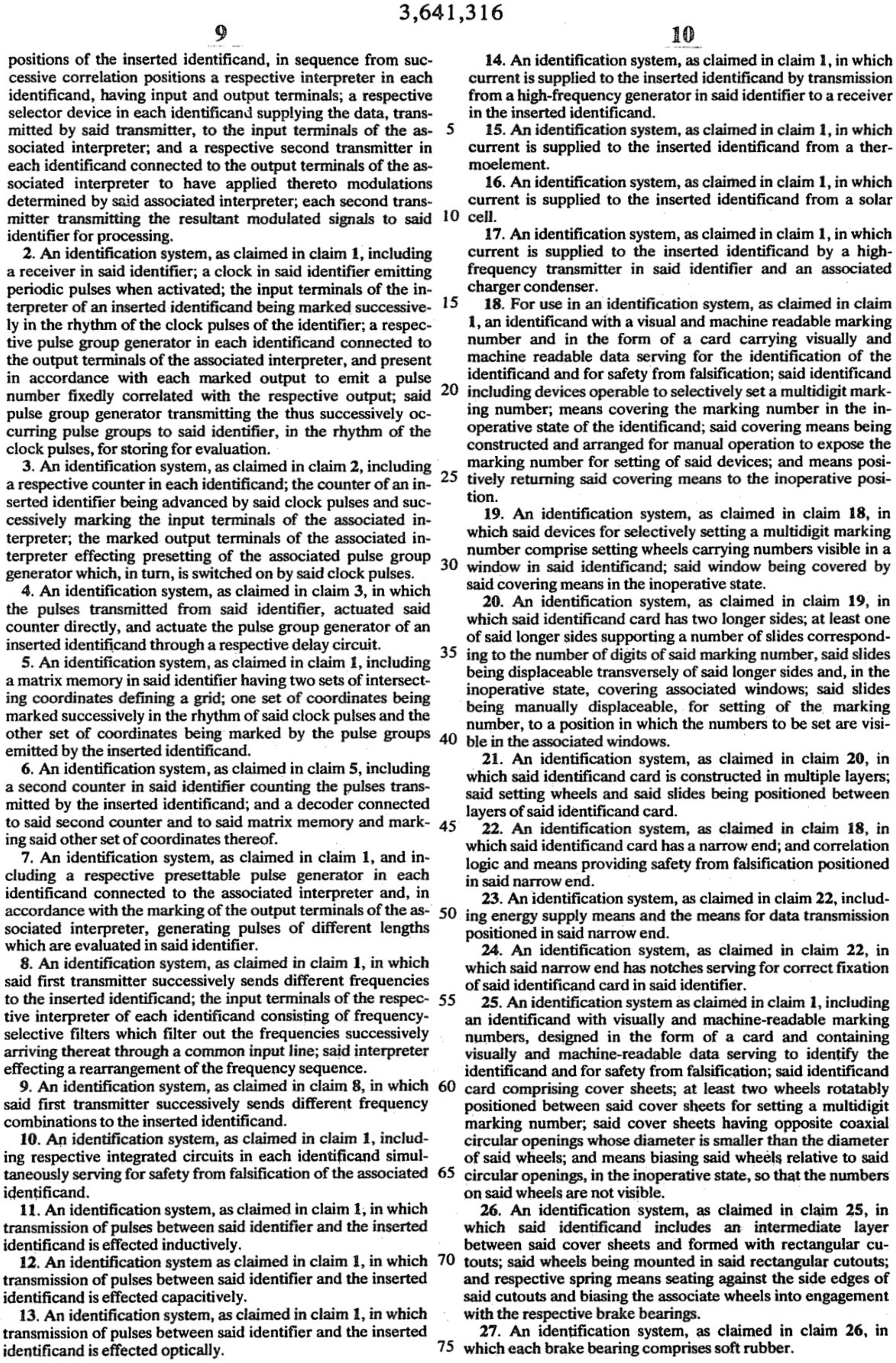
If the then following examination of the set marking number shows that the setting was correct, then the processes subsequent to the identification are initiated in the identifier and the appertaining devices, such as automatic vendors, etc. If the setting was wrong, the subscriber is given a second chance to repeat the setting. For this purpose, the identification card **52** is moved out, by means of pawl **67**, through introduction slot **63**, but partly remains in the identifier and is arrested therein by pawl **67**. At the partially projected or extracted position of the identification card **52**, the three setting wheels **58** are well accessible and the markings **68** can be seen clearly so that, although card **52** is retained in the identifier, a new setting can be made. After this new setting, the checking process is initiated once more by a releasing mechanism especially provided for this purpose, and proceeds as described above. If the rechecking process does not provide a satisfactory result either, an alarm is set off and possibly the identification card is locked inside the identifier.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. An identification system comprising, in combination, a number of freely transportable indentificands carrying data to be identified arranged at plural correlation positions; an identifier cooperable with said identificands to check the identity of a user thereof; a first transmitter in said identifier transmitting, to an identificand inserted into said identifier, a number of data, corresponding to the number of correlation

Figure B.206: Helmut Gröttrup and Jürgen Dethloff invented the smart card, or chip card, in 1966. Earlier, Gröttrup developed avionics systems in Germany during the war and led the German-speaking contributions to the postwar Soviet ballistic missile program.



positions of the inserted identificand, in sequence from successive correlation positions a respective interpreter in each identificand, having input and output terminals; a respective selector device in each identificand supplying the data, transmitted by said transmitter, to the input terminals of the associated interpreter; and a respective second transmitter in each identificand connected to the output terminals of the associated interpreter to have applied thereto modulations determined by said associated interpreter; each second transmitter transmitting the resultant modulated signals to said identifier for processing.

2. An identification system, as claimed in claim **1**, including a receiver in said identifier; a clock in said identifier emitting periodic pulses when activated; the input terminals of the interpreter of an inserted identificand being marked successively in the rhythm of the clock pulses of the identifier; a respective pulse group generator in each identificand connected to the output terminals of the associated interpreter, and present in accordance with each marked output to emit a pulse number fixedly correlated with the respective output; said pulse group generator transmitting the thus successively occurring pulse groups to said identifier, in the rhythm of the clock pulses, for storing for evaluation.

3. An identification system, as claimed in claim **2**, including a respective counter in each identificand; the counter of an inserted identifier being advanced by said clock pulses and successively marking the input terminals of the associated interpreter; the marked output terminals of the associated interpreter effecting presetting of the associated pulse group generator which, in turn, is switched on by said clock pulses.

4. An identification system, as claimed in claim **3**, in which the pulses transmitted from said identifier, actuated said counter directly, and actuate the pulse group generator of an inserted identificand through a respective delay circuit.

5. An identification system, as claimed in claim **1**, including a matrix memory in said identifier having two sets of intersecting coordinates defining a grid; one set of coordinates being marked successively in the rhythm of said clock pulses and the other set of coordinates being marked by the pulse groups emitted by the inserted identificand.

6. An identification system, as claimed in claim **5**, including a second counter in said identifier counting the pulses transmitted by the inserted identificand; and a decoder connected to said second counter and to said matrix memory and marking said other set of coordinates thereof.

7. An identification system, as claimed in claim **1**, and including a respective presettable pulse generator in each identificand connected to the associated interpreter and, in accordance with the marking of the output terminals of the associated interpreter, generating pulses of different lengths which are evaluated in said identifier.

8. An identification system, as claimed in claim **1**, in which said first transmitter successively sends different frequencies to the inserted identificand; the input terminals of the respective interpreter of each identificand consisting of frequency-selective filters which filter out the frequencies successively arriving thereat through a common input line; said interpreter effecting a rearrangement of the frequency sequence.

9. An identification system, as claimed in claim **8**, in which said first transmitter successively sends different frequency combinations to the inserted identificand.

10. An identification system, as claimed in claim **1**, including respective integrated circuits in each identificand simultaneously serving for safety from falsification of the associated identificand.

11. An identification system, as claimed in claim **1**, in which transmission of pulses between said identifier and the inserted identificand is effected inductively.

12. An identification system as claimed in claim **1**, in which transmission of pulses between said identifier and the inserted identificand is effected capacitively.

13. An identification system, as claimed in claim **1**, in which transmission of pulses between said identifier and the inserted identificand is effected optically.

14. An identification system, as claimed in claim **1**, in which current is supplied to the inserted identificand by transmission from a high-frequency generator in said identifier to a receiver in the inserted identificand.

15. An identification system, as claimed in claim **1**, in which current is supplied to the inserted identificand from a thermoelement.

16. An identification system, as claimed in claim **1**, in which current is supplied to the inserted identificand from a solar cell.

17. An identification system, as claimed in claim **1**, in which current is supplied to the inserted identificand by a high-frequency transmitter in said identifier and an associated charger condenser.

18. For use in an identification system, as claimed in claim **1**, an identificand with a visual and machine readable marking number and in the form of a card carrying visually and machine readable data serving for the identification of the identificand and for safety from falsification; said identificand including devices operable to selectively set a multidigit marking number; means covering the marking number in the inoperative state of the identificand; said covering means being constructed and arranged for manual operation to expose the marking number for setting of said devices; and means positively returning said covering means to the inoperative position.

19. An identification system, as claimed in claim **18**, in which said devices for selectively setting a multidigit marking number comprise setting wheels carrying numbers visible in a window in said identificand; said window being covered by said covering means in the inoperative state.

20. An identification system, as claimed in claim **19**, in which said identificand card has two longer sides; at least one of said longer sides supporting a number of slides corresponding to the number of digits of said marking number, said slides being displaceable transversely of said longer sides and, in the inoperative state, covering associated windows; said slides being manually displaceable, for setting of the marking number, to a position in which the numbers to be set are visible in the associated windows.

21. An identification system, as claimed in claim **20**, in which said identificand card is constructed in multiple layers; said setting wheels and said slides being positioned between layers of said identificand card.

22. An identification system, as claimed in claim **18**, in which said identificand card has a narrow end; and correlation logic and means providing safety from falsification positioned in said narrow end.

23. An identification system, as claimed in claim **22**, including energy supply means and the means for data transmission positioned in said narrow end.

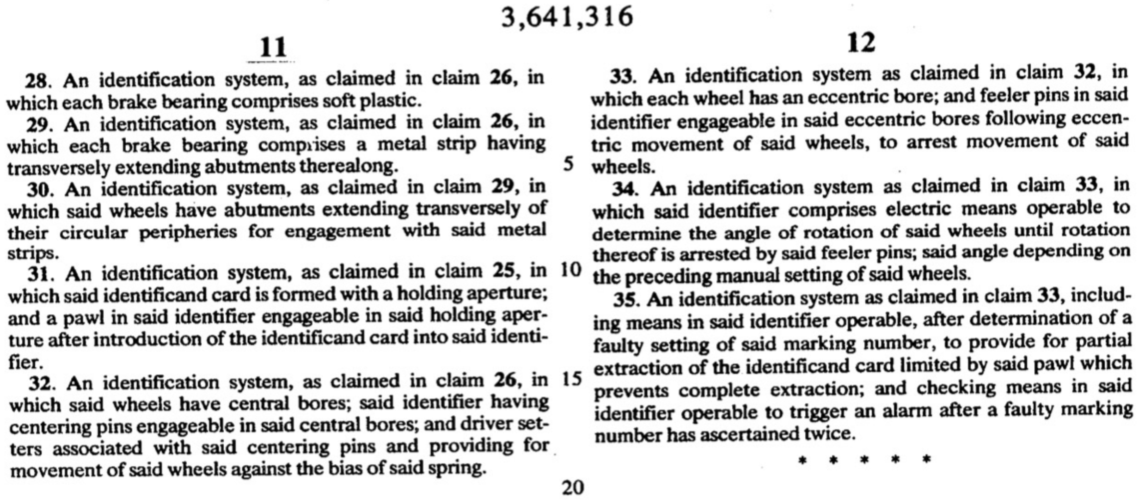
24. An identification system, as claimed in claim **22**, in which said narrow end has notches serving for correct fixation of said identificand card in said identifier.

25. An identification system as claimed in claim **1**, including an identificand with visually and machine-readable marking numbers, designed in the form of a card and containing visually and machine-readable data serving to identify the identificand and for safety from falsification; said identificand card comprising cover sheets; at least two wheels rotatably positioned between said cover sheets for setting a multidigit marking number; said cover sheets having opposite coaxial circular openings whose diameter is smaller than the diameter of said wheels; and means biasing said wheels relative to said circular openings, in the inoperative state, so that the numbers on said wheels are not visible.

26. An identification system, as claimed in claim **25**, in which said identificand includes an intermediate layer between said cover sheets and formed with rectangular cutouts; said wheels being mounted in said rectangular cutouts; and respective spring means seating against the side edges of said cutouts and biasing the associate wheels into engagement with the respective brake bearings.

27. An identification system, as claimed in claim **26**, in which each brake bearing comprises soft rubber.

Figure B.207: Helmut Gröttrup and Jürgen Dethloff invented the smart card, or chip card, in 1966. Earlier, Gröttrup developed avionics systems in Germany during the war and led the German-speaking contributions to the postwar Soviet ballistic missile program.



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28. An identification system, as claimed in claim **26,** in which each brake bearing comprises soft plastic.

29. An identification system, as claimed in claim **26,** in which each brake bearing comprises a metal strip having transversely extending abutments therealong.

30. An identification system, as claimed in claim **29,** in which said wheels have abutments extending transversely of their circular peripheries for engagement with said metal strips.

31. An identification system, as claimed in claim **25,** in which said identificand card is formed with a holding aperture; and a pawl in said identifier engageable in said holding aperture after introduction of the identificand card into said identifier.

32. An identification system, as claimed in claim **26,** in which said wheels have central bores; said identifier having centering pins engageable in said central bores; and driver setters associated with said centering pins and providing for movement of said wheels against the bias of said spring.

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33. An identification system as claimed in claim **32,** in which each wheel has an eccentric bore; and feeler pins in said identifier engageable in said eccentric bores following eccentric movement of said wheels, to arrest movement of said wheels.

34. An identification system as claimed in claim **33,** in which said identifier comprises electric means operable to determine the angle of rotation of said wheels until rotation thereof is arrested by said feeler pins; said angle depending on the preceding manual setting of said wheels.

35. An identification system as claimed in claim **33,** including means in said identifier operable, after determination of a faulty setting of said marking number, to provide for partial extraction of the identificand card limited by said pawl which prevents complete extraction; and checking means in said identifier operable to trigger an alarm after a faulty marking number has ascertained twice.

* * * * *

Figure B.208: Helmut Gröttrup and Jürgen Dethloff invented the smart card, or chip card, in 1966. Earlier, Gröttrup developed avionics systems in Germany during the war and led the German-speaking contributions to the postwar Soviet ballistic missile program.

B.4 Light Emitting Diodes (LEDs) and Laser Diodes

[German-speaking scientists played leading roles in the development of light emitting diodes (LEDs) and laser diodes. LEDs are much more energy-efficient than incandescent and even fluorescent bulbs, so they are now widely used for everything from illuminated video screens to room lighting. Laser diodes are more compact, rugged, and efficient than most other types of lasers, so they are used for everything from optical disc drives to laser pointers. Both LEDs and laser diodes are utilized in different types of bar code scanners.

Bernhard Gudden (German, 1892–1945) and Robert Pohl (German, 1884–1976) developed and demonstrated the first electroluminescent semiconductor devices, the forerunners of LEDs, during the period 1919–1923 [*Zeitschrift für Physik* 18:1:199–206 (1923)]. They also developed improved photoelectric cells. See pp. 1106 and 2889.

Zoltan Bay (Hungarian, 1900–1992) and György Szigeti (Hungarian, 1905–1978) extended the work of Gudden and Pohl and filed patent applications on true LEDs in 1939, as shown on pp. 2890–2894.

Kurt Lehovec (Bohemian/Austrian/Czech, 1918–2012) worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs, quite possibly based on wartime work. See pp. 1097, 2757–2759, and 2895–2910.

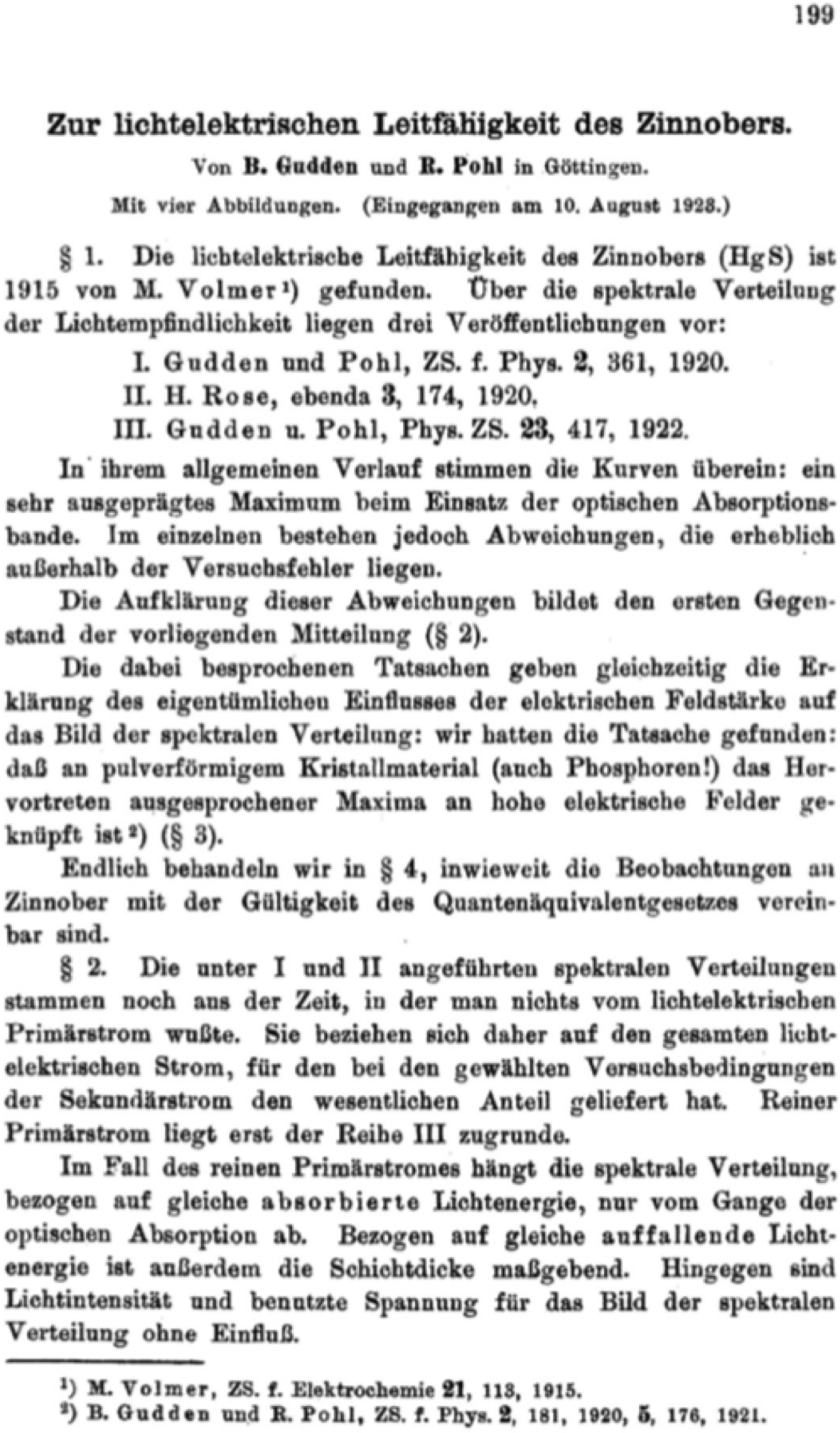
John von Neumann (Hungarian, 1903–1957) made a detailed proposal for laser diodes in 1953, which was likely circulated via his many consulting roles in government and industry, and therefore had a broad and profound influence [*IEEE Journal of Quantum Electronics* 23:6:659–673 (1987)]. See p. 2911.

Walter Heywang (German, 1923–2010) filed detailed patent applications on laser diodes in 1958 (pp. 2912–2916)

Herbert Kroemer (German, 1928–) filed patent applications on the double-heterostructure laser diode in 1963 (pp. 2917–2922). He also invented the drift transistor in 1953 and III-V semiconductor heterostructures in 1966. Kroemer won the Nobel Prize in Physics in 2000 for his innovations in microelectronics (p. 1104).

Other groups produced various types of laser diodes around the same time as Heywang and Kroemer. More archival research is needed to determine whether work in the other laser diode groups was seeded by Heywang's or Kroemer's ideas prior to their formal patent applications, by von Neumann's 1953 proposal, or by other German-speaking work going back to World War II.]

Bernhard Gudden (1892–1945) and Robert Pohl (1884–1976) developed electroluminescent semiconductor devices (1919–1923) [*Zeitschrift für Physik* 18:1:199–206 (1923)]



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Zur lichtelektrischen Leitfähigkeit des Zinnobers.

Von **B. Gudden** und **R. Pohl** in Göttingen.

Mit vier Abbildungen. (Eingegangen am 10. August 1923.)

§ 1. Die lichtelektrische Leitfähigkeit des Zinnobers (HgS) ist 1915 von M. Volmer[1]) gefunden. Über die spektrale Verteilung der Lichtempfindlichkeit liegen drei Veröffentlichungen vor:

I. Gudden und Pohl, ZS. f. Phys. **2**, 361, 1920.
II. H. Rose, ebenda **3**, 174, 1920.
III. Gudden u. Pohl, Phys. ZS. **23**, 417, 1922.

In ihrem allgemeinen Verlauf stimmen die Kurven überein: ein sehr ausgeprägtes Maximum beim Einsatz der optischen Absorptionsbande. Im einzelnen bestehen jedoch Abweichungen, die erheblich außerhalb der Versuchsfehler liegen.

Die Aufklärung dieser Abweichungen bildet den ersten Gegenstand der vorliegenden Mitteilung (§ 2).

Die dabei besprochenen Tatsachen geben gleichzeitig die Erklärung des eigentümlichen Einflusses der elektrischen Feldstärke auf das Bild der spektralen Verteilung: wir hatten die Tatsache gefunden: daß an pulverförmigem Kristallmaterial (auch Phosphoren!) das Hervortreten ausgesprochener Maxima an hohe elektrische Felder geknüpft ist[2]) (§ 3).

Endlich behandeln wir in § 4, inwieweit die Beobachtungen an Zinnober mit der Gültigkeit des Quantenäquivalentgesetzes vereinbar sind.

§ 2. Die unter I und II angeführten spektralen Verteilungen stammen noch aus der Zeit, in der man nichts vom lichtelektrischen Primärstrom wußte. Sie beziehen sich daher auf den gesamten lichtelektrischen Strom, für den bei den gewählten Versuchsbedingungen der Sekundärstrom den wesentlichen Anteil geliefert hat. Reiner Primärstrom liegt erst der Reihe III zugrunde.

Im Fall des reinen Primärstromes hängt die spektrale Verteilung, bezogen auf gleiche absorbierte Lichtenergie, nur vom Gange der optischen Absorption ab. Bezogen auf gleiche auffallende Lichtenergie ist außerdem die Schichtdicke maßgebend. Hingegen sind Lichtintensität und benutzte Spannung für das Bild der spektralen Verteilung ohne Einfluß.

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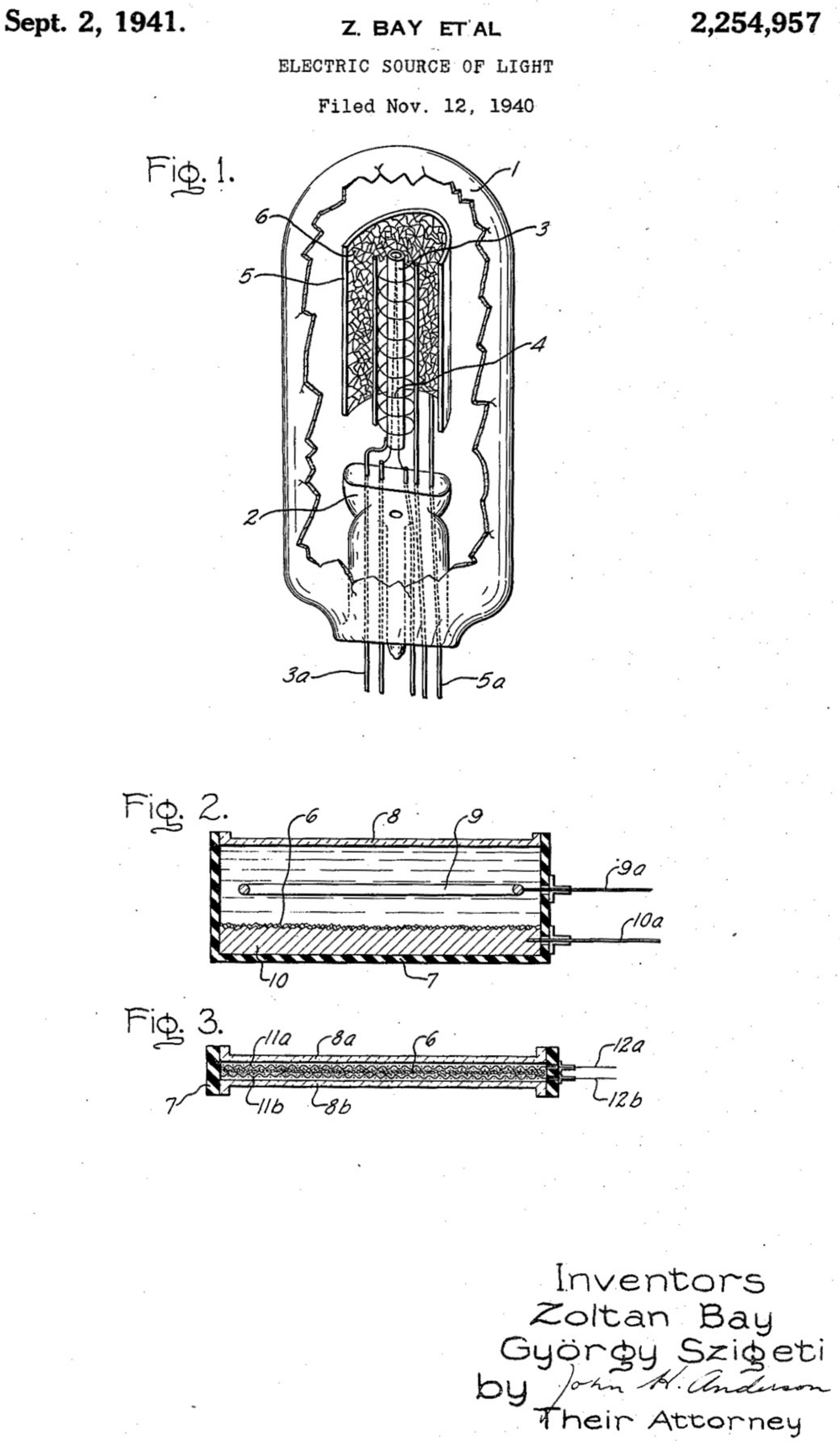
[1]) M. Volmer, ZS. f. Elektrochemie **21**, 113, 1915.
[2]) B. Gudden und R. Pohl, ZS. f. Phys. **2**, 181, 1920, **5**, 176, 1921.

Figure B.209: Bernhard Gudden and Robert Pohl developed electroluminescent semiconductor devices 1919–1923 [*Zeitschrift für Physik* 18:1:199–206 (1923)].



Sept. 2, 1941. Z. BAY ET AL **2,254,957**

ELECTRIC SOURCE OF LIGHT

Filed Nov. 12, 1940

Fig. 1.

1
6
3
5
4
2
3a
5a

Fig. 2.

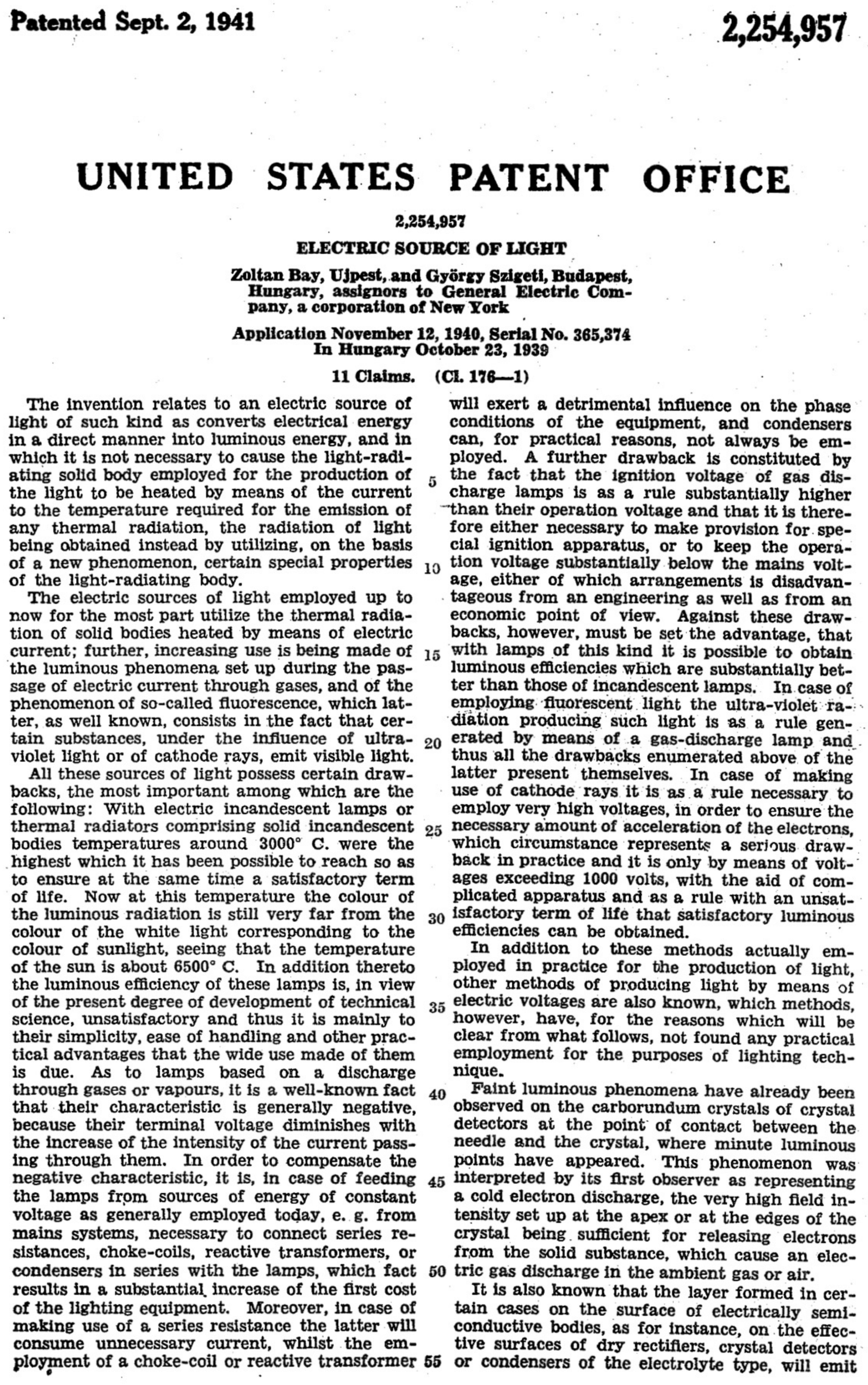
6
8
9
9a
10a
10
7

Fig. 3.

11a
8a
6
12a
7
11b
8b
12b

Inventors
Zoltan Bay
György Szigeti
by John H. Anderson
Their Attorney

Figure B.210: Zoltan Bay and György Szigeti filed patent applications on light emitting diodes (LEDs) in 1939.



Patented Sept. 2, 1941 **2,254,957**

UNITED STATES PATENT OFFICE

2,254,957

ELECTRIC SOURCE OF LIGHT

Zoltan Bay, Ujpest, and György Szigeti, Budapest, Hungary, assignors to General Electric Company, a corporation of New York

Application November 12, 1940, Serial No. 365,374
In Hungary October 23, 1939

11 Claims. (Cl. 176—1)

The invention relates to an electric source of light of such kind as converts electrical energy in a direct manner into luminous energy, and in which it is not necessary to cause the light-radiating solid body employed for the production of the light to be heated by means of the current to the temperature required for the emission of any thermal radiation, the radiation of light being obtained instead by utilizing, on the basis of a new phenomenon, certain special properties of the light-radiating body.

The electric sources of light employed up to now for the most part utilize the thermal radiation of solid bodies heated by means of electric current; further, increasing use is being made of the luminous phenomena set up during the passage of electric current through gases, and of the phenomenon of so-called fluorescence, which latter, as well known, consists in the fact that certain substances, under the influence of ultra-violet light or of cathode rays, emit visible light.

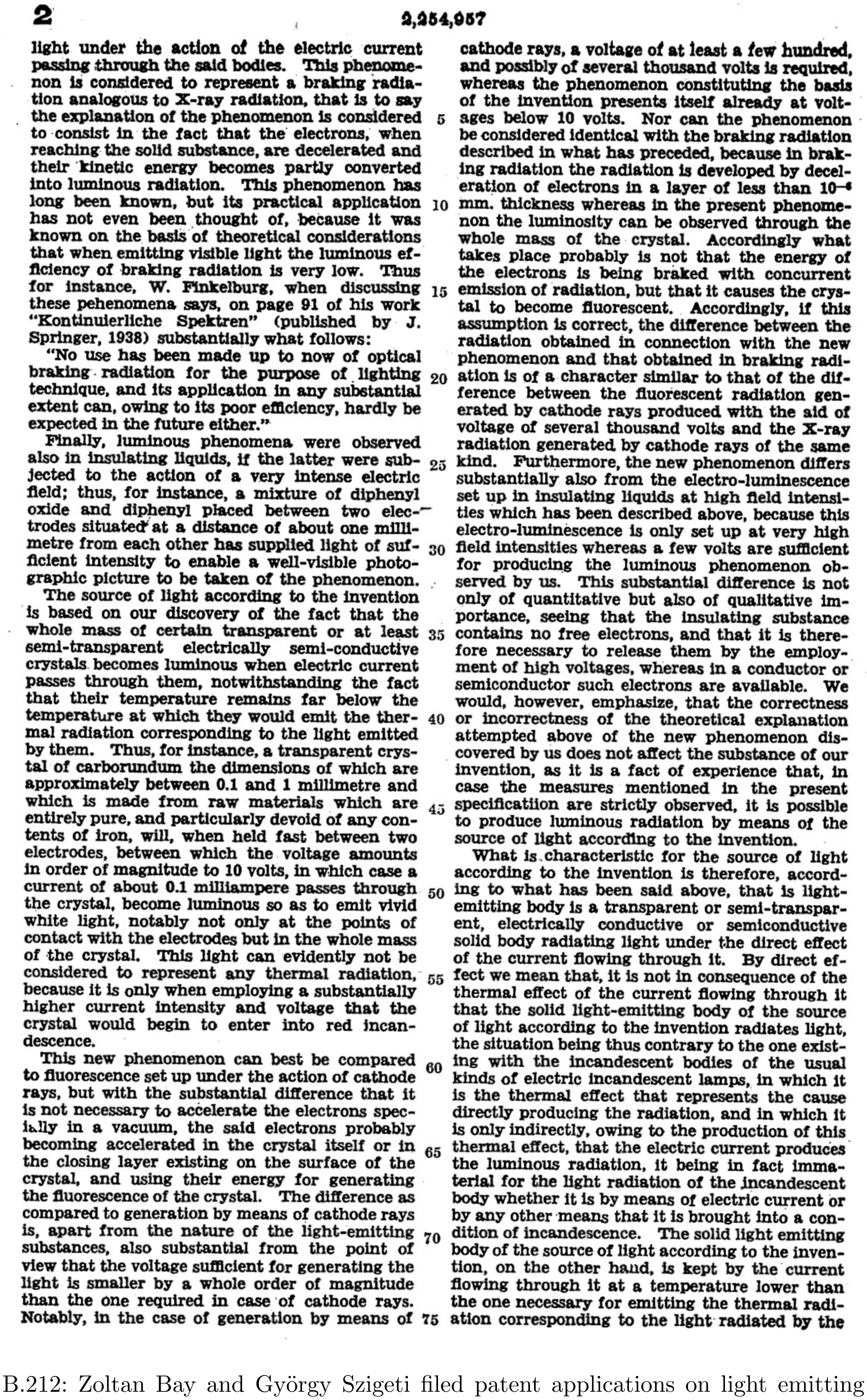
All these sources of light possess certain drawbacks, the most important among which are the following: With electric incandescent lamps or thermal radiators comprising solid incandescent bodies temperatures around 3000° C. were the highest which it has been possible to reach so as to ensure at the same time a satisfactory term of life. Now at this temperature the colour of the luminous radiation is still very far from the colour of the white light corresponding to the colour of sunlight, seeing that the temperature of the sun is about 6500° C. In addition thereto the luminous efficiency of these lamps is, in view of the present degree of development of technical science, unsatisfactory and thus it is mainly to their simplicity, ease of handling and other practical advantages that the wide use made of them is due. As to lamps based on a discharge through gases or vapours, it is a well-known fact that their characteristic is generally negative, because their terminal voltage diminishes with the increase of the intensity of the current passing through them. In order to compensate the negative characteristic, it is, in case of feeding the lamps from sources of energy of constant voltage as generally employed today, e. g. from mains systems, necessary to connect series resistances, choke-coils, reactive transformers, or condensers in series with the lamps, which fact results in a substantial increase of the first cost of the lighting equipment. Moreover, in case of making use of a series resistance the latter will consume unnecessary current, whilst the employment of a choke-coil or reactive transformer will exert a detrimental influence on the phase conditions of the equipment, and condensers can, for practical reasons, not always be employed. A further drawback is constituted by the fact that the ignition voltage of gas discharge lamps is as a rule substantially higher than their operation voltage and that it is therefore either necessary to make provision for special ignition apparatus, or to keep the operation voltage substantially below the mains voltage, either of which arrangements is disadvantageous from an engineering as well as from an economic point of view. Against these drawbacks, however, must be set the advantage, that with lamps of this kind it is possible to obtain luminous efficiencies which are substantially better than those of incandescent lamps. In case of employing fluorescent light the ultra-violet radiation producing such light is as a rule generated by means of a gas-discharge lamp and thus all the drawbacks enumerated above of the latter present themselves. In case of making use of cathode rays it is as a rule necessary to employ very high voltages, in order to ensure the necessary amount of acceleration of the electrons, which circumstance represents a serious drawback in practice and it is only by means of voltages exceeding 1000 volts, with the aid of complicated apparatus and as a rule with an unsatisfactory term of life that satisfactory luminous efficiencies can be obtained.

In addition to these methods actually employed in practice for the production of light, other methods of producing light by means of electric voltages are also known, which methods, however, have, for the reasons which will be clear from what follows, not found any practical employment for the purposes of lighting technique.

Faint luminous phenomena have already been observed on the carborundum crystals of crystal detectors at the point of contact between the needle and the crystal, where minute luminous points have appeared. This phenomenon was interpreted by its first observer as representing a cold electron discharge, the very high field intensity set up at the apex or at the edges of the crystal being sufficient for releasing electrons from the solid substance, which cause an electric gas discharge in the ambient gas or air.

It is also known that the layer formed in certain cases on the surface of electrically semiconductive bodies, as for instance, on the effective surfaces of dry rectifiers, crystal detectors or condensers of the electrolyte type, will emit

Figure B.211: Zoltan Bay and György Szigeti filed patent applications on light emitting diodes (LEDs) in 1939.



2 2,254,957

light under the action of the electric current passing through the said bodies. This phenomenon is considered to represent a braking radiation analogous to X-ray radiation, that is to say the explanation of the phenomenon is considered to consist in the fact that the electrons, when reaching the solid substance, are decelerated and their kinetic energy becomes partly converted into luminous radiation. This phenomenon has long been known, but its practical application has not even been thought of, because it was known on the basis of theoretical considerations that when emitting visible light the luminous efficiency of braking radiation is very low. Thus for instance, W. Finkelburg, when discussing these pehenomena says, on page 91 of his work "Kontinuierliche Spektren" (published by J. Springer, 1938) substantially what follows:

"No use has been made up to now of optical braking radiation for the purpose of lighting technique, and its application in any substantial extent can, owing to its poor efficiency, hardly be expected in the future either."

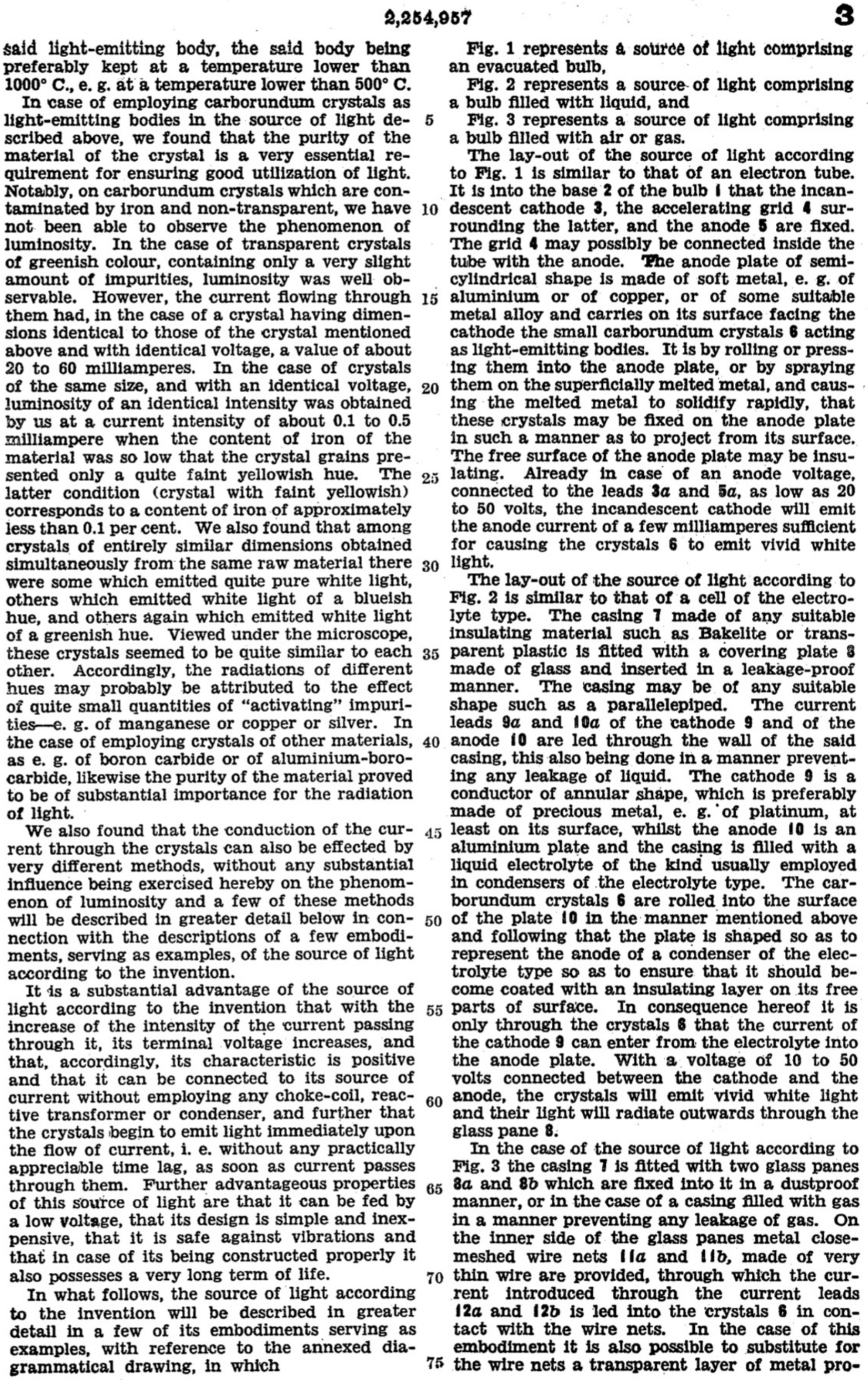
Finally, luminous phenomena were observed also in insulating liquids, if the latter were subjected to the action of a very intense electric field; thus, for instance, a mixture of diphenyl oxide and diphenyl placed between two electrodes situated at a distance of about one millimetre from each other has supplied light of sufficient intensity to enable a well-visible photographic picture to be taken of the phenomenon.

The source of light according to the invention is based on our discovery of the fact that the whole mass of certain transparent or at least semi-transparent electrically semi-conductive crystals becomes luminous when electric current passes through them, notwithstanding the fact that their temperature remains far below the temperature at which they would emit the thermal radiation corresponding to the light emitted by them. Thus, for instance, a transparent crystal of carborundum the dimensions of which are approximately between 0.1 and 1 millimetre and which is made from raw materials which are entirely pure, and particularly devoid of any contents of iron, will, when held fast between two electrodes, between which the voltage amounts in order of magnitude to 10 volts, in which case a current of about 0.1 milliampere passes through the crystal, become luminous so as to emit vivid white light, notably not only at the points of contact with the electrodes but in the whole mass of the crystal. This light can evidently not be considered to represent any thermal radiation, because it is only when employing a substantially higher current intensity and voltage that the crystal would begin to enter into red incandescence.

This new phenomenon can best be compared to fluorescence set up under the action of cathode rays, but with the substantial difference that it is not necessary to accelerate the electrons specially in a vacuum, the said electrons probably becoming accelerated in the crystal itself or in the closing layer existing on the surface of the crystal, and using their energy for generating the fluorescence of the crystal. The difference as compared to generation by means of cathode rays is, apart from the nature of the light-emitting substances, also substantial from the point of view that the voltage sufficient for generating the light is smaller by a whole order of magnitude than the one required in case of cathode rays. Notably, in the case of generation by means of cathode rays, a voltage of at least a few hundred, and possibly of several thousand volts is required, whereas the phenomenon constituting the basis of the invention presents itself already at voltages below 10 volts. Nor can the phenomenon be considered identical with the braking radiation described in what has preceded, because in braking radiation the radiation is developed by deceleration of electrons in a layer of less than 10^{-6} mm. thickness whereas in the present phenomenon the luminosity can be observed through the whole mass of the crystal. Accordingly what takes place probably is not that the energy of the electrons is being braked with concurrent emission of radiation, but that it causes the crystal to become fluorescent. Accordingly, if this assumption is correct, the difference between the radiation obtained in connection with the new phenomenon and that obtained in braking radiation is of a character similar to that of the difference between the fluorescent radiation generated by cathode rays produced with the aid of voltage of several thousand volts and the X-ray radiation generated by cathode rays of the same kind. Furthermore, the new phenomenon differs substantially also from the electro-luminescence set up in insulating liquids at high field intensities which has been described above, because this electro-luminescence is only set up at very high field intensities whereas a few volts are sufficient for producing the luminous phenomenon observed by us. This substantial difference is not only of quantitative but also of qualitative importance, seeing that the insulating substance contains no free electrons, and that it is therefore necessary to release them by the employment of high voltages, whereas in a conductor or semiconductor such electrons are available. We would, however, emphasize, that the correctness or incorrectness of the theoretical explanation attempted above of the new phenomenon discovered by us does not affect the substance of our invention, as it is a fact of experience that, in case the measures mentioned in the present specificatiion are strictly observed, it is possible to produce luminous radiation by means of the source of light according to the invention.

What is characteristic for the source of light according to the invention is therefore, according to what has been said above, that is light-emitting body is a transparent or semi-transparent, electrically conductive or semiconductive solid body radiating light under the direct effect of the current flowing through it. By direct effect we mean that, it is not in consequence of the thermal effect of the current flowing through it that the solid light-emitting body of the source of light according to the invention radiates light, the situation being thus contrary to the one existing with the incandescent bodies of the usual kinds of electric incandescent lamps, in which it is the thermal effect that represents the cause directly producing the radiation, and in which it is only indirectly, owing to the production of this thermal effect, that the electric current produces the luminous radiation, it being in fact immaterial for the light radiation of the incandescent body whether it is by means of electric current or by any other means that it is brought into a condition of incandescence. The solid light emitting body of the source of light according to the invention, on the other hand, is kept by the current flowing through it at a temperature lower than the one necessary for emitting the thermal radiation corresponding to the light radiated by the

Figure B.212: Zoltan Bay and György Szigeti filed patent applications on light emitting diodes (LEDs) in 1939.



said light-emitting body, the said body being preferably kept at a temperature lower than 1000° C., e. g. at a temperature lower than 500° C.

In case of employing carborundum crystals as light-emitting bodies in the source of light described above, we found that the purity of the material of the crystal is a very essential requirement for ensuring good utilization of light. Notably, on carborundum crystals which are contaminated by iron and non-transparent, we have not been able to observe the phenomenon of luminosity. In the case of transparent crystals of greenish colour, containing only a very slight amount of impurities, luminosity was well observable. However, the current flowing through them had, in the case of a crystal having dimensions identical to those of the crystal mentioned above and with identical voltage, a value of about 20 to 60 milliamperes. In the case of crystals of the same size, and with an identical voltage, luminosity of an identical intensity was obtained by us at a current intensity of about 0.1 to 0.5 milliampere when the content of iron of the material was so low that the crystal grains presented only a quite faint yellowish hue. The latter condition (crystal with faint yellowish) corresponds to a content of iron of approximately less than 0.1 per cent. We also found that among crystals of entirely similar dimensions obtained simultaneously from the same raw material there were some which emitted quite pure white light, others which emitted white light of a blueish hue, and others again which emitted white light of a greenish hue. Viewed under the microscope, these crystals seemed to be quite similar to each other. Accordingly, the radiations of different hues may probably be attributed to the effect of quite small quantities of "activating" impurities—e. g. of manganese or copper or silver. In the case of employing crystals of other materials, as e. g. of boron carbide or of aluminium-borocarbide, likewise the purity of the material proved to be of substantial importance for the radiation of light.

We also found that the conduction of the current through the crystals can also be effected by very different methods, without any substantial influence being exercised hereby on the phenomenon of luminosity and a few of these methods will be described in greater detail below in connection with the descriptions of a few embodiments, serving as examples, of the source of light according to the invention.

It is a substantial advantage of the source of light according to the invention that with the increase of the intensity of the current passing through it, its terminal voltage increases, and that, accordingly, its characteristic is positive and that it can be connected to its source of current without employing any choke-coil, reactive transformer or condenser, and further that the crystals begin to emit light immediately upon the flow of current, i. e. without any practically appreciable time lag, as soon as current passes through them. Further advantageous properties of this source of light are that it can be fed by a low voltage, that its design is simple and inexpensive, that it is safe against vibrations and that in case of its being constructed properly it also possesses a very long term of life.

In what follows, the source of light according to the invention will be described in greater detail in a few of its embodiments serving as examples, with reference to the annexed diagrammatical drawing, in which

Fig. 1 represents a source of light comprising an evacuated bulb,

Fig. 2 represents a source of light comprising a bulb filled with liquid, and

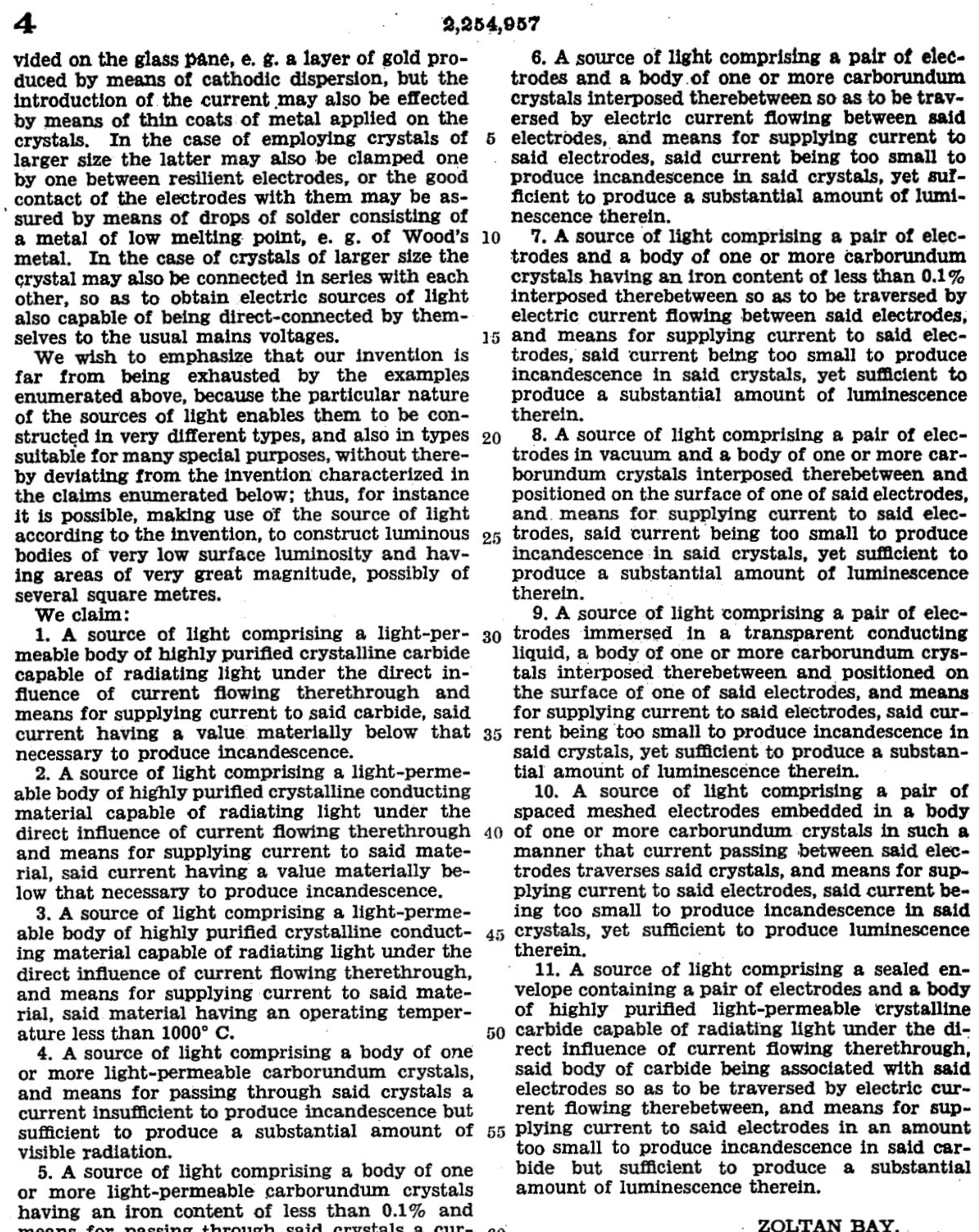
Fig. 3 represents a source of light comprising a bulb filled with air or gas.

The lay-out of the source of light according to Fig. 1 is similar to that of an electron tube. It is into the base 2 of the bulb 1 that the incandescent cathode 3, the accelerating grid 4 surrounding the latter, and the anode 5 are fixed. The grid 4 may possibly be connected inside the tube with the anode. The anode plate of semicylindrical shape is made of soft metal, e. g. of aluminium or of copper, or of some suitable metal alloy and carries on its surface facing the cathode the small carborundum crystals 6 acting as light-emitting bodies. It is by rolling or pressing them into the anode plate, or by spraying them on the superficially melted metal, and causing the melted metal to solidify rapidly, that these crystals may be fixed on the anode plate in such a manner as to project from its surface. The free surface of the anode plate may be insulating. Already in case of an anode voltage, connected to the leads 3*a* and 5*a*, as low as 20 to 50 volts, the incandescent cathode will emit the anode current of a few milliamperes sufficient for causing the crystals 6 to emit vivid white light.

The lay-out of the source of light according to Fig. 2 is similar to that of a cell of the electrolyte type. The casing 7 made of any suitable insulating material such as Bakelite or transparent plastic is fitted with a covering plate 8 made of glass and inserted in a leakage-proof manner. The casing may be of any suitable shape such as a parallelepiped. The current leads 9*a* and 10*a* of the cathode 9 and of the anode 10 are led through the wall of the said casing, this also being done in a manner preventing any leakage of liquid. The cathode 9 is a conductor of annular shape, which is preferably made of precious metal, e. g. of platinum, at least on its surface, whilst the anode 10 is an aluminium plate and the casing is filled with a liquid electrolyte of the kind usually employed in condensers of the electrolyte type. The carborundum crystals 6 are rolled into the surface of the plate 10 in the manner mentioned above and following that the plate is shaped so as to represent the anode of a condenser of the electrolyte type so as to ensure that it should become coated with an insulating layer on its free parts of surface. In consequence hereof it is only through the crystals 6 that the current of the cathode 9 can enter from the electrolyte into the anode plate. With a voltage of 10 to 50 volts connected between the cathode and the anode, the crystals will emit vivid white light and their light will radiate outwards through the glass pane 8.

In the case of the source of light according to Fig. 3 the casing 7 is fitted with two glass panes 8*a* and 8*b* which are fixed into it in a dustproof manner, or in the case of a casing filled with gas in a manner preventing any leakage of gas. On the inner side of the glass panes metal close-meshed wire nets 11*a* and 11*b*, made of very thin wire are provided, through which the current introduced through the current leads 12*a* and 12*b* is led into the crystals 6 in contact with the wire nets. In the case of this embodiment it is also possible to substitute for the wire nets a transparent layer of metal pro-

Figure B.213: Zoltan Bay and György Szigeti filed patent applications on light emitting diodes (LEDs) in 1939.



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vided on the glass pane, e. g. a layer of gold produced by means of cathodic dispersion, but the introduction of the current may also be effected by means of thin coats of metal applied on the crystals. In the case of employing crystals of larger size the latter may also be clamped one by one between resilient electrodes, or the good contact of the electrodes with them may be assured by means of drops of solder consisting of a metal of low melting point, e. g. of Wood's metal. In the case of crystals of larger size the crystal may also be connected in series with each other, so as to obtain electric sources of light also capable of being direct-connected by themselves to the usual mains voltages.

We wish to emphasize that our invention is far from being exhausted by the examples enumerated above, because the particular nature of the sources of light enables them to be constructed in very different types, and also in types suitable for many special purposes, without thereby deviating from the invention characterized in the claims enumerated below; thus, for instance it is possible, making use of the source of light according to the invention, to construct luminous bodies of very low surface luminosity and having areas of very great magnitude, possibly of several square metres.

We claim:

1. A source of light comprising a light-permeable body of highly purified crystalline carbide capable of radiating light under the direct influence of current flowing therethrough and means for supplying current to said carbide, said current having a value materially below that necessary to produce incandescence.

2. A source of light comprising a light-permeable body of highly purified crystalline conducting material capable of radiating light under the direct influence of current flowing therethrough and means for supplying current to said material, said current having a value materially below that necessary to produce incandescence.

3. A source of light comprising a light-permeable body of highly purified crystalline conducting material capable of radiating light under the direct influence of current flowing therethrough, and means for supplying current to said material, said material having an operating temperature less than 1000° C.

4. A source of light comprising a body of one or more light-permeable carborundum crystals, and means for passing through said crystals a current insufficient to produce incandescence but sufficient to produce a substantial amount of visible radiation.

5. A source of light comprising a body of one or more light-permeable carborundum crystals having an iron content of less than 0.1% and means for passing through said crystals a current insufficient in magnitude to produce incandescence but sufficient to produce a substantial amount of visible radiation.

6. A source of light comprising a pair of electrodes and a body of one or more carborundum crystals interposed therebetween so as to be traversed by electric current flowing between said electrodes, and means for supplying current to said electrodes, said current being too small to produce incandescence in said crystals, yet sufficient to produce a substantial amount of luminescence therein.

7. A source of light comprising a pair of electrodes and a body of one or more carborundum crystals having an iron content of less than 0.1% interposed therebetween so as to be traversed by electric current flowing between said electrodes, and means for supplying current to said electrodes, said current being too small to produce incandescence in said crystals, yet sufficient to produce a substantial amount of luminescence therein.

8. A source of light comprising a pair of electrodes in vacuum and a body of one or more carborundum crystals interposed therebetween and positioned on the surface of one of said electrodes, and means for supplying current to said electrodes, said current being too small to produce incandescence in said crystals, yet sufficient to produce a substantial amount of luminescence therein.

9. A source of light comprising a pair of electrodes immersed in a transparent conducting liquid, a body of one or more carborundum crystals interposed therebetween and positioned on the surface of one of said electrodes, and means for supplying current to said electrodes, said current being too small to produce incandescence in said crystals, yet sufficient to produce a substantial amount of luminescence therein.

10. A source of light comprising a pair of spaced meshed electrodes embedded in a body of one or more carborundum crystals in such a manner that current passing between said electrodes traverses said crystals, and means for supplying current to said electrodes, said current being too small to produce incandescence in said crystals, yet sufficient to produce luminescence therein.

11. A source of light comprising a sealed envelope containing a pair of electrodes and a body of highly purified light-permeable crystalline carbide capable of radiating light under the direct influence of current flowing therethrough, said body of carbide being associated with said electrodes so as to be traversed by electric current flowing therebetween, and means for supplying current to said electrodes in an amount too small to produce incandescence in said carbide but sufficient to produce a substantial amount of luminescence therein.

ZOLTAN BAY.
GYÖRGY SZIGETI.

Figure B.214: Zoltan Bay and György Szigeti filed patent applications on light emitting diodes (LEDs) in 1939.

Jan. 1, 1957 K. LEHOVEC **2,776,367**

PHOTON MODULATION IN SEMICONDUCTORS

Filed Nov. 18, 1952 2 Sheets-Sheet 1

Fig. 1

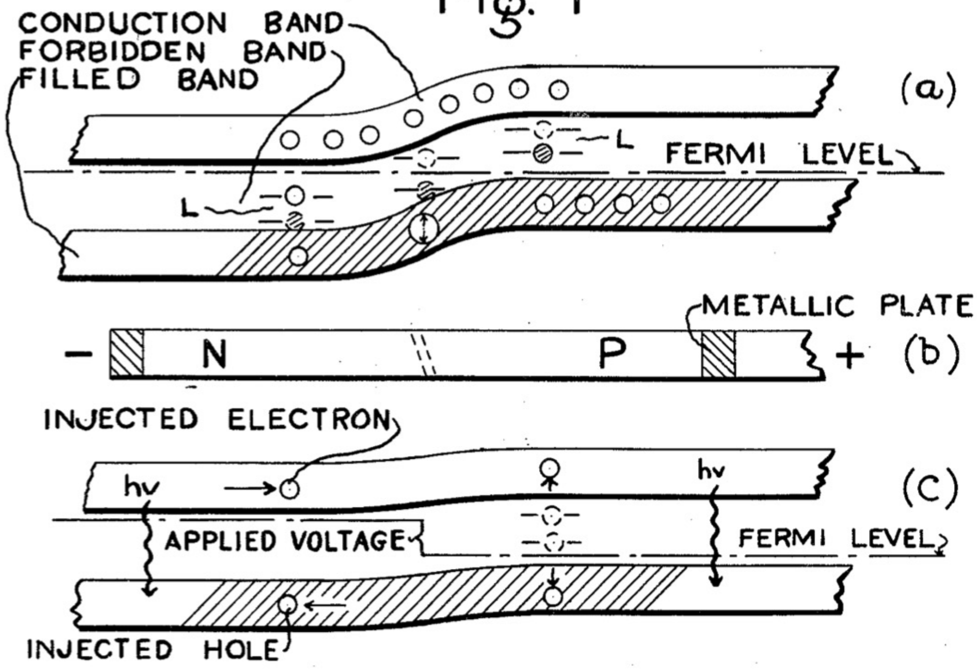
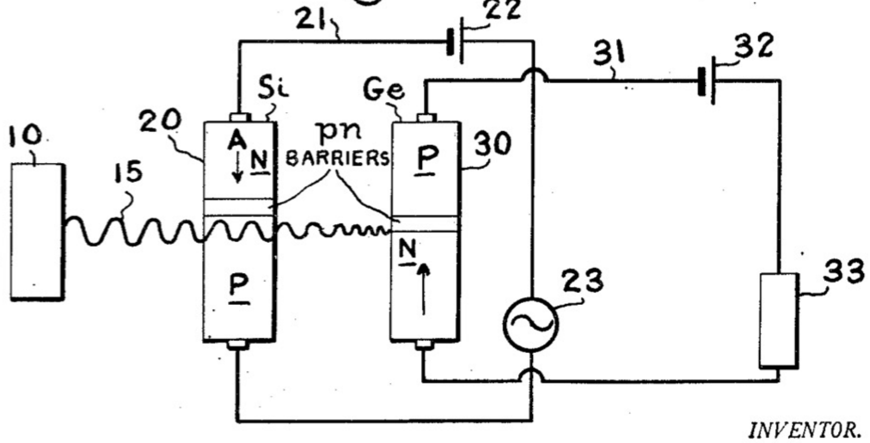
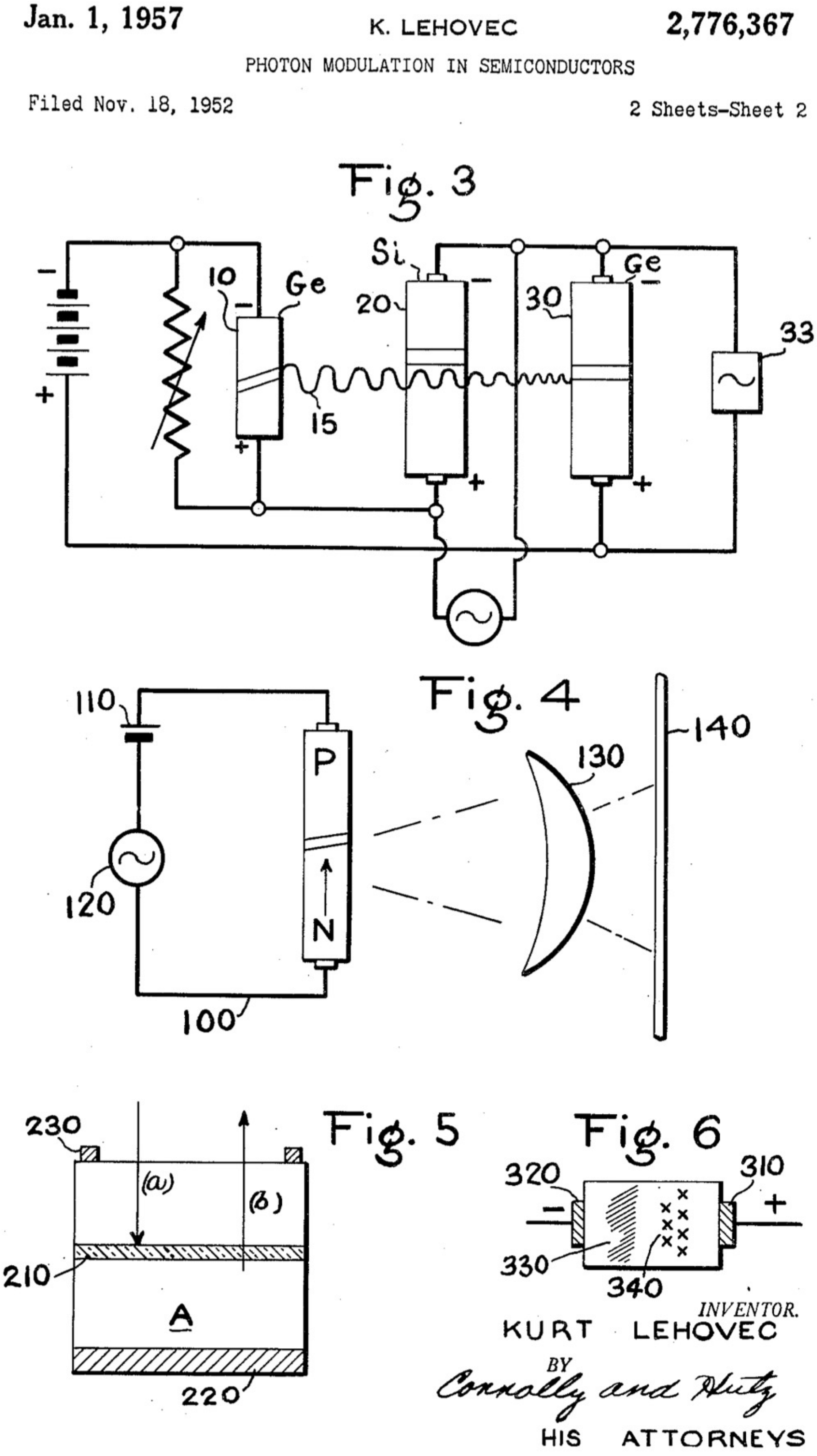

CONDUCTION BAND
FORBIDDEN BAND
FILLED BAND
(a)
L
L
FERMI LEVEL
METALLIC PLATE
− N P + (b)
INJECTED ELECTRON
hv
hv
(c)
APPLIED VOLTAGE
FERMI LEVEL
INJECTED HOLE

Fig. 2


21
22
31
32
Si
Ge
10
20
15
A
N
pn
BARRIERS
P
30
P
N
23
33

INVENTOR.
KURT LEHOVEC
BY
Connolly and Hutz
HIS ATTORNEYS

Figure B.215: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



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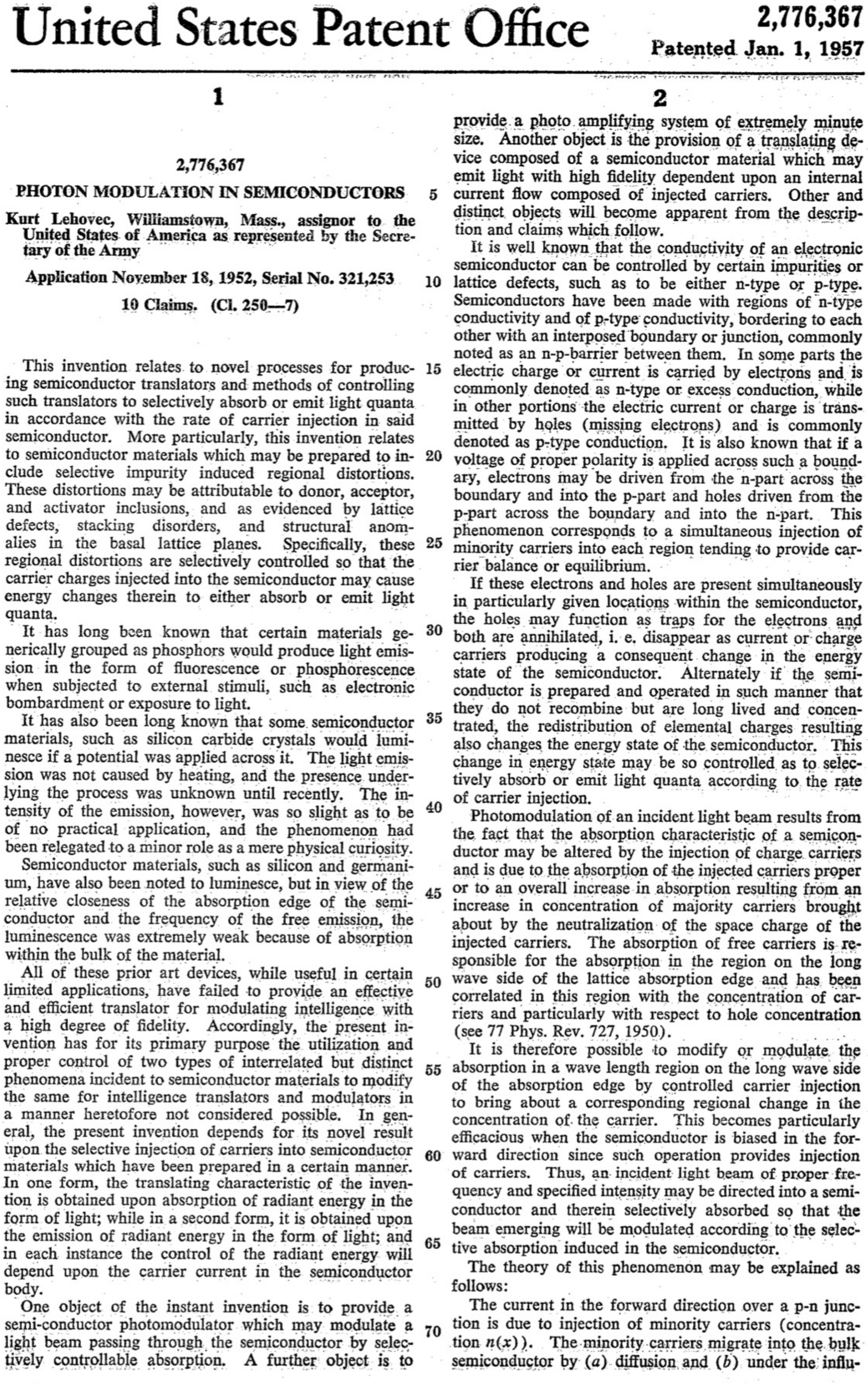
PHOTON MODULATION IN SEMICONDUCTORS

Filed Nov. 18, 1952 2 Sheets-Sheet 2

Fig. 3
Si
Ge
10
Ge
20
30
33
15
Fig. 4
110
140
130
P
N
120
100
Fig. 5
230
(a)
(b)
210
A
220
Fig. 6
320
310
330
340

INVENTOR.
KURT LEHOVEC
BY
Connolly and Hutz
HIS ATTORNEYS

Figure B.216: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



United States Patent Office

2,776,367

Patented Jan. 1, 1957

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PHOTON MODULATION IN SEMICONDUCTORS

Kurt Lehovec, Williamstown, Mass., assignor to the United States of America as represented by the Secretary of the Army

Application November 18, 1952, Serial No. 321,253

10 Claims. (Cl. 250—7)

This invention relates to novel processes for producing semiconductor translators and methods of controlling such translators to selectively absorb or emit light quanta in accordance with the rate of carrier injection in said semiconductor. More particularly, this invention relates to semiconductor materials which may be prepared to include selective impurity induced regional distortions. These distortions may be attributable to donor, acceptor, and activator inclusions, and as evidenced by lattice defects, stacking disorders, and structural anomalies in the basal lattice planes. Specifically, these regional distortions are selectively controlled so that the carrier charges injected into the semiconductor may cause energy changes therein to either absorb or emit light quanta.

It has long been known that certain materials generically grouped as phosphors would produce light emission in the form of fluorescence or phosphorescence when subjected to external stimuli, such as electronic bombardment or exposure to light.

It has also been long known that some semiconductor materials, such as silicon carbide crystals would luminesce if a potential was applied across it. The light emission was not caused by heating, and the presence underlying the process was unknown until recently. The intensity of the emission, however, was so slight as to be of no practical application, and the phenomenon had been relegated to a minor role as a mere physical curiosity.

Semiconductor materials, such as silicon and germanium, have also been noted to luminesce, but in view of the relative closeness of the absorption edge of the semiconductor and the frequency of the free emission, the luminescence was extremely weak because of absorption within the bulk of the material.

All of these prior art devices, while useful in certain limited applications, have failed to provide an effective and efficient translator for modulating intelligence with a high degree of fidelity. Accordingly, the present invention has for its primary purpose the utilization and proper control of two types of interrelated but distinct phenomena incident to semiconductor materials to modify the same for intelligence translators and modulators in a manner heretofore not considered possible. In general, the present invention depends for its novel result upon the selective injection of carriers into semiconductor materials which have been prepared in a certain manner. In one form, the translating characteristic of the invention is obtained upon absorption of radiant energy in the form of light; while in a second form, it is obtained upon the emission of radiant energy in the form of light; and in each instance the control of the radiant energy will depend upon the carrier current in the semiconductor body.

One object of the instant invention is to provide a semi-conductor photomodulator which may modulate a light beam passing through the semiconductor by selectively controllable absorption. A further object is to

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provide a photo amplifying system of extremely minute size. Another object is the provision of a translating device composed of a semiconductor material which may emit light with high fidelity dependent upon an internal current flow composed of injected carriers. Other and distinct objects will become apparent from the description and claims which follow.

It is well known that the conductivity of an electronic semiconductor can be controlled by certain impurities or lattice defects, such as to be either n-type or p-type. Semiconductors have been made with regions of n-type conductivity and of p-type conductivity, bordering to each other with an interposed boundary or junction, commonly noted as an n-p-barrier between them. In some parts the electric charge or current is carried by electrons and is commonly denoted as n-type or excess conduction, while in other portions the electric current or charge is transmitted by holes (missing electrons) and is commonly denoted as p-type conduction. It is also known that if a voltage of proper polarity is applied across such a boundary, electrons may be driven from the n-part across the boundary and into the p-part and holes driven from the p-part across the boundary and into the n-part. This phenomenon corresponds to a simultaneous injection of minority carriers into each region tending to provide carrier balance or equilibrium.

If these electrons and holes are present simultaneously in particularly given locations within the semiconductor, the holes may function as traps for the electrons and both are annihilated, i. e. disappear as current or charge carriers producing a consequent change in the energy state of the semiconductor. Alternately if the semiconductor is prepared and operated in such manner that they do not recombine but are long lived and concentrated, the redistribution of elemental charges resulting also changes the energy state of the semiconductor. This change in energy state may be so controlled as to selectively absorb or emit light quanta according to the rate of carrier injection.

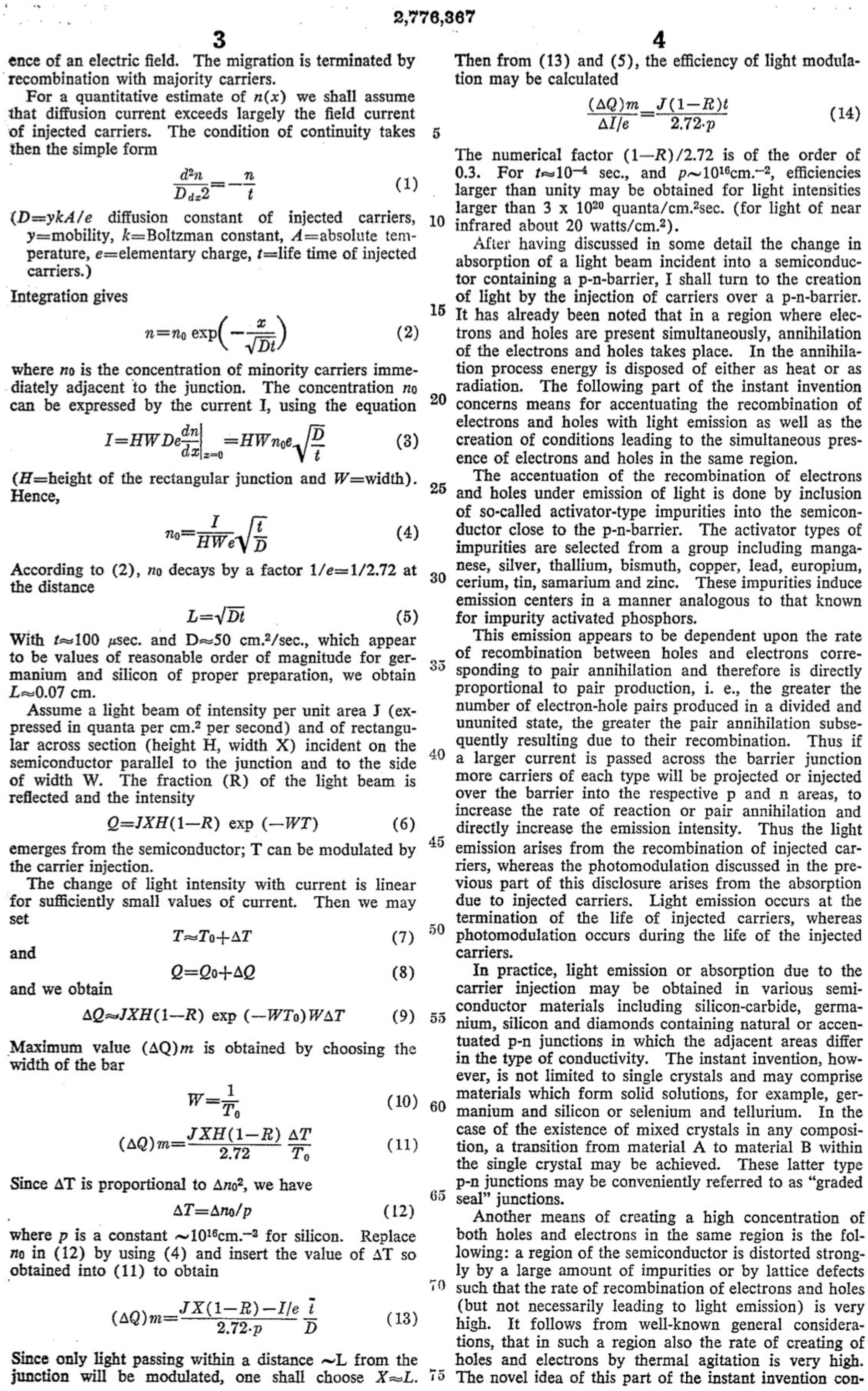
Photomodulation of an incident light beam results from the fact that the absorption characteristic of a semiconductor may be altered by the injection of charge carriers and is due to the absorption of the injected carriers proper or to an overall increase in absorption resulting from an increase in concentration of majority carriers brought about by the neutralization of the space charge of the injected carriers. The absorption of free carriers is responsible for the absorption in the region on the long wave side of the lattice absorption edge and has been correlated in this region with the concentration of carriers and particularly with respect to hole concentration (see 77 Phys. Rev. 727, 1950).

It is therefore possible to modify or modulate the absorption in a wave length region on the long wave side of the absorption edge by controlled carrier injection to bring about a corresponding regional change in the concentration of the carrier. This becomes particularly efficacious when the semiconductor is biased in the forward direction since such operation provides injection of carriers. Thus, an incident light beam of proper frequency and specified intensity may be directed into a semiconductor and therein selectively absorbed so that the beam emerging will be modulated according to the selective absorption induced in the semiconductor.

The theory of this phenomenon may be explained as follows:

The current in the forward direction over a p-n junction is due to injection of minority carriers (concentration $n(x)$). The minority carriers migrate into the bulk semiconductor by (a) diffusion and (b) under the influ-

Figure B.217: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



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ence of an electric field. The migration is terminated by recombination with majority carriers.

For a quantitative estimate of $n(x)$ we shall assume that diffusion current exceeds largely the field current of injected carriers. The condition of continuity takes then the simple form

$$\frac{d^2n}{D_{dx}2}=-\frac{n}{t} \tag{1}$$

($D=ykA/e$ diffusion constant of injected carriers, y=mobility, k=Boltzman constant, A=absolute temperature, e=elementary charge, t=life time of injected carriers.)

Integration gives

$$n=n_0 \exp\left(-\frac{x}{\sqrt{Dt}}\right) \tag{2}$$

where n_0 is the concentration of minority carriers immediately adjacent to the junction. The concentration n_0 can be expressed by the current I, using the equation

$$I=HWDe\frac{dn}{dx}\bigg|_{x=0}=HWn_0e\sqrt{\frac{D}{t}} \tag{3}$$

(H=height of the rectangular junction and W=width). Hence,

$$n_0=\frac{I}{HWe}\sqrt{\frac{t}{D}} \tag{4}$$

According to (2), n_0 decays by a factor $1/e=1/2.72$ at the distance

$$L=\sqrt{Dt} \tag{5}$$

With $t\approx100$ μsec. and $D\approx50$ cm.^{2}/sec., which appear to be values of reasonable order of magnitude for germanium and silicon of proper preparation, we obtain $L\approx0.07$ cm.

Assume a light beam of intensity per unit area J (expressed in quanta per cm.^{2} per second) and of rectangular across section (height H, width X) incident on the semiconductor parallel to the junction and to the side of width W. The fraction (R) of the light beam is reflected and the intensity

$$Q=JXH(1-R)\ \exp\ (-WT) \tag{6}$$

emerges from the semiconductor; T can be modulated by the carrier injection.

The change of light intensity with current is linear for sufficiently small values of current. Then we may set

$$T\approx T_0+\Delta T \tag{7}$$

and

$$Q=Q_0+\Delta Q \tag{8}$$

and we obtain

$$\Delta Q\approx JXH(1-R)\ \exp\ (-WT_0)W\Delta T \tag{9}$$

Maximum value $(\Delta Q)m$ is obtained by choosing the width of the bar

$$W=\frac{1}{T_0} \tag{10}$$

$$(\Delta Q)m=\frac{JXH(1-R)}{2.72}\,\frac{\Delta T}{T_0} \tag{11}$$

Since ΔT is proportional to Δn_0^2, we have

$$\Delta T=\Delta n_0/p \tag{12}$$

where p is a constant $\sim10^{16}$cm.$^{-2}$ for silicon. Replace n_0 in (12) by using (4) and insert the value of ΔT so obtained into (11) to obtain

$$(\Delta Q)m=\frac{JX(1-R)-I/e}{2.72\cdot p}\,\frac{\bar{t}}{D} \tag{13}$$

Since only light passing within a distance $\sim$L from the junction will be modulated, one shall choose $X\approx L$.

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Then from (13) and (5), the efficiency of light modulation may be calculated

$$\frac{(\Delta Q)m}{\Delta I/e}=\frac{J(1-R)t}{2.72\cdot p} \tag{14}$$

The numerical factor $(1-R)/2.72$ is of the order of 0.3. For $t\approx10^{-4}$ sec., and $p\sim10^{16}$cm.$^{-2}$, efficiencies larger than unity may be obtained for light intensities larger than 3 x 10^{20} quanta/cm.^{2}sec. (for light of near infrared about 20 watts/cm.^{2}).

After having discussed in some detail the change in absorption of a light beam incident into a semiconductor containing a p-n-barrier, I shall turn to the creation of light by the injection of carriers over a p-n-barrier. It has already been noted that in a region where electrons and holes are present simultaneously, annihilation of the electrons and holes takes place. In the annihilation process energy is disposed of either as heat or as radiation. The following part of the instant invention concerns means for accentuating the recombination of electrons and holes with light emission as well as the creation of conditions leading to the simultaneous presence of electrons and holes in the same region.

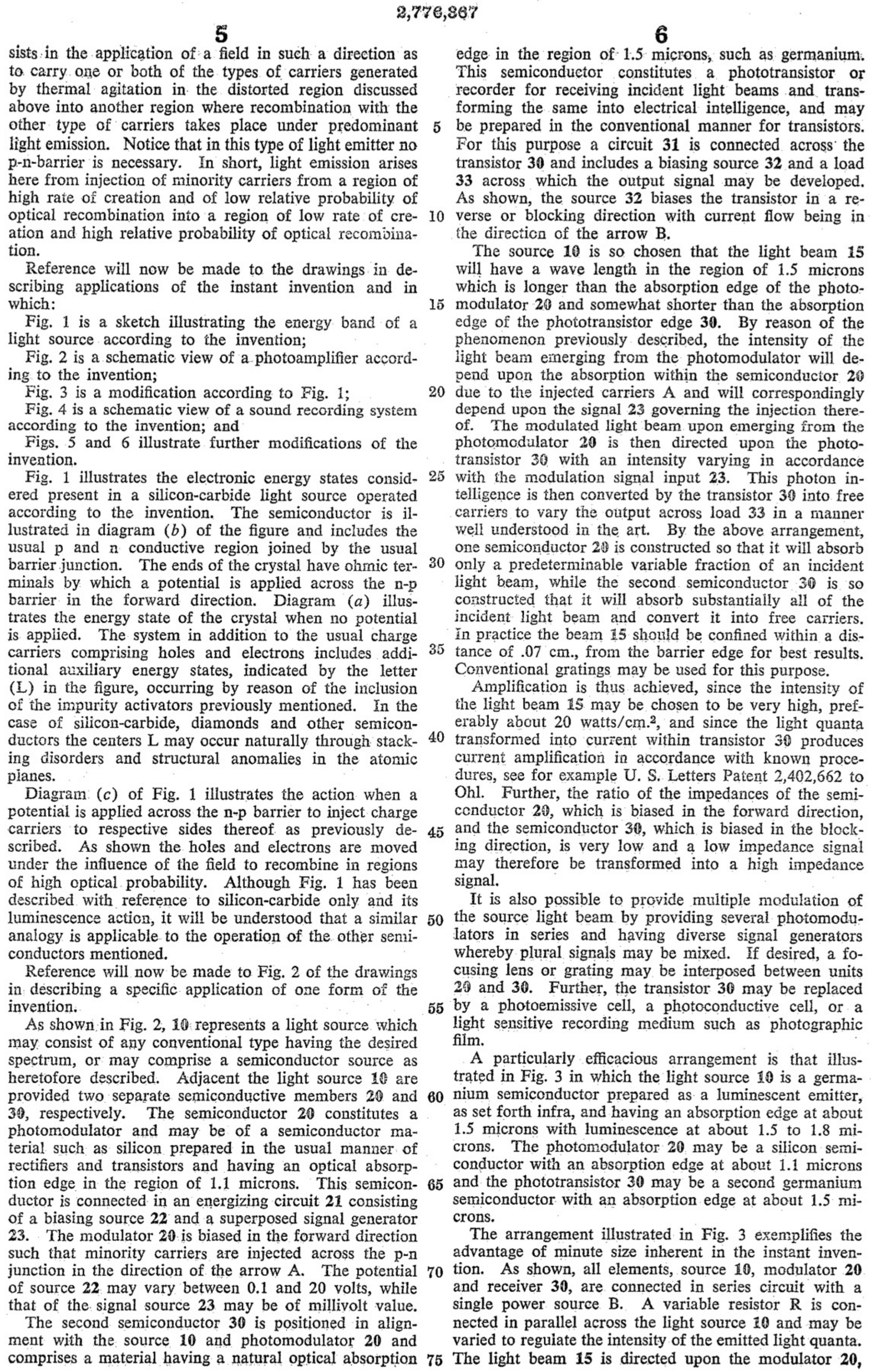
The accentuation of the recombination of electrons and holes under emission of light is done by inclusion of so-called activator-type impurities into the semiconductor close to the p-n-barrier. The activator types of impurities are selected from a group including manganese, silver, thallium, bismuth, copper, lead, europium, cerium, tin, samarium and zinc. These impurities induce emission centers in a manner analogous to that known for impurity activated phosphors.

This emission appears to be dependent upon the rate of recombination between holes and electrons corresponding to pair annihilation and therefore is directly proportional to pair production, i. e., the greater the number of electron-hole pairs produced in a divided and ununited state, the greater the pair annihilation subsequently resulting due to their recombination. Thus if a larger current is passed across the barrier junction more carriers of each type will be projected or injected over the barrier into the respective p and n areas, to increase the rate of reaction or pair annihilation and directly increase the emission intensity. Thus the light emission arises from the recombination of injected carriers, whereas the photomodulation discussed in the previous part of this disclosure arises from the absorption due to injected carriers. Light emission occurs at the termination of the life of injected carriers, whereas photomodulation occurs during the life of the injected carriers.

In practice, light emission or absorption due to the carrier injection may be obtained in various semiconductor materials including silicon-carbide, germanium, silicon and diamonds containing natural or accentuated p-n junctions in which the adjacent areas differ in the type of conductivity. The instant invention, however, is not limited to single crystals and may comprise materials which form solid solutions, for example, germanium and silicon or selenium and tellurium. In the case of the existence of mixed crystals in any composition, a transition from material A to material B within the single crystal may be achieved. These latter type p-n junctions may be conveniently referred to as "graded seal" junctions.

Another means of creating a high concentration of both holes and electrons in the same region is the following: a region of the semiconductor is distorted strongly by a large amount of impurities or by lattice defects such that the rate of recombination of electrons and holes (but not necessarily leading to light emission) is very high. It follows from well-known general considerations, that in such a region also the rate of creating of holes and electrons by thermal agitation is very high. The novel idea of this part of the instant invention con-

Figure B.218: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



sists in the application of a field in such a direction as to carry one or both of the types of carriers generated by thermal agitation in the distorted region discussed above into another region where recombination with the other type of carriers takes place under predominant light emission. Notice that in this type of light emitter no p-n-barrier is necessary. In short, light emission arises here from injection of minority carriers from a region of high rate of creation and of low relative probability of optical recombination into a region of low rate of creation and high relative probability of optical recombination.

Reference will now be made to the drawings in describing applications of the instant invention and in which:

Fig. 1 is a sketch illustrating the energy band of a light source according to the invention;

Fig. 2 is a schematic view of a photoamplifier according to the invention;

Fig. 3 is a modification according to Fig. 1;

Fig. 4 is a schematic view of a sound recording system according to the invention; and

Figs. 5 and 6 illustrate further modifications of the invention.

Fig. 1 illustrates the electronic energy states considered present in a silicon-carbide light source operated according to the invention. The semiconductor is illustrated in diagram (*b*) of the figure and includes the usual p and n conductive region joined by the usual barrier junction. The ends of the crystal have ohmic terminals by which a potential is applied across the n-p barrier in the forward direction. Diagram (*a*) illustrates the energy state of the crystal when no potential is applied. The system in addition to the usual charge carriers comprising holes and electrons includes additional auxiliary energy states, indicated by the letter (L) in the figure, occurring by reason of the inclusion of the impurity activators previously mentioned. In the case of silicon-carbide, diamonds and other semiconductors the centers L may occur naturally through stacking disorders and structural anomalies in the atomic planes.

Diagram (*c*) of Fig. 1 illustrates the action when a potential is applied across the n-p barrier to inject charge carriers to respective sides thereof as previously described. As shown the holes and electrons are moved under the influence of the field to recombine in regions of high optical probability. Although Fig. 1 has been described with reference to silicon-carbide only and its luminescence action, it will be understood that a similar analogy is applicable to the operation of the other semiconductors mentioned.

Reference will now be made to Fig. 2 of the drawings in describing a specific application of one form of the invention.

As shown in Fig. 2, **10** represents a light source which may consist of any conventional type having the desired spectrum, or may comprise a semiconductor source as heretofore described. Adjacent the light source **10** are provided two separate semiconductive members **20** and **30**, respectively. The semiconductor **20** constitutes a photomodulator and may be of a semiconductor material such as silicon prepared in the usual manner of rectifiers and transistors and having an optical absorption edge in the region of 1.1 microns. This semiconductor is connected in an energizing circuit **21** consisting of a biasing source **22** and a superposed signal generator **23**. The modulator **20** is biased in the forward direction such that minority carriers are injected across the p-n junction in the direction of the arrow A. The potential of source **22** may vary between 0.1 and 20 volts, while that of the signal source **23** may be of millivolt value.

The second semiconductor **30** is positioned in alignment with the source **10** and photomodulator **20** and comprises a material having a natural optical absorption edge in the region of 1.5 microns, such as germanium. This semiconductor constitutes a phototransistor or recorder for receiving incident light beams and transforming the same into electrical intelligence, and may be prepared in the conventional manner for transistors. For this purpose a circuit **31** is connected across the transistor **30** and includes a biasing source **32** and a load **33** across which the output signal may be developed. As shown, the source **32** biases the transistor in a reverse or blocking direction with current flow being in the direction of the arrow B.

The source **10** is so chosen that the light beam **15** will have a wave length in the region of 1.5 microns which is longer than the absorption edge of the photomodulator **20** and somewhat shorter than the absorption edge of the phototransistor edge **30**. By reason of the phenomenon previously described, the intensity of the light beam emerging from the photomodulator will depend upon the absorption within the semiconductor **20** due to the injected carriers A and will correspondingly depend upon the signal **23** governing the injection thereof. The modulated light beam upon emerging from the photomodulator **20** is then directed upon the phototransistor **30** with an intensity varying in accordance with the modulation signal input **23**. This photon intelligence is then converted by the transistor **30** into free carriers to vary the output across load **33** in a manner well understood in the art. By the above arrangement, one semiconductor **20** is constructed so that it will absorb only a predeterminable variable fraction of an incident light beam, while the second semiconductor **30** is so constructed that it will absorb substantially all of the incident light beam and convert it into free carriers. In practice the beam **15** should be confined within a distance of .07 cm., from the barrier edge for best results. Conventional gratings may be used for this purpose.

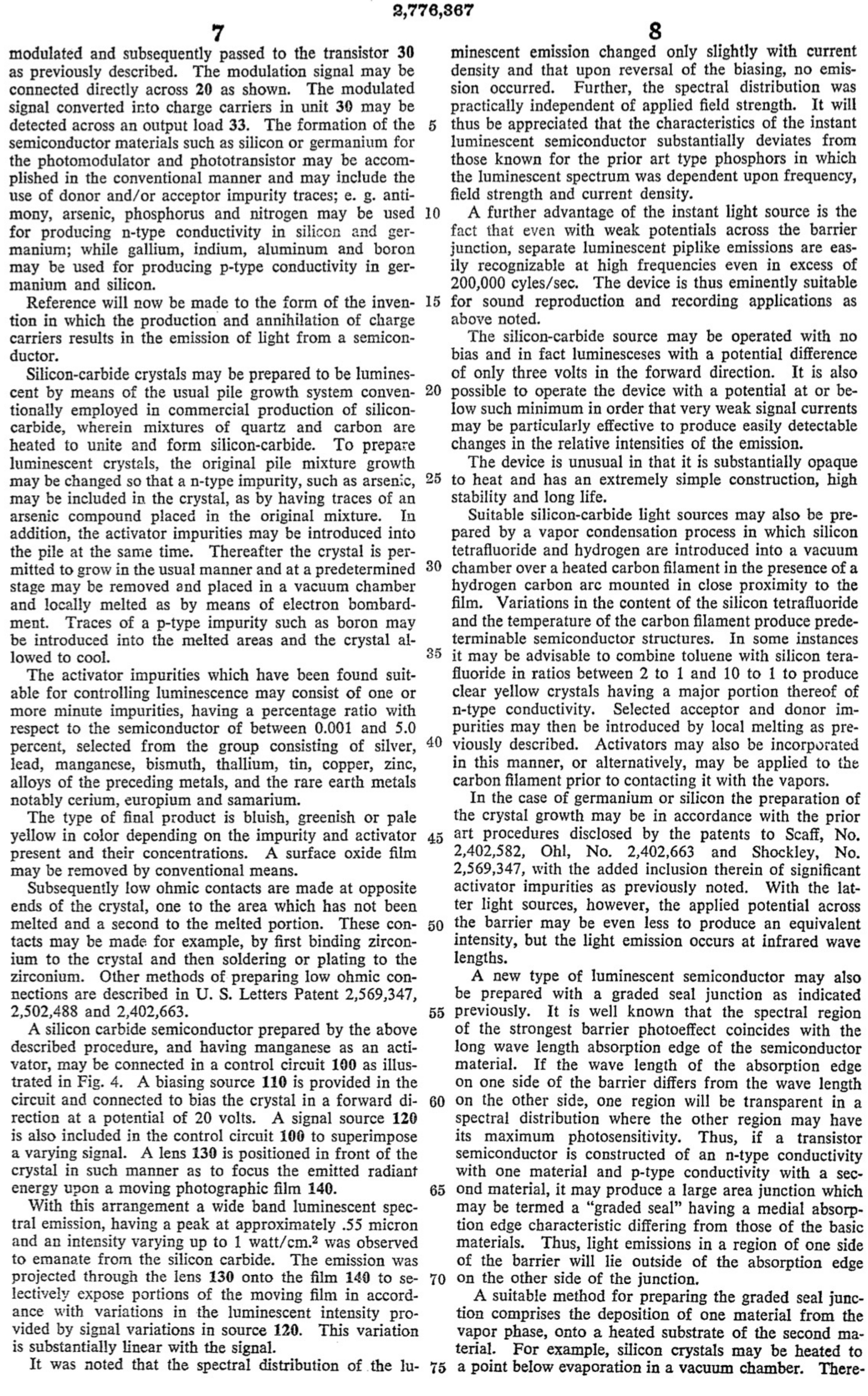
Amplification is thus achieved, since the intensity of the light beam **15** may be chosen to be very high, preferably about 20 watts/cm.^{2}, and since the light quanta transformed into current within transistor **30** produces current amplification in accordance with known procedures, see for example U. S. Letters Patent 2,402,662 to Ohl. Further, the ratio of the impedances of the semiconductor **20**, which is biased in the forward direction, and the semiconductor **30**, which is biased in the blocking direction, is very low and a low impedance signal may therefore be transformed into a high impedance signal.

It is also possible to provide multiple modulation of the source light beam by providing several photomodulators in series and having diverse signal generators whereby plural signals may be mixed. If desired, a focusing lens or grating may be interposed between units **20** and **30**. Further, the transistor **30** may be replaced by a photoemissive cell, a photoconductive cell, or a light sensitive recording medium such as photographic film.

A particularly efficacious arrangement is that illustrated in Fig. 3 in which the light source **10** is a germanium semiconductor prepared as a luminescent emitter, as set forth infra, and having an absorption edge at about 1.5 microns with luminescence at about 1.5 to 1.8 microns. The photomodulator **20** may be a silicon semiconductor with an absorption edge at about 1.1 microns and the phototransistor **30** may be a second germanium semiconductor with an absorption edge at about 1.5 microns.

The arrangement illustrated in Fig. 3 exemplifies the advantage of minute size inherent in the instant invention. As shown, all elements, source **10**, modulator **20** and receiver **30**, are connected in series circuit with a single power source B. A variable resistor R is connected in parallel across the light source **10** and may be varied to regulate the intensity of the emitted light quanta. The light beam **15** is directed upon the modulator **20**,

Figure B.219: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



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modulated and subsequently passed to the transistor **30** as previously described. The modulation signal may be connected directly across **20** as shown. The modulated signal converted into charge carriers in unit **30** may be detected across an output load **33**. The formation of the semiconductor materials such as silicon or germanium for the photomodulator and phototransistor may be accomplished in the conventional manner and may include the use of donor and/or acceptor impurity traces; e. g. antimony, arsenic, phosphorus and nitrogen may be used for producing n-type conductivity in silicon and germanium; while gallium, indium, aluminum and boron may be used for producing p-type conductivity in germanium and silicon.

Reference will now be made to the form of the invention in which the production and annihilation of charge carriers results in the emission of light from a semiconductor.

Silicon-carbide crystals may be prepared to be luminescent by means of the usual pile growth system conventionally employed in commercial production of silicon-carbide, wherein mixtures of quartz and carbon are heated to unite and form silicon-carbide. To prepare luminescent crystals, the original pile mixture growth may be changed so that a n-type impurity, such as arsenic, may be included in the crystal, as by having traces of an arsenic compound placed in the original mixture. In addition, the activator impurities may be introduced into the pile at the same time. Thereafter the crystal is permitted to grow in the usual manner and at a predetermined stage may be removed and placed in a vacuum chamber and locally melted as by means of electron bombardment. Traces of a p-type impurity such as boron may be introduced into the melted areas and the crystal allowed to cool.

The activator impurities which have been found suitable for controlling luminescence may consist of one or more minute impurities, having a percentage ratio with respect to the semiconductor of between 0.001 and 5.0 percent, selected from the group consisting of silver, lead, manganese, bismuth, thallium, tin, copper, zinc, alloys of the preceding metals, and the rare earth metals notably cerium, europium and samarium.

The type of final product is bluish, greenish or pale yellow in color depending on the impurity and activator present and their concentrations. A surface oxide film may be removed by conventional means.

Subsequently low ohmic contacts are made at opposite ends of the crystal, one to the area which has not been melted and a second to the melted portion. These contacts may be made for example, by first binding zirconium to the crystal and then soldering or plating to the zirconium. Other methods of preparing low ohmic connections are described in U. S. Letters Patent 2,569,347, 2,502,488 and 2,402,663.

A silicon carbide semiconductor prepared by the above described procedure, and having manganese as an activator, may be connected in a control circuit **100** as illustrated in Fig. 4. A biasing source **110** is provided in the circuit and connected to bias the crystal in a forward direction at a potential of 20 volts. A signal source **120** is also included in the control circuit **100** to superimpose a varying signal. A lens **130** is positioned in front of the crystal in such manner as to focus the emitted radiant energy upon a moving photographic film **140**.

With this arrangement a wide band luminescent spectral emission, having a peak at approximately .55 micron and an intensity varying up to 1 watt/cm.^{2} was observed to emanate from the silicon carbide. The emission was projected through the lens **130** onto the film **140** to selectively expose portions of the moving film in accordance with variations in the luminescent intensity provided by signal variations in source **120**. This variation is substantially linear with the signal.

It was noted that the spectral distribution of the luminescent emission changed only slightly with current density and that upon reversal of the biasing, no emission occurred. Further, the spectral distribution was practically independent of applied field strength. It will thus be appreciated that the characteristics of the instant luminescent semiconductor substantially deviates from those known for the prior art type phosphors in which the luminescent spectrum was dependent upon frequency, field strength and current density.

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A further advantage of the instant light source is the fact that even with weak potentials across the barrier junction, separate luminescent piplike emissions are easily recognizable at high frequencies even in excess of 200,000 cyles/sec. The device is thus eminently suitable for sound reproduction and recording applications as above noted.

The silicon-carbide source may be operated with no bias and in fact luminesceses with a potential difference of only three volts in the forward direction. It is also possible to operate the device with a potential at or below such minimum in order that very weak signal currents may be particularly effective to produce easily detectable changes in the relative intensities of the emission.

The device is unusual in that it is substantially opaque to heat and has an extremely simple construction, high stability and long life.

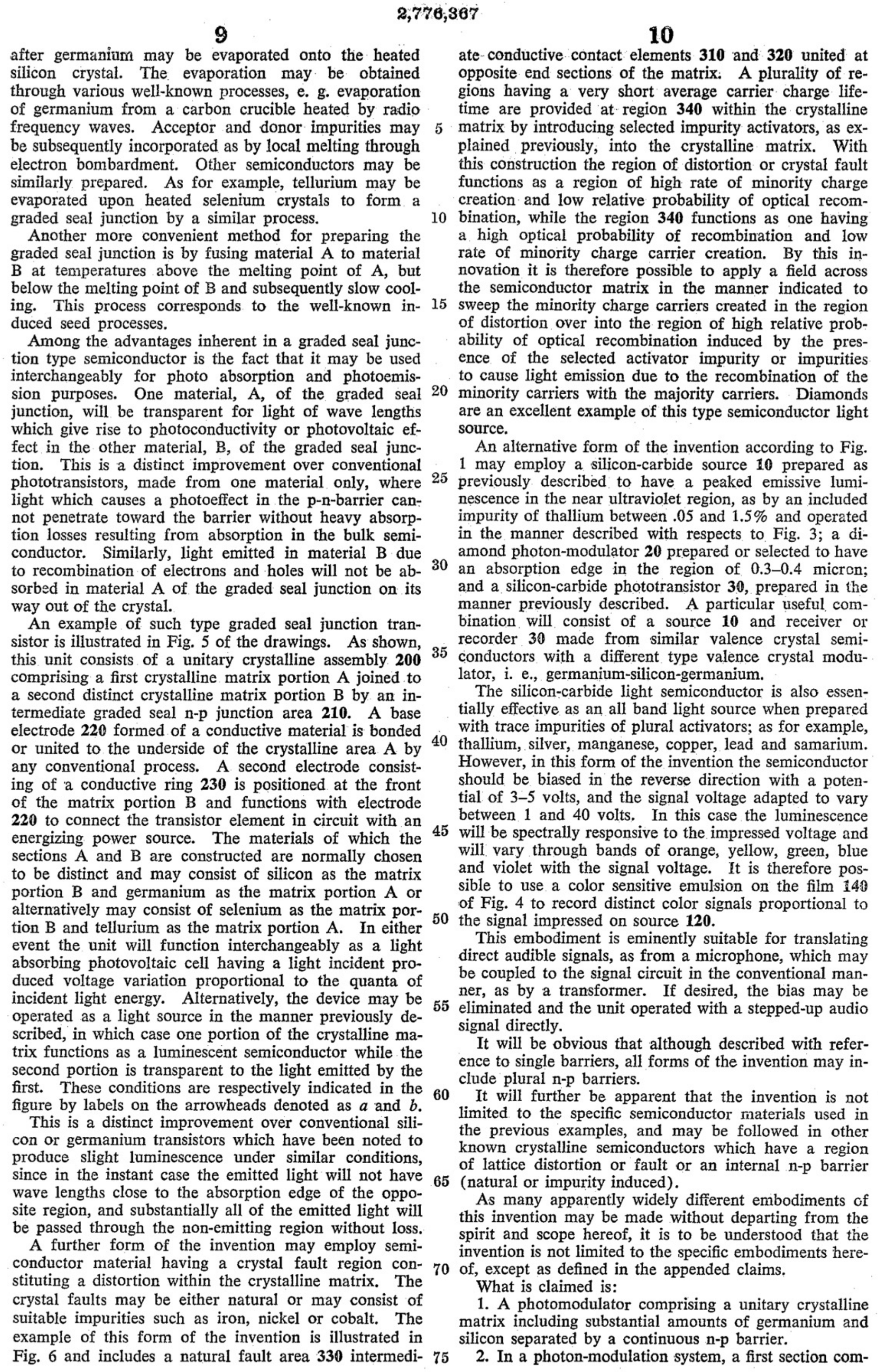
Suitable silicon-carbide light sources may also be prepared by a vapor condensation process in which silicon tetrafluoride and hydrogen are introduced into a vacuum chamber over a heated carbon filament in the presence of a hydrogen carbon arc mounted in close proximity to the film. Variations in the content of the silicon tetrafluoride and the temperature of the carbon filament produce predeterminable semiconductor structures. In some instances it may be advisable to combine toluene with silicon terafluoride in ratios between 2 to 1 and 10 to 1 to produce clear yellow crystals having a major portion thereof of n-type conductivity. Selected acceptor and donor impurities may then be introduced by local melting as previously described. Activators may also be incorporated in this manner, or alternatively, may be applied to the carbon filament prior to contacting it with the vapors.

In the case of germanium or silicon the preparation of the crystal growth may be in accordance with the prior art procedures disclosed by the patents to Scaff, No. 2,402,582, Ohl, No. 2,402,663 and Shockley, No. 2,569,347, with the added inclusion therein of significant activator impurities as previously noted. With the latter light sources, however, the applied potential across the barrier may be even less to produce an equivalent intensity, but the light emission occurs at infrared wave lengths.

A new type of luminescent semiconductor may also be prepared with a graded seal junction as indicated previously. It is well known that the spectral region of the strongest barrier photoeffect coincides with the long wave length absorption edge of the semiconductor material. If the wave length of the absorption edge on one side of the barrier differs from the wave length on the other side, one region will be transparent in a spectral distribution where the other region may have its maximum photosensitivity. Thus, if a transistor semiconductor is constructed of an n-type conductivity with one material and p-type conductivity with a second material, it may produce a large area junction which may be termed a "graded seal" having a medial absorption edge characteristic differing from those of the basic materials. Thus, light emissions in a region of one side of the barrier will lie outside of the absorption edge on the other side of the junction.

A suitable method for preparing the graded seal junction comprises the deposition of one material from the vapor phase, onto a heated substrate of the second material. For example, silicon crystals may be heated to a point below evaporation in a vacuum chamber. There-

Figure B.220: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



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after germanium may be evaporated onto the heated silicon crystal. The evaporation may be obtained through various well-known processes, e. g. evaporation of germanium from a carbon crucible heated by radio frequency waves. Acceptor and donor impurities may be subsequently incorporated as by local melting through electron bombardment. Other semiconductors may be similarly prepared. As for example, tellurium may be evaporated upon heated selenium crystals to form a graded seal junction by a similar process.

Another more convenient method for preparing the graded seal junction is by fusing material A to material B at temperatures above the melting point of A, but below the melting point of B and subsequently slow cooling. This process corresponds to the well-known induced seed processes.

Among the advantages inherent in a graded seal junction type semiconductor is the fact that it may be used interchangeably for photo absorption and photoemission purposes. One material, A, of the graded seal junction, will be transparent for light of wave lengths which give rise to photoconductivity or photovoltaic effect in the other material, B, of the graded seal junction. This is a distinct improvement over conventional phototransistors, made from one material only, where light which causes a photoeffect in the p-n-barrier cannot penetrate toward the barrier without heavy absorption losses resulting from absorption in the bulk semiconductor. Similarly, light emitted in material B due to recombination of electrons and holes will not be absorbed in material A of the graded seal junction on its way out of the crystal.

An example of such type graded seal junction transistor is illustrated in Fig. 5 of the drawings. As shown, this unit consists of a unitary crystalline assembly **200** comprising a first crystalline matrix portion A joined to a second distinct crystalline matrix portion B by an intermediate graded seal n-p junction area **210**. A base electrode **220** formed of a conductive material is bonded or united to the underside of the crystalline area A by any conventional process. A second electrode consisting of a conductive ring **230** is positioned at the front of the matrix portion B and functions with electrode **220** to connect the transistor element in circuit with an energizing power source. The materials of which the sections A and B are constructed are normally chosen to be distinct and may consist of silicon as the matrix portion B and germanium as the matrix portion A or alternatively may consist of selenium as the matrix portion B and tellurium as the matrix portion A. In either event the unit will function interchangeably as a light absorbing photovoltaic cell having a light incident produced voltage variation proportional to the quanta of incident light energy. Alternatively, the device may be operated as a light source in the manner previously described, in which case one portion of the crystalline matrix functions as a luminescent semiconductor while the second portion is transparent to the light emitted by the first. These conditions are respectively indicated in the figure by labels on the arrowheads denoted as *a* and *b*.

This is a distinct improvement over conventional silicon or germanium transistors which have been noted to produce slight luminescence under similar conditions, since in the instant case the emitted light will not have wave lengths close to the absorption edge of the opposite region, and substantially all of the emitted light will be passed through the non-emitting region without loss.

A further form of the invention may employ semiconductor material having a crystal fault region constituting a distortion within the crystalline matrix. The crystal faults may be either natural or may consist of suitable impurities such as iron, nickel or cobalt. The example of this form of the invention is illustrated in Fig. 6 and includes a natural fault area **330** intermediate conductive contact elements **310** and **320** united at opposite end sections of the matrix. A plurality of regions having a very short average carrier charge lifetime are provided at region **340** within the crystalline matrix by introducing selected impurity activators, as explained previously, into the crystalline matrix. With this construction the region of distortion or crystal fault functions as a region of high rate of minority charge creation and low relative probability of optical recombination, while the region **340** functions as one having a high optical probability of recombination and low rate of minority charge carrier creation. By this innovation it is therefore possible to apply a field across the semiconductor matrix in the manner indicated to sweep the minority charge carriers created in the region of distortion over into the region of high relative probability of optical recombination induced by the presence of the selected activator impurity or impurities to cause light emission due to the recombination of the minority carriers with the majority carriers. Diamonds are an excellent example of this type semiconductor light source.

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An alternative form of the invention according to Fig. 1 may employ a silicon-carbide source **10** prepared as previously described to have a peaked emissive luminescence in the near ultraviolet region, as by an included impurity of thallium between .05 and 1.5% and operated in the manner described with respects to Fig. 3; a diamond photon-modulator **20** prepared or selected to have an absorption edge in the region of 0.3–0.4 micron; and a silicon-carbide phototransistor **30**, prepared in the manner previously described. A particular useful combination will consist of a source **10** and receiver or recorder **30** made from similar valence crystal semiconductors with a different type valence crystal modulator, i. e., germanium-silicon-germanium.

The silicon-carbide light semiconductor is also essentially effective as an all band light source when prepared with trace impurities of plural activators; as for example, thallium, silver, manganese, copper, lead and samarium. However, in this form of the invention the semiconductor should be biased in the reverse direction with a potential of 3–5 volts, and the signal voltage adapted to vary between 1 and 40 volts. In this case the luminescence will be spectrally responsive to the impressed voltage and will vary through bands of orange, yellow, green, blue and violet with the signal voltage. It is therefore possible to use a color sensitive emulsion on the film **140** of Fig. 4 to record distinct color signals proportional to the signal impressed on source **120**.

This embodiment is eminently suitable for translating direct audible signals, as from a microphone, which may be coupled to the signal circuit in the conventional manner, as by a transformer. If desired, the bias may be eliminated and the unit operated with a stepped-up audio signal directly.

It will be obvious that although described with reference to single barriers, all forms of the invention may include plural n-p barriers.

It will further be apparent that the invention is not limited to the specific semiconductor materials used in the previous examples, and may be followed in other known crystalline semiconductors which have a region of lattice distortion or fault or an internal n-p barrier (natural or impurity induced).

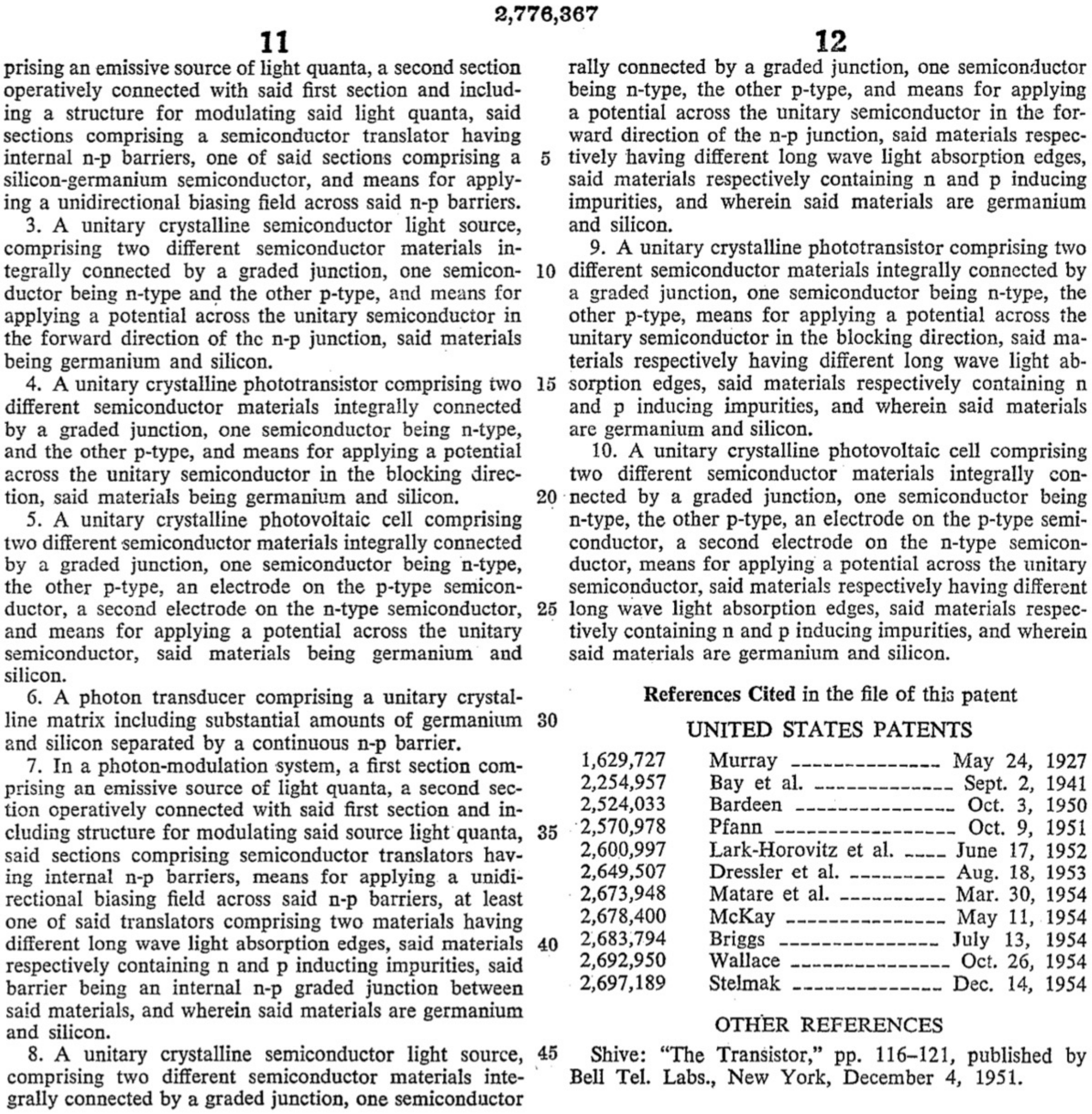
As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope hereof, it is to be understood that the invention is not limited to the specific embodiments hereof, except as defined in the appended claims.

What is claimed is:

1. A photomodulator comprising a unitary crystalline matrix including substantial amounts of germanium and silicon separated by a continuous n-p barrier.

2. In a photon-modulation system, a first section com-

Figure B.221: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



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prising an emissive source of light quanta, a second section operatively connected with said first section and including a structure for modulating said light quanta, said sections comprising a semiconductor translator having internal n-p barriers, one of said sections comprising a silicon-germanium semiconductor, and means for applying a unidirectional biasing field across said n-p barriers.

3. A unitary crystalline semiconductor light source, comprising two different semiconductor materials integrally connected by a graded junction, one semiconductor being n-type and the other p-type, and means for applying a potential across the unitary semiconductor in the forward direction of the n-p junction, said materials being germanium and silicon.

4. A unitary crystalline phototransistor comprising two different semiconductor materials integrally connected by a graded junction, one semiconductor being n-type, and the other p-type, and means for applying a potential across the unitary semiconductor in the blocking direction, said materials being germanium and silicon.

5. A unitary crystalline photovoltaic cell comprising two different semiconductor materials integrally connected by a graded junction, one semiconductor being n-type, the other p-type, an electrode on the p-type semiconductor, a second electrode on the n-type semiconductor, and means for applying a potential across the unitary semiconductor, said materials being germanium and silicon.

6. A photon transducer comprising a unitary crystalline matrix including substantial amounts of germanium and silicon separated by a continuous n-p barrier.

7. In a photon-modulation system, a first section comprising an emissive source of light quanta, a second section operatively connected with said first section and including structure for modulating said source light quanta, said sections comprising semiconductor translators having internal n-p barriers, means for applying a unidirectional biasing field across said n-p barriers, at least one of said translators comprising two materials having different long wave light absorption edges, said materials respectively containing n and p inducting impurities, said barrier being an internal n-p graded junction between said materials, and wherein said materials are germanium and silicon.

8. A unitary crystalline semiconductor light source, comprising two different semiconductor materials integrally connected by a graded junction, one semiconductor

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being n-type, the other p-type, and means for applying a potential across the unitary semiconductor in the forward direction of the n-p junction, said materials respectively having different long wave light absorption edges, said materials respectively containing n and p inducing impurities, and wherein said materials are germanium and silicon.

9. A unitary crystalline phototransistor comprising two different semiconductor materials integrally connected by a graded junction, one semiconductor being n-type, the other p-type, means for applying a potential across the unitary semiconductor in the blocking direction, said materials respectively having different long wave light absorption edges, said materials respectively containing n and p inducing impurities, and wherein said materials are germanium and silicon.

10. A unitary crystalline photovoltaic cell comprising two different semiconductor materials integrally connected by a graded junction, one semiconductor being n-type, the other p-type, an electrode on the p-type semiconductor, a second electrode on the n-type semiconductor, means for applying a potential across the unitary semiconductor, said materials respectively having different long wave light absorption edges, said materials respectively containing n and p inducing impurities, and wherein said materials are germanium and silicon.

References Cited in the file of this patent

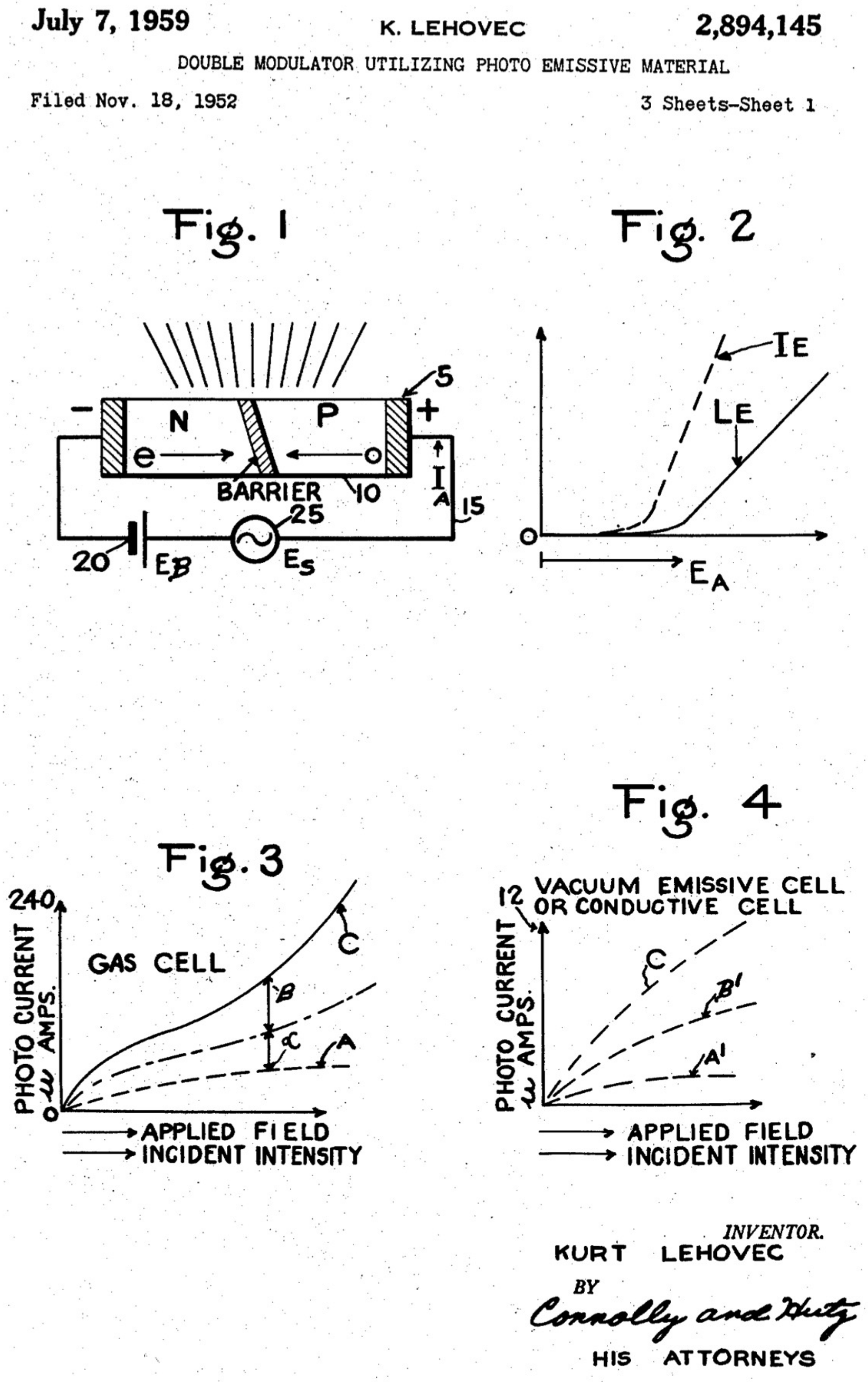
UNITED STATES PATENTS

1,629,727	Murray	May 24, 1927
2,254,957	Bay et al.	Sept. 2, 1941
2,524,033	Bardeen	Oct. 3, 1950
2,570,978	Pfann	Oct. 9, 1951
2,600,997	Lark-Horovitz et al.	June 17, 1952
2,649,507	Dressler et al.	Aug. 18, 1953
2,673,948	Matare et al.	Mar. 30, 1954
2,678,400	McKay	May 11, 1954
2,683,794	Briggs	July 13, 1954
2,692,950	Wallace	Oct. 26, 1954
2,697,189	Stelmak	Dec. 14, 1954

OTHER REFERENCES

Shive: "The Transistor," pp. 116–121, published by Bell Tel. Labs., New York, December 4, 1951.

Figure B.222: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



July 7, 1959 K. LEHOVEC **2,894,145**

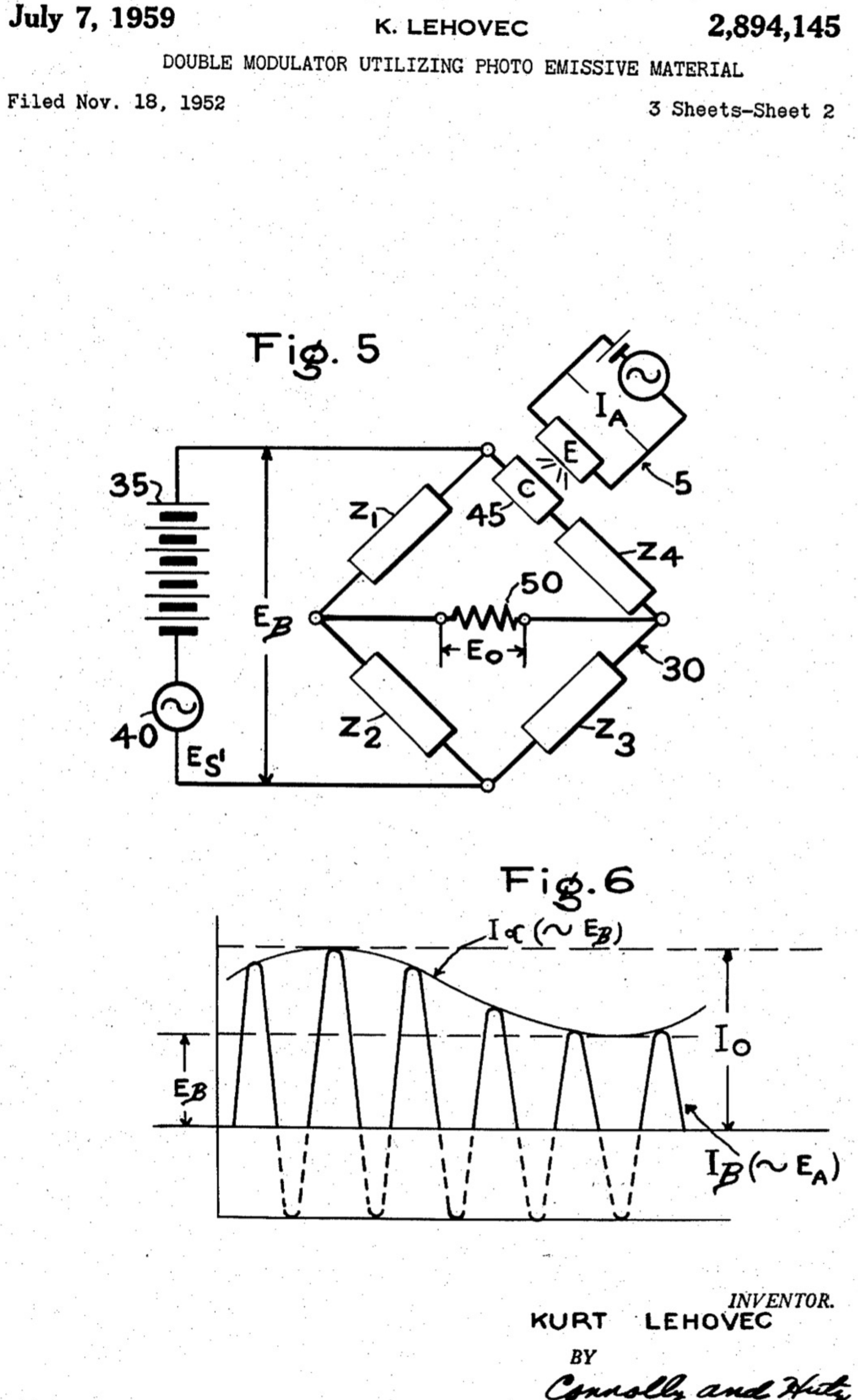
DOUBLE MODULATOR UTILIZING PHOTO EMISSIVE MATERIAL

Filed Nov. 18, 1952 3 Sheets-Sheet 1

Fig. 1
N
P
e
o
BARRIER
5
10
+
−
I
A
15
20
E_B
25
E_S
Fig. 2
I_E
L_E
0
E_A
Fig. 3
240
GAS CELL
C
B
α
A
PHOTO CURRENT ω AMPS.
0
APPLIED FIELD
INCIDENT INTENSITY
Fig. 4
12
VACUUM EMISSIVE CELL
OR CONDUCTIVE CELL
C
B'
A'
PHOTO CURRENT ω AMPS.
APPLIED FIELD
INCIDENT INTENSITY

INVENTOR.
KURT LEHOVEC
BY
Connolly and Hutz
HIS ATTORNEYS

Figure B.223: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



July 7, 1959 **K. LEHOVEC** **2,894,145**

DOUBLE MODULATOR UTILIZING PHOTO EMISSIVE MATERIAL

Filed Nov. 18, 1952 3 Sheets-Sheet 2

Fig. 5

Fig. 6

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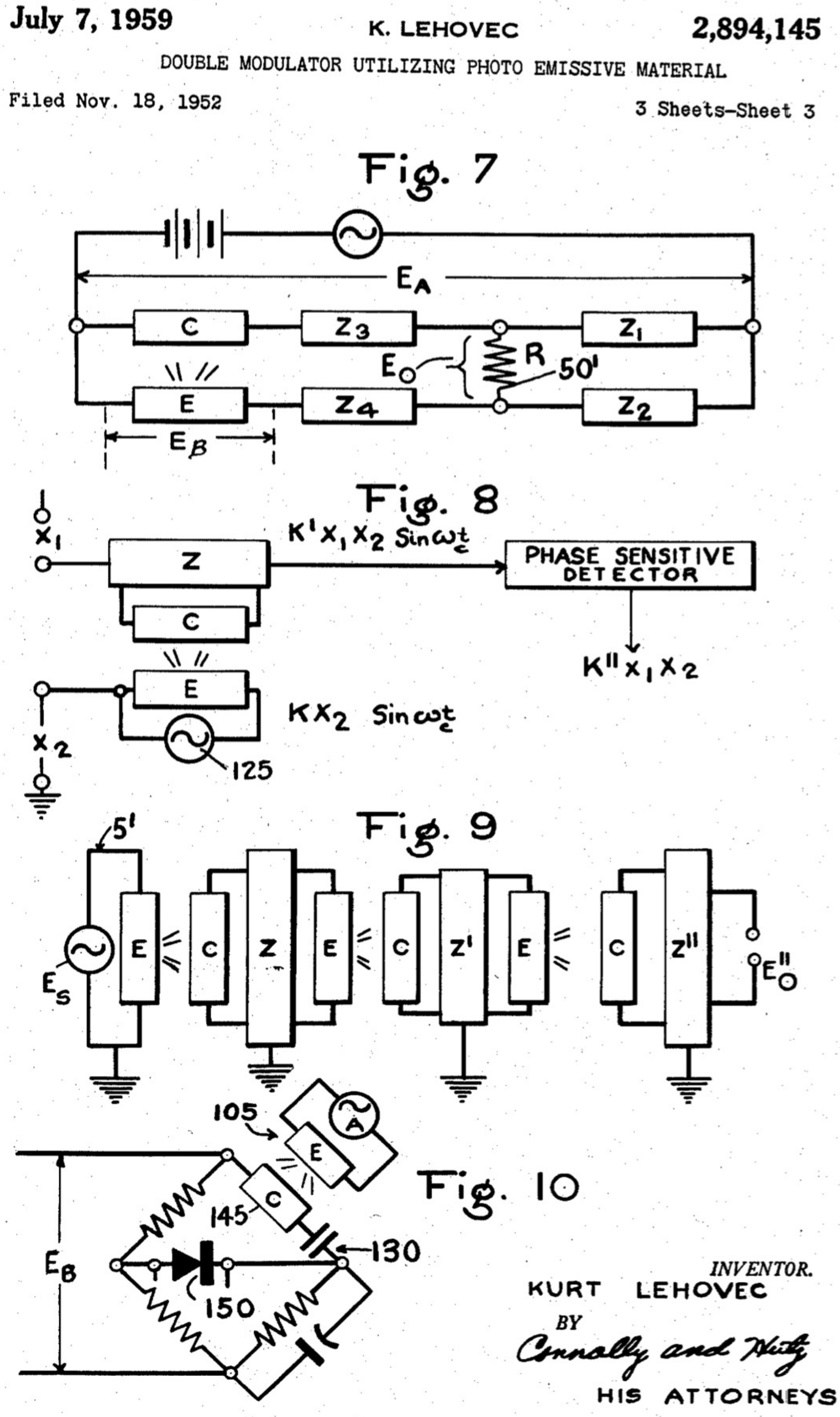
Figure B.224: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



July 7, 1959 K. LEHOVEC **2,894,145**

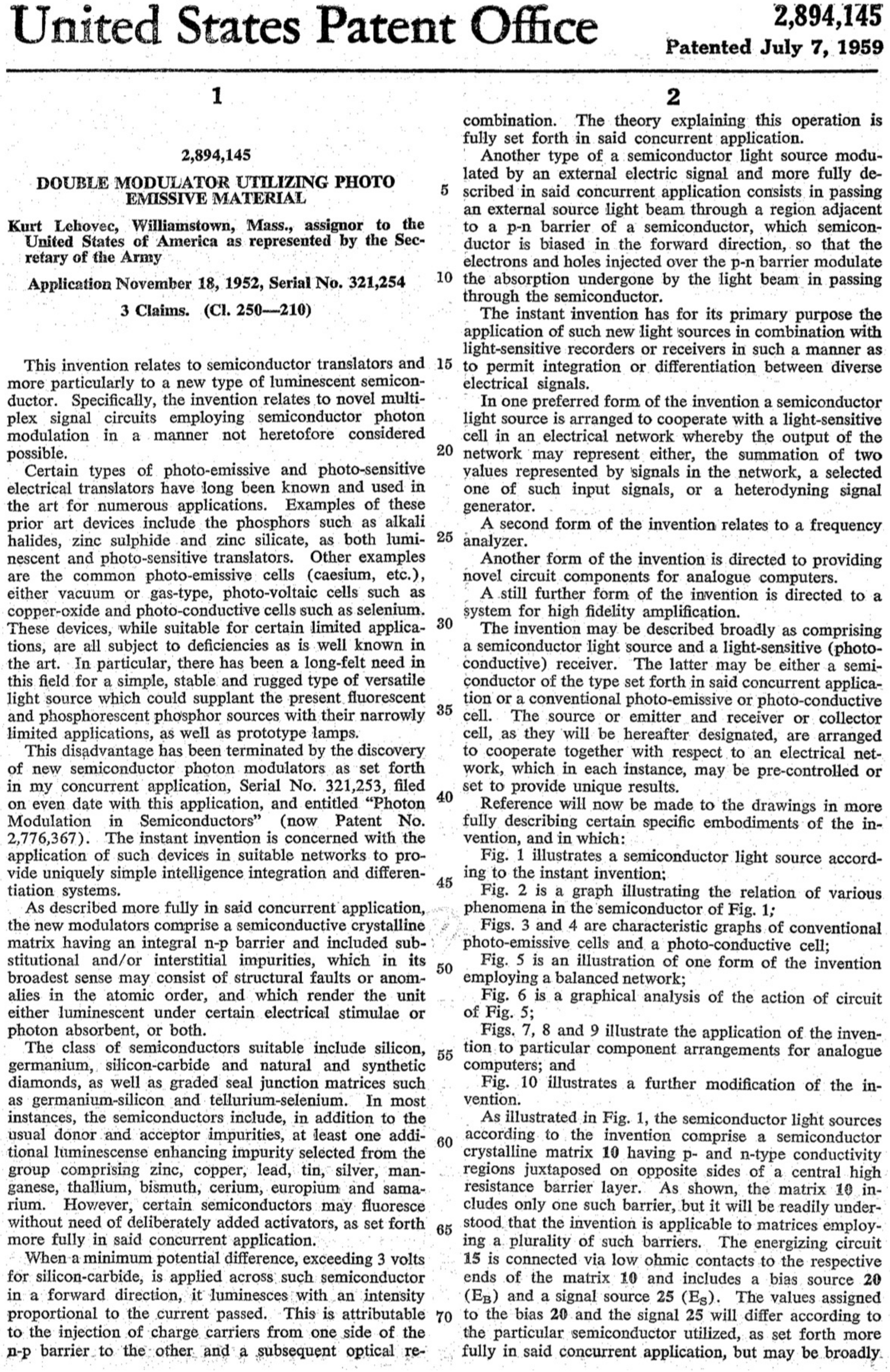
DOUBLE MODULATOR UTILIZING PHOTO EMISSIVE MATERIAL

Filed Nov. 18, 1952 3 Sheets-Sheet 3

INVENTOR.
KURT LEHOVEC
BY
Connolly and Hutz
HIS ATTORNEYS

Fig. 7
E_A
C
Z_3
Z_1
E_O
R
50'
E
Z_4
Z_2
E_B
Fig. 8
X_1
Z
$K'X_1X_2 \sin\omega_c t$
PHASE SENSITIVE DETECTOR
C
$K''X_1X_2$
E
$KX_2 \sin\omega_c t$
X_2
125
Fig. 9
5'
E
C
Z
E
C
Z'
E
C
Z''
E_S
E''_O
105
A
E
C
Fig. 10
145
130
E_B
150

Figure B.225: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



United States Patent Office 2,894,145 Patented July 7, 1959

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2,894,145

DOUBLE MODULATOR UTILIZING PHOTO EMISSIVE MATERIAL

Kurt Lehovec, Williamstown, Mass., assignor to the United States of America as represented by the Secretary of the Army

Application November 18, 1952, Serial No. 321,254

3 Claims. (Cl. 250—210)

This invention relates to semiconductor translators and more particularly to a new type of luminescent semiconductor. Specifically, the invention relates to novel multiplex signal circuits employing semiconductor photon modulation in a manner not heretofore considered possible.

Certain types of photo-emissive and photo-sensitive electrical translators have long been known and used in the art for numerous applications. Examples of these prior art devices include the phosphors such as alkali halides, zinc sulphide and zinc silicate, as both luminescent and photo-sensitive translators. Other examples are the common photo-emissive cells (caesium, etc.), either vacuum or gas-type, photo-voltaic cells such as copper-oxide and photo-conductive cells such as selenium. These devices, while suitable for certain limited applications, are all subject to deficiencies as is well known in the art. In particular, there has been a long-felt need in this field for a simple, stable and rugged type of versatile light source which could supplant the present fluorescent and phosphorescent phosphor sources with their narrowly limited applications, as well as prototype lamps.

This disadvantage has been terminated by the discovery of new semiconductor photon modulators as set forth in my concurrent application, Serial No. 321,253, filed on even date with this application, and entitled "Photon Modulation in Semiconductors" (now Patent No. 2,776,367). The instant invention is concerned with the application of such devices in suitable networks to provide uniquely simple intelligence integration and differentiation systems.

As described more fully in said concurrent application, the new modulators comprise a semiconductive crystalline matrix having an integral n-p barrier and included substitutional and/or interstitial impurities, which in its broadest sense may consist of structural faults or anomalies in the atomic order, and which render the unit either luminescent under certain electrical stimulae or photon absorbent, or both.

The class of semiconductors suitable include silicon, germanium, silicon-carbide and natural and synthetic diamonds, as well as graded seal junction matrices such as germanium-silicon and tellurium-selenium. In most instances, the semiconductors include, in addition to the usual donor and acceptor impurities, at least one additional luminescense enhancing impurity selected from the group comprising zinc, copper, lead, tin, silver, manganese, thallium, bismuth, cerium, europium and samarium. However, certain semiconductors may fluoresce without need of deliberately added activators, as set forth more fully in said concurrent application.

When a minimum potential difference, exceeding 3 volts for silicon-carbide, is applied across such semiconductor in a forward direction, it luminesces with an intensity proportional to the current passed. This is attributable to the injection of charge carriers from one side of the n-p barrier to the other and a subsequent optical recombination. The theory explaining this operation is fully set forth in said concurrent application.

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Another type of a semiconductor light source modulated by an external electric signal and more fully described in said concurrent application consists in passing an external source light beam through a region adjacent to a p-n barrier of a semiconductor, which semiconductor is biased in the forward direction, so that the electrons and holes injected over the p-n barrier modulate the absorption undergone by the light beam in passing through the semiconductor.

The instant invention has for its primary purpose the application of such new light sources in combination with light-sensitive recorders or receivers in such a manner as to permit integration or differentiation between diverse electrical signals.

In one preferred form of the invention a semiconductor light source is arranged to cooperate with a light-sensitive cell in an electrical network whereby the output of the network may represent either, the summation of two values represented by signals in the network, a selected one of such input signals, or a heterodyning signal generator.

A second form of the invention relates to a frequency analyzer.

Another form of the invention is directed to providing novel circuit components for analogue computers.

A still further form of the invention is directed to a system for high fidelity amplification.

The invention may be described broadly as comprising a semiconductor light source and a light-sensitive (photo-conductive) receiver. The latter may be either a semiconductor of the type set forth in said concurrent application or a conventional photo-emissive or photo-conductive cell. The source or emitter and receiver or collector cell, as they will be hereafter designated, are arranged to cooperate together with respect to an electrical network, which in each instance, may be pre-controlled or set to provide unique results.

Reference will now be made to the drawings in more fully describing certain specific embodiments of the invention, and in which:

Fig. 1 illustrates a semiconductor light source according to the instant invention;

Fig. 2 is a graph illustrating the relation of various phenomena in the semiconductor of Fig. 1;

Figs. 3 and 4 are characteristic graphs of conventional photo-emissive cells and a photo-conductive cell;

Fig. 5 is an illustration of one form of the invention employing a balanced network;

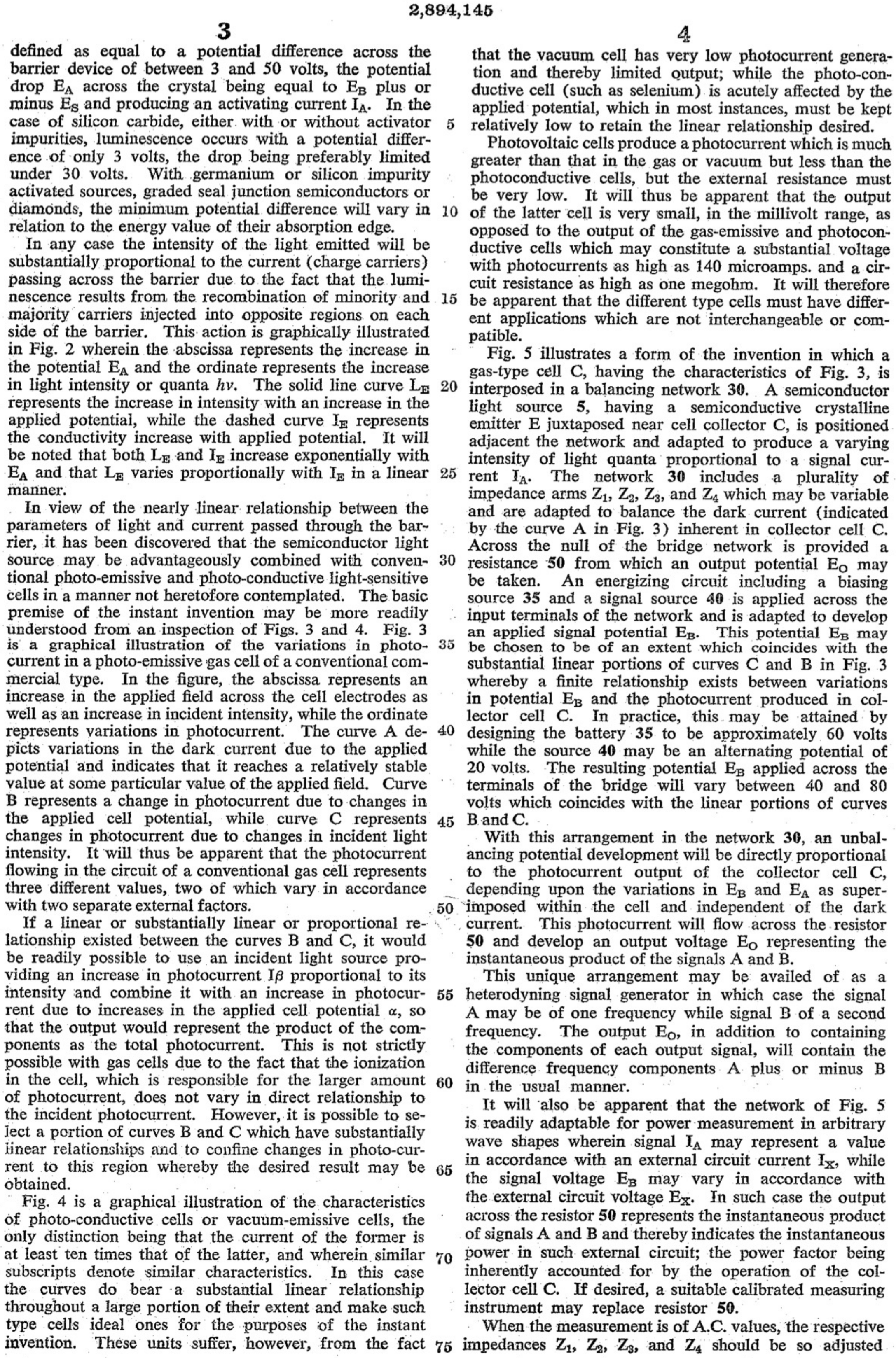
Fig. 6 is a graphical analysis of the action of circuit of Fig. 5;

Figs. 7, 8 and 9 illustrate the application of the invention to particular component arrangements for analogue computers; and

Fig. 10 illustrates a further modification of the invention.

As illustrated in Fig. 1, the semiconductor light sources according to the invention comprise a semiconductor crystalline matrix **10** having p- and n-type conductivity regions juxtaposed on opposite sides of a central high resistance barrier layer. As shown, the matrix **10** includes only one such barrier, but it will be readily understood that the invention is applicable to matrices employing a plurality of such barriers. The energizing circuit **15** is connected via low ohmic contacts to the respective ends of the matrix **10** and includes a bias source **20** (E_B) and a signal source **25** (E_S). The values assigned to the bias **20** and the signal **25** will differ according to the particular semiconductor utilized, as set forth more fully in said concurrent application, but may be broadly

Figure B.226: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



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defined as equal to a potential difference across the barrier device of between 3 and 50 volts, the potential drop E_A across the crystal being equal to E_B plus or minus E_S and producing an activating current I_A. In the case of silicon carbide, either with or without activator impurities, luminescence occurs with a potential difference of only 3 volts, the drop being preferably limited under 30 volts. With germanium or silicon impurity activated sources, graded seal junction semiconductors or diamonds, the minimum potential difference will vary in relation to the energy value of their absorption edge.

In any case the intensity of the light emitted will be substantially proportional to the current (charge carriers) passing across the barrier due to the fact that the luminescence results from the recombination of minority and majority carriers injected into opposite regions on each side of the barrier. This action is graphically illustrated in Fig. 2 wherein the abscissa represents the increase in the potential E_A and the ordinate represents the increase in light intensity or quanta $h\nu$. The solid line curve L_E represents the increase in intensity with an increase in the applied potential, while the dashed curve I_E represents the conductivity increase with applied potential. It will be noted that both L_E and I_E increase exponentially with E_A and that L_E varies proportionally with I_E in a linear manner.

In view of the nearly linear relationship between the parameters of light and current passed through the barrier, it has been discovered that the semiconductor light source may be advantageously combined with conventional photo-emissive and photo-conductive light-sensitive cells in a manner not heretofore contemplated. The basic premise of the instant invention may be more readily understood from an inspection of Figs. 3 and 4. Fig. 3 is a graphical illustration of the variations in photocurrent in a photo-emissive gas cell of a conventional commercial type. In the figure, the abscissa represents an increase in the applied field across the cell electrodes as well as an increase in incident intensity, while the ordinate represents variations in photocurrent. The curve A depicts variations in the dark current due to the applied potential and indicates that it reaches a relatively stable value at some particular value of the applied field. Curve B represents a change in photocurrent due to changes in the applied cell potential, while curve C represents changes in photocurrent due to changes in incident light intensity. It will thus be apparent that the photocurrent flowing in the circuit of a conventional gas cell represents three different values, two of which vary in accordance with two separate external factors.

If a linear or substantially linear or proportional relationship existed between the curves B and C, it would be readily possible to use an incident light source providing an increase in photocurrent $I\beta$ proportional to its intensity and combine it with an increase in photocurrent due to increases in the applied cell potential α, so that the output would represent the product of the components as the total photocurrent. This is not strictly possible with gas cells due to the fact that the ionization in the cell, which is responsible for the larger amount of photocurrent, does not vary in direct relationship to the incident photocurrent. However, it is possible to select a portion of curves B and C which have substantially linear relationships and to confine changes in photo-current to this region whereby the desired result may be obtained.

Fig. 4 is a graphical illustration of the characteristics of photo-conductive cells or vacuum-emissive cells, the only distinction being that the current of the former is at least ten times that of the latter, and wherein similar subscripts denote similar characteristics. In this case the curves do bear a substantial linear relationship throughout a large portion of their extent and make such type cells ideal ones for the purposes of the instant invention. These units suffer, however, from the fact that the vacuum cell has very low photocurrent generation and thereby limited output; while the photo-conductive cell (such as selenium) is acutely affected by the applied potential, which in most instances, must be kept relatively low to retain the linear relationship desired.

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Photovoltaic cells produce a photocurrent which is much greater than that in the gas or vacuum but less than the photoconductive cells, but the external resistance must be very low. It will thus be apparent that the output of the latter cell is very small, in the millivolt range, as opposed to the output of the gas-emissive and photoconductive cells which may constitute a substantial voltage with photocurrents as high as 140 microamps. and a circuit resistance as high as one megohm. It will therefore be apparent that the different type cells must have different applications which are not interchangeable or compatible.

Fig. 5 illustrates a form of the invention in which a gas-type cell C, having the characteristics of Fig. 3, is interposed in a balancing network **30**. A semiconductor light source **5**, having a semiconductive crystalline emitter E juxtaposed near cell collector C, is positioned adjacent the network and adapted to produce a varying intensity of light quanta proportional to a signal current I_A. The network **30** includes a plurality of impedance arms Z_1, Z_2, Z_3, and Z_4 which may be variable and are adapted to balance the dark current (indicated by the curve A in Fig. 3) inherent in collector cell C. Across the null of the bridge network is provided a resistance **50** from which an output potential E_O may be taken. An energizing circuit including a biasing source **35** and a signal source **40** is applied across the input terminals of the network and is adapted to develop an applied signal potential E_B. This potential E_B may be chosen to be of an extent which coincides with the substantial linear portions of curves C and B in Fig. 3 whereby a finite relationship exists between variations in potential E_B and the photocurrent produced in collector cell C. In practice, this may be attained by designing the battery **35** to be approximately 60 volts while the source **40** may be an alternating potential of 20 volts. The resulting potential E_B applied across the terminals of the bridge will vary between 40 and 80 volts which coincides with the linear portions of curves B and C.

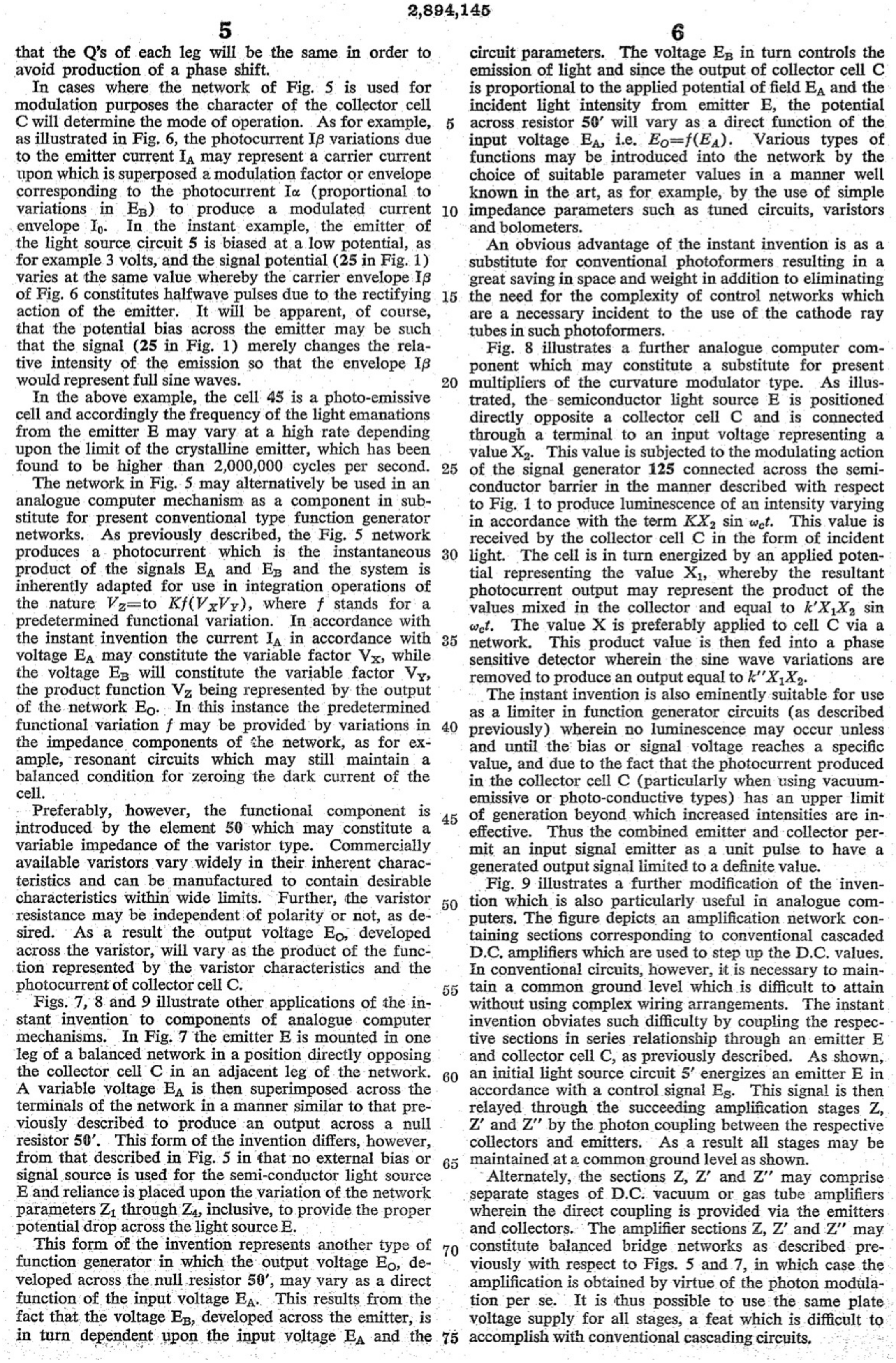
With this arrangement in the network **30**, an unbalancing potential development will be directly proportional to the photocurrent output of the collector cell C, depending upon the variations in E_B and E_A as superimposed within the cell and independent of the dark current. This photocurrent will flow across the resistor **50** and develop an output voltage E_O representing the instantaneous product of the signals A and B.

This unique arrangement may be availed of as a heterodyning signal generator in which case the signal A may be of one frequency while signal B of a second frequency. The output E_O, in addition to containing the components of each output signal, will contain the difference frequency components A plus or minus B in the usual manner.

It will also be apparent that the network of Fig. 5 is readily adaptable for power measurement in arbitrary wave shapes wherein signal I_A may represent a value in accordance with an external circuit current I_X, while the signal voltage E_B may vary in accordance with the external circuit voltage E_X. In such case the output across the resistor **50** represents the instantaneous product of signals A and B and thereby indicates the instantaneous power in such external circuit; the power factor being inherently accounted for by the operation of the collector cell C. If desired, a suitable calibrated measuring instrument may replace resistor **50**.

When the measurement is of A.C. values, the respective impedances Z_1, Z_2, Z_3, and Z_4 should be so adjusted

Figure B.227: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



that the Q's of each leg will be the same in order to avoid production of a phase shift.

In cases where the network of Fig. 5 is used for modulation purposes the character of the collector cell C will determine the mode of operation. As for example, as illustrated in Fig. 6, the photocurrent $I\beta$ variations due to the emitter current I_A may represent a carrier current upon which is superposed a modulation factor or envelope corresponding to the photocurrent $I\alpha$ (proportional to variations in E_B) to produce a modulated current envelope I_0. In the instant example, the emitter of the light source circuit **5** is biased at a low potential, as for example 3 volts, and the signal potential (**25** in Fig. 1) varies at the same value whereby the carrier envelope $I\beta$ of Fig. 6 constitutes halfwave pulses due to the rectifying action of the emitter. It will be apparent, of course, that the potential bias across the emitter may be such that the signal (**25** in Fig. 1) merely changes the relative intensity of the emission so that the envelope $I\beta$ would represent full sine waves.

In the above example, the cell **45** is a photo-emissive cell and accordingly the frequency of the light emanations from the emitter E may vary at a high rate depending upon the limit of the crystalline emitter, which has been found to be higher than 2,000,000 cycles per second.

The network in Fig. 5 may alternatively be used in an analogue computer mechanism as a component in substitute for present conventional type function generator networks. As previously described, the Fig. 5 network produces a photocurrent which is the instantaneous product of the signals E_A and E_B and the system is inherently adapted for use in integration operations of the nature V_Z=to $Kf(V_XV_Y)$, where f stands for a predetermined functional variation. In accordance with the instant invention the current I_A in accordance with voltage E_A may constitute the variable factor V_X, while the voltage E_B will constitute the variable factor V_Y, the product function V_Z being represented by the output of the network E_O. In this instance the predetermined functional variation f may be provided by variations in the impedance components of the network, as for example, resonant circuits which may still maintain a balanced condition for zeroing the dark current of the cell.

Preferably, however, the functional component is introduced by the element **50** which may constitute a variable impedance of the varistor type. Commercially available varistors vary widely in their inherent characteristics and can be manufactured to contain desirable characteristics within wide limits. Further, the varistor resistance may be independent of polarity or not, as desired. As a result the output voltage E_O, developed across the varistor, will vary as the product of the function represented by the varistor characteristics and the photocurrent of collector cell C.

Figs. 7, 8 and 9 illustrate other applications of the instant invention to components of analogue computer mechanisms. In Fig. 7 the emitter E is mounted in one leg of a balanced network in a position directly opposing the collector cell C in an adjacent leg of the network. A variable voltage E_A is then superimposed across the terminals of the network in a manner similar to that previously described to produce an output across a null resistor **50′**. This form of the invention differs, however, from that described in Fig. 5 in that no external bias or signal source is used for the semi-conductor light source E and reliance is placed upon the variation of the network parameters Z_1 through Z_4, inclusive, to provide the proper potential drop across the light source E.

This form of the invention represents another type of function generator in which the output voltage E_O, developed across the null resistor **50′**, may vary as a direct function of the input voltage E_A. This results from the fact that the voltage E_B, developed across the emitter, is in turn dependent upon the input voltage E_A and the circuit parameters. The voltage E_B in turn controls the emission of light and since the output of collector cell C is proportional to the applied potential of field E_A and the incident light intensity from emitter E, the potential across resistor **50′** will vary as a direct function of the input voltage E_A, i.e. $E_O=f(E_A)$. Various types of functions may be introduced into the network by the choice of suitable parameter values in a manner well known in the art, as for example, by the use of simple impedance parameters such as tuned circuits, varistors and bolometers.

An obvious advantage of the instant invention is as a substitute for conventional photoformers resulting in a great saving in space and weight in addition to eliminating the need for the complexity of control networks which are a necessary incident to the use of the cathode ray tubes in such photoformers.

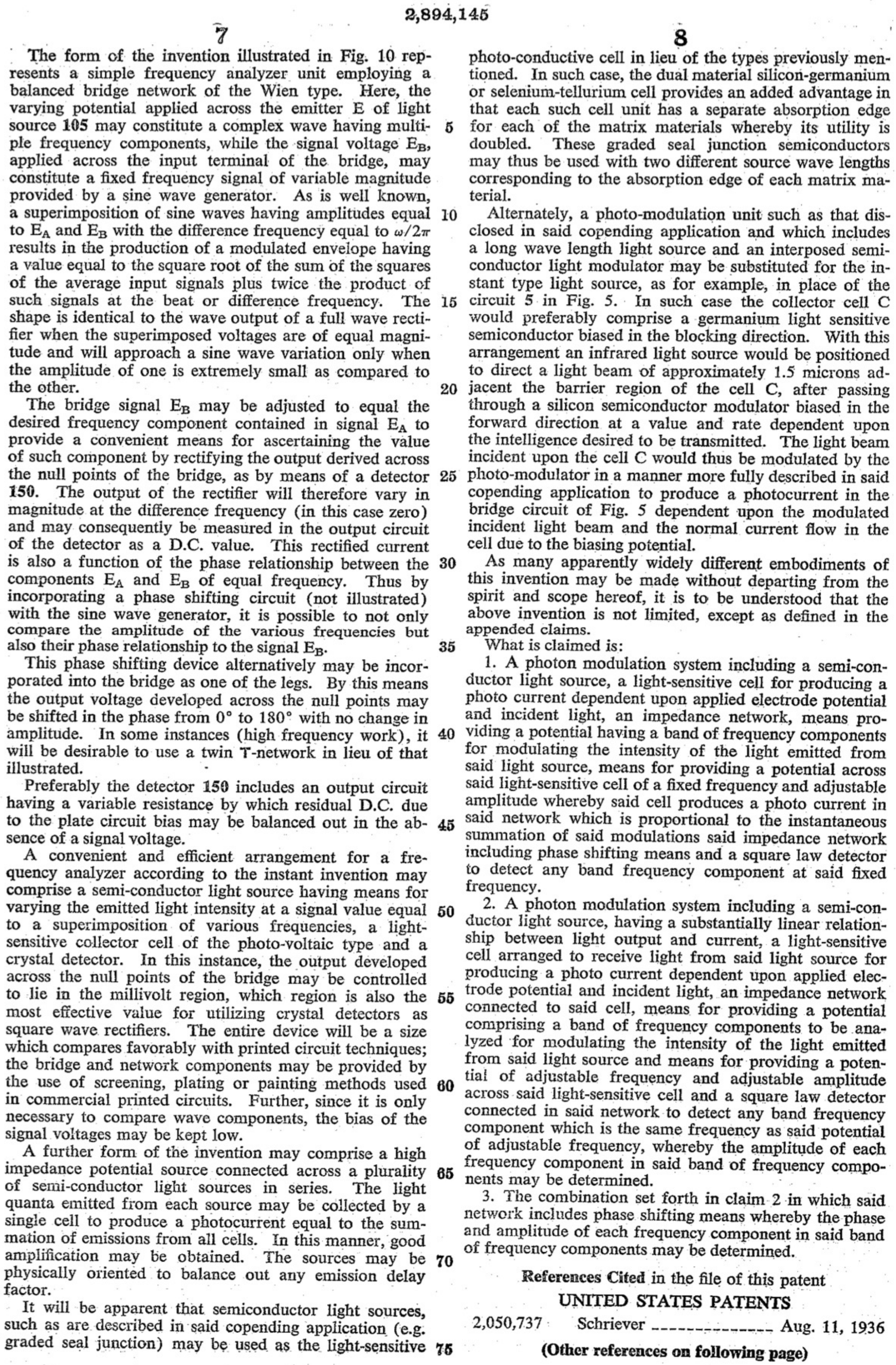
Fig. 8 illustrates a further analogue computer component which may constitute a substitute for present multipliers of the curvature modulator type. As illustrated, the semiconductor light source E is positioned directly opposite a collector cell C and is connected through a terminal to an input voltage representing a value X_2. This value is subjected to the modulating action of the signal generator **125** connected across the semiconductor barrier in the manner described with respect to Fig. 1 to produce luminescence of an intensity varying in accordance with the term $KX_2 \sin \omega_c t$. This value is received by the collector cell C in the form of incident light. The cell is in turn energized by an applied potential representing the value X_1, whereby the resultant photocurrent output may represent the product of the values mixed in the collector and equal to $k'X_1X_2 \sin \omega_c t$. The value X is preferably applied to cell C via a network. This product value is then fed into a phase sensitive detector wherein the sine wave variations are removed to produce an output equal to $k''X_1X_2$.

The instant invention is also eminently suitable for use as a limiter in function generator circuits (as described previously) wherein no luminescence may occur unless and until the bias or signal voltage reaches a specific value, and due to the fact that the photocurrent produced in the collector cell C (particularly when using vacuum-emissive or photo-conductive types) has an upper limit of generation beyond which increased intensities are ineffective. Thus the combined emitter and collector permit an input signal emitter as a unit pulse to have a generated output signal limited to a definite value.

Fig. 9 illustrates a further modification of the invention which is also particularly useful in analogue computers. The figure depicts an amplification network containing sections corresponding to conventional cascaded D.C. amplifiers which are used to step up the D.C. values. In conventional circuits, however, it is necessary to maintain a common ground level which is difficult to attain without using complex wiring arrangements. The instant invention obviates such difficulty by coupling the respective sections in series relationship through an emitter E and collector cell C, as previously described. As shown, an initial light source circuit **5′** energizes an emitter E in accordance with a control signal E_S. This signal is then relayed through the succeeding amplification stages Z, Z′ and Z″ by the photon coupling between the respective collectors and emitters. As a result all stages may be maintained at a common ground level as shown.

Alternately, the sections Z, Z′ and Z″ may comprise separate stages of D.C. vacuum or gas tube amplifiers wherein the direct coupling is provided via the emitters and collectors. The amplifier sections Z, Z′ and Z″ may constitute balanced bridge networks as described previously with respect to Figs. 5 and 7, in which case the amplification is obtained by virtue of the photon modulation per se. It is thus possible to use the same plate voltage supply for all stages, a feat which is difficult to accomplish with conventional cascading circuits.

Figure B.228: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



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The form of the invention illustrated in Fig. 10 represents a simple frequency analyzer unit employing a balanced bridge network of the Wien type. Here, the varying potential applied across the emitter E of light source **105** may constitute a complex wave having multiple frequency components, while the signal voltage E_B, applied across the input terminal of the bridge, may constitute a fixed frequency signal of variable magnitude provided by a sine wave generator. As is well known, a superimposition of sine waves having amplitudes equal to E_A and E_B with the difference frequency equal to $\omega/2\pi$ results in the production of a modulated envelope having a value equal to the square root of the sum of the squares of the average input signals plus twice the product of such signals at the beat or difference frequency. The shape is identical to the wave output of a full wave rectifier when the superimposed voltages are of equal magnitude and will approach a sine wave variation only when the amplitude of one is extremely small as compared to the other.

The bridge signal E_B may be adjusted to equal the desired frequency component contained in signal E_A to provide a convenient means for ascertaining the value of such component by rectifying the output derived across the null points of the bridge, as by means of a detector **150**. The output of the rectifier will therefore vary in magnitude at the difference frequency (in this case zero) and may consequently be measured in the output circuit of the detector as a D.C. value. This rectified current is also a function of the phase relationship between the components E_A and E_B of equal frequency. Thus by incorporating a phase shifting circuit (not illustrated) with the sine wave generator, it is possible to not only compare the amplitude of the various frequencies but also their phase relationship to the signal E_B.

This phase shifting device alternatively may be incorporated into the bridge as one of the legs. By this means the output voltage developed across the null points may be shifted in the phase from 0° to 180° with no change in amplitude. In some instances (high frequency work), it will be desirable to use a twin T-network in lieu of that illustrated.

Preferably the detector **150** includes an output circuit having a variable resistance by which residual D.C. due to the plate circuit bias may be balanced out in the absence of a signal voltage.

A convenient and efficient arrangement for a frequency analyzer according to the instant invention may comprise a semi-conductor light source having means for varying the emitted light intensity at a signal value equal to a superimposition of various frequencies, a light-sensitive collector cell of the photo-voltaic type and a crystal detector. In this instance, the output developed across the null points of the bridge may be controlled to lie in the millivolt region, which region is also the most effective value for utilizing crystal detectors as square wave rectifiers. The entire device will be a size which compares favorably with printed circuit techniques; the bridge and network components may be provided by the use of screening, plating or painting methods used in commercial printed circuits. Further, since it is only necessary to compare wave components, the bias of the signal voltages may be kept low.

A further form of the invention may comprise a high impedance potential source connected across a plurality of semi-conductor light sources in series. The light quanta emitted from each source may be collected by a single cell to produce a photocurrent equal to the summation of emissions from all cells. In this manner, good amplification may be obtained. The sources may be physically oriented to balance out any emission delay factor.

It will be apparent that semiconductor light sources, such as are described in said copending application (e.g. graded seal junction) may be used as the light-sensitive

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photo-conductive cell in lieu of the types previously mentioned. In such case, the dual material silicon-germanium or selenium-tellurium cell provides an added advantage in that each such cell unit has a separate absorption edge for each of the matrix materials whereby its utility is doubled. These graded seal junction semiconductors may thus be used with two different source wave lengths corresponding to the absorption edge of each matrix material.

Alternately, a photo-modulation unit such as that disclosed in said copending application and which includes a long wave length light source and an interposed semiconductor light modulator may be substituted for the instant type light source, as for example, in place of the circuit 5 in Fig. 5. In such case the collector cell C would preferably comprise a germanium light sensitive semiconductor biased in the blocking direction. With this arrangement an infrared light source would be positioned to direct a light beam of approximately 1.5 microns adjacent the barrier region of the cell C, after passing through a silicon semiconductor modulator biased in the forward direction at a value and rate dependent upon the intelligence desired to be transmitted. The light beam incident upon the cell C would thus be modulated by the photo-modulator in a manner more fully described in said copending application to produce a photocurrent in the bridge circuit of Fig. 5 dependent upon the modulated incident light beam and the normal current flow in the cell due to the biasing potential.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope hereof, it is to be understood that the above invention is not limited, except as defined in the appended claims.

What is claimed is:

1. A photon modulation system including a semi-conductor light source, a light-sensitive cell for producing a photo current dependent upon applied electrode potential and incident light, an impedance network, means providing a potential having a band of frequency components for modulating the intensity of the light emitted from said light source, means for providing a potential across said light-sensitive cell of a fixed frequency and adjustable amplitude whereby said cell produces a photo current in said network which is proportional to the instantaneous summation of said modulations said impedance network including phase shifting means and a square law detector to detect any band frequency component at said fixed frequency.

2. A photon modulation system including a semi-conductor light source, having a substantially linear relationship between light output and current, a light-sensitive cell arranged to receive light from said light source for producing a photo current dependent upon applied electrode potential and incident light, an impedance network connected to said cell, means for providing a potential comprising a band of frequency components to be analyzed for modulating the intensity of the light emitted from said light source and means for providing a potential of adjustable frequency and adjustable amplitude across said light-sensitive cell and a square law detector connected in said network to detect any band frequency component which is the same frequency as said potential of adjustable frequency, whereby the amplitude of each frequency component in said band of frequency components may be determined.

3. The combination set forth in claim 2 in which said network includes phase shifting means whereby the phase and amplitude of each frequency component in said band of frequency components may be determined.

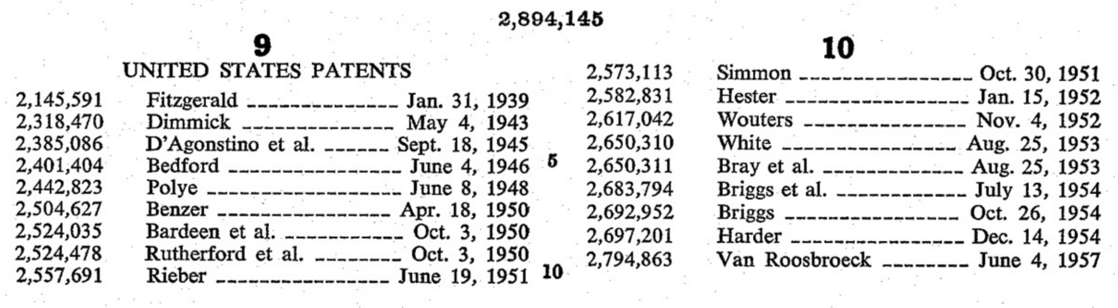
References Cited in the file of this patent

UNITED STATES PATENTS

2,050,737	Schriever	Aug. 11, 1936

(Other references on following page)

Figure B.229: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).



2,894,145

9

UNITED STATES PATENTS

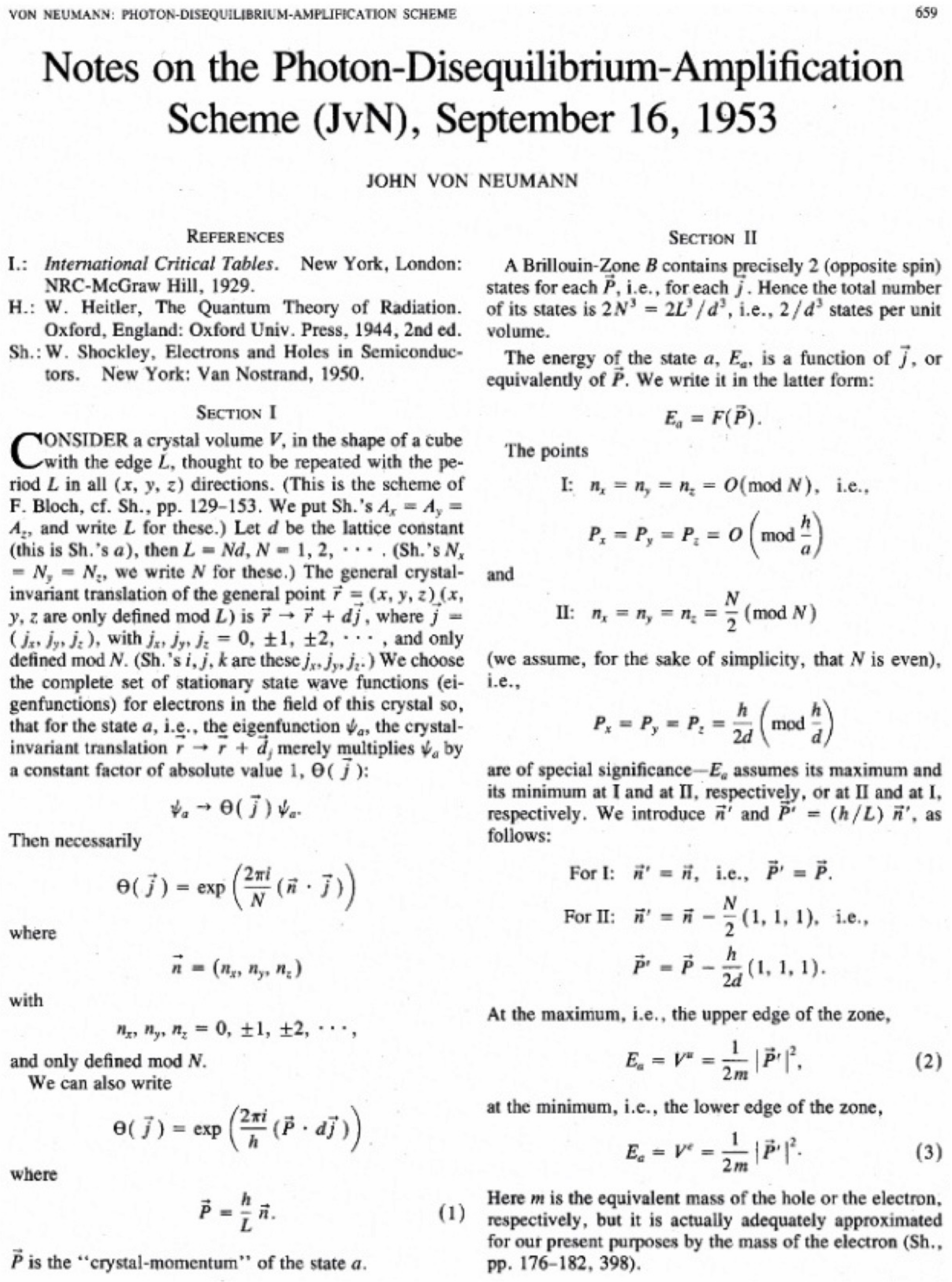
2,145,591	Fitzgerald	Jan. 31, 1939
2,318,470	Dimmick	May 4, 1943
2,385,086	D'Agonstino et al.	Sept. 18, 1945
2,401,404	Bedford	June 4, 1946
2,442,823	Polye	June 8, 1948
2,504,627	Benzer	Apr. 18, 1950
2,524,035	Bardeen et al.	Oct. 3, 1950
2,524,478	Rutherford et al.	Oct. 3, 1950
2,557,691	Rieber	June 19, 1951

10

2,573,113	Simmon	Oct. 30, 1951
2,582,831	Hester	Jan. 15, 1952
2,617,042	Wouters	Nov. 4, 1952
2,650,310	White	Aug. 25, 1953
2,650,311	Bray et al.	Aug. 25, 1953
2,683,794	Briggs et al.	July 13, 1954
2,692,952	Briggs	Oct. 26, 1954
2,697,201	Harder	Dec. 14, 1954
2,794,863	Van Roosbroeck	June 4, 1957

Figure B.230: Kurt Lehovec worked under Bernhard Gudden during World War II, was extensively interrogated by and came to the United States after the war, and filed detailed patent applications on improved LEDs (possibly based on wartime work).

John von Neuman (1903–1957) made a detailed proposal for laser diodes in 1953, which was likely circulated via his many consulting roles [*IEEE Journal of Quantum Electronics* 23:6:659–673 (1987)]



Notes on the Photon-Disequilibrium-Amplification Scheme (JvN), September 16, 1953

JOHN VON NEUMANN

REFERENCES

I.: *International Critical Tables.* New York, London: NRC-McGraw Hill, 1929.
H.: W. Heitler, The Quantum Theory of Radiation. Oxford, England: Oxford Univ. Press, 1944, 2nd ed.
Sh.: W. Shockley, Electrons and Holes in Semiconductors. New York: Van Nostrand, 1950.

SECTION I

CONSIDER a crystal volume V, in the shape of a cube with the edge L, thought to be repeated with the period L in all (x, y, z) directions. (This is the scheme of F. Bloch, cf. Sh., pp. 129–153. We put Sh.'s $A_x = A_y = A_z$, and write L for these.) Let d be the lattice constant (this is Sh.'s a), then $L = Nd$, $N = 1, 2, \cdots$. (Sh.'s $N_x = N_y = N_z$, we write N for these.) The general crystal-invariant translation of the general point $\vec{r} = (x, y, z)$ (x, y, z are only defined mod L) is $\vec{r} \rightarrow \vec{r} + d\vec{j}$, where $\vec{j} = (j_x, j_y, j_z)$, with $j_x, j_y, j_z = 0, \pm 1, \pm 2, \cdots$, and only defined mod N. (Sh.'s i, j, k are these j_x, j_y, j_z.) We choose the complete set of stationary state wave functions (eigenfunctions) for electrons in the field of this crystal so, that for the state a, i.e., the eigenfunction ψ_a, the crystal-invariant translation $\vec{r} \rightarrow \vec{r} + \vec{d}_j$ merely multiplies ψ_a by a constant factor of absolute value 1, $\Theta(\vec{j})$:

$$\psi_a \rightarrow \Theta(\vec{j})\, \psi_a.$$

Then necessarily

$$\Theta(\vec{j}) = \exp\left(\frac{2\pi i}{N}(\vec{n} \cdot \vec{j})\right)$$

where

$$\vec{n} = (n_x, n_y, n_z)$$

with

$$n_x, n_y, n_z = 0, \pm 1, \pm 2, \cdots,$$

and only defined mod N.

We can also write

$$\Theta(\vec{j}) = \exp\left(\frac{2\pi i}{h}(\vec{P} \cdot d\vec{j})\right)$$

where

$$\vec{P} = \frac{h}{L}\,\vec{n}. \tag{1}$$

$\vec{P}$ is the "crystal-momentum" of the state a.

SECTION II

A Brillouin-Zone B contains precisely 2 (opposite spin) states for each $\vec{P}$, i.e., for each $\vec{j}$. Hence the total number of its states is $2N^3 = 2L^3/d^3$, i.e., $2/d^3$ states per unit volume.

The energy of the state a, E_a, is a function of $\vec{j}$, or equivalently of $\vec{P}$. We write it in the latter form:

$$E_a = F(\vec{P}).$$

The points

$$\text{I:} \quad n_x = n_y = n_z = O(\text{mod } N), \quad \text{i.e.,}$$

$$P_x = P_y = P_z = O\left(\text{mod } \frac{h}{a}\right)$$

and

$$\text{II:} \quad n_x = n_y = n_z = \frac{N}{2}(\text{mod } N)$$

(we assume, for the sake of simplicity, that N is even), i.e.,

$$P_x = P_y = P_z = \frac{h}{2d}\left(\text{mod } \frac{h}{d}\right)$$

are of special significance—E_a assumes its maximum and its minimum at I and at II, respectively, or at II and at I, respectively. We introduce $\vec{n}'$ and $\vec{P}' = (h/L)\,\vec{n}'$, as follows:

$$\text{For I:} \quad \vec{n}' = \vec{n}, \quad \text{i.e.,} \quad \vec{P}' = \vec{P}.$$

$$\text{For II:} \quad \vec{n}' = \vec{n} - \frac{N}{2}(1, 1, 1), \quad \text{i.e.,}$$

$$\vec{P}' = \vec{P} - \frac{h}{2d}(1, 1, 1).$$

At the maximum, i.e., the upper edge of the zone,

$$E_a = V^u = \frac{1}{2m}|\vec{P}'|^2, \tag{2}$$

at the minimum, i.e., the lower edge of the zone,

$$E_a = V^e = \frac{1}{2m}|\vec{P}'|^2. \tag{3}$$

Here m is the equivalent mass of the hole or the electron, respectively, but it is actually adequately approximated for our present purposes by the mass of the electron (Sh., pp. 176–182, 398).

Figure B.231: John von Neumann made a detailed proposal for laser diodes in 1953, which was likely circulated via his many consulting roles in government and industry [*IEEE Journal of Quantum Electronics* 23:6:659–673 (1987)].

Feb. 11, 1964 **W. HEYWANG** **3,121,203**

SEMICONDUCTOR MASER WITH MODULATING MEANS

Filed April 22, 1959 2 Sheets-Sheet 1

Fig.1

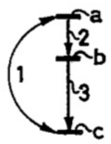


Fig.2a

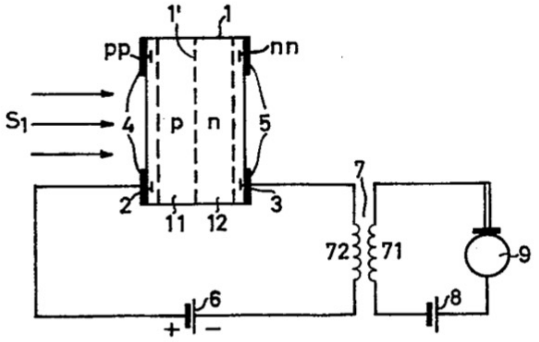

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Fig.2b

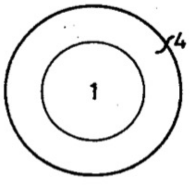
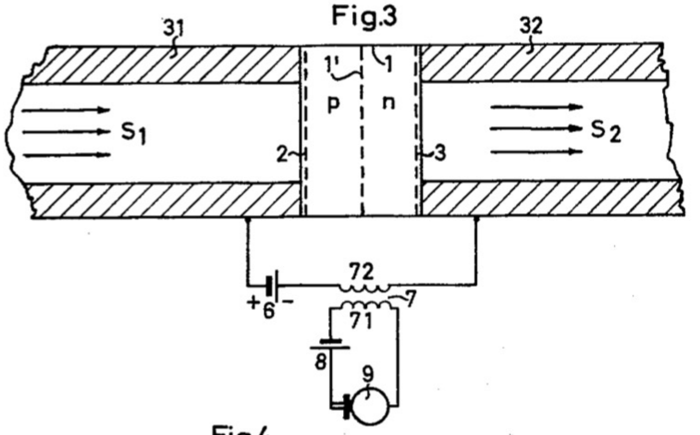


Fig.3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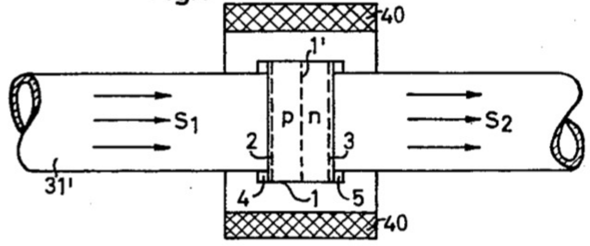
p
n
S1
S2
2
3
72
+6–
7
71
8
9

Fig.4


40
1'
S1
p
n
S2
2
3
31'
4
1
5
40

Inventor:
Walter Heywang.
By. Atty.

Figure B.232: Walter Heywang filed detailed patent applications on laser diodes in 1958.

Feb. 11, 1964 **W. HEYWANG** **3,121,203**

SEMICONDUCTOR MASER WITH MODULATING MEANS

Filed April 22, 1959 2 Sheets-Sheet 2

Fig.5

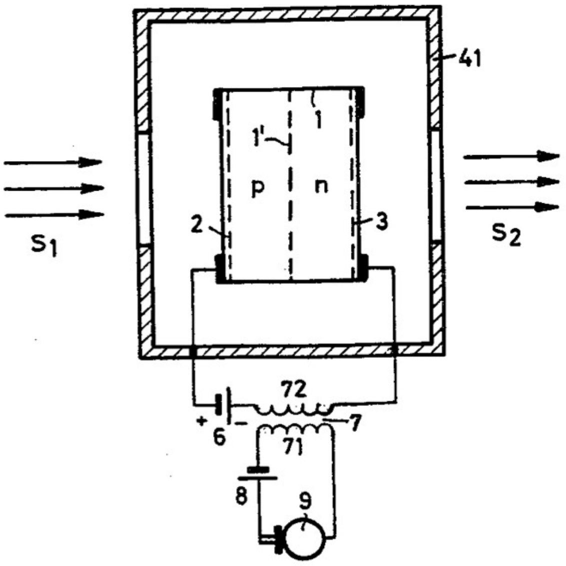
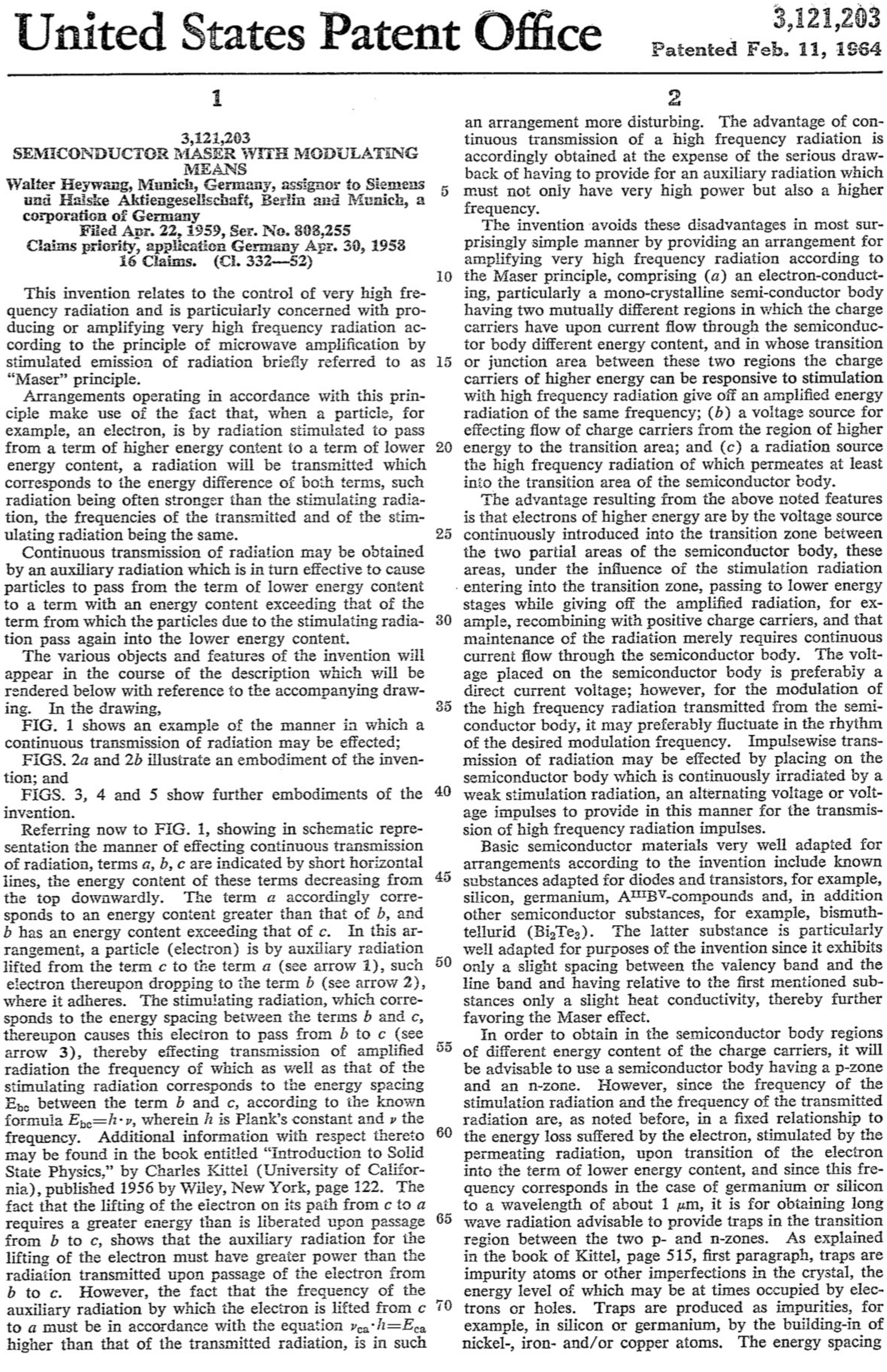


Figure B.233: Walter Heywang filed detailed patent applications on laser diodes in 1958.



United States Patent Office

3,121,203
Patented Feb. 11, 1964

3,121,203

SEMICONDUCTOR MASER WITH MODULATING MEANS

Walter Heywang, Munich, Germany, assignor to Siemens und Halske Aktiengesellschaft, Berlin and Munich, a corporation of Germany
Filed Apr. 22, 1959, Ser. No. 808,255
Claims priority, application Germany Apr. 30, 1958
16 Claims. (Cl. 332—52)

This invention relates to the control of very high frequency radiation and is particularly concerned with producing or amplifying very high frequency radiation according to the principle of microwave amplification by stimulated emission of radiation briefly referred to as "Maser" principle.

Arrangements operating in accordance with this principle make use of the fact that, when a particle, for example, an electron, is by radiation stimulated to pass from a term of higher energy content to a term of lower energy content, a radiation will be transmitted which corresponds to the energy difference of both terms, such radiation being often stronger than the stimulating radiation, the frequencies of the transmitted and of the stimulating radiation being the same.

Continuous transmission of radiation may be obtained by an auxiliary radiation which is in turn effective to cause particles to pass from the term of lower energy content to a term with an energy content exceeding that of the term from which the particles due to the stimulating radiation pass again into the lower energy content.

The various objects and features of the invention will appear in the course of the description which will be rendered below with reference to the accompanying drawing. In the drawing,

FIG. 1 shows an example of the manner in which a continuous transmission of radiation may be effected;

FIGS. 2*a* and 2*b* illustrate an embodiment of the invention; and

FIGS. 3, 4 and 5 show further embodiments of the invention.

Referring now to FIG. 1, showing in schematic representation the manner of effecting continuous transmission of radiation, terms *a*, *b*, *c* are indicated by short horizontal lines, the energy content of these terms decreasing from the top downwardly. The term *a* accordingly corresponds to an energy content greater than that of *b*, and *b* has an energy content exceeding that of *c*. In this arrangement, a particle (electron) is by auxiliary radiation lifted from the term *c* to the term *a* (see arrow 1), such electron thereupon dropping to the term *b* (see arrow 2), where it adheres. The stimulating radiation, which corresponds to the energy spacing between the terms *b* and *c*, thereupon causes this electron to pass from *b* to *c* (see arrow 3), thereby effecting transmission of amplified radiation the frequency of which as well as that of the stimulating radiation corresponds to the energy spacing E_{bc} between the term *b* and *c*, according to the known formula $E_{bc}=h\cdot\nu$, wherein h is Plank's constant and ν the frequency. Additional information with respect thereto may be found in the book entitled "Introduction to Solid State Physics," by Charles Kittel (University of California), published 1956 by Wiley, New York, page 122. The fact that the lifting of the electron on its path from *c* to *a* requires a greater energy than is liberated upon passage from *b* to *c*, shows that the auxiliary radiation for the lifting of the electron must have greater power than the radiation transmitted upon passage of the electron from *b* to *c*. However, the fact that the frequency of the auxiliary radiation by which the electron is lifted from *c* to *a* must be in accordance with the equation $\nu_{ca}\cdot h=E_{ca}$ higher than that of the transmitted radiation, is in such an arrangement more disturbing. The advantage of continuous transmission of a high frequency radiation is accordingly obtained at the expense of the serious drawback of having to provide for an auxiliary radiation which must not only have very high power but also a higher frequency.

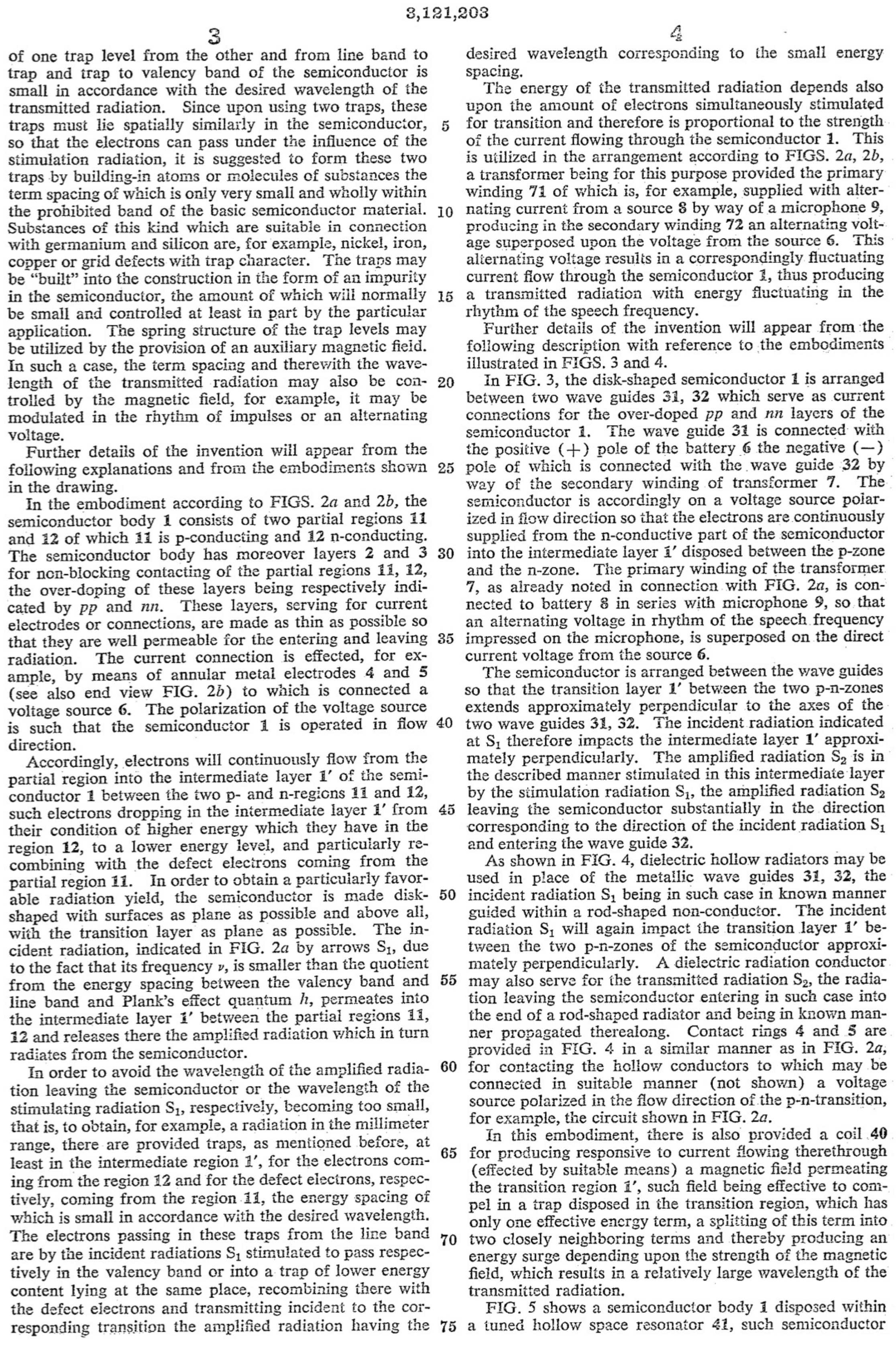
The invention avoids these disadvantages in most surprisingly simple manner by providing an arrangement for amplifying very high frequency radiation according to the Maser principle, comprising (*a*) an electron-conducting, particularly a mono-crystalline semi-conductor body having two mutually different regions in which the charge carriers have upon current flow through the semiconductor body different energy content, and in whose transition or junction area between these two regions the charge carriers of higher energy can be responsive to stimulation with high frequency radiation give off an amplified energy radiation of the same frequency; (*b*) a voltage source for effecting flow of charge carriers from the region of higher energy to the transition area; and (*c*) a radiation source the high frequency radiation of which permeates at least into the transition area of the semiconductor body.

The advantage resulting from the above noted features is that electrons of higher energy are by the voltage source continuously introduced into the transition zone between the two partial areas of the semiconductor body, these areas, under the influence of the stimulation radiation entering into the transition zone, passing to lower energy stages while giving off the amplified radiation, for example, recombining with positive charge carriers, and that maintenance of the radiation merely requires continuous current flow through the semiconductor body. The voltage placed on the semiconductor body is preferably a direct current voltage; however, for the modulation of the high frequency radiation transmitted from the semiconductor body, it may preferably fluctuate in the rhythm of the desired modulation frequency. Impulsewise transmission of radiation may be effected by placing on the semiconductor body which is continuously irradiated by a weak stimulation radiation, an alternating voltage or voltage impulses to provide in this manner for the transmission of high frequency radiation impulses.

Basic semiconductor materials very well adapted for arrangements according to the invention include known substances adapted for diodes and transistors, for example, silicon, germanium, $A^{III}B^{V}$-compounds and, in addition other semiconductor substances, for example, bismuthtellurid (Bi_2Te_3). The latter substance is particularly well adapted for purposes of the invention since it exhibits only a slight spacing between the valency band and the line band and having relative to the first mentioned substances only a slight heat conductivity, thereby further favoring the Maser effect.

In order to obtain in the semiconductor body regions of different energy content of the charge carriers, it will be advisable to use a semiconductor body having a p-zone and an n-zone. However, since the frequency of the stimulation radiation and the frequency of the transmitted radiation are, as noted before, in a fixed relationship to the energy loss suffered by the electron, stimulated by the permeating radiation, upon transition of the electron into the term of lower energy content, and since this frequency corresponds in the case of germanium or silicon to a wavelength of about 1 μm, it is for obtaining long wave radiation advisable to provide traps in the transition region between the two p- and n-zones. As explained in the book of Kittel, page 515, first paragraph, traps are impurity atoms or other imperfections in the crystal, the energy level of which may be at times occupied by electrons or holes. Traps are produced as impurities, for example, in silicon or germanium, by the building-in of nickel-, iron- and/or copper atoms. The energy spacing

Figure B.234: Walter Heywang filed detailed patent applications on laser diodes in 1958.



of one trap level from the other and from line band to trap and trap to valency band of the semiconductor is small in accordance with the desired wavelength of the transmitted radiation. Since upon using two traps, these traps must lie spatially similarly in the semiconductor, so that the electrons can pass under the influence of the stimulation radiation, it is suggested to form these two traps by building-in atoms or molecules of substances the term spacing of which is only very small and wholly within the prohibited band of the basic semiconductor material. Substances of this kind which are suitable in connection with germanium and silicon are, for example, nickel, iron, copper or grid defects with trap character. The traps may be "built" into the construction in the form of an impurity in the semiconductor, the amount of which will normally be small and controlled at least in part by the particular application. The spring structure of the trap levels may be utilized by the provision of an auxiliary magnetic field. In such a case, the term spacing and therewith the wavelength of the transmitted radiation may also be controlled by the magnetic field, for example, it may be modulated in the rhythm of impulses or an alternating voltage.

Further details of the invention will appear from the following explanations and from the embodiments shown in the drawing.

In the embodiment according to FIGS. 2*a* and 2*b*, the semiconductor body 1 consists of two partial regions 11 and 12 of which 11 is p-conducting and 12 n-conducting. The semiconductor body has moreover layers 2 and 3 for non-blocking contacting of the partial regions 11, 12, the over-doping of these layers being respectively indicated by *pp* and *nn*. These layers, serving for current electrodes or connections, are made as thin as possible so that they are well permeable for the entering and leaving radiation. The current connection is effected, for example, by means of annular metal electrodes 4 and 5 (see also end view FIG. 2*b*) to which is connected a voltage source 6. The polarization of the voltage source is such that the semiconductor 1 is operated in flow direction.

Accordingly, electrons will continuously flow from the partial region into the intermediate layer 1′ of the semiconductor 1 between the two p- and n-regions 11 and 12, such electrons dropping in the intermediate layer 1′ from their condition of higher energy which they have in the region 12, to a lower energy level, and particularly recombining with the defect electrons coming from the partial region 11. In order to obtain a particularly favorable radiation yield, the semiconductor is made disk-shaped with surfaces as plane as possible and above all, with the transition layer as plane as possible. The incident radiation, indicated in FIG. 2*a* by arrows S_1, due to the fact that its frequency ν, is smaller than the quotient from the energy spacing between the valency band and line band and Plank's effect quantum h, permeates into the intermediate layer 1′ between the partial regions 11, 12 and releases there the amplified radiation which in turn radiates from the semiconductor.

In order to avoid the wavelength of the amplified radiation leaving the semiconductor or the wavelength of the stimulating radiation S_1, respectively, becoming too small, that is, to obtain, for example, a radiation in the millimeter range, there are provided traps, as mentioned before, at least in the intermediate region 1′, for the electrons coming from the region 12 and for the defect electrons, respectively, coming from the region 11, the energy spacing of which is small in accordance with the desired wavelength. The electrons passing in these traps from the line band are by the incident radiations S_1 stimulated to pass respectively in the valency band or into a trap of lower energy content lying at the same place, recombining there with the defect electrons and transmitting incident to the corresponding transition the amplified radiation having the desired wavelength corresponding to the small energy spacing.

The energy of the transmitted radiation depends also upon the amount of electrons simultaneously stimulated for transition and therefore is proportional to the strength of the current flowing through the semiconductor 1. This is utilized in the arrangement according to FIGS. 2*a*, 2*b*, a transformer being for this purpose provided the primary winding 71 of which is, for example, supplied with alternating current from a source 8 by way of a microphone 9, producing in the secondary winding 72 an alternating voltage superposed upon the voltage from the source 6. This alternating voltage results in a correspondingly fluctuating current flow through the semiconductor 1, thus producing a transmitted radiation with energy fluctuating in the rhythm of the speech frequency.

Further details of the invention will appear from the following description with reference to the embodiments illustrated in FIGS. 3 and 4.

In FIG. 3, the disk-shaped semiconductor 1 is arranged between two wave guides 31, 32 which serve as current connections for the over-doped *pp* and *nn* layers of the semiconductor 1. The wave guide 31 is connected with the positive (+) pole of the battery 6 the negative (−) pole of which is connected with the wave guide 32 by way of the secondary winding of transformer 7. The semiconductor is accordingly on a voltage source polarized in flow direction so that the electrons are continuously supplied from the n-conductive part of the semiconductor into the intermediate layer 1′ disposed between the p-zone and the n-zone. The primary winding of the transformer 7, as already noted in connection with FIG. 2*a*, is connected to battery 8 in series with microphone 9, so that an alternating voltage in rhythm of the speech frequency impressed on the microphone, is superposed on the direct current voltage from the source 6.

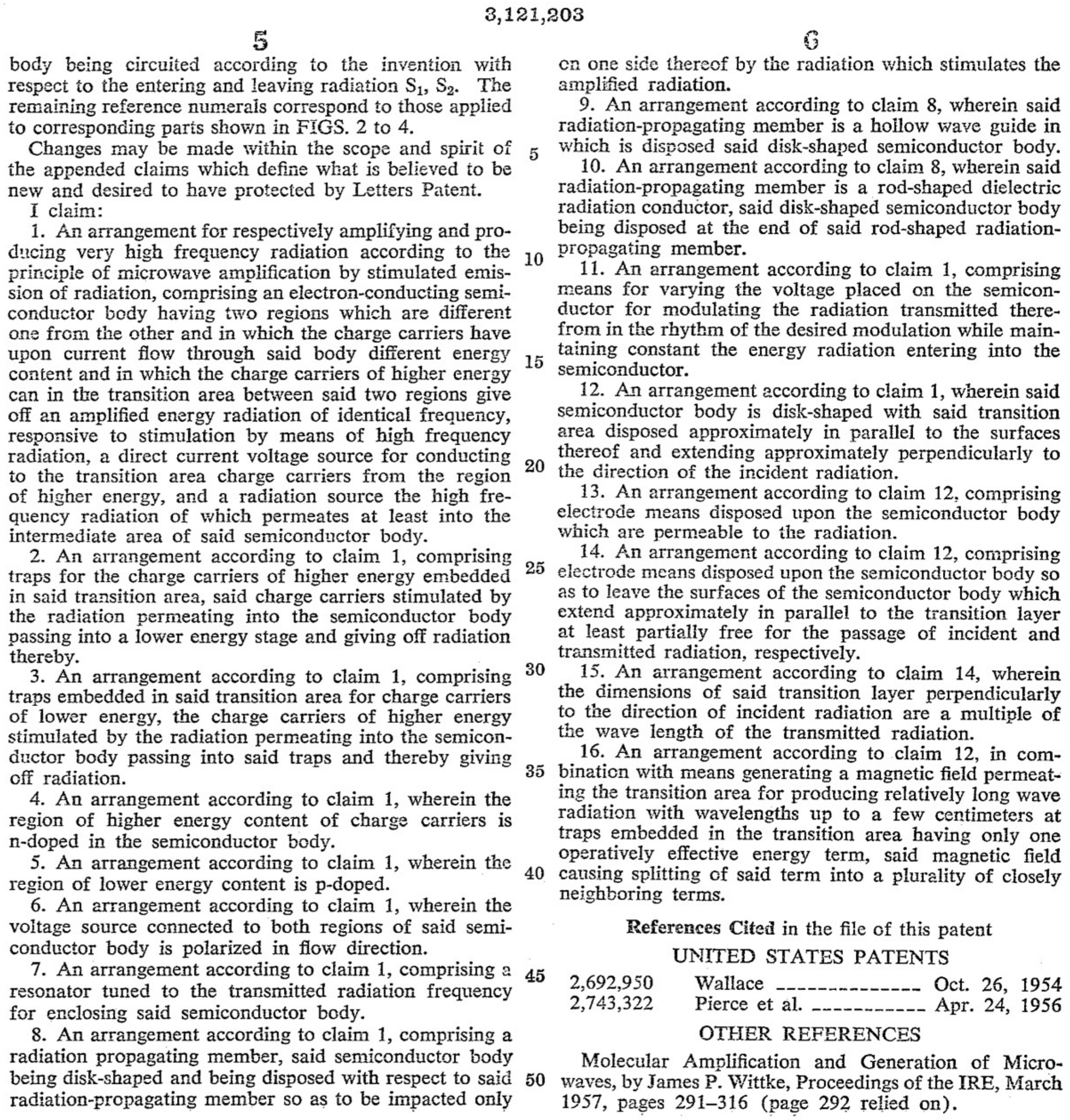
The semiconductor is arranged between the wave guides so that the transition layer 1′ between the two p-n-zones extends approximately perpendicular to the axes of the two wave guides 31, 32. The incident radiation indicated at S_1 therefore impacts the intermediate layer 1′ approximately perpendicularly. The amplified radiation S_2 is in the described manner stimulated in this intermediate layer by the stimulation radiation S_1, the amplified radiation S_2 leaving the semiconductor substantially in the direction corresponding to the direction of the incident radiation S_1 and entering the wave guide 32.

As shown in FIG. 4, dielectric hollow radiators may be used in place of the metallic wave guides 31, 32, the incident radiation S_1 being in such case in known manner guided within a rod-shaped non-conductor. The incident radiation S_1 will again impact the transition layer 1′ between the two p-n-zones of the semiconductor approximately perpendicularly. A dielectric radiation conductor may also serve for the transmitted radiation S_2, the radiation leaving the semiconductor entering in such case into the end of a rod-shaped radiator and being in known manner propagated therealong. Contact rings 4 and 5 are provided in FIG. 4 in a similar manner as in FIG. 2*a*, for contacting the hollow conductors to which may be connected in suitable manner (not shown) a voltage source polarized in the flow direction of the p-n-transition, for example, the circuit shown in FIG. 2*a*.

In this embodiment, there is also provided a coil 40 for producing responsive to current flowing therethrough (effected by suitable means) a magnetic field permeating the transition region 1′, such field being effective to compel in a trap disposed in the transition region, which has only one effective energy term, a splitting of this term into two closely neighboring terms and thereby producing an energy surge depending upon the strength of the magnetic field, which results in a relatively large wavelength of the transmitted radiation.

FIG. 5 shows a semiconductor body 1 disposed within a tuned hollow space resonator 41, such semiconductor

Figure B.235: Walter Heywang filed detailed patent applications on laser diodes in 1958.



body being circuited according to the invention with respect to the entering and leaving radiation S_1, S_2. The remaining reference numerals correspond to those applied to corresponding parts shown in FIGS. 2 to 4.

Changes may be made within the scope and spirit of the appended claims which define what is believed to be new and desired to have protected by Letters Patent.

I claim:

1. An arrangement for respectively amplifying and producing very high frequency radiation according to the principle of microwave amplification by stimulated emission of radiation, comprising an electron-conducting semiconductor body having two regions which are different one from the other and in which the charge carriers have upon current flow through said body different energy content and in which the charge carriers of higher energy can in the transition area between said two regions give off an amplified energy radiation of identical frequency, responsive to stimulation by means of high frequency radiation, a direct current voltage source for conducting to the transition area charge carriers from the region of higher energy, and a radiation source the high frequency radiation of which permeates at least into the intermediate area of said semiconductor body.

2. An arrangement according to claim 1, comprising traps for the charge carriers of higher energy embedded in said transition area, said charge carriers stimulated by the radiation permeating into the semiconductor body passing into a lower energy stage and giving off radiation thereby.

3. An arrangement according to claim 1, comprising traps embedded in said transition area for charge carriers of lower energy, the charge carriers of higher energy stimulated by the radiation permeating into the semiconductor body passing into said traps and thereby giving off radiation.

4. An arrangement according to claim 1, wherein the region of higher energy content of charge carriers is n-doped in the semiconductor body.

5. An arrangement according to claim 1, wherein the region of lower energy content is p-doped.

6. An arrangement according to claim 1, wherein the voltage source connected to both regions of said semiconductor body is polarized in flow direction.

7. An arrangement according to claim 1, comprising a resonator tuned to the transmitted radiation frequency for enclosing said semiconductor body.

8. An arrangement according to claim 1, comprising a radiation propagating member, said semiconductor body being disk-shaped and being disposed with respect to said radiation-propagating member so as to be impacted only on one side thereof by the radiation which stimulates the amplified radiation.

9. An arrangement according to claim 8, wherein said radiation-propagating member is a hollow wave guide in which is disposed said disk-shaped semiconductor body.

10. An arrangement according to claim 8, wherein said radiation-propagating member is a rod-shaped dielectric radiation conductor, said disk-shaped semiconductor body being disposed at the end of said rod-shaped radiation-propagating member.

11. An arrangement according to claim 1, comprising means for varying the voltage placed on the semiconductor for modulating the radiation transmitted therefrom in the rhythm of the desired modulation while maintaining constant the energy radiation entering into the semiconductor.

12. An arrangement according to claim 1, wherein said semiconductor body is disk-shaped with said transition area disposed approximately in parallel to the surfaces thereof and extending approximately perpendicularly to the direction of the incident radiation.

13. An arrangement according to claim 12, comprising electrode means disposed upon the semiconductor body which are permeable to the radiation.

14. An arrangement according to claim 12, comprising electrode means disposed upon the semiconductor body so as to leave the surfaces of the semiconductor body which extend approximately in parallel to the transition layer at least partially free for the passage of incident and transmitted radiation, respectively.

15. An arrangement according to claim 14, wherein the dimensions of said transition layer perpendicularly to the direction of incident radiation are a multiple of the wave length of the transmitted radiation.

16. An arrangement according to claim 12, in combination with means generating a magnetic field permeating the transition area for producing relatively long wave radiation with wavelengths up to a few centimeters at traps embedded in the transition area having only one operatively effective energy term, said magnetic field causing splitting of said term into a plurality of closely neighboring terms.

References Cited in the file of this patent

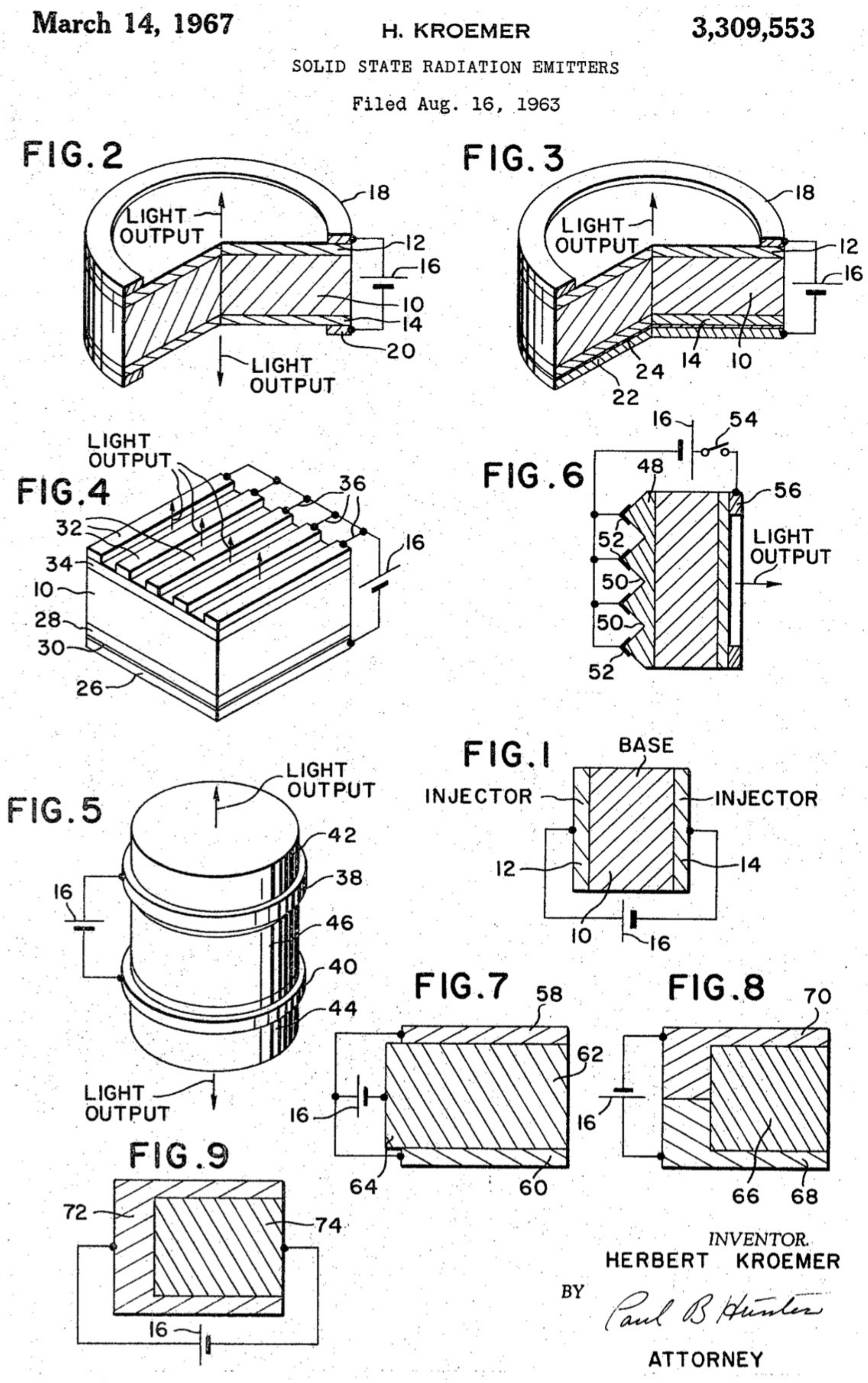
UNITED STATES PATENTS

2,692,950	Wallace	Oct. 26, 1954
2,743,322	Pierce et al.	Apr. 24, 1956

OTHER REFERENCES

Molecular Amplification and Generation of Microwaves, by James P. Wittke, Proceedings of the IRE, March 1957, pages 291–316 (page 292 relied on).

Figure B.236: Walter Heywang filed detailed patent applications on laser diodes in 1958.



March 14, 1967 H. KROEMER **3,309,553**

SOLID STATE RADIATION EMITTERS

Filed Aug. 16, 1963

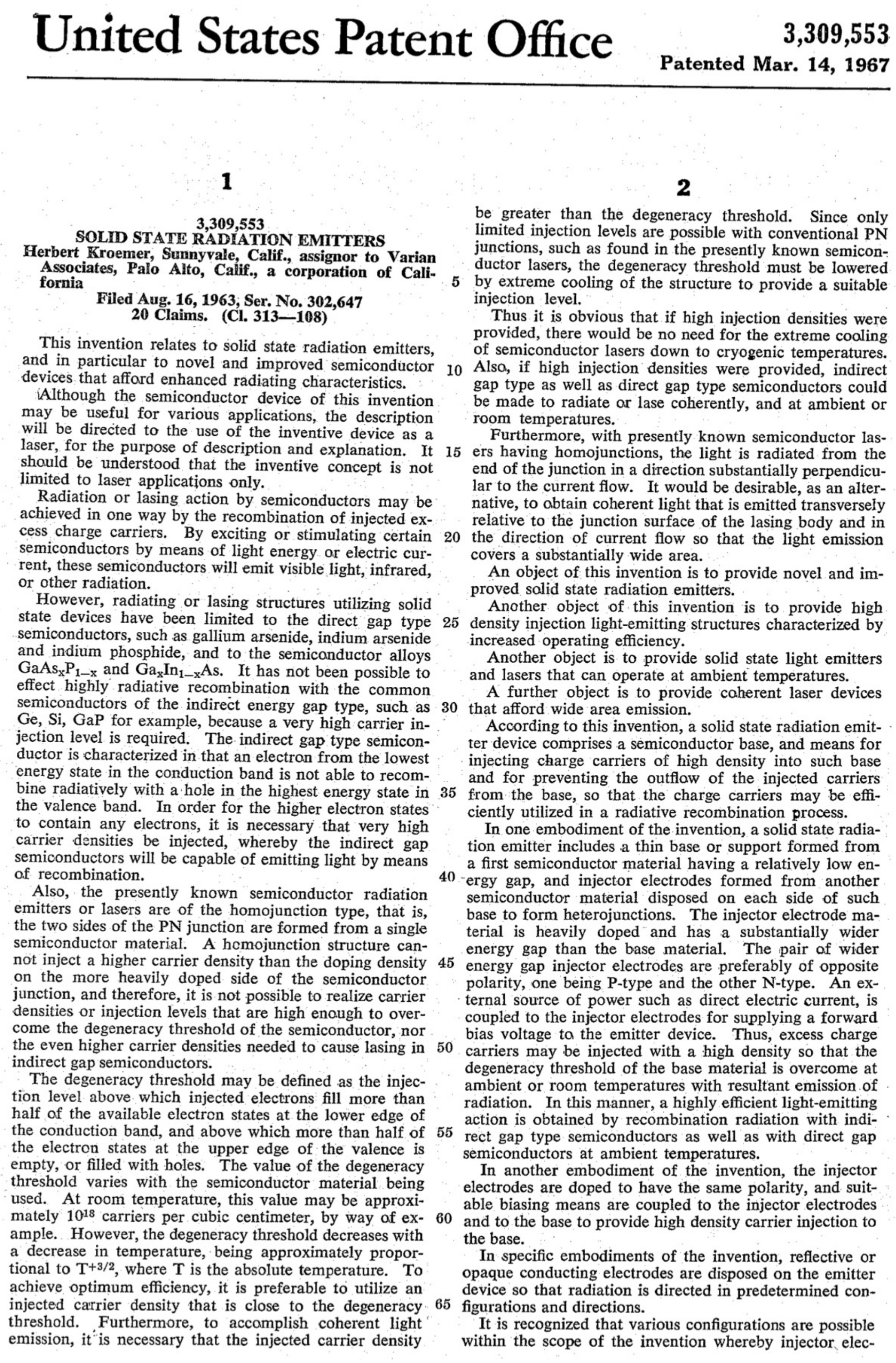
INVENTOR.
HERBERT KROEMER

BY Paul B Hunter

ATTORNEY

FIG.2
LIGHT OUTPUT
18
12
16
10
14
20
LIGHT OUTPUT
FIG.3
LIGHT OUTPUT
18
12
16
24
14
10
22
LIGHT OUTPUT
FIG.4
36
32
34
10
28
30
26
16
16
54
FIG.6
48
56
52
50
50
52
LIGHT OUTPUT
FIG.1
BASE
INJECTOR
INJECTOR
12
14
10
16
FIG.5
LIGHT OUTPUT
42
38
16
46
40
44
LIGHT OUTPUT
FIG.7
58
62
16
64
60
FIG.8
70
16
66
68
FIG.9
72
74
16

Figure B.237: Herbert Kroemer invented the double-heterostructure laser diode in 1963.



United States Patent Office

3,309,553
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3,309,553

SOLID STATE RADIATION EMITTERS

Herbert Kroemer, Sunnyvale, Calif., assignor to Varian Associates, Palo Alto, Calif., a corporation of California

Filed Aug. 16, 1963, Ser. No. 302,647
20 Claims. (Cl. 313—108)

This invention relates to solid state radiation emitters, and in particular to novel and improved semiconductor devices that afford enhanced radiating characteristics.

Although the semiconductor device of this invention may be useful for various applications, the description will be directed to the use of the inventive device as a laser, for the purpose of description and explanation. It should be understood that the inventive concept is not limited to laser applications only.

Radiation or lasing action by semiconductors may be achieved in one way by the recombination of injected excess charge carriers. By exciting or stimulating certain semiconductors by means of light energy or electric current, these semiconductors will emit visible light, infrared, or other radiation.

However, radiating or lasing structures utilizing solid state devices have been limited to the direct gap type semiconductors, such as gallium arsenide, indium arsenide and indium phosphide, and to the semiconductor alloys $GaAs_xP_{1-x}$ and $Ga_xIn_{1-x}As$. It has not been possible to effect highly radiative recombination with the common semiconductors of the indirect energy gap type, such as Ge, Si, GaP for example, because a very high carrier injection level is required. The indirect gap type semiconductor is characterized in that an electron from the lowest energy state in the conduction band is not able to recombine radiatively with a hole in the highest energy state in the valence band. In order for the higher electron states to contain any electrons, it is necessary that very high carrier densities be injected, whereby the indirect gap semiconductors will be capable of emitting light by means of recombination.

Also, the presently known semiconductor radiation emitters or lasers are of the homojunction type, that is, the two sides of the PN junction are formed from a single semiconductor material. A homojunction structure cannot inject a higher carrier density than the doping density on the more heavily doped side of the semiconductor junction, and therefore, it is not possible to realize carrier densities or injection levels that are high enough to overcome the degeneracy threshold of the semiconductor, nor the even higher carrier densities needed to cause lasing in indirect gap semiconductors.

The degeneracy threshold may be defined as the injection level above which injected electrons fill more than half of the available electron states at the lower edge of the conduction band, and above which more than half of the electron states at the upper edge of the valence is empty, or filled with holes. The value of the degeneracy threshold varies with the semiconductor material being used. At room temperature, this value may be approximately 10^{18} carriers per cubic centimeter, by way of example. However, the degeneracy threshold decreases with a decrease in temperature, being approximately proportional to $T^{+3/2}$, where T is the absolute temperature. To achieve optimum efficiency, it is preferable to utilize an injected carrier density that is close to the degeneracy threshold. Furthermore, to accomplish coherent light emission, it is necessary that the injected carrier density

2

be greater than the degeneracy threshold. Since only limited injection levels are possible with conventional PN junctions, such as found in the presently known semiconductor lasers, the degeneracy threshold must be lowered by extreme cooling of the structure to provide a suitable injection level.

Thus it is obvious that if high injection densities were provided, there would be no need for the extreme cooling of semiconductor lasers down to cryogenic temperatures. Also, if high injection densities were provided, indirect gap type as well as direct gap type semiconductors could be made to radiate or lase coherently, and at ambient or room temperatures.

Furthermore, with presently known semiconductor lasers having homojunctions, the light is radiated from the end of the junction in a direction substantially perpendicular to the current flow. It would be desirable, as an alternative, to obtain coherent light that is emitted transversely relative to the junction surface of the lasing body and in the direction of current flow so that the light emission covers a substantially wide area.

An object of this invention is to provide novel and improved solid state radiation emitters.

Another object of this invention is to provide high density injection light-emitting structures characterized by increased operating efficiency.

Another object is to provide solid state light emitters and lasers that can operate at ambient temperatures.

A further object is to provide coherent laser devices that afford wide area emission.

According to this invention, a solid state radiation emitter device comprises a semiconductor base, and means for injecting charge carriers of high density into such base and for preventing the outflow of the injected carriers from the base, so that the charge carriers may be efficiently utilized in a radiative recombination process.

In one embodiment of the invention, a solid state radiation emitter includes a thin base or support formed from a first semiconductor material having a relatively low energy gap, and injector electrodes formed from another semiconductor material disposed on each side of such base to form heterojunctions. The injector electrode material is heavily doped and has a substantially wider energy gap than the base material. The pair of wider energy gap injector electrodes are preferably of opposite polarity, one being P-type and the other N-type. An external source of power such as direct electric current, is coupled to the injector electrodes for supplying a forward bias voltage to the emitter device. Thus, excess charge carriers may be injected with a high density so that the degeneracy threshold of the base material is overcome at ambient or room temperatures with resultant emission of radiation. In this manner, a highly efficient light-emitting action is obtained by recombination radiation with indirect gap type semiconductors as well as with direct gap semiconductors at ambient temperatures.

In another embodiment of the invention, the injector electrodes are doped to have the same polarity, and suitable biasing means are coupled to the injector electrodes and to the base to provide high density carrier injection to the base.

In specific embodiments of the invention, reflective or opaque conducting electrodes are disposed on the emitter device so that radiation is directed in predetermined configurations and directions.

It is recognized that various configurations are possible within the scope of the invention whereby injector elec-

Figure B.238: Herbert Kroemer invented the double-heterostructure laser diode in 1963.

trodes formed from a semiconductor material with a higher energy gap are disposed adjacent to a semiconductor base with a relatively lower energy gap, and energizing means are provided for actuating injection of high density charge carriers into the base. The injector electrodes are so located relative to the base that carrier outflow from the base and surface recombination are prevented.

The invention will be described in greater detail with reference to the drawing in which:

FIGURE 1 is a representational schematic diagram of a semiconductor laser, in accordance with this invention;

FIGURES 2 and 3 are isometric views, partly broken away, of embodiments of this invention;

FIGURES 4 and 5 are isometric views of alternative embodiments of the inventive structure;

FIGURE 6 is a sectional view of another alternative embodiment; and

FIGURES 7–9 are representational schematic diagrams of other embodiments of the invention.

Similar numerals refer to similar parts throughout the drawing. It is to be noted that the figures of the drawing are merely illustrative, and that the parts are not represented in exact proportion.

In the schematic diagram of FIGURE 1, a semiconductor radiation emitter structure, according to this invention, comprises a weakly doped base **10** formed from a lower energy gap material; a higher energy gap P-type injector electrode **12** on one surface of the base; and a higher energy gap N-type injector electrode **14** disposed on the opposite surface of the base **10**. A direct current source **16** supplies a positive potential to the P-type injector electrode **12**, whereas a negative potential is supplied to the N-type injector electrode **14**.

In one embodiment of the invention, the lasing base **10** is formed from a single crystal germanium (Ge) wafer, and the injector electrodes **12** and **14** are made from gallium arsenide (GaAs) that has been suitably doped. The junctions formed between the dissimilar materials are referred to as heterojunctions, in contrast to homojunctions. When manufacturing the inventive laser utilizing these particular materials, a pair of layers of GaAs are grown on a germanium wafer or base having a thickness of about 100 microns or less.

The GaAs layers are formed by first preparing a melt consisting of gallium with a small percentage of arsenic. The arsenic content in the melt depends on the growing temperature, which may range from 350° to 750° C. by way of example. At a growing temperature of 500° C., a mixture comprising approximately 5 atomic percent of arsenic is used. The prepared melt is slowly heated to about 600° C. so that the arsenic reacts with the gallium to form GaAs. (Alternatively, an appropriate amount of GaAs may be dissolved in gallium to provide a suitable mixture.) In order to dissolve the residual arsenic that has not reacted, the melt is stirred repeatedly for the first ten minutes of the slow heating process. When the melt reaches about 600° C., the temperature is maintained for at least ten minutes to allow the excess arsenic to be evaporated, and to remove any condensation nuclei. The temperature of the melt is then reduced rapidly by about 100° C., within a period of less than ten minutes. When the temperature of the melt approaches approximately 500° C., the Ge wafer is quickly immersed into the supercooled melt.

The wafer acts as a seed so that the GaAs grows on the wafer support epitaxially. Before immersion, the Ge wafer is heated to a temperature higher than the melt, i.e. over 600° C., for example. The wafer is left in the melt for at least one minute and then withdrawn, providing a GaAs layer that is about 5–20 microns thick, for example. The above steps are performed in a reducing atmosphere, such as in pure hydrogen.

It is known that commercial arsenic contains impurities which produce only N-type GaAs injector electrodes. To increase the intensity of the N-type doping whereby higher injection levels are realized, an N-type dopant such as tin is added to the melt in a 1% proportion relative to the mixture.

However, in order to obtain a highly efficient semiconductor laser, one of the two GaAs layers is preferably made as a P-type injector electrode **12** by diffusing a P-type dopant such as zinc therein. To introduce the Zn into the GaAs layer, the base wafer and Zn doping material are heated within an evacuated quartz ampoule at about 800° C. for about one hour. The Zn dopant may comprise an alloy of 90% indium and 10% zinc, where the zinc is the primary diffusant and the indium acts as a buffer to prevent excess Zn vapor pressure. In order to retain the N-type doping of the other GaAs injector electrode, the N-type layer is masked with a film of evaporated or vapor-deposited SiO_2 prior to the introduction of the Zn dopant. The Zn diffuses rapidly in the exposed GaAs layer, but relatively slowly in the Ge wafer, and the diffusion virtually stops at the Ge-GaAs junction interface. After diffusion, the SiO_2 masking film is removed from the N-type layer with hydrochloric acid.

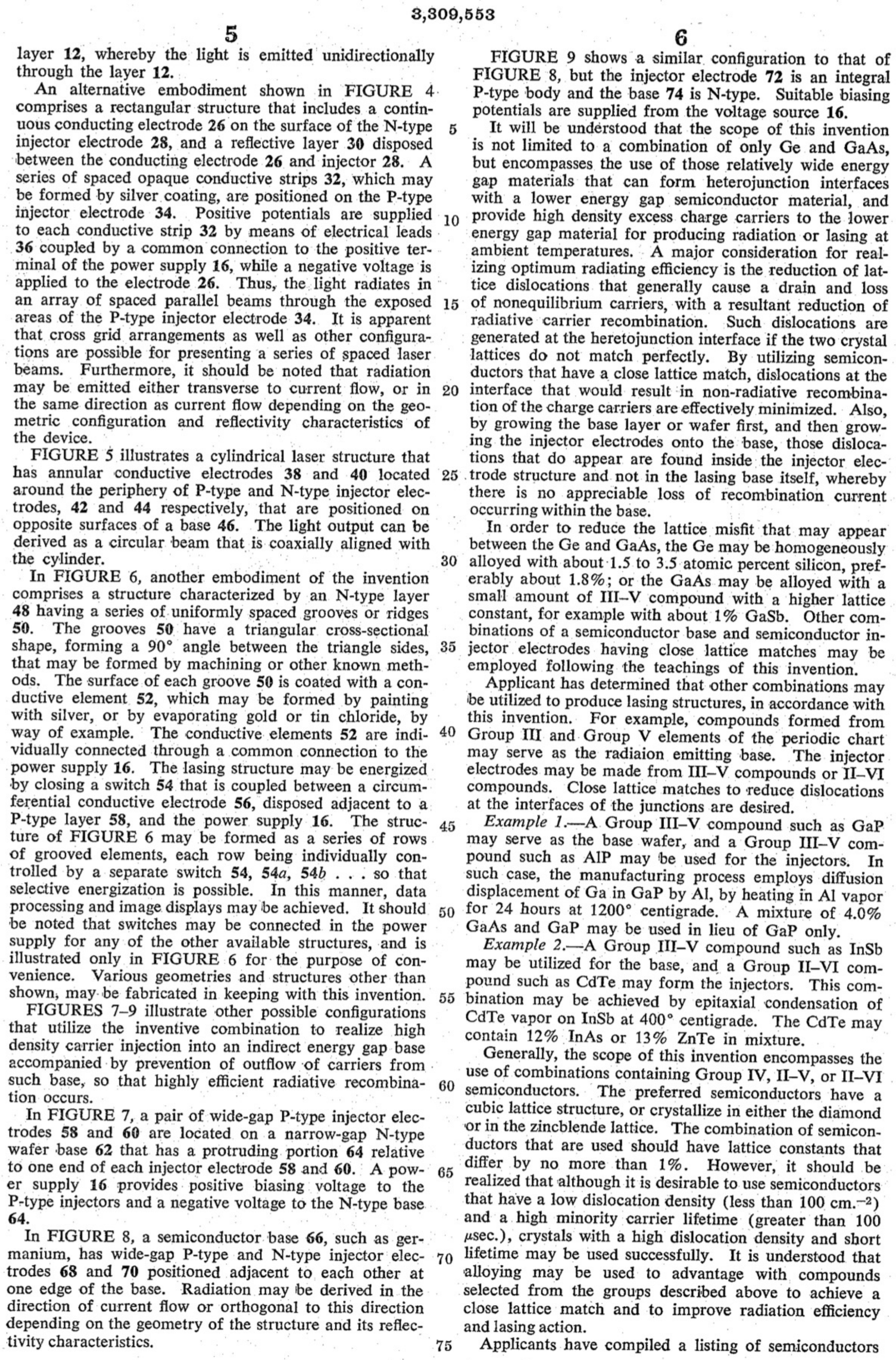
An alternative method of forming the semiconductor laser structure, with opposite polarity injector electrodes disposed on each side of a lasing base, employs a pair of Ge wafers that are placed back-to-back in a GaAs solution. N-type GaAs is grown on the exposed side of each wafer, while the surfaces that are positioned closely adjacent to each other are maintained unwetted. The edge surfaces also remain unwetted by coating the wafer edges with colloidal graphite. After growing suitable N-type injector electrodes, the wafers are then placed in a second GaAs solution that has been made P-type by adding one percent Zn, with the two coated N-type grown layers closely adjacent to each other in a back-to-back position. The P-type injector electrodes are then grown, and the graphite coating is subsequently removed from the edges of the two wafers. It is recognized that laser structure with injector electrodes may be produced by vapor epitaxy techniques.

After growing the injector electrode layers of opposite polarity, the structures are cut or cleaved to a desired shape or size, such as illustrated in FIGURES 2–6. Suitable conducting electrodes **18** and **20** are formed on the injector electrodes by evaporation, plating or other known means in any desired configuration, using screening or masking techniques. The electrodes may be formed by brushing or spraying silver paint or by evaporating thin conducting films, such as tin chloride or gold, in a well-known manner. The conducting electrodes may be made opaque or light-transmitting; or may be formed as a combination of opaque and transparent areas to allow selective areal transmission of light.

Various structures incorporating the inventive combination are shown in FIGURES 2–6. With reference to FIGURE 2, an embodiment of the invention includes a disk-like base structure **10** (shown in part) sandwiched between a P-type injector electrode **12** and N-type injector electrode **14.** Annular conducting electrodes **18** and **20**, which may be formed from silver paint, are disposed on the injector electrodes **12** and **14** respectively, and are connected to the terminals of a direct current supply **16.** Upon application of D.C. current, for example 1.0 volt, radiation or light is transmitted transversely to the plane of the base disk **10.** It is understood that the diameter of the base **10** may be of such length that the radiation is emitted radially from the base **10.**

FIGURE 3 illustrates a laser structure similar to that of FIGURE 2, but provides a continuous conducting electrode **22** covering the entire surface of the N-type injector electrode **14.** A reflecting layer **24**, formed from aluminum, for example, that has been positioned between the N-type injector layer **14** and the conductive electrode **22** serves to reflect the light radiation towards the P-type

Figure B.239: Herbert Kroemer invented the double-heterostructure laser diode in 1963.



layer **12**, whereby the light is emitted unidirectionally through the layer **12**.

An alternative embodiment shown in FIGURE 4 comprises a rectangular structure that includes a continuous conducting electrode **26** on the surface of the N-type injector electrode **28**, and a reflective layer **30** disposed between the conducting electrode **26** and injector **28**. A series of spaced opaque conductive strips **32**, which may be formed by silver coating, are positioned on the P-type injector electrode **34**. Positive potentials are supplied to each conductive strip **32** by means of electrical leads **36** coupled by a common connection to the positive terminal of the power supply **16**, while a negative voltage is applied to the electrode **26**. Thus, the light radiates in an array of spaced parallel beams through the exposed areas of the P-type injector electrode **34**. It is apparent that cross grid arrangements as well as other configurations are possible for presenting a series of spaced laser beams. Furthermore, it should be noted that radiation may be emitted either transverse to current flow, or in the same direction as current flow depending on the geometric configuration and reflectivity characteristics of the device.

FIGURE 5 illustrates a cylindrical laser structure that has annular conductive electrodes **38** and **40** located around the periphery of P-type and N-type injector electrodes, **42** and **44** respectively, that are positioned on opposite surfaces of a base **46**. The light output can be derived as a circular beam that is coaxially aligned with the cylinder.

In FIGURE 6, another embodiment of the invention comprises a structure characterized by an N-type layer **48** having a series of uniformly spaced grooves or ridges **50**. The grooves **50** have a triangular cross-sectional shape, forming a 90° angle between the triangle sides, that may be formed by machining or other known methods. The surface of each groove **50** is coated with a conductive element **52**, which may be formed by painting with silver, or by evaporating gold or tin chloride, by way of example. The conductive elements **52** are individually connected through a common connection to the power supply **16**. The lasing structure may be energized by closing a switch **54** that is coupled between a circumferential conductive electrode **56**, disposed adjacent to a P-type layer **58**, and the power supply **16**. The structure of FIGURE 6 may be formed as a series of rows of grooved elements, each row being individually controlled by a separate switch **54**, **54***a*, **54***b* . . . so that selective energization is possible. In this manner, data processing and image displays may be achieved. It should be noted that switches may be connected in the power supply for any of the other available structures, and is illustrated only in FIGURE 6 for the purpose of convenience. Various geometries and structures other than shown, may be fabricated in keeping with this invention.

FIGURES 7–9 illustrate other possible configurations that utilize the inventive combination to realize high density carrier injection into an indirect energy gap base accompanied by prevention of outflow of carriers from such base, so that highly efficient radiative recombination occurs.

In FIGURE 7, a pair of wide-gap P-type injector electrodes **58** and **60** are located on a narrow-gap N-type wafer base **62** that has a protruding portion **64** relative to one end of each injector electrode **58** and **60**. A power supply **16** provides positive biasing voltage to the P-type injectors and a negative voltage to the N-type base **64**.

In FIGURE 8, a semiconductor base **66**, such as germanium, has wide-gap P-type and N-type injector electrodes **68** and **70** positioned adjacent to each other at one edge of the base. Radiation may be derived in the direction of current flow or orthogonal to this direction depending on the geometry of the structure and its reflectivity characteristics.

FIGURE 9 shows a similar configuration to that of FIGURE 8, but the injector electrode **72** is an integral P-type body and the base **74** is N-type. Suitable biasing potentials are supplied from the voltage source **16**.

It will be understood that the scope of this invention is not limited to a combination of only Ge and GaAs, but encompasses the use of those relatively wide energy gap materials that can form heterojunction interfaces with a lower energy gap semiconductor material, and provide high density excess charge carriers to the lower energy gap material for producing radiation or lasing at ambient temperatures. A major consideration for realizing optimum radiating efficiency is the reduction of lattice dislocations that generally cause a drain and loss of nonequilibrium carriers, with a resultant reduction of radiative carrier recombination. Such dislocations are generated at the heretojunction interface if the two crystal lattices do not match perfectly. By utilizing semiconductors that have a close lattice match, dislocations at the interface that would result in non-radiative recombination of the charge carriers are effectively minimized. Also, by growing the base layer or wafer first, and then growing the injector electrodes onto the base, those dislocations that do appear are found inside the injector electrode structure and not in the lasing base itself, whereby there is no appreciable loss of recombination current occurring within the base.

In order to reduce the lattice misfit that may appear between the Ge and GaAs, the Ge may be homogeneously alloyed with about 1.5 to 3.5 atomic percent silicon, preferably about 1.8%; or the GaAs may be alloyed with a small amount of III–V compound with a higher lattice constant, for example with about 1% GaSb. Other combinations of a semiconductor base and semiconductor injector electrodes having close lattice matches may be employed following the teachings of this invention.

Applicant has determined that other combinations may be utilized to produce lasing structures, in accordance with this invention. For example, compounds formed from Group III and Group V elements of the periodic chart may serve as the radiaion emitting base. The injector electrodes may be made from III–V compounds or II–VI compounds. Close lattice matches to reduce dislocations at the interfaces of the junctions are desired.

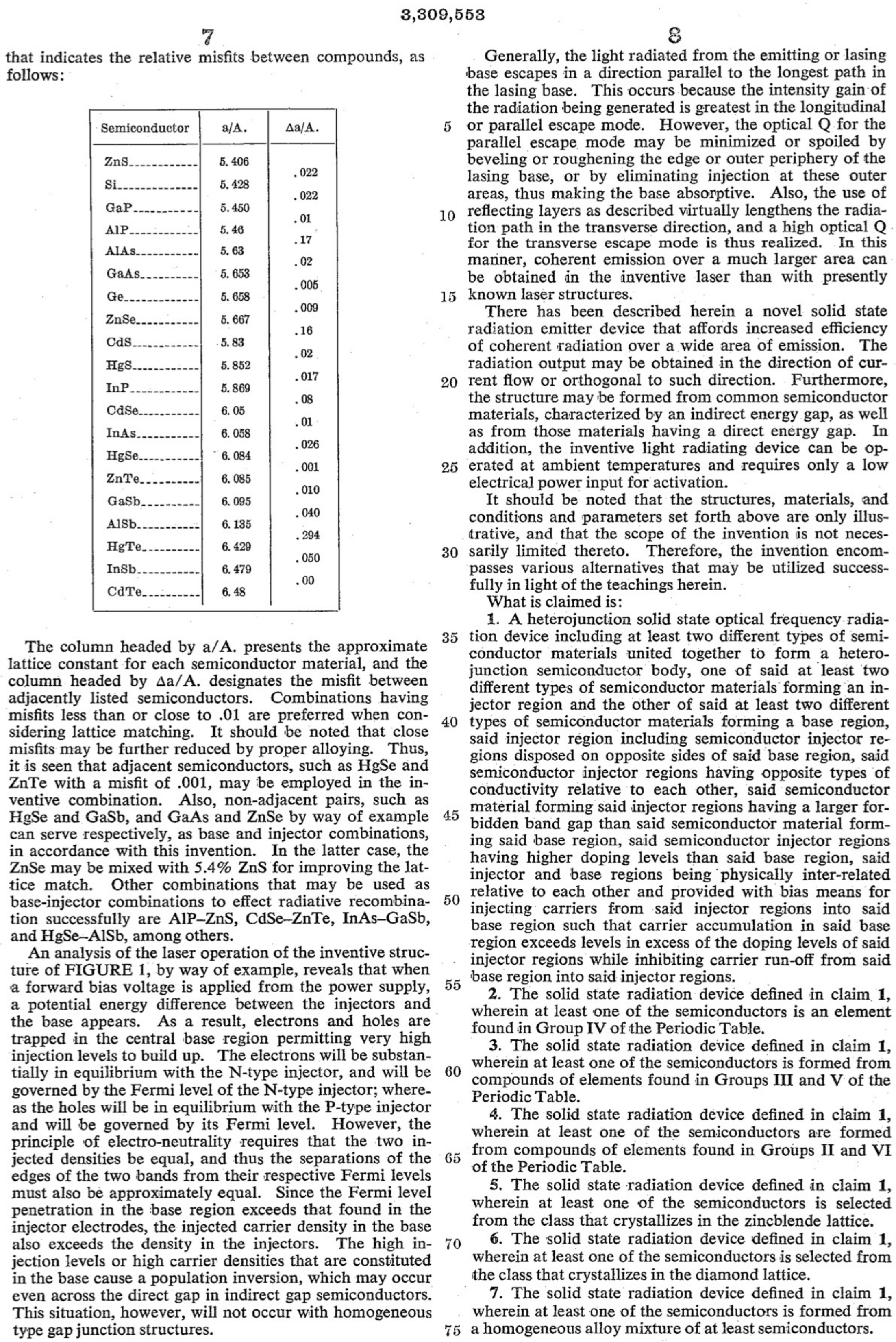
Example 1.—A Group III–V compound such as GaP may serve as the base wafer, and a Group III–V compound such as AlP may be used for the injectors. In such case, the manufacturing process employs diffusion displacement of Ga in GaP by Al, by heating in Al vapor for 24 hours at 1200° centigrade. A mixture of 4.0% GaAs and GaP may be used in lieu of GaP only.

Example 2.—A Group III–V compound such as InSb may be utilized for the base, and a Group II–VI compound such as CdTe may form the injectors. This combination may be achieved by epitaxial condensation of CdTe vapor on InSb at 400° centigrade. The CdTe may contain 12% InAs or 13% ZnTe in mixture.

Generally, the scope of this invention encompasses the use of combinations containing Group IV, II–V, or II–VI semiconductors. The preferred semiconductors have a cubic lattice structure, or crystallize in either the diamond or in the zincblende lattice. The combination of semiconductors that are used should have lattice constants that differ by no more than 1%. However, it should be realized that although it is desirable to use semiconductors that have a low dislocation density (less than 100 cm.$^{-2}$) and a high minority carrier lifetime (greater than 100 μsec.), crystals with a high dislocation density and short lifetime may be used successfully. It is understood that alloying may be used to advantage with compounds selected from the groups described above to achieve a close lattice match and to improve radiation efficiency and lasing action.

Applicants have compiled a listing of semiconductors

Figure B.240: Herbert Kroemer invented the double-heterostructure laser diode in 1963.



that indicates the relative misfits between compounds, as follows:

Semiconductor	a/A.	Δa/A.
ZnS	5.406	
		.022
Si	5.428	
		.022
GaP	5.450	
		.01
AlP	5.46	
		.17
AlAs	5.63	
		.02
GaAs	5.653	
		.005
Ge	5.658	
		.009
ZnSe	5.667	
		.16
CdS	5.83	
		.02
HgS	5.852	
		.017
InP	5.869	
		.08
CdSe	6.05	
		.01
InAs	6.058	
		.026
HgSe	6.084	
		.001
ZnTe	6.085	
		.010
GaSb	6.095	
		.040
AlSb	6.135	
		.294
HgTe	6.429	
		.050
InSb	6.479	
		.00
CdTe	6.48	

The column headed by a/A. presents the approximate lattice constant for each semiconductor material, and the column headed by Δa/A. designates the misfit between adjacently listed semiconductors. Combinations having misfits less than or close to .01 are preferred when considering lattice matching. It should be noted that close misfits may be further reduced by proper alloying. Thus, it is seen that adjacent semiconductors, such as HgSe and ZnTe with a misfit of .001, may be employed in the inventive combination. Also, non-adjacent pairs, such as HgSe and GaSb, and GaAs and ZnSe by way of example can serve respectively, as base and injector combinations, in accordance with this invention. In the latter case, the ZnSe may be mixed with 5.4% ZnS for improving the lattice match. Other combinations that may be used as base-injector combinations to effect radiative recombination successfully are AlP–ZnS, CdSe–ZnTe, InAs–GaSb, and HgSe–AlSb, among others.

An analysis of the laser operation of the inventive structure of FIGURE 1, by way of example, reveals that when a forward bias voltage is applied from the power supply, a potential energy difference between the injectors and the base appears. As a result, electrons and holes are trapped in the central base region permitting very high injection levels to build up. The electrons will be substantially in equilibrium with the N-type injector, and will be governed by the Fermi level of the N-type injector; whereas the holes will be in equilibrium with the P-type injector and will be governed by its Fermi level. However, the principle of electro-neutrality requires that the two injected densities be equal, and thus the separations of the edges of the two bands from their respective Fermi levels must also be approximately equal. Since the Fermi level penetration in the base region exceeds that found in the injector electrodes, the injected carrier density in the base also exceeds the density in the injectors. The high injection levels or high carrier densities that are constituted in the base cause a population inversion, which may occur even across the direct gap in indirect gap semiconductors. This situation, however, will not occur with homogeneous type gap junction structures.

Generally, the light radiated from the emitting or lasing base escapes in a direction parallel to the longest path in the lasing base. This occurs because the intensity gain of the radiation being generated is greatest in the longitudinal or parallel escape mode. However, the optical Q for the parallel escape mode may be minimized or spoiled by beveling or roughening the edge or outer periphery of the lasing base, or by eliminating injection at these outer areas, thus making the base absorptive. Also, the use of reflecting layers as described virtually lengthens the radiation path in the transverse direction, and a high optical Q for the transverse escape mode is thus realized. In this manner, coherent emission over a much larger area can be obtained in the inventive laser than with presently known laser structures.

There has been described herein a novel solid state radiation emitter device that affords increased efficiency of coherent radiation over a wide area of emission. The radiation output may be obtained in the direction of current flow or orthogonal to such direction. Furthermore, the structure may be formed from common semiconductor materials, characterized by an indirect energy gap, as well as from those materials having a direct energy gap. In addition, the inventive light radiating device can be operated at ambient temperatures and requires only a low electrical power input for activation.

It should be noted that the structures, materials, and conditions and parameters set forth above are only illustrative, and that the scope of the invention is not necessarily limited thereto. Therefore, the invention encompasses various alternatives that may be utilized successfully in light of the teachings herein.

What is claimed is:

1. A heterojunction solid state optical frequency radiation device including at least two different types of semiconductor materials united together to form a heterojunction semiconductor body, one of said at least two different types of semiconductor materials forming an injector region and the other of said at least two different types of semiconductor materials forming a base region, said injector region including semiconductor injector regions disposed on opposite sides of said base region, said semiconductor injector regions having opposite types of conductivity relative to each other, said semiconductor material forming said injector regions having a larger forbidden band gap than said semiconductor material forming said base region, said semiconductor injector regions having higher doping levels than said base region, said injector and base regions being physically inter-related relative to each other and provided with bias means for injecting carriers from said injector regions into said base region such that carrier accumulation in said base region exceeds levels in excess of the doping levels of said injector regions while inhibiting carrier run-off from said base region into said injector regions.

2. The solid state radiation device defined in claim **1**, wherein at least one of the semiconductors is an element found in Group IV of the Periodic Table.

3. The solid state radiation device defined in claim **1**, wherein at least one of the semiconductors is formed from compounds of elements found in Groups III and V of the Periodic Table.

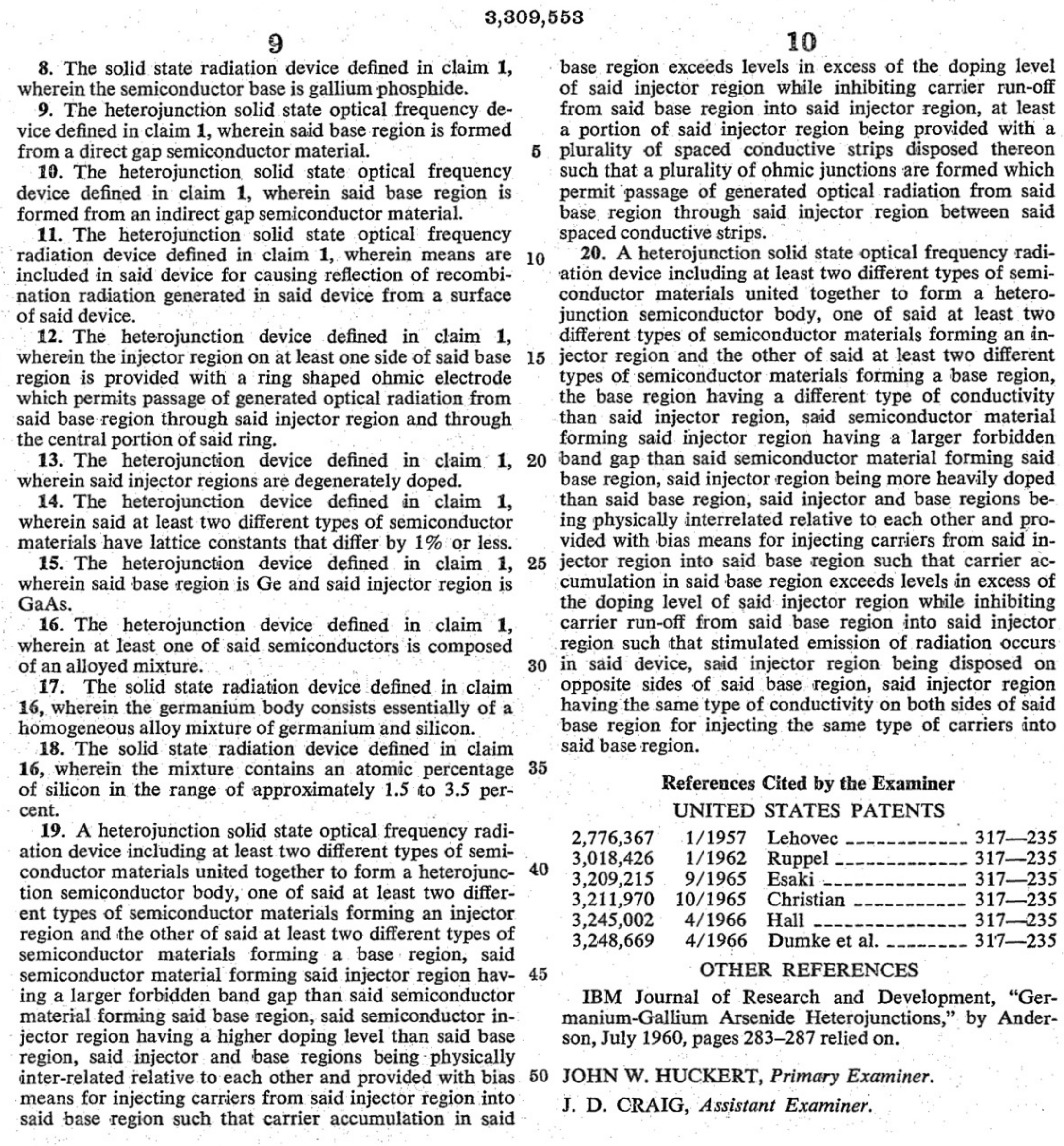
4. The solid state radiation device defined in claim **1**, wherein at least one of the semiconductors are formed from compounds of elements found in Groups II and VI of the Periodic Table.

5. The solid state radiation device defined in claim **1**, wherein at least one of the semiconductors is selected from the class that crystallizes in the zincblende lattice.

6. The solid state radiation device defined in claim **1**, wherein at least one of the semiconductors is selected from the class that crystallizes in the diamond lattice.

7. The solid state radiation device defined in claim **1**, wherein at least one of the semiconductors is formed from a homogeneous alloy mixture of at least semiconductors.

Figure B.241: Herbert Kroemer invented the double-heterostructure laser diode in 1963.



8. The solid state radiation device defined in claim **1**, wherein the semiconductor base is gallium phosphide.

9. The heterojunction solid state optical frequency device defined in claim **1**, wherein said base region is formed from a direct gap semiconductor material.

10. The heterojunction solid state optical frequency device defined in claim **1**, wherein said base region is formed from an indirect gap semiconductor material.

11. The heterojunction solid state optical frequency radiation device defined in claim **1**, wherein means are included in said device for causing reflection of recombination radiation generated in said device from a surface of said device.

12. The heterojunction device defined in claim **1**, wherein the injector region on at least one side of said base region is provided with a ring shaped ohmic electrode which permits passage of generated optical radiation from said base region through said injector region and through the central portion of said ring.

13. The heterojunction device defined in claim **1**, wherein said injector regions are degenerately doped.

14. The heterojunction device defined in claim **1**, wherein said at least two different types of semiconductor materials have lattice constants that differ by 1% or less.

15. The heterojunction device defined in claim **1**, wherein said base region is Ge and said injector region is GaAs.

16. The heterojunction device defined in claim **1**, wherein at least one of said semiconductors is composed of an alloyed mixture.

17. The solid state radiation device defined in claim **16**, wherein the germanium body consists essentially of a homogeneous alloy mixture of germanium and silicon.

18. The solid state radiation device defined in claim **16**, wherein the mixture contains an atomic percentage of silicon in the range of approximately 1.5 to 3.5 percent.

19. A heterojunction solid state optical frequency radiation device including at least two different types of semiconductor materials united together to form a heterojunction semiconductor body, one of said at least two different types of semiconductor materials forming an injector region and the other of said at least two different types of semiconductor materials forming a base region, said semiconductor material forming said injector region having a larger forbidden band gap than said semiconductor material forming said base region, said semiconductor injector region having a higher doping level than said base region, said injector and base regions being physically inter-related relative to each other and provided with bias means for injecting carriers from said injector region into said base region such that carrier accumulation in said base region exceeds levels in excess of the doping level of said injector region while inhibiting carrier run-off from said base region into said injector region, at least a portion of said injector region being provided with a plurality of spaced conductive strips disposed thereon such that a plurality of ohmic junctions are formed which permit passage of generated optical radiation from said base region through said injector region between said spaced conductive strips.

20. A heterojunction solid state optical frequency radiation device including at least two different types of semiconductor materials united together to form a heterojunction semiconductor body, one of said at least two different types of semiconductor materials forming an injector region and the other of said at least two different types of semiconductor materials forming a base region, the base region having a different type of conductivity than said injector region, said semiconductor material forming said injector region having a larger forbidden band gap than said semiconductor material forming said base region, said injector region being more heavily doped than said base region, said injector and base regions being physically interrelated relative to each other and provided with bias means for injecting carriers from said injector region into said base region such that carrier accumulation in said base region exceeds levels in excess of the doping level of said injector region while inhibiting carrier run-off from said base region into said injector region such that stimulated emission of radiation occurs in said device, said injector region being disposed on opposite sides of said base region, said injector region having the same type of conductivity on both sides of said base region for injecting the same type of carriers into said base region.

References Cited by the Examiner

UNITED STATES PATENTS

2,776,367	1/1957	Lehovec	317—235
3,018,426	1/1962	Ruppel	317—235
3,209,215	9/1965	Esaki	317—235
3,211,970	10/1965	Christian	317—235
3,245,002	4/1966	Hall	317—235
3,248,669	4/1966	Dumke et al.	317—235

OTHER REFERENCES

IBM Journal of Research and Development, "Germanium-Gallium Arsenide Heterojunctions," by Anderson, July 1960, pages 283–287 relied on.

JOHN W. HUCKERT, *Primary Examiner.*

J. D. CRAIG, *Assistant Examiner.*

Figure B.242: Herbert Kroemer invented the double-heterostructure laser diode in 1963.

B.5 Postwar Transfer of Microelectronics Technologies

[Detailed technical information on semiconductors and microelectronics technologies was transferred from the German-speaking world to Allied countries after World War II. Some examples have already been mentioned earlier in this appendix. Pages 2926–3013 present additional examples of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge. There was likely a great deal of additional technology transfer that was not recorded in official documents.

The financially and politically powerful combined corporate entity American Telephone & Telegraph (AT&T), Bell Telephone Laboratories (Bell Labs), and Western Electric (the manufacturing arm of the corporation) committed a number of its personnel to studying technology from the German-speaking world, both collecting information in Europe and analyzing information that had been sent from Europe to the United States. While certainly not an exhaustive list, some representative examples of involved personnel include:

- Edwin Y. Webb Jr. worked for AT&T 1928–1944 before entering government service during the war. He was Chief in charge of investigating and transferring electronics and communications-related technologies out of the German-speaking world for the United States.
- George Richert worked for Bell Telephone 1927–1942 before entering government service during the war. He was Assistant Chief in charge of investigating and transferring electronics and communications-related technologies out of the German-speaking world for the United States.
- T. M. Odarenko worked for Bell Telephone 1928–1943 before entering government service during the war. He was one of the senior U.S. scientists involved in investigating and transferring electronics and other technologies out of Germany and Austria.
- Pierre Mertz worked at Bell Labs and visited Germany to transfer electronics and related technologies.
- Frederick E. Henderson worked at Western Electric and visited Germany to transfer electronics and related technologies.
- Roland H. McCarthy worked at Western Electric and visited Germany to transfer electronics and related technologies.
- John A. Parrott worked at AT&T and visited Germany to transfer electronics and related technologies.
- R. E. Russell worked at AT&T and visited Germany to transfer electronics and related technologies.
- John R. Townsend worked at Bell Labs and studied German hardware and information both in Europe and at Bell.
- Victor Ronci worked at Bell Labs developing improved versions of vacuum tubes, and was involved in analyzing captured German hardware and information that was sent to Bell Labs.

- Lloyd Espenschied worked at Bell Labs to study captured German hardware and information that was sent to the lab.
- John N. Shive worked at Bell Labs to study captured German hardware and information that was sent to the lab.
- F. A. Cowan worked at AT&T and advised the U.S. government what specific targets and topics to investigate with regard to wire communications systems.
- George W. Gilman worked at Bell Labs and advised the U.S. government what specific targets and topics to investigate with regard to radio communications systems.
- R. E. Poole worked at Bell Labs and advised the U.S. government what specific targets and topics to investigate with regard to radar systems.
- W. H. Martin worked at Bell Labs and advised the U.S. government what specific targets and topics to investigate with regard to "special systems."
- Julian Blanchard was assigned by AT&T/Bell/Western Electric to work full time in Washington, D.C. during 1946–1947 searching the many tons of captured German reports for any useful information he could send to the corporation.
- Both William Shockley and John Bardeen of Bell Labs visited laboratories in several European countries during a research trip from June through August 1947. During that time, Shockley or Bardeen may have encountered scientists, reports, or information from the earlier transistor work that had been conducted in the German-speaking world. Alternatively they might have encountered Allied investigators who had already examined that work and could pass along useful information. Shockley and Bardeen's transistor experiments at Bell Labs were entirely unsuccessful during the long period before their European trip, and extremely successful very shortly after their trip [Hoddeson and Daitch 2002, pp. 128–131].

Other American and British electronics and other companies also committed large numbers of investigators to study and bring back technologies from the German-speaking world.

Many English-language reports were written about German microelectronics technologies. Some examples include:

BIOS 724. *Electronic Principles as Applied in Germany to the Testing of Materials.* [Piezo-electric, electronic materials testing]

BIOS 725. *German Research on Rectifiers and Semi-Conductors.*

BIOS 980. *Electro-Acoustics in Germany. Part I & II.*

BIOS 1751. *German Research on Semi-Conductors, Metal Rectifiers, Detectors and Photocells.*

FIAT 54. *German Developments in Semi-Conducting Materials.* [by T. M. Odarenko]

FIAT 56. *Selenium Rectifier Development in Germany.* [by T. M. Odarenko]

> FIAT 272. *Telefunken A.G. Dachau, Germany and C. H. F. Mueller A.G. Fuhlsbuettel, Hamburg.* [Silicon crystals]
>
> FIAT 294. *Interrogation of German Television and Electronic Authorities.* [Electronics developments, photoelectric, IR image tubes, silicon detector cells]
>
> FIAT 641. *The Interrogation of German Scientists Regarding Quartz Crystals and other Piezoelectric Materials.*
>
> FIAT 706. *Report on Selenium Dry Rectifier Developments.*
>
> FIAT 954. *A Highly Sensitive D.C. Controlling & Measuring Device.* [Amplifier]

For example, BIOS 725 described how German groups were making wafers of monocrystalline pure silicon, doping semiconductor materials with impurities to create the desired electrical properties, and producing semiconductor devices both from silicon and from germanium:

> Impurities in a semi-conductor produce additional energy-levels; perhaps a pure material could not be a semi-conductor. There must be some broadening of the energy levels into bands... Joos tried to produce large crystals of silicon for use in silicon-carbon detectors for cm. waves. The method was deposition from a solution of silicon in molten aluminum. The crystals so obtained were spectroscopically pure... They were aggregations of thin plates... Prof. Pohl confirmed that Dr. König had studied germanium and silicon rectifiers at Göttingen...

Countless tons of both electronics equipment and German technical documents were shipped to the United States and other countries.

German-speaking scientists were repeatedly interrogated in Europe, and/or brought to the United States or other countries to work, as covered in Chapter 11. For example, Hans K. Ziegler (German, 1911–1999) came to the United States in Operation Paperclip. He became the Chief Scientist of a U.S. Army laboratory in Fort Monmouth, New Jersey, that employed many other German-speaking scientists and harnessed many microelectronics technologies acquired from Germany, Austria, and Czech territory [Fort Monmouth Historical Office 2008]. See pp. 1153–1154, 2760, and 3013. Many other German-speaking scientists were hired by other U.S. laboratories or companies.

On top of all of the technology transfer that was documented to have occurred, it seems likely that there was a considerable amount of additional technology transfer that was not recorded in official documents. The German-speaking world was filled with advanced technologies, and it would have been a great temptation for any Allied investigator or company to try to claim some of those technologies in order to get ahead of their rivals. Thus the innovations from the German-speaking world probably had a much greater postwar impact on the United States and other countries than can be strictly proven from the existing archival documents.]

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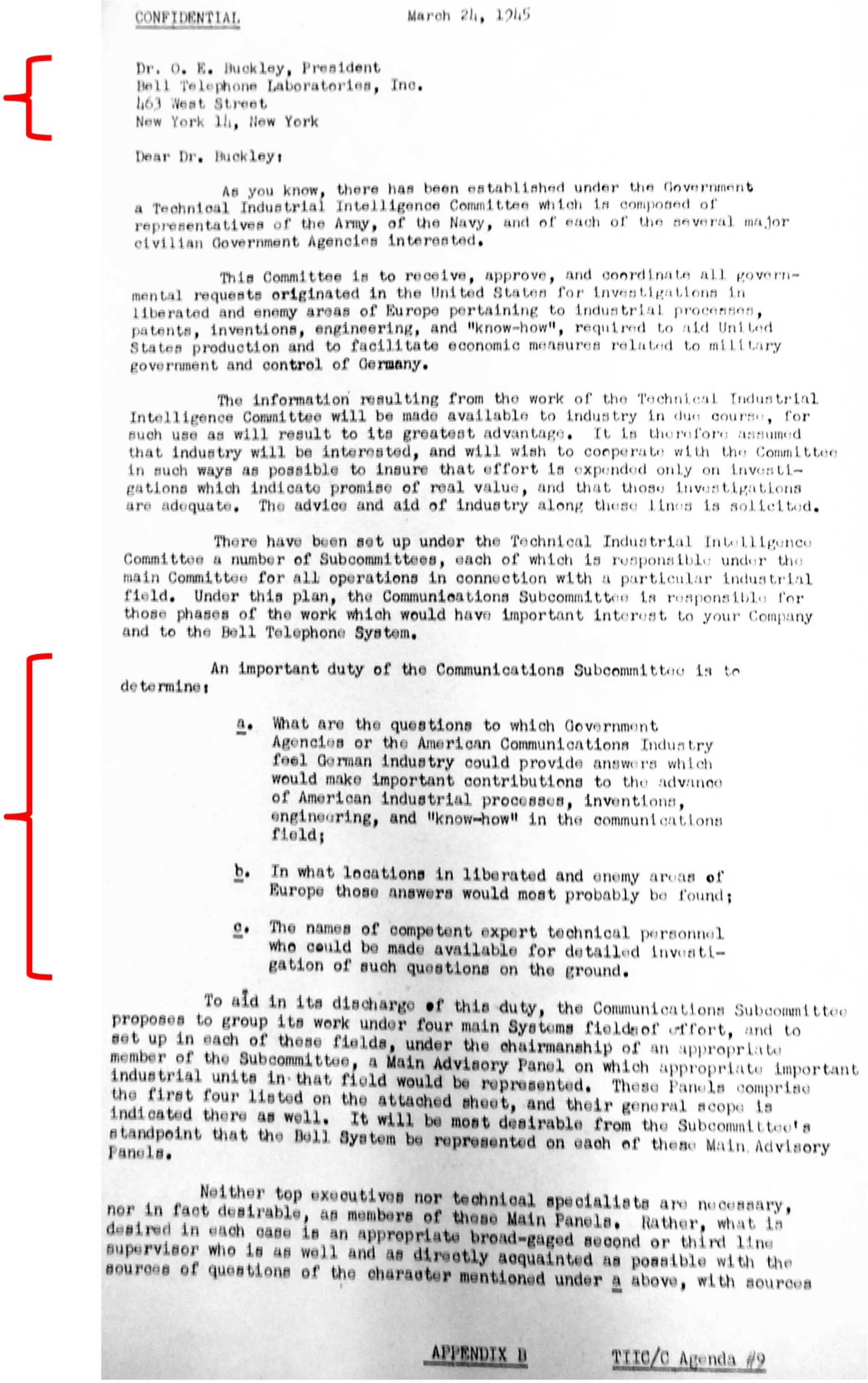

CONFIDENTIAL March 24, 1945

Dr. O. E. Buckley, President
Bell Telephone Laboratories, Inc.
463 West Street
New York 14, New York

Dear Dr. Buckley:

As you know, there has been established under the Government a Technical Industrial Intelligence Committee which is composed of representatives of the Army, of the Navy, and of each of the several major civilian Government Agencies interested.

This Committee is to receive, approve, and coordinate all governmental requests originated in the United States for investigations in liberated and enemy areas of Europe pertaining to industrial processes, patents, inventions, engineering, and "know-how", required to aid United States production and to facilitate economic measures related to military government and control of Germany.

The information resulting from the work of the Technical Industrial Intelligence Committee will be made available to industry in due course, for such use as will result to its greatest advantage. It is therefore assumed that industry will be interested, and will wish to cooperate with the Committee in such ways as possible to insure that effort is expended only on investigations which indicate promise of real value, and that those investigations are adequate. The advice and aid of industry along these lines is solicited.

There have been set up under the Technical Industrial Intelligence Committee a number of Subcommittees, each of which is responsible under the main Committee for all operations in connection with a particular industrial field. Under this plan, the Communications Subcommittee is responsible for those phases of the work which would have important interest to your Company and to the Bell Telephone System.

An important duty of the Communications Subcommittee is to determine:

a. What are the questions to which Government Agencies or the American Communications Industry feel German industry could provide answers which would make important contributions to the advance of American industrial processes, inventions, engineering, and "know-how" in the communications field;

b. In what locations in liberated and enemy areas of Europe those answers would most probably be found;

c. The names of competent expert technical personnel who could be made available for detailed investigation of such questions on the ground.

To aid in its discharge of this duty, the Communications Subcommittee proposes to group its work under four main Systems fields of effort, and to set up in each of these fields, under the chairmanship of an appropriate member of the Subcommittee, a Main Advisory Panel on which appropriate important industrial units in that field would be represented. These Panels comprise the first four listed on the attached sheet, and their general scope is indicated there as well. It will be most desirable from the Subcommittee's standpoint that the Bell System be represented on each of these Main Advisory Panels.

Neither top executives nor technical specialists are necessary, nor in fact desirable, as members of these Main Panels. Rather, what is desired in each case is an appropriate broad-gaged second or third line supervisor who is as well and as directly acquainted as possible with the sources of questions of the character mentioned under a above, with sources

APPENDIX B TTIC/C Agenda #9

NARA RG 40, Entry UD-75, Box 23, Folder
Communications Subcommittee Agenda

Figure B.243: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 23, Folder Communications Subcommittee Agenda]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

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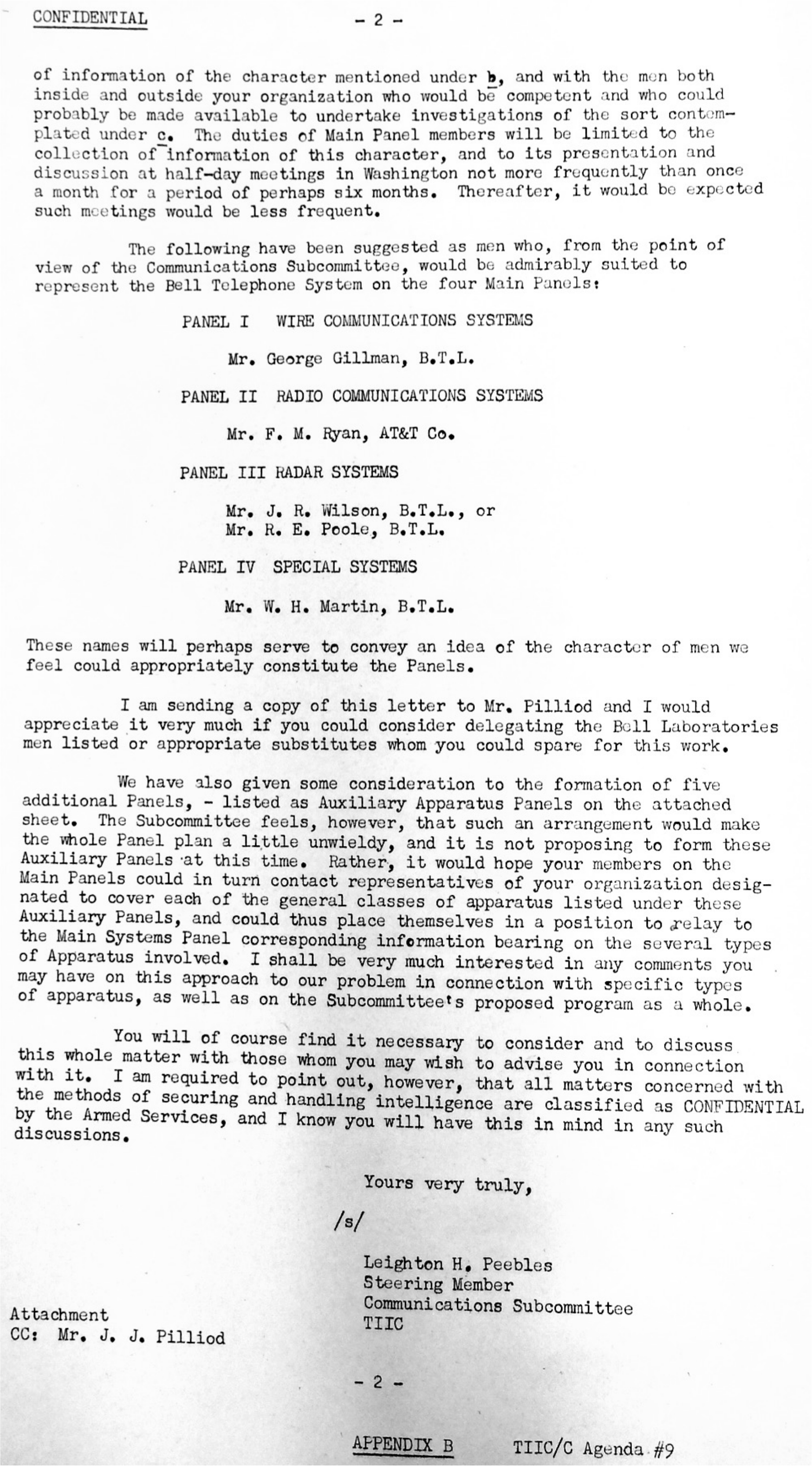


CONFIDENTIAL - 2 -

of information of the character mentioned under b, and with the men both inside and outside your organization who would be competent and who could probably be made available to undertake investigations of the sort contemplated under c. The duties of Main Panel members will be limited to the collection of information of this character, and to its presentation and discussion at half-day meetings in Washington not more frequently than once a month for a period of perhaps six months. Thereafter, it would be expected such meetings would be less frequent.

The following have been suggested as men who, from the point of view of the Communications Subcommittee, would be admirably suited to represent the Bell Telephone System on the four Main Panels:

PANEL I WIRE COMMUNICATIONS SYSTEMS

Mr. George Gillman, B.T.L.

PANEL II RADIO COMMUNICATIONS SYSTEMS

Mr. F. M. Ryan, AT&T Co.

PANEL III RADAR SYSTEMS

Mr. J. R. Wilson, B.T.L., or
Mr. R. E. Poole, B.T.L.

PANEL IV SPECIAL SYSTEMS

Mr. W. H. Martin, B.T.L.

These names will perhaps serve to convey an idea of the character of men we feel could appropriately constitute the Panels.

I am sending a copy of this letter to Mr. Pilliod and I would appreciate it very much if you could consider delegating the Bell Laboratories men listed or appropriate substitutes whom you could spare for this work.

We have also given some consideration to the formation of five additional Panels, - listed as Auxiliary Apparatus Panels on the attached sheet. The Subcommittee feels, however, that such an arrangement would make the whole Panel plan a little unwieldy, and it is not proposing to form these Auxiliary Panels at this time. Rather, it would hope your members on the Main Panels could in turn contact representatives of your organization designated to cover each of the general classes of apparatus listed under these Auxiliary Panels, and could thus place themselves in a position to relay to the Main Systems Panel corresponding information bearing on the several types of Apparatus involved. I shall be very much interested in any comments you may have on this approach to our problem in connection with specific types of apparatus, as well as on the Subcommittee's proposed program as a whole.

You will of course find it necessary to consider and to discuss this whole matter with those whom you may wish to advise you in connection with it. I am required to point out, however, that all matters concerned with the methods of securing and handling intelligence are classified as CONFIDENTIAL by the Armed Services, and I know you will have this in mind in any such discussions.

Yours very truly,

/s/

Leighton H. Peebles
Steering Member
Communications Subcommittee
TIIC

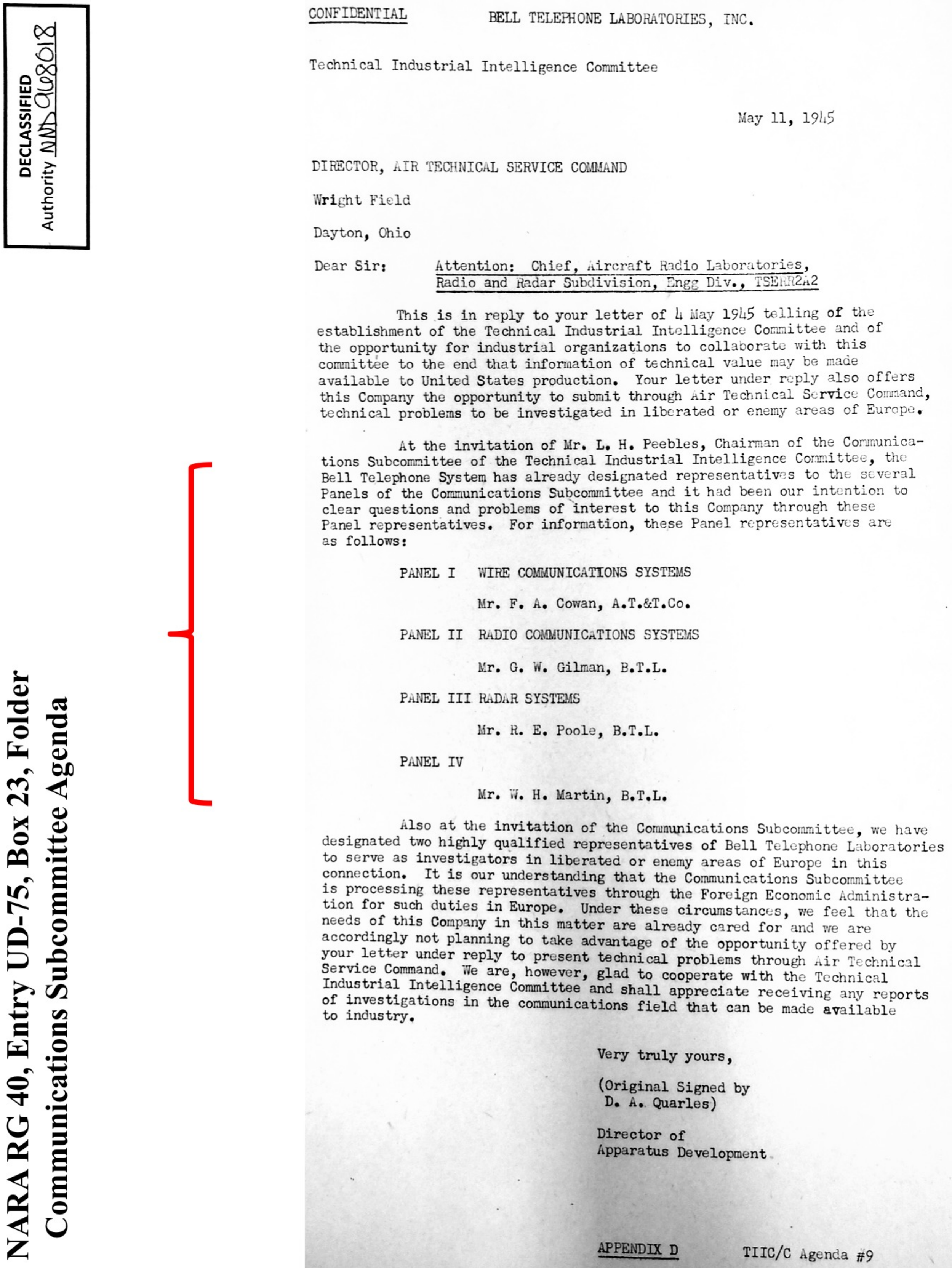
Attachment
CC: Mr. J. J. Pilliod

- 2 -

APPENDIX B TIIC/C Agenda #9

NARA RG 40, Entry UD-75, Box 23, Folder
Communications Subcommittee Agenda

Figure B.244: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 23, Folder Communications Subcommittee Agenda]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



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NARA RG 40, Entry UD-75, Box 23, Folder Communications Subcommittee Agenda

CONFIDENTIAL BELL TELEPHONE LABORATORIES, INC.

Technical Industrial Intelligence Committee

May 11, 1945

DIRECTOR, AIR TECHNICAL SERVICE COMMAND

Wright Field

Dayton, Ohio

Dear Sir: Attention: Chief, Aircraft Radio Laboratories, Radio and Radar Subdivision, Engg Div., TSERR2A2

This is in reply to your letter of 4 May 1945 telling of the establishment of the Technical Industrial Intelligence Committee and of the opportunity for industrial organizations to collaborate with this committee to the end that information of technical value may be made available to United States production. Your letter under reply also offers this Company the opportunity to submit through Air Technical Service Command, technical problems to be investigated in liberated or enemy areas of Europe.

At the invitation of Mr. L. H. Peebles, Chairman of the Communications Subcommittee of the Technical Industrial Intelligence Committee, the Bell Telephone System has already designated representatives to the several Panels of the Communications Subcommittee and it had been our intention to clear questions and problems of interest to this Company through these Panel representatives. For information, these Panel representatives are as follows:

PANEL I WIRE COMMUNICATIONS SYSTEMS

Mr. F. A. Cowan, A.T.&T.Co.

PANEL II RADIO COMMUNICATIONS SYSTEMS

Mr. G. W. Gilman, B.T.L.

PANEL III RADAR SYSTEMS

Mr. R. E. Poole, B.T.L.

PANEL IV

Mr. W. H. Martin, B.T.L.

Also at the invitation of the Communications Subcommittee, we have designated two highly qualified representatives of Bell Telephone Laboratories to serve as investigators in liberated or enemy areas of Europe in this connection. It is our understanding that the Communications Subcommittee is processing these representatives through the Foreign Economic Administration for such duties in Europe. Under these circumstances, we feel that the needs of this Company in this matter are already cared for and we are accordingly not planning to take advantage of the opportunity offered by your letter under reply to present technical problems through Air Technical Service Command. We are, however, glad to cooperate with the Technical Industrial Intelligence Committee and shall appreciate receiving any reports of investigations in the communications field that can be made available to industry.

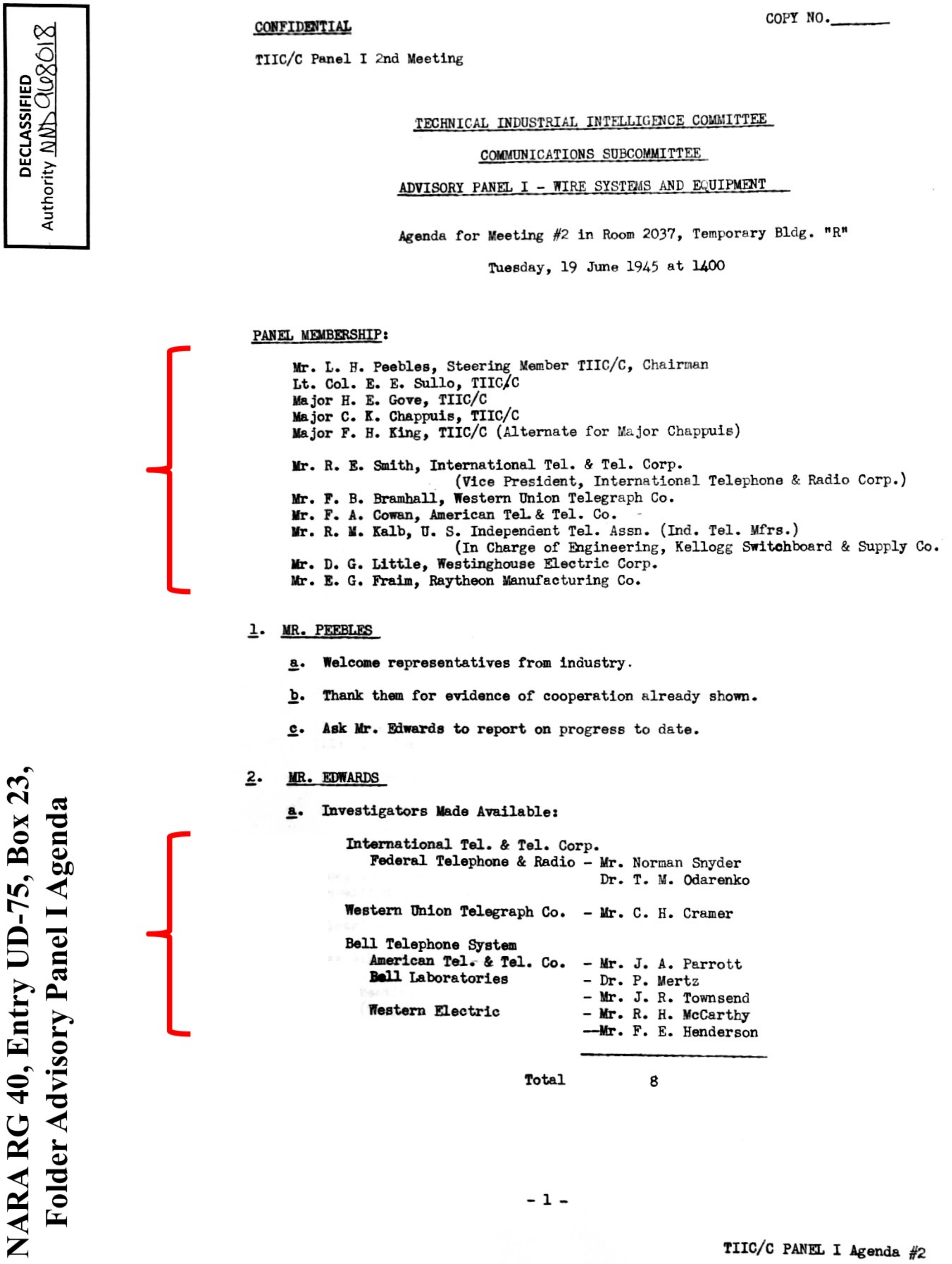
Very truly yours,

(Original Signed by
D. A. Quarles)

Director of
Apparatus Development

APPENDIX D TIIC/C Agenda #9

Figure B.245: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 23, Folder Communications Subcommittee Agenda]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



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TIIC/C Panel I 2nd Meeting

TECHNICAL INDUSTRIAL INTELLIGENCE COMMITTEE
COMMUNICATIONS SUBCOMMITTEE
ADVISORY PANEL I - WIRE SYSTEMS AND EQUIPMENT

Agenda for Meeting #2 in Room 2037, Temporary Bldg. "R"
Tuesday, 19 June 1945 at 1400

PANEL MEMBERSHIP:

Mr. L. H. Peebles, Steering Member TIIC/C, Chairman
Lt. Col. E. E. Sullo, TIIC/C
Major H. E. Gove, TIIC/C
Major C. K. Chappuis, TIIC/C
Major F. H. King, TIIC/C (Alternate for Major Chappuis)

Mr. R. E. Smith, International Tel. & Tel. Corp.
(Vice President, International Telephone & Radio Corp.)
Mr. F. B. Bramhall, Western Union Telegraph Co.
Mr. F. A. Cowan, American Tel. & Tel. Co.
Mr. R. M. Kalb, U. S. Independent Tel. Assn. (Ind. Tel. Mfrs.)
(In Charge of Engineering, Kellogg Switchboard & Supply Co.
Mr. D. G. Little, Westinghouse Electric Corp.
Mr. E. G. Fraim, Raytheon Manufacturing Co.

1. MR. PEEBLES

a. Welcome representatives from industry.

b. Thank them for evidence of cooperation already shown.

c. Ask Mr. Edwards to report on progress to date.

2. MR. EDWARDS

a. Investigators Made Available:

International Tel. & Tel. Corp.
Federal Telephone & Radio - Mr. Norman Snyder
Dr. T. M. Odarenko

Western Union Telegraph Co. - Mr. C. H. Cramer

Bell Telephone System
American Tel. & Tel. Co. - Mr. J. A. Parrott
Bell Laboratories - Dr. P. Mertz
- Mr. J. R. Townsend
Western Electric - Mr. R. H. McCarthy
—Mr. F. E. Henderson

Total 8

- 1 -

TIIC/C PANEL I Agenda #2

NARA RG 40, Entry UD-75, Box 23,
Folder Advisory Panel I Agenda

Figure B.246: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 23, Folder Advisory Panel I Agenda]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

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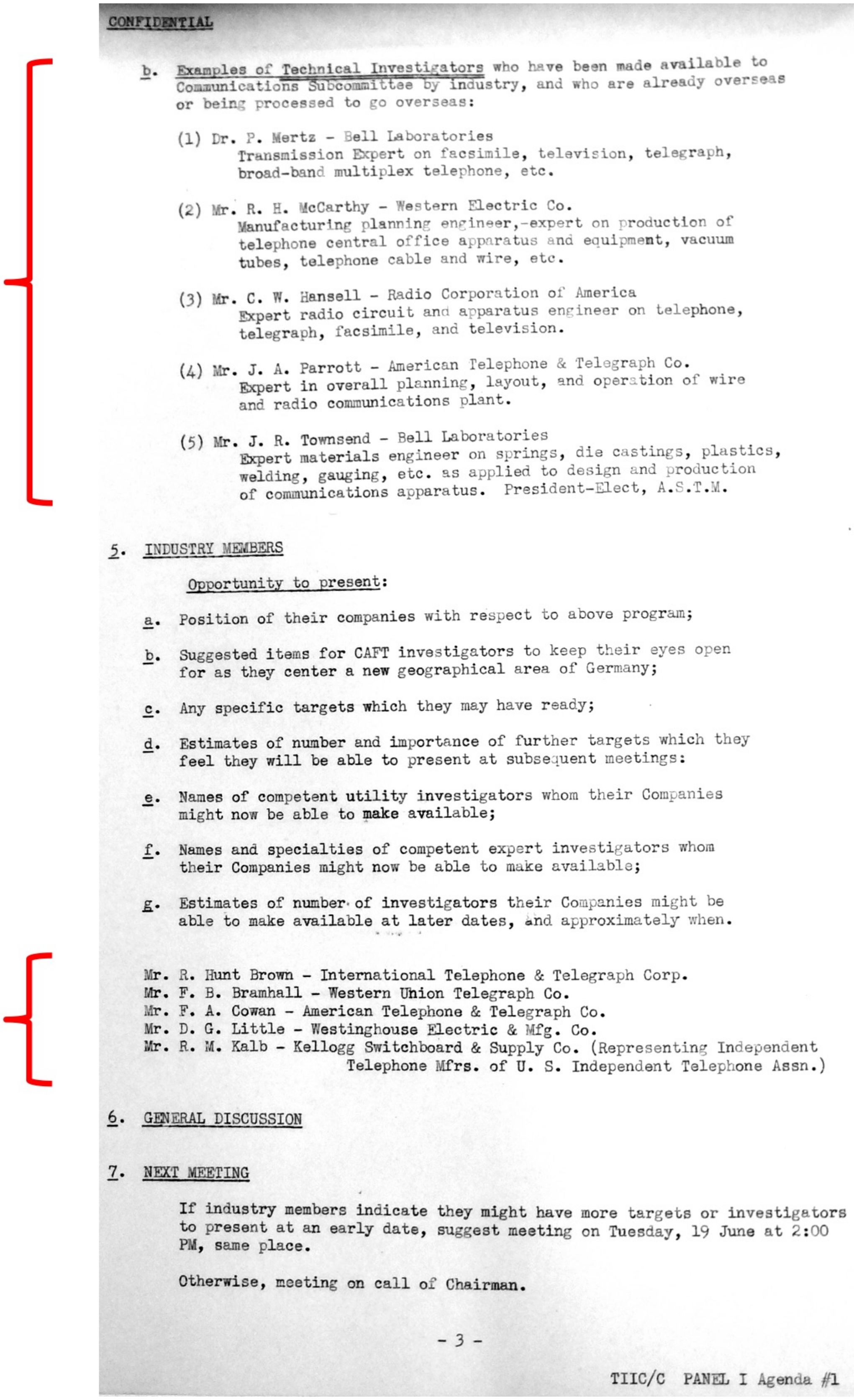

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b. Examples of Technical Investigators who have been made available to Communications Subcommittee by industry, and who are already overseas or being processed to go overseas:

(1) Dr. P. Mertz - Bell Laboratories
Transmission Expert on facsimile, television, telegraph, broad-band multiplex telephone, etc.

(2) Mr. R. H. McCarthy - Western Electric Co.
Manufacturing planning engineer,-expert on production of telephone central office apparatus and equipment, vacuum tubes, telephone cable and wire, etc.

(3) Mr. C. W. Hansell - Radio Corporation of America
Expert radio circuit and apparatus engineer on telephone, telegraph, facsimile, and television.

(4) Mr. J. A. Parrott - American Telephone & Telegraph Co.
Expert in overall planning, layout, and operation of wire and radio communications plant.

(5) Mr. J. R. Townsend - Bell Laboratories
Expert materials engineer on springs, die castings, plastics, welding, gauging, etc. as applied to design and production of communications apparatus. President-Elect, A.S.T.M.

5. INDUSTRY MEMBERS

Opportunity to present:

a. Position of their companies with respect to above program;

b. Suggested items for CAFT investigators to keep their eyes open for as they center a new geographical area of Germany;

c. Any specific targets which they may have ready;

d. Estimates of number and importance of further targets which they feel they will be able to present at subsequent meetings:

e. Names of competent utility investigators whom their Companies might now be able to make available;

f. Names and specialties of competent expert investigators whom their Companies might now be able to make available;

g. Estimates of number of investigators their Companies might be able to make available at later dates, and approximately when.

Mr. R. Hunt Brown - International Telephone & Telegraph Corp.
Mr. F. B. Bramhall - Western Union Telegraph Co.
Mr. F. A. Cowan - American Telephone & Telegraph Co.
Mr. D. G. Little - Westinghouse Electric & Mfg. Co.
Mr. R. M. Kalb - Kellogg Switchboard & Supply Co. (Representing Independent Telephone Mfrs. of U. S. Independent Telephone Assn.)

6. GENERAL DISCUSSION

7. NEXT MEETING

If industry members indicate they might have more targets or investigators to present at an early date, suggest meeting on Tuesday, 19 June at 2:00 PM, same place.

Otherwise, meeting on call of Chairman.

- 3 -

TIIC/C PANEL I Agenda #1

NARA RG 40, Entry UD-75, Box 23,
Folder Advisory Panel I Agenda

Figure B.247: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 23, Folder Advisory Panel I Agenda]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

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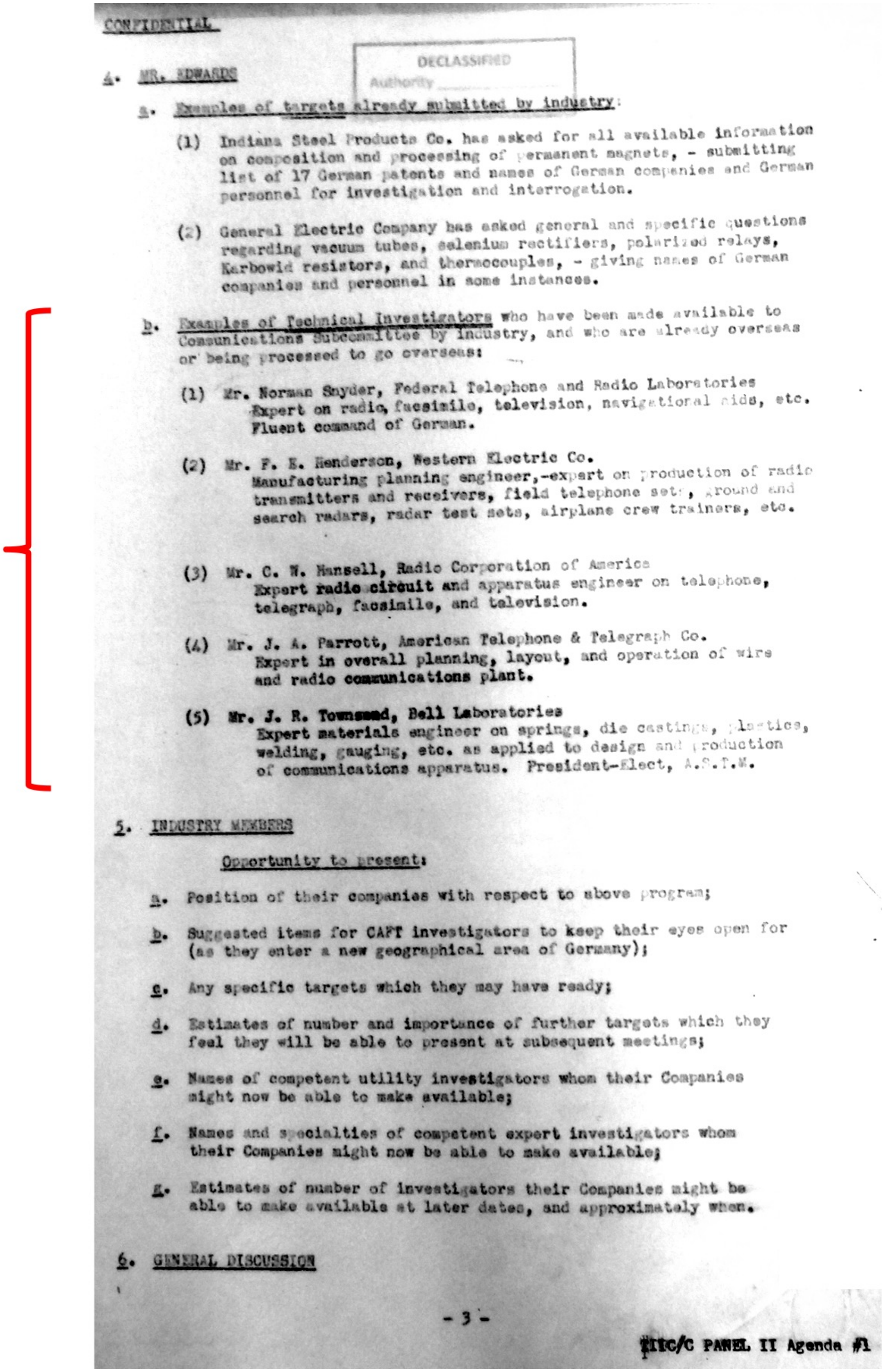

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4. MR. EDWARDS

a. Examples of targets already submitted by industry:

(1) Indiana Steel Products Co. has asked for all available information on composition and processing of permanent magnets, - submitting list of 17 German patents and names of German companies and German personnel for investigation and interrogation.

(2) General Electric Company has asked general and specific questions regarding vacuum tubes, selenium rectifiers, polarized relays, Karbowid resistors, and thermocouples, - giving names of German companies and personnel in some instances.

b. Examples of Technical Investigators who have been made available to Communications Subcommittee by industry, and who are already overseas or being processed to go overseas:

(1) Mr. Norman Snyder, Federal Telephone and Radio Laboratories
Expert on radio, facsimile, television, navigational aids, etc.
Fluent command of German.

(2) Mr. F. E. Henderson, Western Electric Co.
Manufacturing planning engineer,-expert on production of radio transmitters and receivers, field telephone sets, ground and search radars, radar test sets, airplane crew trainers, etc.

(3) Mr. C. W. Mansell, Radio Corporation of America
Expert radio circuit and apparatus engineer on telephone, telegraph, facsimile, and television.

(4) Mr. J. A. Parrott, American Telephone & Telegraph Co.
Expert in overall planning, layout, and operation of wire and radio communications plant.

(5) Mr. J. R. Townsend, Bell Laboratories
Expert materials engineer on springs, die castings, plastics, welding, gauging, etc. as applied to design and production of communications apparatus. President-Elect, A.S.T.M.

5. INDUSTRY MEMBERS

Opportunity to present:

a. Position of their companies with respect to above program;

b. Suggested items for CAFT investigators to keep their eyes open for (as they enter a new geographical area of Germany);

c. Any specific targets which they may have ready;

d. Estimates of number and importance of further targets which they feel they will be able to present at subsequent meetings;

e. Names of competent utility investigators whom their Companies might now be able to make available;

f. Names and specialties of competent expert investigators whom their Companies might now be able to make available;

g. Estimates of number of investigators their Companies might be able to make available at later dates, and approximately when.

6. GENERAL DISCUSSION

- 3 -

TIIC/C PANEL II Agenda #1

NARA RG 40, Entry UD-75, Box 23,
Folder Advisory Panel II Agenda

Figure B.248: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 23, Folder Advisory Panel II Agenda]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

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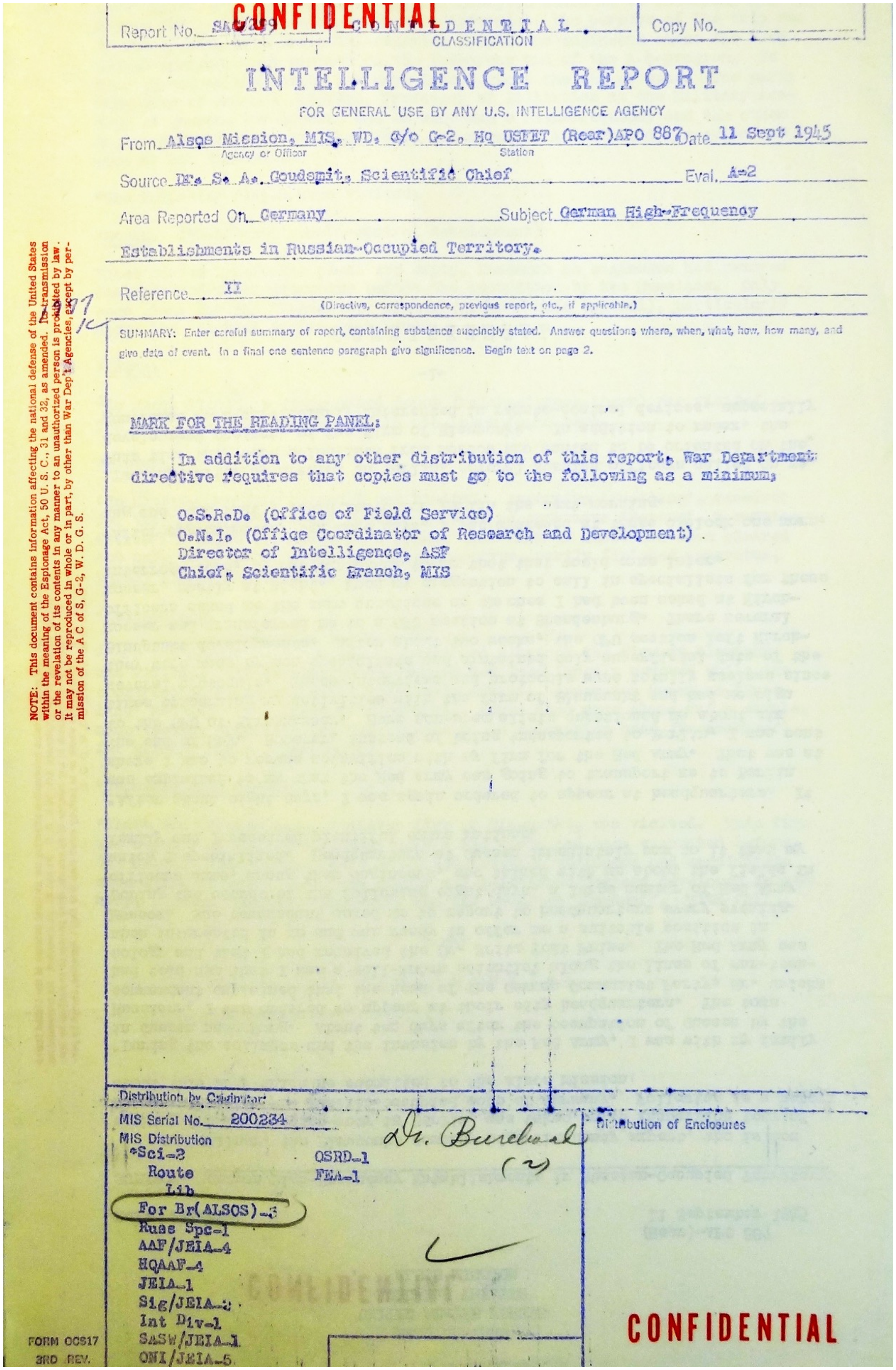
NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL



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Report No. SA/239 C O N F I D E N T I A L Copy No. ____
CLASSIFICATION

INTELLIGENCE REPORT

FOR GENERAL USE BY ANY U.S. INTELLIGENCE AGENCY

From Alsos Mission, MIS, WD, c/o G-2, Hq USFET (Rear) APO 887 Date 11 Sept 1945
Agency or Officer Station

Source Dr. S. A. Goudsmit, Scientific Chief Eval. A-2

Area Reported On Germany Subject German High-Frequency Establishments in Russian-Occupied Territory.

Reference II
(Directive, correspondence, previous report, etc., if applicable.)

SUMMARY: Enter careful summary of report, containing substance succinctly stated. Answer questions where, when, what, how, how many, and give date of event. In a final one sentence paragraph give significance. Begin text on page 2.

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MARK FOR THE READING PANEL:

In addition to any other distribution of this report, War Department directive requires that copies must go to the following as a minimum:

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O.N.I. (Office Coordinator of Research and Development)
Director of Intelligence, ASF
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Figure B.249: Account from a German electrical engineer regarding some former German advanced electronics facilities that were now in Soviet-controlled territory [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

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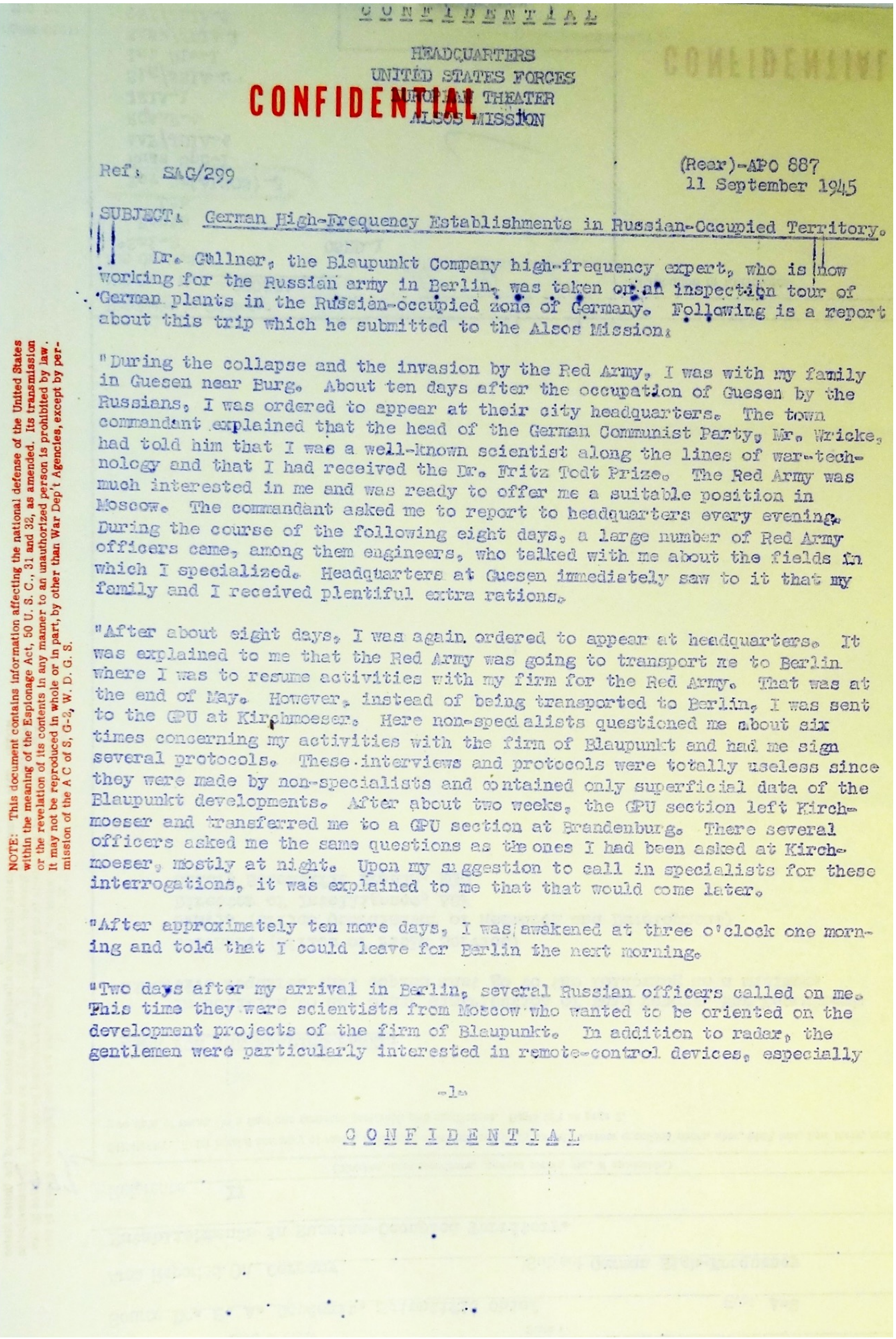

C O N F I D E N T I A L

HEADQUARTERS
UNITED STATES FORCES
EUROPEAN THEATER
ALSOS MISSION

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Ref: SAG/299

(Rear)-APO 887
11 September 1945

SUBJECT: German High-Frequency Establishments in Russian-Occupied Territory.

Dr. Güllner, the Blaupunkt Company high-frequency expert, who is now working for the Russian army in Berlin, was taken on an inspection tour of German plants in the Russian-occupied zone of Germany. Following is a report about this trip which he submitted to the Alsos Mission:

"During the collapse and the invasion by the Red Army, I was with my family in Guesen near Burg. About ten days after the occupation of Guesen by the Russians, I was ordered to appear at their city headquarters. The town commandant explained that the head of the German Communist Party, Mr. Wricke, had told him that I was a well-known scientist along the lines of war-technology and that I had received the Dr. Fritz Todt Prize. The Red Army was much interested in me and was ready to offer me a suitable position in Moscow. The commandant asked me to report to headquarters every evening. During the course of the following eight days, a large number of Red Army officers came, among them engineers, who talked with me about the fields in which I specialized. Headquarters at Guesen immediately saw to it that my family and I received plentiful extra rations.

"After about eight days, I was again ordered to appear at headquarters. It was explained to me that the Red Army was going to transport me to Berlin where I was to resume activities with my firm for the Red Army. That was at the end of May. However, instead of being transported to Berlin, I was sent to the GPU at Kirchmoeser. Here non-specialists questioned me about six times concerning my activities with the firm of Blaupunkt and had me sign several protocols. These interviews and protocols were totally useless since they were made by non-specialists and contained only superficial data of the Blaupunkt developments. After about two weeks, the GPU section left Kirchmoeser and transferred me to a GPU section at Brandenburg. There several officers asked me the same questions as the ones I had been asked at Kirchmoeser, mostly at night. Upon my suggestion to call in specialists for these interrogations, it was explained to me that that would come later.

"After approximately ten more days, I was awakened at three o'clock one morning and told that I could leave for Berlin the next morning.

"Two days after my arrival in Berlin, several Russian officers called on me. This time they were scientists from Moscow who wanted to be oriented on the development projects of the firm of Blaupunkt. In addition to radar, the gentlemen were particularly interested in remote-control devices, especially

-1-

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NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL

Figure B.250: Account from a German electrical engineer regarding some former German advanced electronics facilities that were now in Soviet-controlled territory [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

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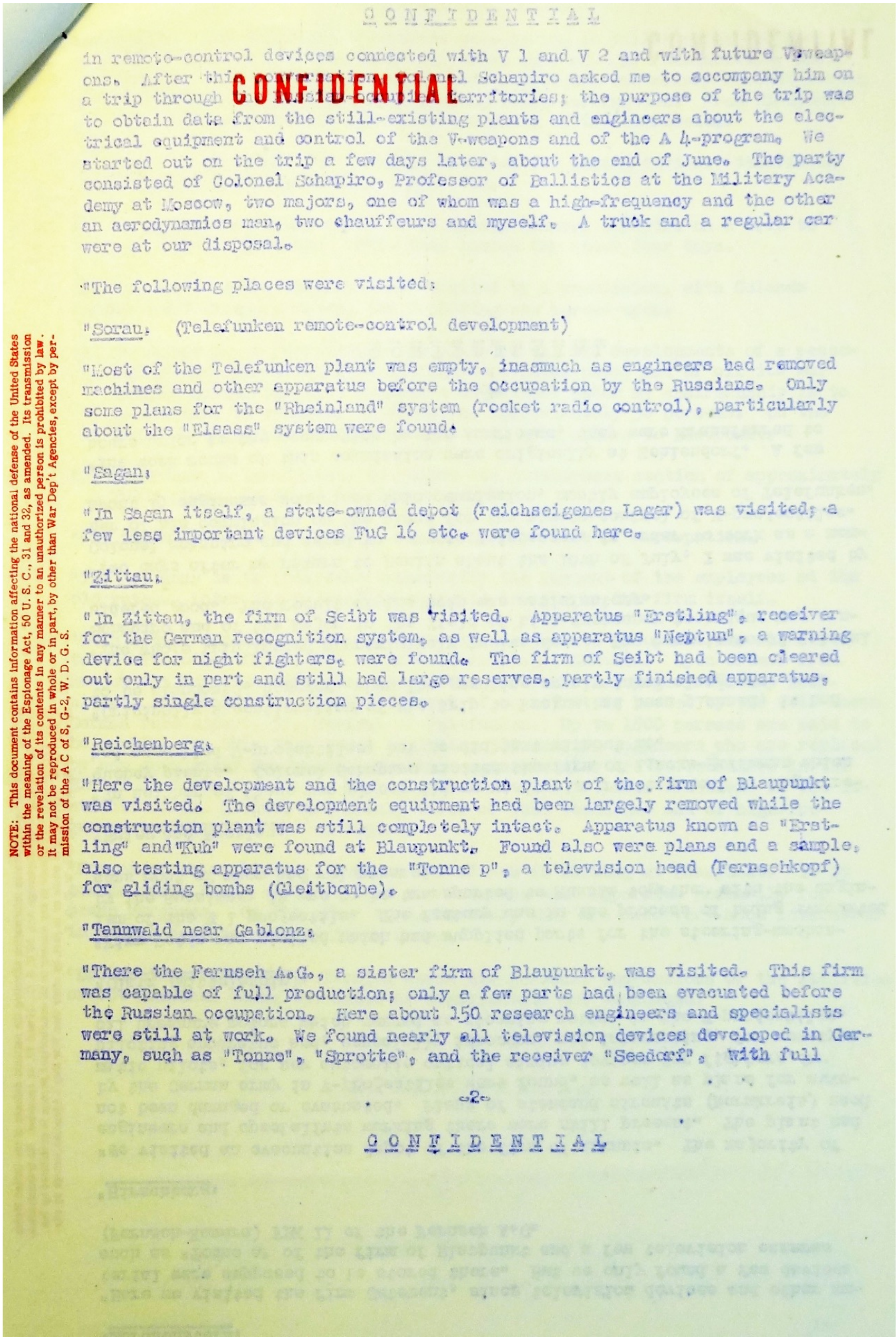
NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL



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in remote-control devices connected with V 1 and V 2 and with future V-weapons. After this conversation Colonel Schapiro asked me to accompany him on a trip through the Russian-occupied territories; the purpose of the trip was to obtain data from the still-existing plants and engineers about the electrical equipment and control of the V-weapons and of the A 4-program. We started out on the trip a few days later, about the end of June. The party consisted of Colonel Schapiro, Professor of Ballistics at the Military Academy at Moscow, two majors, one of whom was a high-frequency and the other an aerodynamics man, two chauffeurs and myself. A truck and a regular car were at our disposal.

"The following places were visited:

"Sorau: (Telefunken remote-control development)

"Most of the Telefunken plant was empty, inasmuch as engineers had removed machines and other apparatus before the occupation by the Russians. Only some plans for the "Rheinland" system (rocket radio control), particularly about the "Elsass" system were found.

"Sagan:

"In Sagan itself, a state-owned depot (reichseigenes Lager) was visited; a few less important devices FuG 16 etc. were found here.

"Zittau.

"In Zittau, the firm of Seibt was visited. Apparatus "Erstling", receiver for the German recognition system, as well as apparatus "Neptun", a warning device for night fighters, were found. The firm of Seibt had been cleared out only in part and still had large reserves, partly finished apparatus, partly single construction pieces.

"Reichenberg:

"Here the development and the construction plant of the firm of Blaupunkt was visited. The development equipment had been largely removed while the construction plant was still completely intact. Apparatus known as "Erstling" and "Kuh" were found at Blaupunkt. Found also were plans and a sample, also testing apparatus for the "Tonne p", a television head (Fernsehkopf) for gliding bombs (Gleitbombe).

"Tannwald near Gablonz:

"There the Fernseh A.G., a sister firm of Blaupunkt, was visited. This firm was capable of full production; only a few parts had been evacuated before the Russian occupation. Here about 150 research engineers and specialists were still at work. We found nearly all television devices developed in Germany, such as "Tonne", "Sprotte", and the receiver "Seedorf", with full

-2-

C O N F I D E N T I A L

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Figure B.251: Account from a German electrical engineer regarding some former German advanced electronics facilities that were now in Soviet-controlled territory [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

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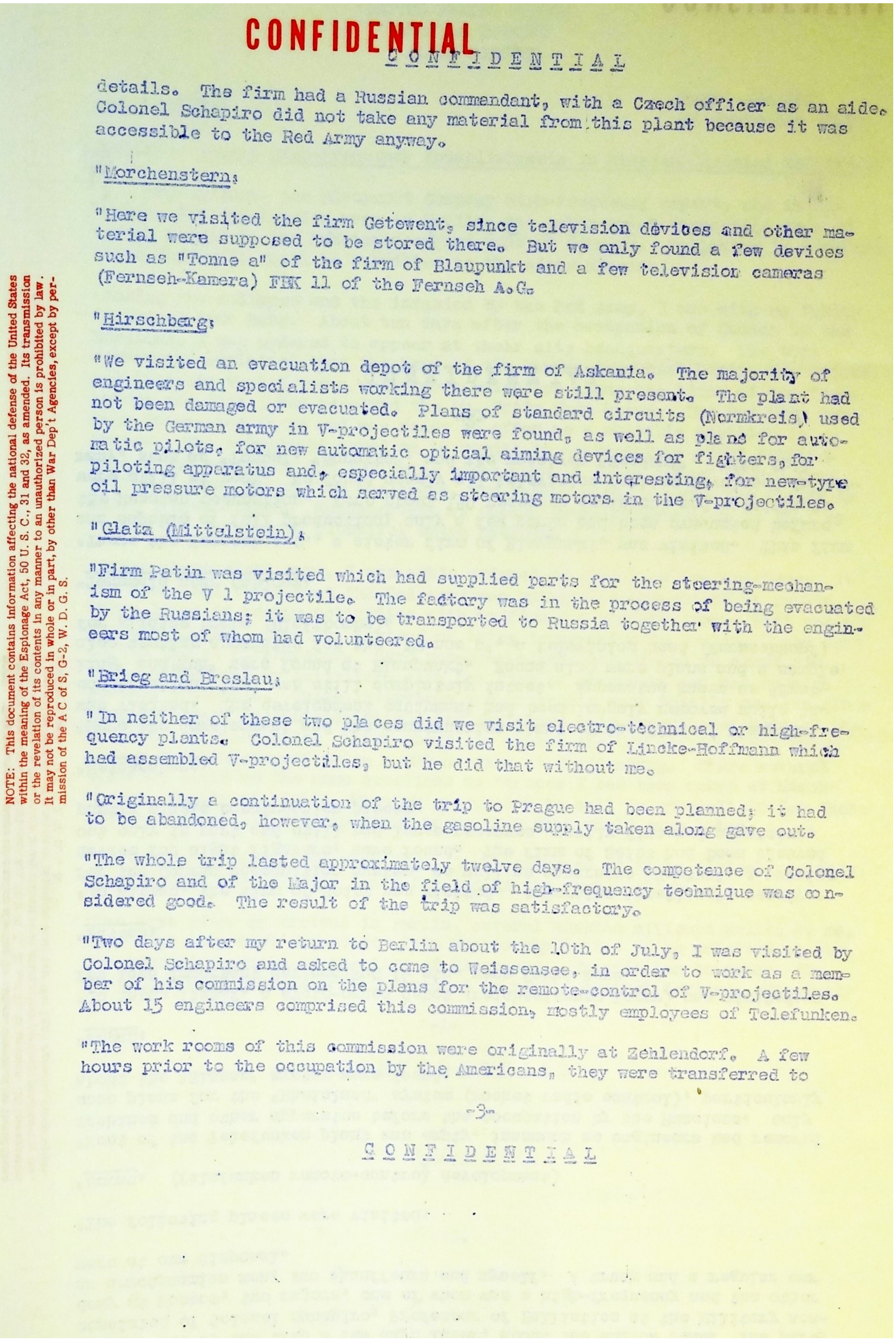

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details. The firm had a Russian commandant, with a Czech officer as an aide. Colonel Schapiro did not take any material from this plant because it was accessible to the Red Army anyway.

"Morchenstern:

"Here we visited the firm Getewent, since television devices and other material were supposed to be stored there. But we only found a few devices such as "Tonne a" of the firm of Blaupunkt and a few television cameras (Fernseh-Kamera) FHK 11 of the Fernseh A.G.

"Hirschberg:

"We visited an evacuation depot of the firm of Askania. The majority of engineers and specialists working there were still present. The plant had not been damaged or evacuated. Plans of standard circuits (Normkreis) used by the German army in V-projectiles were found, as well as plans for automatic pilots, for new automatic optical aiming devices for fighters, for piloting apparatus and, especially important and interesting, for new-type oil pressure motors which served as steering motors in the V-projectiles.

"Glatz (Mittelstein):

"Firm Patin was visited which had supplied parts for the steering-mechanism of the V 1 projectile. The factory was in the process of being evacuated by the Russians; it was to be transported to Russia together with the engineers most of whom had volunteered.

"Brieg and Breslau:

"In neither of these two places did we visit electro-technical or high-frequency plants. Colonel Schapiro visited the firm of Lincke-Hoffmann which had assembled V-projectiles, but he did that without me.

"Originally a continuation of the trip to Prague had been planned; it had to be abandoned, however, when the gasoline supply taken along gave out.

"The whole trip lasted approximately twelve days. The competence of Colonel Schapiro and of the Major in the field of high-frequency technique was considered good. The result of the trip was satisfactory.

"Two days after my return to Berlin about the 10th of July, I was visited by Colonel Schapiro and asked to come to Weissensee, in order to work as a member of his commission on the plans for the remote-control of V-projectiles. About 15 engineers comprised this commission, mostly employees of Telefunken.

"The work rooms of this commission were originally at Zehlendorf. A few hours prior to the occupation by the Americans, they were transferred to

-3-

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**NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL**

Figure B.252: Account from a German electrical engineer regarding some former German advanced electronics facilities that were now in Soviet-controlled territory [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

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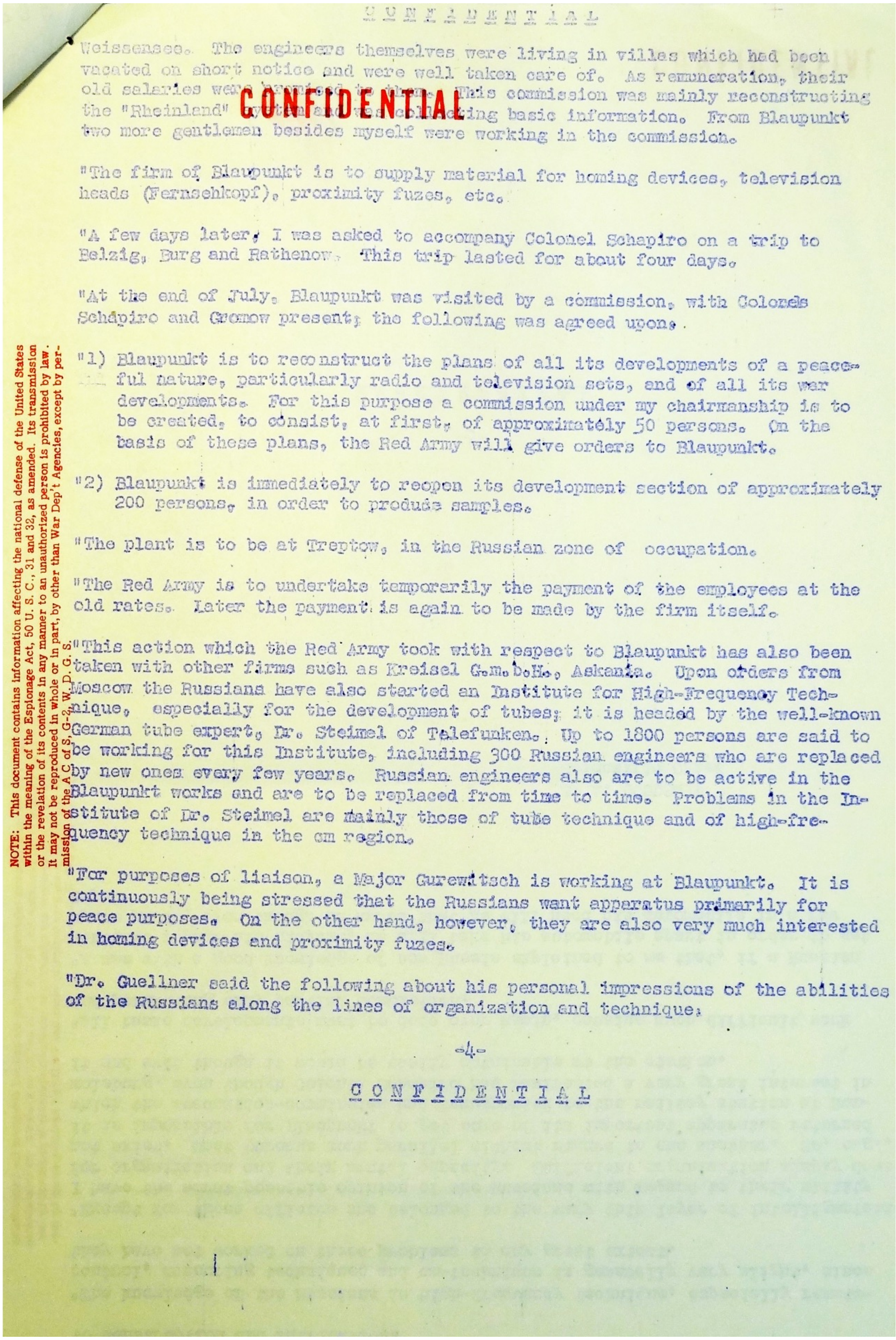

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Weissensee. The engineers themselves were living in villas which had been vacated on short notice and were well taken care of. As remuneration, their old salaries were promised to them. This commission was mainly reconstructing the "Rheinland" system and was collecting basic information. From Blaupunkt two more gentlemen besides myself were working in the commission.

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"The firm of Blaupunkt is to supply material for homing devices, television heads (Fernsehkopf), proximity fuzes, etc.

"A few days later, I was asked to accompany Colonel Schapiro on a trip to Belzig, Burg and Rathenow. This trip lasted for about four days.

"At the end of July, Blaupunkt was visited by a commission, with Colonels Schapiro and Gromow present; the following was agreed upon.

"1) Blaupunkt is to reconstruct the plans of all its developments of a peaceful nature, particularly radio and television sets, and of all its war developments. For this purpose a commission under my chairmanship is to be created, to consist, at first, of approximately 50 persons. On the basis of these plans, the Red Army will give orders to Blaupunkt.

"2) Blaupunkt is immediately to reopen its development section of approximately 200 persons, in order to produce samples.

"The plant is to be at Treptow, in the Russian zone of occupation.

"The Red Army is to undertake temporarily the payment of the employees at the old rates. Later the payment is again to be made by the firm itself.

"This action which the Red Army took with respect to Blaupunkt has also been taken with other firms such as Kreisel G.m.b.H., Askania. Upon orders from Moscow the Russians have also started an Institute for High-Frequency Technique, especially for the development of tubes; it is headed by the well-known German tube expert, Dr. Steimel of Telefunken. Up to 1800 persons are said to be working for this Institute, including 300 Russian engineers who are replaced by new ones every few years. Russian engineers also are to be active in the Blaupunkt works and are to be replaced from time to time. Problems in the Institute of Dr. Steimel are mainly those of tube technique and of high-frequency technique in the cm region.

"For purposes of liaison, a Major Gurewitsch is working at Blaupunkt. It is continuously being stressed that the Russians want apparatus primarily for peace purposes. On the other hand, however, they are also very much interested in homing devices and proximity fuzes.

"Dr. Guellner said the following about his personal impressions of the abilities of the Russians along the lines of organization and technique:

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NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL

Figure B.253: Account from a German electrical engineer regarding some former German advanced electronics facilities that were now in Soviet-controlled territory [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

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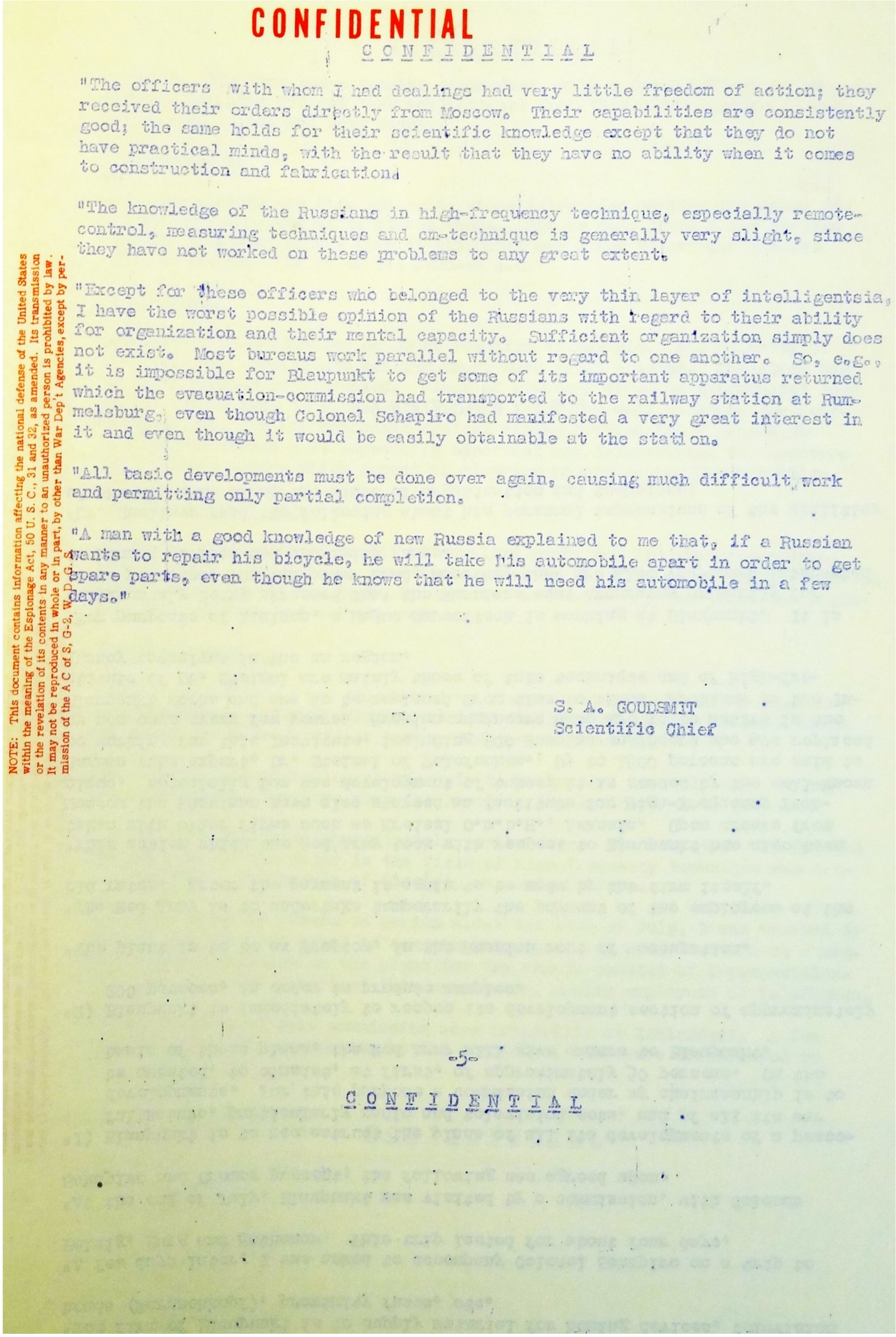
NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL



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"The officers with whom I had dealings had very little freedom of action; they received their orders directly from Moscow. Their capabilities are consistently good; the same holds for their scientific knowledge except that they do not have practical minds, with the result that they have no ability when it comes to construction and fabrication.

"The knowledge of the Russians in high-frequency technique, especially remote-control, measuring techniques and cm-technique is generally very slight, since they have not worked on these problems to any great extent.

"Except for these officers who belonged to the very thin layer of intelligentsia, I have the worst possible opinion of the Russians with regard to their ability for organization and their mental capacity. Sufficient organization simply does not exist. Most bureaus work parallel without regard to one another. So, e.g., it is impossible for Blaupunkt to get some of its important apparatus returned which the evacuation-commission had transported to the railway station at Rummelsburg, even though Colonel Schapiro had manifested a very great interest in it and even though it would be easily obtainable at the station.

"All basic developments must be done over again, causing much difficult work and permitting only partial completion.

"A man with a good knowledge of new Russia explained to me that, if a Russian wants to repair his bicycle, he will take his automobile apart in order to get spare parts, even though he knows that he will need his automobile in a few days."

S. A. GOUDSMIT
Scientific Chief

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Figure B.254: Account from a German electrical engineer regarding some former German advanced electronics facilities that were now in Soviet-controlled territory [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Klaus-Dietmar Henke. 2015. *Die amerikanische Besetzung Deutschlands.* 2nd ed. Berlin: De Gruyter. pp. 754–758. https://books.google.com/books?id=J73yCQAAQBAJ

Ebenfalls im Mai hatte sich, wie gezeigt, in der Truman-Administration trotz der massiven Einwände Churchills die übereinstimmende Auffassung herauskristallisiert, die amerikanischen Truppen müßten auf jeden Fall in Kürze aus der künftigen sowjetischen Besatzungszone in Mitteldeutschland abgezogen werden. Von Mitte Juni datiert das Telegramm, in dem der amerikanische Präsident dies Stalin mitteilte.[310] Entsprechend zielstrebig ging die Army in Mitteldeutschland vor. Am 25. Mai erfolgte die Weisung an das Ordnance Technical Intelligence Team im Harz, die dortigen Spezialisten samt ihren Familien so weit nach Westen wegzuführen, daß sie mit Sicherheit unter amerikanischer Kontrolle bleiben würden.[311] Bald darauf korrespondierten Eisenhower und Marshall über die Lage im Raum Nordhausen, die Phantasie und Energie der T-Forces so gefangennahm. Dabei verwies der Oberbefehlshaber darauf, daß die Intelligence Teams ihre Arbeit in den unterirdischen Produktionsstätten für Raketen nirgends auch nur annähernd abgeschlossen hätten.[312] Obwohl Eisenhower es nicht erwähnte, galt diese Feststellung natürlich erst recht für die übrigen wissenschaftlich-technischen Objekte in Sachsen und Thüringen, die ebenfalls kriegswichtig, aber weniger spektakulär und deshalb nicht alle von Anfang an mit demselben Nachdruck ausgeforscht worden waren.

Also in May, as shown, the consensus view had emerged in the Truman administration, despite Churchill's massive objections, that American troops would have to be withdrawn from the future Soviet occupation zone in central Germany in any case in the near future. The telegram in which the American president communicated this to Stalin dates from mid-June.[310] The Army proceeded with corresponding determination in central Germany. On May 25, instructions were given to the Ordnance Technical Intelligence team in the Harz Mountains to move the specialists there, together with their families, so far west that they would certainly remain under American control.[311] Soon thereafter, Eisenhower and Marshall corresponded about the situation in the Nordhausen area, which so captured the imagination and energy of the T-Forces. In doing so, the commander in chief pointed out that the intelligence teams had nowhere even remotely completed their work in the underground production facilities for rockets.[312] Although Eisenhower did not mention it, this observation naturally applied a fortiori to the other scientific and technical facilities in Saxony and Thuringia, which were also important to the war effort but less spectacular and therefore had not all been explored with the same vigor from the beginning.

[310] Vgl. Eisenhower-Papers, VI/4.

[311] Lasby, Paperclip, S. 43.

[312] Telegramm Eisenhowers an Marshall v. 7. 6. 1945; Eisenhower-Papers, VI, S. 143 ff.

[310] Cf. Eisenhower Papers, VI/4.

[311] Lasby, Paperclip, p. 43.

[312] Eisenhower's telegram to Marshall v. 7. 6. 1945; Eisenhower Papers, VI, p. 143 ff.

Dieser ärgerliche Umstand mag Eisenhower zwei Tage zuvor besonders schmerzlich bewußt geworden sein, als beim ersten Zusammentreffen der Militärgouverneure in Berlin in aller wünschenswerten Klarheit herauskam, daß die Räumung der sowjetischen Besatzungszone unmöglich noch länger hinausgeschoben werden konnte. Das steigerte die Hektik der allierten T-Forces noch, deren detektivisch-kriminalistische Arbeit überall, aber besonders in Mitteldeutschland, unter einem beträchtlichen Zeit- und Konkurrenzdruck durchgeführt werden mußte. Im Juni steigerte sich die Hektik der Intelligence Teams, die in den überaus ergiebigen, bald zu übergebenden Gebieten noch längst nicht alles unter Dach und Fach hatten, zu kopfloser Hast. Unmittelbar nachdem Truman den britischen Premierminister und Stalin von dem bevorstehenden Rückzug seiner Truppen in Kenntnis gesetzt hatte, erließ das Allierte Oberkommando in Einklang mit der militärischen Führung in Washington am 18. und 19. Juni 1945 die streng geheimen Befehle, beim Abzug alle jene deutschen Wissenschaftler und Techniker zu "evakuieren", deren Fähigkeiten und Kenntnisse Großbritannien und die Vereinigten Staaten nutzen wollten.[313]

Eisenhower may have become particularly painfully aware of this annoying circumstance two days earlier when, at the first meeting of the military governors in Berlin, it emerged with all desirable clarity that the evacuation of the Soviet occupied zone could not possibly be postponed any longer. This increased the hectic pace of the Allied T-Forces, whose detective-criminal work had to be carried out everywhere, but especially in central Germany, under considerable time and competitive pressure. In June, the hectic pace of the intelligence teams, who were far from having everything under control in the extremely productive areas soon to be handed over, increased to headlong haste. Immediately after Truman notified the British prime minister and Stalin of the impending withdrawal of his forces, the Allied High Command, in concert with the military leadership in Washington, issued top-secret orders on 18 and 19 June 1945 to "evacuate" on withdrawal all those German scientists and technicians whose skills and knowledge Britain and the United States wished to use.[313]

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[313] Die Daten dieser Befehle (SHAEF, GBI/FIAT/322-21/1) gehen aus einem Schreiben des Chefs von FIAT an den Kommandierenden General von USFET, ACOS G-5, v. 16. 7. 1945 hervor ("Evacuation of German Scientists from Area now under Russian Occupation"); NA, RG 260, 17/11-1. Gimbel, U.S. and German Scientists, S. 438, nennt als Datum des Befchls den 15. Juni.

[313] The dates of these orders (SHAEF, GBI/FIAT/322-21/1) come from a letter from the chief of FIAT to the commanding general of USFET, ACOS G-5, v. 16 July 1945 ("Evacuation of German Scientists from Area now under Russian Occupation"); NARA, RG 260, 17/11-1. Gimbel, U.S. and German Scientists, p. 438, gives the date of the order as 15 June.

Es begann, was ein Offizier der Air Force als “Griff in die russische Zone” titulierte.[314] Zum zentralen Streitpunkt zwischen den USA und der Sowjetunion sollte bald die Frage werden, ob dabei Gewalt angewandt worden sei oder nicht. Obwohl die Amerikaner dies immer entrüstet abstritten, beharrten die Russen völlig zu Recht darauf, daß es keine einfache Evakuierung, sondern eine Zwangsevakuierung gewesen sei, die die U.S. Army bei ihrem Abzug aus Sachsen und Thüringen in Szene gesetzt habe. Tatsächlich gab es kaum eine Fabrik von technologischer Bedeutung, kaum ein naturwissenschaftliches Institut, das die Amerikaner vor ihrem Abrücken aus Mitteldeutschland nicht durchkämmt hätten, auch kaum einen Experten von Rang, den das CIC und die T-Forces in den beiden letzten Juniwochen nicht zur Abreise in den Westen aufgefordert, gedrängt, genötigt oder gezwungen hätten.

There began what one Air Force officer dubbed a “reach into the Russian zone.”[314] The central point of contention between the United States and the Soviet Union would soon become whether or not force had been used in the process. Although the Americans always indignantly denied this, the Russians quite rightly insisted that it was not a simple evacuation but a forced evacuation that the U.S. Army had staged during its withdrawal from Saxony and Thuringia. In fact, there was hardly a factory of technological importance, hardly a scientific institute that the Americans had not combed before their departure from central Germany, and hardly an expert of rank whom the CIC and the T-Forces had not asked, urged, coerced or forced to leave for the West in the last two weeks of June.

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[314] Lasby, Paperclip, S. 29.

[314] Lasby, Paperclip, p. 29.

Bei Siemens & Halske im thüringischen Arnstadt wurde es am 21. Juni ernst.[315] Am Abend dieses Tages suchten zwei amerikanische Offiziere der 102nd Infantry Division Direktor Lohse in seiner Privatwohnung auf, stellen ihm zunächst einige allgemeine Fragen zur Firmenorganisation, zu den führenden Persönlichkeiten der mitteldeutschen Elektroindustrie (über die sie offenbar Dossiers hatten) und lenkten dann auf den Siemens-Anteil an der V-Waffenproduktion über. Seine Firma habe bestimmte elektrotechnische Bauelemente zugeliefert, erläuterte der für die thüringischen Fabriken bevollmächtigle Siemens-Manager, der nicht zum ersten Mal einer allierten Expertenkommission Rede und Antwort stehen mußte. Doch dann machten ihm die beiden Offiziere einige höchst überraschende Eröffnungen: “Das amerikanische Hauptquartier beabsichtige, im Westen oder Südwesten, jedenfalls nicht in Thüringen, eine Fabrik, die unsere Fertigungen umfassen solle, aufzuziehen”, beschrieb Lohse einige Monate später diese Unterredung. Der endgültige Standort sei ihnen selbst nicht bekannt, sagten die beiden Amerikaner weiter: “Die Fabrik gehöre zunächst keineswegs mehr zu Siemens, sondern unterstände unmittelbar dem Hauptquartier. Es würde aber denkbar sein, daß nach einer gewissen Zeit Fühlungnahme mit den westlichen Siemens-Fabriken möglich sei.”[316]

At Siemens & Halske in Arnstadt, Thuringia, things got serious on June 21.[315] On the evening of that day, two American officers of the 102nd Infantry Division visited Director Lohse in his private apartment, first asked him some general questions about the company’s organization, about the leading figures in the Central German electrical industry (about whom they apparently had dossiers), and then turned their attention to Siemens’ share in the production of V weapons. His company had supplied certain electrotechnical components, explained the Siemens manager authorized for the Thuringian factories, who had not for the first time had to answer the questions of an Allied expert commission. But then the two officers made some highly surprising revelations to him: “The American headquarters intends to set up a factory in the west or southwest, at any rate not in Thuringia, which is to include our production facilities,” Lohse described this conversation a few months later. The final location was not known to them themselves, the two Americans went on to say: “The factory would initially no longer belong to Siemens at all, but would be under the direct control of headquarters. It would be conceivable, however, that after a certain period of time, contact could be made with the Siemens factories in the West.”[316]

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[315] Zur Situation dieses Zweigbetriebes in den Monaten zuvor vgl. VI/4.

[316] “Persönlicher Bericht über die Zeit von Ende März 1945 bis Ende November 1945” (mit Nachträgen von Anfang 1946), verfaßt von Direktor Adolf Lohse in Erlangen am 21. 11. 1945, dessen Richtigkeit von vier seiner leitenden Mitarbeiter durch Unterschrift bestätigt war; Siemens-Archiv, S AA 11.43/Lm 394, von Witzleben.

[315] For the situation of this branch in the months before, see VI/4.

[316] “Personal report on the period from the end of March 1945 to the end of November 1945” (with addenda from the beginning of 1946), written by Director Adolf Lohse in Erlangen on 21 Nov. 1945, the accuracy of which was confirmed by signature of four of his senior staff; Siemens Archives, S AA 11.43/Lm 394, von Witzleben.

Das war starker Tobak, der dem ahnungslosen Siemens-Direktor, welcher eben die Pläne für die Neuorganisation der mitteldeutschen Konzernbetriebe fertig hatte, mit dieser schon auf den ersten Blick ziemlich unglaubhaft klingenden Mitteilung verabreicht wurde. Er erkundigte sich deshalb auch sofort bei seinen Gästen, ob die Spitzenkräfte der thüringischen Betriebe freiwillig oder zwangsweise an den neuen Standort übersiedeln sollten. Lohse war natürlich vom ersten Augenblick an klar, daß ein für das Firmenschicksal derart einschneidender Schritt unmöglich von einem Tag auf den anderen und keinesfalls ohne Abstimmung zumindest mit Ernst von Siemens in München getan werden konnte. Seine beiden späten Besucher beeilten sich zwar zu beteuern, daß es sich "selbstverständlich" um eine freiwillige Ubersiedlung handele, andererseits verlangten die Offiziere aber "kategorisch", daß "die betr. Siemens-Herren ihre Familien an den fraglichen Ort mitnehmen müßten und daß der Abtransport binnen 48 Std. zu erfolgen habe". Schmackhaft gemacht wurde dieses Ultimatum durch das Versprechen, es stünden für die Familien "völlig eingerichtete Wohnungen" zur Verfügung, für Ernährung, Bekleidung und Erziehung der Kinder sorge das Hauptquartier.

"Als ich den Zusagen gegenüber leichte Zweifel äußerte", hielt der Direktor in seinem Rechenschaftsbericht später fest, "antwortete Mr. Ernest sehr empört, daß ich bedenken möge, daß noch nie eine deutsche Regierung ein derartig faires Angebot an Angehörige eines besiegten Volkes gemacht habe. Ich möchte in dieser Beziehung mich doch insbesondere an die Konzentrationslager, die sie auch in Thüringen vorgefunden hätten, rinnern." Direktor Lohse bekam Zeit bis 8.30 Uhr am nächsten Morgen, um die Mitarbeiter zu benennen, die ihn begleiten sollten. Auch sein Hinweis, er sei Kaufmann und kein Techniker und komme deshalb selbst wohl nicht für den geplanten Abtransport in Frage, fruchtete nichts. Das sei ihnen bekannt, verabschiedeten sich die beiden Offiziere, aber aufgrund ihrer Informationen über seine Person müßten sie Wert darauf legen, daß er den "vom Hauptquartier gewünschten Betrieb unbedingt selbst in die Hand nähme".

This was strong stuff, which the unsuspecting Siemens director, who had just finished the plans for the reorganization of the central German group companies, was presented with this announcement, which sounded quite unbelievable even at first glance. He therefore immediately inquired of his guests whether the top employees of the Thuringian plants were to move to the new location voluntarily or forcibly. Of course, it was clear to Lohse from the very first moment that such a drastic step for the fate of the company could not possibly be taken from one day to the next and under no circumstances without at least consulting Ernst von Siemens in Munich. His two late visitors hastened to affirm that it was "of course" a voluntary resettlement, but on the other hand the officers demanded "categorically" that "the Siemens men concerned must take their families with them to the place in question and that the removal must take place within 48 hours." This ultimatum was made palatable by the promise that "completely furnished apartments" would be available for the families, and that the headquarters would provide food, clothing, and education for the children.

"When I expressed slight doubts about the promises," the director later stated in his report, "Mr. Ernest replied very indignantly that I should remember that no German government had ever made such a fair offer to members of a defeated people. In this respect, I would like to recall in particular the concentration camps which they had also found in Thuringia." Director Lohse was given until 8:30 the next morning to name the staff members who were to accompany him. His comment that he was a merchant and not a technician, and that he himself was therefore probably not eligible for the planned removal, was of no avail. They were aware of this, the two officers said, but on the basis of the information they had about him, they would have to insist that he take the operation "desired by headquarters into his own hands."

Noch in derselben Nacht versammelte Lohse maßgebliche Kollegen um sich und beriet mit ihnen die Lage. Mit einer Reihe seiner engsten Mitarbeiter hatte er in den vorangegangenen Tagen schon wiederholt über die bevorstehende sowjetische Besetzung gesprochen, wobei sie sich einig gewesen waren, bis zur möglichen Liquidierung der Siemens-Betriebe durch die neue Besatzungsmacht auf jeden Fall in Thüringen zu bleiben. An diesem Entschluß änderte zunächst auch die amerikanische Aufforderung zur Übersiedlung in den Westen nichts, zumal sich in der nächtlichen Beratung zeigte, daß eine Reihe von Siemens-Mitarbeitern bereit waren, “mit ihren Familien dem Angebot der amerikanischen Regierung zu folgen”. Andere leitende Angestellte dachten ebenso wie Lohse gar nicht daran, auf die Vorschläge der Besatzungsmacht einzugehen.

Als der Morgen des 22. Juni kam, mußte die Siemens-Spitze in Arnstadt feststellen, daß sie überhaupt keine Entscheidungsfreiheit besaß. Die Amerikaner lehnten die vorbereitete Liste von Ersatzleuten, die bereit waren, mit ihnen abzurücken und die besagte neue Fabrik im Westen aufzubauen, glatt ab. “Mr. Ernest nahm kaum Kenntnis von dieser Aufstellung”, so beschreibt Direktor Lohse die Konfrontation mit der Besatzungsmacht, “sondern erklärte in ziemlich steifem Ton, daß er diese meine Stellungnahme erwartet habe nach der ganzen hinhaltenden Besprechung am Abend zuvor. Die Herren hätten inzwischen mit dem Hauptquartier telefonisch gesprochen und müßten mir nunmehr eröffnen, *daß von einer freiwilligen Abreise nicht die Rede sein könne*, sondern auch die Herren, die in Thüringen bleiben wollten, mit ihren Familien sich schnellstens zum Abtransport fertig zu machen hätten.”[317] Lohse und die übrigen maßgeblichen Siemens-Mitarbeiter, hinter denen die Amerikaner her waren, erkannten jetzt, da weitere Debatten sinnlos waren.

That same night, Lohse gathered senior colleagues around him and discussed the situation with them. In the preceding days, he had repeatedly discussed the impending Soviet occupation with a number of his closest coworkers, and they had agreed to remain in Thuringia in any case until the possible liquidation of the Siemens plants by the new occupying power. Initially, the American request to relocate to the West did not change this decision, especially since it became apparent during the nighttime meeting that a number of Siemens employees were prepared to “follow the American government’s offer with their families.” Other senior executives, like Lohse, did not even think of responding to the occupation forces’ proposals.

When the morning of 22 June came, the Siemens top management in Arnstadt had to realize that they had no freedom of decision at all. The Americans flatly rejected the prepared list of replacements who were willing to leave with them and build the new factory in question in the West. “Mr. Ernest hardly took any notice of this list,” is how Director Lohse describes the confrontation with the occupation forces, “but explained in a rather stiff tone that he had expected this statement of mine after the whole stalling meeting the night before. In the meantime, the gentlemen had spoken to headquarters by telephone and would now have to inform me *that there could be no question of a voluntary departure*, but that the gentlemen who wanted to stay in Thuringia would have to get ready for departure with their families as soon as possible.”[317] Lohse and the other key Siemens employees, whom the Americans were after, now realized that further debates were pointless.

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[317] Hervorhebung von mir.

[317] Emphasis mine.

Am Morgen des Sonntag, dem 24. Juni, erfolgte der Abtransport der meisten der “befohlenen Herren” und ihrer Familien. Einigen mag es zur Beruhigung gedient haben, daß der unmittelbar vor der Evakuierung in Arnstadt auftauchende Werner von Siemens aus der Sicht der Konzernleitung keine prinzipiellen Bedenken gegen das amerikanische Vorhaben erhob. Dies genügte freilich nicht allen, um sich auf das Abenteuer der ungewissen Reise einzulassen. Ein leitender Angestellter, Wilhelm Vox, weigerte sich am Sontag noch immer mitzufahren. Daraufhin wurde er von der Besatzungsmacht verhaftet und gesondert abtransportiert. Wenige Tage später fand auch er sich in der US-Zone wieder.

Neben den leitenden Angestellten und deren Familien fuhren die Amerikaner aus dem Arnstadter Werk überdies 18 mit Maschinen und elektrotechnischen Geräten beladene Lastwagen über die Zonengrenze. Direktor Lohse und seinem engsten Mitarbeiter, die darauf bestanden, die Abwicklung auch in anderen Werken noch selbst zu überwachen, hatte die Besatzungsmacht das Recht eingeräumt, dem Haupttransport erst drei Tage später zu folgen. Als sie sich dann selbst nach Westen absetzten, sagten sie dem aufsichtsführenden amerikanischen Offizier unverhohlen ins Gesicht, daß sie “das feste Bewußtsein hätten, nicht eine Fabrik aufzubauen, wohl aber in ein Gefangenenlager zu kommen”.

On the morning of Sunday, 24 June, most of the “commanded gentlemen” and their families were transported away. Some may have been reassured by the fact that Werner von Siemens, who appeared in Arnstadt immediately before the evacuation, did not raise any objections in principle to the American plan from the point of view of the company management. This, of course, was not enough for everyone to embark on the adventure of the uncertain journey. One senior employee, Wilhelm Vox, still refused to go along on Sunday. As a result, he was arrested by the occupying forces and taken away separately. A few days later he too found himself in the U.S. zone.

In addition to the executives and their families, the Americans also drove 18 trucks loaded with machines and electrotechnical equipment from the Arnstadt plant across the zone border. Director Lohse and his closest colleague, who insisted on still supervising the processing in other plants themselves, had been granted the right by the occupying forces to follow the main transport only three days later. When they then set off westward themselves, they blatantly told the supervising American officer to his face that they “were firmly aware that they were not going to build a factory, but that they were going to a prison camp.”

Die Amerikaner haben nicht nur aus Arnstadt, sondern aus allen größeren Siemens-Werken Mitteldeutschlands Spitzenkräfte zwangsevakuiert, aus Rudolstadt ebenso wie aus Gera und aus Beendorf bei Helmstedt oder Molsdorf bei Erfurt.[318] Allein aus Gera und Arnstadt waren es einschließlich der Familienangehörigen ungefähr 125 Personen, darunter insgesamt gewiß mehrere Dutzend erstrangige Kräfte des Konzerns, denn Ende 1945 fanden sich noch immer über 30 von ihnen im Gewahrsam von FIAT; zwei Drittel kamen aus Arnstadt, wo sich die meisten Siemens-Angehörigen gesammelt hatten.[319]

The Americans forcibly evacuated top personnel not only from Arnstadt, but from all the larger Siemens plants in central Germany, from Rudolstadt as well as from Gera and from Beendorf near Helmstedt or Molsdorf near Erfurt.[318] From Gera and Arnstadt alone, there were about 125 people, including family members, among them certainly several dozen first-rate employees of the company, because at the end of 1945, more than 30 of them were still in FIAT custody; two thirds came from Arnstadt, where most Siemens employees had gathered.[319]

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[318] Die Evakuierungen an diesen Standorten sind verschiedentlich erwähnt, so in Lohses Schilderung selbst, aber auch bei Gimbel, U.S. Policy and German Scientists, S. 440, sowie in dem Bericht Marschall Schukows an Stalin von Ende Juni 1945 ("Marshall Zhukov's Report on Removal by the Allies of Equipment and other Property from the factories in the Soviet Zone of Occupation"), auf den weiter unten näher eingegangen wird; abgedruckt in: FRUS, Conference of Berlin, II, S. 906 ff.

[319] Vgl. neben dem Bericht von Direktor Lohse die von FIAT zusammengestellte Liste aus Mitteldeutschland evakuierter Wissenschaftler und Techniker v. 19. 12. 1945; NA, RG 243, European War, G-2 Library, Entry 36, Envelope 760. In dieser umfangreichen Aufstellung, die etwa die Hälfte der insgesamt zwangsevakuierten Experten aufführt, findet sich auch der Name von Dr. Wilhelm Vox, der sich zunächst geweigert hatte, Arnstadt mit den Amerikanern zu verlassen, und daraufhin von der Besatzungsmacht verhaftet worden war.

[318] Evacuations at these sites are mentioned variously, as in Lohse's account itself, but also in Gimbel, U.S. Policy and German Scientists, p. 440, and in Marshal Zhukov's report to Stalin of late June 1945 ("Marshal Zhukov's Report on Removal by the Allies of Equipment and other Property from the factories in the Soviet Zone of Occupation"), discussed in more detail below; reprinted in: FRUS, Conference of Berlin, II, pp. 906 ff.

[319] See, in addition to the report by Director Lohse, the list of scientists and technicians evacuated from central Germany compiled by FIAT, dated December 19, 1945; NARA, RG 243, European War, G-2 Library, Entry 36, Box 760. This extensive list, which lists about half of the total number of forcibly evacuated experts, also includes the name of Dr. Wilhelm Vox, who had initially refused to leave Arnstadt with the Americans and was subsequently arrested by the occupying forces.

Die Zwangsevakuierten von Siemens wurden in das württembergische Heidenheim an der Brenz gebracht. Hier kamen sie zunächst in ein stark bewachtes, mit einem Drahtverhau umgebenes Barackenlager. Bald konnten sie in ein Schulhaus umziehen, und nach und nach wurden sie gewahr, daß sie ihr Schicksal mit Hunderten anderer "Internierter"—so Direktor Lohse—aus Thüringen teilten: "Die wahre Ursache des Transports nach Heidenheim konnte sehr schnell übersehen werden", berichtete er im November 1945 seiner Firma. "Offensichtlich hatte die amerikanische Regierung Wert darauf gelegt, alle Kräfte, die evtl. für den Wiederaufbau bzw. die Fertigungsfortsetzung von V-Waffen nützlich sein könnten, außerhalb Thüringens zu konzentrieren ... Die örtlichen militärischen Stellen der Amerikaner waren jedoch über die Absichten nicht im geringsten im Bilde. Sie hatten, wie mir ein amerikanischer Offizier selbst mitteilte, lediglich den Befehl vom Hauptquartier, as Thüringen verbrachte deutsche Fachkräfte unbedingt und sicher festzuhalten." Von einer "Unzahl von englischen und amerikanischen Militärkommissionen sämtlicher Truppenteile" wurden die Internierten ausgefragt, berichtete Lohse, aber keiner der Offiziere "konnte jemals auf unsere Frage antworten, ob und wann wir aus unserer Internierung entlassen würden". Auch die Bemühungen um Freilassung, die sofort von der Siemens-Gruppenleitung in München eingeleitet wurden, blieben zunächst ohne Erfolg. Erst Anfang Dezember konnten ungefähr zwei Drittel der in Heidenheim festgehaltenen Firmenmitglieder an den Erlanger Konzernstandort übersiedeln. Sie hatten sich weiterhin als interniert zu betrachten, konnten sich aber nun frei in der US-Zone bewegen. Verlassen durften sie das amerikanische Besatzungsgebiet nicht, wofür Direktor Lohse der Militärregierung persönlich zu bürgen hatte.

The forced evacuees from Siemens were taken to Heidenheim an der Brenz in Württemberg. Here they were initially placed in a heavily guarded barracks camp surrounded by a wire enclosure. Soon they were able to move into a schoolhouse, and gradually they became aware that they shared their fate with hundreds of other "internees"—as Director Lohse said—from Thuringia: "The true cause of the transport to Heidenheim could very quickly be overlooked," he reported to his company in November 1945. "Obviously, the American government had attached importance to concentrating outside Thuringia all forces that might be useful for the reconstruction or continuation of the production of V-weapons.... The local American military authorities, however, were not in the least aware of the intentions. They had, as an American officer himself told me, only the order from headquarters to hold German specialists deported to Thuringia absolutely and securely." Internees were questioned by a "number of English and American military commissions of all troop units," Lohse reported, but none of the officers "was ever able to answer our question as to whether and when we would be released from our internment." Efforts to secure release, which were immediately initiated by Siemens Group management in Munich, were also initially unsuccessful. It was not until early December that about two-thirds of the company members held in Heidenheim were able to move to the Erlangen group location. They still had to consider themselves interned, but could now move freely within the U.S. zone. They were not allowed to leave the American occupation zone, for which Director Lohse had to personally vouch to the military government.

Die Labors und Betriebsstätten der Telefunken, Gesellschaft für drahtlose Telegraphie m.b.H., die ebenfalls Bauteile für die V-Waffenproduktion entwickelt und hergestellt hatte, fanden bei den Amerikanern ähnliche Aufmerksamkeit wie die Fabriken des Konkurrenzunternehmens Siemens. Bereits am 16. Juni transportierte die Army (deren Ordnance Teams ja schon seit Ende Mai die Genehmigung hatten, Experten, die in irgendeiner Weise mit dem deutschen Raketetenprogramm verbunden waren, nach Westdeutschland zu bringen) aus der Fertigungsstätte in Bad Liebenstein im thüringischen Landkreis Meiningen den Konstrukteur Professor Fritz Schröter mit Frau und Tochter ab, nach dem sicheren Eindruck des Unternehmens eine Aktion "rein militärischen Charakters"[320]. Neben der Wegführung des prominenten Betriebsstättenleiters gab es auch freiwillige Abwanderungen mehrerer wichtiger Mitarbeiter und ihrer Familien, da die Firmenleitung—vermutlich unter dem Eindruck der bevorstehenden sowjetischen Besetzung—beschlossen hatte, ire während des Krieges nach Mitteldeutschland ausgelagerten Betriebe zurückzuführen. Als ester Sammelpunkt war Göttingen bestimmt worden, wohin deshalb im Laufe des Juni neben den Betriebsangchörigen auch Apparate, Geräte und Konstruktionsunterlagen gebracht wurden. In einer Aufstellung der Wirtschaftskammer Meiningen war sorgsam unterschieden zwischen denjenigen, die "abtransportiert" worden waren, und denen, die den Ort "freiwillig verlassen" hatten oder "unbekannt verzogen" waren. Einige der Abtransportierten—so Professor Hans Rukop (Röhrenexperte), Professor Paul Günther (Radarfachmann), Graf Michael von der Schulenburg oder Erich Chytrek, der auf dem Felde der Quarzkristalle forschte—befanden sich noch Ende des Jahres im Gewahrsam der alliierten Field Intelligence Agency, Technical. Aus dem Telefunken-Labor in Bad Blankenburg bei Rudolstadt hatte die Army bei ihrem Abzug neben wertvollen Apparaturen zwanzig Experten auf dem Gebiet der Funktechnik fortgeschafft.[321] Der Bestimmungsort der meisten Telefunken-Koryphäen war wie der ihrer Siemens-Kollegen das württembergische Städtchen Heidenheim.

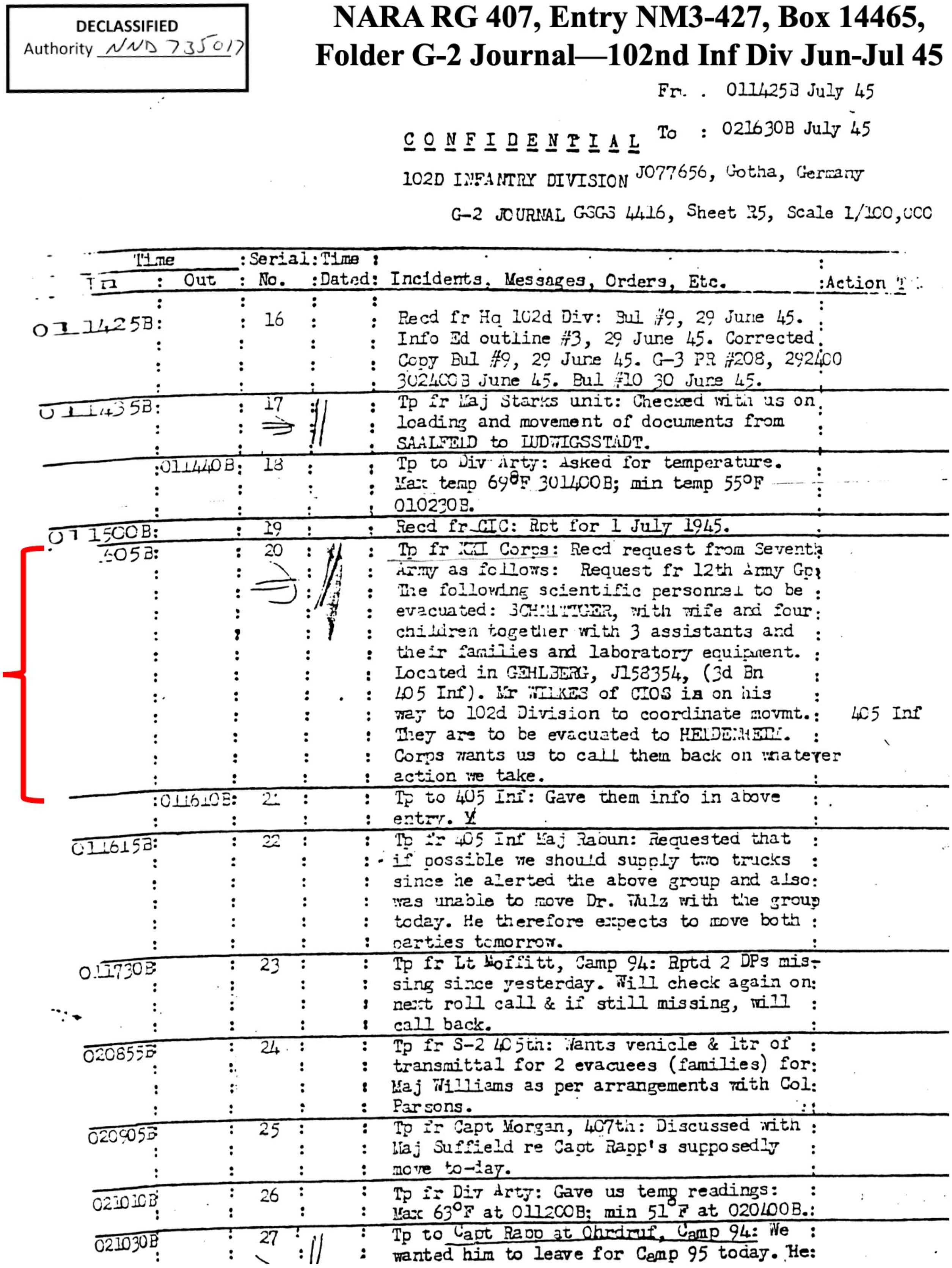
The laboratories and operating facilities of Telefunken, Gesellschaft für drahtlose Telegraphie m.b.H., which had also developed and manufactured components for V-weapon production, attracted similar attention from the Americans as the factories of the rival company Siemens. As early as 16 June, the Army (whose Ordnance Teams had already been authorized since the end of May to bring experts in any way connected with the German missile program to West Germany) transported the designer Professor Fritz Schröter with his wife and daughter from the manufacturing plant in Bad Liebenstein in the Thuringian district of Meiningen, according to the company's clear impression an action of "purely military character."[320] In addition to the departure of the prominent plant manager, there were also voluntary departures of several important employees and their families, since the company management—presumably under the impression of the impending Soviet occupation—had decided to return their operations that had been outsourced to central Germany during the war. Göttingen had been designated as the main assembly point, to which not only the employees but also apparatus, equipment, and design documents were brought in the course of June. In a list compiled by the Meiningen Chamber of Commerce, a careful distinction was made between those who had been "deported" and those who had "voluntarily left" the town or had "moved to an unknown address." Some of the deportees—such as Professor Hans Rukop (tube expert), Professor Paul Günther (radar expert), Count Michael von der Schulenburg, or Erich Chytrek, who was doing research in the field of quartz crystals—were still in the custody of the Allied Field Intelligence Agency, Technical at the end of the year. When the Army withdrew from the Telefunken laboratory in Bad Blankenburg near Rudolstadt, it had taken away twenty experts in the field of radio technology as well as valuable equipment.[321] The destination of most of the Telefunken luminaries, like that of their Siemens colleagues, was the small town of Heidenheim in Württemberg.

[320] Schreiben der Telefunkenbetriebsstätte Bad Liebenstein an den örtlichen Bürgermeister v. 30. 7. 1945. Dokument Nr. 37 im Anhang zu Fuchs, Besatzungspolitik der USA; vgl. auch ebenda, S. 139. Siehe auch Dokument Nr. 38, "Feststeilung der von amerikanischen Besatzungsbehörden mitgeführten Vermögenswerte, Patente, Personen usw." der Geschäftsstelle Meiningen der Wirtschaftskammer Thüringen, ohne Datum, Stichtag 15. 7. 1943. Die genannten Namen finden sich auf der oben erwähnten FIAT-Liste: NA, RG 243. European War, G-2 Library, Entry 36, Envelope 760.

[321] Schukow-Bericht an Stalin; abgedruckt in FRUS, Conference of Berlin II, S. 909.

[320] Letter from Telefunken Betriebsstätte Bad Liebenstein to the local mayor v. 30. 7. 1945. Document No. 37 in the appendix to Fuchs, Besatzungspolitik der USA; cf. also ibid. p. 139. See also Document No. 38, "Festteilung der von amerikanischen Besatzungsbehörden mitgeführten Vermögenswerte, Patente, Personen usw." der Geschäftsstelle Meiningen der Wirtschaftskammer Thüringen, ohne Datum, Stichtag 15. 7. 1943. The names mentioned can be found on the FIAT list mentioned above: NARA, RG 243. European War, G-2 Library, Entry 36, Box 760.

[321] Zhukov report to Stalin; reprinted in FRUS, Conference of Berlin II, p. 909.



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NARA RG 407, Entry NM3-427, Box 14465, Folder G-2 Journal—102nd Inf Div Jun-Jul 45

Fr. . 011425B July 45
To : 021630B July 45

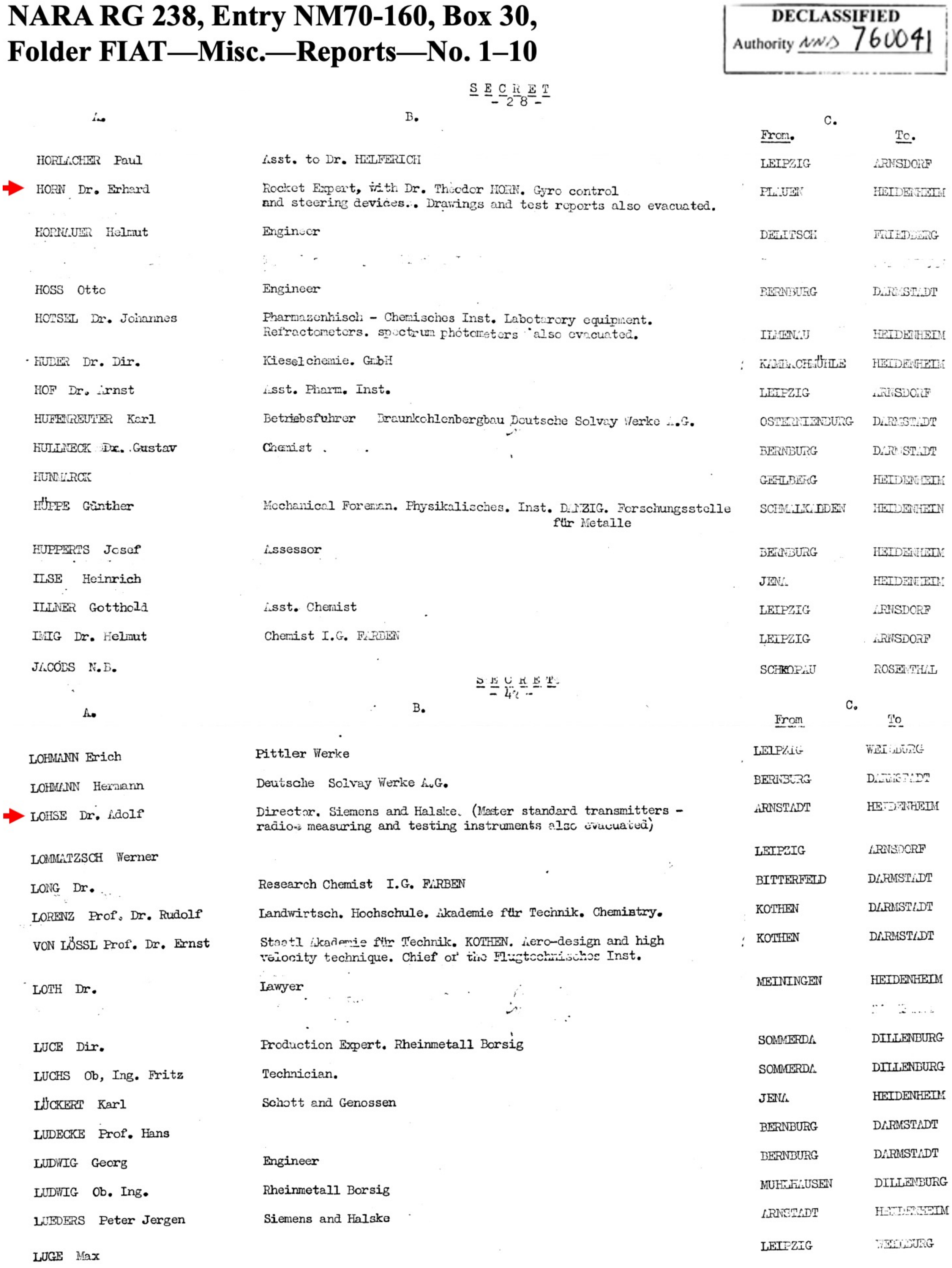
C O N F I D E N T I A L

102D INFANTRY DIVISION J077656, Gotha, Germany

G-2 JOURNAL GSGS 4416, Sheet R5, Scale 1/100,000

Time In	Time Out	Serial No.	Time Dated	Incidents, Messages, Orders, Etc.	Action T
011425B		16		Recd fr Hq 102d Div: Bul #9, 29 June 45. Info Ed outline #3, 29 June 45. Corrected Copy Bul #9, 29 June 45. G-3 PR #208, 292400 302400B June 45. Bul #10 30 June 45.	
011435B		17	//	Tp fr Maj Starks unit: Checked with us on loading and movement of documents from SAALFELD to LUDWIGSSTADT.	
	011440B	18		Tp to Div Arty: Asked for temperature. Max temp 69°F 301400B; min temp 55°F 010230B.	
011500B		19		Recd fr CIC: Rpt for 1 July 1945.	
605B		20	/	Tp fr XXI Corps: Recd request from Seventh Army as follows: Request fr 12th Army Gp; The following scientific personnel to be evacuated: SCHNITTGER, with wife and four children together with 3 assistants and their families and laboratory equipment. Located in GEHLBERG, J158354, (3d Bn 405 Inf). Mr WILKES of CIOS is on his way to 102d Division to coordinate movmt. They are to be evacuated to HEIDENHEIM. Corps wants us to call them back on whatever action we take.	405 Inf
	011610B	21		Tp to 405 Inf: Gave them info in above entry. ✓	
011615B		22		Tp fr 405 Inf Maj Raboun: Requested that if possible we should supply two trucks since he alerted the above group and also was unable to move Dr. Wulz with the group today. He therefore expects to move both parties tomorrow.	
011730B		23		Tp fr Lt Moffitt, Camp 94: Rptd 2 DPs missing since yesterday. Will check again on next roll call & if still missing, will call back.	
020855B		24		Tp fr S-2 405th: Wants vehicle & ltr of transmittal for 2 evacuees (families) for Maj Williams as per arrangements with Col Parsons.	
020905B		25		Tp fr Capt Morgan, 407th: Discussed with Maj Suffield re Capt Rapp's supposedly move to-day.	
021010B		26		Tp fr Div Arty: Gave us temp readings: Max 63°F at 011200B; min 51°F at 020400B.	
021030B		27	//	Tp to Capt Rapp at Ohrdruf, Camp 94: We wanted him to leave for Camp 95 today. He:	

Figure B.255: In summer 1945, the United States "evacuated" German scientists who developed traveling wave tubes for the "master standard transmitter" radio-inertial guidance system on rockets, including Erhard Horn, Adolf Lohse, Herbert Schnitger, and Dieter Weber, as well as their equipment and information [NARA RG 407, Entry NM3-427, Box 14465, Folder G-2 Journal—102nd Inf Div Jun–Jul 45]. See also p. 1221 and Section E.2.



NARA RG 238, Entry NM70-160, Box 30,
Folder FIAT—Misc.—Reports—No. 1–10

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SECRET
- 28 -

A.	B.	C.	
		From.	To.
HORLACHER Paul	Asst. to Dr. HELFERICH	LEIPZIG	ARNSDORF
HORN Dr. Erhard	Rocket Expert, with Dr. Theodor HORN. Gyro control and steering devices.. Drawings and test reports also evacuated.	PLAUEN	HEIDENHEIM
HORNAUER Helmut	Engineer	DELITSCH	FRIEDBERG
HOSS Otto	Engineer	BERNBURG	DARMSTADT
HOTSEL Dr. Johannes	Pharmazenhisch - Chemisches Inst. Labotarory equipment. Refractometers. spectrum photometers also evacuated.	ILMENAU	HEIDENHEIM
HUBER Dr. Dir.	Kieselchemie. GmbH	KAMMACHMÜHLE	HEIDENHEIM
HOF Dr. Arnst	Asst. Pharm. Inst.	LEIPZIG	ARNSDORF
HUFENREUTER Karl	Betriebsfuhrer Braunkohlenbergbau Deutsche Solvay Werke A.G.	OSTERNIENBURG	DARMSTADT
HULLNECK Dr. Gustav	Chemist	BERNBURG	DARMSTADT
HUNMARCK		GEHLBERG	HEIDENHEIM
HÜPPE Günther	Mechanical Foreman. Physikalisches. Inst. DANZIG. Forschungsstelle für Metalle	SCHMALKALDEN	HEIDENHEIM
HUPPERTS Josef	Assessor	BERNBURG	HEIDENHEIM
ILSE Heinrich		JENA	HEIDENHEIM
ILLNER Gotthold	Asst. Chemist	LEIPZIG	ARNSDORF
IMIG Dr. Helmut	Chemist I.G. FARBEN	LEIPZIG	ARNSDORF
JACOBS N.B.		SCHKOPAU	ROSENTHAL

SECRET
- 42 -

A.	B.	C.	
		From	To
LOHMANN Erich	Pittler Werke	LEIPZIG	WEILBURG
LOHMANN Hermann	Deutsche Solvay Werke A.G.	BERNBURG	DARMSTADT
LOHSE Dr. Adolf	Director. Siemens and Halske. (Master standard transmitters - radio measuring and testing instruments also evacuated)	ARNSTADT	HEIDENHEIM
LOMMATZSCH Werner		LEIPZIG	ARNSDORF
LONG Dr.	Research Chemist I.G. FARBEN	BITTERFELD	DARMSTADT
LORENZ Prof. Dr. Rudolf	Landwirtsch. Hochschule. Akademie für Technik. Chemistry.	KOTHEN	DARMSTADT
VON LÖSSL Prof. Dr. Ernst	Staatl Akademie für Technik. KOTHEN. Aero-design and high velocity technique. Chief of the Flugtechnisches Inst.	KOTHEN	DARMSTADT
LOTH Dr.	Lawyer	MEININGEN	HEIDENHEIM
LUCE Dir.	Production Expert. Rheinmetall Borsig	SOMMERDA	DILLENBURG
LUCHS Ob, Ing. Fritz	Technician.	SOMMERDA	DILLENBURG
LÜCKERT Karl	Schott and Genossen	JENA	HEIDENHEIM
LUDECKE Prof. Hans		BERNBURG	DARMSTADT
LUDWIG Georg	Engineer	BERNBURG	DARMSTADT
LUDWIG Ob. Ing.	Rheinmetall Borsig	MUHLHAUSEN	DILLENBURG
LUEDERS Peter Jergen	Siemens and Halske	ARNSTADT	HEIDENHEIM
LUGE Max		LEIPZIG	WEILBURG

Figure B.256: In summer 1945, the United States "evacuated" German scientists who developed traveling wave tubes for the "master standard transmitter" radio-inertial guidance system on rockets, including Erhard Horn, Adolf Lohse, Herbert Schnitger, and Dieter Weber, as well as their equipment and information [NARA RG 238, Entry NM70-160, Box 30, Folder FIAT—Misc.—Reports—No. 1–10]. See also p. 1221 and Section E.2.

NARA RG 238, Entry NM70-160, Box 30, Folder FIAT—Misc.—Reports—No. 1–10

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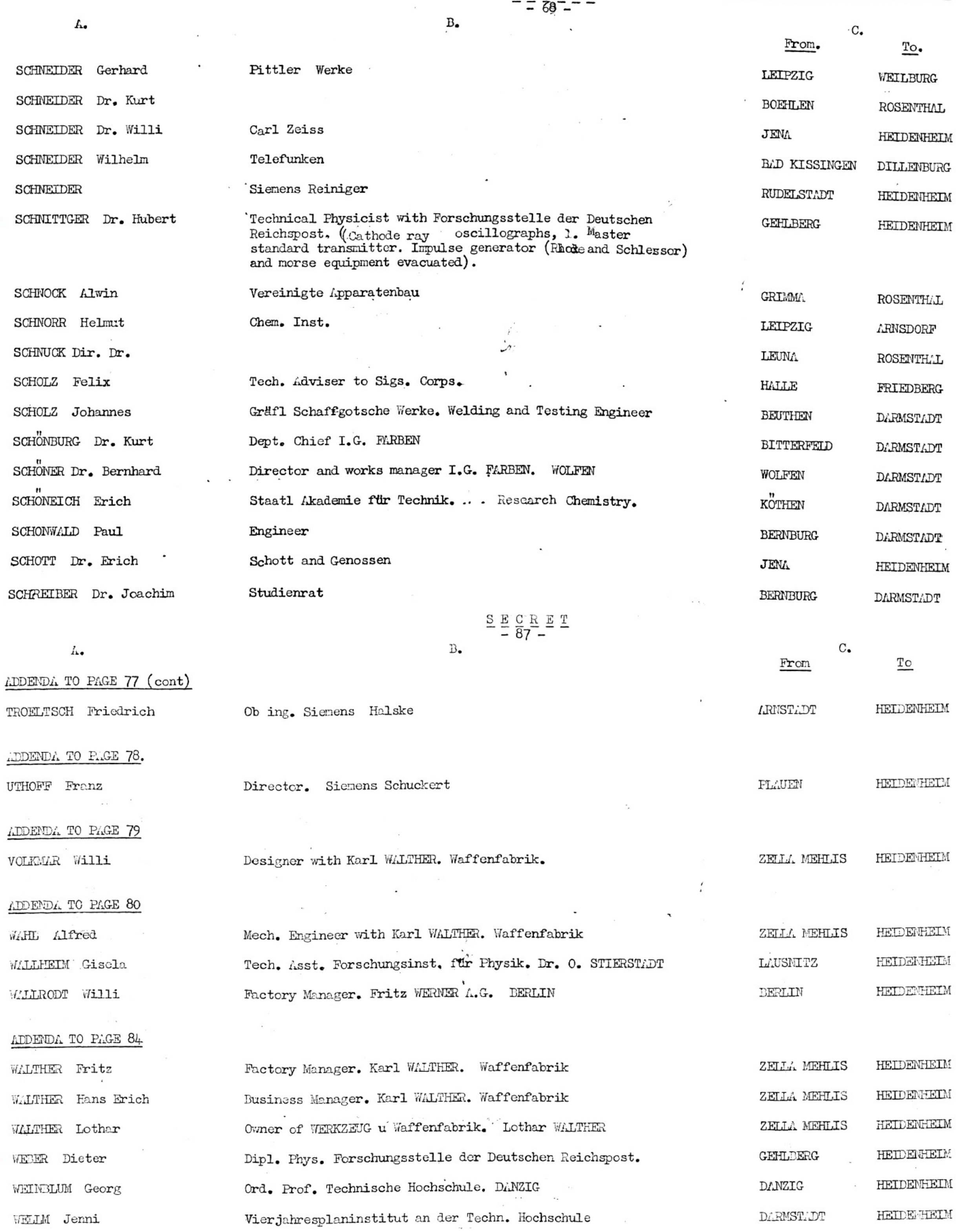

S E C R E T
- 68 -

A.	B.	C. From.	To.
SCHNEIDER Gerhard	Pittler Werke	LEIPZIG	WEILBURG
SCHNEIDER Dr. Kurt		BOEHLEN	ROSENTHAL
SCHNEIDER Dr. Willi	Carl Zeiss	JENA	HEIDENHEIM
SCHNEIDER Wilhelm	Telefunken	BAD KISSINGEN	DILLENBURG
SCHNEIDER	Siemens Reiniger	RUDELSTADT	HEIDENHEIM
SCHNITTGER Dr. Hubert	Technical Physicist with Forschungsstelle der Deutschen Reichspost. (Cathode ray oscillographs, 1. Master standard transmitter. Impulse generator (Rhode and Schlessor) and morse equipment evacuated).	GEHLBERG	HEIDENHEIM
SCHNOCK Alwin	Vereinigte Apparatenbau	GRIMMA	ROSENTHAL
SCHNORR Helmut	Chem. Inst.	LEIPZIG	ARNSDORF
SCHNUCK Dir. Dr.		LEUNA	ROSENTHAL
SCHOLZ Felix	Tech. Adviser to Sigs. Corps.	HALLE	FRIEDBERG
SCHOLZ Johannes	Gräfl Schaffgotsche Werke. Welding and Testing Engineer	BEUTHEN	DARMSTADT
SCHÖNBURG Dr. Kurt	Dept. Chief I.G. FARBEN	BITTERFELD	DARMSTADT
SCHÖNER Dr. Bernhard	Director and works manager I.G. FARBEN. WOLFEN	WOLFEN	DARMSTADT
SCHÖNEICH Erich	Staatl Akademie für Technik. .. . Research Chemistry.	KÖTHEN	DARMSTADT
SCHONWALD Paul	Engineer	BERNBURG	DARMSTADT
SCHOTT Dr. Erich	Schott and Genossen	JENA	HEIDENHEIM
SCHREIBER Dr. Joachim	Studienrat	BERNBURG	DARMSTADT

S E C R E T
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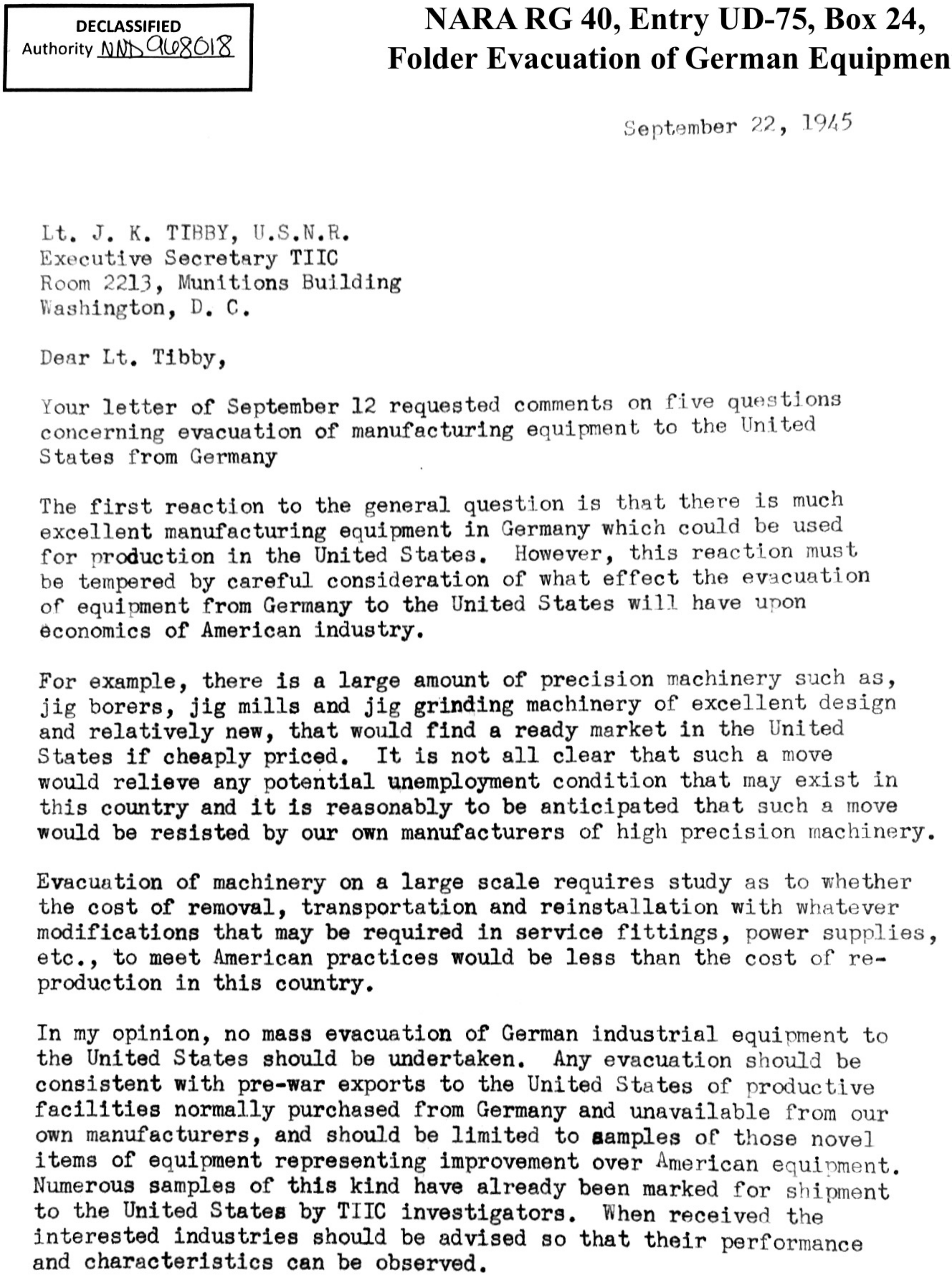
A.	B.	C. From	To
ADDENDA TO PAGE 77 (cont)			
TROELTSCH Friedrich	Ob ing. Siemens Halske	ARNSTADT	HEIDENHEIM
ADDENDA TO PAGE 78.			
UTHOFF Franz	Director. Siemens Schuckert	PLAUEN	HEIDENHEIM
ADDENDA TO PAGE 79			
VOLKMAR Willi	Designer with Karl WALTHER. Waffenfabrik.	ZELLA MEHLIS	HEIDENHEIM
ADDENDA TO PAGE 80			
WAHL Alfred	Mech. Engineer with Karl WALTHER. Waffenfabrik	ZELLA MEHLIS	HEIDENHEIM
WALLHEIM Gisela	Tech. Asst. Forschungsinst. für Physik. Dr. O. STIERSTADT	LAUSNITZ	HEIDENHEIM
WALLRODT Willi	Factory Manager. Fritz WERNER A.G. BERLIN	BERLIN	HEIDENHEIM
ADDENDA TO PAGE 84			
WALTHER Fritz	Factory Manager. Karl WALTHER. Waffenfabrik	ZELLA MEHLIS	HEIDENHEIM
WALTHER Hans Erich	Business Manager. Karl WALTHER. Waffenfabrik	ZELLA MEHLIS	HEIDENHEIM
WALTHER Lothar	Owner of WERKZEUG u Waffenfabrik. Lothar WALTHER	ZELLA MEHLIS	HEIDENHEIM
WEBER Dieter	Dipl. Phys. Forschungsstelle der Deutschen Reichspost.	GEHLBERG	HEIDENHEIM
WEINBLUM Georg	Ord. Prof. Technische Hochschule. DANZIG	DANZIG	HEIDENHEIM
WELLM Jenni	Vierjahresplaninstitut an der Techn. Hochschule	DARMSTADT	HEIDENHEIM

Figure B.257: In summer 1945, the United States “evacuated” German scientists who developed traveling wave tubes for the “master standard transmitter” radio-inertial guidance system on rockets, including Erhard Horn, Adolf Lohse, Herbert Schnitger, and Dieter Weber, as well as their equipment and information [NARA RG 238, Entry NM70-160, Box 30, Folder FIAT—Misc.—Reports—No. 1–10]. See also p. 1221 and Section E.2.



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NARA RG 40, Entry UD-75, Box 24, Folder Evacuation of German Equipment

September 22, 1945

Lt. J. K. TIBBY, U.S.N.R.
Executive Secretary TIIC
Room 2213, Munitions Building
Washington, D. C.

Dear Lt. Tibby,

Your letter of September 12 requested comments on five questions concerning evacuation of manufacturing equipment to the United States from Germany

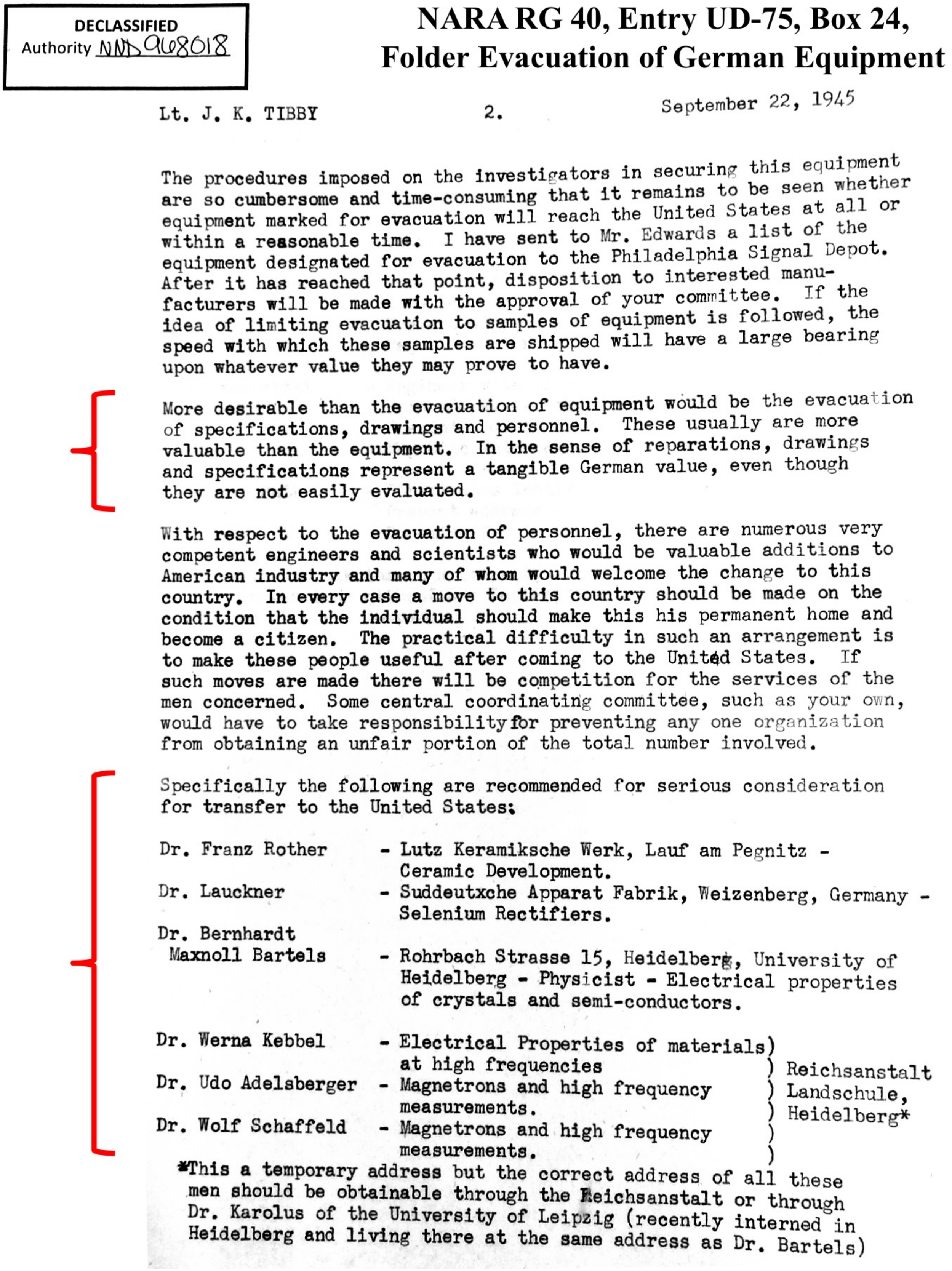
The first reaction to the general question is that there is much excellent manufacturing equipment in Germany which could be used for production in the United States. However, this reaction must be tempered by careful consideration of what effect the evacuation of equipment from Germany to the United States will have upon economics of American industry.

For example, there is a large amount of precision machinery such as, jig borers, jig mills and jig grinding machinery of excellent design and relatively new, that would find a ready market in the United States if cheaply priced. It is not all clear that such a move would relieve any potential unemployment condition that may exist in this country and it is reasonably to be anticipated that such a move would be resisted by our own manufacturers of high precision machinery.

Evacuation of machinery on a large scale requires study as to whether the cost of removal, transportation and reinstallation with whatever modifications that may be required in service fittings, power supplies, etc., to meet American practices would be less than the cost of reproduction in this country.

In my opinion, no mass evacuation of German industrial equipment to the United States should be undertaken. Any evacuation should be consistent with pre-war exports to the United States of productive facilities normally purchased from Germany and unavailable from our own manufacturers, and should be limited to samples of those novel items of equipment representing improvement over American equipment. Numerous samples of this kind have already been marked for shipment to the United States by TIIC investigators. When received the interested industries should be advised so that their performance and characteristics can be observed.

Figure B.258: In summer 1945, the U.S. military and AT&T "evacuated" German scientists who developed traveling wave tubes for the "master standard transmitter" radio-inertial guidance system on rockets, including Erhard Horn, Adolf Lohse, Herbert Schnitger, and Dieter Weber (plus many other electronics experts), as well as their equipment and information [NARA RG 40, Entry UD-75, Box 24, Folder Evacuation of German Equipment]. See also p. 1221 and Section E.2.



DECLASSIFIED
Authority NND968018

NARA RG 40, Entry UD-75, Box 24, Folder Evacuation of German Equipment

Lt. J. K. TIBBY 2. September 22, 1945

The procedures imposed on the investigators in securing this equipment are so cumbersome and time-consuming that it remains to be seen whether equipment marked for evacuation will reach the United States at all or within a reasonable time. I have sent to Mr. Edwards a list of the equipment designated for evacuation to the Philadelphia Signal Depot. After it has reached that point, disposition to interested manufacturers will be made with the approval of your committee. If the idea of limiting evacuation to samples of equipment is followed, the speed with which these samples are shipped will have a large bearing upon whatever value they may prove to have.

More desirable than the evacuation of equipment would be the evacuation of specifications, drawings and personnel. These usually are more valuable than the equipment. In the sense of reparations, drawings and specifications represent a tangible German value, even though they are not easily evaluated.

With respect to the evacuation of personnel, there are numerous very competent engineers and scientists who would be valuable additions to American industry and many of whom would welcome the change to this country. In every case a move to this country should be made on the condition that the individual should make this his permanent home and become a citizen. The practical difficulty in such an arrangement is to make these people useful after coming to the United States. If such moves are made there will be competition for the services of the men concerned. Some central coordinating committee, such as your own, would have to take responsibility for preventing any one organization from obtaining an unfair portion of the total number involved.

Specifically the following are recommended for serious consideration for transfer to the United States:

Dr. Franz Rother - Lutz Keramiksche Werk, Lauf am Pegnitz - Ceramic Development.

Dr. Lauckner - Suddeutxche Apparat Fabrik, Weizenberg, Germany - Selenium Rectifiers.

Dr. Bernhardt Maxnoll Bartels - Rohrbach Strasse 15, Heidelberg, University of Heidelberg - Physicist - Electrical properties of crystals and semi-conductors.

Dr. Werna Kebbel - Electrical Properties of materials at high frequencies)
Dr. Udo Adelsberger - Magnetrons and high frequency measurements.) Reichsanstalt Landschule, Heidelberg*
Dr. Wolf Schaffeld - Magnetrons and high frequency measurements.)

*This a temporary address but the correct address of all these men should be obtainable through the Reichsanstalt or through Dr. Karolus of the University of Leipzig (recently interned in Heidelberg and living there at the same address as Dr. Bartels)

Figure B.259: In summer 1945, the U.S. military and AT&T "evacuated" German scientists who developed traveling wave tubes for the "master standard transmitter" radio-inertial guidance system on rockets, including Erhard Horn, Adolf Lohse, Herbert Schnitger, and Dieter Weber (plus many other electronics experts), as well as their equipment and information [NARA RG 40, Entry UD-75, Box 24, Folder Evacuation of German Equipment]. See also p. 1221 and Section E.2.

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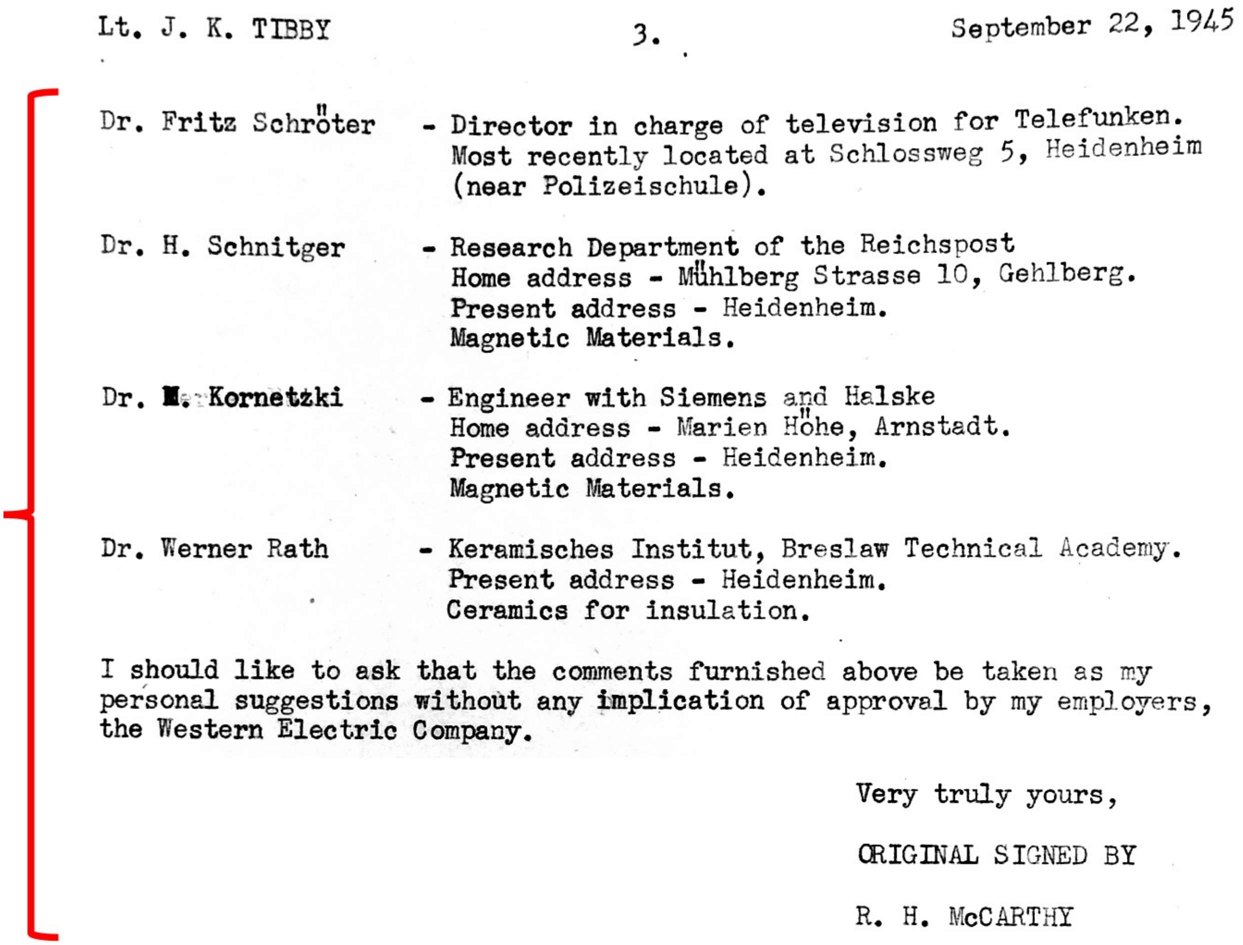
Authority NND968018

NARA RG 40, Entry UD-75, Box 24, Folder Evacuation of German Equipment



Lt. J. K. TIBBY 3. September 22, 1945

Dr. Fritz Schröter	- Director in charge of television for Telefunken. Most recently located at Schlossweg 5, Heidenheim (near Polizeischule).
Dr. H. Schnitger	- Research Department of the Reichspost Home address - Mühlberg Strasse 10, Gehlberg. Present address - Heidenheim. Magnetic Materials.
Dr. M. Kornetzki	- Engineer with Siemens and Halske Home address - Marien Höhe, Arnstadt. Present address - Heidenheim. Magnetic Materials.
Dr. Werner Rath	- Keramisches Institut, Breslaw Technical Academy. Present address - Heidenheim. Ceramics for insulation.

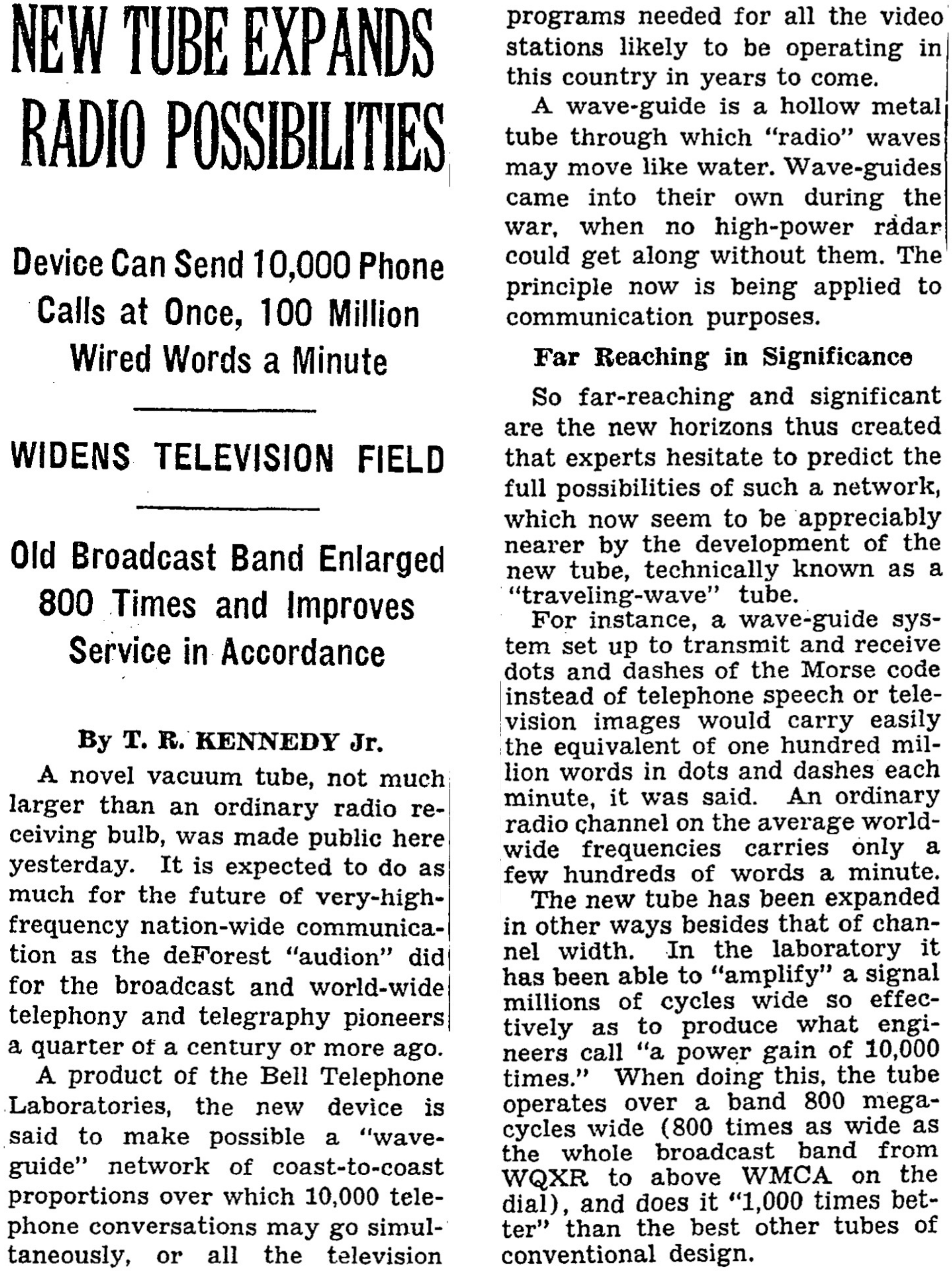
I should like to ask that the comments furnished above be taken as my personal suggestions without any implication of approval by my employers, the Western Electric Company.

Very truly yours,

ORIGINAL SIGNED BY

R. H. McCARTHY

Figure B.260: In summer 1945, the U.S. military and AT&T "evacuated" German scientists who developed traveling wave tubes for the "master standard transmitter" radio-inertial guidance system on rockets, including Erhard Horn, Adolf Lohse, Herbert Schnitger, and Dieter Weber (plus many other electronics experts), as well as their equipment and information [NARA RG 40, Entry UD-75, Box 24, Folder Evacuation of German Equipment]. See also p. 1221 and Section E.2.



NEW TUBE EXPANDS RADIO POSSIBILITIES

Device Can Send 10,000 Phone Calls at Once, 100 Million Wired Words a Minute

WIDENS TELEVISION FIELD

Old Broadcast Band Enlarged 800 Times and Improves Service in Accordance

By T. R. KENNEDY Jr.

A novel vacuum tube, not much larger than an ordinary radio receiving bulb, was made public here yesterday. It is expected to do as much for the future of very-high-frequency nation-wide communication as the deForest "audion" did for the broadcast and world-wide telephony and telegraphy pioneers a quarter of a century or more ago.

A product of the Bell Telephone Laboratories, the new device is said to make possible a "wave-guide" network of coast-to-coast proportions over which 10,000 telephone conversations may go simultaneously, or all the television programs needed for all the video stations likely to be operating in this country in years to come.

A wave-guide is a hollow metal tube through which "radio" waves may move like water. Wave-guides came into their own during the war, when no high-power radar could get along without them. The principle now is being applied to communication purposes.

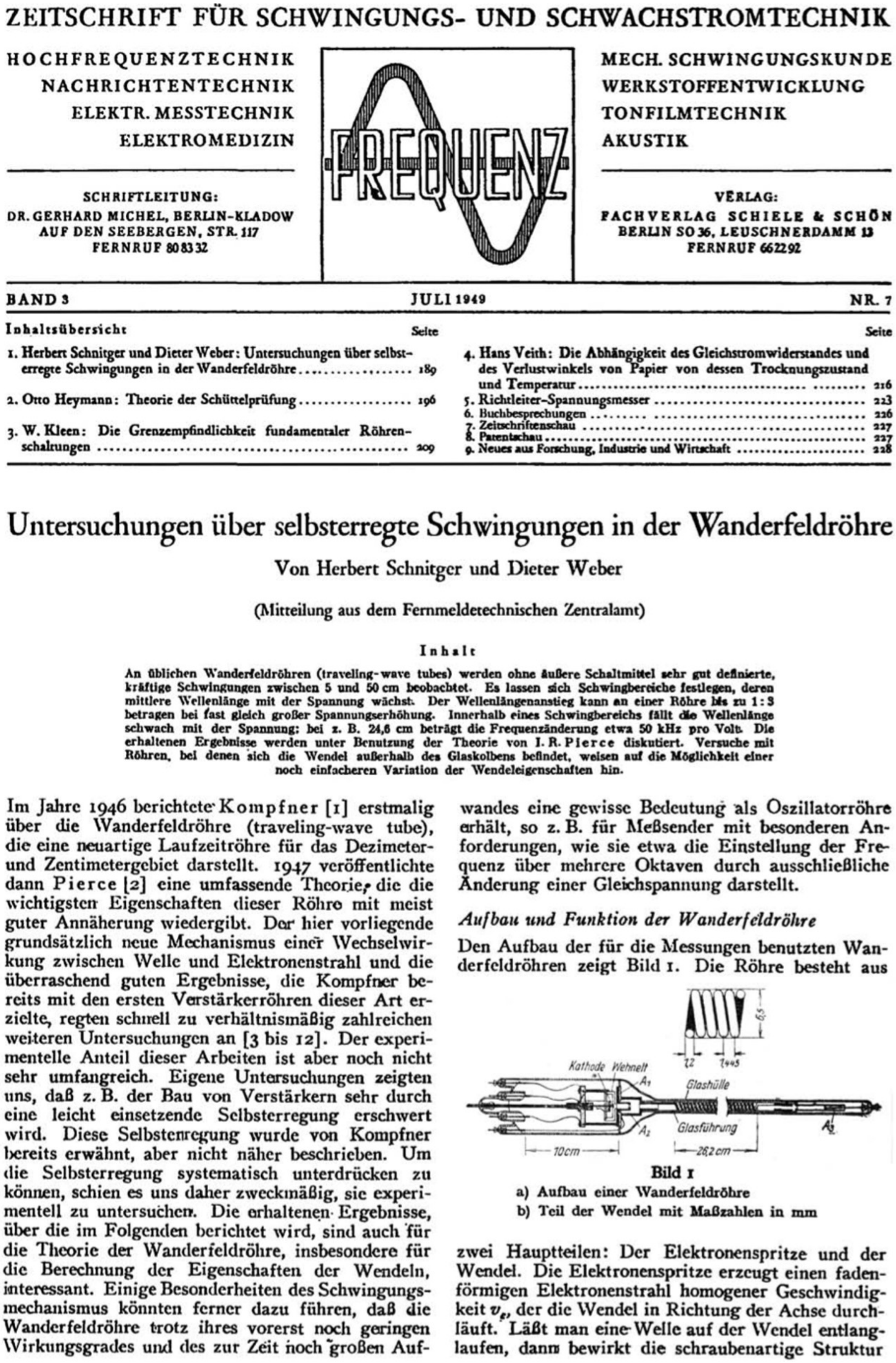
Far Reaching in Significance

So far-reaching and significant are the new horizons thus created that experts hesitate to predict the full possibilities of such a network, which now seem to be appreciably nearer by the development of the new tube, technically known as a "traveling-wave" tube.

For instance, a wave-guide system set up to transmit and receive dots and dashes of the Morse code instead of telephone speech or television images would carry easily the equivalent of one hundred million words in dots and dashes each minute, it was said. An ordinary radio channel on the average world-wide frequencies carries only a few hundreds of words a minute.

The new tube has been expanded in other ways besides that of channel width. In the laboratory it has been able to "amplify" a signal millions of cycles wide so effectively as to produce what engineers call "a power gain of 10,000 times." When doing this, the tube operates over a band 800 megacycles wide (800 times as wide as the whole broadcast band from WQXR to above WMCA on the dial), and does it "1,000 times better" than the best other tubes of conventional design.

Figure B.261: One year later, in summer 1946, AT&T publicly claimed that it had just invented the traveling wave tube, which would revolutionize communications [NYT 1946-07-06].



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BAND 3 JULI 1949 NR. 7

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Untersuchungen über selbsterregte Schwingungen in der Wanderfeldröhre

Von Herbert Schnitger und Dieter Weber

(Mitteilung aus dem Fernmeldetechnischen Zentralamt)

Inhalt

An üblichen Wanderfeldröhren (traveling-wave tubes) werden ohne äußere Schaltmittel sehr gut definierte, kräftige Schwingungen zwischen 5 und 50 cm beobachtet. Es lassen sich Schwingbereiche festlegen, deren mittlere Wellenlänge mit der Spannung wächst. Der Wellenlängenanstieg kann an einer Röhre bis zu 1:3 betragen bei fast gleich großer Spannungserhöhung. Innerhalb eines Schwingbereichs fällt die Wellenlänge schwach mit der Spannung; bei z. B. 24,6 cm beträgt die Frequenzänderung etwa 50 kHz pro Volt. Die erhaltenen Ergebnisse werden unter Benutzung der Theorie von I. R. Pierce diskutiert. Versuche mit Röhren, bei denen sich die Wendel außerhalb des Glaskolbens befindet, weisen auf die Möglichkeit einer noch einfacheren Variation der Wendeleigenschaften hin.

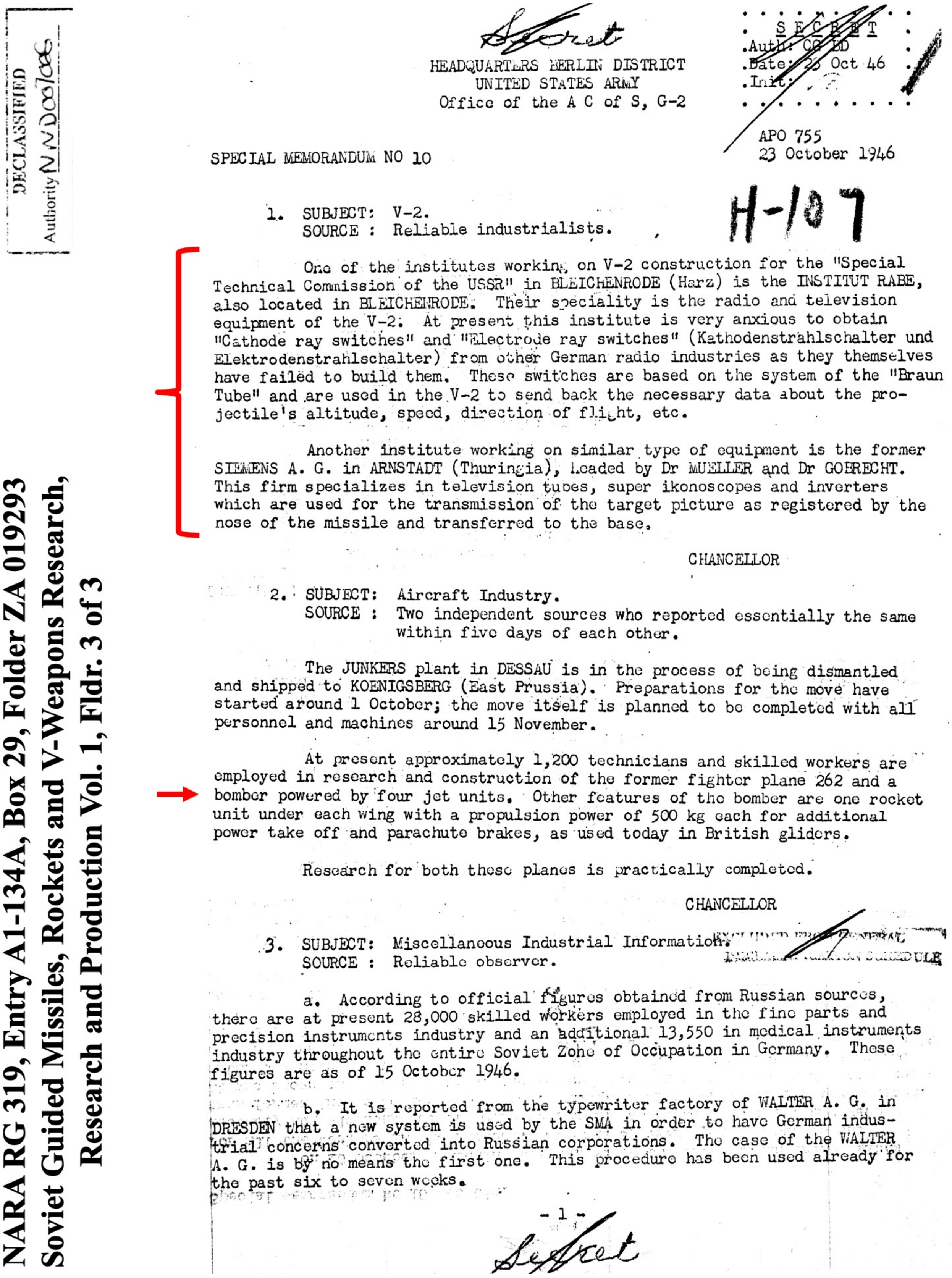
Im Jahre 1946 berichtete Kompfner [1] erstmalig über die Wanderfeldröhre (traveling-wave tube), die eine neuartige Laufzeitröhre für das Dezimeter- und Zentimetergebiet darstellt. 1947 veröffentlichte dann Pierce [2] eine umfassende Theorie, die die wichtigsten Eigenschaften dieser Röhre mit meist guter Annäherung wiedergibt. Der hier vorliegende grundsätzlich neue Mechanismus einer Wechselwirkung zwischen Welle und Elektronenstrahl und die überraschend guten Ergebnisse, die Kompfner bereits mit den ersten Verstärkerröhren dieser Art erzielte, regten schnell zu verhältnismäßig zahlreichen weiteren Untersuchungen an [3 bis 12]. Der experimentelle Anteil dieser Arbeiten ist aber noch nicht sehr umfangreich. Eigene Untersuchungen zeigten uns, daß z. B. der Bau von Verstärkern sehr durch eine leicht einsetzende Selbsterregung erschwert wird. Diese Selbsterregung wurde von Kompfner bereits erwähnt, aber nicht näher beschrieben. Um die Selbsterregung systematisch unterdrücken zu können, schien es uns daher zweckmäßig, sie experimentell zu untersuchen. Die erhaltenen Ergebnisse, über die im Folgenden berichtet wird, sind auch für die Theorie der Wanderfeldröhre, insbesondere für die Berechnung der Eigenschaften der Wendeln, interessant. Einige Besonderheiten des Schwingungsmechanismus könnten ferner dazu führen, daß die Wanderfeldröhre trotz ihres vorerst noch geringen Wirkungsgrades und des zur Zeit noch großen Aufwandes eine gewisse Bedeutung als Oszillatorröhre erhält, so z. B. für Meßsender mit besonderen Anforderungen, wie sie etwa die Einstellung der Frequenz über mehrere Oktaven durch ausschließliche Änderung einer Gleichspannung darstellt.

Aufbau und Funktion der Wanderfeldröhre

Den Aufbau der für die Messungen benutzten Wanderfeldröhren zeigt Bild 1. Die Röhre besteht aus zwei Hauptteilen: Der Elektronenspritze und der Wendel. Die Elektronenspritze erzeugt einen fadenförmigen Elektronenstrahl homogener Geschwindigkeit v_e, der die Wendel in Richtung der Achse durchläuft. Läßt man eine Welle auf der Wendel entlanglaufen, dann bewirkt die schraubenartige Struktur

Bild 1
a) Aufbau einer Wanderfeldröhre
b) Teil der Wendel mit Maßzahlen in mm

Figure B.262: It appears that Herbert Schnitger and Dieter Weber were not allowed to publish their own traveling wave tube work until much later, and much more quietly [Schnitger and Weber 1949].



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HEADQUARTERS BERLIN DISTRICT
UNITED STATES ARMY
Office of the A C of S, G-2

~~S E C R E T~~
~~Auth: CG BD~~
~~Date: 23 Oct 46~~
~~Init:~~

APO 755
23 October 1946

SPECIAL MEMORANDUM NO 10

H-107

1. SUBJECT: V-2.
SOURCE : Reliable industrialists.

One of the institutes working on V-2 construction for the "Special Technical Commission of the USSR" in BLEICHENRODE (Harz) is the INSTITUT RABE, also located in BLEICHENRODE. Their speciality is the radio and television equipment of the V-2. At present this institute is very anxious to obtain "Cathode ray switches" and "Electrode ray switches" (Kathodenstrahlschalter und Elektrodenstrahlschalter) from other German radio industries as they themselves have failed to build them. These switches are based on the system of the "Braun Tube" and are used in the V-2 to send back the necessary data about the projectile's altitude, speed, direction of flight, etc.

Another institute working on similar type of equipment is the former SIEMENS A. G. in ARNSTADT (Thuringia), headed by Dr MUELLER and Dr GOBRECHT. This firm specializes in television tubes, super ikonoscopes and inverters which are used for the transmission of the target picture as registered by the nose of the missile and transferred to the base.

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2. SUBJECT: Aircraft Industry.
SOURCE : Two independent sources who reported essentially the same within five days of each other.

The JUNKERS plant in DESSAU is in the process of being dismantled and shipped to KOENIGSBERG (East Prussia). Preparations for the move have started around 1 October; the move itself is planned to be completed with all personnel and machines around 15 November.

At present approximately 1,200 technicians and skilled workers are employed in research and construction of the former fighter plane 262 and a bomber powered by four jet units. Other features of the bomber are one rocket unit under each wing with a propulsion power of 500 kg each for additional power take off and parachute brakes, as used today in British gliders.

Research for both these planes is practically completed.

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3. SUBJECT: Miscellaneous Industrial Information.
SOURCE : Reliable observer.

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a. According to official figures obtained from Russian sources, there are at present 28,000 skilled workers employed in the fine parts and precision instruments industry and an additional 13,550 in medical instruments industry throughout the entire Soviet Zone of Occupation in Germany. These figures are as of 15 October 1946.

b. It is reported from the typewriter factory of WALTER A. G. in DRESDEN that a new system is used by the SMA in order to have German industrial concerns converted into Russian corporations. The case of the WALTER A. G. is by no means the first one. This procedure has been used already for the past six to seven weeks.

- 1 -

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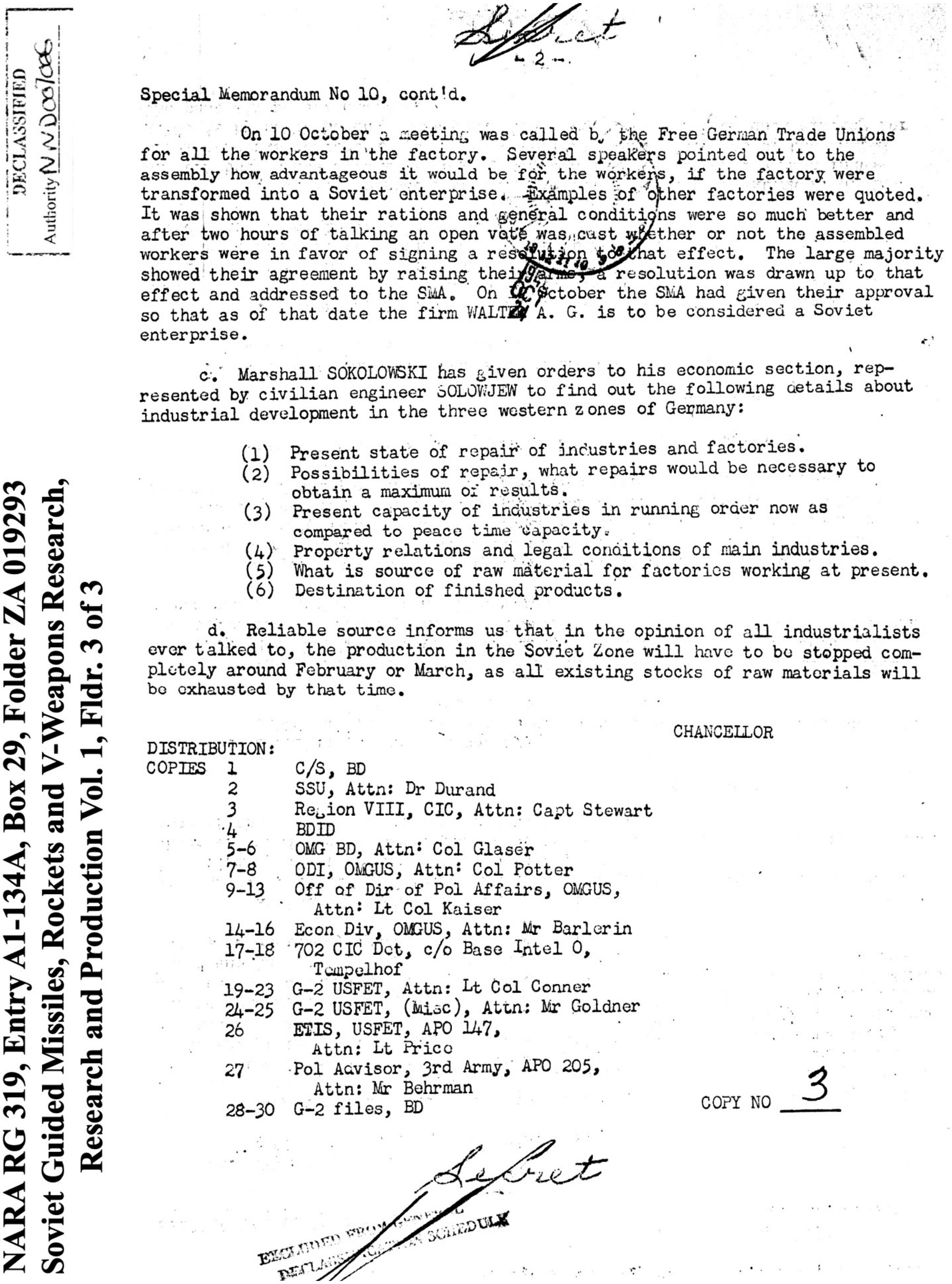
Research and Production Vol. 1, Fldr. 3 of 3

Figure B.263: 1946 U.S. intelligence reports described the struggles of Soviet occupation forces to reconstruct the wartime German work on traveling wave tubes and rocket guidance systems without the evacuated scientists/materials/information, thereby confirming the details of the wartime work [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Vol. 1, Fldr. 3 of 3]. See also Section E.2.



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- 2 -

Special Memorandum No 10, cont'd.

On 10 October a meeting was called by the Free German Trade Unions for all the workers in the factory. Several speakers pointed out to the assembly how advantageous it would be for the workers, if the factory were transformed into a Soviet enterprise. Examples of other factories were quoted. It was shown that their rations and general conditions were so much better and after two hours of talking an open vote was cast whether or not the assembled workers were in favor of signing a resolution to that effect. The large majority showed their agreement by raising their arms, a resolution was drawn up to that effect and addressed to the SMA. On [illegible] October the SMA had given their approval so that as of that date the firm WALTER A. G. is to be considered a Soviet enterprise.

c. Marshall SOKOLOWSKI has given orders to his economic section, represented by civilian engineer SOLOWJEW to find out the following details about industrial development in the three western zones of Germany:

(1) Present state of repair of industries and factories.
(2) Possibilities of repair, what repairs would be necessary to obtain a maximum of results.
(3) Present capacity of industries in running order now as compared to peace time capacity.
(4) Property relations and legal conditions of main industries.
(5) What is source of raw material for factories working at present.
(6) Destination of finished products.

d. Reliable source informs us that in the opinion of all industrialists ever talked to, the production in the Soviet Zone will have to be stopped completely around February or March, as all existing stocks of raw materials will be exhausted by that time.

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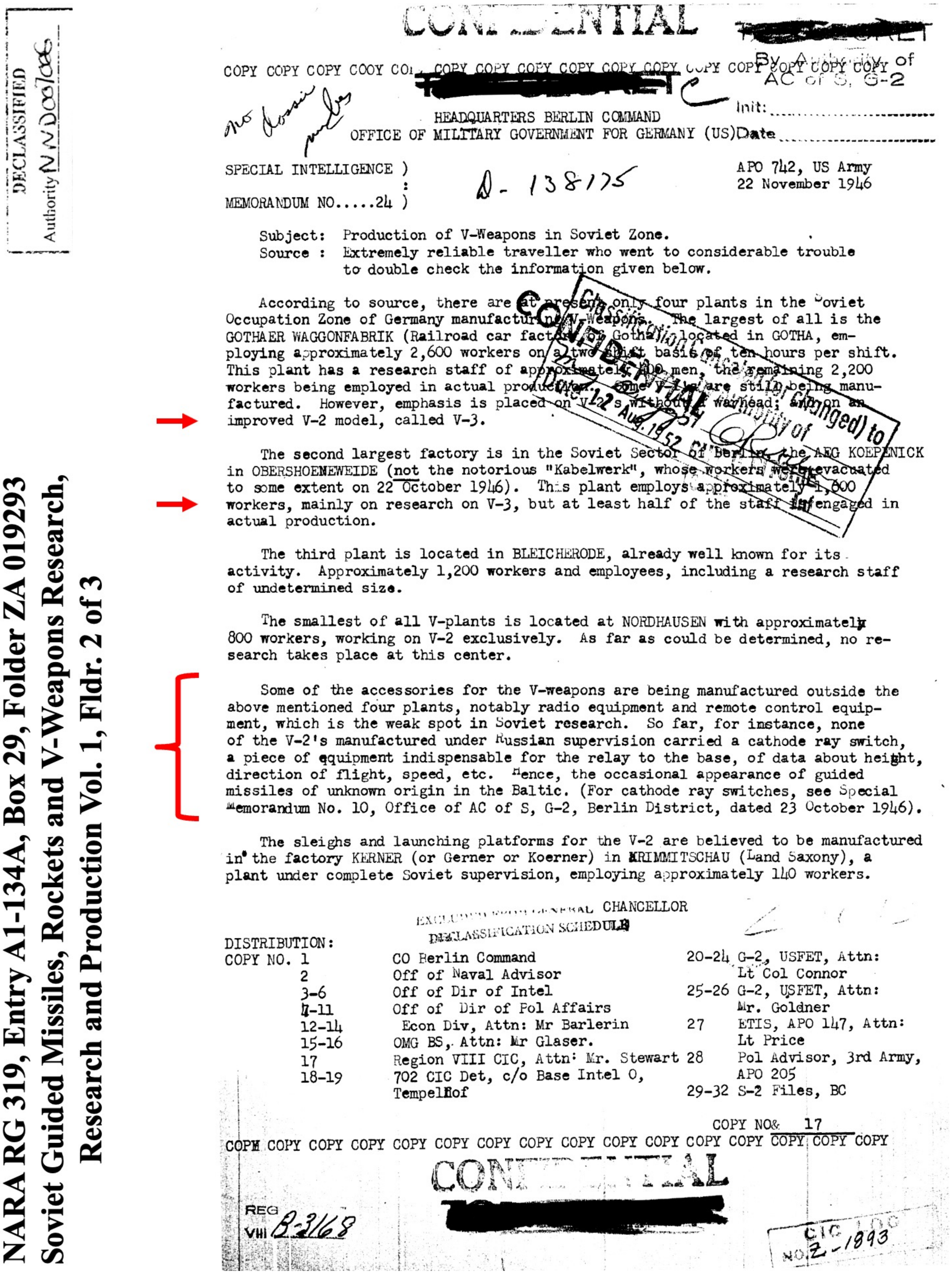
Research and Production Vol. 1, Fldr. 3 of 3

Figure B.264: 1946 U.S. intelligence reports described the struggles of Soviet occupation forces to reconstruct the wartime German work on traveling wave tubes and rocket guidance systems without the evacuated scientists/materials/information, thereby confirming the details of the wartime work [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Vol. 1, Fldr. 3 of 3]. See also Section E.2.



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HEADQUARTERS BERLIN COMMAND
OFFICE OF MILITARY GOVERNMENT FOR GERMANY (US)

SPECIAL INTELLIGENCE)
:
MEMORANDUM NO.....24)

D- 138175

APO 742, US Army
22 November 1946

Subject: Production of V-Weapons in Soviet Zone.
Source : Extremely reliable traveller who went to considerable trouble to double check the information given below.

According to source, there are at present only four plants in the Soviet Occupation Zone of Germany manufacturing V-Weapons. The largest of all is the GOTHAER WAGGONFABRIK (Railroad car factory of Gotha) located in GOTHA, employing approximately 2,600 workers on a two shift basis of ten hours per shift. This plant has a research staff of approximately 400 men, the remaining 2,200 workers being employed in actual production. Some V-2's are still being manufactured. However, emphasis is placed on V-2's without a warhead; and on an improved V-2 model, called V-3.

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by authority of
Date 12 Aug. 1952

The second largest factory is in the Soviet Sector of Berlin, the AEG KOEPENICK in OBERSHOENEWEIDE (not the notorious "Kabelwerk", whose workers were evacuated to some extent on 22 October 1946). This plant employs approximately 1,600 workers, mainly on research on V-3, but at least half of the staff is engaged in actual production.

The third plant is located in BLEICHERODE, already well known for its activity. Approximately 1,200 workers and employees, including a research staff of undetermined size.

The smallest of all V-plants is located at NORDHAUSEN with approximately 800 workers, working on V-2 exclusively. As far as could be determined, no research takes place at this center.

Some of the accessories for the V-weapons are being manufactured outside the above mentioned four plants, notably radio equipment and remote control equipment, which is the weak spot in Soviet research. So far, for instance, none of the V-2's manufactured under Russian supervision carried a cathode ray switch, a piece of equipment indispensable for the relay to the base, of data about height, direction of flight, speed, etc. Hence, the occasional appearance of guided missiles of unknown origin in the Baltic. (For cathode ray switches, see Special Memorandum No. 10, Office of AC of S, G-2, Berlin District, dated 23 October 1946).

The sleighs and launching platforms for the V-2 are believed to be manufactured in the factory KERNER (or Gerner or Koerner) in KRIMMITSCHAU (Land Saxony), a plant under complete Soviet supervision, employing approximately 140 workers.

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CIC LOG NO. Z-1893

Figure B.265: 1946 U.S. intelligence reports described the struggles of Soviet occupation forces to reconstruct the wartime German work on traveling wave tubes and rocket guidance systems without the evacuated scientists/materials/information, thereby confirming the details of the wartime work [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Vol. 1, Fldr. 2 of 3]. See also Section E.2.

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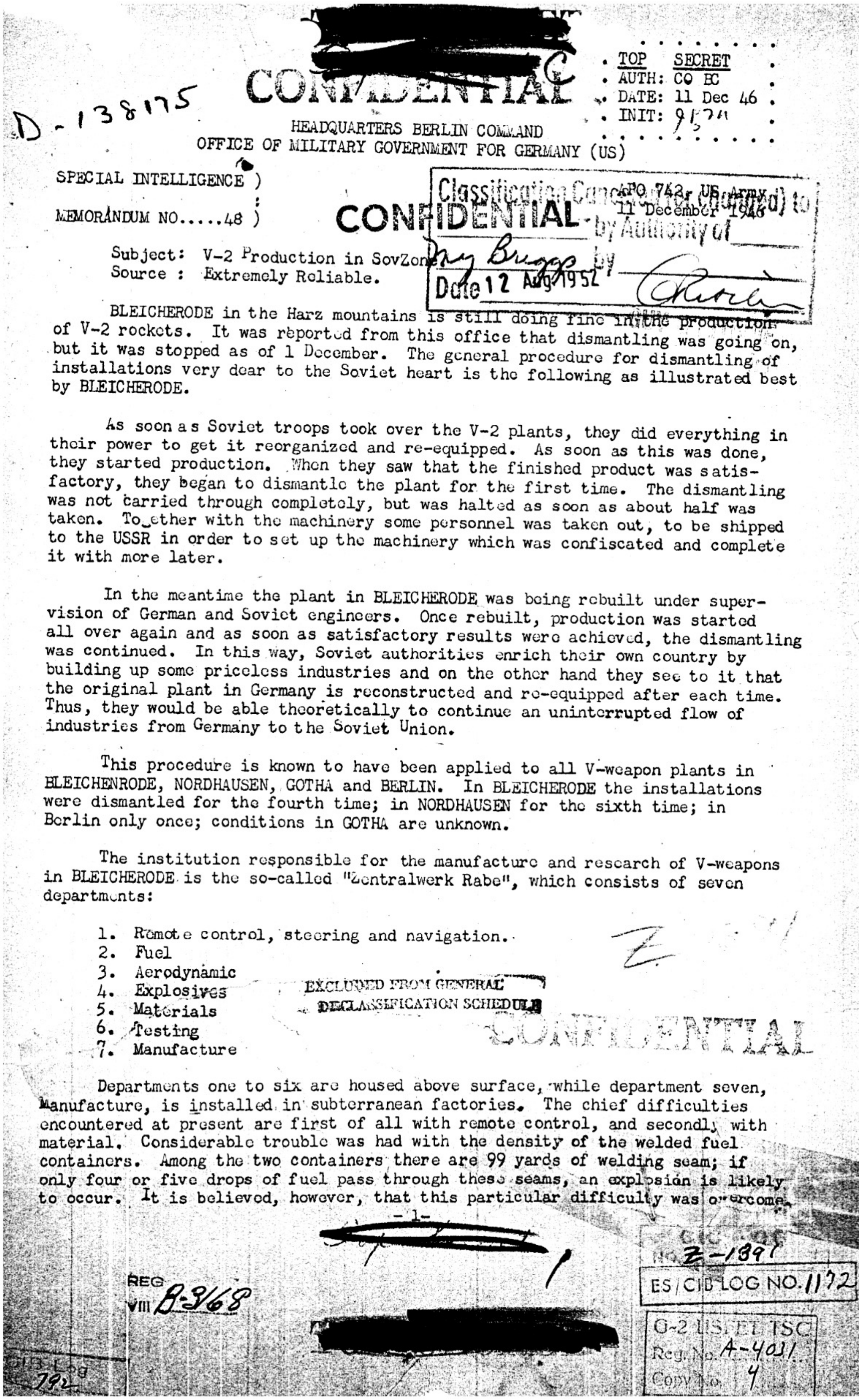
Research and Production Vol. 1, Fldr. 2 of 3**



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D-138175

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HEADQUARTERS BERLIN COMMAND
OFFICE OF MILITARY GOVERNMENT FOR GERMANY (US)

SPECIAL INTELLIGENCE)
MEMORANDUM NO.....48)

APO 742, US Army
11 December 1946

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Classification Cancelled (Changed) to
by Authority of
My Briggs by
Date 12 Aug 1952

Subject: V-2 Production in SovZone
Source : Extremely Reliable.

BLEICHERODE in the Harz mountains is still doing fine in the production of V-2 rockets. It was reported from this office that dismantling was going on, but it was stopped as of 1 December. The general procedure for dismantling of installations very dear to the Soviet heart is the following as illustrated best by BLEICHERODE.

As soon as Soviet troops took over the V-2 plants, they did everything in their power to get it reorganized and re-equipped. As soon as this was done, they started production. When they saw that the finished product was satisfactory, they began to dismantle the plant for the first time. The dismantling was not carried through completely, but was halted as soon as about half was taken. Together with the machinery some personnel was taken out, to be shipped to the USSR in order to set up the machinery which was confiscated and complete it with more later.

In the meantime the plant in BLEICHERODE was being rebuilt under supervision of German and Soviet engineers. Once rebuilt, production was started all over again and as soon as satisfactory results were achieved, the dismantling was continued. In this way, Soviet authorities enrich their own country by building up some priceless industries and on the other hand they see to it that the original plant in Germany is reconstructed and re-equipped after each time. Thus, they would be able theoretically to continue an uninterrupted flow of industries from Germany to the Soviet Union.

This procedure is known to have been applied to all V-weapon plants in BLEICHENRODE, NORDHAUSEN, GOTHA and BERLIN. In BLEICHERODE the installations were dismantled for the fourth time; in NORDHAUSEN for the sixth time; in Berlin only once; conditions in GOTHA are unknown.

The institution responsible for the manufacture and research of V-weapons in BLEICHERODE is the so-called "Zentralwerk Rabe", which consists of seven departments:

1. Remote control, steering and navigation.
2. Fuel
3. Aerodynamic
4. Explosives
5. Materials
6. Testing
7. Manufacture

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Departments one to six are housed above surface, while department seven, Manufacture, is installed in subterranean factories. The chief difficulties encountered at present are first of all with remote control, and secondly with material. Considerable trouble was had with the density of the welded fuel containers. Among the two containers there are 99 yards of welding seam; if only four or five drops of fuel pass through these seams, an explosion is likely to occur. It is believed, however, that this particular difficulty was overcome.

- 1 -

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No. Z-1391

ES/CIB LOG NO. 1172

REG
VIII B-3168

[redacted]

G-2 USFET TSC
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792

Figure B.266: 1946 U.S. intelligence reports described the struggles of Soviet occupation forces to reconstruct the wartime German work on traveling wave tubes and rocket guidance systems without the evacuated scientists/materials/information, thereby confirming the details of the wartime work [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Vol. 1, Fldr. 2 of 3]. See also Section E.2.

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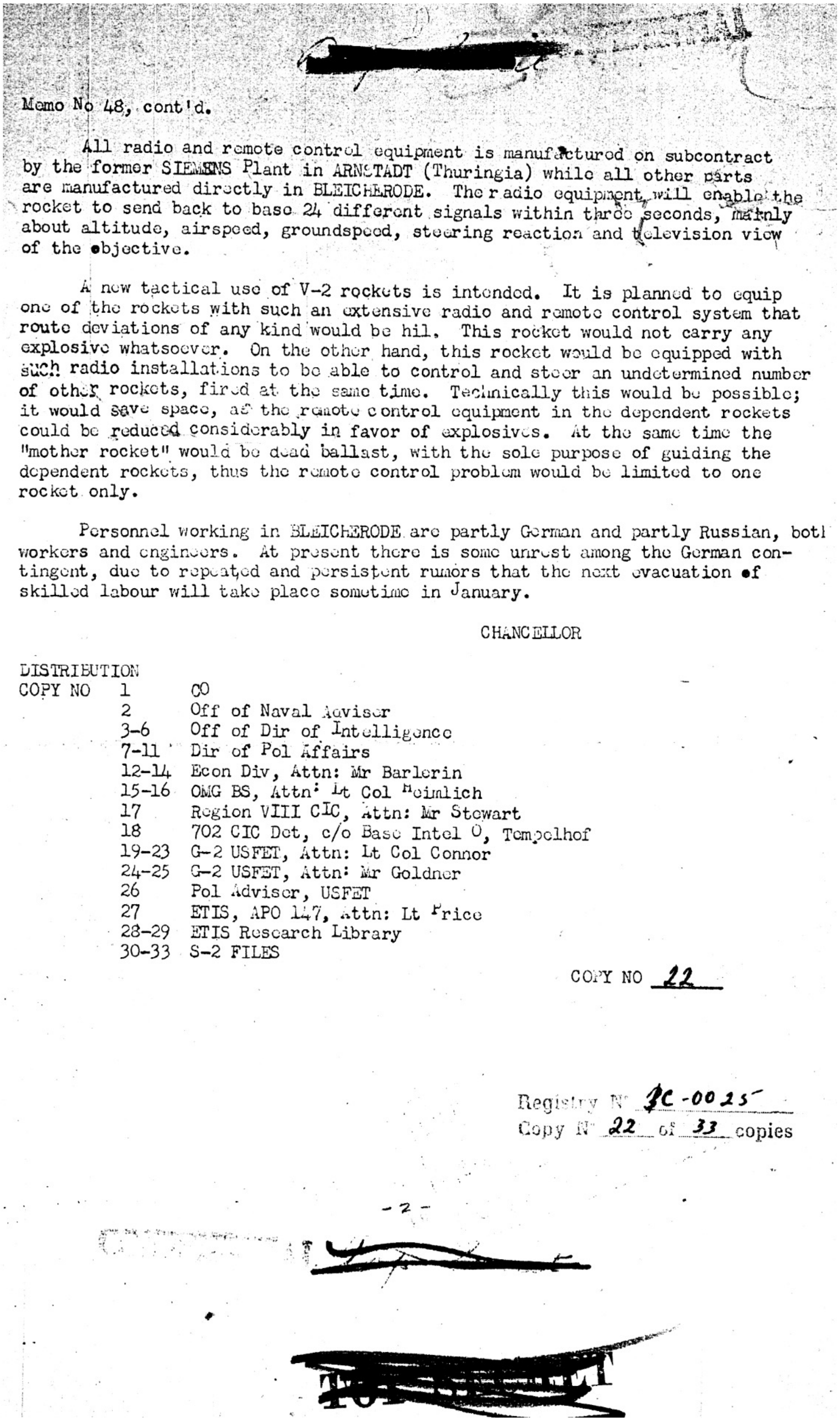

[redacted]

Memo No 48, cont'd.

All radio and remote control equipment is manufactured on subcontract by the former SIEMENS Plant in ARNSTADT (Thuringia) while all other parts are manufactured directly in BLEICHERODE. The radio equipment will enable the rocket to send back to base 24 different signals within three seconds, mainly about altitude, airspeed, groundspeed, steering reaction and television view of the objective.

A new tactical use of V-2 rockets is intended. It is planned to equip one of the rockets with such an extensive radio and remote control system that route deviations of any kind would be hil. This rocket would not carry any explosive whatsoever. On the other hand, this rocket would be equipped with such radio installations to be able to control and steer an undetermined number of other rockets, fired at the same time. Technically this would be possible; it would save space, as the remote control equipment in the dependent rockets could be reduced considerably in favor of explosives. At the same time the "mother rocket" would be dead ballast, with the sole purpose of guiding the dependent rockets, thus the remote control problem would be limited to one rocket only.

Personnel working in BLEICHERODE are partly German and partly Russian, both workers and engineers. At present there is some unrest among the German contingent, due to repeated and persistent rumors that the next evacuation of skilled labour will take place sometime in January.

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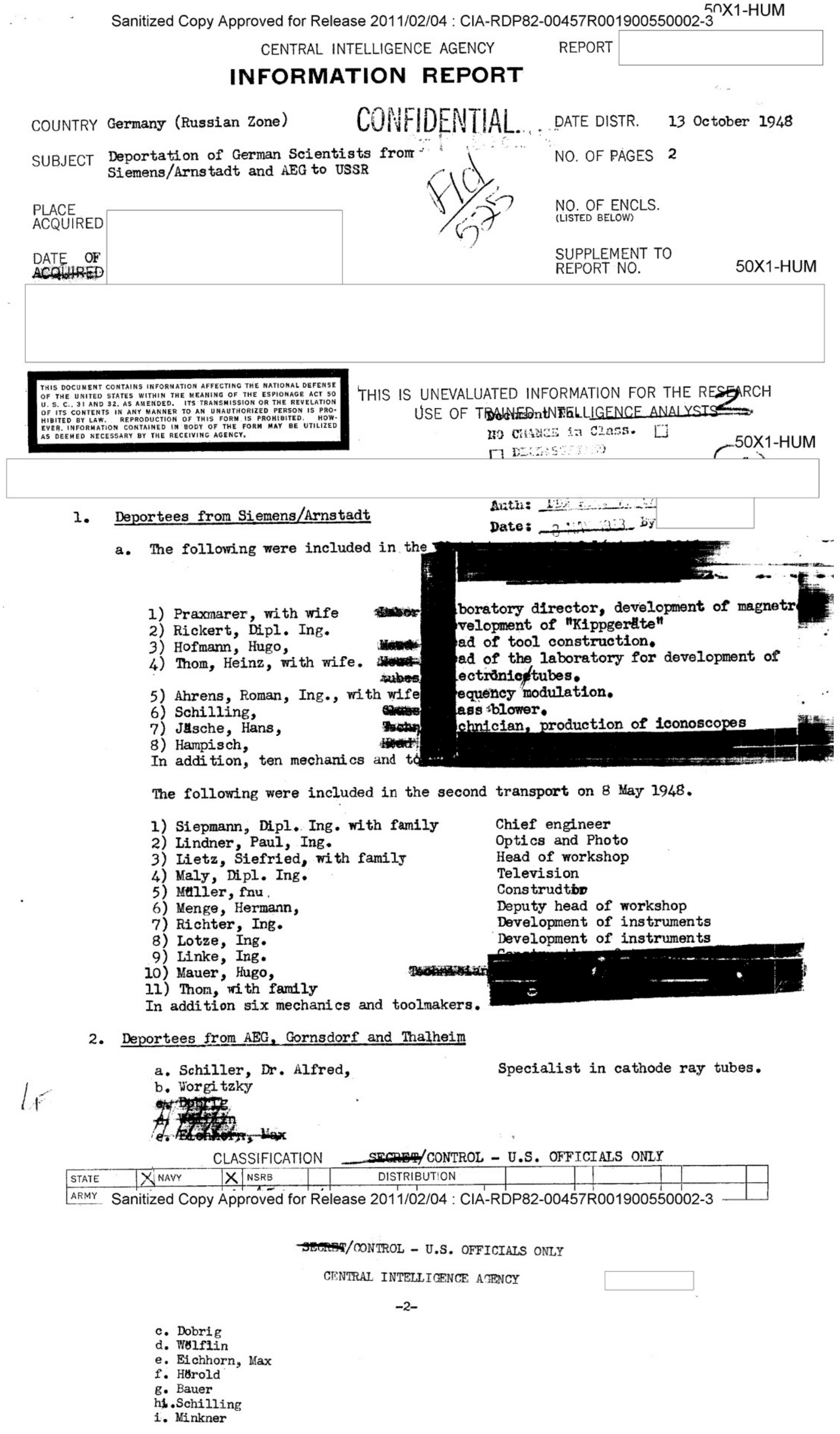
Figure B.267: 1946 U.S. intelligence reports described the struggles of Soviet occupation forces to reconstruct the wartime German work on traveling wave tubes and rocket guidance systems without the evacuated scientists/materials/information, thereby confirming the details of the wartime work [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Vol. 1, Fldr. 2 of 3]. See also Section E.2.



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CENTRAL INTELLIGENCE AGENCY

REPORT [redacted]

INFORMATION REPORT

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COUNTRY	Germany (Russian Zone)
SUBJECT	Deportation of German Scientists from Siemens/Arnstadt and AEG to USSR
PLACE ACQUIRED DATE ~~ACQUIRED~~ OF	[redacted]
DATE DISTR.	13 October 1948
NO. OF PAGES	2
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1. Deportees from Siemens/Arnstadt

a. The following were included in the [redacted]

1) Praxmarer, with wife	boratory director, development of magnetr
2) Rickert, Dipl. Ing.	velopment of "Kippgeräte"
3) Hofmann, Hugo,	ad of tool construction.
4) Thom, Heinz, with wife.	ad of the laboratory for development of tubes, ectrönic/tubes.
5) Ahrens, Roman, Ing., with wife	equency modulation.
6) Schilling,	ass blower.
7) Jäsche, Hans,	chnician, production of iconoscopes
8) Hampisch,	

In addition, ten mechanics and to [redacted]

The following were included in the second transport on 8 May 1948.

1) Siepmann, Dipl. Ing. with family	Chief engineer
2) Lindner, Paul, Ing.	Optics and Photo
3) Lietz, Siefried, with family	Head of workshop
4) Maly, Dipl. Ing.	Television
5) Müller, fnu.	Construdtor
6) Menge, Hermann,	Deputy head of workshop
7) Richter, Ing.	Development of instruments
8) Lotze, Ing.	Development of instruments
9) Linke, Ing.	[redacted]
10) Mauer, Hugo,	[redacted]
11) Thom, with family	

In addition six mechanics and toolmakers.

2. Deportees from AEG, Gornsdorf and Thalheim

a. Schiller, Dr. Alfred,	Specialist in cathode ray tubes.
b. Worgitzky	

~~c. Dobrig~~
~~d. Wölflin~~
~~e. Eichhorn, Max~~

LF

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STATE	☒	NAVY	☒	NSRB	DISTRIBUTION
ARMY					

Sanitized Copy Approved for Release 2011/02/04 : CIA-RDP82-00457R001900550002-3

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CENTRAL INTELLIGENCE AGENCY [redacted]

-2-

c. Dobrig
d. Wölflin
e. Eichhorn, Max
f. Hörold
g. Bauer
h~~i~~.Schilling
i. Minkner

Figure B.268: 1948 U.S. intelligence reports described the struggles of Soviet occupation forces to reconstruct the wartime German work on traveling wave tubes and rocket guidance systems without the evacuated scientists/materials/information, thereby confirming the details of the wartime work [https://www.cia.gov/readingroom/document/cia-rdp82-00457r001900550002-3]. See also Section E.2.

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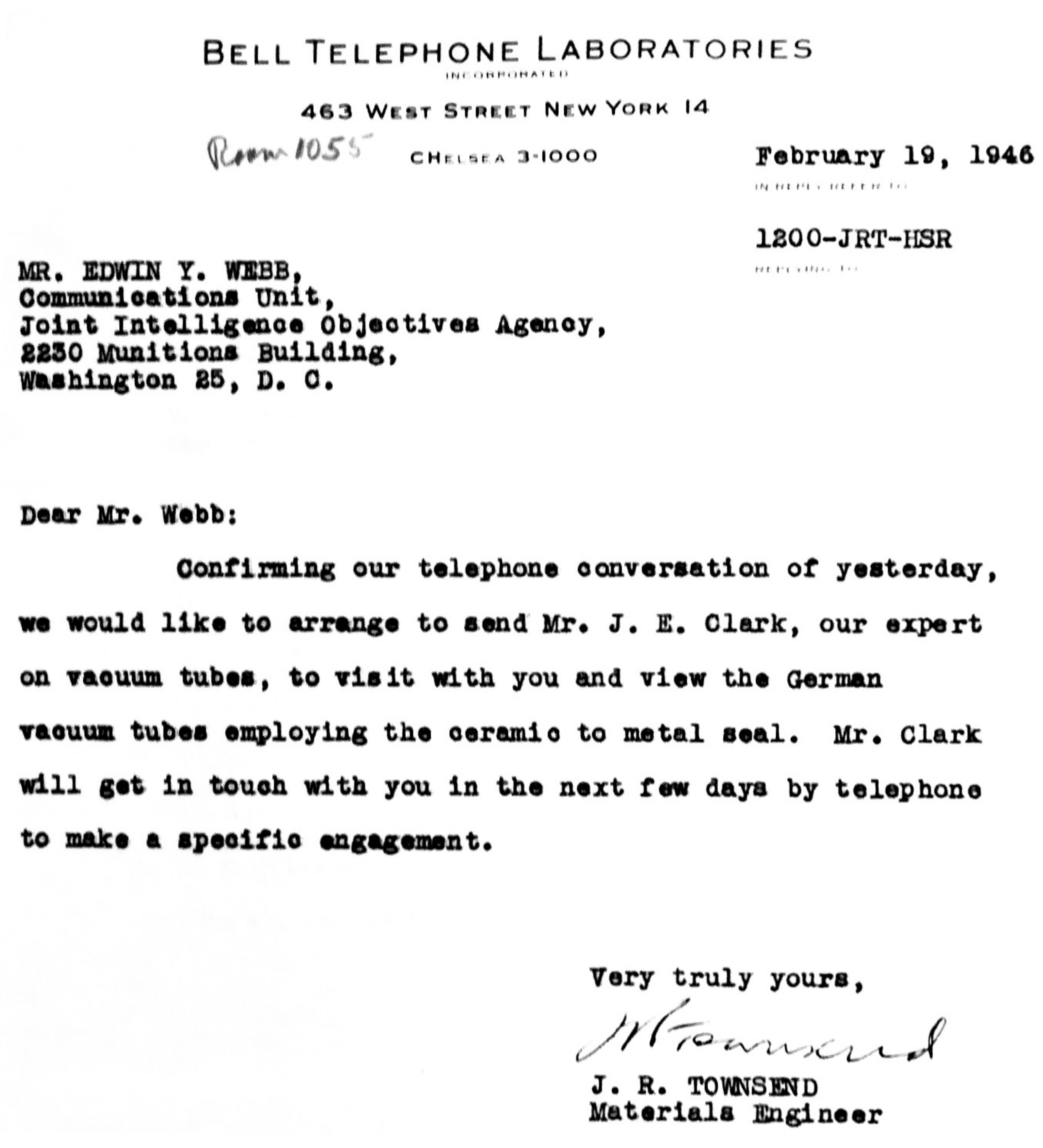
NARA RG 40, Entry UD-75, Box 24, Folder Bell System



BELL TELEPHONE LABORATORIES
INCORPORATED

463 WEST STREET NEW YORK 14

Room 1055 CHELSEA 3-1000

February 19, 1946
IN REPLY REFER TO

1200-JRT-HSR

MR. EDWIN Y. WEBB,
Communications Unit,
Joint Intelligence Objectives Agency,
2230 Munitions Building,
Washington 25, D. C.

Dear Mr. Webb:

Confirming our telephone conversation of yesterday, we would like to arrange to send Mr. J. E. Clark, our expert on vacuum tubes, to visit with you and view the German vacuum tubes employing the ceramic to metal seal. Mr. Clark will get in touch with you in the next few days by telephone to make a specific engagement.

Very truly yours,

J R Townsend

J. R. TOWNSEND
Materials Engineer

Figure B.269: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

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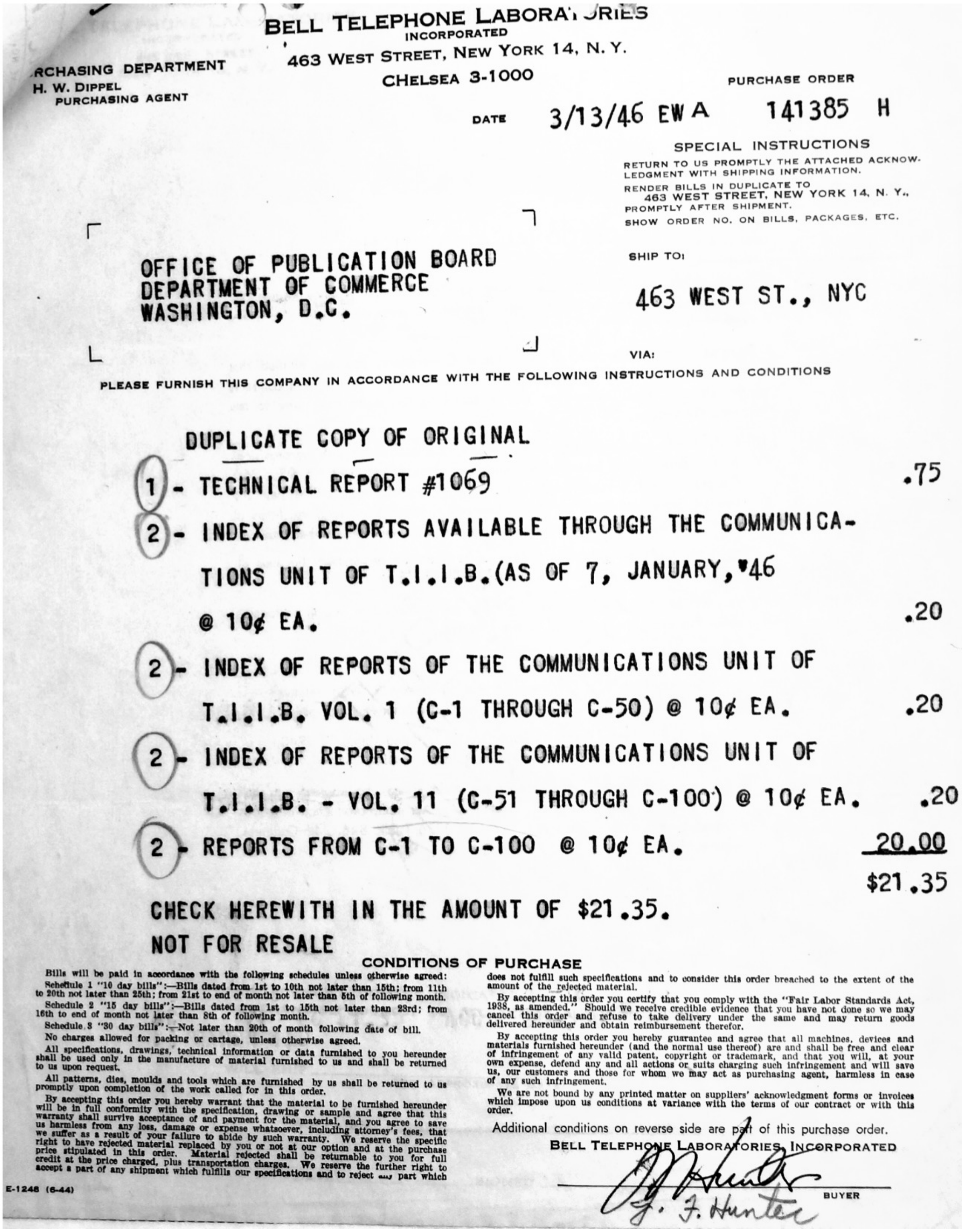
**NARA RG 40, Entry UD-75,
Box 24, Folder Bell System**



BELL TELEPHONE LABORATORIES
INCORPORATED
463 WEST STREET, NEW YORK 14, N. Y.
CHELSEA 3-1000

RCHASING DEPARTMENT
H. W. DIPPEL
PURCHASING AGENT

PURCHASE ORDER

DATE 3/13/46 EW A 141385 H

SPECIAL INSTRUCTIONS
RETURN TO US PROMPTLY THE ATTACHED ACKNOWLEDGMENT WITH SHIPPING INFORMATION.
RENDER BILLS IN DUPLICATE TO
463 WEST STREET, NEW YORK 14, N. Y.,
PROMPTLY AFTER SHIPMENT.
SHOW ORDER NO. ON BILLS, PACKAGES, ETC.

OFFICE OF PUBLICATION BOARD
DEPARTMENT OF COMMERCE
WASHINGTON, D.C.

SHIP TO:
463 WEST ST., NYC

VIA:

PLEASE FURNISH THIS COMPANY IN ACCORDANCE WITH THE FOLLOWING INSTRUCTIONS AND CONDITIONS

DUPLICATE COPY OF ORIGINAL

1	- TECHNICAL REPORT #1069	.75
2	- INDEX OF REPORTS AVAILABLE THROUGH THE COMMUNICATIONS UNIT OF T.I.I.B.(AS OF 7, JANUARY,'46 @ 10¢ EA.	.20
2	- INDEX OF REPORTS OF THE COMMUNICATIONS UNIT OF T.I.I.B. VOL. 1 (C-1 THROUGH C-50) @ 10¢ EA.	.20
2	- INDEX OF REPORTS OF THE COMMUNICATIONS UNIT OF T.I.I.B. - VOL. 11 (C-51 THROUGH C-100) @ 10¢ EA.	.20
2	- REPORTS FROM C-1 TO C-100 @ 10¢ EA.	20.00
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Bills will be paid in accordance with the following schedules unless otherwise agreed:

Schedule 1 "10 day bills":—Bills dated from 1st to 10th not later than 15th; from 11th to 20th not later than 25th; from 21st to end of month not later than 5th of following month.

Schedule 2 "15 day bills":—Bills dated from 1st to 15th not later than 23rd; from 16th to end of month not later than 8th of following month.

Schedule 3 "30 day bills":—Not later than 20th of month following date of bill.

No charges allowed for packing or cartage, unless otherwise agreed.

All specifications, drawings, technical information or data furnished to you hereunder shall be used only in the manufacture of material furnished to us and shall be returned to us upon request.

All patterns, dies, moulds and tools which are furnished by us shall be returned to us promptly upon completion of the work called for in this order.

By accepting this order you hereby warrant that the material to be furnished hereunder will be in full conformity with the specification, drawing or sample and agree that this warranty shall survive acceptance of and payment for the material, and you agree to save us harmless from any loss, damage or expense whatsoever, including attorney's fees, that we suffer as a result of your failure to abide by such warranty. We reserve the specific right to have rejected material replaced by you or not at our option and at the purchase price stipulated in this order. Material rejected shall be returnable to you for full credit at the price charged, plus transportation charges. We reserve the further right to accept a part of any shipment which fulfills our specifications and to reject any part which does not fulfill such specifications and to consider this order breached to the extent of the amount of the rejected material.

By accepting this order you certify that you comply with the "Fair Labor Standards Act, 1938, as amended." Should we receive credible evidence that you have not done so we may cancel this order and refuse to take delivery under the same and may return goods delivered hereunder and obtain reimbursement therefor.

By accepting this order you hereby guarantee and agree that all machines, devices and materials furnished hereunder (and the normal use thereof) are and shall be free and clear of infringement of any valid patent, copyright or trademark, and that you will, at your own expense, defend any and all actions or suits charging such infringement and will save us, our customers and those for whom we may act as purchasing agent, harmless in case of any such infringement.

We are not bound by any printed matter on suppliers' acknowledgment forms or invoices which impose upon us conditions at variance with the terms of our contract or with this order.

Additional conditions on reverse side are part of this purchase order.

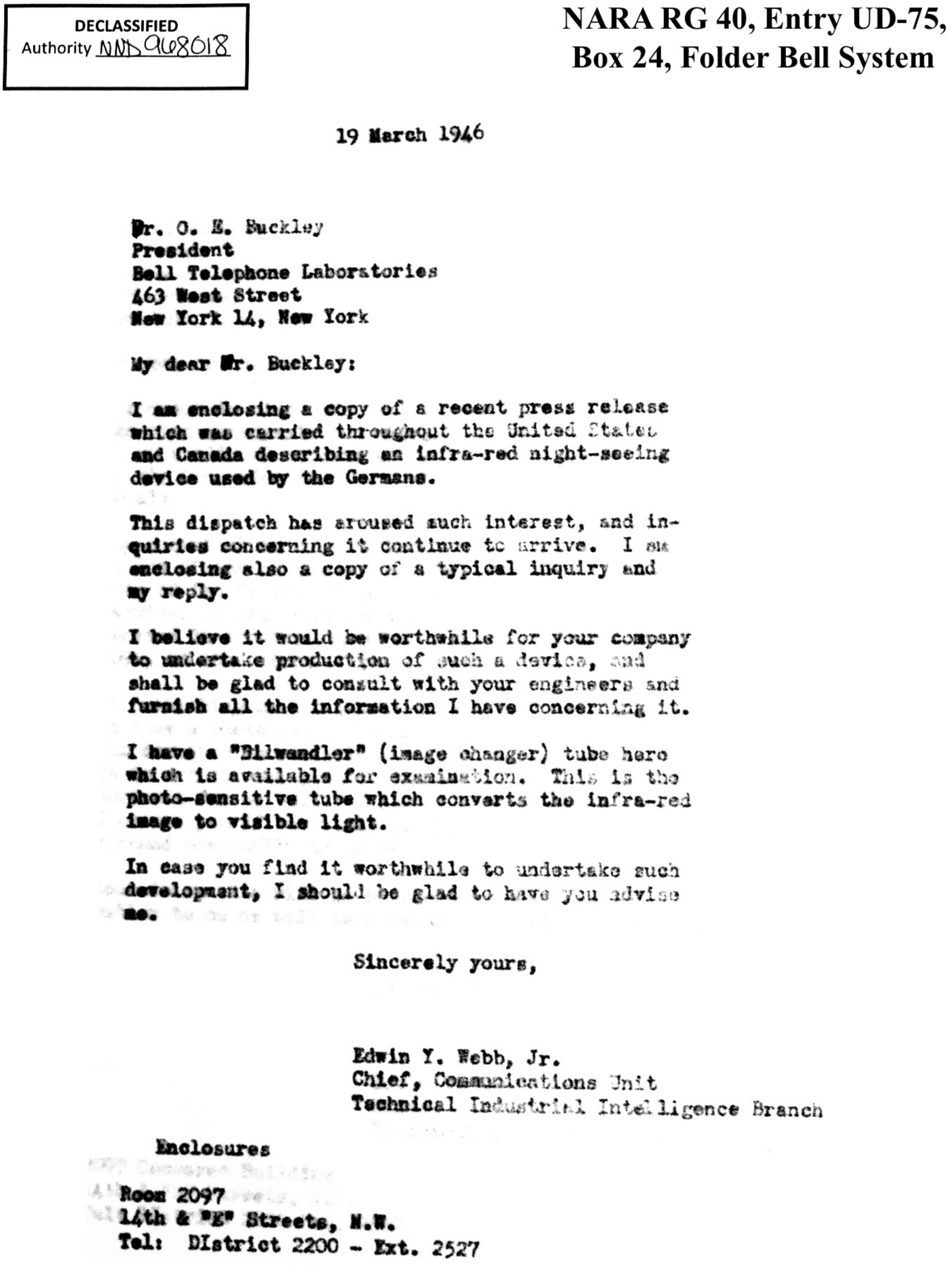
BELL TELEPHONE LABORATORIES, INCORPORATED

BUYER

J. F. Hunter

E-1248 (6-44)

Figure B.270: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



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NARA RG 40, Entry UD-75,
Box 24, Folder Bell System

19 March 1946

Dr. O. E. Buckley
President
Bell Telephone Laboratories
463 West Street
New York 14, New York

My dear Mr. Buckley:

I am enclosing a copy of a recent press release which was carried throughout the United States and Canada describing an infra-red night-seeing device used by the Germans.

This dispatch has aroused such interest, and inquiries concerning it continue to arrive. I am enclosing also a copy of a typical inquiry and my reply.

I believe it would be worthwhile for your company to undertake production of such a device, and shall be glad to consult with your engineers and furnish all the information I have concerning it.

I have a "Bilwandler" (image changer) tube here which is available for examination. This is the photo-sensitive tube which converts the infra-red image to visible light.

In case you find it worthwhile to undertake such development, I should be glad to have you advise me.

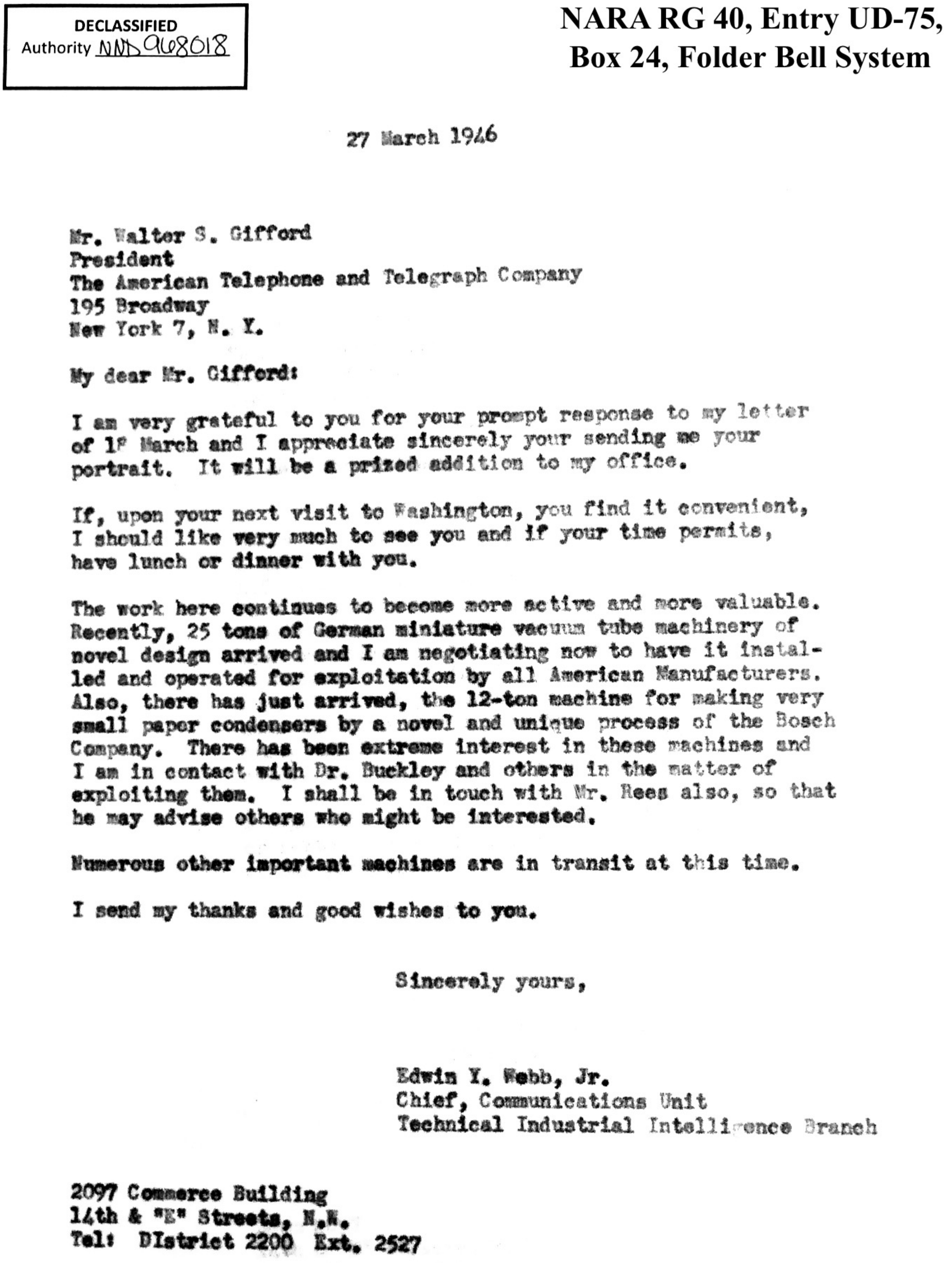
Sincerely yours,

Edwin Y. Webb, Jr.
Chief, Communications Unit
Technical Industrial Intelligence Branch

Enclosures

Room 2097
14th & "E" Streets, N.W.
Tel: DIstrict 2200 - Ext. 2527

Figure B.271: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



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NARA RG 40, Entry UD-75, Box 24, Folder Bell System

27 March 1946

Mr. Walter S. Gifford
President
The American Telephone and Telegraph Company
195 Broadway
New York 7, N. Y.

My dear Mr. Gifford:

I am very grateful to you for your prompt response to my letter of 18 March and I appreciate sincerely your sending me your portrait. It will be a prized addition to my office.

If, upon your next visit to Washington, you find it convenient, I should like very much to see you and if your time permits, have lunch or dinner with you.

The work here continues to become more active and more valuable. Recently, 25 tons of German miniature vacuum tube machinery of novel design arrived and I am negotiating now to have it installed and operated for exploitation by all American Manufacturers. Also, there has just arrived, the 12-ton machine for making very small paper condensers by a novel and unique process of the Bosch Company. There has been extreme interest in these machines and I am in contact with Dr. Buckley and others in the matter of exploiting them. I shall be in touch with Mr. Rees also, so that he may advise others who might be interested.

Numerous other important machines are in transit at this time.

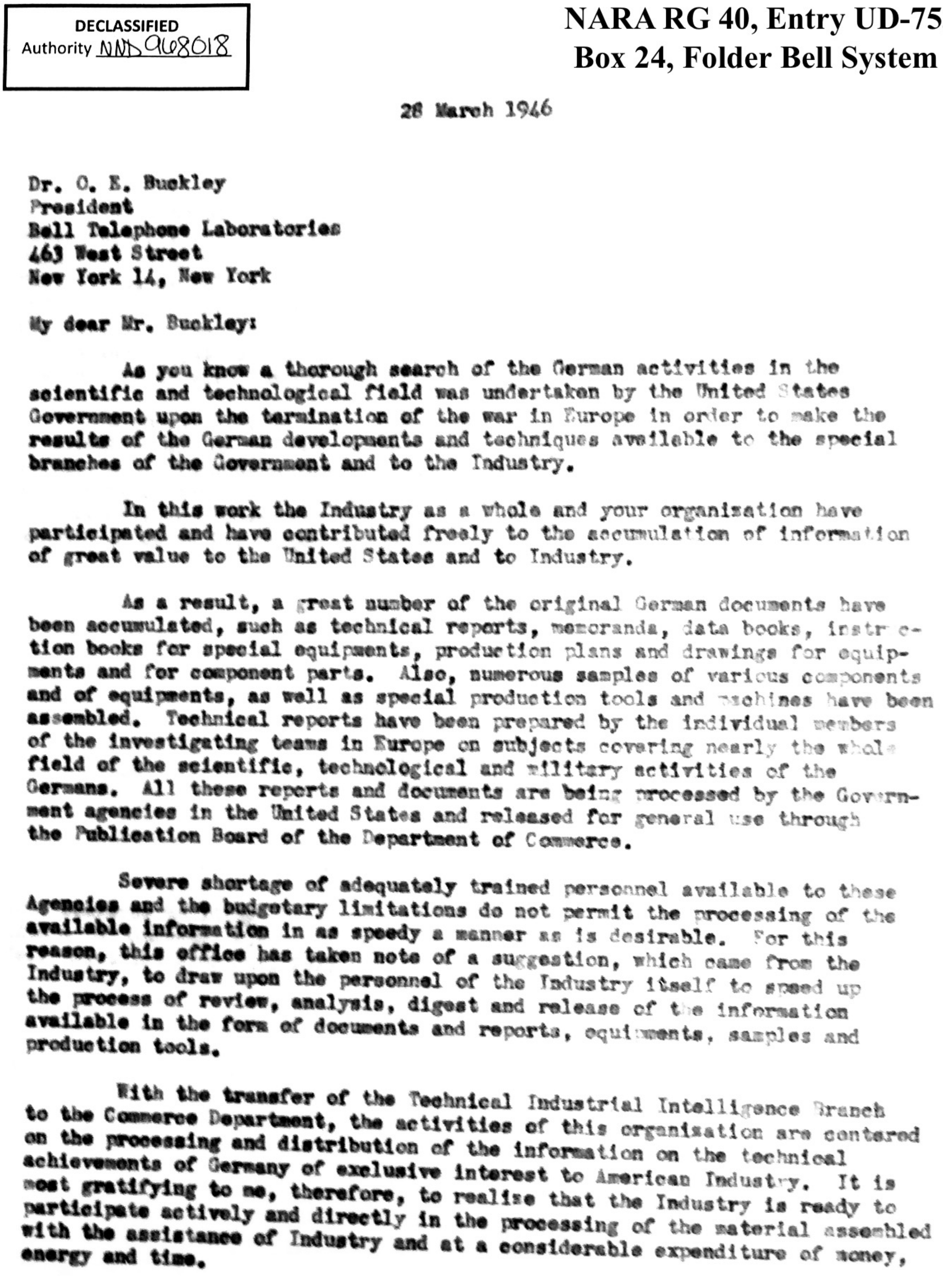
I send my thanks and good wishes to you.

Sincerely yours,

Edwin Y. Webb, Jr.
Chief, Communications Unit
Technical Industrial Intelligence Branch

2097 Commerce Building
14th & "E" Streets, N.W.
Tel: DIstrict 2200 Ext. 2527

Figure B.272: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



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NARA RG 40, Entry UD-75, Box 24, Folder Bell System

28 March 1946

Dr. O. E. Buckley
President
Bell Telephone Laboratories
463 West Street
New York 14, New York

My dear Mr. Buckley:

As you know a thorough search of the German activities in the scientific and technological field was undertaken by the United States Government upon the termination of the war in Europe in order to make the results of the German developments and techniques available to the special branches of the Government and to the Industry.

In this work the Industry as a whole and your organization have participated and have contributed freely to the accumulation of information of great value to the United States and to Industry.

As a result, a great number of the original German documents have been accumulated, such as technical reports, memoranda, data books, instruction books for special equipments, production plans and drawings for equipments and for component parts. Also, numerous samples of various components and of equipments, as well as special production tools and machines have been assembled. Technical reports have been prepared by the individual members of the investigating teams in Europe on subjects covering nearly the whole field of the scientific, technological and military activities of the Germans. All these reports and documents are being processed by the Government agencies in the United States and released for general use through the Publication Board of the Department of Commerce.

Severe shortage of adequately trained personnel available to these Agencies and the budgetary limitations do not permit the processing of the available information in as speedy a manner as is desirable. For this reason, this office has taken note of a suggestion, which came from the Industry, to draw upon the personnel of the Industry itself to speed up the process of review, analysis, digest and release of the information available in the form of documents and reports, equipments, samples and production tools.

With the transfer of the Technical Industrial Intelligence Branch to the Commerce Department, the activities of this organization are centered on the processing and distribution of the information on the technical achievements of Germany of exclusive interest to American Industry. It is most gratifying to me, therefore, to realize that the Industry is ready to participate actively and directly in the processing of the material assembled with the assistance of Industry and at a considerable expenditure of money, energy and time.

Figure B.273: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

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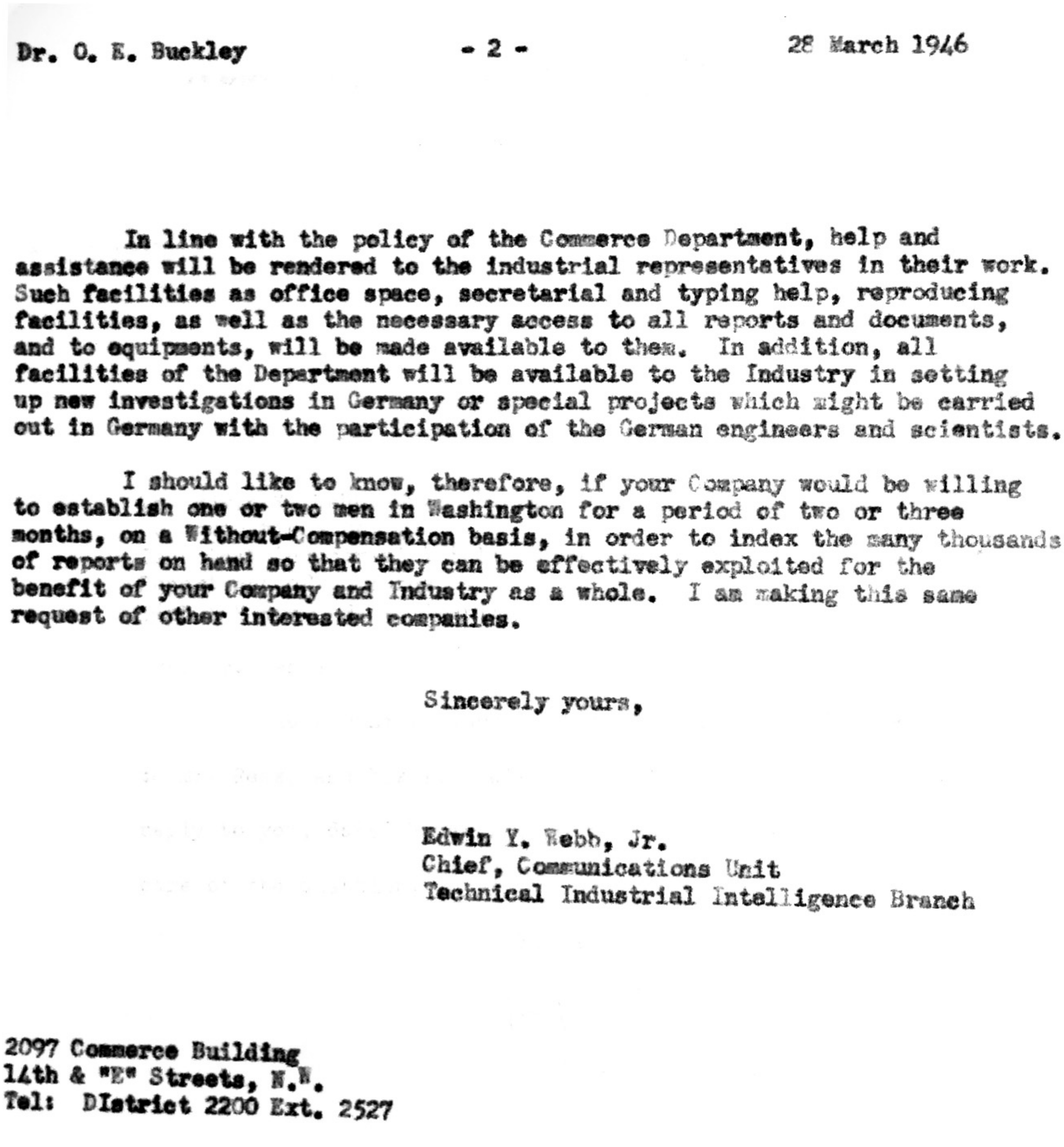
Box 24, Folder Bell System**



Dr. O. E. Buckley - 2 - 28 March 1946

In line with the policy of the Commerce Department, help and assistance will be rendered to the industrial representatives in their work. Such facilities as office space, secretarial and typing help, reproducing facilities, as well as the necessary access to all reports and documents, and to equipments, will be made available to them. In addition, all facilities of the Department will be available to the Industry in setting up new investigations in Germany or special projects which might be carried out in Germany with the participation of the German engineers and scientists.

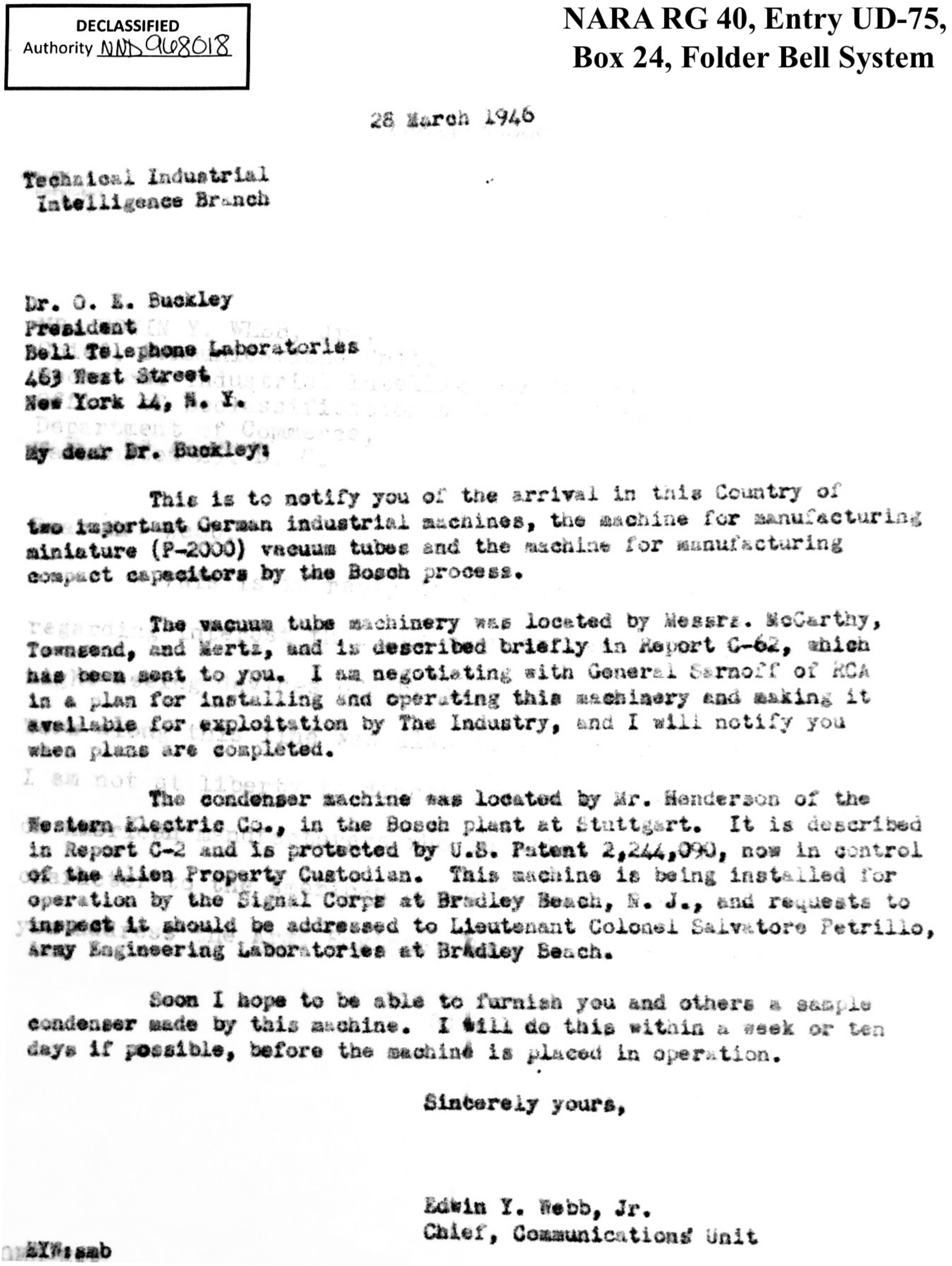
I should like to know, therefore, if your Company would be willing to establish one or two men in Washington for a period of two or three months, on a Without-Compensation basis, in order to index the many thousands of reports on hand so that they can be effectively exploited for the benefit of your Company and Industry as a whole. I am making this same request of other interested companies.

Sincerely yours,

Edwin Y. Webb, Jr.
Chief, Communications Unit
Technical Industrial Intelligence Branch

2097 Commerce Building
14th & "E" Streets, N.W.
Tel: DIstrict 2200 Ext. 2527

Figure B.274: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



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NARA RG 40, Entry UD-75, Box 24, Folder Bell System

28 March 1946

Technical Industrial
Intelligence Branch

Dr. O. E. Buckley
President
Bell Telephone Laboratories
463 West Street
New York 14, N. Y.

My dear Dr. Buckley:

This is to notify you of the arrival in this Country of two important German industrial machines, the machine for manufacturing miniature (P-2000) vacuum tubes and the machine for manufacturing compact capacitors by the Bosch process.

The vacuum tube machinery was located by Messrs. McCarthy, Townsend, and Mertz, and is described briefly in Report C-62, which has been sent to you. I am negotiating with General Sarnoff of RCA in a plan for installing and operating this machinery and making it available for exploitation by The Industry, and I will notify you when plans are completed.

The condenser machine was located by Mr. Henderson of the Western Electric Co., in the Bosch plant at Stuttgart. It is described in Report C-2 and is protected by U.S. Patent 2,244,090, now in control of the Alien Property Custodian. This machine is being installed for operation by the Signal Corps at Bradley Beach, N. J., and requests to inspect it should be addressed to Lieutenant Colonel Salvatore Petrillo, Army Engineering Laboratories at Bradley Beach.

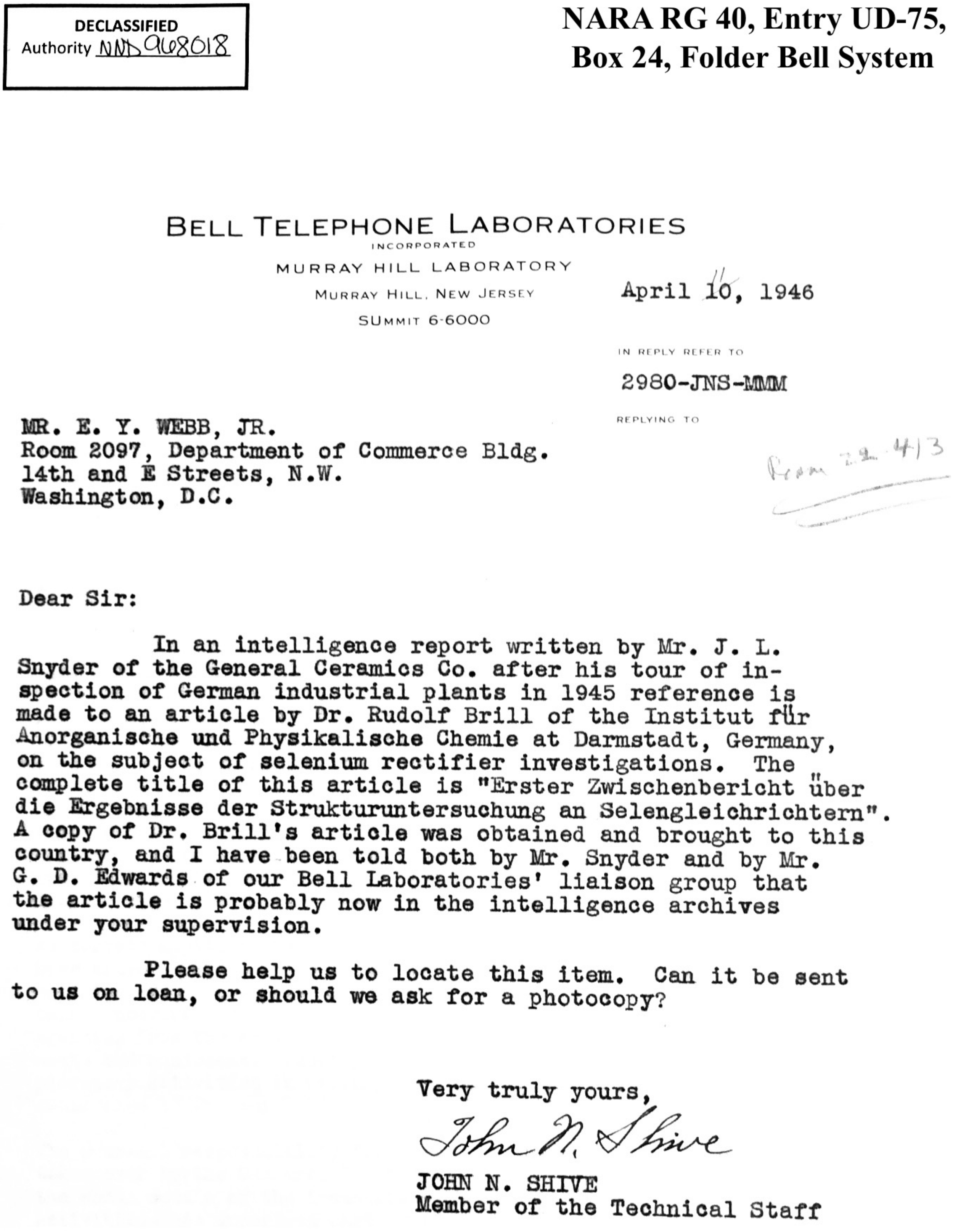
Soon I hope to be able to furnish you and others a sample condenser made by this machine. I will do this within a week or ten days if possible, before the machine is placed in operation.

Sincerely yours,

Edwin Y. Webb, Jr.
Chief, Communications Unit

EYW:smb

Figure B.275: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



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NARA RG 40, Entry UD-75, Box 24, Folder Bell System

BELL TELEPHONE LABORATORIES
INCORPORATED
MURRAY HILL LABORATORY
MURRAY HILL, NEW JERSEY
SUMMIT 6-6000

April ~~10~~ 11, 1946

IN REPLY REFER TO
2980-JNS-MMM

REPLYING TO
Room 22-413

MR. E. Y. WEBB, JR.
Room 2097, Department of Commerce Bldg.
14th and E Streets, N.W.
Washington, D.C.

Dear Sir:

In an intelligence report written by Mr. J. L. Snyder of the General Ceramics Co. after his tour of inspection of German industrial plants in 1945 reference is made to an article by Dr. Rudolf Brill of the Institut für Anorganische und Physikalische Chemie at Darmstadt, Germany, on the subject of selenium rectifier investigations. The complete title of this article is "Erster Zwischenbericht über die Ergebnisse der Strukturuntersuchung an Selengleichrichtern". A copy of Dr. Brill's article was obtained and brought to this country, and I have been told both by Mr. Snyder and by Mr. G. D. Edwards of our Bell Laboratories' liaison group that the article is probably now in the intelligence archives under your supervision.

Please help us to locate this item. Can it be sent to us on loan, or should we ask for a photocopy?

Very truly yours,

John N. Shive

JOHN N. SHIVE
Member of the Technical Staff

Figure B.276: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

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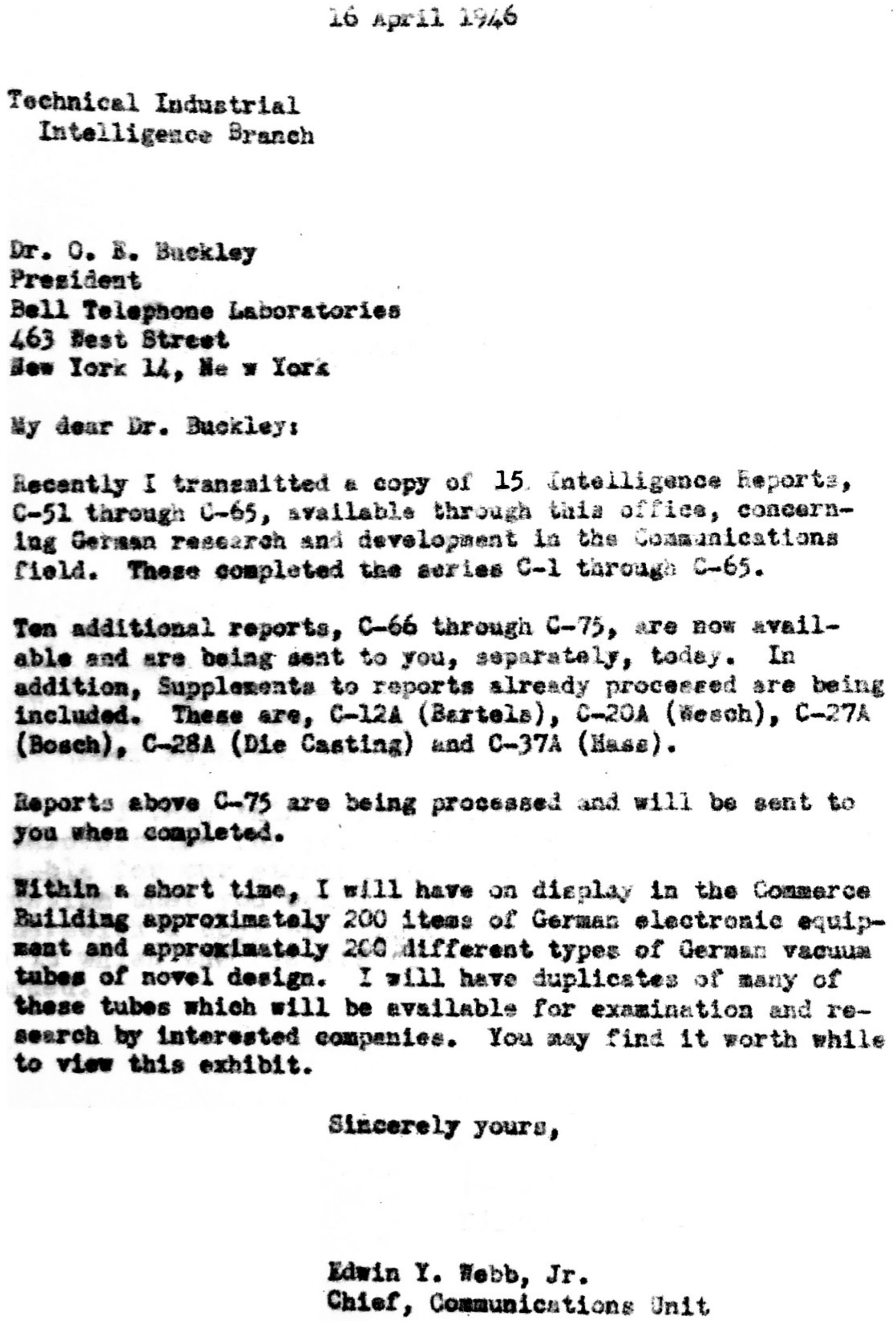


16 April 1946

Technical Industrial
Intelligence Branch

Dr. O. E. Buckley
President
Bell Telephone Laboratories
463 West Street
New York 14, New York

My dear Dr. Buckley:

Recently I transmitted a copy of 15 Intelligence Reports, C-51 through C-65, available through this office, concerning German research and development in the Communications field. These completed the series C-1 through C-65.

Ten additional reports, C-66 through C-75, are now available and are being sent to you, separately, today. In addition, Supplements to reports already processed are being included. These are, C-12A (Bartels), C-20A (Wesch), C-27A (Bosch), C-28A (Die Casting) and C-37A (Hass).

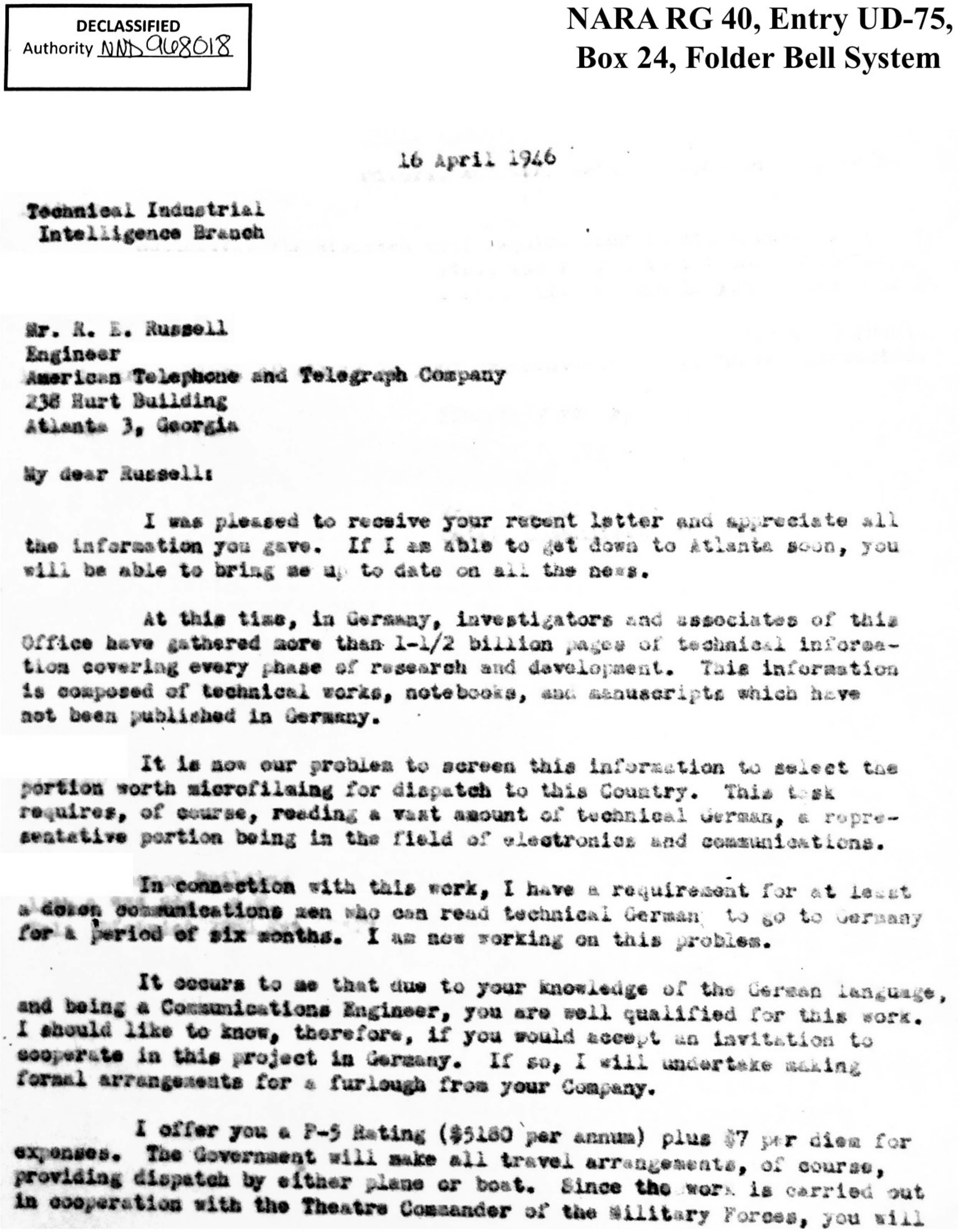
Reports above C-75 are being processed and will be sent to you when completed.

Within a short time, I will have on display in the Commerce Building approximately 200 items of German electronic equipment and approximately 200 different types of German vacuum tubes of novel design. I will have duplicates of many of these tubes which will be available for examination and research by interested companies. You may find it worth while to view this exhibit.

Sincerely yours,

Edwin Y. Webb, Jr.
Chief, Communications Unit

Figure B.277: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



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Authority NND968018

NARA RG 40, Entry UD-75,
Box 24, Folder Bell System

16 April 1946

Technical Industrial
Intelligence Branch

Mr. R. E. Russell
Engineer
American Telephone and Telegraph Company
238 Hurt Building
Atlanta 3, Georgia

My dear Russell:

I was pleased to receive your recent letter and appreciate all the information you gave. If I am able to get down to Atlanta soon, you will be able to bring me up to date on all the news.

At this time, in Germany, investigators and associates of this Office have gathered more than 1-1/2 billion pages of technical information covering every phase of research and development. This information is composed of technical works, notebooks, and manuscripts which have not been published in Germany.

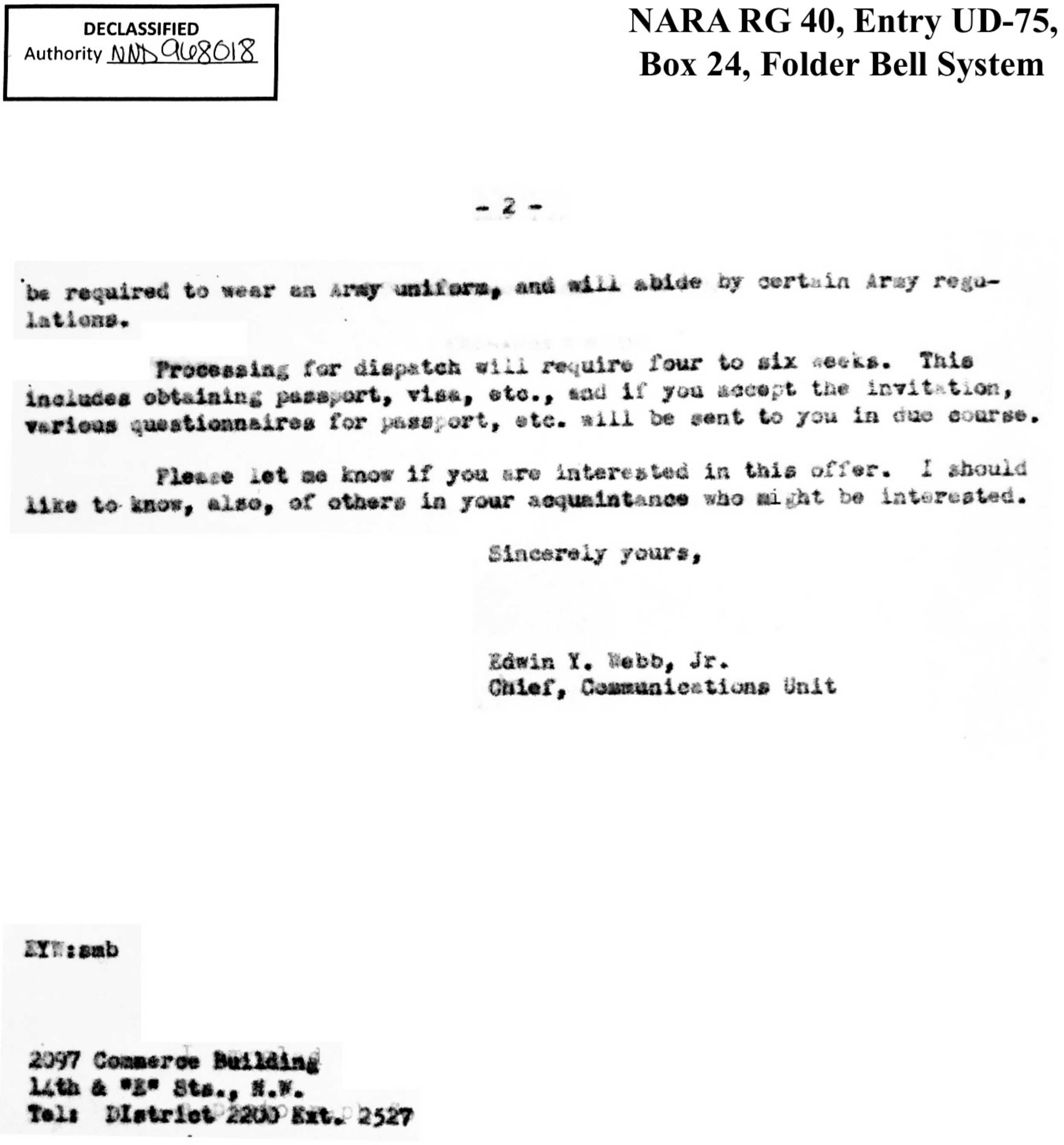
It is now our problem to screen this information to select the portion worth microfilming for dispatch to this Country. This task requires, of course, reading a vast amount of technical German, a representative portion being in the field of electronics and communications.

In connection with this work, I have a requirement for at least a dozen communications men who can read technical German to go to Germany for a period of six months. I am now working on this problem.

It occurs to me that due to your knowledge of the German language, and being a Communications Engineer, you are well qualified for this work. I should like to know, therefore, if you would accept an invitation to cooperate in this project in Germany. If so, I will undertake making formal arrangements for a furlough from your Company.

I offer you a P-5 Rating ($5180 per annum) plus $7 per diem for expenses. The Government will make all travel arrangements, of course, providing dispatch by either plane or boat. Since the work is carried out in cooperation with the Theatre Commander of the Military Forces, you will

Figure B.278: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



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NARA RG 40, Entry UD-75, Box 24, Folder Bell System

- 2 -

be required to wear an Army uniform, and will abide by certain Army regulations.

Processing for dispatch will require four to six weeks. This includes obtaining passport, visa, etc., and if you accept the invitation, various questionnaires for passport, etc. will be sent to you in due course.

Please let me know if you are interested in this offer. I should like to know, also, of others in your acquaintance who might be interested.

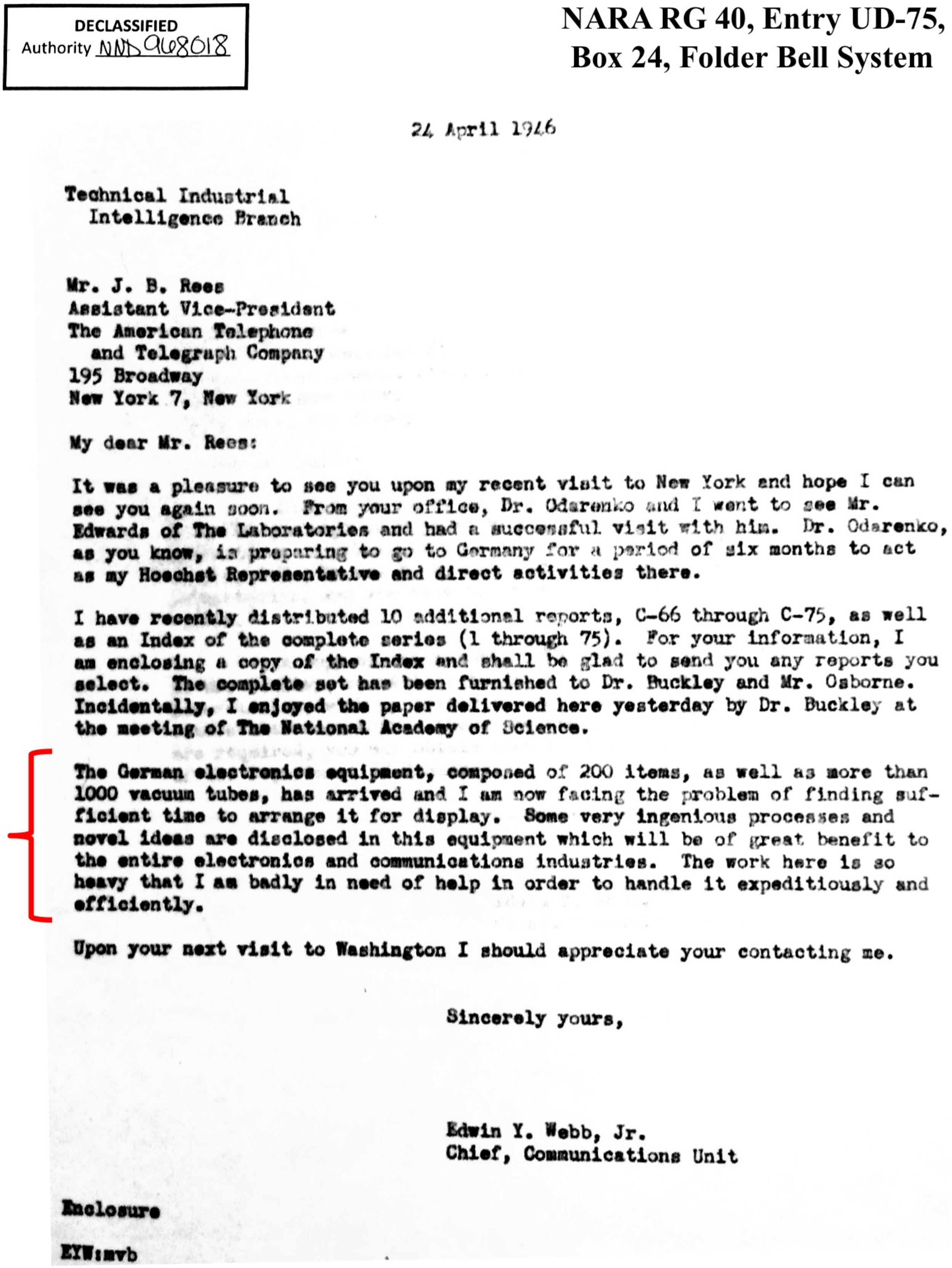
Sincerely yours,

Edwin Y. Webb, Jr.
Chief, Communications Unit

EYW:smb

2097 Commerce Building
14th & "E" Sts., N.W.
Tel: District 2200 Ext. 2527

Figure B.279: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



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Authority NND968018

NARA RG 40, Entry UD-75, Box 24, Folder Bell System

24 April 1946

Technical Industrial
Intelligence Branch

Mr. J. B. Rees
Assistant Vice-President
The American Telephone
and Telegraph Company
195 Broadway
New York 7, New York

My dear Mr. Rees:

It was a pleasure to see you upon my recent visit to New York and hope I can see you again soon. From your office, Dr. Odarenko and I went to see Mr. Edwards of The Laboratories and had a successful visit with him. Dr. Odarenko, as you know, is preparing to go to Germany for a period of six months to act as my Hoechst Representative and direct activities there.

I have recently distributed 10 additional reports, C-66 through C-75, as well as an Index of the complete series (1 through 75). For your information, I am enclosing a copy of the Index and shall be glad to send you any reports you select. The complete set has been furnished to Dr. Buckley and Mr. Osborne. Incidentally, I enjoyed the paper delivered here yesterday by Dr. Buckley at the meeting of The National Academy of Science.

The German electronics equipment, composed of 200 items, as well as more than 1000 vacuum tubes, has arrived and I am now facing the problem of finding sufficient time to arrange it for display. Some very ingenious processes and novel ideas are disclosed in this equipment which will be of great benefit to the entire electronics and communications industries. The work here is so heavy that I am badly in need of help in order to handle it expeditiously and efficiently.

Upon your next visit to Washington I should appreciate your contacting me.

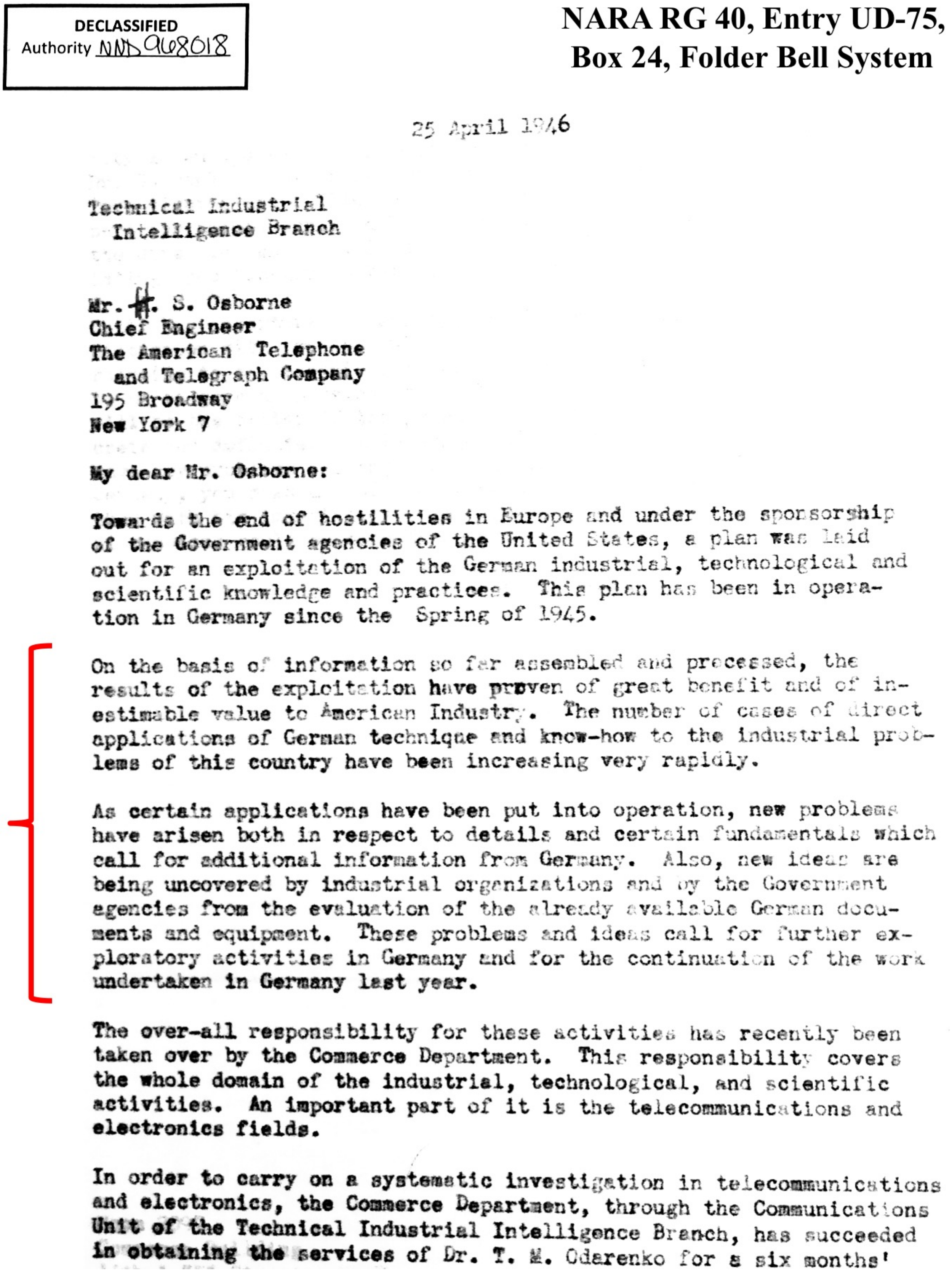
Sincerely yours,

Edwin Y. Webb, Jr.
Chief, Communications Unit

Enclosure

EYW:mvb

Figure B.280: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



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NARA RG 40, Entry UD-75,
Box 24, Folder Bell System

25 April 1946

Technical Industrial
Intelligence Branch

Mr. H. S. Osborne
Chief Engineer
The American Telephone
and Telegraph Company
195 Broadway
New York 7

My dear Mr. Osborne:

Towards the end of hostilities in Europe and under the sponsorship of the Government agencies of the United States, a plan was laid out for an exploitation of the German industrial, technological and scientific knowledge and practices. This plan has been in operation in Germany since the Spring of 1945.

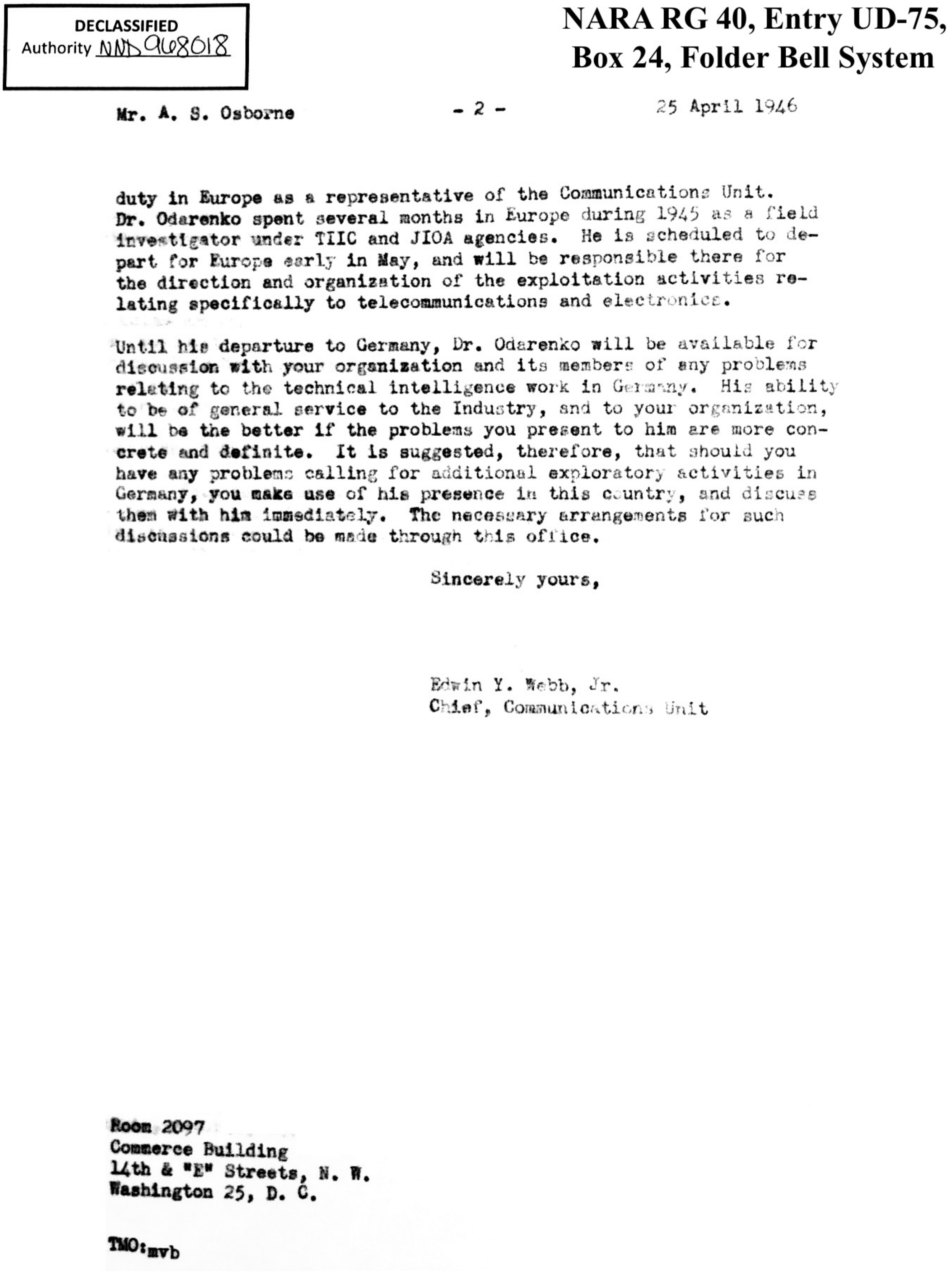
On the basis of information so far assembled and processed, the results of the exploitation have proven of great benefit and of inestimable value to American Industry. The number of cases of direct applications of German technique and know-how to the industrial problems of this country have been increasing very rapidly.

As certain applications have been put into operation, new problems have arisen both in respect to details and certain fundamentals which call for additional information from Germany. Also, new ideas are being uncovered by industrial organizations and by the Government agencies from the evaluation of the already available German documents and equipment. These problems and ideas call for further exploratory activities in Germany and for the continuation of the work undertaken in Germany last year.

The over-all responsibility for these activities has recently been taken over by the Commerce Department. This responsibility covers the whole domain of the industrial, technological, and scientific activities. An important part of it is the telecommunications and electronics fields.

In order to carry on a systematic investigation in telecommunications and electronics, the Commerce Department, through the Communications Unit of the Technical Industrial Intelligence Branch, has succeeded in obtaining the services of Dr. T. M. Odarenko for a six months'

Figure B.281: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND968018

NARA RG 40, Entry UD-75, Box 24, Folder Bell System

Mr. A. S. Osborne - 2 - 25 April 1946

duty in Europe as a representative of the Communications Unit. Dr. Odarenko spent several months in Europe during 1945 as a field investigator under TIIC and JIOA agencies. He is scheduled to depart for Europe early in May, and will be responsible there for the direction and organization of the exploitation activities relating specifically to telecommunications and electronics.

Until his departure to Germany, Dr. Odarenko will be available for discussion with your organization and its members of any problems relating to the technical intelligence work in Germany. His ability to be of general service to the Industry, and to your organization, will be the better if the problems you present to him are more concrete and definite. It is suggested, therefore, that should you have any problems calling for additional exploratory activities in Germany, you make use of his presence in this country, and discuss them with him immediately. The necessary arrangements for such discussions could be made through this office.

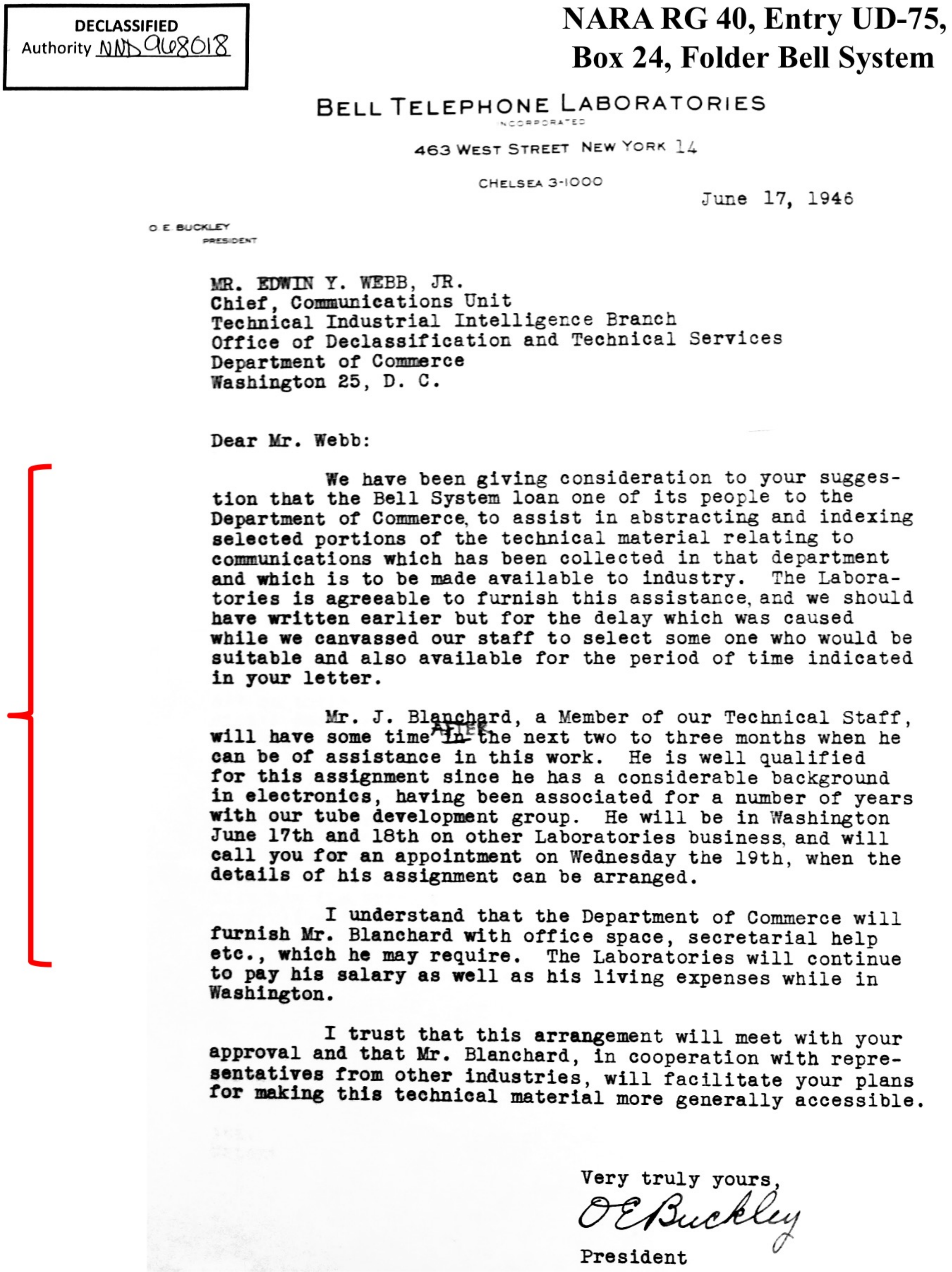
Sincerely yours,

Edwin Y. Webb, Jr.
Chief, Communications Unit

Room 2097
Commerce Building
14th & "E" Streets, N. W.
Washington 25, D. C.

TMO:mvb

Figure B.282: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND968018

NARA RG 40, Entry UD-75, Box 24, Folder Bell System

BELL TELEPHONE LABORATORIES
INCORPORATED
463 WEST STREET NEW YORK 14
CHELSEA 3-1000

O. E. BUCKLEY
PRESIDENT

June 17, 1946

MR. EDWIN Y. WEBB, JR.
Chief, Communications Unit
Technical Industrial Intelligence Branch
Office of Declassification and Technical Services
Department of Commerce
Washington 25, D. C.

Dear Mr. Webb:

We have been giving consideration to your suggestion that the Bell System loan one of its people to the Department of Commerce, to assist in abstracting and indexing selected portions of the technical material relating to communications which has been collected in that department and which is to be made available to industry. The Laboratories is agreeable to furnish this assistance, and we should have written earlier but for the delay which was caused while we canvassed our staff to select some one who would be suitable and also available for the period of time indicated in your letter.

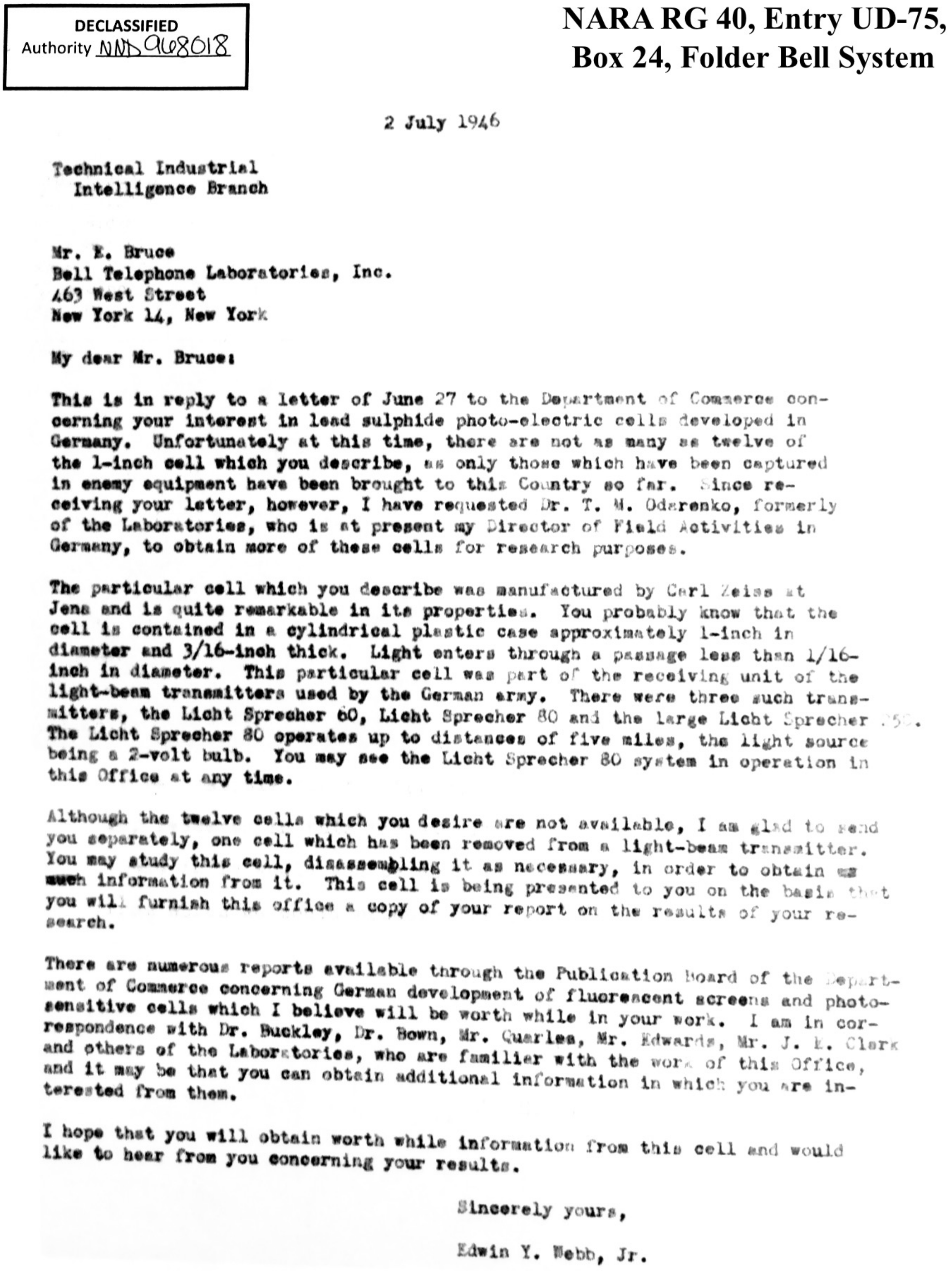
Mr. J. Blanchard, a Member of our Technical Staff, will have some time AFTER ~~in~~ the next two to three months when he can be of assistance in this work. He is well qualified for this assignment since he has a considerable background in electronics, having been associated for a number of years with our tube development group. He will be in Washington June 17th and 18th on other Laboratories business, and will call you for an appointment on Wednesday the 19th, when the details of his assignment can be arranged.

I understand that the Department of Commerce will furnish Mr. Blanchard with office space, secretarial help etc., which he may require. The Laboratories will continue to pay his salary as well as his living expenses while in Washington.

I trust that this arrangement will meet with your approval and that Mr. Blanchard, in cooperation with representatives from other industries, will facilitate your plans for making this technical material more generally accessible.

Very truly yours,
O E Buckley
President

Figure B.283: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND968018

NARA RG 40, Entry UD-75, Box 24, Folder Bell System

2 July 1946

Technical Industrial
Intelligence Branch

Mr. E. Bruce
Bell Telephone Laboratories, Inc.
463 West Street
New York 14, New York

My dear Mr. Bruce:

This is in reply to a letter of June 27 to the Department of Commerce concerning your interest in lead sulphide photo-electric cells developed in Germany. Unfortunately at this time, there are not as many as twelve of the 1-inch cell which you describe, as only those which have been captured in enemy equipment have been brought to this Country so far. Since receiving your letter, however, I have requested Dr. T. M. Odarenko, formerly of the Laboratories, who is at present my Director of Field Activities in Germany, to obtain more of these cells for research purposes.

The particular cell which you describe was manufactured by Carl Zeiss at Jena and is quite remarkable in its properties. You probably know that the cell is contained in a cylindrical plastic case approximately 1-inch in diameter and 3/16-inch thick. Light enters through a passage less than 1/16-inch in diameter. This particular cell was part of the receiving unit of the light-beam transmitters used by the German army. There were three such transmitters, the Licht Sprecher 60, Licht Sprecher 80 and the large Licht Sprecher 250. The Licht Sprecher 80 operates up to distances of five miles, the light source being a 2-volt bulb. You may see the Licht Sprecher 80 system in operation in this Office at any time.

Although the twelve cells which you desire are not available, I am glad to send you separately, one cell which has been removed from a light-beam transmitter. You may study this cell, disassembling it as necessary, in order to obtain as much information from it. This cell is being presented to you on the basis that you will furnish this office a copy of your report on the results of your research.

There are numerous reports available through the Publication Board of the Department of Commerce concerning German development of fluorescent screens and photo-sensitive cells which I believe will be worth while in your work. I am in correspondence with Dr. Buckley, Dr. Bown, Mr. Quarles, Mr. Edwards, Mr. J. E. Clark and others of the Laboratories, who are familiar with the work of this Office, and it may be that you can obtain additional information in which you are interested from them.

I hope that you will obtain worth while information from this cell and would like to hear from you concerning your results.

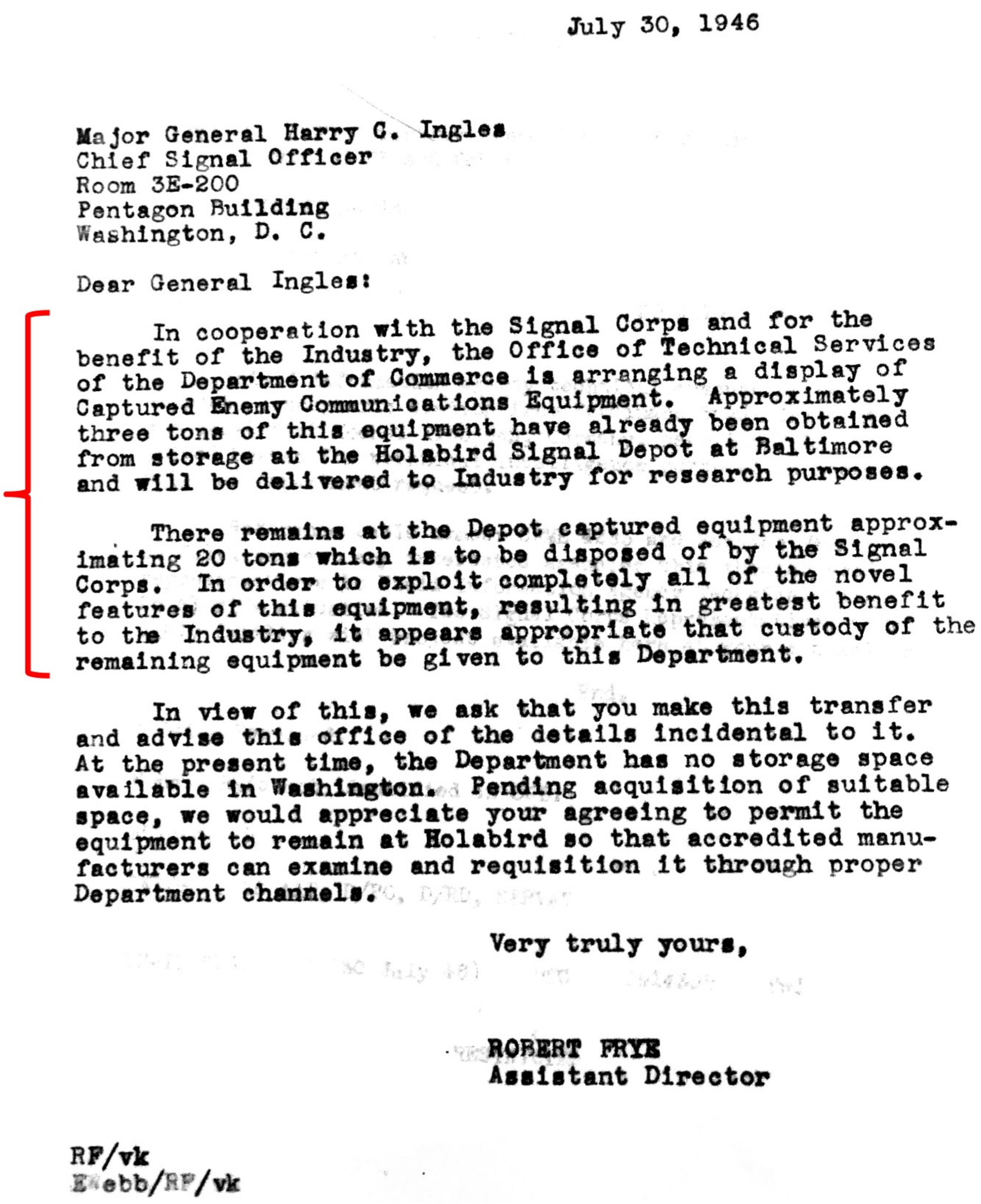
Sincerely yours,

Edwin Y. Webb, Jr.

Figure B.284: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

DECLASSIFIED
Authority NND968018

**NARA RG 40, Entry UD-75, Box 24,
Folder Evacuation of German Equipment**



July 30, 1946

Major General Harry C. Ingles
Chief Signal Officer
Room 3E-200
Pentagon Building
Washington, D. C.

Dear General Ingles:

In cooperation with the Signal Corps and for the benefit of the Industry, the Office of Technical Services of the Department of Commerce is arranging a display of Captured Enemy Communications Equipment. Approximately three tons of this equipment have already been obtained from storage at the Holabird Signal Depot at Baltimore and will be delivered to Industry for research purposes.

There remains at the Depot captured equipment approximating 20 tons which is to be disposed of by the Signal Corps. In order to exploit completely all of the novel features of this equipment, resulting in greatest benefit to the Industry, it appears appropriate that custody of the remaining equipment be given to this Department.

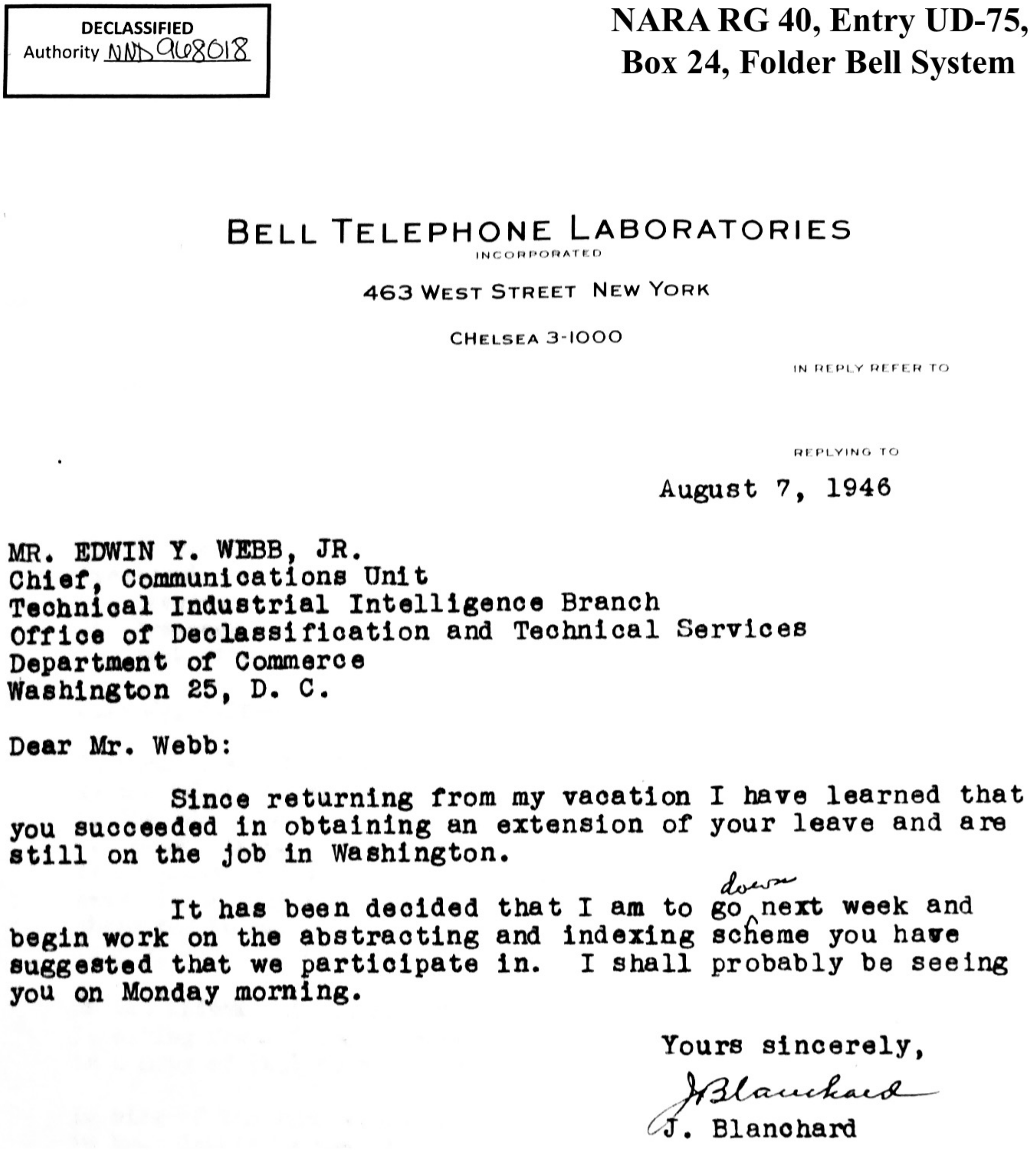
In view of this, we ask that you make this transfer and advise this office of the details incidental to it. At the present time, the Department has no storage space available in Washington. Pending acquisition of suitable space, we would appreciate your agreeing to permit the equipment to remain at Holabird so that accredited manufacturers can examine and requisition it through proper Department channels.

Very truly yours,

ROBERT FRYE
Assistant Director

RF/vk
E.Webb/RF/vk

Figure B.285: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Evacuation of German Equipment]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND 968018

NARA RG 40, Entry UD-75,
Box 24, Folder Bell System

BELL TELEPHONE LABORATORIES
INCORPORATED

463 WEST STREET NEW YORK

CHELSEA 3-1000

IN REPLY REFER TO

REPLYING TO

August 7, 1946

MR. EDWIN Y. WEBB, JR.
Chief, Communications Unit
Technical Industrial Intelligence Branch
Office of Declassification and Technical Services
Department of Commerce
Washington 25, D. C.

Dear Mr. Webb:

Since returning from my vacation I have learned that you succeeded in obtaining an extension of your leave and are still on the job in Washington.

It has been decided that I am to go down next week and begin work on the abstracting and indexing scheme you have suggested that we participate in. I shall probably be seeing you on Monday morning.

Yours sincerely,

J Blanchard

J. Blanchard

Figure B.286: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

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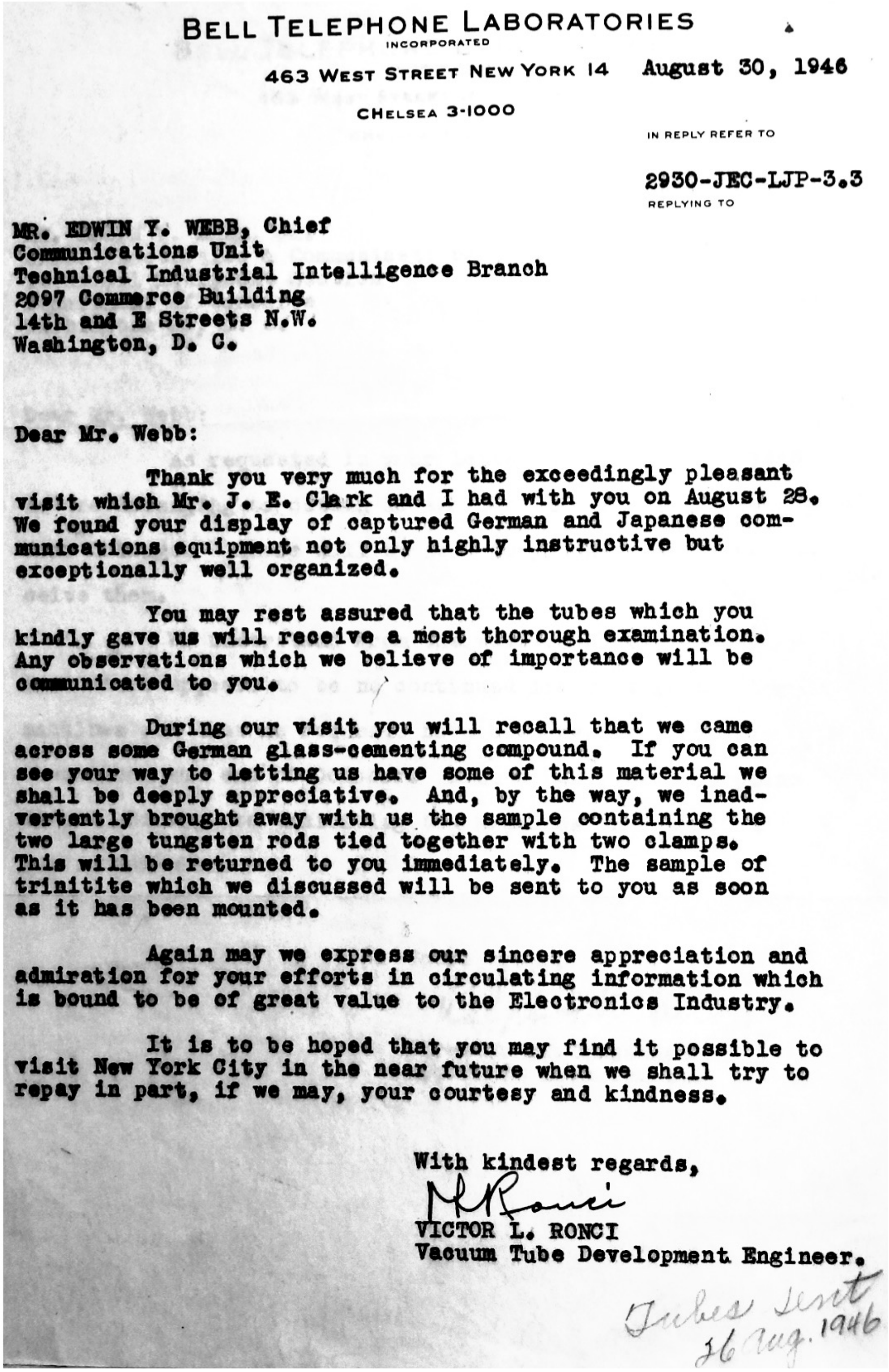
Authority NND968018

NARA RG 40, Entry UD-75, Box 24, Folder Bell System



BELL TELEPHONE LABORATORIES
INCORPORATED
463 WEST STREET NEW YORK 14
CHELSEA 3-1000

August 30, 1946

IN REPLY REFER TO
2930-JEC-LJP-3.3
REPLYING TO

MR. EDWIN Y. WEBB, Chief
Communications Unit
Technical Industrial Intelligence Branch
2097 Commerce Building
14th and E Streets N.W.
Washington, D. C.

Dear Mr. Webb:

Thank you very much for the exceedingly pleasant visit which Mr. J. E. Clark and I had with you on August 28. We found your display of captured German and Japanese communications equipment not only highly instructive but exceptionally well organized.

You may rest assured that the tubes which you kindly gave us will receive a most thorough examination. Any observations which we believe of importance will be communicated to you.

During our visit you will recall that we came across some German glass-cementing compound. If you can see your way to letting us have some of this material we shall be deeply appreciative. And, by the way, we inadvertently brought away with us the sample containing the two large tungsten rods tied together with two clamps. This will be returned to you immediately. The sample of trinitite which we discussed will be sent to you as soon as it has been mounted.

Again may we express our sincere appreciation and admiration for your efforts in circulating information which is bound to be of great value to the Electronics Industry.

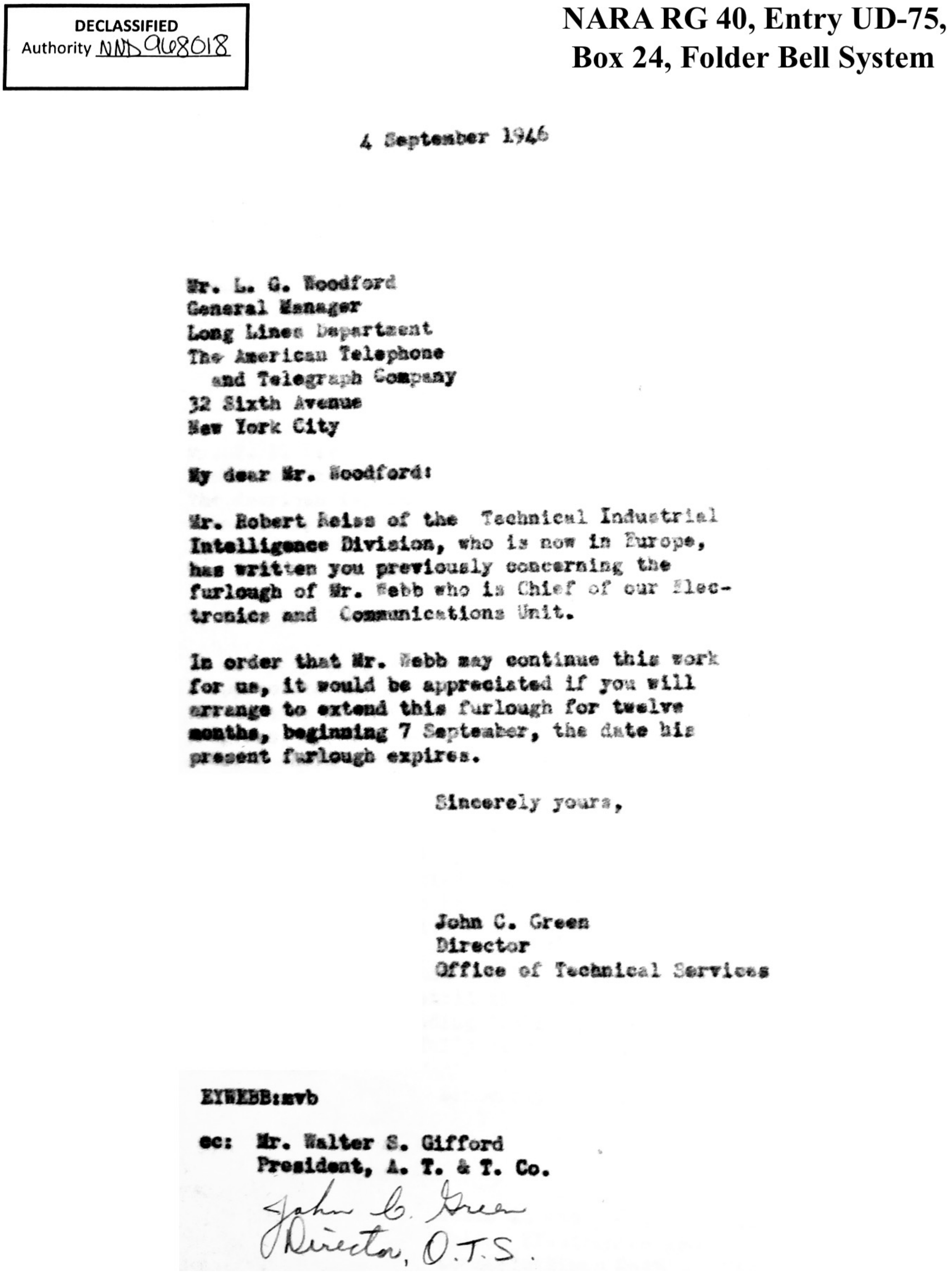
It is to be hoped that you may find it possible to visit New York City in the near future when we shall try to repay in part, if we may, your courtesy and kindness.

With kindest regards,

VLRonci
VICTOR L. RONCI
Vacuum Tube Development Engineer.

Tubes sent
26 Aug. 1946

Figure B.287: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND 968018

NARA RG 40, Entry UD-75, Box 24, Folder Bell System

4 September 1946

Mr. L. G. Woodford
General Manager
Long Lines Department
The American Telephone
and Telegraph Company
32 Sixth Avenue
New York City

My dear Mr. Woodford:

Mr. Robert Reiss of the Technical Industrial Intelligence Division, who is now in Europe, has written you previously concerning the furlough of Mr. Webb who is Chief of our Electronics and Communications Unit.

In order that Mr. Webb may continue this work for us, it would be appreciated if you will arrange to extend this furlough for twelve months, beginning 7 September, the date his present furlough expires.

Sincerely yours,

John C. Green
Director
Office of Technical Services

EYWEBB:mvb

cc: Mr. Walter S. Gifford
President, A. T. & T. Co.

John C. Green
Director, O.T.S.

Figure B.288: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

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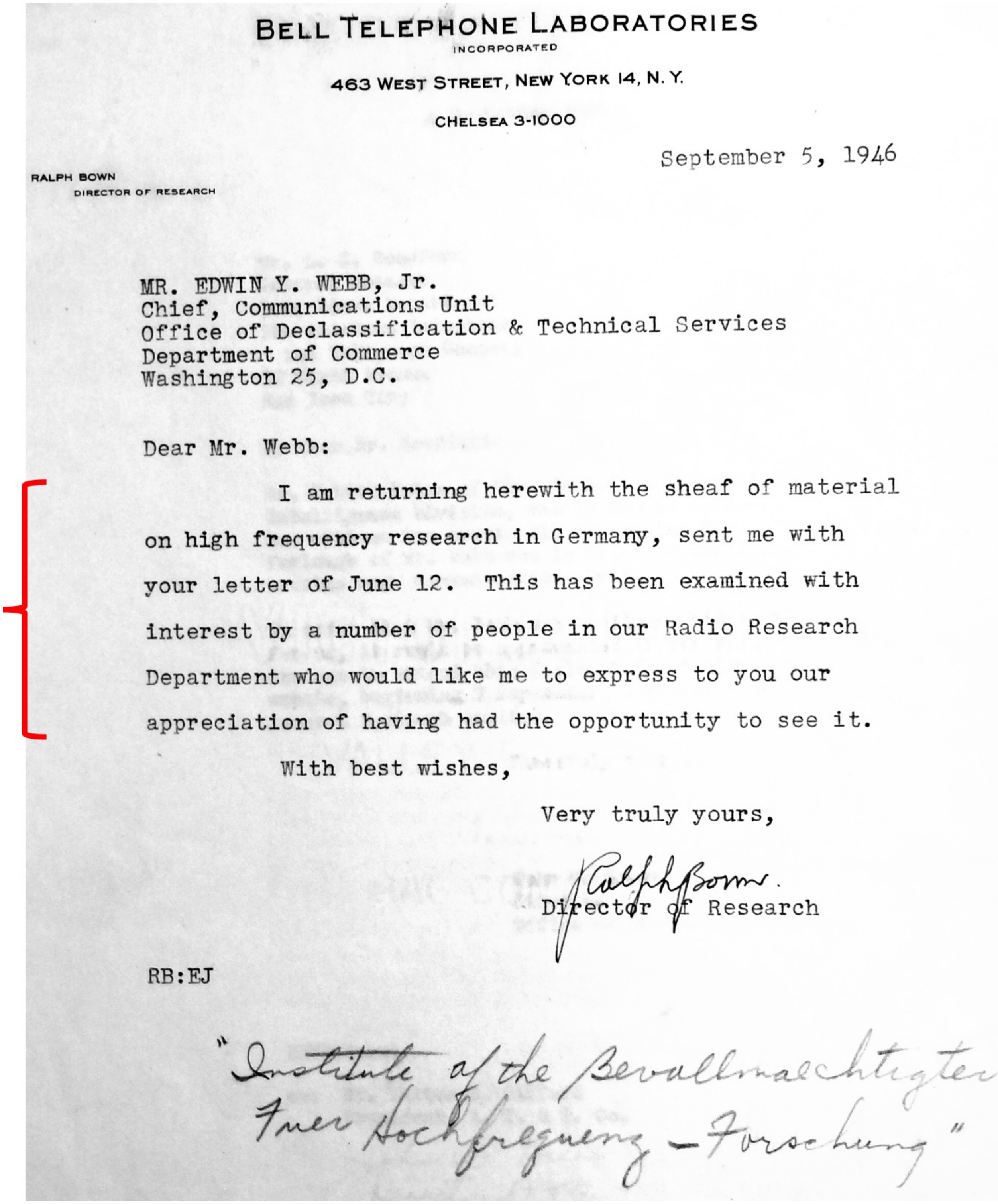
Authority NND968018

**NARA RG 40, Entry UD-75,
Box 24, Folder Bell System**



BELL TELEPHONE LABORATORIES
INCORPORATED
463 WEST STREET, NEW YORK 14, N. Y.
CHELSEA 3-1000

September 5, 1946

RALPH BOWN
DIRECTOR OF RESEARCH

MR. EDWIN Y. WEBB, Jr.
Chief, Communications Unit
Office of Declassification & Technical Services
Department of Commerce
Washington 25, D.C.

Dear Mr. Webb:

I am returning herewith the sheaf of material on high frequency research in Germany, sent me with your letter of June 12. This has been examined with interest by a number of people in our Radio Research Department who would like me to express to you our appreciation of having had the opportunity to see it.

With best wishes,

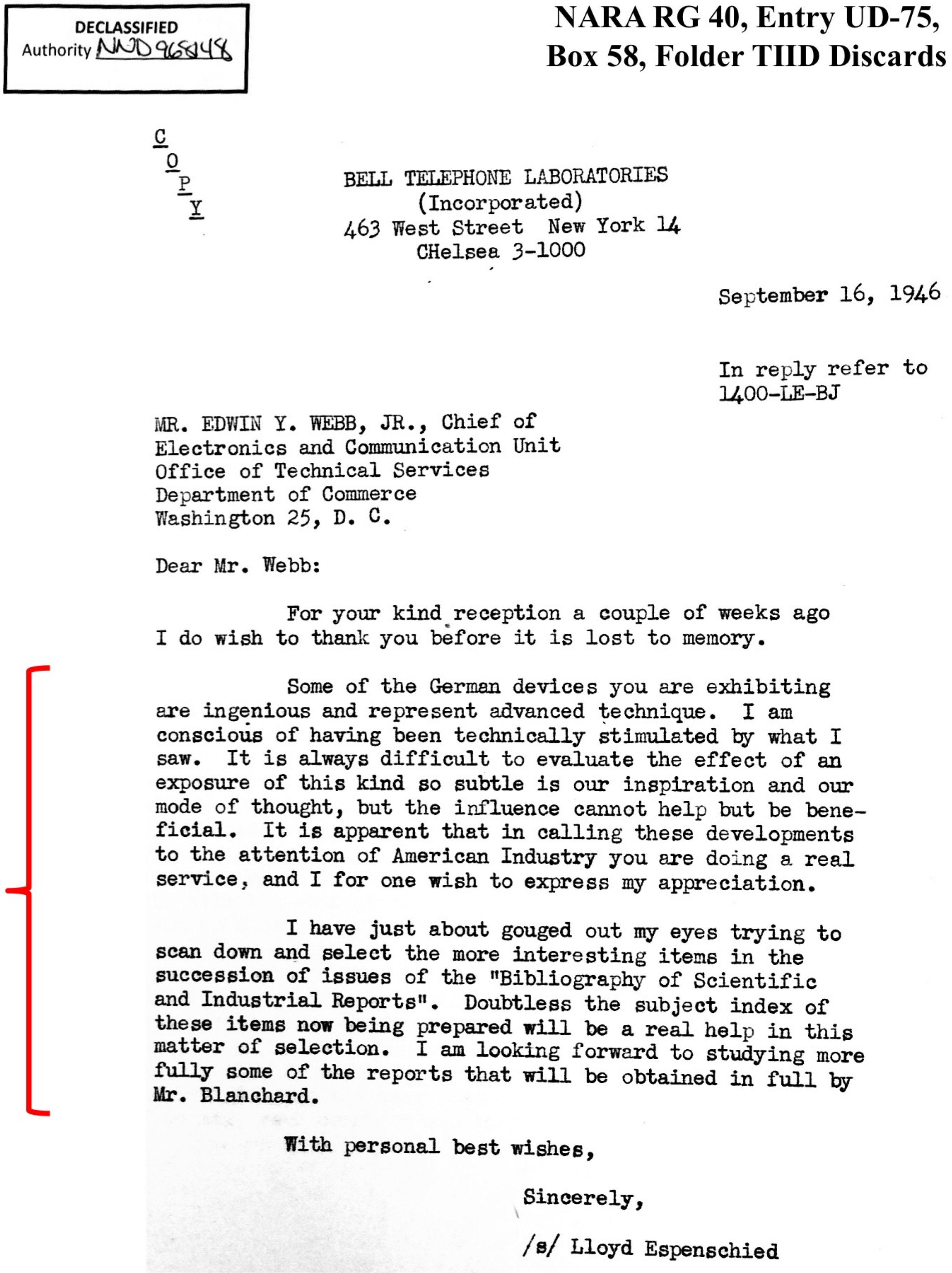
Very truly yours,

Ralph Bown.
Director of Research

RB:EJ

"~~Institute~~ of the Bevollmaechtigter
Fuer Hochfrequenz-Forschung"

Figure B.289: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND 968148

**NARA RG 40, Entry UD-75,
Box 58, Folder TIID Discards**

C
O
P
Y

BELL TELEPHONE LABORATORIES
(Incorporated)
463 West Street New York 14
CHelsea 3-1000

September 16, 1946

In reply refer to
1400-LE-BJ

MR. EDWIN Y. WEBB, JR., Chief of
Electronics and Communication Unit
Office of Technical Services
Department of Commerce
Washington 25, D. C.

Dear Mr. Webb:

For your kind reception a couple of weeks ago I do wish to thank you before it is lost to memory.

Some of the German devices you are exhibiting are ingenious and represent advanced technique. I am conscious of having been technically stimulated by what I saw. It is always difficult to evaluate the effect of an exposure of this kind so subtle is our inspiration and our mode of thought, but the influence cannot help but be beneficial. It is apparent that in calling these developments to the attention of American Industry you are doing a real service, and I for one wish to express my appreciation.

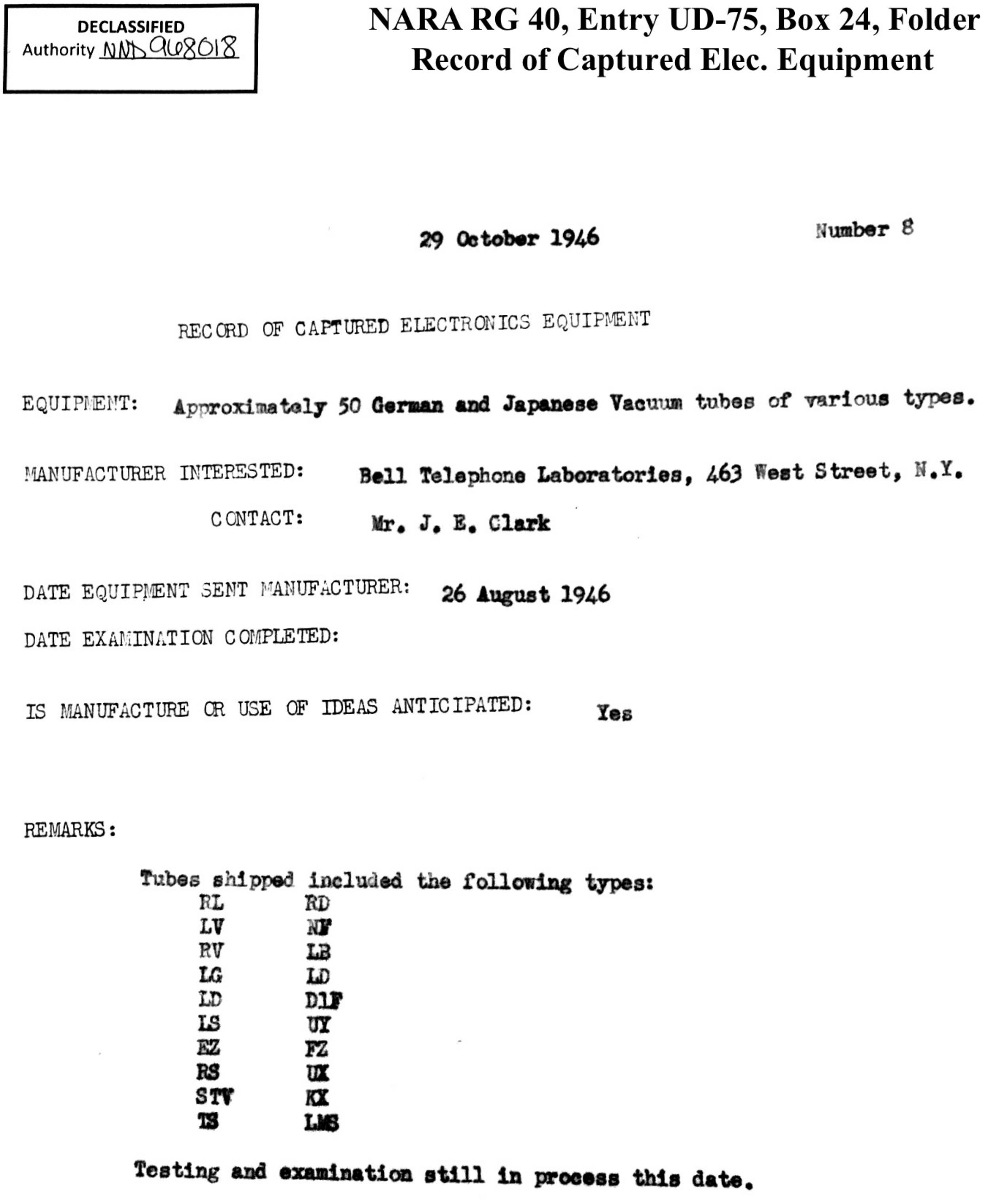
I have just about gouged out my eyes trying to scan down and select the more interesting items in the succession of issues of the "Bibliography of Scientific and Industrial Reports". Doubtless the subject index of these items now being prepared will be a real help in this matter of selection. I am looking forward to studying more fully some of the reports that will be obtained in full by Mr. Blanchard.

With personal best wishes,

Sincerely,

/s/ Lloyd Espenschied

Figure B.290: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND968018

NARA RG 40, Entry UD-75, Box 24, Folder
Record of Captured Elec. Equipment

29 October 1946 Number 8

RECORD OF CAPTURED ELECTRONICS EQUIPMENT

EQUIPMENT: Approximately 50 German and Japanese Vacuum tubes of various types.

MANUFACTURER INTERESTED: Bell Telephone Laboratories, 463 West Street, N.Y.

CONTACT: Mr. J. E. Clark

DATE EQUIPMENT SENT MANUFACTURER: 26 August 1946

DATE EXAMINATION COMPLETED:

IS MANUFACTURE OR USE OF IDEAS ANTICIPATED: Yes

REMARKS:

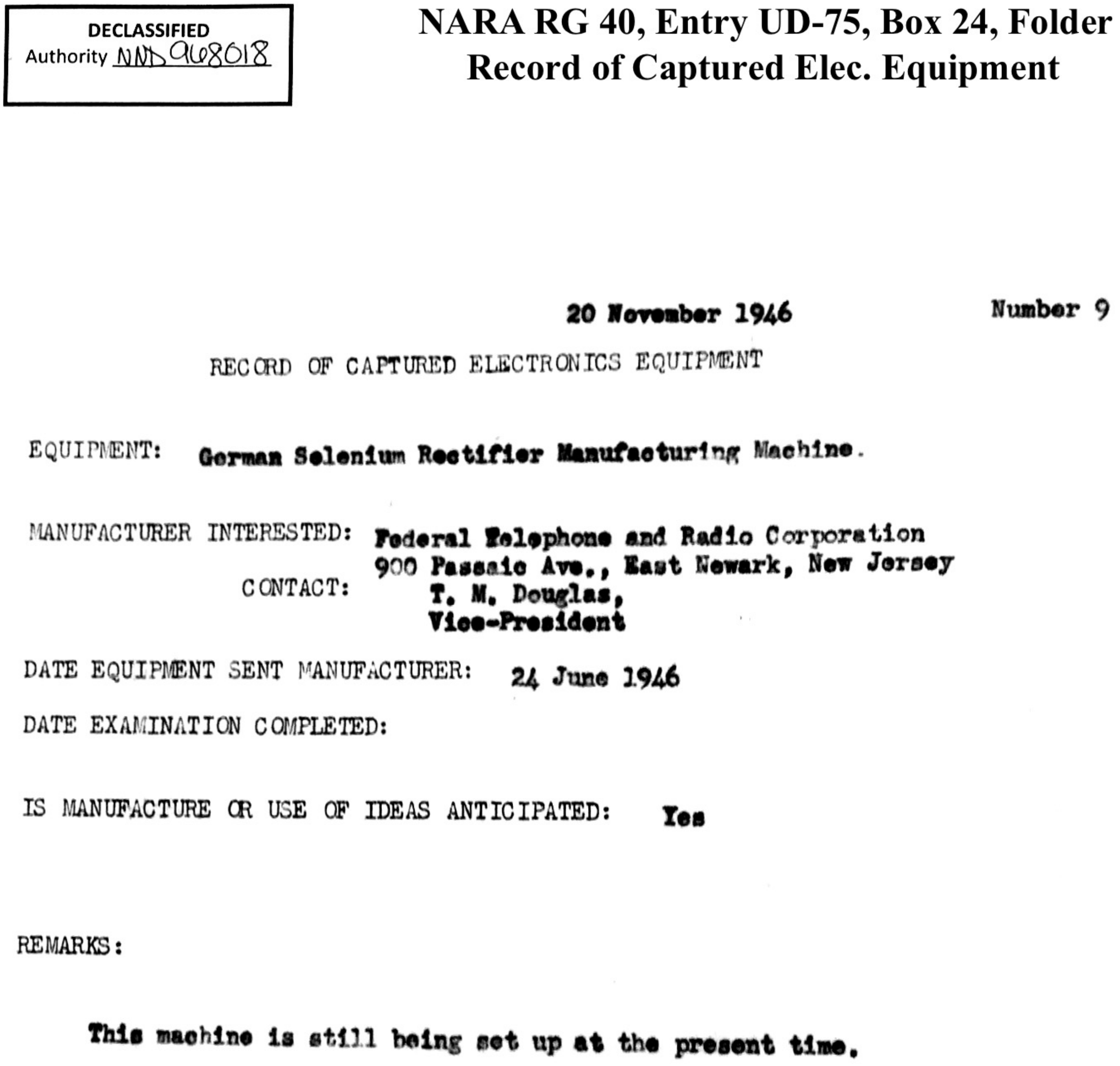
Tubes shipped included the following types:

RL
LV
RV
LG
LD
LS
EZ
RS
STV
TS

RD
NF
LB
LD
D1F
UY
FZ
UX
KX
LMS

Testing and examination still in process this date.

Figure B.291: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Record of Captured Elec. Equipment]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND968018

NARA RG 40, Entry UD-75, Box 24, Folder
Record of Captured Elec. Equipment

20 November 1946 **Number 9**

RECORD OF CAPTURED ELECTRONICS EQUIPMENT

EQUIPMENT: **German Selenium Rectifier Manufacturing Machine.**

MANUFACTURER INTERESTED: **Federal Telephone and Radio Corporation**
900 Passaic Ave., East Newark, New Jersey
CONTACT: **T. M. Douglas,**
Vice-President

DATE EQUIPMENT SENT MANUFACTURER: **24 June 1946**

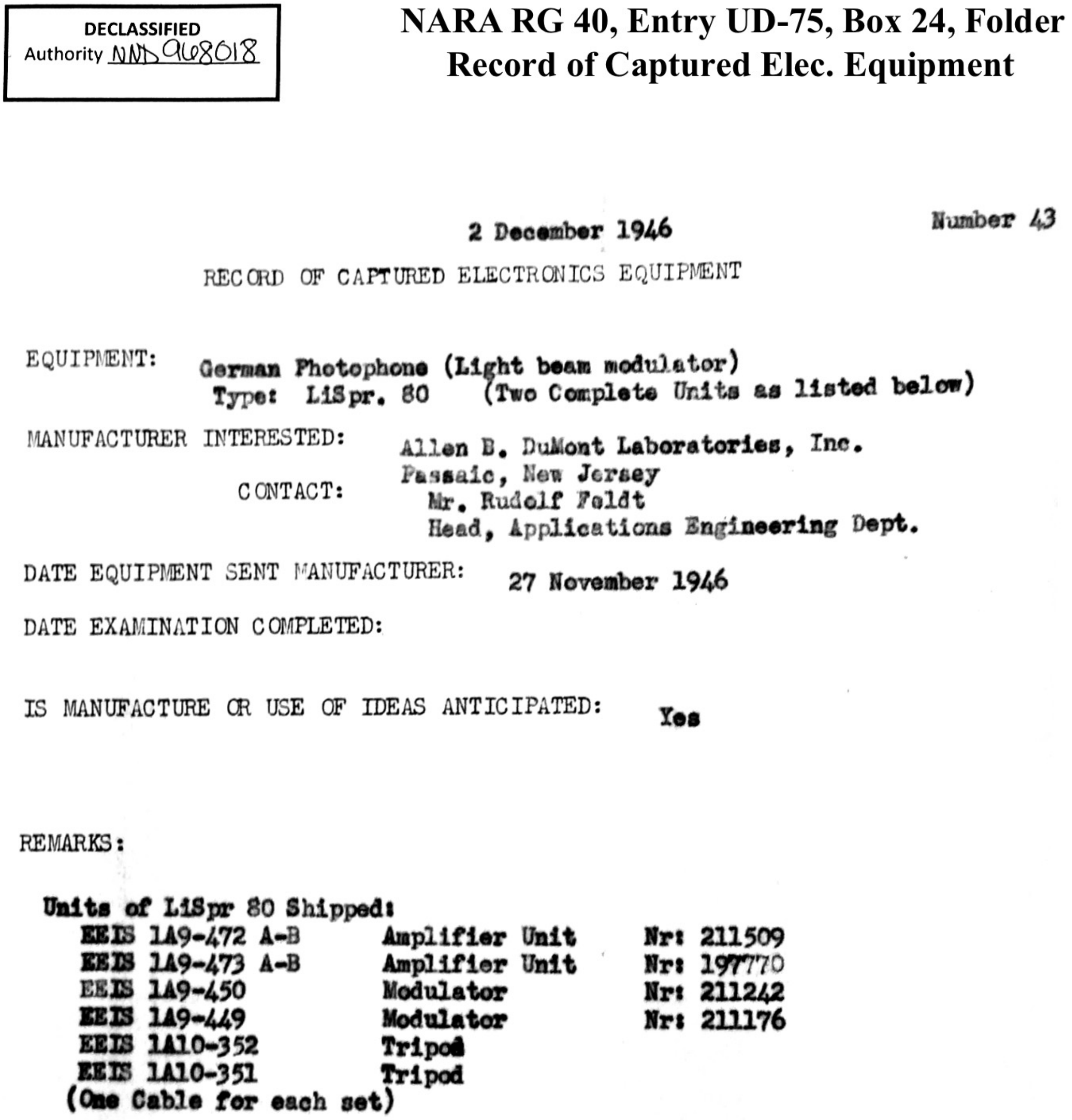
DATE EXAMINATION COMPLETED:

IS MANUFACTURE OR USE OF IDEAS ANTICIPATED: **Yes**

REMARKS:

This machine is still being set up at the present time.

Figure B.292: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Record of Captured Elec. Equipment]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND968018

NARA RG 40, Entry UD-75, Box 24, Folder Record of Captured Elec. Equipment

2 December 1946 Number 43

RECORD OF CAPTURED ELECTRONICS EQUIPMENT

EQUIPMENT: German Photophone (Light beam modulator)
Type: LiSpr. 80 (Two Complete Units as listed below)

MANUFACTURER INTERESTED: Allen B. DuMont Laboratories, Inc.
Passaic, New Jersey

CONTACT: Mr. Rudolf Feldt
Head, Applications Engineering Dept.

DATE EQUIPMENT SENT MANUFACTURER: 27 November 1946

DATE EXAMINATION COMPLETED:

IS MANUFACTURE OR USE OF IDEAS ANTICIPATED: Yes

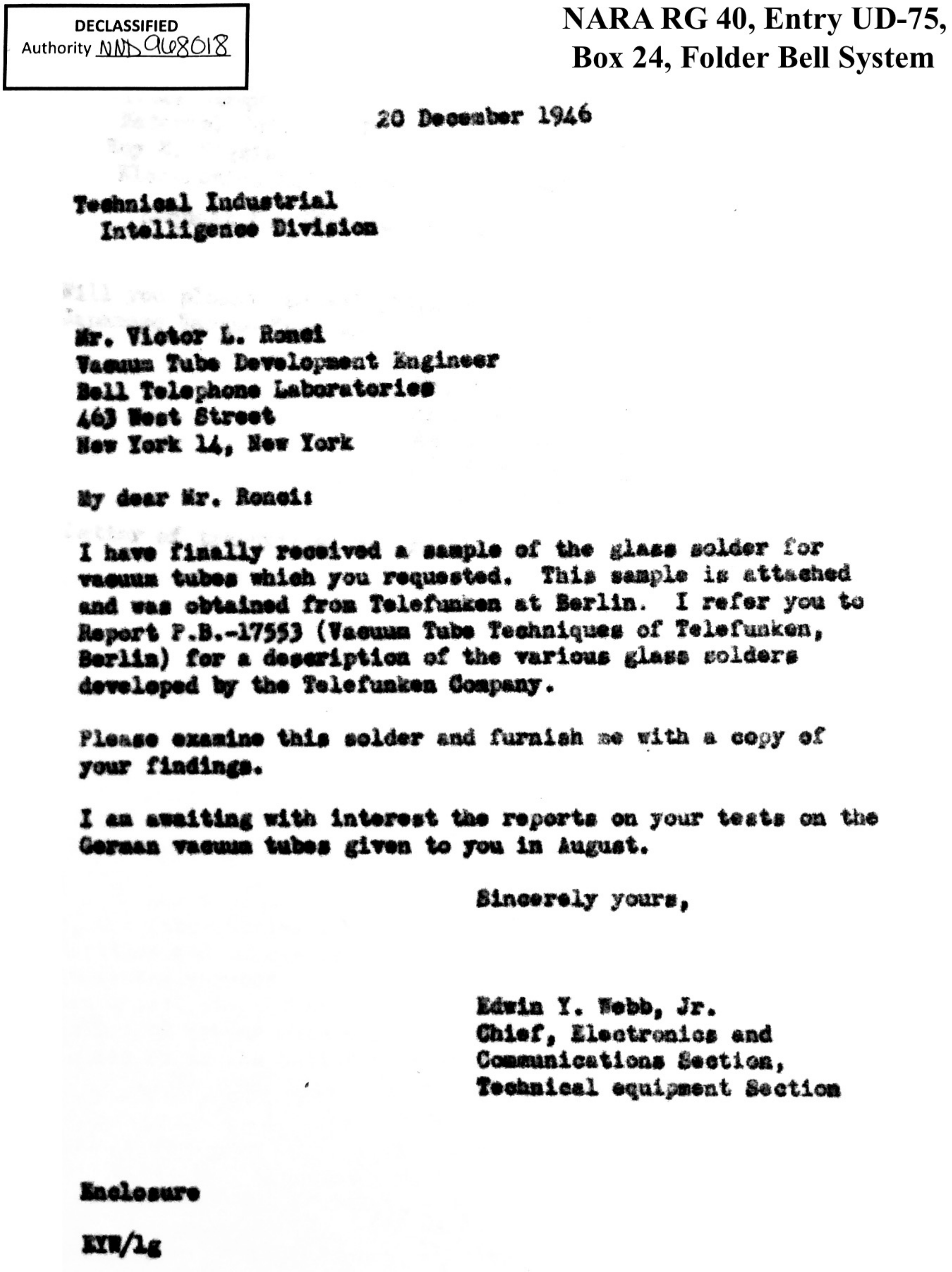
REMARKS:

Units of LiSpr 80 Shipped:

EEIS 1A9-472 A-B	Amplifier Unit	Nr: 211509
EEIS 1A9-473 A-B	Amplifier Unit	Nr: 197770
EEIS 1A9-450	Modulator	Nr: 211242
EEIS 1A9-449	Modulator	Nr: 211176
EEIS 1A10-352	Tripod	
EEIS 1A10-351	Tripod	

(One Cable for each set)

Figure B.293: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Record of Captured Elec. Equipment]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND 968018

NARA RG 40, Entry UD-75,
Box 24, Folder Bell System

20 December 1946

Technical Industrial
Intelligence Division

Mr. Victor L. Ronci
Vacuum Tube Development Engineer
Bell Telephone Laboratories
463 West Street
New York 14, New York

My dear Mr. Ronci:

I have finally received a sample of the glass solder for vacuum tubes which you requested. This sample is attached and was obtained from Telefunken at Berlin. I refer you to Report P.B.-17553 (Vacuum Tube Techniques of Telefunken, Berlin) for a description of the various glass solders developed by the Telefunken Company.

Please examine this solder and furnish me with a copy of your findings.

I am awaiting with interest the reports on your tests on the German vacuum tubes given to you in August.

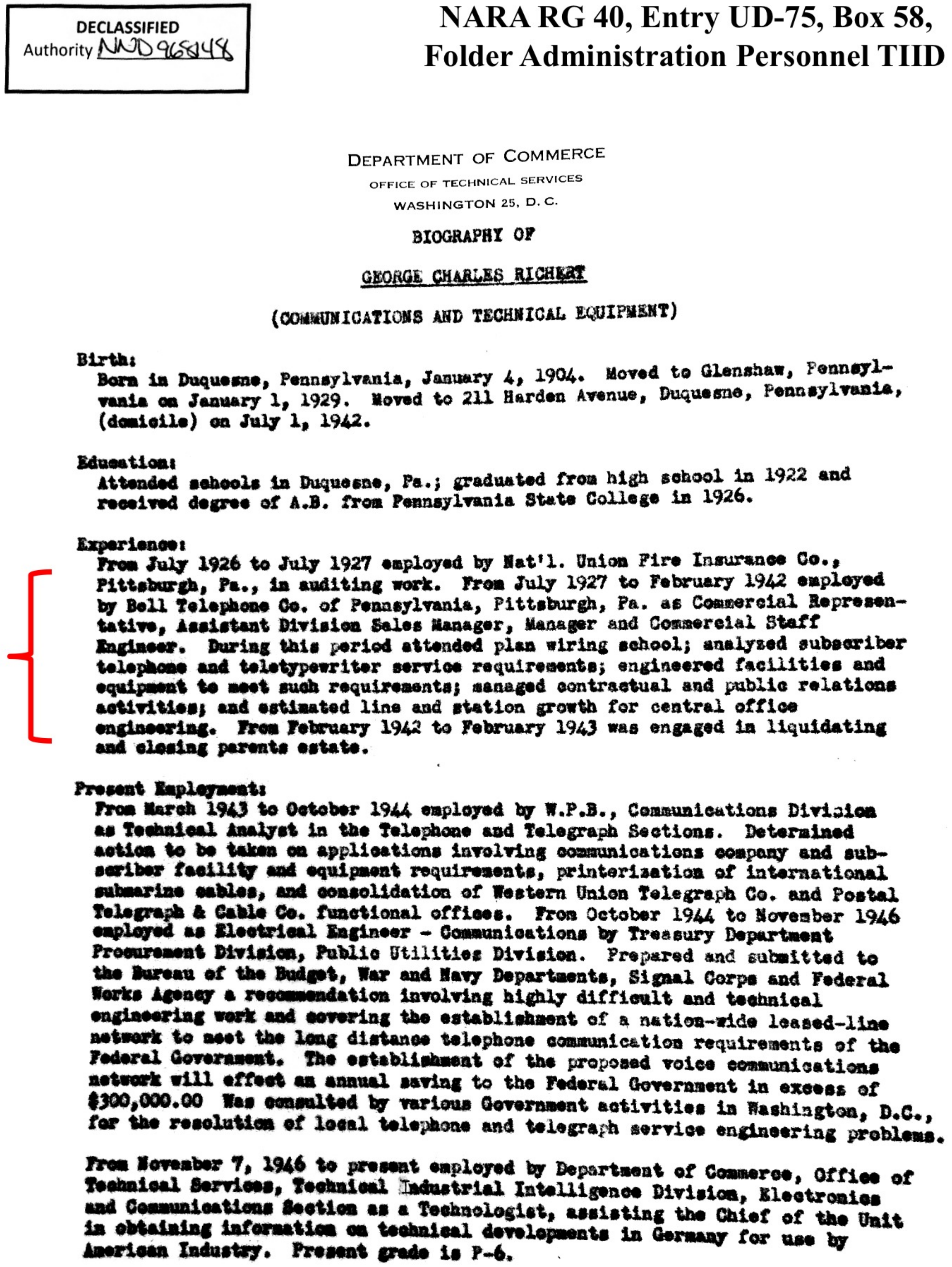
Sincerely yours,

Edwin Y. Webb, Jr.
Chief, Electronics and
Communications Section,
Technical equipment Section

Enclosure

EYW/lg

Figure B.294: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND 968148

NARA RG 40, Entry UD-75, Box 58, Folder Administration Personnel TIID

DEPARTMENT OF COMMERCE
OFFICE OF TECHNICAL SERVICES
WASHINGTON 25, D. C.

BIOGRAPHY OF

GEORGE CHARLES RICHERT

(COMMUNICATIONS AND TECHNICAL EQUIPMENT)

Birth:
Born in Duquesne, Pennsylvania, January 4, 1904. Moved to Glenshaw, Pennsylvania on January 1, 1929. Moved to 211 Harden Avenue, Duquesne, Pennsylvania, (domicile) on July 1, 1942.

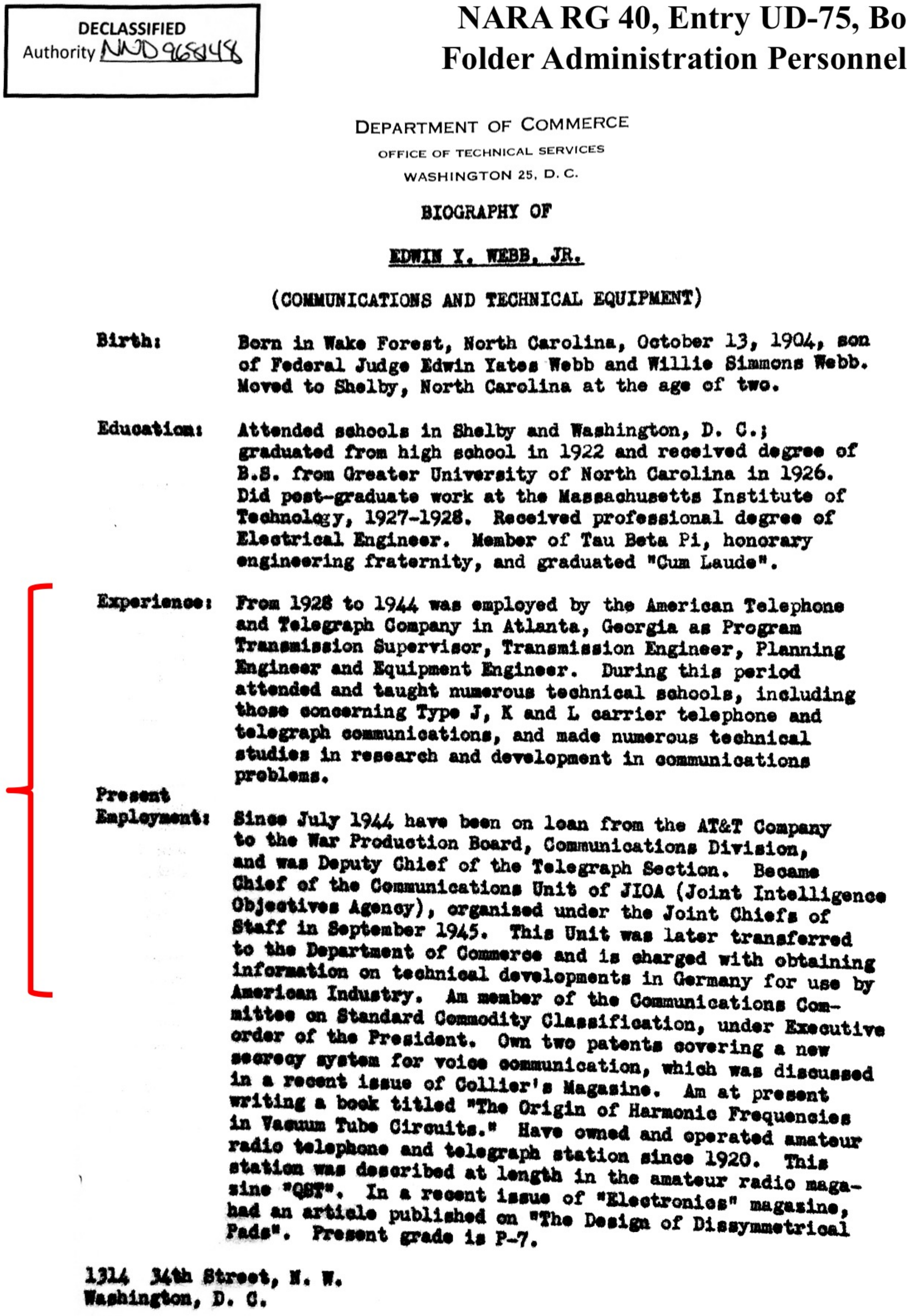
Education:
Attended schools in Duquesne, Pa.; graduated from high school in 1922 and received degree of A.B. from Pennsylvania State College in 1926.

Experience:
From July 1926 to July 1927 employed by Nat'l. Union Fire Insurance Co., Pittsburgh, Pa., in auditing work. From July 1927 to February 1942 employed by Bell Telephone Co. of Pennsylvania, Pittsburgh, Pa. as Commercial Representative, Assistant Division Sales Manager, Manager and Commercial Staff Engineer. During this period attended plan wiring school; analyzed subscriber telephone and teletypewriter service requirements; engineered facilities and equipment to meet such requirements; managed contractual and public relations activities; and estimated line and station growth for central office engineering. From February 1942 to February 1943 was engaged in liquidating and closing parents estate.

Present Employment:
From March 1943 to October 1944 employed by W.P.B., Communications Division as Technical Analyst in the Telephone and Telegraph Sections. Determined action to be taken on applications involving communications company and subscriber facility and equipment requirements, printerization of international submarine cables, and consolidation of Western Union Telegraph Co. and Postal Telegraph & Cable Co. functional offices. From October 1944 to November 1946 employed as Electrical Engineer - Communications by Treasury Department Procurement Division, Public Utilities Division. Prepared and submitted to the Bureau of the Budget, War and Navy Departments, Signal Corps and Federal Works Agency a recommendation involving highly difficult and technical engineering work and covering the establishment of a nation-wide leased-line network to meet the long distance telephone communication requirements of the Federal Government. The establishment of the proposed voice communications network will effect an annual saving to the Federal Government in excess of $300,000.00 Was consulted by various Government activities in Washington, D.C., for the resolution of local telephone and telegraph service engineering problems.

From November 7, 1946 to present employed by Department of Commerce, Office of Technical Services, Technical Industrial Intelligence Division, Electronics and Communications Section as a Technologist, assisting the Chief of the Unit in obtaining information on technical developments in Germany for use by American Industry. Present grade is P-6.

Figure B.295: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 58, Folder Administration Personnel TIID]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND 968148

NARA RG 40, Entry UD-75, Box 58, Folder Administration Personnel TIID

DEPARTMENT OF COMMERCE
OFFICE OF TECHNICAL SERVICES
WASHINGTON 25, D. C.

BIOGRAPHY OF

EDWIN Y. WEBB, JR.

(COMMUNICATIONS AND TECHNICAL EQUIPMENT)

Birth: Born in Wake Forest, North Carolina, October 13, 1904, son of Federal Judge Edwin Yates Webb and Willie Simmons Webb. Moved to Shelby, North Carolina at the age of two.

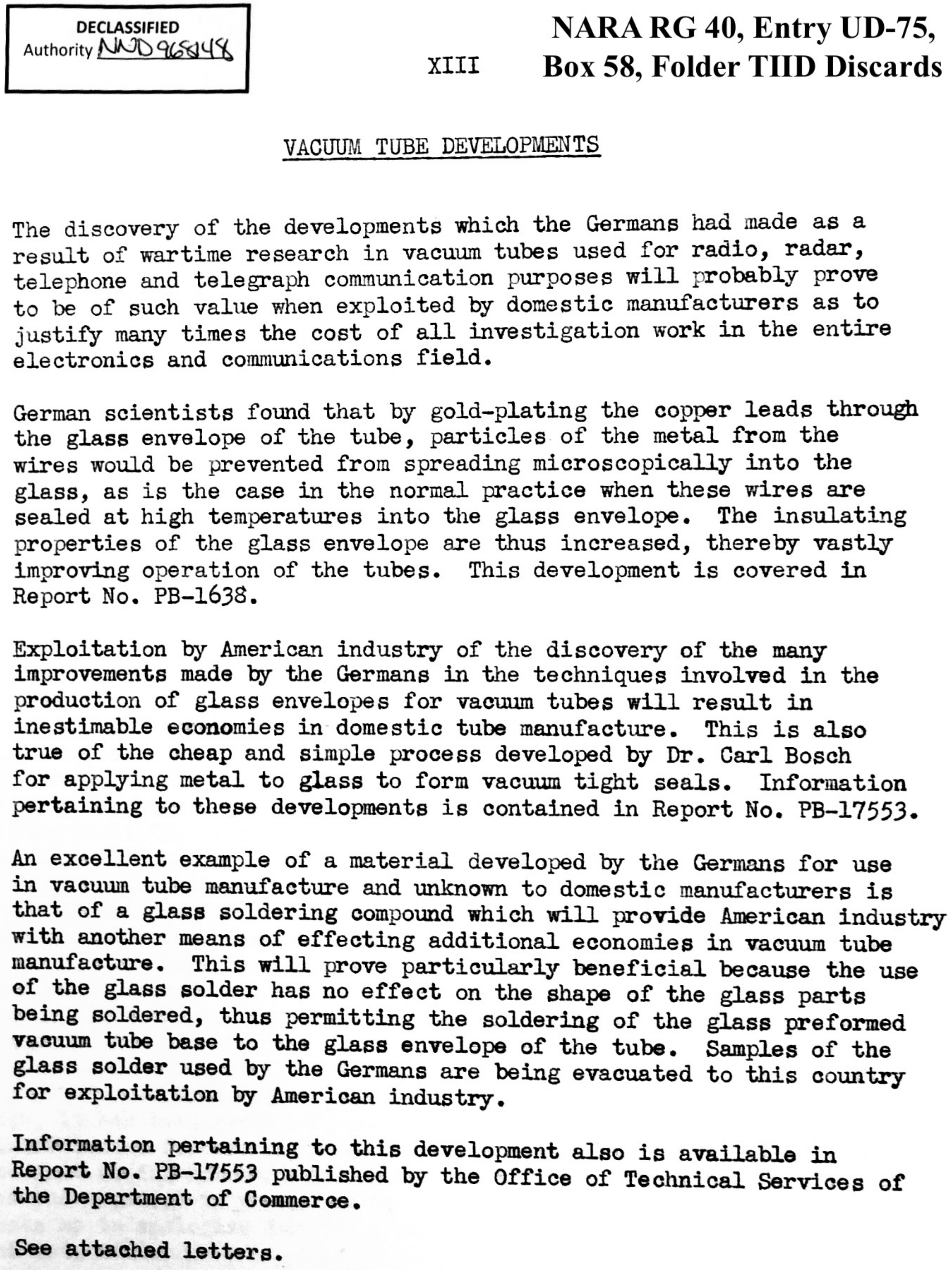
Education: Attended schools in Shelby and Washington, D. C.; graduated from high school in 1922 and received degree of B.S. from Greater University of North Carolina in 1926. Did post-graduate work at the Massachusetts Institute of Technology, 1927-1928. Received professional degree of Electrical Engineer. Member of Tau Beta Pi, honorary engineering fraternity, and graduated "Cum Laude".

Experience: From 1928 to 1944 was employed by the American Telephone and Telegraph Company in Atlanta, Georgia as Program Transmission Supervisor, Transmission Engineer, Planning Engineer and Equipment Engineer. During this period attended and taught numerous technical schools, including those concerning Type J, K and L carrier telephone and telegraph communications, and made numerous technical studies in research and development in communications problems.

Present Employment: Since July 1944 have been on loan from the AT&T Company to the War Production Board, Communications Division, and was Deputy Chief of the Telegraph Section. Became Chief of the Communications Unit of JIOA (Joint Intelligence Objectives Agency), organised under the Joint Chiefs of Staff in September 1945. This Unit was later transferred to the Department of Commerce and is charged with obtaining information on technical developments in Germany for use by American Industry. Am member of the Communications Committee on Standard Commodity Classification, under Executive order of the President. Own two patents covering a new secrecy system for voice communication, which was discussed in a recent issue of Collier's Magazine. Am at present writing a book titled "The Origin of Harmonic Frequencies in Vacuum Tube Circuits." Have owned and operated amateur radio telephone and telegraph station since 1920. This station was described at length in the amateur radio magazine "QST". In a recent issue of "Electronics" magazine, had an article published on "The Design of Dissymmetrical Pads". Present grade is P-7.

1314 34th Street, N. W.
Washington, D. C.

Figure B.296: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 58, Folder Administration Personnel TIID]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



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XIII

NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards

VACUUM TUBE DEVELOPMENTS

The discovery of the developments which the Germans had made as a result of wartime research in vacuum tubes used for radio, radar, telephone and telegraph communication purposes will probably prove to be of such value when exploited by domestic manufacturers as to justify many times the cost of all investigation work in the entire electronics and communications field.

German scientists found that by gold-plating the copper leads through the glass envelope of the tube, particles of the metal from the wires would be prevented from spreading microscopically into the glass, as is the case in the normal practice when these wires are sealed at high temperatures into the glass envelope. The insulating properties of the glass envelope are thus increased, thereby vastly improving operation of the tubes. This development is covered in Report No. PB-1638.

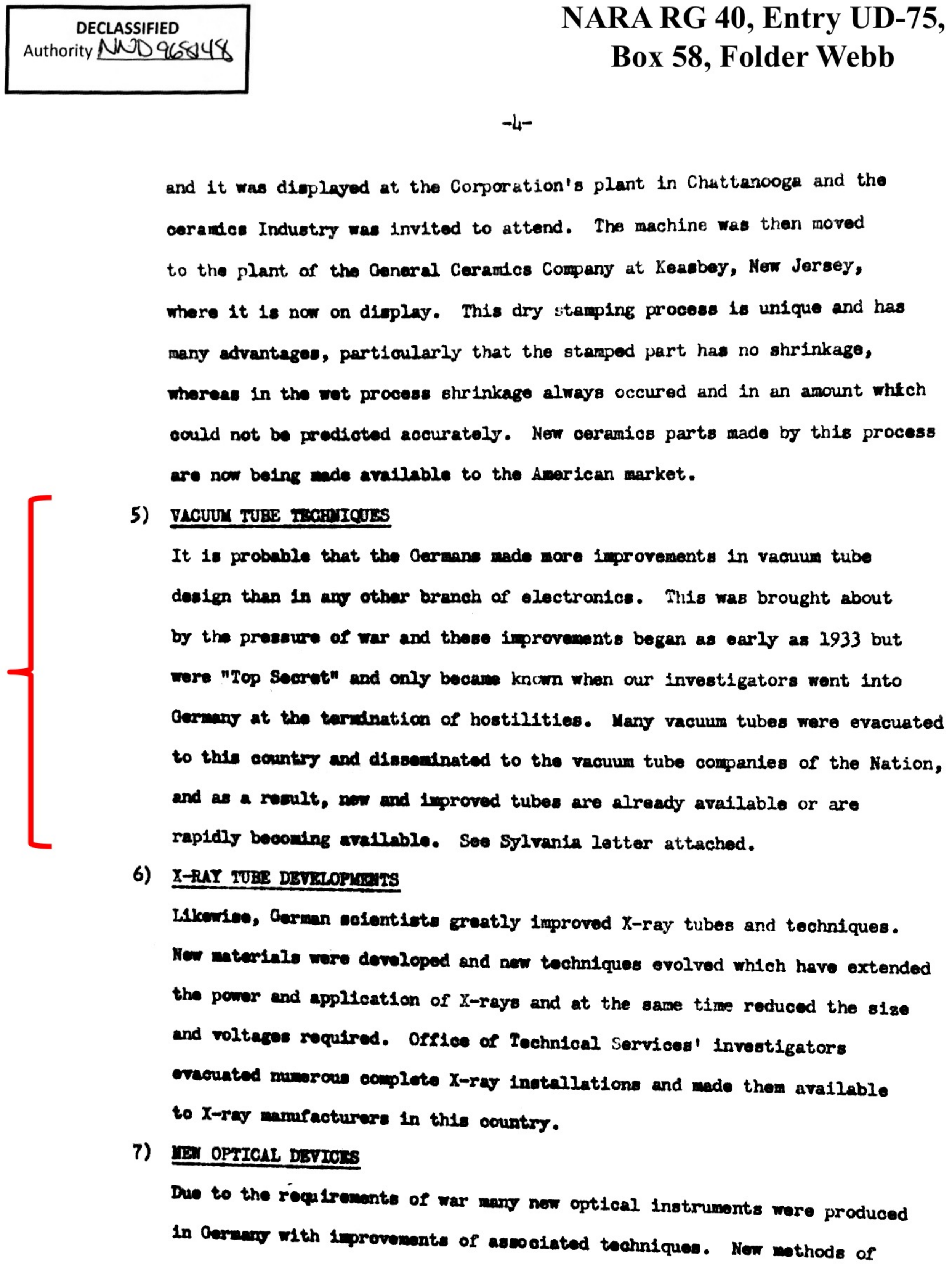
Exploitation by American industry of the discovery of the many improvements made by the Germans in the techniques involved in the production of glass envelopes for vacuum tubes will result in inestimable economies in domestic tube manufacture. This is also true of the cheap and simple process developed by Dr. Carl Bosch for applying metal to glass to form vacuum tight seals. Information pertaining to these developments is contained in Report No. PB-17553.

An excellent example of a material developed by the Germans for use in vacuum tube manufacture and unknown to domestic manufacturers is that of a glass soldering compound which will provide American industry with another means of effecting additional economies in vacuum tube manufacture. This will prove particularly beneficial because the use of the glass solder has no effect on the shape of the glass parts being soldered, thus permitting the soldering of the glass preformed vacuum tube base to the glass envelope of the tube. Samples of the glass solder used by the Germans are being evacuated to this country for exploitation by American industry.

Information pertaining to this development also is available in Report No. PB-17553 published by the Office of Technical Services of the Department of Commerce.

See attached letters.

Figure B.297: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



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Authority NND 968148

NARA RG 40, Entry UD-75, Box 58, Folder Webb

-4-

and it was displayed at the Corporation's plant in Chattanooga and the ceramics Industry was invited to attend. The machine was then moved to the plant of the General Ceramics Company at Keasbey, New Jersey, where it is now on display. This dry stamping process is unique and has many advantages, particularly that the stamped part has no shrinkage, whereas in the wet process shrinkage always occured and in an amount which could not be predicted accurately. New ceramics parts made by this process are now being made available to the American market.

5) VACUUM TUBE TECHNIQUES

It is probable that the Germans made more improvements in vacuum tube design than in any other branch of electronics. This was brought about by the pressure of war and these improvements began as early as 1933 but were "Top Secret" and only became known when our investigators went into Germany at the termination of hostilities. Many vacuum tubes were evacuated to this country and disseminated to the vacuum tube companies of the Nation, and as a result, new and improved tubes are already available or are rapidly becoming available. See Sylvania letter attached.

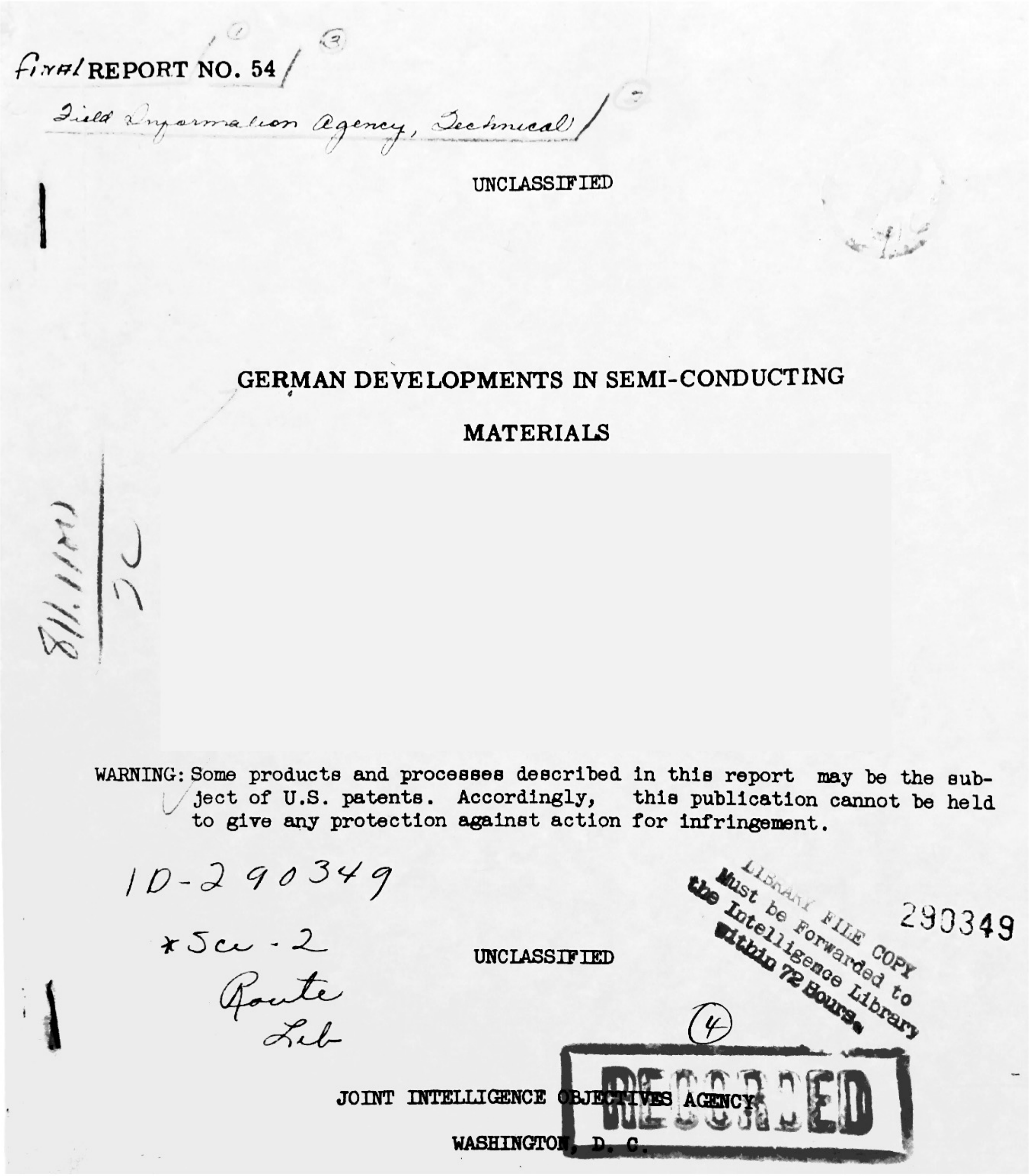
6) X-RAY TUBE DEVELOPMENTS

Likewise, German scientists greatly improved X-ray tubes and techniques. New materials were developed and new techniques evolved which have extended the power and application of X-rays and at the same time reduced the size and voltages required. Office of Technical Services' investigators evacuated numerous complete X-ray installations and made them available to X-ray manufacturers in this country.

7) NEW OPTICAL DEVICES

Due to the requirements of war many new optical instruments were produced in Germany with improvements of associated techniques. New methods of

Figure B.298: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 58, Folder Webb]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



final REPORT NO. 54

Field Information Agency, Technical

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GERMAN DEVELOPMENTS IN SEMI-CONDUCTING MATERIALS

WARNING: Some products and processes described in this report may be the subject of U.S. patents. Accordingly, this publication cannot be held to give any protection against action for infringement.

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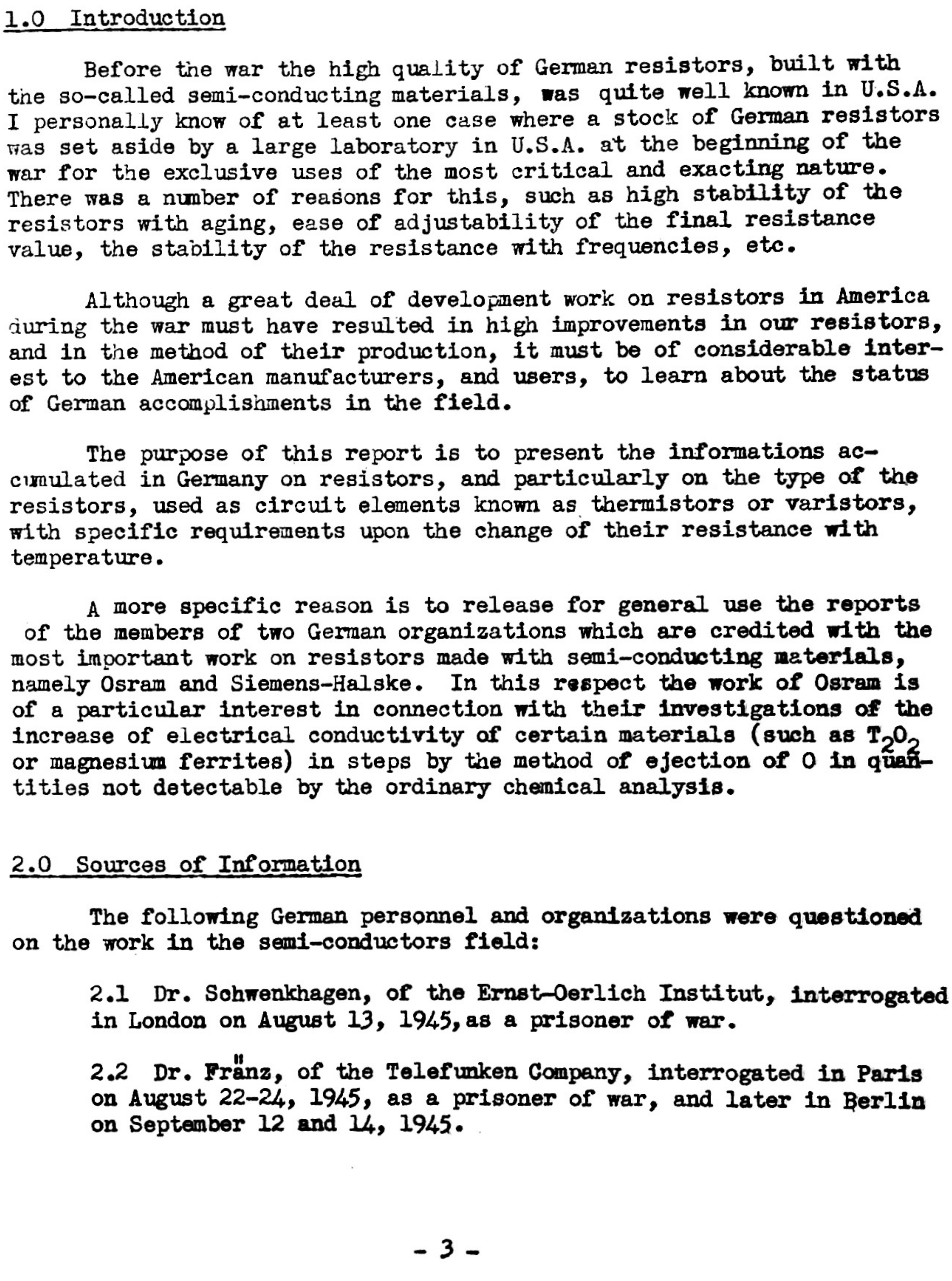
WASHINGTON, D. C.

Figure B.299: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [FIAT 54]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



1.0 Introduction

Before the war the high quality of German resistors, built with the so-called semi-conducting materials, was quite well known in U.S.A. I personally know of at least one case where a stock of German resistors was set aside by a large laboratory in U.S.A. at the beginning of the war for the exclusive uses of the most critical and exacting nature. There was a number of reasons for this, such as high stability of the resistors with aging, ease of adjustability of the final resistance value, the stability of the resistance with frequencies, etc.

Although a great deal of development work on resistors in America during the war must have resulted in high improvements in our resistors, and in the method of their production, it must be of considerable interest to the American manufacturers, and users, to learn about the status of German accomplishments in the field.

The purpose of this report is to present the informations accumulated in Germany on resistors, and particularly on the type of the resistors, used as circuit elements known as thermistors or varistors, with specific requirements upon the change of their resistance with temperature.

A more specific reason is to release for general use the reports of the members of two German organizations which are credited with the most important work on resistors made with semi-conducting materials, namely Osram and Siemens-Halske. In this respect the work of Osram is of a particular interest in connection with their investigations of the increase of electrical conductivity of certain materials (such as T_2O_2 or magnesium ferrites) in steps by the method of ejection of O in quantities not detectable by the ordinary chemical analysis.

2.0 Sources of Information

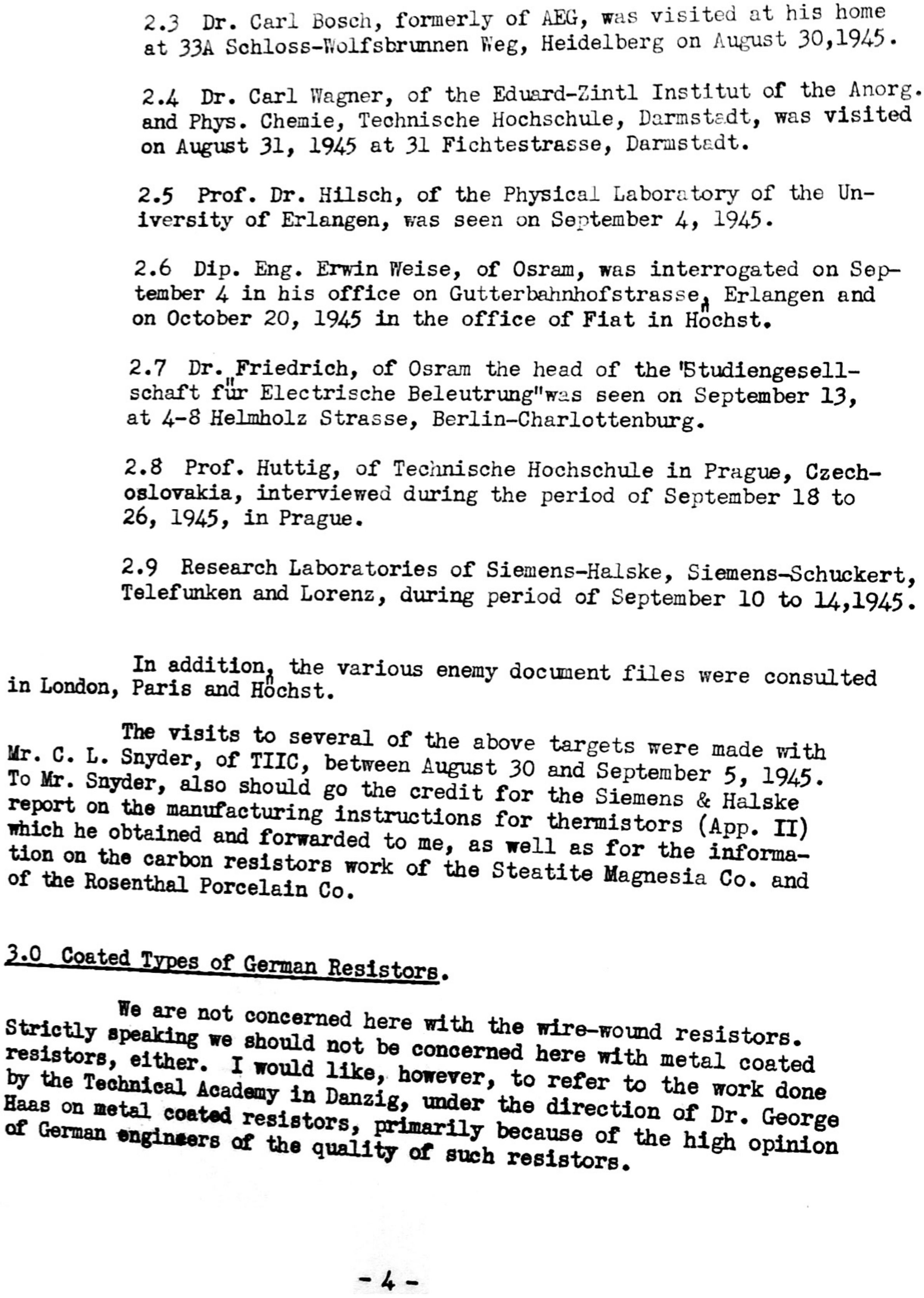
The following German personnel and organizations were questioned on the work in the semi-conductors field:

2.1 Dr. Schwenkhagen, of the Ernst-Oerlich Institut, interrogated in London on August 13, 1945, as a prisoner of war.

2.2 Dr. Fränz, of the Telefunken Company, interrogated in Paris on August 22-24, 1945, as a prisoner of war, and later in Berlin on September 12 and 14, 1945.

- 3 -

Figure B.300: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [FIAT 54]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



2.3 Dr. Carl Bosch, formerly of AEG, was visited at his home at 33A Schloss-Wolfsbrunnen Weg, Heidelberg on August 30,1945.

2.4 Dr. Carl Wagner, of the Eduard-Zintl Institut of the Anorg. and Phys. Chemie, Technische Hochschule, Darmstadt, was visited on August 31, 1945 at 31 Fichtestrasse, Darmstadt.

2.5 Prof. Dr. Hilsch, of the Physical Laboratory of the University of Erlangen, was seen on September 4, 1945.

2.6 Dip. Eng. Erwin Weise, of Osram, was interrogated on September 4 in his office on Gutterbahnhofstrasse, Erlangen and on October 20, 1945 in the office of Fiat in Höchst.

2.7 Dr. Friedrich, of Osram the head of the "Studiengesellschaft für Electrische Beleutrung" was seen on September 13, at 4-8 Helmholz Strasse, Berlin-Charlottenburg.

2.8 Prof. Huttig, of Technische Hochschule in Prague, Czechoslovakia, interviewed during the period of September 18 to 26, 1945, in Prague.

2.9 Research Laboratories of Siemens-Halske, Siemens-Schuckert, Telefunken and Lorenz, during period of September 10 to 14,1945.

In addition, the various enemy document files were consulted in London, Paris and Höchst.

The visits to several of the above targets were made with Mr. C. L. Snyder, of TIIC, between August 30 and September 5, 1945. To Mr. Snyder, also should go the credit for the Siemens & Halske report on the manufacturing instructions for thermistors (App. II) which he obtained and forwarded to me, as well as for the information on the carbon resistors work of the Steatite Magnesia Co. and of the Rosenthal Porcelain Co.

3.0 Coated Types of German Resistors.

We are not concerned here with the wire-wound resistors. Strictly speaking we should not be concerned here with metal coated resistors, either. I would like, however, to refer to the work done by the Technical Academy in Danzig, under the direction of Dr. George Haas on metal coated resistors, primarily because of the high opinion of German engineers of the quality of such resistors.

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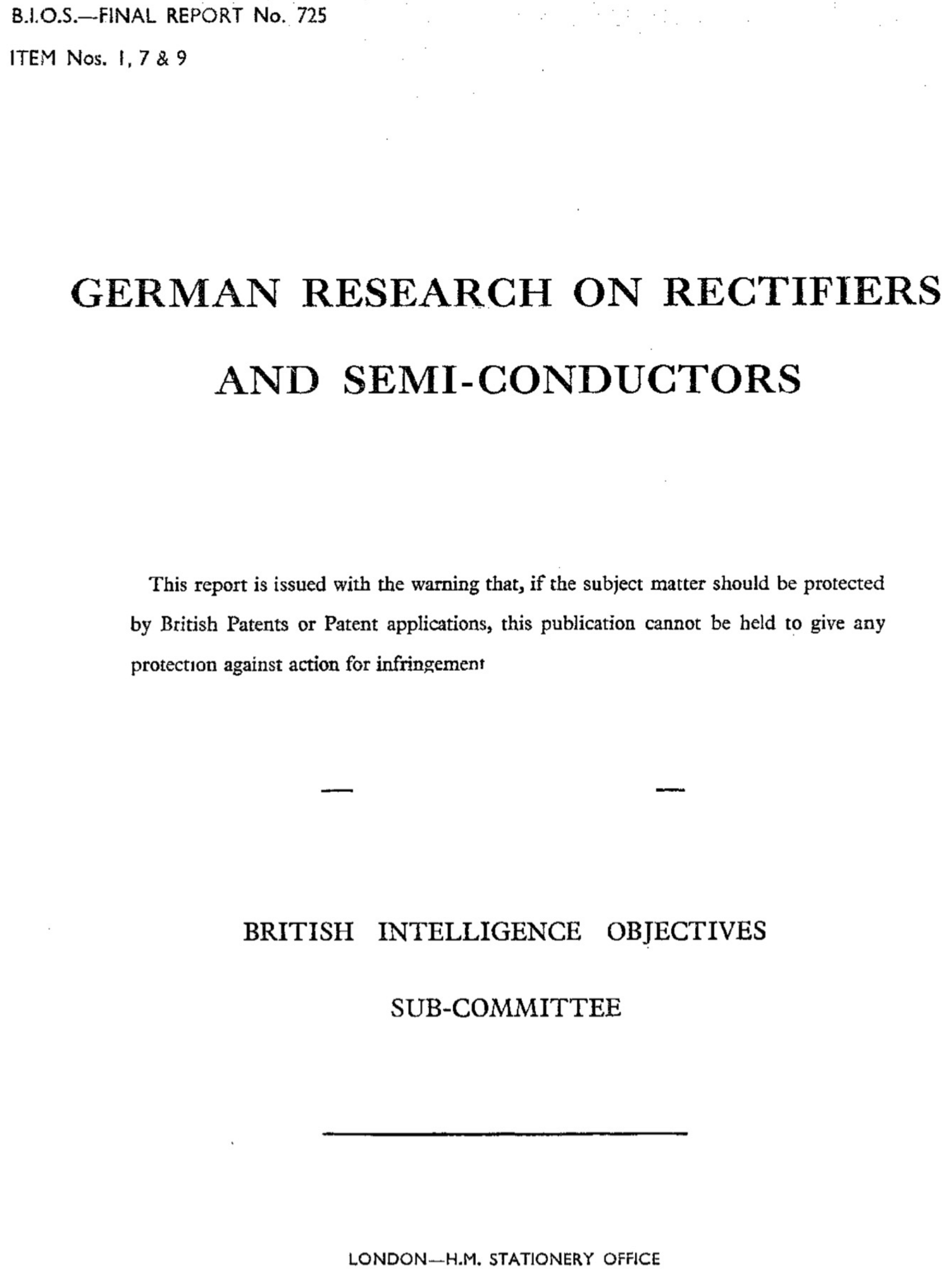
Figure B.301: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [FIAT 54]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



B.I.O.S.—FINAL REPORT No. 725

ITEM Nos. 1, 7 & 9

GERMAN RESEARCH ON RECTIFIERS AND SEMI-CONDUCTORS

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BRITISH INTELLIGENCE OBJECTIVES

SUB-COMMITTEE

LONDON—H.M. STATIONERY OFFICE

Figure B.302: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [BIOS 725]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

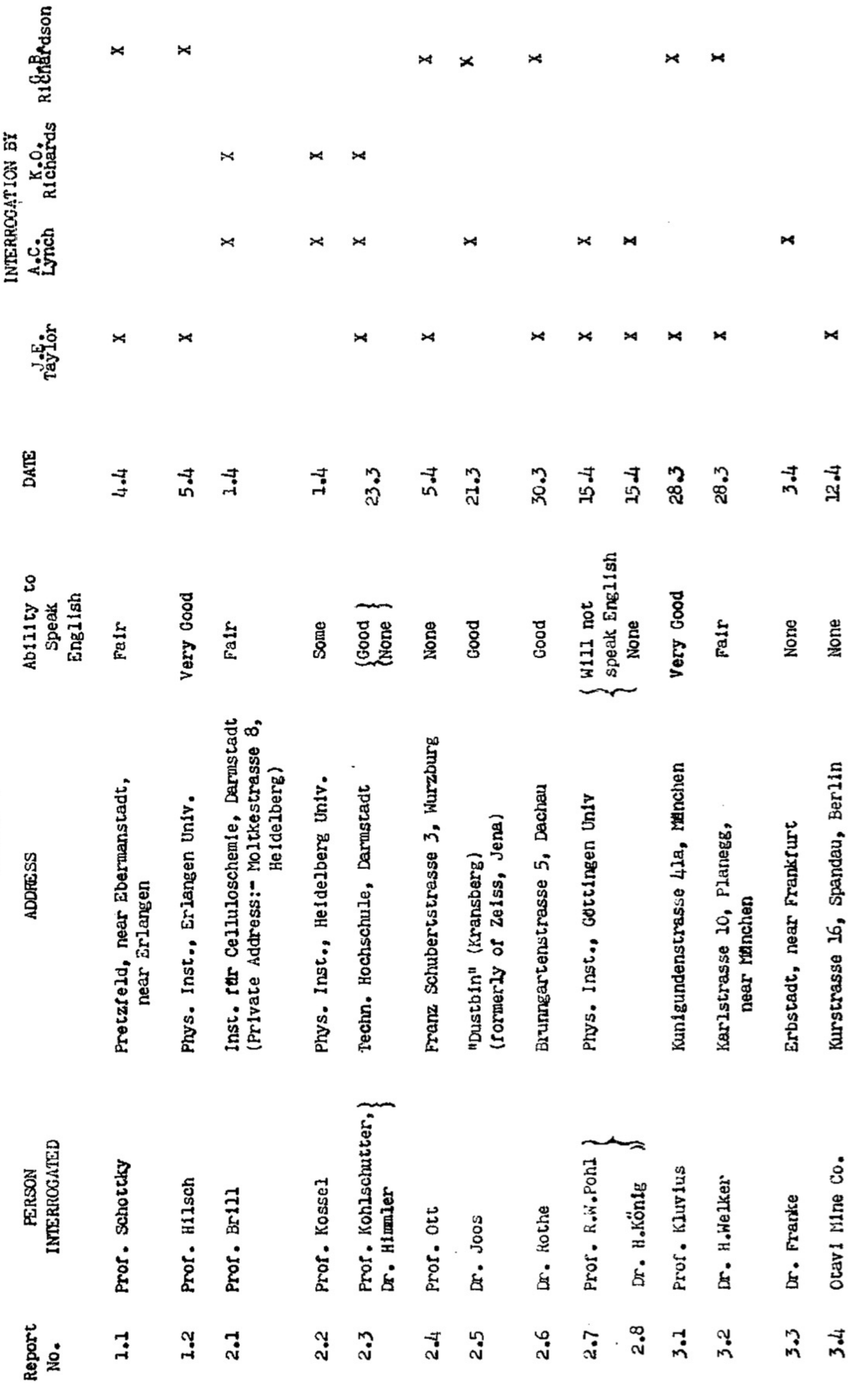

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TABLE 1

Report No.	PERSON INTERROGATED	ADDRESS	Ability to Speak English	DATE	INTERROGATION BY J.E. Taylor	A.C. Lynch	K.O. Richards	G.B. Richardson
1.1	Prof. Schottky	Pretzfeld, near Ebermanstadt, near Erlangen	Fair	4.4	X			X
1.2	Prof. Hilsch	Phys. Inst., Erlangen Univ.	Very Good	5.4	X			X
2.1	Prof. Brill	Inst. für Celluloschemie, Darmstadt (Private Address:- Moltkestrasse 8, Heidelberg)	Fair	1.4		X	X	
2.2	Prof. Kossel	Phys. Inst., Heidelberg Univ.	Some	1.4		X	X	
2.3	Prof. Kohlschutter, Dr. Himmler	Techn. Hochschule, Darmstadt	Good None	23.3	X	X	X	
2.4	Prof. Ott	Franz Schubertstrasse 3, Wurzburg	None	5.4	X			X
2.5	Dr. Joos	"Dustbin" (Kransberg) (formerly of Zeiss, Jena)	Good	21.3		X		X
2.6	Dr. Rothe	Brunngartenstrasse 5, Dachau	Good	30.3	X			X
2.7	Prof. R.W.Pohl	Phys. Inst., Göttingen Univ	Will not speak English	15.4	X	X		
2.8	Dr. H.König		None	15.4	X	X		
3.1	Prof. Kluvius	Kunigundenstrasse 41a, München	Very Good	28.3	X			X
3.2	Dr. H.Welker	Karlstrasse 10, Planegg, near München	Fair	28.3	X			X
3.3	Dr. Franke	Erbstadt, near Frankfurt	None	3.4		X		
3.4	Otavi Mine Co.	Kurstrasse 16, Spandau, Berlin	None	12.4	X			

Figure B.303: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [BIOS 725]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

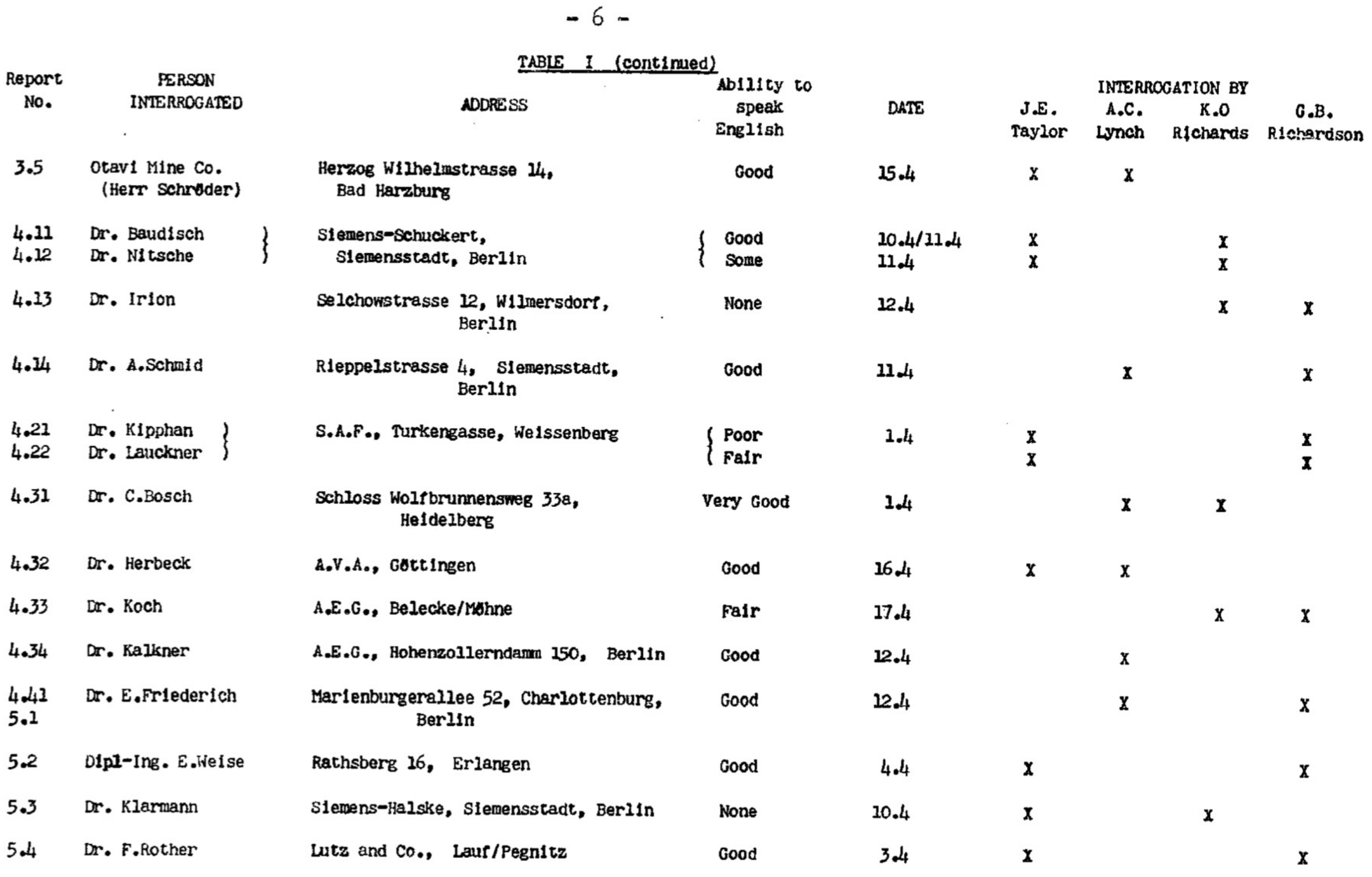

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TABLE I (continued)

Report No.	PERSON INTERROGATED	ADDRESS	Ability to speak English	DATE	INTERROGATION BY J.E. Taylor	A.C. Lynch	K.O Richards	G.B. Richardson
3.5	Otavi Mine Co. (Herr Schröder)	Herzog Wilhelmstrasse 14, Bad Harzburg	Good	15.4	X	X		
4.11	Dr. Baudisch	Siemens-Schuckert, Siemensstadt, Berlin	Good	10.4/11.4	X		X	
4.12	Dr. Nitsche		Some	11.4	X		X	
4.13	Dr. Irion	Selchowstrasse 12, Wilmersdorf, Berlin	None	12.4			X	X
4.14	Dr. A.Schmid	Rieppelstrasse 4, Siemensstadt, Berlin	Good	11.4		X		X
4.21	Dr. Kipphan	S.A.F., Turkengasse, Weissenberg	Poor	1.4	X			X
4.22	Dr. Lauckner		Fair		X			X
4.31	Dr. C.Bosch	Schloss Wolfbrunnensweg 33a, Heidelberg	Very Good	1.4		X	X	
4.32	Dr. Herbeck	A.V.A., Göttingen	Good	16.4	X	X		
4.33	Dr. Koch	A.E.G., Belecke/Möhne	Fair	17.4			X	X
4.34	Dr. Kalkner	A.E.G., Hohenzollerndamm 150, Berlin	Good	12.4		X		
4.41 5.1	Dr. E.Friederich	Marienburgerallee 52, Charlottenburg, Berlin	Good	12.4		X		X
5.2	Dipl-Ing. E.Weise	Rathsberg 16, Erlangen	Good	4.4	X			X
5.3	Dr. Klarmann	Siemens-Halske, Siemensstadt, Berlin	None	10.4	X		X	
5.4	Dr. F.Rother	Lutz and Co., Lauf/Pegnitz	Good	3.4	X			X

Figure B.304: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [BIOS 725]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

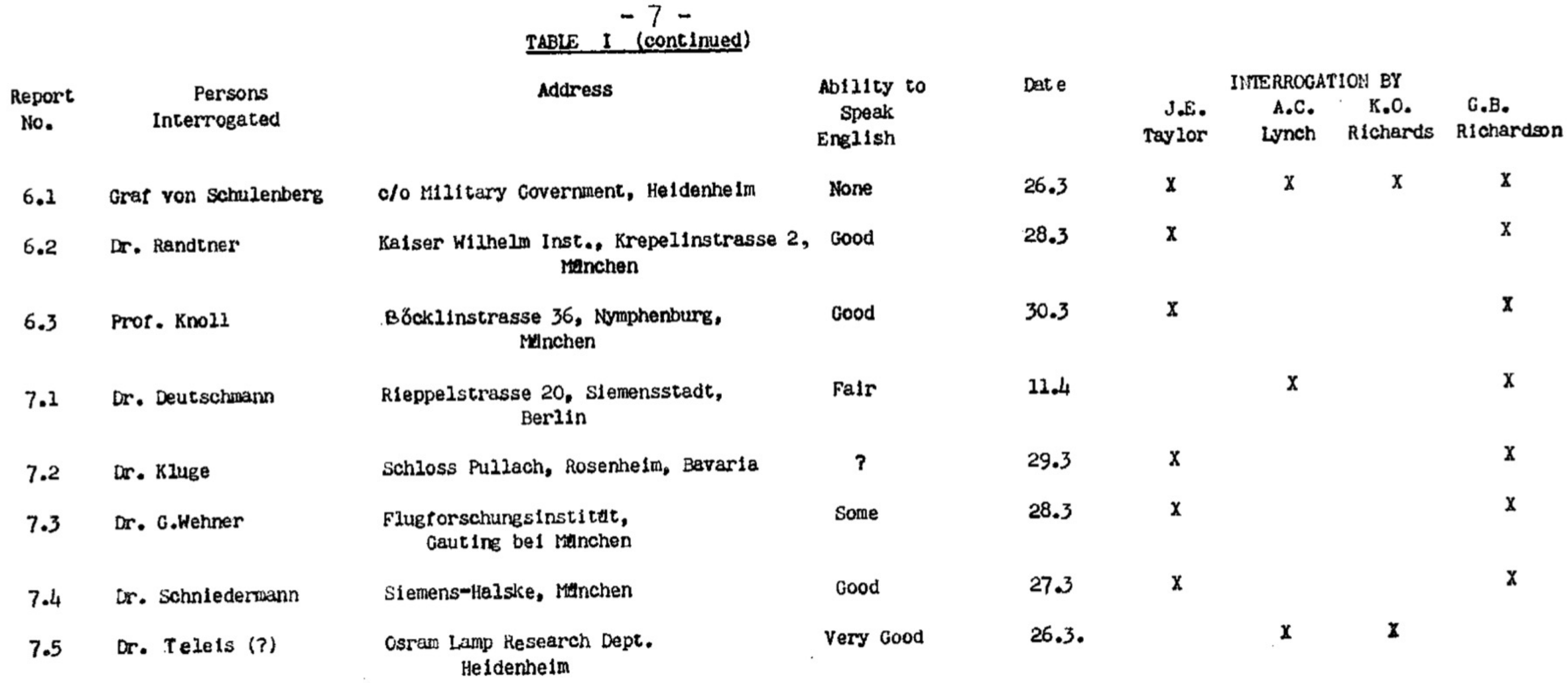

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TABLE I (continued)

Report No.	Persons Interrogated	Address	Ability to Speak English	Date	INTERROGATION BY J.E. Taylor	A.C. Lynch	K.O. Richards	G.B. Richardson
6.1	Graf von Schulenberg	c/o Military Government, Heidenheim	None	26.3	X	X	X	X
6.2	Dr. Randtner	Kaiser Wilhelm Inst., Krepelinstrasse 2, München	Good	28.3	X			X
6.3	Prof. Knoll	Böcklinstrasse 36, Nymphenburg, München	Good	30.3	X			X
7.1	Dr. Deutschmann	Rieppelstrasse 20, Siemensstadt, Berlin	Fair	11.4		X		X
7.2	Dr. Kluge	Schloss Pullach, Rosenheim, Bavaria	?	29.3	X			X
7.3	Dr. G.Wehner	Flugforschungsinstitüt, Gauting bei München	Some	28.3	X			X
7.4	Dr. Schniedermann	Siemens-Halske, München	Good	27.3	X			X
7.5	Dr. Teleis (?)	Osram Lamp Research Dept. Heidenheim	Very Good	26.3.		X	X	

Figure B.305: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [BIOS 725]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

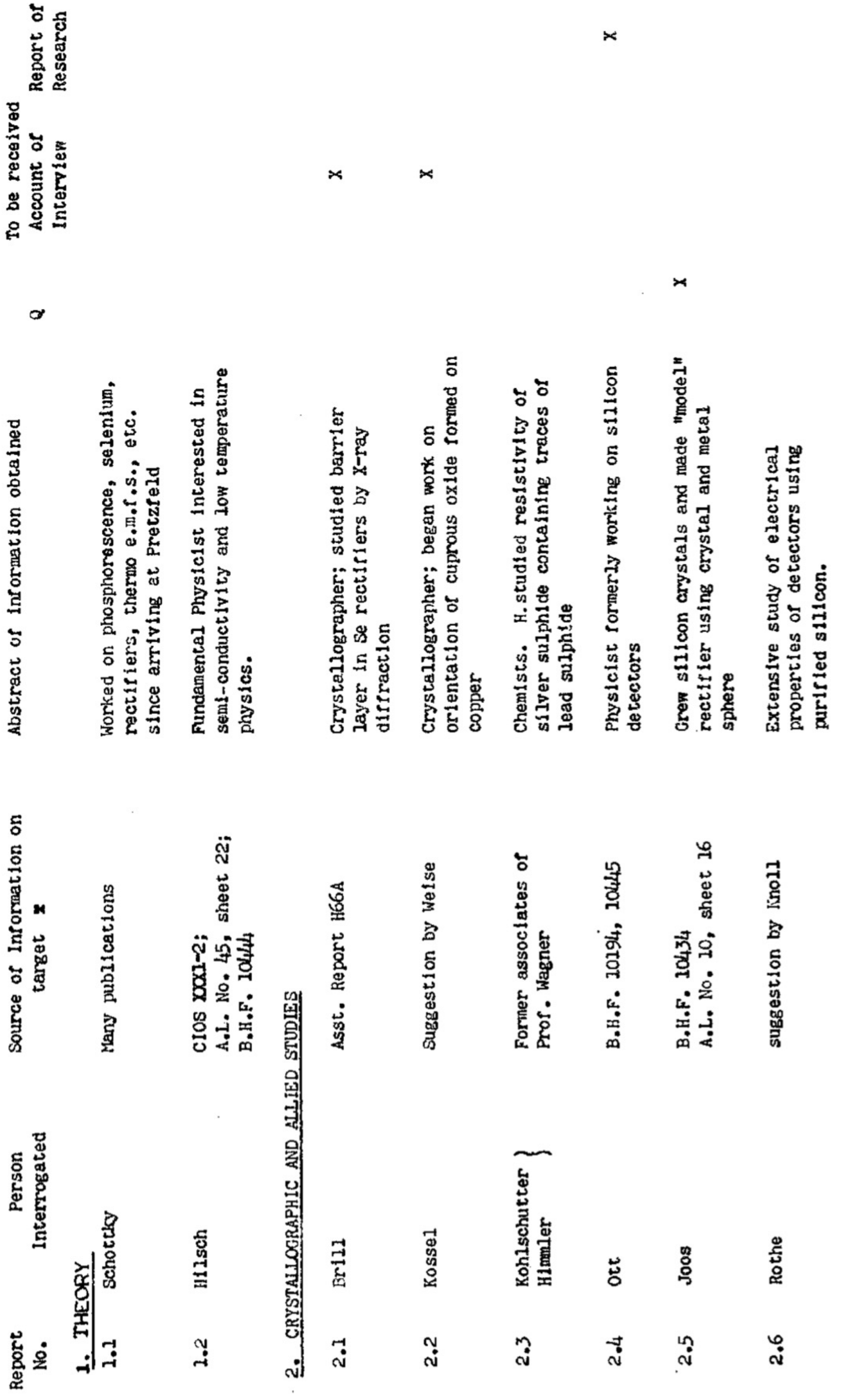

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TABLE II

Report No.	Person Interrogated	Source of Information on target *	Abstract of information obtained	Q	To be received Account of Interview	Report of Research
1. THEORY						
1.1	Schottky	Many publications	Worked on phosphorescence, selenium, rectifiers, thermo e.m.f.s., etc. since arriving at Pretzfeld			
1.2	Hilsch	CIOS XXXI-2; A.L. No. 45, sheet 22; B.H.F. 10444	Fundamental Physicist interested in semi-conductivity and low temperature physics.			
2. CRYSTALLOGRAPHIC AND ALLIED STUDIES						
2.1	Brill	Asst. Report H66A	Crystallographer; studied barrier layer in Se rectifiers by X-ray diffraction		X	
2.2	Kossel	Suggestion by Weise	Crystallographer; began work on orientation of cuprous oxide formed on copper		X	
2.3	Kohlschutter } Himmler }	Former associates of Prof. Wagner	Chemists. H. studied resistivity of silver sulphide containing traces of lead sulphide			
2.4	Ott	B.H.F. 10194, 10445	Physicist formerly working on silicon detectors			X
2.5	Joos	B.H.F. 10434 A.L. No. 10, sheet 16	Grew silicon crystals and made "model" rectifier using crystal and metal sphere	X		
2.6	Rothe	suggestion by Knoll	Extensive study of electrical properties of detectors using purified silicon.			

Figure B.306: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [BIOS 725]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

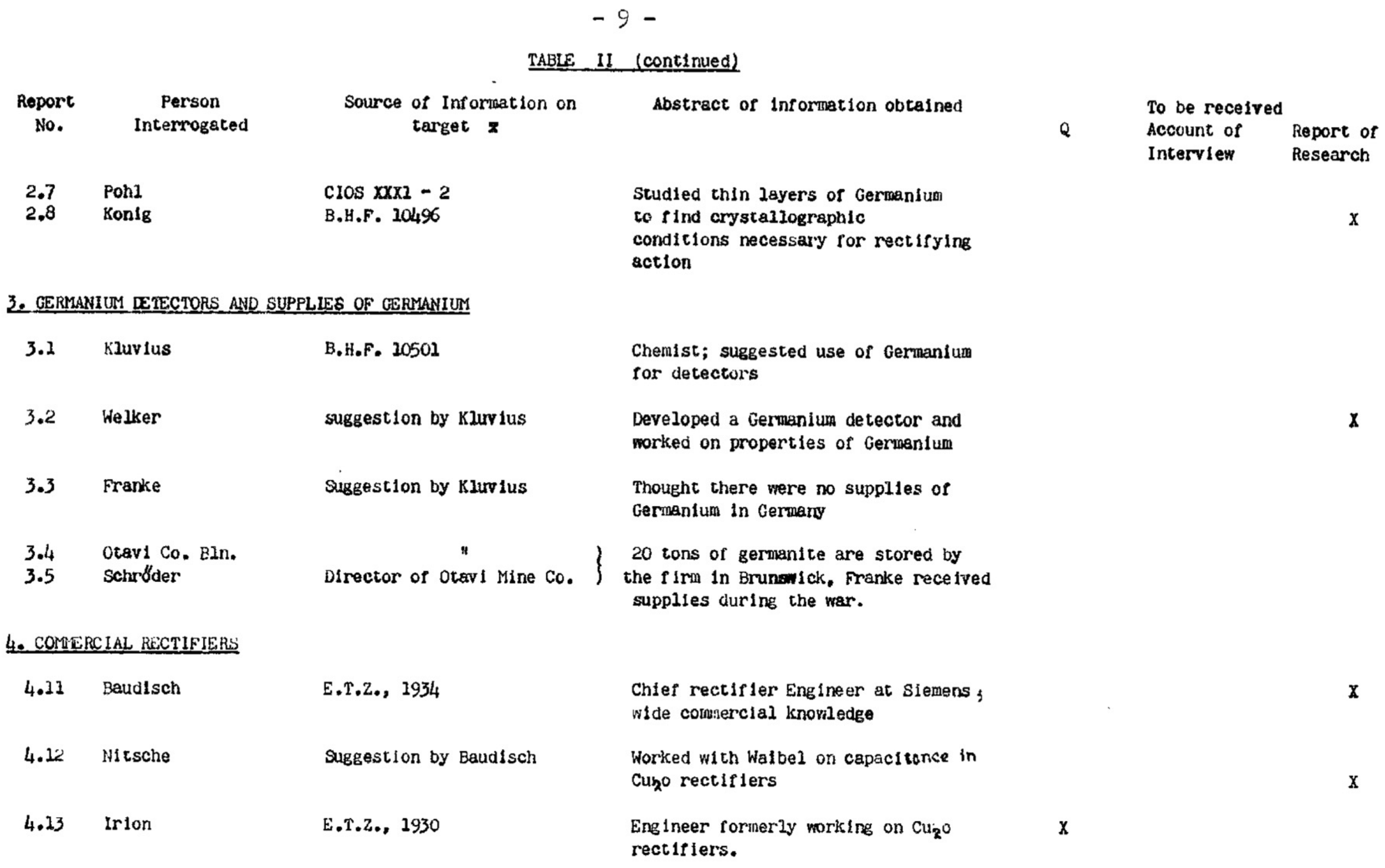

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TABLE II (continued)

Report No.	Person Interrogated	Source of Information on target x	Abstract of information obtained	Q	To be received Account of Interview	Report of Research
2.7 2.8	Pohl Konig	CIOS XXXI - 2 B.H.F. 10496	Studied thin layers of Germanium to find crystallographic conditions necessary for rectifying action			X
3. GERMANIUM DETECTORS AND SUPPLIES OF GERMANIUM						
3.1	Kluvius	B.H.F. 10501	Chemist; suggested use of Germanium for detectors			
3.2	Welker	suggestion by Kluvius	Developed a Germanium detector and worked on properties of Germanium			X
3.3	Franke	Suggestion by Kluvius	Thought there were no supplies of Germanium in Germany			
3.4 3.5	Otavi Co. Bln. Schröder	" Director of Otavi Mine Co.	20 tons of germanite are stored by the firm in Brunswick, Franke received supplies during the war.			
4. COMMERCIAL RECTIFIERS						
4.11	Baudisch	E.T.Z., 1934	Chief rectifier Engineer at Siemens; wide commercial knowledge			X
4.12	Nitsche	Suggestion by Baudisch	Worked with Waibel on capacitance in Cu_2o rectifiers			X
4.13	Irion	E.T.Z., 1930	Engineer formerly working on Cu_2o rectifiers.	X		

Figure B.307: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [BIOS 725]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

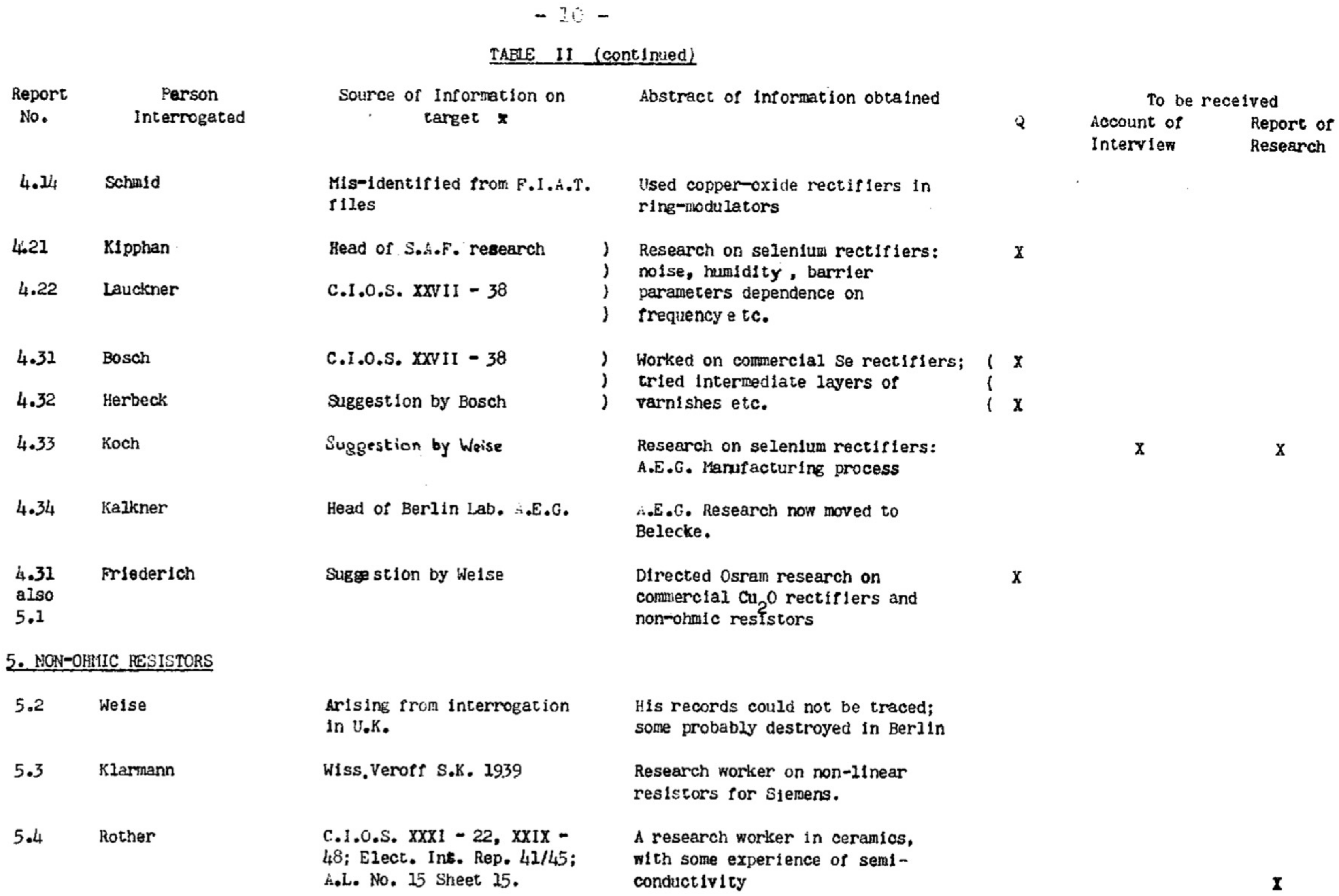

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TABLE II (continued)

Report No.	Person Interrogated	Source of Information on target *	Abstract of information obtained	Q	To be received Account of Interview	To be received Report of Research
4.14	Schmid	Mis-identified from F.I.A.T. files	Used copper-oxide rectifiers in ring-modulators			
4.21	Kipphan	Head of S.A.F. research	Research on selenium rectifiers: noise, humidity, barrier parameters dependence on frequency etc.	X		
4.22	Lauckner	C.I.O.S. XXVII - 38				
4.31	Bosch	C.I.O.S. XXVII - 38	Worked on commercial Se rectifiers; tried intermediate layers of varnishes etc.	X		
4.32	Herbeck	Suggestion by Bosch		X		
4.33	Koch	Suggestion by Weise	Research on selenium rectifiers: A.E.G. Manufacturing process		X	X
4.34	Kalkner	Head of Berlin Lab. A.E.G.	A.E.G. Research now moved to Belecke.			
4.31 also 5.1	Friederich	Suggestion by Weise	Directed Osram research on commercial Cu_2O rectifiers and non-ohmic resistors	X		
5. NON-OHMIC RESISTORS						
5.2	Weise	Arising from interrogation in U.K.	His records could not be traced; some probably destroyed in Berlin			
5.3	Klarmann	Wiss.Veroff S.K. 1939	Research worker on non-linear resistors for Siemens.			
5.4	Rother	C.I.O.S. XXXI - 22, XXIX - 48; Elect. Int. Rep. 41/45; A.L. No. 15 Sheet 15.	A research worker in ceramics, with some experience of semi-conductivity			X

Figure B.308: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [BIOS 725]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

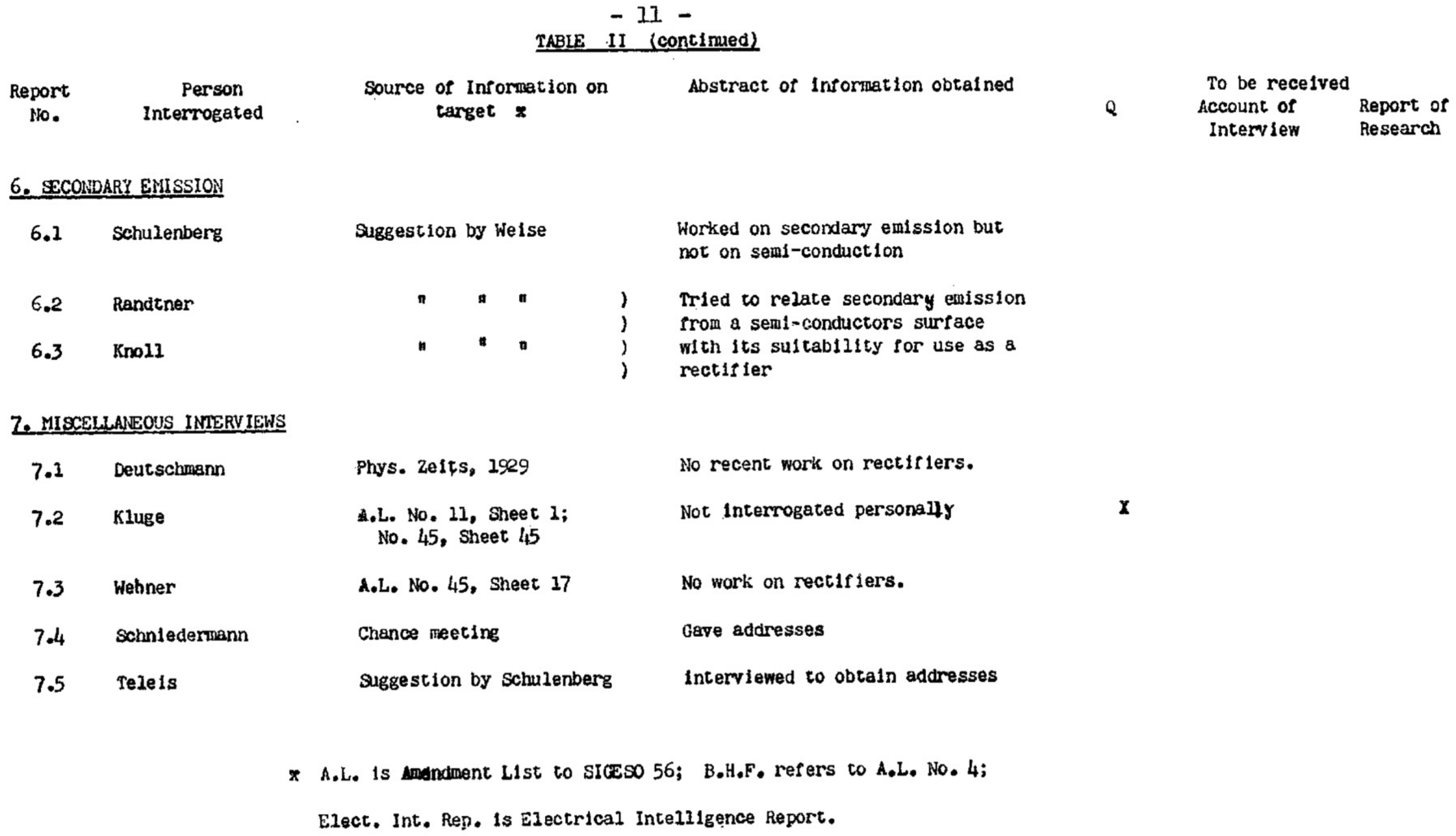

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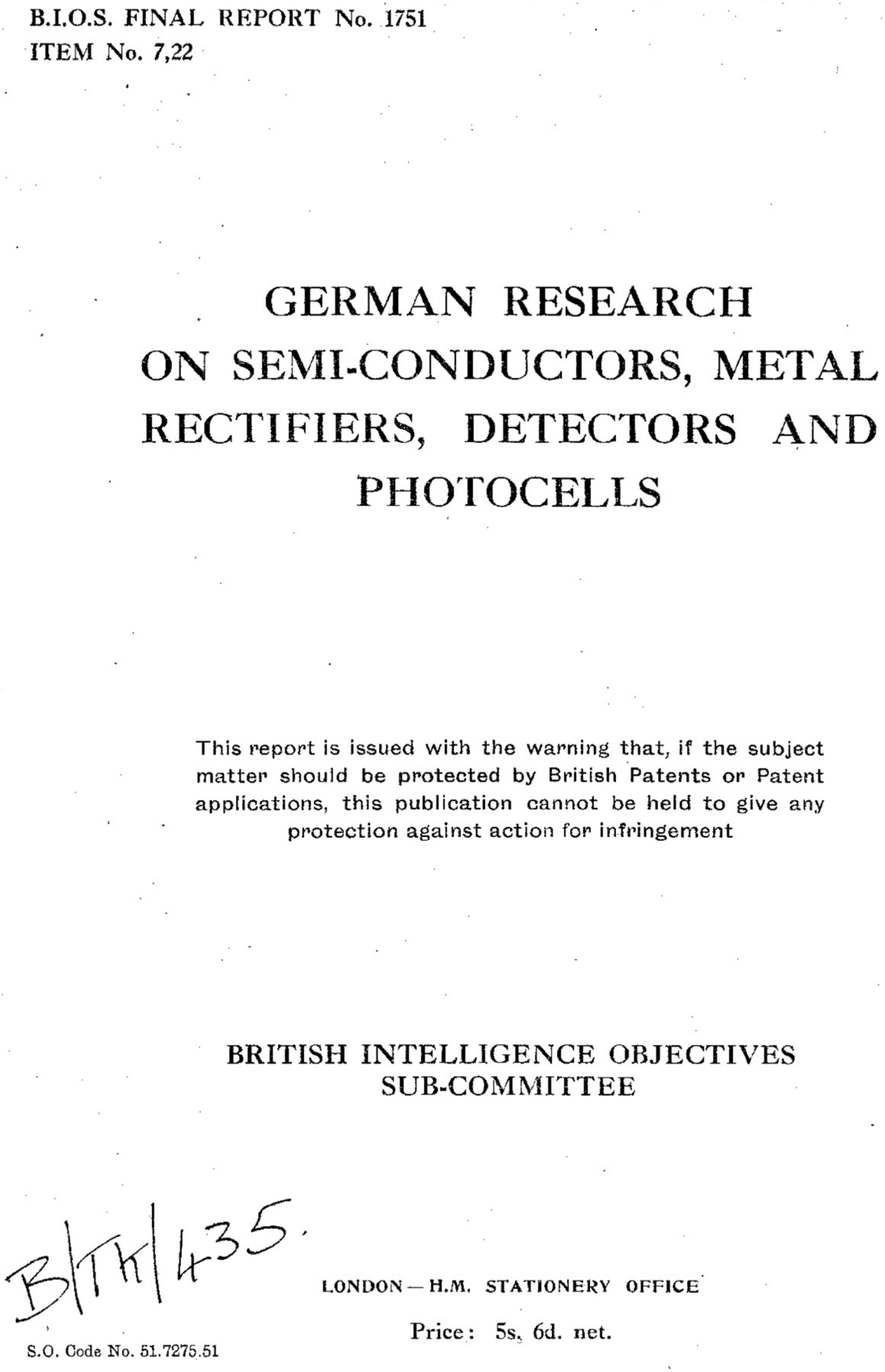
TABLE II (continued)

Report No.	Person Interrogated	Source of Information on target *	Abstract of Information obtained	Q	To be received Account of Interview	Report of Research
6. SECONDARY EMISSION						
6.1	Schulenberg	Suggestion by Weise	Worked on secondary emission but not on semi-conduction			
6.2	Randtner	" " "	Tried to relate secondary emission from a semi-conductors surface with its suitability for use as a rectifier			
6.3	Knoll	" " "				
7. MISCELLANEOUS INTERVIEWS						
7.1	Deutschmann	Phys. Zeits, 1929	No recent work on rectifiers.			
7.2	Kluge	A.L. No. 11, Sheet 1; No. 45, Sheet 45	Not interrogated personally	X		
7.3	Wehner	A.L. No. 45, Sheet 17	No work on rectifiers.			
7.4	Schniedermann	Chance meeting	Gave addresses			
7.5	Teleis	Suggestion by Schulenberg	interviewed to obtain addresses			

* A.L. is Amendment List to SIGESO 56; B.H.F. refers to A.L. No. 4;

Elect. Int. Rep. is Electrical Intelligence Report.

Figure B.309: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [BIOS 725]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



B.I.O.S. FINAL REPORT No. 1751
ITEM No. 7,22

GERMAN RESEARCH ON SEMI-CONDUCTORS, METAL RECTIFIERS, DETECTORS AND PHOTOCELLS

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S.O. Code No. 51.7275.51

Figure B.310: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [BIOS 1751]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

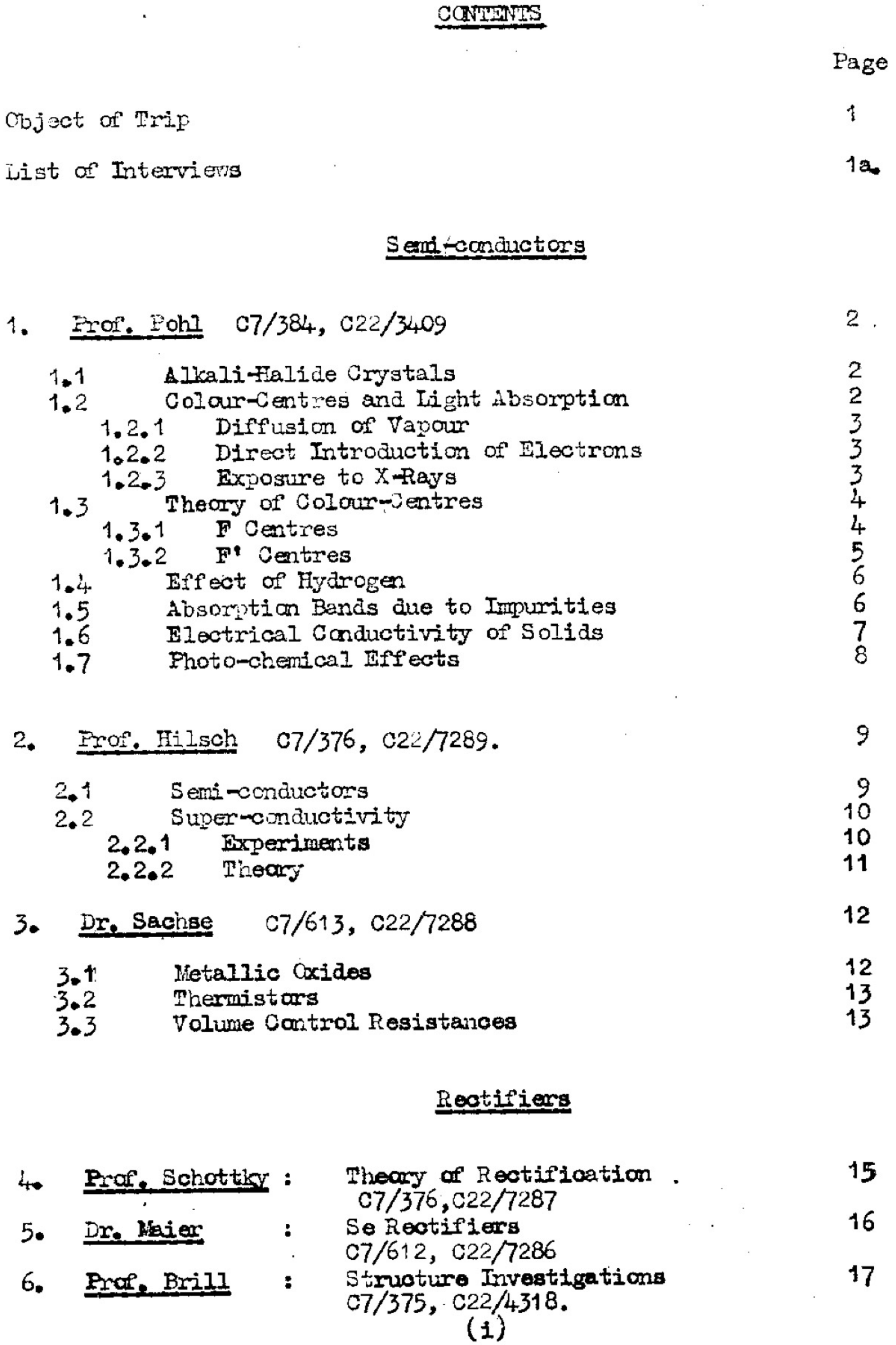

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Figure B.311: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [BIOS 1751]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

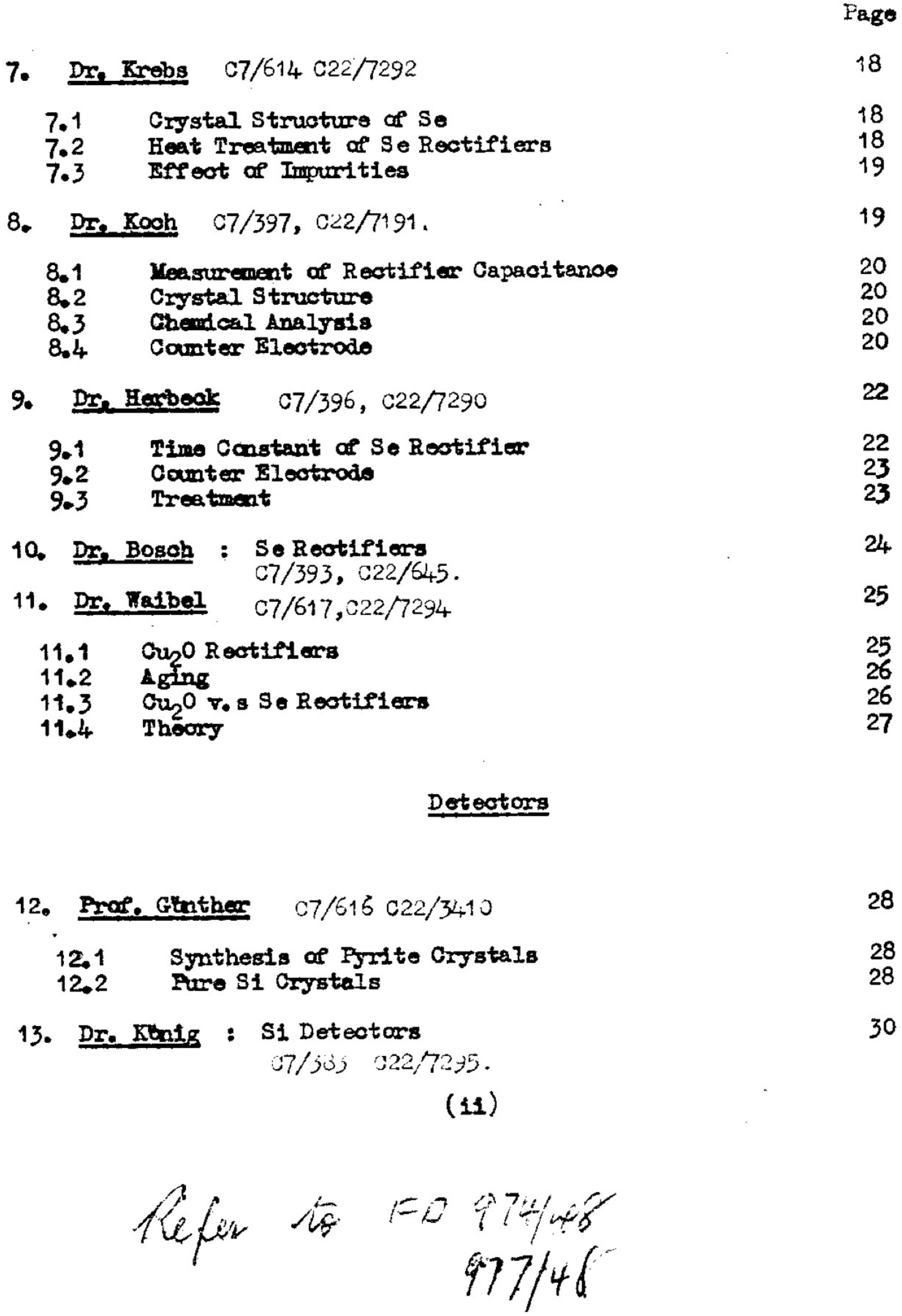

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Figure B.312: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [BIOS 1751]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

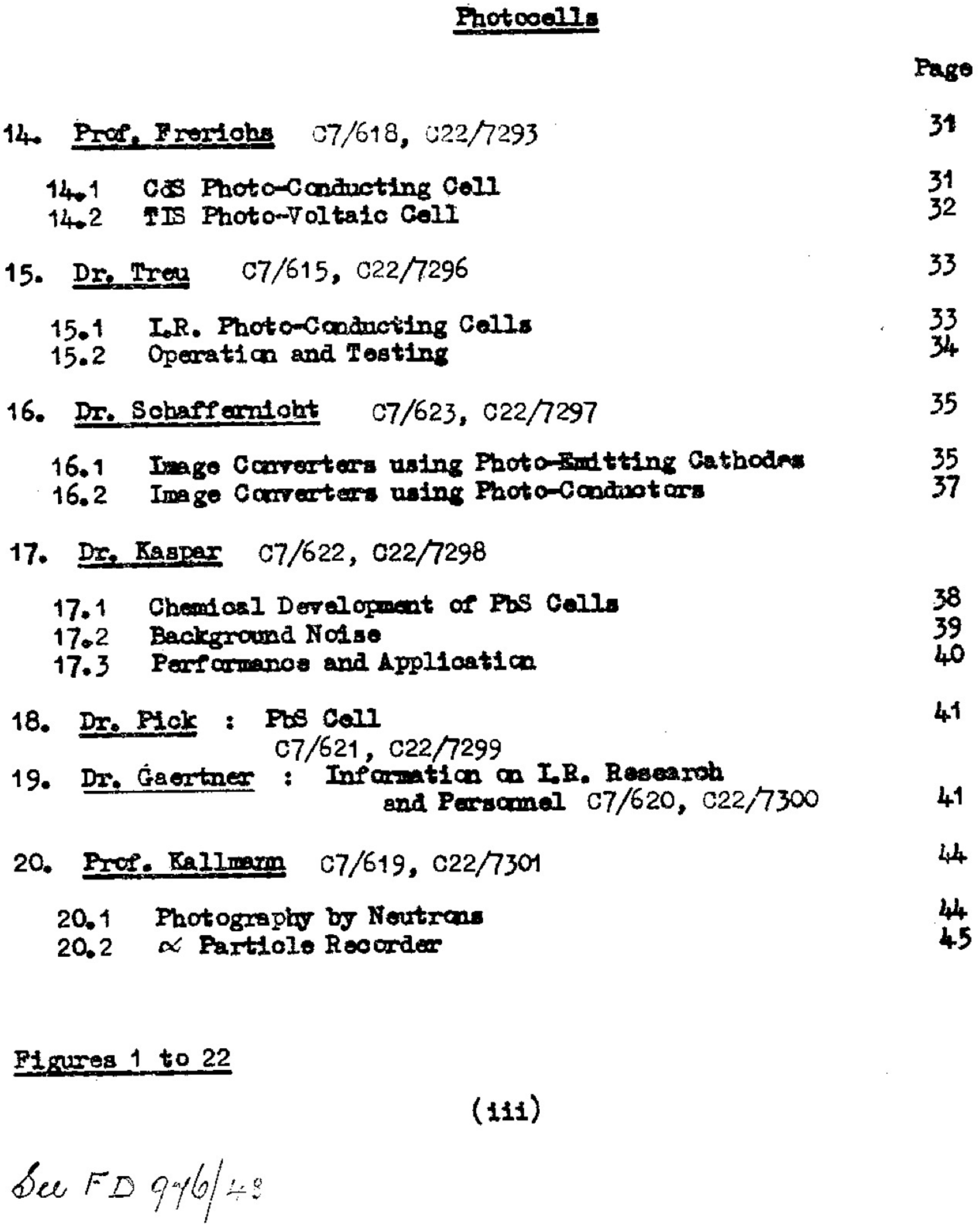

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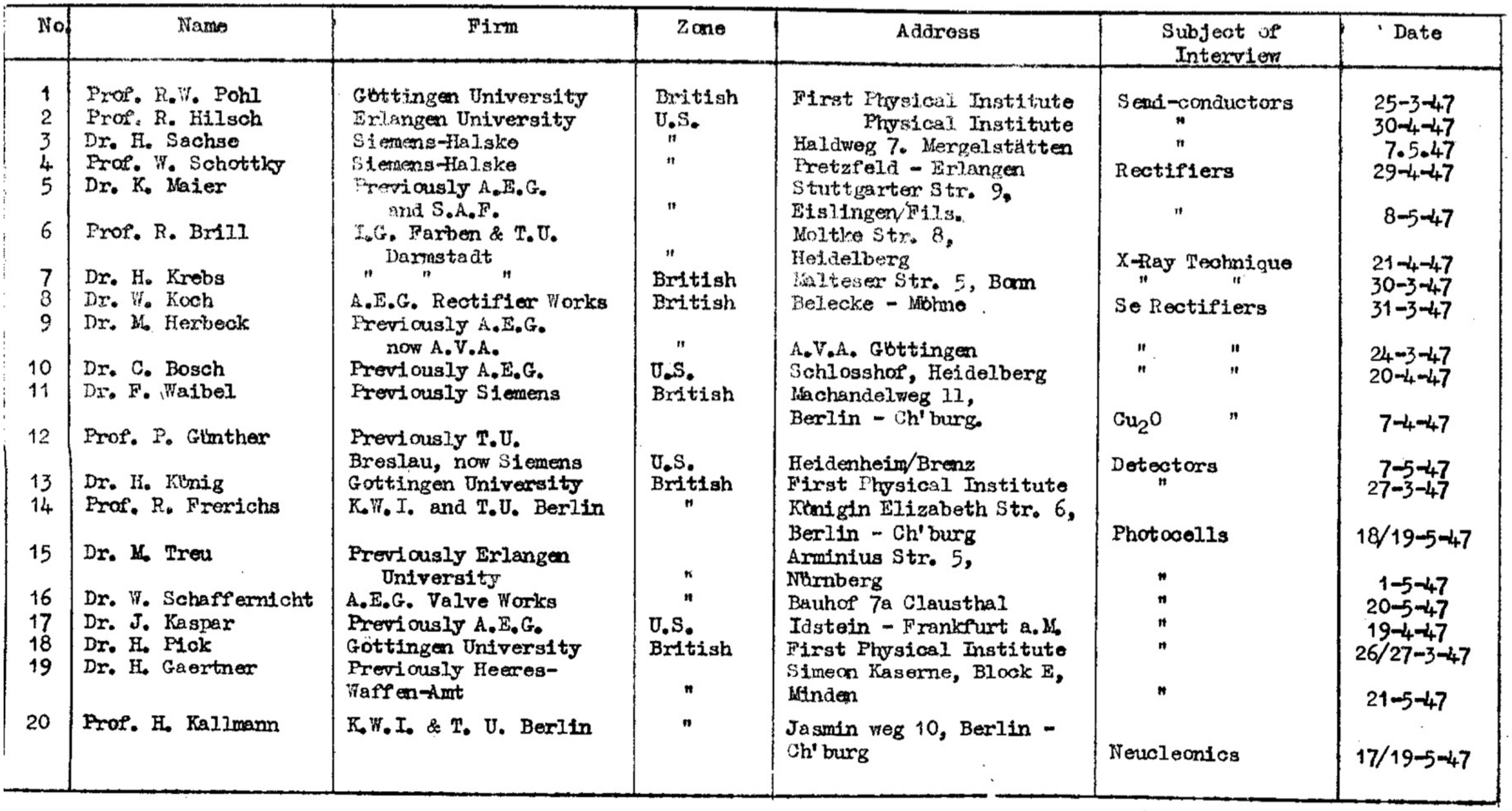
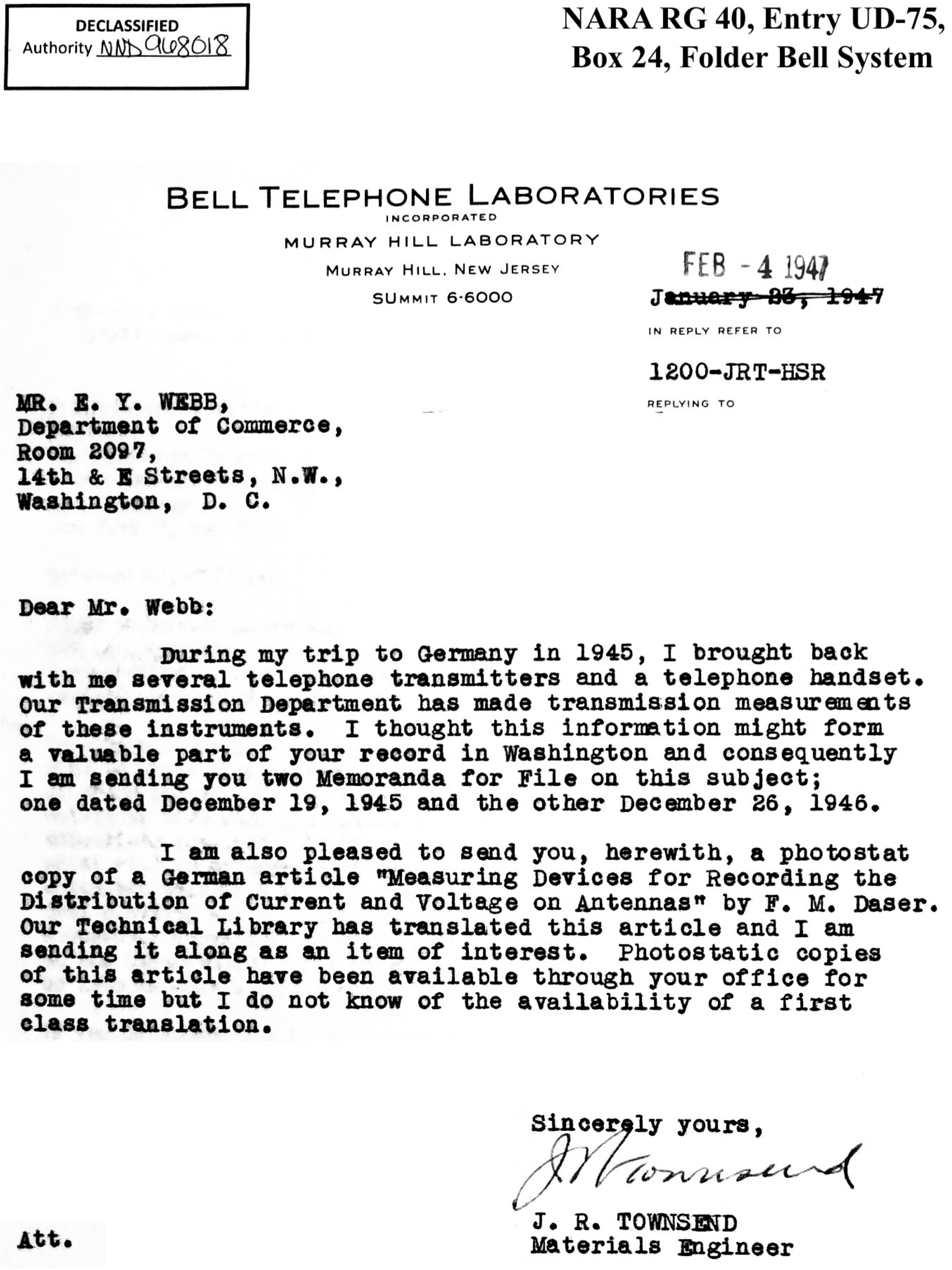
Figure B.313: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [BIOS 1751]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



No.	Name	Firm	Zone	Address	Subject of Interview	Date
1	Prof. R.W. Pohl	Göttingen University	British	First Physical Institute	Semi-conductors	25-3-47
2	Prof. R. Hilsch	Erlangen University	U.S.	Physical Institute	"	30-4-47
3	Dr. H. Sachse	Siemens-Halske	"	Haldweg 7. Mergelstätten	"	7.5.47
4	Prof. W. Schottky	Siemens-Halske	"	Pretzfeld - Erlangen	Rectifiers	29-4-47
5	Dr. K. Maier	Previously A.E.G. and S.A.F.	"	Stuttgarter Str. 9, Eislingen/Fils.	"	8-5-47
6	Prof. R. Brill	I.G. Farben & T.U. Darmstadt	"	Moltke Str. 8, Heidelberg	X-Ray Technique	21-4-47
7	Dr. H. Krebs	" " "	British	Malteser Str. 5, Bonn	" "	30-3-47
8	Dr. W. Koch	A.E.G. Rectifier Works	British	Belecke - Möhne	Se Rectifiers	31-3-47
9	Dr. M. Herbeck	Previously A.E.G. now A.V.A.	"	A.V.A. Göttingen	" "	24-3-47
10	Dr. C. Bosch	Previously A.E.G.	U.S.	Schlosshof, Heidelberg	" "	20-4-47
11	Dr. F. Waibel	Previously Siemens	British	Machandelweg 11, Berlin - Ch'burg.	Cu_2O "	7-4-47
12	Prof. P. Günther	Previously T.U. Breslau, now Siemens	U.S.	Heidenheim/Brenz	Detectors	7-5-47
13	Dr. H. König	Gottingen University	British	First Physical Institute	"	27-3-47
14	Prof. R. Frerichs	K.W.I. and T.U. Berlin	"	Königin Elizabeth Str. 6, Berlin - Ch'burg	Photocells	18/19-5-47
15	Dr. M. Treu	Previously Erlangen University	"	Arminius Str. 5, Nürnberg	"	1-5-47
16	Dr. W. Schaffernicht	A.E.G. Valve Works	"	Bauhof 7a Clausthal	"	20-5-47
17	Dr. J. Kaspar	Previously A.E.G.	U.S.	Idstein - Frankfurt a.M.	"	19-4-47
18	Dr. H. Pick	Göttingen University	British	First Physical Institute	"	26/27-3-47
19	Dr. H. Gaertner	Previously Heeres-Waffen-Amt	"	Simeon Kaserne, Block E, Minden	"	21-5-47
20	Prof. H. Kallmann	K.W.I. & T. U. Berlin	"	Jasmin weg 10, Berlin - Ch'burg	Neucleonics	17/19-5-47

Figure B.314: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [BIOS 1751]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND968018

NARA RG 40, Entry UD-75,
Box 24, Folder Bell System

BELL TELEPHONE LABORATORIES
INCORPORATED
MURRAY HILL LABORATORY
MURRAY HILL, NEW JERSEY
SUMMIT 6-6000

FEB -4 1947
~~January 23, 1947~~

IN REPLY REFER TO

1200-JRT-HSR

REPLYING TO

MR. E. Y. WEBB,
Department of Commerce,
Room 2097,
14th & E Streets, N.W.,
Washington, D. C.

Dear Mr. Webb:

During my trip to Germany in 1945, I brought back with me several telephone transmitters and a telephone handset. Our Transmission Department has made transmission measurements of these instruments. I thought this information might form a valuable part of your record in Washington and consequently I am sending you two Memoranda for File on this subject; one dated December 19, 1945 and the other December 26, 1946.

I am also pleased to send you, herewith, a photostat copy of a German article "Measuring Devices for Recording the Distribution of Current and Voltage on Antennas" by F. M. Daser. Our Technical Library has translated this article and I am sending it along as an item of interest. Photostatic copies of this article have been available through your office for some time but I do not know of the availability of a first class translation.

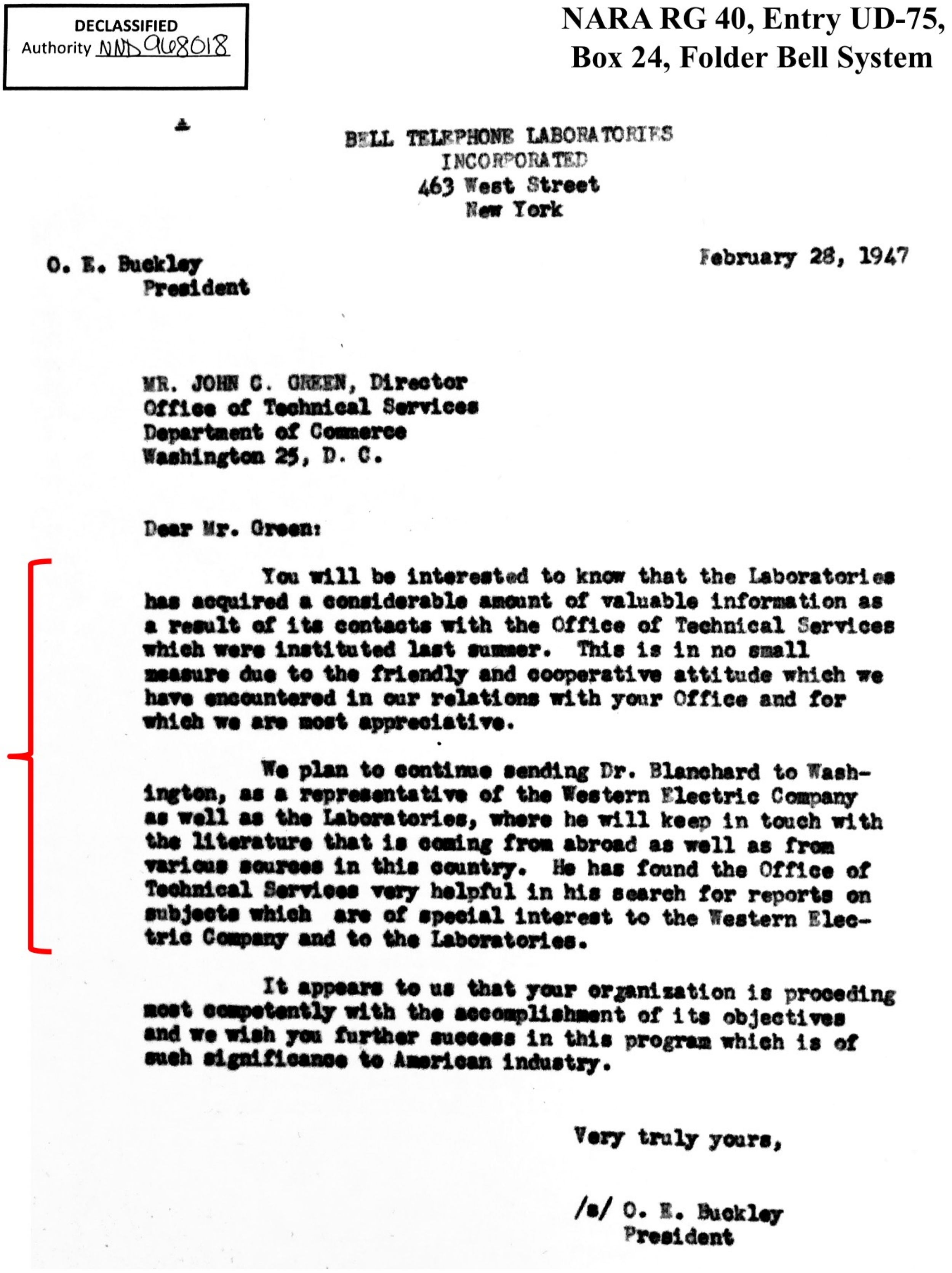
Sincerely yours,

J R Townsend

J. R. TOWNSEND
Materials Engineer

Att.

Figure B.315: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND968018

NARA RG 40, Entry UD-75, Box 24, Folder Bell System

BELL TELEPHONE LABORATORIES
INCORPORATED
463 West Street
New York

O. E. Buckley
President

February 28, 1947

MR. JOHN C. GREEN, Director
Office of Technical Services
Department of Commerce
Washington 25, D. C.

Dear Mr. Green:

You will be interested to know that the Laboratories has acquired a considerable amount of valuable information as a result of its contacts with the Office of Technical Services which were instituted last summer. This is in no small measure due to the friendly and cooperative attitude which we have encountered in our relations with your Office and for which we are most appreciative.

We plan to continue sending Dr. Blanchard to Washington, as a representative of the Western Electric Company as well as the Laboratories, where he will keep in touch with the literature that is coming from abroad as well as from various sources in this country. He has found the Office of Technical Services very helpful in his search for reports on subjects which are of special interest to the Western Electric Company and to the Laboratories.

It appears to us that your organization is proceeding most competently with the accomplishment of its objectives and we wish you further success in this program which is of such significance to American industry.

Very truly yours,

/s/ O. E. Buckley
President

Figure B.316: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

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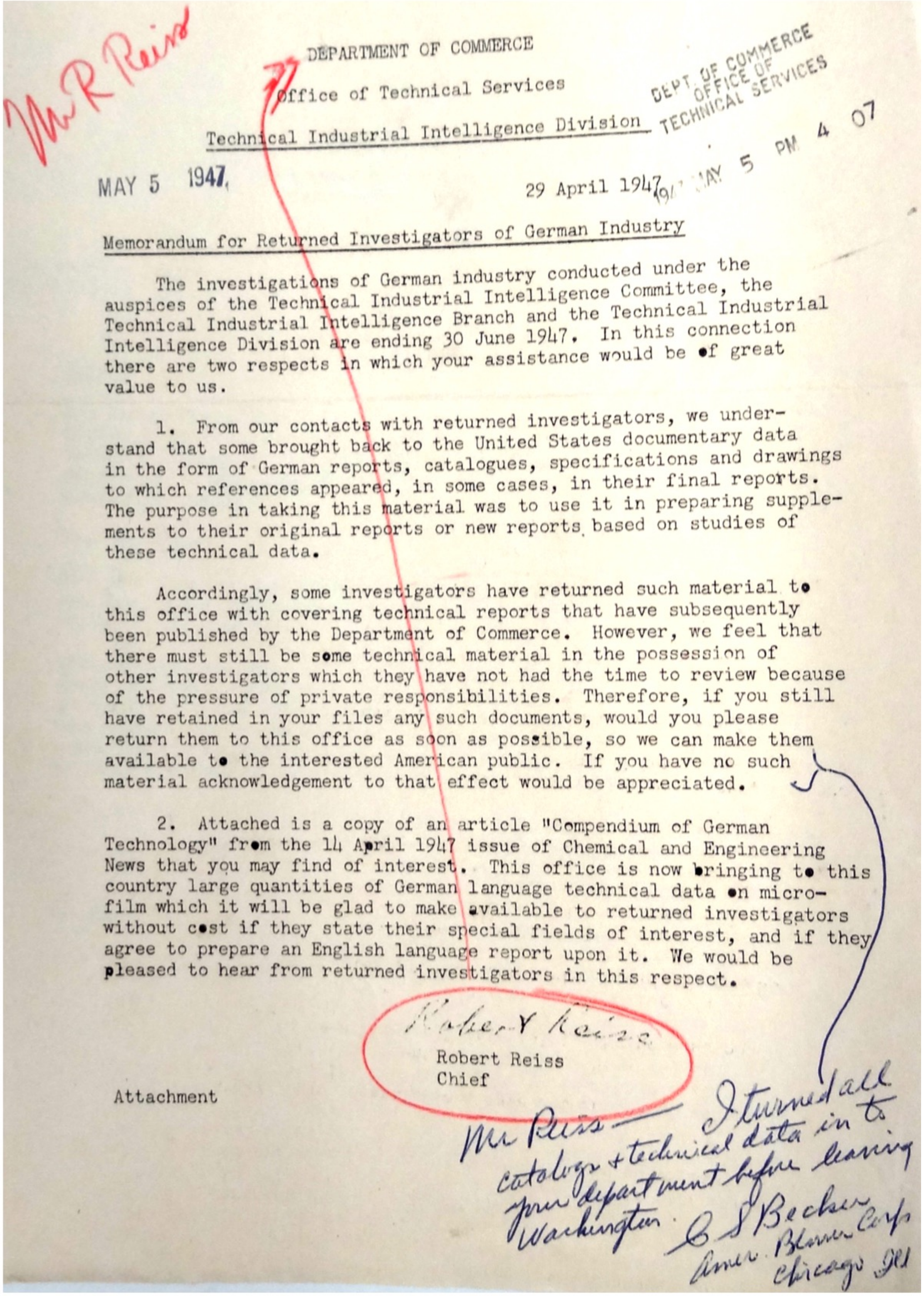
Authority NND 968148



Mr R Reis

77

DEPARTMENT OF COMMERCE

Office of Technical Services

Technical Industrial Intelligence Division

DEPT OF COMMERCE OFFICE OF TECHNICAL SERVICES 1947 MAY 5 PM 4 07

MAY 5 1947

29 April 1947

Memorandum for Returned Investigators of German Industry

The investigations of German industry conducted under the auspices of the Technical Industrial Intelligence Committee, the Technical Industrial Intelligence Branch and the Technical Industrial Intelligence Division are ending 30 June 1947. In this connection there are two respects in which your assistance would be of great value to us.

1. From our contacts with returned investigators, we understand that some brought back to the United States documentary data in the form of German reports, catalogues, specifications and drawings to which references appeared, in some cases, in their final reports. The purpose in taking this material was to use it in preparing supplements to their original reports or new reports based on studies of these technical data.

Accordingly, some investigators have returned such material to this office with covering technical reports that have subsequently been published by the Department of Commerce. However, we feel that there must still be some technical material in the possession of other investigators which they have not had the time to review because of the pressure of private responsibilities. Therefore, if you still have retained in your files any such documents, would you please return them to this office as soon as possible, so we can make them available to the interested American public. If you have no such material acknowledgement to that effect would be appreciated.

2. Attached is a copy of an article "Compendium of German Technology" from the 14 April 1947 issue of Chemical and Engineering News that you may find of interest. This office is now bringing to this country large quantities of German language technical data on microfilm which it will be glad to make available to returned investigators without cost if they state their special fields of interest, and if they agree to prepare an English language report upon it. We would be pleased to hear from returned investigators in this respect.

Robert Reiss

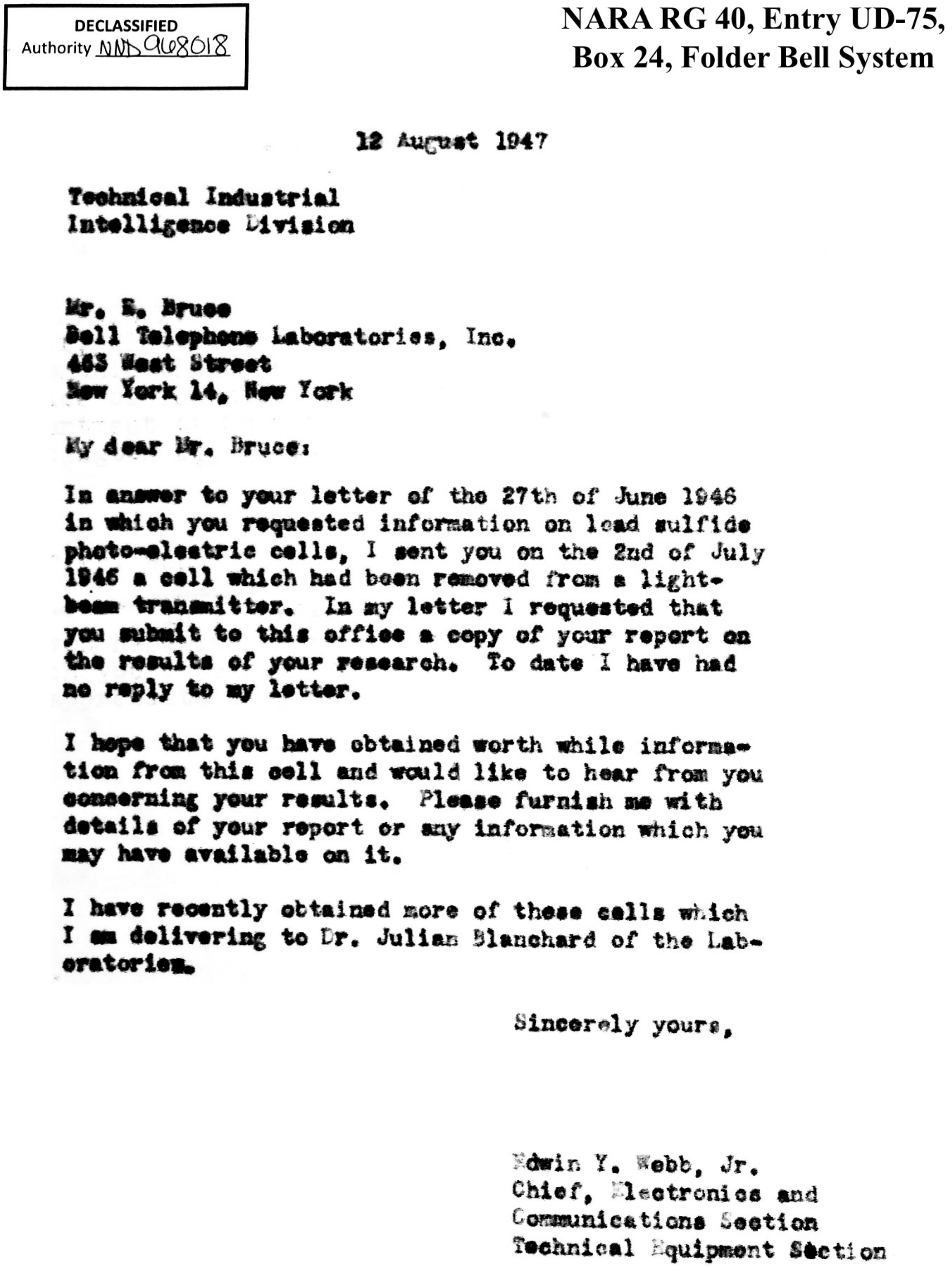
Robert Reiss
Chief

Attachment

Mr Reiss — I turned all catalogs + technical data in to your department before leaving Washington.
C S Becker
Amer. Blower Corp
Chicago Ill

NARA RG 40, Entry UD-75, Box 58, Folder
Replies to Letters of April 29, 1947

Figure B.317: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 58, Folder Replies to Letters of April 29, 1947]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND968018

NARA RG 40, Entry UD-75,
Box 24, Folder Bell System

12 August 1947

Technical Industrial
Intelligence Division

Mr. E. Bruce
Bell Telephone Laboratories, Inc.
463 West Street
New York 14, New York

My dear Mr. Bruce:

In answer to your letter of the 27th of June 1946 in which you requested information on lead sulfide photo-electric cells, I sent you on the 2nd of July 1946 a cell which had been removed from a light-beam transmitter. In my letter I requested that you submit to this office a copy of your report on the results of your research. To date I have had no reply to my letter.

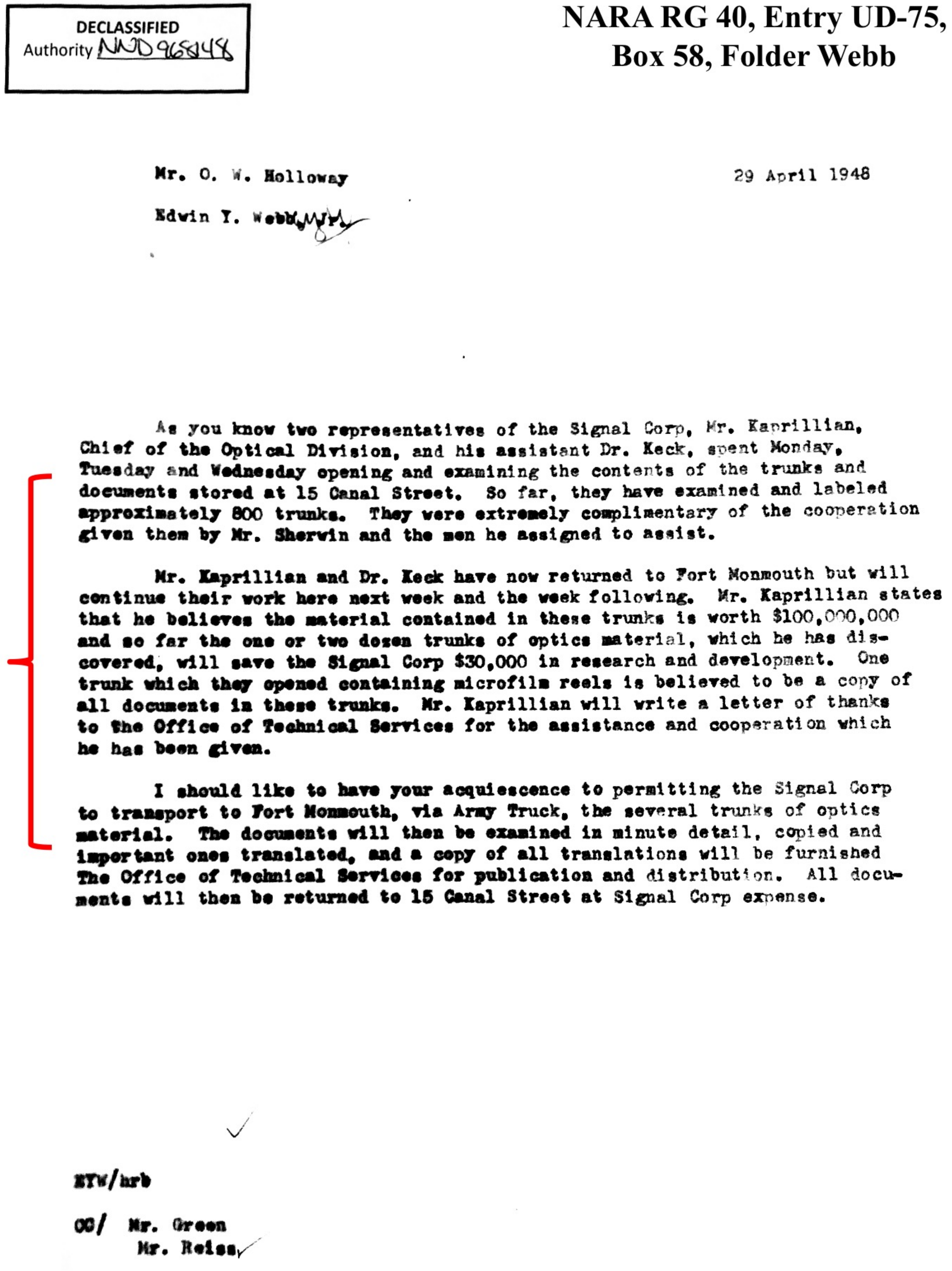
I hope that you have obtained worth while information from this cell and would like to hear from you concerning your results. Please furnish me with details of your report or any information which you may have available on it.

I have recently obtained more of these cells which I am delivering to Dr. Julian Blanchard of the Laboratories.

Sincerely yours,

Edwin Y. Webb, Jr.
Chief, Electronics and
Communications Section
Technical Equipment Section

Figure B.318: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 24, Folder Bell System]. There was likely a great deal of additional technology transfer that was not recorded in official documents.



DECLASSIFIED
Authority NND 968148

NARA RG 40, Entry UD-75, Box 58, Folder Webb

Mr. O. W. Holloway 29 April 1948

Edwin Y. Webb

As you know two representatives of the Signal Corp, Mr. Kaprillian, Chief of the Optical Division, and his assistant Dr. Keck, spent Monday, Tuesday and Wednesday opening and examining the contents of the trunks and documents stored at 15 Canal Street. So far, they have examined and labeled approximately 800 trunks. They were extremely complimentary of the cooperation given them by Mr. Sherwin and the men he assigned to assist.

Mr. Kaprillian and Dr. Keck have now returned to Fort Monmouth but will continue their work here next week and the week following. Mr. Kaprillian states that he believes the material contained in these trunks is worth $100,000,000 and so far the one or two dozen trunks of optics material, which he has discovered, will save the Signal Corp $30,000 in research and development. One trunk which they opened containing microfilm reels is believed to be a copy of all documents in these trunks. Mr. Kaprillian will write a letter of thanks to the Office of Technical Services for the assistance and cooperation which he has been given.

I should like to have your acquiescence to permitting the Signal Corp to transport to Fort Monmouth, via Army Truck, the several trunks of optics material. The documents will then be examined in minute detail, copied and important ones translated, and a copy of all translations will be furnished The Office of Technical Services for publication and distribution. All documents will then be returned to 15 Canal Street at Signal Corp expense.

EYW/hrb

CC/ Mr. Green
Mr. Reiss

Figure B.319: Example of archival documents demonstrating the postwar transfer of microelectronics documents, hardware, personnel, and knowledge [NARA RG 40, Entry UD-75, Box 58, Folder Webb]. There was likely a great deal of additional technology transfer that was not recorded in official documents.

Florian Metzler. 2020. The Transistor, an Emerging Invention: Bell Labs as a Systems Integrator Rather Than a 'House of Magic.' p. 33. https://ssrn.com/abstract=3678081

Karl Darrows, trained as a PhD physicist and a speaker of multiple languages, maintained personal relationships with a large number of leading academic physicists in Europe and the United States. European-trained researchers fulfilled similar tasks such as Foster Nix who received his graduate training in Berlin and was bilingual in English and German (Nix 1975). Relevant scientific news that Bell Labs employees such as Darrows and colleagues might have missed, were often brought to their attention by collaborators in Bell Labs' extended network. An example is Karl Lark-Horovitz, physics department head at Purdue and an Austrian immigrant, who regularly monitored German-language publications and drew attention to relevant new developments in interactions with Bell Labs collaborators (Van Dormael 2004).

Michael Eckert and Helmut Schubert. 1990. *Crystals, Electrons, Transistors: From Scholar's Study to Industrial Research.* pp. 158–163, 166

Bell Laboratories' research director Kelly was giving particular attention to applications in the field of radio for commercial exploitation after the war, once the field of microwaves and radio waves had been opened up to his organization through the radar project. [...] The physical research division was reorganized in July 1945 in order to give more emphasis to solid-state physics. [...]

Shockley, who returned to Bell Laboratories from his war service at the Pentagon in 1945, took charge of the semiconductor group as a theoretical solid-state physicist. The rest of this group consisted of the experimental physicist Brattain, who had been studying the properties of semiconductive surfaces since 1931; Pearson, also an experimental physicist, who had spent many years studying the interior properties of semiconductors; Hilbert Moore, a specialist in electronic circuits; and Robert Gibney, an expert in physical chemistry. To round out his team Shockley suggested to his superior Mr. Kelly that a position be offered to John Bardeen. Bardeen had earned his doctorate at Princeton under Wigner and had worked with van Vleck at Harvard, where Shockley had met him. Both Wigner and van Vleck were among the leading theoreticians in the field of solid-state physics. The general charter of the newly formed group called for the development of fundamental knowledge on the properties of semiconductors, but everyone had "in the back of his mind the objective of building an amplifier out of semiconductive material."

The semiconductor group at Bell Laboratories began its work with a survey of wartime developments in the field of semiconductors in their own research laboratories and those of others. [...]

Shockley could not patent the idea [of a field effect transistor], however, since Julius Lilienfeld had applied for a patent in 1926 on a very similar process, which, however, was never put to practical use. The experiments, however, in which Brattain collaborated, could not demonstrate the predicted effect. [...]

A decisive series of experiments began in November 1947. [...] On November 23, 1947, Bardeen wrote in his laboratory notebook that it was possible to amplify the flow of current from the electron-conducting layer into the metal wire tip by applying a voltage between the drop and the block of silicon. But no change occurred in the voltage between the block and the wire tip. This design, of course, was still entirely unsuitable for practical application. The drop of water evaporated quickly and only slowly changing currents were amplified. [...]

The further experiments in December 1947 were concentrated on the point contact. Bardeen reckoned that a significant amplification would be achieved when the contacts were spaced only some 0.05 mm apart. At that time this was a very difficult problem, which Brattain solved elegantly. He applied gold foil to a three-dimensional prism and cut it on one side of the triangle carefully with a razor blade in order to obtain two closely spaced contacts. This arrangement worked on the first try on December 16, 1947. It amplified signals up to 100 times, and amplification occurred even at frequencies in the radio wave region. A step had been made toward Kelly's research objective in the 1930s, the development of a practical solid-state repeater. A week of intensive work followed to make sure that no errors crept in. On December 23, 1947, the amplifier was shown to management. [...]

When the first germanium point-contact transistors were produced on an industrial scale in 1951 by Western Electric, the manufacturing arm of the Bell System, several other large firms were experimenting with the new component. It turned out to be difficult to build reliable transistors with the two closely space points, and it was almost impossible to produce them with identical characteristics. They had a very limited lifetime and could not process high-frequency currents. Compared with equivalent technical data for amplifier tubes, these transistors were not attractive products.

Jon Gertner. 2012. *The Idea Factory: Bell Labs and the Great Age of American Innovation.* pp. 90–92.

“My calculations showed that very substantial modulation of the resistance should occur,” Shockley later noted. “None was observed. On 23 June 1945, I wrote that the effects were at least 1,500 times smaller than what I predicted should have been observable.” He was vexed. And for close to a year, any attempts to make the field effect work failed. Shockley would eventually call this period “the natural blundering process of finding one’s way.”

Whatever it was, by January 1946 the solid-state group, venturing far beyond the traditional methods of trial-and-error invention, had found neither enlightenment nor promise. As Brattain’s lab mate Gerald Pearson would later note, they were groping in the dark. [...]

Shockley and Bardeen had even spent several weeks together in the summer of 1947 visiting various European laboratories. By late autumn, with the newly planted trees on the Murray Hill campus nearly bereft of leaves, the solid-state team began an experimental regimen on silicon and germanium slices that offered a steady progression of insights.

Lillian Hoddeson and Vicki Daitch. 2002. *True Genius: The Life and Science on John Bardeen.* pp. 128–131.

The group tried many related experiments, but for the next eighteen months they made little progress.

During the remainder of 1946 and throughout 1947, Shockley’s engagement with the field effect studies flagged, for he developed new interests during the summer of 1947, when he and Bardeen took an extended tour of European laboratories. [...]

Bardeen wrote that he had “learned a lot during the trip, and have picked up some information that may be useful to the Lab. Whether or not it’s enough to pay for the trip is hard to judge.” In any case, it had been “very hard work—much harder than you can imagine without doing it—but it’s also been a grand experience.” [...]

The “magic month” that culminated in the transistor began in the middle of November 1947, three months after Bardeen and Shockley returned from Europe.

Werner Grothmann (Heinrich Himmler's adjutant) [Krotzky 2002, p. 48]. For a discussion of the background and reliability of this source, see pp. 3396–3397.

Entweder steuert jemand die Rakete ins Ziel, oder die muß vollautomatisch gehen. Himmler war skeptisch, ob ein Pilot bei der Geschwindigkeit überhaupt reagieren kann. Ich meine, die Rakete sollte ja mit etlichen Tausend Kilometern fliegen. Dann gab es auch gar keine Fernsteuerung, die auf die Entfernung wirklich sicher funktionierte. Da hatte Himmler schon früher mal mit Ohnesorge darüber gesprochen und ich glaube, der hat dazu auch was arbeiten lassen. Was sich da ergeben hat, weiß ich aber nicht. Nur an eines kann ich mich noch erinnern, nämlich unsere Raketenleute hatten ja eine kleine Abteilung von, heute müsste sagen Elektronikern, die haben zur völligen Überraschung von uns und auch von Ohnesorge im Winter 44 eine Sende- und Empfangsanlage entwickelt, die man nicht mehr stören konnte, weil sie selbständig dauernd die Funkfrequenz änderte. Außerdem war die ganz klein, richtig winzig. Die hatte nur ungefähr ein kg, der Empfänger meine ich. Wie die das geschafft haben, diese Technik zu verkleinem, ist mir unbekannt. Himmler aber Befehl gegeben, Ohnesorge den Prototyp zu zeigen. Ob das geschehen ist, kann ich nicht sagen. Ich weiß auch nicht, ob der Sender überhaupt auf die Reichweite bis Amerika ausgelegt war. Nach Krieg hörten wir dann, die Amerikaner hätten den Transistor erfunden. Das hat wohl einige von unseren Leuten sehr aufgeregt, weil der doch von uns stammte. Ein Bekannter sagte mir dazu, bei uns hätte der Transistor "Sperrschicht-Halbleiter" geheißen. Der war von einem Professor an einer technischen Hochschule erfunden worden. Es kann sein das war Aachen.

Either someone pilots the rocket into the target, or it must be fully automatic. Himmler was skeptical whether a pilot could react at all at that speed. I mean, the rocket was supposed to fly several thousand kilometers. Then there was no remote control at all, which really worked safely at that distance. Himmler had already talked to Ohnesorge about this and I think he had something worked out. But I don't know what came of it. I can only remember one thing, namely that our rocket people had a small department of, today I would have to say electronic engineers, who, to the complete surprise of us and also of Ohnesorge, developed a transmitting and receiving system in the winter of 44, which could no longer be jammed, because it constantly changed the radio frequency on its own. It was also very small, really tiny. It weighed only about one kilogram, the receiver I mean. How they managed to miniaturize this technology is unknown to me. But Himmler gave orders to show the prototype to Ohnesorge. Whether this was done, I cannot say. I also don't know if the transmitter was even designed to reach America. After the war, we heard that the Americans had invented the transistor. That must have upset some of our people very much, because it came from us. An acquaintance told me that in our country the transistor was called a "junction semiconductor." It had been invented by a professor at a technical university. It may have been Aachen.

[For other sources that confirmed that highly advanced electronic guidance systems for long-range missiles were developed in Germany during the war and then transferred after the war to the United States, specifically AT&T Bell Laboratories, see for example pp. 2938–2962, 5348, 5444, 5454, 5557.

Evidence such as that presented in this appendix suggests (but does not yet prove—much more investigation is required) that the German-speaking scientists' transistor developments not only preceded those of Bell Laboratories, but may have been directly used by Bell Laboratories as a guide to reproduce the earlier German-speaking work:

- The German-speaking transistor developments came from at least 12 different groups doing extensive work during a period of over two decades collectively.

- During World War II, the German military was keenly interested in funding the development of smaller, more rugged, and more sophisticated electronic guidance systems that could be used in rockets ranging from anti-aircraft missiles to intercontinental ballistic missiles. Transistors derived from the existing German patents and papers would have been an important part of those guidance systems.

- In spring 1945, hundreds of thousands of tons of German-language technical documents were seized by the United States, thousands of German-speaking scientists were interrogated by U.S. scientists and engineers, and countless prototypes, pieces of equipment, and whole laboratories were shipped to the United States.

- Personnel from Bell Laboratories played a prominent role in collecting that scientific information from Europe and processing it in the United States.

- In late 1945, Bell Laboratories put John Bardeen and Walter Brattain to work to try to produce a simple transistor, with some supervision by William Shockley. As noted above, “the semiconductor group at Bell Laboratories began its work with a survey of wartime developments in the field of semiconductors.”

- Bardeen and Shockley conducted detailed visits to numerous European laboratories from June through August 1947. During that time, Bardeen or Shockley could have easily encountered scientists, reports, or information from the earlier transistor development programs of the German-speaking world, or at least Allied investigators who had already studied those programs. Although any transistor-related information that Bardeen and Shockley learned during this time has never been publicly disclosed, Bardeen wrote at the end of the trip: “learned a lot during the trip, and have picked up some information that may be useful to the Lab” [Hoddeson and Daitch 2002, p. 130].

- Bardeen and Brattain did not begin serious experimentation with transistor-like devices until November 1947, two and a half years after the end of the war (and over two and a half years after the collection and study of German microelectronics information began in earnest). Within just a couple of months this very small team created what appears to be a crude replica of the earlier German work.

- Not only did Shockley not give any credit to the earlier German work, but he refused to give proper credit to Bardeen and Brattain, who actually performed the Bell Laboratories experiments.

- Due to their personal differences, the team of Bardeen, Brattain, and Shockley soon split up. Even in 1951, Western Electric (the manufacturing arm of AT&T/Bell Laboratories) was unable to produce reliable transistors. Most transistor development in the United States was carried out by other researchers, including several German-speaking scientists (Kurt Lehovec, Herbert Kroemer, Jean Hoerni, Eugene Kleiner, Karl Heinz Zaininger, etc.) as shown in this appendix.

Much more archival research is needed to determine the true extent of microelectronics innovations in the German-speaking world, as well as how much that influenced postwar work in other countries.]

Appendix C

Advanced Creations in Directed Energy

> In hoc templo, quod totum ex auro paratum est, statuas trium deorum veneratur populus, ita ut potentissimus eorum Thor in medio solium habeat triclinio. [...] ‘Thor’, inquiunt, ‘praesidet in aere, qui tonitrus et fulmina, ventos ymbresque, serena et fruges gubernat.’ [...] Thor autem cum sceptro Iovem simulare videtur.

> In this temple, entirely decked out in gold, it is said, the people worship the statues of three gods, so that the mightiest of them, Thor, occupies a throne in the middle of the chamber. [...] ‘Thor,’ they say, ‘rules the sky; he governs thunder and lightning, winds and storms, fine weather and crops.’ [...] Thor with his scepter apparently resembles Jupiter.

Adam of Bremen. Circa 1075. *Gesta Hammaburgensis Ecclesiae Pontificum*
[*Deeds of the Bishops of Hamburg*]. Book 4 (Descriptio insularum Aquilonis), Chapter 26.

This appendix presents evidence for early German research and development regarding various types of directed energy technologies, such as:

C.1. Particle beams and X-rays.

C.2. Electromagnetic pulse weapons.

C.3. Lasers.

C.4. Focused sound waves.

C.5. Electromagnetic railguns.

Although this evidence is relatively brief and highly incomplete, hopefully it will stimulate much more archival research in the future in order to elucidate the complete work of German-speaking scientists in these areas, as well as the full impact that their work had on later scientists and projects outside the German-speaking world.

C.1 Particle Beams and X-Rays

[German-speaking scientists did an enormous amount of work on particle accelerators before and during the war. Some of that work was simply aimed at developing the relevant technologies or applying them to fundamental physics questions. A significant amount of the work was for nuclear physics, apparently even including electronuclear breeding of weapons-grade fission fuel (see pp. 3954–4022, 4504–4510, and 5133–5134). Yet much of the work on particle accelerators seems to have been intended to create directed energy weapons. Many different versions of such weapons were under development during the war; they would have fired a beam of high-energy electrons and/or ions, or in some cases they would have harnessed the energy from those charged particles to produce an intense beam of X-rays, a burst of high-energy neutrons, or other forms of radiation. If some of the reports available in archives are correct (and one could certainly debate whether they are, unless or until more conclusive evidence is found), at least some of these weapons apparently reached the stage of successful tests against laboratory animals or solid targets.

The known amount of literature on this topic is quite large, so this section can only present some highlights. Even so, much more archival research should be conducted to unearth new information on these programs, in order to determine exactly how far they progressed and how much they influenced programs in other countries.

All accelerators use an electric field to accelerate charged particles. However, different types of accelerators produce the electric field in different ways, accelerate particles either continuously or by a series of impulses, and employ either circular or linear geometries:

- In a betatron, electrons follow a circular orbit in a magnetic field. Changing the magnetic flux passing through the orbit induces an accelerating electric field around the orbit. The increasing magnetic field keeps the orbital radius constant despite the increasing particle energies. The iron pole pieces are shaped to provide a stronger magnetic field inside the orbit than at the orbital radius.

- In a cyclotron, an accelerating electric field is applied each time the particles pass between two D-shaped electrodes. Particles are allowed to spiral outward as their energy increases.

- In a synchrotron, an accelerating electric field is applied each time the particles cross an electrode gap. Magnetic sections bend the particle trajectories into a closed orbit. Straight, magnetic-field-free sections are useful for injecting or extracting particles. By allowing a large orbital radius and adjusting the electric and magnetic fields as particles are accelerated, energies of > 1 TeV can be obtained.

- In a linear accelerator, particles travel down the center of a long, straight tube. There is a traveling or standing electromagnetic wave in the tube, and a series of irises in the tube makes the wave ricochet back and forth off the walls instead of passing straight down the tube. The ricocheting slows the wave's longitudinal velocity to match the particle velocity and also makes the wave have an electric field component in the longitudinal direction, suitable for accelerating the particles.]

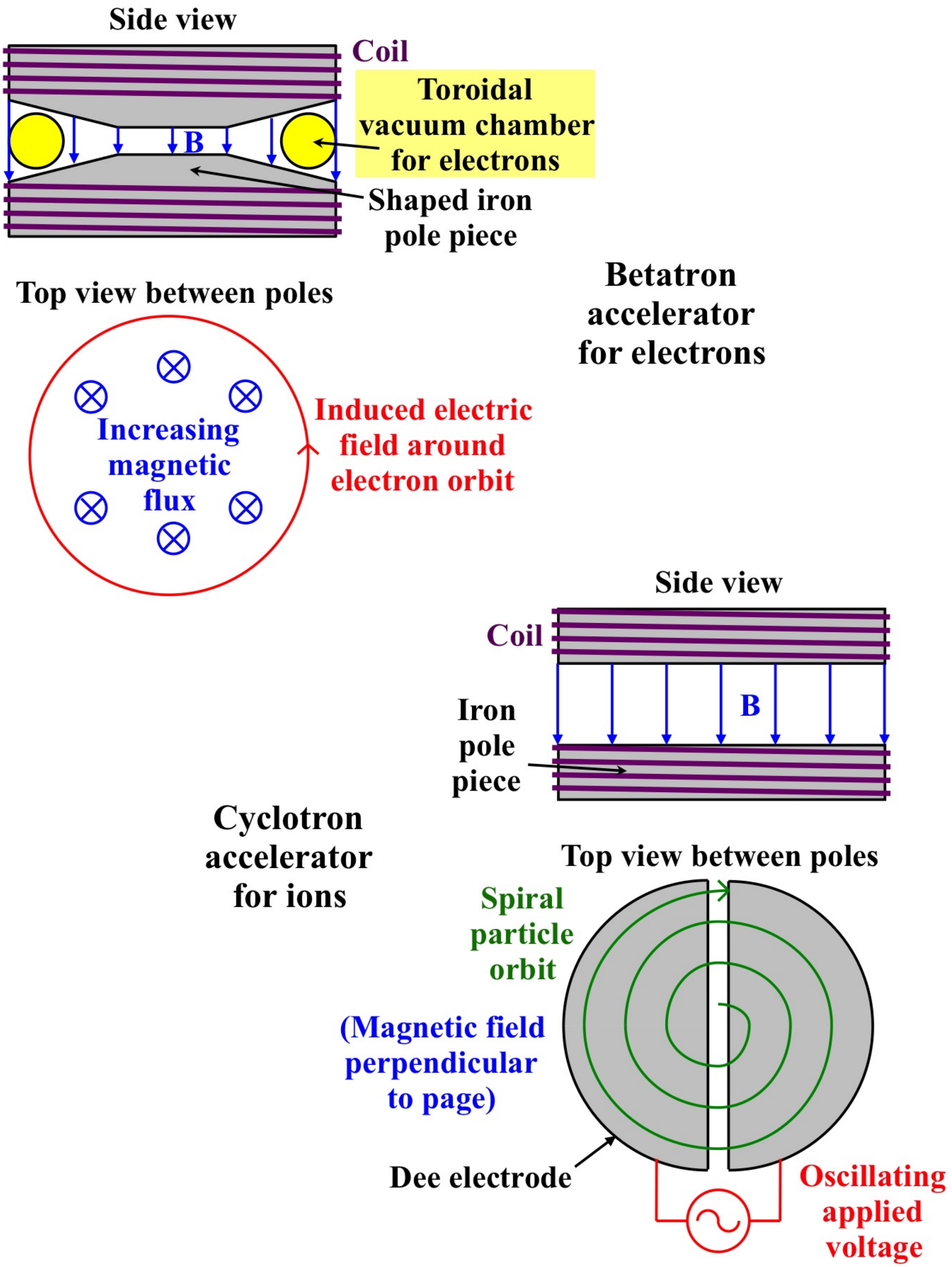

Side view
Coil
Toroidal vacuum chamber for electrons
B
Shaped iron pole piece
Top view between poles
Betatron accelerator for electrons
Increasing magnetic flux
Induced electric field around electron orbit
Side view
Coil
B
Iron pole piece
Cyclotron accelerator for ions
Top view between poles
Spiral particle orbit
(Magnetic field perpendicular to page)
Dee electrode
Oscillating applied voltage

Figure C.1: Betatron circular accelerator for electrons, and cyclotron circular accelerator for ions.

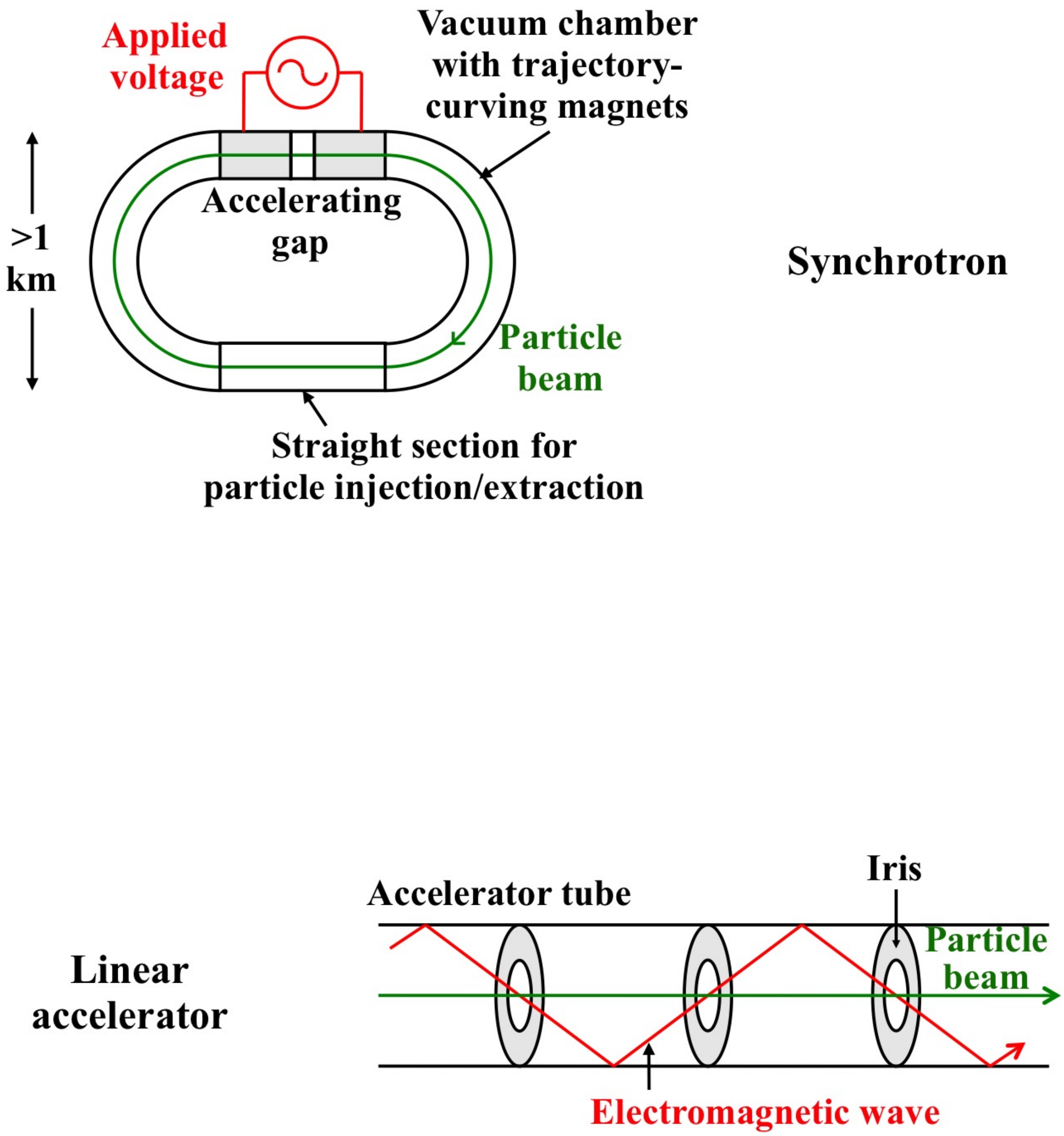

Applied voltage
Vacuum chamber with trajectory-curving magnets
Accelerating gap
>1 km
Particle beam
Straight section for particle injection/extraction
Synchrotron
Linear accelerator
Accelerator tube
Iris
Particle beam
Electromagnetic wave

Figure C.2: Synchrotron circular accelerator for very high-energy particles, and linear accelerator that uses an electromagnetic wave to accelerate charged particles in a tube.

Pedro Waloschek. 2012. *Death-Rays as Life-Savers in the Third Reich.* Draft English translation of *Todesstrahlen als Lebensretter* pp. 98–100 [http://www-library.desy.de/preparch/books/death-rays.pdf].

Rolf Wideröe was born on July 11, 1902 in Oslo where he also went to school. His father was a well situated importer of wine, cognac and oils. His mother was of German origin. After getting his A-levels ("Abitur") in 1920 he started studying electrical engineering at the Technical University in Karlsruhe. Already as a student he had quite original ideas, like i.e. a device which could accelerate electrons to very high energies. Such electrons could be used to investigate the structure of atoms (he admired Lord Rutherford's discoveries). His accelerator should work on the principle of the well known electric current transformer. The secondary windings of the transformer would be substituted with an electron beam turning around in an evacuated tube [Wi23]. So he called his accelerator "beam transformer" or "ray transformer" ("Strahlentransformator").

But Wideröe's beam-transformer did not work. Later on he understood why. Therefore he could not use it for his doctoral thesis. So he built another particle accelerator, this time with positive result. He applied an idea of the Swedish physicist Gustav Ising which consisted in using an available high voltage several times to accelerate the same particles.

With 25,000 Volt available he was able to accelerate particles as if he would have 50,000 Volts! This device was worldwide the first successfully running "linear accelerator" and is considered as an important pioneer achievement in the field.

Wideröe's report on his results was accepted as doctoral thesis and published in a well known journal edited by Rogowski, the "Archiv für Elektrotechnik". As an appendix he added his ideas about a beam-transformer and described an important condition which the used magnet should satisfy. This was later on known as the "Wideröe 2 to 1" condition.

The American physicist Ernest Orlando Lawrence (1901–1958) saw Wideröe's publication in the Library of his Institute, could not understand much of the German texts, but very well the included illustrations. This inspired him to an interesting idea. The principle of the linear accelerator could be used several times on the same particles, if their orbit would be would up with the help of a magnetic field. This was the starting idea for the famous "cyclotron", which in the following years became one of the most important instruments for nuclear physics research. For the development of the cyclotron Lawrence was awarded in 1939 the Nobel Prize in physics. He always acknowledged thankfully Wideröe's initial suggestion [La31]. A curiosity: The cyclotron-principle was at about the same time also presented in their institutes by two German physicists, Eugen Flegler and Max Steenbeck. To my knowledge Flegler never published his ideas and Steenbeck did so, but much too late.

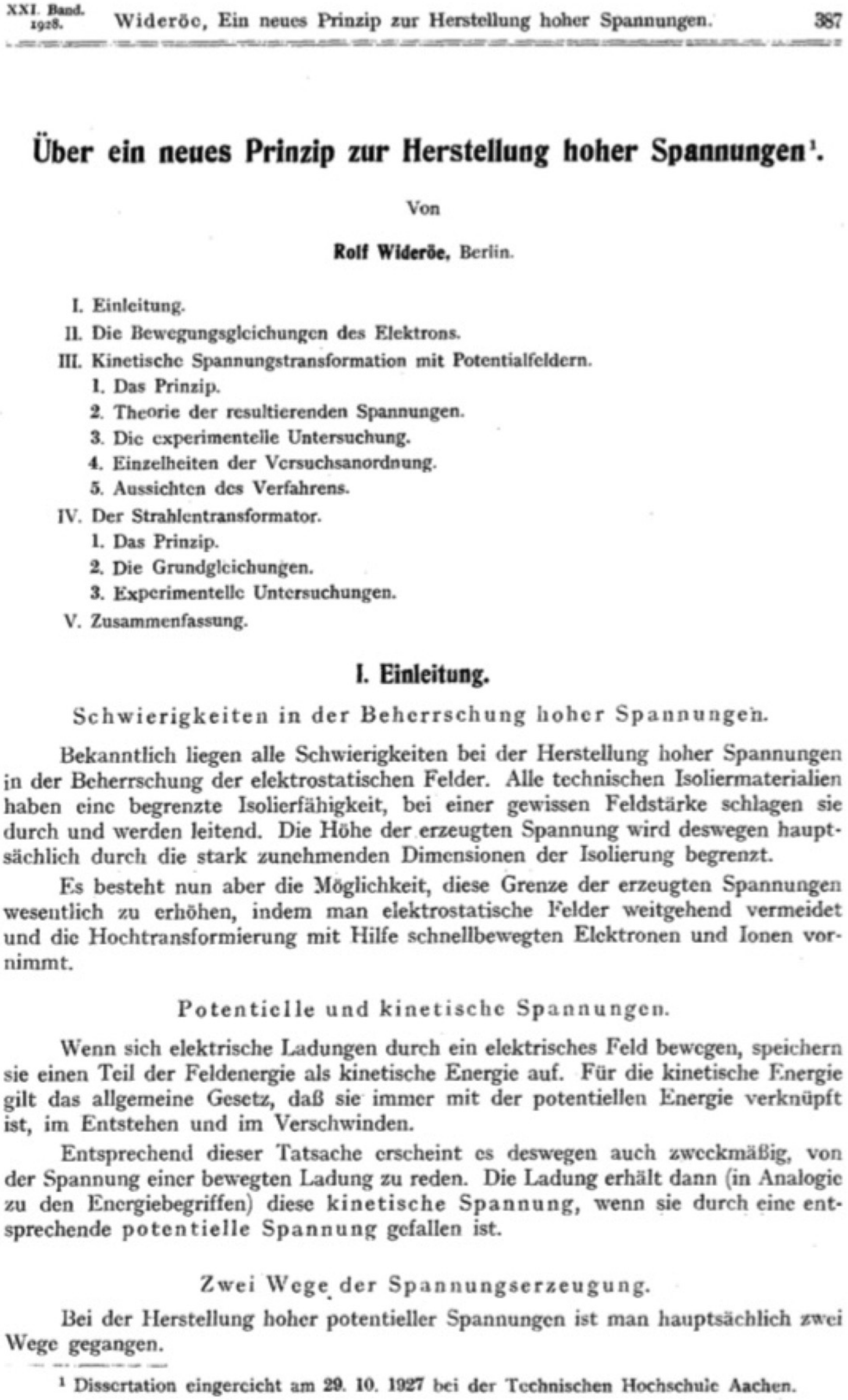
[See also:

Giulia Pancheri. 2022. *Bruno Touschek's Extraordinary Journey: From Death Rays to Antimatter.* Berlin: Springer.

Aashild Sørheim. 2020. *Obsessed by a Dream: The Physicist Rolf Widerøe—a Giant in the History of Accelerators.* Berlin: Springer.

Pedro Waloschek. 2004. *Todesstrahlen als Lebensretter: Tatsachenberichte aus dem Dritten Reich.* 2nd ed. Norderstedt: Books on Demand.

Pedro Waloschek. 2007. *Rolf Wideröe 1902–1996: A Pioneer of Particle Accelerators and Radiation Therapy.* 2nd ed. Books on Demand.]



Über ein neues Prinzip zur Herstellung hoher Spannungen[1].

Von

Rolf Wideröe, Berlin.

I. Einleitung.
II. Die Bewegungsgleichungen des Elektrons.
III. Kinetische Spannungstransformation mit Potentialfeldern.
  1. Das Prinzip.
  2. Theorie der resultierenden Spannungen.
  3. Die experimentelle Untersuchung.
  4. Einzelheiten der Versuchsanordnung.
  5. Aussichten des Verfahrens.
IV. Der Strahlentransformator.
  1. Das Prinzip.
  2. Die Grundgleichungen.
  3. Experimentelle Untersuchungen.
V. Zusammenfassung.

I. Einleitung.

Schwierigkeiten in der Beherrschung hoher Spannungen.

Bekanntlich liegen alle Schwierigkeiten bei der Herstellung hoher Spannungen in der Beherrschung der elektrostatischen Felder. Alle technischen Isoliermaterialien haben eine begrenzte Isolierfähigkeit, bei einer gewissen Feldstärke schlagen sie durch und werden leitend. Die Höhe der erzeugten Spannung wird deswegen hauptsächlich durch die stark zunehmenden Dimensionen der Isolierung begrenzt.

Es besteht nun aber die Möglichkeit, diese Grenze der erzeugten Spannungen wesentlich zu erhöhen, indem man elektrostatische Felder weitgehend vermeidet und die Hochtransformierung mit Hilfe schnellbewegten Elektronen und Ionen vornimmt.

Potentielle und kinetische Spannungen.

Wenn sich elektrische Ladungen durch ein elektrisches Feld bewegen, speichern sie einen Teil der Feldenergie als kinetische Energie auf. Für die kinetische Energie gilt das allgemeine Gesetz, daß sie immer mit der potentiellen Energie verknüpft ist, im Entstehen und im Verschwinden.

Entsprechend dieser Tatsache erscheint es deswegen auch zweckmäßig, von der Spannung einer bewegten Ladung zu reden. Die Ladung erhält dann (in Analogie zu den Energiebegriffen) diese kinetische Spannung, wenn sie durch eine entsprechende potentielle Spannung gefallen ist.

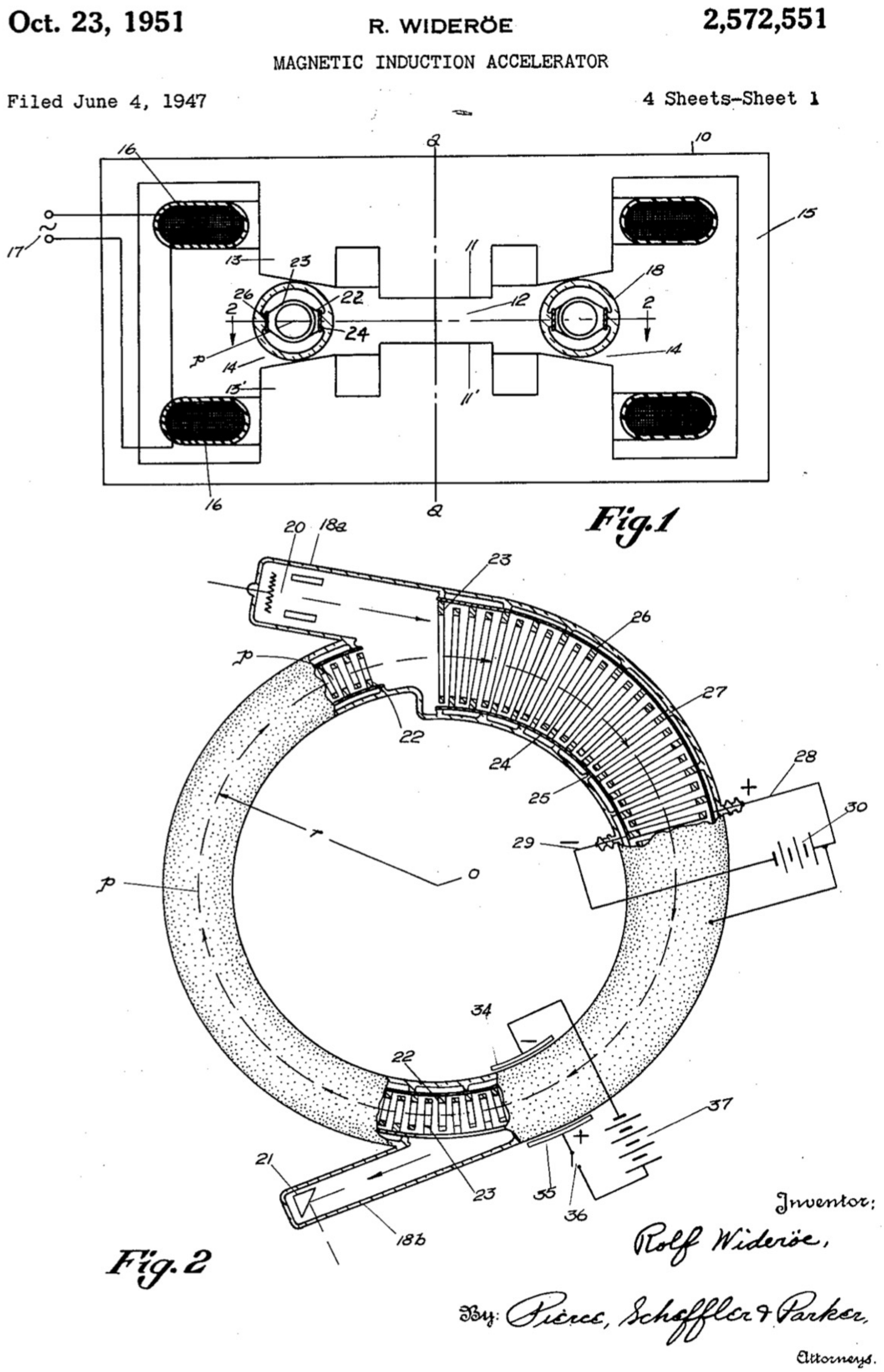
Zwei Wege der Spannungserzeugung.

Bei der Herstellung hoher potentieller Spannungen ist man hauptsächlich zwei Wege gegangen.

---

[1] Dissertation eingereicht am 29. 10. 1927 bei der Technischen Hochschule Aachen.

Figure C.3: Rolf Wideröe's landmark 1928 paper on particle accelerators [*Archiv für Elektrotechnik* (1928) 21:4:387–406].



Oct. 23, 1951 R. WIDERÖE **2,572,551**

MAGNETIC INDUCTION ACCELERATOR

Filed June 4, 1947 4 Sheets-Sheet 1

10
15
16
17
13
13'
23
26
22
24
18
12
11
11'
14
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Fig. 1
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18a
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25
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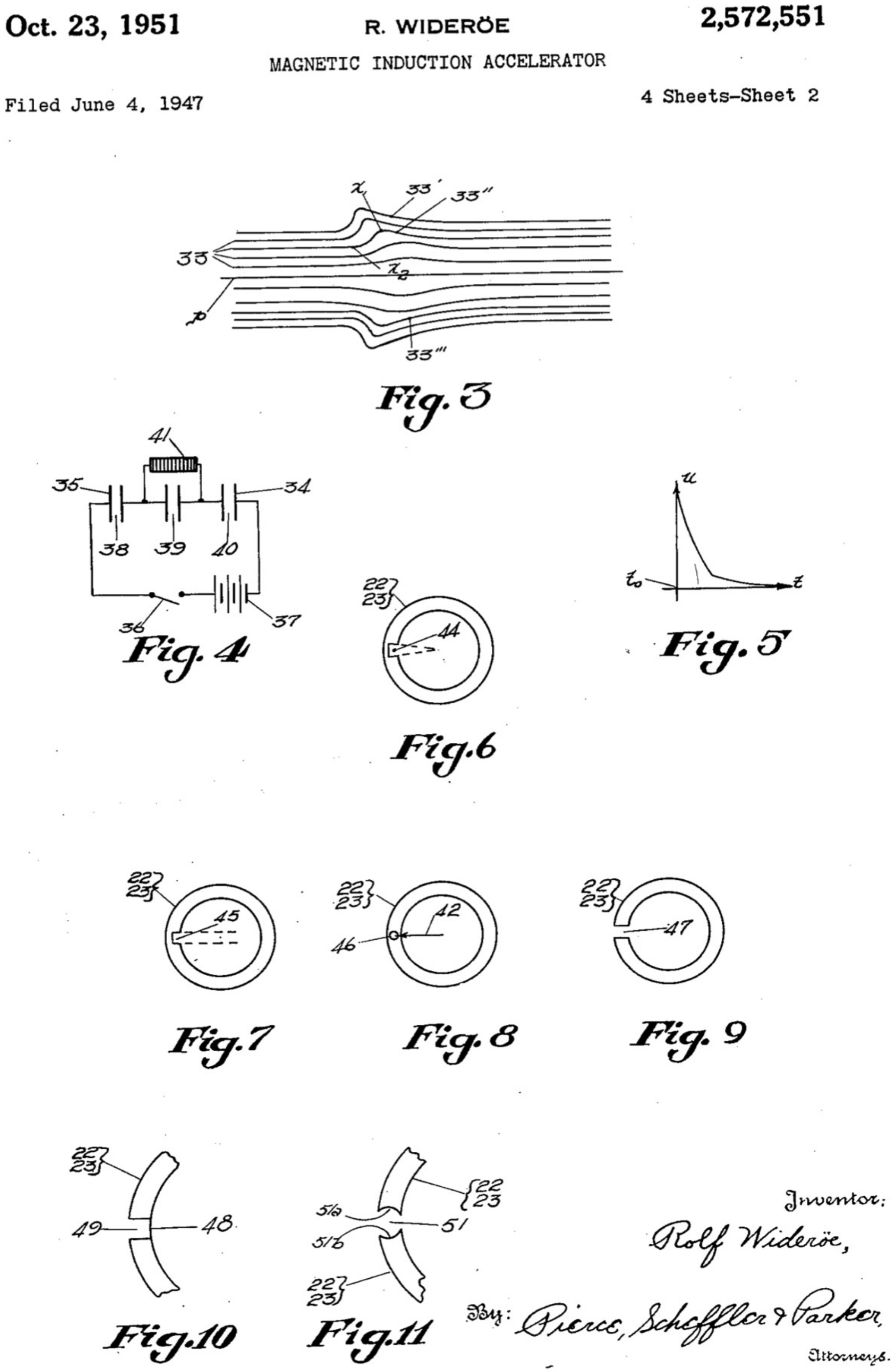
29
30
r
o
p
34
22
37
23
35
36
21
18b
Fig. 2

Inventor:
Rolf Wideröe,
By: Pierce, Scheffler & Parker,
Attorneys.

Figure C.4: Figures from one of Rolf Wideröe's wartime patents on particle accelerators.



Oct. 23, 1951 **R. WIDERÖE** **2,572,551**

MAGNETIC INDUCTION ACCELERATOR

Filed June 4, 1947 4 Sheets-Sheet 2

x_1
33'
33''
33
x_2
p
33'''
Fig. 3
41
35
34
38
39
40
36
37
Fig. 4
22
23
44
Fig. 6
u
t_0
t
Fig. 5
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23
45
Fig. 7
22
23
42
46
Fig. 8
22
23
47
Fig. 9
22
23
49
48
Fig. 10
22
23
51a
51b
51
22
23
Fig. 11

Inventor:
Rolf Wideröe,
By: Pierce, Scheffler & Parker,
Attorneys.

Figure C.5: Figures from one of Rolf Wideröe's wartime patents on particle accelerators.

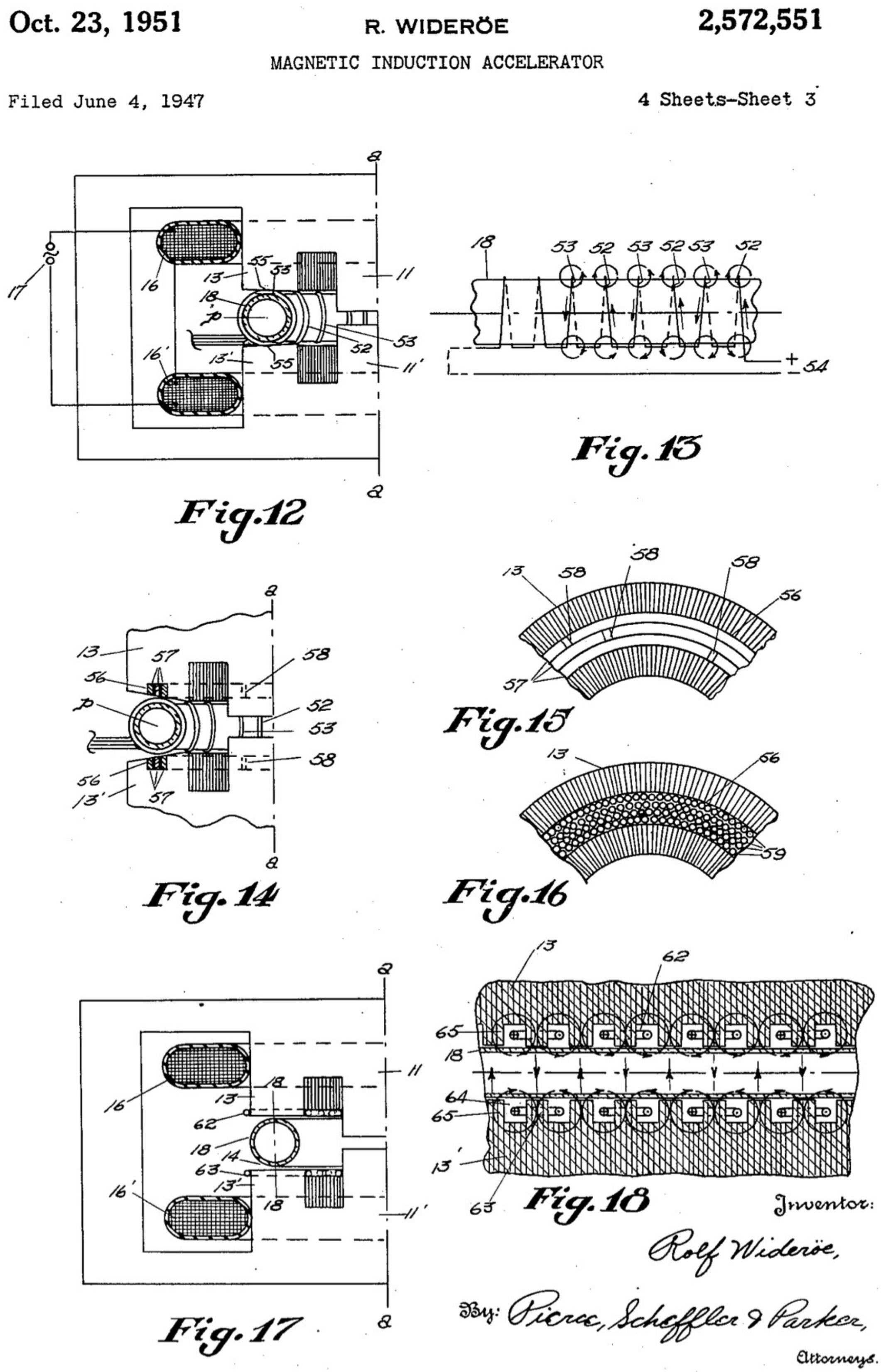
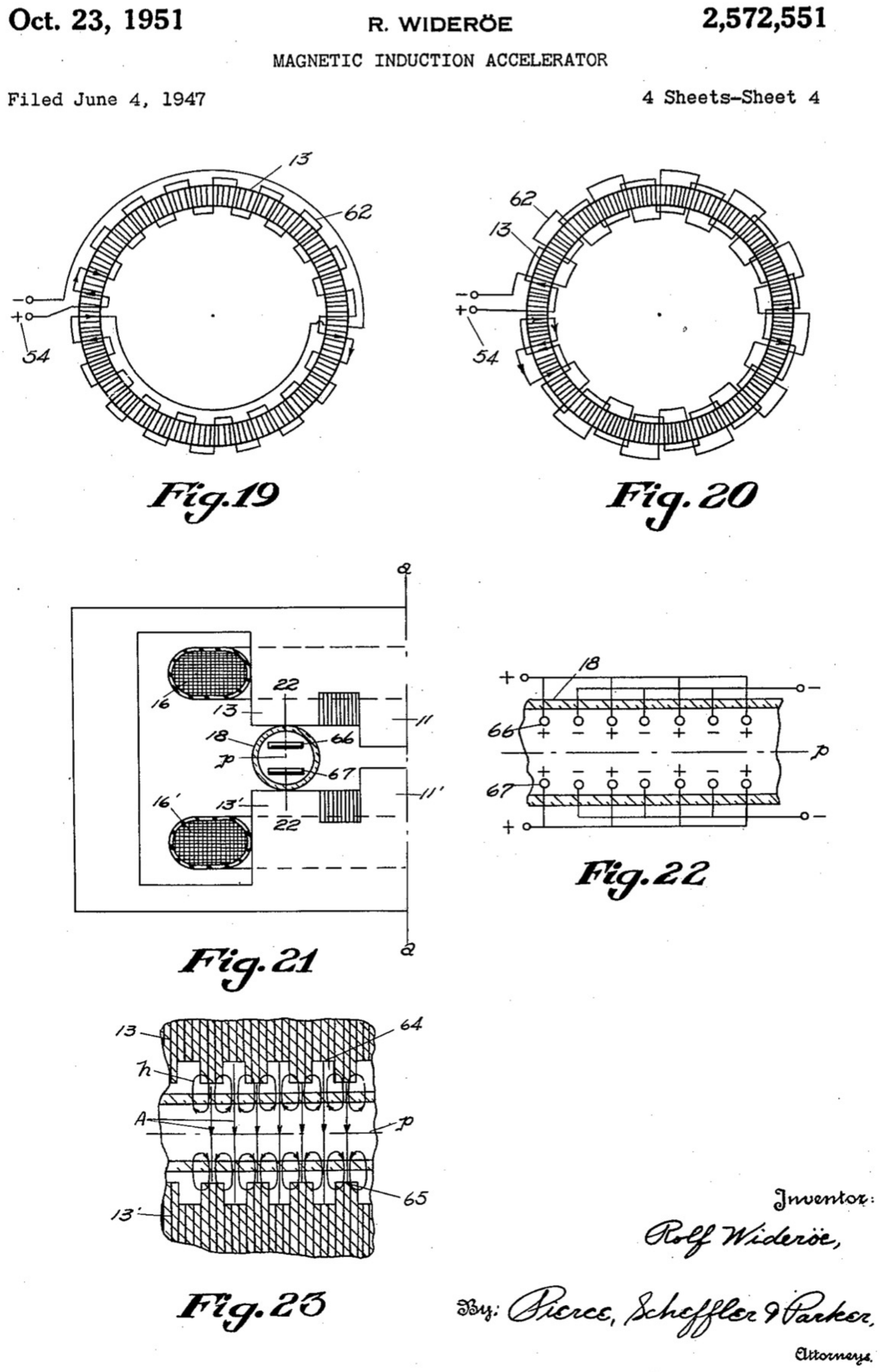

Oct. 23, 1951
R. WIDERÖE
2,572,551
MAGNETIC INDUCTION ACCELERATOR
Filed June 4, 1947
4 Sheets-Sheet 3
Fig.12
Fig.13
Fig.14
Fig.15
Fig.16
Fig.17
Fig.18
8
11
11'
13
13'
14
16
16'
17
18
p
52
53
54
55
56
57
58
59
62
63
64
65
Inventor:
Rolf Wideröe,
By: Pierce, Scheffler & Parker,
Attorneys.

Figure C.6: Figures from one of Rolf Wideröe's wartime patents on particle accelerators.



Oct. 23, 1951 **R. WIDERÖE** **2,572,551**

MAGNETIC INDUCTION ACCELERATOR

Filed June 4, 1947 4 Sheets–Sheet 4

13
62
−
+
54
Fig.19
62
13
−
+
54
Fig. 20
a
16
22
13
18
66
p
67
16′
13′
22
11
11′
a
Fig. 21
+
18
−
66
+ − + − + − +
p
+ − + − + − +
67
+
−
Fig. 22
13
64
h
A
p
65
13′
Fig. 23

Inventor:
Rolf Wideröe,
By: Pierce, Scheffler & Parker,
Attorneys.

Figure C.7: Figures from one of Rolf Wideröe's wartime patents on particle accelerators.

Dec. 28, 1954 R. WIDERÖE **2,698,384**

MAGNETIC INDUCTION ACCELERATOR

Filed Nov. 8, 1946 3 Sheets-Sheet 1

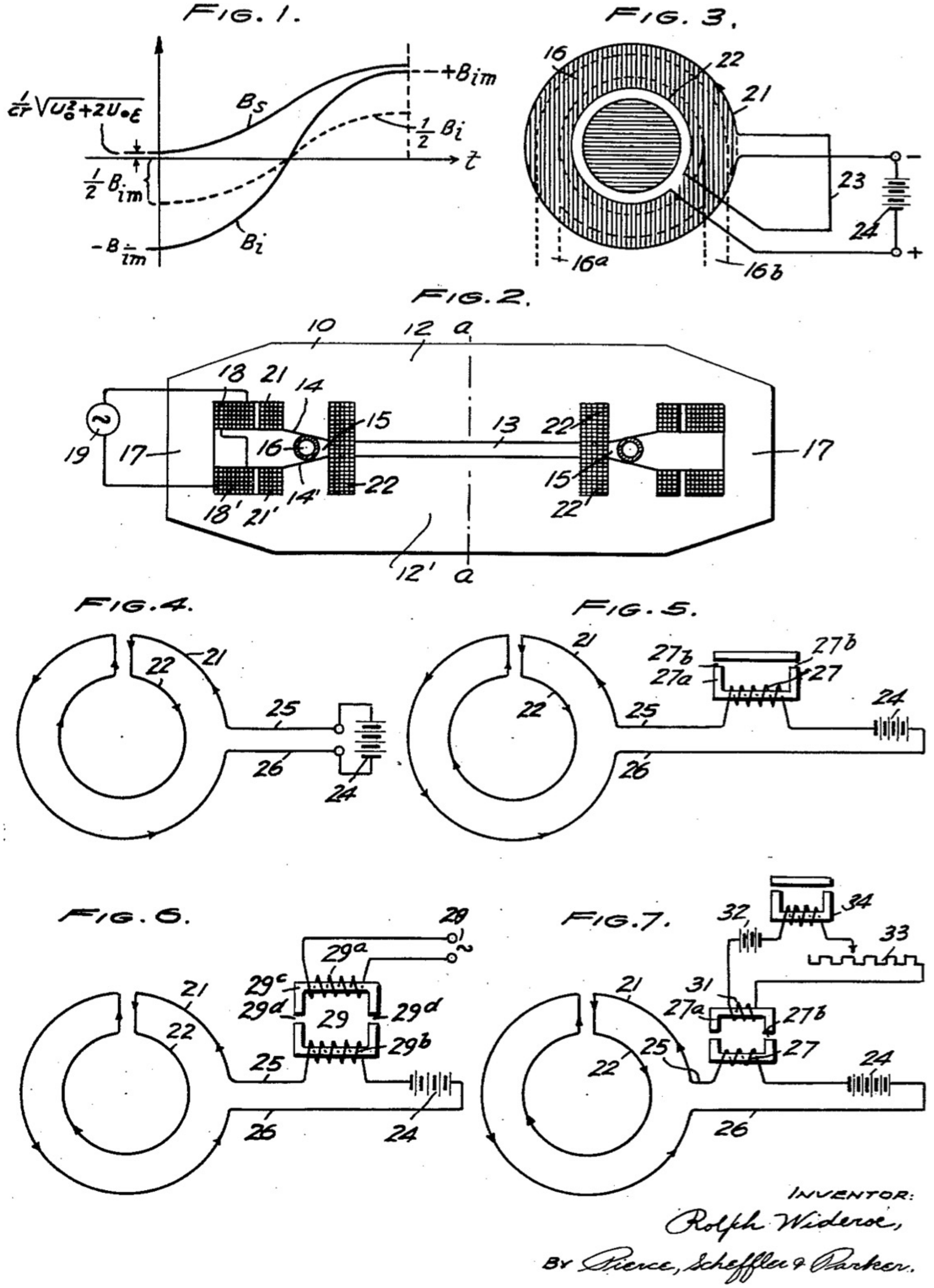
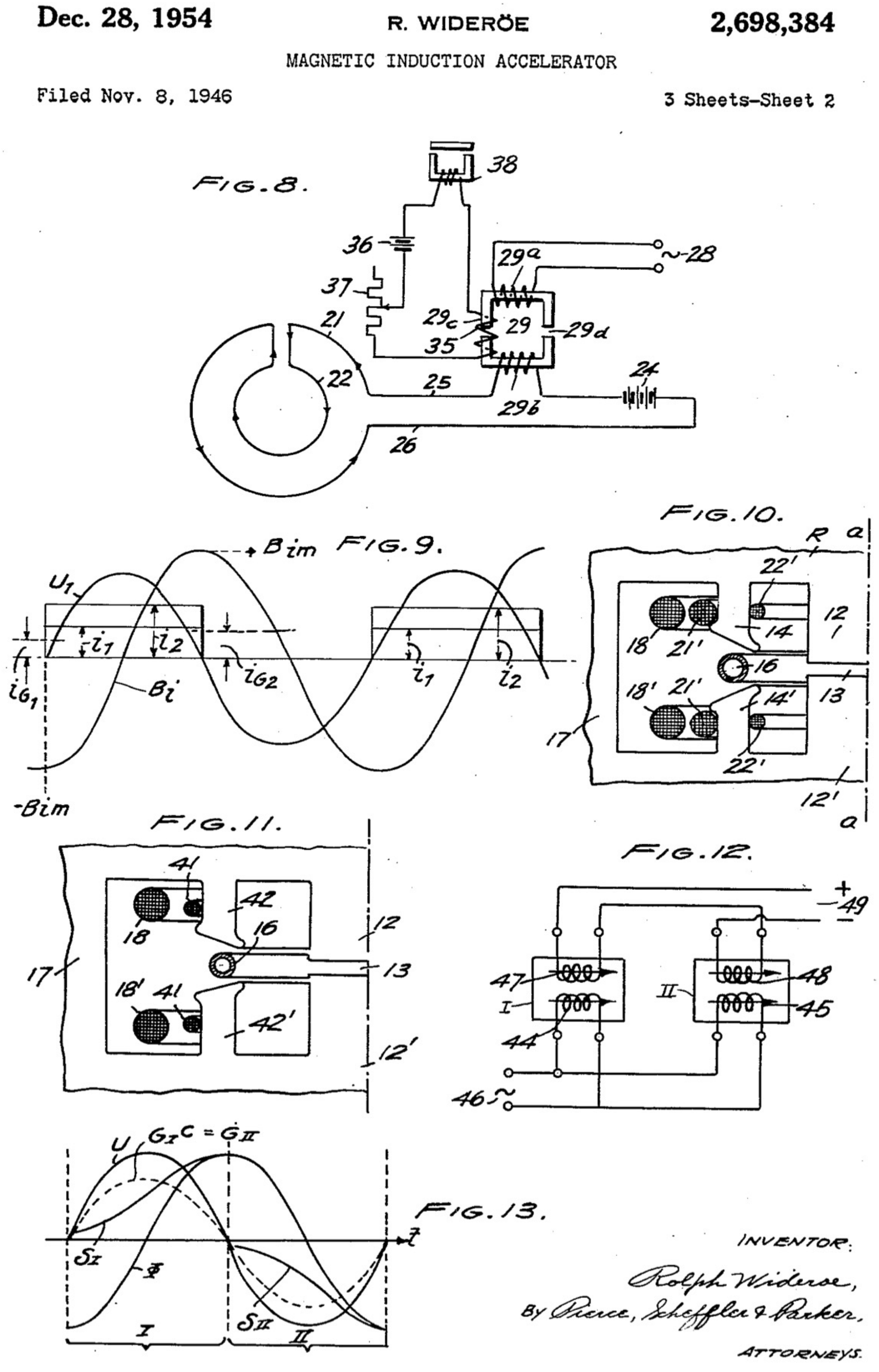


FIG. 1.
$\frac{1}{cr}\sqrt{U_0^2+2U_0\varepsilon}$
$+B_{im}$
B_s
$\frac{1}{2}B_i$
t
$\frac{1}{2}B_{im}$
$-B_{im}$
B_i
FIG. 3.
16
22
21
23
24
16a
16b
−
+
FIG. 2.
10
12
a
18
21
14
15
13
22
17
19
16
14'
22
15
22'
18'
21'
12'
a
17
FIG. 4.
21
22
25
26
24
FIG. 5.
21
27b
27a
27b
27
22
25
24
26
FIG. 6.
29
29a
29c
29d
29
29d
29b
21
22
25
24
26
24
FIG. 7.
32
34
33
21
31
27a
27b
25
27
22
24
26

INVENTOR:
Rolph Wideröe,
BY Pierce, Scheffler & Parker.
ATTORNEYS.

Figure C.8: Figures from one of Rolf Wideröe's wartime patents on particle accelerators.



Dec. 28, 1954 **R. WIDERÖE** **2,698,384**

MAGNETIC INDUCTION ACCELERATOR

Filed Nov. 8, 1946 3 Sheets-Sheet 2

FIG. 8.
38
36
37
21
22
29a
~28
29c
29
35
29d
25
24
29b
26
Bim
FIG. 9.
U1
i1
i2
iG1
Bi
iG2
i1
i2
-Bim
FIG. 10.
R
a
22'
18
21'
14
12
16
13
18'
21'
14'
17
22'
12'
a
FIG. 11.
41
42
18
16
12
17
13
18'
41
42'
12'
FIG. 12.
+
-49
-
47
48
I
II
45
44
46~
U
GI
C = GII
FIG. 13.
t
SI
Φ
SII
I
II

INVENTOR:
Rolph Wideröe,
BY Pierce, Scheffler & Parker,
ATTORNEYS.

Figure C.9: Figures from one of Rolf Wideröe's wartime patents on particle accelerators.

Dec. 28, 1954 R. WIDERÖE **2,698,384**

MAGNETIC INDUCTION ACCELERATOR

Filed Nov. 8, 1946 3 Sheets-Sheet 3

FIG. 14.

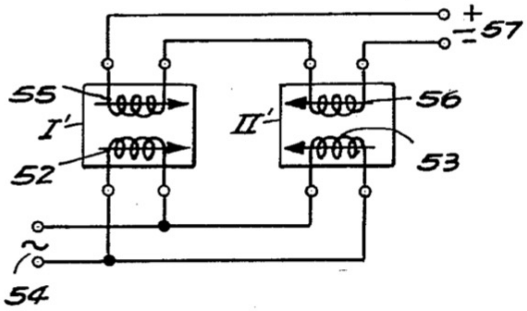

+
57
55
I'
52
56
II'
53
~
54

FIG. 15.

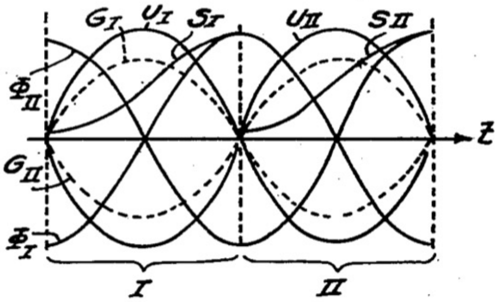
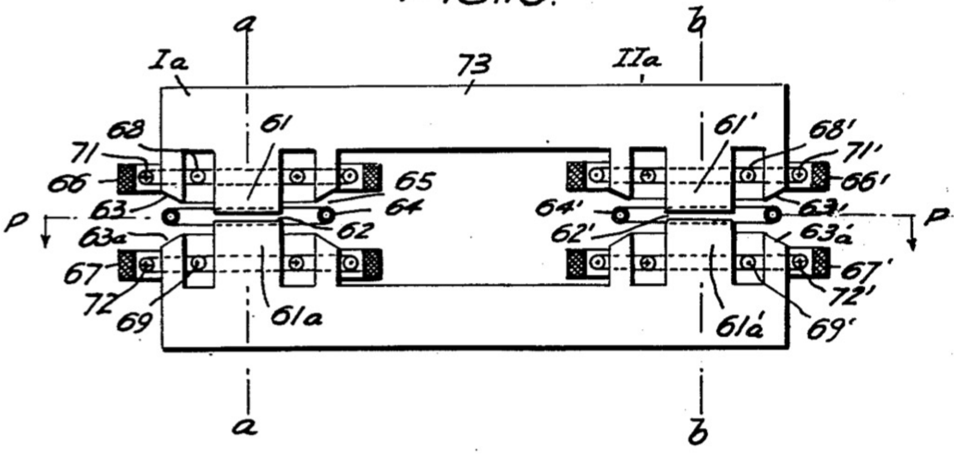


FIG. 16.


a
b
Ia
73
IIa
68
61
71
66
65
63
64
62
63a
67
72
69
61a
61'
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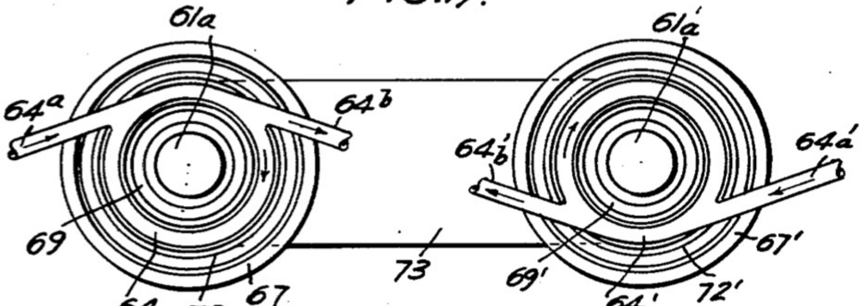
71'
66'
64'
63'
62'
63a'
67'
72'
69'
61a'
p
p
a
b

FIG. 17.


61a
64a
64b
69
64
72
67
73
61a'
64'b
64'a
67'
69'
64'
72'

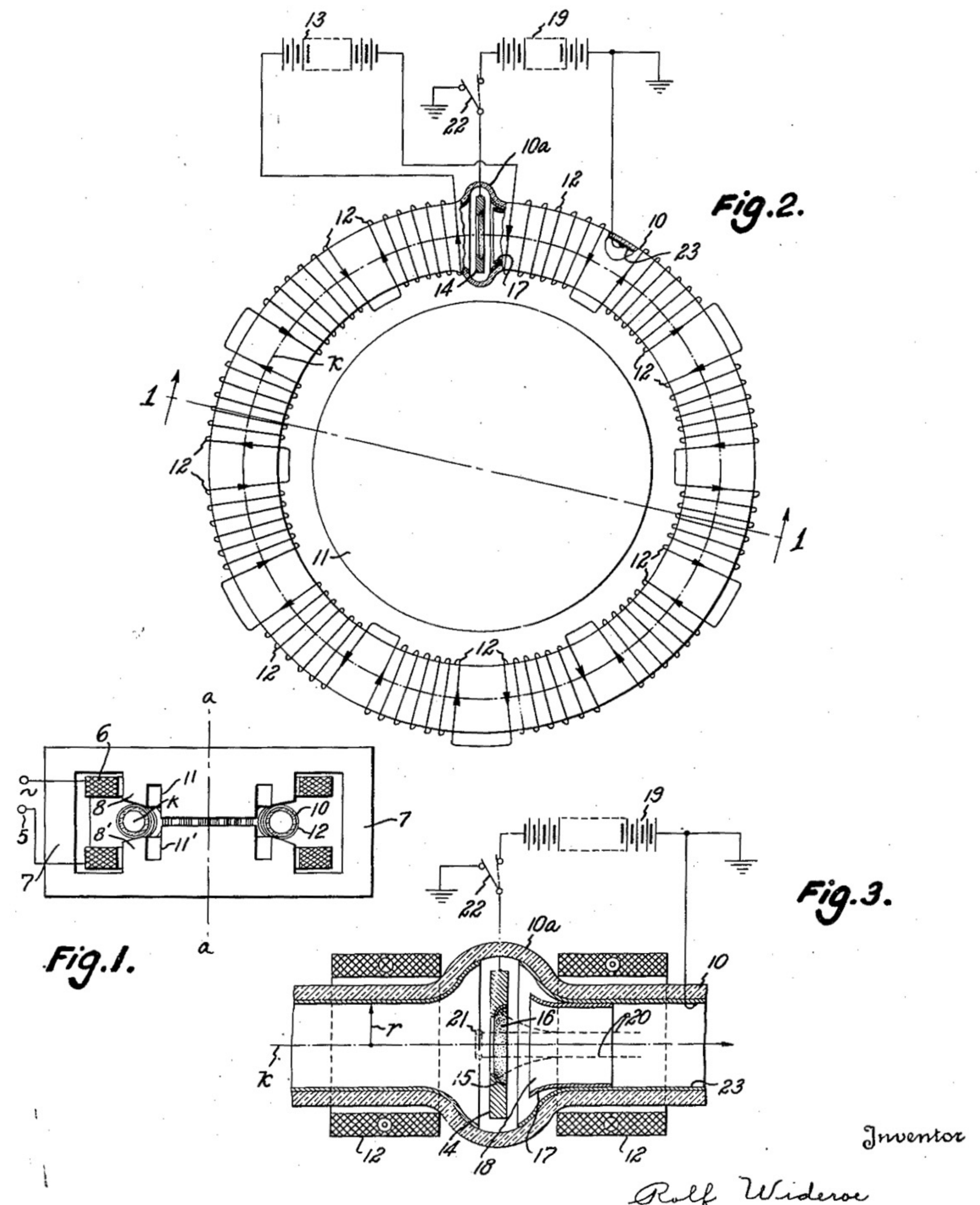
INVENTOR:
Rolph Wideroe,
BY Pierce, Scheffler & Parker,
ATTORNEYS.

Figure C.10: Figures from one of Rolf Wideröe's wartime patents on particle accelerators.

June 6, 1950 **R. WIDEROE** **2,510,448**

MAGNETIC INDUCTION ACCELERATOR

Filed Dec. 23, 1947


13
19
22
10a
12
Fig.2.
10
23
14
17
K
1
12
11
1
12
a
6
11
8
k
10
8'
12
11'
7
5
7
a
Fig.1.
19
22
Fig.3.
10a
10
21
16
20
r
k
15
23
12
14
18
17
12

Inventor

Rolf Wideroe

By

Pierce, Scheffler & Parker
Attorneys

Figure C.11: Figures from one of Rolf Wideröe's wartime patents on particle accelerators.

March 10, 1953 **R. WIDEROE** **2,631,234**

MAGNETIC INDUCTION ACCELERATOR

Filed Dec. 22, 1947

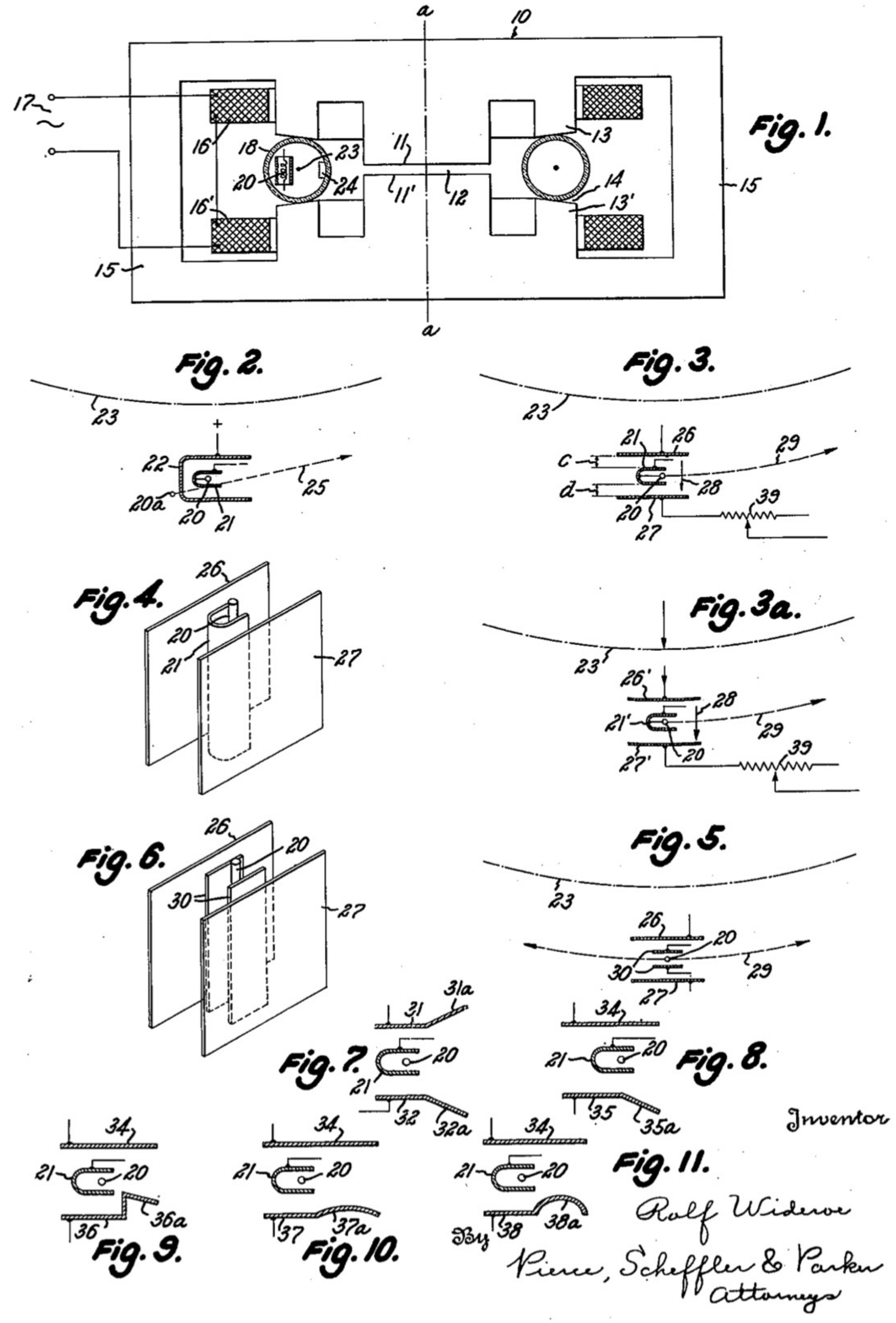


Fig. 1.
a
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16'
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24
11
11'
12
13
13'
14
15
Fig. 2.
23
+
22
20a
20
21
25
Fig. 3.
23
21
26
29
c
d
28
20
27
39
Fig. 4.
26
20
21
27
Fig. 3a.
23
26'
28
21'
29
20
27'
39
Fig. 6.
26
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27
Fig. 5.
23
26
20
30
29
27
Fig. 7.
31
31a
20
21
32
32a
Fig. 8.
34
21
20
35
35a
Fig. 9.
34
21
20
36
36a
Fig. 10.
34
21
20
37
37a
Fig. 11.
34
21
20
38
38a

Inventor

Rolf Wideroe

By Pierce, Scheffler & Parker
Attorneys

Figure C.12: Figures from one of Rolf Wideröe's wartime patents on particle accelerators.

April 24, 1951 R. WIDERÖE **2,550,212**

MAGNETIC INDUCTION ACCELERATOR

Filed Dec. 17, 1946

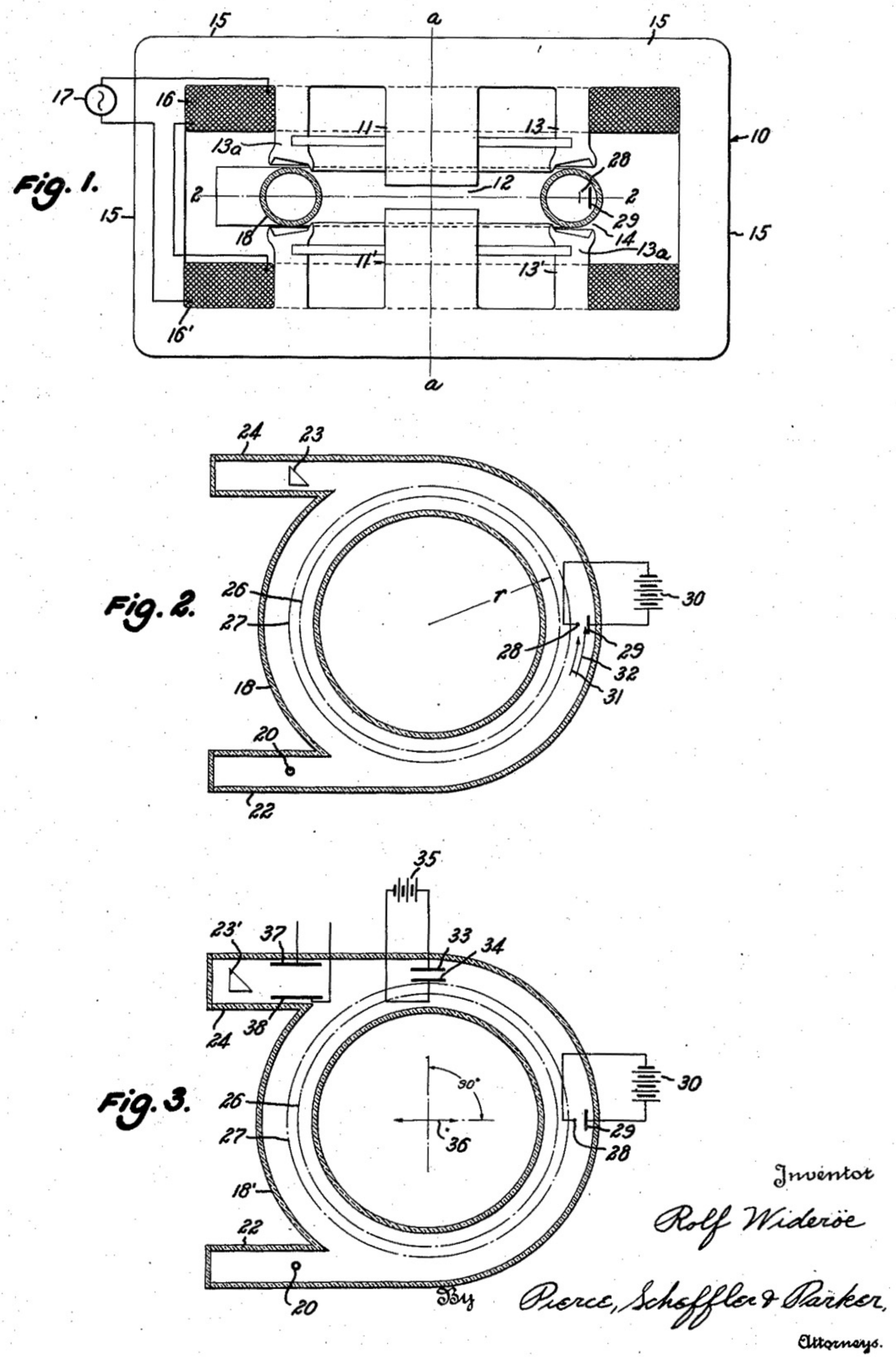
Fig. 1.
15
a
15
17
16
11
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10
13a
28
12
2
2
15
29
18
14
13a
15
11'
13'
16'
a
Fig. 2.
24
23
26
27
r
30
28
29
32
31
18
20
22
Fig. 3.
35
23'
37
33
34
24
38
30
90°
26
27
36
29
28
18'
22
20

Inventor

Rolf Wideröe

By Pierce, Schaffler & Parker,

Attorneys.

Figure C.13: Figures from one of Rolf Wideröe's wartime patents on particle accelerators.

Pedro Waloschek. 2012. *Death-Rays as Life-Savers in the Third Reich.* Draft English translation of *Todesstrahlen als Lebensretter* p. 175 [http://www-library.desy.de/preparch/books/death-rays.pdf].

Already in 1927/28 Steenbeck had developed the basic ideas for an accelerator which corresponded exactly to the "Cyclotron" proposed in 1931 by Lawrence. And he also sketched the first ideas for a later on called "Synchrocyclotron". Encouraged by his colleagues at Siemens he wrote all this down in a report which he wanted to publish in the journal "Naturwissenschaften". Due to a misunderstanding with his boss Rüdeneberg (who had asked him for a discussion of his ideas) the paper was never published.

In 1934 Steenbeck had already seen the PhD-thesis published in 1928 by Wideröe and included in his patents the conclusions to which Wideröe had arrived. Wideröe had also tried to submit his ideas as patents in 1929 but did not care about it in the following years, as he was working on a completely different subject (relays).

Max Steenbeck. German Patent DE 698,867. Vorrichtung zur Erzeugung von Elektronen hoher Energie durch das elektrische Wirbelfeld eines sich zeitlich aendernden magnetischen Hauptfeldes. [Device for Generating High Energy Electrons by the Electric Vortex Field of a Time-Varying Main Magnetic Field.] Filed 1935.

[Building on Rolf Wideröe's earliest ideas, Max Steenbeck (German, 1904–1981) invented the first practical betatron (circular particle accelerator for electrons) in 1935. Please see his first betatron patent, German Patent DE 698,867, on the following pages.

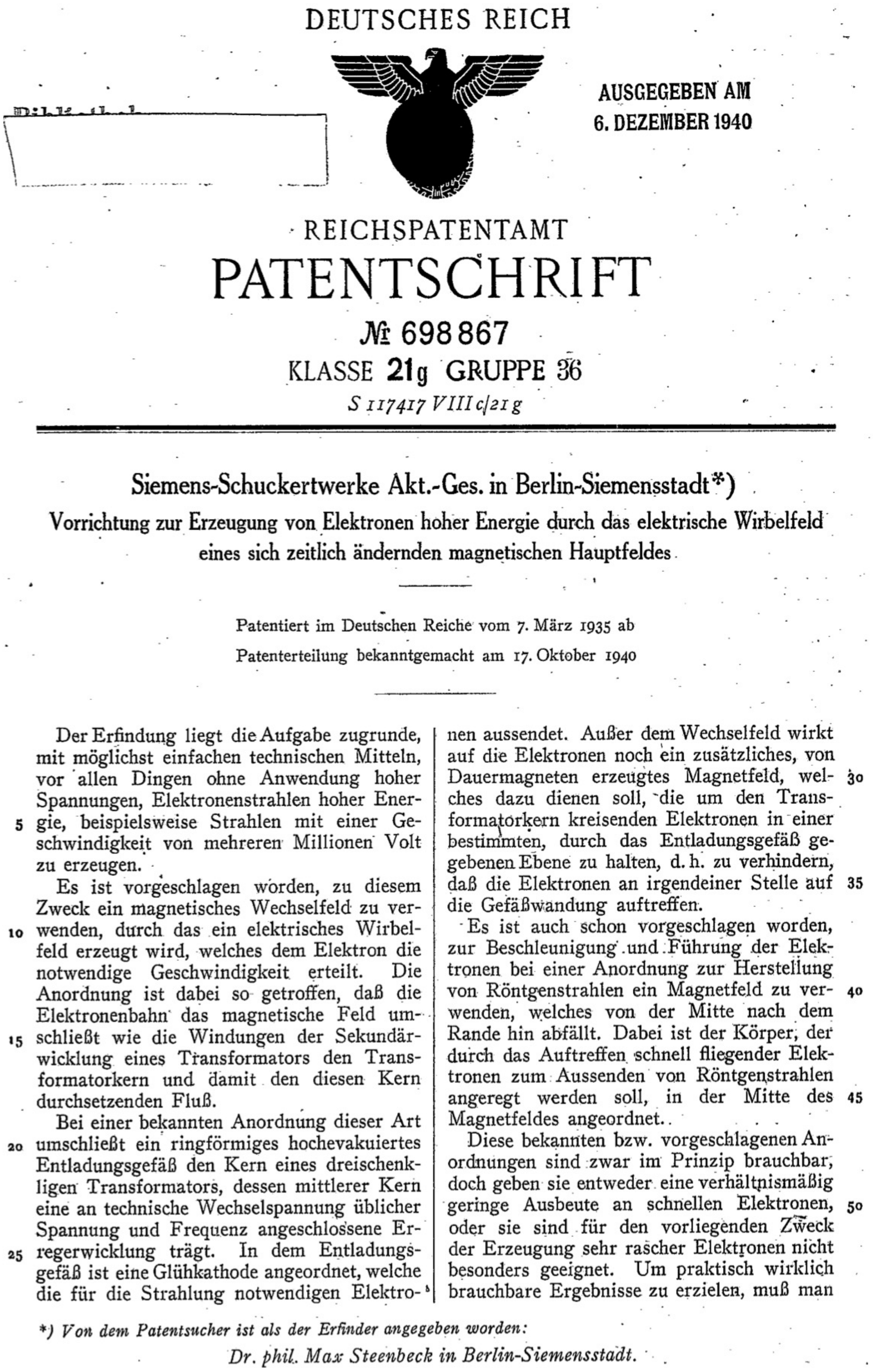
Steenbeck obtained similar patents in many other countries, including U.S. Patent 2,103,303, which was issued in 1937. Using the detailed designs in Steenbeck's patents, Donald Kerst copied Steenbeck's device and built the first U.S. circular accelerator for electrons in 1940. Kerst's only original contribution was to rename the device as the "betatron," and the name stuck. (German-speaking scientists seemed to prefer the name "rheotron" in the early years.) Kerst then became widely and incorrectly known as the "inventor" of the betatron while Steenbeck remained virtually unknown.

Some of Steenbeck's experimental results with betatrons were published as:

> Max Steenbeck. 1943. Beschleunigung von Elektronen durch elektrische Wirbelfelder. *Die Naturwissenschaften* 31: 234–235.

From official histories, it is unclear exactly what Steenbeck did during the war, but it seems likely that he worked on the German nuclear weapons program. After the war he spent ten years helping to develop and run major parts of the Soviet nuclear weapons program. He wrote about some of his experiences in his autobiography:

> Max Steenbeck. 1980. *Impulse und Wirkungen.* 3rd ed. Berlin: Verlag der Nation.
>
> See also Helmbold 2016.]



DEUTSCHES REICH

AUSGEGEBEN AM
6. DEZEMBER 1940

REICHSPATENTAMT

PATENTSCHRIFT

№ 698867

KLASSE 21g GRUPPE 36

S 117417 VIII c/21 g

Siemens-Schuckertwerke Akt.-Ges. in Berlin-Siemensstadt*)

Vorrichtung zur Erzeugung von Elektronen hoher Energie durch das elektrische Wirbelfeld eines sich zeitlich ändernden magnetischen Hauptfeldes

Patentiert im Deutschen Reiche vom 7. März 1935 ab

Patenterteilung bekanntgemacht am 17. Oktober 1940

Der Erfindung liegt die Aufgabe zugrunde, mit möglichst einfachen technischen Mitteln, vor allen Dingen ohne Anwendung hoher Spannungen, Elektronenstrahlen hoher Energie, beispielsweise Strahlen mit einer Geschwindigkeit von mehreren Millionen Volt zu erzeugen.

Es ist vorgeschlagen worden, zu diesem Zweck ein magnetisches Wechselfeld zu verwenden, durch das ein elektrisches Wirbelfeld erzeugt wird, welches dem Elektron die notwendige Geschwindigkeit erteilt. Die Anordnung ist dabei so getroffen, daß die Elektronenbahn das magnetische Feld umschließt wie die Windungen der Sekundärwicklung eines Transformators den Transformatorkern und damit den diesen Kern durchsetzenden Fluß.

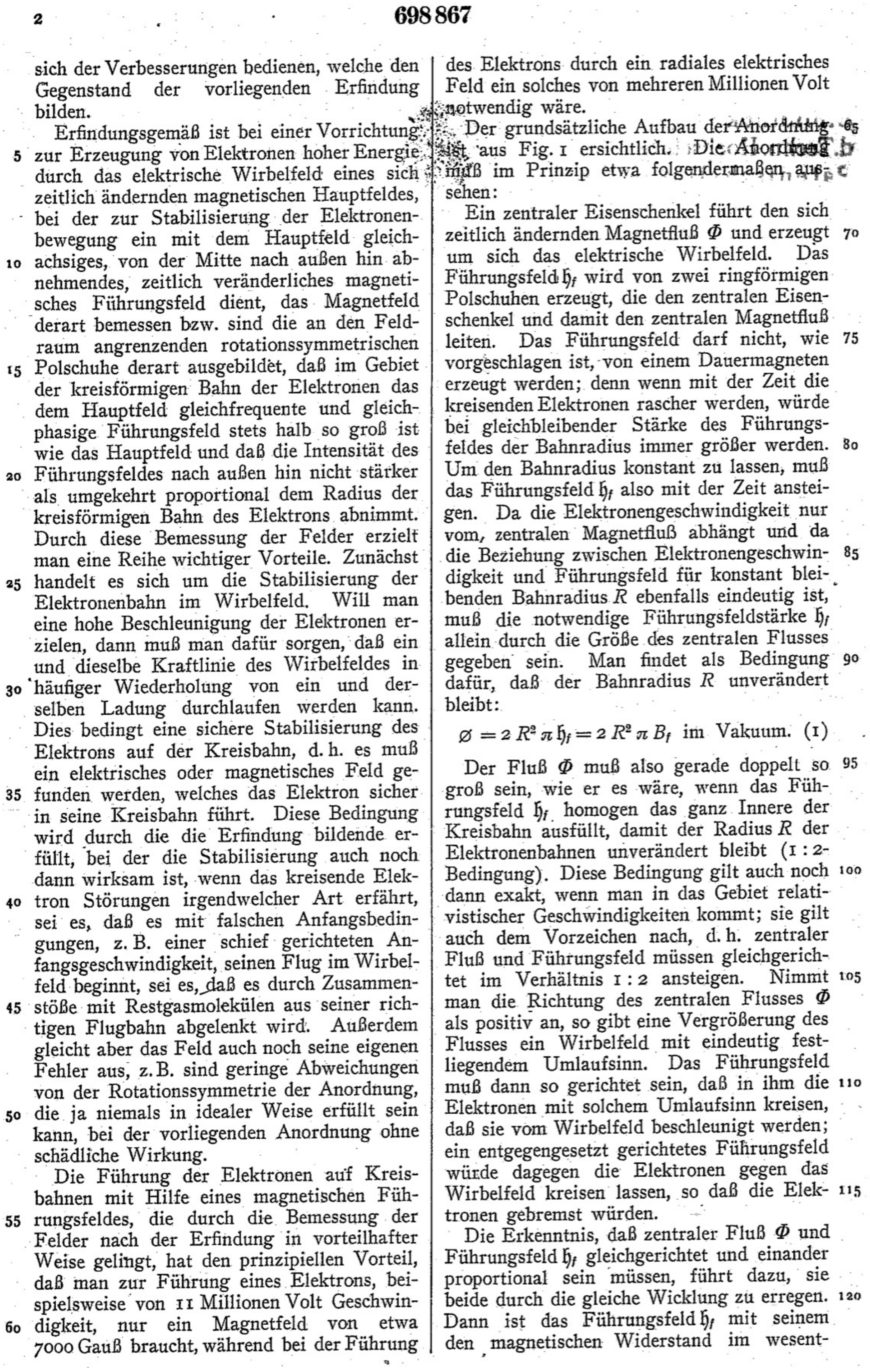
Bei einer bekannten Anordnung dieser Art umschließt ein ringförmiges hochevakuiertes Entladungsgefäß den Kern eines dreischenkligen Transformators, dessen mittlerer Kern eine an technische Wechselspannung üblicher Spannung und Frequenz angeschlossene Erregerwicklung trägt. In dem Entladungsgefäß ist eine Glühkathode angeordnet, welche die für die Strahlung notwendigen Elektronen aussendet. Außer dem Wechselfeld wirkt auf die Elektronen noch ein zusätzliches, von Dauermagneten erzeugtes Magnetfeld, welches dazu dienen soll, die um den Transformatorkern kreisenden Elektronen in einer bestimmten, durch das Entladungsgefäß gegebenen Ebene zu halten, d. h. zu verhindern, daß die Elektronen an irgendeiner Stelle auf die Gefäßwandung auftreffen.

Es ist auch schon vorgeschlagen worden, zur Beschleunigung und Führung der Elektronen bei einer Anordnung zur Herstellung von Röntgenstrahlen ein Magnetfeld zu verwenden, welches von der Mitte nach dem Rande hin abfällt. Dabei ist der Körper, der durch das Auftreffen schnell fliegender Elektronen zum Aussenden von Röntgenstrahlen angeregt werden soll, in der Mitte des Magnetfeldes angeordnet.

Diese bekannten bzw. vorgeschlagenen Anordnungen sind zwar im Prinzip brauchbar, doch geben sie entweder eine verhältnismäßig geringe Ausbeute an schnellen Elektronen, oder sie sind für den vorliegenden Zweck der Erzeugung sehr rascher Elektronen nicht besonders geeignet. Um praktisch wirklich brauchbare Ergebnisse zu erzielen, muß man

*) *Von dem Patentsucher ist als der Erfinder angegeben worden:*
Dr. phil. Max Steenbeck in Berlin-Siemensstadt.

Figure C.14: Max Steenbeck's first patent on betatrons (DE 698,867), filed in 1935.



sich der Verbesserungen bedienen, welche den Gegenstand der vorliegenden Erfindung bilden.

Erfindungsgemäß ist bei einer Vorrichtung zur Erzeugung von Elektronen hoher Energie durch das elektrische Wirbelfeld eines sich zeitlich ändernden magnetischen Hauptfeldes, bei der zur Stabilisierung der Elektronenbewegung ein mit dem Hauptfeld gleichachsiges, von der Mitte nach außen hin abnehmendes, zeitlich veränderliches magnetisches Führungsfeld dient, das Magnetfeld derart bemessen bzw. sind die an den Feldraum angrenzenden rotationssymmetrischen Polschuhe derart ausgebildet, daß im Gebiet der kreisförmigen Bahn der Elektronen das dem Hauptfeld gleichfrequente und gleichphasige Führungsfeld stets halb so groß ist wie das Hauptfeld und daß die Intensität des Führungsfeldes nach außen hin nicht stärker als umgekehrt proportional dem Radius der kreisförmigen Bahn des Elektrons abnimmt. Durch diese Bemessung der Felder erzielt man eine Reihe wichtiger Vorteile. Zunächst handelt es sich um die Stabilisierung der Elektronenbahn im Wirbelfeld. Will man eine hohe Beschleunigung der Elektronen erzielen, dann muß man dafür sorgen, daß ein und dieselbe Kraftlinie des Wirbelfeldes in häufiger Wiederholung von ein und derselben Ladung durchlaufen werden kann. Dies bedingt eine sichere Stabilisierung des Elektrons auf der Kreisbahn, d. h. es muß ein elektrisches oder magnetisches Feld gefunden werden, welches das Elektron sicher in seine Kreisbahn führt. Diese Bedingung wird durch die die Erfindung bildende erfüllt, bei der die Stabilisierung auch noch dann wirksam ist, wenn das kreisende Elektron Störungen irgendwelcher Art erfährt, sei es, daß es mit falschen Anfangsbedingungen, z. B. einer schief gerichteten Anfangsgeschwindigkeit, seinen Flug im Wirbelfeld beginnt, sei es, daß es durch Zusammenstöße mit Restgasmolekülen aus seiner richtigen Flugbahn abgelenkt wird. Außerdem gleicht aber das Feld auch noch seine eigenen Fehler aus, z. B. sind geringe Abweichungen von der Rotationssymmetrie der Anordnung, die ja niemals in idealer Weise erfüllt sein kann, bei der vorliegenden Anordnung ohne schädliche Wirkung.

Die Führung der Elektronen auf Kreisbahnen mit Hilfe eines magnetischen Führungsfeldes, die durch die Bemessung der Felder nach der Erfindung in vorteilhafter Weise gelingt, hat den prinzipiellen Vorteil, daß man zur Führung eines Elektrons, beispielsweise von 11 Millionen Volt Geschwindigkeit, nur ein Magnetfeld von etwa 7000 Gauß braucht, während bei der Führung des Elektrons durch ein radiales elektrisches Feld ein solches von mehreren Millionen Volt notwendig wäre.

Der grundsätzliche Aufbau der Anordnung ist aus Fig. 1 ersichtlich. Die Anordnung muß im Prinzip etwa folgendermaßen aussehen:

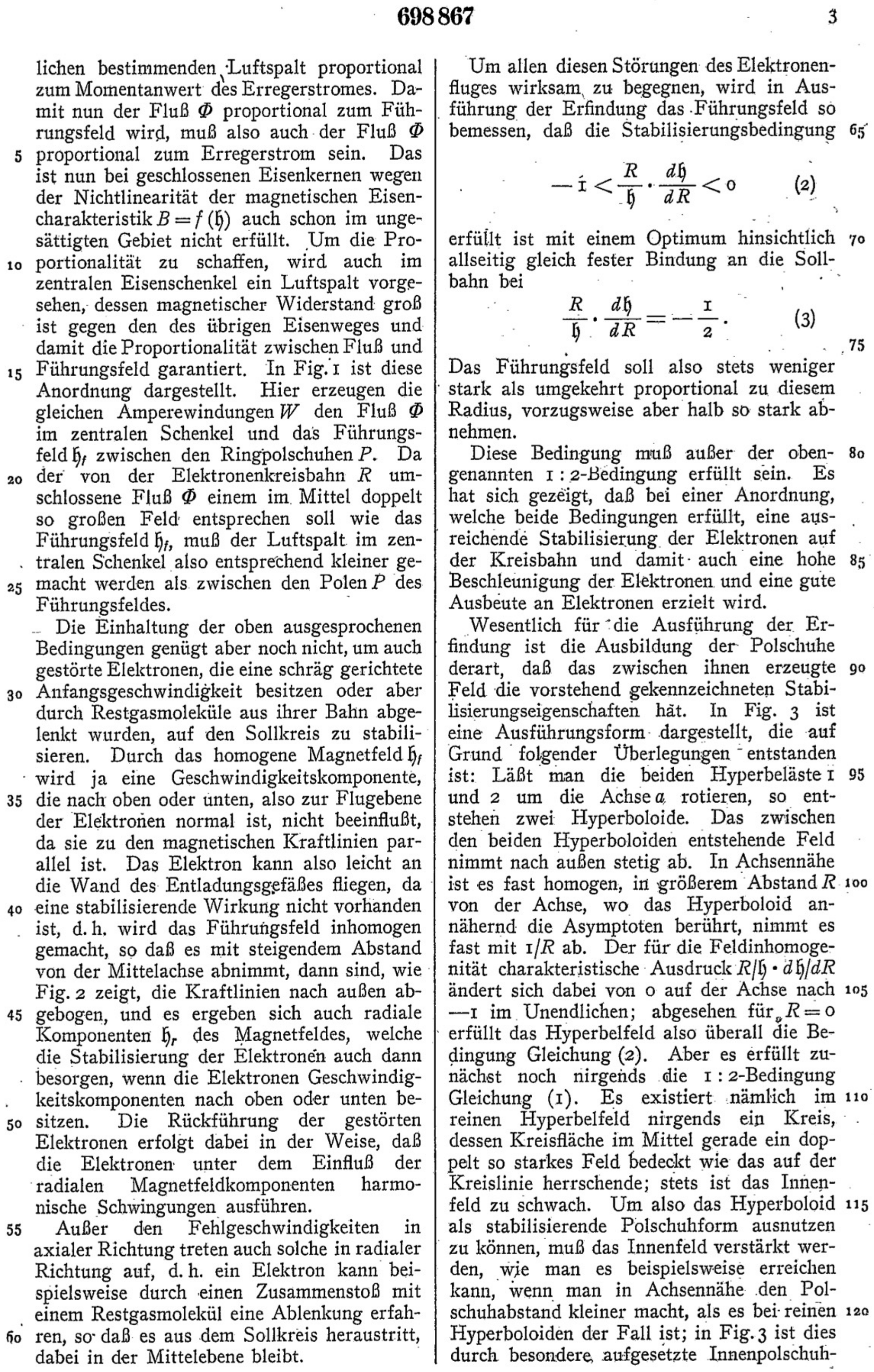
Ein zentraler Eisenschenkel führt den sich zeitlich ändernden Magnetfluß Φ und erzeugt um sich das elektrische Wirbelfeld. Das Führungsfeld $\mathfrak{h}_f$ wird von zwei ringförmigen Polschuhen erzeugt, die den zentralen Eisenschenkel und damit den zentralen Magnetfluß leiten. Das Führungsfeld darf nicht, wie vorgeschlagen ist, von einem Dauermagneten erzeugt werden; denn wenn mit der Zeit die kreisenden Elektronen rascher werden, würde bei gleichbleibender Stärke des Führungsfeldes der Bahnradius immer größer werden. Um den Bahnradius konstant zu lassen, muß das Führungsfeld $\mathfrak{h}_f$ also mit der Zeit ansteigen. Da die Elektronengeschwindigkeit nur vom zentralen Magnetfluß abhängt und da die Beziehung zwischen Elektronengeschwindigkeit und Führungsfeld für konstant bleibenden Bahnradius R ebenfalls eindeutig ist, muß die notwendige Führungsfeldstärke $\mathfrak{h}_f$ allein durch die Größe des zentralen Flusses gegeben sein. Man findet als Bedingung dafür, daß der Bahnradius R unverändert bleibt:

$$\varnothing = 2\, R^2 \pi\, \mathfrak{h}_f = 2\, R^2 \pi\, B_f \text{ im Vakuum.} \quad (1)$$

Der Fluß Φ muß also gerade doppelt so groß sein, wie er es wäre, wenn das Führungsfeld $\mathfrak{h}_f$ homogen das ganz Innere der Kreisbahn ausfüllt, damit der Radius R der Elektronenbahnen unverändert bleibt (1 : 2-Bedingung). Diese Bedingung gilt auch noch dann exakt, wenn man in das Gebiet relativistischer Geschwindigkeiten kommt; sie gilt auch dem Vorzeichen nach, d. h. zentraler Fluß und Führungsfeld müssen gleichgerichtet im Verhältnis 1 : 2 ansteigen. Nimmt man die Richtung des zentralen Flusses Φ als positiv an, so gibt eine Vergrößerung des Flusses ein Wirbelfeld mit eindeutig festliegendem Umlaufsinn. Das Führungsfeld muß dann so gerichtet sein, daß in ihm die Elektronen mit solchem Umlaufsinn kreisen, daß sie vom Wirbelfeld beschleunigt werden; ein entgegengesetzt gerichtetes Führungsfeld würde dagegen die Elektronen gegen das Wirbelfeld kreisen lassen, so daß die Elektronen gebremst würden.

Die Erkenntnis, daß zentraler Fluß Φ und Führungsfeld $\mathfrak{h}_f$ gleichgerichtet und einander proportional sein müssen, führt dazu, sie beide durch die gleiche Wicklung zu erregen. Dann ist das Führungsfeld $\mathfrak{h}_f$ mit seinem den magnetischen Widerstand im wesent-

Figure C.15: Max Steenbeck's first patent on betatrons (DE 698,867), filed in 1935.



lichen bestimmenden Luftspalt proportional zum Momentanwert des Erregerstromes. Damit nun der Fluß Φ proportional zum Führungsfeld wird, muß also auch der Fluß Φ proportional zum Erregerstrom sein. Das ist nun bei geschlossenen Eisenkernen wegen der Nichtlinearität der magnetischen Eisencharakteristik $B = f(\mathfrak{h})$ auch schon im ungesättigten Gebiet nicht erfüllt. Um die Proportionalität zu schaffen, wird auch im zentralen Eisenschenkel ein Luftspalt vorgesehen, dessen magnetischer Widerstand groß ist gegen den des übrigen Eisenweges und damit die Proportionalität zwischen Fluß und Führungsfeld garantiert. In Fig. 1 ist diese Anordnung dargestellt. Hier erzeugen die gleichen Amperewindungen W den Fluß Φ im zentralen Schenkel und das Führungsfeld $\mathfrak{h}_f$ zwischen den Ringpolschuhen P. Da der von der Elektronenkreisbahn R umschlossene Fluß Φ einem im Mittel doppelt so großen Feld entsprechen soll wie das Führungsfeld $\mathfrak{h}_f$, muß der Luftspalt im zentralen Schenkel also entsprechend kleiner gemacht werden als zwischen den Polen P des Führungsfeldes.

Die Einhaltung der oben ausgesprochenen Bedingungen genügt aber noch nicht, um auch gestörte Elektronen, die eine schräg gerichtete Anfangsgeschwindigkeit besitzen oder aber durch Restgasmoleküle aus ihrer Bahn abgelenkt wurden, auf den Sollkreis zu stabilisieren. Durch das homogene Magnetfeld $\mathfrak{h}_f$ wird ja eine Geschwindigkeitskomponente, die nach oben oder unten, also zur Flugebene der Elektronen normal ist, nicht beeinflußt, da sie zu den magnetischen Kraftlinien parallel ist. Das Elektron kann also leicht an die Wand des Entladungsgefäßes fliegen, da eine stabilisierende Wirkung nicht vorhanden ist, d. h. wird das Führungsfeld inhomogen gemacht, so daß es mit steigendem Abstand von der Mittelachse abnimmt, dann sind, wie Fig. 2 zeigt, die Kraftlinien nach außen abgebogen, und es ergeben sich auch radiale Komponenten $\mathfrak{h}_r$ des Magnetfeldes, welche die Stabilisierung der Elektronen auch dann besorgen, wenn die Elektronen Geschwindigkeitskomponenten nach oben oder unten besitzen. Die Rückführung der gestörten Elektronen erfolgt dabei in der Weise, daß die Elektronen unter dem Einfluß der radialen Magnetfeldkomponenten harmonische Schwingungen ausführen.

Außer den Fehlgeschwindigkeiten in axialer Richtung treten auch solche in radialer Richtung auf, d. h. ein Elektron kann beispielsweise durch einen Zusammenstoß mit einem Restgasmolekül eine Ablenkung erfahren, so daß es aus dem Sollkreis heraustritt, dabei in der Mittelebene bleibt.

Um allen diesen Störungen des Elektronenfluges wirksam zu begegnen, wird in Ausführung der Erfindung das Führungsfeld so bemessen, daß die Stabilisierungsbedingung

$$-1 < \frac{R}{\mathfrak{h}} \cdot \frac{d\mathfrak{h}}{dR} < 0 \qquad (2)$$

erfüllt ist mit einem Optimum hinsichtlich allseitig gleich fester Bindung an die Sollbahn bei

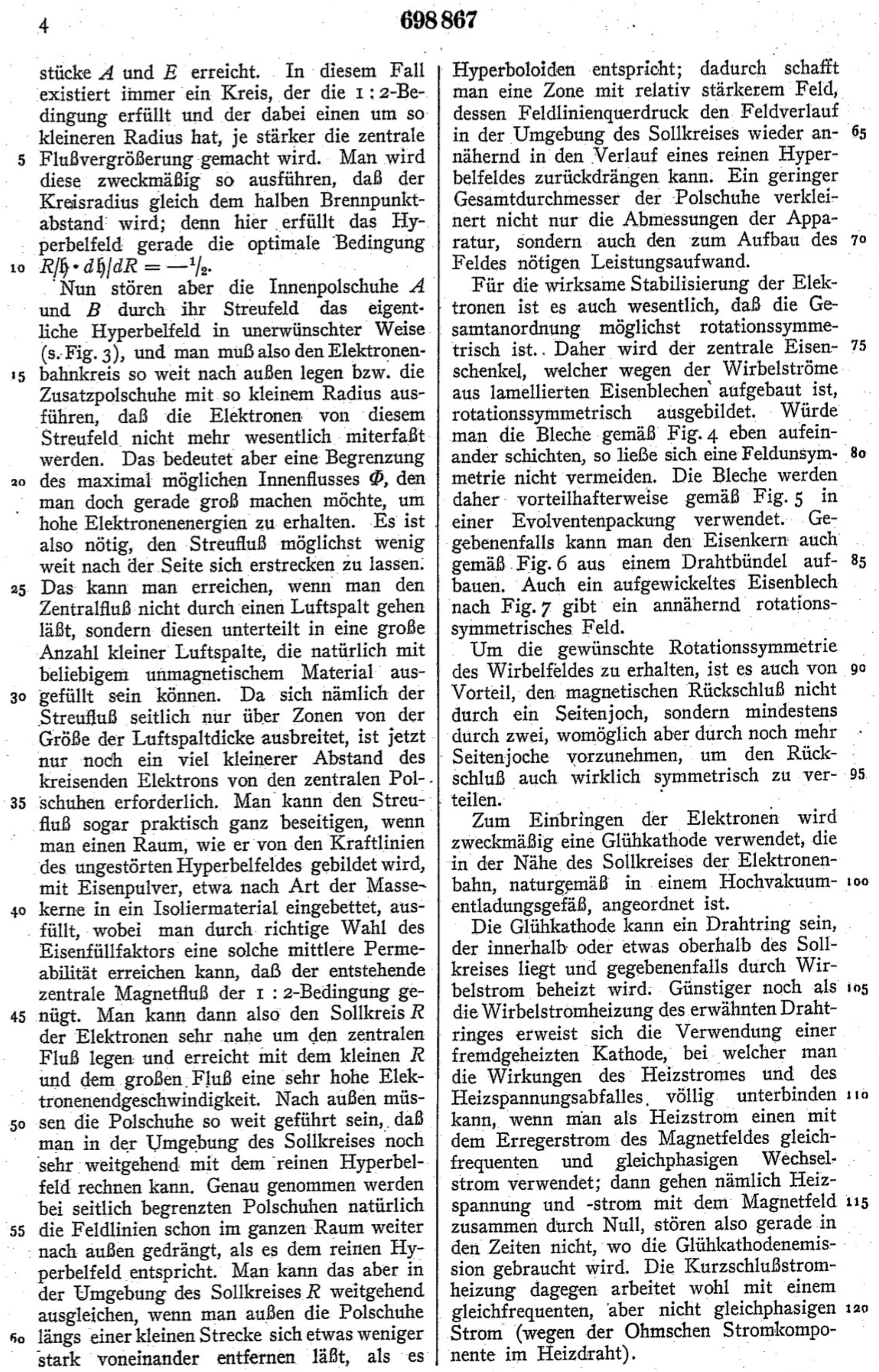
$$\frac{R}{\mathfrak{h}} \cdot \frac{d\mathfrak{h}}{dR} = -\frac{1}{2}. \qquad (3)$$

Das Führungsfeld soll also stets weniger stark als umgekehrt proportional zu diesem Radius, vorzugsweise aber halb so stark abnehmen.

Diese Bedingung muß außer der obengenannten 1 : 2-Bedingung erfüllt sein. Es hat sich gezeigt, daß bei einer Anordnung, welche beide Bedingungen erfüllt, eine ausreichende Stabilisierung der Elektronen auf der Kreisbahn und damit auch eine hohe Beschleunigung der Elektronen und eine gute Ausbeute an Elektronen erzielt wird.

Wesentlich für die Ausführung der Erfindung ist die Ausbildung der Polschuhe derart, daß das zwischen ihnen erzeugte Feld die vorstehend gekennzeichneten Stabilisierungseigenschaften hat. In Fig. 3 ist eine Ausführungsform dargestellt, die auf Grund folgender Überlegungen entstanden ist: Läßt man die beiden Hyperbeläste 1 und 2 um die Achse a rotieren, so entstehen zwei Hyperboloide. Das zwischen den beiden Hyperboloiden entstehende Feld nimmt nach außen stetig ab. In Achsennähe ist es fast homogen, in größerem Abstand R von der Achse, wo das Hyperboloid annähernd die Asymptoten berührt, nimmt es fast mit $1/R$ ab. Der für die Feldinhomogenität charakteristische Ausdruck $R/\mathfrak{h} \cdot d\mathfrak{h}/dR$ ändert sich dabei von 0 auf der Achse nach -1 im Unendlichen; abgesehen für $R = 0$ erfüllt das Hyperbelfeld also überall die Bedingung Gleichung (2). Aber es erfüllt zunächst noch nirgends die 1 : 2-Bedingung Gleichung (1). Es existiert nämlich im reinen Hyperbelfeld nirgends ein Kreis, dessen Kreisfläche im Mittel gerade ein doppelt so starkes Feld bedeckt wie das auf der Kreislinie herrschende; stets ist das Innenfeld zu schwach. Um also das Hyperboloid als stabilisierende Polschuhform ausnutzen zu können, muß das Innenfeld verstärkt werden, wie man es beispielsweise erreichen kann, wenn man in Achsennähe den Polschuhabstand kleiner macht, als es bei reinen Hyperboloiden der Fall ist; in Fig. 3 ist dies durch besondere, aufgesetzte Innenpolschuh-

Figure C.16: Max Steenbeck's first patent on betatrons (DE 698,867), filed in 1935.



stücke *A* und *E* erreicht. In diesem Fall existiert immer ein Kreis, der die 1 : 2-Bedingung erfüllt und der dabei einen um so kleineren Radius hat, je stärker die zentrale Flußvergrößerung gemacht wird. Man wird diese zweckmäßig so ausführen, daß der Kreisradius gleich dem halben Brennpunktabstand wird; denn hier erfüllt das Hyperbelfeld gerade die optimale Bedingung $R/\mathfrak{H} \cdot d\mathfrak{H}/dR = -{}^1/_2$.

Nun stören aber die Innenpolschuhe *A* und *B* durch ihr Streufeld das eigentliche Hyperbelfeld in unerwünschter Weise (s. Fig. 3), und man muß also den Elektronenbahnkreis so weit nach außen legen bzw. die Zusatzpolschuhe mit so kleinem Radius ausführen, daß die Elektronen von diesem Streufeld nicht mehr wesentlich miterfaßt werden. Das bedeutet aber eine Begrenzung des maximal möglichen Innenflusses Φ, den man doch gerade groß machen möchte, um hohe Elektronenenergien zu erhalten. Es ist also nötig, den Streufluß möglichst wenig weit nach der Seite sich erstrecken zu lassen. Das kann man erreichen, wenn man den Zentralfluß nicht durch einen Luftspalt gehen läßt, sondern diesen unterteilt in eine große Anzahl kleiner Luftspalte, die natürlich mit beliebigem unmagnetischem Material ausgefüllt sein können. Da sich nämlich der Streufluß seitlich nur über Zonen von der Größe der Luftspaltdicke ausbreitet, ist jetzt nur noch ein viel kleinerer Abstand des kreisenden Elektrons von den zentralen Polschuhen erforderlich. Man kann den Streufluß sogar praktisch ganz beseitigen, wenn man einen Raum, wie er von den Kraftlinien des ungestörten Hyperbelfeldes gebildet wird, mit Eisenpulver, etwa nach Art der Massekerne in ein Isoliermaterial eingebettet, ausfüllt, wobei man durch richtige Wahl des Eisenfüllfaktors eine solche mittlere Permeabilität erreichen kann, daß der entstehende zentrale Magnetfluß der 1 : 2-Bedingung genügt. Man kann dann also den Sollkreis *R* der Elektronen sehr nahe um den zentralen Fluß legen und erreicht mit dem kleinen *R* und dem großen Fluß eine sehr hohe Elektronenendgeschwindigkeit. Nach außen müssen die Polschuhe so weit geführt sein, daß man in der Umgebung des Sollkreises noch sehr weitgehend mit dem reinen Hyperbelfeld rechnen kann. Genau genommen werden bei seitlich begrenzten Polschuhen natürlich die Feldlinien schon im ganzen Raum weiter nach außen gedrängt, als es dem reinen Hyperbelfeld entspricht. Man kann das aber in der Umgebung des Sollkreises *R* weitgehend ausgleichen, wenn man außen die Polschuhe längs einer kleinen Strecke sich etwas weniger stark voneinander entfernen läßt, als es Hyperboloiden entspricht; dadurch schafft man eine Zone mit relativ stärkerem Feld, dessen Feldlinienquerdruck den Feldverlauf in der Umgebung des Sollkreises wieder annähernd in den Verlauf eines reinen Hyperbelfeldes zurückdrängen kann. Ein geringer Gesamtdurchmesser der Polschuhe verkleinert nicht nur die Abmessungen der Apparatur, sondern auch den zum Aufbau des Feldes nötigen Leistungsaufwand.

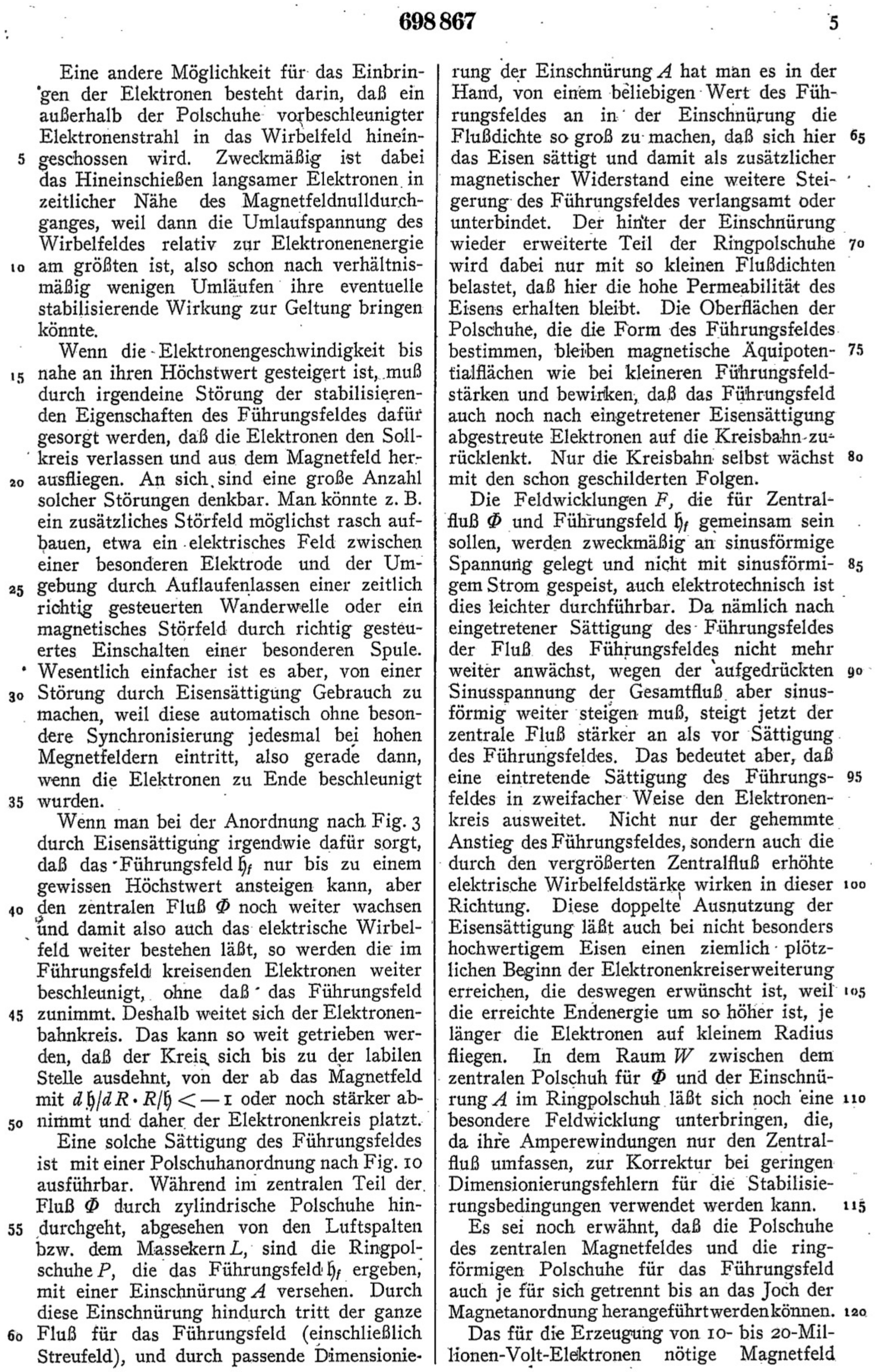
Für die wirksame Stabilisierung der Elektronen ist es auch wesentlich, daß die Gesamtanordnung möglichst rotationssymmetrisch ist. Daher wird der zentrale Eisenschenkel, welcher wegen der Wirbelströme aus lamellierten Eisenblechen aufgebaut ist, rotationssymmetrisch ausgebildet. Würde man die Bleche gemäß Fig. 4 eben aufeinander schichten, so ließe sich eine Feldunsymmetrie nicht vermeiden. Die Bleche werden daher vorteilhafterweise gemäß Fig. 5 in einer Evolventenpackung verwendet. Gegebenenfalls kann man den Eisenkern auch gemäß Fig. 6 aus einem Drahtbündel aufbauen. Auch ein aufgewickeltes Eisenblech nach Fig. 7 gibt ein annähernd rotationssymmetrisches Feld.

Um die gewünschte Rotationssymmetrie des Wirbelfeldes zu erhalten, ist es auch von Vorteil, den magnetischen Rückschluß nicht durch ein Seitenjoch, sondern mindestens durch zwei, womöglich aber durch noch mehr Seitenjoche vorzunehmen, um den Rückschluß auch wirklich symmetrisch zu verteilen.

Zum Einbringen der Elektronen wird zweckmäßig eine Glühkathode verwendet, die in der Nähe des Sollkreises der Elektronenbahn, naturgemäß in einem Hochvakuumentladungsgefäß, angeordnet ist.

Die Glühkathode kann ein Drahtring sein, der innerhalb oder etwas oberhalb des Sollkreises liegt und gegebenenfalls durch Wirbelstrom beheizt wird. Günstiger noch als die Wirbelstromheizung des erwähnten Drahtringes erweist sich die Verwendung einer fremdgeheizten Kathode, bei welcher man die Wirkungen des Heizstromes und des Heizspannungsabfalles völlig unterbinden kann, wenn man als Heizstrom einen mit dem Erregerstrom des Magnetfeldes gleichfrequenten und gleichphasigen Wechselstrom verwendet; dann gehen nämlich Heizspannung und -strom mit dem Magnetfeld zusammen durch Null, stören also gerade in den Zeiten nicht, wo die Glühkathodenemission gebraucht wird. Die Kurzschlußstromheizung dagegen arbeitet wohl mit einem gleichfrequenten, aber nicht gleichphasigen Strom (wegen der Ohmschen Stromkomponente im Heizdraht).

Figure C.17: Max Steenbeck's first patent on betatrons (DE 698,867), filed in 1935.



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Eine andere Möglichkeit für das Einbringen der Elektronen besteht darin, daß ein außerhalb der Polschuhe vorbeschleunigter Elektronenstrahl in das Wirbelfeld hineingeschossen wird. Zweckmäßig ist dabei das Hineinschießen langsamer Elektronen in zeitlicher Nähe des Magnetfeldnulldurchganges, weil dann die Umlaufspannung des Wirbelfeldes relativ zur Elektronenenergie am größten ist, also schon nach verhältnismäßig wenigen Umläufen ihre eventuelle stabilisierende Wirkung zur Geltung bringen könnte.

Wenn die Elektronengeschwindigkeit bis nahe an ihren Höchstwert gesteigert ist, muß durch irgendeine Störung der stabilisierenden Eigenschaften des Führungsfeldes dafür gesorgt werden, daß die Elektronen den Sollkreis verlassen und aus dem Magnetfeld herausfliegen. An sich sind eine große Anzahl solcher Störungen denkbar. Man könnte z. B. ein zusätzliches Störfeld möglichst rasch aufbauen, etwa ein elektrisches Feld zwischen einer besonderen Elektrode und der Umgebung durch Auflaufenlassen einer zeitlich richtig gesteuerten Wanderwelle oder ein magnetisches Störfeld durch richtig gesteuertes Einschalten einer besonderen Spule. Wesentlich einfacher ist es aber, von einer Störung durch Eisensättigung Gebrauch zu machen, weil diese automatisch ohne besondere Synchronisierung jedesmal bei hohen Megnetfeldern eintritt, also gerade dann, wenn die Elektronen zu Ende beschleunigt wurden.

Wenn man bei der Anordnung nach Fig. 3 durch Eisensättigung irgendwie dafür sorgt, daß das Führungsfeld $\mathfrak{h}_f$ nur bis zu einem gewissen Höchstwert ansteigen kann, aber den zentralen Fluß Φ noch weiter wachsen und damit also auch das elektrische Wirbelfeld weiter bestehen läßt, so werden die im Führungsfeld kreisenden Elektronen weiter beschleunigt, ohne daß das Führungsfeld zunimmt. Deshalb weitet sich der Elektronenbahnkreis. Das kann so weit getrieben werden, daß der Kreis sich bis zu der labilen Stelle ausdehnt, von der ab das Magnetfeld mit $d\mathfrak{h}/dR \cdot R/\mathfrak{h} < -1$ oder noch stärker abnimmt und daher der Elektronenkreis platzt.

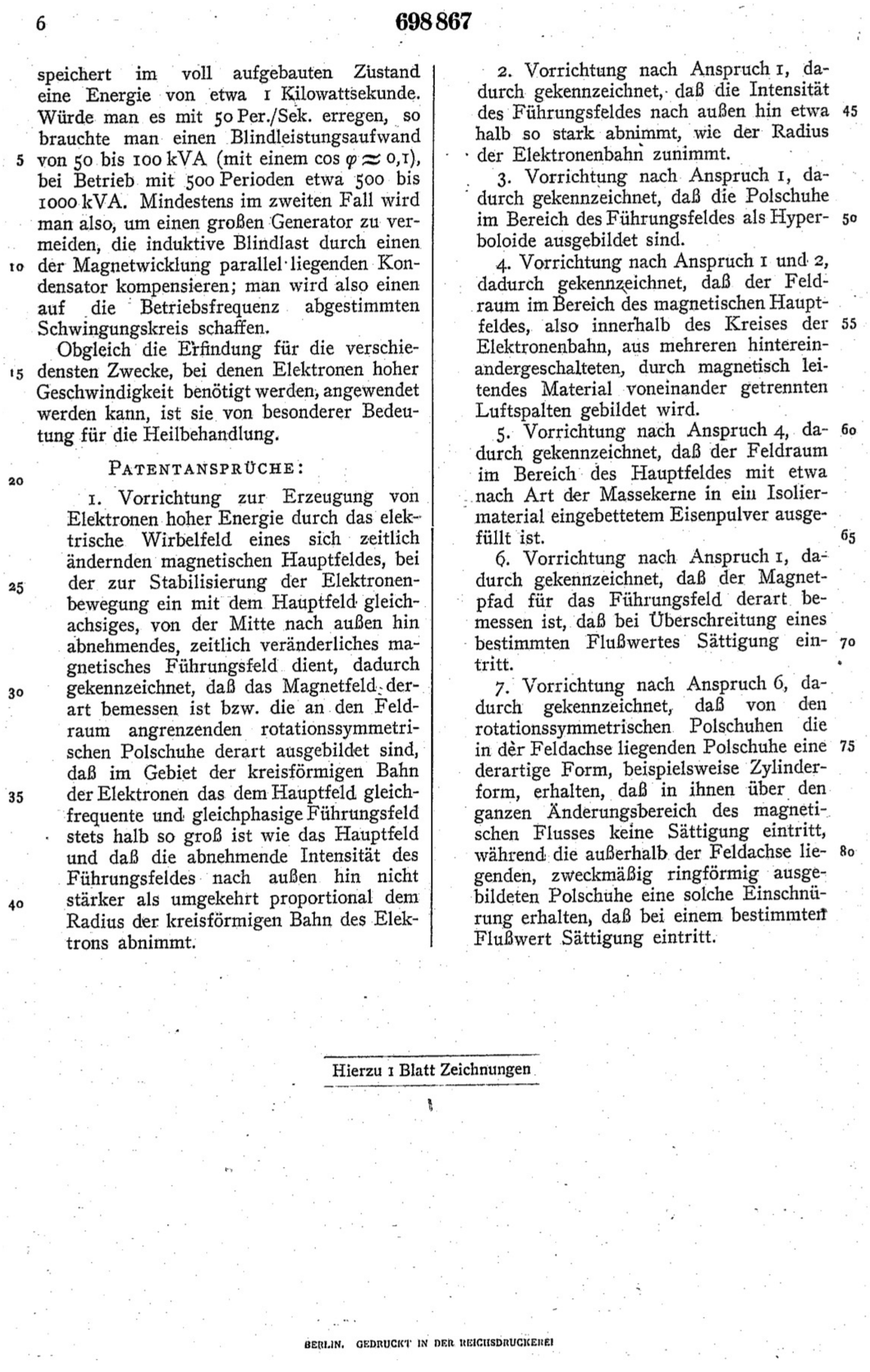
Eine solche Sättigung des Führungsfeldes ist mit einer Polschuhanordnung nach Fig. 10 ausführbar. Während im zentralen Teil der Fluß Φ durch zylindrische Polschuhe hindurchgeht, abgesehen von den Luftspalten bzw. dem Massekern L, sind die Ringpolschuhe P, die das Führungsfeld $\mathfrak{h}_f$ ergeben, mit einer Einschnürung A versehen. Durch diese Einschnürung hindurch tritt der ganze Fluß für das Führungsfeld (einschließlich Streufeld), und durch passende Dimensionierung der Einschnürung A hat man es in der Hand, von einem beliebigen Wert des Führungsfeldes an in der Einschnürung die Flußdichte so groß zu machen, daß sich hier das Eisen sättigt und damit als zusätzlicher magnetischer Widerstand eine weitere Steigerung des Führungsfeldes verlangsamt oder unterbindet. Der hinter der Einschnürung wieder erweiterte Teil der Ringpolschuhe wird dabei nur mit so kleinen Flußdichten belastet, daß hier die hohe Permeabilität des Eisens erhalten bleibt. Die Oberflächen der Polschuhe, die die Form des Führungsfeldes bestimmen, bleiben magnetische Äquipotentialflächen wie bei kleineren Führungsfeldstärken und bewirken, daß das Führungsfeld auch noch nach eingetretener Eisensättigung abgestreute Elektronen auf die Kreisbahn zurücklenkt. Nur die Kreisbahn selbst wächst mit den schon geschilderten Folgen.

Die Feldwicklungen F, die für Zentralfluß Φ und Führungsfeld $\mathfrak{h}_f$ gemeinsam sein sollen, werden zweckmäßig an sinusförmige Spannung gelegt und nicht mit sinusförmigem Strom gespeist, auch elektrotechnisch ist dies leichter durchführbar. Da nämlich nach eingetretener Sättigung des Führungsfeldes der Fluß des Führungsfeldes nicht mehr weiter anwächst, wegen der aufgedrückten Sinusspannung der Gesamtfluß aber sinusförmig weiter steigen muß, steigt jetzt der zentrale Fluß stärker an als vor Sättigung des Führungsfeldes. Das bedeutet aber, daß eine eintretende Sättigung des Führungsfeldes in zweifacher Weise den Elektronenkreis ausweitet. Nicht nur der gehemmte Anstieg des Führungsfeldes, sondern auch die durch den vergrößerten Zentralfluß erhöhte elektrische Wirbelfeldstärke wirken in dieser Richtung. Diese doppelte Ausnutzung der Eisensättigung läßt auch bei nicht besonders hochwertigem Eisen einen ziemlich plötzlichen Beginn der Elektronenkreiserweiterung erreichen, die deswegen erwünscht ist, weil die erreichte Endenergie um so höher ist, je länger die Elektronen auf kleinem Radius fliegen. In dem Raum W zwischen dem zentralen Polschuh für Φ und der Einschnürung A im Ringpolschuh läßt sich noch eine besondere Feldwicklung unterbringen, die, da ihre Amperewindungen nur den Zentralfluß umfassen, zur Korrektur bei geringen Dimensionierungsfehlern für die Stabilisierungsbedingungen verwendet werden kann.

Es sei noch erwähnt, daß die Polschuhe des zentralen Magnetfeldes und die ringförmigen Polschuhe für das Führungsfeld auch je für sich getrennt bis an das Joch der Magnetanordnung herangeführt werden können.

Das für die Erzeugung von 10- bis 20-Millionen-Volt-Elektronen nötige Magnetfeld

Figure C.18: Max Steenbeck's first patent on betatrons (DE 698,867), filed in 1935.



speichert im voll aufgebauten Zustand eine Energie von etwa 1 Kilowattsekunde. Würde man es mit 50 Per./Sek. erregen, so brauchte man einen Blindleistungsaufwand von 50 bis 100 kVA (mit einem $\cos\varphi \approx 0{,}1$), bei Betrieb mit 500 Perioden etwa 500 bis 1000 kVA. Mindestens im zweiten Fall wird man also, um einen großen Generator zu vermeiden, die induktive Blindlast durch einen der Magnetwicklung parallel liegenden Kondensator kompensieren; man wird also einen auf die Betriebsfrequenz abgestimmten Schwingungskreis schaffen.

Obgleich die Erfindung für die verschiedensten Zwecke, bei denen Elektronen hoher Geschwindigkeit benötigt werden, angewendet werden kann, ist sie von besonderer Bedeutung für die Heilbehandlung.

PATENTANSPRÜCHE:

1. Vorrichtung zur Erzeugung von Elektronen hoher Energie durch das elektrische Wirbelfeld eines sich zeitlich ändernden magnetischen Hauptfeldes, bei der zur Stabilisierung der Elektronenbewegung ein mit dem Hauptfeld gleichachsiges, von der Mitte nach außen hin abnehmendes, zeitlich veränderliches magnetisches Führungsfeld dient, dadurch gekennzeichnet, daß das Magnetfeld derart bemessen ist bzw. die an den Feldraum angrenzenden rotationssymmetrischen Polschuhe derart ausgebildet sind, daß im Gebiet der kreisförmigen Bahn der Elektronen das dem Hauptfeld gleichfrequente und gleichphasige Führungsfeld stets halb so groß ist wie das Hauptfeld und daß die abnehmende Intensität des Führungsfeldes nach außen hin nicht stärker als umgekehrt proportional dem Radius der kreisförmigen Bahn des Elektrons abnimmt.

2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Intensität des Führungsfeldes nach außen hin etwa halb so stark abnimmt, wie der Radius der Elektronenbahn zunimmt.

3. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Polschuhe im Bereich des Führungsfeldes als Hyperboloide ausgebildet sind.

4. Vorrichtung nach Anspruch 1 und 2, dadurch gekennzeichnet, daß der Feldraum im Bereich des magnetischen Hauptfeldes, also innerhalb des Kreises der Elektronenbahn, aus mehreren hintereinandergeschalteten, durch magnetisch leitendes Material voneinander getrennten Luftspalten gebildet wird.

5. Vorrichtung nach Anspruch 4, dadurch gekennzeichnet, daß der Feldraum im Bereich des Hauptfeldes mit etwa nach Art der Massekerne in ein Isoliermaterial eingebettetem Eisenpulver ausgefüllt ist.

6. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß der Magnetpfad für das Führungsfeld derart bemessen ist, daß bei Überschreitung eines bestimmten Flußwertes Sättigung eintritt.

7. Vorrichtung nach Anspruch 6, dadurch gekennzeichnet, daß von den rotationssymmetrischen Polschuhen die in der Feldachse liegenden Polschuhe eine derartige Form, beispielsweise Zylinderform, erhalten, daß in ihnen über den ganzen Änderungsbereich des magnetischen Flusses keine Sättigung eintritt, während die außerhalb der Feldachse liegenden, zweckmäßig ringförmig ausgebildeten Polschuhe eine solche Einschnürung erhalten, daß bei einem bestimmten Flußwert Sättigung eintritt.

Hierzu 1 Blatt Zeichnungen

BERLIN. GEDRUCKT IN DER REICHSDRUCKEREI

Figure C.19: Max Steenbeck's first patent on betatrons (DE 698,867), filed in 1935.

Zu der Patentschrift **698 867**
Kl. **21g** Gr. 36

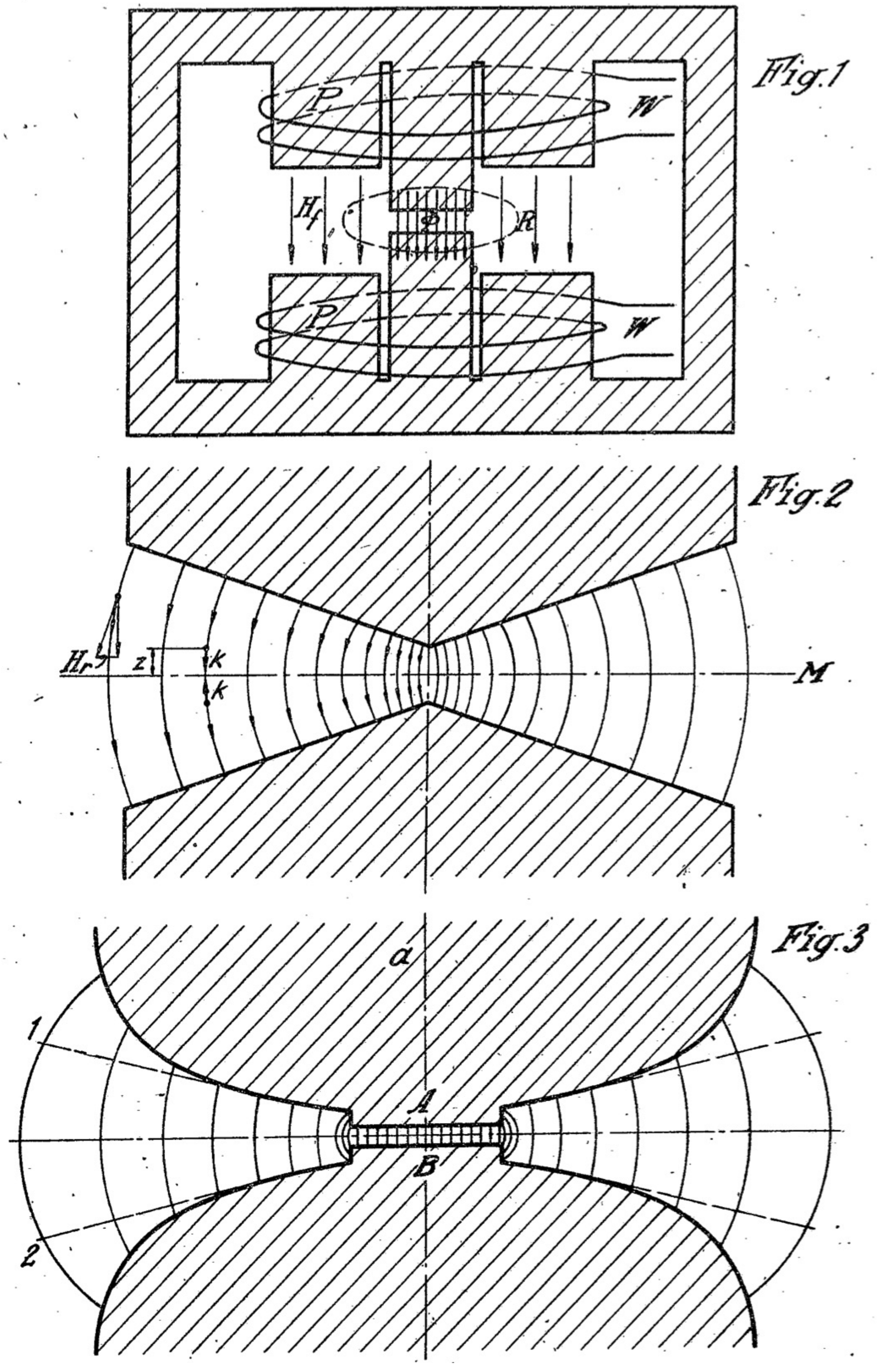
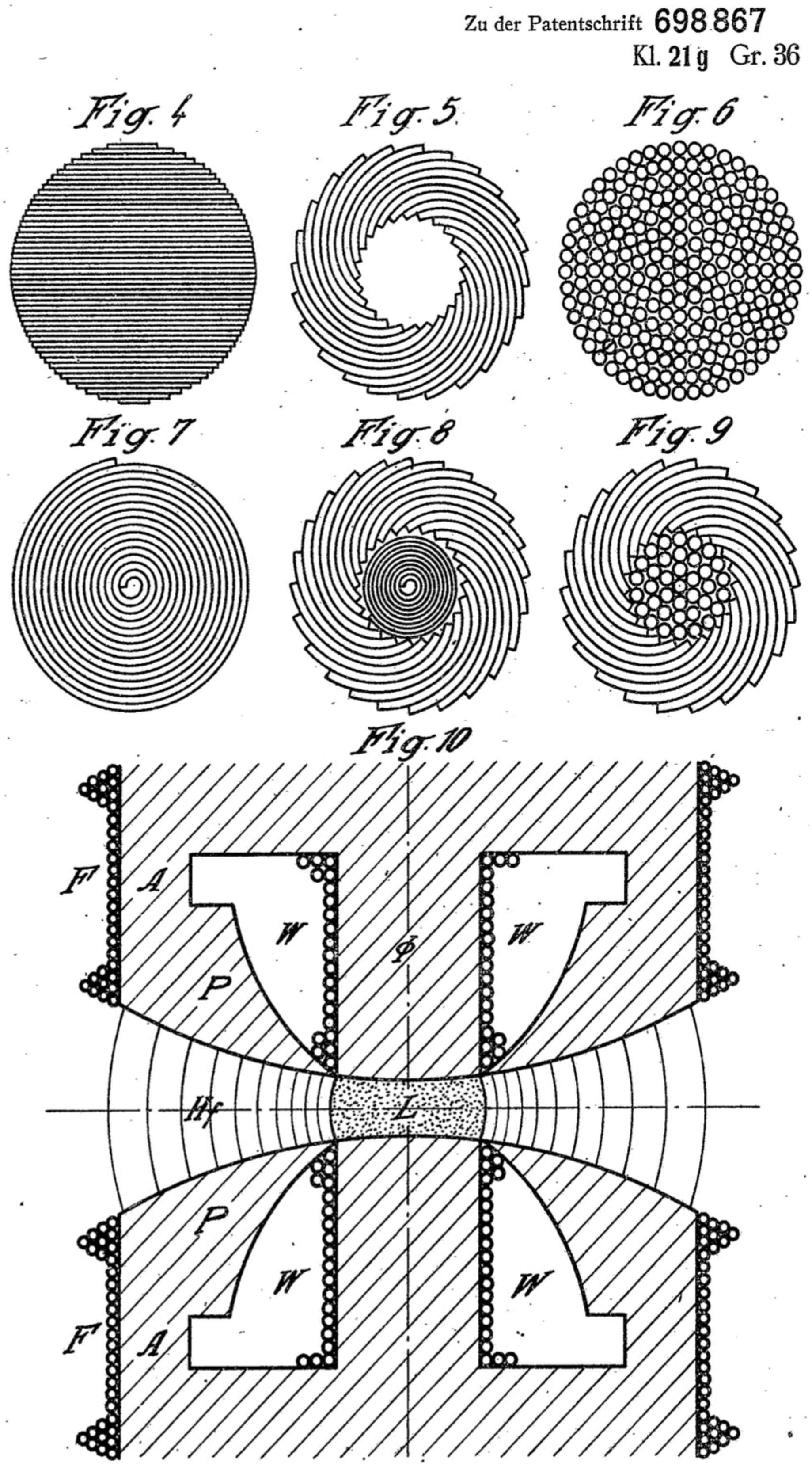


Fig.1
P
W
H_f
R
P
W
Fig.2
H_r
z
k
k
M
Fig.3
a
1
A
B
2

Figure C.20: Max Steenbeck's first patent on betatrons (DE 698,867), filed in 1935.


Zu der Patentschrift 698 867
Kl. 21g Gr. 36
Fig. 4
Fig. 5
Fig. 6
Fig. 7
Fig. 8
Fig. 9
Fig. 10
F
A
W
Φ
W
P
Hf
L
P
W
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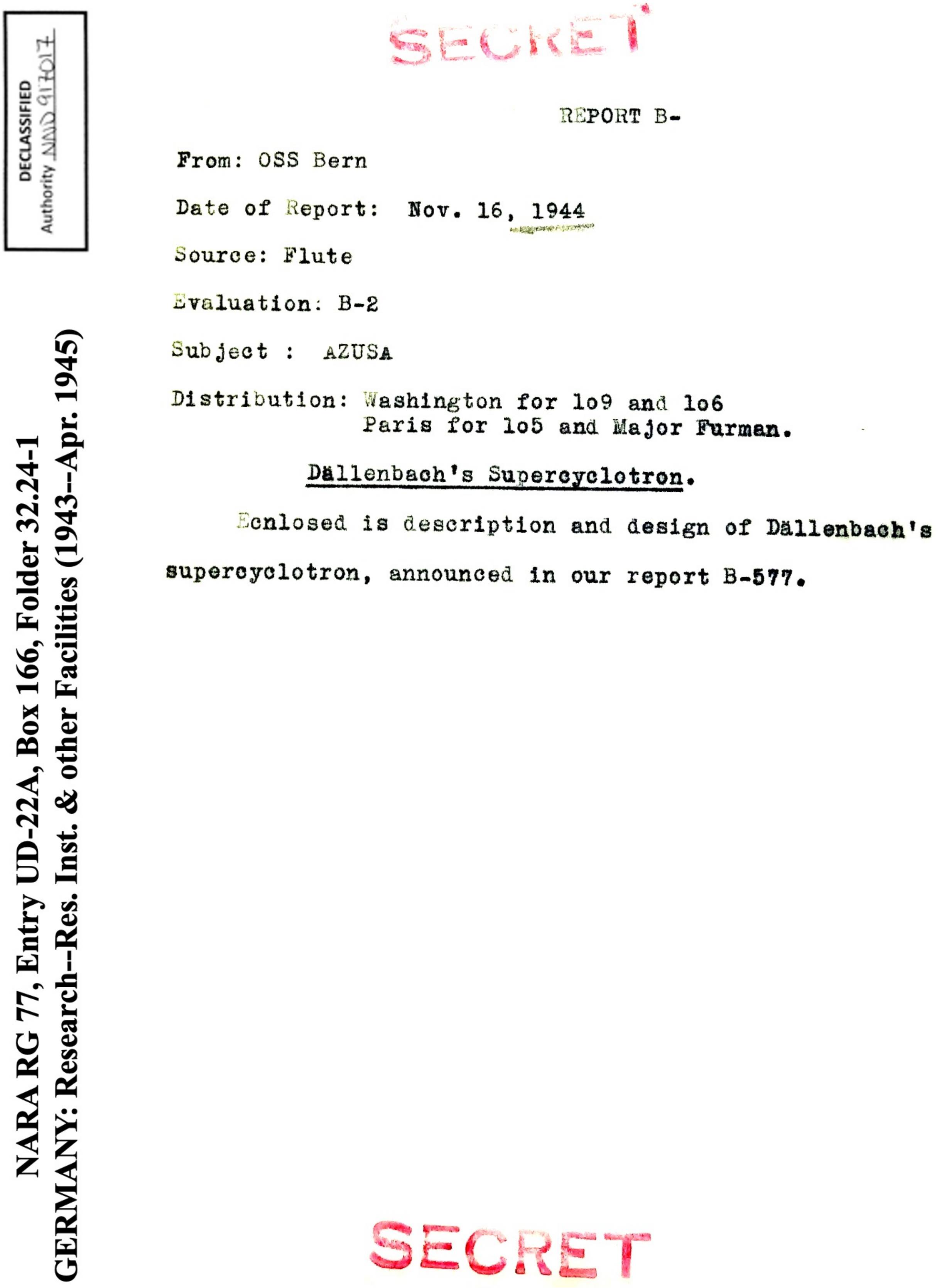
F
A

Figure C.21: Max Steenbeck's first patent on betatrons (DE 698,867), filed in 1935.



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SECRET

REPORT B-

From: OSS Bern

Date of Report: Nov. 16, 1944

Source: Flute

Evaluation: B-2

Subject : AZUSA

Distribution: Washington for lo9 and lo6
Paris for lo5 and Major Furman.

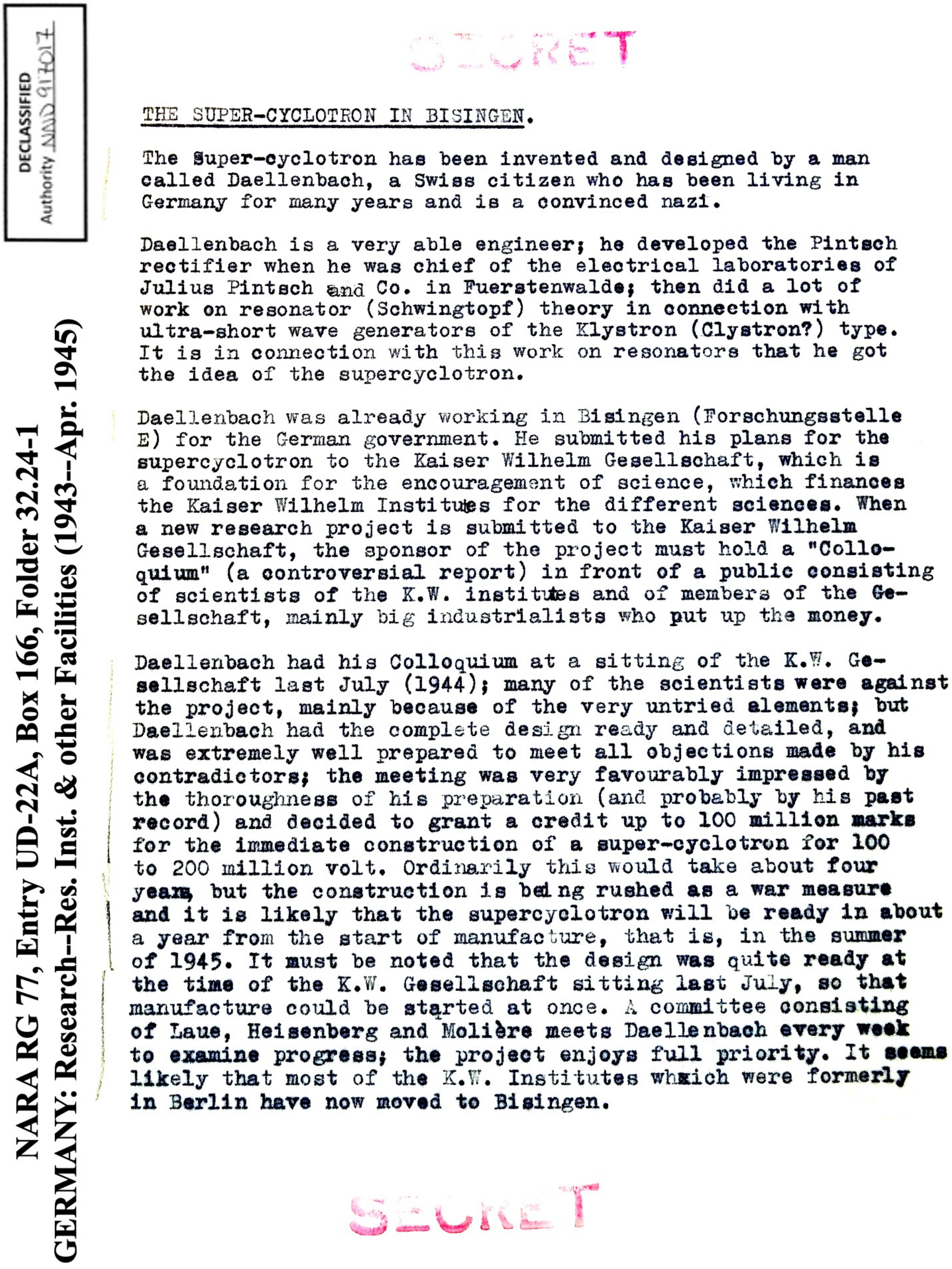
Dällenbach's Supercyclotron.

Ecnlosed is description and design of Dällenbach's supercyclotron, announced in our report B-577.

SECRET

NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1
GERMANY: Research--Res. Inst. & other Facilities (1943--Apr. 1945)

Figure C.22: OSS Bern intelligence from "Flute" (Paul Scherrer). 16 November 1944 [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)]



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THE SUPER-CYCLOTRON IN BISINGEN.

The Super-cyclotron has been invented and designed by a man called Daellenbach, a Swiss citizen who has been living in Germany for many years and is a convinced nazi.

Daellenbach is a very able engineer; he developed the Pintsch rectifier when he was chief of the electrical laboratories of Julius Pintsch and Co. in Fuerstenwalde; then did a lot of work on resonator (Schwingtopf) theory in connection with ultra-short wave generators of the Klystron (Clystron?) type. It is in connection with this work on resonators that he got the idea of the supercyclotron.

Daellenbach was already working in Bisingen (Forschungsstelle E) for the German government. He submitted his plans for the supercyclotron to the Kaiser Wilhelm Gesellschaft, which is a foundation for the encouragement of science, which finances the Kaiser Wilhelm Institutes for the different sciences. When a new research project is submitted to the Kaiser Wilhelm Gesellschaft, the sponsor of the project must hold a "Colloquium" (a controversial report) in front of a public consisting of scientists of the K.W. institutes and of members of the Gesellschaft, mainly big industrialists who put up the money.

Daellenbach had his Colloquium at a sitting of the K.W. Gesellschaft last July (1944); many of the scientists were against the project, mainly because of the very untried elements; but Daellenbach had the complete design ready and detailed, and was extremely well prepared to meet all objections made by his contradictors; the meeting was very favourably impressed by the thoroughness of his preparation (and probably by his past record) and decided to grant a credit up to 100 million marks for the immediate construction of a super-cyclotron for 100 to 200 million volt. Ordinarily this would take about four years, but the construction is being rushed as a war measure and it is likely that the supercyclotron will be ready in about a year from the start of manufacture, that is, in the summer of 1945. It must be noted that the design was quite ready at the time of the K.W. Gesellschaft sitting last July, so that manufacture could be started at once. A committee consisting of Laue, Heisenberg and Molière meets Daellenbach every week to examine progress; the project enjoys full priority. It seems likely that most of the K.W. Institutes which were formerly in Berlin have now moved to Bisingen.

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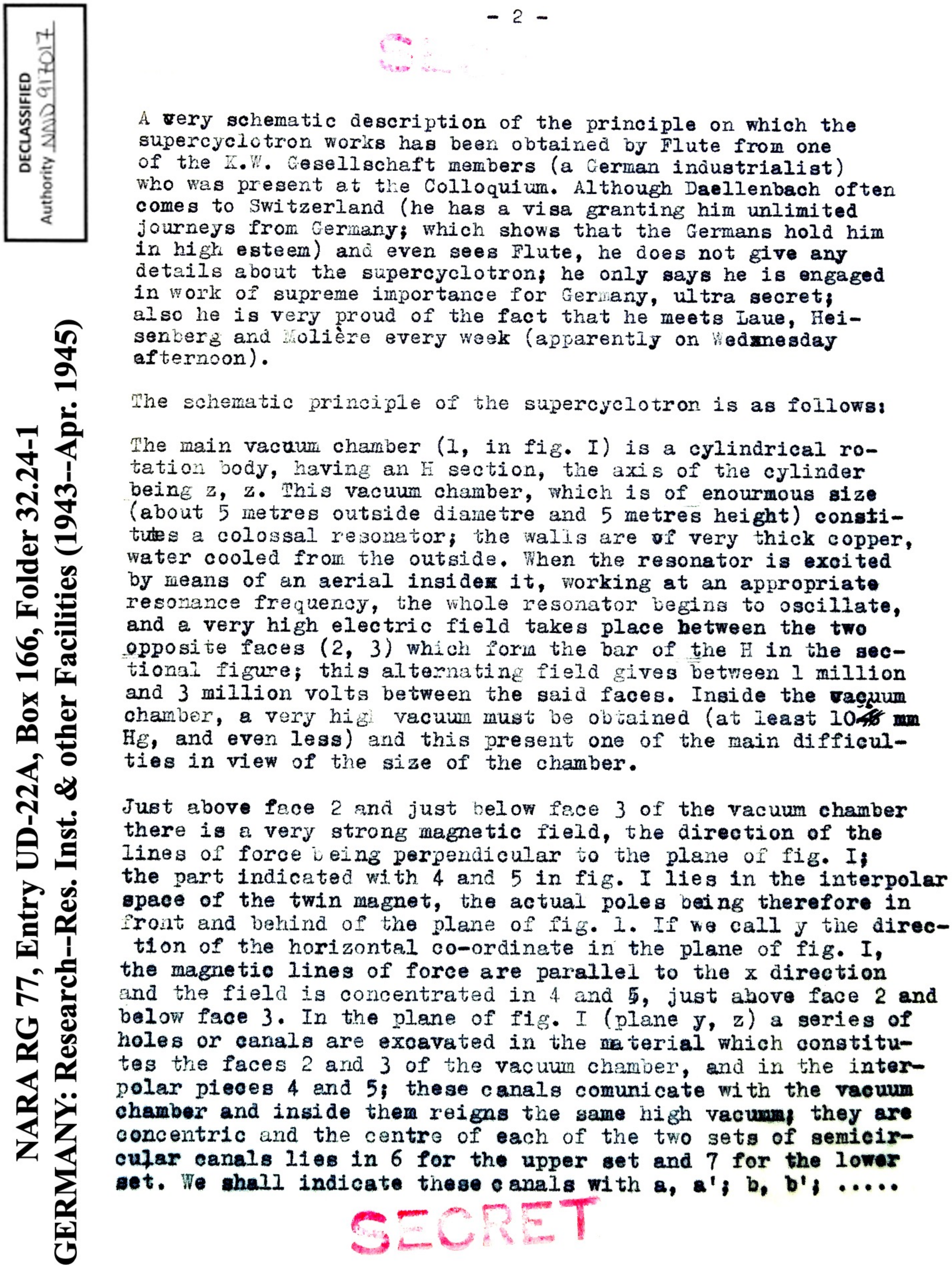
Figure C.23: OSS Bern intelligence from “Flute” (Paul Scherrer). 16 November 1944 [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)]



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A very schematic description of the principle on which the supercyclotron works has been obtained by Flute from one of the K.W. Gesellschaft members (a German industrialist) who was present at the Colloquium. Although Daellenbach often comes to Switzerland (he has a visa granting him unlimited journeys from Germany; which shows that the Germans hold him in high esteem) and even sees Flute, he does not give any details about the supercyclotron; he only says he is engaged in work of supreme importance for Germany, ultra secret; also he is very proud of the fact that he meets Laue, Heisenberg and Molière every week (apparently on Wedmnesday afternoon).

The schematic principle of the supercyclotron is as follows:

The main vacuum chamber (1, in fig. I) is a cylindrical rotation body, having an H section, the axis of the cylinder being z, z. This vacuum chamber, which is of enourmous size (about 5 metres outside diametre and 5 metres height) constitutes a colossal resonator; the walls are of very thick copper, water cooled from the outside. When the resonator is excited by means of an aerial insidem it, working at an appropriate resonance frequency, the whole resonator begins to oscillate, and a very high electric field takes place between the two opposite faces (2, 3) which form the bar of the H in the sectional figure; this alternating field gives between 1 million and 3 million volts between the said faces. Inside the vacuum chamber, a very high vacuum must be obtained (at least 10^{-6} mm Hg, and even less) and this present one of the main difficulties in view of the size of the chamber.

Just above face 2 and just below face 3 of the vacuum chamber there is a very strong magnetic field, the direction of the lines of force being perpendicular to the plane of fig. I; the part indicated with 4 and 5 in fig. I lies in the interpolar space of the twin magnet, the actual poles being therefore in front and behind of the plane of fig. 1. If we call y the direction of the horizontal co-ordinate in the plane of fig. I, the magnetic lines of force are parallel to the x direction and the field is concentrated in 4 and 5, just above face 2 and below face 3. In the plane of fig. I (plane y, z) a series of holes or canals are excavated in the material which constitutes the faces 2 and 3 of the vacuum chamber, and in the interpolar pieces 4 and 5; these canals comunicate with the vacuum chamber and inside them reigns the same high vacumm; they are concentric and the centre of each of the two sets of semicircular canals lies in 6 for the upper set and 7 for the lower set. We shall indicate these canals with a, a'; b, b'; .....

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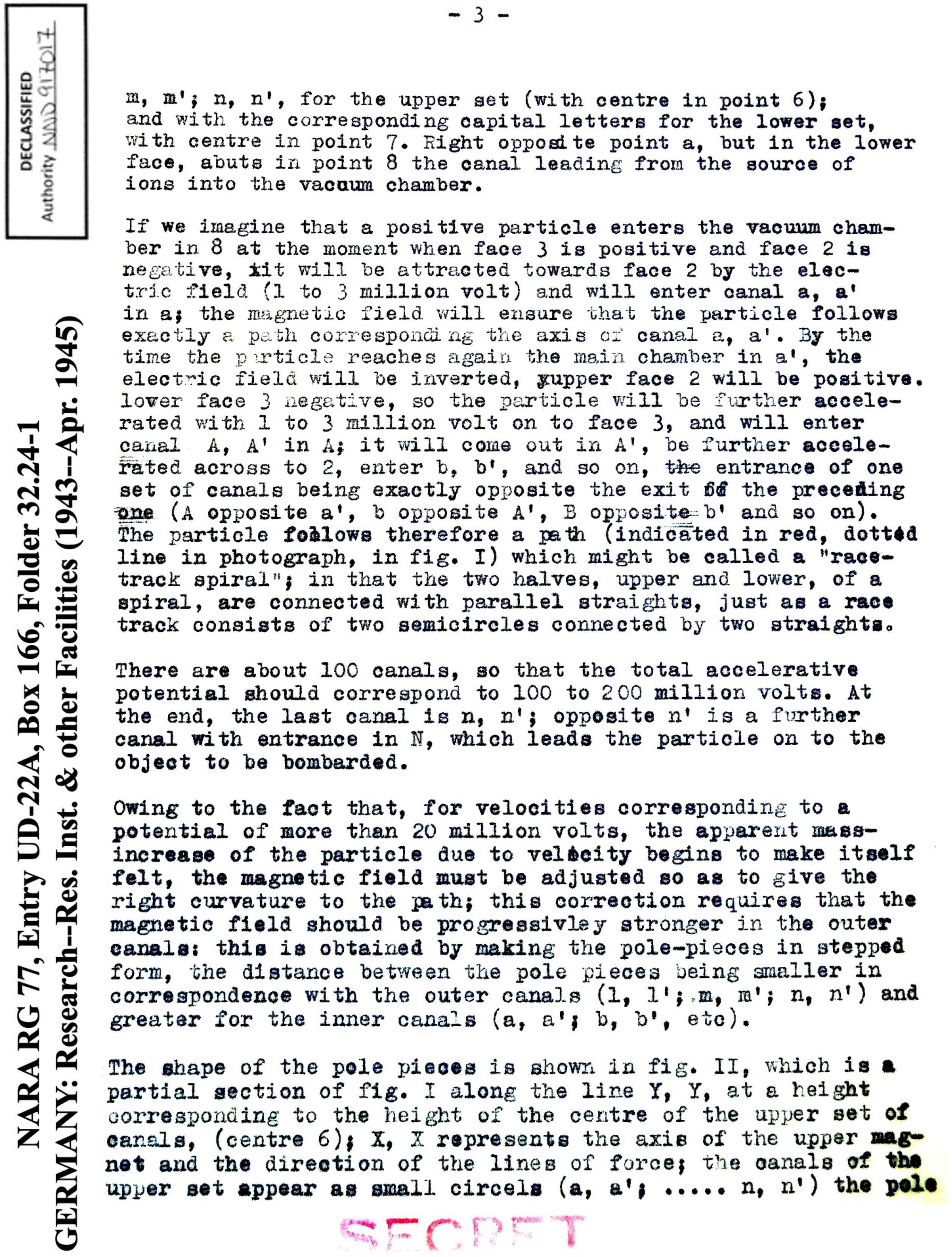
Figure C.24: OSS Bern intelligence from "Flute" (Paul Scherrer). 16 November 1944 [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)]



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- 3 -

m, m'; n, n', for the upper set (with centre in point 6); and with the corresponding capital letters for the lower set, with centre in point 7. Right opposite point a, but in the lower face, abuts in point 8 the canal leading from the source of ions into the vacuum chamber.

If we imagine that a positive particle enters the vacuum chamber in 8 at the moment when face 3 is positive and face 2 is negative, ~~x~~it will be attracted towards face 2 by the electric field (1 to 3 million volt) and will enter canal a, a' in a; the magnetic field will ensure that the particle follows exactly a path corresponding the axis of canal a, a'. By the time the particle reaches again the main chamber in a', the electric field will be inverted, ~~y~~upper face 2 will be positive. lower face 3 negative, so the particle will be further accelerated with 1 to 3 million volt on to face 3, and will enter canal A, A' in A; it will come out in A', be further accelerated across to 2, enter b, b', and so on, ~~the~~ entrance of one set of canals being exactly opposite the exit of the preceding one (A opposite a', b opposite A', B opposite b' and so on). The particle follows therefore a path (indicated in red, dotted line in photograph, in fig. I) which might be called a "race-track spiral"; in that the two halves, upper and lower, of a spiral, are connected with parallel straights, just as a race track consists of two semicircles connected by two straights.

There are about 100 canals, so that the total accelerative potential should correspond to 100 to 200 million volts. At the end, the last canal is n, n'; opposite n' is a further canal with entrance in N, which leads the particle on to the object to be bombarded.

Owing to the fact that, for velocities corresponding to a potential of more than 20 million volts, the apparent mass-increase of the particle due to velocity begins to make itself felt, the magnetic field must be adjusted so as to give the right curvature to the path; this correction requires that the magnetic field should be progressivley stronger in the outer canals: this is obtained by making the pole-pieces in stepped form, the distance between the pole pieces being smaller in correspondence with the outer canals (l, l'; m, m'; n, n') and greater for the inner canals (a, a'; b, b', etc).

The shape of the pole pieces is shown in fig. II, which is a partial section of fig. I along the line Y, Y, at a height corresponding to the height of the centre of the upper set of canals, (centre 6); X, X represents the axis of the upper magnet and the direction of the lines of force; the canals of the upper set appear as small circels (a, a'; ..... n, n') the pole

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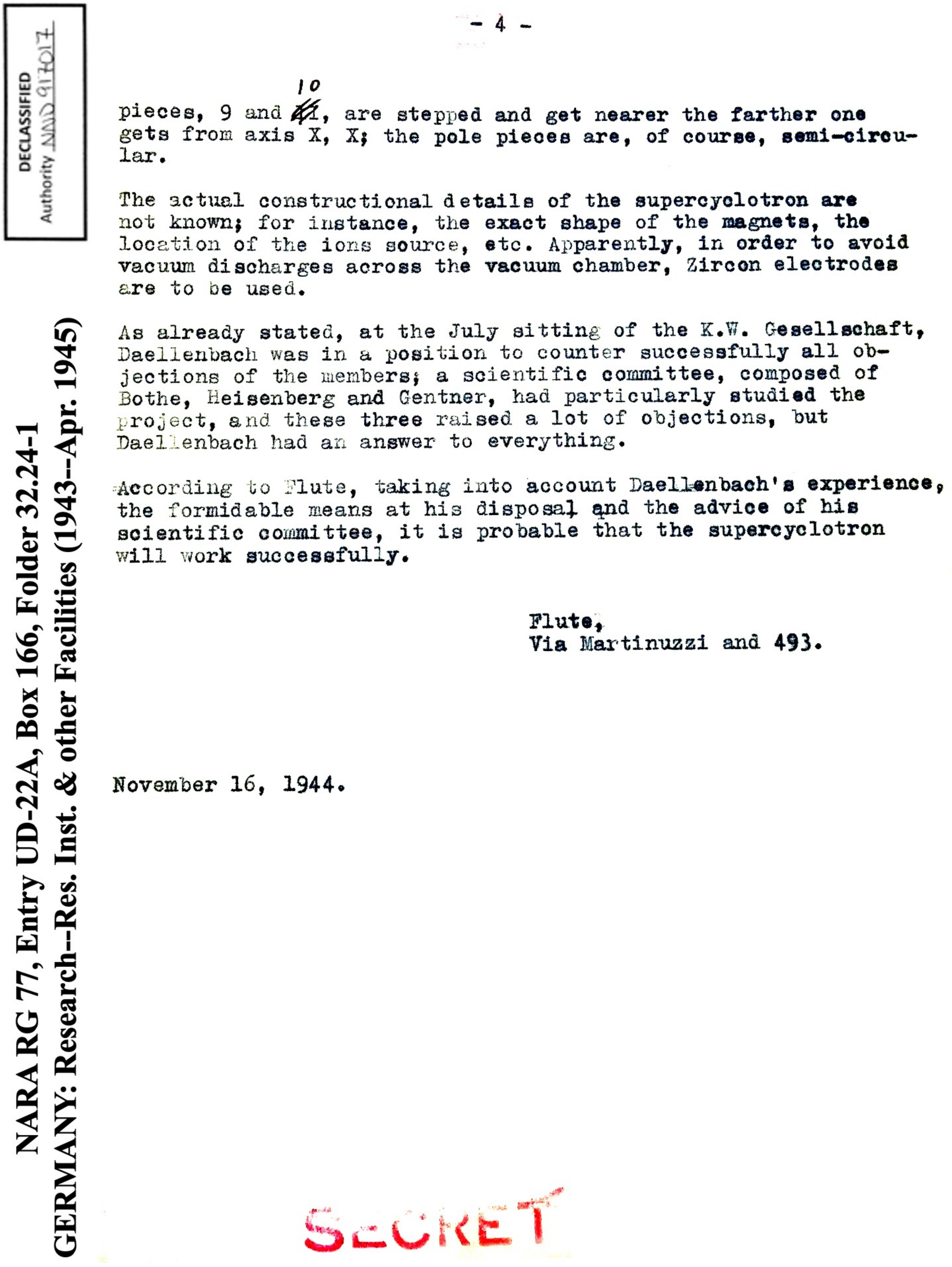
Figure C.25: OSS Bern intelligence from "Flute" (Paul Scherrer). 16 November 1944 [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)]



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GERMANY: Research--Res. Inst. & other Facilities (1943--Apr. 1945)

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pieces, 9 and ~~11~~ 10, are stepped and get nearer the farther one gets from axis X, X; the pole pieces are, of course, semi-circular.

The actual constructional details of the supercyclotron are not known; for instance, the exact shape of the magnets, the location of the ions source, etc. Apparently, in order to avoid vacuum discharges across the vacuum chamber, Zircon electrodes are to be used.

As already stated, at the July sitting of the K.W. Gesellschaft, Daellenbach was in a position to counter successfully all objections of the members; a scientific committee, composed of Bothe, Heisenberg and Gentner, had particularly studied the project, and these three raised a lot of objections, but Daellenbach had an answer to everything.

According to Flute, taking into account Daellenbach's experience, the formidable means at his disposal and the advice of his scientific committee, it is probable that the supercyclotron will work successfully.

Flute,
Via Martinuzzi and 493.

November 16, 1944.

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Figure C.26: OSS Bern intelligence from "Flute" (Paul Scherrer). 16 November 1944 [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)]

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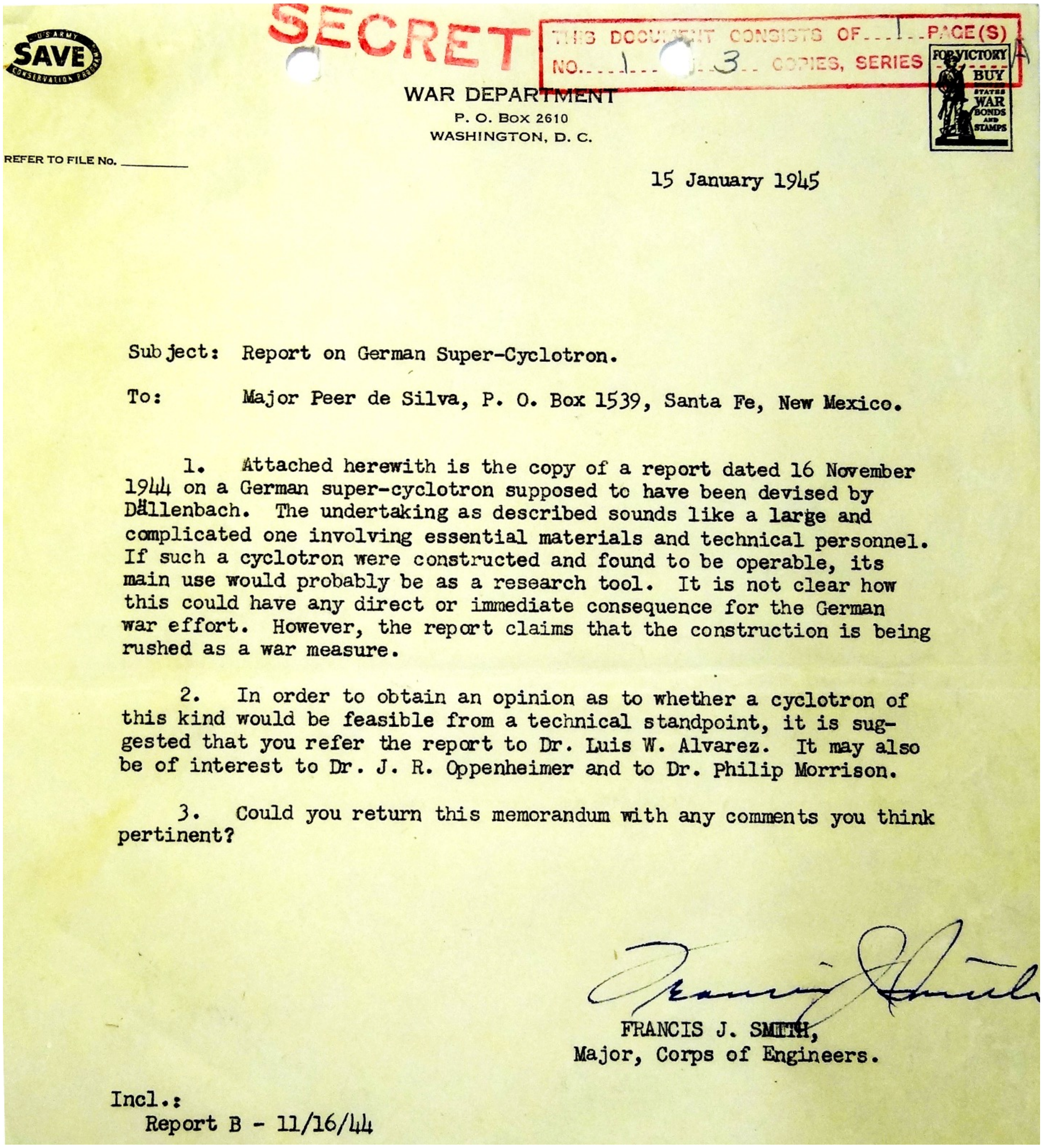

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FOR VICTORY BUY UNITED STATES WAR BONDS AND STAMPS

WAR DEPARTMENT
P. O. Box 2610
WASHINGTON, D. C.

REFER TO FILE No. ________

15 January 1945

Subject: Report on German Super-Cyclotron.

To: Major Peer de Silva, P. O. Box 1539, Santa Fe, New Mexico.

1. Attached herewith is the copy of a report dated 16 November 1944 on a German super-cyclotron supposed to have been devised by Dällenbach. The undertaking as described sounds like a large and complicated one involving essential materials and technical personnel. If such a cyclotron were constructed and found to be operable, its main use would probably be as a research tool. It is not clear how this could have any direct or immediate consequence for the German war effort. However, the report claims that the construction is being rushed as a war measure.

2. In order to obtain an opinion as to whether a cyclotron of this kind would be feasible from a technical standpoint, it is suggested that you refer the report to Dr. Luis W. Alvarez. It may also be of interest to Dr. J. R. Oppenheimer and to Dr. Philip Morrison.

3. Could you return this memorandum with any comments you think pertinent?

FRANCIS J. SMITH,
Major, Corps of Engineers.

Incl.:
Report B - 11/16/44

Figure C.27: Francis J. Smith to Peer de Silva. 15 January 1945. Subject: Report on German Super-Cyclotron [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)]

NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research--Res. Inst. & other Facilities (1943--Apr. 1945)

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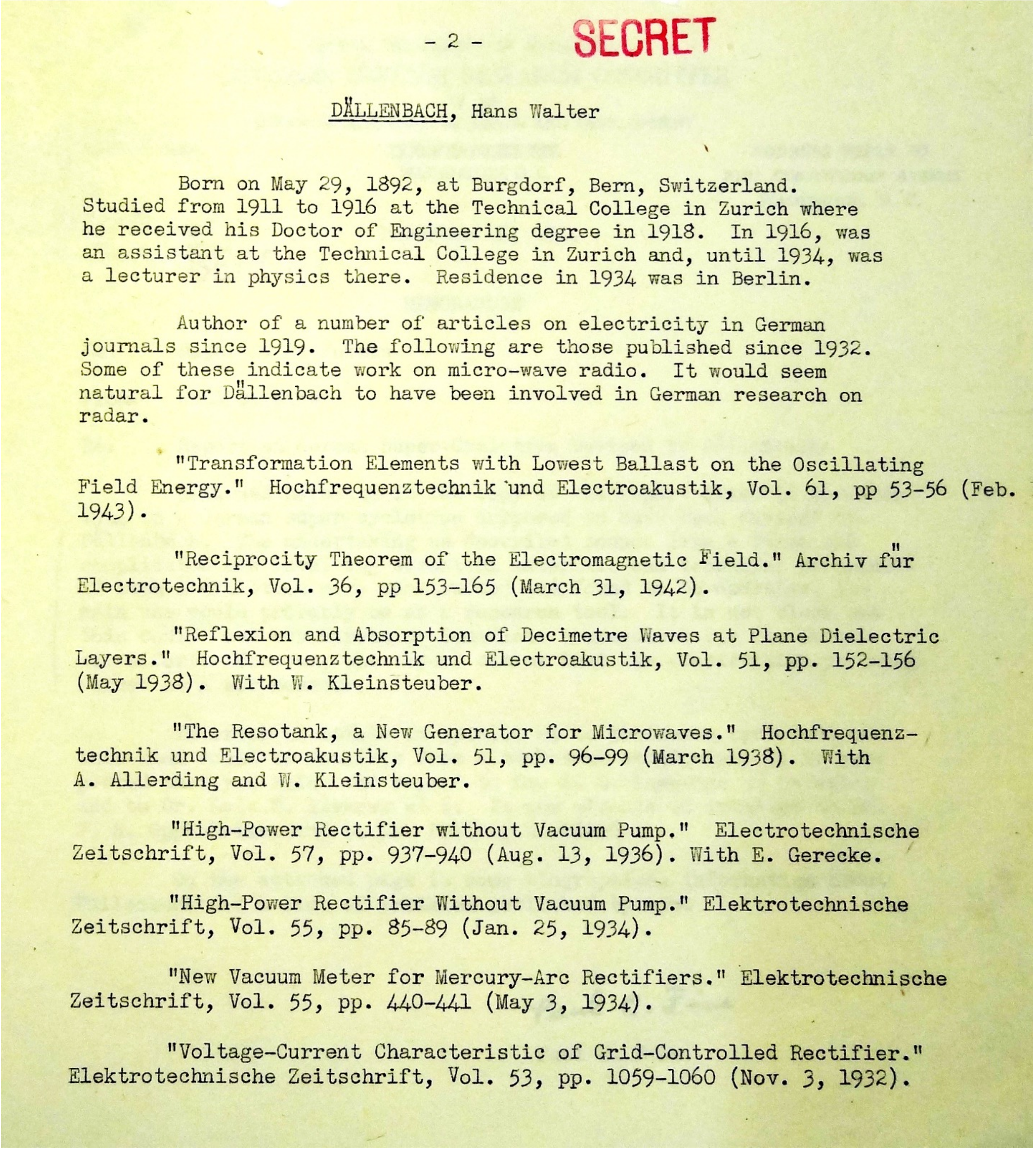

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DÄLLENBACH, Hans Walter

Born on May 29, 1892, at Burgdorf, Bern, Switzerland. Studied from 1911 to 1916 at the Technical College in Zurich where he received his Doctor of Engineering degree in 1918. In 1916, was an assistant at the Technical College in Zurich and, until 1934, was a lecturer in physics there. Residence in 1934 was in Berlin.

Author of a number of articles on electricity in German journals since 1919. The following are those published since 1932. Some of these indicate work on micro-wave radio. It would seem natural for Dällenbach to have been involved in German research on radar.

"Transformation Elements with Lowest Ballast on the Oscillating Field Energy." Hochfrequenztechnik und Electroakustik, Vol. 61, pp 53-56 (Feb. 1943).

"Reciprocity Theorem of the Electromagnetic Field." Archiv für Electrotechnik, Vol. 36, pp 153-165 (March 31, 1942).

"Reflexion and Absorption of Decimetre Waves at Plane Dielectric Layers." Hochfrequenztechnik und Electroakustik, Vol. 51, pp. 152-156 (May 1938). With W. Kleinsteuber.

"The Resotank, a New Generator for Microwaves." Hochfrequenztechnik und Electroakustik, Vol. 51, pp. 96-99 (March 1938). With A. Allerding and W. Kleinsteuber.

"High-Power Rectifier without Vacuum Pump." Electrotechnische Zeitschrift, Vol. 57, pp. 937-940 (Aug. 13, 1936). With E. Gerecke.

"High-Power Rectifier Without Vacuum Pump." Elektrotechnische Zeitschrift, Vol. 55, pp. 85-89 (Jan. 25, 1934).

"New Vacuum Meter for Mercury-Arc Rectifiers." Elektrotechnische Zeitschrift, Vol. 55, pp. 440-441 (May 3, 1934).

"Voltage-Current Characteristic of Grid-Controlled Rectifier." Elektrotechnische Zeitschrift, Vol. 53, pp. 1059-1060 (Nov. 3, 1932).

Figure C.28: Francis J. Smith to Peer de Silva. 15 January 1945. Subject: Report on German Super-Cyclotron [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)]

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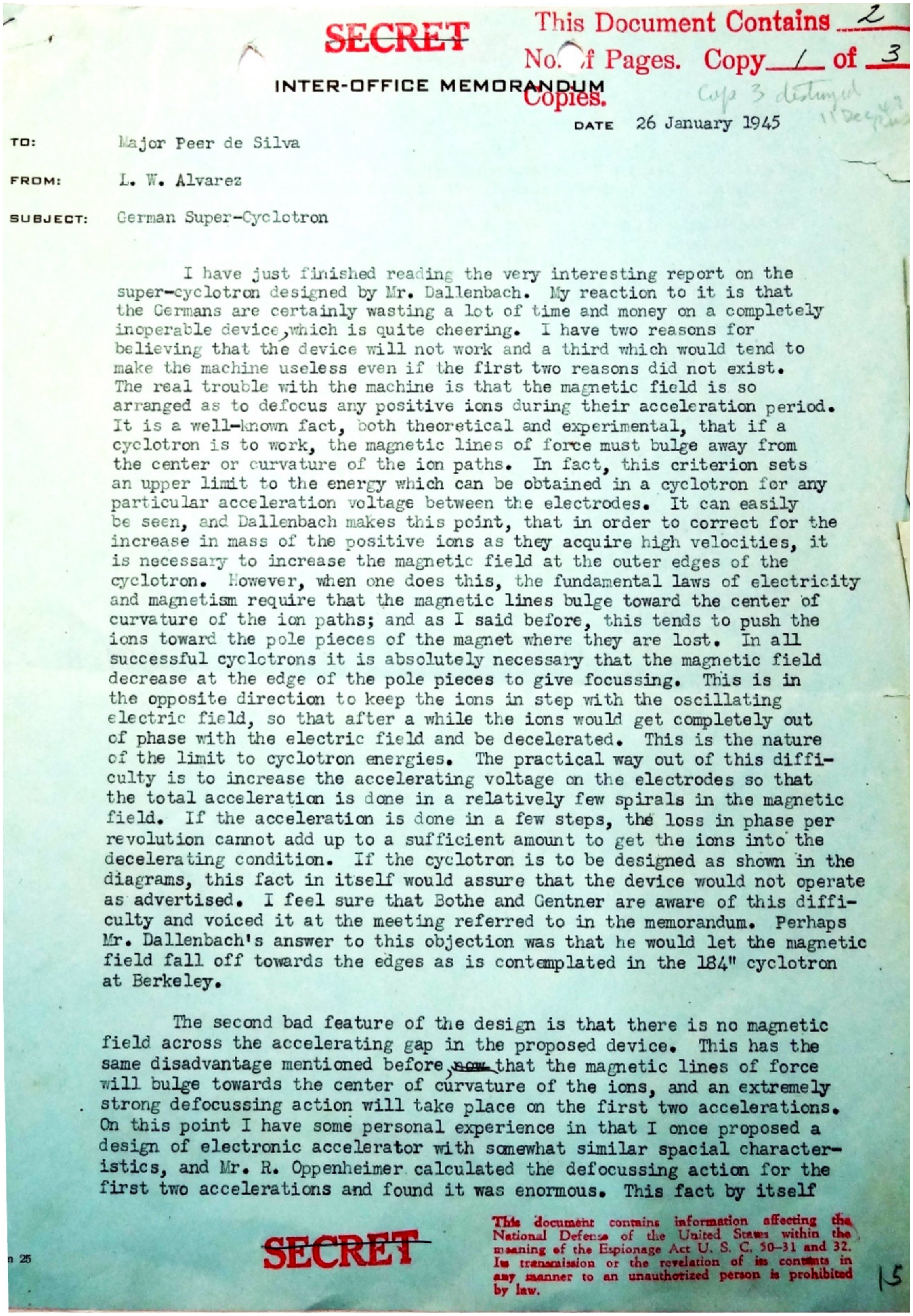
NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1
GERMANY: Research--Res. Inst. & other Facilities (1943--Apr. 1945)



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INTER-OFFICE MEMORANDUM

DATE 26 January 1945

TO: Major Peer de Silva

FROM: L. W. Alvarez

SUBJECT: German Super-Cyclotron

I have just finished reading the very interesting report on the super-cyclotron designed by Mr. Dallenbach. My reaction to it is that the Germans are certainly wasting a lot of time and money on a completely inoperable device, which is quite cheering. I have two reasons for believing that the device will not work and a third which would tend to make the machine useless even if the first two reasons did not exist. The real trouble with the machine is that the magnetic field is so arranged as to defocus any positive ions during their acceleration period. It is a well-known fact, both theoretical and experimental, that if a cyclotron is to work, the magnetic lines of force must bulge away from the center or curvature of the ion paths. In fact, this criterion sets an upper limit to the energy which can be obtained in a cyclotron for any particular acceleration voltage between the electrodes. It can easily be seen, and Dallenbach makes this point, that in order to correct for the increase in mass of the positive ions as they acquire high velocities, it is necessary to increase the magnetic field at the outer edges of the cyclotron. However, when one does this, the fundamental laws of electricity and magnetism require that the magnetic lines bulge toward the center of curvature of the ion paths; and as I said before, this tends to push the ions toward the pole pieces of the magnet where they are lost. In all successful cyclotrons it is absolutely necessary that the magnetic field decrease at the edge of the pole pieces to give focussing. This is in the opposite direction to keep the ions in step with the oscillating electric field, so that after a while the ions would get completely out of phase with the electric field and be decelerated. This is the nature of the limit to cyclotron energies. The practical way out of this difficulty is to increase the accelerating voltage on the electrodes so that the total acceleration is done in a relatively few spirals in the magnetic field. If the acceleration is done in a few steps, the loss in phase per revolution cannot add up to a sufficient amount to get the ions into the decelerating condition. If the cyclotron is to be designed as shown in the diagrams, this fact in itself would assure that the device would not operate as advertised. I feel sure that Bothe and Gentner are aware of this difficulty and voiced it at the meeting referred to in the memorandum. Perhaps Mr. Dallenbach's answer to this objection was that he would let the magnetic field fall off towards the edges as is contemplated in the 184" cyclotron at Berkeley.

The second bad feature of the design is that there is no magnetic field across the accelerating gap in the proposed device. This has the same disadvantage mentioned before, ~~now~~ that the magnetic lines of force will bulge towards the center of curvature of the ions, and an extremely strong defocussing action will take place on the first two accelerations. On this point I have some personal experience in that I once proposed a design of electronic accelerator with somewhat similar spacial characteristics, and Mr. R. Oppenheimer calculated the defocussing action for the first two accelerations and found it was enormous. This fact by itself

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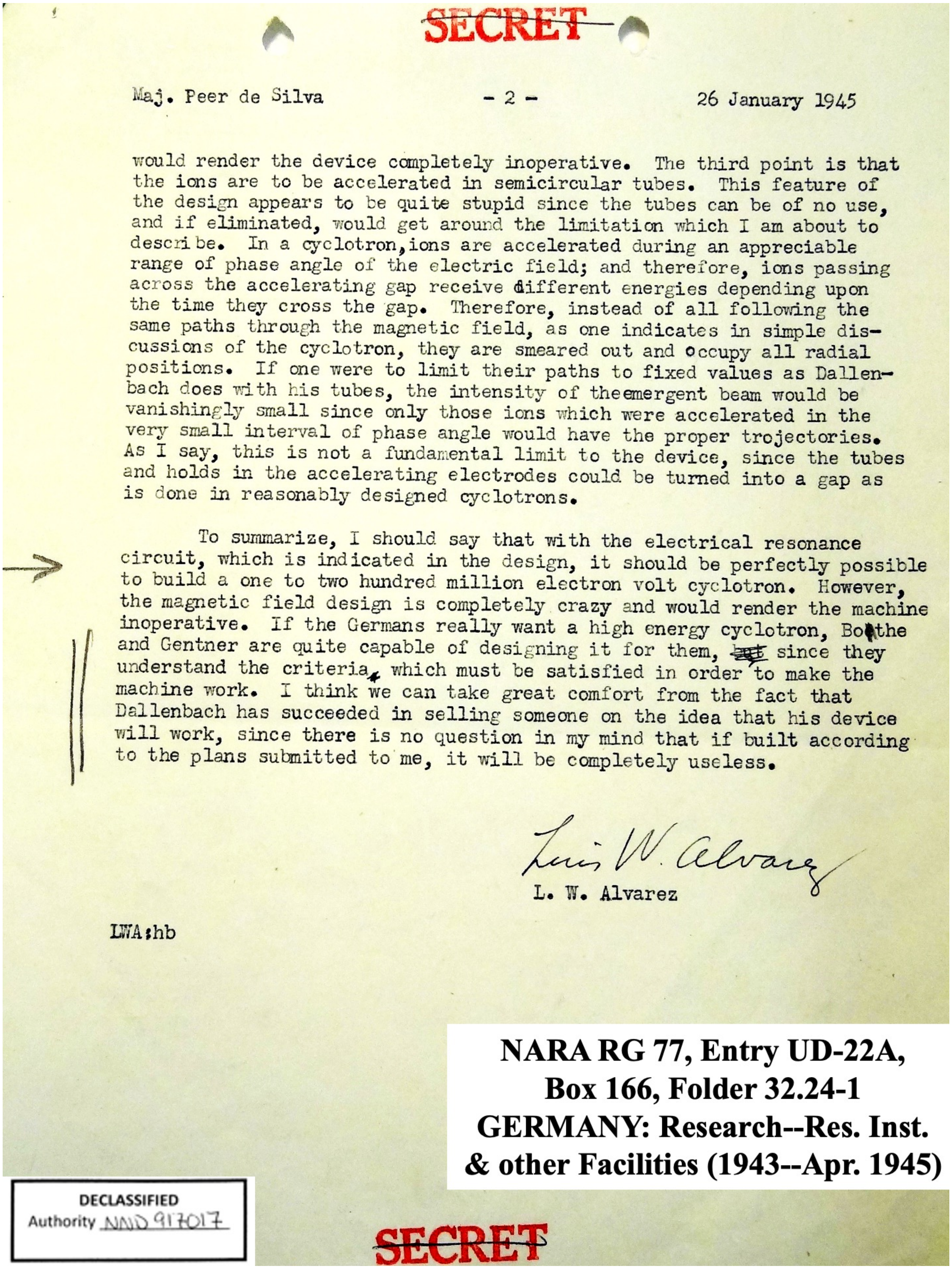
Figure C.29: Luis W. Alvarez to Peer de Silva. 26 January 1945. SUBJECT: German Super-Cyclotron [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)]



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Maj. Peer de Silva - 2 - 26 January 1945

would render the device completely inoperative. The third point is that the ions are to be accelerated in semicircular tubes. This feature of the design appears to be quite stupid since the tubes can be of no use, and if eliminated, would get around the limitation which I am about to describe. In a cyclotron,ions are accelerated during an appreciable range of phase angle of the electric field; and therefore, ions passing across the accelerating gap receive different energies depending upon the time they cross the gap. Therefore, instead of all following the same paths through the magnetic field, as one indicates in simple discussions of the cyclotron, they are smeared out and occupy all radial positions. If one were to limit their paths to fixed values as Dallenbach does with his tubes, the intensity of theemergent beam would be vanishingly small since only those ions which were accelerated in the very small interval of phase angle would have the proper trojectories. As I say, this is not a fundamental limit to the device, since the tubes and holds in the accelerating electrodes could be turned into a gap as is done in reasonably designed cyclotrons.

To summarize, I should say that with the electrical resonance circuit, which is indicated in the design, it should be perfectly possible to build a one to two hundred million electron volt cyclotron. However, the magnetic field design is completely crazy and would render the machine inoperative. If the Germans really want a high energy cyclotron, Bothe and Gentner are quite capable of designing it for them, ~~but~~ since they understand the criteria, which must be satisfied in order to make the machine work. I think we can take great comfort from the fact that Dallenbach has succeeded in selling someone on the idea that his device will work, since there is no question in my mind that if built according to the plans submitted to me, it will be completely useless.

Luis W. Alvarez

L. W. Alvarez

LWA:hb

NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research--Res. Inst. & other Facilities (1943--Apr. 1945)

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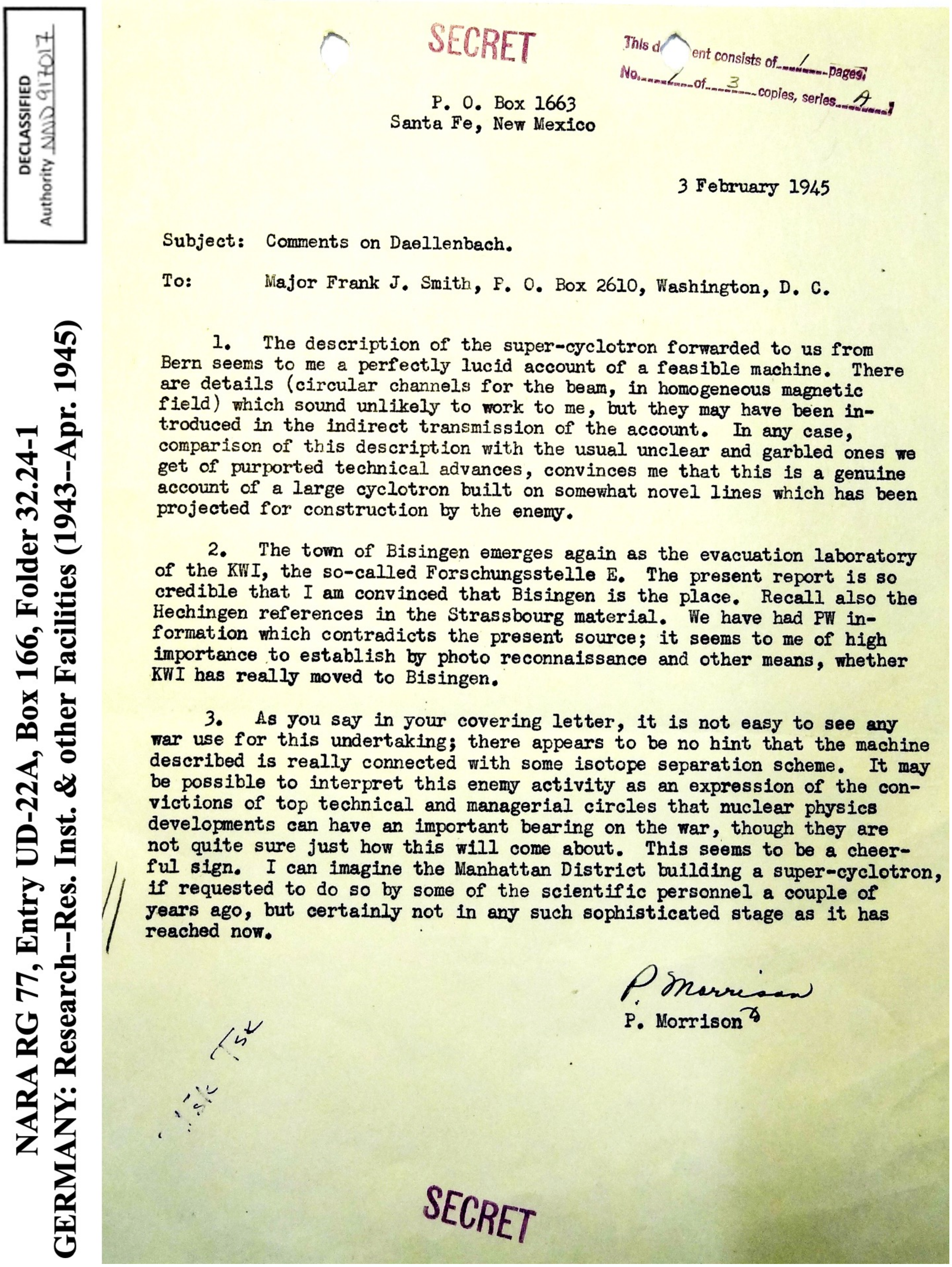
Figure C.30: Luis W. Alvarez to Peer de Silva. 26 January 1945. SUBJECT: German Super-Cyclotron [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)]



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This d[illegible]ent consists of 1 pages,
No. 2 of 3 copies, series A.

P. O. Box 1663
Santa Fe, New Mexico

3 February 1945

Subject: Comments on Daellenbach.

To: Major Frank J. Smith, P. O. Box 2610, Washington, D. C.

1. The description of the super-cyclotron forwarded to us from Bern seems to me a perfectly lucid account of a feasible machine. There are details (circular channels for the beam, in homogeneous magnetic field) which sound unlikely to work to me, but they may have been introduced in the indirect transmission of the account. In any case, comparison of this description with the usual unclear and garbled ones we get of purported technical advances, convinces me that this is a genuine account of a large cyclotron built on somewhat novel lines which has been projected for construction by the enemy.

2. The town of Bisingen emerges again as the evacuation laboratory of the KWI, the so-called Forschungsstelle E. The present report is so credible that I am convinced that Bisingen is the place. Recall also the Hechingen references in the Strassbourg material. We have had PW information which contradicts the present source; it seems to me of high importance to establish by photo reconnaissance and other means, whether KWI has really moved to Bisingen.

3. As you say in your covering letter, it is not easy to see any war use for this undertaking; there appears to be no hint that the machine described is really connected with some isotope separation scheme. It may be possible to interpret this enemy activity as an expression of the convictions of top technical and managerial circles that nuclear physics developments can have an important bearing on the war, though they are not quite sure just how this will come about. This seems to be a cheerful sign. I can imagine the Manhattan District building a super-cyclotron, if requested to do so by some of the scientific personnel a couple of years ago, but certainly not in any such sophisticated stage as it has reached now.

P. Morrison

P. Morrison

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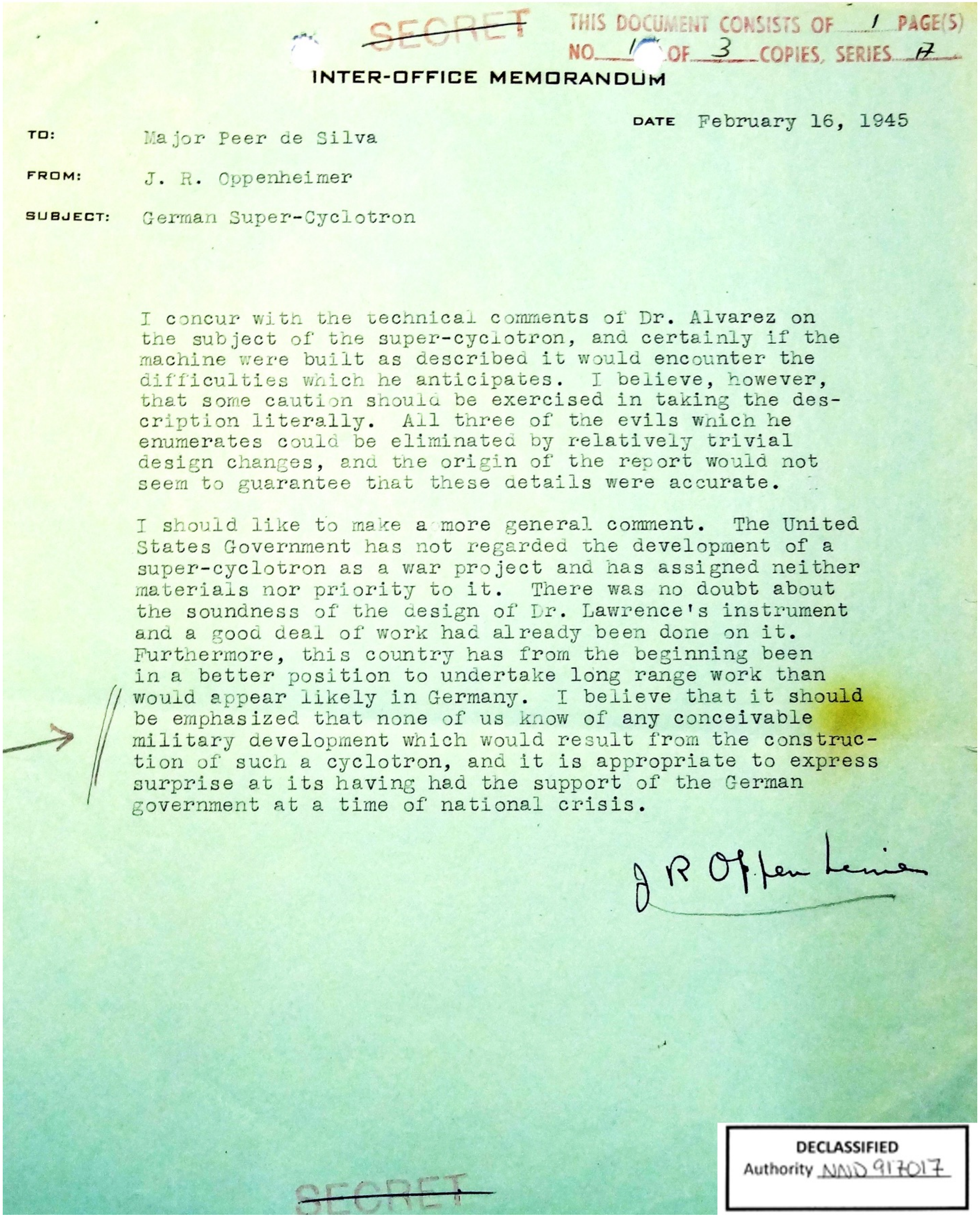
Figure C.31: Philip Morrison to Francis J. Smith. 3 February 1945. Subject: Comments on Daellenbach [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)]

NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1
GERMANY: Research--Res. Inst. & other Facilities (1943--Apr. 1945)



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INTER-OFFICE MEMORANDUM

DATE February 16, 1945

TO: Major Peer de Silva

FROM: J. R. Oppenheimer

SUBJECT: German Super-Cyclotron

I concur with the technical comments of Dr. Alvarez on the subject of the super-cyclotron, and certainly if the machine were built as described it would encounter the difficulties which he anticipates. I believe, however, that some caution should be exercised in taking the description literally. All three of the evils which he enumerates could be eliminated by relatively trivial design changes, and the origin of the report would not seem to guarantee that these details were accurate.

I should like to make a more general comment. The United States Government has not regarded the development of a super-cyclotron as a war project and has assigned neither materials nor priority to it. There was no doubt about the soundness of the design of Dr. Lawrence's instrument and a good deal of work had already been done on it. Furthermore, this country has from the beginning been in a better position to undertake long range work than would appear likely in Germany. I believe that it should be emphasized that none of us know of any conceivable military development which would result from the construction of such a cyclotron, and it is appropriate to express surprise at its having had the support of the German government at a time of national crisis.

J R Oppenheimer

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Figure C.32: J. Robert Oppenheimer to Peer de Silva. 16 February 1945. SUBJECT: German Super-Cyclotron [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)]

Captured Personnel and Material Branch. 4 September 1944. Special Report 23 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)]

Estimate of veracity: Source is considered reliable, talks freely on all matters pertaining to Communication Engineering

Source has been in the German Army since 1928, when he first enlisted and became a Radio Operator. Since that time he was sent to the Technische Hochschule in Berlin on several occasions to study research work for the German Army. He witnessed a very interesting experiment which impressed him very much during the latter part of 1937 and 1938.

The demonstration was performed at the Müggelsee near Berlin and the talk among Army Personnel attending indicated that Neutron Rays were to be employed. A small balloon was released from a boat on the lake which also housed the equipment and the operating personnel. When the rays struck the balloon several hundred feet in the air, it exploded. Source states that when the beam struck the balloon the Hydrogen gas was bombarded causing it to explode.

The beams were then directed upon some old brick buildings. After a short period of waiting for the beam to do its work, it was turned off and the Army spectators were permitted to inspect the brick building. It was discovered that the bricks could be taken and crumbled by a light blow of a hammer. This they were told was brought about by the Neutron ray which was beamed on the building. Very deadly secondary rays are produced by such a beam, they were told, however, it required a tremendous amount of equipment to project such a beam and because of the strong secondary ray which sometimes destroyed the equipment itself, the Army officials decided it would be unwise to employ such equipment for combat.

They were also experimenting with Schumann Rays, which are shorter than Gamma Rays. The idea is to obtain certain gases, such as helium, krypton, and neon, by breaking down atoms. Considerable difficulty is experienced in controlling these rays and on one experiment, source's best friend was killed due to the secondary effect.

Helium is produced by this principle in a factory at Merseburg, near Halle. Facilities are not available to produce it in large quantities. Source never visited this place. He knew of this factory in 1938.

[See document photo on p. 3057.

"Schumann Rays" appears to be a reference to Gerhard Schumann, a particle accelerator physicist known to have developed and tested high-energy accelerators during the war. This report seems to indicate that Schumann, Steenbeck, or other scientists were producing, projecting, and testing intense particle beams as potential weapons by 1937–1938.]

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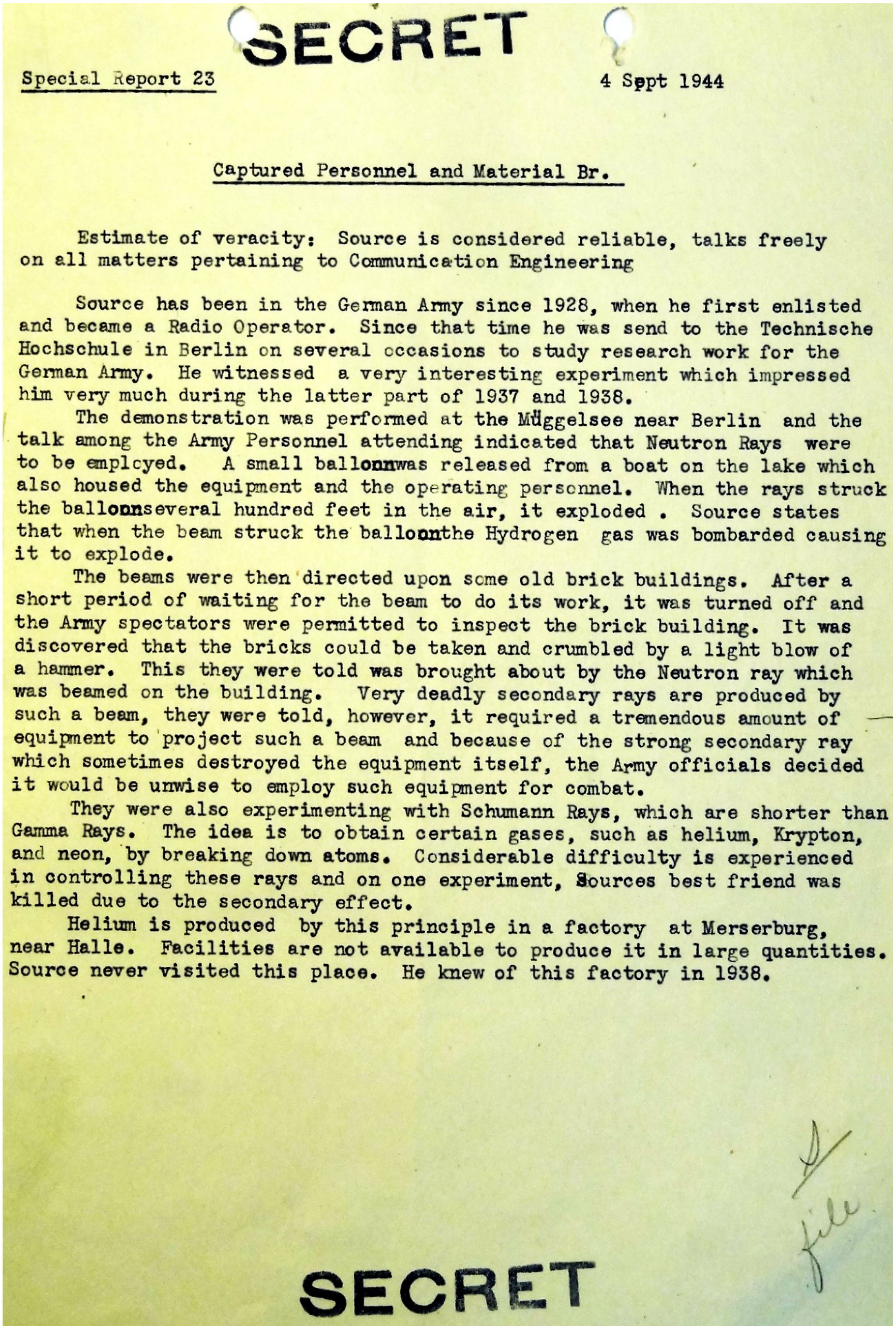
NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July-October 1944)



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Special Report 23 4 Sppt 1944

Captured Personnel and Material Br.

Estimate of veracity: Source is considered reliable, talks freely on all matters pertaining to Communication Engineering

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They were also experimenting with Schumann Rays, which are shorter than Gamma Rays. The idea is to obtain certain gases, such as helium, Krypton, and neon, by breaking down atoms. Considerable difficulty is experienced in controlling these rays and on one experiment, Sources best friend was killed due to the secondary effect.

Helium is produced by this principle in a factory at Merserburg, near Halle. Facilities are not available to produce it in large quantities. Source never visited this place. He knew of this factory in 1938.

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Figure C.33: Captured Personnel and Material Branch. 4 September 1944. Special Report 23 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

Captured Personnel and Material Branch. 1 November 1944. Report 1363. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

[...] V. DEATH RAY:

A P/W who is a graduate engineer and an inventor with training in chemical metallurgy, gives the following account of a death ray experiment he witnessed at the Berlin Hagenuk ("Hanseatische Apparat Bau Gesellschaft Neufeld & Kuhnke", cf. C.S.D.I.C. (UK) S.I.R. 1029) testing grounds at Tempelhof.

P/W was conducting some experiments there in February 1939. He had just completed experiments of his own when he noticed people assembling on the adjacent testing grounds which belonged to A.E.G. Siemenstadt, Berlin. He inquired regarding the nature of the experiment to take place and was told some form of ray would be displayed. He was permitted to view the experiments by a Dip. Ingenieur, an employee of the A.E.G., who was in charge and with whom P/W was friendly, they having attended the Technische Hochschule at Aachen together. P/W's uncle, Eng. Sauer, Technical Director at the A.E.G. in Berlin, was also instrumental in his obtaining permission to view the experiments.

The generating apparatus was housed in a small brick building four meters square and three meters high. On one side of the building was a window one meter wide, and 50 cm. high. P/W was unable to look through this window as it was made of quartz glass and some form of metal was also distributed around the glass so as to prevent stray radiations.

At a distance of 200 meters from the side of the building that contained the quartz glass window was placed a small wooden crate with live guinea pigs in it. The spectators were first permitted to inspect the crate and the live creatures. Everyone was then requested to move back behind some white ropes so placed that they were safely protected, in a position even with the side of the building. A Dr. Schuetze then entered the small brick building and switched on the apparatus. No one was permitted to enter this building other than Dr. Schuetze, who remained inside the building as long as the apparatus was in operation. A humming noise could be heard similar to that made by a generator running at high speed. The ray was invisible. After about ten minutes, Dr. Schuetze turned the apparatus off and the spectators were then permitted to examine the box which contained the guinea pigs.

P/W inspected the guinea pigs closely. Not a sign of life was present. Even when a lighted match was held close to their noses, they showed no signs of life. Dr. Schuetze told P/W that the rays had destroyed the white corpuscles of the blood and had thus caused sudden death. P/W never again saw nor heard of any other such experiments. [...]

[See document photo on p. 3059.

This is another report (from an apparently very knowledgeable and trustworthy source) that indicates scientists were producing, projecting, and testing intense particle beams as potential weapons by early 1939, before the war even started.]

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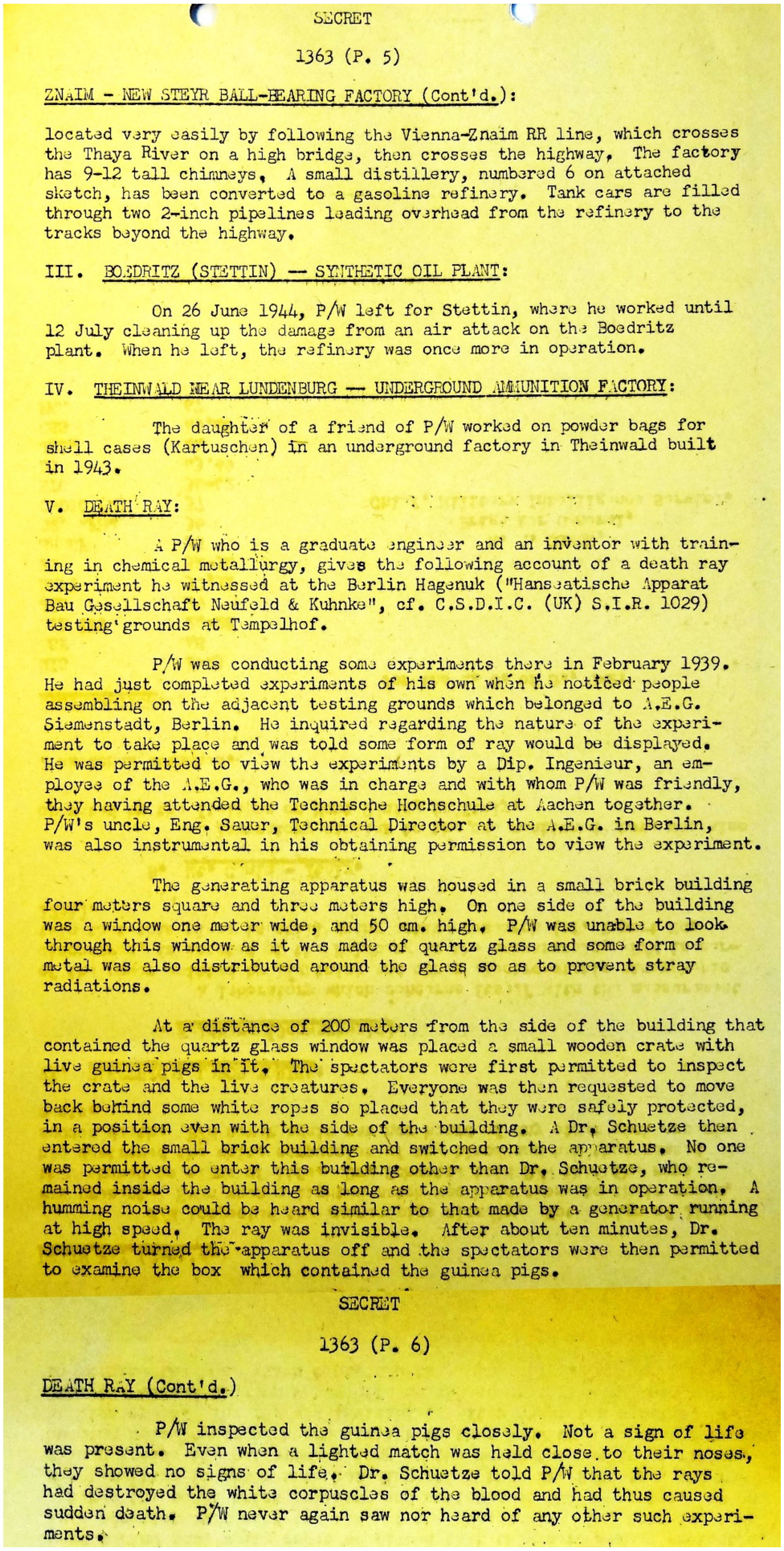
GERMANY: US Wartime Positive Int. (Nov. 44-June 45)



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1363 (P. 5)

ZNAIM - NEW STEYR BALL-BEARING FACTORY (Cont'd.):

located very easily by following the Vienna-Znaim RR line, which crosses the Thaya River on a high bridge, then crosses the highway. The factory has 9-12 tall chimneys. A small distillery, numbered 6 on attached sketch, has been converted to a gasoline refinery. Tank cars are filled through two 2-inch pipelines leading overhead from the refinery to the tracks beyond the highway.

III. BOEDRITZ (STETTIN) — SYNTHETIC OIL PLANT:

On 26 June 1944, P/W left for Stettin, where he worked until 12 July cleaning up the damage from an air attack on the Boedritz plant. When he left, the refinery was once more in operation.

IV. THEINWALD NEAR LUNDENBURG — UNDERGROUND AMMUNITION FACTORY:

The daughter of a friend of P/W worked on powder bags for shell cases (Kartuschen) in an underground factory in Theinwald built in 1943.

V. DEATH RAY:

A P/W who is a graduate engineer and an inventor with training in chemical metallurgy, gives the following account of a death ray experiment he witnessed at the Berlin Hagenuk ("Hanseatische Apparat Bau Gesellschaft Neufeld & Kuhnke", cf. C.S.D.I.C. (UK) S.I.R. 1029) testing grounds at Tempelhof.

P/W was conducting some experiments there in February 1939. He had just completed experiments of his own when he noticed people assembling on the adjacent testing grounds which belonged to A.E.G. Siemenstadt, Berlin. He inquired regarding the nature of the experiment to take place and was told some form of ray would be displayed. He was permitted to view the experiments by a Dip. Ingenieur, an employee of the A.E.G., who was in charge and with whom P/W was friendly, they having attended the Technische Hochschule at Aachen together. P/W's uncle, Eng. Sauer, Technical Director at the A.E.G. in Berlin, was also instrumental in his obtaining permission to view the experiment.

The generating apparatus was housed in a small brick building four meters square and three meters high. On one side of the building was a window one meter wide, and 50 cm. high. P/W was unable to look through this window as it was made of quartz glass and some form of metal was also distributed around the glass so as to prevent stray radiations.

At a distance of 200 meters from the side of the building that contained the quartz glass window was placed a small wooden crate with live guinea pigs in it. The spectators were first permitted to inspect the crate and the live creatures. Everyone was then requested to move back behind some white ropes so placed that they were safely protected, in a position even with the side of the building. A Dr. Schuetze then entered the small brick building and switched on the apparatus. No one was permitted to enter this building other than Dr. Schuetze, who remained inside the building as long as the apparatus was in operation. A humming noise could be heard similar to that made by a generator running at high speed. The ray was invisible. After about ten minutes, Dr. Schuetze turned the apparatus off and the spectators were then permitted to examine the box which contained the guinea pigs.

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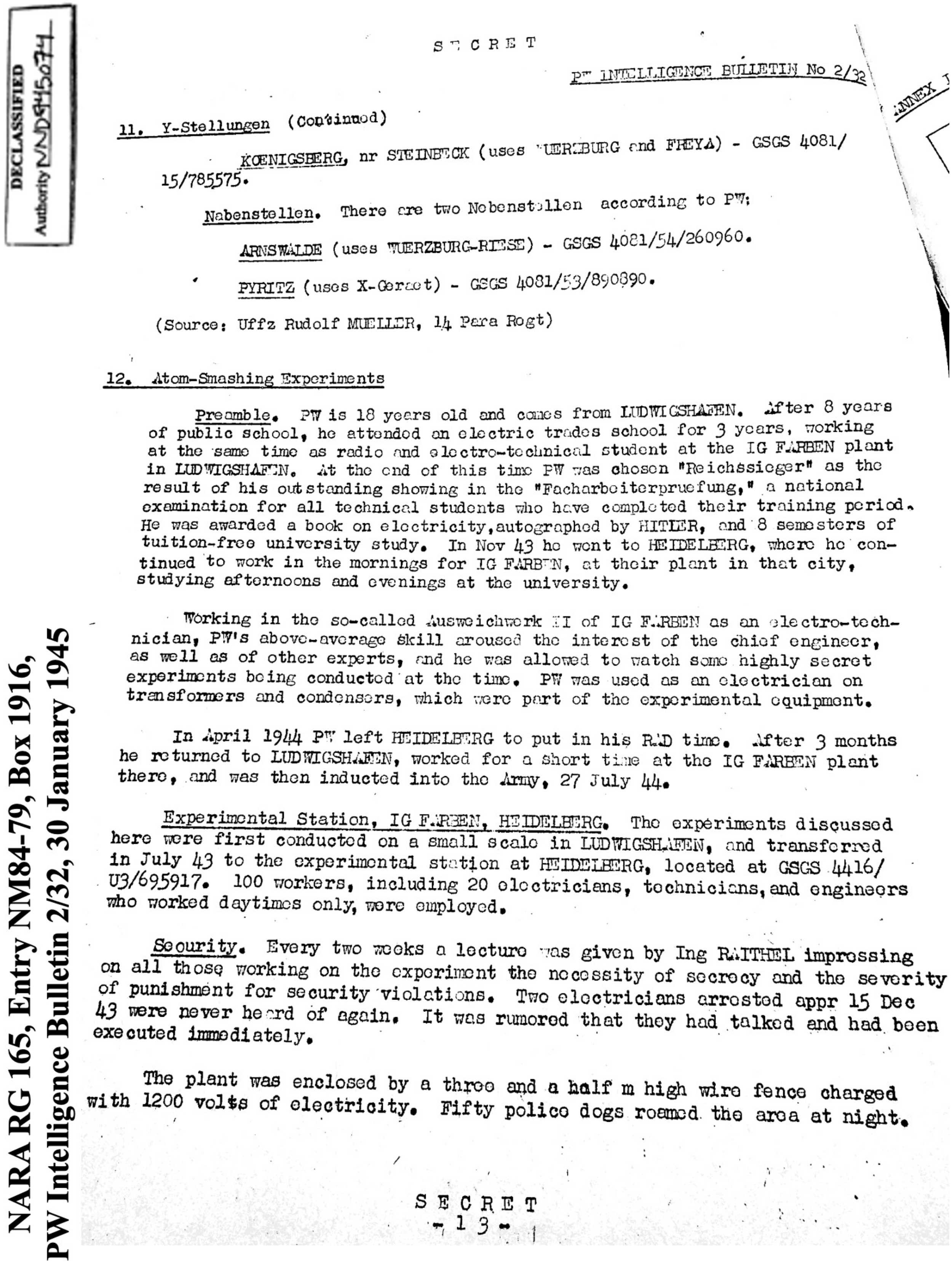
1363 (P. 6)

DEATH RAY (Cont'd.)

P/W inspected the guinea pigs closely. Not a sign of life was present. Even when a lighted match was held close to their noses, they showed no signs of life. Dr. Schuetze told P/W that the rays had destroyed the white corpuscles of the blood and had thus caused sudden death. P/W never again saw nor heard of any other such experiments.

Figure C.34: Captured Personnel and Material Branch. 1 November 1944. Report 1363 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].



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PW INTELLIGENCE BULLETIN No 2/32

ANNEX I

11. Y-Stellungen (Continued)

KOENIGSBERG, nr STEINBECK (uses WUERZBURG and FREYA) - GSGS 4081/15/785575.

Nabenstellen. There are two Nebenstellen according to PW:

ARNSWALDE (uses WUERZBURG-RIESE) - GSGS 4081/54/260960.

PYRITZ (uses X-Geraet) - GSGS 4081/53/890890.

(Source: Uffz Rudolf MUELLER, 14 Para Regt)

12. Atom-Smashing Experiments

Preamble. PW is 18 years old and comes from LUDWIGSHAFEN. After 8 years of public school, he attended an electric trades school for 3 years, working at the same time as radio and electro-technical student at the IG FARBEN plant in LUDWIGSHAFEN. At the end of this time PW was chosen "Reichssieger" as the result of his outstanding showing in the "Facharbeiterpruefung," a national examination for all technical students who have completed their training period. He was awarded a book on electricity, autographed by HITLER, and 8 semesters of tuition-free university study. In Nov 43 he went to HEIDELBERG, where he continued to work in the mornings for IG FARBEN, at their plant in that city, studying afternoons and evenings at the university.

Working in the so-called Ausweichwerk II of IG FARBEN as an electro-technician, PW's above-average skill aroused the interest of the chief engineer, as well as of other experts, and he was allowed to watch some highly secret experiments being conducted at the time. PW was used as an electrician on transformers and condensers, which were part of the experimental equipment.

In April 1944 PW left HEIDELBERG to put in his RAD time. After 3 months he returned to LUDWIGSHAFEN, worked for a short time at the IG FARBEN plant there, and was then inducted into the Army, 27 July 44.

Experimental Station, IG FARBEN, HEIDELBERG. The experiments discussed here were first conducted on a small scale in LUDWIGSHAFEN, and transferred in July 43 to the experimental station at HEIDELBERG, located at GSGS 4416/U3/695917. 100 workers, including 20 electricians, technicians, and engineers who worked daytimes only, were employed.

Security. Every two weeks a lecture was given by Ing RAITHEL impressing on all those working on the experiment the necessity of secrecy and the severity of punishment for security violations. Two electricians arrested appr 15 Dec 43 were never heard of again. It was rumored that they had talked and had been executed immediately.

The plant was enclosed by a three and a half m high wire fence charged with 1200 volts of electricity. Fifty police dogs roamed the area at night.

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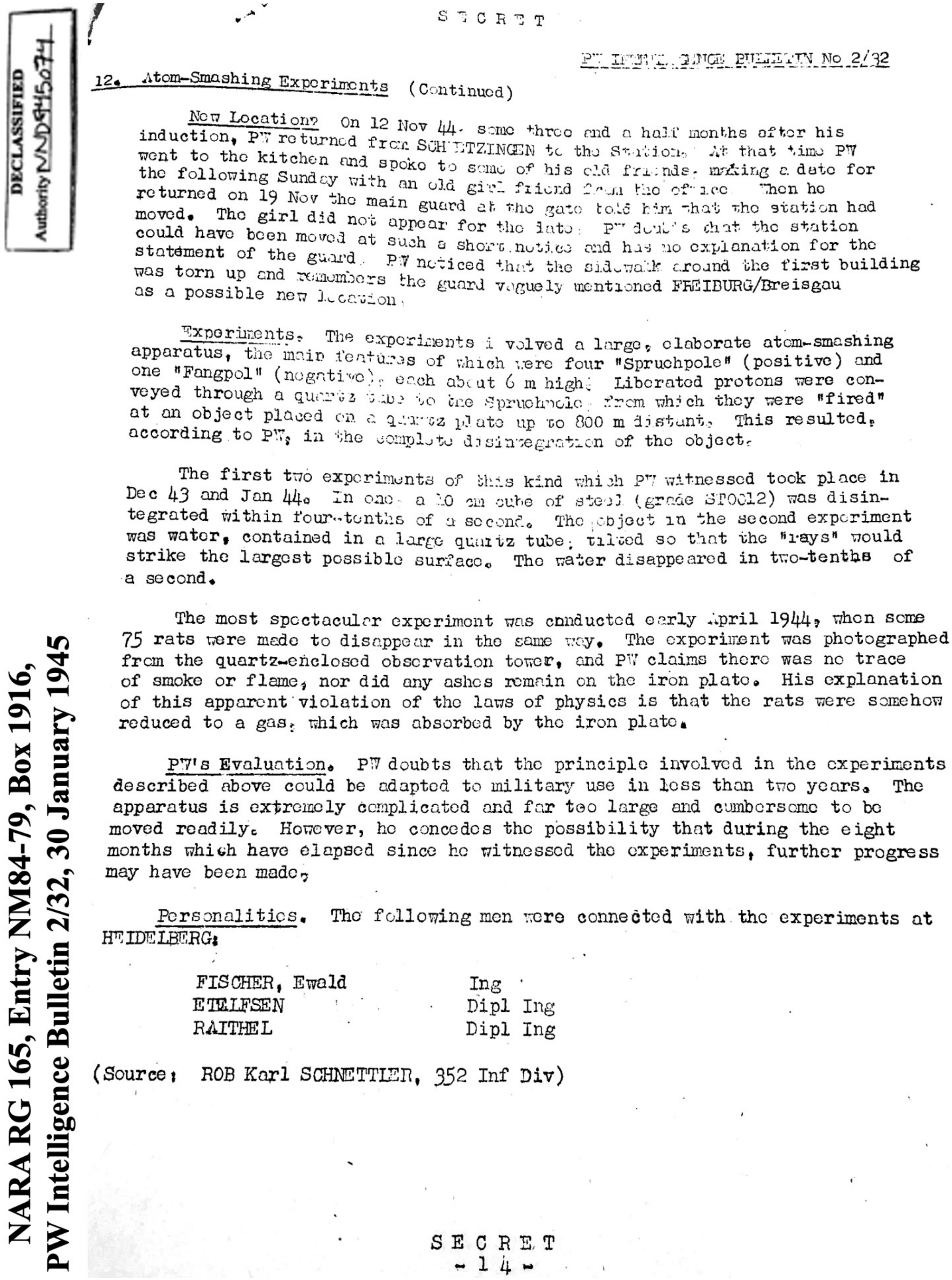
NARA RG 165, Entry NM84-79, Box 1916,
PW Intelligence Bulletin 2/32, 30 January 1945

Figure C.35: PW Intelligence Bulletin 2/32, 30 January 1945. [NARA RG 165, Entry NM84-79, Box 1916].



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PW Intelligence Bulletin 2/32, 30 January 1945

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PW INTELLIGENCE BULLETIN No 2/32

12. Atom-Smashing Experiments (Continued)

New Location? On 12 Nov 44, some three and a half months after his induction, PW returned from SCHWETZINGEN to the Station. At that time PW went to the kitchen and spoke to some of his old friends, making a date for the following Sunday with an old girl friend from the office. When he returned on 19 Nov the main guard at the gate told him that the station had moved. The girl did not appear for the date. PW doubts that the station could have been moved at such a short notice and has no explanation for the statement of the guard. PW noticed that the sidewalk around the first building was torn up and remembers the guard vaguely mentioned FREIBURG/Breisgau as a possible new location.

Experiments. The experiments involved a large, elaborate atom-smashing apparatus, the main features of which were four "Spruchpole" (positive) and one "Fangpol" (negative), each about 6 m high. Liberated protons were conveyed through a quartz tube to the Spruchpole, from which they were "fired" at an object placed on a quartz plate up to 800 m distant. This resulted, according to PW, in the complete disintegration of the object.

The first two experiments of this kind which PW witnessed took place in Dec 43 and Jan 44. In one, a 10 cm cube of steel (grade ST0012) was disintegrated within four-tenths of a second. The object in the second experiment was water, contained in a large quartz tube, tilted so that the "rays" would strike the largest possible surface. The water disappeared in two-tenths of a second.

The most spectacular experiment was conducted early April 1944, when some 75 rats were made to disappear in the same way. The experiment was photographed from the quartz-enclosed observation tower, and PW claims there was no trace of smoke or flame, nor did any ashes remain on the iron plate. His explanation of this apparent violation of the laws of physics is that the rats were somehow reduced to a gas, which was absorbed by the iron plate.

PW's Evaluation. PW doubts that the principle involved in the experiments described above could be adapted to military use in less than two years. The apparatus is extremely complicated and far too large and cumbersome to be moved readily. However, he concedes the possibility that during the eight months which have elapsed since he witnessed the experiments, further progress may have been made.

Personalities. The following men were connected with the experiments at HEIDELBERG:

FISCHER, Ewald	Ing
ETELFSEN	Dipl Ing
RAITHEL	Dipl Ing

(Source: ROB Karl SCHNETTLER, 352 Inf Div)

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Figure C.36: PW Intelligence Bulletin 2/32, 30 January 1945. [NARA RG 165, Entry NM84-79, Box 1916].

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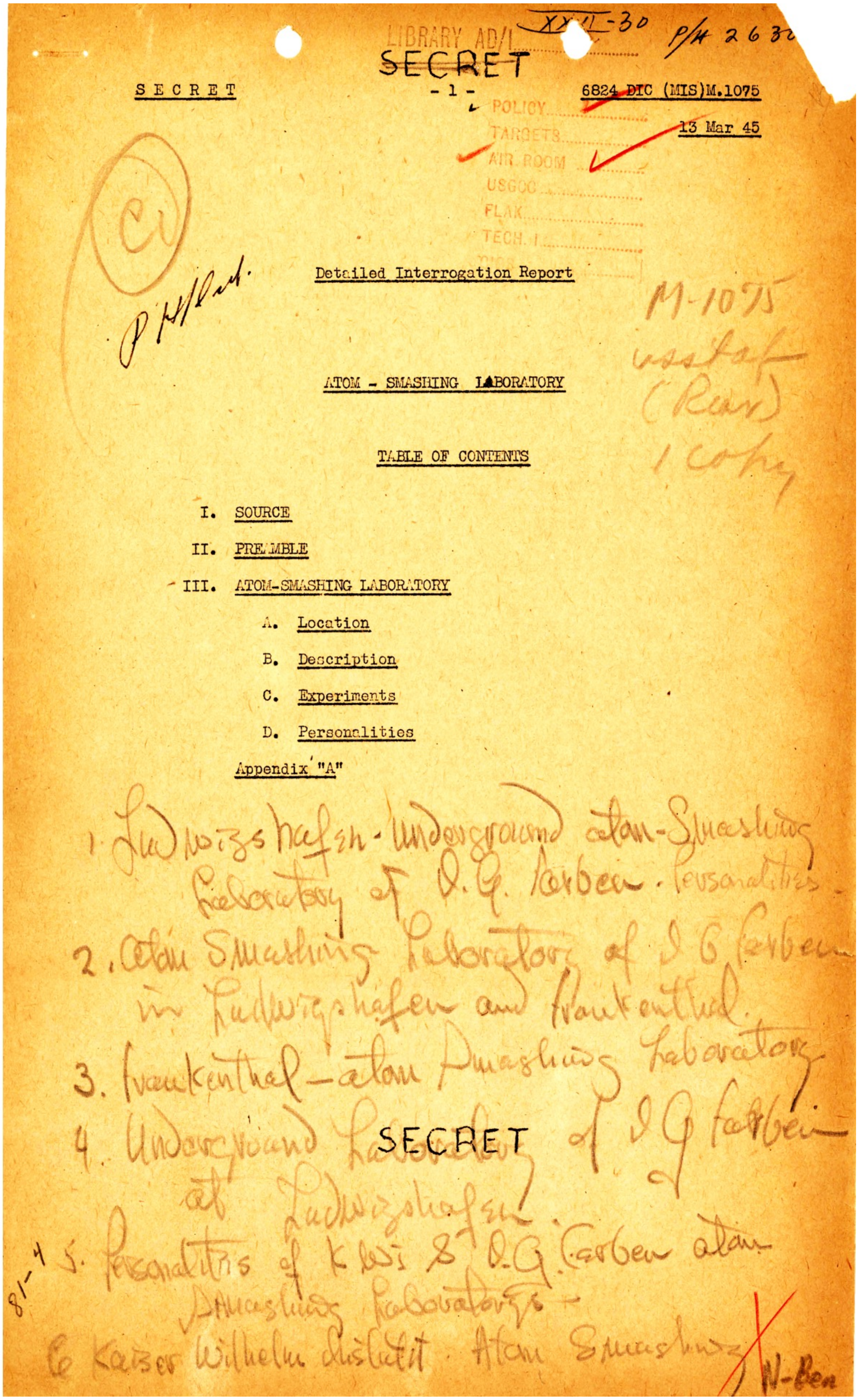

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Detailed Interrogation Report

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ATOM - SMASHING LABORATORY

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6 Kaiser Wilhelm Institut Atom Smashing

81-4

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Figure C.37: Detailed Interrogation Report 6824 DTC (MIS) M. 1075: Atom-Smashing Laboratory. 13 March 1945. [AFHRA folder 519.6501-2 1945; AFHRA A5730, frames 0488–0492]

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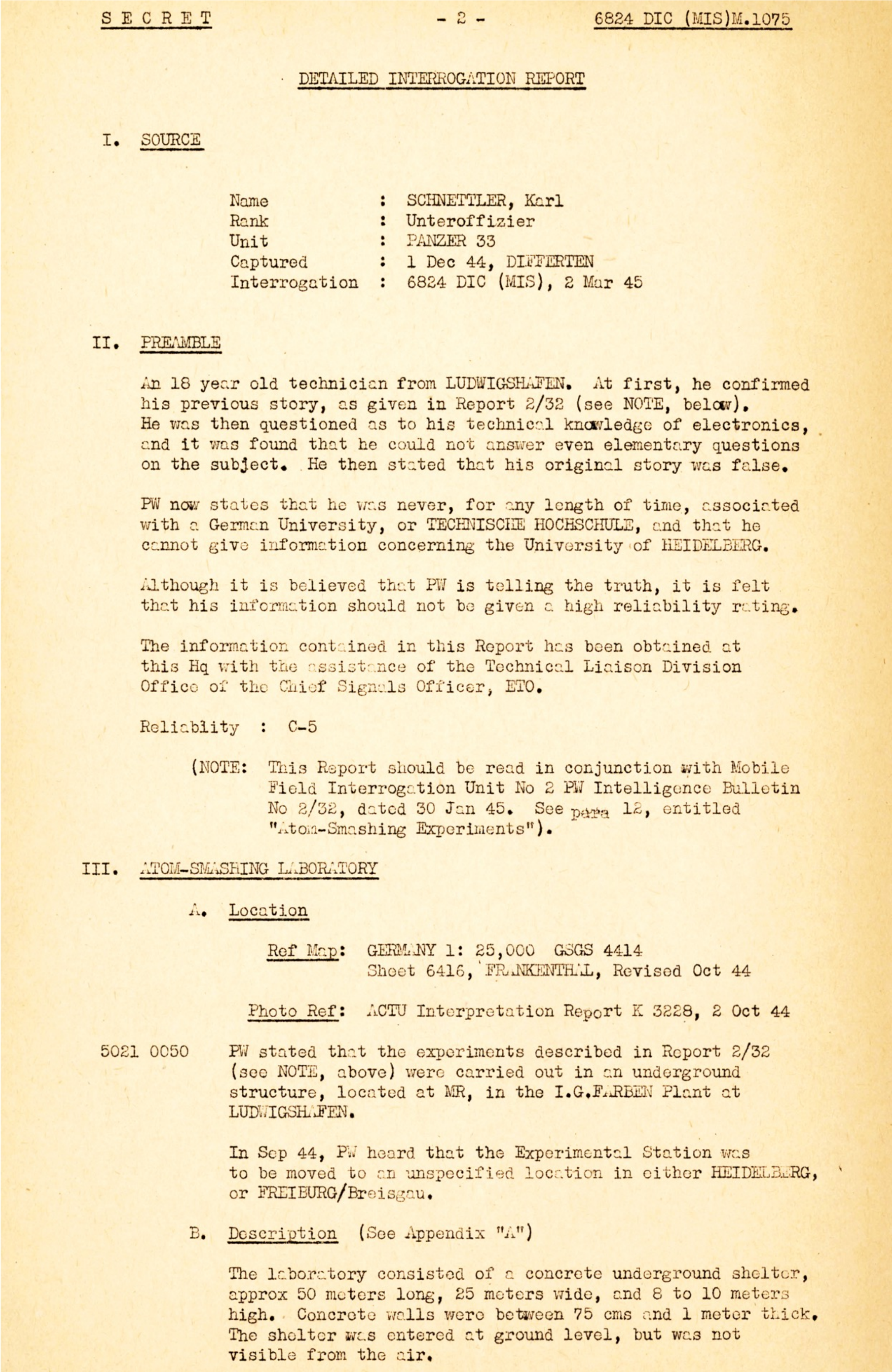
AFHRA folder 519.6501-2 1945



SECRET - 2 - 6824 DIC (MIS)M.1075

DETAILED INTERROGATION REPORT

I. SOURCE

Name : SCHNETTLER, Karl
Rank : Unteroffizier
Unit : PANZER 33
Captured : 1 Dec 44, DIFFERTEN
Interrogation : 6824 DIC (MIS), 2 Mar 45

II. PREAMBLE

An 18 year old technician from LUDWIGSHAFEN. At first, he confirmed his previous story, as given in Report 2/32 (see NOTE, below). He was then questioned as to his technical knowledge of electronics, and it was found that he could not answer even elementary questions on the subject. He then stated that his original story was false.

PW now states that he was never, for any length of time, associated with a German University, or TECHNISCHE HOCHSCHULE, and that he cannot give information concerning the University of HEIDELBERG.

Although it is believed that PW is telling the truth, it is felt that his information should not be given a high reliability rating.

The information contained in this Report has been obtained at this Hq with the assistance of the Technical Liaison Division Office of the Chief Signals Officer, ETO.

Reliability : C-5

(NOTE: This Report should be read in conjunction with Mobile Field Interrogation Unit No 2 PW Intelligence Bulletin No 2/32, dated 30 Jan 45. See para 12, entitled "Atom-Smashing Experiments").

III. ATOM-SMASHING LABORATORY

A. Location

Ref Map: GERMANY 1: 25,000 GSGS 4414
Sheet 6416, FRANKENTHAL, Revised Oct 44

Photo Ref: ACIU Interpretation Report K 3228, 2 Oct 44

5021 0050 PW stated that the experiments described in Report 2/32 (see NOTE, above) were carried out in an underground structure, located at MR, in the I.G.FARBEN Plant at LUDWIGSHAFEN.

In Sep 44, PW heard that the Experimental Station was to be moved to an unspecified location in either HEIDELBERG, or FREIBURG/Breisgau.

B. Description (See Appendix "A")

The laboratory consisted of a concrete underground shelter, approx 50 meters long, 25 meters wide, and 8 to 10 meters high. Concrete walls were between 75 cms and 1 meter thick. The shelter was entered at ground level, but was not visible from the air.

Figure C.38: Detailed Interrogation Report 6824 DTC (MIS) M. 1075: Atom-Smashing Laboratory. 13 March 1945. [AFHRA folder 519.6501-2 1945; AFHRA A5730, frames 0488–0492]

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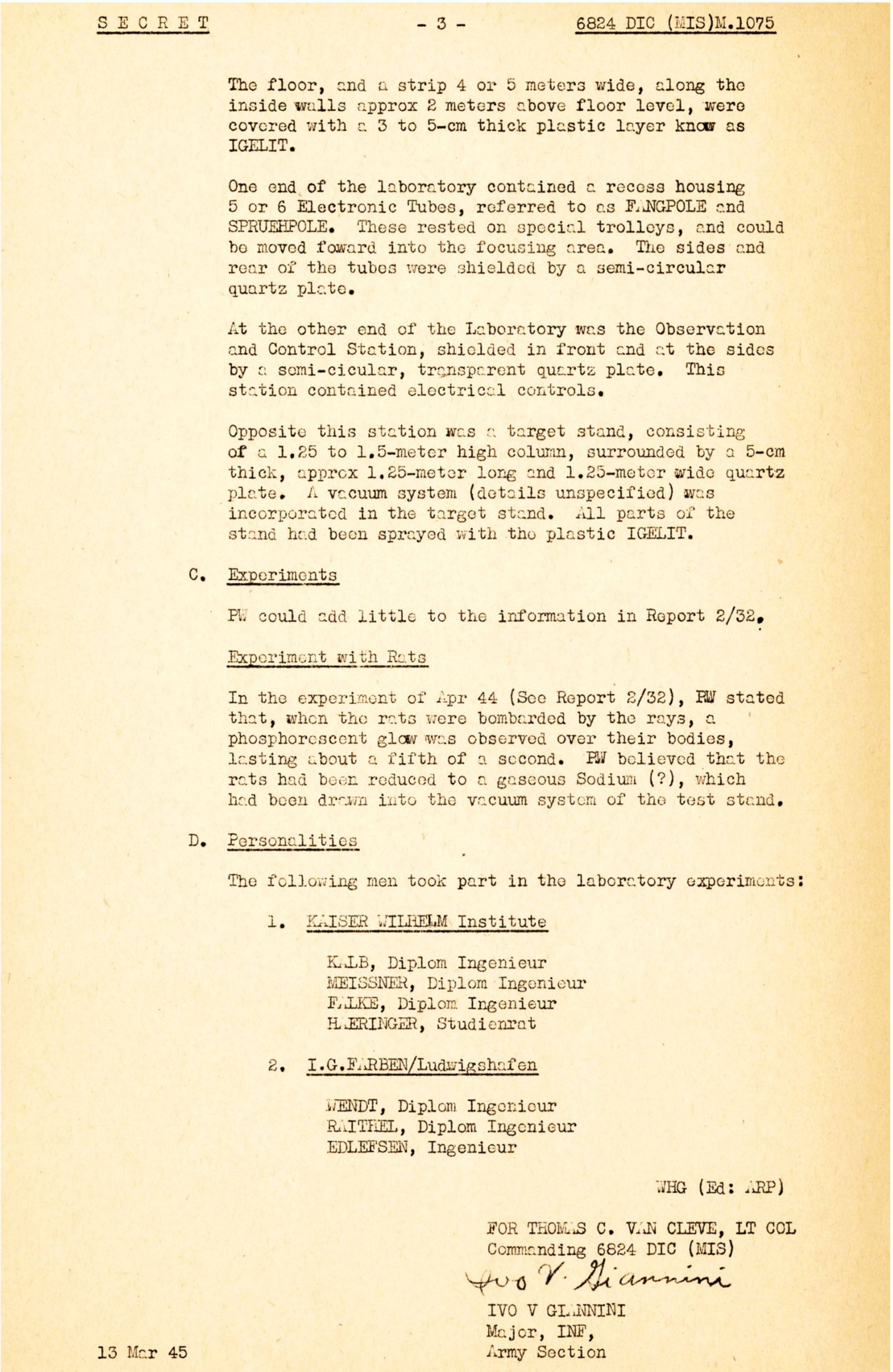

SECRET - 3 - 6824 DIC (MIS)M.1075

The floor, and a strip 4 or 5 meters wide, along the inside walls approx 2 meters above floor level, were covered with a 3 to 5-cm thick plastic layer know as IGELIT.

One end of the laboratory contained a recess housing 5 or 6 Electronic Tubes, referred to as FANGPOLE and SPRUEHPOLE. These rested on special trolleys, and could be moved foward into the focusing area. The sides and rear of the tubes were shielded by a semi-circular quartz plate.

At the other end of the Laboratory was the Observation and Control Station, shielded in front and at the sides by a semi-cicular, transparent quartz plate. This station contained electrical controls.

Opposite this station was a target stand, consisting of a 1.25 to 1.5-meter high column, surrounded by a 5-cm thick, approx 1.25-meter long and 1.25-meter wide quartz plate. A vacuum system (details unspecified) was incorporated in the target stand. All parts of the stand had been sprayed with the plastic IGELIT.

C. Experiments

PW could add little to the information in Report 2/32.

Experiment with Rats

In the experiment of Apr 44 (See Report 2/32), PW stated that, when the rats were bombarded by the rays, a phosphorescent glow was observed over their bodies, lasting about a fifth of a second. PW believed that the rats had been reduced to a gaseous Sodium (?), which had been drawn into the vacuum system of the test stand.

D. Personalities

The following men took part in the laboratory experiments:

1. KAISER WILHELM Institute

   KALB, Diplom Ingenieur
   MEISSNER, Diplom Ingenieur
   FALKE, Diplom Ingenieur
   HAERINGER, Studienrat

2. I.G.FARBEN/Ludwigshafen

   WENDT, Diplom Ingenieur
   RAITHEL, Diplom Ingenieur
   EDLEFSEN, Ingenieur

WHG (Ed: ARP)

FOR THOMAS C. VAN CLEVE, LT COL
Commanding 6824 DIC (MIS)
Ivo V. Giannini
IVO V GIANNINI
Major, INF,
Army Section

13 Mar 45

Figure C.39: Detailed Interrogation Report 6824 DTC (MIS) M. 1075: Atom-Smashing Laboratory. 13 March 1945. [AFHRA folder 519.6501-2 1945; AFHRA A5730, frames 0488–0492]

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AFHRA folder 519.6501-2 1945

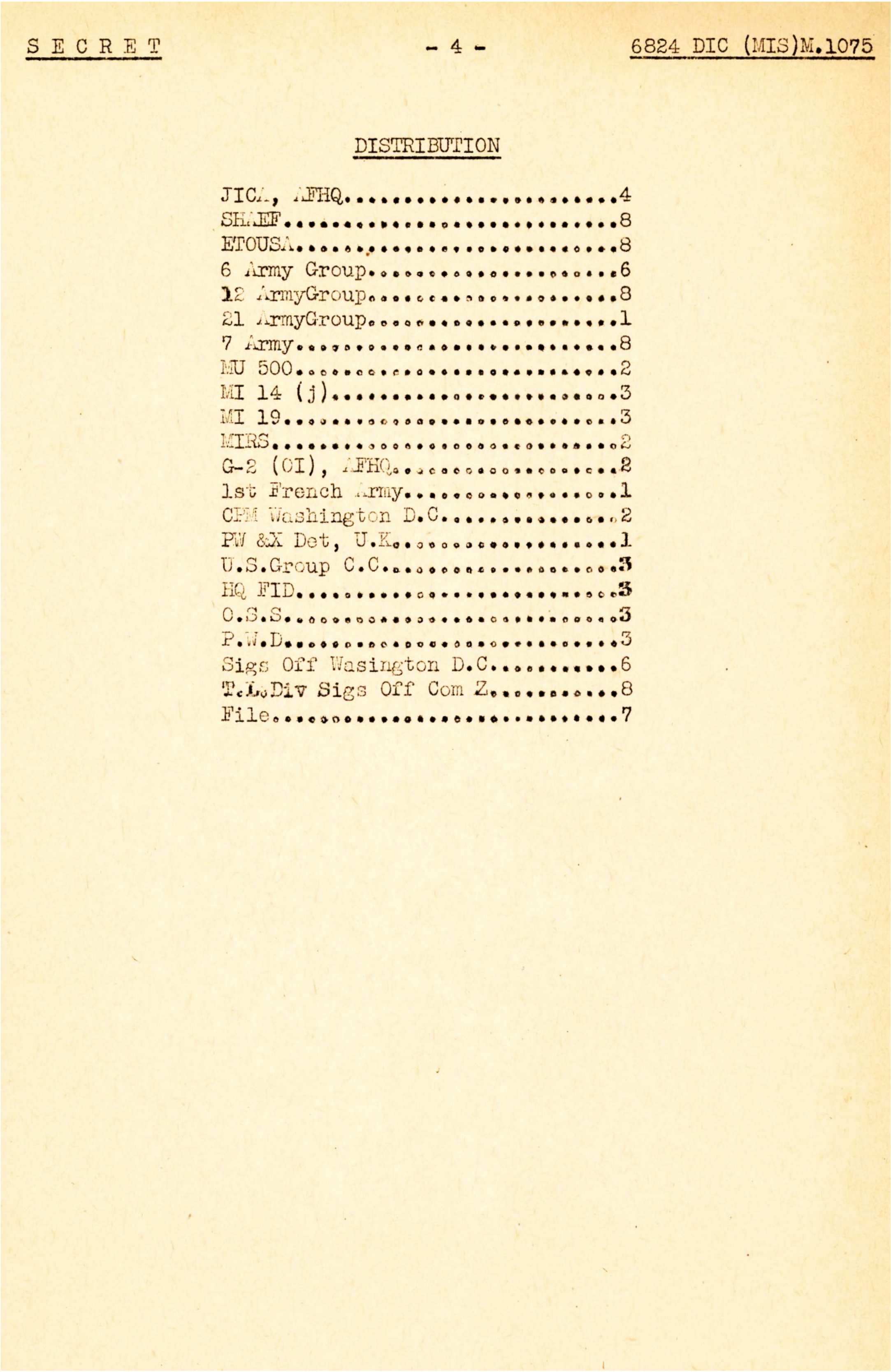

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Figure C.40: Detailed Interrogation Report 6824 DTC (MIS) M. 1075: Atom-Smashing Laboratory. 13 March 1945. [AFHRA folder 519.6501-2 1945; AFHRA A5730, frames 0488–0492]

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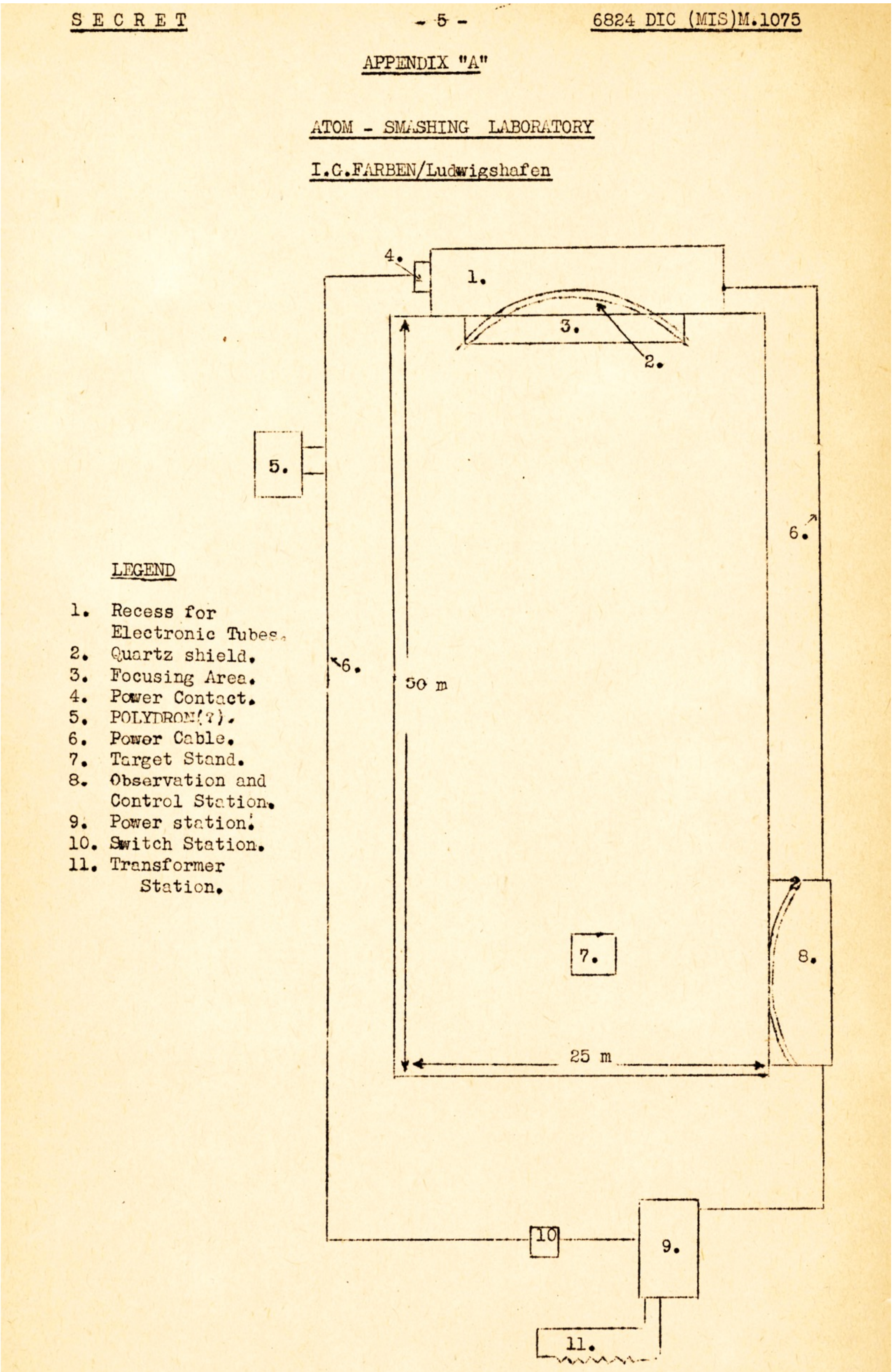

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APPENDIX "A"

ATOM - SMASHING LABORATORY

I.G.FARBEN/Ludwigshafen

LEGEND

1. Recess for Electronic Tubes.
2. Quartz shield.
3. Focusing Area.
4. Power Contact.
5. POLYDRON(?).
6. Power Cable.
7. Target Stand.
8. Observation and Control Station.
9. Power station.
10. Switch Station.
11. Transformer Station.

1.
2.
3.
4.
5.
6.
6.
50 m
25 m
7.
8.
9.
10
11.

Figure C.41: Detailed Interrogation Report 6824 DTC (MIS) M. 1075: Atom-Smashing Laboratory. 13 March 1945. [AFHRA folder 519.6501-2 1945; AFHRA A5730, frames 0488–0492]

PW Intelligence Bulletin 2/32. Atom-Smashing Experiments. 30 January 1945. [NARA RG 165, Entry NM84-79, Box 1916]

The first two experiments of this kind which PW [German prisoner of war] witnessed took place in Dec 43 and Jan 44. In one, a 10 cm cube of steel (grade ST0012) was disintegrated within four-tenths of a second. The object in the second experiment was water, contained in a large quartz tube, tilted so that the “rays” would strike the largest possible surface. The water disappeared in two-tenths of a second.

The most spectacular experiment was conducted early April 1944, when some 75 rats were made to disappear in the same way. The experiment was photographed from the quartz-enclosed observation tower, and PW claims there was no trace of smoke or flame, nor did any ashes remain on the iron plate. His explanation of this apparent violation of the laws of physics is that the rats were somehow reduced to a gas, which was absorbed by the iron plate.

[See document photos on pp. 3060–3061.]

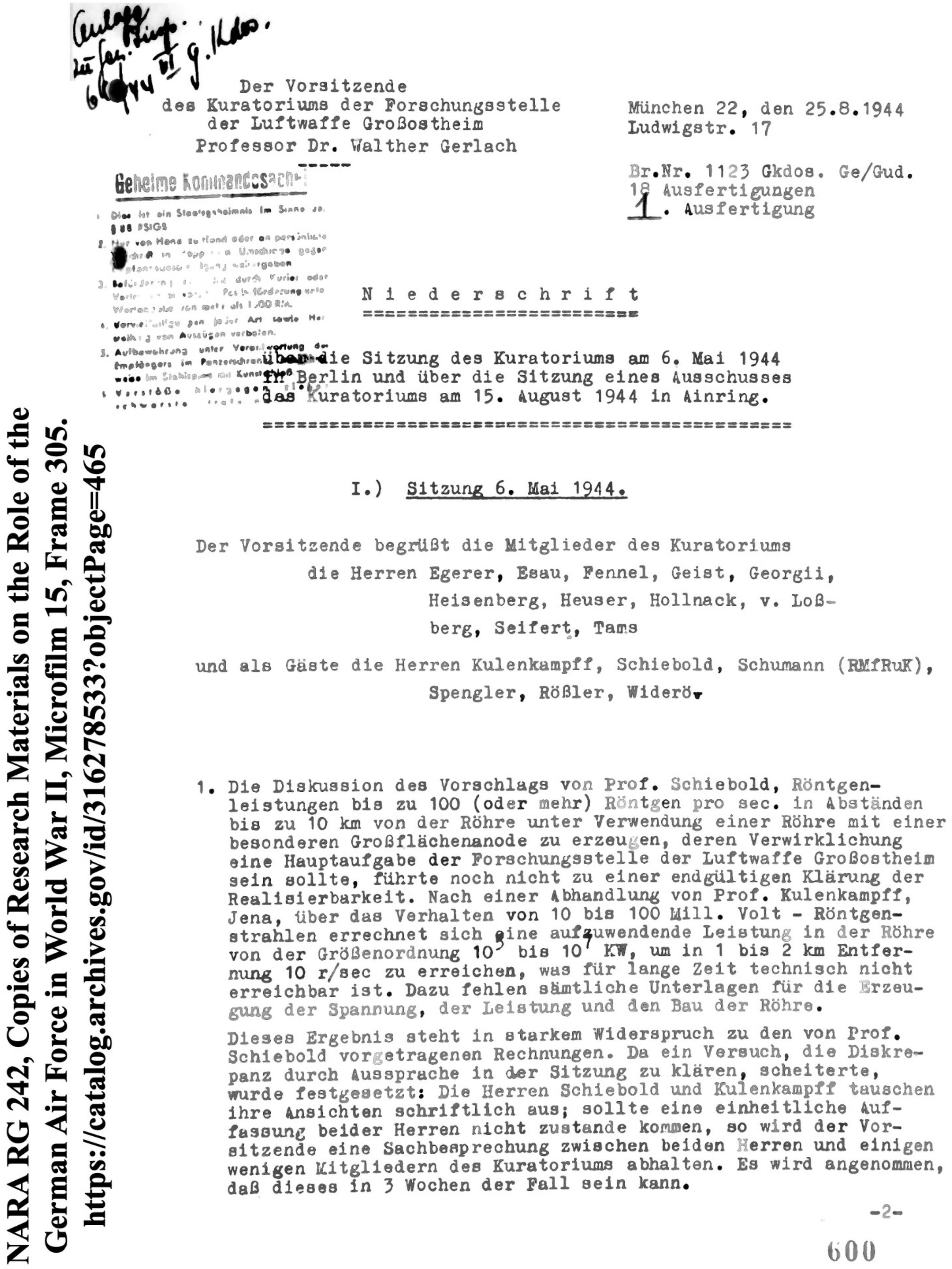
Detailed Interrogation Report 6824 DTC (MIS) M. 1075: Atom-Smashing Laboratory. 13 March 1945. [AFHRA folder 519.6501-2 1945; AFHRA A5730, frames 0488–0492]

In the experiment of Apr 44 (See Report 2/32), PW stated that, when the rats were bombarded by the rays, a phosphorescent glow was observed over their bodies, lasting about a fifth of a second. PW believed that the rats had been reduced to a gaseous [form], which had been driven into the vacuum system of the test stand.

[See document photos on pp. 3062–3066.]

[This seems to be a later report of the testing of intense particle beams as potential weapons, describing experiments from December 1943 through April 44. If the description of the effects was accurate, the results were quite impressive, and the technology had clearly advanced a great deal since the 1937–1939 experiments described in the previous reports. Even so, such a particle beam weapon would have required a huge power source, which would have made it impractical for most military applications during the war, and may explain why it was never deployed.

Judging from several reports discovered in Walther Gerlach’s files by the U.S. Alsos Mission, in 1944 there were a number of very active projects aimed at developing and testing weapons based on particle accelerators that produced high-energy beams of electrons, ions, and/or X-rays [NARA RG 319 Entry NM3-82A, Box 6, Folder ALSOS G-20]. Gerlach was closely tied to the physics community, the Reich Research Council, and the SS, and he appears to have been appointed the chief scientific official responsible for funding and evaluating all or at least many of the particle beam weapon projects. Please see the following pages for a few examples from these reports.]



Anlage zu [illegible] 6.9.44 [illegible] g. Kdos.

Der Vorsitzende
des Kuratoriums der Forschungsstelle
der Luftwaffe Großostheim
Professor Dr. Walther Gerlach

München 22, den 25.8.1944
Ludwigstr. 17

Br.Nr. 1123 Gkdos. Ge/Gud.
18 Ausfertigungen
1. Ausfertigung

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4. Vervielfältigung jeder Art sowie Herstellung von Auszügen verboten.
5. Aufbewahrung unter Verantwortung des Empfängers im Panzerschrank [illegible] im Stahlschrank mit Kunstschloß
6. Verstöße hiergegen [illegible] schwerste [illegible]

Niederschrift

über die Sitzung des Kuratoriums am 6. Mai 1944 in Berlin und über die Sitzung eines Ausschusses des Kuratoriums am 15. August 1944 in Ainring.

I.) Sitzung 6. Mai 1944.

Der Vorsitzende begrüßt die Mitglieder des Kuratoriums die Herren Egerer, Esau, Fennel, Geist, Georgii, Heisenberg, Heuser, Hollnack, v. Loßberg, Seifert, Tams

und als Gäste die Herren Kulenkampff, Schiebold, Schumann (RMfRuK), Spengler, Rößler, Widerö.

1. Die Diskussion des Vorschlags von Prof. Schiebold, Röntgenleistungen bis zu 100 (oder mehr) Röntgen pro sec. in Abständen bis zu 10 km von der Röhre unter Verwendung einer Röhre mit einer besonderen Großflächenanode zu erzeugen, deren Verwirklichung eine Hauptaufgabe der Forschungsstelle der Luftwaffe Großostheim sein sollte, führte noch nicht zu einer endgültigen Klärung der Realisierbarkeit. Nach einer Abhandlung von Prof. Kulenkampff, Jena, über das Verhalten von 10 bis 100 Mill. Volt - Röntgenstrahlen errechnet sich eine aufzuwendende Leistung in der Röhre von der Größenordnung 10^5 bis 10^7 KW, um in 1 bis 2 km Entfernung 10 r/sec zu erreichen, was für lange Zeit technisch nicht erreichbar ist. Dazu fehlen sämtliche Unterlagen für die Erzeugung der Spannung, der Leistung und den Bau der Röhre.

   Dieses Ergebnis steht in starkem Widerspruch zu den von Prof. Schiebold vorgetragenen Rechnungen. Da ein Versuch, die Diskrepanz durch Aussprache in der Sitzung zu klären, scheiterte, wurde festgesetzt: Die Herren Schiebold und Kulenkampff tauschen ihre Ansichten schriftlich aus; sollte eine einheitliche Auffassung beider Herren nicht zustande kommen, so wird der Vorsitzende eine Sachbesprechung zwischen beiden Herren und einigen wenigen Mitgliedern des Kuratoriums abhalten. Es wird angenommen, daß dieses in 3 Wochen der Fall sein kann.

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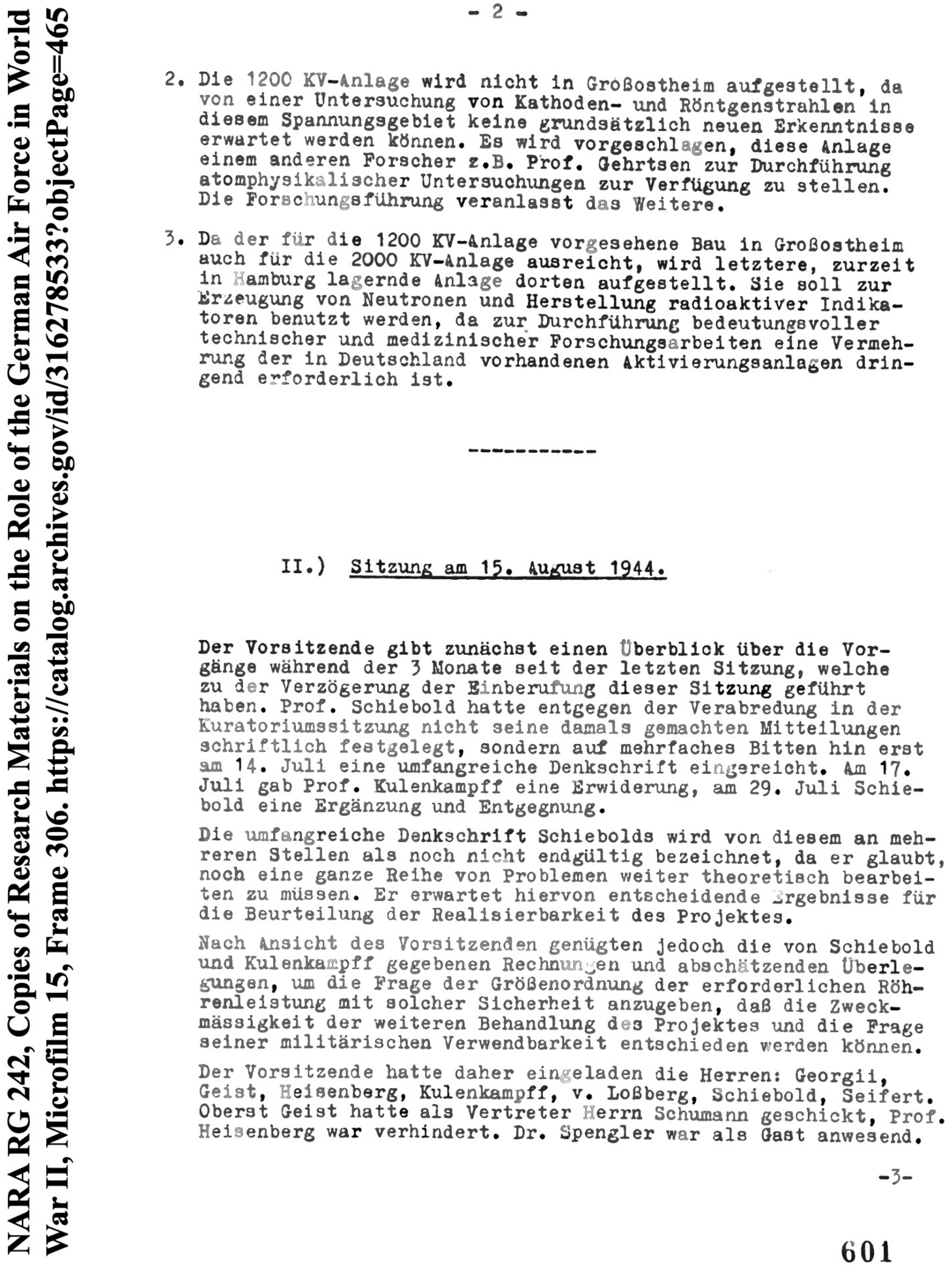
NARA RG 242, Copies of Research Materials on the Role of the German Air Force in World War II, Microfilm 15, Frame 305. https://catalog.archives.gov/id/316278533?objectPage=465

Figure C.42: Notes from 1944 meetings of Walther Gerlach with Ernst Schiebold, Helmuth Kulenkampff, Rolf Wideröe, Gerhard Schumann, and others involved in the development of particle beam weapons. [NARA RG 242, Copies of Research Materials on the Role of the German Air Force in World War II, Microfilm 15, Frames 305–310. https://catalog.archives.gov/id/316278533?objectPage=465]



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2. Die 1200 KV-Anlage wird nicht in Großostheim aufgestellt, da von einer Untersuchung von Kathoden- und Röntgenstrahlen in diesem Spannungsgebiet keine grundsätzlich neuen Erkenntnisse erwartet werden können. Es wird vorgeschlagen, diese Anlage einem anderen Forscher z.B. Prof. Gehrtsen zur Durchführung atomphysikalischer Untersuchungen zur Verfügung zu stellen. Die Forschungsführung veranlasst das Weitere.

3. Da der für die 1200 KV-Anlage vorgesehene Bau in Großostheim auch für die 2000 KV-Anlage ausreicht, wird letztere, zurzeit in Hamburg lagernde Anlage dorten aufgestellt. Sie soll zur Erzeugung von Neutronen und Herstellung radioaktiver Indikatoren benutzt werden, da zur Durchführung bedeutungsvoller technischer und medizinischer Forschungsarbeiten eine Vermehrung der in Deutschland vorhandenen Aktivierungsanlagen dringend erforderlich ist.

II.) Sitzung am 15. August 1944.

Der Vorsitzende gibt zunächst einen Überblick über die Vorgänge während der 3 Monate seit der letzten Sitzung, welche zu der Verzögerung der Einberufung dieser Sitzung geführt haben. Prof. Schiebold hatte entgegen der Verabredung in der Kuratoriumssitzung nicht seine damals gemachten Mitteilungen schriftlich festgelegt, sondern auf mehrfaches Bitten hin erst am 14. Juli eine umfangreiche Denkschrift eingereicht. Am 17. Juli gab Prof. Kulenkampff eine Erwiderung, am 29. Juli Schiebold eine Ergänzung und Entgegnung.

Die umfangreiche Denkschrift Schiebolds wird von diesem an mehreren Stellen als noch nicht endgültig bezeichnet, da er glaubt, noch eine ganze Reihe von Problemen weiter theoretisch bearbeiten zu müssen. Er erwartet hiervon entscheidende Ergebnisse für die Beurteilung der Realisierbarkeit des Projektes.

Nach Ansicht des Vorsitzenden genügten jedoch die von Schiebold und Kulenkampff gegebenen Rechnungen und abschätzenden Überlegungen, um die Frage der Größenordnung der erforderlichen Röhrenleistung mit solcher Sicherheit anzugeben, daß die Zweckmässigkeit der weiteren Behandlung des Projektes und die Frage seiner militärischen Verwendbarkeit entschieden werden können.

Der Vorsitzende hatte daher eingeladen die Herren: Georgii, Geist, Heisenberg, Kulenkampff, v. Loßberg, Schiebold, Seifert. Oberst Geist hatte als Vertreter Herrn Schumann geschickt, Prof. Heisenberg war verhindert. Dr. Spengler war als Gast anwesend.

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Figure C.43: Notes from 1944 meetings of Walther Gerlach with Ernst Schiebold, Helmuth Kulenkampff, Rolf Wideröe, Gerhard Schumann, and others involved in the development of particle beam weapons. [NARA RG 242, Copies of Research Materials on the Role of the German Air Force in World War II, Microfilm 15, Frames 305–310. https://catalog.archives.gov/id/316278533?objectPage=465]

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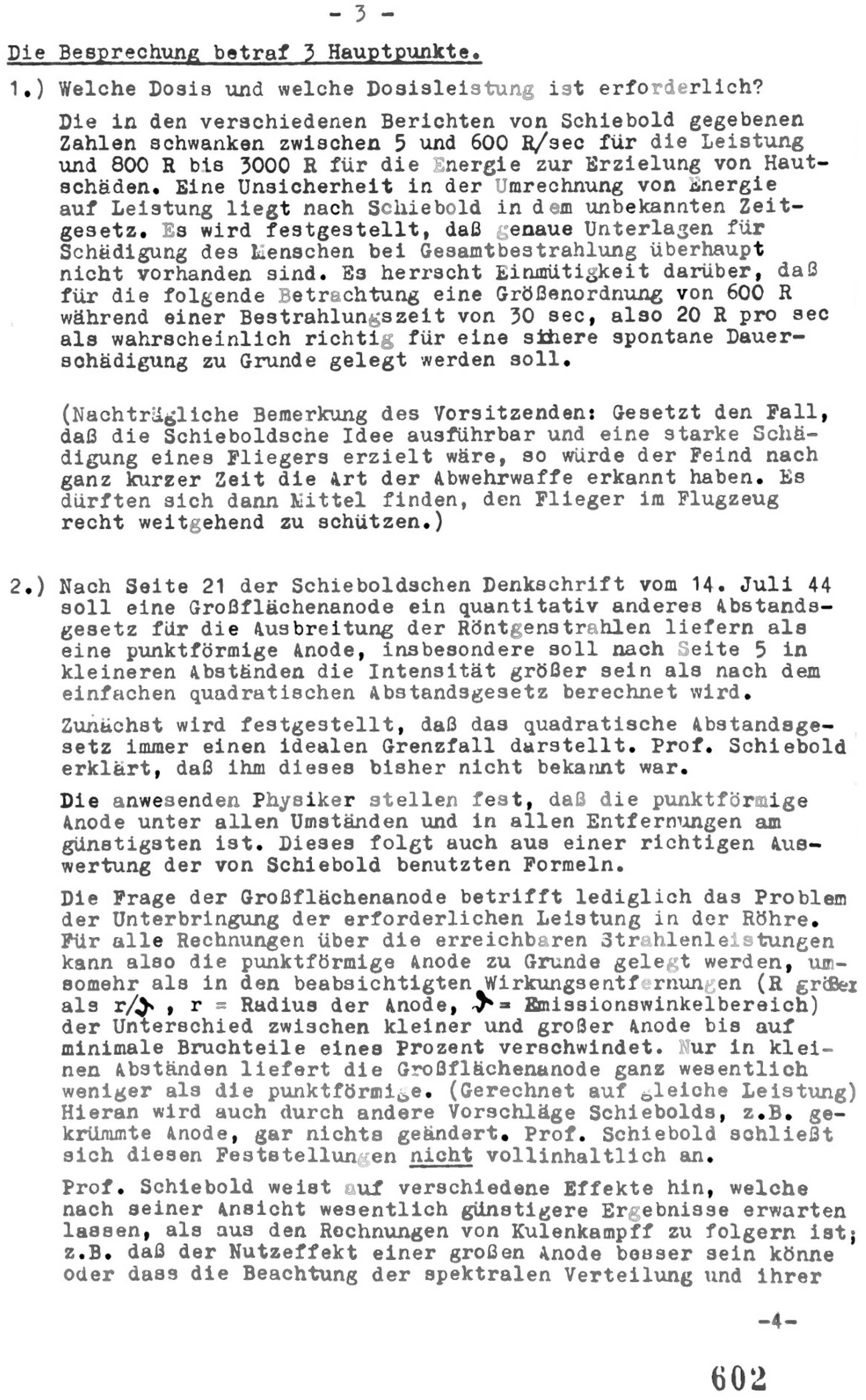

- 3 -

Die Besprechung betraf 3 Hauptpunkte.

1.) Welche Dosis und welche Dosisleistung ist erforderlich?

Die in den verschiedenen Berichten von Schiebold gegebenen Zahlen schwanken zwischen 5 und 600 R/sec für die Leistung und 800 R bis 3000 R für die Energie zur Erzielung von Hautschäden. Eine Unsicherheit in der Umrechnung von Energie auf Leistung liegt nach Schiebold in dem unbekannten Zeitgesetz. Es wird festgestellt, daß genaue Unterlagen für Schädigung des Menschen bei Gesamtbestrahlung überhaupt nicht vorhanden sind. Es herrscht Einmütigkeit darüber, daß für die folgende Betrachtung eine Größenordnung von 600 R während einer Bestrahlungszeit von 30 sec, also 20 R pro sec als wahrscheinlich richtig für eine sichere spontane Dauerschädigung zu Grunde gelegt werden soll.

(Nachträgliche Bemerkung des Vorsitzenden: Gesetzt den Fall, daß die Schieboldsche Idee ausführbar und eine starke Schädigung eines Fliegers erzielt wäre, so würde der Feind nach ganz kurzer Zeit die Art der Abwehrwaffe erkannt haben. Es dürften sich dann Mittel finden, den Flieger im Flugzeug recht weitgehend zu schützen.)

2.) Nach Seite 21 der Schieboldschen Denkschrift vom 14. Juli 44 soll eine Großflächenanode ein quantitativ anderes Abstandsgesetz für die Ausbreitung der Röntgenstrahlen liefern als eine punktförmige Anode, insbesondere soll nach Seite 5 in kleineren Abständen die Intensität größer sein als nach dem einfachen quadratischen Abstandsgesetz berechnet wird.

Zunächst wird festgestellt, daß das quadratische Abstandsgesetz immer einen idealen Grenzfall darstellt. Prof. Schiebold erklärt, daß ihm dieses bisher nicht bekannt war.

Die anwesenden Physiker stellen fest, daß die punktförmige Anode unter allen Umständen und in allen Entfernungen am günstigsten ist. Dieses folgt auch aus einer richtigen Auswertung der von Schiebold benutzten Formeln.

Die Frage der Großflächenanode betrifft lediglich das Problem der Unterbringung der erforderlichen Leistung in der Röhre. Für alle Rechnungen über die erreichbaren Strahlenleistungen kann also die punktförmige Anode zu Grunde gelegt werden, umsomehr als in den beabsichtigten Wirkungsentfernungen (R größer als r/ϑ, r = Radius der Anode, ϑ = Emissionswinkelbereich) der Unterschied zwischen kleiner und großer Anode bis auf minimale Bruchteile eines Prozent verschwindet. Nur in kleinen Abständen liefert die Großflächenanode ganz wesentlich weniger als die punktförmige. (Gerechnet auf gleiche Leistung) Hieran wird auch durch andere Vorschläge Schiebolds, z.B. gekrümmte Anode, gar nichts geändert. Prof. Schiebold schließt sich diesen Feststellungen nicht vollinhaltlich an.

Prof. Schiebold weist auf verschiedene Effekte hin, welche nach seiner Ansicht wesentlich günstigere Ergebnisse erwarten lassen, als aus den Rechnungen von Kulenkampff zu folgern ist; z.B. daß der Nutzeffekt einer großen Anode besser sein könne oder dass die Beachtung der spektralen Verteilung und ihrer

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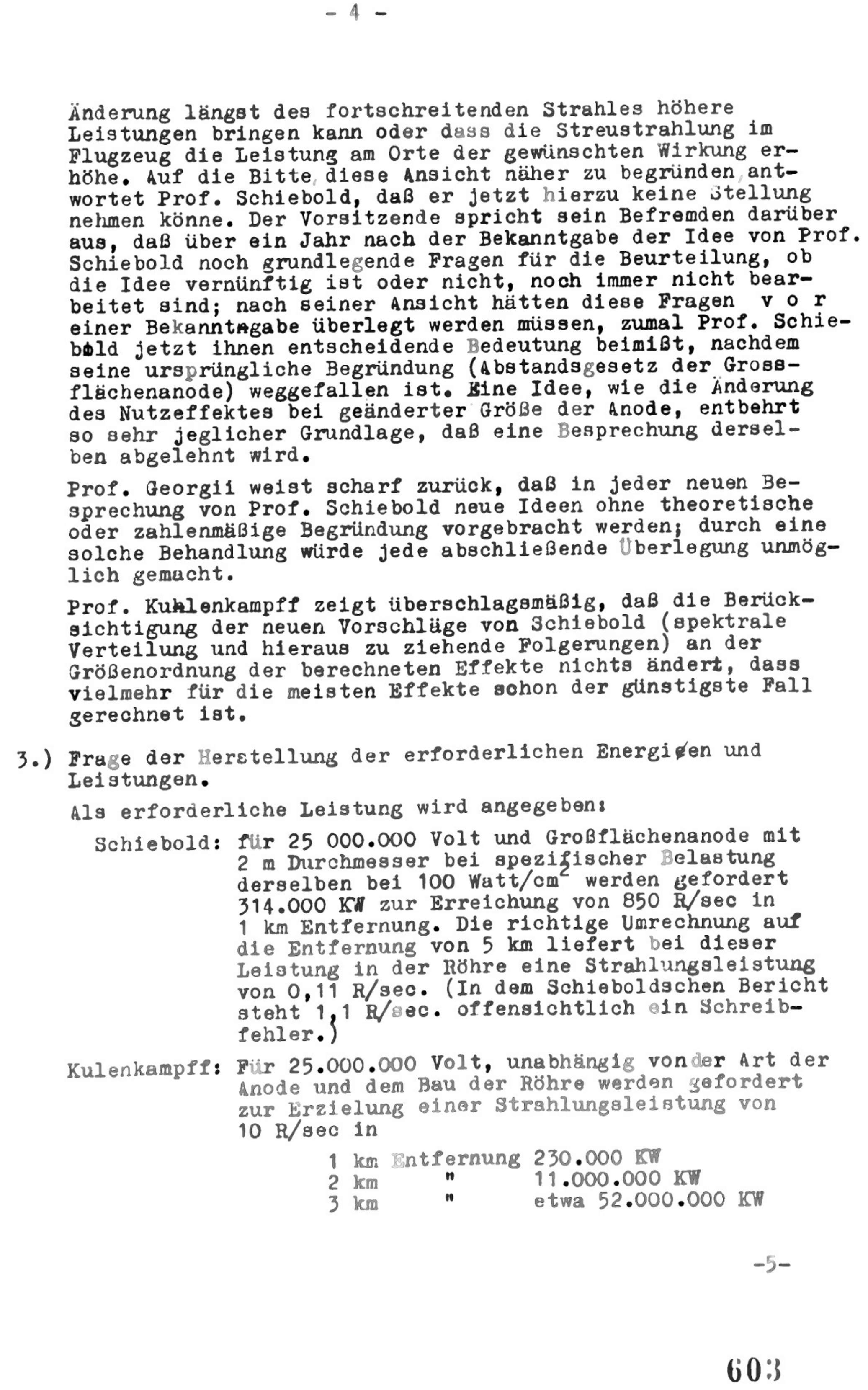
Figure C.44: Notes from 1944 meetings of Walther Gerlach with Ernst Schiebold, Helmuth Kulenkampff, Rolf Wideröe, Gerhard Schumann, and others involved in the development of particle beam weapons. [NARA RG 242, Copies of Research Materials on the Role of the German Air Force in World War II, Microfilm 15, Frames 305–310. https://catalog.archives.gov/id/316278533?objectPage=465]



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Änderung längst des fortschreitenden Strahles höhere Leistungen bringen kann oder dass die Streustrahlung im Flugzeug die Leistung am Orte der gewünschten Wirkung erhöhe. Auf die Bitte, diese Ansicht näher zu begründen, antwortet Prof. Schiebold, daß er jetzt hierzu keine Stellung nehmen könne. Der Vorsitzende spricht sein Befremden darüber aus, daß über ein Jahr nach der Bekanntgabe der Idee von Prof. Schiebold noch grundlegende Fragen für die Beurteilung, ob die Idee vernünftig ist oder nicht, noch immer nicht bearbeitet sind; nach seiner Ansicht hätten diese Fragen vor einer Bekanntgabe überlegt werden müssen, zumal Prof. Schiebold jetzt ihnen entscheidende Bedeutung beimißt, nachdem seine ursprüngliche Begründung (Abstandsgesetz der Grossflächenanode) weggefallen ist. Eine Idee, wie die Änderung des Nutzeffektes bei geänderter Größe der Anode, entbehrt so sehr jeglicher Grundlage, daß eine Besprechung derselben abgelehnt wird.

Prof. Georgii weist scharf zurück, daß in jeder neuen Besprechung von Prof. Schiebold neue Ideen ohne theoretische oder zahlenmäßige Begründung vorgebracht werden; durch eine solche Behandlung würde jede abschließende Überlegung unmöglich gemacht.

Prof. Kuhlenkampff zeigt überschlagsmäßig, daß die Berücksichtigung der neuen Vorschläge von Schiebold (spektrale Verteilung und hieraus zu ziehende Folgerungen) an der Größenordnung der berechneten Effekte nichts ändert, dass vielmehr für die meisten Effekte schon der günstigste Fall gerechnet ist.

3.) Frage der Herstellung der erforderlichen Energi~~e~~en und Leistungen.

Als erforderliche Leistung wird angegeben:

Schiebold: für 25 000.000 Volt und Großflächenanode mit 2 m Durchmesser bei spezifischer Belastung derselben bei 100 Watt/cm^2 werden gefordert 314.000 KW zur Erreichung von 850 R/sec in 1 km Entfernung. Die richtige Umrechnung auf die Entfernung von 5 km liefert bei dieser Leistung in der Röhre eine Strahlungsleistung von 0,11 R/sec. (In dem Schieboldschen Bericht steht 1,1 R/sec. offensichtlich ein Schreibfehler.)

Kulenkampff: Für 25.000.000 Volt, unabhängig von der Art der Anode und dem Bau der Röhre werden gefordert zur Erzielung einer Strahlungsleistung von 10 R/sec in

1 km	Entfernung	230.000 KW
2 km	"	11.000.000 KW
3 km	"	etwa 52.000.000 KW

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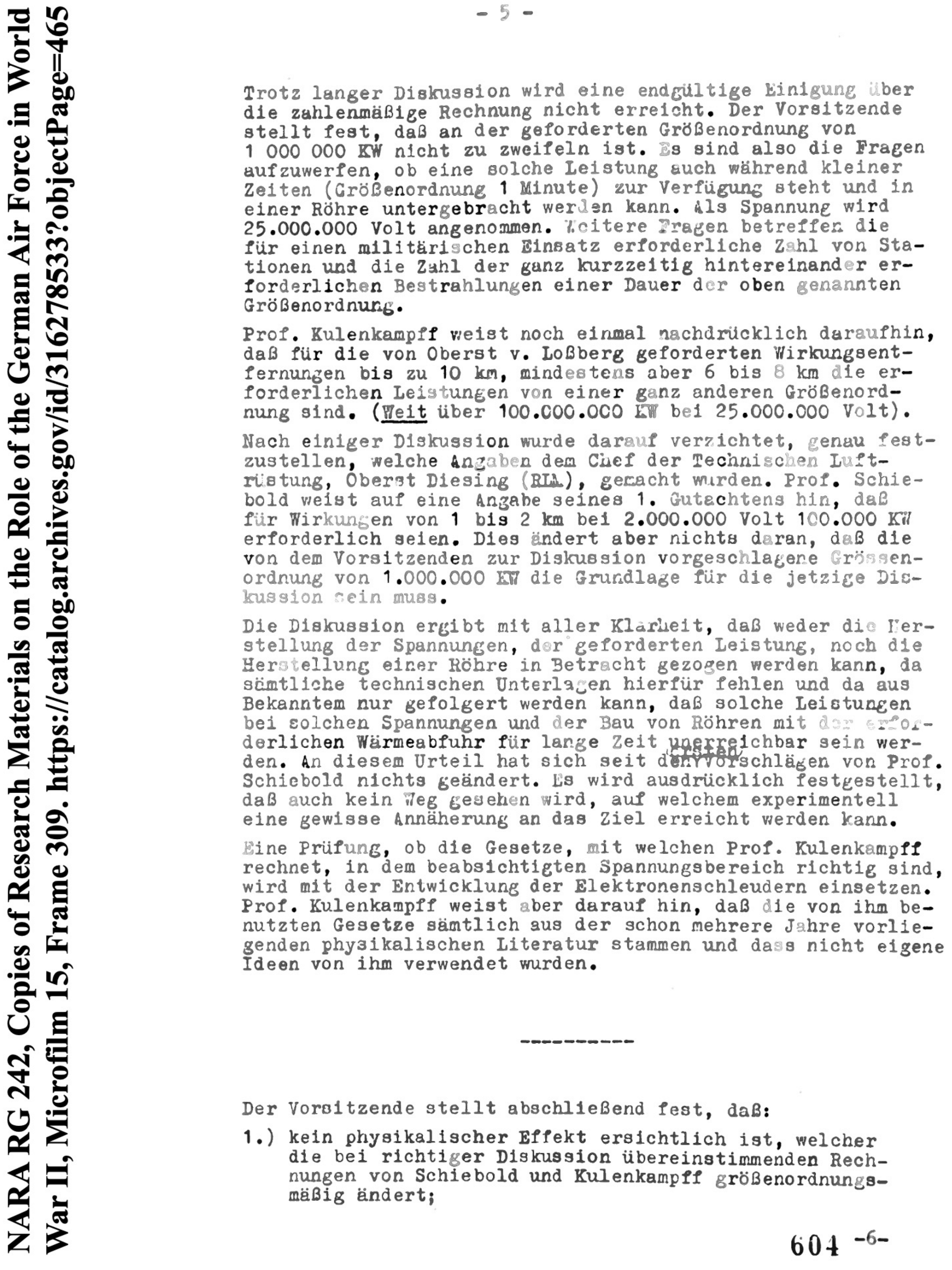
Figure C.45: Notes from 1944 meetings of Walther Gerlach with Ernst Schiebold, Helmuth Kulenkampff, Rolf Wideröe, Gerhard Schumann, and others involved in the development of particle beam weapons. [NARA RG 242, Copies of Research Materials on the Role of the German Air Force in World War II, Microfilm 15, Frames 305–310. https://catalog.archives.gov/id/316278533?objectPage=465]



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Trotz langer Diskussion wird eine endgültige Einigung über die zahlenmäßige Rechnung nicht erreicht. Der Vorsitzende stellt fest, daß an der geforderten Größenordnung von 1 000 000 KW nicht zu zweifeln ist. Es sind also die Fragen aufzuwerfen, ob eine solche Leistung auch während kleiner Zeiten (Größenordnung 1 Minute) zur Verfügung steht und in einer Röhre untergebracht werden kann. Als Spannung wird 25.000.000 Volt angenommen. Weitere Fragen betreffen die für einen militärischen Einsatz erforderliche Zahl von Stationen und die Zahl der ganz kurzzeitig hintereinander erforderlichen Bestrahlungen einer Dauer der oben genannten Größenordnung.

Prof. Kulenkampff weist noch einmal nachdrücklich daraufhin, daß für die von Oberst v. Loßberg geforderten Wirkungsentfernungen bis zu 10 km, mindestens aber 6 bis 8 km die erforderlichen Leistungen von einer ganz anderen Größenordnung sind. (Weit über 100.000.000 KW bei 25.000.000 Volt).

Nach einiger Diskussion wurde darauf verzichtet, genau festzustellen, welche Angaben dem Chef der Technischen Luftrüstung, Oberst Diesing (RLM), gemacht wurden. Prof. Schiebold weist auf eine Angabe seines 1. Gutachtens hin, daß für Wirkungen von 1 bis 2 km bei 2.000.000 Volt 100.000 KW erforderlich seien. Dies ändert aber nichts daran, daß die von dem Vorsitzenden zur Diskussion vorgeschlagene Grössenordnung von 1.000.000 KW die Grundlage für die jetzige Diskussion sein muss.

Die Diskussion ergibt mit aller Klarheit, daß weder die Herstellung der Spannungen, der geforderten Leistung, noch die Herstellung einer Röhre in Betracht gezogen werden kann, da sämtliche technischen Unterlagen hierfür fehlen und da aus Bekanntem nur gefolgert werden kann, daß solche Leistungen bei solchen Spannungen und der Bau von Röhren mit der erforderlichen Wärmeabfuhr für lange Zeit unerreichbar sein werden. An diesem Urteil hat sich seit den ersten Vorschlägen von Prof. Schiebold nichts geändert. Es wird ausdrücklich festgestellt, daß auch kein Weg gesehen wird, auf welchem experimentell eine gewisse Annäherung an das Ziel erreicht werden kann.

Eine Prüfung, ob die Gesetze, mit welchen Prof. Kulenkampff rechnet, in dem beabsichtigten Spannungsbereich richtig sind, wird mit der Entwicklung der Elektronenschleudern einsetzen. Prof. Kulenkampff weist aber darauf hin, daß die von ihm benutzten Gesetze sämtlich aus der schon mehrere Jahre vorliegenden physikalischen Literatur stammen und dass nicht eigene Ideen von ihm verwendet wurden.

Der Vorsitzende stellt abschließend fest, daß:

1.) kein physikalischer Effekt ersichtlich ist, welcher die bei richtiger Diskussion übereinstimmenden Rechnungen von Schiebold und Kulenkampff größenordnungsmäßig ändert;

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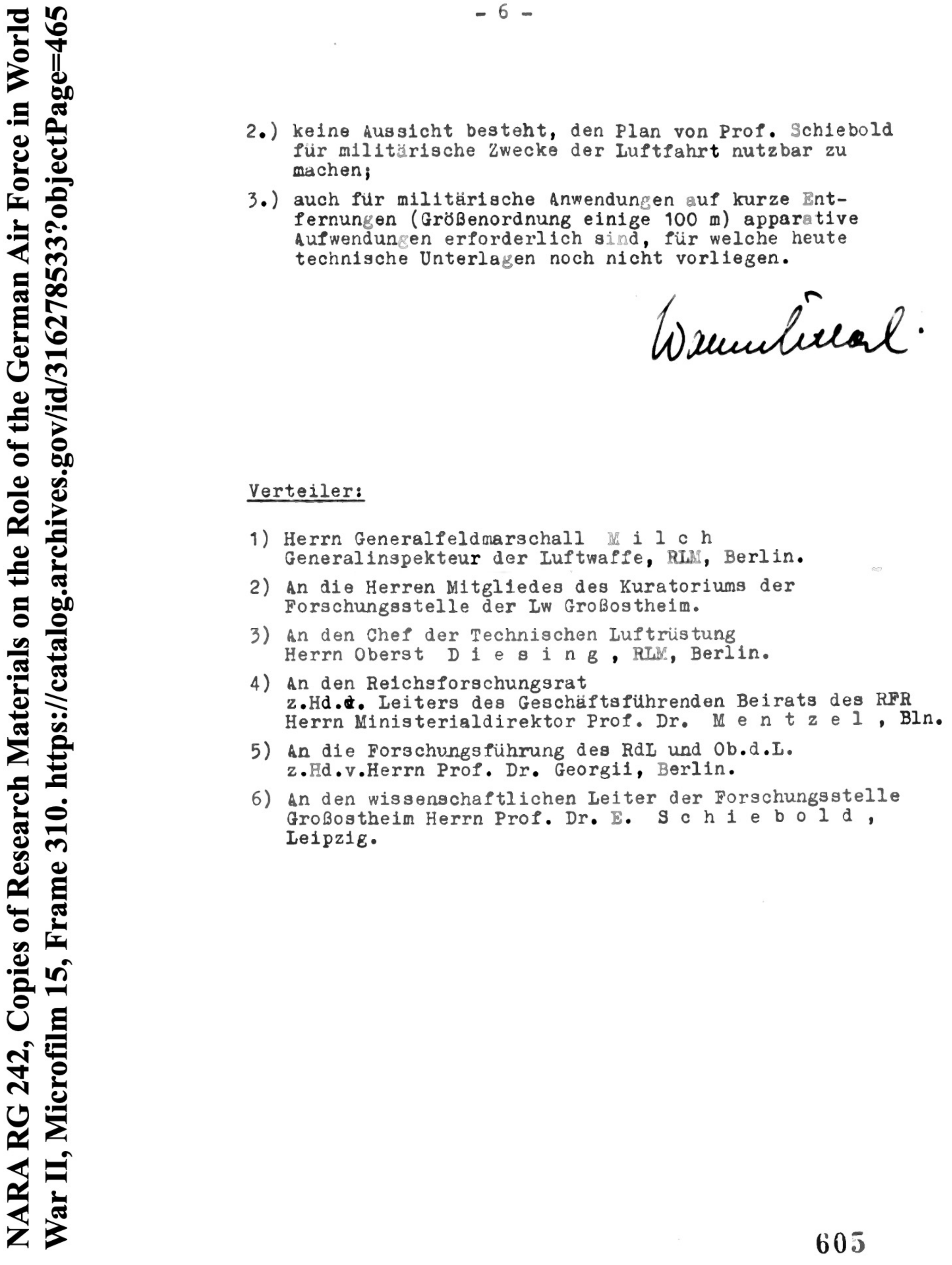
Figure C.46: Notes from 1944 meetings of Walther Gerlach with Ernst Schiebold, Helmuth Kulenkampff, Rolf Wideröe, Gerhard Schumann, and others involved in the development of particle beam weapons. [NARA RG 242, Copies of Research Materials on the Role of the German Air Force in World War II, Microfilm 15, Frames 305–310. https://catalog.archives.gov/id/316278533?objectPage=465]



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- 6 -

2.) keine Aussicht besteht, den Plan von Prof. Schiebold für militärische Zwecke der Luftfahrt nutzbar zu machen;

3.) auch für militärische Anwendungen auf kurze Entfernungen (Größenordnung einige 100 m) apparative Aufwendungen erforderlich sind, für welche heute technische Unterlagen noch nicht vorliegen.

Verteiler:

1) Herrn Generalfeldmarschall Milch
Generalinspekteur der Luftwaffe, RLM, Berlin.

2) An die Herren Mitgliedes des Kuratoriums der
Forschungsstelle der Lw Großostheim.

3) An den Chef der Technischen Luftrüstung
Herrn Oberst Diesing, RLM, Berlin.

4) An den Reichsforschungsrat
z.Hd.d. Leiters des Geschäftsführenden Beirats des RFR
Herrn Ministerialdirektor Prof. Dr. Mentzel, Bln.

5) An die Forschungsführung des RdL und Ob.d.L.
z.Hd.v.Herrn Prof. Dr. Georgii, Berlin.

6) An den wissenschaftlichen Leiter der Forschungsstelle
Großostheim Herrn Prof. Dr. E. Schiebold,
Leipzig.

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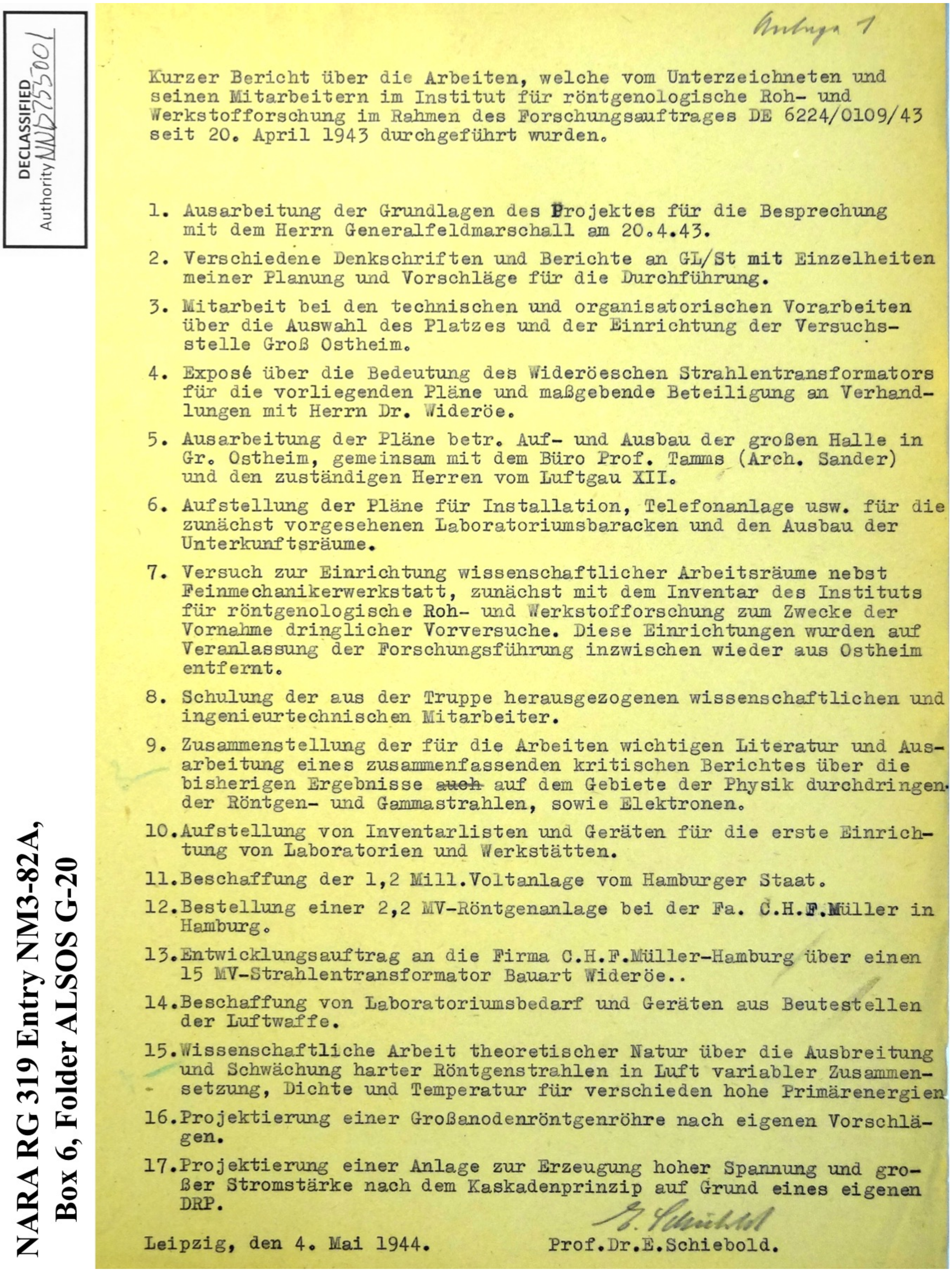
Figure C.47: Notes from 1944 meetings of Walther Gerlach with Ernst Schiebold, Helmuth Kulenkampff, Rolf Wideröe, Gerhard Schumann, and others involved in the development of particle beam weapons. [NARA RG 242, Copies of Research Materials on the Role of the German Air Force in World War II, Microfilm 15, Frames 305–310. https://catalog.archives.gov/id/316278533?objectPage=465]



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Anlage 1

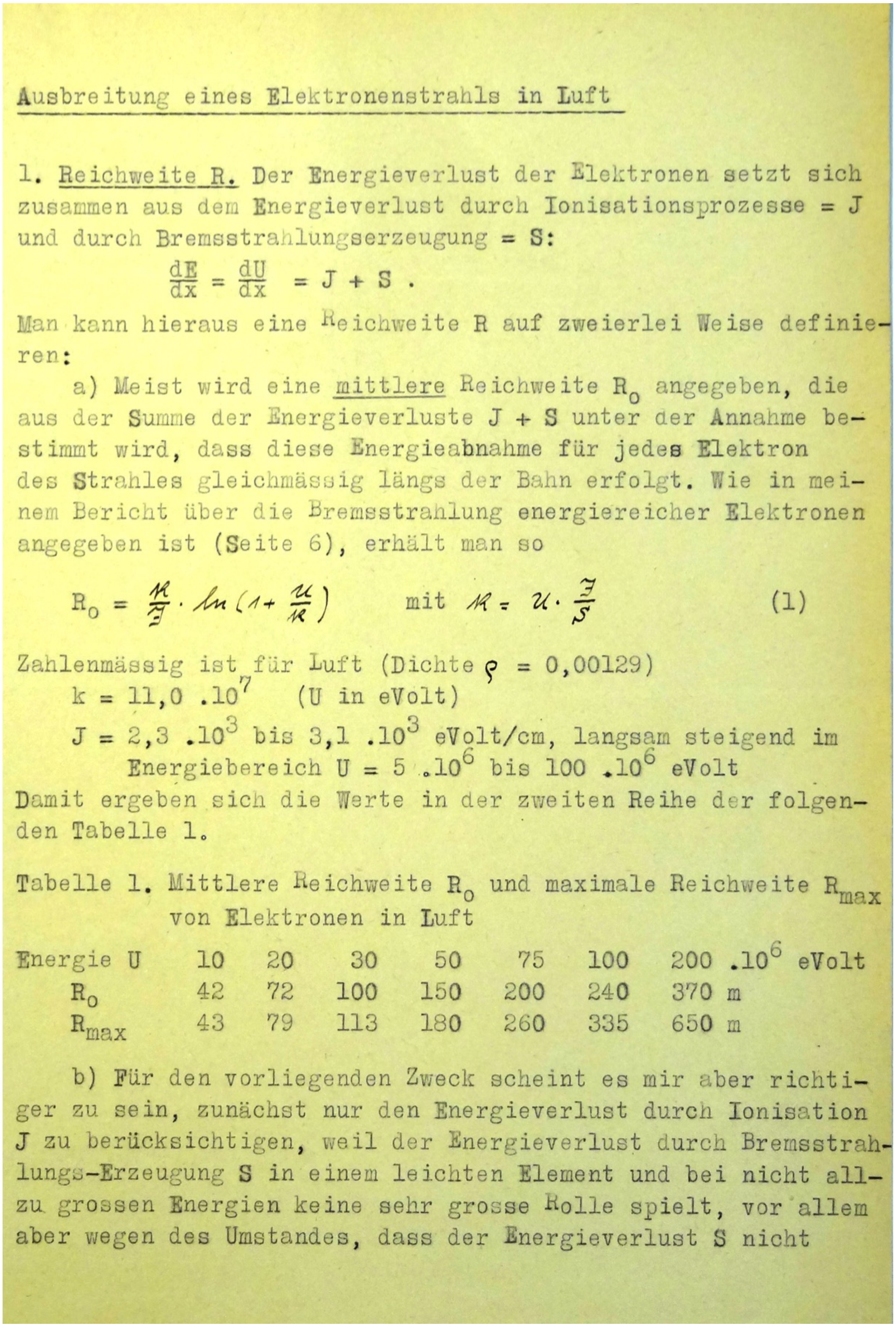
Kurzer Bericht über die Arbeiten, welche vom Unterzeichneten und seinen Mitarbeitern im Institut für röntgenologische Roh- und Werkstofforschung im Rahmen des Forschungsauftrages DE 6224/0109/43 seit 20. April 1943 durchgeführt wurden.

1. Ausarbeitung der Grundlagen des Projektes für die Besprechung mit dem Herrn Generalfeldmarschall am 20.4.43.
2. Verschiedene Denkschriften und Berichte an GL/St mit Einzelheiten meiner Planung und Vorschläge für die Durchführung.
3. Mitarbeit bei den technischen und organisatorischen Vorarbeiten über die Auswahl des Platzes und der Einrichtung der Versuchsstelle Groß Ostheim.
4. Exposé über die Bedeutung des Wideröeschen Strahlentransformators für die vorliegenden Pläne und maßgebende Beteiligung an Verhandlungen mit Herrn Dr. Wideröe.
5. Ausarbeitung der Pläne betr. Auf- und Ausbau der großen Halle in Gr. Ostheim, gemeinsam mit dem Büro Prof. Tamms (Arch. Sander) und den zuständigen Herren vom Luftgau XII.
6. Aufstellung der Pläne für Installation, Telefonanlage usw. für die zunächst vorgesehenen Laboratoriumsbaracken und den Ausbau der Unterkunftsräume.
7. Versuch zur Einrichtung wissenschaftlicher Arbeitsräume nebst Feinmechanikerwerkstatt, zunächst mit dem Inventar des Instituts für röntgenologische Roh- und Werkstofforschung zum Zwecke der Vornahme dringlicher Vorversuche. Diese Einrichtungen wurden auf Veranlassung der Forschungsführung inzwischen wieder aus Ostheim entfernt.
8. Schulung der aus der Truppe herausgezogenen wissenschaftlichen und ingenieurtechnischen Mitarbeiter.
9. Zusammenstellung der für die Arbeiten wichtigen Literatur und Ausarbeitung eines zusammenfassenden kritischen Berichtes über die bisherigen Ergebnisse ~~auch~~ auf dem Gebiete der Physik durchdringen der Röntgen- und Gammastrahlen, sowie Elektronen.
10. Aufstellung von Inventarlisten und Geräten für die erste Einrichtung von Laboratorien und Werkstätten.
11. Beschaffung der 1,2 Mill. Voltanlage vom Hamburger Staat.
12. Bestellung einer 2,2 MV-Röntgenanlage bei der Fa. C.H.F.Müller in Hamburg.
13. Entwicklungsauftrag an die Firma C.H.F.Müller-Hamburg über einen 15 MV-Strahlentransformator Bauart Wideröe..
14. Beschaffung von Laboratoriumsbedarf und Geräten aus Beutestellen der Luftwaffe.
15. Wissenschaftliche Arbeit theoretischer Natur über die Ausbreitung und Schwächung harter Röntgenstrahlen in Luft variabler Zusammensetzung, Dichte und Temperatur für verschieden hohe Primärenergien
16. Projektierung einer Großanodenröntgenröhre nach eigenen Vorschlägen.
17. Projektierung einer Anlage zur Erzeugung hoher Spannung und großer Stromstärke nach dem Kaskadenprinzip auf Grund eines eigenen DRP.

Leipzig, den 4. Mai 1944. Prof. Dr. E. Schiebold.

NARA RG 319 Entry NM3-82A,
Box 6, Folder ALSOS G-20

Figure C.48: Page from a 4 May 1944 progress report from Ernst Schiebold to Walther Gerlach on the development of particle beam weapons [NARA RG 319 Entry NM3-82A, Box 6, Folder ALSOS G-20].



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Ausbreitung eines Elektronenstrahls in Luft

1. Reichweite R. Der Energieverlust der Elektronen setzt sich zusammen aus dem Energieverlust durch Ionisationsprozesse = J und durch Bremsstrahlungserzeugung = S:

$$\frac{dE}{dx} = \frac{dU}{dx} = J + S \, .$$

Man kann hieraus eine Reichweite R auf zweierlei Weise definieren:

a) Meist wird eine mittlere Reichweite R_0 angegeben, die aus der Summe der Energieverluste J + S unter der Annahme bestimmt wird, dass diese Energieabnahme für jedes Elektron des Strahles gleichmässig längs der Bahn erfolgt. Wie in meinem Bericht über die Bremsstrahlung energiereicher Elektronen angegeben ist (Seite 6), erhält man so

$$R_0 = \frac{\varkappa}{J} \cdot \ln\left(1 + \frac{U}{\varkappa}\right) \qquad \text{mit } \varkappa = U \cdot \frac{J}{S} \qquad (1)$$

Zahlenmässig ist für Luft (Dichte ρ = 0,00129)

$k = 11{,}0 \cdot 10^7$ (U in eVolt)

$J = 2{,}3 \cdot 10^3$ bis $3{,}1 \cdot 10^3$ eVolt/cm, langsam steigend im Energiebereich $U = 5 \cdot 10^6$ bis $100 \cdot 10^6$ eVolt

Damit ergeben sich die Werte in der zweiten Reihe der folgenden Tabelle 1.

Tabelle 1. Mittlere Reichweite R_0 und maximale Reichweite R_{max} von Elektronen in Luft

Energie U	10	20	30	50	75	100	200 $\cdot 10^6$ eVolt
R_0	42	72	100	150	200	240	370 m
R_{max}	43	79	113	180	260	335	650 m

b) Für den vorliegenden Zweck scheint es mir aber richtiger zu sein, zunächst nur den Energieverlust durch Ionisation J zu berücksichtigen, weil der Energieverlust durch Bremsstrahlungs-Erzeugung S in einem leichten Element und bei nicht allzu grossen Energien keine sehr grosse Rolle spielt, vor allem aber wegen des Umstandes, dass der Energieverlust S nicht

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Figure C.49: Page from a 27 June 1944 progress report from Helmuth Kulenkampff to Walther Gerlach on the development of particle beam weapons [NARA RG 319 Entry NM3-82A, Box 6, Folder ALSOS G-20].

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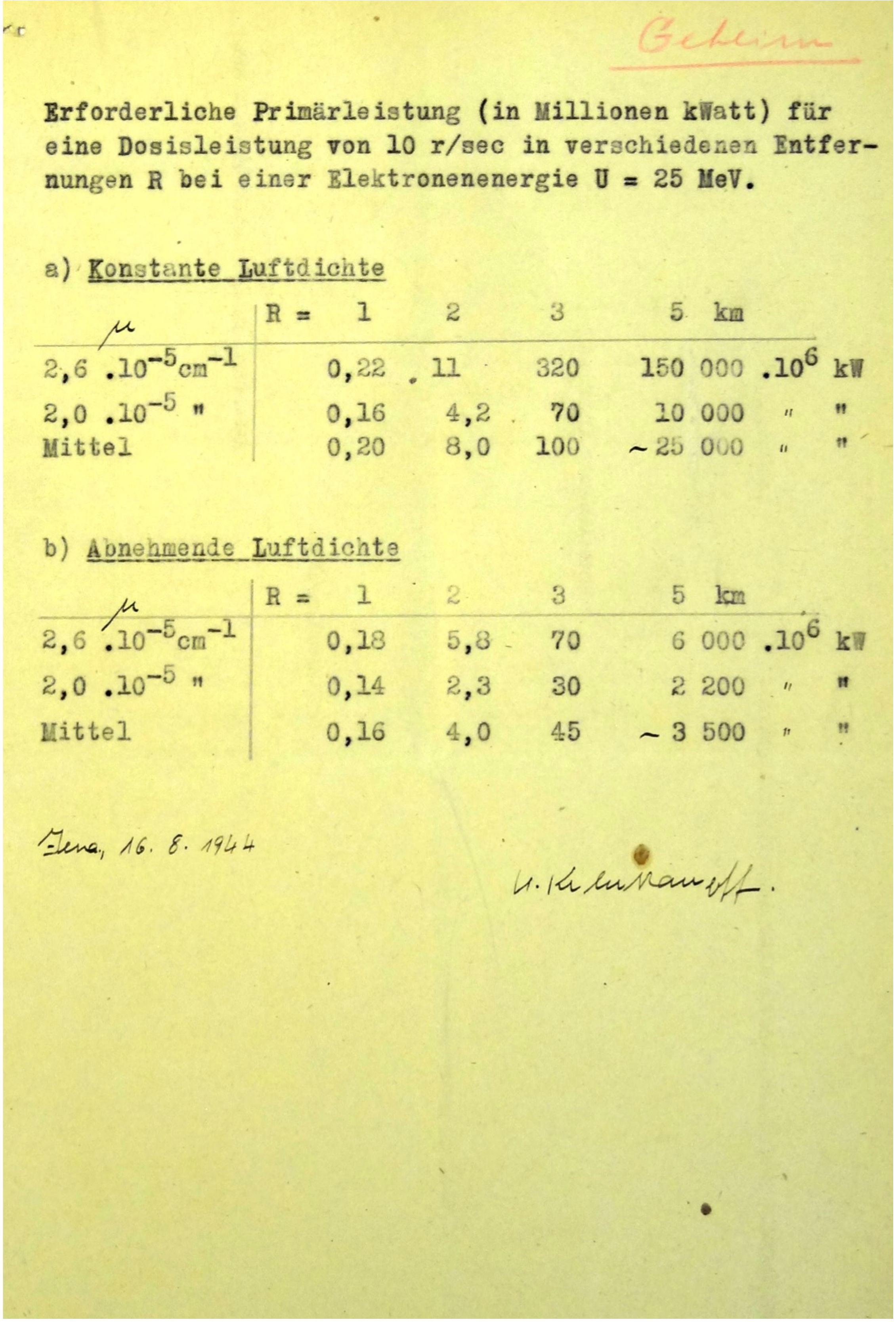

Geheim

Erforderliche Primärleistung (in Millionen kWatt) für eine Dosisleistung von 10 r/sec in verschiedenen Entfernungen R bei einer Elektronenenergie U = 25 MeV.

a) Konstante Luftdichte

μ	R = 1	2	3	5 km	
$2{,}6 \cdot 10^{-5}\,\mathrm{cm}^{-1}$	0,22	11	320	150 000	$\cdot 10^6$ kW
$2{,}0 \cdot 10^{-5}$ "	0,16	4,2	70	10 000	" "
Mittel	0,20	8,0	100	~ 25 000	" "

b) Abnehmende Luftdichte

μ	R = 1	2	3	5 km	
$2{,}6 \cdot 10^{-5}\,\mathrm{cm}^{-1}$	0,18	5,8	70	6 000	$\cdot 10^6$ kW
$2{,}0 \cdot 10^{-5}$ "	0,14	2,3	30	2 200	" "
Mittel	0,16	4,0	45	~ 3 500	" "

Jena, 16. 8. 1944

H. Kulenkampff.

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Figure C.50: Page from a 16 August 1944 progress report from Helmuth Kulenkampff to Walther Gerlach on the development of particle beam weapons [NARA RG 319 Entry NM3-82A, Box 6, Folder ALSOS G-20].

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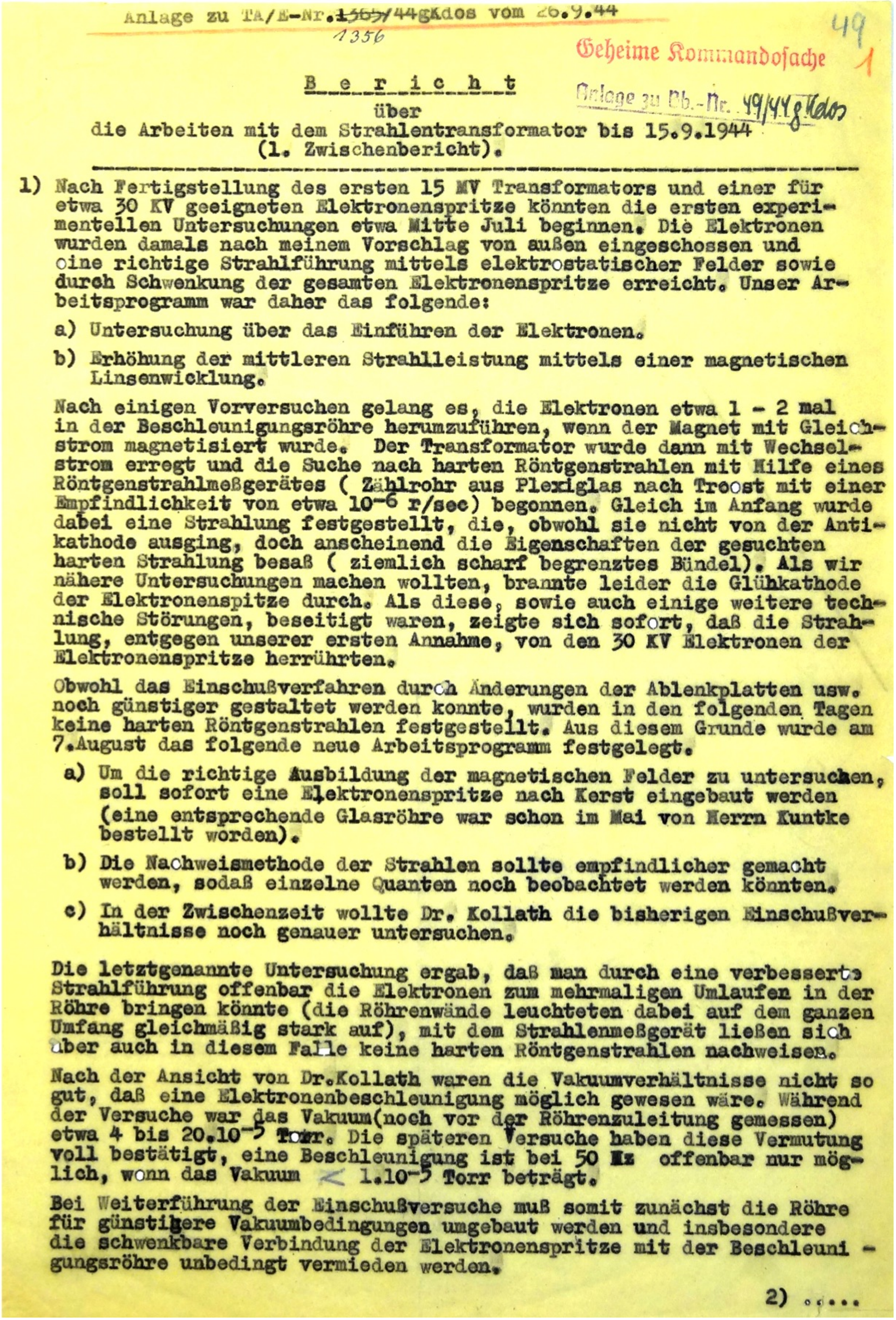

Anlage zu TA/E-Nr.~~1365~~/44gKdos vom 26.9.44
1356

49
Geheime Kommandosache
1

Anlage zu Pb.-Nr. 49/44 g.Kdos

Bericht
über
die Arbeiten mit dem Strahlentransformator bis 15.9.1944
(1. Zwischenbericht).

---

1) Nach Fertigstellung des ersten 15 MV Transformators und einer für etwa 30 KV geeigneten Elektronenspritze könnten die ersten experimentellen Untersuchungen etwa Mitte Juli beginnen. Die Elektronen wurden damals nach meinem Vorschlag von außen eingeschossen und eine richtige Strahlführung mittels elektrostatischer Felder sowie durch Schwenkung der gesamten Elektronenspritze erreicht. Unser Arbeitsprogramm war daher das folgende:

a) Untersuchung über das Einführen der Elektronen.

b) Erhöhung der mittleren Strahlleistung mittels einer magnetischen Linsenwicklung.

Nach einigen Vorversuchen gelang es, die Elektronen etwa 1 - 2 mal in der Beschleunigungsröhre herumzuführen, wenn der Magnet mit Gleichstrom magnetisiert wurde. Der Transformator wurde dann mit Wechselstrom erregt und die Suche nach harten Röntgenstrahlen mit Hilfe eines Röntgenstrahlmeßgerätes (Zählrohr aus Plexiglas nach Troost mit einer Empfindlichkeit von etwa 10^{-6} r/sec) begonnen. Gleich im Anfang wurde dabei eine Strahlung festgestellt, die, obwohl sie nicht von der Antikathode ausging, doch anscheinend die Eigenschaften der gesuchten harten Strahlung besaß (ziemlich scharf begrenztes Bündel). Als wir nähere Untersuchungen machen wollten, brannte leider die Glühkathode der Elektronenspitze durch. Als diese, sowie auch einige weitere technische Störungen, beseitigt waren, zeigte sich sofort, daß die Strahlung, entgegen unserer ersten Annahme, von den 30 KV Elektronen der Elektronenspritze herrührten.

Obwohl das Einschußverfahren durch Änderungen der Ablenkplatten usw. noch günstiger gestaltet werden konnte, wurden in den folgenden Tagen keine harten Röntgenstrahlen festgestellt. Aus diesem Grunde wurde am 7.August das folgende neue Arbeitsprogramm festgelegt.

a) Um die richtige Ausbildung der magnetischen Felder zu untersuchen, soll sofort eine Elektronenspritze nach Kerst eingebaut werden (eine entsprechende Glasröhre war schon im Mai von Herrn Kuntke bestellt worden).

b) Die Nachweismethode der Strahlen sollte empfindlicher gemacht werden, sodaß einzelne Quanten noch beobachtet werden könnten.

c) In der Zwischenzeit wollte Dr. Kollath die bisherigen Einschußverhältnisse noch genauer untersuchen.

Die letztgenannte Untersuchung ergab, daß man durch eine verbesserte Strahlführung offenbar die Elektronen zum mehrmaligen Umlaufen in der Röhre bringen könnte (die Röhrenwände leuchteten dabei auf dem ganzen Umfang gleichmäßig stark auf), mit dem Strahlenmeßgerät ließen sich aber auch in diesem Falle keine harten Röntgenstrahlen nachweisen.

Nach der Ansicht von Dr.Kollath waren die Vakuumverhältnisse nicht so gut, daß eine Elektronenbeschleunigung möglich gewesen wäre. Während der Versuche war das Vakuum(noch vor der Röhrenzuleitung gemessen) etwa 4 bis 20.10^{-5} Torr. Die späteren Versuche haben diese Vermutung voll bestätigt, eine Beschleunigung ist bei 50 Hz offenbar nur möglich, wenn das Vakuum $<$ 1.10^{-5} Torr beträgt.

Bei Weiterführung der Einschußversuche muß somit zunächst die Röhre für günstigere Vakuumbedingungen umgebaut werden und insbesondere die schwenkbare Verbindung der Elektronenspritze mit der Beschleunigungsröhre unbedingt vermieden werden.

2) .....

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Figure C.51: Page from a 15 September 1944 progress report from Rolf Wideröe to Walther Gerlach on the development of particle beam weapons [NARA RG 319 Entry NM3-82A, Box 6, Folder ALSOS G-20].

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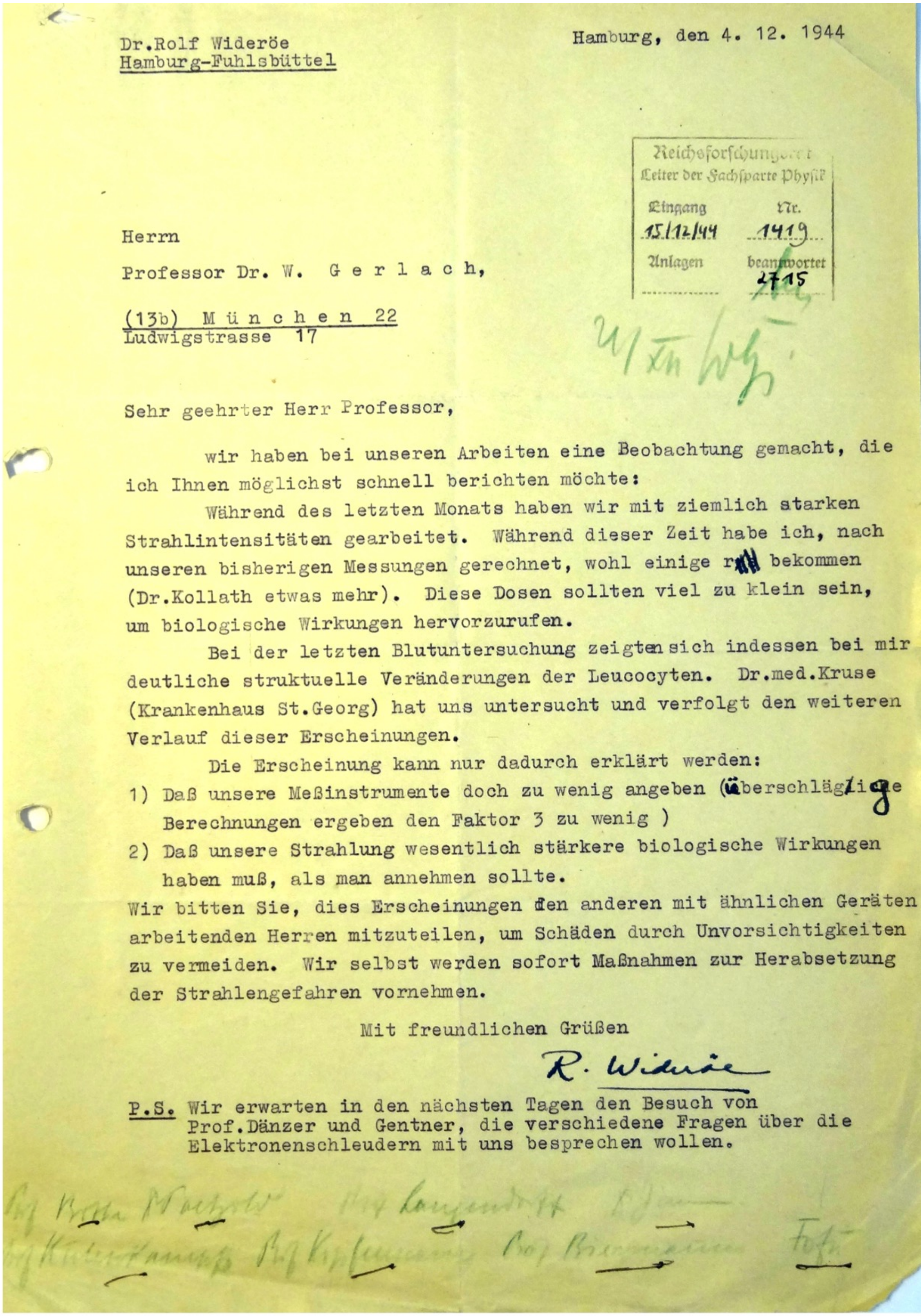

Dr.Rolf Wideröe
Hamburg-Fuhlsbüttel

Hamburg, den 4. 12. 1944

Reichsforschungsrat
Leiter der Fachsparte Physik
Eingang 15/12/44
Nr. 1419
Anlagen
beantwortet 2715

21/XII Wg.

Herrn
Professor Dr. W. Gerlach,

(13b) München 22
Ludwigstrasse 17

Sehr geehrter Herr Professor,

wir haben bei unseren Arbeiten eine Beobachtung gemacht, die ich Ihnen möglichst schnell berichten möchte:

Während des letzten Monats haben wir mit ziemlich starken Strahlintensitäten gearbeitet. Während dieser Zeit habe ich, nach unseren bisherigen Messungen gerechnet, wohl einige r bekommen (Dr.Kollath etwas mehr). Diese Dosen sollten viel zu klein sein, um biologische Wirkungen hervorzurufen.

Bei der letzten Blutuntersuchung zeigten sich indessen bei mir deutliche struktuelle Veränderungen der Leucocyten. Dr.med.Kruse (Krankenhaus St.Georg) hat uns untersucht und verfolgt den weiteren Verlauf dieser Erscheinungen.

Die Erscheinung kann nur dadurch erklärt werden:

1) Daß unsere Meßinstrumente doch zu wenig angeben (überschlägige Berechnungen ergeben den Faktor 3 zu wenig)
2) Daß unsere Strahlung wesentlich stärkere biologische Wirkungen haben muß, als man annehmen sollte.

Wir bitten Sie, dies Erscheinungen den anderen mit ähnlichen Geräten arbeitenden Herren mitzuteilen, um Schäden durch Unvorsichtigkeiten zu vermeiden. Wir selbst werden sofort Maßnahmen zur Herabsetzung der Strahlengefahren vornehmen.

Mit freundlichen Grüßen

R. Wideröe

P.S. Wir erwarten in den nächsten Tagen den Besuch von Prof.Dänzer und Gentner, die verschiedene Fragen über die Elektronenschleudern mit uns besprechen wollen.

Prof Bothe Prof Wetzold Prof Langendorff [illegible]
Prof Kulenkampff Prof Kopfermann Prof Biermann [illegible]

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Figure C.52: Page from a 4 December 1944 progress report from Rolf Wideröe to Walther Gerlach on the development of particle beam weapons [NARA RG 319 Entry NM3-82A, Box 6, Folder ALSOS G-20].

[Many other German reports captured by the U.S. Alsos Mission also show that there was extensive work throughout the war on particle accelerators, especially types of accelerators that would have been highly suitable for electronuclear breeding of fission fuel. (See Appendix D for more information.) Unless otherwise noted, text for G-series captured German nuclear reports cited here consists of the English-language abstracts prepared by American scientists who studied the German reports.]

G-4. W. Wiebe. The Cyclotron as a Method of Accelerating Light Ions. A Survey of the Literature and Report on the Construction of a Cyclotron at the University of Bonn. G-123. W. Wiebe. Investigation of the Construction of a Cyclotron.

Comprehensive literature survey of cyclotron theory and operation as well as a report on the construction of a cyclotron at the Roentgen Research Institute of the University of Bonn. Some results obtained with this cyclotron are also included.

G-187. W. Schmitz and W. Wiebe. Technical Experiences in the Construction of the Bonn Cyclotron. 1942.

Brief description of some features of the Bonn cyclotron which has been put into partial operation. Because of financial restrictions, magnet has 50 cm pole diameter. It is air cooled, 2000 windings, 3 amp/mm^2, 10,000 Gauss. Temperature rise after 1 hour operation = 50^o which increases resistance of copper 15%. Homogeneity between the cylindrical poles = 1.6; with shimming, field strength is 20% higher in the slits (5 mm). Descriptions also of the current regulator, the high frequency generator, and the Dees.

G-204. Walther Bothe. Radiation Shielding Walls. 1943.

Analysis of shielding required for a cyclotron (8 MeV) operated with deuterons and the operator 8 m from the apparatus.

G-205. Walther Bothe. The Research Tools of Nuclear Physics. 1943.

General semipopular lecture delivered before German air force personnel describing the various particle accelerators used in nuclear physics including cascade transformers, electrostatic generators, Van de Graaff accelerators, cyclotrons, rheotrons, and also the uranium pile. Concludes with plea for needed personnel.

G-209. Walter Dällenbach. Patent Application and General Correspondence with the German Patent Office on a Particle Accelerator. 1943.

This is not a complete report on a particle accelerator but rather a patent application on certain features of the proposed unit.

[Dällenbach was a Swiss physicist, but the German government funded his own research center, Forschungsstelle D, for the development of high-energy particle accelerators during the war [Dippel 1992; Burghard Weiss 1996].]

G-232. H. Lange and K. Fink. The Possibility of Saving Material in Building Cyclotron Magnets. 1943.

A general manual on the design of 15,000 gauss cyclotron magnets giving data on pole diameters (ranging from 100 to 120 cm), pole gap (20 to 40 cm) and the efficiency of various materials as windings. Special emphasis is laid on the use of aluminum wire as a substitute for copper.

G-247. Otto Baier. Report on the Design of the Vacuum Tank and Oscillator for the Cyclotron of the Physics Section of the German Post Office Department Research Institution. 1944.

Vacuum tank with radiation chamber, ion source and probe, deflector, electrode dees and their mounting, are described, also the oscillator and the flange connecting the oscillator tank with the main vacuum tank, and the mechanism for introduction of the target. Plans for this equipment are illustrated.

G-255. Siegfried Flügge. Observations Concerning the Theory of the Rheotron. 1944.

A rheotron is a particle accelerator built on the principle of a magnetic field variable in time producing a circular electric field. Charged particles with very high energies result if the magnetic power increases until the desired energy of the particle is reached, and if the accelerated particle keeps a circular path of the same diameter. Equations are computed for the electron path, energy increase, stability of the path, and axial and radial oscillations. The path traveled by the electrons is figured to be several 100 km. Interactions with the vacuum atmosphere are considered.

[Richard Gans and Heinz Schmellenmeier did considerable work on rheotrons during the war [Waloschek 2004, pp. 33–64].]

G-282. H. Salow. The High Frequency Circuit for a Cyclotron. 1944.

A method to achieve a high potential (100 kV or more) with the least high frequency energy output, allowing for a resonance wave length range of 26–30 m for the accelerated particles, and a capacity of the dee electrodes of about 100 cm is discussed. Various possible high frequency systems are examined, namely the L-C circuit (inductance L completing the capacity to an oscillating circuit), concentric double circuits, and a shielded double circuit system. Energy losses of the circuit and coupling of the feeding line are considered.

G-284. Ernst Schiebold. On the Possibility of Biological Effects of Shortwave X Rays or Gamma Rays, Using Specially Constructed X-Ray Tubes, at Long Distances. Lecture Given at the Meeting of the Kuratorium of the German Air Force Research Institute Grossostheim. 6 May 1944.

This is a detailed discussion of the possibilities of using x irradiation and electrons in radiological warfare over long distances. The report is not based on experiments but entirely on estimations. Construction of x-ray tubes, scattering and absorption in air, intensity decrease due to various factors, dosage, etc. are discussed.

G-286. W. Schmitz and A. Weckesser. Investigations of High Frequency Currents for Construction of a Large Cyclotron. 1944.

In very large cyclotrons the potential distribution in the acceleration gap between the dees is no longer constant. In order to obtain information on the voltage increase to be expected, measurements of potentials were conducted on a model of decreased size with wave length shortened accordingly. An improved wiring and oscillator system are designed. A procedure is developed for calculation of the effect of the increase in potential on the particle path.

G-292. W. Wiebe. Consideration for Construction of a 80 Million Volt Cyclotron. 1944.

Considerations on construction of a large cyclotron include calculations concerning magnetic field focusing, relation between magnetic field and particle path, relative increase in mass and resonance, and design of vacuum chamber and voltage source. [...] For production of the desired particle path a magnetic field of 17,610 maximal and of 7450 gauss minimal strength is calculated to be needed. The diameter of the poles is figured to be 175 cm, iron weight of the magnets is anticipated as 1500 tons. The path of the deuterons would have a total length of 2500 m, deuterons of 80 MeV and alpha particles of 160 MeV can be produced.

FA 002/0384. Letter from Rudolf Fleischmann to Maurer. 10 February 1943. Archive of Deutsches Museum Munich.

Fleischmann visited Mentzel on Jan. 28 and heard that Esau had been put in charge of nuclear physics by the Reichsmarschall. From Siemens man, he heard that Siemens has been constructing since four years a large cyclotron with 1.60 meter diameter. He did not say for whom. There can be hardly any doubt that it is for an organization of the armed forces. Is this the large cyclotron for WaF?

FA 002/0362. Letter from Maurer to Rudolf Fleischmann. 12 January 1943. Archive of Deutsches Museum Munich.

[...]The two people from the Reichspost were here. Their magnet gives only 16,000 Gauss, 160 mm gap, diameter 1080 mm. They hope to get 10 million volt.

FA 002/0362. Letter from Maurer to Rudolf Fleischmann. 5 March 1943. Archive of Deutsches Museum Munich.

Esau and Bothe have left Paris. Maurer was present at a discussion between Esau and Bothe. Maurer pointed out to Bothe the egotistic behaviour of the firm of Siemens and that he regrets that Fleischmann as nuclear physicist has to go empty handed whereas the Reichspost and Siemens are allowed to build with mere beginners. Maurer asks what is going to happen with the second Siemens magnet. [...] Bothe is no end fed up.

[After the war, Allied investigators wrote several reports about particle accelerators they found in Germany or former German-controlled territories.]

BIOS Misc 77 = NavTechMisEu 331-45. *European Electron Induction Accelerators.* [https://www.cdvandt.org/BIOS-Miscell-77.pdf]

SUMMARY

Betatrons, induction electron accelerators for the production of high energy x-radiation, were under development in Germany during the war and are also to some extent at present. This work is reviewed for the most part and details are given on the constructional features of 6 and 15 million volt betatrons and on the theory and design of 15 and 200 million volt betatrons. The smaller units, especially the Siemens 6 Mv are quite successful and more advanced than comparable American units. While no large machines were actually built the projected 200 Mv Wideröe design introduces new features of value. Betatron patent ideas are reviewed.

I. Introduction.

A. History of Betatron Developments on Continent.

The first work on the subject of electron induction acceleration which appeared in Europe was the doctoral dissertation of Rolf Wideröe of Bergen, Norway, which appeared in 1927 and was published in print the following year. [...]

Developments on the continent have been based on Wideröe's work. The basic ideas were by Steenbeck in his patents of 1937 [...] in which the necessary properties of the magnetic accelerating and guiding fields are formulated.

An induction electron accelerator was built on these principles and tried with success, it is claimed, although the intensities of radiation produced were only of cosmic ray intensity order. [...]

The betatron development was carried out by three separate groups. One was the Megavolt Versuchsanstalt (MVA) or Megavolt Research Association which worked under the guidance of Dr. Wideröe. Siemens and AEG also had projects. MVA laid plans for a 15 Mv and a 200 Mv accelerator. The former was begun early in 1944 and brought to successful completion in the fall of the same year. The design of the 200 Mv accelerator was completed about this time and the construction work turned over to the Brown Boveri firm in Heidelberg. Recent investigation showed that MVA had no further connection with this project.

The basic ideas underlying the design of these two induction accelerators were published by Wideröe in two papers. These discuss the special problems involved such as axial and radial stabilization by properly designed guiding fields, injection and extraction of electrons, the useful load of the apparatus, the maximum electron filling of the acceleration chamber, dependence on injection voltage (using auxiliary lens system), the stabilization of electronic orbits with electrical lenses, especially for high radiation energies, the effects of gas molecules, technical transformer construction details for high energy production, and finally the fields of application of the betatron: cancer treatment, radiography, and nuclear physics.

In collaboration with the design work of Wideröe, a considerable amount of theoretical work has been carried out by Touschek. This is known to have been of invaluable aid in the development of the 15 Mv accelerator. Further theoretical work has also been done by Touschek in the starting of electrons in the accelerator. [...]

BIOS 1730. *Industrial Electrical Research in Germany.* pp. 91–94, 133–136.

A betatron having an output of about 15 MeV, .01 Röntgens per second at 1 metre, is in working condition at this place [M.V. Forschungs-Vereinigung]. An outline of the design in Fig. 39 has been prepared from sketches from a drawing at Wrist.

The following particulars were provided by Touschek:–

Operating frequency	50 cycles per second.
Orbit radius.	14 cms.
Core details:–	
Length	92 cms.
Height.	56 cms.
Radius of centre core.	11 cms.
Pole pieces have inner dia.	27.6 cms.
” ” ” outer dia.	29.8 cms.
Air gaps of centre core.	2 cms.
” ” between pole pieces.	6 cms.
Cross section of main yokes.	13 x 32 cms.
Weight:–	
Iron.	816 Kg.
Copper.	188 Kg.
Magnetic circuit particulars:–	
Max. induction in core.	11,300 gauss.
Average induction with orbit	7,400 gauss.
Induction at orbit (R=14 cms).	3,700 gauss.
Max. induction in yoke.	10,200 gauss.
Main Coils:–	
Current.	48 amps. R.M.S.
Voltage.	4,780 volts.
KVA.	230
Ampere turns, peak	19,000
Volts per turn.	17.1
Cooling.	By air.
Copper losses.	500 Watts
Iron losses, core	156 Watts.
” ” poles.	150 Watts.
” ” yoke.	960 Watts.
Power factor correction condenser.	33 MFD at 5000 volts.

The core is built up from low-loss transformer steel; a loss figure of 1.1 watts per Kg, at 10,000 gauss, 50 cycles per second, was quoted. Ten different sizes of radial laminations, each 0.35 mm. thick, are used in the core. A lower grade of transformer steel is used for the yoke.

The “doughnut” is of glass (Pyrex type), built up from two semicircular moulds, and is continuously pumped. The internal surfaces are aquadag coated. The resistance of the aquadag coating measured across a diameter was understood to be 30 ohms.

An approximate sketch of the gun, and target carried on the gun is given in Fig. 40. The current at injection has an average value of 0.125 mA. and a peak value of 12.5 mA, approximately. It was stated that about 10% of the injection current arrived in the orbit. An injection pulse time of about 2.0 microseconds was aimed at, but the actual time achieved was about 250 microseconds. With the present betatron up to 30 MEV has been obtained.

The characteristic at the orbit was stated to be H = K r^{-6}. The expansion of the orbit is by magnetic saturation; expansion onto the target takes place after about 60 degrees from flux zero.

In order to utilise the maximum change of A.C. flux, a D.C. biasing scheme is proposed, using a D.C. bias winding embracing the pole pieces in the manner shown in Fig. 41. The bucking transformer shown is to compensate for the induced e.m.f. caused by A.C. flux which links with the added D.C. winding.

A scheme for getting electrons out of the chamber was briefly described. Two additional sets of electrodes would be placed in the doughnut. The first electrode at a potential of some kV would upset the stability conditions so that electrons would leave the stable orbit, and be directed to a pair of electrodes (plates) which would deflect the electrons further from the orbit and focus them into a beam, which then leaves the doughnut in a linear manner. The apparently optimistic figure of 60% was mentioned as the number of electrons which would be removed from the orbit and given a linear path.

[...]

Two betatrons were seen at the Erlangen works of the Siemens Reiniger concern, one in running condition and the other very nearly complete. Both are for providing X-rays corresponding to 6 MEV.

The essential particulars of the completed betatron are as follows:–

Output—6 MEV; X-ray output 0.2 röntgens per minute
—15 gr. radium at 1 metre.

A.C. supply frequency.	550 cycles/sec.
Orbit radius.	8.3 cms.
Target radius.	11.0 cms.
Injection radius	6.3 cms.
Injection current (mean) (5 milliamps possible)	1.0 milliamp.
Voltage at injection.	4000/5000
Injection time.	10^{-5} second.
K.V.A. to main coils (100 amps 3 KV. to give 6 MEV).	300
Expansion time.	2 x 10^{-5} second.
X-ray time.	5 x 10^{-6} second.
Vacuum (see curve Fig. 69)	3 x 10^{-5} mm.
Current in orbit	5 x 10^{-7} amp.
Approx. characteristic at orbit.	H $r^{-1/2}$
H at orbit.	1400 gauss.
Total losses, approximately.	3 KW.
Copper losses.	800 watts.

Doughnut; Ceramic in two main disc sections, metallised
and soft soldered; pumped, (see Fig. 68)
Iron circuit; overall dimensions 26" x 8" x 19" approx.

For details of pole pieces (see Fig. 68) the outer annulus comprises about 2000 suitably shaped laminations, as A, bent to fit to the required diameter. Inside A is a core section B built up of radially displaced laminations, similarly bent. The central section C is made up from small packets of strip laminations about 2 to 3 mm. wide, total of about 11,000 strips. All of these laminations are of ordinary silicon steel 0.3 mm. thick. Shims G of magnetic dust materials are place between B and a ribbed bakelite spacer H, possibly to allow for cooling. The assembly of pole pieces, etc., and the doughnut comprises one unit which can be inserted or withdrawn from the main core and coil assembly without disturbing the latter.

The orbit is expanded into the target by auxiliary coils energised from a thyratron circuit, which serves to discharge a 2 MFD condenser at 1000 volts through these said coils. The circuit arrangement is shown in Fig. 70.

The main magnetic circuit is water cooled, the conductors being a number of strands of Ltz wire wound round brass tubing through which water flows.

Siemens Reiniger have another betatron of similar physical size and rating nearly completed; it is for operation on a 50 cycles supply.

S.R.W. have apparently paid appreciable attention to conditions at injections and had built a model to study the effect of various types of gun. A constant field is evidently applied to the model and the adjustable fluorescent screen; a number of viewing windows are provided in the chamber.

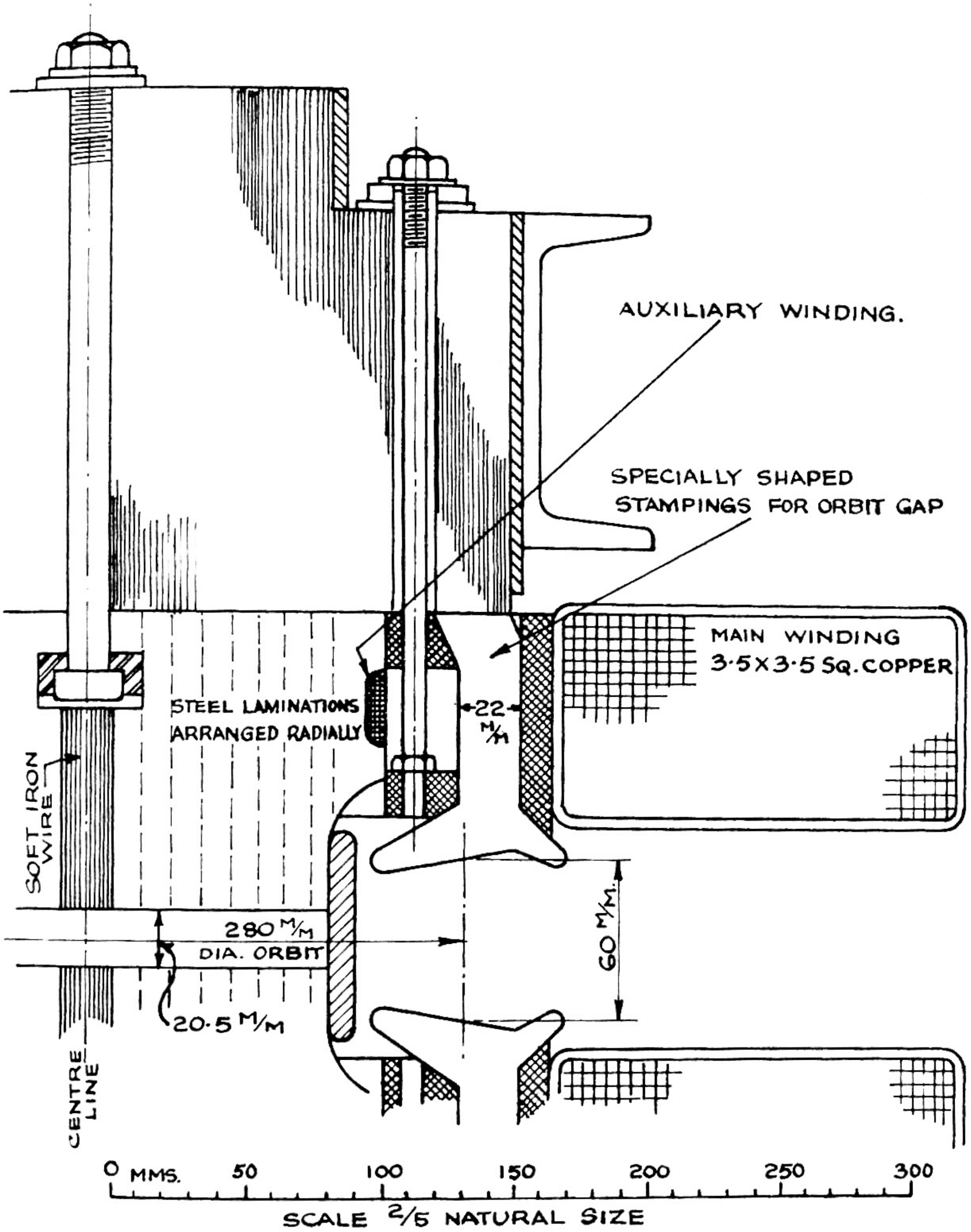

AUXILIARY WINDING.
SPECIALLY SHAPED STAMPINGS FOR ORBIT GAP
MAIN WINDING 3·5X3·5 SQ. COPPER
STEEL LAMINATIONS ARRANGED RADIALLY
22 M/M
SOFT IRON WIRE
280 M/M DIA. ORBIT
20·5 M/M
60 M/M.
CENTRE LINE
0 MMS. 50 100 150 200 250 300
SCALE 2/5 NATURAL SIZE

FIG. 39
BETATRON AT WRIST
FROM M-V. FORSCHUNGS VEREINIGUNG DRG. No. 178/10

Figure C.53: 15 MeV betatron [BIOS 1730].

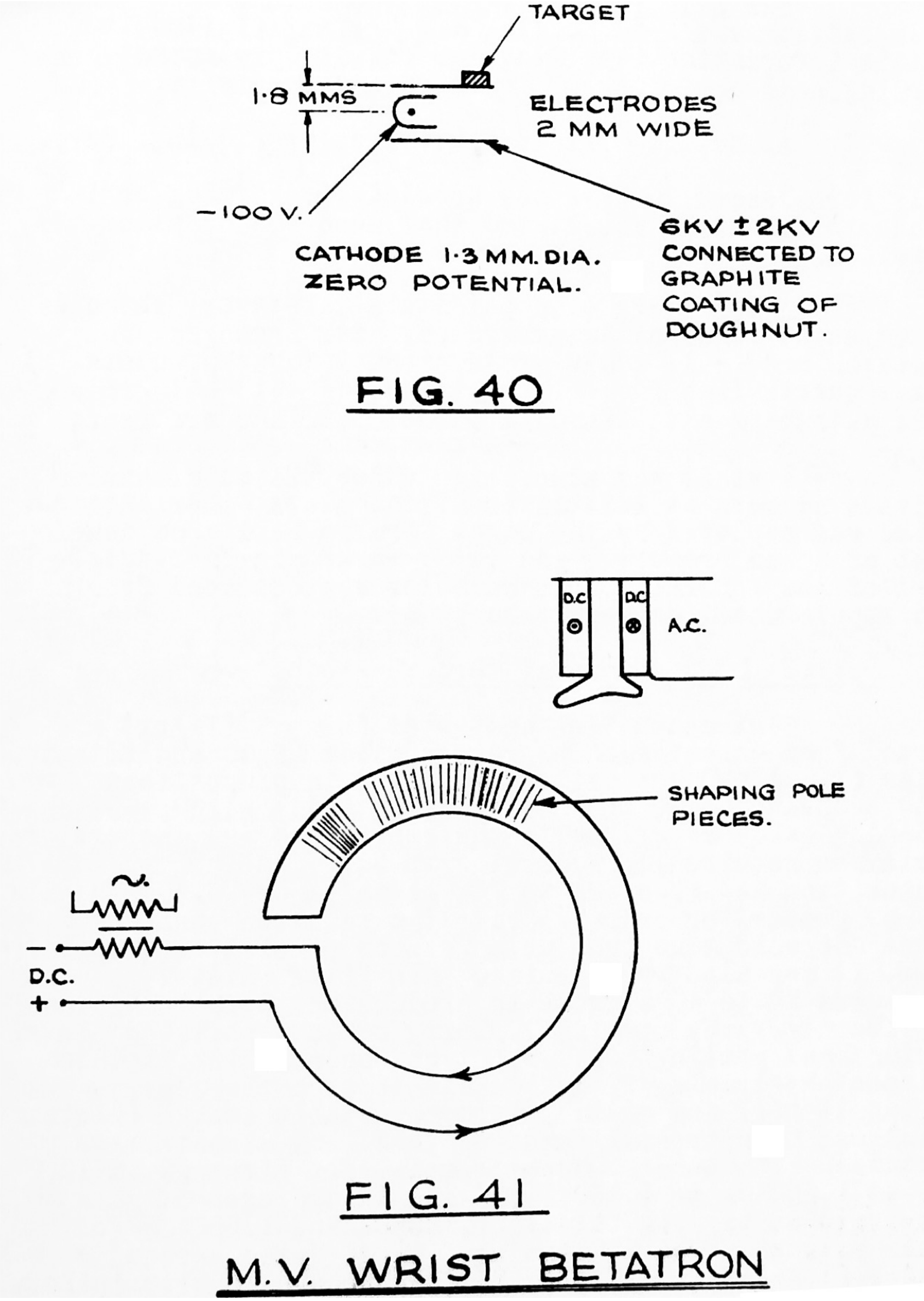

TARGET
1·8 MMS
ELECTRODES
2 MM WIDE
−100 V.
6KV ± 2KV
CONNECTED TO
GRAPHITE
COATING OF
DOUGHNUT.
CATHODE 1·3 MM. DIA.
ZERO POTENTIAL.
FIG. 40
D.C
D.C
A.C.
SHAPING POLE
PIECES.
~
−
D.C.
+
FIG. 41
M.V. WRIST BETATRON

Figure C.54: 15 MeV betatron [BIOS 1730].

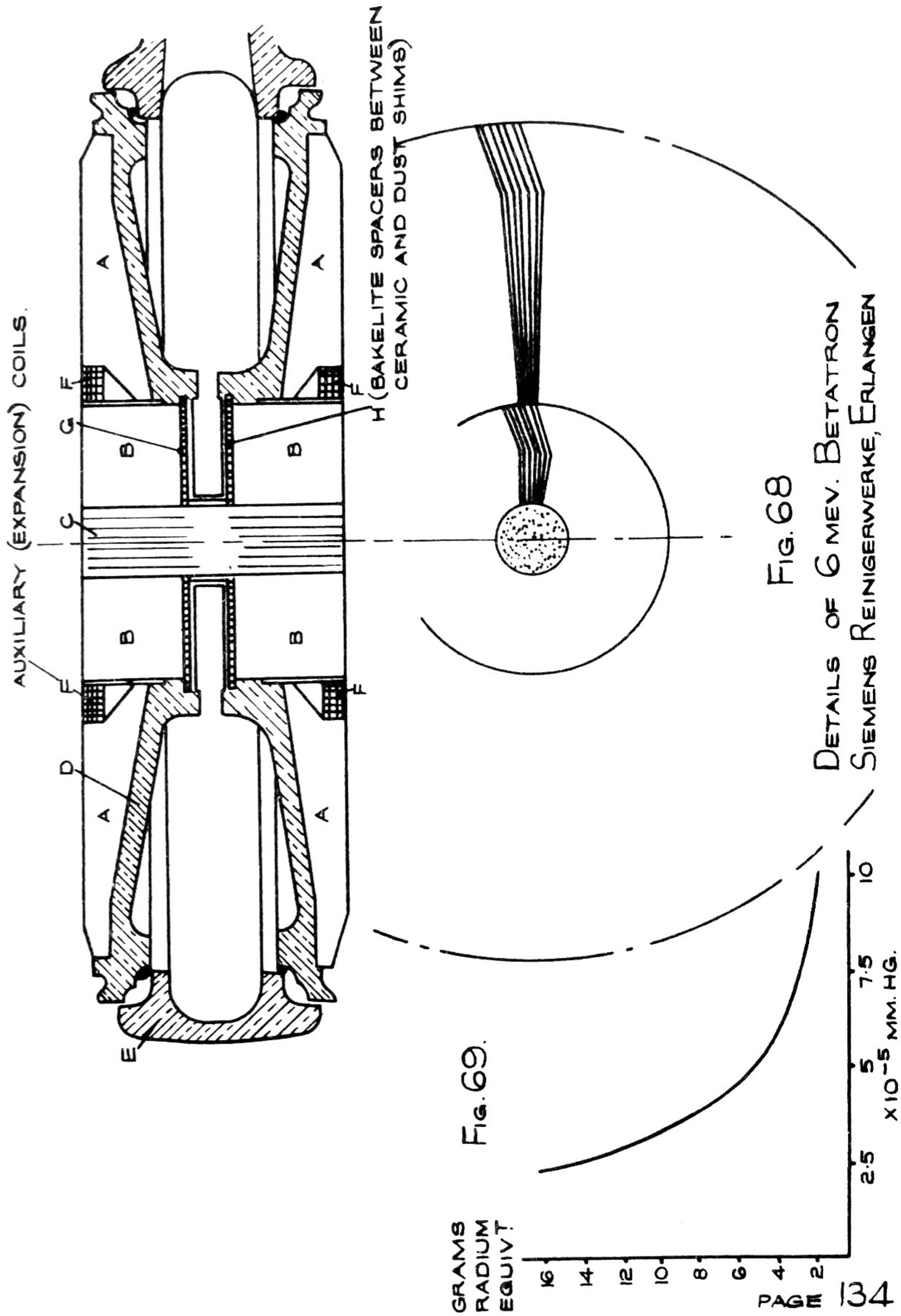
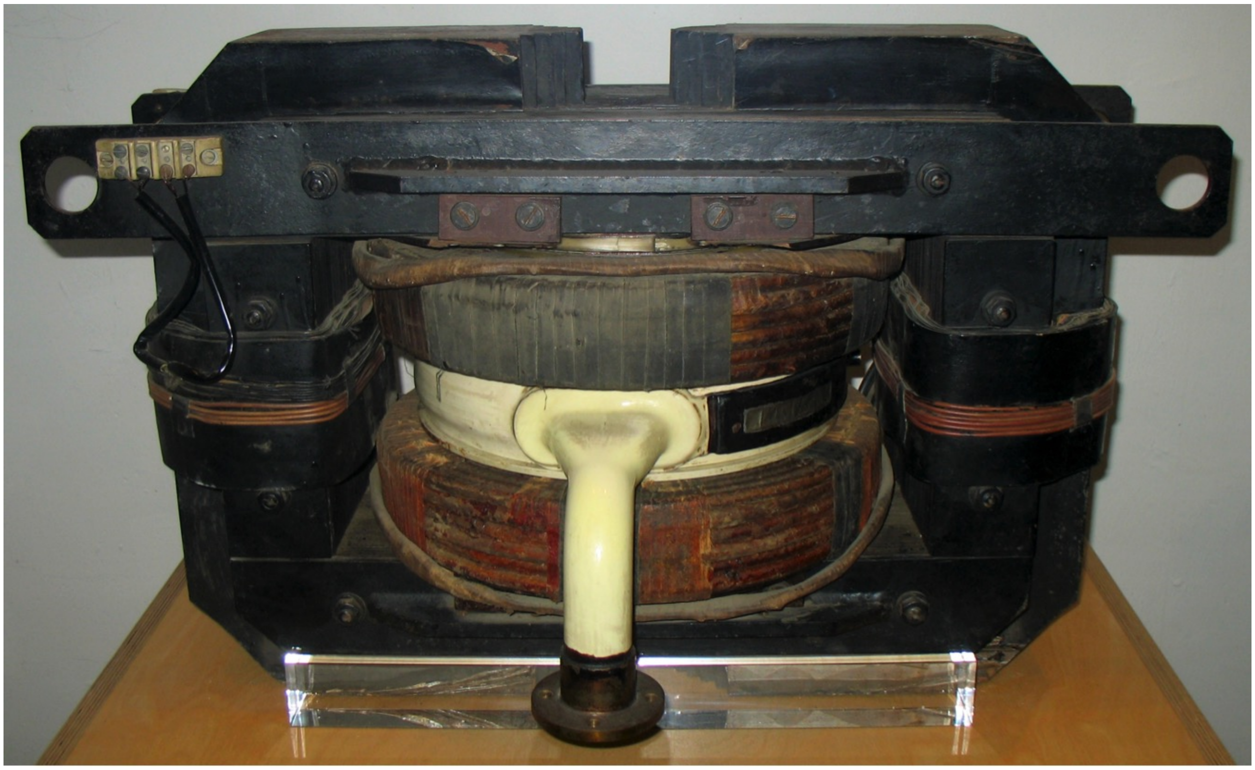

AUXILIARY (EXPANSION) COILS.
A
B
C
D
E
F
G
H (BAKELITE SPACERS BETWEEN CERAMIC AND DUST SHIMS)
FIG. 68
DETAILS OF 6 MEV. BETATRON
SIEMENS REINIGERWERKE, ERLANGEN
FIG. 69.
GRAMS RADIUM EQUIV'T
16
14
12
10
8
6
4
2
2·5
5
7·5
10
X10^{-5} MM. HG.
PAGE 134

Figure C.55: 6 MeV betatron [BIOS 1730].



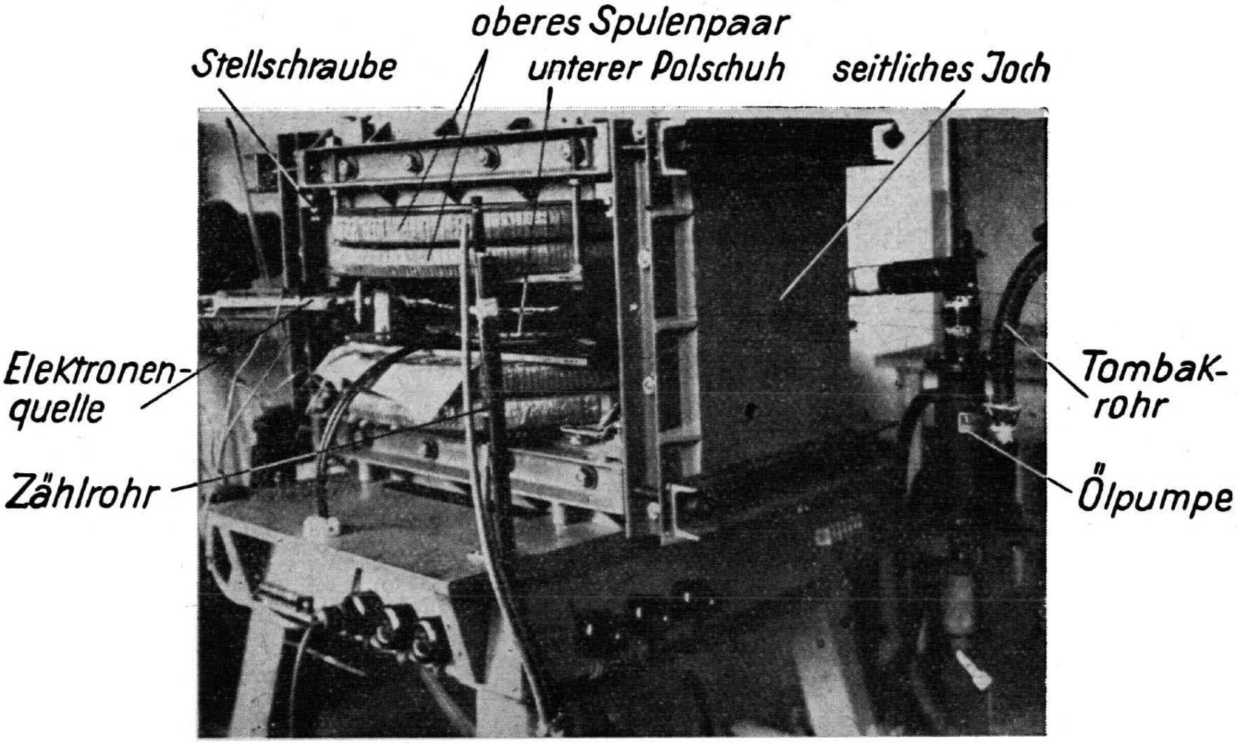

oberes Spulenpaar
Stellschraube
unterer Polschuh
seitliches Joch
Elektronenquelle
Tombakrohr
Zählrohr
Ölpumpe

Abb. 2. Photo des 15-MV-Betatrons.

Figure C.56: Top: 6 MeV betatron, now on display in the Deutsches Museum Bonn, with a mass (given by the museum) of 272 kg. Bottom: 15 MeV betatron.

BIOS 201. ***Visit to C.H.F. Müller AG Röntgenstr. 24 Bahrenfeld, Hamburg.***

[...] Müller had built in conjunction with a Norwegian scientist [Wideröe], a 15 million volt Betatron. This has been moved to Wrist. Dr. Fehr stated that this had been experimented with for the Luftwaffe with the hope (?) of obtaining a death-ray for anti-aircraft work. [...]

BIOS 212. ***Ultra-sonic Research and Development in X-Ray Equipment. Siemens-Reiniger Werke, AG Erlangen.***

[...] Another source of hard X-rays was a very efficient betatron that was built in Dr. Gund's laboratory. Using a 550 cycle supply energies up to 6 Mev. were obtained. The anode used was of gold and a thermocouple attached to it acted as a measure of the current intensity. 20% of the electron energy was assumed to go into radiation. The radiation intensity was equivalent to about 12 gm. of radium. [...]

[See also:

BIOS 148. *German Betatrons.*

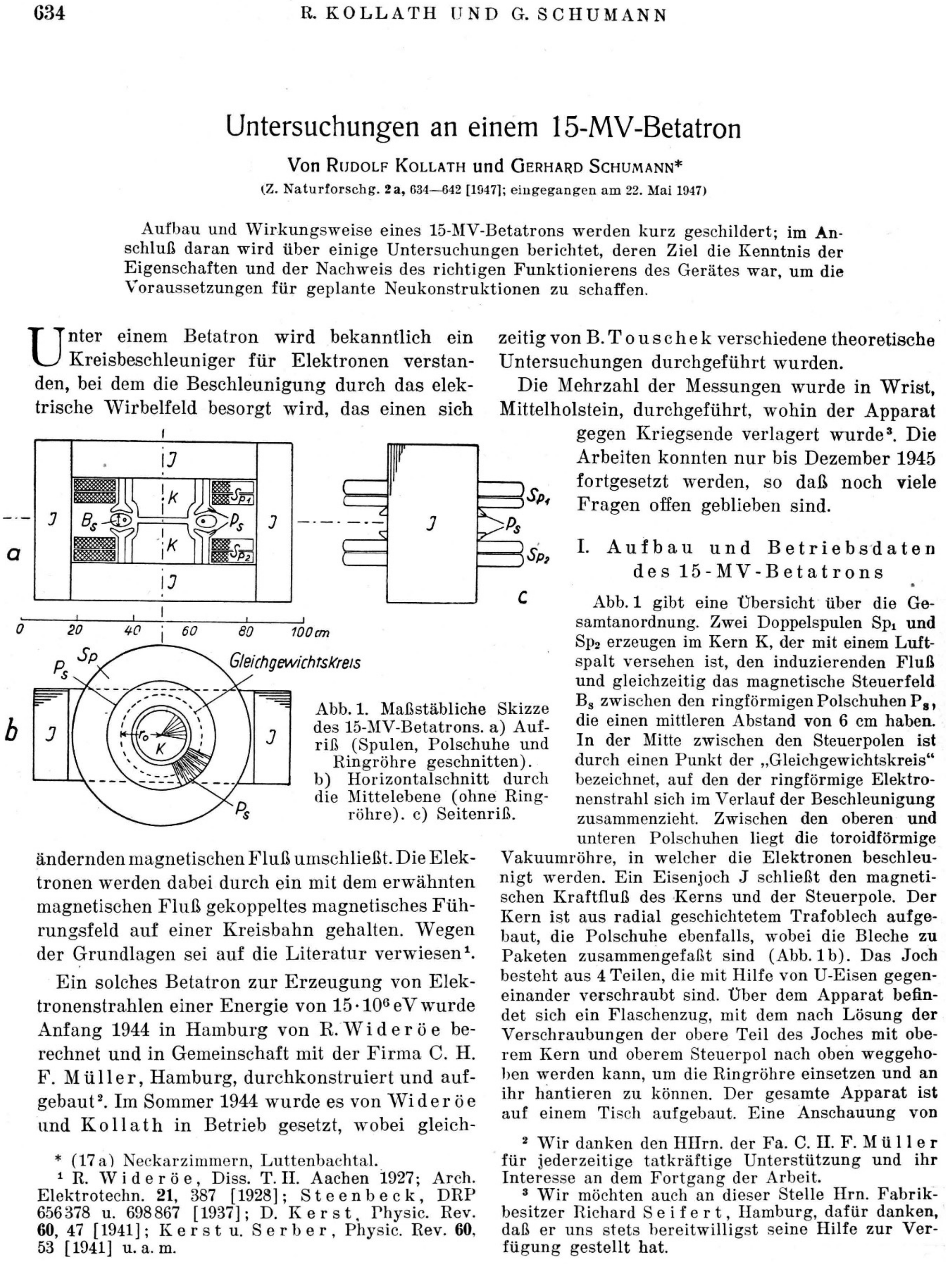
CIOS XXVIII-31. *Investigation of the X-Ray Industry in Germany.* (See pp. 3957–3970.)

FIAT 534. *Betatron Development in Germany.*

After the war, two scientists who worked on the 15 MeV betatron published a paper about it:

Rudolf Kollath and Gerhard Schumann. 1947. Untersuchungen an einem 15-MV-Betatron. *Zeitschrift für Naturforschung* 2a:634–642 [http://zfn.mpdl.mpg.de/data/Reihe_A/2/ZNA-1947-2a-0634.pdf].

See Fig. C.57.]



Untersuchungen an einem 15-MV-Betatron

Von Rudolf Kollath und Gerhard Schumann*

(Z. Naturforschg. **2a**, 634—642 [1947]; eingegangen am 22. Mai 1947)

Aufbau und Wirkungsweise eines 15-MV-Betatrons werden kurz geschildert; im Anschluß daran wird über einige Untersuchungen berichtet, deren Ziel die Kenntnis der Eigenschaften und der Nachweis des richtigen Funktionierens des Gerätes war, um die Voraussetzungen für geplante Neukonstruktionen zu schaffen.

Unter einem Betatron wird bekanntlich ein Kreisbeschleuniger für Elektronen verstanden, bei dem die Beschleunigung durch das elektrische Wirbelfeld besorgt wird, das einen sich ändernden magnetischen Fluß umschließt. Die Elektronen werden dabei durch ein mit dem erwähnten magnetischen Fluß gekoppeltes magnetisches Führungsfeld auf einer Kreisbahn gehalten. Wegen der Grundlagen sei auf die Literatur verwiesen[1].

Abb. 1. Maßstäbliche Skizze des 15-MV-Betatrons. a) Aufriß (Spulen, Polschuhe und Ringröhre geschnitten). b) Horizontalschnitt durch die Mittelebene (ohne Ringröhre). c) Seitenriß.

Ein solches Betatron zur Erzeugung von Elektronenstrahlen einer Energie von $15\cdot10^6$ eV wurde Anfang 1944 in Hamburg von R. Wideröe berechnet und in Gemeinschaft mit der Firma C. H. F. Müller, Hamburg, durchkonstruiert und aufgebaut[2]. Im Sommer 1944 wurde es von Wideröe und Kollath in Betrieb gesetzt, wobei gleichzeitig von B. Touschek verschiedene theoretische Untersuchungen durchgeführt wurden.

Die Mehrzahl der Messungen wurde in Wrist, Mittelholstein, durchgeführt, wohin der Apparat gegen Kriegsende verlagert wurde[3]. Die Arbeiten konnten nur bis Dezember 1945 fortgesetzt werden, so daß noch viele Fragen offen geblieben sind.

I. Aufbau und Betriebsdaten des 15-MV-Betatrons

Abb. 1 gibt eine Übersicht über die Gesamtanordnung. Zwei Doppelspulen Sp_1 und Sp_2 erzeugen im Kern K, der mit einem Luftspalt versehen ist, den induzierenden Fluß und gleichzeitig das magnetische Steuerfeld B_s zwischen den ringförmigen Polschuhen P_s, die einen mittleren Abstand von 6 cm haben. In der Mitte zwischen den Steuerpolen ist durch einen Punkt der „Gleichgewichtskreis“ bezeichnet, auf den der ringförmige Elektronenstrahl sich im Verlauf der Beschleunigung zusammenzieht. Zwischen den oberen und unteren Polschuhen liegt die toroidförmige Vakuumröhre, in welcher die Elektronen beschleunigt werden. Ein Eisenjoch J schließt den magnetischen Kraftfluß des Kerns und der Steuerpole. Der Kern ist aus radial geschichtetem Trafoblech aufgebaut, die Polschuhe ebenfalls, wobei die Bleche zu Paketen zusammengefaßt sind (Abb. 1b). Das Joch besteht aus 4 Teilen, die mit Hilfe von U-Eisen gegeneinander verschraubt sind. Über dem Apparat befindet sich ein Flaschenzug, mit dem nach Lösung der Verschraubungen der obere Teil des Joches mit oberem Kern und oberem Steuerpol nach oben weggehoben werden kann, um die Ringröhre einsetzen und an ihr hantieren zu können. Der gesamte Apparat ist auf einem Tisch aufgebaut. Eine Anschauung von

---

* (17a) Neckarzimmern, Luttenbachtal.

[1] R. Wideröe, Diss. T. H. Aachen 1927; Arch. Elektrotechn. **21**, 387 [1928]; Steenbeck, DRP 656378 u. 698867 [1937]; D. Kerst, Physic. Rev. **60**, 47 [1941]; Kerst u. Serber, Physic. Rev. **60**, 53 [1941] u. a. m.

[2] Wir danken den HHrn. der Fa. C. H. F. Müller für jederzeitige tatkräftige Unterstützung und ihr Interesse an dem Fortgang der Arbeit.

[3] Wir möchten auch an dieser Stelle Hrn. Fabrikbesitzer Richard Seifert, Hamburg, dafür danken, daß er uns stets bereitwilligst seine Hilfe zur Verfügung gestellt hat.

Figure C.57: Paper on the 15 MeV betatron.

George B. Davis to Francis J. Smith. 7 July 1945. Subject: JANISZEWSKI, Raman. Ref No SAIC/PIR/31 [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Attached is a copy of an interrogation report which indicates that PW [prisoner of war] has some knowledge along TA [tubealloy, or nuclear] lines. I have written to Captain Speer and asked him to arrange to intercept any reports of interviews of this man which might jeopardize TA security. We have made no arrangement to have him interviewed on our behalf as he does not appear to have been engaged in TA during the war.

Paul Kubala. 26 June 1945. Ref No SAIC/PIR/31. Seventh Army Interrogation Center. Preliminary Interrogation Report [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

SOURCE: JANISZEWSKI, Raman, Scientist

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1. PERSONAL DATA

Subject was born in 1891 in JANOWICE, Poland and studied engineering in POSEN and BERLIN. He devoted most of his life to research, ranging from mechanics to atom smashing. He had his own laboratories in WARSAW and POSEN and claims to have patented 86 inventions so far. In 1927 he was called by the President of Poland and received a secret assignment which he is unwilling to describe in any greater detail other than that it concerned research on war materials.

Source developed an apparatus to radio-activate metals, especially mercury. He claims that the rays produced by this machine black out radio waves, offset magnets, and have a deadly paralyzing effect on humans. He claims this machine is especially important in that it destroys the function of the gyroscope. Source declares his willingness to disclose all details of this machine and demonstrate it at his laboratory in the TYROL. He states that the secret of this machine has not fallen into German hands.

2. ADMINISTRATIVE DATA

Source was arrested by 103 MP Det, arrived this CENTER 24 May 45 on authority G-2, Seventh Army. Documents: blueprints and patent for tire-changing apparatus; papers on radio-activation of metals; and on invention of a special ignition coil.

3. KNOWLEDGE BRIEF

a. Details on radio-activation of metals, and atom smashing.

b. Tire-changing apparatus.

c. Other inventions.

4. INTERROGATION PLAN

Interrogation will be withheld until an expert in his field can exploit prisoner's knowledge.

5. COMMENTS AND RECOMMENDATIONS

It is suggested that subject be interrogated by a technical expert. The recipients of this report are requested to submit special briefs of any subject upon which this man should be interrogated.

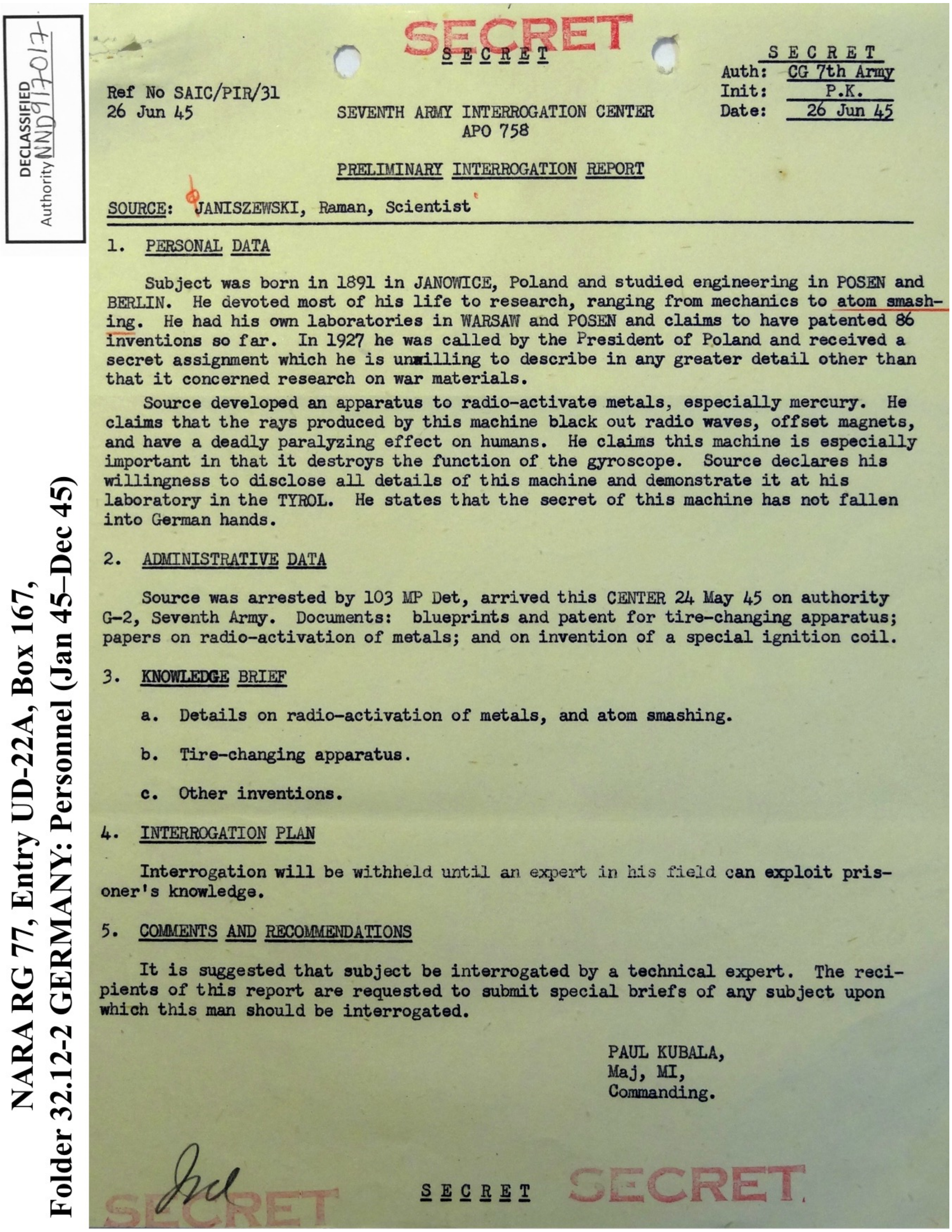
[Igor Witkowski received significant publicity for his claims that a mysterious German device called "die Glocke" or "the Bell" was built and tested in Poland during World War II [Cook 2001; Witkowski 2010, 2011, 2012, 2013; https://igorwitkowski.com/english.html]. Witkowski's claims about the Bell have been repeated by numerous books, television programs, and websites and have taken on a life of their own. As far as I am aware, Witkowski's personal statements are the only source of information that the Bell even existed, let alone what its historical and technical details were, and he has never presented any documents to substantiate his claims.

All of Witkowski's original books and articles are in Polish. Only a few of his books have been translated into German or English [Witkowski 2010, 2011, 2012, 2013]. Another Polish author, Bartosz Rdułtowski, analyzed the complete history of Witkowski's Polish writings and statements in considerable detail, and made what sounds like a very credible case that Witkowski simply invented the story of the Bell [Rdułtowski 2012b]. Even in the most charitable interpretation, the story of the Bell came to Witkowski from a source, who got it from another source, who likely got it from another source, none of whom were scientists, so one would expect the technical details to have gotten garbled along the way, as in the children's game of telephone.

The above interrogation report on Raman Janiszewski (see also Fig. C.58) has a few details that seem similar to some of those in Witkowski's Bell story: a device was developed in Poland during the war, it involved mercury, and it produced various strange and dangerous effects in its surroundings. The Janiszewski interrogation report does not say that the device was bell-shaped, or give any other details that have been claimed by Witkowski. It is not clear if the similarities are a coincidence, or if Witkowski used actual information such as that from Janiszewski and then added many fictional elaborations to the story, or if there may actually be some historical reality to the story of the Bell after all.

Even limiting the discussion to the Janiszewski interrogation report, it is not clear how credible Janiszewski was, how his device worked, and whether it would actually produce any of the variety of effects that he attributed to it. The Manhattan Project foreign intelligence officials, George Davis and Francis Smith, seemed to take his claims seriously though.

Can other information on Raman Janiszewski's background, his research, and his interrogations be located? Can any other similar documents be found?]



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Authority NND917017

SECRET

SECRET

Ref No SAIC/PIR/31
26 Jun 45

SEVENTH ARMY INTERROGATION CENTER
APO 758

SECRET
Auth: CG 7th Army
Init: P.K.
Date: 26 Jun 45

PRELIMINARY INTERROGATION REPORT

SOURCE: JANISZEWSKI, Raman, Scientist

1. PERSONAL DATA

Subject was born in 1891 in JANOWICE, Poland and studied engineering in POSEN and BERLIN. He devoted most of his life to research, ranging from mechanics to atom smashing. He had his own laboratories in WARSAW and POSEN and claims to have patented 86 inventions so far. In 1927 he was called by the President of Poland and received a secret assignment which he is unwilling to describe in any greater detail other than that it concerned research on war materials.

Source developed an apparatus to radio-activate metals, especially mercury. He claims that the rays produced by this machine black out radio waves, offset magnets, and have a deadly paralyzing effect on humans. He claims this machine is especially important in that it destroys the function of the gyroscope. Source declares his willingness to disclose all details of this machine and demonstrate it at his laboratory in the TYROL. He states that the secret of this machine has not fallen into German hands.

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c. Other inventions.

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Interrogation will be withheld until an expert in his field can exploit prisoner's knowledge.

5. COMMENTS AND RECOMMENDATIONS

It is suggested that subject be interrogated by a technical expert. The recipients of this report are requested to submit special briefs of any subject upon which this man should be interrogated.

PAUL KUBALA,
Maj, MI,
Commanding.

SECRET

SECRET

SECRET

NARA RG 77, Entry UD-22A, Box 167,
Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)

Figure C.58: Preliminary interrogation report on Raman Janiszewski [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Paul E. Todd, U.S. Air Forces in Europe, U.S. Air/Air Ministry Branch, to Assistant Chief of Staff, A-2, Headquarters, USAFE. 19 November 1946. Activities Report (11 through 16 November 1946). [AFHRA C5088 electronic version p. 957]

[...] (4) X-Death Ray report completed and forwarded, thru channels, to Assistant Chief of Staff, A-2, USAFE, A.D.I. (Science), Mr. Gerrard, and Joint Intelligence Bureau, Major Rushmore. [...]

[What German X-ray directed energy weapon was important enough and sufficiently well developed by the end of the war in Europe that the U.S. Army Air Forces was still writing a report on it 18 months after the war ended, and forwarding that report to high levels?

Can a copy of this report be located now?]

C.2 Electromagnetic Pulse

[Several Allied intelligence reports described the development and successful testing of some sort of German electromagnetic pulse (EMP) weapons capable of knocking out the electrical systems of engines, or other electrical devices. A nuclear explosion will generate a large EMP, but the German EMP generators described in the reports appear to have been non-nuclear. Many countries now have non-nuclear EMP weapons in their arsenals.]

Extract of Information—Source: Letter #1172/EM, 11 Mar. 1944 to Col. H. A. Kenyon from Col. A. J. P. Le Bel. [**AFHRA A1263 frame 213**]

Notable Incidents.

a.) On November 19, on the outskirts of Lens at 5:30 P.M. a British Plane was downed with no apparent struggle. The plane was flying normally when all of a sudden, it pitched to the ground and was crushed.

b.) English pilots, interned in Switzerland, have declared that as they flew over the Eastern part of France their apparatus had been deranged—also—reports have pointed to the fact that centers for the transmission of these rays have been installed at Ardennes.

These two facts lead us to surmise that the Germans have experimented with their secret weapon and that these rays or waves are capable of hampering Electric parts of plane motors and to disturb the apparatus on board.

Report Received from G-2, 12 April 1944 and Filed in Ski Site File.

Allen W. Dulles. 1 September 1944 OSS report. [**Allen W. Dulles Papers: Digital Files Series, MC019-09, Public Policy Papers, Department of Special Collections, Princeton University Library. https://findingaids.princeton.edu/catalog/MC019-09_c015 Correspondence_General_English_1942-1974_and_undated 1940s 19440901_0000031626.pdf**]

Sorrel reports that Breakers messenger on his last trip to Switzerland around July 10th, referred to a new secret weapon. This weapon is reported to consist of an apparatus by which the operation of motors in planes and tanks can be interrupted through some kind of secret long-distance interference by rays or waves. At the same time it was reported that experiments with this secret weapon had been successfully concluded and that production was to be started.

History of the Counter Intelligence Corps, Volume XX, Germany Overrun–Part I. March 1959. pp. XX-61–XX-62 [NARA RG 319, Entry UD-1080, Box 6].

Secret Weapons

That the Nazis had hoped to win the war by secret weapons became evident to XVIII Corps CIC Agents with the capture and subsequent interrogation of Werner Piel, a special air courier of secret technical devices for the Luftwaffe.

Piel claimed that the German laboratories that had produced V-1 and V-2 missiles had also perfected an array of diabolical devices that needed only large scale production before they could be used against the Allied armies.

The strangest and most fascinating of these secret weapons was described as a “secret ray” that would paralyze any vehicle to a halt. The instrument, which the Germans called “Adlergeraet” or “Eagle Apparatus,” was demonstrated to Piel and others at a proving ground near Danzig in July 1944. Piel asserted that an automobile driven across the testing area was brought to a complete standstill by the ray as if the spark of the vehicle had suddenly failed.

The mechanism was principally adapted for use by the Luftwaffe in night fighting. Planes equipped with the Adlergeraet could allegedly trail behind an adversary, bring him in range and then drop him from the sky by “konking out” his engines without firing a single round. This was the theory. No estimate of actual effectiveness had been made.

Piel’s connection with the secret devices was largely during the six weeks prior to his capture when he ferried the equipment from Berlin to Glasshuette, where the finished devices were made, and then delivered them to aircraft manufacturers.

Before CIC completed the interrogation of the ray-obsessed Piel, the Agents learned the current disposition of the informant’s organization, the Air Force High Command, Chief of Technical Division for Air Armament Transport. Apparently, Allied bombing of Berlin had been so effective that this German technical air wing had to be split into two branches, one in Austria and the other along the Baltic sea.[80]

80. XVIII Corps (Abn) G2 Periodic Rpt Nr 9, Annex Nr 1, “CIC Notes,” dtd 5 May 45, in FUSA G2 Jnl and File, 7–8 May 45, L-558 (UNCLASSIFIED), (Departmental Records Branch, AGO, Alexandria, Va.)

[Note that the interrogation of Piel seems to indicate that advanced research projects associated with the Luftwaffe were largely centered in Berlin (until they had to be evacuated due to Allied bombing), the Baltic coast, and Austria. That agrees with many other documents that indicate that Berlin, the Baltic coast, and Austria were three of the areas that had especially large concentrations of high technology development during the war.]

Merillat Moses, Chief, Scientific Branch, U.S. Military Intelligence Service, to Major Francis J. Smith. 16 November 1944. Evaluation of Reports on Rays or Charges to Neutralize Aircraft Motors. [**AFHRA A1263 frames 129–130**]

1. The Military Intelligence Service is in receipt of various reports dealing with rays for stopping or neutralizing aircraft motors such as:

> a. An ultra-violet ray for stalling airplane motors is being worked upon hard, but as yet without practical success.
>
> b. Experiments were being made on another electrical apparatus whereby vehicles coming within its field could be stopped.
>
> c. The famous “Death Ray” is spoken of again and it is said that several airplanes have been made to fall in the neighborhood of this installation.
>
> d. The use of radio ray [that] emits wave that slows down the motors of Allied planes flying over region.
>
> e. In February it was reported that the Germans were working on some mechanism to stop aircraft motors.
>
> f. A source who states that he has done much work for the P.T.T. at Tempelhof in Berlin and for the Reichspostforschungsanstalt claims that 80% of their laboratory work is on aviation. A high official and an engineer there have informed him that they have completed a new A/A weapon which will be turned out in mass production in two or three months.
>
> g. Experiments with “Death Rays” were conducted by AEG-Siemenstadt Berlin at Tempelhof in 1939. Guinea pigs were killed at a distance of 200 meters.
>
> h. An individual employed “on electrical matters”, not named or otherwise described, told the prisoner that the Germans had for years been experimenting with these death rays.
>
> j. Experiments of which he knew, (1) destroying the functions of aircraft motors with induced magnetic fields, (2) exploding aircraft in the air by direct ultra-violet ray.
>
> k. This weapon which emits waves or rays based on piezo-electricity is a development of the death ray. It is known that tests were made in 1938 and that [at] a distance of eight hundred meters an automobile motor was successfully stopped.
>
> l. The Germans will use within the next three weeks new generator which is capable of stopping motors.

2. An hypothesis has been received stating that by use of rays or charges the atmosphere surrounding the airplane engine could be ionized, causing the ignition system to spark at joints and also where the insulation has been cracked or broken, thereby causing a short circuit of the spark plug.

3. Any evaluation or opinion you may be able to render on the existence or practicability of any rays or charges, to include probably type of emission, range, size of installation required, would be highly appreciated.

Headquarters, United States Strategic Air Forces [USSTAF] in Europe, Office of the Director of Intelligence, An Evaluation of German Capabilities in 1945. The Commanders Intelligence Digest. 19 January 1945 [AFHRA folder 519.635 1945 Intelligence Digest; AFHRA A5729 electronic version pp. 255 onward and 561 onward; NARA RG 319, Entry UD-1041, Box 27, Folder 925497]].

1. In the following paragraphs are listed the actual or potential weapons which the Germans may use against USSTAF operations in 1945. For the most part they include the so-called V weapons. No consideration is given to those for which there is lacking evidence of possible use for some time to come. [...]

5. MAGNETIC WAVE: The best information available is from very secret and reliable sources, and forces the conclusion that this weapon exists as a possibility. It is designed to cause failure of various electrical apparatus in aircraft. [...]

[See document photos on pp. 5338–5340.

Point 1 above suggests that there is significant evidence for those weapons that are then listed.

Point 5 shows that an EMP weapon was reported by "very secret and reliable sources."]

V. W. Petersen, Headquarters United States Strategic Air Forces in Europe (Rear), Office of the Director of Intelligence, to General George C. McDonald. 24 January 1945. Preliminary Report on Suspected Magnetic Ray. [AFHRA A1263 frames 141–142]

1. This is a preliminary report on investigation of the P-38 aircraft which flew sortie No. 3832 over Frankfurt and the interrogation of the Pilot, Lt. Hitt. Over this area the Pilot encountered a freakish condition which indicates that the enemy may be using some new device (suspected as being a magnetic ray) as a defence measure against our aircraft.

2. The Pilot made three passes over the target area which was the northern part of Frankfurt for the purpose of taking aerial photographs. He took a number of frames on his first two passes, at approximately 22,000 ft. and 20,000 feet, but on his third pass at 17,500 ft. he ran into trouble with his aircraft. At this time he was flying in a straight slightly climbing condition, no flak of any kind was encountered and no evasive action was taken during the whole time over the target area.

3. In beginning his third pass his instruments began acting up and his left engine became very rough. [...]

4. The other gauges and instruments which were affected included the fuel level gauges, gyro compass and the artificial horizon. The hands on the fuel level gauges started spinning in the same direction. The gyro compass was also spinning through 360^o revolutions. The Pilot caged the compass at three different times and after uncaging each time the compass continued to spin through 360^o revolutions. The artificial horizon was floating in a peculiar attitude so that it could not be used. [...]

8. The instruments on Lt. Hitt's ship continued acting up for a period of eight to ten minutes; after this time they appeared to be functioning properly. [...]

Taylor Drysdale, P/W and X Detachment, U.S. Military Intelligence Service, to Col. H. G. Bunker, Director of Technical Services, Hq. USSTAF (Rear). 25 January 1945. ETOIB/Ext No. 101. [AFHRA A1263 frame 148]

The following information was given by German P/W (W/T Specialist) on German Experiments with Remote Control of Automobile and Airplane Motors.

(This material was written originally by P/W in German and has since been translated into English.)

In the year 1934 successful experiments were made in Germany on the paralyzing of combustion in Automobile Engine viz. the stopping of the motors. Subject heard also last year from a Laboratory Engineer of the Weapons Office, that vehicles and motors could be stopped at a distance of 150 meters (about 166 yards).

An Engineer belonging to a Research Institute of the R.M.V. who attended these experiments, said that the same thing could be done with airplanes.

In 1938, two German Aircraft Plants were entrusted with the order to study motors for aircraft without electrical ignition.

Between Augsburg and Munich, experiments were made in driving an electric motor by wireless.

During the last experiments a small ventilator motor (in Augsburg) was set in motion by a dispatcher controlled in Munich. The power used by the dispatching station in Munich was reported to be very strong.

[Unfortunately none of the available reports on German EMP weapons give any technical details about how the weapons actually worked. If such weapons were indeed developed during the war, how exactly did they generate an EMP? What was their range?

Several countries now have non-nuclear EMP weapons [see for example Fig. C.59 and
https://apps.dtic.mil/dtic/tr/fulltext/u2/a332511.pdf
https://sgp.fas.org/othergov/doe/lanl/pubs/00326620.pdf
and additional scientific references cited at the end of
https://en.wikipedia.org/wiki/Explosively_pumped_flux_compression_generator].

Were these modern weapons derived from captured hardware, documents, or personnel from wartime German EMP programs?]

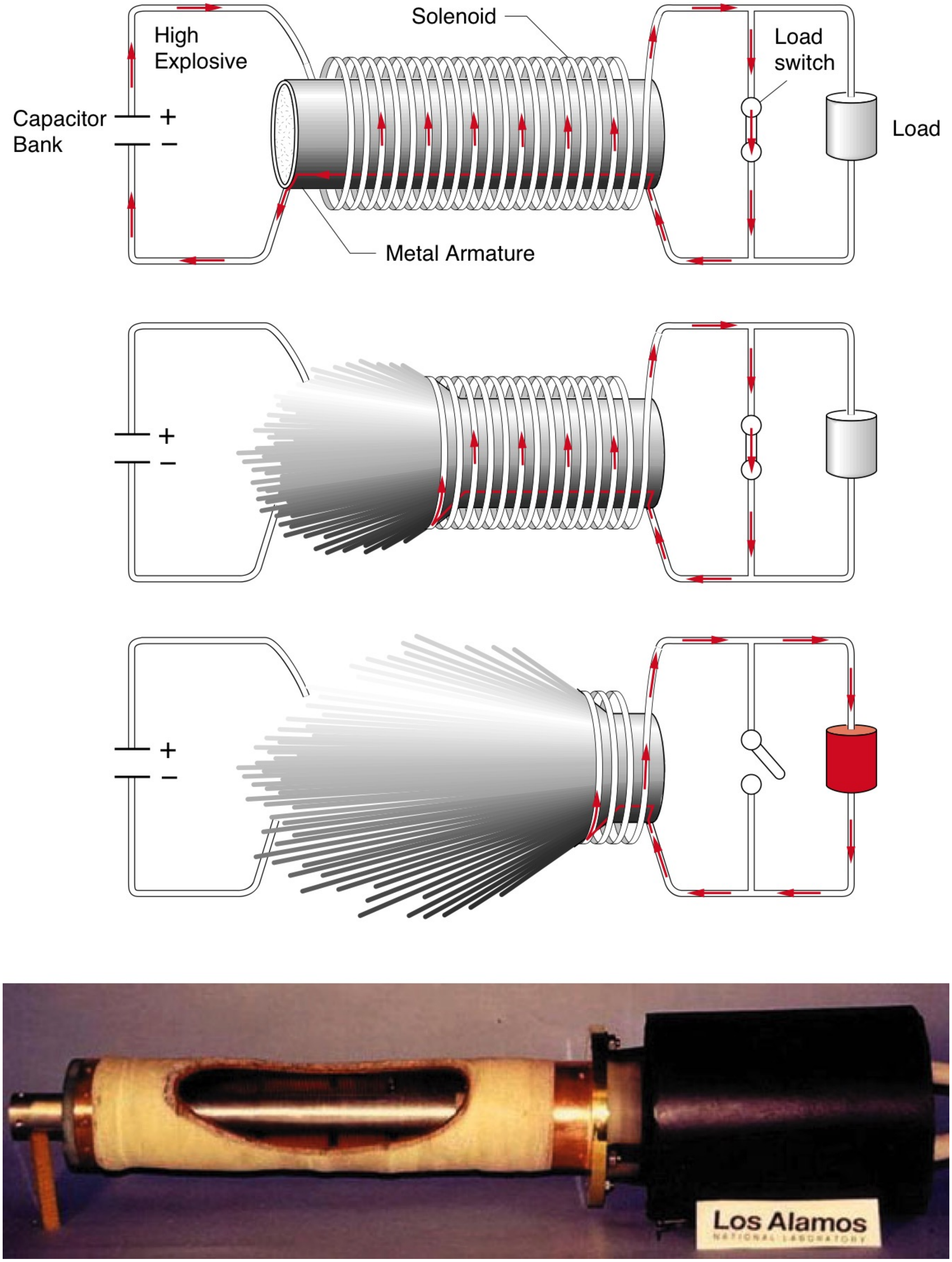
Solenoid
High Explosive
Load switch
Capacitor Bank
+
−
Load
Metal Armature
Los Alamos
NATIONAL LABORATORY

Figure C.59: Example of a modern electromagnetic pulse weapon.

C.3 Lasers

[A laser (Light Amplification by Stimulated Emission of Radiation) produces light that all has the same wavelength and the same phase, which enables all of the optical power to be concentrated into just one wavelength or color instead of a broader spectrum, and also allows the beam to remain much more tightly focused than a normal beam of light can. (Because the laser light all has the same wavelength and phase unlike a normal light beam, constructive interference with itself keeps it on course, and destructive interference with itself prevents it from veering off course.) According to official histories, the idea of a laser was not proposed until the late 1950s by Charles Townes, Arthur Schawlow, and Gordon Gould, and the first laser was not built until 1960 by Theodore Maiman, all in the United States.[1] As the following documents illustrate, most of the discoveries and innovations that led to lasers were made much earlier by German-speaking scientists, and there is some evidence that German-speaking scientists may have even been the first to produce a working laser. Documents on the German-derived work were sent to the United States and may have directly contributed to the U.S. work in this field in the late 1950s and early 1960s. Much more archival research is needed to investigate the complete history and the true impact of work in this field by German-speaking scientists [Albrecht 2019; Bertolotti 2015; Lemmerich 1987].]

Walter Isaacson. 2007. *Einstein: His Life and Universe.* pp. 322–323.

Einstein used Bohr's model as the foundation for a series of papers in 1916, the most important of which, "On the Quantum Theory of Radiation," was also formally published in a journal in 1917.

Einstein began with a thought experiment in which a chamber is filled with a cloud of atoms. They are being bathed by light (or any form of electromagnetic radiation). Einstein then combined Bohr's model of the atom with Max Planck's theory of the quanta. If each change in an electron orbit corresponded to the absorption or emission of one light quantum, then—presto!—it resulted in a new and better way to derive Planck's formula for explaining blackbody radiation. As Einstein boasted to Michele Besso, "A brilliant idea dawned on me about radiation absorption and emission. It will interest you. An astonishingly simple derivation, I should say *the* derivation of Planck's formula. A thoroughly quantized affair."

Atoms emit radiation in a spontaneous fashion, but Einstein theorized that this process could also be stimulated. A roughly simplified way to picture this is to suppose than an atom is already in a high-energy state from having absorbed a photon. If another photon with a particular wavelength is then fired into it, two photons of the same wavelength and direction can be emitted.

What Einstein discovered was slightly more complex. Suppose there is a gas of atoms with energy being pumped into it, say by pulses of electricity or light. Many of the atoms will absorb energy and go into a higher energy state, and they will begin to emit photons. Einstein argued that the presence of this cloud of photons made it even more likely that a photon of the same wavelength and direction as the other photons in the cloud would be emitted. This process of stimulated emission would, almost forty years later, be the basis for the invention of the laser, an acronym for "light amplification by the stimulated emission of radiation."

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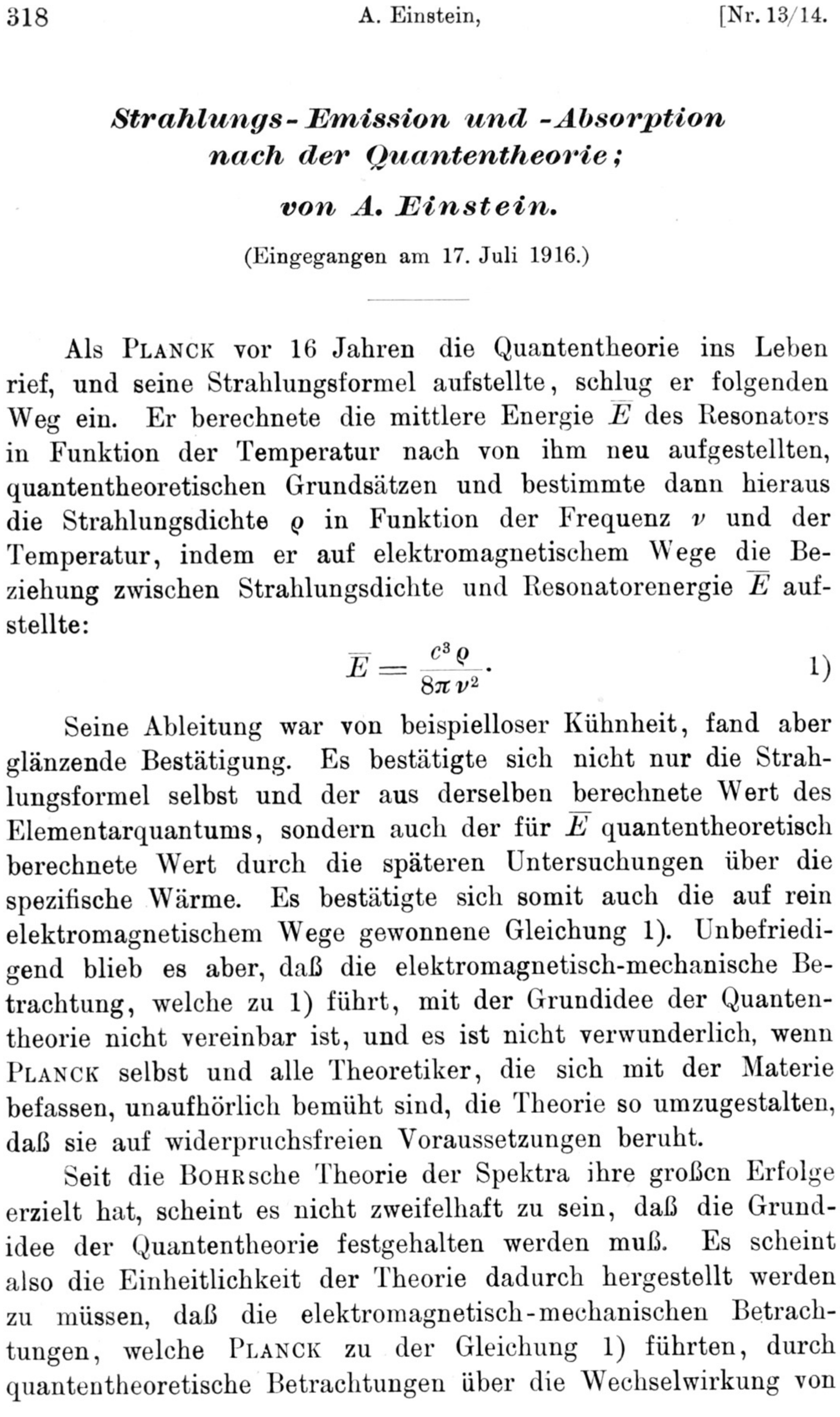
[1] See for example: Bertolotti 2015; Bromberg 1991; Hecht 2010; Taylor 2000; Townes 1999.



318 A. Einstein, [Nr. 13/14.

Strahlungs-Emission und -Absorption nach der Quantentheorie;

von A. Einstein.

(Eingegangen am 17. Juli 1916.)

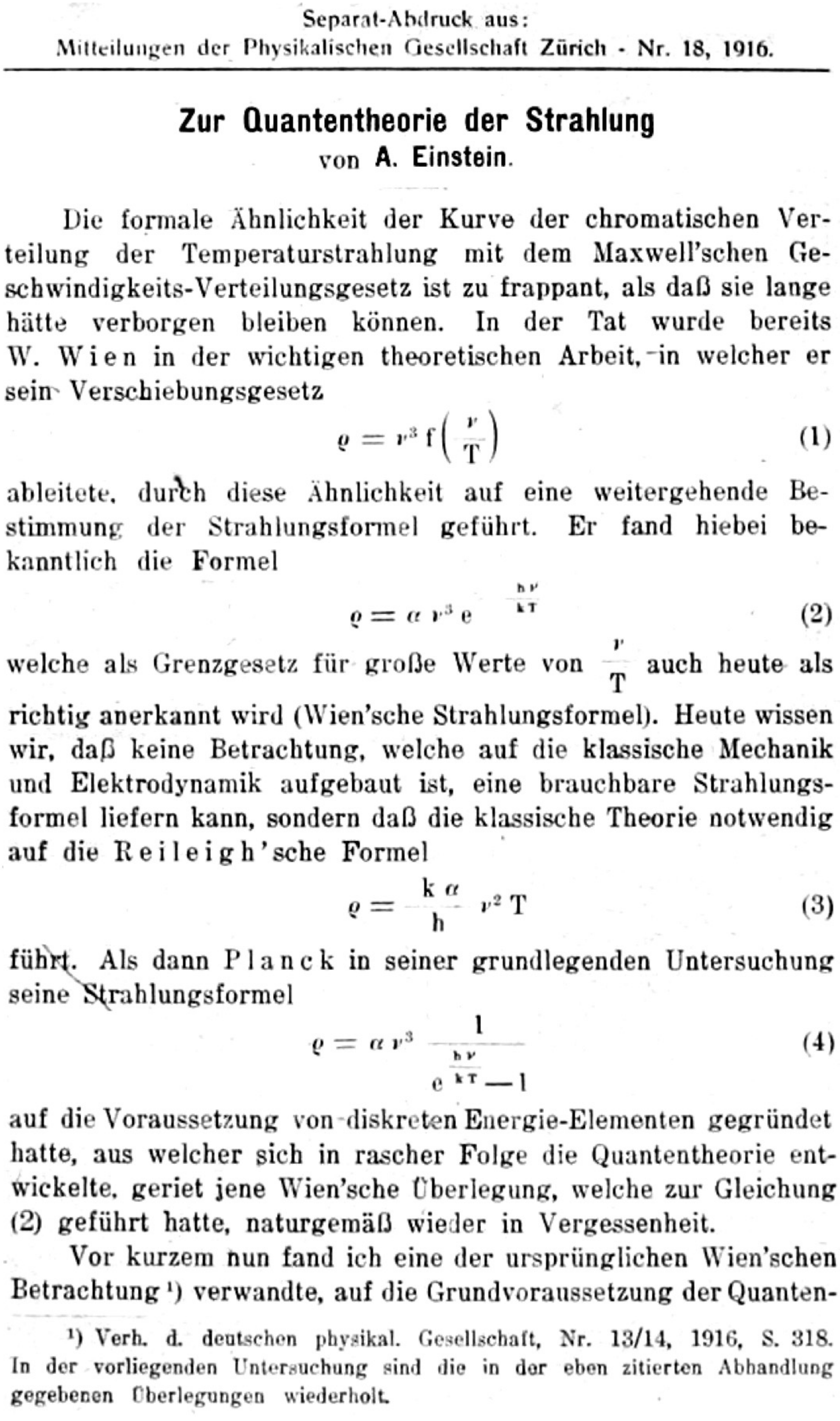
Als Planck vor 16 Jahren die Quantentheorie ins Leben rief, und seine Strahlungsformel aufstellte, schlug er folgenden Weg ein. Er berechnete die mittlere Energie $\overline{E}$ des Resonators in Funktion der Temperatur nach von ihm neu aufgestellten, quantentheoretischen Grundsätzen und bestimmte dann hieraus die Strahlungsdichte ϱ in Funktion der Frequenz ν und der Temperatur, indem er auf elektromagnetischem Wege die Beziehung zwischen Strahlungsdichte und Resonatorenergie $\overline{E}$ aufstellte:

$$\overline{E} = \frac{c^3 \varrho}{8\pi \nu^2}. \qquad 1)$$

Seine Ableitung war von beispielloser Kühnheit, fand aber glänzende Bestätigung. Es bestätigte sich nicht nur die Strahlungsformel selbst und der aus derselben berechnete Wert des Elementarquantums, sondern auch der für $\overline{E}$ quantentheoretisch berechnete Wert durch die späteren Untersuchungen über die spezifische Wärme. Es bestätigte sich somit auch die auf rein elektromagnetischem Wege gewonnene Gleichung 1). Unbefriedigend blieb es aber, daß die elektromagnetisch-mechanische Betrachtung, welche zu 1) führt, mit der Grundidee der Quantentheorie nicht vereinbar ist, und es ist nicht verwunderlich, wenn Planck selbst und alle Theoretiker, die sich mit der Materie befassen, unaufhörlich bemüht sind, die Theorie so umzugestalten, daß sie auf widerpruchsfreien Voraussetzungen beruht.

Seit die Bohrsche Theorie der Spektra ihre großen Erfolge erzielt hat, scheint es nicht zweifelhaft zu sein, daß die Grundidee der Quantentheorie festgehalten werden muß. Es scheint also die Einheitlichkeit der Theorie dadurch hergestellt werden zu müssen, daß die elektromagnetisch-mechanischen Betrachtungen, welche Planck zu der Gleichung 1) führten, durch quantentheoretische Betrachtungen über die Wechselwirkung von

Figure C.60: Albert Einstein first proposed the idea of stimulated light emission from atoms (amplification of the number of photons of light from atoms) in 1916 [*Verhandlungen der Deutschen Physikalischen Gesellschaft* (1916) 18:13–14:318–323].



Separat-Abdruck aus:
Mitteilungen der Physikalischen Gesellschaft Zürich - Nr. 18, 1916.

Zur Quantentheorie der Strahlung

von **A. Einstein**.

Die formale Ähnlichkeit der Kurve der chromatischen Verteilung der Temperaturstrahlung mit dem Maxwell'schen Geschwindigkeits-Verteilungsgesetz ist zu frappant, als daß sie lange hätte verborgen bleiben können. In der Tat wurde bereits W. Wien in der wichtigen theoretischen Arbeit, in welcher er sein Verschiebungsgesetz

$$\varrho = \nu^3 \, f\left(\frac{\nu}{T}\right) \tag{1}$$

ableitete, durch diese Ähnlichkeit auf eine weitergehende Bestimmung der Strahlungsformel geführt. Er fand hiebei bekanntlich die Formel

$$\varrho = \alpha \, \nu^3 \, e^{-\frac{h\nu}{kT}} \tag{2}$$

welche als Grenzgesetz für große Werte von $\frac{\nu}{T}$ auch heute als richtig anerkannt wird (Wien'sche Strahlungsformel). Heute wissen wir, daß keine Betrachtung, welche auf die klassische Mechanik und Elektrodynamik aufgebaut ist, eine brauchbare Strahlungsformel liefern kann, sondern daß die klassische Theorie notwendig auf die Reileigh'sche Formel

$$\varrho = \frac{k\alpha}{h} \nu^2 T \tag{3}$$

führt. Als dann Planck in seiner grundlegenden Untersuchung seine Strahlungsformel

$$\varrho = \alpha \, \nu^3 \frac{1}{e^{\frac{h\nu}{kT}} - 1} \tag{4}$$

auf die Voraussetzung von diskreten Energie-Elementen gegründet hatte, aus welcher sich in rascher Folge die Quantentheorie entwickelte, geriet jene Wien'sche Überlegung, welche zur Gleichung (2) geführt hatte, naturgemäß wieder in Vergessenheit.

Vor kurzem nun fand ich eine der ursprünglichen Wien'schen Betrachtung¹) verwandte, auf die Grundvoraussetzung der Quanten-

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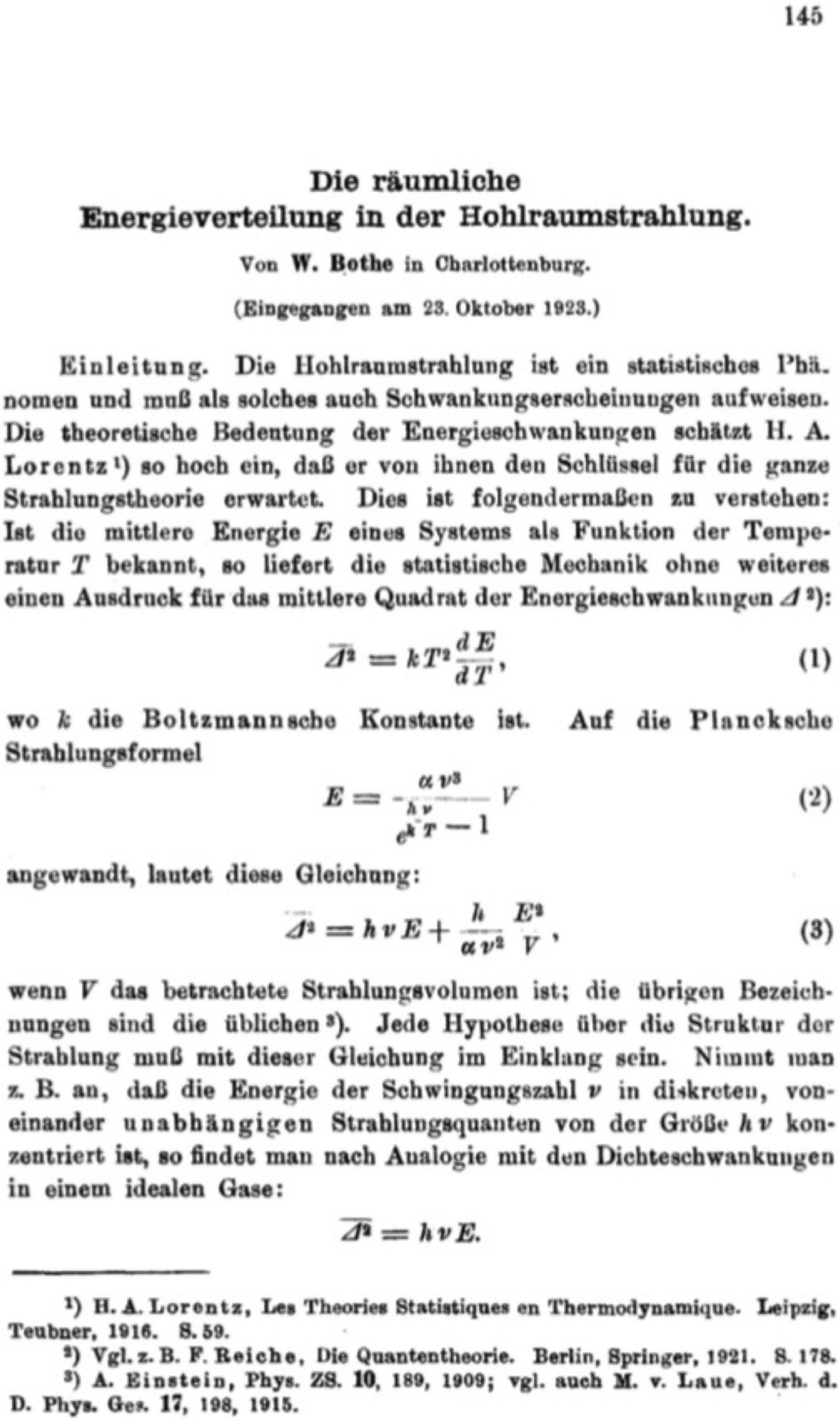
¹) Verh. d. deutschen physikal. Gesellschaft, Nr. 13/14, 1916, S. 318. In der vorliegenden Untersuchung sind die in der eben zitierten Abhandlung gegebenen Überlegungen wiederholt.

Figure C.61: Albert Einstein first proposed the idea of stimulated light emission from atoms (amplification of the number of photons of light from atoms) in 1916 [*Mitteilungen der Physikalischen Gesellschaft Zürich* (1916) 18:47–62].



145

Die räumliche Energieverteilung in der Hohlraumstrahlung.

Von **W. Bothe** in Charlottenburg.

(Eingegangen am 23. Oktober 1923.)

Einleitung. Die Hohlraumstrahlung ist ein statistisches Phänomen und muß als solches auch Schwankungserscheinungen aufweisen. Die theoretische Bedeutung der Energieschwankungen schätzt H. A. Lorentz 1) so hoch ein, daß er von ihnen den Schlüssel für die ganze Strahlungstheorie erwartet. Dies ist folgendermaßen zu verstehen: Ist die mittlere Energie E eines Systems als Funktion der Temperatur T bekannt, so liefert die statistische Mechanik ohne weiteres einen Ausdruck für das mittlere Quadrat der Energieschwankungen $\varDelta$ 2):

$$\overline{\varDelta^2} = kT^2 \frac{dE}{dT}, \tag{1}$$

wo k die Boltzmannsche Konstante ist. Auf die Plancksche Strahlungsformel

$$E = \frac{\alpha\nu^3}{e^{\frac{h\nu}{kT}} - 1} V \tag{2}$$

angewandt, lautet diese Gleichung:

$$\overline{\varDelta^2} = h\nu E + \frac{h}{\alpha\nu^2} \frac{E^2}{V}, \tag{3}$$

wenn V das betrachtete Strahlungsvolumen ist; die übrigen Bezeichnungen sind die üblichen 3). Jede Hypothese über die Struktur der Strahlung muß mit dieser Gleichung im Einklang sein. Nimmt man z. B. an, daß die Energie der Schwingungszahl ν in diskreten, voneinander unabhängigen Strahlungsquanten von der Größe $h\nu$ konzentriert ist, so findet man nach Analogie mit den Dichteschwankungen in einem idealen Gase:

$$\overline{\varDelta^2} = h\nu E.$$

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1) H. A. Lorentz, Les Theories Statistiques en Thermodynamique. Leipzig, Teubner, 1916. S. 59.

2) Vgl. z. B. F. Reiche, Die Quantentheorie. Berlin, Springer, 1921. S. 178.

3) A. Einstein, Phys. ZS. 10, 189, 1909; vgl. auch M. v. Laue, Verh. d. D. Phys. Ges. 17, 198, 1915.

Figure C.62: Walther Bothe further developed the theory of stimulated light emission from atoms (amplification of the number of photons of light from atoms) in 1923 [*Zeitschrift für Physik* (1923) 20:1:145–152].

Jost Lemmerich. 2011. *Science and Conscience: The Life of James Franck.* pp. 64–65.

[James Franck] pointed out furthermore that in electrical excitation of gases and vapors the series of spectrum lines are stimulated only very incompletely, since the higher terms of the series are weak in intensity. On the basis of his 1916 research with Hertz, Franck realized that this difficulty could be circumvented if a gas with a low excitation potential was added to one with a high excitation potential. Then very sharply defined lines of a sufficient intensity are easily obtained for the higher series of the gas of low excitation potential. Thus with an admixture of helium, hydrogen could be analyzed well. Such experiments became an important tool for verifying the different theories.

The next three papers brought Franck step by step closer to an experimental proof of a new behavior of electrons in the excited state inside an atom. Many decades later, these results would prove useful in the development of the laser.

[...] A footnote contained a premonition of the future discovery of the laser:

> [O]n the whole, the interesting fact that according to Paschen excited helium, that is, helium in an alkali-like state, exhibits a resonance emission, seems to us to offer a hint that the alkali-like state of helium is somewhat metastable. An electron raised out of this orbit into the next one always returns to this biquantum orbit and never jumps directly into the monoquantum stable orbit.

Franck was clearly on the way to discovering the metastable state of helium. The issue of the *Physikalische Zeitschrift* containing this paper appeared on November 1 [1919].

Heinrich Gerhard Kuhn. 1965. James Franck 1882–1964. *Biographical Memoirs of Fellows of the Royal Society* 11:52–74.
[https://royalsocietypublishing.org/doi/pdf/10.1098/rsbm.1965.0004]

Jointly with a number of co-workers Franck continued the study of the inelastic collisions of electrons with both atoms and molecules, of *excitation*- and *ionization-potentials*, but now with Bohr's theory as a guiding principle. The theoretical adviser of the group was Fritz Reiche, and it was Franck, Knipping and Reiche who coined the word '*metastable level*' and established the important part of metastable states in excitation processes. The question of how metastable atoms finally lose their energy, now strongly occupied Franck's attention.

Jost Lemmerich. 1987. *Zur Geschichte der Entwicklung des Lasers.* Berlin: DAVID. pp. 22–26, 59–60

In Berlin, an der Physikalisch-Technischen Reichsanstalt, war schon vor dem Ersten Weltkrieg Walther Bothe, der bei Planck promoviert hatte, für Hans Geiger als Mitarbeiter eingestellt worden. Bothe veröffentlichte 1923 als Fortführung der Arbeit Einsteins: "*Die räumliche Energieverteilung in der Hohlraumstrahlung*" <9>. In der Einleitung faßte er noch einmal die Ergebnisse von Einsteins Veröffentlichungen zusammen und benutzt dabei die Nomenklatur *spontane Emission* für den üblichen Vorgang der Ausstrahlung bei der Anregung von Atomen, *Absorption* bzw. *positive Einstrahlung* und *erzwungene Emission* bzw. *negative Einstrahlung.* Wörtlich heißt es dann bei der Interpretation von Einsteins Ergebnissen:

"*Weiterhin schließt Einstein durch Impulsbetrachtungen, daß ein ungestörtes thermodynamisches Gleichgewicht zwischen der Strahlung und der Wärmebewegung eines Gases nur möglich ist, wenn die drei angegebenen Elementarprozesse streng gerichtet verlaufen, d.h. absorbiert eine Molekul Strahlung, so entnimmt sie diese einem Strahlenbündel von unendlich kleiner Konvergenz; entsprechend wird bei der Emission die Energie in einem unendlich kleinen Raumwinkel gestrahlt, sie breitet sich nicht seitlich aus; im Falle der erzwungenen Emission ist die Emissionsrichtung genau die desjenigen einfallenden Strahlenbündels, welches die Emission verursacht, während die Richtung der spontane Emission dem Zufall unterliegt.*"

Wiederum war damit deutlich ausgesprochen, daß die erzwungene, stimulierte Emission zu einer Lichtquelle in einem kleinen Raumwinkel führen müßte. Die Frage der Kohärenz wird—wie auch bei Einsteins Arbeit—durch Bothe nicht angesprochen.

In Berlin, at the Physikalisch-Technische Reichsanstalt, Walther Bothe, who had completed his doctorate under Planck, had already been employed by Hans Geiger before the First World War. Bothe published in 1923 as a continuation of Einstein's work: "*The spatial energy distribution in cavity radiation*" <9>. In the introduction he once again summarized the results of Einstein's publications and used the nomenclature *spontaneous emission* for the usual process of radiation from the excitation of atoms, *absorption* or *positive irradiation* and *stimulated emission* or *negative irradiation.* The interpretation of Einstein's results literally means:

"*In addition, Einstein concludes by impulse considerations that an undisturbed thermodynamic equilibrium between the radiation and the thermal motion of a gas is only possible if the three specified elementary processes are strictly directional, i.e. if a molecule absorbs radiation, it takes it from a beam of infinitely small convergence; accordingly, during emission, the energy is radiated in an infinitely small solid angle, it does not propagate laterally; in the case of stimulated emission, the direction of emission is exactly that of the incident beam causing the emission, while the direction of spontaneous emission is random.*"

Again it was clearly stated that the forced, stimulated emission must lead to a light source within a small solid angle. The question of coherence is not addressed by Bothe—as also in Einstein's work.

Der Hauptteil der Botheschen Arbeit behandelt den Vorgang des Auftretens von Quantenpaaren, also doppelten und mehrfachen davon, bei der erzwungenen Emission. Bothe gibt auch eine Methode zum Nachweis der Quantenpaare an.

Nur ein Jahr nach Bothes Arbeit erschien das *Physikalische Handwörterbuch* <10>, herausgegeben von Arnold Berliner und Karl Scheel. Für das Stichwort Lichtquanten referiert A. Smekal. Während Smekal die Lichtquantenhypothese Einsteins für die Wechselwirkung zwischen Strahlung und Materie anerkennt, fährt er fort:

"*Einsteins Betrachtungen über das Impulsgleichgewicht zwischen Materie und Strahlung (s. Nadelstrahlung) beweisen zwar, daß die Strahlungsemission nicht in Kugelwellen—wie nach der klassischen Elektrodynamik—, sondern im gewissen Sinne einseitig, also gerichtet, erfolgt, was zweifellos nicht zu ungunsten der Lichtquanten spricht, doch lassen sich bindende Schlüsse auf die Eigenschaft freier Lichtquanten hieraus ebenfalls nicht ziehen. Eine endgültige Beurteilung der Lichtquantenhypothese, die übrigens zu gewissen Schwierigkeiten mit dem Kausalitätsprinzip zu führen scheint, ist daher bis jetzt noch nicht möglich gewesen.*"

Seit 1900 hatte die Experimentalphysik große Fortschritte gemacht. Für die technische Durchgestaltung der Glühlampe war es notwendig gewesen, bessere Vakuumpumpen zu entwicklen. Ebenso erforderte die Herstellung von Verstärkerröhren einfach zu handhabende Hochvakuumpumpen. Diese technischen Möglichkeiten der Vakuumerzeugung nutzen die Physiker, um ihrerseits intensiv die Erforschung der Physik der Gasentladungen aufzugreifen.

The main part of Bothe's work deals with the process of the occurrence of quantum pairs, i.e. double and multiple quantum pairs, in stimulated emission. Bothe also gives a method for the detection of quantum pairs.

Only one year after Bothe's work the *Dictionary of Physics* <10>, edited by Arnold Berliner and Karl Scheel, appeared. A. Smekal writes the entry on light quanta. While Smekal acknowledges Einstein's light quantum hypothesis for the interaction between radiation and matter, he continues:

"*Einstein's considerations about the impulse equilibrium between matter and radiation (see directional radiation) prove indeed that the radiation emission does not take place in spherical waves—like according to the classical electrodynamics—, but is in a certain sense one-sided, thus directed, which undoubtedly does not speak to the disadvantage of the light quanta, but binding conclusions about the property of free light quanta cannot be drawn from this either. A final evaluation of the light quantum hypothesis, which by the way seems to lead to certain difficulties with the causality principle, has therefore not yet been possible.*"

Since 1900 experimental physics had made great progress. For the technical design of the incandescent lamp it had been necessary to develop better vacuum pumps. The manufacture of amplifier tubes also required high-vacuum pumps that were easy to handle. The physicists used these technical possibilities of vacuum generation to intensively investigate the physics of gas discharges.

Am Kaiser-Wilhelm-Institut für Physikalische Chemie in Berlin untersucht Fritz Reiche und Paul Knipping unter Leitung von James Franck die Wechselwirkung von Elektronen mit Atomen. Regt man Atome mit Elektronen an, wie dies James Franck und Gustav Hertz in ihrem klassischen Experiment 1913 getan hatten, so kann mann nicht nur die Energieniveaus der Elektronen im Atom bestimmen, sondern konnte damals bereits erste Angaben über die Lebensdauer der angeregten Zustände machen. In der Veröffentlichung von 1920 in der Zeitschrift für Physik beschreiben Franck und Reiche die Ergebnisse ihrer Messungen an Helium <11>. Die übliche Verweilzeit von Elektronen im angeregten Zustand beträgt nur etwa 10^{-8} Sekunden. Franck und Reiche konnten zeigen, daß im angeregten Helium ein Zustand existierte, der wesentlich langlebiger ist, den sie metastabilen Zustand nannten. Dieser metastabile Zustand hat ein etwas niedrigeres Energieniveau als der sehr viel kurzlebigere.

Nachdem James Franck einen Ruf an die Universität Göttingen annahm, führte er dort mit seinen Mitarbeitern die Untersuchungen weiter und fand, daß es bei Gasgemischen möglich ist, über die Anregung eines Bestandteiles der andern Bestandteil anzuregen. Dies geschieht durch die Übertragung der Anregungsenergie, ohne daß es dabei zur Aussendung von Strahlung kommt. Man bezeichnet dies als Stöße zweiter Art <12>.

Nach dem Fortgang von Franck nach Göttingen trat Rudolf Ladenburg in das Kaiser-Wilhelm-Institut für Physikalische Chemie ein und Ende der 20er Jahre erschien in rascher Folge eine Reihe von Arbeiten über die Untersuchung der anomalen Dispersion bei Gasentladungen <13>.

At the Kaiser Wilhelm Institute for Physical Chemistry in Berlin, Fritz Reiche and Paul Knipping, led by James Franck, are investigating the interaction of electrons with atoms. If one excites atoms with electrons, as James Franck and Gustav Hertz had done in their classical experiment of 1913, then one can not only determine the energy levels of the electrons in the atom, but could also make initial statements about the lifetime of the excited states at that time. In the publication of 1920 in the Zeitschrift für Physik Franck and Reiche describe the results of their measurements of helium <11>. The usual residence time of electrons in the excited state is only about 10^{-8} seconds. Franck and Reiche were able to show that in excited helium a state existed which is much more long-lived, which they called a metastable state. This metastable state has a slightly lower energy level than the much shorter one.

After James Franck accepted a call to the University of Göttingen, he and his colleagues continued the investigations and found that in gas mixtures it is possible to stimulate one component by stimulating the other component. This is done by transferring the excitation energy without emitting radiation. This is called second type shock <12>.

After Franck had left for Göttingen, Rudolf Ladenburg joined the Kaiser Wilhelm Institute for Physical Chemistry and at the end of the 1920s a series of papers on the investigation of the anomalous dispersion in gas discharges <13> appeared in rapid succession.

Ladenburg arbeitete mit verschiedenen Mitarbeitern zusammen, u.a. mit Hans Kopfermann. Das Ziel ihrer Versuche war die Untersuchung des Gleichgewichtes zwischen den Elektronen und angeregten Atomen. Dazu führten sie spektroskopische Messungen an Gasentladungen durch, die in verhältnismäßig dünnen und langen Röhren—ähnlich den späteren Laser-Röhren—brannten. Durch die angewendeten Anregungsbedingungen erreichten sie eine sogenannte Inversion der Besetzungszustände im Neon. Das heißt, in einem angeregten Energieniveau befanden sich mehr Elektronen als im Grundzustand. Eine Grundbedingung, um einen Laser zu betreiben.

Zusammenfassend referierte Ladenburg über diese Arbeiten nach seiner Übersiedlung nach Amerika vor 1933 in der Zeitschrift Reviews of Modern Physics unter dem Titel “*Dispersion in electrically excited gases*” <14>.

Franck und Ladenburg waren mit Einstein, der immer an experimentellen Arbeiten interessiert war, gut befreundet. Es ist verwunderlich, daß sie offenbar niemals über diese Arbeiten im Zusammenhang mit seinem Ideen über die erzwungene Emission diskutierten, zumal Ladenburg bei seinem Arbeiten zusammen mit Levy zur Untersuchung der Struktur den Linien seiner Gasentladungen ein Fabry-Perot-Inteferometer <15> anwendete. Dieses Interferometer besteht aus zwei senkrecht in einem festen Abstand zueinander stehenden Spiegeln. Es stellt einer Art optischen Hohlraumresonator dar und kann als Rückkopplung der Strahlung in den dazwischenliegenden Hohlraum betrachtet werden. (Die damals verwendeten Spiegel mit versilberten Oberflächen hätten allerdings nicht die Möglichkeit zugelassen, mit einer Gasentladung einen Laser in Gang zu setzen, da die Reflexion zu niedrig war.)

Ladenburg worked with various collaborators, including Hans Kopfermann. The aim of their experiments was to investigate the equilibrium between electrons and excited atoms. For this purpose they carried out spectroscopic measurements on gas discharges, which glowed in relatively thin and long tubes, similar to the later laser tubes. Through the applied excitation conditions they achieved a so-called inversion of the occupation states in the neon. This means that in an excited energy level there were more electrons than in the ground state. A basic condition for operating a laser.

As a summary, Ladenburg spoke about these works after his move to America before 1933 in the journal Reviews of Modern Physics under the title “*Dispersion in electrically excited gases*” <14>.

Franck and Ladenburg were good friends with Einstein, who was always interested in experimental work. It is surprising that they apparently never discussed this work in connection with his ideas about stimulated emission, especially since Ladenburg and Levy used a Fabry-Perot inteferometer <15> to investigate the structure of the gas discharge lines. This interferometer consists of two perpendicular mirrors at a fixed distance from each other. It is a kind of optical cavity resonator and can be considered as feedback of the radiation into the intermediate cavity. (The mirrors with silver-plated surfaces used at that time, however, would not have allowed the possibility of starting a laser with a gas discharge, since the reflection was too low.)

[Lemmerich’s claim that German mirrors circa 1930 were not good enough to make a laser is false. Companies such as Zeiss and Leitz had been making extremely high-quality optical components, including mirrors, since the mid-1800s. Moreover, it is actually preferable for one or both mirrors of a laser not to be perfectly reflecting, so that some of the light can escape to form a beam.]

Im Oktober 1932 schloß Max Born das Manuskript für sein Buch "*Optik—ein Lehrbuch der elektromagnetischen Lichttheorie*" <16> ab. Es wurde einer Generation von Physikern, die sich mit der Theorie der Optik beschäftigten, das wichtigste Lehrbuch. Als die Radartechnik während des Zweiten Weltkrieges entwickelt wurde, griff man auf Borns grundlegendes Buch zurück, denn eine Verbindung von Hochfrequenztechnik und Optik bahnte sich an.

Born ging in seinem Buch ausführlich auf die Erscheinungen der Interferenz und Kohärenz sowie der stehenden Wellen ein, die bereits Wiener 1899 beim Licht nachgewiesen hatte. Detailiert beschrieb er auch die Interferometer, wie das von Fabry-Perot. Als theoretischer Physiker widmete er besondere Sorgfalt den theoretischen Betrachtungen über das Verständnis der Emission, Dispersion und anomalen Dispersion. Born referierte sowohl Einsteins wie auch Ladenburgs Arbeiten. Jedoch wurden Begriffe wie Rückkopplung und phasengerechte Verstärkung im Zusammenhang mit Emissionsvorgängen nicht diskutiert.

In October 1932, Max Born completed the manuscript for his book "*Optics–a Textbook of Electromagnetic Light Theory*" <16>. It became the most important textbook for a generation of physicists working in the theory of optics. When radar technology was developed during the Second World War, Born's basic book was used because a combination of high frequency technology and optics was emerging.

In his book Born dealt in detail with the phenomena of interference and coherence as well as standing waves, which had already been demonstrated by Wiener in 1899. He also described the interferometers in detail, such as that of Fabry-Perot. As a theoretical physicist he devoted special attention to theoretical considerations about the understanding of emission, dispersion and anomalous dispersion. Born lectured on both Einstein's and Ladenburg's work. However, terms such as feedback and phase-adjusted gain were not discussed in connection with emission processes.

Ein Ansatz zum Bau einer intensiven monochromatischen kohärenten Lichtquelle für Untersuchungen in der Optik zeigte sich nicht. Beim Experimentieren mußte man sich mit vorgeschalteten Filtern und einer Lochblende begnügen, um eine kohärente Lichtquelle aus dem Licht einer Glühlampe zu realisieren. Die Intensität war infolge der verwendeten Lochblende meist nur sehr gering und führte zu langen Belichtungszeiten. Ein wenig besser waren gekühlte Spektrallampen; vor allen Dingen die Lampen mit Thallium-Füllung wurden für interferometrische Untersuchungen verwendet. Die Entwicklung von Niederdruckspektrallampen war durch viele Physiker gefördert worden, so auch durch den ungarischen Physiker Dennis Gábor <17>, als er Mitarbeiter der Firma Siemens war. Nach seiner Emigration war er auf vielen Gebieten der angewandten Physik tätig. Ihm gelang 1948 eine aufsehenserregende Erfindung, die Abspeicherung eines dreidimensionalen Bildes auf der zweidimensionalen Photoplatte, die Holographie. Für die Aufnahme benötigte man monochromatische Lichtquelle großer Kohärenzlänge. Aber es gab sie damals noch nicht, und so ging die Entwicklung der Holographie nur langsam voran, denn man konnte nur kleine Objekte aufnehmen. Offenbar hat auch Gábor selbst dieses Problem der Lichtquelle nicht zu lösen versucht <18>.

[...]

9 Bothe, Walter: Zeitschrift für Physik, **20** (1923), H. 2, S. 145.

10 Berliner, Arnold und Scheel, Karl: Physikalisches Handwörterbuch, Berlin 1924.

11. Franck, James u. Reiche, Fritz: Zeitschrift für Physik, **1** (1920), S. 154.

An approach for the construction of an intense monochromatic coherent light source for investigations in optics was not found. When experimenting, one had to be content with filters and a pinhole diaphragm in order to realize a coherent light source from the light of an incandescent lamp. Due to the pinhole aperture used, the intensity was usually very low and led to long exposure times. Cooled spectral lamps were a little better; especially thallium-filled lamps were used for interferometric investigations. The development of low-pressure spectral lamps had been supported by many physicists, including the Hungarian physicist Dennis Gábor <17> when he worked for Siemens. After his emigration he worked in many fields of applied physics. In 1948 he succeeded in a sensational invention, the storage of a three-dimensional image on a two-dimensional photo plate, holography. Monochromatic light sources of long coherence length were required for the recording. But they did not exist at that time, and so the development of holography progressed only slowly, because only small objects could be recorded. Apparently Gábor himself did not try to solve this problem of the light source <18>.

[...]

9 Bothe, Walter: Journal of Physics, **20** (1923), no. 2, p. 145.

10 Berliner, Arnold and Scheel, Karl: Dictionary of Physics, Berlin 1924.

11. Franck, James and Reiche, Fritz: Zeitschrift für Physik, **1** (1920), p. 154.

12. Franck, James: Ergebnisse der Exakten Naturwissenschaften **2** (1920), S. 106.
Franck, James und Jordan, Pascual in: Handbuch der Physik, Bd. 23, 1926, S. 641.

13. Kopfermann, Hans und Ladenburg, Rudolf: Zeitschrift für Physik **48** (1928), S. 26, 51 und **65** (1930), S. 167.

14. Ladenburg, Rudolf: Reviews of Modern Physics **5** (1933), S. 243.

15. Ladenburg, Rudolf und Levy, S.: Zeitschrift für Physik **65** (1930), S. 189.

16. Born, Max: Optik—Ein Lehrbuch der Elektromagnetischen Lichttheorie, Berlin 1933.

17. Gábor, Dennis (früher Dénes) hat im Rahmen seiner Tätigkeit im Forschungslaboratorium der Siemens & Halske AG 1930 zwei Erfindungen über Metallbogenlampen angemeldet, auf die er 1933 die DRP 570606 und 570608 erteilt wurden.

18. Gábor schrieb am 28.5.1963 aus London an Max Born u.a. über Borns Aufsatz "The Scientist Speculates" sowie über seine Gedanken um 1950 einen Laser zu bauen. Er geht dabei auf das Problem, der Verantwortung Ideen zu publizieren, ein. Ein Problem, was sich besonders deutlich bei der Entwicklung des Lasers später zeigt, als immer wieder spekulative Ideen ohne Versuch der Realisierung veröffentlicht wurden und damit die Frage der Priorität nach dem gelungenen Experiment zu diskutieren war.
Der Brief befindet sich im Nachlaß Born, Handschriftenabteilung, Staatsbibliothek Preußischer Kulturbesitz, Berlin.

12. Franck, James: Results of the Exact Natural Sciences **2** (1920), p. 106.
Franck, James and Jordan, Pascual in: Handbook of Physics, vol. 23, 1926, p. 641.
[See p. 3114.]

13. Kopfermann, Hans and Ladenburg, Rudolf: Journal of Physics **48** (1928), p. 26, 51 and **65** (1930), S. 167.

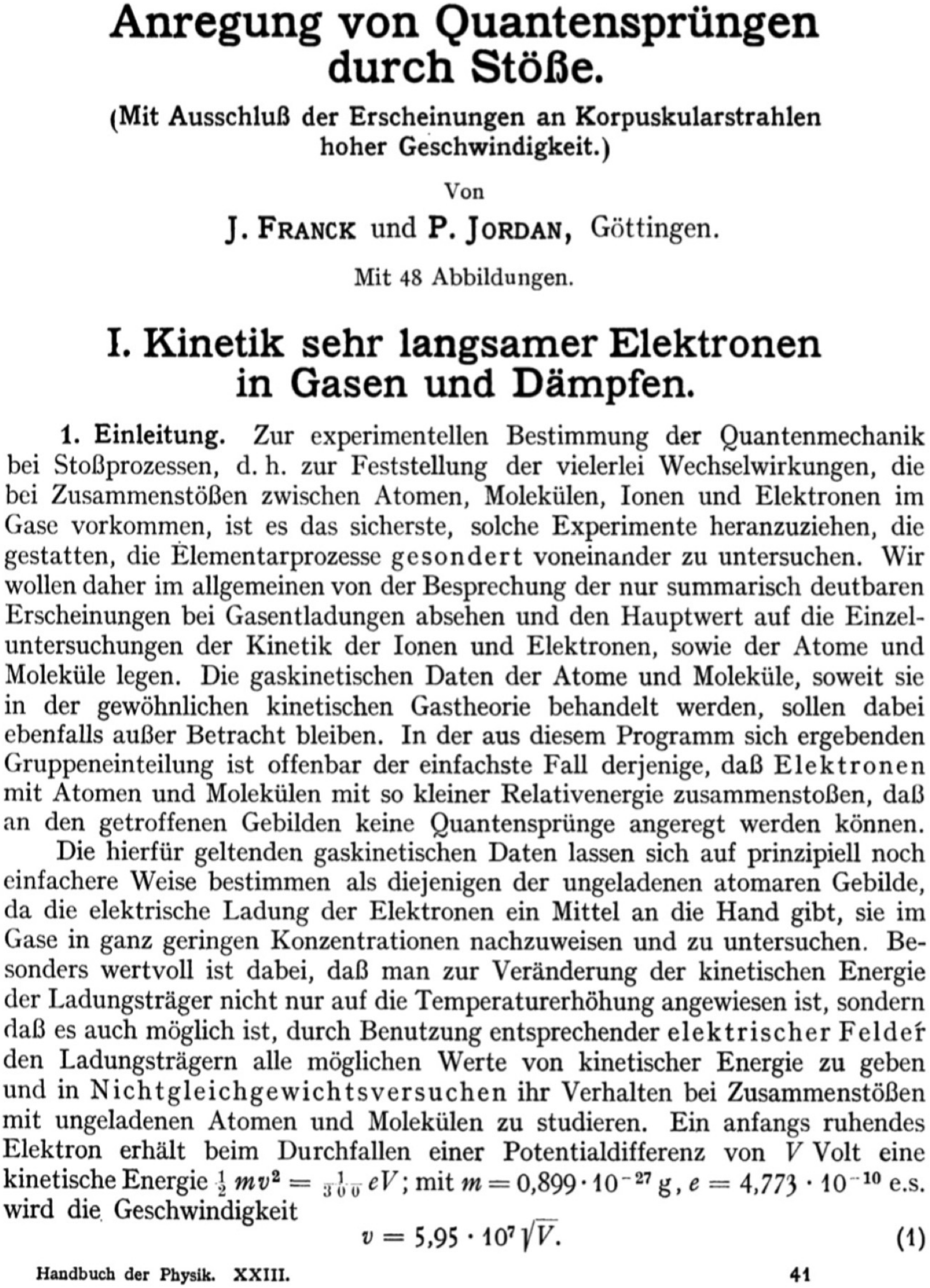
14. Ladenburg, Rudolf: Reviews of Modern Physics **5** (1933), S. 243.

15. Ladenburg, Rudolf and Levy, S.: Journal of Physics **65** (1930), S. 189.

16. Born, Max: Optics—A Textbook of Electromagnetic Light Theory, Berlin 1933.

17. Gábor, Dennis (formerly Dénes) has registered two inventions about metal arc lamps within the scope of his activity in the research laboratory of Siemens & Halske AG in 1930. In 1933 he was granted the DRP 570606 and 570608.

18. Gábor wrote on 28.5.1963 from London to Max Born about Born's essay "The Scientist Speculates" and about his thoughts about building a laser in 1950. He addresses the problem of the responsibility to publish ideas. This problem became particularly apparent later in the development of the laser, when speculative ideas were repeatedly published without any attempt at realization and the question of priority for the successful experiment was discussed.
The letter is in the estate of Born, Manuscript Department, Staatsbibliothek Preußischer Kulturbesitz, Berlin.



Anregung von Quantensprüngen durch Stöße.

(Mit Ausschluß der Erscheinungen an Korpuskularstrahlen hoher Geschwindigkeit.)

Von

J. Franck und **P. Jordan**, Göttingen.

Mit 48 Abbildungen.

I. Kinetik sehr langsamer Elektronen in Gasen und Dämpfen.

1. Einleitung. Zur experimentellen Bestimmung der Quantenmechanik bei Stoßprozessen, d. h. zur Feststellung der vielerlei Wechselwirkungen, die bei Zusammenstößen zwischen Atomen, Molekülen, Ionen und Elektronen im Gase vorkommen, ist es das sicherste, solche Experimente heranzuziehen, die gestatten, die Elementarprozesse gesondert voneinander zu untersuchen. Wir wollen daher im allgemeinen von der Besprechung der nur summarisch deutbaren Erscheinungen bei Gasentladungen absehen und den Hauptwert auf die Einzeluntersuchungen der Kinetik der Ionen und Elektronen, sowie der Atome und Moleküle legen. Die gaskinetischen Daten der Atome und Moleküle, soweit sie in der gewöhnlichen kinetischen Gastheorie behandelt werden, sollen dabei ebenfalls außer Betracht bleiben. In der aus diesem Programm sich ergebenden Gruppeneinteilung ist offenbar der einfachste Fall derjenige, daß Elektronen mit Atomen und Molekülen mit so kleiner Relativenergie zusammenstoßen, daß an den getroffenen Gebilden keine Quantensprünge angeregt werden können.

Die hierfür geltenden gaskinetischen Daten lassen sich auf prinzipiell noch einfachere Weise bestimmen als diejenigen der ungeladenen atomaren Gebilde, da die elektrische Ladung der Elektronen ein Mittel an die Hand gibt, sie im Gase in ganz geringen Konzentrationen nachzuweisen und zu untersuchen. Besonders wertvoll ist dabei, daß man zur Veränderung der kinetischen Energie der Ladungsträger nicht nur auf die Temperaturerhöhung angewiesen ist, sondern daß es auch möglich ist, durch Benutzung entsprechender elektrischer Felder den Ladungsträgern alle möglichen Werte von kinetischer Energie zu geben und in Nichtgleichgewichtsversuchen ihr Verhalten bei Zusammenstößen mit ungeladenen Atomen und Molekülen zu studieren. Ein anfangs ruhendes Elektron erhält beim Durchfallen einer Potentialdifferenz von V Volt eine kinetische Energie $\frac{1}{2} mv^2 = \frac{1}{300} eV$; mit $m = 0{,}899 \cdot 10^{-27}$ g, $e = 4{,}773 \cdot 10^{-10}$ e.s. wird die Geschwindigkeit

$$v = 5{,}95 \cdot 10^7 \sqrt{V}. \qquad (1)$$

Handbuch der Physik. XXIII. 41

Figure C.63: James Franck collaborated with many other scientists such as Pascual Jordan to conduct theoretical and experimental analyses of light emission from atoms (including aspects of stimulated emission) during the late 1910s and the 1920s [*Handbuch der Physik* (1926) 23:641–775].

Hendrik A. Kramers. 1925. *Skand. Mat. Kongr.* p. 145 [quoted in Bertolotti 2015, pp. 20–21].

If the atom is in one of its higher states, also terms belonging to the second sum inside the brackets of [equation] will appear. In the neighborhood of the frequency ν_{em} of an emission line, the atom will then give rise to an anomalous dispersion of similar kind as in the case of an absorption line, with the difference that the sign of P is reversed. This so-called *negative dispersion* is closely connected with the prediction made by Einstein that the atom for such a frequency will exhibit a *negative absorption*, that is, light waves of this frequency, passing through a great number of atoms in the state under consideration, will increase in intensity.

[In 1920–1921, Christian Füchtbauer (German, 1877–1959) and Rudolf Ladenburg (German, 1882–1952) wrote the first papers using newly developed quantum physics methods to calculate normal or positive absorption of light, as well as negative absorption or light amplification due to stimulated emission of photons in a material composed of excited atoms:

> Christian Füchtbauer. 1920. Die Absorption in Spektrallinien im Lichte der Quantentheorie. *Physikalische Zeitschrift* 21:322–324.
>
> Rudolf Ladenburg. 1921. Die quantentheoretische Deutung der Zahl der Dispersionselektronen. *Zeitschrift für Physik* 4:451–468.

Their theoretical result is now known as the Füchtbauer–Ladenburg equation for calculating the optical gain or light amplification of a laser material containing excited atoms.

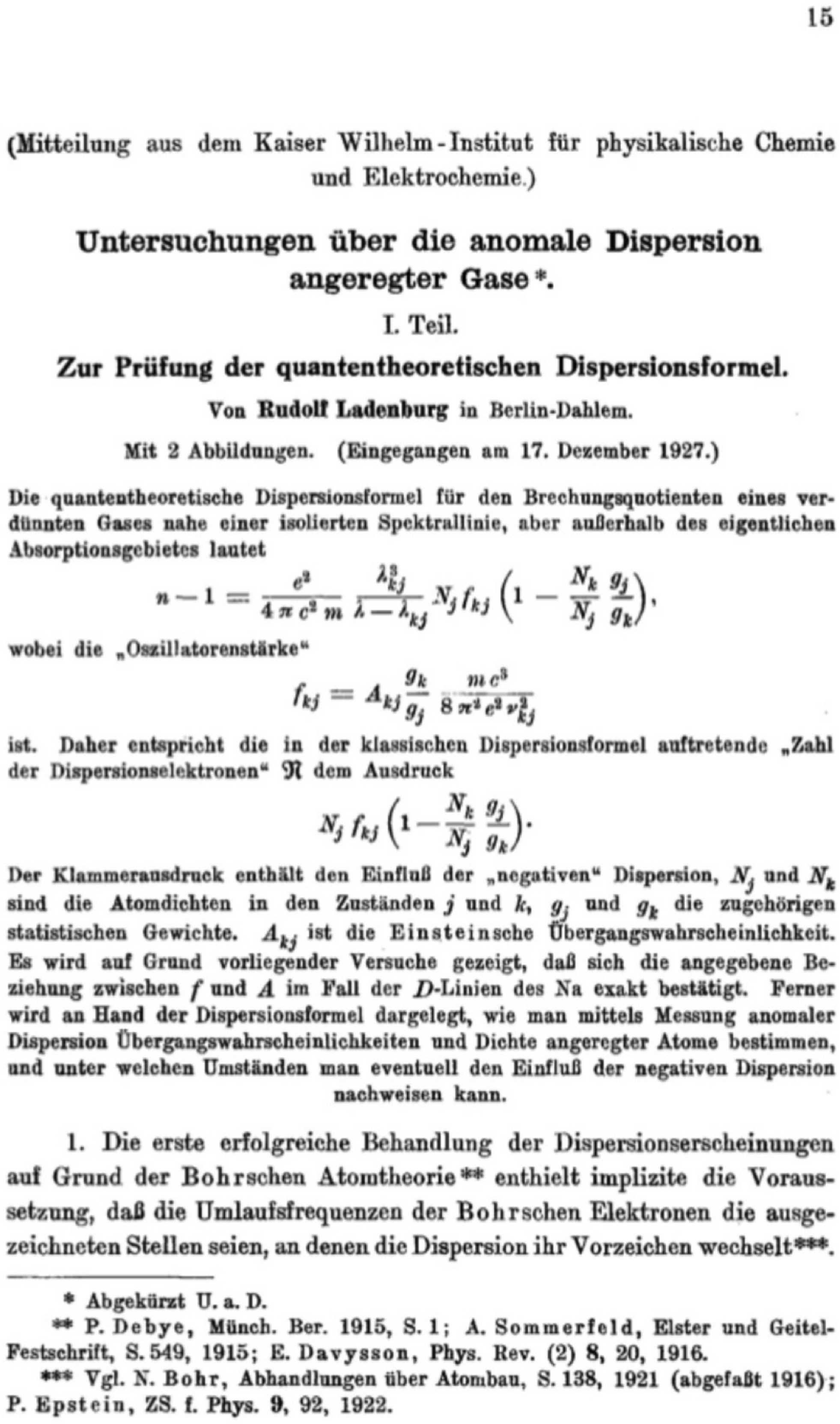
Based on those theoretical predictions, Rudolf Ladenburg and other members of his group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie (such as Hans Kopfermann, Agathe Carst, S. Levy, and Günther Wolfsohn) conducted experiments from the 1920s until 1931 that conclusively demonstrated the existence of stimulated emission and optical amplification in electrically excited gases. Examples of some of the resulting papers are shown on pp. 3116–3127.

However, rising antisemitism in Germany drove Ladenburg to the United States, where he accepted a position in 1931. In 1933, Ladenburg published one last paper on the topic from the United States, basically summarizing the research he had conducted in Germany. It appears that he was unable to interest U.S. sponsors in funding him to continue his revolutionary research program.

If Ladenburg had been allowed to continue leading his research group at the Kaiser Wilhelm Institut, his group might have produced the first laser as early as the 1930s. Even so, his numerous, highly detailed, and highly visible publications on stimulated emission in electrically excited gases had an enormous influence on later work in the German-speaking world, the United States, and elsewhere.]

Rudolf Ladenburg. 1933. Dispersion in Electrically Excited Gases. *Reviews of Modern Physics* 5:243.

All these different experiments prove without doubt that the population of the P levels does increase with the current, and so much so that above 100 mA, the ratio Q $(= N_k g_j / N_j g_k)$ has appreciable value. Therefore the experiments shown by the curves [...] prove the influence of the negative term in the dispersion formula. This "negative dispersion" corresponds to the negative absorption of the theory of radiation and to the term -1 in the denominator of Planck's formula for the radiation of a black body as is easily shown by Einstein's derivation of this formula.



(Mitteilung aus dem Kaiser Wilhelm-Institut für physikalische Chemie und Elektrochemie.)

Untersuchungen über die anomale Dispersion angeregter Gase*.

I. Teil.

Zur Prüfung der quantentheoretischen Dispersionsformel.

Von **Rudolf Ladenburg** in Berlin-Dahlem.

Mit 2 Abbildungen. (Eingegangen am 17. Dezember 1927.)

Die quantentheoretische Dispersionsformel für den Brechungsquotienten eines verdünnten Gases nahe einer isolierten Spektrallinie, aber außerhalb des eigentlichen Absorptionsgebietes lautet

$$n-1=\frac{e^2}{4\pi c^2 m}\frac{\lambda_{kj}^3}{\lambda-\lambda_{kj}}N_j f_{kj}\left(1-\frac{N_k}{N_j}\frac{g_j}{g_k}\right),$$

wobei die „Oszillatorenstärke"

$$f_{kj}=A_{kj}\frac{g_k}{g_j}\frac{m c^3}{8\pi^2 e^2 \nu_{kj}^2}$$

ist. Daher entspricht die in der klassischen Dispersionsformel auftretende „Zahl der Dispersionselektronen" $\mathfrak{N}$ dem Ausdruck

$$N_j f_{kj}\left(1-\frac{N_k}{N_j}\frac{g_j}{g_k}\right).$$

Der Klammerausdruck enthält den Einfluß der „negativen" Dispersion, N_j und N_k sind die Atomdichten in den Zuständen j und k, g_j und g_k die zugehörigen statistischen Gewichte. A_{kj} ist die Einsteinsche Übergangswahrscheinlichkeit. Es wird auf Grund vorliegender Versuche gezeigt, daß sich die angegebene Beziehung zwischen f und A im Fall der D-Linien des Na exakt bestätigt. Ferner wird an Hand der Dispersionsformel dargelegt, wie man mittels Messung anomaler Dispersion Übergangswahrscheinlichkeiten und Dichte angeregter Atome bestimmen, und unter welchen Umständen man eventuell den Einfluß der negativen Dispersion nachweisen kann.

1. Die erste erfolgreiche Behandlung der Dispersionserscheinungen auf Grund der Bohrschen Atomtheorie** enthielt implizite die Voraussetzung, daß die Umlaufsfrequenzen der Bohrschen Elektronen die ausgezeichneten Stellen seien, an denen die Dispersion ihr Vorzeichen wechselt***.

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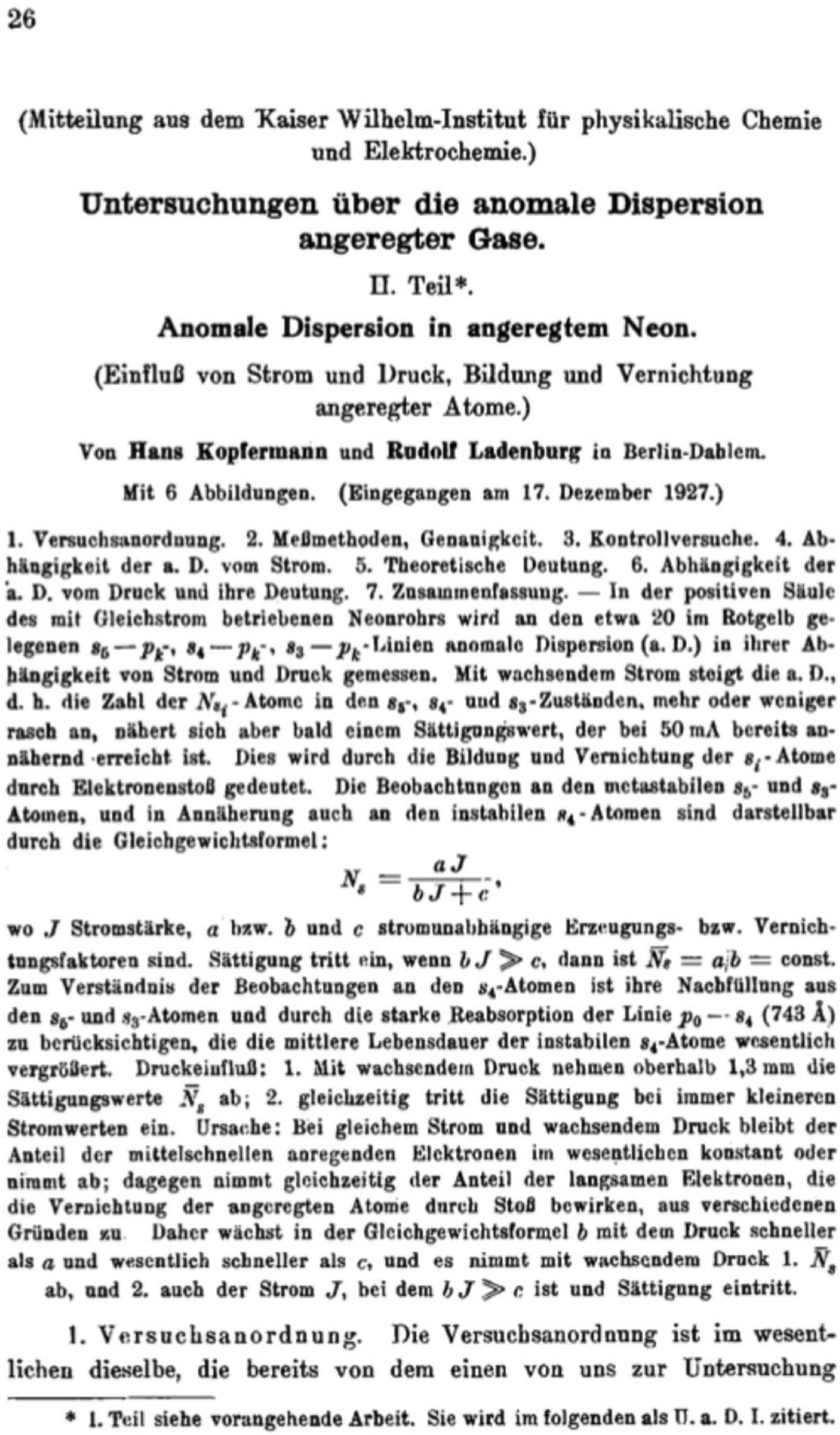
[*] Abgekürzt U. a. D.

[**] P. Debye, Münch. Ber. 1915, S. 1; A. Sommerfeld, Elster und Geitel-Festschrift, S. 549, 1915; E. Davysson, Phys. Rev. (2) 8, 20, 1916.

[***] Vgl. N. Bohr, Abhandlungen über Atombau, S. 138, 1921 (abgefaßt 1916); P. Epstein, ZS. f. Phys. 9, 92, 1922.

Figure C.64: Rudolf Ladenburg and other members of his group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie demonstrated stimulated light emission from atoms (amplification of the number of photons of light from atoms) during the period 1927–1931 [*Zeitschrift für Physik* (1928) 48:1–2:15–25].



26

(Mitteilung aus dem Kaiser Wilhelm-Institut für physikalische Chemie und Elektrochemie.)

Untersuchungen über die anomale Dispersion angeregter Gase.

II. Teil*.

Anomale Dispersion in angeregtem Neon.

(Einfluß von Strom und Druck, Bildung und Vernichtung angeregter Atome.)

Von **Hans Kopfermann** und **Rudolf Ladenburg** in Berlin-Dahlem.

Mit 6 Abbildungen. (Eingegangen am 17. Dezember 1927.)

1. Versuchsanordnung. 2. Meßmethoden, Genauigkeit. 3. Kontrollversuche. 4. Abhängigkeit der a. D. vom Strom. 5. Theoretische Deutung. 6. Abhängigkeit der a. D. vom Druck und ihre Deutung. 7. Zusammenfassung. — In der positiven Säule des mit Gleichstrom betriebenen Neonrohrs wird an den etwa 20 im Rotgelb gelegenen $s_5 - p_k$-, $s_4 - p_k$-, $s_3 - p_k$-Linien anomale Dispersion (a. D.) in ihrer Abhängigkeit von Strom und Druck gemessen. Mit wachsendem Strom steigt die a. D., d. h. die Zahl der N_{s_i}-Atome in den s_5-, s_4- und s_3-Zuständen, mehr oder weniger rasch an, nähert sich aber bald einem Sättigungswert, der bei 50 mA bereits annähernd erreicht ist. Dies wird durch die Bildung und Vernichtung der s_i-Atome durch Elektronenstoß gedeutet. Die Beobachtungen an den metastabilen s_5- und s_3-Atomen, und in Annäherung auch an den instabilen s_4-Atomen sind darstellbar durch die Gleichgewichtsformel:

$$N_s = \frac{a\,J}{b\,J + c},$$

wo J Stromstärke, a bzw. b und c stromunabhängige Erzeugungs- bzw. Vernichtungsfaktoren sind. Sättigung tritt ein, wenn $b\,J \gg c$, dann ist $\overline{N}_s = a/b =$ const. Zum Verständnis der Beobachtungen an den s_4-Atomen ist ihre Nachfüllung aus den s_5- und s_3-Atomen und durch die starke Reabsorption der Linie $p_0 - s_4$ (743 Å) zu berücksichtigen, die die mittlere Lebensdauer der instabilen s_4-Atome wesentlich vergrößert. Druckeinfluß: 1. Mit wachsendem Druck nehmen oberhalb 1,3 mm die Sättigungswerte $\overline{N}_s$ ab; 2. gleichzeitig tritt die Sättigung bei immer kleineren Stromwerten ein. Ursache: Bei gleichem Strom und wachsendem Druck bleibt der Anteil der mittelschnellen anregenden Elektronen im wesentlichen konstant oder nimmt ab; dagegen nimmt gleichzeitig der Anteil der langsamen Elektronen, die die Vernichtung der angeregten Atome durch Stoß bewirken, aus verschiedenen Gründen zu. Daher wächst in der Gleichgewichtsformel b mit dem Druck schneller als a und wesentlich schneller als c, und es nimmt mit wachsendem Druck 1. $\overline{N}_s$ ab, und 2. auch der Strom J, bei dem $b\,J \gg c$ ist und Sättigung eintritt.

1. Versuchsanordnung. Die Versuchsanordnung ist im wesentlichen dieselbe, die bereits von dem einen von uns zur Untersuchung

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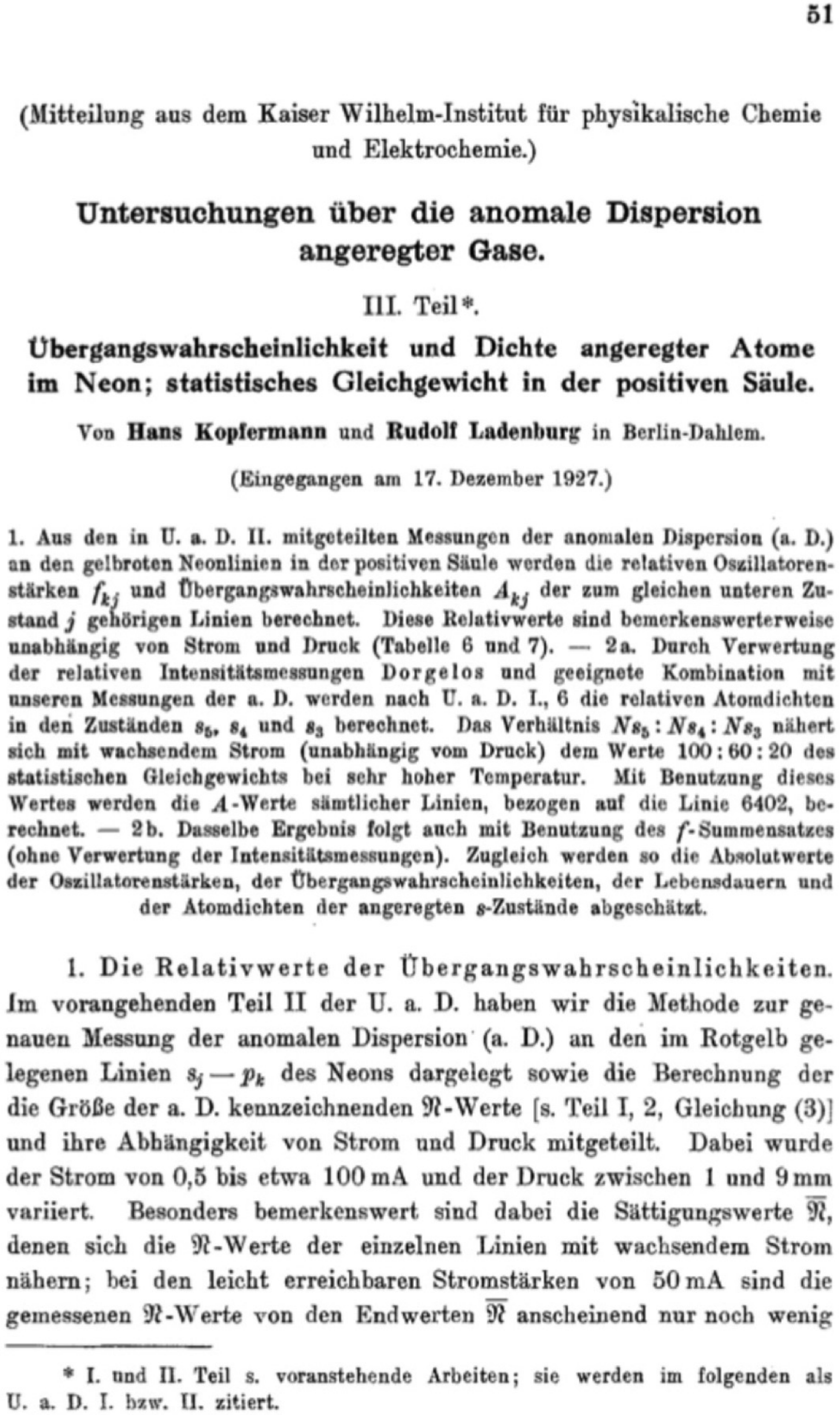
* 1. Teil siehe vorangehende Arbeit. Sie wird im folgenden als U. a. D. I. zitiert.

Figure C.65: Rudolf Ladenburg and other members of his group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie demonstrated stimulated light emission from atoms (amplification of the number of photons of light from atoms) during the period 1927–1931 [*Zeitschrift für Physik* (1928) 48:1–2:26–50].



(Mitteilung aus dem Kaiser Wilhelm-Institut für physikalische Chemie und Elektrochemie.)

Untersuchungen über die anomale Dispersion angeregter Gase.

III. Teil*.

Übergangswahrscheinlichkeit und Dichte angeregter Atome im Neon; statistisches Gleichgewicht in der positiven Säule.

Von **Hans Kopfermann** und **Rudolf Ladenburg** in Berlin-Dahlem.

(Eingegangen am 17. Dezember 1927.)

1. Aus den in U. a. D. II. mitgeteilten Messungen der anomalen Dispersion (a. D.) an den gelbroten Neonlinien in der positiven Säule werden die relativen Oszillatorenstärken f_{kj} und Übergangswahrscheinlichkeiten A_{kj} der zum gleichen unteren Zustand j gehörigen Linien berechnet. Diese Relativwerte sind bemerkenswerterweise unabhängig von Strom und Druck (Tabelle 6 und 7). — 2a. Durch Verwertung der relativen Intensitätsmessungen Dorgelos und geeignete Kombination mit unseren Messungen der a. D. werden nach U. a. D. I., 6 die relativen Atomdichten in den Zuständen s_5, s_4 und s_3 berechnet. Das Verhältnis $Ns_5 : Ns_4 : Ns_3$ nähert sich mit wachsendem Strom (unabhängig vom Druck) dem Werte 100 : 60 : 20 des statistischen Gleichgewichts bei sehr hoher Temperatur. Mit Benutzung dieses Wertes werden die A-Werte sämtlicher Linien, bezogen auf die Linie 6402, berechnet. — 2b. Dasselbe Ergebnis folgt auch mit Benutzung des f-Summensatzes (ohne Verwertung der Intensitätsmessungen). Zugleich werden so die Absolutwerte der Oszillatorenstärken, der Übergangswahrscheinlichkeiten, der Lebensdauern und der Atomdichten der angeregten s-Zustände abgeschätzt.

1. Die Relativwerte der Übergangswahrscheinlichkeiten. Im vorangehenden Teil II der U. a. D. haben wir die Methode zur genauen Messung der anomalen Dispersion (a. D.) an den im Rotgelb gelegenen Linien $s_j - p_k$ des Neons dargelegt sowie die Berechnung der die Größe der a. D. kennzeichnenden $\mathfrak{N}$-Werte [s. Teil I, 2, Gleichung (3)] und ihre Abhängigkeit von Strom und Druck mitgeteilt. Dabei wurde der Strom von 0,5 bis etwa 100 mA und der Druck zwischen 1 und 9 mm variiert. Besonders bemerkenswert sind dabei die Sättigungswerte $\overline{\mathfrak{N}}$, denen sich die $\mathfrak{N}$-Werte der einzelnen Linien mit wachsendem Strom nähern; bei den leicht erreichbaren Stromstärken von 50 mA sind die gemessenen $\mathfrak{N}$-Werte von den Endwerten $\overline{\mathfrak{N}}$ anscheinend nur noch wenig

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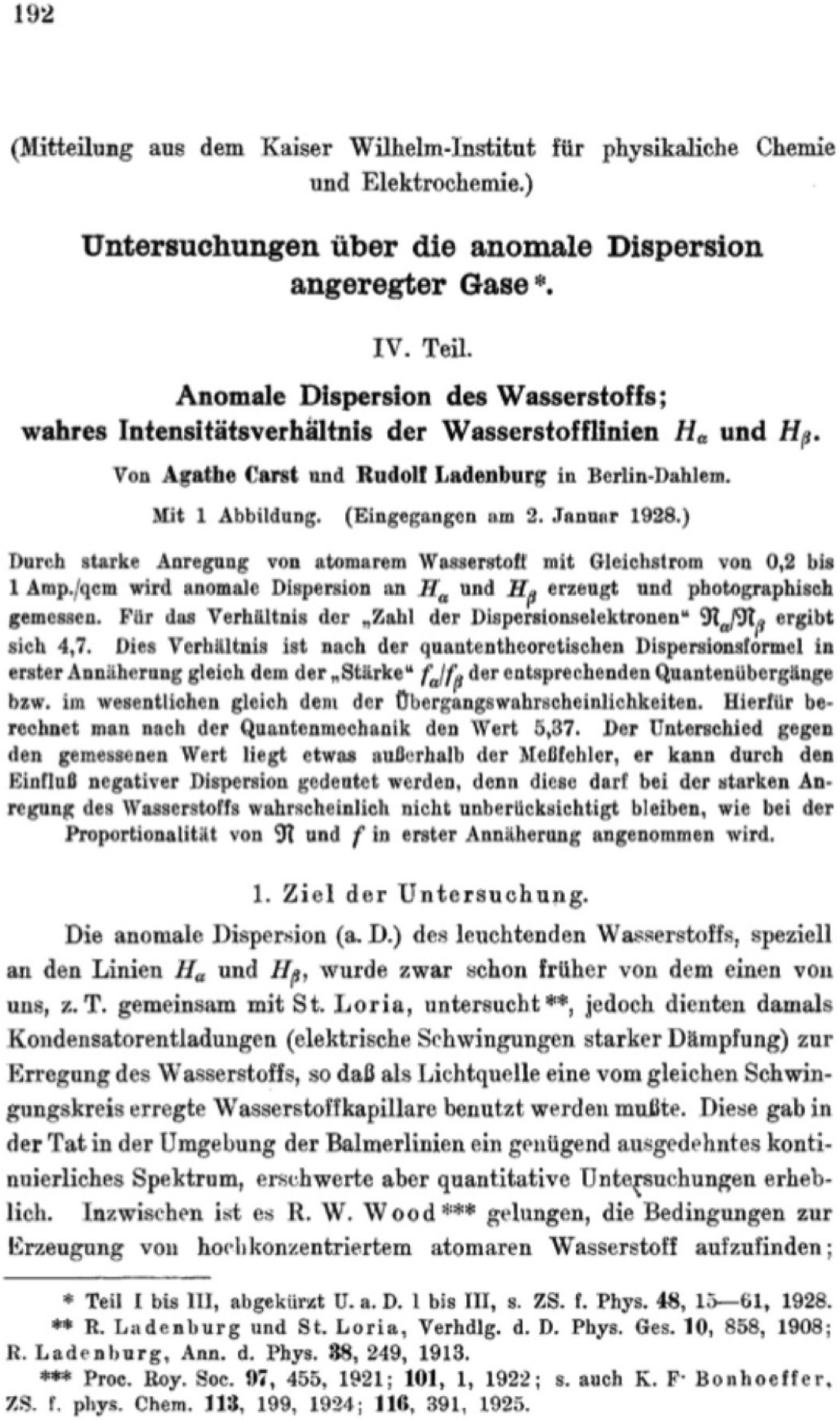
* I. und II. Teil s. voranstehende Arbeiten; sie werden im folgenden als U. a. D. I. bzw. II. zitiert.

Figure C.66: Rudolf Ladenburg and other members of his group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie demonstrated stimulated light emission from atoms (amplification of the number of photons of light from atoms) during the period 1927–1931 [*Zeitschrift für Physik* (1928) 48:1–2:51–61].



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(Mitteilung aus dem Kaiser Wilhelm-Institut für physikaliche Chemie und Elektrochemie.)

Untersuchungen über die anomale Dispersion angeregter Gase*.

IV. Teil.

Anomale Dispersion des Wasserstoffs; wahres Intensitätsverhältnis der Wasserstofflinien H_α und H_β.

Von **Agathe Carst** und **Rudolf Ladenburg** in Berlin-Dahlem.

Mit 1 Abbildung. (Eingegangen am 2. Januar 1928.)

Durch starke Anregung von atomarem Wasserstoff mit Gleichstrom von 0,2 bis 1 Amp./qcm wird anomale Dispersion an H_α und H_β erzeugt und photographisch gemessen. Für das Verhältnis der „Zahl der Dispersionselektronen“ $\mathfrak{N}_\alpha/\mathfrak{N}_\beta$ ergibt sich 4,7. Dies Verhältnis ist nach der quantentheoretischen Dispersionsformel in erster Annäherung gleich dem der „Stärke“ f_α/f_β der entsprechenden Quantenübergänge bzw. im wesentlichen gleich dem der Übergangswahrscheinlichkeiten. Hierfür berechnet man nach der Quantenmechanik den Wert 5,37. Der Unterschied gegen den gemessenen Wert liegt etwas außerhalb der Meßfehler, er kann durch den Einfluß negativer Dispersion gedeutet werden, denn diese darf bei der starken Anregung des Wasserstoffs wahrscheinlich nicht unberücksichtigt bleiben, wie bei der Proportionalität von $\mathfrak{N}$ und f in erster Annäherung angenommen wird.

1. Ziel der Untersuchung.

Die anomale Dispersion (a. D.) des leuchtenden Wasserstoffs, speziell an den Linien H_α und H_β, wurde zwar schon früher von dem einen von uns, z. T. gemeinsam mit St. Loria, untersucht**, jedoch dienten damals Kondensatorentladungen (elektrische Schwingungen starker Dämpfung) zur Erregung des Wasserstoffs, so daß als Lichtquelle eine vom gleichen Schwingungskreis erregte Wasserstoffkapillare benutzt werden mußte. Diese gab in der Tat in der Umgebung der Balmerlinien ein genügend ausgedehntes kontinuierliches Spektrum, erschwerte aber quantitative Untersuchungen erheblich. Inzwischen ist es R. W. Wood*** gelungen, die Bedingungen zur Erzeugung von hochkonzentriertem atomaren Wasserstoff aufzufinden;

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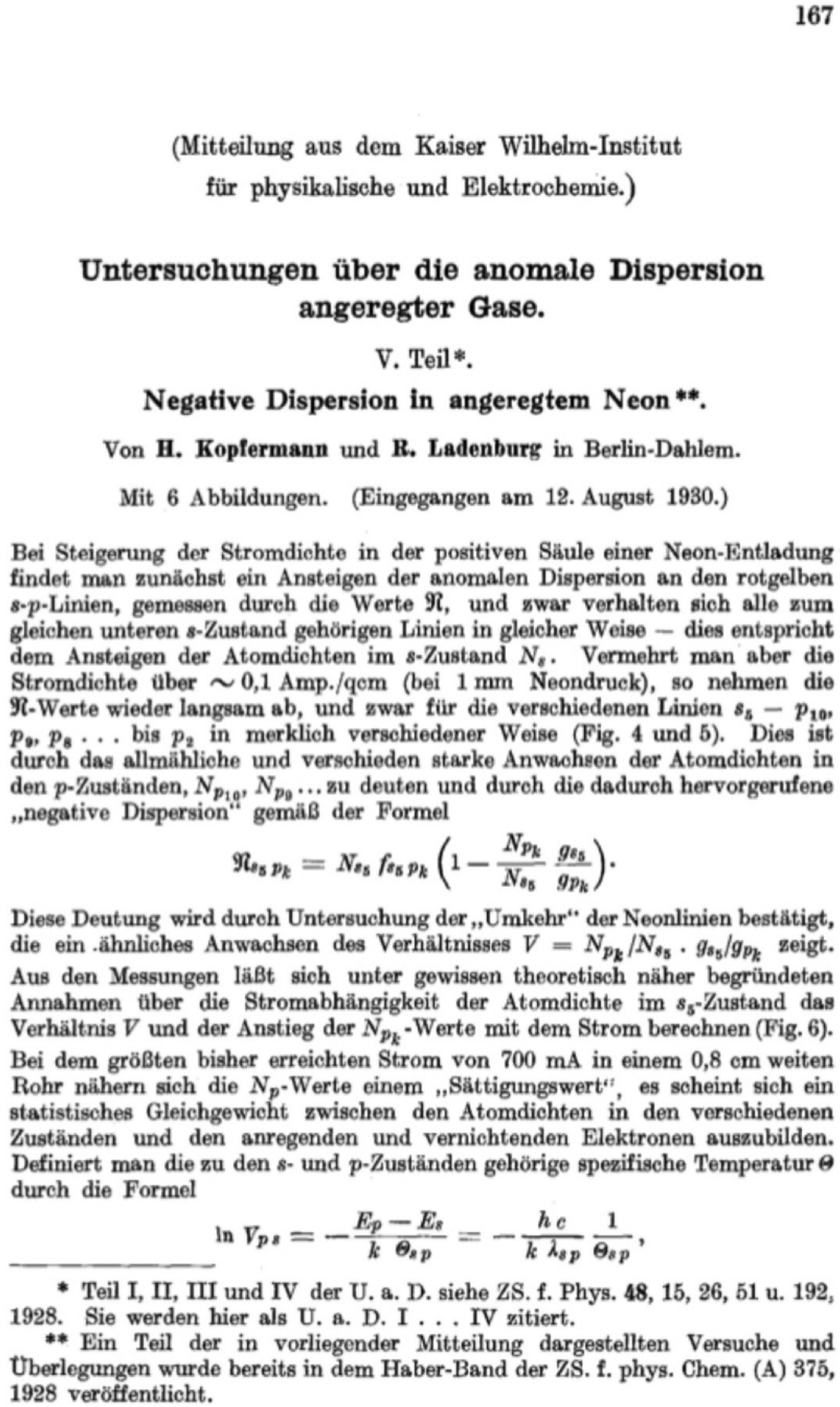
* Teil I bis III, abgekürzt U. a. D. I bis III, s. ZS. f. Phys. **48**, 15—61, 1928.

** R. Ladenburg und St. Loria, Verhdlg. d. D. Phys. Ges. **10**, 858, 1908; R. Ladenburg, Ann. d. Phys. **38**, 249, 1913.

*** Proc. Roy. Soc. **97**, 455, 1921; **101**, 1, 1922; s. auch K. F. Bonhoeffer, ZS. f. phys. Chem. **113**, 199, 1924; **116**, 391, 1925.

Figure C.67: Rudolf Ladenburg and other members of his group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie demonstrated stimulated light emission from atoms (amplification of the number of photons of light from atoms) during the period 1927–1931 [*Zeitschrift für Physik* (1928) 48:3–4:192–204].



(Mitteilung aus dem Kaiser Wilhelm-Institut
für physikalische und Elektrochemie.)

Untersuchungen über die anomale Dispersion angeregter Gase.

V. Teil*.

Negative Dispersion in angeregtem Neon**.

Von **H. Kopfermann** und **R. Ladenburg** in Berlin-Dahlem.

Mit 6 Abbildungen. (Eingegangen am 12. August 1930.)

Bei Steigerung der Stromdichte in der positiven Säule einer Neon-Entladung findet man zunächst ein Ansteigen der anomalen Dispersion an den rotgelben s-p-Linien, gemessen durch die Werte $\mathfrak{N}$, und zwar verhalten sich alle zum gleichen unteren s-Zustand gehörigen Linien in gleicher Weise — dies entspricht dem Ansteigen der Atomdichten im s-Zustand N_s. Vermehrt man aber die Stromdichte über $\sim 0{,}1$ Amp./qcm (bei 1 mm Neondruck), so nehmen die $\mathfrak{N}$-Werte wieder langsam ab, und zwar für die verschiedenen Linien $s_5 - p_{10}$, p_9, p_8 . . . bis p_2 in merklich verschiedener Weise (Fig. 4 und 5). Dies ist durch das allmähliche und verschieden starke Anwachsen der Atomdichten in den p-Zuständen, $N_{p_{10}}$, N_{p_9} . . . zu deuten und durch die dadurch hervorgerufene „negative Dispersion“ gemäß der Formel

$$\mathfrak{N}_{s_5 p_k} = N_{s_5} f_{s_5 p_k}\left(1 - \frac{N_{p_k}}{N_{s_5}} \frac{g_{s_5}}{g_{p_k}}\right).$$

Diese Deutung wird durch Untersuchung der „Umkehr“ der Neonlinien bestätigt, die ein ähnliches Anwachsen des Verhältnisses $V = N_{p_k}/N_{s_5} \cdot g_{s_5}/g_{p_k}$ zeigt. Aus den Messungen läßt sich unter gewissen theoretisch näher begründeten Annahmen über die Stromabhängigkeit der Atomdichte im s_5-Zustand das Verhältnis V und der Anstieg der N_{p_k}-Werte mit dem Strom berechnen (Fig. 6). Bei dem größten bisher erreichten Strom von 700 mA in einem 0,8 cm weiten Rohr nähern sich die N_p-Werte einem „Sättigungswert“, es scheint sich ein statistisches Gleichgewicht zwischen den Atomdichten in den verschiedenen Zuständen und den anregenden und vernichtenden Elektronen auszubilden. Definiert man die zu den s- und p-Zuständen gehörige spezifische Temperatur Θ durch die Formel

$$\ln V_{ps} = -\frac{E_p - E_s}{k\,\Theta_{sp}} = -\frac{h\,c}{k\,\lambda_{sp}}\,\frac{1}{\Theta_{sp}},$$

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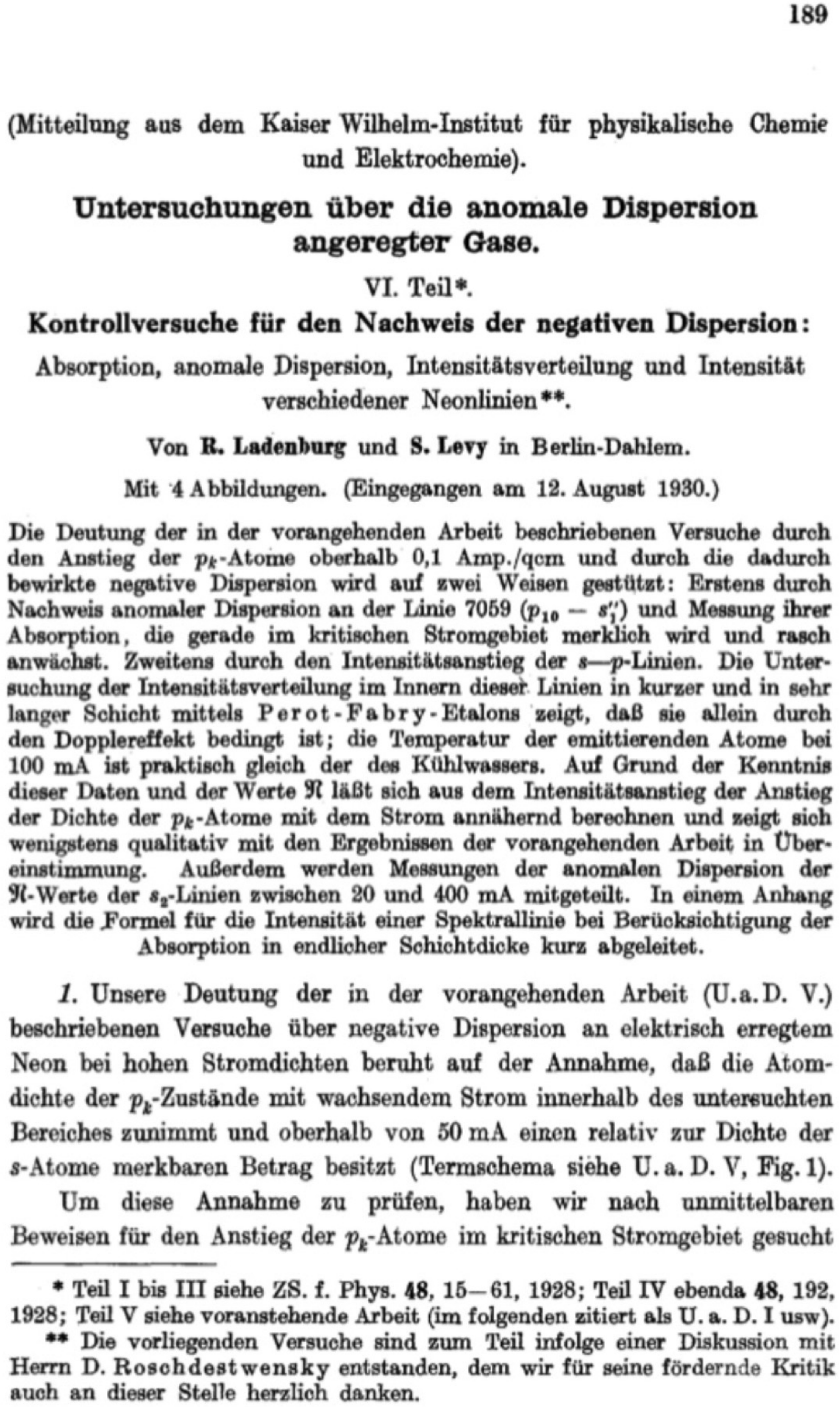
* Teil I, II, III und IV der U. a. D. siehe ZS. f. Phys. **48**, 15, 26, 51 u. 192, 1928. Sie werden hier als U. a. D. I . . . IV zitiert.

** Ein Teil der in vorliegender Mitteilung dargestellten Versuche und Überlegungen wurde bereits in dem Haber-Band der ZS. f. phys. Chem. (A) 375, 1928 veröffentlicht.

Figure C.68: Rudolf Ladenburg and other members of his group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie demonstrated stimulated light emission from atoms (amplification of the number of photons of light from atoms) during the period 1927–1931 [*Zeitschrift für Physik* (1930) 65:3–4:167–188].



(Mitteilung aus dem Kaiser Wilhelm-Institut für physikalische Chemie und Elektrochemie).

Untersuchungen über die anomale Dispersion angeregter Gase.

VI. Teil*.

Kontrollversuche für den Nachweis der negativen Dispersion:

Absorption, anomale Dispersion, Intensitätsverteilung und Intensität verschiedener Neonlinien**.

Von **R. Ladenburg** und **S. Levy** in Berlin-Dahlem.

Mit 4 Abbildungen. (Eingegangen am 12. August 1930.)

Die Deutung der in der vorangehenden Arbeit beschriebenen Versuche durch den Anstieg der p_k-Atome oberhalb 0,1 Amp./qcm und durch die dadurch bewirkte negative Dispersion wird auf zwei Weisen gestützt: Erstens durch Nachweis anomaler Dispersion an der Linie 7059 ($p_{10} - s_1''$) und Messung ihrer Absorption, die gerade im kritischen Stromgebiet merklich wird und rasch anwächst. Zweitens durch den Intensitätsanstieg der s—p-Linien. Die Untersuchung der Intensitätsverteilung im Innern dieser Linien in kurzer und in sehr langer Schicht mittels Perot-Fabry-Etalons zeigt, daß sie allein durch den Dopplereffekt bedingt ist; die Temperatur der emittierenden Atome bei 100 mA ist praktisch gleich der des Kühlwassers. Auf Grund der Kenntnis dieser Daten und der Werte $\mathfrak{R}$ läßt sich aus dem Intensitätsanstieg der Anstieg der Dichte der p_k-Atome mit dem Strom annähernd berechnen und zeigt sich wenigstens qualitativ mit den Ergebnissen der vorangehenden Arbeit in Übereinstimmung. Außerdem werden Messungen der anomalen Dispersion der $\mathfrak{R}$-Werte der s_2-Linien zwischen 20 und 400 mA mitgeteilt. In einem Anhang wird die Formel für die Intensität einer Spektrallinie bei Berücksichtigung der Absorption in endlicher Schichtdicke kurz abgeleitet.

1. Unsere Deutung der in der vorangehenden Arbeit (U.a.D. V.) beschriebenen Versuche über negative Dispersion an elektrisch erregtem Neon bei hohen Stromdichten beruht auf der Annahme, daß die Atomdichte der p_k-Zustände mit wachsendem Strom innerhalb des untersuchten Bereiches zunimmt und oberhalb von 50 mA einen relativ zur Dichte der s-Atome merkbaren Betrag besitzt (Termschema siehe U. a. D. V, Fig. 1).

Um diese Annahme zu prüfen, haben wir nach unmittelbaren Beweisen für den Anstieg der p_k-Atome im kritischen Stromgebiet gesucht

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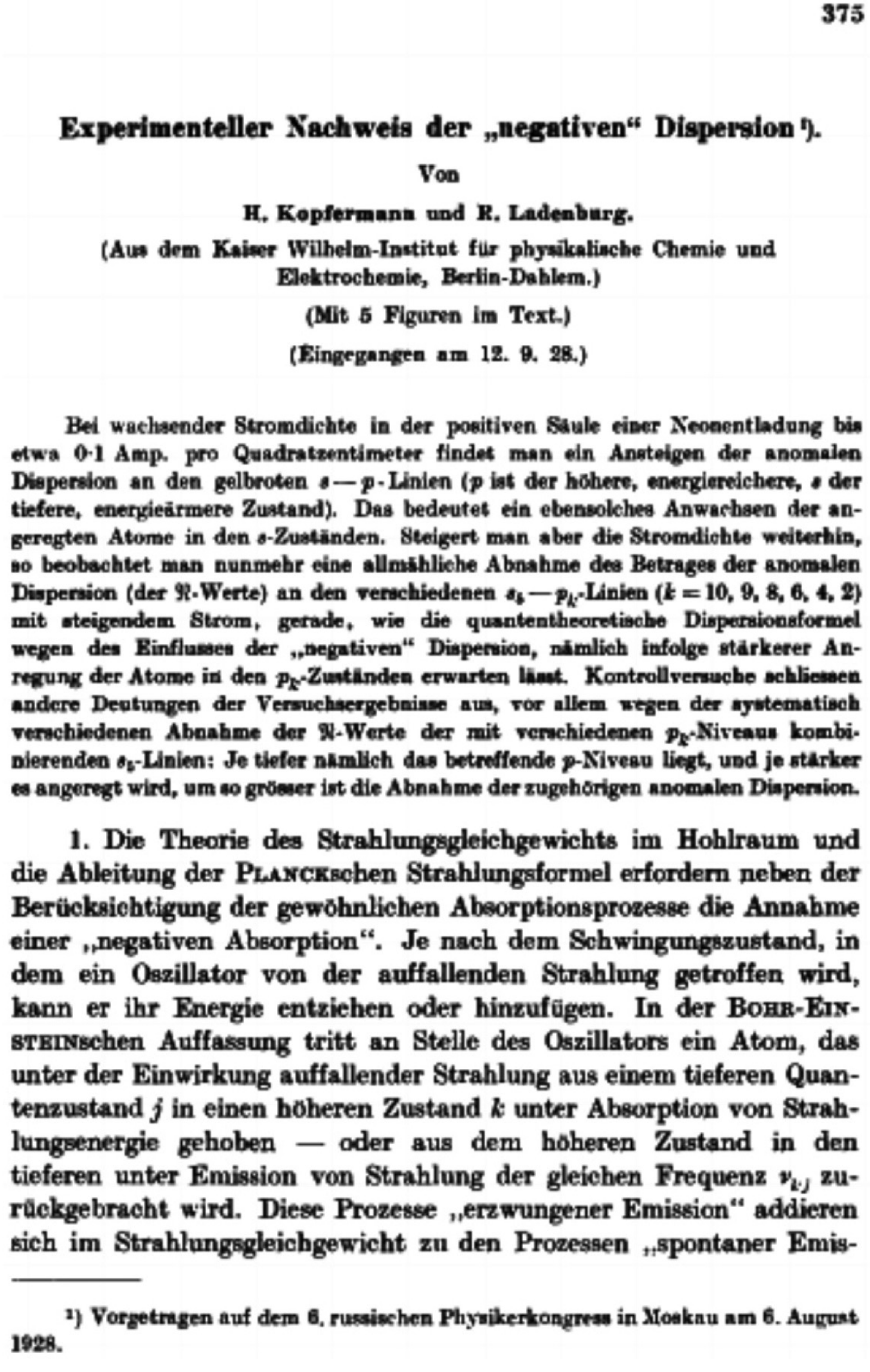
* Teil I bis III siehe ZS. f. Phys. **48**, 15—61, 1928; Teil IV ebenda **48**, 192, 1928; Teil V siehe voranstehende Arbeit (im folgenden zitiert als U. a. D. I usw).

** Die vorliegenden Versuche sind zum Teil infolge einer Diskussion mit Herrn D. Roschdestwensky entstanden, dem wir für seine fördernde Kritik auch an dieser Stelle herzlich danken.

Figure C.69: Rudolf Ladenburg and other members of his group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie demonstrated stimulated light emission from atoms (amplification of the number of photons of light from atoms) during the period 1927–1931 [*Zeitschrift für Physik* (1930) 65:3–4:189–206].



Experimenteller Nachweis der „negativen“ Dispersion [1].

Von

H. Kopfermann und R. Ladenburg.

(Aus dem Kaiser Wilhelm-Institut für physikalische Chemie und Elektrochemie, Berlin-Dahlem.)

(Mit 5 Figuren im Text.)

(Eingegangen am 12. 9. 28.)

Bei wachsender Stromdichte in der positiven Säule einer Neonentladung bis etwa 0·1 Amp. pro Quadratzentimeter findet man ein Ansteigen der anomalen Dispersion an den gelbroten $s - p$-Linien (p ist der höhere, energiereichere, s der tiefere, energieärmere Zustand). Das bedeutet ein ebensolches Anwachsen der angeregten Atome in den s-Zuständen. Steigert man aber die Stromdichte weiterhin, so beobachtet man nunmehr eine allmähliche Abnahme des Betrages der anomalen Dispersion (der $\mathfrak{N}$-Werte) an den verschiedenen $s_k - p_k$-Linien ($k = 10, 9, 8, 6, 4, 2$) mit steigendem Strom, gerade, wie die quantentheoretische Dispersionsformel wegen des Einflusses der „negativen“ Dispersion, nämlich infolge stärkerer Anregung der Atome in den p_k-Zuständen erwarten lässt. Kontrollversuche schliessen andere Deutungen der Versuchsergebnisse aus, vor allem wegen der systematisch verschiedenen Abnahme der $\mathfrak{N}$-Werte der mit verschiedenen p_k-Niveaus kombinierenden s_k-Linien: Je tiefer nämlich das betreffende p-Niveau liegt, und je stärker es angeregt wird, um so grösser ist die Abnahme der zugehörigen anomalen Dispersion.

1. Die Theorie des Strahlungsgleichgewichts im Hohlraum und die Ableitung der Planckschen Strahlungsformel erfordern neben der Berücksichtigung der gewöhnlichen Absorptionsprozesse die Annahme einer „negativen Absorption“. Je nach dem Schwingungszustand, in dem ein Oszillator von der auffallenden Strahlung getroffen wird, kann er ihr Energie entziehen oder hinzufügen. In der Bohr-Einsteinschen Auffassung tritt an Stelle des Oszillators ein Atom, das unter der Einwirkung auffallender Strahlung aus einem tieferen Quantenzustand j in einen höheren Zustand k unter Absorption von Strahlungsenergie gehoben — oder aus dem höheren Zustand in den tieferen unter Emission von Strahlung der gleichen Frequenz ν_{kj} zurückgebracht wird. Diese Prozesse „erzwungener Emission“ addieren sich im Strahlungsgleichgewicht zu den Prozessen „spontaner Emis-

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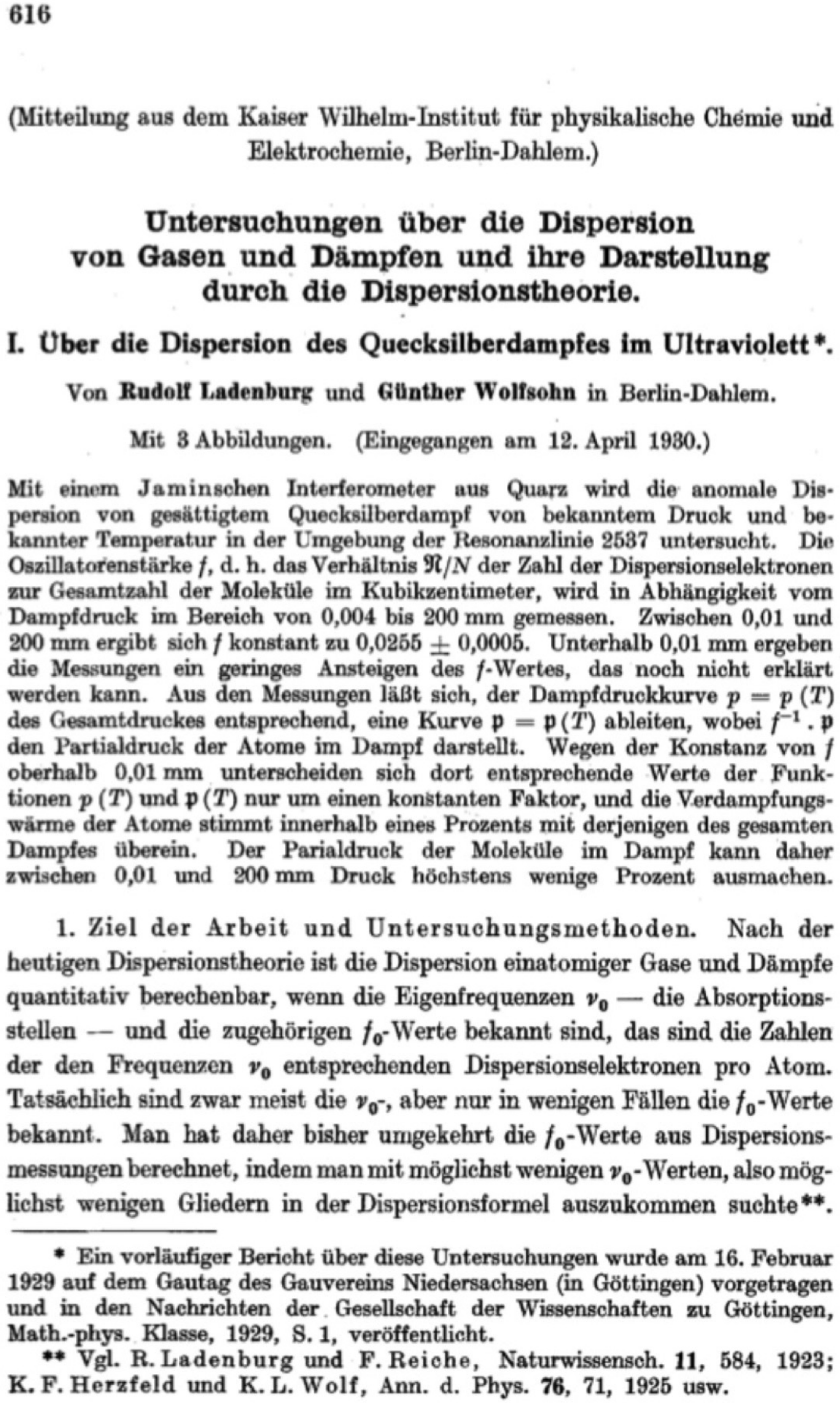
[1] Vorgetragen auf dem 6. russischen Physikerkongress in Moskau am 6. August 1928.

Figure C.70: Rudolf Ladenburg and other members of his group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie demonstrated stimulated light emission from atoms (amplification of the number of photons of light from atoms) during the period 1927–1931 [*Zeitschrift für Physikalische Chemie* (1928) 139:1:375–385].



(Mitteilung aus dem Kaiser Wilhelm-Institut für physikalische Chemie und Elektrochemie, Berlin-Dahlem.)

Untersuchungen über die Dispersion von Gasen und Dämpfen und ihre Darstellung durch die Dispersionstheorie.

I. Über die Dispersion des Quecksilberdampfes im Ultraviolett*.

Von **Rudolf Ladenburg** und **Günther Wolfsohn** in Berlin-Dahlem.

Mit 3 Abbildungen. (Eingegangen am 12. April 1930.)

Mit einem Jaminschen Interferometer aus Quarz wird die anomale Dispersion von gesättigtem Quecksilberdampf von bekanntem Druck und bekannter Temperatur in der Umgebung der Resonanzlinie 2537 untersucht. Die Oszillatorenstärke f, d. h. das Verhältnis $\mathfrak{N}/N$ der Zahl der Dispersionselektronen zur Gesamtzahl der Moleküle im Kubikzentimeter, wird in Abhängigkeit vom Dampfdruck im Bereich von 0,004 bis 200 mm gemessen. Zwischen 0,01 und 200 mm ergibt sich f konstant zu $0{,}0255 \pm 0{,}0005$. Unterhalb 0,01 mm ergeben die Messungen ein geringes Ansteigen des f-Wertes, das noch nicht erklärt werden kann. Aus den Messungen läßt sich, der Dampfdruckkurve $p = p\,(T)$ des Gesamtdruckes entsprechend, eine Kurve $\mathfrak{p} = \mathfrak{p}\,(T)$ ableiten, wobei $f^{-1} \cdot \mathfrak{p}$ den Partialdruck der Atome im Dampf darstellt. Wegen der Konstanz von f oberhalb 0,01 mm unterscheiden sich dort entsprechende Werte der Funktionen $p\,(T)$ und $\mathfrak{p}\,(T)$ nur um einen konstanten Faktor, und die Verdampfungswärme der Atome stimmt innerhalb eines Prozents mit derjenigen des gesamten Dampfes überein. Der Parialdruck der Moleküle im Dampf kann daher zwischen 0,01 und 200 mm Druck höchstens wenige Prozent ausmachen.

1. Ziel der Arbeit und Untersuchungsmethoden. Nach der heutigen Dispersionstheorie ist die Dispersion einatomiger Gase und Dämpfe quantitativ berechenbar, wenn die Eigenfrequenzen ν_0 — die Absorptionsstellen — und die zugehörigen f_0-Werte bekannt sind, das sind die Zahlen der den Frequenzen ν_0 entsprechenden Dispersionselektronen pro Atom. Tatsächlich sind zwar meist die ν_0-, aber nur in wenigen Fällen die f_0-Werte bekannt. Man hat daher bisher umgekehrt die f_0-Werte aus Dispersionsmessungen berechnet, indem man mit möglichst wenigen ν_0-Werten, also möglichst wenigen Gliedern in der Dispersionsformel auszukommen suchte**.

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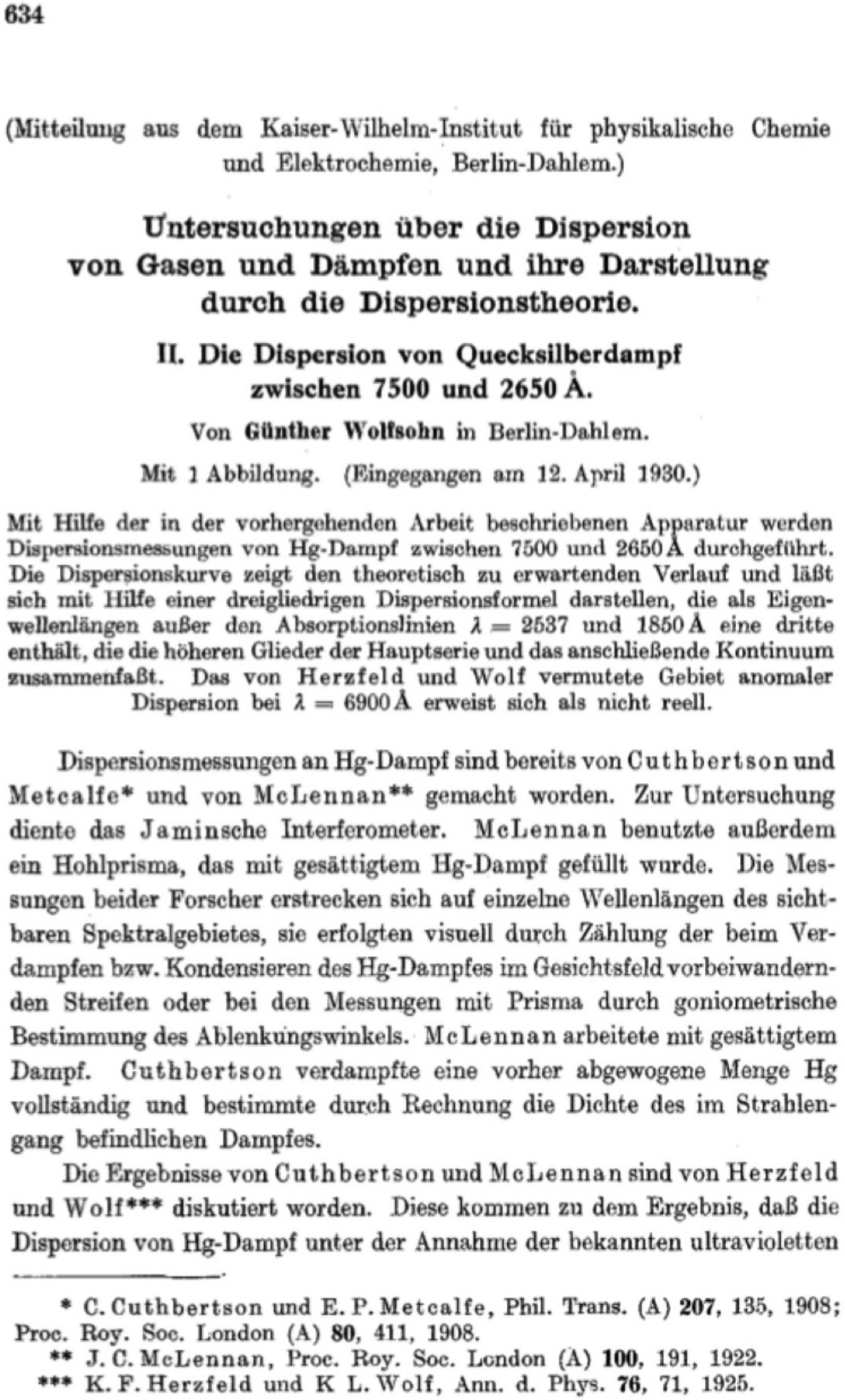
* Ein vorläufiger Bericht über diese Untersuchungen wurde am 16. Februar 1929 auf dem Gautag des Gauvereins Niedersachsen (in Göttingen) vorgetragen und in den Nachrichten der Gesellschaft der Wissenschaften zu Göttingen, Math.-phys. Klasse, 1929, S. 1, veröffentlicht.

** Vgl. R. Ladenburg und F. Reiche, Naturwissensch. **11**, 584, 1923; K. F. Herzfeld und K. L. Wolf, Ann. d. Phys. **76**, 71, 1925 usw.

Figure C.71: Rudolf Ladenburg and other members of his group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie demonstrated stimulated light emission from atoms (amplification of the number of photons of light from atoms) during the period 1927–1931 [*Zeitschrift für Physik* (1930) 63:9–10:616–633].



(Mitteilung aus dem Kaiser-Wilhelm-Institut für physikalische Chemie und Elektrochemie, Berlin-Dahlem.)

Untersuchungen über die Dispersion von Gasen und Dämpfen und ihre Darstellung durch die Dispersionstheorie.

II. Die Dispersion von Quecksilberdampf zwischen 7500 und 2650 Å.

Von **Günther Wolfsohn** in Berlin-Dahlem.

Mit 1 Abbildung. (Eingegangen am 12. April 1930.)

Mit Hilfe der in der vorhergehenden Arbeit beschriebenen Apparatur werden Dispersionsmessungen von Hg-Dampf zwischen 7500 und 2650 Å durchgeführt. Die Dispersionskurve zeigt den theoretisch zu erwartenden Verlauf und läßt sich mit Hilfe einer dreigliedrigen Dispersionsformel darstellen, die als Eigenwellenlängen außer den Absorptionslinien $\lambda = 2537$ und 1850 Å eine dritte enthält, die die höheren Glieder der Hauptserie und das anschließende Kontinuum zusammenfaßt. Das von Herzfeld und Wolf vermutete Gebiet anomaler Dispersion bei $\lambda = 6900$ Å erweist sich als nicht reell.

Dispersionsmessungen an Hg-Dampf sind bereits von Cuthbertson und Metcalfe* und von McLennan** gemacht worden. Zur Untersuchung diente das Jaminsche Interferometer. McLennan benutzte außerdem ein Hohlprisma, das mit gesättigtem Hg-Dampf gefüllt wurde. Die Messungen beider Forscher erstrecken sich auf einzelne Wellenlängen des sichtbaren Spektralgebietes, sie erfolgten visuell durch Zählung der beim Verdampfen bzw. Kondensieren des Hg-Dampfes im Gesichtsfeld vorbeiwandernden Streifen oder bei den Messungen mit Prisma durch goniometrische Bestimmung des Ablenkungswinkels. McLennan arbeitete mit gesättigtem Dampf. Cuthbertson verdampfte eine vorher abgewogene Menge Hg vollständig und bestimmte durch Rechnung die Dichte des im Strahlengang befindlichen Dampfes.

Die Ergebnisse von Cuthbertson und McLennan sind von Herzfeld und Wolf*** diskutiert worden. Diese kommen zu dem Ergebnis, daß die Dispersion von Hg-Dampf unter der Annahme der bekannten ultravioletten

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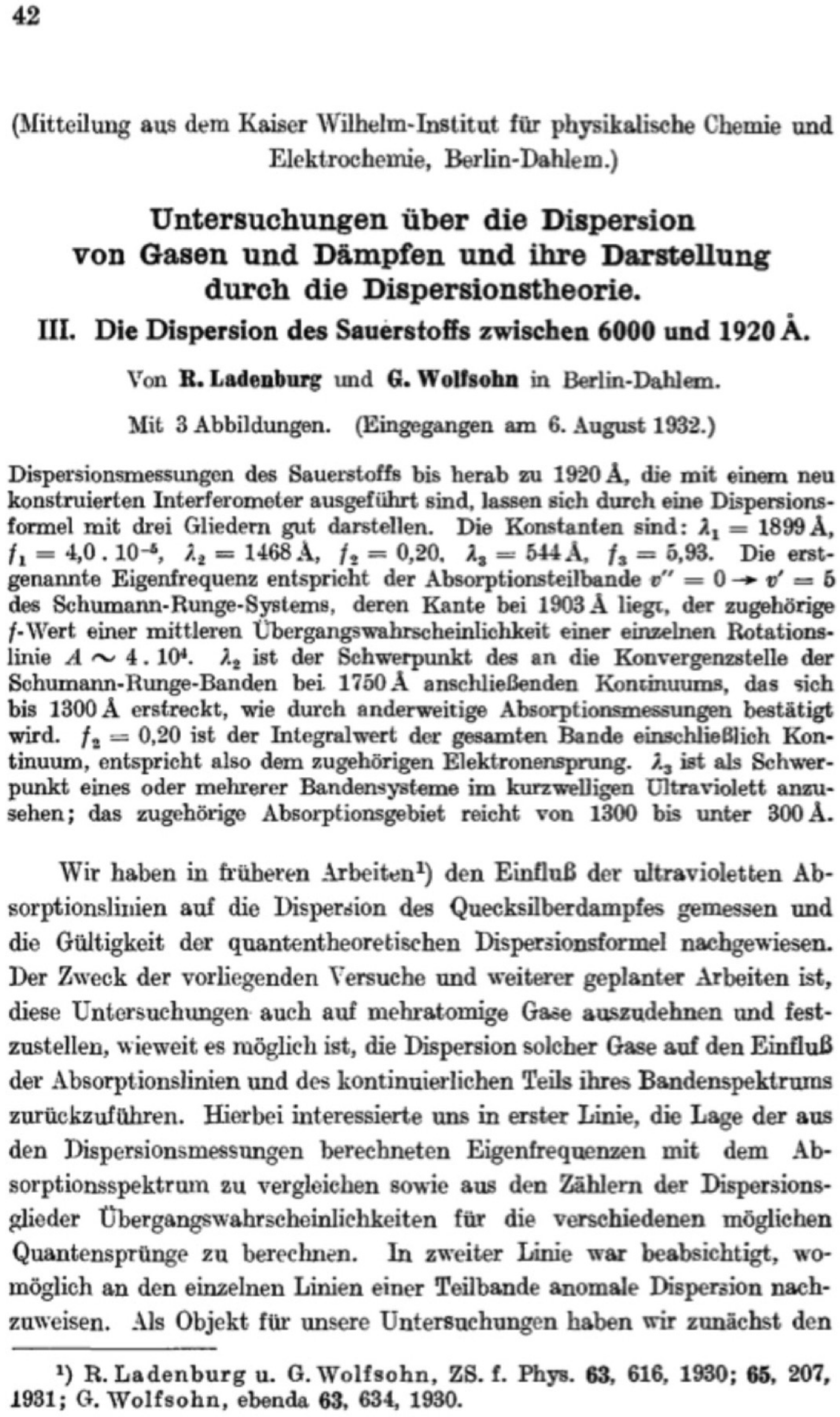
* C. Cuthbertson und E. P. Metcalfe, Phil. Trans. (A) **207**, 135, 1908; Proc. Roy. Soc. London (A) **80**, 411, 1908.

** J. C. McLennan, Proc. Roy. Soc. London (A) **100**, 191, 1922.

*** K. F. Herzfeld und K. L. Wolf, Ann. d. Phys. **76**, 71, 1925.

Figure C.72: Rudolf Ladenburg and other members of his group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie demonstrated stimulated light emission from atoms (amplification of the number of photons of light from atoms) during the period 1927–1931 [*Zeitschrift für Physik* (1930) 63:9–10:634–639].



(Mitteilung aus dem Kaiser Wilhelm-Institut für physikalische Chemie und Elektrochemie, Berlin-Dahlem.)

Untersuchungen über die Dispersion von Gasen und Dämpfen und ihre Darstellung durch die Dispersionstheorie.

III. Die Dispersion des Sauerstoffs zwischen 6000 und 1920 Å.

Von **R. Ladenburg** und **G. Wolfsohn** in Berlin-Dahlem.

Mit 3 Abbildungen. (Eingegangen am 6. August 1932.)

Dispersionsmessungen des Sauerstoffs bis herab zu 1920 Å, die mit einem neu konstruierten Interferometer ausgeführt sind, lassen sich durch eine Dispersionsformel mit drei Gliedern gut darstellen. Die Konstanten sind: $\lambda_1 = 1899$ Å, $f_1 = 4{,}0 \cdot 10^{-5}$, $\lambda_2 = 1468$ Å, $f_2 = 0{,}20$, $\lambda_3 = 544$ Å, $f_3 = 5{,}93$. Die erstgenannte Eigenfrequenz entspricht der Absorptionsteilbande $v'' = 0 \rightarrow v' = 5$ des Schumann-Runge-Systems, deren Kante bei 1903 Å liegt, der zugehörige f-Wert einer mittleren Übergangswahrscheinlichkeit einer einzelnen Rotationslinie $A \sim 4 \cdot 10^4$. λ_2 ist der Schwerpunkt des an die Konvergenzstelle der Schumann-Runge-Banden bei 1750 Å anschließenden Kontinuums, das sich bis 1300 Å erstreckt, wie durch anderweitige Absorptionsmessungen bestätigt wird. $f_2 = 0{,}20$ ist der Integralwert der gesamten Bande einschließlich Kontinuum, entspricht also dem zugehörigen Elektronensprung. λ_3 ist als Schwerpunkt eines oder mehrerer Bandensysteme im kurzwelligen Ultraviolett anzusehen; das zugehörige Absorptionsgebiet reicht von 1300 bis unter 300 Å.

Wir haben in früheren Arbeiten¹) den Einfluß der ultravioletten Absorptionslinien auf die Dispersion des Quecksilberdampfes gemessen und die Gültigkeit der quantentheoretischen Dispersionsformel nachgewiesen. Der Zweck der vorliegenden Versuche und weiterer geplanter Arbeiten ist, diese Untersuchungen auch auf mehratomige Gase auszudehnen und festzustellen, wieweit es möglich ist, die Dispersion solcher Gase auf den Einfluß der Absorptionslinien und des kontinuierlichen Teils ihres Bandenspektrums zurückzuführen. Hierbei interessierte uns in erster Linie, die Lage der aus den Dispersionsmessungen berechneten Eigenfrequenzen mit dem Absorptionsspektrum zu vergleichen sowie aus den Zählern der Dispersionsglieder Übergangswahrscheinlichkeiten für die verschiedenen möglichen Quantensprünge zu berechnen. In zweiter Linie war beabsichtigt, womöglich an den einzelnen Linien einer Teilbande anomale Dispersion nachzuweisen. Als Objekt für unsere Untersuchungen haben wir zunächst den

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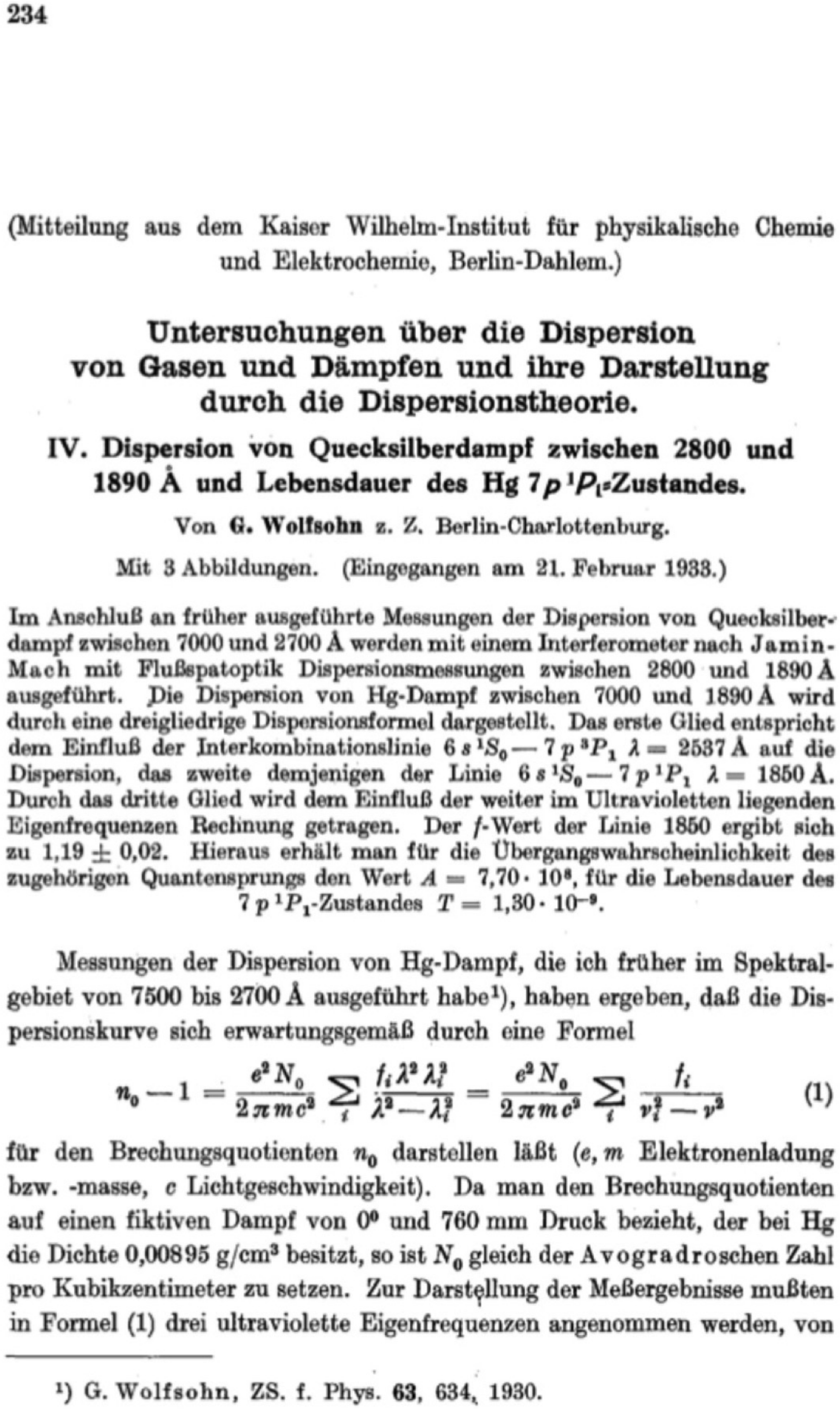
¹) **R. Ladenburg** u. **G. Wolfsohn**, ZS. f. Phys. **63**, 616, 1930; **65**, 207, 1931; **G. Wolfsohn**, ebenda **63**, 634, 1930.

Figure C.73: Rudolf Ladenburg and other members of his group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie demonstrated stimulated light emission from atoms (amplification of the number of photons of light from atoms) during the period 1927–1931 [*Zeitschrift für Physik* (1932) 79:1–2:42–61].



(Mitteilung aus dem Kaiser Wilhelm-Institut für physikalische Chemie
und Elektrochemie, Berlin-Dahlem.)

Untersuchungen über die Dispersion von Gasen und Dämpfen und ihre Darstellung durch die Dispersionstheorie.

IV. Dispersion von Quecksilberdampf zwischen 2800 und 1890 Å und Lebensdauer des Hg $7p\,^1P_1$-Zustandes.

Von **G. Wolfsohn** z. Z. Berlin-Charlottenburg.

Mit 3 Abbildungen. (Eingegangen am 21. Februar 1933.)

Im Anschluß an früher ausgeführte Messungen der Dispersion von Quecksilberdampf zwischen 7000 und 2700 Å werden mit einem Interferometer nach Jamin-Mach mit Flußspatoptik Dispersionsmessungen zwischen 2800 und 1890 Å ausgeführt. Die Dispersion von Hg-Dampf zwischen 7000 und 1890 Å wird durch eine dreigliedrige Dispersionsformel dargestellt. Das erste Glied entspricht dem Einfluß der Interkombinationslinie $6\,s\,^1S_0 - 7\,p\,^3P_1$ $\lambda = 2537$ Å auf die Dispersion, das zweite demjenigen der Linie $6\,s\,^1S_0 - 7\,p\,^1P_1$ $\lambda = 1850$ Å. Durch das dritte Glied wird dem Einfluß der weiter im Ultravioletten liegenden Eigenfrequenzen Rechnung getragen. Der f-Wert der Linie 1850 ergibt sich zu $1{,}19 \pm 0{,}02$. Hieraus erhält man für die Übergangswahrscheinlichkeit des zugehörigen Quantensprungs den Wert $A = 7{,}70 \cdot 10^8$, für die Lebensdauer des $7\,p\,^1P_1$-Zustandes $T = 1{,}30 \cdot 10^{-9}$.

Messungen der Dispersion von Hg-Dampf, die ich früher im Spektralgebiet von 7500 bis 2700 Å ausgeführt habe¹), haben ergeben, daß die Dispersionskurve sich erwartungsgemäß durch eine Formel

$$n_0 - 1 = \frac{e^2 N_0}{2\pi m c^2} \sum_i \frac{f_i \lambda^2 \lambda_i^2}{\lambda^2 - \lambda_i^2} = \frac{e^2 N_0}{2\pi m c^2} \sum_i \frac{f_i}{\nu_i^2 - \nu^2} \qquad (1)$$

für den Brechungsquotienten n_0 darstellen läßt (e, m Elektronenladung bzw. -masse, c Lichtgeschwindigkeit). Da man den Brechungsquotienten auf einen fiktiven Dampf von 0° und 760 mm Druck bezieht, der bei Hg die Dichte 0,00895 g/cm³ besitzt, so ist N_0 gleich der Avogradroschen Zahl pro Kubikzentimeter zu setzen. Zur Darstellung der Meßergebnisse mußten in Formel (1) drei ultraviolette Eigenfrequenzen angenommen werden, von

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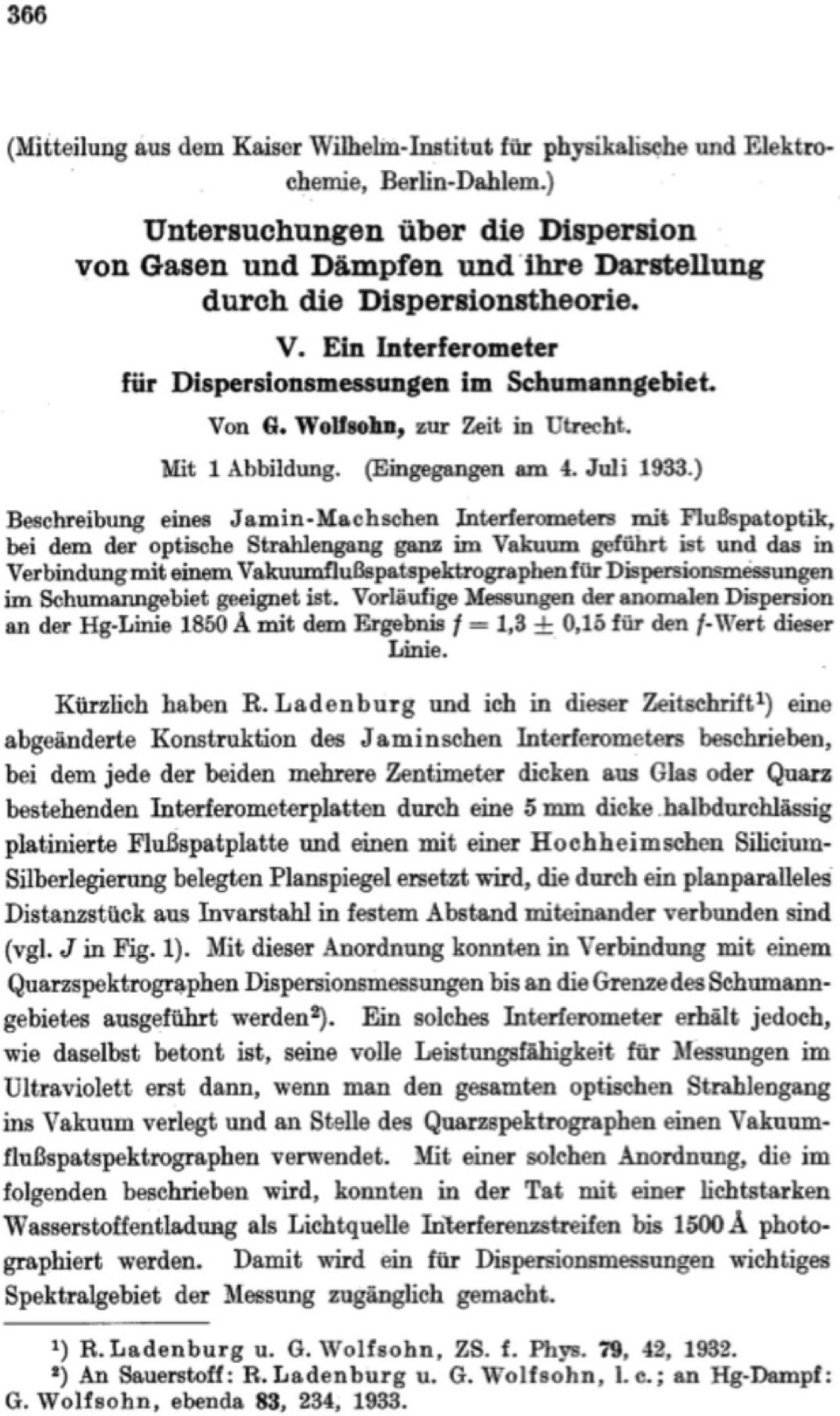
¹) G. Wolfsohn, ZS. f. Phys. **63**, 634, 1930.

Figure C.74: Rudolf Ladenburg and other members of his group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie demonstrated stimulated light emission from atoms (amplification of the number of photons of light from atoms) during the period 1927–1931 [*Zeitschrift für Physik* (1933) 83:3–4:234–246].



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(Mitteilung aus dem Kaiser Wilhelm-Institut für physikalische und Elektrochemie, Berlin-Dahlem.)

Untersuchungen über die Dispersion von Gasen und Dämpfen und ihre Darstellung durch die Dispersionstheorie.

V. Ein Interferometer für Dispersionsmessungen im Schumanngebiet.

Von **G. Wolfsohn,** zur Zeit in Utrecht.

Mit 1 Abbildung. (Eingegangen am 4. Juli 1933.)

Beschreibung eines Jamin-Machschen Interferometers mit Flußspatoptik, bei dem der optische Strahlengang ganz im Vakuum geführt ist und das in Verbindung mit einem Vakuumflußspatspektrographen für Dispersionsmessungen im Schumanngebiet geeignet ist. Vorläufige Messungen der anomalen Dispersion an der Hg-Linie 1850 Å mit dem Ergebnis $f = 1,3 \pm 0,15$ für den f-Wert dieser Linie.

Kürzlich haben R. Ladenburg und ich in dieser Zeitschrift[1]) eine abgeänderte Konstruktion des Jaminschen Interferometers beschrieben, bei dem jede der beiden mehrere Zentimeter dicken aus Glas oder Quarz bestehenden Interferometerplatten durch eine 5 mm dicke halbdurchlässig platinierte Flußspatplatte und einen mit einer Hochheimschen Silicium-Silberlegierung belegten Planspiegel ersetzt wird, die durch ein planparalleles Distanzstück aus Invarstahl in festem Abstand miteinander verbunden sind (vgl. J in Fig. 1). Mit dieser Anordnung konnten in Verbindung mit einem Quarzspektrographen Dispersionsmessungen bis an die Grenze des Schumanngebietes ausgeführt werden[2]). Ein solches Interferometer erhält jedoch, wie daselbst betont ist, seine volle Leistungsfähigkeit für Messungen im Ultraviolett erst dann, wenn man den gesamten optischen Strahlengang ins Vakuum verlegt und an Stelle des Quarzspektrographen einen Vakuumflußspatspektrographen verwendet. Mit einer solchen Anordnung, die im folgenden beschrieben wird, konnten in der Tat mit einer lichtstarken Wasserstoffentladung als Lichtquelle Interferenzstreifen bis 1500 Å photographiert werden. Damit wird ein für Dispersionsmessungen wichtiges Spektralgebiet der Messung zugänglich gemacht.

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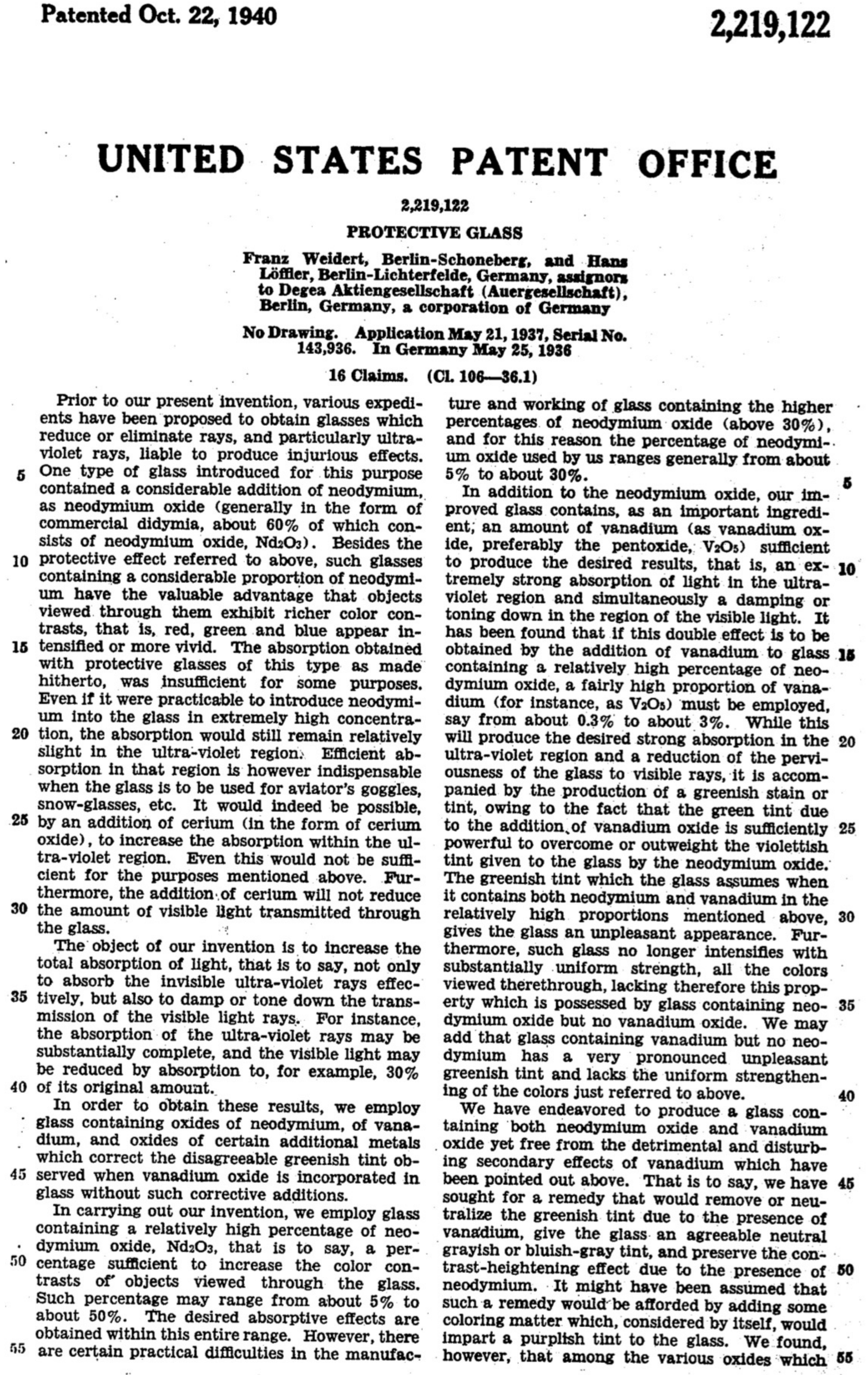
[1]) R. Ladenburg u. G. Wolfsohn, ZS. f. Phys. **79**, 42, 1932.

[2]) An Sauerstoff: R. Ladenburg u. G. Wolfsohn, l. c.; an Hg-Dampf: G. Wolfsohn, ebenda **83**, 234, 1933.

Figure C.75: Rudolf Ladenburg and other members of his group at the Kaiser Wilhelm Institut für Physikalische und Elektrochemie demonstrated stimulated light emission from atoms (amplification of the number of photons of light from atoms) during the period 1927–1931 [*Zeitschrift für Physik* (1933) 85:5–6:366–372].



Patented Oct. 22, 1940 **2,219,122**

UNITED STATES PATENT OFFICE

2,219,122

PROTECTIVE GLASS

Franz Weidert, Berlin-Schoneberg, and Hans Löffler, Berlin-Lichterfelde, Germany, assignors to Degea Aktiengesellschaft (Auergesellschaft), Berlin, Germany, a corporation of Germany

No Drawing. Application May 21, 1937, Serial No. 143,936. In Germany May 25, 1936

16 Claims. (Cl. 106—36.1)

Prior to our present invention, various expedients have been proposed to obtain glasses which reduce or eliminate rays, and particularly ultra-violet rays, liable to produce injurious effects. One type of glass introduced for this purpose contained a considerable addition of neodymium, as neodymium oxide (generally in the form of commercial didymia, about 60% of which consists of neodymium oxide, Nd_2O_3). Besides the protective effect referred to above, such glasses containing a considerable proportion of neodymium have the valuable advantage that objects viewed through them exhibit richer color contrasts, that is, red, green and blue appear intensified or more vivid. The absorption obtained with protective glasses of this type as made hitherto, was insufficient for some purposes. Even if it were practicable to introduce neodymium into the glass in extremely high concentration, the absorption would still remain relatively slight in the ultra-violet region. Efficient absorption in that region is however indispensable when the glass is to be used for aviator's goggles, snow-glasses, etc. It would indeed be possible, by an addition of cerium (in the form of cerium oxide), to increase the absorption within the ultra-violet region. Even this would not be sufficient for the purposes mentioned above. Furthermore, the addition of cerium will not reduce the amount of visible light transmitted through the glass.

The object of our invention is to increase the total absorption of light, that is to say, not only to absorb the invisible ultra-violet rays effectively, but also to damp or tone down the transmission of the visible light rays. For instance, the absorption of the ultra-violet rays may be substantially complete, and the visible light may be reduced by absorption to, for example, 30% of its original amount.

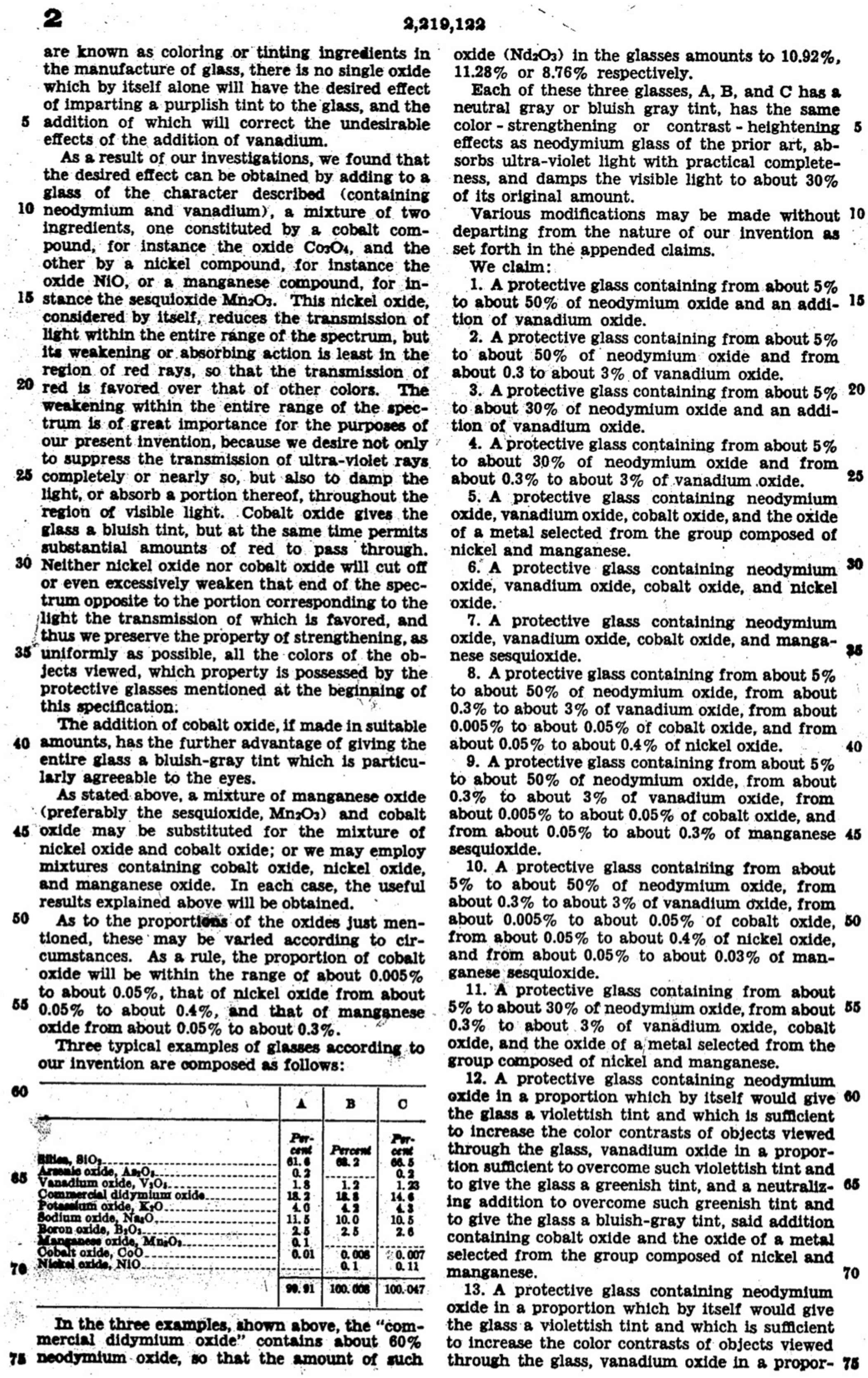
In order to obtain these results, we employ glass containing oxides of neodymium, of vanadium, and oxides of certain additional metals which correct the disagreeable greenish tint observed when vanadium oxide is incorporated in glass without such corrective additions.

In carrying out our invention, we employ glass containing a relatively high percentage of neodymium oxide, Nd_2O_3, that is to say, a percentage sufficient to increase the color contrasts of objects viewed through the glass. Such percentage may range from about 5% to about 50%. The desired absorptive effects are obtained within this entire range. However, there are certain practical difficulties in the manufacture and working of glass containing the higher percentages of neodymium oxide (above 30%), and for this reason the percentage of neodymium oxide used by us ranges generally from about 5% to about 30%.

In addition to the neodymium oxide, our improved glass contains, as an important ingredient, an amount of vanadium (as vanadium oxide, preferably the pentoxide, V_2O_5) sufficient to produce the desired results, that is, an extremely strong absorption of light in the ultra-violet region and simultaneously a damping or toning down in the region of the visible light. It has been found that if this double effect is to be obtained by the addition of vanadium to glass containing a relatively high percentage of neodymium oxide, a fairly high proportion of vanadium (for instance, as V_2O_5) must be employed, say from about 0.3% to about 3%. While this will produce the desired strong absorption in the ultra-violet region and a reduction of the perviousness of the glass to visible rays, it is accompanied by the production of a greenish stain or tint, owing to the fact that the green tint due to the addition of vanadium oxide is sufficiently powerful to overcome or outweight the violettish tint given to the glass by the neodymium oxide. The greenish tint which the glass assumes when it contains both neodymium and vanadium in the relatively high proportions mentioned above, gives the glass an unpleasant appearance. Furthermore, such glass no longer intensifies with substantially uniform strength, all the colors viewed therethrough, lacking therefore this property which is possessed by glass containing neodymium oxide but no vanadium oxide. We may add that glass containing vanadium but no neodymium has a very pronounced unpleasant greenish tint and lacks the uniform strengthening of the colors just referred to above.

We have endeavored to produce a glass containing both neodymium oxide and vanadium oxide yet free from the detrimental and disturbing secondary effects of vanadium which have been pointed out above. That is to say, we have sought for a remedy that would remove or neutralize the greenish tint due to the presence of vanadium, give the glass an agreeable neutral grayish or bluish-gray tint, and preserve the contrast-heightening effect due to the presence of neodymium. It might have been assumed that such a remedy would be afforded by adding some coloring matter which, considered by itself, would impart a purplish tint to the glass. We found, however, that among the various oxides which

Figure C.76: In 1934, Franz Weidert and Hans Löffler invented neodymium glass with unusual spectral properties that made it suitable for a variety of optical applications (ultimately including neodymium glass lasers).



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are known as coloring or tinting ingredients in the manufacture of glass, there is no single oxide which by itself alone will have the desired effect of imparting a purplish tint to the glass, and the addition of which will correct the undesirable effects of the addition of vanadium.

As a result of our investigations, we found that the desired effect can be obtained by adding to a glass of the character described (containing neodymium and vanadium), a mixture of two ingredients, one constituted by a cobalt compound, for instance the oxide Co_3O_4, and the other by a nickel compound, for instance the oxide NiO, or a manganese compound, for instance the sesquioxide Mn_2O_3. This nickel oxide, considered by itself, reduces the transmission of light within the entire range of the spectrum, but its weakening or absorbing action is least in the region of red rays, so that the transmission of red is favored over that of other colors. The weakening within the entire range of the spectrum is of great importance for the purposes of our present invention, because we desire not only to suppress the transmission of ultra-violet rays completely or nearly so, but also to damp the light, or absorb a portion thereof, throughout the region of visible light. Cobalt oxide gives the glass a bluish tint, but at the same time permits substantial amounts of red to pass through. Neither nickel oxide nor cobalt oxide will cut off or even excessively weaken that end of the spectrum opposite to the portion corresponding to the light the transmission of which is favored, and thus we preserve the property of strengthening, as uniformly as possible, all the colors of the objects viewed, which property is possessed by the protective glasses mentioned at the beginning of this specification.

The addition of cobalt oxide, if made in suitable amounts, has the further advantage of giving the entire glass a bluish-gray tint which is particularly agreeable to the eyes.

As stated above, a mixture of manganese oxide (preferably the sesquioxide, Mn_2O_3) and cobalt oxide may be substituted for the mixture of nickel oxide and cobalt oxide; or we may employ mixtures containing cobalt oxide, nickel oxide, and manganese oxide. In each case, the useful results explained above will be obtained.

As to the proportions of the oxides just mentioned, these may be varied according to circumstances. As a rule, the proportion of cobalt oxide will be within the range of about 0.005% to about 0.05%, that of nickel oxide from about 0.05% to about 0.4%, and that of manganese oxide from about 0.05% to about 0.3%.

Three typical examples of glasses according to our invention are composed as follows:

	A	B	C
	Percent	Percent	Percent
Silica, SiO_2	61.6	68.2	66.5
Arsenic oxide, As_2O_3	0.2		0.2
Vanadium oxide, V_2O_5	1.8	1.2	1.23
Commercial didymium oxide	18.2	13.8	14.6
Potassium oxide, K_2O	4.0	4.2	4.3
Sodium oxide, Na_2O	11.5	10.0	10.5
Boron oxide, B_2O_3	2.5	2.5	2.6
Manganese oxide, Mn_2O_3	0.1		
Cobalt oxide, CoO	0.01	0.008	0.007
Nickel oxide, NiO		0.1	0.11
	99.91	100.008	100.047

In the three examples, shown above, the "commercial didymium oxide" contains about 60% neodymium oxide, so that the amount of such oxide (Nd_2O_3) in the glasses amounts to 10.92%, 11.28% or 8.76% respectively.

Each of these three glasses, A, B, and C has a neutral gray or bluish gray tint, has the same color-strengthening or contrast-heightening effects as neodymium glass of the prior art, absorbs ultra-violet light with practical completeness, and damps the visible light to about 30% of its original amount.

Various modifications may be made without departing from the nature of our invention as set forth in the appended claims.

We claim:

1. A protective glass containing from about 5% to about 50% of neodymium oxide and an addition of vanadium oxide.

2. A protective glass containing from about 5% to about 50% of neodymium oxide and from about 0.3 to about 3% of vanadium oxide.

3. A protective glass containing from about 5% to about 30% of neodymium oxide and an addition of vanadium oxide.

4. A protective glass containing from about 5% to about 30% of neodymium oxide and from about 0.3% to about 3% of vanadium oxide.

5. A protective glass containing neodymium oxide, vanadium oxide, cobalt oxide, and the oxide of a metal selected from the group composed of nickel and manganese.

6. A protective glass containing neodymium oxide, vanadium oxide, cobalt oxide, and nickel oxide.

7. A protective glass containing neodymium oxide, vanadium oxide, cobalt oxide, and manganese sesquioxide.

8. A protective glass containing from about 5% to about 50% of neodymium oxide, from about 0.3% to about 3% of vanadium oxide, from about 0.005% to about 0.05% of cobalt oxide, and from about 0.05% to about 0.4% of nickel oxide.

9. A protective glass containing from about 5% to about 50% of neodymium oxide, from about 0.3% to about 3% of vanadium oxide, from about 0.005% to about 0.05% of cobalt oxide, and from about 0.05% to about 0.3% of manganese sesquioxide.

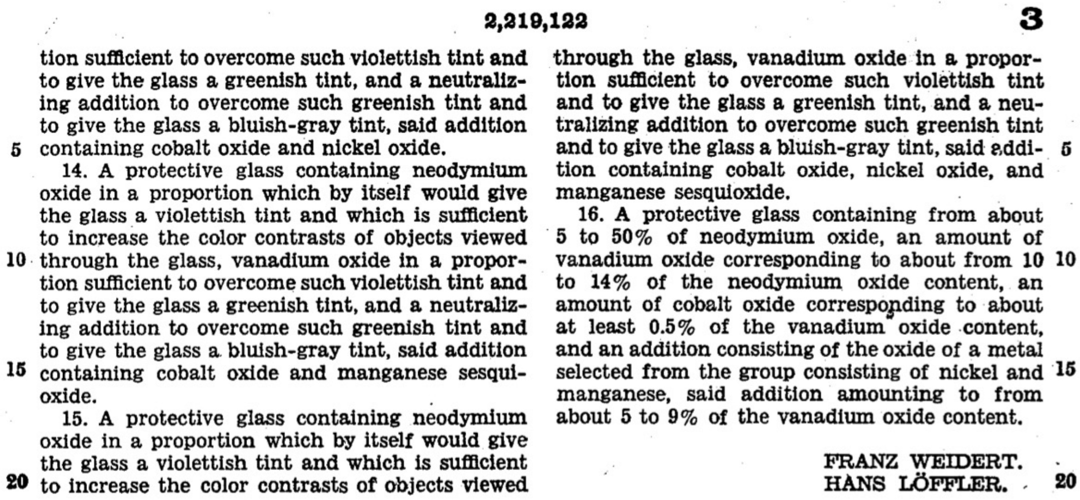
10. A protective glass containing from about 5% to about 50% of neodymium oxide, from about 0.3% to about 3% of vanadium oxide, from about 0.005% to about 0.05% of cobalt oxide, from about 0.05% to about 0.4% of nickel oxide, and from about 0.05% to about 0.03% of manganese sesquioxide.

11. A protective glass containing from about 5% to about 30% of neodymium oxide, from about 0.3% to about 3% of vanadium oxide, cobalt oxide, and the oxide of a metal selected from the group composed of nickel and manganese.

12. A protective glass containing neodymium oxide in a proportion which by itself would give the glass a violettish tint and which is sufficient to increase the color contrasts of objects viewed through the glass, vanadium oxide in a proportion sufficient to overcome such violettish tint and to give the glass a greenish tint, and a neutralizing addition to overcome such greenish tint and to give the glass a bluish-gray tint, said addition containing cobalt oxide and the oxide of a metal selected from the group composed of nickel and manganese.

13. A protective glass containing neodymium oxide in a proportion which by itself would give the glass a violettish tint and which is sufficient to increase the color contrasts of objects viewed through the glass, vanadium oxide in a propor-

Figure C.77: In 1934, Franz Weidert and Hans Löffler invented neodymium glass with unusual spectral properties that made it suitable for a variety of optical applications (ultimately including neodymium glass lasers).



2,219,122 **3**

tion sufficient to overcome such violettish tint and to give the glass a greenish tint, and a neutralizing addition to overcome such greenish tint and to give the glass a bluish-gray tint, said addition containing cobalt oxide and nickel oxide.

14. A protective glass containing neodymium oxide in a proportion which by itself would give the glass a violettish tint and which is sufficient to increase the color contrasts of objects viewed through the glass, vanadium oxide in a proportion sufficient to overcome such violettish tint and to give the glass a greenish tint, and a neutralizing addition to overcome such greenish tint and to give the glass a bluish-gray tint, said addition containing cobalt oxide and manganese sesquioxide.

15. A protective glass containing neodymium oxide in a proportion which by itself would give the glass a violettish tint and which is sufficient to increase the color contrasts of objects viewed through the glass, vanadium oxide in a proportion sufficient to overcome such violettish tint and to give the glass a greenish tint, and a neutralizing addition to overcome such greenish tint and to give the glass a bluish-gray tint, said addition containing cobalt oxide, nickel oxide, and manganese sesquioxide.

16. A protective glass containing from about 5 to 50% of neodymium oxide, an amount of vanadium oxide corresponding to about from 10 to 14% of the neodymium oxide content, an amount of cobalt oxide corresponding to about at least 0.5% of the vanadium oxide content, and an addition consisting of the oxide of a metal selected from the group consisting of nickel and manganese, said addition amounting to from about 5 to 9% of the vanadium oxide content.

FRANZ WEIDERT.
HANS LÖFFLER.

Figure C.78: In 1934, Franz Weidert and Hans Löffler invented neodymium glass with unusual spectral properties that made it suitable for a variety of optical applications (ultimately including neodymium glass lasers).

[Neodymium-doped glass is now widely used to make lasers, especially high-power laser systems. Due to the optical properties of the neodymium glass, that material absorbs ordinary, visible, incoherent light (such as light from photographic flash lamps) and emits infrared coherent (laser) light with a wavelength of approximately 1.06 μm.

As illustrated by the preceding U.S. Patent 2,219,122 and the following FIAT 824 report, Franz Weidert (German, 1878–1954) and Hans Löffler (German, ??–??) invented neodymium glass in or before 1934, and filed several patent applications from 1934 onward. They described its unusual spectral properties and developed a wide variety of optical applications for it.

FIAT 824 (p. 3132) stated that much of the optical industry of the German-speaking world was located in areas that were taken over by Russian forces after the war (Russian-occupied zones of Germany and Austria, and also Czech and Polish territory). Therefore even after the war, Western Allied countries did not have much information regarding just how far neodymium glass and other potentially laser-related optical technologies had advanced in the German-speaking world by 1945.

However, it is clear that scientists in the German-speaking world:

- Had been working with neodymium-doped glass since at least 1934 and were fully aware of its spectral properties and potential optical applications that those enabled (pp. 3128–3132).

- Were well aware of the high-profile publications by Albert Einstein, Walther Bothe, James Franck, Rudolf Ladenburg, and others during the period 1916–1931 demonstrating the theoretical feasibility and experimental evidence for stimulated emission of light in laser-like optical systems (pp. 3102–3127).

- Were keenly interested in developing monochromatic light sources—something like a laser that would only emit light of one particular wavelength (pp. 3137–3156).

- Were doing extensive research on new methods of producing and detecting infrared light, as well as developing a wide variety of applications of infrared light (pp. 1131–1156).

Given all of these known facts, it is not unreasonable to wonder whether laser-like applications of neodymium glass may have been proposed or investigated in wartime Germany, or whether such work may have influenced the development of neodymium glass lasers in other countries after the war.

According to official histories, neodymium lasers were first demonstrated in 1961 in the United States [Bromberg 1991, p. 101]. Was that development directly or indirectly aided by the large amount of advanced optical materials, information, and scientists that the United States obtained from Germany and Austria at the end of World War II (see for example pp. 624–642, 680–688, 1131–1156, 1260–1285, and 2923–3018)?

Much more archival research needs to be conducted to investigate these questions and the relevant history.]

FIAT 824. ***The Miscellaneous Glass Industry of Central Europe.***

[p. 1:] This report presents the results of an extensive study of the miscellaneous glass industry in the British, French, and American Occupied Zones of Germany and Austria, from December 1945 to May 1946. [...] Much of the German and Austrian glass industry is located in the Russian Zone from which no direct information could be obtained. In many instances this presented unusual difficulties arising from the fact that suppliers of equipment and materials, as well as glass manufacturing plants, were not accessible. [...]

[pp. 3–4:] Rare earths are in wide use in the production of special glasses, particularly ultra-violet and infra-red absorbing protective glasses. Cerium is commonly used in the form of ignited cerium dioxide. Several grades of neodymium compounds of varying purity were found to be in use[...]

[p. 31:] A glass of relatively high neodymium content has come into rather wide use during the war under the trade name of Neophan (See Table 15 Appendix 4). Glasses containing neodymium have been used for spectacles and other special purposes for some time, and even the Neophan series have been known from the Weidert patents, but the wide extent and purposes of its more recent use seem worthy of comment. These glasses have been used for sun glasses, for military aviators and anti-aircraft crews, for locomotive engineers, and in short, for all purposes for which the readier and more precise discrimination among colors, particularly signal colors, is of importance. They have also been used for illuminating ball rooms and butcher shops to yield more desirable color observations. They have been used as mirrors in hospitals, since the patients think that they "look better" when they view themselves in such mirrors. It is believed that the compositions used for all of these purposes are variants of the composition listed. The essential feature apparently resides in the characteristic neodymium absorption bands. [...]

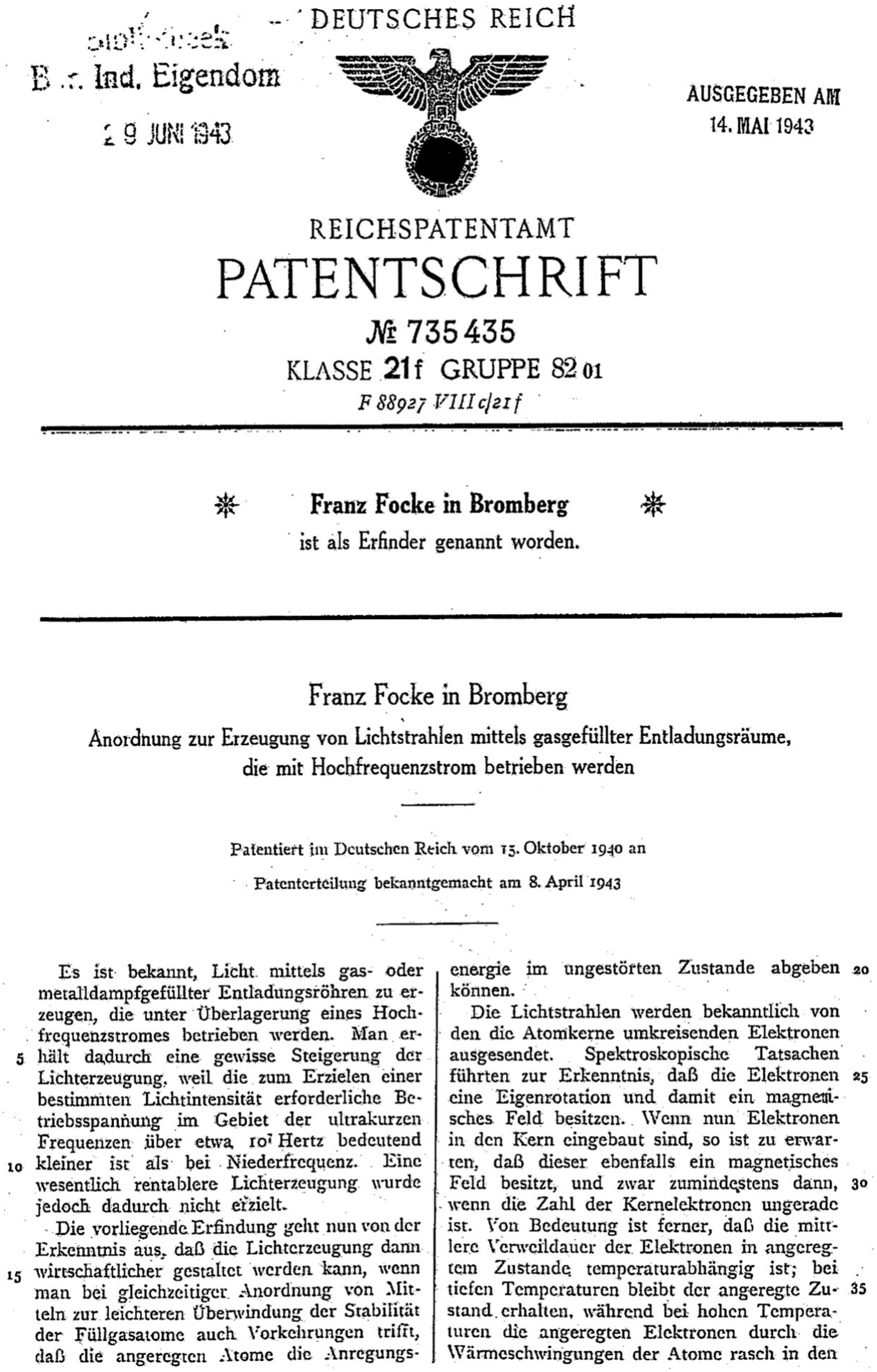
[p. 55:]

TABLE 15

NEOPHAN GLASS

Syntheses	
SiO_2	61.6
Na_2O	9.7
K_2O	5.88
As_2O_3	0.57
Nd_2O_3	12.03
Pr_2O_3	3.11
La_2O_3	5.6
Vd_2O_4	1.24
Cr_2O_3	0.02
Ce_2O_3	0.16
NiO	0.14
CoO	0.05

Melted in open pots with blocking during melt
Blown into cylinders, split and flattened
Used for eye protection and aiding color discrimination
This glass is 75% light absorbing, but it is also made with 25, 50 and 90% light absorption
Derivatives are used for a variety of purposes as described on page 31
See U.S. Patent No. 2,219,122



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29 JUNI 1943

DEUTSCHES REICH

AUSGEGEBEN AM
14. MAI 1943

REICHSPATENTAMT

PATENTSCHRIFT

№ 735 435

KLASSE 21f GRUPPE 82 01

F 88927 VIII c/21 f

Franz Focke in Bromberg
ist als Erfinder genannt worden.

Franz Focke in Bromberg

Anordnung zur Erzeugung von Lichtstrahlen mittels gasgefüllter Entladungsräume, die mit Hochfrequenzstrom betrieben werden

Patentiert im Deutschen Reich vom 15. Oktober 1940 an

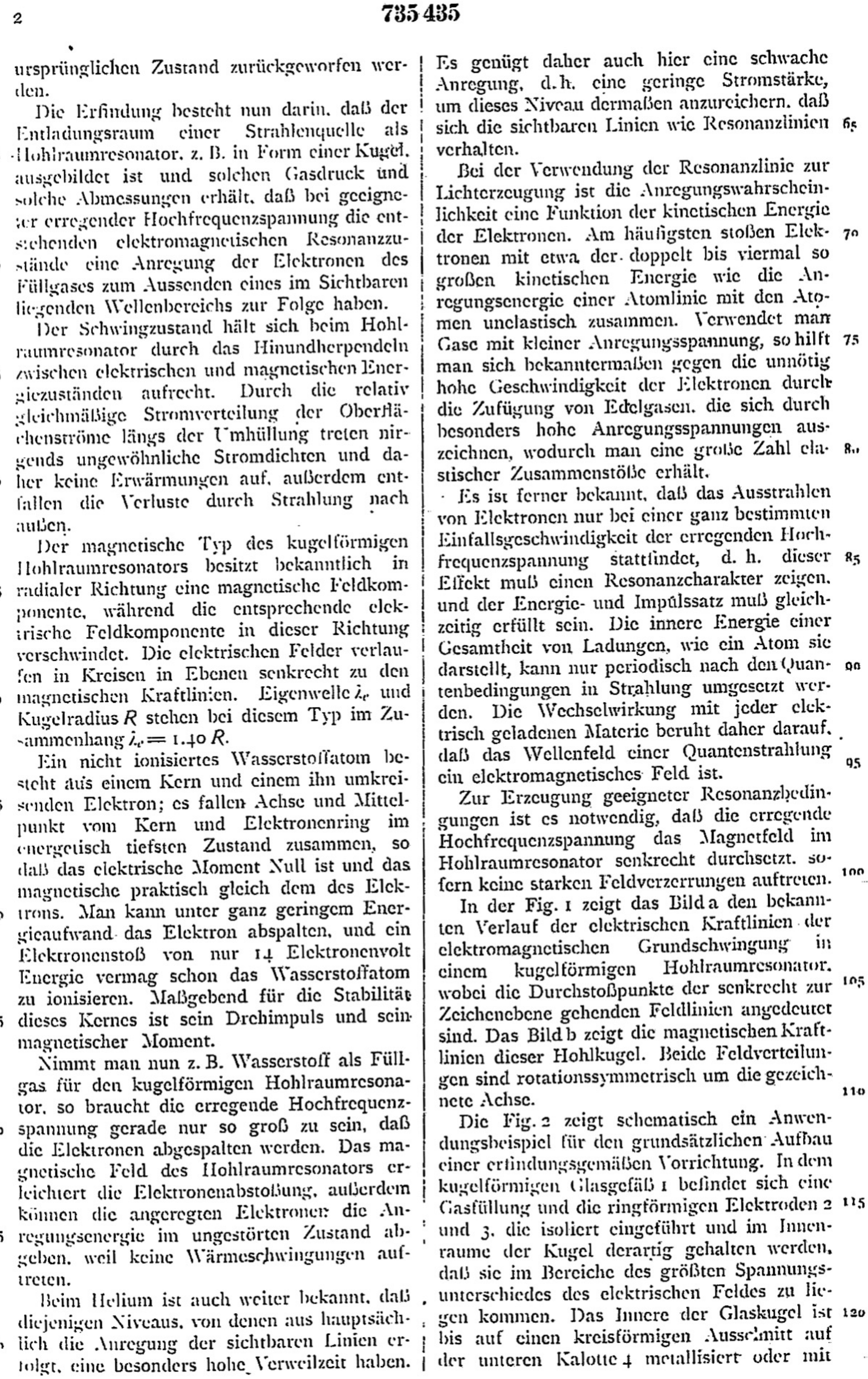
Patenterteilung bekanntgemacht am 8. April 1943

Es ist bekannt, Licht mittels gas- oder metalldampfgefüllter Entladungsröhren zu erzeugen, die unter Überlagerung eines Hochfrequenzstromes betrieben werden. Man erhält dadurch eine gewisse Steigerung der Lichterzeugung, weil die zum Erzielen einer bestimmten Lichtintensität erforderliche Betriebsspannung im Gebiet der ultrakurzen Frequenzen über etwa 10^7 Hertz bedeutend kleiner ist als bei Niederfrequenz. Eine wesentlich rentablere Lichterzeugung wurde jedoch dadurch nicht erzielt.

Die vorliegende Erfindung geht nun von der Erkenntnis aus, daß die Lichterzeugung dann wirtschaftlicher gestaltet werden kann, wenn man bei gleichzeitiger Anordnung von Mitteln zur leichteren Überwindung der Stabilität der Füllgasatome auch Vorkehrungen trifft, daß die angeregten Atome die Anregungsenergie im ungestörten Zustande abgeben können.

Die Lichtstrahlen werden bekanntlich von den die Atomkerne umkreisenden Elektronen ausgesendet. Spektroskopische Tatsachen führten zur Erkenntnis, daß die Elektronen eine Eigenrotation und damit ein magnetisches Feld besitzen. Wenn nun Elektronen in den Kern eingebaut sind, so ist zu erwarten, daß dieser ebenfalls ein magnetisches Feld besitzt, und zwar zumindestens dann, wenn die Zahl der Kernelektronen ungerade ist. Von Bedeutung ist ferner, daß die mittlere Verweildauer der Elektronen in angeregtem Zustande temperaturabhängig ist; bei tiefen Temperaturen bleibt der angeregte Zustand erhalten, während bei hohen Temperaturen die angeregten Elektronen durch die Wärmeschwingungen der Atome rasch in den

Figure C.79: In 1940, Franz Focke filed a patent application on using resonant excitation to create a population inversion of electron energy levels in a gas, in order to create a light beam with a particular wavelength.



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ursprünglichen Zustand zurückgeworfen werden.

Die Erfindung besteht nun darin, daß der Entladungsraum einer Strahlenquelle als Hohlraumresonator, z. B. in Form einer Kugel, ausgebildet ist und solchen Gasdruck und solche Abmessungen erhält, daß bei geeigneter erregender Hochfrequenzspannung die entstehenden elektromagnetischen Resonanzzustände eine Anregung der Elektronen des Füllgases zum Aussenden eines im Sichtbaren liegenden Wellenbereichs zur Folge haben.

Der Schwingzustand hält sich beim Hohlraumresonator durch das Hinundherpendeln zwischen elektrischen und magnetischen Energiezuständen aufrecht. Durch die relativ gleichmäßige Stromverteilung der Oberflächenströme längs der Umhüllung treten nirgends ungewöhnliche Stromdichten und daher keine Erwärmungen auf, außerdem entfallen die Verluste durch Strahlung nach außen.

Der magnetische Typ des kugelförmigen Hohlraumresonators besitzt bekanntlich in radialer Richtung eine magnetische Feldkomponente, während die entsprechende elektrische Feldkomponente in dieser Richtung verschwindet. Die elektrischen Felder verlaufen in Kreisen in Ebenen senkrecht zu den magnetischen Kraftlinien. Eigenwelle λ_e und Kugelradius R stehen bei diesem Typ im Zusammenhang $\lambda_e = 1.40\, R$.

Ein nicht ionisiertes Wasserstoffatom besteht aus einem Kern und einem ihn umkreisenden Elektron; es fallen Achse und Mittelpunkt vom Kern und Elektronenring im energetisch tiefsten Zustand zusammen, so daß das elektrische Moment Null ist und das magnetische praktisch gleich dem des Elektrons. Man kann unter ganz geringem Energieaufwand das Elektron abspalten, und ein Elektronenstoß von nur 14 Elektronenvolt Energie vermag schon das Wasserstoffatom zu ionisieren. Maßgebend für die Stabilität dieses Kernes ist sein Drehimpuls und sein magnetischer Moment.

Nimmt man nun z. B. Wasserstoff als Füllgas für den kugelförmigen Hohlraumresonator, so braucht die erregende Hochfrequenzspannung gerade nur so groß zu sein, daß die Elektronen abgespalten werden. Das magnetische Feld des Hohlraumresonators erleichtert die Elektronenabstoßung, außerdem können die angeregten Elektronen die Anregungsenergie im ungestörten Zustand abgeben, weil keine Wärmeschwingungen auftreten.

Beim Helium ist auch weiter bekannt, daß diejenigen Niveaus, von denen aus hauptsächlich die Anregung der sichtbaren Linien erfolgt, eine besonders hohe Verweilzeit haben. Es genügt daher auch hier eine schwache Anregung, d. h. eine geringe Stromstärke, um dieses Niveau dermaßen anzureichern, daß sich die sichtbaren Linien wie Resonanzlinien verhalten.

Bei der Verwendung der Resonanzlinie zur Lichterzeugung ist die Anregungswahrscheinlichkeit eine Funktion der kinetischen Energie der Elektronen. Am häufigsten stoßen Elektronen mit etwa der doppelt bis viermal so großen kinetischen Energie wie die Anregungsenergie einer Atomlinie mit den Atomen unelastisch zusammen. Verwendet man Gase mit kleiner Anregungsspannung, so hilft man sich bekanntermaßen gegen die unnötig hohe Geschwindigkeit der Elektronen durch die Zufügung von Edelgasen, die sich durch besonders hohe Anregungsspannungen auszeichnen, wodurch man eine große Zahl elastischer Zusammenstöße erhält.

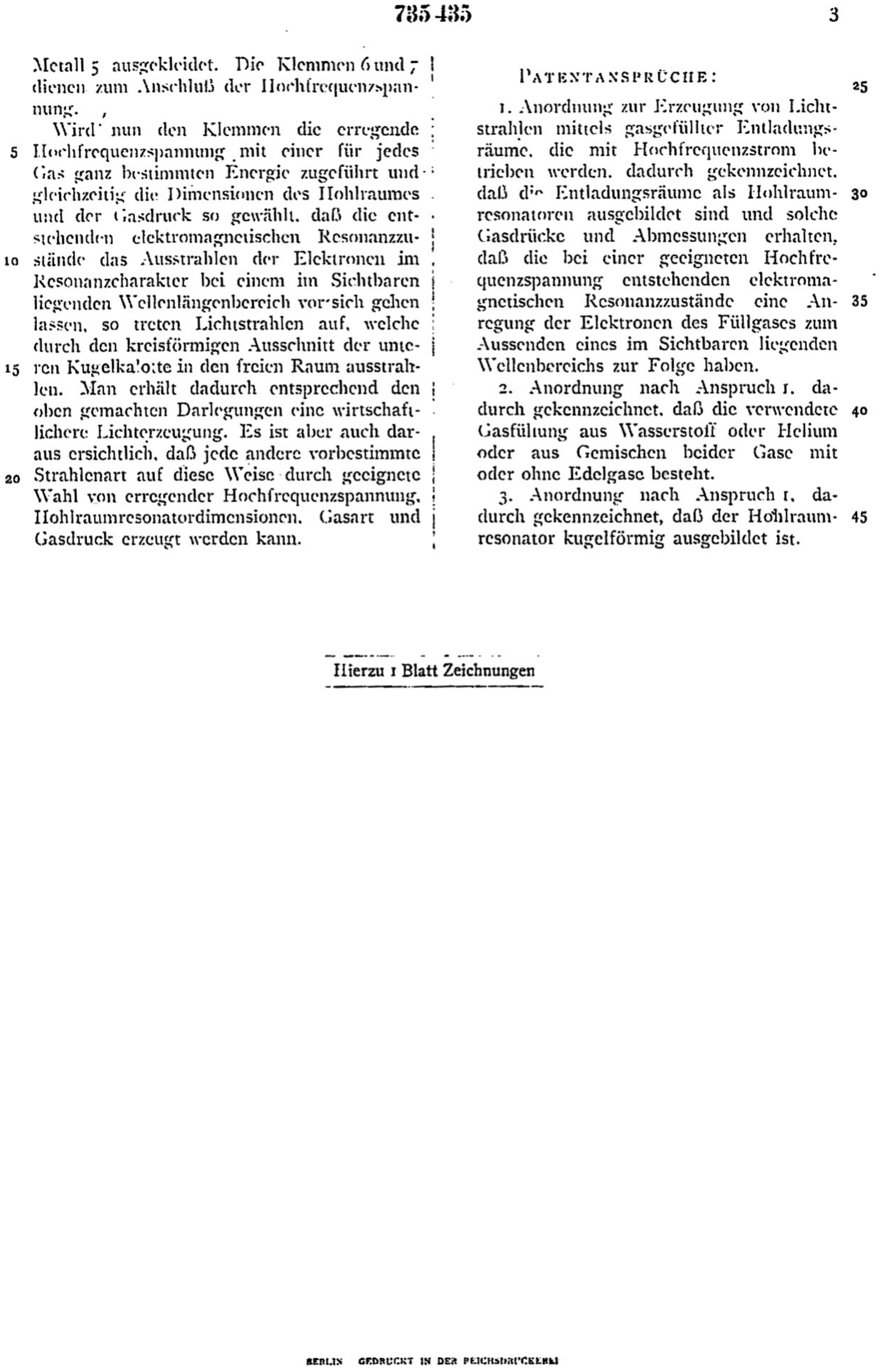
Es ist ferner bekannt, daß das Ausstrahlen von Elektronen nur bei einer ganz bestimmten Einfallsgeschwindigkeit der erregenden Hochfrequenzspannung stattfindet, d. h. dieser Effekt muß einen Resonanzcharakter zeigen, und der Energie- und Impulssatz muß gleichzeitig erfüllt sein. Die innere Energie einer Gesamtheit von Ladungen, wie ein Atom sie darstellt, kann nur periodisch nach den Quantenbedingungen in Strahlung umgesetzt werden. Die Wechselwirkung mit jeder elektrisch geladenen Materie beruht daher darauf, daß das Wellenfeld einer Quantenstrahlung ein elektromagnetisches Feld ist.

Zur Erzeugung geeigneter Resonanzbedingungen ist es notwendig, daß die erregende Hochfrequenzspannung das Magnetfeld im Hohlraumresonator senkrecht durchsetzt, sofern keine starken Feldverzerrungen auftreten.

In der Fig. 1 zeigt das Bild a den bekannten Verlauf der elektrischen Kraftlinien der elektromagnetischen Grundschwingung in einem kugelförmigen Hohlraumresonator, wobei die Durchstoßpunkte der senkrecht zur Zeichenebene gehenden Feldlinien angedeutet sind. Das Bild b zeigt die magnetischen Kraftlinien dieser Hohlkugel. Beide Feldverteilungen sind rotationssymmetrisch um die gezeichnete Achse.

Die Fig. 2 zeigt schematisch ein Anwendungsbeispiel für den grundsätzlichen Aufbau einer erfindungsgemäßen Vorrichtung. In dem kugelförmigen Glasgefäß 1 befindet sich eine Gasfüllung und die ringförmigen Elektroden 2 und 3, die isoliert eingeführt und im Innenraume der Kugel derartig gehalten werden, daß sie im Bereiche des größten Spannungsunterschiedes des elektrischen Feldes zu liegen kommen. Das Innere der Glaskugel ist bis auf einen kreisförmigen Ausschnitt auf der unteren Kalotte 4 metallisiert oder mit

Figure C.80: In 1940, Franz Focke filed a patent application on using resonant excitation to create a population inversion of electron energy levels in a gas, in order to create a light beam with a particular wavelength.



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Metall 5 ausgekleidet. Die Klemmen 6 und 7 dienen zum Anschluß der Hochfrequenzspannung.

Wird nun den Klemmen die erregende Hochfrequenzspannung mit einer für jedes Gas ganz bestimmten Energie zugeführt und gleichzeitig die Dimensionen des Hohlraumes und der Gasdruck so gewählt, daß die entstehenden elektromagnetischen Resonanzzustände das Ausstrahlen der Elektronen im Resonanzcharakter bei einem im Sichtbaren liegenden Wellenlängenbereich vor sich gehen lassen, so treten Lichtstrahlen auf, welche durch den kreisförmigen Ausschnitt der unteren Kugelkalotte in den freien Raum ausstrahlen. Man erhält dadurch entsprechend den oben gemachten Darlegungen eine wirtschaftlichere Lichterzeugung. Es ist aber auch daraus ersichtlich, daß jede andere vorbestimmte Strahlenart auf diese Weise durch geeignete Wahl von erregender Hochfrequenzspannung, Hohlraumresonatordimensionen, Gasart und Gasdruck erzeugt werden kann.

PATENTANSPRÜCHE:

1. Anordnung zur Erzeugung von Lichtstrahlen mittels gasgefüllter Entladungsräume, die mit Hochfrequenzstrom betrieben werden, dadurch gekennzeichnet, daß die Entladungsräume als Hohlraumresonatoren ausgebildet sind und solche Gasdrücke und Abmessungen erhalten, daß die bei einer geeigneten Hochfrequenzspannung entstehenden elektromagnetischen Resonanzzustände eine Anregung der Elektronen des Füllgases zum Aussenden eines im Sichtbaren liegenden Wellenbereichs zur Folge haben.

2. Anordnung nach Anspruch 1, dadurch gekennzeichnet, daß die verwendete Gasfüllung aus Wasserstoff oder Helium oder aus Gemischen beider Gase mit oder ohne Edelgase besteht.

3. Anordnung nach Anspruch 1, dadurch gekennzeichnet, daß der Hohlraumresonator kugelförmig ausgebildet ist.

Hierzu 1 Blatt Zeichnungen

BERLIN. GEDRUCKT IN DER REICHSDRUCKEREI

Figure C.81: In 1940, Franz Focke filed a patent application on using resonant excitation to create a population inversion of electron energy levels in a gas, in order to create a light beam with a particular wavelength.

Zu der Patentschrift 735 435
Kl. 21 f Gr. 82 01

Fig. 1.

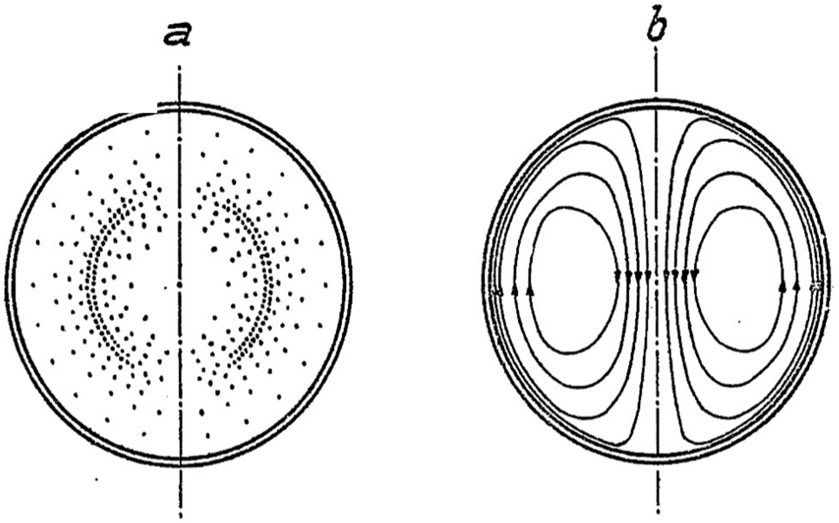

Fig. 2.

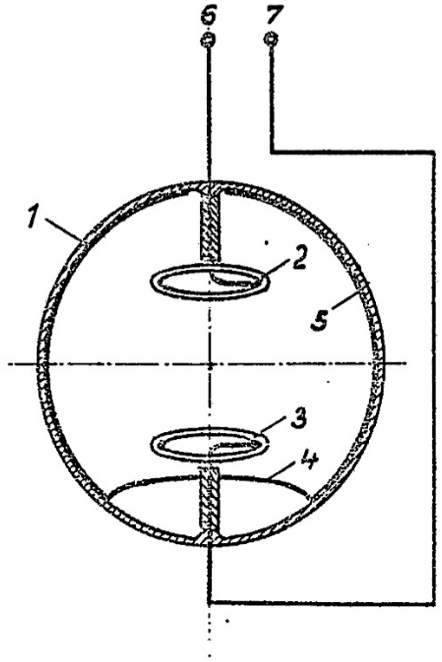

Figure C.82: In 1940, Franz Focke filed a patent application on using resonant excitation to create a population inversion of electron energy levels in a gas, in order to create a light beam with a particular wavelength.

Wilhelm von Meyeren. 20 February 1945 report on the development of a novel monochromatic light source. [NARA RG 319, Entry NM3-82A, Box 6, Folder G3]

Forschungsstelle für Experimentalphysik
Dr. W. von Meyeren
an der Deutschen Karls-Universität

Prag II,
Am Karlshof 3
den 20. Februar 1945

An den
Reichsforschungsrat,
z. Hd. Herrn Professor Dr. W. Gerlach
als Leiter der Fachsparte "Physik"
München 22
Ludwigstrasse 17.–

Betr.: Forschungsauftrag S 4891-5460/1715/3/

Bezug: RFR Brb.-Nr. 2822/45-Ge/Neu.

Angeschlossen füge ich einen Bericht über die bisherigen Ergebnisse meiner Untersuchungen im Rahmen des o.a. Forschungsauftrages bei.

Infolge völliger Inanspruchnahme durch zwei weitere SS-Aufträge seitens des OKH und des OKM bin ich erst jetzt in der Lage gewesen, den Bericht fertigzustellen. Ich bitte deshalb die Verzögerung entschuldigen zu wollen. [...]

Problemstellung.

Es sollen die Atome eines Gases oder Dampfes vom Grundzustand aus in den ersten angeregten /nicht metastabilen/ Zustand gehoben werden, derart, dass dabei höher angeregte Zustände möglischst nicht oder doch nur in verschwindend geringer Zahl vorkommen. Das Gas bezw. der Dampf kann dann lediglich die Resonanzlinie des betr. Atoms emittieren, stellt dann also eine praktisch monochromatische Lichtquelle dar.

Research Center for Experimental Physics
Dr. W. von Meyeren
at the German Charles University

Prague II,
At Karlshof 3
20 February 1945

To the
Reich Research Council,
Attn. Professor Dr. W. Gerlach
as head of the "Physics" division
Munich 22
Ludwigstrasse 17.–

Regarding: Research assignment S 4891-5460/1715/3/

Reference: RFR Brb.-Nr. 2822/45-Ge/New.

Attached I include a report on the results of my investigations to date within the framework of the above-mentioned research assignment.

Due to being fully occupied with two other SS projects for the Army and Navy, I have only now been able to complete the report. I therefore apologize for the delay. [...]

Problem statement.

The atoms of a gas or vapor shall be lifted from the ground state into the first excited (not metastable) state, in such a way that higher excited states do not occur at all or only in a negligibly small number. The gas or vapor can then only emit the resonance line of the atom in question, thus representing a practically monochromatic light source.

Bei der Verwendung von Rubidium- oder Cäsiumdampf wäre dann lediglich Strahlung der Wellenlängen 7984 und 7800 A.E. /Rb/ bezw. 8944 und 8521 A.E. /Cs/ zu erwarten, also je zwei diskrete im nahen ultraroten Spektralgebiet gelegene Strahlungsfrequenzen. Dass für jedes Atom zwei Frequenzen auftreten müssen, rührt von der Dublettaufspaltung der P-Terme her.

Um eine solche Lichtquelle von hinreichend grosser Strahlungsintensität zu erhalten, muss die Zahl der im ersten angeregten Zustand befindlichen Atome möglichst gross gemacht werden. Es kommt deshalb nur Anregung durch Elektronenstoss in Frage unter Verwendung einer ergiebigen Glühkathode als Elektronenquelle.

Ferner liegt es nahe, ein Gas bezw. einen Dampf von hoher Dichte zu benutzen, um eine grosse Zahl angeregter Zustände zu erhalten.

Die Verwendung eines hohen Gas- bezw. Dampfdruckes erweist sich aber aus folgenden Gründen als ungeeignet. Durch unvermeidliche Mehrfachstösse werden auch stets höhere Terme der Atome angeregt, und zwar umso mehr, je höher Gasdruck und Stromdichte sind. Ferner steigt mit zunehmender Gasdichte die Wahrscheinlichkeit für das Eintreten von Stössen 2. Art. Diese verursachen wiederum grosse Geschwindigkeiten der stossenden Elektronen und damit eine Vergrösserung der Anregungswahrscheinlichkeit für höhere Atomzustände.–

If rubidium or cesium vapor were used, only radiation of the wavelengths 7984 and 7800 Angstroms (Rb) or 8944 and 8521 Angstroms (Cs) would be expected, i.e. two discrete radiation frequencies in the near infrared spectral region. The fact that two frequencies must occur for each atom is due to the doublet splitting of the P terms.

In order to obtain such a light source of sufficiently high radiation intensity, the number of atoms in the first excited state must be made as large as possible. Therefore, only excitation by electron impact using a high-intensity cathode as electron source is possible.

It also makes sense to use a high density gas or vapor to obtain a large number of excited states.

However, the use of a high gas density or vapor pressure is unsuitable for the following reasons. Due to unavoidable multiple excitations, the higher the gas pressure and current density, the higher the levels of the atoms are excited. Furthermore, with increasing gas density, the probability of the occurrence of collisions increases as the square [of the density]. These in turn cause high velocities of the impinging electrons and thus an increase of the excitation probability for higher atomic states.

In früheren Untersuchungen hat Verf. gezeigt, dass auch in Gasen von sehr kleiner Dichte durch Elektronen kleiner Stromdichte eine sehr starke Anregung möglich ist. Die mittlere freie Weglänge der Elektronen nimmt zwar bei abnehmendem Gasdruck zu und erreicht bereits bei Drucken von der Grössenordnung 0,01 Torr die linearen Dimensionen der gebräuchlichen Entladungsgefässe, also einige Zentimeter. Zwingt man aber durch Anlegen eines äusseren Magnetfeldes die Elektronen auf krummlinige Bahnen /Cykloiden, Kegelschraubenbahnen, u. dgl./, so lässt sich selbst bei sehr niederen Gasdrucken in normalen Entladungsgefässen die Zahl der anregenden Zusammenstösse zwischen Elektronen und Atomen ungeheuer steigern und ein intensives Gasleuchten erreichen. Gleichzeitig ist bei einer solchen Anordnung der weitere Vorteil verbunden, dass bei dem niederen Druck eine strahlungslose Rückkehr der angeregten Atome durch Zusammenstösse mit nichtangeregten Atomen nur selten vorkommt. Untersuchungen dieser Art sind früher mit Stosselektronen grosser Geschwindigkeit /etwa 2.10^3 e-Volt/ durchgeführt worden. Bei diesen Versuchsbedingungen werden auch hochangeregte Atomzustände und auch angeregte Zustände des Atomions in grosser Zahl geschaffen.

Zur möglichst alleinigen Anregung der Resonanzlinie des Atoms muss daher versucht werden, bei niederem Gasdruck mit langsamen Elektronen anzuregen. Für die Fälle der Rubidium- und Cäsiumatoms dürfen die Elektronengeschwindigkeiten dabei nur etwa 2 e-Volt betragen. Dann befindet man sich einmal etwa im Maximum der Anregungsfunktion für den ersten angeregten Zustand, erreicht also die bestmögliche Stossausbeute, zum anderen ist die Wahrscheinlichkeit für die Anregung höherer Atomzustände noch gering.

In earlier investigations the author has shown that even in gases of very low density, a very strong excitation is possible by electrons of low current density. The mean free path length of the electrons increases with decreasing gas pressure and reaches the linear dimensions of the common discharge vessels at pressures of 0.01 Torr, i.e. a few centimeters. If, however, the electrons are forced onto curvilinear orbits (cycloids, conical screw orbits, etc.) by the application of an external magnetic field, the number of stimulating collisions between electrons and atoms can be enormously increased even at very low gas pressures in normal discharge vessels and an intensive gas glow can be achieved. At the same time such an arrangement has the further advantage that at low pressure a return without radiation of the excited atoms due to collisions with non-excited atoms occurs only rarely. Investigations of this kind used to be carried out with high velocity impact electrons (about 2×10^3 electron-Volts). At these experimental conditions both highly excited atomic states and also excited atomic states are created in large numbers.

In order to excite solely the resonance line of the atom as much as possible, an attempt must therefore be made to excite with slow electrons at low gas pressure. For the cases of rubidium and cesium atoms, the electron velocities may only be about 2 electron-Volts. Then one is at the maximum of the excitation function for the first excited state, thus achieving the best possible shock yield, on the other hand the probability for the excitation of higher atomic states is still low.

Als geeignete Entladungsform mit derartig geringen Elektronengeschwindigkeiten kommt allein der Niedervoltbogen in Frage, und zwar die abnormale Bogenform. Es ist daher das erste Ziel der geplanten Untersuchung, einen Niedervoltbogen bei möglichst niederem Gasdruck aufrecht zu erhalten. Ferner ist dann zu untersuchen, ob ein solcher Bogen auch bei Anlegung eines äusseren Magnetfeldes weiterbestehen kann.–

Der Niedervoltbogen ist eine halbselbständige Gasentladung und benutzt als Quelle für die primären Ladungsträger eine Glühkathode. Der Gas- bezw. Dampfdruck beträgt zwischen 5 und 50 Torr.

Beim abnormalen Bogen beträgt die Spannung zwischen Kathode und Anode /Brennspannung/ unter Berücksichtigung der Kontaktpotentiale und der thermischen Anfangsgeschwindigkeit der Glühelektronen nur einen Bruchteil der ersten Anregungsspannung des betr. Atoms. Zunächst erscheint es unmöglich, bei so niederen Brennspannungen überhaupt eine Gasentladung aufrecht erhalten zu können. Genaue Untersuchungen haben jedoch ergeben, dass im Raum zwischen Kathode und Anode, und zwar in Kathodennähe, eine positive Raumladung zustande kommt. Diese bewirkt, dass das Raumpotential zwischen den Elektroden höher liegt als das Anodenpotential und im Maximum einen Wert erreicht, der gleich dem ersten Anregungspotential der betr. Gases oder Dampfes ist. Da nun zur Aufrechterhaltung der Entladung eine ständige Neubildung von positiven Ladungsträgern /Atomionen/ notwendig ist, das Raumpotential jedoch das Ionisierungspotential bei weitem nicht erreicht, so muss eine Trägerneubildung durch stufenweise Ionisierung erfolgen.

Only the low-voltage arc, the unusual arc shape, can be considered as a suitable form of discharge with such low electron speeds. It is therefore the first objective of the planned investigation to maintain a low-voltage arc at the lowest possible gas pressure. Furthermore, it has to be investigated whether such an arc can continue to exist even if an external magnetic field is applied.–

The low-voltage arc is a semi-autonomous gas discharge and uses a hot cathode as the source for the primary charge carriers. The gas or vapor pressure is between 5 and 50 Torr.

With an unusual arc, the voltage between cathode and anode (heating voltage) is only a fraction of the first excitation voltage of the respective atom, taking into account the contact potentials and the initial thermal velocity of the annealing electrons. At first it seems impossible to maintain a gas discharge at such low voltages. However, precise investigations have shown that a positive space charge is generated in the space between cathode and anode, close to the cathode. This causes the space charge potential between the electrodes to be higher than the anode potential and to reach a maximum value equal to the first excitation potential of the gas or vapor concerned. Since a constant new formation of positive charge carriers (atomic ions) is necessary to maintain the discharge, but the space charge potential does not reach the ionization potential by far, a new carrier formation must take place by stepwise ionization.

Im Spektrum des abnormalen Niedervoltbogens treten deshalb ausser den Atomlinien auch stets die Funkenlinien auf. Es ist zunächst die günstigste Versuchsbedingung zu ermitteln, unter welcher die Resonanzlinie des Atoms mit überwiegender Intensität emittiert wird, um dem Ideal einer monochromatischen Lichtquelle möglichst nahe zu kommen.–

Untersuchung des abnormalen Niedervoltbogens bei niederen Drucken.

Als erste Aufgabe wurde die Untersuchung in Angriff genommen mit dem Ziel, bis zu welchen Drucken ein abnormaler Niedervoltbogen überhaupt noch möglich ist. Da alle früheren Untersuchungen am Niedervoltbogen im Druckbereich zwischen 50 und 5 Torr durchgeführt worden sind, ist jetzt bei Drucken unterhalb von 5 Torr gearbeitet worden. Ferner sind zunächst die Untersuchungen nicht an Alkalidämpfen, also z.B. Rubidium oder Cäsium, vorgenommen worden, sondern zunächst einmal an Argon. Dies ist aus folgenden Gründen geschehen. Um die geeignete Form und die beste geometrische Anordnung der Elektroden zu finden, muss das Innere des Entladungsrohres leicht zugänglich sein. Die Elektroden müssen also mit Hilfe von Schliffen ausgewechselt werden können. Bei der Verwendung von Alkalidämpfen ist wegen deren chemischer Aktivität ein solches Entladungsrohr nicht zu benutzen. Ferner muss bei Alkalidämpfen das Entladungsrohr aus alkalifestem Glas hergestellt werden. Dies ist wegen der schwierigen Beschaffung dieser Glassorte zurzeit nicht möglich gewesen. Wenn auch die am Edelgas erhaltenen Ergebnisse nicht in allen Einzelheiten auf Alkalidämpfe übertragen werden können, so werden trotzdem die mit der Edelgas erhaltenen Befunde doch im grossen und ganzen den Weg zeigen, auf welchem die Entwicklung des gewünschten Entladung zu erfolgen hat.

In der abnormalen Entladungsform bei verschiedenen Drucken unterhalb 5 Torr ist zunächst das Raumpotential zwischen Kathode und Anode durch Sondermessungen festgestellt worden.

In the spectrum of the unusually low-voltage arc, therefore, emission lines always occur in addition to atomic lines. The first step is to determine the most favorable experimental condition under which the resonance line of the atom is emitted with predominant intensity in order to come as close as possible to the ideal of a monochromatic light source.–

Investigation of the unusually low voltage arc at low pressure.

The first task was to investigate up to which pressures an unusually low-voltage shock is still possible. Since all previous investigations on the low-voltage arc were carried out in the pressure range between 50 and 5 Torr, work has now been carried out on pressures below 5 Torr. Furthermore, the investigations were not initially carried out on alkali vapours, e.g. rubidium or cesium, but on argon. This was done for the following reasons. In order to find the suitable shape and the best geometrical arrangement of the electrodes, the inside of the discharge tube must be easily accessible. It must therefore be possible to replace the electrodes with the aid of ground joints. When alkali fumes are used, such a discharge tube cannot be used because of their chemical activity. In the case of alkali fumes, the discharge tube must also be made of alkali-resistant glass. This has not been possible at present due to the difficult procurement of this type of glass. Even if the results obtained on the inert gas cannot be transferred in all details to alkali vapours, the findings obtained with the inert gas will nevertheless largely show the way in which the development of the desired discharge must take place.

In the unusual discharge form at various pressures below 5 Torr, the space charge potential between cathode and anode was first determined by special measurements.

Fig. 1 zeigt das benutzte Entladungsgefäss. Als Anode ist ein Nickelblech, als Kathode teils eine Oxydkathode teils eine Wolframwendel benutzt worden.

Die Sonde ist im Raum zwischen Anode und Kathode messbar beweglich angeordnet. Teils ist eine ebene, teils eine Zylindersonde benutzt worden.

Die Figuren 2–5 zeigen die Ergebnisse einigen Sondenmessungen.

Es folgt daraus, dass auch bei Gasdrucken zwischen 6 und 1,5 Torr die Form des abnormalen Niedervoltbogens existiert und dass das Raumpotential über dem Anodenpotential liegt. Das Maximum des Raumpotentials erreicht bei einem Druck von 5,6 Torr gerade das erste Anregungspotential des Argons /11,5 Volt/. Bei abnehmenden Drucken nimmt der Maximalwert des Raumpotentials zu. Die Brennspannung liegt dabei stets unterhalb der ersten Anregungsspannung. Bei Gasdrucken unter 1,5 Torr erreicht die Brennspannung die erste Anregungsspannung, das Potentialmaximum im Entladungsraum erreicht dann die Ionisierungsspannung des Gases /für Argon 15,68 Volt/. Das bedeutet, dass bei diesen Drucken der abnormale Bogen nicht mehr existenzfähig ist. Er ist vielmehr in die Form des normalen Bogens übergegangen. Dies zeigt die Figur 6. Hier—bei einem Druck von 0,5 Torr liegt die Brennspannung zwischen der ersten Anregungs- und der Ionisierungsspannung. Bemerkenswert und bei höheren Gasdrucken noch nicht beobachtet ist weiter die Tatsache, dass trotzdem das Raumpotential höher ist als das Anodenpotential und im Maximum das Ionisierungspotential erreicht oder sogar etwas überschreitet. Die Trägerneubildung erfolgt hier zweifellos in einem Elementarakt durch direkten Stoss und nicht, wie beim abnormalen Bogen, durch stufenweise Ionisierung!

Fig. 1 shows the discharge vessel used. A nickel plate has been used as an anode, and sometimes an oxide cathode and sometimes a tungsten filament as a cathode.

The probe is arranged in the space between anode and cathode so that it is measurably movable. Sometimes a flat probe and sometimes a cylindrical probe has been used.

Figures 2–5 show the results of some probe measurements.

It follows from this that even at gas pressures between 6 and 1.5 Torr the shape of the unusually low-voltage arc exists and that the space charge potential is above the anode potential. The maximum of the space charge potential at a pressure of 5.6 Torr just reaches the first excitation potential of argon (11.5 Volts). With decreasing pressures the maximum value of the space charge potential increases. The heating voltage is always below the first excitation voltage. At gas pressures below 1.5 Torr the heating voltage reaches the first excitation voltage, the potential maximum in the discharge chamber then reaches the ionization voltage of the gas (for argon 15.68 Volts). This means that at these pressures the unusual arc is no longer viable. Rather, it has changed into the form of the normal arc. This is shown in Figure 5. Here, at a pressure of 0.5 Torr, the heating voltage lies between the first excitation voltage and the ionization voltage. Remarkable and not yet observed at higher gas pressures is the fact that the space charge potential is still higher than the anode potential and reaches or even slightly exceeds the ionization potential at the maximum. The formation of the new carrier is undoubtedly an elementary act by direct impact and not, as in an abnormal arc, by gradual ionization!

Die Sondenmessungen ergeben gleichzeitig die Elektronenkonzentration und die Elektronentemperatur an den betr. Orten des Entlandungsraumes. Diese Werte sind in den Figuren 2–5 mit eingetragen.–

Bei allen untersuchten Drucken tritt in der Entlandung des abnormalen Bogens das Funkenspektrum des Argons /das blaue Spektrum/ mit merklicher Intensität neben dem Atomspektrum /rotes Spektrum/ auf. Die Zahl der durch Mehrfachstösse gebildeten Ionen ist also erheblich.–

Bei Anlegung eines äusseren Magnetfeldes in der Weise, dass die Feldlinien denen des elektrischen Feldes zwischen Kathode und Anode parallel verlaufen, müssen die Ladungsträger, besonders die Elektronen, längs ihrer freien Wegstrecken Schraubenbahnen beschreiben. Bei magnetischen Feldstärken zwischen 0 und 150 Oe ist nun ein Instabilwerden der Entladung beobachtet worden, die bisher nur durch Erhöhung der Brennspannung bis mindestens zur Ionisierungsspannung behoben werden kann. Damit ist die Entladung aber in die Form des normalen Niedervoltbogens übergegangen. Ebenso tritt das Funkenspektrum sehr intensiv hervor.–

Zurziet sind daher Versuche im Gang die Brennspannung bei Anlegung eines äusseren Magnetfeldes durch andere Hilfsmittel wieder zu senken. U.a. wird eine gitterförmige Hilfselektrode dicht vor die Glühkathode gesetzt, ähnlich dem Raumladungsgitter der Doppelgitter-Elektronenröhren. Es wird versucht, durch geeignete Aufladung dieser Hilfselektrode die Magnetfeldentladung auch bei sehr niederen Brennspannungen zu stabilisieren. Ergebnisse dieser Versuche stehen noch aus.

The probe measurements give simultaneously the electron concentration and the electron temperature at the respective locations of the mixing area. These values are shown in Figures 2–5.–

At all investigated pressures, in the mixing of the unusual arc, the emission spectrum of the argon (the blue spectrum) occurs with noticeable intensity next to the atomic spectrum (the red spectrum). The number of ions formed by multiple bursts is therefore considerable.–

When an external magnetic field is applied in such a way that the field lines run parallel to those of the electric field between cathode and anode, the charge carriers, especially the electrons, must describe helical paths along their free paths. At magnetic field strengths between 0 and 150 Oersted, an instability of the discharge has now been observed, which so far can only be remedied by increasing the heating voltage to at least the ionization voltage. However, the discharge is now in the form of a normal low-voltage arc. The emission spectrum also emerges very intensely.–

Therefore, attempts are made to reduce the heating voltage by applying an external magnetic field with other aids. Among other things, a grid-shaped auxiliary electrode is placed close to the hot cathode, similar to the space charge grid of the double grid electron tubes. An attempt is made to stabilize the magnetic field discharge even at very low heating voltages by charging this auxiliary electrode appropriately. Results of these experiments are still pending.

Erläuterung zu den Figg. 2–5:

U_B: gemessene Brennspannung
U'_B: korrigierte Brennspannung
U_R: gemessenes Raumpotential
U'_R: korrigiertes Raumpotential
U_k: Kontaktpotential
T_-: Elektronentemperatur
N_-: Elektronenkonzentration.

Als Abszisse ist stets der Abstand zwischen Kathode u. Anode in mm aufgetragen.

Explanation of Figs. 2–5:

U_B: measured heating voltage
U'_B: corrected heating voltage
U_R: measured space charge potential
U'_R: corrected space charge potential
U_k: contact potential
T_-: electron temperature
N_-: electron concentration.

The abscissa is always the distance in mm between cathode and anode.

[This one paper rather miraculously survived. How many other laser-like experiments were there in this group, and in other groups?

Wilhelm von Meyeren's research was in Prague, and funded by and closely tied to the SS, directed energy beam weapons development, and nuclear programs (via Walther Gerlach). Was it the same as, or at least somehow related to, the SS-funded laser work that Wilhelm Voss said was being conducted by Skoda Pilsen (see p. 3157)?

While it is not stated in this one surviving document, it seems quite plausible that von Meyeren might have been planning a photon chain reaction with reflectors once he managed to create a population inversion in the gas atoms, especially since he was reporting to Walther Gerlach, who was also in charge of neutron chain reactions with reflectors, as well as a variety of projects to develop directed energy beam weapons (e.g., pp. 3074–3078). Perhaps other documents can be discovered in order to shed more light on how large this laser-like research program was, how far it progressed, and how much it influenced postwar work in other countries.]

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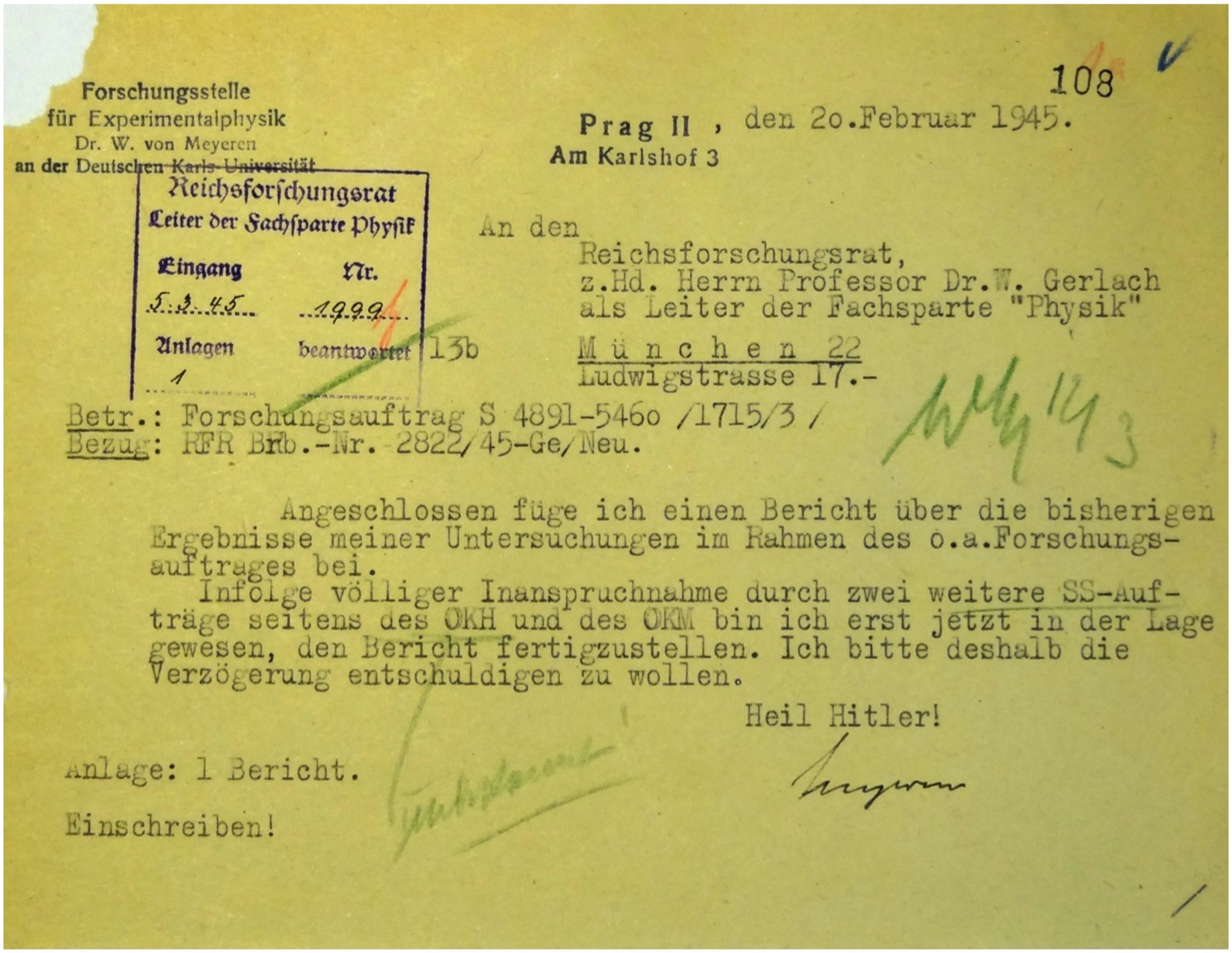

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Forschungsstelle
für Experimentalphysik
Dr. W. von Meyeren
an der Deutschen ~~Karls-Universität~~

Prag II, den 20.Februar 1945.
Am Karlshof 3

Reichsforschungsrat
Leiter der Fachsparte Physik
Eingang 5.3.45 Nr. 1999
Anlagen 1 beantwortet

13b

An den
Reichsforschungsrat,
z.Hd. Herrn Professor Dr.W. Gerlach
als Leiter der Fachsparte "Physik"
München 22
Ludwigstrasse 17.-

Betr.: Forschungsauftrag S 4891-5460 /1715/3 /
Bezug: RFR Brb.-Nr. 2822/45-Ge/Neu.

Angeschlossen füge ich einen Bericht über die bisherigen Ergebnisse meiner Untersuchungen im Rahmen des o.a.Forschungsauftrages bei.

Infolge völliger Inanspruchnahme durch zwei weitere SS-Aufträge seitens des OKH und des OKM bin ich erst jetzt in der Lage gewesen, den Bericht fertigzustellen. Ich bitte deshalb die Verzögerung entschuldigen zu wollen.

Heil Hitler!

Meyeren

Anlage: 1 Bericht.

Einschreiben!

Figure C.83: Wilhelm von Meyeren's 20 February 1945 report on experiments with laser-like monochromatic stimulated light emission from electron population inversions in argon, cesium, or rubidium gases [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

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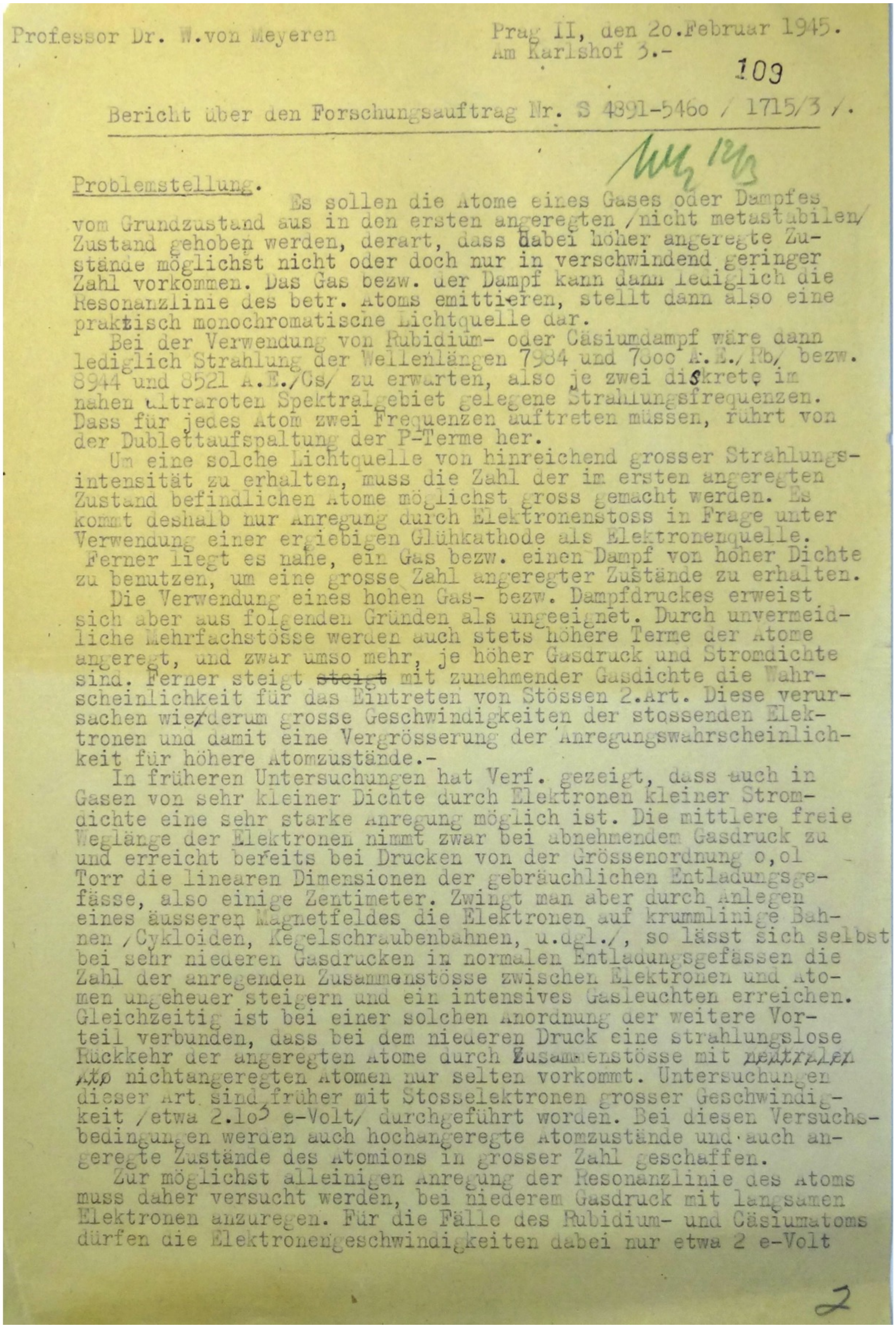

Professor Dr. W.von Meyeren

Prag II, den 20.Februar 1945.
Am Karlshof 3.-

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Bericht über den Forschungsauftrag Nr. S 4891-5460 / 1715/3 /.

12/3

Problemstellung.
Es sollen die Atome eines Gases oder Dampfes vom Grundzustand aus in den ersten angeregten /nicht metastabilen/ Zustand gehoben werden, derart, dass dabei höher angeregte Zustände möglichst nicht oder doch nur in verschwindend geringer Zahl vorkommen. Das Gas bezw. der Dampf kann dann lediglich die Resonanzlinie des betr. Atoms emittieren, stellt dann also eine praktisch monochromatische Lichtquelle dar.

Bei der Verwendung von Rubidium- oder Cäsiumdampf wäre dann lediglich Strahlung der Wellenlängen 7984 und 7800 A.E./Rb/ bezw. 8944 und 8521 A.E./Cs/ zu erwarten, also je zwei diskrete im nahen ultraroten Spektralgebiet gelegene Strahlungsfrequenzen. Dass für jedes Atom zwei Frequenzen auftreten müssen, rührt von der Dublettaufspaltung der P-Terme her.

Um eine solche Lichtquelle von hinreichend grosser Strahlungsintensität zu erhalten, muss die Zahl der im ersten angeregten Zustand befindlichen Atome möglichst gross gemacht werden. Es kommt deshalb nur Anregung durch Elektronenstoss in Frage unter Verwendung einer ergiebigen Glühkathode als Elektronenquelle.

Ferner liegt es nahe, ein Gas bezw. einen Dampf von höher Dichte zu benutzen, um eine grosse Zahl angeregter Zustände zu erhalten.

Die Verwendung eines hohen Gas- bezw. Dampfdruckes erweist sich aber aus folgenden Gründen als ungeeignet. Durch unvermeidliche Mehrfachstösse werden auch stets höhere Terme der Atome angeregt, und zwar umso mehr, je höher Gasdruck und Stromdichte sind. Ferner steigt ~~steigt~~ mit zunehmender Gasdichte die Wahrscheinlichkeit für das Eintreten von Stössen 2.Art. Diese verursachen wiederum grosse Geschwindigkeiten der stossenden Elektronen und damit eine Vergrösserung der Anregungswahrscheinlichkeit für höhere Atomzustände.-

In früheren Untersuchungen hat Verf. gezeigt, dass auch in Gasen von sehr kleiner Dichte durch Elektronen kleiner Stromdichte eine sehr starke Anregung möglich ist. Die mittlere freie Weglänge der Elektronen nimmt zwar bei abnehmendem Gasdruck zu und erreicht bereits bei Drucken von der Grössenordnung 0,01 Torr die linearen Dimensionen der gebräuchlichen Entladungsgefässe, also einige Zentimeter. Zwingt man aber durch Anlegen eines äusseren Magnetfeldes die Elektronen auf krummlinige Bahnen /Cykloiden, Kegelschraubenbahnen, u.dgl./, so lässt sich selbst bei sehr niederen Gasdrucken in normalen Entladungsgefässen die Zahl der anregenden Zusammenstösse zwischen Elektronen und Atomen ungeheuer steigern und ein intensives Gasleuchten erreichen. Gleichzeitig ist bei einer solchen Anordnung der weitere Vorteil verbunden, dass bei dem niederen Druck eine strahlungslose Rückkehr der angeregten Atome durch Zusammenstösse mit ~~neutralen Ato~~ nichtangeregten Atomen nur selten vorkommt. Untersuchungen dieser Art sind früher mit Stosselektronen grosser Geschwindigkeit /etwa 2.10^5 e-Volt/ durchgeführt worden. Bei diesen Versuchsbedingungen werden auch hochangeregte Atomzustände und auch angeregte Zustände des Atomions in grosser Zahl geschaffen.

Zur möglichst alleinigen Anregung der Resonanzlinie des Atoms muss daher versucht werden, bei niederem Gasdruck mit langsamen Elektronen anzuregen. Für die Fälle des Rubidium- und Cäsiumatoms dürfen die Elektronengeschwindigkeiten dabei nur etwa 2 e-Volt

2

Figure C.84: Wilhelm von Meyeren's 20 February 1945 report on experiments with laser-like monochromatic stimulated light emission from electron population inversions in argon, cesium, or rubidium gases [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

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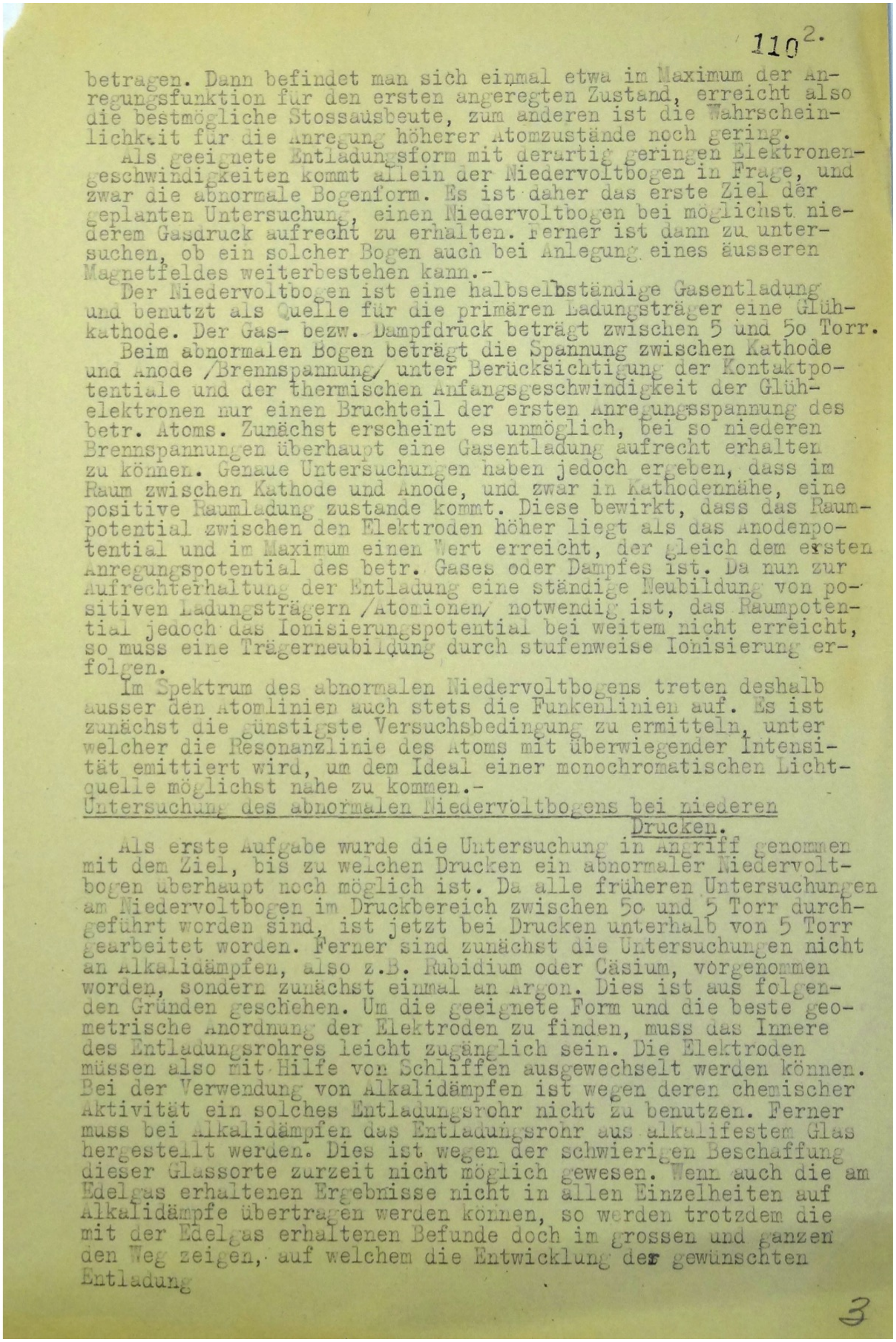


110 2.

betragen. Dann befindet man sich einmal etwa im Maximum der Anregungsfunktion für den ersten angeregten Zustand, erreicht also die bestmögliche Stossausbeute, zum anderen ist die Wahrscheinlichkeit für die Anregung höherer Atomzustände noch gering.

Als geeignete Entladungsform mit derartig geringen Elektronengeschwindigkeiten kommt allein der Niedervoltbogen in Frage, und zwar die abnormale Bogenform. Es ist daher das erste Ziel der geplanten Untersuchung, einen Niedervoltbogen bei möglichst niederem Gasdruck aufrecht zu erhalten. Ferner ist dann zu untersuchen, ob ein solcher Bogen auch bei Anlegung eines äusseren Magnetfeldes weiterbestehen kann.-

Der Niedervoltbogen ist eine halbselbständige Gasentladung und benutzt als Quelle für die primären Ladungsträger eine Glühkathode. Der Gas- bezw. Dampfdruck beträgt zwischen 5 und 5o Torr.

Beim abnormalen Bogen beträgt die Spannung zwischen Kathode und Anode /Brennspannung/ unter Berücksichtigung der Kontaktpotentiale und der thermischen Anfangsgeschwindigkeit der Glühelektronen nur einen Bruchteil der ersten Anregungsspannung des betr. Atoms. Zunächst erscheint es unmöglich, bei so niederen Brennspannungen überhaupt eine Gasentladung aufrecht erhalten zu können. Genaue Untersuchungen haben jedoch ergeben, dass im Raum zwischen Kathode und Anode, und zwar in Kathodennähe, eine positive Raumladung zustande kommt. Diese bewirkt, dass das Raumpotential zwischen den Elektroden höher liegt als das Anodenpotential und im Maximum einen Wert erreicht, der gleich dem ersten Anregungspotential des betr. Gases oder Dampfes ist. Da nun zur Aufrechterhaltung der Entladung eine ständige Neubildung von positiven Ladungsträgern /Atomionen/ notwendig ist, das Raumpotential jedoch das Ionisierungspotential bei weitem nicht erreicht, so muss eine Trägerneubildung durch stufenweise Ionisierung erfolgen.

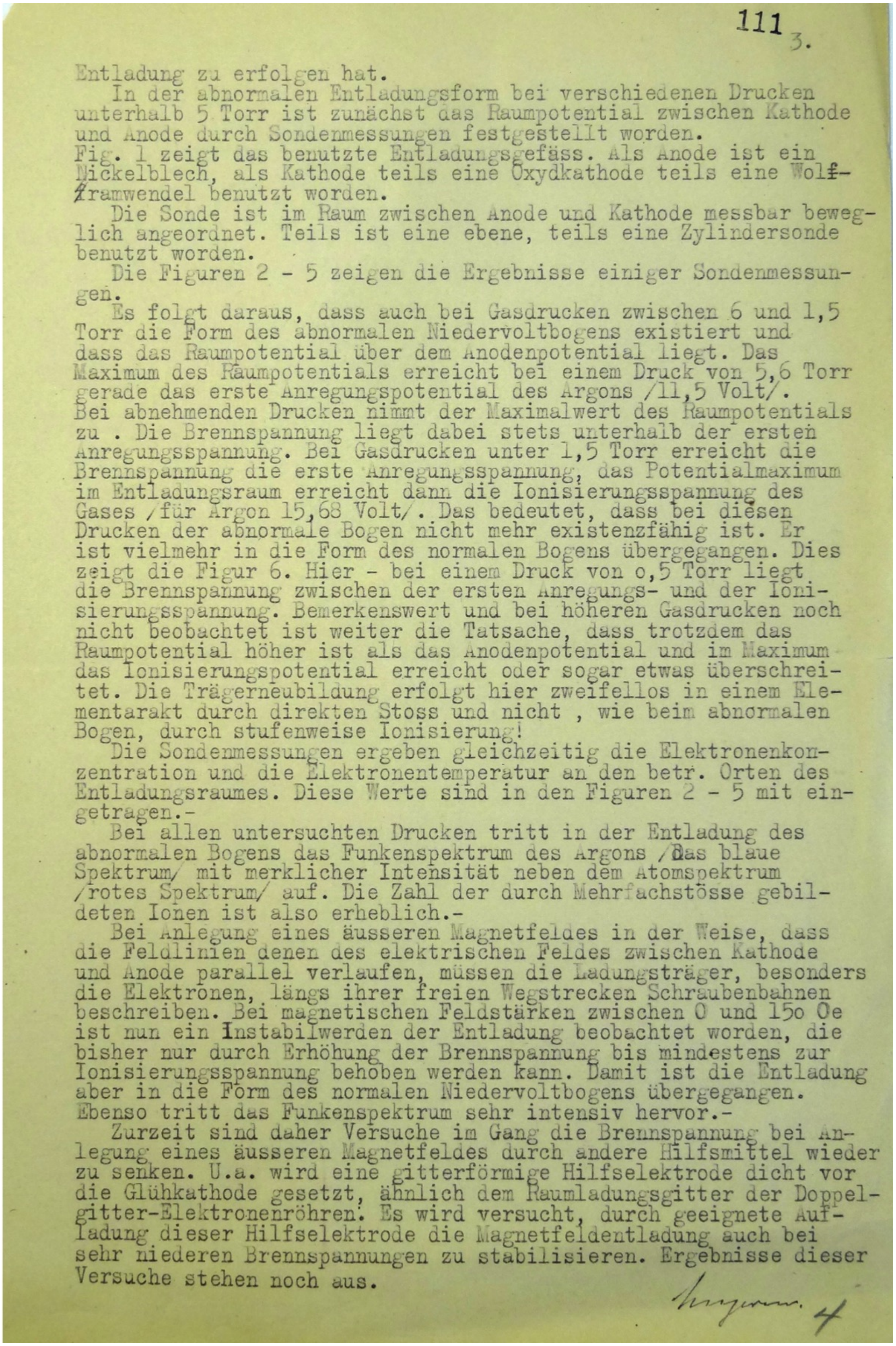
Im Spektrum des abnormalen Niedervoltbogens treten deshalb ausser den Atomlinien auch stets die Funkenlinien auf. Es ist zunächst die günstigste Versuchsbedingung zu ermitteln, unter welcher die Resonanzlinie des Atoms mit überwiegender Intensität emittiert wird, um dem Ideal einer monochromatischen Lichtquelle möglichst nahe zu kommen.-

Untersuchung des abnormalen Niedervoltbogens bei niederen Drucken.

Als erste Aufgabe wurde die Untersuchung in Angriff genommen mit dem Ziel, bis zu welchen Drucken ein abnormaler Niedervoltbogen überhaupt noch möglich ist. Da alle früheren Untersuchungen am Niedervoltbogen im Druckbereich zwischen 5o und 5 Torr durchgeführt worden sind, ist jetzt bei Drucken unterhalb von 5 Torr gearbeitet worden. Ferner sind zunächst die Untersuchungen nicht an Alkalidämpfen, also z.B. Rubidium oder Cäsium, vorgenommen worden, sondern zunächst einmal an Argon. Dies ist aus folgenden Gründen geschehen. Um die geeignete Form und die beste geometrische Anordnung der Elektroden zu finden, muss das Innere des Entladungsrohres leicht zugänglich sein. Die Elektroden müssen also mit Hilfe von Schliffen ausgewechselt werden können. Bei der Verwendung von Alkalidämpfen ist wegen deren chemischer Aktivität ein solches Entladungsrohr nicht zu benutzen. Ferner muss bei Alkalidämpfen das Entladungsrohr aus alkalifestem Glas hergestellt werden. Dies ist wegen der schwierigen Beschaffung dieser Glassorte zurzeit nicht möglich gewesen. Wenn auch die am Edelgas erhaltenen Ergebnisse nicht in allen Einzelheiten auf Alkalidämpfe übertragen werden können, so werden trotzdem die mit der Edelgas erhaltenen Befunde doch im grossen und ganzen den Weg zeigen, auf welchem die Entwicklung der gewünschten Entladung

3

Figure C.85: Wilhelm von Meyeren's 20 February 1945 report on experiments with laser-like monochromatic stimulated light emission from electron population inversions in argon, cesium, or rubidium gases [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].



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Entladung zu erfolgen hat.

In der abnormalen Entladungsform bei verschiedenen Drucken unterhalb 5 Torr ist zunächst das Raumpotential zwischen Kathode und Anode durch Sondenmessungen festgestellt worden.
Fig. 1 zeigt das benutzte Entladungsgefäss. Als Anode ist ein Nickelblech, als Kathode teils eine Oxydkathode teils eine Wolframwendel benutzt worden.

Die Sonde ist im Raum zwischen Anode und Kathode messbar beweglich angeordnet. Teils ist eine ebene, teils eine Zylindersonde benutzt worden.

Die Figuren 2 - 5 zeigen die Ergebnisse einiger Sondenmessungen.

Es folgt daraus, dass auch bei Gasdrucken zwischen 6 und 1,5 Torr die Form des abnormalen Niedervoltbogens existiert und dass das Raumpotential über dem Anodenpotential liegt. Das Maximum des Raumpotentials erreicht bei einem Druck von 5,6 Torr gerade das erste Anregungspotential des Argons /11,5 Volt/.
Bei abnehmenden Drucken nimmt der Maximalwert des Raumpotentials zu . Die Brennspannung liegt dabei stets unterhalb der ersten Anregungsspannung. Bei Gasdrucken unter 1,5 Torr erreicht die Brennspannung die erste Anregungsspannung, das Potentialmaximum im Entladungsraum erreicht dann die Ionisierungsspannung des Gases /für Argon 15,68 Volt/. Das bedeutet, dass bei diesen Drucken der abnormale Bogen nicht mehr existenzfähig ist. Er ist vielmehr in die Form des normalen Bogens übergegangen. Dies zeigt die Figur 6. Hier - bei einem Druck von o,5 Torr liegt die Brennspannung zwischen der ersten Anregungs- und der Ionisierungsspannung. Bemerkenswert und bei höheren Gasdrucken noch nicht beobachtet ist weiter die Tatsache, dass trotzdem das Raumpotential höher ist als das Anodenpotential und im Maximum das Ionisierungspotential erreicht oder sogar etwas überschreitet. Die Trägerneubildung erfolgt hier zweifellos in einem Elementarakt durch direkten Stoss und nicht , wie beim abnormalen Bogen, durch stufenweise Ionisierung!

Die Sondenmessungen ergeben gleichzeitig die Elektronenkonzentration und die Elektronentemperatur an den betr. Orten des Entladungsraumes. Diese Werte sind in den Figuren 2 - 5 mit eingetragen.-

Bei allen untersuchten Drucken tritt in der Entladung des abnormalen Bogens das Funkenspektrum des Argons /das blaue Spektrum/ mit merklicher Intensität neben dem Atomspektrum /rotes Spektrum/ auf. Die Zahl der durch Mehrfachstösse gebildeten Ionen ist also erheblich.-

Bei Anlegung eines äusseren Magnetfeldes in der Weise, dass die Feldlinien denen des elektrischen Feldes zwischen Kathode und Anode parallel verlaufen, müssen die Ladungsträger, besonders die Elektronen, längs ihrer freien Wegstrecken Schraubenbahnen beschreiben. Bei magnetischen Feldstärken zwischen 0 und 15o Oe ist nun ein Instabilwerden der Entladung beobachtet worden, die bisher nur durch Erhöhung der Brennspannung bis mindestens zur Ionisierungsspannung behoben werden kann. Damit ist die Entladung aber in die Form des normalen Niedervoltbogens übergegangen. Ebenso tritt das Funkenspektrum sehr intensiv hervor.-

Zurzeit sind daher Versuche im Gang die Brennspannung bei Anlegung eines äusseren Magnetfeldes durch andere Hilfsmittel wieder zu senken. U.a. wird eine gitterförmige Hilfselektrode dicht vor die Glühkathode gesetzt, ähnlich dem Raumladungsgitter der Doppelgitter-Elektronenröhren. Es wird versucht, durch geeignete Aufladung dieser Hilfselektrode die Magnetfeldentladung auch bei sehr niederen Brennspannungen zu stabilisieren. Ergebnisse dieser Versuche stehen noch aus.

Meyeren. 4

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Figure C.86: Wilhelm von Meyeren's 20 February 1945 report on experiments with laser-like monochromatic stimulated light emission from electron population inversions in argon, cesium, or rubidium gases [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

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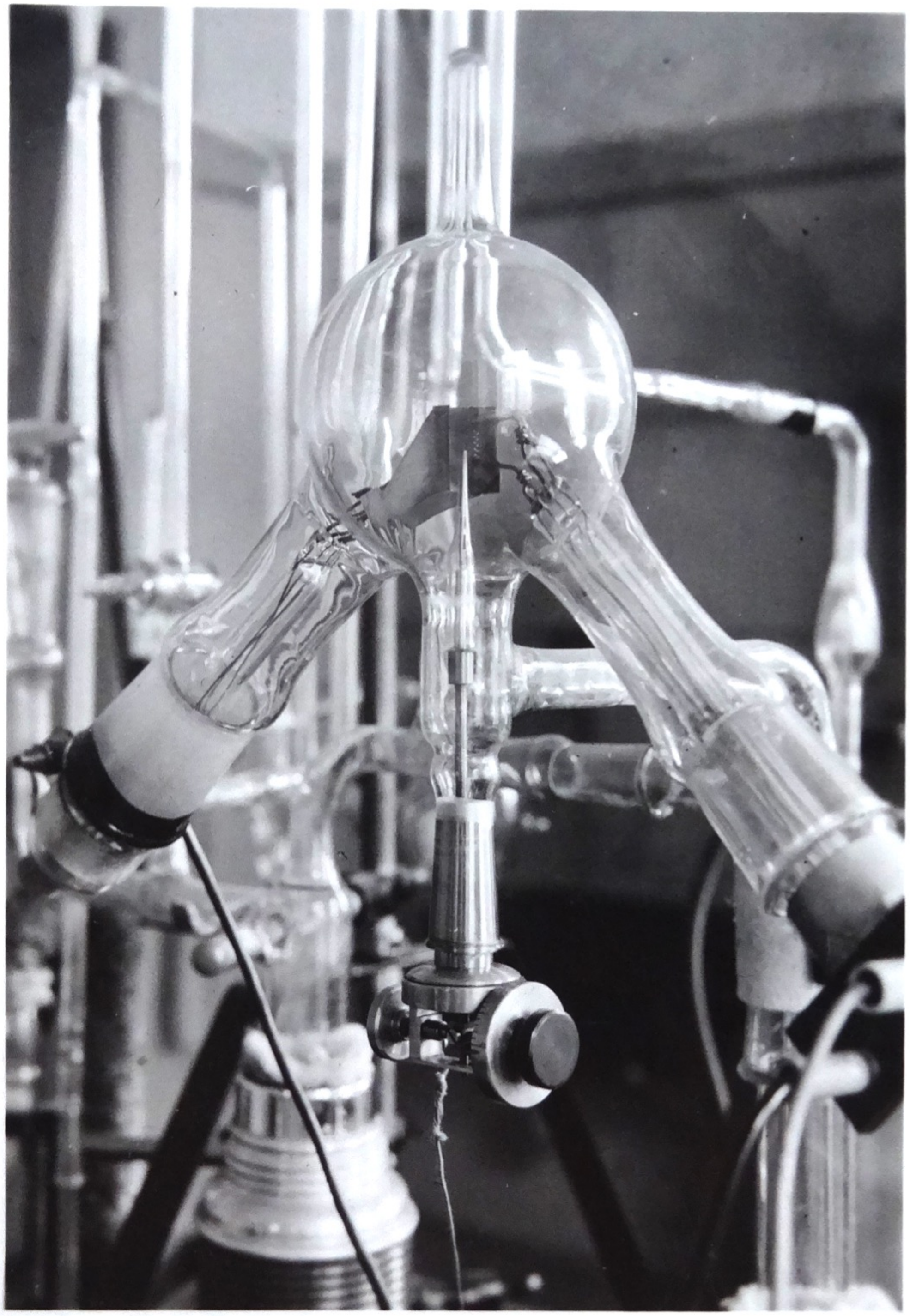

Figur 1.

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Figure C.87: Wilhelm von Meyeren's 20 February 1945 report on experiments with laser-like monochromatic stimulated light emission from electron population inversions in argon, cesium, or rubidium gases [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

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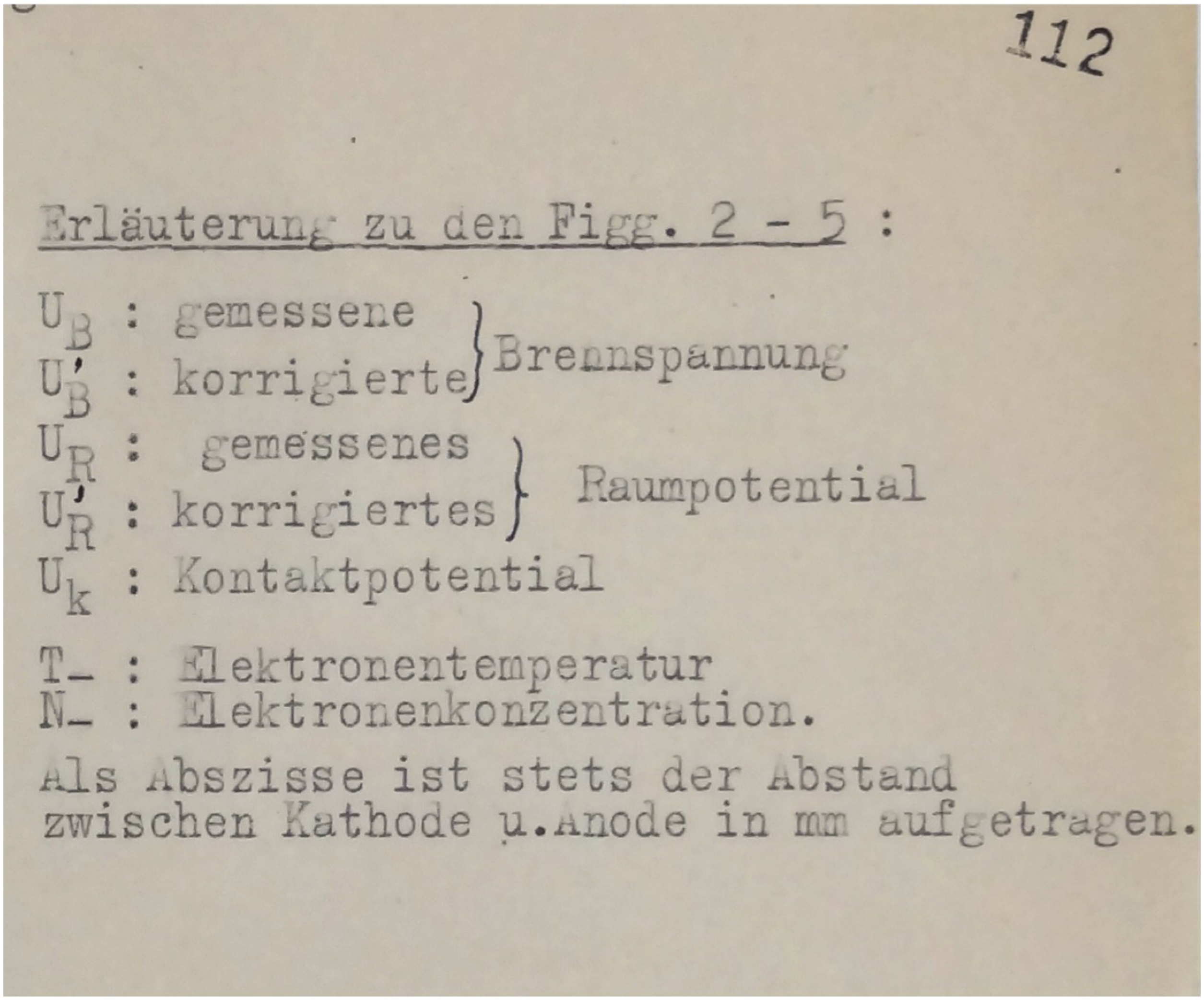

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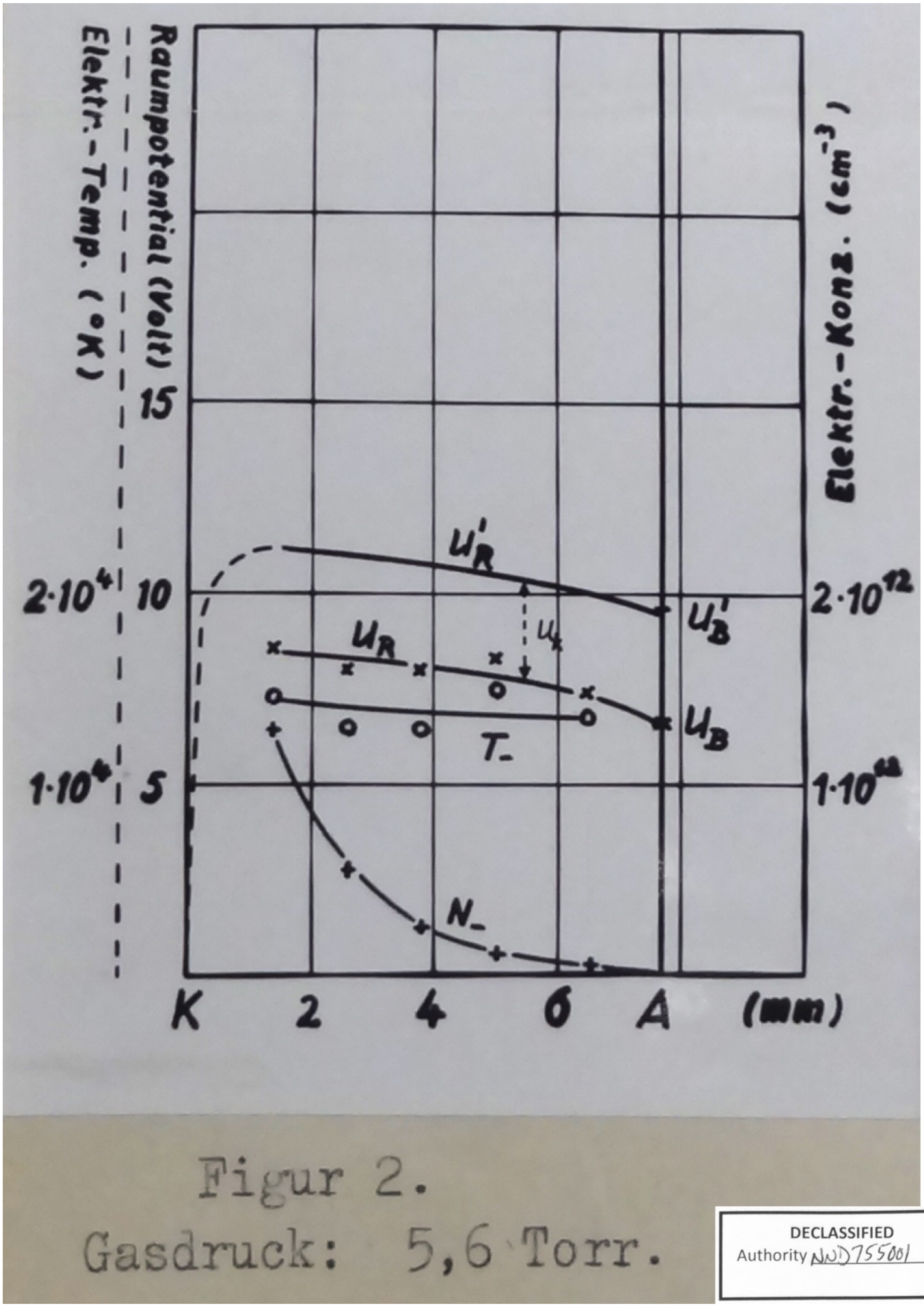
Erläuterung zu den Figg. 2 - 5 :

U_B : gemessene
U'_B : korrigierte } Brennspannung
U_R : gemessenes
U'_R : korrigiertes } Raumpotential
U_k : Kontaktpotential

T_- : Elektronentemperatur
N_- : Elektronenkonzentration.

Als Abszisse ist stets der Abstand zwischen Kathode u.Anode in mm aufgetragen.

Figure C.88: Wilhelm von Meyeren's 20 February 1945 report on experiments with laser-like monochromatic stimulated light emission from electron population inversions in argon, cesium, or rubidium gases [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].



Figur 2.
Gasdruck: 5,6 Torr.

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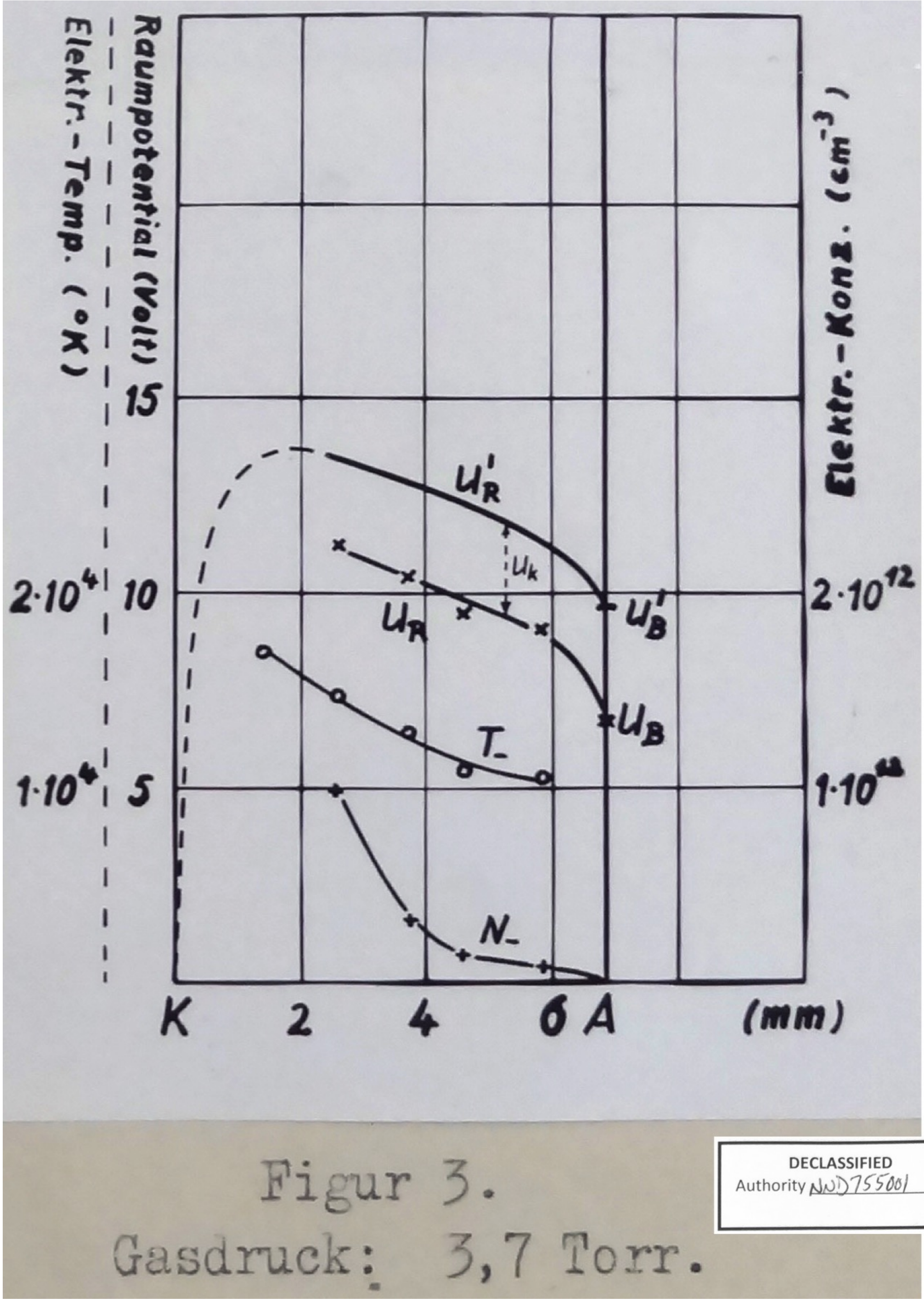
Figure C.89: Wilhelm von Meyeren's 20 February 1945 report on experiments with laser-like monochromatic stimulated light emission from electron population inversions in argon, cesium, or rubidium gases [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].



Figur 3.
Gasdruck: 3,7 Torr.

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Figure C.90: Wilhelm von Meyeren's 20 February 1945 report on experiments with laser-like monochromatic stimulated light emission from electron population inversions in argon, cesium, or rubidium gases [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

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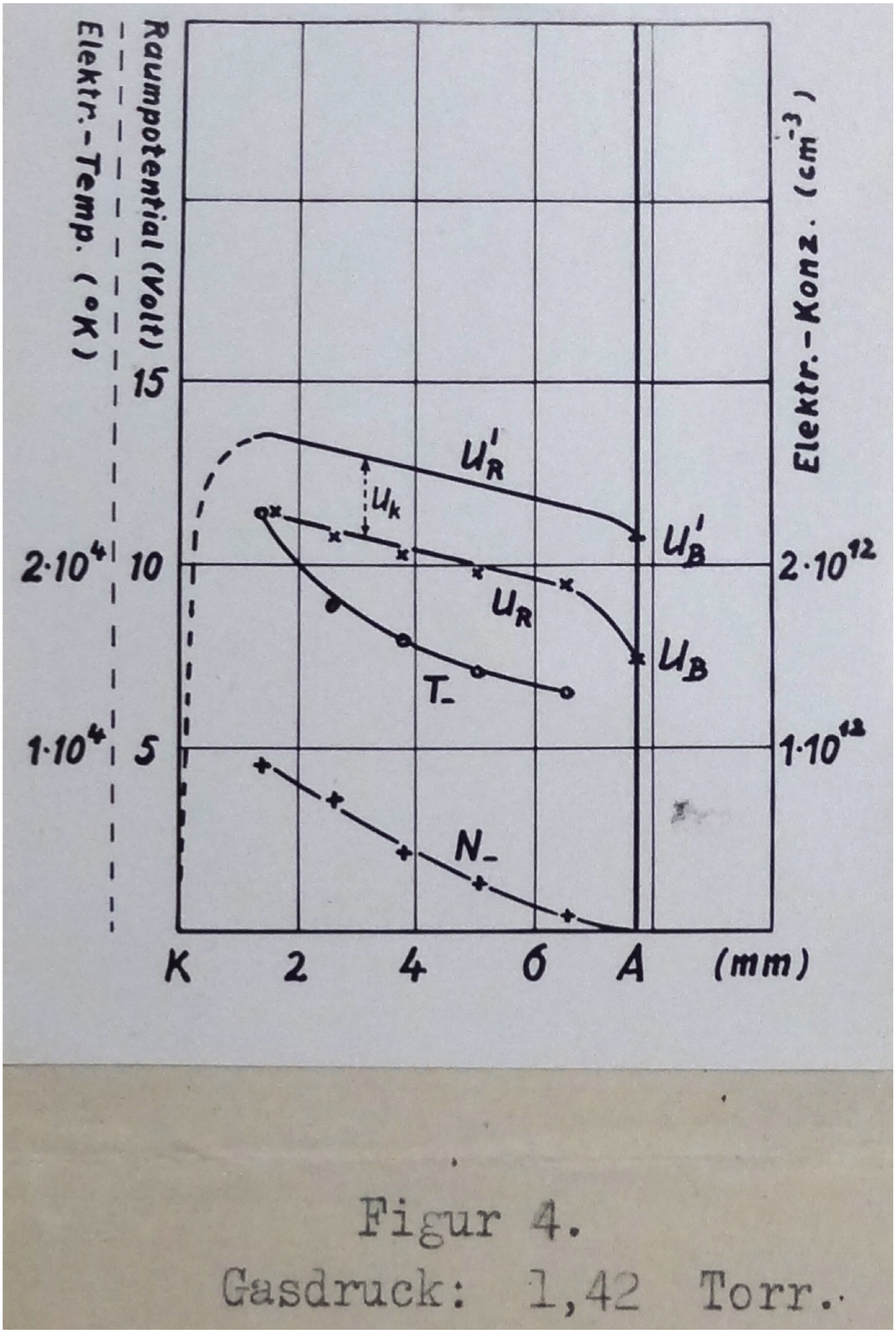

Figur 4.
Gasdruck: 1,42 Torr.

NARA RG 319, Entry NM3-82A,
Box 6, Folder G3

Figure C.91: Wilhelm von Meyeren's 20 February 1945 report on experiments with laser-like monochromatic stimulated light emission from electron population inversions in argon, cesium, or rubidium gases [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

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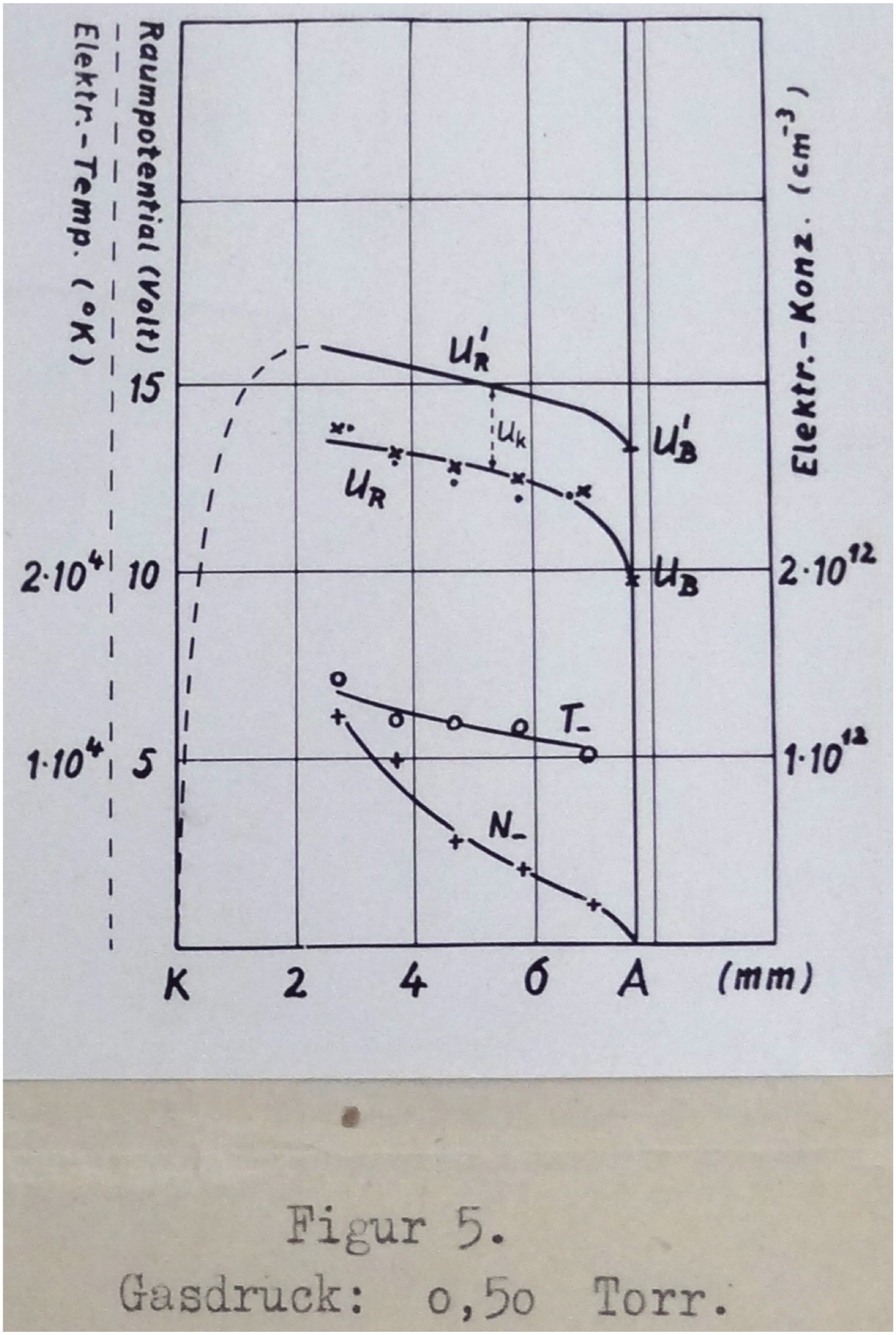


Figur 5.
Gasdruck: o,5o Torr.

NARA RG 319, Entry NM3-82A,
Box 6, Folder G3

Figure C.92: Wilhelm von Meyeren's 20 February 1945 report on experiments with laser-like monochromatic stimulated light emission from electron population inversions in argon, cesium, or rubidium gases [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

Military Intelligence Division W.D.G.S., Military Attaché Report Czechoslovakia. Subject: Scientists Experimenting on Secret Weapons. I.G. No. 0403.0700. Prague. Report No. R-42. 2 October 1945. [NARA RG 319, Entry NM3-85M, Box 19, Folder 925256]

Source and degree of reliability: Czechoslovak Counter Intelligence Officer — A-3

1. In accordance with directions contained in War Department Cable No. 68418, of 24 September 1945, the following list of scientists, Czech and German, with their specialties and present status, is submitted. [...]

Professor Dr. v. MEYEREN, specialist on Measuring Devices, German, in protective custody.

A. Hinzpeter. 1983. *Physikalische Blätter* 39:5:130. [https://onlinelibrary.wiley.com/doi/pdf/10.1002/phbl.19830390508]

Zum Tode von Wilhelm von Meyeren

Am 4. Februar 1983 verstarb in Hannover der emeritierte Professor Dr. phil. Wilhelm von Meyeren, ehemals Direktor des Instituts für Festkörperphysik der Universität Hannover. W. von Meyeren wurde am 26. April 1905 in Berlin geboren, promovierte 1929 bei R. W. Pohl in Göttingen mit einer Arbeit über Alkalihalogenidphosphore und war bis 1935 Assistent am Physikalischen Institut in Karlsruhe bei dem Altmeister der Hochvakuumtechnik Wolfgang Gaede, danach Oberingenieur am Physikalischen Institut der damaligen Technischen Hochschule Hannover. Dort habilitierte er sich 1937 und wurde 1941 auf den Lehrstuhl für Experimentalphysik der damaligen Deutschen Karls-Universität in Prag berufen. 1945 unter unmenschlichen Umständen mit seiner Ehefrau Hedi von Meyeren vertrieben, gelangte er nach schweren Jahren als Professor wieder nach Hannover auf einen Lehrstuhl für Atomphysik und baute dort das 1962 neugegründete Institut für Experimentalphysik B, das jetzige Institut für Festkorperphysik, auf.

On the death of Wilhelm von Meyeren

On 4 February 1983 in Hanover, the emeritus professor Dr. phil. Wilhelm von Meyeren, former director of the Institute of Solid State Physics at the University of Hanover, died. W. von Meyeren was born on 26 April 1905 in Berlin, received his doctorate in 1929 from R. W. Pohl in Göttingen with a thesis on alkali halide phosphors and was assistant at the Physikalisches Institut in Karlsruhe until 1935 to the old master of high vacuum technology Wolfgang Gaede, then chief engineer at the Physikalisches Institut of the then Technische Hochschule Hannover. There he habilitated in 1937 and in 1941 was appointed to the Chair of Experimental Physics at the then German Charles University in Prague. In 1945 he was expelled under terrible circumstances with his wife Hedi von Meyeren. After many difficult years as a professor, he returned to Hanover to take up a chair in atomic physics, where he built up the Institute for Experimental Physics B, newly founded in 1962, now the Institute of Solid State Physics.

Seine wissenschaftlichen Arbeiten behinhalten—ausgehend von den Anfängen der Festkörperphysik der Pohlschen Schule—die Hochvakuumphysik (Gasaufzehrung), die Spektroskopie verdünnter Gase und mündeten schließlich in der modernen Halbleiterphysik. In der Zeit zwischen seiner Lehrtätigkeit in Prag und in Hannover erscheint W. von Meyeren als Mitautor mehrerer Sammelwerke wie Fiat-Review, Angerer-Ebert, Technische Kunstgriffe, des Gmelin-Handbuchs, sowie des Physikalischen Wörterbuches von Westphal.

W. von Meyeren war mit Stolz ein Physiker alter Schule und darüber hinaus ein guter Pädagoge, der seine Pflichten als Hochschullehrer sehr ernst nahm. Lange Jahre galt seine Aufmerksamkeit der Allround-Ausbildung der Physiker in einer Art höherer Experimentalphysik ebenso wie einem Einführungsseminar für Studienanfänger mit ihrer so erschreckend differierenden Schulvorbildung. Ein besonderes Anliegen war ihm auch die Einführung der Ingenieur-Studenten in die sich rasant entwickelnde Festkörperphysik, insbesondere die Metallphysik.

Kollegen und auch seine Schüler, denen er ein väterlicher Freund war, wissen von seiner steten Hilfsbereitschaft zu berichten. Manche seiner zahlreichen Freunde und Bekannten erinnern sich gern an sein gastfreundliches Haus.

His scientific work includes—originating from the beginnings of solid-state physics of the Pohl school—high vacuum physics (gas consumption), the spectroscopy of diluted gases, and finally modern semiconductor physics. In the period between his teaching activities in Prague and Hanover, W. von Meyeren co-authored several anthologies such as *FIAT Review*, *Angerer-Ebert*, *Technical Methods*, the *Gmelin Handbook*, and the *Physics Dictionary* of Westphal.

W. von Meyeren was proud to be an old school physicist and a good teacher who took his duties as a university teacher very seriously. For many years his attention was focused on the all-round training of physicists in a kind of higher experimental physics as well as on an introductory seminar for first-year students with their so frighteningly different prior school education. He was also particularly interested in the introduction of engineering students to the rapidly developing field of solid state physics, especially metal physics.

Colleagues and also his students, to whom he was a fatherly friend, know about and describe his constant helpfulness. Some of his numerous friends and acquaintances fondly remember his hospitable house.

Tom Agoston. 1985. *Blunder! How the U.S. Gave Away Nazi Supersecrets to Russia.* New York: Dodd, Mead. pp. 12-13.

By quirk of fate, the careers of Kammler and Voss overlapped at Skoda, where they jointly set up and operated what was generally regarded by insiders as the Reich's most advanced high-technology military research center. Working as a totally independent undercover operation for the SS, the center was under the special auspices of Hitler and Himmler. [...] In so doing the SS group was to go beyond the first generation of secret weapons.

Its purpose was to pave the way for building nuclear-powered aircraft, working on the application of nuclear energy for propelling missiles and aircraft; laser beams, then still referred to as "death rays"; a variety of homing rockets, and to seek other potential areas for high-technology breakthrough. In modern high-tech jargon, the operation would probably be referred to as an "SS research think tank." Some work on second-generation secret weapons, including the application of nuclear propulsion for aircraft and missiles, was already well advanced.

It was far from a mad Nazi scientist's dream of getting to the end of the nuclear rainbow. The field had been pioneered by Dr. Wernher von Braun, designer of the V-2, in the early 1930s. In addition, it was recently disclosed that one of the first top German engineers cleared for urgent work for the U.S. Air Force in 1945 was Dr. Franz Josef Neugebauer, a specialist in thermal systems for aircraft nuclear propulsion. In 1958 the United States launched Project Orion to probe the applicability of nuclear propulsion for aircraft, employing some Czech scientists. The project was continued until 1965 and then was turned over to the U.S. Air Force, plans for its application for the civilian space programs having been dropped.

The SS research operation at Skoda had been set up without the knowledge of Goering, Speer, or the German research centers. The builders of the V-1 and V-2 were likewise kept out of the picture. The undercover SS research operation fitted in with Himmler's dream that, as the Rheingold of the Nibelung's, if shaped into a ring, would give its possessor mastery of the world, so would the SS team give the Greater Reich mastery of much of the world.

A study of intelligence reports shows that blueprints, drawings, calculations, and other relevant documentation or materials were protected by a triple ring of SS counter-intelligence specialists Himmler had assigned to Pilsen to prevent security leaks and sabotage in the research divisions and the plant in general. The SS team was internally referred to as the Kammler Group. Taking a leaf from the armament ministry name for the special section Kammler headed there to iron out aircraft production bottlenecks, they were called the Kammler stab or Kammler "staff."

Heinz Schaeffer. 1952. *U-Boat 977.* p. 187–188.

It took twenty-four hours to reach Berlin—we had air-raid warnings at regular intervals and took cover underneath the train till it could go on again. Next to me sat an S.S. officer who, in spite of my flatly contradicting him, simply would not stop talking about decisive new secret weapons. I was fed up with secret weapons by now for I knew perfectly well from my own experience that if all the blueprints were there so were the air-raids on our factories. "Well, of course, you aren't really in a position to judge," he said, but he was, naturally, because he was working at some S.S. H.Q. or other and was out watching the tests every day. If I would only come and look him up I would see something that would make me sit up.

When I got to Berlin I really did look him up, and after I had waited at the H.Q. entrance for some time my new acquaintance appeared and started showing me round. Everybody there was certain we were going to win, with a conviction I'd never seen the like of even after the fall of France. Among the fantastic contrivances of which I was shown photographs was one called a death ray which my friend wanted me to come back and see in action next day.

But I wasn't wasting any more time. I wanted to see my mother, for it was obvious the Russians were advancing on Berlin and that the last battle was going to be fought there. The city was being transformed into a fortress, with tram-cars overturned and barricades going up everywhere. I wanted to get my mother away, but she said she meant to stay in Berlin at all costs; she would manage the Russians all right, she said. And so she did.

Herbert A. Werner. 1969. *Iron Coffins: A Personal Account of the German U-Boat Battles of World War II.* p. 228.

I was thinking about our much-discussed new weapons, including death rays and atom bombs, which were now in the development stage...

United States Air Force Oral History Program: Interview #K239.0512-724 of Lt General Donald L. Putt by Dr. James C. Hasdorff. 1–3 April 1974. [AFHRA 43826 electronic version pp. 1009–1010]

H[asdorff]: Why was there such a slow application of laser technology in the US? I understand we were dabbling with it during World War II.

P[utt]: Well, I'm not an expert on lasers, but it's my understanding that the phenomenon was discovered which gave one the capability of having coherent beams. But for a long time nobody could figure out what it was good for. It was one of these scientific curiosities, and it just took a long time to find the application. Now whether we proceeded as fast as could have been done if there were no budgetary restraints or anything like that, I guess I'm not familiar enough with the field to know that. But in the early days I know that was one of the problems; we said, "Here's something that's very interesting, but what can we use it for?" And now we're finding all kinds of uses for it, of course, in civil work, et cetera.

[In the United States, theoretical design work on lasers did not begin until the mid–late 1950s, and the first working laser was not built until 1960, at least according to official histories.

In the above question and answer, were Hasdorff and Putt simply confused, or were they referring to actual earlier work on lasers?

If they were referring to earlier work that indeed occurred, was it wartime work in the United States, perhaps by or based on the earlier research of German-speaking immigrant scientists such as Rudolf Ladenburg or James Franck?

Alternatively, since Putt was deeply involved in rounding up German-speaking scientists and information from Europe at the end of the war and putting them to use in the postwar United States, were Hasdorff and/or Putt referring to wartime German work on lasers (perhaps such as that of Wilhelm von Meyeren) that was brought to the United States after the war?]

Michel Bar-Zohar. 1967. *The Hunt for the German Scientists.* pp. 140, 207.

There was also a vague report on the mysterious Zimmermann—the man believed to have invented the 'death ray' and even to have used it effectively against the Russians in the Carpathians on 30 August 1944. The report said that he had been captured and taken to Russia just before the end of the war. [...]

Dr. Hans Ehrhardt, who was expelled from Switzerland for having experimented with a mysterious green death ray...

[Can any information be found regarding Zimmermann and his alleged directed energy weapon?

Hans Ehrhardt's laser-like work is discussed on the following pages. If Bar-Zohar's information is accurate, Ehrhardt's beam was green. That suggests that it may have been an argon gas laser or something similar. Could Erhardt's work have been directly related to von Meyeren's wartime work on laser-like light emission from electrically excited argon gas?]

Schweiz/Todesstrahlen: Schnee geschmolzen. *Der Spiegel.* 24 July 1963 p. 58. [https://www.spiegel.de/spiegel/print/d-46171297.html]

24.07.1963
SCHWEIZ / TODESSTRAHLEN
Schnee geschmolzen

Ungewöhnliche Order lief Anfang vergangener Woche bei eidgenössischen Polizeidienststellen ein:

Die Gesetzeshüter wurden angehalten, nach einem Mann zu fahnden—freilich nicht, um ihn zu verhaften. Vielmehr sollte sichergestellt werden, daß der Gesuchte wirklich verschwunden ist und damit die eidgenössische Bürokratie von einer Blamage befreit hat.

Der Gesuchte nennt sich Dr. Hans Ehrhardt und hieß früher Hans Engelke. Als Amateur-Physiker war er—nach eigenen Angaben zusammen mit Wernher von Braun—in der Rüstungsindustrie des Dritten Reiches beschäftigt gewesen.

Dabei erfand er eine Wunderwaffe: Engelke wollte in den von feindlichen Bomberstaffeln durchflogenen Luftschichten dichte Wolken feinster Kohlenstoffpartikel verteilen. Mittels einer Zündrakete sollte beim Herannahen von Feindflugzeugen ein Schlagwetter in der Atmosphäre erzeugt werden. Beim ersten und einzigen Versuch mit seiner Wunderwaffe, so fabulierte Engelke-Ehrhardt, seien im April 1945 gleich 36 Bomber auf einen Schlag vom Himmel geholt worden.

Nach Krieg und alliierter Internierung wandte sich Autodidakt Ehrhardt einem anderen physikalischen Phänomen zu: Er begann Versuche mit Strahlen, die laut eigener Aussage “im Frieden Kranke heilen und im Kriege Feinde töten” sollten.

24 July 1963
SWITZERLAND / DEATH RAYS
Melted snow

An unusual order arrived at the beginning of last week at the national police station:

The law enforcers were spared from having to find and arrest a man. Rather they were to make sure that the wanted man had really disappeared and thus the national bureaucracy had been saved from embarrassment.

The person for whom they searched called himself Dr. Hans Ehrhardt and earlier Hans Engelke. As an amateur physicist he had been—by his own account together with Wernher von Braun—employed in the armament industry of the Third Reich.

Back then he invented a miracle weapon: Engelke wanted to distribute dense clouds of fine carbon particles in the air layers through which enemy bombers flew. By means of an igniting rocket, an explosion in the atmosphere should be generated at the approach of enemy aircraft. The first and only attempt with his silver bullet, claimed Engelke-Ehrhardt, had knocked as many as 36 bombers from the sky with one explosion in April 1945.

After the war and Allied internment, the autodidact Ehrhardt turned to another physical phenomenon: he began experiments with beams that should in his words “heal sick people in peacetime and kill enemies in wartime.”

Aus einer Gasplasma-Quelle gedachte der Erfinder mit großen Hohlspiegeln einen gebundelten ultravioletten Lichtstrahl herzustellen. Dieser Todesstrahl sollte einerseits 30 000 Kilometer weit wirken und eine “ungeheure Zerstörungskraft” (so Ehrhardt) entwickeln, andererseits aber Krebskranke von ihren Leiden befreien, “ohne daß Knoten oder Kapselungen zurückbleiben”.

In der Bundesrepublik gelang es dem modernen Cagliostro nicht, seine Ideen zu verkaufen, obgleich Deutschland stets ein dankbares Feld für Wundermänner war: Nach dem Ersten Weltkrieg gelang es dem geisteskranken Österreichischen Landbriefträger Karl Schappeller, Ex-Kaiser Wilhelm II. große Summen für einen Plan zu entlocken, Deutschland “durch die Nutzung ungeheurer Energien aus dem kosmischen Raum zur ersten Weltmacht zu machen”. Zur selben Zeit begeisterte ein Betrüger namens Franz Tausend den General Ludendorff mit seiner angeblichen Fähigkeit, aus Eisen und Blei Gold zu gewinnen.

Dem Strahlenmagier Ehrhardt glückte es hingegen Anfang 1961, die Kriegstechnische Abteilung (KTA) des Eidgenössischen Militärdepartements in Bern für seine phantastischen Projekte zu interessieren.

Die schweizerischen Landesverteidiger luden Ehrhardt am 24. Februar 1961 zu einer Besprechung ein und forderten ihn auf, schriftliche Unterlagen beizubringen. Eine Prüfung des Ehrhardt -Exposes durch Züricher TH-Professoren veranlaßte freilich die KTA am 31. Mai 1961 dazu, auf eine weitere Zusammenarbeit mit Ehrhardt zu verzichten.

From a gas plasma source, the inventor intended to use large concave mirrors to produce a narrow ultraviolet light beam. This death ray should in one case have a range of 30,000 kilometers and (according to Ehrhardt) develop a “monstrous destructive power,” but in the other case free cancer patients from their suffering “without a node or capsule remaining.”

In West Germany this modern Cagliostro was unable to sell his ideas, even though Germany has always been a grateful field for miracle workers: After World War I the insane Austrian postman Karl Schappeller succeeded in obtaining large sums from ex-Kaiser Wilhelm II for a plan to make Germany “the greatest power in the world through the use of monstrous energy from cosmic space.” At the same time an impostor named Franz Tausend interested General Ludendorff with his alleged ability to turn iron and lead into gold.

At the beginning of 1961, however, the ray magician Ehrhardt succeeded in interesting the War Technical Department (KTA) of the Federal Military Department in Bern in his fantastic projects.

The Swiss defense officials invited Ehrhardt to a meeting on 24 February 1961 and asked him to bring written proposals. An examination of Ehrhardt’s documents by Zurich Technical University professors prompted the KTA on 31 May 1961 to refrain from further cooperation with Ehrhardt.

Interessiert an den Künsten des deutschen Physikers blieb indes weiterhin ein Beamter der KTA: Adjunkt Eugen Burkhard, Chef der Rüstungszentrale der Kriegstechnischen Abteilung, erhoffte sich von Ehrhardts Ideen Entdecker-Ruhm und förderte den Deutschen in eigener Regie.

Als KTA-Beamten fiel es Burkhard leicht, dem Forscher Aufenthaltsbewilligung und Wohnung zu verschaffen. Im August 1961 siedelte sich der Waffenrevolutionär mit Gattin Ilse und vier Sprößlingen am Sarner See im Kanton Obwalden an.

Rückendeckung für die folgenden Versuche wurde Ehrhardt durch die “Bewilligung 2524” der KTA zuteil, in der dem Physiker gegen Entrichtung von 50 Franken Gebühr und 80 Rappen Porto routinegemäß erlaubt wird, “Prototypen zu Geschossen ohne Patronenhülsen bis zum Kaliber 30 mm herzustellen”.

In Wahrheit experimentierte der Sarner Neubürger aber nicht mit 30-mm-Geschossen, sondern mit “Todesstrahlen”. Mit diesen Produkten seines Erfindergeistes schmolz Ehrhardt im letzten Frühjahr—so erzählte er der “Deutschen National-Zeitung”—auf eine Entfernung von zwölf Kilometern binnen Sekunden anderthalb Meter hohen Gletscherschnee. Applaudierte die DNZ: “Erfinder Dr. Ehrhardt, Herr über Tod und Leben.”

Ungemach näherte sich dem Herrn über Tod und Leben freilich, als Anfang Juni ein Photo erschien, das den Ehrhardtschen Todesstrahl als drohend himmelwärts gerichteten Finger über dem Sarner See zeigte.

Interest in the creations of the German physicist remained, however, for one official of the KTA: Adjunct Eugen Burkhard, head of the Armament Center of the War Technical Department, hoped that Ehrhardt’s ideas were pioneering and supported the German on his own.

As a KTA official, it was easy for Burkhard to obtain a residence permit and housing for the researcher. In August 1961, the weapon revolutionizer and his wife Ilse and four offspring settled on Sarner Lake in the canton Obwalden.

Ehrhardt received support for the ensuing experiments through the KTA “Permit 2524,” by which the physicist routinely accepted payments of 50 francs fee and 80 cents postage “to produce prototype projectiles without shell casings up to 30 mm caliber.”

In truth, the new Sarner resident experimented not with 30-mm projectiles, but with “death rays.” With these products of his ingenuity, last spring Ehrhardt melted—so he told the *German National Newspaper* (DNZ)—one and a half meters of glacier snow within seconds at a distance of twelve kilometers. The DNZ applauded: ”inventor Dr. Ehrhardt, master of life and death.”

Trouble approached the master of life and death, as at the beginning of June, a photo was published that showed Ehrhardt’s death ray as a threatening finger pointed skyward over the Sarner Lake.

Die eidgenössische Presse, von der schockierten Fremdenindustrie alarmiert, überhäufte die nichtsahnende Kriegstechnische Abteilung mit Vorwürfen wegen dieser “lebensgefährlichen Experimente”, während die Sarner Gastwirte Schadenersatz für die Gäste forderten, die wegen der Todesstrahlen fernbleiben würden.

Das Militärdepartement ließ eilends verlauten, Ehrhardt habe “keinen Rappen” schweizerischer Steuergelder für seine Experimente erhalten. Zugleich interessierte sich die eidgenössische Sicherheits- und Fremdenpolizei eingehend für den Deutschen.

Dabei ergab sich laut Polizeibericht, daß Ehrhardt “über wesentliche Punkte seiner Person und seines Vorlebens unwahre Angaben gemacht hatte, so über seine Tätigkeit in der DDR”.

Da witterten die Behörden die Chance, sich des peinlichen Gastes zu entledigen: Am 4. Juni eröffnete die Fremdenpolizei Obwalden dem Ehrhardt, daß sein Aufenthalt bis zum 15. Juli 1963 befristet sei.

Zwei Tage vor Ablauf der Frist, in der Nacht vom 13. auf den 14. Juli, verschwand Ehrhardt aus seinem Sarner Domizil, ohne sich abzumelden oder eine Adresse zu hinterlassen.

Mit seinem allzu stillen Abschied wurde Ehrhardt freilich gezwungen, vorerst auch auf die Verwirklichung eines Planes zu verzichten, den er in der Ende 1962 herausgegebenen Schrift “Der neue Weg” publik gemacht hatte: die Nutzbarmachung eines von ihm erdachten Perpetuum mobile.

Erfinder Ehrhardt

“Ungeheure Zerstörungskraft... über 30 000 Kilometer”: Ehrhardt-Strahl am Sarner See

The national press, alarmed by this shocking outsider industry, showered the unsuspecting War Technical Department with allegations of these “perilous experiments,” while the Sarner innkeepers demanded compensation for losing guests who would stay away because of the death rays.

The Military Department hastily announced that Ehrhardt had received “not a cent” of Swiss tax money for his experiments. At the same time, the national security and immigration police became interested in details about the German.

According to the police report, it was found that Ehrhardt “had given untrue information regarding significant points about himself and his prior life, as well as his activities in East Germany.”

Here the authorities sensed the chance to get rid of the embarrassing guest: On June 4, the Obwalden immigration police disclosed to Ehrhardt that his stay must end by 15 July 1963.

Two days before the deadline, in the night from 13 to 14 July, Ehrhardt disappeared from his Sarner home without checking out or leaving a forwarding address.

With his all too silent departure, Ehrhardt was indeed forced to abandon the realization of a plan, which he had made public in his writing “The New Way” published at the end of 1962: harnessing a perpetual energy source he had devised.

Inventor Ehrhard [Fig. C.93]

“Monstrous destructive power... over 30,000 kilometers”: Ehrhardt’s ray over Sarner Lake [Fig. C.95]

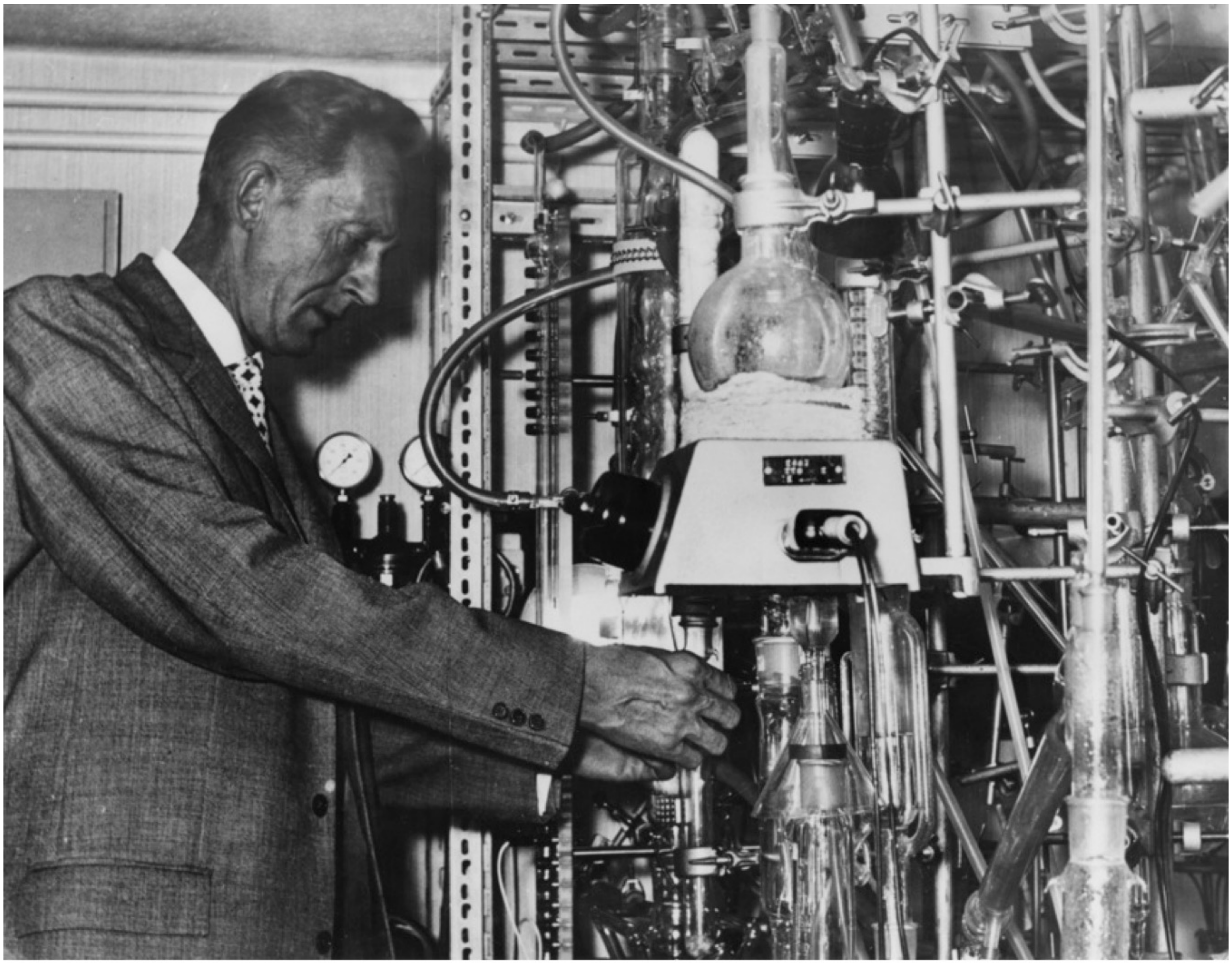


Figure C.93: Hans Ehrhardt/Engelke in his 1961–1963 Swiss lab.

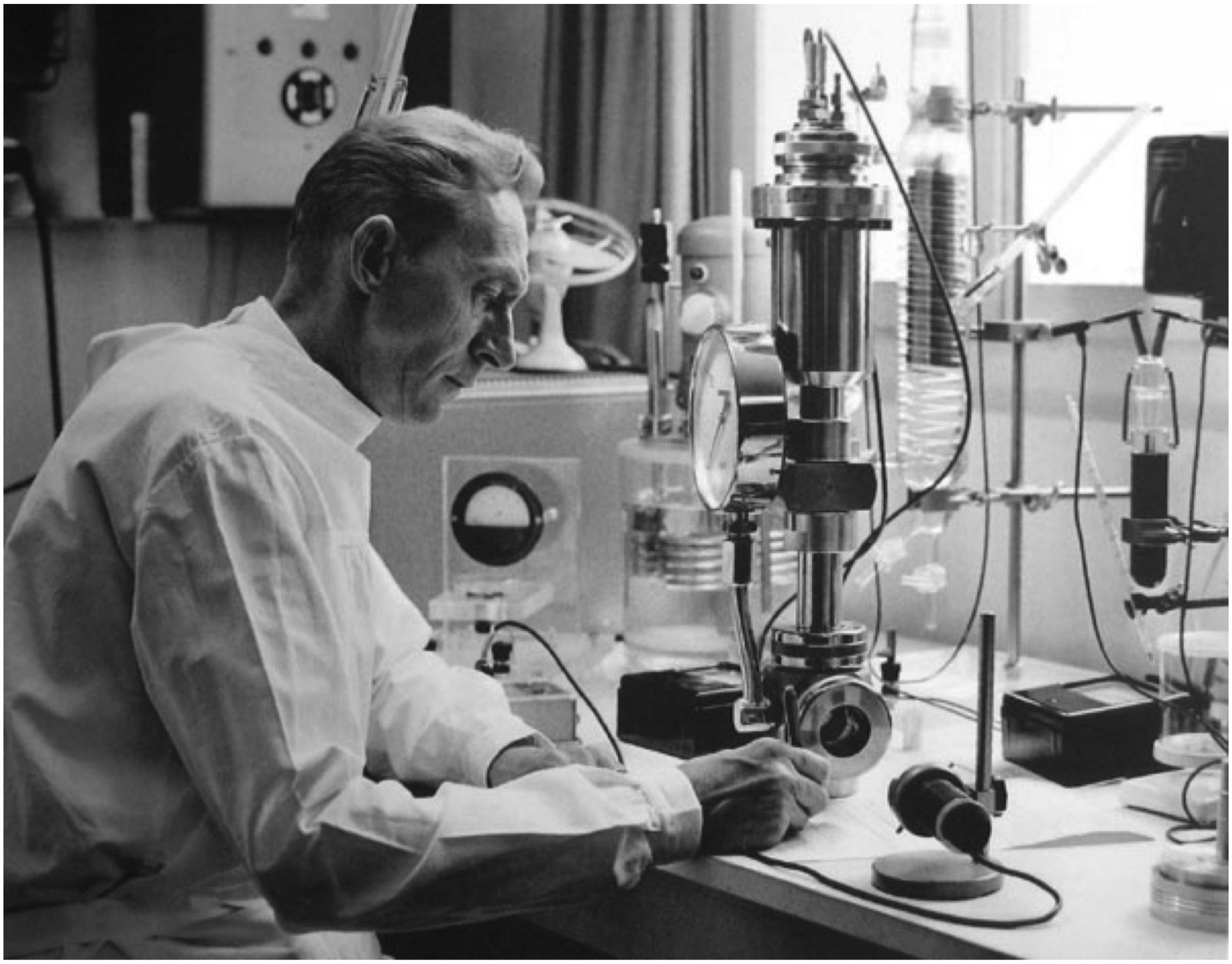


Figure C.94: Hans Ehrhardt/Engelke in his 1961–1963 Swiss lab, working on a device that appears to resemble a gas laser.

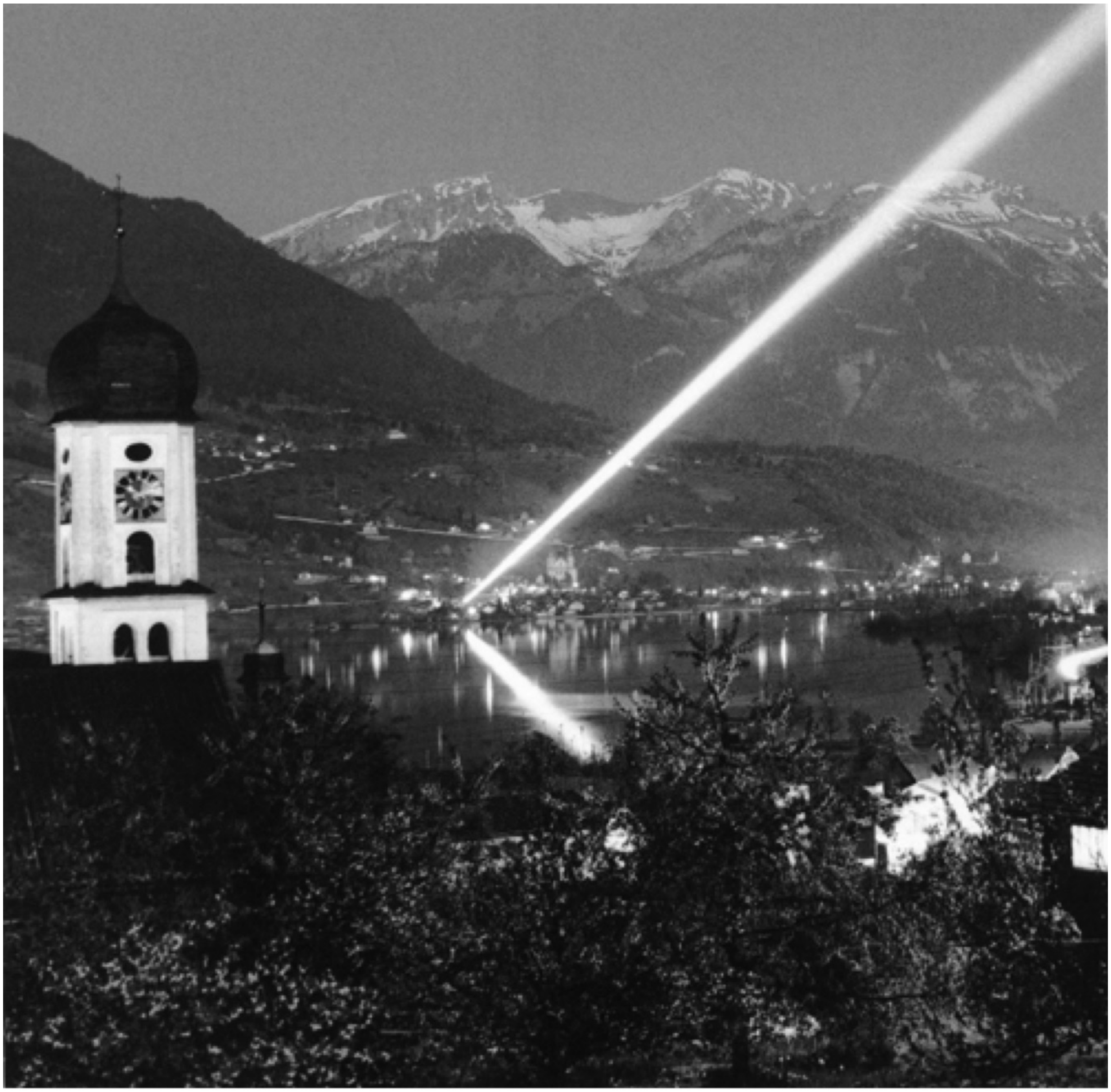


Figure C.95: Demonstration of Hans Ehrhardt's/Engelke's laser-like beam over the Swiss Sarner See. The clock hands indicate 10:10, which could be a.m. or p.m. Based on the lights visible in the buildings and reflected in the water, this photo was taken at night, so 10:10 p.m. The brightness of the sky suggests a long exposure and/or moonlit night. Even just the small fraction of light scattered by dust particles out of the beam toward the camera is clearly much brighter than the building lights, so the light within the beam would have been quite intense. Most of the apparent expansion of the beam is due to the perspective of the beam coming from the distance toward the camera; the beam is remarkably well collimated. Although the photo is black and white, observers reported that the beam was green.

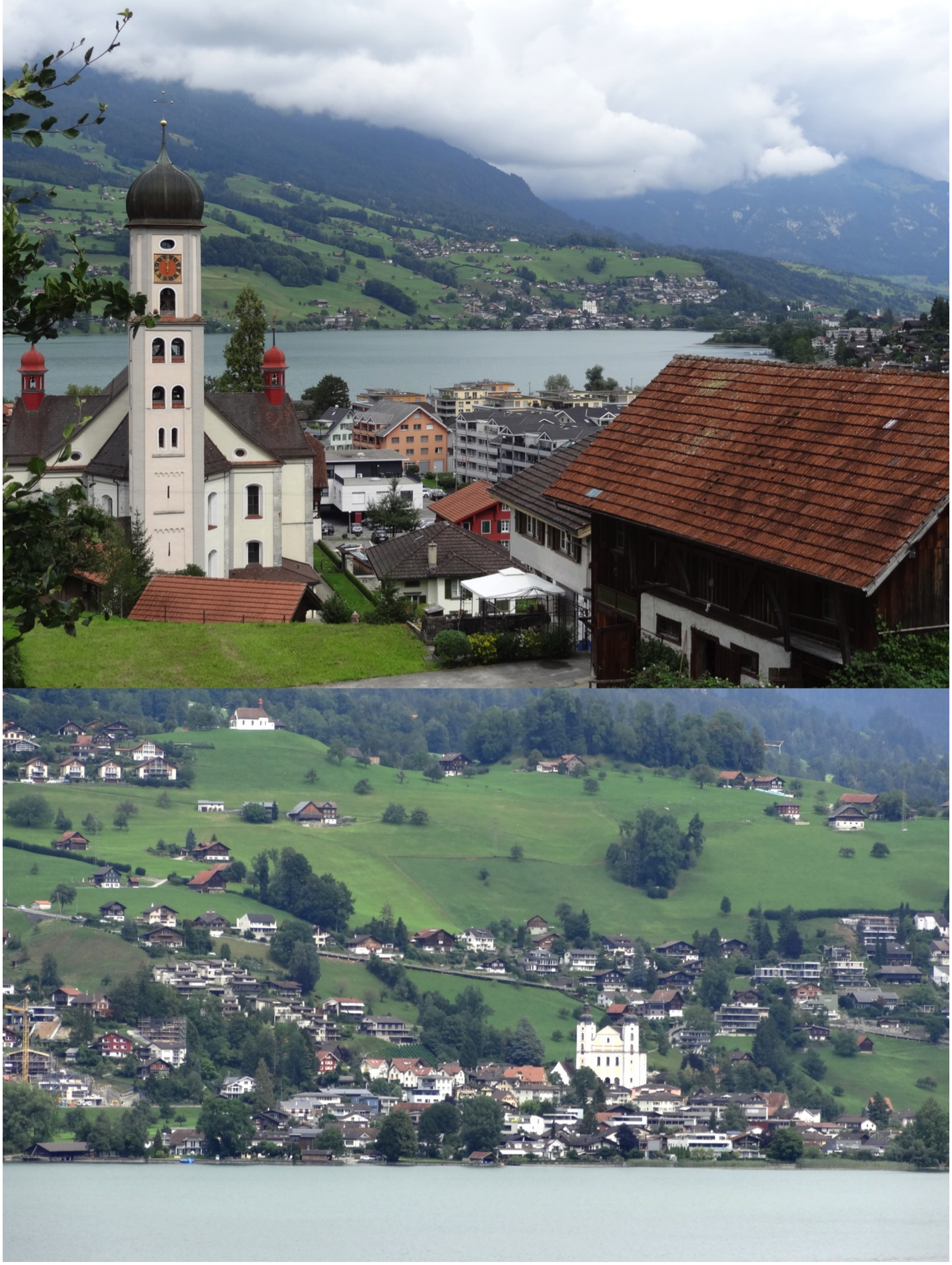


Figure C.96: The view now from a hill behind the Pfarr- und Wallfahrtskirche Sachseln church in Sachseln looking toward the north, across the Sarner See toward the Pfarrkirche St. Peter und Paul church in Sarnen. Hans Ehrhardt's/Engelke's laser-like beam was apparently fired from the vicinity of a waterfront house or hotel somewhat to the left of the Sarnen church.

"Todesstrahlen" über dem Sarner See: Über den "deutschen Physiker" Hans Ehrhardt, der in der Schweiz beinahe das Perpetuum mobile erfunden hat. *Physikalische Blätter* 19:11:511–516. November 1963.
[**https://onlinelibrary.wiley.com/doi/abs/10.1002/phbl.19630191104**]

[...] Mit dem Doktor ist es nichts, mit dem Studium dürfte es auch nichts sein; jedenfalls ist Hans Ehrhardt kein Physiker in unserem Sinn, d.h. nicht ein Mann, der eine wissenschaftliche Schulung in der Physik durchlaufen und sein Studium mit der Prüfung an einer Universität oder Hochschule abgeschlossen hat. Ehrhardt nennt sich Ingenieur, gelegentlich aber auch Physiker; er dürfte Autodidakt sein, der schon vor 1945 sonderbaren Ideen nachging, wie der einer neuartigen Flugabwehrwaffe mit gebündelten Ultraviolettstrahlen, deren Wirksamkeit er auf mehrere 10000 km Distanz glaubte garantieren zu können. [...]

Das Gutachten aus dem Laboratorium für Festkörperphysik der ETH trifft den Nagel auf den Kopf. In dem uns von Prof. Dr. Gärnicher freundlicherweise zugestellten Schriftstück, das übrigens nur durch Indiskretion in die Öffentlichkeit gelangte und das von einem Doktoranden des Laboratoriums (nicht des Phys. Inst.) erstattet worden ist, heisst es: "Die untersuchte Arbeit ist wissenschaftlich wertlos. Der Verfasser stellt darin Behauptungen auf, welche darin gipfeln, er habe das Perpetuum mobile erster Art erfunden... Das konfuse physikalische Weltbild des Verfassers lässt sich etwa folgendermassen zusammenfassen: Raum und Materie sind durchsetzt von Wolken freier Elektronen in unterschiedlicher Dichte. Diese freien Elektronen sind in dauernder ungeordneter Bewegung, verursacht durch "Urkräfte der Materie". Nun braucht man nur diese Bewegung zu ordnen, was an Halbleiter- und Grenzschichten geschehen soll, um einen dauernden elektrischen Stromfluss zu erhalten..."

[...] There is nothing to his doctorate; there should also be nothing to his education; in any case Hans Ehrhardt is not a physicist in our sense, i.e. not a man, who went through a scientific training in physics and finished his study with the examination at a university or college. Ehrhardt calls himself an engineer, but occasionally also a physicist; he is probably self-taught, who already before 1945 pursued strange ideas, such as that of a novel anti-aircraft weapon with bundled ultraviolet rays, the effectiveness of which he believed he could guarantee over a distance of several 10000 km. [...]

The report from the Laboratory for Solid State Physics at ETH Zurich hits the nail on the head. In the document kindly sent to us by Prof. Dr. Gärnicher, which, by the way, only came into the public eye through indiscretion and which was reimbursed by a doctoral student of the laboratory (not of the Phys. Inst.), it says: "The work examined is scientifically worthless. The author makes claims in it, which culminate in the fact that he invented perpetual motion of the first kind... The confused physical world view of the author can be summarized as follows: Space and matter are interspersed with clouds of free electrons of different density. These free electrons are in constant disordered motion, caused by 'forces of matter.' Now one only needs to order this movement, what should happen at semiconductor and boundary layers, in order to receive a continuous electric current flow..."

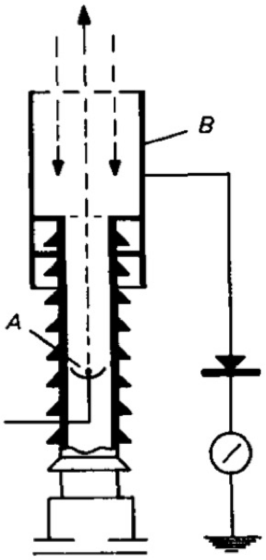
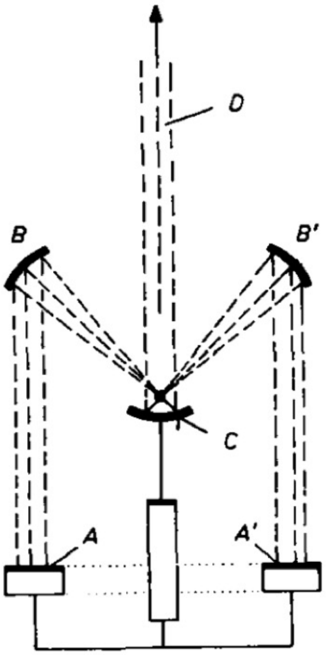


Abb. 3: „Experimentalschema V einer sukzessiven Entladung hochgespannter Ströme. Würde nach diesem Schema zumindest in stark gewittergefährdeten Gebieten verfahren, dann könnte es dort keine Blitzeinschläge mehr geben.“ A = Lichtquelle, B = Gitterantenne als Elektronenfalle

◀

▶

Abb. 4: Experimentalschema VI, „Quantenturbotron“. Die Ultraviolett-Strahlung von A und A’ wird durch die Parabolspiegel B und B’ nach G konzentriert. Dort wird ein leichtes Gas zugeführt und die Strahlung nun in Richtung D gesandt, wo sie einen mit Knallgas gefüllten Ballon in 1000 m Abstand „mit Sicherheit zur Explosion“ bringt



[Fig. 3: “Experimental scheme V of a successive discharge of high voltage currents. If this scheme were to be applied at least in thunderstorm endangered areas, then lightning strikes could no longer occur there.” A = light source, B = grid antenna as electron trap.

Fig. 4: Experimental scheme VI, “quantum turbotron.” The ultraviolet radiation of A and A' is concentrated to G by the parabolic mirrors B and B'. There, a light gas is supplied and the radiation is now sent in the direction of D, where it causes a balloon filled with oxyhydrogen gas to “explode” at a distance of 1000 m.]

Figure C.97: Diagrams from a page left behind in Switzerland by Hans Ehrhardt/Engelke.

Der Erfinder wartet mit konkreten Vorschlägen auf: Das Experimentalschema V für seine Versuche (Abb. 3) zeigt eine Röhre, durch die das Licht an der Lichtquelle A senkrecht nach oben geschickt wird, während B eine “Gitterantenne” ist, die am Isolator abgebogen ist. Sie dient als “Elektronenfalle”. Mit dieser Anordnung, dem “Quantenturbutron”, will der Erfinder Elektronen mit dem Lichtstrahl mitschiessen und sie zur Abgabe grosser Energien zwingen, denn: “sind sie (die Elektronen) einmal eingefangen und ausgerichtet, dann geben sie grosse Mengen Energie ab”. (S. 19)

Ein anderes aufschlussreiches Experimentalschema zeigt Abb. 4. Die Bildlegende enthält, was der Erfinder dazu sagt.

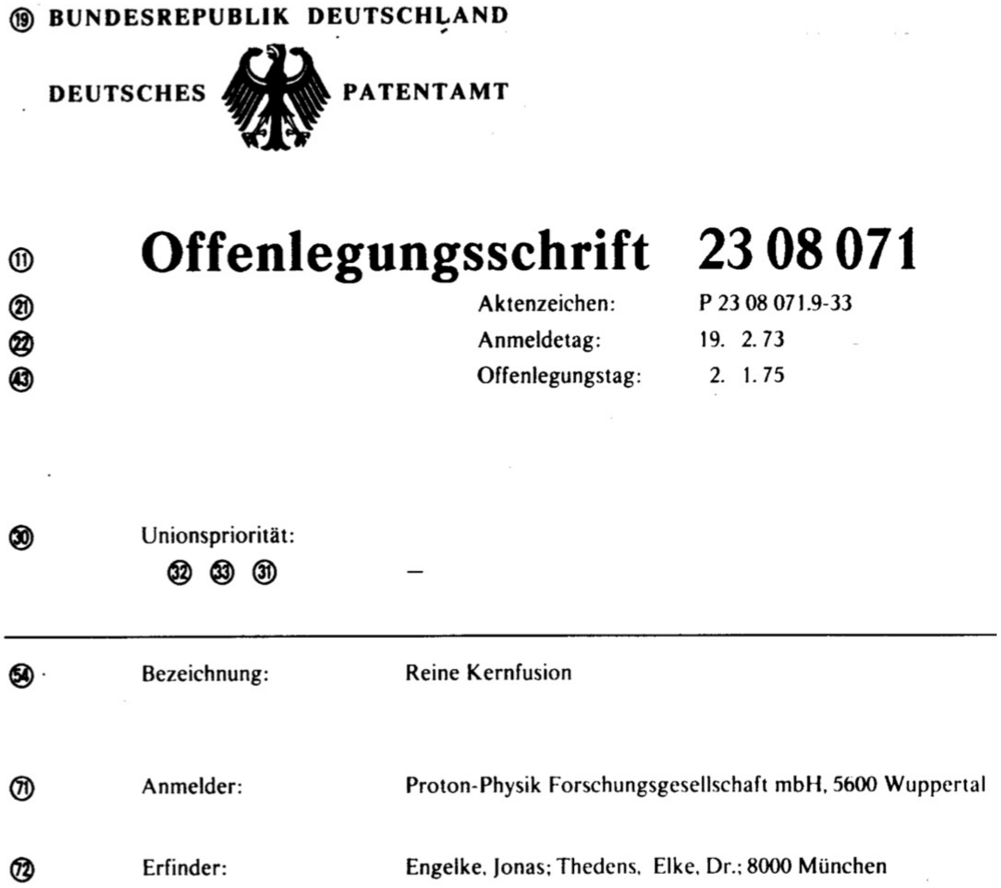
The inventor comes up with concrete proposals: The experimental scheme V for his experiments (Fig. 3) shows a tube through which the light at light source A is sent vertically upwards, while B is a “grating antenna” which is bent off at the insulator. It serves as an “electron trap.” With this arrangement, the “quantum turbutron,” the inventor wants to shoot electrons with the light beam and force them to emit large energies, because: “Once they (the electrons) are captured and aligned, they emit large amounts of energy.” (p. 19)

Another informative experimental scheme is shown in Fig. 4. The caption contains what the inventor says about it.

[The unnamed author of this article stated that he never met Ehrhardt/Engelke or saw his experiments in person, yet he proceeded to spend most of the article ridiculing Ehrhardt/Engelke as an uneducated crackpot who was trying to build perpetual motion machines. (Figs. C.93–C.95 look nothing like perpetual motion machines or the work of a scientific illiterate.) However, the unnamed author did find a few pages about Ehrhardt/Engelke's research that had been written by Ehrhardt/Engelke or by his Swiss scientific evaluators. The author quoted a few intriguing lines and two figures from those documents.

The provided information is insufficient to judge how or whether Ehrhardt/Engelke's designs would work, but they do offer some hints:

- The unnamed author seemed to have reason to believe that Ehrhardt/Engelke's research on producing powerful light beams dated back to wartime work.
- Ehrhardt/Engelke dubbed his device a “quantum turbo.” Considering that a “turbojet” produces a highly ordered, tightly directed jet or stream of gas, a “turbo” that produces a highly ordered, tightly directed stream of “quanta” (photons) would not be a bad description of a laser.
- The device contained a gas in an optically transparent glass tube that was electrically excited at the desired energy, which would certainly be reasonable in a laser.
- The device used mirrors, as would be expected in a laser.
- The device was ultimately intended to produce a beam of ultraviolet light. The beam photographed over the Sarner See appears to be visible light (unless the film was exposed by ultraviolet light), but perhaps Ehrhardt/Engelke's current experiments used visible light as a stepping stone to future experiments with ultraviolet.
- The device was intended to produce a highly focused light beam of sufficient intensity to heat objects (balloons, snow, or aircraft) at a distance, or if short-wavelength ultraviolet light were used, perhaps even to create enough ionization in the air to affect the preferred direction of lightning discharges from thunderstorms.]



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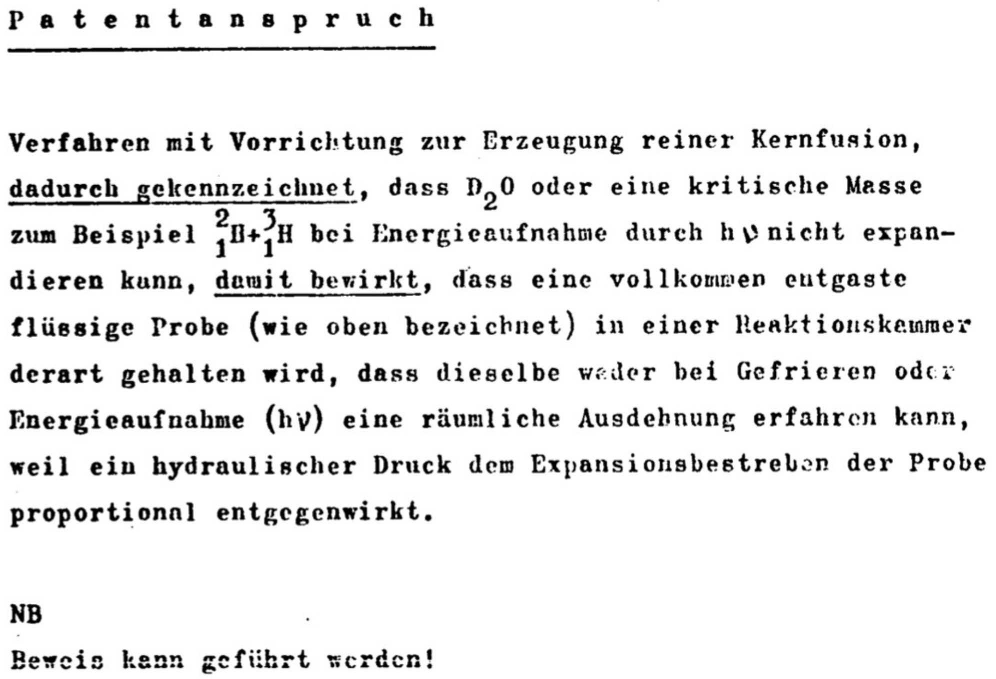
(54) Bezeichnung: Reine Kernfusion

(71) Anmelder: Proton-Physik Forschungsgesellschaft mbH, 5600 Wuppertal

(72) Erfinder: Engelke, Jonas; Thedens, Elke, Dr.; 8000 München



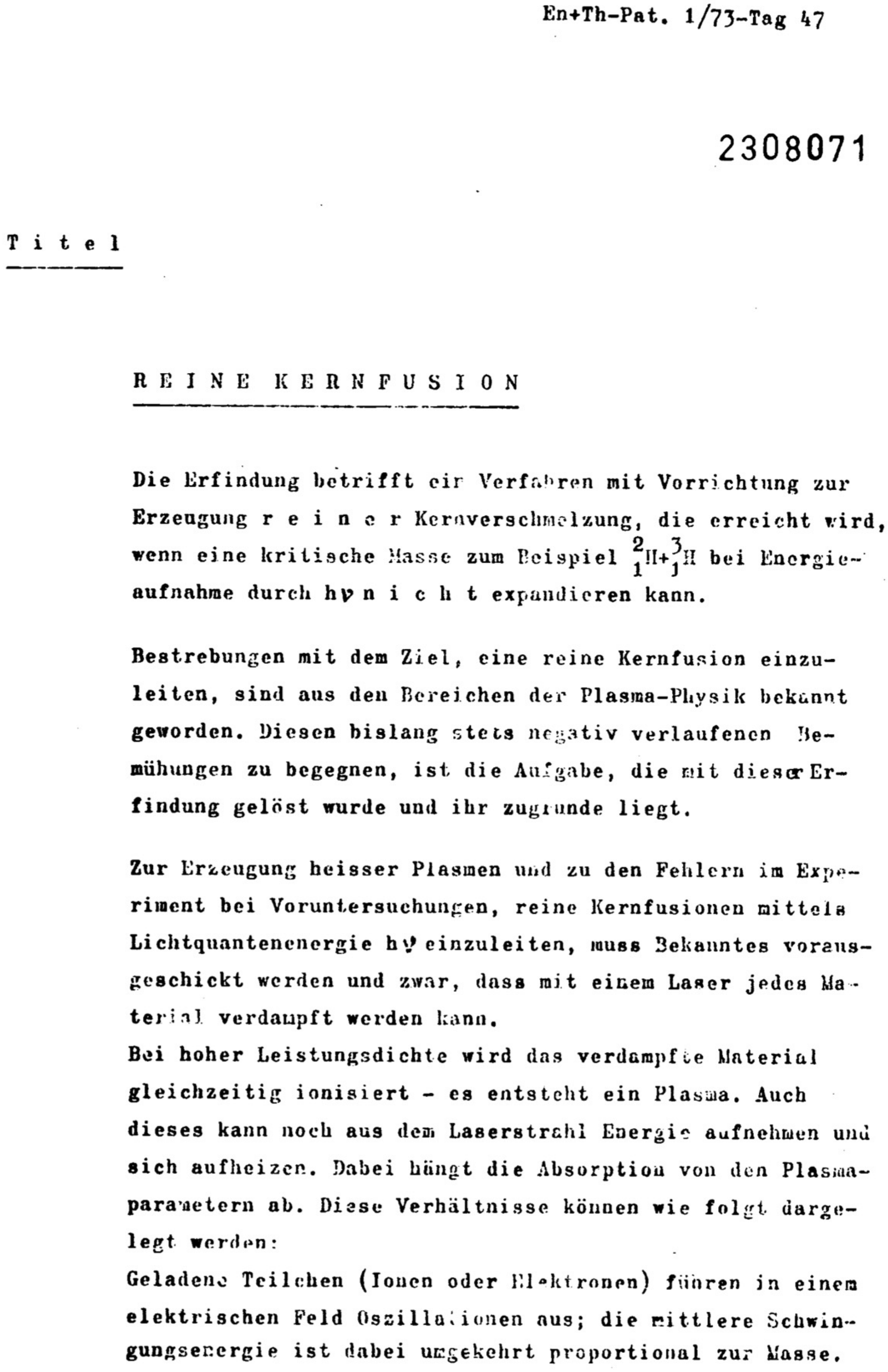
Patentanspruch

Verfahren mit Vorrichtung zur Erzeugung reiner Kernfusion, dadurch gekennzeichnet, dass D_20 oder eine kritische Masse zum Beispiel ${}^2_1H+{}^3_1H$ bei Energieaufnahme durch $h\nu$ nicht expandieren kann, damit bewirkt, dass eine vollkommen entgaste flüssige Probe (wie oben bezeichnet) in einer Reaktionskammer derart gehalten wird, dass dieselbe weder bei Gefrieren oder Energieaufnahme ($h\nu$) eine räumliche Ausdehnung erfahren kann, weil ein hydraulischer Druck dem Expansionsbestreben der Probe proportional entgegenwirkt.

NB

Beweis kann geführt werden!

Figure C.98: In 1973, an inventor listed as Jonas Engelke filed a detailed patent application (later issued as German patent DE2308071) on a method of inducing nuclear fusion reactions using converging high-power laser beams. Was the inventor the same person as the mysterious Engelke/Ehrhardt from a decade earlier?



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Titel

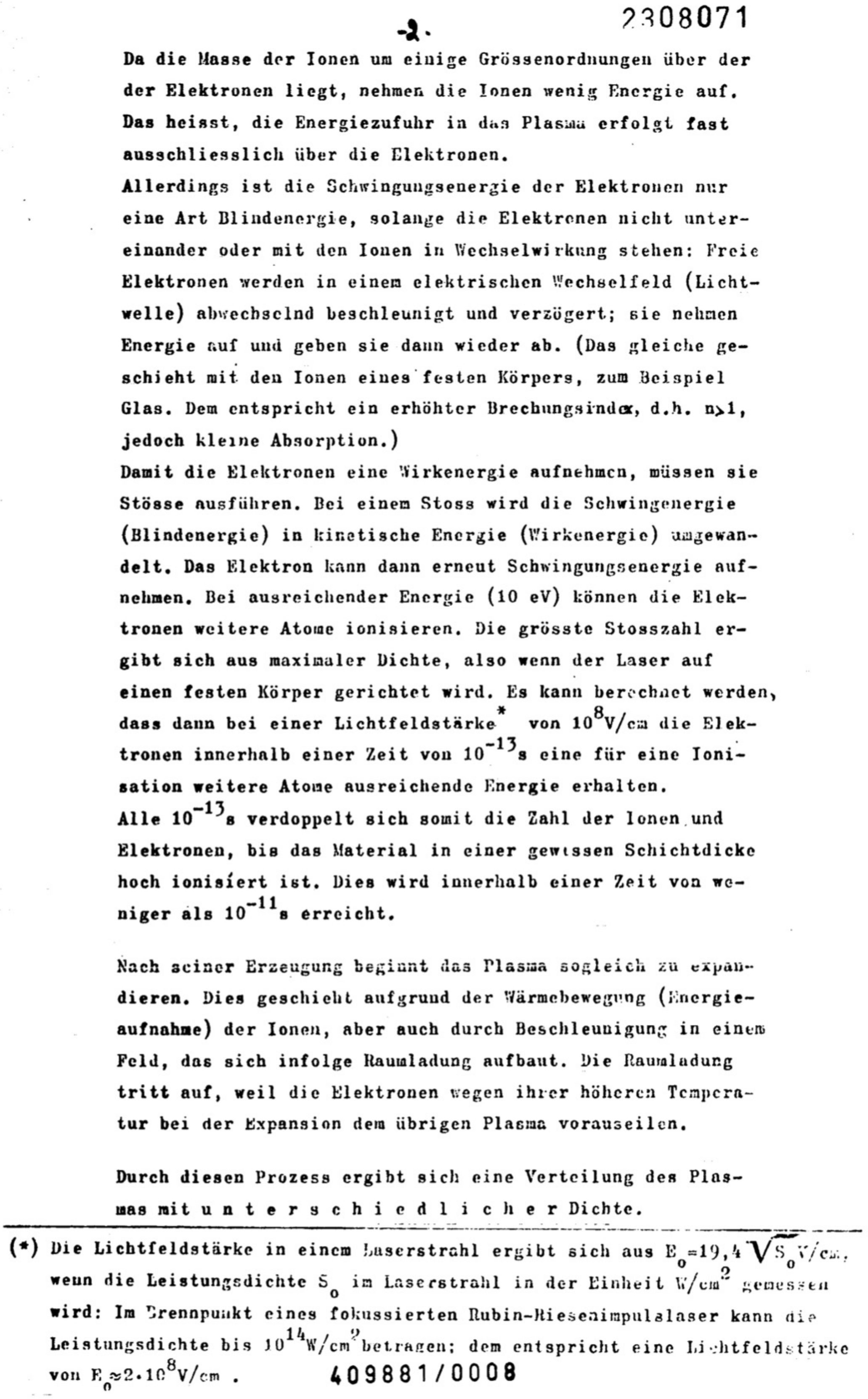
REINE KERNFUSION

Die Erfindung betrifft ein Verfahren mit Vorrichtung zur Erzeugung reiner Kernverschmelzung, die erreicht wird, wenn eine kritische Masse zum Beispiel $^{2}_{1}H+^{3}_{1}H$ bei Energieaufnahme durch $h\nu$ nicht expandieren kann.

Bestrebungen mit dem Ziel, eine reine Kernfusion einzuleiten, sind aus den Bereichen der Plasma-Physik bekannt geworden. Diesen bislang stets negativ verlaufenen Bemühungen zu begegnen, ist die Aufgabe, die mit dieser Erfindung gelöst wurde und ihr zugrunde liegt.

Zur Erzeugung heisser Plasmen und zu den Fehlern im Experiment bei Voruntersuchungen, reine Kernfusionen mittels Lichtquantenenergie $h\nu$ einzuleiten, muss Bekanntes vorausgeschickt werden und zwar, dass mit einem Laser jedes Material verdampft werden kann.
Bei hoher Leistungsdichte wird das verdampfte Material gleichzeitig ionisiert – es entsteht ein Plasma. Auch dieses kann noch aus dem Laserstrahl Energie aufnehmen und sich aufheizen. Dabei hängt die Absorption von den Plasmaparametern ab. Diese Verhältnisse können wie folgt dargelegt werden:
Geladene Teilchen (Ionen oder Elektronen) führen in einem elektrischen Feld Oszillationen aus; die mittlere Schwingungsenergie ist dabei umgekehrt proportional zur Masse.

Figure C.99: In 1973, an inventor listed as Jonas Engelke filed a detailed patent application (later issued as German patent DE2308071) on a method of inducing nuclear fusion reactions using converging high-power laser beams. Was the inventor the same person as the mysterious Engelke/Ehrhardt from a decade earlier?



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Da die Masse der Ionen um einige Grössenordnungen über der der Elektronen liegt, nehmen die Ionen wenig Energie auf. Das heisst, die Energiezufuhr in das Plasma erfolgt fast ausschliesslich über die Elektronen.

Allerdings ist die Schwingungsenergie der Elektronen nur eine Art Blindenergie, solange die Elektronen nicht untereinander oder mit den Ionen in Wechselwirkung stehen: Freie Elektronen werden in einem elektrischen Wechselfeld (Lichtwelle) abwechselnd beschleunigt und verzögert; sie nehmen Energie auf und geben sie dann wieder ab. (Das gleiche geschieht mit den Ionen eines festen Körpers, zum Beispiel Glas. Dem entspricht ein erhöhter Brechungsindex, d.h. $n>1$, jedoch kleine Absorption.)

Damit die Elektronen eine Wirkenergie aufnehmen, müssen sie Stösse ausführen. Bei einem Stoss wird die Schwingenergie (Blindenergie) in kinetische Energie (Wirkenergie) umgewandelt. Das Elektron kann dann erneut Schwingungsenergie aufnehmen. Bei ausreichender Energie (10 eV) können die Elektronen weitere Atome ionisieren. Die grösste Stosszahl ergibt sich aus maximaler Dichte, also wenn der Laser auf einen festen Körper gerichtet wird. Es kann berechnet werden, dass dann bei einer Lichtfeldstärke* von 10^8V/cm die Elektronen innerhalb einer Zeit von 10^{-13}s eine für eine Ionisation weitere Atome ausreichende Energie erhalten.

Alle 10^{-13}s verdoppelt sich somit die Zahl der Ionen und Elektronen, bis das Material in einer gewissen Schichtdicke hoch ionisiert ist. Dies wird innerhalb einer Zeit von weniger als 10^{-11}s erreicht.

Nach seiner Erzeugung beginnt das Plasma sogleich zu expandieren. Dies geschieht aufgrund der Wärmebewegung (Energieaufnahme) der Ionen, aber auch durch Beschleunigung in einem Feld, das sich infolge Raumladung aufbaut. Die Raumladung tritt auf, weil die Elektronen wegen ihrer höheren Temperatur bei der Expansion dem übrigen Plasma vorauseilen.

Durch diesen Prozess ergibt sich eine Verteilung des Plasmas mit unterschiedlicher Dichte.

(*) Die Lichtfeldstärke in einem Laserstrahl ergibt sich aus $E_0=19,4\sqrt{S_0}$ V/cm, wenn die Leistungsdichte S_0 im Laserstrahl in der Einheit W/cm^2 gemessen wird: Im Brennpunkt eines fokussierten Rubin-Riesenimpulslaser kann die Leistungsdichte bis 10^{14}W/cm^2 betragen; dem entspricht eine Lichtfeldstärke von $E_0\approx2\cdot10^8$V/cm .

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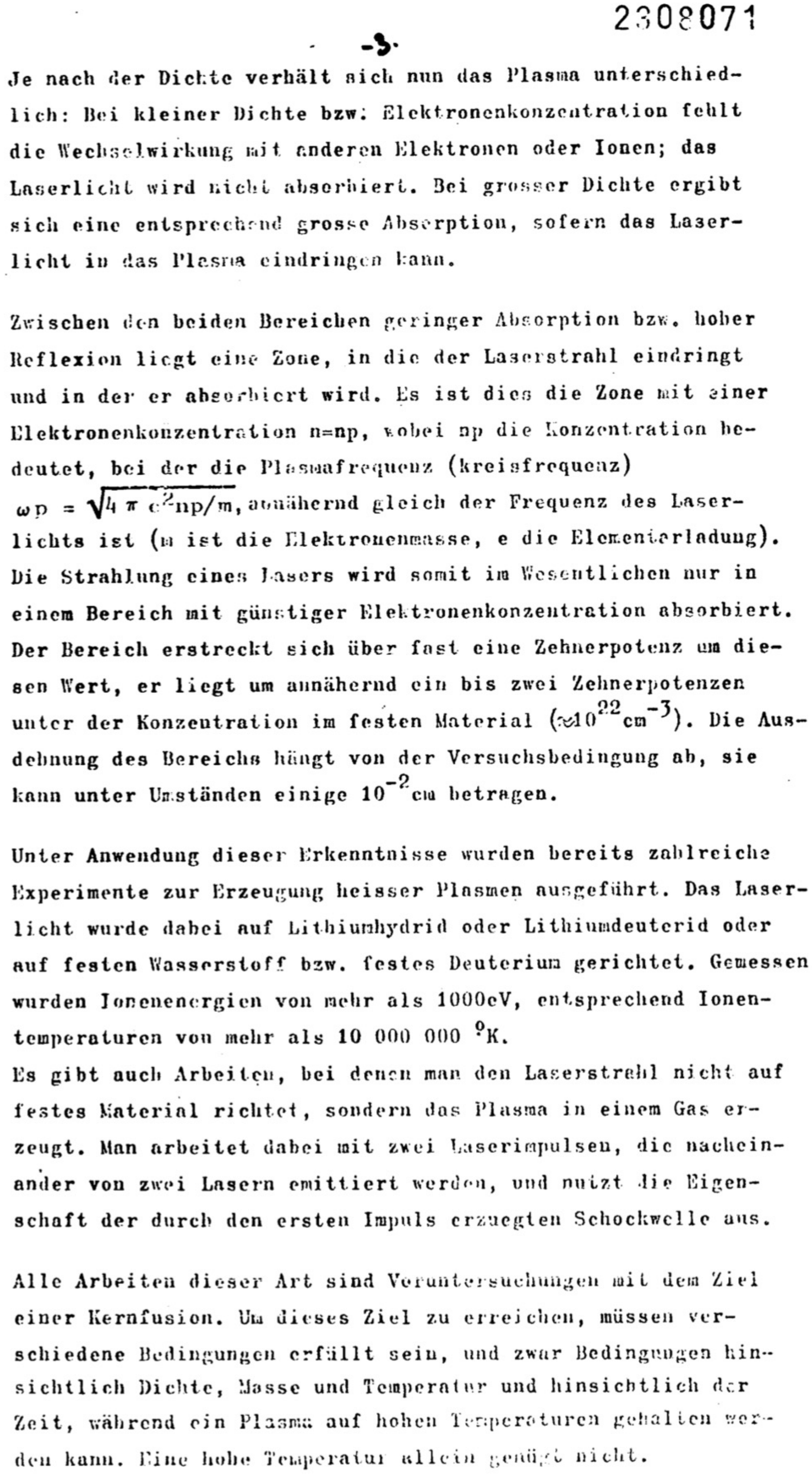
Figure C.100: In 1973, an inventor listed as Jonas Engelke filed a detailed patent application (later issued as German patent DE2308071) on a method of inducing nuclear fusion reactions using converging high-power laser beams. Was the inventor the same person as the mysterious Engelke/Ehrhardt from a decade earlier?



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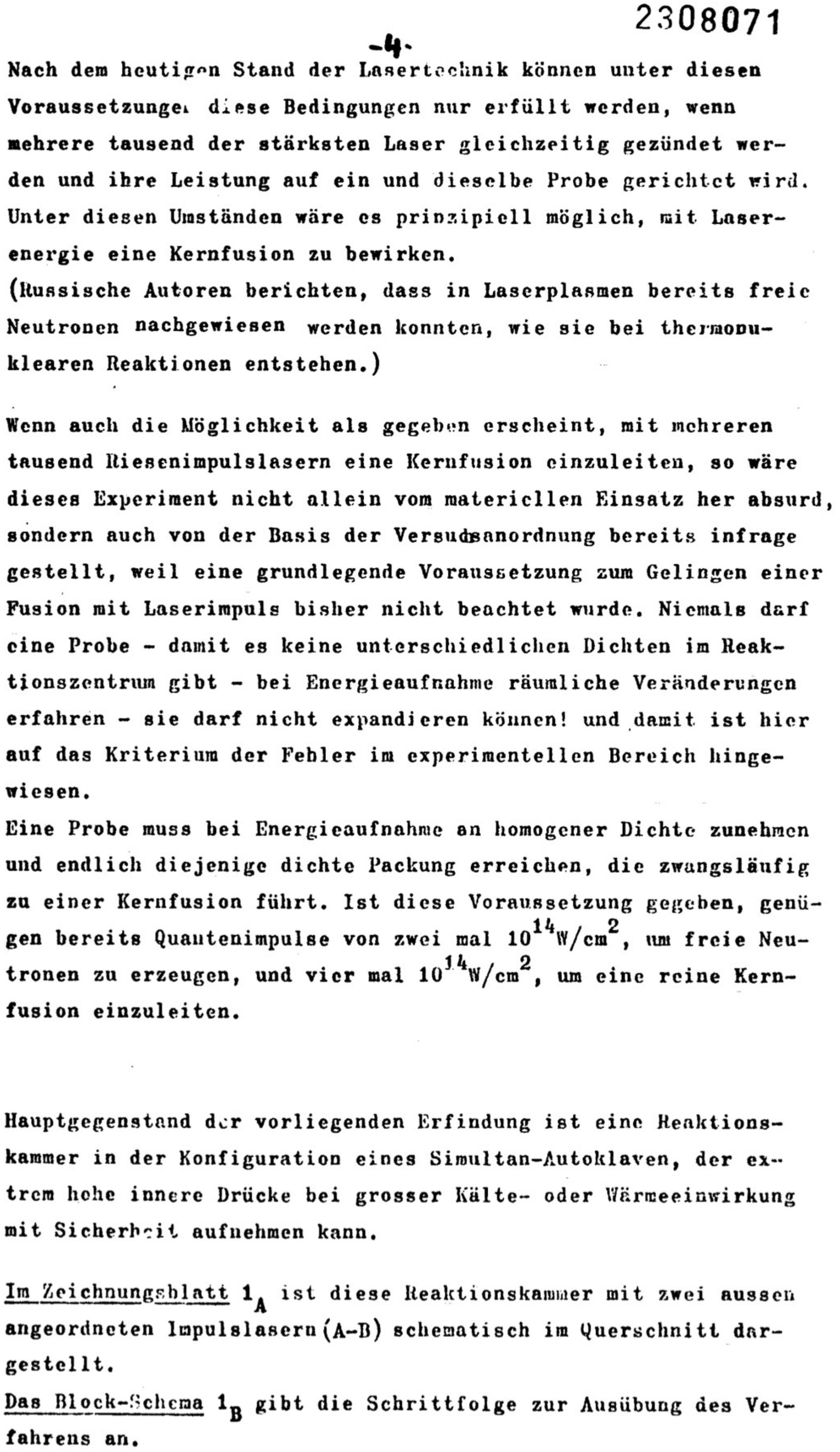
Je nach der Dichte verhält sich nun das Plasma unterschiedlich: Bei kleiner Dichte bzw. Elektronenkonzentration fehlt die Wechselwirkung mit anderen Elektronen oder Ionen; das Laserlicht wird nicht absorbiert. Bei grosser Dichte ergibt sich eine entsprechend grosse Absorption, sofern das Laserlicht in das Plasma eindringen kann.

Zwischen den beiden Bereichen geringer Absorption bzw. hoher Reflexion liegt eine Zone, in die der Laserstrahl eindringt und in der er absorbiert wird. Es ist dies die Zone mit einer Elektronenkonzentration n=np, wobei np die Konzentration bedeutet, bei der die Plasmafrequenz (kreisfrequenz) $\omega p = \sqrt{4 \pi e^2 np/m}$, annähernd gleich der Frequenz des Laserlichts ist (m ist die Elektronenmasse, e die Elementarladung). Die Strahlung eines Lasers wird somit im Wesentlichen nur in einem Bereich mit günstiger Elektronenkonzentration absorbiert. Der Bereich erstreckt sich über fast eine Zehnerpotenz um diesen Wert, er liegt um annähernd ein bis zwei Zehnerpotenzen unter der Konzentration im festen Material ($\approx 10^{22}$ cm^{-3}). Die Ausdehnung des Bereichs hängt von der Versuchsbedingung ab, sie kann unter Umständen einige 10^{-2} cm betragen.

Unter Anwendung dieser Erkenntnisse wurden bereits zahlreiche Experimente zur Erzeugung heisser Plasmen ausgeführt. Das Laserlicht wurde dabei auf Lithiumhydrid oder Lithiumdeuterid oder auf festen Wasserstoff bzw. festes Deuterium gerichtet. Gemessen wurden Ionenenergien von mehr als 1000eV, entsprechend Ionentemperaturen von mehr als 10 000 000 °K.
Es gibt auch Arbeiten, bei denen man den Laserstrahl nicht auf festes Material richtet, sondern das Plasma in einem Gas erzeugt. Man arbeitet dabei mit zwei Laserimpulsen, die nacheinander von zwei Lasern emittiert werden, und nutzt die Eigenschaft der durch den ersten Impuls erzeugten Schockwelle aus.

Alle Arbeiten dieser Art sind Voruntersuchungen mit dem Ziel einer Kernfusion. Um dieses Ziel zu erreichen, müssen verschiedene Bedingungen erfüllt sein, und zwar Bedingungen hinsichtlich Dichte, Masse und Temperatur und hinsichtlich der Zeit, während ein Plasma auf hohen Temperaturen gehalten werden kann. Eine hohe Temperatur allein genügt nicht.

Figure C.101: In 1973, an inventor listed as Jonas Engelke filed a detailed patent application (later issued as German patent DE2308071) on a method of inducing nuclear fusion reactions using converging high-power laser beams. Was the inventor the same person as the mysterious Engelke/Ehrhardt from a decade earlier?



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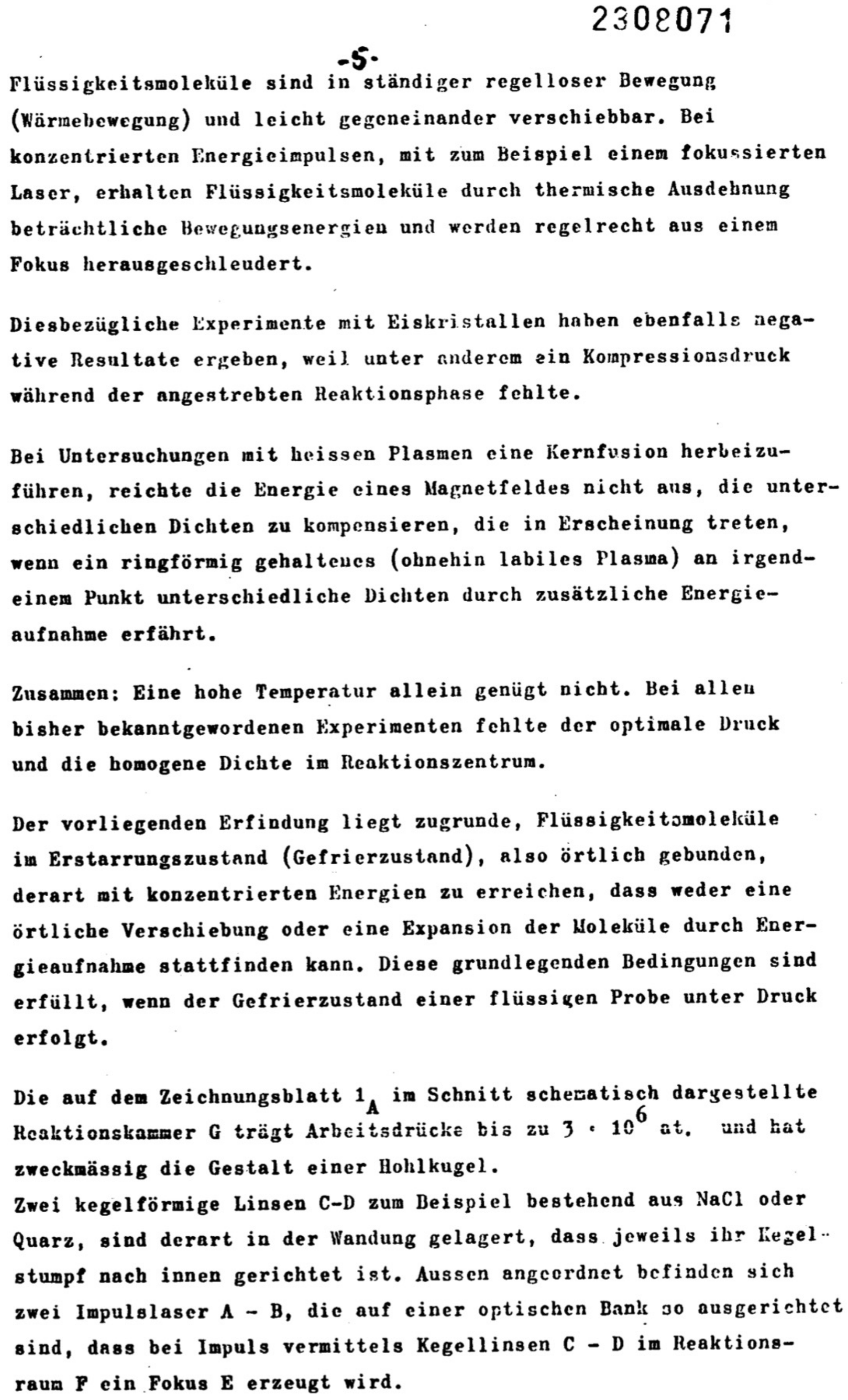
Nach dem heutigen Stand der Lasertechnik können unter diesen Voraussetzungen diese Bedingungen nur erfüllt werden, wenn mehrere tausend der stärksten Laser gleichzeitig gezündet werden und ihre Leistung auf ein und dieselbe Probe gerichtet wird. Unter diesen Umständen wäre es prinzipiell möglich, mit Laserenergie eine Kernfusion zu bewirken.
(Russische Autoren berichten, dass in Laserplasmen bereits freie Neutronen nachgewiesen werden konnten, wie sie bei thermonuklearen Reaktionen entstehen.)

Wenn auch die Möglichkeit als gegeben erscheint, mit mehreren tausend Riesenimpulslasern eine Kernfusion einzuleiten, so wäre dieses Experiment nicht allein vom materiellen Einsatz her absurd, sondern auch von der Basis der Versuchsanordnung bereits infrage gestellt, weil eine grundlegende Voraussetzung zum Gelingen einer Fusion mit Laserimpuls bisher nicht beachtet wurde. Niemals darf eine Probe - damit es keine unterschiedlichen Dichten im Reaktionszentrum gibt - bei Energieaufnahme räumliche Veränderungen erfahren - sie darf nicht expandieren können! und damit ist hier auf das Kriterium der Fehler im experimentellen Bereich hingewiesen.
Eine Probe muss bei Energieaufnahme an homogener Dichte zunehmen und endlich diejenige dichte Packung erreichen, die zwangsläufig zu einer Kernfusion führt. Ist diese Voraussetzung gegeben, genügen bereits Quantenimpulse von zwei mal 10^{14}W/cm^2, um freie Neutronen zu erzeugen, und vier mal 10^{14}W/cm^2, um eine reine Kernfusion einzuleiten.

Hauptgegenstand der vorliegenden Erfindung ist eine Reaktionskammer in der Konfiguration eines Simultan-Autoklaven, der extrem hohe innere Drücke bei grosser Kälte- oder Wärmeeinwirkung mit Sicherheit aufnehmen kann.

Im Zeichnungsblatt 1_A ist diese Reaktionskammer mit zwei aussen angeordneten Impulslasern (A-B) schematisch im Querschnitt dargestellt.
Das Block-Schema 1_B gibt die Schrittfolge zur Ausübung des Verfahrens an.

Figure C.102: In 1973, an inventor listed as Jonas Engelke filed a detailed patent application (later issued as German patent DE2308071) on a method of inducing nuclear fusion reactions using converging high-power laser beams. Was the inventor the same person as the mysterious Engelke/Ehrhardt from a decade earlier?



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Flüssigkeitsmoleküle sind in ständiger regelloser Bewegung (Wärmebewegung) und leicht gegeneinander verschiebbar. Bei konzentrierten Energieimpulsen, mit zum Beispiel einem fokussierten Laser, erhalten Flüssigkeitsmoleküle durch thermische Ausdehnung beträchtliche Bewegungsenergien und werden regelrecht aus einem Fokus herausgeschleudert.

Diesbezügliche Experimente mit Eiskristallen haben ebenfalls negative Resultate ergeben, weil unter anderem ein Kompressionsdruck während der angestrebten Reaktionsphase fehlte.

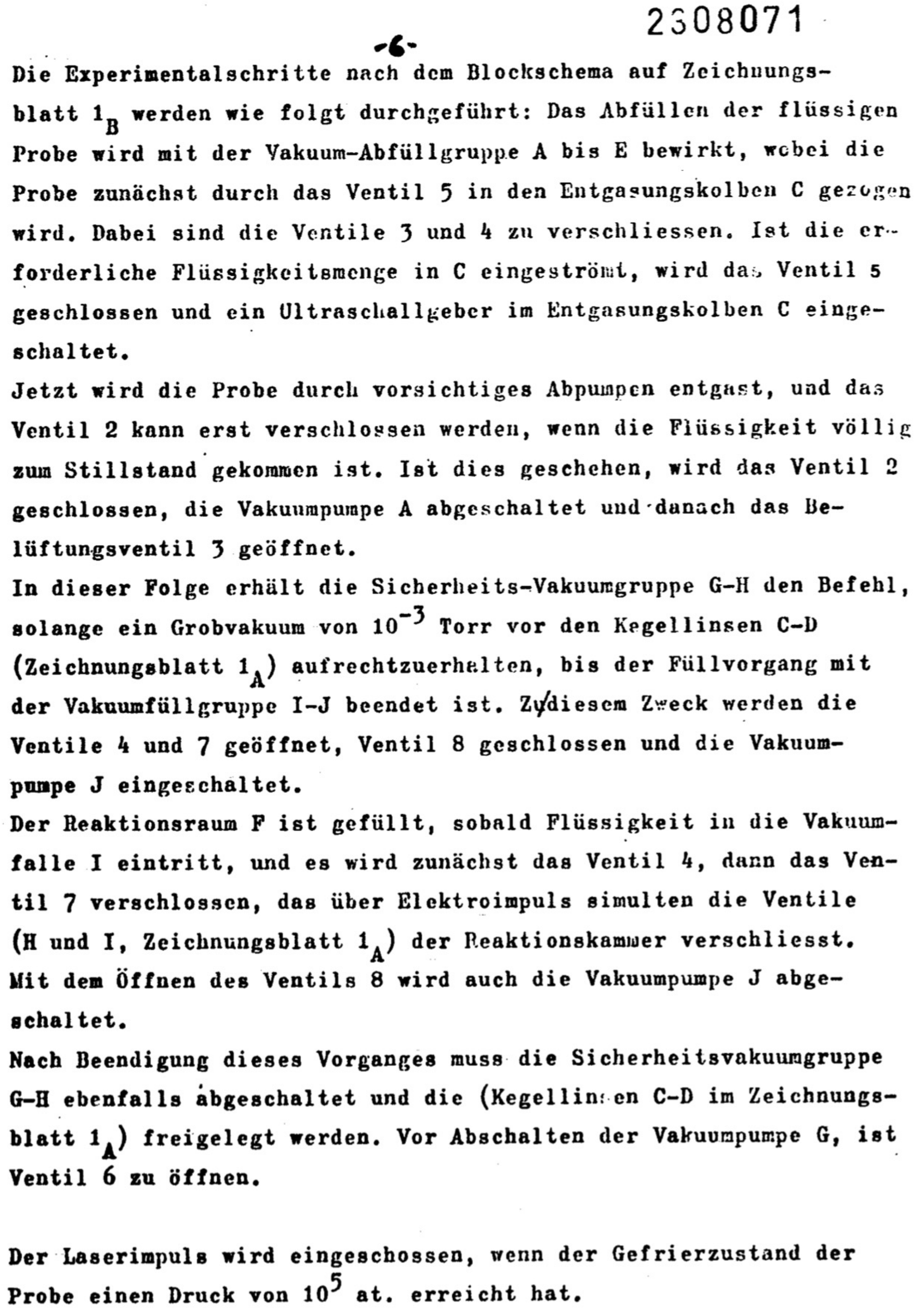
Bei Untersuchungen mit heissen Plasmen eine Kernfusion herbeizuführen, reichte die Energie eines Magnetfeldes nicht aus, die unterschiedlichen Dichten zu kompensieren, die in Erscheinung treten, wenn ein ringförmig gehaltenes (ohnehin labiles Plasma) an irgendeinem Punkt unterschiedliche Dichten durch zusätzliche Energieaufnahme erfährt.

Zusammen: Eine hohe Temperatur allein genügt nicht. Bei allen bisher bekanntgewordenen Experimenten fehlte der optimale Druck und die homogene Dichte im Reaktionszentrum.

Der vorliegenden Erfindung liegt zugrunde, Flüssigkeitsmoleküle im Erstarrungszustand (Gefrierzustand), also örtlich gebunden, derart mit konzentrierten Energien zu erreichen, dass weder eine örtliche Verschiebung oder eine Expansion der Moleküle durch Energieaufnahme stattfinden kann. Diese grundlegenden Bedingungen sind erfüllt, wenn der Gefrierzustand einer flüssigen Probe unter Druck erfolgt.

Die auf dem Zeichnungsblatt 1_A im Schnitt schematisch dargestellte Reaktionskammer G trägt Arbeitsdrücke bis zu $3 \cdot 10^6$ at. und hat zweckmässig die Gestalt einer Hohlkugel.
Zwei kegelförmige Linsen C-D zum Beispiel bestehend aus NaCl oder Quarz, sind derart in der Wandung gelagert, dass jeweils ihr Kegelstumpf nach innen gerichtet ist. Aussen angeordnet befinden sich zwei Impulslaser A - B, die auf einer optischen Bank so ausgerichtet sind, dass bei Impuls vermittels Kegellinsen C - D im Reaktionsraum F ein Fokus E erzeugt wird.

Figure C.103: In 1973, an inventor listed as Jonas Engelke filed a detailed patent application (later issued as German patent DE2308071) on a method of inducing nuclear fusion reactions using converging high-power laser beams. Was the inventor the same person as the mysterious Engelke/Ehrhardt from a decade earlier?



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Die Experimentalschritte nach dem Blockschema auf Zeichnungsblatt 1_B werden wie folgt durchgeführt: Das Abfüllen der flüssigen Probe wird mit der Vakuum-Abfüllgruppe A bis E bewirkt, wobei die Probe zunächst durch das Ventil 5 in den Entgasungskolben C gezogen wird. Dabei sind die Ventile 3 und 4 zu verschliessen. Ist die erforderliche Flüssigkeitsmenge in C eingeströmt, wird das Ventil 5 geschlossen und ein Ultraschallgeber im Entgasungskolben C eingeschaltet.

Jetzt wird die Probe durch vorsichtiges Abpumpen entgast, und das Ventil 2 kann erst verschlossen werden, wenn die Flüssigkeit völlig zum Stillstand gekommen ist. Ist dies geschehen, wird das Ventil 2 geschlossen, die Vakuumpumpe A abgeschaltet und danach das Belüftungsventil 3 geöffnet.

In dieser Folge erhält die Sicherheits-Vakuumgruppe G-H den Befehl, solange ein Grobvakuum von 10^{-3} Torr vor den Kegellinsen C-D (Zeichnungsblatt 1_A) aufrechtzuerhalten, bis der Füllvorgang mit der Vakuumfüllgruppe I-J beendet ist. Zu diesem Zweck werden die Ventile 4 und 7 geöffnet, Ventil 8 geschlossen und die Vakuumpumpe J eingeschaltet.

Der Reaktionsraum F ist gefüllt, sobald Flüssigkeit in die Vakuumfalle I eintritt, und es wird zunächst das Ventil 4, dann das Ventil 7 verschlossen, das über Elektroimpuls simulten die Ventile (H und I, Zeichnungsblatt 1_A) der Reaktionskammer verschliesst.

Mit dem Öffnen des Ventils 8 wird auch die Vakuumpumpe J abgeschaltet.

Nach Beendigung dieses Vorganges muss die Sicherheitsvakuumgruppe G-H ebenfalls abgeschaltet und die (Kegellinsen C-D im Zeichnungsblatt 1_A) freigelegt werden. Vor Abschalten der Vakuumpumpe G, ist Ventil 6 zu öffnen.

Der Laserimpuls wird eingeschossen, wenn der Gefrierzustand der Probe einen Druck von 10^5 at. erreicht hat.

Figure C.104: In 1973, an inventor listed as Jonas Engelke filed a detailed patent application (later issued as German patent DE2308071) on a method of inducing nuclear fusion reactions using converging high-power laser beams. Was the inventor the same person as the mysterious Engelke/Ehrhardt from a decade earlier?

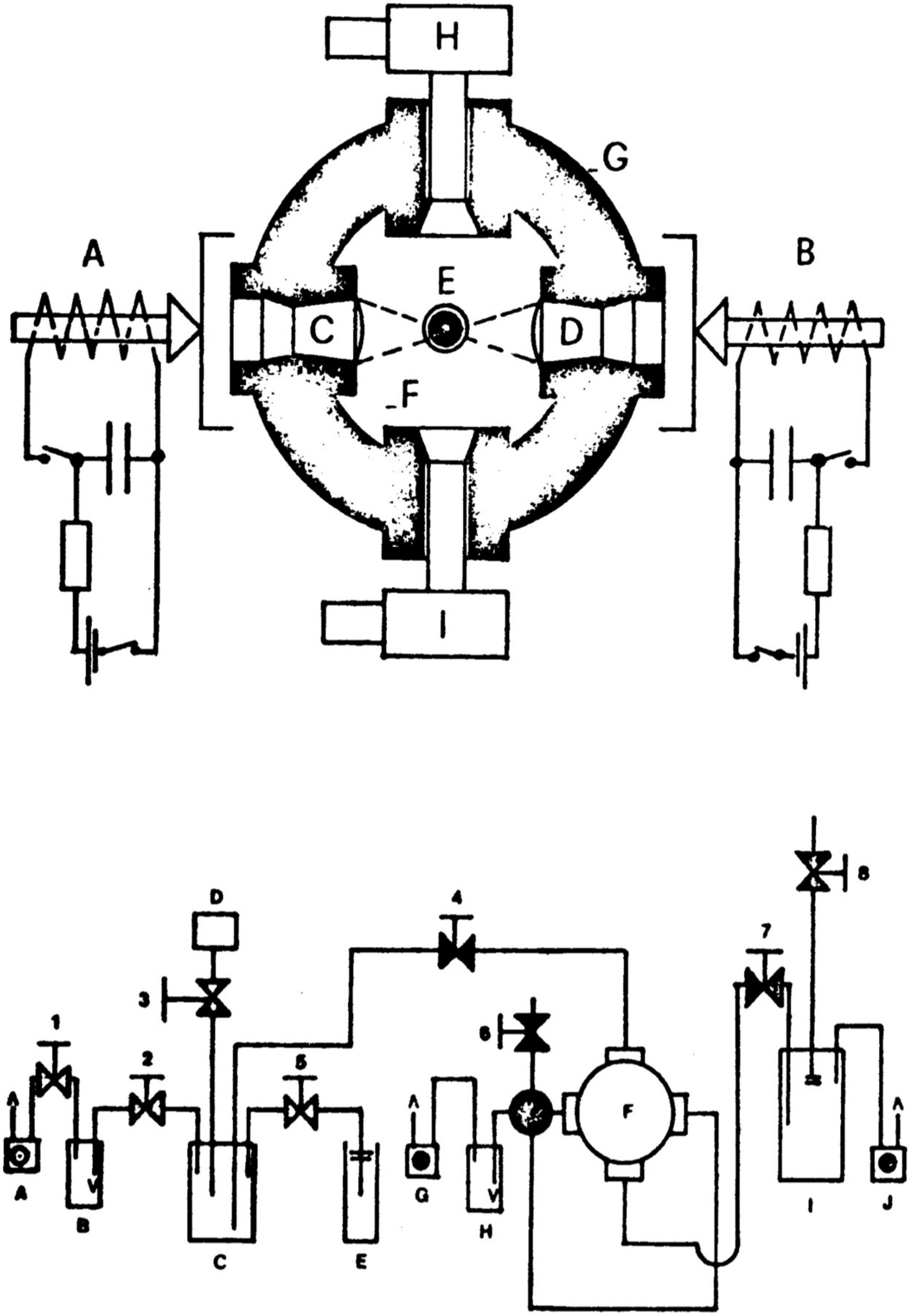


Figure C.105: In 1973, an inventor listed as Jonas Engelke filed a detailed patent application (later issued as German patent DE2308071) on a method of inducing nuclear fusion reactions using converging high-power laser beams. Was the inventor the same person as the mysterious Engelke/Ehrhardt from a decade earlier?

[There are many mysteries regarding Hans Ehrhardt/Engelke and his laser-like experiments:

- “Ehrhardt” was clearly not the person’s real name, and “Engelke” likely was not either. If his real last name was something else, it may have begun with an E. At least one of his names was an alias and he could have chosen anything, yet he chose to use the same initial letter for some reason. (E is a somewhat less common first letter for German last names.)

- Hans Ehrhardt/Engelke was building and testing optics equipment for novel high-luminosity light sources. Did he have a formal university education and/or previous job experience in optics, perhaps under some other name?

- Swiss accounts said that Hans Ehrhardt/Engelke claimed to have been born in 1918, which would have made him 43–45 years old in 1961–1963. The 1961–1963 photos of Hans Ehrhardt/Engelke look like a man who was perhaps a decade older than that. While it is possible that Hans Ehrhardt/Engelke simply looked older than his true age due to the hard life he had led, there is the very real possibility that he was born earlier than he claimed. His true age would have large implications for what his real identity might have been, and what his true educational and work background might have been.

- Hans Ehrhardt/Engelke had a wife and four children in 1961–1963. Can more information about him be traced from his family’s history either before or after that time period?

- Hans Ehrhardt/Engelke claimed that he helped to develop fuel-air explosives during the war. One of the main groups conducting such work was a large Luftwaffe-funded team led by Mario Zippermayr (see p. 541). Had Hans Ehrhardt/Engelke been a member of Mario Zippermayr’s group (or perhaps some other fuel-air explosive group) during the war?

- Hans Ehrhardt/Engelke had worked for the Russians but wanted to leave that behind. He likely would have applied to work for the United States. Do U.S. Foreign Scientist Case Files at NARA (or other files) contain information on Hans Ehrhardt/Engelke under those or any other names?

- Hans Ehrhardt/Engelke appeared to have been blacklisted, wandering from place to place, unable to find someone (other than the Russians) willing to provide him a home and a job. That would have been a good motivation not to use his real name and identity, and suggests that he was not using his real name and identity.

- What was the real name, age, and background of Hans Ehrhardt/Engelke?

- The laser-like research of Hans Ehrhardt/Engelke seemed to date back to the war, based on some of his mysterious statements. If so, was Ehrhardt/Engelke’s research also related to the wartime work of Wilhem von Meyeren or others?

- How widespread, and how advanced, was work on laser-like technologies in the Third Reich?

- What influence did German-derived laser-like technologies have on the development of lasers in the United States, Russia, and other countries in the 1950s–1960s?

- What additional relevant documents can be discovered in archives or family collections around the world?]

William B. Bridges. Laser Oscillation in Singly Ionized Argon in the Visible Spectrum. *Applied Physics Letters* 4:7:128 (1964)

Ten new laser wavelengths in the green and blue portions of the visible spectrum have been observed in a pulsed argon discharge. The responsible transitions occur in the singly ionized state of the Ar atom (A^{II} spectrum). Measured wavelengths, tentative level assignments, and a few estimates of [...]

[Officially, the first laser was not built until 1960 (by Ted Maiman), and the argon gas laser was not invented until 1964 (by William Bridges), both at Hughes Aircraft in the United States.]

[For examples of German-speaking scientists who pioneered the development of semiconductor lasers, or laser diodes, see pp. 2911–2922.]

C.4 Focused Sound Waves

[German-speaking scientists took the lead in harnessing focused sound waves for a wide variety of applications, ranging from the first ultrasound imaging devices to the first directed acoustic weapons. The following documents demonstrate that those technologies were developed and successfully demonstrated in Germany and Austria during the war, and then directly transferred to other countries in 1945, leading to modern acoustic and ultrasound devices.]

BIOS 1504. *Industrial Applications of Ultrasonics.* pp. 3–11 [Reports on two laboratories developing ultrasonic generators and applications of them.]

I. PRODUCTION OF ULTRASONICS.

(a) General.

In the last ten years possible industrial applications for ultrasonics became apparent, and Siemens-Schuckert (S.S.) started research work on the production of intense sources of ultrasonics just prior to the war. [...]

Most of the development work was carried out with magneto strictive and piezo-electric generators, but some work was also done with an acoustic mechanical method based on the Galton whistle. The magneto strictive generators were usually worked at frequencies between 10 and 25 k.c., the piezo-electric generators at 300–400 k.c. and the whistle at 15–20 k.c. Each of these methods had its own particular advantages, and the choice of the one to be employed depends on the particular application.

(b) Magneto strictive generators.

These depend upon the property of ferromagnetic metals to change their dimensions in the direction of an applied magnetic field. In practice an alternating current was superimposed on constant D.C. current, both of which magnetised a nickel rod which is set into oscillations of the same frequency as the A.C. current. Only if the frequency is equal to the natural mechanical frequency of the rod are large amplitude oscillations produced. The ultrasonics are radiated from the end surfaces of the rod into the surrounding medium. [...]

Fig. 1 shows the fundamental arrangement for treating liquids. The nickel rod (1) is let in through the bottom of the glass container (2) and is partly immersed in the liquid (4) which can be circulated through tubes (6) and (7). The tube is held by a rubber gasket (3) which should be at a node of the rod so as not to damp the oscillations. The external section of the rod is surrounded by a coil (5) through which both the A.C. and D.C. is passed. Sometimes two coils are employed; one to carry the A.C. and the other the D.C. [...]

The oscillator is tuned before use to the natural frequency of (1) with L_2. The nickel rod is usually 11 cms. long corresponding to 23 k.c. or sometimes 20 cms. corresponding to 12.75 k.c. An experimental oscillator was said to give 300 watts of ultrasonics with a current consumption of 800 watts.

The major advantage of the magneto strictive oscillator is its simplicity and ruggedness, and its major disadvantage the low frequencies at which it has to operate since it depends on the natural frequency of the rod. Another disadvantage often encountered is the small area from which the ultrasonics radiate. These disadvantages are absent in a piezo-electric generator.

(c) Piezo-electric oscillators.

Quartz crystals were the only piezo-electric materials employed. A suitably cut quartz crystal oscillated with a frequency depending on the thickness and an amplitude depending on the applied voltage. [...]

S.S. always mounted their crystal in oil to prevent arcing, and a typical ceramic container [...] is shown in Fig. 5. [...]

Fig. 6 shows the generator in action. The materials to be irradiated are placed in thin-walled glass containers and suspended in the oil fountain[...]

The generator uses 2.7 k.w., dissipates 1.6 k.w. of high frequency and produces 400 w. of ultrasonics. [...]

(d) Mechanical generators.

It is very difficult to build large generators of the magneto strictive or piezo-electric type, and so for industrial applications many small units would have to be operated side to side. This is cumbersome and expensive and in order to obtain high power generators S.S. developed the ultrasonic whistle, which proved valuable for making emulsions.

The general design of all of these is based on a Galton whistle, but operated with a liquid instead of a gas.

Fig. 10 shows a simple type of Galton whistle, consisting of a tube (1) with a hole (2) having a sharp lip (5). The air stream passes through the narrow slit (6) impinging on the lip which oscillates. The air column (7) will oscillate in resonance if the plug (4) is suitably adjusted.

Exactly the same principle applies when liquid is substituted for a gas. However, S.S. preferred to use a slightly modified design shown in Fig. 11. Here the liquid is forced through a very narrow circular orifice (6) formed by the plug (10), held in position by vanes (11) and impinges on a circular lip (5). [...]

A performance result of a whistle of the last type was quoted. The whistle used had an overall length of 15–20 cms. and 50 litres of emulsion were prepared in a few seconds. The pressure at which the liquid was expelled through the whistle was thought to have been between 10 and 20 atmospheres. The distance between orifice and lip was approximately 1 cm. and the frequency produced about 15 k.c.

These were the only quantitative data which the S.S. personnel interviewed could remember.

II. APPLICATIONS OF ULTRASONICS.

(a) General.

[...] S.S. were not primarily interested in finding applications for ultrasonics. Their interest lay in developing methods of production, and they preferred to carry out joint researchers with prospective users. Occasionally they even made available equipment to firms who did not disclose what they intended to do with it. [...]

(c) Emulsification.

The most common use for ultrasonics is the formation of emulsions or dispersion in liquids. [...] From an experimental point of view, piezo-electric generators were convenient, since the material to be irradiated need only be placed in a beaker and held in the oil fountain. A number of generators of this type illustrated in Fig. 9 were sold for this purpose.

In Professor Hertz's laboratory magneto striction oscillators were developed, and Drs. Schöfer and Barwich studied the mechanism of emulsion formation. This was caused, not by the sound waves themselves, but by the cavitation effects produced in the liquid. The breaking up of the droplets occurred entirely in the zones of cavitation. This is not a new observation but appears to have been very thoroughly substantiated at S.S.

It is very advantageous to produce a course dispersion before breaking up to emulsion size. This was done by low frequency agitation (at 100 cycles per sec.) with the aid of an electro-magnetic feed with waves 50 cycle A.C. [...]

(d) Disinfection.

Ultrasonics were tried for the disinfection of water, milk and other liquids. Definite effects were observed but they were not striking and work was discontinued in favour of promising methods, but it was hoped to re-examine this question later. It was found that some non-pathogenic organisms, such as B[acillus]. coli, were destroyed most effectively, but the radiations had much less effect on cocci. [...]

(g) Soldering.

It is well known that the presence of an oxide layer on the surfaces of metals to be soldered prevents a firm joint from being formed. Normally the oxide layer is removed with a suitable flux. [...] S.S. discovered that if the molten solder when in contact with the metal is in ultrasonic vibrations then a good join is produced without the necessity for any flux. The vibrations break up the oxide layer and expose the metal to the solder in which the former remains dispersed without impairing the strength of the join. [...]

S.S. had intended in 1941 to use several hundred of these ultrasonic soldering irons in their valve factories, but urgent war requirements prevented more than a few from being built.

(h) Welding.

Ultrasonics were applied to electrical welding but proved of doubtful value. [...] If the two electrodes are set into vibration whilst the welding current is heating and melting the point at which the metals are to be joined, an improvement of the crystal structure of the weld is obtained. Yet in spite of a considerable decrease in the grain size the joint is not appreciably strengthened.

Vibrations of lower frequencies were examined and it was found that the lower the frequency the stronger the joint. A single blow during the welding produced the strongest joint. However, only high frequency oscillations produced the improved crystal structure at the weld.

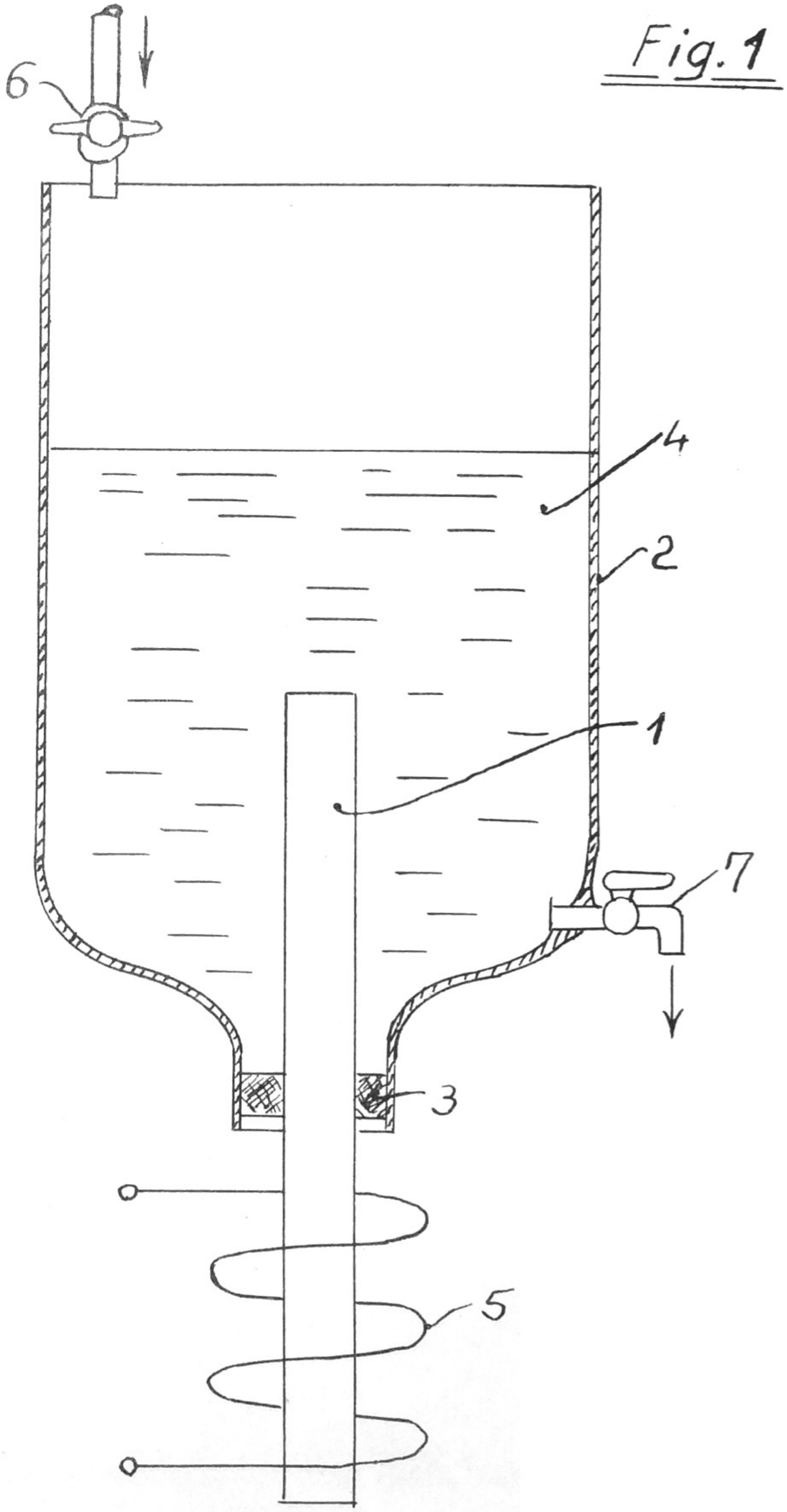


Fig. 1
6
4
2
1
7
3
5

Figure C.106: Ultrasonic sonicator [BIOS 1504].

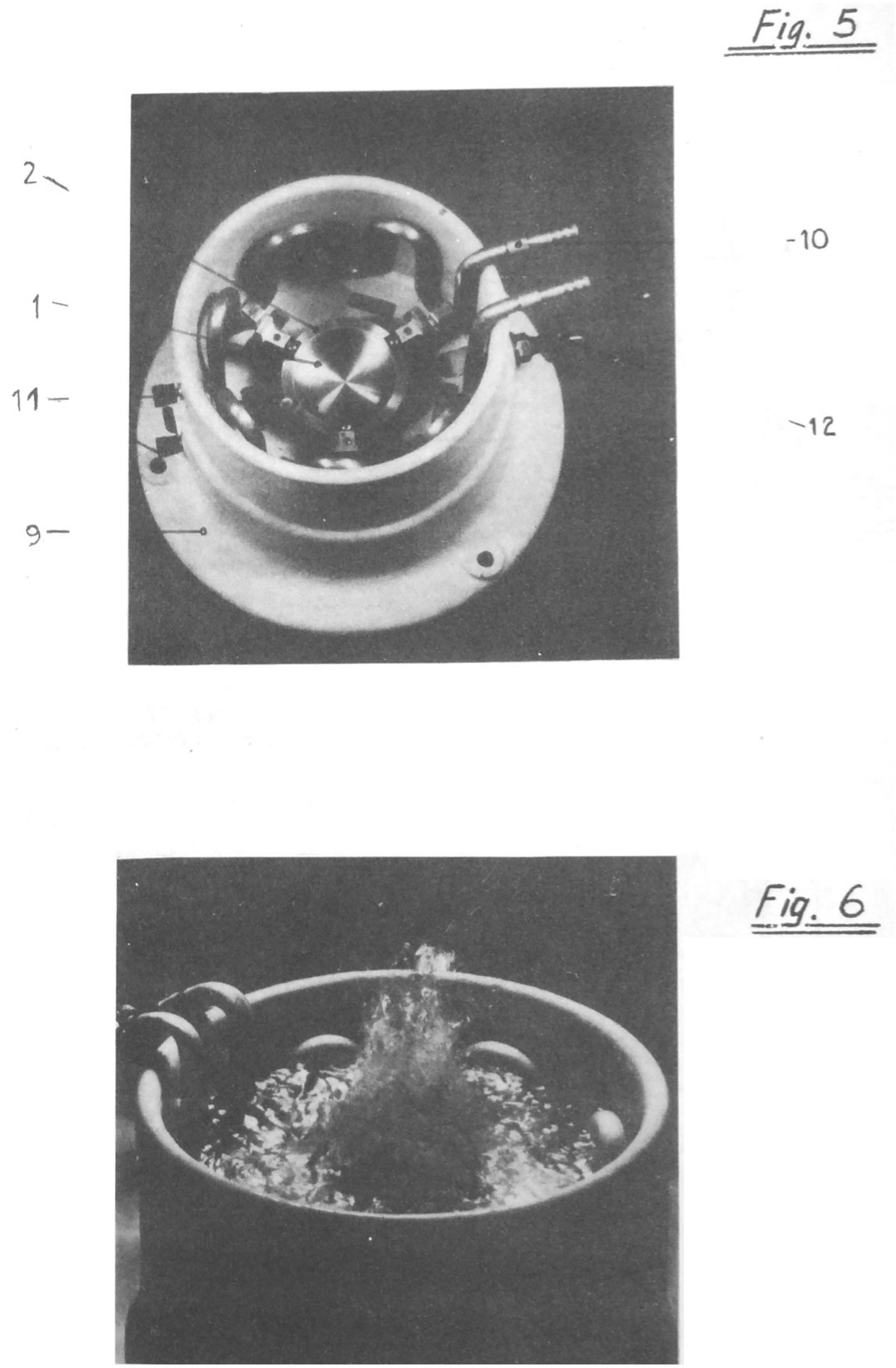


Fig. 5
2
1
11
9
10
12
Fig. 6

Figure C.107: Ultrasonic sonicator [BIOS 1504].

Fig. 8

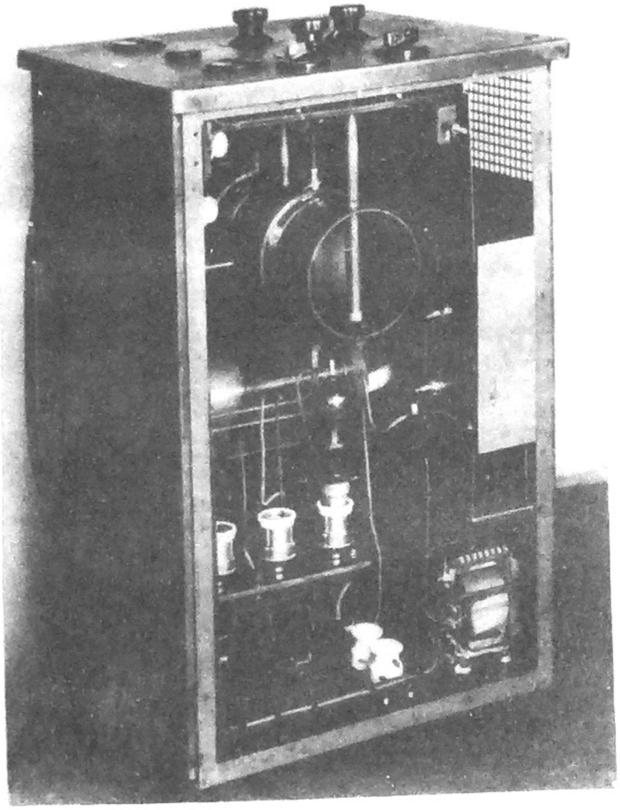


Fig. 9

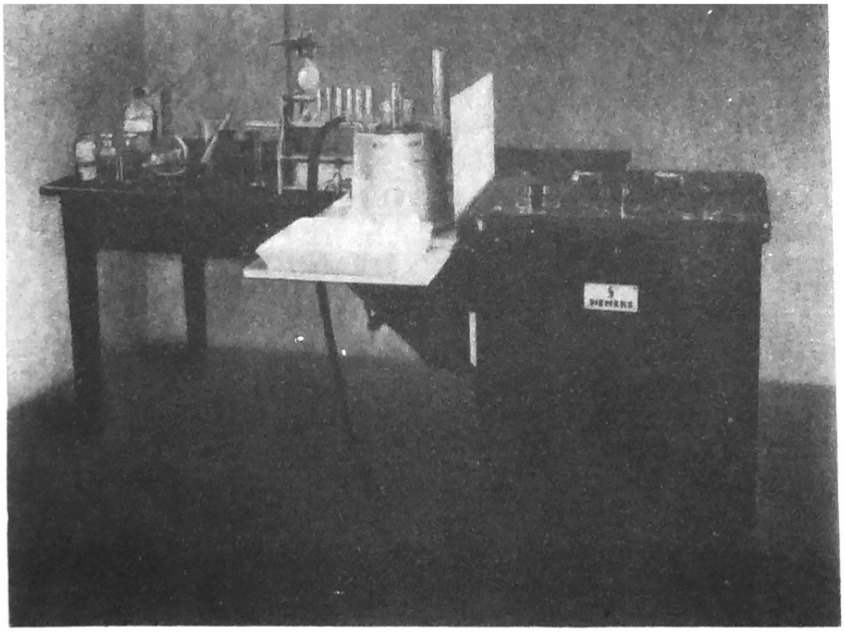


Figure C.108: Ultrasonic sonicators [BIOS 1504].

Fig. 10

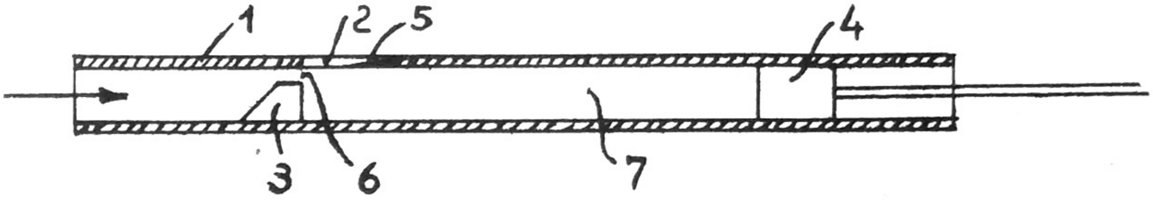


Fig. 11

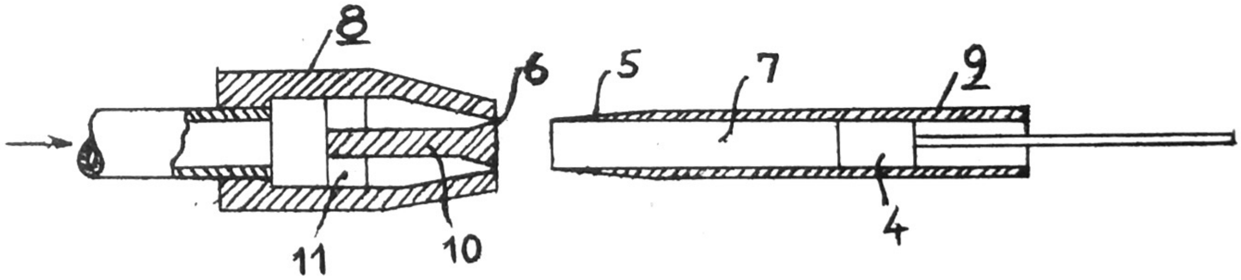

8
6
5
7
9
11
10
4

Figure C.109: Ultrasonic sonicators [BIOS 1504].

BIOS 1688. *Radiological Activities in Germany.* p. 11.

4. Ultra-sonic Methods of Testing

The R.R.S. was alive to the possibility of applying ultra-sonics but had only used the method for the detection of laminations. It appears that 4 sets had been constructed using transmitted sonic energy and they had all been destroyed by bombing. The output was 30 watts at a frequency of one megacycle.

BIOS 609. *Non-destructive Testing of Materials.* pp. 2–3.

[...] Details of the detector used were obtained partly from Professor Trendelburg but chiefly from Dr. Pohlman at Erlangen. [...]

A schematic diagram of one form of the apparatus used is shown in Fig. 1. (A photograph of this apparatus was seen.) The high frequency source is the usual quartz crystal, oscillating at a frequency of about 1.6 MHz. It is coupled to the "work" by mercury, oil or vaseline. The detecting and observing unit consists of a tubular housing, full of xylene, which contains the detector cell, a semi-transparent mirror and an ordinary optical lens. The housing is closed at one end by a sonic lens of aluminium and at the other end by a viewing screen. A lateral branch of the housing encloses a lamp for illumination of the cell.

The velocity of sound in aluminium is nearly four times its velocity in xylene and so a sonic beam passing from aluminium into xylene, by way of a surface, which is concave with respect to the aluminium, is converged. The pattern formed in the cell is thus a reduced image of the beam as it passes (and is modified by any flaws) through the work. To observe this pattern an image of the cell is projected optically on the viewing screen. The scheme is sufficiently indicated in Fig. 1.

Photographs were seen of a considerable number of cell patterns obtained on examining such subjects as steel containing hair cracks, laminated strip, spot welds, light alloy bars. The degree of detail shown was far higher than I expected.

Considerable use is made of sonic lenses. One example is shown in Fig. 1. Commonly they are constructed of two thin saucer shaped sheets of brass or aluminium fastened together in the form of a double convex lens, the vessel so formed being filled with some convenient liquid such as carbon tetrachloride. If this arrangement is immersed in xylene it acts as a converging lens (the velocity of sound in xylene is 1.45 times its velocity in carbon tetrachloride). Diverging lenses may be made on similar principles.

Obtaining efficient coupling between the oscillator and the work was made light of by Pohlman who said there was rarely any difficulty, though each case had to be considered on its merits. Considerable distances in liquid are often traversed by the sonic beam. Bromoform is a common coupling liquid used.

The arrangement used for the examination of small shell blanks is indicated in Fig. 2. [...] The cell pattern forms in 1 to 2 seconds. Inspection is carried out at the rate of 500 per hour. [...]

[See also BIOS 214 for a brief second-hand description of Pohlman's ultrasound imager. The following document, BIOS 1679, gives a detailed description by Pohlman himself.]

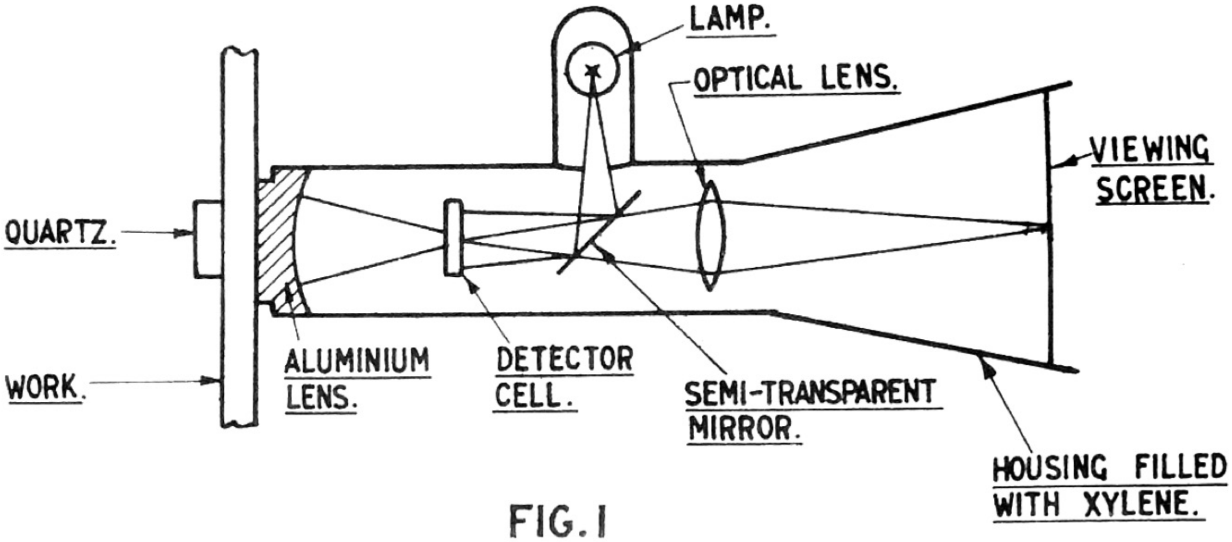

LAMP.
OPTICAL LENS.
VIEWING SCREEN.
QUARTZ.
WORK.
ALUMINIUM LENS.
DETECTOR CELL.
SEMI-TRANSPARENT MIRROR.
HOUSING FILLED WITH XYLENE.

FIG. I

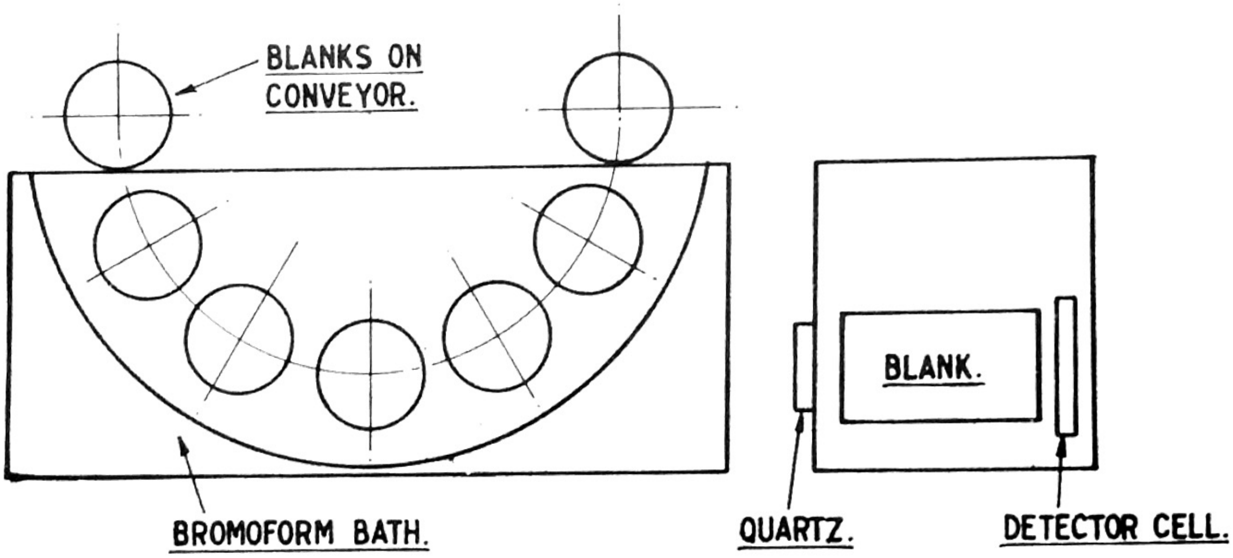

BLANKS ON CONVEYOR.
BLANK.
BROMOFORM BATH.
QUARTZ.
DETECTOR CELL.

FIG. 2.

Figure C.110: Ultrasound imaging device [BIOS 609].

BIOS 1679. ***Ultrasonic Material Testing and Other Applications.*** [Reports on 20 other laboratories developing ultrasonic generators and applications of them, including many scientific papers from those laboratories.]

[pp. 28–29:]

17. INTERROGATION OF DR. POHLMAN, SIEMENS REINIGER,
ERLANGEN, 11/4/46.

Material Testing by Ultrasonics.

Dr. Pohlman's method was stated to give an actual picture of the faults in steel plates, and the equipment was stated to give a discrimination down to 0.4 of a millimetre. [...]

One model of this equipment was used by the Deutsche Waffen und Munition Werke at Posen to check the blanks for 20 mm. cannon shells at the rate of 600/hr. The apparatus was also used to check spot welds, and a further apparatus was used by Junkers to check a main butt weld in aircraft. Attached hereto is an account of his method written by Dr. Pohlman.

Unfortunately we were not able to check the claims made by Dr. Pohlman either as stated in the above account or in his attached account. Dr. Pohlman claimed that all equipments had been taken by the Russians, but Lt Cmdr. Goudge later informed us than an equipment of this type had been evacuated by the Americans. [...]

Medical Uses of Ultrasonics.

Dr. Pohlman is at present employed in experiments with ultrasonic generators for therapeutical purposes. These operated at 800 Kc/s and a power of about 1 watt/sq. cm. The application time was usually about 10 minutes and they were used in attempts to relieve asthma, sinus troubles, and rheumatism with some success.

[pp. 31–32:]

18.
IS IT POSSIBLE TO PRODUCE THERAPEUTIC EFFECTS BY MEANS OF ULTRASONICS?
by
DR. REIMAR POHLMAN. BERLIN.

Research has been pursued in many directions to determine the action and the effect of ultrasonics on living organisms. The results have been found to be mostly destructive, but a large number of phenomena remain unexplained. Micro-organisms were disrupted, red blood corpuscles expanded, lost their colour, and finally broke down, fish and small animals were killed, and the virulence of pathogenic organisms was enhanced or diminished according to the nature of the organism and the conditions of the experiment.

The cause of these very diverse phenomena may be partly ascribed to the following processes. An ultrasonic wave induces very violent dispersion of two media in one another owing to its high acceleration factor (reaching 10^8 cm/sec.^{2}). High intensities rupture the liquid, and lead to cavitation and to a fairly strong de-aeration connected therewith. Several investigators have been able to show that this cavitation accounts for many of the biological effects of ultrasonics. Upon raising the pressure i.e., reducing cavitation, the effects do not take place.

It is noteworthy that the phenomena mentioned occur practically exclusively at high intensities, so that the idea could not altogether be rejected that other effects might take place at lower intensities and possibly prove to be of a therapeutic nature. That theory received support from the characteristic properties of ultrasonic waves. [...]

These facts left the possibility open that it might be possible to produce therapeutic effects by means of ultrasonic radiation. Practical trials to discover and study these effects could only be carried out on individuals. A large number of preliminary trials had, of course, to be carried out and the limit of energy at which deleterious effects take place had to be determined in order to prevent injury under all circumstances. It was further necessary to ascertain whether latent or secondary lesions might not appear as sequelae of a larger number of normal exposures to the rays. And thirdly. the question arose as to whether more than a negligible percentage of the rays would reach the depth intended. Careful measurements showed that absorption of ultrasonics in human tissues is comparatively slight, but that it practically corresponds to that of a highly absorbent homogeneous liquid. As might be expected, absorption and hence the depth effect of ultrasonic radiation depends on the wave length; and it was found that radiation at a frequency of 800 kc/sec. drops by one half at a depth of 5 cm.

[pp. 35–38:]

19. MATERIAL TESTING BY ULTRASOUND IMAGE METHOD.
BY R. POHLMAN. ERLANGEN, 14/3/46.

[...] In this method the ultrasound radiated from a quartz crystal passes through the object to be tested and is then by means of an ultrasound lens imaged on to an image converter. The image converter makes visible the picture resulting from the flaws. [...]

Fig. 15 shows such photographs. At the top there is a model experiment in which two blocks of iron were screwed together. The picture on the right was obtained by radiating at right angles to the screw. One can see clearly the screw thread and the air gap which is between the milled surfaces of the two metal blocks which are pressed together. [...]

Trials on patients were carried out with the cooperation of two physicians, R. Richter and E. Parow, at the Martin-Luther-Hospital, Berlin. [...]

[p. 72:]

It was reported that Submarine Signals delivered an ultrasonic equipment to dairies for the purpose of treating milk, and it is found that milk so treated can be more readily absorbed by some infants; in some cases a litre of milk can be digested four times as fast after treatment, and in addition the treatment kills bacteria.

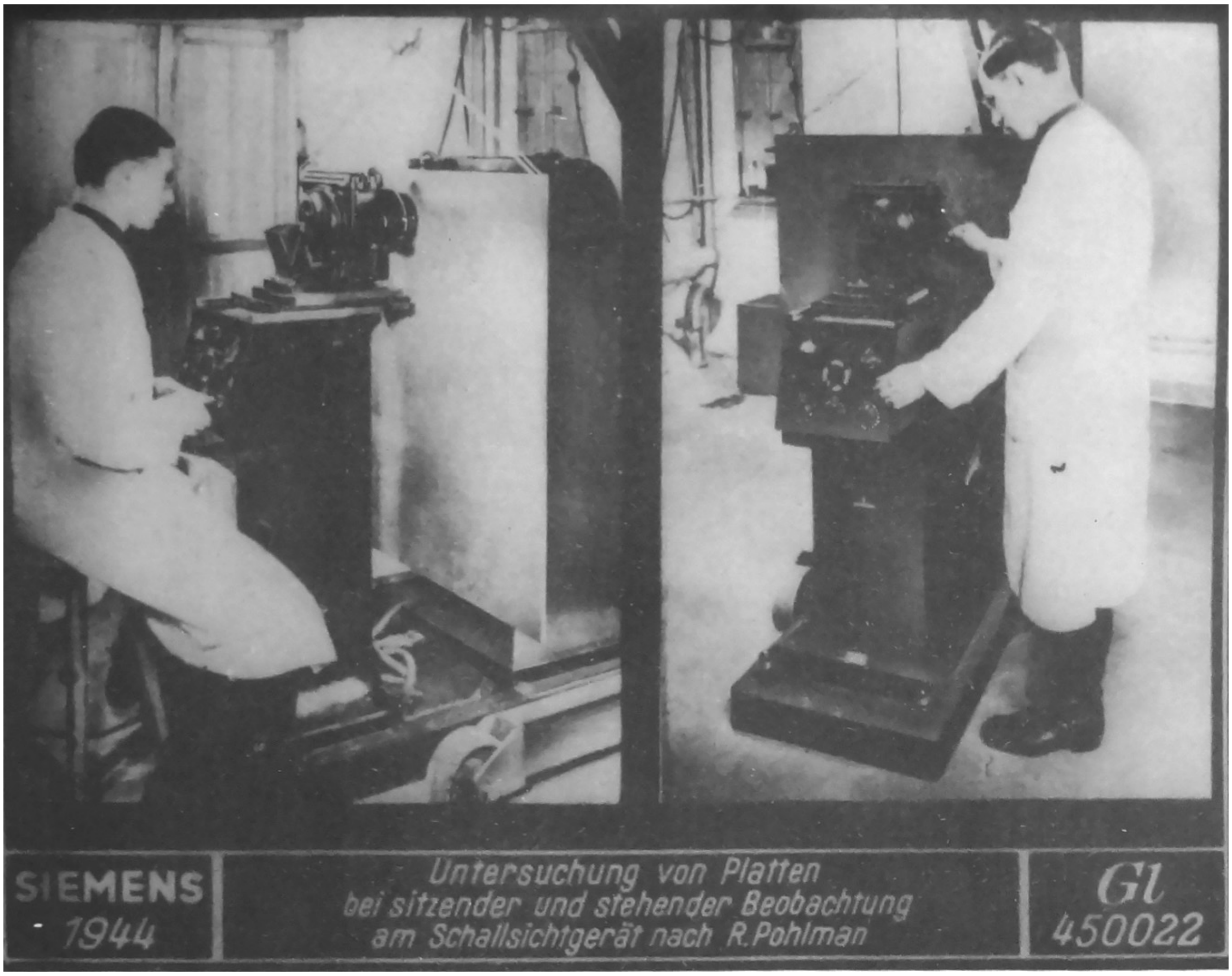

SIEMENS
1944
Untersuchung von Platten
bei sitzender und stehender Beobachtung
am Schallsichtgerät nach R.Pohlman
Gl
450022

Figure C.111: Ultrasound imaging device [BIOS 1679].

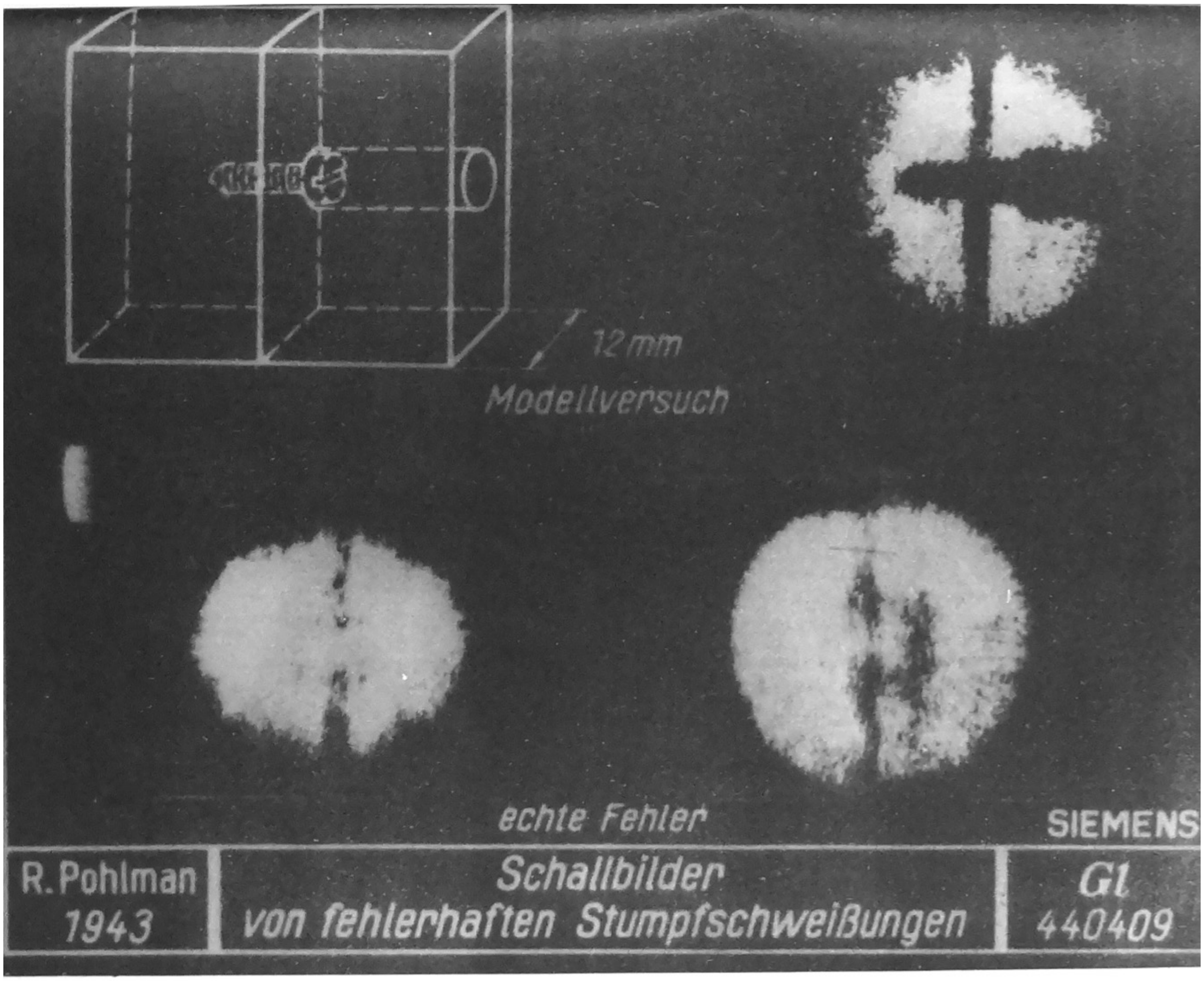

12 mm
Modellversuch
echte Fehler
SIEMENS
R. Pohlman
1943
Schallbilder
von fehlerhaften Stumpfschweißungen
Gl
440409

FIG. 15

Figure C.112: Ultrasound imaging device [BIOS 1679].

[In addition to Reimar Pohlman, some other important German-speaking pioneers of ultrasound imaging were:

- Karl Theodore Dussik (Austrian, 1908–1968) [www.ob-ultrasound.net/dussikbio.html]
- Theodor Hueter (German?, 19??–19??) [www.ob-ultrasound.net/hueter.html]
- Paul Kretz (German?, 19??–19??) [www.ob-ultrasound.net/kretztechnik.html]
- Heinrich Netheler (German?, 19??–19??) [www.ob-ultrasound.net/netheler.html]

As documented in BIOS 1504 and BIOS 1679, at least 22 different German and Austrian laboratories were doing research on ultrasonic generators and applications during the war. Reports such as these, as well as countless documents, hardware, and many of the scientists themselves were transferred to the United States, United Kingdom, Soviet Union, and other countries after the war. Presumably many postwar ultrasonic development programs in those countries could be traced back to the German-speaking creators.]

CIOS XXXII-77 = NavTecMisEu 198-45. *The Production of Intense Audio Sounds by an Intermittent Flame.*

SUMMARY

A project was sponsored by the Speer Ministry aimed at the production of a sound beam so intense it would render troops unfit for combat at ranges up to 15 kilometers. This project, which was pursued for two years, culminated in the development of an 800 cycle generator capable of producing a sound pressure of 1,000 microbars 60 meters from the source. Although this was a very loud source of sound, its effective range was found to be not over 100 meters. The details of the generator, which was based on an intermittent flame principle, is of some scientific interest.

1. Introduction

The information contained in this report was obtained during an interrogation of Dr. Richard Wallauschek who was a member of the Hochtal Laboratory at Lofer, Austria. This laboratory, which has been in existence since 1943, was a pet project of Reichsminister Speer and was originally known as Forschungsstelle-S. Major Barisani was director of the laboratory but during the closing weeks of the war Dr. Zippermayr was made a co-director. The laboratory employed about fifty people.

The development of intense sources of sound was the first major project assigned to the Hochtal Laboratory. The project was based on ideas of Dr. Walkhoff who convinced the Speer Ministry that enemy troops could be rendered unfit for combat by intense sound beams at ranges up to 15 to 20 kilometers. Dr. Wallauschek, formerly of Telefunken, was relieved from the Army to head to the project. Realizing the absurdity of the basic assumption, he agreed only to develop the loudest source of sound he could and make such tests as were required, a job he succeeded in extending over a period of two years.

The source of sound, finally evolved, was based upon the well-known principle of the intermittent flame. The frequency of the flame was controlled by a quarter wave-length resonant tube closely coupled to the combustion chamber. The sound was formed into a beam by use of a parabolic reflector. The best model built was capable of producing a sound pressure of 1000 microbars at 800 cps at a distance of 60 meters from the generator.

2. Description of the Apparatus

The apparatus is composed of two parts: a sound generator and a parabolic reflector. The external appearance of the part is shown in Fig. 1a. An explanation of the operation of the sound generator will be made with the help of the schematic diagram, Fig. 2a. It consists of a combustion chamber and a resonant tube coupled together, plus a water jacket which surrounds the entire unit. The combustion chamber is shown at the left end of Fig. 2a. Oxygen at a pressure of 6 atmospheres is introduced into the combustion chamber through an axially located tube having a 6 mm orifice. Methane is introduced at the same pressure through a second tube located near the side of the chamber. This gas is made to pass through a set of vanes which causes it to assume a whirling motion before it reaches the combustion region near the orifice of the oxygen tube. The arrangement of the vanes is illustrated in Figure 2b.

The rate of combustion is made to vary by the use of a quarter wave-length resonant tube acoustically coupled to the combustion chamber. The resonant tube has a small conical flare. The exact rate of flare has no significant effect upon the action of the device as long as its valve is small. The tube acts as if the right end is free and the left end blocked so that the fundamental resonance of the pipe is such that its length is equal to a quarter of a wave-length. A standing wave within the pipe produces fluctuations in pressure within the combustion chamber, which fluctuations will cause the rate of combustion to vary at the same frequency. The periodic release of thermal energy serves to maintain the system in oscillation. In order to increase the thermo-dynamical efficiency of the unit, both the combustion chamber and the resonant tube are surrounded by a pocket through which water is circulated, thus cooling the combustion products as they pass through the combustion chamber.

An approximate equal-pressure contour of the sound field produced by the generator above is shown in Figure 3. It is obvious that most of the sound is propagated radially from the sound generator, that is to say, a "disk" of sound is produced. The absence of propagation in the axial direction is caused by the well-known phenomenon of the scattering of sound by hot columns of gases.

The purpose of the original project was to produce a beam of sound—not a "disk" of sound. In order to produce a beam, the sound generator is mounted along the axis of a parabolic mirror with the open end of the resonant tube located in the focal plane. When so mounted, the contour of the sound field is changed from the disk of Figure 3 to the conical beam of Figure 4. This beam is neither narrow (as shown by the 30^o spread between the first minima) nor highly directive (as shown by the 3 to 1 ratio of amplitudes between the main beam and the first side lobe).

Several models using the above principles were constructed which varied in operating frequency from 400 to 1000 cps. The most powerful unit built operated at 800 cps and used the larger of the parabolic mirrors shown in Figure 1b, the diameter of which was 320 cm. This unit was able to produce a pressure of 1000 microbars on the axis of the main beam 60 meters from the generator. The development thus culminated in a powerful source of sound radiating over 100 watts of acoustical energy.

Remarks

The device failed in its original objective, as might have been expected, for it was concluded that it would be of no military value at ranges greater than 100 meters. The project is of importance because it furnishes concrete evidence of the failure of an idea after proposed as a military weapon. Furthermore, this method of producing intense audio frequency sounds in air may be of some scientific interest.

Prepared by:

H. M. TRENT,

Technician.

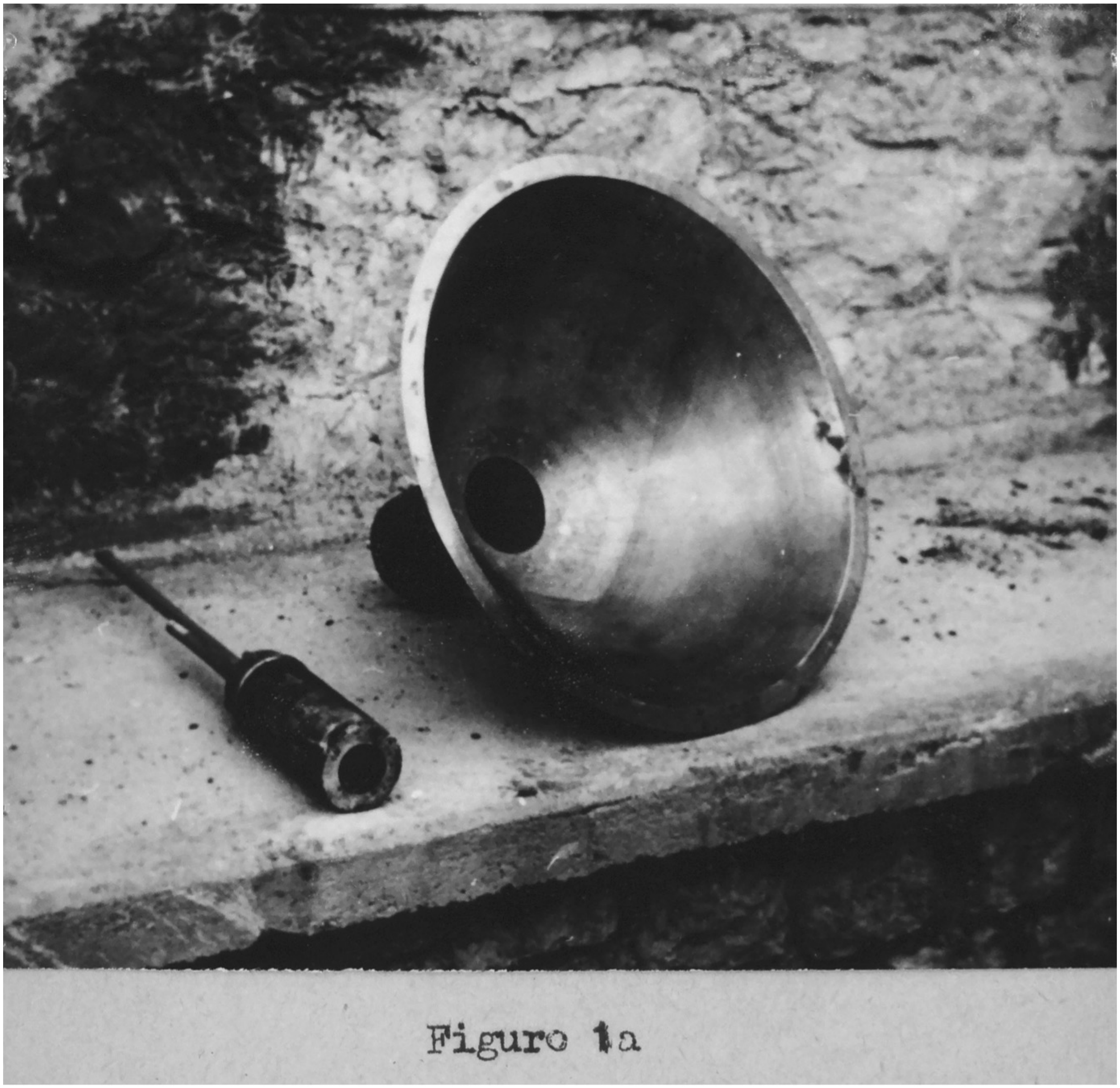


Figure C.113: Prototype acoustic weapon [CIOS XXXII-77].

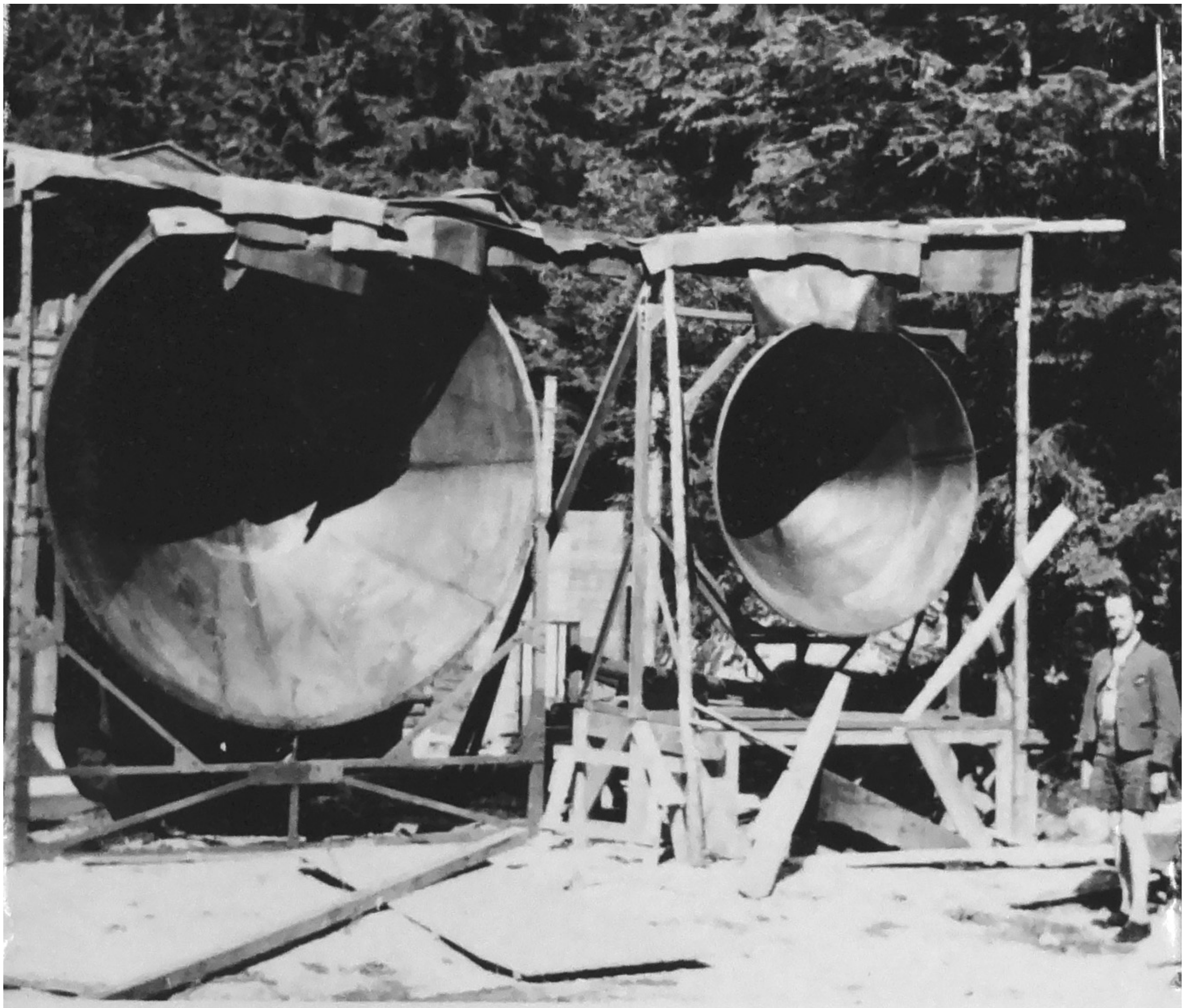
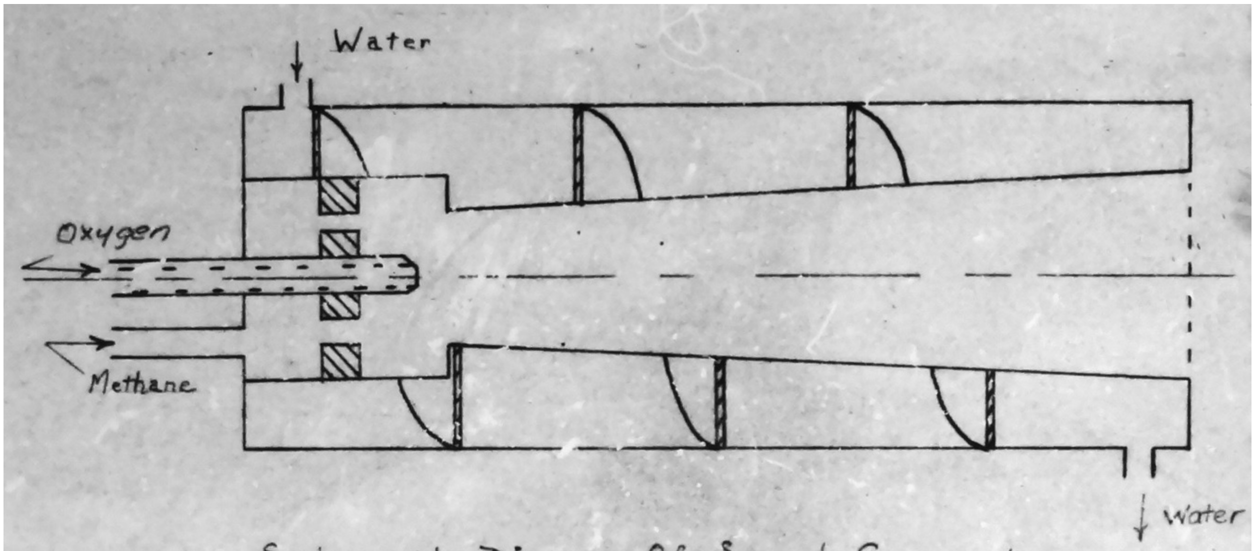


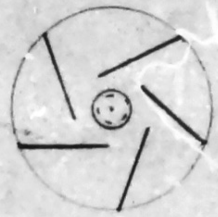
Figure 1b

Parabolic Reflectors for Sound Generator

Figure C.114: Prototype acoustic weapon [CIOS XXXII-77].


Water
Oxygen
Methane
Water

Schematic Diagram Of Sound Generator
Figure 2a



Schematic Arrangement Of Vanes
Figure 2b

UNCLASSIFIED

Figure C.115: Prototype acoustic weapon [CIOS XXXII-77].

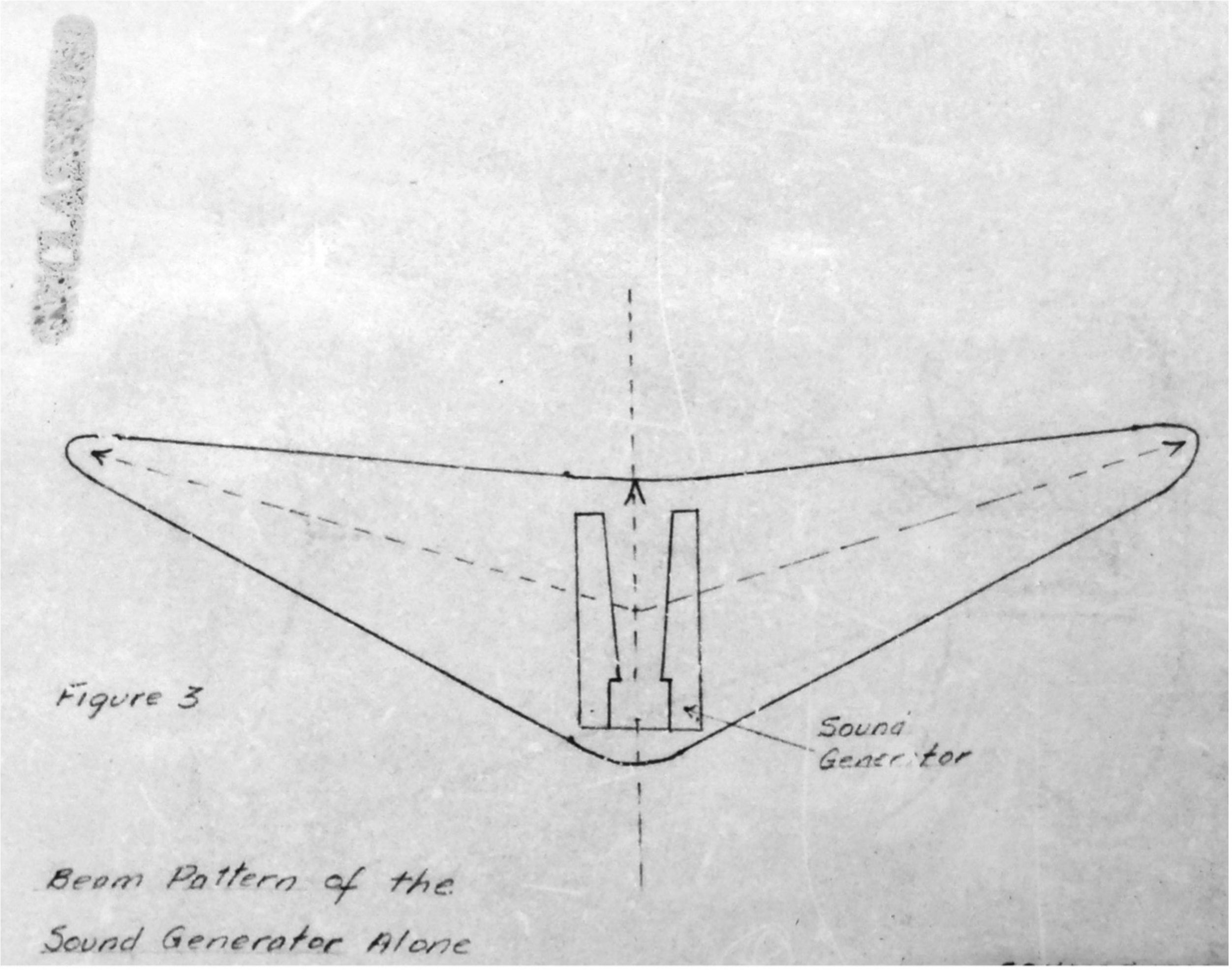


Figure 3
Sound Generator
Beam Pattern of the Sound Generator Alone

Figure C.116: Prototype acoustic weapon [CIOS XXXII-77].

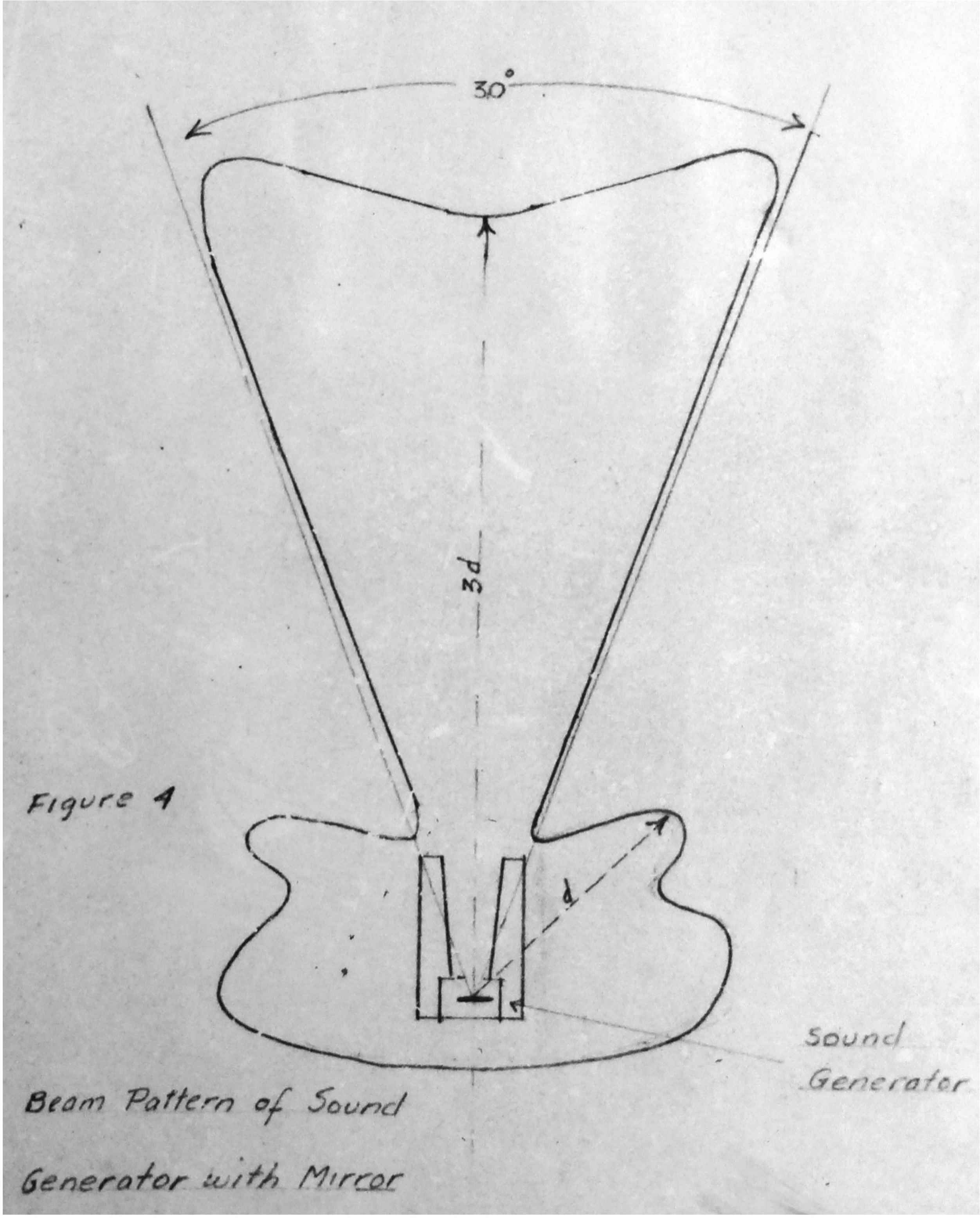

30°
3d
d
Figure 4
Sound Generator
Beam Pattern of Sound Generator with Mirror

Figure C.117: Prototype acoustic weapon [CIOS XXXII-77].

Sound Waves Kill in Tests by Army. *New York Times.* 30 November 1947 p. 14.

Sound Waves Kill in Tests by Army

Inaudible to Humans, They Fell Mice and Other Pests and Burn Experimenters

WASHINGTON, Nov. 29.—The discovery of sound waves which produce such intense heat that they are lethal to mice and small insects was announced today by the Army.

In tests for the Signal Corps at Penn State College white mice died one minute after exposure to the ultra-sonic waves, which are of such high pitch that they are inaudible to human ears.

Other experiments were performed on the common roach, firebrats, yellow-fever mosquitoes, blow flies, meal worms and caterpillars, and in each case death resulted from the waves' radiation.

Extensive possibilities for pest control were suggested by the experiments, but there was no indication that the discoveries might lead to the use of sound waves as a war weapon.

Nevertheless, it was pointed out that scientists at work on the supersonic project found it difficult to put objects into the sound field or retrieve them without burning their fingers and hands.

They did not expose themselves to the direct beam and wore ear plugs, but even then it was difficult for them to avoid exposure to the radiated sound. Effects ran from loss of a sense of equilibrium to dizziness.

"Supersonics, the science dealing with waves similar to ordinary sound waves but above the audible range, is not expected to serve any immediate domestic uses but offers promise in finding and developing more interesting uses which may be applied to industry," the Army said.

In previous experiments the high-frequency waves have been found useful in detecting defects in metal castings and other materials. They have also be used in emulsifying or colloidizing liquids by dispersion, as is done in producing homogenized milk.

"Experts in the study of supersonics feel that the principle has many unknown qualities that no doubt will be brought out through continued research," the Army explained.

Headquarters for the work are at the Evans Signal Laboratory, Belmar, N. J., and at Penn State College.

[This "new discovery" by the U.S. Army appears to have been directly borrowed from the earlier German and Austrian work, such as that reported in BIOS 1504 and BIOS 1679, down to the specific descriptions of the experiments and their effects and applications. In English at that time, "supersonic" (generally used to describe objects moving faster than the speed of sound) was sometimes used to mean "ultrasonic" (sound frequencies higher than the human ear can detect); this article used both terms. Evans Signal Laboratory was part of the larger Army electronics research complex at Fort Monmouth, New Jersey [Fort Monmouth Historical Office 2008]. It participated in many wartime and postwar missions analyzing German science and technology, and it acquired numerous German scientists and their technologies after the war.]

[Richard Wallauschek's acoustic weapon reported in CIOS XXXII-77 and other wartime acoustic technologies were the forerunners of modern acoustic weapons such as LRAD (Long Range Acoustic Device), shown in Fig. C.118. Even LRAD's specifications are reminiscent of Wallauschek's wartime acoustic weapon. LRAD has a maximum continuous output of 153 dB at 1 meter, with a frequency of 1 kHz and a beam width $\pm 15^o$.

Thus the wartime German work appears directly linked to modern applications of acoustics and ultrasound for imaging, pest control, industry, weapons, etc.]

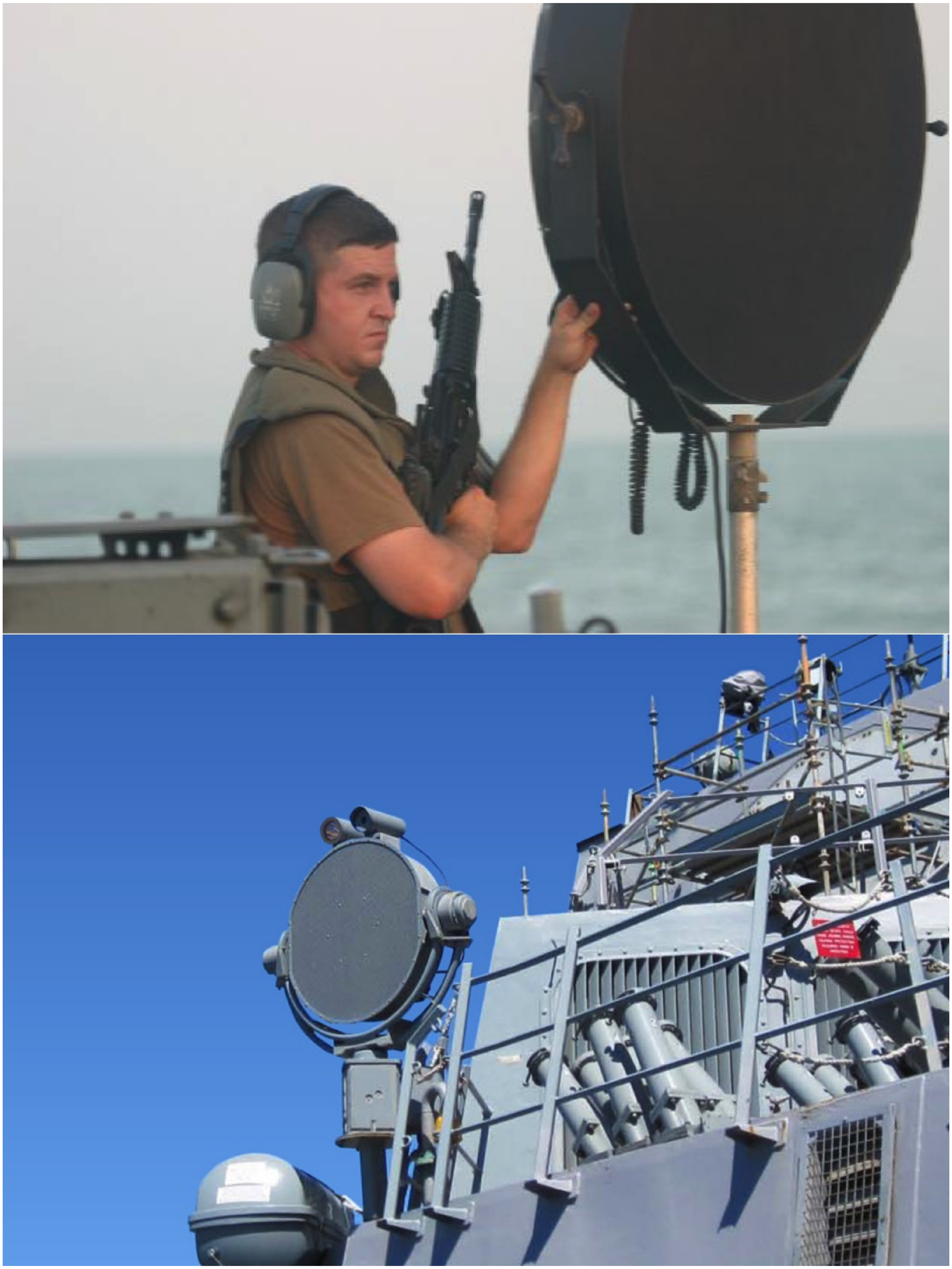


Figure C.118: Modern LRAD (Long Range Acoustic Device) acoustic weapon used by the U.S. Navy and other ships to deter pirates.

C.5 Magnetic Levitation and Electromagnetic Railguns

[Another category of directed energy technologies covers devices that produce large amounts of electromagnetic energy, but then transfer that to a physical object in the form of kinetic energy. Both magnetic levitation systems and railguns employ strong electromagnetic fields and rails to propel and guide an object. In magnetic levitation, such methods are used to support and propel very large objects (such as trains) at relatively low speeds. In electromagnetic railguns, similar methods are used to support and propel very small objects (projectiles) at extremely high speeds. The following documents demonstrate that German-speaking scientists pioneered both of these applications.]

Alfred Zehden. U.S. Patent 782,312. Electric Traction Apparatus. Filed 21 June 1902.

[...] Having thus described my invention, what I claim as new therein, and desire to secure by Letters Patent of the United States of America, is—

1. The combination of a rail-like armature, a traveling field-magnet, and means for neutralizing the magnetic attraction of the latter, substantially as set forth.

2. The combination of a plurality of rail-like armatures, and a plurality of traveling field-magnets arranged to act thereon in opposite directions, substantially as set forth.

3. The combination of a rail-like armature located between the rails, and a traveling field-magnet, said armature being located between the poles of said magnet, so that by the cooperation of these parts the carriage is not only moved forward, but also its weight, namely wheel-pressure, diminished, substantially as set forth.

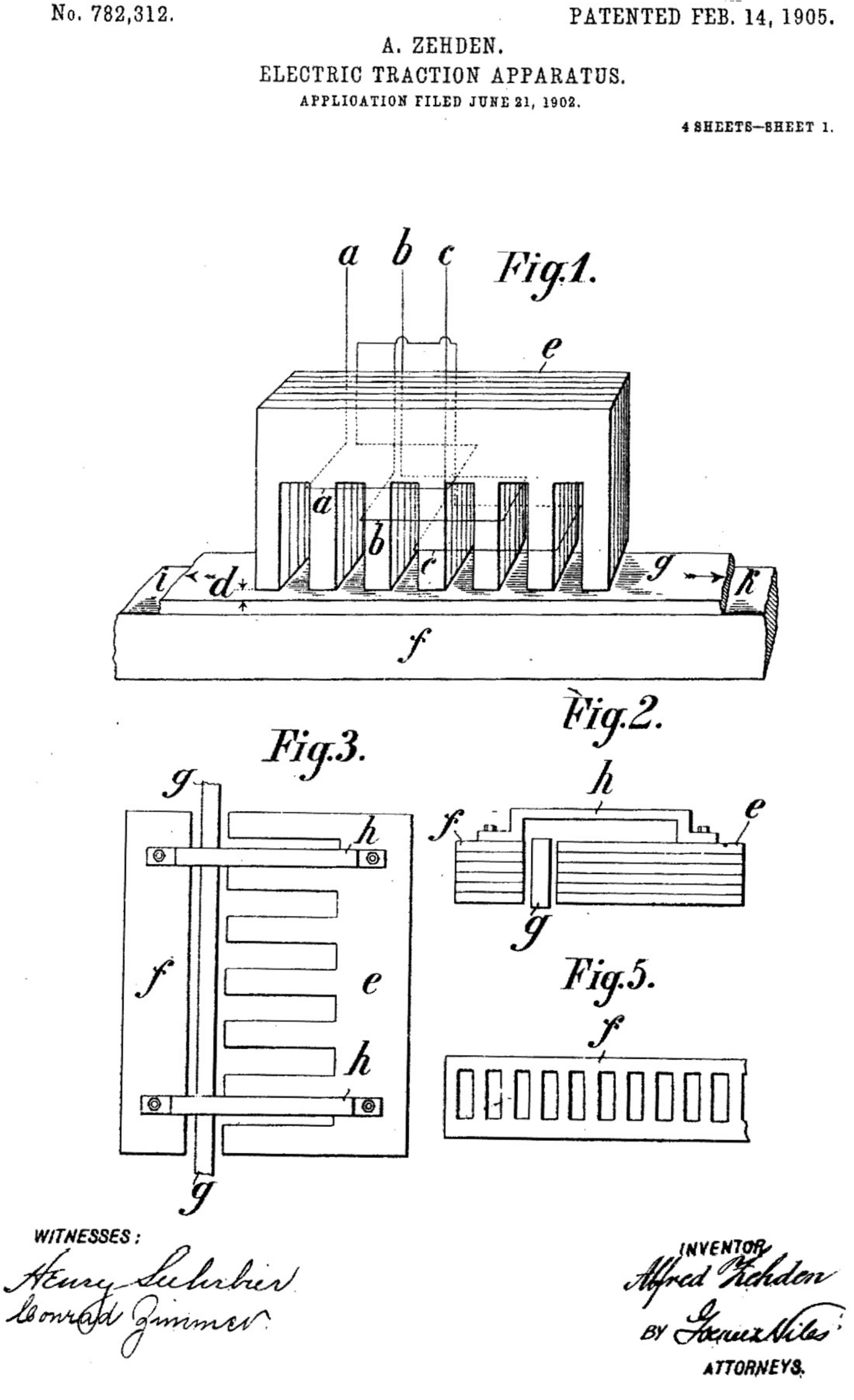
4. The combination of a rail-like armature provided with openings, and a traveling field-magnet arranged in juxtaposition to said armature, substantially as set forth.

5. The combination of a rail-like armature provided with openings of different breadths, a traveling field-magnet, and means for neutralizing the magnetic attraction of said magnet, substantially as set forth.

6. The combination of a rail-like armature, a traveling field-magnet movable transversely to said armature, means for neutralizing the magnetic attraction of said magnet, and means for guiding said magnet out of contact with said armature, substantially as set forth.

7. The combination of a rail-like armature, reinforced at its outer sides at curves, a traveling field-magnet, and means for neutralizing the magnetic attraction of said magnet, substantially as set forth.

[Alfred Zehden (German, 1876–19??) appears to have been the first scientist or engineer to seriously design magnetically levitated trains. The patent cited above is reproduced in full on the following pages. Zehden filed very similar patents on magnetically levitated trains in several countries at the same time. It is not clear how far he actually got with corresponding experiments for this technology.]



No. 782,312. PATENTED FEB. 14, 1905.

A. ZEHDEN.

ELECTRIC TRACTION APPARATUS.

APPLICATION FILED JUNE 21, 1902.

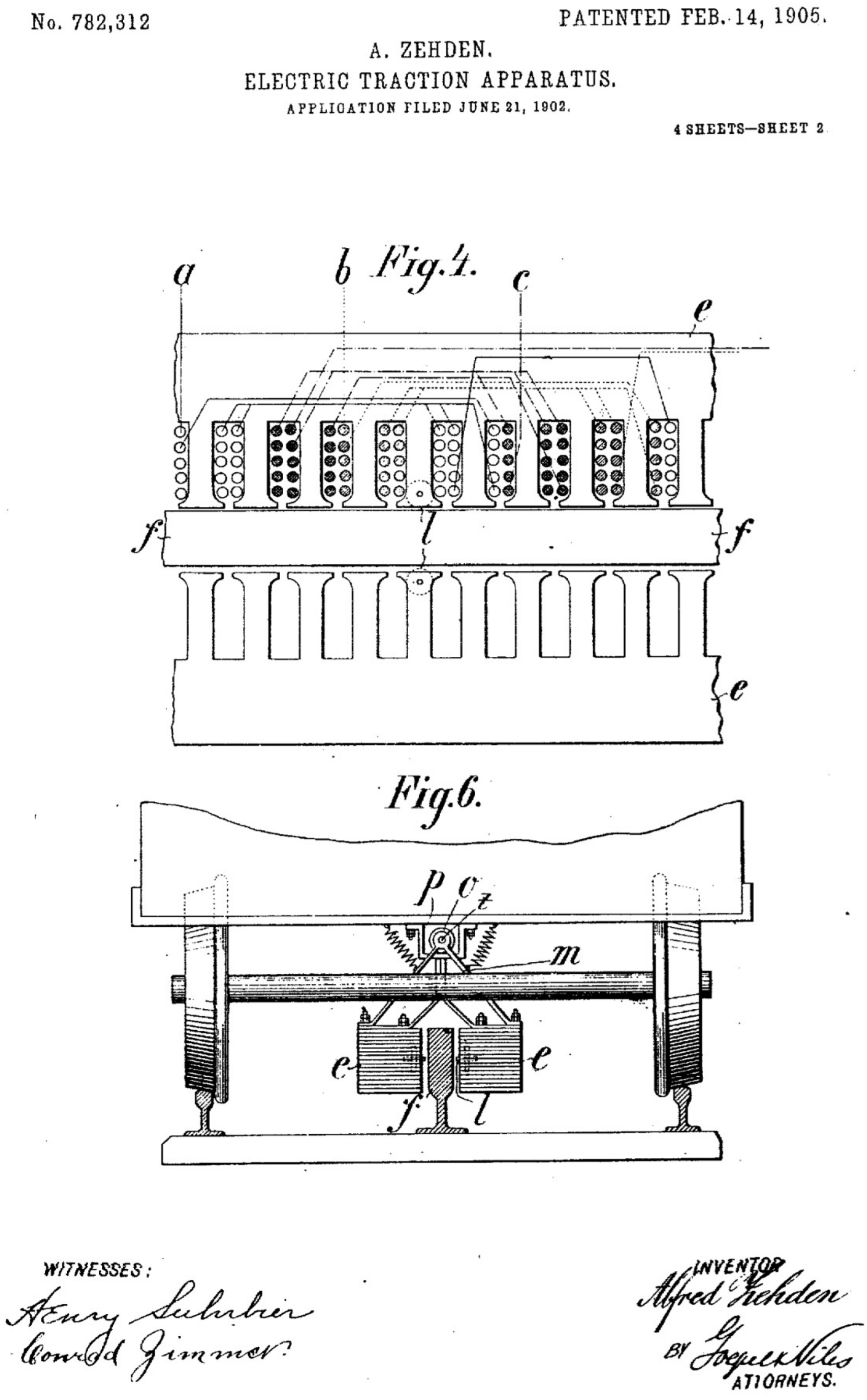
4 SHEETS—SHEET 1.

Fig.1.
a
b
c
e
a
b
c
i
d
g
k
f
Fig.2.
h
f
e
g
Fig.3.
g
h
f
e
h
g
Fig.5.
f

WITNESSES:
Henry Seelerbier
Conrad Zimmer

INVENTOR
Alfred Zehden
BY
ATTORNEYS.

Figure C.119: U.S. patent 782,312 on magnetically levitated trains, filed by Alfred Zehden in 1902.



No. 782,312

PATENTED FEB. 14, 1905.

A. ZEHDEN.

ELECTRIC TRACTION APPARATUS.

APPLICATION FILED JUNE 21, 1902.

4 SHEETS—SHEET 2.

WITNESSES:

Henry Suhrbier

Conrad Zimmer

INVENTOR

Alfred Zehden

BY Goepel & Niles

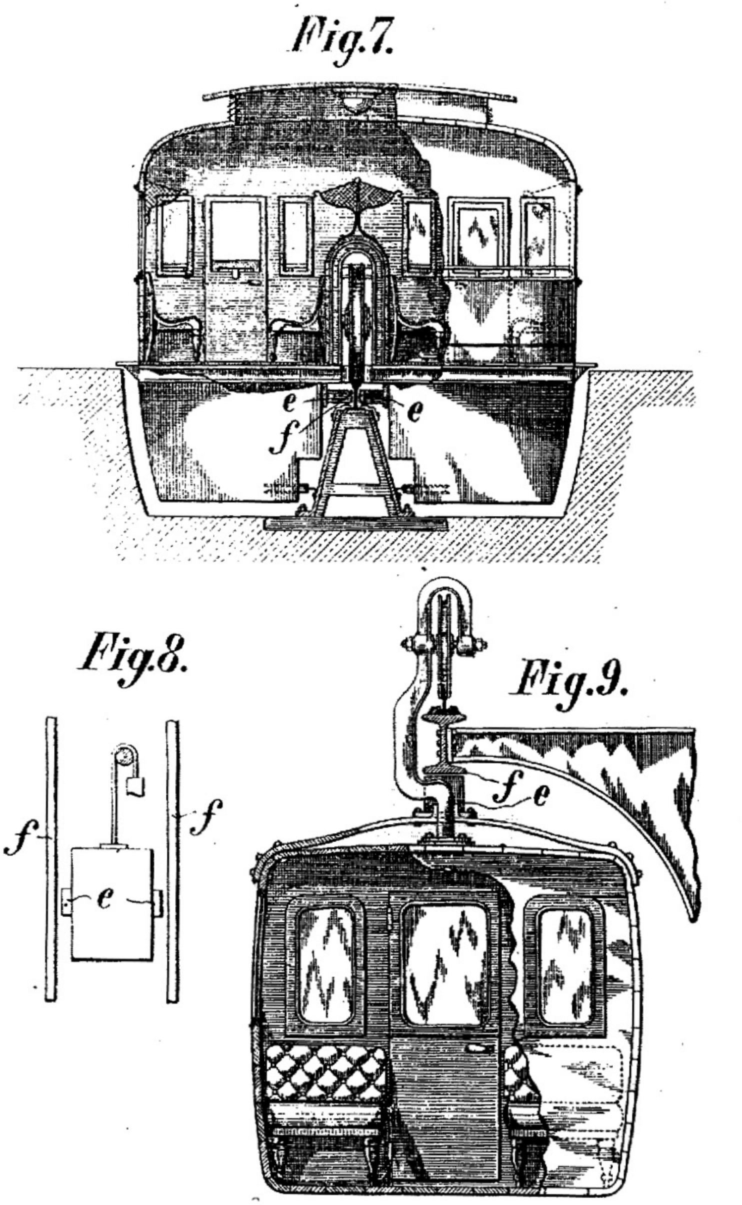
ATTORNEYS.

Figure C.120: U.S. patent 782,312 on magnetically levitated trains, filed by Alfred Zehden in 1902.

No. 782,312. PATENTED FEB. 14, 1905.

A. ZEHDEN.
ELECTRIC TRACTION APPARATUS.
APPLICATION FILED JUNE 21, 1902.

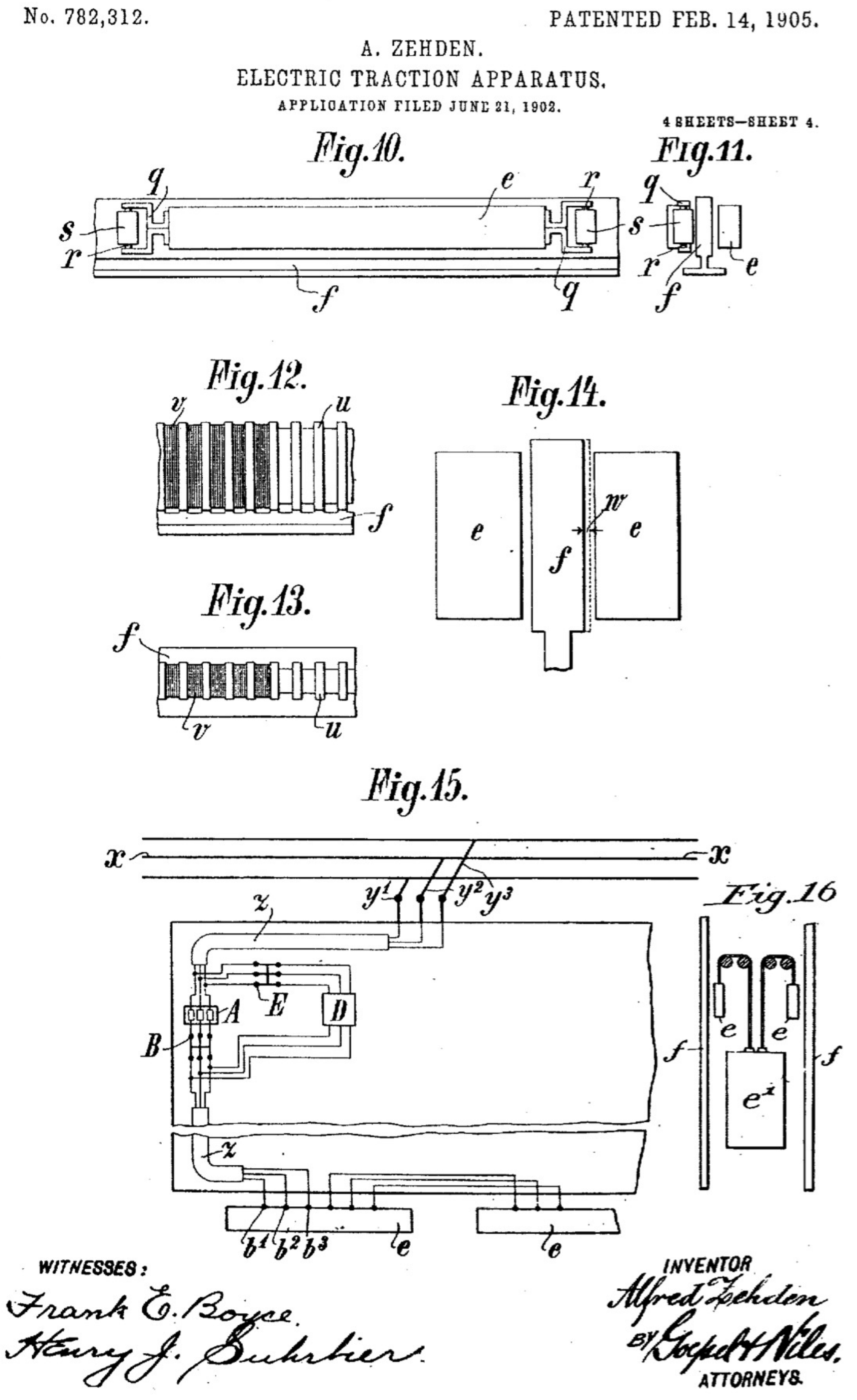
4 SHEETS—SHEET 3.



WITNESSES:
Conrad Zimmer.
Henry Suhrbier.

INVENTOR
Alfred Zehden
BY Goepel & Giles
ATTORNEYS.

Figure C.121: U.S. patent 782,312 on magnetically levitated trains, filed by Alfred Zehden in 1902.



No. 782,312. PATENTED FEB. 14, 1905.

A. ZEHDEN.

ELECTRIC TRACTION APPARATUS.

APPLICATION FILED JUNE 21, 1902.

4 SHEETS—SHEET 4.

WITNESSES:

Frank E. Boyce.

Henry J. Suhrbier.

INVENTOR

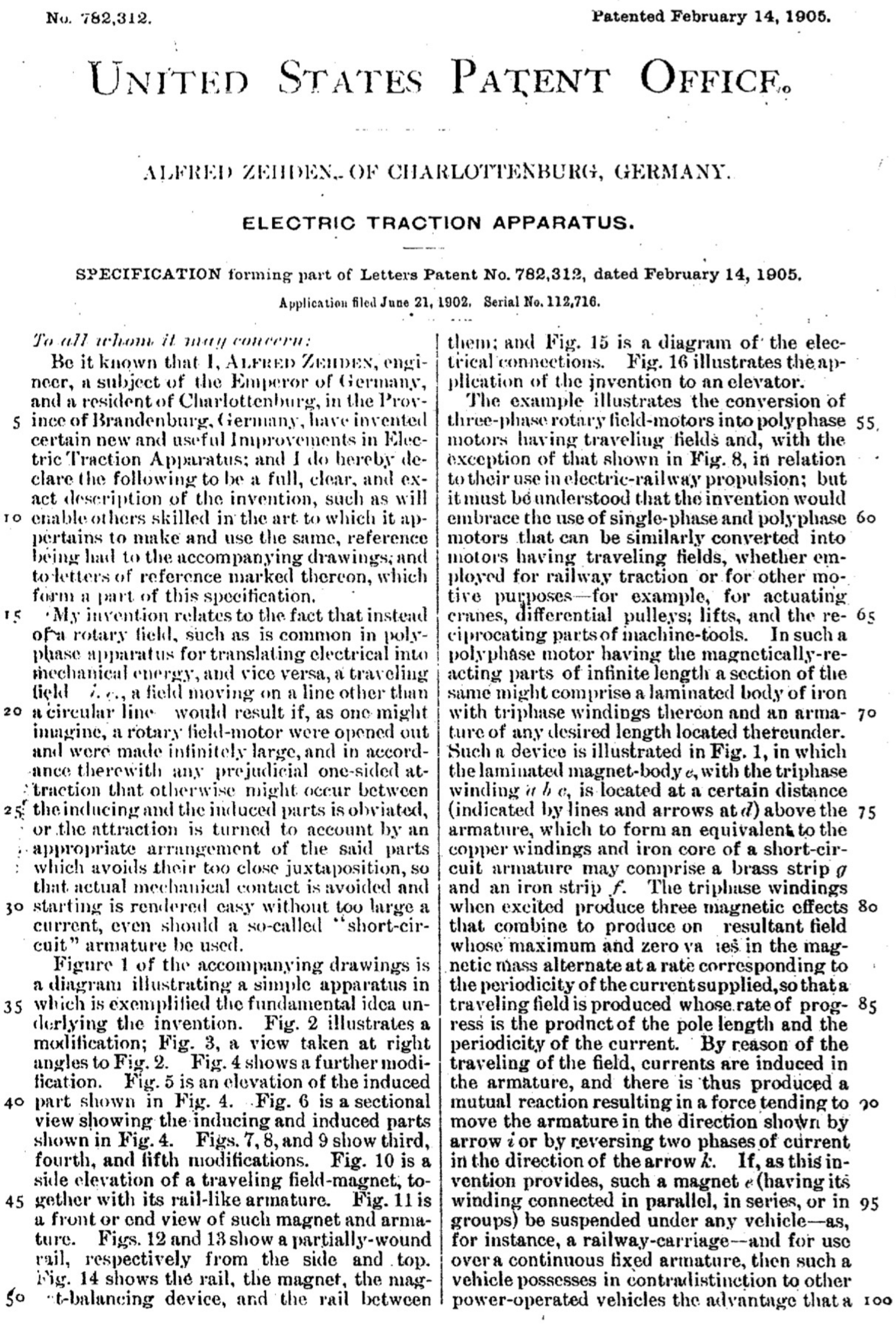
Alfred Zehden

BY Goepel & Niles.

ATTORNEYS.

Fig. 10.
q
e
r
s
r
f
Fig. 11.
q
s
r
f
e
Fig. 12.
v
u
f
Fig. 13.
f
v
u
Fig. 14.
e
w
f
Fig. 15.
x
y^1
y^2
y^3
z
A
E
D
B
b^1
b^2
b^3
e
Fig. 16
e^1

Figure C.122: U.S. patent 782,312 on magnetically levitated trains, filed by Alfred Zehden in 1902.



No. 782,312. **Patented February 14, 1905.**

UNITED STATES PATENT OFFICE.

ALFRED ZEHDEN, OF CHARLOTTENBURG, GERMANY.

ELECTRIC TRACTION APPARATUS.

SPECIFICATION forming part of Letters Patent No. 782,312, dated February 14, 1905.

Application filed June 21, 1902. Serial No. 112,716.

To all whom it may concern:

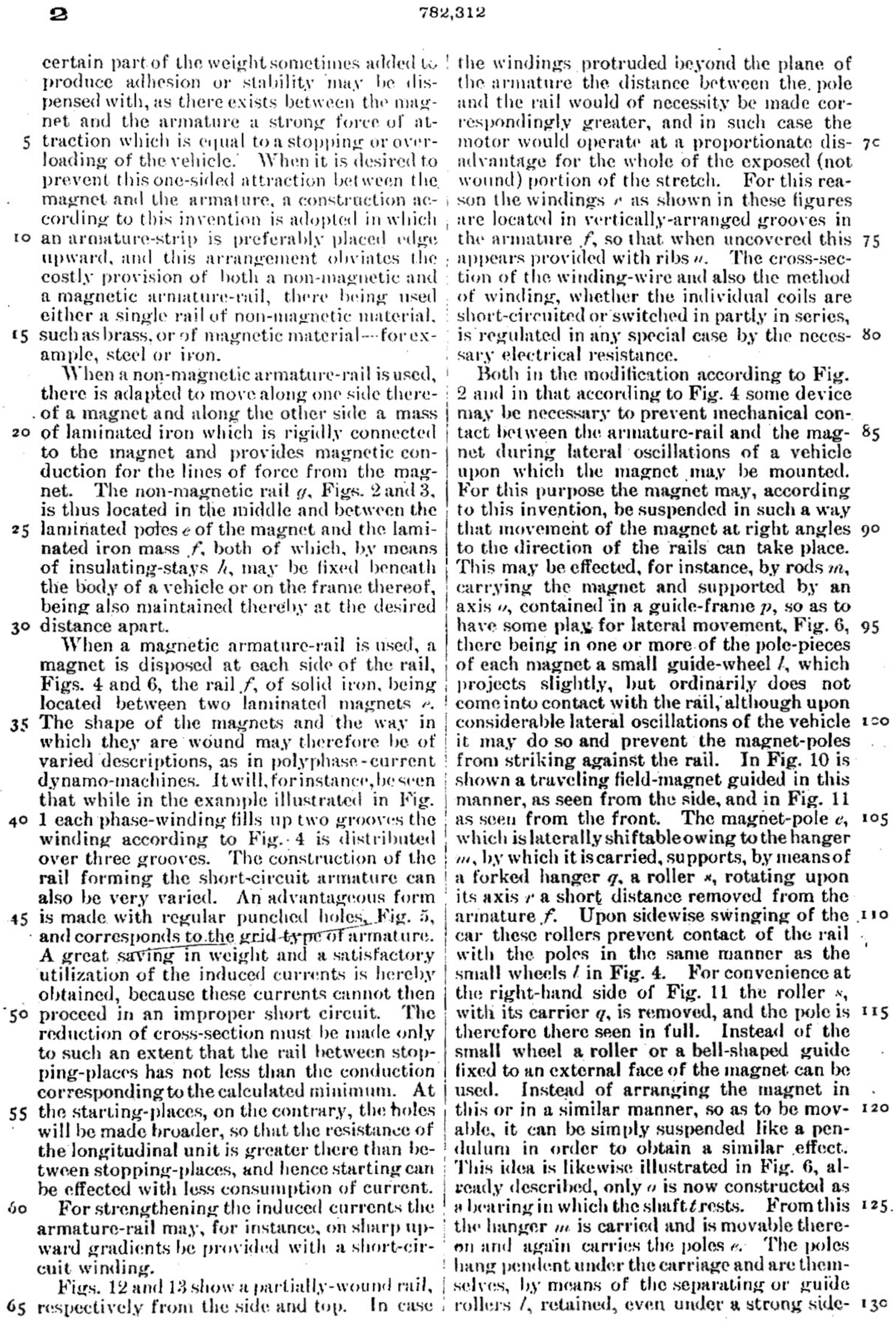
Be it known that I, Alfred Zehden, engineer, a subject of the Emperor of Germany, and a resident of Charlottenburg, in the Province of Brandenburg, Germany, have invented certain new and useful Improvements in Electric Traction Apparatus; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same, reference being had to the accompanying drawings, and to letters of reference marked thereon, which form a part of this specification.

My invention relates to the fact that instead of a rotary field, such as is common in polyphase apparatus for translating electrical into mechanical energy, and vice versa, a traveling field—*i. e.*, a field moving on a line other than a circular line—would result if, as one might imagine, a rotary field-motor were opened out and were made infinitely large, and in accordance therewith any prejudicial one-sided attraction that otherwise might occur between the inducing and the induced parts is obviated, or the attraction is turned to account by an appropriate arrangement of the said parts which avoids their too close juxtaposition, so that actual mechanical contact is avoided and starting is rendered easy without too large a current, even should a so-called "short-circuit" armature be used.

Figure 1 of the accompanying drawings is a diagram illustrating a simple apparatus in which is exemplified the fundamental idea underlying the invention. Fig. 2 illustrates a modification; Fig. 3, a view taken at right angles to Fig. 2. Fig. 4 shows a further modification. Fig. 5 is an elevation of the induced part shown in Fig. 4. Fig. 6 is a sectional view showing the inducing and induced parts shown in Fig. 4. Figs. 7, 8, and 9 show third, fourth, and fifth modifications. Fig. 10 is a side elevation of a traveling field-magnet, together with its rail-like armature. Fig. 11 is a front or end view of such magnet and armature. Figs. 12 and 13 show a partially-wound rail, respectively from the side and top. Fig. 14 shows the rail, the magnet, the magnet-balancing device, and the rail between them; and Fig. 15 is a diagram of the electrical connections. Fig. 16 illustrates the application of the invention to an elevator.

The example illustrates the conversion of three-phase rotary field-motors into polyphase motors having traveling fields and, with the exception of that shown in Fig. 8, in relation to their use in electric-railway propulsion; but it must be understood that the invention would embrace the use of single-phase and polyphase motors that can be similarly converted into motors having traveling fields, whether employed for railway traction or for other motive purposes—for example, for actuating cranes, differential pulleys, lifts, and the reciprocating parts of machine-tools. In such a polyphase motor having the magnetically-reacting parts of infinite length a section of the same might comprise a laminated body of iron with triphase windings thereon and an armature of any desired length located thereunder. Such a device is illustrated in Fig. 1, in which the laminated magnet-body *e*, with the triphase winding *a b c*, is located at a certain distance (indicated by lines and arrows at *d*) above the armature, which to form an equivalent to the copper windings and iron core of a short-circuit armature may comprise a brass strip *g* and an iron strip *f*. The triphase windings when excited produce three magnetic effects that combine to produce one resultant field whose maximum and zero values in the magnetic mass alternate at a rate corresponding to the periodicity of the current supplied, so that a traveling field is produced whose rate of progress is the prodnct of the pole length and the periodicity of the current. By reason of the traveling of the field, currents are induced in the armature, and there is thus produced a mutual reaction resulting in a force tending to move the armature in the direction shown by arrow *i* or by reversing two phases of current in the direction of the arrow *k*. If, as this invention provides, such a magnet *e* (having its winding connected in parallel, in series, or in groups) be suspended under any vehicle—as, for instance, a railway-carriage—and for use over a continuous fixed armature, then such a vehicle possesses in contradistinction to other power-operated vehicles the advantage that a

Figure C.123: U.S. patent 782,312 on magnetically levitated trains, filed by Alfred Zehden in 1902.



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certain part of the weight sometimes added to produce adhesion or stability may be dispensed with, as there exists between the magnet and the armature a strong force of attraction which is equal to a stopping or overloading of the vehicle. When it is desired to prevent this one-sided attraction between the magnet and the armature, a construction according to this invention is adopted in which an armature-strip is preferably placed edge upward, and this arrangement obviates the costly provision of both a non-magnetic and a magnetic armature-rail, there being used either a single rail of non-magnetic material, such as brass, or of magnetic material—for example, steel or iron.

When a non-magnetic armature-rail is used, there is adapted to move along one side thereof a magnet and along the other side a mass of laminated iron which is rigidly connected to the magnet and provides magnetic conduction for the lines of force from the magnet. The non-magnetic rail *g*, Figs. 2 and 3, is thus located in the middle and between the laminated poles *e* of the magnet and the laminated iron mass *f*, both of which, by means of insulating-stays *h*, may be fixed beneath the body of a vehicle or on the frame thereof, being also maintained thereby at the desired distance apart.

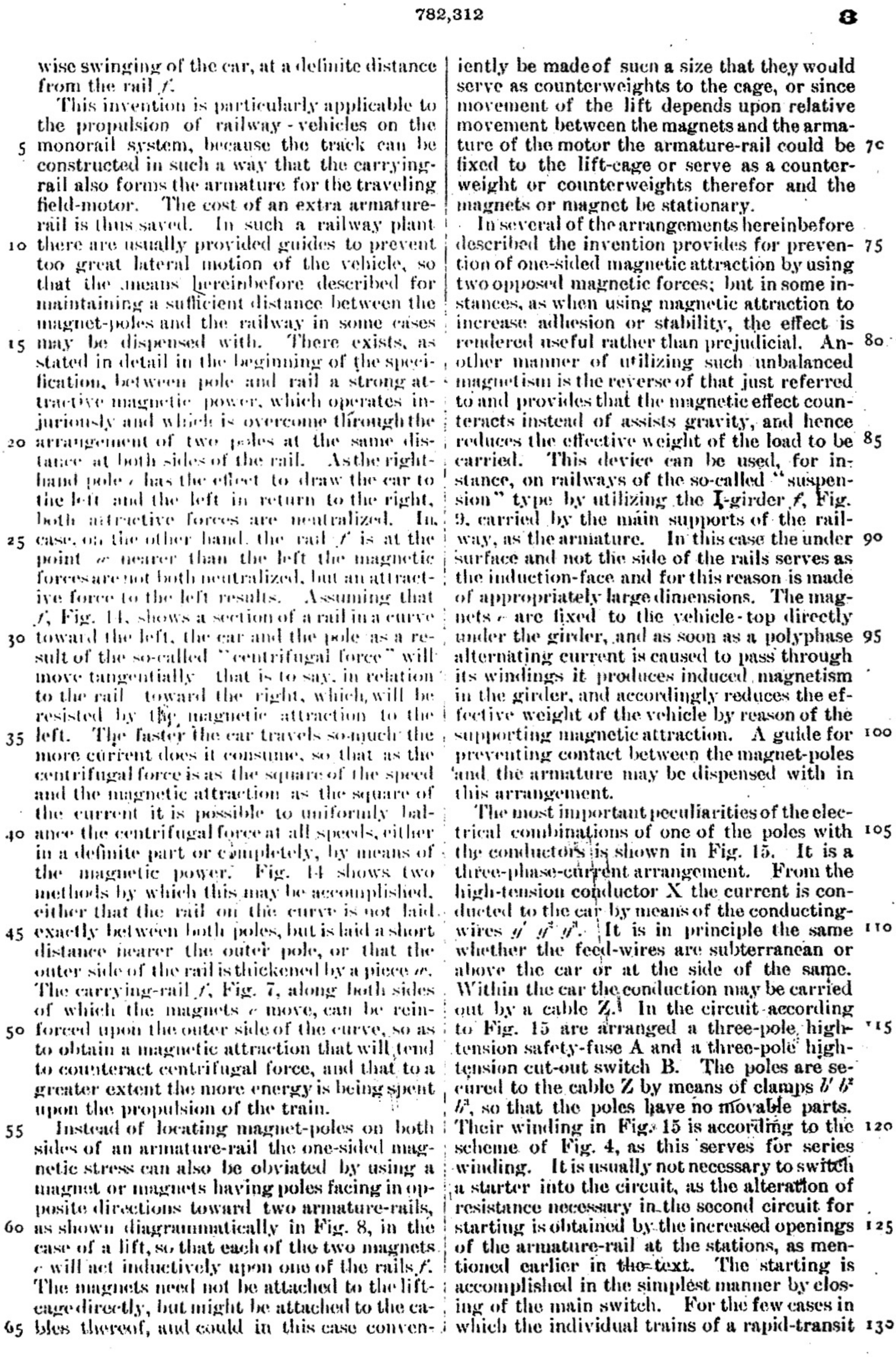
When a magnetic armature-rail is used, a magnet is disposed at each side of the rail, Figs. 4 and 6, the rail *f*, of solid iron, being located between two laminated magnets *e*. The shape of the magnets and the way in which they are wound may therefore be of varied descriptions, as in polyphase-current dynamo-machines. It will, for instance, be seen that while in the example illustrated in Fig. 1 each phase-winding fills up two grooves the winding according to Fig. 4 is distributed over three grooves. The construction of the rail forming the short-circuit armature can also be very varied. An advantageous form is made with regular punched holes, Fig. 5, and corresponds to the grid type of armature. A great saving in weight and a satisfactory utilization of the induced currents is hereby obtained, because these currents cannot then proceed in an improper short circuit. The reduction of cross-section must be made only to such an extent that the rail between stopping-places has not less than the conduction corresponding to the calculated minimum. At the starting-places, on the contrary, the holes will be made broader, so that the resistance of the longitudinal unit is greater there than between stopping-places, and hence starting can be effected with less consumption of current.

For strengthening the induced currents the armature-rail may, for instance, on sharp upward gradients be provided with a short-circuit winding.

Figs. 12 and 13 show a partially-wound rail, respectively from the side and top. In case the windings protruded beyond the plane of the armature the distance between the pole and the rail would of necessity be made correspondingly greater, and in such case the motor would operate at a proportionate disadvantage for the whole of the exposed (not wound) portion of the stretch. For this reason the windings *e* as shown in these figures are located in vertically-arranged grooves in the armature *f*, so that when uncovered this appears provided with ribs *u*. The cross-section of the winding-wire and also the method of winding, whether the individual coils are short-circuited or switched in partly in series, is regulated in any special case by the necessary electrical resistance.

Both in the modification according to Fig. 2 and in that according to Fig. 4 some device may be necessary to prevent mechanical contact between the armature-rail and the magnet during lateral oscillations of a vehicle upon which the magnet may be mounted. For this purpose the magnet may, according to this invention, be suspended in such a way that movement of the magnet at right angles to the direction of the rails can take place. This may be effected, for instance, by rods *m*, carrying the magnet and supported by an axis *o*, contained in a guide-frame *p*, so as to have some play for lateral movement, Fig. 6, there being in one or more of the pole-pieces of each magnet a small guide-wheel *l*, which projects slightly, but ordinarily does not come into contact with the rail, although upon considerable lateral oscillations of the vehicle it may do so and prevent the magnet-poles from striking against the rail. In Fig. 10 is shown a traveling field-magnet guided in this manner, as seen from the side, and in Fig. 11 as seen from the front. The magnet-pole *e*, which is laterally shiftable owing to the hanger *m*, by which it is carried, supports, by means of a forked hanger *q*, a roller *x*, rotating upon its axis *r* a short distance removed from the armature *f*. Upon sidewise swinging of the car these rollers prevent contact of the rail with the poles in the same manner as the small wheels *l* in Fig. 4. For convenience at the right-hand side of Fig. 11 the roller *s*, with its carrier *q*, is removed, and the pole is therefore there seen in full. Instead of the small wheel a roller or a bell-shaped guide fixed to an external face of the magnet can be used. Instead of arranging the magnet in this or in a similar manner, so as to be movable, it can be simply suspended like a pendulum in order to obtain a similar effect. This idea is likewise illustrated in Fig. 6, already described, only *o* is now constructed as a bearing in which the shaft *t* rests. From this the hanger *m* is carried and is movable thereon and again carries the poles *e*. The poles hang pendent under the carriage and are themselves, by means of the separating or guide rollers *l*, retained, even under a strong side-

Figure C.124: U.S. patent 782,312 on magnetically levitated trains, filed by Alfred Zehden in 1902.



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wise swinging of the car, at a definite distance from the rail *f*.

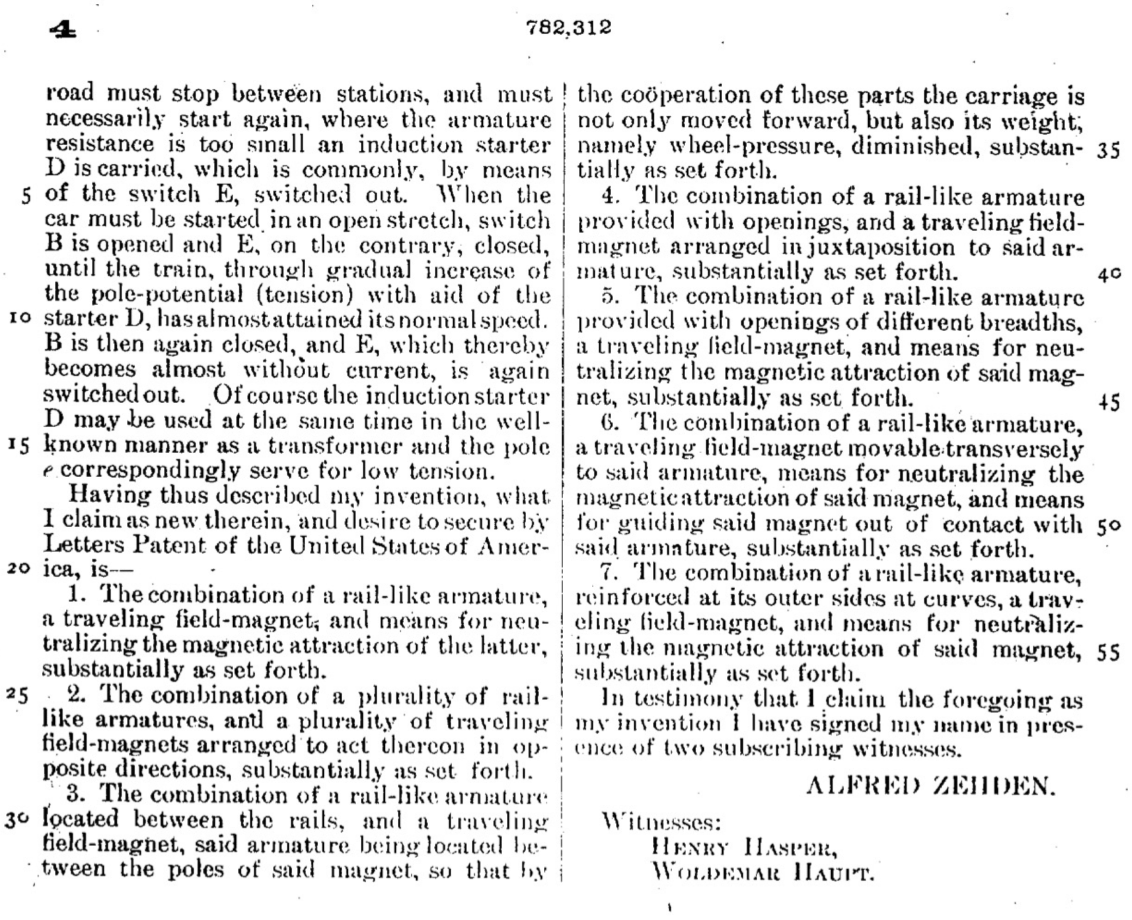
This invention is particularly applicable to the propulsion of railway-vehicles on the monorail system, because the track can be constructed in such a way that the carrying-rail also forms the armature for the traveling field-motor. The cost of an extra armature-rail is thus saved. In such a railway plant there are usually provided guides to prevent too great lateral motion of the vehicle, so that the means hereinbefore described for maintaining a sufficient distance between the magnet-poles and the railway in some cases may be dispensed with. There exists, as stated in detail in the beginning of the specification, between pole and rail a strong attractive magnetic power, which operates injuriously and which is overcome through the arrangement of two poles at the same distance at both sides of the rail. As the right-hand pole *e* has the effect to draw the car to the left and the left in return to the right, both attractive forces are neutralized. In case, on the other hand, the rail *f* is at the point *w* nearer than the left the magnetic forces are not both neutralized, but an attractive force to the left results. Assuming that *f*, Fig. 14, shows a section of a rail in a curve toward the left, the car and the pole as a result of the so-called "centrifugal force" will move tangentially that is to say, in relation to the rail toward the right, which, will be resisted by the magnetic attraction to the left. The faster the car travels so much the more current does it consume, so that as the centrifugal force is as the square of the speed and the magnetic attraction as the square of the current it is possible to uniformly balance the centrifugal force at all speeds, either in a definite part or completely, by means of the magnetic power. Fig. 14 shows two methods by which this may be accomplished, either that the rail on the curve is not laid exactly between both poles, but is laid a short distance nearer the outer pole, or that the outer side of the rail is thickened by a piece *w*. The carrying-rail *f*, Fig. 7, along both sides of which the magnets *e* move, can be reinforced upon the outer side of the curve, so as to obtain a magnetic attraction that will tend to counteract centrifugal force, and that to a greater extent the more energy is being spent upon the propulsion of the train.

Instead of locating magnet-poles on both sides of an armature-rail the one-sided magnetic stress can also be obviated by using a magnet or magnets having poles facing in opposite directions toward two armature-rails, as shown diagrammatically in Fig. 8, in the case of a lift, so that each of the two magnets *e* will act inductively upon one of the rails *f*. The magnets need not be attached to the lift-cage directly, but might be attached to the cables thereof, and could in this case conveniently be made of such a size that they would serve as counterweights to the cage, or since movement of the lift depends upon relative movement between the magnets and the armature of the motor the armature-rail could be fixed to the lift-cage or serve as a counterweight or counterweights therefor and the magnets or magnet be stationary.

In several of the arrangements hereinbefore described the invention provides for prevention of one-sided magnetic attraction by using two opposed magnetic forces; but in some instances, as when using magnetic attraction to increase adhesion or stability, the effect is rendered useful rather than prejudicial. Another manner of utilizing such unbalanced magnetism is the reverse of that just referred to and provides that the magnetic effect counteracts instead of assists gravity, and hence reduces the effective weight of the load to be carried. This device can be used, for instance, on railways of the so-called "suspension" type by utilizing the I-girder *f*, Fig. 9, carried by the main supports of the railway, as the armature. In this case the under surface and not the side of the rails serves as the induction-face and for this reason is made of appropriately large dimensions. The magnets *e* are fixed to the vehicle-top directly under the girder, and as soon as a polyphase alternating current is caused to pass through its windings it produces induced magnetism in the girder, and accordingly reduces the effective weight of the vehicle by reason of the supporting magnetic attraction. A guide for preventing contact between the magnet-poles and the armature may be dispensed with in this arrangement.

The most important peculiarities of the electrical combinations of one of the poles with the conductors is shown in Fig. 15. It is a three-phase-current arrangement. From the high-tension conductor X the current is conducted to the car by means of the conducting-wires g' g^2 g^3. It is in principle the same whether the feed-wires are subterranean or above the car or at the side of the same. Within the car the conduction may be carried out by a cable Z. In the circuit according to Fig. 15 are arranged a three-pole high-tension safety-fuse A and a three-pole high-tension cut-out switch B. The poles are secured to the cable Z by means of clamps b' b^2 b^3, so that the poles have no movable parts. Their winding in Fig. 15 is according to the scheme of Fig. 4, as this serves for series winding. It is usually not necessary to switch a starter into the circuit, as the alteration of resistance necessary in the second circuit for starting is obtained by the increased openings of the armature-rail at the stations, as mentioned earlier in the text. The starting is accomplished in the simplest manner by closing of the main switch. For the few cases in which the individual trains of a rapid-transit

Figure C.125: U.S. patent 782,312 on magnetically levitated trains, filed by Alfred Zehden in 1902.



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road must stop between stations, and must necessarily start again, where the armature resistance is too small an induction starter D is carried, which is commonly, by means of the switch E, switched out. When the car must be started in an open stretch, switch B is opened and E, on the contrary, closed, until the train, through gradual increase of the pole-potential (tension) with aid of the starter D, has almost attained its normal speed. B is then again closed, and E, which thereby becomes almost without current, is again switched out. Of course the induction starter D may be used at the same time in the well-known manner as a transformer and the pole correspondingly serve for low tension.

Having thus described my invention, what I claim as new therein, and desire to secure by Letters Patent of the United States of America, is—

1. The combination of a rail-like armature, a traveling field-magnet, and means for neutralizing the magnetic attraction of the latter, substantially as set forth.

2. The combination of a plurality of rail-like armatures, and a plurality of traveling field-magnets arranged to act thereon in opposite directions, substantially as set forth.

3. The combination of a rail-like armature located between the rails, and a traveling field-magnet, said armature being located between the poles of said magnet, so that by the coöperation of these parts the carriage is not only moved forward, but also its weight, namely wheel-pressure, diminished, substantially as set forth.

4. The combination of a rail-like armature provided with openings, and a traveling field-magnet arranged in juxtaposition to said armature, substantially as set forth.

5. The combination of a rail-like armature provided with openings of different breadths, a traveling field-magnet, and means for neutralizing the magnetic attraction of said magnet, substantially as set forth.

6. The combination of a rail-like armature, a traveling field-magnet movable transversely to said armature, means for neutralizing the magnetic attraction of said magnet, and means for guiding said magnet out of contact with said armature, substantially as set forth.

7. The combination of a rail-like armature, reinforced at its outer sides at curves, a traveling field-magnet, and means for neutralizing the magnetic attraction of said magnet, substantially as set forth.

In testimony that I claim the foregoing as my invention I have signed my name in presence of two subscribing witnesses.

ALFRED ZEHDEN.

Witnesses:
HENRY HASPER,
WOLDEMAR HAUPT.

Figure C.126: U.S. patent 782,312 on magnetically levitated trains, filed by Alfred Zehden in 1902.

Hermann Kemper. Patent DE643316. Schwebebahn mit raederlosen Fahrzeugen, die an eisernen Fahrschienen mittels magnetischer Felder schwebend entlang gefuehrt werden. [Suspension Railway with Vehicles without Wheels, which Are Guided along Iron Rails by Means of Magnetic Fields.] Filed 11 August 1934.

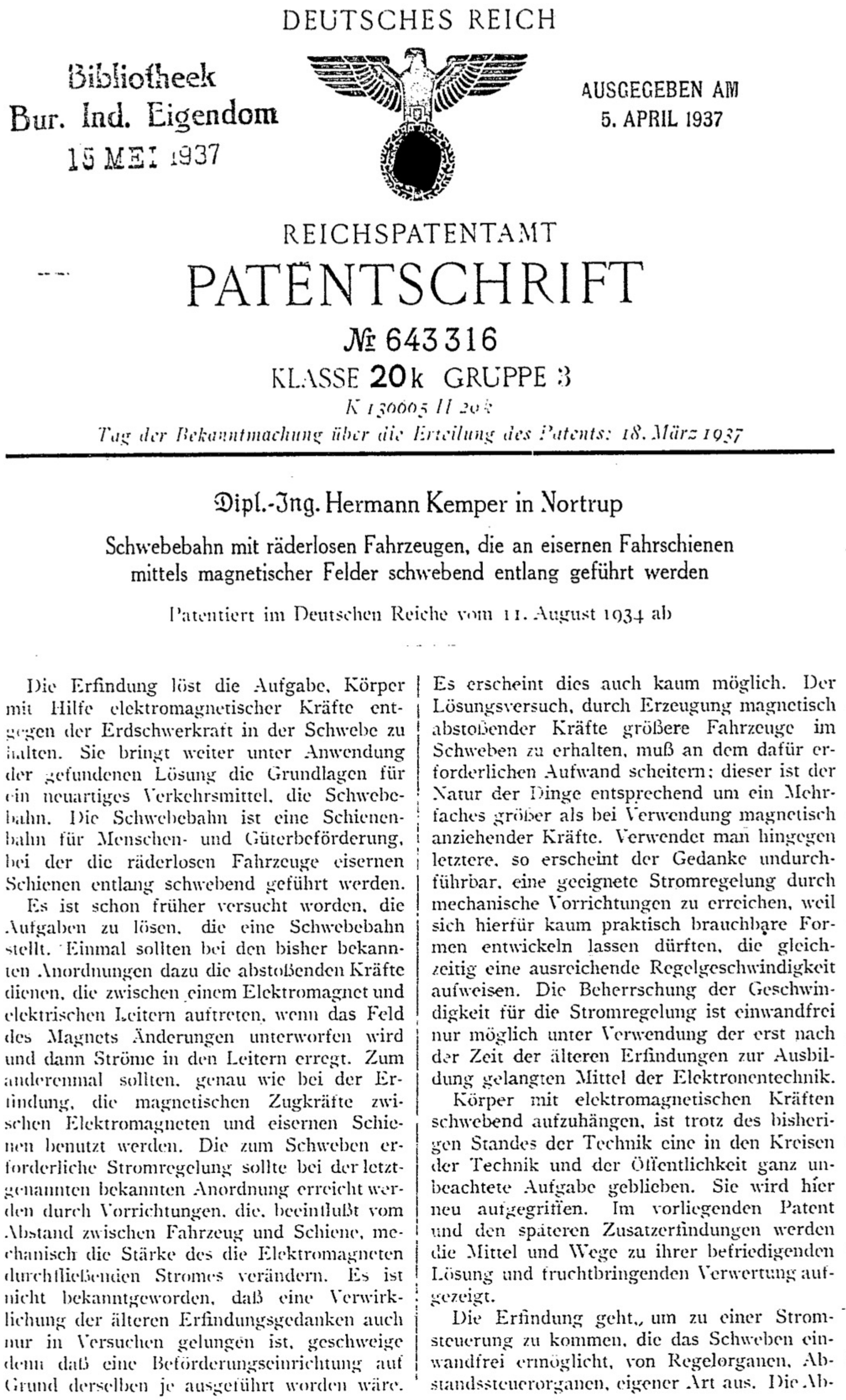
[...] PATENTANSPRUCH:

Schwebebahn mit räderlosen Fahrzeugen, die an eisernen Fahrschienen mittels magnetischer, in zwischen den Schienen und an den Fahrzeugen verteilt befestigten Elektromagneten erzeugter Felder schwebend entlang geführt werden, dadurch gekennzeichnet, daß die Regelung der magnetischen Felder durch Abstandssteuerorgane geschieht, die an den Schwebewagen (3) gegenüber den Führungsschienen (2) räumlich nahe den von ihnen zu steuernden Elektromagneten befestigt sind. Die Abstandssteuerorgane (Abb. 4, 5) sind mechanisch unveränderliche, jedoch in ihrem elektrischen Widerstand durch den Abstand von den Schienen beeinflußte elektrische oder magnetische Anordnungen (z. B. Kondensatoren 8, 9 oder Drosselspulen 10, 11) und werden in elektrische Stromkreise eingeschaltet, wobei sie an ihren Polen Spannungen erzeugen, die sich mit dem Abstand von den Führungsschienen unverzüglich ändern. Diese Spannungen werden, soweit erforderlich, in ebenfalls trägheitsarmen Schaltungen verstärkt und, gegebenenfalls gleichgerichtet, elektrischen Röhren zu deren Steuerung zugeführt (Abb. 6). Der Sinn und die Größe dieser Steuerspannungen ist so zu wählen, daß durch die von den Röhren den Elektromagneten zugeleiteten Ströme magnetische Zugkräfte erzeugt werden, die der Schwerkraft das Gleichgewicht halten, wenn der Abstand der Fahrzeuge von den Schienen das vorgeschriebene Maß hat, die dagegen die Schwerkraft übersteigen, wenn der Abstand zu groß wird, sie endlich unterschreiten, wenn der Abstand unter das Sollmaß herabsinkt.

[...] PATENT CLAIM:

Suspension railway with wheelless vehicles which are guided along iron rails in a floating manner by means of magnetic fields generated in electromagnets fixed in a distributed manner between the rails and on the vehicles, characterized in that the magnetic fields are controlled by distance control elements which are fixed to the suspension wagons (3) relative to the guide rails (2) spatially close to the electromagnets to be controlled by them. The distance control devices (Figs. 4, 5) are electrical or magnetic arrangements (e.g. capacitors 8, 9 or generators 10, 11) which are mechanically fixed but whose electrical resistance is influenced by the distance from the rails, and are connected to electrical circuits, generating voltages at their poles which change immediately with the distance from the guide rails. If necessary, these voltages are amplified in circuits with low inertia and, if necessary in the same direction, supplied to electrical tubes for their control (Fig. 6). The sense and magnitude of these control voltages shall be such that the currents supplied by the tubes to the electromagnets generate magnetic tractive forces which maintain the equilibrium of gravity when the distance of the vehicles from the rails is greater than the prescribed value but which exceed gravity when the distance becomes too great and finally fall below it when the distance falls below the required value.

[Hermann Kemper (German, 1892–1977) built on Alfred Zehden's earlier work on magnetic levitation for trains. His complete patent is reproduced on the following pages. It is not clear how far Kemper got with corresponding experiments for this technology.]



DEUTSCHES REICH

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PATENTSCHRIFT

№ 643316

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K 130605 II 20k

Tag der Bekanntmachung über die Erteilung des Patents: 18. März 1937

Dipl.-Ing. Hermann Kemper in Nortrup

Schwebebahn mit räderlosen Fahrzeugen, die an eisernen Fahrschienen mittels magnetischer Felder schwebend entlang geführt werden

Patentiert im Deutschen Reiche vom 11. August 1934 ab

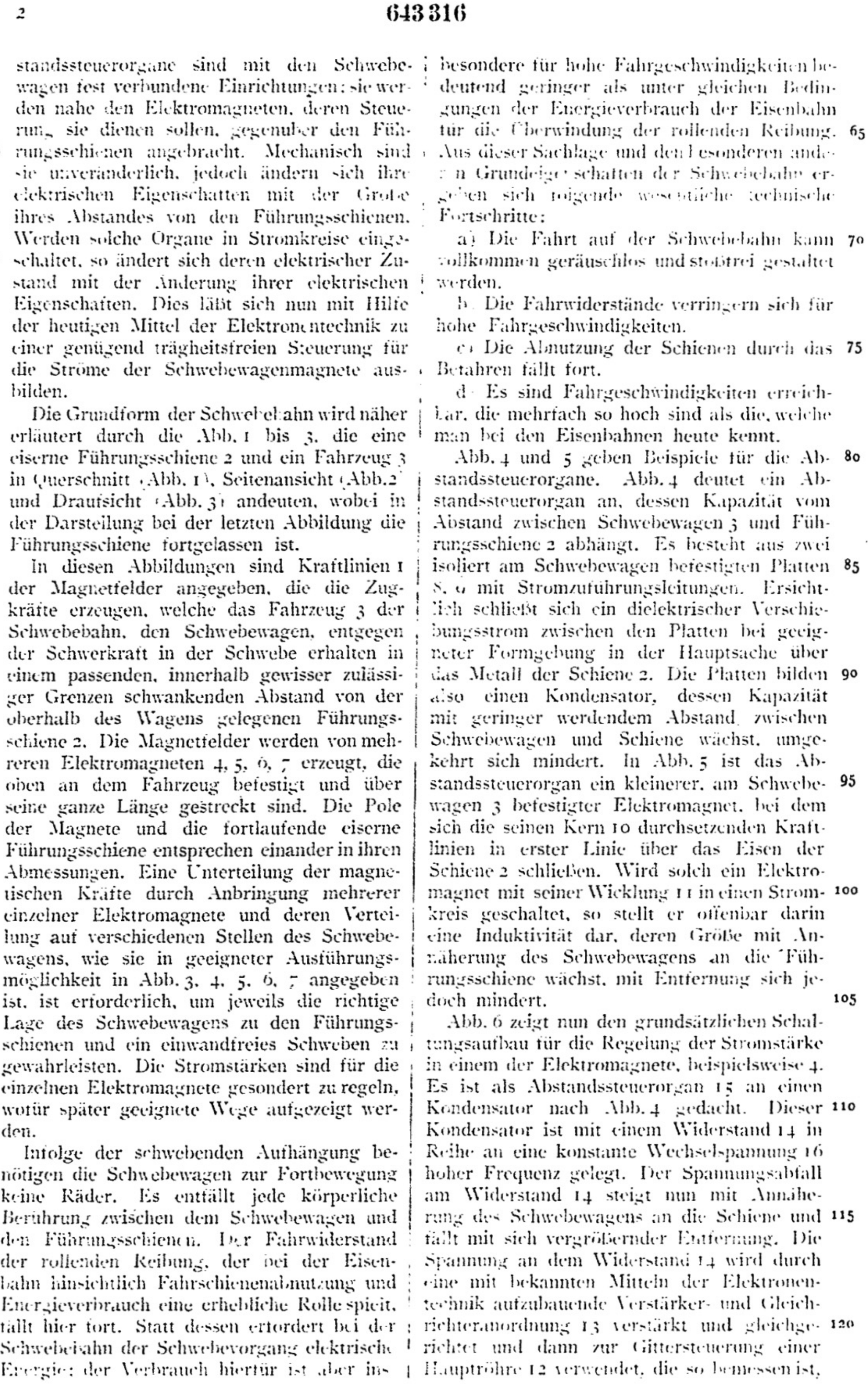
Die Erfindung löst die Aufgabe, Körper mit Hilfe elektromagnetischer Kräfte entgegen der Erdschwerkraft in der Schwebe zu halten. Sie bringt weiter unter Anwendung der gefundenen Lösung die Grundlagen für ein neuartiges Verkehrsmittel, die Schwebebahn. Die Schwebebahn ist eine Schienenbahn für Menschen- und Güterbeförderung, bei der die räderlosen Fahrzeuge eisernen Schienen entlang schwebend geführt werden.

Es ist schon früher versucht worden, die Aufgaben zu lösen, die eine Schwebebahn stellt. Einmal sollten bei den bisher bekannten Anordnungen dazu die abstoßenden Kräfte dienen, die zwischen einem Elektromagnet und elektrischen Leitern auftreten, wenn das Feld des Magnets Änderungen unterworfen wird und dann Ströme in den Leitern erregt. Zum anderenmal sollten, genau wie bei der Erfindung, die magnetischen Zugkräfte zwischen Elektromagneten und eisernen Schienen benutzt werden. Die zum Schweben erforderliche Stromregelung sollte bei der letztgenannten bekannten Anordnung erreicht werden durch Vorrichtungen, die, beeinflußt vom Abstand zwischen Fahrzeug und Schiene, mechanisch die Stärke des die Elektromagneten durchfließenden Stromes verändern. Es ist nicht bekanntgeworden, daß eine Verwirklichung der älteren Erfindungsgedanken auch nur in Versuchen gelungen ist, geschweige denn daß eine Beförderungseinrichtung auf Grund derselben je ausgeführt worden wäre. Es erscheint dies auch kaum möglich. Der Lösungsversuch, durch Erzeugung magnetisch abstoßender Kräfte größere Fahrzeuge im Schweben zu erhalten, muß an dem dafür erforderlichen Aufwand scheitern; dieser ist der Natur der Dinge entsprechend um ein Mehrfaches größer als bei Verwendung magnetisch anziehender Kräfte. Verwendet man hingegen letztere, so erscheint der Gedanke undurchführbar, eine geeignete Stromregelung durch mechanische Vorrichtungen zu erreichen, weil sich hierfür kaum praktisch brauchbare Formen entwickeln lassen dürften, die gleichzeitig eine ausreichende Regelgeschwindigkeit aufweisen. Die Beherrschung der Geschwindigkeit für die Stromregelung ist einwandfrei nur möglich unter Verwendung der erst nach der Zeit der älteren Erfindungen zur Ausbildung gelangten Mittel der Elektronentechnik.

Körper mit elektromagnetischen Kräften schwebend aufzuhängen, ist trotz des bisherigen Standes der Technik eine in den Kreisen der Technik und der Öffentlichkeit ganz unbeachtete Aufgabe geblieben. Sie wird hier neu aufgegriffen. Im vorliegenden Patent und den späteren Zusatzerfindungen werden die Mittel und Wege zu ihrer befriedigenden Lösung und fruchtbringenden Verwertung aufgezeigt.

Die Erfindung geht, um zu einer Stromsteuerung zu kommen, die das Schweben einwandfrei ermöglicht, von Regelorganen, Abstandssteuerorganen, eigener Art aus. Die Ab-

Figure C.127: German patent DE643316 on magnetically levitated trains, filed by Hermann Kemper in 1934.



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standssteuerorgane sind mit den Schwebewagen fest verbundene Einrichtungen; sie werden nahe den Elektromagneten, deren Steuerung sie dienen sollen, gegenüber den Führungsschienen angebracht. Mechanisch sind sie unveränderlich, jedoch ändern sich ihre elektrischen Eigenschaften mit der Größe ihres Abstandes von den Führungsschienen. Werden solche Organe in Stromkreise eingeschaltet, so ändert sich deren elektrischer Zustand mit der Änderung ihrer elektrischen Eigenschaften. Dies läßt sich nun mit Hilfe der heutigen Mittel der Elektronentechnik zu einer genügend trägheitsfreien Steuerung für die Ströme der Schwebewagenmagnete ausbilden.

Die Grundform der Schwebebahn wird näher erläutert durch die Abb. 1 bis 3, die eine eiserne Führungsschiene 2 und ein Fahrzeug 3 in Querschnitt (Abb. 1), Seitenansicht (Abb. 2) und Draufsicht (Abb. 3) andeuten, wobei in der Darstellung bei der letzten Abbildung die Führungsschiene fortgelassen ist.

In diesen Abbildungen sind Kraftlinien 1 der Magnetfelder angegeben, die die Zugkräfte erzeugen, welche das Fahrzeug 3 der Schwebebahn, den Schwebewagen, entgegen der Schwerkraft in der Schwebe erhalten in einem passenden, innerhalb gewisser zulässiger Grenzen schwankenden Abstand von der oberhalb des Wagens gelegenen Führungsschiene 2. Die Magnetfelder werden von mehreren Elektromagneten 4, 5, 6, 7 erzeugt, die oben an dem Fahrzeug befestigt und über seine ganze Länge gestreckt sind. Die Pole der Magnete und die fortlaufende eiserne Führungsschiene entsprechen einander in ihren Abmessungen. Eine Unterteilung der magnetischen Kräfte durch Anbringung mehrerer einzelner Elektromagnete und deren Verteilung auf verschiedenen Stellen des Schwebewagens, wie sie in geeigneter Ausführungsmöglichkeit in Abb. 3, 4, 5, 6, 7 angegeben ist, ist erforderlich, um jeweils die richtige Lage des Schwebewagens zu den Führungsschienen und ein einwandfreies Schweben zu gewährleisten. Die Stromstärken sind für die einzelnen Elektromagnete gesondert zu regeln, wofür später geeignete Wege aufgezeigt werden.

Infolge der schwebenden Aufhängung benötigen die Schwebewagen zur Fortbewegung keine Räder. Es entfällt jede körperliche Berührung zwischen dem Schwebewagen und den Führungsschienen. Der Fahrwiderstand der rollenden Reibung, der bei der Eisenbahn hinsichtlich Fahrschienenabnutzung und Energieverbrauch eine erhebliche Rolle spielt, fällt hier fort. Statt dessen erfordert bei der Schwebebahn der Schwebevorgang elektrische Energie; der Verbrauch hierfür ist aber insbesondere für hohe Fahrgeschwindigkeiten bedeutend geringer als unter gleichen Bedingungen der Energieverbrauch der Eisenbahn für die Überwindung der rollenden Reibung. Aus dieser Sachlage und den besonderen anderen Grundeigenschaften der Schwebebahn ergeben sich folgende wesentliche technische Fortschritte:

a) Die Fahrt auf der Schwebebahn kann vollkommen geräuschlos und stoßfrei gestaltet werden.

b) Die Fahrwiderstände verringern sich für hohe Fahrgeschwindigkeiten.

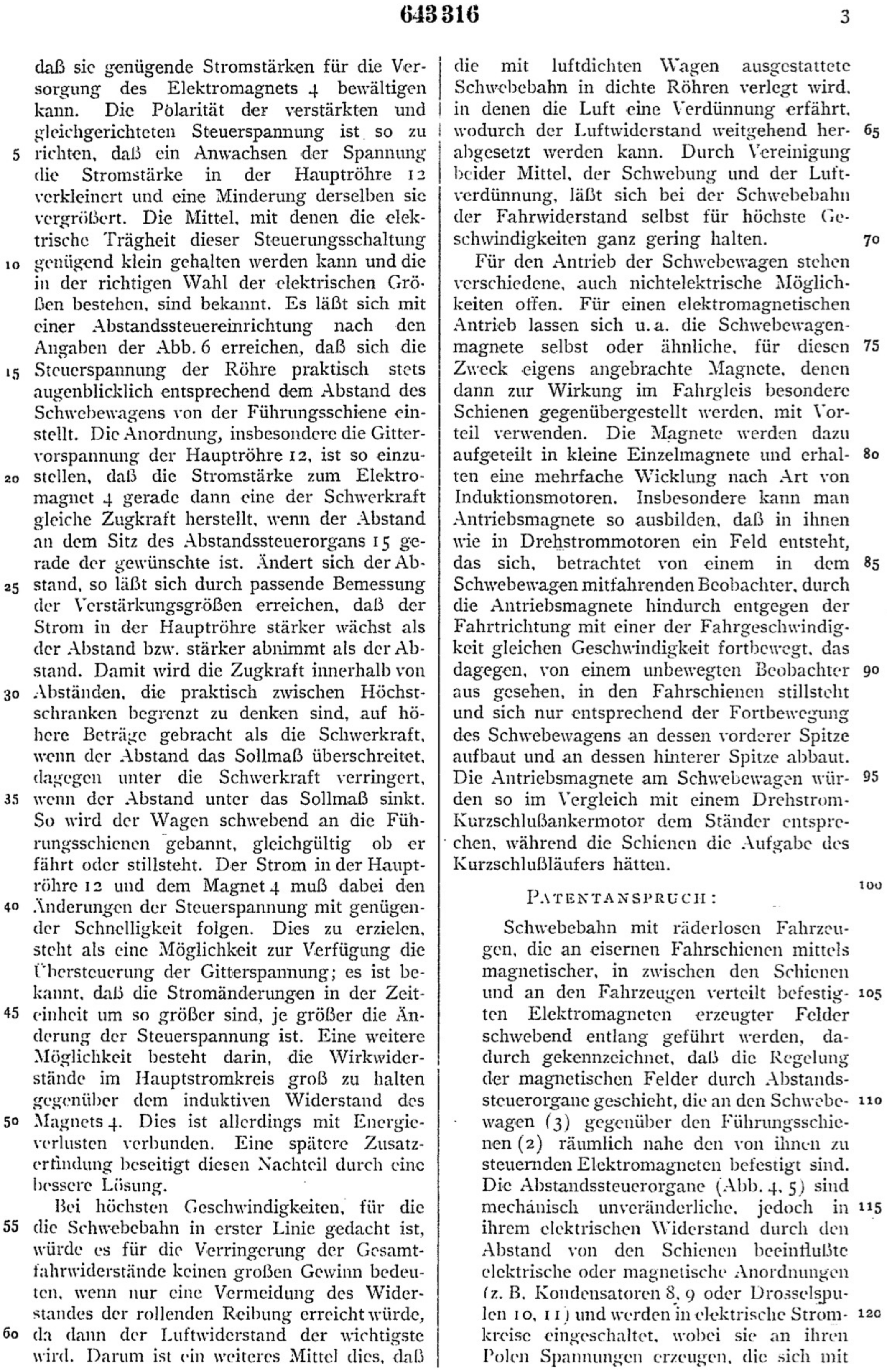
c) Die Abnutzung der Schienen durch das Befahren fällt fort.

d) Es sind Fahrgeschwindigkeiten erreichbar, die mehrfach so hoch sind als die, welche man bei den Eisenbahnen heute kennt.

Abb. 4 und 5 geben Beispiele für die Abstandssteuerorgane. Abb. 4 deutet ein Abstandssteuerorgan an, dessen Kapazität vom Abstand zwischen Schwebewagen 3 und Führungsschiene 2 abhängt. Es besteht aus zwei isoliert am Schwebewagen befestigten Platten 8, 9 mit Stromzuführungsleitungen. Ersichtlich schließt sich ein dielektrischer Verschiebungsstrom zwischen den Platten bei geeigneter Formgebung in der Hauptsache über das Metall der Schiene 2. Die Platten bilden also einen Kondensator, dessen Kapazität mit geringer werdendem Abstand zwischen Schwebewagen und Schiene wächst, umgekehrt sich mindert. In Abb. 5 ist das Abstandssteuerorgan ein kleinerer, am Schwebewagen 3 befestigter Elektromagnet, bei dem sich die seinen Kern 10 durchsetzenden Kraftlinien in erster Linie über das Eisen der Schiene 2 schließen. Wird solch ein Elektromagnet mit seiner Wicklung 11 in einen Stromkreis geschaltet, so stellt er offenbar darin eine Induktivität dar, deren Größe mit Annäherung des Schwebewagens an die Führungsschiene wächst, mit Entfernung sich jedoch mindert.

Abb. 6 zeigt nun den grundsätzlichen Schaltungsaufbau für die Regelung der Stromstärke in einem der Elektromagnete, beispielsweise 4. Es ist als Abstandssteuerorgan 15 an einen Kondensator nach Abb. 4 gedacht. Dieser Kondensator ist mit einem Widerstand 14 in Reihe an eine konstante Wechselspannung 16 hoher Frequenz gelegt. Der Spannungsabfall am Widerstand 14 steigt nun mit Annäherung des Schwebewagens an die Schiene und fällt mit sich vergrößernder Entfernung. Die Spannung an dem Widerstand 14 wird durch eine mit bekannten Mitteln der Elektronentechnik aufzubauende Verstärker- und Gleichrichteranordnung 13 verstärkt und gleichgerichtet und dann zur Gittersteuerung einer Hauptröhre 12 verwendet, die so bemessen ist,

Figure C.128: German patent DE643316 on magnetically levitated trains, filed by Hermann Kemper in 1934.



daß sie genügende Stromstärken für die Versorgung des Elektromagnets 4 bewältigen kann. Die Polarität der verstärkten und gleichgerichteten Steuerspannung ist so zu richten, daß ein Anwachsen der Spannung die Stromstärke in der Hauptröhre 12 verkleinert und eine Minderung derselben sie vergrößert. Die Mittel, mit denen die elektrische Trägheit dieser Steuerungsschaltung genügend klein gehalten werden kann und die in der richtigen Wahl der elektrischen Größen bestehen, sind bekannt. Es läßt sich mit einer Abstandssteuereinrichtung nach den Angaben der Abb. 6 erreichen, daß sich die Steuerspannung der Röhre praktisch stets augenblicklich entsprechend dem Abstand des Schwebewagens von der Führungsschiene einstellt. Die Anordnung, insbesondere die Gittervorspannung der Hauptröhre 12, ist so einzustellen, daß die Stromstärke zum Elektromagnet 4 gerade dann eine der Schwerkraft gleiche Zugkraft herstellt, wenn der Abstand an dem Sitz des Abstandssteuerorgans 15 gerade der gewünschte ist. Ändert sich der Abstand, so läßt sich durch passende Bemessung der Verstärkungsgrößen erreichen, daß der Strom in der Hauptröhre stärker wächst als der Abstand bzw. stärker abnimmt als der Abstand. Damit wird die Zugkraft innerhalb von Abständen, die praktisch zwischen Höchstschranken begrenzt zu denken sind, auf höhere Beträge gebracht als die Schwerkraft, wenn der Abstand das Sollmaß überschreitet, dagegen unter die Schwerkraft verringert, wenn der Abstand unter das Sollmaß sinkt. So wird der Wagen schwebend an die Führungsschienen gebannt, gleichgültig ob er fährt oder stillsteht. Der Strom in der Hauptröhre 12 und dem Magnet 4 muß dabei den Änderungen der Steuerspannung mit genügender Schnelligkeit folgen. Dies zu erzielen, steht als eine Möglichkeit zur Verfügung die Übersteuerung der Gitterspannung; es ist bekannt, daß die Stromänderungen in der Zeiteinheit um so größer sind, je größer die Änderung der Steuerspannung ist. Eine weitere Möglichkeit besteht darin, die Wirkwiderstände im Hauptstromkreis groß zu halten gegenüber dem induktiven Widerstand des Magnets 4. Dies ist allerdings mit Energieverlusten verbunden. Eine spätere Zusatzerfindung beseitigt diesen Nachteil durch eine bessere Lösung.

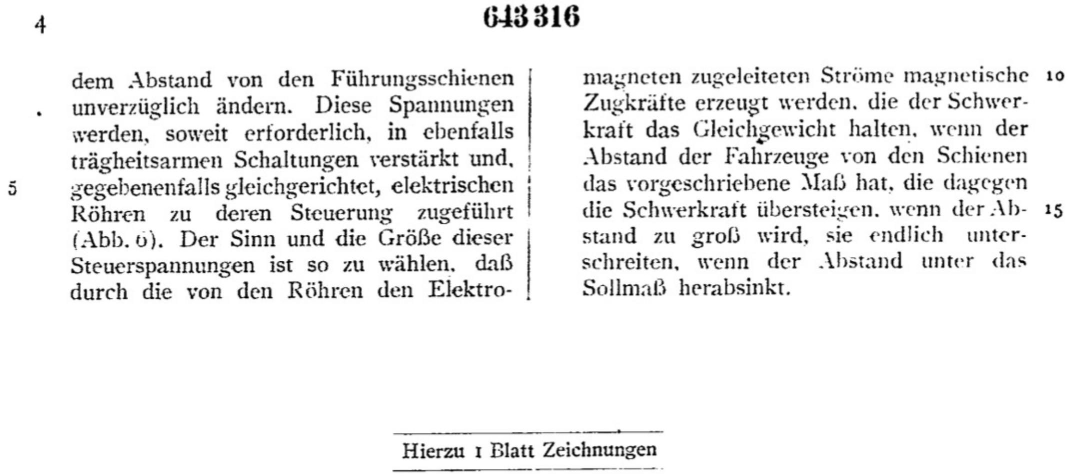
Bei höchsten Geschwindigkeiten, für die die Schwebebahn in erster Linie gedacht ist, würde es für die Verringerung der Gesamtfahrwiderstände keinen großen Gewinn bedeuten, wenn nur eine Vermeidung des Widerstandes der rollenden Reibung erreicht würde, da dann der Luftwiderstand der wichtigste wird. Darum ist ein weiteres Mittel dies, daß die mit luftdichten Wagen ausgestattete Schwebebahn in dichte Röhren verlegt wird, in denen die Luft eine Verdünnung erfährt, wodurch der Luftwiderstand weitgehend herabgesetzt werden kann. Durch Vereinigung beider Mittel, der Schwebung und der Luftverdünnung, läßt sich bei der Schwebebahn der Fahrwiderstand selbst für höchste Geschwindigkeiten ganz gering halten.

Für den Antrieb der Schwebewagen stehen verschiedene, auch nichtelektrische Möglichkeiten offen. Für einen elektromagnetischen Antrieb lassen sich u. a. die Schwebewagenmagnete selbst oder ähnliche, für diesen Zweck eigens angebrachte Magnete, denen dann zur Wirkung im Fahrgleis besondere Schienen gegenübergestellt werden, mit Vorteil verwenden. Die Magnete werden dazu aufgeteilt in kleine Einzelmagnete und erhalten eine mehrfache Wicklung nach Art von Induktionsmotoren. Insbesondere kann man Antriebsmagnete so ausbilden, daß in ihnen wie in Drehstrommotoren ein Feld entsteht, das sich, betrachtet von einem in dem Schwebewagen mitfahrenden Beobachter, durch die Antriebsmagnete hindurch entgegen der Fahrtrichtung mit einer der Fahrgeschwindigkeit gleichen Geschwindigkeit fortbewegt, das dagegen, von einem unbewegten Beobachter aus gesehen, in den Fahrschienen stillsteht und sich nur entsprechend der Fortbewegung des Schwebewagens an dessen vorderer Spitze aufbaut und an dessen hinterer Spitze abbaut. Die Antriebsmagnete am Schwebewagen würden so im Vergleich mit einem Drehstrom-Kurzschlußankermotor dem Ständer entsprechen, während die Schienen die Aufgabe des Kurzschlußläufers hätten.

PATENTANSPRUCH:

Schwebebahn mit räderlosen Fahrzeugen, die an eisernen Fahrschienen mittels magnetischer, in zwischen den Schienen und an den Fahrzeugen verteilt befestigten Elektromagneten erzeugter Felder schwebend entlang geführt werden, dadurch gekennzeichnet, daß die Regelung der magnetischen Felder durch Abstandssteuerorgane geschieht, die an den Schwebewagen (3) gegenüber den Führungsschienen (2) räumlich nahe den von ihnen zu steuernden Elektromagneten befestigt sind. Die Abstandssteuerorgane (Abb. 4, 5) sind mechanisch unveränderliche, jedoch in ihrem elektrischen Widerstand durch den Abstand von den Schienen beeinflußte elektrische oder magnetische Anordnungen (z. B. Kondensatoren 8, 9 oder Drosselspulen 10, 11) und werden in elektrische Stromkreise eingeschaltet, wobei sie an ihren Polen Spannungen erzeugen, die sich mit

Figure C.129: German patent DE643316 on magnetically levitated trains, filed by Hermann Kemper in 1934.



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dem Abstand von den Führungsschienen unverzüglich ändern. Diese Spannungen werden, soweit erforderlich, in ebenfalls trägheitsarmen Schaltungen verstärkt und, gegebenenfalls gleichgerichtet, elektrischen Röhren zu deren Steuerung zugeführt (Abb. 6). Der Sinn und die Größe dieser Steuerspannungen ist so zu wählen, daß durch die von den Röhren den Elektromagneten zugeleiteten Ströme magnetische Zugkräfte erzeugt werden, die der Schwerkraft das Gleichgewicht halten, wenn der Abstand der Fahrzeuge von den Schienen das vorgeschriebene Maß hat, die dagegen die Schwerkraft übersteigen, wenn der Abstand zu groß wird, sie endlich unterschreiten, wenn der Abstand unter das Sollmaß herabsinkt.

Hierzu 1 Blatt Zeichnungen

Figure C.130: German patent DE643316 on magnetically levitated trains, filed by Hermann Kemper in 1934.

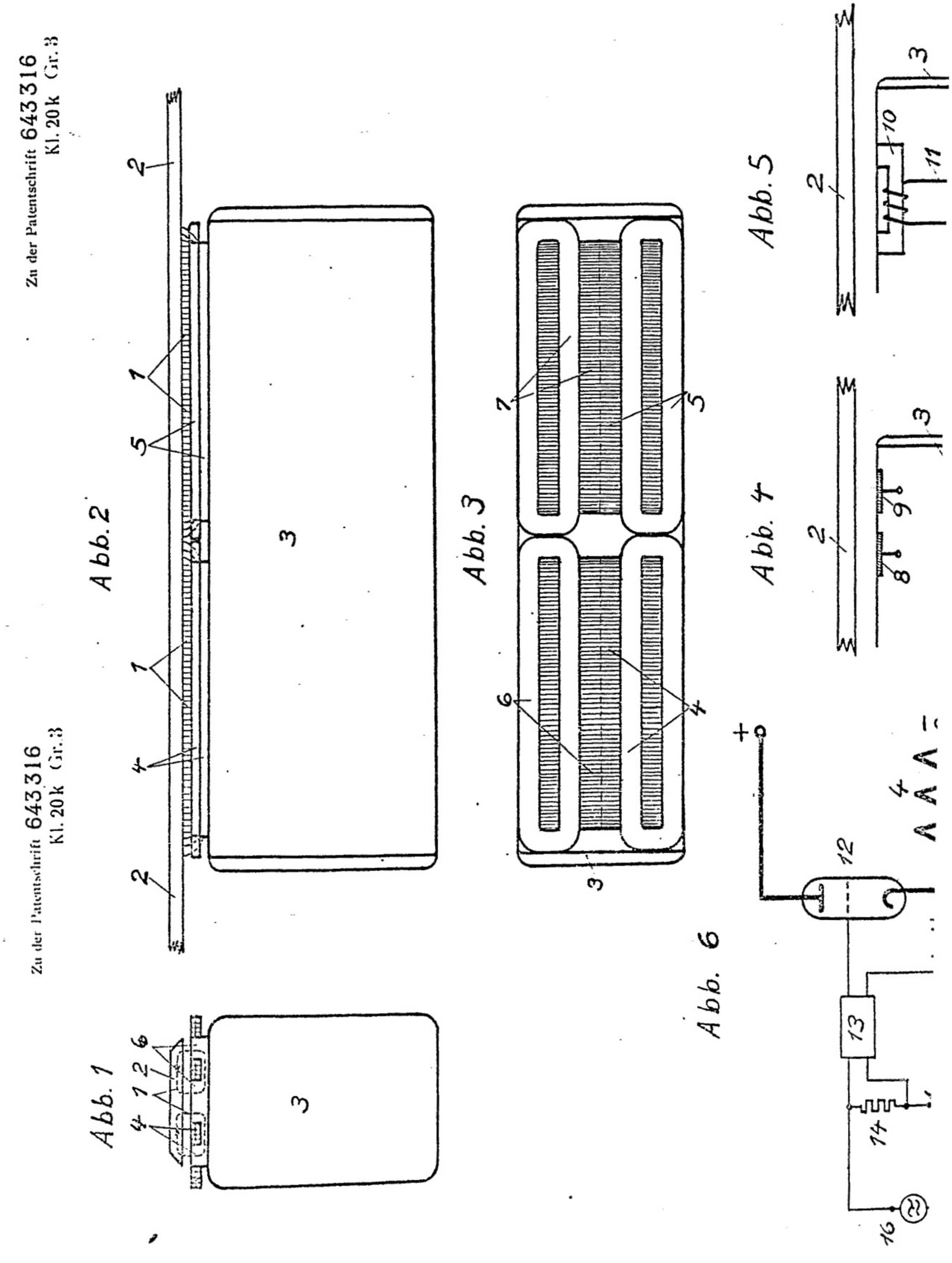
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Figure C.131: German patent DE643316 on magnetically levitated trains, filed by Hermann Kemper in 1934.

[Multiple groups of German-speaking scientists developed and demonstrated electromagnetic railguns. The best-documented group was led by Joachim Hänsler (German, 19??–19??), but there were other groups as well. Manfred von Ardenne led a large program that was actually mass-producing railguns for battlefield use. The following documents describe some of the wartime work on railguns.]

CIOS XXXI-59. *Gesellschaft für Geratebau.* pp. 3–4.

The above-named target, which was formerly post of the Heereswaffenamt in Berlin, is an experimental station for the study of electrical means for accelerating projectiles. Although it has not yet produced practical results (only laboratory tests have so far been made), the project merits the attention of Army Ordnance.

Attempts to replace powder by electricity are not new. Many schemes were tried by this laboratory, and the method developed during the last war by Fauchon-Villiplee was finally adopted. The great difficulty is, of course, the developing of enough power to launch a projectile. It has been possible here to accelerate a body weighing 12 g to 1100 m/sec. in a 2-meter tube, which corresponds to an acceleration of about 30,000 times gravity. Coupling two such tubes was not very successful, 1200 m/sec. being obtained.

The projectile is accelerated by a "linear motor", which consists in its simplest form of two conductors (parallel rails) across which the projectile completes the circuit by means of fins attached to its rear. When current passes through the circuit, the projectile travels forward. The conventional electromagnetic equations apply to the process.

The principle was demonstrated to me in a 50 cm. tube with the projectiles submitted with this report. After firing, the edges of the copper fins are melted. The muzzle velocity in the demonstration was low.

The difficulties in the way of a suitable power source are formidable. Lead-sulfuric acid storage batteries with very thin plates are used for experimental work; 9000 kW is available from this source. Condensers to give 2000 volts with 24,000 microfarads capacity are also installed.

The great advantages of the electrical scheme would be (1) gun barrel unnecessary (2) higher velocity than is attainable with powder (3) higher efficiency than with powder (4) lower energy cost than with powder.

Work was about to begin on a projectile 1 cm. in diameter, weighing 60 or 70 grams. An A.A. gun was planned (see the attached report), which would have required a maximum current of 1,500,000 amperes at 1300 volts to launch a 4 cm. projectile. The power was to be obtained from three unipolar generators weighing 150 tons each.

Projectiles electrically launched would have to be fin-stabilized since they could not be rotated. Fin-stabilization presupposes wind-tunnel work, which explains the close cooperation between this target and the Peenemünde wind tunnel personnel at Kochel.

[The remaining pages of CIOS XXXI-59 include an English translation of a few pages of Joachim Hänsler's theoretical calculations.]

CIOS XXXI-84. ***German and Danish Industries.*** **pp. 103–105**

REPORT ON VISIT TO GESELLSCHAFT FÜR GERÄTEBAU m.b.H.
AT KLAIS NEAR MITTENWALD

The above firm moved from Berlin in April 1944, and succeeded in establishing itself, with all of its equipment, in a house near Mittenwald. The entire staff (of 30 people) was brought from Berlin.

The object of the undertaking was the development of a high velocity electro-magnetic gun. Dr. Hänsler, head of the firm, was interviewed. It is understood that Wing Commander Day, RAF, team leader of CIOS trip No. 415, had visited the firm on the 13th June, 1945, and took copies of two reports, giving an account of theory of operation of the gun, and of experiments carried out between the 4th September 1944, and the 31st May 1945. We also took copies of these reports.

Dr. Hänsler began by giving reasons why the development of a high velocity electro-magnetic gun was desirable. Theoretical calculations, supported by practical evidence, had led to the surprising conclusion that the charge of hitting with a heavy A.A. gun (e.g. 88 mm) was greater with a direct action fuse than with a time fuse. If a direct action fuse is used, a small projectile, containing a charge of only 500 gm, is sufficient to destroy an aircraft, whereas with a time fuse, as large a shell as possible is required. If, therefore, a means of firing a small shell with a high muzzle velocity (m-v) could be developed, a large economy could be effected. The rate of fire would also be greater than with a heavy gun.

A second reason given by Dr. Hänsler for requiring a high m-v, was that to engage a high speed aircraft flying at 12 or 15 km, it is necessary to open fire at a range of 20 or 30 km at least, and a high m-v is necessary to reach this range.

There is a theoretical upper limit, of 2,800 m/sec to the velocity attainable, using explosive propellant, and the maximum ever achieved in practise is 1600 m/s. An m-v of 2,000 m/sec or more is required. Dr. Hänsler had in mind a shell of diameter 4 cm and length 80 cm, unrotated and stabilised by fins.

Various types of electro-magnetic guns have been described in the literature. At first, Dr. Hänsler made some experiments with a solenoid gun, but soon dropped this system for the one described below. We were shown photographs of solenoids which had burst in operation.

The method of propulsion finally adopted was to have two parallel copper conductors, running the length of the gun, to which a potential was applied. A sliding copper bridge was propelled along these conductors under the action of the electro-mechanical forces resulting from the very heavy currents which flowed.

In the model guns made up at the present time there was also a “field winding” consisting of a single turn of heavy copper running the length of the gun, in the same plane as the conductors. This can be connected either in series or in parallel with the conductors. Use is made of iron to concentrate the magnetic field. In the next experimental gun, which is designed, but not built, the field winding will be omitted, and no magnetic material will be used, except for an outer sheath.

We were shown an experimental gun 2 m long which was capable of firing a 10 gm projectile with a velocity of 1200 m/s. This was not in operation, but if permission were given, could be made to work in two weeks time. We were given a demonstration with a model gun 50 cm long, working off two 12 v car batteries. This was said to given an m-v of 60 m/s.

Power for the experimental 2 m gun was obtained from a battery of 1,000 12 v accumulators of standard lead-acid type, each capable of giving 9 kw for a short time.

Development work was going on at Friemann and Wolf at Zwickau with a view to producing a special type of accumulator capable of giving a high current for a short time, the principle being to increase the surface area of the plates as much as possible. The firm were making 50 of a type that would give 20,000 to 40,000 amps for one tenth to one hundredth part of a second: the size of this accumulator, which was of the lead acid type, was to be 20 x 17 x 40 cm. These were not however, delivered when the war ended.

The use of condensers as a source of power had also been considered and a battery of condensers (24,000 mfd, 200 v) was installed in the laboratory. Little work had been done on this method, but Herr Muck of Staffelsee near Murnau, was said to have ideas on the subject. It was stressed that the power supplies used up to the present were suitable for laboratory experiments only. Work had just been started on a rotating machine which, it was hoped, would be capable of development into a practical device.

Briefly, this consisted of two rotating copper rings, like slip rings, but cut and insulated at one place. These rings were joined together on one side of the cut. Each ring had a copper brush bearing on it, from which the power output was taken. If, when the rings were rotating, a pulse of current from a condenser were applied at the correct time, a magnetic field would be built up rapidly and the machine would deliver power for one rotation. This machine had not yet been completed.

The 2 m gun referred to above, behaved in accordance with theory, as regards relation between field and conductor currents and m-v. When an attempt to put two together and make a 4 m gun was made, however, the expected increase in m-v was not obtained.

The next gun projected was to fire a 6.5 kg projectile, which would be so designed that the propelling bridge would drop off as soon as it left the gun.

In addition to work on the gun itself, a number of associated investigations were being carried out: they were

(1) Development of a conductor with a low self inductance for connecting the gun to the power supply. This was obtained by mounting the two conductors very close together with a layer of insulating material between.

(2) Development of a method of measuring self inductances less than 10^{-5} henries. The method was to form a tuned circuit including the self inductance, shock excite it, and record the resulting damped wave on an oscillograph.

(3) Development of an iron inductance shunt for measuring heavy currents. The principle was as in one (1)

The laboratory was well equipped for measuring m-v. The method was to fire the projectile through wire screens, and record the resulting electrical impulses on a moving film using a high speed loop oscilloscope. Current waveforms in the gun could be recorded at the same time. We were shown an electrical counter device which would give a direct reading of transit time in milli-secs. This had not been designed by the firm but had been purchased. It was about to be put into use in conjunction with a pair of photo-electric devices for recording the passage of the projectile.

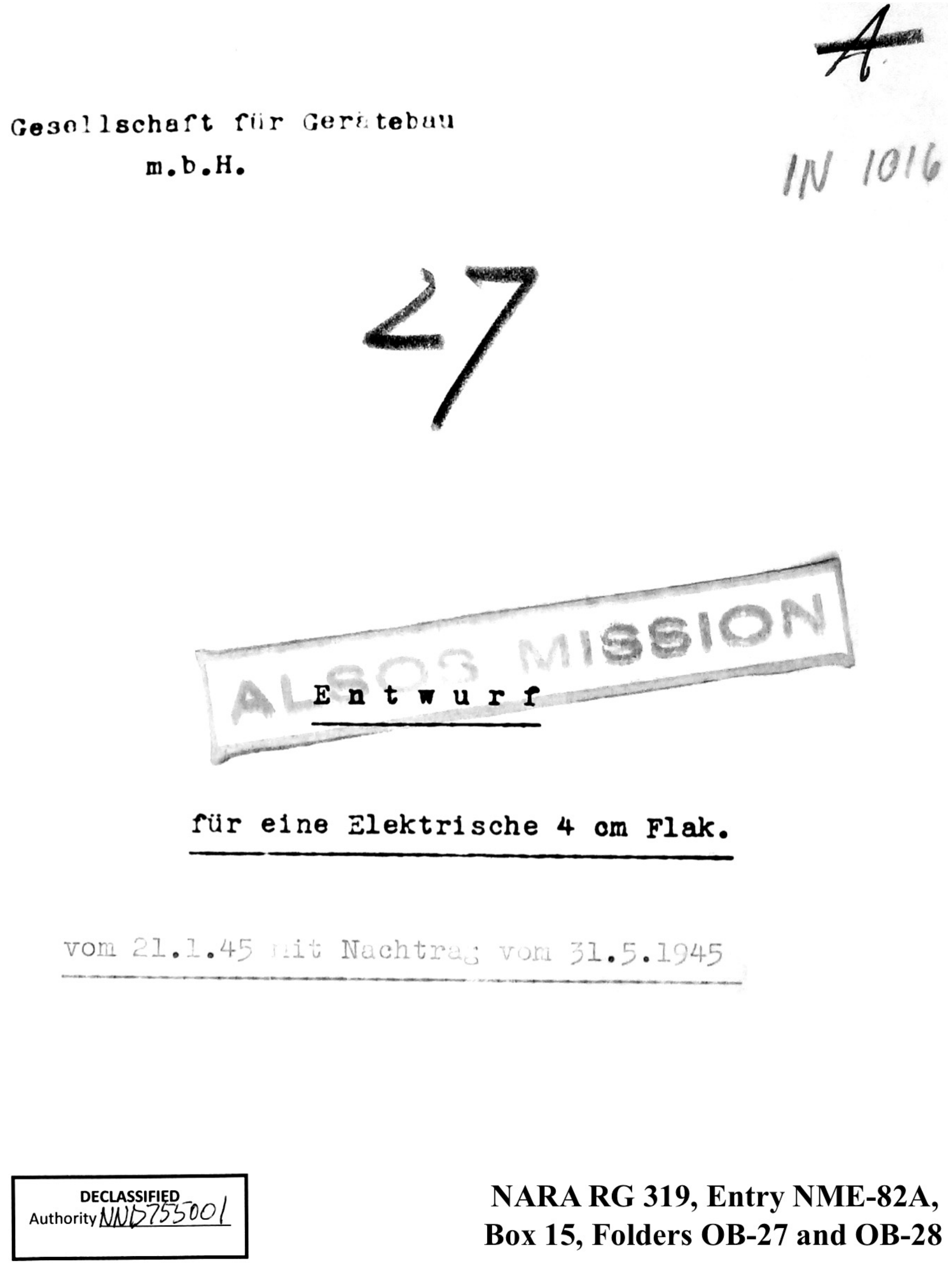
These were two slow motion cameras for photographing the projectile in flight. A high speed oscilloscope using a Cathode Ray tube was being developed.

On the whole we formed the impression that the work being carried out by this firm was very far from having any military application.

Joachim Hänsler. 1945 reports. [NARA RG 319, Entry NM-82A, Box 15, Folders OB-27 and OB-28]

[The copies of Hänsler's reports that were obtained and filed by the U.S. Alsos Mission are quite lengthy and extremely detailed, covering his designs, theoretical calculations, experimental measurements, and photographs of the projectiles that he tested. Please see photos of selected pages from these reports on the following pages.

As documented in these reports and the preceding CIOS reports, Hänsler built and demonstrated electromagnetic railguns capable of launching projectiles at velocities up to 1200 meters/second, or over 3.5 times the speed of sound. As of the time of these reports, he was continuing to develop larger and faster railguns, planning to reach velocities over 2000 meters/second.]



A

Gesellschaft für Gerätebau
m.b.H.

IN 1016

27

ALSOS MISSION

Entwurf

für eine Elektrische 4 cm Flak.

vom 21.1.45 mit Nachtrag vom 31.5.1945

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Figure C.132: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.

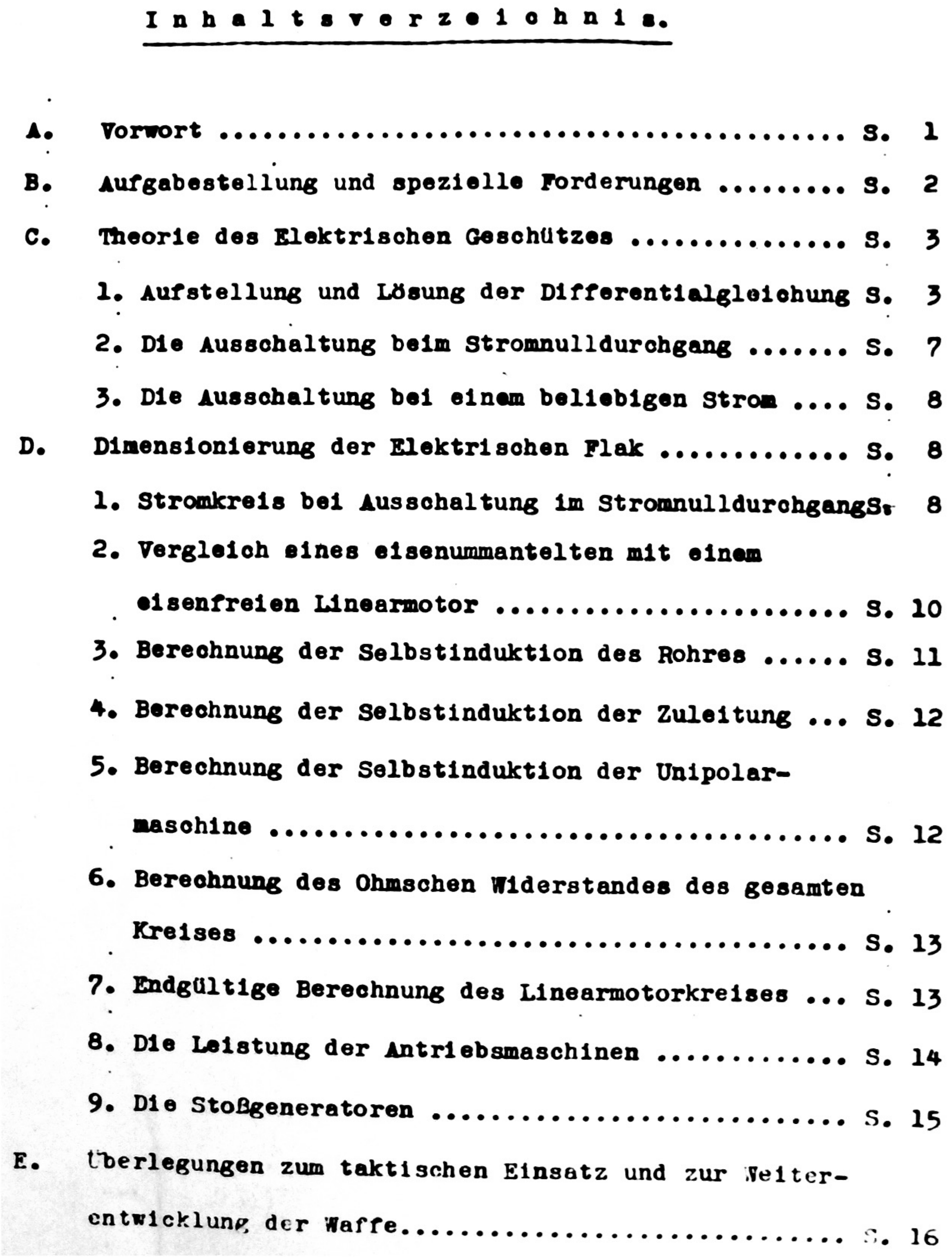

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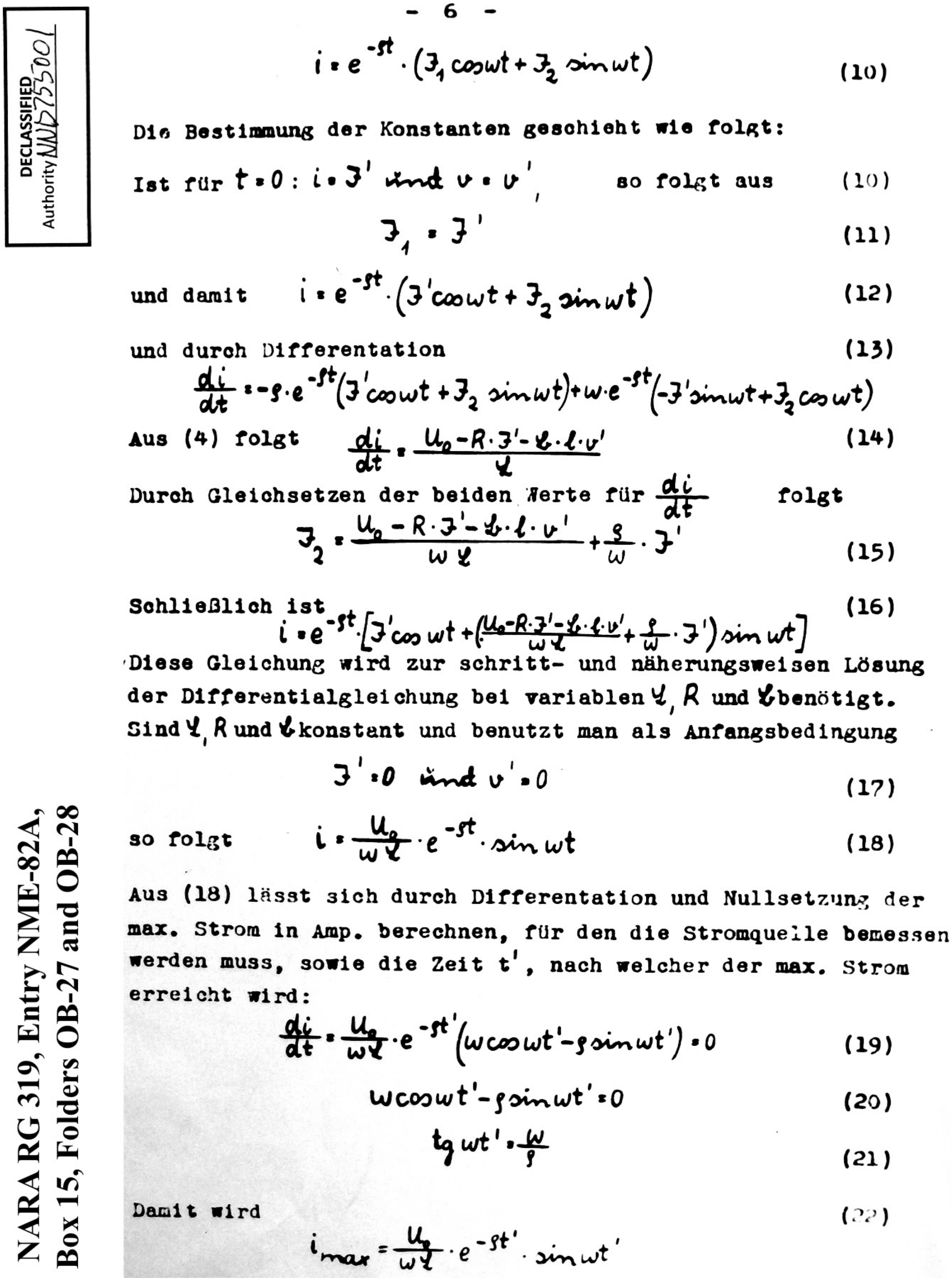
Figure C.133: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.



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- 6 -

$$i = e^{-\varrho t}\cdot\left(\mathfrak{J}_1\cos\omega t + \mathfrak{J}_2\sin\omega t\right) \qquad (10)$$

Die Bestimmung der Konstanten geschieht wie folgt:

Ist für $t = 0$: $i = \mathfrak{J}'$ und $v = v'$, so folgt aus (10)

$$\mathfrak{J}_1 = \mathfrak{J}' \qquad (11)$$

und damit $i = e^{-\varrho t}\cdot\left(\mathfrak{J}'\cos\omega t + \mathfrak{J}_2\sin\omega t\right)$ (12)

und durch Differentation (13)

$$\frac{di}{dt} = -\varrho\cdot e^{-\varrho t}\left(\mathfrak{J}'\cos\omega t + \mathfrak{J}_2\sin\omega t\right) + \omega\cdot e^{-\varrho t}\left(-\mathfrak{J}'\sin\omega t + \mathfrak{J}_2\cos\omega t\right)$$

Aus (4) folgt $\dfrac{di}{dt} = \dfrac{U_0 - R\cdot\mathfrak{J}' - \mathfrak{B}\cdot\ell\cdot v'}{\mathfrak{L}}$ (14)

Durch Gleichsetzen der beiden Werte für $\dfrac{di}{dt}$ folgt

$$\mathfrak{J}_2 = \frac{U_0 - R\cdot\mathfrak{J}' - \mathfrak{B}\cdot\ell\cdot v'}{\omega\mathfrak{L}} + \frac{\varrho}{\omega}\cdot\mathfrak{J}' \qquad (15)$$

Schließlich ist (16)

$$i = e^{-\varrho t}\cdot\left[\mathfrak{J}'\cos\omega t + \left(\frac{U_0 - R\cdot\mathfrak{J}' - \mathfrak{B}\cdot\ell\cdot v'}{\omega\mathfrak{L}} + \frac{\varrho}{\omega}\cdot\mathfrak{J}'\right)\sin\omega t\right]$$

Diese Gleichung wird zur schritt- und näherungsweisen Lösung der Differentialgleichung bei variablen $\mathfrak{L}$, R und $\mathfrak{B}$ benötigt. Sind $\mathfrak{L}$, R und $\mathfrak{B}$ konstant und benutzt man als Anfangsbedingung

$$\mathfrak{J}' = 0 \text{ und } v' = 0 \qquad (17)$$

so folgt $i = \dfrac{U_0}{\omega\mathfrak{L}}\cdot e^{-\varrho t}\cdot\sin\omega t$ (18)

Aus (18) lässt sich durch Differentation und Nullsetzung der max. Strom in Amp. berechnen, für den die Stromquelle bemessen werden muss, sowie die Zeit t', nach welcher der max. Strom erreicht wird:

$$\frac{di}{dt} = \frac{U_0}{\omega\mathfrak{L}}\cdot e^{-\varrho t'}\left(\omega\cos\omega t' - \varrho\sin\omega t'\right) = 0 \qquad (19)$$

$$\omega\cos\omega t' - \varrho\sin\omega t' = 0 \qquad (20)$$

$$\mathrm{tg}\,\omega t' = \frac{\omega}{\varrho} \qquad (21)$$

Damit wird (22)

$$i_{max} = \frac{U_0}{\omega\mathfrak{L}}\cdot e^{-\varrho t'}\cdot\sin\omega t'$$

Figure C.134: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.

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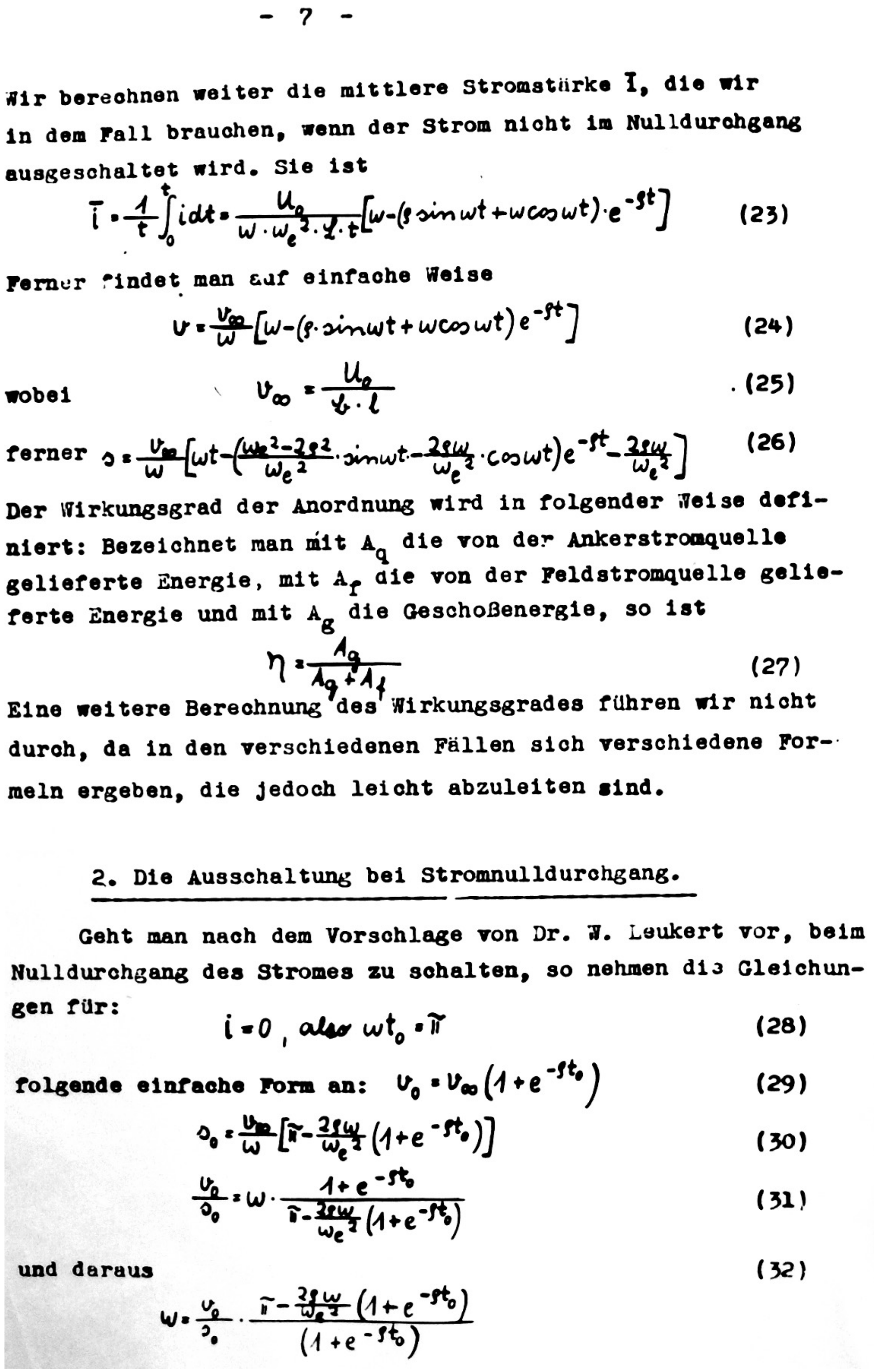

- 7 -

Wir berechnen weiter die mittlere Stromstärke $\bar{I}$, die wir in dem Fall brauchen, wenn der Strom nicht im Nulldurchgang ausgeschaltet wird. Sie ist

$$\bar{i} = \frac{1}{t}\int_0^t i\,dt = \frac{U_e}{\omega\cdot\omega_e^2\cdot\mathcal{L}\cdot t}\left[\omega-(\rho\sin\omega t+\omega\cos\omega t)\cdot e^{-\rho t}\right] \qquad (23)$$

Ferner findet man auf einfache Weise

$$v = \frac{v_\infty}{\omega}\left[\omega-(\rho\cdot\sin\omega t+\omega\cos\omega t)e^{-\rho t}\right] \qquad (24)$$

wobei

$$v_\infty = \frac{U_e}{\mathcal{L}\cdot l} \qquad .(25)$$

ferner $s = \frac{v_\infty}{\omega}\left[\omega t-\left(\frac{\omega_e^2-2\rho^2}{\omega_e^2}\cdot\sin\omega t-\frac{2\rho\omega}{\omega_e^2}\cdot\cos\omega t\right)e^{-\rho t}-\frac{2\rho\omega}{\omega_e^2}\right]$ (26)

Der Wirkungsgrad der Anordnung wird in folgender Weise definiert: Bezeichnet man mit A_q die von der Ankerstromquelle gelieferte Energie, mit A_f die von der Feldstromquelle gelieferte Energie und mit A_g die Geschoßenergie, so ist

$$\eta = \frac{A_g}{A_q+A_f} \qquad (27)$$

Eine weitere Berechnung des Wirkungsgrades führen wir nicht durch, da in den verschiedenen Fällen sich verschiedene Formeln ergeben, die jedoch leicht abzuleiten sind.

2. Die Ausschaltung bei Stromnulldurchgang.

Geht man nach dem Vorschlage von Dr. W. Leukert vor, beim Nulldurchgang des Stromes zu schalten, so nehmen die Gleichungen für:

$$i = 0\,,\ \text{also}\ \omega t_0 = \pi \qquad (28)$$

folgende einfache Form an: $v_0 = v_\infty\left(1+e^{-\rho t_0}\right)$ (29)

$$s_0 = \frac{v_\infty}{\omega}\left[\pi-\frac{2\rho\omega}{\omega_e^2}\left(1+e^{-\rho t_0}\right)\right] \qquad (30)$$

$$\frac{v_0}{s_0} = \omega\cdot\frac{1+e^{-\rho t_0}}{\pi-\frac{2\rho\omega}{\omega_e^2}\left(1+e^{-\rho t_0}\right)} \qquad (31)$$

und daraus (32)

$$\omega = \frac{v_0}{s_0}\cdot\frac{\pi-\frac{2\rho\omega}{\omega_e^2}\left(1+e^{-\rho t_0}\right)}{\left(1+e^{-\rho t_0}\right)}$$

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Figure C.135: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.

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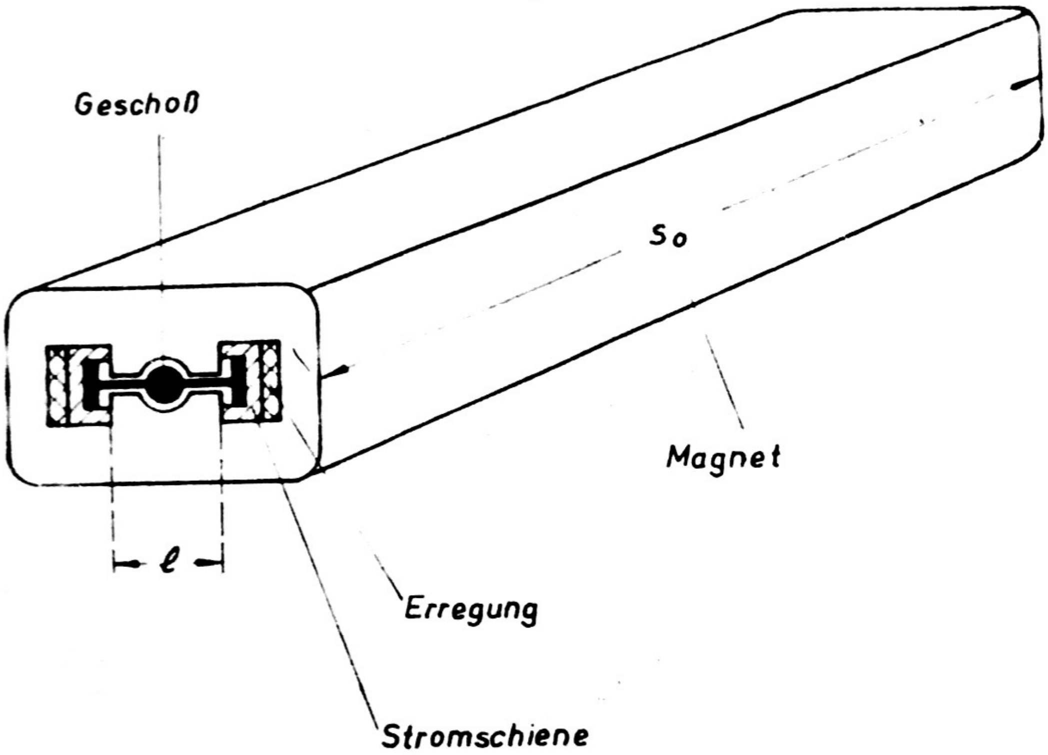
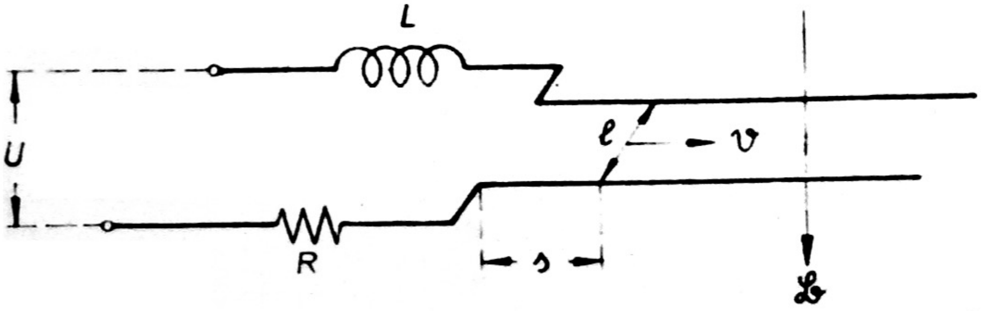

Geschoß
s_0
Magnet
ℓ
Erregung
Stromschiene

Linearmotor
Bild 1


L
U
ℓ
v
R
s
$\mathfrak{L}$

Stromkreis des Linearmotors
Bild 2

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Figure C.136: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.

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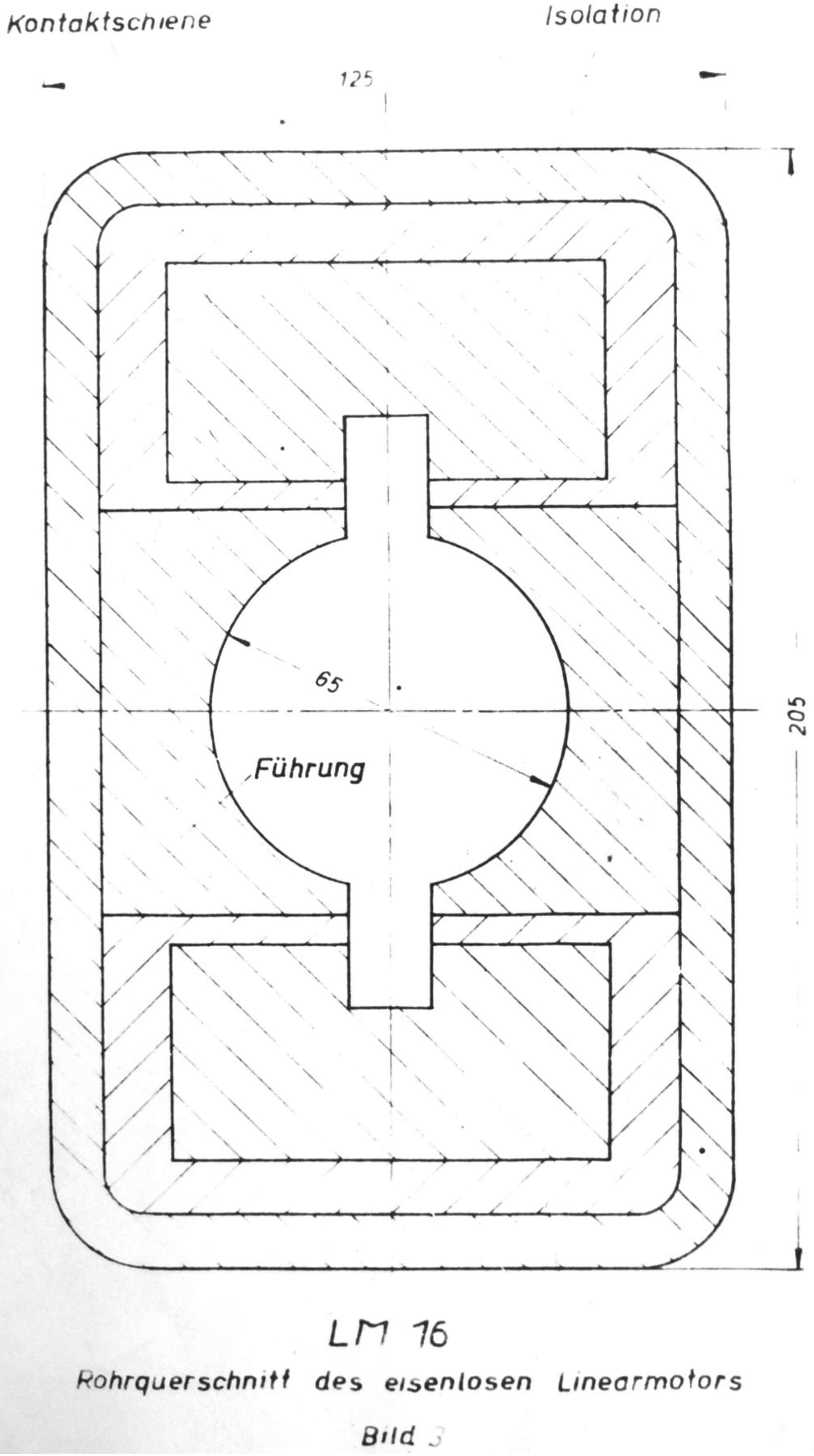
Kontaktschiene
Isolation
125
65
Führung
205
LM 16
Rohrquerschnitt des eisenlosen Linearmotors
Bild 3

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Box 15, Folders OB-27 and OB-28

Figure C.137: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.

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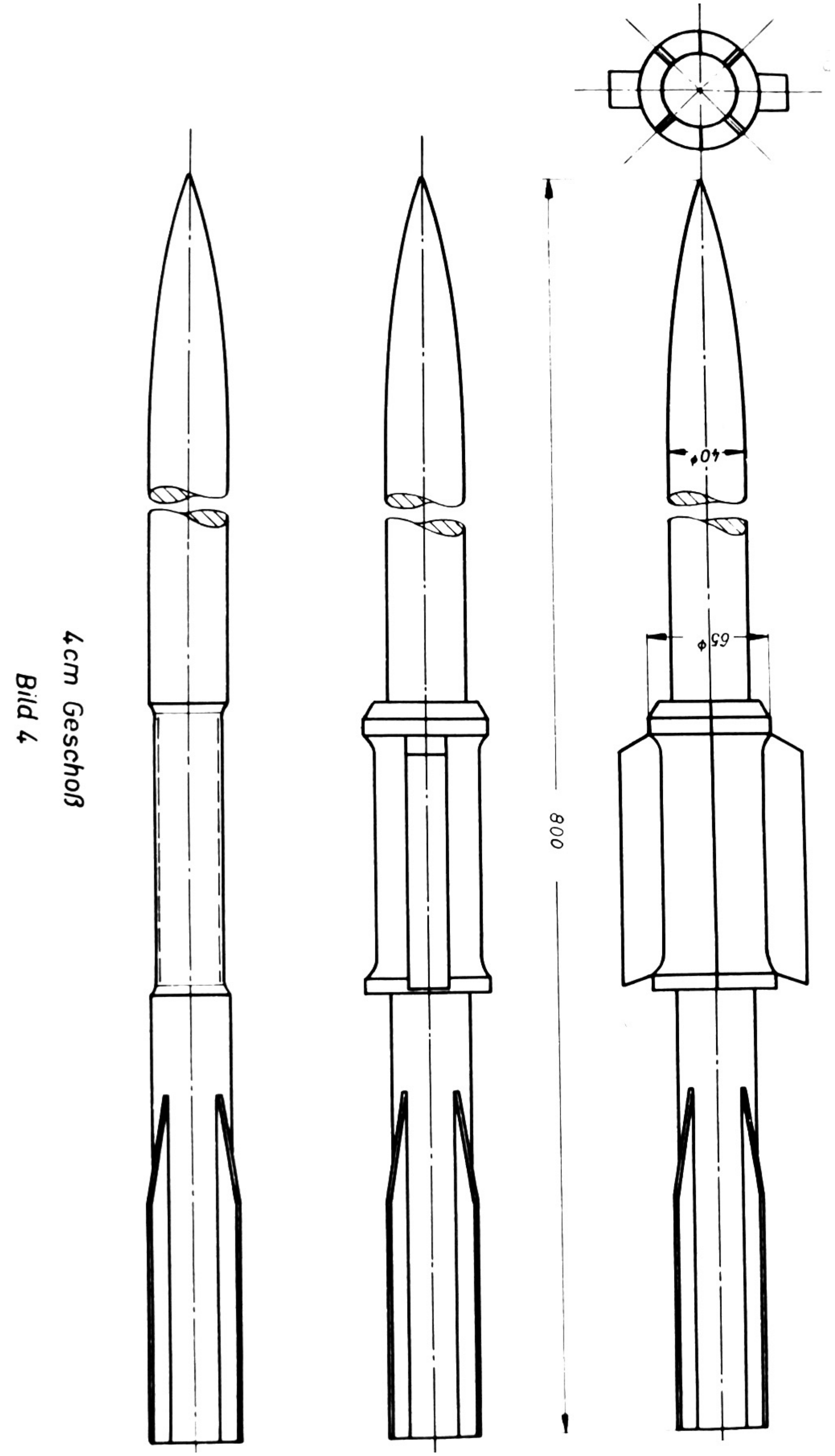
4cm Geschoß
Bild 4
800
φ40
φ65

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Figure C.138: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.

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Box 15, Folders OB-27 and OB-28**

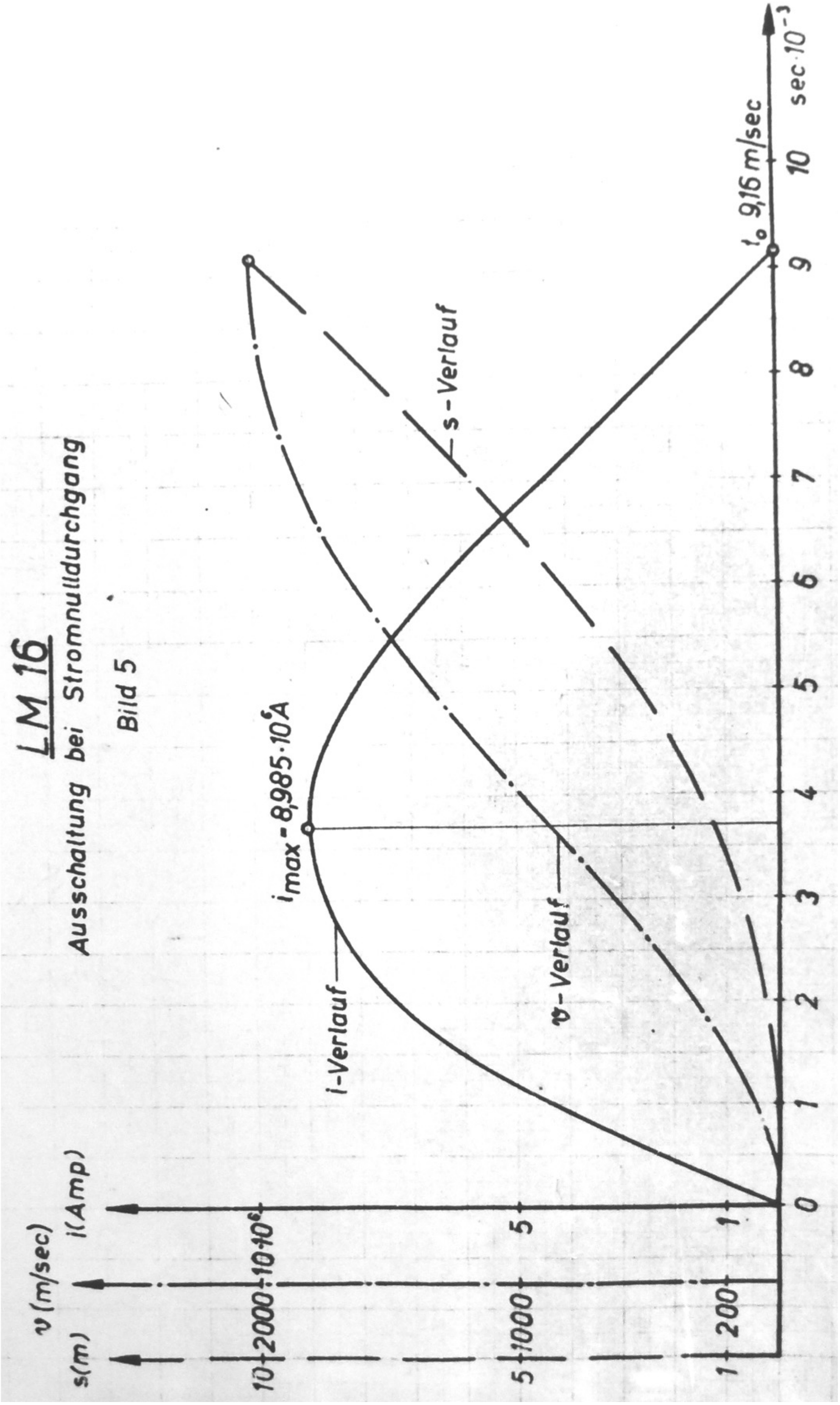

Figure C.139: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.

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**NARA RG 319, Entry NME-82A,
Box 15, Folders OB-27 and OB-28**

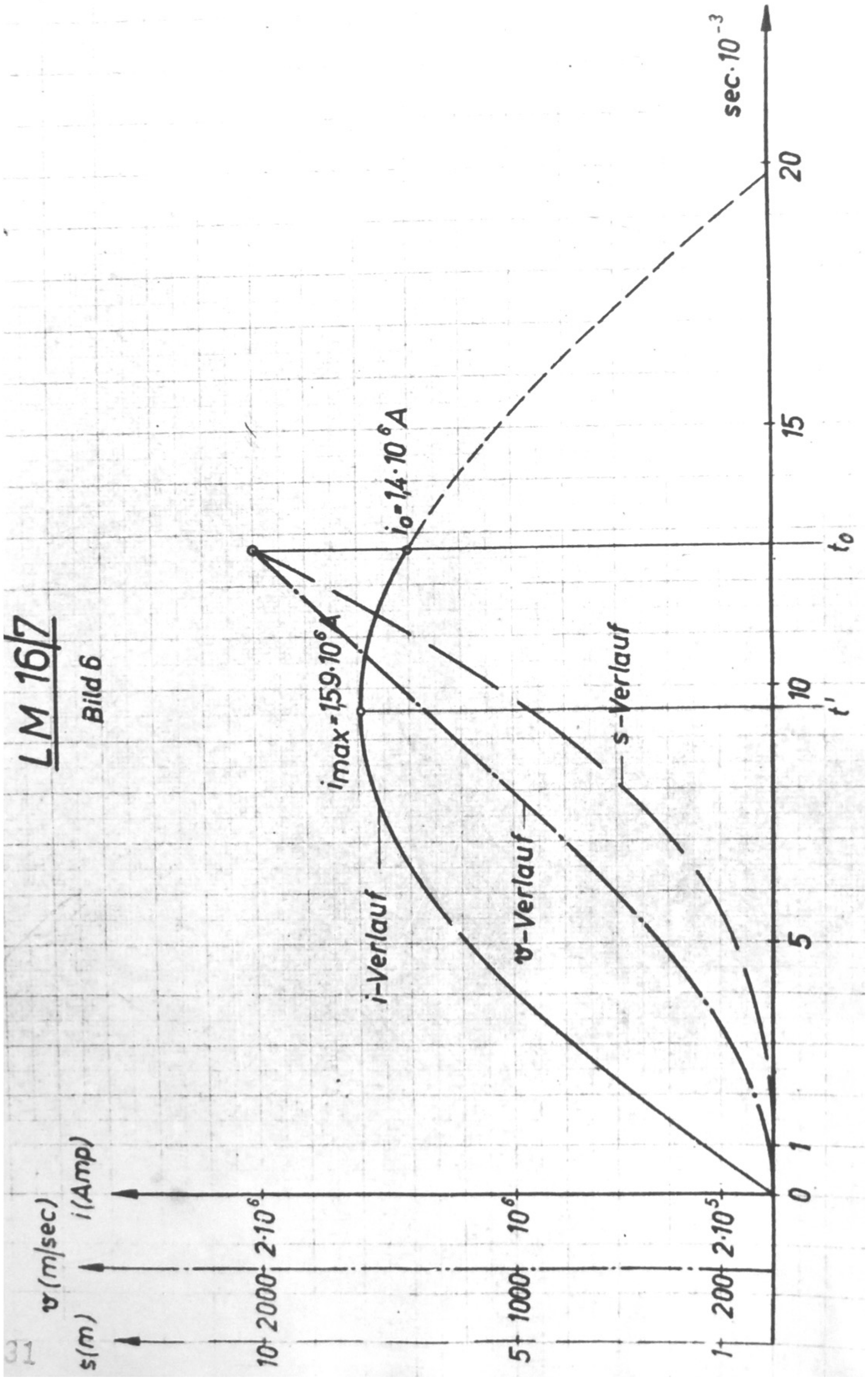
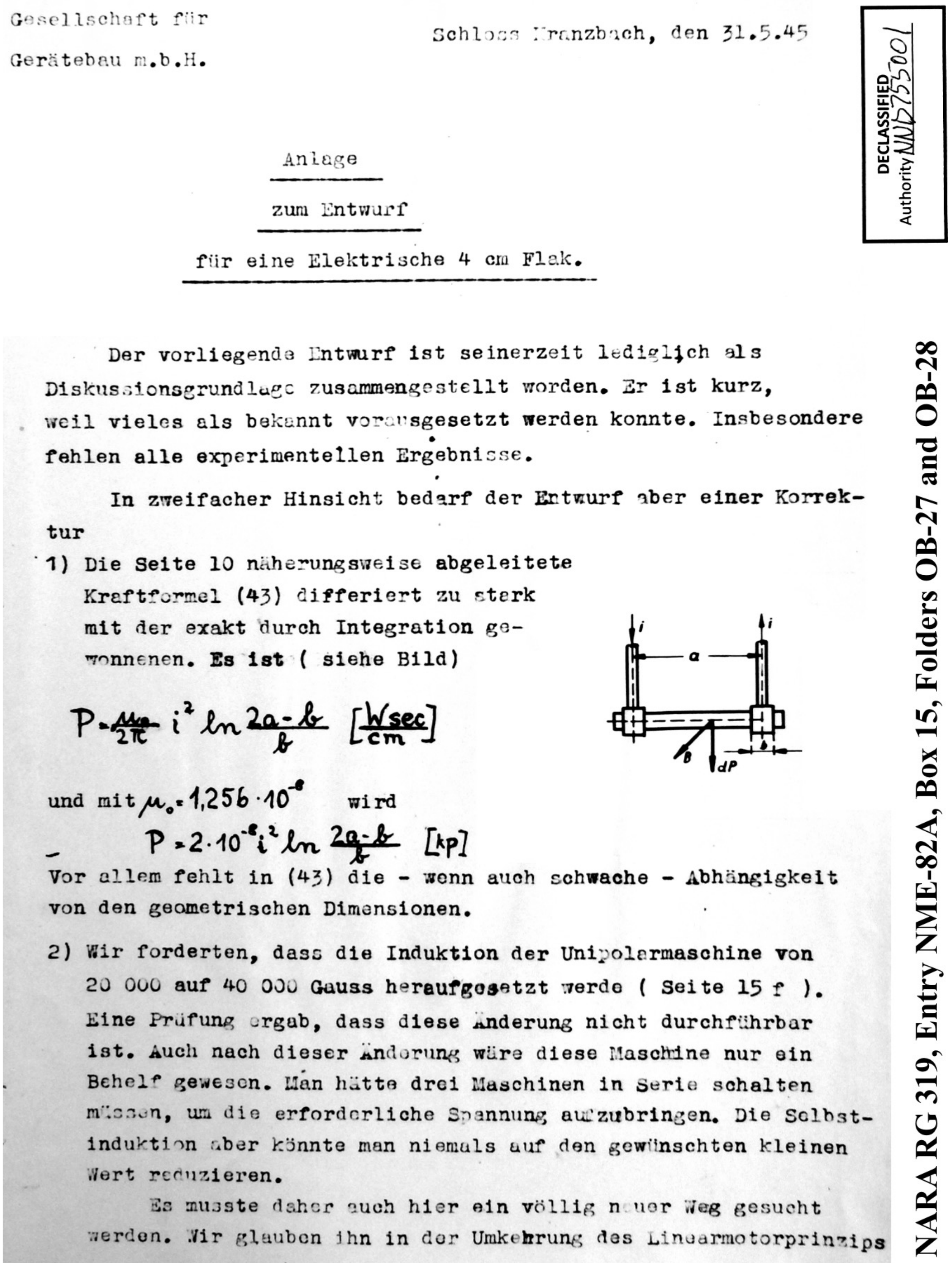


Figure C.140: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.



Gesellschaft für
Gerätebau m.b.H.

Schloss Kranzbach, den 31.5.45

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Anlage

zum Entwurf

für eine Elektrische 4 cm Flak.

Der vorliegende Entwurf ist seinerzeit lediglich als Diskussionsgrundlage zusammengestellt worden. Er ist kurz, weil vieles als bekannt vorausgesetzt werden konnte. Insbesondere fehlen alle experimentellen Ergebnisse.

In zweifacher Hinsicht bedarf der Entwurf aber einer Korrektur

1) Die Seite 10 näherungsweise abgeleitete Kraftformel (43) differiert zu stark mit der exakt durch Integration gewonnenen. Es ist (siehe Bild)

$$P = \frac{\mu_0}{2\pi} i^2 \ln \frac{2a-b}{b} \left[\frac{Wsec}{cm}\right]$$

und mit $\mu_0 = 1{,}256 \cdot 10^{-8}$ wird

$$P = 2 \cdot 10^{-8} i^2 \ln \frac{2a-b}{b} \quad [kp]$$

Vor allem fehlt in (43) die - wenn auch schwache - Abhängigkeit von den geometrischen Dimensionen.

2) Wir forderten, dass die Induktion der Unipolarmaschine von 20 000 auf 40 000 Gauss heraufgesetzt werde (Seite 15 f). Eine Prüfung ergab, dass diese Änderung nicht durchführbar ist. Auch nach dieser Änderung wäre diese Maschine nur ein Behelf gewesen. Man hätte drei Maschinen in Serie schalten müssen, um die erforderliche Spannung aufzubringen. Die Selbstinduktion aber könnte man niemals auf den gewünschten kleinen Wert reduzieren.

Es musste daher auch hier ein völlig neuer Weg gesucht werden. Wir glauben ihn in der Umkehrung des Linearmotorprinzips

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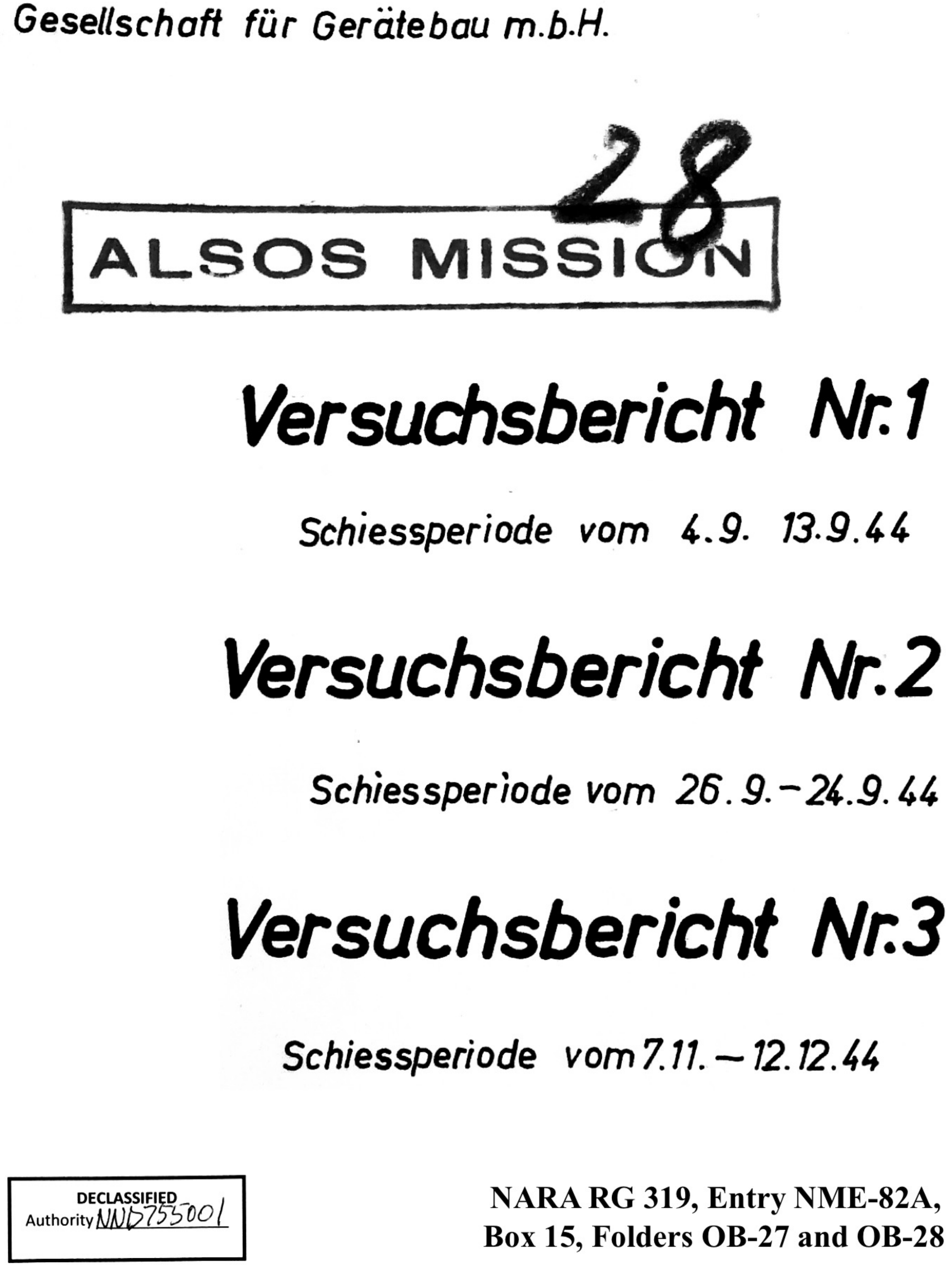
Figure C.141: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.



Gesellschaft für Gerätebau m.b.H.

28

ALSOS MISSION

Versuchsbericht Nr.1

Schiessperiode vom 4.9. 13.9.44

Versuchsbericht Nr.2

Schiessperiode vom 26.9.–24.9.44

Versuchsbericht Nr.3

Schiessperiode vom 7.11.–12.12.44

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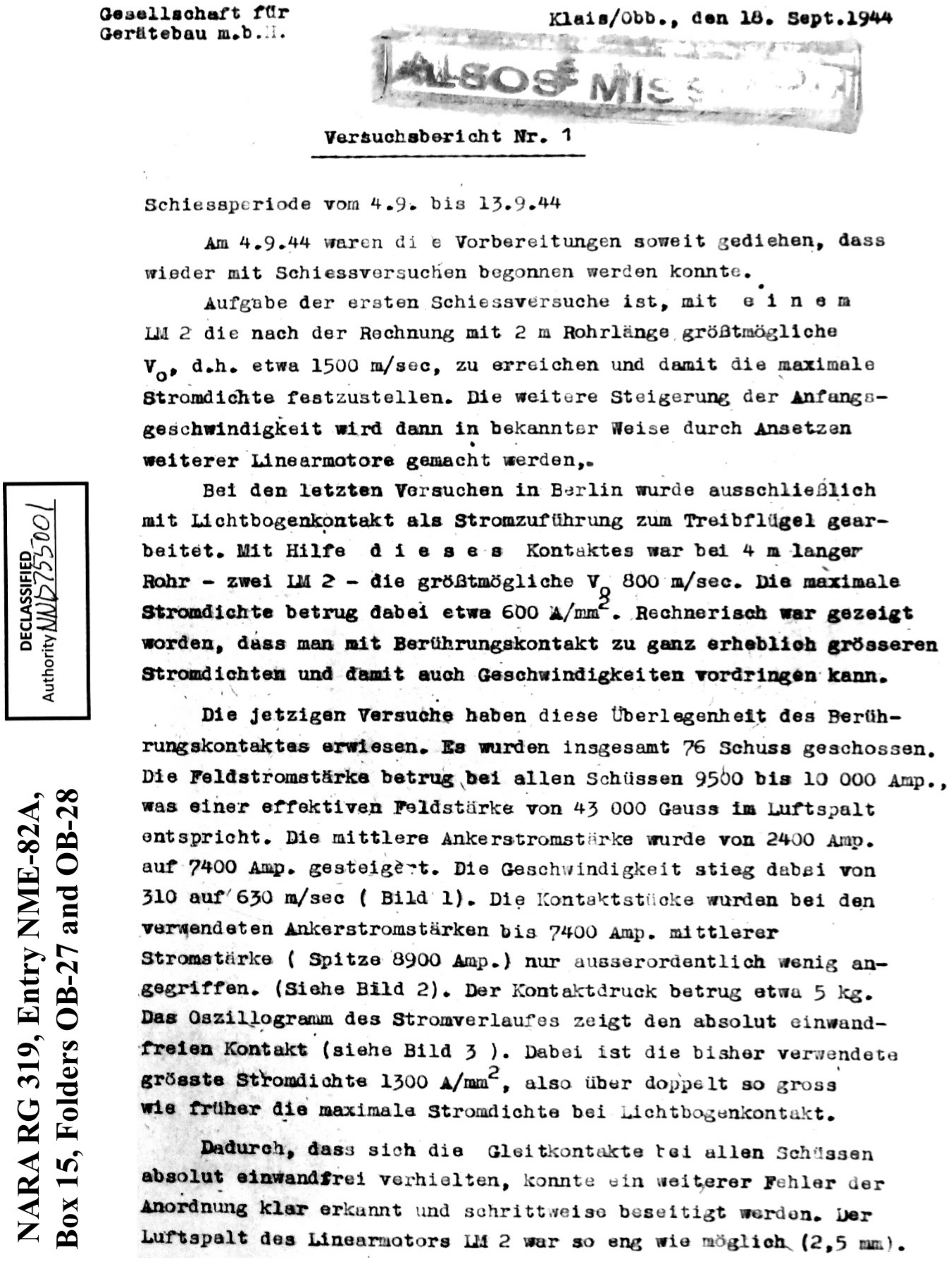
Figure C.142: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.



Gesellschaft für
Gerätebau m.b.H.

Klais/Obb., den 18. Sept.1944

ALSOS MIS

Versuchsbericht Nr. 1

Schiessperiode vom 4.9. bis 13.9.44

Am 4.9.44 waren die Vorbereitungen soweit gediehen, dass wieder mit Schiessversuchen begonnen werden konnte.

Aufgabe der ersten Schiessversuche ist, mit einem LM 2 die nach der Rechnung mit 2 m Rohrlänge größtmögliche V_0, d.h. etwa 1500 m/sec, zu erreichen und damit die maximale Stromdichte festzustellen. Die weitere Steigerung der Anfangsgeschwindigkeit wird dann in bekannter Weise durch Ansetzen weiterer Linearmotore gemacht werden,.

Bei den letzten Versuchen in Berlin wurde ausschließlich mit Lichtbogenkontakt als Stromzuführung zum Treibflügel gearbeitet. Mit Hilfe dieses Kontaktes war bei 4 m langer Rohr – zwei LM 2 – die größtmögliche V_0 800 m/sec. Die maximale Stromdichte betrug dabei etwa 600 A/mm^2. Rechnerisch war gezeigt worden, dass man mit Berührungskontakt zu ganz erheblich grösseren Stromdichten und damit auch Geschwindigkeiten vordringen kann.

Die jetzigen Versuche haben diese Überlegenheit des Berührungskontaktes erwiesen. Es wurden insgesamt 76 Schuss geschossen. Die Feldstromstärke betrug bei allen Schüssen 9500 bis 10 000 Amp., was einer effektiven Feldstärke von 43 000 Gauss im Luftspalt entspricht. Die mittlere Ankerstromstärke wurde von 2400 Amp. auf 7400 Amp. gesteigert. Die Geschwindigkeit stieg dabei von 310 auf 630 m/sec (Bild 1). Die Kontaktstücke wurden bei den verwendeten Ankerstromstärken bis 7400 Amp. mittlerer Stromstärke (Spitze 8900 Amp.) nur ausserordentlich wenig angegriffen. (Siehe Bild 2). Der Kontaktdruck betrug etwa 5 kg. Das Oszillogramm des Stromverlaufes zeigt den absolut einwandfreien Kontakt (siehe Bild 3). Dabei ist die bisher verwendete grösste Stromdichte 1300 A/mm^2, also über doppelt so gross wie früher die maximale Stromdichte bei Lichtbogenkontakt.

Dadurch, dass sich die Gleitkontakte bei allen Schüssen absolut einwandfrei verhielten, konnte ein weiterer Fehler der Anordnung klar erkannt und schrittweise beseitigt werden. Der Luftspalt des Linearmotors LM 2 war so eng wie möglich (2,5 mm).

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Figure C.143: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.

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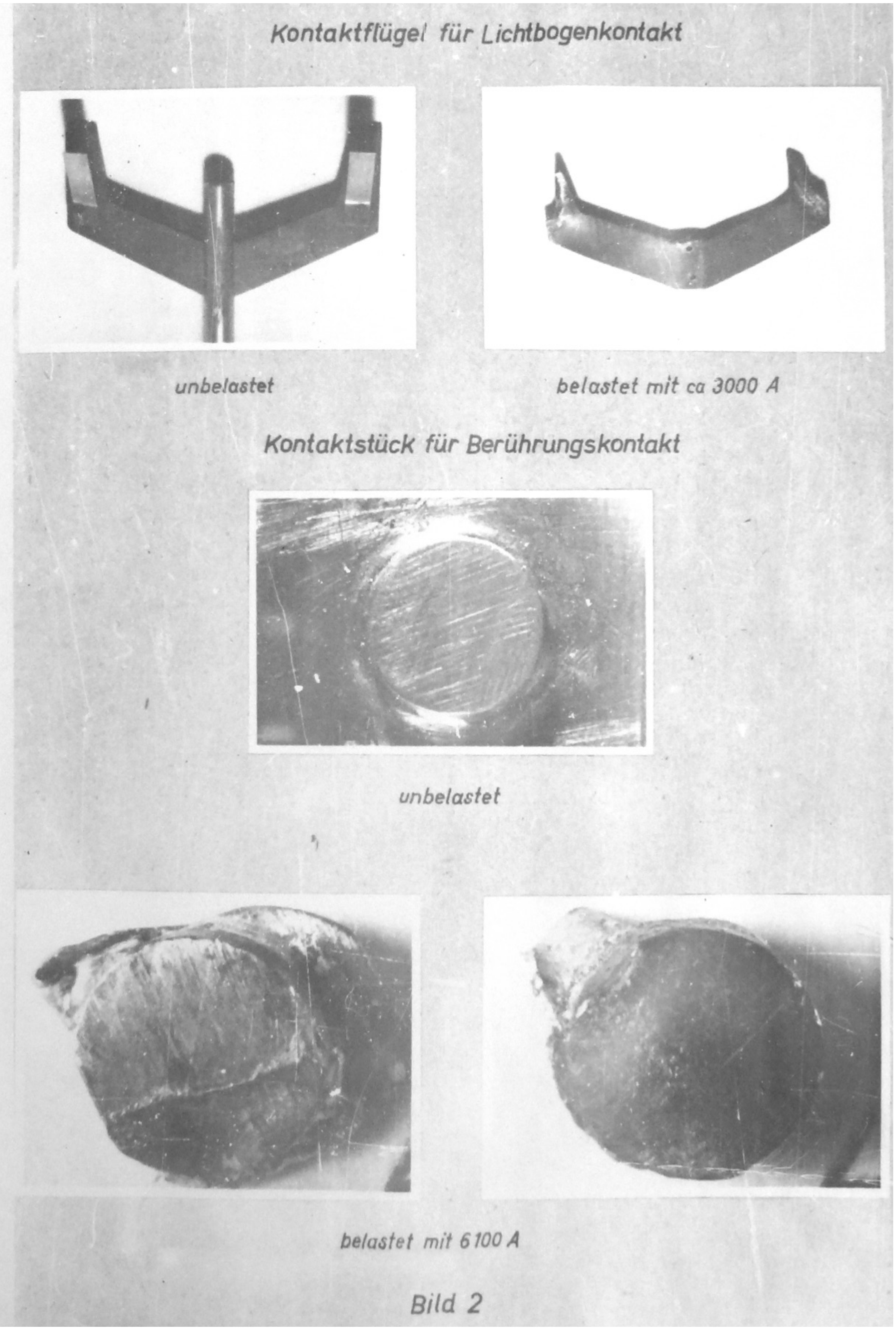


Kontaktflügel für Lichtbogenkontakt

unbelastet

belastet mit ca 3000 A

Kontaktstück für Berührungskontakt

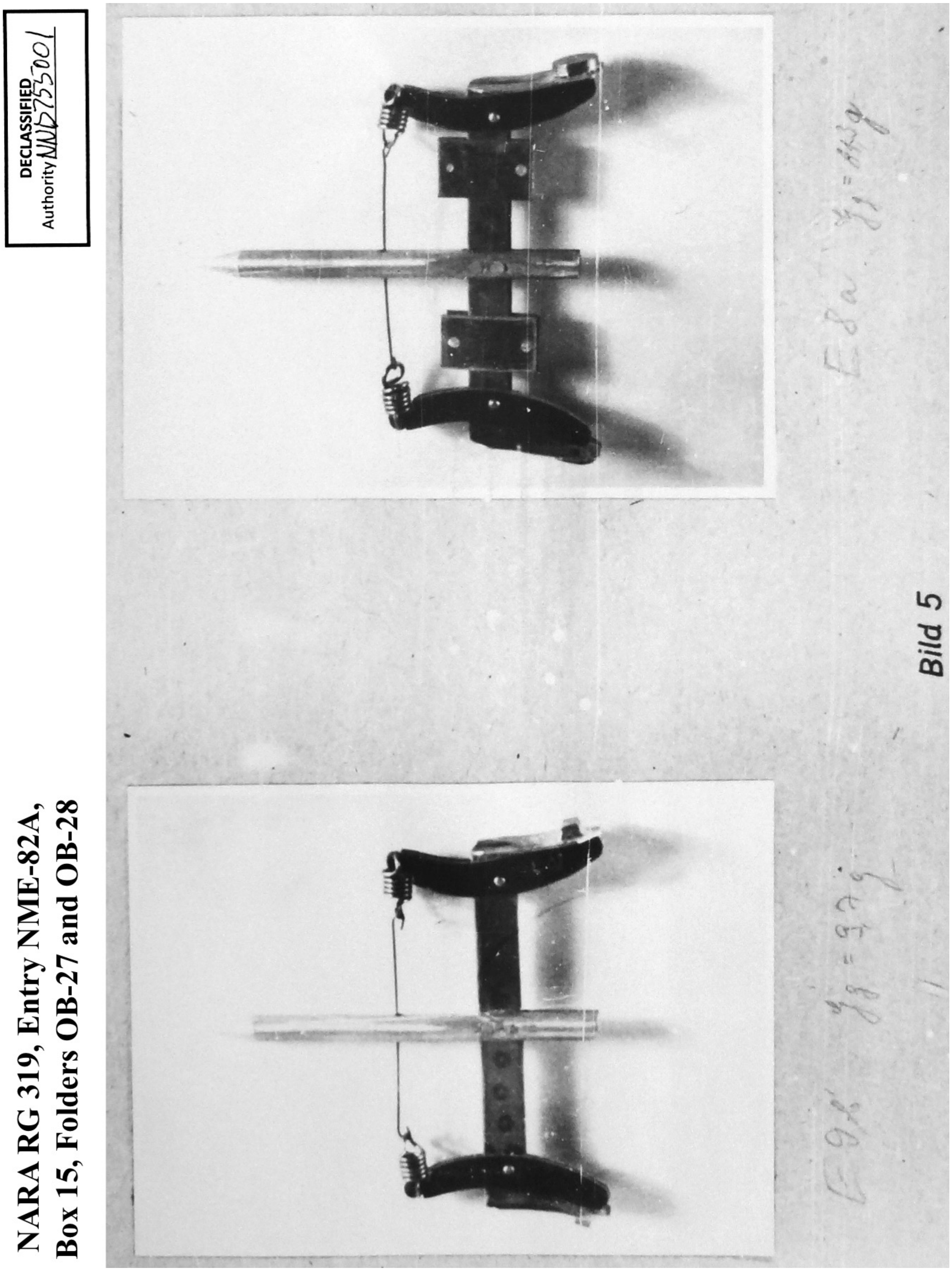
unbelastet

belastet mit 6100 A

Bild 2

NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28

Figure C.144: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.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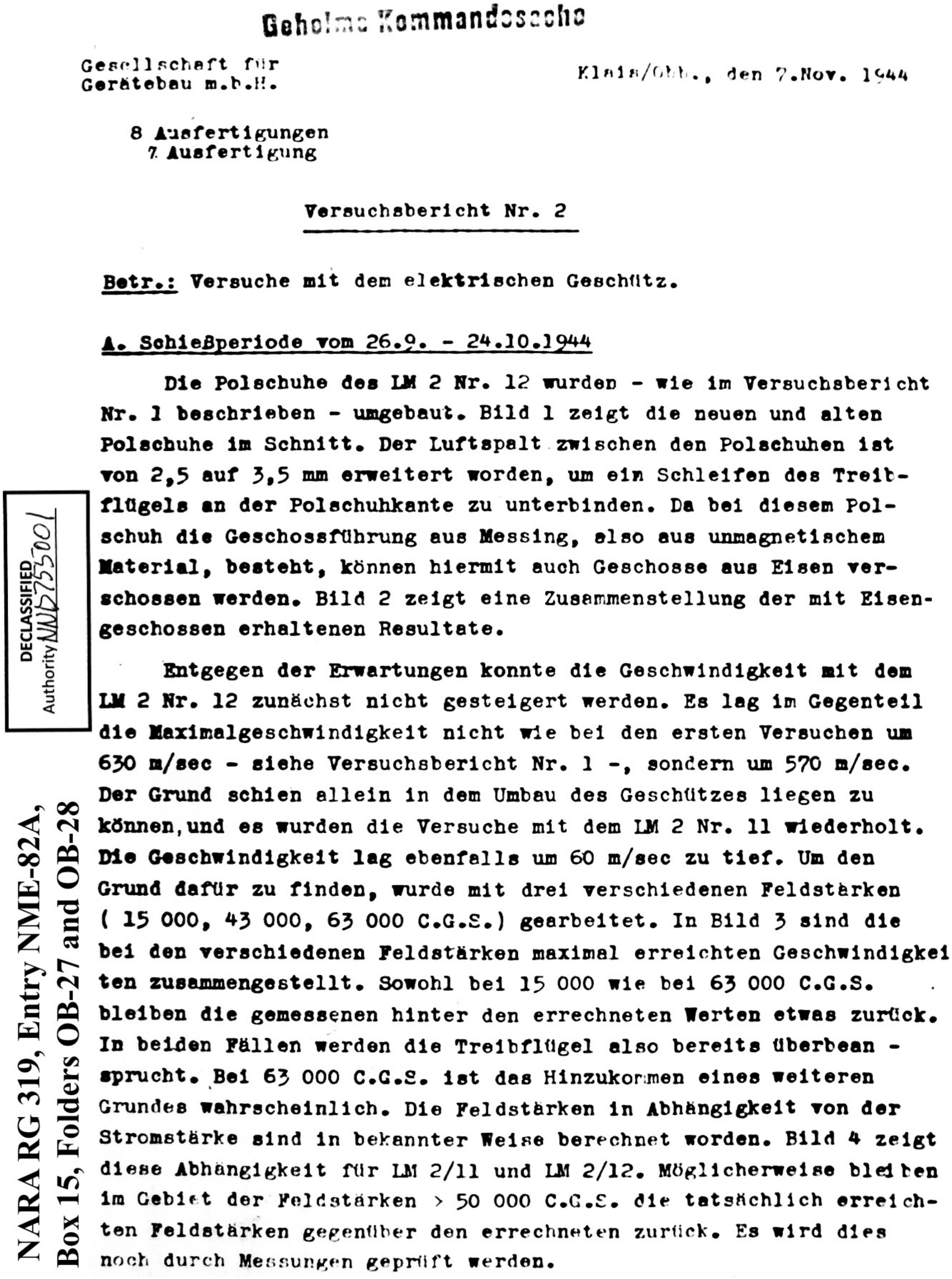
NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28
E 9a g_8 = 97 g
Bild 5
E 8a g_1 = 113 g

Figure C.145: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.



Geheime Kommandosache

Gesellschaft für
Gerätebau m.b.H.

Klais/Obb., den 7.Nov. 1944

8 Ausfertigungen
7. Ausfertigung

Versuchsbericht Nr. 2

Betr.: Versuche mit dem elektrischen Geschütz.

A. Schießperiode vom 26.9. - 24.10.1944

Die Polschuhe des LM 2 Nr. 12 wurden - wie im Versuchsbericht Nr. 1 beschrieben - umgebaut. Bild 1 zeigt die neuen und alten Polschuhe im Schnitt. Der Luftspalt zwischen den Polschuhen ist von 2,5 auf 3,5 mm erweitert worden, um ein Schleifen des Treibflügels an der Polschuhkante zu unterbinden. Da bei diesem Polschuh die Geschossführung aus Messing, also aus unmagnetischem Material, besteht, können hiermit auch Geschosse aus Eisen verschossen werden. Bild 2 zeigt eine Zusammenstellung der mit Eisengeschossen erhaltenen Resultate.

Entgegen der Erwartungen konnte die Geschwindigkeit mit dem LM 2 Nr. 12 zunächst nicht gesteigert werden. Es lag im Gegenteil die Maximalgeschwindigkeit nicht wie bei den ersten Versuchen um 630 m/sec - siehe Versuchsbericht Nr. 1 -, sondern um 570 m/sec. Der Grund schien allein in dem Umbau des Geschützes liegen zu können,und es wurden die Versuche mit dem LM 2 Nr. 11 wiederholt. Die Geschwindigkeit lag ebenfalls um 60 m/sec zu tief. Um den Grund dafür zu finden, wurde mit drei verschiedenen Feldstärken (15 000, 43 000, 63 000 C.G.S.) gearbeitet. In Bild 3 sind die bei den verschiedenen Feldstärken maximal erreichten Geschwindigkeiten zusammengestellt. Sowohl bei 15 000 wie bei 63 000 C.G.S. bleiben die gemessenen hinter den errechneten Werten etwas zurück. In beiden Fällen werden die Treibflügel also bereits überbeansprucht. Bei 63 000 C.G.S. ist das Hinzukommen eines weiteren Grundes wahrscheinlich. Die Feldstärken in Abhängigkeit von der Stromstärke sind in bekannter Weise berechnet worden. Bild 4 zeigt diese Abhängigkeit für LM 2/11 und LM 2/12. Möglicherweise bleiben im Gebiet der Feldstärken > 50 000 C.G.S. die tatsächlich erreichten Feldstärken gegenüber den errechneten zurück. Es wird dies noch durch Messungen geprüft werden.

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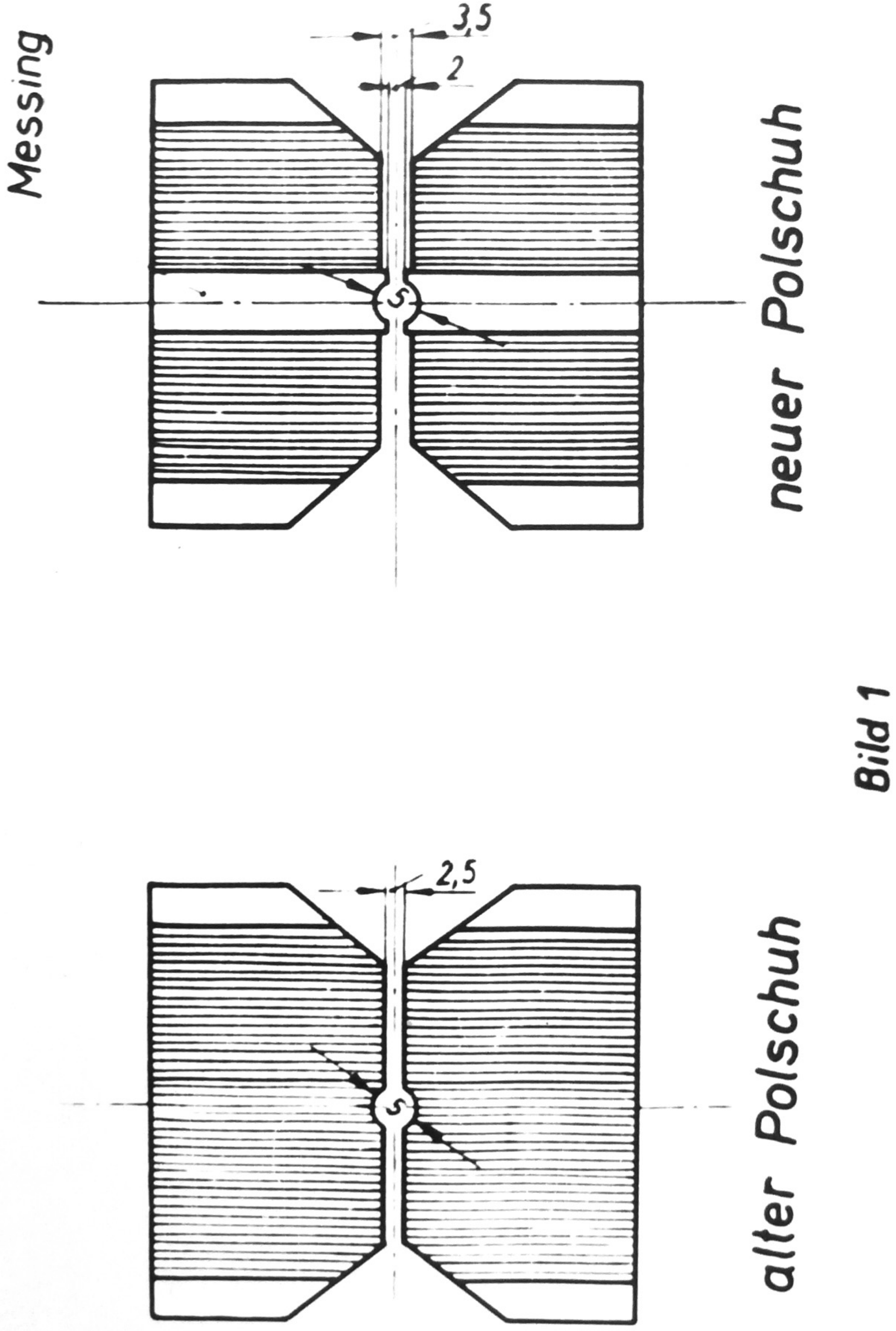
NARA RG 319, Entry NME-82A,
Box 15, Folders OB-27 and OB-28

Figure C.146: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.


Messing
3,5
2
S
neuer Polschuh
Bild 1
2,5
S
alter Polschuh

DECLASSIFIED
Authority NND755001

NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28

Figure C.147: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.

DECLASSIFIED
Authority NND755001

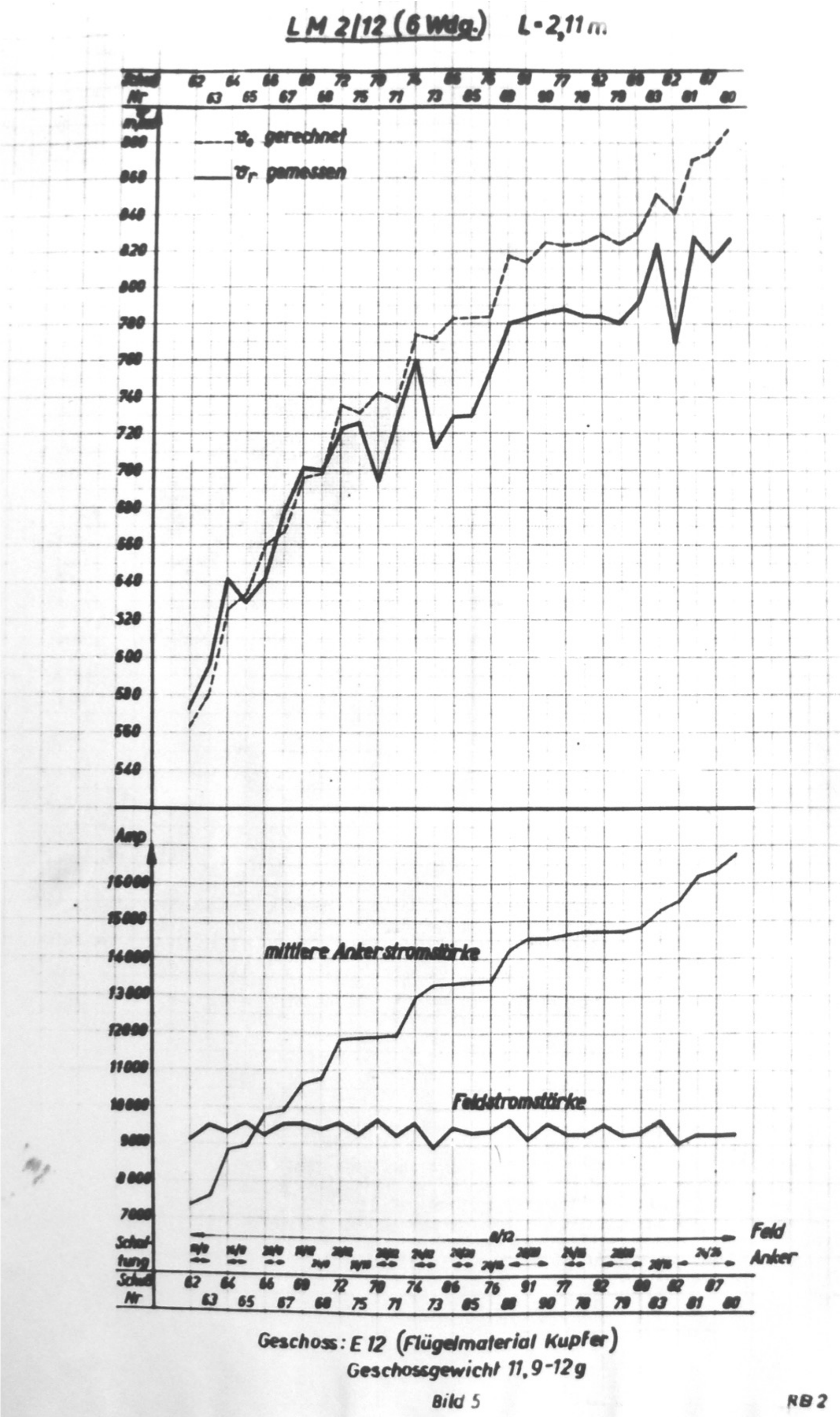
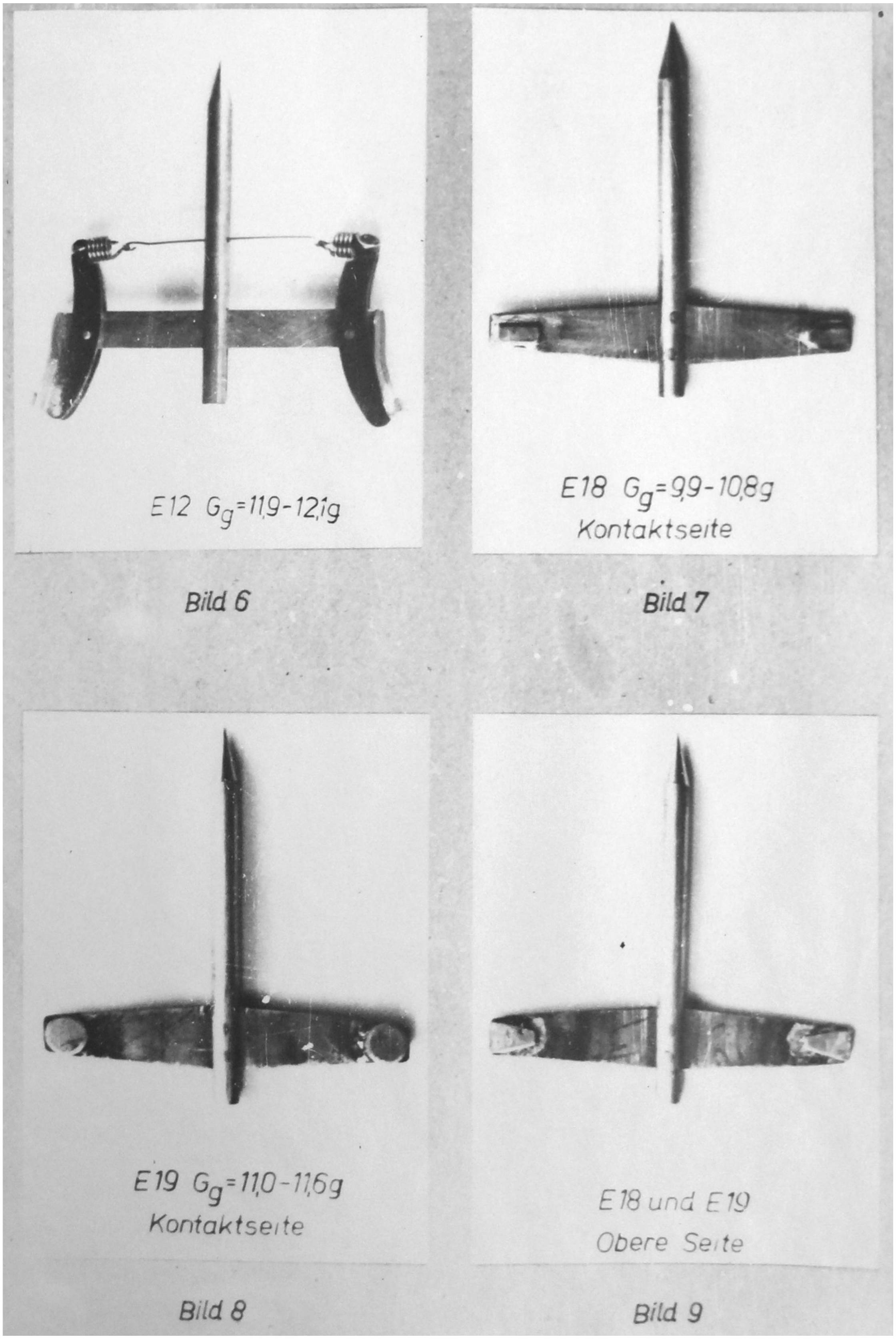


Figure C.148: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.

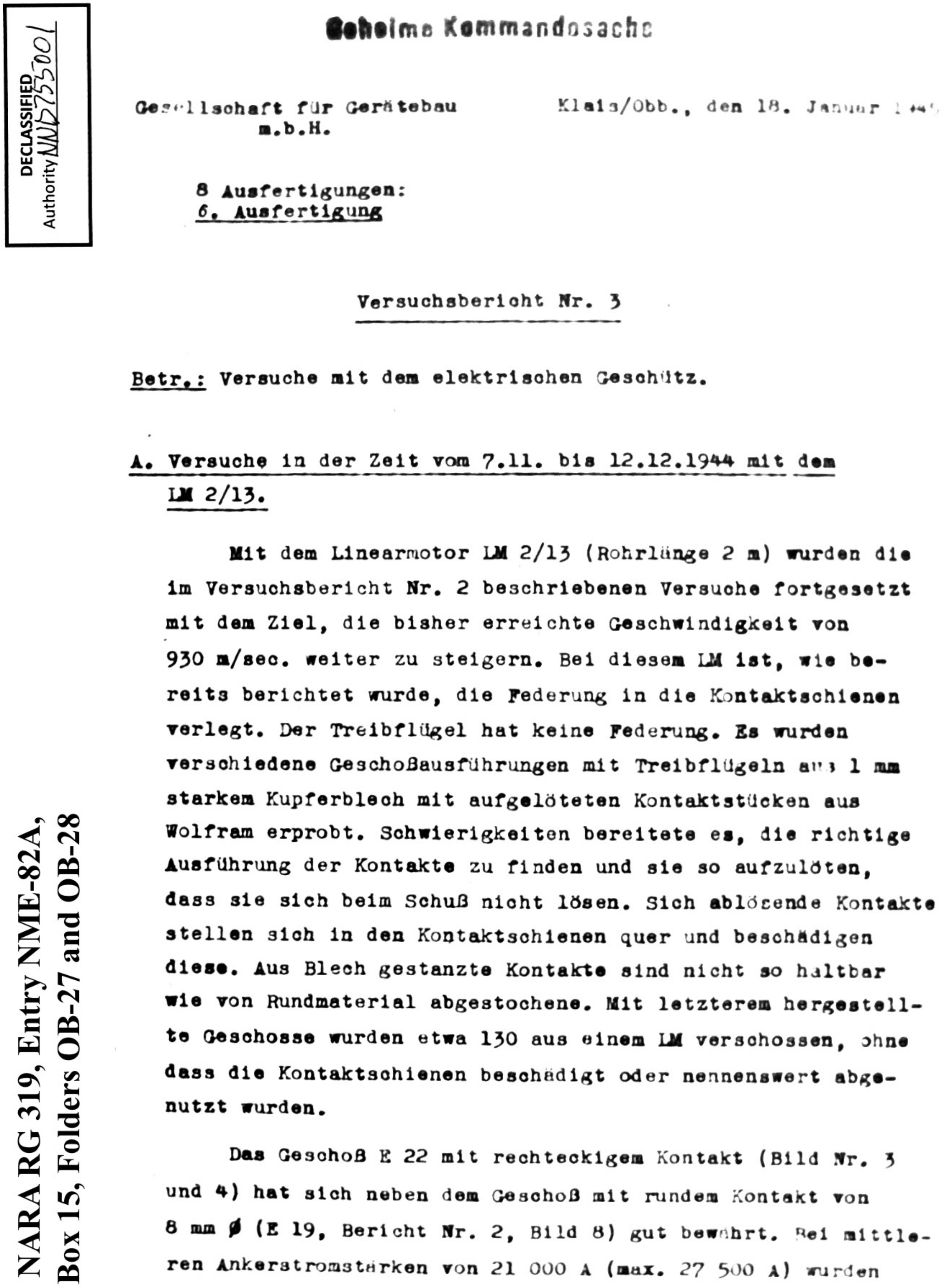
NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28

DECLASSIFIED
Authority NND755001


E12 G_g=11,9-12,1g
Bild 6
E18 G_g=9,9-10,8g
Kontaktseite
Bild 7
E19 G_g=11,0-11,6g
Kontaktseite
Bild 8
E18 und E19
Obere Seite
Bild 9

NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28

Figure C.149: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.



DECLASSIFIED
Authority NND735001

Geheime Kommandosache

Gesellschaft für Gerätebau m.b.H.

Klais/Obb., den 18. Januar 1945

8 Ausfertigungen:
6. Ausfertigung

Versuchsbericht Nr. 3

Betr.: Versuche mit dem elektrischen Geschütz.

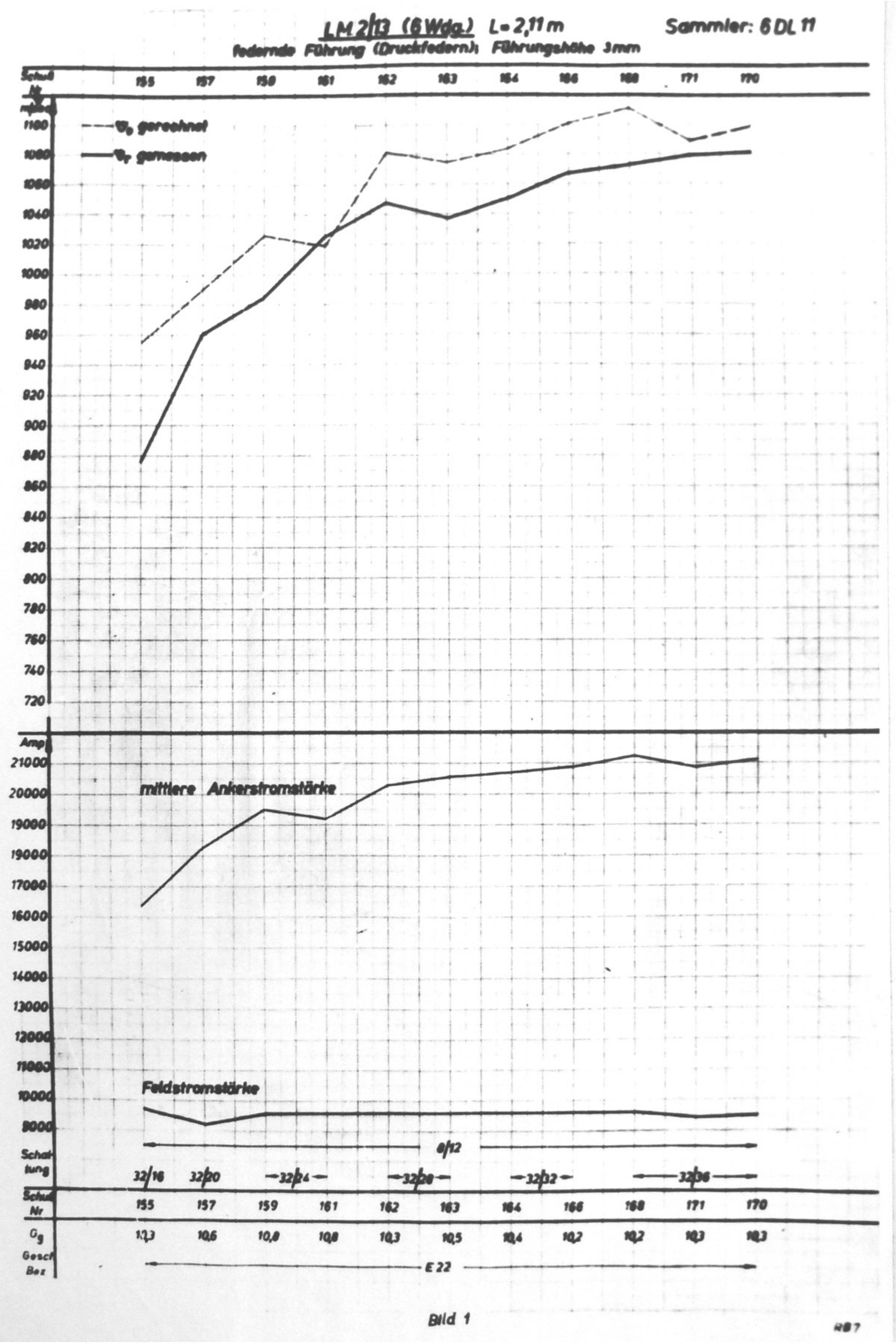
A. Versuche in der Zeit vom 7.11. bis 12.12.1944 mit dem LM 2/13.

Mit dem Linearmotor LM 2/13 (Rohrlänge 2 m) wurden die im Versuchsbericht Nr. 2 beschriebenen Versuche fortgesetzt mit dem Ziel, die bisher erreichte Geschwindigkeit von 930 m/sec. weiter zu steigern. Bei diesem LM ist, wie bereits berichtet wurde, die Federung in die Kontaktschienen verlegt. Der Treibflügel hat keine Federung. Es wurden verschiedene Geschoßausführungen mit Treibflügeln aus 1 mm starkem Kupferblech mit aufgelöteten Kontaktstücken aus Wolfram erprobt. Schwierigkeiten bereitete es, die richtige Ausführung der Kontakte zu finden und sie so aufzulöten, dass sie sich beim Schuß nicht lösen. Sich ablösende Kontakte stellen sich in den Kontaktschienen quer und beschädigen diese. Aus Blech gestanzte Kontakte sind nicht so haltbar wie von Rundmaterial abgestochene. Mit letzterem hergestellte Geschosse wurden etwa 130 aus einem LM verschossen, ohne dass die Kontaktschienen beschädigt oder nennenswert abgenutzt wurden.

Das Geschoß E 22 mit rechteckigem Kontakt (Bild Nr. 3 und 4) hat sich neben dem Geschoß mit rundem Kontakt von 8 mm ø (E 19, Bericht Nr. 2, Bild 8) gut bewährt. Bei mittleren Ankerstromstärken von 21 000 A (max. 27 500 A) wurden

Figure C.150: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.

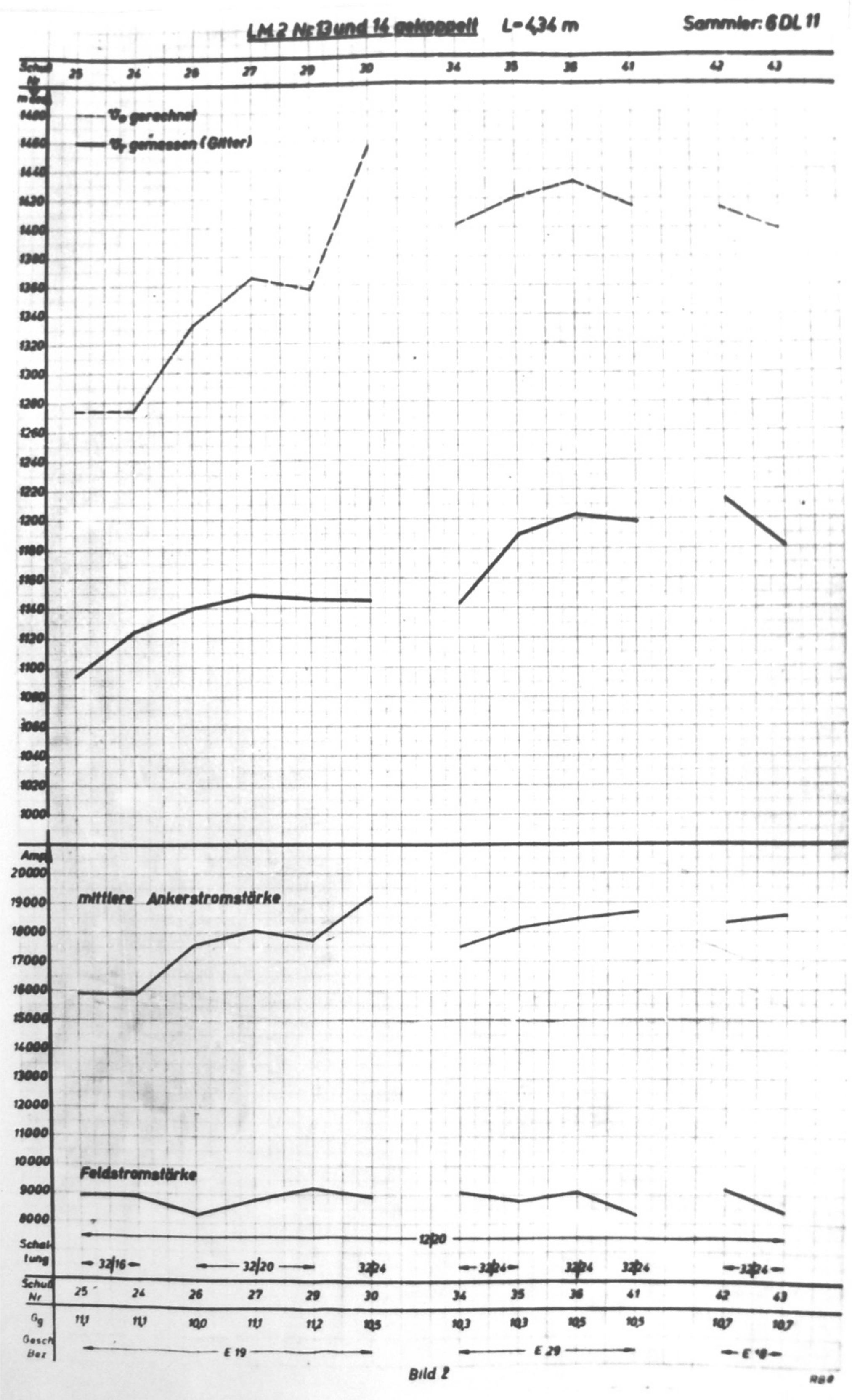
DECLASSIFIED
Authority NND755001



NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28

Figure C.151: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.

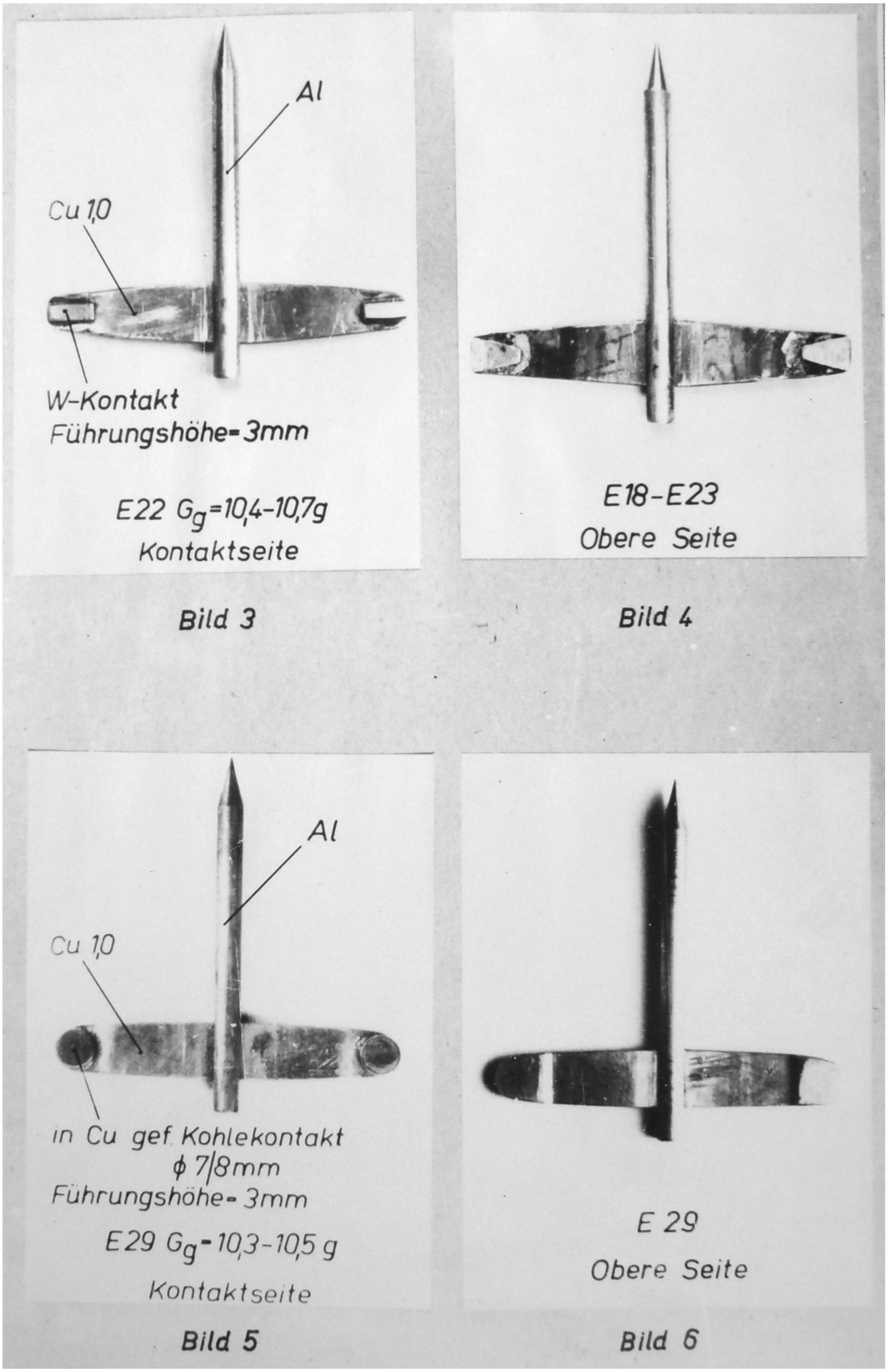
DECLASSIFIED
Authority NND755001



NARA RG 319, Entry NME-82A,
Box 15, Folders OB-27 and OB-28

Figure C.152: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.

DECLASSIFIED
Authority NND755001


Al
Cu 1,0
W-Kontakt
Al
Cu 1,0
in Cu gef. Kohlekontakt
ϕ 7/8mm

Führungshöhe = 3mm

E22 G_g=10,4-10,7g
Kontaktseite

Bild 3

E18-E23
Obere Seite

Bild 4

Führungshöhe = 3mm

E29 G_g = 10,3-10,5 g
Kontaktseite

Bild 5

E 29
Obere Seite

Bild 6

NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28

Figure C.153: Part of Joachim Hänsler's 1945 reports on the development and testing of electromagnetic railguns.

May 1944 U.S. intelligence summary [AFHRA 25216 electronic version p. 423]

HEADQUARTERS
MEDITERRANEAN ALLIED AIR FORCES
Target Intelligence Section
APO 650

COUNTRY	POLAND	Location & Coord:	
LOCALITY	POSEN		
TARGET	Seven unidentified factories		
CATEGORY	SECRET WEAPONS	SUB CATEGORY	Electromagnetic Rocket

I. SUMMARY OF CURRENT INTELLIGENCE

The apparatus is in course of being perfected and is under research by the Electric Research Society of Van Arden [Manfred von Ardenne]. (OSS. B-3 6/900 R.G. 22.5.44)

Manufacture of electrical part will be transferred from Siemens & Halske at Siemenstadt, suburb of Berlin (Factory destroyed) to the annex of Posen. Moving has been set for 22.4.44. (OSS 21.4.44)

Secret Weapons: Electromagnetic Rocket. 31 May 1944. [AFHRA 25193 No. 2641 Posen]

ALGIERS, 31 May 1944

D. G. S. S.
DIRECTION TECHNIQUE
S.R. "OPERATIONS"

Source: Good
Value: B.3
Date: 16 May 1944

No. 7280 /R.G.

INFORMATION
FRANCE

SECRET WEAPONS

ELECTROMAGNETIC ROCKET

ELEKTROMAGNETISCHE RÜCKSTOSSRAKETE

(Reference Note No. 6.900/R.G. of 22 May 1944).

This rocket is under research by the Electric Research Society of Von Arden [Manfred von Ardenne].

The apparatus is in course of being perfected, its manufacture is being carried out on seven factories of Posen. Launching emplacements have been completed. The wave length used is 2 m 40.

ELECTROMAGNETIC ROCKET
ELEKTROMAGNETISCHE RÜCKSTOSSRAKETE

It concerns a rocket of a caliber of 603 mm, launched electromagnetically through a smooth barrel of a length of 8 meters, by the successive cutting off of the current through a coil around the barrel.

The rocket is propelled through regeneration. The closing is controlled by a cathode oscillator loading the condenser blades. The apparatus is under research by Von Ardenne.

The direction of the rocket is controlled by means of ailerons. The principal difficulty is the low speed of the rocket, estimated at 150 m/sec at the exit of the barrel, which makes it subject to atmospheric disturbances.

The construction controlled by the Navy is carried on in two groups:

1) Mechanical part: Barrel and rocket by MAGIRUS at Ula.
   Electrical part: by Siemens Schuckert at Nuremberg.
   This group has only been working for a few months.

2) Mechanical part: by Borsig at Borsigwald -Berlin-. Factory destroyed, manufacture transferred to Schwartzkoff, turbine constructor (in the suburb of Berlin) not yet ready. Electrical part: by Siemens & Halske at Siemensstadt, suburb north of Berlin. Factory destroyed—manufacture will be transferred to the annex of Posen. Moving has been set for the 22nd of April 1944.

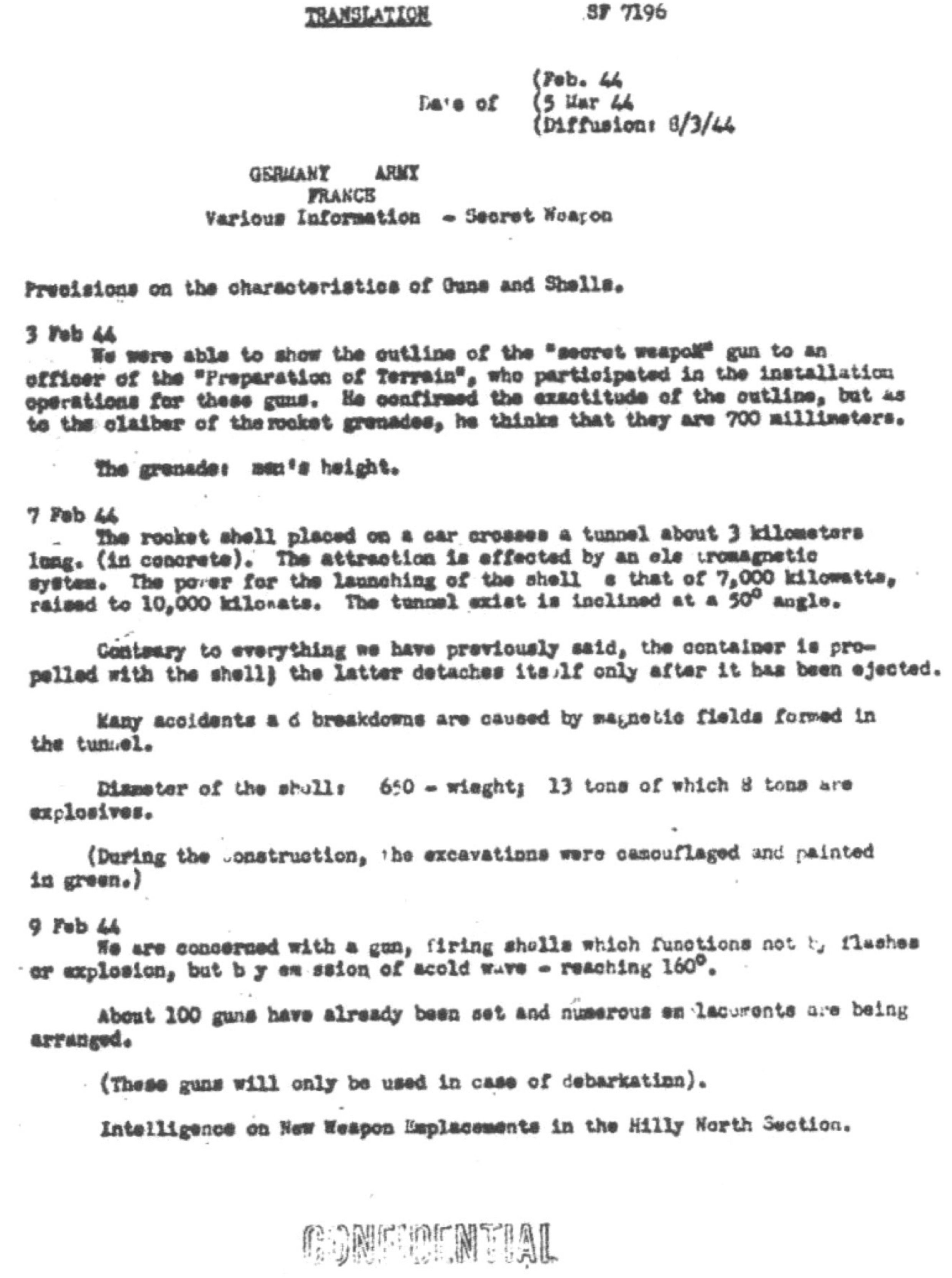
Electrical control material: constructed by the research group Von Ardenne, is in course of being transferred to Posen.

Rocket ailerons are constructed by Karl Mahr at Esslingen (Würtemberg).

Precision material necessary for the equipment of the factories is collected in France for a total of 120 million francs at the official rate.

[In some of Igor Witkowski's books, he published an archival document that was an English translation of French intelligence reports from February 1944 [Witkowski 2010, pp. 129–131, and 2013, pp. 93–94]. See Figs. C.154–C.156. The document summarized several somewhat contradictory and garbled French intelligence reports, but they described French coastal emplacements for very large electromagnetic railguns with powers up to "10,000 kilowatts." The document may be related to the above French intelligence report. Witkowski did not give an archival source for the document in his books. Can the archive and archival location be identified?

Collectively these reports appear to demonstrate that during the war, electromagnetic railguns had moved beyond the stage of simple experiments. Very large railguns were being mass-produced in several factories, and sites were being built to house and power them on the battlefield.]



TRANSLATION SF 7196

Date of (Feb. 44
(5 Mar 44
(Diffusion: 8/3/44

GERMANY ARMY
FRANCE
Various Information - Secret Weapon

Precisions on the characteristics of Guns and Shells.

3 Feb 44

We were able to show the outline of the "secret weapon" gun to an officer of the "Preparation of Terrain", who participated in the installation operations for these guns. He confirmed the exactitude of the outline, but as to the claiber of the rocket grenades, he thinks that they are 700 millimeters.

The grenade: man's height.

7 Feb 44

The rocket shell placed on a car crosses a tunnel about 3 kilometers long. (in concrete). The attraction is effected by an electromagnetic system. The power for the launching of the shell is that of 7,000 kilowatts, raised to 10,000 kilowats. The tunnel exist is inclined at a 50° angle.

Contrary to everything we have previously said, the container is propelled with the shell; the latter detaches itself only after it has been ejected.

Many accidents and breakdowns are caused by magnetic fields formed in the tunnel.

Diameter of the shell: 650 - wieght; 13 tons of which 8 tons are explosives.

(During the construction, the excavatinns were camouflaged and painted in green.)

9 Feb 44

We are concerned with a gun, firing shells which functions not by flashes or explosion, but by emission of acold wave - reaching 160°.

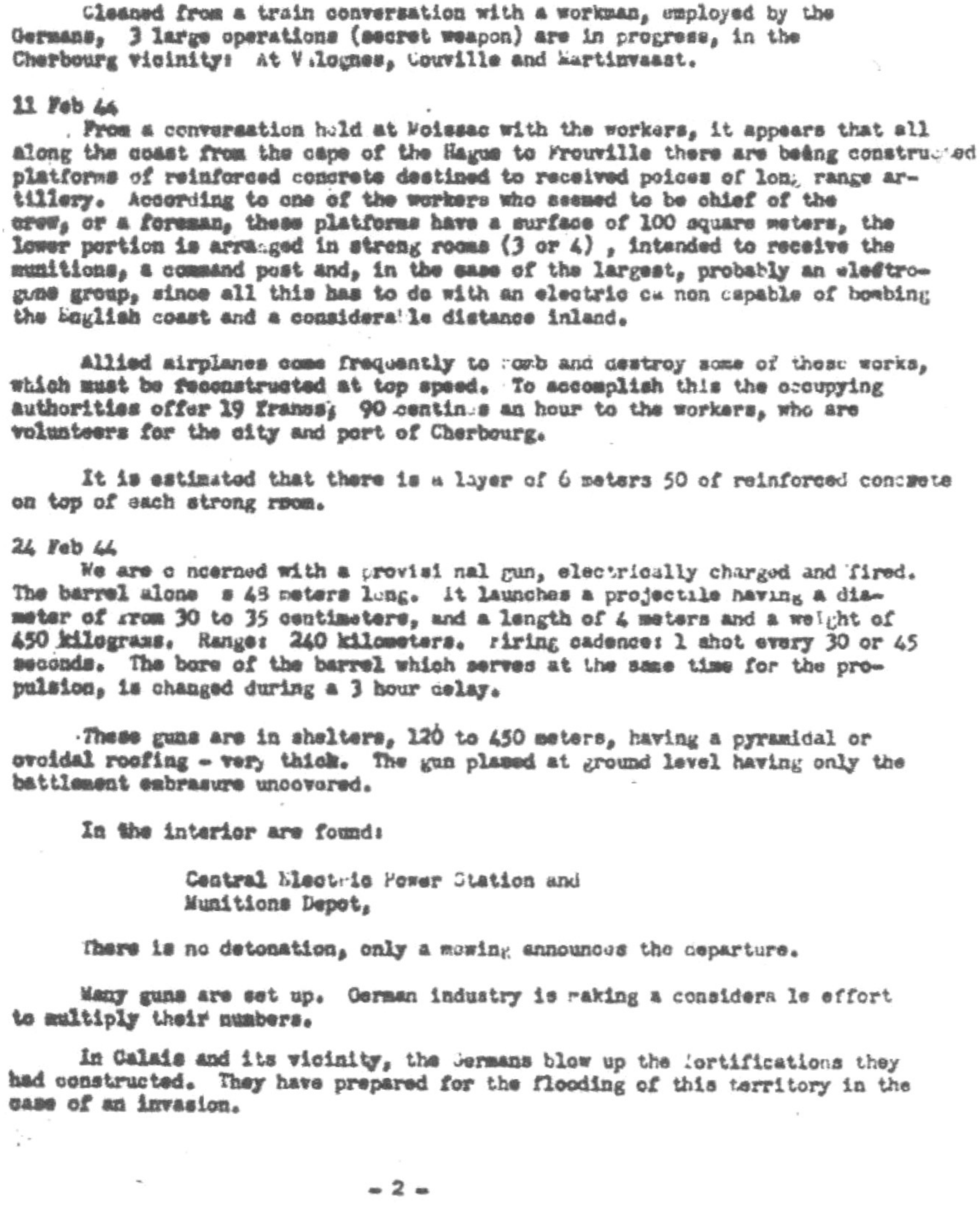
About 100 guns have already been set and numerous emplacements are being arranged.

(These guns will only be used in case of debarkatinn).

Intelligence on New Weapon Emplacements in the Hilly North Section.

CONFIDENTIAL

Figure C.154: English translation of French intelligence reports from February 1944 describing French coastal emplacements for very large electromagnetic railguns with powers up to "10,000 kilowatts" [Witkowski 2010, pp. 129–131, and 2013, pp. 93–94].



Gleaned from a train conversation with a workman, employed by the Germans, 3 large operations (secret weapon) are in progress, in the Cherbourg vicinity: At Valognes, Couville and Martinvaast.

11 Feb 44

From a conversation held at Moissac with the workers, it appears that all along the coast from the cape of the Hague to Frouville there are being constructed platforms of reinforced concrete destined to received pieces of long range artillery. According to one of the workers who seemed to be chief of the crew, or a foreman, these platforms have a surface of 100 square meters, the lower portion is arranged in strong rooms (3 or 4), intended to receive the munitions, a command post and, in the case of the largest, probably an electrogene group, since all this has to do with an electric canon capable of bombing the English coast and a considerable distance inland.

Allied airplanes come frequently to bomb and destroy some of these works, which must be reconstructed at top speed. To accomplish this the occupying authorities offer 19 francs, 90 centimes an hour to the workers, who are volunteers for the city and port of Cherbourg.

It is estimated that there is a layer of 6 meters 50 of reinforced concrete on top of each strong room.

24 Feb 44

We are concerned with a provisional gun, electrically charged and fired. The barrel alone is 48 meters long. It launches a projectile having a diameter of from 30 to 35 centimeters, and a length of 4 meters and a weight of 450 kilograms. Range: 240 kilometers. Firing cadence: 1 shot every 30 or 45 seconds. The bore of the barrel which serves at the same time for the propulsion, is changed during a 3 hour delay.

These guns are in shelters, 120 to 450 meters, having a pyramidal or ovoidal roofing - very thick. The gun placed at ground level having only the battlement embrasure uncovered.

In the interior are found:

Central Electric Power Station and
Munitions Depot,

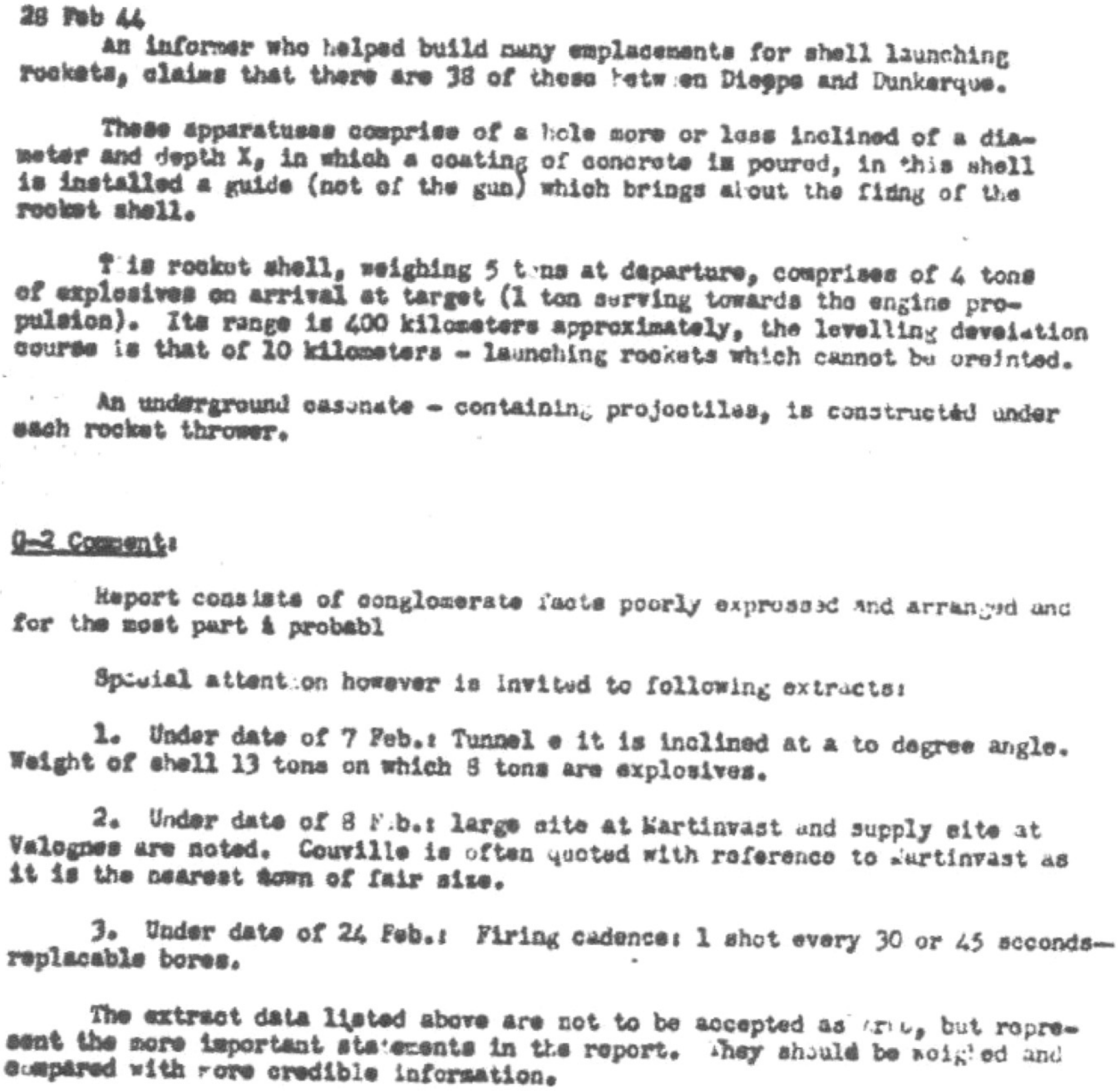
There is no detonation, only a mowing announces the departure.

Many guns are set up. German industry is making a considerable effort to multiply their numbers.

In Calais and its vicinity, the Germans blow up the fortifications they had constructed. They have prepared for the flooding of this territory in the case of an invasion.

- 2 -

Figure C.155: English translation of French intelligence reports from February 1944 describing French coastal emplacements for very large electromagnetic railguns with powers up to "10,000 kilowatts" [Witkowski 2010, pp. 129–131, and 2013, pp. 93–94].



28 Feb 44

An informer who helped build many emplacements for shell launching rockets, claims that there are 38 of these between Dieppe and Dunkerque.

These apparatuses comprise of a hole more or less inclined of a diameter and depth X, in which a coating of concrete is poured, in this shell is installed a guide (not of the gun) which brings about the firing of the rocket shell.

This rocket shell, weighing 5 tons at departure, comprises of 4 tons of explosives on arrival at target (1 ton serving towards the engine propulsion). Its range is 400 kilometers approximately, the levelling deveiation course is that of 10 kilometers - launching rockets which cannot be oreinted.

An underground casemate - containing projectiles, is constructed under each rocket thrower.

G-2 Comment:

Report consists of conglomerate facts poorly expressed and arranged and for the most part & probabl

Special attention however is invited to following extracts:

1. Under date of 7 Feb.: Tunnel e it is inclined at a to degree angle. Weight of shell 13 tons on which 8 tons are explosives.

2. Under date of 8 Feb.: large site at Martinvast and supply site at Valognes are noted. Couville is often quoted with reference to Martinvast as it is the nearest town of fair size.

3. Under date of 24 Feb.: Firing cadence: 1 shot every 30 or 45 seconds—replacable bores.

The extract data listed above are not to be accepted as true, but represent the more important statements in the report. They should be weighed and compared with more credible information.

Figure C.156: English translation of French intelligence reports from February 1944 describing French coastal emplacements for very large electromagnetic railguns with powers up to "10,000 kilowatts" [Witkowski 2010, pp. 129–131, and 2013, pp. 93–94].

Brendan Borrell. Electromagnetic Railgun Blasts Off. *Technology Review.* 6 February 2008. [https://www.technologyreview.com/2008/02/06/128211/electromagnetic-railgun-blasts-off/]

A supersonic bullet is fired with a record-breaking 10 megajoules of muzzle energy.

Last week at the Naval Surface Warfare Center, in Dahlgren, VA, a seven-pound bullet emerged from a truck-sized contraption at seven times the speed of sound and sent a visible shockwave through the air before crashing into a metal bunker filled with sand. With 10.6 megajoules of kinetic energy, this aluminum slug was propelled not by explosives but by an electric field, making this the most powerful electromagnetic railgun ever fired. The device is part of the navy's railgun development program.

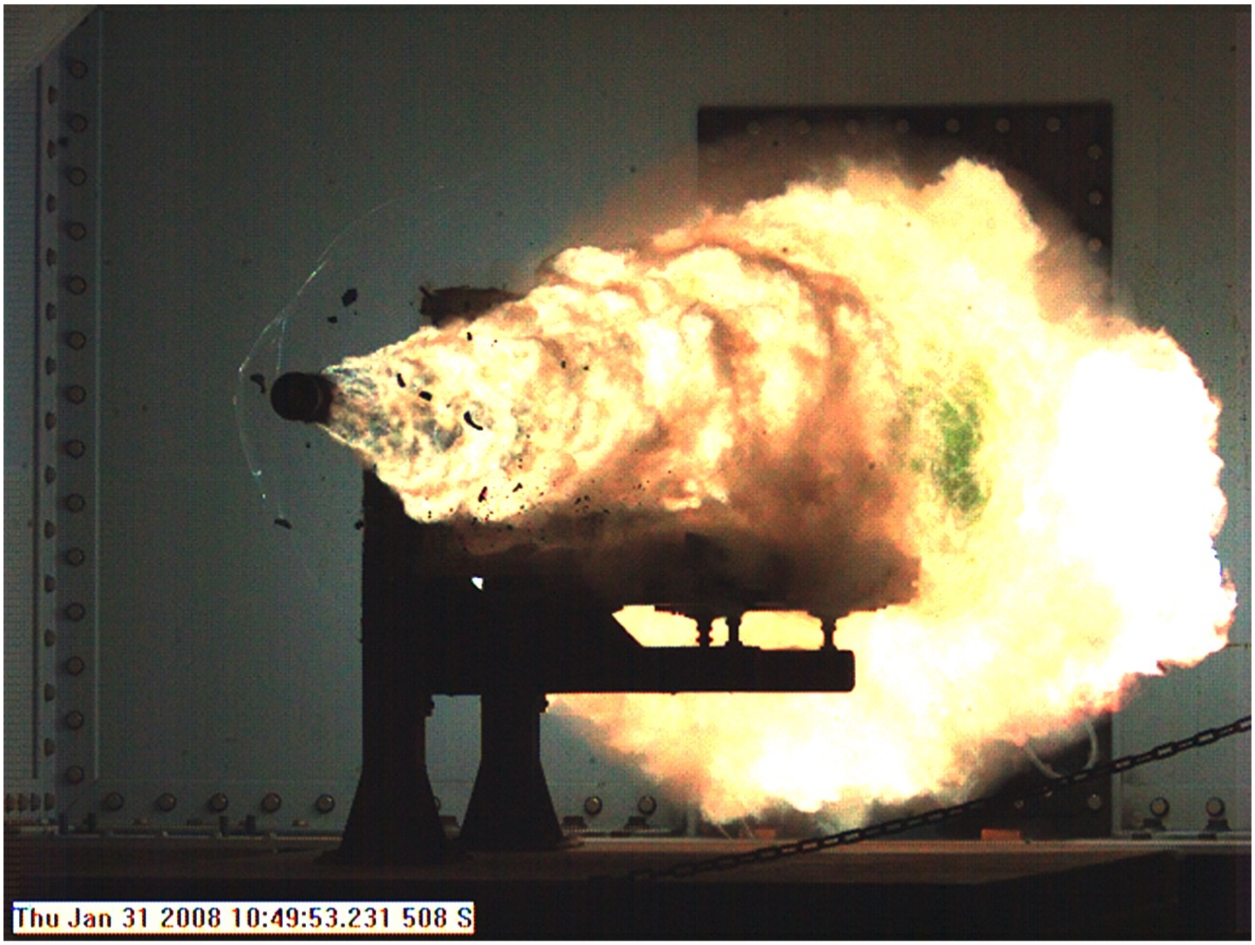
While propellant-driven shells have been mainstays of naval warships for the past hundred years, the cost and safety issues related to storing explosive materials have driven engineers to seek alternatives like the electromagnetic railgun. "There are physical limits to what you can do with gunpowder," says Charles Garnett, the manager at Dahlgren, referring to the maximum velocities that explosions can produce. A railgun could eventually send a 40-pound slug 200 miles in six minutes—10 times the range of the navy's primary surface support gun, the MK 45—and it could be used to support Marine troops engaged in land-based operations.

"A lot of people think a railgun is not going to make a lot of noise," Garnett says. "It's electrically fired, and they expect a whoosh and no sound." In reality, when the bullet emerges, it lets out a crack as electricity arcs through the air like lightning.

The railgun gets its name from two highly conductive rails, which form a complete electric circuit once the metal projectile and a sliding armature are put in place. When current starts flowing through the device, it creates a powerful electromagnetic field that accelerates the projectile down the barrel at 40,000 gs, launching it in a matter of milliseconds. Aerodynamic drag along with a million amps of current heats the bullet to 1,000 ^{o}C, igniting aluminum particles and leaving a trail of flame in its wake. The researchers estimate the muzzle energy based on the mass and velocity of the bullet in the barrel and from precisely timed x-ray snapshots during flight.

"What's important," says Garnett, "is that this is the first step on the way to building a tactically viable system with 64 megajoules of energy." [...]

**U.S. Navy. 2008. [https://www.navy.mil/view_image.asp?id=54942
https://fortune.com/2016/05/31/navy-new-railgun-military/
https://taskandpurpose.com/news/navy-electromagnetic-railgun-dead/]**



080131-N-0000X-001

DAHLGREN, Va. (Jan. 31, 2008) Photograph taken from a high-speed video camera during a record-setting firing of an electromagnetic railgun (EMRG) at Naval Surface Warfare Center, Dahlgren, Va., on January 31, 2008, firing at 10.64MJ (megajoules) with a muzzle velocity of 2520 meters per second. The Office of Naval Research's EMRG program is part of the Department of the Navy's Science and Technology investments, focused on developing new technologies to support Navy and Marine Corps war fighting needs. This photograph is a frame taken from a high-speed video camera. U.S. Navy Photograph

Figure C.157: Test firing of a modern railgun by the U.S. Navy in 2008.

BAE Systems. 2013. Electromagnetic (EM) Railgun.
[https://www.baesystems.com/en/product/electromagnetic–em–railgun]

We are honored to lead the way in the development of the Office of Naval Research (ONR) Electromagnetic (EM) Railgun Innovative Naval Prototype.

This fascinating technology, which uses high-power electromagnetic energy instead of explosive chemical propellants to launch projectiles farther and faster than any previous system, is currently in Phase 2 of the program. During this phase, we will advance the railgun by maturing the launcher and pulsed power from a single shot operation to a multi-shot capability. Auto-loading and thermal management systems will also be incorporated. We received a $34.5M contract from ONR in 2013 to pursue these efforts.

“We’re committed to developing this innovative and game changing technology that will revolutionize naval warfare,” said Chris Hughes, vice president and general manager of Weapon Systems at BAE Systems. “The Railgun’s ability to defend against enemy threats from distances greater than ever before improves the capabilities of our armed forces.”

On December 10, 2010, the U.S. Navy made history at the Naval Surface Warfare Center-Dahlgren Division with our Laboratory Railgun. A 33-Megajoule shot was fired, the energy equivalent of 110 nmi range. In 2012, during Phase 1 of the INP program, engineers at the Naval Surface Warfare Center successfully fired our EM Railgun prototype at tactical energy levels.

Not content with just merely building the launch platform, We are also pursuing the development of a Hyper Velocity Projectile (HVP). In late 2013, we received a $33.6 million contract from ONR to develop and demonstrate a HVP—a next-generation, guided projectile capable of completing multiple missions for the Electromagnetic Railgun, as well as existing 5-inch and 155-mm gun systems.

[Even nowadays, electromagnetic railguns are considered to be a high-tech “weapon of the future.” The best modern railguns are essentially just larger versions of Joachim Hänsler’s and Manfred von Ardenne’s 1944–1945 devices, and can now fire projectiles at approximately twice the velocity of Hänsler’s wartime railguns. Since Hänsler’s (and perhaps von Ardenne’s) detailed technical reports and even some of his equipment were brought back to the United States by the Alsos Mission, CIOS, and other teams of investigators in 1945, it appears that such modern railguns are directly derived from the wartime German work.

Much more archival research should be conducted to elucidate the history of electromagnetic railguns in the German-speaking world, as well as the impact of those innovators and innovations on postwar electromagnetic railguns in other countries.]

Appendix D

Advanced Creations in Nuclear Engineering

Der Welt Erbe gewänne zu eigen, wer aus dem Rheingold schüfe den Ring, der maßlose Macht ihm verlieh'.	The whole world can be possessed by one who from the Rhinegold forges the Ring, which can bestow immeasurable power.

Richard Wagner. 1854. *Das Rheingold.* Scene I. Wellgunde.

As discussed in Chapter 8, contributions by the German-speaking research world to fundamental nuclear science are very well documented.[1] Wilhelm Röntgen discovered X-rays in 1895, and Ludwig Zehnder was making detailed whole-body X-ray photos of humans by 1896. Hans Geiger and Walther Müller developed accurate radiation meter designs (Geiger counters or Geiger-Müller tubes) during the period 1908–1928 that are still in use today. Nuclear fission reactions were first proposed by Ida Tacke Noddack in 1934, and demonstrated and explained by Otto Hahn, Fritz Strassmann, Lise Meitner, and Otto Frisch in 1938–1939. Nuclear fusion reactions were proposed by Fritz Houtermans and his student Robert Atkinson in 1928–1929, and refined by Carl Friedrich von Weizsäcker and Hans Bethe in 1938. Detailed mathematical models of the nucleus, essential for accurately predicting nuclear decays and reactions, were first developed by von Weizsäcker in 1935 and ultimately finalized by Otto Haxel, Johannes Hans Jensen, Maria Goeppert Mayer, Hans Suess, and Eugene Wigner by 1949.

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[1] See for example: Bethe 1991, 1997; Blatt and Weisskopf 1952; Brown and Lee 2006; Otto Hahn 1968; Irving 1967; L'Annunziata 2016; Nachmansohn 1979; Rife 1999; Schweber 2012; Sime 1996; Szanton 1992; Wigner 1967.

In contrast, progress toward nuclear engineering applications within the German-speaking research world is much less well understood by modern scholarship. Much of the relevant archival evidence has only been declassified and rediscovered in recent years, and was not publicly available when earlier historical assessments were made.[2] As presented in this appendix, the evidence that is now available demonstrates that wartime nuclear engineering programs in Germany were considerably larger and more advanced than has previously been generally understood. Some of the evidence even strongly suggests (but does not conclusively prove) that Germany may have developed and successfully tested fission bombs, and that it may have had a megaton-level hydrogen bomb in an advanced stage of development when the war ended.

For a much shorter overview than this appendix, see Section 8.8.

This appendix presents evidence of:

D.1. Flaws in the conventional historical view of the German program.

D.2. The fundamental scientific knowledge and planning of the program.

D.3. Sources of uranium and thorium.

D.4. Enrichment of uranium-235.

D.5. Fission reactors for breeding plutonium-239 and/or uranium-233.

D.6. Electronuclear systems for breeding plutonium-239 and/or uranium-233.

D.7. The production of other potentially nuclear-related materials.

D.8. Fission bomb designs.

D.9. Hydrogen bomb designs.

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[2] With access to some of the previously unavailable former Soviet and East German archives and witness testimony, as well as newly discovered and released U.S. and British documents, beginning in the 1990s several authors argued (with varying degrees of success and accuracy—*caveat emptor*) that wartime German work on nuclear weapons was actually much more extensive, involved many more scientists, and progressed much further than had been accepted by the conventional historical narrative. See for example: Brooks 1992, 2002; Frank Döbert in *Walpersberg Geschichts- und Forschungsjournal* 2015, 2016; Eilers 2007, 2015; Fäth 1999, 2000; Fengler 2014; Fengler and Sachse 2012; *Geheimnis Jonastal* 2002–2024; Georg 2009; Henshall 1998, 2000, 2002; Hirschfeld and Brooks 1996; Hydrick 1998, 2016; Karlsch 2005, 2006, 2011; Karlsch and Laufer 2002; Karlsch and Petermann 2007; Karlsch and Zeman 2016; Mayer and Mehner 2001, 2002, 2004a, 2004b, 2009, 2010, 2016, 2019; Mehner 2004; Nagel 2003, 2011, 2012a, 2016; Oleynikov 2000; Petermann 2000; Schmitzberger 2004; Stevens 2007; Sulzer and Brauburger 2015; Matthias Uhl quoted in Schauka 2015; Wilcox 2019; Zeman and Karlsch 2008.

D.10. An October 1944 test explosion on the Baltic coast.

D.11. A circa November 1944 test explosion in Poland.

D.12. March 1945 test explosions in Thuringia.

D.13. Axis belief in the reality of German nuclear weapons.

D.14. Allied belief in the reality of German nuclear weapons.

D.15. Further research that is needed.

These claims may seem controversial. It is possible that the reports of wartime German nuclear weapons tests arose from tests of non-nuclear weapons (such as fuel-air explosives or chemical warfare agents), false wartime propaganda, or other factors. However, it is known that there were extensive and highly secretive nuclear programs in wartime Germany, that numerous military research and production sites were severely bombed by the Allies during the war and/or sanitized by the Germans at the end of the war, that Germans destroyed or hid large amounts of documents and research at the end of the war, and that Soviet, U.S., U.K., and French forces vacuumed up as many scientists and documents and as much equipment as they could find along the way. If the new evidence is indeed correct, one could understand why the Germans involved would have been loath to admit their deeds afterward for fear of being prosecuted as war criminals, or why any Allied forces that found secret evidence of German nuclear accomplishments would have preferred to claim those technologies and achievements exclusively for themselves.

The currently available evidence that is presented in this appendix does not conclusively prove that Germany successfully developed a nuclear weapon during the war. Nonetheless, the available evidence appears to be strongly suggestive of and highly consistent with that conclusion. Therefore, it is vitally important for researchers to thoroughly search all relevant government and personal archives in Russia, the United States, the United Kingdom, France, Germany, Austria, Czechia, Poland, Switzerland, Italy, the Netherlands, Belgium, Norway, Japan, and elsewhere to find additional documents that could fully elucidate the scope, history, and accomplishments of the wartime German nuclear program. Industrial archaeology and chemical analyses at sites where nuclear work may have taken place could also shed a great deal of light on the methods and results of the nuclear program.

D.1 Conventional Historical View of the German Program

[The conventional historical view that has been held since 1945 is that Germany was still trying to complete its first prototype fission reactor when World War II ended in Europe, and that Germany never even made a serious attempt to develop nuclear weapons.[3] This view is based on three categories of evidence, although each category has its own limitations as summarized below:

Evidence	**Limitations**
1. The U.S.-led Alsos Mission searching Germany for evidence of nuclear-weapons-related work at the end of the war found the incomplete fission reactor at Haigerloch, some papers on basic nuclear physics, and apparently not much else, according to the public accounts [Goudsmit 1945, 1947; Groves 1962; Pash 1969].	1. The Alsos Mission failed to properly investigate numerous specific organizations, scientists, and locations that could have revealed a more advanced nuclear program. If any more advanced nuclear work had in fact been discovered, that information would have been automatically classified at the time, and could remain classified or buried in archives and unreleased to this day.
2. Ten German nuclear scientists (Erich Bagge, Kurt Diebner, Walther Gerlach, Otto Hahn, Paul Harteck, Werner Heisenberg, Horst Korsching, Max von Laue, Carl Friedrich von Weizsäcker, and Karl Wirtz) rounded up by the Alsos Mission were kept under house arrest from July 1945 until January 1946 at Farm Hall in the United Kingdom, where their private conversations were recorded without their knowledge. The transcripts, which were not released to the public until 1992, record the scientists' surprise at news of the 6 August 1945 Hiroshima bombing and do not reveal significant apparent knowledge of nuclear weapons design and development [Bernstein 2001; Frank 1993; Hoffmann 2023].	2. A huge number of relevant nuclear scientists were not at Farm Hall. There is evidence that those who were there suspected surveillance and conducted their conversations accordingly. The preserved transcripts document only a small fraction of the discussions that would have occurred among ten people and their British attendants during those six months. Moreover, the transcripts are English translations, which may not accurately reflect the original German conversations. Both the original recordings and the original German transcripts are said to have been permanently lost, a shocking lapse for such an important operation.
3. In their public interviews and writings in the years after the war, German nuclear scientists professed a lack of desire, plans, materials and/or political support to produce nuclear weapons for the Third Reich [Cassidy 1992; Heisenberg 1953, 1971; Irving 1967; Powers 1993; NYT 1948-12-28 p. 10].	3. Only a small number of nuclear scientists went on the public record. It is not clear how much of what they said was factual history versus personal spin meant to avoid postwar criticism; the answer may vary for different scientists in question. Certainly it would have been in their best personal interests to downplay their support for weapons-related work as much as possible.]

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[3] E.g., Goudsmit 1947; Hentschel and Hentschel 1996; Hoffmann 2023; Irving 1967; Powers 1993; Rose 1998; Walker 1989, 1995, 2020, 2024a, 2024b.

D.1.1 Alsos Mission

[Popular accounts of the Alsos Mission were written by Samuel Goudsmit, the scientific leader of Alsos, Boris Pash, the military leader, and Leslie Groves, their U.S.-based supervisor. In addition, many Alsos documents, long classified, are now available.

As illustrated by the documents in this section, the Alsos Mission failed to properly pursue a large number of leads that might have revealed that the German nuclear program was much larger and much more advanced than Alsos claimed. Some of the fundamental problems included:

- Whatever evidence Samuel Goudsmit wanted to pursue (or not), and whatever conclusions he drew from that evidence, apparently became the official view of Alsos. Boris Pash and other military men were there to move the Alsos scientists around safely and to retrieve any German scientists/materials that the Alsos scientists wanted, not to express their own opinions in Alsos reports. Likewise, there does not appear to be any documentation of junior Alsos scientists offering different opinions or disagreeing with Goudsmit through official channels.[4] Contemporary documents from U.S. officials show that they realized that Alsos basically was Goudsmit (pp. 3292–3293).

- Goudsmit was trained as a physicist, yet his only significant scientific accomplishment (calculations of electron spin) occurred when he was still a student, and it may have been due much more to his doctoral adviser Paul Ehrenfest and his fellow student George Uhlenbeck than to Goudsmit himself. Goudsmit was selected for Alsos specifically because he did not know or understand the scientific details of the Manhattan Project, in case he was captured by the Germans or the Russians. He spent his postwar career not as a scientifically innovative researcher, but rather as a bureaucratic administrator in scientific organizations who apparently concealed the fact that was a secret CIA asset (pp. 4778–4779).

- In his writings, Goudsmit appeared to show a strong belief in the superiority of his own insight and an equally deep prejudice against Germans, specifically a strong desire to believe that wartime German science and German scientists were inferior and incompetent. Almost certainly Goudsmit's mindset was strongly influenced by his parents having been killed during the war, although perhaps other factors influenced him as well. While his grief would be quite understandable, he did not sound at all like an open-minded and intellectually rigorous investigator for this topic, based on his own words. U.S. officials who worked with Goudsmit openly stated that he had a number of undesirable psychological characteristics (see for example pp. 3260–3261, 3264–3265, 3266–3269, 3274–3275, 3278, 3285–3287, 3288–3289, 3292–3293, 3294–3296, 3321).

- Goudsmit and other investigators incorrectly assumed that any significant details about the German nuclear program would be widely shared among German scientists and freely divulged by those scientists to Alsos investigators. Yet in fact the German program seems to have been highly compartmentalized, with each person knowing only as much as they needed to know to perform their own job in the program. Furthermore, it was in the best personal interests of any German scientists interviewed by Goudsmit to minimize their wartime knowledge, work, and accomplishments as much as possible, in order to avoid further interrogations, detention (at Farm Hall, Dustbin, Ashcan, in the United States, etc.), or war crimes trials that could lead to their imprisonment or execution. Thus they told Goudsmit exactly what he wanted to hear—that German science was inferior and had not accomplished much. Goudsmit was apparently very satisfied with that answer. Even if Goudsmit had been more open-minded, he had been trained as a physicist to hold academic discussions and to accept the answers at face value, not to hold strong, probing, skeptical interrogations and to apply as much psychological pressure as possible.

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[4] Lt. Col. George R. Eckman's "Final Report on the ALSOS Mission," written in December 1945, seems to be missing from modern archives (p. 3333). If it could be located, it is possible that it might give a different opinion than Goudsmit's public statements.

- Goudsmit and the rest of Alsos never investigated work, personnel, equipment, or documents in the large and scientifically very important Soviet-occupied areas of Germany (apart from a token trip to the Kaiser Wilhelm Institute for Physics in Berlin in late July 1945, after the Soviets had already stripped it bare).

- Alsos never investigated other Soviet-occupied territory such as Poland, Czechoslovakia, Hungary, Romania, and Bulgaria, where considerable German work is known to have occurred (pp. 3271–3273).

- Alsos never investigated Norway and Denmark, where important German work had also been conducted.

- Alsos never investigated sites in Thuringia other than Stadtilm and Nordhausen, even though Thuringia was filled with a large number of potentially relevant sites, especially underground.

- Alsos did not seriously investigate Austria (apart from interviewing some scientists from Vienna, after the Soviets had already removed personnel and materials from Austria).

- Alsos dismissed and did not seriously pursue work that had been conducted by the Reichspost, Wilhelm Ohnesorge, Manfred von Ardenne, Fritz Houtermans, Siegfried Flügge, etc.

- Alsos dismissed and did not seriously pursue work that had been conducted by the Army Ordnance Office, Erich Schumann, Walter Trinks, etc.

- Alsos dismissed and did not seriously pursue work that had been conducted under the SS.

- Alsos did not seriously investigate work that had been conducted at I.G. Farben.

- Alsos did not consider the large number of German documents that were destroyed, hidden, or captured by other groups from the United States or from other countries (especially the Soviet Union).

- From the outset, Alsos was highly focused on a few German scientists such as Heisenberg who were already well known before the war. Alsos dismissed and did not seriously pursue other, newer, or previously unknown scientists and engineers that it encountered.

- Alsos stated incorrectly that German scientists had no concept for a bomb, other than a vision of a highly impractical and inefficient out-of-control fission reactor.

- Alsos stated incorrectly that German scientists had not given serious consideration to producing and using plutonium.

- Richard Kuhn was one of the top brains behind Germany's massive, long-running, and highly advanced chemical weapons program that successfully researched, developed, tested, mass-produced, and stockpiled the world's first nerve gases. Despite interrogating Richard Kuhn in April 1945, Goudsmit and the other Alsos investigators were completely oblivious to the existence of the nerve gas program or Kuhn's role in it. Even when they pressed Kuhn for more information in September 1945, all they learned was that he had been involved in the production of plastics and other basic materials (p. 3316). By that time Alsos had spent more than a year searching all of Europe for any evidence of any types of German weapons of mass destruction. This demonstrable and complete failure by Alsos to even discover (let alone properly understand) the massive German chemical weapons program appears to cast grave doubt on the competence of Goudsmit and the other Alsos investigators, as well as the validity of their conclusions about the German nuclear program, which involved many of the same organizations as the nerve gas program (Army Ordnance, SS, I.G. Farben, etc.).

- Before the war even ended, Goudsmit and/or his superiors apparently decided to divert most of the personnel, time, and resources of the Alsos Mission away from weapons of mass destruction (WMD), and instead to analyze other German technological developments such as anti-aircraft missiles and proximity fuses (e.g., pp. 3270, 3285, 3306). That shift is documented by the large number of reports that Alsos personnel wrote on those other subjects in spring and summer 1945. That effort duplicated non-WMD field work that was being carried out by many other teams of Allied investigators (BIOS, CIOS, FIAT, NavTecMisEu, etc.). It also left Alsos even less able to track down leads on German nuclear or other WMD programs. (Or perhaps it got Alsos out of the way so that some much more capable but more secretive Allied team could investigate the German nuclear program?)

- If Goudsmit concluded that there was no advanced German nuclear program, and stated that in official reports and public statements at the time, it would have been in his own best interests to keep saying that, even if he eventually learned otherwise sometime after the war. Goudsmit's ego about his own abilities, his prejudice against German scientists (including his bizarre lifelong personal fixation on Heisenberg), and his desire not to jeopardize his continuing U.S.-government-funded career and his public credibility would have been strong reasons for him to maintain his conclusions, even if sometime after the war he eventually heard some secret evidence that did not fit into his conclusions.

- In May 1945, SHAEF G-2 Generals Thomas J. Betts (p. 5030) and George Bryan Conrad plus AAF General Henry Arnold's advisor Prof. Edward L. Bowles of MIT (pp. 4711, 5319) concluded that Alsos had failed to do its primary job of investigating the German nuclear program (pp. 3285–3287). Robert Furman admitted that there were so many German nuclear sites and documents that his team did not even try to investigate them.

If there was in fact an advanced German nuclear program and the United States learned of that during or after the war, that knowledge does not appear to have flowed through or been shared with the Alsos Mission. Any such knowledge seems to have resided with whatever officials or groups warned Franklin Roosevelt of an advanced German nuclear program; directed advancing U.S. forces straight to Thuringia, Austria, and Czechoslovakia; captured and interrogated Hans Kammler; handled the personnel and materials from the German submarine U-234 and other captured submarines; etc. (see p. 4692).]

[According to Robert Furman, "everything done by Alsos was done by Goudsmit" (p. 3292). Other than the brief mention by Thomas Powers below, why do the many books on the Alsos mission completely omit the fact that in early December 1944, long before Allied forces even reached Germany, Samuel Goudsmit went on such an extreme tirade against German people that he had a nervous breakdown, was relieved of duty, and was sent back to the United States for most of the remainder of the war in Europe? That seems like an important detail in evaluating the history of the Alsos mission and the quality of its work in investigating the German nuclear program.]

Thomas Powers. 1993. *Heisenberg's War: The Secret History of the German Bomb.* New York: Alfred A. Knopf. pp. 371–372, 382, 560.

Robert Furman wasn't quite sure what brought it on—war causes terrible pressures. They'd been out in Strasbourg that day, had suddenly found themselves in a field surrounded by howitzers right at the edge of the war. Back at headquarters they'd seen some victims of shell shock, trembling, weeping men. Goudsmit had been terribly worried about his parents; he'd heard nothing since their final letter of farewell in March 1943, and the news of Eindhoven in September promised no hope.

That night in Strasbourg, when Furman and Goudsmit were alone together, Goudsmit "just went off his rocker—he was furious at the Germans, weeping and thrashing around."[13] It took Furman half an hour to pull Goudsmit together. Goudsmit barely alluded to this episode when he wrote his wife from Paris four or five days later. "The grim part of the venture," he told her, "was that I had to face for the first time a small number of people like myself, but on the other side." He told her he longed for a visit home, and Furman quietly arranged it. Goudsmit had been working closely with Furman for some months on what he had described to Walter Colby as "Major RRF's project for Germany," and Furman had planned to send Goudsmit to Switzerland to lay the groundwork. But the episode in Haagen's apartment in Strasbourg ended all that; it seemed obvious to Furman that Goudsmit was not up to the tension or the delicacy of such an effort. [...]

[O]n November 20, Donovan and Buxton cabled Dulles, "Am told Goudsmit somewhat tactless and possibly should not be included to work with temperamental people. Wardenburg said to be the better informed." But Goudsmit remained a part of the plan until mid-December, when his name abruptly disappeared from operational cables after his strange breakdown under the strain of Strasbourg. [...]

13. Interview with Furman, March 6, 1990.

William Donovan to Allen Dulles. 20 November 1944. Cable Out 23415. [NARA RG 226, Entry A1-134, Box 219, Folder 1371: OUT AZUSA Nov. '43 Sept. '45]

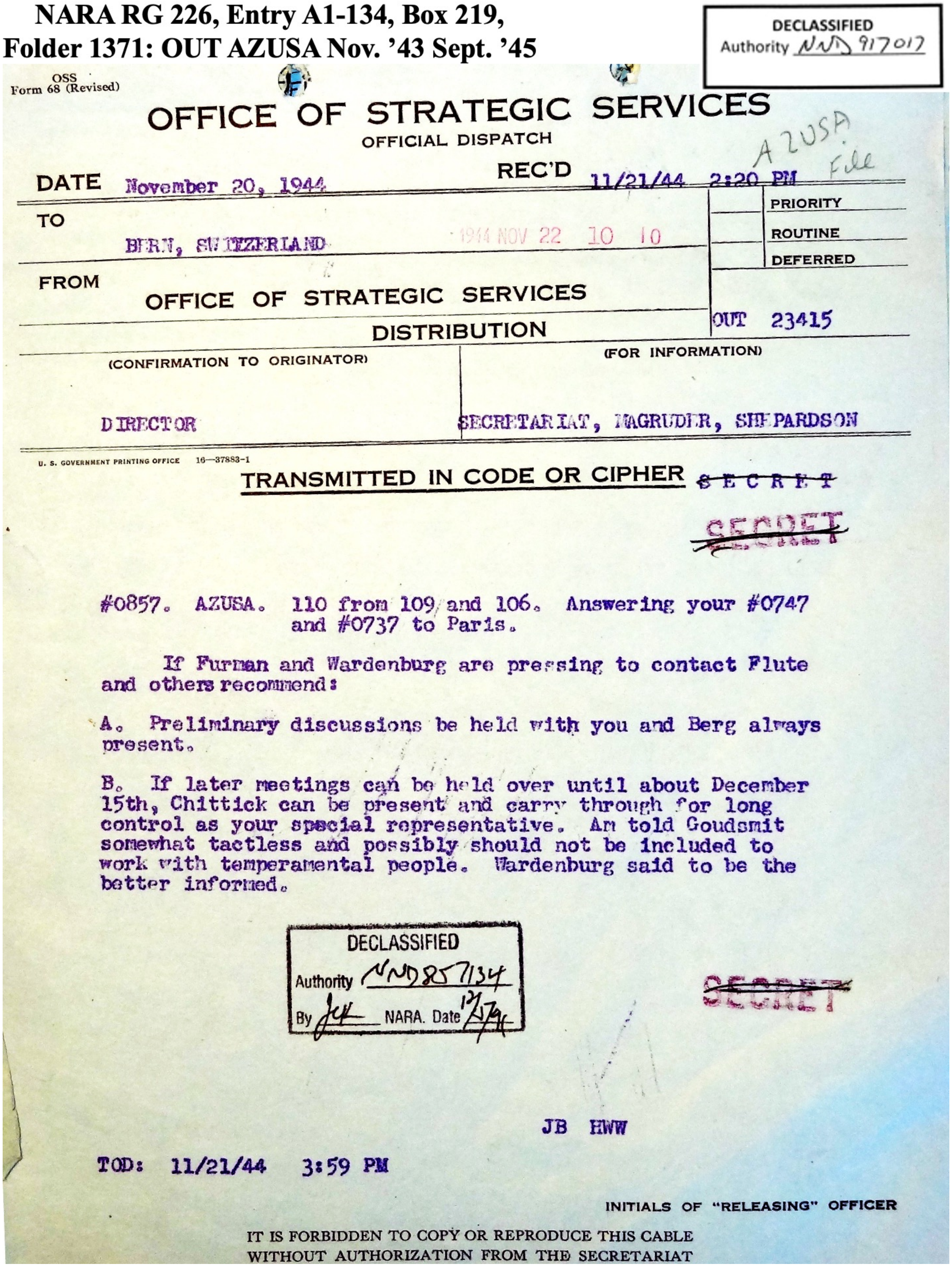
#0857. AZUSA. 110 from 109 and 106. Answering your #0747 and #737 to Paris.

If Furman and Wardenburg are pressing to contact Flute [Paul Scherrer] and others recommend:

A. Preliminary discussions be held with you and [Moe] Berg always present.

B. If later meetings can be held over until about December 15th, [Martin] Chittick can be present and carry through for long control as your special representative. Am told Goudsmit somewhat tactless and possibly should not be included to work with temperamental people. Wardenburg said to be the better informed.

[See p. 3261. According to OSS Director William Donovan, Samuel Goudsmit was "tactless," not recommended to work with people, and even less "informed" about nuclear weapons physics than Frederic Wardenburg, a junior Alsos member and middle manager from Du Pont whose only scientific education was a bachelor's degree in electrical engineering from two decades earlier (1927).]



NARA RG 226, Entry A1-134, Box 219, Folder 1371: OUT AZUSA Nov. '43 Sept. '45

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Form 68 (Revised)

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#0857. AZUSA. 110 from 109 and 106. Answering your #0747 and #0737 to Paris.

If Furman and Wardenburg are pressing to contact Flute and others recommend:

A. Preliminary discussions be held with you and Berg always present.

B. If later meetings can be held over until about December 15th, Chittick can be present and carry through for long control as your special representative. Am told Goudsmit somewhat tactless and possibly should not be included to work with temperamental people. Wardenburg said to be the better informed.

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JB HWW

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Figure D.1: OSS Director William Donovan to Allen Dulles. 20 November 1944. Cable Out 23415 [NARA RG 226, Entry A1-134, Box 219, Folder 1371: OUT AZUSA Nov. '43 Sept. '45].

NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002
GERMANY—ALSOS MISSION * Administrative Matters (1940-1945)

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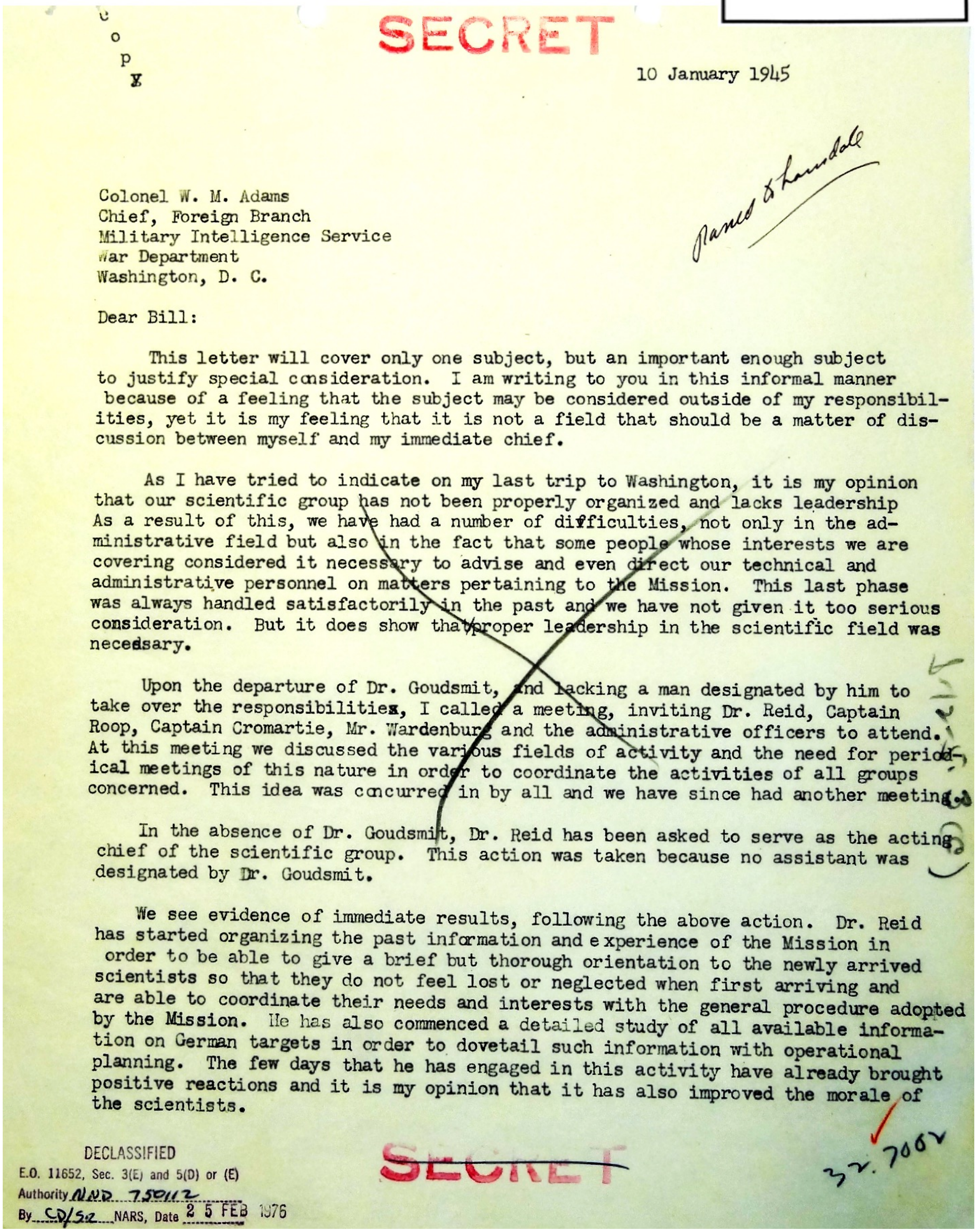

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10 January 1945

Passed to Lansdale

Colonel W. M. Adams
Chief, Foreign Branch
Military Intelligence Service
War Department
Washington, D. C.

Dear Bill:

This letter will cover only one subject, but an important enough subject to justify special consideration. I am writing to you in this informal manner because of a feeling that the subject may be considered outside of my responsibilities, yet it is my feeling that it is not a field that should be a matter of discussion between myself and my immediate chief.

As I have tried to indicate on my last trip to Washington, it is my opinion that our scientific group has not been properly organized and lacks leadership As a result of this, we have had a number of difficulties, not only in the administrative field but also in the fact that some people whose interests we are covering considered it necessary to advise and even direct our technical and administrative personnel on matters pertaining to the Mission. This last phase was always handled satisfactorily in the past and we have not given it too serious consideration. But it does show that proper leadership in the scientific field was necessary.

Upon the departure of Dr. Goudsmit, and lacking a man designated by him to take over the responsibilities, I called a meeting, inviting Dr. Reid, Captain Roop, Captain Cromartie, Mr. Wardenburg and the administrative officers to attend. At this meeting we discussed the various fields of activity and the need for periodical meetings of this nature in order to coordinate the activities of all groups concerned. This idea was concurred in by all and we have since had another meeting.

In the absence of Dr. Goudsmit, Dr. Reid has been asked to serve as the acting chief of the scientific group. This action was taken because no assistant was designated by Dr. Goudsmit.

We see evidence of immediate results, following the above action. Dr. Reid has started organizing the past information and experience of the Mission in order to be able to give a brief but thorough orientation to the newly arrived scientists so that they do not feel lost or neglected when first arriving and are able to coordinate their needs and interests with the general procedure adopted by the Mission. He has also commenced a detailed study of all available information on German targets in order to dovetail such information with operational planning. The few days that he has engaged in this activity have already brought positive reactions and it is my opinion that it has also improved the morale of the scientists.

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By CD/S2 NARS, Date 25 FEB 1976

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Figure D.2: Boris Pash to W. M. Adams. 10 January 1945. Selection of a replacement chief scientist of Alsos after Samuel Goudsmit's nervous breakdown and removal [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)].

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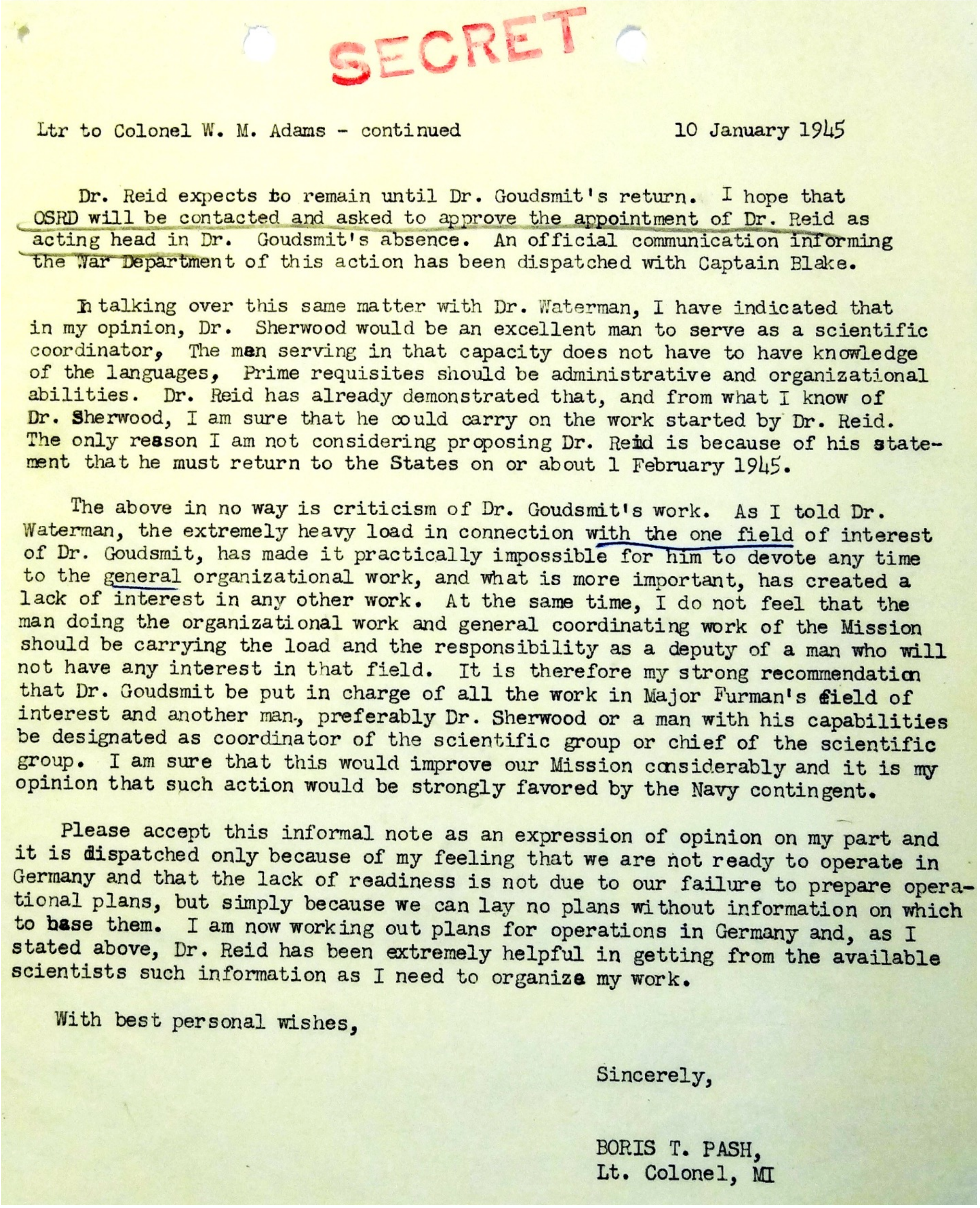
NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002
GERMANY—ALSOS MISSION * Administrative Matters (1940-1945)



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Ltr to Colonel W. M. Adams - continued 10 January 1945

Dr. Reid expects to remain until Dr. Goudsmit's return. I hope that OSRD will be contacted and asked to approve the appointment of Dr. Reid as acting head in Dr. Goudsmit's absence. An official communication informing the War Department of this action has been dispatched with Captain Blake.

In talking over this same matter with Dr. Waterman, I have indicated that in my opinion, Dr. Sherwood would be an excellent man to serve as a scientific coordinator, The man serving in that capacity does not have to have knowledge of the languages, Prime requisites should be administrative and organizational abilities. Dr. Reid has already demonstrated that, and from what I know of Dr. Sherwood, I am sure that he could carry on the work started by Dr. Reid. The only reason I am not considering proposing Dr. Reid is because of his statement that he must return to the States on or about 1 February 1945.

The above in no way is criticism of Dr. Goudsmit's work. As I told Dr. Waterman, the extremely heavy load in connection with the one field of interest of Dr. Goudsmit, has made it practically impossible for him to devote any time to the general organizational work, and what is more important, has created a lack of interest in any other work. At the same time, I do not feel that the man doing the organizational work and general coordinating work of the Mission should be carrying the load and the responsibility as a deputy of a man who will not have any interest in that field. It is therefore my strong recommendation that Dr. Goudsmit be put in charge of all the work in Major Furman's field of interest and another man, preferably Dr. Sherwood or a man with his capabilities be designated as coordinator of the scientific group or chief of the scientific group. I am sure that this would improve our Mission considerably and it is my opinion that such action would be strongly favored by the Navy contingent.

Please accept this informal note as an expression of opinion on my part and it is dispatched only because of my feeling that we are not ready to operate in Germany and that the lack of readiness is not due to our failure to prepare operational plans, but simply because we can lay no plans without information on which to base them. I am now working out plans for operations in Germany and, as I stated above, Dr. Reid has been extremely helpful in getting from the available scientists such information as I need to organize my work.

With best personal wishes,

Sincerely,

BORIS T. PASH,
Lt. Colonel, MI

Figure D.3: Boris Pash to W. M. Adams. 10 January 1945. Selection of a replacement chief scientist of Alsos after Samuel Goudsmit's nervous breakdown and removal [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)].

A. E. Britt to Francis J. Smith. 7 March 1945. SUBJECT: Conversation between Col. Lansdale and Dr. Harold Wilson [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)]

1. Col. Lansdale talked to Dr. Tolman and the latter stated that Dr. Harold Wilson was concerned about the complaints received from Goudsmit. This apparently is the recent letter of which you are cognizant. Col. Lansdale told Dr. Wilson—

a. That we are not concerned with the organization of Alsos in the Theater;

b. This organization [Alsos] is not responsible for TA in the Theater, however that Furman and our organization is and that it is up to us to determine what we want, and how much of what they have obtained that we want and the priority to be established;

c. That it was none of Goudsmit's business as to whether or not the reports were sent to Dr. Tolman. Goudsmit is inclined to want to write reports and direct them to scientists. He was told that it was his responsibility to write reports in a way that non-scientists could understand them inasmuch as this office is the using office.

2. There is some question as to whether or not the above points contradict the basic principles of the Alsos agreement. However in talking to Dr. Wilson, Col. Lansdale pointed out to him that we did not think such as the case.

3. Suggest you talk to Col. Lansdale regarding the above matter.

BRITT

[See document photo on p. 3265.

Goudsmit complained about many other people, and many other people complained about Goudsmit's behavior and performance.

For some other examples, see pp. 3260–3261, 3266–3269, 3274–3275, 3278, 3285–3287, 3288–3289, 3292–3293, 3294–3296, 3321.

Quarrelsome behavior so severe as to leave such a paper trail was quite unusual for a senior scientific "professional," and certainly would have been detrimental to the proper functioning and the quality of the results of a high-priority intelligence mission being conducted in the midst of a world war.]

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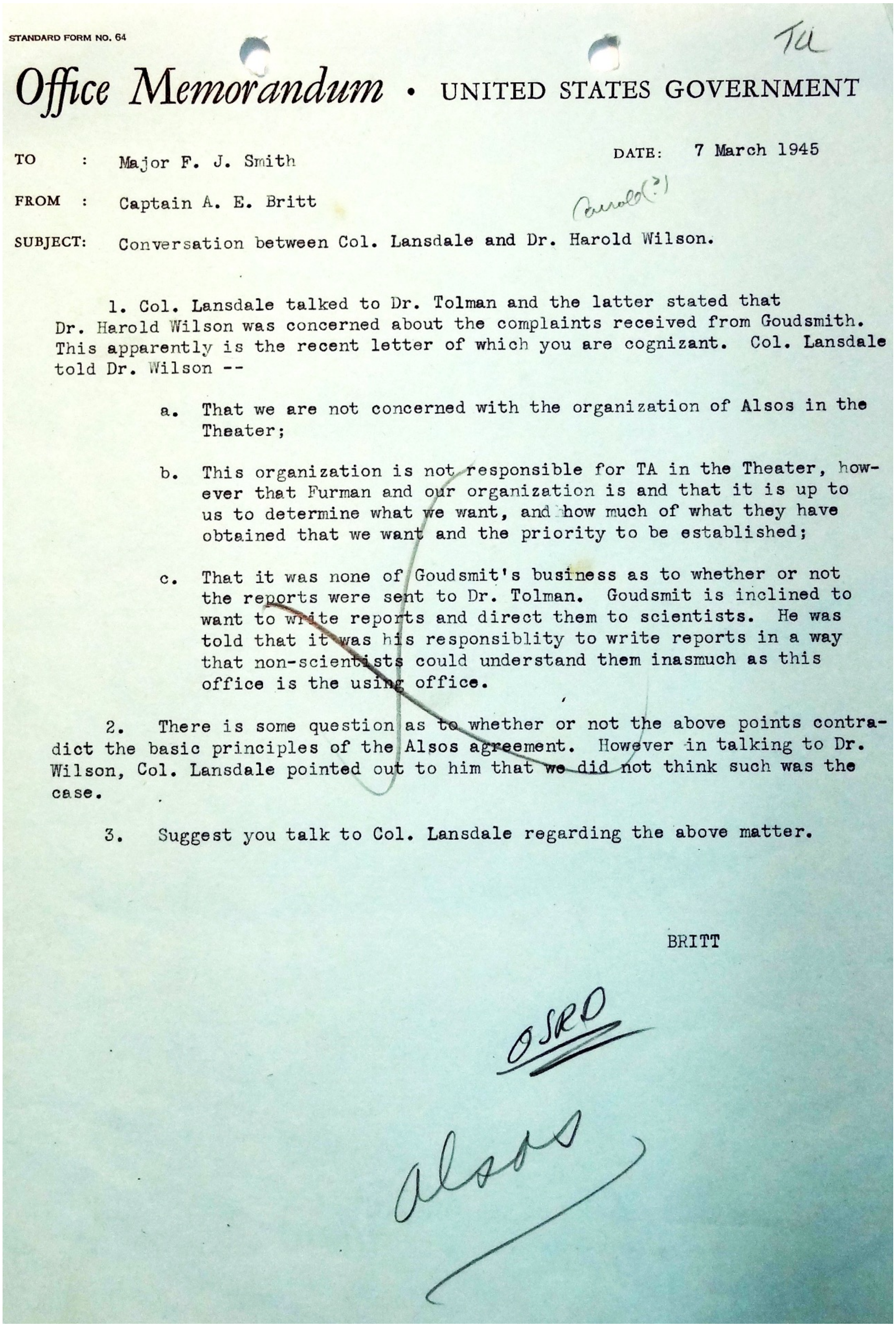
NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002
GERMANY—ALSOS MISSION * Administrative Matters (1940-1945)



STANDARD FORM NO. 64

TA

Office Memorandum • UNITED STATES GOVERNMENT

TO : Major F. J. Smith

DATE: 7 March 1945

FROM : Captain A. E. Britt

Carroll(?)

SUBJECT: Conversation between Col. Lansdale and Dr. Harold Wilson.

1. Col. Lansdale talked to Dr. Tolman and the latter stated that Dr. Harold Wilson was concerned about the complaints received from Goudsmith. This apparently is the recent letter of which you are cognizant. Col. Lansdale told Dr. Wilson --

a. That we are not concerned with the organization of Alsos in the Theater;

b. This organization is not responsible for TA in the Theater, however that Furman and our organization is and that it is up to us to determine what we want, and how much of what they have obtained that we want and the priority to be established;

c. That it was none of Goudsmit's business as to whether or not the reports were sent to Dr. Tolman. Goudsmit is inclined to want to write reports and direct them to scientists. He was told that it was his responsiblity to write reports in a way that non-scientists could understand them inasmuch as this office is the using office.

2. There is some question as to whether or not the above points contradict the basic principles of the Alsos agreement. However in talking to Dr. Wilson, Col. Lansdale pointed out to him that we did not think such was the case.

3. Suggest you talk to Col. Lansdale regarding the above matter.

BRITT

OSRD

alsos

Figure D.4: A. E. Britt to Francis J. Smith. 7 March 1945. SUBJECT: Conversation between Col. Lansdale and Dr. Harold Wilson [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)]. Goudsmit complained about many other people, and many other people complained about Goudsmit's behavior and performance.

Vannevar Bush to Samuel A. Goudsmit. 15 March 1945. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION * Administrative Matters (1940–1945)]

There were several matters which you discussed with Dr. Waterman and Mr. Wilson, prior to your return to the ETO, relating to the activities of the ALSOS Mission on behalf of the Special Project. Subsequent discussion of these matters with Dr. Tolman and Lt. Col. Lansdale have, I believe, clarified the points which were on your mind and resulted in bringing these matters into satisfactory form. Undoubtedly since you have now returned, you will be conferring with Major Furman and Major Calvert and the scientific members of ALSOS who are concerned with this subject and will presently have a full picture of the situation as it now stands in the ETO.

One point which I believe you felt needed clarification concerned the action which you and your colleagues should take in regard to the execution of plans for gathering intelligence in this area, which might be requested from Washington and alter materially the priorities and plans already agreed upon by the military and scientific group in the ETO. I do not anticipate that such situations are likely to arise, but if this were to occur, I understand it was your feeling that you would be satisfied if you were assured that any major changes were reviewed by and concurred in by Dr. Tolman. I am assured by Dr. Tolman and Colonel Lansdale that such will be the case. I expect that you will find upon your return that plans for targets and priorities are fairly well agreed upon and details have been worked out to the extent possible with available data. I understand that these plans have been closely coordinated with the requirements and information available in Washington. I expect that these plans are now clear enough so that there is little likelihood of important differences of opinion.

Another matter which has been discussed with Dr. Tolman and Colonel Lansdale concerns the nature of the intelligence reports which you prepare relating to the Special Project. We can give you full assurance that all of these reports are available to Dr. Tolman and reach him. As to the matter of writing them in "lay language," this writing must be done either in the ETO or here. If your reports are not received in such form someone here, namely Dr. Tolman, would have to re-write them in a form understandable to the non-scientific group. This is a burden which Dr. Tolman cannot take on nor can his staff. Hence we feel that it is reasonable to ask that your group prepare these reports in a form directly useable by the military group. Moreover, such reports can best be prepared with the full information available in the ETO rather than attempt to expand abbreviated scientific reports.

On the matter of interviewing German scientists taken into custody and sent to this country, this comes under two headings; firstly, interviewing for information on the Special Project; and secondly, interviewing for information in other fields. As to the first, it is Colonel Lansdale's group which can arrange the interviews. As to the second, it is a matter for Colonel Adams to arrange, for it is a G-2 function, and I understand that Dr. Waterman is taking this up with Colonel Adams. As to the PW's described in your memorandum, it is the conclusion of Colonel Lansdale's group, with which Dr. Tolman concurs, that the marginal material on the Special Project which might be obtained from these men, in addition to that already obtained by you and your colleagues in the interviews in the ETO, is not sufficiently promising to warrant the risks involved in giving them more information which might result from further interviews on this subject. Dr. Waterman will advise you of the results of his discussion with Colonel Adams regarding interviews for the purpose of obtaining information on other subjects.

I believe that you have found upon your return that the organization of intelligence on the Special Project from the military side has been clarified since your departure in December, and I trust that matters will progress smoothly during the remainder of this important and interesting assignment. I also hope that the targets will soon be available and that the circumstances, planning and execution of the missions will permit achieving results which are up to the Strasbourg standard. I am sure that all groups concerned will exert their best efforts to bring about this result.

Very sincerely yours,

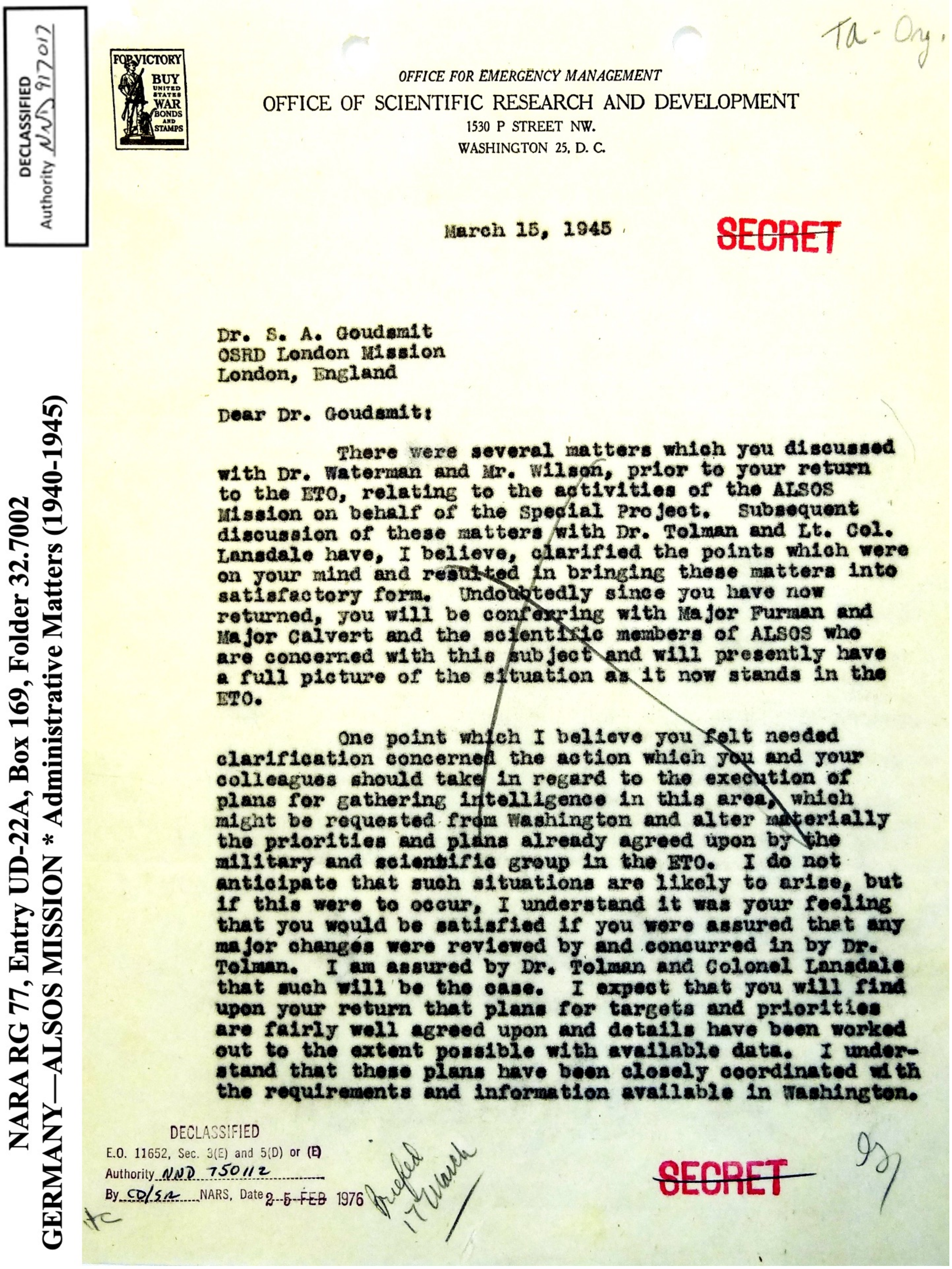
V. Bush, Director

cc: General Groves
Dr. Tolman
Dr. Waterman

[See document photos on pp. 3268–3269.

Vannevar Bush, who ran all wartime U.S. R&D, apparently agreed with all of the concerns about Goudsmit. Bush's letter to Goudsmit was diplomatically phrased but undoubtedly severe.

Goudsmit had been ordered out of Europe from December 1944 until sometime in March 1945, and Alsos wrapped up most of its duties by early May 1945. Thus Goudsmit spent very little time in Europe during the critical final six months of the war.]



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Authority NND 917017

NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002
GERMANY—ALSOS MISSION * Administrative Matters (1940-1945)

TA - Org.

FOR VICTORY BUY UNITED STATES WAR BONDS AND STAMPS

OFFICE FOR EMERGENCY MANAGEMENT
OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT
1530 P STREET NW.
WASHINGTON 25, D. C.

March 15, 1945

SECRET

Dr. S. A. Goudsmit
OSRD London Mission
London, England

Dear Dr. Goudsmit:

There were several matters which you discussed with Dr. Waterman and Mr. Wilson, prior to your return to the ETO, relating to the activities of the ALSOS Mission on behalf of the Special Project. Subsequent discussion of these matters with Dr. Tolman and Lt. Col. Lansdale have, I believe, clarified the points which were on your mind and resulted in bringing these matters into satisfactory form. Undoubtedly since you have now returned, you will be conferring with Major Furman and Major Calvert and the scientific members of ALSOS who are concerned with this subject and will presently have a full picture of the situation as it now stands in the ETO.

One point which I believe you felt needed clarification concerned the action which you and your colleagues should take in regard to the execution of plans for gathering intelligence in this area, which might be requested from Washington and alter materially the priorities and plans already agreed upon by the military and scientific group in the ETO. I do not anticipate that such situations are likely to arise, but if this were to occur, I understand it was your feeling that you would be satisfied if you were assured that any major changes were reviewed by and concurred in by Dr. Tolman. I am assured by Dr. Tolman and Colonel Lansdale that such will be the case. I expect that you will find upon your return that plans for targets and priorities are fairly well agreed upon and details have been worked out to the extent possible with available data. I understand that these plans have been closely coordinated with the requirements and information available in Washington.

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Authority NND 750112
By CD/SR NARS, Date 25 FEB 1976

Briefed 17 March

~~SECRET~~

tc

Figure D.5: Vannevar Bush to Samuel A. Goudsmit. 15 March 1945 [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)].

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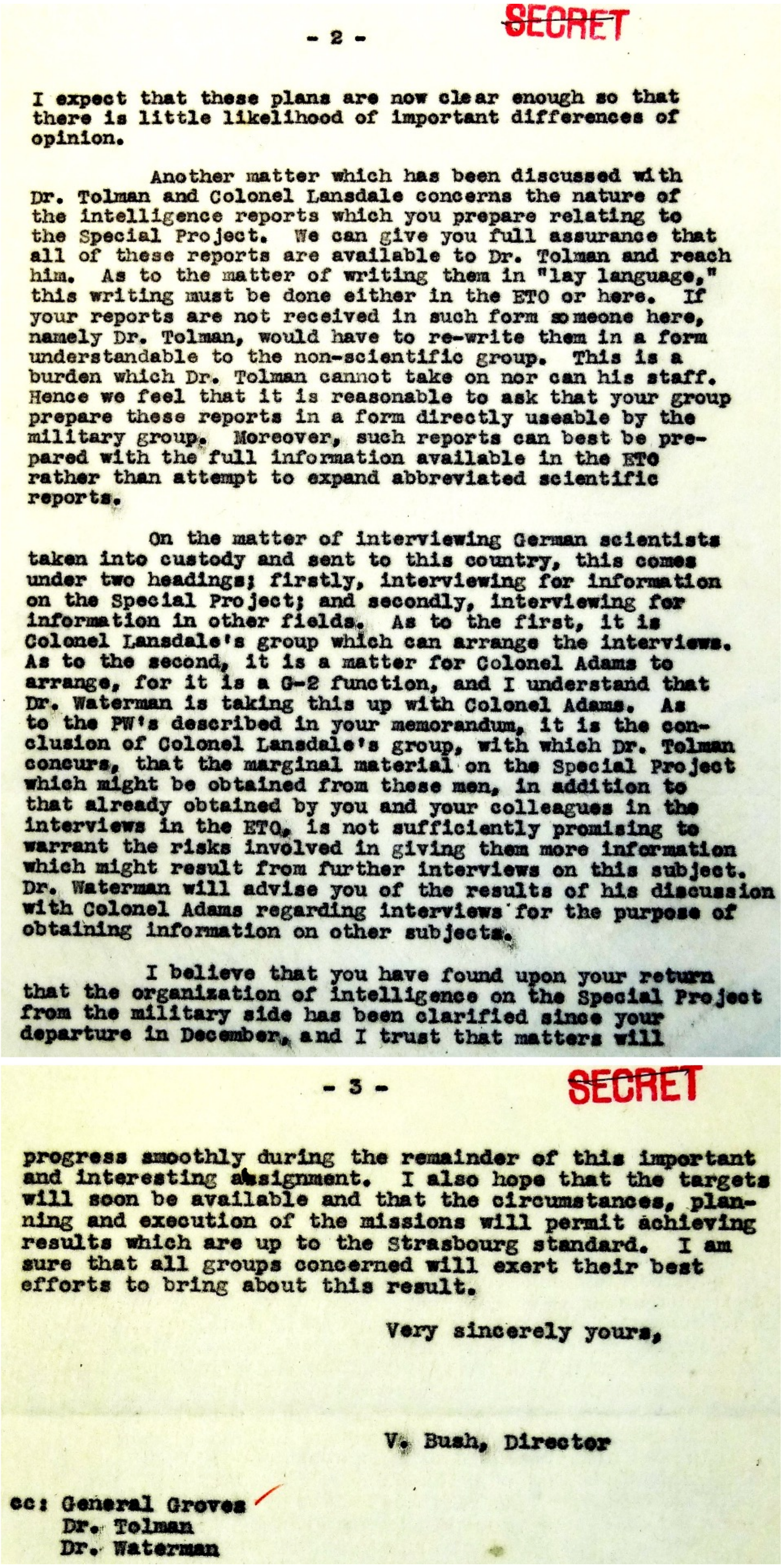
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002
GERMANY—ALSOS MISSION * Administrative Matters (1940-1945)



- 2 - SECRET

I expect that these plans are now clear enough so that there is little likelihood of important differences of opinion.

Another matter which has been discussed with Dr. Tolman and Colonel Lansdale concerns the nature of the intelligence reports which you prepare relating to the Special Project. We can give you full assurance that all of these reports are available to Dr. Tolman and reach him. As to the matter of writing them in "lay language," this writing must be done either in the ETO or here. If your reports are not received in such form someone here, namely Dr. Tolman, would have to re-write them in a form understandable to the non-scientific group. This is a burden which Dr. Tolman cannot take on nor can his staff. Hence we feel that it is reasonable to ask that your group prepare these reports in a form directly useable by the military group. Moreover, such reports can best be prepared with the full information available in the ETO rather than attempt to expand abbreviated scientific reports.

On the matter of interviewing German scientists taken into custody and sent to this country, this comes under two headings; firstly, interviewing for information on the Special Project; and secondly, interviewing for information in other fields. As to the first, it is Colonel Lansdale's group which can arrange the interviews. As to the second, it is a matter for Colonel Adams to arrange, for it is a G-2 function, and I understand that Dr. Waterman is taking this up with Colonel Adams. As to the PW's described in your memorandum, it is the conclusion of Colonel Lansdale's group, with which Dr. Tolman concurs, that the marginal material on the Special Project which might be obtained from these men, in addition to that already obtained by you and your colleagues in the interviews in the ETO, is not sufficiently promising to warrant the risks involved in giving them more information which might result from further interviews on this subject. Dr. Waterman will advise you of the results of his discussion with Colonel Adams regarding interviews for the purpose of obtaining information on other subjects.

I believe that you have found upon your return that the organization of intelligence on the Special Project from the military side has been clarified since your departure in December, and I trust that matters will

- 3 - SECRET

progress smoothly during the remainder of this important and interesting assignment. I also hope that the targets will soon be available and that the circumstances, planning and execution of the missions will permit achieving results which are up to the Strasbourg standard. I am sure that all groups concerned will exert their best efforts to bring about this result.

Very sincerely yours,

V. Bush, Director

cc: General Groves
Dr. Tolman
Dr. Waterman

Figure D.6: Vannevar Bush to Samuel A. Goudsmit. 15 March 1945 [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)].

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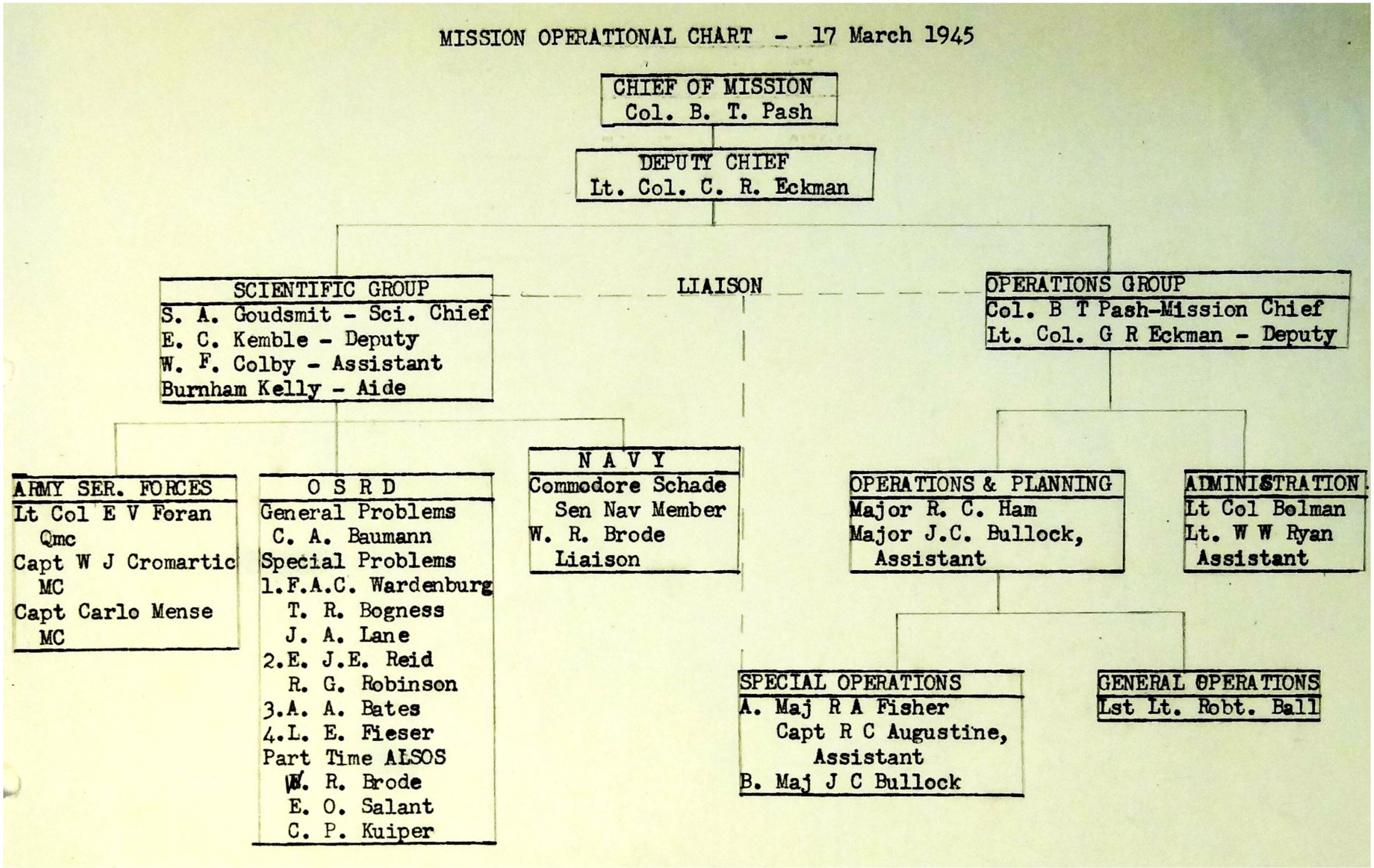
NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002
GERMANY—ALSOS MISSION * Administrative Matters (1940-1945)



MISSION OPERATIONAL CHART - 17 March 1945

CHIEF OF MISSION
Col. B. T. Pash

DEPUTY CHIEF
Lt. Col. C. R. Eckman

SCIENTIFIC GROUP
S. A. Goudsmit - Sci. Chief
E. C. Kemble - Deputy
W. F. Colby - Assistant
Burnham Kelly - Aide

LIAISON

OPERATIONS GROUP
Col. B T Pash-Mission Chief
Lt. Col. G R Eckman - Deputy

ARMY SER. FORCES
Lt Col E V Foran
Qmc
Capt W J Cromartic
MC
Capt Carlo Mense
MC

O S R D
General Problems
C. A. Baumann
Special Problems
1.F.A.C. Wardenburg
T. R. Bogness
J. A. Lane
2.E. J.E. Reid
R. G. Robinson
3.A. A. Bates
4.L. E. Fieser
Part Time ALSOS
W. R. Brode
E. O. Salant
C. P. Kuiper

N A V Y
Commodore Schade
Sen Nav Member
W. R. Brode
Liaison

OPERATIONS & PLANNING
Major R. C. Ham
Major J.C. Bullock,
Assistant

ADMINISTRATION
Lt Col Bolman
Lt. W W Ryan
Assistant

SPECIAL OPERATIONS
A. Maj R A Fisher
Capt R C Augustine,
Assistant
B. Maj J C Bullock

GENERAL OPERATIONS
1st Lt. Robt. Ball

Figure D.7: Alsos Mission Operational Chart. 17 March 1945 [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)]. "Special Problems 1" was the German nuclear program; Alsos also investigated many other unrelated topics. Even at its brief peak in the final two months of the war in Europe, Alsos was far too understaffed and overstretched to conduct a proper investigation of the nuclear program.

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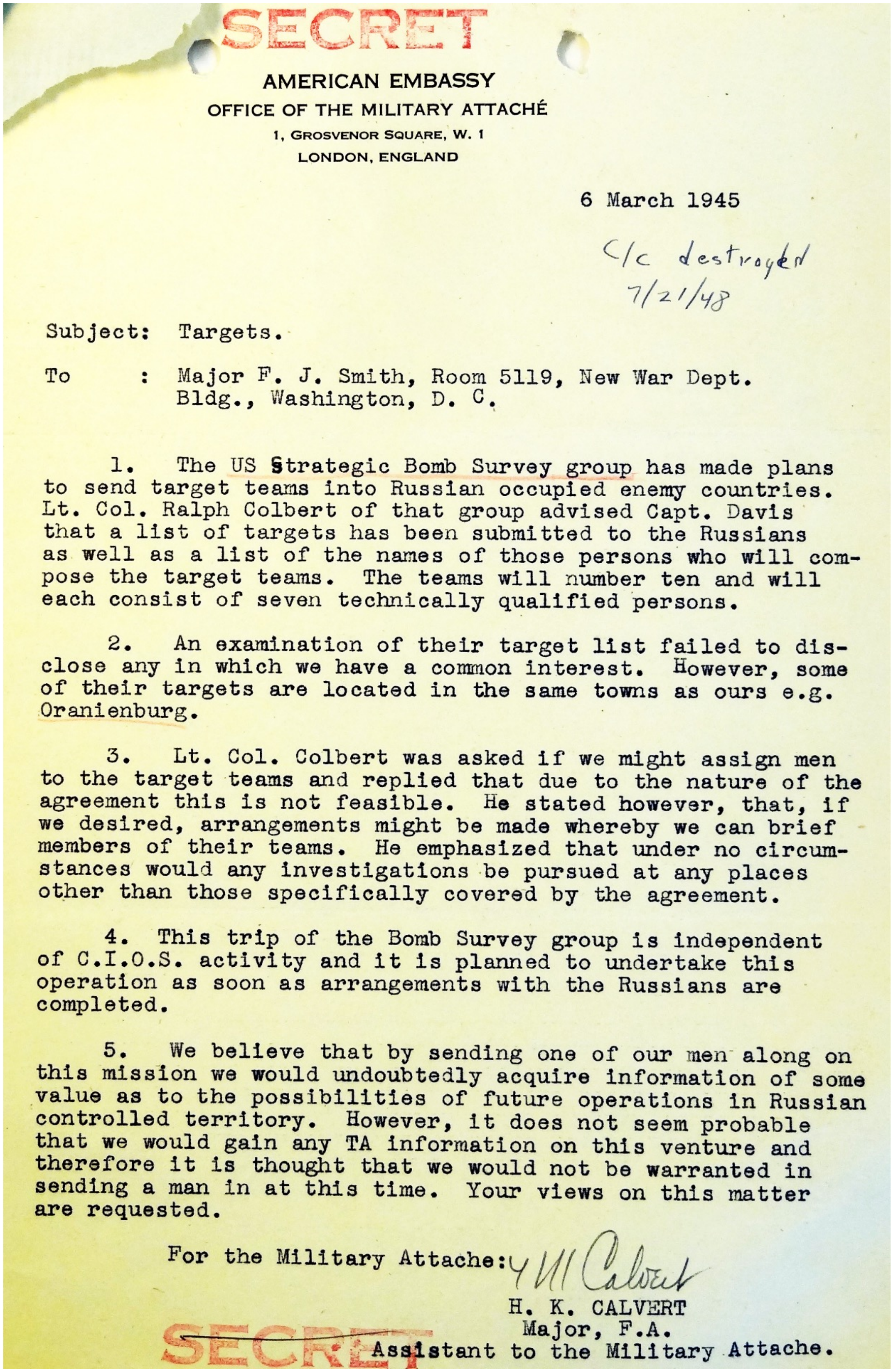

SECRET

AMERICAN EMBASSY
OFFICE OF THE MILITARY ATTACHÉ
1, GROSVENOR SQUARE, W. 1
LONDON, ENGLAND

6 March 1945

C/c destroyed
7/21/48

Subject: Targets.

To : Major F. J. Smith, Room 5119, New War Dept. Bldg., Washington, D. C.

1. The US Strategic Bomb Survey group has made plans to send target teams into Russian occupied enemy countries. Lt. Col. Ralph Colbert of that group advised Capt. Davis that a list of targets has been submitted to the Russians as well as a list of the names of those persons who will compose the target teams. The teams will number ten and will each consist of seven technically qualified persons.

2. An examination of their target list failed to disclose any in which we have a common interest. However, some of their targets are located in the same towns as ours e.g. Oranienburg.

3. Lt. Col. Colbert was asked if we might assign men to the target teams and replied that due to the nature of the agreement this is not feasible. He stated however, that, if we desired, arrangements might be made whereby we can brief members of their teams. He emphasized that under no circumstances would any investigations be pursued at any places other than those specifically covered by the agreement.

4. This trip of the Bomb Survey group is independent of C.I.O.S. activity and it is planned to undertake this operation as soon as arrangements with the Russians are completed.

5. We believe that by sending one of our men along on this mission we would undoubtedly acquire information of some value as to the possibilities of future operations in Russian controlled territory. However, it does not seem probable that we would gain any TA information on this venture and therefore it is thought that we would not be warranted in sending a man in at this time. Your views on this matter are requested.

For the Military Attache: H K Calvert
H. K. CALVERT
Major, F.A.
Assistant to the Military Attache.

SECRET

NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)

Figure D.8: Leslie Groves issued an order for Alsos not to investigate any nuclear sites or people in the vast amount of formerly German-controlled territory that became occupied by Soviet forces, thereby making most of the Germans nuclear program off-limits to Alsos [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

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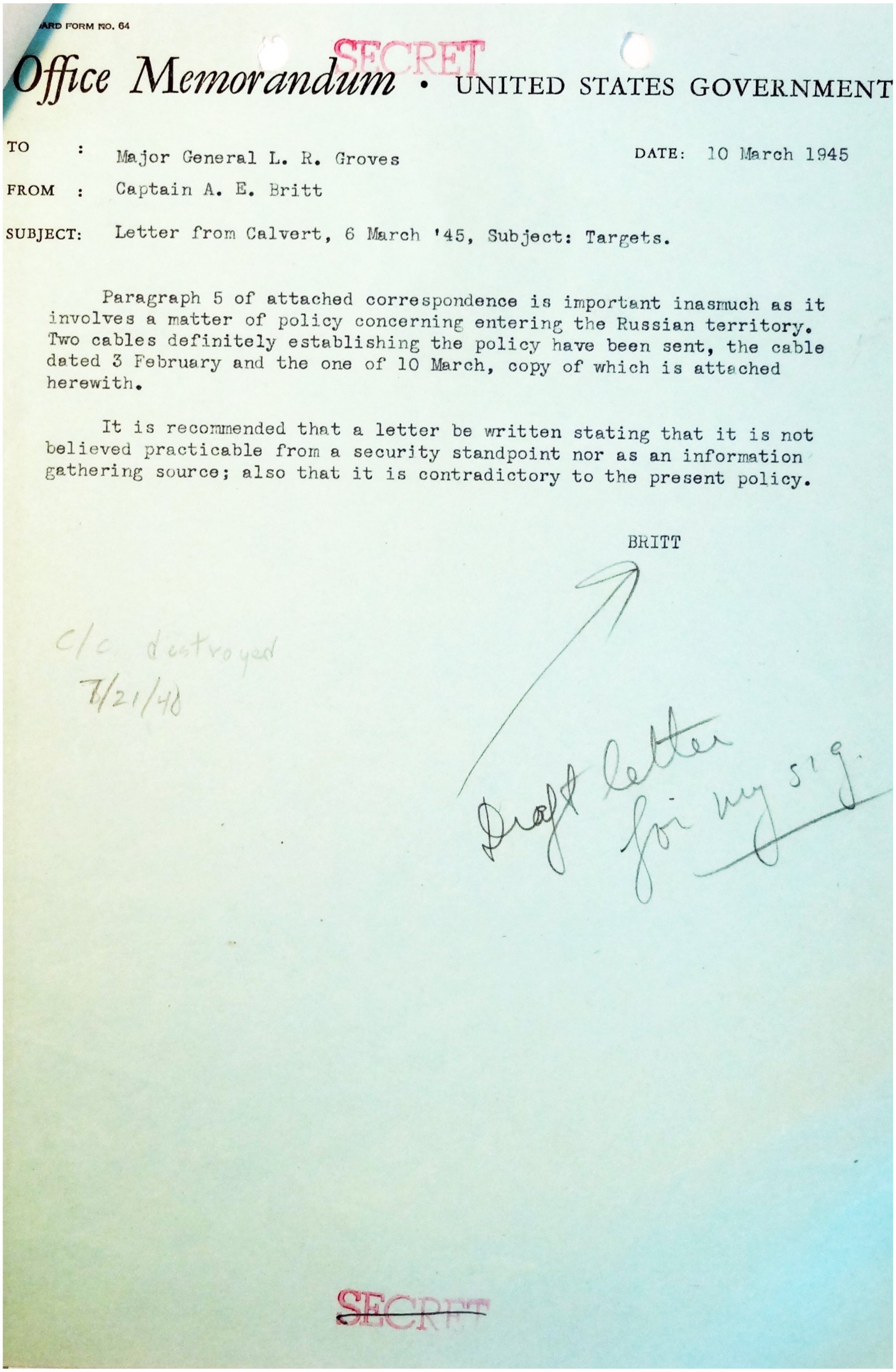

ARD FORM NO. 64

SECRET

Office Memorandum • UNITED STATES GOVERNMENT

TO : Major General L. R. Groves
DATE: 10 March 1945
FROM : Captain A. E. Britt
SUBJECT: Letter from Calvert, 6 March '45, Subject: Targets.

Paragraph 5 of attached correspondence is important inasmuch as it involves a matter of policy concerning entering the Russian territory. Two cables definitely establishing the policy have been sent, the cable dated 3 February and the one of 10 March, copy of which is attached herewith.

It is recommended that a letter be written stating that it is not believed practicable from a security standpoint nor as an information gathering source; also that it is contradictory to the present policy.

BRITT

c/c destroyed
7/21/48

Draft letter for my sig.

~~SECRET~~

NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)

Figure D.9: Leslie Groves issued an order for Alsos not to investigate any nuclear sites or people in the vast amount of formerly German-controlled territory that became occupied by Soviet forces, thereby making most of the German nuclear program off-limits to Alsos [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

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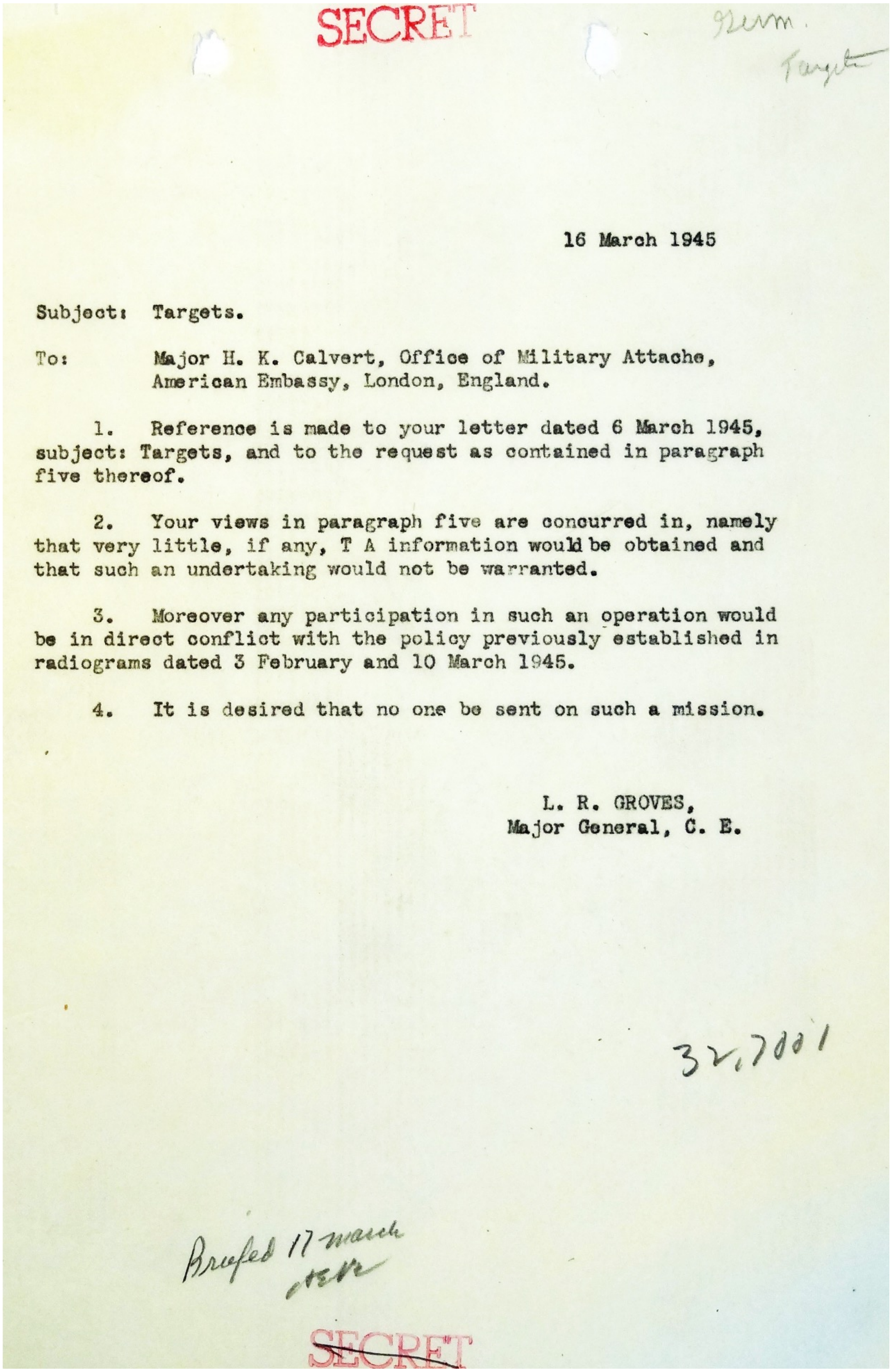
Authority NND947017



SECRET

Germ.
Targets

16 March 1945

Subject: Targets.

To: Major H. K. Calvert, Office of Military Attache,
American Embassy, London, England.

1. Reference is made to your letter dated 6 March 1945, subject: Targets, and to the request as contained in paragraph five thereof.

2. Your views in paragraph five are concurred in, namely that very little, if any, T A information would be obtained and that such an undertaking would not be warranted.

3. Moreover any participation in such an operation would be in direct conflict with the policy previously established in radiograms dated 3 February and 10 March 1945.

4. It is desired that no one be sent on such a mission.

L. R. GROVES,
Major General, C. E.

32.7001

Briefed 17 March
HKC

~~SECRET~~

NARA RG 77, Entry UD-22A, Box 171, Folder
32.60-2 GERMANY: Summary Reports (1945–1946)

Figure D.10: Leslie Groves issued an order for Alsos not to investigate any nuclear sites or people in the vast amount of formerly German-controlled territory that became occupied by Soviet forces, thereby making most of the German nuclear program off-limits to Alsos [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Samuel Goudsmit. 18 April 1945. SUBJECT: Preliminary Report on TA Information Obtained at Stadtilm. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

[...] 2. Targets to be removed from TA list.

a. Freiburg.

b. Posthalde bei Hinterzarten in the Black Forest.

c. Miersdorf bei Zeuthen, where the Reichspost worked.

d. Gottow

e. Berlin

f. Oranienburg, Auer.

All of the above places have been evacuated as far as TA targets are concerned.

[...] 6. Evaluation.

We are more convinced that the German TA effort is small. [...]

Note attached to Samuel Goudsmit's 18 April 1945 memo. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

Capt BRITT

This report seems a bit "fuzzy" to me—the arrangement (indentation, e. g.,) doesn't clarify the meaning for me.

R.

I imagine Goudsmit's talking thru 'is 'at when he says certain Targets are to be REMOVED from TA list—on what ground? Freiburg, e. g., he hasn't been there that I know of.

[Handwritten:] Major Smith has read.

[See document photos on p. 3275.

Even officers who were supporting Goudsmit's activities were exasperated by his penchant for declaring that no significant nuclear (TA) evidence could exist at certain places without even bothering to visit or investigate them. According to them, Goudsmit was known for "talking through his hat," a colloquial British phrase for talking about something without understanding it at all.]

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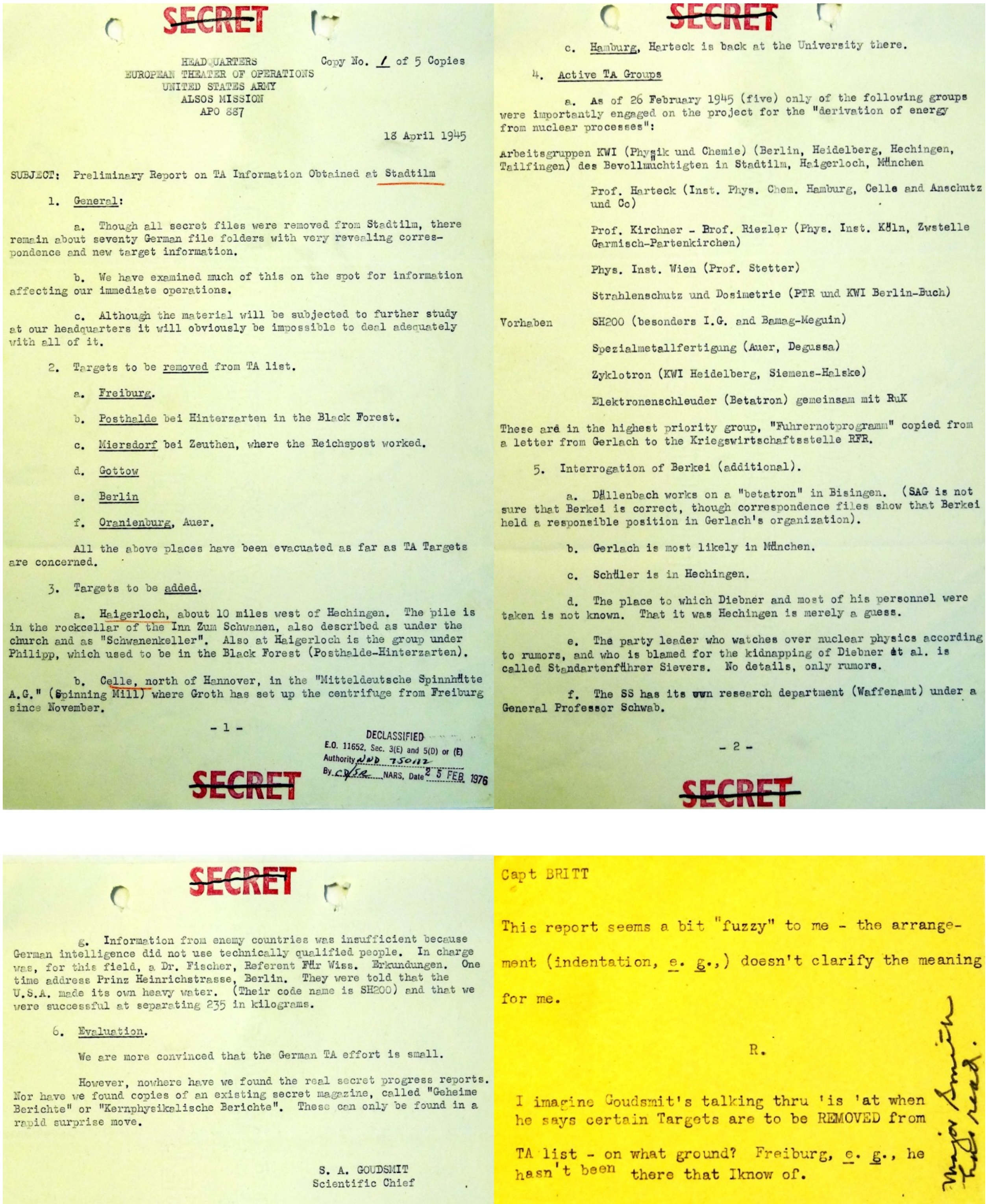
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3
GERMANY: US Wartime Positive Int. (Nov. 44–June 45)



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HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS MISSION
APO 887

Copy No. 1 of 5 Copies

18 April 1945

SUBJECT: Preliminary Report on TA Information Obtained at Stadtilm

1. General:

a. Though all secret files were removed from Stadtilm, there remain about seventy German file folders with very revealing correspondence and new target information.

b. We have examined much of this on the spot for information affecting our immediate operations.

c. Although the material will be subjected to further study at our headquarters it will obviously be impossible to deal adequately with all of it.

2. Targets to be removed from TA list.

a. Freiburg.

b. Posthalde bei Hinterzarten in the Black Forest.

c. Miersdorf bei Zeuthen, where the Reichspost worked.

d. Gottow

e. Berlin

f. Oranienburg, Auer.

All the above places have been evacuated as far as TA Targets are concerned.

3. Targets to be added.

a. Haigerloch, about 10 miles west of Hechingen. The pile is in the rockcellar of the Inn Zum Schwanen, also described as under the church and as "Schwanenkeller". Also at Haigerloch is the group under Philipp, which used to be in the Black Forest (Posthalde-Hinterzarten).

b. Celle, north of Hannover, in the "Mitteldeutsche Spinnhütte A.G." (Spinning Mill) where Groth has set up the centrifuge from Freiburg since November.

- 1 -

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Authority NND 750122
By CD/SR NARS, Date 25 FEB 1976

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c. Hamburg, Harteck is back at the University there.

4. Active TA Groups

a. As of 26 February 1945 (five) only of the following groups were importantly engaged on the project for the "derivation of energy from nuclear processes":

Arbeitsgruppen KWI (Physik und Chemie) (Berlin, Heidelberg, Hechingen, Tailfingen) des Bevollmächtigten in Stadtilm, Haigerloch, München

Prof. Harteck (Inst. Phys. Chem. Hamburg, Celle and Anschutz und Co)

Prof. Kirchner - Brof. Riezler (Phys. Inst. Köln, Zwstelle Garmisch-Partenkirchen)

Phys. Inst. Wien (Prof. Stetter)

Strahlenschutz und Dosimetrie (PTR und KWI Berlin-Buch)

Vorhaben SH200 (besonders I.G. and Bamag-Meguin)

Spezialmetallfertigung (Auer, Degussa)

Zyklotron (KWI Heidelberg, Siemens-Halske)

Elektronenschleuder (Betatron) gemeinsam mit RuK

These are in the highest priority group, "Fuhrernotprogramm" copied from a letter from Gerlach to the Kriegswirtschaftsstelle RFR.

5. Interrogation of Berkei (additional).

a. Dällenbach works on a "betatron" in Bisingen. (SAG is not sure that Berkei is correct, though correspondence files show that Berkei held a responsible position in Gerlach's organization).

b. Gerlach is most likely in München.

c. Schüler is in Hechingen.

d. The place to which Diebner and most of his personnel were taken is not known. That it was Hechingen is merely a guess.

e. The party leader who watches over nuclear physics according to rumors, and who is blamed for the kidnapping of Diebner et al. is called Standartenführer Sievers. No details, only rumors.

f. The SS has its own research department (Waffenamt) under a General Professor Schwab.

- 2 -

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g. Information from enemy countries was insufficient because German intelligence did not use technically qualified people. In charge was, for this field, a Dr. Fischer, Referent Für Wiss. Erkundungen. One time address Prinz Heinrichstrasse, Berlin. They were told that the U.S.A. made its own heavy water. (Their code name is SH200) and that we were successful at separating 235 in kilograms.

6. Evaluation.

We are more convinced that the German TA effort is small.

However, nowhere have we found the real secret progress reports. Nor have we found copies of an existing secret magazine, called "Geheime Berichte" or "Kernphysikalische Berichte". These can only be found in a rapid surprise move.

S. A. GOUDSMIT
Scientific Chief

Capt BRITT

This report seems a bit "fuzzy" to me - the arrangement (indentation, e. g.,) doesn't clarify the meaning for me.

R.

I imagine Goudsmit's talking thru 'is 'at when he says certain Targets are to be REMOVED from TA list - on what ground? Freiburg, e. g., he hasn't been there that Iknow of.

Major Smith has read.

Figure D.11: Samuel Goudsmit. 18 April 1945. SUBJECT: Preliminary Report on TA Information Obtained at Stadtilm. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

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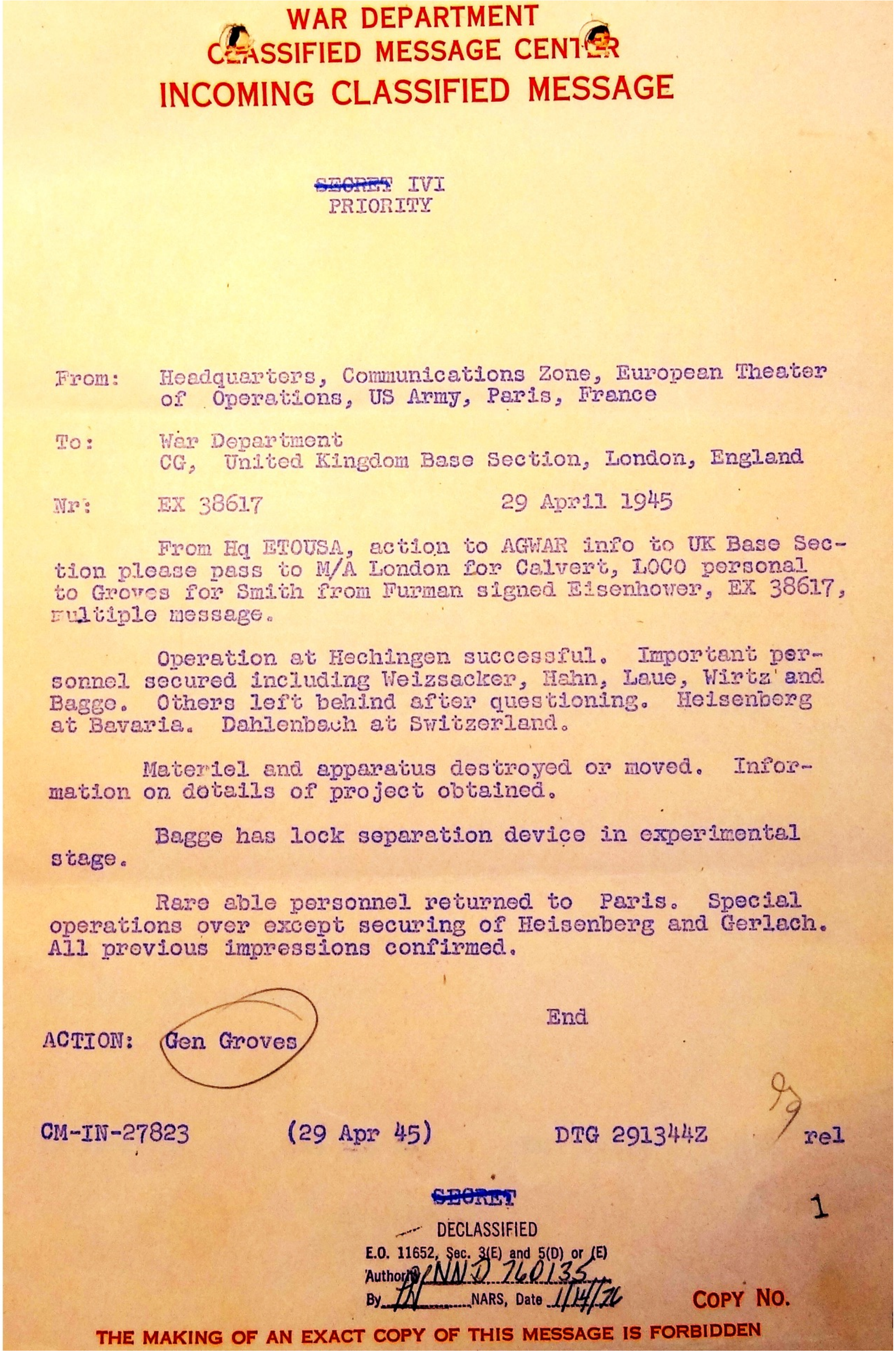
Authority NND 917017



WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
INCOMING CLASSIFIED MESSAGE

~~SECRET~~ IVI
PRIORITY

From: Headquarters, Communications Zone, European Theater of Operations, US Army, Paris, France

To: War Department
CG, United Kingdom Base Section, London, England

Nr: EX 38617 29 April 1945

From Hq ETOUSA, action to AGWAR info to UK Base Section please pass to M/A London for Calvert, LOCO personal to Groves for Smith from Furman signed Eisenhower, EX 38617, multiple message.

Operation at Hechingen successful. Important personnel secured including Weizsacker, Hahn, Laue, Wirtz and Bagge. Others left behind after questioning. Heisenberg at Bavaria. Dahlenbach at Switzerland.

Materiel and apparatus destroyed or moved. Information on details of project obtained.

Bagge has lock separation device in experimental stage.

Rare able personnel returned to Paris. Special operations over except securing of Heisenberg and Gerlach. All previous impressions confirmed.

End

ACTION: Gen Groves

CM-IN-27823 (29 Apr 45) DTG 291344Z 99 rel

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Authority NND 760135
By NARS, Date 1/14/76

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NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45

Figure D.12: 29 April 1945 [NARA RG 77, Entry UD-22A, Box 160, Folder APR–Dec. '45]. "Rare able personnel returned to Paris. Special operations over except securing of Heisenberg and Gerlach. All previous impressions confirmed."

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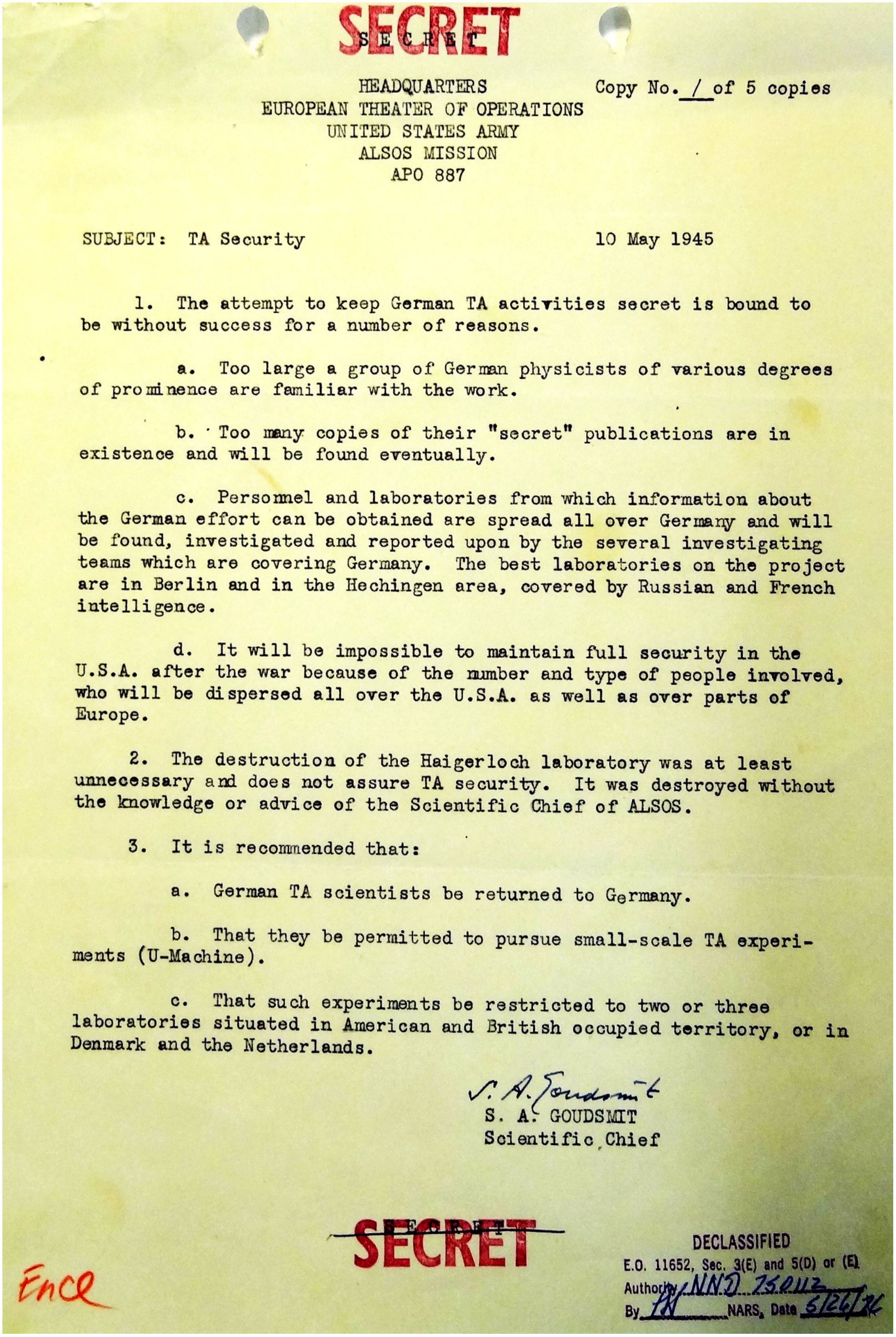
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002
GERMANY—ALSOS MISSION * Administrative Matters (1940-1945)



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HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS MISSION
APO 887

Copy No. 1 of 5 copies

SUBJECT: TA Security

10 May 1945

1. The attempt to keep German TA activities secret is bound to be without success for a number of reasons.

a. Too large a group of German physicists of various degrees of prominence are familiar with the work.

b. Too many copies of their "secret" publications are in existence and will be found eventually.

c. Personnel and laboratories from which information about the German effort can be obtained are spread all over Germany and will be found, investigated and reported upon by the several investigating teams which are covering Germany. The best laboratories on the project are in Berlin and in the Hechingen area, covered by Russian and French intelligence.

d. It will be impossible to maintain full security in the U.S.A. after the war because of the number and type of people involved, who will be dispersed all over the U.S.A. as well as over parts of Europe.

2. The destruction of the Haigerloch laboratory was at least unnecessary and does not assure TA security. It was destroyed without the knowledge or advice of the Scientific Chief of ALSOS.

3. It is recommended that:

a. German TA scientists be returned to Germany.

b. That they be permitted to pursue small-scale TA experiments (U-Machine).

c. That such experiments be restricted to two or three laboratories situated in American and British occupied territory, or in Denmark and the Netherlands.

S. A. Goudsmit
S. A. GOUDSMIT
Scientific Chief

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SECRET

Encl

DECLASSIFIED
E.O. 11652, Sec. 3(E) and 5(D) or (E)
Authority NND 750112
By PN NARS, Date 5/26/76

Figure D.13: Samuel Goudsmit. 10 May 1945. SUBJECT: TA Security [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)]. Even Goudsmit said that Alsos was far too small compared to the number of other Allied investigators and the size of the German nuclear program to conduct a proper investigation. Note that Goudsmit missed out on the Haigerloch site, the greatest "success" of Alsos.

Sean Longden. 2009. *T-Force.* p. 193, citing TNA FO800/565 or some other TNA document???

Among the 106 targets investigated by T-Force in the ruins of Hamburg were some that related to nuclear research. They included the laboratory of the nuclear physicist Dr Paul Harteck, an associate of Dr Groth. In May 1945, his detention caused some controversy, since he was picked up by a specialist team with an interest in nuclear research [Alsos] that was working within the 21st Army Group's area. This team had been operating without notifying T-Force HQ or coordinating their activities with T-Force teams in the field. As a result, the atomic research team's work within the British zone was temporarily suspended and similar teams were withdrawn from the area. The issue was rectified when the team in question agreed to abide by existing operational orders. [...]

Upon arriving back in Germany, Dr. Groth discovered that the centrifuge needed for his work was missing. Investigations carried out by T-Force HQ revealed that the centrifuge had been disassembled and sent to SHAEF for the attention of the Operation Alsos mission. It was one of the few examples of evacuations that had been unsuccessful. The hurried nature of the work and the involvement of outsiders, added to the importance of the research equipment, meant that the standard procedures had not been followed. Due to an administrative oversight, no serial number had been issued and the shipment was untraceable. Dr. Harteck was later informed that the centrifuge was unlikely to be located...

[The Alsos Mission was officially reprimanded and removed from the field for behaving improperly and/or finding things they should not have. Apparently they also carelessly lost (or perhaps confiscated and deliberately concealed?) a highly important advanced uranium gas centrifuge prototype.]

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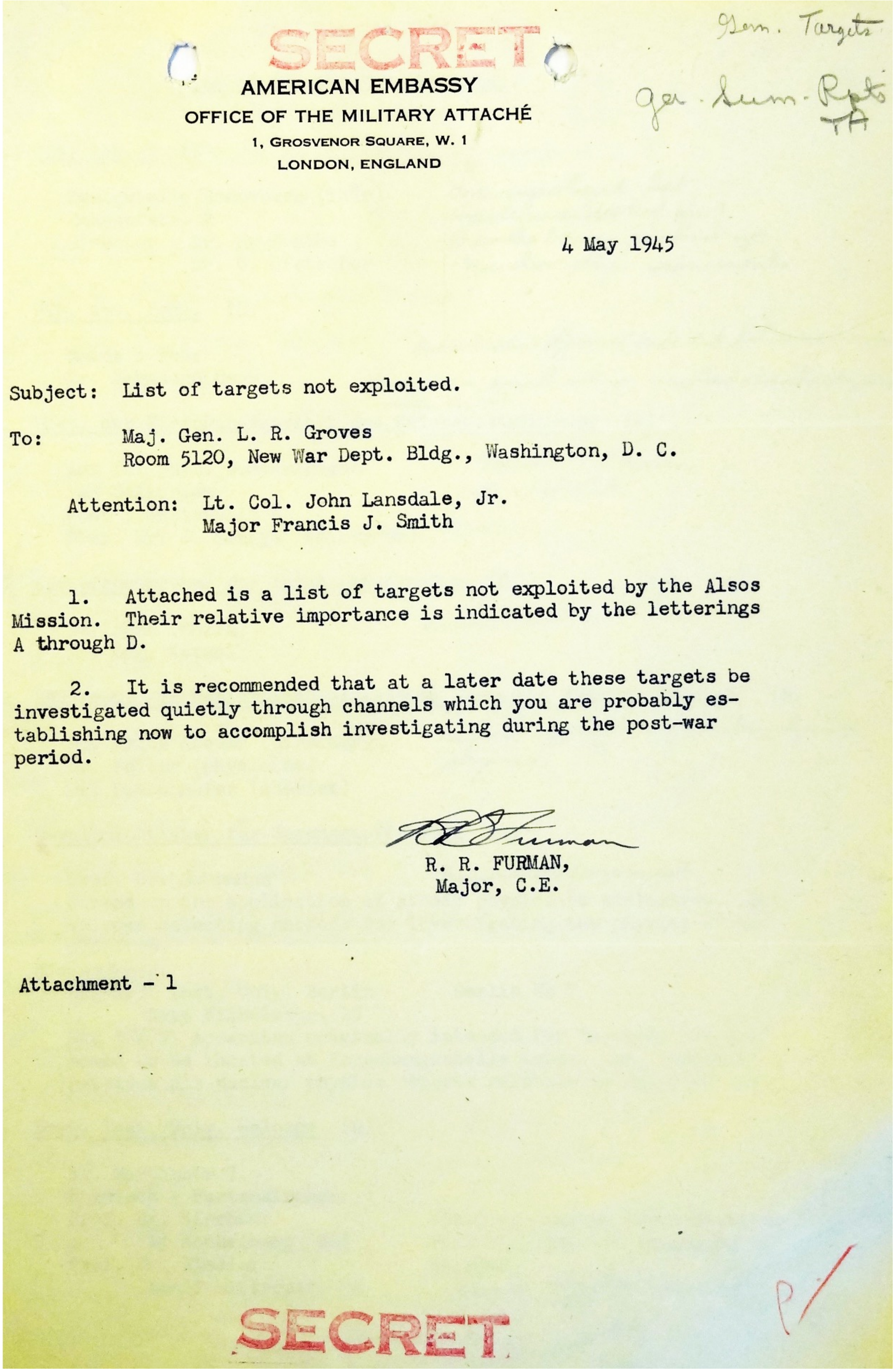
Authority NND947017



Ger. Targets

SECRET

AMERICAN EMBASSY
OFFICE OF THE MILITARY ATTACHÉ
1, GROSVENOR SQUARE, W. 1
LONDON, ENGLAND

Ger. Sum. Rpts
TA

4 May 1945

Subject: List of targets not exploited.

To: Maj. Gen. L. R. Groves
Room 5120, New War Dept. Bldg., Washington, D. C.

Attention: Lt. Col. John Lansdale, Jr.
Major Francis J. Smith

1. Attached is a list of targets not exploited by the Alsos Mission. Their relative importance is indicated by the letterings A through D.

2. It is recommended that at a later date these targets be investigated quietly through channels which you are probably establishing now to accomplish investigating during the post-war period.

R R Furman
R. R. FURMAN,
Major, C.E.

Attachment - 1

P/

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NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)

Figure D.14: On 4 May 1945, Alsos sent Leslie Groves a long (yet still highly incomplete) list of nuclear sites and people that they never bothered to visit, did not plan to visit, and even discouraged other investigators from visiting (e.g., grades C and D) [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

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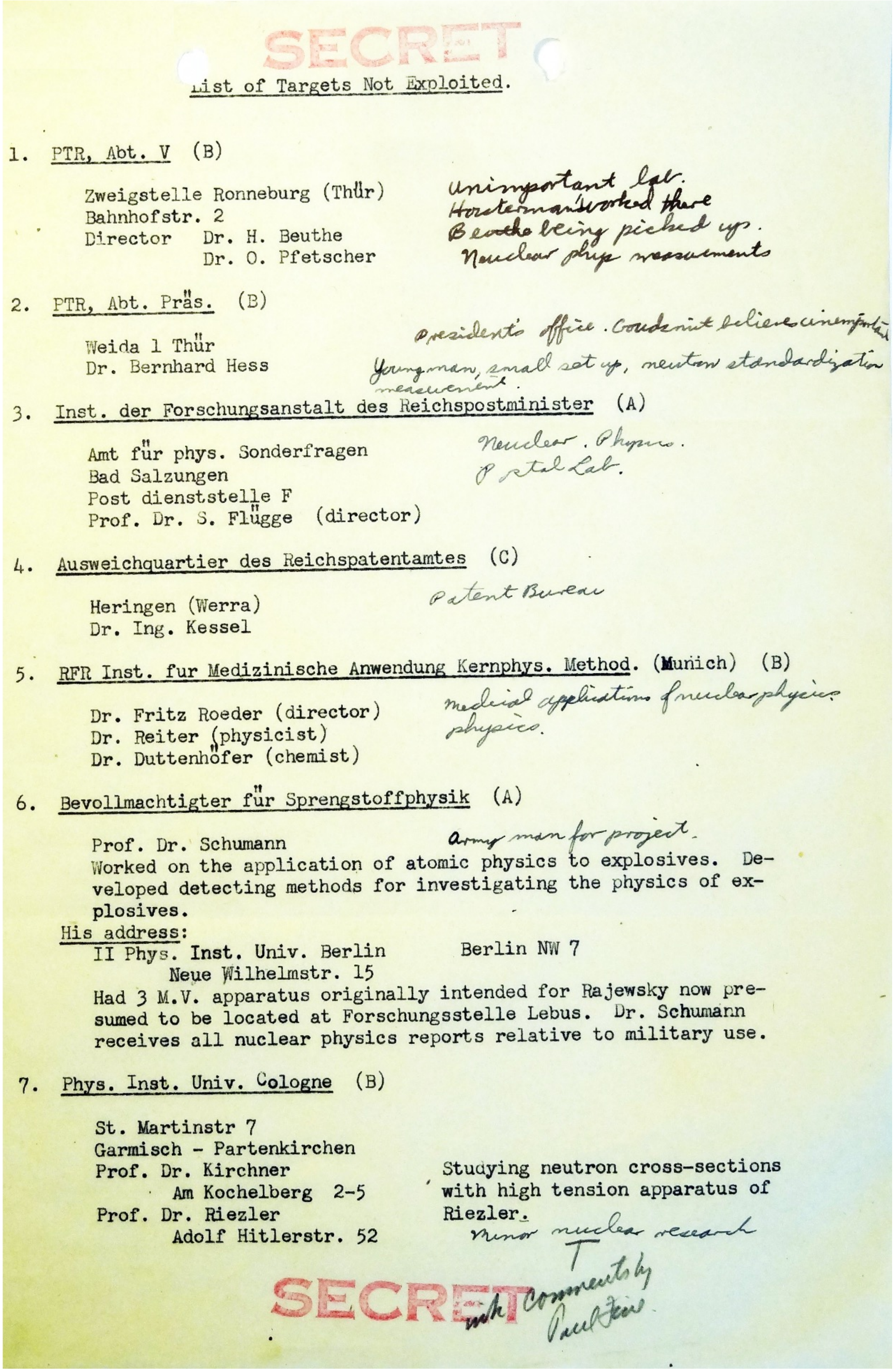

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List of Targets Not Exploited.

1. PTR, Abt. V (B)

Zweigstelle Ronneburg (Thür)
Bahnhofstr. 2
Director Dr. H. Beuthe
Dr. O. Pfetscher

Unimportant lab.
Horsterman worked there
Beuthe being picked up.
Neuclear phys measurements

2. PTR, Abt. Präs. (B)

Weida 1 Thür
Dr. Bernhard Hess

President's office. Couldn't believe unimportant
Young man, small set up, neutron standardization measurement.

3. Inst. der Forschungsanstalt des Reichspostminister (A)

Amt für phys. Sonderfragen
Bad Salzungen
Post dienststelle F
Prof. Dr. S. Flügge (director)

Neuclear. Physics.
Postal Lab.

4. Ausweichquartier des Reichspatentamtes (C)

Heringen (Werra)
Dr. Ing. Kessel

Patent Bureau

5. RFR Inst. fur Medizinische Anwendung Kernphys. Method. (Munich) (B)

Dr. Fritz Roeder (director)
Dr. Reiter (physicist)
Dr. Duttenhöfer (chemist)

medical applications of nuclear physics.
physics.

6. Bevollmachtigter für Sprengstoffphysik (A)

Prof. Dr. Schumann

Army man for project.

Worked on the application of atomic physics to explosives. Developed detecting methods for investigating the physics of explosives.

His address:
II Phys. Inst. Univ. Berlin Berlin NW 7
Neue Wilhelmstr. 15

Had 3 M.V. apparatus originally intended for Rajewsky now presumed to be located at Forschungsstelle Lebus. Dr. Schumann receives all nuclear physics reports relative to military use.

7. Phys. Inst. Univ. Cologne (B)

St. Martinstr 7
Garmisch - Partenkirchen
Prof. Dr. Kirchner
Am Kochelberg 2-5
Prof. Dr. Riezler
Adolf Hitlerstr. 52

Studying neutron cross-sections with high tension apparatus of Riezler.

minor nuclear research

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with comments by
Paul Fine

Figure D.15: On 4 May 1945, Alsos sent Leslie Groves a long (yet still highly incomplete) list of nuclear sites and people that they never bothered to visit, did not plan to visit, and even discouraged other investigators from visiting (e.g., grades C and D) [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

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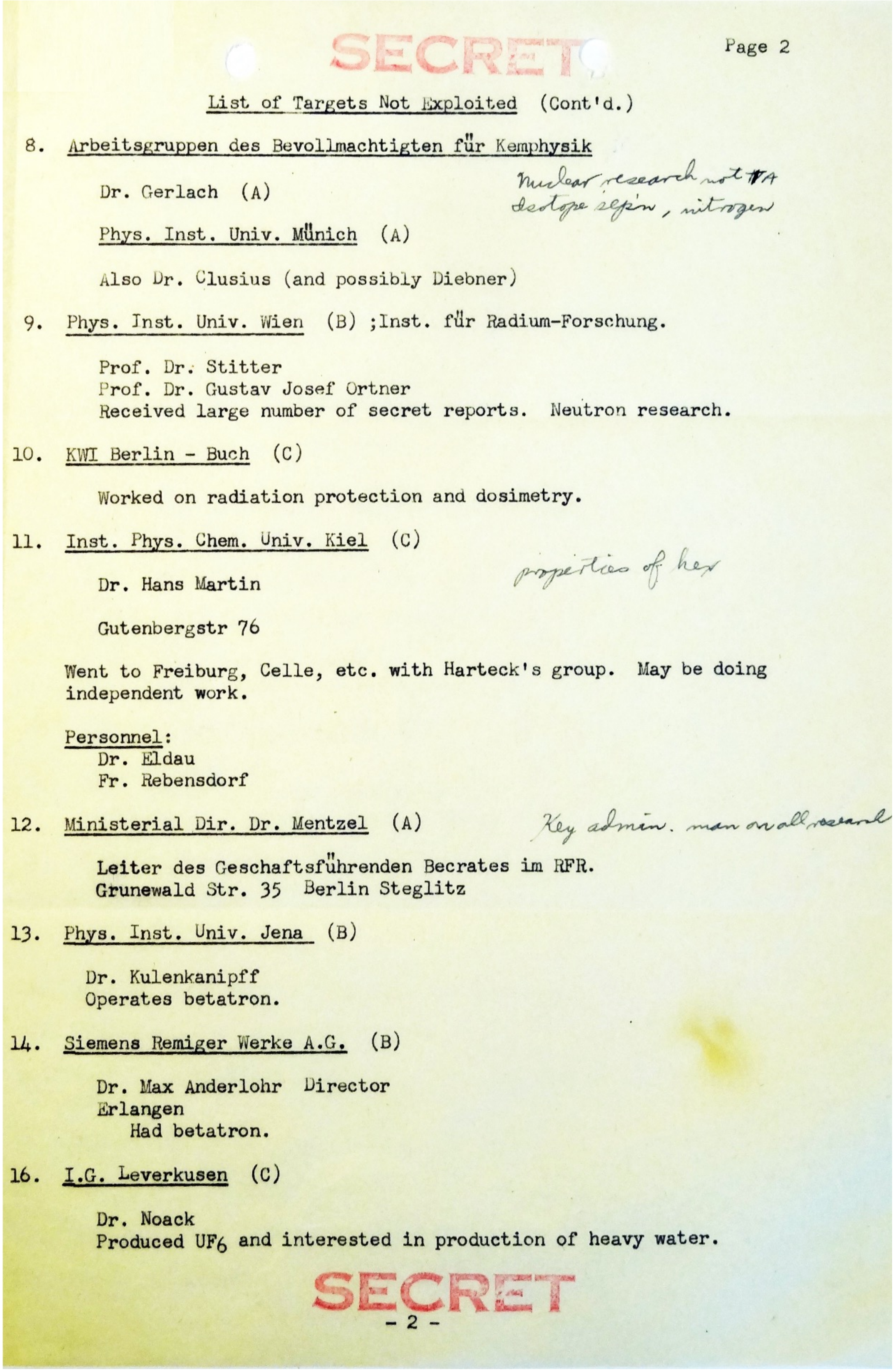

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Page 2

List of Targets Not Exploited (Cont'd.)

8. Arbeitsgruppen des Bevollmachtigten für Kemphysik

Dr. Gerlach (A)

Nuclear research not #A
Isotope sepn, nitrogen

Phys. Inst. Univ. München (A)

Also Dr. Clusius (and possibly Diebner)

9. Phys. Inst. Univ. Wien (B) ;Inst. für Radium-Forschung.

Prof. Dr. Stitter
Prof. Dr. Gustav Josef Ortner
Received large number of secret reports. Neutron research.

10. KWI Berlin - Buch (C)

Worked on radiation protection and dosimetry.

11. Inst. Phys. Chem. Univ. Kiel (C)

Dr. Hans Martin

properties of hex

Gutenbergstr 76

Went to Freiburg, Celle, etc. with Harteck's group. May be doing independent work.

Personnel:
Dr. Eldau
Fr. Rebensdorf

12. Ministerial Dir. Dr. Mentzel (A)

Key admin. man overall research

Leiter des Geschaftsführenden Becrates im RFR.
Grunewald Str. 35 Berlin Steglitz

13. Phys. Inst. Univ. Jena (B)

Dr. Kulenkanipff
Operates betatron.

14. Siemens Remiger Werke A.G. (B)

Dr. Max Anderlohr Director
Erlangen
Had betatron.

16. I.G. Leverkusen (C)

Dr. Noack
Produced UF_6 and interested in production of heavy water.

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NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)

Figure D.16: On 4 May 1945, Alsos sent Leslie Groves a long (yet still highly incomplete) list of nuclear sites and people that they never bothered to visit, did not plan to visit, and even discouraged other investigators from visiting (e.g., grades C and D) [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

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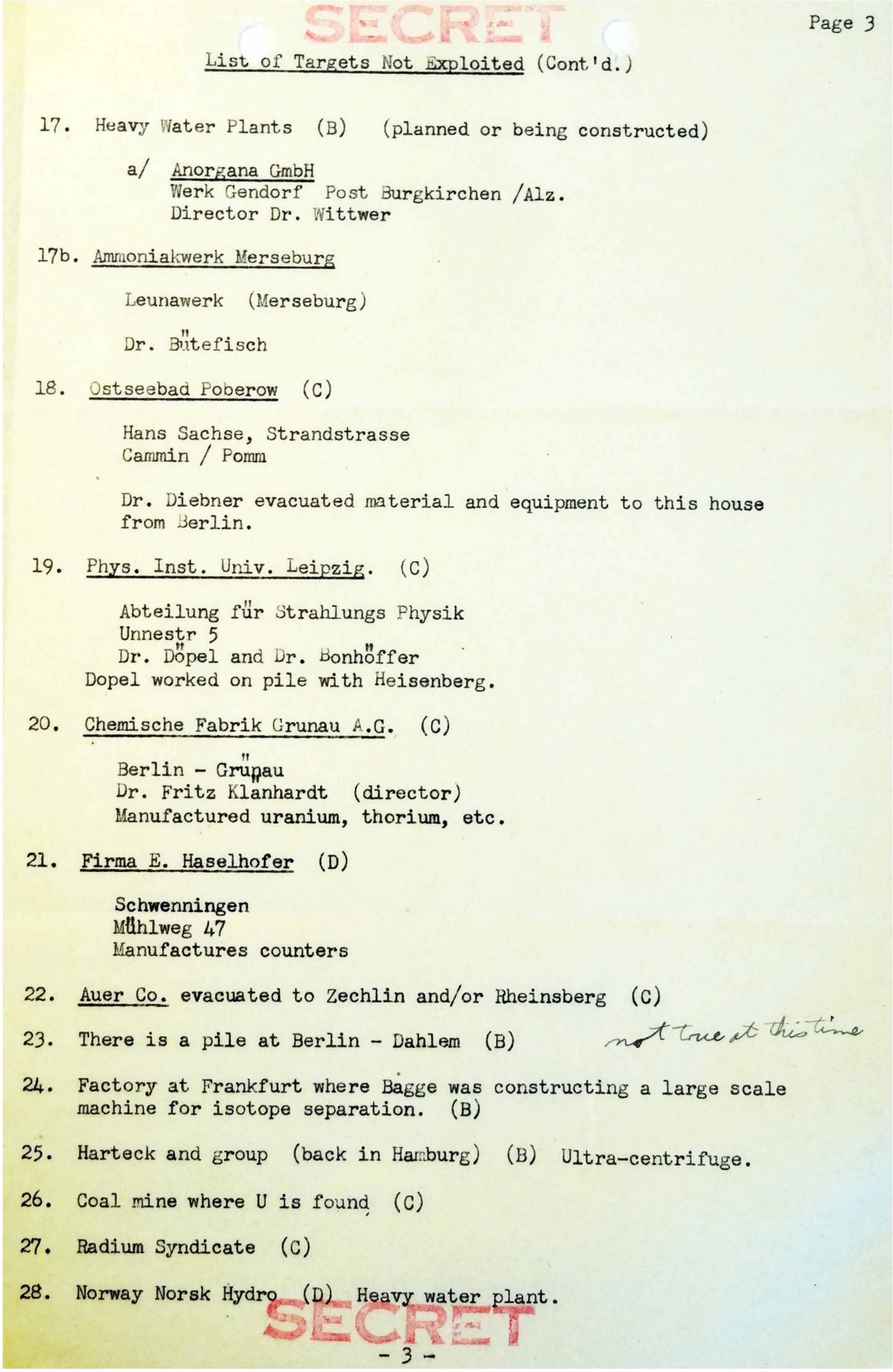

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Page 3

List of Targets Not Exploited (Cont'd.)

17. Heavy Water Plants (B) (planned or being constructed)

a/ Anorgana GmbH
Werk Gendorf Post Burgkirchen /Alz.
Director Dr. Wittwer

17b. Ammoniakwerk Merseburg

Leunawerk (Merseburg)

Dr. Bütefisch

18. Ostseebad Poberow (C)

Hans Sachse, Strandstrasse
Cammin / Pomm

Dr. Diebner evacuated material and equipment to this house from Berlin.

19. Phys. Inst. Univ. Leipzig. (C)

Abteilung für Strahlungs Physik
Unnestr 5
Dr. Döpel and Dr. Bonhöffer
Dopel worked on pile with Heisenberg.

20. Chemische Fabrik Grunau A.G. (C)

Berlin - Grünau
Dr. Fritz Klanhardt (director)
Manufactured uranium, thorium, etc.

21. Firma E. Haselhofer (D)

Schwenningen
Mühlweg 47
Manufactures counters

22. Auer Co. evacuated to Zechlin and/or Rheinsberg (C)

23. There is a pile at Berlin - Dahlem (B) not true at this time

24. Factory at Frankfurt where Bagge was constructing a large scale machine for isotope separation. (B)

25. Harteck and group (back in Hamburg) (B) Ultra-centrifuge.

26. Coal mine where U is found (C)

27. Radium Syndicate (C)

28. Norway Norsk Hydro (D) Heavy water plant.

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NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)

Figure D.17: On 4 May 1945, Alsos sent Leslie Groves a long (yet still highly incomplete) list of nuclear sites and people that they never bothered to visit, did not plan to visit, and even discouraged other investigators from visiting (e.g., grades C and D) [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

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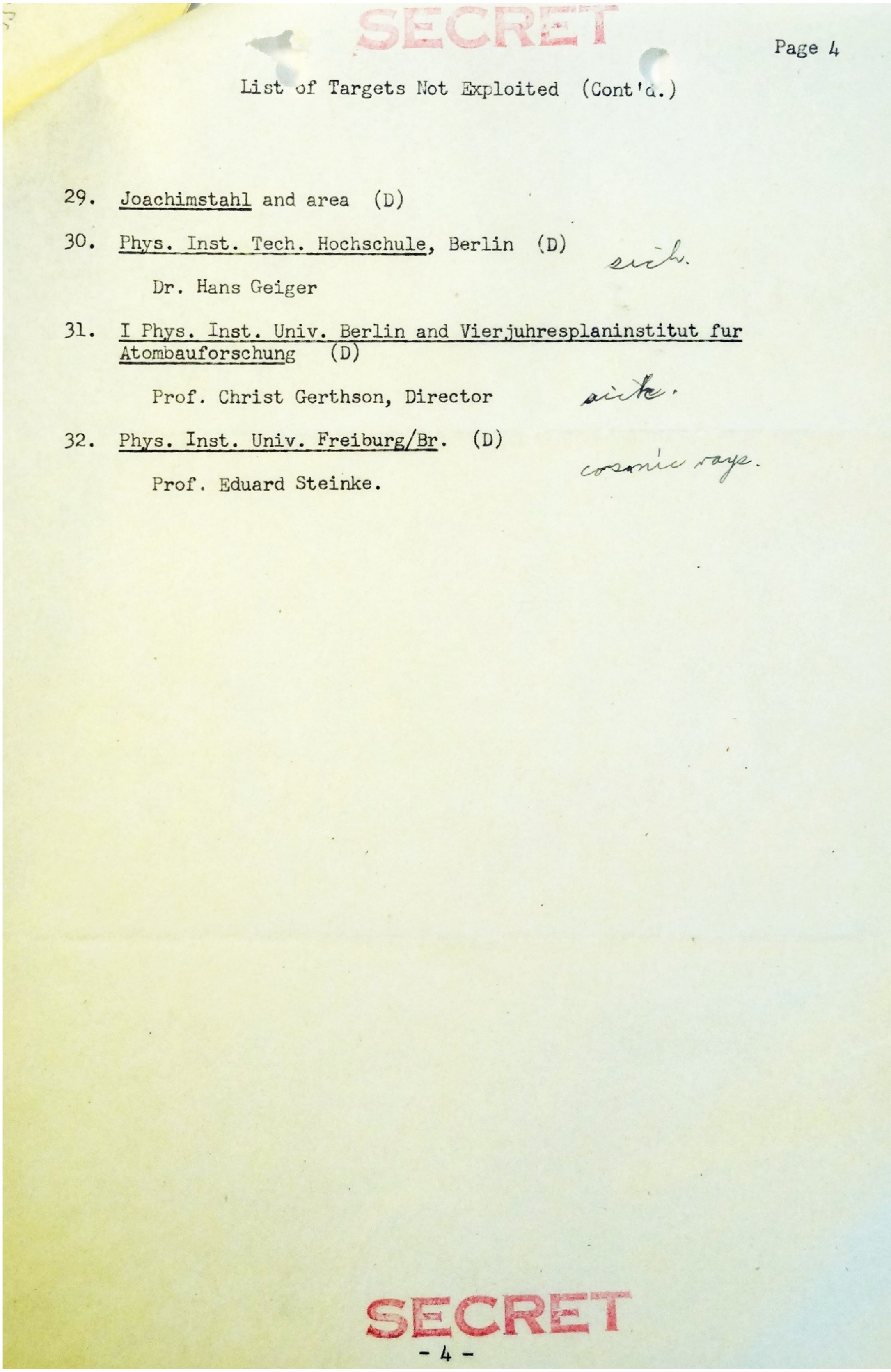

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Page 4

List of Targets Not Exploited (Cont'd.)

29. Joachimstahl and area (D)

30. Phys. Inst. Tech. Hochschule, Berlin (D) sick.

Dr. Hans Geiger

31. I Phys. Inst. Univ. Berlin and Vierjuhresplaninstitut fur Atombauforschung (D)

Prof. Christ Gerthson, Director sick.

32. Phys. Inst. Univ. Freiburg/Br. (D)

Prof. Eduard Steinke. cosmic rays.

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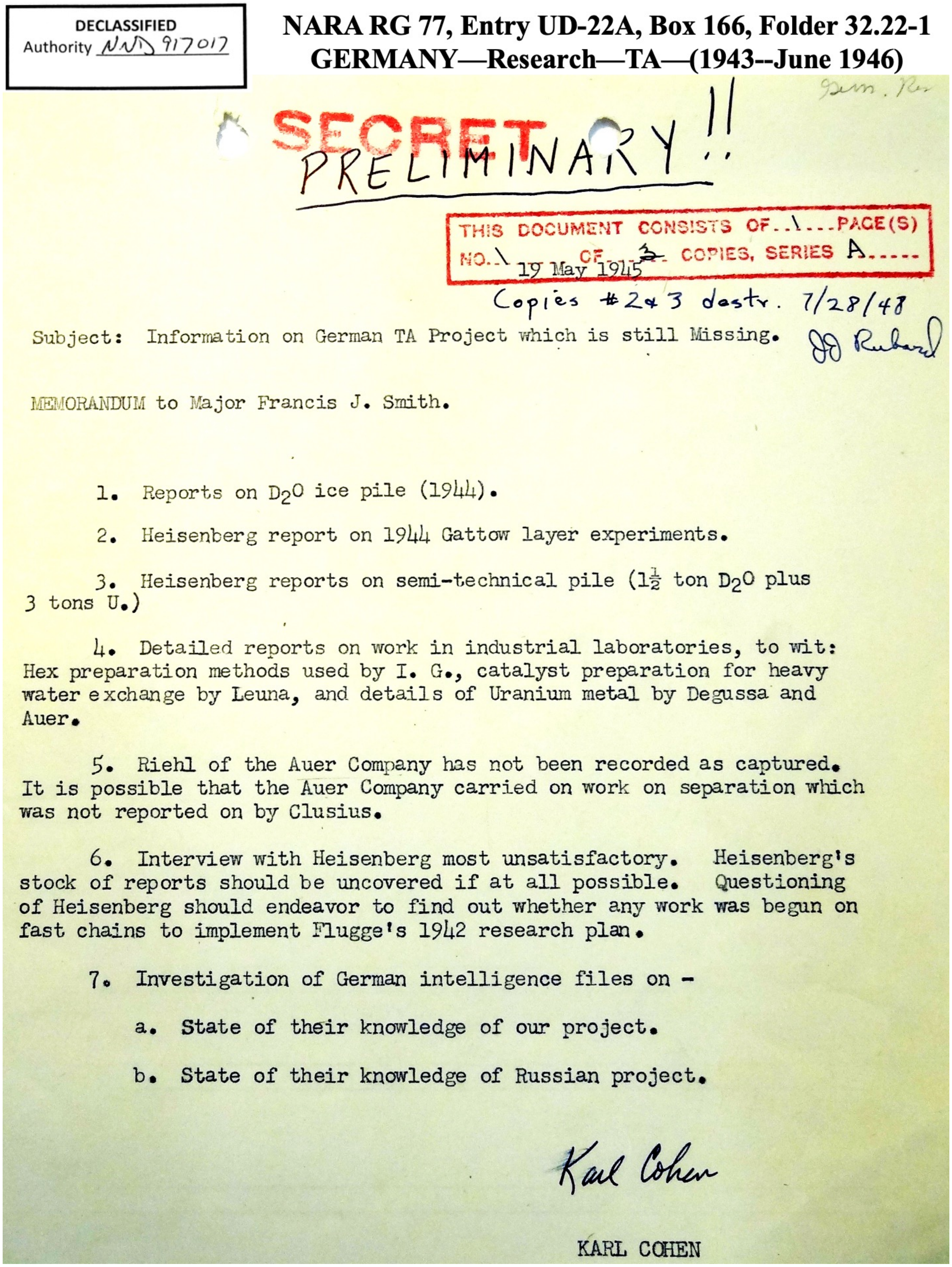
- 4 -

NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)

Figure D.18: On 4 May 1945, Alsos sent Leslie Groves a long (yet still highly incomplete) list of nuclear sites and people that they never bothered to visit, did not plan to visit, and even discouraged other investigators from visiting (e.g., grades C and D) [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].



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NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1
GERMANY—Research—TA—(1943--June 1946)

Gem. Res

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PRELIMINARY!!

THIS DOCUMENT CONSISTS OF..1...PAGE(S)
NO..1... OF..3.. COPIES, SERIES A.....

19 May 1945

Copies #2&3 destr. 7/28/48

Subject: Information on German TA Project which is still Missing.

MEMORANDUM to Major Francis J. Smith.

1. Reports on D_2O ice pile (1944).

2. Heisenberg report on 1944 Gattow layer experiments.

3. Heisenberg reports on semi-technical pile ($1\frac{1}{2}$ ton D_2O plus 3 tons U.)

4. Detailed reports on work in industrial laboratories, to wit: Hex preparation methods used by I. G., catalyst preparation for heavy water exchange by Leuna, and details of Uranium metal by Degussa and Auer.

5. Riehl of the Auer Company has not been recorded as captured. It is possible that the Auer Company carried on work on separation which was not reported on by Clusius.

6. Interview with Heisenberg most unsatisfactory. Heisenberg's stock of reports should be uncovered if at all possible. Questioning of Heisenberg should endeavor to find out whether any work was begun on fast chains to implement Flugge's 1942 research plan.

7. Investigation of German intelligence files on -

   a. State of their knowledge of our project.

   b. State of their knowledge of Russian project.

Karl Cohen

KARL COHEN

Figure D.19: Karl Cohen to Francis J. Smith. 19 May 1945. Subject: Information on German TA Project which is still Missing [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA—(1943–June 1946)]. As this document demonstrates, even for the fairly small number of people and sites that Alsos focused on, they failed to collect a great deal of important information.

Robert Furman to John Lansdale. 22 May 1945. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.]

Boris [Pash] left here for home to try to convince authorities that the Alsos job is over. But in this theater, [General Thomas J.] Betts, [General George Bryan] Conrad and [MIT Professor Edward L.] Bowles are not agreeing that the job for which Alsos was set up to do is in any way completed. More scientists have now arrived. Proximity fuzes, BW [biological warfare] and NACA [aerospace] investigations are now absorbing the energies of Tarryton equipment and personnel.

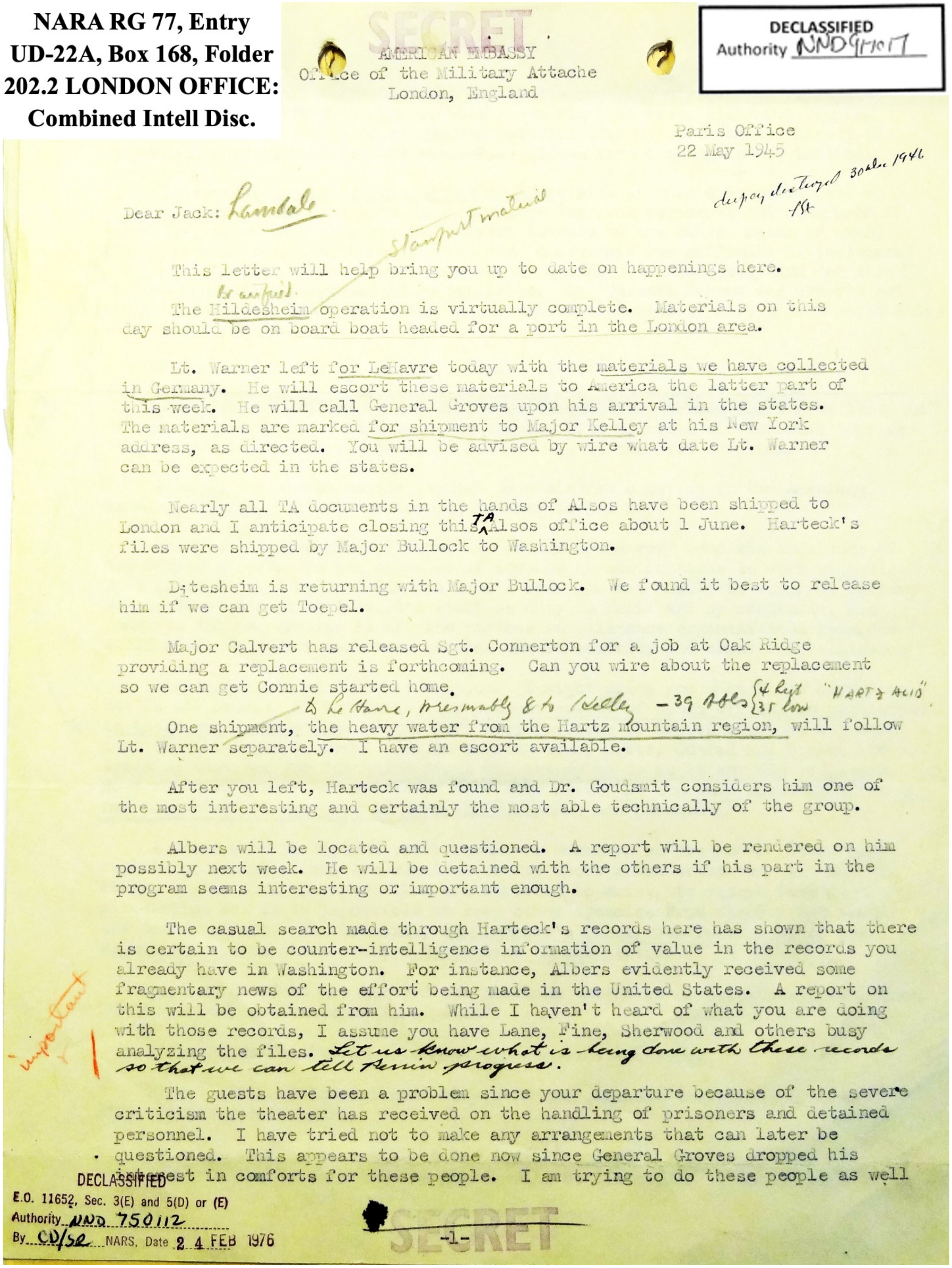
A great many TA [tube alloy = nuclear] reports still remain in Germany, as you know. Therefore, reports on installations are received weekly about which we do very little. We always try to pick papers that are reported to exist, to remove them from circulation but it is impossible to keep other agencies from finding out about the German effort. For instance, in Osenberg's files, was found some of the essential reports which you had taken back to the States.

[See document photos on pp. 3286–3287.

According to Robert Furman, in May 1945, three very senior and extremely well-informed U.S. intelligence officials concluded that Alsos had failed to do its primary job of investigating the German nuclear program:

- SHAEF intelligence (G-2) General Thomas J. Betts (see pp. 5028–5030).
- SHAEF intelligence (G-2) General George Bryan Conrad.
- AAF General Henry Arnold's advisor Prof. Edward L. Bowles of MIT (see pp. 4711, 5319).

Robert Furman admitted that there were so many German nuclear sites and documents that his team did not even try to investigate them.]



NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.

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AMERICAN EMBASSY
Office of the Military Attache
London, England

Paris Office
22 May 1945

dupcy destroyed 30 Dec 1946
RSt

Dear Jack: Lansdale

Transport material

This letter will help bring you up to date on happenings here.

be confirmed.

The Hildesheim operation is virtually complete. Materials on this day should be on board boat headed for a port in the London area.

Lt. Warner left for LeHavre today with the materials we have collected in Germany. He will escort these materials to America the latter part of this week. He will call General Groves upon his arrival in the states. The materials are marked for shipment to Major Kelley at his New York address, as directed. You will be advised by wire what date Lt. Warner can be expected in the states.

Nearly all TA documents in the hands of Alsos have been shipped to London and I anticipate closing this TA Alsos office about 1 June. Harteck's files were shipped by Major Bullock to Washington.

Diebner is returning with Major Bullock. We found it best to release him if we can get Toepel.

Major Calvert has released Sgt. Connerton for a job at Oak Ridge providing a replacement is forthcoming. Can you wire about the replacement so we can get Connie started home.

to Le Havre, presumably & to Kelley – 39 bbls {4 kept / 35 low} "HARTZ ACID"

One shipment, the heavy water from the Hartz mountain region, will follow Lt. Warner separately. I have an escort available.

After you left, Harteck was found and Dr. Goudsmit considers him one of the most interesting and certainly the most able technically of the group.

Albers will be located and questioned. A report will be rendered on him possibly next week. He will be detained with the others if his part in the program seems interesting or important enough.

The casual search made through Harteck's records here has shown that there is certain to be counter-intelligence information of value in the records you already have in Washington. For instance, Albers evidently received some fragmentary news of the effort being made in the United States. A report on this will be obtained from him. While I haven't heard of what you are doing with those records, I assume you have Lane, Fine, Sherwood and others busy analyzing the files. Let us know what is being done with these records so that we can tell Perrin progress.

important

The guests have been a problem since your departure because of the severe criticism the theater has received on the handling of prisoners and detained personnel. I have tried not to make any arrangements that can later be questioned. This appears to be done now since General Groves dropped his interest in comforts for these people. I am trying to do these people as well

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By CD/SE NARS, Date 24 FEB 1976

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Figure D.20: Robert Furman to John Lansdale. 22 May 1945. SHAEF G-2 Generals Thomas J. Betts (p. 5030) and George Bryan Conrad plus AAF General Henry Arnold's advisor Prof. Edward L. Bowles of MIT (pp. 4711, 5319) concluded that Alsos had failed to do its job. Furman admitted that there were so many German nuclear sites and documents that his team did not even try to investigate them [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.].

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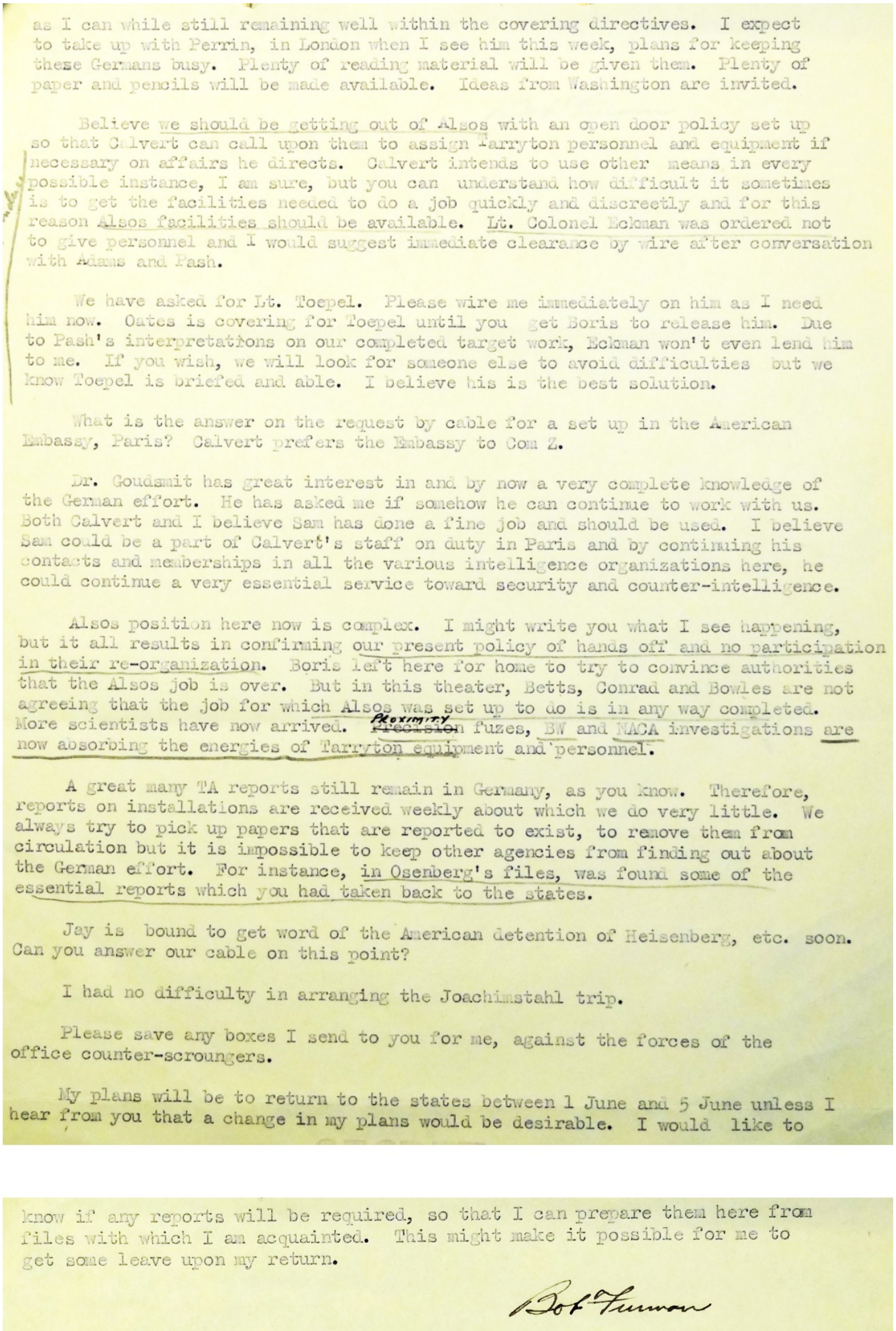
NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.



as I can while still remaining well within the covering directives. I expect to take up with Perrin, in London when I see him this week, plans for keeping these Germans busy. Plenty of reading material will be given them. Plenty of paper and pencils will be made available. Ideas from Washington are invited.

Believe we should be getting out of Alsos with an open door policy set up so that Calvert can call upon them to assign Tarryton personnel and equipment if necessary on affairs he directs. Calvert intends to use other means in every possible instance, I am sure, but you can understand how difficult it sometimes is to get the facilities needed to do a job quickly and discreetly and for this reason Alsos facilities should be available. Lt. Colonel Eckman was ordered not to give personnel and I would suggest immediate clearance by wire after conversation with Adams and Pash.

We have asked for Lt. Toepel. Please wire me immediately on him as I need him now. Oates is covering for Toepel until you get Boris to release him. Due to Pash's interpretations on our completed target work, Eckman won't even lend him to me. If you wish, we will look for someone else to avoid difficulties but we know Toepel is briefed and able. I believe his is the best solution.

What is the answer on the request by cable for a set up in the American Embassy, Paris? Calvert prefers the Embassy to Com Z.

Dr. Goudsmit has great interest in and by now a very complete knowledge of the German effort. He has asked me if somehow he can continue to work with us. Both Calvert and I believe Sam has done a fine job and should be used. I believe Sam could be a part of Calvert's staff on duty in Paris and by continuing his contacts and memberships in all the various intelligence organizations here, he could continue a very essential service toward security and counter-intelligence.

Alsos position here now is complex. I might write you what I see happening, but it all results in confirming our present policy of hands off and no participation in their re-organization. Boris left here for home to try to convince authorities that the Alsos job is over. But in this theater, Betts, Conrad and Bowles are not agreeing that the job for which Alsos was set up to do is in any way completed. More scientists have now arrived. ~~Precision~~ PROXIMITY fuzes, BW and NACA investigations are now absorbing the energies of Tarryton equipment and personnel.

A great many TA reports still remain in Germany, as you know. Therefore, reports on installations are received weekly about which we do very little. We always try to pick up papers that are reported to exist, to remove them from circulation but it is impossible to keep other agencies from finding out about the German effort. For instance, in Osenberg's files, was found some of the essential reports which you had taken back to the states.

Jay is bound to get word of the American detention of Heisenberg, etc. soon. Can you answer our cable on this point?

I had no difficulty in arranging the Joachimstahl trip.

Please save any boxes I send to you for me, against the forces of the office counter-scroungers.

My plans will be to return to the states between 1 June and 5 June unless I hear from you that a change in my plans would be desirable. I would like to know if any reports will be required, so that I can prepare them here from files with which I am acquainted. This might make it possible for me to get some leave upon my return.

Bob Furman

Figure D.21: Robert Furman to John Lansdale. 22 May 1945. SHAEF G-2 Generals Thomas J. Betts (pp. 5028–5030) and George Bryan Conrad plus AAF General Henry Arnold's advisor Prof. Edward L. Bowles of MIT (pp. 4711, 5319) concluded that Alsos had failed to do its job. Furman admitted that there were so many German nuclear sites and documents that his team did not even try to investigate them [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.].

Samuel Goudsmit to George Eckman. 7 June 1945. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-2 GERMANY: Research—Res. Inst. & other Facilities (May 45–Dec 46)]

1. I request that this document and all attachments [from Hans Martin on uranium gas centrifuges] be handed over to Major Furman at once. They are an excellent example of the type of TA information which is picked up by other agencies and finally arrives in our hands.

2. At the end of the report, the conceited German makes certain demands which may impress the Military Government. I request that you send through the proper channels the following information:

> a. The intelligence in connection with the scientific work of Professor Martin of Kiel has been completely covered by information and documents obtained elsewhere.
>
> b. His own activities are considered relatively insignificant and do not warrant any special action or privileges.

3. I think this information should reach the hands of all those who had anything to do with this case.

[See document photo on p. 3289. Hans Martin developed advanced uranium gas centrifuges (pp. 3517–3528). Alsos never visited Martin and discouraged other investigators from doing so (p. 3281, grade C). When Martin gave documents to other investigators, Goudsmit confiscated them and strongly discouraged further examination of Martin or his centrifuges.

Without ever even meeting Hans Martin or seeing his uranium gas centrifuges, Goudsmit labelled Martin just another example of "the conceited German," declared the uranium gas centrifuges "relatively insignificant," and broadcast those conclusions to other agencies to try to prevent any further discussions of the topic. Thus this letter illustrates three aspects of Goudsmit's personality that shine through in many of his writings:

1. A raging prejudice against all Germans, including those he had never even met.
2. An obsessive need to keep claiming his own intellectual superiority over other people (especially career scientists such as Hans Martin, Werner Heisenberg, and many others who made much more important scientific discoveries and inventions than Goudsmit did in his lifelong career as a government bureaucrat).
3. Abuse of the power of his U.S.-government-granted position to harm other people, even people he had never met or interacted with, simply to gratify his own impulses.

Goudsmit's behavior had already led to a four-month removal from duty as well as meetings and letters of reprimand (e.g., pp. 3260–3269, 3321), yet as shown in this letter, he persisted in that behavior even after he was reinstated.

Goudsmit's behavior was highly counterproductive for the work that he was expected to perform: conducting a detailed investigation of the German nuclear program. In this particular case, Goudsmit, who had no expertise with any uranium enrichment methods whatsoever, succeeded in suffocating the U.S. government's interest in German uranium gas centrifuges. Ultimately those centrifuges proved to be so much more efficient than the U.S.'s own methods of uranium enrichment that they dominated the global market and drove the U.S. enrichment facilities out of business (pp. 3549–3553).]

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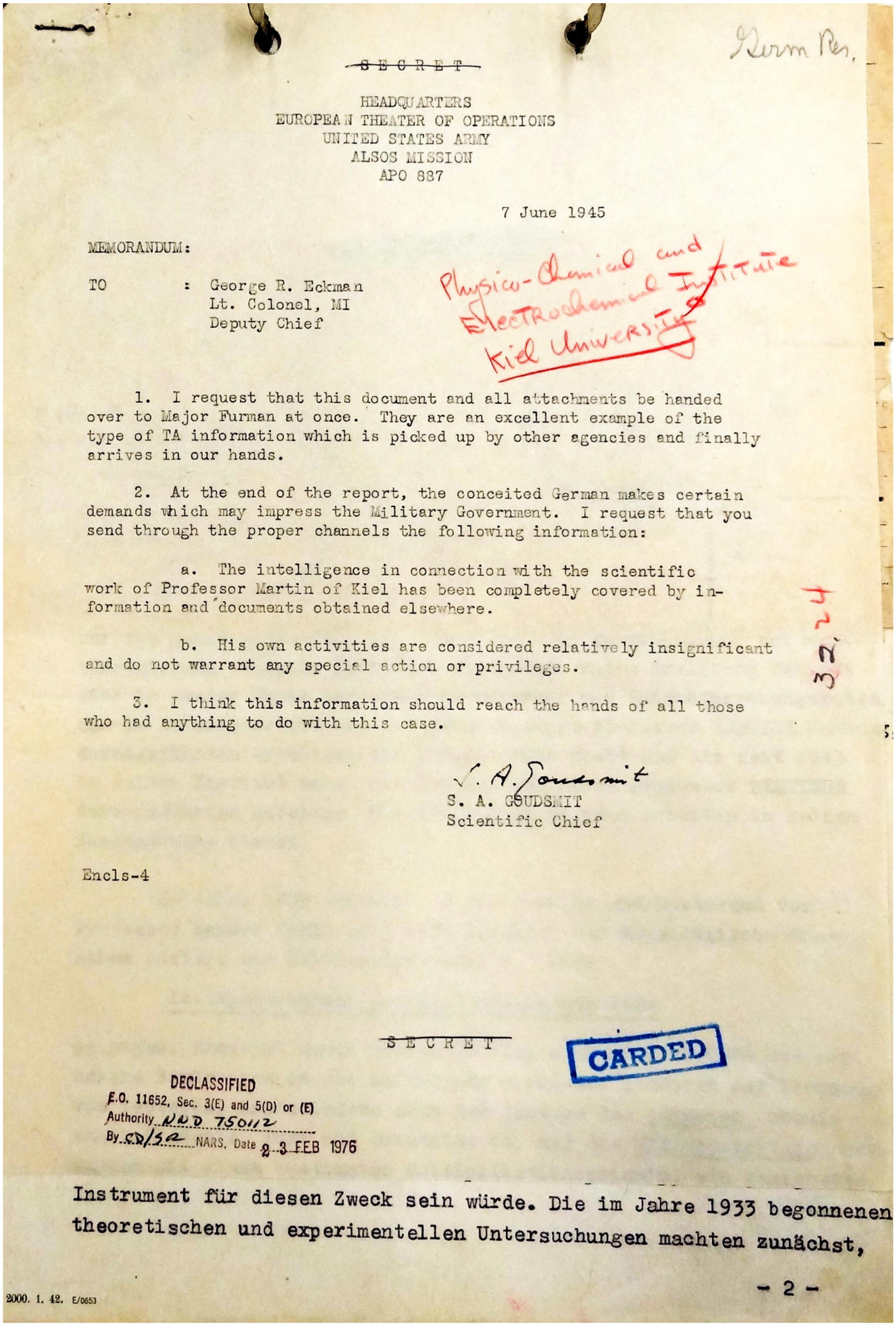
GERMANY: Research—Res. Inst. & other Facilities (May 45–Dec 46)



Germ Res.

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HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS MISSION
APO 887

7 June 1945

MEMORANDUM:

TO : George R. Eckman
Lt. Colonel, MI
Deputy Chief

Physico-Chemical and Electrochemical Institute Kiel University

1. I request that this document and all attachments be handed over to Major Furman at once. They are an excellent example of the type of TA information which is picked up by other agencies and finally arrives in our hands.

2. At the end of the report, the conceited German makes certain demands which may impress the Military Government. I request that you send through the proper channels the following information:

a. The intelligence in connection with the scientific work of Professor Martin of Kiel has been completely covered by information and documents obtained elsewhere.

b. His own activities are considered relatively insignificant and do not warrant any special action or privileges.

3. I think this information should reach the hands of all those who had anything to do with this case.

32,24

S. A. Goudsmit
S. A. GOUDSMIT
Scientific Chief

Encls-4

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CARDED

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Authority NND 750112
By CD/SR NARS, Date 23 FEB 1976

Instrument für diesen Zweck sein würde. Die im Jahre 1933 begonnenen theoretischen und experimentellen Untersuchungen machten zunächst,

- 2 -

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Figure D.22: Samuel Goudsmit to George Eckman. 7 June 1945 [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-2 GERMANY: Research—Res. Inst. & other Facilities (May 45–Dec 46)]. Hans Martin developed advanced uranium gas centrifuges (pp. 3517–3528). Alsos never visited Martin and discouraged other investigators from doing so (p. 3281, grade C). When Martin gave documents to other investigators, Goudsmit confiscated them and strongly discouraged further investigations.

James A. Lane to Francis J. Smith. 16 June 1945. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)]

Attached is presented an overall summary of the German nuclear physics work obtained from an analysis of the captured technical and correspondence files. The previous indication given by the Strassburg report that the German nuclear physics project was only a "Class B" enterprise is verified in all respects by this more complete set of documents. It is apparent that the German scientists and military leaders early in the war abandoned hope for a military application of nuclear physics, but at the same time realized that it would be a mistake for Germany to fall behind other countries in the field. Their project was therefore developed on a scale approximately comparable to a normal peace time enterprise. According to Berkei the nuclear physics project cost a total of 15,000,000 marks ($1,500,000) in the period 1940–1945. A rough estimate gives the following distribution of costs:

Cost of uranium metal	$200,000
Cost of heavy water	100,000
High voltage apparatus and cyclotrons	500,000
Experimental work and salaries 1940–42	150,000
” 1943	200,000
” 1944	300,000
” to May 1945	50,000
	$1,500,000

These figures should be considered only as qualitative evidence of the emphasis on various phases of the German project since the captured financial reports are not complete enough for a more accurate determination of expenditures.

[See document photo on p. 3291. Friedrich Berkei, a junior scientist working on small fission pile experiments, gave his personal rough estimate of the total cost of those experiments that he knew about (or was willing to admit to Allied investigators that he knew about): 15 million marks.

Authors from Samuel Goudsmit (p. 3298) onward have falsely represented that as the total cost of the entire wartime German nuclear program.

The true total cost of the program would have to include work at a large number of organizations (p. 5109) and sites all over Europe (from Norway to East Prussia to Bulgaria to Portugal), as demonstrated by the documents in the rest of this appendix.

An analogous situation would be asking a junior scientist helping with Enrico Fermi's Chicago pile experiments to give a personal rough estimate of the cost of those experiments, then claiming that that estimate was the total cost of the entire Manhattan Project. No credible scholar would do that. Likewise no credible scholar should claim that Berkei's estimate is the true total cost of the entire wartime German nuclear program. (This criticism is not directed at James Lane, who was merely filing a field report recounting what Berkei had told him.)]

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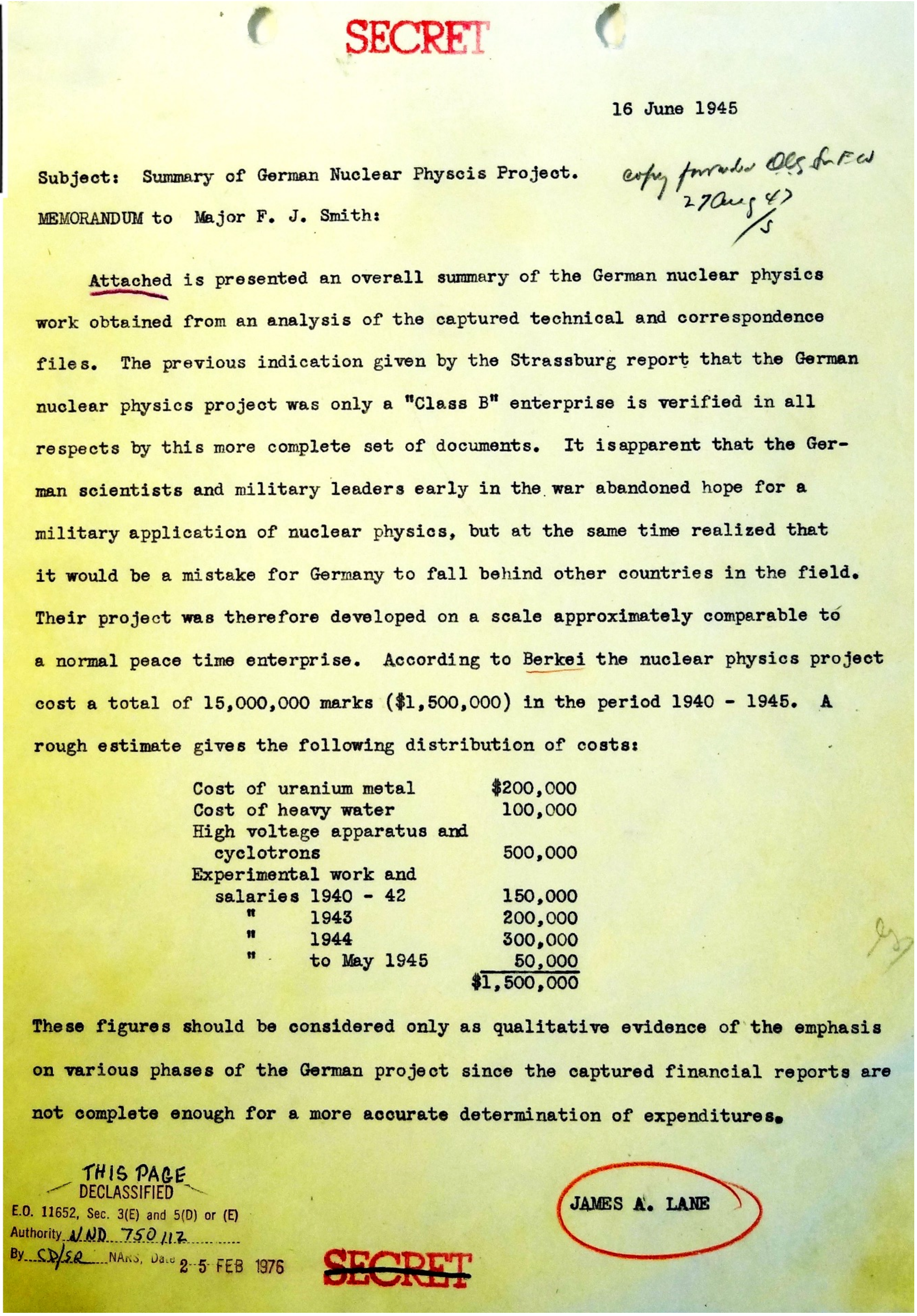

SECRET

16 June 1945

Subject: Summary of German Nuclear Physcis Project.

copy forwarded OCS for FEW 27 Aug 47 /s

MEMORANDUM to Major F. J. Smith:

Attached is presented an overall summary of the German nuclear physics work obtained from an analysis of the captured technical and correspondence files. The previous indication given by the Strassburg report that the German nuclear physics project was only a "Class B" enterprise is verified in all respects by this more complete set of documents. It isapparent that the German scientists and military leaders early in the war abandoned hope for a military application of nuclear physics, but at the same time realized that it would be a mistake for Germany to fall behind other countries in the field. Their project was therefore developed on a scale approximately comparable to a normal peace time enterprise. According to Berkei the nuclear physics project cost a total of 15,000,000 marks ($1,500,000) in the period 1940 - 1945. A rough estimate gives the following distribution of costs:

Cost of uranium metal	$200,000
Cost of heavy water	100,000
High voltage apparatus and cyclotrons	500,000
Experimental work and salaries 1940 - 42	150,000
" 1943	200,000
" 1944	300,000
" to May 1945	50,000
	$1,500,000

These figures should be considered only as qualitative evidence of the emphasis on various phases of the German project since the captured financial reports are not complete enough for a more accurate determination of expenditures.

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E.O. 11652, Sec. 3(E) and 5(D) or (E)
Authority NND 750117
By CD/SR NARS, Date 2-5 FEB 1976

JAMES A. LANE

~~SECRET~~

NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)

Figure D.23: James A. Lane to Francis J. Smith. 16 June 1945 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)]. Friedrich Berkei, a junior scientist working on small fission pile experiments, estimated the total cost of those experiments that he knew about (or admitted knowing about): 15 million marks. Authors from Samuel Goudsmit onward have falsely represented that as the total cost of the wartime German nuclear program, which actually included a large number of organizations and sites all over Europe.

W. A. Consodine to Leslie Groves. 12 July 1945. Intelligence Setup in Europe. [NARA RG 77, Entry UD-22A, Box 168, Folder British–U.S. Relations on Atomic Energy Intelligence (War Period) to 8 Oct 1945]

1. In a discussion with Major Furman I learned his ideas as to the Intelligence setup in Europe as you requested me. He thinks there should be a study of German research in Tube Alloys and industrial research and also of personnel. He thinks that now is the time to do it in Germany. He also believes that all reports of all other U.S. and U.K. agencies should be correlated as quickly as possible.

2. He says that there is no one in Paris now and someone should be there who reads and speaks German, who has a knowledge of the project, who is field grade in rank, preferably Lieut. Colonel, who can work with Spears, Oaks and Davis, etc.

3. He commented that there are a lot of T.A. reports in various American channels now. He thinks that Goudsmit is the ideal man to do the German job in Paris. He mentioned that he has a personality difficulty. He, however, said that Goudsmit is the one who did the job for Alsos and that everything done by Alsos was done by Goudsmit. He said the British respect Goudsmit.

4. He mentioned that Welsh was insecure and a braggart. He substantiated previous statements that he is anti-American. He said that Gattiger is hard to control but all right. He stressed that we must start right away, that if we do not we will lose the advantages we can get out of the transition period.

5. He concluded that the man or men you use must have the following qualifications: (1) knowledge of American and British scientific war groups (2) rank (3) know the project (4) be able to handle prima donna scientists and prima donna military officers.

[See document photo on p. 3293.

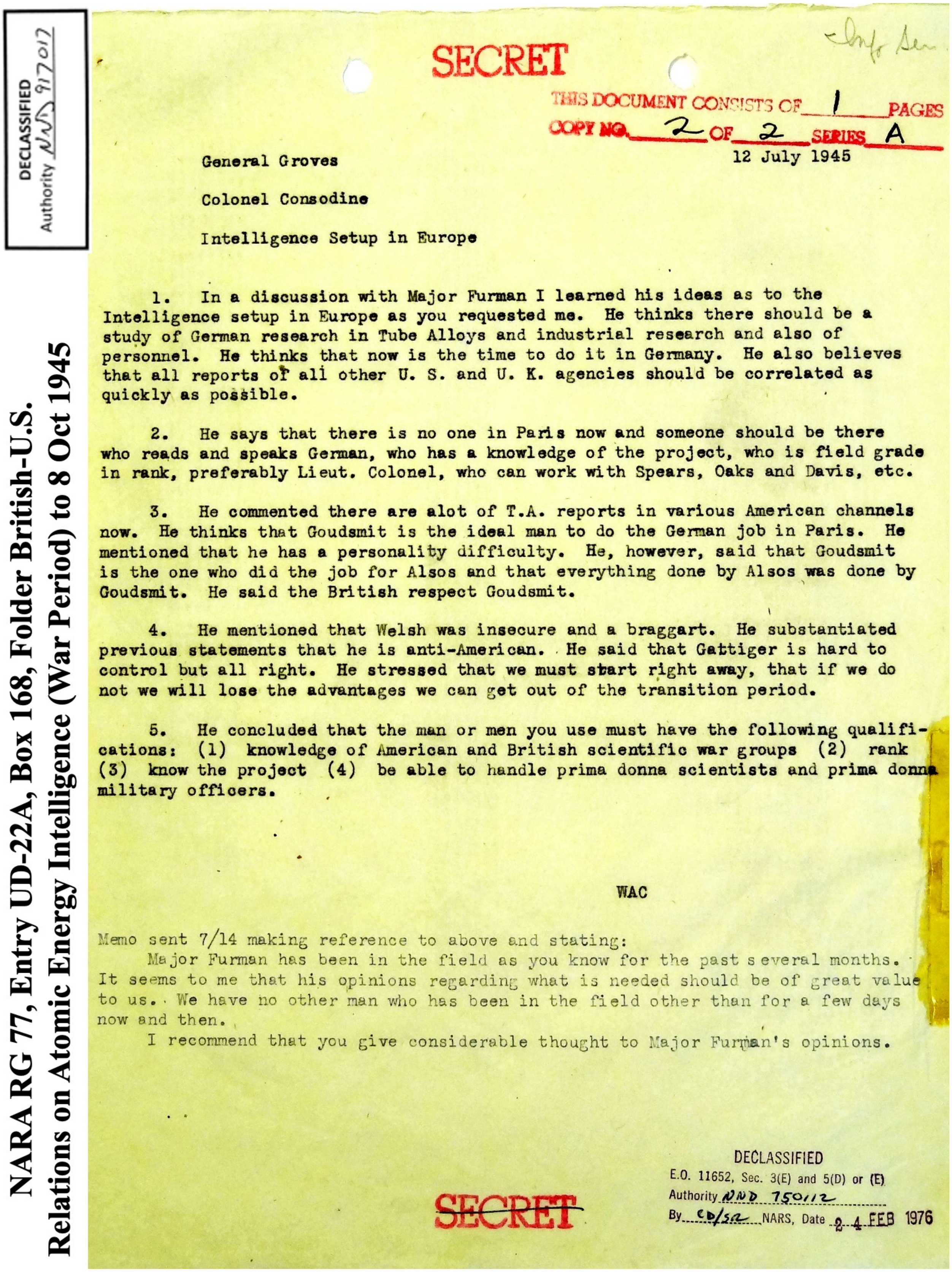
If the German nuclear program was as small and accomplished as little as Alsos reported, why did Robert Furman recommend that a detailed study of the German nuclear program's research, industry, and personnel be conducted in July 1945, after Alsos had basically already wrapped up its mission and (officially at least) already learned everything important about the German program?

Recall that in a 22 May 1945 letter, Furman had privately admitted that there were so many German nuclear sites and documents that his team did not even try to investigate them (p. 3287).

In addition to the reports written by Alsos, there were "a lot of T.A. reports in various American channels" as of July 1945. Furman also referred to "all reports of all other U.S. and U.K. agencies" on the subject. Who wrote all of those other reports, and where are the reports now?

Similarly, in his 22 May 1945 letter, Furman had written that there were so many German nuclear sites and documents that "it is impossible to keep other agencies from finding out about the German effort" (p. 3287).

According to the document above, Furman explicitly stated that Samuel Goudsmit had "a personality difficulty" and that "everything done by Alsos was done by Goudsmit."]



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NARA RG 77, Entry UD-22A, Box 168, Folder British-U.S. Relations on Atomic Energy Intelligence (War Period) to 8 Oct 1945

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Info Sec

THIS DOCUMENT CONSISTS OF 1 PAGES
COPY NO. 2 OF 2 SERIES A

12 July 1945

General Groves

Colonel Consodine

Intelligence Setup in Europe

1. In a discussion with Major Furman I learned his ideas as to the Intelligence setup in Europe as you requested me. He thinks there should be a study of German research in Tube Alloys and industrial research and also of personnel. He thinks that now is the time to do it in Germany. He also believes that all reports of all other U. S. and U. K. agencies should be correlated as quickly as possible.

2. He says that there is no one in Paris now and someone should be there who reads and speaks German, who has a knowledge of the project, who is field grade in rank, preferably Lieut. Colonel, who can work with Spears, Oaks and Davis, etc.

3. He commented there are alot of T.A. reports in various American channels now. He thinks that Goudsmit is the ideal man to do the German job in Paris. He mentioned that he has a personality difficulty. He, however, said that Goudsmit is the one who did the job for Alsos and that everything done by Alsos was done by Goudsmit. He said the British respect Goudsmit.

4. He mentioned that Welsh was insecure and a braggart. He substantiated previous statements that he is anti-American. He said that Gattiger is hard to control but all right. He stressed that we must start right away, that if we do not we will lose the advantages we can get out of the transition period.

5. He concluded that the man or men you use must have the following qualifications: (1) knowledge of American and British scientific war groups (2) rank (3) know the project (4) be able to handle prima donna scientists and prima donna military officers.

WAC

Memo sent 7/14 making reference to above and stating:
Major Furman has been in the field as you know for the past several months. It seems to me that his opinions regarding what is needed should be of great value to us. We have no other man who has been in the field other than for a few days now and then.
I recommend that you give considerable thought to Major Furman's opinions.

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Authority NND 750112
By CD/SR NARS, Date 24 FEB 1976

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Figure D.24: W. A. Consodine to Leslie Groves. 12 July 1945. Intelligence Setup in Europe [NARA RG 77, Entry UD-22A, Box 168, Folder British–U.S. Relations on Atomic Energy Intelligence (War Period) to 8 Oct 1945]. Robert Furman explicitly stated that Samuel Goudsmit had "a personality difficulty" and that "everything done by Alsos was done by Goudsmit."

Samuel Goudsmit to Reginald C. Augustine, 18 September 1945. [NARA RG GOUDS, Entry UD-7420, Box 6, Folder Rosbaud]

1. It is still of primary importance to Alsos and to other intelligence agencies to locate Professor (or General) Erich Schumann about whom I have written you before. Recently, a new lead on this man was discovered in Berlin by Major Clark. I believe it is definitely worthwhile to follow it up. The contact in Berlin may actually know where Schumann is. I propose that Rosenberger go to Berlin to squeeze the information out of him, or at least as much as can be obtained. Schumann is supposed to be in Bavaria somewhere. At one time, we sent Previti down to find some of Schumann's disciples. He returned without any information about Schumann. I think this angle should be pushed a little harder after Rosenberger returns from Berlin.

2. Here follow the details: The man in Berlin in Professor Erhard Landt, born 22 June 1900. He was Dozentenbundsführer and Dozentenschaftsleiter of Berlin University where he was a professor of physical and chemical technology and an honorary professor of physics. His present address is Berlin-Schmargendorf, Königsallee 67, British Zone. Landt was interrogated by Major Clark and Pfc. Strauss. Major Clark was interested in finding a man by the name of Rudi Schall who, at one time, worked with Schumann. Major Clark made it appear that Schall might be useful on a job in the U.S.A. At that suggestion, Landt intimated that he knew that Schall was in Bavaria, that Schumann was there also, that Schumann was the better man and that he (Landt) might be able to contact him.

3. I wish that Rosenberger would pick up this lead as if he came from Major Clark [i.e., lie] and, in that way, obtain Schumann's location.

4. I should like to point out again that Schumann, though he had a very high position, is regarded by all scientists, including old and competent German scientists, as definitely a second-rater. We even possess a Gestapo evaluation of him, mentioning that he was incompetent and not possessing the right character for the job he was holding. The fact that Landt praises him very much proves that he is also an incompetent charlatan. Landt was very much surprised that Clark had found him. He is a cagey, unreliable man who asks more questions than he gives out information. If everything fails, there may be enough reasons to have him detained. I have a feeling that he was an ardent supporter of the party. If Rosenberger needs any assistance in Berlin, he might contact Dr. P. Rosbaud who has been exceedingly helpful to us so far. Rosenberger can tell him what he is after—he knows about it. He has also helped Major Clark. His last known address was Boltzmannstrasse 1. He is keeping in contact with G-2 of Group CC whose office is at Boltzmannstrasse 20. If Rosenberger is successful in Berlin, the information obtained should be followed up immediately by a trip to Bavaria. Even if it is not successful, someone should once more go back on the trail which Marti Previti tried to follow and use some forceful inducements on those fellows to find their boss. I return herewith one copy of Previti's report.

[See document photo on p. 3296.

To the modern reader, Samuel Goudsmit's tone and message throughout this letter are truly shocking. This does not sound like a professional business letter written by a well-known theoretical physicist or a diligent government investigator. It sounds more like an organized crime boss ranting about someone he hates and then ordering all of his goons to use extreme measures to track down that person and deal with him.

Erich Schumann designed and apparently built fission implosion bombs during the war (pp. 4185–4277, 4640–4664, 4257–4259).

When Alsos finished its major operations in May 1945, it had not located Schumann, but it strongly recommended that other investigators do so (p. 3280, grade A). In this letter, Goudsmit sounded willing to go to any lengths to find Schumann. This letter also mentioned past and planned future attempts to locate Schumann.

Schumann appears to have hidden with various friends in Germany until summer 1947, when he was given official sanctuary in the British-controlled zone of Germany in exchange for information and/or work that U.K. officials considered sufficiently valuable to shield Schumann from the United States and from the ongoing war crimes trials. See pp. 4910–4911.

Despite all of this evidence about Schumann's wartime work on sophisticated nuclear weapon designs and despite Goudsmit's months-long frantic searches for Schumann, Goudsmit knowingly gave false testimony to the United States Senate by claiming that Schumann's "main interest was the physics of piano strings" (p. 3297). Goudsmit repeated this deliberate falsehood in his 1947 book, *Alsos* (p. 3317).

Goudsmit even included some gratuitous slander in this letter, seemingly oblivious to the fact that it was clearly disproven by the very request he was so urgently making in the letter.

Without providing any evidence, Goudsmit claimed that any person who "praises" Schumann's work "proves that he is also an incompetent charlatan." By Goudsmit's definition, such incompetent charlatans must then include the Allied investigator Major J. C. Clark mentioned in Goudsmit's letter (p. 4190), the U.S. Army Ordnance Department (p. 4187), the British government (pp. 4910–4911), the Soviet government (p. 4642), Max Planck (p. 4910), Wernher von Braun after the Apollo 11 moon landing (1984), and even Alsos itself (p. 3280, grade A).

Goudsmit claimed that a Gestapo evaluation proved that Schumann was incompetent. Actually Schumann was one of Heinrich Himmler's top scientific advisors, and the United States was well aware of that fact after the war (p. 3393).

What were the "other intelligence agencies" to whom it was of "primary importance... to locate... Schumann"? CIC, OSS, or otherwise? Even without explicitly identifying them, this is a written admission by Samuel Goudsmit that U.S. government organizations that were not Alsos were also doing an official (and probably more thorough) investigation of the wartime German nuclear program.]

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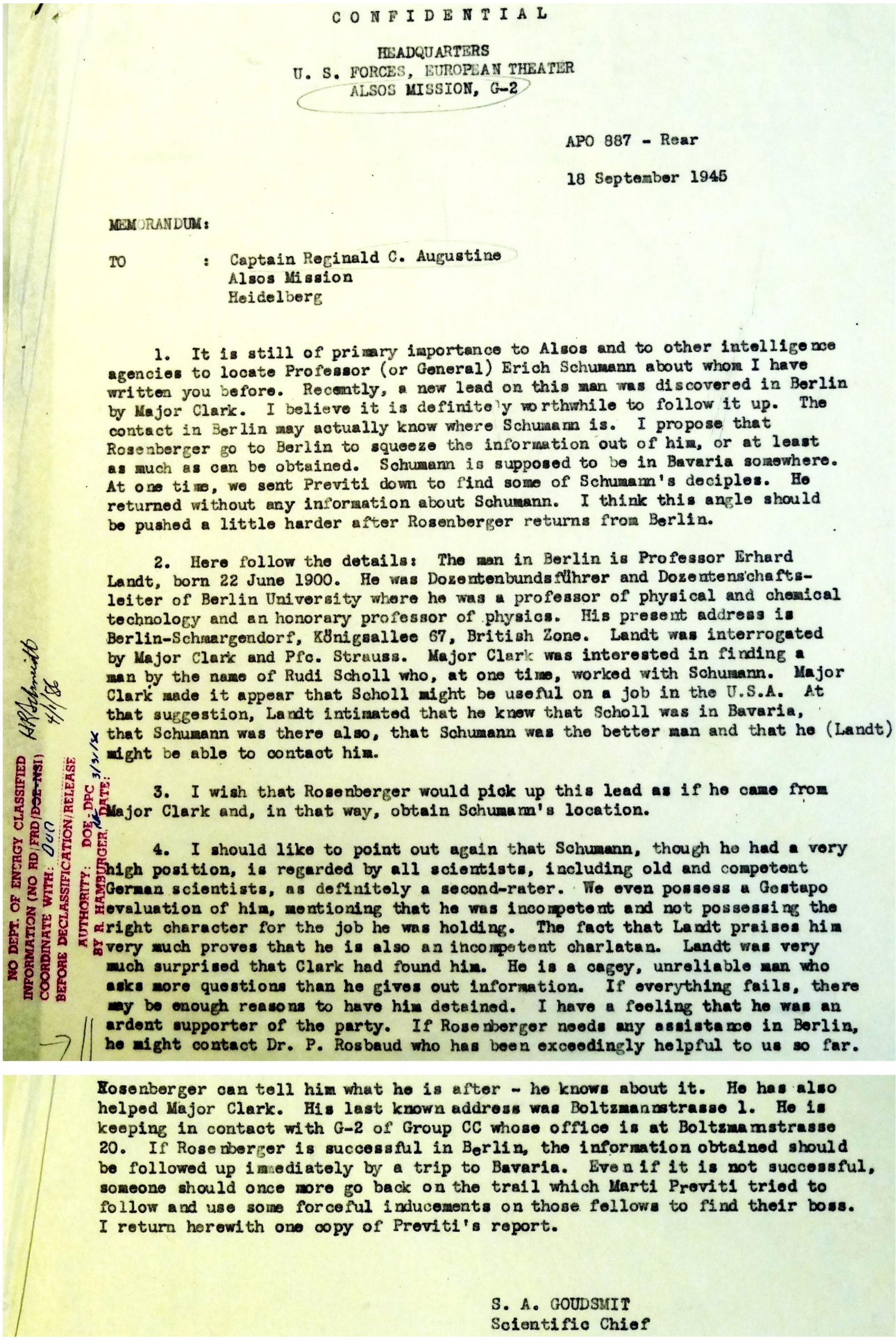

CONFIDENTIAL

HEADQUARTERS
U. S. FORCES, EUROPEAN THEATER
ALSOS MISSION, G-2

APO 887 - Rear

18 September 1945

MEMORANDUM:

TO : Captain Reginald C. Augustine
Alsos Mission
Heidelberg

1. It is still of primary importance to Alsos and to other intelligence agencies to locate Professor (or General) Erich Schumann about whom I have written you before. Recently, a new lead on this man was discovered in Berlin by Major Clark. I believe it is definitely worthwhile to follow it up. The contact in Berlin may actually know where Schumann is. I propose that Rosenberger go to Berlin to squeeze the information out of him, or at least as much as can be obtained. Schumann is supposed to be in Bavaria somewhere. At one time, we sent Previti down to find some of Schumann's deciples. He returned without any information about Schumann. I think this angle should be pushed a little harder after Rosenberger returns from Berlin.

2. Here follow the details: The man in Berlin is Professor Erhard Landt, born 22 June 1900. He was Dozentenbundsführer and Dozentenschaftsleiter of Berlin University where he was a professor of physical and chemical technology and an honorary professor of physics. His present address is Berlin-Schmargendorf, Königsallee 67, British Zone. Landt was interrogated by Major Clark and Pfc. Strauss. Major Clark was interested in finding a man by the name of Rudi Scholl who, at one time, worked with Schumann. Major Clark made it appear that Scholl might be useful on a job in the U.S.A. At that suggestion, Landt intimated that he knew that Scholl was in Bavaria, that Schumann was there also, that Schumann was the better man and that he (Landt) might be able to contact him.

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BY R. HAMBURGER DATE: 3/31/16

HR Schmidt
4/1/16

3. I wish that Rosenberger would pick up this lead as if he came from Major Clark and, in that way, obtain Schumann's location.

4. I should like to point out again that Schumann, though he had a very high position, is regarded by all scientists, including old and competent German scientists, as definitely a second-rater. We even possess a Gestapo evaluation of him, mentioning that he was incompetent and not possessing the right character for the job he was holding. The fact that Landt praises him very much proves that he is also an incompetent charlatan. Landt was very much surprised that Clark had found him. He is a cagey, unreliable man who asks more questions than he gives out information. If everything fails, there may be enough reasons to have him detained. I have a feeling that he was an ardent supporter of the party. If Rosenberger needs any assistance in Berlin, he might contact Dr. P. Rosbaud who has been exceedingly helpful to us so far. Rosenberger can tell him what he is after - he knows about it. He has also helped Major Clark. His last known address was Boltzmannstrasse 1. He is keeping in contact with G-2 of Group CC whose office is at Boltzmannstrasse 20. If Rosenberger is successful in Berlin, the information obtained should be followed up immediately by a trip to Bavaria. Even if it is not successful, someone should once more go back on the trail which Marti Previti tried to follow and use some forceful inducements on those fellows to find their boss. I return herewith one copy of Previti's report.

S. A. GOUDSMIT
Scientific Chief

NARA RG GOUDS, Entry UD-7420, Box 6, Folder Rosbaud

Figure D.25: Samuel Goudsmit to Reginald C. Augustine, 18 September 1945: "It is still of primary importance to Alsos and to other intelligence agencies to locate Professor (or General) Erich Schumann about whom I have written you before" [NARA RG GOUDS, Entry UD-7420, Box 6, Folder Rosbaud]. Schumann designed and apparently built fission implosion bombs during the war (pp. 4185–4277, 4640–4664, 4257–4259). When Alsos finished its major operations in May 1945, it had not located Schumann but recommended that other investigators do so (p. 3280, grade A). See p. 4190 for Major Clark.

Samuel Goudsmit's 6 December 1945 testimony to the U.S. Senate. *Hearings Before the Special Committee on Atomic Energy, United States Senate, Seventy-Ninth Congress, First Session, Pursuant to S. Res. 179, a Resolution Creating a Special Committee to Investigate Problems Relating to the Development, Use, and Control of Atomic Energy, Part 2, December 5, 6, 10, and 12, 1945.* Washington, D.C.: U.S. Government Printing Office, 1946. [Goudsmit 1945]

In spite of certain preliminary newspaper reports, we can say that the Germans did not have anything at all. They were way behind. They just did not have the vision which the Allied scientists had, I believe.

[...] For instance, as I mentioned before, the German scientists seem to have lacked the vision. They did not believe in its success from the very beginning. They knew its importance, and were convinced that the project was important; but they did not believe that it could be done within a reasonable time, 50 to 100 years. [...]

Himmler's SS men went around and spread the rumor that very soon the Germans were going to use a uranium bomb, scaring the scientists who knew they were 50 or a hundred years away from such a goal.

Other reasons why the Germans did not make any real progress were probably, as I mentioned before, that the key men in administrative positions were utterly incompetent. For instance, Army Ordnance had as its chief advisor on military matters a second-rate physicist named Schumann, like the musician Schumann. In fact, his main interest was the physics of piano strings. [...]

That man had a small project going on in one of the Army proving grounds near Berlin, and the scientists he had working with him were definitely inferior compared with the scientists which were available in Germany for such a project; so there was one group working.

There was another group working in the so-called Kaiser-Wilhelm Institute for physics. [...]

A private scientist, Baron von Ardenne, a clever technician and businessman, got the Minister of Post and Telegraph, Ohnesorge, interested in his research. Ohnesorge was near to Hitler and kept the Fuehrer informed about the importance of the project. For awhile, Von Ardenne was considered by the German authorities to be the expert on the uranium problem, much to the dismay of the really competent scientists. [...]

At the beginning of 1945, most of the research was still in practically the same state as it had been in 1943. Isotope separation had been tried on a very small scale only by means of a centrifuge. [...]

Some of the key scientists worked only part time on this important research and the rest of the time did routine teaching or administrative work. The lack of proper large-scale facilities necessary for this kind of work was, of course, another reason for the lack of success.

At the slow pace at which they were progressing, it is obvious that German scientists did not believe a bomb would be constructed within the course of the war. They were confident that perhaps a uranium machine, or at least its basic principles, could be obtained within a reasonable length of time. It is remarkable, however, how incomplete their knowledge was. They were, according to their research reports, scarcely aware of some of the basic difficulties which they were likely to encounter in their efforts. Most surprising is the fact that not even their best scientists had given any thought to the use of plutonium.

Attempts were made to have German chemical industry produce heavy water because the Norwegian plant had been destroyed. However, not much progress was made with this plan either. [...]

The effort was small, though it had the highest priority among all scientific research projects in Germany. The total expenditure was about 15,000,000 marks, which is perhaps equivalent to some $10,000,000. The appropriation for 1944–45 was 3 ¼ million marks with a subsequent supplement of 1,000,000.

It is estimated that approximately 100 scientists were active on this project. They were divided into several rather small groups working on different phases of the problem and were spread all over Germany. [...]

Toward the end of the war, the German experiments had indicated that it was possible to obtain an increase in the number of neutrons, but no self-sustaining neutron source had been constructed as yet. [...] Gerlach was quite upset when, shortly afterward, the S. S. spread rumors that the Germans were soon going to use a uranium bomb. The scientists knew that they were still a hundred years away from that goal.

Himmler's S. S. had begun to take an active interest in research and especially in the uranium project. This organization had threatened to evacuate key scientists and their equipment to the Bavarian redoubt where they would be forced to complete the work under pressure. To the relief of the frightened German scientists, this plan failed, probably because of the rapidity of the German collapse. Only one group was actually kidnapped by the S. S. and let loose in Bavaria.

But, the German scientists believed in their superiority. They attempted to hide their research reports and all information about their work from Allied investigators—of course, in vain.

Not until they learned about the use of the atomic bomb by the Allies did they realize how far behind they were. They had lost not only the military war, but also the war of science.

[Samuel Goudsmit knowingly and repeatedly gave completely false testimony to the United States Senate, as shown by many documents from Alsos's own files, including but not limited to those on:

- Erich Schumann and his implosion bomb experiments (e.g., pp. 3280, 3296, 4190).
- Manfred von Ardenne's calutron (all of Section D.4.3, especially p. 3562).
- Reports on plutonium from Ida Tacke Noddack (pp. 3795–3794), Carl Friedrich von Weizsäcker (pp. 3800–3807), Fritz Houtermans (pp. 3814–3823), Otto Hahn (p. 3825) and Josef Schintlemeister (pp. 3794, 3827–3830).
- The fact that the 15,000,000 marks only covered a small set of fission pile experiments and was not at all the total cost of the wartime German nuclear program, which included a large number of organizations and sites all over Europe (p. 3291).
- The German nuclear program being too large for Alsos to even investigate more than a small fraction of it (e.g., pp. 3271–3273, 3279–3283, 3285–3287, 3292–3293).
- SHAEF G-2 Generals Thomas J. Betts (p. 5030) and George Bryan Conrad plus AAF General Henry Arnold's advisor Prof. Edward L. Bowles of MIT (pp. 4711, 5319) concluding that Alsos had failed to do its primary job of investigating the German nuclear program (pp. 3285–3287).
- Statements by knowledgeable participants that German nuclear weapons were ready or nearly ready by the end of the war and that would have been known to Alsos (e.g., pp. 4186–4190, 4275–4277, 4396–4419, plus many documents in Sections D.13 and D.14).

Goudsmit repeated most of these false claims in his 1947 book and other writings.

In view of this overwhelming evidence that Samuel Goudsmit was a serial fabulist, scholars and journalists must treat Goudsmit and any information derived from him accordingly.]

Questions from Senator Edwin Johnson during Samuel Goudsmit's 6 December 1945 testimony to the U.S. Senate. ***Hearings Before the Special Committee on Atomic Energy, United States Senate, Seventy-Ninth Congress, First Session, Pursuant to S. Res. 179, a Resolution Creating a Special Committee to Investigate Problems Relating to the Development, Use, and Control of Atomic Energy, Part 2, December 5, 6, 10, and 12, 1945.*** **Washington, D.C.: U.S. Government Printing Office, 1946, p. 254. [Goudsmit 1945]**

Dr. GOUDSMIT. [...] The total effort expended by the Germans on the project was rather small, but it was among the scientific projects the one of the highest priority; still it was very small compared to our effort.

Senator JOHNSON. In your investigation of the German effort, did you have access to all of the efforts of Germany? Press reports have inferred, or at least I have understood from them, that certain German efforts had been taken over by the Russians, and that such plants as they took over were not open to inspection.

Now, did you have access to all the plants in Germany, and when you speak of what the Germans did, are you speaking of everything that the Germans did in the Russian-occupied zone as well as in the American-occupied zone?

Dr. GOUDSMIT. I speak with confidence of everything the Germans did on the atomic bomb project. I am certain that I have inspected all the papers and have talked to all the key men on the project, and have seen all the documents and most of the laboratories have been visited by me or by men who worked in connection with me.

Senator JOHNSON. In the Russian-occupied as well as in the American- and British-occupied zones? Have you visited any Russian-occupied laboratories?

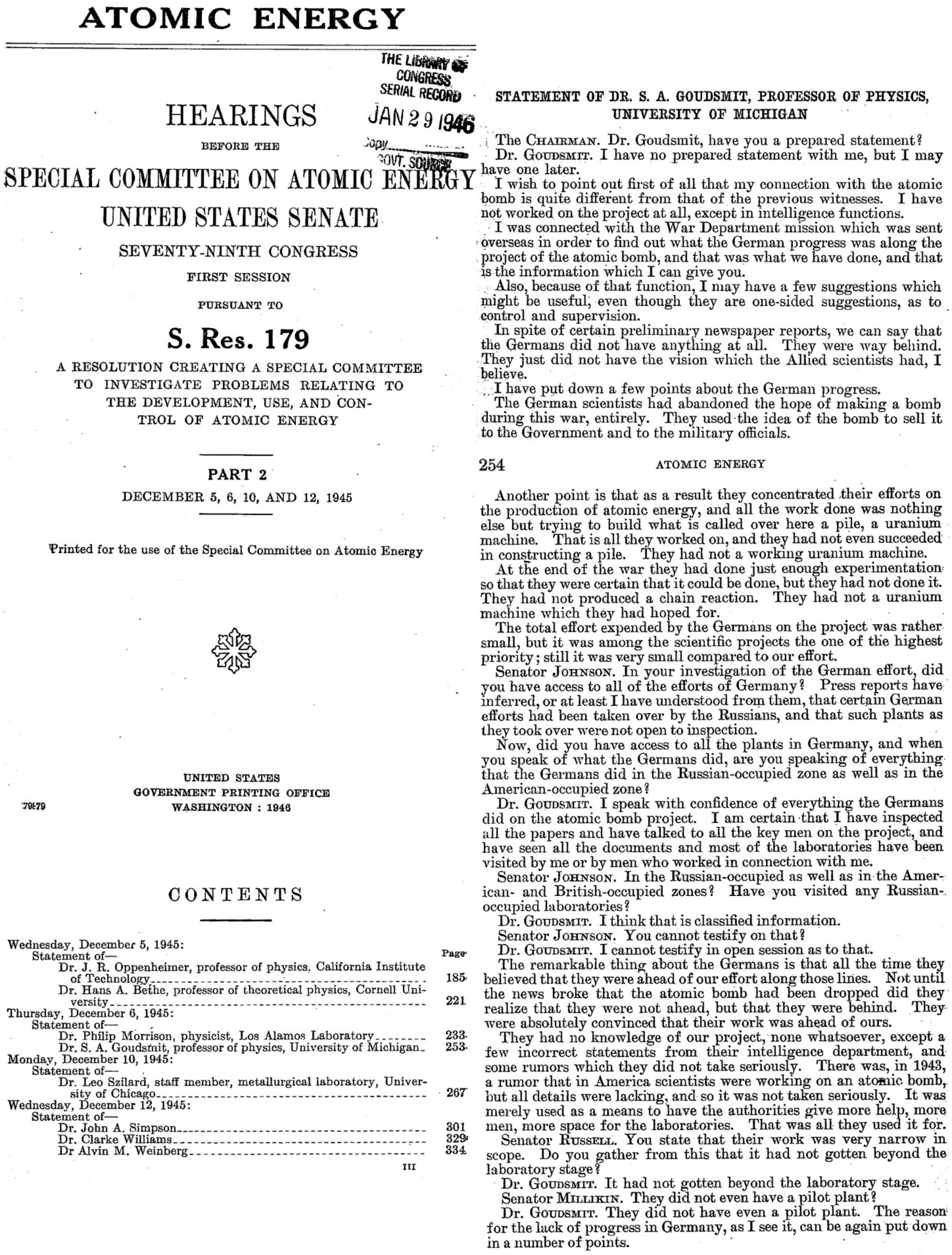
Dr. GOUDSMIT. I think that is classified information.

Senator JOHNSON. You cannot testify on that?

Dr. GOUDSMIT. I cannot testify in open session as to that.

[From this exchange, it appears that Goudsmit had additional information about the German nuclear program that he was unwilling to share with the U.S. Senate. What exactly was that information?

Alternatively, was Goudsmit simply bluffing the U.S. Senate? If providing honest answers to Senator Johnson's questions would have revealed that Goudsmit had failed to pursue many important leads, did Goudsmit evade Johnson's questions by falsely claiming that the answers were "classified information" that he could not discuss?]



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HEARINGS

BEFORE THE

SPECIAL COMMITTEE ON ATOMIC ENERGY
UNITED STATES SENATE

SEVENTY-NINTH CONGRESS
FIRST SESSION
PURSUANT TO

S. Res. 179

A RESOLUTION CREATING A SPECIAL COMMITTEE
TO INVESTIGATE PROBLEMS RELATING TO
THE DEVELOPMENT, USE, AND CON-
TROL OF ATOMIC ENERGY

PART 2
DECEMBER 5, 6, 10, AND 12, 1945

Printed for the use of the Special Committee on Atomic Energy

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STATEMENT OF DR. S. A. GOUDSMIT, PROFESSOR OF PHYSICS, UNIVERSITY OF MICHIGAN

The CHAIRMAN. Dr. Goudsmit, have you a prepared statement?

Dr. GOUDSMIT. I have no prepared statement with me, but I may have one later.

I wish to point out first of all that my connection with the atomic bomb is quite different from that of the previous witnesses. I have not worked on the project at all, except in intelligence functions.

I was connected with the War Department mission which was sent overseas in order to find out what the German progress was along the project of the atomic bomb, and that was what we have done, and that is the information which I can give you.

Also, because of that function, I may have a few suggestions which might be useful, even though they are one-sided suggestions, as to control and supervision.

In spite of certain preliminary newspaper reports, we can say that the Germans did not have anything at all. They were way behind. They just did not have the vision which the Allied scientists had, I believe.

I have put down a few points about the German progress.

The German scientists had abandoned the hope of making a bomb during this war, entirely. They used the idea of the bomb to sell it to the Government and to the military officials.

Another point is that as a result they concentrated their efforts on the production of atomic energy, and all the work done was nothing else but trying to build what is called over here a pile, a uranium machine. That is all they worked on, and they had not even succeeded in constructing a pile. They had not a working uranium machine.

At the end of the war they had done just enough experimentation so that they were certain that it could be done, but they had not done it. They had not produced a chain reaction. They had not a uranium machine which they had hoped for.

The total effort expended by the Germans on the project was rather small, but it was among the scientific projects the one of the highest priority; still it was very small compared to our effort.

Senator JOHNSON. In your investigation of the German effort, did you have access to all of the efforts of Germany? Press reports have inferred, or at least I have understood from them, that certain German efforts had been taken over by the Russians, and that such plants as they took over were not open to inspection.

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Dr. GOUDSMIT. I think that is classified information.

Senator JOHNSON. You cannot testify on that?

Dr. GOUDSMIT. I cannot testify in open session as to that.

The remarkable thing about the Germans is that all the time they believed that they were ahead of our effort along those lines. Not until the news broke that the atomic bomb had been dropped did they realize that they were not ahead, but that they were behind. They were absolutely convinced that their work was ahead of ours.

They had no knowledge of our project, none whatsoever, except a few incorrect statements from their intelligence department, and some rumors which they did not take seriously. There was, in 1943, a rumor that in America scientists were working on an atomic bomb, but all details were lacking, and so it was not taken seriously. It was merely used as a means to have the authorities give more help, more men, more space for the laboratories. That was all they used it for.

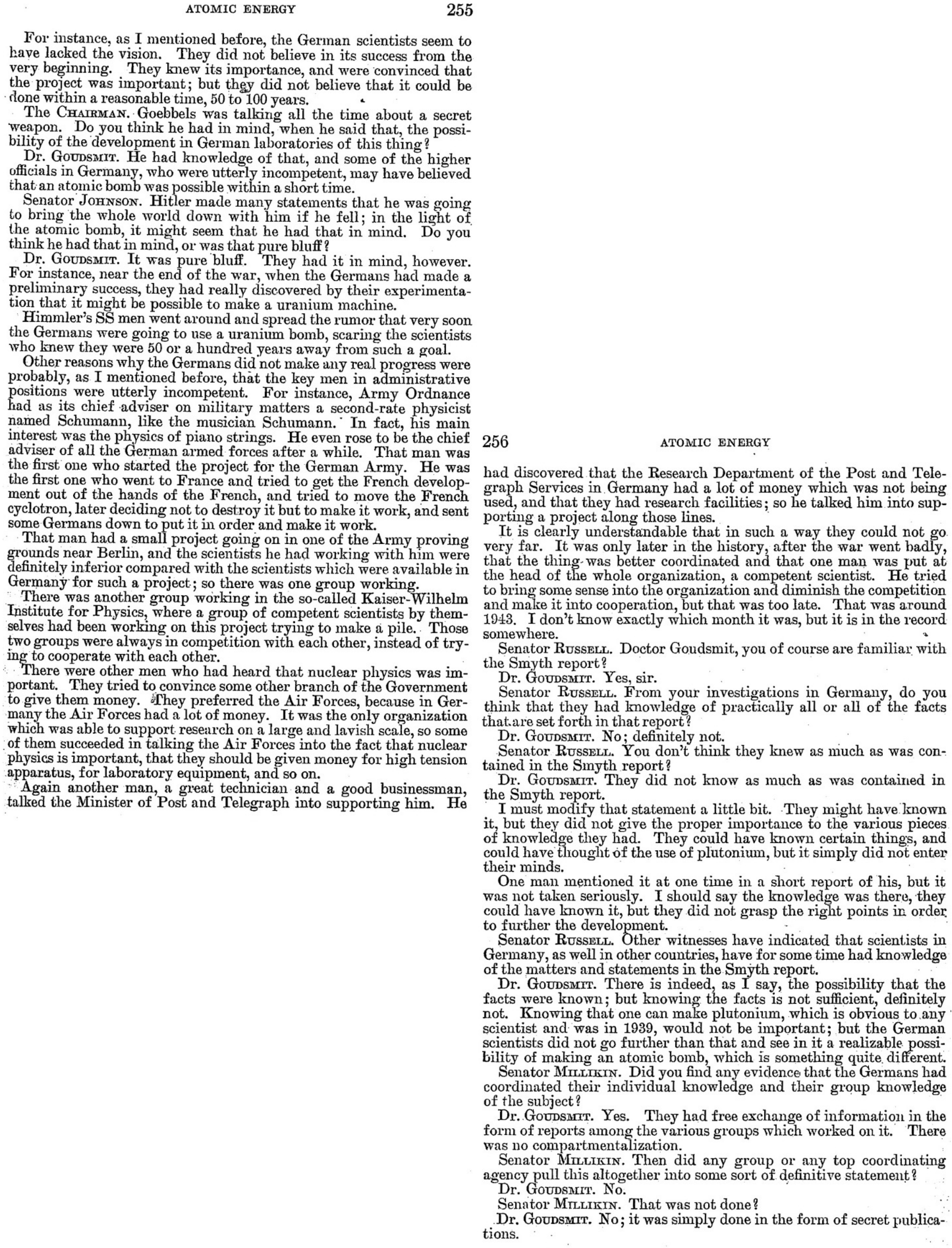
Senator RUSSELL. You state that their work was very narrow in scope. Do you gather from this that it had not gotten beyond the laboratory stage?

Dr. GOUDSMIT. It had not gotten beyond the laboratory stage.

Senator MILLIKIN. They did not even have a pilot plant?

Dr. GOUDSMIT. They did not have even a pilot plant. The reason for the lack of progress in Germany, as I see it, can be again put down in a number of points.

Figure D.26: Samuel Goudsmit's 6 December 1945 testimony to the U.S. Senate [Goudsmit 1945].



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For instance, as I mentioned before, the German scientists seem to have lacked the vision. They did not believe in its success from the very beginning. They knew its importance, and were convinced that the project was important; but they did not believe that it could be done within a reasonable time, 50 to 100 years.

The CHAIRMAN. Goebbels was talking all the time about a secret weapon. Do you think he had in mind, when he said that, the possibility of the development in German laboratories of this thing?

Dr. GOUDSMIT. He had knowledge of that, and some of the higher officials in Germany, who were utterly incompetent, may have believed that an atomic bomb was possible within a short time.

Senator JOHNSON. Hitler made many statements that he was going to bring the whole world down with him if he fell; in the light of the atomic bomb, it might seem that he had that in mind. Do you think he had that in mind, or was that pure bluff?

Dr. GOUDSMIT. It was pure bluff. They had it in mind, however. For instance, near the end of the war, when the Germans had made a preliminary success, they had really discovered by their experimentation that it might be possible to make a uranium machine.

Himmler's SS men went around and spread the rumor that very soon the Germans were going to use a uranium bomb, scaring the scientists who knew they were 50 or a hundred years away from such a goal.

Other reasons why the Germans did not make any real progress were probably, as I mentioned before, that the key men in administrative positions were utterly incompetent. For instance, Army Ordnance had as its chief adviser on military matters a second-rate physicist named Schumann, like the musician Schumann. In fact, his main interest was the physics of piano strings. He even rose to be the chief adviser of all the German armed forces after a while. That man was the first one who started the project for the German Army. He was the first one who went to France and tried to get the French development out of the hands of the French, and tried to move the French cyclotron, later deciding not to destroy it but to make it work, and sent some Germans down to put it in order and make it work.

That man had a small project going on in one of the Army proving grounds near Berlin, and the scientists he had working with him were definitely inferior compared with the scientists which were available in Germany for such a project; so there was one group working.

There was another group working in the so-called Kaiser-Wilhelm Institute for Physics, where a group of competent scientists by themselves had been working on this project trying to make a pile. Those two groups were always in competition with each other, instead of trying to cooperate with each other.

There were other men who had heard that nuclear physics was important. They tried to convince some other branch of the Government to give them money. They preferred the Air Forces, because in Germany the Air Forces had a lot of money. It was the only organization which was able to support research on a large and lavish scale, so some of them succeeded in talking the Air Forces into the fact that nuclear physics is important, that they should be given money for high tension apparatus, for laboratory equipment, and so on.

Again another man, a great technician and a good businessman, talked the Minister of Post and Telegraph into supporting him. He had discovered that the Research Department of the Post and Telegraph Services in Germany had a lot of money which was not being used, and that they had research facilities; so he talked him into supporting a project along those lines.

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It is clearly understandable that in such a way they could not go very far. It was only later in the history, after the war went badly, that the thing was better coordinated and that one man was put at the head of the whole organization, a competent scientist. He tried to bring some sense into the organization and diminish the competition and make it into cooperation, but that was too late. That was around 1943. I don't know exactly which month it was, but it is in the record somewhere.

Senator RUSSELL. Doctor Goudsmit, you of course are familiar with the Smyth report?

Dr. GOUDSMIT. Yes, sir.

Senator RUSSELL. From your investigations in Germany, do you think that they had knowledge of practically all or all of the facts that are set forth in that report?

Dr. GOUDSMIT. No; definitely not.

Senator RUSSELL. You don't think they knew as much as was contained in the Smyth report?

Dr. GOUDSMIT. They did not know as much as was contained in the Smyth report.

I must modify that statement a little bit. They might have known it, but they did not give the proper importance to the various pieces of knowledge they had. They could have known certain things, and could have thought of the use of plutonium, but it simply did not enter their minds.

One man mentioned it at one time in a short report of his, but it was not taken seriously. I should say the knowledge was there, they could have known it, but they did not grasp the right points in order to further the development.

Senator RUSSELL. Other witnesses have indicated that scientists in Germany, as well in other countries, have for some time had knowledge of the matters and statements in the Smyth report.

Dr. GOUDSMIT. There is indeed, as I say, the possibility that the facts were known; but knowing the facts is not sufficient, definitely not. Knowing that one can make plutonium, which is obvious to any scientist and was in 1939, would not be important; but the German scientists did not go further than that and see in it a realizable possibility of making an atomic bomb, which is something quite different.

Senator MILLIKIN. Did you find any evidence that the Germans had coordinated their individual knowledge and their group knowledge of the subject?

Dr. GOUDSMIT. Yes. They had free exchange of information in the form of reports among the various groups which worked on it. There was no compartmentalization.

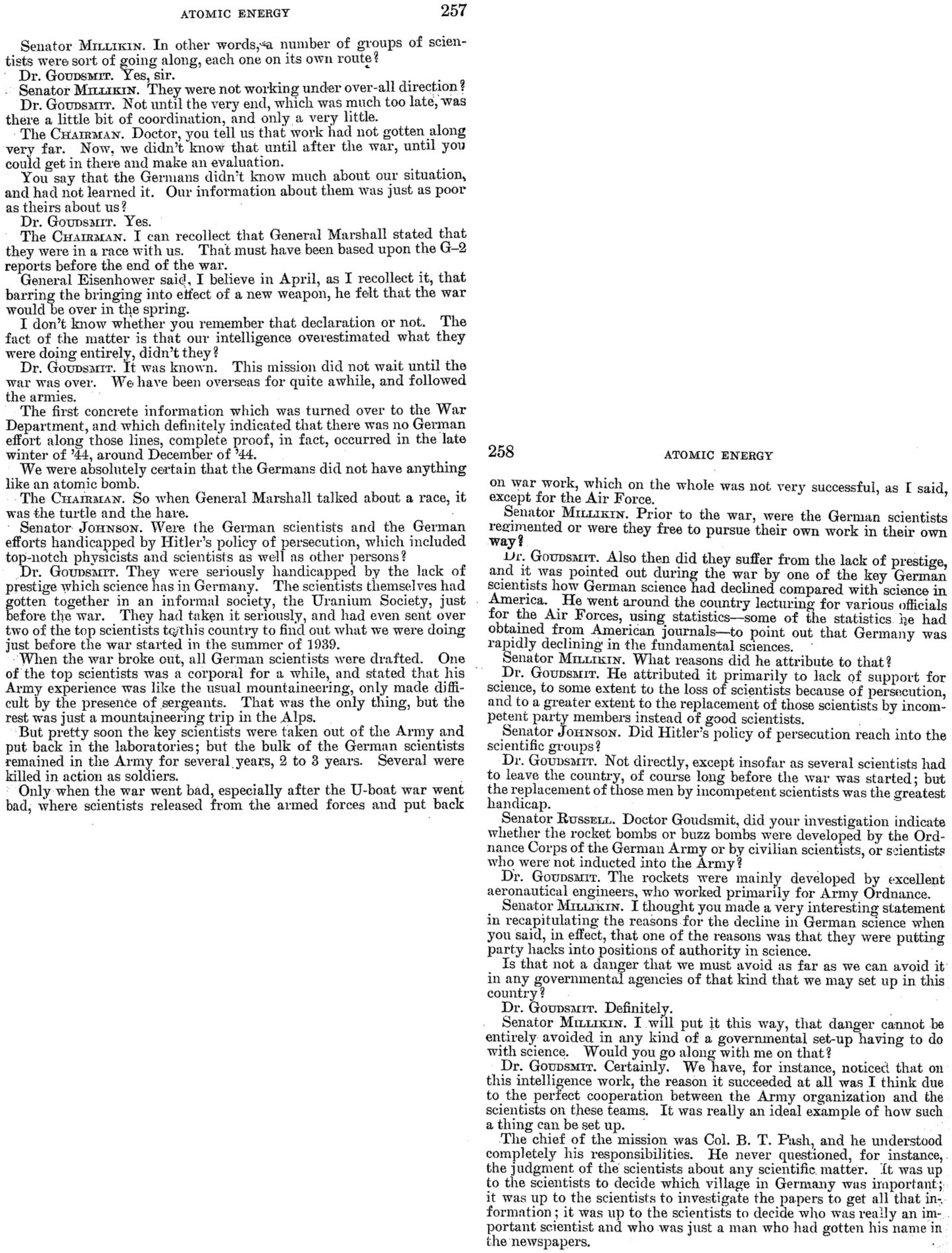
Senator MILLIKIN. Then did any group or any top coordinating agency pull this altogether into some sort of definitive statement?

Dr. GOUDSMIT. No.

Senator MILLIKIN. That was not done?

Dr. GOUDSMIT. No; it was simply done in the form of secret publications.

Figure D.27: Samuel Goudsmit's 6 December 1945 testimony to the U.S. Senate [Goudsmit 1945].



Senator MILLIKIN. In other words, a number of groups of scientists were sort of going along, each one on its own route?

Dr. GOUDSMIT. Yes, sir.

Senator MILLIKIN. They were not working under over-all direction?

Dr. GOUDSMIT. Not until the very end, which was much too late, was there a little bit of coordination, and only a very little.

The CHAIRMAN. Doctor, you tell us that work had not gotten along very far. Now, we didn't know that until after the war, until you could get in there and make an evaluation.

You say that the Germans didn't know much about our situation, and had not learned it. Our information about them was just as poor as theirs about us?

Dr. GOUDSMIT. Yes.

The CHAIRMAN. I can recollect that General Marshall stated that they were in a race with us. That must have been based upon the G–2 reports before the end of the war.

General Eisenhower said, I believe in April, as I recollect it, that barring the bringing into effect of a new weapon, he felt that the war would be over in the spring.

I don't know whether you remember that declaration or not. The fact of the matter is that our intelligence overestimated what they were doing entirely, didn't they?

Dr. GOUDSMIT. It was known. This mission did not wait until the war was over. We have been overseas for quite awhile, and followed the armies.

The first concrete information which was turned over to the War Department, and which definitely indicated that there was no German effort along those lines, complete proof, in fact, occurred in the late winter of '44, around December of '44.

We were absolutely certain that the Germans did not have anything like an atomic bomb.

The CHAIRMAN. So when General Marshall talked about a race, it was the turtle and the hare.

Senator JOHNSON. Were the German scientists and the German efforts handicapped by Hitler's policy of persecution, which included top-notch physicists and scientists as well as other persons?

Dr. GOUDSMIT. They were seriously handicapped by the lack of prestige which science has in Germany. The scientists themselves had gotten together in an informal society, the Uranium Society, just before the war. They had taken it seriously, and had even sent over two of the top scientists to this country to find out what we were doing just before the war started in the summer of 1939.

When the war broke out, all German scientists were drafted. One of the top scientists was a corporal for a while, and stated that his Army experience was like the usual mountaineering, only made difficult by the presence of sergeants. That was the only thing, but the rest was just a mountaineering trip in the Alps.

But pretty soon the key scientists were taken out of the Army and put back in the laboratories; but the bulk of the German scientists remained in the Army for several years, 2 to 3 years. Several were killed in action as soldiers.

Only when the war went bad, especially after the U-boat war went bad, where scientists released from the armed forces and put back

on war work, which on the whole was not very successful, as I said, except for the Air Force.

Senator MILLIKIN. Prior to the war, were the German scientists regimented or were they free to pursue their own work in their own way?

Dr. GOUDSMIT. Also then did they suffer from the lack of prestige, and it was pointed out during the war by one of the key German scientists how German science had declined compared with science in America. He went around the country lecturing for various officials for the Air Forces, using statistics—some of the statistics he had obtained from American journals—to point out that Germany was rapidly declining in the fundamental sciences.

Senator MILLIKIN. What reasons did he attribute to that?

Dr. GOUDSMIT. He attributed it primarily to lack of support for science, to some extent to the loss of scientists because of persecution, and to a greater extent to the replacement of those scientists by incompetent party members instead of good scientists.

Senator JOHNSON. Did Hitler's policy of persecution reach into the scientific groups?

Dr. GOUDSMIT. Not directly, except insofar as several scientists had to leave the country, of course long before the war was started; but the replacement of those men by incompetent scientists was the greatest handicap.

Senator RUSSELL. Doctor Goudsmit, did your investigation indicate whether the rocket bombs or buzz bombs were developed by the Ordnance Corps of the German Army or by civilian scientists, or scientists who were not inducted into the Army?

Dr. GOUDSMIT. The rockets were mainly developed by excellent aeronautical engineers, who worked primarily for Army Ordnance.

Senator MILLIKIN. I thought you made a very interesting statement in recapitulating the reasons for the decline in German science when you said, in effect, that one of the reasons was that they were putting party hacks into positions of authority in science.

Is that not a danger that we must avoid as far as we can avoid it in any governmental agencies of that kind that we may set up in this country?

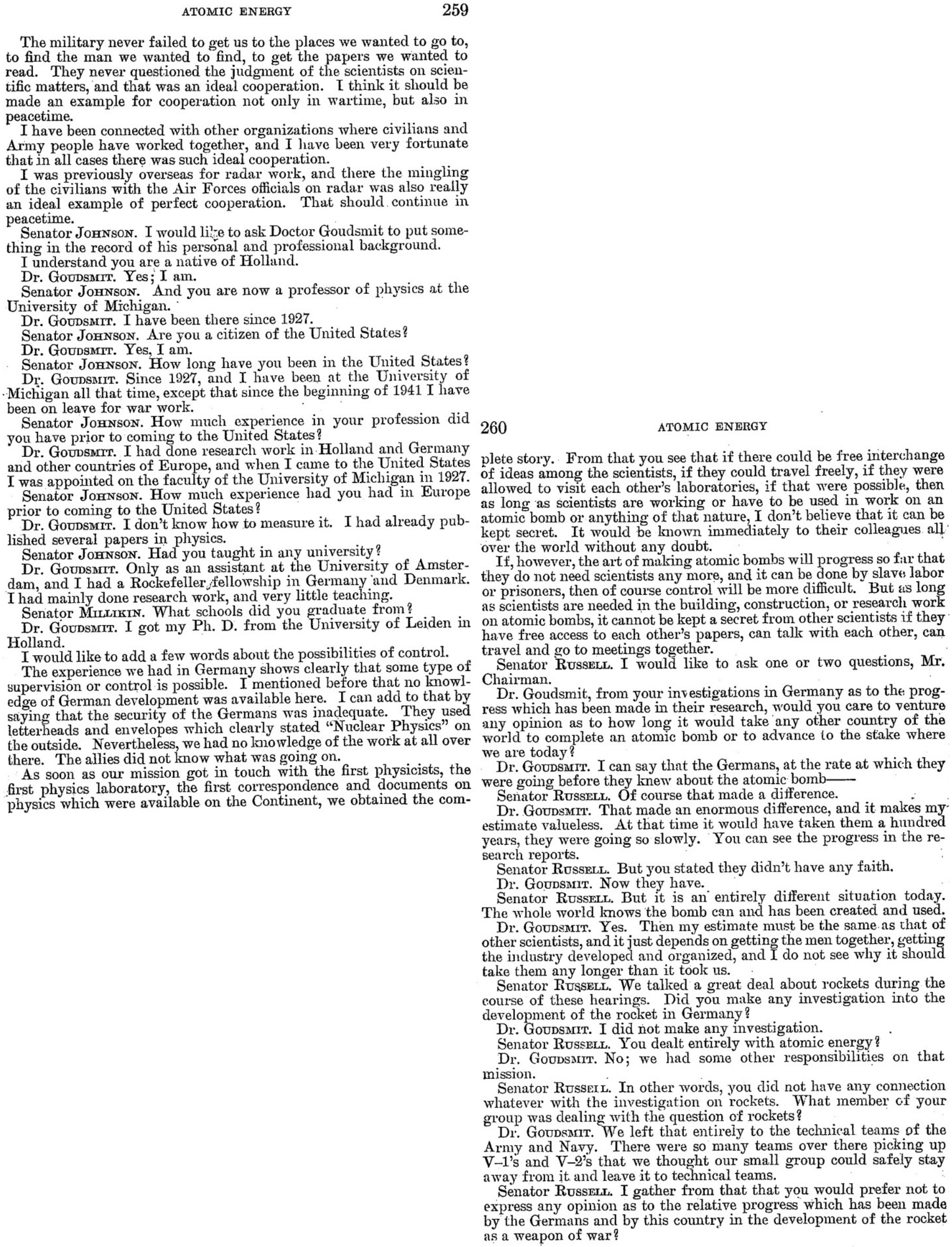
Dr. GOUDSMIT. Definitely.

Senator MILLIKIN. I will put it this way, that danger cannot be entirely avoided in any kind of a governmental set-up having to do with science. Would you go along with me on that?

Dr. GOUDSMIT. Certainly. We have, for instance, noticed that on this intelligence work, the reason it succeeded at all was I think due to the perfect cooperation between the Army organization and the scientists on these teams. It was really an ideal example of how such a thing can be set up.

The chief of the mission was Col. B. T. Pash, and he understood completely his responsibilities. He never questioned, for instance, the judgment of the scientists about any scientific matter. It was up to the scientists to decide which village in Germany was important; it was up to the scientists to investigate the papers to get all that information; it was up to the scientists to decide who was really an important scientist and who was just a man who had gotten his name in the newspapers.

Figure D.28: Samuel Goudsmit's 6 December 1945 testimony to the U.S. Senate [Goudsmit 1945].



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The military never failed to get us to the places we wanted to go to, to find the man we wanted to find, to get the papers we wanted to read. They never questioned the judgment of the scientists on scientific matters, and that was an ideal cooperation. I think it should be made an example for cooperation not only in wartime, but also in peacetime.

I have been connected with other organizations where civilians and Army people have worked together, and I have been very fortunate that in all cases there was such ideal cooperation.

I was previously overseas for radar work, and there the mingling of the civilians with the Air Forces officials on radar was also really an ideal example of perfect cooperation. That should continue in peacetime.

Senator JOHNSON. I would like to ask Doctor Goudsmit to put something in the record of his personal and professional background.

I understand you are a native of Holland.

Dr. GOUDSMIT. Yes; I am.

Senator JOHNSON. And you are now a professor of physics at the University of Michigan.

Dr. GOUDSMIT. I have been there since 1927.

Senator JOHNSON. Are you a citizen of the United States?

Dr. GOUDSMIT. Yes, I am.

Senator JOHNSON. How long have you been in the United States?

Dr. GOUDSMIT. Since 1927, and I have been at the University of Michigan all that time, except that since the beginning of 1941 I have been on leave for war work.

Senator JOHNSON. How much experience in your profession did you have prior to coming to the United States?

Dr. GOUDSMIT. I had done research work in Holland and Germany and other countries of Europe, and when I came to the United States I was appointed on the faculty of the University of Michigan in 1927.

Senator JOHNSON. How much experience had you had in Europe prior to coming to the United States?

Dr. GOUDSMIT. I don't know how to measure it. I had already published several papers in physics.

Senator JOHNSON. Had you taught in any university?

Dr. GOUDSMIT. Only as an assistant at the University of Amsterdam, and I had a Rockefeller fellowship in Germany and Denmark. I had mainly done research work, and very little teaching.

Senator MILLIKIN. What schools did you graduate from?

Dr. GOUDSMIT. I got my Ph. D. from the University of Leiden in Holland.

I would like to add a few words about the possibilities of control.

The experience we had in Germany shows clearly that some type of supervision or control is possible. I mentioned before that no knowledge of German development was available here. I can add to that by saying that the security of the Germans was inadequate. They used letterheads and envelopes which clearly stated "Nuclear Physics" on the outside. Nevertheless, we had no knowledge of the work at all over there. The allies did not know what was going on.

As soon as our mission got in touch with the first physicists, the first physics laboratory, the first correspondence and documents on physics which were available on the Continent, we obtained the complete story. From that you see that if there could be free interchange of ideas among the scientists, if they could travel freely, if they were allowed to visit each other's laboratories, if that were possible, then as long as scientists are working or have to be used in work on an atomic bomb or anything of that nature, I don't believe that it can be kept secret. It would be known immediately to their colleagues all over the world without any doubt.

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If, however, the art of making atomic bombs will progress so far that they do not need scientists any more, and it can be done by slave labor or prisoners, then of course control will be more difficult. But as long as scientists are needed in the building, construction, or research work on atomic bombs, it cannot be kept a secret from other scientists if they have free access to each other's papers, can talk with each other, can travel and go to meetings together.

Senator RUSSELL. I would like to ask one or two questions, Mr. Chairman.

Dr. Goudsmit, from your investigations in Germany as to the progress which has been made in their research, would you care to venture any opinion as to how long it would take any other country of the world to complete an atomic bomb or to advance to the stake where we are today?

Dr. GOUDSMIT. I can say that the Germans, at the rate at which they were going before they knew about the atomic bomb——

Senator RUSSELL. Of course that made a difference.

Dr. GOUDSMIT. That made an enormous difference, and it makes my estimate valueless. At that time it would have taken them a hundred years, they were going so slowly. You can see the progress in the research reports.

Senator RUSSELL. But you stated they didn't have any faith.

Dr. GOUDSMIT. Now they have.

Senator RUSSELL. But it is an entirely different situation today. The whole world knows the bomb can and has been created and used.

Dr. GOUDSMIT. Yes. Then my estimate must be the same as that of other scientists, and it just depends on getting the men together, getting the industry developed and organized, and I do not see why it should take them any longer than it took us.

Senator RUSSELL. We talked a great deal about rockets during the course of these hearings. Did you make any investigation into the development of the rocket in Germany?

Dr. GOUDSMIT. I did not make any investigation.

Senator RUSSELL. You dealt entirely with atomic energy?

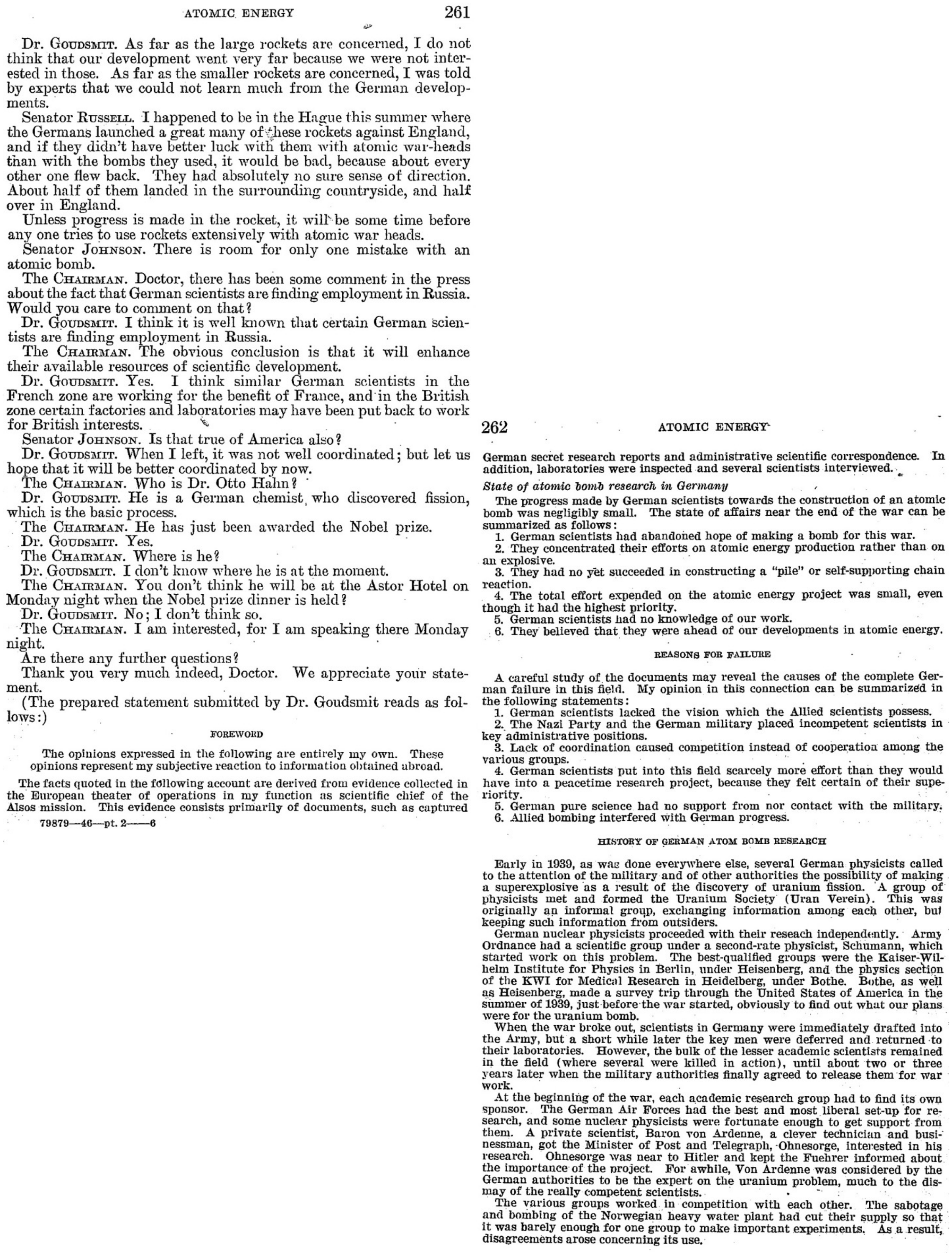
Dr. GOUDSMIT. No; we had some other responsibilities on that mission.

Senator RUSSELL. In other words, you did not have any connection whatever with the investigation on rockets. What member of your group was dealing with the question of rockets?

Dr. GOUDSMIT. We left that entirely to the technical teams of the Army and Navy. There were so many teams over there picking up V–1's and V–2's that we thought our small group could safely stay away from it and leave it to technical teams.

Senator RUSSELL. I gather from that that you would prefer not to express any opinion as to the relative progress which has been made by the Germans and by this country in the development of the rocket as a weapon of war?

Figure D.29: Samuel Goudsmit's 6 December 1945 testimony to the U.S. Senate [Goudsmit 1945].



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Dr. Goudsmit. As far as the large rockets are concerned, I do not think that our development went very far because we were not interested in those. As far as the smaller rockets are concerned, I was told by experts that we could not learn much from the German developments.

Senator Russell. I happened to be in the Hague this summer where the Germans launched a great many of these rockets against England, and if they didn't have better luck with them with atomic war-heads than with the bombs they used, it would be bad, because about every other one flew back. They had absolutely no sure sense of direction. About half of them landed in the surrounding countryside, and half over in England.

Unless progress is made in the rocket, it will be some time before any one tries to use rockets extensively with atomic war heads.

Senator Johnson. There is room for only one mistake with an atomic bomb.

The Chairman. Doctor, there has been some comment in the press about the fact that German scientists are finding employment in Russia. Would you care to comment on that?

Dr. Goudsmit. I think it is well known that certain German scientists are finding employment in Russia.

The Chairman. The obvious conclusion is that it will enhance their available resources of scientific development.

Dr. Goudsmit. Yes. I think similar German scientists in the French zone are working for the benefit of France, and in the British zone certain factories and laboratories may have been put back to work for British interests.

Senator Johnson. Is that true of America also?

Dr. Goudsmit. When I left, it was not well coordinated; but let us hope that it will be better coordinated by now.

The Chairman. Who is Dr. Otto Hahn?

Dr. Goudsmit. He is a German chemist who discovered fission, which is the basic process.

The Chairman. He has just been awarded the Nobel prize.

Dr. Goudsmit. Yes.

The Chairman. Where is he?

Dr. Goudsmit. I don't know where he is at the moment.

The Chairman. You don't think he will be at the Astor Hotel on Monday night when the Nobel prize dinner is held?

Dr. Goudsmit. No; I don't think so.

The Chairman. I am interested, for I am speaking there Monday night.

Are there any further questions?

Thank you very much indeed, Doctor. We appreciate your statement.

(The prepared statement submitted by Dr. Goudsmit reads as follows:)

FOREWORD

The opinions expressed in the following are entirely my own. These opinions represent my subjective reaction to information obtained abroad.

The facts quoted in the following account are derived from evidence collected in the European theater of operations in my function as scientific chief of the Alsos mission. This evidence consists primarily of documents, such as captured German secret research reports and administrative scientific correspondence. In addition, laboratories were inspected and several scientists interviewed.

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State of atomic bomb research in Germany

The progress made by German scientists towards the construction of an atomic bomb was negligibly small. The state of affairs near the end of the war can be summarized as follows:

1. German scientists had abandoned hope of making a bomb for this war.
2. They concentrated their efforts on atomic energy production rather than on an explosive.
3. They had no yet succeeded in constructing a "pile" or self-supporting chain reaction.
4. The total effort expended on the atomic energy project was small, even though it had the highest priority.
5. German scientists had no knowledge of our work.
6. They believed that they were ahead of our developments in atomic energy.

REASONS FOR FAILURE

A careful study of the documents may reveal the causes of the complete German failure in this field. My opinion in this connection can be summarized in the following statements:

1. German scientists lacked the vision which the Allied scientists possess.
2. The Nazi Party and the German military placed incompetent scientists in key administrative positions.
3. Lack of coordination caused competition instead of cooperation among the various groups.
4. German scientists put into this field scarcely more effort than they would have into a peacetime research project, because they felt certain of their superiority.
5. German pure science had no support from nor contact with the military.
6. Allied bombing interfered with German progress.

HISTORY OF GERMAN ATOM BOMB RESEARCH

Early in 1939, as was done everywhere else, several German physicists called to the attention of the military and of other authorities the possibility of making a superexplosive as a result of the discovery of uranium fission. A group of physicists met and formed the Uranium Society (Uran Verein). This was originally an informal group, exchanging information among each other, but keeping such information from outsiders.

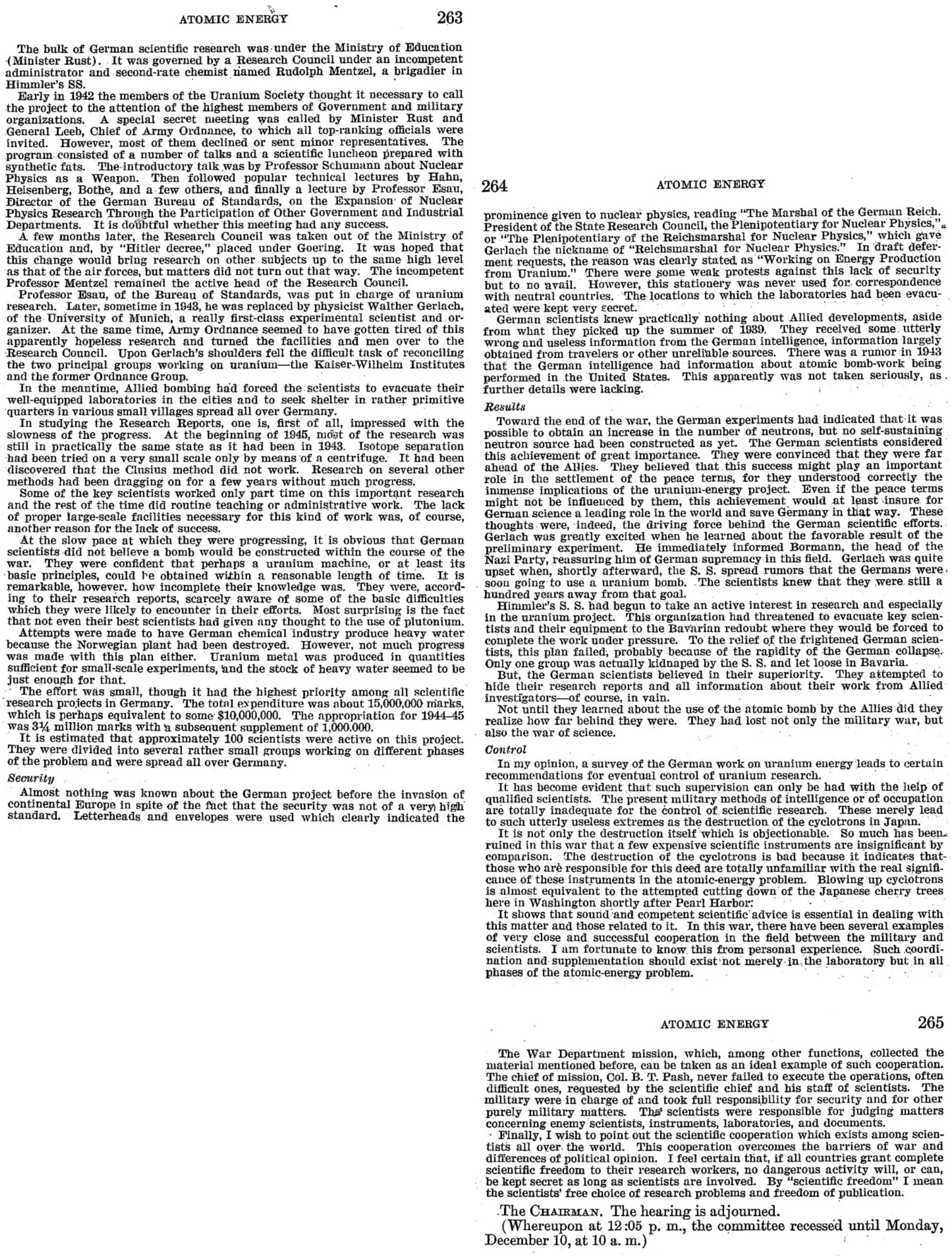
German nuclear physicists proceeded with their reseach independently. Army Ordnance had a scientific group under a second-rate physicist, Schumann, which started work on this problem. The best-qualified groups were the Kaiser-Wilhelm Institute for Physics in Berlin, under Heisenberg, and the physics section of the KWI for Medical Research in Heidelberg, under Bothe. Bothe, as well as Heisenberg, made a survey trip through the United States of America in the summer of 1939, just before the war started, obviously to find out what our plans were for the uranium bomb.

When the war broke out, scientists in Germany were immediately drafted into the Army, but a short while later the key men were deferred and returned to their laboratories. However, the bulk of the lesser academic scientists remained in the field (where several were killed in action), until about two or three years later when the military authorities finally agreed to release them for war work.

At the beginning of the war, each academic research group had to find its own sponsor. The German Air Forces had the best and most liberal set-up for research, and some nuclear physicists were fortunate enough to get support from them. A private scientist, Baron von Ardenne, a clever technician and businessman, got the Minister of Post and Telegraph, Ohnesorge, interested in his research. Ohnesorge was near to Hitler and kept the Fuehrer informed about the importance of the project. For awhile, Von Ardenne was considered by the German authorities to be the expert on the uranium problem, much to the dismay of the really competent scientists.

The various groups worked in competition with each other. The sabotage and bombing of the Norwegian heavy water plant had cut their supply so that it was barely enough for one group to make important experiments. As a result, disagreements arose concerning its use.

Figure D.30: Samuel Goudsmit's 6 December 1945 testimony to the U.S. Senate [Goudsmit 1945].



The bulk of German scientific research was under the Ministry of Education (Minister Rust). It was governed by a Research Council under an incompetent administrator and second-rate chemist named Rudolph Mentzel, a brigadier in Himmler's SS.

Early in 1942 the members of the Uranium Society thought it necessary to call the project to the attention of the highest members of Government and military organizations. A special secret meeting was called by Minister Rust and General Leeb, Chief of Army Ordnance, to which all top-ranking officials were invited. However, most of them declined or sent minor representatives. The program consisted of a number of talks and a scientific luncheon prepared with synthetic fats. The introductory talk was by Professor Schumann about Nuclear Physics as a Weapon. Then followed popular technical lectures by Hahn, Heisenberg, Bothe, and a few others, and finally a lecture by Professor Esau, Director of the German Bureau of Standards, on the Expansion of Nuclear Physics Research Through the Participation of Other Government and Industrial Departments. It is doubtful whether this meeting had any success.

A few months later, the Research Council was taken out of the Ministry of Education and, by "Hitler decree," placed under Goering. It was hoped that this change would bring research on other subjects up to the same high level as that of the air forces, but matters did not turn out that way. The incompetent Professor Mentzel remained the active head of the Research Council.

Professor Esau, of the Bureau of Standards, was put in charge of uranium research. Later, sometime in 1943, he was replaced by physicist Walther Gerlach, of the University of Munich, a really first-class experimental scientist and organizer. At the same time, Army Ordnance seemed to have gotten tired of this apparently hopeless research and turned the facilities and men over to the Research Council. Upon Gerlach's shoulders fell the difficult task of reconciling the two principal groups working on uranium—the Kaiser-Wilhelm Institutes and the former Ordnance Group.

In the meantime, Allied bombing had forced the scientists to evacuate their well-equipped laboratories in the cities and to seek shelter in rather primitive quarters in various small villages spread all over Germany.

In studying the Research Reports, one is, first of all, impressed with the slowness of the progress. At the beginning of 1945, most of the research was still in practically the same state as it had been in 1943. Isotope separation had been tried on a very small scale only by means of a centrifuge. It had been discovered that the Clusius method did not work. Research on several other methods had been dragging on for a few years without much progress.

Some of the key scientists worked only part time on this important research and the rest of the time did routine teaching or administrative work. The lack of proper large-scale facilities necessary for this kind of work was, of course, another reason for the lack of success.

At the slow pace at which they were progressing, it is obvious that German scientists did not believe a bomb would be constructed within the course of the war. They were confident that perhaps a uranium machine, or at least its basic principles, could be obtained within a reasonable length of time. It is remarkable, however, how incomplete their knowledge was. They were, according to their research reports, scarcely aware of some of the basic difficulties which they were likely to encounter in their efforts. Most surprising is the fact that not even their best scientists had given any thought to the use of plutonium.

Attempts were made to have German chemical industry produce heavy water because the Norwegian plant had been destroyed. However, not much progress was made with this plan either. Uranium metal was produced in quantities sufficient for small-scale experiments, and the stock of heavy water seemed to be just enough for that.

The effort was small, though it had the highest priority among all scientific research projects in Germany. The total expenditure was about 15,000,000 marks, which is perhaps equivalent to some $10,000,000. The appropriation for 1944–45 was 3¼ million marks with a subsequent supplement of 1,000,000.

It is estimated that approximately 100 scientists were active on this project. They were divided into several rather small groups working on different phases of the problem and were spread all over Germany.

Security

Almost nothing was known about the German project before the invasion of continental Europe in spite of the fact that the security was not of a very high standard. Letterheads and envelopes were used which clearly indicated the

prominence given to nuclear physics, reading "The Marshal of the German Reich, President of the State Research Council, the Plenipotentiary for Nuclear Physics," or "The Plenipotentiary of the Reichsmarshal for Nuclear Physics," which gave Gerlach the nickname of "Reichsmarshal for Nuclear Physics." In draft deferment requests, the reason was clearly stated as "Working on Energy Production from Uranium." There were some weak protests against this lack of security but to no avail. However, this stationery was never used for correspondence with neutral countries. The locations to which the laboratories had been evacuated were kept very secret.

German scientists knew practically nothing about Allied developments, aside from what they picked up the summer of 1939. They received some utterly wrong and useless information from the German intelligence, information largely obtained from travelers or other unreliable sources. There was a rumor in 1943 that the German intelligence had information about atomic bomb-work being performed in the United States. This apparently was not taken seriously, as further details were lacking.

Results

Toward the end of the war, the German experiments had indicated that it was possible to obtain an increase in the number of neutrons, but no self-sustaining neutron source had been constructed as yet. The German scientists considered this achievement of great importance. They were convinced that they were far ahead of the Allies. They believed that this success might play an important role in the settlement of the peace terms, for they understood correctly the immense implications of the uranium-energy project. Even if the peace terms might not be influenced by them, this achievement would at least insure for German science a leading role in the world and save Germany in that way. These thoughts were, indeed, the driving force behind the German scientific efforts. Gerlach was greatly excited when he learned about the favorable result of the preliminary experiment. He immediately informed Bormann, the head of the Nazi Party, reassuring him of German supremacy in this field. Gerlach was quite upset when, shortly afterward, the S. S. spread rumors that the Germans were soon going to use a uranium bomb. The scientists knew that they were still a hundred years away from that goal.

Himmler's S. S. had begun to take an active interest in research and especially in the uranium project. This organization had threatened to evacuate key scientists and their equipment to the Bavarian redoubt where they would be forced to complete the work under pressure. To the relief of the frightened German scientists, this plan failed, probably because of the rapidity of the German collapse. Only one group was actually kidnaped by the S. S. and let loose in Bavaria.

But, the German scientists believed in their superiority. They attempted to hide their research reports and all information about their work from Allied investigators—of course, in vain.

Not until they learned about the use of the atomic bomb by the Allies did they realize how far behind they were. They had lost not only the military war, but also the war of science.

Control

In my opinion, a survey of the German work on uranium energy leads to certain recommendations for eventual control of uranium research.

It has become evident that such supervision can only be had with the help of qualified scientists. The present military methods of intelligence or of occupation are totally inadequate for the control of scientific research. These merely lead to such utterly useless extremes as the destruction of the cyclotrons in Japan.

It is not only the destruction itself which is objectionable. So much has been ruined in this war that a few expensive scientific instruments are insignificant by comparison. The destruction of the cyclotrons is bad because it indicates that those who are responsible for this deed are totally unfamiliar with the real significance of these instruments in the atomic-energy problem. Blowing up cyclotrons is almost equivalent to the attempted cutting down of the Japanese cherry trees here in Washington shortly after Pearl Harbor.

It shows that sound and competent scientific advice is essential in dealing with this matter and those related to it. In this war, there have been several examples of very close and successful cooperation in the field between the military and scientists. I am fortunate to know this from personal experience. Such coordination and supplementation should exist not merely in the laboratory but in all phases of the atomic-energy problem.

The War Department mission, which, among other functions, collected the material mentioned before, can be taken as an ideal example of such cooperation. The chief of mission, Col. B. T. Pash, never failed to execute the operations, often difficult ones, requested by the scientific chief and his staff of scientists. The military were in charge of and took full responsibility for security and for other purely military matters. The scientists were responsible for judging matters concerning enemy scientists, instruments, laboratories, and documents.

Finally, I wish to point out the scientific cooperation which exists among scientists all over the world. This cooperation overcomes the barriers of war and differences of political opinion. I feel certain that, if all countries grant complete scientific freedom to their research workers, no dangerous activity will, or can, be kept secret as long as scientists are involved. By "scientific freedom" I mean the scientists' free choice of research problems and freedom of publication.

The CHAIRMAN. The hearing is adjourned.

(Whereupon at 12:05 p. m., the committee recessed until Monday, December 10, at 10 a. m.)

Figure D.31: Samuel Goudsmit's 6 December 1945 testimony to the U.S. Senate [Goudsmit 1945].

Samuel A. Goudsmit. 7 December 1945. Report by the Scientific Chief of the Alsos Mission, pp. 15–16 [NARA RG GOUDS, Entry UD-7420, Box 6, Folder Alsos Mission].

Limitations of Fields of Interest

Experience has shown that it was impossible to cover efficiently the whole field of scientific research in Germany. The amount of material, such as documents, personnel and laboratories, encountered during operations was so overwhelming that no intelligence agency of reasonable size could handle it all. A very thorough job could be done, however, on such scientific subjects for which there existed at home or in the field a definite demand for intelligence information. For this reason, the Alsos Mission, more or less automatically, restricted its investigations to the following subjects:

a. The Uranium Problem

b. Bacteriological Warfare

c. Organization of Enemy Scientific Research

d. Aeronautical Research

e. Proximity Fuzes

f. German Research Facilities for Guided Missiles

g. The Speer Ministry's Interest in Research

h. Chemical Research

i. Metallurgical Research

j. Shale Oil Development

k. Miscellaneous Intelligence [...]

Scientific Results Obtained by the Alsos Mission

a. The Uranium Project.

The Alsos Mission was the only intelligence team authorized to investigate for United States and British interests the German progress on the Atom Bomb. Documents found at Strasbourg indicated that the enemy had made practically no progress in this field, though it had the highest priority of all scientific research projects. The Alsos Mission located all the centers of Uranium research in Germany. The laboratories were investigated and key personnel detained and questioned. The enemy tried in vain to hide essential materials and research reports. They were all recovered by the Alsos Mission. It is certain that complete research data and all key scientists fell into the hands of the Alsos Mission.

The evaluation of the intelligence indicated that the Germans believed that they were far ahead of American development in this field. In reality, the Germans, though they had started sooner, were far behind. They had given up altogether the idea of making a bomb and were concentrating their efforts on constructing an energy producing machine, which they called a "Uranium Burner". At the end of the war, they had not even succeeded in constructing a self-sustaining chain reaction or "pile". Nevertheless, they believed their progress to be so important that they offered to assist United States scientists in their efforts to harness atomic energy. They were convinced that their work would help Germany to dominate the world of science even though the military struggle had been lost. Not until the news of the Atomic Bomb reached them on August 7, 1945, did German scientists realize that they had also lost the war of physics. [...]

Conclusion

It is the opinion of the Scientific Chief that the Mission has been highly successful. It has taught us lessons in intelligence procedure which may be of great value in peacetime, too. This fact is of greater importance than the actual scientific information which was collected, the bulk of which was negative.

Only the method used by the Alsos Mission could have revealed, immediately after the fall of Strasbourg, that no threat of a German Atom Bomb existed. From a military point of view, this was the most important result obtained by the Mission.

The Alsos method, it must be emphasized, succeeded only because of the close cooperation and mutual trust of the military and the scientists. For all members, this Mission has been a unique undertaking, giving the inner satisfaction of having actively contributed to the success of the Allied cause.

[Samuel Goudsmit's final report for the Alsos mission was 25 pages long, yet devoted only approximately one page to the German nuclear program, giving little detail. Goudsmit spent far more pages of the report on extreme self-promotion and a long series of petty complaints, such as that the U.S. government had declined his requests to give him his own private plane.

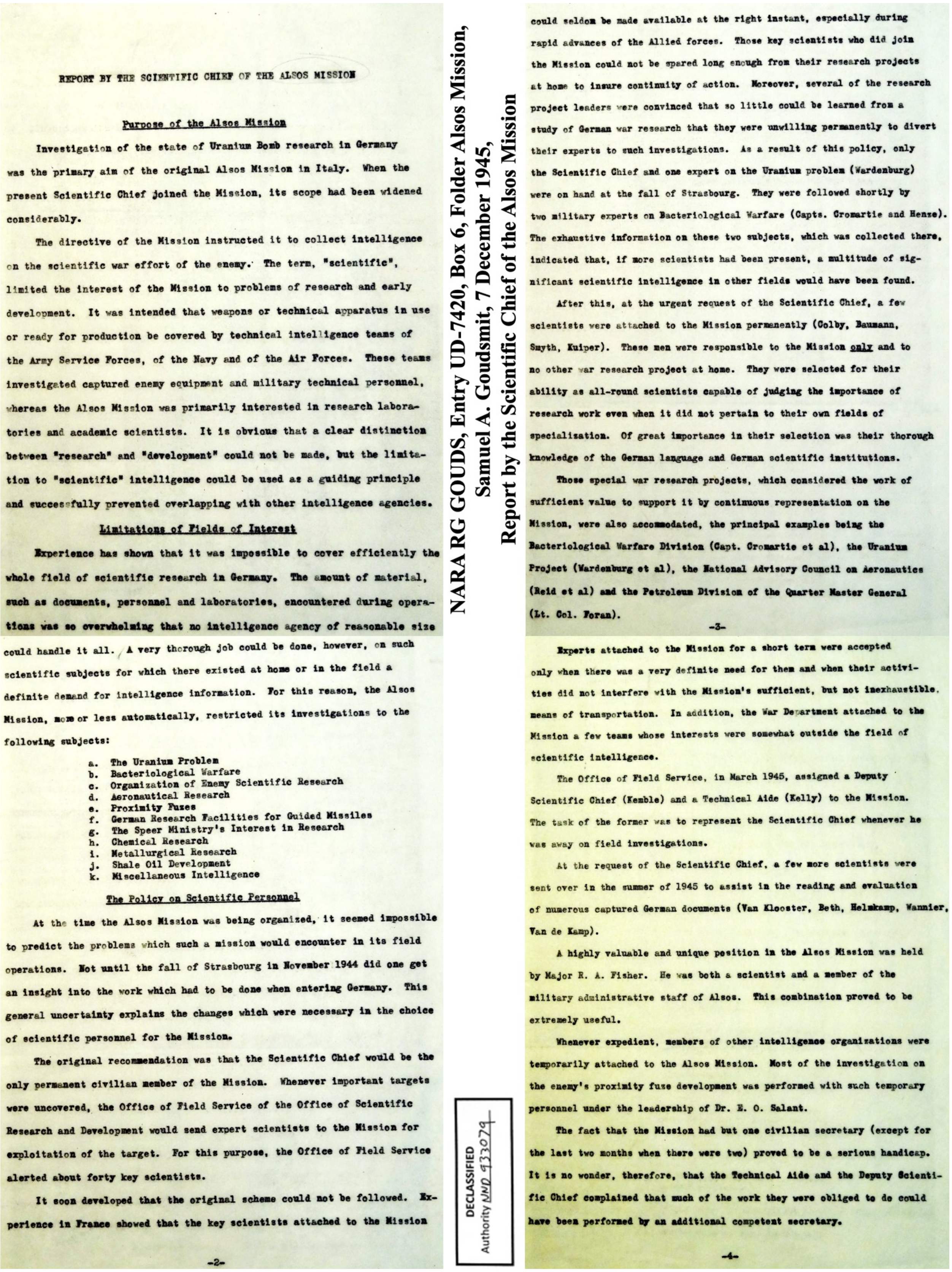
Goudsmit was especially proud of his own unique method that "revealed... no threat of a German Atom Bomb existed" before he had ever even visited any sites in Germany or its eastern occupied territories, read any documents from those sites, seen any equipment from those sites, or interrogated any personnel from those sites. Undoubtedly that was indeed a unique method.

Alsos's own files prove that Goudsmit was knowingly making false statements when he wrote claims such as: "The Alsos Mission located all the centers of Uranium research in Germany. The laboratories were investigated... It is certain that complete research data and all key scientists fell into the hands of the Alsos Mission." (See for example pp. 3271–3273, 3279–3283, 3285–3287, 3294–3296, 3288–3289, 3292–3293.)

Note the long list of German fields of research (each quite vast, as shown by other sections of this book) for which Goudsmit, with only a small number of assistants for a few months, claims to have done "a very thorough job."

In stark contrast to Goudsmit's glowing evaluation of himself, the archival record shows that he:

- Had a nervous breakdown long before Allied forces even entered Germany and spent most of the final months of the war in the United States (e.g., pp. 3260–3269).
- Quarreled with and was criticized by a long list of people (e.g., pp. 3260–3261, 3264–3265, 3266–3269, 3274–3275, 3278, 3285–3287, 3288–3289, 3292–3293, 3294–3296, 3321).
- Failed to investigate a huge number of nuclear sites and personnel (e.g., pp. 3279–3283).
- Was ultimately judged to have failed in his mission by SHAEF G-2 Generals Thomas J. Betts and George Bryan Conrad plus AAF General Henry Arnold's advisor Prof. Edward L. Bowles of MIT (pp. 3285–3287).
- Knowingly and repeatedly gave false testimony to the United States Senate (pp. 3297–3305).]



REPORT BY THE SCIENTIFIC CHIEF OF THE ALSOS MISSION

Purpose of the Alsos Mission

Investigation of the state of Uranium Bomb research in Germany was the primary aim of the original Alsos Mission in Italy. When the present Scientific Chief joined the Mission, its scope had been widened considerably.

The directive of the Mission instructed it to collect intelligence on the scientific war effort of the enemy. The term, "scientific", limited the interest of the Mission to problems of research and early development. It was intended that weapons or technical apparatus in use or ready for production be covered by technical intelligence teams of the Army Service Forces, of the Navy and of the Air Forces. These teams investigated captured enemy equipment and military technical personnel, whereas the Alsos Mission was primarily interested in research laboratories and academic scientists. It is obvious that a clear distinction between "research" and "development" could not be made, but the limitation to "scientific" intelligence could be used as a guiding principle and successfully prevented overlapping with other intelligence agencies.

Limitations of Fields of Interest

Experience has shown that it was impossible to cover efficiently the whole field of scientific research in Germany. The amount of material, such as documents, personnel and laboratories, encountered during operations was so overwhelming that no intelligence agency of reasonable size could handle it all. A very thorough job could be done, however, on such scientific subjects for which there existed at home or in the field a definite demand for intelligence information. For this reason, the Alsos Mission, more or less automatically, restricted its investigations to the following subjects:

a. The Uranium Problem
b. Bacteriological Warfare
c. Organization of Enemy Scientific Research
d. Aeronautical Research
e. Proximity Fuzes
f. German Research Facilities for Guided Missiles
g. The Speer Ministry's Interest in Research
h. Chemical Research
i. Metallurgical Research
j. Shale Oil Development
k. Miscellaneous Intelligence

The Policy on Scientific Personnel

At the time the Alsos Mission was being organized, it seemed impossible to predict the problems which such a mission would encounter in its field operations. Not until the fall of Strasbourg in November 1944 did one get an insight into the work which had to be done when entering Germany. This general uncertainty explains the changes which were necessary in the choice of scientific personnel for the Mission.

The original recommendation was that the Scientific Chief would be the only permanent civilian member of the Mission. Whenever important targets were uncovered, the Office of Field Service of the Office of Scientific Research and Development would send expert scientists to the Mission for exploitation of the target. For this purpose, the Office of Field Service alerted about forty key scientists.

It soon developed that the original scheme could not be followed. Experience in France showed that the key scientists attached to the Mission

-2-

NARA RG GOUDS, Entry UD-7420, Box 6, Folder Alsos Mission,
Samuel A. Goudsmit, 7 December 1945,
Report by the Scientific Chief of the Alsos Mission

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could seldom be made available at the right instant, especially during rapid advances of the Allied forces. Those key scientists who did join the Mission could not be spared long enough from their research projects at home to insure continuity of action. Moreover, several of the research project leaders were convinced that so little could be learned from a study of German war research that they were unwilling permanently to divert their experts to such investigations. As a result of this policy, only the Scientific Chief and one expert on the Uranium problem (Wardenburg) were on hand at the fall of Strasbourg. They were followed shortly by two military experts on Bacteriological Warfare (Capts. Cromartie and Henze). The exhaustive information on these two subjects, which was collected there, indicated that, if more scientists had been present, a multitude of significant scientific intelligence in other fields would have been found.

After this, at the urgent request of the Scientific Chief, a few scientists were attached to the Mission permanently (Colby, Baumann, Smyth, Kuiper). These men were responsible to the Mission only and to no other war research project at home. They were selected for their ability as all-round scientists capable of judging the importance of research work even when it did not pertain to their own fields of specialization. Of great importance in their selection was their thorough knowledge of the German language and German scientific institutions.

Those special war research projects, which considered the work of sufficient value to support it by continuous representation on the Mission, were also accommodated, the principal examples being the Bacteriological Warfare Division (Capt. Cromartie et al), the Uranium Project (Wardenburg et al), the National Advisory Council on Aeronautics (Reid et al) and the Petroleum Division of the Quarter Master General (Lt. Col. Foran).

-3-

Experts attached to the Mission for a short term were accepted only when there was a very definite need for them and when their activities did not interfere with the Mission's sufficient, but not inexhaustible, means of transportation. In addition, the War Department attached to the Mission a few teams whose interests were somewhat outside the field of scientific intelligence.

The Office of Field Service, in March 1945, assigned a Deputy Scientific Chief (Kemble) and a Technical Aide (Kelly) to the Mission. The task of the former was to represent the Scientific Chief whenever he was away on field investigations.

At the request of the Scientific Chief, a few more scientists were sent over in the summer of 1945 to assist in the reading and evaluation of numerous captured German documents (Van Klooster, Beth, Helmkamp, Wannier, Van de Kamp).

A highly valuable and unique position in the Alsos Mission was held by Major R. A. Fisher. He was both a scientist and a member of the military administrative staff of Alsos. This combination proved to be extremely useful.

Whenever expedient, members of other intelligence organizations were temporarily attached to the Alsos Mission. Most of the investigation on the enemy's proximity fuse development was performed with such temporary personnel under the leadership of Dr. E. O. Salant.

The fact that the Mission had but one civilian secretary (except for the last two months when there were two) proved to be a serious handicap. It is no wonder, therefore, that the Technical Aide and the Deputy Scientific Chief complained that much of the work they were obliged to do could have been performed by an additional competent secretary.

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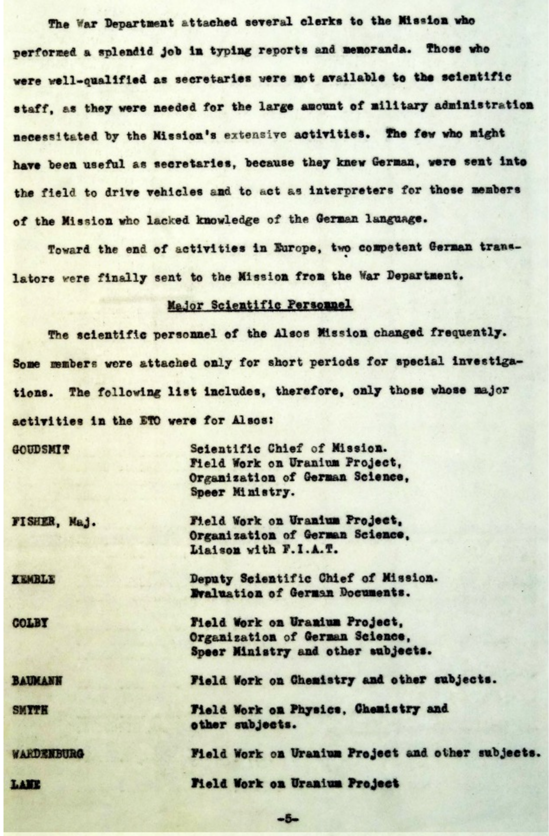
Figure D.32: Samuel A. Goudsmit. 7 December 1945. Report by the Scientific Chief of the Alsos Mission [NARA RG GOUDS, Entry UD-7420, Box 6, Folder Alsos Mission].



The War Department attached several clerks to the Mission who performed a splendid job in typing reports and memoranda. Those who were well-qualified as secretaries were not available to the scientific staff, as they were needed for the large amount of military administration necessitated by the Mission's extensive activities. The few who might have been useful as secretaries, because they knew German, were sent into the field to drive vehicles and to act as interpreters for those members of the Mission who lacked knowledge of the German language.

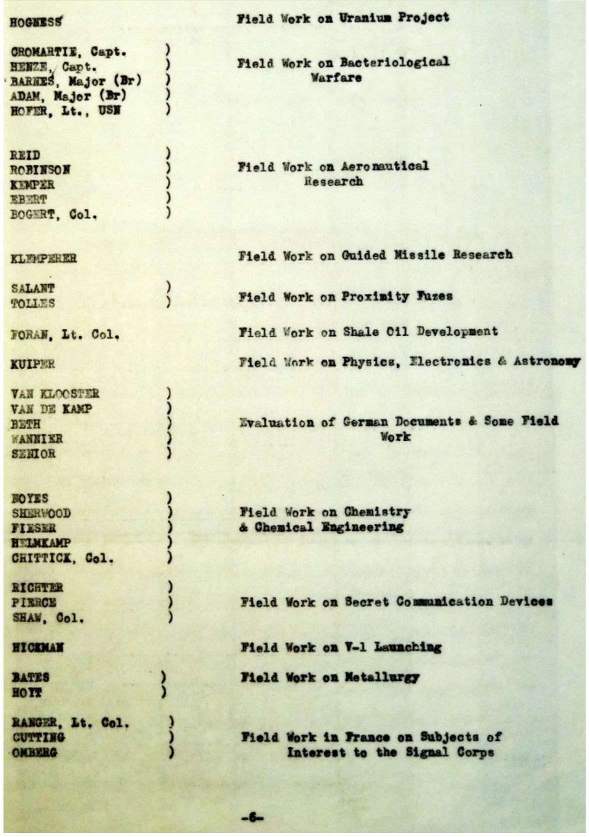
Toward the end of activities in Europe, two competent German translators were finally sent to the Mission from the War Department.

Major Scientific Personnel

The scientific personnel of the Alsos Mission changed frequently. Some members were attached only for short periods for special investigations. The following list includes, therefore, only those whose major activities in the ETO were for Alsos:

GOUDSMIT	Scientific Chief of Mission. Field Work on Uranium Project, Organization of German Science, Speer Ministry.
FISHER, Maj.	Field Work on Uranium Project, Organization of German Science, Liaison with F.I.A.T.
KEMBLE	Deputy Scientific Chief of Mission. Evaluation of German Documents.
COLBY	Field Work on Uranium Project, Organization of German Science, Speer Ministry and other subjects.
BAUMANN	Field Work on Chemistry and other subjects.
SMITH	Field Work on Physics, Chemistry and other subjects.
WARDENBURG	Field Work on Uranium Project and other subjects.
LANE	Field Work on Uranium Project

-5-



HOGNESS	Field Work on Uranium Project
CROMARTIE, Capt.)	Field Work on Bacteriological Warfare
HENZE, Capt.)	
BARNES, Major (Br))	
ADAM, Major (Br))	
HOFER, Lt., USN)	
REID)	Field Work on Aeronautical Research
ROBINSON)	
KEMPER)	
EBERT)	
BOGERT, Col.)	
KLEMPERER	Field Work on Guided Missile Research
SALANT)	Field Work on Proximity Fuzes
TOLLES)	
FORAN, Lt. Col.	Field Work on Shale Oil Development
KUIPER	Field Work on Physics, Electronics & Astronomy
VAN KLOOSTER)	Evaluation of German Documents & Some Field Work
VAN DE KAMP)	
BETH)	
WANNIER)	
SENIOR)	
NOYES)	Field Work on Chemistry & Chemical Engineering
SHERWOOD)	
FIESER)	
HELMKAMP)	
CHITTICK, Col.)	
RICHTER)	Field Work on Secret Communication Devices
PIERCE)	
SHAW, Col.)	
HICKMAN	Field Work on V-1 Launching
BATES)	Field Work on Metallurgy
HOYT)	
RANGER, Lt. Col.)	Field Work in France on Subjects of Interest to the Signal Corps
CUTTING)	
OMBERG)	

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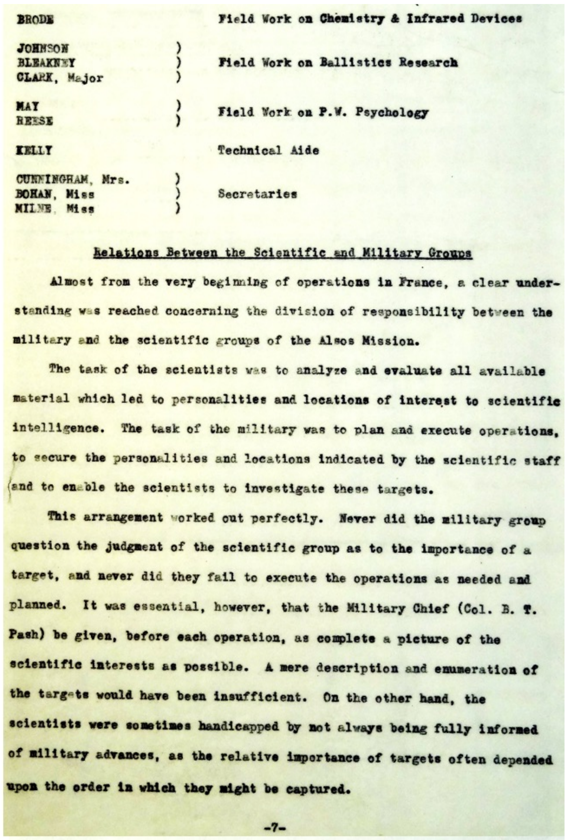
NARA RG GOUDS, Entry UD-7420, Box 6, Folder Alsos Mission,
Samuel A. Goudsmit, 7 December 1945,
Report by the Scientific Chief of the Alsos Mission



BRODE	Field Work on Chemistry & Infrared Devices
JOHNSON)	Field Work on Ballistics Research
BLEAKNEY)	
CLARK, Major)	
MAY)	Field Work on P.W. Psychology
REESE)	
KELLY	Technical Aide
CUNNINGHAM, Mrs.)	Secretaries
BOHAN, Miss)	
MILNE, Miss)	

Relations Between the Scientific and Military Groups

Almost from the very beginning of operations in France, a clear understanding was reached concerning the division of responsibility between the military and the scientific groups of the Alsos Mission.

The task of the scientists was to analyze and evaluate all available material which led to personalities and locations of interest to scientific intelligence. The task of the military was to plan and execute operations, to secure the personalities and locations indicated by the scientific staff and to enable the scientists to investigate these targets.

This arrangement worked out perfectly. Never did the military group question the judgment of the scientific group as to the importance of a target, and never did they fail to execute the operations as needed and planned. It was essential, however, that the Military Chief (Col. B. T. Pash) be given, before each operation, as complete a picture of the scientific interests as possible. A mere description and enumeration of the targets would have been insufficient. On the other hand, the scientists were sometimes handicapped by not always being fully informed of military advances, as the relative importance of targets often depended upon the order in which they might be captured.

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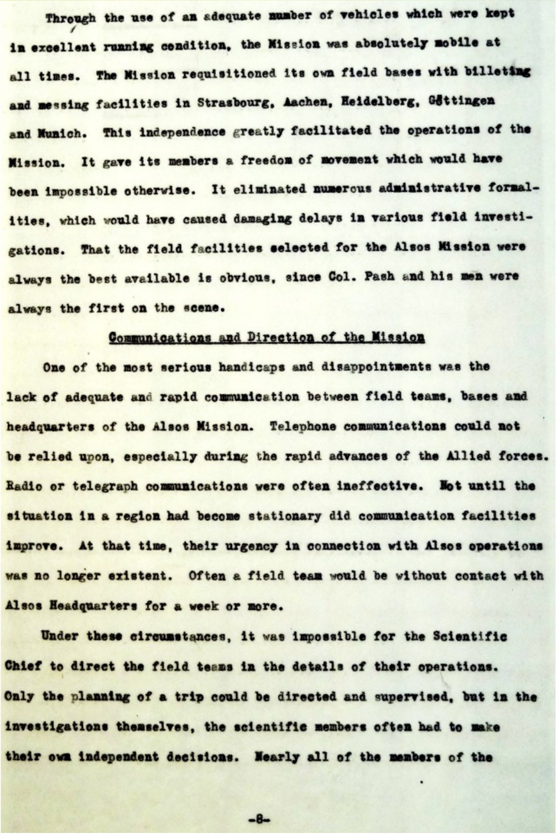

Through the use of an adequate number of vehicles which were kept in excellent running condition, the Mission was absolutely mobile at all times. The Mission requisitioned its own field bases with billeting and messing facilities in Strasbourg, Aachen, Heidelberg, Göttingen and Munich. This independence greatly facilitated the operations of the Mission. It gave its members a freedom of movement which would have been impossible otherwise. It eliminated numerous administrative formalities, which would have caused damaging delays in various field investigations. That the field facilities selected for the Alsos Mission were always the best available is obvious, since Col. Pash and his men were always the first on the scene.

Communications and Direction of the Mission

One of the most serious handicaps and disappointments was the lack of adequate and rapid communication between field teams, bases and headquarters of the Alsos Mission. Telephone communications could not be relied upon, especially during the rapid advances of the Allied forces. Radio or telegraph communications were often ineffective. Not until the situation in a region had become stationary did communication facilities improve. At that time, their urgency in connection with Alsos operations was no longer existent. Often a field team would be without contact with Alsos Headquarters for a week or more.

Under these circumstances, it was impossible for the Scientific Chief to direct the field teams in the details of their operations. Only the planning of a trip could be directed and supervised, but in the investigations themselves, the scientific members often had to make their own independent decisions. Nearly all of the members of the

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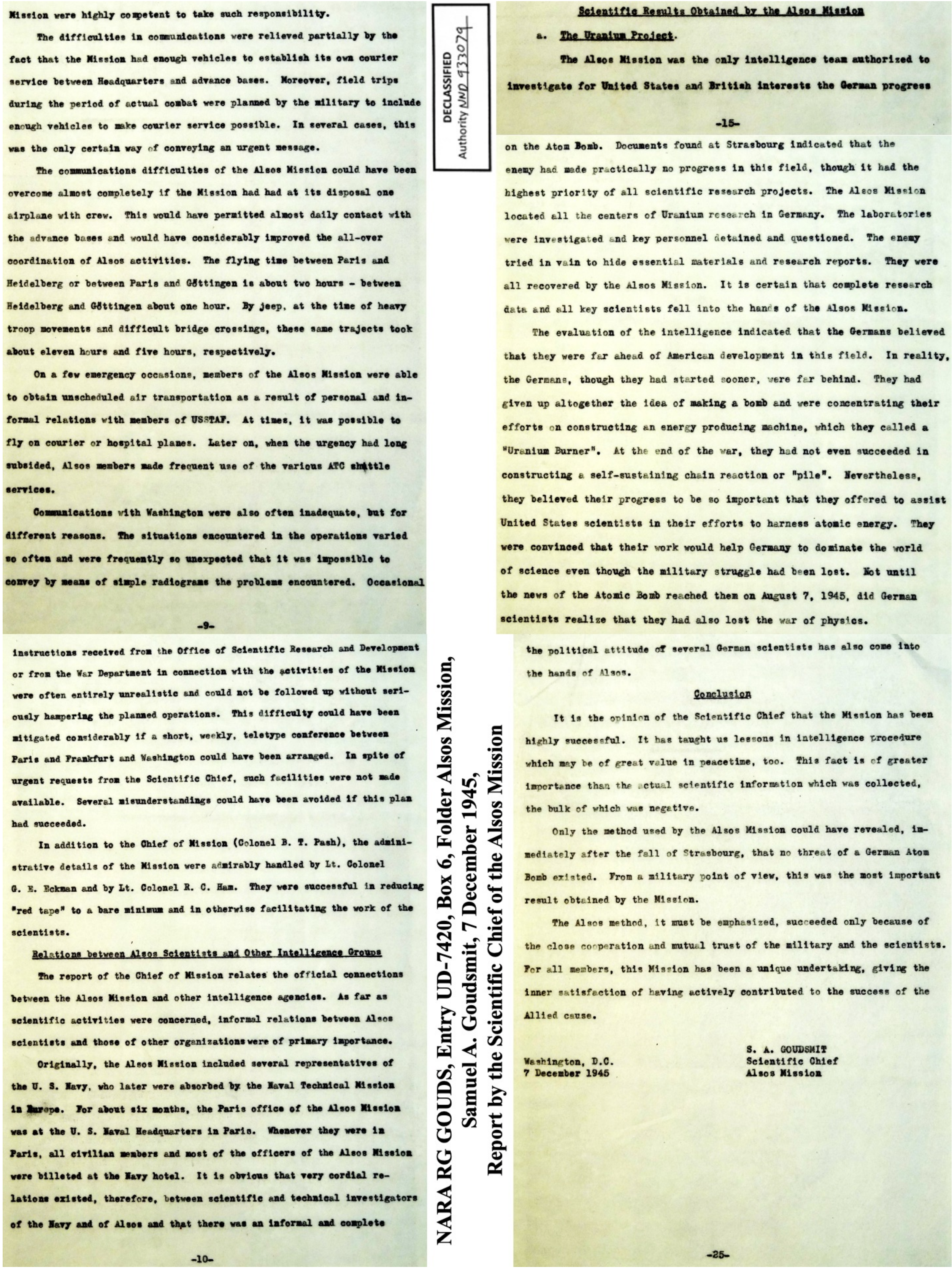
Figure D.33: Samuel A. Goudsmit. 7 December 1945. Report by the Scientific Chief of the Alsos Mission [NARA RG GOUDS, Entry UD-7420, Box 6, Folder Alsos Mission].



Mission were highly competent to take such responsibility.

The difficulties in communications were relieved partially by the fact that the Mission had enough vehicles to establish its own courier service between Headquarters and advance bases. Moreover, field trips during the period of actual combat were planned by the military to include enough vehicles to make courier service possible. In several cases, this was the only certain way of conveying an urgent message.

The communications difficulties of the Alsos Mission could have been overcome almost completely if the Mission had had at its disposal one airplane with crew. This would have permitted almost daily contact with the advance bases and would have considerably improved the all-over coordination of Alsos activities. The flying time between Paris and Heidelberg or between Paris and Göttingen is about two hours - between Heidelberg and Göttingen about one hour. By jeep, at the time of heavy troop movements and difficult bridge crossings, these same trajects took about eleven hours and five hours, respectively.

On a few emergency occasions, members of the Alsos Mission were able to obtain unscheduled air transportation as a result of personal and informal relations with members of USSTAF. At times, it was possible to fly on courier or hospital planes. Later on, when the urgency had long subsided, Alsos members made frequent use of the various ATC shuttle services.

Communications with Washington were also often inadequate, but for different reasons. The situations encountered in the operations varied so often and were frequently so unexpected that it was impossible to convey by means of simple radiograms the problems encountered. Occasional instructions received from the Office of Scientific Research and Development or from the War Department in connection with the activities of the Mission were often entirely unrealistic and could not be followed up without seriously hampering the planned operations. This difficulty could have been mitigated considerably if a short, weekly, teletype conference between Paris and Frankfurt and Washington could have been arranged. In spite of urgent requests from the Scientific Chief, such facilities were not made available. Several misunderstandings could have been avoided if this plan had succeeded.

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In addition to the Chief of Mission (Colonel B. T. Pash), the administrative details of the Mission were admirably handled by Lt. Colonel G. E. Eckman and by Lt. Colonel R. C. Ham. They were successful in reducing "red tape" to a bare minimum and in otherwise facilitating the work of the scientists.

Relations between Alsos Scientists and Other Intelligence Groups

The report of the Chief of Mission relates the official connections between the Alsos Mission and other intelligence agencies. As far as scientific activities were concerned, informal relations between Alsos scientists and those of other organizations were of primary importance.

Originally, the Alsos Mission included several representatives of the U. S. Navy, who later were absorbed by the Naval Technical Mission in Europe. For about six months, the Paris office of the Alsos Mission was at the U. S. Naval Headquarters in Paris. Whenever they were in Paris, all civilian members and most of the officers of the Alsos Mission were billeted at the Navy hotel. It is obvious that very cordial relations existed, therefore, between scientific and technical investigators of the Navy and of Alsos and that there was an informal and complete

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Scientific Results Obtained by the Alsos Mission

a. The Uranium Project.

The Alsos Mission was the only intelligence team authorized to investigate for United States and British interests the German progress

-15-

on the Atom Bomb. Documents found at Strasbourg indicated that the enemy had made practically no progress in this field, though it had the highest priority of all scientific research projects. The Alsos Mission located all the centers of Uranium research in Germany. The laboratories were investigated and key personnel detained and questioned. The enemy tried in vain to hide essential materials and research reports. They were all recovered by the Alsos Mission. It is certain that complete research data and all key scientists fell into the hands of the Alsos Mission.

The evaluation of the intelligence indicated that the Germans believed that they were far ahead of American development in this field. In reality, the Germans, though they had started sooner, were far behind. They had given up altogether the idea of making a bomb and were concentrating their efforts on constructing an energy producing machine, which they called a "Uranium Burner". At the end of the war, they had not even succeeded in constructing a self-sustaining chain reaction or "pile". Nevertheless, they believed their progress to be so important that they offered to assist United States scientists in their efforts to harness atomic energy. They were convinced that their work would help Germany to dominate the world of science even though the military struggle had been lost. Not until the news of the Atomic Bomb reached them on August 7, 1945, did German scientists realize that they had also lost the war of physics.

the political attitude of several German scientists has also come into the hands of Alsos.

Conclusion

It is the opinion of the Scientific Chief that the Mission has been highly successful. It has taught us lessons in intelligence procedure which may be of great value in peacetime, too. This fact is of greater importance than the actual scientific information which was collected, the bulk of which was negative.

Only the method used by the Alsos Mission could have revealed, immediately after the fall of Strasbourg, that no threat of a German Atom Bomb existed. From a military point of view, this was the most important result obtained by the Mission.

The Alsos method, it must be emphasized, succeeded only because of the close cooperation and mutual trust of the military and the scientists. For all members, this Mission has been a unique undertaking, giving the inner satisfaction of having actively contributed to the success of the Allied cause.

Washington, D.C.
7 December 1945

S. A. GOUDSMIT
Scientific Chief
Alsos Mission

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NARA RG GOUDS, Entry UD-7420, Box 6, Folder Alsos Mission,
Samuel A. Goudsmit, 7 December 1945,
Report by the Scientific Chief of the Alsos Mission

Figure D.34: Samuel A. Goudsmit. 7 December 1945. Report by the Scientific Chief of the Alsos Mission [NARA RG GOUDS, Entry UD-7420, Box 6, Folder Alsos Mission].

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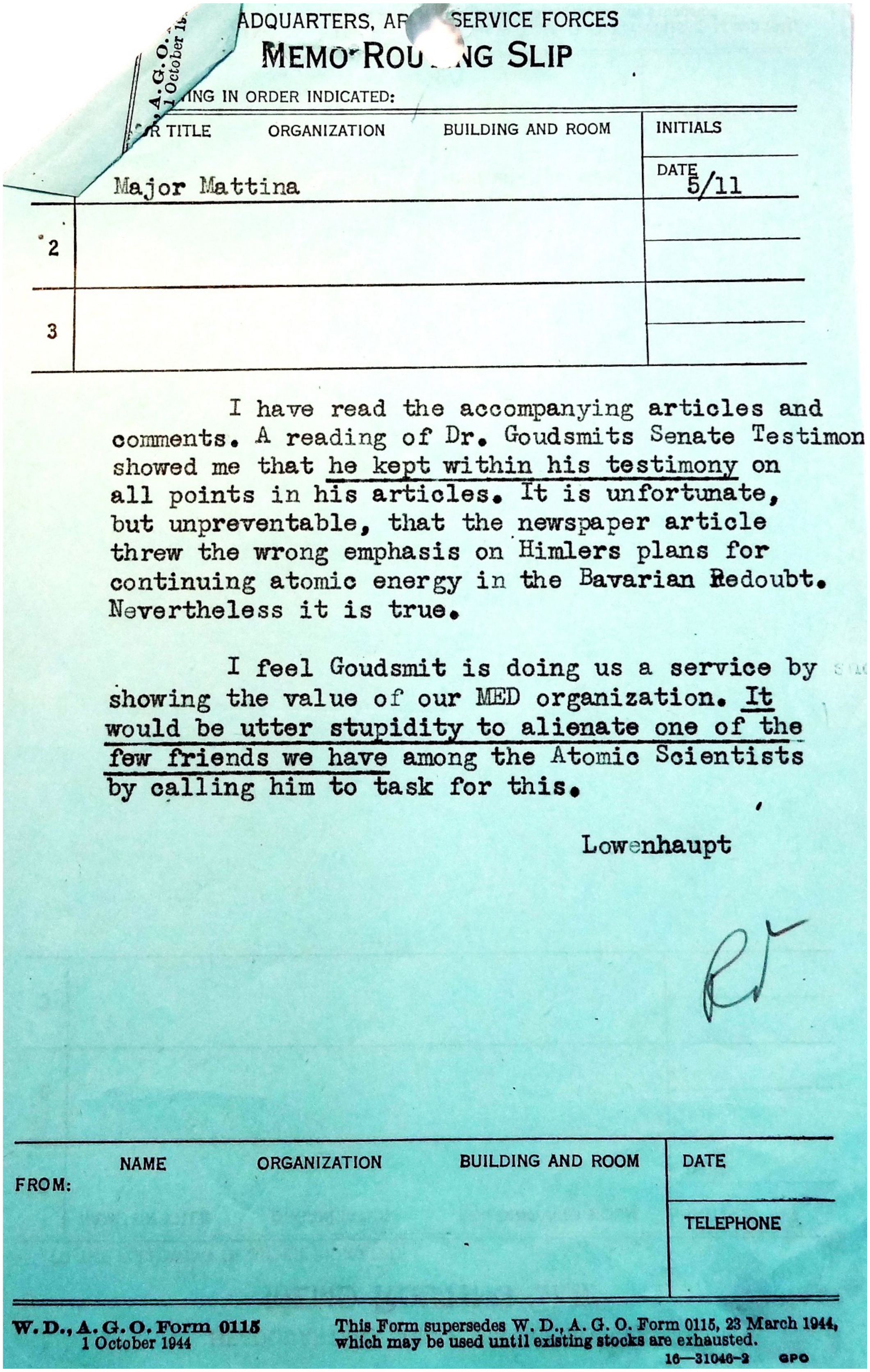


A. G. O.
1 October 19

ADQUARTERS, AR SERVICE FORCES

MEMO ROU NG SLIP

ING IN ORDER INDICATED:

	R TITLE	ORGANIZATION	BUILDING AND ROOM	INITIALS
	Major Mattina			DATE 5/11
2				
3				

I have read the accompanying articles and comments. A reading of Dr. Goudsmits Senate Testimon showed me that he kept within his testimony on all points in his articles. It is unfortunate, but unpreventable, that the newspaper article threw the wrong emphasis on Himlers plans for continuing atomic energy in the Bavarian Redoubt. Nevertheless it is true.

I feel Goudsmit is doing us a service by showing the value of our MED organization. It would be utter stupidity to alienate one of the few friends we have among the Atomic Scientists by calling him to task for this.

Lowenhaupt

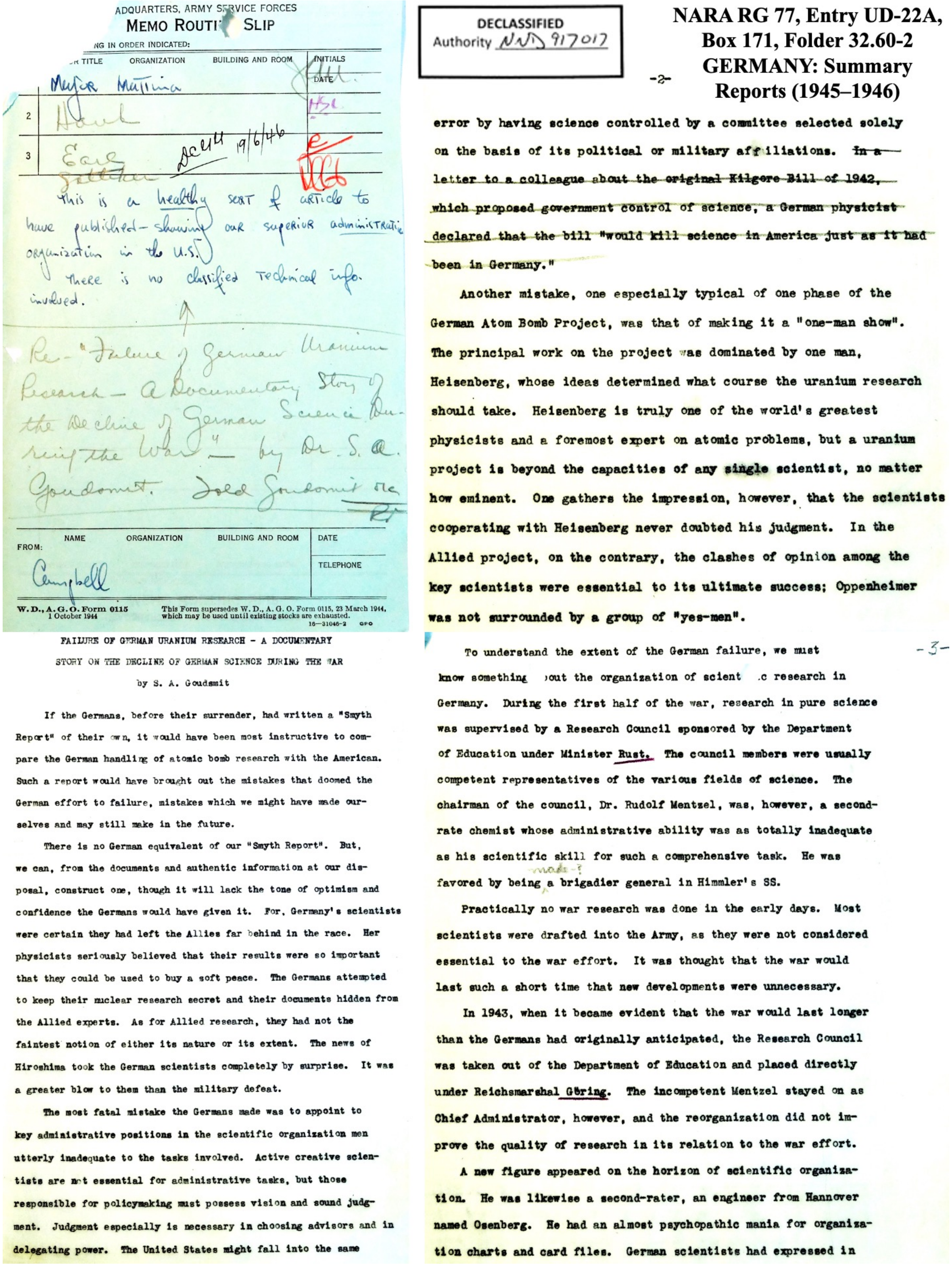
FROM:	NAME	ORGANIZATION	BUILDING AND ROOM	DATE
				TELEPHONE

W. D., A. G. O. Form 0115
1 October 1944

This Form supersedes W. D., A. G. O. Form 0115, 23 March 1944, which may be used until existing stocks are exhausted.
16—31046-2 GPO

NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1
GERMANY—Research—TA—(1943--June 1946)

Figure D.35: After the war, Goudsmit lived under the threat of government action against him if he made any public statements that deviated significantly from his initial story about the wartime German nuclear program. This memo appears to acknowledge that the real German nuclear program was headed by Heinrich Himmler's SS and was deemed a high priority to the very end of the war. Henry Lowenhaupt to Major Mattina. 11 May 1946. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA—(1943–June 1946)].



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This is a healthy sort of article to have published — showing our superior administrative organization in the U.S.

There is no classified technical info. involved.

Re- "Failure of German Uranium Research — a Documentary Story of the Decline of German Science During the War" — by Dr. S. A. Goudsmit. Told Goudsmit ok

FROM: NAME	ORGANIZATION	BUILDING AND ROOM	DATE
Campbell			TELEPHONE

W. D., A. G. O. Form 0115
1 October 1944

This Form supersedes W. D., A. G. O. Form 0115, 23 March 1944, which may be used until existing stocks are exhausted.
16—31046-2 GPO

FAILURE OF GERMAN URANIUM RESEARCH - A DOCUMENTARY
STORY ON THE DECLINE OF GERMAN SCIENCE DURING THE WAR

by S. A. Goudsmit

If the Germans, before their surrender, had written a "Smyth Report" of their own, it would have been most instructive to compare the German handling of atomic bomb research with the American. Such a report would have brought out the mistakes that doomed the German effort to failure, mistakes which we might have made ourselves and may still make in the future.

There is no German equivalent of our "Smyth Report". But, we can, from the documents and authentic information at our disposal, construct one, though it will lack the tone of optimism and confidence the Germans would have given it. For, Germany's scientists were certain they had left the Allies far behind in the race. Her physicists seriously believed that their results were so important that they could be used to buy a soft peace. The Germans attempted to keep their nuclear research secret and their documents hidden from the Allied experts. As for Allied research, they had not the faintest notion of either its nature or its extent. The news of Hiroshima took the German scientists completely by surprise. It was a greater blow to them than the military defeat.

The most fatal mistake the Germans made was to appoint to key administrative positions in the scientific organization men utterly inadequate to the tasks involved. Active creative scientists are not essential for administrative tasks, but those responsible for policymaking must possess vision and sound judgment. Judgment especially is necessary in choosing advisors and in delegating power. The United States might fall into the same

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error by having science controlled by a committee selected solely on the basis of its political or military affiliations. ~~In a letter to a colleague about the original Kilgore Bill of 1942, which proposed government control of science, a German physicist declared that the bill "would kill science in America just as it had been in Germany."~~

Another mistake, one especially typical of one phase of the German Atom Bomb Project, was that of making it a "one-man show". The principal work on the project was dominated by one man, Heisenberg, whose ideas determined what course the uranium research should take. Heisenberg is truly one of the world's greatest physicists and a foremost expert on atomic problems, but a uranium project is beyond the capacities of any single scientist, no matter how eminent. One gathers the impression, however, that the scientists cooperating with Heisenberg never doubted his judgment. In the Allied project, on the contrary, the clashes of opinion among the key scientists were essential to its ultimate success; Oppenheimer was not surrounded by a group of "yes-men".

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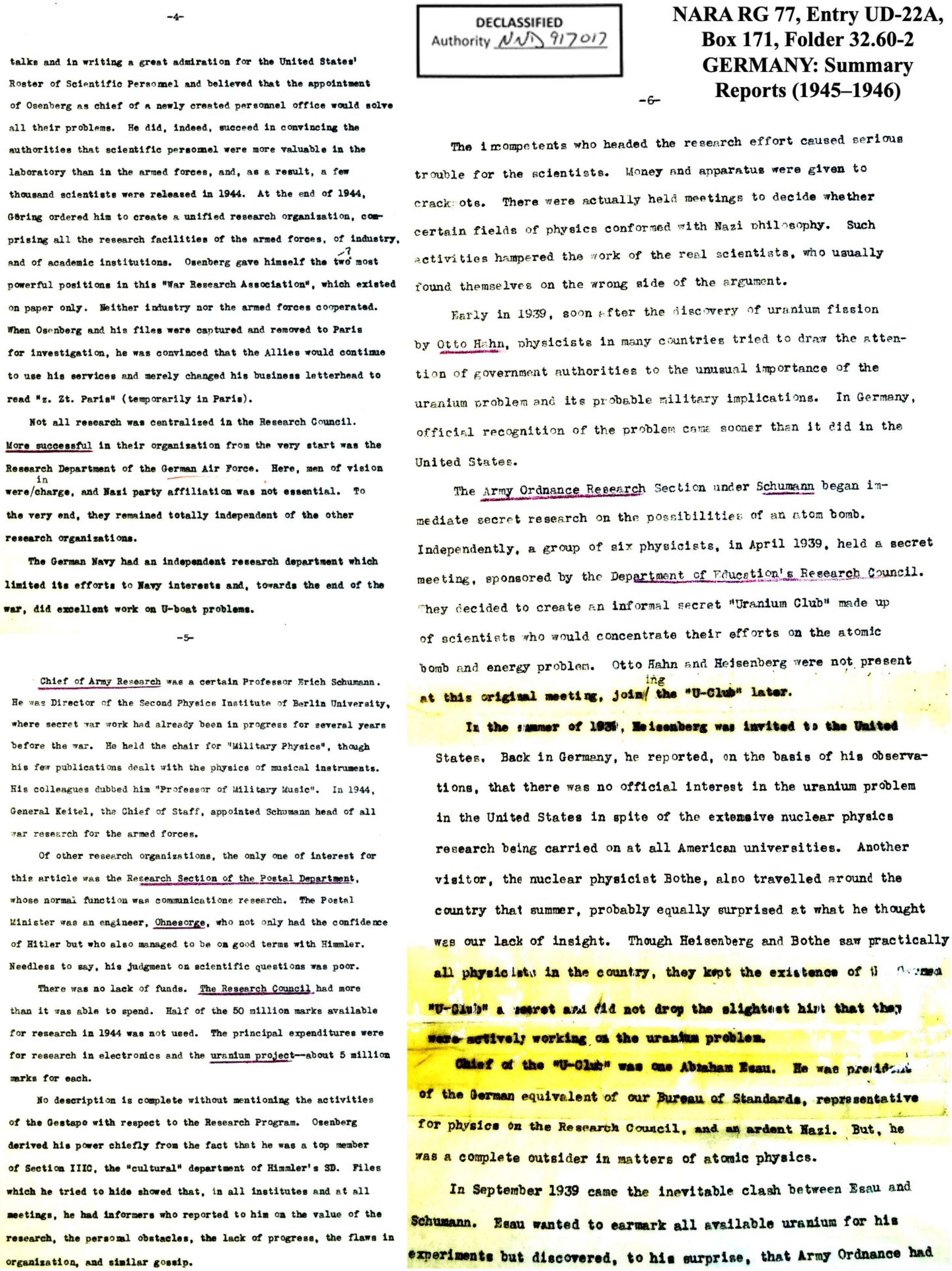
To understand the extent of the German failure, we must know something out the organization of scient c research in Germany. During the first half of the war, research in pure science was supervised by a Research Council sponsored by the Department of Education under Minister Rust. The council members were usually competent representatives of the various fields of science. The chairman of the council, Dr. Rudolf Mentzel, was, however, a second-rate chemist whose administrative ability was as totally inadequate as his scientific skill for such a comprehensive task. He was favored by being made-? a brigadier general in Himmler's SS.

Practically no war research was done in the early days. Most scientists were drafted into the Army, as they were not considered essential to the war effort. It was thought that the war would last such a short time that new developments were unnecessary.

In 1943, when it became evident that the war would last longer than the Germans had originally anticipated, the Research Council was taken out of the Department of Education and placed directly under Reichsmarshal Göring. The incompetent Mentzel stayed on as Chief Administrator, however, and the reorganization did not improve the quality of research in its relation to the war effort.

A new figure appeared on the horizon of scientific organization. He was likewise a second-rater, an engineer from Hannover named Osenberg. He had an almost psychopathic mania for organization charts and card files. German scientists had expressed in

Figure D.36: Samuel Goudsmit. Failure of German Uranium Research—A Documentary Story of the Decline of German Science During the War. June 1946 draft article for publication [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].



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talks and in writing a great admiration for the United States' Roster of Scientific Personnel and believed that the appointment of Osenberg as chief of a newly created personnel office would solve all their problems. He did, indeed, succeed in convincing the authorities that scientific personnel were more valuable in the laboratory than in the armed forces, and, as a result, a few thousand scientists were released in 1944. At the end of 1944, Göring ordered him to create a unified research organization, comprising all the research facilities of the armed forces, of industry, and of academic institutions. Osenberg gave himself the two? most powerful positions in this "War Research Association", which existed on paper only. Neither industry nor the armed forces cooperated. When Osenberg and his files were captured and removed to Paris for investigation, he was convinced that the Allies would continue to use his services and merely changed his business letterhead to read "z. Zt. Paris" (temporarily in Paris).

Not all research was centralized in the Research Council. More successful in their organization from the very start was the Research Department of the German Air Force. Here, men of vision were in charge, and Nazi party affiliation was not essential. To the very end, they remained totally independent of the other research organizations.

The German Navy had an independent research department which limited its efforts to Navy interests and, towards the end of the war, did excellent work on U-boat problems.

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Chief of Army Research was a certain Professor Erich Schumann. He was Director of the Second Physics Institute of Berlin University, where secret war work had already been in progress for several years before the war. He held the chair for "Military Physics", though his few publications dealt with the physics of musical instruments. His colleagues dubbed him "Professor of Military Music". In 1944, General Keitel, the Chief of Staff, appointed Schumann head of all war research for the armed forces.

Of other research organizations, the only one of interest for this article was the Research Section of the Postal Department, whose normal function was communications research. The Postal Minister was an engineer, Ohnesorge, who not only had the confidence of Hitler but who also managed to be on good terms with Himmler. Needless to say, his judgment on scientific questions was poor.

There was no lack of funds. The Research Council had more than it was able to spend. Half of the 50 million marks available for research in 1944 was not used. The principal expenditures were for research in electronics and the uranium project--about 5 million marks for each.

No description is complete without mentioning the activities of the Gestapo with respect to the Research Program. Osenberg derived his power chiefly from the fact that he was a top member of Section IIIC, the "cultural" department of Himmler's SD. Files which he tried to hide showed that, in all institutes and at all meetings, he had informers who reported to him on the value of the research, the personal obstacles, the lack of progress, the flaws in organization, and similar gossip.

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The incompetents who headed the research effort caused serious trouble for the scientists. Money and apparatus were given to crackpots. There were actually held meetings to decide whether certain fields of physics conformed with Nazi philosophy. Such activities hampered the work of the real scientists, who usually found themselves on the wrong side of the argument.

Early in 1939, soon after the discovery of uranium fission by Otto Hahn, physicists in many countries tried to draw the attention of government authorities to the unusual importance of the uranium problem and its probable military implications. In Germany, official recognition of the problem came sooner than it did in the United States.

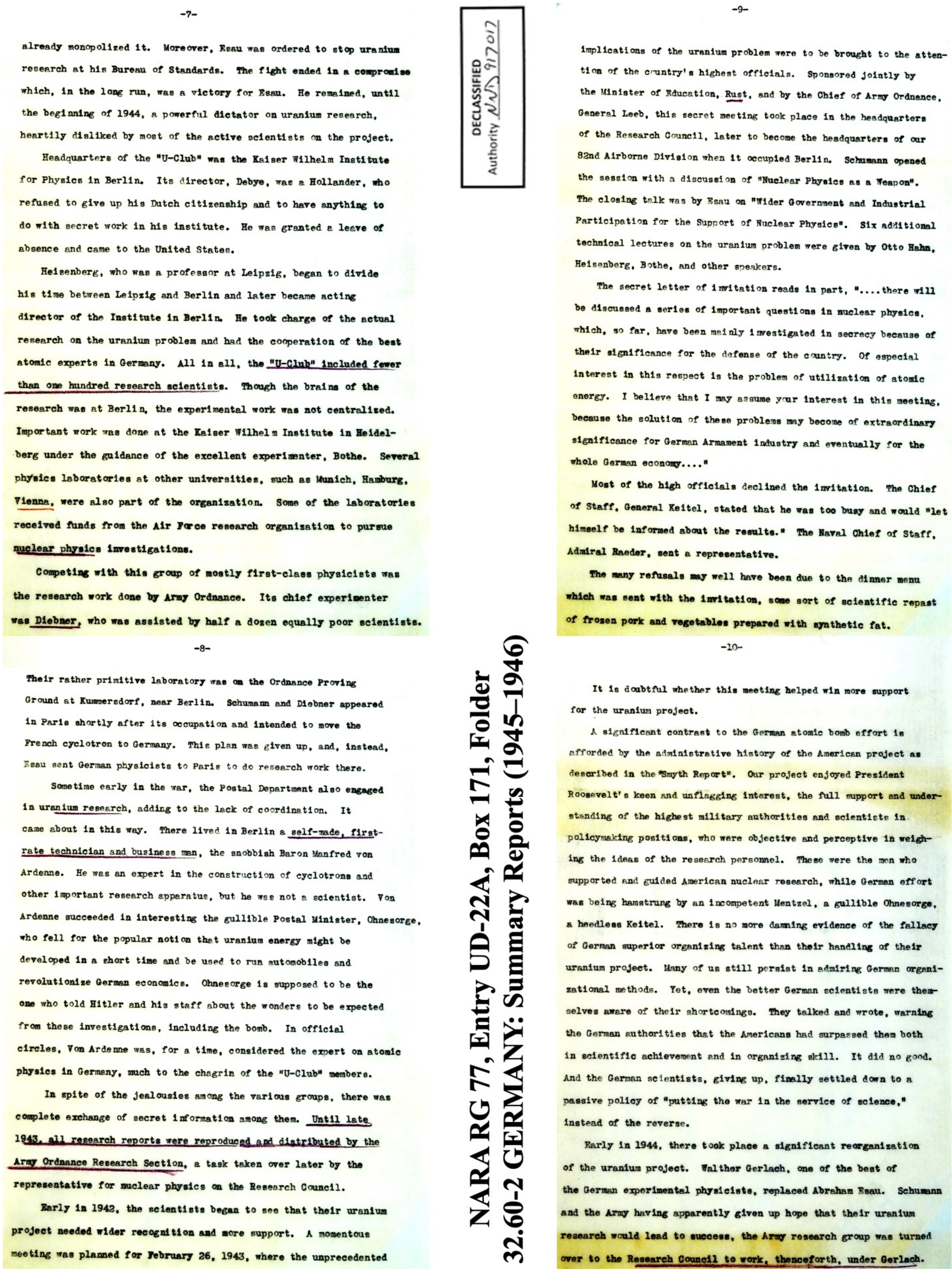
The Army Ordnance Research Section under Schumann began immediate secret research on the possibilities of an atom bomb. Independently, a group of six physicists, in April 1939, held a secret meeting, sponsored by the Department of Education's Research Council. They decided to create an informal secret "Uranium Club" made up of scientists who would concentrate their efforts on the atomic bomb and energy problem. Otto Hahn and Heisenberg were not present at this original meeting, joining the "U-Club" later.

In the summer of 1939, Heisenberg was invited to the United States. Back in Germany, he reported, on the basis of his observations, that there was no official interest in the uranium problem in the United States in spite of the extensive nuclear physics research being carried on at all American universities. Another visitor, the nuclear physicist Bothe, also travelled around the country that summer, probably equally surprised at what he thought was our lack of insight. Though Heisenberg and Bothe saw practically all physicists in the country, they kept the existence of [illegible] German "U-Club" a secret and did not drop the slightest hint that they were actively working on the uranium problem.

Chief of the "U-Club" was one Abraham Esau. He was president of the German equivalent of our Bureau of Standards, representative for physics on the Research Council, and an ardent Nazi. But, he was a complete outsider in matters of atomic physics.

In September 1939 came the inevitable clash between Esau and Schumann. Esau wanted to earmark all available uranium for his experiments but discovered, to his surprise, that Army Ordnance had

Figure D.37: Samuel Goudsmit. Failure of German Uranium Research—A Documentary Story of the Decline of German Science During the War. June 1946 draft article for publication [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].



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already monopolized it. Moreover, Esau was ordered to stop uranium research at his Bureau of Standards. The fight ended in a compromise which, in the long run, was a victory for Esau. He remained, until the beginning of 1944, a powerful dictator on uranium research, heartily disliked by most of the active scientists on the project.

Headquarters of the "U-Club" was the Kaiser Wilhelm Institute for Physics in Berlin. Its director, Debye, was a Hollander, who refused to give up his Dutch citizenship and to have anything to do with secret work in his institute. He was granted a leave of absence and came to the United States.

Heisenberg, who was a professor at Leipzig, began to divide his time between Leipzig and Berlin and later became acting director of the Institute in Berlin. He took charge of the actual research on the uranium problem and had the cooperation of the best atomic experts in Germany. All in all, the "U-Club" included fewer than one hundred research scientists. Though the brains of the research was at Berlin, the experimental work was not centralized. Important work was done at the Kaiser Wilhelm Institute in Heidelberg under the guidance of the excellent experimenter, Bothe. Several physics laboratories at other universities, such as Munich, Hamburg, Vienna, were also part of the organization. Some of the laboratories received funds from the Air Force research organization to pursue nuclear physics investigations.

Competing with this group of mostly first-class physicists was the research work done by Army Ordnance. Its chief experimenter was Diebner, who was assisted by half a dozen equally poor scientists.

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Their rather primitive laboratory was on the Ordnance Proving Ground at Kummersdorf, near Berlin. Schumann and Diebner appeared in Paris shortly after its occupation and intended to move the French cyclotron to Germany. This plan was given up, and, instead, Esau sent German physicists to Paris to do research work there.

Sometime early in the war, the Postal Department also engaged in uranium research, adding to the lack of coordination. It came about in this way. There lived in Berlin a self-made, first-rate technician and business man, the snobbish Baron Manfred von Ardenne. He was an expert in the construction of cyclotrons and other important research apparatus, but he was not a scientist. Von Ardenne succeeded in interesting the gullible Postal Minister, Ohnesorge, who fell for the popular notion that uranium energy might be developed in a short time and be used to run automobiles and revolutionize German economics. Ohnesorge is supposed to be the one who told Hitler and his staff about the wonders to be expected from these investigations, including the bomb. In official circles, Von Ardenne was, for a time, considered the expert on atomic physics in Germany, much to the chagrin of the "U-Club" members.

In spite of the jealousies among the various groups, there was complete exchange of secret information among them. Until late 1943, all research reports were reproduced and distributed by the Army Ordnance Research Section, a task taken over later by the representative for nuclear physics on the Research Council.

Early in 1942, the scientists began to see that their uranium project needed wider recognition and more support. A momentous meeting was planned for February 26, 1943, where the unprecedented

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implications of the uranium problem were to be brought to the attention of the country's highest officials. Sponsored jointly by the Minister of Education, Rust, and by the Chief of Army Ordnance, General Leeb, this secret meeting took place in the headquarters of the Research Council, later to become the headquarters of our 82nd Airborne Division when it occupied Berlin. Schumann opened the session with a discussion of "Nuclear Physics as a Weapon". The closing talk was by Esau on "Wider Government and Industrial Participation for the Support of Nuclear Physics". Six additional technical lectures on the uranium problem were given by Otto Hahn, Heisenberg, Bothe, and other speakers.

The secret letter of invitation reads in part, "....there will be discussed a series of important questions in nuclear physics, which, so far, have been mainly investigated in secrecy because of their significance for the defense of the country. Of especial interest in this respect is the problem of utilization of atomic energy. I believe that I may assume your interest in this meeting, because the solution of these problems may become of extraordinary significance for German Armament industry and eventually for the whole German economy...."

Most of the high officials declined the invitation. The Chief of Staff, General Keitel, stated that he was too busy and would "let himself be informed about the results." The Naval Chief of Staff, Admiral Raeder, sent a representative.

The many refusals may well have been due to the dinner menu which was sent with the invitation, some sort of scientific repast of frozen pork and vegetables prepared with synthetic fat.

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It is doubtful whether this meeting helped win more support for the uranium project.

A significant contrast to the German atomic bomb effort is afforded by the administrative history of the American project as described in the "Smyth Report". Our project enjoyed President Roosevelt's keen and unflagging interest, the full support and understanding of the highest military authorities and scientists in policymaking positions, who were objective and perceptive in weighing the ideas of the research personnel. These were the men who supported and guided American nuclear research, while German effort was being hamstrung by an incompetent Mentzel, a gullible Ohnesorge, a heedless Keitel. There is no more damning evidence of the fallacy of German superior organizing talent than their handling of their uranium project. Many of us still persist in admiring German organizational methods. Yet, even the better German scientists were themselves aware of their shortcomings. They talked and wrote, warning the German authorities that the Americans had surpassed them both in scientific achievement and in organizing skill. It did no good. And the German scientists, giving up, finally settled down to a passive policy of "putting the war in the service of science," instead of the reverse.

Early in 1944, there took place a significant reorganization of the uranium project. Walther Gerlach, one of the best of the German experimental physicists, replaced Abraham Esau. Schumann and the Army having apparently given up hope that their uranium research would lead to success, the Army research group was turned over to the Research Council to work, thenceforth, under Gerlach.

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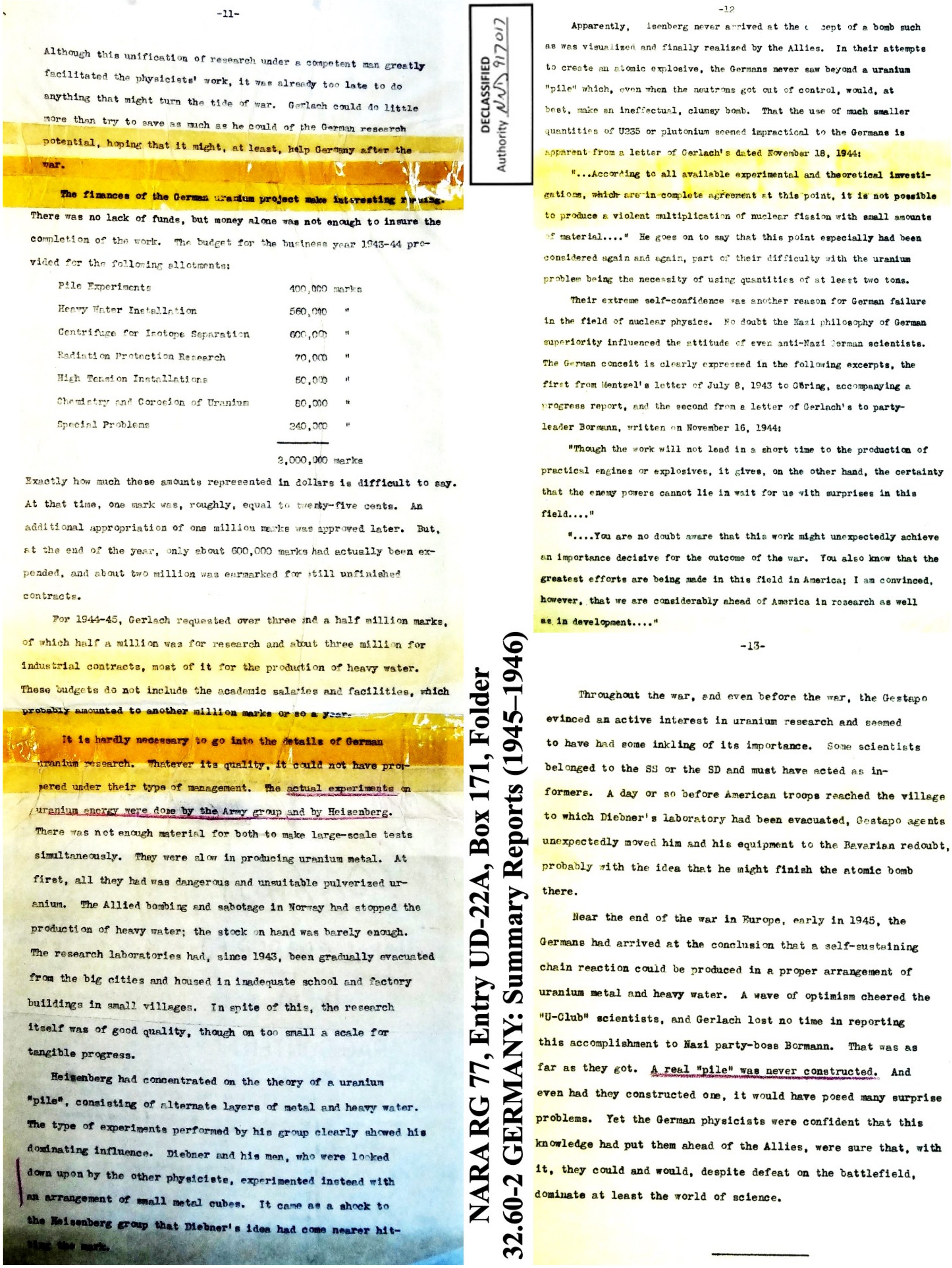
Figure D.38: Samuel Goudsmit. Failure of German Uranium Research—A Documentary Story of the Decline of German Science During the War. June 1946 draft article for publication [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].



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Although this unification of research under a competent man greatly facilitated the physicists' work, it was already too late to do anything that might turn the tide of war. Gerlach could do little more than try to save as much as he could of the German research potential, hoping that it might, at least, help Germany after the war.

The finances of the German uranium project make interesting reading. There was no lack of funds, but money alone was not enough to insure the completion of the work. The budget for the business year 1943-44 provided for the following allotments:

Pile Experiments	400,000 marks
Heavy Water Installation	560,000 "
Centrifuge for Isotope Separation	600,000 "
Radiation Protection Research	70,000 "
High Tension Installations	50,000 "
Chemistry and Corosion of Uranium	80,000 "
Special Problems	240,000 "
	2,000,000 marks

Exactly how much these amounts represented in dollars is difficult to say. At that time, one mark was, roughly, equal to twenty-five cents. An additional appropriation of one million marks was approved later. But, at the end of the year, only about 600,000 marks had actually been expended, and about two million was earmarked for still unfinished contracts.

For 1944-45, Gerlach requested over three and a half million marks, of which half a million was for research and about three million for industrial contracts, most of it for the production of heavy water. These budgets do not include the academic salaries and facilities, which probably amounted to another million marks or so a year.

It is hardly necessary to go into the details of German uranium research. Whatever its quality, it could not have prospered under their type of management. The actual experiments on uranium energy were done by the Army group and by Heisenberg. There was not enough material for both to make large-scale tests simultaneously. They were slow in producing uranium metal. At first, all they had was dangerous and unsuitable pulverized uranium. The Allied bombing and sabotage in Norway had stopped the production of heavy water; the stock on hand was barely enough. The research laboratories had, since 1943, been gradually evacuated from the big cities and housed in inadequate school and factory buildings in small villages. In spite of this, the research itself was of good quality, though on too small a scale for tangible progress.

Heisenberg had concentrated on the theory of a uranium "pile", consisting of alternate layers of metal and heavy water. The type of experiments performed by his group clearly showed his dominating influence. Diebner and his men, who were looked down upon by the other physicists, experimented instead with an arrangement of small metal cubes. It came as a shock to the Heisenberg group that Diebner's idea had come nearer hitting the mark.

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Apparently, Heisenberg never arrived at the concept of a bomb such as was visualized and finally realized by the Allies. In their attempts to create an atomic explosive, the Germans never saw beyond a uranium "pile" which, even when the neutrons got out of control, would, at best, make an ineffectual, clumsy bomb. That the use of much smaller quantities of U235 or plutonium seemed impractical to the Germans is apparent from a letter of Gerlach's dated November 18, 1944:

"...According to all available experimental and theoretical investigations, which are in complete agreement at this point, it is not possible to produce a violent multiplication of nuclear fission with small amounts of material...." He goes on to say that this point especially had been considered again and again, part of their difficulty with the uranium problem being the necessity of using quantities of at least two tons.

Their extreme self-confidence was another reason for German failure in the field of nuclear physics. No doubt the Nazi philosophy of German superiority influenced the attitude of even anti-Nazi German scientists. The German conceit is clearly expressed in the following excerpts, the first from Mentzel's letter of July 8, 1943 to Göring, accompanying a progress report, and the second from a letter of Gerlach's to party-leader Bormann, written on November 16, 1944:

"Though the work will not lead in a short time to the production of practical engines or explosives, it gives, on the other hand, the certainty that the enemy powers cannot lie in wait for us with surprises in this field...."

"....You are no doubt aware that this work might unexpectedly achieve an importance decisive for the outcome of the war. You also know that the greatest efforts are being made in this field in America; I am convinced, however, that we are considerably ahead of America in research as well as in development...."

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Throughout the war, and even before the war, the Gestapo evinced an active interest in uranium research and seemed to have had some inkling of its importance. Some scientists belonged to the SS or the SD and must have acted as informers. A day or so before American troops reached the village to which Diebner's laboratory had been evacuated, Gestapo agents unexpectedly moved him and his equipment to the Bavarian redoubt, probably with the idea that he might finish the atomic bomb there.

Near the end of the war in Europe, early in 1945, the Germans had arrived at the conclusion that a self-sustaining chain reaction could be produced in a proper arrangement of uranium metal and heavy water. A wave of optimism cheered the "U-Club" scientists, and Gerlach lost no time in reporting this accomplishment to Nazi party-boss Bormann. That was as far as they got. A real "pile" was never constructed. And even had they constructed one, it would have posed many surprise problems. Yet the German physicists were confident that this knowledge had put them ahead of the Allies, were sure that, with it, they could and would, despite defeat on the battlefield, dominate at least the world of science.

Figure D.39: Samuel Goudsmit. Failure of German Uranium Research—A Documentary Story of the Decline of German Science During the War. June 1946 draft article for publication [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Samuel A. Goudsmit. 1947. *Alsos.* New York: Henry Schuman.

[pp. 11–12]: If only we could get hold of a German atomic physicist, we felt, we could soon find out what the rest of them were up to. To us physicists the problem seemed very simple. Even those of us who were not working on the atom bomb project knew pretty well what was going on over here. No amount of military security could have prevented us from knowing, difficult as it was for the military to understand this. Active scientists engaged in the same general field of research inevitably form a kind of clan; they work closely together and know all about each other's specialties and whereabouts. [...] The same thing, we knew, would be true of the Germans.

[pp. 31–33]: There are still a few secrets which members of the Mission are not supposed to reveal. We are not supposed to tell just who among the Army personnel were directly connected with the A-bomb Intelligence. We cannot divulge how much uranium and heavy water was found in Germany and what was done with it. We helped find it, but never knew how much it was until later press dispatches from Germany told us about it. [...]

To an outsider, a professor is a professor, but we knew that no one but Professor Heisenberg could be the brains of a German uranium project and every physicist throughout the world knew that.

There are people who ask us every so often, whether we are absolutely sure we now know everything the Germans did. How can we be sure that somewhere in Germany, still hidden, there isn't a group of men, whom we have never heard of, secretly manufacturing atom bombs even now. There were even Intelligence reports referring to such a possibility. During the time the Russians occupied the Danish island of Bornholm, one heard frequent official and unofficial rumors to the effect that there was a group of German scientists on the island who had completed an atom bomb. We came across similar rumors frequently during our investigations.

I still do not know how to explain the absurdity of these rumors and how to convince non-scientists. Possibly a paper hanger can become a military expert, and a wine merchant a diplomat; but an outsider simply can't acquire the necessary scientific knowledge for making an atom bomb overnight. We are always told, with some exaggeration, that only a dozen people in the world understand Einstein. It follows that at least one of that dozen must be included in any atom bomb project since its construction is so closely tied up with Einstein's theory! In other words, we knew who our chief targets were in Germany before we started. What we had to find out was how far they had advanced on their atom bomb project.

[pp. 80–83]: The director at that Medical Institute was the famous organic chemist, Richard Kuhn. When the chemists with our Mission, Professors Louis Fieser of Harvard and Carl Baumann of Wisconsin, met him, Kuhn was most co-operative. They had known him before and he welcomed them back in his laboratory. He told them that he had no connection with war work, but that it was all directed by the chemist Thiessen in Berlin. He had no secret reports and had merely worked on the chemistry of modern drugs. [...]

Richard Kuhn's record did not seem too clean to me. As president of the German Chemical Society he had followed the Nazi cult and rites quite faithfully. [...] I could not believe that he was not familiar with important war work, although I had no time to look into this matter further. We knew, however, that he had been one of the administration bosses of German war chemistry, and later in Berlin Baumann discovered some valuable secret reports on applied chemistry which were no doubt familiar to Kuhn. Back in Heidelberg we had him picked up by one of our officers.

I showed him the secret reports, and reproached him for not having told us about them half a year earlier, when he knew all the time what we were after and when he acted as if he were co-operating with us. [...]

It was quite important. It contained articles on industrially valuable applications of chemistry, such as the production of plastics, asbestos, the use of coal tar, aluminum, cellulose, sulfur, etc. This rare set of documents is now in the possession of the American Chemical Society, and I am still sore for allowing myself to be fooled by Herr Kuhn. We could have got these documents in April instead of September.

[pp. 112]: A few days afterward Munich fell. Here Carl Baumann, accompanied by a few officers and men, located Walther Gerlach, who had been in charge of nuclear research and all physics research for the last year. He also discovered Diebner and the uranium, which the Gestapo had taken from the secret laboratory in Thüringen, and brought back more interesting documents.

[pp. 121–122]: [Gerlach's] only wish was to save and to promote German physics without the help or obstruction of the Nazis. [...] But it was all too late. The war was over before Gerlach's influence took hold.

We could get nothing out of Diebner. He was as sullen as a real prisoner. He must have felt like an outcast, living in the same house with members of the Heisenberg clique. Their conversations with him were limited to monosyllables.

[pp. 123–126]: It was not until late in July that a small Alsos group was allowed to enter Berlin. As we expected, we found no new information but what we learned was very satisfying. It was like the last pieces of a jigsaw puzzle; the pieces of haphazard information we gathered completed the picture, plugged up a few minor holes, but the pattern remained the same.

We found, for instance, the chief chemist of the Auer Chemical Company, for whom we had been looking ever since we had entered Belgium. But he could tell us nothing we did not already know, nor could the few industrial physicists who still remained in Berlin. The Gestapo scientists had all cleared out before our arrival, some of them leaving sufficient clues in their deserted homes for us to track them down later. [...]

Our chief visit was, of course, to the now empty Kaiser Wilhelm Institute for Physics, where the uranium research had started in 1939. [...] We went in and found one room furnished with two desks and one officer. [...] He did not understand our interest in this building.

"It's all empty," he said. "Everything, even switches and wiring, has been removed by the Russians. We found some junk which we dumped in the back yard." [...]

We inspected the place thoroughly. The backyard "junk" contained various pieces of equipment for nuclear physics as well as blocks of pressed uranium oxide. There were also some notebooks indicating the type of research that had been going on.

[pp. 142–145]: Army research was conducted by the Ordnance Department headed by the mediocre physicist, Erich Schumann. Professor Schumann's right hand man was Diebner. [...]

Schumann was actually professor of military physics at the University of Berlin, although his few publications deal only with the vibrations of piano strings—an interest derived, presumably, from the fact that he was a descendant of the composer, Schumann.[...]

In Schumann's case, the work had been shrouded in secrecy even before the war, and so no one knew quite what was going on in the Second Institute, although the first rate physicists knew, from the type of personnel he was using, it could not be very important or successful. [...]

But the uranium problem is rather more difficult than the mysteries of piano strings and Schumann became impatient. By the end of 1942 he had lost interest in the project; he turned Diebner, personnel, equipment and material over to the civilian research organization, the Reich's Research Council, which had just been placed under Goering. He did not, however, turn over the two million marks his research group had been granted by the Army.

Schumann next devoted his talents to bacterial warfare. It is probable that in this field his competence was even less than in physics and its wartime applications. But he liked to be involved in things that looked important and his name shows up on many rosters of research committees.

When Berlin fell, Schumann fled to Bavaria. The Alsos Mission followed his trail for a short while, mainly out of curiousity, but we soon gave up. He was so obviously unimportant.

[pp. 160, 164–166]: As scientific adviser to Army Ordnance, Professor Schumann made immediate preparations for secret research into the uranium problem with a view to producing the super-explosive. But he himself was only a second-rate physicist, and his helpers were not much better. [...]

What made this even more irritating was that the academic scientists considered Schumann and his group far below their level. They thought it outrageous that such men should be given so much power, and felt certain that they would never succeed in their researches. [...]

Von Ardenne was not a physicist in the German academic sense, but he was a first-rate experimenter; a designer and builder of important laboratory apparatus, and a successful business man. He found out that the Postal Department had a research section with a large budget that was not being used. Contacting Ohnesorge, the gullible Postal Minister, he told him all about the wonders of atomic power and explosives.

And so it came about that Von Ardenne's Berlin laboratory was made a branch of Postal Research, and Ohnesorge, at a cabinet meeting, informed Hitler about the uranium bomb. [...]

For a time the technician Baron Manfred von Ardenne was the official expert on nuclear physics to the Nazi government. Even today the academic physicists refer to this as one of the severest insults they ever received from the government, and the reason for some of them becoming anti-Nazi. "If only the government had taken the true scientists into its confidence instead of those charlatans like Von Ardenne and Schumann," they complained to us on the Alsos Mission. [...]

The real brains of the project was Werner Heisenberg.

[pp. 176–177]: They knew, of course, of the possibility of a U-235 bomb, but they considered it practically impossible to separate pure U-235. One can hardly blame them for this. Perhaps only in America could one have visualized and realized an Oak Ridge, where pure U-235 was produced by the huge combined efforts of science, engineering, industry, and the Army. No such vision was apparent among the German scientists and certainly no such gigantic combination of all forces working on all cylinders.

Furthermore, the Germans never thought of using plutonium in the bomb, which enormously simplified the problem. The existence and probable properties of plutonium, though still unnamed, had been mentioned in scientific literature before the war, and in a few German secret reports, but they overlooked the practical phase of this side of the problem completely.

In fact, the whole German idea of the bomb was quite different from ours and more primitive in its conception. They thought that it might eventually be possible to construct a pile in which the chain reaction went so fast that it would produce an explosion. Their bomb, that is, was merely an explosive pile and would have proved a fizz compared to the real bomb.

[pp. 201–202:] During the war the SS had a few technical research laboratories of its own, under the direction of an SS-General Schwab, but these did not amount to anything. They tried some work on heavy water, but soon gave up and sent their "expert" on this subject to the University of Hamburg to continue his work with the legitimate physicists.

The principal "scientific" interest of the SS was ancient Germanic history, with a view to proving the greatness of their Teutonic ancestry. It was for this purpose that Himmler created his own "scientific academy" in 1935, Das Ahnenerbe, or Academy of Ancestral Heritage. Because some of the activities of this strange academy were shrouded in mystery that might just possibly have concealed something really important, we assigned Carl Baumann to make a thorough investigation of the organization for Alsos.

Except for Himmler's letter to hangman Heydrich about the physicist Heisenberg, [...] Baumann did not discover anything connected with atomic research in the Ahnenerbe material. [...]

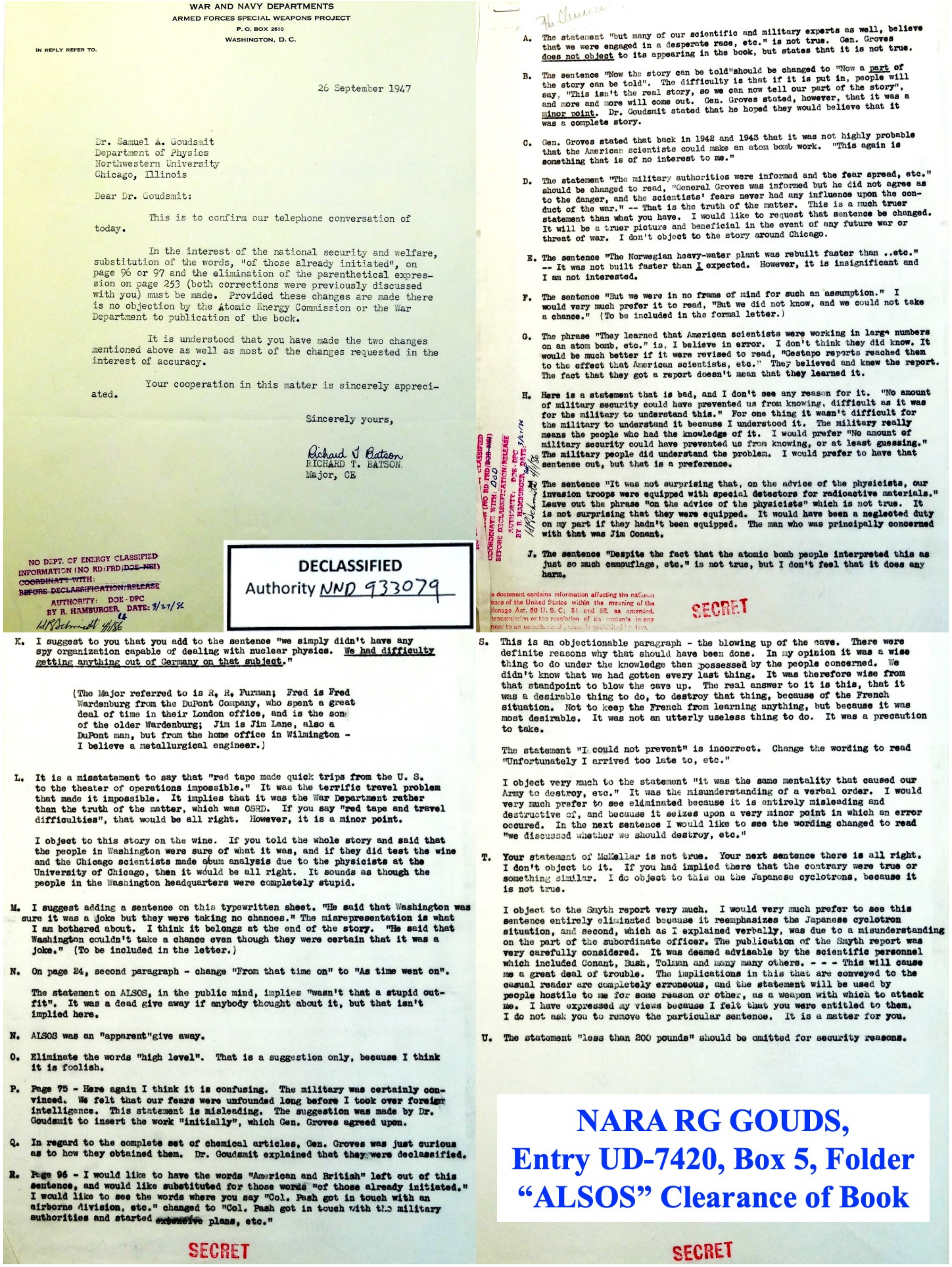
[In his 1947 book, Samuel Goudsmit repeated the erroneous claims he had made when he knowingly gave false testimony to the United States Senate in December 1945 (pp. 3297–3305). Goudsmit would have been well aware that his claims were false based on documents from Alsos's own files, including but not limited to those listed on p. 3298.

In this book publicly praising his own performance, Goudsmit also conveniently failed to include many details such as those listed on p. 3307.

Due to censorship in 1947, Goudsmit could only refer to Major Robert Furman as the "Mysterious Major," and he could not mention the specific quantities of uranium that had been found. In their books written much later, in the 1960s, Groves and Pash were able to mention the name of Robert Furman and the specific quantities of uranium.

Even as Goudsmit complained about the "absurdity" of people asking him if he might have overlooked any German scientists who could build atomic bombs, in 1947 there were literally hundreds of German scientists whom Goudsmit had overlooked and who were developing the Soviet Union's first atomic bombs.

Goudsmit's opinion that (unlike America) Germany was incapable of "huge combined efforts of science, engineering, industry, and the Army" is clearly contradicted by a number of massive and very successful German programs that involved all of those sectors: the missile programs, the nerve gas program, the jet programs, programs that developed and mass-produced synthetic fuels and rubber, and many others. In fact, whereas the United States was still very new to that sort of approach, it had been the foundation of German research and development for many decades.]



WAR AND NAVY DEPARTMENTS
ARMED FORCES SPECIAL WEAPONS PROJECT
P. O. BOX 2610
WASHINGTON, D. C.

IN REPLY REFER TO.

26 September 1947

Dr. Samuel A. Goudsmit
Department of Physics
Northwestern University
Chicago, Illinois

Dear Dr. Goudsmit:

This is to confirm our telephone conversation of today.

In the interest of the national security and welfare, substitution of the words, "of those already initiated", on page 96 or 97 and the elimination of the parenthetical expression on page 253 (both corrections were previously discussed with you) must be made. Provided these changes are made there is no objection by the Atomic Energy Commission or the War Department to publication of the book.

It is understood that you have made the two changes mentioned above as well as most of the changes requested in the interest of accuracy.

Your cooperation in this matter is sincerely appreciated.

Sincerely yours,

Richard T. Batson
RICHARD T. BATSON.
Major, CE

NO DEPT. OF ENERGY CLASSIFIED
INFORMATION (NO RD/FRD/~~DOE-NSI~~)
~~COORDINATE WITH:~~
~~BEFORE DECLASSIFICATION/RELEASE~~
AUTHORITY: DOE-DPC
BY R. HAMBURGER, DATE: 3/27/86
H R Schmidt 4/1/86

DECLASSIFIED
Authority NND 933079

The Clearance

A. The statement "but many of our scientific and military experts as well, believe that we were engaged in a desperate race, etc." is not true. Gen. Groves does not object to its appearing in the book, but states that it is not true.

B. The sentence "Now the story can be told"should be changed to "Now a part of the story can be told". The difficulty is that if it is put in, people will say, "This isn't the real story, so we can now tell our part of the story", and more and more will come out. Gen. Groves stated, however, that it was a minor point. Dr. Goudsmit stated that he hoped they would believe that it was a complete story.

C. Gen. Groves stated that back in 1942 and 1943 that it was not highly probable that the American scientists could make an atom bomb work. "This again is something that is of no interest to me."

D. The statement "The military authorities were informed and the fear spread, etc." should be changed to read, "General Groves was informed but he did not agree as to the danger, and the scientists' fears never had any influence upon the conduct of the war." -- That is the truth of the matter. This is a much truer statement than what you have. I would like to request that sentence be changed. It will be a truer picture and beneficial in the event of any future war or threat of war. I don't object to the story around Chicago.

E. The sentence "The Norwegian heavy-water plant was rebuilt faster than ..etc." -- It was not built faster than I expected. However, it is insignificant and I am not interested.

F. The sentence "But we were in no frame of mind for such an assumption." I would very much prefer it to read, "But we did not know, and we could not take a chance." (To be included in the formal letter.)

G. The phrase "They learned that American scientists were working in large numbers on an atom bomb, etc." is, I believe in error. I don't think they did know. It would be much better if it were revised to read, "Gestapo reports reached them to the effect that American scientists, etc." They believed and knew the report. The fact that they got a report doesn't mean that they learned it.

H. Here is a statement that is bad, and I don't see any reason for it. "No amount of military security could have prevented us from knowing, difficult as it was for the military to understand this." For one thing it wasn't difficult for the military to understand it because I understood it. The military really means the people who had the knowledge of it. I would prefer "No amount of military security could have prevented us from knowing, or at least guessing." The military people did understand the problem. I would prefer to have that sentence out, but that is a preference.

I. The sentence "It was not surprising that, on the advice of the physicists, our invasion troops were equipped with special detectors for radioactive materials." Leave out the phrase "on the advice of the physicists" which is not true. It is not surprising that they were equipped. It would have been a neglected duty on my part if they hadn't been equipped. The man who was principally concerned with that was Jim Conant.

J. The sentence "Despite the fact that the atomic bomb people interpreted this as just so much camouflage, etc." is not true, but I don't feel that it does any harm.

SECRET

K. I suggest to you that you add to the sentence "we simply didn't have any spy organization capable of dealing with nuclear physics. We had difficulty getting anything out of Germany on that subject."

(The Major referred to is R, R, Furman; Fred is Fred Wardenburg from the DuPont Company, who spent a great deal of time in their London office, and is the son of the older Wardenburg; Jim is Jim Lane, also a DuPont man, but from the home office in Wilmington - I believe a metallurgical engineer.)

L. It is a misstatement to say that "red tape made quick trips from the U. S. to the theater of operations impossible." It was the terrific travel problem that made it impossible. It implies that it was the War Department rather than the truth of the matter, which was OSRD. If you say "red tape and travel difficulties", that would be all right. However, it is a minor point.

I object to this story on the wine. If you told the whole story and said that the people in Washington were sure of what it was, and if they did test the wine and the Chicago scientists made sbum analysis due to the physicists at the University of Chicago, then it would be all right. It sounds as though the people in the Washington headquarters were completely stupid.

M. I suggest adding a sentence on this typewritten sheet. "He said that Washington was sure it was a joke but they were taking no chances." The misrepresentation is what I am bothered about. I think it belongs at the end of the story. "He said that Washington couldn't take a chance even though they were certain that it was a joke." (To be included in the letter.)

N. On page 24, second paragraph - change "From that time on" to "As time went on".

The statement on ALSOS, in the public mind, implies "wasn't that a stupid outfit". It was a dead give away if anybody thought about it, but that isn't implied here.

N. ALSOS was an "apparent"give away.

O. Eliminate the words "high level". That is a suggestion only, because I think it is foolish.

P. Page 75 - Here again I think it is confusing. The military was certainly convinced. We felt that our fears were unfounded long before I took over foreign intelligence. This statement is misleading. The suggestion was made by Dr. Goudsmit to insert the work "initially", which Gen. Groves agreed upon.

Q. In regard to the complete set of chemical articles, Gen. Groves was just curious as to how they obtained them. Dr. Goudsmit explained that they were declassified.

R. Page 96 - I would like to have the words "American and British" left out of this sentence, and would like substituted for those words "of those already initiated." I would like to see the words where you say "Col. Pash got in touch with an airborne division, etc." changed to "Col. Pash got in touch with the military authorities and started ~~extensive~~ plans, etc."

SECRET

S. This is an objectionable paragraph - the blowing up of the cave. There were definite reasons why that should have been done. In my opinion it was a wise thing to do under the knowledge then possessed by the people concerned. We didn't know that we had gotten every last thing. It was therefore wise from that standpoint to blow the cave up. The real answer to it is this, that it was a desirable thing to do, to destroy that thing, because of the French situation. Not to keep the French from learning anything, but because it was most desirable. It was not an utterly useless thing to do. It was a precaution to take.

The statement "I could not prevent" is incorrect. Change the wording to read "Unfortunately I arrived too late to, etc."

I object very much to the statement "it was the same mentality that caused our Army to destroy, etc." It was the misunderstanding of a verbal order. I would very much prefer to see eliminated because it is entirely misleading and destructive of, and because it seizes upon a very minor point in which an error occured. In the next sentence I would like to see the wording changed to read "we discussed whether we should destroy, etc."

T. Your statement of McKellar is not true. Your next sentence there is all right. I don't object to it. If you had implied there that the contrary were true or something similar. I do object to this on the Japanese cyclotrons, because it is not true.

I object to the Smyth report very much. I would very much prefer to see this sentence entirely eliminated because it reemphasizes the Japanese cyclotron situation, and second, which as I explained verbally, was due to a misunderstanding on the part of the subordinate officer. The publication of the Smyth report was very carefully considered. It was deemed advisable by the scientific personnel which included Conant, Bush, Tolman and many many others. - - - This will cause me a great deal of trouble. The implications in this that are conveyed to the casual reader are completely erroneous, and the statement will be used by people hostile to me for some reason or other, as a weapon with which to attack me. I have expressed my views because I felt that you were entitled to them. I do not ask you to remove the particular sentence. It is a matter for you.

U. The statement "less than 200 pounds" should be omitted for security reasons.

NARA RG GOUDS,
Entry UD-7420, Box 5, Folder
"ALSOS" Clearance of Book

SECRET

Figure D.40: Example of U.S. government censorship of Samuel Goudsmit's 1947 book, *Alsos* [NARA RG GOUDS, Entry UD-7420, Box 5, Folder "ALSOS" Clearance of Book]. "The sentence 'Now the story can be told' should be changed to 'Now a part of the story can be told'. The difficulty is that if it is put in, people will say, 'This isn't the real story, so we can now tell our part of the story', and more and more will come out... Dr. Goudsmit stated that he hoped they would believe that it was a complete story."

Boris T. Pash. 1969. *The Alsos Mission.* New York: Award House.

[pp. 156–158:] Our scientists soon joined us in Strasbourg. Bob Furman and Lt. Tony Biot, a Navy physicist, had already arrived. Sam Goudsmit and Fred Wardenberg reported two days later.

[...] Our scientific sleuths were more than usually agitated by the material probed although they would be the last to admit it. After a while, I heard Sam Goudsmit exclaim, “We’ve got it!”

“I know we have it,” I remarked. “But do they?”

The two scientists were the only ones who knew to what I was referring. They smiled, and Sam Goudsmit’s eyes were wide with excitement.

“No, no!” he said. “That’s it. They don’t!” The scientists remained up far into the night, poring over the papers. [...]

Interrogation of the captured scientists, study of the seized documents and inspection of the laboratories took several days. But the two days during which Sam Goudsmit, Fred Wardenberg and Bob Furman worked on our priority interest were as important to our top leaders and to the British as any other phase of the war. It was our Strasbourg operation which disclosed that it was unlikely that the Nazi could unleash an atom bomb in the near future.

Thus Alsos exploded the Nazi super-weapon myth that had so alarmed Allied leaders. The fact that a German atom bomb was not an immediate threat was probably the most significant single piece of military intelligence developed throughout the war. Alone, that information was enough to fully justify Alsos. [...]

[p. 162, early December 1944:] But in Paris I learned there was to be no rest for any of us. It was my turn to be called back to Washington, Sam Goudsmit having already preceded me there. He had left without designating a replacement for himself. Fortunately, among the scientists who had joined us for the Strasbourg operation was Dr. Henry Reid, an able and pleasant engineer.

After a conference with Commodore Schade, I asked Reid to assume the duties of Deputy Scientific Chief. This proved a good move. Henry’s organizational and administrative skills were to be of great value to us during the winter of 1944–45 when the unit was rapidly expanding.

In Washington, the status of our scientists and their activities were the primary concern, formally and informally. While no one made any comments which could imply criticism, it was evident that some rumblings from the field might not have been complimentary.

Sam and I soon cleared the air. Even those previously hostile were mollified by our reports. [...]

[pp. 216–218:] In Hechingen, the entire Alsos scientific contingent was interrogating the German scientists and trying to locate significant lab reports and documents. [...]

Upon our return we learned that the secreted uranium of the Haigerloch pile, as well as the supply of heavy water, was buried near an old water-drive grist mill outside town. [...]

The 1269th provided trucks that hauled the uranium and heavy water, along with recovered graphite, to SHAEF Scientific Section for transhipment to the United States.

Thus ended Operation Big.

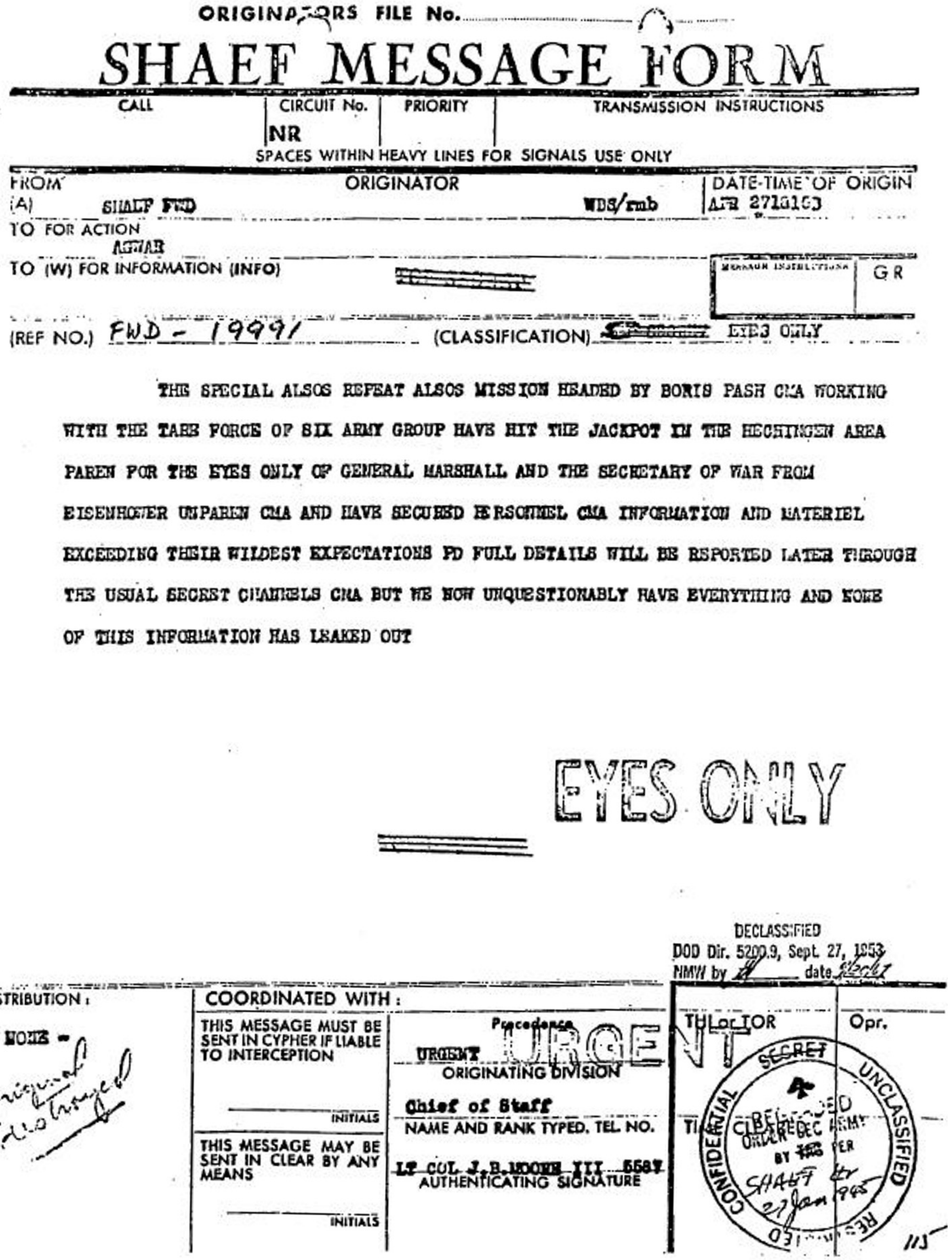
With the exception of Doctors Heisenberg, Gerlach and Diebner [who were found shortly later], Alsos had taken into custody every German scientist whose name appeared on the "wanted" list.

And the German atomic pile, with all related equipment and documents, were in American hands.

Upon receiving my report that "Alsos has hit the jackpot," General Harrison immediately sent a message to General Devers stating, "Boris Pash has hit the jackpot." [See p. 3323.]

[Pash confirmed that the scientific conclusions of Alsos were dominated by Goudsmit, that those conclusions were reached in Strasbourg in November 1944 (long before visiting most of the areas and scientists involved in the nuclear program), that Alsos was only interested in a few famous scientists on their short predetermined list, and that they were satisfied they were finished once they found the Haigerloch fission pile.

Pash also confirmed that Goudsmit had been suddenly relieved of duty in early December 1944 and sent back to the United States. Pash added that he himself had also been sent back to the United States, and that both he and Goudsmit had then had to answer criticisms of their performance in high-level meetings in Washington. Although Pash did not specify the criticisms, they must have been quite serious to warrant such actions in the middle of the war when Alsos personnel were urgently needed in Europe.]



ORIGINATORS FILE No.

SHAEF MESSAGE FORM

CALL | CIRCUIT No. NR | PRIORITY | TRANSMISSION INSTRUCTIONS

SPACES WITHIN HEAVY LINES FOR SIGNALS USE ONLY

FROM (A) ORIGINATOR SHAEF FWD WDS/rmb

DATE-TIME OF ORIGIN APR 271610B

TO FOR ACTION AGWAR

TO (W) FOR INFORMATION (INFO)

MESSAGE INSTRUCTIONS GR

(REF NO.) FWD - 19991 (CLASSIFICATION) ~~[illegible]~~ EYES ONLY

THE SPECIAL ALSOS REPEAT ALSOS MISSION HEADED BY BORIS PASH CMA WORKING WITH THE TARE FORCE OF SIX ARMY GROUP HAVE HIT THE JACKPOT IN THE HECHINGEN AREA PAREN FOR THE EYES ONLY OF GENERAL MARSHALL AND THE SECRETARY OF WAR FROM EISENHOWER UNPAREN CMA AND HAVE SECURED PERSONNEL CMA INFORMATION AND MATERIEL EXCEEDING THEIR WILDEST EXPECTATIONS PD FULL DETAILS WILL BE REPORTED LATER THROUGH THE USUAL SECRET CHANNELS CMA BUT WE NOW UNQUESTIONABLY HAVE EVERYTHING AND NONE OF THIS INFORMATION HAS LEAKED OUT

EYES ONLY

DECLASSIFIED
DOD Dir. 5200.9, Sept. 27, 1958
NMW by [illegible] date [illegible]

DISTRIBUTION: NONE - original destroyed

COORDINATED WITH:

THIS MESSAGE MUST BE SENT IN CYPHER IF LIABLE TO INTERCEPTION

INITIALS

THIS MESSAGE MAY BE SENT IN CLEAR BY ANY MEANS

INITIALS

Precedence URGENT URGENT

ORIGINATING DIVISION Chief of Staff

NAME AND RANK TYPED. TEL. NO. LT COL. J.B.MOORE III 5587

AUTHENTICATING SIGNATURE

THI or TOR | Opr.

TIME

SECRET CONFIDENTIAL UNCLASSIFIED REGRADED ORDER SEC ARMY BY TAG PER SHAEF ltr 27 Jan 1945

113

Figure D.41: “For the Eyes Only of General Marshall and the Secretary of War from Eisenhower... have secured personnel, information and materiel exceeding their wildest expectations” [Pash 1969, frontispiece; also NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. ’45].

***Manhattan District History*, Book I, Volume 14, Foreign Intelligence Supplement No. 1. Undated but apparently ∼1947.**
[**https://ia803409.us.archive.org/14/items/ManhattanDistrictHistory/**]

[Some original Alsos documents are reproduced near the end of this file, with varying degrees of legibility. Why are nearly all of the references in this file redacted, when nothing else seems to be?]

4-1. General.

[...] Lt. Col. Boris T. Pash and Dr. Samuel A. Goudsmit had respectively been appointed Mission Chief and Scientific Chief.

[...] Based on preliminary lists from the United States, much of the early definition of German intelligence targets was accomplished at the London headquarters with the assistance of British technical and intelligence personnel. Priorities were assigned to locations and personnel, and while later events proved some of the investigations to be unproductive, no important elements were missed as far as the interest in atomic energy was concerned. [...]

4-2. Paris Operations.

[...] Advance personnel of the ALSOS Mission entered Paris on August 1944, with leading elements of the Allied troops, and promptly secured initial targets. [...] Joliot [...] added very little to the knowledge already possessed by the Manhattan Project; however, the following items were clarified:

(1) The College de France (Joliot's laboratory) cyclotron had remained in service at that institution, although, at one time, the enemy had given some consideration to transporting it into Germany

(2) Schumann, Diebner, Bothe, Esau, Gentner, Bagge, and Maurer, all enemy personnel of interest to the Manhattan Project, had spent varying lengths of time during the war at the College de France laboratory, concerning themselves with the cyclotron operation. [...]

[...] ALSOS Mission reached Brussels, Belgium, on 5 September 1944. A Mr. Gaston André, in charge of uranium, at the main office of the Union Minière du Haut Katanga, was contacted. [...]

(1) Prior to the war a number of German firms had received uranium products from Belgium for normal peacetime application or retrade. The shipments had, in general, consisted of quantities of less than one ton per month of assorted refined materia.

(2) From June, 1940, until August, 1941, the Auer Gesellschaft, a well-known German chemical concern, which had not been a recipient prior to the war, suddenly became an outstanding consumer of uranium products. Auer received about 60 tons of refined material during that period. It was learned that a Dr. Ihwe was apparently in charge of purchases for the Auer company.

(3) The next large German shipment of interest was in November, 1941, and consisted of about nine tons of uranium products to [...] Degussa. [...]

(4) During June, 1942, unusually large amounts of uranium products were sent to "Roges, m.b.H". [...] Within this organization a Dr. Faust was in charge of uranium ores. The amounts of uranium products ordered by Roges consisted of about 115 tons of assorted refined and half refined materials. In addition they obtained 610 tons of crude material, 17 tons of ferro-uranium, and about 110 tons of impure products (rejects). Also, in January and May, 1943, respectively, 50 tons and 80 tons of refined products were delivered to them.

[...] During the preceding investigation at Brussels, a preliminary study of uranium stock, by the Union Minière du Haut Katanga, indicated that a quantity of material remained in Belgium. [...] The captured material, amounting to 68 tons, was placed under joint American and British control and removed from Belgium.

[...I]t was learned that nine carloads of uranium (approximate total net weight 72 tons) had been shipped, in advance of the German invasion, from Hoboken, Belgium to le Havre, France, in May, 1940. Reports indicated subsequent German seizure, at le Havre, of two of the nine carloads and the movement of the remainder to Bordeaux. [...] 30 tons of the reported material was found at the Poudrerie de Toulouse, in Toulouse. This material was secured and shipped from Marseilles to the United States. Investigation continued for the remaining 42 tons, but that particular search was not successful. [...]

4-3. Strasbourg Operation.

On 25 November 1944, advance military members of the ALSOS Mission joined the T-Force in Strasbourg.

[...] Concerning the interest of the Manhattan Project, four of the academic personal targets—Rudolf Fleischmann, Head of the Physics Department; Fritz Weygand, Head of the Chemistry Department; Hugo Neuert, Experimental Physicist; and Werner Maurer, Experimental Physicist, had such backgrounds and occupations as to warrant their separation from other internees and transfer, at a later date, to the United States. [...] Field interrogation of these individuals failed to confirm that any of them had engaged in direct research on a nuclear weapon, and their replies to repeated questioning actually provided little worth-while information. [...] In contrast to the meager information obtained from personal targets, the written matter located at Strasbourg served as a source of outstanding intelligence. [...] While the information was unclassified, through the mediums of notes of meetings, fragments of computations, protocols of experiments and vague hints in personal correspondence, a revealing picture of the German nuclear research program was presented.

[...] That evidence in a great measure modified the fear of enemy competition with the Manhattan Project, but it was still believed to be highly essential that those encouraging indications be confirmed beyond all possible doubt. [...] All of the foregoing information, after being subjected to an analysis by both the Manhattan District and the OSRD, resulted in a comprehensive report “TA Targets–German” [...] which served as a dependable guide for subsequent exploitation.

4-4. Heidelberg Operation.

[...] Professor Walther Bothe, Director, Physics Division of KWI for Medical Research, Heidelberg, was interrogated on 30 and 31 March [...]

(1) It was confirmed that Hahn had been evacuated to Tailfingen, and that Heisenberg and von Laue were at Hechingen.

(2) The installation, including the experimental uranium pile which was at Berlin-Gottow, had been removed to Haigerloch.

(3) A German shortage of heavy water was reported, and reference was made to the only production having been that in Norway.

(4) Professor Bothe listed the following as having worked on the nuclear physics phase of the uranium problem.

- (a) Himself, with three helpers
- (b) Heisenberg, with ten men
- (c) Döpel, in Leipzig, assisted by his wife only
- (d) Kirchner, in Garmisch, with possibly two men
- (e) Stetter, in Vienna, with four or five men

(5) Approval of Gerlach was required for physicists to secure means for scientific work, and if a “DE” (highest) priority was desired the additional approval of [Albert] Speer, Minister of War Production, had to be obtained.

(6) Bothe expressed his opinion that the separation of uranium isotopes by the thermal diffusion method was impossible. He indicated that the only work on isotope separation in Germany was being done by the centrifugal method under the direction of Harteck. Bothe was not aware of the location of this activity.

(7) Bothe believed that uranium hexafluoride was made by I.G. Farben, at Leverkusen.

(8) Bothe stated that no element higher than 93 was definitely known; however, he recognized that, as element 93 was a beta emitter, 94 must exist.

(9) Bothe repeatedly expressed his opinion that the uranium pile, as a source of energy, was decades from realization and that the use of uranium as an explosive was impracticable. He claimed not to know of any theoretical or experimental work being done in Germany on the military application of nuclear fission; but indicated that such work could be under way without his knowledge.

(10) After repeated questioning concerning the military value of the cyclotron, Bothe said it had been considered as a means of obtaining radioactive material for bombs.

(11) All secret documents in connection with his work were reported by Bothe to have been burned in accordance with government instructions.

[...] Dr. Wolfgang Gentner was interrogated on 1 April and, in general, confirmed the information given by Bothe. [...]

4-5. Frankfurt Operation.

On 31 March and 1 April, 1945, several of the Degussa plants were contacted and a number of the employees were interviewed. It was confirmed that Degussa had produced uranium metal under the name of “Spezialmetall”; however, personnel investigated professed indefinite knowledge concerning the use of the metal and the ultimate destinations to which it was shipped.

[...] Dr. Kohl, Works Manager, Degussa Plant No. 2, was interrogated on 3 April 1945, concerning the manufacture of “Spezialmetall”. According to him the material was required by the Reich’s Research Council (RFR) and all administrative matters were handled directly with RFR by Auer, in Oranienburg. Degussa acted as a sub-contractor for Auer and Kohl understood that deliveries of metal were made either to Auer or to the RFR, at Berlin-Dahlem. The use of the metal was secret, but Kohl believed it to be concerned with experiments in atomic physics. He stated that the material was manufactured, to a purity of 98 to 99 percent, from ammonium uranate which was converted to U_3O_8. The ammonium uranate was secured either from Joachimstahl or the Union Minière du Haut Katanga. Kohl referred to an early process where metallic uranium had been mixed with coal dust, with Tragacanth gum as a binding material, and pressed into blocks. The material was later delivered as powdered metallic uranium, production being between one and two tons. Kohl was emphatic that no deliveries of uranium were made to I. G. Farben Industrie. The Degussa plant, at Frankfurt, had been partially destroyed and parts of the equipment were reported to have initially been moved to a location in Mark Brandenburg, and later to the plant of the Chemische Fabrik Grünau at Berlin-Grünau. Approximately three tons of ammonium uranate were shipped with the equipment to Berlin-Grünau. It was reported that, prior to the war, about three tons per month of sodium uranate were used in the ceramic color business but that during the war such use had been prohibited.

[...] Dr. Baerwind, director of Degussa in charge of technical matters, was also interrogated at Frankfurt, on 3 April. Subject to the following comments Baerwind's statements in general confirmed those previously made by Kohl.

(1) While Baerwind was then a member of the Supervisory Board of Auer, nevertheless he was not familiar with the dealings between Auer and the nuclear scientists.

(2) Baerwind indicated his unfamiliarity with the technical details, and expressed his opinion that Kohl might also have been uninformed; however, he stated definitively that the uranium powder was not mixed with coal dust.

(3) Reference was made to Degussa production of from five to six tons per year of beryllium metal. Most of this material was reported to have been sent to Heraeus, for the manufacture of beryllium copper alloys, but a small amount had been sent to the RFR for experiments with radioactive materials.

(4) Baerwind believed that the "Spezialmetall", even under the secret handling, could have nothing to do with military weapons because the quantities involved were so small. He stated definitively that Degussa was the only manufacturer of uranium metal in Germany and that until 1944 the Frankfurt plant production constituted all of the Degussa production.

[...] In September, 1945, an account of the production of uranium metal by Degussa was obtained by the ALSOS Mission. This account was prepared by a Degussa employee (Völkel [...]) and presented production and shipping details as well as a description of the process employed. It revealed that the Frankfurt Plant No. 2 had handled about 12,8000 kg. of the material from 1940 to 1945. [...] The progress of the war had caused manufacture of uranium metal to be transferred from the Degussa, Frankfurt, plant to a factory at Berlin-Grünau. Production at Grünau started at the end of 1944. It was indicated that "Spezialmetall" had only been manufactured in quantities suitable for experimental purposes and that the purity of the product was not impressively high.

[...] The ALSOS Mission had learned that 11 tons of crude sodium uranate had been delivered to the Radium Chemie Companie, of Frankfurt, from Wirtschaftliche Forschungsgesellschaft, in July, 1943, and that information prompted a contact with the Frankfurt firm on 25 April, 1945. [...] Through questioning the Deputy Director of the firm it was learned that a stock of 11 tons of uranium products, ½ ton of Schmiedberg ore and a few drums of monazite sand were on hand. That material was confiscated. In addition to the material obtained, this operation proved to be of interest in providing evidence that the Joachimstahl mines were being worked and that the shortage of radium in Germany made it worth while to exploit the Schmiedeberg deposits. [...]

4-6. Stadtilm Operation.

[...] ALSOS team arrived at Stadtilm, Thuringen, on 12 April 1945, directly after fighting in the town had ceased. The laboratory and offices of Dr. Kurt Diebner were located in an old schoolhouse. It was found that the majority of the target personnel, together with their documents, materials and equipment, had been evacuated by the Gestapo, on 8 April, in order that they might carry on their work elsewhere. However, the following individuals, of interest to the ALSOS Mission, had been allowed to remain at Stadtilm: Hartwig, Physicist; Ebeling, Mechanic; Leimert, Librarian; Stuhlinger, Physicist; Pfetscher, Physicist; Berkei, Physicist; Ehlert, Office Manager; Seeger, Engineer; and Schutzmeister, Physicist.

[...] Gerlach was a frequent visitor at Stadtilm.

[...] The physics institute of the KWI and of the THS [Technische Hochschule] Berlin had been partially evacuated to Stadtilm about 6 months previously but, for some unknown reason, a number of the personnel had been extremely slow in the relocation.

[...] Documents, materials and equipment at Stadtilm consisted of: many files; 8 tons of uranium oxide; parts of a small low temperature pile; air liquefaction apparatus; heavy water equipment from Norway; counters; miscellaneous equipment; and an extensive physics laboratory.

For about four years [Dr. Berkei] had worked for the KWI for Physics, at Berlin-Dahlem and Berlin-Gottow, and later served as administrative assistant to Diebner. While, in his administrative capacity, he had not had the opportunity to learn of many of the technical details, nevertheless Berkei appeared to have a good overall picture of Diebner's work...

4-7. Göttingen Operation.

The subject of interest to the Manhattan Project was discussed with Professors Kopfermann and Houtermans, at Göttingen, on 17 April 1945. [...] Kopfermann and Houtermans had been only on the fringe of the German nuclear fission project and were unable to contribute additional intelligence of any particular consequence. [...]

4-8. Lindau Operation.

[...] Osenberg surrendered with some ceremony, making his personnel, files and the general establishment available for investigation. ALSOS scientific members began their examination of the Planning Board on the afternoon of 12 April, and continued with the interrogation of Osenberg, questioning of his personnel and study of his papers during the following three days. [...]

4-9. Celle Operation.

[...] Those Mission members entered Celle on 17 April and readily located the centrifuge laboratory. That laboratory was found to be under British guard. [...]

(1) The ultra-centrifuge experments, evacuated the preceding November from Hannover, were located within a spinning mill at Celle.

(2) The director of the activity, Harteck, was not present and was reported to be at Hamburg. Dr.

W. Groth was in charge of the Celle laboratory, together with Dr. Suhr and Dr. Faltings.

(3) The equipment consisted of a small-scale set-up. When working smoothly it was estimated to be capable of a production of 50 grams per day of enriched material. The enrichment was at best about 15 percent.

(4) The separation was done with gaseous UF_6. Groth discovered that it was possible to produce the gas directly from the oxide, without having to make metal first. This method had been patented by him, and the material was produced by I. G. Farben, at Leverkusen, in quantities of about 30 pounds per month.

(5) The oil used in the centrifuge contained powered sodium fluoride in suspension so as to saturate against the effect of UF_6.

(6) The centrifuge was manufactured by Anschütz Gesellschaft at Kiel.

(7) In general, the net result of the investigation was that it confirmed former investigations in revealing the nuclear energy effort in Germany to be on a relatively small scale.

4-10. Stassfurt Operation.

The ALSOS Mission investigation at Brussels, Belgium, in September 1944, revealed that certain quantities of Belgian uranium products had been removed to Germany. [...] Based upon that intelligence a considerable portion of the material was believed to have been delivered to a plant of the Wirtschaftliche Forschungsgesellschaft (WIFO), on the outskirts of Leopoldshall, near Stassfurt. That firm had been formed during the war as a storage agency for Roges. [...]

Removal of 260 truck loads of the material to the Hildesheim Air Strip was accomplished between 20 and 27 April. The material seized consisted of crude sodium uranate, refined products and ferro-uranium. The total weight was in the neighborhood of 1,000 metric tons. It was held at Hildesheim until 30 April, moved to Antwerp and then shipped to a location under Allied control.

4-11. Caterode and Nordhausen Operations.

Fragmentary information suggested material possibilities at Caterode and Nordhausen and these targets were visited with negative or minor results.

4-12. Haigerloch, Hechingen, Bisingen, and Tailfingen Operations.

Scientific members of the ALSOS Mission left Heidelberg on 23 April and proceeded to Haigerloch where it was found that the targets had been secured and placed under guard. Those members of the Mission then went directly to Hechingen.

At Hechingen, the branch of the KWI for Physics was located and secured. Important personnel apprehended consisted of von Weizsäcker, Wirtz, von Laue, Moliere, Hoecker, Hiby, Sauerwein, Gysae, Bagge, Korsching, Bopp, Fischer and Menzer. [...] The enemy personnel at first stated that all secret documents had been burned in accordance with a government order, but, later following the capture of a complete set of secret reports at Tailfingen, and after demands had been made, von Weizsäcker admitted that certain reports had been concealed in a cesspool. Those reports were recovered. Two new isotope separation experiments of interest were in progress at Hechingen—Bagge's velocity selector, and Korsching's diffusion apparatus. The facilities for both of these experiments were dismantled and evacuated.

[...] The experimental pile [at Haigerloch...] had been located in a cave. The pile did not contain metal or heavy water. It was photographed, dismantled and the cave laboratory destroyed by explosives. Approximately one and one-half tons of heavy water and one and one-half tons of uranium metal were subsequently found buried near Haigerloch. This material was evacuated to a more secure location.

On 24 April, Bisingen was taken and a research station (Forschungsstelle D) of the Kaiser-Wilhelm Gesellschaft was secured. Dällenbach, the Director, had gone to Switzerland in December 1944 but his assistant, Dr. Karl Weimer, was interrogated. Construction of a small experimental model of a 10,000,000 volt cyclotron had been started, and drawings, technical data and patent specifications were secured.

Tailfingen was captured on 24 April, and, with it, headquarters of the KWI Für Chemie. All members of Hahn's staff including Hahn, Mattauch, Strassmann, Erbacher, Klemm, Flammersfeld, Radoch, Seelmann-Eggebert, Waldmann, Wietig and others were located. The three groups of the KWI Für Chemie at Tailfingen were led respectively by Hahn, Mattauch and Erbacher.

Professor Hahn's group had been working on the separation, distribution and energy of the fission products of uranium. According to him the results of that work had all been published, even though it was originally treated as secret. [...] He stated that the development of an atomic bomb was not then possible, and had so been considered by the Germans since 1942. Hahn did, however, believe that the pile as a source of energy would be successfully developed in a few years. [...]

Dr. Erbacher assisted in an inspection of his laboratory where work was being done on the chemical separation of isotopes; on the protection of uranium from corrosion, and on the separation of an active element from its inactive isotopes. [...]

Dr. Mattauch's laboratory was then inspected. Work was being performed at that location on the mass-spectrographic method of fission-product (or isotope) analysis. One member of Mattauch's group had been working on a method of isotope separation by the electrolysis of a fused salt; however, such a method had not at that time proved feasible.

From the Manhattan Project viewpoint the above operations were the most important of the ALSOS Mission investigations of the German effort in nuclear development. Interrogation of the enemy scientists, study of the documents obtained and inspection of the experimental equipment added further confirmation to previous evidence and definitely revealed the extremely small-scale activity of the whole German uranium project. In view of the fact that this exploitation involved the main group of laboratories it could be appreciated that the German work was far behind that which had been accomplished in the United States. [...]

4-13. Urfeld and Munich Operations.

[...] The advance to Urfeld was resumed and on 3 May the ALSOS group was successful in contacting Heisenberg. Heisenberg was taken to Heidelberg on the next day.

The second ALSOS team had entered Munich on 1 May 1945, and located the residence of Gerlach. Gerlach was not at home, but was found at the Physics Laboratory of the University of Munich. [...] On 2 May, a portion of the ALSOS group went to Schongeising, located their target and evacuated Diebner, certain of his documents, and a quantity of uranium (previously evacuated by the Gestapo from the laboratory at Stadtilm), to Munich. On 3 May, Gerlach and Diebner together with the captured material were transferred to Heidelberg.

Heisenberg, Gerlach and Diebner were interrogated upon their arrival at Heidelberg. As was expected, the interrogations failed to produce any new positive information of interest to the Manhattan Project.

[...] Gerlach was merely in administrative charge of the nuclear physics project. He had a superficial knowledge of the status of the project but knew little of the technical details.

[...] Diebner was not cooperative and seemed to be rather antagonistic toward Heisenberg. Gerlach and Heisenberg were on very cordial terms with each other but appeared to consider Diebner an inferior scientist.

4-14. Hamburg Operation.

After the City of Hamburg had fallen into Allied hands, members of the ALSOS Mission went to that location, on 5 May 1945, to contact Professor P. Harteck.

[...] Harteck's statement was to the effect that after the initial research it was soon discovered that the development of a weapon was unlikely, if not entirely impossible. Emphasis was then placed on the production of energy from a uranium pile, but, in this connection also, he was of the opinion that there were numerous detailed questions which had to be solved before such a device could be successful.

[...] Harteck referred to a plan which had been considered to provide ultra-centrifuge machines, each of which was to produce above 180 kgs. of 1 percent enriched material per year. The centrifuges were planned to be located at Kandern, but the progress of the war prevented the work.

[...] Harteck had studied the production of heavy water and believed that his improved method would have made it possible to reach a production of almost 10 tons per year, at an appreciable reduction in the pre-war cost. It was stated that the Norsk-Hydro project was under the supervision of I. G. Farben.

4-15. Berlin Operation.

The Berlin location of the Kaiser-Wilhelm Institute for Physics was inspected on 30 July 1945. It was found that practically all of the laboratory equipment had been evacuated by the Russians. [...]

4-16. Vienna Operation.

Dr. C. P. Smyth and other members of the ALSOS Mission visited Vienna during the later part of August, 1945, and obtained information of the research carried out at the Physical Institute and the Radium Institute. Information of uranium materials taken by Russian investigators in May, 1945, as well as of the transportation to Moscow of Drs. Wombacker and Ortner, was obtained. Little additional useful intelligence of the German uranium projected resulted.

4-17. Overall Results and Termination of Western and Central European Investigations.

a. The rapid advance of the Allies in Germany caused difficulty in making thorough and deliberate investigations of many of the detailed items of enemy nuclear research. Nevertheless, all principal locations of that research activity were contacted, and, as of May, 1945, the ALSOS Mission had apprehended the following German scientific personnel of interest to the Manhattan Project:

- At Strasbourg.
  - Fleischmann
  - Weygand
  - Neuert
  - Maurer

- At Heidelberg.
  - Bothe
  - Kuhn
  - Gentner

- At Hechingen.
  - von Weizsäcker
  - Wirtz
  - von Laue
  - Moliere
  - Hoecker
  - Hiby
  - Sauerwein
  - Gysae
  - Bagge
  - Korsching
  - Bopp
  - Fischer
  - Menzer

- At Bisingen.
  - Weimer

- At Hamburg.
  - Harteck

- At Marburg.
  - Justi

- At Stadtilm.
  - Hartwig
  - Berkei

- At Göttengen.
  - Houtermans
  - Kofpermann

- At Lindau
  - Osenberg

- At Celle.
  - Groth

- At Tailfingen.
  - Hahn
  - Mattauch
  - Strassmann
  - Erbacher
  - Klemm
  - Flammersfeld
  - Radoch
  - Seelmann-Eggebert
  - Waldmann
  - Wietig

- At Urfeld.
  - Heisenberg

- At Munich
  - Gerlach

- At Schongeising
  - Diebner

Early in the German endeavor the uranium problem had been separately approached by a number of more or less competing groups. There was one group under Army Ordnance, another under the Kaiser-Wilhelm Institute for Physics, and still another under the Postal Department. A certain amount of bickering over the supply of material and a non-cooperative attitude in the exchange of information existed between those groups. The research efforts of the Postal Department amounted to little and did not continue for very long. [...] Many German scientists worked along their own lines and were not required to work at particular projects. Development of an atomic weapon was not believed to be possible.

As a consequence of the foregoing, atomic energy development in Germany did not pass beyond the laboratory stage; utilization for power production rather than for an explosive was the principal consideration; and, though German science was interested in this new field, other scientific objectives received greater official attention.

***The History of the CIC in the US Army* (30 Volumes). Volume VIII (*The CIC With Special Projects*). Part-III: *CIC With the ALSOS Mission*, pp. 116–130 [NARA RG 319, Entry UD-1080, Box 3]**

[This document generally gives the same information as the *Manhattan District History* previously quoted, but in much less detail. The few noteworthy exceptions are included below.]

[...] In December 1945 Lt Col George R. Eckman prepared a final report on the ALSOS Mission; it is from this document that the following history of CIC in the Mission has been extracted.[128]

128 "Final Report on the ALSOS Mission," prepared by Lt Col George R. Eckman, (Conf), is on file in the G2 Documents Lib, Pentagon, Wash DC.

[...] On 22 March, Colonel Pash led the ALSOS "spearhead" group into Ludwigshaven while the city was still being shelled by the enemy, who were holding their bridgehead on the west side of the Rhine to protect their retreat. The ALSOS party proceeded at once to the huge I. G. Farben Industries plant and secured guards for this important target from the armored unit driving through the city toward the Rhine. This major war plant was held by the ALSOS team and attached guards until the "T" Force moved in the next day.

[...] Other targets visited by members of the Northern Base during this closing period of the war in Europe included personnel and institutional objectives at Hamburg, Jena, Braunschweig, Clauthal, Halle, Erfurt, and Essen. In the early days of May, ALSOS investigators uncovered additional caches of uranium compounds and "heavy" water which had been hidden away by the Nazis in the Harz and the Bavarian Mountains.

[...] During the early planning stages of ALSOS in 1943 and early 1944, many potential Berlin targets had been evaluated and listed for ultimate examination. However, as ALSOS intelligence was collected in operations in the liberated countries and Western Germany, it became evident that Berlin would become an area of only secondary interest. Most high priority targets had already been discovered by the ALSOS teams.

As the Air Force continued to rain down high explosives on the city, many of the war research laboratories and bureaus of institutes and factories were evacuated or obliterated. Following the German surrender and the Soviet Occupation of Berlin, it was expected that what ALSOS targets remained had been thoroughly "worked over" by Russian intelligence agencies.

There were certain missing items, however, that ALSOS officials thought might be discovered among the rubble of Berlin, and Colonel Pash headed a party of 14 Mission members that entered Berlin on 28 July. Three weeks were spent in following investigative leads, including documents and personnel of the Kaiser Wilhelm Institute. The effort was well spent, for a number of additional facts were added to the ALSOS dossiers.

The Berlin Operation was the last major expedition of the Mission. Colonel Pash returned to Paris headquarters in the second week of August 1945.

[The Pentagon Library told me that they do not have a copy of Eckman's final report. Did the Pentagon Library actually lose the final report of one of their most famous missions? Can a copy of this report be located someplace?]

Leslie R. Groves. 1962. *Now It Can Be Told: The Story of the Manhattan Project.* New York: Harper.

[The three chapters on Alsos in Groves's book appear to be very closely based on the *Manhattan District History* quoted previously. The events, details, and wording of the sentences are all highly similar. The most noteworthy exceptions are included below.]

[pp. 196–197:] Thorium seemed out of the question, since it is mined chiefly in Brazil and India and, because of embargoes, Germany had been unable to import any since the war began, and had had only insignificant stocks on hand before the war. The basic fuel was thought to be uranium. Considering our own firsthand knowledge of the enormous industrial effort required to produce U-235, we were confident that we would have seen evidences of any such program had one existed. It seemed more likely that they would use plutonium. That they had enough to launch an atomic program seemed to be within the realm of possibility, for we knew there had been a large stockpile of refined uranium ore at Oolen, Belgium, a few miles outside Brussels, which originally had been the property of Union Minière.

The only other possible supply of uranium was the mines at Joachimsthal, Czechoslovakia, which was not a particularly significant source. Most of this ore was shipped to a uranium plant outside Berlin, the Auer-Gesellschaft. British Intelligence kept in touch with the activities of these mines, and in July, 1944, Calvert's group started periodic aerial surveillance over the entire mining area, studying the pictures in detail for new shafts and aboveground activity. Tailing piles from each mine were microscopically measured from one reconnaissance to the next. By knowing the general grade of the ore and measuring the piles, we could determine with some degree of accuracy the mine's daily production. There were no signs of extraordinary activity.

[pp. 230–231:] I have always considered Goudsmit's opinion much to the point: "On the whole, we gained the definite impression that German scientists did not support their country in the war effort. The principal thing was to obtain money from the government for their own researches, pretending that they might be of value to the war effort. One genuine selling point which they used extensively was that pure research in Germany in many fields was far behind the United States."

Although most of our objectives in Germany lay in the French zone of advance, one that was particularly important to us—the Auergesellschaft Works in Oranienburg, about fifteen miles north of Berlin—lay in what was to be the Russian zone. The information that Alsos had uncovered in Strasbourg had confirmed our earlier suspicions that the plant was engaged in the manufacture of thorium and uranium metals which were to be used in the production of atomic energy and hence probably for the manufacture of an atomic bomb. Since there was not even the remotest possibility that Alsos could seize the works I recommended to General Marshall that the plant be destroyed by air attack.

When he approved, I sent Major F. J. Smith, of my office, to explain the mission to General Carl Spaatz, who was then in command of our Strategic Air Forces in Europe. Spaatz co-operated wholeheartedly and, in the period of about thirty minutes during the afternoon of March 15, 612 Flying Fortresses of the Eighth Air Force dropped 1,507 tons of high explosives and 178 tons of incendiary bombs on the target. Poststrike analysis indicated that all parts of the plant that were aboveground had been completely destroyed.

[pp. 238–239:] [...O]n April 23, I handed the following memorandum to General Marshall:

> In 1940 the German Army in Belgium confiscated and removed to Germany about 1200 tons of uranium ore. So long as this material remained hidden under the control of the enemy, we could not be sure but that he might be preparing to use atomic weapons.
>
> Yesterday I was notified by cable that personnel in my office had located this material near Stassfurt, Germany, and that it was now being removed to a safe place outside of Germany where it would be under the complete control of American and British authorities.
>
> The capture of this material, which was the bulk of uranium supplies available in Europe, would seem to remove definitely any possibility of the Germans making any use of an atomic bomb in this war.

[pp. 245–246:] In the fall of 1944, Himmler's Security Service Organization apparently became interested in the atomic project and formed a War Research Pool, which remained under Göring to avoid duplication and useless work. Himmler's people did not seem to be entirely satisfied with progress under the National Research Council, however, and they subsequently proposed a plan to remove all obstacles to the project and obtain maximum results. Although this plan was sound, it came too late.

[p. 248:] After V-E Day, a number of searches for specific information and materials were conducted in various parts of Germany. Alsos sent groups to Berlin and Salzburg, but, by that time, I was no longer too much concerned with their work, beyond insuring that no information remained that might eventually fall into Russian hands. These operations only confirmed what we already knew and it was quite clear that there was nothing in Europe of further interest to us.

[In his book, Groves concealed most of his knowledge of and interactions with the German nuclear program.

For much more information on what really happened, see the files and sources in Section D.14.

As also shown in Section D.14, there are many further files that still remain classified even after all this time. People should advocate to have all files on this topic located, declassified, and released in archival collections around the world.]

D.1.2 Farm Hall Recordings

[Ten German nuclear scientists (Erich Bagge, Kurt Diebner, Walther Gerlach, Otto Hahn, Paul Harteck, Werner Heisenberg, Horst Korsching, Max von Laue, Carl Friedrich von Weizsäcker, and Karl Wirtz) rounded up by the Alsos Mission were kept under house arrest from July 1945 until January 1946 at Farm Hall in Great Britain, where their private conversations were recorded without their knowledge. The transcripts were not released to the public until 1992.]

Farm Hall transcripts [page numbers refer to Frank 1993; see also Bernstein 2001, Hoffmann 2023, and NARA RG 77, Entry UD-22A, Boxes 164–165.]

[Farm Hall Report 1, 6 July, soon after arrival, p. 33:]

DIEBNER: I wonder whether there are microphones installed here?

HEISENBERG: Microphones installed? (laughing) Oh no, they're not as cute as all that. I don't think they know the real Gestapo methods; they're a bit old fashioned in that respect.

[Farm Hall Report 2, 18 July, p. 46:]

WIRTZ: A man like GOUDSMIT doesn't really want to help us; he has lost his parents.

HARTECK: Of course GOUDSMIT can't forget that we [Germans] murdered his parents. That's true too and it doesn't make it easy for him.

DIEBNER: I would imagine that we will be given more freedom the moment the Russians say: "We agree, you will take over the scientists". They are negotiating with the Russians as to who shall be handed over to Russia and who shall not. Presumably that is being discussed in Berlin now.

[Farm Hall Report 2, 21 July, pp. 55–57:]

BAGGE: For the sake of the money, I should like to work on the Uranium-engine; on the other hand, I should like to work on cosmic rays. I feel like DIEBNER about this.

KORSCHING: Would you both like to construct a Uranium-engine?

DIEBNER: This is the chance to earn a living.

KORSCHING: Every layman can see that these ideas are exceedingly important. Hence there won't be any money in it. You only make money on ideas which have escaped the general public. If you invent something like artificial rubies for the watch making industry, you will make more money than with the Uranium-engine. Well, DIEBNER, we'll both go to the Argentine.

DIEBNER: I shall come with you. [...]

KORSCHING: Still, I should like to get to HECHINGEN once more to collect the rest of my things. After all I still have all my books there and the telescope—though mind you I have hidden it from the French. Of course I did not hand that over. I have got all my glass prisms, lenses, etc. I lifted a floorboard, hid the stuff and nailed the board down again. [...]

KORSCHING: [Talking to BAGGE...] (DIEBNER leaves the room) If you work together with HEISENBERG on a Uranium-engine, then you can write off your share. If you want to work on a Uranium-engine, then you would have to do it somewhere else. Of course it would be an idea to go to the Argentine with 2 people and say: “Here we are, we know how to do this and that; we have a good method for the separation of isotopes, we do not need to produce heavy water.” Somehow in this fashion we have to do it. It would not come to anything if you collaborated with HEISENBERG on a Uranium-engine. They did not even bring along the small fry to this place; that is how outsiders judge the work. They get there and read all the secret reports before they take the people away from there.

BAGGE: How long before did they have the secret reports?

KORSCHING: Two or three days before. The principal question which GOUDSMIT put to me, was “Is that your idea? Has that been published already is that anything new?”—that is all he wanted to know. And BOPP and FISCHER they just ignore one and say “Oh well, they just made some calculations for HEISENBERG.” Apart from that for instance, the ordering of apparatus from the firms and all the other various things which we have done, WIRTZ just told him (GOUDSMIT): “I have done that.” Do you think WIRTZ is going to be modest in front of Mr. GOUDSMIT? No [...] And that is how WIRTZ has excluded them. GOUDSMIT takes his word for it. BOPP was quite disgusted and astonished that suddenly he was dropped like that. And that is how it is all over the world. A scientist is asked “What have you thought out, where is your idea?” If you then make the strategic mistake of moving in the shadow of a man who is already world famous, then you are out of the limelight for the rest of your life and if you then raise your voice against that, then on top of it you will be called a trouble maker.

[Farm Hall Report 2, 30 July, p. 50:]

HAHN: I read an article in the Picture Post about the Uranium bomb; it said that the newspapers had mentioned that such a bomb was being made in Germany. Now you can understand that we are being “detained” because we are such men. They will not let us go until they are absolutely certain that no harm can be done or that we will not fall into Russian hands or anything like that. To my mind it is a mistake to do anything. [...]

[Farm Hall Report 3, 5 August, p. 68:]

DIEBNER: It doesn’t look as though BOTHE will join us.

BAGGE: I think GEHLEN (?) is behind it. It looks as though GEHLEN (?) had the decency to keep BOTHE informed of what was going on so that BOTHE could make his plans as far as these people are concerned and act accordingly. [...]

DIEBNER: In the end we really had no more radium. There was an awful row as someone wanted some. I fetched another 3 grammes at the last moment.

BAGGE: Didn't firms like BRAUNSCHWEIGISCHE CHEMIEFABRIK have any more?

DIEBNER: I don't know. They may have had 1 gramme; all the rest had been requisitioned by the State. I got mine from the HARZ, I sent a car specially for it.

BAGGE: That was the Reichsstelle for radium?

DIEBNER: Yes, the Reichsstelle for Chemistry had the radium—25 g (?).

BAGGE: It's a pity they didn't hide 10 grammes out of the 24 grammes.

DIEBNER: I wasn't there. If I had been there we wouldn't have handed it over. The cars drove up and it disappeared. A pity, I had made up my mind not to hand it over.

[Farm Hall Report 4, 6 August discussion after learning of Hiroshima, pp. 70–79:]

HAHN: They can only have done that if they have uranium isotope separation.

WIRTZ: They have it too.

HAHN: I remember SEGRE's, DUNNING's and my assistant GROSSE's work; they had separated a fraction of a milligramme before the war, in 1939.

LAUE: 235?

HAHN: Yes, 235.

HARTECK: That's not absolutely necessary. If they let a uranium engine run, they separate "93".

HAHN: For that they must have an engine which can make sufficient quantities of "93" to be weighed.

GERLACH: If they want to get that, they must use a whole ton. [...]

GERLACH: They have got "93" and have been separating it for two years, somehow stabilised it at low temperature and separated "93" continuously.

HAHN: But you need the engine for that.

DIEBNER: We always thought we would need two years for one bomb. [...]

HEISENBERG: I still don't believe a word about the bomb but I may be wrong. I consider it perfectly possible that they have about ten tons of enriched uranium, but not that they can have ten tons of pure U. 235.

HAHN: I thought that one needed only very little 235.

HEISENBERG: If they only enrich it slightly, they can build an engine which will go but with that they can't make an explosive which will—

HAHN: But if they have, let us say, 30 kilogrammes of pure 235, couldn't they make a bomb with it?

HEISENBERG: But it still wouldn't go off, as the mean free path is still too big.

HAHN: But tell me why you used to tell me that one needed 50 kilogrammes of 235 in order to do anything. Now you say one needs two tons.

HEISENBERG: I wouldn't like to commit myself for the moment, but it is certainly a fact that the mean free paths are pretty big. [...]

HARTECK: Do you want 4 or 5 centimetres,—then it would break up on the first or second collision.

HEISENBERG: But it needn't have the diameter of only 4 or 5 centimetres.

HAHN: I think it's absolutely impossible to produce one ton of uranium 235 by separating isotopes.

WEIZSACKER: What do you do with these centrifuges.

HARTECK: You can never get pure 235 with the centrifuge. But I don't believe that it can be done with the . . . centrifuge.

WIRTZ: No, certainly not.

HAHN: Yes, but they could do it too with the mass-spectrographs. EWALD has some patent.

DIEBNER: There is also a photo-chemical process. [...]

WIRTZ: I would bet that it is a separation by diffusion with recycling. [...]

HARTECK: They have managed it either with mass-spectrographs on a large scale or else they have been successful with a photo-chemical process.

WIRTZ: Well I would say photo-chemistry or diffusion. Ordinary diffusion. They irradiate it with a particular wave-length.—(all talking together).

HARTECK: Or using mass spectrographs in enormous quantities. It is perhaps possible for a mass-spectrograph to make one milligramme in one day—say of "235". They could make quite a cheap mass-spectrograph which, in very large quantities, might cost a hundred dollars. You could do it with a hundred thousand mass-spectrographs.

HEISENBERG: Yes, of course, if you do it like that; and they seem to have worked on that scale. 180,000 people were working on it.

HARTECK: Which is a hundred times more than we had.

BAGGE: GOUDSMIT led us up the garden path.

HEISENBERG: Yes, he did that very cleverly. [...]

KORSCHING: That shows at any rate that the Americans are capable of real cooperation on a tremendous scale. That would have been impossible in Germany. Each one said that the other was unimportant.

GERLACH: You really can't say that as far as the uranium group is concerned. You can't imagine any greater cooperation and trust than there was in that group. You can't say that any one of them said that the other was unimportant.

KORSCHING: Not officially of course.

GERLACH: (Shouting). Not unofficially either. Don't contradict me. There are far too many other people here who know. [...]

WEIZSACKER: How many people were working on the V 1 and V 2?

DIEBNER: Thousands worked on that. [...]

HARTECK: Considering the figures involved I think it must have been mass-spectrographs. If they had had some other good method they wouldn't have needed to spend so much. One wouldn't have needed so many men. [...]

HEISENBERG: I must say I think your theory is right and that it is spectrographs.

WIRTZ: I am prepared to bet that it isn't.

HEISENBERG: What would one want 60,000 men for?

KORSCHING: You try and vaporise one ton of uranium.

HARTECK: You only need ten men for that. I was amazed at what I saw at I.G.

HEISENBERG: It is possible that the war will be over tomorrow.

HARTECK: The following day we will go home.

KORSCHING: We will never go home again.

HARTECK: If we had worked on an even larger scale we would have been killed by the "Secret Service". Let's be glad that we are still alive. Let us celebrate this evening in that spirit.

DIEBNER: Professor GERLACH would be an Obergruppenführer and would be sitting in LUXEMBOURG as a war criminal. [...]

WEIZSACKER: If you had wanted to a make a bomb we would probably have concentrated more on the separation of isotopes and less on heavy water.

(HAHN leaves the room)

WEIZSACKER: If we had started this business soon enough we could have got somewhere. If they were able to complete it in the summer of 1945, we might have had the luck to complete it in the winter of 1944/45.

WIRTZ: The result would have been that we would have obliterated LONDON but would still not have conquered the world, and then they would have dropped them on us. [...]

HARTECK: The uranium content in the stone in the radium mines near GASTEIN was said to be so great that the question of price does not come into it.

BAGGE: There must be enormous quantities of uranium in UPPER SILESIA. Mining experts have told me that.

DIEBNER: Those are quite small quantities. [...]

HEISENBERG: About a year ago, I heard from SEGNER (?) from the Foreign Office that the Americans had threatened to drop a uranium bomb on Dresden if we didn't surrender soon. At that time I was asked whether I thought it possible, and, with complete conviction, I replied: "No."

WIRTZ: I think it characteristic that the Germans made the discovery and didn't use it, whereas the Americans have used it. I must say I didn't think the Americans would dare to use it.

Top Secret cable 70221 from U.S. Military Attaché London England to War Department. 25 January 1946 [NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret January 1946 thru December 1946]

Signed Tindall to MILID serial nbr 70221 TOP SECRET Loco personal to Groves for Shuler from Dean

Conference held yesterday afternoon at War Cabinet Office on disposition of GUESTS. [...]

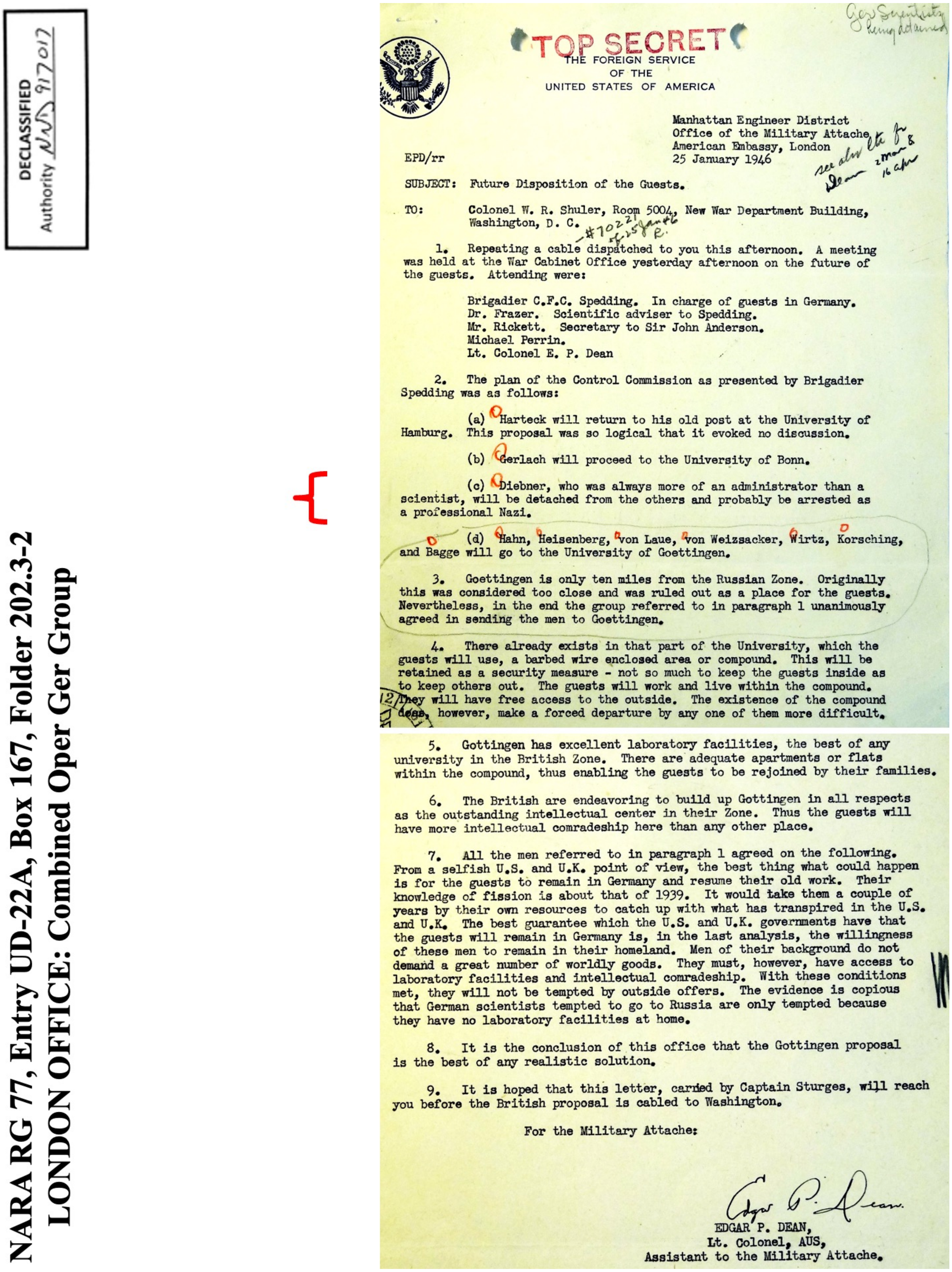
(A) Harteck to return to his old position University of Hamburg. This proposal so logical it evoked no discussion.

(B) Gerlach to proceed to University of Bonn.

(C) Diebner more of an administrator than scientist will be detached and probably arrested as professional Nazi.

(D) Hahn, Heisenberg, Von Laue, Von Weizsäcker, Bagge, Korsching and Wirtz go to University of Göttingen. [...]

[See the related document on p. 3342.]



DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 167, Folder 202.3-2
LONDON OFFICE: Combined Oper Ger Group

Ger Scientists being detained

TOP SECRET

THE FOREIGN SERVICE
OF THE
UNITED STATES OF AMERICA

Manhattan Engineer District
Office of the Military Attache
American Embassy, London
25 January 1946

see also ltr fr Dean 2 Mar & 16 Apr

EPD/rr

SUBJECT: Future Disposition of the Guests.

TO: Colonel W. R. Shuler, Room 5004, New War Department Building, Washington, D. C.

-#7022 f. 25 Jan 46 R.

1. Repeating a cable dispatched to you this afternoon. A meeting was held at the War Cabinet Office yesterday afternoon on the future of the guests. Attending were:

Brigadier C.F.C. Spedding. In charge of guests in Germany.
Dr. Frazer. Scientific adviser to Spedding.
Mr. Rickett. Secretary to Sir John Anderson.
Michael Perrin.
Lt. Colonel E. P. Dean

2. The plan of the Control Commission as presented by Brigadier Spedding was as follows:

(a) Harteck will return to his old post at the University of Hamburg. This proposal was so logical that it evoked no discussion.

(b) Gerlach will proceed to the University of Bonn.

(c) Diebner, who was always more of an administrator than a scientist, will be detached from the others and probably be arrested as a professional Nazi.

(d) Hahn, Heisenberg, von Laue, von Weizsacker, Wirtz, Korsching, and Bagge will go to the University of Goettingen.

3. Goettingen is only ten miles from the Russian Zone. Originally this was considered too close and was ruled out as a place for the guests. Nevertheless, in the end the group referred to in paragraph 1 unanimously agreed in sending the men to Goettingen.

4. There already exists in that part of the University, which the guests will use, a barbed wire enclosed area or compound. This will be retained as a security measure - not so much to keep the guests inside as to keep others out. The guests will work and live within the compound. They will have free access to the outside. The existence of the compound does, however, make a forced departure by any one of them more difficult.

5. Gottingen has excellent laboratory facilities, the best of any university in the British Zone. There are adequate apartments or flats within the compound, thus enabling the guests to be rejoined by their families.

6. The British are endeavoring to build up Gottingen in all respects as the outstanding intellectual center in their Zone. Thus the guests will have more intellectual comradeship here than any other place.

7. All the men referred to in paragraph 1 agreed on the following. From a selfish U.S. and U.K. point of view, the best thing what could happen is for the guests to remain in Germany and resume their old work. Their knowledge of fission is about that of 1939. It would take them a couple of years by their own resources to catch up with what has transpired in the U.S. and U.K. The best guarantee which the U.S. and U.K. governments have that the guests will remain in Germany is, in the last analysis, the willingness of these men to remain in their homeland. Men of their background do not demand a great number of worldly goods. They must, however, have access to laboratory facilities and intellectual comradeship. With these conditions met, they will not be tempted by outside offers. The evidence is copious that German scientists tempted to go to Russia are only tempted because they have no laboratory facilities at home.

8. It is the conclusion of this office that the Gottingen proposal is the best of any realistic solution.

9. It is hoped that this letter, carried by Captain Sturges, will reach you before the British proposal is cabled to Washington.

For the Military Attache:

Edgar P. Dean.
EDGAR P. DEAN,
Lt. Colonel, AUS,
Assistant to the Military Attache.

Figure D.42: Edgar P. Dean to W. R. Shuler. 25 January 1946 [NARA RG 77, Entry UD-22A, Box 167, Folder 202.3-2 LONDON OFFICE: Combined Oper Ger Group].
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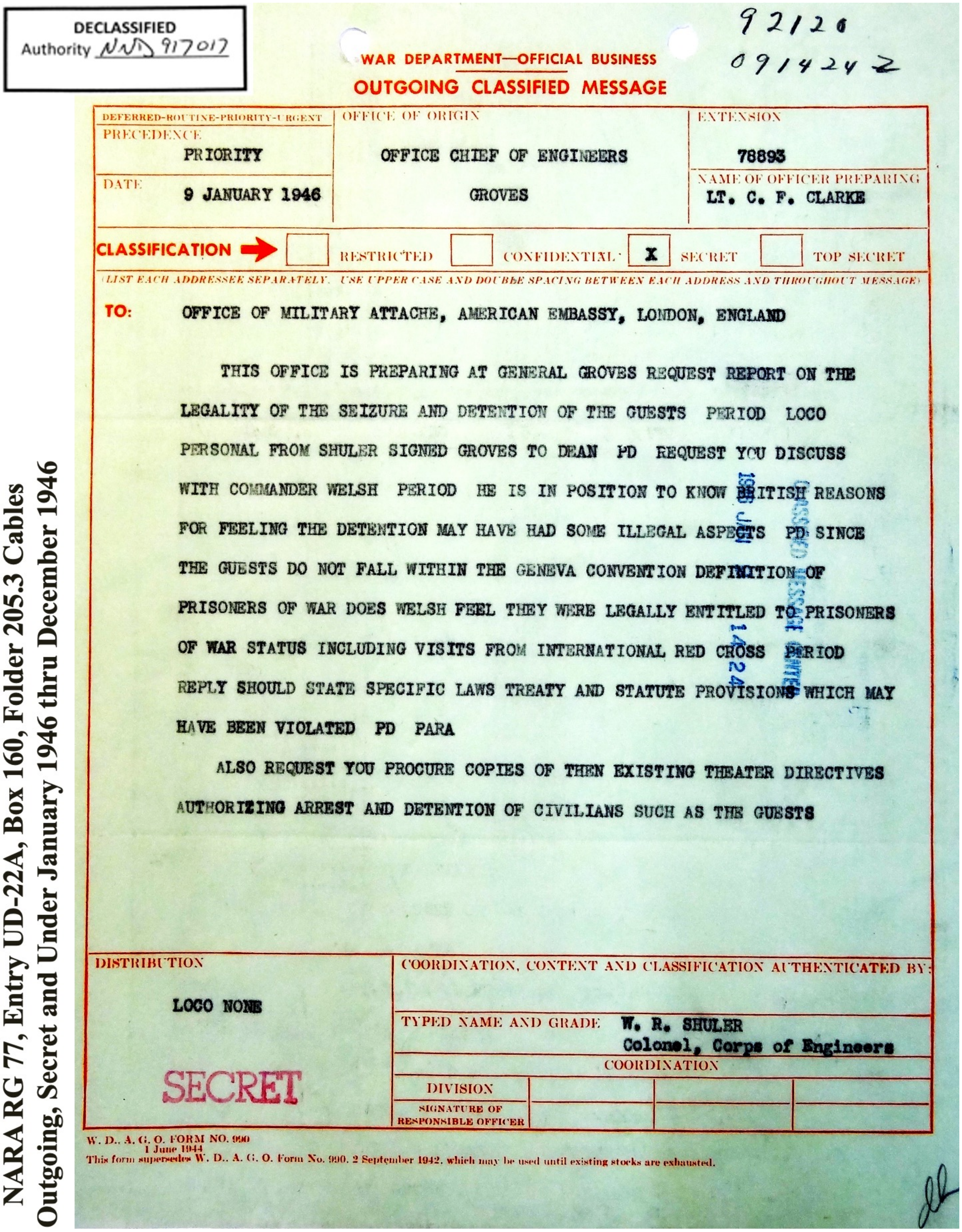

DECLASSIFIED
Authority NND 917017

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WAR DEPARTMENT—OFFICIAL BUSINESS
OUTGOING CLASSIFIED MESSAGE

DEFERRED-ROUTINE-PRIORITY-URGENT PRECEDENCE PRIORITY	OFFICE OF ORIGIN OFFICE CHIEF OF ENGINEERS	EXTENSION 78893
DATE 9 JANUARY 1946	GROVES	NAME OF OFFICER PREPARING LT. C. F. CLARKE

CLASSIFICATION ☐ RESTRICTED ☐ CONFIDENTIAL ☒ SECRET ☐ TOP SECRET

(LIST EACH ADDRESSEE SEPARATELY. USE UPPER CASE AND DOUBLE SPACING BETWEEN EACH ADDRESS AND THROUGHOUT MESSAGE)

TO: OFFICE OF MILITARY ATTACHE, AMERICAN EMBASSY, LONDON, ENGLAND

THIS OFFICE IS PREPARING AT GENERAL GROVES REQUEST REPORT ON THE LEGALITY OF THE SEIZURE AND DETENTION OF THE GUESTS PERIOD LOCO PERSONAL FROM SHULER SIGNED GROVES TO DEAN PD REQUEST YOU DISCUSS WITH COMMANDER WELSH PERIOD HE IS IN POSITION TO KNOW BRITISH REASONS FOR FEELING THE DETENTION MAY HAVE HAD SOME ILLEGAL ASPECTS PD SINCE THE GUESTS DO NOT FALL WITHIN THE GENEVA CONVENTION DEFINITION OF PRISONERS OF WAR DOES WELSH FEEL THEY WERE LEGALLY ENTITLED TO PRISONERS OF WAR STATUS INCLUDING VISITS FROM INTERNATIONAL RED CROSS PERIOD REPLY SHOULD STATE SPECIFIC LAWS TREATY AND STATUTE PROVISIONS WHICH MAY HAVE BEEN VIOLATED PD PARA

ALSO REQUEST YOU PROCURE COPIES OF THEN EXISTING THEATER DIRECTIVES AUTHORIZING ARREST AND DETENTION OF CIVILIANS SUCH AS THE GUESTS

1946 JAN 9 14 24
CLASSIFIED MESSAGE CENTER

DISTRIBUTION
LOCO NONE

SECRET

COORDINATION, CONTENT AND CLASSIFICATION AUTHENTICATED BY:
TYPED NAME AND GRADE W. R. SHULER
Colonel, Corps of Engineers

COORDINATION
DIVISION
SIGNATURE OF RESPONSIBLE OFFICER

W. D., A. G. O. FORM NO. 990
1 June 1944
This form supersedes W. D., A. G. O. Form No. 990, 2 September 1942, which may be used until existing stocks are exhausted.

NARA RG 77, Entry UD-22A, Box 160, Folder 205.3 Cables Outgoing, Secret and Under January 1946 thru December 1946

Figure D.43: W. R. Shuler to Office of Military Attaché London. 9 January 1946 [NARA RG 77, Entry UD-22A, Box 160, Folder 205.3 Cables Outgoing, Secret and Under January 1946 thru December 1946]. Even the officials responsible for imprisoning and secretly recording ten civilians for six months with no charges, no judicial process, and no International Red Cross visitation stated in writing that they were concerned the operation was illegal. That raises interesting questions, such as whether the modern families of those ten civilians might be entitled to financial and legal restitution from the U.K. and U.S. governments.

[The Farm Hall transcripts record the scientists' surprise at news of the 6 August 1945 Hiroshima bombing and do not reveal significant apparent knowledge of nuclear weapons design and development. Proponents of the conventional history use that evidence to argue that the German nuclear program never attempted or accomplished much. However, that argument assumes that all of the following three conditions are true:

1. It assumes that these ten scientists knew all of the details of the German nuclear program. Wartime German programs such as the nuclear work, chemical weapons development, and other advanced military programs were highly secretive and compartmentalized, such that each individual scientist knew only what they needed to know in order to do their job. Max von Laue does not appear to have even been involved in the wartime nuclear program, and some of the others may not have played major roles in it.

2. It assumes that the scientists were telling the truth and the whole truth in their recorded conversations. These scientists had just survived more than a decade in Germany where secret SS informers and hidden microphones were commonplace, so that they had had to be very careful with their words at all times in order to survive. Almost immediately after arriving at Farm Hall, Diebner openly speculated to the other scientists that there could be microphones there. Later, Hahn stated that the German scientists would only be released if the Allies were convinced that they were harmless. Still later, Harteck said they would be killed if the Allies thought they had done "larger scale" work. Diebner said they would be tried as war criminals if that were the case. The 25 January 1946 cable demonstrates that even at the end of the Farm Hall internment, Allied officials were still formally debating which if any of the German scientists to put on trial. In addition to the Germans' open acknowledgement of the possibility that microphones might be present, presumably they would have been very cognizant that their British hosts might overhear their conversations, or even that some of their own members (such as von Laue or others) might give the British information about the others' conversations. Thus it would be reasonable to assume that the scientists withheld a great deal of useful information from their conversations, or even gave false information to make themselves appear as naive as possible for any audience that might be listening.

3. It assumes that the published Farm Hall transcripts contain all relevant conversations. However, the transcripts give just a small faction of the conversations that would have occurred with ten scientists interacting among themselves and with their British hosts on a daily basis over a period of six months. The original tapes were reused for new recordings and consequently unavailable. Even the original German conversations are unavailable—all that survives in the written transcripts are English translations of those conversations. It is possible that the scientists found locations or methods for conversing that were not recorded. Finally, if a particular conversation had revealed an advanced German nuclear program, would that conversation have been released with the other transcripts (which were all classified until 1992), or might it have been handled differently and remain classified to this day?

For comparison, imagine that after World War II, ten scientists from the United States (a few who had held significant positions in the Manhattan Project but most who had not) were captured by Soviet forces and held for six months in a house in Moscow that they knew was bugged. Imagine that those captured scientists deeply feared that if they said the wrong thing, they could be forced to work in the Soviet Union for the rest of their lives, be imprisoned for the rest of their lives, or be executed as war criminals. No credible scholars would expect the resulting transcripts to be a complete and accurate account of all people, places, and work that had been involved in the entire

Manhattan Project. Likewise no credible scholars should expect the Farm Hall transcripts to be a complete and accurate account of all people, places, and work that had been involved in the entire German nuclear program.

Hahn complained that during that war, Heisenberg used to say "that one needed 50 kilogrammes of 235 in order to do anything" (which is a very good value for the required mass of U-235 without implosive compression; the U.S. Little Boy bomb used 64 kg of 80% U-235), but that in Allied custody Heisenberg had changed to saying he thought it was two tons. This seems to be a good example of the German scientists making their Allied interrogators believe that the wartime work was much less advanced than it actually was.

The conventional historical view is that roughly 100 or fewer people worked on the German nuclear program. Harteck seemed to indicate that he knew of approximately 1800 people working on the program, and there may have been many others of whom he was not aware.

The scientists remarked that Samuel Goudsmit was very prejudiced because his parents had been killed in the Holocaust. They were surprised that Goudsmit simply asked each scientist what work he had done and just "takes his word for it."

Harteck said that one ton of uranium could be vaporized for enrichment by as few as ten men, saying that he was "amazed at what [he] saw at I.G." Farben. What did he see? Which I.G. Farben facility was that? Did I.G. Farben have a large-scale uranium enrichment program, or technologies that could have been readily adapted to large-scale enrichment? Note that as soon as Harteck brought up this mysterious large-scale activity at I.G. Farben, the other scientists immediately changed the subject.

For more information on the development in the German-speaking world of a "photochemical process" for isotope separation that requires irradiation "with a particular wavelength," see p. 3664.]

D.1.3 Postwar Public Statements by a Few German Nuclear Scientists

[In their public interviews and writings in the years after the war, German scientists professed a lack of desire, plans, materials and/or political support to produce nuclear weapons for the Third Reich [Cassidy 1992; Heisenberg 1953, 1971; Irving 1967; Powers 1993; NYT 1948-12-28 p. 10].

However, only a small number of nuclear scientists went on the public record. It is not clear how much of what they said was factual history versus personal spin meant to avoid postwar criticism; the answer may vary for different scientists in question. Certainly it would have been in their best personal interests to downplay their support for weapons-related work as much as possible.

Based on these postwar statements, as well as the Alsos and Farm Hall reports, history books for the last 75+ years have primarily focused on Werner Heisenberg's KWI research group without sufficiently considering other groups, and have concluded that Germany never even made a serious attempt to build an atomic bomb, let alone made significant progress toward one. The greatest difference among these books is where they fall on a spectrum ranging from viewing the German scientists' motives and competence more favorably [e.g., Irving 1967; Powers 1993], in relatively neutral terms [e.g., Walker 1989, 1995, 2020, 2024a, 2024b], or less favorably [e.g., Goudsmit 1947; Rose 1998].]

Werner Heisenberg. 1971. *Physics and Beyond: Encounters and Conversations*. New York: Harper & Row. pp. 182–183.

In the autumn of 1941, when we thought we had a fairly clear picture of the technical possibilities, we asked the German Embassy in Copenhagen to arrange a public lecture for me there. I think I arrived in Denmark in October 1941, and when I visited Niels in his home in Carlsberg, I did not broach the dangerous subject until we took our evening walk. Since I had reason to think that Niels was being watched by German agents, I spoke with the utmost circumspection. I hinted that it was now possible in principle to build atom bombs, but that a tremendous technological effort was needed, and that physicists ought perhaps to ask themselves whether they should work in this field at all. Unfortunately, as soon as I mentioned the mere possibility of making atom bombs, Niels became so horrified that he failed to take in the most important part of my report, namely, that an enormous technical effort was needed. Now this, to me, was so important precisely because it gave physicists the possibility of deciding whether or not the construction of atom bombs should be attempted. They could either advise their governments that atom bombs would come too late for use in the present war, and that work on them therefore detracted from the war effort, or else contend that, with the utmost exertions, it might just be possible to bring them into the conflict. Both views could be put forward with equal conviction, and, in fact, during the war it turned out that even in America, where conditions were incomparably more favorable for the attempt than in Germany, the atom bomb was not made ready before V-E Day.

Niels, as I have said, was so horrified by the very possibility of producing atomic weapons that he did not follow the rest of my remarks. Perhaps he was also too filled with justifiable bitterness at the brutal occupation of his country by German troops to entertain any hopes of international understanding among physicists. I found it most painful to see how complete was the isolation to which our policy had brought us Germans, and to realize how war can cut into even the most long-standing friendships, at least for a time.

Despite this failure of my mission to Copenhagen, the German "uranium club" was in a relatively simple situation. The government decided (in June 1942) that work on the reactor project must be continued, but only on a modest scale. No orders were given to build atom bombs, and none of us had cause to call for a different decision. As a result, our work helped to pave the way for a peaceful atomic technology in the postwar period, and as such it was to bear useful fruits, despite and after all the destruction.

[Heisenberg's postwar claims that Germany never attempted to develop nuclear weapons are disproven by:

- Niels Bohr's letter below.
- Heisenberg's 1942 presentation to German government and military officials informing them that a uranium-235 or plutonium bomb with a fission pit about the size of a pineapple could destroy a large Allied city and could be built within two years if sufficient resources were allocated (pp. 3350– 3351).
- Photos from 1943 of Hitler with Heisenberg and other nuclear scientists who were working on a high-priority project for the war (pp. 3877–3879).
- The 15 September 1945 final report by the joint chairs of CIOS, U.S. General Thomas Jeffries Betts, Deputy G-2 of SHAEF, and U.K. Ministry of Supply chief advisor and F.R.S. Professor Reginald Patrick Linstead: "Authorities stated that KWI had repeatedly assured Hitler that an atomic explosive would be available for use within a comparatively short time" (p. 5030).
- Hundreds of other documents quoted or cited throughout the rest of this appendix.]

Unsent draft letter from Niels Bohr to Werner Heisenberg, undated (circa 1958). [Document 1 at: https://www.nbarchive.dk/collections/bohr-heisenberg/documents/ See also other Bohr letters to the same effect at that website.]

[...] Personally, I remember every word of our conversations, which took place on a background of extreme sorrow and tension for us here in Denmark. In particular, it made a strong impression both on Margrethe and me, and on everyone at the Institute that the two of you spoke to, that you and Weizsäcker expressed your definite conviction that Germany would win and that it was therefore quite foolish for us to maintain the hope of a different outcome of the war and to be reticent as regards all German offers of cooperation. I also remember quite clearly our conversation in my room at the Institute, where in vague terms you spoke in a manner that could only give me the firm impression that, under your leadership, everything was being done in Germany to develop atomic weapons and that you said that there was no need to talk about details since you were completely familiar with them and had spent the past two years working more or less exclusively on such preparations. I listened to this without speaking since [a] great matter for mankind was at issue in which, despite our personal friendship, we had to be regarded as representatives of two sides engaged in mortal combat. That my silence and gravity, as you write in the letter, could be taken as an expression of shock at your reports that it was possible to make an atomic bomb is a quite peculiar misunderstanding, which must be due to the great tension in your own mind. [...] If anything in my behaviour could be interpreted as shock, it did not derive from such reports but rather from the news, as I had to understand it, that Germany was participating vigorously in a race to be the first with atomic weapons.

Besides, at the time I knew nothing about how far one had already come in England and America, which I learned only the following year when I was able to go to England after being informed that the German occupation force in Denmark had made preparations for my arrest.

Document Section, Third Army, Freising, Bavaria. 1945 translation. Memo on a letter re Heisenberg from Himmler to the SS Dozentenführer in Leipzig (in the files at Freising). [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)]

Memo on a letter re Heisenberg from Himmler to the SS Dozentenführer in Leipzig (in the files at Freising)

1. Himmler thanks and congratulates the Leipzig SD for the very thorough and accurate report on Heisenberg.

2. While it is evident that Heisenberg's attitude (I think he used the word "Anshauung") was not exactly in line with that prescribed by the party, I (Himmler) regard him as essentially decent (anständig), and want the SS and SD organizations in Leipzig and the University informed of that fact.

3. In view of his comparative youth and influence and ability to attract future scientists (Nachwuchs), we cannot permit ourselves to remove or to kill him. (können wir uns es nicht erlauben diesen Mann beiseite zu setzen oder zu töten.)

4. It would be highly desirable to get Heisenberg to write a scientific article for one of the publications of the SS. Dr. Wüst is probably the best person to approach him on this subject.

5. It is hoped that Heisenberg can ultimately be brought to work with us, possibly within the framework on the Ahnenerbe.

[See document photo on p. 3349.

This document does not indicate the date of the Himmler letter it is translating, but that was probably July 1938; see for example Powers 1993, pp. 41–43.]

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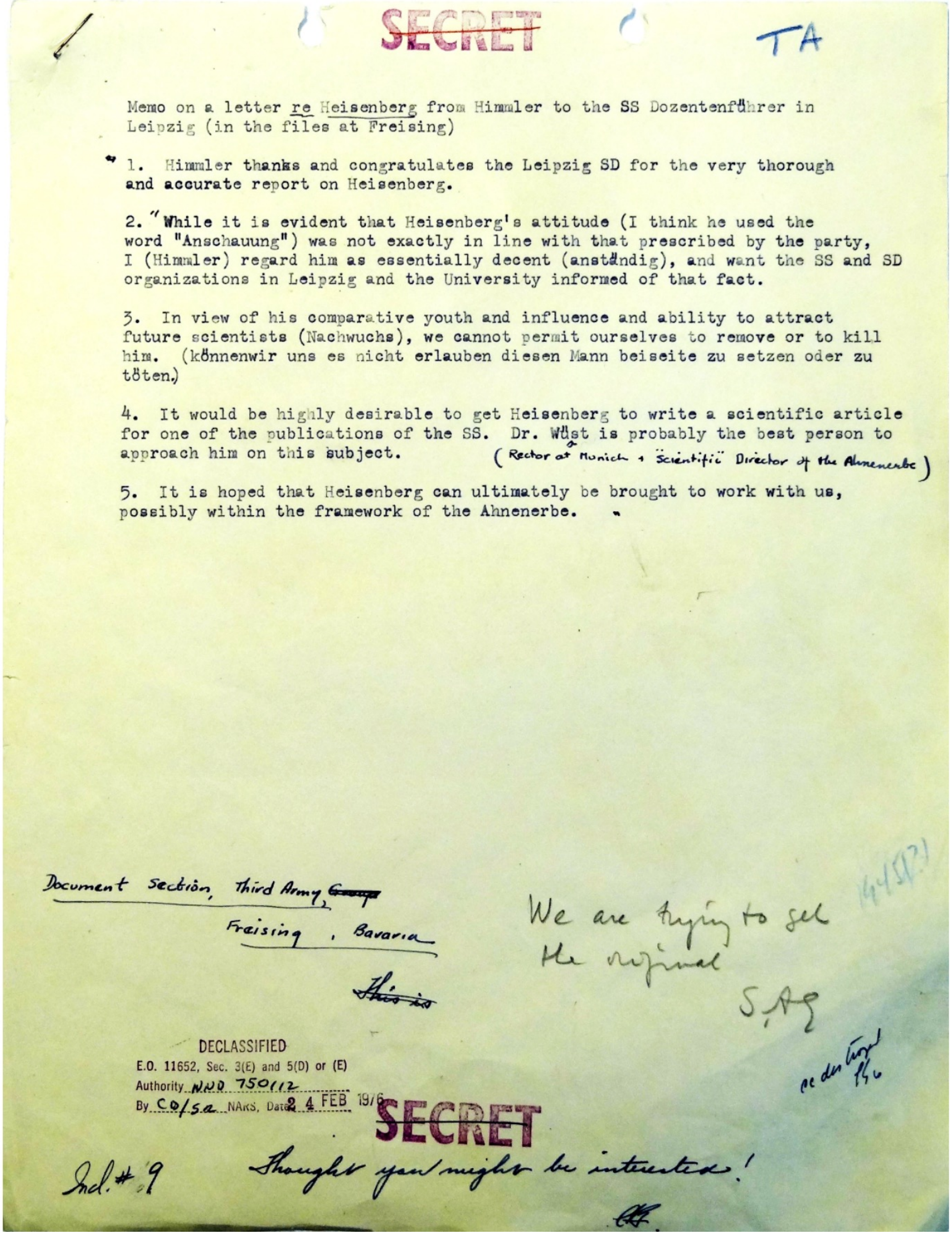
NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45--Dec 45)



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TA

Memo on a letter re Heisenberg from Himmler to the SS Dozentenführer in Leipzig (in the files at Freising)

1. Himmler thanks and congratulates the Leipzig SD for the very thorough and accurate report on Heisenberg.

2. "While it is evident that Heisenberg's attitude (I think he used the word "Anschauung") was not exactly in line with that prescribed by the party, I (Himmler) regard him as essentially decent (anständig), and want the SS and SD organizations in Leipzig and the University informed of that fact.

3. In view of his comparative youth and influence and ability to attract future scientists (Nachwuchs), we cannot permit ourselves to remove or to kill him. (könnenwir uns es nicht erlauben diesen Mann beiseite zu setzen oder zu töten.)

4. It would be highly desirable to get Heisenberg to write a scientific article for one of the publications of the SS. Dr. Wüst is probably the best person to approach him on this subject. (Rector at Munich + "Scientific" Director of the Ahnenerbe)

5. It is hoped that Heisenberg can ultimately be brought to work with us, possibly within the framework of the Ahnenerbe. "

Document Section, Third Army, ~~Group~~
Freising, Bavaria

~~This is~~

We are trying to get
the original
S.A.G.

[illegible]

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E.O. 11652, Sec. 3(E) and 5(D) or (E)
Authority NND 750112
By CO/sa NARS, Date 24 FEB 1976

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Incl. # 9

Thought you might be interested!

Figure D.44: Document Section, Third Army, Freising, Bavaria. 1945 translation. Memo on a letter re Heisenberg from Himmler to the SS Dozentenführer in Leipzig (in the files at Freising) [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)]. The Himmler letter being translated was probably from July 1938.

So gross wie eine Ananas... *Der Spiegel* 4 June 1967, pp. 80–93.

Noch während der Vorbereitungen, am 4. Juni 1942, wurde Heisenberg zur entscheidenden Geheimsitzung des deutschen Atom-Gremiums nach Berlin berufen: Die Mitglieder der “Uran-Gemeinschaft” sollten dem neuen Reichsminister für Bewaffnung und Munition, Albert Speer, Bericht erstatten und mit ihm die Zukunft der deutschen Uranforschung erörtern.

Zwei Monate zuvor hatte Göring Order gegeben, daß alle Programme, die nur für die Nachkriegszeit Bedeutung hätten, zu unterlassen seien. Allein Albert Speer konnte entscheiden, ob irgendein Unternehmen von dieser Bestimmung ausgenommen wurde.

Sie trafen sich im Helmholtz-Hörsaal des Harnack-Hauses in Dahlem:

> Auf der einen Seite die Forscher Hahn und Heisenberg, Diebner, Harteck und Wirtz sowie der Präsident der Kaiser-Wilhelm-Gesellschaft, Dr. Albert Vögler.

> Auf der anderen Seite Rüstungsminister Speer, sein technischer Berater Karl-Otto Saur, VW-Konstrukteur Ferdinand Porsche sowie die Militärs Leeb, Fromm, Milch und Witzell.

Man muß sich vergegenwärtigen, daß während der vorangegangenen Wochen die schweren Flächenangriffe der Royal Air Force auf deutsche Städte begonnen hatten. Lübeck und Rostock lagen bereits in Trümmern, Köln war in der Nacht zum 31. Mai von mehr als tausend britischen Bombern heimgesucht worden—und der Generalinspekteur und Generalzeugmeister der Luftwaffe, Generalfeldmarschall Erhard Milch, war begierig auf Vergeltung.

So kam Heisenberg sogleich auf die militärischen Anwendungsmöglichkeiten der Kernspaltung zu sprechen—auf Uran 235 und auf Plutonium.

While preparations were still underway, on 4 June 1942 Heisenberg was summoned to Berlin for the crucial secret meeting of the German atomic body: The members of the “uranium club” were to report to the new Reich Minister of Armaments and Munitions, Albert Speer, and discuss with him the future of German uranium research.

Two months earlier, Goering had given orders that all programs that were only relevant to the postwar period were to be omitted. Albert Speer alone could decide whether any enterprise was exempt from this provision.

They met in the Helmholtz lecture hall of the Harnack House in Dahlem:

> On one side the researchers Hahn and Heisenberg, Diebner, Harteck and Wirtz, and the president of the Kaiser Wilhelm Society, Dr. Albert Vögler.

> On the other side, armaments minister Speer, his technical advisor Karl-Otto Saur, VW designer Ferdinand Porsche, and the military officers Leeb, Fromm, Milch and Witzell.

It must be remembered that during the preceding weeks, the Royal Air Force’s heavy area raids on German cities had begun. Lübeck and Rostock were already in ruins, Cologne had been hit by more than a thousand British bombers on the night of May 31—and the Inspector General and Generalzeugmeister of the Luftwaffe, Field Marshal Erhard Milch, was eager for retaliation.

So Heisenberg immediately turned to the military applications of nuclear fission—to uranium-235 and to plutonium.

Als er sein Referat beendet hatte, ergab sich ein knapper Dialog, der allen Anwesenden lebhaft in Erinnerung geblieben ist.

Milch erkundigte sich nach der Größe einer Bombe, deren Wirkung genügen würde, eine große Stadt zu zerstören.

Heisenberg: “Etwa so groß wie eine Ananas.” Er bezog sich auf die Explosivladung und demonstrierte ihren Umfang mit den Händen.

Als er der Unruhe unter den anwesenden Militärs gewahr wurde, dämpfte er ihren Enthusiasmus: Eine solche Waffe lasse sich nicht innerhalb weniger Monate produzieren; und sollten die Amerikaner auch bald einen Uranmeiler und in frühestens zwei Jahren eine Uranbombe haben—in Deutschland sei ihre Herstellung unter den gegebenen Umständen eine wirtschaftliche Unmöglichkeit.

“Ich war sehr glücklich”, so gestand Heisenberg sechs Jahre später in einem Brief, “daß uns jede Entscheidung abgenommen war: Die damals ausgegebenen Führerbefehle verhinderten jeden großen Einsatz für Atombomben.”

Hingegen betonte Heisenberg immer wieder, ein Reaktor sei von größter Bedeutung, sowohl für aktuelle militärische als auch für zivile Zwecke nach dem Kriege.

Die Partie, die eine Entscheidung hatte bringen sollen, endete pari: Das Vorhaben wurde weder eingestellt noch besonders unterstützt.

Speer genehmigte den Bau eines Bunkers, der—auf dem Gelände des Kaiser-Wilhelm-Instituts für Physik—den ersten großen deutschen Uranreaktor aufnehmen sollte.

When he had finished his paper, a brief dialogue ensued that has been vividly remembered by all present.

Milch inquired about the size of a bomb whose effect would be enough to destroy a large city.

Heisenberg: “About the size of a pineapple.” He referred to the [fissile] explosive charge and demonstrated its size with his hands.

When he became aware of the agitation among the military officers present, he dampened their enthusiasm: Such a weapon could not be produced within a few months. The Americans might also soon have a uranium pile, and in two years at the earliest a uranium bomb. In Germany producing it was an economic impossibility under the given circumstances.

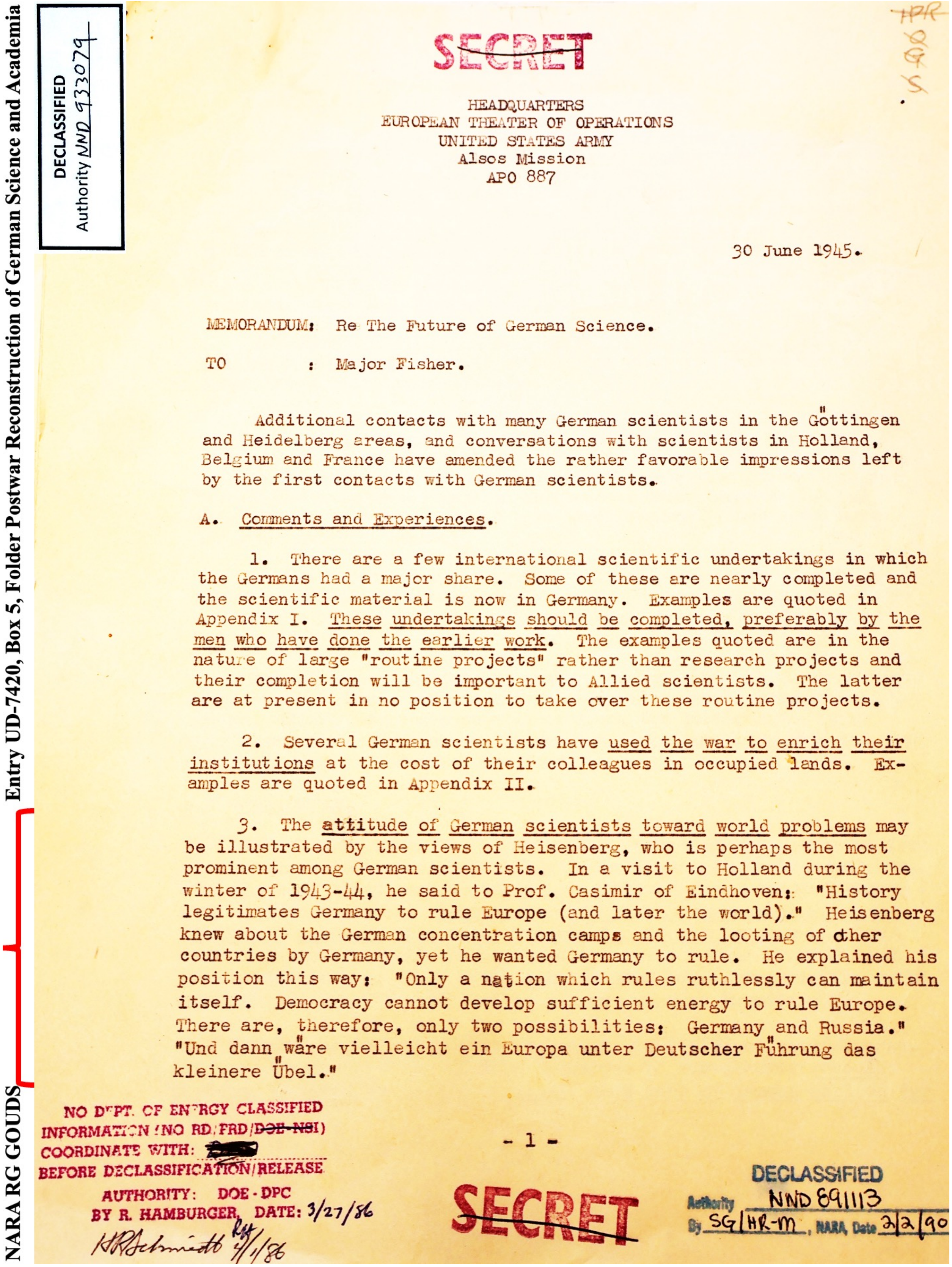
“I was very happy,” Heisenberg confessed in a letter six years later, “that every decision had been taken from us: the Führer orders issued at that time prevented any great effort for atomic bombs.”

By contrast, Heisenberg repeatedly stressed that a reactor was of paramount importance, both for current military and postwar civilian purposes.

The match that should have brought a decision ended at par: the project was neither stopped nor particularly supported.

Speer approved the construction of a bunker that would house—on the site of the Kaiser Wilhelm Institute of Physics—the first large German uranium reactor.

[There are several other accounts of the “pineapple” story; see for example the sources in Powers 1993, pp. 515–516.]



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HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
Alsos Mission
APO 887

30 June 1945.

MEMORANDUM: Re The Future of German Science.

TO : Major Fisher.

Additional contacts with many German scientists in the Göttingen and Heidelberg areas, and conversations with scientists in Holland, Belgium and France have amended the rather favorable impressions left by the first contacts with German scientists.

A. Comments and Experiences.

1. There are a few international scientific undertakings in which the Germans had a major share. Some of these are nearly completed and the scientific material is now in Germany. Examples are quoted in Appendix I. These undertakings should be completed, preferably by the men who have done the earlier work. The examples quoted are in the nature of large "routine projects" rather than research projects and their completion will be important to Allied scientists. The latter are at present in no position to take over these routine projects.

2. Several German scientists have used the war to enrich their institutions at the cost of their colleagues in occupied lands. Examples are quoted in Appendix II.

3. The attitude of German scientists toward world problems may be illustrated by the views of Heisenberg, who is perhaps the most prominent among German scientists. In a visit to Holland during the winter of 1943-44, he said to Prof. Casimir of Eindhoven: "History legitimates Germany to rule Europe (and later the world)." Heisenberg knew about the German concentration camps and the looting of other countries by Germany, yet he wanted Germany to rule. He explained his position this way: "Only a nation which rules ruthlessly can maintain itself. Democracy cannot develop sufficient energy to rule Europe. There are, therefore, only two possibilities: Germany and Russia." "Und dann wäre vielleicht ein Europa unter Deutscher Führung das kleinere Übel."

NO DEPT. OF ENERGY CLASSIFIED
INFORMATION (NO RD/FRD/~~DOE-NSI~~)
COORDINATE WITH: [redacted]
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AUTHORITY: DOE-DPC
BY R. HAMBURGER, DATE: 3/27/86
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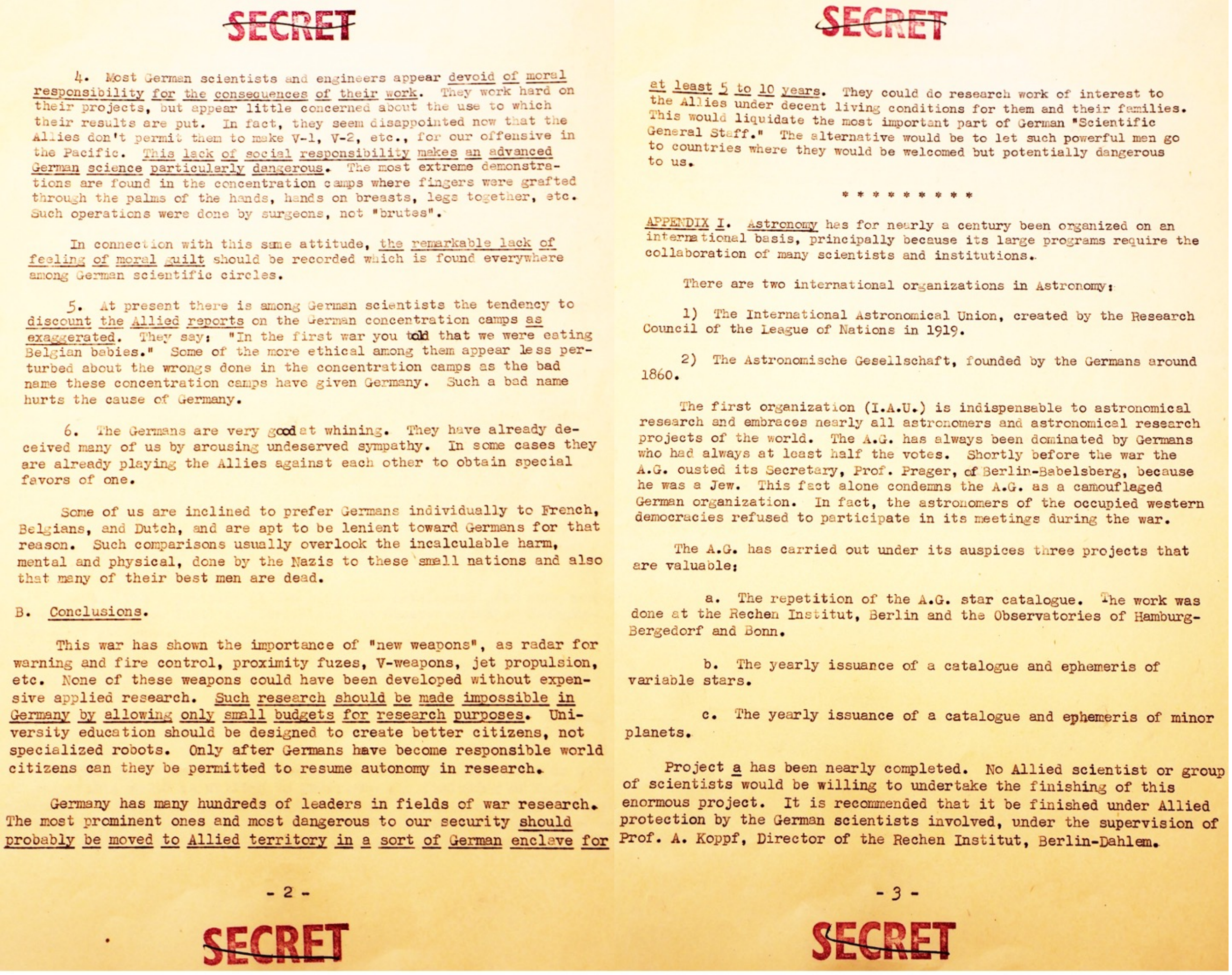
Figure D.45: Gerard P. Kuiper to Major Fisher. 30 June 1945. Re The Future of German Science [NARA RG GOUDS, Entry UD-7420, Box 5, Folder Postwar Reconstruction of German Science and Academia]. “Heisenberg... said to Prof. Casimir of Eindhoven: ‘History legitimates Germany to rule Europe (and later the world)... Only a nation which rules ruthlessly can maintain itself.’”



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4. Most German scientists and engineers appear devoid of moral responsibility for the consequences of their work. They work hard on their projects, but appear little concerned about the use to which their results are put. In fact, they seem disappointed now that the Allies don't permit them to make V-1, V-2, etc., for our offensive in the Pacific. This lack of social responsibility makes an advanced German science particularly dangerous. The most extreme demonstrations are found in the concentration camps where fingers were grafted through the palms of the hands, hands on breasts, legs together, etc. Such operations were done by surgeons, not "brutes".

In connection with this same attitude, the remarkable lack of feeling of moral guilt should be recorded which is found everywhere among German scientific circles.

5. At present there is among German scientists the tendency to discount the Allied reports on the German concentration camps as exaggerated. They say: "In the first war you told that we were eating Belgian babies." Some of the more ethical among them appear less perturbed about the wrongs done in the concentration camps as the bad name these concentration camps have given Germany. Such a bad name hurts the cause of Germany.

6. The Germans are very good at whining. They have already deceived many of us by arousing undeserved sympathy. In some cases they are already playing the Allies against each other to obtain special favors of one.

Some of us are inclined to prefer Germans individually to French, Belgians, and Dutch, and are apt to be lenient toward Germans for that reason. Such comparisons usually overlook the incalculable harm, mental and physical, done by the Nazis to these small nations and also that many of their best men are dead.

B. Conclusions.

This war has shown the importance of "new weapons", as radar for warning and fire control, proximity fuzes, V-weapons, jet propulsion, etc. None of these weapons could have been developed without expensive applied research. Such research should be made impossible in Germany by allowing only small budgets for research purposes. University education should be designed to create better citizens, not specialized robots. Only after Germans have become responsible world citizens can they be permitted to resume autonomy in research.

Germany has many hundreds of leaders in fields of war research. The most prominent ones and most dangerous to our security should probably be moved to Allied territory in a sort of German enclave for

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at least 5 to 10 years. They could do research work of interest to the Allies under decent living conditions for them and their families. This would liquidate the most important part of German "Scientific General Staff." The alternative would be to let such powerful men go to countries where they would be welcomed but potentially dangerous to us.

* * * * * * * * *

APPENDIX I. Astronomy has for nearly a century been organized on an international basis, principally because its large programs require the collaboration of many scientists and institutions.

There are two international organizations in Astronomy:

1) The International Astronomical Union, created by the Research Council of the League of Nations in 1919.

2) The Astronomische Gesellschaft, founded by the Germans around 1860.

The first organization (I.A.U.) is indispensable to astronomical research and embraces nearly all astronomers and astronomical research projects of the world. The A.G. has always been dominated by Germans who had always at least half the votes. Shortly before the war the A.G. ousted its Secretary, Prof. Prager, of Berlin-Babelsberg, because he was a Jew. This fact alone condemns the A.G. as a camouflaged German organization. In fact, the astronomers of the occupied western democracies refused to participate in its meetings during the war.

The A.G. has carried out under its auspices three projects that are valuable:

a. The repetition of the A.G. star catalogue. The work was done at the Rechen Institut, Berlin and the Observatories of Hamburg-Bergedorf and Bonn.

b. The yearly issuance of a catalogue and ephemeris of variable stars.

c. The yearly issuance of a catalogue and ephemeris of minor planets.

Project a has been nearly completed. No Allied scientist or group of scientists would be willing to undertake the finishing of this enormous project. It is recommended that it be finished under Allied protection by the German scientists involved, under the supervision of Prof. A. Koppf, Director of the Rechen Institut, Berlin-Dahlem.

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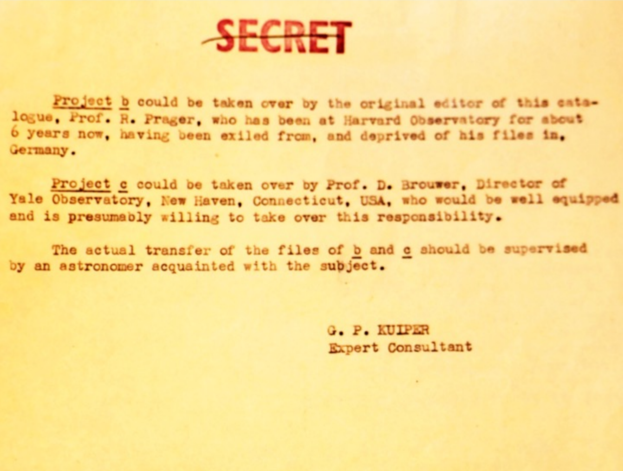

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Project b could be taken over by the original editor of this catalogue, Prof. R. Prager, who has been at Harvard Observatory for about 6 years now, having been exiled from, and deprived of his files in, Germany.

Project c could be taken over by Prof. D. Brouwer, Director of Yale Observatory, New Haven, Connecticut, USA, who would be well equipped and is presumably willing to take over this responsibility.

The actual transfer of the files of b and c should be supervised by an astronomer acquainted with the subject.

G. P. KUIPER
Expert Consultant

Figure D.46: Gerard P. Kuiper to Major Fisher. 30 June 1945. Re The Future of German Science [NARA RG GOUDS, Entry UD-7420, Box 5, Folder Postwar Reconstruction of German Science and Academia]. "Heisenberg... said to Prof. Casimir of Eindhoven: 'History legitimates Germany to rule Europe (and later the world)... Only a nation which rules ruthlessly can maintain itself.'"

Albert Speer. 1970. *Inside the Third Reich.* New York: Macmillan. Chapter 16.

I met regularly for lunch with General Friedrich Fromm in a *chambre séparée* at Horcher's Restaurant. In the course of one of these meetings, at the end of April 1942, he remarked that our only chance of winning the war lay in developing a weapon with totally new effects. He said he had contacts with a group of scientists who were on the track of a weapon which could annihilate whole cities, perhaps throw the island of England out of the fight. Fromm proposed that we pay a joint visit to these men. It seemed to him important, he said, at least to have spoken with them.

Dr. Albert Vögler, head of the largest German steel company and president of the Kaiser Wilhelm Gesellschaft, also called my attention at this time to the neglected field of nuclear research. He complained of the inadequate support fundamental research was receiving from the Ministry of Education and Science, which naturally did not have much influence during wartime. On May 6, 1942, I discussed this situation with Hitler and proposed that Goering be placed at the head of the Reich Research Council—thus emphasizing its importance.[23] A month later, on June 9, 1942, Goering was appointed to this post.

Around the same time the three military representatives of armaments production, Milch, Fromm, and Witzell, met with me at Harnack House, the Berlin center of the Kaiser Wilhelm Gesellschaft, to be briefed on the subject of German atomic research. Along with scientists whose names I no longer recall, the subsequent Nobel Prize winners Otto Hahn and Werner Heisenberg were present. After a few demonstration lectures on the matter as a whole, Heisenberg reported on "Atom-smashing and the development of the uranium machine [sic] and the cyclotron."[24] Heisenberg had bitter words to say about the Ministry of Education's neglect of nuclear research, about the lack of funds and materials, and the drafting of scientific men into the services. Excerpts from American technical journals suggested that plenty of technical and financial resources were available there for nuclear research. This meant that America probably had a head start in the matter, whereas Germany had been in the forefront of these studies only a few years ago. In view of the revolutionary possibilities of nuclear fission, dominance in this field was fraught with enormous consequences.

After the lecture I asked Heisenberg how nuclear physics could be applied to the manufacture of atom bombs. His answer was by no means encouraging. He declared, to be sure, that the scientific solution had already been found and that theoretically nothing stood in the way of building such a bomb. But the technical prerequisites for production would take years to develop, two years at the earliest, even provided that the program was given maximum support. Difficulties were compounded, Heisenberg explained, by the fact that Europe possessed only one cyclotron, and that of minimal capacity. Moreover, it was located in Paris and because of the need for secrecy could not be used to full advantage. I proposed that with the powers at my disposal as Minister of Armaments we build cyclotrons as large as or larger than those in the United States. But Heisenberg said that because we lacked experience we would have to begin by building only a relatively small type.

Nevertheless, General Fromm offered to release several hundred scientific assistants from the services, while I urged the scientists to inform me of the measures, the sums of money, and the materials they would need to further nuclear research. A few weeks later they presented their request: an appropriation of several hundred thousand marks and some small amounts of steel, nickel, and other priority metals. In addition, they asked for the building of a bunker, the erection of several barracks, and the pledge that their experiments would be given highest priority. Plans for building the first German cyclotron had already been approved. Rather put out by these modest requests in a matter of such crucial importance, I suggested that they take one or two million marks and correspondingly larger quantities of materials. But apparently more could not be utilized for the present,[25] and in any case I had been given the impression that the atom bomb could no longer have any bearing on the course of the war.

I was familiar with Hitler's tendency to push fantastic projects by making senseless demands, so that on June 23, 1942, I reported to him only very briefly on the nuclear-fission conference and what we had decided to do.[26] Hitler received more detailed and more glowing reports from his photographer, Heinrich Hoffmann, who was friendly with Post Office Minister Ohnesorge. Goebbels, too, may have told him something about it. Ohnesorge was interested in nuclear research and was supporting—like the SS—an independent research apparatus under the direction of Manfred von Ardenne, a young physicist. It is significant that Hitler did not choose the direct route of obtaining information on this matter from responsible people but depended instead on unreliable and incompetent informants to give him a Sunday-supplement account. Here again was proof of his love for amateurishness and his lack of understanding of fundamental scientific research.

Hitler had sometimes spoken to me about the possibility of an atom bomb, but the idea quite obviously strained his intellectual capacity. He was also unable to grasp the revolutionary nature of nuclear physics. In the twenty-two hundred recorded points of my conferences with Hitler, nuclear fission comes up only once, and then is mentioned with extreme brevity. Hitler did sometimes comment on its prospects, but what I told him of my conference with the physicists confirmed his view that there was not much profit in the matter. Actually, Professor Heisenberg had not given any final answer to my question whether a successful nuclear fission could be kept under control with absolute certainty or might continue as a chain reaction. Hitler was plainly not delighted with the possibility that the earth under his rule might be transformed into a glowing star. Occasionally, however, he joked that the scientists in their unworldly urge to lay bare all the secrets under heaven might someday set the globe on fire. But undoubtedly a good deal of time would pass before that came about, Hitler said; he would certainly not live to see it.

I am sure that Hitler would not have hesitated for a moment to employ atom bombs against England. I remember his reaction to the final scene of a newsreel on the bombing of Warsaw in the autumn of 1939. We were sitting with him and Goebbels in his Berlin salon watching the film. Clouds of smoke darkened the sky; dive bombers tilted and hurtled toward their goal; we could watch the flight of the released bombs, the pull-out of the planes and the cloud from the explosions expanding gigantically. The effect was enhanced by running the film in slow motion. Hitler was fascinated. The film ended with a montage showing a plane diving toward the outlines of the British Isles. A burst of flame followed, and the island flew into the air in tatters. Hitler's enthusiasm was unbounded. "That is what will happen to them!" he cried out, carried away. "That is how we will annihilate them!"

On the suggestion of the nuclear physicists we scuttled the project to develop an atom bomb by the autumn of 1942, after I had again queried them about deadlines and been told that we could not count on anything for three or four years. The war would certainly have been decided long before then. Instead I authorized the development of an energy-producing uranium motor for propelling machinery. The navy was interested in that for its submarines.

In the course of a visit to the Krupp Works I asked to be shown parts of our first cyclotron and asked the technician in charge whether we could not go on and build a considerably larger apparatus. But he confirmed what Professor Heisenberg had previously said: We lacked the technical experience. At Heidelberg in the summer of 1944, I was shown our first cyclotron splitting an atomic nucleus. To my questions, Professor Walther Bothe explained that this cyclotron would be useful for medical and biological research. I had to rest content with that.

In the summer of 1943, wolframite imports from Portugal were cut off, which created a critical situation for the production of solid-core ammunition. I thereupon ordered the use of uranium cores for this type of ammunition.[27] My release of our uranium stocks of about twelve hundred metric tons showed that we no longer had any thought of producing atom bombs.

Perhaps it would have proved possible to have the atom bomb ready for employment in 1945. But it would have meant mobilizing all our technical and financial resources to that end, as well as our scientific talent. It would have meant giving up all other projects, such as the development of the rocket weapons. From this point of view, too, Peenemünde was not only our biggest but our most misguided project.*

Our failure to pursue the possibilities of atomic warfare can be partly traced to ideological reasons. Hitler had great respect for Philipp Lenard, the physicist who had received the Nobel Prize in 1920 and was one of the few early adherents of Nazism among the ranks of the scientists. Lenard had instilled the idea in Hitler that the Jews were exerting a seditious influence in their concern with nuclear physics and the relativity theory.**

To his table companions Hitler occasionally referred to nuclear physics as "Jewish physics"—citing Lenard as his authority for this. This view was taken up by Rosenberg. It thus becomes clearer why the Minister of Education was not inclined to support nuclear research.

But even if Hitler had not had this prejudice against nuclear research and even if the state of our fundamental research in June 1942 could have freed several billion instead of several million marks for the production of atom bombs, it would have been impossible—given the strain on our economic resources—to have provided the materials, priorities, and technical workers corresponding to such an investment. For it was not only superior productive capacity that allowed the United States to undertake this gigantic project. The increasing air raids had long since created an armaments emergency in Germany which ruled out any such ambitious enterprise. At best, with extreme concentration of all our resources, we could have had a German atom bomb by 1947, but certainly we could not beat the Americans, whose bomb was ready by August 1945.

23. *Office Journal*, May 6, 1942.

24. *Office Journal*, 1942: "On June 4 the Minister flew back to Berlin. . . . That evening there was a lecture in Harnack House on atom-smashing and the development of the uranium machine [sic] and the cyclotron."

25. As late as December 19, 1944, I wrote to Professor Gerlach, who had been placed in charge of the uranium project: "You can always count on me to help you overcome any obstacles that may interfere with your work. Despite the very heavy drain on the labor force by the armaments industry, the relatively small [!] needs of your project can still be met."

26. *Führerprotokoll*, June 23, 1942, Point 15, states only: "Reported briefly to the Fuehrer on the conference on splitting the atom and on the backing we have given the project."

27. *Office Journal*, August 31, 1942, and March 1944. In 1940 twelve hundred metric tons of uranium ore had been seized in Belgium. Mining of domestic ore in Joachimstal was not pushed with any real urgency.

$*$ From 1937 to 1940 the army spent five hundred and fifty million marks on the development of a large rocket. But success was out of the question, for Hitler's principle of scattering responsibility meant that even scientific research teams were divided and often at odds with one another. According to the *Office Journal*, August 17, 1944, not only the three branches of the armed forces but also other organizations, the SS, the postal system, and such, had separate research facilities. In the United States, on the other hand, all the atomic physicists—to take an example—were in one organization.

$**$ According to L. W. Helwig, *Persönlichkeiten der Gegenwart* (1940), Lenard inveighed against "relativity theories produced by alien minds." In his four-volume work, *Die Deutsche Physik* (1935), Helwig considered physics "cleansed of the outgrowths which the by now well-known findings of race research have shown to be the exclusive products of the Jewish mind and which the German *Volk* must shun as racially incompatible with itself."

[In the above passage, Albert Speer made numerous claims about the German nuclear program that have been uncritically accepted and repeated by many historians, journalists, and members of the public in the decades since then. There is clear evidence that Speer's claims were false, and even that he knew they were false. For example:

Speer falsely claimed:	**In fact:**
"Dr. Albert Vögler... called my attention at this time to the neglected field of nuclear research... On May 6, 1942, I discussed this situation with Hitler and proposed that Goering be placed at the head of the Reich Research Council—thus emphasizing its importance."	Far from being neglected, German nuclear weapons research had been going strong since the late 1930s (e.g., pp. 3362–4389). Speer's claim that the nuclear program did not begin until 1942 also contradicts his own claim that the program *ended* in 1942 (see below).
Any German nuclear work, or any information on nuclear work, other than that by Heisenberg was "unreliable," "incompetent," and characterized by "amateurishness."	After the war, Heisenberg remained in (West) Germany and did not do any significant nuclear work, but many hundreds of what Speer called "unreliable," "incompetent," and "amateurish" former German nuclear scientists helped the Soviet Union, France, United Kingdom, United States, and other countries design and build nuclear weapons (Sections 8.7, 8.9, and D.14, plus pp. 2061–2074, 4268–4269).
"[T]he possibility of an atom bomb... quite obviously strained [Hitler's] intellectual capacity. He was also unable to grasp the revolutionary nature of nuclear physics."	Quotes from many independent sources and even photographs prove that Hitler was very supportive of nuclear weapons development and had high hopes for its applications in the war (e.g., pp. 3877–3879, 4575–4576, 4591, 4594, 4634, 4635–4639, 4640–4664, 4667, 4670). There are also many other sources demonstrating strong support and expectations for the nuclear program from the German government (e.g., Section D.13).
"Our failure to pursue the possibilities of atomic warfare can be partly traced to ideological reasons... Hitler occasionally referred to nuclear physics as 'Jewish physics'... Hitler... had this prejudice against nuclear research."	
"Hitler would not have hesitated for a moment to employ atom bombs against England" if he had possessed them; thus the fact that he did not supposedly proves Germany did not have any atom bombs.	Allied leaders publicly and repeatedly threatened to use their own weapons of mass destruction (mustard, phosgene, anthrax, etc.) against Germany if Germany used any form of weapons of mass destruction, which effectively deterred the use of German nuclear weapons through the end of the war in Europe (e.g., pp. 2632–2651, 3786–3791, 4668–4670).
"We scuttled the project to develop an atom bomb by the autumn of 1942."	The German nuclear weapons program continued at full speed from 1942 to the end of the war (e.g., pp. 3998, 4390–5081). Speer's claim that the program ended in 1942 contradicts his own claim that it began in 1942 (see above).

Speer falsely claimed:	**In fact:**
“Instead I authorized the development of an energy-producing uranium motor for propelling machinery.”	Wartime programs to develop nuclear propulsion for submarines, aircraft, and rockets existed, but those programs were not directed by Speer (e.g., pp. 1474, 5757–5771).
“We lacked the technical experience. At Heidelberg in the summer of 1944, I was shown our first cyclotron splitting an atomic nucleus.”	Germany had been designing and building particle accelerators since the 1920s, and it built and used many accelerators throughout the war (Sections C.1, D.6; pp. 4504–4510).
“In the summer of 1943... I thereupon ordered the use of uranium cores for this type of [conventional] ammunition. My release of our uranium stocks of about twelve hundred metric tons showed that we no longer had any thought of producing atom bombs.”	Clearly Speer did not send the 1200 tons of uranium stocks off to be made into ammunition in the summer of 1943, since that 1200 tons of uranium was found in 1945 (e.g., p. 3457) and battlefields littered with German uranium bullets were not found.
“[I]t would have been impossible—given the strain on our economic resources—to have provided the materials, priorities, and technical workers corresponding to such an investment. For it was not only superior productive capacity that allowed the United States to undertake this gigantic project.” “[T]o have the atom bomb ready for employment... would have meant mobilizing all our technical and financial resources to that end, as well as our scientific talent. It would have meant giving up all other projects, such as the development of the rocket weapons.”	If much smaller and poorer nations have been able to successfully develop nuclear weapons, then the industrial power of almost all of Europe under German control certainly could have done so. Indeed, at sites all over Europe, Germany was mining and processing uranium (Sections D.3, D.4) and producing enormous quantities of other nuclear-related materials (Section D.7). Europe had sufficient population, industry, and resources to perform those plus all the other wartime tasks, just as the United States did (though German-controlled Europe could not outcompete the U.S. plus the British Empire plus the Soviet Union for sheer numbers).
“The increasing air raids had long since created an armaments emergency in Germany which ruled out any such ambitious enterprise.”	The German nuclear weapons program began long before Allied bombing (e.g., pp. 3364–3403). For protection against Allied bombing later in the war, German industries were divided among a large number of sites, many of which were underground and/or in the east, which allowed them to continue effectively (e.g., pp. 2075–2076). Likewise the German nuclear weapons program was divided among a large number of sites, many of which were underground and/or in the east (e.g., pp. 4400–4403).

Speer falsely claimed:	**In fact:**
"Mining of domestic [uranium] ore in Joachimstal was not pushed with any real urgency."	Based on postwar inspections, 1946 U.S. intelligence reports on the Joachimstal uranium mine stated: "The Germans put mining on a high priority and only mining was done throughout the 6 years occupation. The ore was delivered by special planes to Germany and Austria" (p. 3998). "The Germans continued operations in this mine to the very last moment" (p. 4981). Germany was also actively mining uranium at many other sites from Portugal to Bulgaria (Section D.3).
"Hitler's principle of scattering responsibility meant that even scientific research teams were divided and often at odds with one another. According to the Office Journal, August 17, 1944, not only the three branches of the armed forces but also other organizations, the SS, the postal system, and such, had separate research facilities. In the United States, on the other hand, all the atomic physicists—to take an example—were in one organization."	The different parts of the German nuclear weapons program were coordinated with each other at the highest levels by the SS (e.g., pp. 3378–3403, 4914–4961, 4998–4999). The compartmentalization of the program made it more resistant to Allied intelligence, sabotage, and bombing.
In different parts of this passage, Speer claimed that Germany could have created an atom bomb as early as 1945, no earlier than 1947, or not at all.	Speer was making so many false statements that he could not even keep them consistent from one page to the next. According to numerous other sources, Germany appears to have successfully created and tested atomic bombs by 1944 (Sections D.10 and D.11).

Although Speer was not in charge of the German nuclear weapons program, he was in sufficiently close communication with those who were to know that his above statements were false (e.g., pp. 3350, 4458, 4593, 4616–4617, 4640–4664, 4938, 5322, 5343).

Thus the evidence presented throughout Appendix D demonstrates that Speer made a whole series of false claims about the German nuclear program just within this short passage. In several cases, what Speer wrote in one paragraph completely contradicted what he had written in another paragraph in this book, or in his other writings (e.g., pp. 4593, 4931).

Beyond the German nuclear program, other researchers have already documented Albert Speer's dishonesty about all sorts of personal and historical events [see for example: Kitchen 2015; Van Der Vat 1997]. The history books of the world should not be founded upon the postwar claims of Speer, a clearly proven serial fabulist. Anything he said should be viewed with extreme skepticism and compared very closely with more trustworthy sources.]

Paul Lawrence Rose. 1998. *Heisenberg and the Nazi Atomic Bomb Project: A Study in German Culture*. Berkeley, California: University of California Press. pp. xvi–xvii.

Since the war an apologetic campaign has been mounted by Heisenberg and other German physicists and historians to demonstrate that he understood fully both the moral and scientific issues involved in this work as chief physicist for the Nazi atomic bomb project from 1939 to 1945. [...] If we are to understand Heisenberg as he really was, we must enter into the German frame of mind, or mentality, or mind-set and sensibility, that had evolved out of the German culture of the nineteenth and twentieth centuries, strange though that mentality appears now to non-Germans, and even to those Germans who have been shaped by the changed and Westernized German culture that has been developing since 1945.

I cannot say that my British background has made me entirely sympathetic to German culture. Although I would be the first to admit its outstanding achievements in science, music, and intellectual life in general, its insistent abstraction as well as the more sinister traditions that accompanied it induce in me a certain skepticism and even aversion. As the American liberal philosopher John Dewey once observed, even Kant's categorical imperative has a whiff of the Prussian drill sergeant about it; the grand moral principle depended, despite its apparent universal reasonableness, on an all too German demand for conforming obedience. Some readers may be put off by what seems, following this spirit of distrust of Kant, the *Tendenz* of the present book, its lack of sympathy with German culture, and its seeming moral and scientific denigration of a great physicist who found himself born into an evil time. [...] The only real test of the historical truth of the present reconstruction is whether it makes better sense of the central problem of the Heisenberg affair and conforms more exactly to the facts as far as we may know them about Heisenberg, the German atomic bomb project, and German culture and society before, during, and after the Third Reich than do other versions. [...]

In this book I have tried to penetrate into how Germans think—or rather, perhaps, used to think—and to show how radically different are German and what I have termed "Western" mentalities and sensibilities. My regret is that in order to expose the nature and fallacies of much of this German thinking and feeling, I have, I fear, often been forced to be tediously analytical. This is not, in consequence, a graceful book, I am sorry to confess, but perhaps Heisenberg and his company have benefited too long from grace of various sorts.

[Such statements from the "expert historians" of this field should spur modern scholars to set aside this conventional historical narrative and make a *de novo*, detailed, and fully independent evaluation of the wartime German nuclear program. The rest of this appendix attempts to do just that, and also to offer leads for future scholars who would like to investigate this subject in further detail.]

D.2 Fundamental Scientific Knowledge and Program Planning

[Beginning in 1939, scientists such as Kurt Diebner (German, 1905–1964), Siegfried Flügge (German, 1912–1997), Paul Harteck (Austrian, 1902–1985), Fritz Houtermans (German, 1903–1966), Josef Schintlmeister (Austrian, 1908–1971), Georg Stetter (Austrian, 1895–1988), and Carl Friedrich von Weizsäcker (German, 1912–2007) gave detailed descriptions of how fission fuel could be used to create either reactors or bombs. They received support from the German government in 1939 and began ambitious programs to create fission reactors and bombs. During 1939–1942, the programs were coordinated by the German army. During 1942–1945, the programs were coordinated by the SS.

For early scientific knowledge regarding the breeding of fission fuel, see Section D.5.1.

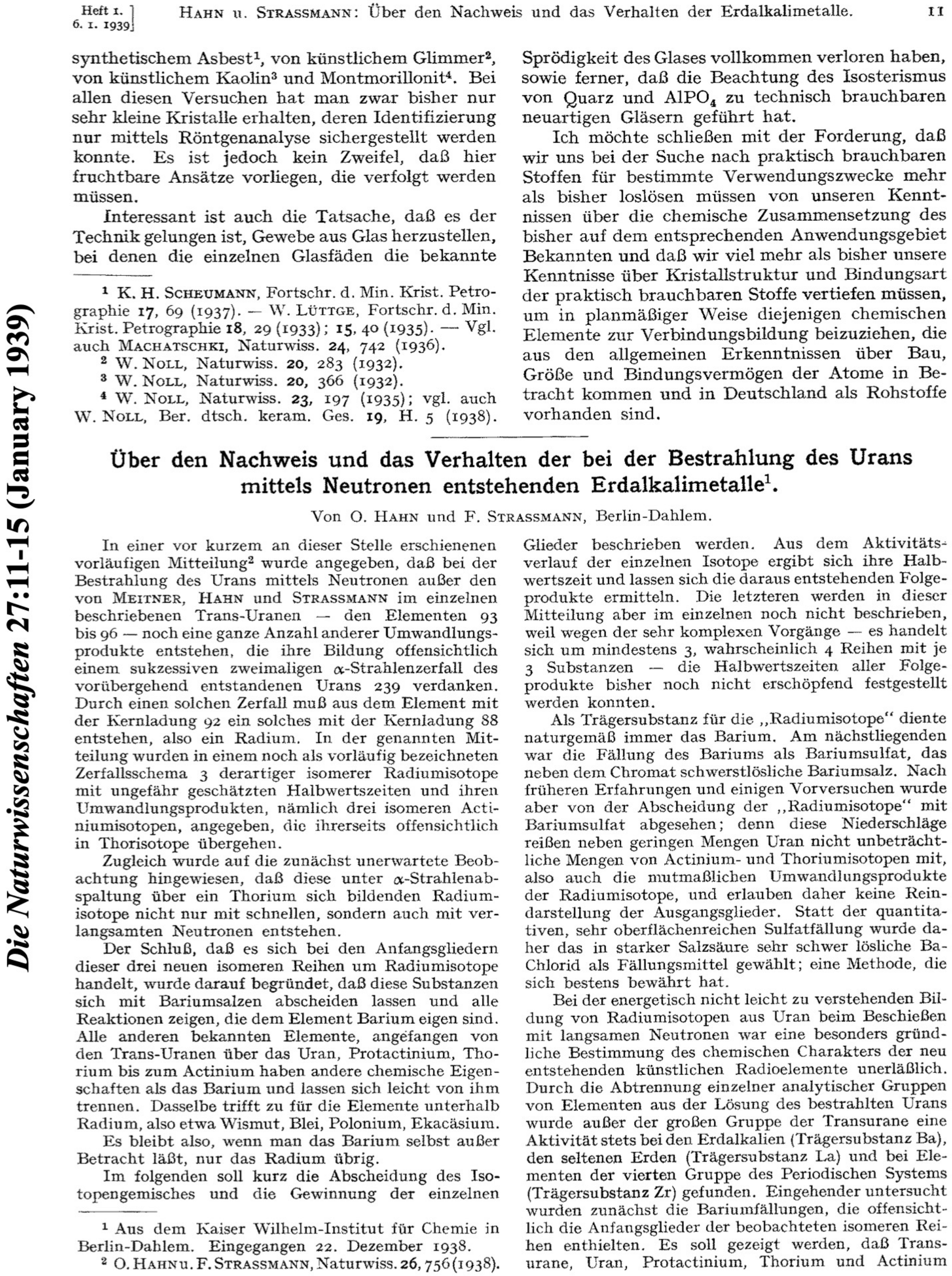
For an organization chart and some key personnel from the programs, see pp. 1568, 1611–1629.]

Otto Hahn and Fritz Strassmann. January 1939. Über den Nachweis und das Verhalten der bei der Bestrahlung des Urans mittels Neutronen entstehenden Erdalkalimetalle. [About the Detection and Behavior of the Alkaline Earth Metals Formed During the Irradiation of Uranium with Neutrons.] ***Die Naturwissenschaften*** **27:11–15.**

[...] Bei der energetisch nicht leicht zu verstehenden Bildung von Radiumisotopen aus Uran beim Beschießen mit langsamen Neutronen war eine besonders gründliche Bestimmung des chemischen Charakters der neu entstehenden künstlichen Radioelemente unerläßlich. Durch die Abtrennung einzelner analytischer Gruppen von Elementen aus der Lösung des bestrahlten Urans wurde außer der großen Gruppe der Transurane eine Aktivität stets bei den Erdalkalien (Trägersubstanz Ba), den seltenen Erden (Trägersubstanz La) und bei Elementen der vierten Gruppe des Periodischen Systems (Trägersubstanz Zr) gefunden. Eingehender untersucht wurden zunächst die Bariumfällungen, die offensichtlich die Anfangsglieder der beobachteten isomeren Reihen enthielten. Es soll gezeigt werden, daß Transurane, Uran, Protactinium, Thorium und Actinium sich stets leicht und vollständig von der mit Barium ausfallenden Aktivität trennen lassen. [...]

[...] Since it is not easy to understand from energy considerations how radium isotopes can be produced when uranium is bombarded with slow neutrons, a very careful determination of the chemical properties of the new artificially made radioelements was necessary. Various analytic groups of elements were separated from a solution containing the irradiated uranium. Besides the large group of transuranic elements, some radioactivity was always found in the alkaline-earth group (barium carrier), the rare-earth group (lanthanum carrier), and also with elements in group IV of the periodic table (zirconium carrier). The barium precipitate was the first to be investigated more thoroughly, since it apparently contains the parent isotopes of the observed isomeric series. The goal was to show that the transuranic elements, and also uranium, protactinium, thorium, and actinium could always be separated easily and completely from the activity which precipitates with barium. [...]

[At the Kaiser Wilhelm Institute for Chemistry in Berlin-Dahlem, Hahn and Strassmann discovered neutron-induced fission of uranium into lighter elements in 1938, and published their results in January 1939.]



Die Naturwissenschaften **27:11-15 (January 1939)**

synthetischem Asbest[1], von künstlichem Glimmer[2], von künstlichem Kaolin[3] und Montmorillonit[4]. Bei allen diesen Versuchen hat man zwar bisher nur sehr kleine Kristalle erhalten, deren Identifizierung nur mittels Röntgenanalyse sichergestellt werden konnte. Es ist jedoch kein Zweifel, daß hier fruchtbare Ansätze vorliegen, die verfolgt werden müssen.

Interessant ist auch die Tatsache, daß es der Technik gelungen ist, Gewebe aus Glas herzustellen, bei denen die einzelnen Glasfäden die bekannte Sprödigkeit des Glases vollkommen verloren haben, sowie ferner, daß die Beachtung des Isosterismus von Quarz und $AlPO_4$ zu technisch brauchbaren neuartigen Gläsern geführt hat.

Ich möchte schließen mit der Forderung, daß wir uns bei der Suche nach praktisch brauchbaren Stoffen für bestimmte Verwendungszwecke mehr als bisher loslösen müssen von unseren Kenntnissen über die chemische Zusammensetzung des bisher auf dem entsprechenden Anwendungsgebiet Bekannten und daß wir viel mehr als bisher unsere Kenntnisse über Kristallstruktur und Bindungsart der praktisch brauchbaren Stoffe vertiefen müssen, um in planmäßiger Weise diejenigen chemischen Elemente zur Verbindungsbildung beizuziehen, die aus den allgemeinen Erkenntnissen über Bau, Größe und Bindungsvermögen der Atome in Betracht kommen und in Deutschland als Rohstoffe vorhanden sind.

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[1] K. H. SCHEUMANN, Fortschr. d. Min. Krist. Petrographie **17**, 69 (1937). — W. LÜTTGE, Fortschr. d. Min. Krist. Petrographie **18**, 29 (1933); **15**, 40 (1935). — Vgl. auch MACHATSCHKI, Naturwiss. **24**, 742 (1936).

[2] W. NOLL, Naturwiss. **20**, 283 (1932).

[3] W. NOLL, Naturwiss. **20**, 366 (1932).

[4] W. NOLL, Naturwiss. **23**, 197 (1935); vgl. auch W. NOLL, Ber. dtsch. keram. Ges. **19**, H. 5 (1938).

Über den Nachweis und das Verhalten der bei der Bestrahlung des Urans mittels Neutronen entstehenden Erdalkalimetalle[1].

Von O. HAHN und F. STRASSMANN, Berlin-Dahlem.

In einer vor kurzem an dieser Stelle erschienenen vorläufigen Mitteilung[2] wurde angegeben, daß bei der Bestrahlung des Urans mittels Neutronen außer den von MEITNER, HAHN und STRASSMANN im einzelnen beschriebenen Trans-Uranen — den Elementen 93 bis 96 — noch eine ganze Anzahl anderer Umwandlungsprodukte entstehen, die ihre Bildung offensichtlich einem sukzessiven zweimaligen α-Strahlenzerfall des vorübergehend entstandenen Urans 239 verdanken. Durch einen solchen Zerfall muß aus dem Element mit der Kernladung 92 ein solches mit der Kernladung 88 entstehen, also ein Radium. In der genannten Mitteilung wurden in einem noch als vorläufig bezeichneten Zerfallsschema 3 derartiger isomerer Radiumisotope mit ungefähr geschätzten Halbwertszeiten und ihren Umwandlungsprodukten, nämlich drei isomeren Actiniumisotopen, angegeben, die ihrerseits offensichtlich in Thorisotope übergehen.

Zugleich wurde auf die zunächst unerwartete Beobachtung hingewiesen, daß diese unter α-Strahlenabspaltung über ein Thorium sich bildenden Radiumisotope nicht nur mit schnellen, sondern auch mit verlangsamten Neutronen entstehen.

Der Schluß, daß es sich bei den Anfangsgliedern dieser drei neuen isomeren Reihen um Radiumisotope handelt, wurde darauf begründet, daß diese Substanzen sich mit Bariumsalzen abscheiden lassen und alle Reaktionen zeigen, die dem Element Barium eigen sind. Alle anderen bekannten Elemente, angefangen von den Trans-Uranen über das Uran, Protactinium, Thorium bis zum Actinium haben andere chemische Eigenschaften als das Barium und lassen sich leicht von ihm trennen. Dasselbe trifft zu für die Elemente unterhalb Radium, also etwa Wismut, Blei, Polonium, Ekacäsium.

Es bleibt also, wenn man das Barium selbst außer Betracht läßt, nur das Radium übrig.

Im folgenden soll kurz die Abscheidung des Isotopengemisches und die Gewinnung der einzelnen Glieder beschrieben werden. Aus dem Aktivitätsverlauf der einzelnen Isotope ergibt sich ihre Halbwertszeit und lassen sich die daraus entstehenden Folgeprodukte ermitteln. Die letzteren werden in dieser Mitteilung aber im einzelnen noch nicht beschrieben, weil wegen der sehr komplexen Vorgänge — es handelt sich um mindestens 3, wahrscheinlich 4 Reihen mit je 3 Substanzen — die Halbwertszeiten aller Folgeprodukte bisher noch nicht erschöpfend festgestellt werden konnten.

Als Trägersubstanz für die „Radiumisotope" diente naturgemäß immer das Barium. Am nächstliegenden war die Fällung des Bariums als Bariumsulfat, das neben dem Chromat schwerstlösliche Bariumsalz. Nach früheren Erfahrungen und einigen Vorversuchen wurde aber von der Abscheidung der „Radiumisotope" mit Bariumsulfat abgesehen; denn diese Niederschläge reißen neben geringen Mengen Uran nicht unbeträchtliche Mengen von Actinium- und Thoriumisotopen mit, also auch die mutmaßlichen Umwandlungsprodukte der Radiumisotope, und erlauben daher keine Reindarstellung der Ausgangsglieder. Statt der quantitativen, sehr oberflächenreichen Sulfatfällung wurde daher das in starker Salzsäure sehr schwer lösliche Ba-Chlorid als Fällungsmittel gewählt; eine Methode, die sich bestens bewährt hat.

Bei der energetisch nicht leicht zu verstehenden Bildung von Radiumisotopen aus Uran beim Beschießen mit langsamen Neutronen war eine besonders gründliche Bestimmung des chemischen Charakters der neu entstehenden künstlichen Radioelemente unerläßlich. Durch die Abtrennung einzelner analytischer Gruppen von Elementen aus der Lösung des bestrahlten Urans wurde außer der großen Gruppe der Transurane eine Aktivität stets bei den Erdalkalien (Trägersubstanz Ba), den seltenen Erden (Trägersubstanz La) und bei Elementen der vierten Gruppe des Periodischen Systems (Trägersubstanz Zr) gefunden. Eingehender untersucht wurden zunächst die Bariumfällungen, die offensichtlich die Anfangsglieder der beobachteten isomeren Reihen enthielten. Es soll gezeigt werden, daß Transurane, Uran, Protactinium, Thorium und Actinium

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[1] Aus dem Kaiser Wilhelm-Institut für Chemie in Berlin-Dahlem. Eingegangen 22. Dezember 1938.

[2] O. HAHN u. F. STRASSMANN, Naturwiss. **26**, 756 (1938).

Figure D.47: Otto Hahn and Fritz Strassmann. January 1939. Über den Nachweis und das Verhalten der bei der Bestrahlung des Urans mittels Neutronen entstehenden Erdalkalimetalle. *Die Naturwissenschaften* 27:11–15.

Paul Harteck and Wilhelm Groth to German War Office. 24 April 1939. [English translation in Samuel Goudsmit to Robert Furman, 25 May 1945, NARA RG GOUDS, Entry UD-7420, Box 6, Folder ALSOS—Reports and Operations; also NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)]

We take the liberty of calling to your attention the newest developments in nuclear physics which, in our opinion, will perhaps make it possible to produce an explosive which is many orders of magnitude more effective than the present one. [...]

It is obvious that, if the possibility of energy production outlined above can be realized, which certainly is within the realm of possibilities, that country which first makes use of it has an unsurpassable advantage over the others.

[Paul Harteck (1902–1985) and Wilhelm Groth (1904–1977) at the University of Hamburg were among the first to point out that Hahn and Strassmann's discovery of nuclear fission could be applied to create a new explosive thousands of times more powerful than conventional explosives, and they notified the German War Office. Harteck and Groth worked on many different important aspects of the German nuclear program throughout the war.]

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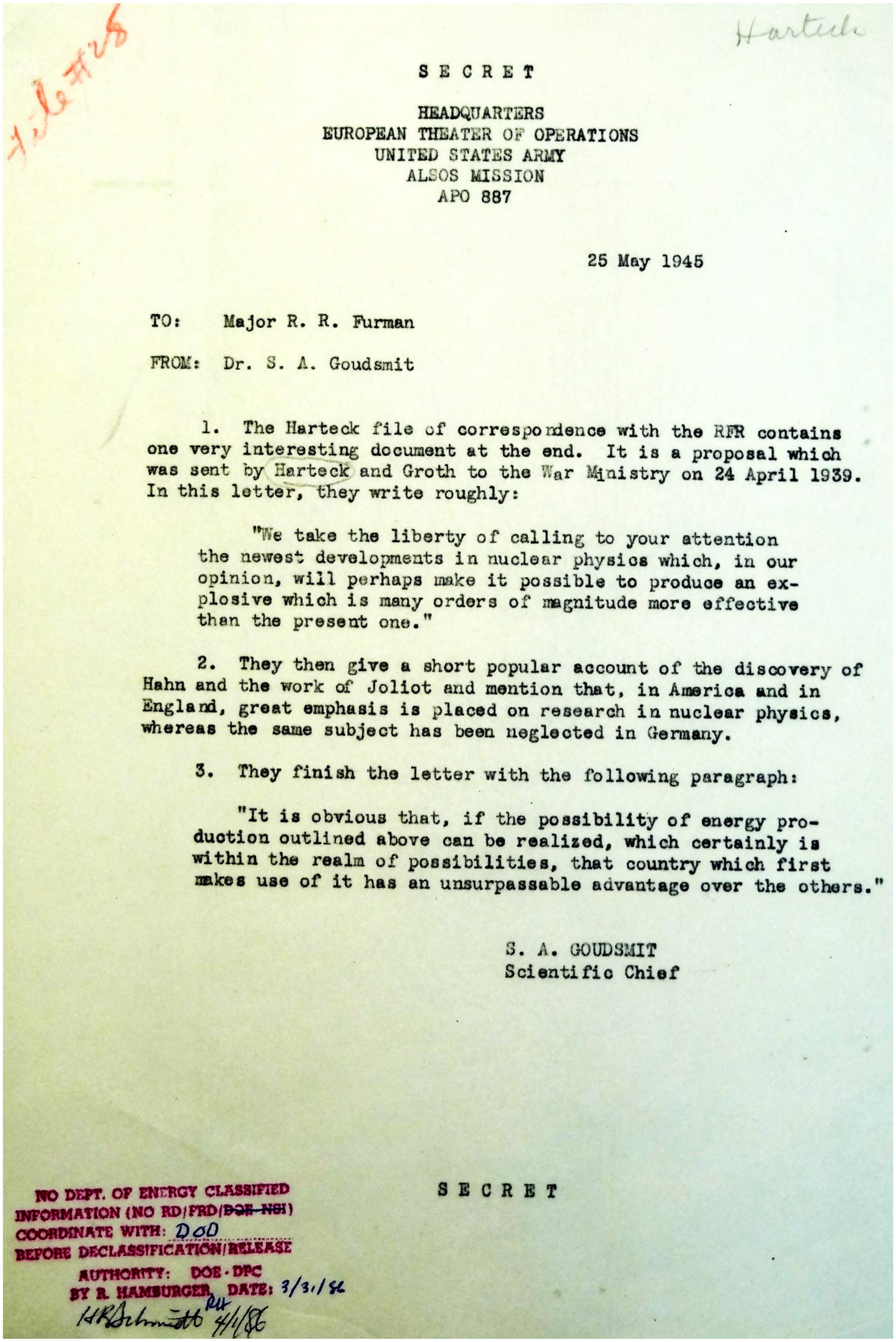
NARA RG GOUDS, Entry UD-7420, Box 6, Folder ALSOS—Reports and Operations



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Harteck

SECRET

HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS MISSION
APO 887

25 May 1945

TO: Major R. R. Furman

FROM: Dr. S. A. Goudsmit

1. The Harteck file of correspondence with the RFR contains one very interesting document at the end. It is a proposal which was sent by Harteck and Groth to the War Ministry on 24 April 1939. In this letter, they write roughly:

> "We take the liberty of calling to your attention the newest developments in nuclear physics which, in our opinion, will perhaps make it possible to produce an explosive which is many orders of magnitude more effective than the present one."

2. They then give a short popular account of the discovery of Hahn and the work of Joliot and mention that, in America and in England, great emphasis is placed on research in nuclear physics, whereas the same subject has been neglected in Germany.

3. They finish the letter with the following paragraph:

> "It is obvious that, if the possibility of energy production outlined above can be realized, which certainly is within the realm of possibilities, that country which first makes use of it has an unsurpassable advantage over the others."

S. A. GOUDSMIT
Scientific Chief

SECRET

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BY R. HAMBURGER DATE: 3/31/86
HRSchmidt RW 4/1/86

Figure D.48: Samuel Goudsmit to Robert Furman. 25 May 1945 [NARA RG GOUDS, Entry UD-7420, Box 6, Folder ALSOS—Reports and Operations].

Siegfried Flügge. Kann der Energieinhalt der Atomkerne technisch nutzbar gemacht werden? [Can the Energy Content of Atomic Nuclei Be Made Technically Usable?] *Die Naturwissenschaften* 27:23/24:402–410. 9 June 1939. [For consistency, all numbers on this page use U.S. decimal points in place of German commas.]

[...] Als Beispiel betrachten wir zunächst die Verhältnisse an reinem Uranmetall. Für schnelle Neutronen besteht kein merkbarer Einfangquerschnitt; wir haben außer $\sigma_{Sp} = 0.1 \cdot 10^{-24}$ cm^2 nur noch Streuprozesse mit rund $6 \cdot 10^{-24}$ cm^2. Metallisches Uran (Dichte 18.6) enthält rund $2.2 \cdot 10^{22}$ Atome je Kubikzentimeter; es wird dann bei einer Neutronengeschwindigkeit von $2 \cdot 10^9$ cm/sec, entsprechend einer mittleren Energie der frei gesetzten Neutronen von 2 MeV:

[...] As an example, we consider the relations for pure uranium metal. For fast neutrons there is no significant capture cross-section; we have outside of [the fission cross section] $\sigma_{Sp} = 0.1 \cdot 10^{-24}$ cm^2 only scattering processes with around $6 \cdot 10^{-24}$ cm^2. Metallic uranium (density 18.6) contains around $2.2 \cdot 10^{22}$ atoms per cubic centimeter; there will be then, at a neutron velocity of $2 \cdot 10^9$ cm/sec, corresponding to a mean energy of released neutrons of 2 MeV [ν is the number of neutrons released per fission]:

$$\frac{1}{n}\frac{dn}{dt} = 0.44\,(\nu - 1) \cdot 10^7 \quad \mathrm{sec}^{-1} .$$

Die Integration dieser Differentialgleichung ergibt

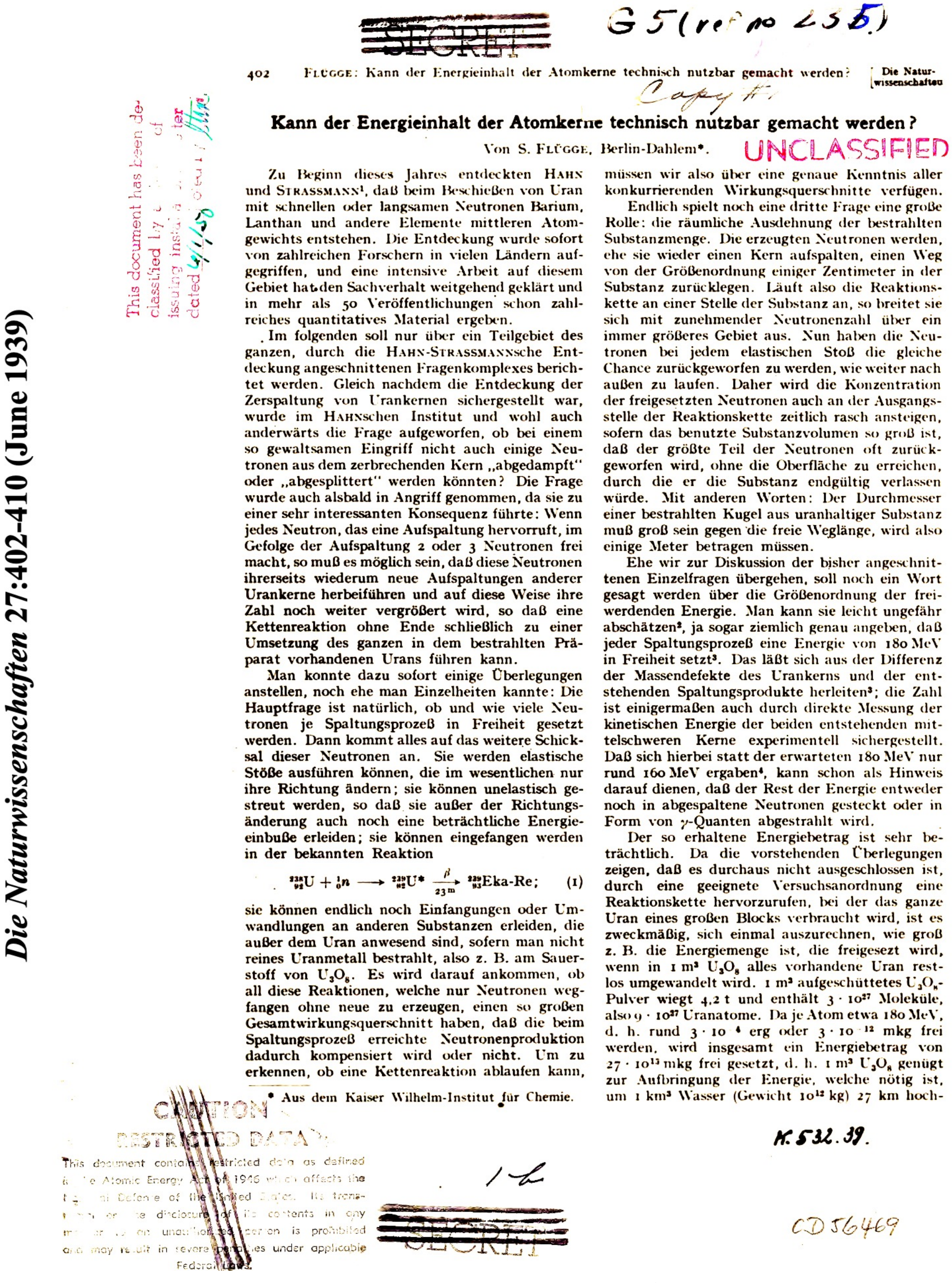
The integration of this differential equation yields

$$n(t) = n_0\, e^{0.44(\nu-1)\cdot 10^7 t} .$$

Läßt man die Reaktionskette mit $n_0 = 1$ Neutron zur Zeit $t = 0$ anlaufen und nimmt man den wahrscheinlichsten Wert $\nu = 2$, so findet man, da je Spaltung $3 \cdot 10^{-12}$ mkg frei werden, folgende Energiebeträge: Nach 10^{-7} sec: $4.7 \cdot 10^{-12}$ mkg, nach 10^{-6} sec: $2.4 \cdot 10^{-11}$ mkg, nach 10^{-5} sec: $3 \cdot 10^{+7}$ mkg und nach 10^{-4} sec: $3 \cdot 10^{+78}$ mkg. Die letzte Zahl hat natürlich keinen Sinn mehr; sie bedeutet nur, daß in weniger als 10^{-4} sec das gesamte Uran umgesetzt wird. Die Energiebefreiung geschieht also in einer so kurzen Zeit, daß wir es mit einer außerordentlich heftigen Explosion zu tun haben. [...]

If the reaction chain is started with $n_0 = 1$ neutron at time $t = 0$ and if the most probable value is $\nu = 2$, then one finds, if each fission releases $3 \cdot 10^{-12}$ mkg [9.8 Joules per meter-kilogram], the following energy amounts: After 10^{-7} sec: $4.7 \cdot 10^{-12}$ mkg, after 10^{-6} sec: $2.4 \cdot 10^{-11}$ mkg, after 10^{-5} sec: $3 \cdot 10^{+7}$ mkg and after 10^{-4} sec: $3 \cdot 10^{+78}$ mkg. The last number naturally has no more meaning; it only means that in less than 10^{-4} sec, the entire uranium is converted. The energy release happens in such a short time that we are dealing with an extraordinarily violent explosion. [...]

[Siegfried Flügge (German, 1912–1997) was a nuclear physicist at the Kaiser Wilhelm Institute for Chemistry. In this article, he explicitly showed the feasibility of using pure uranium fuel and fast neutrons to create an explosive chain reaction, estimating both the time scale and energy release for the explosion. Elsewhere in the article, he explicitly proposed water-moderated fission power reactors using thermal neutrons, derived and used the neutron diffusion and kinetics equations that are still taught in modern nuclear engineering textbooks, and correctly stated that cadmium could be used as a neutron absorber to maintain control of the neutron-induced fission reactions. A popularized version of this *Naturwissenschaften* article was published: Siegfried Flügge. Die Ausnutzung der Atomenergie. Vom Laboratoriumsversuch zur Uranmaschine—Forschungsergebnisse in Dahlem. *Deutsche Allgemeine Zeitung* No. 387, Supplement. 15 August 1939. [English translation in Hentschel and Hentschel 1996, pp. 197–206]. Flügge subsequently moved to the Reichspost, where he apparently played a key role in the wartime German nuclear program (pp. 3608, 4996).]



Die Naturwissenschaften 27:402-410 (June 1939)

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Kann der Energieinhalt der Atomkerne technisch nutzbar gemacht werden?

Von S. FLÜGGE, Berlin-Dahlem*.

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Zu Beginn dieses Jahres entdeckten HAHN und STRASSMANN[1], daß beim Beschießen von Uran mit schnellen oder langsamen Neutronen Barium, Lanthan und andere Elemente mittleren Atomgewichts entstehen. Die Entdeckung wurde sofort von zahlreichen Forschern in vielen Ländern aufgegriffen, und eine intensive Arbeit auf diesem Gebiet hat den Sachverhalt weitgehend geklärt und in mehr als 50 Veröffentlichungen schon zahlreiches quantitatives Material ergeben.

Im folgenden soll nur über ein Teilgebiet des ganzen, durch die HAHN-STRASSMANNsche Entdeckung angeschnittenen Fragenkomplexes berichtet werden. Gleich nachdem die Entdeckung der Zerspaltung von Urankernen sichergestellt war, wurde im HAHNschen Institut und wohl auch anderwärts die Frage aufgeworfen, ob bei einem so gewaltsamen Eingriff nicht auch einige Neutronen aus dem zerbrechenden Kern „abgedampft" oder „abgesplittert" werden könnten? Die Frage wurde auch alsbald in Angriff genommen, da sie zu einer sehr interessanten Konsequenz führte: Wenn jedes Neutron, das eine Aufspaltung hervorruft, im Gefolge der Aufspaltung 2 oder 3 Neutronen frei macht, so muß es möglich sein, daß diese Neutronen ihrerseits wiederum neue Aufspaltungen anderer Urankerne herbeiführen und auf diese Weise ihre Zahl noch weiter vergrößert wird, so daß eine Kettenreaktion ohne Ende schließlich zu einer Umsetzung des ganzen in dem bestrahlten Präparat vorhandenen Urans führen kann.

Man konnte dazu sofort einige Überlegungen anstellen, noch ehe man Einzelheiten kannte: Die Hauptfrage ist natürlich, ob und wie viele Neutronen je Spaltungsprozeß in Freiheit gesetzt werden. Dann kommt alles auf das weitere Schicksal dieser Neutronen an. Sie werden elastische Stöße ausführen können, die im wesentlichen nur ihre Richtung ändern; sie können unelastisch gestreut werden, so daß sie außer der Richtungsänderung auch noch eine beträchtliche Energieeinbuße erleiden; sie können eingefangen werden in der bekannten Reaktion

$$ {}^{238}_{92}\mathrm{U} + {}^{1}_{0}n \longrightarrow {}^{239}_{92}\mathrm{U}^{*} \xrightarrow[23\,\mathrm{m}]{\beta} {}^{239}_{93}\mathrm{Eka\text{-}Re}; \qquad (1) $$

sie können endlich noch Einfangungen oder Umwandlungen an anderen Substanzen erleiden, die außer dem Uran anwesend sind, sofern man nicht reines Uranmetall bestrahlt, also z. B. am Sauerstoff von U_3O_8. Es wird darauf ankommen, ob all diese Reaktionen, welche nur Neutronen wegfangen ohne neue zu erzeugen, einen so großen Gesamtwirkungsquerschnitt haben, daß die beim Spaltungsprozeß erreichte Neutronenproduktion dadurch kompensiert wird oder nicht. Um zu erkennen, ob eine Kettenreaktion ablaufen kann, müssen wir also über eine genaue Kenntnis aller konkurrierenden Wirkungsquerschnitte verfügen.

Endlich spielt noch eine dritte Frage eine große Rolle: die räumliche Ausdehnung der bestrahlten Substanzmenge. Die erzeugten Neutronen werden, ehe sie wieder einen Kern aufspalten, einen Weg von der Größenordnung einiger Zentimeter in der Substanz zurücklegen. Läuft also die Reaktionskette an einer Stelle der Substanz an, so breitet sie sich mit zunehmender Neutronenzahl über ein immer größeres Gebiet aus. Nun haben die Neutronen bei jedem elastischen Stoß die gleiche Chance zurückgeworfen zu werden, wie weiter nach außen zu laufen. Daher wird die Konzentration der freigesetzten Neutronen auch an der Ausgangsstelle der Reaktionskette zeitlich rasch ansteigen, sofern das benutzte Substanzvolumen so groß ist, daß der größte Teil der Neutronen oft zurückgeworfen wird, ohne die Oberfläche zu erreichen, durch die er die Substanz endgültig verlassen würde. Mit anderen Worten: Der Durchmesser einer bestrahlten Kugel aus uranhaltiger Substanz muß groß sein gegen die freie Weglänge, wird also einige Meter betragen müssen.

Ehe wir zur Diskussion der bisher angeschnittenen Einzelfragen übergehen, soll noch ein Wort gesagt werden über die Größenordnung der freiwerdenden Energie. Man kann sie leicht ungefähr abschätzen[2], ja sogar ziemlich genau angeben, daß jeder Spaltungsprozeß eine Energie von 180 MeV in Freiheit setzt[3]. Das läßt sich aus der Differenz der Massendefekte des Urankerns und der entstehenden Spaltungsprodukte herleiten[3]; die Zahl ist einigermaßen auch durch direkte Messung der kinetischen Energie der beiden entstehenden mittelschweren Kerne experimentell sichergestellt. Daß sich hierbei statt der erwarteten 180 MeV nur rund 160 MeV ergaben[4], kann schon als Hinweis darauf dienen, daß der Rest der Energie entweder noch in abgespaltene Neutronen gesteckt oder in Form von γ-Quanten abgestrahlt wird.

Der so erhaltene Energiebetrag ist sehr beträchtlich. Da die vorstehenden Überlegungen zeigen, daß es durchaus nicht ausgeschlossen ist, durch eine geeignete Versuchsanordnung eine Reaktionskette hervorzurufen, bei der das ganze Uran eines großen Blocks verbraucht wird, ist es zweckmäßig, sich einmal auszurechnen, wie groß z. B. die Energiemenge ist, die freigesezt wird, wenn in 1 m^3 U_3O_8 alles vorhandene Uran restlos umgewandelt wird. 1 m^3 aufgeschüttetes U_3O_8-Pulver wiegt 4,2 t und enthält $3 \cdot 10^{27}$ Moleküle, also $9 \cdot 10^{27}$ Uranatome. Da je Atom etwa 180 MeV, d. h. rund $3 \cdot 10^{-4}$ erg oder $3 \cdot 10^{-12}$ mkg frei werden, wird insgesamt ein Energiebetrag von $27 \cdot 10^{15}$ mkg frei gesetzt, d. h. 1 m^3 U_3O_8 genügt zur Aufbringung der Energie, welche nötig ist, um 1 km^3 Wasser (Gewicht 10^{12} kg) 27 km hoch-

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* Aus dem Kaiser Wilhelm-Institut für Chemie.

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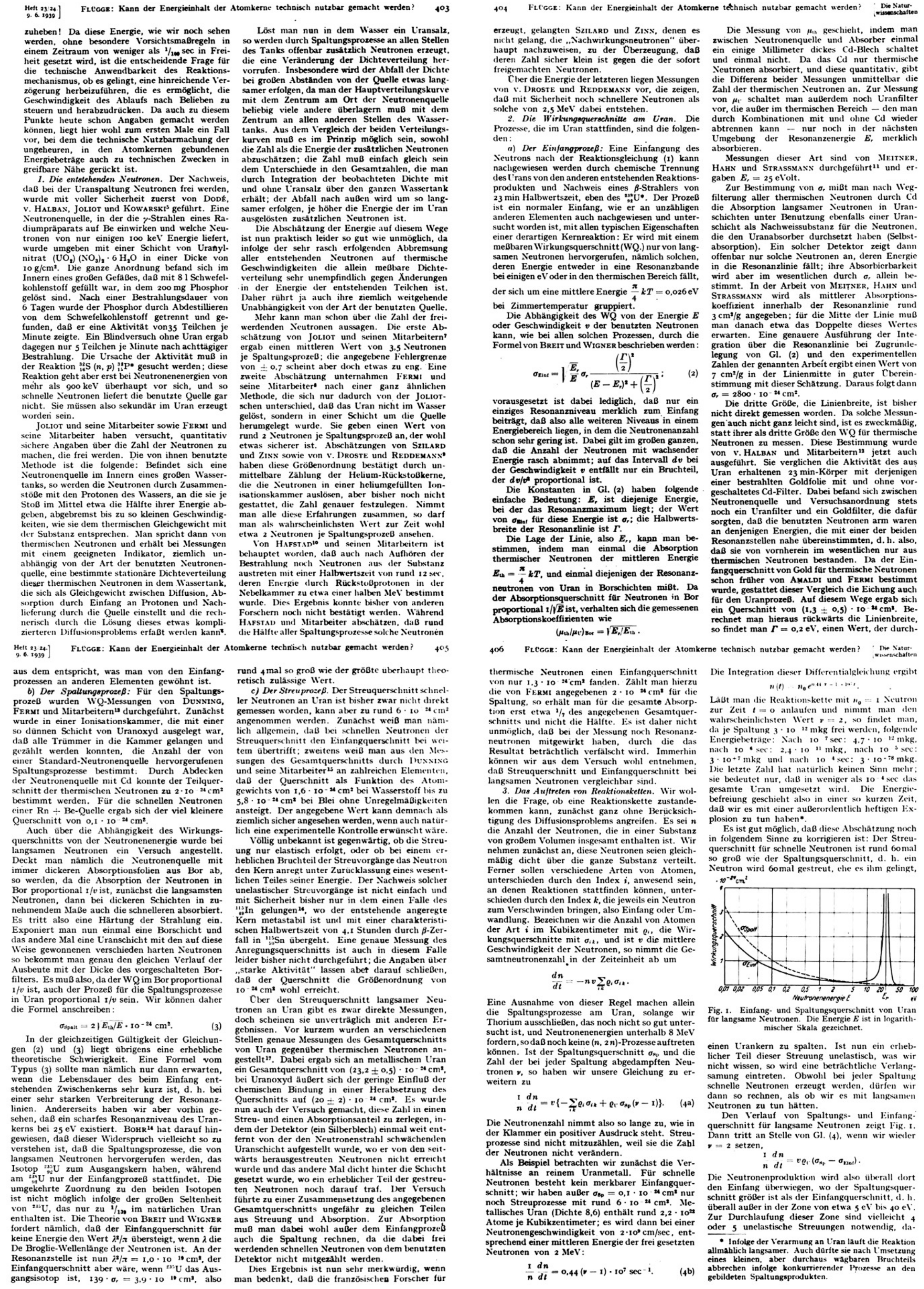
Figure D.49: Siegfried Flügge. Kann der Energieinhalt der Atomkerne technisch nutzbar gemacht werden? *Die Naturwissenschaften* 27:402–410. 9 June 1939. [https://digital.deutsches-museum.de/item/FA-002-746]

***Die Naturwissenschaften* 27:402-410 (June 1939)**



zuheben! Da diese Energie, wie wir noch sehen werden, ohne besondere Vorsichtsmaßregeln in einem Zeitraum von weniger als $^1/_{100}$ sec in Freiheit gesetzt wird, ist die entscheidende Frage für die technische Anwendbarkeit des Reaktionsmechanismus, ob es gelingt, eine hinreichende Verzögerung herbeizuführen, die es ermöglicht, die Geschwindigkeit des Ablaufs nach Belieben zu steuern und herabzudrücken. Da auch zu diesem Punkte heute schon Angaben gemacht werden können, liegt hier wohl zum ersten Male ein Fall vor, bei dem die technische Nutzbarmachung der ungeheuren, in den Atomkernen gebundenen Energiebeträge auch zu technischen Zwecken in greifbare Nähe gerückt ist.

1. Die entstehenden Neutronen. Der Nachweis, daß bei der Uranspaltung Neutronen frei werden, wurde mit voller Sicherheit zuerst von Dodé, v. Halban, Joliot und Kowarski[5] geführt. Eine Neutronenquelle, in der die γ-Strahlen eines Radiumpräparats auf Be einwirken und welche Neutronen von nur einigen 100 keV Energie liefert, wurde umgeben mit einer Schicht von Uranylnitrat $(UO_2)(NO_3)_2 \cdot 6\,H_2O$ in einer Dicke von 10 g/cm². Die ganze Anordnung befand sich im Innern eines großen Gefäßes, daß mit 8 l Schwefelkohlenstoff gefüllt war, in dem 200 mg Phosphor gelöst sind. Nach einer Bestrahlungsdauer von 6 Tagen wurde der Phosphor durch Abdestillieren von dem Schwefelkohlenstoff getrennt und gefunden, daß er eine Aktivität von 35 Teilchen je Minute zeigte. Ein Blindversuch ohne Uran ergab dagegen nur 5 Teilchen je Minute nach achttägiger Bestrahlung. Die Ursache der Aktivität muß in der Reaktion $^{32}_{16}S\,(n,p)\,^{32}_{15}P^*$ gesucht werden; diese Reaktion geht aber erst bei Neutronenenergien von mehr als 900 keV überhaupt vor sich, und so schnelle Neutronen liefert die benutzte Quelle gar nicht. Sie müssen also sekundär im Uran erzeugt worden sein.

Joliot und seine Mitarbeiter sowie Fermi und seine Mitarbeiter haben versucht, quantitativ sichere Angaben über die Zahl der Neutronen zu machen, die frei werden. Die von ihnen benutzte Methode ist die folgende: Befindet sich eine Neutronenquelle im Innern eines großen Wassertanks, so werden die Neutronen durch Zusammenstöße mit den Protonen des Wassers, an die sie je Stoß im Mittel etwa die Hälfte ihrer Energie abgeben, abgebremst bis zu so kleinen Geschwindigkeiten, wie sie dem thermischen Gleichgewicht mit der Substanz entsprechen. Man spricht dann von thermischen Neutronen und erhält bei Messungen mit einem geeigneten Indikator, ziemlich unabhängig von der Art der benutzten Neutronenquelle, eine bestimmte stationäre Dichteverteilung dieser thermischen Neutronen in dem Wassertank, die sich als Gleichgewicht zwischen Diffusion, Absorption durch Einfang an Protonen und Nachlieferung durch die Quelle einstellt und die rechnerisch durch die Lösung dieses etwas komplizierteren Diffusionsproblems erfaßt werden kann[6].

Löst man nun in dem Wasser ein Uransalz, so werden durch Spaltungsprozesse an allen Stellen des Tanks offenbar zusätzlich Neutronen erzeugt, die eine Veränderung der Dichteverteilung hervorrufen. Insbesondere wird der Abfall der Dichte bei großen Abständen von der Quelle etwas langsamer erfolgen, da man der Hauptverteilungskurve mit dem Zentrum am Ort der Neutronenquelle beliebig viele andere überlagern muß mit dem Zentrum an allen anderen Stellen des Wassertanks. Aus dem Vergleich der beiden Verteilungskurven muß es im Prinzip möglich sein, sowohl die Zahl als die Energie der zusätzlichen Neutronen abzuschätzen; die Zahl muß einfach gleich sein dem Unterschiede in den Gesamtzahlen, die man durch Integration der beobachteten Dichte mit und ohne Uransalz über den ganzen Wassertank erhält; der Abfall nach außen wird um so langsamer erfolgen, je höher die Energie der im Uran ausgelösten zusätzlichen Neutronen ist.

Die Abschätzung der Energie auf diesem Wege ist nun praktisch leider so gut wie unmöglich, da infolge der sehr rasch erfolgenden Abbremsung aller entstehenden Neutronen auf thermische Geschwindigkeiten die allein meßbare Dichteverteilung sehr unempfindlich gegen Änderungen in der Energie der entstehenden Teilchen ist. Daher rührt ja auch ihre ziemlich weitgehende Unabhängigkeit von der Art der benutzten Quelle.

Mehr kann man schon über die Zahl der freiwerdenden Neutronen aussagen. Die erste Abschätzung von Joliot und seinen Mitarbeitern[7] ergab einen mittleren Wert von 3,5 Neutronen je Spaltungsprozeß; die angegebene Fehlergrenze von $\pm$ 0,7 scheint aber doch etwas zu eng. Eine zweite Abschätzung unternahmen Fermi und seine Mitarbeiter[8] nach einer ganz ähnlichen Methode, die sich nur dadurch von der Joliotschen unterschied, daß das Uran nicht im Wasser gelöst, sondern in einer Schicht um die Quelle herumgelegt wurde. Sie geben einen Wert von rund 2 Neutronen je Spaltungsprozeß an, der wohl etwas sicherer ist. Abschätzungen von Szilard und Zinn sowie von v. Droste und Reddemann[9] haben diese Größenordnung bestätigt durch unmittelbare Zählung der Helium-Rückstoßkerne, die die Neutronen in einer heliumgefüllten Ionisationskammer auslösen, aber bisher noch nicht gestattet, die Zahl genauer festzulegen. Nimmt man alle diese Erfahrungen zusammen, so darf man als wahrscheinlichsten Wert zur Zeit wohl etwa 2 Neutronen je Spaltungsprozeß ansehen.

Von Hafstad[10] und seinen Mitarbeitern ist behauptet worden, daß auch nach Aufhören der Bestrahlung noch Neutronen aus der Substanz austreten mit einer Halbwertszeit von rund 12 sec, deren Energie durch Rückstoßprotonen in der Nebelkammer zu etwa einer halben MeV bestimmt wurde. Dies Ergebnis konnte bisher von anderen Forschern noch nicht bestätigt werden. Während Hafstad und Mitarbeiter abschätzen, daß rund die Hälfte aller Spaltungsprozesse solche Neutronen erzeugt, gelangten Szilard und Zinn, denen es nicht gelang, die „Nachwirkungsneutronen" überhaupt nachzuweisen, zu der Überzeugung, daß deren Zahl sicher klein ist gegen die der sofort freigemachten Neutronen.

Über die Energie der letzteren liegen Messungen von v. Droste und Reddemann vor, die zeigen, daß mit Sicherheit noch schnellere Neutronen als solche von 2,5 MeV dabei entstehen.

2. Die Wirkungsquerschnitte am Uran. Die Prozesse, die im Uran stattfinden, sind die folgenden:

a) Der Einfangprozeß: Eine Einfangung des Neutrons nach der Reaktionsgleichung (1) kann nachgewiesen werden durch chemische Trennung des Urans von den anderen entstehenden Reaktionsprodukten und Nachweis eines β-Strahlers von 23 min Halbwertszeit, eben des $^{239}_{92}U^*$. Der Prozeß ist ein normaler Einfang, wie er an unzähligen anderen Elementen auch nachgewiesen und untersucht worden ist, mit allen typischen Eigenschaften einer derartigen Kernreaktion: Er wird mit einem meßbaren Wirkungsquerschnitt (WQ.) nur von langsamen Neutronen hervorgerufen, nämlich solchen, deren Energie entweder in eine Resonanzbande bei einigen eV oder in den thermischen Bereich fällt, der sich um eine mittlere Energie $\frac{\pi}{4}kT = 0{,}026$ eV bei Zimmertemperatur gruppiert.

Die Abhängigkeit des WQ von der Energie E oder Geschwindigkeit v der benutzten Neutronen kann, wie bei allen solchen Prozessen, durch die Formel von Breit und Wigner beschrieben werden:

$$\sigma_{\text{Einf}} = \sqrt{\frac{E_r}{E}}\,\sigma_r\,\frac{\left(\frac{\Gamma}{2}\right)^2}{(E-E_r)^2+\left(\frac{\Gamma}{2}\right)^2}; \qquad (2)$$

vorausgesetzt ist dabei lediglich, daß nur ein einziges Resonanzniveau merklich zum Einfang beiträgt, daß also alle weiteren Niveaus in einem Energiebereich liegen, in dem die Neutronenanzahl schon sehr gering ist. Dabei gilt im großen ganzen, daß die Anzahl der Neutronen mit wachsender Energie rasch abnimmt; auf das Intervall dv bei der Geschwindigkeit v entfällt nur ein Bruchteil, der dv/v^3 proportional ist.

Die Konstanten in Gl. (2) haben folgende einfache Bedeutung: E_r ist diejenige Energie, bei der das Resonanzmaximum liegt; der Wert von σ_{Einf} für diese Energie ist σ_r; die Halbwertsbreite der Resonanzlinie ist Γ.

Die Lage der Linie, also E_r, kann man bestimmen, indem man einmal die Absorption thermischer Neutronen der mittleren Energie $E_{\text{th}} = \frac{\pi}{4}kT$, und einmal diejenigen der Resonanzneutronen von Uran in Borschichten mißt. Da der Absorptionsquerschnitt für Neutronen in Bor proportional $1/\sqrt{E}$ ist, verhalten sich die gemessenen Absorptionskoeffizienten wie

$$(\mu_{\text{th}}/\mu_{\text{U}})_{\text{Bor}} = \sqrt{E_r/E_{\text{th}}}\,.$$

Die Messung von μ_{th} geschieht, indem man zwischen Neutronenquelle und Absorber einmal ein einige Millimeter dickes Cd-Blech schaltet und einmal nicht. Da das Cd nur thermische Neutronen absorbiert, und diese quantitativ, gibt die Differenz beider Messungen unmittelbar die Zahl der thermischen Neutronen an. Zur Messung von μ_{U} schaltet man außerdem noch Uranfilter vor, die außer im thermischen Bereich — den man durch Kombinationen mit und ohne Cd wieder abtrennen kann — nur noch in der nächsten Umgebung der Resonanzenergie E_r merklich absorbieren.

Messungen dieser Art sind von Meitner, Hahn und Strassmann durchgeführt[11] und ergaben $E_r = 25$ eVolt.

Zur Bestimmung von σ_r mißt man nach Wegfilterung aller thermischen Neutronen durch Cd die Absorption langsamer Neutronen in Uranschichten unter Benutzung ebenfalls einer Uranschicht als Nachweissubstanz für die Neutronen, die den Uranabsorber durchsetzt haben (Selbstabsorption). Ein solcher Detektor zeigt dann offenbar nur solche Neutronen an, deren Energie in die Resonanzlinie fällt; ihre Absorbierbarkeit wird aber im wesentlichen durch σ_r allein bestimmt. In der Arbeit von Meitner, Hahn und Strassmann wird als mittlerer Absorptionskoeffizient innerhalb der Resonanzlinie rund 3 cm²/g angegeben; für die Mitte der Linie muß man danach etwa das Doppelte dieses Wertes erwarten. Eine genauere Ausführung der Integration über die Resonanzlinie bei Zugrundelegung von Gl. (2) und den experimentellen Zahlen der genannten Arbeit ergibt einen Wert von 7 cm²/g in der Linienmitte in guter Übereinstimmung mit dieser Schätzung. Daraus folgt dann $\sigma_r = 2800 \cdot 10^{-24}$ cm².

Die dritte Größe, die Linienbreite, ist bisher nicht direkt gemessen worden. Da solche Messungen auch nicht ganz leicht sind, ist es zweckmäßig, statt ihrer als dritte Größe den WQ für thermische Neutronen zu messen. Diese Bestimmung wurde von v. Halban und Mitarbeitern[12] jetzt auch ausgeführt. Sie verglichen die Aktivität des aus Uran erhaltenen 23 min-Körper mit derjenigen einer bestrahlten Goldfolie mit und ohne vorgeschaltetes Cd-Filter. Dabei befand sich zwischen Neutronenquelle und Versuchsanordnung stets noch ein Uranfilter und ein Goldfilter, die dafür sorgten, daß die benutzten Neutronen arm waren an denjenigen Energien, die mit einer der beiden Resonanzstellen nahe übereinstimmten, d. h. also, daß sie von vornherein im wesentlichen nur aus thermischen Neutronen bestanden. Da der Einfangquerschnitt von Gold für thermische Neutronen schon früher von Amaldi und Fermi bestimmt wurde, gestattet dieser Vergleich die Eichung auch für den Uranprozeß. Auf diesem Wege ergab sich ein Querschnitt von $(1{,}3 \pm 0{,}5) \cdot 10^{-24}$ cm². Berechnet man hieraus rückwärts die Linienbreite, so findet man $\Gamma = 0{,}2$ eV, einen Wert, der durchaus dem entspricht, was man von den Einfangprozessen an anderen Elementen gewöhnt ist.

b) Der Spaltungsprozeß: Für den Spaltungsprozeß wurden WQ-Messungen von Dunning, Fermi und Mitarbeitern[13] durchgeführt. Zunächst wurde in einer Ionisationskammer, die mit einer so dünnen Schicht von Uranoxyd ausgelegt war, daß alle Trümmer in die Kammer gelangen und gezählt werden konnten, die Anzahl der von einer Standard-Neutronenquelle hervorgerufenen Spaltungsprozesse bestimmt. Durch Abdecken der Neutronenquelle mit Cd konnte der Teilquerschnitt der thermischen Neutronen zu $2 \cdot 10^{-24}$ cm² bestimmt werden. Für die schnellen Neutronen einer Rn + Be-Quelle ergab sich der viel kleinere Querschnitt von $0{,}1 \cdot 10^{-24}$ cm².

Auch über die Abhängigkeit des Wirkungsquerschnitts von der Neutronenenergie wurde bei langsamen Neutronen ein Versuch angestellt. Deckt man nämlich die Neutronenquelle mit immer dickeren Absorptionsfolien aus Bor ab, so werden, da die Absorption der Neutronen in Bor proportional $1/v$ ist, zunächst die langsamsten Neutronen, dann bei dickeren Schichten in zunehmendem Maße auch die schnelleren absorbiert. Es tritt also eine Härtung der Strahlung ein. Exponiert man nun einmal eine Borschicht und das andere Mal eine Uranschicht mit den auf diese Weise gewonnenen verschieden harten Neutronen so bekommt man genau den gleichen Verlauf der Ausbeute mit der Dicke des vorgeschalteten Borfilters. Es muß also, da der WQ im Bor proportional $1/v$ ist, auch der Prozeß für die Spaltungsprozesse in Uran proportional $1/v$ sein. Wir können daher die Formel anschreiben:

$$\sigma_{\text{Spalt}} = 2\sqrt{E_{\text{th}}/E} \cdot 10^{-24}\ \text{cm}^2. \qquad (3)$$

In der gleichzeitigen Gültigkeit der Gleichungen (2) und (3) liegt übrigens eine erhebliche theoretische Schwierigkeit. Eine Formel vom Typus (3) sollte man nämlich nur dann erwarten, wenn die Lebensdauer des beim Einfang entstehenden Zwischenkerns sehr kurz ist, d. h. bei einer sehr starken Verbreiterung der Resonanzlinien. Andererseits haben wir aber vorhin gesehen, daß ein scharfes Resonanzniveau des Urankerns bei 25 eV existiert. Bohr[14] hat darauf hingewiesen, daß dieser Widerspruch vielleicht so zu verstehen ist, daß die Spaltungsprozesse, die von langsamen Neutronen hervorgerufen werden, das Isotop $^{235}_{92}U$ zum Ausgangskern haben, während am $^{238}_{92}U$ nur der Einfangprozeß stattfindet. Die umgekehrte Zuordnung zu den beiden Isotopen ist nicht möglich infolge der großen Seltenheit von ^{235}U, das nur zu $^1/_{139}$ im natürlichen Uran enthalten ist. Die Theorie von Breit und Wigner fordert nämlich, daß der Einfangquerschnitt für keine Energie den Wert λ^2/π übersteigt, wenn λ die De Broglie-Wellenlänge der Neutronen ist. An der Resonanzstelle ist nun $\lambda^2/\pi = 1{,}0 \cdot 10^{-19}$ cm², der Einfangquerschnitt aber wäre, wenn ^{235}U das Ausgangsisotop ist, $139 \cdot \sigma_r = 3{,}9 \cdot 10^{-19}$ cm², also rund 4 mal so groß wie der größte überhaupt theoretisch zulässige Wert.

c) Der Streuprozeß. Der Streuquerschnitt schneller Neutronen an Uran ist bisher zwar nicht direkt gemessen worden, kann aber zu rund $6 \cdot 10^{-24}$ cm² angenommen werden. Zunächst weiß man nämlich allgemein, daß bei schnellen Neutronen der Streuquerschnitt den Einfangquerschnitt bei weitem übertrifft; zweitens weiß man aus den Messungen des Gesamtquerschnitts durch Dunning und seine Mitarbeiter[15] an zahlreichen Elementen, daß der Querschnitt als Funktion des Atomgewichts von $1{,}6 \cdot 10^{-24}$ cm² bei Wasserstoff bis zu $5{,}8 \cdot 10^{-24}$ cm² bei Blei ohne Unregelmäßigkeiten ansteigt. Der angegebene Wert kann demnach als ziemlich sicher angesehen werden, wenn auch natürlich eine experimentelle Kontrolle erwünscht wäre.

Völlig unbekannt ist gegenwärtig, ob die Streuung nur elastisch erfolgt, oder ob bei einem erheblichen Bruchteil der Streuvorgänge das Neutron den Kern anregt unter Zurücklassung eines wesentlichen Teiles seiner Energie. Der Nachweis solcher unelastischer Streuvorgänge ist nicht einfach und mit Sicherheit bisher nur in dem einen Falle des $^{115}_{49}In$ gelungen[16], wo der entstehende angeregte Kern metastabil ist und mit einer charakteristischen Halbwertszeit von 4,1 Stunden durch β-Zerfall in $^{115}_{50}Sn$ übergeht. Eine genaue Messung des Anregungsquerschnitts ist auch in diesem Falle leider bisher nicht durchgeführt; die Angaben über „starke Aktivität" lassen aber darauf schließen, daß der Querschnitt die Größenordnung von 10^{-24} cm² wohl erreicht.

Über den Streuquerschnitt langsamer Neutronen an Uran gibt es zwar direkte Messungen, doch scheinen sie unverträglich mit anderen Ergebnissen. Vor kurzem wurden an verschiedenen Stellen genaue Messungen des Gesamtquerschnitts von Uran gegenüber thermischen Neutronen angestellt[17]. Dabei ergab sich an metallischem Uran ein Gesamtquerschnitt von $(23{,}2 \pm 0{,}5) \cdot 10^{-24}$ cm², bei Uranoxyd äußert sich der geringe Einfluß der chemischen Bindung in einer Herabsetzung des Querschnitts auf $(20 \pm 2) \cdot 10^{-24}$ cm². Es wurde nun auch der Versuch gemacht, diese Zahl in einen Streu- und einen Absorptionsanteil zu zerlegen, indem der Detektor (ein Silberblech) einmal weit entfernt von der den Neutronenstrahl schwächenden Uranschicht aufgestellt wurde, wo er von den seitwärts herausgestreuten Neutronen nicht erreicht wurde und das andere Mal dicht hinter die Schicht gesetzt wurde, wo ein erheblicher Teil der gestreuten Neutronen noch darauf traf. Der Versuch führte zu einer Zusammensetzung des angegebenen Gesamtquerschnitts ungefähr zu gleichen Teilen aus Streuung und Absorption. Zur Absorption muß man dabei wohl außer dem Einfangprozeß auch die Spaltung rechnen, da die dabei frei werdenden schnellen Neutronen von dem benutzten Detektor nicht mitgezählt werden.

Dies Ergebnis ist nun sehr merkwürdig, wenn man bedenkt, daß die französischen Forscher für thermische Neutronen einen Einfangquerschnitt von nur $1{,}3 \cdot 10^{-24}$ cm² fanden. Zählt man hierzu die von Fermi angegebenen $2 \cdot 10^{-24}$ cm² für die Spaltung, so erhält man für die gesamte Absorption erst etwa $^1/_7$ des angegebenen Gesamtquerschnitts und nicht die Hälfte. Es ist daher nicht unmöglich, daß bei der Messung noch Resonanzneutronen mitgewirkt haben, durch die das Resultat beträchtlich verfälscht wird. Immerhin können wir aus dem Versuch wohl entnehmen, daß Streuquerschnitt und Einfangquerschnitt bei langsamen Neutronen vergleichbar sind.

3. Das Auftreten von Reaktionsketten. Wir wollen die Frage, ob eine Reaktionskette zustandekommen kann, zunächst ganz ohne Berücksichtigung des Diffusionsproblems angreifen. Es sei n die Anzahl der Neutronen, die in einer Substanz von großem Volumen insgesamt enthalten ist. Wir nehmen zunächst an, diese Neutronen seien gleichmäßig dicht über die ganze Substanz verteilt. Ferner sollen verschiedene Arten von Atomen, unterschieden durch den Index i, anwesend sein, an denen Reaktionen stattfinden können, unterschieden durch den Index k, die jeweils ein Neutron zum Verschwinden bringen, also Einfang oder Umwandlung. Bezeichnen wir die Anzahl von Atomen der Art i im Kubikzentimeter mit ϱ_i, die Wirkungsquerschnitte mit σ_{ik}, und ist v die mittlere Geschwindigkeit der Neutronen, so nimmt die Gesamtneutronenzahl in der Zeiteinheit ab um

$$\frac{dn}{dt} = -n\,v \sum_{ik} \varrho_i\,\sigma_{ik}\,.$$

Eine Ausnahme von dieser Regel machen allein die Spaltungsprozesse am Uran, solange wir Thorium ausschließen, das noch nicht so gut untersucht ist, und Neutronenenergien unterhalb 8 MeV fordern, so daß noch keine $(n, 2n)$-Prozesse auftreten können. Ist der Spaltungsquerschnitt σ_{Sp} und die Zahl der bei jeder Spaltung abgedampften Neutronen ν, so haben wir unsere Gleichung zu erweitern zu

$$\frac{1}{n}\,\frac{dn}{dt} = v\Big\{-\sum_{ik} \varrho_i\,\sigma_{ik} + \varrho_{\text{U}}\,\sigma_{\text{Sp}}\,(\nu - 1)\Big\}. \qquad (4a)$$

Die Neutronenzahl nimmt also so lange zu, wie in der Klammer ein positiver Ausdruck steht. Streuprozesse sind nicht mitzuzählen, weil sie die Zahl der Neutronen nicht verändern.

Als Beispiel betrachten wir zunächst die Verhältnisse an reinem Uranmetall. Für schnelle Neutronen besteht kein merkbarer Einfangquerschnitt; wir haben außer $\sigma_{\text{Sp}} = 0{,}1 \cdot 10^{-24}$ cm² nur noch Streuprozesse mit rund $6 \cdot 10^{-24}$ cm². Metallisches Uran (Dichte 8,6) enthält rund $2{,}2 \cdot 10^{22}$ Atome je Kubikzentimeter; es wird dann bei einer Neutronengeschwindigkeit von $2 \cdot 10^9$ cm/sec, entsprechend einer mittleren Energie der frei gesetzten Neutronen von 2 MeV:

$$\frac{1}{n}\,\frac{dn}{dt} = 0{,}44\,(\nu - 1) \cdot 10^7\ \text{sec}^{-1}. \qquad (4b)$$

Die Integration dieser Differentialgleichung ergibt

$$n(t) = n_0\,e^{0{,}44(\nu-1)\cdot 10^7 t}.$$

Läßt man die Reaktionskette mit $n_0 = 1$ Neutron zur Zeit $t = 0$ anlaufen und nimmt man den wahrscheinlichsten Wert $\nu = 2$, so findet man, da je Spaltung $3 \cdot 10^{-12}$ mkg frei werden, folgende Energiebeträge: Nach 10^{-7} sec: $4{,}7 \cdot 10^{-12}$ mkg, nach 10^{-6} sec: $2{,}4 \cdot 10^{-11}$ mkg, nach 10^{-5} sec: $3 \cdot 10^{+7}$ mkg und nach 10^{-4} sec: $3 \cdot 10^{+78}$ mkg. Die letzte Zahl hat natürlich keinen Sinn mehr; sie bedeutet nur, daß in weniger als 10^{-4} sec das gesamte Uran umgesetzt wird. Die Energiebefreiung geschieht also in einer so kurzen Zeit, daß wir es mit einer außerordentlich heftigen Explosion zu tun haben[*].

Es ist gut möglich, daß diese Abschätzung noch in folgendem Sinne zu korrigieren ist: Der Streuquerschnitt für schnelle Neutronen ist rund 60 mal so groß wie der Spaltungsquerschnitt, d. h. ein Neutron wird 60 mal gestreut, ehe es ihm gelingt, einen Urankern zu spalten. Ist nun ein erheblicher Teil dieser Streuung unelastisch, was wir nicht wissen, so wird eine beträchtliche Verlangsamung eintreten. Obwohl bei jeder Spaltung schnelle Neutronen erzeugt werden, dürfen wir dann so rechnen, als ob wir es mit langsamen Neutronen zu tun hätten.

Fig. 1. Einfang- und Spaltungsquerschnitt von Uran für langsame Neutronen. Die Energie E ist in logarithmischer Skala gezeichnet.

Den Verlauf von Spaltungs- und Einfangquerschnitt für langsame Neutronen zeigt Fig. 1. Dann tritt an Stelle von Gl. (4), wenn wir wieder $\nu = 2$ setzen,

$$\frac{1}{n}\,\frac{dn}{dt} = v\,\varrho_{\text{U}}\,(\sigma_{\text{Sp}} - \sigma_{\text{Einf}})\,.$$

Die Neutronenproduktion wird also überall dort den Einfang überwiegen, wo der Spaltungsquerschnitt größer ist als der Einfangquerschnitt, d. h. überall außer in der Zone von etwa 5 eV bis 40 eV. Zur Durchlaufung dieser Zone sind vielleicht 4 oder 5 unelastische Streuungen notwendig, da-

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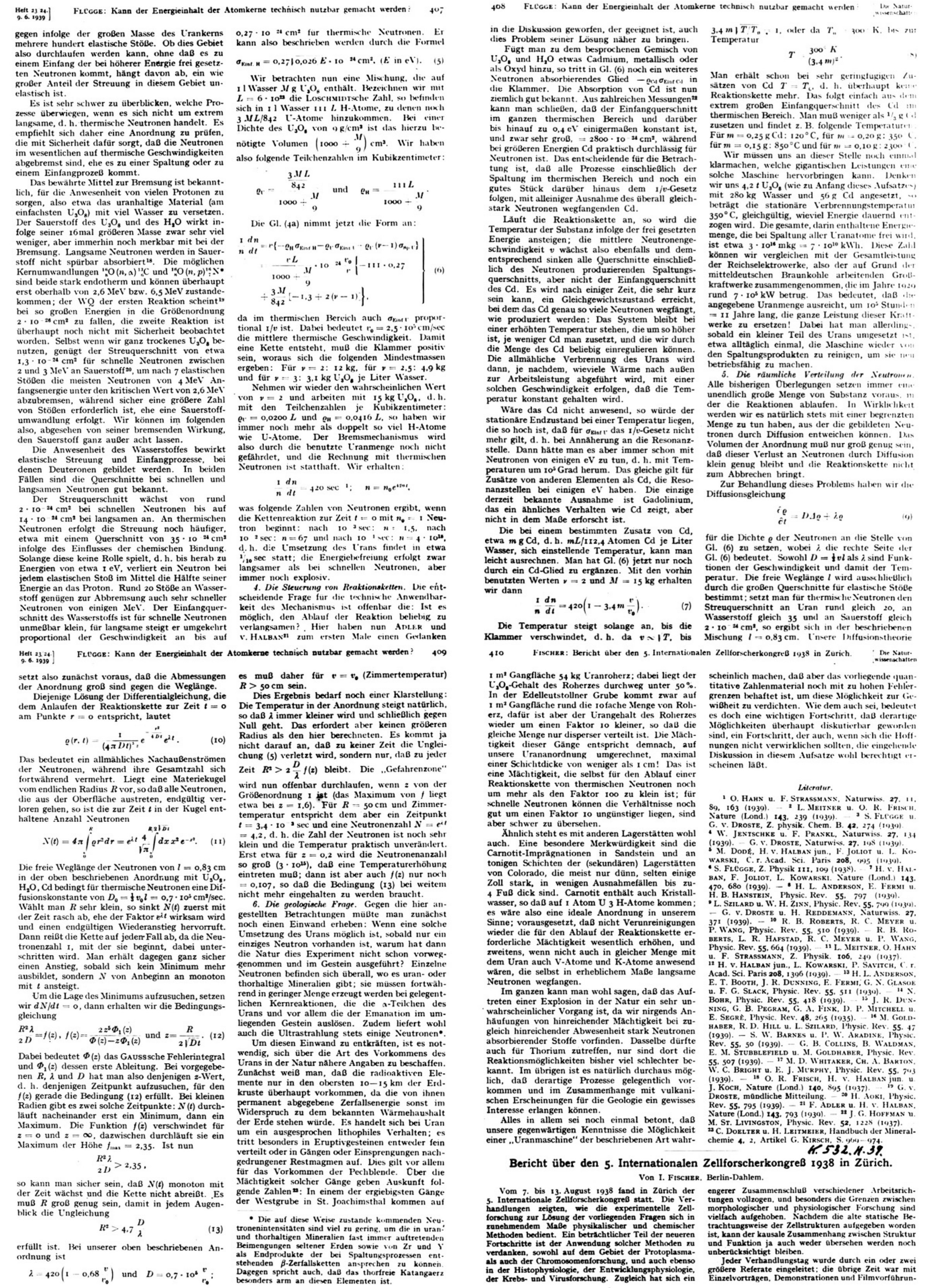
[*] Infolge der Verarmung an Uran läuft die Reaktion allmählich langsamer. Auch dürfte sie nach Umsetzung eines kleinen, aber durchaus wägbaren Bruchteils abbrechen infolge konkurrierender Prozesse an den gebildeten Spaltungsprodukten.

Figure D.50: Siegfried Flügge. Kann der Energieinhalt der Atomkerne technisch nutzbar gemacht werden? *Die Naturwissenschaften* 27:402–410. 9 June 1939. [https://digital.deutsches-museum.de/item/FA-002-746]

Die Naturwissenschaften 27:402-410 (June 1939)



gegen infolge der großen Masse des Urankerns mehrere hundert elastische Stöße. Ob dies Gebiet also durchlaufen werden kann, ohne daß es zu einem Einfang der bei höherer Energie frei gesetzten Neutronen kommt, hängt davon ab, ein wie großer Anteil der Streuung in diesem Gebiet unelastisch ist.

Es ist sehr schwer zu überblicken, welche Prozesse überwiegen, wenn es sich nicht um extrem langsame, d. h. thermische Neutronen handelt. Es empfiehlt sich daher eine Anordnung zu prüfen, die mit Sicherheit dafür sorgt, daß die Neutronen im wesentlichen auf thermische Geschwindigkeiten abgebremst sind, ehe es zu einer Spaltung oder zu einem Einfangprozeß kommt.

Das bewährte Mittel zur Bremsung ist bekanntlich, für die Anwesenheit von vielen Protonen zu sorgen, also etwa das uranhaltige Material (am einfachsten U_3O_8) mit viel Wasser zu versetzen. Der Sauerstoff des U_3O_8 und des H_2O wirkt infolge seiner 16mal größeren Masse zwar sehr viel weniger, aber immerhin noch merkbar mit bei der Bremsung. Langsame Neutronen werden in Sauerstoff nicht spürbar absorbiert[18]. Die möglichen Kernumwandlungen ${}^{16}_{8}O(n,\alpha){}^{13}_{6}C$ und ${}^{16}_{8}O(n,p){}^{16}_{7}N^*$ sind beide stark endotherm und können überhaupt erst oberhalb von 2,6 MeV bzw. 6,5 MeV zustandekommen; der WQ der ersten Reaktion scheint[19] bei so großen Energien in die Größenordnung $2\cdot 10^{-26}\,\text{cm}^2$ zu fallen, die zweite Reaktion ist überhaupt noch nicht mit Sicherheit beobachtet worden. Selbst wenn wir ganz trockenes U_3O_8 benutzen, genügt der Streuquerschnitt von etwa $1{,}3\cdot 10^{-24}\,\text{cm}^2$ für schnelle Neutronen zwischen 2 und 3 MeV an Sauerstoff[20], um nach 7 elastischen Stößen die meisten Neutronen von 4 MeV Anfangsenergie unter den kritischen Wert von 2,6 MeV abzubremsen, während sicher eine größere Zahl von Stößen erforderlich ist, ehe eine Sauerstoffumwandlung erfolgt. Wir können im folgenden also, abgesehen von seiner bremsenden Wirkung, den Sauerstoff ganz außer acht lassen.

Die Anwesenheit des Wasserstoffes bewirkt elastische Streuung und Einfangprozesse, bei denen Deuteronen gebildet werden. In beiden Fällen sind die Querschnitte bei schnellen und langsamen Neutronen gut bekannt.

Der Streuquerschnitt wächst von rund $2\cdot 10^{-24}\,\text{cm}^2$ bei schnellen Neutronen bis auf $14\cdot 10^{-24}\,\text{cm}^2$ bei langsamen an. An thermischen Neutronen erfolgt die Streuung noch häufiger, etwa mit einem Querschnitt von $35\cdot 10^{-24}\,\text{cm}^2$ infolge des Einflusses der chemischen Bindung. Solange diese keine Rolle spielt, d. h. bis herab zu Energien von etwa 1 eV, verliert ein Neutron bei jedem elastischen Stoß im Mittel die Hälfte seiner Energie an das Proton. Rund 20 Stöße an Wasserstoff genügen zur Abbremsung auch sehr schneller Neutronen von einigen MeV. Der Einfangquerschnitt des Wasserstoffs ist für schnelle Neutronen unmeßbar klein, für langsame steigt er umgekehrt proportional der Geschwindigkeit an bis auf $0{,}27\cdot 10^{-24}\,\text{cm}^2$ für thermische Neutronen. Er kann also beschrieben werden durch die Formel

$$\sigma_{\text{Einf. H}} = 0{,}27\sqrt{0{,}026\,E}\cdot 10^{-24}\,\text{cm}^2, \quad (E \text{ in eV}). \qquad (5)$$

Wir betrachten nun eine Mischung, die auf 1 l Wasser M g U_3O_8 enthält. Bezeichnen wir mit $L = 6\cdot 10^{23}$ die LOSCHMIDTsche Zahl, so befinden sich in 1 l Wasser 111 L H-Atome, zu denen noch $3\,ML/842$ U-Atome hinzukommen. Bei einer Dichte des U_3O_8 von 9 g/cm³ ist das hierzu benötigte Volumen $\left(1000+\frac{M}{9}\right)$ cm³. Wir haben also folgende Teilchenzahlen im Kubikzentimeter:

$$\varrho_U = \frac{\frac{3\,ML}{842}}{1000+\frac{M}{9}} \quad \text{und} \quad \varrho_H = \frac{111\,L}{1000+\frac{M}{9}}.$$

Die Gl. (4a) nimmt jetzt die Form an:

$$\left.\begin{aligned}\frac{1}{n}\frac{dn}{dt} &= v\{-\varrho_H\sigma_{\text{Einf H}} - \varrho_U\sigma_{\text{Einf U}} + \varrho_U(\nu-1)\sigma_{\text{Sp U}}\}\\ &= \frac{vL}{1000+\frac{M}{9}}\cdot 10^{-24}\,\frac{v_0}{v}\Big\{-111\cdot 0{,}27\\ &\quad + \frac{3M}{842}[-1{,}3+2(\nu-1)]\Big\},\end{aligned}\right\} \qquad (6)$$

da im thermischen Bereich auch $\sigma_{\text{Einf U}}$ proportional $1/v$ ist. Dabei bedeutet $v_0 = 2{,}5\cdot 10^5$ cm/sec die mittlere thermische Geschwindigkeit. Damit eine Kette entsteht, muß die Klammer positiv sein, woraus sich die folgenden Mindestmassen ergeben: Für $\nu = 2$: 12 kg, für $\nu = 2{,}5$: 4,9 kg und für $\nu = 3$: 3,1 kg U_3O_8 je Liter Wasser.

Nehmen wir wieder den wahrscheinlichen Wert von $\nu = 2$ und arbeiten mit 15 kg U_3O_8, d. h. mit den Teilchenzahlen je Kubikzentimeter: $\varrho_U = 0{,}0200\,L$ und $\varrho_H = 0{,}0416\,L$, so haben wir immer noch mehr als doppelt so viel H-Atome wie U-Atome. Der Bremsmechanismus wird also durch die benutzte Uranmenge noch nicht gefährdet, und die Rechnung mit thermischen Neutronen ist statthaft. Wir erhalten:

$$\frac{1}{n}\frac{dn}{dt} = 420\,\text{sec}^{-1}; \quad n = n_0 e^{420t},$$

was folgende Zahlen von Neutronen ergibt, wenn die Kettenreaktion zur Zeit $t = 0$ mit $n_0 = 1$ Neutron beginnt: nach 10^{-3} sec: $n = 1{,}5$, nach 10^{-2} sec: $n = 67$ und nach 10^{-1} sec: $n = 4\cdot 10^{18}$, d. h. die Umsetzung des Urans findet in etwa $^1/_{10}$ sec statt; die Energiebefreiung erfolgt zwar langsamer als bei schnellen Neutronen, aber immer noch explosiv.

4. Die Steuerung von Reaktionsketten. Die entscheidende Frage für die technische Anwendbarkeit des Mechanismus ist offenbar die: Ist es möglich, den Ablauf der Reaktion beliebig zu verlangsamen? Hier haben nun ADLER und v. HALBAN[21] zum ersten Male einen Gedanken in die Diskussion geworfen, der geeignet ist, auch dies Problem seiner Lösung näher zu bringen.

Fügt man zu dem besprochenen Gemisch von U_3O_8 und H_2O etwas Cadmium, metallisch oder als Oxyd hinzu, so tritt in Gl. (6) noch ein weiteres Neutronen absorbierendes Glied $-\varrho_{\text{Cd}}\sigma_{\text{Einf Cd}}$ in die Klammer. Die Absorption von Cd ist nun ziemlich gut bekannt. Aus zahlreichen Messungen[22] kann man schließen, daß der Einfangquerschnitt im ganzen thermischen Bereich und darüber bis hinauf zu 0,4 eV einigermaßen konstant ist, und zwar sehr groß, $= 2800\cdot 10^{-24}\,\text{cm}^2$, während bei größeren Energien Cd praktisch durchlässig für Neutronen ist. Das entscheidende für die Betrachtung ist, daß alle Prozesse einschließlich der Spaltung im thermischen Bereich und noch ein gutes Stück darüber hinaus dem $1/v$-Gesetz folgen, mit alleiniger Ausnahme des überall gleichstark Neutronen wegfangenden Cd.

Läuft die Reaktionskette an, so wird die Temperatur der Substanz infolge der frei gesetzten Energie ansteigen; die mittlere Neutronengeschwindigkeit v wächst also ebenfalls und dementsprechend sinken alle Querschnitte einschließlich des Neutronen produzierenden Spaltungsquerschnitts, aber nicht der Einfangquerschnitt des Cd. Es wird nach einiger Zeit, die sehr kurz sein kann, ein Gleichgewichtszustand erreicht, bei dem das Cd genau so viele Neutronen wegfängt, wie produziert werden: Das System bleibt bei einer erhöhten Temperatur stehen, die um so höher ist, je weniger Cd man zusetzt, und die wir durch die Menge des Cd beliebig einregulieren können. Die allmähliche Verbrennung des Urans wird dann, je nachdem, wieviele Wärme nach außen zur Arbeitsleistung abgeführt wird, mit einer solchen Geschwindigkeit erfolgen, daß die Temperatur konstant gehalten wird.

Wäre das Cd nicht anwesend, so würde der stationäre Endzustand bei einer Temperatur liegen, die so hoch ist, daß für $\sigma_{\text{Einf U}}$ das $1/v$-Gesetz nicht mehr gilt, d. h. bei Annäherung an die Resonanzstelle. Dann hätte man es aber immer schon mit Neutronen von einigen eV zu tun, d. h. mit Temperaturen um 10^5 Grad herum. Das gleiche gilt für Zusätze von anderen Elementen als Cd, die Resonanzstellen bei einigen eV haben. Die einzige derzeit bekannte Ausnahme ist Gadolinium, das ein ähnliches Verhalten wie Cd zeigt, aber nicht in dem Maße erforscht ist.

Die bei einem bestimmten Zusatz von Cd, etwa m g Cd, d. h. $mL/112{,}4$ Atomen Cd je Liter Wasser, sich einstellende Temperatur, kann man leicht ausrechnen. Man hat Gl. (6) jetzt nur noch durch ein Cd-Glied zu ergänzen. Mit den vorhin benutzten Werten $\nu = 2$ und $M = 15$ kg erhalten wir dann

$$\frac{1}{n}\frac{dn}{dt} = 420\left(1 - 3{,}4\,m\,\frac{v}{v_0}\right). \qquad (7)$$

Die Temperatur steigt solange an, bis die Klammer verschwindet, d. h. da $v \sim \sqrt{T}$, bis $3{,}4\,m\sqrt{T/T_0} = 1$, oder da $T_0 = 300°$ K, bis zur Temperatur

$$T = \frac{300°\,K}{(3{,}4\,m)^2}. \qquad (8)$$

Man erhält schon bei sehr geringfügigen Zusätzen von Cd $T = T_0$, d. h. überhaupt keine Reaktionskette mehr. Das folgt einfach aus dem extrem großen Einfangquerschnitt des Cd im thermischen Bereich. Man muß weniger als $^1/_3$ g Cd zusetzen und findet z. B. folgende Temperaturen: Für $m = 0{,}25$ g Cd: 120° C, für $m = 0{,}20$ g: 350° C, für $m = 0{,}15$ g: 850° C und für $m = 0{,}10$ g: 2300° C.

Wir müssen uns an dieser Stelle noch einmal klarmachen, welche gigantischen Leistungen eine solche Maschine hervorbringen kann. Denken wir uns 4,2 t U_3O_8 (wie zu Anfang dieses Aufsatzes) mit 280 kg Wasser und 56 g Cd angesetzt, so beträgt die stationäre Verbrennungstemperatur 350° C, gleichgültig, wieviel Energie dauernd entzogen wird. Die gesamte, darin enthaltene Energiemenge, die bei Spaltung aller Uranatome frei wird, ist etwa $3\cdot 10^{16}$ mkg $= 7\cdot 10^{10}$ kWh. Diese Zahl können wir vergleichen mit der Gesamtleistung der Reichselektrowerke, also der auf Grund der mitteldeutschen Braunkohle arbeitenden Großkraftwerke zusammengenommen, die im Jahre 1020 rund $7\cdot 10^5$ kW betrug. Das bedeutet, daß die angegebene Uranmenge ausreicht, um 10^5 Stunden $= 11$ Jahre lang, die ganze Leistung dieser Kraftwerke zu ersetzen! Dabei hat man allerdings, sobald ein kleiner Teil des Urans umgesetzt ist, etwa alltäglich einmal, die Maschine wieder von den Spaltungsprodukten zu reinigen, um sie neu betriebsfähig zu machen.

5. Die räumliche Verteilung der Neutronen. Alle bisherigen Überlegungen setzen immer eine unendlich große Menge von Substanz voraus, in der die Reaktionen ablaufen. In Wirklichkeit werden wir es natürlich stets mit einer begrenzten Menge zu tun haben, aus der die gebildeten Neutronen durch Diffusion entweichen können. Das Volumen der Anordnung muß nur groß genug sein, daß dieser Verlust an Neutronen durch Diffusion klein genug bleibt und die Reaktionskette nicht zum Abbrechen bringt.

Zur Behandlung dieses Problems haben wir die Diffusionsgleichung

$$\frac{\partial\varrho}{\partial t} = D\Delta\varrho + \lambda\varrho \qquad (9)$$

für die Dichte ϱ der Neutronen an die Stelle von Gl. (6) zu setzen, wobei λ die rechte Seite der Gl. (6) bedeutet. Sowohl $D = \frac{1}{3}vl$ als λ sind Funktionen der Geschwindigkeit und damit der Temperatur. Die freie Weglänge l wird ausschließlich durch die großen Querschnitte für elastische Stöße bestimmt; setzt man für thermische Neutronen den Streuquerschnitt an Uran rund gleich 20, an Wasserstoff gleich 35 und an Sauerstoff gleich $2\cdot 10^{-24}\,\text{cm}^2$, so ergibt sich in der beschriebenen Mischung $l = 0{,}83$ cm. Unsere Diffusionstheorie setzt also zunächst voraus, daß die Abmessungen der Anordnung groß sind gegen die Weglänge.

Diejenige Lösung der Differentialgleichung, die dem Anlaufen der Reaktionskette zur Zeit $t = 0$ am Punkte $r = 0$ entspricht, lautet

$$\varrho(r,t) = \frac{1}{(4\pi Dt)^{3/2}}\,e^{-\frac{r^2}{4Dt}}\,e^{\lambda t}. \qquad (10)$$

Das bedeutet ein allmähliches Nachaußenströmen der Neutronen, während ihre Gesamtzahl sich fortwährend vermehrt. Liegt eine Materiekugel vom endlichen Radius R vor, so daß alle Neutronen, die aus der Oberfläche austreten, endgültig verloren gehen, so ist die zur Zeit t in der Kugel enthaltene Anzahl Neutronen

$$N(t) = 4\pi\int_0^R \varrho r^2\,dr = e^{\lambda t}\,\frac{4}{\sqrt{\pi}}\int_0^{R/2\sqrt{Dt}} dx\,x^2 e^{-x^2}. \qquad (11)$$

Die freie Weglänge der Neutronen von $l = 0{,}83$ cm in der oben beschriebenen Anordnung mit U_3O_8, H_2O, Cd bedingt für thermische Neutronen eine Diffusionskonstante von $D_0 = \frac{1}{3}v_0 l = 0{,}7\cdot 10^5\,\text{cm}^2/\text{sec}$. Wählt man R sehr klein, so sinkt $N(t)$ zuerst mit der Zeit rasch ab, ehe der Faktor $e^{\lambda t}$ wirksam wird und einen endgültigen Wiederanstieg hervorruft. Dann reißt die Kette auf jeden Fall ab, da die Neutronenzahl 1, mit der sie beginnt, dabei unterschritten wird. Man erhält dagegen ganz sicher einen Anstieg, sobald sich kein Minimum mehr ausbildet, sondern N von Anbeginn an monoton mit t ansteigt.

Um die Lage des Minimums aufzusuchen, setzen wir $dN/dt = 0$, dann erhalten wir die Bedingungsgleichung

$$\frac{R^2\lambda}{2D} = f(z), \quad f(z) = \frac{2z^5\Phi_1(z)}{\Phi(z) - z\Phi_1(z)} \quad \text{und} \quad z = \frac{R}{2\sqrt{Dt}}. \qquad (12)$$

Dabei bedeutet $\Phi(z)$ das GAUSSsche Fehlerintegral und $\Phi_1(z)$ dessen erste Ableitung. Bei vorgegebenen R, λ und D hat man also denjenigen z-Wert, d. h. denjenigen Zeitpunkt aufzusuchen, für den $f(z)$ gerade die Bedingung (12) erfüllt. Bei kleinen Radien gibt es zwei solche Zeitpunkte: $N(t)$ durchläuft nacheinander erst ein Minimum, dann ein Maximum. Die Funktion $f(z)$ verschwindet für $z = 0$ und $z = \infty$, dazwischen durchläuft sie ein Maximum der Höhe $f_{\max} = 2{,}35$. Ist nun

$$\frac{R^2\lambda}{2D} > 2{,}35,$$

so kann man sicher sein, daß $N(t)$ monoton mit der Zeit wächst und die Kette nicht abreißt. Es muß R groß genug sein, damit in jedem Augenblick die Ungleichung

$$R^2 > 4{,}7\,\frac{D}{\lambda} \qquad (13)$$

erfüllt ist. Bei unserer oben beschriebenen Anordnung ist

$$\lambda = 420\left(1 - 0{,}68\,\frac{v}{v_0}\right) \quad \text{und} \quad D = 0{,}7\cdot 10^5\,\frac{v}{v_0};$$

es muß daher für $v = v_0$ (Zimmertemperatur) $R > 50$ cm sein.

Dies Ergebnis bedarf noch einer Klarstellung: Die Temperatur in der Anordnung steigt natürlich, so daß λ immer kleiner wird und schließlich gegen Null geht. Das erfordert aber keinen größeren Radius als den hier berechneten. Es kommt ja nicht darauf an, daß zu keiner Zeit die Ungleichung (5) verletzt wird, sondern nur, daß zu jeder Zeit $R^2 > 2\,\frac{D}{\lambda}\,f(z)$ bleibt. Die „Gefahrenzone" wird nun offenbar durchlaufen, wenn z von der Größenordnung 1 ist (das Maximum von f liegt etwa bei $z = 1{,}6$). Für $R = 50$ cm und Zimmertemperatur entspricht dem aber ein Zeitpunkt $t = 3{,}4\cdot 10^{-3}$ sec und eine Neutronenzahl $N = e^{\lambda t} = 4{,}2$, d. h. die Zahl der Neutronen ist noch sehr klein und die Temperatur praktisch unverändert. Erst etwa für $z = 0{,}2$ wird die Neutronenanzahl so groß ($3\cdot 10^{15}$), daß eine Temperaturerhöhung eintreten muß; dann ist aber auch $f(z)$ nur noch $= 0{,}107$, so daß die Bedingung (13) bei weitem nicht mehr eingehalten zu werden braucht.

6. Die geologische Frage. Gegen die hier angestellten Betrachtungen müßte man zunächst noch einen Einwand erheben: Wenn eine solche Umsetzung des Urans möglich ist, sobald nur ein einziges Neutron vorhanden ist, warum hat dann die Natur dies Experiment nicht schon vorweggenommen und im Gestein ausgeführt? Einzelne Neutronen befinden sich überall, wo es uran- oder thorhaltige Mineralien gibt; sie müssen fortwährend in geringer Menge erzeugt werden bei gelegentlichen Kernreaktionen, die die α-Teilchen des Urans und vor allem die der Emanation im umliegenden Gestein auslösen. Zudem liefert wohl auch die Ultrastrahlung stets einige Neutronen*.

Um diesen Einwand zu entkräften, ist es notwendig, sich über die Art des Vorkommens des Urans in der Natur nähere Angaben zu beschaffen. Zunächst weiß man, daß die radioaktiven Elemente nur in den obersten 10—15 km der Erdkruste überhaupt vorkommen, da die von ihnen permanent abgegebene Zerfallsenergie sonst im Widerspruch zu dem bekannten Wärmehaushalt der Erde stehen würde. Es handelt sich bei Uran um ein ausgesprochen lithophiles Verhalten; es tritt besonders in Eruptivgesteinen entweder fein verteilt oder in Gängen oder Einsprengungen nachgedrungener Restmagmen auf. Dies gilt vor allem für das Vorkommen der Pechblende. Über die Mächtigkeit solcher Gänge geben Auskunft folgende Zahlen[23]: In einem der ergiebigsten Gänge der Westgrube in St. Joachimsthal kommen auf 1 m² Gangfläche 54 kg Uranroherz; dabei liegt der U_3O_8-Gehalt des Roherzes durchweg unter 50%. In der Edelleutstollner Grube kommt zwar auf 1 m² Gangfläche rund die 10fache Menge von Roherz, dafür ist aber der Urangehalt des Roherzes wieder um einen Faktor 10 kleiner, so daß die gleiche Menge nur disperser verteilt ist. Die Mächtigkeit dieser Gänge entspricht demnach, auf unsere Urananordnung umgerechnet, maximal einer Schichtdicke von weniger als 1 cm! Das ist eine Mächtigkeit, die selbst für den Ablauf einer Reaktionskette von thermischen Neutronen noch um mehr als den Faktor 100 zu klein ist; für schnelle Neutronen können die Verhältnisse noch gut um einen Faktor 10 ungünstiger liegen, sind aber schwer zu übersehen.

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* Die auf diese Weise zustande kommenden Neutronenintensitäten sind viel zu gering, um die in uran- und thorhaltigen Mineralien fast immer auftretenden Beimengungen seltener Erden sowie von Zr und Y als Endprodukte der bei Spaltungsprozessen entstehenden β-Zerfallsketten ansprechen zu können. Dagegen spricht auch, daß das thorfreie Katangaerz besonders arm an diesen Elementen ist.

Ähnlich steht es mit anderen Lagerstätten wohl auch. Eine besondere Merkwürdigkeit sind die Carnotit-Imprägnationen in Sandstein und an tonigen Schichten der (sekundären) Lagerstätten von Colorado, die meist nur dünn, selten einige Zoll stark, in wenigen Ausnahmefällen bis zu 4 Fuß dick sind. Carnotit enthält auch Kristallwasser, so daß auf 1 Atom U 3 H-Atome kommen; es wäre also eine ideale Anordnung in unserem Sinne; vorausgesetzt, daß nicht Verunreinigungen wieder die für den Ablauf der Reaktionskette erforderliche Mächtigkeit wesentlich erhöhen, und zweitens, wenn nicht auch in gleicher Menge mit dem Uran auch V-Atome und K-Atome anwesend wären, die selbst in erheblichem Maße langsame Neutronen wegfangen.

Im ganzen kann man wohl sagen, daß das Auftreten einer Explosion in der Natur ein sehr unwahrscheinlicher Vorgang ist, da wir nirgends Anhäufungen von hinreichender Mächtigkeit bei zugleich hinreichender Abwesenheit stark Neutronen absorbierender Stoffe vorfinden. Dasselbe dürfte auch für Thorium zutreffen, nur sind dort die Reaktionsmöglichkeiten bisher viel schlechter bekannt. Im übrigen ist es natürlich durchaus möglich, daß derartige Prozesse gelegentlich vorkommen und im Zusammenhange mit vulkanischen Erscheinungen für die Geologie ein gewisses Interesse erlangen können.

Alles in allem sei noch einmal betont, daß unsere gegenwärtigen Kenntnisse die Möglichkeit einer „Uranmaschine" der beschriebenen Art wahrscheinlich machen, daß aber das vorliegende quantitative Zahlenmaterial noch mit zu hohen Fehlergrenzen behaftet ist, um diese Möglichkeit zur Gewißheit zu verdichten. Wie dem auch sei, bedeutet es doch eine wichtigen Fortschritt, daß derartige Möglichkeiten überhaupt diskutierbar geworden sind, ein Fortschritt, der auch, wenn sich die Hoffnungen nicht verwirklichen sollten, die eingehende Diskussion in diesem Aufsatze wohl berechtigt erscheinen läßt.

Literatur.

[1] O. HAHN u. F. STRASSMANN, Naturwiss. **27**, 11, 89, 163 (1939). — [2] L. MEITNER u. O. R. FRISCH, Nature (Lond.) **143**, 239 (1939). — [3] S. FLÜGGE u. G. v. DROSTE, Z. physik. Chem. B. **42**, 274 (1939). [4] W. JENTSCHKE u. F. PRANKL, Naturwiss. **27**, 134 (1939). — G. v. DROSTE, Naturwiss. **27**, 198 (1939). [5] M. DODÉ, H. v. HALBAN jun., F. JOLIOT u. L. KOWARSKI, C. r. Acad. Sci. Paris **208**, 995 (1939). [6] S. FLÜGGE, Z. Physik **111**, 109 (1938). — [7] H. v. HALBAN, F. JOLIOT, L. KOWARSKI, Nature (Lond.) **143**, 470, 680 (1939). — [8] H. L. ANDERSON, E. FERMI u. H. B. HANSTEIN, Physic. Rev. **55**, 797 (1939). [9] L. SZILARD u. W. H. ZINN, Physic. Rev. **55**, 799 (1939). — G. v. DROSTE u. H. REDDEMANN, Naturwiss. **27**, 371 (1939). — [10] R. B. ROBERTS, R. C. MEYER u. P. WANG, Physic. Rev. **55**, 510 (1939). — R. B. ROBERTS, L. R. HAFSTAD, R. C. MEYER u. P. WANG, Physic. Rev. **55**, 664 (1939). — [11] L. MEITNER, O. HAHN u. F. STRASSMANN, Z. Physik. **106**, 249 (1937). [12] H. v. HALBAN jun., L. KOWARSKI, P. SAVITCH, C. r. Acad. Sci. Paris **208**, 1396 (1939). — [13] H. L. ANDERSON, E. T. BOOTH, J. R. DUNNING, E. FERMI, G. N. GLASOE u. F. G. SLACK, Physic. Rev. **55**, 511 (1939). — [14] N. BOHR, Physic. Rev. **55**, 418 (1939). — [15] J. R. DUNNING, G. B. PEGRAM, G. A. FINK, D. P. MITCHELL u. E. SEGRÈ, Physic. Rev. **48**, 265 (1935). — [16] M. GOLDHABER, R. D. HILL u. L. SZILARD, Physic. Rev. **55**, 47 (1939). — S. W. BARNES u. P. W. ARADINE, Physic. Rev. **55**, 50 (1939). — G. B. COLLINS, B. WALDMAN, E. M. STUBBLEFIELD u. M. GOLDHABER, Physic. Rev. **55**, 507 (1939). — [17] M. D. WHITAKER, CH. A. BARTON, W. C. BRIGHT u. E. J. MURPHY, Physic. Rev. **55**, 793 (1939). — [18] O. R. FRISCH, H. v. HALBAN jun. u. J. KOCH, Nature (Lond.) **140**, 895 (1937). — [19] G. v. DROSTE, mündliche Mitteilung. — [20] H. AOKI, Physic. Rev. **55**, 795 (1939). — [21] F. ADLER u. H. v. HALBAN, Nature (Lond.) **143**, 793 (1939). — [22] J. G. HOFFMAN u. M. ST. LIVINGSTON, Physic. Rev. **52**, 1228 (1937). [23] C. DOELTER u. H. LEITMEIER, Handbuch der Mineralchemie **4**, 2, Artikel G. KIRSCH, S. 969—974.

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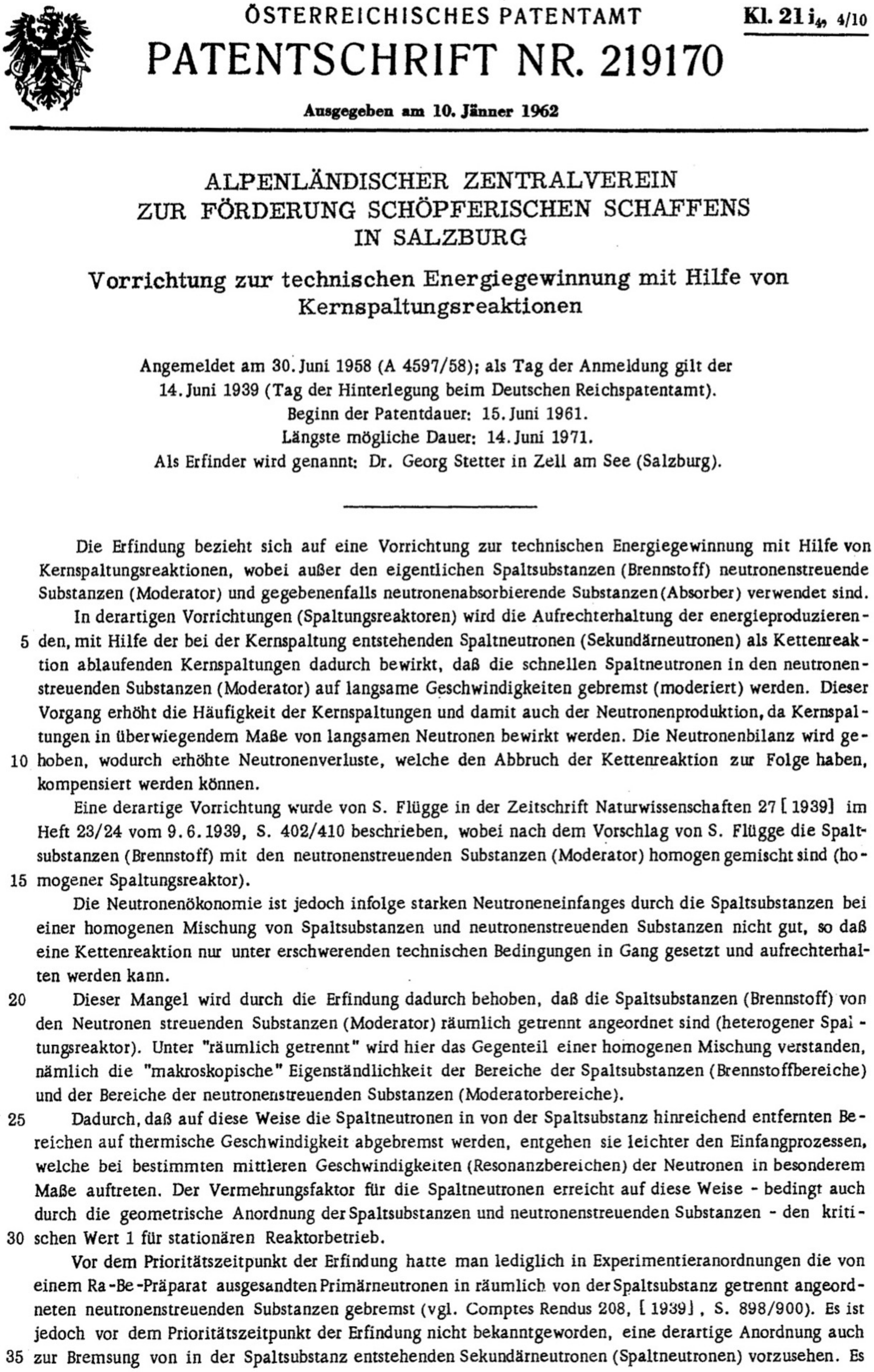
Bericht über den 5. Internationalen Zellforscherkongreß 1938 in Zürich.

Von I. FISCHER, Berlin-Dahlem.

Vom 7. bis 13. August 1938 fand in Zürich der 5. Internationale Zellforscherkongreß statt. Die Verhandlungen zeigten, wie die experimentelle Zellforschung zur Lösung der vorliegenden Fragen sich in zunehmendem Maße physikalischer und chemischer Methoden bedient. Ein beträchtlicher Teil der neueren Fortschritte ist der Anwendung solcher Methoden zu verdanken, sowohl auf dem Gebiet der Protoplasma- als auch der Chromosomenforschung, und auch ebenso in der Histophysiologie, der Entwicklungsphysiologie, der Krebs- und Virusforschung. Zugleich hat sich ein engerer Zusammenschluß verschiedener Arbeitsrichtungen vollzogen, und besonders die Grenzen zwischen morphologischer und physiologischer Forschung sind vielfach aufgehoben. Nachdem die alte statische Betrachtungsweise der Zellstrukturen aufgegeben worden ist, kann der kausale Zusammenhang zwischen Struktur und Funktion ja auch weder übersehen werden noch unberücksichtigt bleiben.

Jeder Verhandlungstag wurde durch ein oder zwei größere Referate eingeleitet; die übrige Zeit war mit Einzelvorträgen, Demonstrationen und Filmvorführun-

Figure D.51: Siegfried Flügge. Kann der Energieinhalt der Atomkerne technisch nutzbar gemacht werden? *Die Naturwissenschaften* 27:402–410. 9 June 1939. [https://digital.deutsches-museum.de/item/FA-002-746]



ÖSTERREICHISCHES PATENTAMT

Kl. 21 i$_{4}$, 4/10

PATENTSCHRIFT NR. 219170

Ausgegeben am 10. Jänner 1962

ALPENLÄNDISCHER ZENTRALVEREIN ZUR FÖRDERUNG SCHÖPFERISCHEN SCHAFFENS IN SALZBURG

Vorrichtung zur technischen Energiegewinnung mit Hilfe von Kernspaltungsreaktionen

Angemeldet am 30. Juni 1958 (A 4597/58); als Tag der Anmeldung gilt der
14. Juni 1939 (Tag der Hinterlegung beim Deutschen Reichspatentamt).
Beginn der Patentdauer: 15. Juni 1961.
Längste mögliche Dauer: 14. Juni 1971.
Als Erfinder wird genannt: Dr. Georg Stetter in Zell am See (Salzburg).

Die Erfindung bezieht sich auf eine Vorrichtung zur technischen Energiegewinnung mit Hilfe von Kernspaltungsreaktionen, wobei außer den eigentlichen Spaltsubstanzen (Brennstoff) neutronenstreuende Substanzen (Moderator) und gegebenenfalls neutronenabsorbierende Substanzen (Absorber) verwendet sind.

In derartigen Vorrichtungen (Spaltungsreaktoren) wird die Aufrechterhaltung der energieproduzierenden, mit Hilfe der bei der Kernspaltung entstehenden Spaltneutronen (Sekundärneutronen) als Kettenreaktion ablaufenden Kernspaltungen dadurch bewirkt, daß die schnellen Spaltneutronen in den neutronenstreuenden Substanzen (Moderator) auf langsame Geschwindigkeiten gebremst (moderiert) werden. Dieser Vorgang erhöht die Häufigkeit der Kernspaltungen und damit auch der Neutronenproduktion, da Kernspaltungen in überwiegendem Maße von langsamen Neutronen bewirkt werden. Die Neutronenbilanz wird gehoben, wodurch erhöhte Neutronenverluste, welche den Abbruch der Kettenreaktion zur Folge haben, kompensiert werden können.

Eine derartige Vorrichtung wurde von S. Flügge in der Zeitschrift Naturwissenschaften 27 [1939] im Heft 23/24 vom 9. 6. 1939, S. 402/410 beschrieben, wobei nach dem Vorschlag von S. Flügge die Spaltsubstanzen (Brennstoff) mit den neutronenstreuenden Substanzen (Moderator) homogen gemischt sind (homogener Spaltungsreaktor).

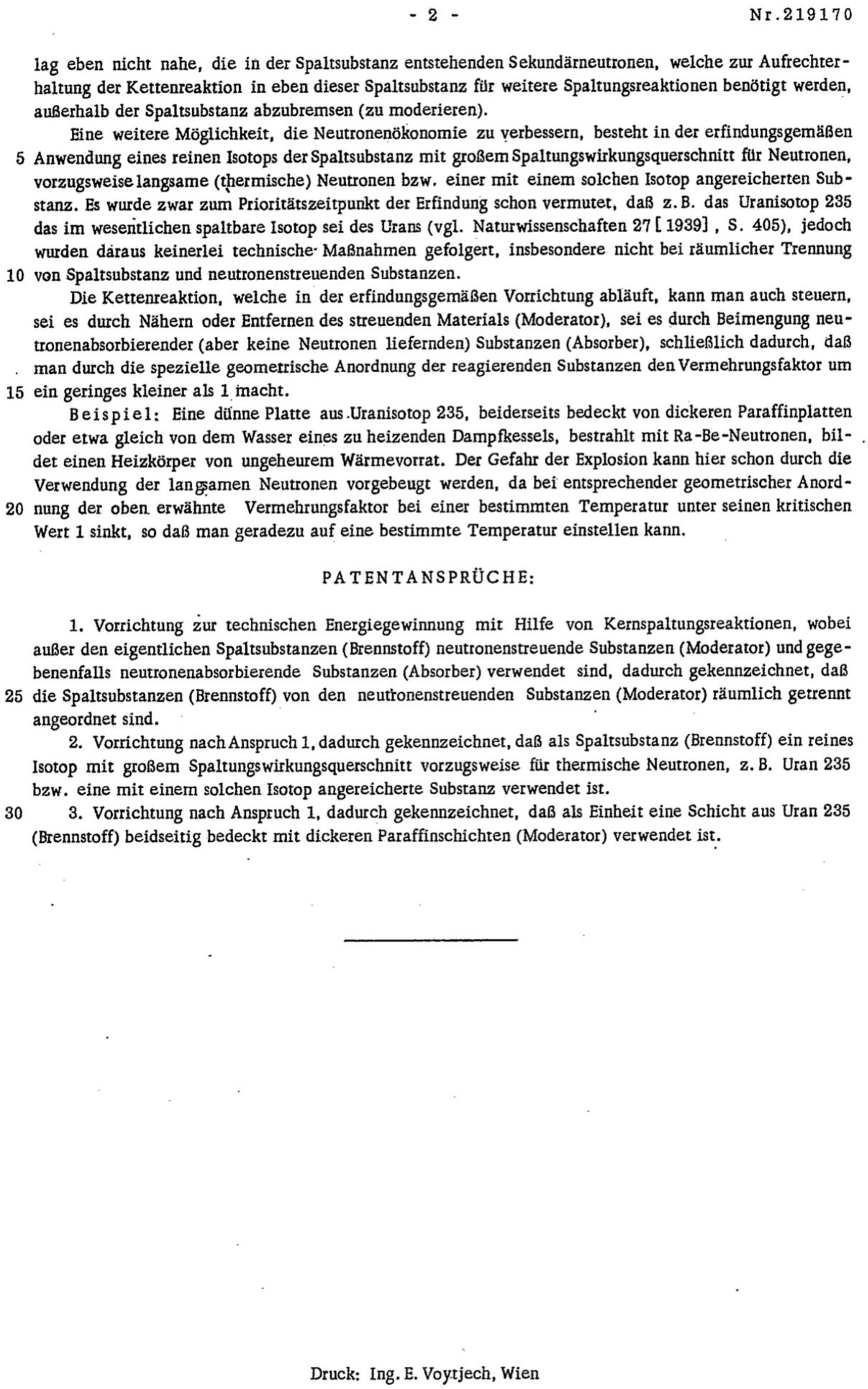
Die Neutronenökonomie ist jedoch infolge starken Neutroneneinfanges durch die Spaltsubstanzen bei einer homogenen Mischung von Spaltsubstanzen und neutronenstreuenden Substanzen nicht gut, so daß eine Kettenreaktion nur unter erschwerenden technischen Bedingungen in Gang gesetzt und aufrechterhalten werden kann.

Dieser Mangel wird durch die Erfindung dadurch behoben, daß die Spaltsubstanzen (Brennstoff) von den Neutronen streuenden Substanzen (Moderator) räumlich getrennt angeordnet sind (heterogener Spaltungsreaktor). Unter "räumlich getrennt" wird hier das Gegenteil einer homogenen Mischung verstanden, nämlich die "makroskopische" Eigenständlichkeit der Bereiche der Spaltsubstanzen (Brennstoffbereiche) und der Bereiche der neutronenstreuenden Substanzen (Moderatorbereiche).

Dadurch, daß auf diese Weise die Spaltneutronen in von der Spaltsubstanz hinreichend entfernten Bereichen auf thermische Geschwindigkeit abgebremst werden, entgehen sie leichter den Einfangprozessen, welche bei bestimmten mittleren Geschwindigkeiten (Resonanzbereichen) der Neutronen in besonderem Maße auftreten. Der Vermehrungsfaktor für die Spaltneutronen erreicht auf diese Weise - bedingt auch durch die geometrische Anordnung der Spaltsubstanzen und neutronenstreuenden Substanzen - den kritischen Wert 1 für stationären Reaktorbetrieb.

Vor dem Prioritätszeitpunkt der Erfindung hatte man lediglich in Experimentieranordnungen die von einem Ra-Be-Präparat ausgesandten Primärneutronen in räumlich von der Spaltsubstanz getrennt angeordneten neutronenstreuenden Substanzen gebremst (vgl. Comptes Rendus 208, [1939], S. 898/900). Es ist jedoch vor dem Prioritätszeitpunkt der Erfindung nicht bekanntgeworden, eine derartige Anordnung auch zur Bremsung von in der Spaltsubstanz entstehenden Sekundärneutronen (Spaltneutronen) vorzusehen. Es

Figure D.52: Georg Stetter. Austrian patent AT219170. Vorrichtung zur technischen Energiegewinnung mit Hilfe von Kernspaltungsreaktionen [Apparatus for Technical Energy Production by Means of Nuclear Fission Reactions]. Filed 14 June 1939.



lag eben nicht nahe, die in der Spaltsubstanz entstehenden Sekundärneutronen, welche zur Aufrechterhaltung der Kettenreaktion in eben dieser Spaltsubstanz für weitere Spaltungsreaktionen benötigt werden, außerhalb der Spaltsubstanz abzubremsen (zu moderieren).

Eine weitere Möglichkeit, die Neutronenökonomie zu verbessern, besteht in der erfindungsgemäßen Anwendung eines reinen Isotops der Spaltsubstanz mit großem Spaltungswirkungsquerschnitt für Neutronen, vorzugsweise langsame (thermische) Neutronen bzw. einer mit einem solchen Isotop angereicherten Substanz. Es wurde zwar zum Prioritätszeitpunkt der Erfindung schon vermutet, daß z.B. das Uranisotop 235 das im wesentlichen spaltbare Isotop sei des Urans (vgl. Naturwissenschaften 27 [1939], S. 405), jedoch wurden daraus keinerlei technische Maßnahmen gefolgert, insbesondere nicht bei räumlicher Trennung von Spaltsubstanz und neutronenstreuenden Substanzen.

Die Kettenreaktion, welche in der erfindungsgemäßen Vorrichtung abläuft, kann man auch steuern, sei es durch Nähern oder Entfernen des streuenden Materials (Moderator), sei es durch Beimengung neutronenabsorbierender (aber keine Neutronen liefernden) Substanzen (Absorber), schließlich dadurch, daß man durch die spezielle geometrische Anordnung der reagierenden Substanzen den Vermehrungsfaktor um ein geringes kleiner als 1 macht.

Beispiel: Eine dünne Platte aus Uranisotop 235, beiderseits bedeckt von dickeren Paraffinplatten oder etwa gleich von dem Wasser eines zu heizenden Dampfkessels, bestrahlt mit Ra-Be-Neutronen, bildet einen Heizkörper von ungeheurem Wärmevorrat. Der Gefahr der Explosion kann hier schon durch die Verwendung der langsamen Neutronen vorgebeugt werden, da bei entsprechender geometrischer Anordnung der oben erwähnte Vermehrungsfaktor bei einer bestimmten Temperatur unter seinen kritischen Wert 1 sinkt, so daß man geradezu auf eine bestimmte Temperatur einstellen kann.

PATENTANSPRÜCHE:

1. Vorrichtung zur technischen Energiegewinnung mit Hilfe von Kernspaltungsreaktionen, wobei außer den eigentlichen Spaltsubstanzen (Brennstoff) neutronenstreuende Substanzen (Moderator) und gegebenenfalls neutronenabsorbierende Substanzen (Absorber) verwendet sind, dadurch gekennzeichnet, daß die Spaltsubstanzen (Brennstoff) von den neutronenstreuenden Substanzen (Moderator) räumlich getrennt angeordnet sind.

2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß als Spaltsubstanz (Brennstoff) ein reines Isotop mit großem Spaltungswirkungsquerschnitt vorzugsweise für thermische Neutronen, z.B. Uran 235 bzw. eine mit einem solchen Isotop angereicherte Substanz verwendet ist.

3. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß als Einheit eine Schicht aus Uran 235 (Brennstoff) beidseitig bedeckt mit dickeren Paraffinschichten (Moderator) verwendet ist.

Druck: Ing. E. Voytjech, Wien

Figure D.53: Georg Stetter. Austrian patent AT219170. Vorrichtung zur technischen Energiegewinnung mit Hilfe von Kernspaltungsreaktionen [Apparatus for Technical Energy Production by Means of Nuclear Fission Reactions]. Filed 14 June 1939.

Georg Stetter. Austrian patent AT219170. Vorrichtung zur technischen Energiegewinnung mit Hilfe von Kernspaltungsreaktionen [Apparatus for Technical Energy Production by Means of Nuclear Fission Reactions]. Filed 14 June 1939.

Die Erfindung bezieht sich auf eine Vorrichtung zur technischen Energiegewinnung mit Hilfe von Kernspaltungsreaktionen, wobei ausser den eigentlichen Spaltsubstanzen (Brennstoff) neutronenstreuende Substanzen (Moderator) und gegebenenfalls neutronenabsorbierende Substanzen (Absorber) verwendet sind.

In derartigen Vorrichtungen (Spaltungsreaktoren) wird die Aufrechterhaltung der energieproduzierenden, mit Hilfe der bei der Kernspaltung entstehenden Spaltneutronen (Sekundärneutronen) als Kettenreaktion ablaufenden Kernspaltungen dadurch bewirkt, dass die schnellen Spaltneutronen in den neutronenstreuenden Substanzen (Moderator) auf langsame Geschwindigkeiten gebremst (moderiert) werden. Dieser Vorgang erhöht die Häufigkeit der Kernspaltungen und damit auch der Neutronenproduktion, da Kernspaltungen in überwiegendem Masse von langsamen Neutronen bewirkt werden. Die Neutronenbilanz wird gehoben, wodurch erhöhte Neutronenverluste, welche den Abbruch der Kettenreaktion zur Folge haben, kompensiert werden können.

Eine derartige Vorrichtung wurde von S. Flügge in der Zeitschrift *Naturwissenschaften* 27 [1939] im Heft 23/24 vom 9. 6. 1939, S. 402/410 beschrieben, wobei nach dem Vorschlag von S. Flügge die Spaltsubstanzen (Brennstoff) mit den neutronenstreuenden Substanzen (Moderator) homogen gemischt sind (homogener Spaltungsreaktor).

Die Neutronenökonomie ist jedoch infolge starken Neutroneneinfanges durch die Spaltsubstanzen bei einer homogenen Mischung von Spaltsubstanzen und neutronenstreuenden Substanzen nicht gut, so dass eine Kettenreaktion nur unter erschwerenden technischen Bedingungen in Gang gesetzt und aufrechterhalten werden kann.

The invention relates to a device for the production of technical energy by means of nuclear fission reactions. Apart from the actual fission substances (fuel), neutron scattering substances (moderator) and possibly neutron-absorbing substances (absorbers) are used.

In such devices (fission reactors), the maintenance of the energy-producing nuclear fissions occurring as a chain reaction during secondary fission (secondary fission) is effected by slowing (moderating) the fast fission neutrons in the neutron scattering substances (moderator) to slow speeds. This process increases the frequency of nuclear fission and thus also neutron production, since nuclear fission is predominantly caused by slow neutrons. The neutron balance is lifted, as a result of which increased neutron losses, which result in the termination of the chain reaction, can be compensated for.

Such a device has been described by S. Flügge in the journal *Naturwissenschaften* 27 [1939] in issue 23/24 of 9 June 1939, p. 402/410. According to the proposal by S. Flügge, the fission substances (fuel) are homogeneously mixed with the neutron scattering substances (moderator) (homogeneous fission reactor).

The neutron economy, however, is not good due to strong neutron capture by the fission substances in a homogeneous mixture of fission substances and neutron scattering substances so that a chain reaction can only be initiated and maintained under aggravating technical conditions.

Dieser Mangel wird durch die Erfindung dadurch behoben, dass die Spaltsubstanzen (Brennstoff) von den Neutronen streuenden Substanzen (Moderator) räumlich getrennt angeordnet sind (heterogener Spaltungsreaktor). Unter “räumlich getrennt” wird hier das Gegenteil einer homogenen Mischung verstanden, nämlich die “makroskopische” Eigenständlichkeit der Bereiche der Spaltsubstanzen (Brennstoffbereiche) und der Bereiche der neutronenstreuenden Substanzen (Moderatorbereiche).

Dadurch, dass auf diese Weise die Spaltneutronen in von der Spaltsubstanz hinrei-chend entfernten Bereichen auf thermische Geschwindigkeit abgebremst werden, entgehen sie leichter den Einfangprozessen, welche bei bestimmten mittleren Geschwindigkeiten (Resonanzbereichen) der Neutronen in besonderem Masse auftreten. Der Vermehrungsfaktor für die Spaltneutronen erreicht auf diese Weise—bedingt auch durch die geometrische Anordnung der Spaltsubstanzen und neutronenstreuenden Substanzen—den kritischen Wert 1 für stationären Reaktorbetrieb.

Vor dem Prioritätszeitpunkt der Erfindung hatte man lediglich in Experimentier-anordnungen die von einem Ra-Be-Präparat ausgesandten Primärneutronen in räumlich von der Spaltsubstanz getrennt angeordneten neutronenstreuenden Substanzen gebremst (vgl. *Comptes Rendus* 208, [1939] S. 898/900). Es ist jedoch vor dem Prioritätszeitpunkt der Erfindung nicht bekanntgeworden, eine derartige Anordnung auch zur Bremsung von in der Spaltsubstanz entstehenden Sekundärneutronen (Spaltneutronen) vorzusehen. Es lag eben nicht nahe, die in der Spaltsubstanz entstehenden Sekundärneutronen, welche zur Aufrechterhaltung der Kettenreaktion in eben dieser Spaltsubstanz für weitere Spaltungsreaktionen benötigt werden, ausserhalb der Spaltsubstanz abzubremsen (zu moderieren).

This deficiency is remedied by the invention in that the fissionable substances (fuel) from the neutron-scattering substances (moderator) are spatially separated (heterogeneous splitting reactor). The term “spatially separated” is understood here to mean the opposite of a homogeneous mixture, namely the “macroscopic” independence of the regions of the fissile substances (fuel regions) and the regions of the neutron scattering substances (moderator regions).

By slowing the fission neutrons to thermal speed in areas which are sufficiently remote from the fissile substance, they are more likely to escape the capture processes which occur particularly at certain mean velocities (resonance regions) of the neutrons. In this way, the multiplication factor for the fission neutrons achieves the critical value 1 for stationary reactor operation, which is also due to the geometric arrangement of the fissionable substances and neutron-scattering substances.

Before the priority date of the invention, the primary neutrons emitted from a Ra-Be preparation had been slowed only in experimental setups in neutron scattering substances spatially separated from the fissile substance (cf. *Comptes Rendus* 208, [1939] p. 898–900). However, before the priority date of the invention, it was not known to provide such an arrangement also for slowing secondary neutrons (fission neutrons) arising in the fissile substance. It was not obvious to moderate (moderate) the secondary neutrons formed in the fissionable substance, which are needed to maintain the chain reaction in the same fissionable substance for further fission reactions, outside the fissionable substance.

Eine weitere Möglichkeit, die Neutronenökonomie zu verbessern, besteht in der erfindungsgemässen Anwendung eines reinen Isotops der Spaltsubstanz mit grossem Spaltungswirkungsquerschnitt für Neutronen, vorzugsweise langsame (thermische) Neutronen bzw. einer mit einem solchen Isotop angereicherten Substanz. Es wurde zwar zum Prioritätszeitpunkt der Erfindung schon vermutet, dass z. B. das Uranisotop 235 das im wesentlichen spaltbare Isotop sei des Urans (vgl. *Naturwissenschaften* 27 [1939], S. 405), jedoch wurden daraus keinerlei technische Massnahmen gefolgert, insbesondere nicht bei räumlicher Trennung von Spaltsubstanz und neutronenstreuenden Substanzen.

Die Kettenreaktion, welche in der erfindungsgemässen Vorrichtung abläuft, kann man auch steuern, sei es durch Nähern oder Entfernen des streuenden Materials (Moderator), sei es durch Beimengung neutronenabsorbierender (aber keine Neutronen liefernden) Substanzen (Absorber), schliesslich dadurch, dass man durch die spezielle geometrische Anordnung der reagierenden Substanzen den Vermehrungsfaktor um ein Geringes kleiner als 1 macht.

Beispiel: Eine dünne Platte aus Uranisotop 235, beiderseits bedeckt von dickeren Paraffinplatten oder etwa gleich von dem Wasser eines zu heizenden Dampfkessels, bestrahlt mit Ra-Be-Neutronen, bildet einen Heizkörper von ungeheurem Wärmevorrat. Der Gefahr der Explosion kann hier schon durch die Verwendung der langsamen Neutronen vorgebeugt werden, da bei entsprechender geometrischer Anordnung der oben erwähnte Vermehrungsfaktor bei einer bestimmten Temperatur unter seinen kritischen Wert 1 sinkt, so dass man geradezu auf eine bestimmte Temperatur einstellen kann.

A further possibility of improving the neutron economy consists in the application according to the invention of a pure isotope of the fissionable substance with a large fission reaction cross-section for neutrons, preferably slow (thermal) neutrons or a substance enriched with such an isotope. Although it was already assumed at the priority date of the invention that the uranium isotope 235 is the essentially fissionable isotope of uranium (cf. *Naturwissenschaften* 27 [1939], p. 405), however, no technical measures were taken from this, especially in the case of spatial separation of fissile substances and neutron-scattering substances.

The chain reaction which proceeds in the apparatus according to the invention can also be controlled, whether by inserting or removing the scattering material (moderator), or by admixing neutron-absorbing (but not neutron-supplying) substances (absorbers), finally, the particular geometric arrangement of the reacting substances makes the multiplication factor a little less than 1.

Example: A thin plate of Uranisotope 235, on either side covered by thicker paraffin plates or already by the water of a boiler to be heated, irradiated with Ra-Be neutrons, forms a radiator of immense heat. The danger of the explosion can already be presented here by the use of the slow neutrons, since, given the corresponding geometrical arrangement, the multiplication factor mentioned above drops below its critical value 1 at a certain temperature, so that it is virtually possible to adjust to a certain temperature.

PATENTANSPRÜCHE:	PATENT CLAIMS:
1. Vorrichtung zur technischen Energiegewinnung mit Hilfe von Kernspaltungsreaktionen, wobei ausser den eigentlichen Spaltsubstanzen (Brennstoff) neutronenstreuende Substanzen (Moderator) und gegebenenfalls neutronenabsorbierende Substanzen (Absorber) verwendet sind, dadurch gekennzeichnet, dass die Spaltsubstanzen (Brennstoff) von den neutronenstreuenden Substanzen (Moderator) räumlich getrennt angeordnet sind.	1. Apparatus for technical energy production by means of nuclear fission reactions, wherein neutron-scattering substances (moderator) and optionally neutron-absorbing substances (absorber) are used in addition to the actual fission substances (fuel), characterized in that the fission substances (fuel) are arranged spatially separate from the neutron-scattering substances (moderator).
2. Vorrichtung nach Anspruch l, dadurch gekennzeichnet, dass als Spaltsubstanz (Brennstoff) ein reines Isotop mit grossem Spaltungswirkungsquerschnitt vorzugsweise für thermische Neutronen, z. B. Uran 235 bzw. eine mit einem solchen Isotop angereicherte Substanz verwendet ist.	2. A device according to claim 1, characterized in that a pure isotope with a large fission reaction cross section, preferably for thermal neutrons, e.g. uranium 235 or a substance enriched with such an isotope, is used as the fission substance (fuel).
3. Vorrichtung nach Anspruch l, dadurch gekennzeichnet, dass als Einheit eine Schicht aus Uran 235 (Brennstoff) beidseitig bedeckt mit dickeren Paraffinschichten (Moderator) verwendet ist.	3. Device according to claim 1, characterized in that a layer of uranium 235 (fuel) is coated as a unit on both sides with thicker paraffin layers (moderator).

[Georg Stetter (Austrian, 1895–1988) led a nuclear physics group at the University of Vienna. In this patent application, Stetter gave a remarkably detailed description of a fission reactor.

See document photos on pp. 3370–3371. For an early 1939 draft of this patent application that also includes fusion reactions, see German nuclear report G-378 (p. 4330).

Austria was part of Germany from 1938 until the end of the war. Stetter and his group apparently played important roles in the wartime German nuclear program (pp. 4330–4345, 4788–4800, 4992).]

Philip Morrison to Samuel K. Allison. 20 December 1943. Report on Enemy Physics Literature: Survey Report P. [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]

Several high-voltage machines are in operation. Excluding apparatus below 1 Mev (which may be good neutron sources for many purposes) there are machines: [...]

2) At Berlin-Lichterfelde, in the private laboratory of the radio engineer, M. von Ardenne. At this laboratory some neutron work is being done, and at least one well-known neutron physicist (Houtermans) is employed.(20) It is interesting that an electronic research laboratory should extend into nuclear physics in war-time. Ardenne mentions that he was urged to do nuclear physics in 1939 by the Reichspostminister Ohnesorge. [...]

(Can the presence and scale of secret work of these laboratories be determined?) [...]

(20) Physik. Z., 44, 167 (1943)

David Irving. 1967. *The Virus House*. London: William Kimber.

[p. 33:] The conference took place in all secrecy on 29th April 1939 at the Ministry's [Reich Ministry of Education, in charge of universities] building at Unter den Linden in Berlin.[1] [...]

[1] Those at this first meeting were: Professor [Abraham] Esau (*chairman*); Professors [Georg] Joos, [Wilhelm] Hanle, [Hans] Geiger, [Josef] Mattauch, [Walther] Bothe and [Gerhard] Hoffmann; and the Ministry's representative, Doctor [Wilhelm] Dames.

Professor Esau recommended that they secure at once all available uranium stocks in Germany. [...]

A general ban was placed on the export of uranium compounds from Germany, and negotiations were opened with the Reich Ministry of Economics for the provision of radium from the recently captured mines at Joachimsthal (Jachymov) in Czechoslovakia. [...]

[pp. 38–43:] The letter [from Harteck and Groth on 24 April 1939] had been passed to General Becker's Army Ordnance Department, and thence to the research branch under Professor Erich Schumann. Schumann in turn forwarded it to Doctor Kurt Diebner, the Army's expert on nuclear physics and explosives, and another key figure in this history. [...]

Diebner was at the time 34 years old. He had read nuclear physics at the University of Halle under Professor Pose, and graduated with a thesis on the ionisation [by] alpha rays late in 1931. For a time he had worked at the Bureau of Standards laboratory on the construction of a new high-voltage particle accelerator for atomic transformations; but in 1934 the Army had appointed him to an Ordnance Department research branch where together with Doctor Friedrich Berkei he had investigated hollow-charge explosives—a development similar to one being undertaken by the air force's Professor Schardin at Berlin-Gatow. [...] Doctor Kurt Diebner had at this time a growing reputation in nuclear physics with some twenty publications to his name. [...]

During the summer [of 1939], with further encouragement from Flügge's articles, and in particular from a patent application by the Viennese Professor Stetter for a process for extracting atomic energy, they obtained the first Army funds to start research on uranium and a laboratory was erected at Gottow, a section of the Army's vast Kummersdorf rocket-projectiles and explosives research establishment outside Berlin. An independent nuclear research office was at last opened in the Army Ordnance Department, and Diebner was put in charge. [...]

The energetic steps taken by Esau seem to have stimulated the War Office team to intensify their own efforts. [...] Together with Professor Schumann, Diebner explained that [Erich] Bagge had been sent for to help the War Office arrange an immediate secret conference to decide on the feasibility of a uranium project. Between them, Diebner and Bagge drew up a short list of the physicists and chemists most clearly concerned, including Professor Walther Bothe, Professor Geiger, Professor Stetter, Professor Hoffmann, Professor Mattauch, and Doctors Bagge, Diebner and Flügge. Otto Hahn was also summoned to attend. [...]

The 'important matter' was now a State secret. From this stage on, all reference to the possibilities of uranium reactors and atomic bombs was suppressed. [...I]n general nothing else appeared in print in Germany until 1942 when the impatient nuclear scientists were given permission to publish some of their lesser research papers, provided that no mention of their context was made.

[pp. 70–71:] Early in 1940, Baron Manfred von Ardenne, an outstanding technician in his particular field, tried to persuade Otto Hahn's instrumentation and equipment specialist, Professor Philipp, to apply for a subsidy from General Göring for the construction of large 'atom-smashing' installations. [...]

Von Ardenne cast around for a source of large-scale funds, and learned that the Post Office had a large and rich research department. He called personally on the Minister of Posts, Ohnesorge, and in general terms explained how Hahn's discovery made uranium bombs now possible; he called particular attention to hints about 'powering ships with uranium reactors' dropped in a commentary to the US naval construction programme. In personal exchanges between the Dahlem laboratories and his own laboratory in Lichterfelde, von Ardenne had asked both Hahn and Heisenberg outright how much pure uranium-235 was necessary for an atomic explosion. He was told it would be only a few kilograms. 'During these discussions,' von Ardenne describes, 'I expressed an opinion that it was technically quite feasible, by means of high-yield electromagnetic mass-separators (which we already had on our drawing boards) to make quantities of a few kilograms of uranium-235 available, if only the Reich government would resolve to direct the talents of the big electrical combines to that end.'

Minister Ohnesorge was so impressed by von Ardenne's argument, that he secured an audience with Adolf Hitler soon after, and informed him of the uranium bomb. [...]

Von Ardenne saw Ohnesorge return angry and disappointed, but not defeated: he resolved to support von Ardenne's project within the framework of German Post Office research. There were thus now three factions in the nuclear research effort: the scientists allied to Doctor Diebner—including Berkei, Czulius, Herrmann, Hartwig and Kamin—at the Army Ordnance Department's Gottow laboratory; the scientists attracted to von Ardenne's laboratory; and the institutes of physics of the Kaiser-Wilhelm Foundation.

[Although David Irving was neither a trained historian nor a scientist (and ultimately went off the deep end), his book contains a great deal of useful information since he personally interviewed many of the German nuclear scientists within two decades after the end of the war.

Wilhelm Ohnesorge studied physics at the university before becoming head of the Reichspost. He had a large amount of research funding at his disposal, since his organization collected payments for all letters, packages, and telegrams sent throughout the Third Reich. He used that funding to support very advanced research programs in electronics, and he could have easily used it to support the early years of a nuclear weapons program as well. As reported by Irving, Ohnesorge sought larger amounts of nuclear funding from Hitler and was rejected, at least initially. Yet as also described by Irving, Ohnesorge did not give up easily.

Beginning no later than June 1942, Ohnesorge began a research collaboration with Heinrich Himmler and the SS, which could supply large amounts of funding, personnel, facilities, and other resources (see pp. 3378–3387 for a few surviving documents). In September 1942, Ohnesorge again lobbied Hitler for political and financial support, revealing his knowledge of the U.S. Manhattan Project in the process (p. 3379): "According to his [Ohnesorge's] observations, at the moment America is gathering all the professors of physics and chemistry to produce special achievements. He would like to give a short lecture about this to the Führer." However the further discussions with Hitler turned out, the collaboration between the Reichspost and the SS appears to have continued until the end of the war, with large investments of resources in the program.

Kurt Diebner's research group also appears to have become aligned with the SS as the war progressed.]

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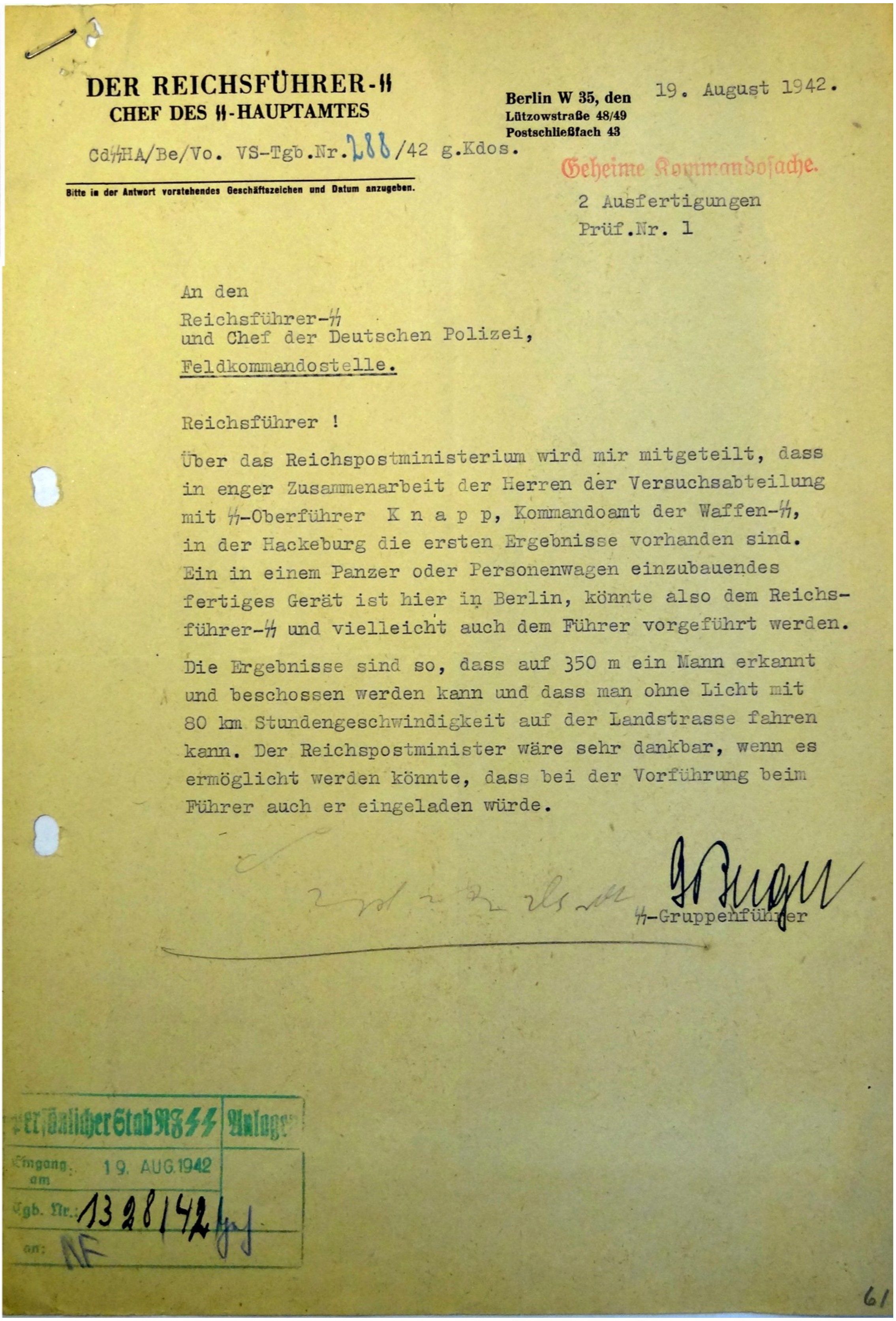
Authority NND 755001



DER REICHSFÜHRER-SS
CHEF DES SS-HAUPTAMTES

Cd SS HA/Be/Vo. VS-Tgb.Nr. 288 /42 g.Kdos.

Bitte in der Antwort vorstehendes Geschäftszeichen und Datum anzugeben.

Berlin W 35, den 19. August 1942.
Lützowstraße 48/49
Postschließfach 43

Geheime Kommandosache.

2 Ausfertigungen
Prüf.Nr. 1

An den
Reichsführer-SS
und Chef der Deutschen Polizei,
Feldkommandostelle.

Reichsführer !

Über das Reichspostministerium wird mir mitgeteilt, dass in enger Zusammenarbeit der Herren der Versuchsabteilung mit SS-Oberführer Knapp, Kommandoamt der Waffen-SS, in der Hackeburg die ersten Ergebnisse vorhanden sind. Ein in einem Panzer oder Personenwagen einzubauendes fertiges Gerät ist hier in Berlin, könnte also dem Reichsführer-SS und vielleicht auch dem Führer vorgeführt werden.

Die Ergebnisse sind so, dass auf 350 m ein Mann erkannt und beschossen werden kann und dass man ohne Licht mit 80 km Stundengeschwindigkeit auf der Landstrasse fahren kann. Der Reichspostminister wäre sehr dankbar, wenn es ermöglicht werden könnte, dass bei der Vorführung beim Führer auch er eingeladen würde.

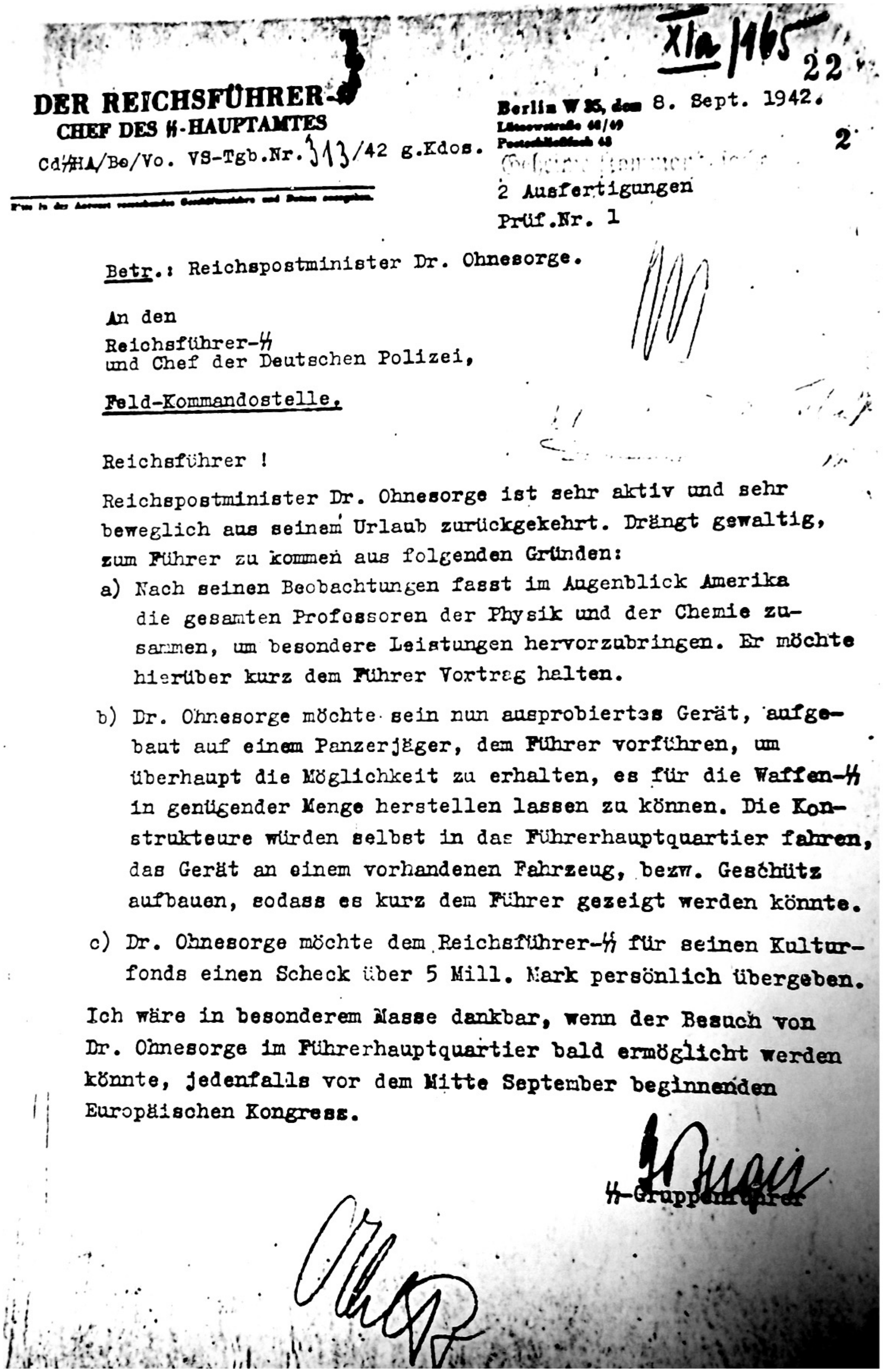
Berger
SS-Gruppenführer

Persönlicher Stab RF SS | Anlage
Eingang am: 19. AUG. 1942
Tgb. Nr.: 1328/42 gj
an: NF

61

NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made

Figure D.54: A few surviving documents reveal that Wilhelm Ohnesorge and Heinrich Himmler collaborated on research projects from June 1942 onward [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].



XIa/1465

22

DER REICHSFÜHRER-ᛋᛋ
CHEF DES ᛋᛋ-HAUPTAMTES
Cd/ᛋᛋHA/Be/Vo. VS-Tgb.Nr. 313/42 g.Kdos.

Berlin W 35, den 8. Sept. 1942.
Lützowstraße 48/49
Postschließfach 48

2

2 Ausfertigungen
Prüf.Nr. 1

Betr.: Reichspostminister Dr. Ohnesorge.

An den
Reichsführer-ᛋᛋ
und Chef der Deutschen Polizei,
Feld-Kommandostelle.

Reichsführer !

Reichspostminister Dr. Ohnesorge ist sehr aktiv und sehr beweglich aus seinem Urlaub zurückgekehrt. Drängt gewaltig, zum Führer zu kommen aus folgenden Gründen:

a) Nach seinen Beobachtungen fasst im Augenblick Amerika die gesamten Professoren der Physik und der Chemie zusammen, um besondere Leistungen hervorzubringen. Er möchte hierüber kurz dem Führer Vortrag halten.

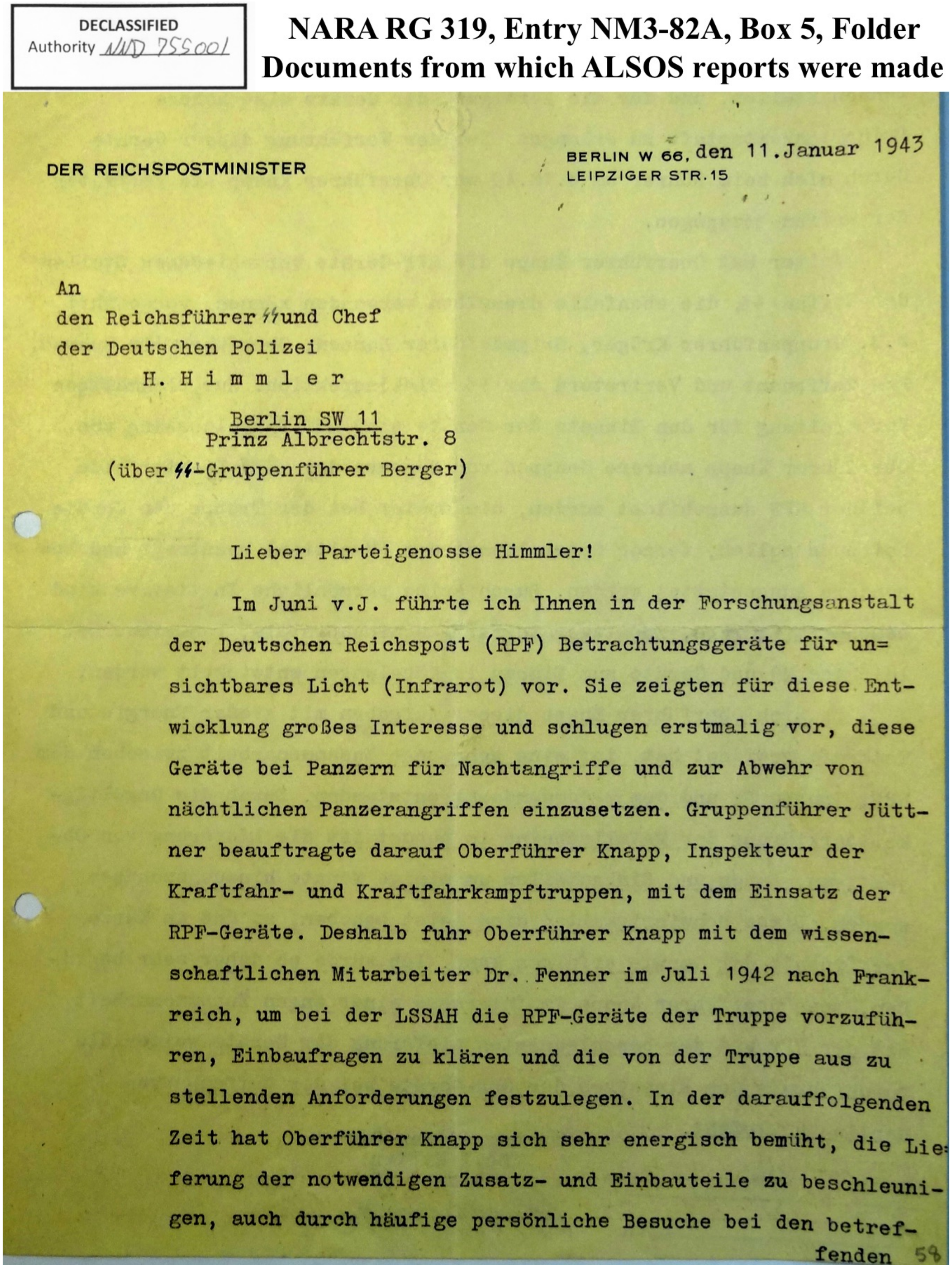
b) Dr. Ohnesorge möchte sein nun ausprobiertes Gerät, aufgebaut auf einem Panzerjäger, dem Führer vorführen, um überhaupt die Möglichkeit zu erhalten, es für die Waffen-ᛋᛋ in genügender Menge herstellen lassen zu können. Die Konstrukteure würden selbst in das Führerhauptquartier fahren, das Gerät an einem vorhandenen Fahrzeug, bezw. Geschütz aufbauen, sodass es kurz dem Führer gezeigt werden könnte.

c) Dr. Ohnesorge möchte dem Reichsführer-ᛋᛋ für seinen Kulturfonds einen Scheck über 5 Mill. Mark persönlich übergeben.

Ich wäre in besonderem Masse dankbar, wenn der Besuch von Dr. Ohnesorge im Führerhauptquartier bald ermöglicht werden könnte, jedenfalls vor dem Mitte September beginnenden Europäischen Kongress.

Berger
ᛋᛋ-Gruppenführer

Figure D.55: A few surviving documents reveal that Wilhelm Ohnesorge and Heinrich Himmler collaborated on research projects from June 1942 onward [Bundesarchiv Lichterfelde, NS 19-2012.]. Point a) reveals very early and accurate German knowledge of the U.S. Manhattan Project: “According to his [Ohnesorge’s] observations, at the moment America is gathering all the professors of physics and chemistry to produce special achievements. He would like to give a short lecture about this to the Führer.”



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Authority NND 755001

NARA RG 319, Entry NM3-82A, Box 5, Folder
Documents from which ALSOS reports were made

DER REICHSPOSTMINISTER

BERLIN W 66, LEIPZIGER STR. 15

den 11. Januar 1943

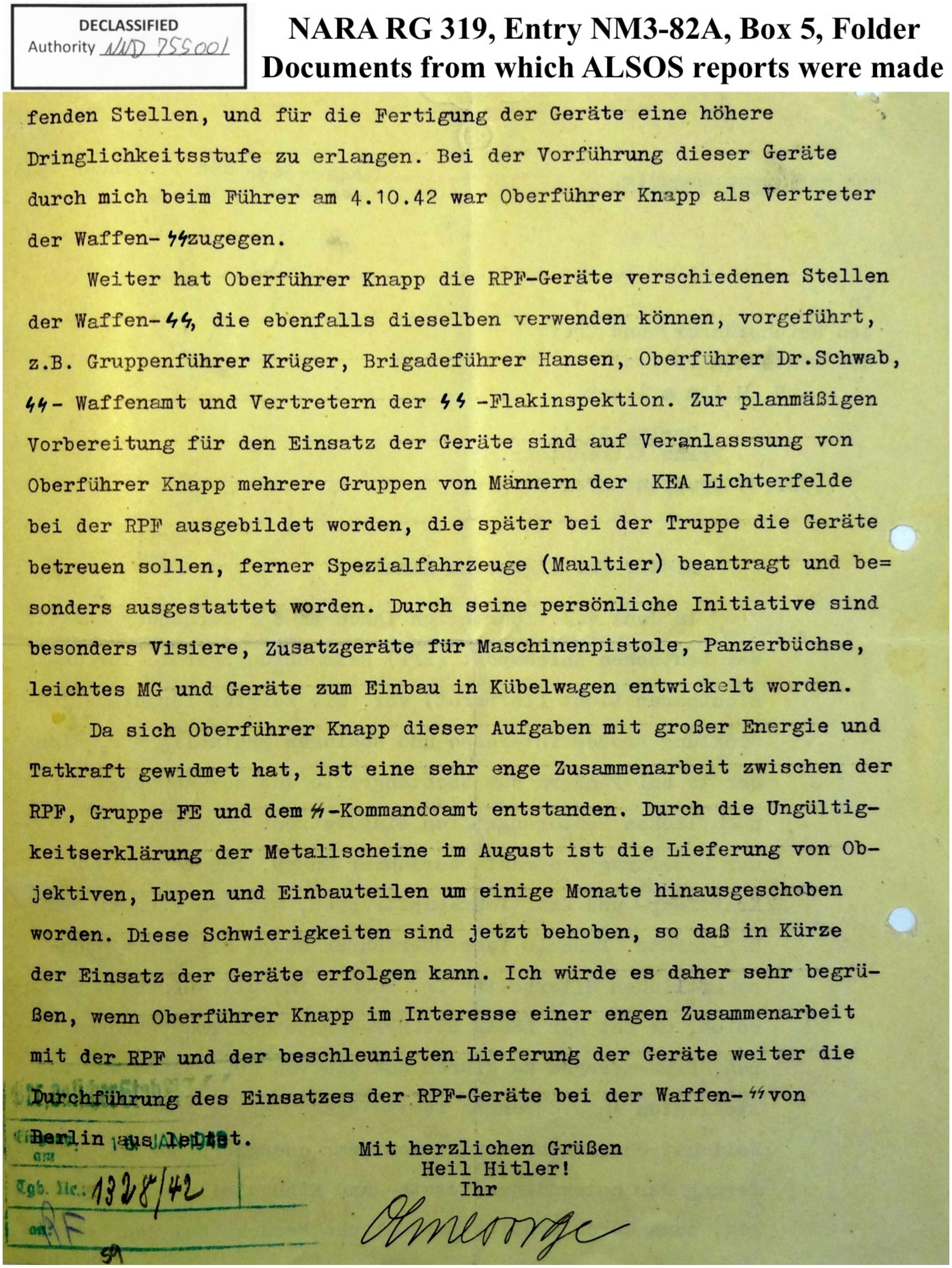
An
den Reichsführer ᛋᛋ und Chef
der Deutschen Polizei
H. Himmler
Berlin SW 11
Prinz Albrechtstr. 8
(über ᛋᛋ-Gruppenführer Berger)

Lieber Parteigenosse Himmler!

Im Juni v.J. führte ich Ihnen in der Forschungsanstalt der Deutschen Reichspost (RPF) Betrachtungsgeräte für unsichtbares Licht (Infrarot) vor. Sie zeigten für diese Entwicklung großes Interesse und schlugen erstmalig vor, diese Geräte bei Panzern für Nachtangriffe und zur Abwehr von nächtlichen Panzerangriffen einzusetzen. Gruppenführer Jüttner beauftragte darauf Oberführer Knapp, Inspekteur der Kraftfahr- und Kraftfahrkampftruppen, mit dem Einsatz der RPF-Geräte. Deshalb fuhr Oberführer Knapp mit dem wissenschaftlichen Mitarbeiter Dr. Fenner im Juli 1942 nach Frankreich, um bei der LSSAH die RPF-Geräte der Truppe vorzuführen, Einbaufragen zu klären und die von der Truppe aus zu stellenden Anforderungen festzulegen. In der darauffolgenden Zeit hat Oberführer Knapp sich sehr energisch bemüht, die Lieferung der notwendigen Zusatz- und Einbauteile zu beschleunigen, auch durch häufige persönliche Besuche bei den betref-

fenden

Figure D.56: A few surviving documents reveal that Wilhelm Ohnesorge and Heinrich Himmler collaborated on research projects from June 1942 onward [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].



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Authority NND 755001

NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made

fenden Stellen, und für die Fertigung der Geräte eine höhere Dringlichkeitsstufe zu erlangen. Bei der Vorführung dieser Geräte durch mich beim Führer am 4.10.42 war Oberführer Knapp als Vertreter der Waffen-ϟϟzugegen.

Weiter hat Oberführer Knapp die RPF-Geräte verschiedenen Stellen der Waffen-ϟϟ, die ebenfalls dieselben verwenden können, vorgeführt, z.B. Gruppenführer Krüger, Brigadeführer Hansen, Oberführer Dr.Schwab, ϟϟ- Waffenamt und Vertretern der ϟϟ -Flakinspektion. Zur planmäßigen Vorbereitung für den Einsatz der Geräte sind auf Veranlasssung von Oberführer Knapp mehrere Gruppen von Männern der KEA Lichterfelde bei der RPF ausgebildet worden, die später bei der Truppe die Geräte betreuen sollen, ferner Spezialfahrzeuge (Maultier) beantragt und besonders ausgestattet worden. Durch seine persönliche Initiative sind besonders Visiere, Zusatzgeräte für Maschinenpistole, Panzerbüchse, leichtes MG und Geräte zum Einbau in Kübelwagen entwickelt worden.

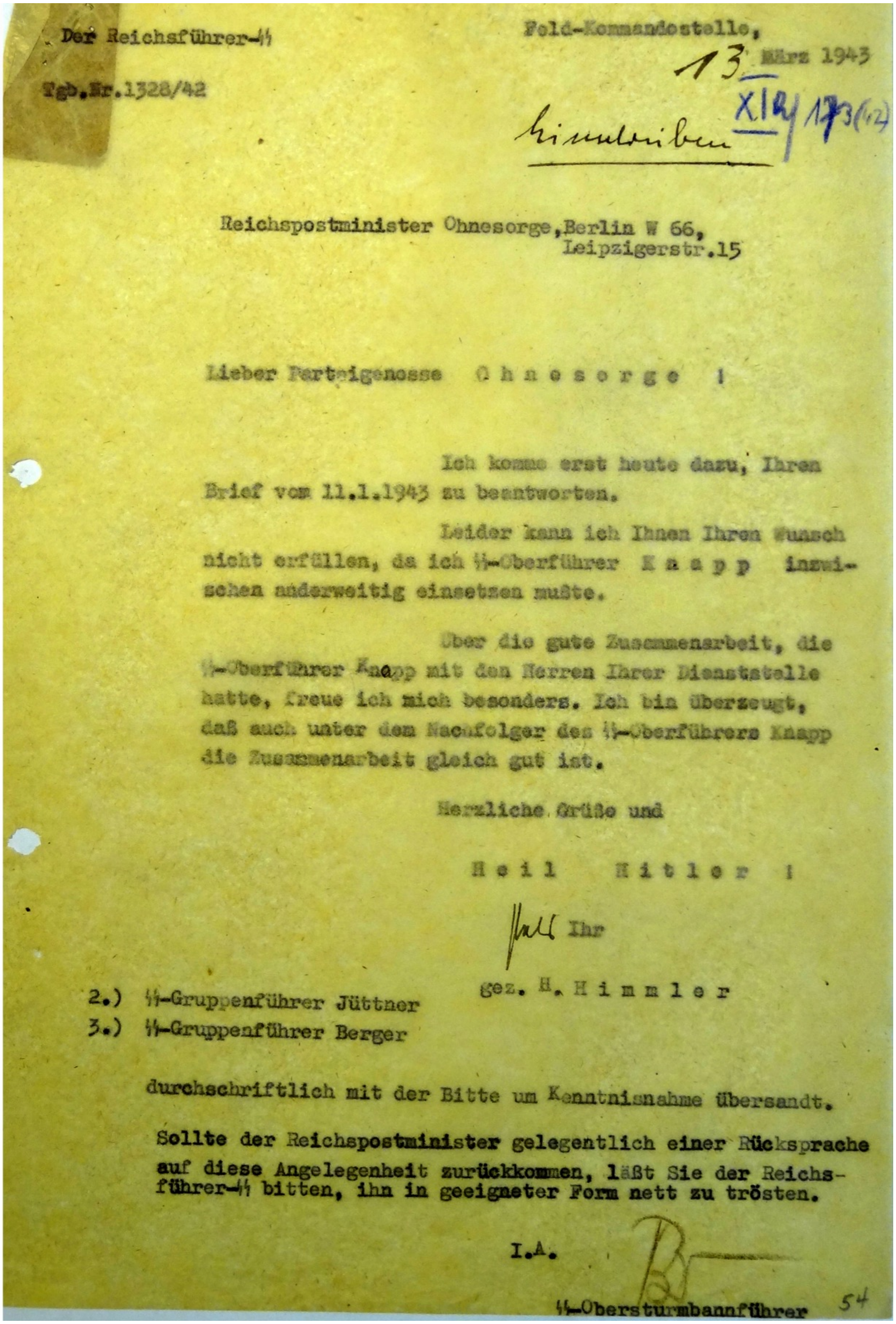
Da sich Oberführer Knapp dieser Aufgaben mit großer Energie und Tatkraft gewidmet hat, ist eine sehr enge Zusammenarbeit zwischen der RPF, Gruppe FE und dem ϟϟ-Kommandoamt entstanden. Durch die Ungültigkeitserklärung der Metallscheine im August ist die Lieferung von Objektiven, Lupen und Einbauteilen um einige Monate hinausgeschoben worden. Diese Schwierigkeiten sind jetzt behoben, so daß in Kürze der Einsatz der Geräte erfolgen kann. Ich würde es daher sehr begrüßen, wenn Oberführer Knapp im Interesse einer engen Zusammenarbeit mit der RPF und der beschleunigten Lieferung der Geräte weiter die Durchführung des Einsatzes der RPF-Geräte bei der Waffen-ϟϟ von Berlin aus leitet.

Mit herzlichen Grüßen
Heil Hitler!
Ihr
Ohnesorge

14 JAN 1943
Tgb. Nr.: 1328/42
RF

59

Figure D.57: A few surviving documents reveal that Wilhelm Ohnesorge and Heinrich Himmler collaborated on research projects from June 1942 onward [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].



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Authority NND 755001

Der Reichsführer-ᛋᛋ

Tgb.Nr.1328/42

Feld-Kommandostelle,
13 März 1943

Einschreiben

XIa/173(42)

Reichspostminister Ohnesorge, Berlin W 66,
Leipzigerstr.15

Lieber Parteigenosse Ohnesorge !

Ich komme erst heute dazu, Ihren Brief vom 11.1.1943 zu beantworten.

Leider kann ich Ihnen Ihren Wunsch nicht erfüllen, da ich ᛋᛋ-Oberführer Knapp inzwischen anderweitig einsetzen mußte.

Über die gute Zusammenarbeit, die ᛋᛋ-Oberführer Knapp mit den Herren Ihrer Dienststelle hatte, freue ich mich besonders. Ich bin überzeugt, daß auch unter dem Nachfolger des ᛋᛋ-Oberführers Knapp die Zusammenarbeit gleich gut ist.

Herzliche Grüße und

Heil Hitler !

Ihr

gez. H. Himmler

2.) ᛋᛋ-Gruppenführer Jüttner
3.) ᛋᛋ-Gruppenführer Berger

durchschriftlich mit der Bitte um Kenntnisnahme übersandt.

Sollte der Reichspostminister gelegentlich einer Rücksprache auf diese Angelegenheit zurückkommen, läßt Sie der Reichsführer-ᛋᛋ bitten, ihn in geeigneter Form nett zu trösten.

I.A.

ᛋᛋ-Obersturmbannführer

54

NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made

Figure D.58: A few surviving documents reveal that Wilhelm Ohnesorge and Heinrich Himmler collaborated on research projects from June 1942 onward [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].

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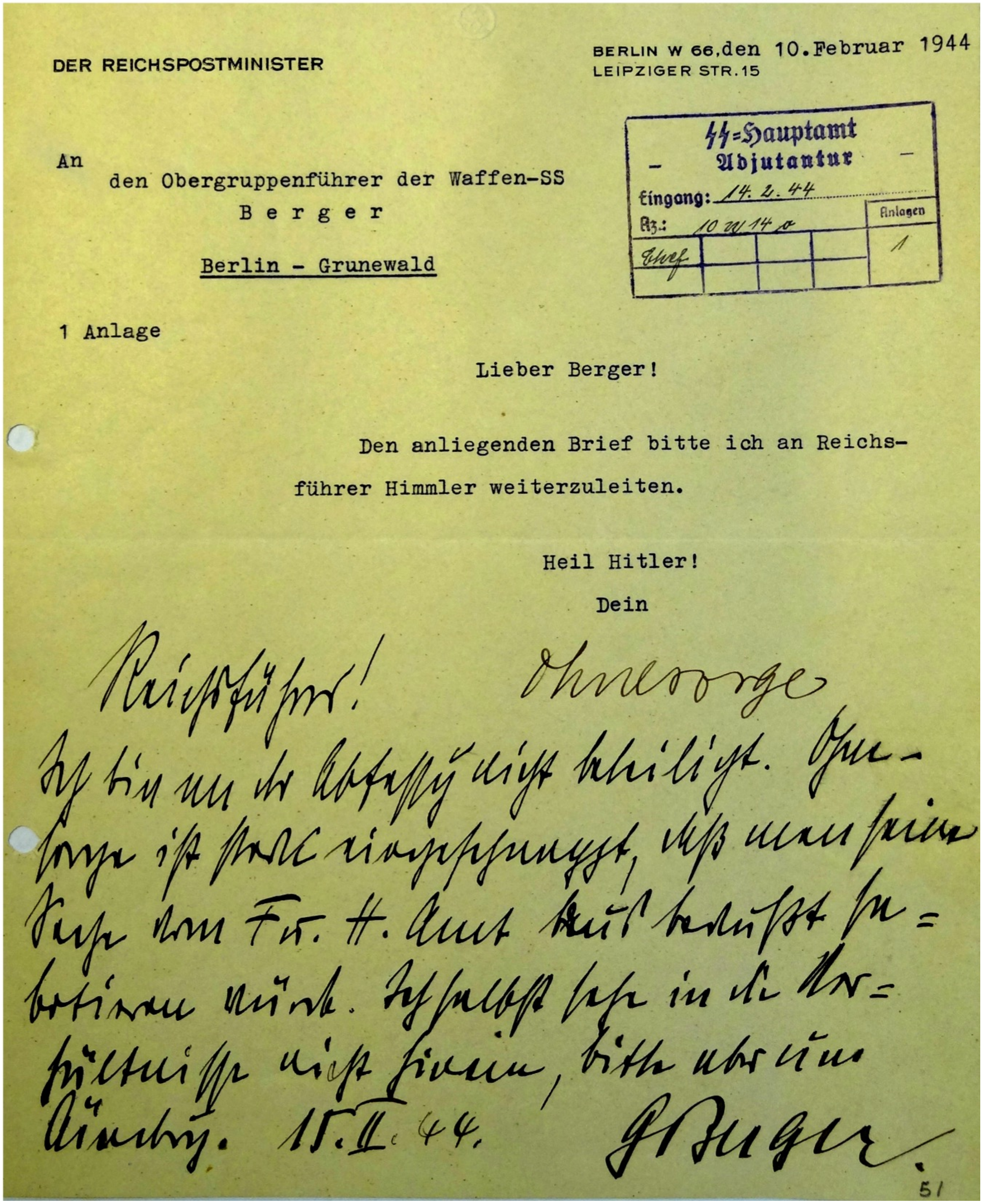
NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made



DER REICHSPOSTMINISTER

BERLIN W 66, den 10. Februar 1944
LEIPZIGER STR. 15

SS-Hauptamt
– Adjutantur –
Eingang: 14. 2. 44
Az.: 10 W 14 a
Anlagen 1
Chef

An
den Obergruppenführer der Waffen-SS
Berger
Berlin - Grunewald

1 Anlage

Lieber Berger!

Den anliegenden Brief bitte ich an Reichsführer Himmler weiterzuleiten.

Heil Hitler!
Dein
Ohnesorge

Reichsführer!
Ich bin an der Abfassung nicht beteiligt. Ohnesorge ist stark eingeschnappt, daß man seine Sache vom Fr. H. Amt auch bewußt sabotieren würde. Ich selbst sehe in die Verhältnisse nicht hinein, bitte aber um Änderung. 15.II.44.
G Berger.

51

Figure D.59: A few surviving documents reveal that Wilhelm Ohnesorge and Heinrich Himmler collaborated on research projects from June 1942 onward [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].

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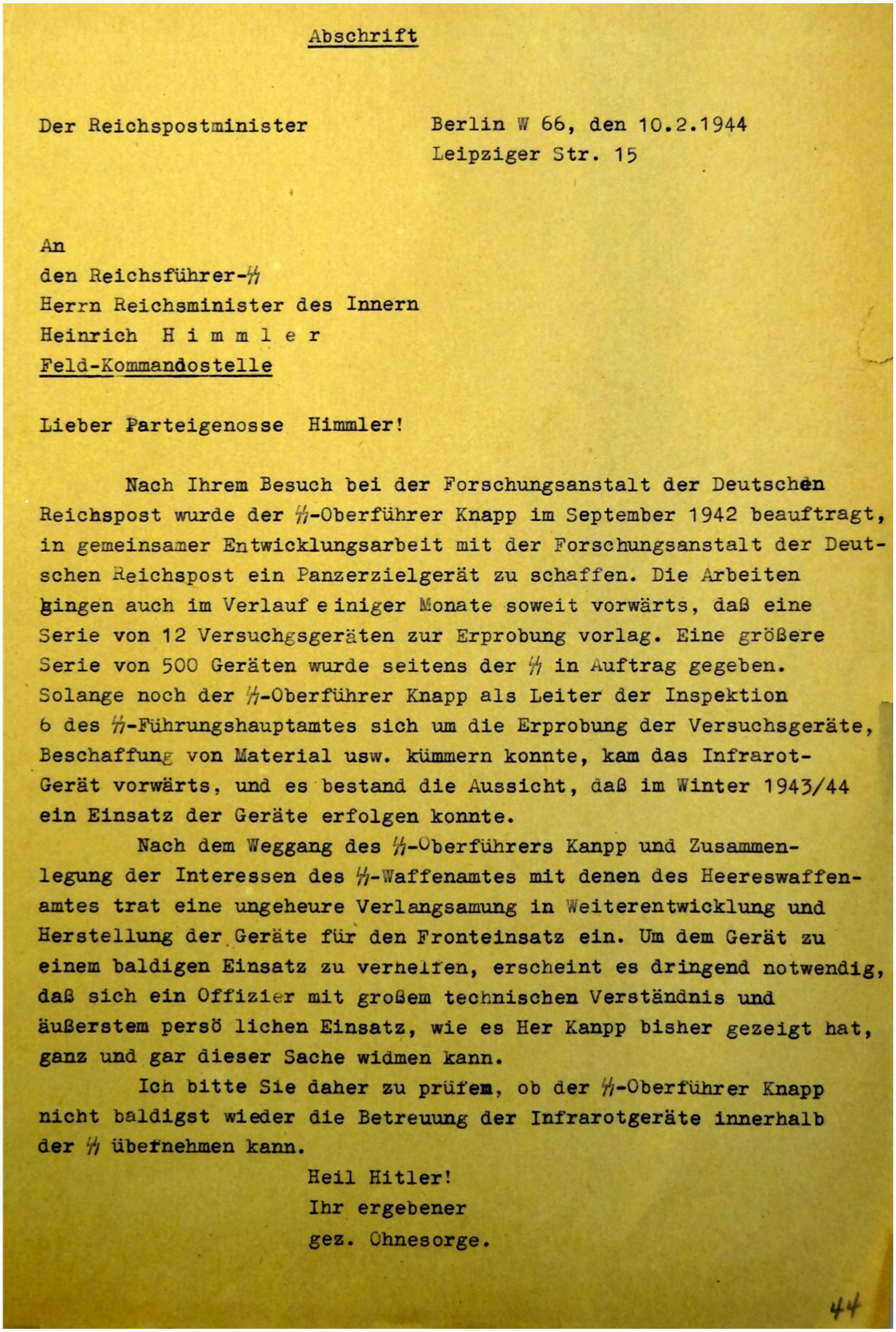
Authority NND 755001

NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made



Abschrift

Der Reichspostminister

Berlin W 66, den 10.2.1944
Leipziger Str. 15

An
den Reichsführer-ᛋᛋ
Herrn Reichsminister des Innern
Heinrich Himmler
Feld-Kommandostelle

Lieber Parteigenosse Himmler!

Nach Ihrem Besuch bei der Forschungsanstalt der Deutschen Reichspost wurde der ᛋᛋ-Oberführer Knapp im September 1942 beauftragt, in gemeinsamer Entwicklungsarbeit mit der Forschungsanstalt der Deutschen Reichspost ein Panzerzielgerät zu schaffen. Die Arbeiten gingen auch im Verlauf einiger Monate soweit vorwärts, daß eine Serie von 12 Versuchgsgeräten zur Erprobung vorlag. Eine größere Serie von 500 Geräten wurde seitens der ᛋᛋ in Auftrag gegeben. Solange noch der ᛋᛋ-Oberführer Knapp als Leiter der Inspektion 6 des ᛋᛋ-Führungshauptamtes sich um die Erprobung der Versuchsgeräte, Beschaffung von Material usw. kümmern konnte, kam das Infrarot-Gerät vorwärts, und es bestand die Aussicht, daß im Winter 1943/44 ein Einsatz der Geräte erfolgen konnte.

Nach dem Weggang des ᛋᛋ-Oberführers Kanpp und Zusammenlegung der Interessen des ᛋᛋ-Waffenamtes mit denen des Heereswaffenamtes trat eine ungeheure Verlangsamung in Weiterentwicklung und Herstellung der Geräte für den Fronteinsatz ein. Um dem Gerät zu einem baldigen Einsatz zu verhelfen, erscheint es dringend notwendig, daß sich ein Offizier mit großem technischen Verständnis und äußerstem persö lichen Einsatz, wie es Her Kanpp bisher gezeigt hat, ganz und gar dieser Sache widmen kann.

Ich bitte Sie daher zu prüfem, ob der ᛋᛋ-Oberführer Knapp nicht baldigst wieder die Betreuung der Infrarotgeräte innerhalb der ᛋᛋ übernehmen kann.

Heil Hitler!
Ihr ergebener
gez. Ohnesorge.

44

Figure D.60: A few surviving documents reveal that Wilhelm Ohnesorge and Heinrich Himmler collaborated on research projects from June 1942 onward [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].

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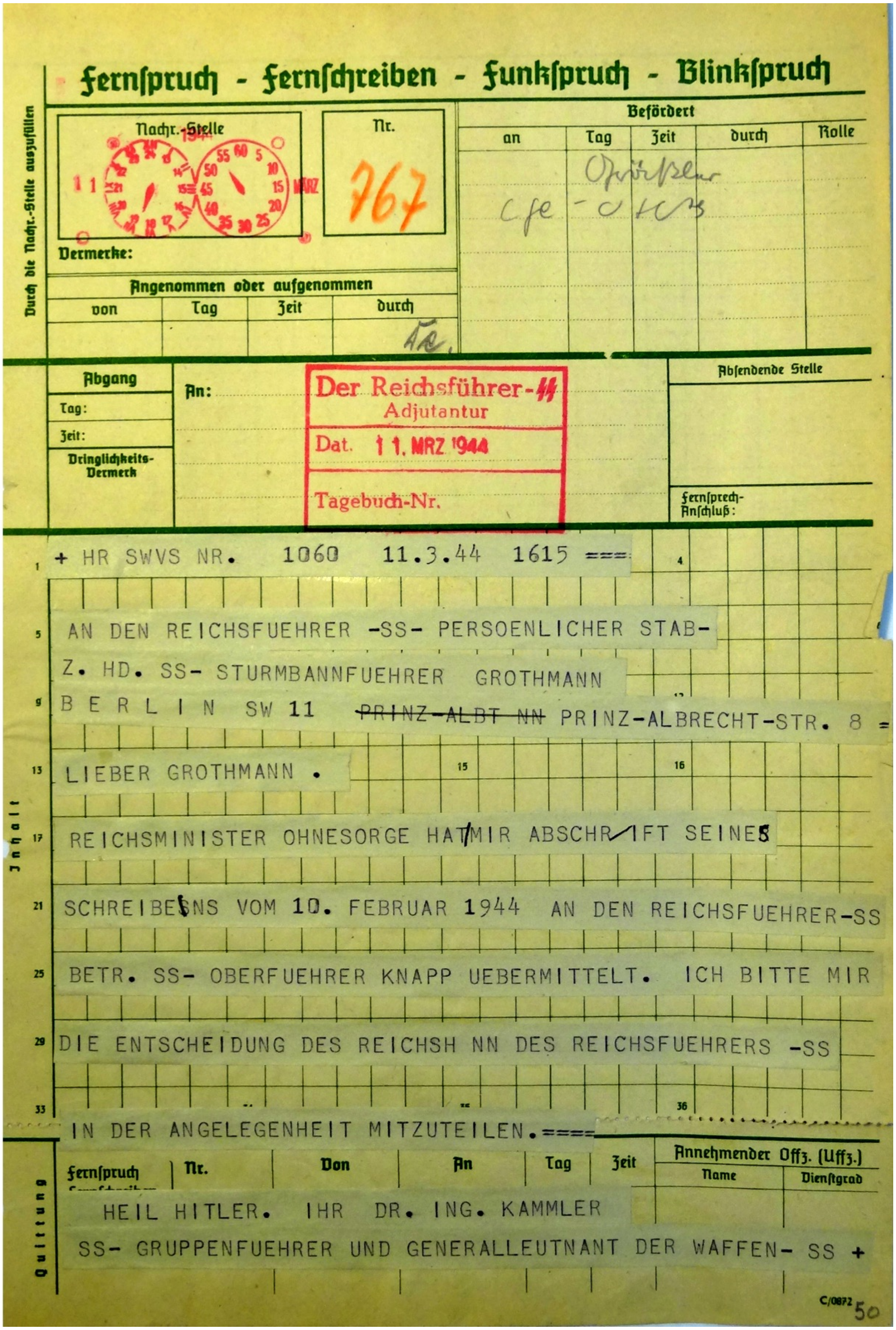
Authority NND 755001



Fernſpruch - Fernſchreiben - Funkſpruch - Blinkſpruch

Durch die Nachr.-Stelle auszufüllen

Nachr.-Stelle 11 MÄRZ 1944

Nr. 767

Befördert: an / Tag / Zeit / durch / Rolle

Vermerke:

Angenommen oder aufgenommen: von / Tag / Zeit / durch

Abgang: Tag: / Zeit: / Dringlichkeits-Vermerk

An:

Der Reichsführer-SS
Adjutantur
Dat. 11. MRZ 1944
Tagebuch-Nr.

Abſendende Stelle

Fernſprech-Anſchluß:

Inhalt

+ HR SWVS NR. 1060 11.3.44 1615 ===

AN DEN REICHSFUEHRER -SS- PERSOENLICHER STAB-
Z. HD. SS- STURMBANNFUEHRER GROTHMANN
B E R L I N SW 11 ~~PRINZ-ALBT NN~~ PRINZ-ALBRECHT-STR. 8 =

LIEBER GROTHMANN .

REICHSMINISTER OHNESORGE HAT MIR ABSCHRIFT SEINES SCHREIBENS VOM 10. FEBRUAR 1944 AN DEN REICHSFUEHRER-SS BETR. SS- OBERFUEHRER KNAPP UEBERMITTELT. ICH BITTE MIR DIE ENTSCHEIDUNG DES REICHSH NN DES REICHSFUEHRERS -SS IN DER ANGELEGENHEIT MITZUTEILEN.====

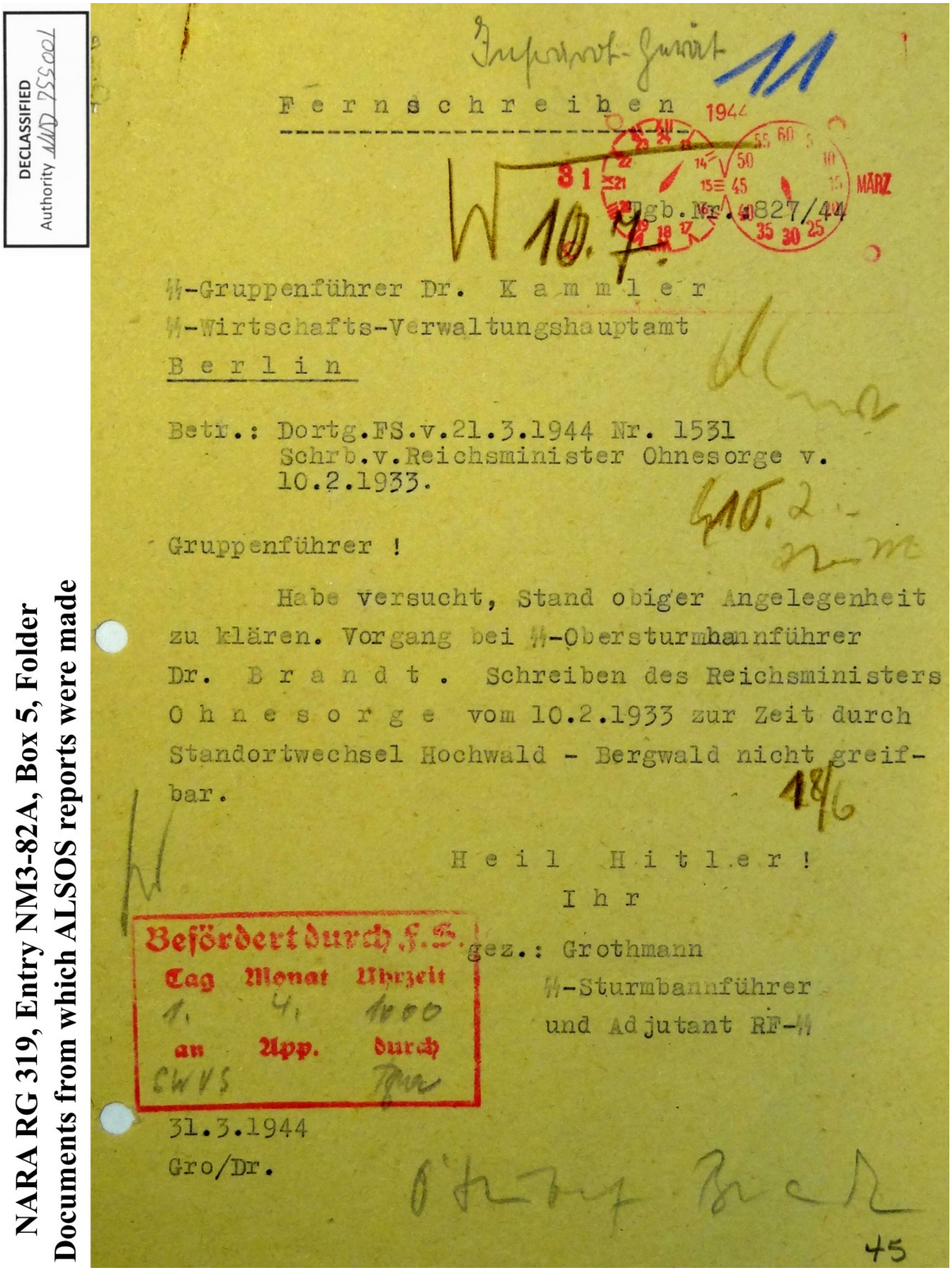
Quittung: Fernſpruch / Nr. / Von / An / Tag / Zeit / Annehmender Offz. (Uffz.) Name / Dienſtgrad

HEIL HITLER. IHR DR. ING. KAMMLER
SS- GRUPPENFUEHRER UND GENERALLEUTNANT DER WAFFEN- SS +

C/0872 50

NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made

Figure D.61: A few surviving documents reveal that Wilhelm Ohnesorge and Heinrich Himmler collaborated on research projects from June 1942 onward [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].



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Authority NND 775001

NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made

Infrarot-Gerät 11

Fernschreiben

1944 31 MÄRZ

W 10.7.

Tgb.Nr. 0827/44

ᛋᛋ-Gruppenführer Dr. Kammler
ᛋᛋ-Wirtschafts-Verwaltungshauptamt
Berlin

Betr.: Dortg.FS.v.21.3.1944 Nr. 1531
Schrb.v.Reichsminister Ohnesorge v.
10.2.1933.

4/10.2.

Gruppenführer !

Habe versucht, Stand obiger Angelegenheit zu klären. Vorgang bei ᛋᛋ-Obersturmbannführer Dr. Brandt. Schreiben des Reichsministers Ohnesorge vom 10.2.1933 zur Zeit durch Standortwechsel Hochwald - Bergwald nicht greifbar.

18/6

Heil Hitler!
Ihr
gez.: Grothmann
ᛋᛋ-Sturmbannführer
und Adjutant RF-ᛋᛋ

Befördert durch F.S.
Tag 1. Monat 4. Uhrzeit 1600
an SWVS App. durch

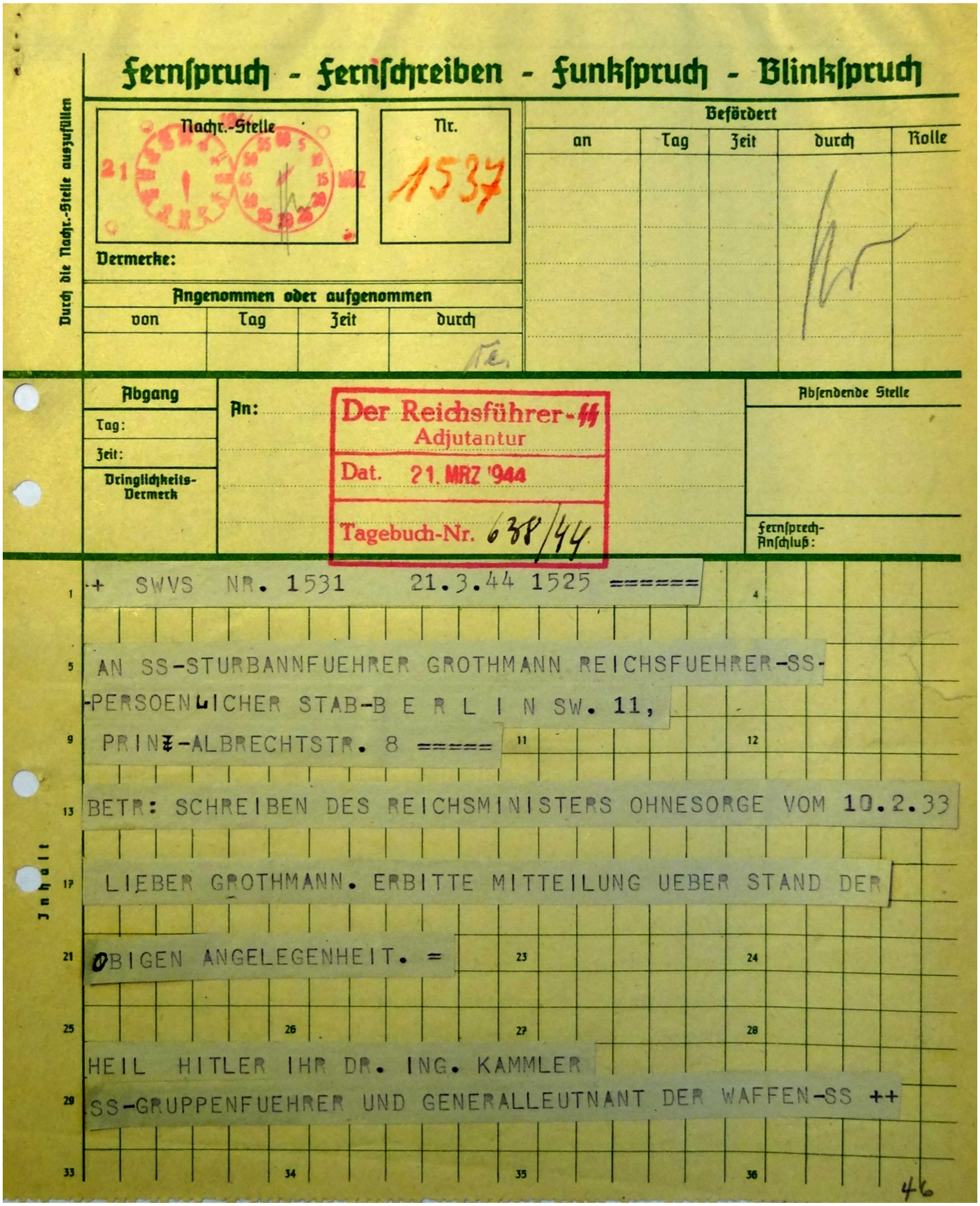
31.3.1944
Gro/Dr.

45

Figure D.62: A few surviving documents reveal that Wilhelm Ohnesorge and Heinrich Himmler collaborated on research projects from June 1942 onward [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].

DECLASSIFIED
Authority NND 755001

NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made



Fernſpruch - Fernſchreiben - Funkſpruch - Blinkſpruch

Durch die Nachr.-Stelle auszufüllen

Nachr.-Stelle: 21 1944 MRZ

Nr. 1537

Vermerke:

Angenommen oder aufgenommen

von	Tag	Zeit	durch
			Te.

Befördert

an	Tag	Zeit	durch	Rolle

Abgang
Tag:
Zeit:
Dringlichkeits-Vermerk

An:

Der Reichsführer-SS
Adjutantur
Dat. 21. MRZ 1944
Tagebuch-Nr. 638/44

Abſendende Stelle

Fernſprech-Anſchluß:

Inhalt

+ SWVS NR. 1531 21.3.44 1525 ======

AN SS-STURBANNFUEHRER GROTHMANN REICHSFUEHRER-SS-
-PERSOENLICHER STAB-B E R L I N SW. 11,
PRINZ-ALBRECHTSTR. 8 =====

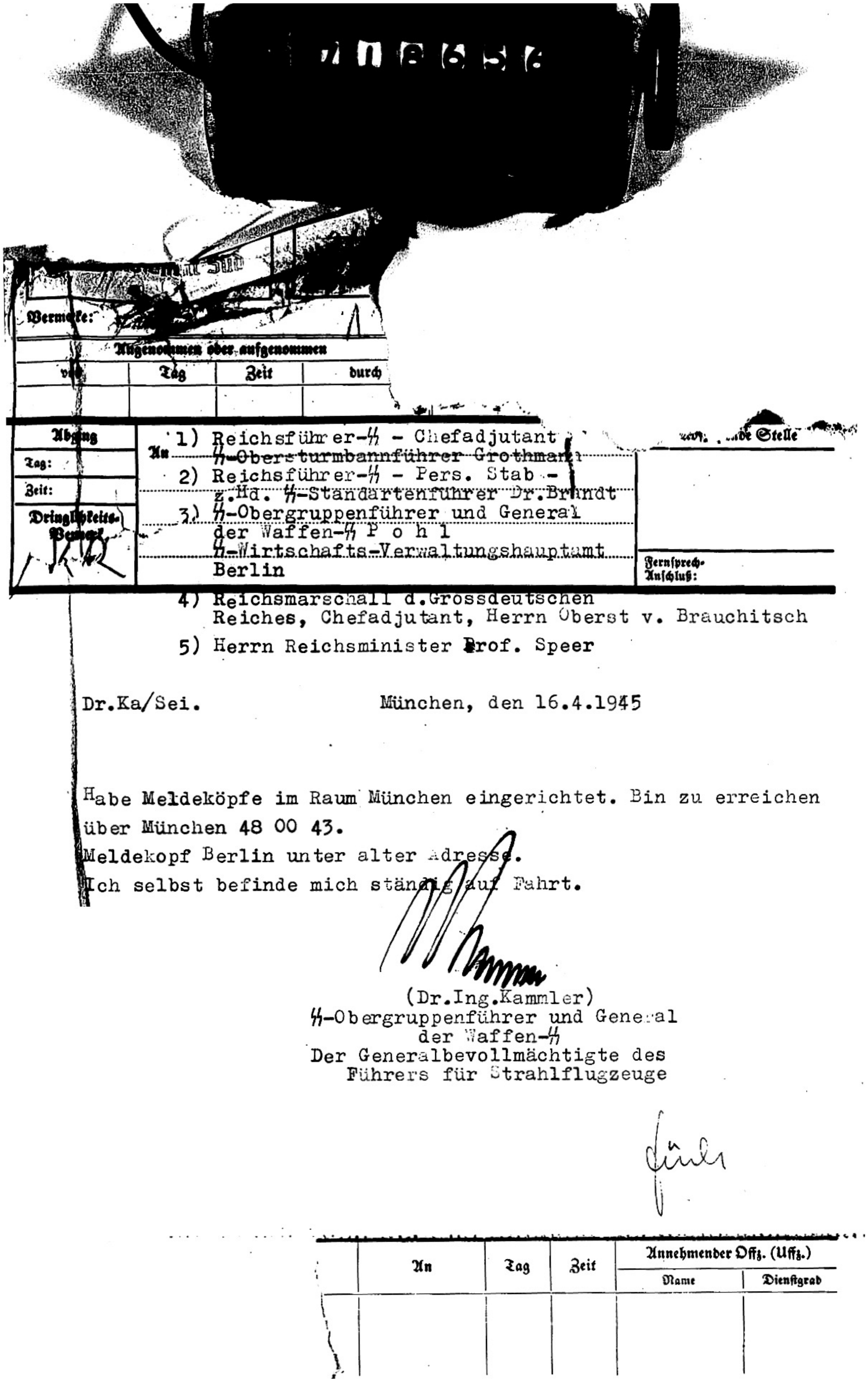
BETR: SCHREIBEN DES REICHSMINISTERS OHNESORGE VOM 10.2.33

LIEBER GROTHMANN. ERBITTE MITTEILUNG UEBER STAND DER
OBIGEN ANGELEGENHEIT. =

HEIL HITLER IHR DR. ING. KAMMLER
SS-GRUPPENFUEHRER UND GENERALLEUTNANT DER WAFFEN-SS ++

46

Figure D.63: A few surviving documents reveal that Wilhelm Ohnesorge and Heinrich Himmler collaborated on research projects from June 1942 onward [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].



Vermerke:

Angenommen oder aufgenommen

von	Tag	Zeit	durch

Abgang

Tag:

Zeit:

Dringlichkeits-Vermerk:

An

1) Reichsführer-ᛋᛋ - Chefadjutant
ᛋᛋ-Obersturmbannführer Grothmann
2) Reichsführer-ᛋᛋ - Pers. Stab -
z.Hd. ᛋᛋ-Standartenführer Dr.Brandt
3) ᛋᛋ-Obergruppenführer und General
der Waffen-ᛋᛋ Pohl
ᛋᛋ-Wirtschafts-Verwaltungshauptamt
Berlin
4) Reichsmarschall d.Grossdeutschen
Reiches, Chefadjutant, Herrn Oberst v. Brauchitsch
5) Herrn Reichsminister Prof. Speer

...de Stelle

Fernsprech-Anschluß:

Dr.Ka/Sei. München, den 16.4.1945

Habe Meldeköpfe im Raum München eingerichtet. Bin zu erreichen über München 48 00 43.
Meldekopf Berlin unter alter Adresse.
Ich selbst befinde mich ständig auf Fahrt.

(Dr.Ing.Kammler)
ᛋᛋ-Obergruppenführer und General
der Waffen-ᛋᛋ
Der Generalbevollmächtigte des
Führers für Strahlflugzeuge

An	Tag	Zeit	Annehmender Offz. (Uffz.)	
			Name	Dienstgrad

NARA RG 242, Records of the Reich Leader of the Schutzstaffel (SS) and Chief of the German Police, Microfilm 183, NAID 273992206 (https://catalog.archives.gov/id/273992206)

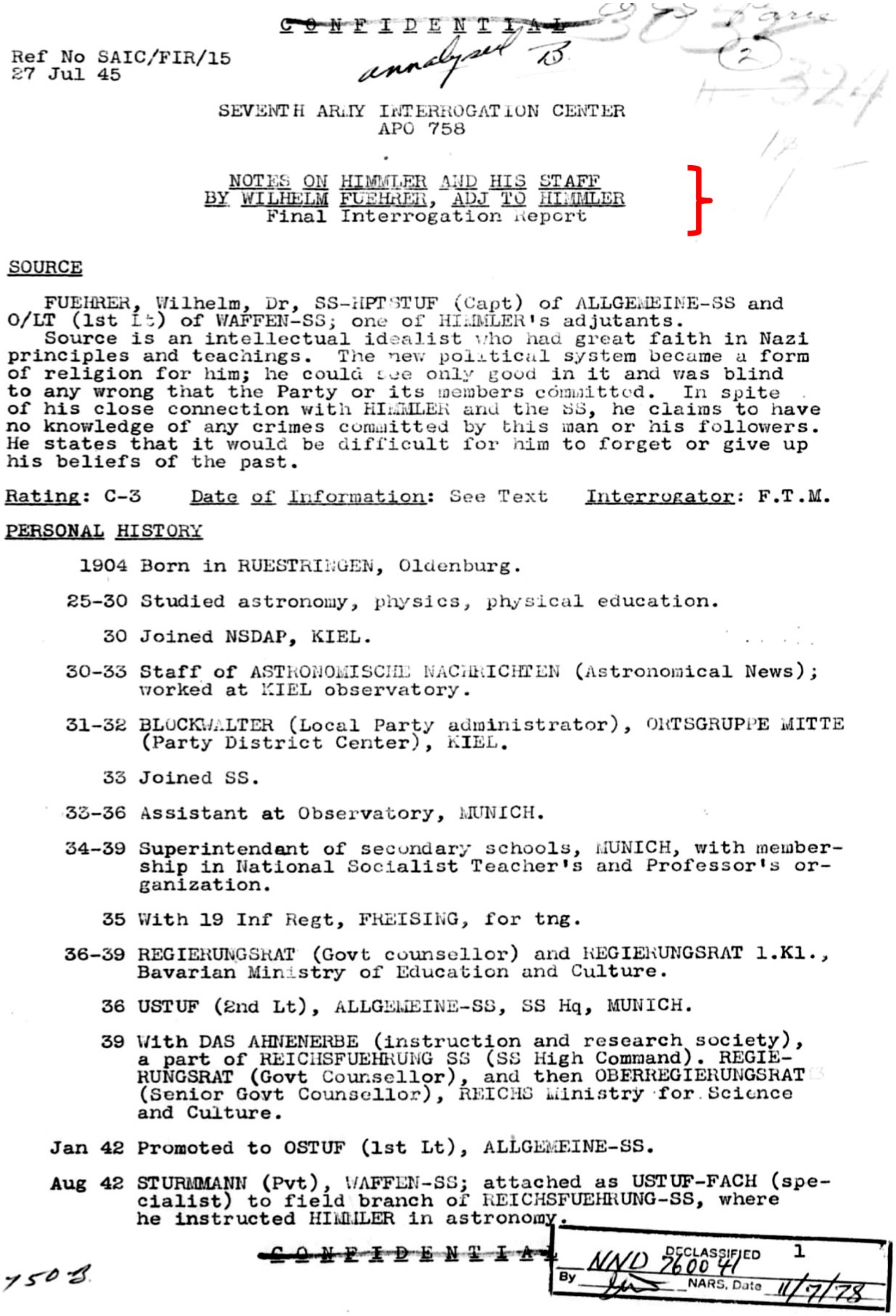
Figure D.64: Hans Kammler. 16 April 1945 telegram [NARA RG 242, Records of the Reich Leader of the Schutzstaffel (SS) and Chief of the German Police, Microfilm 183, NAID 273992206 (https://catalog.archives.gov/id/273992206)]. Note that Werner Grothmann is first on the list.

[NARA RG 238, Microfilm M1270, Interrogation Records Prepared for War Crimes Proceedings at Nuernberg, Roll 24]

[In postwar interrogations, one of Himmler's adjutants stated that Himmler had a panel of top science advisors. Of the eleven advisors named in the document, six were nuclear experts and the other five had expertise that could have been very useful for a nuclear weapons program:

- Erich Schumann (German, 1898–1985) appears first in this list, suggesting that he may have been one of Himmler's most important or most frequent scientific advisors. He ran the nuclear program of the Heereswaffenamt (Army Ordnance Office), was directly involved in designing and testing spherical implosion bombs (pp. 4187–4255), and was closely tied to other programs to develop biological weapons, rockets, etc. [Nagel 2012a].
- Christian Gerthsen (German, 1894–1956) was a top-ranked nuclear physicist (p. 4780) whose wartime activities have never been publicly described.
- Hans Geiger (German, 1882–1945) was one of Germany's earliest nuclear physicists (having invented the Geiger counter in 1908, p. 1518) and had been involved in the wartime German nuclear program at the highest levels since early 1939 (p. 3376).
- Walther Gerlach (German, 1889–1979) was the head scientific administrator of the German nuclear weapons program as well as some other advanced technology programs.
- Rudolf Tomaschek (German, 1895–1966) played an important but currently mysterious role in the wartime German H-bomb development program (p. 4334).
- Fritz Kirchner (German, 1896–1967) was a nuclear physicist who worked with the Heereswaffenamt (Army Ordnance Office) during the war. While the full extent of his wartime activities is unclear from currently available documents, he is known to have worked on particle accelerators, fission reactions, and fusion reactions [G-47, G-101, G-270, G-271, and pp. 3608, 4316, 4521, 3326, 4781].
- Leo von zur Mühlen (German, 1888–1953) was an expert on mining resources in central and eastern Europe, which would have been extremely useful for nuclear and other programs.
- August Schmauß (German, 1877–1954) was an expert on meteorology, which would have been important for planning battles in general, and attacks with weapons of mass destruction in particular.
- Heinrich von Ficker (German/Austrian, 1881–1957) was another authority on meteorology.
- Paul Guthnick (German, 1879–1947) was a noted astronomer; his input might have been useful for planning suborbital ballistic trajectories, teaching intercontinental pilots how to navigate to their targets by the stars, or developing other methods of reaching strategic objectives.
- Otto Heckmann (German, 1901–1983) was another astronomy expert.

See pp. 3390–3394 for photos of this document.]



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Ref No SAIC/FIR/15
27 Jul 45

SEVENTH ARMY INTERROGATION CENTER
APO 758

NOTES ON HIMMLER AND HIS STAFF
BY WILHELM FUEHRER, ADJ TO HIMMLER
Final Interrogation Report

SOURCE

FUEHRER, Wilhelm, Dr, SS-HPTSTUF (Capt) of ALLGEMEINE-SS and O/LT (1st Lt) of WAFFEN-SS; one of HIMMLER's adjutants.

Source is an intellectual idealist who had great faith in Nazi principles and teachings. The new political system became a form of religion for him; he could see only good in it and was blind to any wrong that the Party or its members committed. In spite of his close connection with HIMMLER and the SS, he claims to have no knowledge of any crimes committed by this man or his followers. He states that it would be difficult for him to forget or give up his beliefs of the past.

Rating: C-3   **Date of Information**: See Text   **Interrogator**: F.T.M.

PERSONAL HISTORY

1904	Born in RUESTRINGEN, Oldenburg.
25-30	Studied astronomy, physics, physical education.
30	Joined NSDAP, KIEL.
30-33	Staff of ASTRONOMISCHE NACHRICHTEN (Astronomical News); worked at KIEL observatory.
31-32	BLOCKWALTER (Local Party administrator), ORTSGRUPPE MITTE (Party District Center), KIEL.
33	Joined SS.
33-36	Assistant at Observatory, MUNICH.
34-39	Superintendant of secondary schools, MUNICH, with membership in National Socialist Teacher's and Professor's organization.
35	With 19 Inf Regt, FREISING, for tng.
36-39	REGIERUNGSRAT (Govt counsellor) and REGIERUNGSRAT 1.Kl., Bavarian Ministry of Education and Culture.
36	USTUF (2nd Lt), ALLGEMEINE-SS, SS Hq, MUNICH.
39	With DAS AHNENERBE (instruction and research society), a part of REICHSFUEHRUNG SS (SS High Command). REGIERUNGSRAT (Govt Counsellor), and then OBERREGIERUNGSRAT (Senior Govt Counsellor), REICHS Ministry for Science and Culture.
Jan 42	Promoted to OSTUF (1st Lt), ALLGEMEINE-SS.
Aug 42	STURMMANN (Pvt), WAFFEN-SS; attached as USTUF-FACH (specialist) to field branch of REICHSFUEHRUNG-SS, where he instructed HIMMLER in astronomy.

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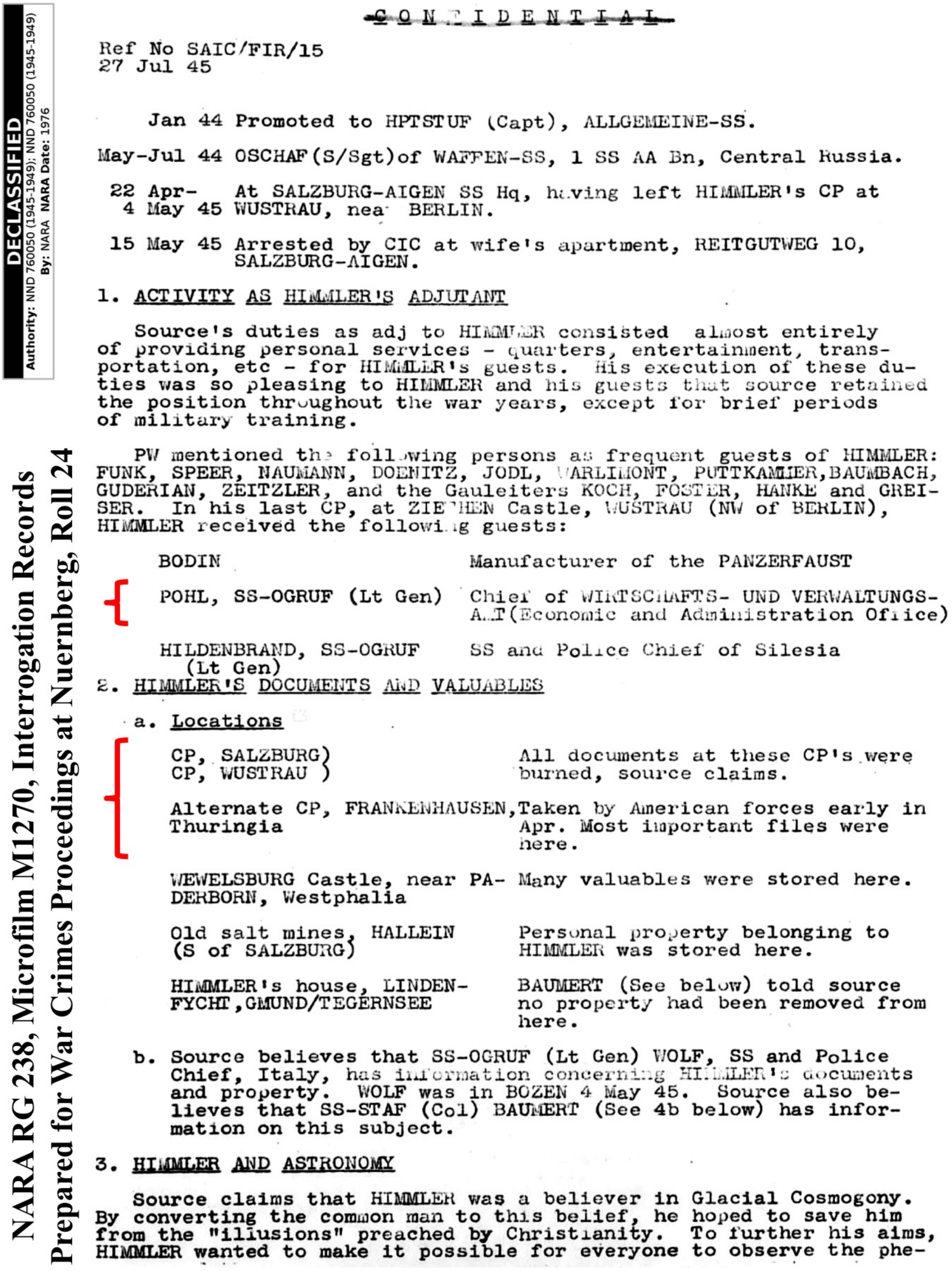
Figure D.65: In postwar interrogations, one of Himmler's adjutants stated that Himmler had a panel of top science advisors, including Walther Gerlach, Erich Schumann, and other nuclear scientists [NARA RG 238, Microfilm M1270, Interrogation Records Prepared for War Crimes Proceedings at Nuernberg, Roll 24].



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Jan 44	Promoted to HPTSTUF (Capt), ALLGEMEINE-SS.
May-Jul 44	OSCHAF(S/Sgt)of WAFFEN-SS, 1 SS AA Bn, Central Russia.
22 Apr- 4 May 45	At SALZBURG-AIGEN SS Hq, having left HIMMLER's CP at WUSTRAU, near BERLIN.
15 May 45	Arrested by CIC at wife's apartment, REITGUTWEG 10, SALZBURG-AIGEN.

1. ACTIVITY AS HIMMLER'S ADJUTANT

Source's duties as adj to HIMMLER consisted almost entirely of providing personal services - quarters, entertainment, transportation, etc - for HIMMLER's guests. His execution of these duties was so pleasing to HIMMLER and his guests that source retained the position throughout the war years, except for brief periods of military training.

PW mentioned the following persons as frequent guests of HIMMLER: FUNK, SPEER, NAUMANN, DOENITZ, JODL, WARLIMONT, PUTTKAMMER,BAUMBACH, GUDERIAN, ZEITZLER, and the Gauleiters KOCH, FOSTER, HANKE and GREISER. In his last CP, at ZIETHEN Castle, WUSTRAU (NW of BERLIN), HIMMLER received the following guests:

BODIN	Manufacturer of the PANZERFAUST
POHL, SS-OGRUF (Lt Gen)	Chief of WIRTSCHAFTS- UND VERWALTUNGS-AMT(Economic and Administration Office)
HILDENBRAND, SS-OGRUF (Lt Gen)	SS and Police Chief of Silesia

2. HIMMLER'S DOCUMENTS AND VALUABLES

a. Locations

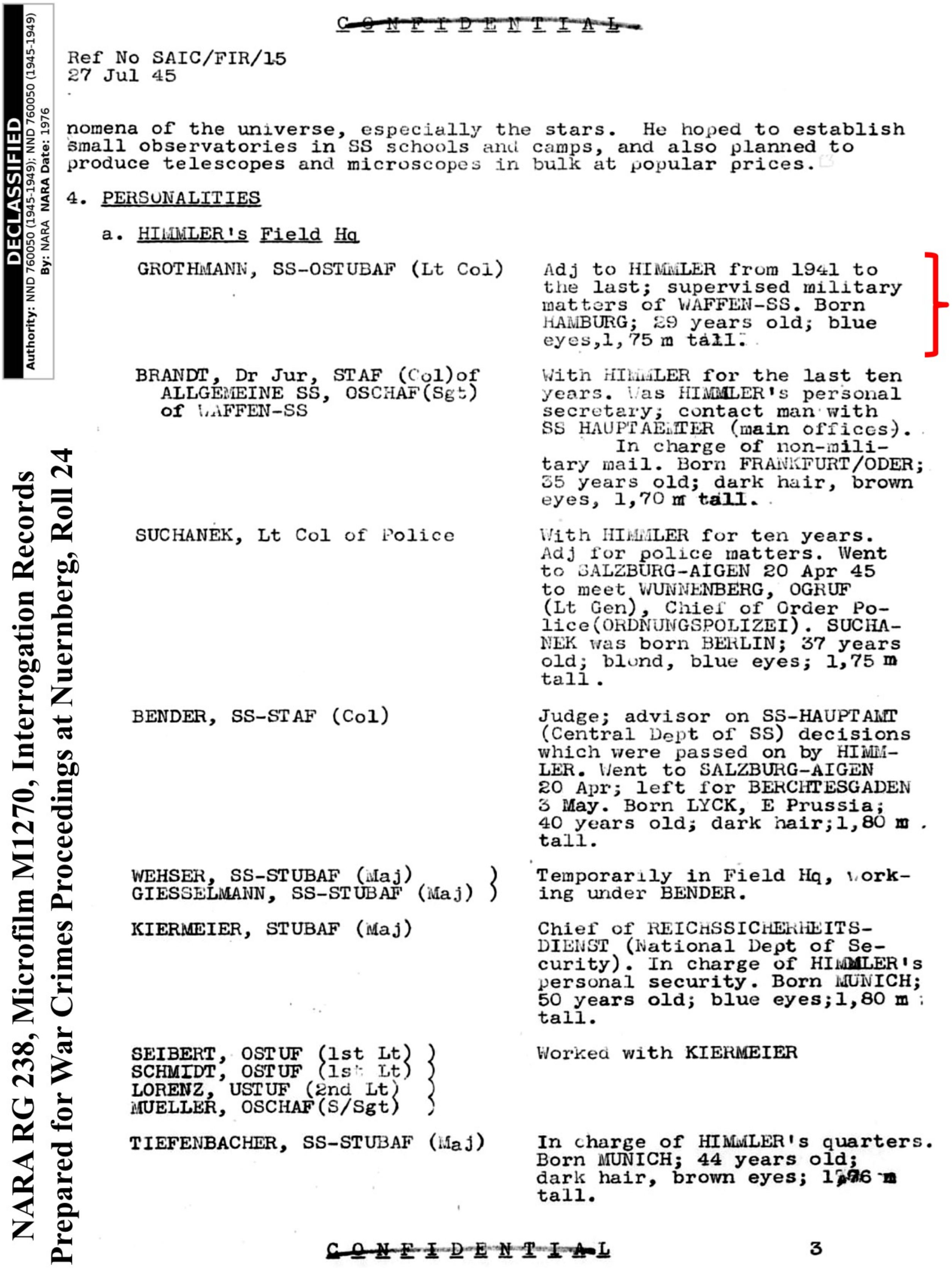
CP, SALZBURG) CP, WUSTRAU)	All documents at these CP's were burned, source claims.
Alternate CP, FRANKENHAUSEN, Thuringia	Taken by American forces early in Apr. Most important files were here.
WEWELSBURG Castle, near PADERBORN, Westphalia	Many valuables were stored here.
Old salt mines, HALLEIN (S of SALZBURG)	Personal property belonging to HIMMLER was stored here.
HIMMLER's house, LINDENFYCHT,GMUND/TEGERNSEE	BAUMERT (See below) told source no property had been removed from here.

b. Source believes that SS-OGRUF (Lt Gen) WOLF, SS and Police Chief, Italy, has information concerning HIMMLER's documents and property. WOLF was in BOZEN 4 May 45. Source also believes that SS-STAF (Col) BAUMERT (See 4b below) has information on this subject.

3. HIMMLER AND ASTRONOMY

Source claims that HIMMLER was a believer in Glacial Cosmogony. By converting the common man to this belief, he hoped to save him from the "illusions" preached by Christianity. To further his aims, HIMMLER wanted to make it possible for everyone to observe the phe-

Figure D.66: In postwar interrogations, one of Himmler's adjutants stated that Himmler had a panel of top science advisors, including Walther Gerlach, Erich Schumann, and other nuclear scientists [NARA RG 238, Microfilm M1270, Interrogation Records Prepared for War Crimes Proceedings at Nuernberg, Roll 24].



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nomena of the universe, especially the stars. He hoped to establish small observatories in SS schools and camps, and also planned to produce telescopes and microscopes in bulk at popular prices.

4. PERSONALITIES

a. HIMMLER's Field Hq

GROTHMANN, SS-OSTUBAF (Lt Col)	Adj to HIMMLER from 1941 to the last; supervised military matters of WAFFEN-SS. Born HAMBURG; 29 years old; blue eyes, 1,75 m tall.
BRANDT, Dr Jur, STAF (Col) of ALLGEMEINE SS, OSCHAF (Sgt) of WAFFEN-SS	With HIMMLER for the last ten years. Was HIMMLER's personal secretary; contact man with SS HAUPTAEMTER (main offices). In charge of non-military mail. Born FRANKFURT/ODER; 35 years old; dark hair, brown eyes, 1,70 m tall.
SUCHANEK, Lt Col of Police	With HIMMLER for ten years. Adj for police matters. Went to SALZBURG-AIGEN 20 Apr 45 to meet WUNNENBERG, OGRUF (Lt Gen), Chief of Order Police (ORDNUNGSPOLIZEI). SUCHANEK was born BERLIN; 37 years old; blond, blue eyes; 1,75 m tall.
BENDER, SS-STAF (Col)	Judge; advisor on SS-HAUPTAMT (Central Dept of SS) decisions which were passed on by HIMMLER. Went to SALZBURG-AIGEN 20 Apr; left for BERCHTESGADEN 3 May. Born LYCK, E Prussia; 40 years old; dark hair; 1,80 m tall.
WEHSER, SS-STUBAF (Maj) GIESSELMANN, SS-STUBAF (Maj)	Temporarily in Field Hq, working under BENDER.
KIERMEIER, STUBAF (Maj)	Chief of REICHSSICHERHEITSDIENST (National Dept of Security). In charge of HIMMLER's personal security. Born MUNICH; 50 years old; blue eyes; 1,80 m tall.
SEIBERT, OSTUF (1st Lt) SCHMIDT, OSTUF (1st Lt) LORENZ, USTUF (2nd Lt) MUELLER, OSCHAF (S/Sgt)	Worked with KIERMEIER
TIEFENBACHER, SS-STUBAF (Maj)	In charge of HIMMLER's quarters. Born MUNICH; 44 years old; dark hair, brown eyes; 1,76 m tall.

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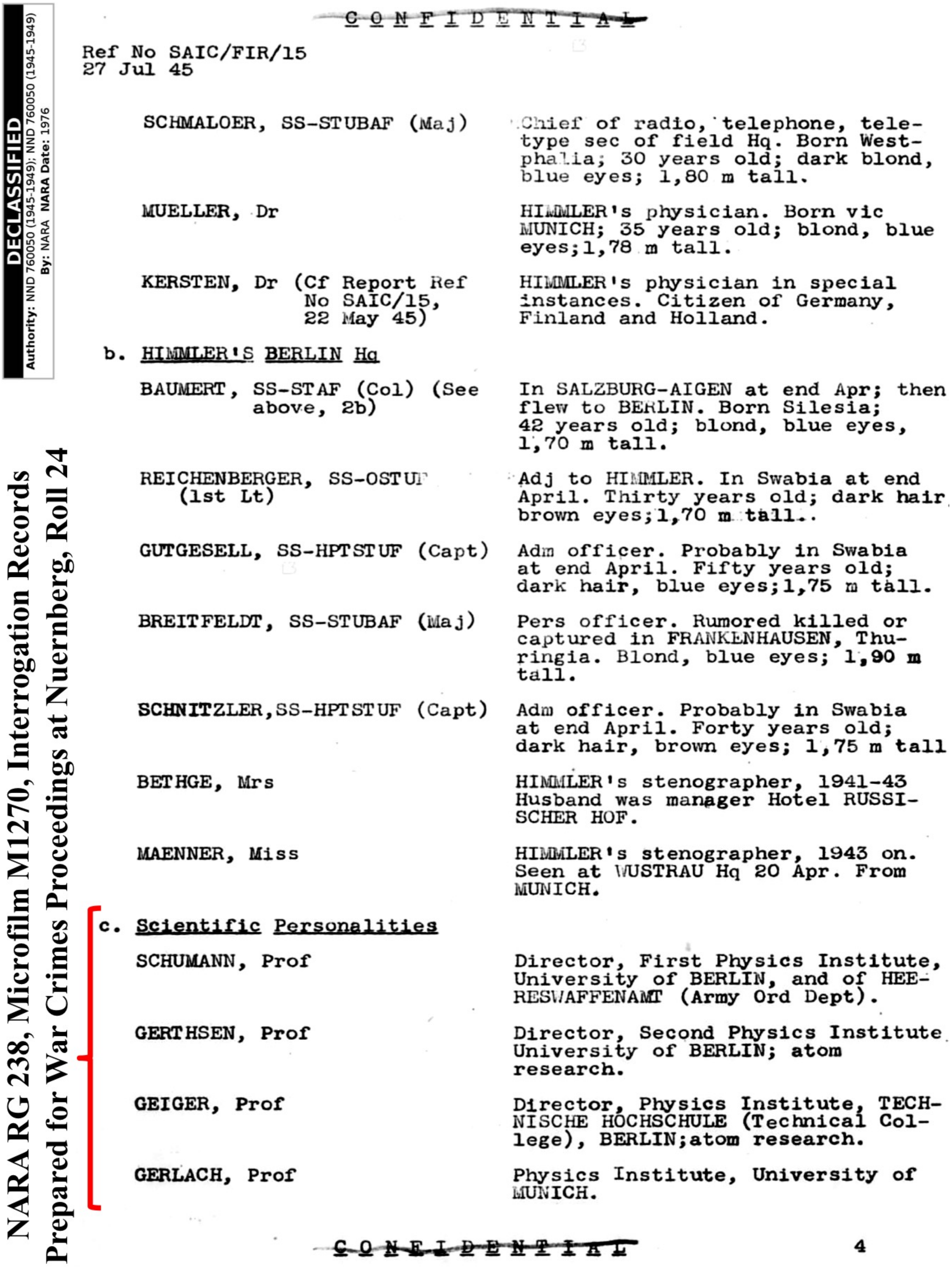
Figure D.67: In postwar interrogations, one of Himmler's adjutants stated that Himmler had a panel of top science advisors, including Walther Gerlach, Erich Schumann, and other nuclear scientists [NARA RG 238, Microfilm M1270, Interrogation Records Prepared for War Crimes Proceedings at Nuernberg, Roll 24].



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SCHMALOER, SS-STUBAF (Maj)	Chief of radio, telephone, teletype sec of field Hq. Born Westphalia; 30 years old; dark blond, blue eyes; 1,80 m tall.
MUELLER, Dr	HIMMLER's physician. Born vic MUNICH; 35 years old; blond, blue eyes;1,78 m tall.
KERSTEN, Dr (Cf Report Ref No SAIC/15, 22 May 45)	HIMMLER's physician in special instances. Citizen of Germany, Finland and Holland.

b. HIMMLER'S BERLIN Hq

BAUMERT, SS-STAF (Col) (See above, 2b)	In SALZBURG-AIGEN at end Apr; then flew to BERLIN. Born Silesia; 42 years old; blond, blue eyes, 1,70 m tall.
REICHENBERGER, SS-OSTUF (1st Lt)	Adj to HIMMLER. In Swabia at end April. Thirty years old; dark hair brown eyes;1,70 m tall.
GUTGESELL, SS-HPTSTUF (Capt)	Adm officer. Probably in Swabia at end April. Fifty years old; dark hair, blue eyes;1,75 m tall.
BREITFELDT, SS-STUBAF (Maj)	Pers officer. Rumored killed or captured in FRANKENHAUSEN, Thuringia. Blond, blue eyes; 1,90 m tall.
SCHNITZLER,SS-HPTSTUF (Capt)	Adm officer. Probably in Swabia at end April. Forty years old; dark hair, brown eyes; 1,75 m tall
BETHGE, Mrs	HIMMLER's stenographer, 1941-43 Husband was manager Hotel RUSSISCHER HOF.
MAENNER, Miss	HIMMLER's stenographer, 1943 on. Seen at WUSTRAU Hq 20 Apr. From MUNICH.

c. Scientific Personalities

SCHUMANN, Prof	Director, First Physics Institute, University of BERLIN, and of HEERESWAFFENAMT (Army Ord Dept).
GERTHSEN, Prof	Director, Second Physics Institute University of BERLIN; atom research.
GEIGER, Prof	Director, Physics Institute, TECHNISCHE HOCHSCHULE (Technical College), BERLIN;atom research.
GERLACH, Prof	Physics Institute, University of MUNICH.

C O N F I D E N T I A L

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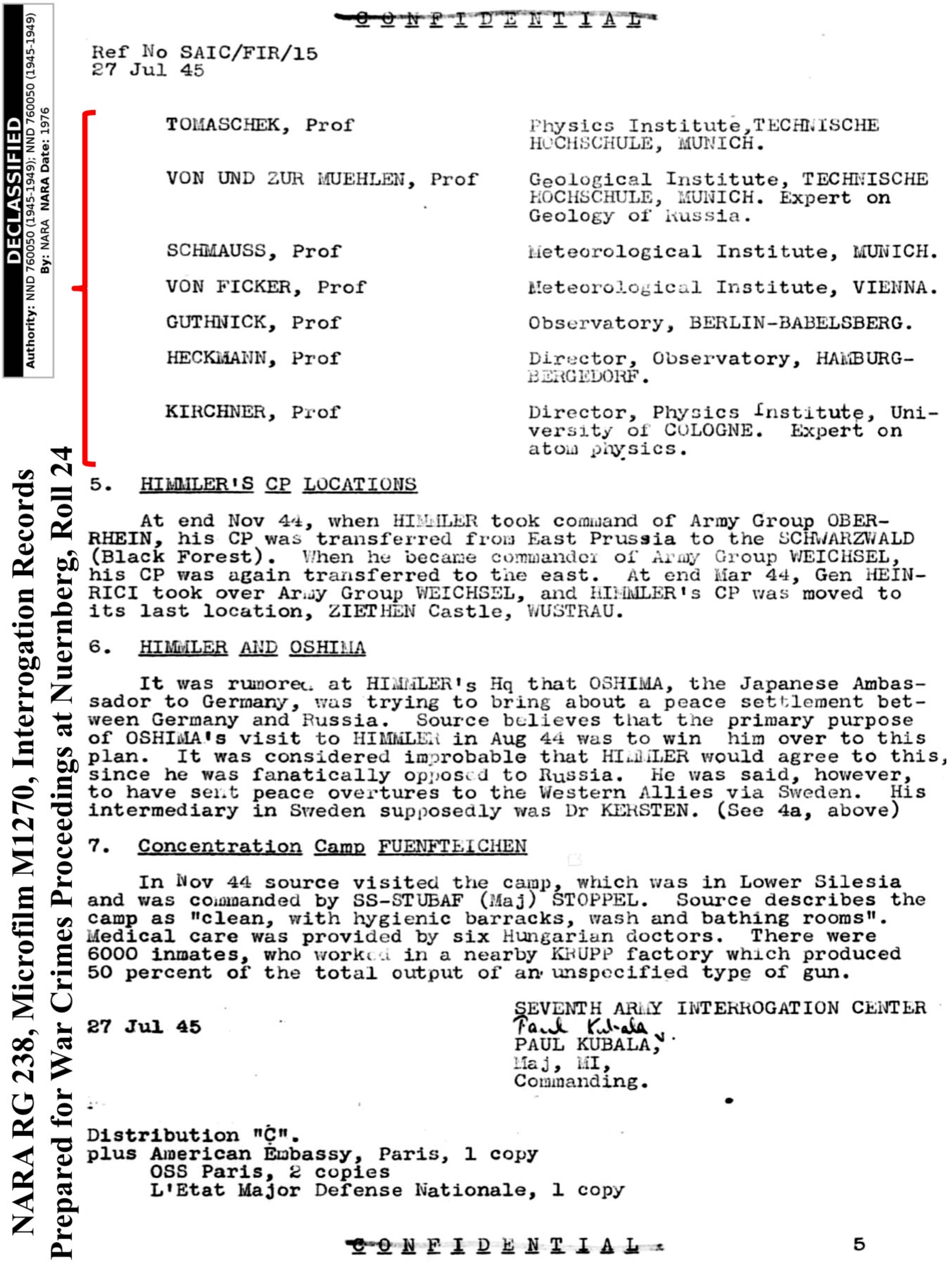
Figure D.68: In postwar interrogations, one of Himmler's adjutants stated that Himmler had a panel of top science advisors, including Walther Gerlach, Erich Schumann, and other nuclear scientists [NARA RG 238, Microfilm M1270, Interrogation Records Prepared for War Crimes Proceedings at Nuernberg, Roll 24].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TOMASCHEK, Prof	Physics Institute, TECHNISCHE HOCHSCHULE, MUNICH.
VON UND ZUR MUEHLEN, Prof	Geological Institute, TECHNISCHE HOCHSCHULE, MUNICH. Expert on Geology of Russia.
SCHMAUSS, Prof	Meteorological Institute, MUNICH.
VON FICKER, Prof	Meteorological Institute, VIENNA.
GUTHNICK, Prof	Observatory, BERLIN-BABELSBERG.
HECKMANN, Prof	Director, Observatory, HAMBURG-BERGEDORF.
KIRCHNER, Prof	Director, Physics Institute, University of COLOGNE. Expert on atom physics.

5. HIMMLER'S CP LOCATIONS

At end Nov 44, when HIMMLER took command of Army Group OBERRHEIN, his CP was transferred from East Prussia to the SCHWARZWALD (Black Forest). When he became commander of Army Group WEICHSEL, his CP was again transferred to the east. At end Mar 44, Gen HEINRICI took over Army Group WEICHSEL, and HIMMLER's CP was moved to its last location, ZIETHEN Castle, WUSTRAU.

6. HIMMLER AND OSHIMA

It was rumored at HIMMLER's Hq that OSHIMA, the Japanese Ambassador to Germany, was trying to bring about a peace settlement between Germany and Russia. Source believes that the primary purpose of OSHIMA's visit to HIMMLER in Aug 44 was to win him over to this plan. It was considered improbable that HIMMLER would agree to this, since he was fanatically opposed to Russia. He was said, however, to have sent peace overtures to the Western Allies via Sweden. His intermediary in Sweden supposedly was Dr KERSTEN. (See 4a, above)

7. Concentration Camp FUENFTEICHEN

In Nov 44 source visited the camp, which was in Lower Silesia and was commanded by SS-STUBAF (Maj) STOPPEL. Source describes the camp as "clean, with hygienic barracks, wash and bathing rooms". Medical care was provided by six Hungarian doctors. There were 6000 inmates, who worked in a nearby KRUPP factory which produced 50 percent of the total output of an unspecified type of gun.

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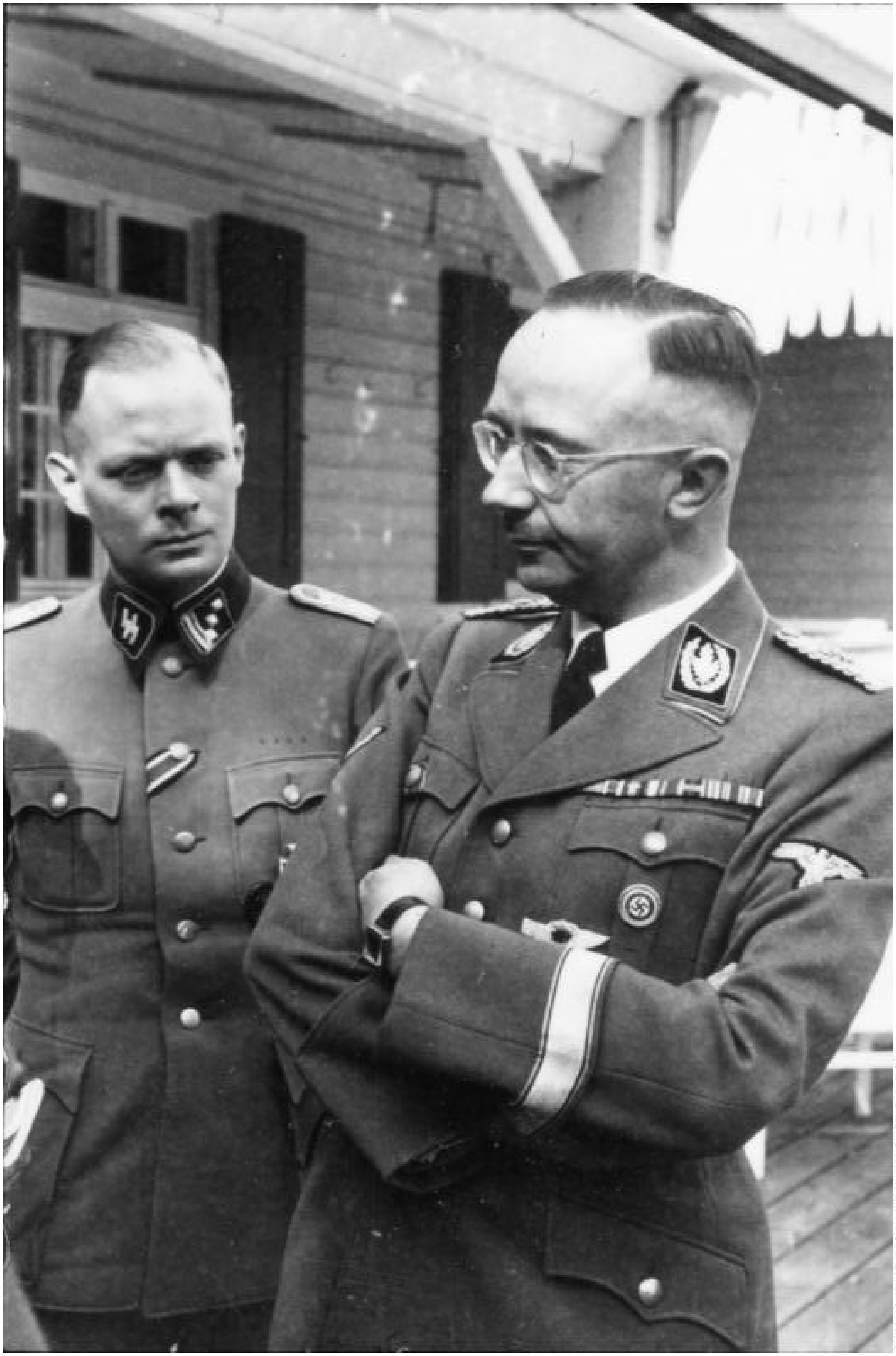
Figure D.69: In postwar interrogations, one of Himmler's adjutants stated that Himmler had a panel of top science advisors, including Walther Gerlach, Erich Schumann, and other nuclear scientists [NARA RG 238, Microfilm M1270, Interrogation Records Prepared for War Crimes Proceedings at Nuernberg, Roll 24].



Bundesarchiv, Bild 101III-Alber-064-27A
Foto: Alber, Kurt | 1943

Figure D.70: Werner Grothmann with Heinrich Himmler (1943).

Heinrich Himmler's adjutant Werner Grothmann, transcript of interview by Wolf Krotzky [Krotzky 2002]

[Werner Grothmann (German, 1915–2002) was the chief adjutant or executive assistant of Heinrich Himmler (see pp. 3392, 3395). At the end of his life, during 2000–2002, Grothmann agreed to a series of interviews with Wolf Krotzky, one of his neighbors. Krotzky recorded the interviews on tapes and transcribed Grothmann's words in an unpublished document that is available in the archives of the Jonastalverein in Arnstadt. In the transcripts, Grothmann provided very important details about secret wartime German programs to develop nuclear weapons and improved rockets. Unfortunately, Krotzky said that he did not save the tapes,[5] and Grothmann is now dead and unable to confirm the information in the transcripts.

Without the recorded tapes or Grothmann himself, one cannot rule out the possibilities that Krotzky may have improperly prompted the elderly Grothmann to say certain things that he did not really mean, that Krotzky may have altered the transcripts after the fact, or that Krotzky may have even made up all the transcripts. Furthermore, even if Krotzky and the transcripts were trustworthy, there is no guarantee that Grothmann was trustworthy—his memories may have been incorrect after so long, or he may have had a personal motivation to make false claims about the past.

However, since so few sources are currently available regarding the most secretive details of the wartime German nuclear and advanced rocket programs, and the details provided by Grothmann would be extremely useful if they are real, it is important not to reject this source without careful consideration. In fact, there are many different lines of evidence that suggest that this source is indeed real and accurate (or as accurate as one could expect for a person's recollections so long after the events):

- Historians have been able to independently confirm a large number of details about people, places, dates, and events mentioned in the interviews that are so obscure they would probably not have been independently known by Krotzky [see for example: Karlsch and Petermann 2007, p. 29; Karlsch 2006; Nagel 2011, p. 64].

- Grothmann provided details of the March 1945 test explosion in Thuringia that are in excellent agreement with Ilyichev's March 1945 report to Stalin (see p. 4485), which was discovered in a Moscow archive only after Grothmann had already died.

- Grothmann's statements agree with many other sources about the secret wartime programs that have only emerged in recent years.

- Although Grothmann was not a scientist or engineer and recounted events and discussions from long ago, the scientific details that he mentioned are very consistent with known physics and engineering principles.

---

[5] Perhaps because they were reused to record each interview, and then later unrelated interviews? Or might Krotzky have been pressured by government officials who wanted to keep state secrets?

- In the transcript, Grothmann repeatedly said that he did not know many of the details of the programs, either because he did not have a need to know such classified details in his daily secretarial duties for Himmler, or else because he had forgotten some details over time. If Grothmann or Krotzky had been making up a story, one would have expected the narrator to claim a comprehensive and accurate knowledge of the secret programs, so it is reassuring that Grothmann did not.

- Grothmann frequently described various weapon systems as being unready, imperfect, or unproven by the end of the war. If he were making up a story, one would have expected him to make grander and more dramatic claims for wartime German accomplishments, so again, it is reassuring that he did not.

- In the transcript, Grothmann repeatedly mentioned bureaucratic obstacles, bad decisions, and political disagreements, from Hitler on down through the government. This demonstrates that Grothmann was not trying to make up a story to paint Hitler and the rest of the Third Reich in a positive light.

The complete Grothmann interview transcript is very long and unstructured (see for example pp. 3398–3399). I have translated some of the most relevant excerpts from the transcript, grouped them by topic, and placed them in the appropriate sections of this book. Those topics and page numbers are:

Research on nuclear propulsion for submarines (p. 1474).

Development of transistors and other microelectronics (p. 3017).

Secrecy of the German nuclear program (p. 3400).

Organization of the German nuclear program (pp. 3401–3403).

Enrichment of ^{235}U (pp. 3708–3709).

Fission reactor breeding of ^{239}Pu or ^{233}U (pp. 3865–3866).

Electronuclear (particle accelerator) breeding of ^{239}Pu or ^{233}U (pp. 4024–4025).

Nuclear weapon designs (pp. 4271–4273).

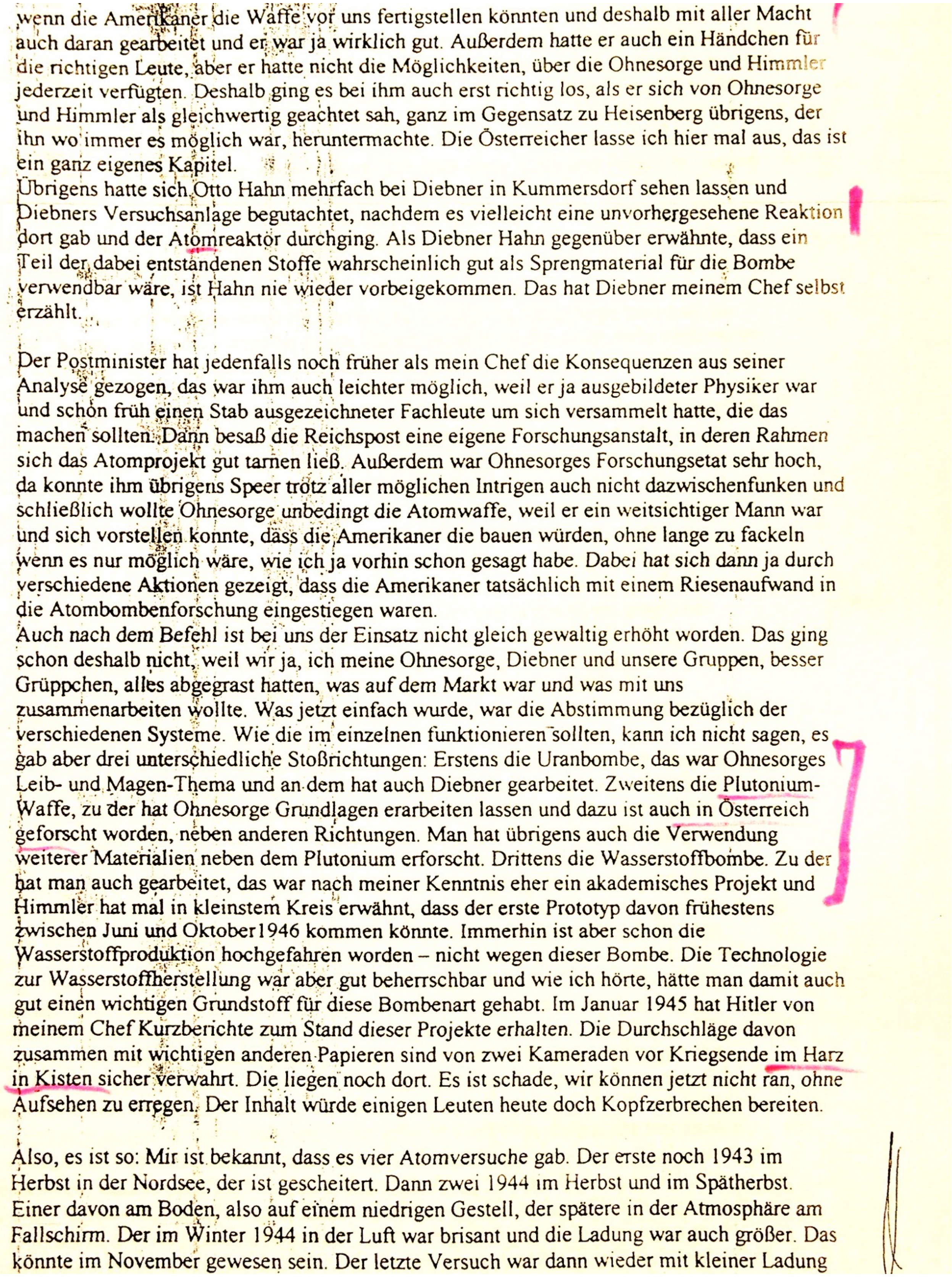
Nuclear weapon tests (pp. 4436–4439).

Reasons why German nuclear weapons were not used in combat (pp. 4668–4669).

Transfer of German nuclear technologies (pp. 5040–5043).

Development of rockets larger than the A-4/V-2 (pp. 5355–5359).

Research on nuclear propulsion for aircraft and rockets (p. 5769).]



wenn die Amerikaner die Waffe vor uns fertigstellen könnten und deshalb mit aller Macht auch daran gearbeitet und er war ja wirklich gut. Außerdem hatte er auch ein Händchen für die richtigen Leute, aber er hatte nicht die Möglichkeiten, über die Ohnesorge und Himmler jederzeit verfügten. Deshalb ging es bei ihm auch erst richtig los, als er sich von Ohnesorge und Himmler als gleichwertig geachtet sah, ganz im Gegensatz zu Heisenberg übrigens, der ihn wo immer es möglich war, heruntermachte. Die Österreicher lasse ich hier mal aus, das ist ein ganz eigenes Kapitel.

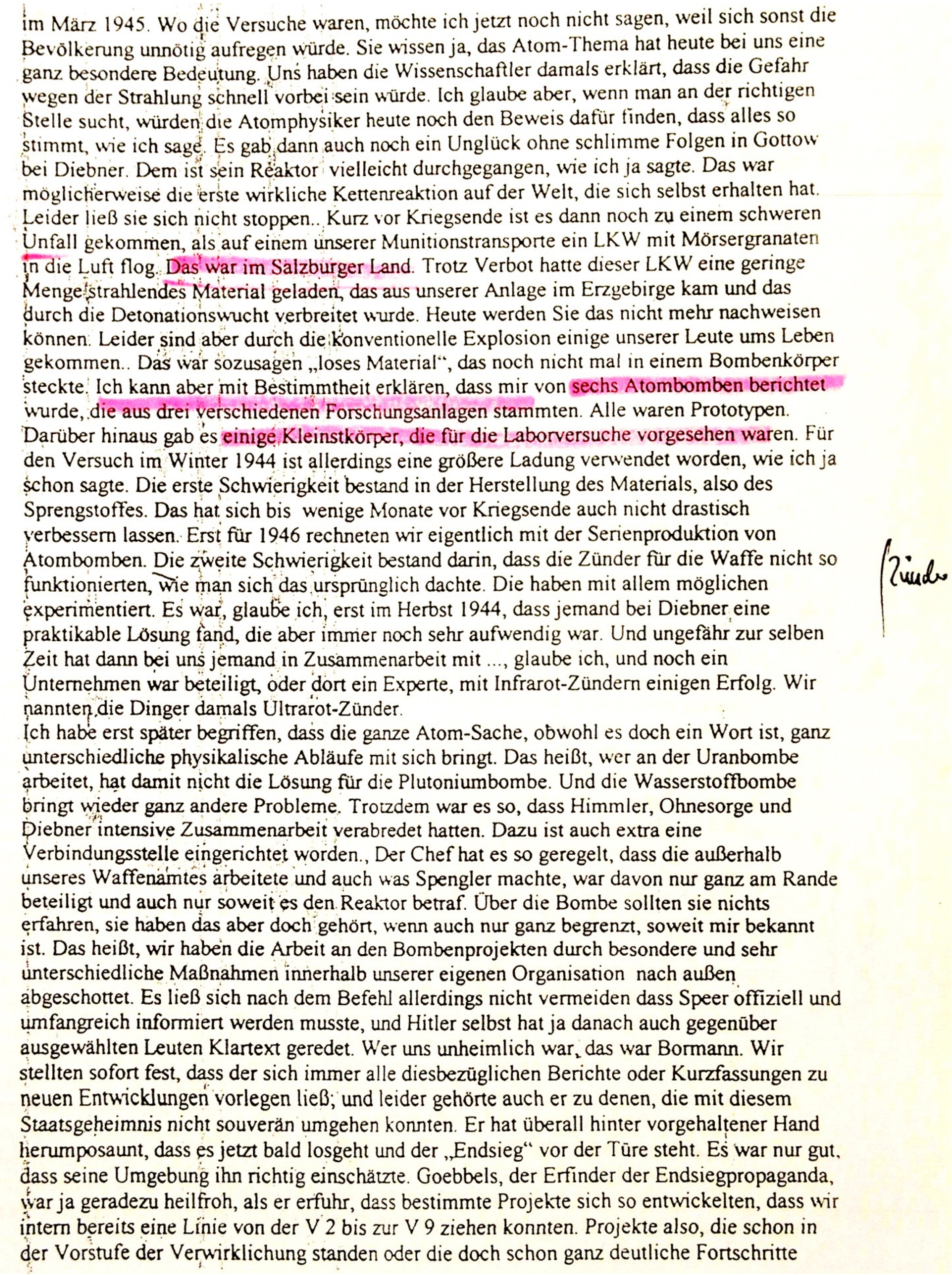
Übrigens hatte sich Otto Hahn mehrfach bei Diebner in Kummersdorf sehen lassen und Diebners Versuchsanlage begutachtet, nachdem es vielleicht eine unvorhergesehene Reaktion dort gab und der Atomreaktor durchging. Als Diebner Hahn gegenüber erwähnte, dass ein Teil der dabei entstandenen Stoffe wahrscheinlich gut als Sprengmaterial für die Bombe verwendbar wäre, ist Hahn nie wieder vorbeigekommen. Das hat Diebner meinem Chef selbst erzählt.

Der Postminister hat jedenfalls noch früher als mein Chef die Konsequenzen aus seiner Analyse gezogen, das war ihm auch leichter möglich, weil er ja ausgebildeter Physiker war und schon früh einen Stab ausgezeichneter Fachleute um sich versammelt hatte, die das machen sollten. Dann besaß die Reichspost eine eigene Forschungsanstalt, in deren Rahmen sich das Atomprojekt gut tarnen ließ. Außerdem war Ohnesorges Forschungsetat sehr hoch, da konnte ihm übrigens Speer trotz aller möglichen Intrigen auch nicht dazwischenfunken und schließlich wollte Ohnesorge unbedingt die Atomwaffe, weil er ein weitsichtiger Mann war und sich vorstellen konnte, dass die Amerikaner die bauen würden, ohne lange zu fackeln wenn es nur möglich wäre, wie ich ja vorhin schon gesagt habe. Dabei hat sich dann ja durch verschiedene Aktionen gezeigt, dass die Amerikaner tatsächlich mit einem Riesenaufwand in die Atombombenforschung eingestiegen waren.

Auch nach dem Befehl ist bei uns der Einsatz nicht gleich gewaltig erhöht worden. Das ging schon deshalb nicht, weil wir ja, ich meine Ohnesorge, Diebner und unsere Gruppen, besser Grüppchen, alles abgegrast hatten, was auf dem Markt war und was mit uns zusammenarbeiten wollte. Was jetzt einfach wurde, war die Abstimmung bezüglich der verschiedenen Systeme. Wie die im einzelnen funktionieren sollten, kann ich nicht sagen, es gab aber drei unterschiedliche Stoßrichtungen: Erstens die Uranbombe, das war Ohnesorges Leib- und Magen-Thema und an dem hat auch Diebner gearbeitet. Zweitens die Plutonium-Waffe, zu der hat Ohnesorge Grundlagen erarbeiten lassen und dazu ist auch in Österreich geforscht worden, neben anderen Richtungen. Man hat übrigens auch die Verwendung weiterer Materialien neben dem Plutonium erforscht. Drittens die Wasserstoffbombe. Zu der hat man auch gearbeitet, das war nach meiner Kenntnis eher ein akademisches Projekt und Himmler hat mal in kleinstem Kreis erwähnt, dass der erste Prototyp davon frühestens zwischen Juni und Oktober1946 kommen könnte. Immerhin ist aber schon die Wasserstoffproduktion hochgefahren worden – nicht wegen dieser Bombe. Die Technologie zur Wasserstoffherstellung war aber gut beherrschbar und wie ich hörte, hätte man damit auch gut einen wichtigen Grundstoff für diese Bombenart gehabt. Im Januar 1945 hat Hitler von meinem Chef Kurzberichte zum Stand dieser Projekte erhalten. Die Durchschläge davon zusammen mit wichtigen anderen Papieren sind von zwei Kameraden vor Kriegsende im Harz in Kisten sicher verwahrt. Die liegen noch dort. Es ist schade, wir können jetzt nicht ran, ohne Aufsehen zu erregen. Der Inhalt würde einigen Leuten heute doch Kopfzerbrechen bereiten.

Also, es ist so: Mir ist bekannt, dass es vier Atomversuche gab. Der erste noch 1943 im Herbst in der Nordsee, der ist gescheitert. Dann zwei 1944 im Herbst und im Spätherbst. Einer davon am Boden, also auf einem niedrigen Gestell, der spätere in der Atmosphäre am Fallschirm. Der im Winter 1944 in der Luft war brisant und die Ladung war auch größer. Das könnte im November gewesen sein. Der letzte Versuch war dann wieder mit kleiner Ladung

Figure D.71: A page from the interview of Werner Grothmann [Krotzky 2002, p. 31, Jonastalverein Archive, Arnstadt].



im März 1945. Wo die Versuche waren, möchte ich jetzt noch nicht sagen, weil sich sonst die Bevölkerung unnötig aufregen würde. Sie wissen ja, das Atom-Thema hat heute bei uns eine ganz besondere Bedeutung. Uns haben die Wissenschaftler damals erklärt, dass die Gefahr wegen der Strahlung schnell vorbei sein würde. Ich glaube aber, wenn man an der richtigen Stelle sucht, würden die Atomphysiker heute noch den Beweis dafür finden, dass alles so stimmt, wie ich sage. Es gab dann auch noch ein Unglück ohne schlimme Folgen in Gottow bei Diebner. Dem ist sein Reaktor vielleicht durchgegangen, wie ich ja sagte. Das war möglicherweise die erste wirkliche Kettenreaktion auf der Welt, die sich selbst erhalten hat. Leider ließ sie sich nicht stoppen.. Kurz vor Kriegsende ist es dann noch zu einem schweren Unfall gekommen, als auf einem unserer Munitionstransporte ein LKW mit Mörsergranaten in die Luft flog. Das war im Salzburger Land. Trotz Verbot hatte dieser LKW eine geringe Menge strahlendes Material geladen, das aus unserer Anlage im Erzgebirge kam und das durch die Detonationswucht verbreitet wurde. Heute werden Sie das nicht mehr nachweisen können. Leider sind aber durch die konventionelle Explosion einige unserer Leute ums Leben gekommen.. Das war sozusagen „loses Material", das noch nicht mal in einem Bombenkörper steckte. Ich kann aber mit Bestimmtheit erklären, dass mir von sechs Atombomben berichtet wurde, die aus drei verschiedenen Forschungsanlagen stammten. Alle waren Prototypen. Darüber hinaus gab es einige Kleinstkörper, die für die Laborversuche vorgesehen waren. Für den Versuch im Winter 1944 ist allerdings eine größere Ladung verwendet worden, wie ich ja schon sagte. Die erste Schwierigkeit bestand in der Herstellung des Materials, also des Sprengstoffes. Das hat sich bis wenige Monate vor Kriegsende auch nicht drastisch verbessern lassen. Erst für 1946 rechneten wir eigentlich mit der Serienproduktion von Atombomben. Die zweite Schwierigkeit bestand darin, dass die Zünder für die Waffe nicht so funktionierten, wie man sich das ursprünglich dachte. Die haben mit allem möglichen experimentiert. Es war, glaube ich, erst im Herbst 1944, dass jemand bei Diebner eine praktikable Lösung fand, die aber immer noch sehr aufwendig war. Und ungefähr zur selben Zeit hat dann bei uns jemand in Zusammenarbeit mit ..., glaube ich, und noch ein Unternehmen war beteiligt, oder dort ein Experte, mit Infrarot-Zündern einigen Erfolg. Wir nannten die Dinger damals Ultrarot-Zünder.

Zünder

Ich habe erst später begriffen, dass die ganze Atom-Sache, obwohl es doch ein Wort ist, ganz unterschiedliche physikalische Abläufe mit sich bringt. Das heißt, wer an der Uranbombe arbeitet, hat damit nicht die Lösung für die Plutoniumbombe. Und die Wasserstoffbombe bringt wieder ganz andere Probleme. Trotzdem war es so, dass Himmler, Ohnesorge und Diebner intensive Zusammenarbeit verabredet hatten. Dazu ist auch extra eine Verbindungsstelle eingerichtet worden., Der Chef hat es so geregelt, dass die außerhalb unseres Waffenamtes arbeitete und auch was Spengler machte, war davon nur ganz am Rande beteiligt und auch nur soweit es den Reaktor betraf. Über die Bombe sollten sie nichts erfahren, sie haben das aber doch gehört, wenn auch nur ganz begrenzt, soweit mir bekannt ist. Das heißt, wir haben die Arbeit an den Bombenprojekten durch besondere und sehr unterschiedliche Maßnahmen innerhalb unserer eigenen Organisation nach außen abgeschottet. Es ließ sich nach dem Befehl allerdings nicht vermeiden dass Speer offiziell und umfangreich informiert werden musste, und Hitler selbst hat ja danach auch gegenüber ausgewählten Leuten Klartext geredet. Wer uns unheimlich war, das war Bormann. Wir stellten sofort fest, dass der sich immer alle diesbezüglichen Berichte oder Kurzfassungen zu neuen Entwicklungen vorlegen ließ; und leider gehörte auch er zu denen, die mit diesem Staatsgeheimnis nicht souverän umgehen konnten. Er hat überall hinter vorgehaltener Hand herumposaunt, dass es jetzt bald losgeht und der „Endsieg" vor der Türe steht. Es war nur gut, dass seine Umgebung ihn richtig einschätzte. Goebbels, der Erfinder der Endsiegpropaganda, war ja geradezu heilfroh, als er erfuhr, dass bestimmte Projekte sich so entwickelten, dass wir intern bereits eine Linie von der V 2 bis zur V 9 ziehen konnten. Projekte also, die schon in der Vorstufe der Verwirklichung standen oder die doch schon ganz deutliche Fortschritte

Figure D.72: A page from the interview of Werner Grothmann [Krotzky 2002, p. 32, Jonastalverein Archive, Arnstadt].

Werner Grothmann on the secrecy of the nuclear program [Krotzky 2002]

[S. 1] Bloß war es so, dass die einzelnen Bearbeiter eines Projekts nicht über Dinge informiert wurden, die sie nichts angingen. Ich habe lange nach dem Krieg mal gelesen, wie die Amerikaner ihre Forschung und Entwicklung organisiert hatten. Ich glaube, das war besser und wirkungsvoller als bei uns. Vielleicht hatten die ja nicht solche Sorge vor Verrat, obwohl es den bei ihnen auch gab. Aber wenn man bedenkt, wie es bei uns geregelt war und dann sieht, wie viel trotzdem verraten wurde, glaube ich, dass durch die besondere Abschottung bei speziellen Projekten doch manches verzögert wurde. Bei der Atomforschung hatten wir ja extra eine Koordinierungsstelle eingerichtet. Das soll sich bewährt haben, wie ich hörte.

[S. 6] Wenn man sich überlegt, warum die Wissenschaftler und Techniker geschwiegen haben, muß man sehen, dass ja längst nicht alle, die an der Atombombe gearbeitet haben, auch erfahren mussten, wie weit die Entwicklung überhaupt kam. Ich kenne die Zahl nicht, es sind aber bestimmt nicht sehr viele gewesen, die das gesamte Geheimnis kannten.

[p. 1] It was just that the individual workers on a project were not informed about things that did not concern them. Long after the war, I read about how the Americans had organized their research and development. I think [their organization] was better and more effective than ours. Perhaps they did not have such concern about treason, although there was also some with them. But when you consider, how it was protected by us and then see how much was nevertheless betrayed, I believe that by the special security in special projects some things were delayed. In nuclear research, we had set up a special coordination center. That would have proved itself, as I have heard.

[p. 6] If you consider why the scientists and technicians were silent, you have to see that not all those who worked on the atomic bomb needed at all to know how far the development came. I do not know the number, but there were certainly not very many who knew the whole secret.

[Grothmann stated that the nuclear program was highly compartmentalized, with every person who was involved only knowing as much information as they absolutely needed in order to do their job. The wartime German chemical weapons program operated in this same fashion [Tucker 2006]. Grothmann repeatedly mentioned how little even he knew about the program. This extreme secrecy would help explain why so little information about the nuclear program leaked out during the war or in the years since.]

Werner Grothmann on the organization of the nuclear program [Krotzky 2002]

[S. 29] Außerdem hatten wir ja bereits Ende 1943 wenn zunächst auch ganz bescheiden, mit unserem eigenen Atomprojekt begonnen, während doch Diebner, Ohnesorge und die Österreicher viel früher gestartet waren.

[S. 31] Auch nach dem Befehl ist bei uns der Einsatz nicht gleich gewaltig erhöht worden. Das ging schon deshalb nicht, weil wir ja, ich meine Ohnesorge, Diebner und unsere Gruppen, besser Grüppchen, alles abgegrast hatten, was auf dem Markt war und was mit uns zusammenarbeiten wollte. Was jetzt einfach wurde, war die Abstimmung bezüglich der verschiedenen Systeme. Wie die im einzelnen funktionieren sollten, kann ich nicht sagen, es gab aber drei unterschiedliche Stoßrichtungen:

Erstens die Uranbombe, das war Ohnesorges Leib- und Magen-Thema und an dem hat auch Diebner gearbeitet.

Zweitens die Plutonium-Waffe, zu der hat Ohnesorge Grundlagen erarbeiten lassen und dazu ist auch in Österreich geforscht worden, neben anderen Richtungen. Man hat übrigens auch die Verwendung weiterer Materialien neben dem Plutonium erforscht.

Drittens die Wasserstoffbombe. Zu der hat man auch gearbeitet, das war nach meiner Kenntnis eher ein akademisches Projekt und Himmler hat mal in kleinstem Kreis erwähnt, dass der erste Prototyp davon frühestens zwischen Juni und Oktober 1946 kommen könnte.

[p. 29] Besides, at the end of 1943, we were very modest at first; we [SS scientists] had begun with our own atom project, while Diebner, Ohnesorge, and the Austrians had started much earlier.

[p. 31] Even after the [Hitler] order, the program was not increased accordingly. This was not possible, because we, I mean Ohnesorge, Diebner and our [SS] groups, or rather little groups, had already worked out what resources were available and who would work with us. What now became easy was the coordination of the different systems. How the details were supposed to work, I cannot say, but there were three different directions:

First the uranium bomb, which was Ohnesorge's main passion and on which Diebner also worked.

Second the plutonium weapon, on which Ohnesorge had worked on the fundamentals, and which was also researched in Austria, along with other directions. Incidentally, the use of other materials besides plutonium was also investigated.

Third the hydrogen bomb. That was also worked on; to my knowledge, it was rather an academic project, and Himmler once mentioned in a small circle that the first prototype of this could come at the earliest between June and October 1946.

[Grothmann's comment that "the use of other materials besides plutonium was also investigated" for fission bombs likely refers to converting thorium-232, which was readily available from monazite ore, into uranium-233, another excellent fission fuel (pp. 3832–3839).]

[S. 7] Zu unserem Verbindungsbüro muß ich noch was sagen. Das sollte auch sicherstellen, daß bloß keine Doppelarbeit mehr gemacht würde. Das ist aber trotzdem so geblieben, weil ja die Reichspost ihre eigene Forschung weiterbetrieben hat, eigentlich bis zum Schluß. In den letzten Kriegsjahren, kann im Herbst 43 gewesen sein, ist aber zwischen Ohnesorge und Himmler eine enge Abstimmung beschlossen worden. Die Einzelheiten kenne ich bis heute nicht, Kammler war aber eingeweiht. Wenn also die Reichspost und natürlich die Diebner-Gruppen einbezogen sind, heißt das nicht, daß es viele Leute sein mußten. Für die spätere Serienproduktion sah es anders aus, aber dann hätten wir ja gegenüber den anderen Gruppen einen Vorsprung besessen und wir hätten auch Mittel gefunden, um den Geheimnisverrat zu begrenzen.

[p. 7] I have something to say about our liaison office. That should also make it clear that there would be no more duplication of effort. That remained the case, however, because the Reichspost continued its own research, right to the end. During the last years of the war, that may have been in autumn 1943, a close agreement was reached between Ohnesorge and Himmler. I still do not know the details, but Kammler was privy. So if the Reichspost and of course the Diebner groups are included, that does not mean that there had to be many people. It looked different for the later serial production, but then we would have had a lead over the other groups and we would also have found means to limit the betrayal of secrets.

[Grothmann described an extensive nuclear program that was spread over several autonomous organizations, which coordinated with each other and also with a central office run by the SS:

- Beginning no later than 1942, the SS provided coordination of all nuclear (and other research) activities through Heinrich Himmler and Hans Kammler, secretive funding for other organizations involved in the work, in-house R&D and production facilities, underground facilities, and massive amounts of slave labor.

- The Heereswaffenamt or Army Ordnance Office, with its own Army funding, had a scientific team led by Kurt Diebner and (except possibly during the final stages of the war) by Erich Schumann. It worked on implosion bomb designs and testing, fission chain reactions, gas centrifuges for uranium enrichment, and other aspects of the program. During 1939–1942, the Heereswaffenamt appears to have helped to coordinate the program with other organizations. After the overall coordination was assumed by the SS, Kurt Diebner seems to have continued to help manage the scientific details of the overall program.

- The Reichspost or Post Office, led by the physicist Wilhelm Ohnesorge, used its considerable direct income from postal payments to secretly fund its own nuclear laboratories and scientists, including Manfred von Ardenne, Fritz Houtermans, and Siegfried Flügge. The Reichspost began work no later than 1939 (p. 3375), and focused largely on enriching uranium for an implosion bomb, although it was also involved with other aspects of the overall program. No later than 1942, the Reichspost program became closely coupled to and partially funded by the SS, due to a close working relationship between Ohnesorge and Himmler (pp. 3378–3379).

- Austrians played a major role in the overall nuclear program, although Grothmann did not name or described them in detail. The most prominent Austrian nuclear physicists were the group led by Georg Stetter in Vienna. They began working on nuclear physics no later than 1928, and began seriously pursuing both fission and fusion devices no later than 1939 (pp. 3372–3375, 4330–4345, 4788–4800, 4992). There were a number of known or suspected nuclear-related sites in Austria (p. 3673). According to Grothmann, the Austrian scientists played critical roles in the development of both plutonium weapons and the hydrogen bomb.

- Czechs also played an important role in the overall nuclear program, yet Grothmann provided even less detail about that. There were many known or suspected nuclear-related sites in Czech territory (p. 3674).

- Grothmann mentioned a late-1944 nuclear bomb test that was conducted in Poland, indicating that there was also important nuclear work in Poland, but he did not give any details about work there. There were many known or suspected nuclear-related sites in Polish territory (p. 3674).

- Grothmann mentioned that only a few companies could provide what the nuclear program needed. Although he did not name the companies, they would likely include the major companies for uranium (especially Union Minière, Auer/Degussa, Buchler Braunschweig, and Treibacher Chemische Werke), the major chemical company (I. G. Farben, for chemical compounds involved in uranium enrichment or plutonium extraction), and the major companies for large electrical machinery (especially Siemens and AEG).

- Grothmann stated that Werner Heisenberg and Otto Hahn were not supportive of the nuclear weapons program and therefore were not involved in it. Their experiments were funded separately and at a relatively low level. The U.S. Alsos Mission and most books on the history of the German nuclear program have focused on that sideline and ignored the main program described by Grothmann and numerous documents in this appendix.

- It is possible that other important organizations were involved in aspects of the overall nuclear program yet not named by Grothmann; perhaps he either did not know much about their roles or else focused on other areas in his interviews. Among the most prominent organizations not named by Grothmann are the Kriegsmarine or Navy, the Luftwaffe or Air Force, and a group of scientists led by Paul Harteck in the Hamburg/Kiel area. More information is needed to clarify whether or how these organizations played roles in the overall nuclear program.

Grothmann's statements about the secrecy, organization, and achievements of the wartime German nuclear program are supported by many other documents presented in this appendix. As just one example, the next pages show several surviving documents that demonstrate that Wilhelm Ohnesorge and Heinrich Himmler began collaborating on various research projects no later than June 1942 and continued to do so thereafter, involving both Werner Grothmann and Hans Kammler in their communications about the projects, exactly as claimed in the transcripts of Grothmann's 2000–2002 interviews with Wolf Krotzky.

Of course, communications specifically regarding any nuclear weapons project would have been destroyed or never committed to writing in the first place, but these handful of surviving documents do demonstrate the general research collaboration between the Reichspost and the SS, as well as several of the key people who were involved.

I am not aware of any documents that contradict or disprove Grothmann's statements.

Thus while Krotzky's method of preserving Grothmann's testimony was unorthodox, relevant statements from Grothmann will be presented periodically throughout this appendix so that their details may be compared with those from other sources.]

D.3 Sources of Uranium and Thorium

[During the war, Germany had access to large amounts of natural uranium and thorium ore by (see map on p. 3405):

- Acquiring at least 1200 tons, and according to some well-informed sources 3500 tons, of uranium compounds (originally mined in the Belgian Congo) from Union Minière in Brussels [e.g., pp. 3335, 3408–3414].
- Expanding uranium mining at St. Joachimsthal (Jachymov), Bohemia [e.g., pp. 3418–3429, 3445, 3469–3470, 4978–4984; Hayes 2004, pp. 132–133, 235, 243].
- Mining uranium at Příbram/Przibram/Pibrans, Bohemia [e.g, pp. 3424, 3470, 3751–3754].
- Mining uranium at Schmiedeberg, Silesia [e.g., pp. 3328, 3424, 3429, 3445, 3471].
- Possibly using any of several uranium deposits in Thuringia [e.g., pp. 3468–3469; Zeman and Karlsch 2008].
- Mining uranium at Schneeberg, Saxony [e.g., pp. 3416, 3424, 3426–3428, 3433–3437, 3445, 3456, 3468–3469, 3708, 4922; Zeman and Karlsch 2008].
- Mining uranium at Johanngeorgenstadt, Saxony [e.g., pp. 3416, 3424, 3426–3428, 3433–3437, 3456, 3468–3469, 3708, 4922; Zeman and Karlsch 2008].
- Mining uranium at Freiberg, Saxony [e.g., pp. 3424, 3426–3429, 3445, 3468–3469].
- Mining uranium at Durrnaul near Marienbad [e.g., p. 3424].
- Mining or planning to mine uranium at Mladkov/Wichstadt, Bohemia [e.g., p. 3425].
- Operating and receiving shipments from Bulgarian uranium mines such as a mine at Buchovo (or Buhovo, a suburb of Sofia), since 1938 [e.g., Hayes 2004, p. 235; https://ejatlas.org/conflict/life-after-the-uranium-mines-in-buhovo-bulgaria]. See also pp. 3446, 3470, 4588.
- Mining uranium at Băiţa-Plai and other sites in Romania [e.g., pp. 3449–3455, 3471].
- Acquiring uranium from mines at Viseu and Guarda, Portugal [e.g., p. 3445; Hayes 2004, p. 235].
- Procuring all available monazite thorium ore in occupied Europe [e.g., Irving 1967].
- Exploiting other possible sources—Spain, Scandinavia, etc.?

One 1946 U.S. intelligence report on Czech uranium mines noted, “The Germans put mining on a high priority and only mining was done throughout the 6 years occupation. The ore was delivered by special planes to Germany and Austria” (p. 3998). Another 1946 U.S. intelligence report added: “The Germans continued operations in this mine to the very last moment” (p. 4981).

Thus Germany began actively mining uranium in 1938 and continued until the end of the war. During that time, Germany had access to (1) the same quality and a comparable quantity of Congolese uranium that served the Manhattan Project well, (2) Central/Eastern European uranium mines that later served the Soviet nuclear program well, and (3) additional uranium mines too.

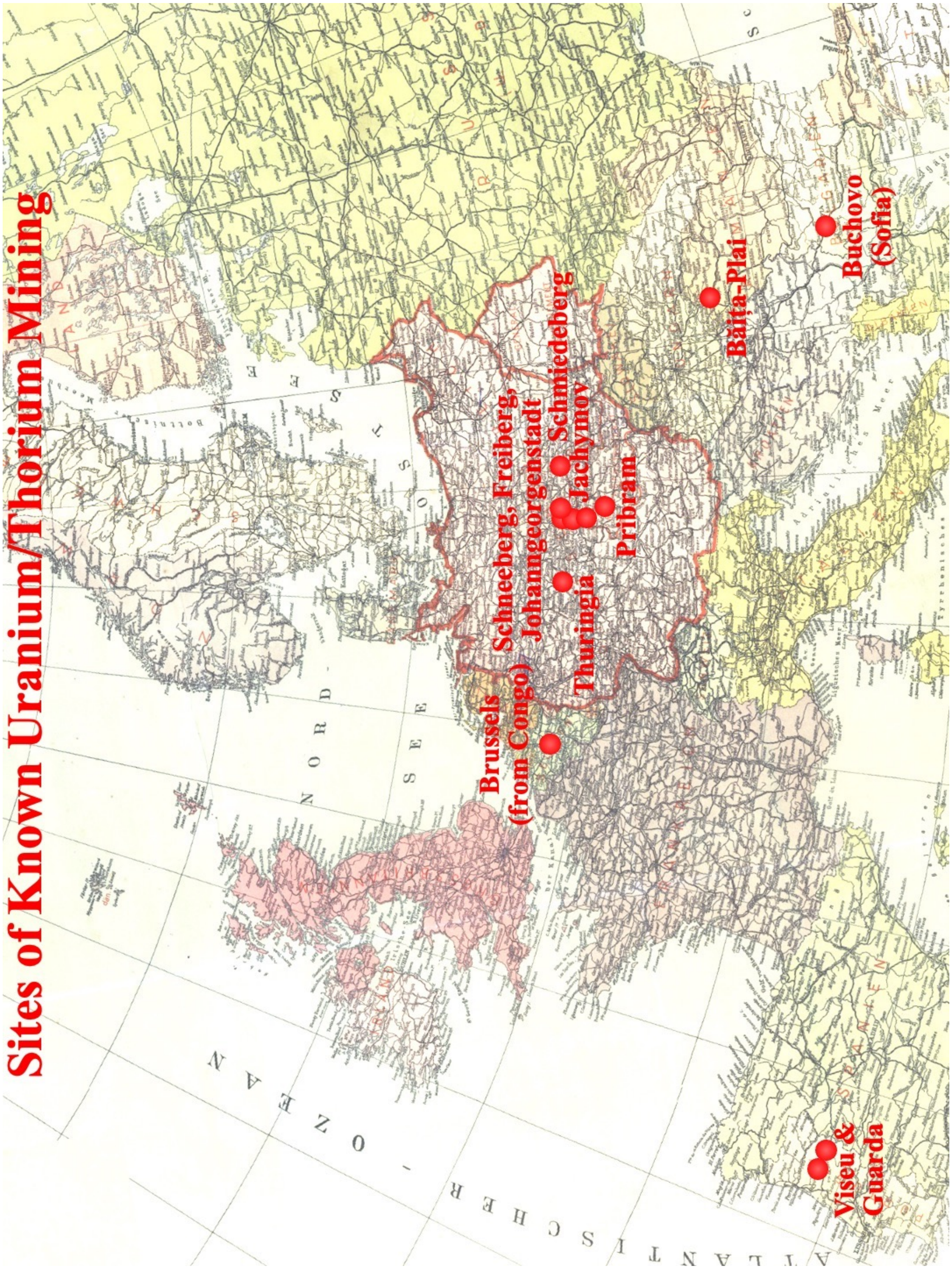

Sites of Known Uranium/Thorium Mining
Brussels (from Congo)
Schneeberg, Freiberg, Johanngeorgenstadt
Schmiedeberg
Jachymov
Pribram
Thuringia
Băița-Plai
Buchovo (Sofia)
Viseu & Guarda
NORD SEE
OSTSEE
ATLANTISCHER OZEAN

Figure D.73: Sites of known uranium/thorium mining for the German nuclear program.

Germany processed uranium and thorium ore to uranium oxide and thorium oxide, and thence to uranium or thorium metal or to a variety of useful chemical compounds—uranium hexafluoride, uranium tetrachloride, uranium nitrate, etc.—at numerous locations including (see map on p. 3407):

- Union Minière in Brussels [e.g., pp. 3335, 3408–3414; Irving 1967, p. 65].
- Auer in Oranienburg, Katowice/Kattowitz, and other locations [e.g., pp. 3446, 3458, 3461–3463, 3465, 4980; Nagel 2016].
- Buchler in Braunschweig [e.g., pp. 3420, 3430–3431, 3458, 3460–3463, 3465, 4980].
- Treibacher Chemische Werke in Althofen, Austria [e.g., pp. 3420, 3432–3437, 3458, 3460, 4980; Gollmann 1994].
- Degussa in Frankfurt, Berlin, Stadtilm, and possibly other locations [e.g., pp. 3458, 3461–3465; Hayes 2004; Nagel 2016].
- Chemische Fabrik Grünau in Berlin [e.g., pp. 3438–3439, 3461–3463].
- I.G. Farben in Leverkusen and other locations [e.g., pp. 3488–3489, 3492–3493, 3678–3680, 3748–3750, 4440–4477; Mader 1965, pp. 193–202, 229-233].
- Krupp in Essen [e.g., pp. 3458, 3461–3463, 3465–3467].
- W. de Boer in Hamburg and Wittingen [e.g., pp. 3458, 3461–3463, 3465].
- Radium-Chemie AG in Frankfurt [e.g., pp. 3440–3441, 3458, 3465].
- W. Maier KG Radiumchemische Industrie und Laboratorium in Villingen-Schwenningen am Neckar and other locations [e.g., Oleynikov 2000].
- Příbram/Przibram/Pibrans, Bohemia [e.g., pp. 3423, 3751–3754].
- Facilities in Dresden [e.g., pp. 3423, 3426].
- Reichswerke Hermann Göring in Linz and other locations [e.g., pp. 3877–3880].
- Possibly other facilities.

At the end of the war, Allied countries removed over 2800 tons of uranium and thorium compounds from former German-controlled territory (p. 3456). In addition, in 1974, Alwin Urff, deputy technical plant manager of the Asse nuclear disposal site in Germany, stated: "When we began storage in 1967, our company first sank radioactive waste from the last war, that uranium waste which arose in the preparation of the German atomic bomb" (p. 3472).]

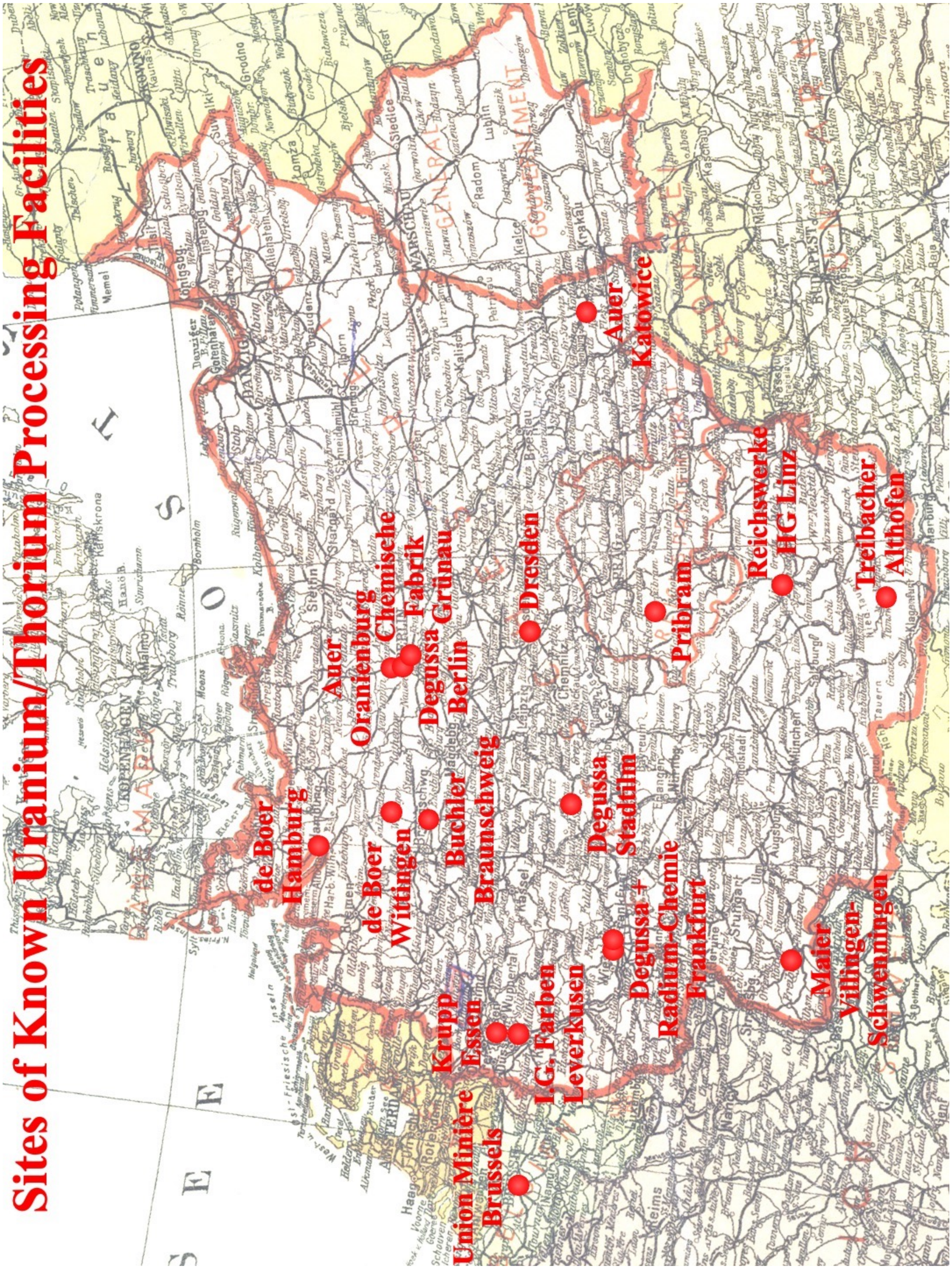

Sites of Known Uranium/Thorium Processing Facilities
Union Minière Brussels
Krupp Essen
I.G. Farben Leverkusen
Degussa + Radium-Chemie Frankfurt
Maier Villingen-Schwenningen
de Boer Hamburg
de Boer Wittingen
Buchler Braunschweig
Degussa Stadtilm
Auer Oranienburg
Degussa Berlin
Chemische Fabrik Grünau
Dresden
Pribram
Reichswerke HG Linz
Treibacher Althofen
Auer Katowice

Figure D.74: Sites of known uranium/thorium processing facilities for the German nuclear program.

[While uranium ores found at various sites in Europe were good (and later proved sufficient for the large postwar Soviet nuclear weapons program), the ore with the highest natural concentration of uranium was found in Congo, which was controlled by Belgium at that time [Susan Williams 2016].

Just exactly how much Congolese ore did the whole German nuclear program manage to acquire, via Belgium or any other means?

Most sources give a total number of 1200 tons or so (see for example p. 3335).

However, at least two sources say that the actual amount was 3500 tons:]

1. Nikolaus Riehl, the head nuclear chemist at Auergesellschaft, in information that he gave to David Irving [Irving 1967, pp. 65, 90–91].

The Ministry of Economic Warfare, whose department it was, was requested to attempt to deprive the Germans of the stockpiles of uranium-oxide in Belgium; Tizard opposed the outright purchase of the thousands of tons of uranium-oxide there, and proposed that it should merely be moved to the United Kingdom. The Ministry acted with ponderous precision, and when the German armies fell upon Belgium a month later by far the greater part of the uranium was still there.

Up to June 1940, Union Minière had sold no more than about a ton of the various compounds to Germany each month; the company now received an immediate order for sixty tons of refined uranium compounds, to be supplied to the Auer company in Berlin. During the next five years, the Germans seized three thousand five hundred tons of uranium compounds from the Belgium stockpiles, and shipped it under the general supervision of Dr. Egon Ihwe[6] back to Central Germany, where it was stacked in the surface buildings of the old salt-mines at Stassfurt, owned by the Industrial Research Association (*WiFo*). It was from this huge stockpile of sodium- and ammonium-uranate that the Auer company would now meet its requirements. [...]

[T]he committee stressed: '[...] Although steps were taken beforehand to induce the Belgian company to reduce stocks of uranium oxide, some of which are now in Canada, some eight tons[7] are believed to have fallen into the hands of the Germans when Belgium was invaded.'

---

[6] General Manager of Auer's subsidiary, the Oranienburg Rare Earths Factory; and an agent of the *Reichsstelle Chemie*, the Reich Chemicals Authority.

[7] Margaret Gowing, *Britain and Atomic Energy 1939–1945*, quoting the committee's report, drew attention to this error and said that it was discovered that the Germans had acquired the equivalent of 600 tons of uranium-oxide; but Professor N. Riehl has informed the author that it was in fact very much more.

2. William Casey, who was a senior official in the OSS and later head of the CIA, and thus should have been in a position to know the correct answer, along with his staff archivists and analysts [Casey 1988, p. 49].

When the British government learned that the Germans, on occupying Norway and Belgium, were increasing Norwegian heavy water production and had seized 3500 tons of uranium from Union Minière in Belgium, the Ministry of Supply was directed to study what would happen if an atom bomb was detonated in the center of a large British city.

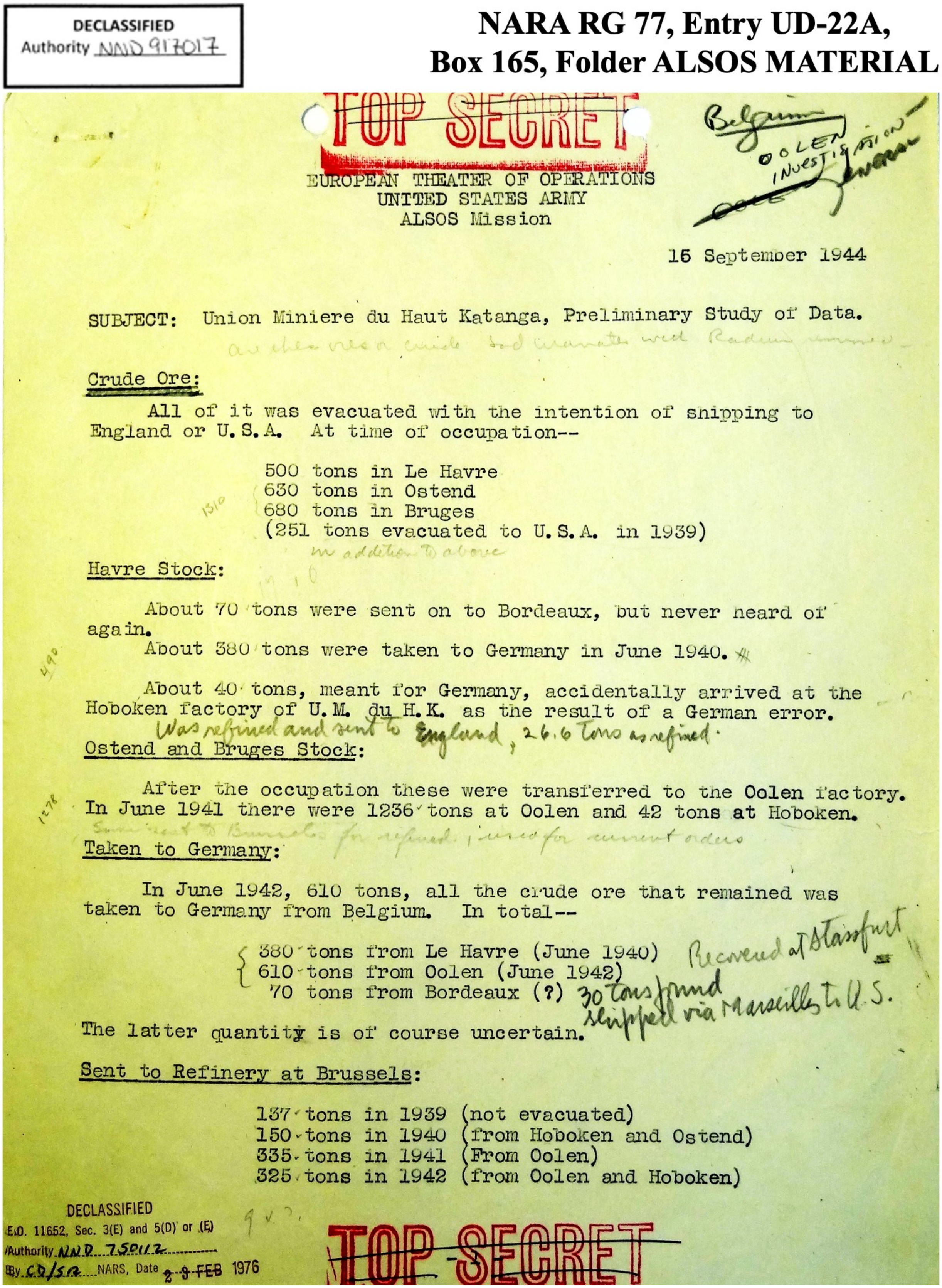
[Dust jacket back flap:] WILLIAM CASEY was Chief of the London OSS headquarters during World War II, and Chief of Secret Intelligence for General Dwight D. Eisenhower's European operations. He was awarded the Bronze Star. In 1981 Mr. Casey became director of the CIA. He died May 6, 1987.

[During the war, the United States had a comparable amount of the same Congolese ore (~1100 metric tons from a warehouse in New York, with more arriving later in the war) and managed most of the Manhattan Project with that stock. See for example:

https://www.osti.gov/includes/opennet/includes/MED_scans/Book%20VII%20-%20%20Volume%201%20-%20Feed%20Materials%20and%20Special%20Procuremen.pdf

https://www.governmentattic.org/5docs/TheNewWorld1939-1946.pdf

The Germans could potentially have done just as well with what they had.]



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NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL

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Belgium
OOLEN INVESTIGATION
~~OOLE~~

EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS Mission

16 September 1944

SUBJECT: Union Miniere du Haut Katanga, Preliminary Study of Data.

[illegible]

Crude Ore:

All of it was evacuated with the intention of shipping to England or U. S. A. At time of occupation--

500 tons in Le Havre
630 tons in Ostend
1310 680 tons in Bruges
(251 tons evacuated to U. S. A. in 1939)
in addition to above

Havre Stock:

About 70 tons were sent on to Bordeaux, but never heard of again.

490 About 380 tons were taken to Germany in June 1940.

About 40 tons, meant for Germany, accidentally arrived at the Hoboken factory of U. M. du H. K. as the result of a German error.
Was refined and sent to England, 26.6 tons as refined.

Ostend and Bruges Stock:

After the occupation these were transferred to the Oolen factory.
1278 In June 1941 there were 1236 tons at Oolen and 42 tons at Hoboken.
Some sent to Brussels for refined; used for current orders

Taken to Germany:

In June 1942, 610 tons, all the crude ore that remained was taken to Germany from Belgium. In total--

380 tons from Le Havre (June 1940) Recovered at Stassfurt
610 tons from Oolen (June 1942)
70 tons from Bordeaux (?) 30 tons found shipped via Marseilles to U.S.

The latter quantity is of course uncertain.

Sent to Refinery at Brussels:

137 tons in 1939 (not evacuated)
150 tons in 1940 (from Hoboken and Ostend)
335 tons in 1941 (From Oolen)
325 tons in 1942 (from Oolen and Hoboken)

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Figure D.75: Samuel A. Goudsmit. 15 September 1944. SUBJECT: Union Minière du Haut Katanga, Preliminary Study of Data [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

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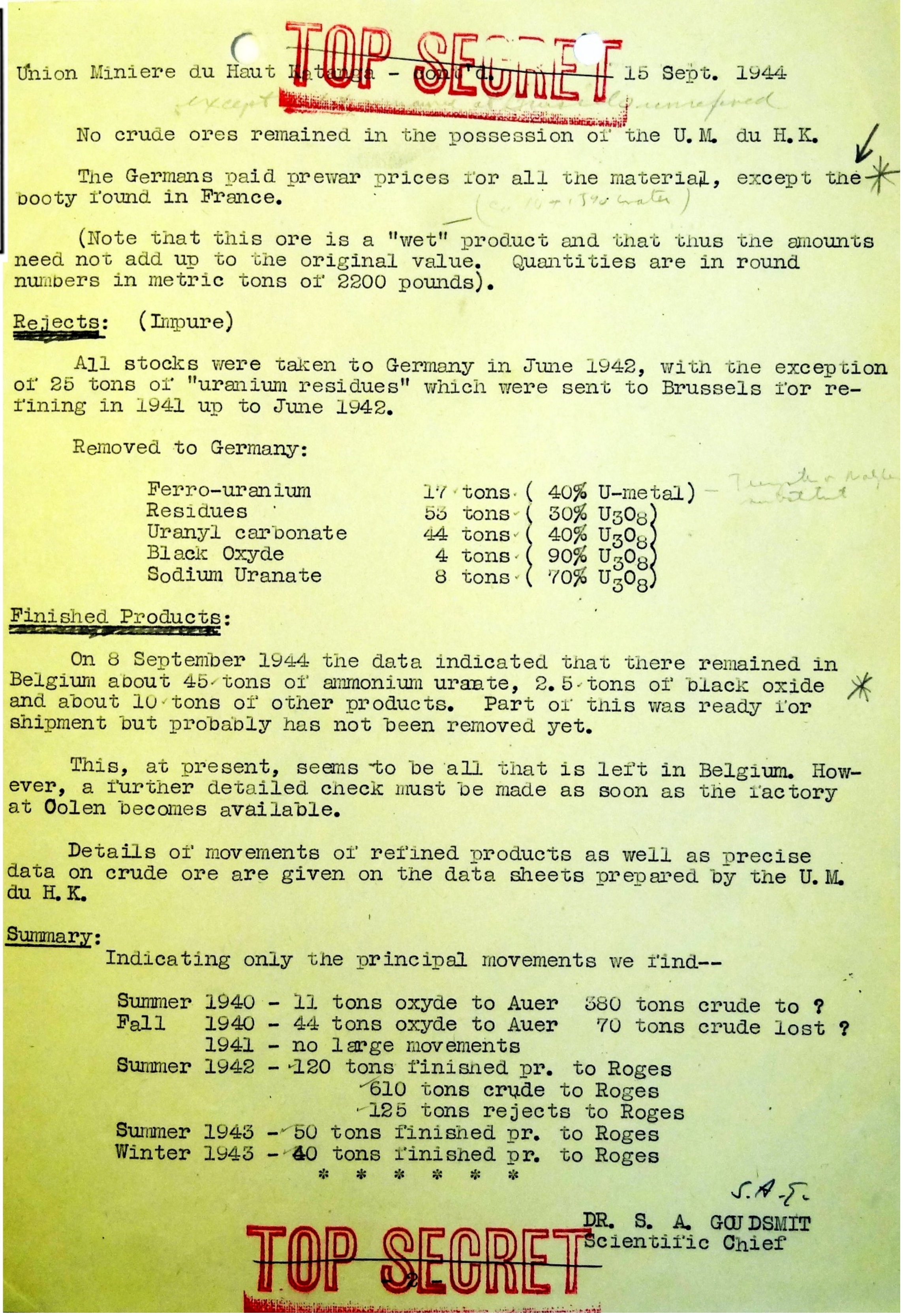

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Union Miniere du Haut Katanga - cont'd. 15 Sept. 1944

except [illegible] unrefined

No crude ores remained in the possession of the U. M. du H. K.

The Germans paid prewar prices for all the material, except the booty found in France. *

(ca 10 + 13% water)

(Note that this ore is a "wet" product and that thus the amounts need not add up to the original value. Quantities are in round numbers in metric tons of 2200 pounds).

Rejects: (Impure)

All stocks were taken to Germany in June 1942, with the exception of 25 tons of "uranium residues" which were sent to Brussels for refining in 1941 up to June 1942.

Removed to Germany:

Ferro-uranium	17 tons	(40% U-metal) – Tungsten or Molybden substitute
Residues	53 tons	(30% U_3O_8)
Uranyl carbonate	44 tons	(40% U_3O_8)
Black Oxyde	4 tons	(90% U_3O_8)
Sodium Uranate	8 tons	(70% U_3O_8)

Finished Products:

On 8 September 1944 the data indicated that there remained in Belgium about 45 tons of ammonium urate, 2.5 tons of black oxide and about 10 tons of other products. Part of this was ready for shipment but probably has not been removed yet. *

This, at present, seems to be all that is left in Belgium. However, a further detailed check must be made as soon as the factory at Oolen becomes available.

Details of movements of refined products as well as precise data on crude ore are given on the data sheets prepared by the U. M. du H. K.

Summary:

Indicating only the principal movements we find--

Summer 1940 - 11 tons oxyde to Auer 380 tons crude to ?
Fall 1940 - 44 tons oxyde to Auer 70 tons crude lost ?
1941 - no large movements
Summer 1942 - 120 tons finished pr. to Roges
610 tons crude to Roges
125 tons rejects to Roges
Summer 1943 - 50 tons finished pr. to Roges
Winter 1943 - 40 tons finished pr. to Roges

* * * * * *

S.A.G.

DR. S. A. GOUDSMIT
Scientific Chief

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NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL

Figure D.76: Samuel A. Goudsmit. 15 September 1944. SUBJECT: Union Minière du Haut Katanga, Preliminary Study of Data [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

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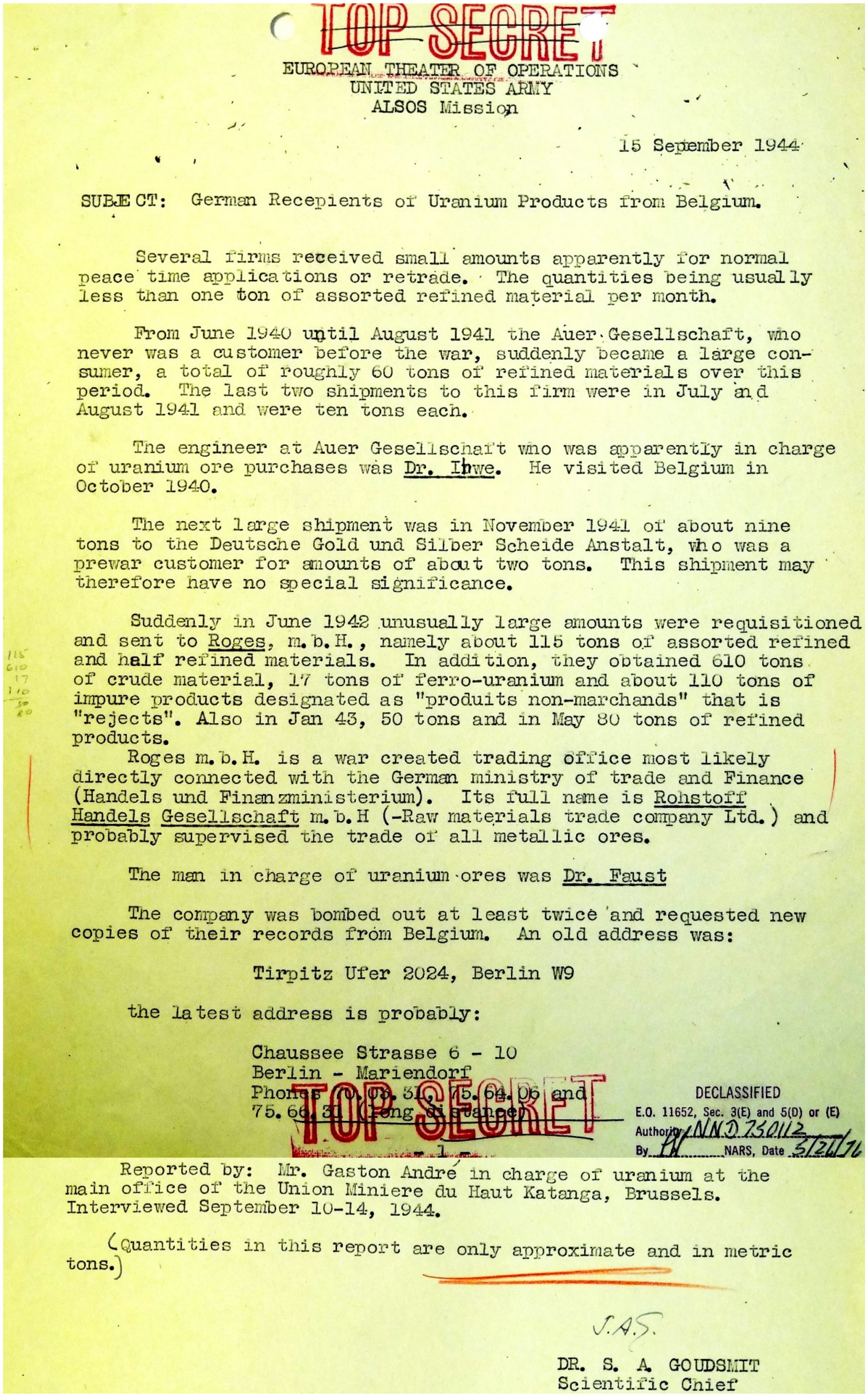

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EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS Mission

15 September 1944

SUBJECT: German Recepients of Uranium Products from Belgium.

Several firms received small amounts apparently for normal peace time applications or retrade. The quantities being usually less than one ton of assorted refined material per month.

From June 1940 until August 1941 the Auer Gesellschaft, who never was a customer before the war, suddenly became a large consumer, a total of roughly 60 tons of refined materials over this period. The last two shipments to this firm were in July and August 1941 and were ten tons each.

The engineer at Auer Gesellschaft who was apparently in charge of uranium ore purchases was Dr. Ihwe. He visited Belgium in October 1940.

The next large shipment was in November 1941 of about nine tons to the Deutsche Gold und Silber Scheide Anstalt, who was a prewar customer for amounts of about two tons. This shipment may therefore have no special significance.

Suddenly in June 1942 unusually large amounts were requisitioned and sent to Roges, m.b.H., namely about 115 tons of assorted refined and half refined materials. In addition, they obtained 610 tons of crude material, 17 tons of ferro-uranium and about 110 tons of impure products designated as "produits non-marchands" that is "rejects". Also in Jan 43, 50 tons and in May 80 tons of refined products.

115
610
17
110
50
80

Roges m.b.H. is a war created trading office most likely directly connected with the German ministry of trade and Finance (Handels und Finanzministerium). Its full name is Rohstoff Handels Gesellschaft m.b.H (-Raw materials trade company Ltd.) and probably supervised the trade of all metallic ores.

The man in charge of uranium ores was Dr. Faust

The company was bombed out at least twice and requested new copies of their records from Belgium. An old address was:

Tirpitz Ufer 2024, Berlin W9

the latest address is probably:

Chaussee Strasse 6 - 10
Berlin - Mariendorf
Phones 70.03.31, 75.64.06 and
75.66.31 (long distance)

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By PH NARS, Date 5/26/76

- 1 -

Reported by: Mr. Gaston André in charge of uranium at the main office of the Union Miniere du Haut Katanga, Brussels. Interviewed September 10-14, 1944.

(Quantities in this report are only approximate and in metric tons.)

S.A.G.

DR. S. A. GOUDSMIT
Scientific Chief

NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL

Figure D.77: Samuel A. Goudsmit. 15 September 1944. SUBJECT: German Recipients of Uranium Products from Belgium [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

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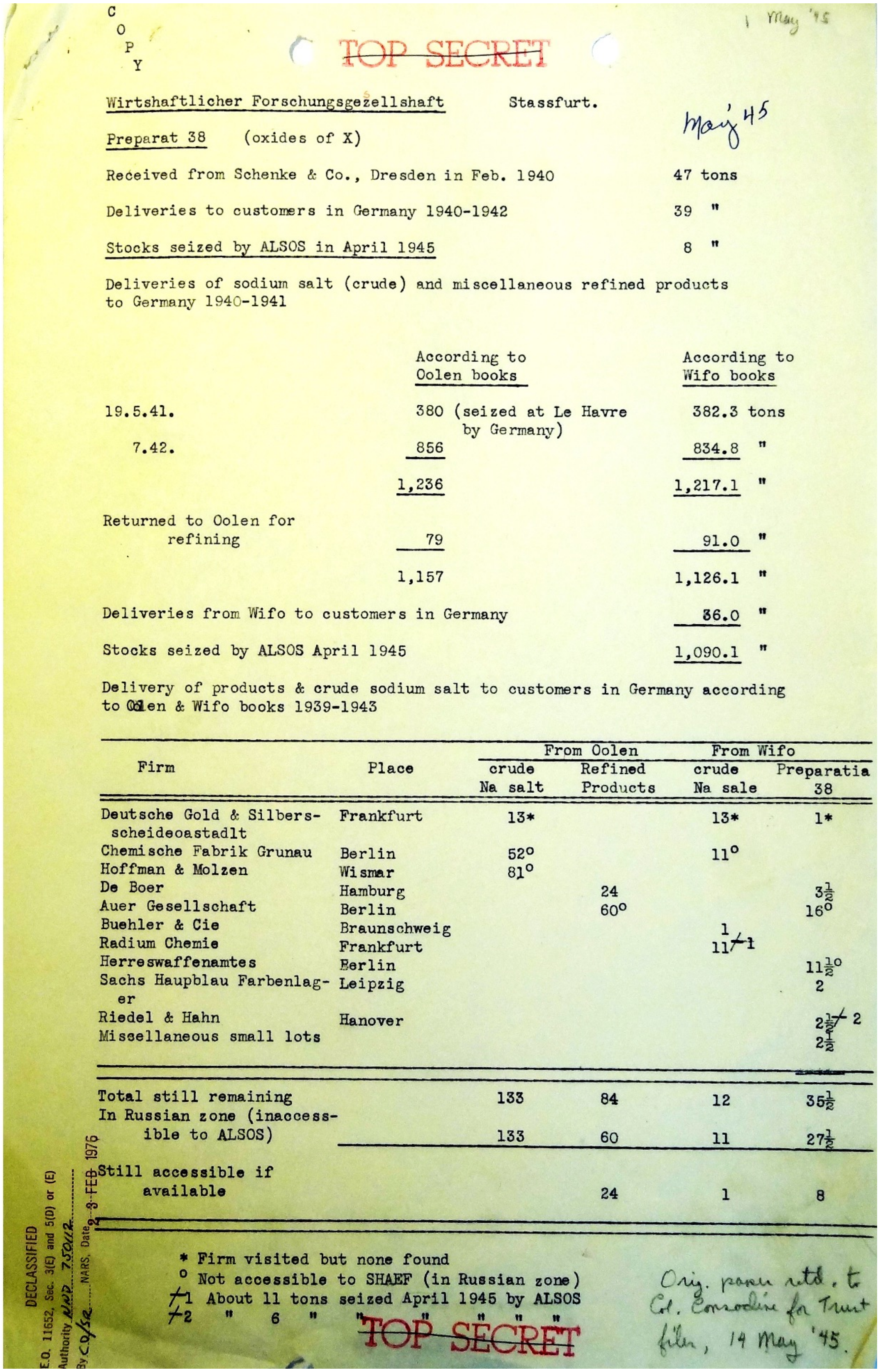
NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL



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1 May '45

Wirtshaftlicher Forschungsgezellshaft Stassfurt.

May 45

Preparat 38 (oxides of X)

Received from Schenke & Co., Dresden in Feb. 1940	47 tons
Deliveries to customers in Germany 1940-1942	39 "
Stocks seized by ALSOS in April 1945	8 "

Deliveries of sodium salt (crude) and miscellaneous refined products to Germany 1940-1941

	According to Oolen books	According to Wifo books
19.5.41.	380 (seized at Le Havre by Germany)	382.3 tons
7.42.	856	834.8 "
	1,236	1,217.1 "
Returned to Oolen for refining	79	91.0 "
	1,157	1,126.1 "
Deliveries from Wifo to customers in Germany		36.0 "
Stocks seized by ALSOS April 1945		1,090.1 "

Delivery of products & crude sodium salt to customers in Germany according to Oolen & Wifo books 1939-1943

Firm	Place	From Oolen		From Wifo	
		crude Na salt	Refined Products	crude Na sale	Preparatia 38
Deutsche Gold & Silbers-scheideoastadlt	Frankfurt	13*		13*	1*
Chemische Fabrik Grunau	Berlin	52°		11°	
Hoffman & Molzen	Wismar	81°			
De Boer	Hamburg		24		3½
Auer Gesellschaft	Berlin		60°		16°
Buehler & Cie	Braunschweig			1	
Radium Chemie	Frankfurt			11†1	
Herreswaffenamtes	Berlin				11½°
Sachs Haupblau Farbenlager	Leipzig				2
Riedel & Hahn	Hanover				2½†2
Miscellaneous small lots					2½
Total still remaining		133	84	12	35½
In Russian zone (inaccessible to ALSOS)		133	60	11	27½
Still accessible if available			24	1	8

* Firm visited but none found
° Not accessible to SHAEF (in Russian zone)
†1 About 11 tons seized April 1945 by ALSOS
†2 " 6 " " " " " "

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Orig. paper retd. to Col. Consodine for Trust file, 14 May '45.

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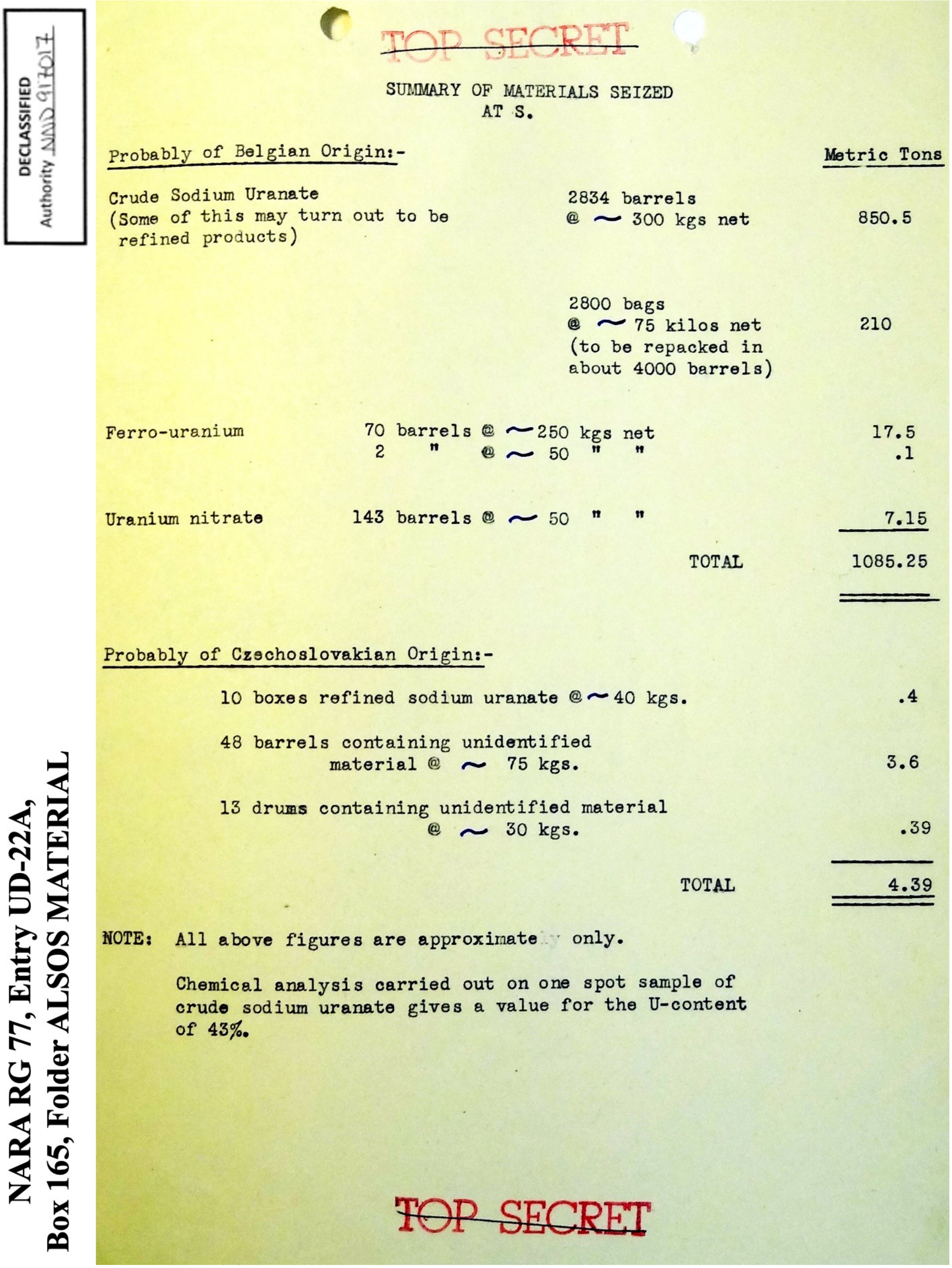
Figure D.78: 1 May 1945. Wirtschaftlicher Forschungsgesellschaft Stassfurt [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].



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SUMMARY OF MATERIALS SEIZED
AT S.

Probably of Belgian Origin:-		Metric Tons
Crude Sodium Uranate (Some of this may turn out to be refined products)	2834 barrels @ ~ 300 kgs net	850.5
	2800 bags @ ~ 75 kilos net (to be repacked in about 4000 barrels)	210
Ferro-uranium	70 barrels @ ~ 250 kgs net	17.5
	2 " @ ~ 50 " "	.1
Uranium nitrate	143 barrels @ ~ 50 " "	7.15
	TOTAL	1085.25

Probably of Czechoslovakian Origin:-	Metric Tons
10 boxes refined sodium uranate @ ~ 40 kgs.	.4
48 barrels containing unidentified material @ ~ 75 kgs.	3.6
13 drums containing unidentified material @ ~ 30 kgs.	.39
TOTAL	4.39

NOTE: All above figures are approximately only.

Chemical analysis carried out on one spot sample of crude sodium uranate gives a value for the U-content of 43%.

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NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL

Figure D.79: Summary of Materials Seized at S[tassfurt]. [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL]

Jonathan E. Helmreich. 1986. *Gathering Rare Ores: The Diplomacy of Uranium Acquisition, 1943–1954.* Princeton, New Jersey: Princeton University Press. p. 70.

The CDT [Combined Development Trust, run by Leslie Groves] was aware of the uranium at Joachimstal and apparently did not think the Russians would be able to mine there extensively enough to gain the needed amounts of oxide. Despite the survey efforts of the UMDC and the Murray Hill area, however, the CDT did not know of the valuable deposits in Saxony, just north of the East German border with Czechoslovakia and the Joachimstal mines. Discovered by the Germans in 1943, the deposits were explored by the Soviets in the months after June 1945; mining operations began a year later and were feverishly expanded after April 1948.

[The Saxony/Erzgebirge uranium deposits were enormous, and the Soviet Union mined them for decades after the war to supply uranium for its nuclear weapons program.

Germany began exploiting those deposits during the war (see also for example pp. 3433, 3456–3416, 3708, 4922), so it had access to even more uranium ore than it is already publicly known to have possessed.]

Zbynek Zeman and Rainer Karlsch. 2008. *Uranium Matters: Central European Uranium in International Politics 1900-1960.* Budapest: Central European University Press. pp. 25–29, 24.

The Soviets were initially more interested in tracing the German atomic program and recruiting German scientists than in the search for uranium. Despite strong opposition from the Communist Party bureaucracy, Zaveniagin sent a group of forty Soviet physicists to Germany. They succeeded in convincing eminent German scientists, including Manfred von Ardenne, Gustav Hertz, Heinz Pose, Nikolaus Riehl, Peter Adolf Thiessen and Max Volmer, to work for the Soviet atomic program.

As early as 15 May 1945, NKVD presented in Moscow the results of their investigations into the German plants and research institutes which concerned themselves with nuclear matters. Among the institutions visited were the Kaiser-Wilhelm-Institut für Physik in Berlin-Dahlem, Manfred von Ardenne's institute in Berlin-Lichterfelde, Institut der Reichspostforschungsanstalt in Zeuthen (Miersdorf), the Siemens cyclotron laboratory run by Gustav Hertz, as well as the plants and warehouses of the Auer company in Berlin-Charlottenburg, Berlin-Grunau, Oranienburg and Zechlin.

The objects came under NKVD control and were soon dismantled. Special units found about 300 tons of uranium oxide and 7 tons of uranium metal in Berlin, Gottow, Zechlin, Kagar, and Rheinsberg. In Stadtilm, a small town in Thuringia, the special unit found a uranium processing plant that used to belong to the Degussa Company. The Auer Company's plant in Oranienburg, destroyed in the American air raid in March 1945, was also thoroughly searched; a few tons of pure uranium oxide and several hundred tons of thorium derivatives were found there.

[...] The first group came to Bulgaria at the end of November 1944. It followed a German trace: Soviet troops had discovered some German documents concerning uranium reserves in the vicinity of the town of Buchovo. [...] Political prisoners were employed in the uranium mines and, by the middle of 1946, the company had produced 272 tons of pitchblende, which was then sent to the Soviet Union.

[...] Beria's special committee for the atomic bomb received the first report on Jáchymov [Sankt Joachimsthal, Bohemia until 1945, then Czechoslovakia] on 14 September 1945. The estimated uranium reserves in Jáchymov amounted to 300 tons.

[...] Early in August 1945, an expedition of Soviet geologists, led by Professor Kreiter, came to Saxony. The geologists visited the headquarters of the Sachsenerz-Bergwerks AG in Freiberg and the mines near Schneeberg and Johanngeorgenstadt. [...] the estimates reached the figure of 1,600 tons.

[...] by the time mining was concluded there after 1989, it would produce over 231,000 tons of uranium.

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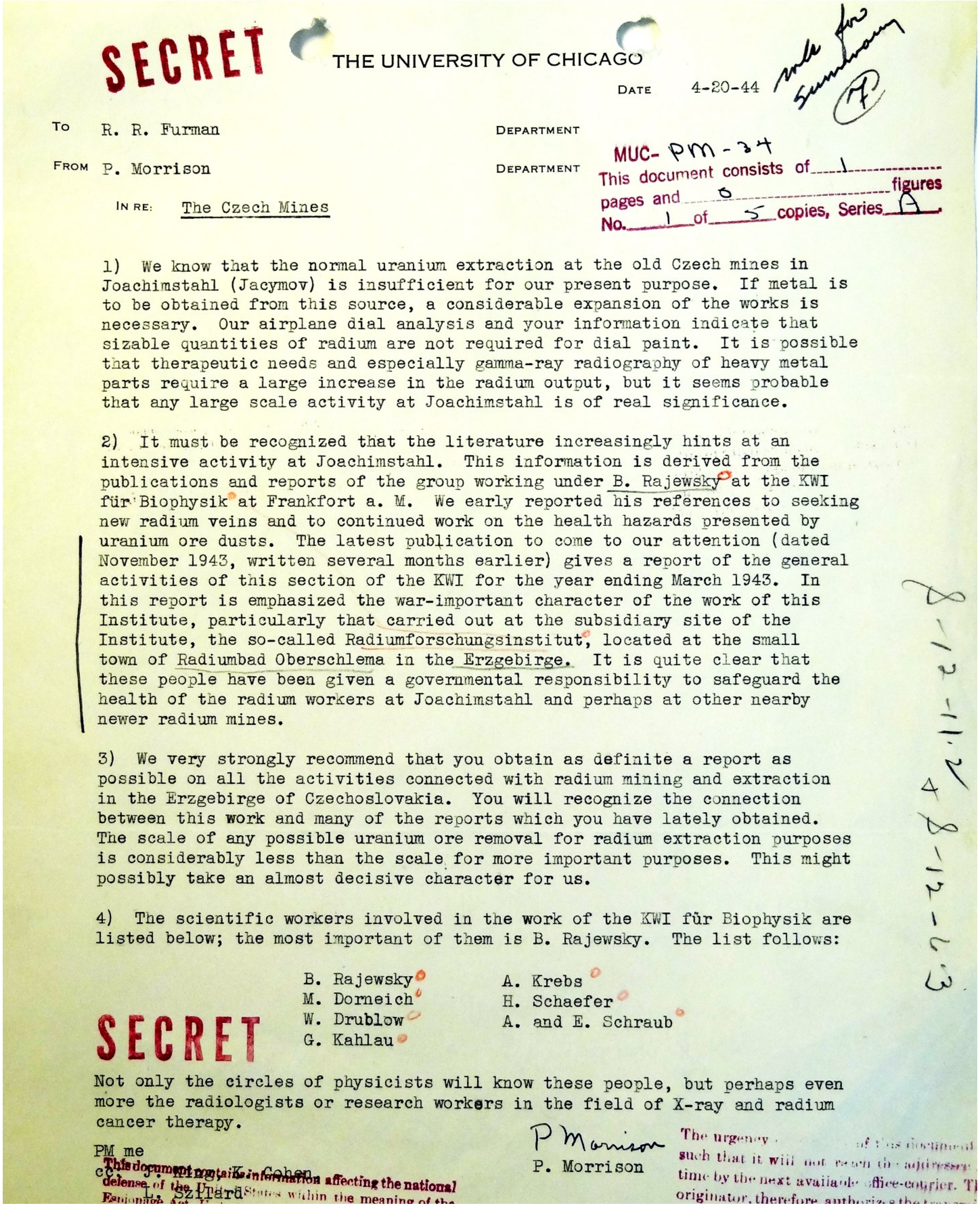
NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)



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THE UNIVERSITY OF CHICAGO

DATE 4-20-44

note for Summary
(7)

TO R. R. Furman DEPARTMENT

FROM P. Morrison DEPARTMENT

MUC- PM-34
This document consists of 1 pages and 0 figures
No. 1 of 5 copies, Series A.

IN RE: The Czech Mines

1) We know that the normal uranium extraction at the old Czech mines in Joachimstahl (Jacymov) is insufficient for our present purpose. If metal is to be obtained from this source, a considerable expansion of the works is necessary. Our airplane dial analysis and your information indicate that sizable quantities of radium are not required for dial paint. It is possible that therapeutic needs and especially gamma-ray radiography of heavy metal parts require a large increase in the radium output, but it seems probable that any large scale activity at Joachimstahl is of real significance.

2) It must be recognized that the literature increasingly hints at an intensive activity at Joachimstahl. This information is derived from the publications and reports of the group working under B. Rajewsky at the KWI für Biophysik at Frankfort a. M. We early reported his references to seeking new radium veins and to continued work on the health hazards presented by uranium ore dusts. The latest publication to come to our attention (dated November 1943, written several months earlier) gives a report of the general activities of this section of the KWI for the year ending March 1943. In this report is emphasized the war-important character of the work of this Institute, particularly that carried out at the subsidiary site of the Institute, the so-called Radiumforschungsinstitut, located at the small town of Radiumbad Oberschlema in the Erzgebirge. It is quite clear that these people have been given a governmental responsibility to safeguard the health of the radium workers at Joachimstahl and perhaps at other nearby newer radium mines.

8-12-1.2 4 8-12-2.3

3) We very strongly recommend that you obtain as definite a report as possible on all the activities connected with radium mining and extraction in the Erzgebirge of Czechoslovakia. You will recognize the connection between this work and many of the reports which you have lately obtained. The scale of any possible uranium ore removal for radium extraction purposes is considerably less than the scale for more important purposes. This might possibly take an almost decisive character for us.

4) The scientific workers involved in the work of the KWI für Biophysik are listed below; the most important of them is B. Rajewsky. The list follows:

B. Rajewsky
M. Dorneich
W. Drublow
G. Kahlau

A. Krebs
H. Schaefer
A. and E. Schraub

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Not only the circles of physicists will know these people, but perhaps even more the radiologists or research workers in the field of X-ray and radium cancer therapy.

P Morrison
P. Morrison

PM me
cc: J. King, K. Cohen
L. Szilard

This document contains information affecting the national defense of the United States within the meaning of the Espionage Act,

The urgency of this document such that it will not reach the addressee time by the next available office-courier. The originator, therefore authorizes the

Figure D.80: Philip Morrison to Robert R. Furman. 20 April 1944. In Re: The Czech Mines [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]. An important new German nuclear research institute was built at Oberschlema, within the rich uranium mining area immediately around Schneeberg.

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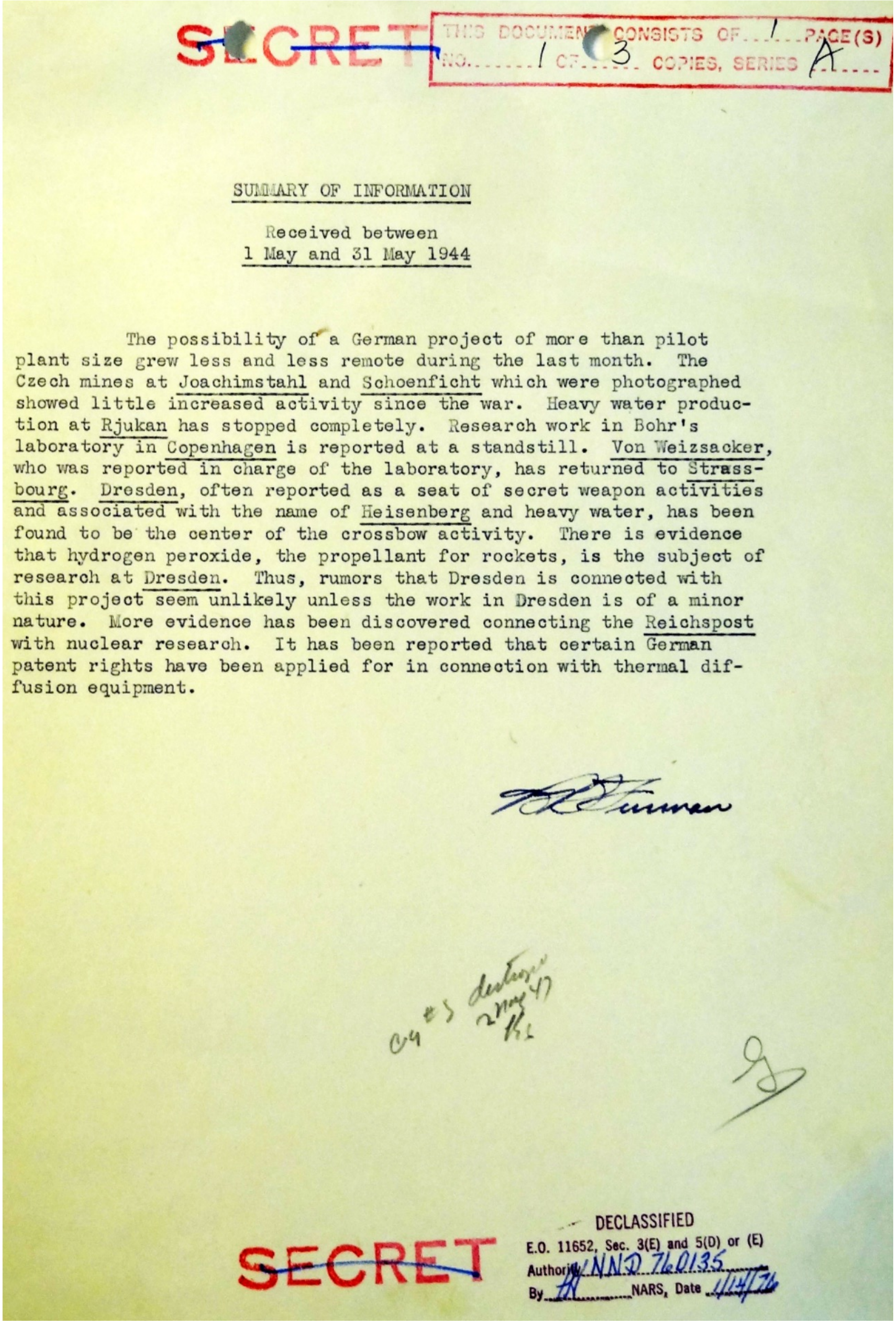
NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)



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NO. 1 OF 3 COPIES, SERIES A

SUMMARY OF INFORMATION

Received between
1 May and 31 May 1944

The possibility of a German project of more than pilot plant size grew less and less remote during the last month. The Czech mines at Joachimstahl and Schoenficht which were photographed showed little increased activity since the war. Heavy water production at Rjukan has stopped completely. Research work in Bohr's laboratory in Copenhagen is reported at a standstill. Von Weizsacker, who was reported in charge of the laboratory, has returned to Strassbourg. Dresden, often reported as a seat of secret weapon activities and associated with the name of Heisenberg and heavy water, has been found to be the center of the crossbow activity. There is evidence that hydrogen peroxide, the propellant for rockets, is the subject of research at Dresden. Thus, rumors that Dresden is connected with this project seem unlikely unless the work in Dresden is of a minor nature. More evidence has been discovered connecting the Reichspost with nuclear research. It has been reported that certain German patent rights have been applied for in connection with thermal diffusion equipment.

Furman

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By AH NARS, Date 1/14/76

Figure D.81: Robert R. Furman. Summary of Information Received between 1 May and 31 May 1944 [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]. Note uranium mining at Schoenficht.

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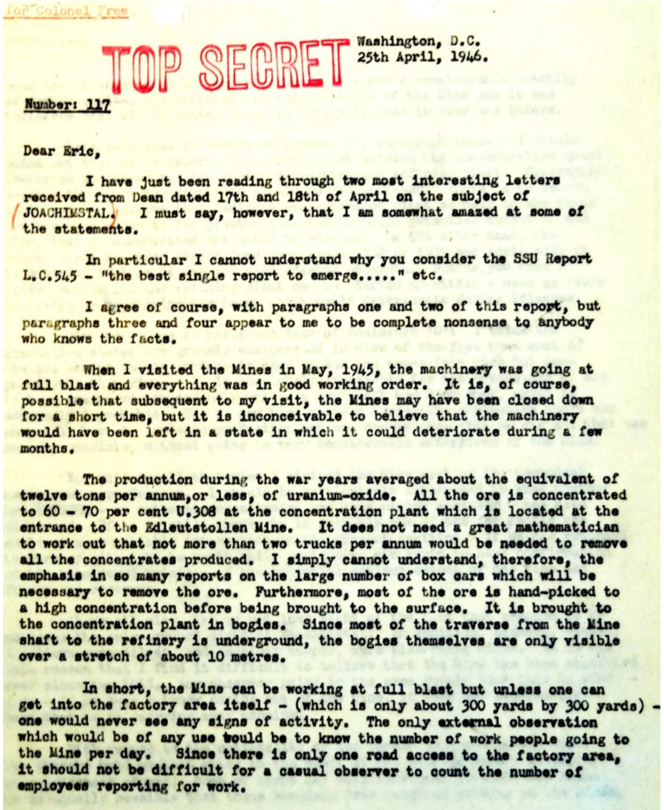

for Colonel Free

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Washington, D.C.
25th April, 1946.

Number: 117

Dear Eric,

I have just been reading through two most interesting letters received from Dean dated 17th and 18th of April on the subject of JOACHIMSTAL. I must say, however, that I am somewhat amazed at some of the statements.

In particular I cannot understand why you consider the SSU Report L.C.545 - "the best single report to emerge....." etc.

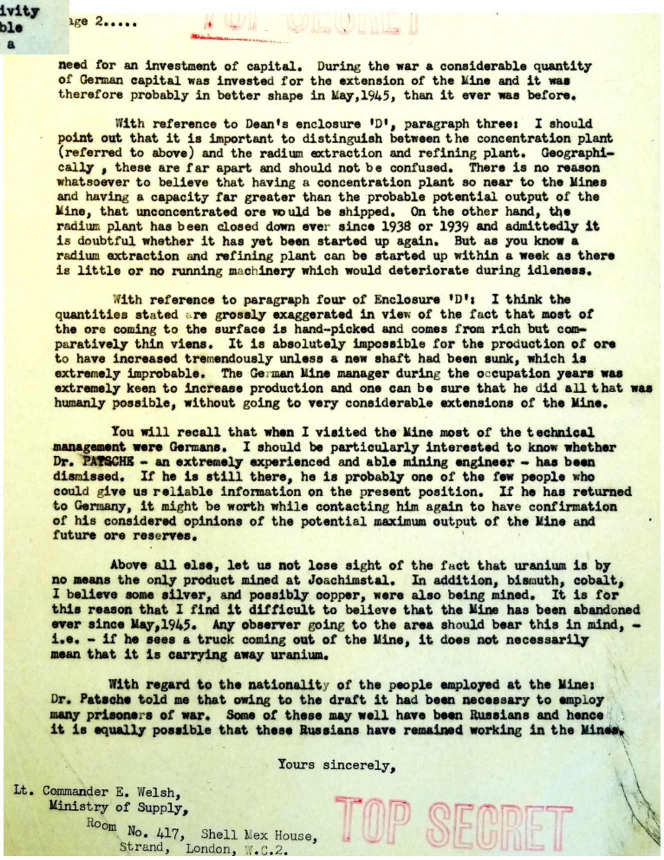
I agree of course, with paragraphs one and two of this report, but paragraphs three and four appear to me to be complete nonsense to anybody who knows the facts.

When I visited the Mines in May, 1945, the machinery was going at full blast and everything was in good working order. It is, of course, possible that subsequent to my visit, the Mines may have been closed down for a short time, but it is inconceivable to believe that the machinery would have been left in a state in which it could deteriorate during a few months.

The production during the war years averaged about the equivalent of twelve tons per annum, or less, of uranium-oxide. All the ore is concentrated to 60 - 70 per cent U.308 at the concentration plant which is located at the entrance to the Edleutstollen Mine. It does not need a great mathematician to work out that not more than two trucks per annum would be needed to remove all the concentrates produced. I simply cannot understand, therefore, the emphasis in so many reports on the large number of box cars which will be necessary to remove the ore. Furthermore, most of the ore is hand-picked to a high concentration before being brought to the surface. It is brought to the concentration plant in bogies. Since most of the traverse from the Mine shaft to the refinery is underground, the bogies themselves are only visible over a stretch of about 10 metres.

In short, the Mine can be working at full blast but unless one can get into the factory area itself - (which is only about 300 yards by 300 yards) - one would never see any signs of activity. The only external observation which would be of any use would be to know the number of work people going to the Mine per day. Since there is only one road access to the factory area, it should not be difficult for a casual observer to count the number of employees reporting for work.

With regard to paragraph four: I can conceive of no unusual activity which would be necessary to rehabilitate the Mine which would be noticeable to an outside observer, and I can think of no reason why there should be a



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need for an investment of capital. During the war a considerable quantity of German capital was invested for the extension of the Mine and it was therefore probably in better shape in May,1945, than it ever was before.

With reference to Dean's enclosure 'D', paragraph three: I should point out that it is important to distinguish between the concentration plant (referred to above) and the radium extraction and refining plant. Geographically, these are far apart and should not be confused. There is no reason whatsoever to believe that having a concentration plant so near to the Mines and having a capacity far greater than the probable potential output of the Mine, that unconcentrated ore would be shipped. On the other hand, the radium plant has been closed down ever since 1938 or 1939 and admittedly it is doubtful whether it has yet been started up again. But as you know a radium extraction and refining plant can be started up within a week as there is little or no running machinery which would deteriorate during idleness.

With reference to paragraph four of Enclosure 'D': I think the quantities stated are grossly exaggerated in view of the fact that most of the ore coming to the surface is hand-picked and comes from rich but comparatively thin viens. It is absolutely impossible for the production of ore to have increased tremendously unless a new shaft had been sunk, which is extremely improbable. The German Mine manager during the occupation years was extremely keen to increase production and one can be sure that he did all that was humanly possible, without going to very considerable extensions of the Mine.

You will recall that when I visited the Mine most of the technical management were Germans. I should be particularly interested to know whether Dr. PATSCHE - an extremely experienced and able mining engineer - has been dismissed. If he is still there, he is probably one of the few people who could give us reliable information on the present position. If he has returned to Germany, it might be worth while contacting him again to have confirmation of his considered opinions of the potential maximum output of the Mine and future ore reserves.

Above all else, let us not lose sight of the fact that uranium is by no means the only product mined at Joachimstal. In addition, bismuth, cobalt, I believe some silver, and possibly copper, were also being mined. It is for this reason that I find it difficult to believe that the Mine has been abandoned ever since May,1945. Any observer going to the area should bear this in mind, - i.e. - if he sees a truck coming out of the Mine, it does not necessarily mean that it is carrying away uranium.

With regard to the nationality of the people employed at the Mine: Dr. Patsche told me that owing to the draft it had been necessary to employ many prisoners of war. Some of these may well have been Russians and hence it is equally possible that these Russians have remained working in the Mines.

Yours sincerely,

Lt. Commander E. Welsh,
Ministry of Supply,
Room No. 417, Shell Mex House,
Strand, London, W.C.2.

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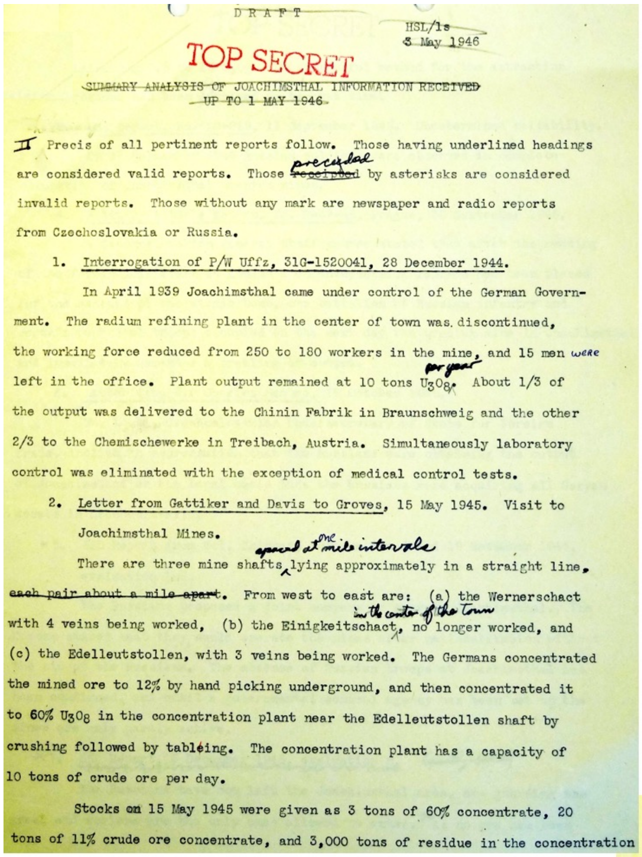
NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia

Figure D.82: George C. Davis or David Gattiker to Eric Welsh. 25 April 1946 [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].



~~DRAFT~~

~~HSL/ls~~
~~3 May 1946~~

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~~SUMMARY ANALYSIS OF JOACHIMSTHAL INFORMATION RECEIVED~~
~~UP TO 1 MAY 1946~~

I Precis of all pertinent reports follow. Those having underlined headings are considered valid reports. Those ~~receipted~~ preceded by asterisks are considered invalid reports. Those without any mark are newspaper and radio reports from Czechoslovakia or Russia.

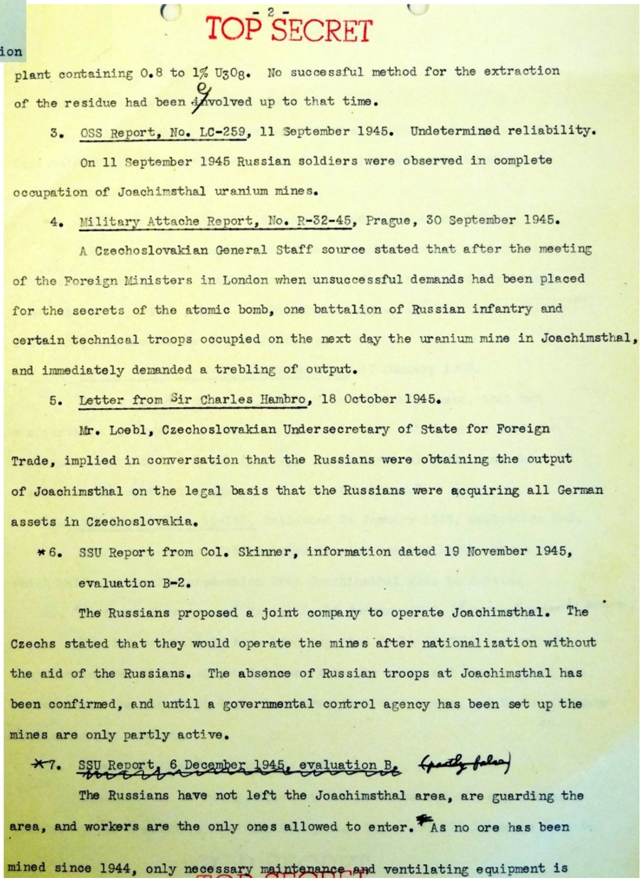
1. Interrogation of P/W Uffz, 31G-1520041, 28 December 1944.

In April 1939 Joachimsthal came under control of the German Government. The radium refining plant in the center of town was discontinued, the working force reduced from 250 to 180 workers in the mine, and 15 men were left in the office. Plant output remained at 10 tons U_3O_8 per year. About 1/3 of the output was delivered to the Chinin Fabrik in Braunschweig and the other 2/3 to the Chemischewerke in Treibach, Austria. Simultaneously laboratory control was eliminated with the exception of medical control tests.

2. Letter from Gattiker and Davis to Groves, 15 May 1945. Visit to Joachimsthal Mines.

There are three mine shafts spaced at one mile intervals lying approximately in a straight line, ~~each pair about a mile apart~~. From west to east are: (a) the Wernerschact with 4 veins being worked, (b) the Einigkeitschact in the center of the town, no longer worked, and (c) the Edelleutstollen, with 3 veins being worked. The Germans concentrated the mined ore to 12% by hand picking underground, and then concentrated it to 60% U_3O_8 in the concentration plant near the Edelleutstollen shaft by crushing followed by tabl~~e~~ing. The concentration plant has a capacity of 10 tons of crude ore per day.

Stocks on 15 May 1945 were given as 3 tons of 60% concentrate, 20 tons of 11% crude ore concentrate, and 3,000 tons of residue in the concentration



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plant containing 0.8 to 1% U_3O_8. No successful method for the extraction of the residue had been ~~i~~evolved up to that time.

3. OSS Report, No. LC-259, 11 September 1945. Undetermined reliability.

On 11 September 1945 Russian soldiers were observed in complete occupation of Joachimsthal uranium mines.

4. Military Attache Report, No. R-32-45, Prague, 30 September 1945.

A Czechoslovakian General Staff source stated that after the meeting of the Foreign Ministers in London when unsuccessful demands had been placed for the secrets of the atomic bomb, one battalion of Russian infantry and certain technical troops occupied on the next day the uranium mine in Joachimsthal, and immediately demanded a trebling of output.

5. Letter from Sir Charles Hambro, 18 October 1945.

Mr. Loebl, Czechoslovakian Undersecretary of State for Foreign Trade, implied in conversation that the Russians were obtaining the output of Joachimsthal on the legal basis that the Russians were acquiring all German assets in Czechoslovakia.

*6. SSU Report from Col. Skinner, information dated 19 November 1945, evaluation B-2.

The Russians proposed a joint company to operate Joachimsthal. The Czechs stated that they would operate the mines after nationalization without the aid of the Russians. The absence of Russian troops at Joachimsthal has been confirmed, and until a governmental control agency has been set up the mines are only partly active.

*7. ~~SSU Report, 6 December 1945, evaluation B.~~ (partly false)

The Russians have not left the Joachimsthal area, are guarding the area, and workers are the only ones allowed to enter. *As no ore has been mined since 1944, only necessary maintenance and ventilating equipment is

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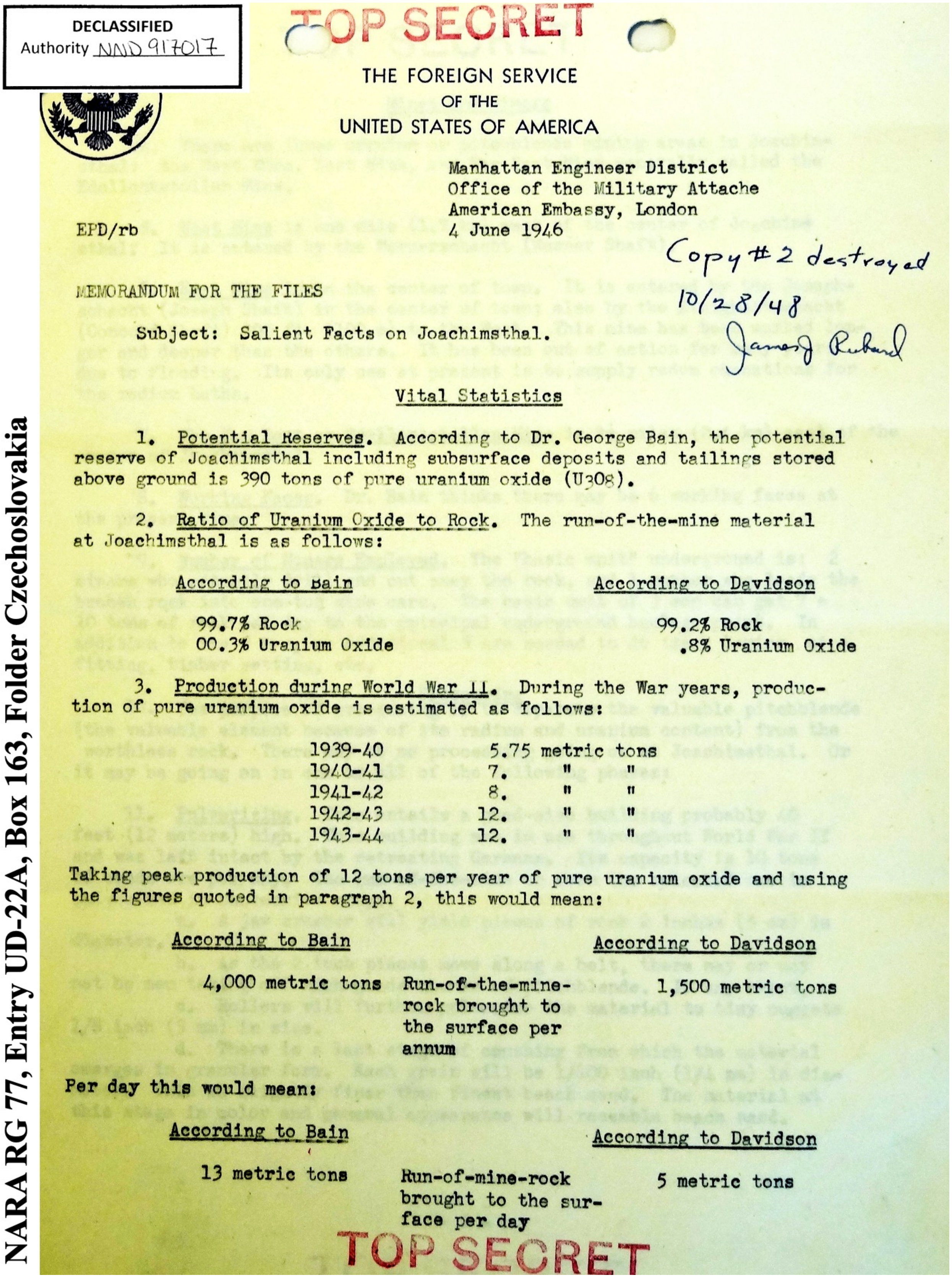
Figure D.83: H. S. Lowenhaupt. 3 May 1946. Draft: Summary Analysis of Joachimsthal Information Received Up To 1 May 1946 (only the first two pages shown) [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].



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THE FOREIGN SERVICE
OF THE
UNITED STATES OF AMERICA

Manhattan Engineer District
Office of the Military Attache
American Embassy, London
4 June 1946

EPD/rb

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10/28/48

MEMORANDUM FOR THE FILES

Subject: Salient Facts on Joachimsthal.

Vital Statistics

1. Potential Reserves. According to Dr. George Bain, the potential reserve of Joachimsthal including subsurface deposits and tailings stored above ground is 390 tons of pure uranium oxide (U_3O_8).

2. Ratio of Uranium Oxide to Rock. The run-of-the-mine material at Joachimsthal is as follows:

According to Bain	According to Davidson
99.7% Rock	99.2% Rock
00.3% Uranium Oxide	.8% Uranium Oxide

3. Production during World War II. During the War years, production of pure uranium oxide is estimated as follows:

1939-40	5.75 metric tons
1940-41	7. " "
1941-42	8. " "
1942-43	12. " "
1943-44	12. " "

Taking peak production of 12 tons per year of pure uranium oxide and using the figures quoted in paragraph 2, this would mean:

According to Bain		According to Davidson
4,000 metric tons	Run-of-the-mine-rock brought to the surface per annum	1,500 metric tons

Per day this would mean:

According to Bain		According to Davidson
13 metric tons	Run-of-mine-rock brought to the surface per day	5 metric tons

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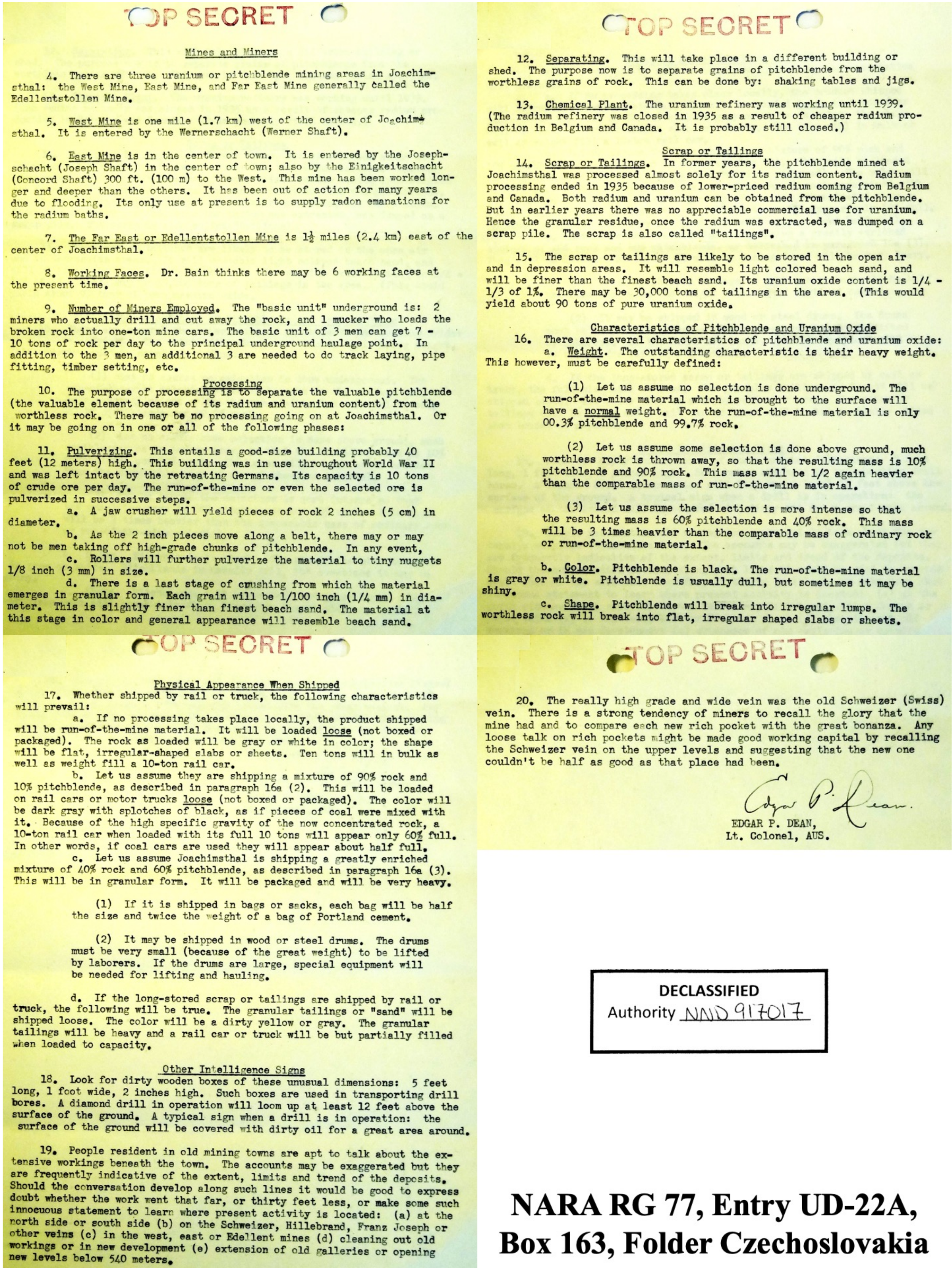
Figure D.84: U.S. Military Attaché London. 4 June 1946. Subject: Salient Facts on Joachimsthal [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].



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Mines and Miners

4. There are three uranium or pitchblende mining areas in Joachimsthal: the West Mine, East Mine, and Far East Mine generally called the Edellentstollen Mine.

5. West Mine is one mile (1.7 km) west of the center of Joachimsthal. It is entered by the Wernerschacht (Werner Shaft).

6. East Mine is in the center of town. It is entered by the Josephschacht (Joseph Shaft) in the center of town; also by the Einigkeitschacht (Concord Shaft) 300 ft. (100 m) to the West. This mine has been worked longer and deeper than the others. It has been out of action for many years due to flooding. Its only use at present is to supply radon emanations for the radium baths.

7. The Far East or Edellentstollen Mine is 1½ miles (2.4 km) east of the center of Joachimsthal.

8. Working Faces. Dr. Bain thinks there may be 6 working faces at the present time.

9. Number of Miners Employed. The "basic unit" underground is: 2 miners who actually drill and cut away the rock, and 1 mucker who loads the broken rock into one-ton mine cars. The basic unit of 3 men can get 7 - 10 tons of rock per day to the principal underground haulage point. In addition to the 3 men, an additional 3 are needed to do track laying, pipe fitting, timber setting, etc.

Processing

10. The purpose of processing is to separate the valuable pitchblende (the valuable element because of its radium and uranium content) from the worthless rock. There may be no processing going on at Joachimsthal. Or it may be going on in one or all of the following phases:

11. Pulverizing. This entails a good-size building probably 40 feet (12 meters) high. This building was in use throughout World War II and was left intact by the retreating Germans. Its capacity is 10 tons of crude ore per day. The run-of-the-mine or even the selected ore is pulverized in successive steps.

a. A jaw crusher will yield pieces of rock 2 inches (5 cm) in diameter.

b. As the 2 inch pieces move along a belt, there may or may not be men taking off high-grade chunks of pitchblende. In any event,

c. Rollers will further pulverize the material to tiny nuggets 1/8 inch (3 mm) in size.

d. There is a last stage of crushing from which the material emerges in granular form. Each grain will be 1/100 inch (1/4 mm) in diameter. This is slightly finer than finest beach sand. The material at this stage in color and general appearance will resemble beach sand.

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12. Separating. This will take place in a different building or shed. The purpose now is to separate grains of pitchblende from the worthless grains of rock. This can be done by: shaking tables and jigs.

13. Chemical Plant. The uranium refinery was working until 1939. (The radium refinery was closed in 1935 as a result of cheaper radium production in Belgium and Canada. It is probably still closed.)

Scrap or Tailings

14. Scrap or Tailings. In former years, the pitchblende mined at Joachimsthal was processed almost solely for its radium content. Radium processing ended in 1935 because of lower-priced radium coming from Belgium and Canada. Both radium and uranium can be obtained from the pitchblende. But in earlier years there was no appreciable commercial use for uranium. Hence the granular residue, once the radium was extracted, was dumped on a scrap pile. The scrap is also called "tailings".

15. The scrap or tailings are likely to be stored in the open air and in depression areas. It will resemble light colored beach sand, and will be finer than the finest beach sand. Its uranium oxide content is 1/4 - 1/3 of 1%. There may be 30,000 tons of tailings in the area. (This would yield about 90 tons of pure uranium oxide.

Characteristics of Pitchblende and Uranium Oxide

16. There are several characteristics of pitchblende and uranium oxide:

a. Weight. The outstanding characteristic is their heavy weight. This however, must be carefully defined:

(1) Let us assume no selection is done underground. The run-of-the-mine material which is brought to the surface will have a normal weight. For the run-of-the-mine material is only 00.3% pitchblende and 99.7% rock.

(2) Let us assume some selection is done above ground, much worthless rock is thrown away, so that the resulting mass is 10% pitchblende and 90% rock. This mass will be 1/2 again heavier than the comparable mass of run-of-the-mine material.

(3) Let us assume the selection is more intense so that the resulting mass is 60% pitchblende and 40% rock. This mass will be 3 times heavier than the comparable mass of ordinary rock or run-of-the-mine material.

b. Color. Pitchblende is black. The run-of-the-mine material is gray or white. Pitchblende is usually dull, but sometimes it may be shiny.

c. Shape. Pitchblende will break into irregular lumps. The worthless rock will break into flat, irregular shaped slabs or sheets.

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Physical Appearance When Shipped

17. Whether shipped by rail or truck, the following characteristics will prevail:

a. If no processing takes place locally, the product shipped will be run-of-the-mine material. It will be loaded loose (not boxed or packaged). The rock as loaded will be gray or white in color; the shape will be flat, irregular-shaped slabs or sheets. Ten tons will in bulk as well as weight fill a 10-ton rail car.

b. Let us assume they are shipping a mixture of 90% rock and 10% pitchblende, as described in paragraph 16a (2). This will be loaded on rail cars or motor trucks loose (not boxed or packaged). The color will be dark gray with splotches of black, as if pieces of coal were mixed with it. Because of the high specific gravity of the now concentrated rock, a 10-ton rail car when loaded with its full 10 tons will appear only 60% full. In other words, if coal cars are used they will appear about half full.

c. Let us assume Joachimsthal is shipping a greatly enriched mixture of 40% rock and 60% pitchblende, as described in paragraph 16a (3). This will be in granular form. It will be packaged and will be very heavy.

(1) If it is shipped in bags or sacks, each bag will be half the size and twice the weight of a bag of Portland cement.

(2) It may be shipped in wood or steel drums. The drums must be very small (because of the great weight) to be lifted by laborers. If the drums are large, special equipment will be needed for lifting and hauling.

d. If the long-stored scrap or tailings are shipped by rail or truck, the following will be true. The granular tailings or "sand" will be shipped loose. The color will be a dirty yellow or gray. The granular tailings will be heavy and a rail car or truck will be but partially filled when loaded to capacity.

Other Intelligence Signs

18. Look for dirty wooden boxes of these unusual dimensions: 5 feet long, 1 foot wide, 2 inches high. Such boxes are used in transporting drill bores. A diamond drill in operation will loom up at least 12 feet above the surface of the ground. A typical sign when a drill is in operation: the surface of the ground will be covered with dirty oil for a great area around.

19. People resident in old mining towns are apt to talk about the extensive workings beneath the town. The accounts may be exaggerated but they are frequently indicative of the extent, limits and trend of the deposits. Should the conversation develop along such lines it would be good to express doubt whether the work went that far, or thirty feet less, or make some such innocuous statement to learn where present activity is located: (a) at the north side or south side (b) on the Schweizer, Hillebrand, Franz Joseph or other veins (c) in the west, east or Edellent mines (d) cleaning out old workings or in new development (e) extension of old galleries or opening new levels below 540 meters.

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20. The really high grade and wide vein was the old Schweizer (Swiss) vein. There is a strong tendency of miners to recall the glory that the mine had and to compare each new rich pocket with the great bonanza. Any loose talk on rich pockets might be made good working capital by recalling the Schweizer vein on the upper levels and suggesting that the new one couldn't be half as good as that place had been.

Edgar P. Dean.

EDGAR P. DEAN,
Lt. Colonel, AUS.

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Figure D.85: U.S. Military Attaché London. 4 June 1946. Subject: Salient Facts on Joachimsthal [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

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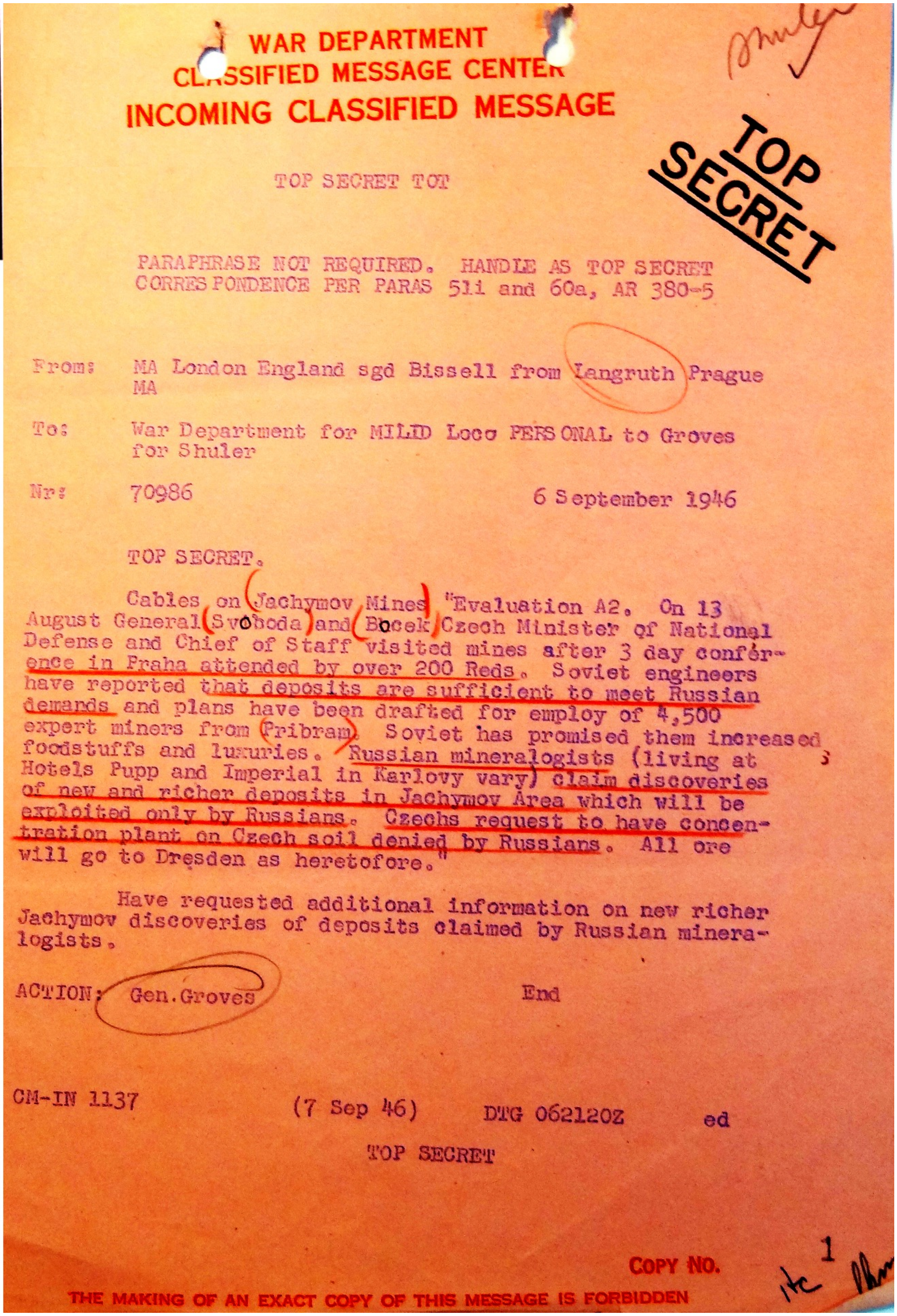
NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret January 1946 thru December 1946



Shuler

WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
INCOMING CLASSIFIED MESSAGE

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PARAPHRASE NOT REQUIRED. HANDLE AS TOP SECRET CORRESPONDENCE PER PARAS 51i and 60a, AR 380-5

From: MA London England sgd Bissell from Langruth Prague MA

To: War Department for MILID Loco PERSONAL to Groves for Shuler

Nr: 70986 6 September 1946

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Cables on Jachymov Mines "Evaluation A2. On 13 August General Svoboda and Bocek Czech Minister of National Defense and Chief of Staff visited mines after 3 day conference in Praha attended by over 200 Reds. Soviet engineers have reported that deposits are sufficient to meet Russian demands and plans have been drafted for employ of 4,500 expert miners from Pribram. Soviet has promised them increased foodstuffs and luxuries. Russian mineralogists (living at Hotels Pupp and Imperial in Karlovy vary) claim discoveries of new and richer deposits in Jachymov Area which will be exploited only by Russians. Czechs request to have concentration plant on Czech soil denied by Russians. All ore will go to Dresden as heretofore."

Have requested additional information on new richer Jachymov discoveries of deposits claimed by Russian mineralogists.

ACTION: Gen. Groves End

CM-IN 1137 (7 Sep 46) DTG 062120Z ed

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COPY NO. 1

THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN

Figure D.86: U.S. Military Attaché London to Leslie Groves. 6 September 1946 [NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret January 1946 thru December 1946]

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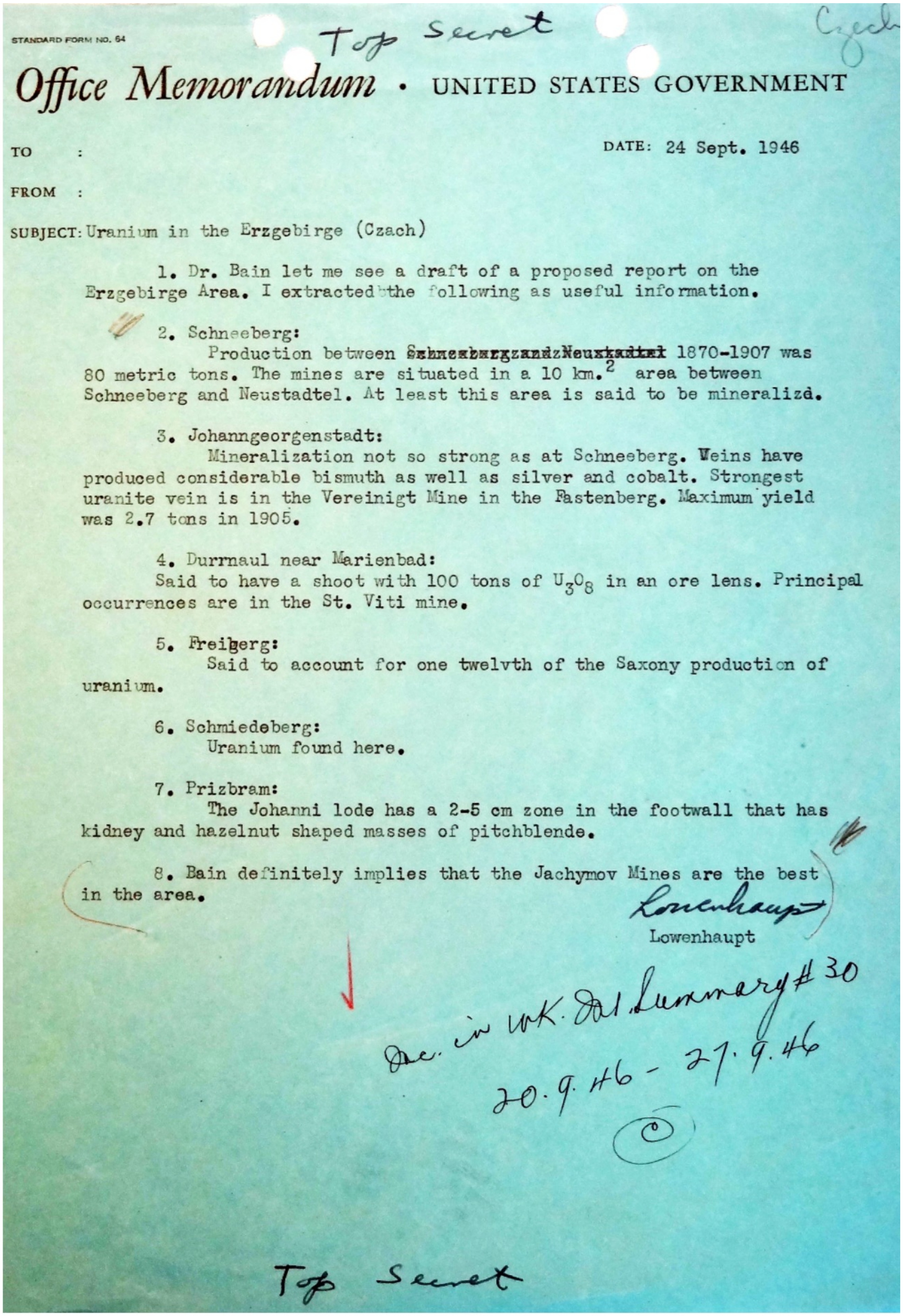

Top Secret

Czech

STANDARD FORM NO. 64

Office Memorandum • UNITED STATES GOVERNMENT

TO :

DATE: 24 Sept. 1946

FROM :

SUBJECT: Uranium in the Erzgebirge (Czach)

1. Dr. Bain let me see a draft of a proposed report on the Erzgebirge Area. I extracted the following as useful information.

2. Schneeberg:
Production between ~~Schneeberg and Neustadtel~~ 1870-1907 was 80 metric tons. The mines are situated in a 10 km.^{2} area between Schneeberg and Neustadtel. At least this area is said to be mineralizd.

3. Johanngeorgenstadt:
Mineralization not so strong as at Schneeberg. Veins have produced considerable bismuth as well as silver and cobalt. Strongest uranite vein is in the Vereinigt Mine in the Fastenberg. Maximum yield was 2.7 tons in 1905.

4. Durrnaul near Marienbad:
Said to have a shoot with 100 tons of U_3O_8 in an ore lens. Principal occurrences are in the St. Viti mine.

5. Freiberg:
Said to account for one twelvth of the Saxony production of uranium.

6. Schmiedeberg:
Uranium found here.

7. Prizbram:
The Johanni lode has a 2-5 cm zone in the footwall that has kidney and hazelnut shaped masses of pitchblende.

8. Bain definitely implies that the Jachymov Mines are the best in the area.

Lowenhaupt
Lowenhaupt

Inc. in Wk. Int. Summary #30
20.9.46 - 27.9.46

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NARA RG 77, Entry UD-22A,
Box 163, Folder Czechoslovakia

Figure D.87: H. S. Lowenhaupt. 24 September 1946. SUBJECT: Uranium in the Erzgebirge (Czech) [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

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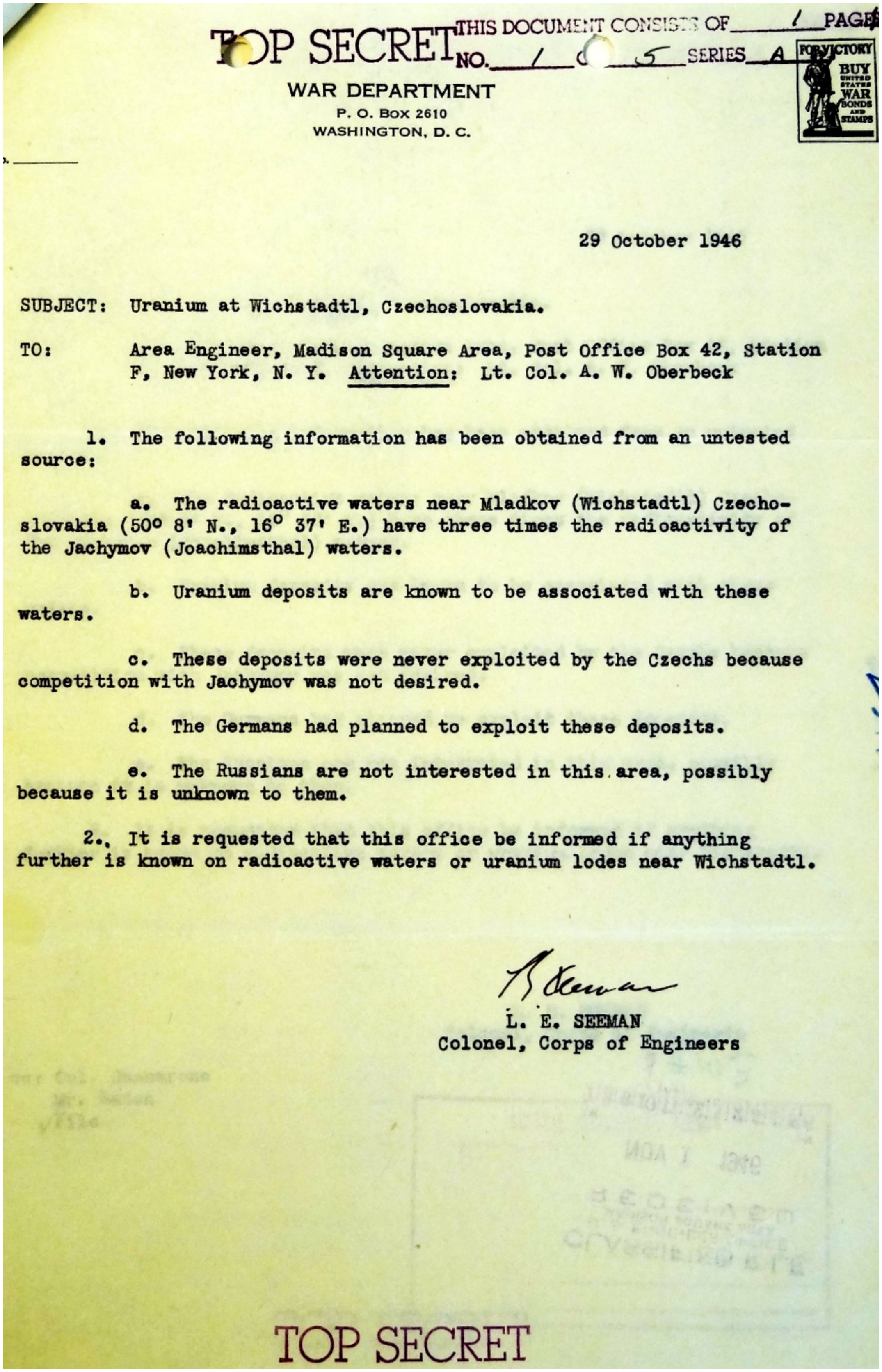

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NO. 1 O 5 SERIES A

FOR VICTORY BUY UNITED STATES WAR BONDS AND STAMPS

WAR DEPARTMENT
P. O. Box 2610
WASHINGTON, D. C.

29 October 1946

SUBJECT: Uranium at Wichstadtl, Czechoslovakia.

TO: Area Engineer, Madison Square Area, Post Office Box 42, Station F, New York, N. Y. Attention: Lt. Col. A. W. Oberbeck

1. The following information has been obtained from an untested source:

a. The radioactive waters near Mladkov (Wichstadtl) Czechoslovakia (50° 8' N., 16° 37' E.) have three times the radioactivity of the Jachymov (Joachimsthal) waters.

b. Uranium deposits are known to be associated with these waters.

c. These deposits were never exploited by the Czechs because competition with Jachymov was not desired.

d. The Germans had planned to exploit these deposits.

e. The Russians are not interested in this area, possibly because it is unknown to them.

2. It is requested that this office be informed if anything further is known on radioactive waters or uranium lodes near Wichstadtl.

L. E. SEEMAN
Colonel, Corps of Engineers

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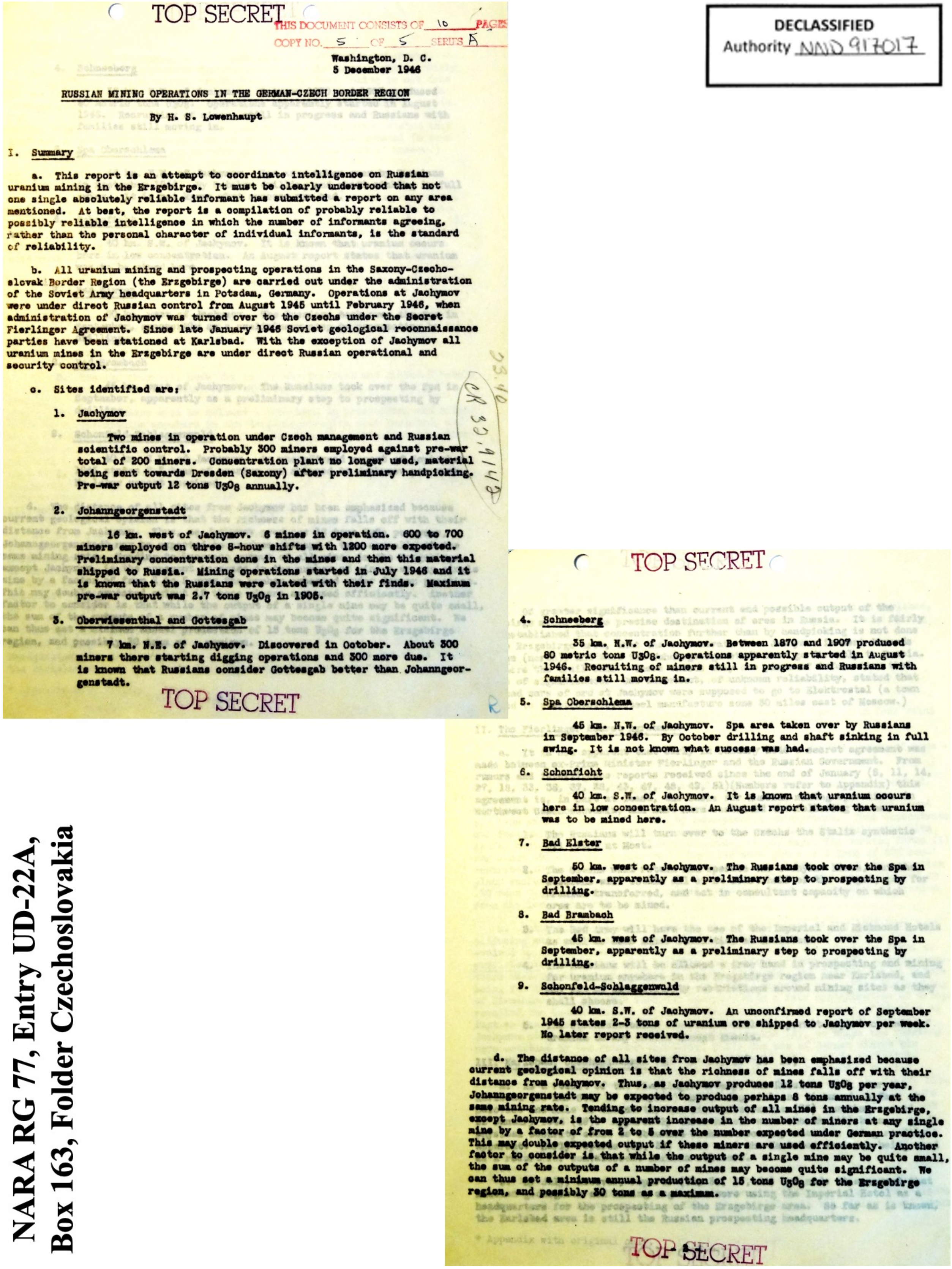
NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia

Figure D.88: Lyle E. Seeman. 29 October 1946. SUBJECT: Uranium at Wichstadtl, Czechoslovakia [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].



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THIS DOCUMENT CONSISTS OF 10 PAGES
COPY NO. 5 OF 5 SERIES A

Washington, D. C.
5 December 1946

RUSSIAN MINING OPERATIONS IN THE GERMAN-CZECH BORDER REGION

By H. S. Lowenhaupt

I. Summary

a. This report is an attempt to coordinate intelligence on Russian uranium mining in the Erzgebirge. It must be clearly understood that not one single absolutely reliable informant has submitted a report on any area mentioned. At best, the report is a compilation of probably reliable to possibly reliable intelligence in which the number of informants agreeing, rather than the personal character of individual informants, is the standard of reliability.

b. All uranium mining and prospecting operations in the Saxony-Czechoslovak Border Region (the Erzgebirge) are carried out under the administration of the Soviet Army headquarters in Potsdam, Germany. Operations at Jachymov were under direct Russian control from August 1945 until February 1946, when administration of Jachymov was turned over to the Czechs under the Secret Fierlinger Agreement. Since late January 1946 Soviet geological reconnaissance parties have been stationed at Karlsbad. With the exception of Jachymov all uranium mines in the Erzgebirge are under direct Russian operational and security control.

c. Sites identified are;

1. Jachymov

Two mines in operation under Czech management and Russian scientific control. Probably 300 miners employed against pre-war total of 200 miners. Concentration plant no longer used, material being sent towards Dresden (Saxony) after preliminary handpicking. Pre-war output 12 tons U_3O_8 annually.

2. Johanngeorgenstadt

16 km. west of Jachymov. 6 mines in operation. 600 to 700 miners employed on three 8-hour shifts with 1200 more expected. Preliminary concentration done in the mines and then this material shipped to Russia. Mining operations started in July 1946 and it is known that the Russians were elated with their finds. Maximum pre-war output was 2.7 tons U_3O_8 in 1905.

3. Oberwiesenthal and Gottesgab

7 km. N.E. of Jachymov. Discovered in October. About 300 miners there starting digging operations and 300 more due. It is known that Russians consider Gottesgab better than Johanngeorgenstadt.

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4. Schneeberg

35 km. N.W. of Jachymov. Between 1870 and 1907 produced 80 metric tons U_3O_8. Operations apparently started in August 1946. Recruiting of miners still in progress and Russians with families still moving in.

5. Spa Oberschlema

45 km. N.W. of Jachymov. Spa area taken over by Russians in September 1946. By October drilling and shaft sinking in full swing. It is not known what success was had.

6. Schonficht

40 km. S.W. of Jachymov. It is known that uranium occurs here in low concentration. An August report states that uranium was to be mined here.

7. Bad Elster

50 km. west of Jachymov. The Russians took over the Spa in September, apparently as a preliminary step to prospecting by drilling.

8. Bad Brambach

45 km. west of Jachymov. The Russians took over the Spa in September, apparently as a preliminary step to prospecting by drilling.

9. Schonfeld-Schlaggenwald

40 km. S.W. of Jachymov. An unconfirmed report of September 1945 states 2-3 tons of uranium ore shipped to Jachymov per week. No later report received.

d. The distance of all sites from Jachymov has been emphasized because current geological opinion is that the richness of mines falls off with their distance from Jachymov. Thus, as Jachymov produces 12 tons U_3O_8 per year, Johanngeorgenstadt may be expected to produce perhaps 8 tons annually at the same mining rate. Tending to increase output of all mines in the Erzgebirge, except Jachymov, is the apparent increase in the number of miners at any single mine by a factor of from 2 to 5 over the number expected under German practice. This may double expected output if these miners are used efficiently. Another factor to consider is that while the output of a single mine may be quite small, the sum of the outputs of a number of mines may become quite significant. We can thus set a minimum annual production of 15 tons U_3O_8 for the Erzgebirge region, and possibly 30 tons as a maximum.

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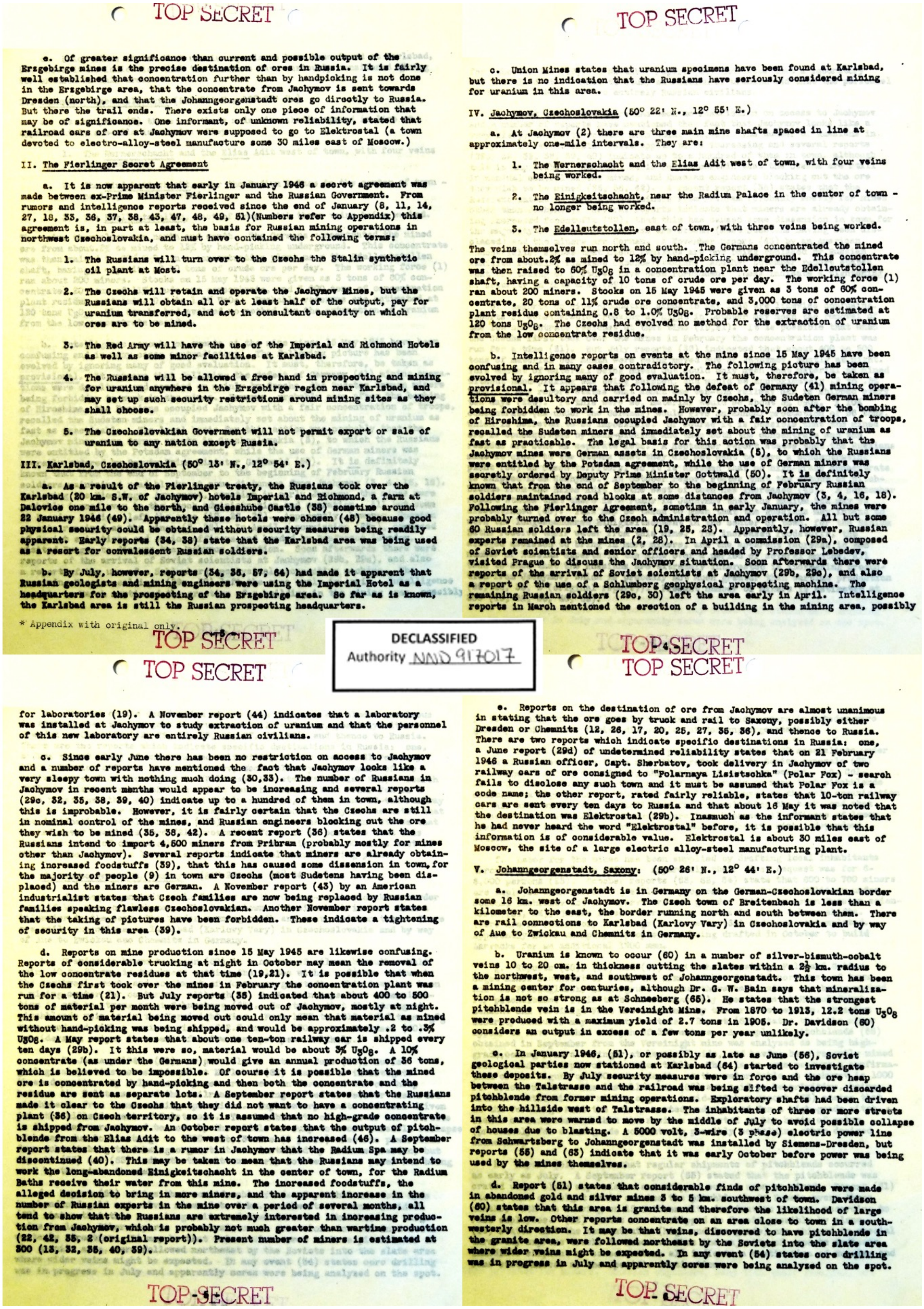
Figure D.89: H. S. Lowenhaupt. 5 December 1946. Russian Mining Operations in the German-Czech Border Region [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia



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e. Of greater significance than current and possible output of the Erzgebirge mines is the precise destination of ores in Russia. It is fairly well established that concentration further than by handpicking is not done in the Erzgebirge area, that the concentrate from Jachymov is sent towards Dresden (north), and that the Johanngeorgenstadt ores go directly to Russia. But there the trail ends. There exists only one piece of information that may be of significance. One informant, of unknown reliability, stated that railroad cars of ore at Jachymov were supposed to go to Elektrostal (a town devoted to electro-alloy-steel manufacture some 30 miles east of Moscow.)

II. The Fierlinger Secret Agreement

a. It is now apparent that early in January 1946 a secret agreement was made between ex-Prime Minister Fierlinger and the Russian Government. From rumors and intelligence reports received since the end of January (8, 11, 14, 27, 18, 33, 36, 37, 38, 43, 47, 48, 49, 51)(Numbers refer to Appendix) this agreement is, in part at least, the basis for Russian mining operations in northwest Czechoslovakia, and must have contained the following terms:

1. The Russians will turn over to the Czechs the Stalin synthetic oil plant at Most.
2. The Czechs will retain and operate the Jachymov Mines, but the Russians will obtain all or at least half of the output, pay for uranium transferred, and act in consultant capacity on which ores are to be mined.
3. The Red Army will have the use of the Imperial and Richmond Hotels as well as some minor facilities at Karlsbad.
4. The Russians will be allowed a free hand in prospecting and mining for uranium anywhere in the Erzgebirge region near Karlsbad, and may set up such security restrictions around mining sites as they shall choose.
5. The Czechoslovakian Government will not permit export or sale of uranium to any nation except Russia.

III. Karlsbad, Czechoslovakia (50° 13' N., 12° 54' E.)

a. As a result of the Fierlinger treaty, the Russians took over the Karlsbad (20 km. S.W. of Jachymov) hotels Imperial and Richmond, a farm at Dalovice one mile to the north, and Giesshube Castle (38) sometime around 22 January 1946 (49). Apparently these hotels were chosen (48) because good physical security could be obtained without security measures being readily apparent. Early reports (34, 38) state that the Karlsbad area was being used as a resort for convalescent Russian soldiers.

b. By July, however, reports (34, 36, 57, 64) had made it apparent that Russian geologists and mining engineers were using the Imperial Hotel as a headquarters for the prospecting of the Erzgebirge area. So far as is known, the Karlsbad area is still the Russian prospecting headquarters.

* Appendix with original only.

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c. Union Mines states that uranium specimens have been found at Karlsbad, but there is no indication that the Russians have seriously considered mining for uranium in this area.

IV. Jachymov, Czechoslovakia (50° 22' N., 12° 55' E.)

a. At Jachymov (2) there are three main mine shafts spaced in line at approximately one-mile intervals. They are:

1. The Wernerschacht and the Elias Adit west of town, with four veins being worked.
2. The Einigkeitschacht, near the Radium Palace in the center of town - no longer being worked.
3. The Edelleutstollen, east of town, with three veins being worked.

The veins themselves run north and south. The Germans concentrated the mined ore from about .2% as mined to 12% by hand-picking underground. This concentrate was then raised to 60% U_3O_8 in a concentration plant near the Edelleutstollen shaft, having a capacity of 10 tons of crude ore per day. The working force (1) ran about 200 miners. Stocks on 15 May 1945 were given as 3 tons of 60% concentrate, 20 tons of 11% crude ore concentrate, and 3,000 tons of concentration plant residue containing 0.8 to 1.0% U_3O_8. Probable reserves are estimated at 120 tons U_3O_8. The Czechs had evolved no method for the extraction of uranium from the low concentrate residue.

b. Intelligence reports on events at the mine since 15 May 1945 have been confusing and in many cases contradictory. The following picture has been evolved by ignoring many of good evaluation. It must, therefore, be taken as provisional. It appears that following the defeat of Germany (41) mining operations were desultory and carried on mainly by Czechs, the Sudeten German miners being forbidden to work in the mines. However, probably soon after the bombing of Hiroshima, the Russians occupied Jachymov with a fair concentration of troops, recalled the Sudeten miners and immediately set about the mining of uranium as fast as practicable. The legal basis for this action was probably that the Jachymov mines were German assets in Czechoslovakia (5), to which the Russians were entitled by the Potsdam agreement, while the use of German miners was secretly ordered by Deputy Prime Minister Gottwald (50). It is definitely known that from the end of September to the beginning of February Russian soldiers maintained road blocks at some distances from Jachymov (3, 4, 16, 18). Following the Fierlinger Agreement, sometime in early January, the mines were probably turned over to the Czech administration and operation. All but some 60 Russian soldiers left the area (19, 25, 28). Apparently, however, Russian experts remained at the mines (2, 28). In April a commission (29a), composed of Soviet scientists and senior officers and headed by Professor Lebedev, visited Prague to discuss the Jachymov situation. Soon afterwards there were reports of the arrival of Soviet scientists at Jachymov (29b, 29c), and also a report of the use of a Schlumberg geophysical prospecting machine. The remaining Russian soldiers (29c, 30) left the area early in April. Intelligence reports in March mentioned the erection of a building in the mining area, possibly for laboratories (19). A November report (44) indicates that a laboratory was installed at Jachymov to study extraction of uranium and that the personnel of this new laboratory are entirely Russian civilians.

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c. Since early June there has been no restriction on access to Jachymov and a number of reports have mentioned the fact that Jachymov looks like a very sleepy town with nothing much doing (30,33). The number of Russians in Jachymov in recent months would appear to be increasing and several reports (29c, 32, 35, 38, 39, 40) indicate up to a hundred of them in town, although this is improbable. However, it is fairly certain that the Czechs are still in nominal control of the mines, and Russian engineers blocking out the ore they wish to be mined (35, 38, 42). A recent report (36) states that the Russians intend to import 4,500 miners from Pribram (probably mostly for mines other than Jachymov). Several reports indicate that miners are already obtaining increased foodstuffs (39), that this has caused some dissension in town, for the majority of people (9) in town are Czechs (most Sudetens having been displaced) and the miners are German. A November report (43) by an American industrialist states that Czech families are now being replaced by Russian families speaking flawless Czechoslovakian. Another November report states that the taking of pictures have been forbidden. These indicate a tightening of security in this area (39).

d. Reports on mine production since 15 May 1945 are likewise confusing. Reports of considerable trucking at night in October may mean the removal of the low concentrate residues at that time (19,21). It is possible that when the Czechs first took over the mines in February the concentration plant was run for a time (21). But July reports (35) indicated that about 400 to 500 tons of material per month were being moved out of Jachymov, mostly at night. This amount of material being moved out could only mean that material as mined without hand-picking was being shipped, and would be approximately .2 to .3% U_3O_8. A May report states that about one ten-ton railway car is shipped every ten days (29b). It this were so, material would be about 3% U_3O_8. A 10% concentrate (as under the Germans) would give an annual production of 36 tons, which is believed to be impossible. Of course it is possible that the mined ore is concentrated by hand-picking and then both the concentrate and the residue are sent as separate lots. A September report states that the Russians made it clear to the Czechs that they did not want to have a concentrating plant (36) on Czech territory, so it is assumed that no high-grade concentrate is shipped from Jachymov. An October report states that the output of pitchblende from the Elias Adit to the west of town has increased (46). A September report states that there is a rumor in Jachymov that the Radium Spa may be discontinued (40). This may be taken to mean that the Russians may intend to work the long-abandoned Einigkeitschacht in the center of town, for the Radium Baths receive their water from this mine. The increased foodstuffs, the alleged decision to bring in more miners, and the apparent increase in the number of Russian experts in the mine over a period of several months, all tend to show that the Russians are extremely interested in increasing production from Jachymov, which is probably not much greater than wartime production (22, 42, 35, 2 (original report)). Present number of miners is estimated at 300 (13, 32, 35, 40, 39).

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e. Reports on the destination of ore from Jachymov are almost unanimous in stating that the ore goes by truck and rail to Saxony, possibly either Dresden or Chemnitz (12, 26, 17, 20, 25, 27, 35, 36), and thence to Russia. There are two reports which indicate specific destinations in Russia: one, a June report (29d) of undetermined reliability states that on 21 February 1946 a Russian officer, Capt. Sherbatov, took delivery in Jachymov of two railway cars of ore consigned to "Polarnaya Lisistschka" (Polar Fox) - search fails to disclose any such town and it must be assumed that Polar Fox is a code name; the other report, rated fairly reliable, states that 10-ton railway cars are sent every ten days to Russia and that about 16 May it was noted that the destination was Elektrostal (29b). Inasmuch as the informant states that he had never heard the word "Elektrostal" before, it is possible that this information is of considerable value. Elektrostal is about 30 miles east of Moscow, the site of a large electric alloy-steel manufacturing plant.

V. Johanngeorgenstadt, Saxony: (50° 26' N., 12° 44' E.)

a. Johanngeorgenstadt is in Germany on the German-Czechoslovakian border some 16 km. west of Jachymov. The Czech town of Breitenbach is less than a kilometer to the east, the border running north and south between them. There are rail connections to Karlsbad (Karlovy Vary) in Czechoslovakia and by way of Aue to Zwickau and Chemnitz in Germany.

b. Uranium is known to occur (60) in a number of silver-bismuth-cobalt veins 10 to 20 cm. in thickness cutting the slates within a 2½ km. radius to the northwest, west, and southwest of Johanngeorgenstadt. This town has been a mining center for centuries, although Dr. G. W. Bain says that mineralization is not so strong as at Schneeberg (65). He states that the strongest pitchblende vein is in the Vereinight Mine. From 1870 to 1913, 12.2 tons U_3O_8 were produced with a maximum yield of 2.7 tons in 1905. Dr. Davidson (60) considers an output in excess of a few tons per year unlikely.

c. In January 1946, (51), or possibly as late as June (56), Soviet geological parties now stationed at Karlsbad (64) started to investigate these deposits. By July security measures were in force and the ore heap between the Talstrasse and the railroad was being sifted to recover discarded pitchblende from former mining operations. Exploratory shafts had been driven into the hillside west of Talstrasse. The inhabitants of three or more streets in this area were warned to move by the middle of July to avoid possible collapse of houses due to blasting. A 5000 volt, 3-wire (3 phase) electric power line from Schwartzberg to Johanngeorgenstadt was installed by Siemens-Dresden, but reports (55) and (63) indicate that it was early October before power was being used by the mines themselves.

d. Report (51) states that considerable finds of pitchblende were made in abandoned gold and silver mines 3 to 5 km. southwest of town. Davidson (60) states that this area is granite and therefore the likelihood of large veins is low. Other reports concentrate on an area close to town in a southwesterly direction. It may be that veins, discovered to have pitchblende in the granite area, were followed northeast by the Soviets into the slate area where wider veins might be expected. In any event (54) states core drilling was in progress in July and apparently cores were being analyzed on the spot.

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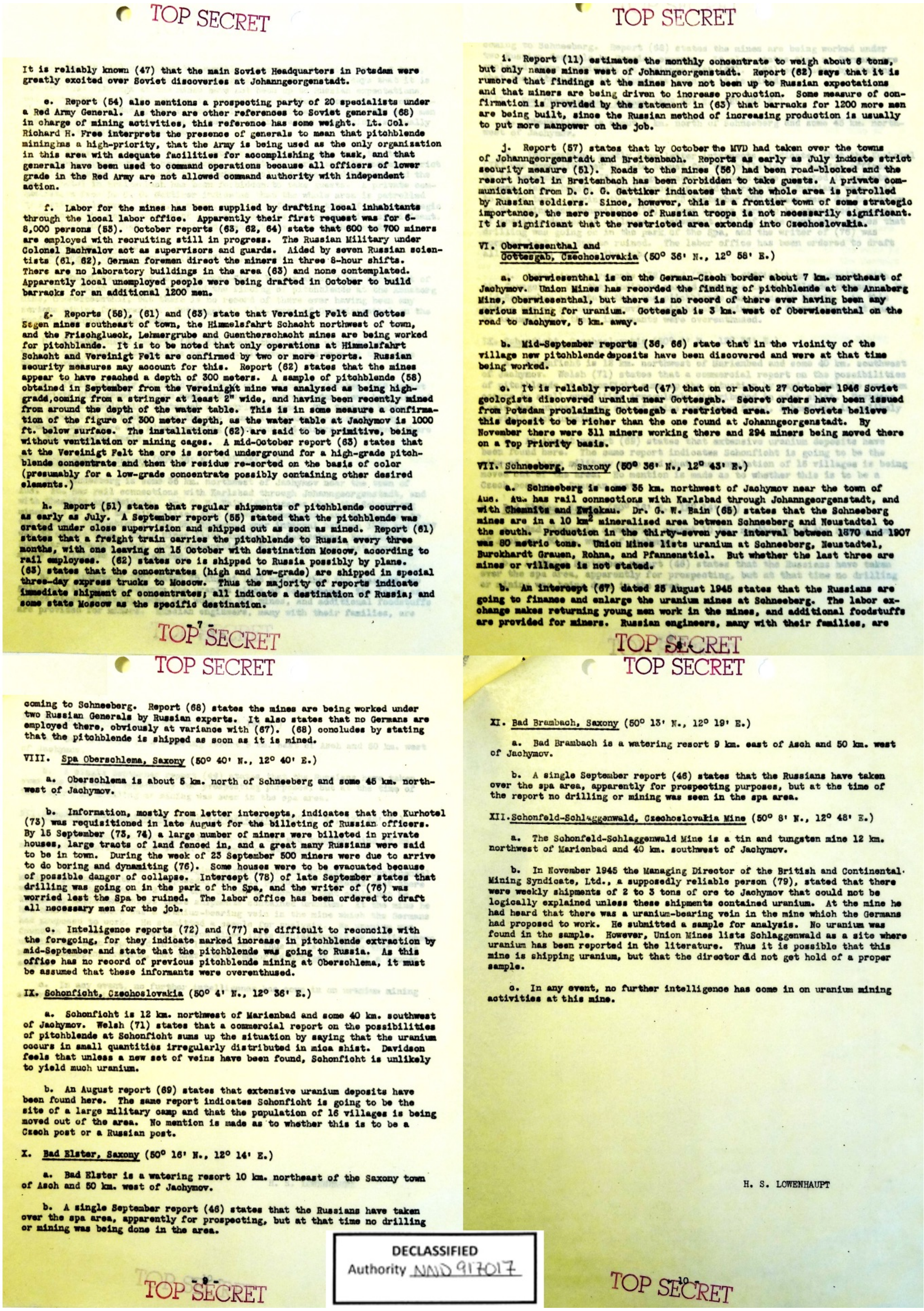
Figure D.90: H. S. Lowenhaupt. 5 December 1946. Russian Mining Operations in the German-Czech Border Region [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia



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It is reliably known (47) that the main Soviet Headquarters in Potsdam were greatly excited over Soviet discoveries at Johanngeorgenstadt.

e. Report (54) also mentions a prospecting party of 20 specialists under a Red Army General. As there are other references to Soviet generals (68) in charge of mining activities, this reference has some weight. Lt. Col. Richard H. Free interprets the presence of generals to mean that pitchblende mininghas a high-priority, that the Army is being used as the only organization in this area with adequate facilities for accomplishing the task, and that generals have been used to command operations because all officers of lower grade in the Red Army are not allowed command authority with independent action.

f. Labor for the mines has been supplied by drafting local inhabitants through the local labor office. Apparently their first request was for 6-8,000 persons (53). October reports (63, 62, 64) state that 600 to 700 miners are employed with recruiting still in progress. The Russian Military under Colonel Bachvalov act as supervisors and guards. Aided by seven Russian scientists (61, 62), German foremen direct the miners in three 8-hour shifts. There are no laboratory buildings in the area (63) and none contemplated. Apparently local unemployed people were being drafted in October to build barracks for an additional 1200 men.

g. Reports (58), (61) and (63) state that Vereinigt Felt and Gottes Segen mines southeast of town, the Himmelsfahrt Schacht northwest of town, and the Frischglueck, Lehmergrube and Guentherschacht mines are being worked for pitchblende. It is to be noted that only operations at Himmelsfahrt Schacht and Vereinigt Felt are confirmed by two or more reports. Russian security measures may account for this. Report (62) states that the mines appear to have reached a depth of 300 meters. A sample of pitchblende (58) obtained in September from the Vereinight mine was analyzed as being high-gradd,coming from a stringer at least 2" wide, and having been recently mined from around the depth of the water table. This is in some measure a confirmation of the figure of 300 meter depth, as the water table at Jachymov is 1000 ft. below surface. The installations (62) are said to be primitive, being without ventilation or mining cages. A mid-October report (63) states that at the Vereinigt Felt the ore is sorted underground for a high-grade pitchblende concentrate and then the residue re-sorted on the basis of color (presumably for a low-grade concentrate possibly containing other desired elements.)

h. Report (51) states that regular shipments of pitchblende occurred as early as July. A September report (55) stated that the pitchblende was crated under close supervision and shipped out as soon as mined. Report (61) states that a freight train carries the pitchblende to Russia every three months, with one leaving on 15 October with destination Moscow, according to rail employees. (62) states ore is shipped to Russia possibly by plane. (63) states that the concentrates (high and low-grade) are shipped in special three-day express trucks to Moscow. Thus the majority of reports indicate immediate shipment of concentrates; all indicate a destination of Russia; and some state Moscow as the specific destination.

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i. Report (11) estimates the monthly concentrate to weigh about 6 tons, but only names mines west of Johanngeorgenstadt. Report (62) says that it is rumored that findings at the mines have not been up to Russian expectations and that miners are being driven to increase production. Some measure of confirmation is provided by the statement in (63) that barracks for 1200 more men are being built, since the Russian method of increasing production is usually to put more manpower on the job.

j. Report (57) states that by October the MVD had taken over the towns of Johanngeorgenstadt and Breitenbach. Reports as early as July indicate strict security measure (51). Roads to the mines (56) had been road-blocked and the resort hotel in Breitenbach has been forbidden to take guests. A private communication from D. C. G. Gattiker indicates that the whole area is patrolled by Russian soldiers. Since, however, this is a frontier town of some strategic importance, the mere presence of Russian troops is not necessarily significant. It is significant that the restricted area extends into Czechoslovakia.

VI. Oberwiesenthal and
Gottesgab, Czechoslovakia (50° 36' N., 12° 58' E.)

a. Oberwiesenthal is on the German-Czech border about 7 km. northeast of Jachymov. Union Mines has recorded the finding of pitchblende at the Annaberg Mine, Oberwiesenthal, but there is no record of there ever having been any serious mining for uranium. Gottesgab is 3 km. west of Oberwiesenthal on the road to Jachymov, 5 km. away.

b. Mid-September reports (36, 66) state that in the vicinity of the village new pitchblende deposits have been discovered and were at that time being worked.

c. It is reliably reported (47) that on or about 27 October 1946 Soviet geologists discovered uranium near Gottesgab. Secret orders have been issued from Potsdam proclaiming Gottesgab a restricted area. The Soviets believe this deposit to be richer than the one found at Johanngeorgenstadt. By November there were 311 miners working there and 294 miners being moved there on a Top Priority basis.

VII. Schneeberg, Saxony (50° 36' N., 12° 43' E.)

a. Schneeberg is some 35 km. northwest of Jachymov near the town of Aue. Aue has rail connections with Karlsbad through Johanngeorgenstadt, and with Chemnitz and Zwickau. Dr. G. W. Bain (65) states that the Schneeberg mines are in a 10 km^2 mineralized area between Schneeberg and Neustadtel to the south. Production in the thirty-seven year interval between 1870 and 1907 was 80 metric tons. Union Mines lists uranium at Schneeberg, Neustadtel, Burckhardt Grauen, Rohna, and Pfannenstiel. But whether the last three are mines or villages is not stated.

b. An intercept (67) dated 25 August 1945 states that the Russians are going to finance and enlarge the uranium mines at Schneeberg. The labor exchange makes returning young men work in the mines, and additional foodstuffs are provided for miners. Russian engineers, many with their families, are

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coming to Schneeberg. Report (68) states the mines are being worked under two Russian Generals by Russian experts. It also states that no Germans are employed there, obviously at variance with (67). (68) concludes by stating that the pitchblende is shipped as soon as it is mined.

VIII. Spa Oberschlema, Saxony (50° 40' N., 12° 40' E.)

a. Oberschlema is about 5 km. north of Schneeberg and some 45 km. northwest of Jachymov.

b. Information, mostly from letter intercepts, indicates that the Kurhotel (73) was requisitioned in late August for the billeting of Russian officers. By 15 September (73, 74) a large number of miners were billeted in private houses, large tracts of land fenced in, and a great many Russians were said to be in town. During the week of 23 September 500 miners were due to arrive to do boring and dynamiting (76). Some houses were to be evacuated because of possible danger of collapse. Intercept (78) of late September states that drilling was going on in the park of the Spa, and the writer of (76) was worried lest the Spa be ruined. The labor office has been ordered to draft all necessary men for the job.

c. Intelligence reports (72) and (77) are difficult to reconcile with the foregoing, for they indicate marked increase in pitchblende extraction by mid-September and state that the pitchblende was going to Russia. As this office has no record of previous pitchblende mining at Oberschlema, it must be assumed that these informants were overenthused.

IX. Schonficht, Czechoslovakia (50° 4' N., 12° 36' E.)

a. Schonficht is 12 km. northwest of Marienbad and some 40 km. southwest of Jachymov. Welsh (71) states that a commercial report on the possibilities of pitchblende at Schonficht sums up the situation by saying that the uranium occurs in small quantities irregularly distributed in mica shist. Davidson feels that unless a new set of veins have been found, Schonficht is unlikely to yield much uranium.

b. An August report (69) states that extensive uranium deposits have been found here. The same report indicates Schonficht is going to be the site of a large military camp and that the population of 16 villages is being moved out of the area. No mention is made as to whether this is to be a Czech post or a Russian post.

X. Bad Elster, Saxony (50° 16' N., 12° 14' E.)

a. Bad Elster is a watering resort 10 km. northeast of the Saxony town of Asch and 50 km. west of Jachymov.

b. A single September report (46) states that the Russians have taken over the spa area, apparently for prospecting, but at that time no drilling or mining was being done in the area.

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XI. Bad Brambach, Saxony (50° 13' N., 12° 19' E.)

a. Bad Brambach is a watering resort 9 km. east of Asch and 50 km. west of Jachymov.

b. A single September report (46) states that the Russians have taken over the spa area, apparently for prospecting purposes, but at the time of the report no drilling or mining was seen in the spa area.

XII. Schonfeld-Schlaggenwald, Czechoslovakia Mine (50° 8' N., 12° 48' E.)

a. The Schonfeld-Schlaggenwald Mine is a tin and tungsten mine 12 km. northwest of Marienbad and 40 km. southwest of Jachymov.

b. In November 1945 the Managing Director of the British and Continental Mining Syndicate, Ltd., a supposedly reliable person (79), stated that there were weekly shipments of 2 to 3 tons of ore to Jachymov that could not be logically explained unless these shipments contained uranium. At the mine he had heard that there was a uranium-bearing vein in the mine which the Germans had proposed to work. He submitted a sample for analysis. No uranium was found in the sample. However, Union Mines lists Schlaggenwald as a site where uranium has been reported in the literature. Thus it is possible that this mine is shipping uranium, but that the director did not get hold of a proper sample.

c. In any event, no further intelligence has come in on uranium mining activities at this mine.

H. S. LOWENHAUPT

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Figure D.91: H. S. Lowenhaupt. 5 December 1946. Russian Mining Operations in the German-Czech Border Region [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

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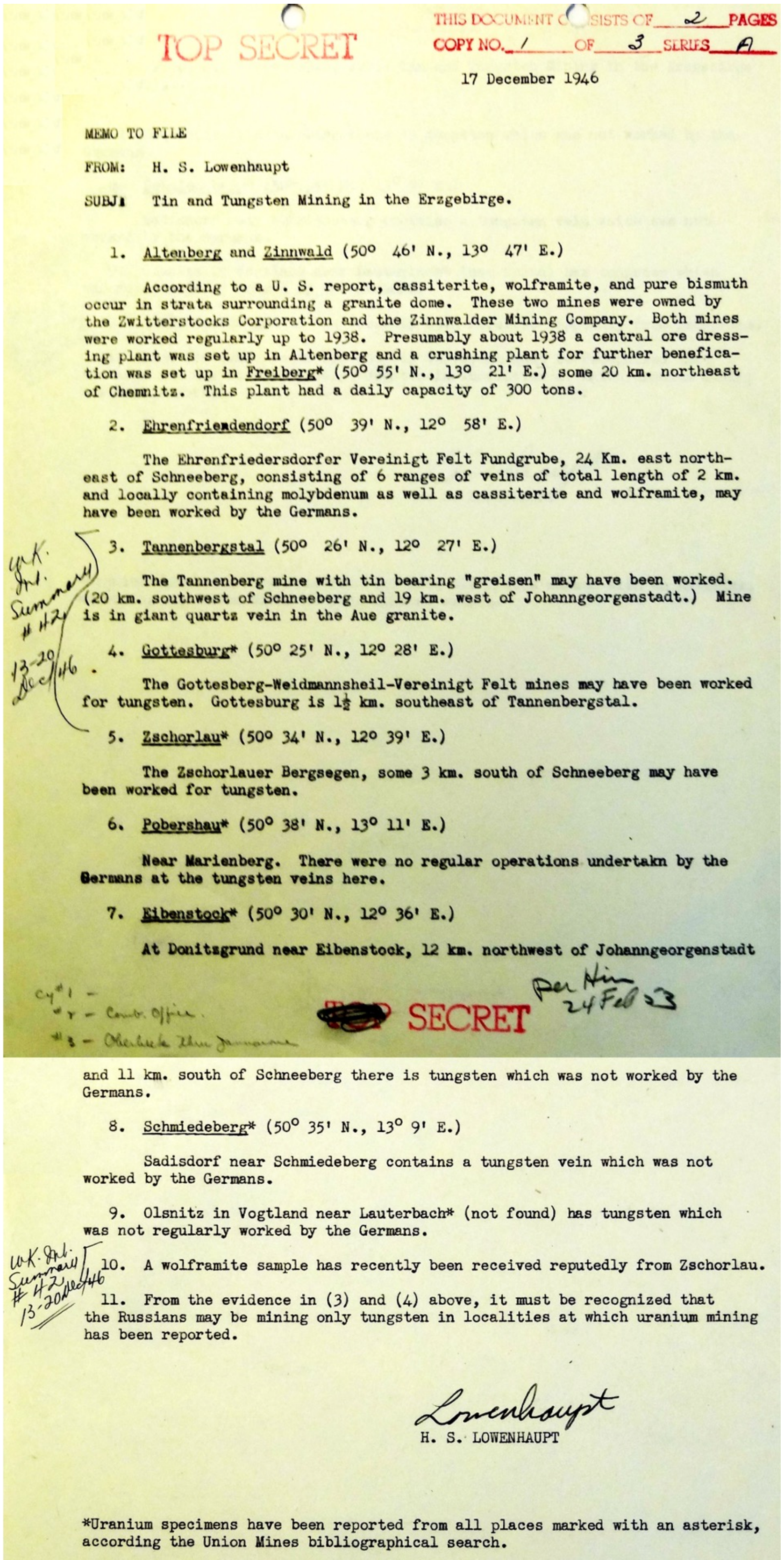
NARA RG 77, Entry UD-22A,
Box 163, Folder Australia



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THIS DOCUMENT CONSISTS OF 2 PAGES
COPY NO. 1 OF 3 SERIES A

17 December 1946

MEMO TO FILE

FROM: H. S. Lowenhaupt

SUBJ: Tin and Tungsten Mining in the Erzgebirge.

1. Altenberg and Zinnwald (50° 46' N., 13° 47' E.)

According to a U. S. report, cassiterite, wolframite, and pure bismuth occur in strata surrounding a granite dome. These two mines were owned by the Zwitterstocks Corporation and the Zinnwalder Mining Company. Both mines were worked regularly up to 1938. Presumably about 1938 a central ore dressing plant was set up in Altenberg and a crushing plant for further benefication was set up in Freiberg* (50° 55' N., 13° 21' E.) some 20 km. northeast of Chemnitz. This plant had a daily capacity of 300 tons.

2. Ehrenfriesdendorf (50° 39' N., 12° 58' E.)

The Ehrenfriedersdorfer Vereinigt Felt Fundgrube, 24 Km. east northeast of Schneeberg, consisting of 6 ranges of veins of total length of 2 km. and locally containing molybdenum as well as cassiterite and wolframite, may have been worked by the Germans.

U.K. Int. Summary #42 13-20 Dec/46

3. Tannenbergstal (50° 26' N., 12° 27' E.)

The Tannenberg mine with tin bearing "greisen" may have been worked. (20 km. southwest of Schneeberg and 19 km. west of Johanngeorgenstadt.) Mine is in giant quartz vein in the Aue granite.

4. Gottesburg* (50° 25' N., 12° 28' E.)

The Gottesberg-Weidmannsheil-Vereinigt Felt mines may have been worked for tungsten. Gottesburg is 1½ km. southeast of Tannenbergstal.

5. Zschorlau* (50° 34' N., 12° 39' E.)

The Zschorlauer Bergsegen, some 3 km. south of Schneeberg may have been worked for tungsten.

6. Pobershau* (50° 38' N., 13° 11' E.)

Near Marienberg. There were no regular operations undertakn by the Germans at the tungsten veins here.

7. Eibenstock* (50° 30' N., 12° 36' E.)

At Donitzgrund near Eibenstock, 12 km. northwest of Johanngeorgenstadt

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and 11 km. south of Schneeberg there is tungsten which was not worked by the Germans.

8. Schmiedeberg* (50° 35' N., 13° 9' E.)

Sadisdorf near Schmiedeberg contains a tungsten vein which was not worked by the Germans.

9. Olsnitz in Vogtland near Lauterbach* (not found) has tungsten which was not regularly worked by the Germans.

U.K. Int. Summary #42 13-20 Dec/46

10. A wolframite sample has recently been received reputedly from Zschorlau.

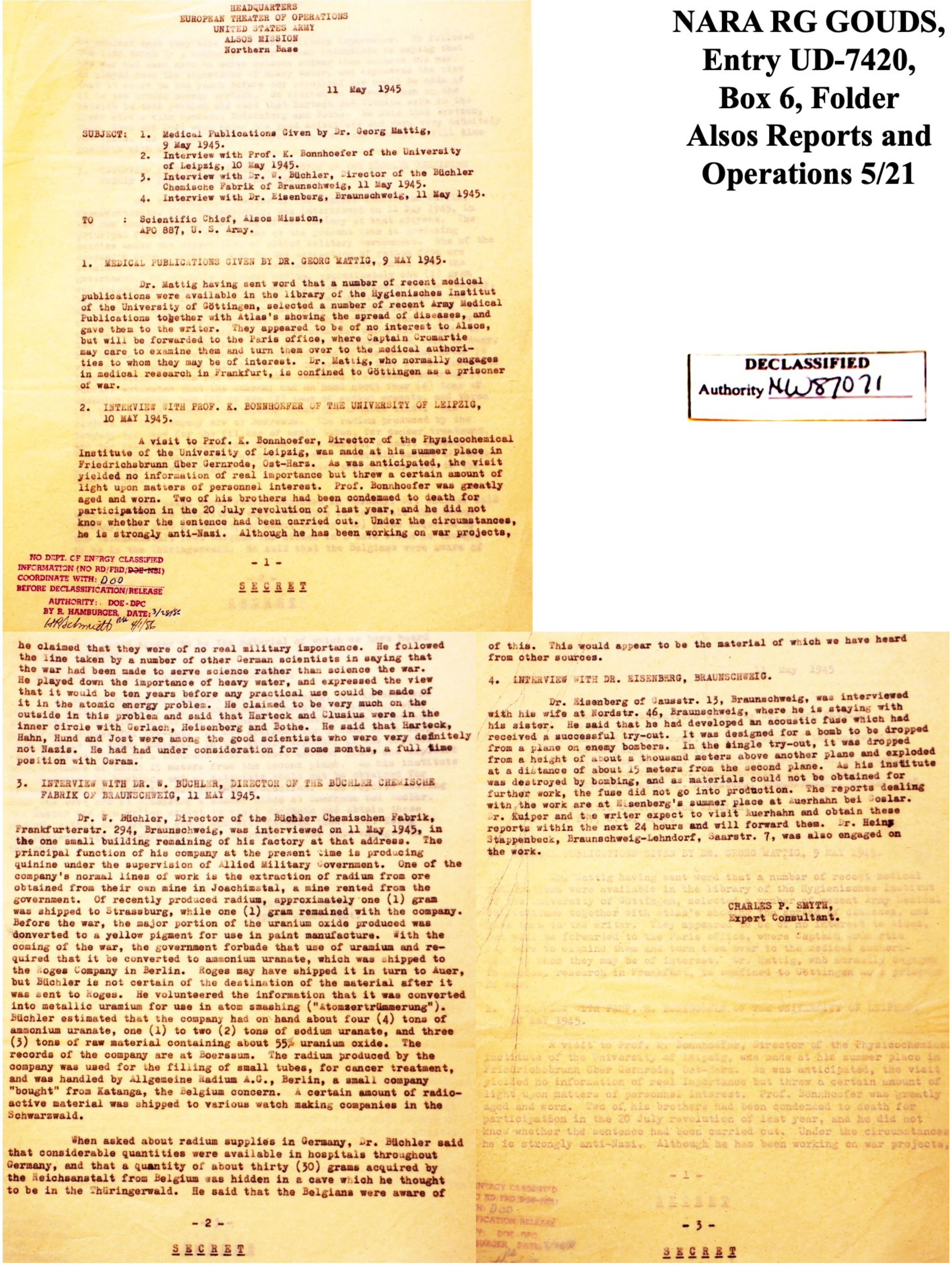
11. From the evidence in (3) and (4) above, it must be recognized that the Russians may be mining only tungsten in localities at which uranium mining has been reported.

Lowenhaupt
H. S. LOWENHAUPT

*Uranium specimens have been reported from all places marked with an asterisk, according the Union Mines bibliographical search.

Figure D.92: H. S. Lowenhaupt. 17 December 1946. SUBJ: Tin and Tungsten Mining in the Erzgebirge [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

NARA RG GOUDS, Entry UD-7420, Box 6, Folder Alsos Reports and Operations 5/21



HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS MISSION
Northern Base

11 May 1945

SUBJECT: 1. Medical Publications Given by Dr. Georg Mattig, 9 May 1945.
2. Interview with Prof. K. Bonnhoefer of the University of Leipzig, 10 May 1945.
3. Interview with Dr. W. Büchler, Director of the Büchler Chemische Fabrik of Braunschweig, 11 May 1945.
4. Interview with Dr. Eisenberg, Braunschweig, 11 May 1945.

TO : Scientific Chief, Alsos Mission,
APO 887, U. S. Army.

1. MEDICAL PUBLICATIONS GIVEN BY DR. GEORG MATTIG, 9 MAY 1945.

Dr. Mattig having sent word that a number of recent medical publications were available in the library of the Hygienisches Institut of the University of Göttingen, selected a number of recent Army Medical Publications together with Atlas's showing the spread of diseases, and gave them to the writer. They appeared to be of no interest to Alsos, but will be forwarded to the Paris office, where Captain Cromartie may care to examine them and turn them over to the medical authorities to whom they may be of interest. Dr. Mattig, who normally engages in medical research in Frankfurt, is confined to Göttingen as a prisoner of war.

2. INTERVIEW WITH PROF. K. BONNHOEFER OF THE UNIVERSITY OF LEIPZIG, 10 MAY 1945.

A visit to Prof. K. Bonnhoefer, Director of the Physicochemical Institute of the University of Leipzig, was made at his summer place in Friedrichsbrunn über Gernrode, Ost-Harz. As was anticipated, the visit yielded no information of real importance but threw a certain amount of light upon matters of personnel interest. Prof. Bonnhoefer was greatly aged and worn. Two of his brothers had been condemmed to death for participation in the 20 July revolution of last year, and he did not know whether the sentence had been carried out. Under the circumstances, he is strongly anti-Nazi. Although he has been working on war projects,

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he claimed that they were of no real military importance. He followed the line taken by a number of other German scientists in saying that the war had been made to serve science rather than science the war. He played down the importance of heavy water, and expressed the view that it would be ten years before any practical use could be made of it in the atomic energy problem. He claimed to be very much on the outside in this problem and said that Harteck and Clusius were in the inner circle with Gerlach, Heisenberg and Bothe. He said that Harteck, Hahn, Hund and Jost were among the good scientists who were very definitely not Nazis. He had had under consideration for some months, a full time position with Osram.

3. INTERVIEW WITH DR. W. BÜCHLER, DIRECTOR OF THE BÜCHLER CHEMISCHE FABRIK OF BRAUNSCHWEIG, 11 MAY 1945.

Dr. W. Büchler, Director of the Büchler Chemischen Fabrik, Frankfurterstr. 294, Braunschweig, was interviewed on 11 May 1945, in the one small building remaining of his factory at that address. The principal function of his company at the present time is producing quinine under the supervision of Allied Military Government. One of the company's normal lines of work is the extraction of radium from ore obtained from their own mine in Joachimstal, a mine rented from the government. Of recently produced radium, approximately one (1) gram was shipped to Strassburg, while one (1) gram remained with the company. Before the war, the major portion of the uranium oxide produced was donverted to a yellow pigment for use in paint manufacture. With the coming of the war, the government forbade that use of uramium and required that it be converted to ammonium uranate, which was shipped to the Roges Company in Berlin. Roges may have shipped it in turn to Auer, but Büchler is not certain of the destination of the material after it was sent to Roges. He volunteered the information that it was converted into metallic uramium for use in atom smashing ("Atomzertrümmerung"). Büchler estimated that the company had on hand about four (4) tons of ammonium uranate, one (1) to two (2) tons of sodium uranate, and three (3) tons of raw material containing about 55% uranium oxide. The records of the company are at Boerssum. The radium produced by the company was used for the filling of small tubes, for cancer treatment, and was handled by Allgemeine Radium A.G., Berlin, a small company "bought" from Katanga, the Belgium concern. A certain amount of radioactive material was shipped to various watch making companies in the Schwarzwald.

When asked about radium supplies in Germany, Dr. Büchler said that considerable quantities were available in hospitals throughout Germany, and that a quantity of about thirty (30) grams acquired by the Reichsanstalt from Belgium was hidden in a cave which he thought to be in the Thüringerwald. He said that the Belgians were aware of

- 2 -

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of this. This would appear to be the material of which we have heard from other sources.

4. INTERVIEW WITH DR. EISENBERG, BRAUNSCHWEIG.

Dr. Eisenberg of Gausstr. 13, Braunschweig, was interviewed with his wife at Nordstr. 46, Braunschweig, where he is staying with his sister. He said that he had developed an acoustic fuse which had received a successful try-out. It was designed for a bomb to be dropped from a plane on enemy bombers. In the single try-out, it was dropped from a height of about a thousand meters above another plane and exploded at a distance of about 15 meters from the second plane. As his institute was destroyed by bombing, and as materials could not be obtained for further work, the fuse did not go into production. The reports dealing with the work are at Eisenberg's summer place at Auerhahn bei Goslar. Dr. Kuiper and the writer expect to visit Auerhahn and obtain these reports within the next 24 hours and will forward them. Dr. Heinz Stappenbeck, Braunschweig-Lehndorf, Saarstr. 7, was also engaged on the work.

CHARLES P. SMYTH,
Expert Consultant.

- 3 -

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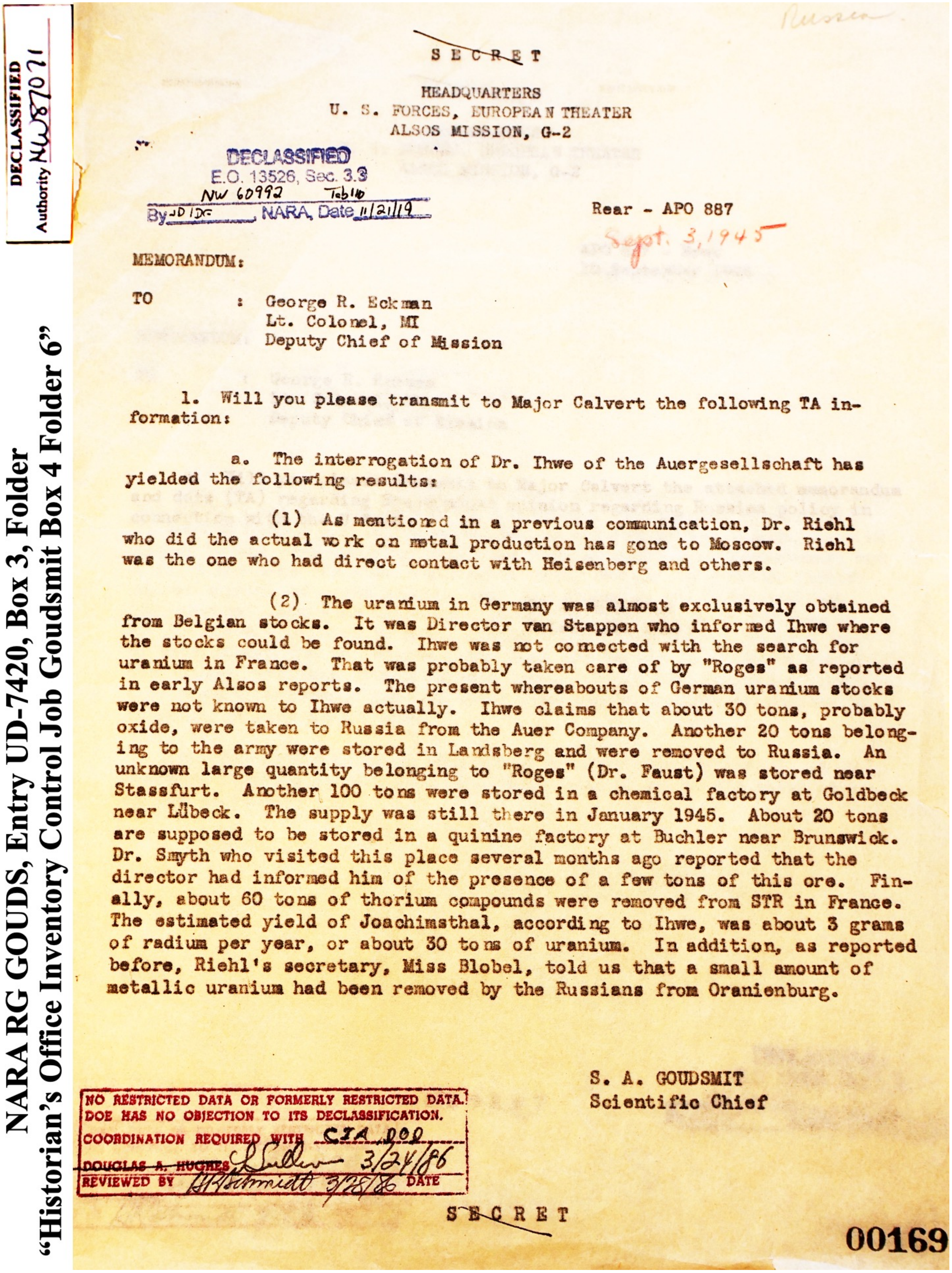
Figure D.93: Charles P. Smyth. 11 May 1945. SUBJECT... 3. Interview with Dr. W. Buchler, Director of the Buchler Chemische Fabrik of Braunschweig, 11 May 1945... [NARA RG GOUDS, Entry UD-7420, Box 6, Folder Alsos Reports and Operations 5/21].



NARA RG GOUDS, Entry UD-7420, Box 3, Folder
"Historian's Office Inventory Control Job Goudsmit Box 4 Folder 6"

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HEADQUARTERS
U. S. FORCES, EUROPEAN THEATER
ALSOS MISSION, G-2

DECLASSIFIED
E.O. 13526, Sec. 3.3
NW 60992 Tab 16
By JD/DC, NARA, Date 11/21/19

Rear - APO 887
Sept. 3, 1945

MEMORANDUM:

TO : George R. Eckman
Lt. Colonel, MI
Deputy Chief of Mission

1. Will you please transmit to Major Calvert the following TA information:

a. The interrogation of Dr. Ihwe of the Auergesellschaft has yielded the following results:

(1) As mentioned in a previous communication, Dr. Riehl who did the actual work on metal production has gone to Moscow. Riehl was the one who had direct contact with Heisenberg and others.

(2) The uranium in Germany was almost exclusively obtained from Belgian stocks. It was Director van Stappen who informed Ihwe where the stocks could be found. Ihwe was not connected with the search for uranium in France. That was probably taken care of by "Roges" as reported in early Alsos reports. The present whereabouts of German uranium stocks were not known to Ihwe actually. Ihwe claims that about 30 tons, probably oxide, were taken to Russia from the Auer Company. Another 20 tons belonging to the army were stored in Landsberg and were removed to Russia. An unknown large quantity belonging to "Roges" (Dr. Faust) was stored near Stassfurt. Another 100 tons were stored in a chemical factory at Goldbeck near Lübeck. The supply was still there in January 1945. About 20 tons are supposed to be stored in a quinine factory at Buchler near Brunswick. Dr. Smyth who visited this place several months ago reported that the director had informed him of the presence of a few tons of this ore. Finally, about 60 tons of thorium compounds were removed from STR in France. The estimated yield of Joachimsthal, according to Ihwe, was about 3 grams of radium per year, or about 30 tons of uranium. In addition, as reported before, Riehl's secretary, Miss Blobel, told us that a small amount of metallic uranium had been removed by the Russians from Oranienburg.

S. A. GOUDSMIT
Scientific Chief

NO RESTRICTED DATA OR FORMERLY RESTRICTED DATA.
DOE HAS NO OBJECTION TO ITS DECLASSIFICATION.
COORDINATION REQUIRED WITH CIA DOD
~~DOUGLAS A. HUGHES~~ 3/24/86
REVIEWED BY H H Schmidt 3/28/86 DATE

~~SECRET~~

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Figure D.94: Samuel Goudsmit to George R. Eckman. 3 September 1945 [NARA RG GOUDS, Entry UD-7420, Box 3, Folder "Historian's Office Inventory Control Job Goudsmit Box 4 Folder 6"]. "About 20 tons are supposed to be stored in a quinine factory at Buchler near Brunswick."

Sabine Elisabeth Gollmann. 1994. *Die Radium- und Uranabteilung der Treibacher Chemischen Werke: Unter Berücksichtigung des deutschen Atombombenprojektes während des Zweiten Weltkrieges.* Ph.D. thesis. Graz: University of Graz. p. 128.

Der Anschluß an das Dritte Reich wurde seitens der Treibacher Geschäftsleitung sehr positiv aufgenommen, da man sich eine Verbesserung der wirtschaftlichen Lage erhoffte. 1939 wurden die TCW Mitglied der St. Joachimsthaler Bergbaugesellschaft m. b. H. und bezogen dadurch den größten Teil der Rohstoffe aus St. Joachimsthal (Böhmen). Das Kärntner Unternehmen erhielt von dieser wichtigen Erzlagerstätte auch Uranpechblende und es wurde 1940 innerhalb der Radiumabteilung ein eigener Bereich für Uran eingerichtet. Ein Gesellschaftspartner der JOBERG war die Auergesellschaft in Berlin, welche eng mit dem deutschen Atombombenprojekt im Zweiten Weltkrieg verknüpft war. Die Berliner Firma ließ während des Krieges ihre Erzkonzentrate aus St. Joachimsthal in Treibach umarbeiten. Daher sind Beziehungen der TCW, wenn auch über Dritte, zum Kernenergieprojekt sehr wahrscheinlich. Mehrere Indizien sprechen dafür, absolute Beweise sind allerdings nicht mehr auffindbar. Wichtig ist sicherlich, daß ab Anfang der vierziger Jahre radioaktive Substanzen nur mehr für Rüstungszwecke verwendet werden durften. So wurde Radium ab 1942 nur mehr für die Leuchtfarbenherstellung innerhalb der Rüstungsindustrie genutzt.

Im Mai 1945 wurde Kärnten von englischen Truppen besetzt. Die Treibacher Werke wurden als Deutsches Eigentum eingestuft, da ein beträchtlicher Aktienanteil im Besitz eines deutschen Unternehmens gewesen ist. Das gesamte Mesothor und Radiothor wurde von den Engländer beschlagnahmt und später entschädigt. Auf Grund des dadurch entstandenen Rohstoffmangels wurde die Radium- und Uranabteilung 1946 stillgelegt.

The [Austrian] Anschluss by the Third Reich was very positively received by the Treibacher management, because they hoped for an improvement of the economic situation. In 1939 the TCW became a member of the St. Joachimsthaler Bergbaugesellschaft m. b. H. and thus obtained most of the raw materials from St. Joachimsthal (Bohemia). The Carinthian company also received uranium pitch blends from this important ore deposit and in 1940 a separate uranium division was set up within the radium department. One of JOBERG's partners was the Auergesellschaft in Berlin, which was closely linked to the German atomic bomb project in the Second World War. During the war, the Berlin company had its ore concentrates from St. Joachimsthal reworked in Treibach. Therefore, TCW's relations to the nuclear energy project, albeit via third parties, are very probable. There are several indications, but absolute evidence is no longer to be found. It is certainly important to note that from the beginning of the forties radioactive substances were only allowed to be used for armament purposes. From 1942 onwards, radium was only used for the production of fluorescent paints within the armaments industry.

In May 1945 Carinthia was occupied by British troops. The Treibacher Werke were classified as German property, as a considerable share was owned by a German company. All of the mesothorium and radiothorium was confiscated by the British and later compensated. Due to the resulting shortage of raw materials, the radium and uranium division was shut down in 1946.

[Treibacher Chemical Works in Austria had very similar uranium- and thorium-processing capabilities to Auergesellschaft in Germany, yet historically it has been much less well known and much less studied. How much work could Treibacher Chemical Works have done for a nuclear weapons program during the war? From how many different sources did Treibacher receive uranium and thorium ore? How much uranium and thorium did Treibacher process during the war? Where did Treibacher send the uranium and thorium that it processed?]

Report on Treibacher Chemical Works AG. 10 October 1945. [CIOS ER 343, AFHRA A1008 frames 0794–0797]

[...]

Firm representatives seen:

Dr. Harmann Auer von Welsbach
Dr. Techn. Fritz Gemillscheg
Dr. Karl Buche
Dr. Haas (?) (in charge of radium plant)

1. This firm was founded in its present form by the great chemist Auer von Welsbach who invented the Thorium oxide gas mantle, “Mischmetall” lighter flint metal and did a great deal of research work on “Rare Earth” group of elements.

This is a firm of first class importance as it is one of the very few firms in the world which produces radium.

2. Principal Products.

(a) Radium Salts

Before the war this firm produced on an average of 8 or 9 grammes of Radium (as Radium Bromide) per year. This is a very large output. The radium was produced mostly on British orders from Pitchblende ore imported from the Congo. During the war they used Pitchblende from Joachimstahl in Czechoslovakia (where it was first discovered) and from Erzgebirge. These sources of supply are now closed, and the firm has not pitchblende in stock. [...]

(b) Mesothorium Salts

This element is even more powerfully radioactive and more dangerous to handle than Radium. It is produced in small quantities.

(c) Uranium Salts

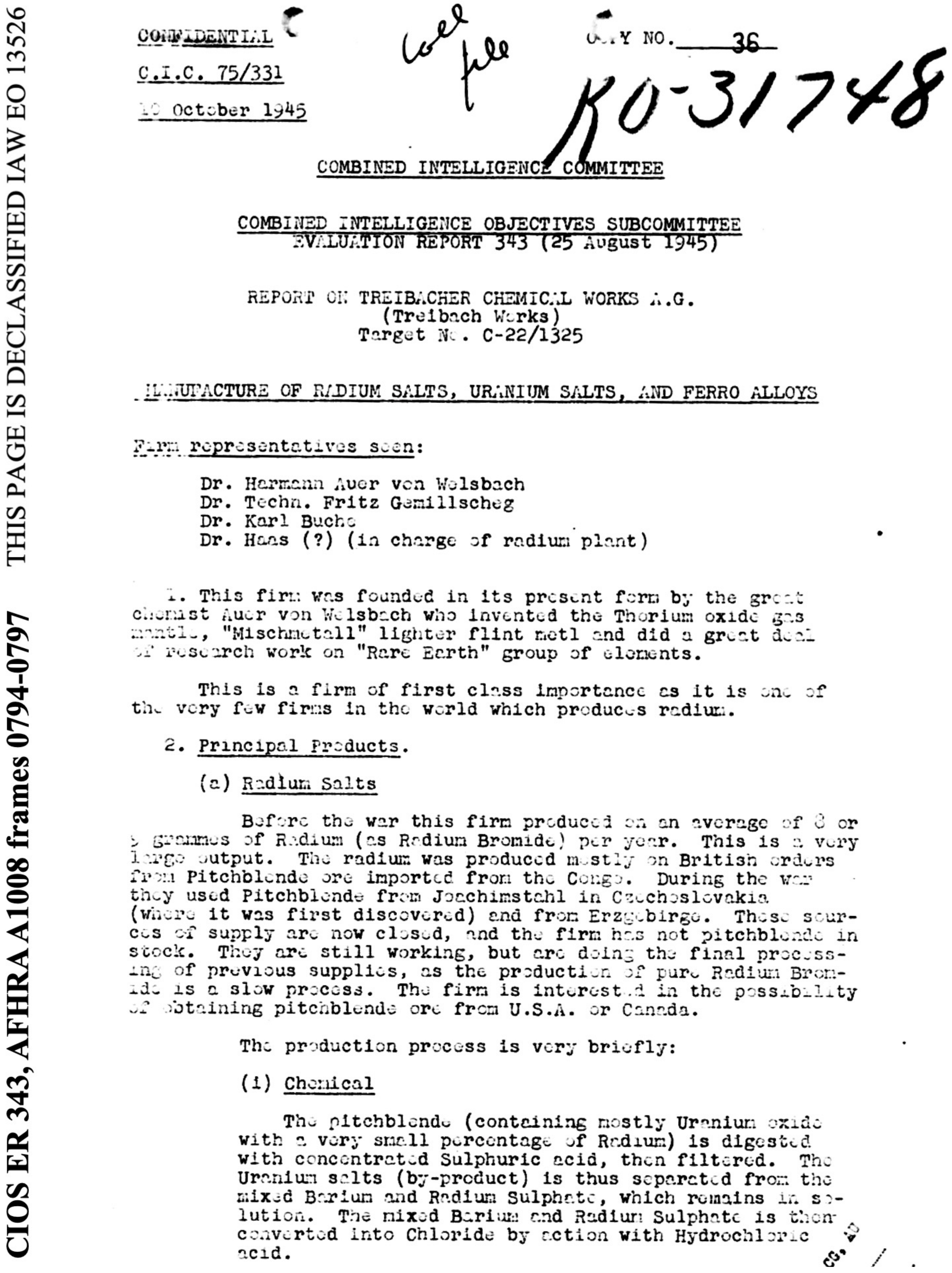
These are used chiefly in the ceramic industry. They are produced as a by-product of the production of Radium from Pitchblende (Pitchblende is really principally an Uranium ore.) [...]

Finally

It is considered that this firm is of first-class importance, with a very highly trained expert staff of chemists and chemical engineers and workpeople. Their most important product being radium and Mesothorium salts, with Uranium salts, lighter flint metal, salts of the “Rare Earth” metals, and Ferro alloys, as their less vitally important products.

Lt. Col. R. Bailey
Major M. W. H. Head

20 June 1945



CIOS ER 343, AFHRA A1008 frames 0794-0797 THIS PAGE IS DECLASSIFIED IAW EO 13526

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C.I.C. 75/331

10 October 1945

Col file

COPY NO. 36

KO-31748

COMBINED INTELLIGENCE COMMITTEE

COMBINED INTELLIGENCE OBJECTIVES SUBCOMMITTEE
EVALUATION REPORT 343 (25 August 1945)

REPORT ON TREIBACHER CHEMICAL WORKS A.G.
(Treibach Works)
Target No. C-22/1325

MANUFACTURE OF RADIUM SALTS, URANIUM SALTS, AND FERRO ALLOYS

Firm representatives seen:

Dr. Harmann Auer von Welsbach
Dr. Techn. Fritz Gemillscheg
Dr. Karl Buche
Dr. Haas (?) (in charge of radium plant)

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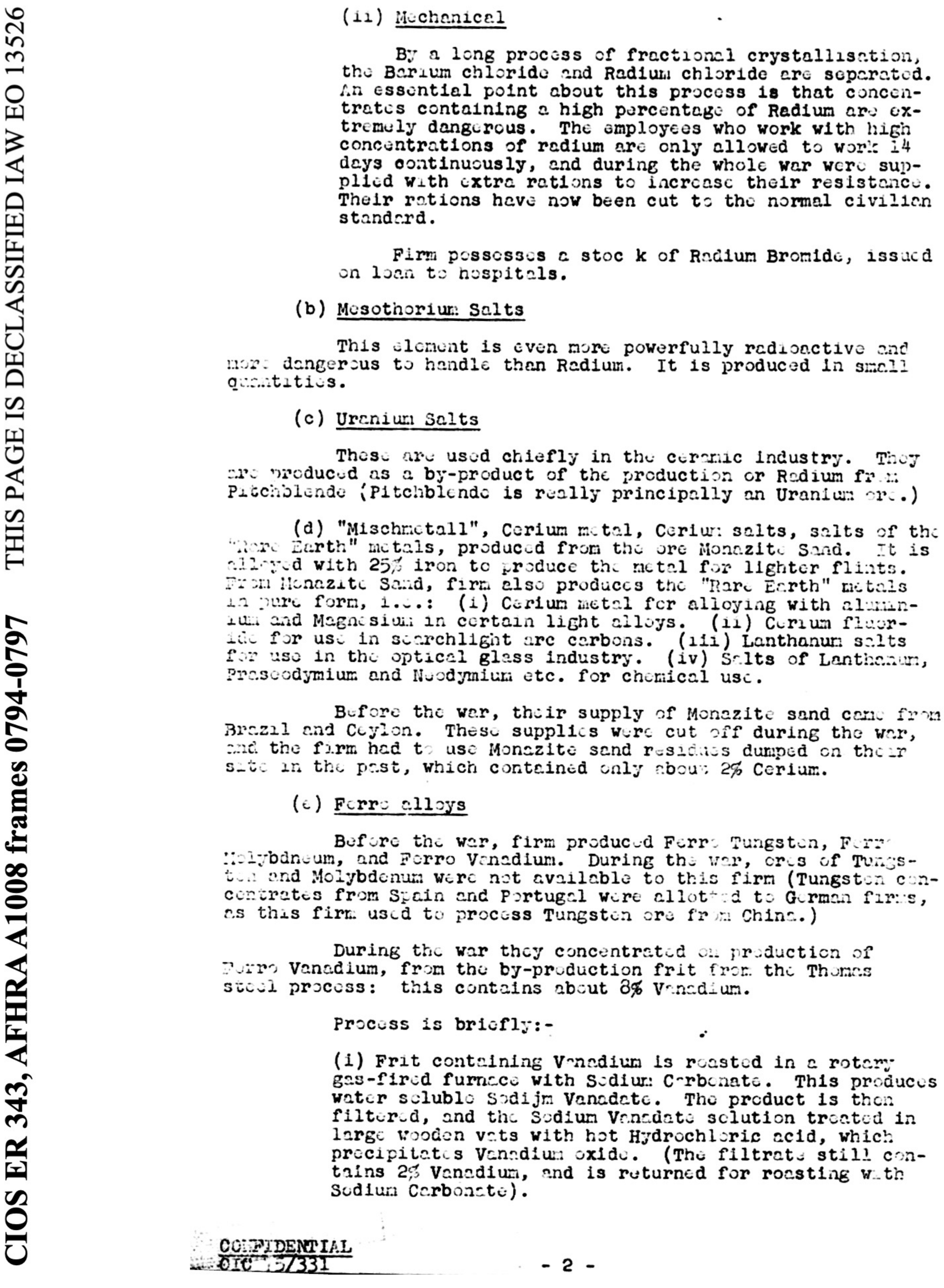
The production process is very briefly:

(i) Chemical

The pitchblende (containing mostly Uranium oxide with a very small percentage of Radium) is digested with concentrated Sulphuric acid, then filtered. The Uranium salts (by-product) is thus separated from the mixed Barium and Radium Sulphate, which remains in solution. The mixed Barium and Radium Sulphate is then converted into Chloride by action with Hydrochloric acid.

Figure D.95: Report on Treibacher Chemical Works AG. 10 October 1945 [CIOS ER 343, AFHRA A1008 frames 0794–0797].



CIOS ER 343, AFHRA A1008 frames 0794-0797 THIS PAGE IS DECLASSIFIED IAW EO 13526

(ii) Mechanical

By a long process of fractional crystallisation, the Barium chloride and Radium chloride are separated. An essential point about this process is that concentrates containing a high percentage of Radium are extremely dangerous. The employees who work with high concentrations of radium are only allowed to work 14 days continuously, and during the whole war were supplied with extra rations to increase their resistance. Their rations have now been cut to the normal civilian standard.

Firm possesses a stoc k of Radium Bromide, issued on loan to hospitals.

(b) Mesothorium Salts

This element is even more powerfully radioactive and more dangerous to handle than Radium. It is produced in small quantities.

(c) Uranium Salts

These are used chiefly in the ceramic industry. They are produced as a by-product of the production or Radium from Pitchblende (Pitchblende is really principally an Uranium ore.)

(d) "Mischmetall", Cerium metal, Cerium salts, salts of the "Rare Earth" metals, produced from the ore Monazite Sand. It is alloyed with 25% iron to produce the metal for lighter flints. From Monazite Sand, firm also produces the "Rare Earth" metals in pure form, i.e.: (i) Cerium metal for alloying with aluminium and Magnesium in certain light alloys. (ii) Cerium fluoride for use in searchlight arc carbons. (iii) Lanthanum salts for use in the optical glass industry. (iv) Salts of Lanthanum, Praseodymium and Neodymium etc. for chemical use.

Before the war, their supply of Monazite sand came from Brazil and Ceylon. These supplies were cut off during the war, and the firm had to use Monazite sand residues dumped on their site in the past, which contained only about 2% Cerium.

(e) Ferro alloys

Before the war, firm produced Ferro Tungsten, Ferro Molybdneum, and Ferro Vanadium. During the war, ores of Tungsten and Molybdenum were not available to this firm (Tungsten concentrates from Spain and Portugal were allotted to German firms, as this firm used to process Tungsten ore from China.)

During the war they concentrated on production of Ferro Vanadium, from the by-production frit from the Thomas steel process: this contains about 8% Vanadium.

Process is briefly:-

(i) Frit containing Vanadium is roasted in a rotary gas-fired furnace with Sodium Carbonate. This produces water soluble Sodijm Vanadate. The product is then filtered, and the Sodium Vanadate solution treated in large wooden vats with hot Hydrochloric acid, which precipitates Vanadium oxide. (The filtrate still contains 2% Vanadium, and is returned for roasting with Sodium Carbonate).

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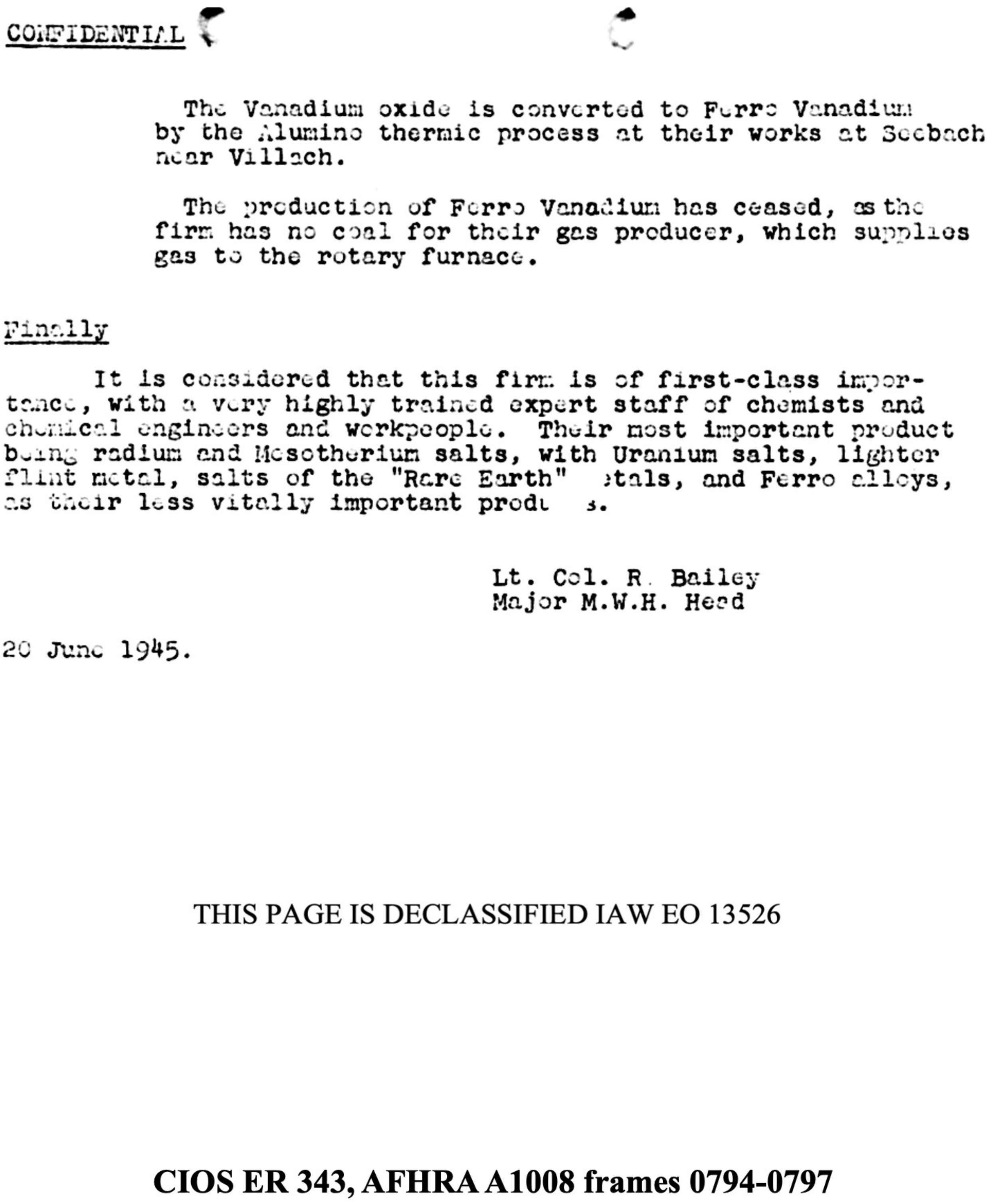
- 2 -

Figure D.96: Report on Treibacher Chemical Works AG. 10 October 1945 [CIOS ER 343, AFHRA A1008 frames 0794–0797].



CONFIDENTIAL

The Vanadium oxide is converted to Ferro Vanadium by the Alumino thermic process at their works at Seebach near Villach.

The production of Ferro Vanadium has ceased, as the firm has no coal for their gas producer, which supplies gas to the rotary furnace.

Finally

It is considered that this firm is of first-class importance, with a very highly trained expert staff of chemists and chemical engineers and workpeople. Their most important product being radium and Mesotherium salts, with Uranium salts, lighter flint metal, salts of the "Rare Earth" metals, and Ferro alloys, as their less vitally important products.

Lt. Col. R. Bailey
Major M.W.H. Head

20 June 1945.

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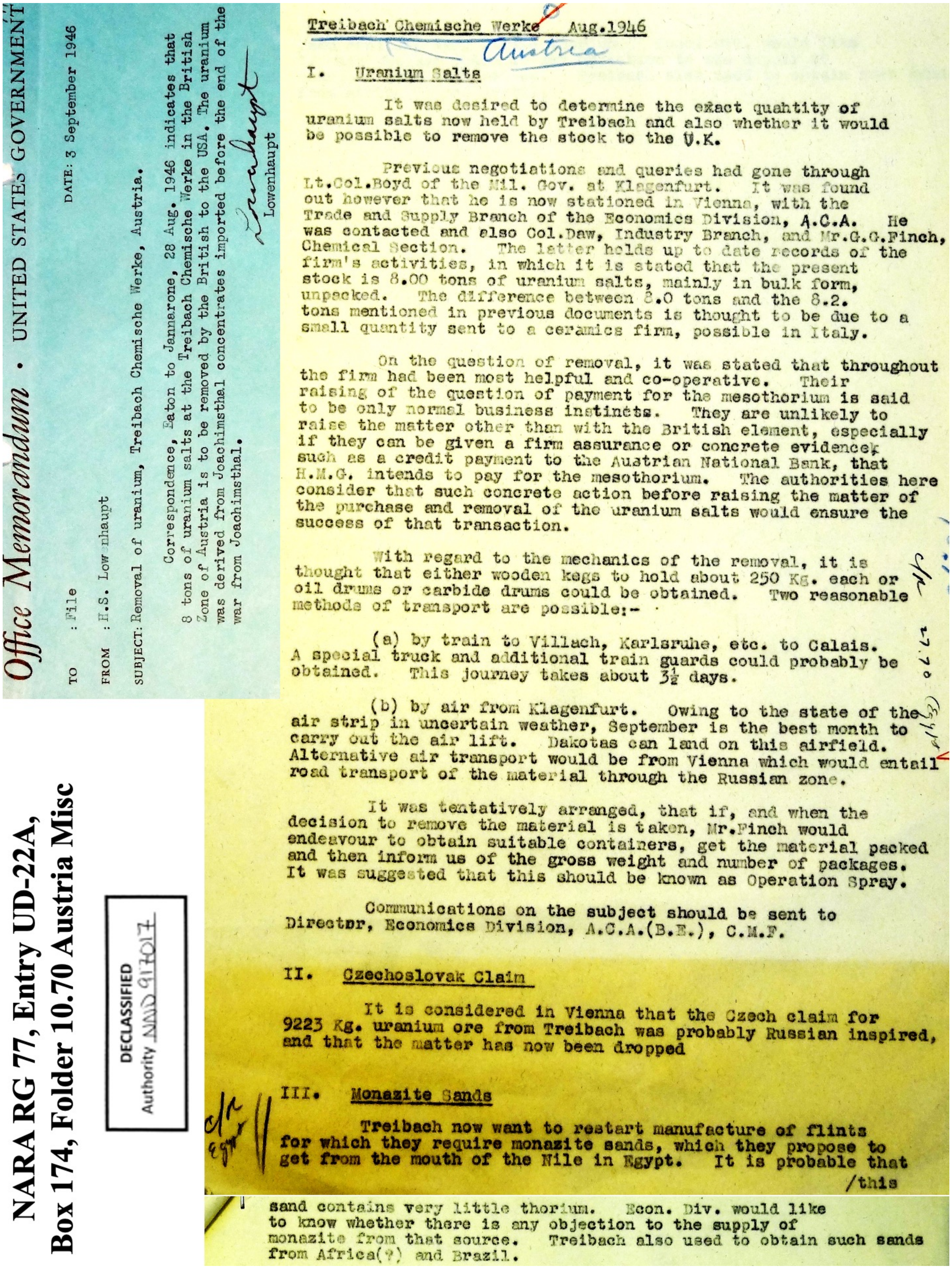
CIOS ER 343, AFHRA A1008 frames 0794-0797

Figure D.97: Report on Treibacher Chemical Works AG. 10 October 1945 [CIOS ER 343, AFHRA A1008 frames 0794–0797].



Office Memorandum • UNITED STATES GOVERNMENT

TO : File DATE: 3 September 1946

FROM : H.S. Lowenhaupt

SUBJECT: Removal of uranium, Treibach Chemische Werke, Austria.

Correspondence, Eaton to Jannarone, 28 Aug. 1946 indicates that 8 tons of uranium salts at the Treibach Chemische Werke in the British Zone of Austria is to be removed by the British to the USA. The uranium was derived from Joachimsthal concentrates imported before the end of the war from Joachimsthal.

Lowenhaupt
Lowenhaupt

NARA RG 77, Entry UD-22A,
Box 174, Folder 10.70 Austria Misc

DECLASSIFIED
Authority NND 917017

Treibach Chemische Werke Aug.1946
Austria

I. Uranium Salts

It was desired to determine the exact quantity of uranium salts now held by Treibach and also whether it would be possible to remove the stock to the U.K.

Previous negotiations and queries had gone through Lt.Col.Boyd of the Mil. Gov. at Klagenfurt. It was found out however that he is now stationed in Vienna, with the Trade and Supply Branch of the Economics Division, A.C.A. He was contacted and also Col.Daw, Industry Branch, and Mr.G.G.Finch, Chemical Section. The latter holds up to date records of the firm's activities, in which it is stated that the present stock is 8.00 tons of uranium salts, mainly in bulk form, unpacked. The difference between 8.0 tons and the 8.2. tons mentioned in previous documents is thought to be due to a small quantity sent to a ceramics firm, possible in Italy.

On the question of removal, it was stated that throughout the firm had been most helpful and co-operative. Their raising of the question of payment for the mesothorium is said to be only normal business instincts. They are unlikely to raise the matter other than with the British element, especially if they can be given a firm assurance or concrete evidence, such as a credit payment to the Austrian National Bank, that H.M.G. intends to pay for the mesothorium. The authorities here consider that such concrete action before raising the matter of the purchase and removal of the uranium salts would ensure the success of that transaction.

With regard to the mechanics of the removal, it is thought that either wooden kegs to hold about 250 Kg. each or oil drums or carbide drums could be obtained. Two reasonable methods of transport are possible:- C/r

(a) by train to Villach, Karlsruhe, etc. to Calais. A special truck and additional train guards could probably be obtained. This journey takes about 3½ days. 10.70

(b) by air from Klagenfurt. Owing to the state of the air strip in uncertain weather, September is the best month to carry out the air lift. Dakotas can land on this airfield. Alternative air transport would be from Vienna which would entail road transport of the material through the Russian zone. (Egypt)

It was tentatively arranged, that if, and when the decision to remove the material is taken, Mr.Finch would endeavour to obtain suitable containers, get the material packed and then inform us of the gross weight and number of packages. It was suggested that this should be known as Operation Spray.

Communications on the subject should be sent to Director, Economics Division, A.C.A.(B.E.), C.M.F.

II. Czechoslovak Claim

It is considered in Vienna that the Czech claim for 9223 Kg. uranium ore from Treibach was probably Russian inspired, and that the matter has now been dropped

C/r Egypt

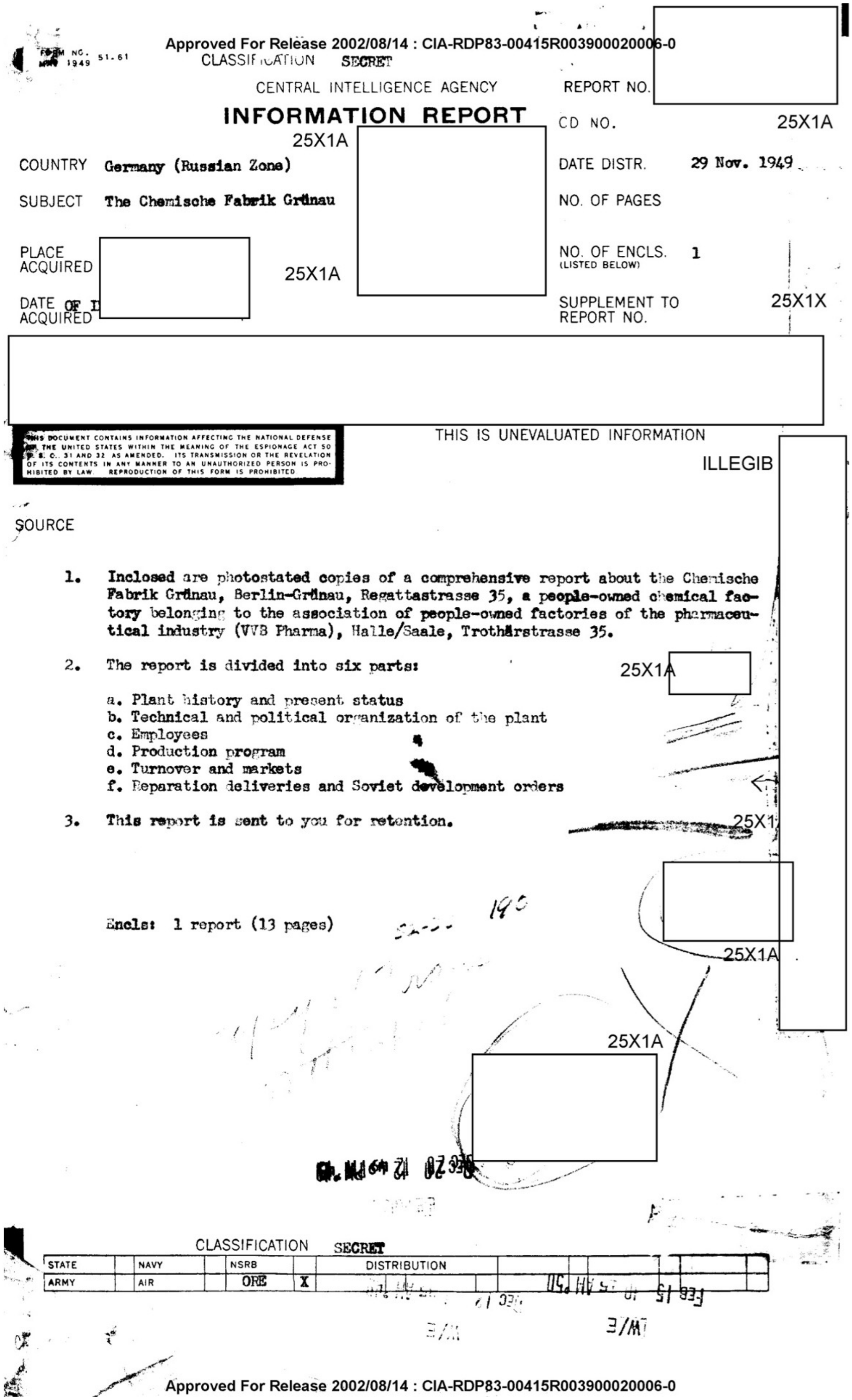
III. Monazite Sands

Treibach now want to restart manufacture of flints for which they require monazite sands, which they propose to get from the mouth of the Nile in Egypt. It is probable that /this

sand contains very little thorium. Econ. Div. would like to know whether there is any objection to the supply of monazite from that source. Treibach also used to obtain such sands from Africa(?) and Brazil.

Figure D.98: H. S. Lowenhaupt. 3 September 1946. SUBJECT: Removal of uranium, Treibach Chemische Werke, Austria [NARA RG 77, Entry UD-22A, Box 174, Folder 10.70 Austria Misc].

https://www.cia.gov/readingroom/document/cia-rdp83-00415r003900020006-0



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FORM NO. 51-61
1949

CLASSIFICATION **SECRET**

CENTRAL INTELLIGENCE AGENCY

INFORMATION REPORT

REPORT NO. [redacted]

CD NO. 25X1A

25X1A [redacted]

COUNTRY **Germany (Russian Zone)**

SUBJECT **The Chemische Fabrik Grünau**

PLACE ACQUIRED [redacted] 25X1A

DATE OF I ACQUIRED

DATE DISTR. **29 Nov. 1949**

NO. OF PAGES

NO. OF ENCLS. (LISTED BELOW) 1

SUPPLEMENT TO REPORT NO. 25X1X

[redacted]

THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE ACT 50 U. S. C. 31 AND 32 AS AMENDED. ITS TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW. REPRODUCTION OF THIS FORM IS PROHIBITED.

THIS IS UNEVALUATED INFORMATION

ILLEGIB [redacted]

SOURCE

1. Inclosed are photostated copies of a comprehensive report about the Chemische Fabrik Grünau, Berlin-Grünau, Regattastrasse 35, a people-owned chemical factory belonging to the association of people-owned factories of the pharmaceutical industry (VVB Pharma), Halle/Saale, Trothärstrasse 35.

2. The report is divided into six parts: 25X1A [redacted]

   a. Plant history and present status
   b. Technical and political organization of the plant
   c. Employees
   d. Production program
   e. Turnover and markets
   f. Reparation deliveries and Soviet development orders

3. This report is sent to you for retention. 25X1

[redacted] 25X1A

Encls: 1 report (13 pages)

25X1A [redacted]

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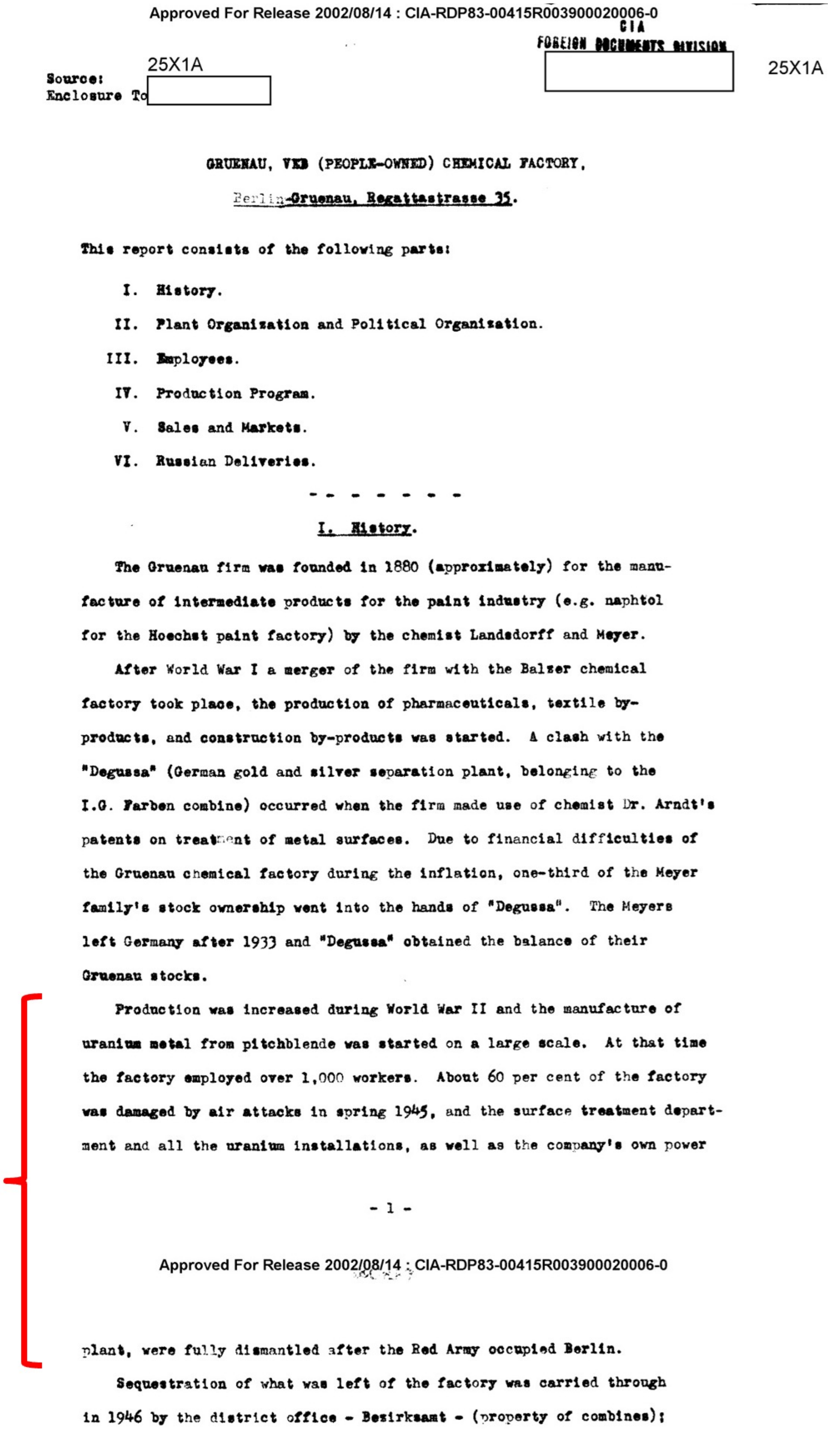
Figure D.99: CIA Information Report: The Chemische Fabrik Grünau. 29 November 1949 [https://www.cia.gov/readingroom/document/cia-rdp83-00415r003900020006-0]. “Production was increased during World War II and the manufacture of uranium metal from pitchblende was started on a large scale. At that time the factory employed over 1,000 workers. About 60 per cent of the factory was damaged by air attacks in spring 1945, and... all the uranium installations, as well as the company’s own power plant, were fully dismantled after the Red Army occupied Berlin.”

https://www.cia.gov/readingroom/document/cia-rdp83-00415r003900020006-0



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CIA
FOREIGN DOCUMENTS DIVISION

25X1A

25X1A

Source:
Enclosure To

GRUENAU, VEB (PEOPLE-OWNED) CHEMICAL FACTORY,

Berlin-Gruenau, Regattastrasse 35.

This report consists of the following parts:

I. History.
II. Plant Organization and Political Organization.
III. Employees.
IV. Production Program.
V. Sales and Markets.
VI. Russian Deliveries.

- - - - - - -

I. History.

The Gruenau firm was founded in 1880 (approximately) for the manufacture of intermediate products for the paint industry (e.g. naphtol for the Hoechst paint factory) by the chemist Landsdorff and Meyer.

After World War I a merger of the firm with the Balzer chemical factory took place, the production of pharmaceuticals, textile by-products, and construction by-products was started. A clash with the "Degussa" (German gold and silver separation plant, belonging to the I.G. Farben combine) occurred when the firm made use of chemist Dr. Arndt's patents on treatment of metal surfaces. Due to financial difficulties of the Gruenau chemical factory during the inflation, one-third of the Meyer family's stock ownership went into the hands of "Degussa". The Meyers left Germany after 1933 and "Degussa" obtained the balance of their Gruenau stocks.

Production was increased during World War II and the manufacture of uranium metal from pitchblende was started on a large scale. At that time the factory employed over 1,000 workers. About 60 per cent of the factory was damaged by air attacks in spring 1945, and the surface treatment department and all the uranium installations, as well as the company's own power

- 1 -

Approved For Release 2002/08/14 : CIA-RDP83-00415R003900020006-0

plant, were fully dismantled after the Red Army occupied Berlin.

Sequestration of what was left of the factory was carried through in 1946 by the district office - Bezirksamt - (property of combines);

Figure D.100: CIA Information Report: The Chemische Fabrik Grünau. 29 November 1949 [https://www.cia.gov/readingroom/document/cia-rdp83-00415r003900020006-0]. “Production was increased during World War II and the manufacture of uranium metal from pitchblende was started on a large scale. At that time the factory employed over 1,000 workers. About 60 per cent of the factory was damaged by air attacks in spring 1945, and... all the uranium installations, as well as the company’s own power plant, were fully dismantled after the Red Army occupied Berlin.”

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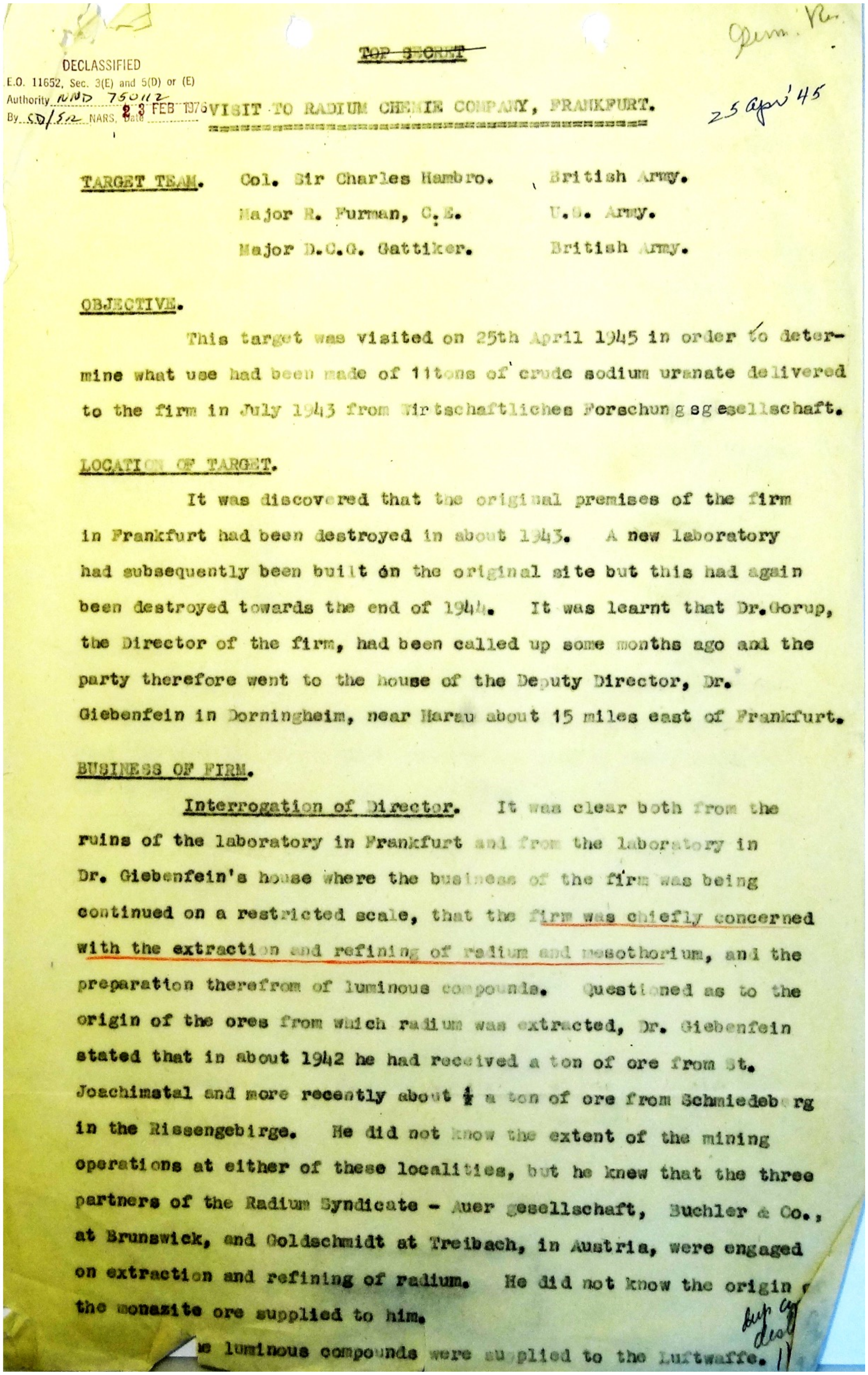
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL



Germ. Re.

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E.O. 11652, Sec. 3(E) and 5(D) or (E)
Authority NND 750112
By CD/SR NARS, Date 23 FEB 1976

VISIT TO RADIUM CHEMIE COMPANY, FRANKFURT.

25 Apr '45

TARGET TEAM.	Col. Sir Charles Hambro.	British Army.
	Major R. Furman, C.E.	U.S. Army.
	Major D.C.G. Gattiker.	British Army.

OBJECTIVE.

This target was visited on 25th April 1945 in order to determine what use had been made of 11 tons of crude sodium uranate delivered to the firm in July 1943 from Wirtschaftliches Forschungsgesellschaft.

LOCATION OF TARGET.

It was discovered that the original premises of the firm in Frankfurt had been destroyed in about 1943. A new laboratory had subsequently been built on the original site but this had again been destroyed towards the end of 1944. It was learnt that Dr.Gorup, the Director of the firm, had been called up some months ago and the party therefore went to the house of the Deputy Director, Dr. Giebenfein in Dorningheim, near Harau about 15 miles east of Frankfurt.

BUSINESS OF FIRM.

Interrogation of Director. It was clear both from the ruins of the laboratory in Frankfurt and from the laboratory in Dr. Giebenfein's house where the business of the firm was being continued on a restricted scale, that the firm was chiefly concerned with the extraction and refining of radium and mesothorium, and the preparation therefrom of luminous compounds. Questioned as to the origin of the ores from which radium was extracted, Dr. Giebenfein stated that in about 1942 he had received a ton of ore from St. Joachimstal and more recently about ½ a ton of ore from Schmiedeberg in the Rissengebirge. He did not know the extent of the mining operations at either of these localities, but he knew that the three partners of the Radium Syndicate - Auer gesellschaft, Buchler & Co., at Brunswick, and Goldschmidt at Treibach, in Austria, were engaged on extraction and refining of radium. He did not know the origin the monazite ore supplied to him.

dup cy dest

e luminous compounds were supplied to the Luftwaffe.

Figure D.101: David C. G. Gattiker. 25 April 1945. Visit to Radium Chemie Company, Frankfurt [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL]

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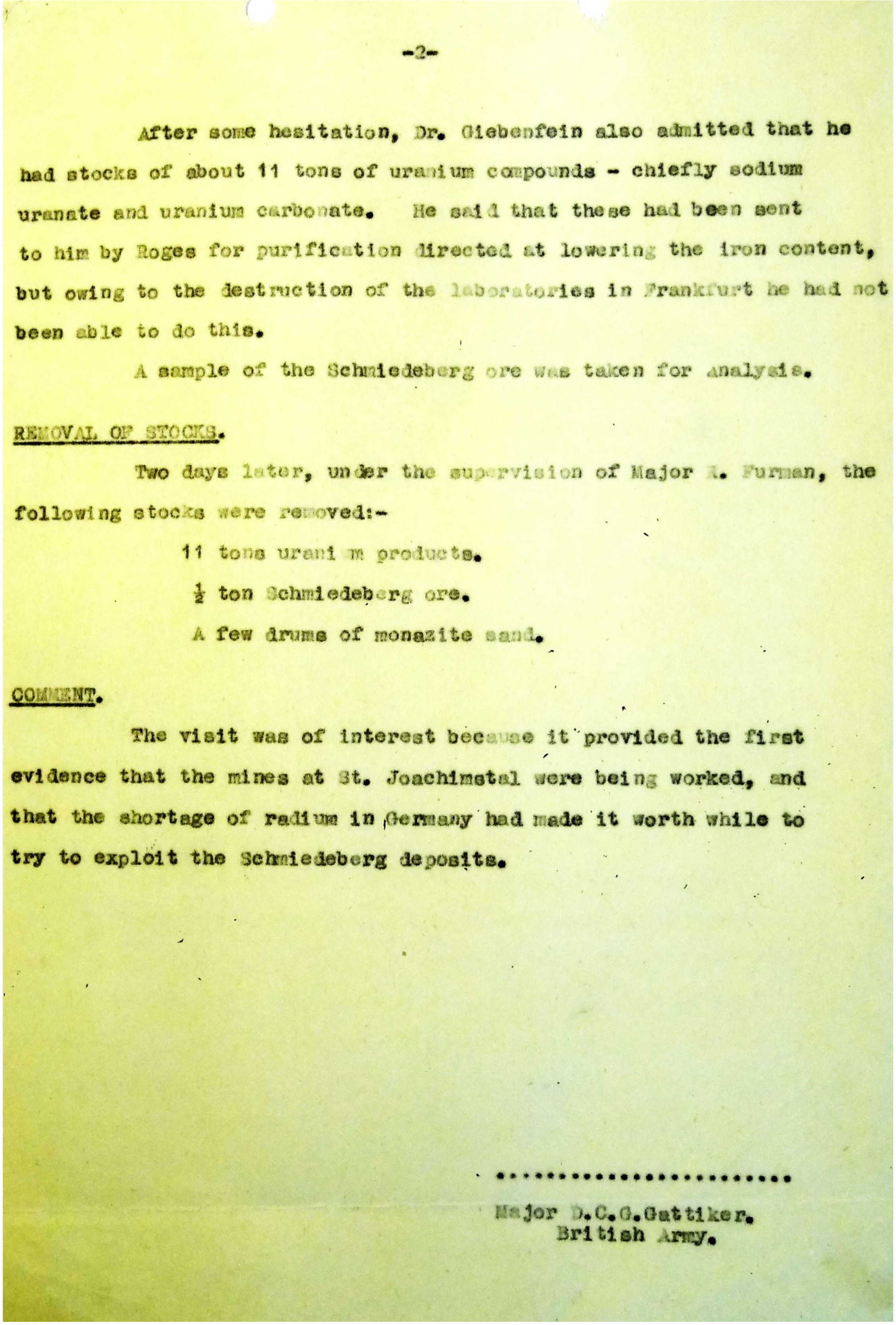

-2-

After some hesitation, Dr. Giebenfein also admitted that he had stocks of about 11 tons of uranium compounds - chiefly sodium uranate and uranium carbonate. He said that these had been sent to him by Roges for purification directed at lowering the iron content, but owing to the destruction of the laboratories in Frankfurt he had not been able to do this.

A sample of the Schmiedeberg ore was taken for analysis.

REMOVAL OF STOCKS.

Two days later, under the supervision of Major A. Furman, the following stocks were removed:-

11 tons uranium products.
½ ton Schmiedeberg ore.
A few drums of monazite sand.

COMMENT.

The visit was of interest because it provided the first evidence that the mines at St. Joachimstal were being worked, and that the shortage of radium in Germany had made it worth while to try to exploit the Schmiedeberg deposits.

....

Major D.C.G.Gattiker.
British Army.

NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL

Figure D.102: David C. G. Gattiker. 25 April 1945. Visit to Radium Chemie Company, Frankfurt [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL]

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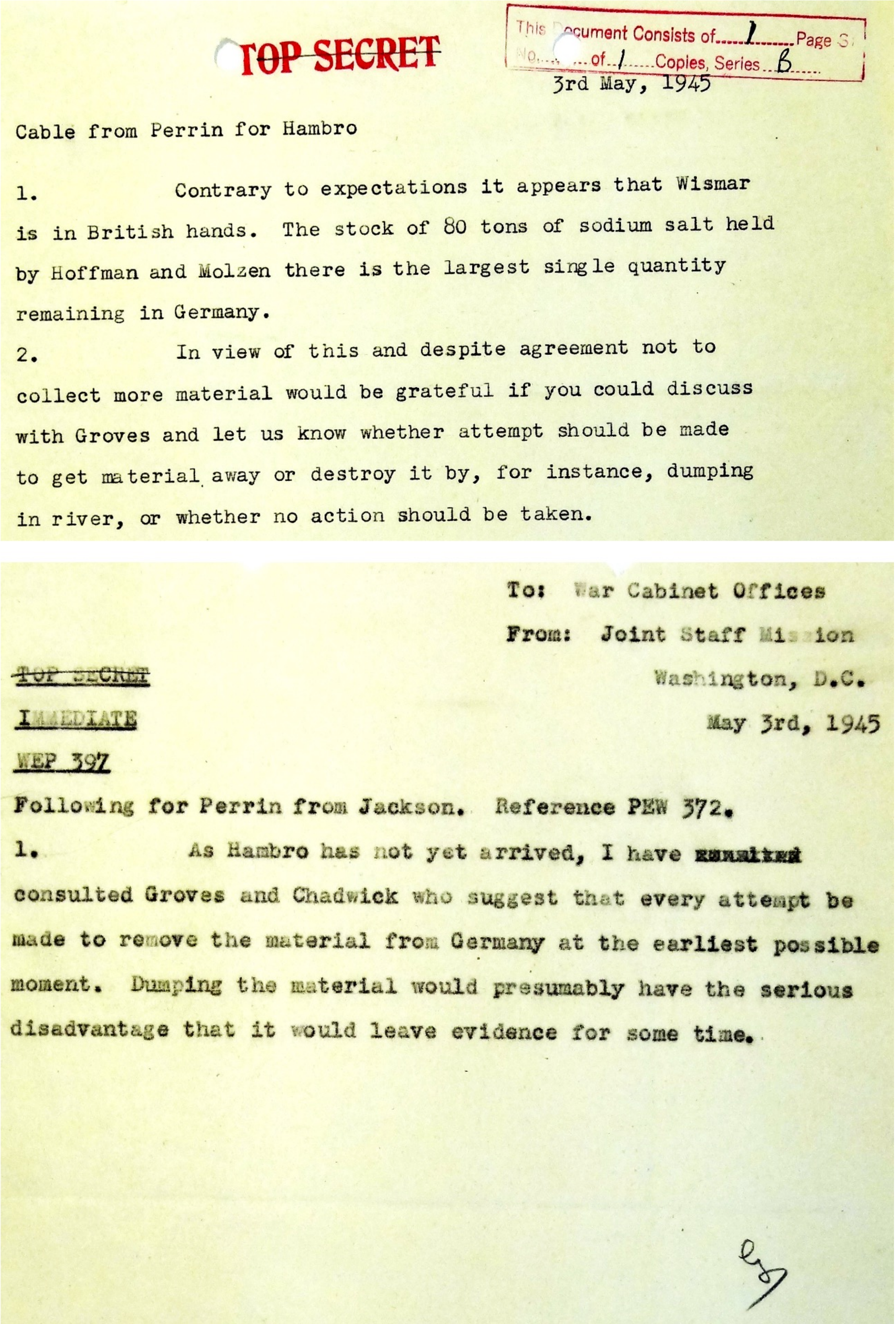
Authority NND 917017



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No. ... of 1 Copies, Series B

3rd May, 1945

Cable from Perrin for Hambro

1. Contrary to expectations it appears that Wismar is in British hands. The stock of 80 tons of sodium salt held by Hoffman and Molzen there is the largest single quantity remaining in Germany.

2. In view of this and despite agreement not to collect more material would be grateful if you could discuss with Groves and let us know whether attempt should be made to get material away or destroy it by, for instance, dumping in river, or whether no action should be taken.

To: War Cabinet Offices
From: Joint Staff Mission
Washington, D.C.
May 3rd, 1945

~~TOP SECRET~~
IMMEDIATE
WEP 397

Following for Perrin from Jackson. Reference PEW 372.

1. As Hambro has not yet arrived, I have consulted Groves and Chadwick who suggest that every attempt be made to remove the material from Germany at the earliest possible moment. Dumping the material would presumably have the serious disadvantage that it would leave evidence for some time.

NARA RG 77, Entry UD-22A, Box 163, Folder Australia

Figure D.103: Top: Michael Perrin to Charles Hambro, 3 May 1945. Bottom: Jackson to Michael Perrin, 3 May 1945 [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

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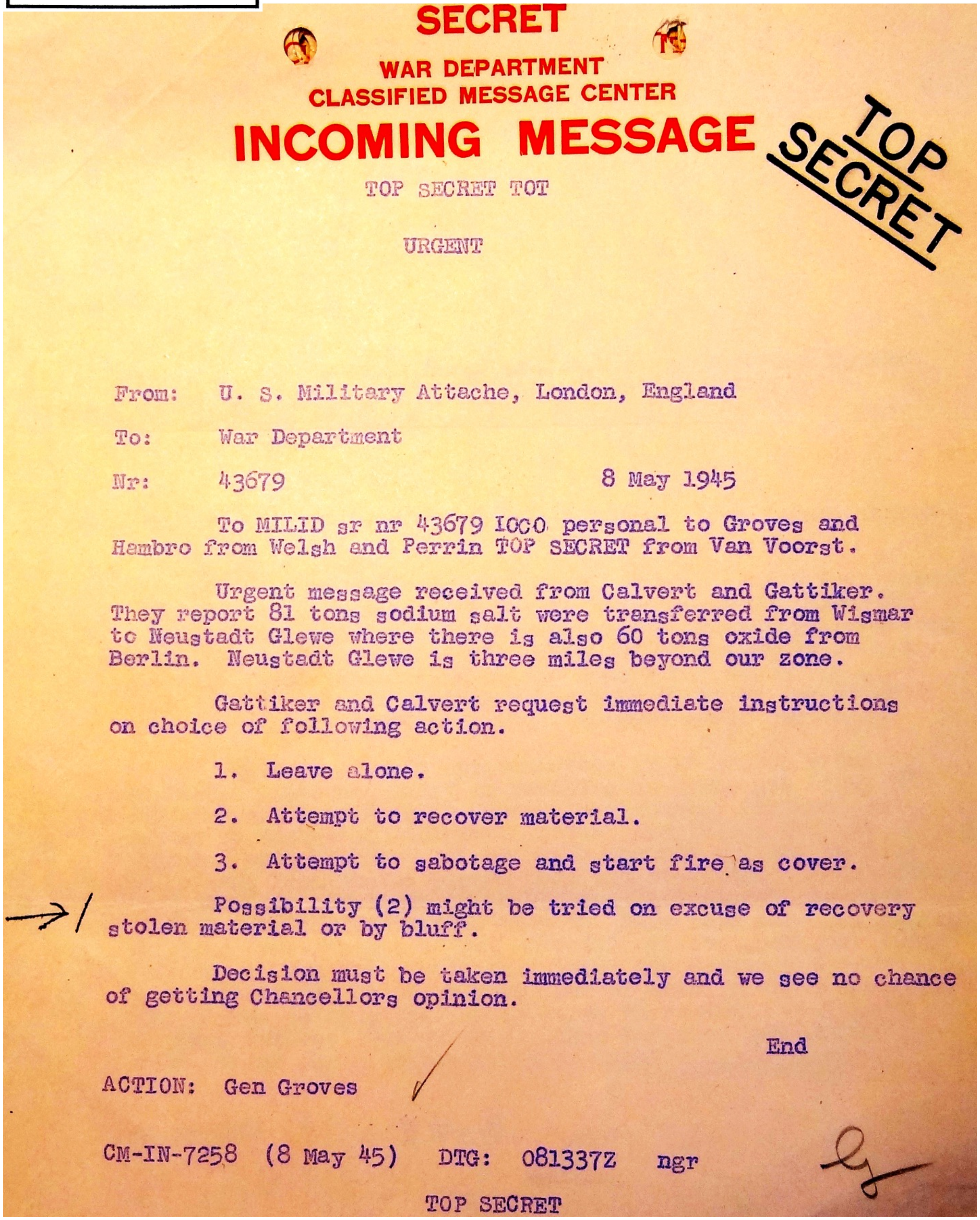
Authority 917017

NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. ’45



SECRET

WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
INCOMING MESSAGE

TOP SECRET

TOP SECRET TOT

URGENT

From: U. S. Military Attache, London, England

To: War Department

Nr: 43679 8 May 1945

To MILID sr nr 43679 ICCO personal to Groves and Hambro from Welsh and Perrin TOP SECRET from Van Voorst.

Urgent message received from Calvert and Gattiker. They report 81 tons sodium salt were transferred from Wismar to Neustadt Glewe where there is also 60 tons oxide from Berlin. Neustadt Glewe is three miles beyond our zone.

Gattiker and Calvert request immediate instructions on choice of following action.

1. Leave alone.
2. Attempt to recover material.
3. Attempt to sabotage and start fire as cover.

→ Possibility (2) might be tried on excuse of recovery stolen material or by bluff.

Decision must be taken immediately and we see no chance of getting Chancellors opinion.

End

ACTION: Gen Groves

CM-IN-7258 (8 May 45) DTG: 081337Z ngr

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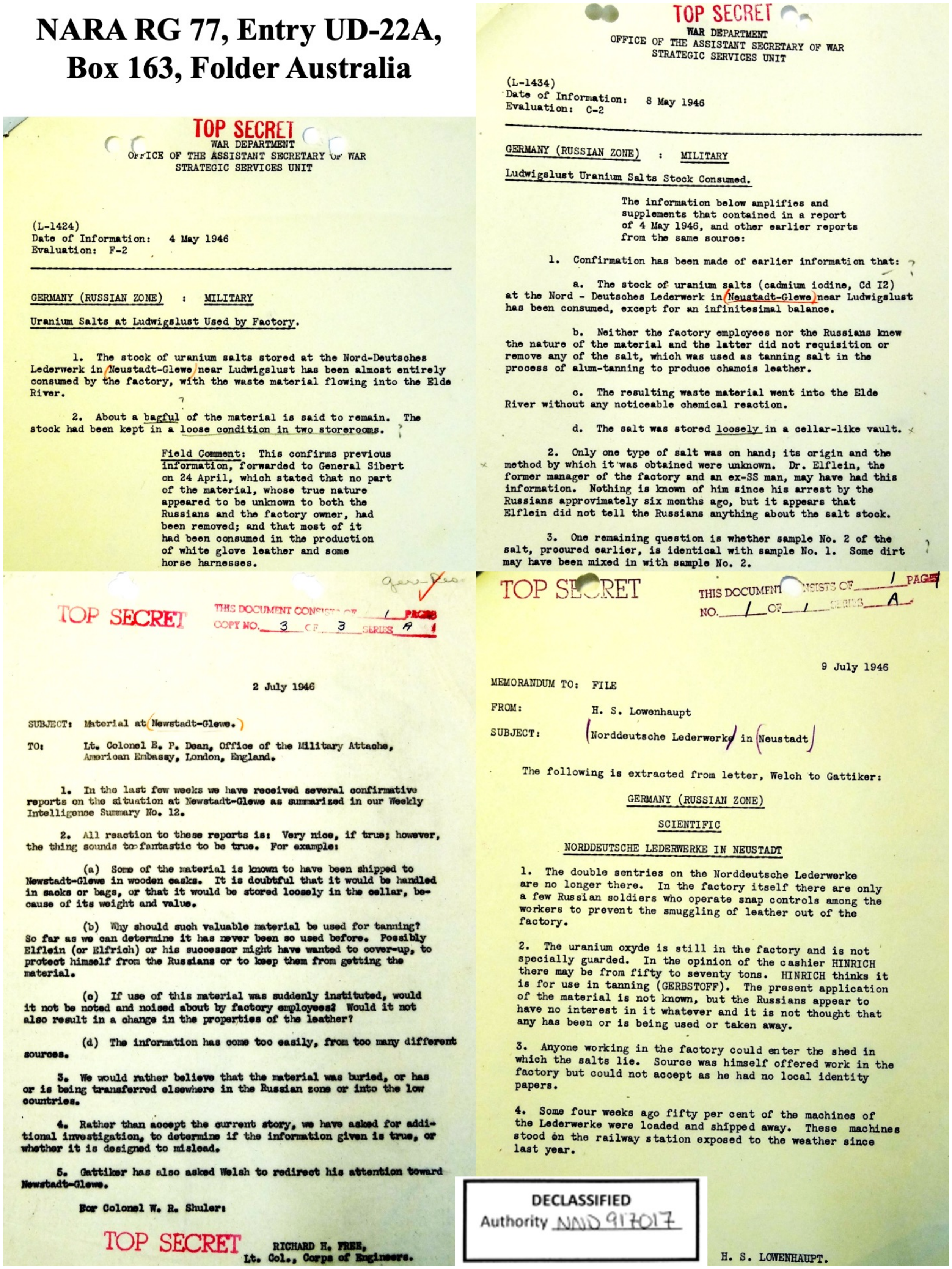
Figure D.104: U.S. Military Attaché London to Leslie Groves. 8 May 1945 [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. ’45].



NARA RG 77, Entry UD-22A, Box 163, Folder Australia

TOP SECRET
WAR DEPARTMENT
OFFICE OF THE ASSISTANT SECRETARY OF WAR
STRATEGIC SERVICES UNIT

(L-1424)
Date of Information: 4 May 1946
Evaluation: F-2

GERMANY (RUSSIAN ZONE) : MILITARY

Uranium Salts at Ludwigslust Used by Factory.

1. The stock of uranium salts stored at the Nord-Deutsches Lederwerk in Neustadt-Glewe near Ludwigslust has been almost entirely consumed by the factory, with the waste material flowing into the Elde River.

2. About a bagful of the material is said to remain. The stock had been kept in a loose condition in two storerooms.

Field Comment: This confirms previous information, forwarded to General Sibert on 24 April, which stated that no part of the material, whose true nature appeared to be unknown to both the Russians and the factory owner, had been removed; and that most of it had been consumed in the production of white glove leather and some horse harnesses.

TOP SECRET
WAR DEPARTMENT
OFFICE OF THE ASSISTANT SECRETARY OF WAR
STRATEGIC SERVICES UNIT

(L-1434)
Date of Information: 8 May 1946
Evaluation: C-2

GERMANY (RUSSIAN ZONE) : MILITARY

Ludwigslust Uranium Salts Stock Consumed.

The information below amplifies and supplements that contained in a report of 4 May 1946, and other earlier reports from the same source:

1. Confirmation has been made of earlier information that: ?

a. The stock of uranium salts (cadmium iodine, Cd I2) at the Nord - Deutsches Lederwerk in Neustadt-Glewe near Ludwigslust has been consumed, except for an infinitesimal balance.

b. Neither the factory employees nor the Russians knew the nature of the material and the latter did not requisition or remove any of the salt, which was used as tanning salt in the process of alum-tanning to produce chamois leather.

c. The resulting waste material went into the Elde River without any noticeable chemical reaction.

d. The salt was stored loosely in a cellar-like vault.

2. Only one type of salt was on hand; its origin and the method by which it was obtained were unknown. Dr. Elflein, the former manager of the factory and an ex-SS man, may have had this information. Nothing is known of him since his arrest by the Russians approvimately six months ago, but it appears that Elflein did not tell the Russians anything about the salt stock.

3. One remaining question is whether sample No. 2 of the salt, procured earlier, is identical with sample No. 1. Some dirt may have been mixed in with sample No. 2.

Ger-Res

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COPY NO. 3 OF 3 SERIES A

2 July 1946

SUBJECT: Material at Newstadt-Glewe.

TO: Lt. Colonel E. P. Dean, Office of the Military Attache, American Embassy, London, England.

1. In the last few weeks we have received several confirmative reports on the situation at Newstadt-Glewe as summarized in our Weekly Intelligense Summary No. 12.

2. All reaction to these reports is: Very nice, if true; however, the thing sounds to fantastic to be true. For example:

(a) Some of the material is known to have been shipped to Newstadt-Glewe in wooden casks. It is doubtful that it would be handled in sacks or bags, or that it would be stored loosely in the cellar, because of its weight and value.

(b) Why should such valuable material be used for tanning? So far as we can determine it has never been so used before. Possibly Elflein (or Elfrich) or his successor might have wanted to cover-up, to protect himself from the Russians or to keep them from getting the material.

(c) If use of this material was suddenly instituted, would it not be noted and noised about by factory employees? Would it not also result in a change in the properties of the leather?

(d) The information has come too easily, from too many different sources.

3. We would rather believe that the material was buried, or has or is being transferred elsewhere in the Russian zone or into the low countries.

4. Rather than accept the current story, we have asked for additional investigation, to determine if the information given is true, or whether it is designed to mislead.

5. Gattiker has also asked Welsh to redirect his attention toward Newstadt-Glewe.

For Colonel W. R. Shuler:

TOP SECRET

RICHARD H. FREE,
Lt. Col., Corps of Engineers.

TOP SECRET

THIS DOCUMENT CONSISTS OF 1 PAGES
NO. 1 OF 1 SERIES A

9 July 1946

MEMORANDUM TO: FILE

FROM: H. S. Lowenhaupt

SUBJECT: Norddeutsche Lederwerke in Neustadt

The following is extracted from letter, Welch to Gattiker:

GERMANY (RUSSIAN ZONE)

SCIENTIFIC

NORDDEUTSCHE LEDERWERKE IN NEUSTADT

1. The double sentries on the Norddeutsche Lederwerke are no longer there. In the factory itself there are only a few Russian soldiers who operate snap controls among the workers to prevent the smuggling of leather out of the factory.

2. The uranium oxyde is still in the factory and is not specially guarded. In the opinion of the cashier HINRICH there may be from fifty to seventy tons. HINRICH thinks it is for use in tanning (GERBSTOFF). The present application of the material is not known, but the Russians appear to have no interest in it whatever and it is not thought that any has been or is being used or taken away.

3. Anyone working in the factory could enter the shed in which the salts lie. Source was himself offered work in the factory but could not accept as he had no local identity papers.

4. Some four weeks ago fifty per cent of the machines of the Lederwerke were loaded and shipped away. These machines stood on the railway station exposed to the weather since last year.

H. S. LOWENHAUPT.

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Authority NND 917017

Figure D.105: Top Secret May–July 1946 reports about wartime uranium storage and usage at Neustadt-Glewe [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

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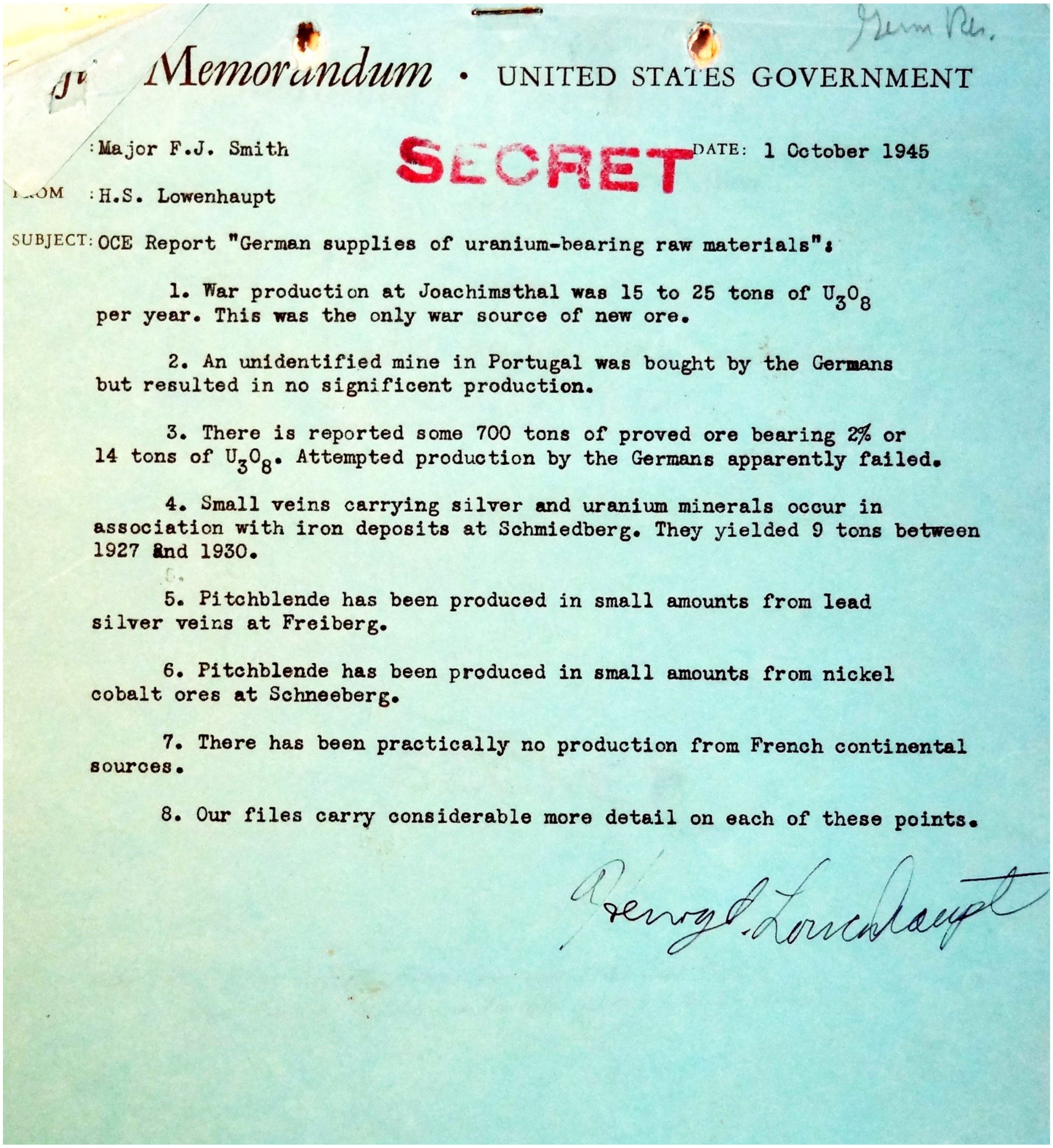
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 163, Folder Australia



Germ Res.

Memorandum • UNITED STATES GOVERNMENT

SECRET

:Major F.J. Smith DATE: 1 October 1945

..OM :H.S. Lowenhaupt

SUBJECT: OCE Report "German supplies of uranium-bearing raw materials":

1. War production at Joachimsthal was 15 to 25 tons of U_3O_8 per year. This was the only war source of new ore.

2. An unidentified mine in Portugal was bought by the Germans but resulted in no significent production.

3. There is reported some 700 tons of proved ore bearing 2% or 14 tons of U_3O_8. Attempted production by the Germans apparently failed.

4. Small veins carrying silver and uranium minerals occur in association with iron deposits at Schmiedberg. They yielded 9 tons between 1927 and 1930.

5. Pitchblende has been produced in small amounts from lead silver veins at Freiberg.

6. Pitchblende has been produced in small amounts from nickel cobalt ores at Schneeberg.

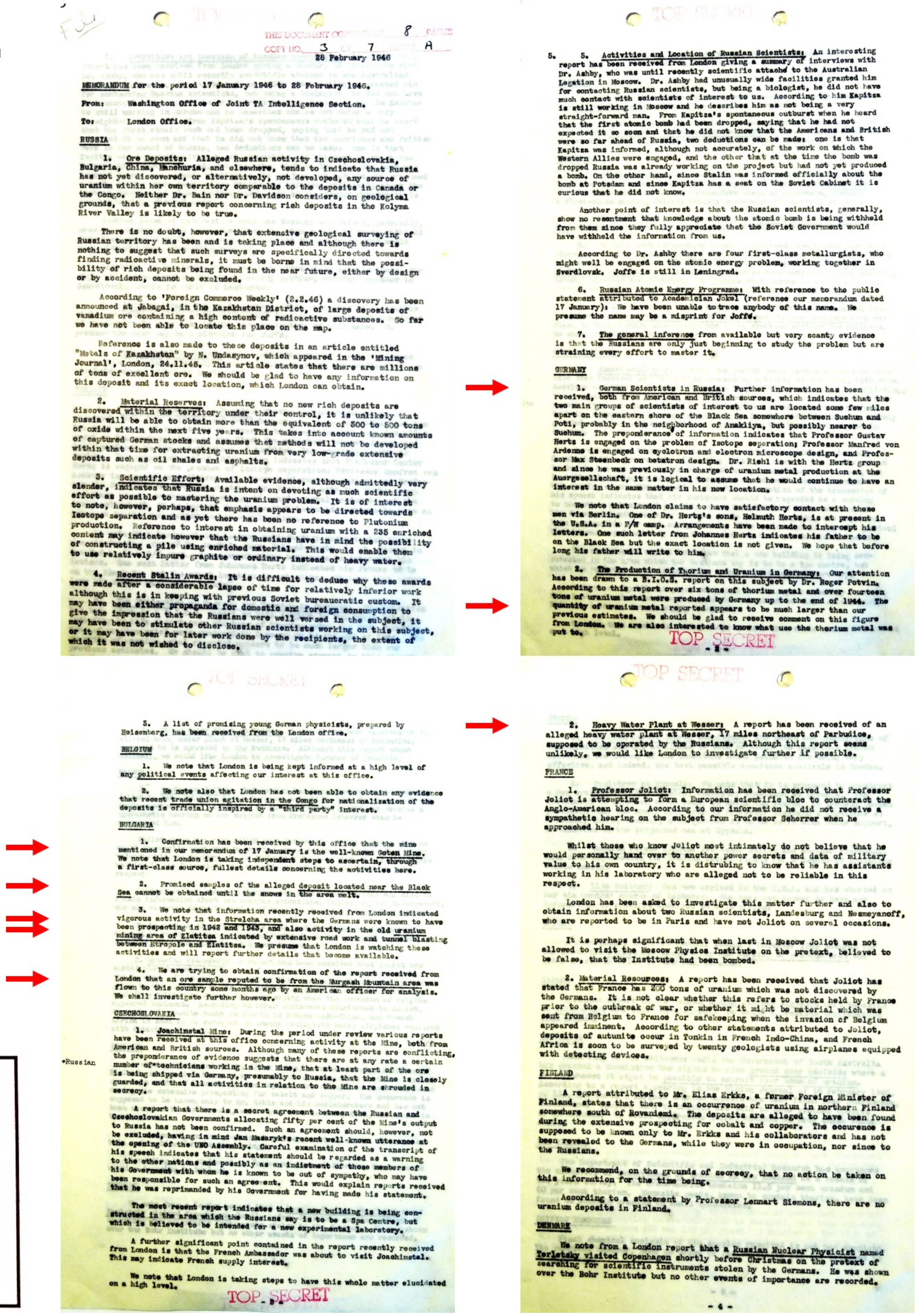
7. There has been practically no production from French continental sources.

8. Our files carry considerable more detail on each of these points.

Henry S. Lowenhaupt

Figure D.106: H. S. Lowenhaupt to Francis J. Smith. 1 October 1945. SUBJECT: OCE Report "German supplies of uranium-bearing raw materials" [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.



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COPY NO. 3 OF 7 SERIES A

28 February 1946

MEMORANDUM for the period 17 January 1946 to 28 February 1946.

From: Washington Office of Joint TA Intelligence Section.

To: London Office.

RUSSIA

1. Ore Deposits: Alleged Russian activity in Czechoslovakia, Bulgaria, China, Manchuria, and elsewhere, tends to indicate that Russia has not yet discovered, or alternatively, not developed, any source of uranium within her own territory comparable to the deposits in Canada or the Congo. Neither Dr. Bain nor Dr. Davidson considers, on geological grounds, that a previous report concerning rich deposits in the Kolyma River Valley is likely to be true.

There is no doubt, however, that extensive geological surveying of Russian territory has been and is taking place and although there is nothing to suggest that such surveys are specifically directed towards finding radioactive minerals, it must be borne in mind that the possibility of rich deposits being found in the near future, either by design or by accident, cannot be excluded.

According to 'Foreign Commerce Weekly' (2.2.46) a discovery has been announced at Jabagai, in the Kazakhstan District, of large deposits of vanadium ore containing a high content of radioactive substances. So far we have not been able to locate this place on the map.

Reference is also made to these deposits in an article entitled "Metals of Kazakhstan" by N. Undasynov, which appeared in the 'Mining Journal', London, 24.11.45. This article states that there are millions of tons of excellent ore. We should be glad to have any information on this deposit and its exact location, which London can obtain.

2. Material Reserves: Assuming that no new rich deposits are discovered within the territory under their control, it is unlikely that Russia will be able to obtain more than the equivalent of 300 to 500 tons of oxide within the next five years. This takes into account known amounts of captured German stocks and assumes that methods will not be developed within that time for extracting uranium from very low-grade extensive deposits such as oil shales and asphalts.

3. Scientific Effort: Available evidence, although admittedly very slender, indicates that Russia is intent on devoting as much scientific effort as possible to mastering the uranium problem. It is of interest to note, however, perhaps, that emphasis appears to be directed towards Isotope separation and as yet there has been no reference to Plutonium production. Reference to interest in obtaining uranium with a 235 enriched content may indicate however that the Russians have in mind the possibility of constructing a pile using enriched material. This would enable them to use relatively impure graphite or ordinary instead of heavy water.

4. Recent Stalin Awards: It is difficult to deduce why these awards were made after a considerable lapse of time for relatively inferior work although this is in keeping with previous Soviet bureaucratic custom. It may have been either propaganda for domestic and foreign consumption to give the impression that the Russians were well versed in the subject, it may have been to stimulate other Russian scientists working on this subject, or it may have been for later work done by the recipients, the extent of which it was not wished to disclose.

TOP SECRET

5. 5. Activities and Location of Russian Scientists: An interesting report has been received from London giving a summary of interviews with Dr. Ashby, who was until recently scientific attaché to the Australian Legation in Moscow. Dr. Ashby had unusually wide facilities granted him for contacting Russian scientists, but being a biologist, he did not have much contact with scientists of interest to us. According to him Kapitza is still working in Moscow and he describes him as not being a very straight-forward man. From Kapitza's spontaneous outburst when he heard that the first atomic bomb had been dropped, saying that he had not expected it so soon and that he did not know that the Americans and British were so far ahead of Russia, two deductions can be made: one is that Kapitza was informed, although not accurately, of the work on which the Western Allies were engaged, and the other that at the time the bomb was dropped Russia was already working on the project but had not yet produced a bomb. On the other hand, since Stalin was informed officially about the bomb at Potsdam and since Kapitza has a seat on the Soviet Cabinet it is curious that he did not know.

Another point of interest is that the Russian scientists, generally, show no resentment that knowledge about the atomic bomb is being withheld from them since they fully appreciate that the Soviet Government would have withheld the information from us.

According to Dr. Ashby there are four first-class metallurgists, who might well be engaged on the atomic energy problem, working together in Sverdlovsk. Joffe is still in Leningrad.

6. Russian Atomic Energy Programme: With reference to the public statement attributed to Academician Jokel (reference our memorandum dated 17 January): We have been unable to trace anybody of this name. We presume the name may be a misprint for Joffé.

7. The general inference from available but very scanty evidence is that the Russians are only just beginning to study the problem but are straining every effort to master it.

GERMANY

1. German Scientists in Russia: Further information has been received, both from American and British sources, which indicates that the two main groups of scientists of interest to us are located some few miles apart on the eastern shore of the Black Sea somewhere between Suchum and Poti, probably in the neighborhood of Anakliya, but possibly nearer to Suchum. The preponderance of information indicates that Professor Gustav Hertz is engaged on the problem of Isotope separation; Professor Manfred von Ardenne is engaged on cyclotron and electron microscope design, and Professor Max Steenbeck on betatron design. Dr. Riehl is with the Hertz group and since he was previously in charge of uranium metal production at the Auergesellschaft, it is logical to assume that he would continue to have an interest in the same matter in his new location.

We note that London claims to have satisfactory contact with these men via Berlin. One of Dr. Hertz's sons, Helmuth Hertz, is at present in the U.S.A. in a P/W camp. Arrangements have been made to intercept his letters. One such letter from Johannes Hertz indicates his father to be on the Black Sea but the exact location is not given. We hope that before long his father will write to him.

2. The Production of Thorium and Uranium in Germany: Our attention has been drawn to a B.I.O.S. report on this subject by Dr. Roger Potvin. According to this report over six tons of thorium metal and over fourteen tons of uranium metal were produced by Germany up to the end of 1944. The quantity of uranium metal reported appears to be much larger than our previous estimates. We should be glad to receive comment on this figure from London. We are also interested to know what use the thorium metal was put to.

TOP SECRET

- 2 -

TOP SECRET

3. A list of promising young German physicists, prepared by Heisenberg, has been received from the London office.

BELGIUM

1. We note that London is being kept informed at a high level of any political events affecting our interest at this office.

2. We note also that London has not been able to obtain any evidence that recent trade union agitation in the Congo for nationalization of the deposits is officially inspired by a "third party" interest.

BULGARIA

1. Confirmation has been received by this office that the mine mentioned in our memorandum of 17 January is the well-known Goten Mine. We note that London is taking independent steps to ascertain, through a first-class source, fullest details concerning the activities here.

2. Promised samples of the alleged deposit located near the Black Sea cannot be obtained until the snows in the area melt.

3. We note that information recently received from London indicated vigorous activity in the Strelcha area where the Germans were known to have been prospecting in 1942 and 1943, and also activity in the old uranium mining area of Zlatitsa indicated by extensive road work and tunnel blasting between Etropole and Zlatitsa. We presume that London is watching these activities and will report further details that become available.

4. We are trying to obtain confirmation of the report received from London that an ore sample reputed to be from the Murgash Mountain area was flown to this country some months ago by an American officer for analysis. We shall investigate further however.

CZECHOSLOVAKIA

1. Joachimstal Mine: During the period under review various reports have been received at this office concerning activity at the Mine, both from American and British sources. Although many of these reports are conflicting, the preponderance of evidence suggests that there are at any rate a certain number of*technicians working in the Mine, that at least part of the ore is being shipped via Germany, presumably to Russia, that the Mine is closely guarded, and that all activities in relation to the Mine are shrouded in secrecy.

*Russian

A report that there is a secret agreement between the Russian and Czechoslovakian Governments allocating fifty per cent of the Mine's output to Russia has not been confirmed. Such an agreement should, however, not be excluded, having in mind Jan Masaryk's recent well-known utterance at the opening of the UNO Assembly. Careful examination of the transcript of his speech indicates that his statement should be regarded as a warning to the other nations and possibly as an indictment of those members of his Government with whom he is known to be out of sympathy, who may have been responsible for such an agreement. This would explain reports received that he was reprimanded by his Government for having made his statement.

The most recent report indicates that a new building is being constructed in the area which the Russians say is to be a Spa Centre, but which is believed to be intended for a new experimental laboratory.

A further significant point contained in the report recently received from London is that the French Ambassador was about to visit Joachimstal. This may indicate French supply interest.

We note that London is taking steps to have this whole matter elucidated on a high level.

TOP SECRET

- 3 -

TOP SECRET

2. Heavy Water Plant at Wesser: A report has been received of an alleged heavy water plant at Wesser, 17 miles northeast of Parbudice, supposed to be operated by the Russians. Although this report seems unlikely, we would like London to investigate further if possible.

FRANCE

1. Professor Joliot: Information has been received that Professor Joliot is attempting to form a European scientific bloc to counteract the Anglo-American bloc. According to our information he did not receive a sympathetic hearing on the subject from Professor Scherrer when he approached him.

Whilst those who know Joliot most intimately do not believe that he would personally hand over to another power secrets and data of military value to his own country, it is distrubing to know that he has assistants working in his laboratory who are alleged not to be reliable in this respect.

London has been asked to investigate this matter further and also to obtain information about two Russian scientists, Landesburg and Nesmeyanoff, who are reported to be in Paris and have met Joliot on several occasions.

It is perhaps significant that when last in Moscow Joliot was not allowed to visit the Moscow Physics Institute on the pretext, believed to be false, that the Institute had been bombed.

2. Material Resources: A report has been received that Joliot has stated that France has 200 tons of uranium which was not discovered by the Germans. It is not clear whether this refers to stocks held by France prior to the outbreak of war, or whether it might be material which was sent from Belgium to France for safekeeping when the invasion of Belgium appeared imminent. According to other statements attributed to Joliot, deposits of autunite occur in Tonkin in French Indo-China, and French Africa is soon to be surveyed by twenty geologists using airplanes equipped with detecting devices.

FINLAND

A report attributed to Mr. Elias Erkks, a former Foreign Minister of Finland, states that there is an occurrence of uranium in northern Finland somewhere south of Rovaniemi. The deposits are alleged to have been found during the extensive prospecting for cobalt and copper. The occurence is supposed to be known only to Mr. Erkks and his collaborators and has not been revealed to the Germans, while they were in occupation, nor since to the Russians.

We recommend, on the grounds of secrecy, that no action be taken on this information for the time being.

According to a statement by Professor Lennart Siemons, there are no uranium deposits in Finland.

DENMARK

We note from a London report that a Russian Nuclear Physicist named Terletsky visited Copenhagen shortly before Christmas on the pretext of searching for scientific instruments stolen by the Germans. He was shown over the Bohr Institute but no other events of importance are recorded.

- 4 -

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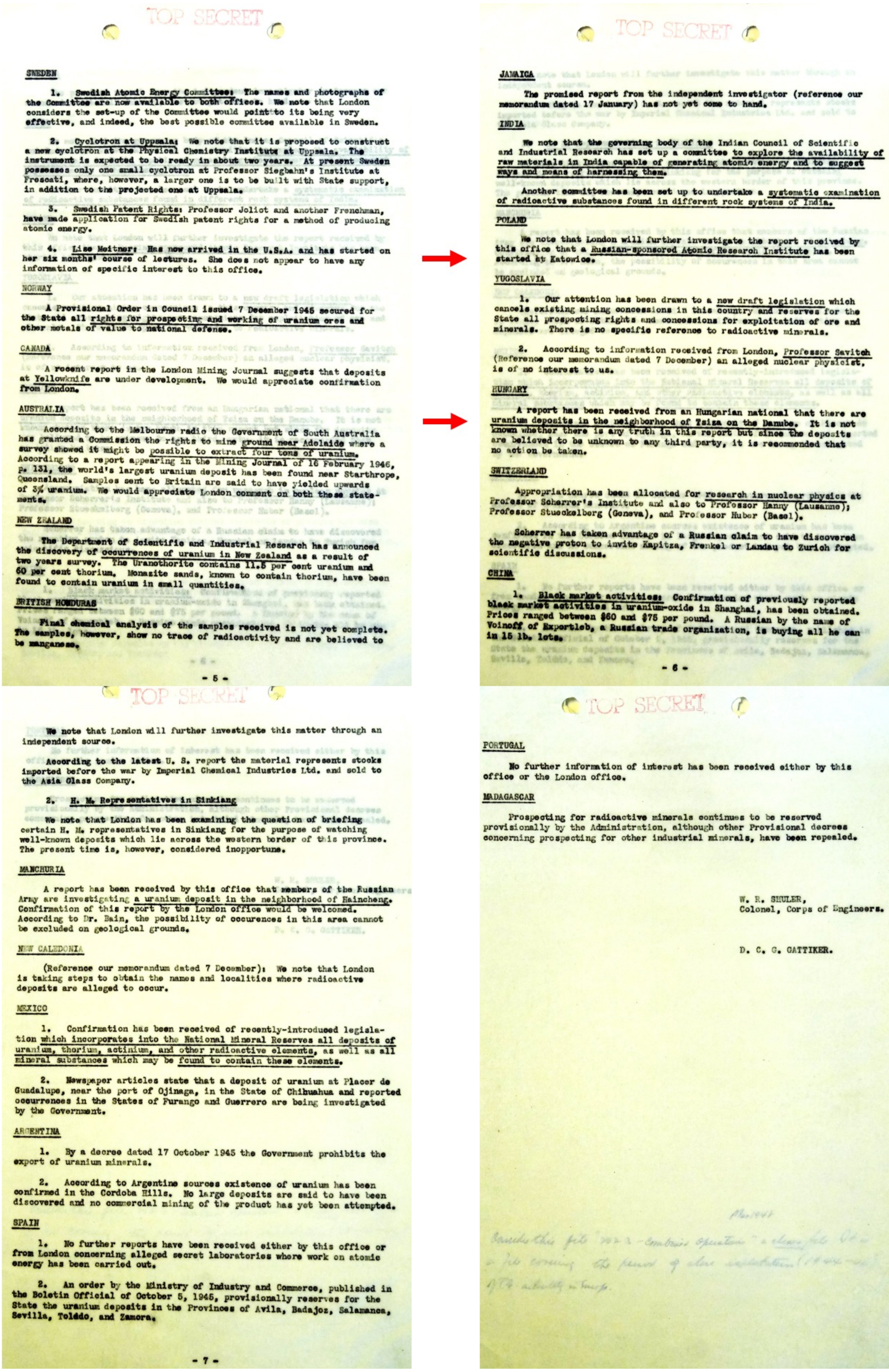
Figure D.107: W. R. Shuler and David C. G. Gattiker. 28 February 1946. Memorandum for the period 17 January 1946 to 28 February 1946 [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.



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SWEDEN

1. Swedish Atomic Energy Committee: The names and photographs of the Committee are now available to both offices. We note that London considers the set-up of the Committee would point to its being very effective, and indeed, the best possible committee available in Sweden.

2. Cyclotron at Uppsala: We note that it is proposed to construct a new cyclotron at the Physical Chemistry Institute at Uppsala. The instrument is expected to be ready in about two years. At present Sweden possesses only one small cyclotron at Professor Siegbahn's Institute at Frescati, where, however, a larger one is to be built with State support, in addition to the projected one at Uppsala.

3. Swedish Patent Rights: Professor Joliot and another Frenchman, have made application for Swedish patent rights for a method of producing atomic energy.

4. Lise Meitner: Has now arrived in the U.S.A. and has started on her six months' course of lectures. She does not appear to have any information of specific interest to this office.

NORWAY

A Provisional Order in Council issued 7 December 1945 secured for the State all rights for prospecting and working of uranium ores and other metals of value to national defense.

CANADA

A recent report in the London Mining Journal suggests that deposits at Yellowknife are under development. We would appreciate confirmation from London.

AUSTRALIA

According to the Melbourne radio the Government of South Australia has granted a Commission the rights to mine ground near Adelaide where a survey showed it might be possible to extract four tons of uranium. According to a report appearing in the Mining Journal of 16 February 1946, p. 131, the world's largest uranium deposit has been found near Starthrope, Queensland. Samples sent to Britain are said to have yielded upwards of 3% uranium. We would appreciate London comment on both these statements.

NEW ZEALAND

The Department of Scientific and Industrial Research has announced the discovery of occurrences of uranium in New Zealand as a result of two years survey. The Uranothorite contains 11.5 per cent uranium and 60 per cent thorium. Monazite sands, known to contain thorium, have been found to contain uranium in small quantities.

BRITISH HONDURAS

Final chemical analysis of the samples received is not yet complete. The samples, however, show no trace of radioactivity and are believed to be manganese.

- 5 -

TOP SECRET

JAMAICA

The promised report from the independent investigator (reference our memorandum dated 17 January) has not yet come to hand.

INDIA

We note that the governing body of the Indian Council of Scientific and Industrial Research has set up a committee to explore the availability of raw materials in India capable of generating atomic energy and to suggest ways and means of harnessing them.

Another committee has been set up to undertake a systematic examination of radioactive substances found in different rock systems of India.

POLAND

We note that London will further investigate the report received by this office that a Russian-sponsored Atomic Research Institute has been started at Katowice.

YUGOSLAVIA

1. Our attention has been drawn to a new draft legislation which cancels existing mining concessions in this country and reserves for the State all prospecting rights and concessions for exploitation of ore and minerals. There is no specific reference to radioactive minerals.

2. According to information received from London, Professor Savitch (Reference our memorandum dated 7 December) an alleged nuclear physicist, is of no interest to us.

HUNGARY

A report has been received from an Hungarian national that there are uranium deposits in the neighborhood of Tsiza on the Danube. It is not known whether there is any truth in this report but since the deposits are believed to be unknown to any third party, it is recommended that no action be taken.

SWITZERLAND

Appropriation has been allocated for research in nuclear physics at Professor Scherrer's Institute and also to Professor Hanny (Lausanne); Professor Stueckelberg (Geneva), and Professor Huber (Basel).

Scherrer has taken advantage of a Russian claim to have discovered the negative proton to invite Kapitza, Frenkel or Landau to Zurich for scientific discussions.

CHINA

1. Black market activities: Confirmation of previously reported black market activities in uranium-oxide in Shanghai, has been obtained. Prices ranged between $60 and $75 per pound. A Russian by the name of Voinoff of Exportleb, a Russian trade organization, is buying all he can in 15 lb. lots.

- 6 -

TOP SECRET

We note that London will further investigate this matter through an independent source.

According to the latest U. S. report the material represents stocks imported before the war by Imperial Chemical Industries Ltd. and sold to the Asia Glass Company.

2. H. M. Representatives in Sinkiang

We note that London has been examining the question of briefing certain H. M. representatives in Sinkiang for the purpose of watching well-known deposits which lie across the western border of this province. The present time is, however, considered inopportune.

MANCHURIA

A report has been received by this office that members of the Russian Army are investigating a uranium deposit in the neighborhood of Haincheng. Confirmation of this report by the London office would be welcomed. According to Dr. Bain, the possibility of occurences in this area cannot be excluded on geological grounds.

NEW CALEDONIA

(Reference our memorandum dated 7 December): We note that London is taking steps to obtain the names and localities where radioactive deposits are alleged to occur.

MEXICO

1. Confirmation has been received of recently-introduced legislation which incorporates into the National Mineral Reserves all deposits of uranium, thorium, actinium, and other radioactive elements, as well as all mineral substances which may be found to contain these elements.

2. Newspaper articles state that a deposit of uranium at Placer de Guadalupe, near the port of Ojinaga, in the State of Chihuahua and reported occurrences in the States of Furango and Guerrero are being investigated by the Government.

ARGENTINA

1. By a decree dated 17 October 1945 the Government prohibits the export of uranium minerals.

2. According to Argentine sources existence of uranium has been confirmed in the Cordoba Hills. No large deposits are said to have been discovered and no commercial mining of the product has yet been attempted.

SPAIN

1. No further reports have been received either by this office or from London concerning alleged secret laboratories where work on atomic energy has been carried out.

2. An order by the Ministry of Industry and Commerce, published in the Boletin Official of October 5, 1945, provisionally reserves for the State the uranium deposits in the Provinces of Avila, Badajoz, Salamanca, Sevilla, Toldedo, and Zamora.

- 7 -

TOP SECRET

PORTUGAL

No further information of interest has been received either by this office or the London office.

MADAGASCAR

Prospecting for radioactive minerals continues to be reserved provisionally by the Administration, although other Provisional decrees concerning prospecting for other industrial minerals, have been repealed.

W. R. SHULER,
Colonel, Corps of Engineers.

D. C. G. GATTIKER.

Mar 1948

Consider this file "202.3 - Combined Operations" a closed file. It is a file covering the period of close collaboration (1944-46) of [illegible] activity in Europe.

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Figure D.108: W. R. Shuler and David C. G. Gattiker. 28 February 1946. Memorandum for the period 17 January 1946 to 28 February 1946 [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

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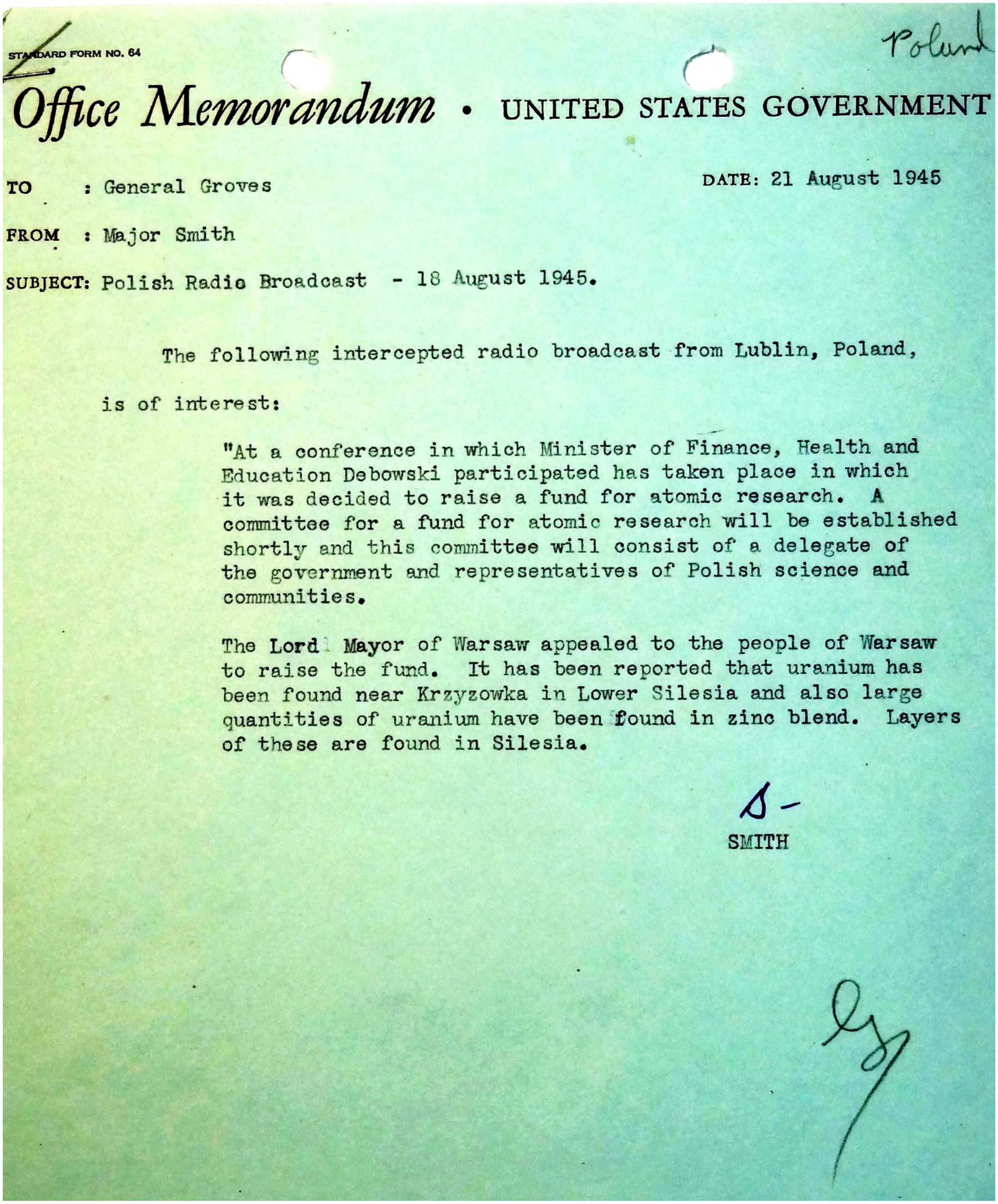
Authority NND917017

NARA RG 77, Entry UD-22A, Box 173, Folder 57.70. Poland Misc



STANDARD FORM NO. 64

Poland

Office Memorandum • UNITED STATES GOVERNMENT

TO : General Groves

FROM : Major Smith

DATE: 21 August 1945

SUBJECT: Polish Radio Broadcast - 18 August 1945.

The following intercepted radio broadcast from Lublin, Poland, is of interest:

> "At a conference in which Minister of Finance, Health and Education Debowski participated has taken place in which it was decided to raise a fund for atomic research. A committee for a fund for atomic research will be established shortly and this committee will consist of a delegate of the government and representatives of Polish science and communities.
>
> The Lord Mayor of Warsaw appealed to the people of Warsaw to raise the fund. It has been reported that uranium has been found near Krzyzowka in Lower Silesia and also large quantities of uranium have been found in zinc blend. Layers of these are found in Silesia.

S-

SMITH

Figure D.109: Postwar report of uranium mines at Krzyzowa and elsewhere in Silesia that were likely worked during the war. It seems unlikely that a completely unexcavated underground deposit of uranium would have been spontaneously discovered immediately after the war, when there were already existing uranium mines plus higher priorities for postwar rebuilding. Francis J. Smith to Leslie Groves. 21 August 1945. SUBJECT: Polish Radio Broadcast—18 August 1945 [NARA RG 77, Entry UD-22A, Box 173, Folder 57.70. Poland Misc].

[There is significant evidence that during the war, Germany was actively mining uranium at multiple sites in Romania for the German nuclear weapons program. Hitler told Romanian Prime Minister Ion Antonescu about some of the results of that program in August 1944 (p. 4594).]

Bomba de la Hiroshima cu uraniu de Băiţa? Exploatarea de uraniu de la Băiţa stârneşte noi controverse. [Hiroshima bomb with uranium from Băiţa? Băiţa uranium mining stirs new controversies.] ***BIHON Ştirile judeţului Bihor.*** **30 January 2015. https://www.bihon.ro/stirile-judetului-bihor/bomba-de-la-hiroshima-cu-uraniu-de-baita-251058/**

Un inginer silvic din Câmpani susţine că din uraniul de la Băiţa s-ar fi construit bombele nucleare de la Hiroshima şi Nagasaki.

Ioan Costea, autorul volumului lansat la finele anului trecut “Uraniul primelor bombe”, a avut o copilărie marcată de poveştile rudelor despre invazia nemţilor în Apuseni. Omul susţine că în laboratoarele secrete ale SS-ului a fost prelucrat uraniul din Băiţa şi că pentru a fi transportat a fost construit viaductul peste Valea Luncoiului. Ioan Costea invocă rapoarte geologice care pomenesc de prospecţiuni făcute de nemţi. “Probabil ca au scos suficient pentru a face o bombă”, spune Ioan Costea, în cartea sa. Autorul recunoaşte că volumul nu are caracter ştiinţific şi că e construit doar pe baza dovezilor, documentelor şi mărturiilor pe care a reuşit să le strângă. [...] “Tot căutând informaţii oficiale care să arate, aşa cum ar fi de aşteptat, că sovieticii au început exploatarea uraniului românesc, nu mică mi-a fost mirarea să descopar că Hitler a fost primul care a început exploatarea uraniului în munţii moţilor. Am aflat că naziştii lui Himmler au folosit o parte a acestui uraniu la construirea câtorva “arme atomice”...Cealaltă parte a uraniului moţilor a ajuns în posesia statului american. Din acest uraniu, dăruit de nazişti, americanii au făcut acele bombe pe care le-au slobozit asupra Japoniei”.

A forestry engineer from Câmpani claims that uranium from Băiţa was used to build the nuclear bombs of Hiroshima and Nagasaki.

Ioan Costea, author of the book *Uranium of the First Bombs*, published at the end of last year, had a childhood marked by stories from relatives about the German invasion of the Apuseni mountains. The man claims that uranium from Baita was processed in secret SS laboratories and that the viaduct across the Luncoiului Valley was built to transport it. Ioan Costea cites geological reports mentioning prospecting by the Germans. “They probably dug up enough to make a bomb,” says Ioan Costea in his book. The author admits that the volume is not scientific and is built solely on the evidence, documents and testimonies he has managed to collect. [...] “Still searching for official information showing, as might be expected, that the Soviets had begun mining Romanian uranium, I was not a little surprised to discover that Hitler was the first to begin mining uranium in the mountains. I found out that Himmler’s Nazis used part of this uranium to build some “atomic weapons”... The other part of the mountains’ uranium came into the possession of the American state. From this uranium, given to them by the Nazis, the Americans made those bombs they dropped on Japan.”

Sabina Paşca fosta soţie a unuia dintre primarii de Arieşeni şi-a amintit că în a doua decadă a anilor'30: "Oamenii din Arieşeni mergeau la lucru la Băiţa Plai cu caii, pe la Colibiţa, pe un drum de picior" şi că exploatau "un fel de praf de puşcă, care-i mai scump decât aurul. O mâna de praf de puşcă de la Băiţa face cât patru mâini de aur". Gheorge Trifon şi-a amintit că în 1995 a fost plătit de un ofiţer rus să întocmească o reţea de 100/100 m pentru detectarea uraniului pe versantul Râului Arieş – Muntele Biharia. "Iţi pot spune cu certitudine că atât harta, cât şi aparatura erau nemteşti", a subliniat omul. [...]

"În această carte arăt că naziştii au dus uraniu din România, în special din zona Băiţa (Biharia) dar am aflat recent că şi din Cheia (Rimetea), de la Cataractele Lotrului şi din Ciudanoviţa–Caransebeş. Din aceste locuri, nemţii le spuneau localnicilor că duceau orice altceva decât uraniu: molibden, cuarţ, piatră de construcţie, aur, cupru etc.Interesant este ca Biharia a deţinut şi încă mai deţine faimosul uraninit (un oxid de uraniu, pechblenda). Se ştie că ruşii, care aveau la finele anului 1944 numai 1 kg de uraniu, au ridicat cu japca din Germania, în perioada apr–iulie 1945, cca 400 tone de uraninit. Să amintim pe scurt şi uraniul ridicat de americani, care, la rândul lor, au golit de uraniu toată partea Germaniei care le-a revenit. Să ţinem seama şi de faptul ca nemţii au transportat cât au putut uraniu din estul spre vestul Germaniei, spre zona americană a Germaniei, pentru a se pune bine cu americanii. Nu pretind că tot uraninitul din Germania, dus de americani, ruşi şi poate şi britanici sau francezi, ar fi provenit din România (putea fi din Cehia, Congo belgian sau din Germania). Important este că cel mai mult uraninit a fost din România şi consider că suntem îndreptăţiţi să aflăm odata cu valoarea exporturilor neplătite şi numele articolelor exportate în perioada nazistă.

Sabina Paşca, the ex-wife of one of the mayors of Arieşeni, recalled that in the second decade of the 1930s: "The people of Arieşeni used to go to work at Băiţa Plai with their horses, on the Colibiţa footpath" and that they mined "a kind of gunpowder, which is more expensive than gold. A handful of gunpowder from Băiţa is worth four hands of gold." Gheorge Trifon recalled that in 1995 he was paid by a Russian officer to draw up a 100/100 m grid for detecting uranium on the Arieş River–Biharia Mountain slope. "I can tell you with certainty that both the map and the equipment were German," the man stressed. [...]

"In this book I show that the Nazis took uranium from Romania, especially from the Băiţa (Biharia) area, but I have recently learned also from Cheia (Rimetea), from Cataractele Lotrului and from Ciudanoviţa–Caransebeş. From these places, the Germans used to tell the locals that they were carrying anything other than uranium: molybdenum, quartz, building stone, gold, copper, etc. Interestingly, Biharia had and still has the famous uraninite (an oxide of uranium, pitchblende). It is known that the Russians, who had only 1 kg of uranium at the end of 1944, collected about 400 tonnes of uraninite from Germany in April–July 1945. Let's also briefly mention the uranium collected by the Americans, who in turn emptied the entire part of Germany that was theirs. Let's also bear in mind that the Germans transported as much uranium as they could from East to West Germany, to the American part of Germany, in order to get in good with the Americans. I'm not claiming that all the uranium in Germany, carried by the Americans, Russians and maybe the British or French, would have come from Romania (it could have come from the Czech Republic, Belgian Congo or Germany). What is important is that most of the uraninite was from Romania, and I think we are entitled to know along with the value of the unpaid exports the names of the items exported during the Nazi period."

Andrei Dicu and Sorin Dumitrescu. 2019. Bomba atomică ruso-americană, hrănită din uraniul românesc [Russian-American Atomic Bombs, Fed by Romanian Uranium]. *Taifasuri* 748.
http://taifasuri.ro/index.php/taifasuri/mozaic/17838-bomba-atomica-ruso-americana-hranita-din-uraniul-romanesc-nr748-sapt19-25-sept-2019

Aurul şi metalele preţioase din Munţii Apuseni au făcut deliciul multor subiecte de presă. Există, însă, un zăcământ incomparabil mai valoros şi "mai" strategic decât aurul sau cuprul. Uraniul, un metal extrem de preţios, mai ales în producerea bombelor atomice, ne-a stat în palmă, până când, ca de obicei, au venit alţii să se hrănească din valorile noastre.

La început a fost Hitler...

Primul care a scris despre acest subiect a fost Ioan Costea, un moţ care, inginer silvic fiind, a lucrat în pădurile şi în păşunile a şase comune (Horea, Albac, Scărişoara, Beliş, Vadu Moţilor şi Gârda), unde, printre altele, a scormonit rămăşiţele rezistenţei anticomuniste a legionarilor şi a partizanilor care au luptat împotriva noii orânduiri. Tot căutând prin munţi după informaţii care să arate că ruşii au început exploatarea uraniului românesc imediat după 23 august 1944, oricum măcar înainte de 1949, când a fost detonată prima bombă nucleară sovietică, nu mică i-a fost mirarea să descopere că, de fapt, Hitler a fost primul care a început exploatarea uraniului, în Munţii Apuseni. [...] Şi aceste exploatări au fost taman în Munţii Apuseni, mai exact în Biharia, la Ştei-Băiţa. Se pare că zăcămintele de uraniu de aici au fost descoperite de aviatorii nemţi care, prin 1938–1939, survolând perimetrul, au observat o scădere de presiune şi o developare bizară a filmelor, fapt care i-a determinat pe germani să facă o cercetare geologică a zonei, cu aparatură modernă, astfel că au instalat 40 de sonde în acea arie.

Gold and precious metals in the Apuseni Mountains have been the subject of much media coverage. But there is an incomparably more valuable and strategic deposit than gold or copper. Uranium, an extremely precious metal, especially in the production of atomic bombs, sat in the palm of our hands until, as usual, others came to feed on our resources.

First it was Hitler...

The first to write on this subject was Ioan Costea, a Moor who, being a forestry engineer, worked in the forests and pastures of six communes (Horea, Albac, Scărişoara, Beliş, Vadu Moţilor and Gârda), where, among other things, he excavated the remains of the anti-communist resistance of the legionaries and partisans who fought against the new order. While searching the mountains for information showing that the Russians had started exploiting Romanian uranium immediately after 23 August 1944, at least before 1949, when the first Soviet nuclear bomb was detonated, he was not a little surprised to discover that it was in fact Hitler who was the first to start exploiting uranium in the Apuseni Mountains. [...] And those mines were in the Apuseni Mountains, in Biharia, at Ştei-Băiţa. It seems that the uranium deposits here were discovered by German aviators who, around 1938–1939, flying over the perimeter, noticed a drop in pressure and a bizarre development of the films, which led the Germans to carry out a geological survey of the area with modern equipment, so they installed 40 probes in the area.

“Un praf de puşcă mai scump ca aurul”

Mulţi dintre localnici povesteau că au luat parte la aceste măsurători, de la care s-au obţinut informaţii că aparatura şi hărţile erau nemţeşti şi că, odată ajunşi în zona Biharia, toate aparatele s-au ars din pricina concentraţiei mari de uraniu. Ce exploatau nemţii? După mărturia unui sătean, “un fel de praf de puşcă, probabil mai scump ca aurul, iar o mână cu praf de puşcă de Băiţa făcea cât patru mâini cu aur”. Uraniul care a fost obţinut din acele exploatări a fost ambalat în caserole de plumb, pentru a preveni iradierea, care au fost transportate la Brad. Acolo erau preluate de serviciul SS şi expediate la laboratoarele din Germania. Pentru a înlesni transportul la scară industrială, nemţii au construit tronsoane noi ale drumului Avram Iancu-Bulzeşti-Baia de Criş şi au finalizat o parte a căii ferate Brad–Deva, o megastructură dotată cu viaducte şi cu tunele impecabile. După invazia sovietică, lucrurile s-au schimbat. În august 1949, când a fost detonată, oficial, prima bombă atomică rusească, întreprinderea Sovrom, sovieto-română, Rom-Kuartit a început exploatarea uraniului. Potrivit istoricului Dan Silviu Boerescu, spionajul şi prospecţiunile ruşilor au început înainte de 23 august 1944 şi au fost urmate de exploatările din zona Băiţa-Arieşeni, Vidra şi probabil din Valea Ierii, iar cel puţin o parte din uraniul provenit din Munţii Apuseni a fost folosit la fabricarea primei bombe atomice sovietice. [...]

“Gunpowder more expensive than gold”

Many of the locals told how they had taken part in these measurements, from which information was obtained that the equipment and maps were German and that, once they arrived in the Biharia area, all the equipment had burned up because of the high concentration of uranium. What were the Germans exploiting? According to one villager, “a kind of gunpowder, probably more expensive than gold, and a handful of Biita gunpowder was as much as four hands of gold.” The uranium that was obtained from those mines was packed in lead casseroles to prevent irradiation, which were transported to Brad. There they were picked up by the SS service and shipped to laboratories in Germany. To facilitate transport on an industrial scale, the Germans built new sections of the Avram Iancu-Bulzeşti-Baia de Criş road and completed part of the Brad–Deva railway, a megastructure with viaducts and impeccable tunnels. After the Soviet invasion, things changed. In August 1949, when the first Russian atomic bomb was officially detonated, the Soviet-Romanian enterprise Sovrom, Rom-Kuartit, began mining uranium. According to historian Dan Silviu Boerescu, Russian spying and prospecting began before 23 August 1944 and was followed by mining in the Băiţa-Arieşeni, Vidra and probably in the Ierii Valley, and at least some of the uranium from the Apuseni Mountains was used to make the first Soviet atomic bomb. [...]

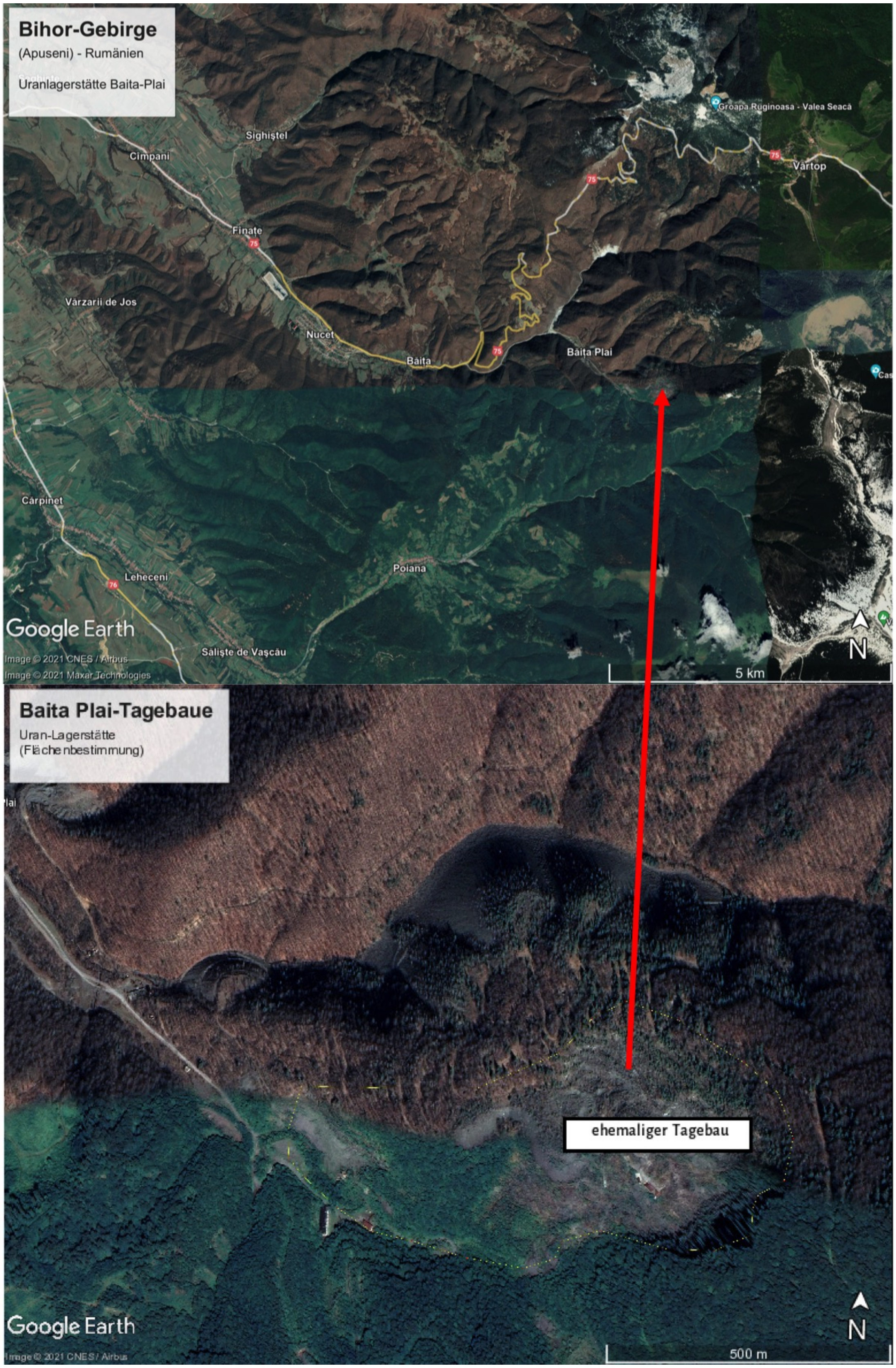
Pavel Sudoplatov, unul dintre adjuncţii lui Beria (fost lider comunist care a intrat în conflict cu Stalin şi a fost asasinat) şi un fel de Himmler al ruşilor, a scris în cartea sa, “Misiuni speciale”, că liderul sovietic era la fel de ahtiat ca şi Hitler în privinţa construirii bombei atomice. KGB-ul a aflat despre exploatarea uraniului din Ţara Moţilor de la comuniştii evrei care prestaseră muncă silnică, sub supravegherea trupelor germane aflate în România. Sudoplatov vorbeşte despre munţii noştri, dar şi despre exploatările care au avut loc la Bukovo, în Bulgaria. Se pare că după ce Germania a pierdut războiul, echipele de misiuni speciale ruseşti şi americane, antrenate în tot ceea ce înseamnă uraniu şi intitulate ALSOS, au găsit la nazişti cantităţi uriaşe de “combustibil”, care era deja apt pentru utilizare.	Pavel Sudoplatov, one of Beria’s deputies (a former Communist leader who clashed with Stalin and was assassinated) and a sort of Himmler of the Russians, wrote in his book, *Special Missions*, that the Soviet leader was as eager as Hitler to build the atomic bomb. The KGB had learned about uranium mining in the Mote Country from Jewish Communists who had been doing forced labour under the supervision of German troops in Romania. Sudoplatov talks about our mountains, but also about mining in Bukovo in Bulgaria. It seems that after Germany lost the war, Russian and American special mission teams, trained in all things uranium and called ALSOS, found huge quantities of “fuel” with the Nazis, which was already fit for use.

Gheorghe Banciu, Ovidiu Banciu, Liviu Suciu, and Constantin Cosma. 2012. Mining Activities in the Superior Basin of Crişul Negru River. *Ecoterra—Journal of Environmental Research and Protection* 33:1–6.

Short history of mining activities in the area. From the subsoil of this region man has exploited many mineral resources such as: gold, silver, iron, copper, lead, zinc, molybdenum, bismuth, wolfram, nickel, cobalt, pyrite, limestone, marble, building face stones and uranium since the Middle Ages. In the beginning, gold and silver has been extracted by the local population. Around 1600, iron compounds have been also extracted, and after 1700, mining activities have increased including the exploitation of lead and zinc. In 1880, 7000 kg of copper, 1567 kg of silver, 5300 kg of lead have been extracted from Băiţa-Bihor area. Around 1890, important molybdenum and bismuth ores have been identified. During the First World War, the extraction of molybdenum has been taken over by a German company as this compound was used in for making cannons. Since 1935, the molybdenum mine was exploited by different Romanian companies. The most intense mining activities concerning non-ferrous mineral resources extraction have been carried out from 1960 until around the early 1990s[...]

Uranium ore mining (1949–1999). Uranium ore geological prospection has been carried out independently in three phases by Romanian geologists (in 1930s), German teams (1943–1944) and by the Soviets (1945–1960), the last two phases being determined by the geopolitical situation of our country at that time. From the Romanian scholars who brought their contribution to the identification of the presence of uranium ores in this region, we can mention professor of geology Popescu-Voinesti, and geologist Dan Giusca who identified and collected uranium bearing minerals from this region, but were not successful in delimiting the exact location of the ore.

[See also: Adina Popescu and Iulian Ghervas. 2009. *Copiii Uraniului* [*Children of Uranium*]. Libra Film. https://www.youtube.com/watch?v=oqb7GjleO4E]


Bihor-Gebirge
(Apuseni) - Rumänien
Uranlagerstätte Baita-Plai
Groapa Ruginoasa - Valea Seacă
Vârtop
Sighiştel
Cimpani
Finaţe
75
Vărzarii de Jos
Nucet
Baita
Baita Plai
Carpinet
Leheceni
76
Poiana
Sălişte de Vaşcău
Google Earth
Image © 2021 CNES / Airbus
Image © 2021 Maxar Technologies
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Uran-Lagerstätte
(Flächenbestimmung)
Plai
ehemaliger Tagebau
Google Earth
Image © 2021 CNES / Airbus
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500 m

Figure D.110: Modern aerial photos of an open-pit mine at Băiţa-Plai, Romania, from which uranium was extracted by the Germans during World War II and by the Soviets after the war [Google Earth, courtesy of Gernot Eilers].

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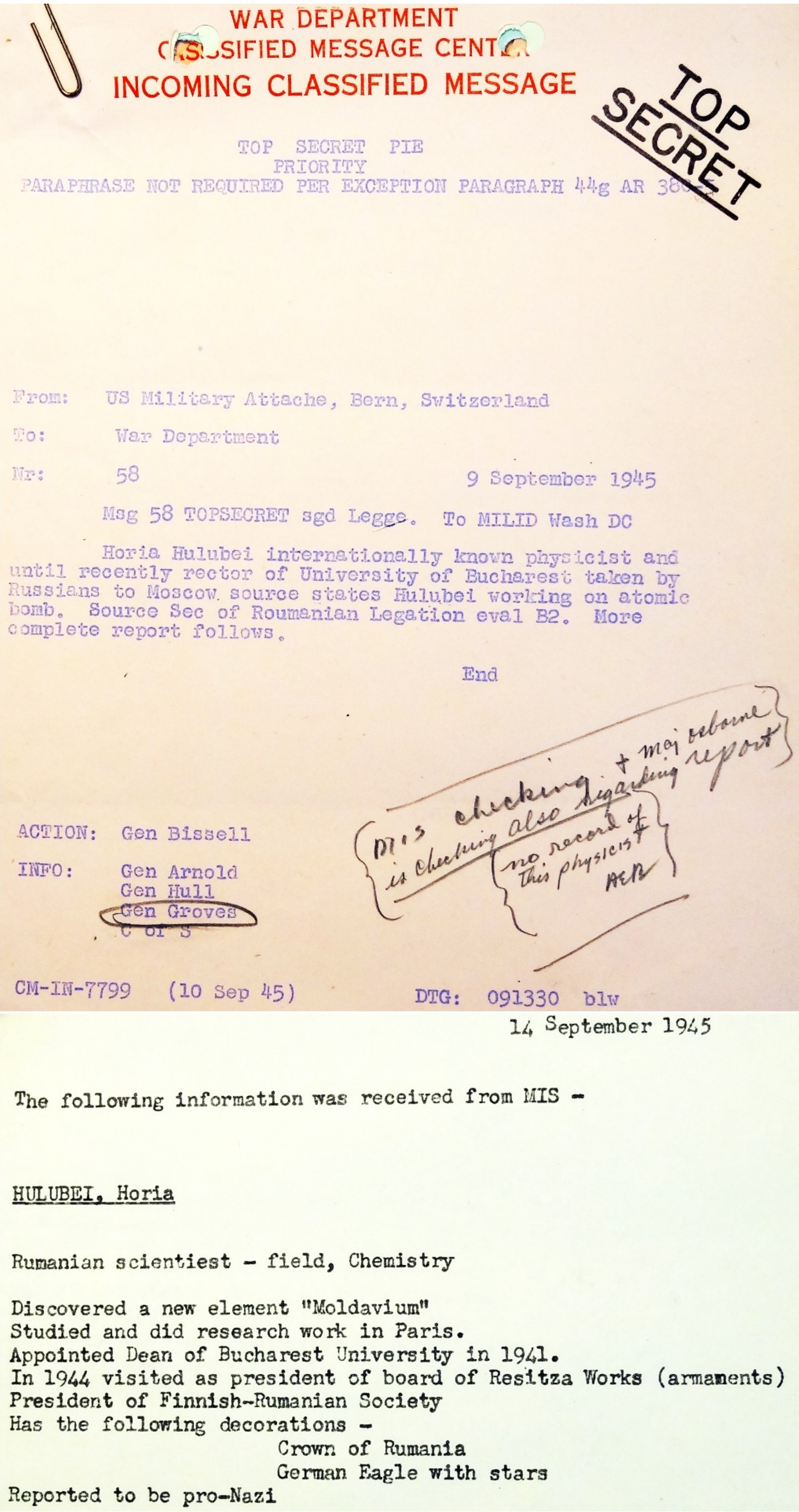
Authority NND 917017



WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
INCOMING CLASSIFIED MESSAGE

TOP SECRET

TOP SECRET PIE
PRIORITY
PARAPHRASE NOT REQUIRED PER EXCEPTION PARAGRAPH 44g AR 38

From: US Military Attache, Bern, Switzerland
To: War Department
Nr: 58 9 September 1945

Msg 58 TOPSECRET sgd Legge. To MILID Wash DC

Horia Hulubei internationally known physicist and until recently rector of University of Bucharest taken by Russians to Moscow. source states Hulubei working on atomic bomb. Source Sec of Roumanian Legation eval B2. More complete report follows.

End

MIS checking + Maj Osborne is checking also regarding report

no record of this physicist
AEB

ACTION: Gen Bissell

INFO: Gen Arnold
Gen Hull
Gen Groves
C of S

CM-IN-7799 (10 Sep 45) DTG: 091330 blw

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14 September 1945

The following information was received from MIS -

HULUBEI, Horia

Rumanian scientiest - field, Chemistry

Discovered a new element "Moldavium"
Studied and did research work in Paris.
Appointed Dean of Bucharest University in 1941.
In 1944 visited as president of board of Resitza Works (armaments)
President of Finnish-Rumanian Society
Has the following decorations -
Crown of Rumania
German Eagle with stars
Reported to be pro-Nazi

NARA RG 77, Entry UD-22A,
Box 160, Folder Apr 45—Dec. '45

Figure D.111: Horia Hulubei was a Romanian nuclear scientist who worked in the Soviet nuclear weapons program after the war. During the war he and Romania supported the Third Reich—what exactly did he work on during that time? Did the Resitza Works do any nuclear-related work? [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45]

Uranium and thorium removed from Germany by the United States and Soviet Union [translated and adapted from Nagel 2016, pp. 543–547]

Taken by United States

Garmisch: uranium
Haigerloch: 1.5 tons uranium metal
Oolen (Belgium): 80 tons uranium ore
Stadtilm: 10 tons uranium oxide
Stassfurt (Kalischacht): uranium ore for Auer 1100–1200 tons
WiFo Leopoldshall (near Calbe): ?? tons uranium ore
Toulouse: 30 tons uranium ore
U-234 submarine: 560 kg uranium oxide (enriched?)

Announced total taken by United States:
Approximately 1200 tons uranium, mostly unprocessed ore

Taken by Soviet Union

Berlin (Auer): uranium oxide
Berlin (KWI Ph): 250 kg uranium metal, 3 tons uranium oxide
Berlin (Schering): 1500 kg thorium oxalate, 50 kg thorotrast
Berlin (Toran): 30 kg mesothorium
Berlin-Grunau (Auer/Degussa): 100 kg uranium products
Goldberg (Mecklenburg): 70 tons? uranium compounds, stored by Roges in Hoffmann and Malzew warehouse
Johanngeorgenstadt (mine): uranium oxide
Kummersdorf (Gottow): 3.5 tons uranium oxide
Landsberg/Warthe: uranium oxide
Neustadt-Glewe (Mecklenburg): 100 tons uranium oxide, stored by Roges in Hoffmann and Molzen warehouse
Oranienburg (Auer): 100 tons uranium oxide, Monazit 1340 tons
Radebeul (Heyden): 300 kg thorium products, 100 kg monazite sand
Schneeberg (mine): uranium oxide
Wien: 560 kg U-Metall 24 kg uranium oxide
Zeuthen/Miersdorf (Reichspost): APS uranium oxide

Announced total taken by Soviet Union
Approximately 300 tons uranium
(not counting vastly more which was extracted from the mines 1945–1989)
Approximately 1340 tons of thorium, mostly unprocessed ore

[These estimates are based on numbers in various individual reports that have been released by the United States and Russia. There may well have been significant amounts of uranium or thorium that were not covered in those reports but that were removed by the United States, Russia, United Kingdom, or France. It is also possible that Germany concealed or disposed of significant amounts, or sent them to other countries.

Some of the seized uranium is still being analyzed. See for example ACS 2021.]

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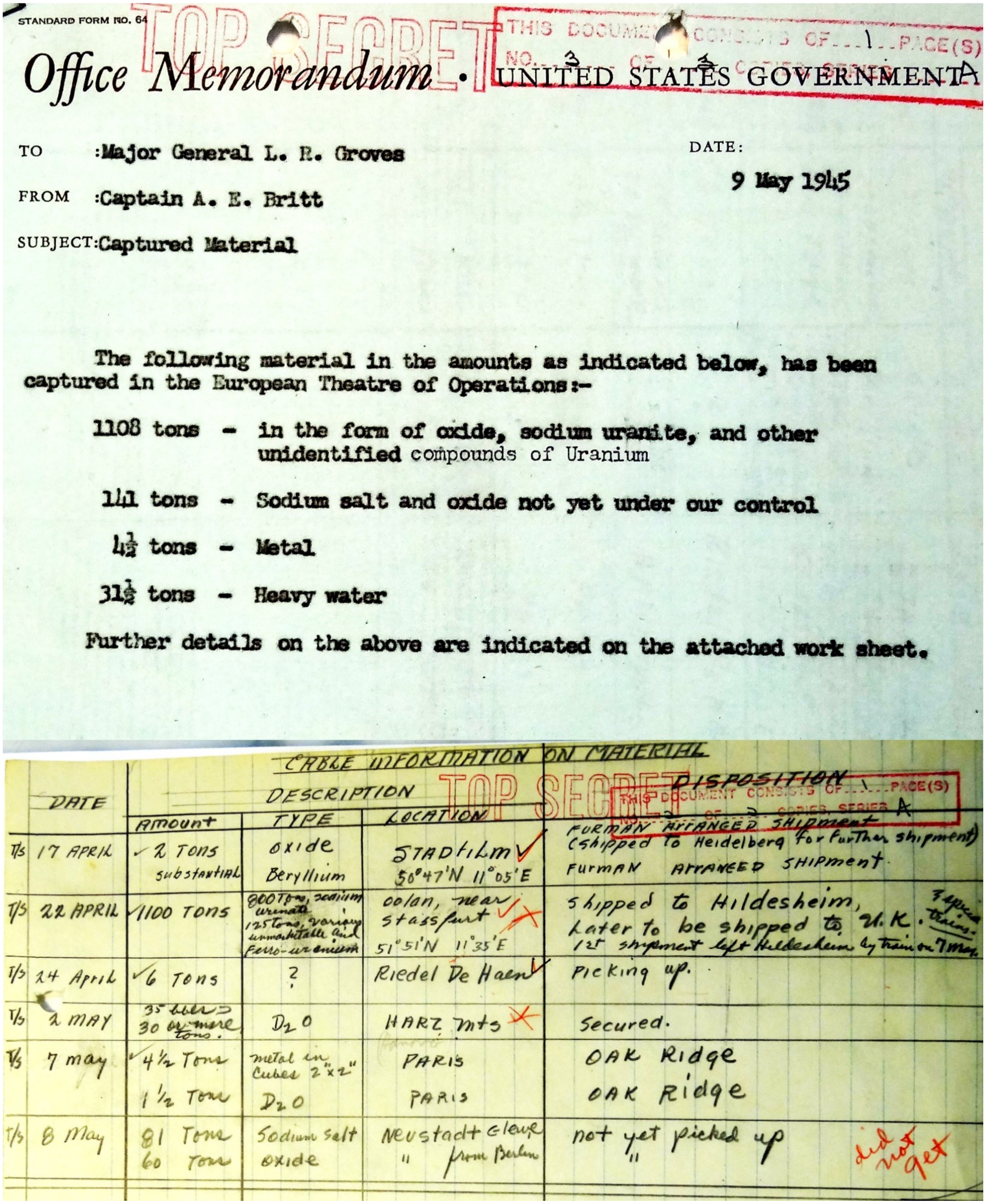
NARA RG 77, Entry UD-22A, Box 169, Folder 32.42.B Germ Captured Materials Uran



STANDARD FORM NO. 64

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NO. 3 OF 4 COPIES, SERIES A

Office Memorandum • UNITED STATES GOVERNMENT

TO :Major General L. R. Groves

FROM :Captain A. E. Britt

SUBJECT:Captured Material

DATE: 9 May 1945

The following material in the amounts as indicated below, has been captured in the European Theatre of Operations:-

1108 tons	-	in the form of oxide, sodium uranite, and other unidentified compounds of Uranium
141 tons	-	Sodium salt and oxide not yet under our control
4½ tons	-	Metal
31½ tons	-	Heavy water

Further details on the above are indicated on the attached work sheet.

CABLE INFORMATION ON MATERIAL

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	DATE	DESCRIPTION			DISPOSITION
		AMOUNT	TYPE	LOCATION	
T/S	17 APRIL	✓ 2 TONS substantial	oxide Beryllium	STADtiLm ✓ 50°47'N 11°05'E	FURMAN ARRANGED SHIPMENT (shipped to Heidelberg for further shipment) FURMAN ARRANGED SHIPMENT.
T/S	22 APRIL	✓1100 TONS	800 Tons, sodium uranate 125 Tons, various unmarketable and Ferro-uranium	oolan, near Stassfurt ✓ ✗ 51°51'N 11°35'E	Shipped to Hildesheim, later to be shipped to U.K. 3 special trains. 1st shipment left Hildesheim by train on 7 May.
T/S	24 April	✓6 TONS	?	Riedel De Haen ✓	Picking up.
T/S	2 MAY	35 bbls > 30 ~~or more~~ tons.	D_2O	HARZ mts ✗	Secured.
T/S	7 may	✓4½ Tons 1½ Tons	metal in Cubes 2"x2" D_2O	PARIS PARIS	OAK Ridge OAK Ridge
T/S	8 May	81 Tons 60 Tons	Sodium salt oxide	Neustadt Gleue " from Berlin	not yet picked up " did not get

Figure D.112: A. E. Britt to Leslie R. Groves. 9 May 1945. SUBJECT: Captured Material [NARA RG 77, Entry UD-22A, Box 169, Folder 32.42.B Germ Captured Materials Uran].

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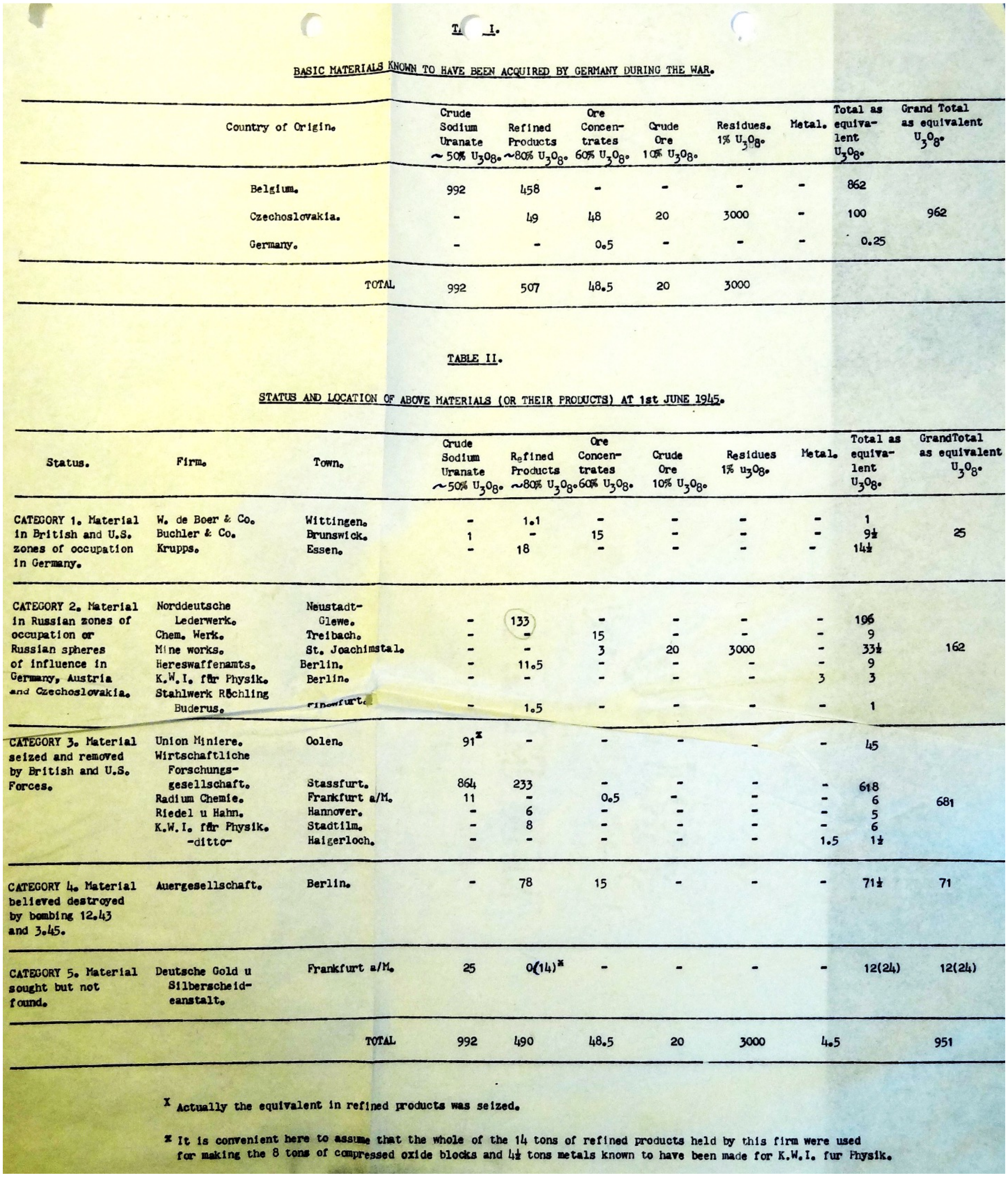
**NARA RG 77, Entry UD-22A,
Box 163, Folder Australia**



TA I.

BASIC MATERIALS KNOWN TO HAVE BEEN ACQUIRED BY GERMANY DURING THE WAR.

Country of Origin.	Crude Sodium Uranate ~ 50% U_3O_8.	Refined Products ~80% U_3O_8.	Ore Concentrates 60% U_3O_8.	Crude Ore 10% U_3O_8.	Residues. 1% U_3O_8.	Metal.	Total as equivalent U_3O_8.	Grand Total as equivalent U_3O_8.
Belgium.	992	458	-	-	-	-	862	962
Czechoslovakia.	-	49	48	20	3000	-	100	
Germany.	-	-	0.5	-	-	-	0.25	
TOTAL	992	507	48.5	20	3000			

TABLE II.

STATUS AND LOCATION OF ABOVE MATERIALS (OR THEIR PRODUCTS) AT 1st JUNE 1945.

Status.	Firm.	Town.	Crude Sodium Uranate ~50% U_3O_8.	Refined Products ~80% U_3O_8.	Ore Concentrates 60% U_3O_8.	Crude Ore 10% U_3O_8.	Residues 1% U_3O_8.	Metal.	Total as equivalent U_3O_8.	GrandTotal as equivalent U_3O_8.
CATEGORY 1. Material in British and U.S. zones of occupation in Germany.	W. de Boer & Co.	Wittingen.	-	1.1	-	-	-	-	1	25
	Buchler & Co.	Brunswick.	1	-	15	-	-	-	9½	
	Krupps.	Essen.	-	18	-	-	-	-	14½	
CATEGORY 2. Material in Russian zones of occupation or Russian spheres of influence in Germany, Austria and Czechoslovakia.	Norddeutsche Lederwerk.	Neustadt-Glewe.	-	133	-	-	-	-	106	162
	Chem. Werk.	Treibach.	-	-	15	-	-	-	9	
	Mine works.	St. Joachimstal.	-	-	3	20	3000	-	33½	
	Hereswaffenamts.	Berlin.	-	11.5	-	-	-	-	9	
	K.W.I. für Physik.	Berlin.	-	-	-	-	-	3	3	
	Stahlwerk Röchling Buderus.	Finowfurt.	-	1.5	-	-	-	-	1	
CATEGORY 3. Material seized and removed by British and U.S. Forces.	Union Miniere.	Oolen.	91[x]	-	-	-	-	-	45	681
	Wirtschaftliche Forschungsgesellschaft.	Stassfurt.	864	233	-	-	-	-	618	
	Radium Chemie.	Frankfurt a/M.	11	-	0.5	-	-	-	6	
	Riedel u Hahn.	Hannover.	-	6	-	-	-	-	5	
	K.W.I. für Physik.	Stadtilm.	-	8	-	-	-	-	6	
	-ditto-	Haigerloch.	-	-	-	-	-	1.5	1½	
CATEGORY 4. Material believed destroyed by bombing 12.43 and 3.45.	Auergesellschaft.	Berlin.	-	78	15	-	-	-	71½	71
CATEGORY 5. Material sought but not found.	Deutsche Gold u Silberscheideanstalt.	Frankfurt a/M.	25	0(14)[*]	-	-	-	-	12(24)	12(24)
		TOTAL	992	490	48.5	20	3000	4.5		951

[x] Actually the equivalent in refined products was seized.

[*] It is convenient here to assume that the whole of the 14 tons of refined products held by this firm were used for making the 8 tons of compressed oxide blocks and 4½ tons metals known to have been made for K.W.I. fur Physik.

Figure D.113: Table I: Basic Materials Known to Have Been Acquired by Germany During the War. Table II: Status and Location of Above Materials (or Their Products) at 1st June 1945 [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

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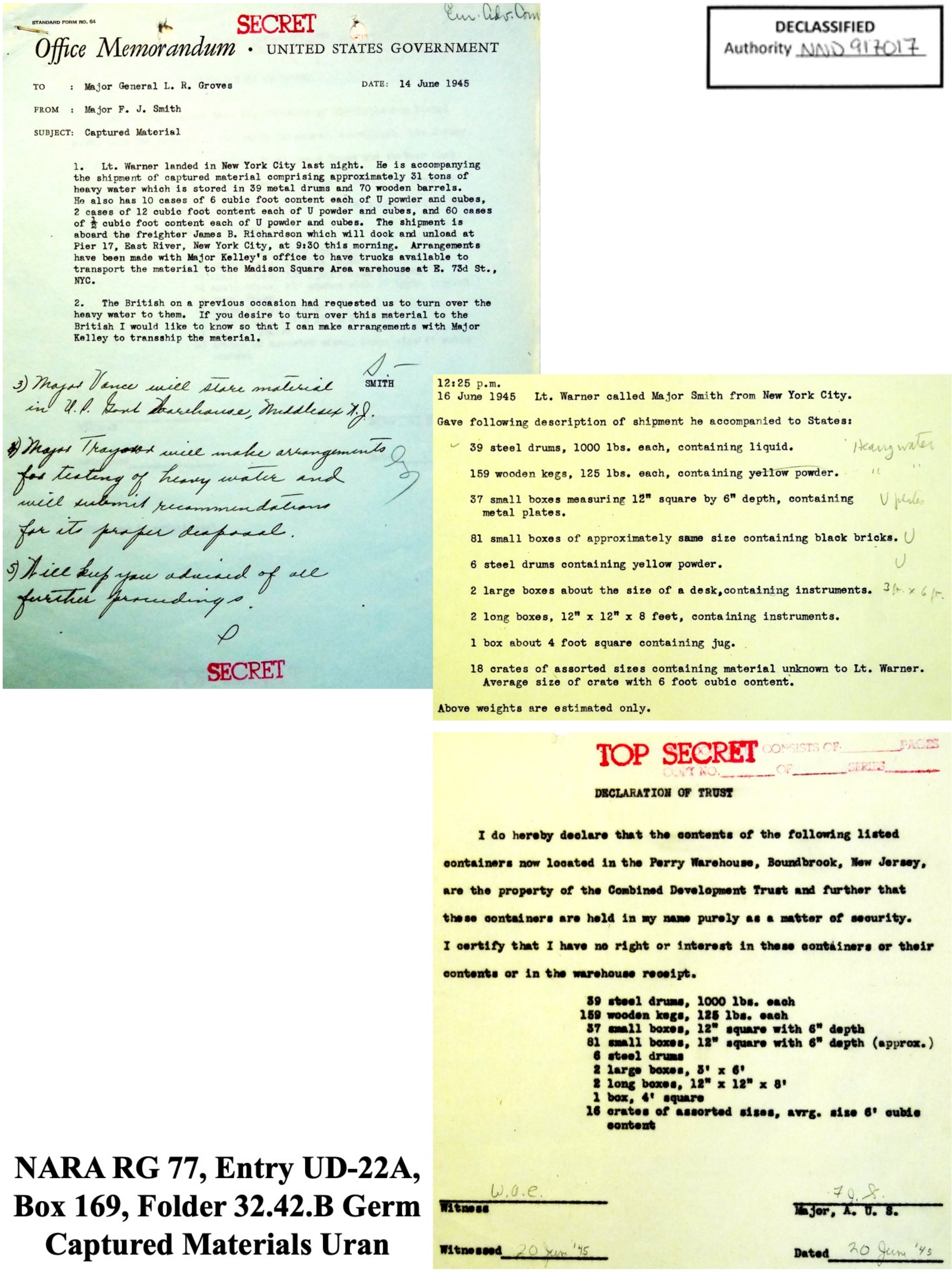

STANDARD FORM NO. 64

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Em. Adv. Com

Office Memorandum • UNITED STATES GOVERNMENT

TO : Major General L. R. Groves DATE: 14 June 1945

FROM : Major F. J. Smith

SUBJECT: Captured Material

1. Lt. Warner landed in New York City last night. He is accompanying the shipment of captured material comprising approximately 31 tons of heavy water which is stored in 39 metal drums and 70 wooden barrels. He also has 10 cases of 6 cubic foot content each of U powder and cubes, 2 cases of 12 cubic foot content each of U powder and cubes, and 60 cases of ½ cubic foot content each of U powder and cubes. The shipment is aboard the freighter James B. Richardson which will dock and unload at Pier 17, East River, New York City, at 9:30 this morning. Arrangements have been made with Major Kelley's office to have trucks available to transport the material to the Madison Square Area warehouse at E. 73d St., NYC.

2. The British on a previous occasion had requested us to turn over the heavy water to them. If you desire to turn over this material to the British I would like to know so that I can make arrangements with Major Kelley to transship the material.

SMITH

3) Major Vance will store material in U.S. Govt Warehouse, Middlesex N.J.

4) Major Traynor will make arrangements for testing of heavy water and will submit recommendations for its proper disposal.

5) Will keep you advised of all further proceedings.

SECRET

12:25 p.m.
16 June 1945 Lt. Warner called Major Smith from New York City.

Gave following description of shipment he accompanied to States:

- 39 steel drums, 1000 lbs. each, containing liquid. Heavy water
- 159 wooden kegs, 125 lbs. each, containing yellow powder. " "
- 37 small boxes measuring 12" square by 6" depth, containing metal plates. U plates
- 81 small boxes of approximately same size containing black bricks. U
- 6 steel drums containing yellow powder. U
- 2 large boxes about the size of a desk, containing instruments. 3 ft. x 6 ft.
- 2 long boxes, 12" x 12" x 8 feet, containing instruments.
- 1 box about 4 foot square containing jug.
- 18 crates of assorted sizes containing material unknown to Lt. Warner. Average size of crate with 6 foot cubic content.

Above weights are estimated only.

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DECLARATION OF TRUST

I do hereby declare that the contents of the following listed containers now located in the Perry Warehouse, Boundbrook, New Jersey, are the property of the Combined Development Trust and further that these containers are held in my name purely as a matter of security. I certify that I have no right or interest in these containers or their contents or in the warehouse receipt.

39 steel drums, 1000 lbs. each
159 wooden kegs, 125 lbs. each
37 small boxes, 12" square with 6" depth
81 small boxes, 12" square with 6" depth (approx.)
6 steel drums
2 large boxes, 3' x 6'
2 long boxes, 12" x 12" x 8'
1 box, 4' square
16 crates of assorted sizes, avrg. size 6' cubic content

W.A.C.
Witness

F.J.S.
Major, A. U. S.

Witnessed 20 Jun '45

Dated 20 Jun '45

NARA RG 77, Entry UD-22A, Box 169, Folder 32.42.B Germ Captured Materials Uran

Figure D.114: Francis J. Smith to Leslie R. Groves. 14–20 June 1945. SUBJECT: Captured Material [NARA RG 77, Entry UD-22A, Box 169, Folder 32.42.B Germ Captured Materials Uran].

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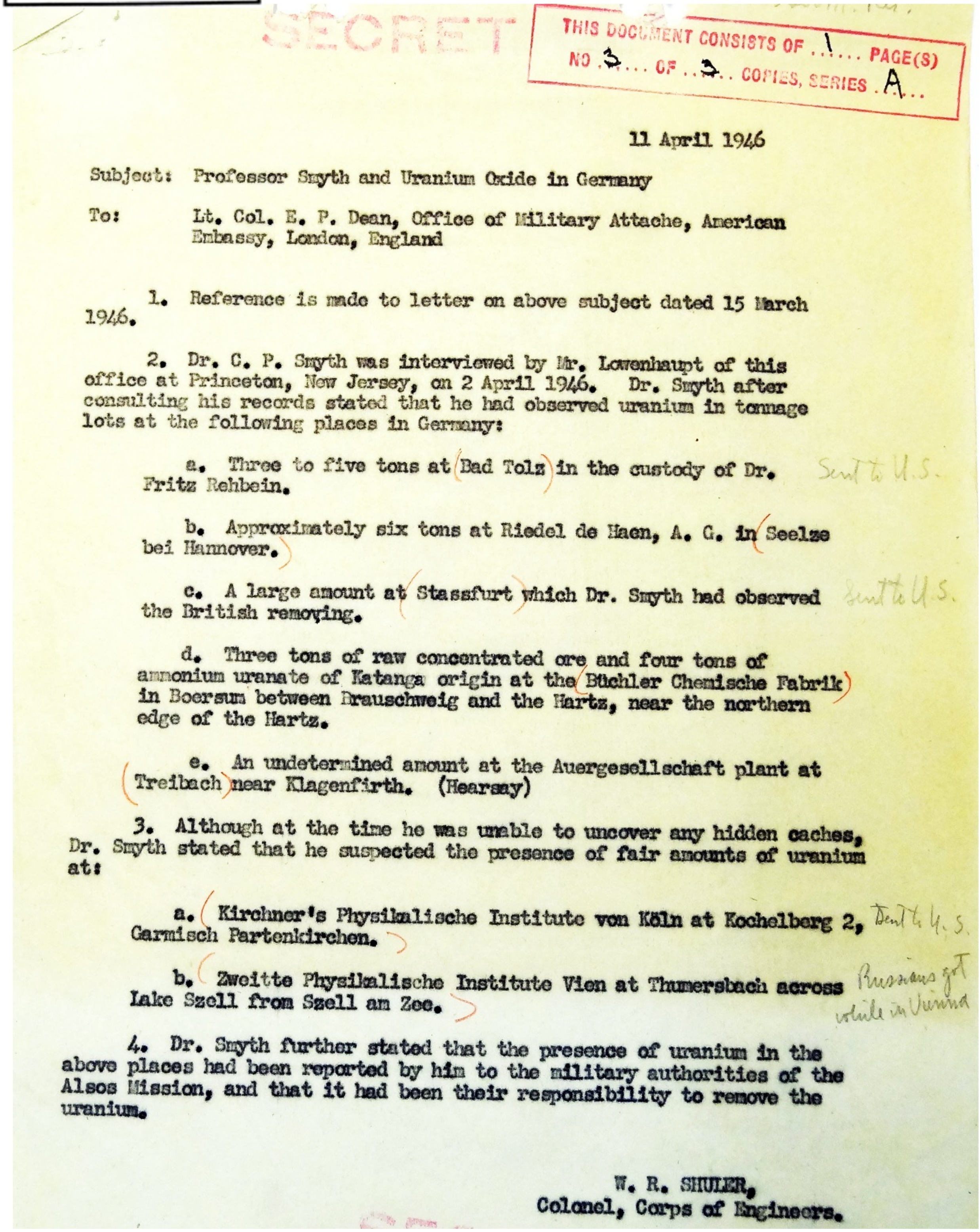
NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Incl. TA



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NO 3 OF 3 COPIES, SERIES A

11 April 1946

Subject: Professor Smyth and Uranium Oxide in Germany

To: Lt. Col. E. P. Dean, Office of Military Attache, American Embassy, London, England

1. Reference is made to letter on above subject dated 15 March 1946.

2. Dr. C. P. Smyth was interviewed by Mr. Lowenhaupt of this office at Princeton, New Jersey, on 2 April 1946. Dr. Smyth after consulting his records stated that he had observed uranium in tonnage lots at the following places in Germany:

a. Three to five tons at Bad Tolz in the custody of Dr. Fritz Rehbein. Sent to U.S.

b. Approximately six tons at Riedel de Haen, A. G. in Seelze bei Hannover.

c. A large amount at Stassfurt which Dr. Smyth had observed the British removing. Sent to U.S.

d. Three tons of raw concentrated ore and four tons of ammonium uranate of Katanga origin at the Büchler Chemische Fabrik in Boersum between Brauschweig and the Hartz, near the northern edge of the Hartz.

e. An undetermined amount at the Auergesellschaft plant at Treibach near Klagenfirth. (Hearsay)

3. Although at the time he was unable to uncover any hidden caches, Dr. Smyth stated that he suspected the presence of fair amounts of uranium at:

a. Kirchner's Physikalische Institute von Köln at Kochelberg 2, Garmisch Partenkirchen. Sent to U.S.

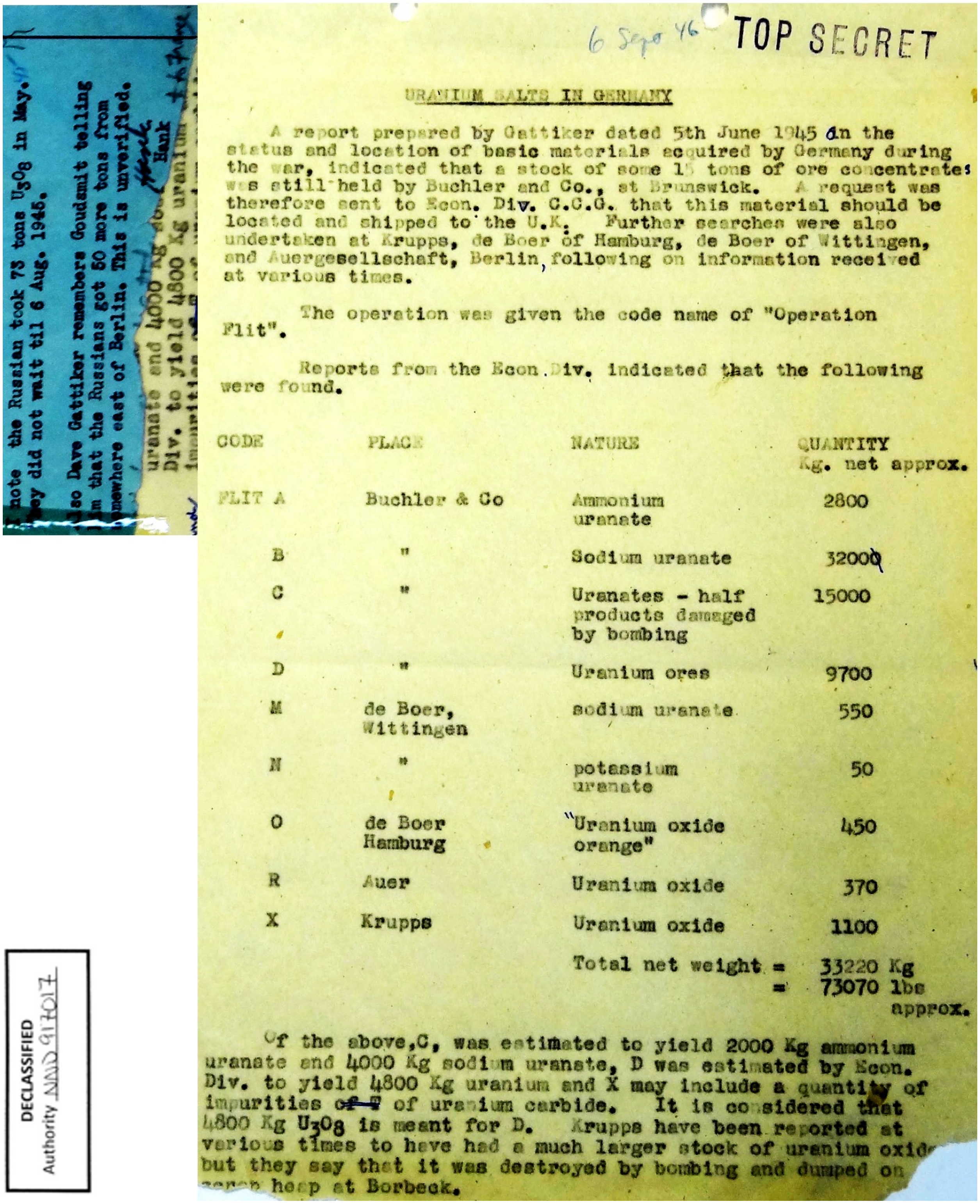
b. Zweitte Physikalische Institute Vien at Thumersbach across Lake Szell from Szell am Zee. Russians got while in Vienna

4. Dr. Smyth further stated that the presence of uranium in the above places had been reported by him to the military authorities of the Alsos Mission, and that it had been their responsibility to remove the uranium.

W. R. SHULER,
Colonel, Corps of Engineers.

Figure D.115: W. R. Shuler to E. P. Dean. 11 April 1946. Subject: Professor Smyth and Uranium Oxide in Germany. This highly incomplete list illustrates the variety of places that processed, stored, and used uranium during the war, as well as the various Allied groups that stumbled across some of those after the war [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Ind. TA



I note the Russian took 73 tons U_3O_8 in May. They did not wait til 6 Aug. 1945.

Also Dave Gattiker remembers Goudsmit telling him that the Russians got 50 more tons from somewhere east of Berlin. This is unverified.

Hank

6 Sept 46

TOP SECRET

URANIUM SALTS IN GERMANY

A report prepared by Gattiker dated 5th June 1945 on the status and location of basic materials acquired by Germany during the war, indicated that a stock of some 15 tons of ore concentrates was still held by Buchler and Co., at Brunswick. A request was therefore sent to Econ. Div. C.C.G. that this material should be located and shipped to the U.K. Further searches were also undertaken at Krupps, de Boer of Hamburg, de Boer of Wittingen, and Auergesellschaft, Berlin, following on information received at various times.

The operation was given the code name of "Operation Flit".

Reports from the Econ. Div. indicated that the following were found.

CODE	PLACE	NATURE	QUANTITY Kg. net approx.
FLIT A	Buchler & Co	Ammonium uranate	2800
B	"	Sodium uranate	32000
C	"	Uranates - half products damaged by bombing	15000
D	"	Uranium ores	9700
M	de Boer, Wittingen	sodium uranate	550
N	"	potassium uranate	50
O	de Boer Hamburg	"Uranium oxide orange"	450
R	Auer	Uranium oxide	370
X	Krupps	Uranium oxide	1100
		Total net weight =	33220 Kg = 73070 lbs approx.

Of the above, C, was estimated to yield 2000 Kg ammonium uranate and 4000 Kg sodium uranate, D was estimated by Econ. Div. to yield 4800 Kg uranium and X may include a quantity of impurities ~~of T~~ of uranium carbide. It is considered that 4800 Kg U_3O_8 is meant for D. Krupps have been reported at various times to have had a much larger stock of uranium oxide but they say that it was destroyed by bombing and dumped on scrap heap at Borbeck.

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Figure D.116: Uranium Salts in Germany. 6 September 1946 [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

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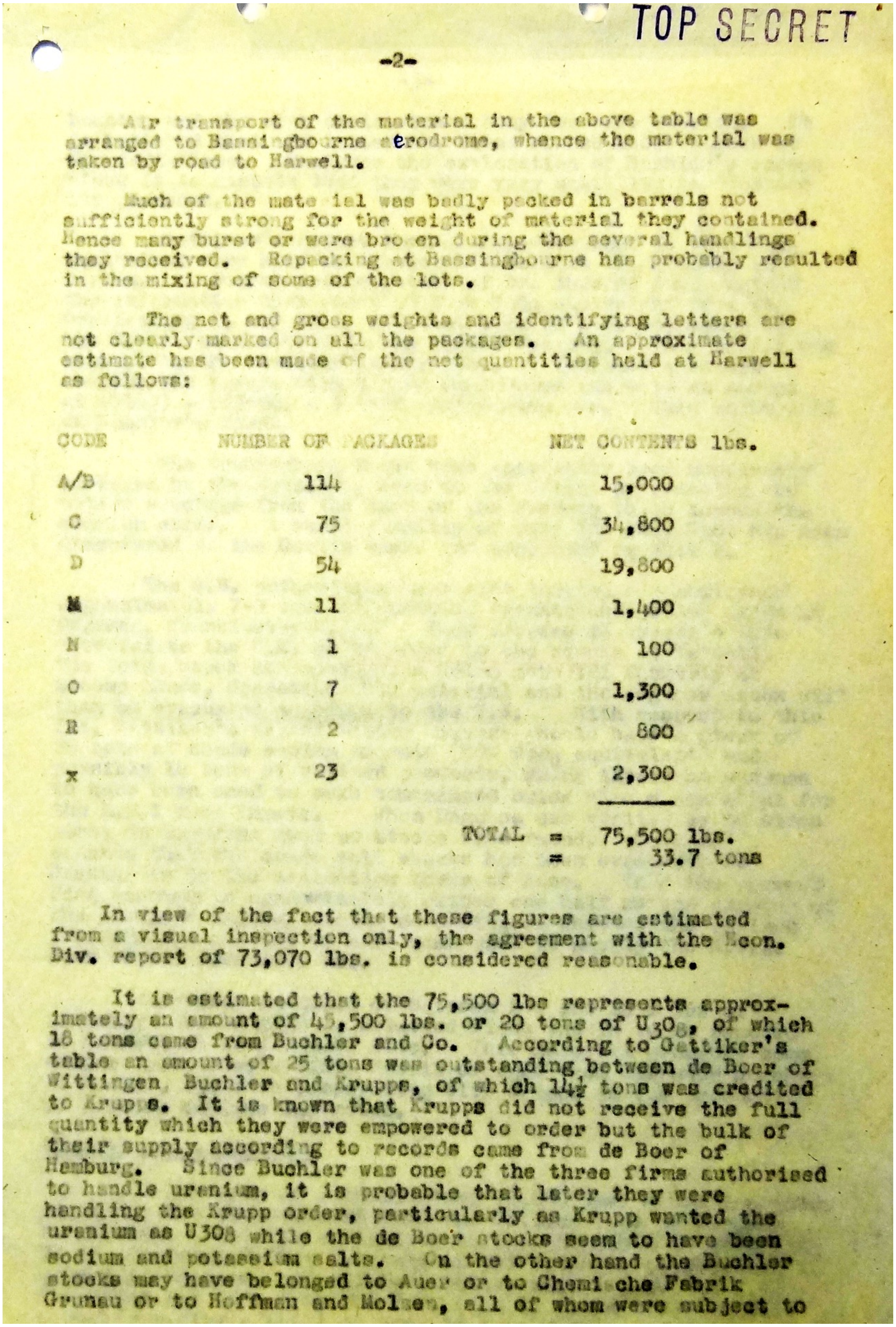
NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Ind. TA



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Air transport of the material in the above table was arranged to Bassingbourne aerodrome, whence the material was taken by road to Harwell.

Much of the material was badly packed in barrels not sufficiently strong for the weight of material they contained. Hence many burst or were broken during the several handlings they received. Repacking at Bassingbourne has probably resulted in the mixing of some of the lots.

The net and gross weights and identifying letters are not clearly marked on all the packages. An approximate estimate has been made of the net quantities held at Harwell as follows:

CODE	NUMBER OF PACKAGES	NET CONTENTS lbs.
A/B	114	15,000
C	75	34,800
D	54	19,800
M	11	1,400
N	1	100
O	7	1,300
R	2	800
X	23	2,300
	TOTAL =	75,500 lbs.
	=	33.7 tons

In view of the fact that these figures are estimated from a visual inspection only, the agreement with the Econ. Div. report of 73,070 lbs. is considered reasonable.

It is estimated that the 75,500 lbs represents approximately an amount of 45,500 lbs. or 20 tons of U_3O_8, of which 18 tons came from Buchler and Co. According to Gattiker's table an amount of 25 tons was outstanding between de Boer of Wittingen, Buchler and Krupps, of which 14½ tons was credited to Krupps. It is known that Krupps did not receive the full quantity which they were empowered to order but the bulk of their supply according to records came from de Boer of Hamburg. Since Buchler was one of the three firms authorised to handle uranium, it is probable that later they were handling the Krupp order, particularly as Krupp wanted the uranium as U_3O_8 while the de Boer stocks seem to have been sodium and potassium salts. On the other hand the Buchler stocks may have belonged to Auer or to Chemische Fabrik Grunau or to Hoffman and Molsen, all of whom were subject to

Figure D.117: Uranium Salts in Germany. 6 September 1946 [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

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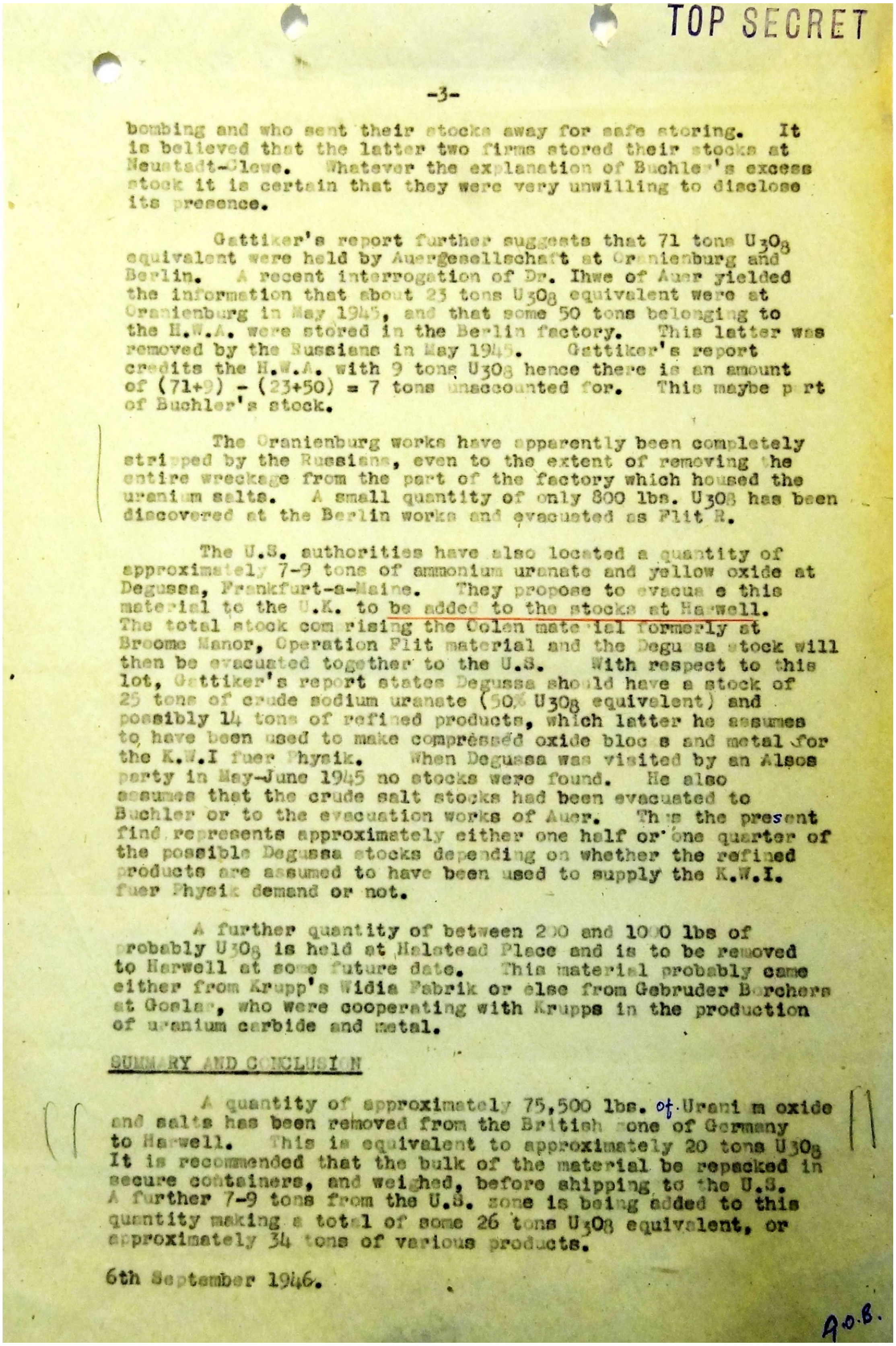

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-3-

bombing and who sent their stocks away for safe storing. It is believed that the latter two firms stored their stocks at Neustadt-Glewe. Whatever the explanation of Buchler's excess stock it is certain that they were very unwilling to disclose its presence.

Gattiker's report further suggests that 71 tons U_3O_8 equivalent were held by Auergesellschaft at Oranienburg and Berlin. A recent interrogation of Dr. Ihwe of Auer yielded the information that about 23 tons U_3O_8 equivalent were at Oranienburg in May 1945, and that some 50 tons belonging to the H.W.A. were stored in the Berlin factory. This latter was removed by the Russians in May 1945. Gattiker's report credits the H.W.A. with 9 tons U_3O_8 hence there is an amount of (71+9) - (23+50) = 7 tons unaccounted for. This maybe part of Buchler's stock.

The Oranienburg works have apparently been completely stripped by the Russians, even to the extent of removing the entire wreckage from the part of the factory which housed the uranium salts. A small quantity of only 800 lbs. U_3O_8 has been discovered at the Berlin works and evacuated as Flit R.

The U.S. authorities have also located a quantity of approximately 7-9 tons of ammonium uranate and yellow oxide at Degussa, Frankfurt-a-Maine. They propose to evacuate this material to the U.K. to be added to the stocks at Harwell. The total stock comprising the Colen material formerly at Broome Manor, Operation Flit material and the Degussa stock will then be evacuated together to the U.S. With respect to this lot, Gattiker's report states Degussa should have a stock of 25 tons of crude sodium uranate (50% U_3O_8 equivalent) and possibly 14 tons of refined products, which latter he assumes to have been used to make compressed oxide blocks and metal for the K.W.I fuer Physik. When Degussa was visited by an Alsos party in May-June 1945 no stocks were found. He also assumes that the crude salt stocks had been evacuated to Buchler or to the evacuation works of Auer. Thus the present find represents approximately either one half or one quarter of the possible Degussa stocks depending on whether the refined products are assumed to have been used to supply the K.W.I. fuer Physik demand or not.

A further quantity of between 200 and 1000 lbs of probably U_3O_8 is held at Halstead Place and is to be removed to Harwell at some future date. This material probably came either from Krupp's Widia Fabrik or else from Gebruder Borchers at Goslar, who were cooperating with Krupps in the production of uranium carbide and metal.

SUMMARY AND CONCLUSION

A quantity of approximately 75,500 lbs. of Uranium oxide and salts has been removed from the British zone of Germany to Harwell. This is equivalent to approximately 20 tons U_3O_8 It is recommended that the bulk of the material be repacked in secure containers, and weighed, before shipping to the U.S. A further 7-9 tons from the U.S. zone is being added to this quantity making a total of some 26 tons U_3O_8 equivalent, or approximately 34 tons of various products.

6th September 1946.

A.O.B.

Figure D.118: Uranium Salts in Germany. 6 September 1946 [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

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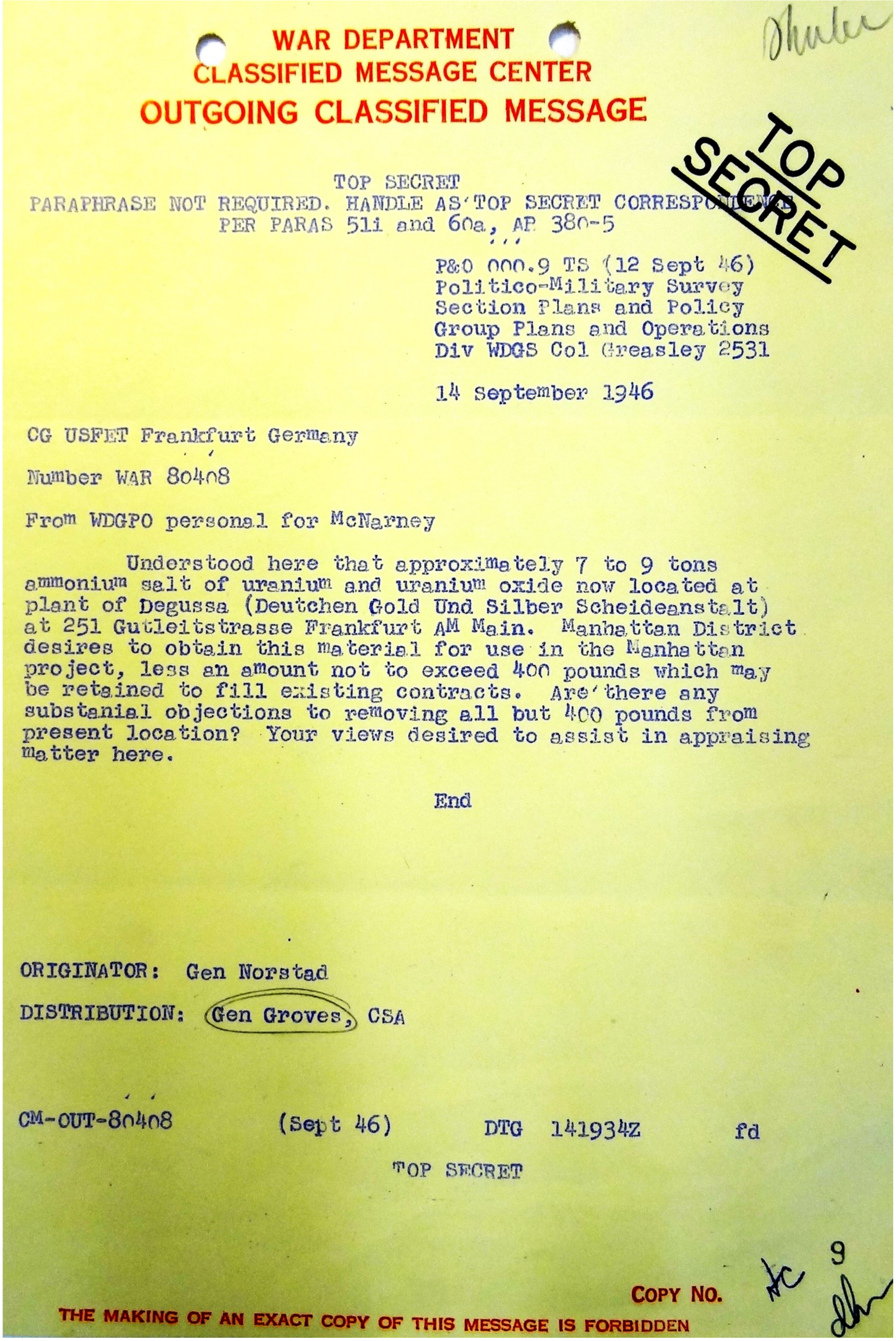

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Shuler

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P&O 000.9 TS (12 Sept 46)
Politico-Military Survey
Section Plans and Policy
Group Plans and Operations
Div WDGS Col Greasley 2531

14 September 1946

CG USFET Frankfurt Germany

Number WAR 80408

From WDGPO personal for McNarney

Understood here that approximately 7 to 9 tons ammonium salt of uranium and uranium oxide now located at plant of Degussa (Deutchen Gold Und Silber Scheideanstalt) at 251 Gutleitstrasse Frankfurt AM Main. Manhattan District desires to obtain this material for use in the Manhattan project, less an amount not to exceed 400 pounds which may be retained to fill existing contracts. Are there any substanial objections to removing all but 400 pounds from present location? Your views desired to assist in appraising matter here.

End

ORIGINATOR: Gen Norstad

DISTRIBUTION: Gen Groves, CSA

CM-OUT-80408 (Sept 46) DTG 141934Z fd

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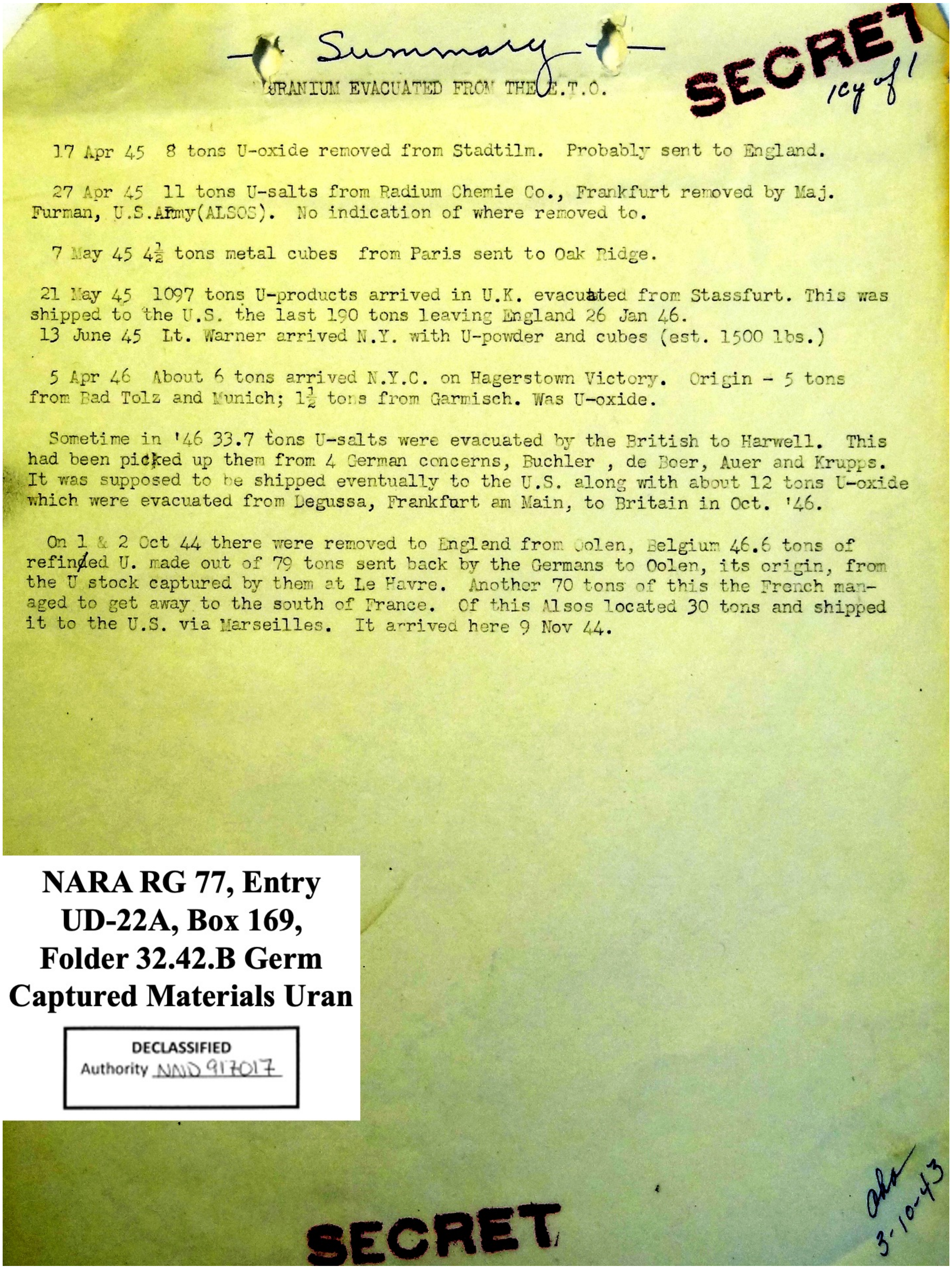
NARA RG 77, Entry UD-22A, Box 160, Folder 205.4 Cables Outgoing, Top Secret

Figure D.119: Lauris Norstad. 14 September 1946 [NARA RG 77, Entry UD-22A, Box 160, Folder 205.4 Cables Outgoing, Top Secret].



Summary

SECRET 1 cy of 1

URANIUM EVACUATED FROM THE E.T.O.

17 Apr 45 8 tons U-oxide removed from Stadtilm. Probably sent to England.

27 Apr 45 11 tons U-salts from Radium Chemie Co., Frankfurt removed by Maj. Furman, U.S.Army(ALSOS). No indication of where removed to.

7 May 45 $4\frac{1}{2}$ tons metal cubes from Paris sent to Oak Ridge.

21 May 45 1097 tons U-products arrived in U.K. evacuated from Stassfurt. This was shipped to the U.S. the last 190 tons leaving England 26 Jan 46.

13 June 45 Lt. Warner arrived N.Y. with U-powder and cubes (est. 1500 lbs.)

5 Apr 46 About 6 tons arrived N.Y.C. on Hagerstown Victory. Origin - 5 tons from Bad Tolz and Munich; $1\frac{1}{2}$ tons from Garmisch. Was U-oxide.

Sometime in '46 33.7 tons U-salts were evacuated by the British to Harwell. This had been picked up them from 4 German concerns, Buchler , de Boer, Auer and Krupps. It was supposed to be shipped eventually to the U.S. along with about 12 tons U-oxide which were evacuated from Degussa, Frankfurt am Main, to Britain in Oct. '46.

On 1 & 2 Oct 44 there were removed to England from Oolen, Belgium 46.6 tons of refin~~d~~ed U. made out of 79 tons sent back by the Germans to Oolen, its origin, from the U stock captured by them at Le Havre. Another 70 tons of this the French managed to get away to the south of France. Of this Alsos located 30 tons and shipped it to the U.S. via Marseilles. It arrived here 9 Nov 44.

NARA RG 77, Entry UD-22A, Box 169, Folder 32.42.B Germ Captured Materials Uran

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Figure D.120: Uranium Evacuated from the E.T.O. Undated but probably Oct.–Dec. 1946 [NARA RG 77, Entry UD-22A, Box 169, Folder 32.42.B Germ Captured Materials Uran].

Michael Howard. 2010 *Otherwise Occupied*, pp. 156–158.

[September 1946, British-occupied zone of Germany:]

One night I was called in the early hours on one of the two telephones by my bed, and a codeword was muttered conspiratorially in my ear. It meant absolutely nothing to me; I had simply not been briefed in advance. It was the GSO2 at HQ T-Force, and he had no option but to identify himself, and to explain to me 'in clear' what the operation consisted of. There were said to be eleven thousand kilos of highly refined uranium ore lying in a loose pile in the cellars of Krupp's Widia Works at Essen (whose main business was in carbide steels). A quadripartite team including four Russians was due to be visiting the site in a couple of days and it was vitally important that there should be no trace of the uranium remaining by the time they arrived, or they would be entitled to make a bid for it. How on earth had it been left sitting there so long?

Nothing for it but to get straight on the phone to Fred Bonney at B Detachment at Heisingen, not five miles from Krupp's Widia Works, and tell him the story in clear. He set to work immediately, and they rustled up from somewhere enough empty steel three-inch mortar bomb boxes, with a handle at each end, which limited the contents to a weight of this dense material that required no more than two men to lift. The entire heap, every scrap, was boxed and loaded onto a ten-ton Mack truck and delivered to me by early afternoon at Kamen. The springs of the truck bore the gross weight of the uranium plus the mortar-bomb boxes surprisingly well. I collared the Mess corporal, Corporal Weatherall, and told him to draw a Sten gun and a couple of magazines, sit on the load, take it up to the RAF at Bückeburg, '...and if any bastard tries to take it away from you, shoot him. And get a receipt.' Which he did, from a squadron leader, for 11,000 kilos.

The material was almost certainly 'yellowcake', a form of triuranium octoxide[...]

About six months later a captain in the Special Investigation Branch (SIB) asked to come and see me. The RAF had weighed the bomb boxes for their own purposes before flying them over to England, but the net weight of the contents was never established until the boxes reached their final destination, when it was found to be 6,000 kilos. It was meant to have been 11,000. Where were the missing 5,000 kilos? 'Search me,' I said. The SIB spent quite a while nosing round, and the only conclusion they could reach was that there had never been 11,000 kilos at Krupp's Widia Works in the first place. As there was no weighing equipment accessible to where the material had been dumped, it had been an estimate, and an inaccurate one. Or had someone in Krupp's been squirreling away a couple of kilos at a time for sixteen months, and had it since crossed the border of Magdeburg [into the Soviet-occupied zone of Germany] in quantities which would go in a haversack? It was a conclusion they shied away from. The pile had appeared undisturbed.

[Michael Howard (British, 1926–2018) was an intelligence officer in the British T-Force, which investigated and removed vast amounts of technology from Germany after the war. This incident that he recounted is important because it demonstrated that:

- Nations other than just the United States and the Soviet Union removed tons of uranium from German territory after the war. (In this case it was the United Kingdom, but perhaps France or maybe even other countries did as well.)

- The discovery and removal of this stockpile of uranium does not appear to be mentioned in official documents that have been released. If Howard had not described it in his memoirs before he died, the public would still be entirely unaware of this incident. What other discoveries of uranium or other aspects of the German nuclear program also remain unreleased to the public?

- As late as at least September 1946, there were large stashes of German uranium that had not already been discovered and removed by Allied forces. Perhaps there were other stockpiles of German uranium (e.g., in underground facilities) that Allied forces continued to overlook, and that remain hidden to this day.

- Uranium was at facilities that had not been believed to be part of the German nuclear program. Why was highly refined uranium oxide at Krupp? Did Krupp (which had extensive expertise with metallurgy) play an important role in the German nuclear program, for example by fabricating uranium metal components for reactors or bombs? Or was the uranium simply dumped there as a hiding place near the end of the war?]

National Intelligence Survey (NIS) 26 (U.S.S.R.), Chapter VII, Section 73 (Atomic Energy). 1955. CIA. https://www.cia.gov/readingroom/docs/DOC_0000198124.pdf https://www.cia.gov/readingroom/document/0000198124 [This report demonstrates that most of the uranium mined for the postwar Soviet nuclear weapons program came from regions that were under German control during World War II. This report explicitly states that several of those uranium sources were exploited by Germany during the war. There is independent evidence that a number of the other sources listed here were also used by Germany during the war. Thus wartime Germany had access to an enormous amount of uranium from these regions—plus the Congolese high-grade uranium ore that Germany obtained from Belgium. Moe Berg's notes (pp. 5051–5063) reference a 1951 version of this report that I have not been able to obtain.]

1. Uranium Supply

Current internal mining operations provide about one third of the estimated annual uranium production available to the USSR. The remaining two thirds are obtained from Germany, Czechoslovakia, Bulgaria, Romania, Poland, and China. Of these latter sources, Germany and Czechoslovakia are outstanding in that they provide almost 90 per cent of the total produced outside the USSR. [...]

a. USSR Sources [...]

b. German Sources

(1) Ore deposits—Deposits in the Soviet Zone of Germany are at present the most productive source of uranium being exploited by the Soviets. It is estimated that this source provided about 50 per cent of the estimated total Soviet uranium production in 1954. Uranium mining operations in eastern Germany were begun by the Soviets in October 1946. At first, they were confined to the Erzgebirge, in Saxony, around the towns of Johanngeorgenstadt, Oberschlema, Niederschlema, Schneeberg, Aue, Annaberg, Marienberg, Schwarzenberg, Freiberg, and Dresden. The operations have continually expanded and in 1954 the area around Auerbach, Oelanitz, Bergen, and Schmiedeberg (East Germany) and Thuringia (near Gera, Ronnebourg, and Sorge Settendorf where large quantities of low-grade ore are mined. Prospecting operations have been conducted in all possible areas. Uranium of all qualities has been mined—a fairly large amount of high-grade ore and very great amounts of low-grade ore. The greatest portion of uranium shipped from Germany is in the form of so called high-grade ore with an average U-metal content of about 1.50 per cent (obtained by hand and machine sorting).

Based upon the present extent of operation, it is estimated that uranium production in Germany will continue at the present level for at least three or four more years before gradually declining.

(2) Operations—Soviet uranium mining operations in Germany are under the control of a Soviet-German company called "Wismut S. D. A. G.". Wismut, formed in June 1947, is headed by MVD Major General Alexei Matveyevich Bogatov. Subordinate units of Wismut are called "Objekts" and, as a rule, are organized for a specific purpose: some are mining combines controlling a number of mine shafts within a local area; some are mine development projects which build facilities, sink new shafts, extend drifts, etc.; some are concentrating plants; some are engaged in making machinery and tools.

Wismut has opened and developed approximately 400 shafts in Germany since operations began in 1946. The individual shafts, or mines, are too numerous to list in this text, but the main mining objects are as follows:

"Objekt"	Headquarters
1	Johanngeorgenstadt
2	Oberschlema
6	Auerbach
7	Bärenstein
9	Aue
90	Gera
96	Dresden

Wismut has mined solely for uranium. Until recently, there was no attempt made to utilize the silver, cobalt, bismuth, nickel, and other ores which were mined along with uranium ore; these other ores were all thrown on huge waste piles.

Mining methods which are fairly standard for working hard rock vein-type deposits are used by Wismut. Some of the ore is suitable for direct shipment to the USSR, but a great deal of the materials is of such low grade that this is impracticable. This latter material must be concentrated to a grade of at least 1 per cent or more uranium metal before being shipped. Wismut has, at present, eight concentrating plants which process low-grade ore. These plants are: Object 31, and Langenfeld; Object 32, at Tannenbergsthal; Factory 95 of Object 96, at Gittersee/Dresden; Factory 96 of Object 96, at Freital/Dresden; Object 98, at Johanngeorgenstadt; Factory 99 of Object 2, at Oberschlema; Object 100, at Aue; and Object 101, at Zwickau/Crossen.

About 150,000 workers are employed by Wismut; at least 90 per cent of them Germans. Because production has increased steadily through the years, it is believed that Wismut is currently producing at its peak. Production will probably continue at the present level for the next three or four years before declining slowly.

c. Czechoslovakian Sources

(1) Ore deposits—The uranium deposits in Czechoslovakia are important source of Soviet uranium. The present output is about 10 per cent of the total estimated production by the USSR in 1954. Unlike East Germany and the other Satellites, mining and supervision is performed by the Czechs. The Soviets are continuing to make great efforts to increase this output and have initiated extensive prospecting and development programs. Prospecting operations have extended throughout Czechoslovakia.

The Soviets took over the uranium mines in Czechoslovakia before September 1945. At that time, a secret agreement was made between the Soviet Government and the Czech Prime Minister Fierlinger whereby the Soviet Government would supervise the exploitation of the Bohemian uranium mines and take the entire output, returning to Czechoslovakia part or all of the recovered radium. Operations were started in the old uranium mines of Jachymov, located on the Czech side of the Erzgebirge. The exploitation was soon extended to the surrounding area and now includes the towns of Vejprty, Abertamy, Potucky, Seify, Bozi Dar, Dürnberg, Maria Sorg, Werlsgrün, and many more. As a result of very intensive exploration programs, new uranium mining areas at Pribram, Horni-Slavkov, Marianske Lazne, Drmoul, Trutnov, and a number of smaller areas have been opened up in Czechoslovakia.

(2) Operations–The uranium mining operations in Czechoslovakia are directly under the control of "The Jachymov Mines National Corporation". That organization, at least at the higher levels, is jointly administered. The Soviets, however, have virtually complete control of the corporation as most of the Czech officials were chosen on a basis of their cooperation with the USSR and communist

party membership. The individual mining areas are under the control of separate enterprises called "Inspectorates". The following are the known Inspectorates with their area of operation:

Inspectorates I and II are located in the area around Jachymov. These are the second most important producer. The principal mines in Inspectorates I and II are the Bratrstvi, Rovnost 1 and 2, Svornost, Joseph, Elias 1 and 2, Marianska, Eduard, Bohumil, Barbara, Eva, and Klavno.

Inspectorate VI is located at Horni Slavkov. At present, this Inspectorate is the largest producer in Czechoslovakia. The principal mines in this inspectorate are Prokop, Barbora, Svatopluk, Lesnice, Zdar Buh, Mines 9, 10, 11, 12, 14, 15, 16, 18, and 19.

Inspectorate K-2 is located at Pribram. It produced a small amount of ore.

The Inspectorate X at Trutnov is still in production. Probably mostly low-grade material is handled here from sedimentary deposits.

Other inspectorates about which little is known and which are probably small producers are the Inspectorate at Marianske Lazne and the Inspectorate at Zvolen.

The method of mining and handling the ore in Czechoslovakia is nearly the same as in Germany. Much of the higher grade ore is sent to the Vykmanov and Njedek collection and shipping depot where it is crushed, sampled, blended, and packed for shipment to the USSR. The low-grade ore is sent to concentrating plants located at the Bratrstvi and the Elias mines in Jachymov. All these plants utilize a mechanical concentration method only. At the present time, there appears to be no chemical concentration plant in operation by the Jachymov Mines National Corporation. The mechanical processing method used is similar to that followed by Wismut. The grade of the concentrate is between 1 and 2 per cent uranium metal. As development and production increase, other concentrating plants may be established in the Norni Slavkov and Pribram areas.

It is estimated that between 15,000 and 25,000 persons are engaged in uranium mining operations in Czechoslovakia. A significant portion of the laborers are Czech political prisoners.

d. Bulgarian sources

(1) Ore deposits—The uranium deposits in Bulgaria are of minor importance and, in 1954, produced approximately 5 per cent of the estimated total uranium obtained by the USSR in that year. The deposits being exploited at this time are composed mostly of secondary uranium minerals which occur mainly as thin coatings along fissures or are disseminated throughout brecciated zones. A certain amount of deep mining may now be taking place from the primary minerals.

The most important uranium deposit in Bulgaria is located in the old lead mining area of Goten Peak, near the monastery of Buhovo, northeast of Sofia. In late 1945, the Soviets continued the former German exploitation of this area. Later exploitation of other areas, such as those in the vicinity of Strelcha and Ihtiman, was begun. Prospecting operations and mining are also underway at a number of other locations.

(2) Operations—The uranium mining operations in Bulgaria are administered by the Soviet-Bulgarian Mining Company. Most of the ore now being produced is low grade and is concentrated before being shipped to the USSR. There is only one well-known ore concentrating plant in Bulgaria which is located at the site of the Buhovo mine. The ore is chemically concentrated, using an acid lead. Some of the ore is reported to be hand-sorted and does not require further concentration before being sent to the USSR, but it is believed that most of it is quite low grade and is first concentrated by the Buhovo plant. The concentrate produced probably contains over 1 per cent

uranium. It is estimated that between 6,000 and 10,000 persons are engaged in uranium mining operations in Bulgaria.

e. Polish Sources

(1) Ore deposits—The uranium deposits in Lower Silesia in Poland are of minor importance as a Soviet source of uranium, and constituted approximately 1 per cent of the total produced by the Soviets in 1954.

Soviet uranium mining operations were initiated in Poland in April 1947, but intensive development did not really begin until early 1948. The initial development was in the Kowary area (the old Schmiedeberg area exploited by the Germans) where uranium was produced before the war, and activities have spread to areas around Jelena Gora (Hirschberg), Miedzianka (Kupferberg), Kamienna Gora (Landeshut), Walbrzch (Waldenburg), Stronie Slaskie (Seitenberg), etc. Exploration is also underway in other areas, but Kowary still seems to be the main producing area.

The uranium deposits in Poland are small fissure veins consisting, in some cases, of martitic iron ore with associated pitchblende. Other veins contain barite and dolomite with some uranium minerals. The extent of the mineralization appears to be somewhat limited but the thoroughness with which the Soviets exploit the deposits, regardless of cost, may produce a small quantity for several years. The quality of the ore produced is not definitely known but is assumed to be the same as that produced in East Germany.

(2) Operations—The Soviet uranium mining operations in Poland are similar to those in East Germany. Concentrating plants are believed to be operating at Miedzianka and Ogorzelec (Dittersbach). The type of process used in these plants is not definitely known, although it is reported that the plant near Ogorzelec uses a mechanical separation process.

The uranium mining operations in Poland are administered by the Lower Silesian Mines, Kowary. This is believed to be a cover organization similar to Wismut, in East Germany, on a much smaller scale. It is estimated that from 6,000 to 10,000 workers are engaged in the uranium mining activities in Poland.

f. Romanian Sources

(1) Ore deposits—The uranium deposits of Romania constitute approximately 2 per cent of the total produced by the Soviets in 1954.

Soviet uranium mining operations were initiated in Romania in late 1952. Mining is presently being carried out in the Baia de Cris/W to Baita region and probably also at Baia Sprie, Baia Mare, Turnu Severin and the Galati areas.

The uranium deposits in Romania are small fissure veins of polymetallic minerals with associated pitchblende. The quality of the ore produced is not known. Probably some of it is hand sorted to a minimum grade of 1 or 2 per cent uranium before being shipped to the USSR.

(2) Operations—The Soviet uranium mining operations in Romania are probably similar to those in other satellite countries, although no information is available on the existence of any concentration plants.

The uranium mining operations in Romania are administered by the Sovrumquartz Company. This is believed to be a cover organization similar to Wismut, in East Germany. It is estimated that some 10,000 workers are engaged in the uranium mining activities in Romania.

Alwin Urff, deputy technical plant manager of the Asse nuclear disposal site in Germany. Hasso Ziegler. Die "Konzertsäle" von Asse sind strahlensicher: Endlagerung radioaktiver Abfallprodukte in 500-Meter tiefen Abbaukammern. *Hannoversche Allgemeine Zeitung.* 29 July 1974.

Wolfenbüttel.—Zehn starke Scheinwerfer tauchen das Betriebsgelände des vor zehn Jahren stillgelegten Salzbergwerks Asse bei Wolfenbüttel—rund acht Kilometer vor der Grenze zur DDR gelegen—des Nachts in taghelles Licht. Die Polizei fährt das abgelegene Bergwerk zwei- bis dreimal pro Nacht an und kontrolliert, ob es besondere Vorkommnisse gibt. Außerdem steht eine telefonische Direktleitung zur Polizei Wolfenbüttel zur Verfügung, um sofort Alarm schlagen zu können. Die Sicherheitsvorkehrungen dienen dem Schutz vor der "verbannten Materie", wie die volkstümliche Umschreibung für die radioaktiven Abfälle lautet, die—zentral für die ganze Bundesrepublik—seit 1967 in dem ehemaligen Salzbergwerk in Tiefen bis zu 750 Metern als "Endlagerung" deponiert werden. [...]

Das ehemalige Salzbergwerk Asse bot im übrigen, als es 1965 von der Bundesregierung für 750 000 Mark von den vorherigen Eigentümern gekauft wurde, ideale Voraussetzungen, um die radioaktiven Abfälle aus der ganzen Bundesrepublik für die nächsten Jahrzehnte deponieren zu können. Von 1908 bis zu seiner Stillegung 1964 waren rund vier Millionen Kubikmeter Salz abgebaut worden, die wiederum rund 130 leergebliebene Abbaukammern hinterließen—in der Größe von durchweg 60 Metern Länge, 40 Metern Breite und 15 Metern Höhe. Knapp die Hälfte dieser leeren, weißglitzernden "Konzertsäle" gelten als geeignet für die Einlagerung radioaktiver Abfälle, ein Volumen mithin von 1,5 Millionen Kubikmetern—genug für Jahrzehnte. [...]

Wolfenbüttel.—Ten powerful headlights illuminate the site of the Asse salt mine near Wolfenbüttel, which was shut down ten years ago, and is located about eight kilometers from the border of East Germany. The police drive to the remote mine two or three times a night and check whether there are any unusual occurrences. In addition, a direct telephone line to the Wolfenbüttel police is available, to be able to respond immediately. The precautionary measures are designed to protect against the "banished matter," as is the national description of radioactive waste, for which the former salt mine at depths up to 750 meters has been the central "final disposal" for the whole of West Germany since 1967. [...]

The former Salzberg mine Asse, when bought in 1965 by the federal government for 750,000 Deutschmarks from the previous owners, was the ideal requirement for the disposal of radioactive waste from all of West Germany for the next decades. Between 1908 and its closure in 1964, around four million cubic meters of salt had been mined, which in turn left behind around 130 empty mining chambers—in the size of 60 meters long, 40 meters wide, and 15 meters high. Just half of these empty white glittering concert halls are considered suitable for the storage of radioactive waste, a volume of 1.5 million cubic meters—enough for decades. [...]

Für die hochaktiven Abfälle schließlich, die frühestens ab 1976 in der Bundesrepublik anfallen und dann in Asse eingelagert werden sollen (vornehmlich die Rückstände aus wiederaufbereiten Spaltprodukten, zum Beispiel Brennstäbe), laufen noch umfangreiche Vorarbeiten. Es ist daran gedacht, sie—zuvor zu Glas verschmolzen—in Spezialkammern (Bohrlöcher) in fünfzehnhundert Meter Tiefe zu versenken.

Über die gelegentlich auftauchenden Hiobsbotschaften befragt, die dann und wann über die vermeintlich gefährliche Lagerung der radioaktiven Abfälle auftauchen, konnte Alwin Urff, Bergingenieur und stellvertretender Betriebsleiter in Asse, im übrigen nur den Kopf schütteln: “Hier im Berg kann jedenfalls nichts mehr passieren. Als wir 1967 mit der Einlagerung begannen, hat unsere Gesellschaft als erstes radioaktive Abfälle aus dem letzten Krieg versenkt, jene Uranabfälle, die bei der Vorbereitung der deutschen Atombombe anfielen. Die mußten wir nämlich aus Betonbunkern in der Nähe von München herausholen, wo sie seinerzeit deponiert worden waren, weil man damals ja nicht wußte, wo in drei Teufels Namen man das Zeug denn lassen sollte...”

Extensive preparatory work is still going on for the highly radioactive waste, which will accumulate at the earliest from 1976 onwards in West Germany and be stored in Asse (mainly the residues from reprocessed fission products, for example reactor fuel rods). It is thought to sink them—vitrified beforehand—in special chambers (drill holes) to a depth of fifteen hundred meters.

Asked about the occasional bad news that appears every now and then regarding the supposedly dangerous storage of radioactive waste, Alwin Urff, mining engineer and deputy technical plant manager in Asse, only shook his head: “Here in the mine nothing can happen anyway. When we began storage in 1967, our company first sank radioactive waste from the last war, that uranium waste which arose in the preparation of the German atomic bomb. Specifically we had to get that out of concrete bunkers near Munich, where it had been deposited at the time, because back then one did not know where the devil one should leave the stuff...”

Rainer Karlsch. 2013. Die Abteilung Atomphysik der PTR in Ronneburg und das deutsche Uranprojekt. *PTB-Mitteilungen* 123:1:73–81.

Den Fassbegleitkarten dieser ersten, versuchsweisen Einlagerung radioaktiver Abfälle in der Schachtanlage Asse II—die vom 4. April bis zum 4. Juli 1967 dauerte und zur Einlagerung von 1722 Fässern in die Kammer 4 auf der 750-m-Sohle führte—ist lediglich zu entnehmen, dass sämtliche Fässer aus Karlsruhe kamen [57].

[57] Mitteilung von Dr. Gernot Eilers vom Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 8.1.2013

From the identification cards accompanying this first experimental emplacement of radioactive waste in the Asse II mine—which lasted from 4 April to 4 July 1967 and led to the emplacement of 1722 drums in chamber 4 on the 750 m level—it can only be inferred that all the drums came from Karlsruhe [57].

[57] Communication from Dr. Gernot Eilers of the Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, 8 January 2013

[As evidence that dangerous radioactive waste could be safely stored in the salt mine, Alwin Urff said that the “radioactive uranium waste” from the “preparation of the German atomic bomb” during the war had been safely stored since 1967. He seemed to be in a position to have detailed and accurate knowledge about that waste, and his statement included several key points:

- Urff’s statement appears to demonstrate that there was a considerable amount of wartime radioactive uranium waste, since it filled multiple concrete bunkers before it was moved to Asse. (What was the actual location of the storage bunkers?) According to Asse’s own records, that particular batch of waste fills 1722 drums.

- Urff’s statement also seems to indicate that the wartime waste was quite radioactive, since he was using it as an example that strongly radioactive modern waste could also be safely stored at Asse. He explicitly called the waste both “radioactive” and “uranium waste.”

- Urff’s statement appears to indicate that all of that particular batch of atomic bomb waste was stored at Asse, which lends strength to his argument about the safety of storage at Asse, and also corresponds to the 1967 date that radioactive waste storage began at Asse. Nonetheless, there is the possibility that he simply meant that his company safely “sank” the bomb waste someplace in 1967, not necessarily all at Asse. Some nuclear waste was even disposed of at sea in the 1960s.

- Contrary to how Urff’s quote was interpreted by many later articles, he did not say that all of the nuclear waste stored in the Asse complex came from the war. 1722 barrels were deposited in April–July 1967, and postwar radioactive waste has been deposited ever since. Erroneously and without any foundation, some later articles attributed over 126,000 barrels of radioactive waste in Asse to the wartime program [e.g., https://www.dailymail.co.uk/news/article-2014146/Nazi-nuclear-waste-Hitlers-secret-A-bomb-programme-mine.html].

Was the waste from a bomb program, or merely a nuclear research program? Large amounts of uranium in various chemical states from the research program were found at locations around Germany and removed by the United States, United Kingdom, and Soviet Union. Why was it so important to bury this particular “radioactive uranium waste”? The waste could have been any (or some combination) of the following:

- Natural (unenriched) uranium in common wartime forms, such as uranium ore, uranium oxide, or uranium metal. That would not be any more radioactive than natural uranium ore from the ground, or any different from all of the uranium materials that were left for Allied forces to find. Moreover, it would be potentially useful material for the postwar nuclear program and not technically waste. Thus this possibility does not seem very likely. However, it may have been desired to simply get rid of any remaining uranium from wartime work, no matter how relatively benign the uranium and the work may have been.

- Chemically toxic and/or corrosive compounds of uranium, such as uranium hexafluoride. But significant quantities of such compounds were stored and found elsewhere in Germany. Why was this waste handled differently, if that is all it was?

- Depleted uranium from which ^{235}U has been extracted. That would be no more radioactive that natural uranium, which was freely stockpiled at Stassfurt and elsewhere without such special handling, and would not seem to serve Urff's example that the wartime waste was quite radioactive and yet had been safely "sunk." On the other hand, if the waste were depleted uranium, that would reveal how much enriched uranium had been produced, and it might have been desirable to hide that evidence in order to cover up the traces of an advanced nuclear program.

- Irradiated uranium that had been in a functioning fission reactor or electronuclear breeder. Such irradiated uranium would have been highly radioactive early on, although that radioactivity would fall off over time. Irradiated uranium would best fit the example that Urff was trying to make, although it may or may not have been what he was actually referring to.

- ^{233}U, ^{235}U (enriched to any degree), ^{237}Np, or ^{239}Pu that was produced but buried to cover up evidence of an advanced nuclear program.

How did Urff know that was indeed "radioactive uranium waste" from the "preparation of the German atomic bomb" during the war? What did he (and others at Asse) do during the war?

In 2013, paragraph 57b of the German Atomic Energy Act was amended to the effect that the radioactive waste stored in the Asse II mine must be retrieved before the mine is decommissioned. The current timetable assumes that retrieval will begin in 2033. Before being prepared for interim and final storage elsewhere, all waste must be examined in order to characterize its composition. If the wartime waste can be distinguished from the later waste, what will be learned from it?]

D.4 Enrichment of Uranium-235

[Only 0.72% of natural uranium is ^{235}U, the fissile isotope. In order to achieve high concentrations of ^{235}U for a fission bomb, it is necessary to enrich or separate ^{235}U from the other uranium isotopes. Currently available documents demonstrate that during the war, Germany developed several different methods of enrichment at least to the level of successful laboratory prototypes, and quite possibly on a large industrial scale:

D.4.1. Production of uranium hexafluoride for uranium-235 enrichment. I.G. Farben and other German-speaking research facilities developed, tested, and mass-produced uranium hexafluoride (UF_6), the preferred uranium compound for use in most enrichment approaches (p. 3478).

D.4.2. Uranium-235 enrichment via centrifugation. Konrad Beyerle (German, 1900–1979), Wilhelm Groth (German, 1904–1977), Werner Holtz (German, 1908–?), Werner Schwietzke (German, 1910–1987), and many others worked in teams that developed gas centrifuges to enrich uranium-235. Centrifugation proved so superior to the U.S.'s enrichment methods that the German gas centrifuge designs are now the worldwide standard for uranium enrichment (p. 3494).

D.4.3. Uranium-235 enrichment via electromagnetic separation. Manfred von Ardenne (German, 1907–1997), Heinz Ewald (German, 1914–1992), Wolfgang Paul (German, 1913–1993), Wilhelm Walcher (German, 1910–2005), and many others worked in teams that developed electromagnetic separators to enrich ^{235}U (p. 3554). These electromagnetic separators were comparable to the Manhattan Project's calutrons. Manfred von Ardenne's work was well funded during the war, and he became a central figure in the Soviet nuclear weapons program after the war.

D.4.4. Uranium-235 enrichment via gaseous diffusion. Gustav Hertz (German, 1887–1975), Erika Cremer (German, 1900–1996), Rudolf Fleischmann (German, 1903–2002), and others developed gaseous diffusion methods suitable for enriching ^{235}U that were comparable to the Manhattan Project's gaseous diffusion technology (p. 3618). Hertz's secret wartime work was deemed so important by the German government that he was allowed to live and work in relative comfort throughout the war despite his Jewish ancestry. After the war, he played a vital role in the Soviet nuclear weapons program. Erich Bagge (German, 1912–1996) invented and successfully demonstrated a unique uranium enrichment device called an isotope sluice, which was essentially an alternative method of gaseous diffusion separation (p. 3651).

D.4.5. Uranium-235 enrichment via photochemical processes. Stanisław Mrozowski (Polish, 1902–1999), K. Zuber (Swiss, 19??–19??), Werner Kuhn, Hans Martin, K. H. Eldau, Paul Harteck, and others developed photochemical methods of isotope separation, demonstrated them with elements such as mercury, and worked to apply them to uranium (p. 3664). It is currently unclear how far that work progressed during the war, but it became the basis of postwar laser isotope separation. (Section C.3 covers early work toward lasers in the German-speaking world).

D.4.6. Possible locations of uranium enrichment facilities. If Germany scaled up any of these proven enrichment methods in order to produce uranium-235 for nuclear weapons, it would have distributed that production capability among a number of small underground locations for protection against Allied bombing. The leading industrialist Adolf Schneider actually confirmed in 1944 that Germany was doing precisely that (p. 4400). Archival documents mention dozens of highly suspicious sites that might have been used for that purpose and that still have not been properly investigated (p. 3670).]

D.4.1 Production of Uranium Hexafluoride for Uranium-235 Enrichment

[Usually uranium is converted into the gaseous compound uranium hexafluoride (UF_6) for enrichment. (Uranium tetrachloride, UCl_4, is generally preferred for electromagnetic separation.) UF_6 is highly corrosive to most materials except nickel. German reports captured by the U.S. Alsos Mission demonstrate that at least as early as 1940, the German program was fully aware of this information and capable of producing UF_6, and that much of that production capability was at I.G. Farben. Unless otherwise noted, text for G-series captured German nuclear reports cited here consists of the English-language abstracts prepared by U.S. scientists who studied the German reports.]

G-32. Wilhelm Groth and Paul Harteck. Corrosion Experiments on Two Alloys (Steel and Light Metal Alloys) with UF_6. 12 May 1940. [See p. 3480.]

Investigations were undertaken in a quartz vessel with very pure UF_6. 10 grams of UF_6 was sublimed into the vessel and the samples were exposed for 14 hours at 100^oC. [...] Same test setup but at 350^oC. [...] Corrosion of steel is excessive. Light metal, however, can be used in installations operating below 250^oC. For high temperature use nickel is the only suitable material.

G-33. Wilhelm Groth and Paul Harteck. Status of Work on Separating ^{235}U und ^{238}U. Stand der Arbeiten zur Trennung der Isotope ^{235}U und ^{238}U. 1940. [See pp. 3481–3483.]

Corrosion tests were made with UF_6 at 100 and 150^oC on monel, nickel, brass, copper, aluminum, silver, iron, and various commercial alloys. Results tabulated. Nickel only material suitable for high temperature use. On the basis of tests made with xenon the U isotopes can quite probably be separated by thermal diffusion using a double jacketed tube with a separating length of 10 m.

Developed method for checking concentration of ^{235}U. When ^{235}U is enriched, ^{234}U is also enriched. The alpha emission of ^{234}U is therefore a measure of ^{235}U concentration.

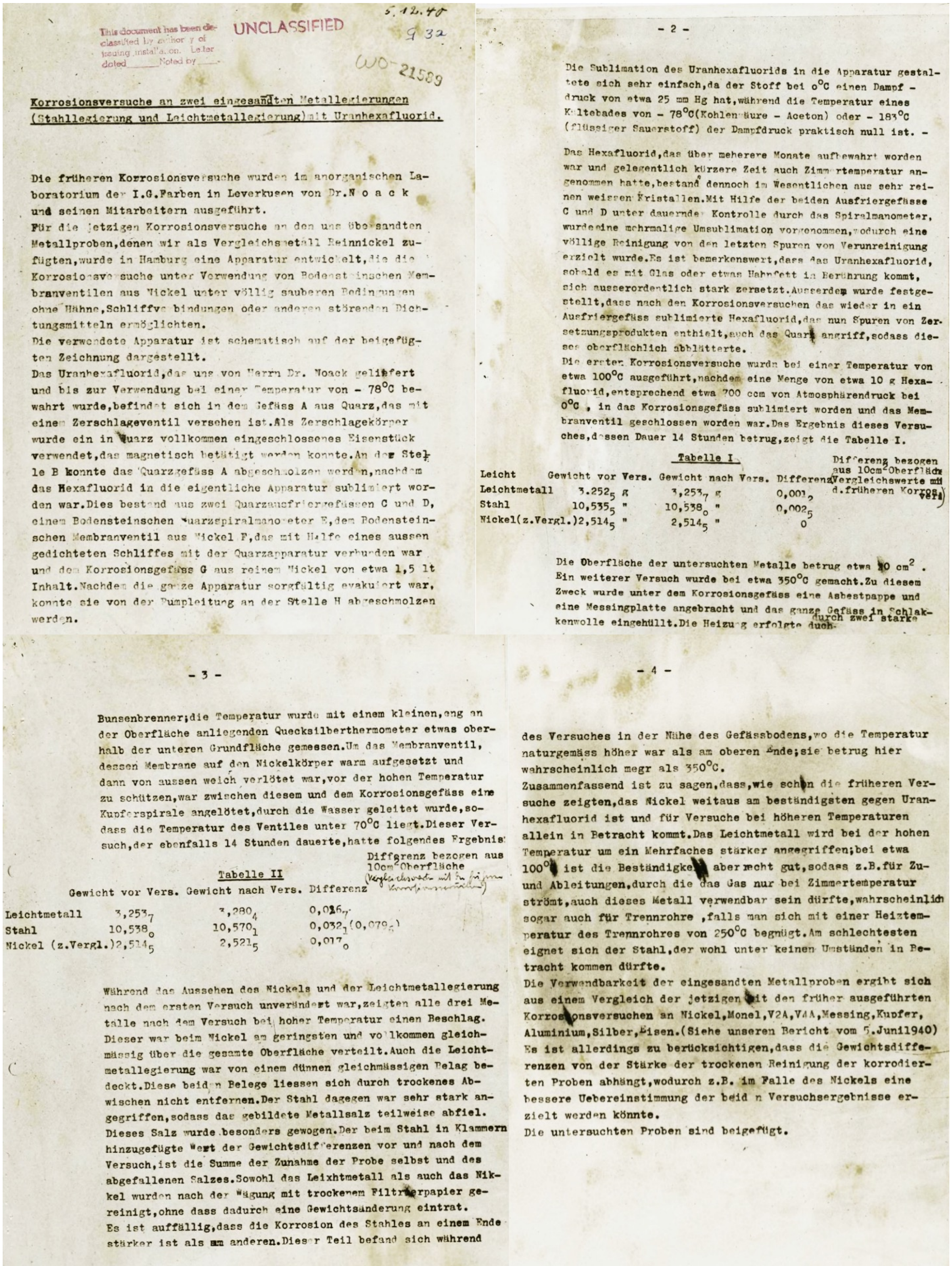
FIAT 1171. ***An Instrument for the Measurement of the Radio-Active Content of Moving Gases.***

G-28. Rudolf Fleischmann. Some Constants and Properties of UF_6. Ueber einige Konstanten und Eigenschaften von UF_6. 1940. [See pp. 3484–3487.]

UF_6, the only U compound which is gaseous at room temperature, is of essential importance for isotope separation. Unfortunately there is no complete theory of the separation process, from which the separation can be calculated from measurable constants of the substance to be separated. The theories of Waldmann and of Furry, Jones, and Onsager deal with the plane case but are qualitatively applicable to the cylindrical case. They permit the calculation of the proper size of the apparatus, when a few constants of the gas employed in the separation are known, particularly the coefficient of viscosity η, the density ρ, and the vapor pressure p as a function of the temperature. [These quantities were measured and reported.] Investigations with UF_6 are complicated by its affinity for water and its corrosive properties, but operation of a small experimental system shows that separation can probably be carried out nevertheless.

G-157. Paul Harteck and Wilhelm Groth (Institut für Phys. Chemie, Hamburg); Erich Noack and Walter Kwasnik (I.G. Farben Leverkusen). Herstellung von Uranhexafluorid im Halbtechnischen Masstab. Untersuchung der Legierungsfähigkeit von metallischem Uran. 11 June 1942. [See pp. 3488–3489.]

Description of usual laboratory method of making UF_6 from metallic U using Cl as catalyst. Kwasnik developed process whereby uranium oxide is carried through a rotating inclined nickel tube heated to 650^{o}C through which a stream of fluorine gas is passed. The UF_6 thus formed is frozen by CO_2 in containers. About 500 grams UF_6 thus produced per hour. The UF_6 to be frozen in large crystalline block to reduce amount of adsorption of other gases. Method of transport and handling of UF_6. Projected improvements of Kwasnik process. Possibility of using U ores directly instead of first purifying U. Costs 22–51 RM/kg. Experiments planned with U alloys of nickel, silicon, and chromium.



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G 32

WO-21589

Korrosionsversuche an zwei eingesandten Metallegierungen (Stahllegierung und Leichtmetallegierung) mit Uranhexafluorid.

Die früheren Korrosionsversuche wurden im anorganischen Laboratorium der I.G.Farben in Leverkusen von Dr.Noack und seinen Mitarbeitern ausgeführt.
Für die jetzigen Korrosionsversuche an den uns übersandten Metallproben,denen wir als Vergleichsmetall Reinnickel zufügten,wurde in Hamburg eine Apparatur entwickelt,die die Korrosionsversuche unter Verwendung von Bodensteinschen Membranventilen aus Nickel unter völlig sauberen Bedingungen ohne Hähne,Schliffverbindungen oder anderen störenden Dichtungsmitteln ermöglichten.
Die verwendete Apparatur ist schematisch auf der beigefügten Zeichnung dargestellt.
Das Uranhexafluorid,das uns von Herrn Dr. Noack geliefert und bis zur Verwendung bei einer Temperatur von - 78°C bewahrt wurde,befindet sich in dem Gefäss A aus Quarz,das mit einem Zerschlageventil versehen ist.Als Zerschlagekörper wurde ein in Quarz vollkommen eingeschlossenes Eisenstück verwendet,das magnetisch betätigt werden konnte.An der Stelle B konnte das Quarzgefäss A abgeschmolzen werden,nachdem das Hexafluorid in die eigentliche Apparatur sublimiert worden war.Dies bestand aus zwei Quarzausfriergefässen C und D, einem Bodensteinschen Quarzspiralmanometer E,dem Bodensteinschen Membranventil aus Nickel F,das mit Hilfe eines aussen gedichteten Schliffes mit der Quarzapparatur verbunden war und dem Korrosionsgefäss G aus reinem Nickel von etwa 1,5 lt Inhalt.Nachdem die ganze Apparatur sorgfältig evakuiert war, konnte sie von der Pumpleitung an der Stelle H abgeschmolzen werden.

- 2 -

Die Sublimation des Uranhexafluorids in die Apparatur gestaltete sich sehr einfach,da der Stoff bei 0°C einen Dampfdruck von etwa 25 mm Hg hat,während die Temperatur eines Kältebades von - 78°C(Kohlensäure - Aceton) oder - 183°C (flüssiger Sauerstoff) der Dampfdruck praktisch null ist. -

Das Hexafluorid,das über meherere Monate aufbewahrt worden war und gelegentlich kürzere Zeit auch Zimmertemperatur angenommen hatte,bestand dennoch im Wesentlichen aus sehr reinen weissen Kristallen.Mit Hilfe der beiden Ausfriergefässe C und D unter dauernder Kontrolle durch das Spiralmanometer, wurde eine mehrmalige Umsublimation vorgenommen,wodurch eine völlige Reinigung von den letzten Spuren von Verunreinigung erzielt wurde.Es ist bemerkenswert,dass das Uranhexafluorid, sobald es mit Glas oder etwas Hahnfett in Berührung kommt, sich ausserordentlich stark zersetzt.Ausserdem wurde festgestellt,dass nach den Korrosionsversuchen das wieder in ein Ausfriergefäss sublimierte Hexafluorid,das nun Spuren von Zersetzungsprodukten enthielt,auch das Quarz angriff,sodass dieses oberflächlich abblätterte.
Die ersten Korrosionsversuche wurden bei einer Temperatur von etwa 100°C ausgeführt,nachdem eine Menge von etwa 10 g Hexafluorid,entsprechend etwa 700 ccm von Atmosphärendruck bei 0°C , in das Korrosionsgefäss sublimiert worden und das Membranventil geschlossen worden war.Das Ergebnis dieses Versuches,dessen Dauer 14 Stunden betrug,zeigt die Tabelle I.

Tabelle I

Leicht	Gewicht vor Vers.	Gewicht nach Vers.	Differenz	Differenz bezogen aus 10cm² Oberfläche (Vergleichswerte mit d.früheren Korros. Vers.)
Leichtmetall	3.252_5 g	$3,253_7$ g	$0,001_2$	
Stahl	$10,535_5$ "	$10,538_0$ "	$0,002_5$	
Nickel(z.Vergl.)	$2,514_5$ "	$2,514_5$ "	0	

Die Oberfläche der untersuchten Metalle betrug etwa 10 cm² .
Ein weiterer Versuch wurde bei etwa 350°C gemacht.Zu diesem Zweck wurde unter dem Korrosionsgefäss eine Asbestpappe und eine Messingplatte angebracht und das ganze Gefäss in Schlakkenwolle eingehüllt.Die Heizung erfolgte ~~duch~~ durch zwei starke

- 3 -

Bunsenbrenner;die Temperatur wurde mit einem kleinen,eng an der Oberfläche anliegenden Quecksilberthermometer etwas oberhalb der unteren Grundfläche gemessen.Um das Membranventil, dessen Membrane auf den Nickelkörper warm aufgesetzt und dann von aussen weich verlötet war,vor der hohen Temperatur zu schützen,war zwischen diesem und dem Korrosionsgefäss eine Kupferspirale angelötet,durch die Wasser geleitet wurde,sodass die Temperatur des Ventiles unter 70°C liegt.Dieser Versuch,der ebenfalls 14 Stunden dauerte,hatte folgendes Ergebnis:

Tabelle II

	Gewicht vor Vers.	Gewicht nach Vers.	Differenz	Differenz bezogen aus 10cm² Oberfläche (Vergleichswerte mit den früheren Korrosionsversuchen)
Leichtmetall	$3,253_7$	$3,280_4$	$0,026_7$	
Stahl	$10,538_0$	$10,570_1$	$0,032_1 (0,079_5)$	
Nickel (z.Vergl.)	$2,514_5$	$2,521_5$	$0,017_0$	

Während das Aussehen des Nickels und der Leichtmetallegierung nach dem ersten Versuch unverändert war,zeigten alle drei Metalle nach dem Versuch bei hoher Temperatur einen Beschlag. Dieser war beim Nickel am geringsten und vollkommen gleichmässig über die gesamte Oberfläche verteilt.Auch die Leichtmetallegierung war von einem dünnen gleichmässigen Belag bedeckt.Diese beiden Belege liessen sich durch trockenes Abwischen nicht entfernen.Der Stahl dagegen war sehr stark angegriffen,sodass das gebildete Metallsalz teilweise abfiel. Dieses Salz wurde besonders gewogen.Der beim Stahl in Klammern hinzugefügte Wert der Gewichtsdifferenzen vor und nach dem Versuch,ist die Summe der Zunahme der Probe selbst und des abgefallenen Salzes.Sowohl das Leixhtmetall als auch das Nikkel wurden nach der Wägung mit trockenem Filtrierpapier gereinigt,ohne dass dadurch eine Gewichtsänderung eintrat.
Es ist auffällig,dass die Korrosion des Stahles an einem Ende stärker ist als am anderen.Dieser Teil befand sich während

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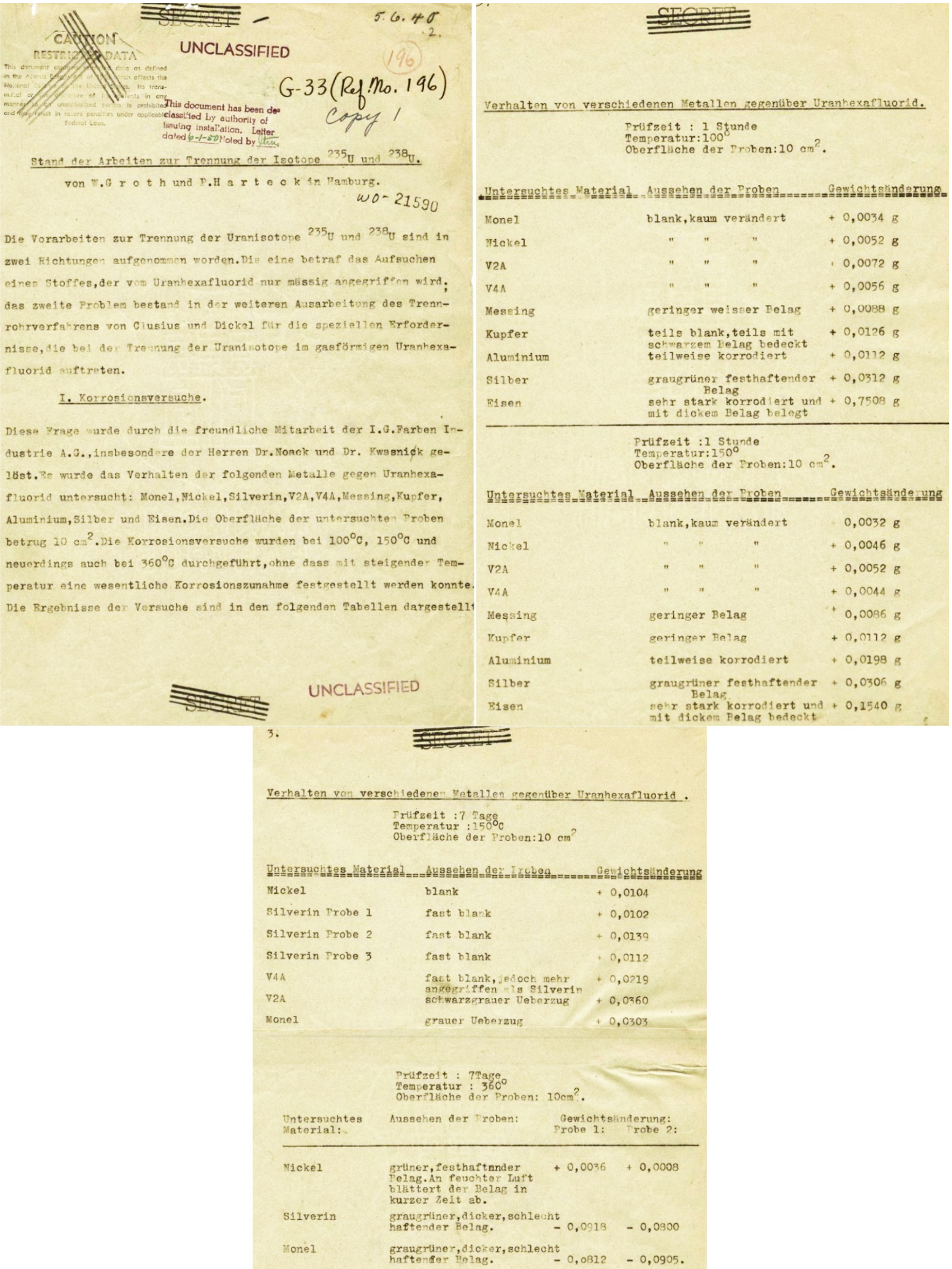
des Versuches in der Nähe des Gefässbodens,wo die Temperatur naturgemäss höher war als am oberen Ende;sie betrug hier wahrscheinlich megr als 350°C.
Zusammenfassend ist zu sagen,dass,wie schon die früheren Versuche zeigten,das Nickel weitaus am beständigsten gegen Uranhexafluorid ist und für Versuche bei höheren Temperaturen allein in Betracht kommt.Das Leichtmetall wird bei der hohen Temperatur um ein Mehrfaches stärker angegriffen;bei etwa 100°C ist die Beständigkeit aber recht gut,sodass z.B.für Zu- und Ableitungen,durch die das Gas nur bei Zimmertemperatur strömt,auch dieses Metall verwendbar sein dürfte,wahrscheinlich sogar auch für Trennrohre ,falls man sich mit einer Heiztemperatur des Trennrohres von 250°C begnügt.Am schlechtesten eignet sich der Stahl,der wohl unter keinen Umständen in Betracht kommen dürfte.
Die Verwendbarkeit der eingesandten Metallproben ergibt sich aus einem Vergleich der jetzigen mit den früher ausgeführten Korrosionsversuchen an Nickel,Monel,V2A,V4A,Messing,Kupfer, Aluminium,Silber,Eisen.(Siehe unseren Bericht vom 5.Juni1940)
Es ist allerdings zu berücksichtigen,dass die Gewichtsdifferenzen von der Stärke der trockenen Reinigung der korrodierten Proben abhängt,wodurch z.B. im Falle des Nickels eine bessere Uebereinstimmung der beiden Versuchsergebnisse erzielt werden könnte.
Die untersuchten Proben sind beigefügt.

Figure D.121: Production and testing of uranium hexafluoride in 1940 [G-32].



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G-33 (Ref. No. 196)

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Stand der Arbeiten zur Trennung der Isotope ^{235}U und ^{238}U.

von W. Groth und P. Harteck in Hamburg.

WO-21590

Die Vorarbeiten zur Trennung der Uranisotope ^{235}U und ^{238}U sind in zwei Richtungen aufgenommen worden. Die eine betraf das Aufsuchen eines Stoffes, der vom Uranhexafluorid nur mässig angegriffen wird; das zweite Problem bestand in der weiteren Ausarbeitung des Trennrohrverfahrens von Clusius und Dickel für die speziellen Erfordernisse, die bei der Trennung der Uranisotope im gasförmigen Uranhexafluorid auftreten.

I. Korrosionsversuche.

Diese Frage wurde durch die freundliche Mitarbeit der I.G. Farben Industrie A.G., insbesondere der Herren Dr. Noack und Dr. Kwasnick gelöst. Es wurde das Verhalten der folgenden Metalle gegen Uranhexafluorid untersucht: Monel, Nickel, Silverin, V2A, V4A, Messing, Kupfer, Aluminium, Silber und Eisen. Die Oberfläche der untersuchten Proben betrug 10 cm². Die Korrosionsversuche wurden bei 100°C, 150°C und neuerdings auch bei 360°C durchgeführt, ohne dass mit steigender Temperatur eine wesentliche Korrosionszunahme festgestellt werden konnte. Die Ergebnisse der Versuche sind in den folgenden Tabellen dargestellt

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Verhalten von verschiedenen Metallen gegenüber Uranhexafluorid.

Prüfzeit : 1 Stunde
Temperatur: 100°
Oberfläche der Proben: 10 cm².

Untersuchtes Material	Aussehen der Proben	Gewichtsänderung
Monel	blank, kaum verändert	+ 0,0034 g
Nickel	" " "	+ 0,0052 g
V2A	" " "	+ 0,0072 g
V4A	" " "	+ 0,0056 g
Messing	geringer weisser Belag	+ 0,0088 g
Kupfer	teils blank, teils mit schwarzem Belag bedeckt	+ 0,0126 g
Aluminium	teilweise korrodiert	+ 0,0112 g
Silber	graugrüner festhaftender Belag	+ 0,0312 g
Eisen	sehr stark korrodiert und mit dickem Belag belegt	+ 0,7508 g

Prüfzeit : 1 Stunde
Temperatur: 150°
Oberfläche der Proben: 10 cm².

Untersuchtes Material	Aussehen der Proben	Gewichtsänderung
Monel	blank, kaum verändert	+ 0,0032 g
Nickel	" " "	+ 0,0046 g
V2A	" " "	+ 0,0052 g
V4A	" " "	+ 0,0044 g
Messing	geringer Belag	+ 0,0086 g
Kupfer	geringer Belag	+ 0,0112 g
Aluminium	teilweise korrodiert	+ 0,0198 g
Silber	graugrüner festhaftender Belag	+ 0,0306 g
Eisen	sehr stark korrodiert und mit dickem Belag bedeckt	+ 0,1540 g

3.

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Verhalten von verschiedenen Metallen gegenüber Uranhexafluorid .

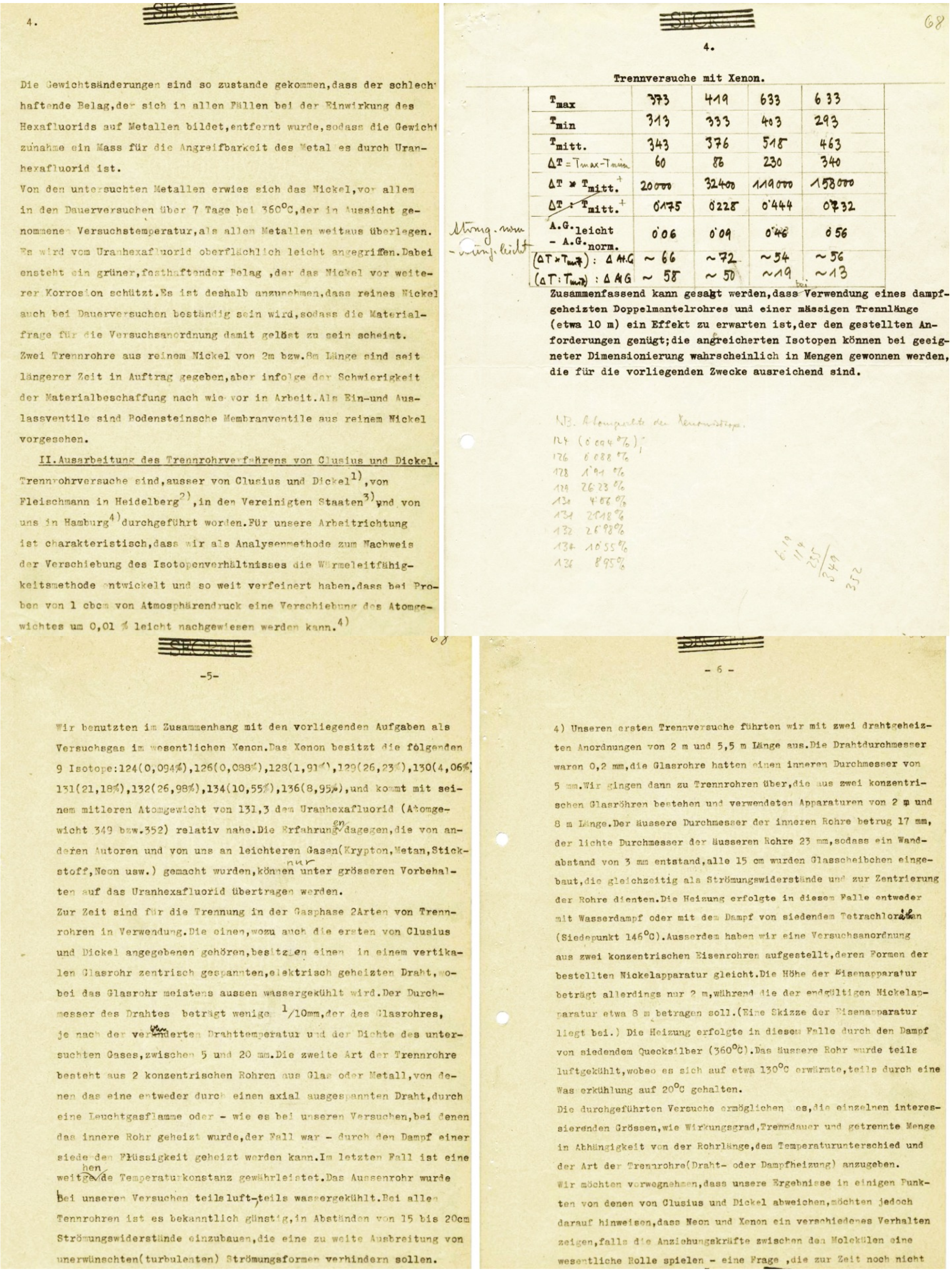
Prüfzeit : 7 Tage
Temperatur : 150°C
Oberfläche der Proben: 10 cm²

Untersuchtes Material	Aussehen der Proben	Gewichtsänderung
Nickel	blank	+ 0,0104
Silverin Probe 1	fast blank	+ 0,0102
Silverin Probe 2	fast blank	+ 0,0139
Silverin Probe 3	fast blank	+ 0,0112
V4A	fast blank, jedoch mehr angegriffen als Silverin	+ 0,0219
V2A	schwarzgrauer Ueberzug	+ 0,0360
Monel	grauer Ueberzug	+ 0,0303

Prüfzeit : 7 Tage
Temperatur : 360°
Oberfläche der Proben: 10 cm².

Untersuchtes Material:	Aussehen der Proben:	Gewichtsänderung: Probe 1:	Gewichtsänderung: Probe 2:
Nickel	grüner, festhaftender Belag. An feuchter Luft blättert der Belag in kurzer Zeit ab.	+ 0,0036	+ 0,0008
Silverin	graugrüner, dicker, schlecht haftender Belag.	– 0,0918	– 0,0800
Monel	graugrüner, dicker, schlecht haftender Belag.	– 0,0812	– 0,0905.

Figure D.122: Production and testing of uranium hexafluoride in 1940 [G-33].



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4.

Die Gewichtsänderungen sind so zustande gekommen, dass der schlechthaftende Belag, der sich in allen Fällen bei der Einwirkung des Hexafluorids auf Metallen bildet, entfernt wurde, sodass die Gewichtzunahme ein Mass für die Angreifbarkeit des Metalles durch Uranhexafluorid ist.

Von den untersuchten Metallen erwies sich das Nickel, vor allem in den Dauerversuchen über 7 Tage bei 360°C, der in Aussicht genommenen Versuchstemperatur, als allen Metallen weitaus überlegen. Es wird vom Uranhexafluorid oberflächlich leicht angegriffen. Dabei ensteht ein grüner, festhaftender Belag, der das Nickel vor weiterer Korrosion schützt. Es ist deshalb anzunehmen, dass reines Nickel auch bei Dauerversuchen beständig sein wird, sodass die Materialfrage für die Versuchsanordnung damit gelöst zu sein scheint.

Zwei Trennrohre aus reinem Nickel von 2m bzw. 8m Länge sind seit längerer Zeit in Auftrag gegeben, aber infolge der Schwierigkeit der Materialbeschaffung nach wie vor in Arbeit. Als Ein-und Auslassventile sind Bodensteinsche Membranventile aus reinem Nickel vorgesehen.

II. Ausarbeitung des Trennrohrverfahrens von Clusius und Dickel.

Trennrohrversuche sind, ausser von Clusius und Dickel[1], von Fleischmann in Heidelberg[2], in den Vereinigten Staaten[3] und von uns in Hamburg[4] durchgeführt worden. Für unsere Arbeitrichtung ist charakteristisch, dass wir als Analysenmethode zum Nachweis der Verschiebung des Isotopenverhältnisses die Wärmeleitfähigkeitsmethode entwickelt und so weit verfeinert haben, dass bei Proben von 1 cbcm von Atmosphärendruck eine Verschiebung des Atomgewichtes um 0,01 % leicht nachgewiesen werden kann.[4]

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4.

Trennversuche mit Xenon.

T_{max}	373	419	633	633
T_{min}	313	333	403	293
$T_{mitt.}$	343	376	518	463
$\Delta T = T_{max} - T_{min}$	60	86	230	340
$\Delta T \times T_{mitt.}{}^{+}$	20000	32400	119000	158000
$\Delta T : T_{mitt.}{}^{+}$	0·175	0·228	0·444	0·732
A.G.$_{leicht}$ − A.G.$_{norm.}$	0·06	0·09	0·46	0·56
$(\Delta T \times T_{mitt})$: Δ At.G	~ 66	~ 72	~ 54	~ 56
$(\Delta T : T_{mitt})$: Δ AG	~ 58	~ 50	~ 19	~ 13

Atomg. norm − Atomg. leicht

Zusammenfassend kann gesagt werden, dass bei Verwendung eines dampfgeheizten Doppelmantelrohres und einer mässigen Trennlänge (etwa 10 m) ein Effekt zu erwarten ist, der den gestellten Anforderungen genügt; die angereicherten Isotopen können bei geeigneter Dimensionierung wahrscheinlich in Mengen gewonnen werden, die für die vorliegenden Zwecke ausreichend sind.

NB. Atomgewichte der Xenonisotope.

124	(0·094 %)
126	0·088 %
128	1·91 %
129	26·23 %
130	4·06 %
131	21·18 %
132	26·98 %
134	10·55 %
136	8·95 %

6·19
11·4
235/349
352

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Wir benutzten im Zusammenhang mit den vorliegenden Aufgaben als Versuchsgas im wesentlichen Xenon. Das Xenon besitzt die fölgenden 9 Isotope: 124(0,094%), 126(0,088%), 128(1,91%), 129(26,23%), 130(4,06%), 131(21,18%), 132(26,98%), 134(10,55%), 136(8,95%), und kommt mit seinem mitleren Atomgewicht von 131,3 dem Uranhexafluorid (Atomgewicht 349 bzw. 352) relativ nahe. Die Erfahrungen dagegen, die von anderen Autoren und von uns an leichteren Gasen (Krypton, Metan, Stickstoff, Neon usw.) gemacht wurden, können nur unter grösseren Vorbehalten auf das Uranhexafluorid übertragen werden.

Zur Zeit sind für die Trennung in der Gasphase 2 Arten von Trennrohren in Verwendung. Die einen, wozu auch die ersten von Clusius und Dickel angegebenen gehören, besitzen einen in einem vertikalen Glasrohr zentrisch gespannten, elektrisch geheizten Draht, wobei das Glasrohr meistens aussen wassergekühlt wird. Der Durchmesser des Drahtes beträgt weniger $^{1}/10$mm, der des Glasrohres, je nach der veränderten Drahttemperatur und der Dichte des untersuchten Gases, zwischen 5 und 20 mm. Die zweite Art der Trennrohre besteht aus 2 konzentrischen Rohren aus Glas oder Metall, von denen das eine entweder durch einen axial ausgespannten Draht, durch eine Leuchtgasflamme oder – wie es bei unseren Versuchen, bei denen das innere Rohr geheizt wurde, der Fall war – durch den Dampf einer siedenden Flüssigkeit geheizt werden kann. Im letzten Fall ist eine weitgehende Temperaturkonstanz gewährleistet. Das Aussenrohr wurde bei unseren Versuchen teils luft-, teils wassergekühlt. Bei allen Tennrohren ist es bekanntlich günstig, in Abständen von 15 bis 20cm Strömungswiderstände einzubauen, die eine zu weite Ausbreitung von unerwünschten (turbulenten) Strömungsformen verhindern sollen.

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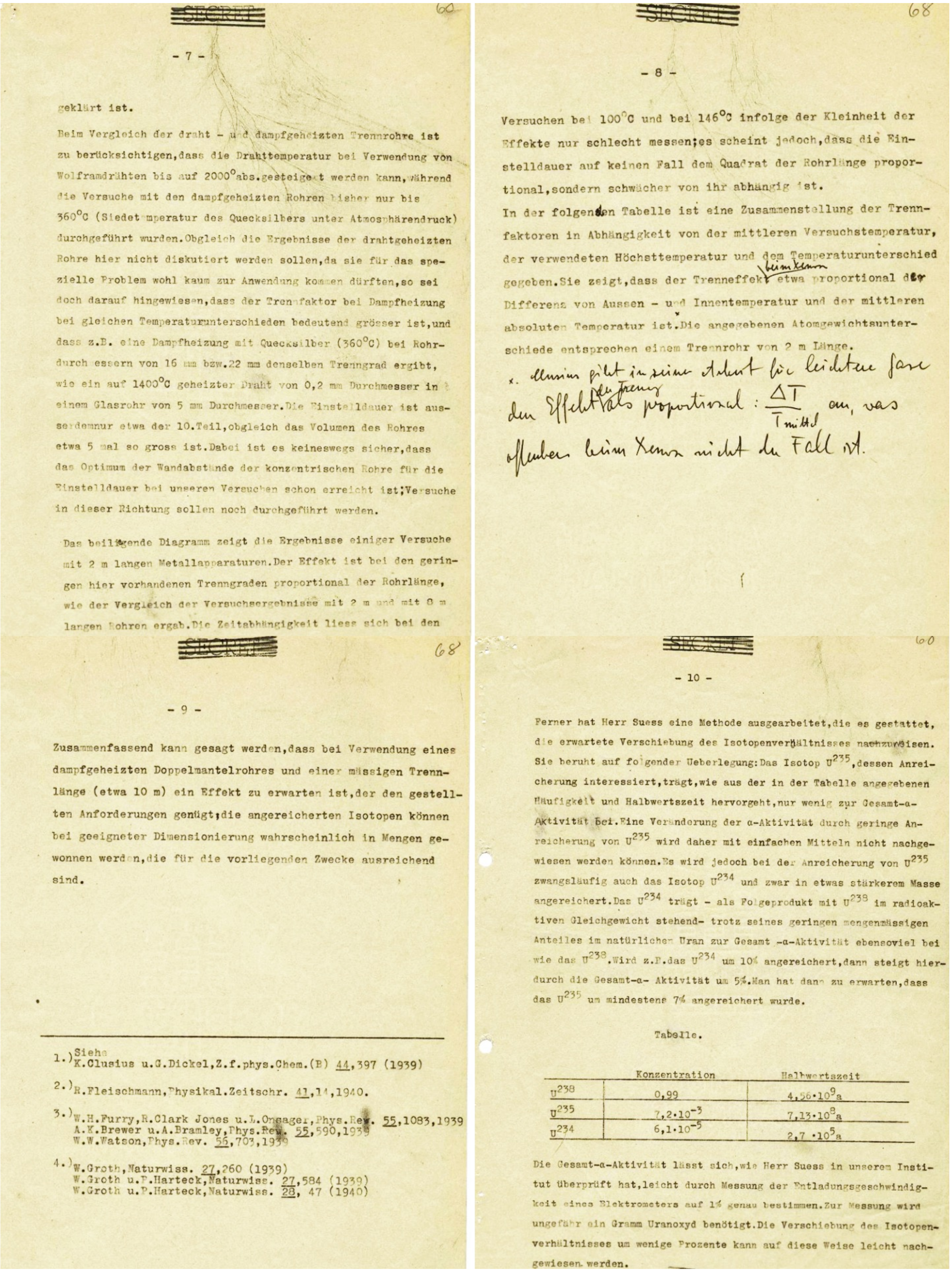
4) Unseren ersten Trennversuche führten wir mit zwei drahtgeheizten Anordnungen von 2 m und 5,5 m Länge aus. Die Drahtdurchmesser waren 0,2 mm, die Glasrohre hatten einen inneren Durchmesser von 5 mm. Wir gingen dann zu Trennrohren über, die aus zwei konzentrischen Glasröhren bestehen und verwendeten Apparaturen von 2 m und 8 m Länge. Der äussere Durchmesser der inneren Rohre betrug 17 mm, der lichte Durchmesser der äusseren Rohre 23 mm, sodass ein Wandabstand von 3 mm entstand, alle 15 cm wurden Glasscheibchen eingebaut, die gleichzeitig als Strömungswiderstände und zur Zentrierung der Rohre dienten. Die Heizung erfolgte in diesem Falle entweder mit Wasserdampf oder mit dem Dampf von siedendem Tetrachloräthan (Siedepunkt 146°C). Ausserdem haben wir eine Versuchsanordnung aus zwei konzentrischen Eisenrohren aufgestellt, deren Formen der bestellten Nickelapparatur gleicht. Die Höhe der Eisenapparatur beträgt allerdings nur 2 m, während die der endgültigen Nickelapparatur etwa 8 m betragen soll. (Eine Skizze der Eisenapparatur liegt bei.) Die Heizung erfolgte in diesem Falle durch den Dampf von siedendem Quecksilber (360°C). Das äussere Rohr wurde teils luftgekühlt, wobeo es sich auf etwa 130°C erwärmte, teils durch eine Wasserkühlung auf 20°C gehalten.

Die durchgeführten Versuche ermöglichen es, die einzelnen interessierenden Grössen, wie Wirkungsgrad, Trenndauer und getrennte Menge in Abhängigkeit von der Rohrlänge, dem Temperaturunterschied und der Art der Trennrohre (Draht- oder Dampfheizung) anzugeben.

Wir möchten vorwegnehmen, dass unsere Ergebnisse in einigen Punkten von denen von Clusius und Dickel abweichen, möchten jedoch darauf hinweisen, dass Neon und Xenon ein verschiedenes Verhalten zeigen, falls die Anziehungskräfte zwischen den Molekülen eine wesentliche Rolle spielen – eine Frage, die zur Zeit noch nicht

Figure D.123: Production and testing of uranium hexafluoride in 1940 [G-33].



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geklärt ist.

Beim Vergleich der draht - und dampfgeheizten Trennrohre ist zu berücksichtigen,dass die Drahttemperatur bei Verwendung von Wolframdrähten bis auf 2000°abs.gesteigert werden kann,während die Versuche mit den dampfgeheizten Rohren bisher nur bis 360°C (Siedetemperatur des Quecksilbers unter Atmosphärendruck) durchgeführt wurden.Obgleich die Ergebnisse der drahtgeheizten Rohre hier nicht diskutiert werden sollen,da sie für das spezielle Problem wohl kaum zur Anwendung kommen dürften,so sei doch darauf hingewiesen,dass der Trennfaktor bei Dampfheizung bei gleichen Temperaturunterschieden bedeutend grösser ist,und dass z.B. eine Dampfheizung mit Quecksilber (360°C) bei Rohrdurchmessern von 16 mm bzw.22 mm denselben Trenngrad ergibt, wie ein auf 1400°C geheizter Draht von 0,2 mm Durchmesser in einem Glasrohr von 5 mm Durchmesser.Die Einstelldauer ist ausserdemnur etwa der 10.Teil,obgleich das Volumen des Rohres etwa 5 mal so gross ist.Dabei ist es keineswegs sicher,dass das Optimum der Wandabstände der konzentrischen Rohre für die Einstelldauer bei unseren Versuchen schon erreicht ist;Versuche in dieser Richtung sollen noch durchgeführt werden.

Das beiliegende Diagramm zeigt die Ergebnisse einiger Versuche mit 2 m langen Metallapparaturen.Der Effekt ist bei den geringen hier vorhandenen Trenngraden proportional der Rohrlänge, wie der Vergleich der Versuchsergebnisse mit 2 m und mit 8 m langen Rohren ergab.Die Zeitabhängigkeit liess sich bei den

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Versuchen bei 100°C und bei 146°C infolge der Kleinheit der Effekte nur schlecht messen;es scheint jedoch,dass die Einstelldauer auf keinen Fall dem Quadrat der Rohrlänge proportional,sondern schwächer von ihr abhängig ist.

In der folgenden Tabelle ist eine Zusammenstellung der Trennfaktoren in Abhängigkeit von der mittleren Versuchstemperatur, der verwendeten Höchsttemperatur und dem Temperaturunterschied gegeben.Sie zeigt,dass der Trenneffekt beim Xenon etwa proportional der Differenz von Aussen - und Innentemperatur und der mittleren absoluten Temperatur ist.x Die angegebenen Atomgewichtsunterschiede entsprechen einem Trennrohr von 2 m Länge.

x. Clusius gibt in seiner Arbeit für leichtere Gase den Effekt der Trennung als proportional: $\frac{\Delta T}{T_{mittel}}$ an, was offenbar beim Xenon nicht der Fall ist.

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Zusammenfassend kann gesagt werden,dass bei Verwendung eines dampfgeheizten Doppelmantelrohres und einer mässigen Trennlänge (etwa 10 m) ein Effekt zu erwarten ist,der den gestellten Anforderungen genügt;die angereicherten Isotopen können bei geeigneter Dimensionierung wahrscheinlich in Mengen gewonnen werden,die für die vorliegenden Zwecke ausreichend sind.

1.) Siehe K.Clusius u.G.Dickel,Z.f.phys.Chem.(B) 44,397 (1939)

2.) R.Fleischmann,Physikal.Zeitschr. 41,14,1940.

3.) W.H.Furry,R.Clark Jones u.L.Onsager,Phys.Rev. 55,1083,1939
A.K.Brewer u.A.Bramley,Phys.Rev. 55,590,1939
W.W.Watson,Phys.Rev. 56,703,1939

4.) W.Groth,Naturwiss. 27,260 (1939)
W.Groth u.P.Harteck,Naturwiss. 27,584 (1939)
W.Groth u.P.Harteck,Naturwiss. 28, 47 (1940)

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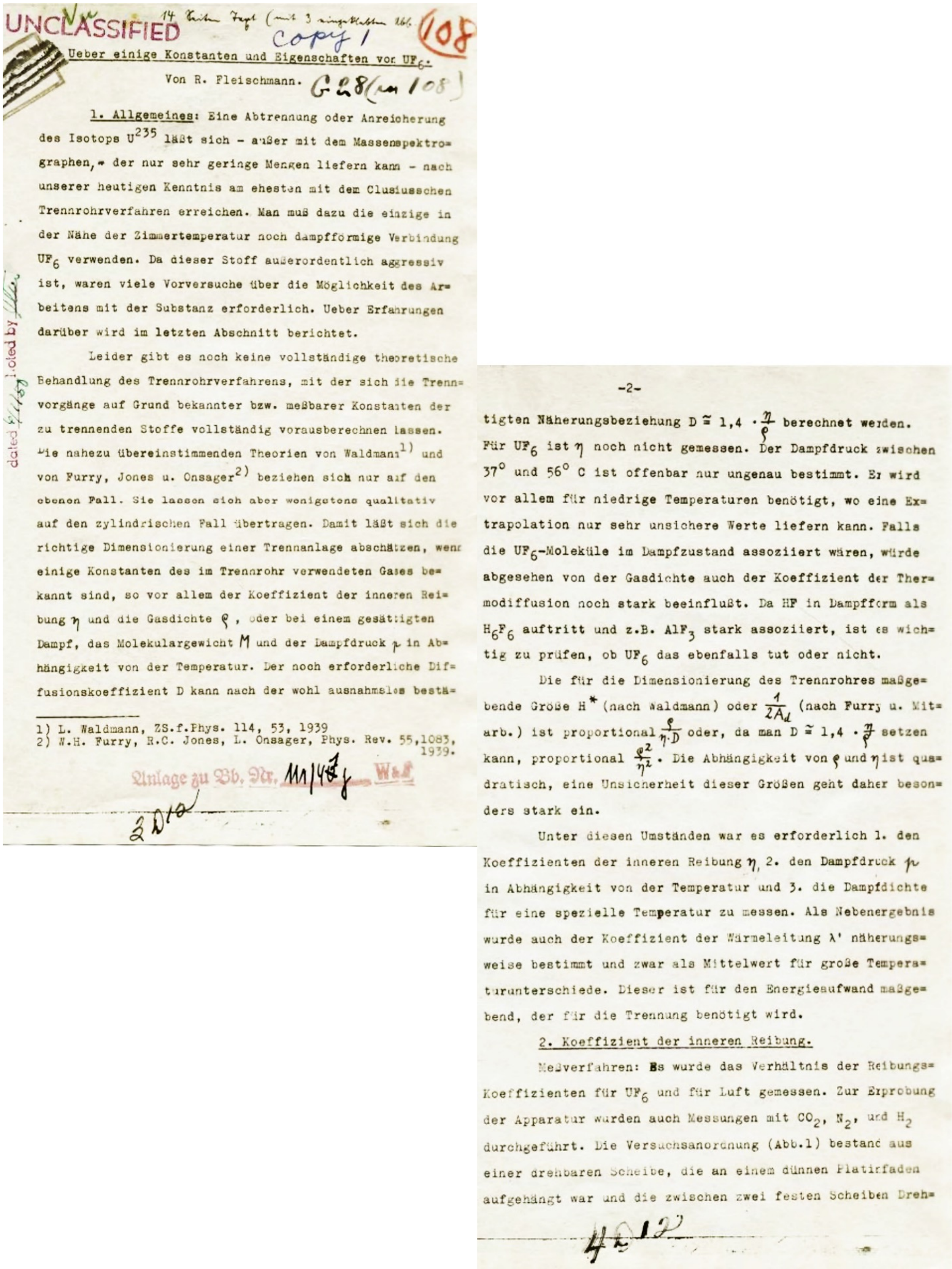
Ferner hat Herr Suess eine Methode ausgearbeitet,die es gestattet, die erwartete Verschiebung des Isotopenverhältnisses nachzuweisen. Sie beruht auf folgender Ueberlegung:Das Isotop U^{235},dessen Anreicherung interessiert,trägt,wie aus der in der Tabelle angegebenen Häufigkeit und Halbwertszeit hervorgeht,nur wenig zur Gesamt-α-Aktivität bei.Eine Veränderung der α-Aktivität durch geringe Anreicherung von U^{235} wird daher mit einfachen Mitteln nicht nachgewiesen werden können.Es wird jedoch bei der Anreicherung von U^{235} zwangsläufig auch das Isotop U^{234} und zwar in etwas stärkerem Masse angereichert.Das U^{234} trägt - als Folgeprodukt mit U^{238} im radioaktiven Gleichgewicht stehend- trotz seines geringen mengenmässigen Anteiles im natürlichen Uran zur Gesamt -α-Aktivität ebensoviel bei wie das U^{238}.Wird z.B.das U^{234} um 10% angereichert,dann steigt hierdurch die Gesamt-α- Aktivität um 5%.Man hat dann zu erwarten,dass das U^{235} um mindestens 7% angereichert wurde.

Tabelle.

	Konzentration	Halbwertszeit
U^{238}	0,99	$4{,}56\cdot10^{9}$a
U^{235}	$7{,}2\cdot10^{-3}$	$7{,}13\cdot10^{8}$a
U^{234}	$6{,}1\cdot10^{-5}$	$2{,}7\cdot10^{5}$a

Die Gesamt-α-Aktivität lässt sich,wie Herr Suess in unserem Institut überprüft hat,leicht durch Messung der Entladungsgeschwindigkeit eines Elektrometers auf 1% genau bestimmen.Zur Messung wird ungefähr ein Gramm Uranoxyd benötigt.Die Verschiebung des Isotopenverhältnisses um wenige Prozente kann auf diese Weise leicht nachgewiesen werden.

Figure D.124: Production and testing of uranium hexafluoride in 1940 [G-33].



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Ueber einige Konstanten und Eigenschaften von UF_6.

Von R. Fleischmann. G 28 (an 108)

1. Allgemeines: Eine Abtrennung oder Anreicherung des Isotops U^{235} läßt sich – außer mit dem Massenspektrographen, – der nur sehr geringe Mengen liefern kann – nach unserer heutigen Kenntnis am ehesten mit dem Clusiusschen Trennrohrverfahren erreichen. Man muß dazu die einzige in der Nähe der Zimmertemperatur noch dampfförmige Verbindung UF_6 verwenden. Da dieser Stoff außerordentlich aggressiv ist, waren viele Vorversuche über die Möglichkeit des Arbeitens mit der Substanz erforderlich. Ueber Erfahrungen darüber wird im letzten Abschnitt berichtet.

dated [illegible] noted by

Leider gibt es noch keine vollständige theoretische Behandlung des Trennrohrverfahrens, mit der sich die Trennvorgänge auf Grund bekannter bzw. meßbarer Konstanten der zu trennenden Stoffe vollständig vorausberechnen lassen. Die nahezu übereinstimmenden Theorien von Waldmann[1)] und von Furry, Jones u. Onsager[2)] beziehen sich nur auf den ebenen Fall. Sie lassen sich aber wenigstens qualitativ auf den zylindrischen Fall übertragen. Damit läßt sich die richtige Dimensionierung einer Trennanlage abschätzen, wenn einige Konstanten des im Trennrohr verwendeten Gases bekannt sind, so vor allem der Koeffizient der inneren Reibung η und die Gasdichte ϱ, oder bei einem gesättigten Dampf, das Molekulargewicht M und der Dampfdruck p in Abhängigkeit von der Temperatur. Der noch erforderliche Diffusionskoeffizient D kann nach der wohl ausnahmslos bestätigten Näherungsbeziehung $D \cong 1{,}4 \cdot \frac{\eta}{\varrho}$ berechnet werden.

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1) L. Waldmann, ZS.f.Phys. 114, 53, 1939
2) W.H. Furry, R.C. Jones, L. Onsager, Phys. Rev. 55,1083, 1939.

Anlage zu Bb. Nr. [illegible]

2 D 10

-2-

Für UF_6 ist η noch nicht gemessen. Der Dampfdruck zwischen 37° und 56° C ist offenbar nur ungenau bestimmt. Er wird vor allem für niedrige Temperaturen benötigt, wo eine Extrapolation nur sehr unsichere Werte liefern kann. Falls die UF_6-Moleküle im Dampfzustand assoziiert wären, würde abgesehen von der Gasdichte auch der Koeffizient der Thermodiffusion noch stark beeinflußt. Da HF in Dampfform als H_6F_6 auftritt und z.B. AlF_3 stark assoziiert, ist es wichtig zu prüfen, ob UF_6 das ebenfalls tut oder nicht.

Die für die Dimensionierung des Trennrohres maßgebende Größe H^* (nach Waldmann) oder $\frac{1}{2A_d}$ (nach Furry u. Mitarb.) ist proportional $\frac{\varrho}{\eta \cdot D}$ oder, da man $D \cong 1{,}4 \cdot \frac{\eta}{\varrho}$ setzen kann, proportional $\frac{\varrho^2}{\eta^2}$. Die Abhängigkeit von ϱ und η ist quadratisch, eine Unsicherheit dieser Größen geht daher besonders stark ein.

Unter diesen Umständen war es erforderlich 1. den Koeffizienten der inneren Reibung η, 2. den Dampfdruck p in Abhängigkeit von der Temperatur und 3. die Dampfdichte für eine spezielle Temperatur zu messen. Als Nebenergebnis wurde auch der Koeffizient der Wärmeleitung λ' näherungsweise bestimmt und zwar als Mittelwert für große Temperaturunterschiede. Dieser ist für den Energieaufwand maßgebend, der für die Trennung benötigt wird.

2. Koeffizient der inneren Reibung.

Meßverfahren: Es wurde das Verhältnis der Reibungskoeffizienten für UF_6 und für Luft gemessen. Zur Erprobung der Apparatur wurden auch Messungen mit CO_2, N_2, und H_2 durchgeführt. Die Versuchsanordnung (Abb.1) bestand aus einer drehbaren Scheibe, die an einem dünnen Platinfaden aufgehängt war und die zwischen zwei festen Scheiben Dreh=

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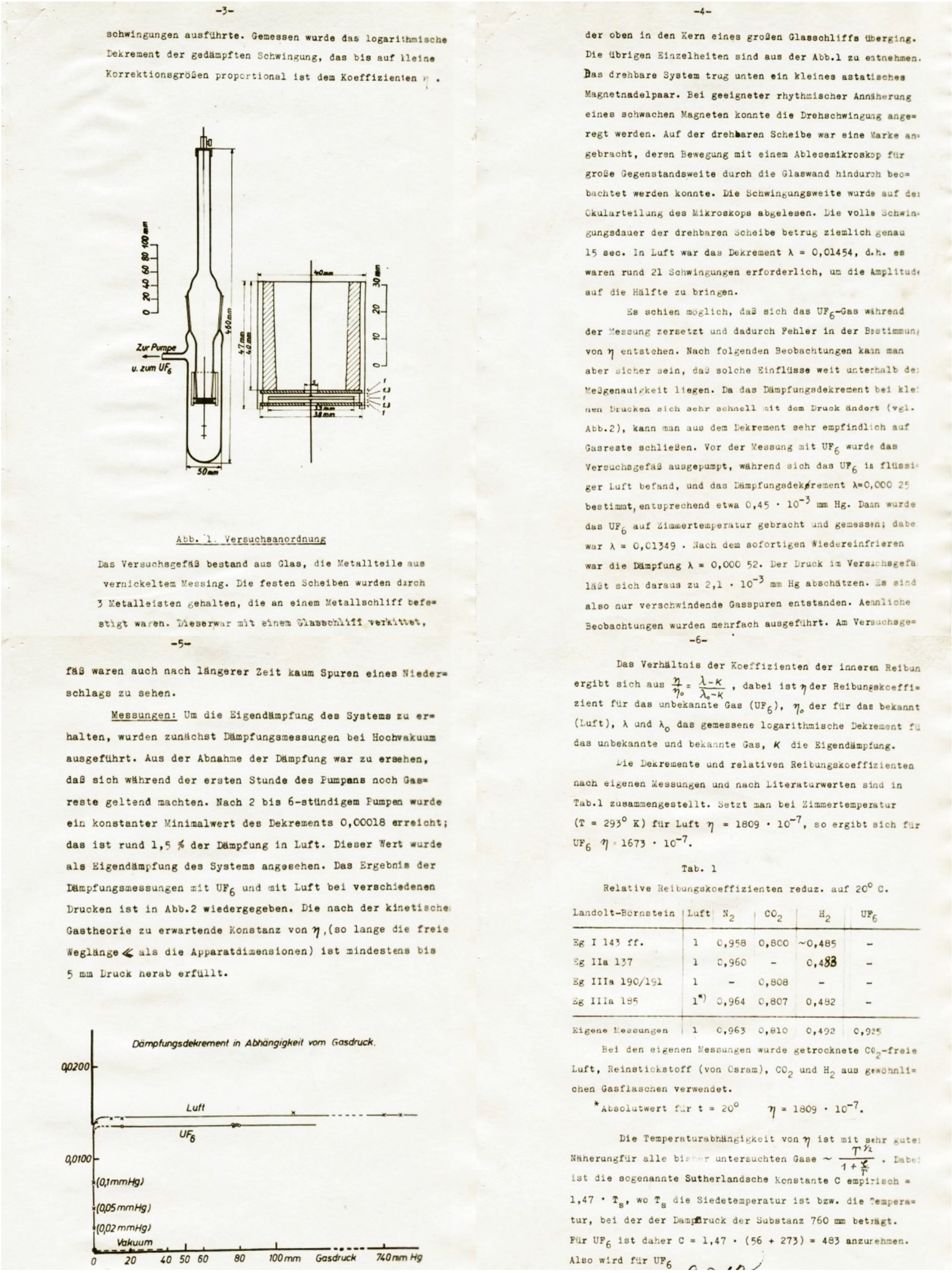
Figure D.125: Production and testing of uranium hexafluoride in 1940 [G-28].


0 20 40 60 80 100 mm
Zur Pumpe
u. zum UF_6
460 mm
50 mm
40 mm
47 mm
40 mm
0 10 20 30 mm
1
1,3
1
1,3
1
33 mm
38 mm
Dämpfungsdekrement in Abhängigkeit vom Gasdruck.
0,0200
0,0100
Luft
UF_6
(0,1 mmHg)
(0,05 mmHg)
(0,02 mmHg)
Vakuum
0
20
40
50
60
80
100 mm
Gasdruck
740 mm Hg

schwingungen ausführte. Gemessen wurde das logarithmische Dekrement der gedämpften Schwingung, das bis auf kleine Korrektionsgrößen proportional ist dem Koeffizienten η.

Abb. 1. Versuchsanordnung

Das Versuchsgefäß bestand aus Glas, die Metallteile aus vernickeltem Messing. Die festen Scheiben wurden durch 3 Metalleisten gehalten, die an einem Metallschliff befestigt waren. Dieserwar mit einem Glasschliff verkittet,

der oben in den Kern eines großen Glasschliffs überging. Die übrigen Einzelheiten sind aus der Abb.1 zu entnehmen. Das drehbare System trug unten ein kleines astatisches Magnetnadelpaar. Bei geeigneter rhythmischer Annäherung eines schwachen Magneten konnte die Drehschwingung angeregt werden. Auf der drehbaren Scheibe war eine Marke angebracht, deren Bewegung mit einem Ablesemikroskop für große Gegenstandsweite durch die Glaswand hindurch beobachtet werden konnte. Die Schwingungsweite wurde auf de Okularteilung des Mikroskops abgelesen. Die volle Schwingungsdauer der drehbaren Scheibe betrug ziemlich genau 15 sec. In Luft war das Dekrement $\lambda = 0,01454$, d.h. es waren rund 21 Schwingungen erforderlich, um die Amplitud auf die Hälfte zu bringen.

Es schien möglich, daß sich das UF_6-Gas während der Messung zersetzt und dadurch Fehler in der Bestimmun von η entstehen. Nach folgenden Beobachtungen kann man aber sicher sein, daß solche Einflüsse weit unterhalb de Meßgenauigkeit liegen. Da das Dämpfungsdekrement bei kle nen Drucken sich sehr schnell mit dem Druck ändert (vgl. Abb.2), kann man aus dem Dekrement sehr empfindlich auf Gasreste schließen. Vor der Messung mit UF_6 wurde das Versuchsgefäß ausgepumpt, während sich das UF_6 in flüssiger Luft befand, und das Dämpfungsdekrement $\lambda = 0,000\,25$ bestimmt, entsprechend etwa $0,45 \cdot 10^{-3}$ mm Hg. Dann wurde das UF_6 auf Zimmertemperatur gebracht und gemessen; dabe war $\lambda = 0,01349$. Nach dem sofortigen Wiedereinfrieren war die Dämpfung $\lambda = 0,000\,52$. Der Druck im Versuchsgefä läßt sich daraus zu $2,1 \cdot 10^{-3}$ mm Hg abschätzen. Es sind also nur verschwindende Gasspuren entstanden. Aehnliche Beobachtungen wurden mehrfach ausgeführt. Am Versuchsge-

fäß waren auch nach längerer Zeit kaum Spuren eines Niederschlags zu sehen.

Messungen: Um die Eigendämpfung des Systems zu erhalten, wurden zunächst Dämpfungsmessungen bei Hochvakuum ausgeführt. Aus der Abnahme der Dämpfung war zu ersehen, daß sich während der ersten Stunde des Pumpens noch Gasreste geltend machten. Nach 2 bis 6-stündigem Pumpen wurde ein konstanter Minimalwert des Dekrements 0,00018 erreicht; das ist rund 1,5 % der Dämpfung in Luft. Dieser Wert wurde als Eigendämpfung des Systems angesehen. Das Ergebnis der Dämpfungsmessungen mit UF_6 und mit Luft bei verschiedenen Drucken ist in Abb.2 wiedergegeben. Die nach der kinetische Gastheorie zu erwartende Konstanz von η, (so lange die freie Weglänge $\ll$ als die Apparatdimensionen) ist mindestens bis 5 mm Druck herab erfüllt.

Das Verhältnis der Koeffizienten der inneren Reibun ergibt sich aus $\frac{\eta}{\eta_0} = \frac{\lambda - K}{\lambda_0 - K}$, dabei ist η der Reibungskoeffizient für das unbekannte Gas (UF_6), η_0 der für das bekannt (Luft), λ und λ_0 das gemessene logarithmische Dekrement fü das unbekannte und bekannte Gas, K die Eigendämpfung.

Die Dekremente und relativen Reibungskoeffizienten nach eigenen Messungen und nach Literaturwerten sind in Tab.1 zusammengestellt. Setzt man bei Zimmertemperatur ($T = 293^\circ$ K) für Luft $\eta = 1809 \cdot 10^{-7}$, so ergibt sich für UF_6 $\eta = 1673 \cdot 10^{-7}$.

Tab. 1

Relative Reibungskoeffizienten reduz. auf 20° C.

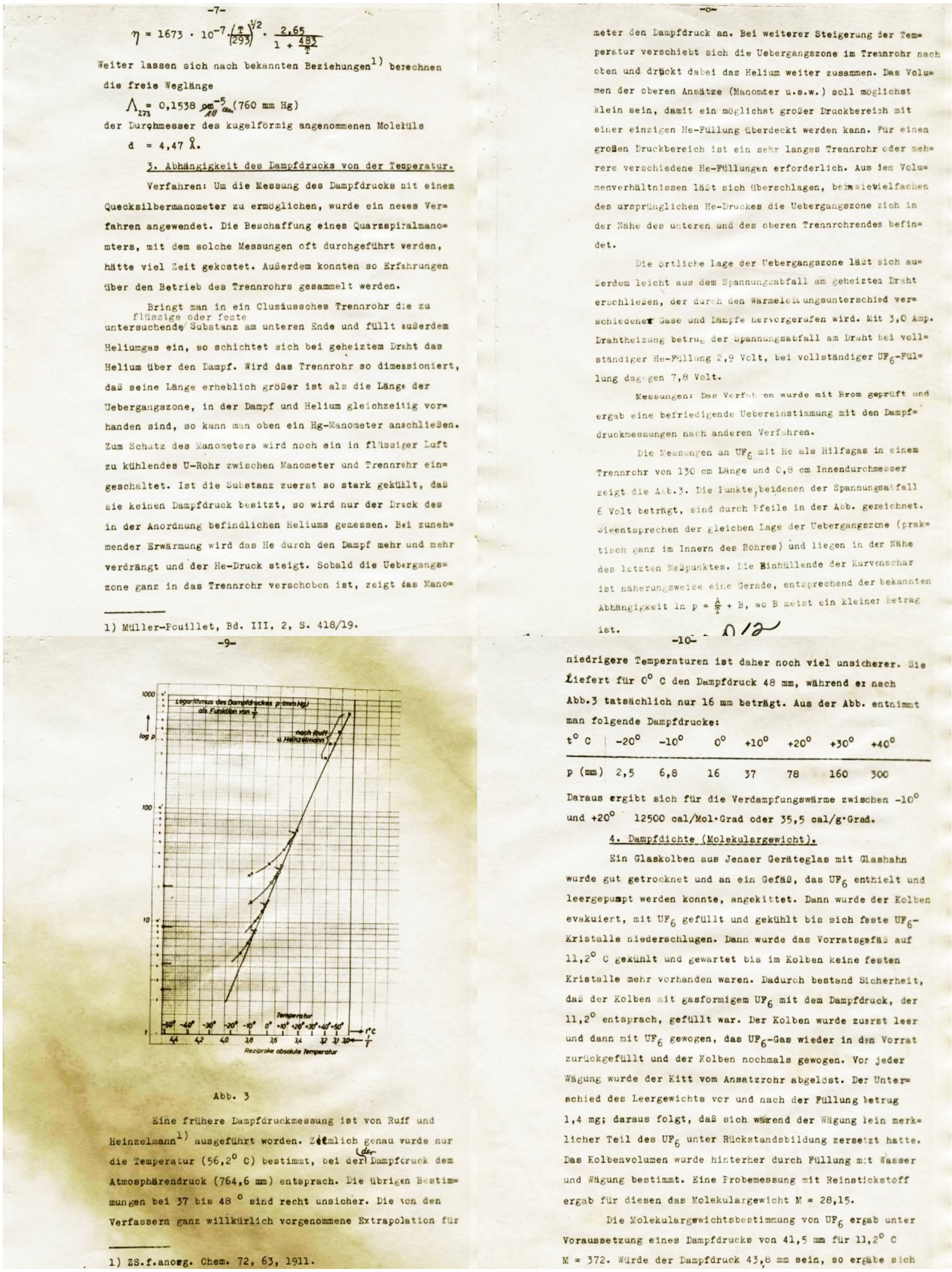
Landolt-Börnstein	Luft	N_2	CO_2	H_2	UF_6
Eg I 143 ff.	1	0,958	0,800	~0,485	–
Eg IIa 137	1	0,960	–	0,483	–
Eg IIIa 190/191	1	–	0,808	–	–
Eg IIIa 185	1*)	0,964	0,807	0,482	–
Eigene Messungen	1	0,963	0,810	0,492	0,925

Bei den eigenen Messungen wurde getrocknete CO_2-freie Luft, Reinstickstoff (von Osram), CO_2 und H_2 aus gewöhnlichen Gasflaschen verwendet.

*Absolutwert für $t = 20^\circ$ $\eta = 1809 \cdot 10^{-7}$.

Die Temperaturabhängigkeit von η ist mit sehr gute Näherungfür alle bisher untersuchten Gase $\sim \frac{T^{1/2}}{1 + \frac{C}{T}}$. Dabe ist die sogenannte Sutherlandsche Konstante C empirisch $= 1,47 \cdot T_s$, wo T_s die Siedetemperatur ist bzw. die Temperatur, bei der der Dampfdruck der Substanz 760 mm beträgt. Für UF_6 ist daher $C = 1,47 \cdot (56 + 273) = 483$ anzunehmen. Also wird für UF_6

Figure D.126: Production and testing of uranium hexafluoride in 1940 [G-28].



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$$\eta = 1673 \cdot 10^{-7} \cdot \left(\frac{T}{293}\right)^{1/2} \cdot \frac{2{,}65}{1 + \frac{483}{T}}$$

Weiter lassen sich nach bekannten Beziehungen[1] berechnen die freie Weglänge

$\Lambda_{273} = 0{,}1538 \cdot 10^{-5}\,\mathrm{cm}$ (760 mm Hg)

der Durchmesser des kugelförmig angenommenen Moleküls

d = 4,47 Å.

3. Abhängigkeit des Dampfdrucks von der Temperatur.

Verfahren: Um die Messung des Dampfdrucks mit einem Quecksilbermanometer zu ermöglichen, wurde ein neues Verfahren angewendet. Die Beschaffung eines Quarzspiralmanometers, mit dem solche Messungen oft durchgeführt werden, hätte viel Zeit gekostet. Außerdem konnten so Erfahrungen über den Betrieb des Trennrohrs gesammelt werden.

Bringt man in ein Clusiussches Trennrohr die zu untersuchende flüssige oder feste Substanz am unteren Ende und füllt außerdem Heliumgas ein, so schichtet sich bei geheiztem Draht das Helium über den Dampf. Wird das Trennrohr so dimensioniert, daß seine Länge erheblich größer ist als die Länge der Uebergangszone, in der Dampf und Helium gleichzeitig vorhanden sind, so kann man oben ein Hg-Manometer anschließen. Zum Schutz des Manometers wird noch ein in flüssiger Luft zu kühlendes U-Rohr zwischen Manometer und Trennrohr eingeschaltet. Ist die Substanz zuerst so stark gekühlt, daß sie keinen Dampfdruck besitzt, so wird nur der Druck des in der Anordnung befindlichen Heliums gemessen. Bei zunehmender Erwärmung wird das He durch den Dampf mehr und mehr verdrängt und der He-Druck steigt. Sobald die Uebergangszone ganz in das Trennrohr verschoben ist, zeigt das Manometer den Dampfdruck an. Bei weiterer Steigerung der Temperatur verschiebt sich die Uebergangszone im Trennrohr nach oben und drückt dabei das Helium weiter zusammen. Das Volumen der oberen Ansätze (Manometer u.s.w.) soll möglichst klein sein, damit ein möglichst großer Druckbereich mit einer einzigen He-Füllung überdeckt werden kann. Für einen großen Druckbereich ist ein sehr langes Trennrohr oder mehrere verschiedene He-Füllungen erforderlich. Aus den Volumenverhältnissen läßt sich überschlagen, beim wievielfachen des ursprünglichen He-Druckes die Uebergangszone sich in der Nähe des unteren und des oberen Trennrohrendes befindet.

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[1] Müller-Pouillet, Bd. III, 2, S. 418/19.

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Die örtliche Lage der Uebergangszone läßt sich außerdem leicht aus dem Spannungsabfall am geheizten Draht erschließen, der durch den Wärmeleitungsunterschied verschiedener Gase und Dämpfe hervorgerufen wird. Mit 3,0 Amp. Drahtheizung betrug der Spannungsabfall am Draht bei vollständiger He-Füllung 2,9 Volt, bei vollständiger UF_6-Füllung dagegen 7,8 Volt.

Messungen: Das Verfahren wurde mit Brom geprüft und ergab eine befriedigende Uebereinstimmung mit den Dampfdruckmessungen nach anderen Verfahren.

Die Messungen an UF_6 mit He als Hilfsgas in einem Trennrohr von 130 cm Länge und 0,8 cm Innendurchmesser zeigt die Abb.3. Die Punkte, bei denen der Spannungsabfall 6 Volt beträgt, sind durch Pfeile in der Abb. gezeichnet. Sie entsprechen der gleichen Lage der Uebergangszone (praktisch ganz im Innern des Rohres) und liegen in der Nähe des letzten Meßpunktes. Die Einhüllende der Kurvenschar ist näherungsweise eine Gerade, entsprechend der bekannten Abhängigkeit $\ln p = \frac{A}{T} + B$, wo B meist ein kleiner Betrag ist.

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Abb. 3

Eine frühere Dampfdruckmessung ist von Ruff und Heinzelmann[1] ausgeführt worden. Ziemlich genau wurde nur die Temperatur (56,2° C) bestimmt, bei der der Dampfdruck dem Atmosphärendruck (764,6 mm) entsprach. Die übrigen Bestimmungen bei 37 bis 48 ° sind recht unsicher. Die von den Verfassern ganz willkürlich vorgenommene Extrapolation für niedrigere Temperaturen ist daher noch viel unsicherer. Sie liefert für 0° C den Dampfdruck 48 mm, während er nach Abb.3 tatsächlich nur 16 mm beträgt. Aus der Abb. entnimmt man folgende Dampfdrucke:

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[1] ZS.f.anorg. Chem. 72, 63, 1911.

-10-

t° C	-20°	-10°	0°	+10°	+20°	+30°	+40°
p (mm)	2,5	6,8	16	37	78	160	300

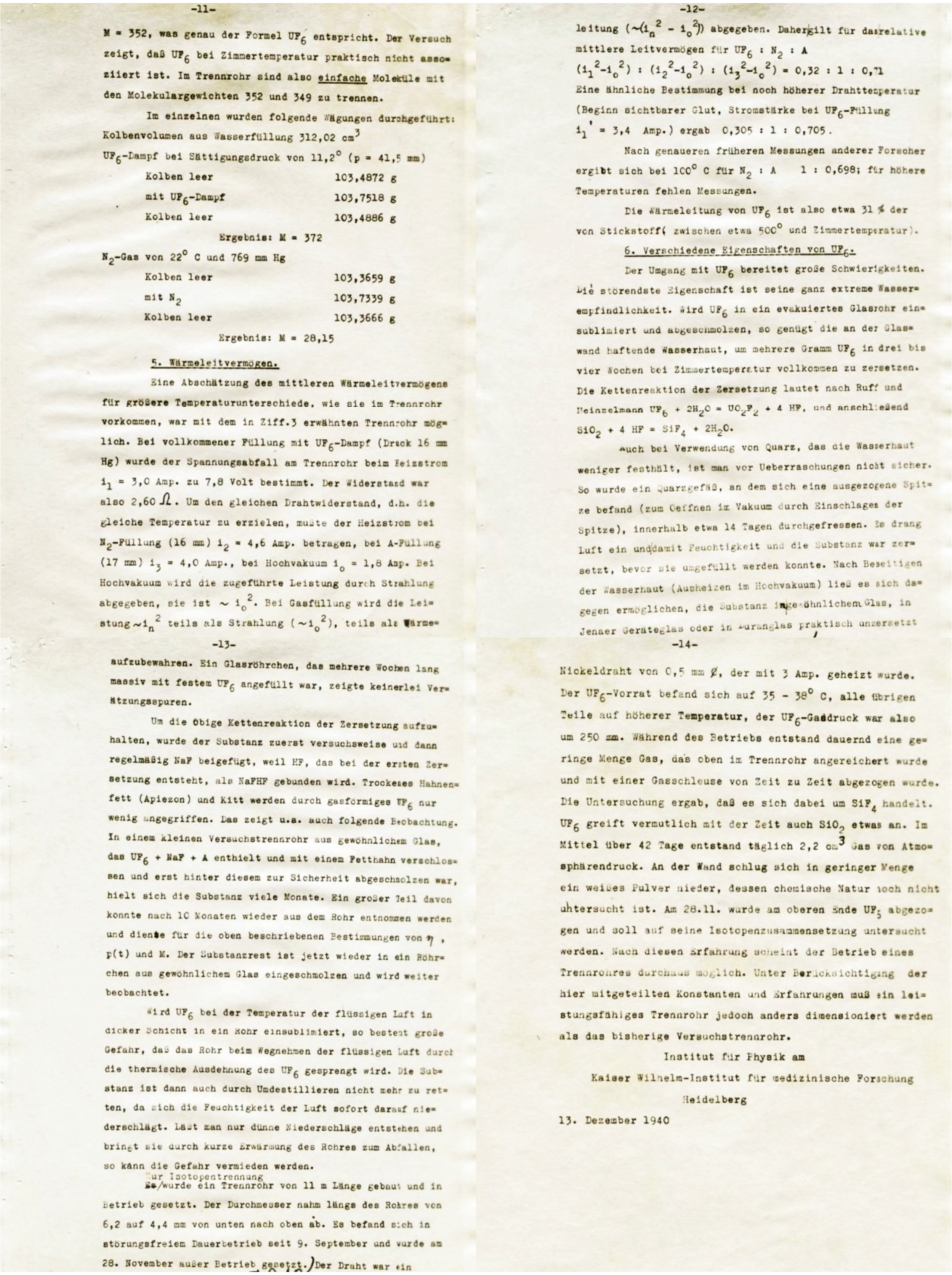
Daraus ergibt sich für die Verdampfungswärme zwischen -10° und +20° 12500 cal/Mol·Grad oder 35,5 cal/g·Grad.

4. Dampfdichte (Molekulargewicht).

Ein Glaskolben aus Jenaer Geräteglas mit Glashahn wurde gut getrocknet und an ein Gefäß, das UF_6 enthielt und leergepumpt werden konnte, angekittet. Dann wurde der Kolben evakuiert, mit UF_6 gefüllt und gekühlt bis sich feste UF_6-Kristalle niederschlugen. Dann wurde das Vorratsgefäß auf 11,2° C gekühlt und gewartet bis im Kolben keine festen Kristalle mehr vorhanden waren. Dadurch bestand Sicherheit, daß der Kolben mit gasförmigem UF_6 mit dem Dampfdruck, der 11,2° entsprach, gefüllt war. Der Kolben wurde zuerst leer und dann mit UF_6 gewogen, das UF_6-Gas wieder in den Vorrat zurückgefüllt und der Kolben nochmals gewogen. Vor jeder Wägung wurde der Kitt vom Ansatzrohr abgelöst. Der Unterschied des Leergewichts vor und nach der Füllung betrug 1,4 mg; daraus folgt, daß sich während der Wägung kein merklicher Teil des UF_6 unter Rückstandsbildung zersetzt hatte. Das Kolbenvolumen wurde hinterher durch Füllung mit Wasser und Wägung bestimmt. Eine Probemessung mit Reinstickstoff ergab für diesen das Molekulargewicht M = 28,15.

Die Molekulargewichtsbestimmung von UF_6 ergab unter Voraussetzung eines Dampfdrucks von 41,5 mm für 11,2° C M = 372. Würde der Dampfdruck 43,8 mm sein, so ergäbe sich

Figure D.127: Production and testing of uranium hexafluoride in 1940 [G-28].



M = 352, was genau der Formel UF_6 entspricht. Der Versuch zeigt, daß UF_6 bei Zimmertemperatur praktisch nicht assoziiert ist. Im Trennrohr sind also einfache Moleküle mit den Molekulargewichten 352 und 349 zu trennen.

Im einzelnen wurden folgende Wägungen durchgeführt:
Kolbenvolumen aus Wasserfüllung 312,02 cm^3
UF_6-Dampf bei Sättigungsdruck von 11,2° (p = 41,5 mm)

Kolben leer	103,4872 g
mit UF_6-Dampf	103,7518 g
Kolben leer	103,4886 g

Ergebnis: M = 372

N_2-Gas von 22° C und 769 mm Hg

Kolben leer	103,3659 g
mit N_2	103,7339 g
Kolben leer	103,3666 g

Ergebnis: M = 28,15

5. Wärmeleitvermögen.

Eine Abschätzung des mittleren Wärmeleitvermögens für größere Temperaturunterschiede, wie sie im Trennrohr vorkommen, war mit dem in Ziff. 3 erwähnten Trennrohr möglich. Bei vollkommener Füllung mit UF_6-Dampf (Druck 16 mm Hg) wurde der Spannungsabfall am Trennrohr beim Heizstrom i_1 = 3,0 Amp. zu 7,8 Volt bestimmt. Der Widerstand war also 2,60 Ω. Um den gleichen Drahtwiderstand, d.h. die gleiche Temperatur zu erzielen, mußte der Heizstrom bei N_2-Füllung (16 mm) i_2 = 4,6 Amp. betragen, bei A-Füllung (17 mm) i_3 = 4,0 Amp., bei Hochvakuum i_o = 1,8 Amp. Bei Hochvakuum wird die zugeführte Leistung durch Strahlung abgegeben, sie ist $\sim i_o^2$. Bei Gasfüllung wird die Leistung $\sim i_n^2$ teils als Strahlung ($\sim i_o^2$), teils als Wärmeleitung ($\sim (i_n^2 - i_o^2)$) abgegeben. Daher gilt für dasrelative mittlere Leitvermögen für $UF_6 : N_2 : A$
$(i_1^2-i_o^2) : (i_2^2-i_o^2) : (i_3^2-i_o^2) = 0,32 : 1 : 0,71$
Eine ähnliche Bestimmung bei noch höherer Drahttemperatur (Beginn sichtbarer Glut, Stromstärke bei UF_6-Füllung i_1' = 3,4 Amp.) ergab 0,305 : 1 : 0,705.

Nach genaueren früheren Messungen anderer Forscher ergibt sich bei 100° C für $N_2 : A$ 1 : 0,698; für höhere Temperaturen fehlen Messungen.

Die Wärmeleitung von UF_6 ist also etwa 31 % der von Stickstoff(zwischen etwa 500° und Zimmertemperatur).

6. Verschiedene Eigenschaften von UF_6.

Der Umgang mit UF_6 bereitet große Schwierigkeiten. Die störendste Eigenschaft ist seine ganz extreme Wasserempfindlichkeit. Wird UF_6 in ein evakuiertes Glasrohr einsublimiert und abgeschmolzen, so genügt die an der Glaswand haftende Wasserhaut, um mehrere Gramm UF_6 in drei bis vier Wochen bei Zimmertemperatur vollkommen zu zersetzen. Die Kettenreaktion der Zersetzung lautet nach Ruff und Heinzelmann $UF_6 + 2H_2O = UO_2F_2 + 4\ HF$, und anschließend $SiO_2 + 4\ HF = SiF_4 + 2H_2O$.

Auch bei Verwendung von Quarz, das die Wasserhaut weniger festhält, ist man vor Ueberraschungen nicht sicher. So wurde ein Quarzgefäß, an dem sich eine ausgezogene Spitze befand (zum Oeffnen im Vakuum durch Einschlagen der Spitze), innerhalb etwa 14 Tagen durchgefressen. Es drang Luft ein und damit Feuchtigkeit und die Substanz war zersetzt, bevor sie umgefüllt werden konnte. Nach Beseitigen der Wasserhaut (Ausheizen im Hochvakuum) ließ es sich dagegen ermöglichen, die Substanz in gewöhnlichem Glas, in Jenaer Geräteglas oder in Duranglas praktisch unzersetzt aufzubewahren. Ein Glasröhrchen, das mehrere Wochen lang massiv mit festem UF_6 angefüllt war, zeigte keinerlei Verätzungsspuren.

Um die obige Kettenreaktion der Zersetzung aufzuhalten, wurde der Substanz zuerst versuchsweise und dann regelmäßig NaF beigefügt, weil HF, das bei der ersten Zersetzung entsteht, als NaFHF gebunden wird. Trockenes Hahnenfett (Apiezon) und Kitt werden durch gasförmiges UF_6 nur wenig angegriffen. Das zeigt u.a. auch folgende Beobachtung. In einem kleinen Versuchstrennrohr aus gewöhnlichem Glas, das UF_6 + NaF + A enthielt und mit einem Fetthahn verschlossen und erst hinter diesem zur Sicherheit abgeschmolzen war, hielt sich die Substanz viele Monate. Ein großer Teil davon konnte nach 10 Monaten wieder aus dem Rohr entnommen werden und diente für die oben beschriebenen Bestimmungen von η, p(t) und M. Der Substanzrest ist jetzt wieder in ein Röhrchen aus gewöhnlichem Glas eingeschmolzen und wird weiter beobachtet.

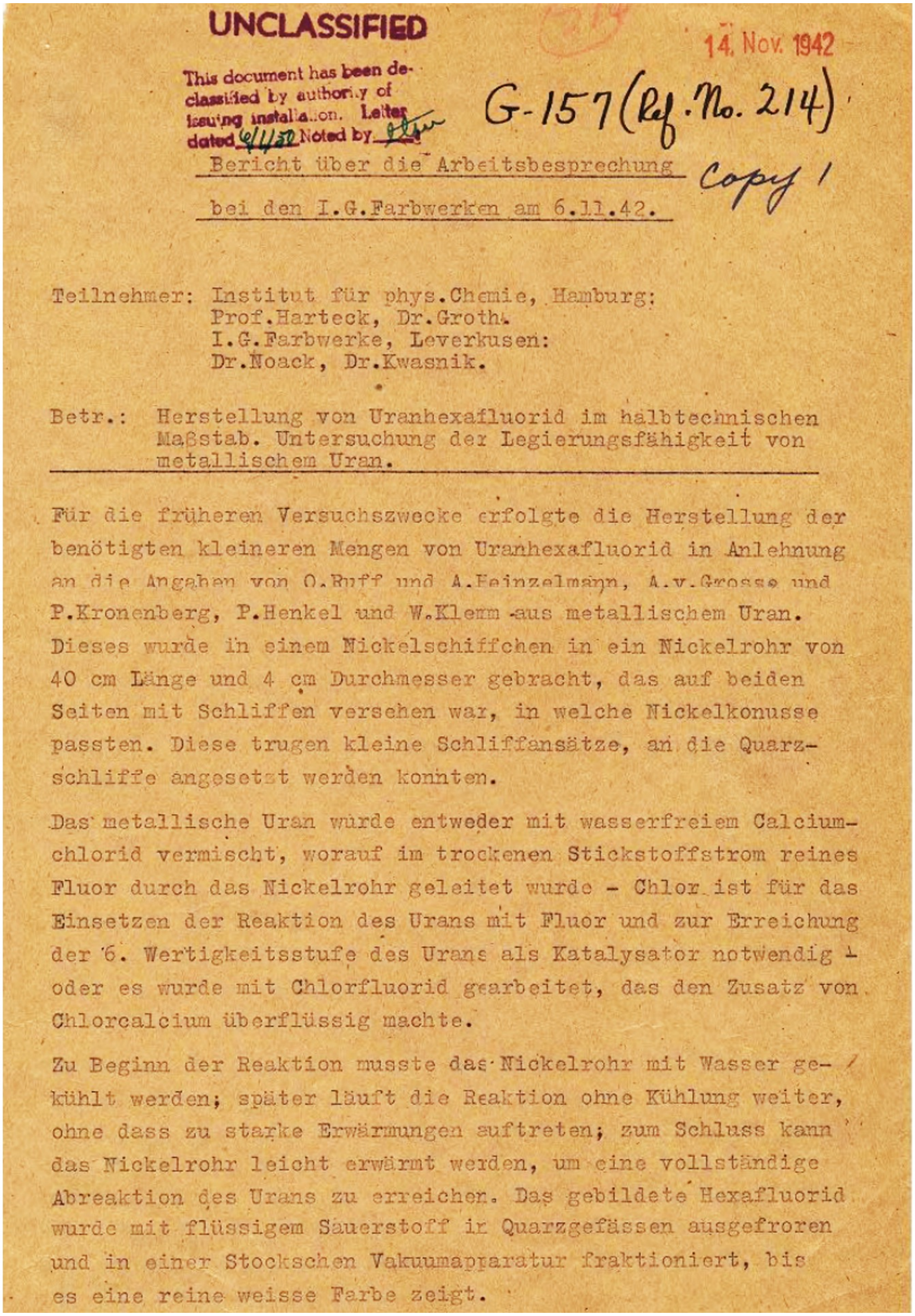
Wird UF_6 bei der Temperatur der flüssigen Luft in dicker Schicht in ein Rohr einsublimiert, so besteht große Gefahr, daß das Rohr beim Wegnehmen der flüssigen Luft durch die thermische Ausdehnung des UF_6 gesprengt wird. Die Substanz ist dann auch durch Umdestillieren nicht mehr zu retten, da sich die Feuchtigkeit der Luft sofort darauf niederschlägt. Läßt man nur dünne Niederschläge entstehen und bringt sie durch kurze Erwärmung des Rohres zum Abfallen, so kann die Gefahr vermieden werden.

~~Es~~ Zur Isotopentrennung wurde ein Trennrohr von 11 m Länge gebaut und in Betrieb gesetzt. Der Durchmesser nahm längs des Rohres von 6,2 auf 4,4 mm von unten nach oben ab. Es befand sich in störungsfreiem Dauerbetrieb seit 9. September und wurde am 28. November außer Betrieb gesetzt.) Der Draht war ein Nickeldraht von 0,5 mm Ø, der mit 3 Amp. geheizt wurde. Der UF_6-Vorrat befand sich auf 35 - 38° C, alle übrigen Teile auf höherer Temperatur, der UF_6-Gasdruck war also um 250 mm. Während des Betriebs entstand dauernd eine geringe Menge Gas, das oben im Trennrohr angereichert wurde und mit einer Gasschleuse von Zeit zu Zeit abgezogen wurde. Die Untersuchung ergab, daß es sich dabei um SiF_4 handelt. UF_6 greift vermutlich mit der Zeit auch SiO_2 etwas an. Im Mittel über 42 Tage entstand täglich 2,2 cm^3 Gas von Atmosphärendruck. An der Wand schlug sich in geringer Menge ein weißes Pulver nieder, dessen chemische Natur noch nicht untersucht ist. Am 28.11. wurde am oberen Ende UF_5 abgezogen und soll auf seine Isotopenzusammensetzung untersucht werden. Nach diesen Erfahrung scheint der Betrieb eines Trennrohres durchaus möglich. Unter Berücksichtigung der hier mitgeteilten Konstanten und Erfahrungen muß ein leistungsfähiges Trennrohr jedoch anders dimensioniert werden als das bisherige Versuchstrennrohr.

Institut für Physik am
Kaiser Wilhelm-Institut für medizinische Forschung
Heidelberg

13. Dezember 1940

Figure D.128: Production and testing of uranium hexafluoride in 1940 [G-28].



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This document has been declassified by authority of issuing installation. Letter dated 6/1/50 Noted by

14. Nov. 1942

G-157 (Ref. No. 214)

Copy 1

Bericht über die Arbeitsbesprechung
bei den I.G.Farbwerken am 6.11.42.

Teilnehmer: Institut für phys.Chemie, Hamburg:
Prof.Harteck, Dr.Groth.
I.G.Farbwerke, Leverkusen:
Dr.Noack, Dr.Kwasnik.

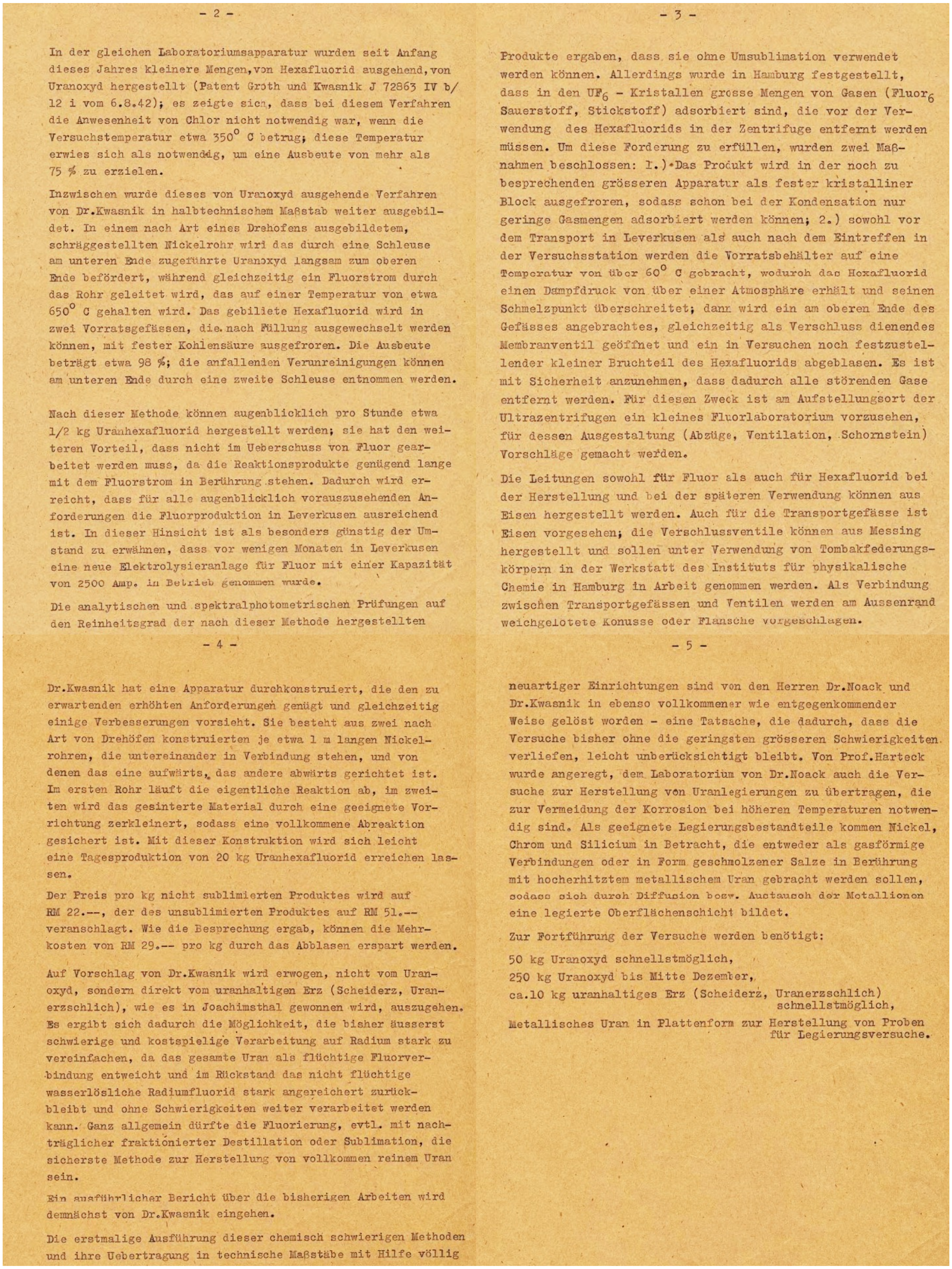
Betr.: Herstellung von Uranhexafluorid im halbtechnischen Maßstab. Untersuchung der Legierungsfähigkeit von metallischem Uran.

Für die früheren Versuchszwecke erfolgte die Herstellung der benötigten kleineren Mengen von Uranhexafluorid in Anlehnung an die Angaben von O.Ruff und A.Heinzelmann, A.v.Grosse und P.Kronenberg, P.Henkel und W.Klemm aus metallischem Uran. Dieses wurde in einem Nickelschiffchen in ein Nickelrohr von 40 cm Länge und 4 cm Durchmesser gebracht, das auf beiden Seiten mit Schliffen versehen war, in welche Nickelkonusse passten. Diese trugen kleine Schliffansätze, an die Quarzschliffe angesetzt werden konnten.

Das metallische Uran wurde entweder mit wasserfreiem Calciumchlorid vermischt, worauf im trockenen Stickstoffstrom reines Fluor durch das Nickelrohr geleitet wurde – Chlor ist für das Einsetzen der Reaktion des Urans mit Fluor und zur Erreichung der 6. Wertigkeitsstufe des Urans als Katalysator notwendig – oder es wurde mit Chlorfluorid gearbeitet, das den Zusatz von Chlorcalcium überflüssig machte.

Zu Beginn der Reaktion musste das Nickelrohr mit Wasser gekühlt werden; später läuft die Reaktion ohne Kühlung weiter, ohne dass zu starke Erwärmungen auftreten; zum Schluss kann das Nickelrohr leicht erwärmt werden, um eine vollständige Abreaktion des Urans zu erreichen. Das gebildete Hexafluorid wurde mit flüssigem Sauerstoff in Quarzgefässen ausgefroren und in einer Stockschen Vakuumapparatur fraktioniert, bis es eine reine weisse Farbe zeigt.

Figure D.129: Production and testing of uranium hexafluoride in 1942 [G-157].



In der gleichen Laboratoriumsapparatur wurden seit Anfang dieses Jahres kleinere Mengen, von Hexafluorid ausgehend, von Uranoxyd hergestellt (Patent Groth und Kwasnik J 72863 IV b/12 i vom 6.8.42); es zeigte sich, dass bei diesem Verfahren die Anwesenheit von Chlor nicht notwendig war, wenn die Versuchstemperatur etwa 350° C betrug; diese Temperatur erwies sich als notwendig, um eine Ausbeute von mehr als 75 % zu erzielen.

Inzwischen wurde dieses von Uranoxyd ausgehende Verfahren von Dr.Kwasnik in halbtechnischem Maßstab weiter ausgebildet. In einem nach Art eines Drehofens ausgebildetem, schräggestellten Nickelrohr wird das durch eine Schleuse am unteren Ende zugeführte Uranoxyd langsam zum oberen Ende befördert, während gleichzeitig ein Fluorstrom durch das Rohr geleitet wird, das auf einer Temperatur von etwa 650° C gehalten wird. Das gebildete Hexafluorid wird in zwei Vorratsgefässen, die nach Füllung ausgewechselt werden können, mit fester Kohlensäure ausgefroren. Die Ausbeute beträgt etwa 98 %; die anfallenden Verunreinigungen können am unteren Ende durch eine zweite Schleuse entnommen werden.

Nach dieser Methode können augenblicklich pro Stunde etwa 1/2 kg Uranhexafluorid hergestellt werden; sie hat den weiteren Vorteil, dass nicht im Ueberschuss von Fluor gearbeitet werden muss, da die Reaktionsprodukte genügend lange mit dem Fluorstrom in Berührung stehen. Dadurch wird erreicht, dass für alle augenblicklich vorauszusehenden Anforderungen die Fluorproduktion in Leverkusen ausreichend ist. In dieser Hinsicht ist als besonders günstig der Umstand zu erwähnen, dass vor wenigen Monaten in Leverkusen eine neue Elektrolysieranlage für Fluor mit einer Kapazität von 2500 Amp. in Betrieb genommen wurde.

Die analytischen und spektralphotometrischen Prüfungen auf den Reinheitsgrad der nach dieser Methode hergestellten Produkte ergaben, dass sie ohne Umsublimation verwendet werden können. Allerdings wurde in Hamburg festgestellt, dass in den UF$_6$ - Kristallen grosse Mengen von Gasen (Fluor$_6$ Sauerstoff, Stickstoff) adsorbiert sind, die vor der Verwendung des Hexafluorids in der Zentrifuge entfernt werden müssen. Um diese Forderung zu erfüllen, wurden zwei Maßnahmen beschlossen: 1.) Das Produkt wird in der noch zu besprechenden grösseren Apparatur als fester kristalliner Block ausgefroren, sodass schon bei der Kondensation nur geringe Gasmengen adsorbiert werden können; 2.) sowohl vor dem Transport in Leverkusen als auch nach dem Eintreffen in der Versuchsstation werden die Vorratsbehälter auf eine Temperatur von über 60° C gebracht, wodurch das Hexafluorid einen Dampfdruck von über einer Atmosphäre erhält und seinen Schmelzpunkt überschreitet; dann wird ein am oberen Ende des Gefässes angebrachtes, gleichzeitig als Verschluss dienendes Membranventil geöffnet und ein in Versuchen noch festzustellender kleiner Bruchteil des Hexafluorids abgeblasen. Es ist mit Sicherheit anzunehmen, dass dadurch alle störenden Gase entfernt werden. Für diesen Zweck ist am Aufstellungsort der Ultrazentrifugen ein kleines Fluorlaboratorium vorzusehen, für dessen Ausgestaltung (Abzüge, Ventilation, Schornstein) Vorschläge gemacht werden.

Die Leitungen sowohl für Fluor als auch für Hexafluorid bei der Herstellung und bei der späteren Verwendung können aus Eisen hergestellt werden. Auch für die Transportgefässe ist Eisen vorgesehen; die Verschlussventile können aus Messing hergestellt und sollen unter Verwendung von Tombakfederungskörpern in der Werkstatt des Instituts für physikalische Chemie in Hamburg in Arbeit genommen werden. Als Verbindung zwischen Transportgefässen und Ventilen werden am Aussenrand weichgelötete Konusse oder Flansche vorgeschlagen.

Dr.Kwasnik hat eine Apparatur durchkonstruiert, die den zu erwartenden erhöhten Anforderungen genügt und gleichzeitig einige Verbesserungen vorsieht. Sie besteht aus zwei nach Art von Drehöfen konstruierten je etwa 1 m langen Nickelrohren, die untereinander in Verbindung stehen, und von denen das eine aufwärts, das andere abwärts gerichtet ist. Im ersten Rohr läuft die eigentliche Reaktion ab, im zweiten wird das gesinterte Material durch eine geeignete Vorrichtung zerkleinert, sodass eine vollkommene Abreaktion gesichert ist. Mit dieser Konstruktion wird sich leicht eine Tagesproduktion von 20 kg Uranhexafluorid erreichen lassen.

Der Preis pro kg nicht sublimierten Produktes wird auf RM 22.--, der des unsublimierten Produktes auf RM 51.-- veranschlagt. Wie die Besprechung ergab, können die Mehrkosten von RM 29.-- pro kg durch das Abblasen erspart werden.

Auf Vorschlag von Dr.Kwasnik wird erwogen, nicht vom Uranoxyd, sondern direkt vom uranhaltigen Erz (Scheiderz, Uranerzschlich), wie es in Joachimsthal gewonnen wird, auszugehen. Es ergibt sich dadurch die Möglichkeit, die bisher äusserst schwierige und kostspielige Verarbeitung auf Radium stark zu vereinfachen, da das gesamte Uran als flüchtige Fluorverbindung entweicht und im Rückstand das nicht flüchtige wasserlösliche Radiumfluorid stark angereichert zurückbleibt und ohne Schwierigkeiten weiter verarbeitet werden kann. Ganz allgemein dürfte die Fluorierung, evtl. mit nachträglicher fraktionierter Destillation oder Sublimation, die sicherste Methode zur Herstellung von vollkommen reinem Uran sein.

Ein ausführlicher Bericht über die bisherigen Arbeiten wird demnächst von Dr.Kwasnik eingehen.

Die erstmalige Ausführung dieser chemisch schwierigen Methoden und ihre Uebertragung in technische Maßstäbe mit Hilfe völlig neuartiger Einrichtungen sind von den Herren Dr.Noack und Dr.Kwasnik in ebenso vollkommener wie entgegenkommender Weise gelöst worden - eine Tatsache, die dadurch, dass die Versuche bisher ohne die geringsten grösseren Schwierigkeiten verliefen, leicht unberücksichtigt bleibt. Von Prof.Harteck wurde angeregt, dem Laboratorium von Dr.Noack auch die Versuche zur Herstellung von Uranlegierungen zu übertragen, die zur Vermeidung der Korrosion bei höheren Temperaturen notwendig sind. Als geeignete Legierungsbestandteile kommen Nickel, Chrom und Silicium in Betracht, die entweder als gasförmige Verbindungen oder in Form geschmolzener Salze in Berührung mit hocherhitztem metallischem Uran gebracht werden sollen, sodass sich durch Diffusion bzw. Austausch der Metallionen eine legierte Oberflächenschicht bildet.

Zur Fortführung der Versuche werden benötigt:

50 kg Uranoxyd schnellstmöglich,
250 kg Uranoxyd bis Mitte Dezember,
ca.10 kg uranhaltiges Erz (Scheiderz, Uranerzschlich) schnellstmöglich,
Metallisches Uran in Plattenform zur Herstellung von Proben für Legierungsversuche.

Figure D.130: Production and testing of uranium hexafluoride in 1942 [G-157].

Robert E. Work. 18 September 1945. Preliminary Interrogation Report. Prof. Dr. Ulrich Hoffmann. [AFHRA A5183 frames 0346, 0609]

e. Education: PhD in chemistry from University of Berlin in 1926. Instructor at University of Berlin until 1936. Called to University of Rostock in 1936 where he became full professor in 1937. In April 1942 he was called to University of Vienna as Director of the Institute for Inorganic and Analytic Chemistry. [...]

3. GENERAL INFORMATION: Dr. Hoffmann's research in the field of air interest was only in the development of the atomic bomb. Claims to have improved method of obtaining FLUOR [fluorine], which is necessary to obtain UF6 [uranium hexafluoride], one of the basic ingredients of the atomic bomb.

[See document photos on p. 3491.

Why was the Luftwaffe funding Dr. Ulrich Hoffmann in Austria to improve the production of uranium hexafluoride to create atomic bombs?

Where are the reports on Hoffmann's interrogations, wartime work, and postwar work?]

AFHRA A5183 frame 0609

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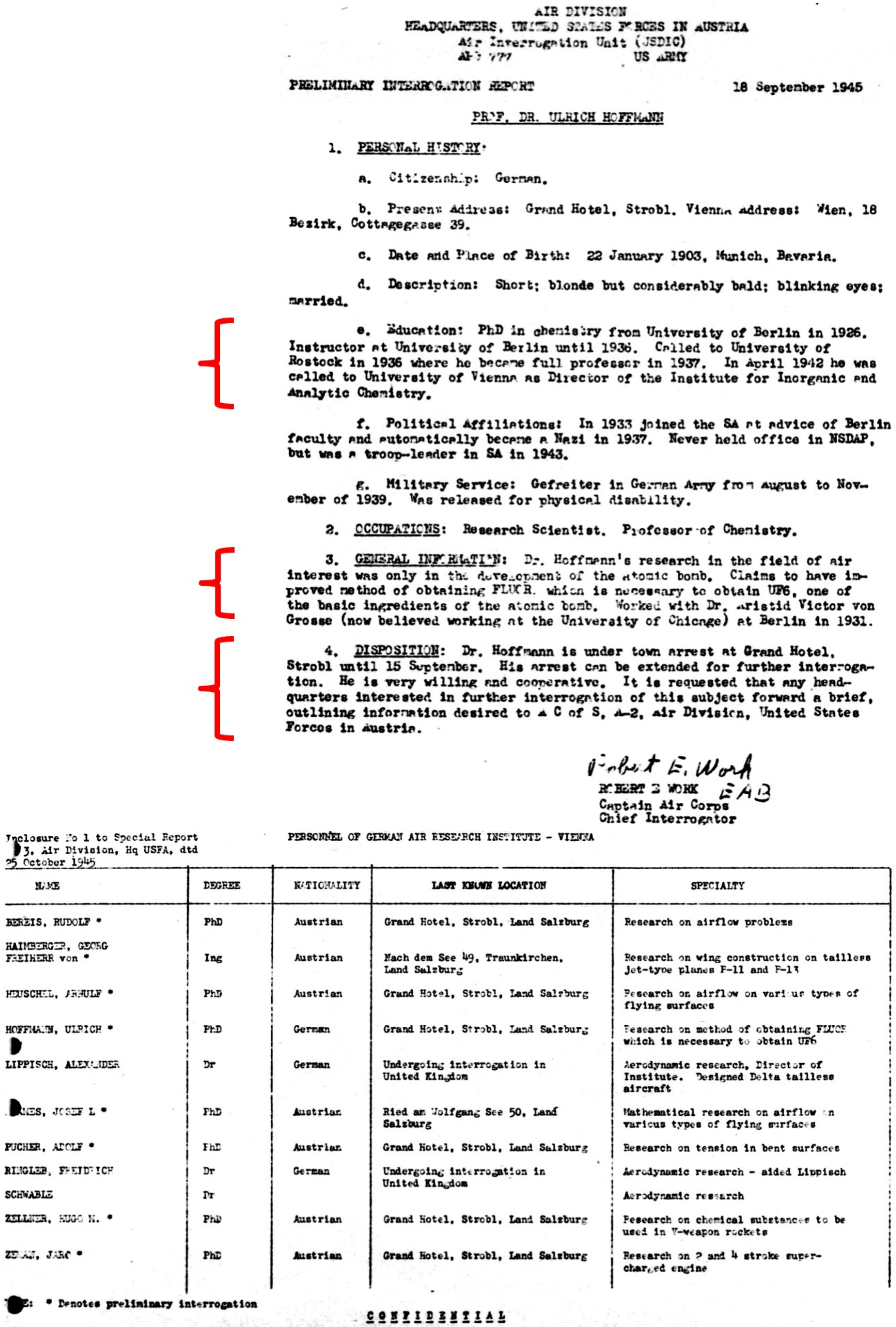
AFHRA A5183 frame 0346



AIR DIVISION
HEADQUARTERS, UNITED STATES FORCES IN AUSTRIA
Air Interrogation Unit (JSDIC)
APO 777 US ARMY

PRELIMINARY INTERROGATION REPORT 18 September 1945

PROF. DR. ULRICH HOFFMANN

1. PERSONAL HISTORY:

a. Citizenship: German.

b. Present Address: Grand Hotel, Strobl. Vienna address: Wien, 18 Bezirk, Cottagegasse 39.

c. Date and Place of Birth: 22 January 1903, Munich, Bavaria.

d. Description: Short; blonde but considerably bald; blinking eyes; married.

e. Education: PhD in chemistry from University of Berlin in 1926. Instructor at University of Berlin until 1936. Called to University of Rostock in 1936 where he became full professor in 1937. In April 1942 he was called to University of Vienna as Director of the Institute for Inorganic and Analytic Chemistry.

f. Political Affiliations: In 1933 joined the SA at advice of Berlin faculty and automatically became a Nazi in 1937. Never held office in NSDAP, but was a troop-leader in SA in 1943.

g. Military Service: Gefreiter in German Army from August to November of 1939. Was released for physical disability.

2. OCCUPATIONS: Research Scientist. Professor of Chemistry.

3. GENERAL INFORMATION: Dr. Hoffmann's research in the field of air interest was only in the development of the atomic bomb. Claims to have improved method of obtaining FLUOR, which is necessary to obtain UF6, one of the basic ingredients of the atomic bomb. Worked with Dr. Aristid Victor von Grosse (now believed working at the University of Chicago) at Berlin in 1931.

4. DISPOSITION: Dr. Hoffmann is under town arrest at Grand Hotel, Strobl until 15 September. His arrest can be extended for further interrogation. He is very willing and cooperative. It is requested that any headquarters interested in further interrogation of this subject forward a brief, outlining information desired to A C of S, A-2, Air Division, United States Forces in Austria.

Robert E. Work
ROBERT E WORK EAB
Captain Air Corps
Chief Interrogator

Inclosure No 1 to Special Report
3, Air Division, Hq USFA, dtd
25 October 1945

PERSONNEL OF GERMAN AIR RESEARCH INSTITUTE - VIENNA

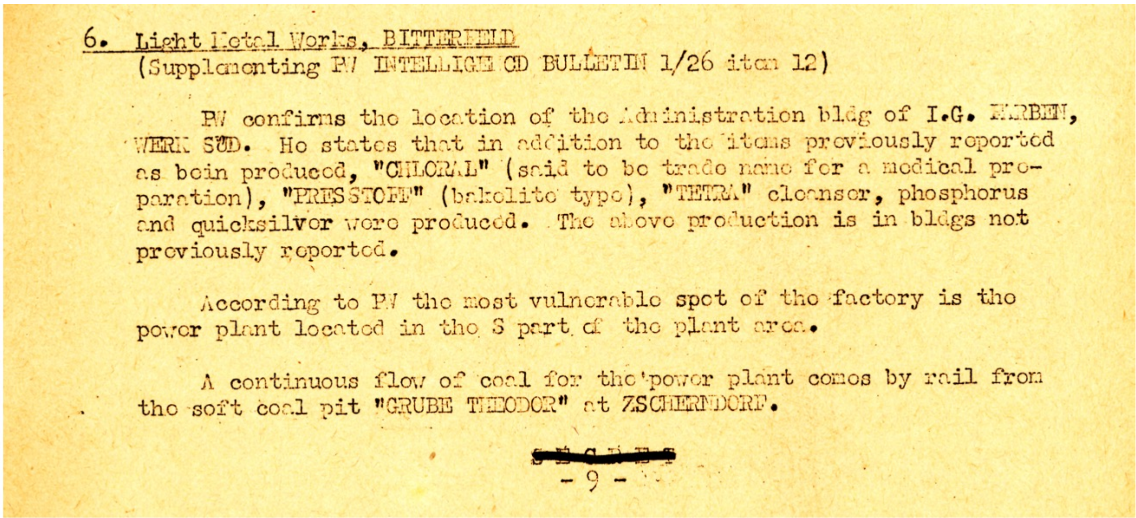
NAME	DEGREE	NATIONALITY	LAST KNOWN LOCATION	SPECIALTY
BEREIS, RUDOLF •	PhD	Austrian	Grand Hotel, Strobl, Land Salzburg	Research on airflow problems
HAIMBERGER, GEORG FREIHERR von •	Ing	Austrian	Nach dem See 49, Traunkirchen, Land Salzburg	Research on wing construction on tailless Jet-type planes P-11 and P-13
HEUSCHEL, ARNULF •	PhD	Austrian	Grand Hotel, Strobl, Land Salzburg	Research on airflow on various types of flying surfaces
HOFFMANN, ULRICH •	PhD	German	Grand Hotel, Strobl, Land Salzburg	Research on method of obtaining FLUOR which is necessary to obtain UF6
LIPPISCH, ALEXANDER	Dr	German	Undergoing interrogation in United Kingdom	Aerodynamic research, Director of Institute. Designed Delta tailless aircraft
[illegible]MES, JOSEF L •	PhD	Austrian	Ried am Wolfgang See 50, Land Salzburg	Mathematical research on airflow on various types of flying surfaces
PUCHER, ADOLF •	PhD	Austrian	Grand Hotel, Strobl, Land Salzburg	Research on tension in bent surfaces
RINGLEB, FRIEDRICH	Dr	German	Undergoing interrogation in United Kingdom	Aerodynamic research - aided Lippisch
SCHWABLE	Dr			Aerodynamic research
ZELLNER, HUGO N. •	PhD	Austrian	Grand Hotel, Strobl, Land Salzburg	Research on chemical substances to be used in V-weapon rockets
ZEMAN, JARO •	PhD	Austrian	Grand Hotel, Strobl, Land Salzburg	Research on 2 and 4 stroke supercharged engine

[illegible]E: • Denotes preliminary interrogation

CONFIDENTIAL

Figure D.131: Why was the Luftwaffe funding Dr. Ulrich Hoffmann in Austria to conduct "research... in the development of the atomic bomb..." to develop "improved method of obtaining FLUOR [fluorine], which is necessary to obtain UF6 [uranium hexafluoride], one of the basic ingredients of the atomic bomb"? Where are the reports on Hoffmann's interrogations, wartime work, and postwar work? [AFHRA A5183 frames 0346, 0609]

PW Intelligence Bulletin No 1/34, AFHRA folder THIS PAGE IS DECLASSIFIED IAW EO 13526
506.61951 Nos. 1/19--1/35 26 Dec 1944--7 Feb 1945, IRIS 207524



6. Light Metal Works, BITTERFELD
(Supplementing PW INTELLIGENCE BULLETIN 1/26 item 12)

PW confirms the location of the Administration bldg of I.G. FARBEN, WERK SÜD. He states that in addition to the items previously reported as bein produced, "CHLORAL" (said to be trade name for a medical preparation), "PRESSTOFF" (bakelite type), "TETRA" cleanser, phosphorus and quicksilver were produced. The above production is in bldgs not previously reported.

According to PW the most vulnerable spot of the factory is the power plant located in the S part of the plant area.

A continuous flow of coal for the power plant comes by rail from the soft coal pit "GRUBE THEODOR" at ZSCHERNDORF.

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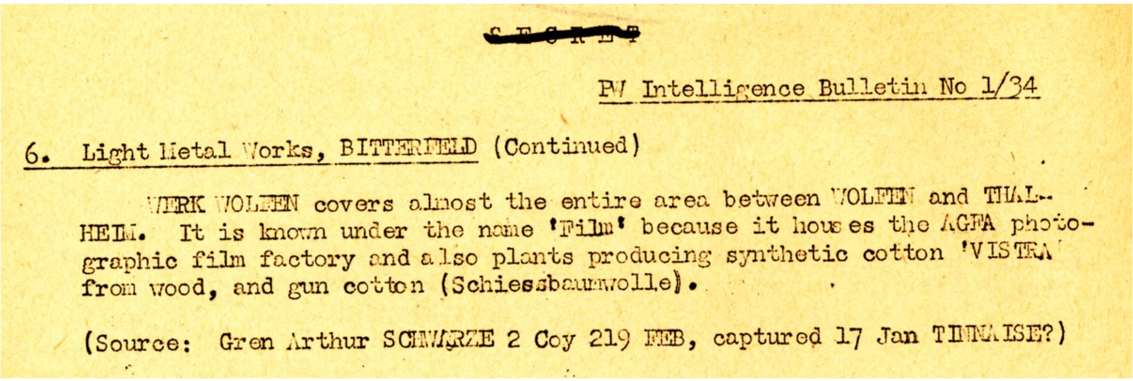

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PW Intelligence Bulletin No 1/34

6. Light Metal Works, BITTERFELD (Continued)

WERK WOLFEN covers almost the entire area between WOLFEN and THALHEIM. It is known under the name 'Film' because it houses the AGFA photographic film factory and also plants producing synthetic cotton 'VISTRA' from wood, and gun cotton (Schiessbaumwolle).

(Source: Gren Arthur SCHWARZE 2 Coy 219 FEB, captured 17 Jan TIMMAISE?)

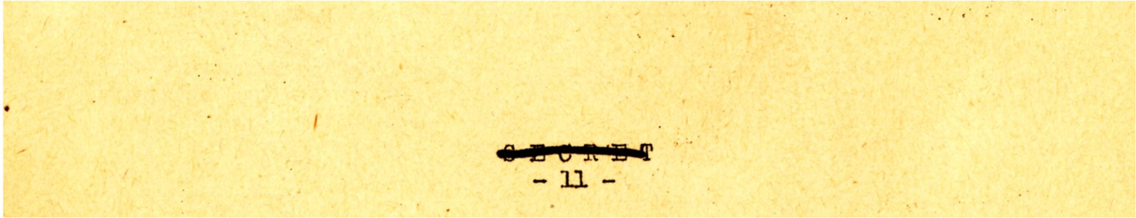

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Figure D.132: Possible production of uranium hexafluoride in an underground facility at I.G. Farben Bitterfeld. PW Intelligence Bulletin No 1/34, 5 February 1945 [AFHRA folder 506.61951 Nos. 1/19–1/35 26 Dec 1944–7 Feb 1945, IRIS 207524; AFHRA A5185 frames 474–476; also NARA RG 165, Entry NM84-79, Box 1915]. Bitterfeld produced several other potentially nuclear-related materials including heavy water (p. 4050), graphite (p. 4110), aluminum (p. 4128), and calcium (pp. 4133, 4136).

PW Intelligence Bulletin No 1/34, AFHRA folder 506.61951 Nos. 1/19--1/35 26 Dec 1944--7 Feb 1945, IRIS 207524

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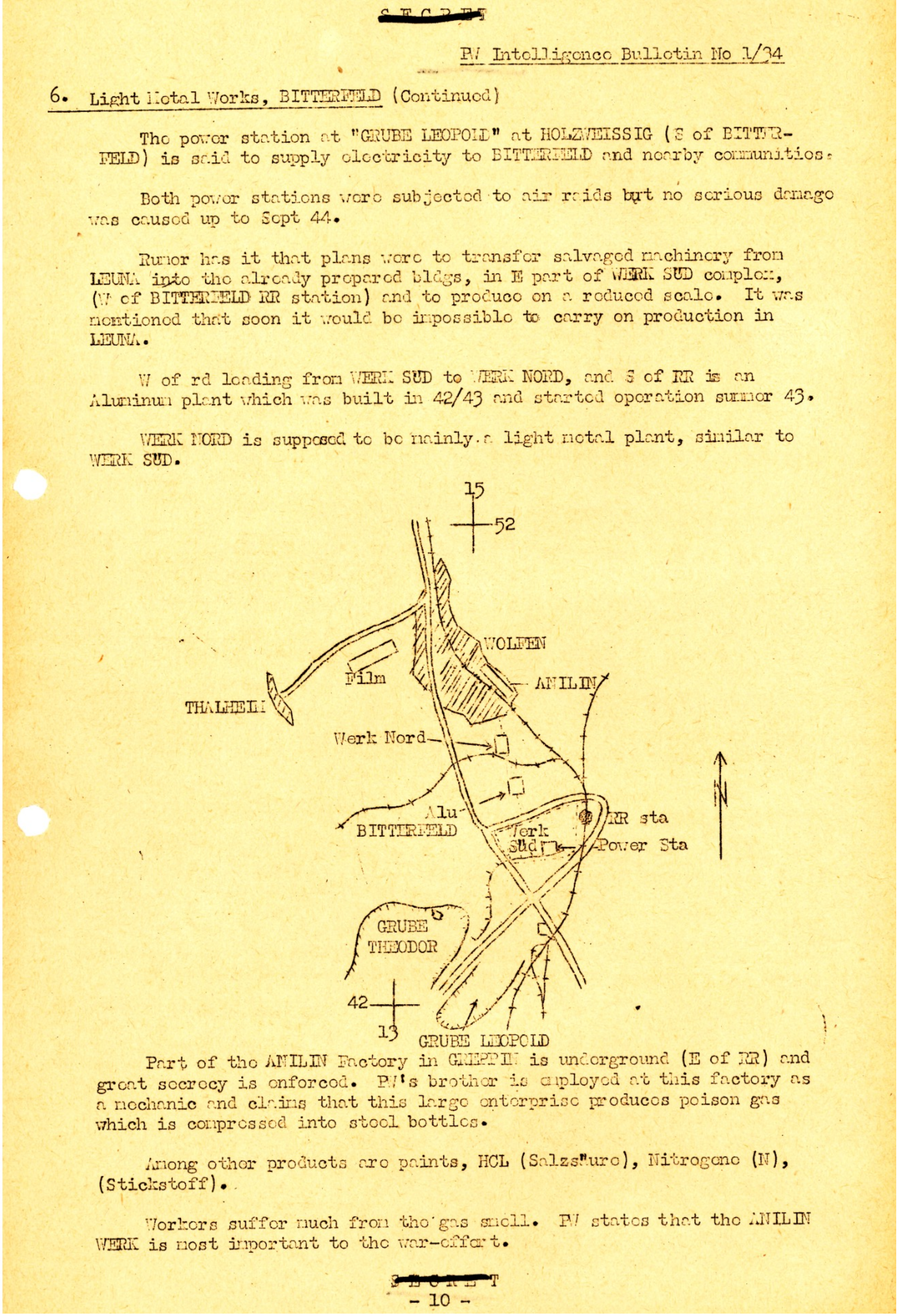

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PW Intelligence Bulletin No 1/34

6. Light Metal Works, BITTERFELD (Continued)

The power station at "GRUBE LEOPOLD" at HOLZWEISSIG (S of BITTERFELD) is said to supply electricity to BITTERFELD and nearby communities.

Both power stations were subjected to air raids but no serious damage was caused up to Sept 44.

Rumor has it that plans were to transfer salvaged machinery from LEUNA into the already prepared bldgs, in E part of WERK SUD complex, (W of BITTERFELD RR station) and to produce on a reduced scale. It was mentioned that soon it would be impossible to carry on production in LEUNA.

W of rd leading from WERK SUD to WERK NORD, and S of RR is an Aluminum plant which was built in 42/43 and started operation summer 43.

WERK NORD is supposed to be mainly a light metal plant, similar to WERK SUD.

Part of the ANILIN Factory in GREPPIN is underground (E of RR) and great secrecy is enforced. PW's brother is employed at this factory as a mechanic and claims that this large enterprise produces poison gas which is compressed into steel bottles.

Among other products are paints, HCL (Salzsäure), Nitrogene (N), (Stickstoff).

Workers suffer much from the gas smell. PW states that the ANILIN WERK is most important to the war-effort.

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- 10 -

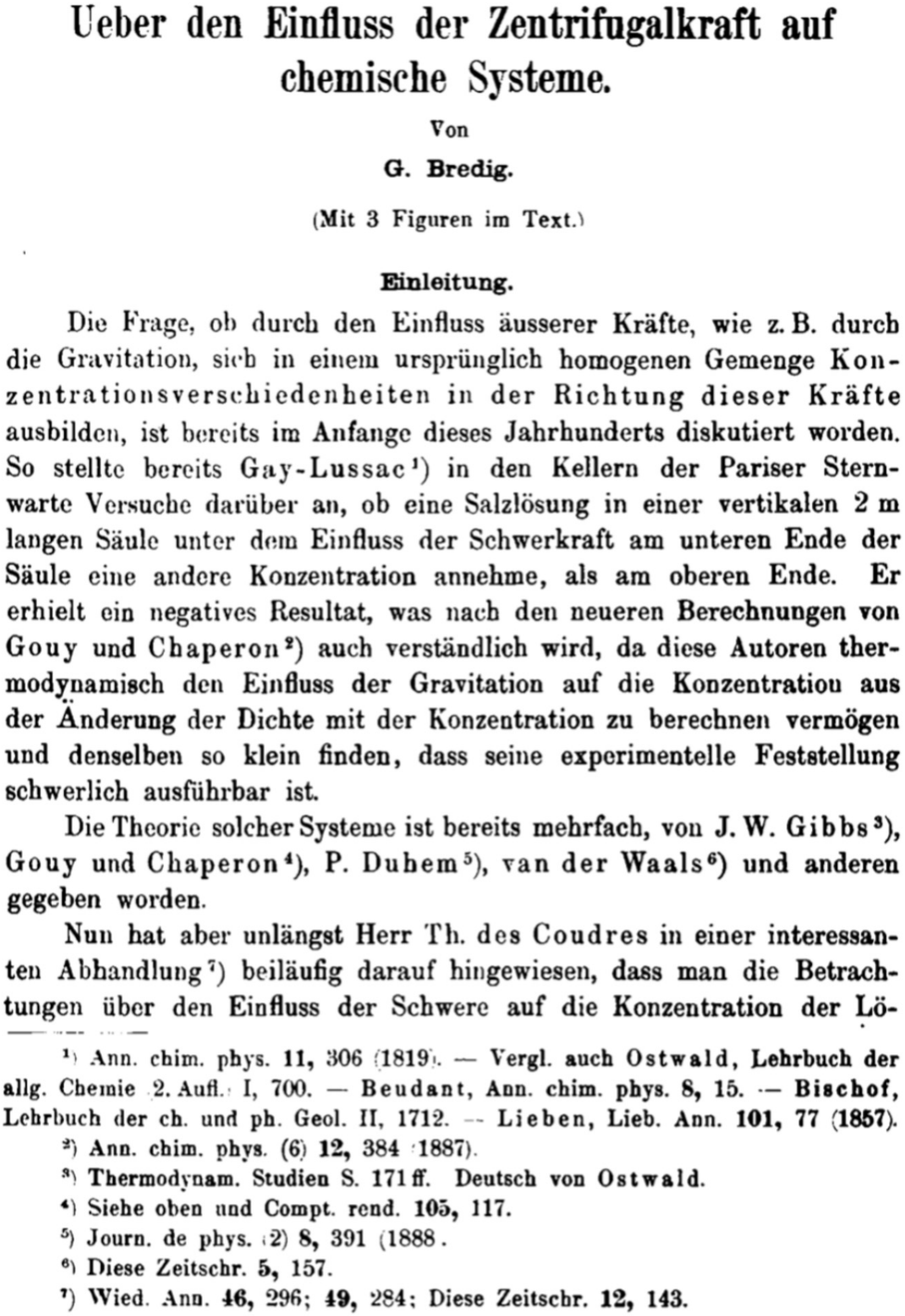
Figure D.133: Possible production of uranium hexafluoride in an underground facility at I.G. Farben Bitterfeld. PW Intelligence Bulletin No 1/34, 5 February 1945 [AFHRA folder 506.61951 Nos. 1/19–1/35 26 Dec 1944–7 Feb 1945, IRIS 207524; AFHRA A5185 frames 474–476; also NARA RG 165, Entry NM84-79, Box 1915]. Bitterfeld produced several other potentially nuclear-related materials including heavy water (p. 4050), graphite (p. 4110), aluminum (p. 4128), and calcium (pp. 4133, 4136).

D.4.2 Uranium-235 Enrichment via Centrifugation

[Antonin Prandtl (German, 1842–1909) invented centrifuges for separating liquid mixtures in 1864. He, Alexander Prandtl, (German, 1840–1896 and Wilhelm Lefeldt (German, 1836–1913) developed improved liquid centrifuges during the 1870s (pp. 2394–2399).

Georg Bredig (German, 1868–1944, p. 718) invented centrifuges for separated gaseous mixtures no later than 1895. He and Fritz Haber (German, 1868–1934, p. 608) continued to develop gas centrifuges into the early 1900s.]

Georg Bredig. 1895. Ueber den Einfluss der Zentrifugalkraft auf chemische Systeme. *Zeitschrift für Physikalische Chemie A* 17:459. See photo of first page on p. 3495.



Ueber den Einfluss der Zentrifugalkraft auf chemische Systeme.

Von

G. Bredig.

(Mit 3 Figuren im Text.)

Einleitung.

Die Frage, ob durch den Einfluss äusserer Kräfte, wie z. B. durch die Gravitation, sich in einem ursprünglich homogenen Gemenge Konzentrationsverschiedenheiten in der Richtung dieser Kräfte ausbilden, ist bereits im Anfange dieses Jahrhunderts diskutiert worden. So stellte bereits Gay-Lussac[1]) in den Kellern der Pariser Sternwarte Versuche darüber an, ob eine Salzlösung in einer vertikalen 2 m langen Säule unter dem Einfluss der Schwerkraft am unteren Ende der Säule eine andere Konzentration annehme, als am oberen Ende. Er erhielt ein negatives Resultat, was nach den neueren Berechnungen von Gouy und Chaperon[2]) auch verständlich wird, da diese Autoren thermodynamisch den Einfluss der Gravitation auf die Konzentration aus der Änderung der Dichte mit der Konzentration zu berechnen vermögen und denselben so klein finden, dass seine experimentelle Feststellung schwerlich ausführbar ist.

Die Theorie solcher Systeme ist bereits mehrfach, von J. W. Gibbs[3]), Gouy und Chaperon[4]), P. Duhem[5]), van der Waals[6]) und anderen gegeben worden.

Nun hat aber unlängst Herr Th. des Coudres in einer interessanten Abhandlung[7]) beiläufig darauf hingewiesen, dass man die Betrachtungen über den Einfluss der Schwere auf die Konzentration der Lö-

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[1]) Ann. chim. phys. **11**, 306 (1819). — Vergl. auch **Ostwald**, Lehrbuch der allg. Chemie (2. Aufl.) I, 700. — **Beudant**, Ann. chim. phys. 8, 15. — **Bischof**, Lehrbuch der ch. und ph. Geol. II, 1712. — **Lieben**, Lieb. Ann. **101, 77** (**1857**).

[2]) Ann. chim. phys. (6) **12**, 384 (1887).

[3]) Thermodynam. Studien S. 171 ff. Deutsch von **Ostwald**.

[4]) Siehe oben und Compt. rend. **105**, 117.

[5]) Journ. de phys. (2) **8**, 391 (1888).

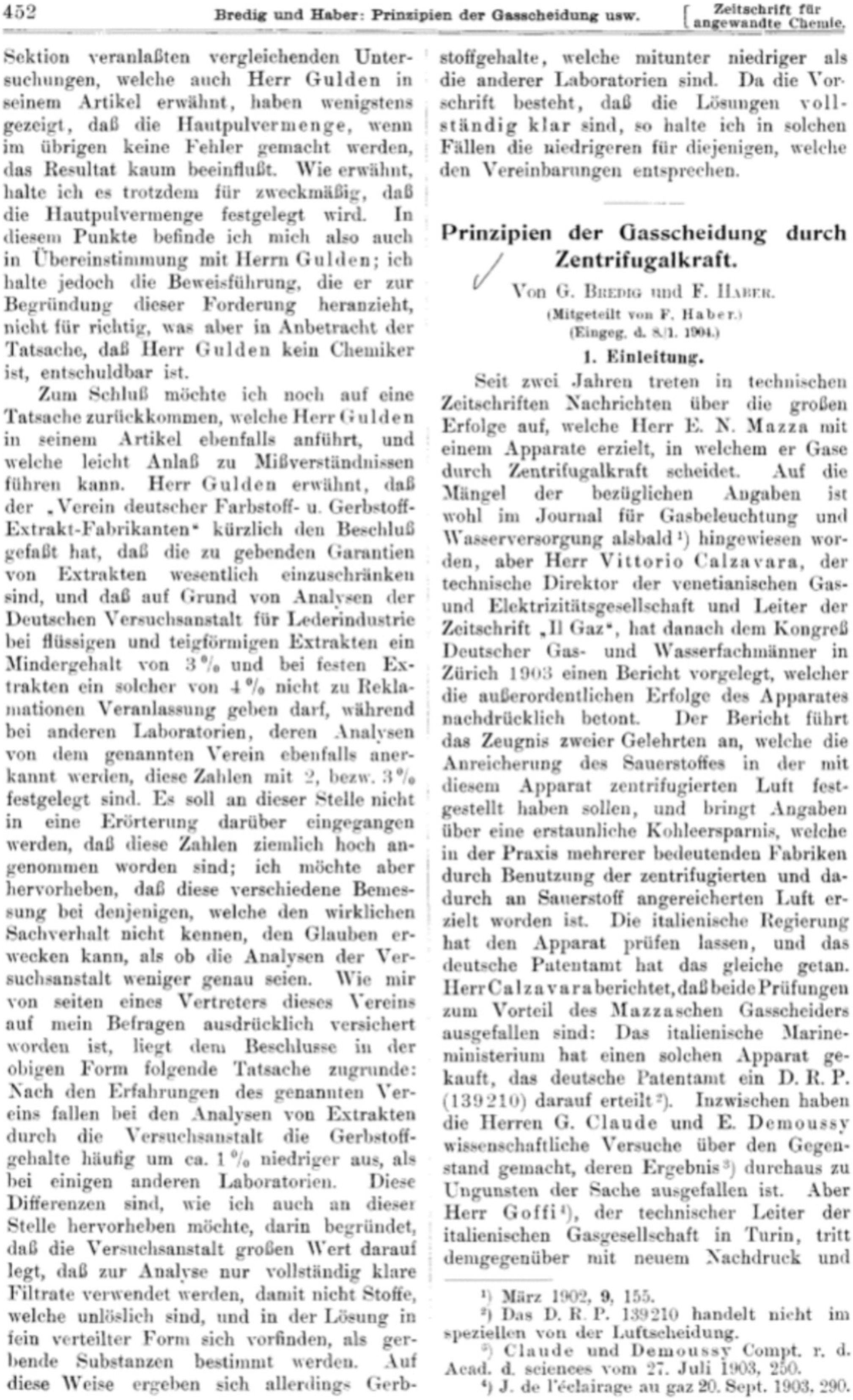
[6]) Diese Zeitschr. **5**, 157.

[7]) Wied. Ann. **46**, 296; **49**, 284; Diese Zeitschr. **12**, **143**.

Figure D.134: Georg Bredig. 1895. Ueber den Einfluss der Zentrifugalkraft auf chemische Systeme. *Zeitschrift für Physikalische Chemie A* 17:459. First page is shown.

Georg Bredig and Fritz Haber. 1904. Prinzipien der Gasscheidung durch Zentrifugalkraft. *Zeitschrift für Angewandte Chemie* 17:452. See photo of first page on p. 3497.

[By the 1930s and early 1940s, gas centrifuges were being produced, improved, and tested by several groups in the German-speaking world. They were demonstrated with various gaseous mixtures for unclassified publications, but they were most seriously pursued for more secretive work on uranium isotope separation.]



452 Bredig und Haber: Prinzipien der Gasscheidung usw. [Zeitschrift für angewandte Chemie.

Sektion veranlaßten vergleichenden Untersuchungen, welche auch Herr Gulden in seinem Artikel erwähnt, haben wenigstens gezeigt, daß die Hautpulvermenge, wenn im übrigen keine Fehler gemacht werden, das Resultat kaum beeinflußt. Wie erwähnt, halte ich es trotzdem für zweckmäßig, daß die Hautpulvermenge festgelegt wird. In diesem Punkte befinde ich mich also auch in Übereinstimmung mit Herrn Gulden; ich halte jedoch die Beweisführung, die er zur Begründung dieser Forderung heranzieht, nicht für richtig, was aber in Anbetracht der Tatsache, daß Herr Gulden kein Chemiker ist, entschuldbar ist.

Zum Schluß möchte ich noch auf eine Tatsache zurückkommen, welche Herr Gulden in seinem Artikel ebenfalls anführt, und welche leicht Anlaß zu Mißverständnissen führen kann. Herr Gulden erwähnt, daß der „Verein deutscher Farbstoff- u. Gerbstoff-Extrakt-Fabrikanten" kürzlich den Beschluß gefaßt hat, daß die zu gebenden Garantien von Extrakten wesentlich einzuschränken sind, und daß auf Grund von Analysen der Deutschen Versuchsanstalt für Lederindustrie bei flüssigen und teigförmigen Extrakten ein Mindergehalt von 3% und bei festen Extrakten ein solcher von 4% nicht zu Reklamationen Veranlassung geben darf, während bei anderen Laboratorien, deren Analysen von dem genannten Verein ebenfalls anerkannt werden, diese Zahlen mit 2, bezw. 3% festgelegt sind. Es soll an dieser Stelle nicht in eine Erörterung darüber eingegangen werden, daß diese Zahlen ziemlich hoch angenommen worden sind; ich möchte aber hervorheben, daß diese verschiedene Bemessung bei denjenigen, welche den wirklichen Sachverhalt nicht kennen, den Glauben erwecken kann, als ob die Analysen der Versuchsanstalt weniger genau seien. Wie mir von seiten eines Vertreters dieses Vereins auf mein Befragen ausdrücklich versichert worden ist, liegt dem Beschlusse in der obigen Form folgende Tatsache zugrunde: Nach den Erfahrungen des genannten Vereins fallen bei den Analysen von Extrakten durch die Versuchsanstalt die Gerbstoffgehalte häufig um ca. 1% niedriger aus, als bei einigen anderen Laboratorien. Diese Differenzen sind, wie ich auch an dieser Stelle hervorheben möchte, darin begründet, daß die Versuchsanstalt großen Wert darauf legt, daß zur Analyse nur vollständig klare Filtrate verwendet werden, damit nicht Stoffe, welche unlöslich sind, und in der Lösung in fein verteilter Form sich vorfinden, als gerbende Substanzen bestimmt werden. Auf diese Weise ergeben sich allerdings Gerbstoffgehalte, welche mitunter niedriger als die anderer Laboratorien sind. Da die Vorschrift besteht, daß die Lösungen vollständig klar sind, so halte ich in solchen Fällen die niedrigeren für diejenigen, welche den Vereinbarungen entsprechen.

Prinzipien der Gasscheidung durch Zentrifugalkraft.

Von G. Bredig und F. Haber.

(Mitgeteilt von F. Haber.)

(Eingeg. d. 8./1. 1904.)

1. Einleitung.

Seit zwei Jahren treten in technischen Zeitschriften Nachrichten über die großen Erfolge auf, welche Herr E. N. Mazza mit einem Apparate erzielt, in welchem er Gase durch Zentrifugalkraft scheidet. Auf die Mängel der bezüglichen Angaben ist wohl im Journal für Gasbeleuchtung und Wasserversorgung alsbald[1]) hingewiesen worden, aber Herr Vittorio Calzavara, der technische Direktor der venetianischen Gas- und Elektrizitätsgesellschaft und Leiter der Zeitschrift „Il Gaz", hat danach dem Kongreß Deutscher Gas- und Wasserfachmänner in Zürich 1903 einen Bericht vorgelegt, welcher die außerordentlichen Erfolge des Apparates nachdrücklich betont. Der Bericht führt das Zeugnis zweier Gelehrten an, welche die Anreicherung des Sauerstoffes in der mit diesem Apparat zentrifugierten Luft festgestellt haben sollen, und bringt Angaben über eine erstaunliche Kohleersparnis, welche in der Praxis mehrerer bedeutenden Fabriken durch Benutzung der zentrifugierten und dadurch an Sauerstoff angereicherten Luft erzielt worden ist. Die italienische Regierung hat den Apparat prüfen lassen, und das deutsche Patentamt hat das gleiche getan. Herr Calzavara berichtet, daß beide Prüfungen zum Vorteil des Mazzaschen Gasscheiders ausgefallen sind: Das italienische Marineministerium hat einen solchen Apparat gekauft, das deutsche Patentamt ein D. R. P. (139210) darauf erteilt[2]). Inzwischen haben die Herren G. Claude und E. Demoussy wissenschaftliche Versuche über den Gegenstand gemacht, deren Ergebnis[3]) durchaus zu Ungunsten der Sache ausgefallen ist. Aber Herr Goffi[4]), der technischer Leiter der italienischen Gasgesellschaft in Turin, tritt demgegenüber mit neuem Nachdruck und

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[1]) März 1902, **9**, 155.

[2]) Das D. R. P. 139210 handelt nicht im speziellen von der Luftscheidung.

[3]) Claude und Demoussy Compt. r. d. Acad. d. sciences vom 27. Juli 1903, 250.

[4]) J. de l'éclairage au gaz 20. Sept. 1903, 290.

Figure D.135: Georg Bredig and Fritz Haber. 1904. Prinzipien der Gasscheidung durch Zentrifugalkraft. *Zeitschrift für Angewandte Chemie* 17:452. First page is shown.

[A research group at Linde Eismaschinen that was led by Helmuth Hausen (German, 1895–1987) and based in the Munich suburb of Höllriegelskreuth presented new work on gas centrifuges at a VDI (Verein Deutscher Ingenieure) German engineering conference in May 1938, which suggests that group began working on gas centrifuges sometime earlier in the 1930s. Although that group expressed concern about limitations on the performance of gas centrifuges in their 1939 journal article (p. 3500), they quickly found solutions to those problems and their work had greatly progressed by their 1942 journal article (p. 3501).]

Helmuth Hausen and R. Schlatterer. 1939. Aussichten der Zerlegung von Gasgemischen durch Zentrifugieren. *Z. VDI Beiheft Verfahrenstechnik* 1939:1:15–21. See p. 3500.

Aussichten der Zerlegung von Gasgemischen durch Zentrifugieren*)

*) Auszugsweise vorgetragen von *H. Hausen* auf der Tagung des Deutschen Kältevereins im VDI in Frankfurt a. M. am 30. Mai 1938.

Auf Grund einer genauen Theorie werden die Aussichten der Gaszerlegung in einer Zentrifuge untersucht. Die erhaltenen Differentialgleichungen werden durch ein Stufenverfahren gelöst. Nach der Rechnung ist nur in besonders günstigen Fällen und bei sehr kleinen Mengen eine befriedigende Zerlegung zu erwarten. [...]

Schon im Jahre 1895 hat *Bredig*³) Wasserstoff und Jodwasserstoff durch Zentrifugieren zu trennen versucht und hierbei in einer Zentrifuge von etwa 42 cm Dmr. bei 2300 U/min nach drei Stunden eine Entmischung um etwa 2,8% beobachtet. Im Jahre 1904 haben *Bredig* und *Haber*⁴) die damals erreichbar scheinende Zerlegungswirkung durch Zentrifugieren theoretisch untersucht und dabei auch den erforderlichen Zeitaufwand abgeschätzt.

³) *G. Bredig*, Z. physik. Chem. A Bd. 17 (1895) S. 459.

⁴) *G. Bredig* u. *F. Haber*, Z. angew. Chem. Bd. 17 (1904) S. 452.

[...]

Prospects for the separation of gas mixtures by centrifugation*)

*) Excerpt presented by *H. Hausen* at the conference of the VDI German Refrigeration Association in Frankfurt a. M. on 30 May 1938.

The prospects of gas separation in a centrifuge are investigated on the basis of a precise theory. The differential equations obtained are solved using a step-by-step method. According to the calculation, a satisfactory separation can only be expected in particularly favorable cases and with very small quantities. [...]

As early as 1895, *Bredig*³) tried to separate hydrogen and hydrogen iodide by centrifugation and observed a separation of about 2.8% after three hours in a centrifuge of about 42 cm diameter at 2300 rpm. In 1904, *Bredig* and *Haber*⁴) theoretically investigated the seemingly achievable separation effect by centrifugation and also estimated the time required.

³) *G. Bredig*, Z. physik. Chem. A vol. 17 (1895) p. 459.

⁴) *G. Bredig* and *F. Haber*, Z. angew. Chem. vol. 17 (1904) p. 452.

[...]

Ergebnis

Die entwickelte Theorie bestätigt im wesentlichen die Richtigkeit der Berechnungen von *Bredig* und *Haber*4), wonach sich in einer Zentrifuge im allgemeinen nur mäßige Anreicherungen erzielen lassen, stets aber nur sehr geringe Gasmengen in der Zeiteinheit zerlegt werden können. Nur in Fällen, wie bei CO_2-H_2- oder Benzol-Luft-Gemischen, in denen der Molekulargewichtsunterschied der Bestandteile groß ist, kann man eine weitergehende Zerlegung erwarten. Bei der höchsten heute erreichten Umfangsgeschwindigkeit von fast 600 m/s läßt sich z. B. Benzol in Luft auf etwa 16% anreichern, wenn der Anfangsgehalt 1% beträgt. Bei weiterer Steigerung der Umfangsgeschwindigkeit würde sich dieser Wert sehr rasch erhöhen, so daß man oberhalb 1000 m/s praktisch reines Benzol gewinnen könnte. Hingegen erscheint selbst bei dieser hohen Umfangsgeschwindigkeit eine Zerlegung von O_2-N_2-Gemischen als praktisch aussichtslos.

Die Hauptschwierigkeit besteht aber darin, daß sich in einer Zentrifuge nur sehr geringe Mengen verarbeiten lassen. Nach der entwickelten Theorie kann durch eine Zentrifuge von 1 m axialer Länge stündliche nur etwa 1 m^3 des Gemisches hindurchströmen, wenn nicht die Anreicherung erheblich zurückgehen soll.

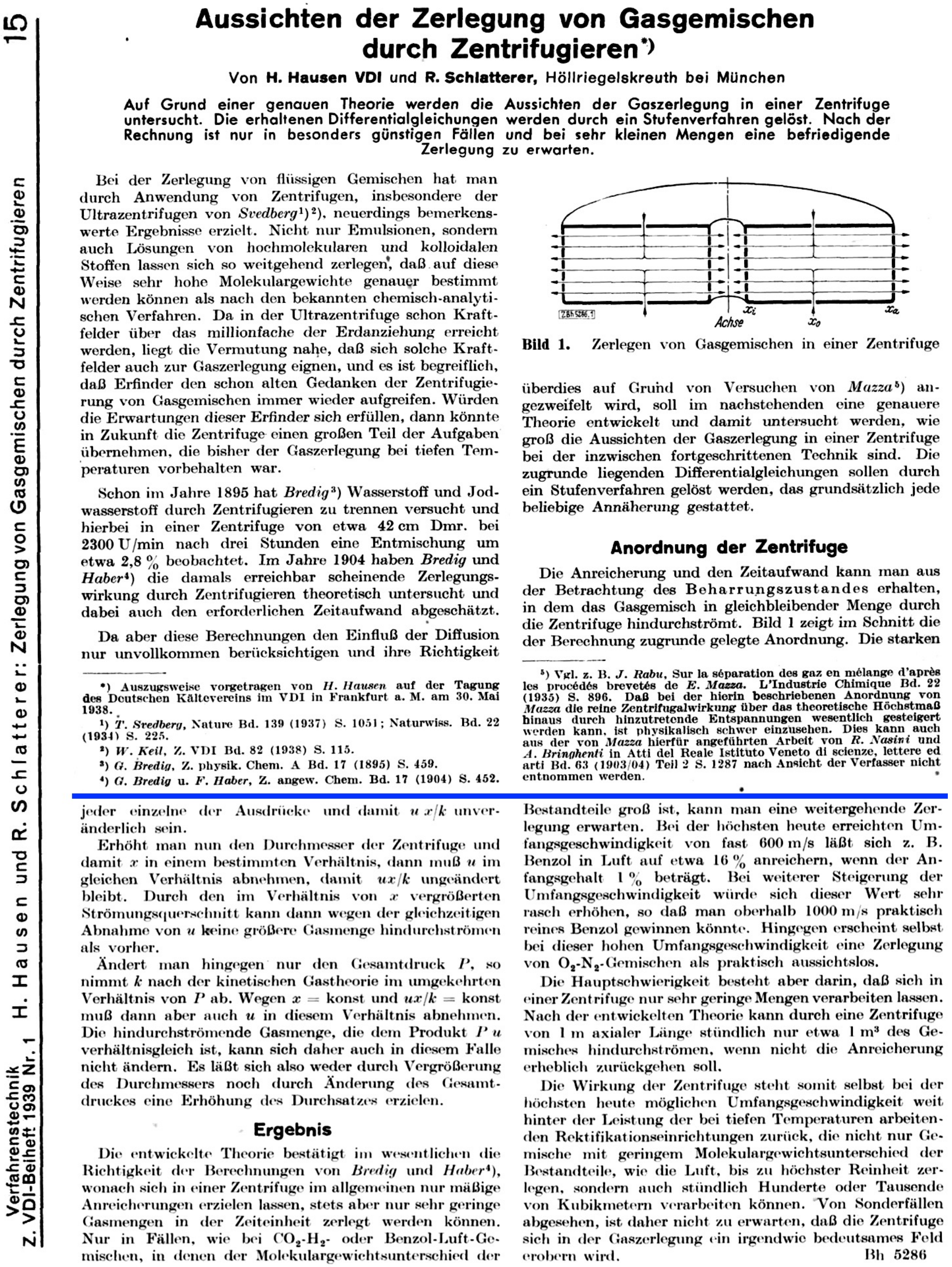
Die Wirkung der Zentrifuge steht somit selbst bei der höchsten heute möglichen Umfangsgeschwindigkeit weit hinter der Leistung der bei tiefen Temperaturen arbeitenden Rektifikationseinrichtungen zurück, die nicht nur Gemische mit geringem Molekulargewichtsunterschied der Bestandteile, wie die Luft, bis zu höchster Reinheit zerlegen, sondern auch stündlich Hunderte oder Tausende von Kubikmetern verarbeiten können. Von Sonderfällen abgesehen, ist daher nicht zu erwarten, daß die Zentrifuge sich in der Gaszerlegung ein irgendwie bedeutsames Feld erobern wird.

Result

The theory developed essentially confirms the correctness of the calculations of *Bredig* and *Haber*4), according to which only moderate enrichments can generally be achieved in a centrifuge, but only very small quantities of gas can always be separated in the time unit. Only in cases such as CO_2-H_2 or benzene-air mixtures, in which the molecular weight difference of the components is large, can further separation be expected. At the highest peripheral speed of almost 600 m/s achieved today, benzene in air, for example, can be enriched to around 16% if the initial content is 1%. If the circumferential speed is increased further, this value would increase very quickly, so that above 1000 m/s practically pure benzene could be obtained. On the other hand, even at this high peripheral speed, the separation of O_2-N_2 mixtures appears to be practically hopeless.

The main difficulty, however, is that only very small quantities can be processed in a centrifuge. According to the theory developed, only about 1 m^3 per hour of the mixture can flow through a centrifuge with an axial length of 1 m if the enrichment is not to be considerably reduced.

Even at the highest peripheral speed possible today, the effect of the centrifuge is therefore far behind the performance of rectification equipment operating at low temperatures, which can not only break down mixtures with a small difference in molecular weight of the components, such as air, to the highest purity, but can also process hundreds or thousands of cubic meters per hour. Apart from special cases, it is therefore unlikely that the centrifuge will conquer any significant field in gas separation.



Aussichten der Zerlegung von Gasgemischen durch Zentrifugieren*)

Von **H. Hausen VDI** und **R. Schlatterer**, Höllriegelskreuth bei München

Auf Grund einer genauen Theorie werden die Aussichten der Gaszerlegung in einer Zentrifuge untersucht. Die erhaltenen Differentialgleichungen werden durch ein Stufenverfahren gelöst. Nach der Rechnung ist nur in besonders günstigen Fällen und bei sehr kleinen Mengen eine befriedigende Zerlegung zu erwarten.

Bei der Zerlegung von flüssigen Gemischen hat man durch Anwendung von Zentrifugen, insbesondere der Ultrazentrifugen von *Svedberg*1)2), neuerdings bemerkenswerte Ergebnisse erzielt. Nicht nur Emulsionen, sondern auch Lösungen von hochmolekularen und kolloidalen Stoffen lassen sich so weitgehend zerlegen, daß auf diese Weise sehr hohe Molekulargewichte genauer bestimmt werden können als nach den bekannten chemisch-analytischen Verfahren. Da in der Ultrazentrifuge schon Kraftfelder über das millionfache der Erdanziehung erreicht werden, liegt die Vermutung nahe, daß sich solche Kraftfelder auch zur Gaszerlegung eignen, und es ist begreiflich, daß Erfinder den schon alten Gedanken der Zentrifugierung von Gasgemischen immer wieder aufgreifen. Würden die Erwartungen dieser Erfinder sich erfüllen, dann könnte in Zukunft die Zentrifuge einen großen Teil der Aufgaben übernehmen, die bisher der Gaszerlegung bei tiefen Temperaturen vorbehalten war.

Schon im Jahre 1895 hat *Bredig*3) Wasserstoff und Jodwasserstoff durch Zentrifugieren zu trennen versucht und hierbei in einer Zentrifuge von etwa 42 cm Dmr. bei 2300 U/min nach drei Stunden eine Entmischung um etwa 2,8 % beobachtet. Im Jahre 1904 haben *Bredig* und *Haber*4) die damals erreichbar scheinende Zerlegungswirkung durch Zentrifugieren theoretisch untersucht und dabei auch den erforderlichen Zeitaufwand abgeschätzt.

Da aber diese Berechnungen den Einfluß der Diffusion nur unvollkommen berücksichtigen und ihre Richtigkeit überdies auf Grund von Versuchen von *Mazza*5) angezweifelt wird, soll im nachstehenden eine genauere Theorie entwickelt und damit untersucht werden, wie groß die Aussichten der Gaszerlegung in einer Zentrifuge bei der inzwischen fortgeschrittenen Technik sind. Die zugrunde liegenden Differentialgleichungen sollen durch ein Stufenverfahren gelöst werden, das grundsätzlich jede beliebige Annäherung gestattet.

Bild 1. Zerlegen von Gasgemischen in einer Zentrifuge

Anordnung der Zentrifuge

Die Anreicherung und den Zeitaufwand kann man aus der Betrachtung des Beharrungszustandes erhalten, in dem das Gasgemisch in gleichbleibender Menge durch die Zentrifuge hindurchströmt. Bild 1 zeigt im Schnitt die der Berechnung zugrunde gelegte Anordnung. Die starken

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*) Auszugsweise vorgetragen von *H. Hausen* auf der Tagung des Deutschen Kältevereins im VDI in Frankfurt a. M. am 30. Mai 1938.

1) *T. Svedberg*, Nature Bd. 139 (1937) S. 1051; Naturwiss. Bd. 22 (1934) S. 225.

2) *W. Keil*, Z. VDI Bd. 82 (1938) S. 115.

3) *G. Bredig*, Z. physik. Chem. A Bd. 17 (1895) S. 459.

4) *G. Bredig* u. *F. Haber*, Z. angew. Chem. Bd. 17 (1904) S. 452.

5) Vgl. z. B. *J. Rabu*, Sur la séparation des gaz en mélange d'après les procédés brevetés de *E. Mazza*. L'Industrie Chimique Bd. 22 (1935) S. 896. Daß bei der hierin beschriebenen Anordnung von *Mazza* die reine Zentrifugalwirkung über das theoretische Höchstmaß hinaus durch hinzutretende Entspannungen wesentlich gesteigert werden kann, ist physikalisch schwer einzusehen. Dies kann auch aus der von *Mazza* hierfür angeführten Arbeit von *R. Nasini* und *A. Bringhenti* in Atti del Reale Istituto Veneto di scienze, lettere ed arti Bd. 63 (1903/04) Teil 2 S. 1287 nach Ansicht der Verfasser nicht entnommen werden.

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jeder einzelne der Ausdrücke und damit $u\,x/k$ unveränderlich sein.

Erhöht man nun den Durchmesser der Zentrifuge und damit x in einem bestimmten Verhältnis, dann muß u im gleichen Verhältnis abnehmen, damit ux/k ungeändert bleibt. Durch den im Verhältnis von x vergrößerten Strömungsquerschnitt kann dann wegen der gleichzeitigen Abnahme von u keine größere Gasmenge hindurchströmen als vorher.

Ändert man hingegen nur den Gesamtdruck P, so nimmt k nach der kinetischen Gastheorie im umgekehrten Verhältnis von P ab. Wegen $x =$ konst und $ux/k =$ konst muß dann aber auch u in diesem Verhältnis abnehmen. Die hindurchströmende Gasmenge, die dem Produkt $P\,u$ verhältnisgleich ist, kann sich daher auch in diesem Falle nicht ändern. Es läßt sich also weder durch Vergrößerung des Durchmessers noch durch Änderung des Gesamtdruckes eine Erhöhung des Durchsatzes erzielen.

Ergebnis

Die entwickelte Theorie bestätigt im wesentlichen die Richtigkeit der Berechnungen von *Bredig* und *Haber*4), wonach sich in einer Zentrifuge im allgemeinen nur mäßige Anreicherungen erzielen lassen, stets aber nur sehr geringe Gasmengen in der Zeiteinheit zerlegt werden können. Nur in Fällen, wie bei CO_2-H_2- oder Benzol-Luft-Gemischen, in denen der Molekulargewichtsunterschied der Bestandteile groß ist, kann man eine weitergehende Zerlegung erwarten. Bei der höchsten heute erreichten Umfangsgeschwindigkeit von fast 600 m/s läßt sich z. B. Benzol in Luft auf etwa 16 % anreichern, wenn der Anfangsgehalt 1 % beträgt. Bei weiterer Steigerung der Umfangsgeschwindigkeit würde sich dieser Wert sehr rasch erhöhen, so daß man oberhalb 1000 m/s praktisch reines Benzol gewinnen könnte. Hingegen erscheint selbst bei dieser hohen Umfangsgeschwindigkeit eine Zerlegung von O_2-N_2-Gemischen als praktisch aussichtslos.

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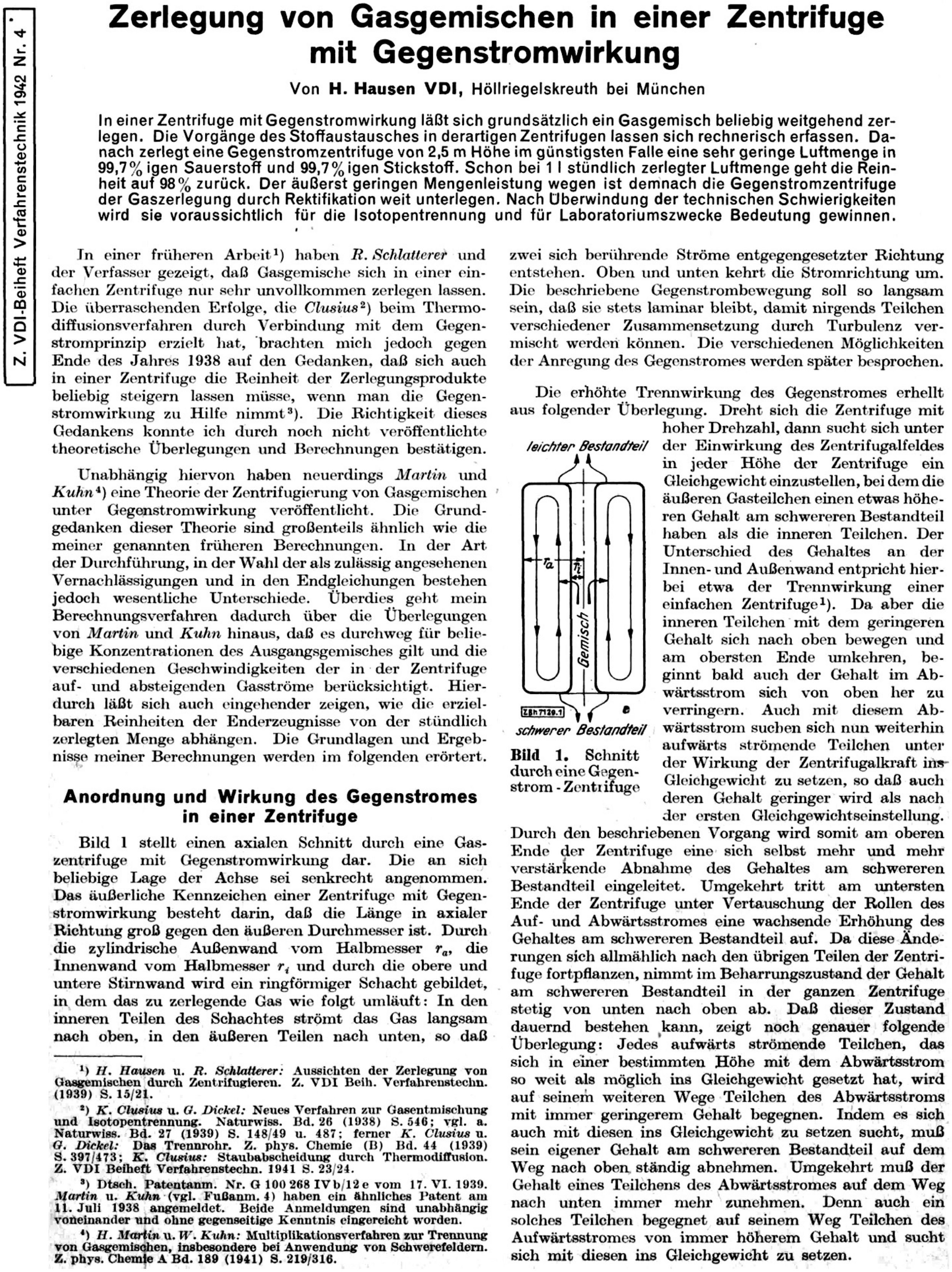
Die Wirkung der Zentrifuge steht somit selbst bei der höchsten heute möglichen Umfangsgeschwindigkeit weit hinter der Leistung der bei tiefen Temperaturen arbeitenden Rektifikationseinrichtungen zurück, die nicht nur Gemische mit geringem Molekulargewichtsunterschied der Bestandteile, wie die Luft, bis zu höchster Reinheit zerlegen, sondern auch stündlich Hunderte oder Tausende von Kubikmetern verarbeiten können. Von Sonderfällen abgesehen, ist daher nicht zu erwarten, daß die Zentrifuge sich in der Gaszerlegung ein irgendwie bedeutsames Feld erobern wird. Bh 5286

Figure D.136: Helmuth Hausen and R. Schlatterer. 1939. Aussichten der Zerlegung von Gasgemischen durch Zentrifugieren. *Z. VDI Beiheft Verfahrenstechnik* 1939:1:15–21. Excerpts from the beginning and end of the paper.



Z. VDI-Beiheft Verfahrenstechnik 1942 Nr. 4

Zerlegung von Gasgemischen in einer Zentrifuge mit Gegenstromwirkung

Von **H. Hausen VDI**, Höllriegelskreuth bei München

In einer Zentrifuge mit Gegenstromwirkung läßt sich grundsätzlich ein Gasgemisch beliebig weitgehend zerlegen. Die Vorgänge des Stoffaustausches in derartigen Zentrifugen lassen sich rechnerisch erfassen. Danach zerlegt eine Gegenstromzentrifuge von 2,5 m Höhe im günstigsten Falle eine sehr geringe Luftmenge in 99,7%igen Sauerstoff und 99,7%igen Stickstoff. Schon bei 1 l stündlich zerlegter Luftmenge geht die Reinheit auf 98% zurück. Der äußerst geringen Mengenleistung wegen ist demnach die Gegenstromzentrifuge der Gaszerlegung durch Rektifikation weit unterlegen. Nach Überwindung der technischen Schwierigkeiten wird sie voraussichtlich für die Isotopentrennung und für Laboratoriumszwecke Bedeutung gewinnen.

In einer früheren Arbeit[1]) haben *R. Schlatterer* und der Verfasser gezeigt, daß Gasgemische sich in einer einfachen Zentrifuge nur sehr unvollkommen zerlegen lassen. Die überraschenden Erfolge, die *Clusius*[2]) beim Thermodiffusionsverfahren durch Verbindung mit dem Gegenstromprinzip erzielt hat, brachten mich jedoch gegen Ende des Jahres 1938 auf den Gedanken, daß sich auch in einer Zentrifuge die Reinheit der Zerlegungsprodukte beliebig steigern lassen müsse, wenn man die Gegenstromwirkung zu Hilfe nimmt[3]). Die Richtigkeit dieses Gedankens konnte ich durch noch nicht veröffentlichte theoretische Überlegungen und Berechnungen bestätigen.

Unabhängig hiervon haben neuerdings *Martin* und *Kuhn*[4]) eine Theorie der Zentrifugierung von Gasgemischen unter Gegenstromwirkung veröffentlicht. Die Grundgedanken dieser Theorie sind großenteils ähnlich wie die meiner genannten früheren Berechnungen. In der Art der Durchführung, in der Wahl der als zulässig angesehenen Vernachlässigungen und in den Endgleichungen bestehen jedoch wesentliche Unterschiede. Überdies geht mein Berechnungsverfahren dadurch über die Überlegungen von *Martin* und *Kuhn* hinaus, daß es durchweg für beliebige Konzentrationen des Ausgangsgemisches gilt und die verschiedenen Geschwindigkeiten der in der Zentrifuge auf- und absteigenden Gasströme berücksichtigt. Hierdurch läßt sich auch eingehender zeigen, wie die erzielbaren Reinheiten der Enderzeugnisse von der stündlich zerlegten Menge abhängen. Die Grundlagen und Ergebnisse meiner Berechnungen werden im folgenden erörtert.

Anordnung und Wirkung des Gegenstromes in einer Zentrifuge

Bild 1 stellt einen axialen Schnitt durch eine Gaszentrifuge mit Gegenstromwirkung dar. Die an sich beliebige Lage der Achse sei senkrecht angenommen. Das äußerliche Kennzeichen einer Zentrifuge mit Gegenstromwirkung besteht darin, daß die Länge in axialer Richtung groß gegen den äußeren Durchmesser ist. Durch die zylindrische Außenwand vom Halbmesser r_a, die Innenwand vom Halbmesser r_i und durch die obere und untere Stirnwand wird ein ringförmiger Schacht gebildet, in dem das zu zerlegende Gas wie folgt umläuft: In den inneren Teilen des Schachtes strömt das Gas langsam nach oben, in den äußeren Teilen nach unten, so daß zwei sich berührende Ströme entgegengesetzter Richtung entstehen. Oben und unten kehrt die Stromrichtung um. Die beschriebene Gegenstrombewegung soll so langsam sein, daß sie stets laminar bleibt, damit nirgends Teilchen verschiedener Zusammensetzung durch Turbulenz vermischt werden können. Die verschiedenen Möglichkeiten der Anregung des Gegenstromes werden später besprochen.

Bild 1. Schnitt durch eine Gegenstrom-Zentrifuge

Die erhöhte Trennwirkung des Gegenstromes erhellt aus folgender Überlegung. Dreht sich die Zentrifuge mit hoher Drehzahl, dann sucht sich unter der Einwirkung des Zentrifugalfeldes in jeder Höhe der Zentrifuge ein Gleichgewicht einzustellen, bei dem die äußeren Gasteilchen einen etwas höheren Gehalt am schwereren Bestandteil haben als die inneren Teilchen. Der Unterschied des Gehaltes an der Innen- und Außenwand entpricht hierbei etwa der Trennwirkung einer einfachen Zentrifuge[1]). Da aber die inneren Teilchen mit dem geringeren Gehalt sich nach oben bewegen und am obersten Ende umkehren, beginnt bald auch der Gehalt im Abwärtsstrom sich von oben her zu verringern. Auch mit diesem Abwärtsstrom suchen sich nun weiterhin aufwärts strömende Teilchen unter der Wirkung der Zentrifugalkraft ins Gleichgewicht zu setzen, so daß auch deren Gehalt geringer wird als nach der ersten Gleichgewichtseinstellung. Durch den beschriebenen Vorgang wird somit am oberen Ende der Zentrifuge eine sich selbst mehr und mehr verstärkende Abnahme des Gehaltes am schwereren Bestandteil eingeleitet. Umgekehrt tritt am untersten Ende der Zentrifuge unter Vertauschung der Rollen des Auf- und Abwärtsstromes eine wachsende Erhöhung des Gehaltes am schwereren Bestandteil auf. Da diese Änderungen sich allmählich nach den übrigen Teilen der Zentrifuge fortpflanzen, nimmt im Beharrungszustand der Gehalt am schwereren Bestandteil in der ganzen Zentrifuge stetig von unten nach oben ab. Daß dieser Zustand dauernd bestehen kann, zeigt noch genauer folgende Überlegung: Jedes aufwärts strömende Teilchen, das sich in einer bestimmten Höhe mit dem Abwärtsstrom so weit als möglich ins Gleichgewicht gesetzt hat, wird auf seinem weiteren Wege Teilchen des Abwärtsstroms mit immer geringerem Gehalt begegnen. Indem es sich auch mit diesen ins Gleichgewicht zu setzen sucht, muß sein eigener Gehalt am schwereren Bestandteil auf dem Weg nach oben ständig abnehmen. Umgekehrt muß der Gehalt eines Teilchens des Abwärtsstromes auf dem Weg nach unten immer mehr zunehmen. Denn auch ein solches Teilchen begegnet auf seinem Weg Teilchen des Aufwärtsstromes von immer höherem Gehalt und sucht sich mit diesen ins Gleichgewicht zu setzen.

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[1]) *H. Hausen* u. *R. Schlatterer:* Aussichten der Zerlegung von Gasgemischen durch Zentrifugieren. Z. VDI Beih. Verfahrenstechn. (1939) S. 15/21.

[2]) *K. Clusius* u. *G. Dickel:* Neues Verfahren zur Gasentmischung und Isotopentrennung. Naturwiss. Bd. 26 (1938) S. 546; vgl. a. Naturwiss. Bd. 27 (1939) S. 148/49 u. 487; ferner *K. Clusius* u. *G. Dickel:* Das Trennrohr. Z. phys. Chemie (B) Bd. 44 (1939) S. 397/473; *K. Clusius:* Staubabscheidung durch Thermodiffusion. Z. VDI Beiheft Verfahrenstechn. 1941 S. 23/24.

[3]) Dtsch. Patentanm. Nr. G 100 268 IV b/12 e vom 17. VI. 1939. *Martin* u. *Kuhn* (vgl. Fußanm. 4) haben ein ähnliches Patent am 11. Juli 1938 angemeldet. Beide Anmeldungen sind unabhängig voneinander und ohne gegenseitige Kenntnis eingereicht worden.

[4]) *H. Martin* u. *W. Kuhn:* Multiplikationsverfahren zur Trennung von Gasgemischen, insbesondere bei Anwendung von Schwerefeldern. Z. phys. Chemie A Bd. 189 (1941) S. 219/316.

Figure D.137: Helmuth Hausen. 1942. Zerlegung von Gasgemischen in einer Zentrifuge mit Gegenstromwirkung. *Z. VDI Beiheft Verfahrenstechnik* 1942:4:93–102. First page is shown.

Helmuth Hausen. 1942. Zerlegung von Gasgemischen in einer Zentrifuge mit Gegenstromwirkung. *Z. VDI Beiheft Verfahrenstechnik* 1942:4:93–102. See p. 3501.

Zerlegung von Gasgemischen in einer Zentrifuge mit Gegenstromwirkung

In einer Zentrifuge mit Gegenstromwirkung läßt sich grundsätzlich ein Gasgemisch beliebig weitgehend zerlegen. Die Vorgänge des Stoffaustausches in derartigen Zentrifugen lassen sich rechnerisch erfassen. Danach zerlegt eine Gegenstromzentrifuge von 2,5 m Höhe im günstigsten Falle eine sehr geringe Luftmenge in 99,7% igen Sauerstoff und 99,7% igen Stickstoff. Schon bei 1 l stündlich zerlegter Luftmenge geht die Reinheit auf 98% zurück. Der äußerst geringen Mengenleistung wegen ist demnach die Gegenstromzentrifuge der Gaszerlegung durch Rektifikation weit unterlegen. Nach Überwindung der technischen Schwierigkeiten wird sie voraussichtlich für die Isotopentrennung und für Laboratoriumszwecke Bedeutung gewinnen.

In einer früheren Arbeit[1]) haben *R. Schlatterer* und der Verfasser gezeigt, daß Gasgemische sich in einer einfachen Zentrifuge nur sehr unvollkommen zerlegen lassen. Die überraschenden Erfolge, die *Clusius*[2]) beim Thermodiffusionsverfahren durch Verbindung mit dem Gegenstromprinzip erzielt hat, brachten mich jedoch gegen Ende des Jahres 1938 auf den Gedanken, daß sich auch in einer Zentrifuge die Reinheit der Zerlegungsprodukte beliebig steigern lassen müsse, wenn man die Gegenstromwirkung zu Hilfe nimmt[3]). Die Richtigkeit dieses Gedankens konnte ich durch noch nicht veröffentlichte theoretische Überlegungen und Berechnungen bestätigen.

Separation of gas mixtures in a centrifuge with countercurrent action

In principle, a gas mixture can be separated to any extent in a countercurrent centrifuge. The processes of mass transfer in such centrifuges can be calculated. According to this, a countercurrent centrifuge with a height of 2.5 m separates a very small amount of air into 99.7% oxygen and 99.7% nitrogen in the best case. The purity drops to 98% with just 1 liter of air separated per hour. The countercurrent centrifuge is therefore far inferior to gas separation by rectification due to its extremely low output. Once the technical difficulties have been overcome, it will probably gain importance for isotope separation and for laboratory purposes.

In an earlier work[1]) *R. Schlatterer* and the author showed that gas mixtures can only be very imperfectly separated in a simple centrifuge. However, the surprising successes achieved by *Clusius*[2]) in the thermodiffusion process in combination with the countercurrent principle gave me the idea towards the end of 1938 that the purity of the separation products in a centrifuge should also be able to be increased at will if the countercurrent effect is used[3]). I was able to confirm the correctness of this idea through theoretical considerations and calculations that had not yet been published.

Unabhängig hiervon haben neuerdings *Martin* und *Kuhn*4)) eine Theorie der Zentrifugierung von Gasgemischen unter Gegenstromwirkung veröffentlicht. Die Grundgedanken dieser Theorie sind großenteils ähnlich wie die meiner genannten früheren Berechnungen. In der Art der Durchführung, in der Wahl der als zulässig angesehenen Vernachlässigungen und in den Endgleichungen bestehen jedoch wesentliche Unterschiede. Überdies geht mein Berechnungsverfahren dadurch über die Überlegungen von *Martin* und *Kuhn* hinaus, daß es durchweg für beliebige Konzentrationen des Ausgangsgemisches gilt und die verschiedenen Geschwindigkeiten der in der Zentrifuge auf- und absteigenden Gasströme berücksichtigt. Hierdurch läßt sich auch eingehender zeigen, wie die erzielbaren Reinheiten der Enderzeugnisse von der stündlich zerlegten Menge abhängen. Die Grundlagen und Ergebnisse meiner Berechnungen werden im folgenden erörtert.

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1) *H. Hausen* u. *R. Schlatterer*: Aussichten der Zerlegung von Gasgemischen durch Zentrifugieren. Z. VDI Beih. Verfahrenstechn. (1939) S. 15/21.

2) *K. Clusius* u. *G. Dickel*: [...]

3) Dtsch. Patentanm. [S. 3505–3507...]. *Martin* u. *Kuhn* [S. 3521–3524...]. Beide Anmeldungen sind unabhängig voneinander und ohne gegenseitige Kenntnis eingereicht worden.

4) *H. Martin* u. *W. Kuhn*: Multiplikationsverfahren zur Trennung von Gasgemischen, insbesondere bei Anwendung von Schwerefeldern. Z. phys. Chemie A Bd. 189 (1941) S. 219/316.

Independently of this, *Martin* and *Kuhn*4) have recently published a theory of the centrifugation of gas mixtures under countercurrent action. The basic ideas of this theory are largely similar to those of my earlier calculations. However, there are significant differences in the way the calculations are carried out, in the choice of neglect considered permissible and in the final equations. In addition, my calculation method goes beyond the considerations of *Martin* and *Kuhn* in that it is valid for any concentration of the initial mixture and takes into account the different velocities of the gas flows ascending and descending in the centrifuge. This also makes it possible to show in more detail how the achievable purities of the end products depend on the quantity separated per hour. The principles and results of my calculations are discussed below.

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1) *H. Hausen* and *R. Schlatterer*: Aussichten der Zerlegung von Gasgemischen durch Zentrifugieren. Z. VDI Beih. Verfahrenstechn. (1939) pp. 15–21.

2) *K. Clusius* and *G. Dickel*: [...]

3) German patent application [pp. 3505–3507...]. *Martin* u. *Kuhn* [pp. 3521–3524...]. Both applications were filed independently of each other and without mutual knowledge.

4) *H. Martin* and *W. Kuhn*: Multiplikationsverfahren zur Trennung von Gasgemischen, insbesondere bei Anwendung von Schwerefeldern. Z. phys. Chemie A vol. 189 (1941) pp. 219–316.

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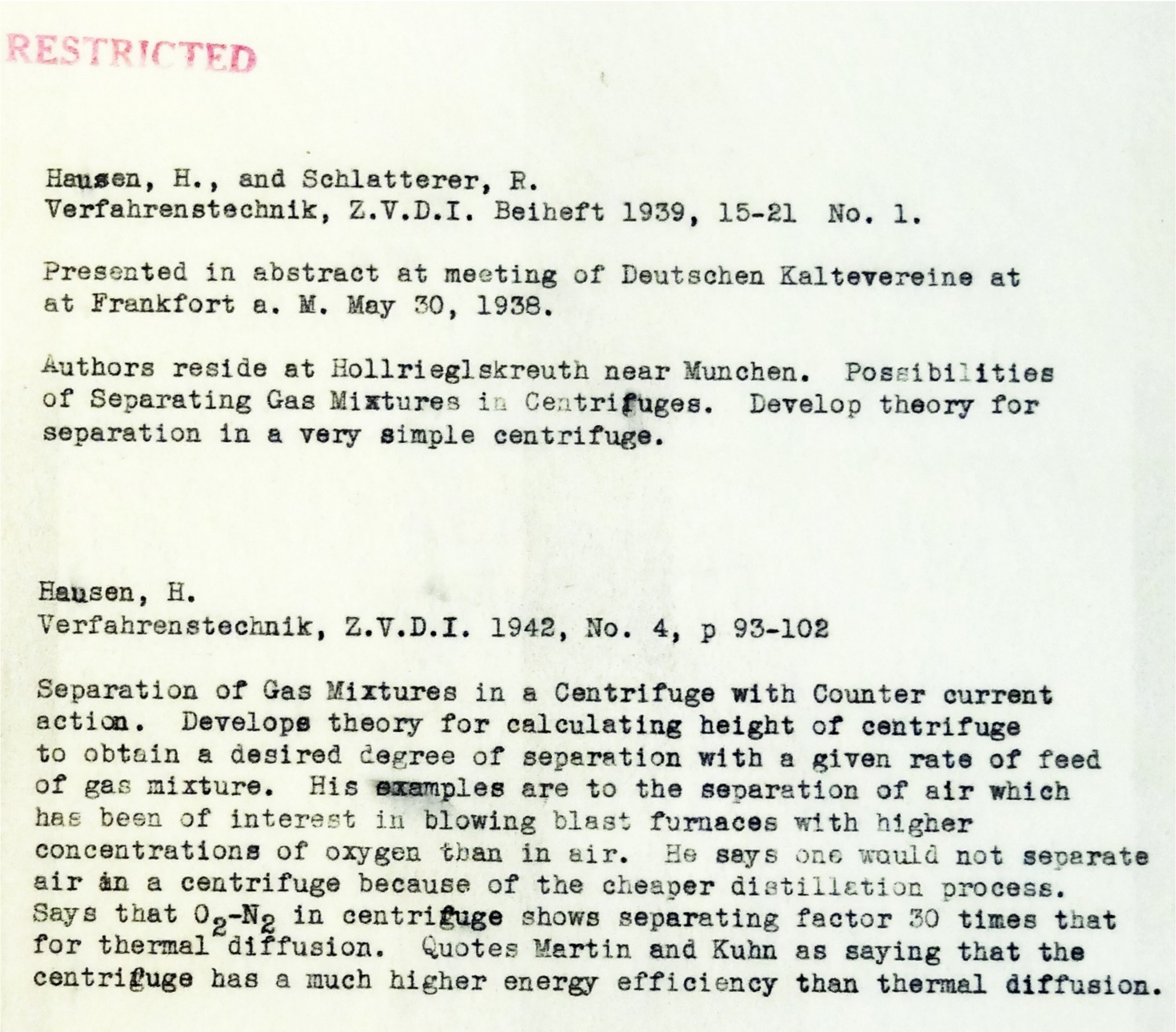
NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)



RESTRICTED

Hausen, H., and Schlatterer, R.
Verfahrenstechnik, Z.V.D.I. Beiheft 1939, 15-21 No. 1.

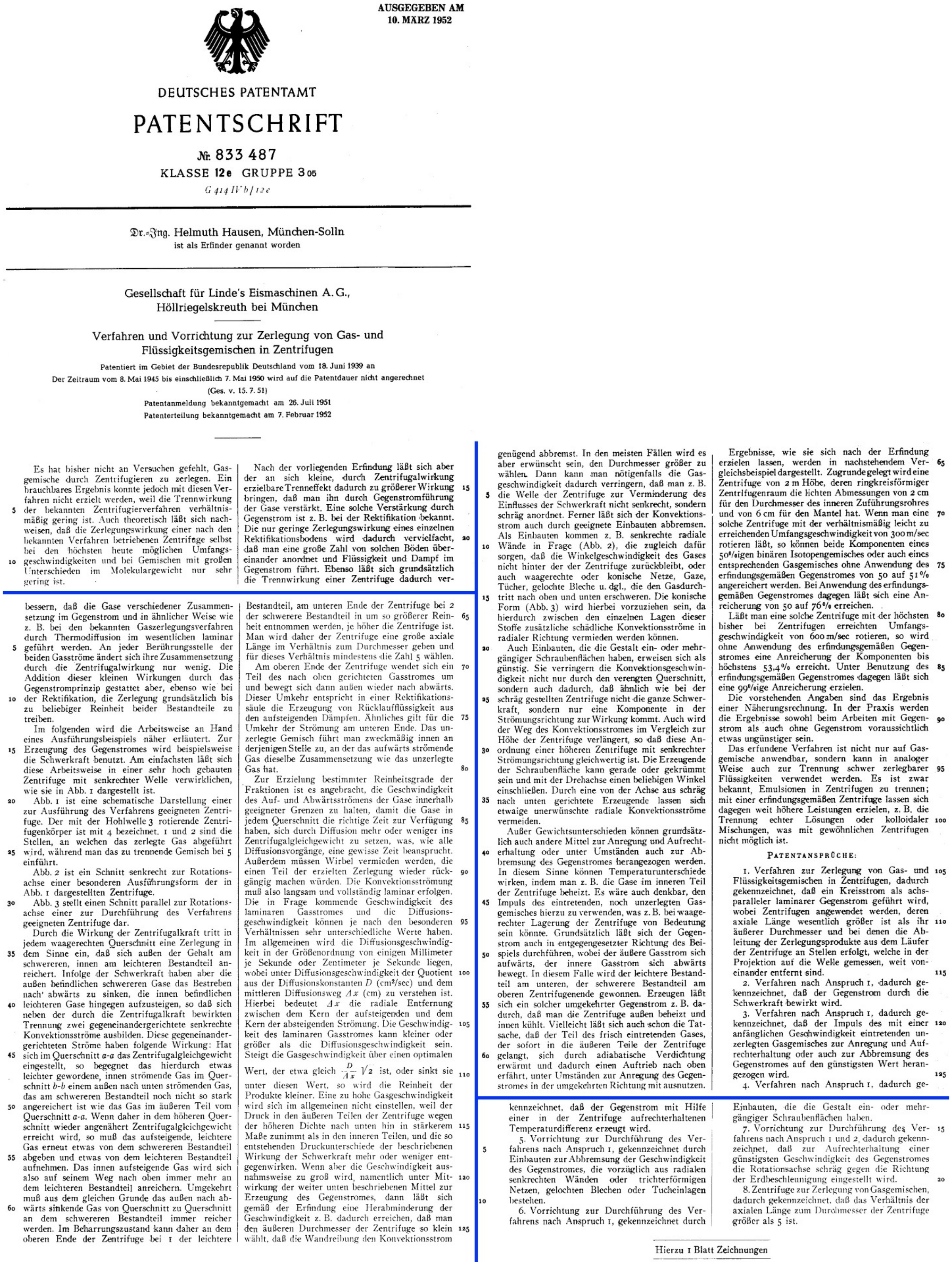
Presented in abstract at meeting of Deutschen Kaltevereine at at Frankfort a. M. May 30, 1938.

Authors reside at Hollrieglskreuth near Munchen. Possibilities of Separating Gas Mixtures in Centrifuges. Develop theory for separation in a very simple centrifuge.

Hausen, H.
Verfahrenstechnik, Z.V.D.I. 1942, No. 4, p 93-102

Separation of Gas Mixtures in a Centrifuge with Counter current action. Develops theory for calculating height of centrifuge to obtain a desired degree of separation with a given rate of feed of gas mixture. His examples are to the separation of air which has been of interest in blowing blast furnaces with higher concentrations of oxygen than in air. He says one would not separate air in a centrifuge because of the cheaper distillation process. Says that O_2-N_2 in centrifuge shows separating factor 30 times that for thermal diffusion. Quotes Martin and Kuhn as saying that the centrifuge has a much higher energy efficiency than thermal diffusion.

Figure D.138: Leslie Groves's office at the U.S. Manhattan Project followed the German work on gas centrifuges [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].



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10. MÄRZ 1952

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 833 487

KLASSE 12e GRUPPE 3 05

G 414 IVb / 12e

Dr.-Ing. Helmuth Hausen, München-Solln
ist als Erfinder genannt worden

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Höllriegelskreuth bei München

Verfahren und Vorrichtung zur Zerlegung von Gas- und Flüssigkeitsgemischen in Zentrifugen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 18. Juni 1939 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
(Ges. v. 15. 7. 51)
Patentanmeldung bekanntgemacht am 26. Juli 1951
Patenterteilung bekanntgemacht am 7. Februar 1952

Es hat bisher nicht an Versuchen gefehlt, Gasgemische durch Zentrifugieren zu zerlegen. Ein brauchbares Ergebnis konnte jedoch mit diesen Verfahren nicht erzielt werden, weil die Trennwirkung der bekannten Zentrifugierverfahren verhältnismäßig gering ist. Auch theoretisch läßt sich nachweisen, daß die Zerlegungswirkung einer nach den bekannten Verfahren betriebenen Zentrifuge selbst bei den höchsten heute möglichen Umfangsgeschwindigkeiten und bei Gemischen mit großen Unterschieden im Molekulargewicht nur sehr gering ist.

Nach der vorliegenden Erfindung läßt sich aber der an sich kleine, durch Zentrifugalwirkung erzielbare Trenneffekt dadurch zu größerer Wirkung bringen, daß man ihn durch Gegenstromführung der Gase verstärkt. Eine solche Verstärkung durch Gegenstrom ist z. B. bei der Rektifikation bekannt. Die nur geringe Zerlegungswirkung eines einzelnen Rektifikationsbodens wird dadurch vervielfacht, daß man eine große Zahl von solchen Böden übereinander anordnet und Flüssigkeit und Dampf im Gegenstrom führt. Ebenso läßt sich grundsätzlich die Trennwirkung einer Zentrifuge dadurch verbessern, daß die Gase verschiedener Zusammensetzung im Gegenstrom und in ähnlicher Weise wie z. B. bei den bekannten Gaszerlegungsverfahren durch Thermodiffusion im wesentlichen laminar geführt werden. An jeder Berührungsstelle der beiden Gasströme ändert sich ihre Zusammensetzung durch die Zentrifugalwirkung nur wenig. Die Addition dieser kleinen Wirkungen durch das Gegenstromprinzip gestattet aber, ebenso wie bei der Rektifikation, die Zerlegung grundsätzlich bis zu beliebiger Reinheit beider Bestandteile zu treiben.

Im folgenden wird die Arbeitsweise an Hand eines Ausführungsbeispiels näher erläutert. Zur Erzeugung des Gegenstromes wird beispielsweise die Schwerkraft benutzt. Am einfachsten läßt sich diese Arbeitsweise in einer sehr hoch gebauten Zentrifuge mit senkrechter Welle verwirklichen, wie sie in Abb. 1 dargestellt ist.

Abb. 1 ist eine schematische Darstellung einer zur Ausführung des Verfahrens geeigneten Zentrifuge. Der mit der Hohlwelle 3 rotierende Zentrifugenkörper ist mit 4 bezeichnet. 1 und 2 sind die Stellen, an welchen das zerlegte Gas abgeführt wird, während man das zu trennende Gemisch bei 5 einführt.

Abb. 2 ist ein Schnitt senkrecht zur Rotationsachse einer besonderen Ausführungsform der in Abb. 1 dargestellten Zentrifuge.

Abb. 3 stellt einen Schnitt parallel zur Rotationsachse einer zur Durchführung des Verfahrens geeigneten Zentrifuge dar.

Durch die Wirkung der Zentrifugalkraft tritt in jedem waagerechten Querschnitt eine Zerlegung in dem Sinne ein, daß sich außen der Gehalt am schwereren, innen am leichteren Bestandteil anreichert. Infolge der Schwerkraft haben aber die außen befindlichen schwereren Gase das Bestreben nach abwärts zu sinken, die innen befindlichen leichteren Gase hingegen aufzusteigen, so daß sich neben der durch die Zentrifugalkraft bewirkten Trennung zwei gegeneinandergerichtete senkrechte Konvektionsströme ausbilden. Diese gegeneinandergerichteten Ströme haben folgende Wirkung: Hat sich im Querschnitt *a-a* das Zentrifugalgleichgewicht eingestellt, so begegnet das hierdurch etwas leichter gewordene, innen strömende Gas im Querschnitt *b-b* einem außen nach unten strömenden Gas, das am schwereren Bestandteil noch nicht so stark angereichert ist wie das Gas im äußeren Teil vom Querschnitt *a-a*. Wenn daher in dem höheren Querschnitt wieder angenähert Zentrifugalgleichgewicht erreicht wird, so muß das aufsteigende, leichtere Gas erneut etwas von dem schwereren Bestandteil abgeben und etwas von dem leichteren Bestandteil aufnehmen. Das innen aufsteigende Gas wird sich also auf seinem Weg nach oben immer mehr an dem leichteren Bestandteil anreichern. Umgekehrt muß aus dem gleichen Grunde das außen nach abwärts sinkende Gas von Querschnitt zu Querschnitt an dem schwereren Bestandteil immer reicher werden. Im Beharrungszustand kann daher an dem oberen Ende der Zentrifuge bei 1 der leichtere Bestandteil, am unteren Ende der Zentrifuge bei 2 der schwerere Bestandteil in um so größerer Reinheit entnommen werden, je höher die Zentrifuge ist. Man wird daher der Zentrifuge eine große axiale Länge im Verhältnis zum Durchmesser geben und für dieses Verhältnis mindestens die Zahl 5 wählen.

Am oberen Ende der Zentrifuge wendet sich ein Teil des nach oben gerichteten Gasstromes um und bewegt sich dann außen wieder nach abwärts. Dieser Umkehr entspricht in einer Rektifikationssäule die Erzeugung von Rücklaufflüssigkeit aus den aufsteigenden Dämpfen. Ähnliches gilt für die Umkehr der Strömung am unteren Ende. Das unzerlegte Gemisch führt man zweckmäßig innen an derjenigen Stelle zu, an der das aufwärts strömende Gas dieselbe Zusammensetzung wie das unzerlegte Gas hat.

Zur Erzielung bestimmter Reinheitsgrade der Fraktionen ist es angebracht, die Geschwindigkeit des Auf- und Abwärtsströmens der Gase innerhalb geeigneter Grenzen zu halten, damit die Gase in jedem Querschnitt die richtige Zeit zur Verfügung haben, sich durch Diffusion mehr oder weniger ins Zentrifugalgleichgewicht zu setzen, was, wie alle Diffusionsvorgänge, eine gewisse Zeit beansprucht. Außerdem müssen Wirbel vermieden werden, die einen Teil der erzielten Zerlegung wieder rückgängig machen würden. Die Konvektionsströmung muß also langsam und vollständig laminar erfolgen. Die in Frage kommende Geschwindigkeit des laminaren Gasstromes und die Diffusionsgeschwindigkeit können je nach den besonderen Verhältnissen sehr unterschiedliche Werte haben. Im allgemeinen wird die Diffusionsgeschwindigkeit in der Größenordnung von einigen Millimeter je Sekunde oder Zentimeter je Sekunde liegen, wobei unter Diffusionsgeschwindigkeit der Quotient aus der Diffusionskonstanten D (cm²/sec) und dem mittleren Diffusionsweg Δx (cm) zu verstehen ist. Hierbei bedeutet Δx die radiale Entfernung zwischen dem Kern der aufsteigenden und dem Kern der absteigenden Strömung. Die Geschwindigkeit des laminaren Gasstromes kann kleiner oder größer als die Diffusionsgeschwindigkeit sein. Steigt die Gasgeschwindigkeit über einen optimalen Wert, der etwa gleich $\frac{D}{\Delta x}\sqrt{2}$ ist, oder sinkt sie unter diesen Wert, so wird die Reinheit der Produkte kleiner. Eine zu hohe Gasgeschwindigkeit wird sich im allgemeinen nicht einstellen, weil der Druck in den äußeren Teilen der Zentrifuge wegen der höheren Dichte nach unten hin in stärkerem Maße zunimmt als in den inneren Teilen, und die so entstehenden Druckunterschiede der beschriebenen Wirkung der Schwerkraft mehr oder weniger entgegenwirken. Wenn aber die Geschwindigkeit ausnahmsweise zu groß wird, namentlich unter Mitwirkung der weiter unten beschriebenen Mittel zur Erzeugung des Gegenstromes, dann läßt sich gemäß der Erfindung eine Herabminderung der Geschwindigkeit z. B. dadurch erreichen, daß man den äußeren Durchmesser der Zentrifuge so klein wählt, daß die Wandreibung den Konvektionsstrom genügend abbremst. In den meisten Fällen wird es aber erwünscht sein, den Durchmesser größer zu wählen. Dann kann man nötigenfalls die Gasgeschwindigkeit dadurch verringern, daß man z. B. die Welle der Zentrifuge zur Verminderung des Einflusses der Schwerkraft nicht senkrecht, sondern schräg anordnet. Ferner läßt sich der Konvektionsstrom auch durch geeignete Einbauten abbremsen. Als Einbauten kommen z. B. senkrechte radiale Wände in Frage (Abb. 2), die zugleich dafür sorgen, daß die Winkelgeschwindigkeit des Gases nicht hinter der der Zentrifuge zurückbleibt, oder auch waagerechte oder konische Netze, Gaze, Tücher, gelochte Bleche u. dgl., die den Gasdurchtritt nach oben und unten erschweren. Die konische Form (Abb. 3) wird hierbei vorzuziehen sein, da hierdurch zwischen den einzelnen Lagen dieser Stoffe zusätzliche schädliche Konvektionsströme in radialer Richtung vermieden werden können.

Auch Einbauten, die die Gestalt ein- oder mehrgängiger Schraubenflächen haben, erweisen sich als günstig. Sie verringern die Konvektionsgeschwindigkeit nicht nur durch den verengten Querschnitt, sondern auch dadurch, daß ähnlich wie bei der schräg gestellten Zentrifuge nicht die ganze Schwerkraft, sondern nur eine Komponente in der Strömungsrichtung zur Wirkung kommt. Auch wird der Weg des Konvektionsstromes im Vergleich zur Höhe der Zentrifuge verlängert, so daß diese Anordnung einer höheren Zentrifuge mit senkrechter Strömungsrichtung gleichwertig ist. Die Erzeugende der Schraubenfläche kann gerade oder gekrümmt sein und mit der Drehachse einen beliebigen Winkel einschließen. Durch eine von der Achse aus schräg nach unten gerichtete Erzeugende lassen sich etwaige unerwünschte radiale Konvektionsströme vermeiden.

Außer Gewichtsunterschieden können grundsätzlich auch andere Mittel zur Anregung und Aufrechterhaltung oder unter Umständen auch zur Abbremsung des Gegenstromes herangezogen werden. In diesem Sinne können Temperaturunterschiede wirken, indem man z. B. die Gase im inneren Teil der Zentrifuge beheizt. Es wäre auch denkbar, den Impuls des eintretenden, noch unzerlegten Gasgemisches hierzu zu verwenden, was z. B. bei waagerechter Lagerung der Zentrifuge von Bedeutung sein könnte. Grundsätzlich läßt sich der Gegenstrom auch in entgegengesetzter Richtung des Beispiels durchführen, wobei der äußere Gasstrom sich aufwärts, der innere Gasstrom sich abwärts bewegt. In diesem Falle wird der leichtere Bestandteil am unteren, der schwerere Bestandteil am oberen Zentrifugenende gewonnen. Erzeugen läßt sich ein solcher umgekehrter Gegenstrom z. B. dadurch, daß man die Zentrifuge außen beheizt und innen kühlt. Vielleicht läßt sich auch schon die Tatsache, daß der Teil des frisch eintretenden Gases, der sofort in die äußeren Teile der Zentrifuge gelangt, sich durch adiabatische Verdichtung erwärmt und dadurch einen Auftrieb nach oben erfährt, unter Umständen zur Anregung des Gegenstromes in der umgekehrten Richtung mit ausnutzen.

Ergebnisse, wie sie sich nach der Erfindung erzielen lassen, werden in nachstehendem Vergleichsbeispiel dargestellt. Zugrunde gelegt wird eine Zentrifuge von 2 m Höhe, deren ringkreisförmiger Zentrifugenraum die lichten Abmessungen von 2 cm für den Durchmesser des inneren Zuführungsrohres und von 6 cm für den Mantel hat. Wenn man eine solche Zentrifuge mit der verhältnismäßig leicht zu erreichenden Umfangsgeschwindigkeit von 300 m/sec rotieren läßt, so können beide Komponenten eines 50%igen binären Isotopengemisches oder auch eines entsprechenden Gasgemisches ohne Anwendung des erfindungsgemäßen Gegenstromes von 50 auf 51 % angereichert werden. Bei Anwendung des erfindungsgemäßen Gegenstromes dagegen läßt sich eine Anreicherung von 50 auf 76 % erreichen.

Läßt man eine solche Zentrifuge mit der höchsten bisher bei Zentrifugen erreichten Umfangsgeschwindigkeit von 600 m/sec rotieren, so wird ohne Anwendung des erfindungsgemäßen Gegenstromes eine Anreicherung der Komponenten bis höchstens 53,4 % erreicht. Unter Benutzung des erfindungsgemäßen Gegenstromes dagegen läßt sich eine 99%ige Anreicherung erzielen.

Die vorstehenden Angaben sind das Ergebnis einer Näherungsrechnung. In der Praxis werden die Ergebnisse sowohl beim Arbeiten mit Gegenstrom als auch ohne Gegenstrom voraussichtlich etwas ungünstiger sein.

Das erfundene Verfahren ist nicht nur auf Gasgemische anwendbar, sondern kann in analoger Weise auch zur Trennung schwer zerlegbarer Flüssigkeiten verwendet werden. Es ist zwar bekannt, Emulsionen in Zentrifugen zu trennen; mit einer erfindungsgemäßen Zentrifuge lassen sich dagegen weit höhere Leistungen erzielen, z. B. die Trennung echter Lösungen oder kolloidaler Mischungen, was mit gewöhnlichen Zentrifugen nicht möglich ist.

PATENTANSPRÜCHE:

1. Verfahren zur Zerlegung von Gas- und Flüssigkeitsgemischen in Zentrifugen, dadurch gekennzeichnet, daß ein Kreisstrom als achsparalleler laminarer Gegenstrom geführt wird, wobei Zentrifugen angewendet werden, deren axiale Länge wesentlich größer ist als ihr äußerer Durchmesser und bei denen die Ableitung der Zerlegungsprodukte aus dem Läufer der Zentrifuge an Stellen erfolgt, welche in der Projektion auf die Welle gemessen, weit voneinander entfernt sind.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß der Gegenstrom durch die Schwerkraft bewirkt wird.

3. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß der Impuls des mit einer anfänglichen Geschwindigkeit eintretenden unzerlegten Gasgemisches zur Anregung und Aufrechterhaltung oder auch zur Abbremsung des Gegenstromes auf den günstigsten Wert herangezogen wird.

4. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß der Gegenstrom mit Hilfe einer in der Zentrifuge aufrechterhaltenen Temperaturdifferenz erzeugt wird.

5. Vorrichtung zur Durchführung des Verfahrens nach Anspruch 1, gekennzeichnet durch Einbauten zur Abbremsung der Geschwindigkeit des Gegenstromes, die vorzüglich aus radialen senkrechten Wänden oder trichterförmigen Netzen, gelochten Blechen oder Tucheinlagen bestehen.

6. Vorrichtung zur Durchführung des Verfahrens nach Anspruch 1, gekennzeichnet durch Einbauten, die die Gestalt ein- oder mehrgängiger Schraubenflächen haben.

7. Vorrichtung zur Durchführung des Verfahrens nach Anspruch 1 und 2, dadurch gekennzeichnet, daß zur Aufrechterhaltung einer günstigsten Geschwindigkeit des Gegenstromes die Rotationsachse schräg gegen die Richtung der Erdbeschleunigung eingestellt wird.

8. Zentrifuge zur Zerlegung von Gasgemischen, dadurch gekennzeichnet, daß das Verhältnis der axialen Länge zum Durchmesser der Zentrifuge größer als 5 ist.

Hierzu 1 Blatt Zeichnungen

Figure D.139: One of Linde Eismaschinen's patents on gas centrifuges, filed by Helmuth Hausen in 1939 [German Patent DE 833,487]. Note the use of countercurrent flow inside the centrifuge to improve the separation efficiency.

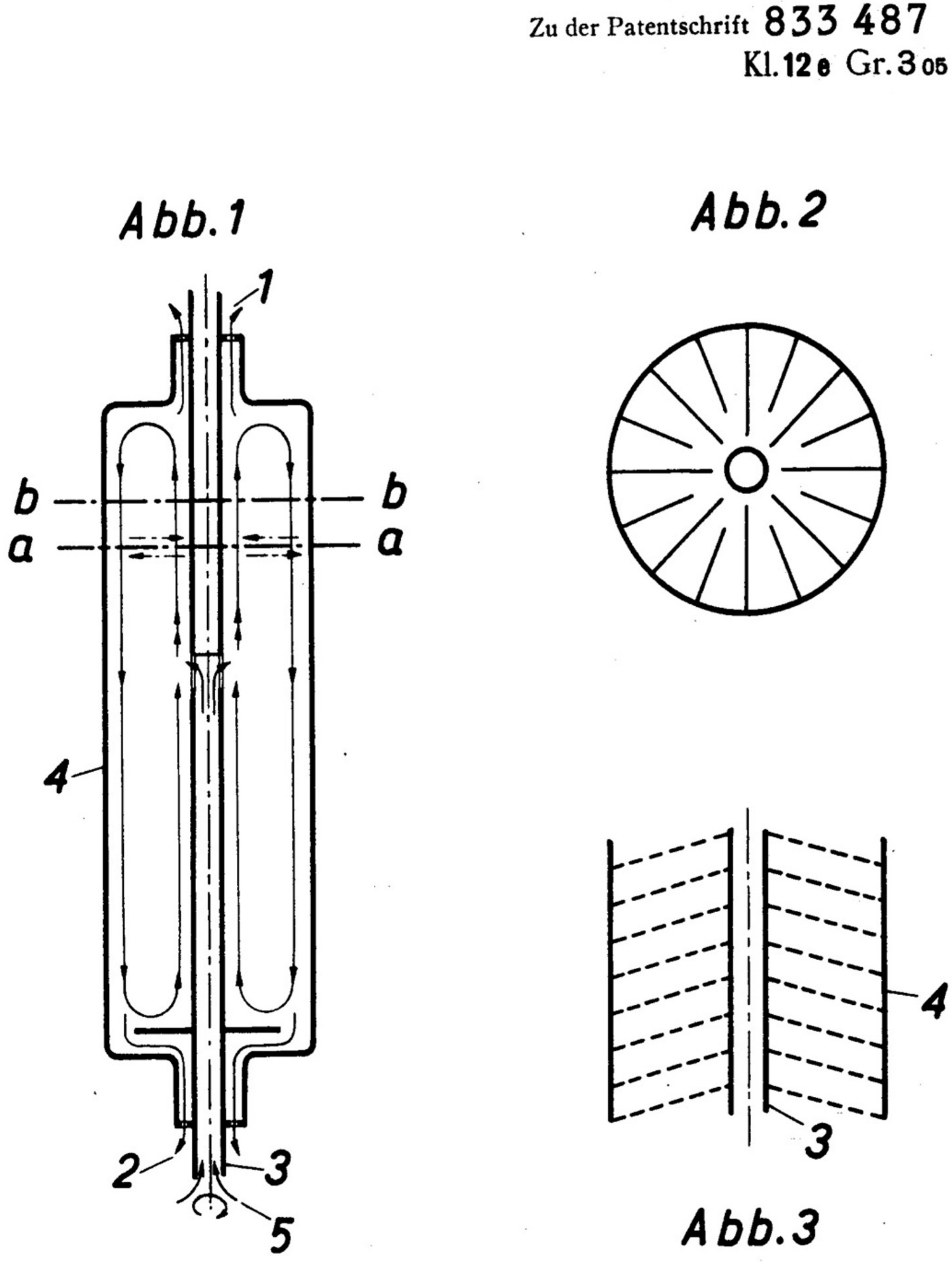
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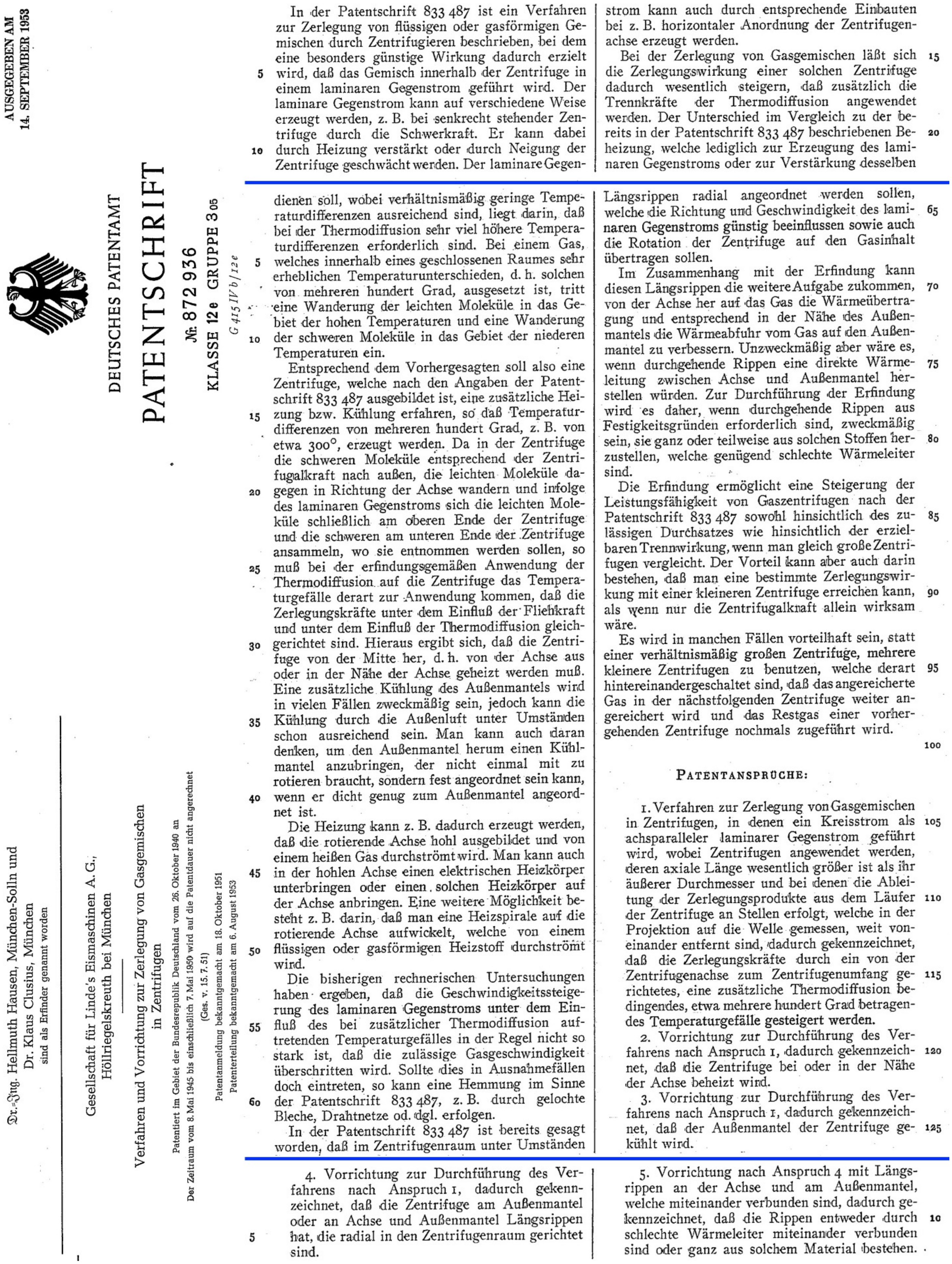
Figure D.140: One of Linde Eismaschinen's patents on gas centrifuges, filed by Helmuth Hausen in 1939 [German Patent DE 833,487]. Note the use of countercurrent flow inside the centrifuge to improve the separation efficiency.



AUSGEGEBEN AM
14. SEPTEMBER 1953

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 872 936

KLASSE 12e GRUPPE 3 05

G 415 IVb/12e

Dr.-Ing. Hellmuth Hausen, München-Solln und
Dr. Klaus Clusius, München
sind als Erfinder genannt worden

Gesellschaft für Linde's Eismaschinen A. G.,
Höllriegelskreuth bei München

Verfahren und Vorrichtung zur Zerlegung von Gasgemischen in Zentrifugen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 26. Oktober 1940 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
(Ges. v. 15. 7. 51)
Patentanmeldung bekanntgemacht am 18. Oktober 1951
Patenterteilung bekanntgemacht am 6. August 1953

In der Patentschrift 833 487 ist ein Verfahren zur Zerlegung von flüssigen oder gasförmigen Gemischen durch Zentrifugieren beschrieben, bei dem eine besonders günstige Wirkung dadurch erzielt wird, daß das Gemisch innerhalb der Zentrifuge in einem laminaren Gegenstrom geführt wird. Der laminare Gegenstrom kann auf verschiedene Weise erzeugt werden, z. B. bei senkrecht stehender Zentrifuge durch die Schwerkraft. Er kann dabei durch Heizung verstärkt oder durch Neigung der Zentrifuge geschwächt werden. Der laminare Gegenstrom kann auch durch entsprechende Einbauten bei z. B. horizontaler Anordnung der Zentrifugenachse erzeugt werden.

Bei der Zerlegung von Gasgemischen läßt sich die Zerlegungswirkung einer solchen Zentrifuge dadurch wesentlich steigern, daß zusätzlich die Trennkräfte der Thermodiffusion angewendet werden. Der Unterschied im Vergleich zu der bereits in der Patentschrift 833 487 beschriebenen Beheizung, welche lediglich zur Erzeugung des laminaren Gegenstroms oder zur Verstärkung desselben dienen soll, wobei verhältnismäßig geringe Temperaturdifferenzen ausreichend sind, liegt darin, daß bei der Thermodiffusion sehr viel höhere Temperaturdifferenzen erforderlich sind. Bei einem Gas, welches innerhalb eines geschlossenen Raumes sehr erheblichen Temperaturunterschieden, d. h. solchen von mehreren hundert Grad, ausgesetzt ist, tritt eine Wanderung der leichten Moleküle in das Gebiet der hohen Temperaturen und eine Wanderung der schweren Moleküle in das Gebiet der niederen Temperaturen ein.

Entsprechend dem Vorhergesagten soll also eine Zentrifuge, welche nach den Angaben der Patentschrift 833 487 ausgebildet ist, eine zusätzliche Heizung bzw. Kühlung erfahren, so daß Temperaturdifferenzen von mehreren hundert Grad, z. B. von etwa 300°, erzeugt werden. Da in der Zentrifuge die schweren Moleküle entsprechend der Zentrifugalkraft nach außen, die leichten Moleküle dagegen in Richtung der Achse wandern und infolge des laminaren Gegenstroms sich die leichten Moleküle schließlich am oberen Ende der Zentrifuge und die schweren am unteren Ende der Zentrifuge ansammeln, wo sie entnommen werden sollen, so muß bei der erfindungsgemäßen Anwendung der Thermodiffusion auf die Zentrifuge das Temperaturgefälle derart zur Anwendung kommen, daß die Zerlegungskräfte unter dem Einfluß der Fliehkraft und unter dem Einfluß der Thermodiffusion gleichgerichtet sind. Hieraus ergibt sich, daß die Zentrifuge von der Mitte her, d. h. von der Achse aus oder in der Nähe der Achse geheizt werden muß. Eine zusätzliche Kühlung des Außenmantels wird in vielen Fällen zweckmäßig sein, jedoch kann die Kühlung durch die Außenluft unter Umständen schon ausreichend sein. Man kann auch daran denken, um den Außenmantel herum einen Kühlmantel anzubringen, der nicht einmal mit zu rotieren braucht, sondern fest angeordnet sein kann, wenn er dicht genug zum Außenmantel angeordnet ist.

Die Heizung kann z. B. dadurch erzeugt werden, daß die rotierende Achse hohl ausgebildet und von einem heißen Gas durchströmt wird. Man kann auch in der hohlen Achse einen elektrischen Heizkörper unterbringen oder einen solchen Heizkörper auf der Achse anbringen. Eine weitere Möglichkeit besteht z. B. darin, daß man eine Heizspirale auf die rotierende Achse aufwickelt, welche von einem flüssigen oder gasförmigen Heizstoff durchströmt wird.

Die bisherigen rechnerischen Untersuchungen haben ergeben, daß die Geschwindigkeitssteigerung des laminaren Gegenstroms unter dem Einfluß des bei zusätzlicher Thermodiffusion auftretenden Temperaturgefälles in der Regel nicht so stark ist, daß die zulässige Gasgeschwindigkeit überschritten wird. Sollte dies in Ausnahmefällen doch eintreten, so kann eine Hemmung im Sinne der Patentschrift 833 487, z. B. durch gelochte Bleche, Drahtnetze od. dgl. erfolgen.

In der Patentschrift 833 487 ist bereits gesagt worden, daß im Zentrifugenraum unter Umständen Längsrippen radial angeordnet werden sollen, welche die Richtung und Geschwindigkeit des laminaren Gegenstroms günstig beeinflussen sowie auch die Rotation der Zentrifuge auf den Gasinhalt übertragen sollen.

Im Zusammenhang mit der Erfindung kann diesen Längsrippen die weitere Aufgabe zukommen, von der Achse her auf das Gas die Wärmeübertragung und entsprechend in der Nähe des Außenmantels die Wärmeabfuhr vom Gas auf den Außenmantel zu verbessern. Unzweckmäßig aber wäre es, wenn durchgehende Rippen eine direkte Wärmeleitung zwischen Achse und Außenmantel herstellen würden. Zur Durchführung der Erfindung wird es daher, wenn durchgehende Rippen aus Festigkeitsgründen erforderlich sind, zweckmäßig sein, sie ganz oder teilweise aus solchen Stoffen herzustellen, welche genügend schlechte Wärmeleiter sind.

Die Erfindung ermöglicht eine Steigerung der Leistungsfähigkeit von Gaszentrifugen nach der Patentschrift 833 487 sowohl hinsichtlich des zulässigen Durchsatzes wie hinsichtlich der erzielbaren Trennwirkung, wenn man gleich große Zentrifugen vergleicht. Der Vorteil kann aber auch darin bestehen, daß man eine bestimmte Zerlegungswirkung mit einer kleineren Zentrifuge erreichen kann, als wenn nur die Zentrifugalkraft allein wirksam wäre.

Es wird in manchen Fällen vorteilhaft sein, statt einer verhältnismäßig großen Zentrifuge, mehrere kleinere Zentrifugen zu benutzen, welche derart hintereinandergeschaltet sind, daß das angereicherte Gas in der nächstfolgenden Zentrifuge weiter angereichert wird und das Restgas einer vorhergehenden Zentrifuge nochmals zugeführt wird.

PATENTANSPRÜCHE:

1. Verfahren zur Zerlegung von Gasgemischen in Zentrifugen, in denen ein Kreisstrom als achsparalleler laminarer Gegenstrom geführt wird, wobei Zentrifugen angewendet werden, deren axiale Länge wesentlich größer ist als ihr äußerer Durchmesser und bei denen die Ableitung der Zerlegungsprodukte aus dem Läufer der Zentrifuge an Stellen erfolgt, welche in der Projektion auf die Welle gemessen, weit voneinander entfernt sind, dadurch gekennzeichnet, daß die Zerlegungskräfte durch ein von der Zentrifugenachse zum Zentrifugenumfang gerichtetes, eine zusätzliche Thermodiffusion bedingendes, etwa mehrere hundert Grad betragendes Temperaturgefälle gesteigert werden.

2. Vorrichtung zur Durchführung des Verfahrens nach Anspruch 1, dadurch gekennzeichnet, daß die Zentrifuge bei oder in der Nähe der Achse beheizt wird.

3. Vorrichtung zur Durchführung des Verfahrens nach Anspruch 1, dadurch gekennzeichnet, daß der Außenmantel der Zentrifuge gekühlt wird.

4. Vorrichtung zur Durchführung des Verfahrens nach Anspruch 1, dadurch gekennzeichnet, daß die Zentrifuge am Außenmantel oder an Achse und Außenmantel Längsrippen hat, die radial in den Zentrifugenraum gerichtet sind.

5. Vorrichtung nach Anspruch 4 mit Längsrippen an der Achse und am Außenmantel, welche miteinander verbunden sind, dadurch gekennzeichnet, daß die Rippen entweder durch schlechte Wärmeleiter miteinander verbunden sind oder ganz aus solchem Material bestehen.

Figure D.141: Another Linde Eismaschinen patent on gas centrifuges, filed by Helmuth Hausen and Klaus Clusius in 1940 [German Patent DE 872,936]. Note the use of countercurrent flow inside the centrifuge to improve the separation efficiency.

[There was a large program spread out among several collaborating groups in the Hamburg-Kiel area to design, build, and operate a series of increasingly sophisticated gas centrifuges for uranium enrichment. That work was conducted by physicists and engineers such as Konrad Beyerle (at Anschütz, a gyroscope company in Kiel that already had decades of experience making high-precision rapidly rotating machinery), K. H. Eldau, Wilhelm Groth, Paul Harteck, Johannes Hans Jensen (who later won a Nobel Prize for the nuclear shell model), Werner Kuhn, Detlof Lyons (who also worked for the Reichspost), Hans Martin, Hans Suess, Albert Suhr, and others.

The U.S. Alsos Mission captured several reports written by this Hamburg-Kiel centrifuge program. Note that these reports do not cover the work of other German centrifuge programs and do not even cover all the work of the Hamburg-Kiel program. The extant reports tend to be from the earlier days of the Hamburg-Kiel program, and to focus on fundamental centrifuge design issues, not mass production or operational use of centrifuges. Unless otherwise indicated, text for G-series captured German nuclear reports cited here consists of the English-language abstracts prepared by U.S. scientists who studied the German reports.]

G-82. Wilhelm Groth. Status of Work on Building an Ultracentrifuge. 1941.

Rotor is 40 cm long and 14.5 cm diameter and operates at 50,000 rpm. On the basis of calculations, with a separation factor of 7.4%, the centrifuge would deliver more than 2 kg of hexafluoride which would be enriched more than 7%. Construction of ultracentrifuge still (Dec. 14, 1941) in progress.

G-83. Wilhelm Groth and Hans Suess. Status of Work on Isotope Separation of Preparation 38 (U_3O_8) at the Institute of Physical Chemistry, University of Hamburg. Separation Column Experiment and Construction of Ultracentrifuge. Analysis of Tests. 1941.

Preparation of UF_6. Corrosion tests showed nickel as only practical construction material, but in separation column the continuous removal of hexafluoride layer from the metal prevented operation of unit at 360^oC (temperature of boiling Hg). 3.7 m separation column was built of nickel. Inner (hot) tube outer diameter was 18 mm, 2 mm wall thickness; outer (cold) tube was 28 mm outside diameter. Separation between two tubes was therefore 3 mm. Separators were provided to reduce convection disturbances. Later a 5.7 m column was built. Tests with xenon and with methane to enrich isotope C^{13} were successful but no success in enriching U^{235} (separation effect less than 1%).

Ultracentrifuge is being built. Rotor to be 400 mm long and 115 mm diameter and to run in a vacuum chamber 625 mm long and 150 mm diameter, air or electric motor drive to be used. Speed up to 120,000 rpm. Lubricant developed consisted of a paste made from apiezon grease and sodium fluoride.

Methods used to check U isotopes separation are outlined.

G-95. Johannes Hans Jensen. The Ultracentrifuge Method for Separating Uranium Isotopes. 1941.

Since the thermal diffusion constants of UF_6 are so very small it was decided to investigate the ultracentrifuge methods of separating the isotopes. On the basis of a theoretical analysis, a 2 meter high centrifuge can enrich to double the value 1.5×10^{-2} grams of hexafluoride per day. This centrifuge is to operate with a laminar countercurrent—"a circulation centrifuge."

Suggest centrifuge divided vertically into chambers to prevent back diffusion. A 12 chamber centrifuge would increase the yield 1.44 times the circulation centrifuge but would require a mechanism so complicated as to be impractical.

Theoretical calculations are given for a centrifuge where the centrifugal forces are so great that the pressure differential between inner and outer wall is very large.

G-107. Hans Martin and K. H. Eldau. Appendix to Report of 15 July 1941 on the Construction of an Ultracentrifuge to Separate Isotopes. The Stability of Some Metals to UF_6 Vapor at Room Temperature and at 50^oC. 1941.

Corrosion tests of UF_6 on various metals and alloys. Description of special apparatus to avoid contamination. Tests run at 20 and 50^oC and at 16 and 55 mm Hg of UF_6 with exposure time varying from 20 to 80 hours. Weight increase of some sample metals in mg/cm^2. Copper = 0.036; lead = 0.25; dural = 0.03; V2A steel = 0.05. Results for other metals tabulated.

G-145. Wilhelm Groth. Report on Conference with Professor Svedberg and Dr. Pedersen of the Institute of Physical Chemistry at the University of Upsala (Sweden). 1942.

Notes on discussions regarding ultracentrifuges, a series of which were planned for Germany.

1. Description of foundations used at Upsala to avoid transmission of shock and reduce bearing loads.

2. Oil and water piping arrangement. Prefer individual piping to each centrifuge in order not to disturb whole series of centrifuges whenever one unit has to be shut down. Position of pumps etc. Use of hydrogen to keep out air and keep uniform temperature.

3. Use of packings. Bearing tolerances (held to .015 mm).

4. Balancing machines developed in Sweden which easily measure rotor unbalance of 0.5 mg cm.

G-146. Wilhelm Groth. Separation of Uranium Isotopes by the Ultracentrifuge. I. Enrichment of the Xenon Isotope in a Single Stage Ultracentrifuge. 1942.

Detailed description of Beams type centrifuge with a rotor 200 mm long and 128 mm outer diameter (58 mm inner diameter) operating in a 10^{-3} mm Hg vacuum. Description how impurities were removed from Xe before centrifuging. Centrifuge operated at 50,000 rpm and with Xe at an average atomic weight of 131.13 the pressure relationship between axis and periphery of rotor was 10.4:1. Separation of Xe isotopes successful. Data presented in tables of sample separations compare favorably with theoretical values. Enrichment obtained was 0.056–0.093. Photographs of centrifuge are included.

G-147. Wilhelm Groth. Separation of the Uranium Isotopes by the Separation Tube and the Ultracentrifuge. 1942.

Attempts to separate U isotopes in separating columns 3.70 meters and 5.70 meters were unsuccessful. Isotope enrichment was less than 1% whereas 8 and 14% enrichments were expected. Columns were built of Ni with the inner tube heated to between 100 and 360^oC and the outer tube kept between 12 and 65^oC. This small separation effect was ascribed to a very small thermodiffusion coefficient. Since experiments seem to prove U isotope separation was not possible with separation column, it was decided to try the ultracentrifuge. Ultracentrifuge on Beams principle was built with a rotor 115 mm inner diameter and 400 mm long. Electric drive used with speeds up to 100,000 rpm. Lubricant was paste of apiezo grease and sodium fluoride. Theoretical separation factors of the ultracentrifuge were determined. With ideal conditions should be able to deliver 2 kg UF_6 with the U^{235} enriched 7%.

G-148. Wilhelm Groth and Hans Suess. Status of Work on Separation of Isotopes of Preparation 38. 1942.

General summary of work done to date (Oct. 1942). Method of preparing UF_6. Corrosion tests with UF_6. Use of Ni with temperature limits at 360^oC in separating columns. (See G-32 and G-83.) Experiments with 3.70 m separating column (18 mm diameter of inner tube, 28 mm diameter outer tube), 3 mm separation with separators to overcome convection (See G-83). Experiments with 5.70 mm separating columns. Separation of U isotopes very small, although tests with Xe and methane (to enrich C^{13}) were successful. This explained by small thermodiffusion coefficient of U. Proposed solution is higher temperature operation of column, but corrosiveness of UF_6 prevents this. Use of ultracentrifuge (See G-147). Proof of separation of U isotopes by measurement of alpha activity with correction for U^{234}.

G-149. Wilhelm Groth and Albert Suhr. Separation of Uranium Isotopes by the Ultracentrifuge. II. Enrichment of Uranium Isotopes U_{234} and U_{235} in a Single Stage Ultracentrifuge. 1942.

Same centrifuge as used in G-146 for Xe now used with UF_6. Use of apiezo grease and sodium fluoride as seal lubricant. In a series of runs, average enrichment of $U^{234} = 3.6\%$ and $U^{235} = 2.7\%$. In another series of runs the following enrichments were achieved $U^{234} = 3.2\%$, $U^{235} = 2.4\%$, and $U^{234} = 5.2\%$, $U^{235} = 3.9\%$. These values are less than theoretically expected and are probably due to contamination which occurs when the samples are drawn off.

G-158. Paul Harteck and Johannes Hans Jensen. Calculation of the Separation Effect and the Yield of Various Arrangements of Centrifuges in Order to Improve the Efficiency of a Single Centrifuge. 1942.

New design gas centrifuge planned which will be a single unit whose rotor will be divided into chambers. The gas flow will go from the axis of one chamber to the periphery of the next chamber. Furthermore there will be a periodic change of direction in the gas stream flowing through the chambers. Calculations are presented for (1) the separation effect of a simple single chamber centrifuge, (2) the separation effect achieved with a multi-chamber centrifuge with undirectional gas flow, (3) the separation effect achieved with a multi-chamber centrifuge with oscillating gas flow, (4) calculations evaluating the pressure differences and thermal effects. Short note on possibilities of a double centrifuge.

G-175. Hans Martin. Spontaneous Gas Convection on Conducting Walls in a High Centrifugal Field. 1942.

Small local temperature changes often disturb the separation in an ultracentrifuge; therefore a mathematical analysis is made of the thermal convection processes within the centrifuge. Gas movements in a high centrifugal field occur close to the wall (hot or cold) but not in the gas filled chamber where the strata are quite stable. Calculations for flow due to temperature differential (flow opposite to the gravitational force). Convection speed. Optimum wall separation in the centrifuge. Convection currents in the ultracentrifuge which are caused by temperature variations are proportionally reduced with higher centrifugal fields, lower gas pressures, and with a reduction in the gas volume which comes in contact with heat conducting walls. Relationship between temperature differentials and velocity of flow.

G-215. Wilhelm Groth, Paul Harteck, and Albert Suhr. Separation of Uranium Isotopes by the Ultracentrifuge. III. Enrichment of Xenon and Uranium Isotopes by the Cascade Method. 1943.

Figs. missing. No illustrations of the equipment described. Progress report on work done in 1943. New type bearing developed and new lubrication system. Use of upper and lower capillary tubes permitted continual operation. Rotor divided into 10 chambers with periphery of one chamber connected to the axis of its neighbor (cascade method). Provisions to prevent temperature differentials. Centrifuge operated on two endurance runs of 100 hours each. Enriched 25 g of hexafluoride 3 1/2 to 7% (U^{234}). Theoretical enrichment value = 14%.

G-234. Hans Martin. Chamber Centrifuge with Axial Temperature Gradient. 1943.

The design of a multi-chambered ultracentrifuge for the enrichment of uranium isotopes in UF_6 is detailed. The unit has a counter-current gas flow based on the thermosiphon principle. The rotor itself is a cylinder about 1 meter long, 10 cm radius, rotating at 66,000 rpm. This rotor is divided into 20 chambers. One end of the unit is heated and the other end is cooled at the same rate. Fins are built into the end chambers to improve heat transmission to the rotor in order to ensure a proper temperature gradient through the individual chambers. This gradient is to be maintained in spite of the heat generated by gas friction. The maximum U^{235} enrichment per chamber is expected to be 5.5% and the daily capacity of the centrifuge 50 g UF_6.

G-276. Detlof Lyons. Theory of Isotope Separation by Ultracentrifuges with Thermal Convection. 1944.

Theoretical equations are derived for gaseous diffusion factors relative to separation of two isotopes and mass-transport through the centrifuge diameter. Thermoconvection is achieved by raising the temperature of an inner cylinder of fluid above that of the outer layer. Equations for computation of optimum values of temperature differences, speed of flow profile, and separation factor are given. A continuous centrifugation process for production purposes is described.

G-330. Konrad Beyerle, Wilhelm Groth, Paul Harteck, et al. Correspondence, Cost Estimates, and Technical Data Concerning the Construction of the Ultracentrifuge by the Anschütz Company. 1944–1945.

Correspondence between Harteck and staff members of the Anschütz Co., cost estimates and reports dated Jan. 1944 to Apr. 1945 are included.

[Includes information on apparently aborted plans to set up multiple centrifuges in Kandern and Freiburg.]

G-331. Konrad Beyerle, Wilhelm Groth, Paul Harteck, et al. Technical Letters Concerning the Ultracentrifuge, Taken from Dr. Groth's File. 1941–1944.

Correspondence between Dr. Groth and K. Beyerle of the Anschütz Co. dated, from 1941 to 1944, makes up most of the file.

G-332. Folder Containing Blueprints for Construction of an Ultracentrifuge.

The 165 blueprints included in this folder are for construction of an ultracentrifuge using the UZ III method of Harteck. A design is included for installation of the gas centrifuge GZA 451 in a building partly underground.

G-333/G-248. Konrad Beyerle. The Gas Centrifuge Setup GZA 451 for the German Federal Research Board. 12 December 1944.

Construction of an improved double ultracentrifuge for isotope separation is considered. An outlet pipe is connected to either top or bottom of each of the two centrifuge cylinders, a pipe connects the opposite sides of the cylinders, and a pipe entering this connecting piece feeds the mixture to be separated into both cylinders. Advantage of this arrangement is that each cylinder is to be provided only with two instead of three pipe connections. Plates with central openings divide the cylinders into a number of chambers. Designs for construction of the centrifuge and all parts are illustrated and described in detail. Advantages and disadvantages of different plans of construction and details of operation are considered.

Report G-248, printed and in more finished form, blueprints of the design, and a report by the Alsos Mission are included in this folder.

G-334. Folder Containing Blueprints for Construction of an Ultracentrifuge.

Seventeen blueprints for construction and operation of an ultracentrifuge using the UZ III method of Harteck, and 5 drawings of pressure-radius curves for different temperatures and rotational speeds of the instrument are included in the folder.

G-335. Folder Containing Drawings, Blueprints and Photographs of the Ultracentrifuge.

Fifteen photographs of the ultracentrifuge setup in Freiburg i/Br., 7 pencil drawings and 8 blueprints for centrifuge construction are included in the folder.

G-336. Folder Containing Blueprints for Construction of an Ultracentrifuge.

Thirteen blueprints and two sketches for construction and operation of the UZ III ultracentrifuge setup are included in this folder.

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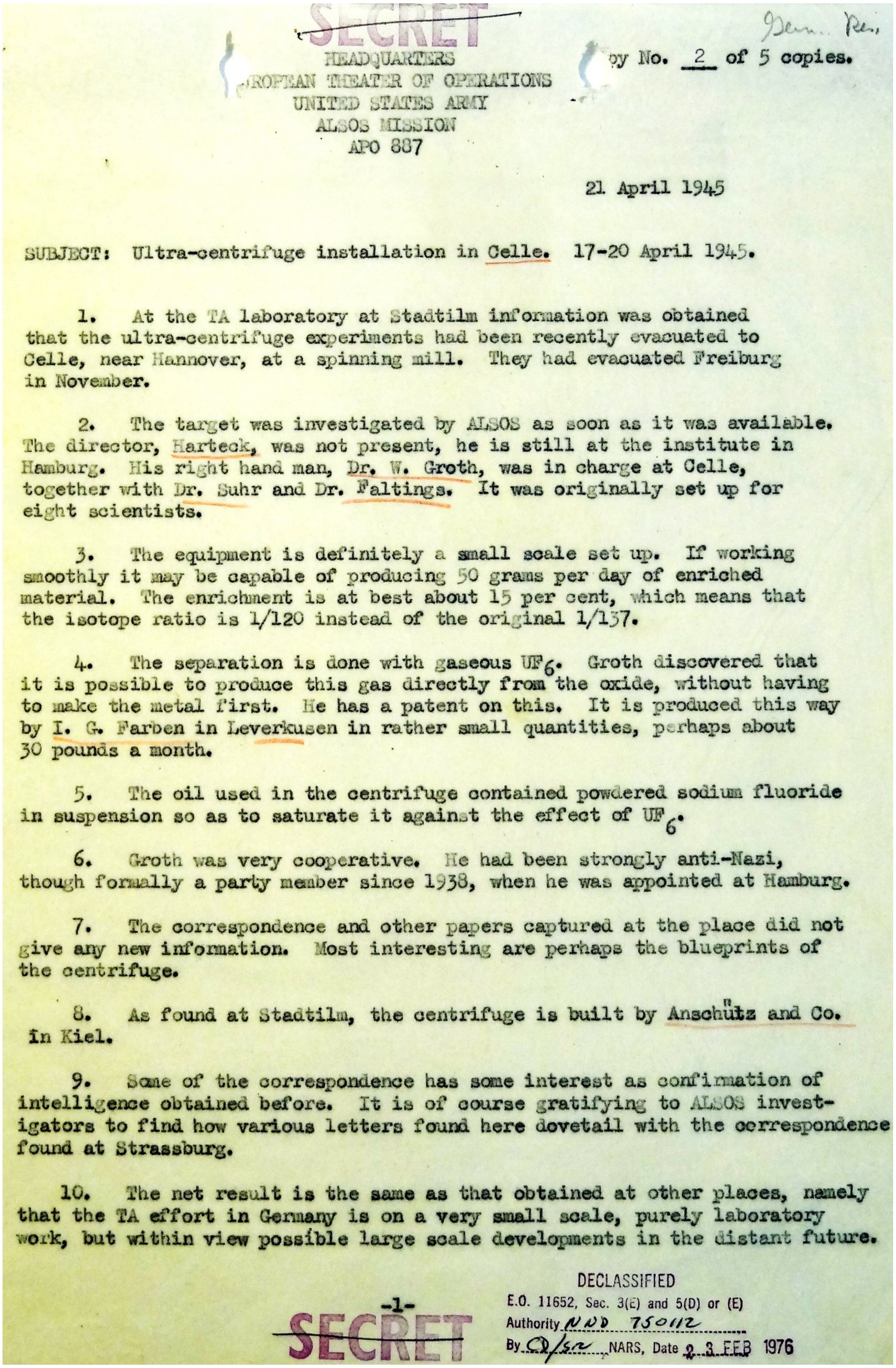

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ALSOS MISSION
APO 887

py No. 2 of 5 copies.

21 April 1945

SUBJECT: Ultra-centrifuge installation in Celle. 17-20 April 1945.

1. At the TA laboratory at Stadtilm information was obtained that the ultra-centrifuge experiments had been recently evacuated to Celle, near Hannover, at a spinning mill. They had evacuated Freiburg in November.

2. The target was investigated by ALSOS as soon as it was available. The director, Harteck, was not present, he is still at the institute in Hamburg. His right hand man, Dr. W. Groth, was in charge at Celle, together with Dr. Suhr and Dr. Faltings. It was originally set up for eight scientists.

3. The equipment is definitely a small scale set up. If working smoothly it may be capable of producing 50 grams per day of enriched material. The enrichment is at best about 15 per cent, which means that the isotope ratio is 1/120 instead of the original 1/137.

4. The separation is done with gaseous UF_6. Groth discovered that it is possible to produce this gas directly from the oxide, without having to make the metal first. He has a patent on this. It is produced this way by I. G. Farben in Leverkusen in rather small quantities, perhaps about 30 pounds a month.

5. The oil used in the centrifuge contained powdered sodium fluoride in suspension so as to saturate it against the effect of UF_6.

6. Groth was very cooperative. He had been strongly anti-Nazi, though formally a party member since 1938, when he was appointed at Hamburg.

7. The correspondence and other papers captured at the place did not give any new information. Most interesting are perhaps the blueprints of the centrifuge.

8. As found at Stadtilm, the centrifuge is built by Anschütz and Co. in Kiel.

9. Some of the correspondence has some interest as confirmation of intelligence obtained before. It is of course gratifying to ALSOS investigators to find how various letters found here dovetail with the correspondence found at Strassburg.

10. The net result is the same as that obtained at other places, namely that the TA effort in Germany is on a very small scale, purely laboratory work, but within view possible large scale developments in the distant future.

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Figure D.142: Alsos Mission. 21 April 1945. SUBJECT: Ultra-centrifuge installation in Celle. 17–20 April 1945 [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)]

[The work described in some of those captured German reports was then summarized in a U.S. report by the American physicist Jesse Beams, who had tried and failed to build useful uranium gas centrifuges in the United States during the war:]

G-344. Jesse W. Beams. Report on the Use of the Centrifuge Method for the Concentration of U^{235} by the Germans. 9 April 1946.

This brief report is based upon a number of captured German reports and letters sent to me by Colonel Peterson. While this list is apparently not complete, it allows one to get an idea of the progress the Germans were able to make.

Immediately after Bohr and other showed that the isotope 235 of Uranium was responsible for the observed Nuclear Fission, the Germans began an intensive search for a suitable method of concentrating it. Their first step was to produce the UF_6 gas in sufficient quantities for use in the Thermal Diffusion Method of Clusius and Dickel. This production was carried out by the I.G. Farben Company under the direction of Dr. Noack. Experiments performed from 1939 to 1941 with the Thermal Diffusion Method using the gas, UF_6, were uniformly unsuccessful although in the meantime the necessary properties of UF_6 such as viscosity and vapor pressure were well established.

In the Summer of 1941 Groth, Harteck, and Jensen in Hamburg and Martin and Kuhn in the University of Kiel focused their attention on the Centrifuge Method for concentrating Uranium 235. They first made a study of the theory and concluded that the method had promise. Accordingly in Sept. 1941 the Firm of Anschütz and Co. in Kiel started construction of a gas centrifuge under the direction of Dr. Beyerle, head of their Research Department. The rotor was 40 cm long with an O.D. of 14.5 cm and was driven electrically up to 60,000 r.p.m. Apparently this first centrifuge was patterned somewhat after some of our early (1936–38) published work on isotope separation by centrifuging. With this apparatus Groth obtained separation of the Xenon isotopes in May 1942 and a concentration increase of 3.9% of Uranium 235 in a small sample in August 1942. During 1943 a large number of technical improvements were made in the centrifuge apparatus, and the workers felt that it was trustworthy for long period operation.

At the suggestion of Harteck a continuous method of operation was adopted, called the “Rocking Method” and designated as UZ III. It was assembled and tested in Freiburg by the Firm of Hellige and Co. Two identical centrifuges were used, one for stripping and the other for concentrating the U 235. Each centrifuge rotor was divided into 10 chambers in such a way that the periphery of one chamber connected through a baffle system to the axis of the next chamber. The bottom ends of the two rotors were connected together and the gas was made to oscillate or flow back and forth in such a manner as to produce enriched U 235 at the top of one rotor and the stripped material at the top of the other rotor. The first experiments with this method gave 40% of the theoretical value and in May 1944 Groth in writing to Gerlach said: “The experiments of the last week have produced a separation of 70% of the theoretical value which is more than had been hoped for.” In the meantime Anschütz and Co. had developed a rotor 70 cm long and 15 cm O.D. which weighed 15 kg. Their rotors were made either of an aluminum alloy, “Bondur,” or of steel and had an inside peripheral speed of about 3.9×10^4 cm/sec.

As an alternate to Harteck's "Rocking Method" Martin and Kuhn at Kiel worked out the theory for a so-called "Thermal Siphon Method" which consisted of cooling the outer walls of the centrifuge and heating along the axis. This was supposed to produce circulation in the manner of the Clusius-Dickel experiment, and the enriched fraction would be drawn off at the top of the rotor. The method apparently was never tried although experiments were planned.

From the reports one gathers that as early as 1942 the Germans arrived at the conclusion that the centrifuge method, even though expensive, probably stood the best chance of success of all of the methods for separating U 235. They placed an ever growing emphasis on the problem but it never reached beyond the experimental stage.

It was abundantly clear that the air war was primarily responsible for a production plant not getting much further than the planning stage. The Anschütz Co. was badly bombed in Kiel and development was slowed down by the difficulty of getting materials from Essen, Vienna, etc. At the end of the war they were planning to put a factory underground near Kandern.

In comparing the progress with the Centrifuge Method of separation made by the Germans and by ourselves it is clear that at the end of the war they were far behind where we were in this country at the end of 1943 when support of the centrifuge project was effectively cut off. However, they made some headway both with the theory and experiment.

[Beams's final editorial comments appear to be countered by the facts that:

- German work on gas centrifuges for a variety of applications began sometime before 1895 (p. 3495), many decades before Beams's work.
- Beams's centrifuge experiments were considered but abandoned by the U.S. Manhattan Project because of their poor performance.
- An enormous amount of the German work on gas centrifuges was not mentioned in these captured G-reports and Beams's analysis of them (as illustrated by other documents in this section).
- The German-developed gas centrifuges became the basis of uranium enrichment worldwide after the war, since they were more efficient than any of the uranium enrichment methods (Beams-type centrifuges, calutrons, gaseous thermal diffusion, and liquid thermal diffusion) developed by the Manhattan Project.]

Hans Martin and Werner Kuhn. 1941. Multiplikationsverfahren zur Trennung von Gasgemischen, insbesondere bei Anwendung von Schwerefeldern. *Zeitschrift für Physikalische Chemie A* 189:219–316. See p. 3525.

Es wird ein Multiplikationsverfahren angegeben, mit dessen Hilfe es allgemein möglich ist, in Gasgemischen (Isotopengemischen) auftretende schwache Entmischungseffekte, wie sie beispielsweise bei Einwirkung eines Gravitationsfeldes oder eines Temperaturgefälles beobachtet werden (Einzeleffekte), grundsätzlich beliebig stark zu vervielfachen und damit eine im Einzeleffekt nur unvollkommene Zerlegung eines Gemisches in beliebigem Maße zu vervollständigen. Es ist ein wesentlicher Bestandteil des Verfahrens, daß das Gemisch innerhalb des Hohlraumes, in welchen es eingeschlossen ist, in bestimmter Weise zirkuliert.

Den überwiegenden Raum in der vorliegenden Mitteilung nimmt die Besprechung der Grundlagen eines Gastrennverfahrens (I. bis III. Kapitel) ein, bei welchem der Einzeleffekt (der vervielfacht werden soll) durch ein starkes künstliches Schwerefeld (I. Kapitel) hervorgerufen wird. Das Schwerefeld wird in einem rasch umlaufenden Zentrifugenkörper erzeugt. Es ergibt sich dabei als zufällige Besonderheit dieses Verfahrens, daß außer dem die Gastrennung verursachenden Einzeleffekt auch der für die Multiplikation dieses Effektes erforderliche Gasumlauf durch dasselbe Schwerefeld hervorgebracht werden kann (Thermokonvektion).

A multiplication method is given by means of which it is generally possible to multiply weak demixing effects occurring in gas mixtures (isotope mixtures), such as those observed, for example, under the influence of a gravitational field or a temperature gradient (single effects), to any desired extent and thus to complete a decomposition of a mixture which is only imperfect in the single effect to any desired extent. It is an essential part of the process that the mixture circulates in a certain way within the cavity in which it is enclosed.

Most of the present communication deals with the fundamentals of a gas separation process (Chapters I to III) in which the single effect (which is to be multiplied) is caused by a strong artificial gravitational field (Chapter I). The gravitational field is generated in a rapidly rotating centrifuge body. An incidental feature of this process is that, in addition to the single effect causing the gas separation, the gas circulation required for the multiplication of this effect can also be produced by the same gravitational field (thermoconvection).

Der Frage nach einer zweckmäßigen Erzeugung der Gaszirkulation kommt nur mittelbare Bedeutung zu. Von grundlegender Bedeutung sind demgegenüber die Vorgänge, die sich als Folge dieser Gaszirkulation ergeben. Ihre Verfolgung an Hand des mitgeteilten Zentrifugenverfahrens führt auf ein Multiplikationsprinzip, welches allgemeinerer Anwendung fähig ist. Die Wirkungsweise dieses Prinzipes wird daher (im II. und III. Kapitel) besonders eingehend behandelt. Daneben werden auch speziellere Fragestellungen diskutiert, sofern diese einen wesentlichen Beitrag zur Lösung des Problems einer wirksamen Gastrennung im Schwerefeld darstellen. Hierher gehört außer der schon erwähnten Frage nach der Hervorbringung der Gaszirkulation insbesondere die Diskussion des Einflusses spezieller (zylindersymmetrischer) Hohlraumformen, wie sie durch die Notwendigkeit der Unterbringung des Gasgemisches in einem rasch rotierenden Zentrifugenkörper nahegelegt werden.

Das Multiplikationsprinzip läßt sich auf zweierlei Weise realisieren, und zwar entweder dadurch, daß der Gesamthohlraum durch Zwischenwände, die geeignete Öffnungen für die Gaszirkulation tragen, in eine größere Anzahl von Einzelkammern unterteilt wird (II. Kapitel), oder dadurch, daß dem Hohlraum eine besonders langgestreckte Form erteilt wird (III. Kapitel). Für den Trennvorgang bei jeder dieser Methoden wird eine einfache, durch Übersichtlichkeit ausgezeichnete Theorie entwickelt, aus welcher sich eine Reihe von quantitativen Ergebnissen ableitet, die die Leistungsfähigkeit der Methode hinsichtlich Trenngüte und Mengenumsatz in Abhängigkeit von den Arbeitsbedingungen und Apparatdimensionierungen zu beurteilen gestatten. Die gemeinsamen und unterscheidenden Merkmale der beiden Methoden werden besprochen.

The question of the appropriate generation of gas circulation is only of indirect importance. In contrast, the processes that occur as a result of this gas circulation are of fundamental importance. Tracing them on the basis of the centrifuge process described leads to a multiplication principle which is capable of more general application. The mode of operation of this principle is therefore dealt with in particular detail (in Chapters II and III). In addition, more specific questions are also discussed, provided that they make a significant contribution to solving the problem of effective gas separation in the gravitational field. In addition to the aforementioned question of how gas circulation is brought about, this includes in particular the discussion of the influence of special (cylindrically symmetrical) cavity shapes, as suggested by the need to accommodate the gas mixture in a rapidly rotating centrifuge body.

The multiplication principle can be realized in two ways, either by subdividing the total cavity into a larger number of individual chambers by means of partitions with suitable openings for gas circulation (Chapter II), or by giving the cavity a particularly elongated shape (Chapter III). For the separation process in each of these methods, a simple theory is developed which is characterized by clarity and from which a series of quantitative results are derived which allow the efficiency of the method to be assessed in terms of separation quality and volume conversion as a function of the working conditions and apparatus dimensions. The common and distinguishing features of the two methods are discussed.

Zum Schlusse (IV. Kapitel) werden die gewonnenen Ergebnisse, soweit sie nicht ausdrücklich den besonderen Verhältnissen auf Zentrifugenkörpern Rechnung tragen, auf das CLUSIUSsche Gastrennverfahren, bei welchem der Einzeleffekt durch Thermodiffusion anstatt Gravitationsdiffusion hervorgerufen wird, übertragen. Im Anschluß an eine vergleichende Diskussion, als deren Ergebnis unter anderem namentlich der im Vergleich zum Zentrifugenverfahren äußerst geringe (theoretische) Nutzeffekt des thermischen Verfahrens zu nennen ist, wird an Hand einer Reihe von in Frage kommenden Maßnahmen eingehend untersucht, ob sich der Nutzeffekt des Thermodiffusionsverfahrens unter Umständen erhöhen läßt. Eine solche Möglichkeit besteht grundsätzlich nicht.

Die verschiedenen zum Zwecke der Trennung von Gasgemischen möglichen Kombinationen eines Schwerefeldes mit einem Temperaturgefälle werden diskutiert.

Finally (Chapter IV), the results obtained are transferred to the CLUSIUS gas separation process, in which the individual effect is caused by thermal diffusion instead of gravitational diffusion, insofar as they do not expressly take into account the special conditions on centrifuge bodies. Following a comparative discussion, one of the results of which is the extremely low (theoretical) efficiency of the thermal process compared to the centrifuge process, a series of possible measures are used to examine in detail whether the efficiency of the thermal diffusion process can be increased under certain circumstances. In principle, there is no such possibility.

The various possible combinations of a gravity field with a temperature gradient for the purpose of separating gas mixtures are discussed.

Werner Kuhn and Hans Martin. 1941. Temperaturabhängigkeit der Adsorbierbarkeit als Mittel zur laufenden Fraktionierung oder Konzentrierung von Lösungen. *Zeitschrift für Physikalische Chemie A* 189:317–326. See p. 3526.

In Verallgemeinerung eines bisher in Spezialfällen angewandten Prinzips wird gezeigt: wenn sich in einem homogenen oder heterogenen System unter bestimmten, stationär aufrecht erhaltbaren Bedingungen (Kraftfelder, Temperaturgradienten usw.) ein Zustand herausbildet, bei welchem an den im Abstand $a/2$ (Abb. 1) befindlichen Punkten P_1 und P_2 ein Unterschied $(1 + \delta)$ in er relativen Konzentration eines in dem System vorhandenen Bestandteiles auftritt, so läßt sich der zunächst vorhandene Unterschied durch eine in dem System hervorgerufene und aufrecht gehaltene Bewegung in grundsätzlich beliebigem Maße steigern. Die anzuwendenden Geschwindigkeiten lassen sich in Abhängigkeit von den gewählten Dimensionierungen des Systems sowie in Abhängigkeit von dem im System maßgebenden Diffusionskoeffizienten angeben.

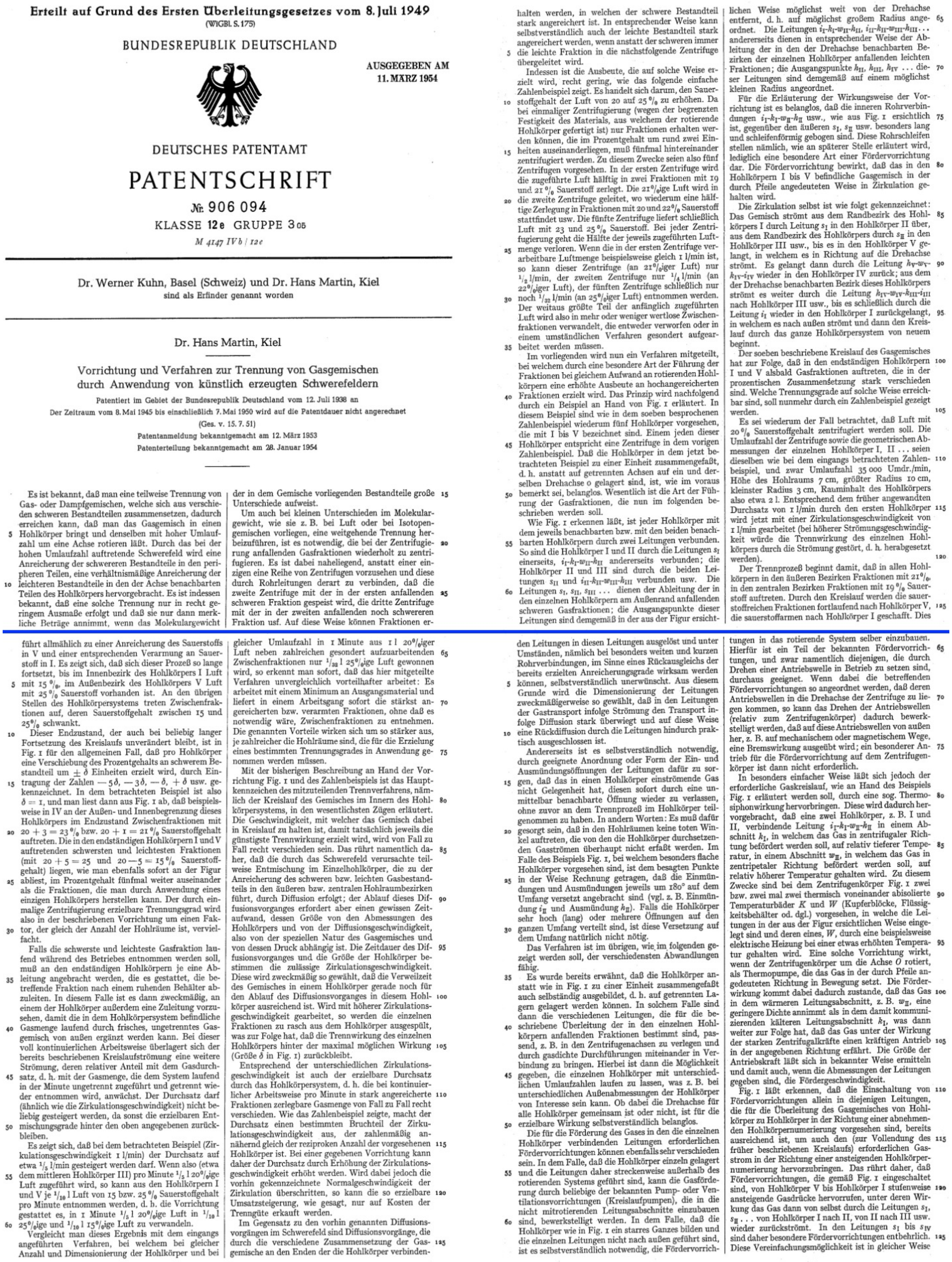
Als Beispiel wird besprochen die Racemattrennung, durchgeführt auf Grund davon, daß der Temperaturkoeffizient der Adsorbierbarkeit der d-Form eines aktiven gelösten Stoffes sich von Temperaturkoeffizienten der l-Form unterscheidet, falls als Adsorptionsmittel ein optisch aktiver fester Stoff gewählt wird.

Es werden ein Apparat und Versuche beschrieben, bei welchen eine teilweise Spaltung racemischer Mandelsäure unter Verwendung von Wolle als Adsorptionsmittel durchgeführt wird.

Generalizing a principle previously applied in special cases, the following is shown: if a state develops in a homogeneous or heterogeneous system under certain conditions (force fields, temperature gradients, etc.) that can be maintained in a stationary state, in which a difference $(1 + \delta)$ in the relative concentration of a component present in the system occurs at the points P_1 and P_2 located at $a/2$ (Fig. 1), the initially existing difference can be increased to any extent by a movement caused and maintained in the system. The velocities to be applied can be specified as a function of the selected dimensions of the system and as a function of the decisive diffusion coefficient in the system.

As an example, racemate separation is discussed, carried out on the basis that the temperature coefficient of adsorbability of the d-form of an active solute differs from temperature coefficients of the l-form if an optically active solid is chosen as adsorbent.

An apparatus and experiments are described in which partial cleavage of racemic mandelic acid is carried out using wool as the adsorbent.



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Dr. Werner Kuhn, Basel (Schweiz) und Dr. Hans Martin, Kiel
sind als Erfinder genannt worden

Dr. Hans Martin, Kiel

Vorrichtung und Verfahren zur Trennung von Gasgemischen durch Anwendung von künstlich erzeugten Schwerefeldern

Patentiert im Gebiet der Bundesrepublik Deutschland vom 12. Juli 1938 an
Der Zeitraum vom 8. Mai 1945 bis einschließlich 7. Mai 1950 wird auf die Patentdauer nicht angerechnet
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Es ist bekannt, daß man eine teilweise Trennung von Gas- oder Dampfgemischen, welche sich aus verschieden schweren Bestandteilen zusammensetzen, dadurch erreichen kann, daß man das Gasgemisch in einen Hohlkörper bringt und denselben mit hoher Umlaufzahl um eine Achse rotieren läßt. Durch das bei der hohen Umlaufzahl auftretende Schwerefeld wird eine Anreicherung der schwereren Bestandteile in den peripheren Teilen, eine verhältnismäßige Anreicherung der leichteren Bestandteile in den der Achse benachbarten Teilen des Hohlkörpers hervorgebracht. Es ist indessen bekannt, daß eine solche Trennung nur in recht geringem Ausmaße erfolgt und daß sie nur dann merkliche Beträge annimmt, wenn das Molekulargewicht der in dem Gemische vorliegenden Bestandteile große Unterschiede aufweist.

Um auch bei kleinen Unterschieden im Molekulargewicht, wie sie z. B. bei Luft oder bei Isotopengemischen vorliegen, eine weitgehende Trennung herbeizuführen, ist es notwendig, die bei der Zentrifugierung anfallenden Gasfraktionen wiederholt zu zentrifugieren. Es ist dabei naheliegend, anstatt einer einzigen eine Reihe von Zentrifugen vorzusehen und diese durch Rohrleitungen derart zu verbinden, daß die zweite Zentrifuge mit der in der ersten anfallenden schweren Fraktion gespeist wird, die dritte Zentrifuge mit der in der zweiten anfallenden noch schwereren Fraktion usf. Auf diese Weise können Fraktionen erhalten werden, in welchen der schwere Bestandteil stark angereichert ist. In entsprechender Weise kann selbstverständlich auch der leichte Bestandteil stark angereichert werden, wenn anstatt der schweren immer die leichte Fraktion in die nächstfolgende Zentrifuge übergeleitet wird.

Indessen ist die Ausbeute, die auf solche Weise erzielt wird, recht gering, wie das folgende einfache Zahlenbeispiel zeigt. Es handelt sich darum, den Sauerstoffgehalt der Luft von 20 auf 25 % zu erhöhen. Da bei einmaliger Zentrifugierung (wegen der begrenzten Festigkeit des Materials, aus welchem der rotierende Hohlkörper gefertigt ist) nur Fraktionen erhalten werden können, die im Prozentgehalt um rund zwei Einheiten auseinanderliegen, muß fünfmal hintereinander zentrifugiert werden. Zu diesem Zwecke seien also fünf Zentrifugen vorgesehen. In der ersten Zentrifuge wird die zugeführte Luft hälftig in zwei Fraktionen mit 19 und 21 % Sauerstoff zerlegt. Die 21 %ige Luft wird in die zweite Zentrifuge geleitet, wo wiederum eine hälftige Zerlegung in Fraktionen mit 20 und 22 % Sauerstoff stattfindet usw. Die fünfte Zentrifuge liefert schließlich Luft mit 23 und 25 % Sauerstoff. Bei jeder Zentrifugierung geht die Hälfte der jeweils zugeführten Luftmenge verloren. Wenn die in der ersten Zentrifuge verarbeitbare Luftmenge beispielsweise gleich 1 l/min ist, so kann dieser Zentrifuge (an 21 %iger Luft) nur $^1/_2$ l/min, der zweiten Zentrifuge nur $^1/_4$ l/min (an 22 %iger Luft), der fünften Zentrifuge schließlich nur noch $^1/_{32}$ l/min (an 25 %iger Luft) entnommen werden. Der weitaus größte Teil der anfänglich zugeführten Luft wird also in mehr oder weniger wertlose Zwischenfraktionen verwandelt, die entweder verworfen oder in einem umständlichen Verfahren gesondert aufgearbeitet werden müssen.

Im vorliegenden wird nun ein Verfahren mitgeteilt, bei welchem durch eine besondere Art der Führung der Fraktionen bei gleichem Aufwand an rotierenden Hohlkörpern eine erhöhte Ausbeute an hochangereicherten Fraktionen erzielt wird. Das Prinzip wird nachfolgend durch ein Beispiel an Hand von Fig. 1 erläutert. In diesem Beispiel sind wie in dem soeben besprochenen Zahlenbeispiel wiederum fünf Hohlkörper vorgesehen, die mit I bis V bezeichnet sind. Einem jeden dieser Hohlkörper entspricht eine Zentrifuge in dem vorigen Zahlenbeispiel. Daß die Hohlkörper in dem jetzt betrachteten Beispiel zu einer Einheit zusammengefaßt, d. h. anstatt auf getrennten Achsen auf ein und derselben Drehachse o gelagert sind, ist, wie im voraus bemerkt sei, belanglos. Wesentlich ist die Art der Führung der Gasfraktionen, die nun im folgenden beschrieben werden soll.

Wie Fig. 1 erkennen läßt, ist jeder Hohlkörper mit dem jeweils benachbarten bzw. mit den beiden benachbarten Hohlkörpern durch zwei Leitungen verbunden. So sind die Hohlkörper I und II durch die Leitungen s_I einerseits, i_I-k_I-w_{II}-h_{II} andererseits verbunden; die Hohlkörper II und III sind durch die beiden Leitungen s_{II} und i_{II}-k_{II}-w_{III}-h_{III} verbunden usw. Die Leitungen s_I, s_{II}, s_{III} … dienen der Ableitung der in den einzelnen Hohlkörpern am Außenrand anfallenden schweren Gasfraktionen; die Ausgangspunkte dieser Leitungen sind demgemäß in der aus der Figur ersichtlichen Weise möglichst weit von der Drehachse entfernt, d. h. auf möglichst großem Radius angeordnet. Die Leitungen i_I-k_I-w_{II}-h_{II}, i_{II}-k_{II}-w_{III}-h_{III} … andererseits dienen in entsprechender Weise der Ableitung der in den der Drehachse benachbarten Bezirken der einzelnen Hohlkörper anfallenden leichten Fraktionen; die Ausgangspunkte h_{II}, h_{III}, h_{IV} … dieser Leitungen sind demgemäß auf einem möglichst kleinen Radius angeordnet.

Für die Erläuterung der Wirkungsweise der Vorrichtung ist es belanglos, daß die inneren Rohrverbindungen i_I-k_I-w_{II}-h_{II} usw., wie aus Fig. 1 ersichtlich ist, gegenüber den äußeren s_I, s_{II} usw. besonders lang und schleifenförmig gebogen sind. Diese Rohrschleifen stellen nämlich, wie an späterer Stelle erläutert wird, lediglich eine besondere Art einer Fördervorrichtung dar. Die Fördervorrichtung bewirkt, daß das in den Hohlkörpern I bis V befindliche Gasgemisch in der durch Pfeile angedeuteten Weise in Zirkulation gehalten wird.

Die Zirkulation selbst ist wie folgt gekennzeichnet: Das Gemisch strömt aus dem Randbezirk des Hohlkörpers I durch Leitung s_I in den Hohlkörper II über, aus dem Randbezirk des Hohlkörpers durch s_{II} in den Hohlkörper III usw., bis es in den Hohlkörper V gelangt, in welchem es in Richtung auf die Drehachse strömt. Es gelangt dann durch die Leitung h_V-w_V-k_{IV}-i_{IV} wieder in den Hohlkörper IV zurück; aus dem der Drehachse benachbarten Bezirk dieses Hohlkörpers strömt es weiter durch die Leitung h_{IV}-w_{IV}-k_{III}-i_{III} nach Hohlkörper III usw., bis es schließlich durch die Leitung i_I wieder in den Hohlkörper I zurückgelangt, in welchem es nach außen strömt und dann den Kreislauf durch das ganze Hohlkörpersystem von neuem beginnt.

Der soeben beschriebene Kreislauf des Gasgemisches hat zur Folge, daß in den endständigen Hohlkörpern I und V alsbald Gasfraktionen auftreten, die in der prozentischen Zusammensetzung stark verschieden sind. Welche Trennungsgrade auf solche Weise erreichbar sind, soll nunmehr durch ein Zahlenbeispiel gezeigt werden.

Es sei wiederum der Fall betrachtet, daß Luft mit 20 % Sauerstoffgehalt zentrifugiert werden soll. Die Umlaufzahl der Zentrifuge sowie die geometrischen Abmessungen der einzelnen Hohlkörper I, II … seien dieselben wie bei dem eingangs betrachteten Zahlenbeispiel, und zwar Umlaufzahl 35 000 Umdr./min, Höhe des Hohlraums 7 cm, größter Radius 10 cm, kleinster Radius 3 cm, Rauminhalt des Hohlkörpers also etwa 2 l. Entsprechend dem früher angewandten Durchsatz von 1 l/min durch den ersten Hohlkörper wird jetzt mit einer Zirkulationsgeschwindigkeit von 1 l/min gearbeitet (bei höherer Strömungsgeschwindigkeit würde die Trennwirkung des einzelnen Hohlkörpers durch die Strömung gestört, d. h. herabgesetzt werden).

Der Trennprozeß beginnt damit, daß in allen Hohlkörpern in den äußeren Bezirken Fraktionen mit 21 %, in den zentralen Bezirken Fraktionen mit 19 % Sauerstoff auftreten. Durch den Kreislauf werden die sauerstoffreichen Fraktionen fortlaufend nach Hohlkörper V, die sauerstoffarmen nach Hohlkörper I geschafft. Dies führt allmählich zu einer Anreicherung des Sauerstoffs in V und einer entsprechenden Verarmung an Sauerstoff in I. Es zeigt sich, daß sich dieser Prozeß so lange fortsetzt, bis im Innenbezirk des Hohlkörpers I Luft mit 15 %, im Außenbezirk des Hohlkörpers V Luft mit 25 % Sauerstoff vorhanden ist. An den übrigen Stellen des Hohlkörpersystems treten Zwischenfraktionen auf, deren Sauerstoffgehalt zwischen 15 und 25 % schwankt.

Dieser Endzustand, der auch bei beliebig langer Fortsetzung des Kreislaufs unverändert bleibt, ist in Fig. 1 für den allgemeinen Fall, daß pro Hohlkörper eine Verschiebung des Prozentgehalts an schwerem Bestandteil um $\pm\,\delta$ Einheiten erzielt wird, durch Eintragung der Zahlen -5δ, -3δ, $-\delta$, $+\delta$ usw. gekennzeichnet. In dem betrachteten Beispiel ist also $\delta = 1$, und man liest dann aus Fig. 1 ab, daß beispielsweise in IV an der Außen- und Innenbegrenzung dieses Hohlkörpers im Endzustand Zwischenfraktionen mit $20 + 3 = 23$ % bzw. $20 + 1 = 21$ % Sauerstoffgehalt auftreten. Die in den endständigen Hohlkörpern I und V auftretenden schwersten und leichtesten Fraktionen (mit $20 + 5 = 25$ und $20 - 5 = 15$ % Sauerstoffgehalt) liegen, wie man ebenfalls sofort an der Figur abliest, im Prozentgehalt fünfmal weiter auseinander als die Fraktionen, die man durch Anwendung eines einzigen Hohlkörpers herstellen kann. Der durch einmalige Zentrifugierung erzielbare Trennungsgrad wird also in der beschriebenen Vorrichtung um einen Faktor, der gleich der Anzahl der Hohlräume ist, vervielfacht.

Falls die schwerste und leichteste Gasfraktion laufend während des Betriebes entnommen werden soll, muß an den endständigen Hohlkörpern je eine Ableitung angebracht werden, die es gestattet, die betreffende Fraktion nach einem ruhenden Behälter abzuleiten. In diesem Falle ist es dann zweckmäßig, an einem der Hohlkörper außerdem eine Zuleitung vorzusehen, damit die in dem Hohlkörpersystem befindliche Gasmenge laufend durch frisches, ungetrenntes Gasgemisch von außen ergänzt werden kann. Bei dieser voll kontinuierlichen Arbeitsweise überlagert sich der bereits beschriebenen Kreislaufströmung eine weitere Strömung, deren relativer Anteil mit dem Gasdurchsatz, d. h. mit der Gasmenge, die dem System laufend in der Minute ungetrennt zugeführt und getrennt wieder entnommen wird, anwächst. Der Durchsatz darf (ähnlich wie die Zirkulationsgeschwindigkeit) nicht beliebig gesteigert werden, da sonst die erzielbaren Entmischungsgrade hinter den oben angegebenen zurückbleiben.

Es zeigt sich, daß bei dem betrachteten Beispiel (Zirkulationsgeschwindigkeit 1 l/min) der Durchsatz auf etwa $^1/_5$ l/min gesteigert werden darf. Wenn also (etwa dem mittleren Hohlkörper III) pro Minute $^1/_5$ l 20 %ige Luft zugeführt wird, so kann aus den Hohlkörpern I und V je $^1/_{10}$ l Luft von 15 bzw. 25 % Sauerstoffgehalt pro Minute entnommen werden, d. h. die Vorrichtung gestattet es, in 1 Minute $^1/_5$ l 20 %ige Luft in $^1/_{10}$ l 25 %ige und $^1/_{10}$ l 15 %ige Luft zu verwandeln.

Vergleicht man dieses Ergebnis mit dem eingangs angeführten Verfahren, bei welchem bei gleicher Anzahl und Dimensionierung der Hohlkörper und bei gleicher Umlaufzahl in 1 Minute aus 1 l 20 %iger Luft neben zahlreichen gesondert aufzuarbeitenden Zwischenfraktionen nur $^1/_{32}$ l 25 %ige Luft gewonnen wird, so erkennt man sofort, daß das hier mitgeteilte Verfahren unvergleichlich vorteilhafter arbeitet: Es arbeitet mit einem Minimum an Ausgangsmaterial und liefert in einem Arbeitsgang sofort die stärkst angereicherten bzw. verarmten Fraktionen, ohne daß es notwendig wäre, Zwischenfraktionen zu entnehmen. Die genannten Vorteile wirken sich um so stärker aus, je zahlreicher die Hohlräume sind, die für die Erzielung eines bestimmten Trennungsgrades in Anwendung genommen werden müssen.

Mit der bisherigen Beschreibung an Hand der Vorrichtung Fig. 1 und des Zahlenbeispiels ist das Hauptkennzeichen des mitzuteilenden Trennverfahrens, nämlich der Kreislauf des Gemisches im Innern des Hohlkörpersystems, in den wesentlichsten Zügen erläutert. Die Geschwindigkeit, mit welcher das Gemisch dabei in Kreislauf zu halten ist, damit tatsächlich jeweils die günstigste Trennwirkung erzielt wird, wird von Fall zu Fall recht verschieden sein. Das rührt namentlich daher, daß die durch das Schwerefeld verursachte teilweise Entmischung im Einzelhohlkörper, die zu der Anreicherung des schweren bzw. leichten Gasbestandteils in den äußeren bzw. zentralen Hohlraumbezirken führt, durch Diffusion erfolgt; der Ablauf dieses Diffusionsvorganges erfordert aber einen gewissen Zeitaufwand, dessen Größe von den Abmessungen des Hohlkörpers und von der Diffusionsgeschwindigkeit, also von der speziellen Natur des Gasgemisches und von dessen Druck abhängig ist. Die Zeitdauer des Diffusionsvorganges und die Größe der Hohlkörper bestimmen die zulässige Zirkulationsgeschwindigkeit. Diese wird zweckmäßig so gewählt, daß die Verweilzeit des Gemisches in einem Hohlkörper gerade noch für den Ablauf des Diffusionsvorganges in diesem Hohlkörper ausreichend ist. Wird mit höherer Zirkulationsgeschwindigkeit gearbeitet, so werden die einzelnen Fraktionen zu rasch aus dem Hohlkörper ausgespült, was zur Folge hat, daß die Trennwirkung des einzelnen Hohlkörpers hinter der maximal möglichen Wirkung (Größe δ in Fig. 1) zurückbleibt.

Entsprechend der unterschiedlichen Zirkulationsgeschwindigkeit ist auch der erzielbare Durchsatz durch das Hohlkörpersystem, d. h. die bei kontinuierlicher Arbeitsweise pro Minute in stark angereicherte Fraktionen zerlegbare Gasmenge von Fall zu Fall recht verschieden. Wie das Zahlenbeispiel zeigte, macht der Durchsatz einen bestimmten Bruchteil der Zirkulationsgeschwindigkeit aus, der zahlenmäßig annähernd gleich der reziproken Anzahl der vorgesehenen Hohlkörper ist. Bei einer gegebenen Vorrichtung kann daher der Durchsatz durch Erhöhung der Zirkulationsgeschwindigkeit erhöht werden. Wird dabei jedoch die vorhin gekennzeichnete Normalgeschwindigkeit der Zirkulation überschritten, so kann die so erzielbare Umsatzsteigerung, wie gesagt, nur auf Kosten der Trenngüte erkauft werden.

Im Gegensatz zu den vorhin genannten Diffusionsvorgängen im Schwerefeld sind Diffusionsvorgänge, die durch die verschiedene Zusammensetzung der Gasgemische an den Enden der die Hohlkörper verbindenden Leitungen in diesen Leitungen ausgelöst und unter Umständen, nämlich bei besonders weiten und kurzen Rohrverbindungen, im Sinne eines Rückausgleichs der bereits erzielten Anreicherungsgrade wirksam werden können, selbstverständlich unerwünscht. Aus diesem Grunde wird die Dimensionierung der Leitungen zweckmäßigerweise so gewählt, daß in den Leitungen der Gastransport infolge Strömung den Transport infolge Diffusion stark überwiegt und auf diese Weise eine Rückdiffusion durch die Leitungen hindurch praktisch ausgeschlossen ist.

Andererseits ist es selbstverständlich notwendig, durch geeignete Anordnung oder Form der Ein- und Ausmündungsöffnungen der Leitungen dafür zu sorgen, daß das in einen Hohlkörper einströmende Gas nicht Gelegenheit hat, diesen sofort durch eine unmittelbar benachbarte Öffnung wieder zu verlassen, ohne zuvor an dem Trennprozeß im Hohlkörper teilgenommen zu haben. In andern Worten: Es muß dafür gesorgt sein, daß in den Hohlräumen keine toten Winkel auftreten, die von den die Hohlkörper durchsetzenden Gasströmen überhaupt nicht erfaßt werden. Im Falle des Beispiels Fig. 1, bei welchem besonders flache Hohlkörper vorgesehen sind, ist dem besagten Punkte in der Weise Rechnung getragen, daß die Einmündungen und Ausmündungen jeweils um 180° auf dem Umfang versetzt angebracht sind (vgl. z. B. Einmündung i_{II} und Ausmündung h_{II}). Falls die Hohlkörper sehr hoch (lang) oder mehrere Öffnungen auf den ganzen Umfang verteilt sind, ist diese Versetzung auf dem Umfang natürlich nicht nötig.

Das Verfahren ist im übrigen, wie im folgenden gezeigt werden soll, der verschiedensten Abwandlungen fähig.

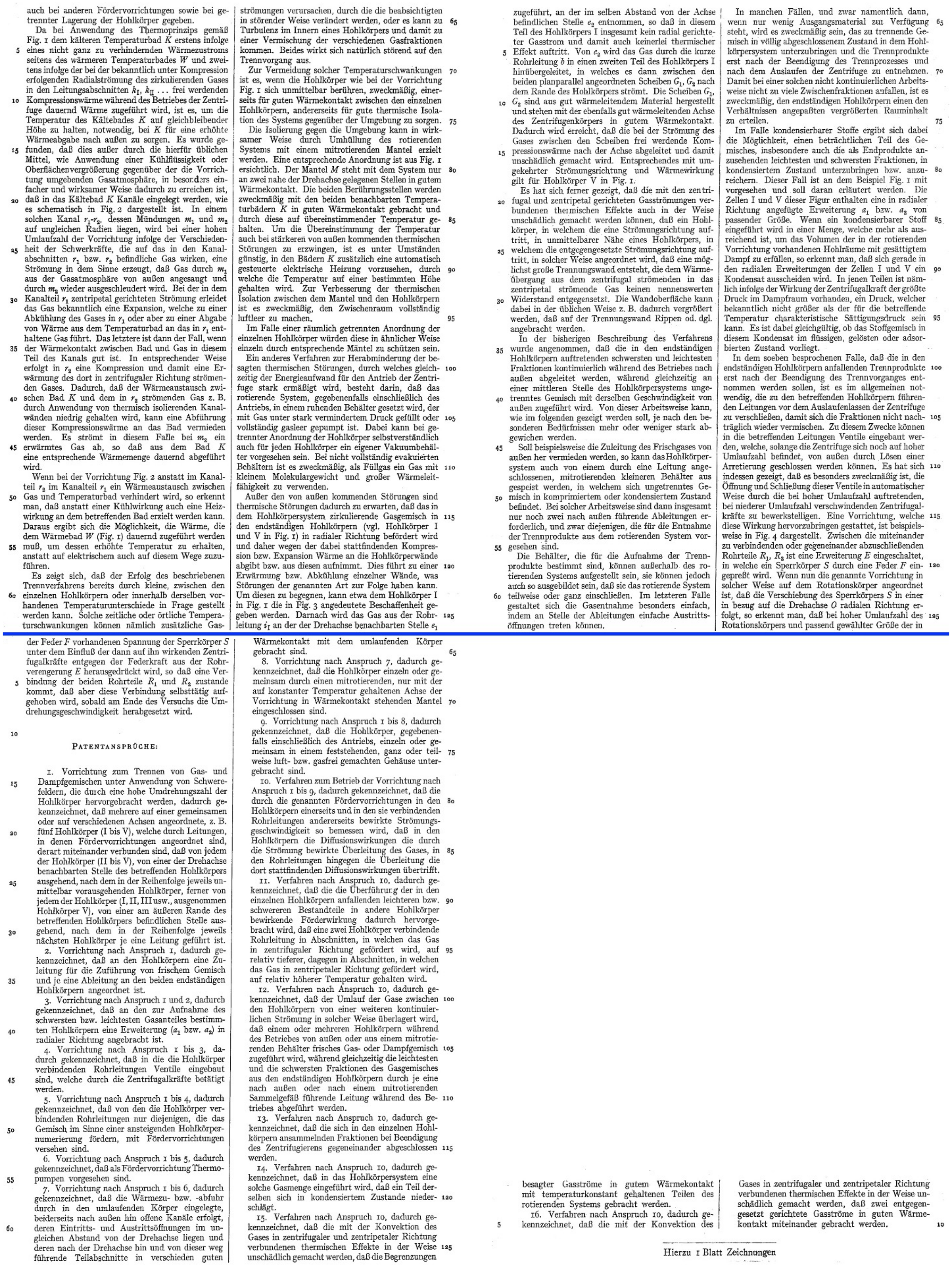
Es wurde bereits erwähnt, daß die Hohlkörper anstatt wie in Fig. 1 zu einer Einheit zusammengefaßt auch selbständig ausgebildet, d. h. auf getrennten Lagern gelagert werden können. In solchem Falle sind dann die verschiedenen Leitungen, die für die beschriebene Überleitung der in den einzelnen Hohlkörpern anfallenden Fraktionen bestimmt sind, passend, z. B. in den Zentrifugenachsen zu verlegen und durch gasdichte Durchführungen miteinander in Verbindung zu bringen. Hierbei ist dann die Möglichkeit gegeben, die einzelnen Hohlkörper mit unterschiedlichen Umlaufzahlen laufen zu lassen, was z. B. bei unterschiedlichen Außenabmessungen der Hohlkörper von Interesse sein kann. Ob dabei die Drehachse für alle Hohlkörper gemeinsam ist oder nicht, ist für die erzielbare Wirkung selbstverständlich belanglos.

Die für die Förderung des Gases in den die einzelnen Hohlkörper verbindenden Leitungen erforderlichen Fördervorrichtungen können ebenfalls sehr verschieden sein. In dem Falle, daß die Hohlkörper einzeln gelagert und die Leitungen daher streckenweise außerhalb des rotierenden Systems geführt sind, kann die Gasförderung durch beliebige der bekannten Pump- oder Ventilationsvorrichtungen (Kreislaufpumpen), die in die nicht mitrotierenden Leitungsabschnitte einzubauen sind, bewerkstelligt werden. In dem Falle, daß die Hohlkörper wie in Fig. 1 ein starres Ganzes bilden und die einzelnen Leitungen nicht nach außen geführt sind, ist es selbstverständlich notwendig, die Fördervorrichtungen in das rotierende System selber einzubauen. Hierfür ist ein Teil der bekannten Fördervorrichtungen, und zwar namentlich diejenigen, die durch Drehen einer Antriebswelle in Betrieb zu setzen sind, durchaus geeignet. Wenn dabei die betreffenden Fördervorrichtungen so angeordnet werden, daß deren Antriebswellen in die Drehachse der Zentrifuge zu liegen kommen, so kann das Drehen der Antriebswellen (relativ zum Zentrifugenkörper) dadurch bewerkstelligt werden, daß auf diese Antriebswellen von außen her, z. B. auf mechanischem oder magnetischem Wege, eine Bremswirkung ausgeübt wird; ein besonderer Antrieb für die Fördervorrichtung auf dem Zentrifugenkörper ist dann nicht erforderlich.

In besonders einfacher Weise läßt sich jedoch der erforderliche Gaskreislauf, wie an Hand des Beispiels Fig. 1 erläutert werden soll, durch eine sog. Thermosiphonwirkung hervorbringen. Diese wird dadurch hervorgebracht, daß eine zwei Hohlkörper, z. B. I und II, verbindende Leitung i_I-k_I-w_{II}-h_{II} in einem Abschnitt k_I, in welchem das Gas in zentrifugaler Richtung befördert werden soll, auf relativ tieferer Temperatur, in einem Abschnitt w_{II}, in welchem das Gas in zentripetaler Richtung befördert werden soll, auf relativ höherer Temperatur gehalten wird. Zu diesem Zwecke sind bei dem Zentrifugenkörper Fig. 1 zwei bzw. zwei mal zwei thermisch voneinander abisolierte Temperaturbäder K und W (Kupferblöcke, Flüssigkeitsbehälter od. dgl.) vorgesehen, in welche die Leitungen in der aus der Figur ersichtlichen Weise eingelegt sind und deren eines, W, durch eine beispielsweise elektrische Heizung bei einer etwas erhöhten Temperatur gehalten wird. Eine solche Vorrichtung wirkt, wenn der Zentrifugenkörper um die Achse O rotiert, als Thermopumpe, die das Gas in der durch Pfeile angedeuteten Richtung in Bewegung setzt. Die Förderwirkung kommt dabei dadurch zustande, daß das Gas in dem wärmeren Leitungsabschnitt, z. B. w_{II}, eine geringere Dichte annimmt als in dem damit kommunizierenden kälteren Leitungsabschnitt k_I, was dann weiter zur Folge hat, daß das Gas unter der Wirkung der starken Zentrifugalkräfte einen kräftigen Antrieb in der angegebenen Richtung erfährt. Die Größe der Antriebskraft läßt sich in bekannter Weise ermitteln und damit auch, wenn die Abmessungen der Leitungen gegeben sind, die Fördergeschwindigkeit.

Fig. 1 läßt erkennen, daß die Einschaltung von Fördervorrichtungen allein in diejenigen Leitungen, die für die Überleitung des Gasgemisches von Hohlkörper zu Hohlkörper in der Richtung einer abnehmenden Hohlkörpernumerierung vorgesehen sind, bereits ausreichend ist, um auch den (zur Vollendung des früher beschriebenen Kreislaufs) erforderlichen Gasstrom in der Richtung einer ansteigenden Hohlkörpernumerierung hervorzubringen. Das rührt daher, daß Fördervorrichtungen, die gemäß Fig. 1 eingeschaltet sind, von Hohlkörper V bis Hohlkörper I stufenweise ansteigende Gasdrücke hervorrufen, unter deren Wirkung das Gas dann von selbst durch die Leitungen s_I, s_{II} … von Hohlkörper I nach II, von II nach III usw. wieder zurückströmt. In den Leitungen s_I bis s_{IV} sind daher besondere Fördervorrichtungen entbehrlich. Diese Vereinfachungsmöglichkeit ist in gleicher Weise

Figure D.143: Patent on gas centrifuges filed by Werner Kuhn and Hans Martin in 1938 [German Patent DE 906,094].



auch bei anderen Fördervorrichtungen sowie bei getrennter Lagerung der Hohlkörper gegeben.

Da bei Anwendung des Thermoprinzips gemäß Fig. 1 dem kälteren Temperaturbad K erstens infolge eines nicht ganz zu verhindernden Wärmezustroms seitens des wärmeren Temperaturbades W und zweitens infolge der bei der bekanntlich unter Kompression erfolgenden Radialströmung des zirkulierenden Gases in den Leitungsabschnitten k_{I}, k_{II} ... frei werdenden Kompressionswärme während des Betriebes der Zentrifuge dauernd Wärme zugeführt wird, ist es, um die Temperatur des Kältebades K auf gleichbleibender Höhe zu halten, notwendig, bei K für eine erhöhte Wärmeabgabe nach außen zu sorgen. Es wurde gefunden, daß dies außer durch die hierfür üblichen Mittel, wie Anwendung einer Kühlflüssigkeit oder Oberflächenvergrößerung gegenüber der die Vorrichtung umgebenden Gasatmosphäre, in besonders einfacher und wirksamer Weise dadurch zu erreichen ist, daß in das Kältebad K Kanäle eingelegt werden, wie es schematisch in Fig. 2 dargestellt ist. In einem solchen Kanal r_1-r_2, dessen Mündungen m_1 und m_2 auf ungleichen Radien liegen, wird bei einer hohen Umlaufzahl der Vorrichtung infolge der Verschiedenheit der Schwerkräfte, die auf das in den Kanalabschnitten r_1 bzw. r_2 befindliche Gas wirken, eine Strömung in dem Sinne erzeugt, daß Gas durch m_1 aus der Gasatmosphäre von außen angesaugt und durch m_2 wieder ausgeschleudert wird. Bei der in dem Kanalteil r_1 zentripetal gerichteten Strömung erleidet das Gas bekanntlich eine Expansion, welche zu einer Abkühlung des Gases in r_1 oder aber zu einer Abgabe von Wärme aus dem Temperaturbad an das in r_1 enthaltene Gas führt. Das letztere ist dann der Fall, wenn der Wärmekontakt zwischen Bad und Gas in diesem Teil des Kanals gut ist. In entsprechender Weise erfolgt in r_2 eine Kompression und damit eine Erwärmung des dort in zentrifugaler Richtung strömenden Gases. Dadurch, daß der Wärmeaustausch zwischen Bad K und dem in r_2 strömenden Gas z. B. durch Anwendung von thermisch isolierenden Kanalwänden niedrig gehalten wird, kann eine Abführung dieser Kompressionswärme an das Bad vermieden werden. Es strömt in diesem Falle bei m_2 ein erwärmtes Gas ab, so daß aus dem Bad K eine entsprechende Wärmemenge dauernd abgeführt wird.

Wenn bei der Vorrichtung Fig. 2 anstatt im Kanalteil r_2 im Kanalteil r_1 ein Wärmeaustausch zwischen Gas und Temperaturbad verhindert wird, so erkennt man, daß anstatt einer Kühlwirkung auch eine Heizwirkung an dem betreffenden Bad erzielt werden kann. Daraus ergibt sich die Möglichkeit, die Wärme, die dem Wärmebad W (Fig. 1) dauernd zugeführt werden muß, um dessen erhöhte Temperatur zu erhalten, anstatt auf elektrischem auch auf diesem Wege zuzuführen.

Es zeigt sich, daß der Erfolg des beschriebenen Trennverfahrens bereits durch kleine, zwischen den einzelnen Hohlkörpern oder innerhalb derselben vorhandenen Temperaturunterschiede in Frage gestellt werden kann. Solche zeitliche oder örtliche Temperaturschwankungen können nämlich zusätzliche Gasströmungen verursachen, durch die die beabsichtigten in störender Weise verändert werden, oder es kann zu Turbulenz im Innern eines Hohlkörpers und damit zu einer Vermischung der verschiedenen Gasfraktionen kommen. Beides wirkt sich natürlich störend auf den Trennvorgang aus.

Zur Vermeidung solcher Temperaturschwankungen ist es, wenn die Hohlkörper wie bei der Vorrichtung Fig. 1 sich unmittelbar berühren, zweckmäßig, einerseits für guten Wärmekontakt zwischen den einzelnen Hohlkörpern, andererseits für gute thermische Isolation des Systems gegenüber der Umgebung zu sorgen.

Die Isolierung gegen die Umgebung kann in wirksamer Weise durch Umhüllung des rotierenden Systems mit einem mitrotierenden Mantel erzielt werden. Eine entsprechende Anordnung ist aus Fig. 1 ersichtlich. Der Mantel M steht mit dem System nur an zwei nahe der Drehachse gelegenen Stellen in gutem Wärmekontakt. Die beiden Berührungsstellen werden zweckmäßig mit den beiden benachbarten Temperaturbädern K in guten Wärmekontakt gebracht und durch diese auf übereinstimmender Temperatur gehalten. Um die Übereinstimmung der Temperatur auch bei stärkeren von außen kommenden thermischen Störungen zu erzwingen, ist es unter Umständen günstig, in den Bädern K zusätzlich eine automatisch gesteuerte elektrische Heizung vorzusehen, durch welche die Temperatur auf einer bestimmten Höhe gehalten wird. Zur Verbesserung der thermischen Isolation zwischen dem Mantel und den Hohlkörpern ist es zweckmäßig, den Zwischenraum vollständig luftleer zu machen.

Im Falle einer räumlich getrennten Anordnung der einzelnen Hohlkörper würden diese in ähnlicher Weise einzeln durch entsprechende Mäntel zu schützen sein.

Ein anderes Verfahren zur Herabminderung der besagten thermischen Störungen, durch welches gleichzeitig der Energieaufwand für den Antrieb der Zentrifuge stark ermäßigt wird, besteht darin, daß das rotierende System, gegebenenfalls einschließlich des Antriebs, in einem ruhenden Behälter gesetzt wird, der mit Gas unter stark vermindertem Druck gefüllt oder vollständig gasleer gepumpt ist. Dabei kann bei getrennter Anordnung der Hohlkörper selbstverständlich auch für jeden Hohlkörper ein eigener Vakuumbehälter vorgesehen sein. Bei nicht vollständig evakuierten Behältern ist es zweckmäßig, als Füllgas ein Gas mit kleinem Molekulargewicht und großer Wärmeleitfähigkeit zu verwenden.

Außer den von außen kommenden Störungen sind thermische Störungen dadurch zu erwarten, daß das in dem Hohlkörpersystem zirkulierende Gasgemisch in den endständigen Hohlkörpern (vgl. Hohlkörper I und V in Fig. 1) in radialer Richtung befördert wird und daher wegen der dabei stattfindenden Kompression bzw. Expansion Wärme an die Hohlkörperwände abgibt bzw. aus diesen aufnimmt. Dies führt zu einer Erwärmung bzw. Abkühlung einzelner Wände, was Störungen der genannten Art zur Folge haben kann. Um diesen zu begegnen, kann etwa dem Hohlkörper I in Fig. 1 die in Fig. 3 angedeutete Beschaffenheit gegeben werden. Darnach wird das Gas aus der Rohrleitung i_{I} an der der Drehachse benachbarten Stelle e_1 zugeführt, an der im selben Abstand von der Achse befindlichen Stelle e_2 entnommen, so daß in diesem Teil des Hohlkörpers I insgesamt kein radial gerichteter Gasstrom und damit auch keinerlei thermischer Effekt auftritt. Von e_2 wird das Gas durch die kurze Rohrleitung b in einen zweiten Teil des Hohlkörpers I hinübergeleitet, in welches es dann zwischen den beiden planparallel angeordneten Scheiben G_1, G_2 nach dem Rande des Hohlkörpers strömt. Die Scheiben G_1, G_2 sind aus gut wärmeleitendem Material hergestellt und stehen mit der ebenfalls gut wärmeleitenden Achse des Zentrifugenkörpers in gutem Wärmekontakt. Dadurch wird erreicht, daß die bei der Strömung des Gases zwischen den Scheiben frei werdende Kompressionswärme nach der Achse abgeleitet und damit unschädlich gemacht wird. Entsprechendes mit umgekehrter Strömungsrichtung und Wärmewirkung gilt für Hohlkörper V in Fig. 1.

Es hat sich ferner gezeigt, daß die mit den zentrifugal und zentripetal gerichteten Gasströmungen verbundenen thermischen Effekte auch in der Weise unschädlich gemacht werden können, daß ein Hohlkörper, in welchem die eine Strömungsrichtung auftritt, in unmittelbarer Nähe eines Hohlkörpers, in welchem die entgegengesetzte Strömungsrichtung auftritt, in solcher Weise angeordnet wird, daß eine möglichst große Trennungswand entsteht, die dem Wärmeübergang aus dem zentrifugal strömenden in das zentripetal strömende Gas keinen nennenswerten Widerstand entgegensetzt. Die Wandoberfläche kann dabei in der üblichen Weise z. B. dadurch vergrößert werden, daß auf der Trennungswand Rippen od. dgl. angebracht werden.

In der bisherigen Beschreibung des Verfahrens wurde angenommen, daß die in den endständigen Hohlkörpern auftretenden schwersten und leichtesten Fraktionen kontinuierlich während des Betriebes nach außen abgeleitet werden, während gleichzeitig an einer mittleren Stelle des Hohlkörpersystems ungetrenntes Gemisch mit derselben Geschwindigkeit von außen zugeführt wird. Von dieser Arbeitsweise kann, wie im folgenden gezeigt werden soll, je nach den besonderen Bedürfnissen mehr oder weniger stark abgewichen werden.

Soll beispielsweise die Zuleitung des Frischgases von außen her vermieden werden, so kann das Hohlkörpersystem auch von einem durch eine Leitung angeschlossenen, mitrotierenden kleineren Behälter aus gespeist werden, in welchem sich ungetrenntes Gemisch in komprimiertem oder kondensiertem Zustand befindet. Bei solcher Arbeitsweise sind dann insgesamt nur noch zwei nach außen führende Ableitungen erforderlich, und zwar diejenigen, die für die Entnahme der Trennprodukte aus dem rotierenden System vorgesehen sind.

Die Behälter, die für die Aufnahme der Trennprodukte bestimmt sind, können außerhalb des rotierenden Systems aufgestellt sein, sie können jedoch auch so ausgebildet sein, daß sie das rotierende System teilweise oder ganz einschließen. Im letzteren Falle gestaltet sich die Gasentnahme besonders einfach, indem an Stelle der Ableitungen einfache Austrittsöffnungen treten können.

In manchen Fällen, und zwar namentlich dann, wenn nur wenig Ausgangsmaterial zur Verfügung steht, wird es zweckmäßig sein, das zu trennende Gemisch in völlig abgeschlossenem Zustand in dem Hohlkörpersystem unterzubringen und die Trennprodukte erst nach der Beendigung des Trennprozesses und nach dem Auslaufen der Zentrifuge zu entnehmen. Damit bei einer solchen nicht kontinuierlichen Arbeitsweise nicht zu viele Zwischenfraktionen anfallen, ist es zweckmäßig, den endständigen Hohlkörpern einen den Verhältnissen angepaßten vergrößerten Rauminhalt zu erteilen.

Im Falle kondensierbarer Stoffe ergibt sich dabei die Möglichkeit, einen beträchtlichen Teil des Gemisches, insbesondere auch die als Endprodukte anzusehenden leichtesten und schwersten Fraktionen, in kondensiertem Zustand unterzubringen bzw. anzureichern. Dieser Fall ist an dem Beispiel Fig. 1 mit vorgesehen und soll daran erläutert werden. Die Zellen I und V dieser Figur enthalten eine in radialer Richtung angefügte Erweiterung a_1 bzw. a_2 von passender Größe. Wenn ein kondensierbarer Stoff eingeführt wird in einer Menge, welche mehr als ausreichend ist, um das Volumen der in der rotierenden Vorrichtung vorhandenen Hohlräume mit gesättigtem Dampf zu erfüllen, so erkennt man, daß sich gerade in den radialen Erweiterungen der Zellen I und V ein Kondensat ausscheiden wird. In jenen Teilen ist nämlich infolge der Wirkung der Zentrifugalkraft der größte Druck im Dampfraum vorhanden, ein Druck, welcher bekanntlich nicht größer als der für die betreffende Temperatur charakteristische Sättigungsdruck sein kann. Es ist dabei gleichgültig, ob das Stoffgemisch in diesem Kondensat im flüssigen, gelösten oder adsorbierten Zustand vorliegt.

In dem soeben besprochenen Falle, daß die in den endständigen Hohlkörpern anfallenden Trennprodukte erst nach der Beendigung des Trennvorganges entnommen werden sollen, ist es im allgemeinen notwendig, die zu den betreffenden Hohlkörpern führenden Leitungen vor dem Auslaufenlassen der Zentrifuge zu verschließen, damit sich die Fraktionen nicht nachträglich wieder vermischen. Zu diesem Zwecke können in die betreffenden Leitungen Ventile eingebaut werden, welche, solange die Zentrifuge sich noch auf hoher Umlaufzahl befindet, von außen durch Lösen einer Arretierung geschlossen werden können. Es hat sich indessen gezeigt, daß es besonders zweckmäßig ist, die Öffnung und Schließung dieser Ventile in automatischer Weise durch die bei hoher Umlaufzahl auftretenden, bei niederer Umlaufzahl verschwindenden Zentrifugalkräfte zu bewerkstelligen. Eine Vorrichtung, welche diese Wirkung hervorzubringen gestattet, ist beispielsweise in Fig. 4 dargestellt. Zwischen die miteinander zu verbindenden oder gegeneinander abzuschließenden Rohrteile R_1, R_2 ist eine Erweiterung E eingeschaltet, in welche ein Sperrkörper S durch eine Feder F eingepreßt wird. Wenn nun die genannte Vorrichtung in solcher Weise auf dem Rotationskörper angeordnet ist, daß die Verschiebung des Sperrkörpers S in einer in bezug auf die Drehachse O radialen Richtung erfolgt, so erkennt man, daß bei hoher Umlaufzahl des Rotationskörpers und passend gewählter Größe der in der Feder F vorhandenen Spannung der Sperrkörper S unter dem Einfluß der dann auf ihn wirkenden Zentrifugalkräfte entgegen der Federkraft aus der Rohrverengerung E herausgedrückt wird, so daß eine Verbindung der beiden Rohrteile R_1 und R_2 zustande kommt, daß aber diese Verbindung selbsttätig aufgehoben wird, sobald am Ende des Versuchs die Umdrehungsgeschwindigkeit herabgesetzt wird.

PATENTANSPRÜCHE:

1. Vorrichtung zum Trennen von Gas- und Dampfgemischen unter Anwendung von Schwerefeldern, die durch eine hohe Umdrehungszahl der Hohlkörper hervorgebracht werden, dadurch gekennzeichnet, daß mehrere auf einer gemeinsamen oder auf verschiedenen Achsen angeordnete, z. B. fünf Hohlkörper (I bis V), welche durch Leitungen, in denen Fördervorrichtungen angeordnet sind, derart miteinander verbunden sind, daß von jedem der Hohlkörper (II bis V), von einer der Drehachse benachbarten Stelle des betreffenden Hohlkörpers ausgehend, nach dem in der Reihenfolge jeweils unmittelbar vorausgehenden Hohlkörper, ferner von jedem der Hohlkörper (I, II, III usw., ausgenommen Hohlkörper V), von einer am äußeren Rande des betreffenden Hohlkörpers befindlichen Stelle ausgehend, nach dem in der Reihenfolge jeweils nächsten Hohlkörper je eine Leitung geführt ist.

2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß an den Hohlkörpern eine Zuleitung für die Zuführung von frischem Gemisch und je eine Ableitung an den beiden endständigen Hohlkörpern angeordnet ist.

3. Vorrichtung nach Anspruch 1 und 2, dadurch gekennzeichnet, daß an den zur Aufnahme des schwersten bzw. leichtesten Gasanteiles bestimmten Hohlkörpern eine Erweiterung (a_1 bzw. a_2) in radialer Richtung angebracht ist.

4. Vorrichtung nach Anspruch 1 bis 3, dadurch gekennzeichnet, daß in die die Hohlkörper verbindenden Rohrleitungen Ventile eingebaut sind, welche durch die Zentrifugalkräfte betätigt werden.

5. Vorrichtung nach Anspruch 1 bis 4, dadurch gekennzeichnet, daß von den die Hohlkörper verbindenden Rohrleitungen nur diejenigen, die das Gemisch im Sinne einer ansteigenden Hohlkörpernumerierung fördern, mit Fördervorrichtungen versehen sind.

6. Vorrichtung nach Anspruch 1 bis 5, dadurch gekennzeichnet, daß als Fördervorrichtung Thermopumpen vorgesehen sind.

7. Vorrichtung nach Anspruch 1 bis 6, dadurch gekennzeichnet, daß die Wärmezu- bzw. -abfuhr durch in den umlaufenden Körper eingelegte, beiderseits nach außen hin offene Kanäle erfolgt, deren Eintritts- und Austrittsöffnungen im ungleichen Abstand von der Drehachse liegen und deren nach der Drehachse hin und von dieser weg führende Teilabschnitte in verschieden guten Wärmekontakt mit dem umlaufenden Körper gebracht sind.

8. Vorrichtung nach Anspruch 7, dadurch gekennzeichnet, daß die Hohlkörper einzeln oder gemeinsam durch einen mitrotierenden, nur mit der auf konstanter Temperatur gehaltenen Achse der Vorrichtung in Wärmekontakt stehenden Mantel eingeschlossen sind.

9. Vorrichtung nach Anspruch 1 bis 8, dadurch gekennzeichnet, daß die Hohlkörper, gegebenenfalls einschließlich des Antriebs, einzeln oder gemeinsam in einem feststehenden, ganz oder teilweise luft- bzw. gasfrei gemachten Gehäuse untergebracht sind.

10. Verfahren zum Betrieb der Vorrichtung nach Anspruch 1 bis 9, dadurch gekennzeichnet, daß die durch die genannten Fördervorrichtungen in den Hohlkörpern einerseits und in den sie verbindenden Rohrleitungen andererseits bewirkte Strömungsgeschwindigkeit so bemessen wird, daß in den Hohlkörpern die Diffusionswirkungen die durch die Strömung bewirkte Überleitung des Gases, in den Rohrleitungen hingegen die Überleitung die dort stattfindenden Diffusionswirkungen übertrifft.

11. Verfahren nach Anspruch 10, dadurch gekennzeichnet, daß die die Überführung der in den einzelnen Hohlkörpern anfallenden leichteren bzw. schwereren Bestandteile in andere Hohlkörper bewirkende Förderwirkung dadurch hervorgebracht wird, daß eine zwei Hohlkörper verbindende Rohrleitung in Abschnitten, in welchen das Gas in zentrifugaler Richtung gefördert wird, auf relativ tieferer, dagegen in Abschnitten, in welchen das Gas in zentripetaler Richtung gefördert wird, auf relativ höherer Temperatur gehalten wird.

12. Verfahren nach Anspruch 10, dadurch gekennzeichnet, daß der Umlauf der Gase zwischen den Hohlkörpern von einer weiteren kontinuierlichen Strömung in solcher Weise überlagert wird, daß einem oder mehreren Hohlkörpern während des Betriebes von außen oder aus einem mitrotierenden Behälter frisches Gas- oder Dampfgemisch zugeführt wird, während gleichzeitig die leichtesten und die schwersten Fraktionen des Gasgemisches aus den endständigen Hohlkörpern durch je eine nach außen oder nach einem mitrotierenden Sammelgefäß führende Leitung während des Betriebes abgeführt werden.

13. Verfahren nach Anspruch 10, dadurch gekennzeichnet, daß die sich in den einzelnen Hohlkörpern ansammelnden Fraktionen bei Beendigung des Zentrifugierens gegeneinander abgeschlossen werden.

14. Verfahren nach Anspruch 10, dadurch gekennzeichnet, daß in das Hohlkörpersystem eine solche Gasmenge eingeführt wird, daß ein Teil derselben sich in kondensiertem Zustande niederschlägt.

15. Verfahren nach Anspruch 10, dadurch gekennzeichnet, daß die mit der Konvektion des Gases in zentrifugaler und zentripetaler Richtung verbundenen thermischen Effekte in der Weise unschädlich gemacht werden, daß die Begrenzungen besagter Gasströme in gutem Wärmekontakt mit temperaturkonstant gehaltenen Teilen des rotierenden Systems gebracht werden.

16. Verfahren nach Anspruch 10, dadurch gekennzeichnet, daß die mit der Konvektion des Gases in zentrifugaler und zentripetaler Richtung verbundenen thermischen Effekte in der Weise unschädlich gemacht werden, daß zwei entgegengesetzt gerichtete Gasströme in guten Wärmekontakt miteinander gebracht werden.

Hierzu 1 Blatt Zeichnungen

Figure D.144: Patent on gas centrifuges filed by Werner Kuhn and Hans Martin in 1938 [German Patent DE 906,094].

Zu der Patentschrift 906 094
Kl. 12e Gr. 3 05

Fig. 1

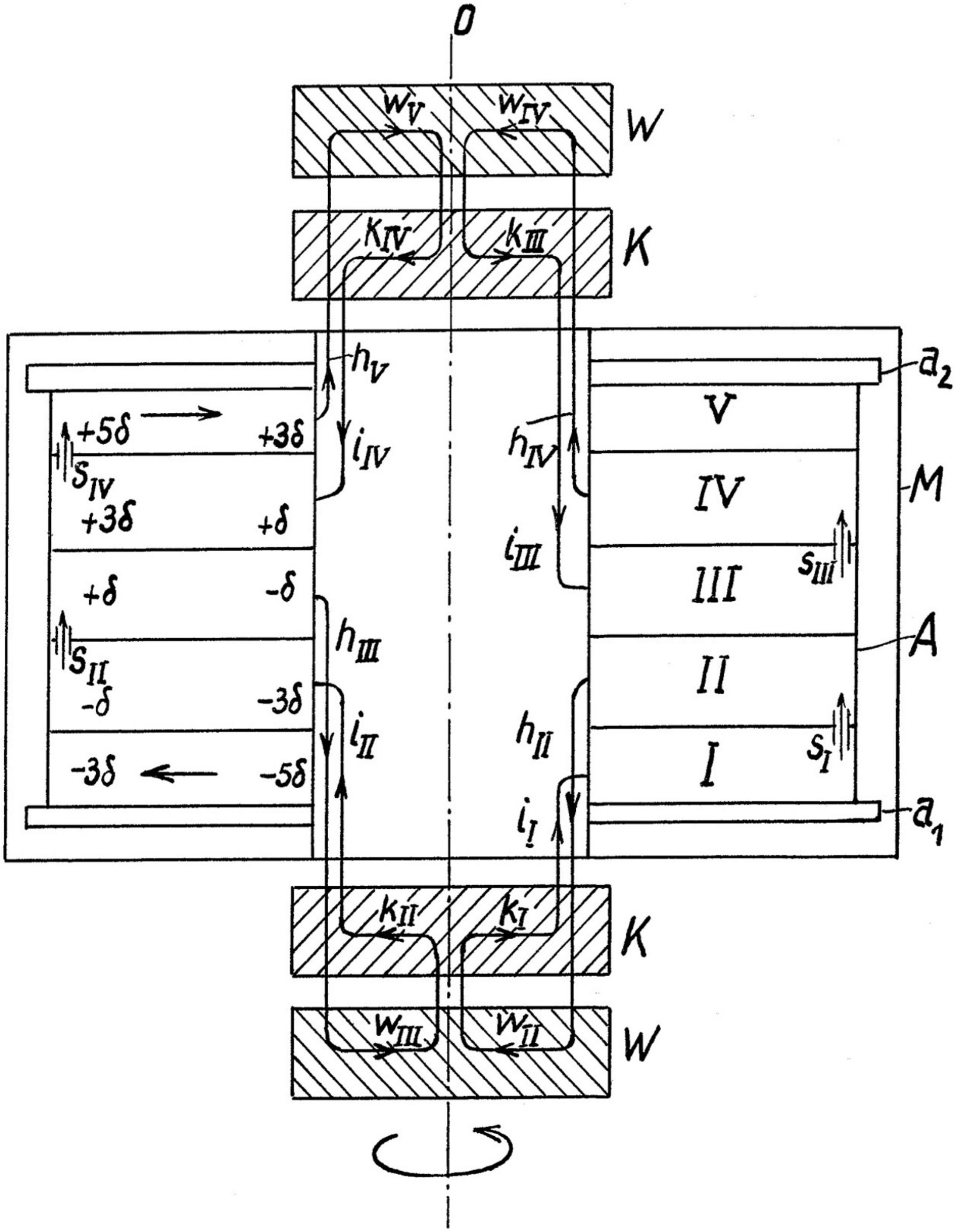

0
w_V
w_{IV}
W
k_{IV}
k_{III}
K
h_V
a_2
+5δ
+3δ
i_{IV}
V
s_{IV}
h_{IV}
IV
M
+3δ
+δ
i_{III}
III
s_{III}
+δ
-δ
h_{III}
A
s_{II}
II
-δ
-3δ
i_{II}
h_{II}
s_I
I
-3δ
-5δ
i_I
a_1
k_{II}
k_I
K
w_{III}
w_{II}
W

Figure D.145: Patent on gas centrifuges filed by Werner Kuhn and Hans Martin in 1938 [German Patent DE 906,094].

Zu der Patentschrift 906 094
Kl. 12e Gr. 3 05

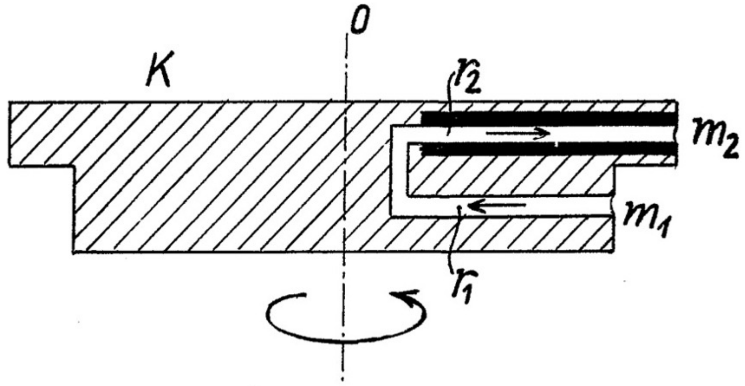

0
K
r_2
m_2
m_1
r_1

Fig. 2

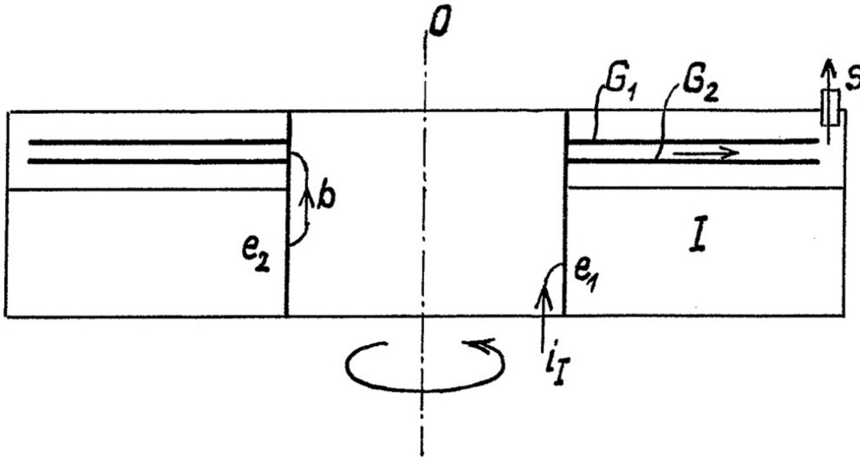

0
G_1
G_2
s_I
b
e_2
I
e_1
i_I

Fig. 3

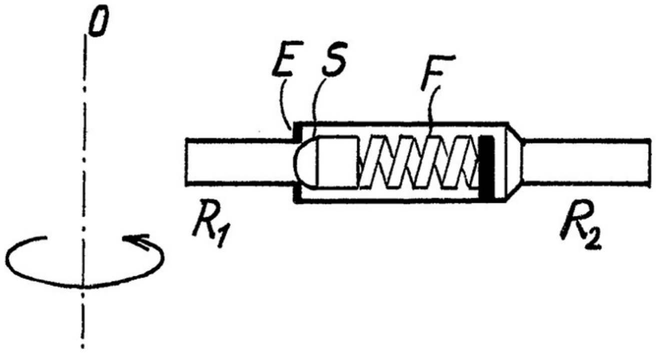
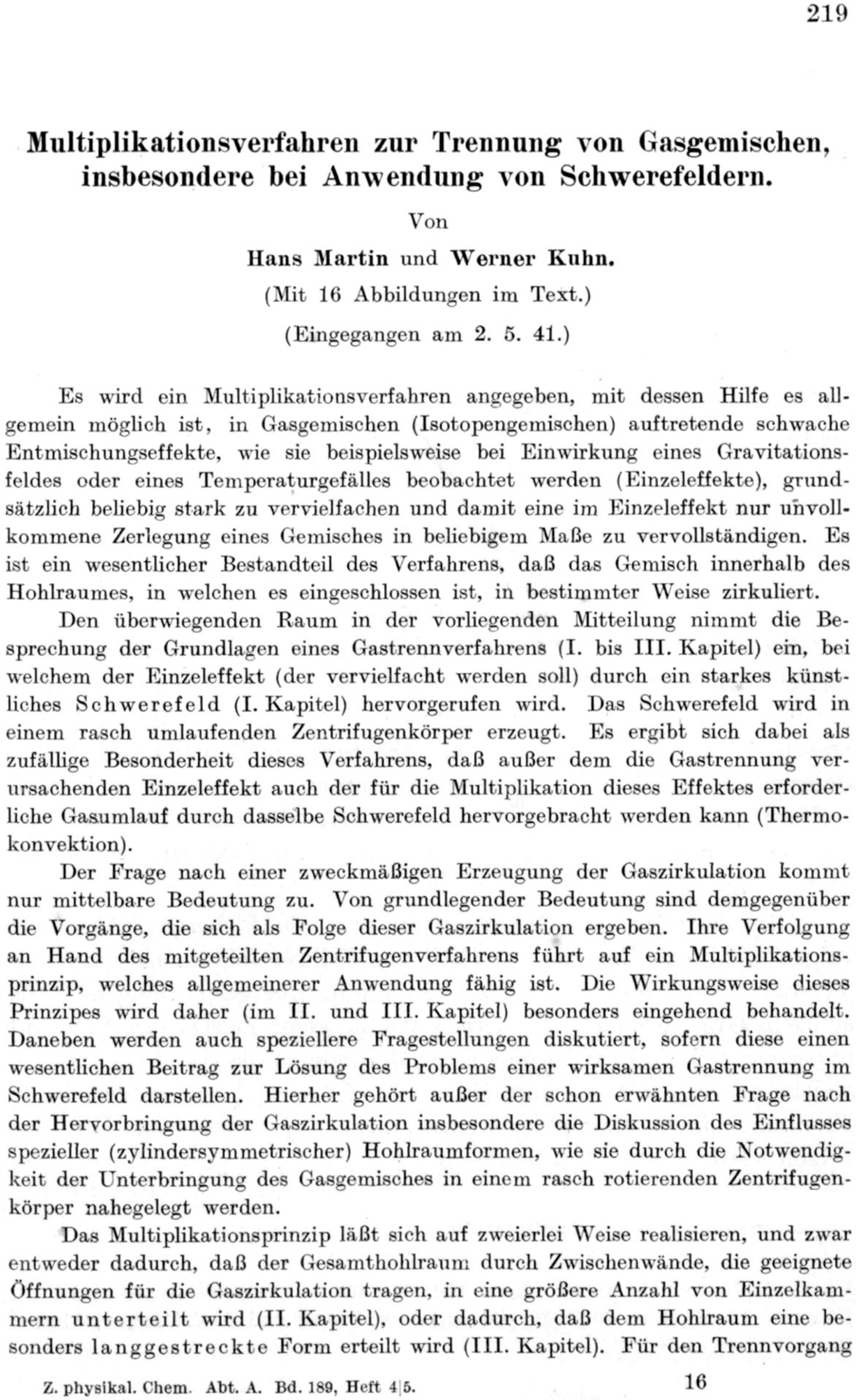


Fig. 4

Figure D.146: Patent on gas centrifuges filed by Werner Kuhn and Hans Martin in 1938 [German Patent DE 906,094].



219

Multiplikationsverfahren zur Trennung von Gasgemischen, insbesondere bei Anwendung von Schwerefeldern.

Von

Hans Martin und **Werner Kuhn.**

(Mit 16 Abbildungen im Text.)

(Eingegangen am 2. 5. 41.)

Es wird ein Multiplikationsverfahren angegeben, mit dessen Hilfe es allgemein möglich ist, in Gasgemischen (Isotopengemischen) auftretende schwache Entmischungseffekte, wie sie beispielsweise bei Einwirkung eines Gravitationsfeldes oder eines Temperaturgefälles beobachtet werden (Einzeleffekte), grundsätzlich beliebig stark zu vervielfachen und damit eine im Einzeleffekt nur unvollkommene Zerlegung eines Gemisches in beliebigem Maße zu vervollständigen. Es ist ein wesentlicher Bestandteil des Verfahrens, daß das Gemisch innerhalb des Hohlraumes, in welchen es eingeschlossen ist, in bestimmter Weise zirkuliert.

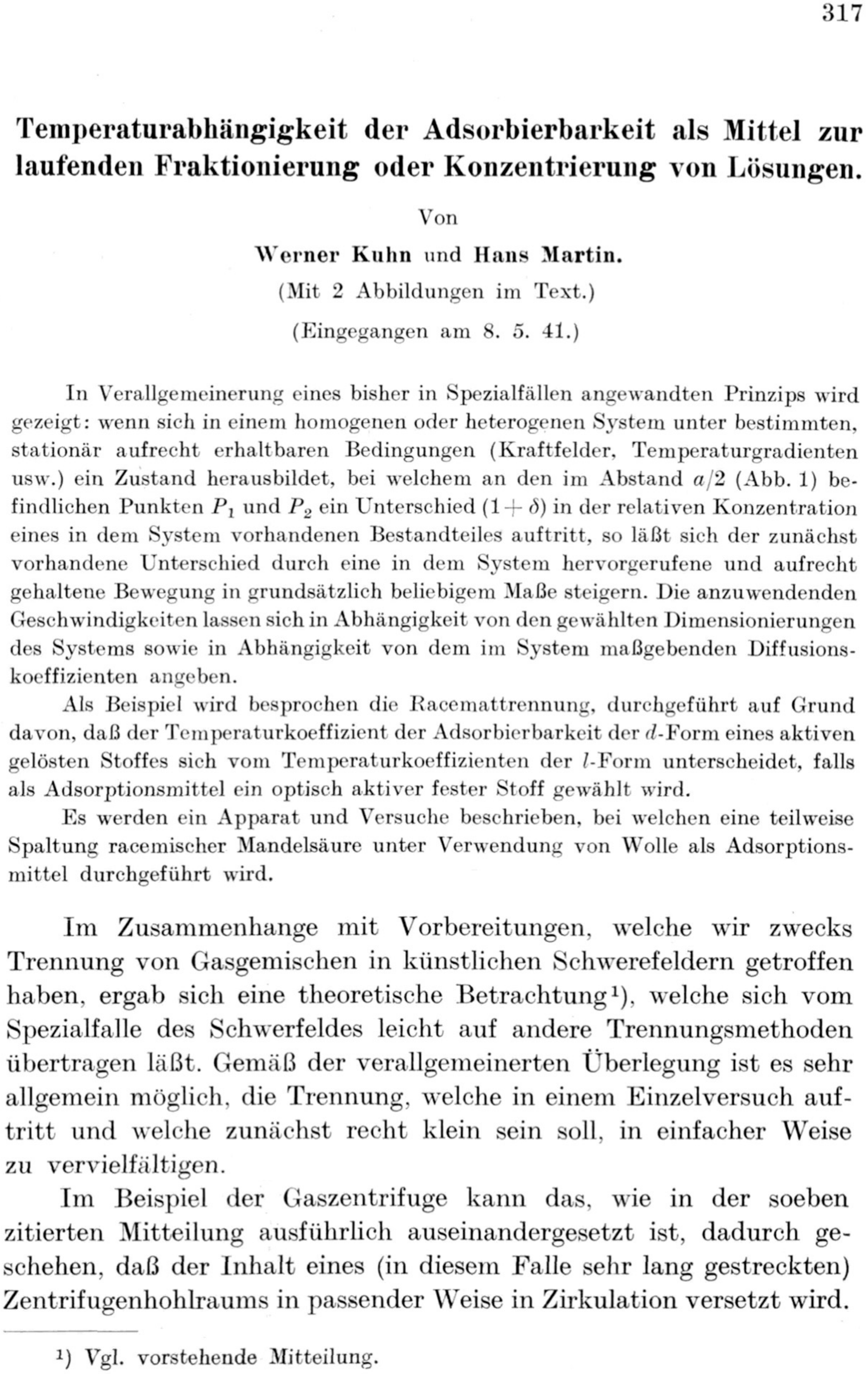
Den überwiegenden Raum in der vorliegenden Mitteilung nimmt die Besprechung der Grundlagen eines Gastrennverfahrens (I. bis III. Kapitel) ein, bei welchem der Einzeleffekt (der vervielfacht werden soll) durch ein starkes künstliches Schwerefeld (I. Kapitel) hervorgerufen wird. Das Schwerefeld wird in einem rasch umlaufenden Zentrifugenkörper erzeugt. Es ergibt sich dabei als zufällige Besonderheit dieses Verfahrens, daß außer dem die Gastrennung verursachenden Einzeleffekt auch der für die Multiplikation dieses Effektes erforderliche Gasumlauf durch dasselbe Schwerefeld hervorgebracht werden kann (Thermokonvektion).

Der Frage nach einer zweckmäßigen Erzeugung der Gaszirkulation kommt nur mittelbare Bedeutung zu. Von grundlegender Bedeutung sind demgegenüber die Vorgänge, die sich als Folge dieser Gaszirkulation ergeben. Ihre Verfolgung an Hand des mitgeteilten Zentrifugenverfahrens führt auf ein Multiplikationsprinzip, welches allgemeinerer Anwendung fähig ist. Die Wirkungsweise dieses Prinzipes wird daher (im II. und III. Kapitel) besonders eingehend behandelt. Daneben werden auch speziellere Fragestellungen diskutiert, sofern diese einen wesentlichen Beitrag zur Lösung des Problems einer wirksamen Gastrennung im Schwerefeld darstellen. Hierher gehört außer der schon erwähnten Frage nach der Hervorbringung der Gaszirkulation insbesondere die Diskussion des Einflusses spezieller (zylindersymmetrischer) Hohlraumformen, wie sie durch die Notwendigkeit der Unterbringung des Gasgemisches in einem rasch rotierenden Zentrifugenkörper nahegelegt werden.

Das Multiplikationsprinzip läßt sich auf zweierlei Weise realisieren, und zwar entweder dadurch, daß der Gesamthohlraum durch Zwischenwände, die geeignete Öffnungen für die Gaszirkulation tragen, in eine größere Anzahl von Einzelkammern unterteilt wird (II. Kapitel), oder dadurch, daß dem Hohlraum eine besonders langgestreckte Form erteilt wird (III. Kapitel). Für den Trennvorgang

Z. physikal. Chem. Abt. A. Bd. 189, Heft 4|5. 16

Figure D.147: Hans Martin and Werner Kuhn. 1941. Multiplikationsverfahren zur Trennung von Gasgemischen, insbesondere bei Anwendung von Schwerefeldern. *Zeitschrift für Physikalische Chemie A* 189:219–316. First page is shown.



Temperaturabhängigkeit der Adsorbierbarkeit als Mittel zur laufenden Fraktionierung oder Konzentrierung von Lösungen.

Von

Werner Kuhn und **Hans Martin.**

(Mit 2 Abbildungen im Text.)

(Eingegangen am 8. 5. 41.)

In Verallgemeinerung eines bisher in Spezialfällen angewandten Prinzips wird gezeigt: wenn sich in einem homogenen oder heterogenen System unter bestimmten, stationär aufrecht erhaltbaren Bedingungen (Kraftfelder, Temperaturgradienten usw.) ein Zustand herausbildet, bei welchem an den im Abstand $a/2$ (Abb. 1) befindlichen Punkten P_1 und P_2 ein Unterschied $(1+\delta)$ in der relativen Konzentration eines in dem System vorhandenen Bestandteiles auftritt, so läßt sich der zunächst vorhandene Unterschied durch eine in dem System hervorgerufene und aufrecht gehaltene Bewegung in grundsätzlich beliebigem Maße steigern. Die anzuwendenden Geschwindigkeiten lassen sich in Abhängigkeit von den gewählten Dimensionierungen des Systems sowie in Abhängigkeit von dem im System maßgebenden Diffusionskoeffizienten angeben.

Als Beispiel wird besprochen die Racemattrennung, durchgeführt auf Grund davon, daß der Temperaturkoeffizient der Adsorbierbarkeit der d-Form eines aktiven gelösten Stoffes sich vom Temperaturkoeffizienten der l-Form unterscheidet, falls als Adsorptionsmittel ein optisch aktiver fester Stoff gewählt wird.

Es werden ein Apparat und Versuche beschrieben, bei welchen eine teilweise Spaltung racemischer Mandelsäure unter Verwendung von Wolle als Adsorptionsmittel durchgeführt wird.

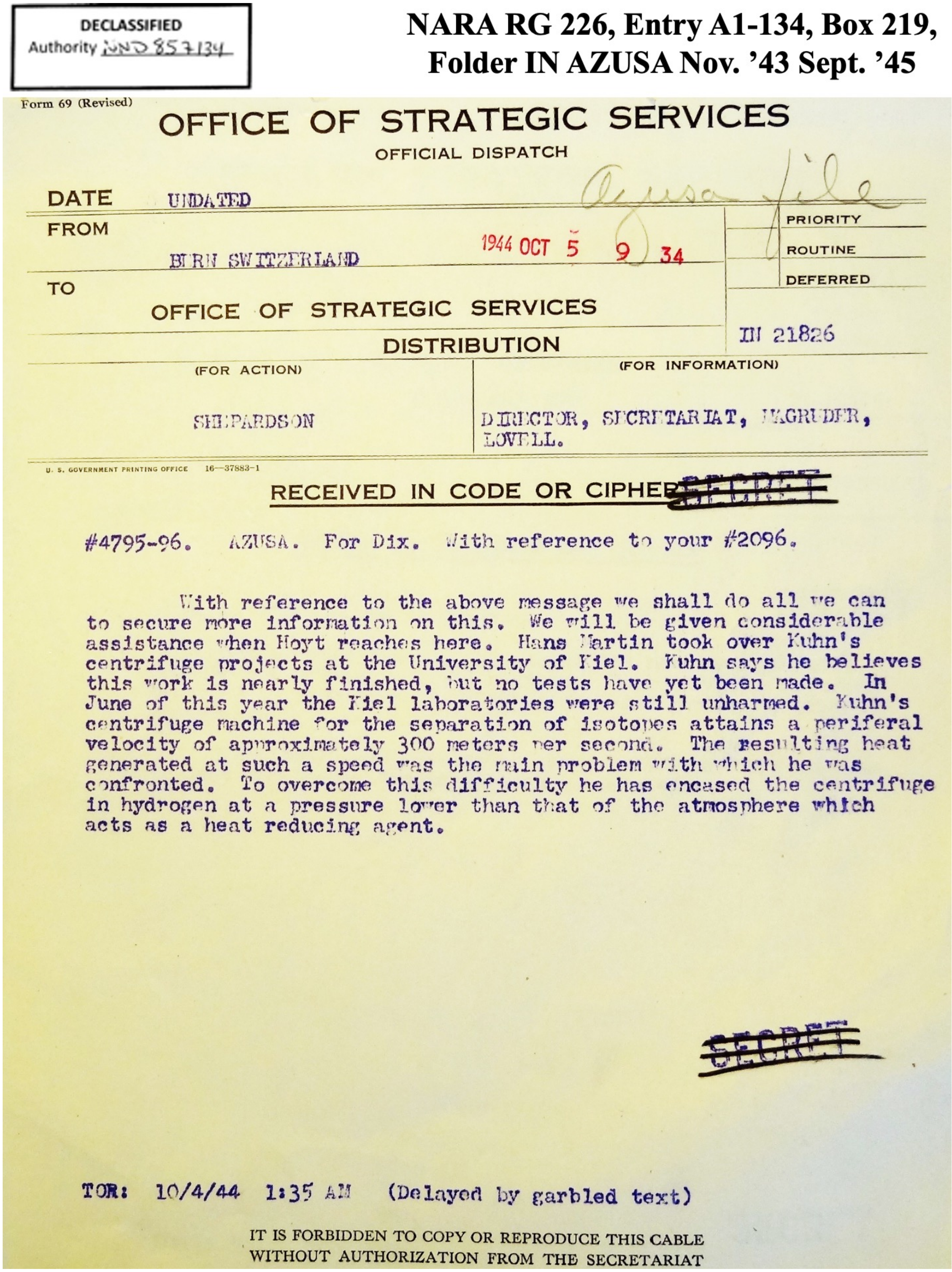
Im Zusammenhange mit Vorbereitungen, welche wir zwecks Trennung von Gasgemischen in künstlichen Schwerefeldern getroffen haben, ergab sich eine theoretische Betrachtung¹), welche sich vom Spezialfalle des Schwerfeldes leicht auf andere Trennungsmethoden übertragen läßt. Gemäß der verallgemeinerten Überlegung ist es sehr allgemein möglich, die Trennung, welche in einem Einzelversuch auftritt und welche zunächst recht klein sein soll, in einfacher Weise zu vervielfältigen.

Im Beispiel der Gaszentrifuge kann das, wie in der soeben zitierten Mitteilung ausführlich auseinandergesetzt ist, dadurch geschehen, daß der Inhalt eines (in diesem Falle sehr lang gestreckten) Zentrifugenhohlraums in passender Weise in Zirkulation versetzt wird.

---

¹) Vgl. vorstehende Mitteilung.

Figure D.148: Werner Kuhn and Hans Martin. 1941. Temperaturabhängigkeit der Adsorbierbarkeit als Mittel zur laufenden Fraktionierung oder Konzentrierung von Lösungen. *Zeitschrift für Physikalische Chemie A* 189:317–326. First page is shown.



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Form 69 (Revised)

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#4795-96. AZUSA. For Dix. With reference to your #2096.

With reference to the above message we shall do all we can to secure more information on this. We will be given considerable assistance when Hoyt reaches here. Hans Martin took over Kuhn's centrifuge projects at the University of Kiel. Kuhn says he believes this work is nearly finished, but no tests have yet been made. In June of this year the Kiel laboratories were still unharmed. Kuhn's centrifuge machine for the separation of isotopes attains a periferal velocity of approximately 300 meters per second. The resulting heat generated at such a speed was the main problem with which he was confronted. To overcome this difficulty he has encased the centrifuge in hydrogen at a pressure lower than that of the atmosphere which acts as a heat reducing agent.

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TOR: 10/4/44 1:35 AM (Delayed by garbled text)

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Figure D.149: OSS Bern Switzerland. 4 October 1944 [NARA RG 226, Entry A1-134, Box 219, Folder IN AZUSA Nov. ’43 Sept. ’45].

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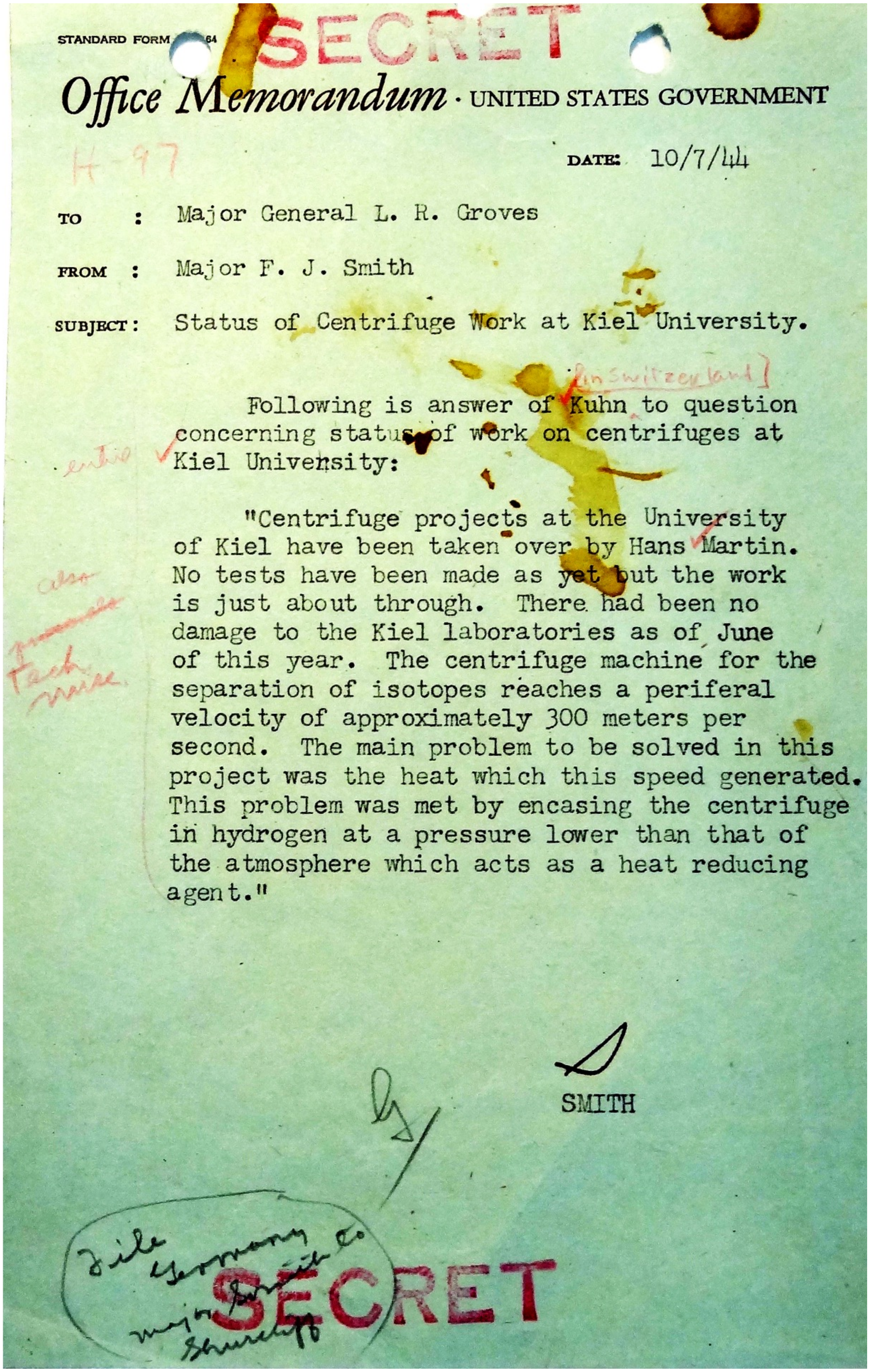
Authority NND 917017



STANDARD FORM 64

SECRET

Office Memorandum · UNITED STATES GOVERNMENT

H-97

DATE: 10/7/44

TO : Major General L. R. Groves

FROM : Major F. J. Smith

SUBJECT: Status of Centrifuge Work at Kiel University.

[in Switzerland]

Following is answer of Kuhn to question concerning status of work on centrifuges at Kiel University:

entire

"Centrifuge projects at the University of Kiel have been taken over by Hans Martin. No tests have been made as yet but the work is just about through. There had been no damage to the Kiel laboratories as of June of this year. The centrifuge machine for the separation of isotopes reaches a periferal velocity of approximately 300 meters per second. The main problem to be solved in this project was the heat which this speed generated. This problem was met by encasing the centrifuge in hydrogen at a pressure lower than that of the atmosphere which acts as a heat reducing agent."

also Tech. misc.

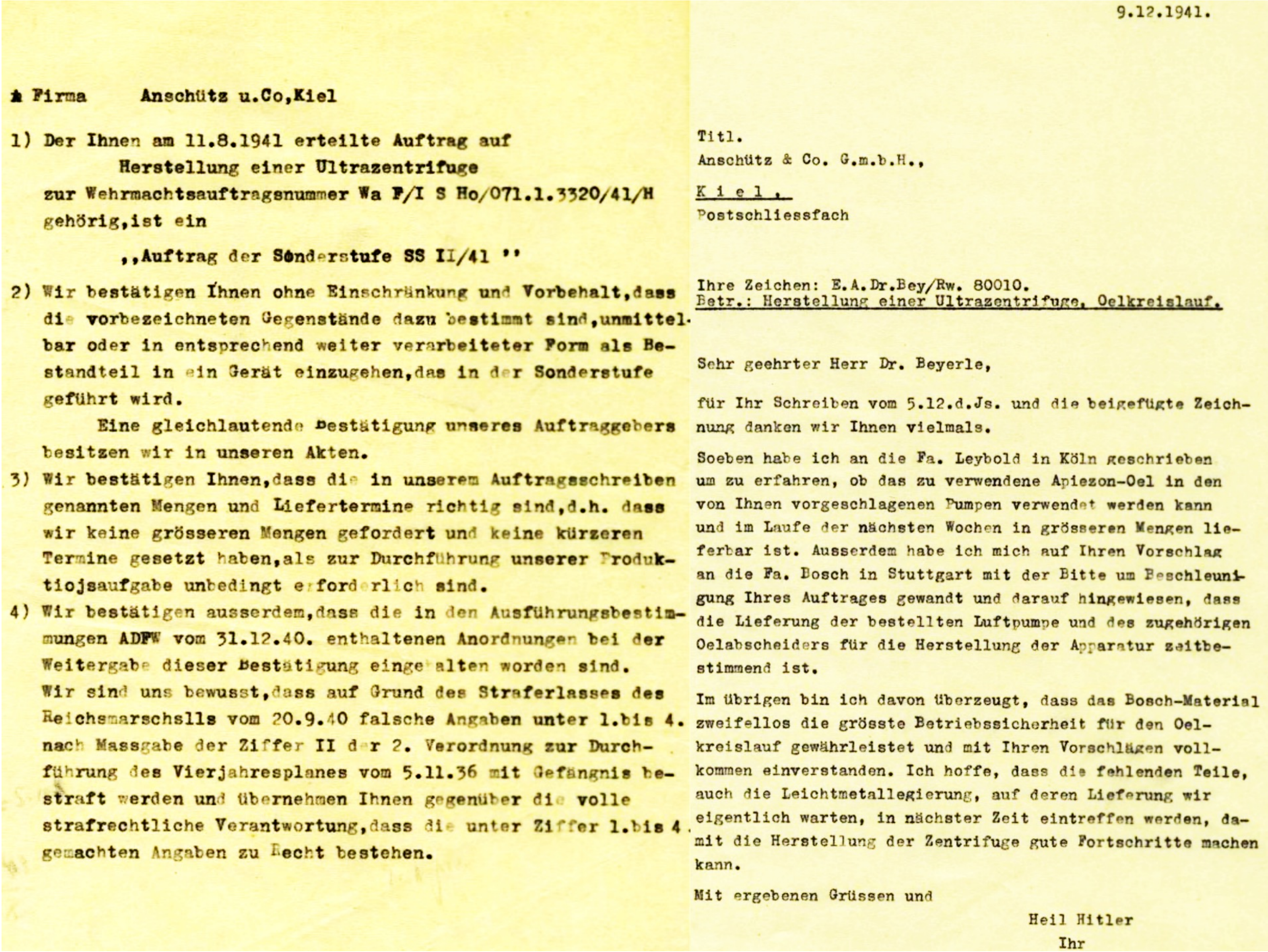
SMITH

File
Germany
major Smith co
Shurcliff

SECRET

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July-Oct. 44)

Figure D.150: Francis J. Smith to Leslie R. Groves. 7 October 1944. SUBJECT: Status of Centrifuge Work at Kiel University [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].



a Firma Anschütz u.Co,Kiel

1) Der Ihnen am 11.8.1941 erteilte Auftrag auf
Herstellung einer Ultrazentrifuge
zur Wehrmachtsauftragsnummer Wa F/I S Ho/071.1.3320/41/H
gehörig,ist ein

„Auftrag der Sonderstufe SS II/41 "

2) Wir bestätigen Ihnen ohne Einschränkung und Vorbehalt,dass die vorbezeichneten Gegenstände dazu bestimmt sind,unmittelbar oder in entsprechend weiter verarbeiteter Form als Bestandteil in ein Gerät einzugehen,das in der Sonderstufe geführt wird.

Eine gleichlautende Bestätigung unseres Auftraggebers besitzen wir in unseren Akten.

3) Wir bestätigen Ihnen,dass die in unserem Auftragsschreiben genannten Mengen und Liefertermine richtig sind,d.h. dass wir keine grösseren Mengen gefordert und keine kürzeren Termine gesetzt haben,als zur Durchführung unserer Produktiojsaufgabe unbedingt erforderlich sind.

4) Wir bestätigen ausserdem,dass die in den Ausführungsbestimmungen ADFW vom 31.12.40. enthaltenen Anordnungen bei der Weitergabe dieser Bestätigung eingehalten worden sind.
Wir sind uns bewusst,dass auf Grund des Straferlasses des Reichsmarschslls vom 20.9.40 falsche Angaben unter 1.bis 4. nach Massgabe der Ziffer II der 2. Verordnung zur Durchführung des Vierjahresplanes vom 5.11.36 mit Gefängnis bestraft werden und übernehmen Ihnen gegenüber die volle strafrechtliche Verantwortung,dass die unter Ziffer 1.bis 4. gemachten Angaben zu Recht bestehen.

9.12.1941.

Titl.
Anschütz & Co. G.m.b.H.,
Kiel.
Postschliessfach

Ihre Zeichen: E.A.Dr.Bey/Rw. 80010.
Betr.: Herstellung einer Ultrazentrifuge, Oelkreislauf.

Sehr geehrter Herr Dr. Beyerle,

für Ihr Schreiben vom 5.12.d.Js. und die beigefügte Zeichnung danken wir Ihnen vielmals.

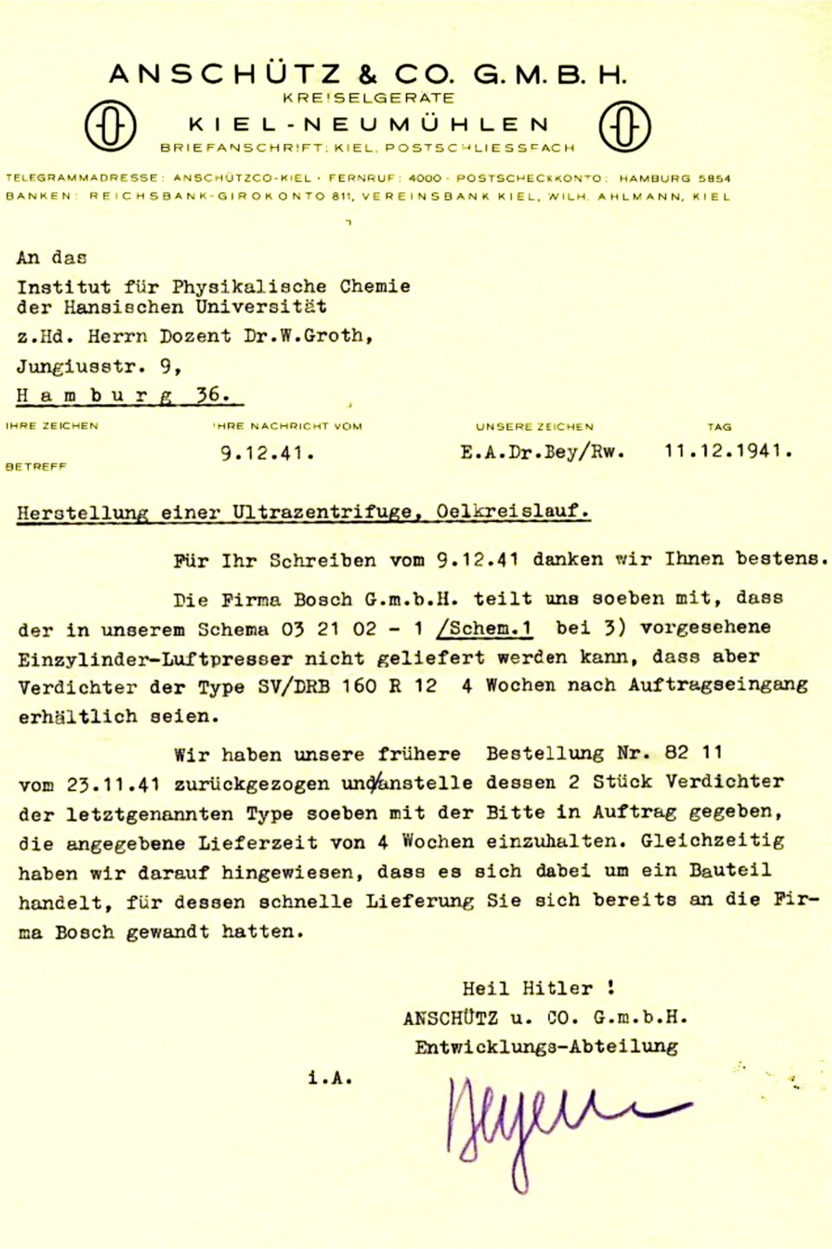
Soeben habe ich an die Fa. Leybold in Köln geschrieben um zu erfahren, ob das zu verwendene Apiezon-Oel in den von Ihnen vorgeschlagenen Pumpen verwendet werden kann und im Laufe der nächsten Wochen in grösseren Mengen lieferbar ist. Ausserdem habe ich mich auf Ihren Vorschlag an die Fa. Bosch in Stuttgart mit der Bitte um Beschleunigung Ihres Auftrages gewandt und darauf hingewiesen, dass die Lieferung der bestellten Luftpumpe und des zugehörigen Oelabscheiders für die Herstellung der Apparatur zeitbestimmend ist.

Im übrigen bin ich davon überzeugt, dass das Bosch-Material zweifellos die grösste Betriebssicherheit für den Oelkreislauf gewährleistet und mit Ihren Vorschlägen vollkommen einverstanden. Ich hoffe, dass die fehlenden Teile, auch die Leichtmetallegierung, auf deren Lieferung wir eigentlich warten, in nächster Zeit eintreffen werden, damit die Herstellung der Zentrifuge gute Fortschritte machen kann.

Mit ergebenen Grüssen und

Heil Hitler
Ihr

Figure D.151: The Anschütz company in Kiel began working on uranium gas centrifuges no later than 1941 [G-331].



ANSCHÜTZ & CO. G.M.B.H.
KREISELGERÄTE
KIEL-NEUMÜHLEN
BRIEFANSCHRIFT: KIEL, POSTSCHLIESSFACH
TELEGRAMMADRESSE: ANSCHÜTZCO-KIEL · FERNRUF: 4000 · POSTSCHECKKONTO: HAMBURG 5854
BANKEN: REICHSBANK-GIROKONTO 811, VEREINSBANK KIEL, WILH. AHLMANN, KIEL

An das
Institut für Physikalische Chemie
der Hansischen Universität
z.Hd. Herrn Dozent Dr.W.Groth,
Jungiusstr. 9,
Hamburg 36.

IHRE ZEICHEN	IHRE NACHRICHT VOM	UNSERE ZEICHEN	TAG
	9.12.41.	E.A.Dr.Bey/Rw.	11.12.1941.

BETREFF

Herstellung einer Ultrazentrifuge, Oelkreislauf.

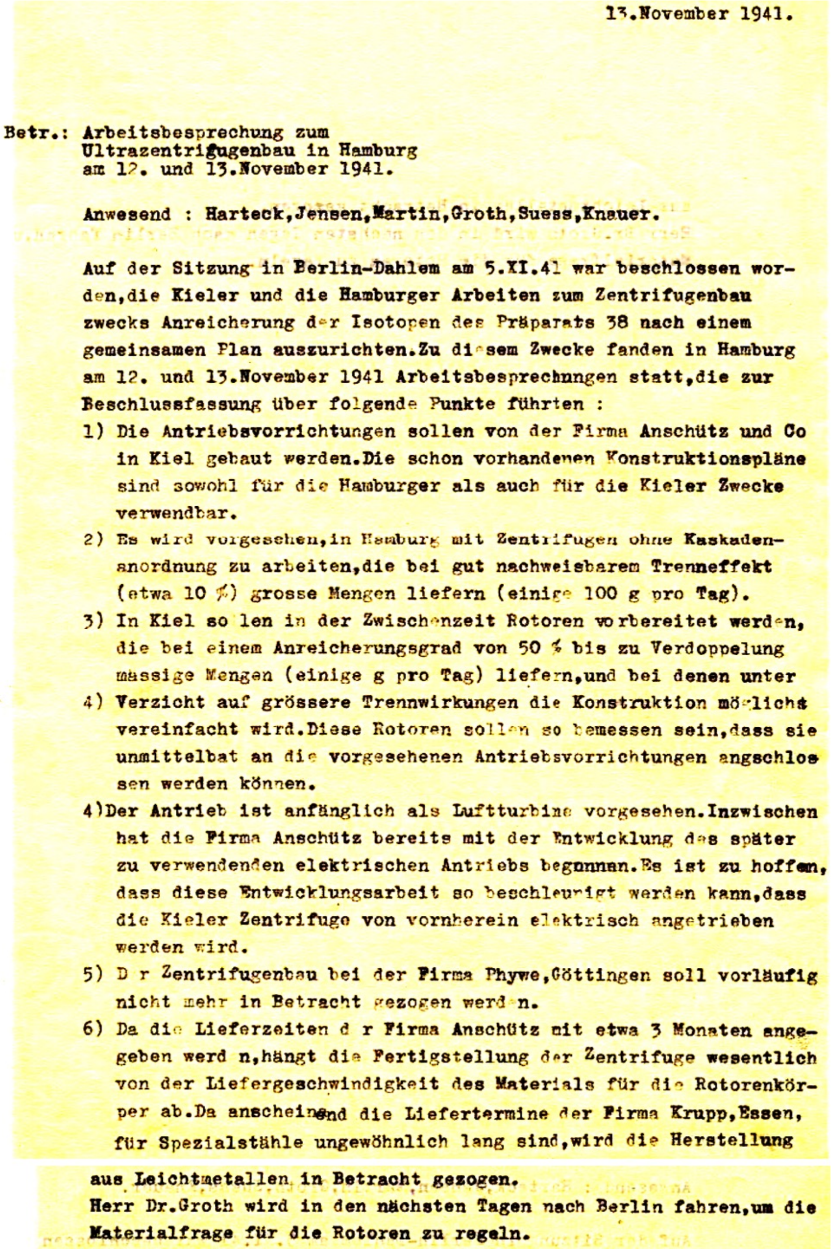
Für Ihr Schreiben vom 9.12.41 danken wir Ihnen bestens.

Die Firma Bosch G.m.b.H. teilt uns soeben mit, dass der in unserem Schema 03 21 02 - 1 /Schem.1 bei 3) vorgesehene Einzylinder-Luftpresser nicht geliefert werden kann, dass aber Verdichter der Type SV/DRB 160 R 12 4 Wochen nach Auftragseingang erhältlich seien.

Wir haben unsere frühere Bestellung Nr. 82 11 vom 23.11.41 zurückgezogen und anstelle dessen 2 Stück Verdichter der letztgenannten Type soeben mit der Bitte in Auftrag gegeben, die angegebene Lieferzeit von 4 Wochen einzuhalten. Gleichzeitig haben wir darauf hingewiesen, dass es sich dabei um ein Bauteil handelt, für dessen schnelle Lieferung Sie sich bereits an die Firma Bosch gewandt hatten.

Heil Hitler !
ANSCHÜTZ u. CO. G.m.b.H.
Entwicklungs-Abteilung

i.A.
Beyer



13.November 1941.

Betr.: Arbeitsbesprechung zum
Ultrazentrifugenbau in Hamburg
am 12. und 13.November 1941.

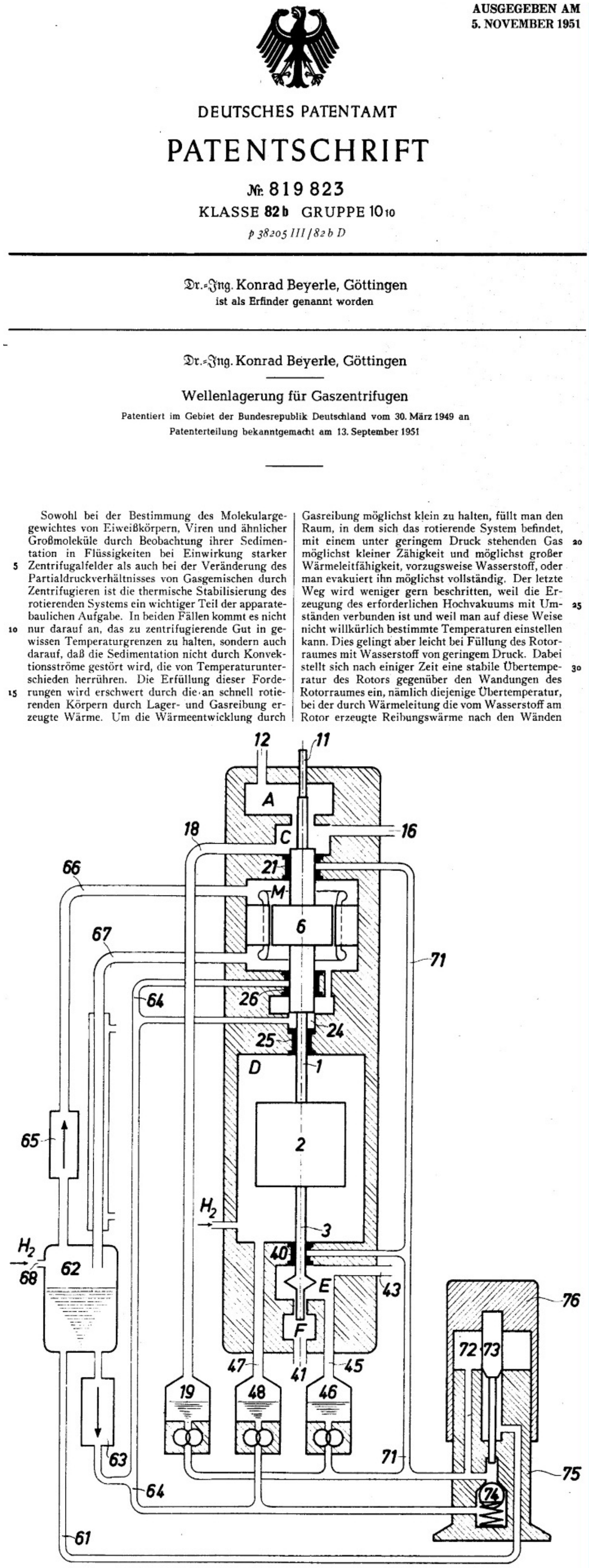
Anwesend : Harteck,Jensen,Martin,Groth,Suess,Knauer.

Auf der Sitzung in Berlin-Dahlem am 5.XI.41 war beschlossen worden,die Kieler und die Hamburger Arbeiten zum Zentrifugenbau zwecks Anreicherung der Isotopen des Präparats 38 nach einem gemeinsamen Plan auszurichten.Zu diesem Zwecke fanden in Hamburg am 12. und 13.November 1941 Arbeitsbesprechungen statt,die zur Beschlussfassung über folgende Punkte führten :

1) Die Antriebsvorrichtungen sollen von der Firma Anschütz und Co in Kiel gebaut werden.Die schon vorhandenen Konstruktionspläne sind sowohl für die Hamburger als auch für die Kieler Zwecke verwendbar.
2) Es wird vorgesehen,in Hamburg mit Zentrifugen ohne Kaskadenanordnung zu arbeiten,die bei gut nachweisbarem Trenneffekt (etwa 10 %) grosse Mengen liefern (einige 100 g pro Tag).
3) In Kiel sollen in der Zwischenzeit Rotoren vorbereitet werden, die bei einem Anreicherungsgrad von 50 % bis zu Verdoppelung mässige Mengen (einige g pro Tag) liefern,und bei denen unter
4) Verzicht auf grössere Trennwirkungen die Konstruktion möglichst vereinfacht wird.Diese Rotoren sollen so bemessen sein,dass sie unmittelbat an die vorgesehenen Antriebsvorrichtungen angschlossen werden können.
4)Der Antrieb ist anfänglich als Luftturbine vorgesehen.Inzwischen hat die Firma Anschütz bereits mit der Entwicklung des später zu verwendenden elektrischen Antriebs begonnen.Es ist zu hoffen, dass diese Entwicklungsarbeit so beschleunigt werden kann,dass die Kieler Zentrifuge von vornherein elektrisch angetrieben werden wird.
5) Der Zentrifugenbau bei der Firma Phywe,Göttingen soll vorläufig nicht mehr in Betracht gezogen werden.
6) Da die Lieferzeiten der Firma Anschütz mit etwa 3 Monaten angegeben werden,hängt die Fertigstellung der Zentrifuge wesentlich von der Liefergeschwindigkeit des Materials für die Rotorenkörper ab.Da anscheinend die Liefertermine der Firma Krupp,Essen, für Spezialstähle ungewöhnlich lang sind,wird die Herstellung aus Leichtmetallen in Betracht gezogen.

Herr Dr.Groth wird in den nächsten Tagen nach Berlin fahren,um die Materialfrage für die Rotoren zu regeln.

Figure D.152: The Anschütz company in Kiel began working on uranium gas centrifuges no later than 1941 [G-331].



AUSGEGEBEN AM
5. NOVEMBER 1951

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 819 823
KLASSE **82b** GRUPPE 10₁₀
p 38205 III/82b D

𝔇𝔯.-𝔍𝔫𝔤. Konrad Beyerle, Göttingen
ist als Erfinder genannt worden

𝔇𝔯.-𝔍𝔫𝔤. Konrad Beyerle, Göttingen

Wellenlagerung für Gaszentrifugen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 30. März 1949 an
Patenterteilung bekanntgemacht am 13. September 1951

Sowohl bei der Bestimmung des Molekulargewichtes von Eiweißkörpern, Viren und ähnlicher Großmoleküle durch Beobachtung ihrer Sedimentation in Flüssigkeiten bei Einwirkung starker Zentrifugalfelder als auch bei der Veränderung des Partialdruckverhältnisses von Gasgemischen durch Zentrifugieren ist die thermische Stabilisierung des rotierenden Systems ein wichtiger Teil der apparatebaulichen Aufgabe. In beiden Fällen kommt es nicht nur darauf an, das zu zentrifugierende Gut in gewissen Temperaturgrenzen zu halten, sondern auch darauf, daß die Sedimentation nicht durch Konvektionsströme gestört wird, die von Temperaturunterschieden herrühren. Die Erfüllung dieser Forderungen wird erschwert durch die an schnell rotierenden Körpern durch Lager- und Gasreibung erzeugte Wärme. Um die Wärmeentwicklung durch Gasreibung möglichst klein zu halten, füllt man den Raum, in dem sich das rotierende System befindet, mit einem unter geringem Druck stehenden Gas möglichst kleiner Zähigkeit und möglichst großer Wärmeleitfähigkeit, vorzugsweise Wasserstoff, oder man evakuiert ihn möglichst vollständig. Der letzte Weg wird weniger gern beschritten, weil die Erzeugung des erforderlichen Hochvakuums mit Umständen verbunden ist und weil man auf diese Weise nicht willkürlich bestimmte Temperaturen einstellen kann. Dies gelingt aber leicht bei Füllung des Rotorraumes mit Wasserstoff von geringem Druck. Dabei stellt sich nach einiger Zeit eine stabile Übertemperatur des Rotors gegenüber den Wandungen des Rotorraumes ein, nämlich diejenige Übertemperatur, bei der durch Wärmeleitung die vom Wasserstoff am Rotor erzeugte Reibungswärme nach den Wänden

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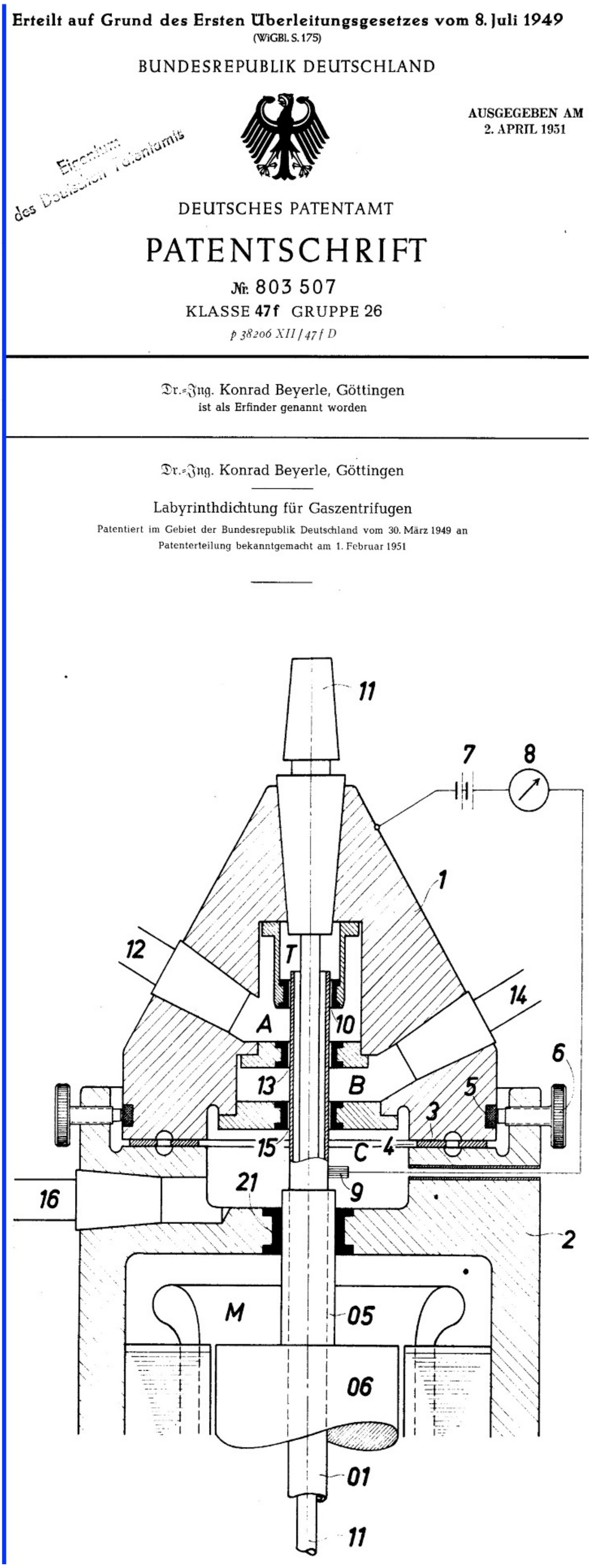


Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

Eigentum des Deutschen Patentamts

AUSGEGEBEN AM
2. APRIL 1951

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 803 507
KLASSE **47f** GRUPPE 26
p 38206 XII/47f D

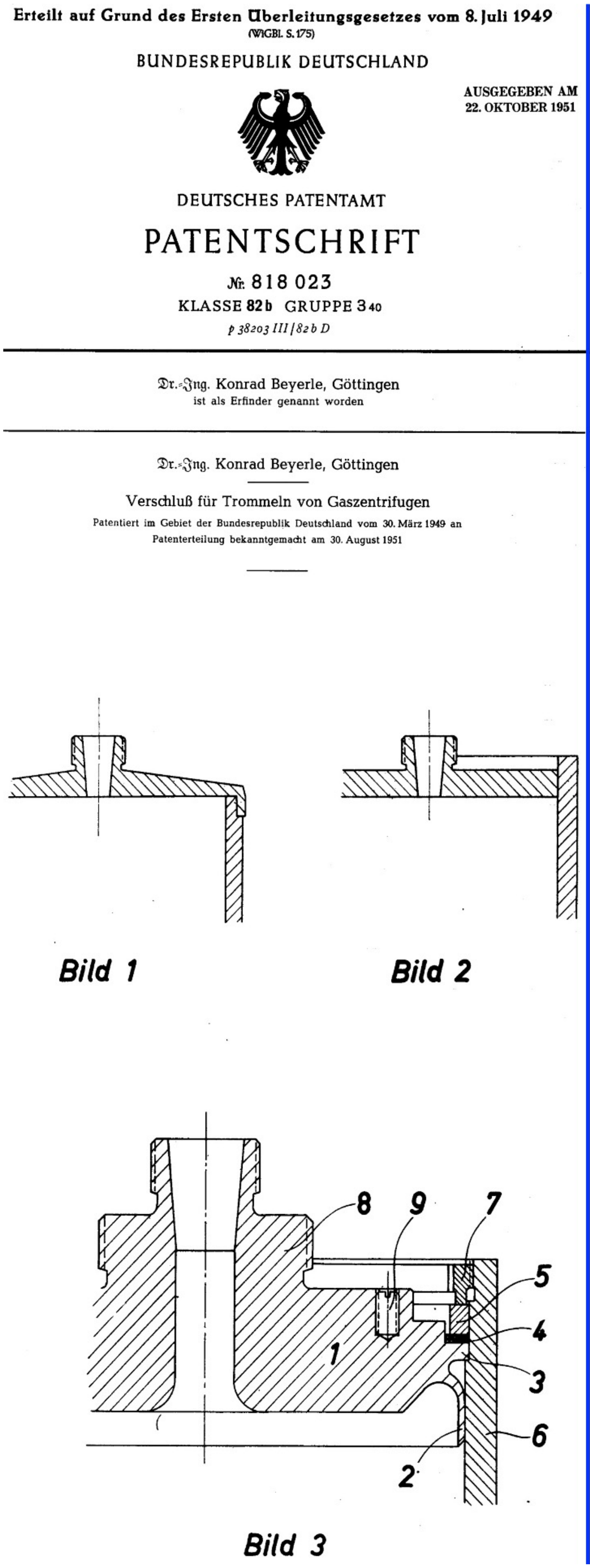
𝔇𝔯.-𝔍𝔫𝔤. Konrad Beyerle, Göttingen
ist als Erfinder genannt worden

𝔇𝔯.-𝔍𝔫𝔤. Konrad Beyerle, Göttingen

Labyrinthdichtung für Gaszentrifugen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 30. März 1949 an
Patenterteilung bekanntgemacht am 1. Februar 1951

Figure D.153: After the (West) German patent office reopened in 1949, Konrad Beyerle filed a number of patent applications on gas centrifuges and closely related technologies, likely based on his wartime work at Anschütz.



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
22. OKTOBER 1951

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 818 023

KLASSE **82b** GRUPPE 3 40

p 38203 III/82b D

Dr.-Ing. Konrad Beyerle, Göttingen
ist als Erfinder genannt worden

Dr.-Ing. Konrad Beyerle, Göttingen

Verschluß für Trommeln von Gaszentrifugen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 30. März 1949 an
Patenterteilung bekanntgemacht am 30. August 1951

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Bild 2
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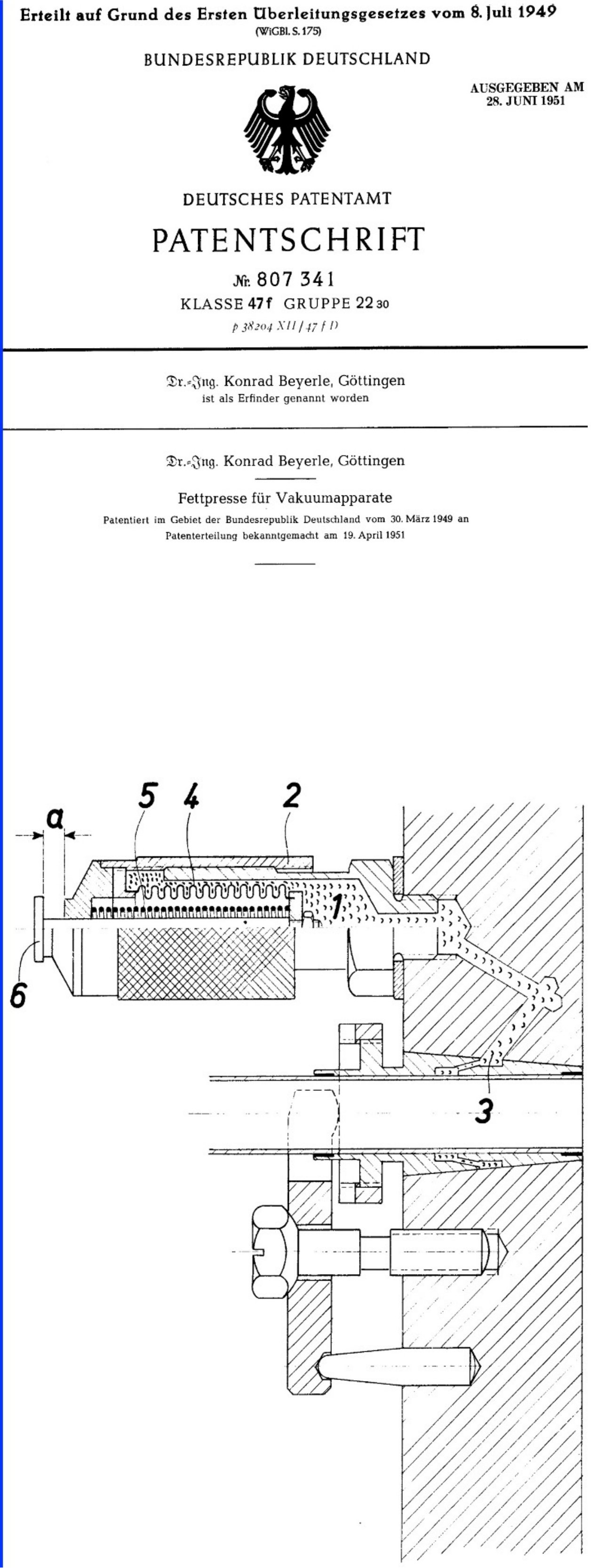
Bild 3



Erteilt auf Grund des Ersten Überleitungsgesetzes vom 8. Juli 1949
(WiGBl. S. 175)

BUNDESREPUBLIK DEUTSCHLAND

AUSGEGEBEN AM
28. JUNI 1951

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 807 341

KLASSE **47f** GRUPPE 22 30

p 38204 XII/47f D

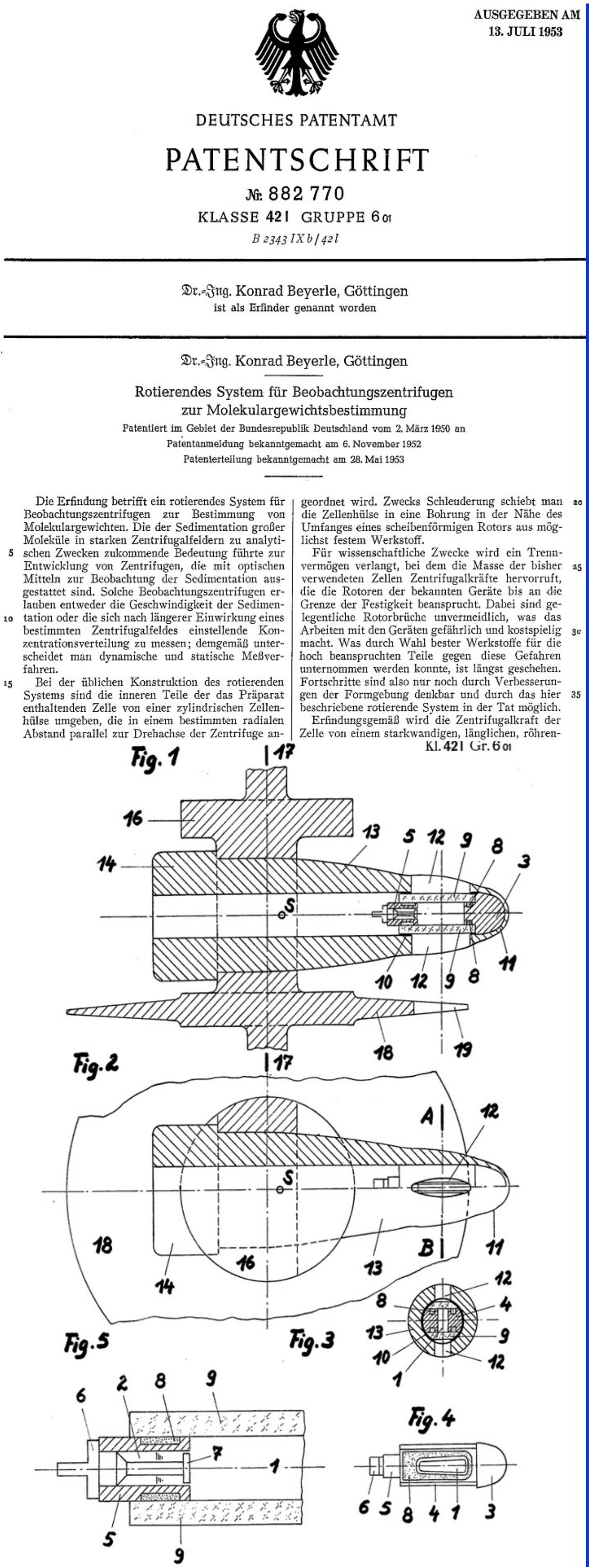
Dr.-Ing. Konrad Beyerle, Göttingen
ist als Erfinder genannt worden

Dr.-Ing. Konrad Beyerle, Göttingen

Fettpresse für Vakuumapparate

Patentiert im Gebiet der Bundesrepublik Deutschland vom 30. März 1949 an
Patenterteilung bekanntgemacht am 19. April 1951

Figure D.154: After the (West) German patent office reopened in 1949, Konrad Beyerle filed a number of patent applications on gas centrifuges and closely related technologies, likely based on his wartime work at Anschütz.



AUSGEGEBEN AM
13. JULI 1953

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 882 770

KLASSE 42l GRUPPE 6 01

B 2343 IX b / 42l

Dr.-Ing. Konrad Beyerle, Göttingen
ist als Erfinder genannt worden

Dr.-Ing. Konrad Beyerle, Göttingen

Rotierendes System für Beobachtungszentrifugen zur Molekulargewichtsbestimmung

Patentiert im Gebiet der Bundesrepublik Deutschland vom 2. März 1950 an
Patentanmeldung bekanntgemacht am 6. November 1952
Patenterteilung bekanntgemacht am 28. Mai 1953

Die Erfindung betrifft ein rotierendes System für Beobachtungszentrifugen zur Bestimmung von Molekulargewichten. Die der Sedimentation großer Moleküle in starken Zentrifugalfeldern zu analytischen Zwecken zukommende Bedeutung führte zur Entwicklung von Zentrifugen, die mit optischen Mitteln zur Beobachtung der Sedimentation ausgestattet sind. Solche Beobachtungszentrifugen erlauben entweder die Geschwindigkeit der Sedimentation oder die sich nach längerer Einwirkung eines bestimmten Zentrifugalfeldes einstellende Konzentrationsverteilung zu messen; demgemäß unterscheidet man dynamische und statische Meßverfahren.

Bei der üblichen Konstruktion des rotierenden Systems sind die inneren Teile der das Präparat enthaltenden Zelle von einer zylindrischen Zellenhülse umgeben, die in einem bestimmten radialen Abstand parallel zur Drehachse der Zentrifuge angeordnet wird. Zwecks Schleuderung schiebt man die Zellenhülse in eine Bohrung in der Nähe des Umfanges eines scheibenförmigen Rotors aus möglichst festem Werkstoff.

Für wissenschaftliche Zwecke wird ein Trennvermögen verlangt, bei dem die Masse der bisher verwendeten Zellen Zentrifugalkräfte hervorruft, die die Rotoren der bekannten Geräte bis an die Grenze der Festigkeit beansprucht. Dabei sind gelegentliche Rotorbrüche unvermeidlich, was das Arbeiten mit den Geräten gefährlich und kostspielig macht. Was durch Wahl bester Werkstoffe für die hoch beanspruchten Teile gegen diese Gefahren unternommen werden konnte, ist längst geschehen. Fortschritte sind also nur noch durch Verbesserungen der Formgebung denkbar und durch das hier beschriebene rotierende System in der Tat möglich.

Erfindungsgemäß wird die Zentrifugalkraft der Zelle von einem starkwandigen, länglichen, röhren-

Kl. 42l Gr. 6 01

Fig. 1
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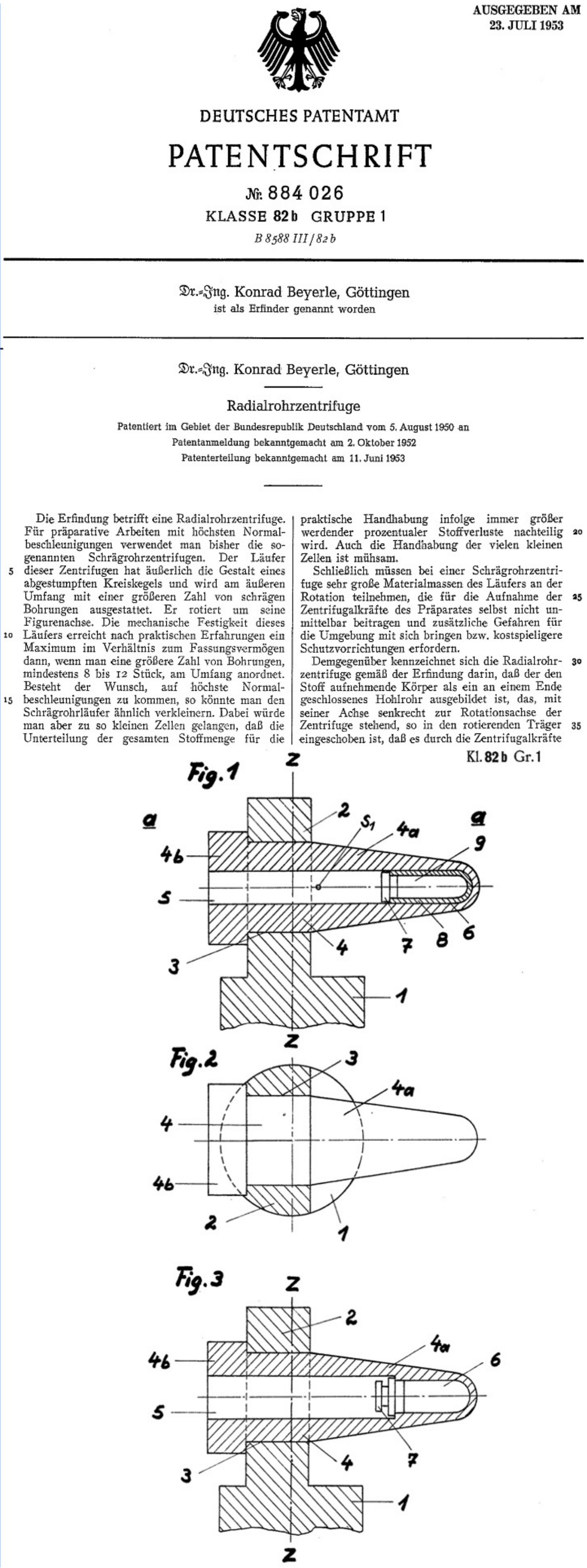


AUSGEGEBEN AM
23. JULI 1953

DEUTSCHES PATENTAMT

PATENTSCHRIFT

№ 884 026

KLASSE 82b GRUPPE 1

B 8588 III / 82 b

Dr.-Ing. Konrad Beyerle, Göttingen
ist als Erfinder genannt worden

Dr.-Ing. Konrad Beyerle, Göttingen

Radialrohrzentrifuge

Patentiert im Gebiet der Bundesrepublik Deutschland vom 5. August 1950 an
Patentanmeldung bekanntgemacht am 2. Oktober 1952
Patenterteilung bekanntgemacht am 11. Juni 1953

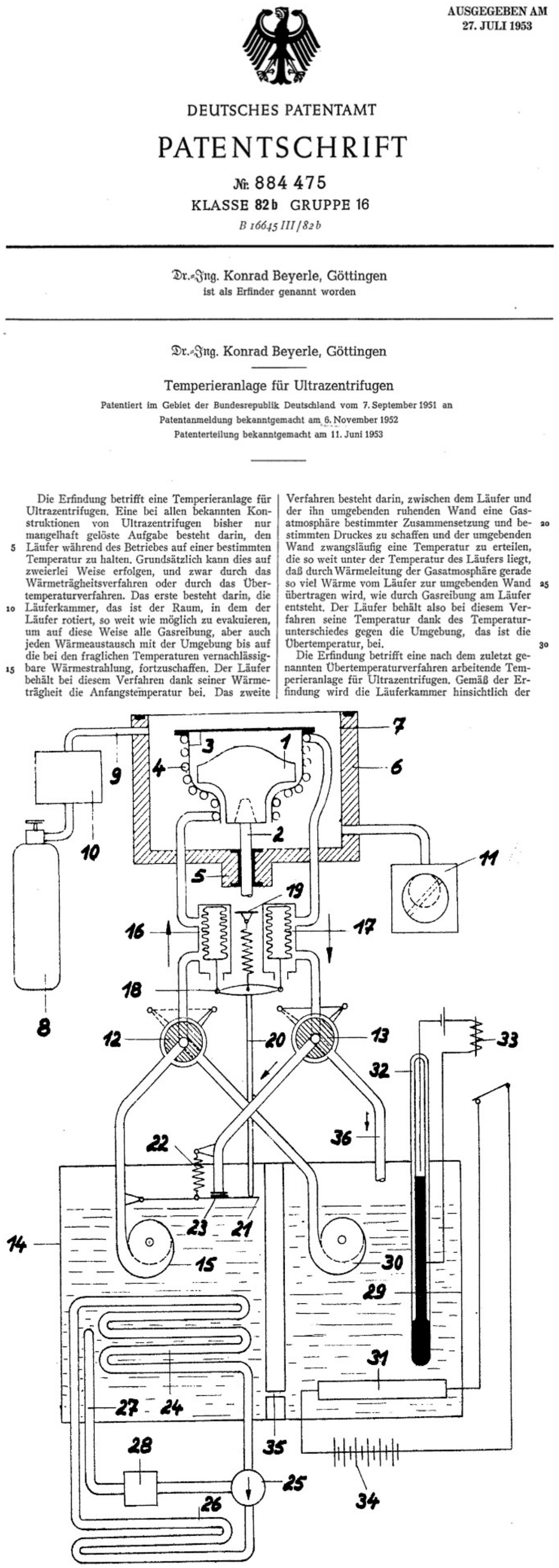
Die Erfindung betrifft eine Radialrohrzentrifuge. Für präparative Arbeiten mit höchsten Normalbeschleunigungen verwendet man bisher die sogenannten Schrägrohrzentrifugen. Der Läufer dieser Zentrifugen hat äußerlich die Gestalt eines abgestumpften Kreiskegels und wird am äußeren Umfang mit einer größeren Zahl von schrägen Bohrungen ausgestattet. Er rotiert um seine Figurenachse. Die mechanische Festigkeit dieses Läufers erreicht nach praktischen Erfahrungen ein Maximum im Verhältnis zum Fassungsvermögen dann, wenn man eine größere Zahl von Bohrungen, mindestens 8 bis 12 Stück, am Umfang anordnet. Besteht der Wunsch, auf höchste Normalbeschleunigungen zu kommen, so könnte man den Schrägrohrläufer ähnlich verkleinern. Dabei würde man aber zu so kleinen Zellen gelangen, daß die Unterteilung der gesamten Stoffmenge für die praktische Handhabung infolge immer größer werdender prozentualer Stoffverluste nachteilig wird. Auch die Handhabung der vielen kleinen Zellen ist mühsam.

Schließlich müssen bei einer Schrägrohrzentrifuge sehr große Materialmassen des Läufers an der Rotation teilnehmen, die für die Aufnahme der Zentrifugalkräfte des Präparates selbst nicht unmittelbar beitragen und zusätzliche Gefahren für die Umgebung mit sich bringen bzw. kostspieligere Schutzvorrichtungen erfordern.

Demgegenüber kennzeichnet sich die Radialrohrzentrifuge gemäß der Erfindung darin, daß der den Stoff aufnehmende Körper als ein an einem Ende geschlossenes Hohlrohr ausgebildet ist, das, mit seiner Achse senkrecht zur Rotationsachse der Zentrifuge stehend, so in den rotierenden Träger eingeschoben ist, daß es durch die Zentrifugalkräfte

Kl. 82b Gr. 1

Figure D.155: After the (West) German patent office reopened in 1949, Konrad Beyerle filed a number of patent applications on gas centrifuges and closely related technologies, likely based on his wartime work at Anschütz.



AUSGEGEBEN AM
27. JULI 1953

DEUTSCHES PATENTAMT

PATENTSCHRIFT

Nr. 884 475
KLASSE 82b GRUPPE 16
B 16645 III/82b

Dr.-Ing. Konrad Beyerle, Göttingen
ist als Erfinder genannt worden

Dr.-Ing. Konrad Beyerle, Göttingen

Temperieranlage für Ultrazentrifugen

Patentiert im Gebiet der Bundesrepublik Deutschland vom 7. September 1951 an
Patentanmeldung bekanntgemacht am 6. November 1952
Patenterteilung bekanntgemacht am 11. Juni 1953

Die Erfindung betrifft eine Temperieranlage für Ultrazentrifugen. Eine bei allen bekannten Konstruktionen von Ultrazentrifugen bisher nur mangelhaft gelöste Aufgabe besteht darin, den Läufer während des Betriebes auf einer bestimmten Temperatur zu halten. Grundsätzlich kann dies auf zweierlei Weise erfolgen, und zwar durch das Wärmeträgheitsverfahren oder durch das Übertemperaturverfahren. Das erste besteht darin, die Läuferkammer, das ist der Raum, in dem der Läufer rotiert, so weit wie möglich zu evakuieren, um auf diese Weise alle Gasreibung, aber auch jeden Wärmeaustausch mit der Umgebung bis auf die bei den fraglichen Temperaturen vernachlässigbare Wärmestrahlung, fortzuschaffen. Der Läufer behält bei diesem Verfahren dank seiner Wärmeträgheit die Anfangstemperatur bei. Das zweite Verfahren besteht darin, zwischen dem Läufer und der ihn umgebenden ruhenden Wand eine Gasatmosphäre bestimmter Zusammensetzung und bestimmten Druckes zu schaffen und der umgebenden Wand zwangsläufig eine Temperatur zu erteilen, die so weit unter der Temperatur des Läufers liegt, daß durch Wärmeleitung der Gasatmosphäre gerade so viel Wärme vom Läufer zur umgebenden Wand übertragen wird, wie durch Gasreibung am Läufer entsteht. Der Läufer behält also bei diesem Verfahren seine Temperatur dank des Temperaturunterschiedes gegen die Umgebung, das ist die Übertemperatur, bei.

Die Erfindung betrifft eine nach dem zuletzt genannten Übertemperaturverfahren arbeitende Temperieranlage für Ultrazentrifugen. Gemäß der Erfindung wird die Läuferkammer hinsichtlich der

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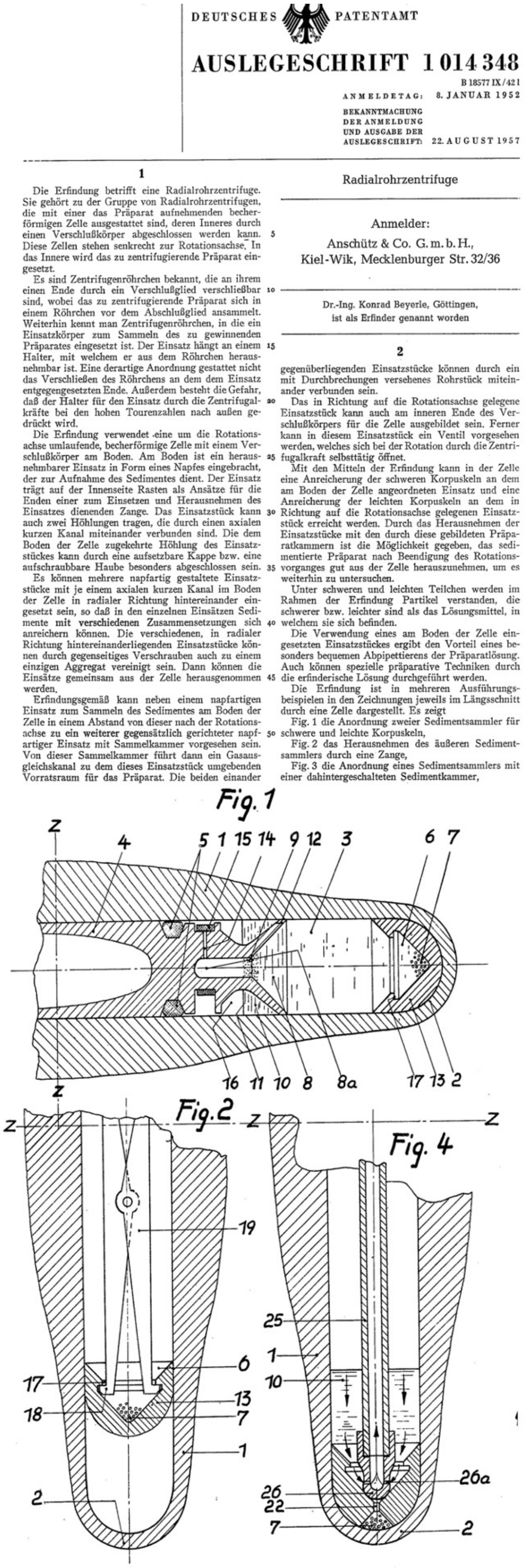

DEUTSCHES PATENTAMT

AUSLEGESCHRIFT 1 014 348

B 18577 IX/42 l
ANMELDETAG: 8. JANUAR 1952
BEKANNTMACHUNG DER ANMELDUNG UND AUSGABE DER AUSLEGESCHRIFT: 22. AUGUST 1957

1

Die Erfindung betrifft eine Radialrohrzentrifuge. Sie gehört zu der Gruppe von Radialrohrzentrifugen, die mit einer das Präparat aufnehmenden becherförmigen Zelle ausgestattet sind, deren Inneres durch einen Verschlußkörper abgeschlossen werden kann. Diese Zellen stehen senkrecht zur Rotationsachse. In das Innere wird das zu zentrifugierende Präparat eingesetzt.

Es sind Zentrifugenröhrchen bekannt, die an ihrem einen Ende durch ein Verschlußglied verschließbar sind, wobei das zu zentrifugierende Präparat sich in einem Röhrchen vor dem Abschlußglied ansammelt. Weiterhin kennt man Zentrifugenröhrchen, in die ein Einsatzkörper zum Sammeln des zu gewinnenden Präparates eingesetzt ist. Der Einsatz hängt an einem Halter, mit welchem er aus dem Röhrchen herausnehmbar ist. Eine derartige Anordnung gestattet nicht das Verschließen des Röhrchens an dem dem Einsatz entgegengesetzten Ende. Außerdem besteht die Gefahr, daß der Halter für den Einsatz durch die Zentrifugalkräfte bei den hohen Tourenzahlen nach außen gedrückt wird.

Die Erfindung verwendet eine um die Rotationsachse umlaufende, becherförmige Zelle mit einem Verschlußkörper am Boden. Am Boden ist ein herausnehmbarer Einsatz in Form eines Napfes eingebracht, der zur Aufnahme des Sedimentes dient. Der Einsatz trägt auf der Innenseite Rasten als Ansätze für die Enden einer zum Einsetzen und Herausnehmen des Einsatzes dienenden Zange. Das Einsatzstück kann auch zwei Höhlungen tragen, die durch einen axialen kurzen Kanal miteinander verbunden sind. Die dem Boden der Zelle zugekehrte Höhlung des Einsatzstückes kann durch eine aufsetzbare Kappe bzw. eine aufschraubbare Haube besonders abgeschlossen sein.

Es können mehrere napfartig gestaltete Einsatzstücke mit je einem axialen kurzen Kanal im Boden der Zelle in radialer Richtung hintereinander eingesetzt sein, so daß in den einzelnen Einsätzen Sedimente mit verschiedenen Zusammensetzungen sich anreichern können. Die verschiedenen, in radialer Richtung hintereinanderliegenden Einsatzstücke können durch gegenseitiges Verschrauben auch zu einem einzigen Aggregat vereinigt sein. Dann können die Einsätze gemeinsam aus der Zelle herausgenommen werden.

Erfindungsgemäß kann neben einem napfartigen Einsatz zum Sammeln des Sedimentes am Boden der Zelle in einem Abstand von dieser nach der Rotationsachse zu ein weiterer gegensätzlich gerichteter napfartiger Einsatz mit Sammelkammer vorgesehen sein. Von dieser Sammelkammer führt dann ein Gasausgleichskanal zu dem dieses Einsatzstück umgebenden Vorratsraum für das Präparat. Die beiden einander

Radialrohrzentrifuge

Anmelder:
Anschütz & Co. G. m. b. H.,
Kiel-Wik, Mecklenburger Str. 32/36

Dr.-Ing. Konrad Beyerle, Göttingen,
ist als Erfinder genannt worden

2

gegenüberliegenden Einsatzstücke können durch ein mit Durchbrechungen versehenes Rohrstück miteinander verbunden sein.

Das in Richtung auf die Rotationsachse gelegene Einsatzstück kann auch am inneren Ende des Verschlußkörpers für die Zelle ausgebildet sein. Ferner kann in diesem Einsatzstück ein Ventil vorgesehen werden, welches sich bei der Rotation durch die Zentrifugalkraft selbsttätig öffnet.

Mit den Mitteln der Erfindung kann in der Zelle eine Anreicherung der schweren Korpuskeln an dem am Boden der Zelle angeordneten Einsatz und eine Anreicherung der leichten Korpuskeln an dem in Richtung auf die Rotationsachse gelegenen Einsatzstück erreicht werden. Durch das Herausnehmen der Einsatzstücke mit den durch diese gebildeten Präparatkammern ist die Möglichkeit gegeben, das sedimentierte Präparat nach Beendigung des Rotationsvorganges gut aus der Zelle herauszunehmen, um es weiterhin zu untersuchen.

Unter schweren und leichten Teilchen werden im Rahmen der Erfindung Partikel verstanden, die schwerer bzw. leichter sind als das Lösungsmittel, in welchem sie sich befinden.

Die Verwendung eines am Boden der Zelle eingesetzten Einsatzstückes ergibt den Vorteil eines besonders bequemen Abpipettierens der Präparatlösung. Auch können spezielle präparative Techniken durch die erfinderische Lösung durchgeführt werden.

Die Erfindung ist in mehreren Ausführungsbeispielen in den Zeichnungen jeweils im Längsschnitt durch eine Zelle dargestellt. Es zeigt

Fig. 1 die Anordnung zweier Sedimentsammler für schwere und leichte Korpuskeln,

Fig. 2 das Herausnehmen des äußeren Sedimentsammlers durch eine Zange,

Fig. 3 die Anordnung eines Sedimentsammlers mit einer dahintergeschalteten Sedimentkammer,

Figure D.156: After the (West) German patent office reopened in 1949, Konrad Beyerle filed a number of patent applications on gas centrifuges and closely related technologies, likely based on his wartime work at Anschütz.

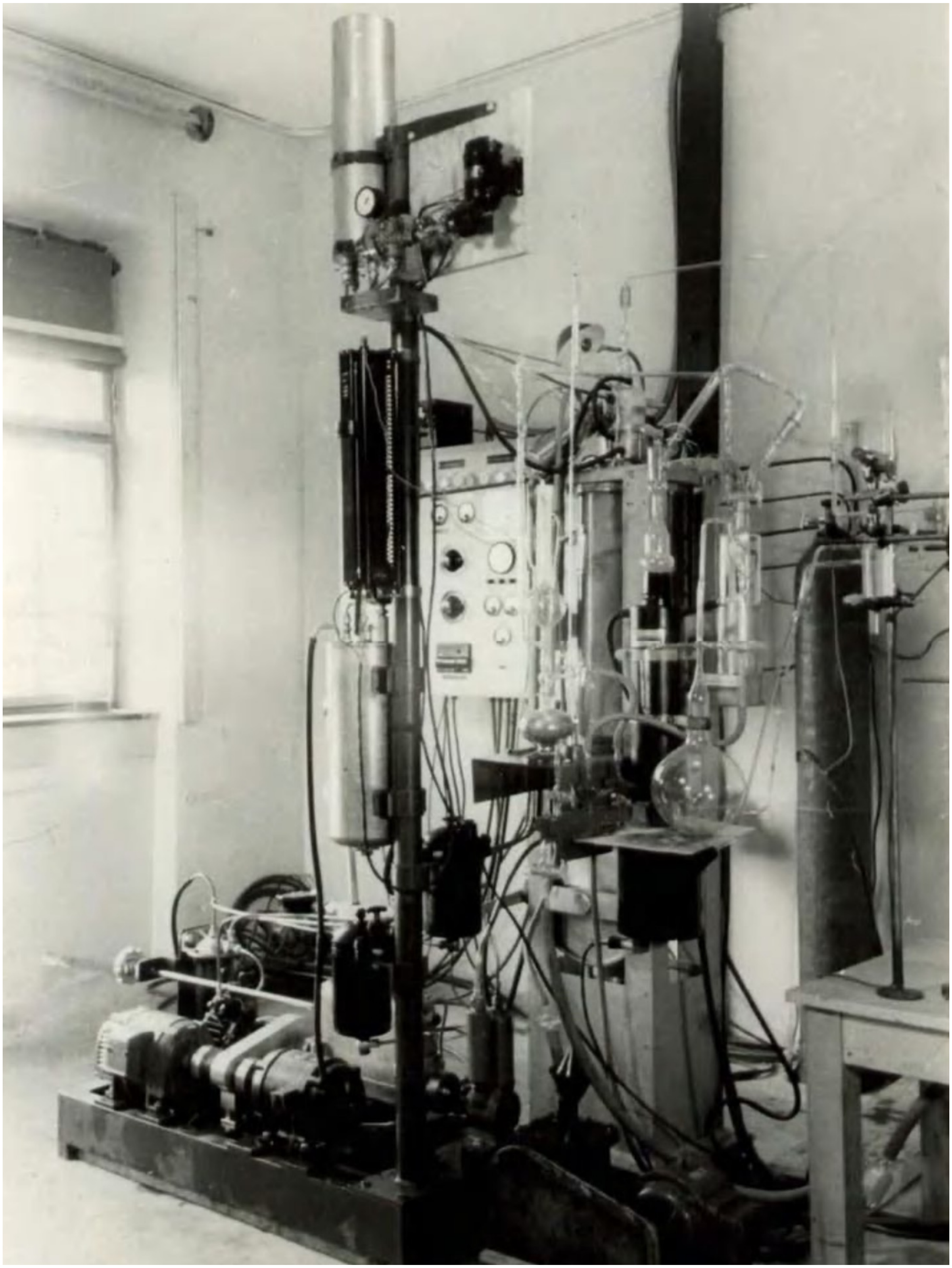

Figure D.157: Two small prototype uranium gas centrifuges manufactured by Hellige in Freiburg, circa 1943 [Deutsches Museum Archive FA 002/811].

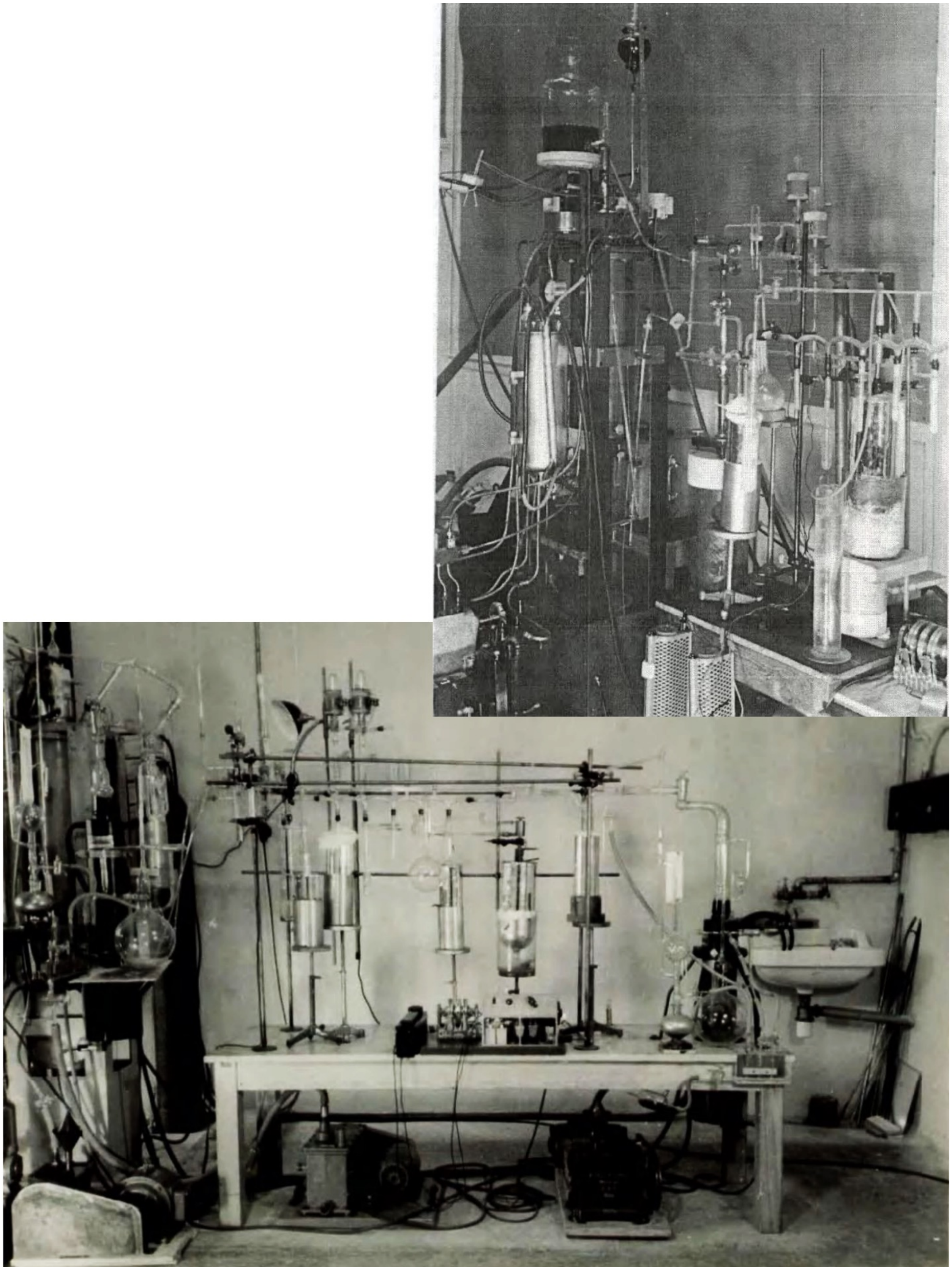

Figure D.158: Systems for collecting and analyzing different fractions produced by uranium gas centrifuges from Hellige in Freiburg, circa 1943 [Deutsches Museum Archive FA 002/811].

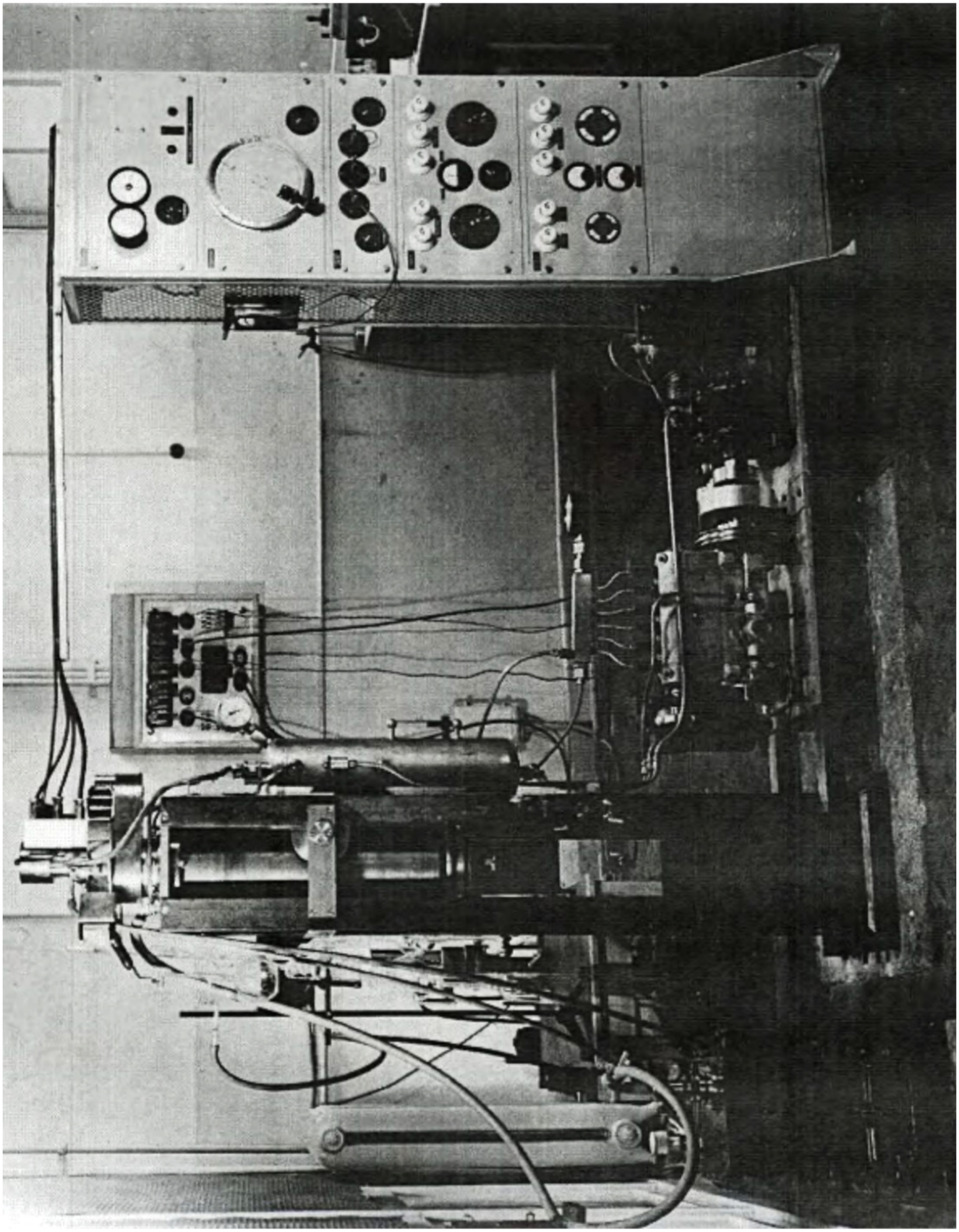

Figure D.159: Large uranium gas centrifuge and control panel manufactured by Hellige in Freiburg, circa 1943 [Deutsches Museum Archive FA 002/811].

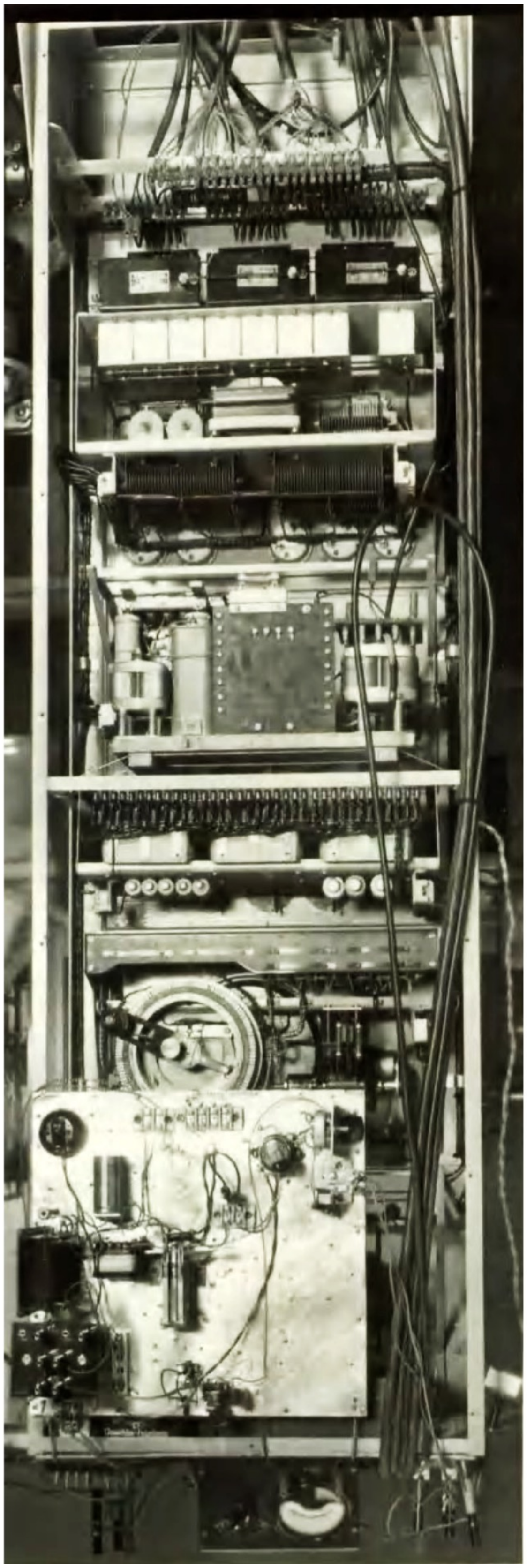

Figure D.160: Interior of the control panel for the large uranium gas centrifuge manufactured by Hellige in Freiburg, circa 1943 [Deutsches Museum Archive FA 002/811].

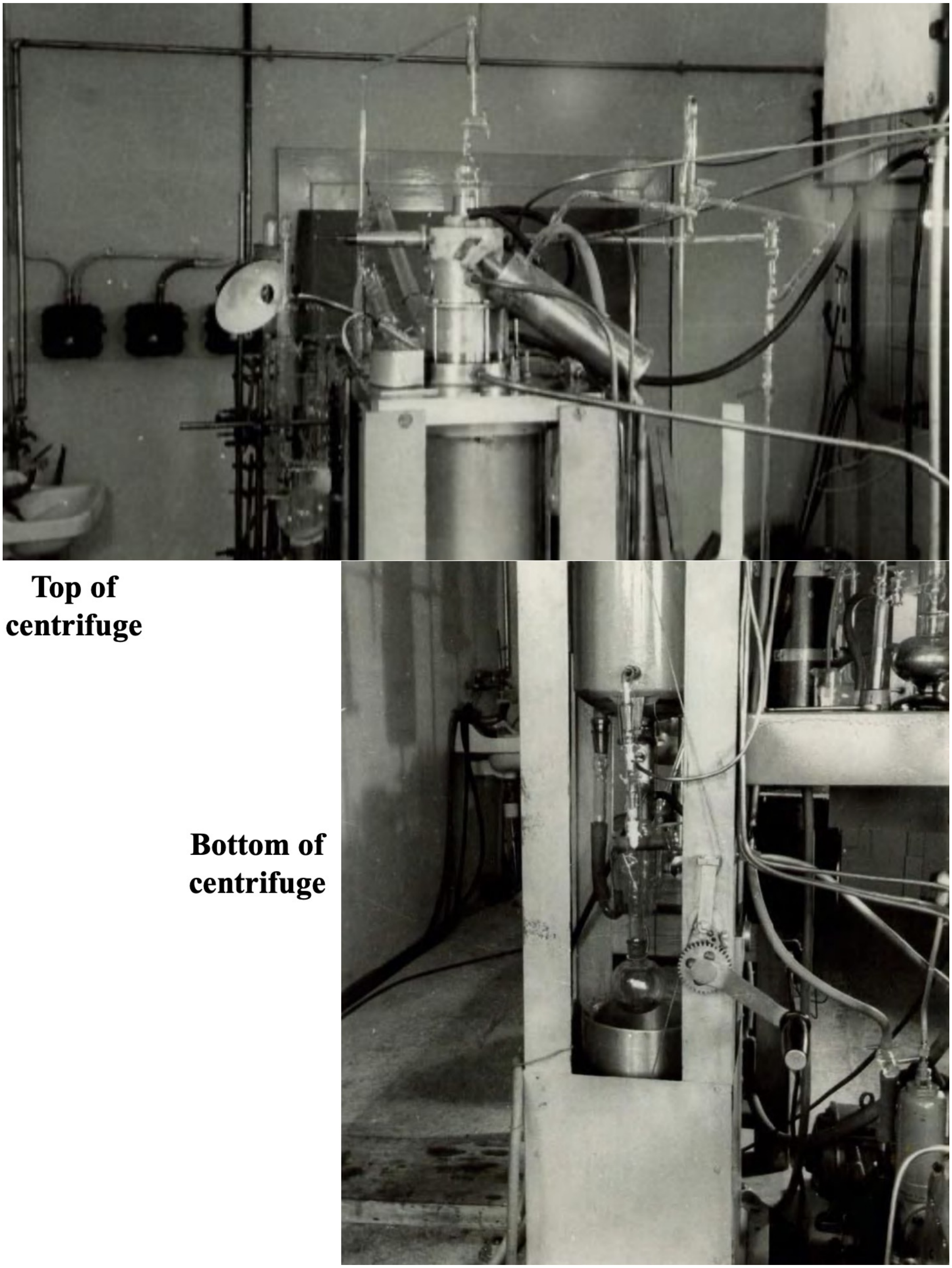
Top of centrifuge
Bottom of centrifuge

Figure D.161: Top and bottom of a large uranium gas centrifuge manufactured by Hellige in Freiburg, circa 1943 [Deutsches Museum Archive FA 002/811].

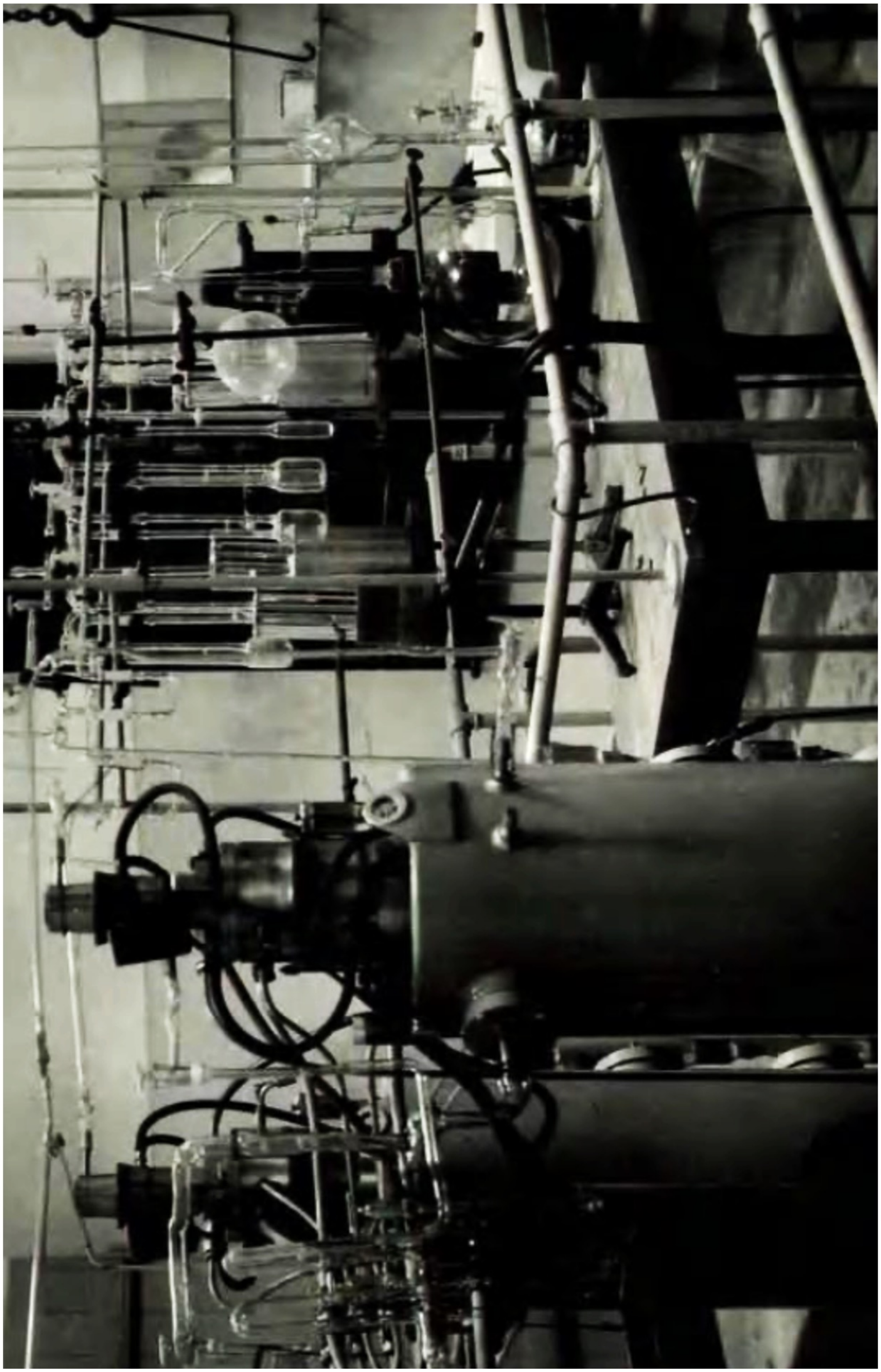

Figure D.162: Two large uranium gas centrifuges manufactured by Hellige in Freiburg, circa 1943 [Deutsches Museum Archive FA 002/811].

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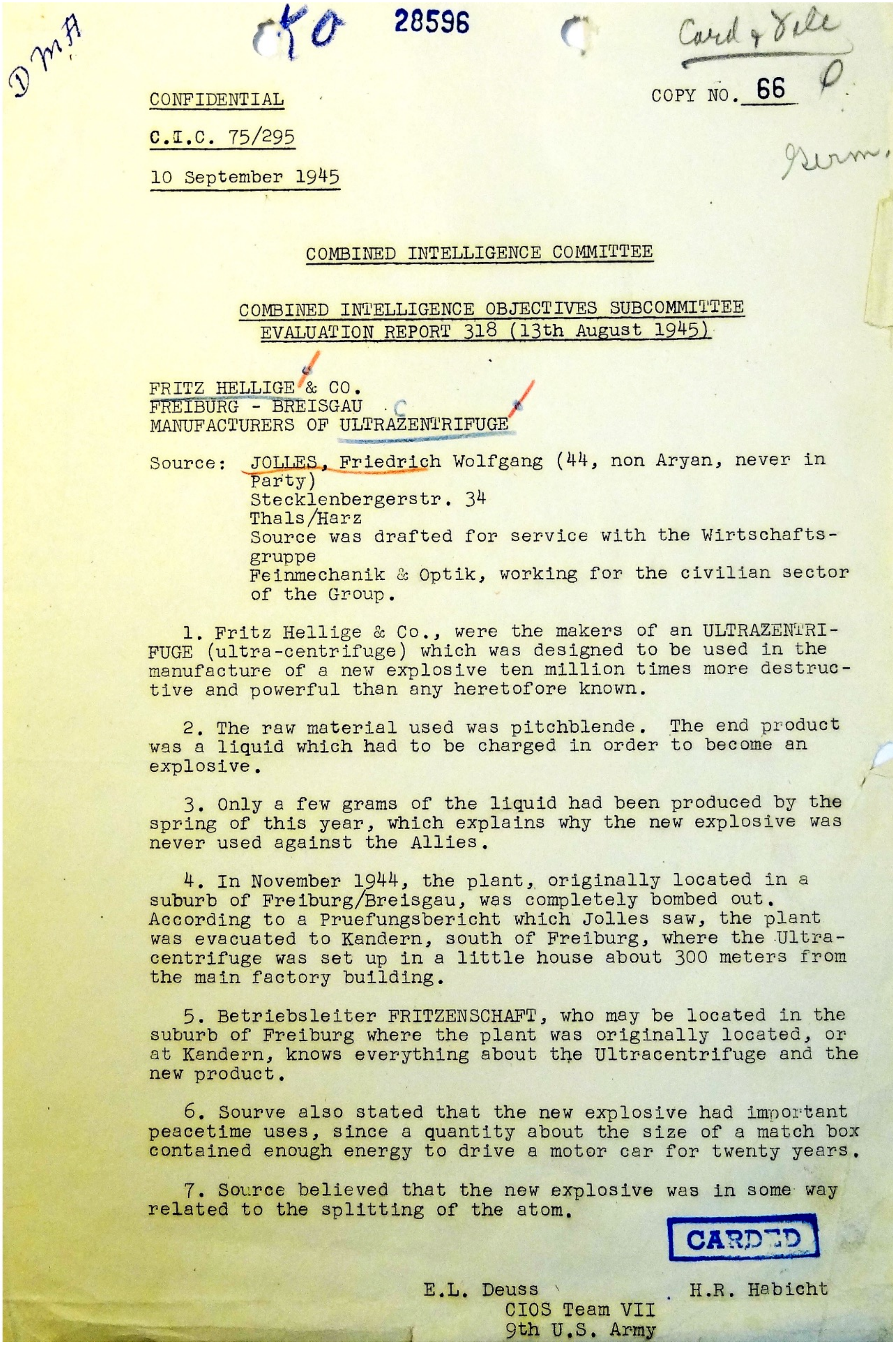
NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1
GERMANY—Research—TA—(1943--June 1946)



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Germ.

10 September 1945

COMBINED INTELLIGENCE COMMITTEE

COMBINED INTELLIGENCE OBJECTIVES SUBCOMMITTEE
EVALUATION REPORT 318 (13th August 1945)

FRITZ HELLIGE & CO.
FREIBURG - BREISGAU
MANUFACTURERS OF ULTRAZENTRIFUGE

Source: JOLLES, Friedrich Wolfgang (44, non Aryan, never in Party)
Stecklenbergerstr. 34
Thals/Harz
Source was drafted for service with the Wirtschaftsgruppe
Feinmechanik & Optik, working for the civilian sector of the Group.

1. Fritz Hellige & Co., were the makers of an ULTRAZENTRIFUGE (ultra-centrifuge) which was designed to be used in the manufacture of a new explosive ten million times more destructive and powerful than any heretofore known.

2. The raw material used was pitchblende. The end product was a liquid which had to be charged in order to become an explosive.

3. Only a few grams of the liquid had been produced by the spring of this year, which explains why the new explosive was never used against the Allies.

4. In November 1944, the plant, originally located in a suburb of Freiburg/Breisgau, was completely bombed out. According to a Pruefungsbericht which Jolles saw, the plant was evacuated to Kandern, south of Freiburg, where the Ultracentrifuge was set up in a little house about 300 meters from the main factory building.

5. Betriebsleiter FRITZENSCHAFT, who may be located in the suburb of Freiburg where the plant was originally located, or at Kandern, knows everything about the Ultracentrifuge and the new product.

6. Sourve also stated that the new explosive had important peacetime uses, since a quantity about the size of a match box contained enough energy to drive a motor car for twenty years.

7. Source believed that the new explosive was in some way related to the splitting of the atom.

CARDED

E.L. Deuss H.R. Habicht
CIOS Team VII
9th U.S. Army

Figure D.163: CIOS ER 318 [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA—(1943–June 1946)].

[Whereas conventional histories only acknowledge the existence of one wartime uranium gas centrifuge program conducted by Beyerle, Groth, Harteck, and collaborators in the Hamburg/Kiel area, there is evidence demonstrating that additional centrifuge programs existed.

For example, Günter Nagel found German documentation of a previously unknown but apparently quite significant uranium gas centrifuge program that was conducted for at least three or four years under the Army Ordnance Office [Karlsch and Petermann 2007, pp. 249–251]:]

Schumann und Diebner waren sich offenkundig schon früh darüber im Klaren, dass die Isotopentrennung eines der zentralen Probleme des Uranprogramms ist. Deshalb wurden auch Kräfte des II. PI dafür herangezogen. So legten Werner Holtz und Werner Schwietzke Anfang 1942 ein zwei Seiten umfassendes Dokument “Ultrazentrifuge zur Trennung von Gasgemischen (Vorbericht)” vor. [...]

Auf die Beteiligung von Holtz und Schwietzke an der Entwicklung einer Ultrazentrifuge wies auch Dr. Herbert Kunz hin. [...]

Einen weiteren Beleg für die Beteiligung von Holtz und Schwietzke an der Zentrifugenentwicklung lieferte Frau Ursula Schulze, die zu ihrer Flucht 1945 in die “neue Verlagerungsstelle des II. Physikalischen Instituts” im Schloss Zandt bei Cham im Bayerischen Wald berichtete: “Auch Holtz und Schwietzke waren dort angelangt. Dann mussten wir alle schriftlichen Unterlagen der Kernzentrifugenforschung, an der auch Ortwin [Schulze] bei Schwietzke mitgearbeitet hatte, verbrennen. Dabei wussten wir noch nicht, dass Schwietzke Duplikate besaß, was ihn durch unsere Hilfe nach Australien weiterhalf.”

Schumann and Diebner were obviously already aware that isotope separation is one of the central problems of the uranium program. For this reason, resources of the Second Physics Institute were used for this. Thus in early 1942, Werner Holtz and Werner Schwietzke presented a two-page document entitled “Ultracentrifuge for the Separation of Gas Mixtures (Preliminary Report).” [...]

The involvement of Holtz and Schwietzke in the development of an ultracentrifuge was also emphasized by Dr. Ing. Herbert Kunz. [...]

Further evidence of the involvement of Holtz and Schwietzke in centrifuge development was provided by Ms. Ursula Schulze, who reported on her escape in 1945 to the “new relocation office of the Second Physics Institute” in Zandt Castle near Cham in the Bavarian Forest: “Holtz and Schwietzke had arrived there, too, and then we had to burn all the written records of the nuclear centrifuge research, on which also Ortwin [Schulze] had worked with Schwietzke. We did not yet know that Schwietzke possessed duplicates, which helped him in Australia.”

[In the National Archives of Australia, Gernot Eilers found postwar documentation on Werner Schwietzke and his gas centrifuge designs, from the time period during which he emigrated to Australia.]

File on Werner Schwietzke. 1947–1951. National Archives of Australia. Series number MT105/8, control symbol 1/6/3094, barcode 934755. Note: pages are numbered in reverse order in red pencil in upper right corner. https://recordsearch.naa.gov.au/SearchNRetrieve/NAAMedia/ShowImage.aspx?B=934755&T=PDF

[p. 41] Schwietzke was checked closely on his party activities. [...] I enquired from Czerny on his political past and was informed I could be sure he had not dabbled in politics any more than was necessary by his profession. Czerny did not hesitate to say he could vouch for him. This was also the opinion I formed. Schwietzke is the type who is interested in academic not political problems.

As requested I attempted to get details of the laboratory centrifuge.

The position is that due to bombing no existing centrifuge or drawings are available to Dr. Schwietzke. He does however feel he has the capacity to design a similar machine quite easily. [...]

The Centrifuge was made by PHYWE (Trade name of Physicalische Werkstatte) of Göttingen from sketches and instructions. No special drawings, and unlikely that PHYNE have useful data there he feels. [...]

As soon as the centrifuge details submitted by Dr. Schwietzke are received they will be transmitted to Australia.

H. P. Matthews.

[pp. 20–19, the end of a detailed 14-page paper written by Schwietzke in German after the war giving an apparently selective account of his early centrifuge experiments during the war:]

Da die theoretischen Berechnungen der Spannungsverteilung des mit hoher Geschwindigkeit umlaufenden Rotors nur mit einer gewissen Annäherung vorgenommen werden können, war es empfehlenswert, den genau ausgewuchteten Rotor einen Probelauf unterhalb der als kritisch errechneten Umlaufhöchstgeschwindigkeit von 65 000 U/Min. ausführen zu lassen und durch Präzisionsmessungen nach dem Lauf die evt. auftretenden Veränderungen des Rotors genauestens zu bestimmen. Nach einer beträchtlichen Anzahl von Versuchsreihen über mehrere Stunden bei 60 000 U/Min. konnte eine Verformung des Rotors niemals festgestellt werden, so dass eine ständige Betriebsdrehzahl von 56 000 U/Min. bei den vorgesehenen Versuchen ohne Gefahr gewählt werden konnte.	Since the theoretical calculations of the stress distribution of the rotor rotating at high speed can only be carried out with a certain approximation, it was recommended that the precisely balanced rotor be subjected to a test run below the maximum rotational speed of 65,000 rpm, which was calculated as critical, and that any changes in the rotor be precisely determined by precision measurements after the run. After a considerable number of test series over several hours at 60,000 rpm a deformation of the rotor never could be detected, so that a constant operating speed of 56,000 rpm could be selected for the intended tests without danger.
Diese wenig Platz und Aufwand erfordernde Ultrazentrifuge hat sich in der Praxis ausserordentlich gut bewährt.	This ultracentrifuge, which requires little space and effort, has proven itself extraordinarily good in practice.

[Werner Schwietzke and his uranium gas centrifuges clearly existed, as shown by the German and Australian evidence, yet they had been completely forgotten by history. The fact that Werner Grothmann mentioned the importance of Schwietzke and his wartime work [p. 3709] strongly supports both the authenticity and the usefulness of the Werner Grothmann interview transcript.

In contrast, the fact that Erich Schumann neglected to mention Schwietzke and his centrifuges in his postwar writings, even though most of that work was conducted directly under Schumann, suggests that Schumann deliberately omitted major people and programs from his writings to make the wartime German program appear much smaller and much less advanced than it actually was.

German gas centrifuges were produced by:

- Anschütz in Kiel (pp. 3494–3515), which had decades of experience making advanced gyroscopes (p. 1500).
- PHYWE (Physicalische Werkstatte) in Göttingen (p. 3543), which also made extremely advanced liquid centrifuges for biochemical research (pp. 2397–2399).
- Linde Eismaschinen in Munich (pp. 3498–3507), which had decades of experience with gas handling and rotating compressor machinery.
- Hellige in Freiburg (pp. 3512–3540).
- Hellige in Breslau/Wrocław (p. 4522).
- One or more factories in Switzerland for export to Germany (pp. 3545–3548). This was reported by Constantin Chilowsky (Russian/French/Swiss, 1880–1958), a distinguished scientist with decades of experience working on sonar and a wide variety of other technologies, who said he had personally seen the factory and the uranium centrifuges.
- Quite possibly other locations as well.

How many uranium gas centrifuges were produced by or for Germany during the war? At what sites were they installed and operated? How much enriched uranium did they produce in total, and how highly enriched was it? Can files that would answer these questions be located in various national archives and declassified?

Centrifugation proved so superior to the U.S. Manhattan Project's enrichment methods that the German gas centrifuge designs are now the worldwide standard for uranium enrichment. The evidence clearly demonstrates that the technology was developed and demonstrated over the course of the war by German scientists and engineers, and spread by German scientists and engineers (as well as the prototypes and documentation they had produced) to other countries after the war. The Soviet Union was one of those countries to which the technology spread (via scientists such as Max Steenbeck and Gernot Zippe), but not the origin of the technology [Helmbold 2016; Kemp 2009, 2012, 2017; NYT 2004-03-23].

Just as most of these German centrifuge programs were kept so quiet during World War II and in all the decades afterward, it is entirely possible that other major wartime programs on advanced nuclear or other technologies are still unknown or poorly understood.]

H. T. Wensel to Robert Furman. 14 March 1944. See document photos on pp. 3546–3548. [NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb, https://downloads.paperlessarchives.com, pp. 6084–6089.]

March 14, 1944

MEMORANDUM

TO: Major R. R. Furman

FROM: H. T. Wensel

This memorandum will put on record the information which I gave you orally yesterday.

Dr. H. C. Urey of Columbia University was approached through a Professor Perrin, who was then an exchange Professor in the Chemistry Department at Columbia University, on behalf of one Constantin Chilowsky. Chilowsky was desirous of selling an invention, the exact method never disclosed to us, for accomplishing the same purpose which the Manhattan District is seeking to. Professor Urey indicated that he was not interested in the matter but passed the information on to the OSRD, and I was asked to interview Chilowsky by Dr. Conant to see what I could find out. I used my credentials as a member of the National Bureau of Standards and indicated to Chilowsky and Professor Perrin that I had no other government connection.

Chilowsky was a Swiss and refused to divulge even the approximate nature of his method but, inasmuch as I indicated that the government would be apathetic to the idea until shown that something practical was involved, in order to "sell" me on the importance of the job, he indicated to me that the Germans were actively engaged on the same objective. In particular, he told me he had personally seen in a factory in Switzerland centrifuges which were being produced to be sent to Germany for the Germans' work on this field.

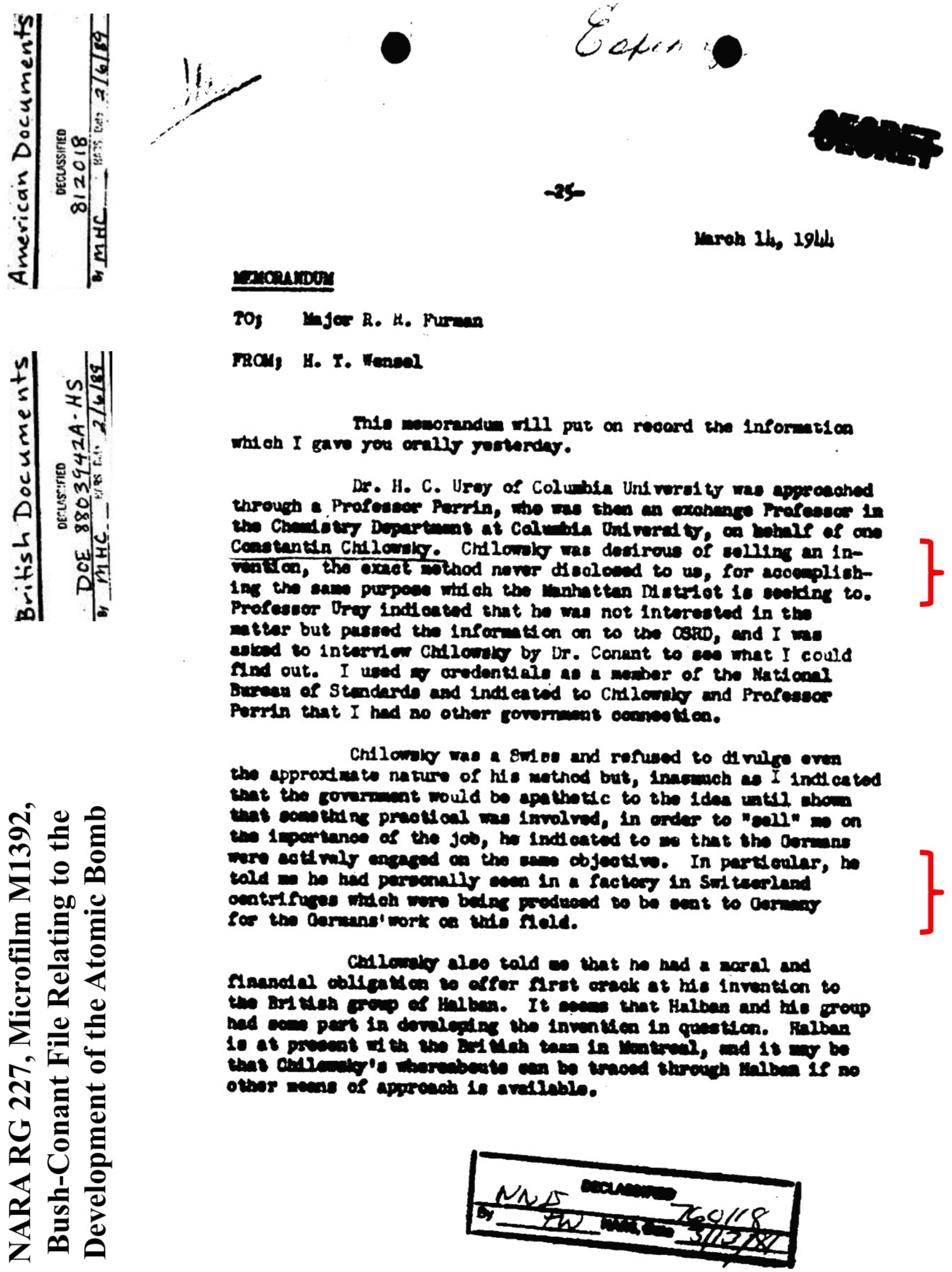
Chilowsky also told me that he had a moral and financial obligation to offer first crack at his invention to the British group of Halban. It seems that Halban and his group had some part in developing the invention in question. Halban is at present with the British team in Montreal, and it may be that Chilowsky's whereabouts can be traced through Halban if no other means of approach is available.

[A Swiss factory was producing uranium centrifuges and sending them to Germany, apparently in 1942 or 1943; details are still classified.

Constantin Chilowsky (Russian/French/Swiss, 1880–1958) was a distinguished scientist with decades of experience working on a wide variety of technologies ranging from sonar to fission reactors:

> Constantin Chilowsky [obituary]. *New York Daily News*, 1 July 1958, p. 386.
> https://www.newspapers.com/article/daily-news-death-of-constantin-chilowsky/114034053/
>
> *Technology Mobilization: Hearings Before a Subcommittee of the Committee on Military Affairs. United States Senate.* 1942. December 12, 14, 17-19. Washington, DC: U.S. Government Printing Office. p. 631: Constantin Chilowsky.
> https://books.google.com/books?id=LzoTAAAAIAAJ&pg=PA631

Thus Chilowsky was a thoroughly qualified and highly reputable source, and he said that he had personally seen the factory and the uranium centrifuges. His story was considered credible and important by French nuclear physicist Francis Perrin and Manhattan Project scientists Harold C. Urey and H. T. Wensel.]



American Documents
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812018
By MHC NARS Date 2/6/89

British Documents
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By MHC NARS Date 2/6/89

NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb

SECRET

-25-

March 14, 1944

MEMORANDUM

TO: Major R. R. Furman

FROM: H. T. Wensel

This memorandum will put on record the information which I gave you orally yesterday.

Dr. H. C. Urey of Columbia University was approached through a Professor Perrin, who was then an exchange Professor in the Chemistry Department at Columbia University, on behalf of one Constantin Chilowsky. Chilowsky was desirous of selling an invention, the exact method never disclosed to us, for accomplishing the same purpose which the Manhattan District is seeking to. Professor Urey indicated that he was not interested in the matter but passed the information on to the OSRD, and I was asked to interview Chilowsky by Dr. Conant to see what I could find out. I used my credentials as a member of the National Bureau of Standards and indicated to Chilowsky and Professor Perrin that I had no other government connection.

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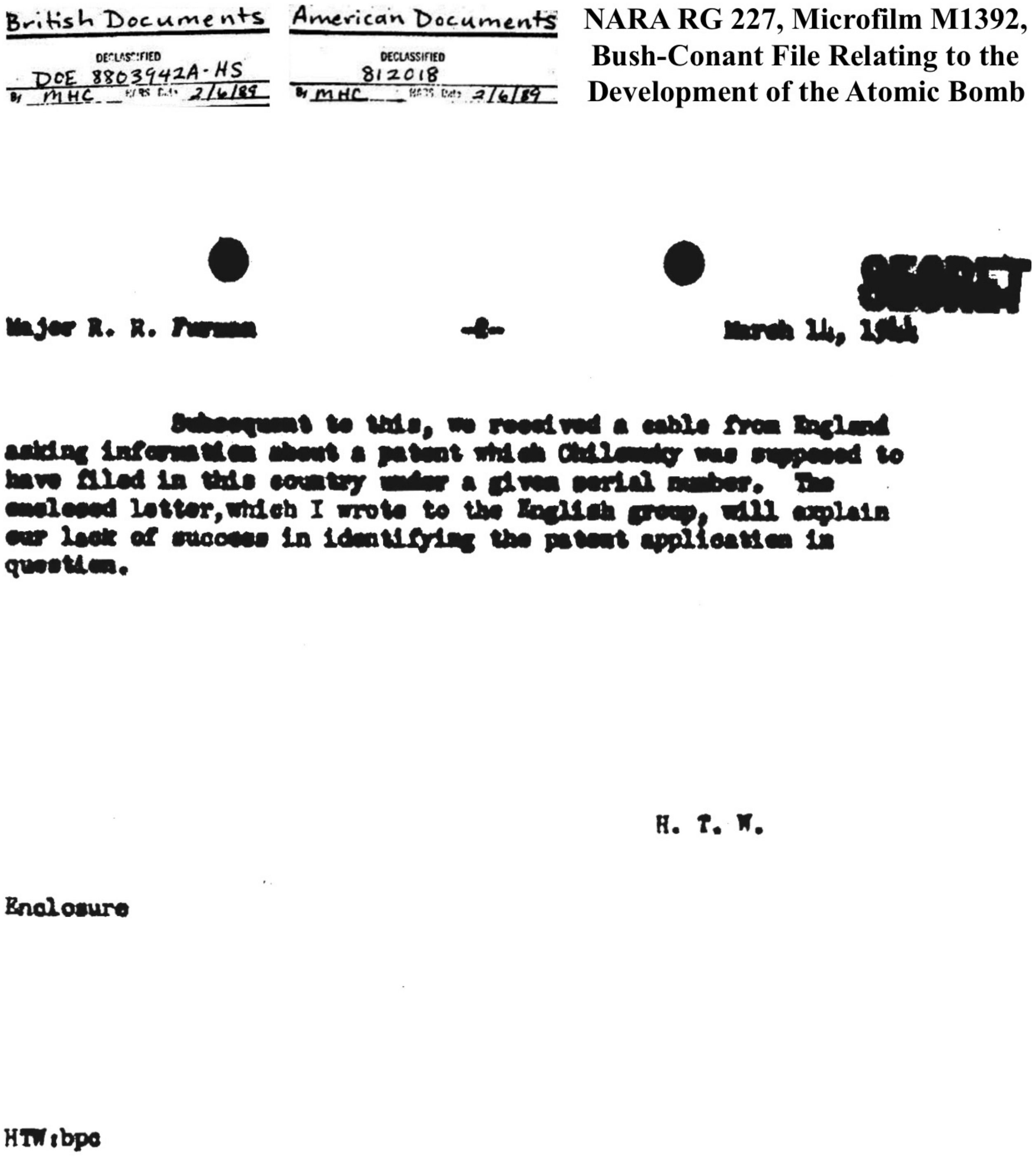
By FW NARA, Date 3/13/81

Figure D.164: A Swiss factory was producing uranium centrifuges and sending them to Germany, apparently in 1942; details are still classified. [H. T. Wensel to Robert Furman, 14 March 1944. NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb, https://downloads.paperlessarchives.com, pp. 6084–6089.]



British Documents
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American Documents
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By MHC NARS Date 2/6/89

NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb

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Major R. R. Furman -2- March 14, 1944

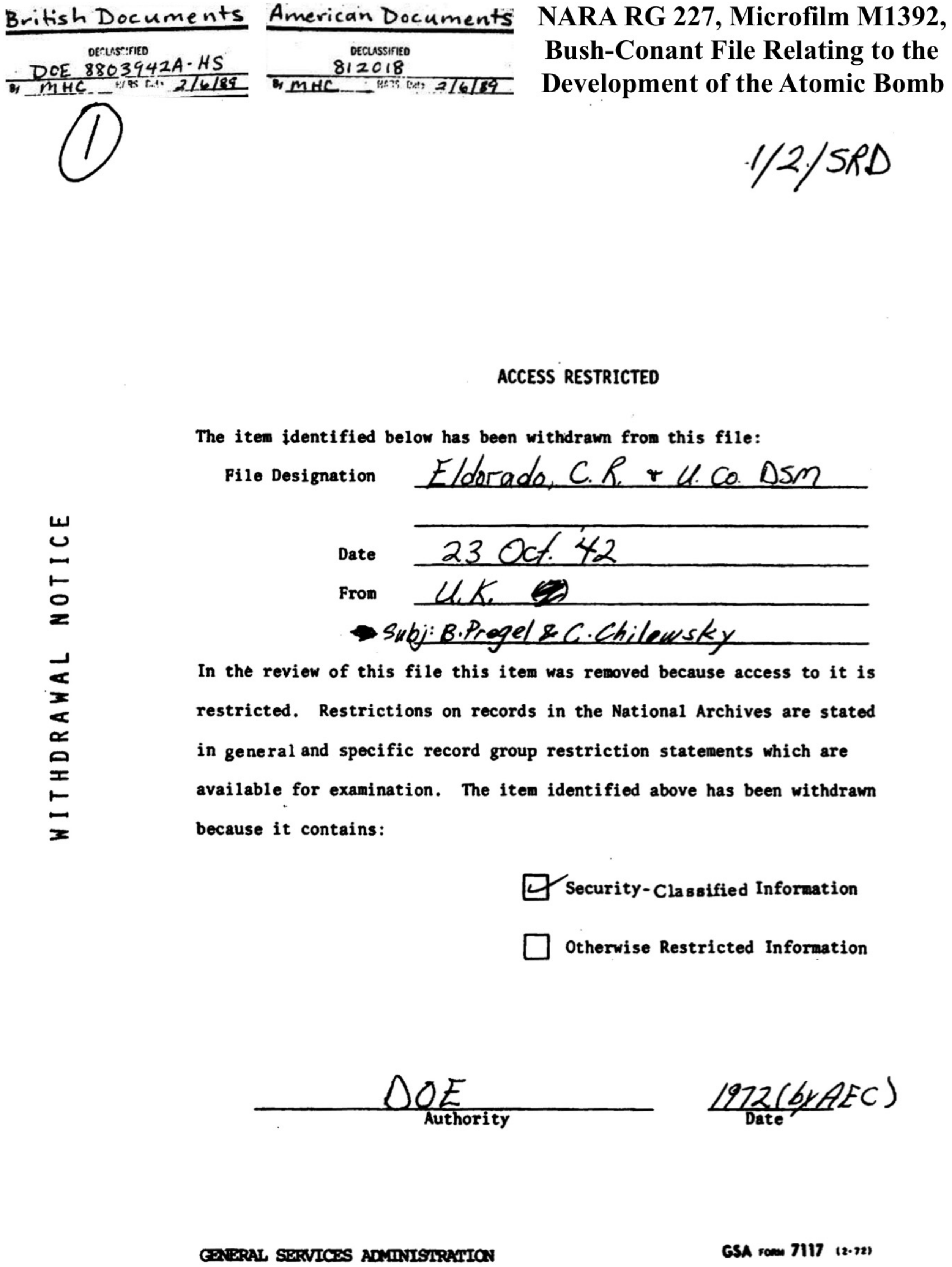
Subsequent to this, we received a cable from England asking information about a patent which Chilowsky was supposed to have filed in this country under a given serial number. The enclosed letter, which I wrote to the English group, will explain our lack of success in identifying the patent application in question.

H. T. W.

Enclosure

HTW:bpc

Figure D.165: A Swiss factory was producing uranium centrifuges and sending them to Germany, apparently in 1942; details are still classified. [H. T. Wensel to Robert Furman, 14 March 1944. NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb, https://downloads.paperlessarchives.com, pp. 6084–6089.]



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File Designation Eldorado, C.R. & U. Co. DSM

Date 23 Oct. 42

From U.K. [redacted]

Subj: B. Pregel & C. Chilowsky

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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☐ **Otherwise Restricted Information**

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Authority

1972 (by AEC)
Date

GENERAL SERVICES ADMINISTRATION **GSA FORM 7117 (2-72)**

Figure D.166: A Swiss factory was producing uranium centrifuges and sending them to Germany, apparently in 1942; details are still classified. [H. T. Wensel to Robert Furman, 14 March 1944. NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb, https://downloads.paperlessarchives.com, pp. 6084–6089.]

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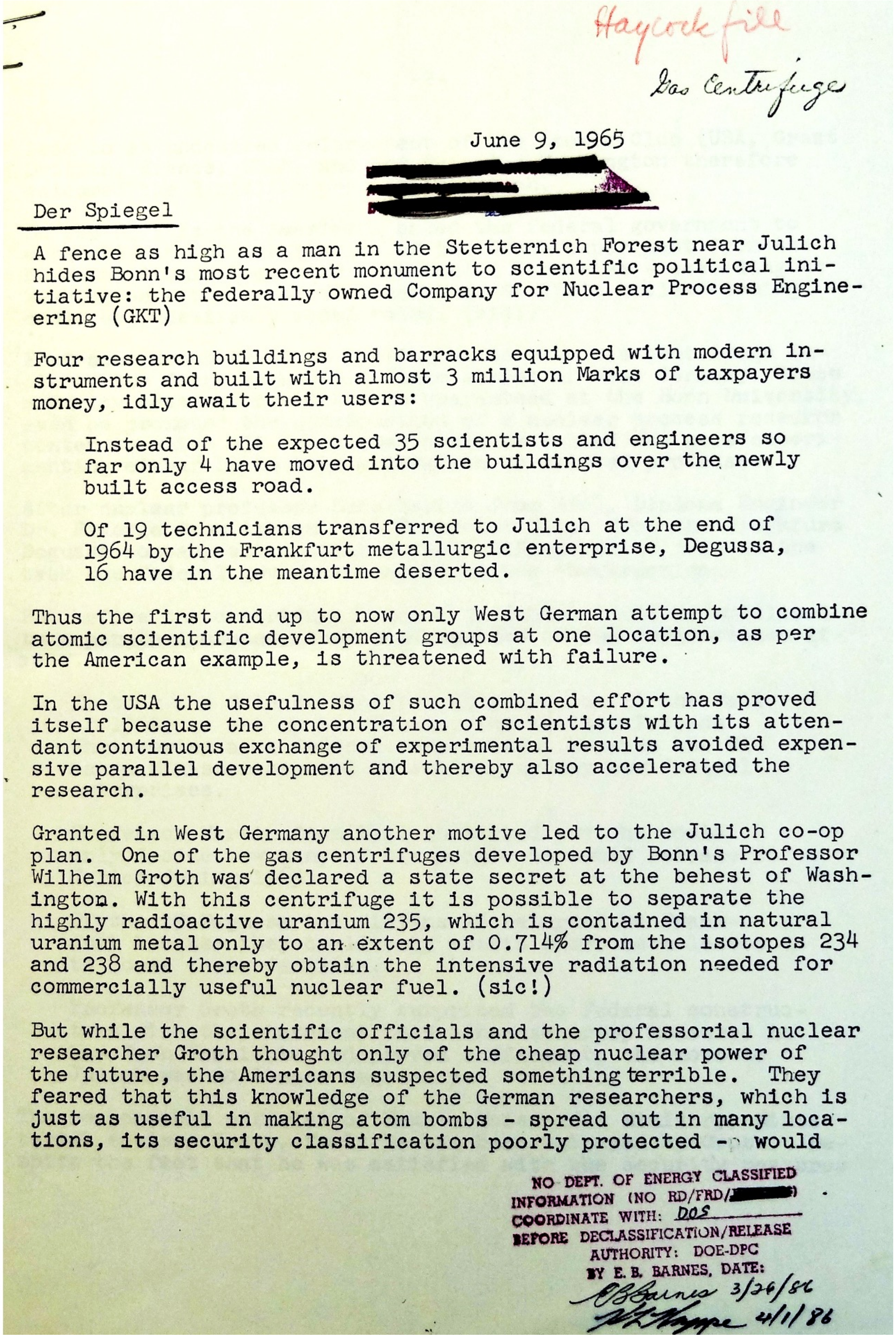

Haycock file

Gas Centrifuge

June 9, 1965

[redacted]

Der Spiegel

A fence as high as a man in the Stetternich Forest near Julich hides Bonn's most recent monument to scientific political initiative: the federally owned Company for Nuclear Process Engineering (GKT)

Four research buildings and barracks equipped with modern instruments and built with almost 3 million Marks of taxpayers money, idly await their users:

> Instead of the expected 35 scientists and engineers so far only 4 have moved into the buildings over the newly built access road.
>
> Of 19 technicians transferred to Julich at the end of 1964 by the Frankfurt metallurgic enterprise, Degussa, 16 have in the meantime deserted.

Thus the first and up to now only West German attempt to combine atomic scientific development groups at one location, as per the American example, is threatened with failure.

In the USA the usefulness of such combined effort has proved itself because the concentration of scientists with its attendant continuous exchange of experimental results avoided expensive parallel development and thereby also accelerated the research.

Granted in West Germany another motive led to the Julich co-op plan. One of the gas centrifuges developed by Bonn's Professor Wilhelm Groth was declared a state secret at the behest of Washington. With this centrifuge it is possible to separate the highly radioactive uranium 235, which is contained in natural uranium metal only to an extent of 0.714% from the isotopes 234 and 238 and thereby obtain the intensive radiation needed for commercially useful nuclear fuel. (sic!)

But while the scientific officials and the professorial nuclear researcher Groth thought only of the cheap nuclear power of the future, the Americans suspected something terrible. They feared that this knowledge of the German researchers, which is just as useful in making atom bombs - spread out in many locations, its security classification poorly protected - would

NO DEPT. OF ENERGY CLASSIFIED
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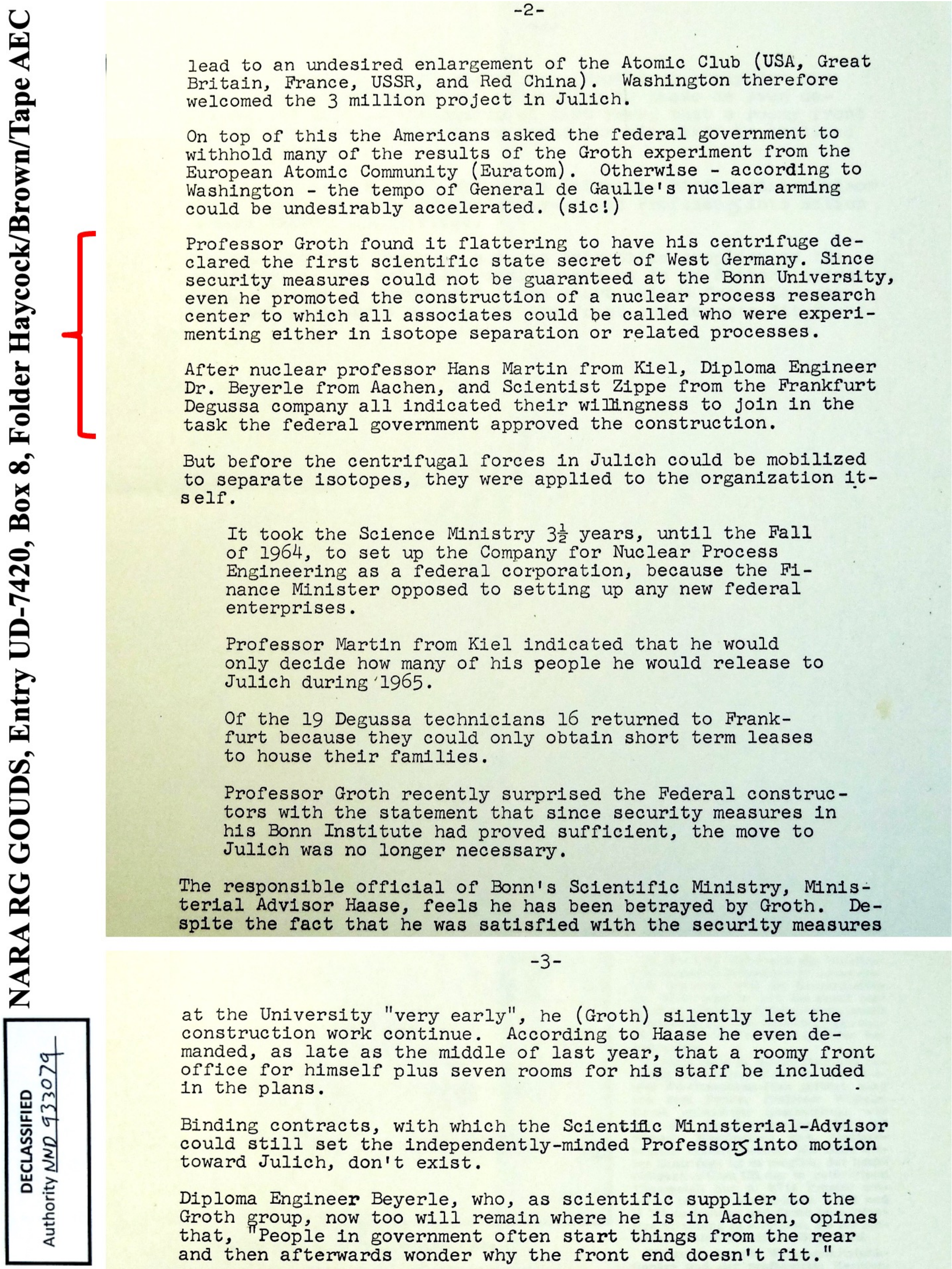
AUTHORITY: DOE-DPC
BY E. B. BARNES, DATE:
EBBarnes 3/26/86
4/1/86

Figure D.167: Samuel Goudsmit's personal copy of an English translation of *Der Spiegel*, 8 June 1965, Kernforschung von hinten [NARA RG GOUDS, Entry UD-7420, Box 8, Folder Haycock/Brown/Tape AEC; https://www.spiegel.de/politik/von-hinten-a-359489f2-0002-0001-0000-000046272934]. The uranium gas centrifuges developed by Hans Martin, Wilhelm Groth, Konrad Beyerle, and other German-speaking experts during the war ultimately became the worldwide preferred method of uranium enrichment despite Goudsmit's best efforts to suppress them (p. 3289).



NARA RG GOUDS, Entry UD-7420, Box 8, Folder Haycock/Brown/Tape AEC

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lead to an undesired enlargement of the Atomic Club (USA, Great Britain, France, USSR, and Red China). Washington therefore welcomed the 3 million project in Julich.

On top of this the Americans asked the federal government to withhold many of the results of the Groth experiment from the European Atomic Community (Euratom). Otherwise - according to Washington - the tempo of General de Gaulle's nuclear arming could be undesirably accelerated. (sic!)

Professor Groth found it flattering to have his centrifuge declared the first scientific state secret of West Germany. Since security measures could not be guaranteed at the Bonn University, even he promoted the construction of a nuclear process research center to which all associates could be called who were experimenting either in isotope separation or related processes.

After nuclear professor Hans Martin from Kiel, Diploma Engineer Dr. Beyerle from Aachen, and Scientist Zippe from the Frankfurt Degussa company all indicated their willingness to join in the task the federal government approved the construction.

But before the centrifugal forces in Julich could be mobilized to separate isotopes, they were applied to the organization itself.

> It took the Science Ministry 3½ years, until the Fall of 1964, to set up the Company for Nuclear Process Engineering as a federal corporation, because the Finance Minister opposed to setting up any new federal enterprises.
>
> Professor Martin from Kiel indicated that he would only decide how many of his people he would release to Julich during 1965.
>
> Of the 19 Degussa technicians 16 returned to Frankfurt because they could only obtain short term leases to house their families.
>
> Professor Groth recently surprised the Federal constructors with the statement that since security measures in his Bonn Institute had proved sufficient, the move to Julich was no longer necessary.

The responsible official of Bonn's Scientific Ministry, Ministerial Advisor Haase, feels he has been betrayed by Groth. Despite the fact that he was satisfied with the security measures

-3-

at the University "very early", he (Groth) silently let the construction work continue. According to Haase he even demanded, as late as the middle of last year, that a roomy front office for himself plus seven rooms for his staff be included in the plans.

Binding contracts, with which the Scientific Ministerial-Advisor could still set the independently-minded Professors into motion toward Julich, don't exist.

Diploma Engineer Beyerle, who, as scientific supplier to the Groth group, now too will remain where he is in Aachen, opines that, "People in government often start things from the rear and then afterwards wonder why the front end doesn't fit."

Figure D.168: Samuel Goudsmit's personal copy of an English translation of *Der Spiegel*, 8 June 1965, Kernforschung von hinten [NARA RG GOUDS, Entry UD-7420, Box 8, Folder Haycock/Brown/Tape AEC; https://www.spiegel.de/politik/von-hinten-a-359489f2-0002-0001-0000-000046272934]. The uranium gas centrifuges developed by Hans Martin, Wilhelm Groth, Konrad Beyerle, and other German-speaking experts during the war ultimately became the worldwide preferred method of uranium enrichment despite Goudsmit's best efforts to suppress them (p. 3289).

R. Scott Kemp. 2009. Gas Centrifuge Theory and Development: A Review of U.S. Programs. ***Science and Global Security*** **17:1–19.**

When the Manhattan Project began, centrifuges of this kind were considered as a candidate technology for concentrating uranium-235 for the first nuclear weapon. [Jesse] Beams was asked to oversee the centrifuge project and led a design team at the University of Virginia. The Westinghouse Research Laboratory was charged with building the first production machines, and testing was done at the Standard Oil Development Company in Bayway, New Jersey. The team at the University of Virginia designed a supercritical machine, 7.35 in diameter and 136 in long, which operated at 270 m/s in a four-stream mode. Westinghouse built a slightly smaller version, 7.2 in diameter by 132 in long, as well as a subcritical machine, 7.2 in diameter by 42 in long. Separation tests began with the subcritical unit in August 1943 and continued for 93 of 99 days before the oil gland developed a leak and caused the centrifuge to crash at 215 m/s in December of 1943. The program was terminated by enrichment-project manager Harold Urey a few weeks later in favor of gaseous diffusion. [...]

In December 1951, the Committee on Isotope Separation of the Division of Research strongly advised against a post-war centrifuge revival, noting that centrifuges could not compete economically with existing gaseous diffusion technology. That would change in 1953 when German groups led by Wilhelm Groth and Konrad Beyerle, and a Dutch group led by Jacob Kistemaker, began asserting that their centrifuges would soon be more economical than American-style diffusion. Fearing a loss of their uranium-enrichment monopoly, the U.S. Atomic Energy Commission decided to revive centrifuge research in September 1954. But the revival was desultory: No machines were built because the AEC was confident that it would have full access to German technology, which was at that time the most advanced in the West. [...]

In the summer of 1956, the Soviet Union began repatriating captive German scientists who had been working on uranium enrichment at Institutes A and G at Sukhumi on the Black Sea. Oswald Francis ("Mike") Schuette of the U.S. Office of Naval Intelligence had the task of interrogating the returning Germans. By chance, one of his subjects was the Austrian scientist Gernot Zippe, who wound up in Germany only because he could not afford rail fare back to his native Austria. Zippe had become a flight instructor for the Luftwaffe after he finished his Ph.D. He was captured by Soviet forces and sent to the Krasnogorsk detention camp, but when the Soviets learned of his technical background he was transferred to Institute A, where he was put in charge of mechanical developments for the Soviet centrifuge program.

Schutte's report of Zippe's activities attracted the interest of the Intelligence Division of the U.S. Atomic Energy Commission. They arranged to bring Zippe to the United States in 1957 under a false passport and the assumed name of "Dr. Schubert." AEC scientists and intelligence officials interrogated Zippe in an all-day session at the Shoreham Hotel in Washington, D.C. This was followed by a more collegial debriefing several days later at the University of Virginia. Zippe revealed that he and the Soviets had worked out a completely novel design that did away with the thrust bearings and oil glands that had been so problematic in the U.S. centrifuge. The AEC arranged to have Zippe return to the United States on contract to the University of Virginia, where he would replicate the Soviet machine in exchange for a $10,000 salary. In August 1958, Zippe returned to Virginia, and less than a year later he produced a working replica of the Soviet machine.

Karl Cohen, whose theoretical contributions appear later in this article, was asked to assess Zippe's work for the Atomic Energy Commission. He was so impressed that he advised the commission to expand its centrifuge efforts in the direction of the Soviet design. By April 1960 the Division of Research approved a program to be housed at the Oak Ridge Gaseous Diffusion Plant under the management of Union Carbide Corporation, Nuclear Division. Work was begun 1 November 1960, and included the construction of a cascade based on the Soviet design, as well as improvements to centrifuge theory, and a continuation of the study on novel materials. [...]

In the late 1970s, the U.S. Department of Energy predicted that the demand for nuclear power, and thus enriched uranium, would grow dramatically in the coming decade. Saddled with only aging gaseous-diffusion plants, the DOE proposed a commercial-scale centrifuge facility to meet future enrichment demand. In 1977, Congress authorized an 8.8 million SWU/yr plant at Portsmouth, Ohio. The first stages of the plant were based on Set III centrifuges, 24 in diameter, 40 feet long, at 200 SWU/yr per machine. In time, however, it became apparent that the demand for enriched uranium had not increased as predicted; competing lifetime-extension programs on sunk-cost gaseous diffusion plants obviated the need for a new plant; and claims of economic mismanagement plagued the centrifuge program. The entire centrifuge effort was cancelled on June 5, 1985. Only 3000 machines had been installed at the Portsmouth facility at a total cost of $2.6 billion.

Despite War, Paying Russia For Uranium. ***New York Times.*** **15 June 2023, p. A1.**

The United States' reliance on nuclear power is primed to grow as the country aims to decrease reliance on fossil fuels. But no American-owned company enriches uranium. The United States once dominated the market, until a swirl of historical factors, including an enriched-uranium-buying deal between Russia and the United States designed to promote Russia's peaceful nuclear program after the Soviet Union's collapse, enabled Russia to corner half the global market. The United States ceased enriching uranium entirely. [...]

Roughly a third of enriched uranium used in the United States is now imported from Russia, the world's cheapest producer [8]. Most of the rest is imported from Europe [9]. A final, smaller portion is produced by a British-Dutch-German consortium operating in the United States [10]. [...]

In the 1950s, as the nuclear era began in earnest, Piketon became the site of one of two enormous enrichment facilities in the Ohio River Valley region, where a process called gaseous diffusion was used.

Meanwhile, the Soviet Union developed centrifuges in a secret program, relying on a team of German physicists and engineers captured toward the end of World War II. Its centrifuges proved to be 20 times as energy efficient as gaseous diffusion. By the end of the Cold War, the United States and Russia had roughly equal enrichment capacities, but huge differences in the cost of production.

In 1993, Washington and Moscow signed an agreement, dubbed Megatons to Megawatts, in which the United States purchased and imported much of Russia's enormous glut of weapons-grade uranium, which it then downgraded to use in power plants. This provided the U.S. with cheap fuel and Moscow with cash, and was seen as a de-escalatory gesture.

But it also destroyed the profitability of America's inefficient enrichment facilities, which were eventually shuttered. Then, instead of investing in upgraded centrifuges in the United States, successive administrations kept buying from Russia.

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[8] [From Rosatom, using German-developed centrifuges.]

[9] [From Urenco, using German-developed centrifuges. See https://www.world-nuclear-news.org/Articles/Urenco-expands-enrichment-capacity]

[10] [Urenco again, using German-developed centrifuges. See https://urencousa.com/about/our-history]

D.4.3 Uranium-235 Enrichment via Electromagnetic Separation

[German reports captured by the U.S. Alsos Mission also show that there was extensive work throughout the war on electromagnetic systems for uranium enrichment (similar to the U.S. calutrons at Oak Ridge). That work was conducted by physicists and engineers such as Manfred von Ardenne, Heinz Ewald, Richard Herzog, Hans Kopfermann, and Wilhelm Walcher. Unless otherwise noted, text for G-series captured German nuclear reports cited here consists of the English-language abstracts prepared by American scientists who studied the German reports.]

G-375. Richard Herzog. Report on the Status of the Work Towards Construction of a Large New Mass Spectrometer. 1943. Vienna.

Construction principles are outlined as they were patented in 1943 and details of the design are described. The manifold ways of focusing (direction focusing in both planes, energy focusing over great regions, radiation focusing of the ion source and the acceleration field) assure great intensity of the mass spectrometer even with great resolution, such intensities as are needed for separation of isotopes. The instrument will enable scientists to detect and determine smallest quantities of elements produced by nuclear reactions and relative abundance of isotopes.

G-256. Mass Spectrograph Construction Planned by the German Post Office Department Research Institution. [Über den Aufbau eines Massenspektrographen bei der Forschungsanstalt der Deutschen Reichspost.] 1944.

Construction is planned of a mass spectrograph equipped with a single lens and with the electric field installed between the pole faces of the magnets. With improved lens correction a very high resolving power is provided and high intensity of beam if the diaphragm is wide open. The instrument is planned to serve as a precision tool for determination of mass defects when the spectrometer slit is narrowed or for isotope separation when the slit is widened. The mass scale is planned to be M/M–8%. Magnet and magnet corrections needed are described in detail.

G-196. Wilhelm Walcher. Report on the Status of Mass Spectroscope Work at Kiel. The Effect of Space Charge on Focussing Properties of Magnetic Sector Fields. 1942.

Mass spectrograph built in Kiel to separate U isotopes. On the basis of tests made with Ag, can expect daily separation of from 2 to 6×10^{-8} moles of U^{235}. Mathematical determination of the effect of electrostatic repulsion of the particles on the cross section of an ion beam.

G-291. Wilhelm Walcher. Report on Investigations of Ion Sources for High Power Installations. 12 October 1944.

Requirements for an ion source best suited for use with high power installations are postulated and a table is given that compares capacity and current characteristics of 8 known ion sources. Experiments are described investigating electron-optical beam characteristics of the pendulum ion source of Heil and of a magnetron ion source, the resulting characteristics of the ion currents are illustrated.

Wilhelm Walcher. 1943. Über die Verwendungsmöglichkeiten von Glühanoden zur massenspektroskopischen Isotopentrennung. [About the Possible uses of Anodes for Mass Spectroscopic Isotope Separation.] *Zeitschrift für Physik* 121:604–613.

Aus der Kenntnis des Emissionsvorganges der Kunsman-Koch-Anode wird geschlossen, daß Elemente mit einer Ionisierungsarbeit, die kleiner als die Austrittsarbeit der Trägersubstanz (Wolfram mit adsorbiertem Sauerstoff, maximal etwa 9 eV) ist, in einer solchen Anode in Ionenform erzeugt werden können. Es zeigt sich jedoch, daß diese Möglichkeit außer bei den Alkalien nur bei der In-, Ga-, Tl-Gruppe besteht, während z. B. die Erdalkalien für eine Ionisierung nach dieser Methode ungeeignet sind. Gründe hierfür werden angegeben. — Die Ausbeute der Alkalianoden wird zu fast 100% des auf der inneren Oberfläche des W-Pulvers adsorbierten Alkalimetalls gefunden, und zwar ist die in Amperestunden gemessene Kapazität konstant und weitgehend unabhängig vom Emissionsstrom, der bei einer Rubidiumanode bis zu 0,7 mA/cm^2 dauernd gesteigert werden kann. Die Ausbeute einer Indiumanode hingegen beträgt nur etwa 5%. — Es wird gezeigt, daß sich die Anoden regenerieren lassen.

From the knowledge of the emission process of the Kunsman-Koch anode it is concluded that elements with an ionization energy which is smaller than the output energy of the carrier substance (tungsten with adsorbed oxygen, maximum about 9 eV) can be produced in such an anode in ion form. However, it has been shown that this possibility exists only for the in-, Ga-, Tl-group except for the alkalis, whereas the alkaline earths are unsuitable for ionization according to this method. Reasons for this are given.—The yield of the alkali anodes is found to almost 100% of the alkali metal adsorbed on the inner surface of the W powder, namely the capacity measured in ampere hours is constant and largely independent of the emission current, which can be continuously increased up to 0.7 mA/cm^2 with a rubidium anode. The yield of an indium anode on the other hand is only about 5%.—It is shown that the anodes can be regenerated.

Wilhelm Walcher. 1943. Der Einfluß der Raumladung auf die Abbildungseigenschaften magnetischer Sektorfelder. [The Influence of Space Charge on the Resolving Power of Sector-Shaped Magnetic Fields.] *Zeitschrift für Physik* 121:719–728.

Es wird gezeigt, daß ein Bündel geladener Teilchen, das auf eine Brennlinie zielt, trotz des abstoßenden Einflusses der Raumladung in einer anderen Brennlinie fokussiert werden kann. Die Fokussierungsbedingungen werden für den feldfreien Raum und für magnetische Sektorfelder angegeben, die Erweiterung der Theorie auf allgemeine Sektorfelder an einem Beispiel besprochen. Folgerungen für den Bau von Massenspektrographen, insbesondere solchen für Isotopentrennung, werden gezogen.

It is shown that a bundle of charged particles aiming at a focal line can be focused in another focal line despite the repulsive influence of space charge. The focusing conditions are given for the field-free space and for magnetic sector fields, the extension of the theory to general sector fields is discussed with an example. Conclusions for the construction of mass spectrographs, especially those for isotope separation, are drawn.

BIOS 1487. *Chemical Laboratory Instrumentation in Germany.* pp. 5–15.

The estimation of stable isotopes for most of the research teams in Germany using them was done on a mass spectrometer designed and made by Dr. W. Paul of the Second Physics Institute Göttingen. A second similar instrument was made at Göttingen for Professor Heisenberg's Institute but was only completed late in the War and was not much used. [...]

The results given by Dr. Paul in his description of the instrument (loc. cit) showed that its resolution was just sufficient to bring the deflection to zero between the two thallium isotopes of mass 203 and 205, whilst its sensitivity could be made sufficient to demonstrate the existence of the radio active potassium isotope K^{40} which is present in the proportion of 0.012%[...] The results of measurements of the relative concentration of the isotopes of rubidium, thallium, potassium, neon, silver and nitrogen are given showing an accuracy of 1% or better.

The instrument was operated by Dr. Paul during our visit. It was clear from this demonstration that the resolving power was as good as was claimed—the isotopes of mercury masses 198–202, from the diffusion pump used to evacuate the apparatus, being shown readily, whilst the sensitivity was ample to show the presence of the rare neon isotope.

[...] It is the more remarkable that apparently most of the workers in Germany doing work with stable isotopes during the War, relied on this instrument for their analyses.

1994. Obituaries: Wolfgang Paul. *Physics Today* 47:7:76. [https://pubs.aip.org/physicstoday/article/47/7/76/407994/Wolfgang-Paul]

[...] After two years with the Technische Hochschule Munich, he went in 1934 to the Technische Hochschule Berlin, where he joined Hans Kopfermann's research group and earned the diploma (1937) and doctorate (1939) degrees. In 1937 he moved with that team and set out to participate in pioneering studies at the universities of Kiel and later Göttingen on the hyperfine structure of atomic spectra and—with Wilhelm Walcher—on mass spectrometry. In 1944 he became a faculty member at Göttingen, where he worked with the legendary 6-MeV betatron, the first of its kind on the European continent.

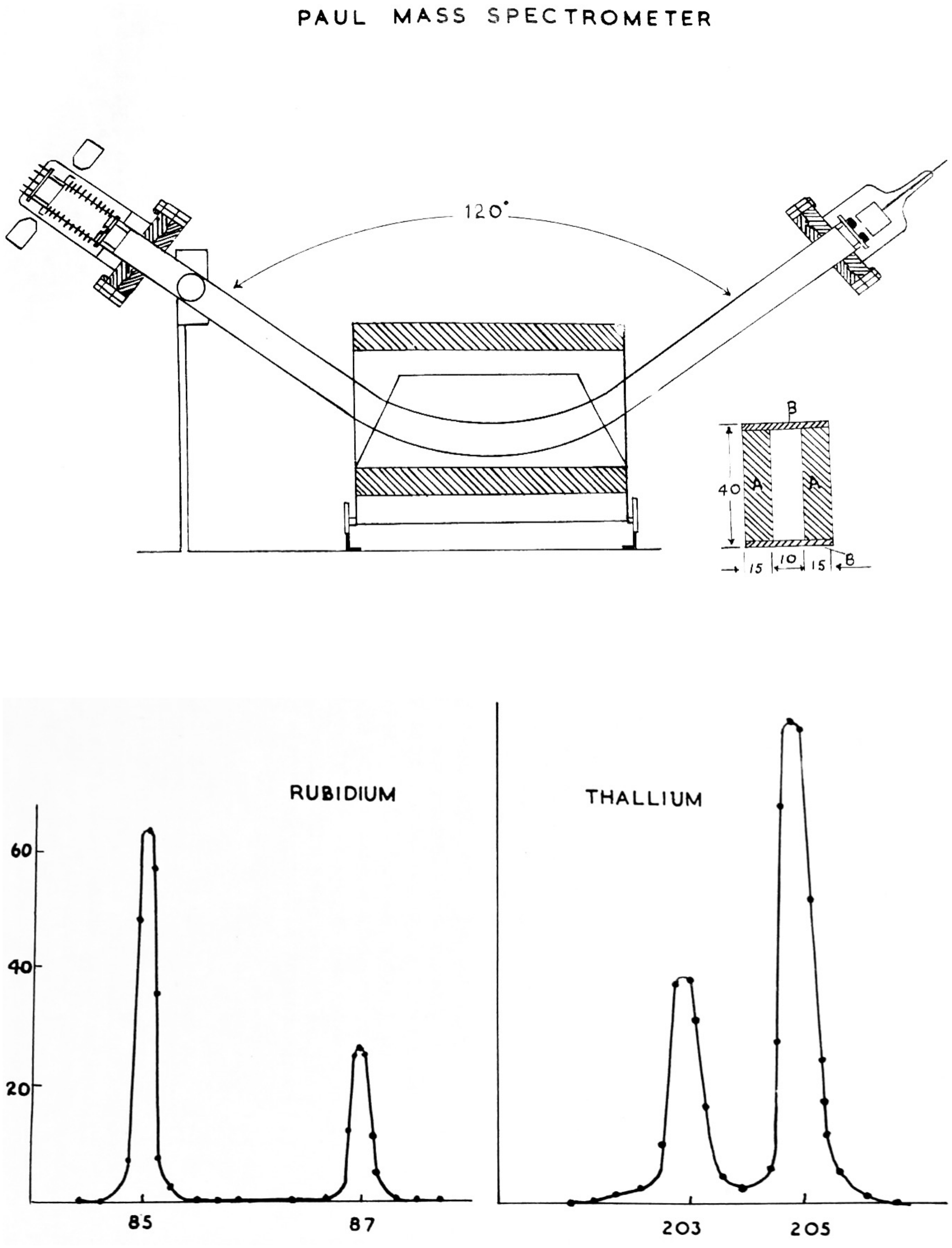
[Wolfgang Paul (German, 1913–1993) won a Nobel Prize in Physics in 1989 for his experimental physics work on the electromagnetic manipulation and trapping of ions, of which the invention described in BIOS 1487 was just one example. Wolfgang Paul should not be confused with Wolfgang Pauli (Austrian, 1900–1958), who won a Nobel Prize in Physics in 1945 for his work on theoretical physics.

Paul's mass spectrometer from BIOS 1487 (or similar instruments) would have been ideal for monitoring the progress of uranium isotope enrichment by providing a rapid and reliable analysis of the uranium isotope ratios at various points in the enrichment process. If the instrument could readily separate isotopes of thallium or mercury with slightly different masses around 200, it could distinguish between uranium isotopes of masses 235 and 238.

Please see figures of Paul's mass spectrometer from BIOS 1487 on the following pages.

In fact, if this design were scaled up, given some modifications, and mass-produced, those mass-produced versions could have been used like calutrons to actually enrich significant amounts of weapons-grade uranium.

From publicly available references, it is unclear just how much nuclear-weapons-related work Wolfgang Paul may have done during the war.]


PAUL MASS SPECTROMETER
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A
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203
205

Figure D.169: Wolfgang Paul's electromagnetic mass spectrometer for separating/analyzing isotope mixtures [BIOS 1487].

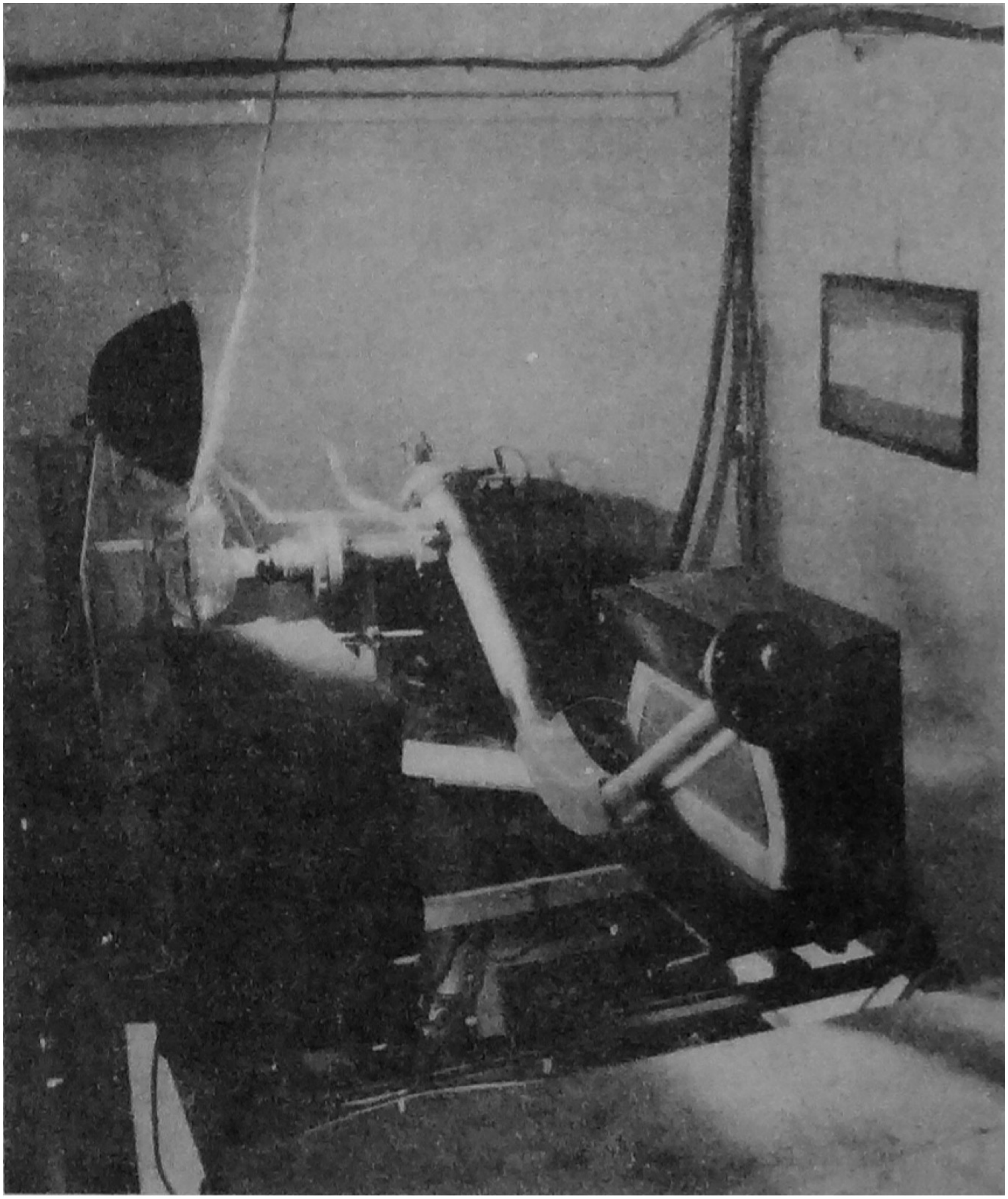

Figure D.170: Wolfgang Paul's electromagnetic mass spectrometer for separating/analyzing isotope mixtures [BIOS 1487].

Kurt Diebner. Listing of nuclear research commissions enclosed with a letter to the president of the Reich Research Council. 18 April 1944. [English translation in Hentschel and Hentschel 1996, pp. 322–324; German in Nagel 2016, pp. 512–513]

No.	Topic	Person Responsible	Priority Level	Secrecy Specification
[...]				
11.	Isotope separation	Inst. for Phys. Chemistry at Hamburg Univ., Prof. Harteck	SS, for special purposes DE	Secret, partly top secret
12.	Isotope separation	Inst. for Phys. Chemistry and Electrochemistry, Kiel, Lec. Dr. Martin	SS	Secret, partly top secret
13.	”	KWI for Chemistry, Berlin, Dr. Klemm	SS, for special purposes DE	Secret
[...]				
15.	Preparation of gaseous uranium compounds for isotope separation	Danzig Polytechnic, Prof. Albers	SS	Secret
16.	”	Chem. Inst. at Bonn Univ., Prof. Schmitz-Dumont	SS	Secret
17.	Construction and development of a mass spectrograph	II. Phys. Inst. at Göttingen Univ., Prof. Kopfermann	SS	Open, partly secret
18.	Development of a mass spectrograph	Deutsche Reichspost, Ministerial Councillor Gerwig	SS	Open, partly secret
19.	Manufacture of an isotope sluice	Bamag-Meguin Co., Berlin	DE	Secret
[...]				

G-139. Heinz Ewald. Eine neue Methode zur Magnetischen Isotopentrennung. [A New Method of Magnetic Isotope Separation.] 3 March 1942.

Reviews use of mass spectrograph to separate isotopes. Limitations of methods used heretofore. Principle of new separation method. Ions of homogeneous energy enter slit B' at angle E into homogeneous magnetic field with limits *bb*, *cc*. Field strength is so regulated that the heavy masses M_2 just leave the magnetic whereas the light masses M_1 cannot quite leave the magnetic field and are bent back toward *b*. Various applications of this principle are illustrated and discussed: (1) Annular magnetic field with ion source in the center. (2) Linear arrangement with rectangular magnetic field. (3) Annular magnetic field with ion source on the outside and target for heavy particles in the center. Calculations are included to demonstrate practicability of this method.

[See pp. 3563–3570. Ewald's design is closely related to Manfred von Ardenne's design below, and both were apparently part of the same project.]

Manfred von Ardenne. Über eine neuen magnetischen Isotopentrenner für hohen Massentransport. April 1942. [From Moscow archive, courtesy of Rainer Karlsch]

[See pp. 3571–3592. In this report, Manfred von Ardenne gave a detailed design for the electromagnetic isotope separator concept that was described in Ewald's report. In particular, he showed how to use a large number of ion beams with only one set of magnets, thereby greatly increasing the production rate of U-235. Von Ardenne's report even included a photograph of a prototype that he had built for experiments (p. 3590).]

Samuel A. Goudsmit. 16 June 1945. SUBJECT: Baron von Ardenne's Isotope Separation. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA—(1943–June 1946)]

1. Among the Reichsforschungsrat papers, we have found the research report of the work which von Ardenne did for the Reichspost. The report is dated April 1942 and describes a magnetic isotope separator in detail. It was sent to the RFR by Esau.

2. Attached is also an interesting commentary by von Ardenne himself. In this, he states that isotope separation is essential to decrease the amount of uranium necessary for the uranium machine. He claims that indications regarding developments, especially in the U.S.A., which aim at a decrease of the uranium quantity in the U-machine, have recently seeped through. Further down, he claims that the method invented by him is new and that, by keeping the development work very secret, an important advantage can be gained over the high level of experimental nuclear physics in the U.S.A.

[For much more information on Manfred von Ardenne's calutron-like electromagnetic isotope separators, see the following pages, as well as pp. 4183–4184.]

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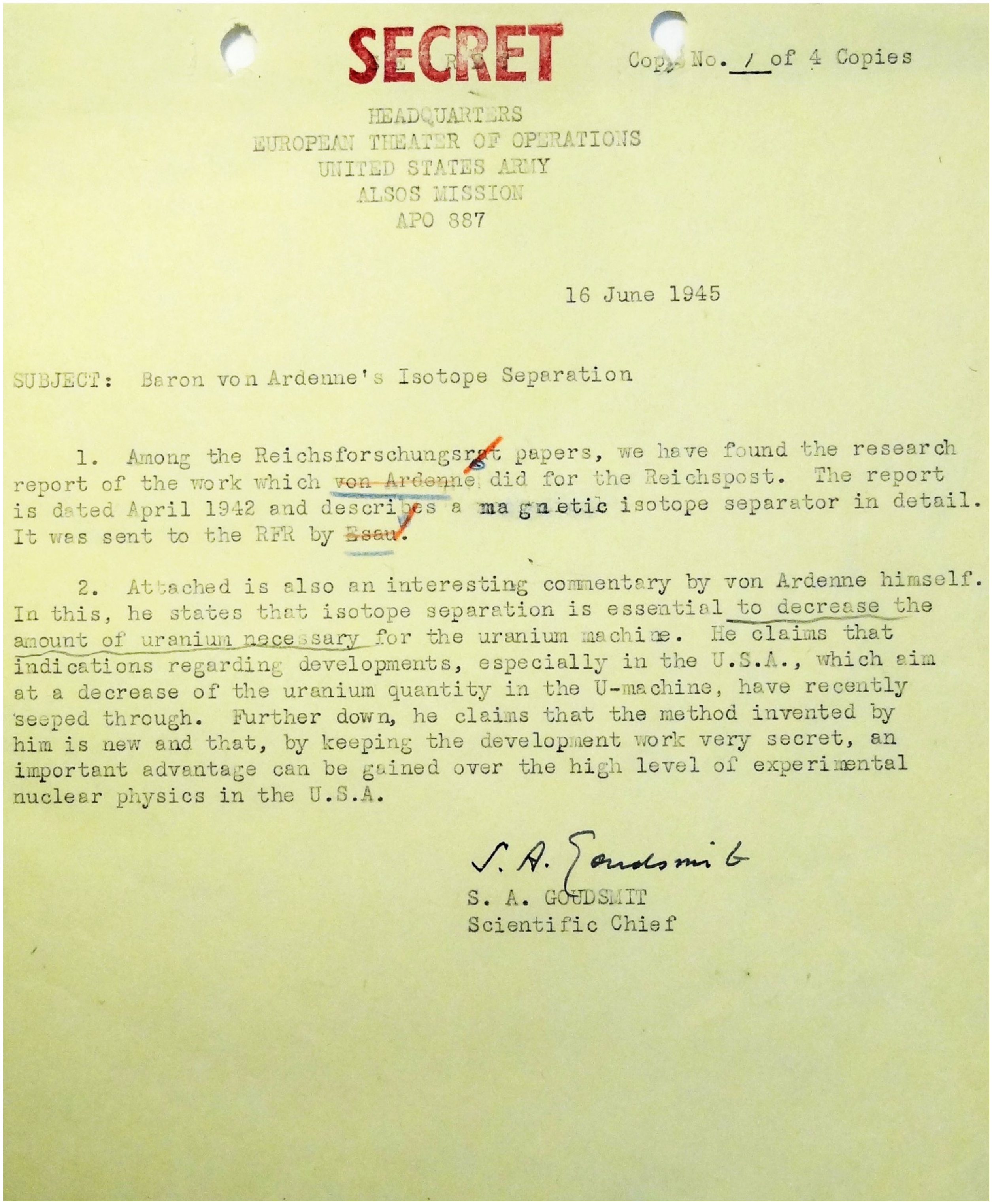
NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA—(1943--June 1946)



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EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS MISSION
APO 887

16 June 1945

SUBJECT: Baron von Ardenne's Isotope Separation

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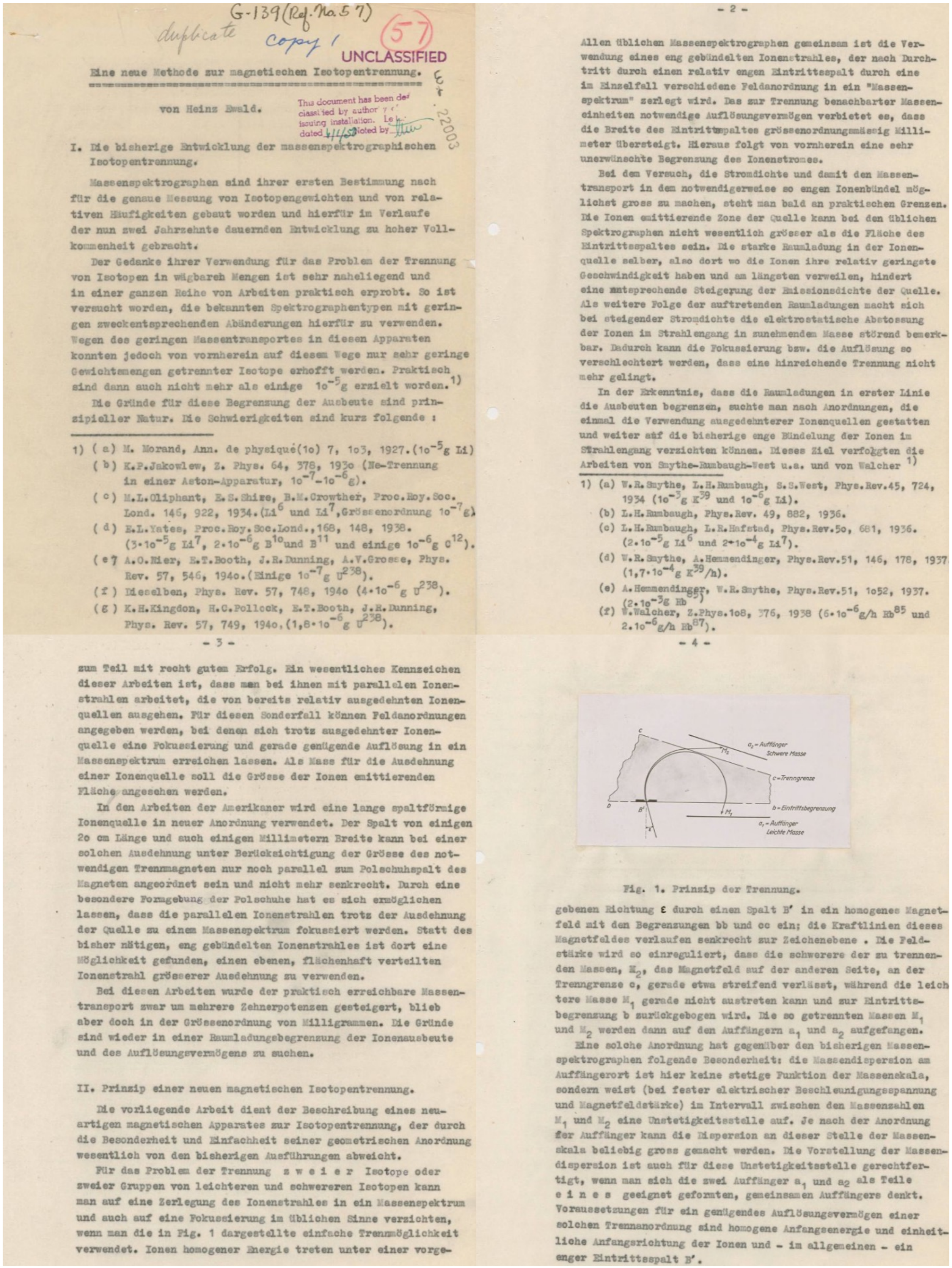
S. A. Goudsmit
S. A. GOUDSMIT
Scientific Chief

Figure D.171: Samuel A. Goudsmit. 16 June 1945. SUBJECT: Baron von Ardenne's Isotope Separation. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA—(1943–June 1946)].



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UNCLASSIFIED

Eine neue Methode zur magnetischen Isotopentrennung.

ET. 22003

von Heinz Ewald.

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I. Die bisherige Entwicklung der massenspektrographischen Isotopentrennung.

Massenspektrographen sind ihrer ersten Bestimmung nach für die genaue Messung von Isotopengewichten und von relativen Häufigkeiten gebaut worden und hierfür im Verlaufe der nun zwei Jahrzehnte dauernden Entwicklung zu hoher Vollkommenheit gebracht.

Der Gedanke ihrer Verwendung für das Problem der Trennung von Isotopen in wägbaren Mengen ist sehr naheliegend und in einer ganzen Reihe von Arbeiten praktisch erprobt. So ist versucht worden, die bekannten Spektrographentypen mit geringen zweckentsprechenden Abänderungen hierfür zu verwenden. Wegen des geringen Massentransportes in diesen Apparaten konnten jedoch von vornherein auf diesem Wege nur sehr geringe Gewichtsmengen getrennter Isotope erhofft werden. Praktisch sind dann auch nicht mehr als einige $1o^{-5}$g erzielt worden.1)

Die Gründe für diese Begrenzung der Ausbeute sind prinzipieller Natur. Die Schwierigkeiten sind kurz folgende :

---

1) (a) M. Morand, Ann. de physiqué(1o) 7, 1o3, 1927.($1o^{-5}$g Li)
   (b) K.P.Jakowlew, Z. Phys. 64, 378, 193o (Ne-Trennung in einer Aston-Apparatur, $1o^{-7}$–$1o^{-6}$g).
   (c) M.L.Oliphant, E.S.Shire, B.M.Crowther, Proc.Roy.Soc. Lond. 146, 922, 1934.(Li^6 und Li^7, Grössenordnung $1o^{-7}$g).
   (d) E.L.Yates, Proc.Roy.Soc.Lond.,168, 148, 1938. ($3\cdot1o^{-5}$g Li^7, $2\cdot1o^{-6}$g B^{10}und B^{11} und einige $1o^{-6}$g C^{12}).
   (e) A.O.Nier, E.T.Booth, J.R.Dunning, A.V.Grosse, Phys. Rev. 57, 546, 194o.(Einige $1o^{-7}$g U^{238}).
   (f) Dieselben, Phys. Rev. 57, 748, 194o ($4\cdot1o^{-6}$g U^{238}).
   (g) K.H.Kingdon, H.C.Pollock, E.T.Booth, J.R.Dunning, Phys. Rev. 57, 749, 194o,($1,8\cdot1o^{-6}$g U^{238}).

Allen üblichen Massenspektrographen gemeinsam ist die Verwendung eines eng gebündelten Ionenstrahles, der nach Durchtritt durch einen relativ engen Eintrittsspalt durch eine im Einzelfall verschiedene Feldanordnung in ein "Massenspektrum" zerlegt wird. Das zur Trennung benachbarter Masseneinheiten notwendige Auflösungsvermögen verbietet es, dass die Breite des Eintrittspaltes grössenordnungsmässig Millimeter übersteigt. Hieraus folgt von vornherein eine sehr unerwünschte Begrenzung des Ionenstromes.

Bei dem Versuch, die Stromdichte und damit den Massentransport in dem notwendigerweise so engen Ionenbündel möglichst gross zu machen, steht man bald an praktischen Grenzen. Die Ionen emittierende Zone der Quelle kann bei den üblichen Spektrographen nicht wesentlich grösser als die Fläche des Eintrittsspaltes sein. Die starke Raumladung in der Ionenquelle selber, also dort wo die Ionen ihre relativ geringste Geschwindigkeit haben und am längsten verweilen, hindert eine entsprechende Steigerung der Emissionsdichte der Quelle. Als weitere Folge der auftretenden Raumladungen macht sich bei steigender Stromdichte die elektrostatische Abstossung der Ionen im Strahlengang in zunehmendem Masse störend bemerkbar. Dadurch kann die Fokussierung bzw. die Auflösung so verschlechtert werden, dass eine hinreichende Trennung nicht mehr gelingt.

In der Erkenntnis, dass die Raumladungen in erster Linie die Ausbeuten begrenzen, suchte man nach Anordnungen, die einmal die Verwendung ausgedehnterer Ionenquellen gestatten und weiter auf die bisherige enge Bündelung der Ionen im Strahlengang verzichten können. Dieses Ziel verfolgten die Arbeiten von Smythe-Rumbaugh-West u.a. und von Walcher 1) zum Teil mit recht gutem Erfolg.

---

1) (a) W.R.Smythe, L.H.Rumbaugh, S.S.West, Phys.Rev.45, 724, 1934 ($1o^{-3}$g K^{39} und $1o^{-6}$g Li).
   (b) L.H.Rumbaugh, Phys.Rev. 49, 882, 1936.
   (c) L.H.Rumbaugh, L.R.Hafstad, Phys.Rev.5o, 681, 1936. ($2\cdot1o^{-5}$g Li^6 und $2\cdot1o^{-4}$g Li^7).
   (d) W.R.Smythe, A.Hemmendinger, Phys.Rev.51, 146, 178, 1937 ($1,7\cdot1o^{-4}$g K^{39}/h).
   (e) A.Hemmendinger, W.R.Smythe, Phys.Rev.51, 1o52, 1937. ($2\cdot1o^{-3}$g Rb^{85})
   (f) W.Walcher, Z.Phys.1o8, 376, 1938 ($6\cdot1o^{-6}$g/h Rb^{85} und $2.1o^{-6}$g/h Rb^{87}).

Ein wesentliches Kennzeichen dieser Arbeiten ist, dass man bei ihnen mit parallelen Ionenstrahlen arbeitet, die von bereits relativ ausgedehnten Ionenquellen ausgehen. Für diesen Sonderfall können Feldanordnungen angegeben werden, bei denen sich trotz ausgedehnter Ionenquelle eine Fokussierung und gerade genügende Auflösung in ein Massenspektrum erreichen lassen. Als Mass für die Ausdehnung einer Ionenquelle soll die Grösse der Ionen emittierenden Fläche angesehen werden.

In den Arbeiten der Amerikaner wird eine lange spaltförmige Ionenquelle in neuer Anordnung verwendet. Der Spalt von einigen 2o cm Länge und auch einigen Millimetern Breite kann bei einer solchen Ausdehnung unter Berücksichtigung der Grösse des notwendigen Trennmagneten nur noch parallel zum Polschuhspalt des Magneten angeordnet sein und nicht mehr senkrecht. Durch eine besondere Formgebung der Polschuhe hat es sich ermöglichen lassen, dass die parallelen Ionenstrahlen trotz der Ausdehnung der Quelle zu einem Massenspektrum fokussiert werden. Statt des bisher nötigen, eng gebündelten Ionenstrahles ist dort eine Möglichkeit gefunden, einen ebenen, flächenhaft verteilten Ionenstrahl grösserer Ausdehnung zu verwenden.

Bei diesen Arbeiten wurde der praktisch erreichbare Massentransport zwar um mehrere Zehnerpotenzen gesteigert, blieb aber doch in der Grössenordnung von Milligrammen. Die Gründe sind wieder in einer Raumladungsbegrenzung der Ionenausbeute und des Auflösungsvermögens zu suchen.

II. Prinzip einer neuen magnetischen Isotopentrennung.

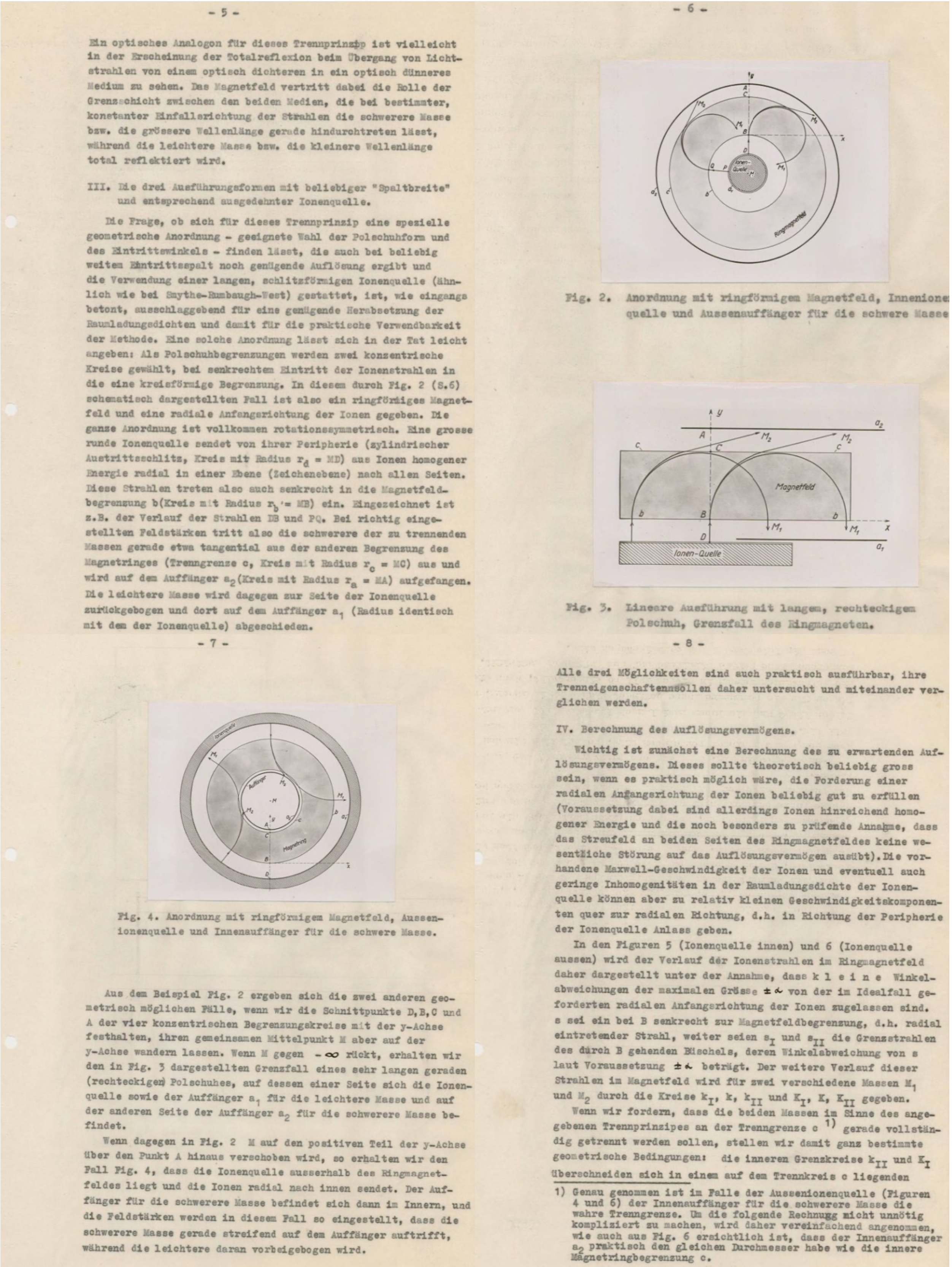
Die vorliegende Arbeit dient der Beschreibung eines neuartigen magnetischen Apparates zur Isotopentrennung, der durch die Besonderheit und Einfachheit seiner geometrischen Anordnung wesentlich von den bisherigen Ausführungen abweicht.

Für das Problem der Trennung zweier Isotope oder zweier Gruppen von leichteren und schwereren Isotopen kann man auf eine Zerlegung des Ionenstrahles in ein Massenspektrum und auch auf eine Fokussierung im üblichen Sinne verzichten, wenn man die in Fig. 1 dargestellte einfache Trennmöglichkeit verwendet. Ionen homogener Energie treten unter einer vorgegebenen Richtung ε durch einen Spalt B' in ein homogenes Magnetfeld mit den Begrenzungen bb und cc ein; die Kraftlinien dieses Magnetfeldes verlaufen senkrecht zur Zeichenebene . Die Feldstärke wird so einreguliert, dass die schwerere der zu trennenden Massen, M_2, das Magnetfeld auf der anderen Seite, an der Trenngrenze c, gerade etwa streifend verlässt, während die leichtere Masse M_1 gerade nicht austreten kann und zur Eintrittsbegrenzung b zurückgebogen wird. Die so getrennten Massen M_1 und M_2 werden dann auf den Auffängern a_1 und a_2 aufgefangen.

Fig. 1. Prinzip der Trennung.

Eine solche Anordnung hat gegenüber den bisherigen Massenspektrographen folgende Besonderheit: die Massendispersion am Auffängerort ist hier keine stetige Funktion der Massenskala, sondern weist (bei fester elektrischer Beschleunigungsspannung und Magnetfeldstärke) im Intervall zwischen den Massenzahlen M_1 und M_2 eine Unstetigkeitsstelle auf. Je nach der Anordnung der Auffänger kann die Dispersion an dieser Stelle der Massenskala beliebig gross gemacht werden. Die Vorstellung der Massendispersion ist auch für diese Unstetigkeitsstelle gerechtfertigt, wenn man sich die zwei Auffänger a_1 und a_2 als Teile eines geeignet geformten, gemeinsamen Auffängers denkt. Voraussetzungen für ein genügendes Auflösungsvermögen einer solchen Trennanordnung sind homogene Anfangsenergie und einheitliche Anfangsrichtung der Ionen und – im allgemeinen – ein enger Eintrittsspalt B'.

Figure D.172: Heinz Ewald's March 1942 design for an electromagnetic isotope separator [G-139].



Ein optisches Analogon für dieses Trennprinzip ist vielleicht in der Erscheinung der Totalreflexion beim Übergang von Lichtstrahlen von einem optisch dichteren in ein optisch dünneres Medium zu sehen. Das Magnetfeld vertritt dabei die Rolle der Grenzschicht zwischen den beiden Medien, die bei bestimmter, konstanter Einfallsrichtung der Strahlen die schwerere Masse bzw. die grössere Wellenlänge gerade hindurchtreten lässt, während die leichtere Masse bzw. die kleinere Wellenlänge total reflektiert wird.

III. Die drei Ausführungsformen mit beliebiger "Spaltbreite" und entsprechend ausgedehnter Ionenquelle.

Die Frage, ob sich für dieses Trennprinzip eine spezielle geometrische Anordnung - geeignete Wahl der Polschuhform und des Eintrittswinkels - finden lässt, die auch bei beliebig weitem Eintrittsspalt noch genügende Auflösung ergibt und die Verwendung einer langen, schlitzförmigen Ionenquelle (ähnlich wie bei Smythe-Rumbaugh-West) gestattet, ist, wie eingangs betont, ausschlaggebend für eine genügende Herabsetzung der Raumladungsdichten und damit für die praktische Verwendbarkeit der Methode. Eine solche Anordnung lässt sich in der Tat leicht angeben: Als Polschuhbegrenzungen werden zwei konzentrische Kreise gewählt, bei senkrechtem Eintritt der Ionenstrahlen in die eine kreisförmige Begrenzung. In diesem durch Fig. 2 (S.6) schematisch dargestellten Fall ist also ein ringförmiges Magnetfeld und eine radiale Anfangsrichtung der Ionen gegeben. Die ganze Anordnung ist vollkommen rotationssymmetrisch. Eine grosse runde Ionenquelle sendet von ihrer Peripherie (zylindrischer Austrittsschlitz, Kreis mit Radius r_d = MD) aus Ionen homogener Energie radial in einer Ebene (Zeichenebene) nach allen Seiten. Diese Strahlen treten also auch senkrecht in die Magnetfeldbegrenzung b(Kreis mit Radius r_b '= MB) ein. Eingezeichnet ist z.B. der Verlauf der Strahlen DB und PQ. Bei richtig eingestellten Feldstärken tritt also die schwerere der zu trennenden Massen gerade etwa tangential aus der anderen Begrenzung des Magnetringes (Trenngrenze c, Kreis mit Radius r_c = MC) aus und wird auf dem Auffänger a_2(Kreis mit Radius r_a = MA) aufgefangen. Die leichtere Masse wird dagegen zur Seite der Ionenquelle zurückgebogen und dort auf dem Auffänger a_1 (Radius identisch mit dem der Ionenquelle) abgeschieden.

Fig. 2. Anordnung mit ringförmigem Magnetfeld, Innenione quelle und Aussenauffänger für die schwere Masse

Fig. 3. Lineare Ausführung mit langem, rechteckigem Polschuh, Grenzfall des Ringmagneten.

Fig. 4. Anordnung mit ringförmigem Magnetfeld, Aussenionenquelle und Innenauffänger für die schwere Masse.

Aus dem Beispiel Fig. 2 ergeben sich die zwei anderen geometrisch möglichen Fälle, wenn wir die Schnittpunkte D,B,C und A der vier konzentrischen Begrenzungskreise mit der y-Achse festhalten, ihren gemeinsamen Mittelpunkt M aber auf der y-Achse wandern lassen. Wenn M gegen $-\infty$ rückt, erhalten wir den in Fig. 3 dargestellten Grenzfall eines sehr langen geraden (rechteckigen) Polschuhes, auf dessen einer Seite sich die Ionenquelle sowie der Auffänger a_1 für die leichtere Masse und auf der anderen Seite der Auffänger a_2 für die schwerere Masse befindet.

Wenn dagegen in Fig. 2 M auf den positiven Teil der y-Achse über den Punkt A hinaus verschoben wird, so erhalten wir den Fall Fig. 4, dass die Ionenquelle ausserhalb des Ringmagnetfeldes liegt und die Ionen radial nach innen sendet. Der Auffänger für die schwerere Masse befindet sich dann im Innern, und die Feldstärken werden in diesem Fall so eingestellt, dass die schwerere Masse gerade streifend auf dem Auffänger auftrifft, während die leichtere daran vorbeigebogen wird.

Alle drei Möglichkeiten sind auch praktisch ausführbar, ihre Trenneigenschaftennsollen daher untersucht und miteinander verglichen werden.

IV. Berechnung des Auflösungsvermögens.

Wichtig ist zunächst eine Berechnung des zu erwartenden Auflösungsvermögens. Dieses sollte theoretisch beliebig gross sein, wenn es praktisch möglich wäre, die Forderung einer radialen Anfangsrichtung der Ionen beliebig gut zu erfüllen (Voraussetzung dabei sind allerdings Ionen hinreichend homogener Energie und die noch besonders zu prüfende Annahme, dass das Streufeld an beiden Seiten des Ringmagnetfeldes keine wesentliche Störung auf das Auflösungsvermögen ausübt). Die vorhandene Maxwell-Geschwindigkeit der Ionen und eventuell auch geringe Inhomogenitäten in der Raumladungsdichte der Ionenquelle können aber zu relativ kleinen Geschwindigkeitskomponenten quer zur radialen Richtung, d.h. in Richtung der Peripherie der Ionenquelle Anlass geben.

In den Figuren 5 (Ionenquelle innen) und 6 (Ionenquelle aussen) wird der Verlauf der Ionenstrahlen im Ringmagnetfeld daher dargestellt unter der Annahme, dass kleine Winkelabweichungen der maximalen Grösse $\pm\alpha$ von der im Idealfall geforderten radialen Anfangsrichtung der Ionen zugelassen sind. s sei ein bei B senkrecht zur Magnetfeldbegrenzung, d.h. radial eintretender Strahl, weiter seien s_I und s_{II} die Grenzstrahlen des durch B gehenden Büschels, deren Winkelabweichung von s laut Voraussetzung $\pm\alpha$ beträgt. Der weitere Verlauf dieser Strahlen im Magnetfeld wird für zwei verschiedene Massen M_1 und M_2 durch die Kreise k_I, k, k_{II} und K_I, K, K_{II} gegeben.

Wenn wir fordern, dass die beiden Massen im Sinne des angegebenen Trennprinzipes an der Trenngrenze c 1) gerade vollständig getrennt werden sollen, stellen wir damit ganz bestimmte geometrische Bedingungen: die inneren Grenzkreise k_{II} und K_I überschneiden sich in einem auf dem Trennkreis c liegenden

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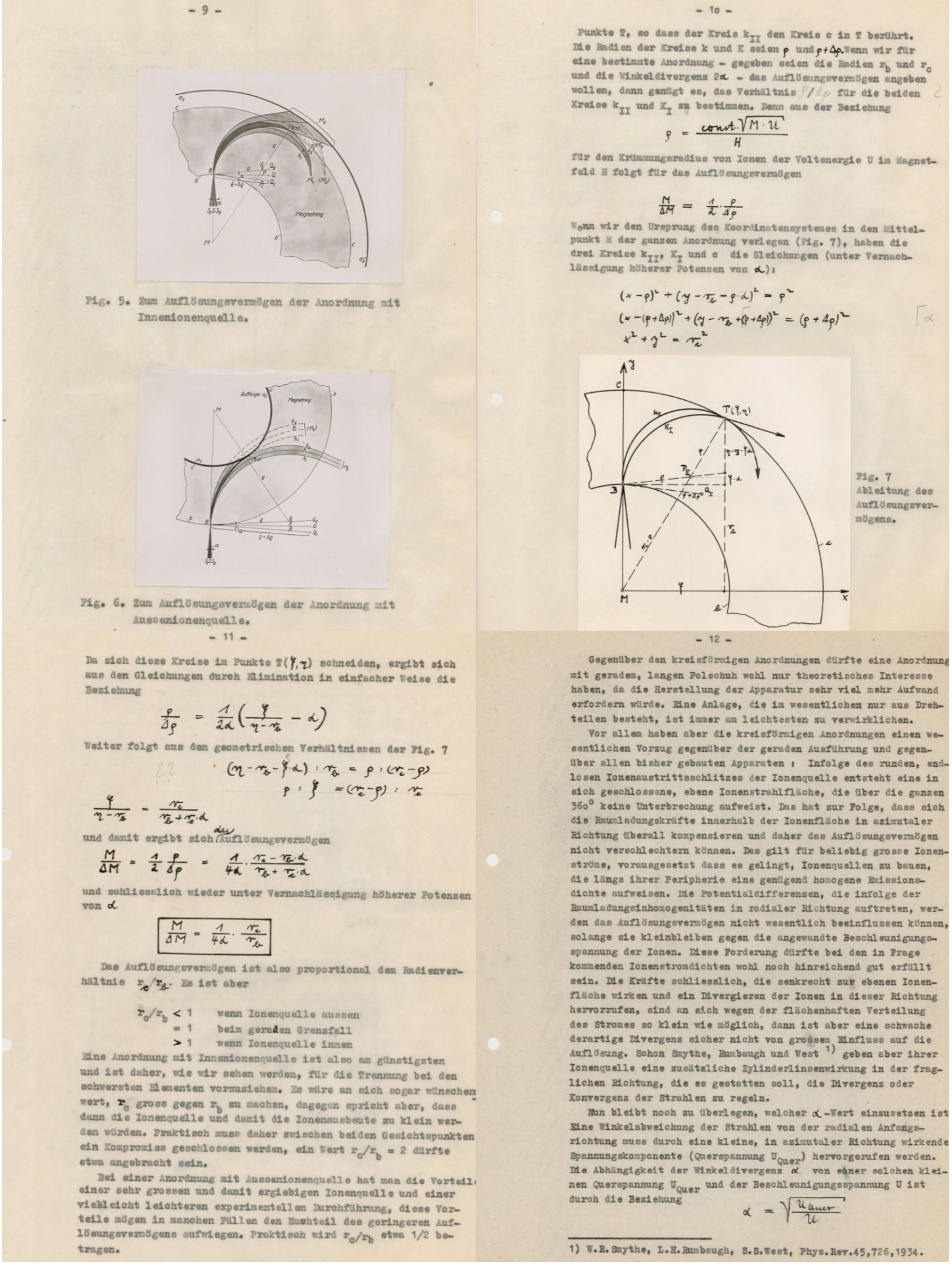
1) Genau genommen ist im Falle der Aussenionenquelle (Figuren 4 und 6) der Innenauffänger für die schwerere Masse die wahre Trenngrenze. Um die folgende Rechnugg nicht unnötig kompliziert zu machen, wird daher vereinfachend angenommen, wie auch aus Fig. 6 ersichtlich ist, dass der Innenauffänger a_2 praktisch den gleichen Durchmesser habe wie die innere Magnetringbegrenzung c.

Figure D.173: Heinz Ewald's March 1942 design for an electromagnetic isotope separator [G-139].



– 9 –

Fig. 5. Zum Auflösungsvermögen der Anordnung mit Innenionenquelle.

Fig. 6. Zum Auflösungsvermögen der Anordnung mit Aussenionenquelle.

– 10 –

Punkte T, so dass der Kreis k_{II} den Kreis c in T berührt. Die Radien der Kreise k und K seien ρ und $\rho+\Delta\rho$. Wenn wir für eine bestimmte Anordnung – gegeben seien die Radien r_b und r_c und die Winkeldivergenz 2α – das Auflösungsvermögen angeben wollen, dann genügt es, das Verhältnis $\rho/\Delta\rho$ für die beiden Kreise k_{II} und K_I zu bestimmen. Denn aus der Beziehung

$$\rho = \frac{\mathrm{const.}\sqrt{M \cdot U}}{H}$$

für den Krümmungsradius von Ionen der Voltenergie U im Magnetfeld H folgt für das Auflösungsvermögen

$$\frac{M}{\Delta M} = \frac{1}{\alpha} \cdot \frac{\rho}{\Delta\rho}$$

Wenn wir den Ursprung des Koordinatensystemes in den Mittelpunkt M der ganzen Anordnung verlegen (Fig. 7), haben die drei Kreise k_{II}, K_I und c die Gleichungen (unter Vernachlässigung höherer Potenzen von α):

$$(x-\rho)^2 + (y - r_b - \rho\cdot\alpha)^2 = \rho^2$$
$$(x-(\rho+\Delta\rho))^2 + (y - r_b + (\rho+\Delta\rho))^2 = (\rho+\Delta\rho)^2$$
$$x^2 + y^2 = r_c^2$$

Fig. 7 Ableitung des Auflösungsvermögens.

– 11 –

Da sich diese Kreise im Punkte $T(\xi,\eta)$ schneiden, ergibt sich aus den Gleichungen durch Elimination in einfacher Weise die Beziehung

$$\frac{\rho}{\Delta\rho} = \frac{1}{2\alpha}\left(\frac{\xi}{\eta - r_b} - \alpha\right)$$

Weiter folgt aus den geometrischen Verhältnissen der Fig. 7

$$(\eta - r_b - \xi\cdot\alpha) : r_b = \rho : (r_c - \rho)$$
$$\rho : \xi = (r_c - \rho) : r_c$$

$$\frac{\xi}{\eta - r_b} = \frac{r_c}{r_b + r_c\cdot\alpha}$$

und damit ergibt sich das Auflösungsvermögen

$$\frac{M}{\Delta M} = \frac{1}{2}\frac{\rho}{\Delta\rho} = \frac{1}{4\alpha}\cdot\frac{r_c - r_b\cdot\alpha}{r_b + r_c\cdot\alpha}$$

und schliesslich wieder unter Vernachlässigung höherer Potenzen von α

$$\boxed{\frac{M}{\Delta M} = \frac{1}{4\alpha}\cdot\frac{r_c}{r_b}}$$

Das Auflösungsvermögen ist also proportional dem Radienverhältnis r_c/r_b. Es ist aber

$r_c/r_b < 1$ wenn Ionenquelle aussen
$= 1$ beim geraden Grenzfall
> 1 wenn Ionenquelle innen

Eine Anordnung mit Innenionenquelle ist also am günstigsten und ist daher, wie wir sehen werden, für die Trennung bei den schwersten Elementen vorzuziehen. Es wäre an sich sogar wünschenswert, r_c gross gegen r_b zu machen, dagegen spricht aber, dass dann die Ionenquelle und damit die Ionenausbeute zu klein werden würden. Praktisch muss daher zwischen beiden Gesichtspunkten ein Kompromiss geschlossen werden, ein Wert $r_c/r_b = 2$ dürfte etwa angebracht sein.

Bei einer Anordnung mit Aussenionenquelle hat man die Vorteile einer sehr grossen und damit ergiebigen Ionenquelle und einer vielleicht leichteren experimentellen Durchführung, diese Vorteile mögen in manchen Fällen den Nachteil des geringeren Auflösungsvermögens aufwiegen. Praktisch wird r_c/r_b etwa 1/2 betragen.

– 12 –

Gegenüber den kreisförmigen Anordnungen dürfte eine Anordnung mit geradem, langen Polschuh wohl nur theoretisches Interesse haben, da die Herstellung der Apparatur sehr viel mehr Aufwand erfordern würde. Eine Anlage, die im wesentlichen nur aus Drehteilen besteht, ist immer am leichtesten zu verwirklichen.

Vor allem haben aber die kreisförmigen Anordnungen einen wesentlichen Vorzug gegenüber der geraden Ausführung und gegenüber allen bisher gebauten Apparaten : Infolge des runden, endlosen Ionenaustrittsschlitzes der Ionenquelle entsteht eine in sich geschlossene, ebene Ionenstrahlfläche, die über die ganzen 360° keine Unterbrechung aufweist. Das hat zur Folge, dass sich die Raumladungskräfte innerhalb der Ionenfläche in azimutaler Richtung überall kompensieren und daher das Auflösungsvermögen nicht verschlechtern können. Das gilt für beliebig grosse Ionenströme, vorausgesetzt dass es gelingt, Ionenquellen zu bauen, die längs ihrer Peripherie eine genügend homogene Emissionsdichte aufweisen. Die Potentialdifferenzen, die infolge der Raumladungsinhomogenitäten in radialer Richtung auftreten, werden das Auflösungsvermögen nicht wesentlich beeinflussen können, solange sie kleinbleiben gegen die angewandte Beschleunigungsspannung der Ionen. Diese Forderung dürfte bei den in Frage kommenden Ionenstromdichten wohl noch hinreichend gut erfüllt sein. Die Kräfte schliesslich, die senkrecht zur ebenen Ionenfläche wirken und ein Divergieren der Ionen in dieser Richtung hervorrufen, sind an sich wegen der flächenhaften Verteilung des Stromes so klein wie möglich, dann ist aber eine schwache derartige Divergenz sicher nicht von grossem Einfluss auf die Auflösung. Schon Smythe, Rumbaugh und West 1) geben aber ihrer Ionenquelle eine zusätzliche Zylinderlinsenwirkung in der fraglichen Richtung, die es gestatten soll, die Divergenz oder Konvergenz der Strahlen zu regeln.

Nun bleibt noch zu überlegen, welcher α-Wert einzusetzen ist. Eine Winkelabweichung der Strahlen von der radialen Anfangsrichtung muss durch eine kleine, in azimutaler Richtung wirkende Spannungskomponente (Querspannung U_{Quer}) hervorgerufen werden. Die Abhängigkeit der Winkeldivergenz α von einer solchen kleinen Querspannung U_{Quer} und der Beschleunigungsspannung U ist durch die Beziehung

$$\alpha = \sqrt{\frac{U_{Quer}}{U}}$$

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1) W.R.Smythe, L.H.Rumbaugh, S.S.West, Phys.Rev.45,726,1934.

Figure D.174: Heinz Ewald's March 1942 design for an electromagnetic isotope separator [G-139].

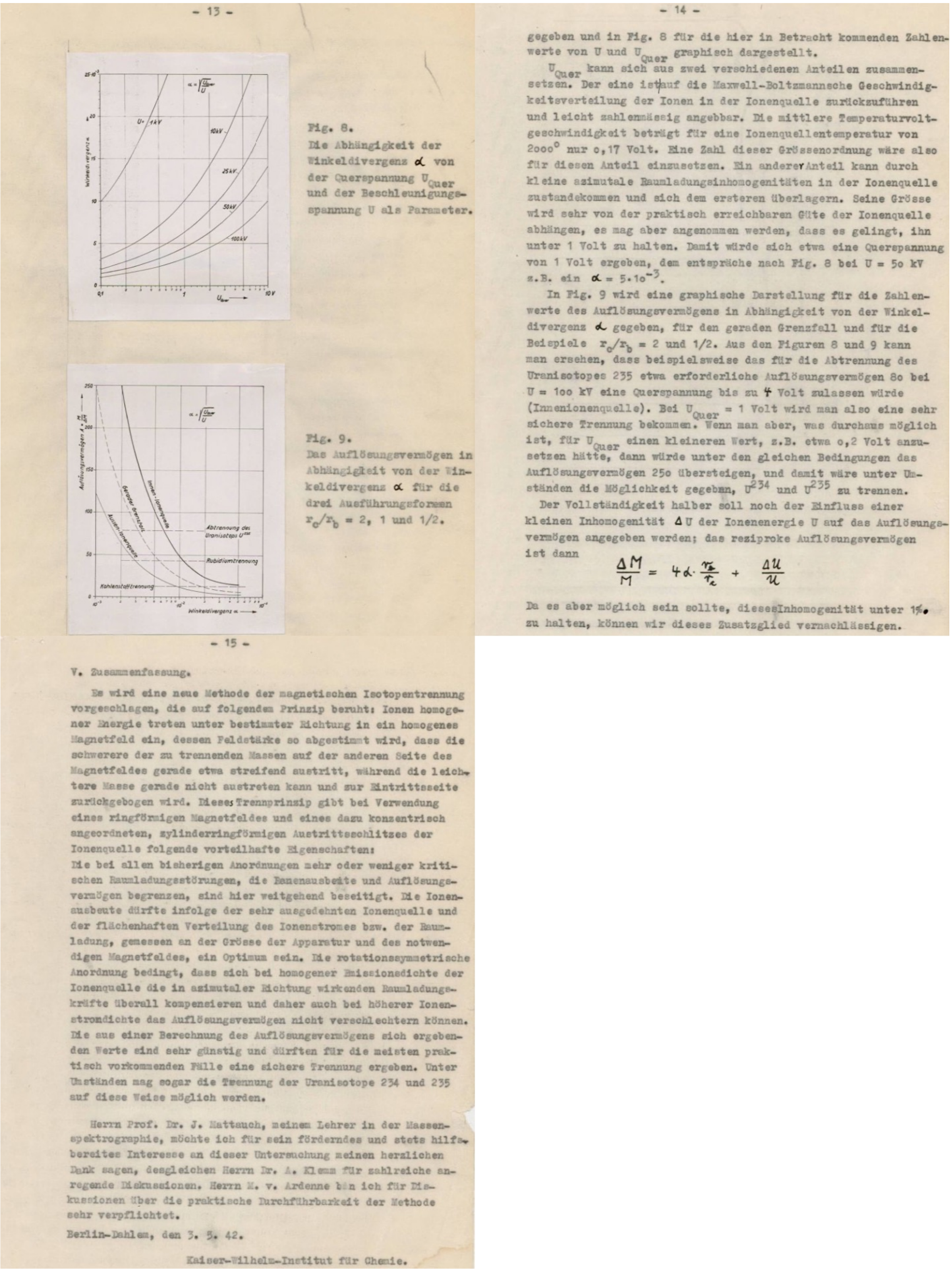

$25 \cdot 10^{-3}$
20
15
10
5
0
Winkeldivergenz α
$\alpha = \sqrt{\frac{U_{Quer}}{U}}$
U = 1 kV
10 kV
25 kV
50 kV
100 kV
0,1
1
10 V
U_{Quer}
250
200
150
100
50
0
Auflösungsvermögen $A = \frac{M}{\Delta M}$
$\alpha = \sqrt{\frac{U_{Quer}}{U}}$
Innen-Ionenquelle
Gerader Grenzfall
Aussen-Ionenquelle
Abtrennung des Uranisotops U^{235}
Rubidiumtrennung
Kohlenstofftrennung
10^{-3}
10^{-2}
10^{-1}
Winkeldivergenz α

Fig. 8.
Die Abhängigkeit der Winkeldivergenz α von der Querspannung U_{Quer} und der Beschleunigungsspannung U als Parameter.

Fig. 9.
Das Auflösungsvermögen in Abhängigkeit von der Winkeldivergenz α für die drei Ausführungsformen r_c/r_b = 2, 1 und 1/2.

gegeben und in Fig. 8 für die hier in Betracht kommenden Zahlenwerte von U und U_{Quer} graphisch dargestellt.

U_{Quer} kann sich aus zwei verschiedenen Anteilen zusammensetzen. Der eine ist auf die Maxwell-Boltzmannsche Geschwindigkeitsverteilung der Ionen in der Ionenquelle zurückzuführen und leicht zahlenmässig angebbar. Die mittlere Temperaturvoltgeschwindigkeit beträgt für eine Ionenquellentemperatur von 2ooo° nur o,17 Volt. Eine Zahl dieser Grössenordnung wäre also für diesen Anteil einzusetzen. Ein anderer Anteil kann durch kleine azimutale Raumladungsinhomogenitäten in der Ionenquelle zustandekommen und sich dem ersteren überlagern. Seine Grösse wird sehr von der praktisch erreichbaren Güte der Ionenquelle abhängen, es mag aber angenommen werden, dass es gelingt, ihn unter 1 Volt zu halten. Damit würde sich etwa eine Querspannung von 1 Volt ergeben, dem entspräche nach Fig. 8 bei U = 5o kV z.B. ein $\alpha = 5 \cdot 1o^{-3}$.

In Fig. 9 wird eine graphische Darstellung für die Zahlenwerte des Auflösungsvermögens in Abhängigkeit von der Winkeldivergenz α gegeben, für den geraden Grenzfall und für die Beispiele r_c/r_b = 2 und 1/2. Aus den Figuren 8 und 9 kann man ersehen, dass beispielsweise das für die Abtrennung des Uranisotopes 235 etwa erforderliche Auflösungsvermögen 8o bei U = 1oo kV eine Querspannung bis zu 4 Volt zulassen würde (Innenionenquelle). Bei U_{Quer} = 1 Volt wird man also eine sehr sichere Trennung bekommen. Wenn man aber, was durchaus möglich ist, für U_{Quer} einen kleineren Wert, z.B. etwa o,2 Volt anzusetzen hätte, dann würde unter den gleichen Bedingungen das Auflösungsvermögen 25o übersteigen, und damit wäre unter Umständen die Möglichkeit gegeben, U^{234} und U^{235} zu trennen.

Der Vollständigkeit halber soll noch der Einfluss einer kleinen Inhomogenität ΔU der Ionenenergie U auf das Auflösungsvermögen angegeben werden; das reziproke Auflösungsvermögen ist dann

$$\frac{\Delta M}{M} = 4\alpha \cdot \frac{r_b}{r_c} + \frac{\Delta U}{U}$$

Da es aber möglich sein sollte, diese Inhomogenität unter 1%. zu halten, können wir dieses Zusatzglied vernachlässigen.

V. Zusammenfassung.

Es wird eine neue Methode der magnetischen Isotopentrennung vorgeschlagen, die auf folgendem Prinzip beruht: Ionen homogener Energie treten unter bestimmter Richtung in ein homogenes Magnetfeld ein, dessen Feldstärke so abgestimmt wird, dass die schwerere der zu trennenden Massen auf der anderen Seite des Magnetfeldes gerade etwa streifend austritt, während die leichtere Masse gerade nicht austreten kann und zur Eintrittsseite zurückgebogen wird. Dieses Trennprinzip gibt bei Verwendung eines ringförmigen Magnetfeldes und eines dazu konzentrisch angeordneten, zylinderringförmigen Austrittsschlitzes der Ionenquelle folgende vorteilhafte Eigenschaften:
Die bei allen bisherigen Anordnungen mehr oder weniger kritischen Raumladungsstörungen, die Ionenausbeute und Auflösungsvermögen begrenzen, sind hier weitgehend beseitigt. Die Ionenausbeute dürfte infolge der sehr ausgedehnten Ionenquelle und der flächenhaften Verteilung des Ionenstromes bzw. der Raumladung, gemessen an der Grösse der Apparatur und des notwendigen Magnetfeldes, ein Optimum sein. Die rotationssymmetrische Anordnung bedingt, dass sich bei homogener Emissionsdichte der Ionenquelle die in azimutaler Richtung wirkenden Raumladungskräfte überall kompensieren und daher auch bei höherer Ionenstromdichte das Auflösungsvermögen nicht verschlechtern können. Die aus einer Berechnung des Auflösungsvermögens sich ergebenden Werte sind sehr günstig und dürften für die meisten praktisch vorkommenden Fälle eine sichere Trennung ergeben. Unter Umständen mag sogar die Trennung der Uranisotope 234 und 235 auf diese Weise möglich werden.

Herrn Prof. Dr. J. Mattauch, meinem Lehrer in der Massenspektrographie, möchte ich für sein förderndes und stets hilfsbereites Interesse an dieser Untersuchung meinen herzlichen Dank sagen, desgleichen Herrn Dr. A. Klemm für zahlreiche anregende Diskussionen. Herrn M. v. Ardenne bin ich für Diskussionen über die praktische Durchführbarkeit der Methode sehr verpflichtet.

Berlin-Dahlem, den 3. 5. 42.

Kaiser-Wilhelm-Institut für Chemie.

Figure D.175: Heinz Ewald's March 1942 design for an electromagnetic isotope separator [G-139].

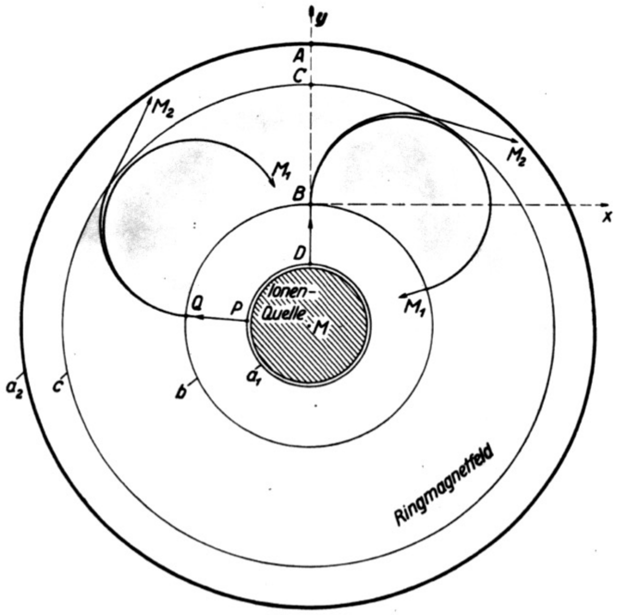

y
A
C
M₂
M₂
M₁
B
x
D
Ionen-Quelle
M
Q
P
M₁
a₂
c
b
a₁
Ringmagnetfeld

Fig. 2. Anordnung mit ringförmigem Magnetfeld, Innenionenquelle und Aussenauffänger für die schwere Masse.

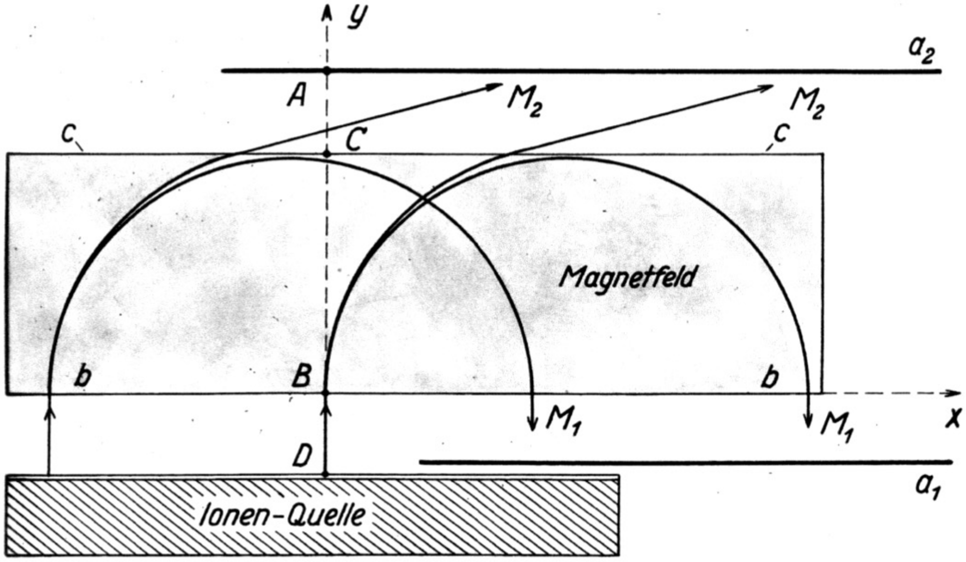

y
a₂
A
M₂
M₂
c
C
c
Magnetfeld
b
B
b
M₁
M₁
x
D
a₁
Ionen-Quelle

Fig. 3. Lineare Ausführung mit langem, rechteckigem Polschuh, Grenzfall des Ringmagneten.

Figure D.176: Heinz Ewald's March 1942 design for an electromagnetic isotope separator [G-139].

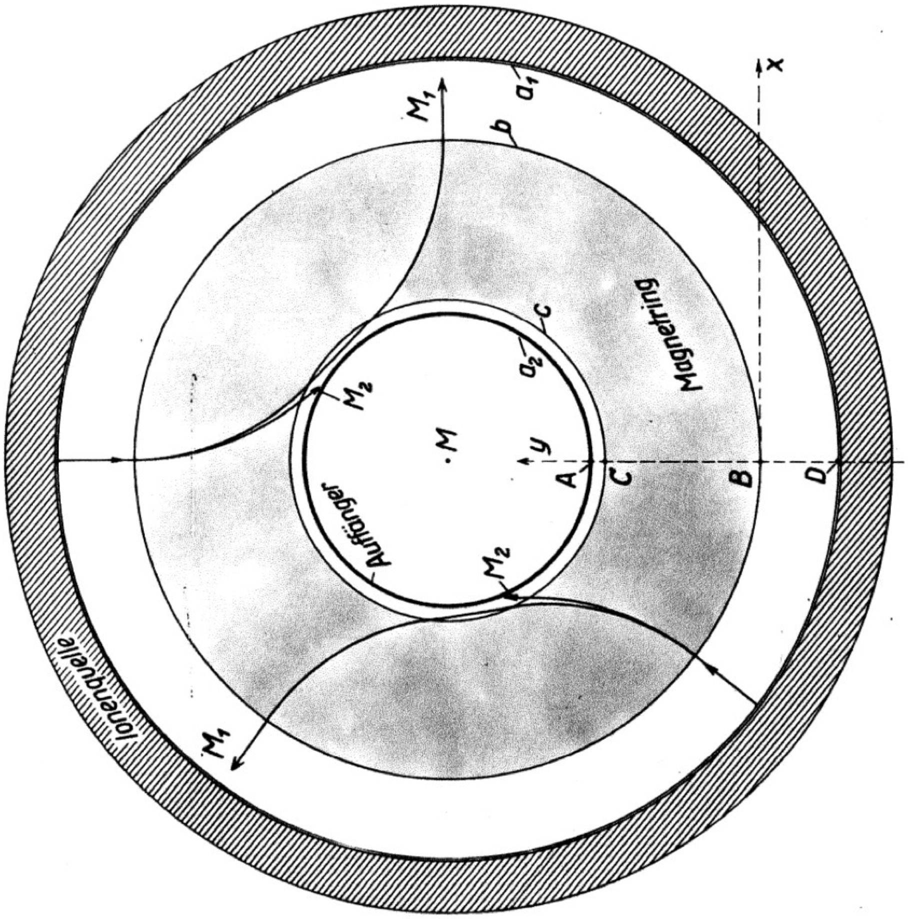

Ionenquelle
M_1
M_1
M_2
M_2
Auffänger
M
y
A
C
B
D
x
a_1
b
c
a_2
Magnetring

Fig. 4. Anordnung mit ringförmigem Magnetfeld, Aussenionenquelle und Innenauffänger für die schwere Masse.

Figure D.177: Heinz Ewald's March 1942 design for an electromagnetic isotope separator [G-139].

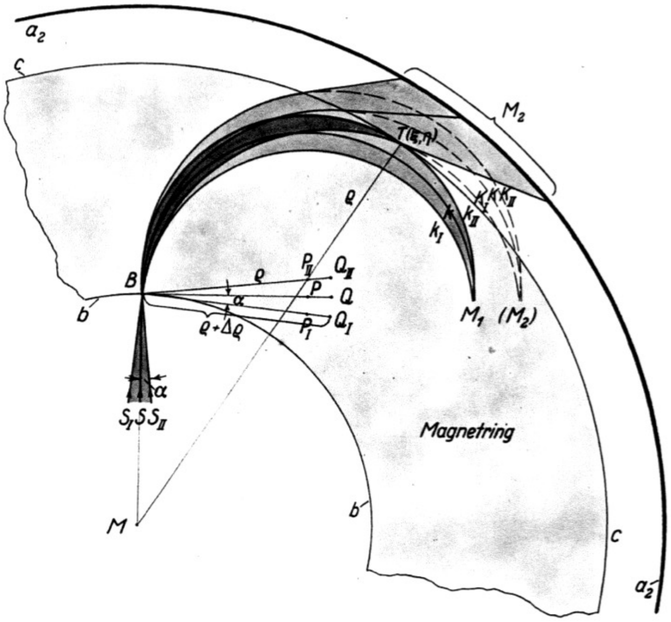

a₂
c
M₂
T(ξ,η)
ϱ
K
K_I
K_II
k
k_I
k_II
B
P_II
Q_II
ϱ
P
Q
α
ϱ+Δϱ
P_I
Q_I
b
M₁
(M₂)
α
S_I S S_II
Magnetring
M
b
c
a₂

Fig. 5. Zum Auflösungsvermögen der Anordnung mit Innenionenquelle.

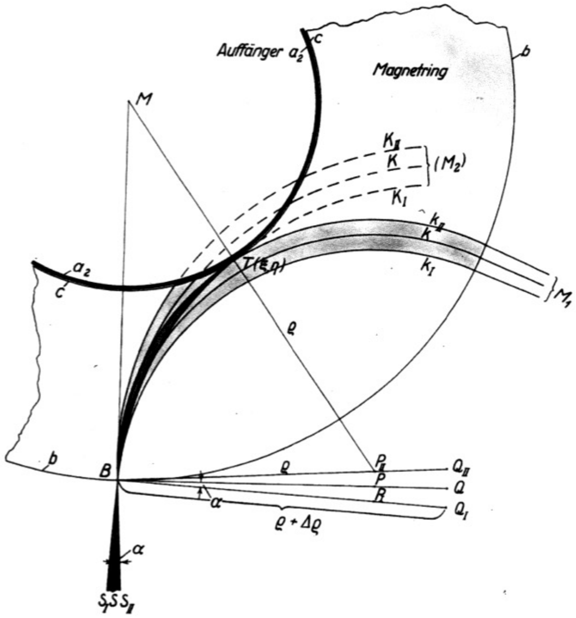

Auffänger a₂
c
b
Magnetring
M
K_II
K
K_I
(M₂)
k_II
k
k_I
T(ξ,η)
M₁
a₂
c
ϱ
b
B
P_II
Q_II
ϱ
P
Q
P_I
Q_I
α
ϱ+Δϱ
α
S_I S S_II

Fig. 6. Zum Auflösungsvermögen der Anordnung mit Aussenionenquelle.

Figure D.178: Heinz Ewald's March 1942 design for an electromagnetic isotope separator [G-139].

für den Krümmungsradius von Ionen der Voltenergie U im Magnetfeld H folgt für das Auflösungsvermögen

$$\frac{M}{\Delta M} = \frac{1}{\alpha}\cdot\frac{\rho}{\Delta\rho}$$

Wenn wir den Ursprung des Koordinatensystemes in den Mittelpunkt M der ganzen Anordnung verlegen (Fig. 7), haben die drei Kreise k_{II}, K_I und c die Gleichungen (unter Vernachlässigung höherer Potenzen von α):

$$(x-\rho)^2 + (y - r_b - \rho\cdot\alpha)^2 = \rho^2$$

$$(x-(\rho+\Delta\rho))^2 + (y - r_b + (\rho+\Delta\rho))^2 = (\rho+\Delta\rho)^2$$

$$x^2 + y^2 = r_c^2$$

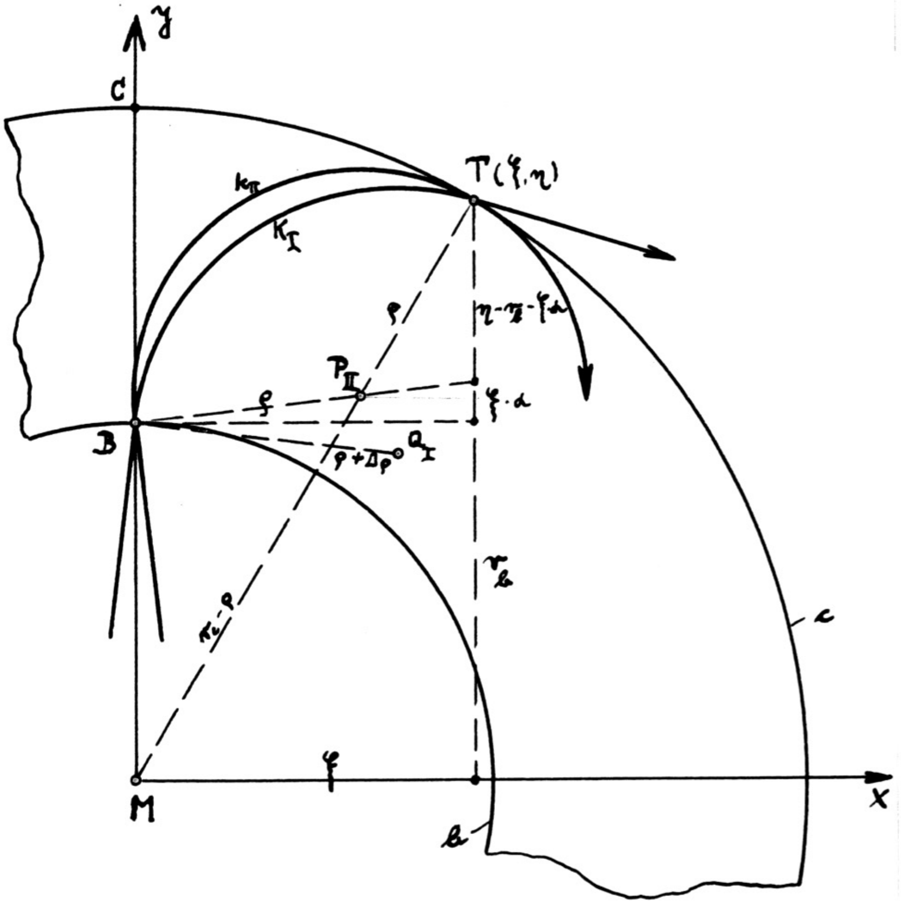
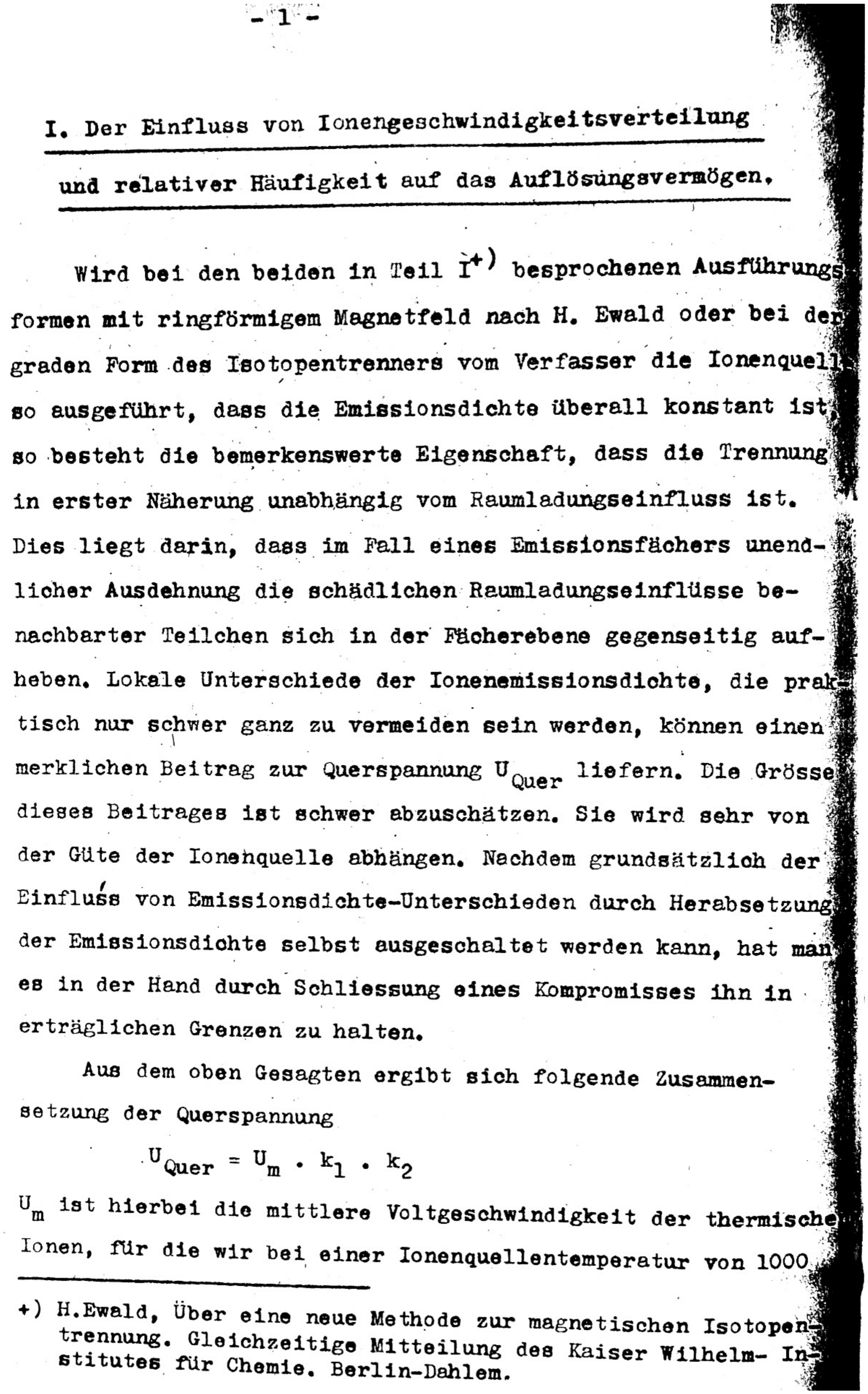


Fig. 7
Ableitung des Auflösungsvermögens.

Figure D.179: Heinz Ewald's March 1942 design for an electromagnetic isotope separator [G-139].



- 1 -

I. Der Einfluss von Ionengeschwindigkeitsverteilung und relativer Häufigkeit auf das Auflösungsvermögen.

Wird bei den beiden in Teil I+) besprochenen Ausführungsformen mit ringförmigem Magnetfeld nach H. Ewald oder bei de graden Form des Isotopentrenners vom Verfasser die Ionenquell so ausgeführt, dass die Emissionsdichte überall konstant ist so besteht die bemerkenswerte Eigenschaft, dass die Trennung in erster Näherung unabhängig vom Raumladungseinfluss ist. Dies liegt darin, dass im Fall eines Emissionsfächers unendlicher Ausdehnung die schädlichen Raumladungseinflüsse benachbarter Teilchen sich in der Fächerebene gegenseitig aufheben. Lokale Unterschiede der Ionenemissionsdichte, die praktisch nur schwer ganz zu vermeiden sein werden, können einen merklichen Beitrag zur Querspannung U_{Quer} liefern. Die Grösse dieses Beitrages ist schwer abzuschätzen. Sie wird sehr von der Güte der Ionenquelle abhängen. Nachdem grundsätzlich der Einfluss von Emissionsdichte-Unterschieden durch Herabsetzung der Emissionsdichte selbst ausgeschaltet werden kann, hat man es in der Hand durch Schliessung eines Kompromisses ihn in erträglichen Grenzen zu halten.

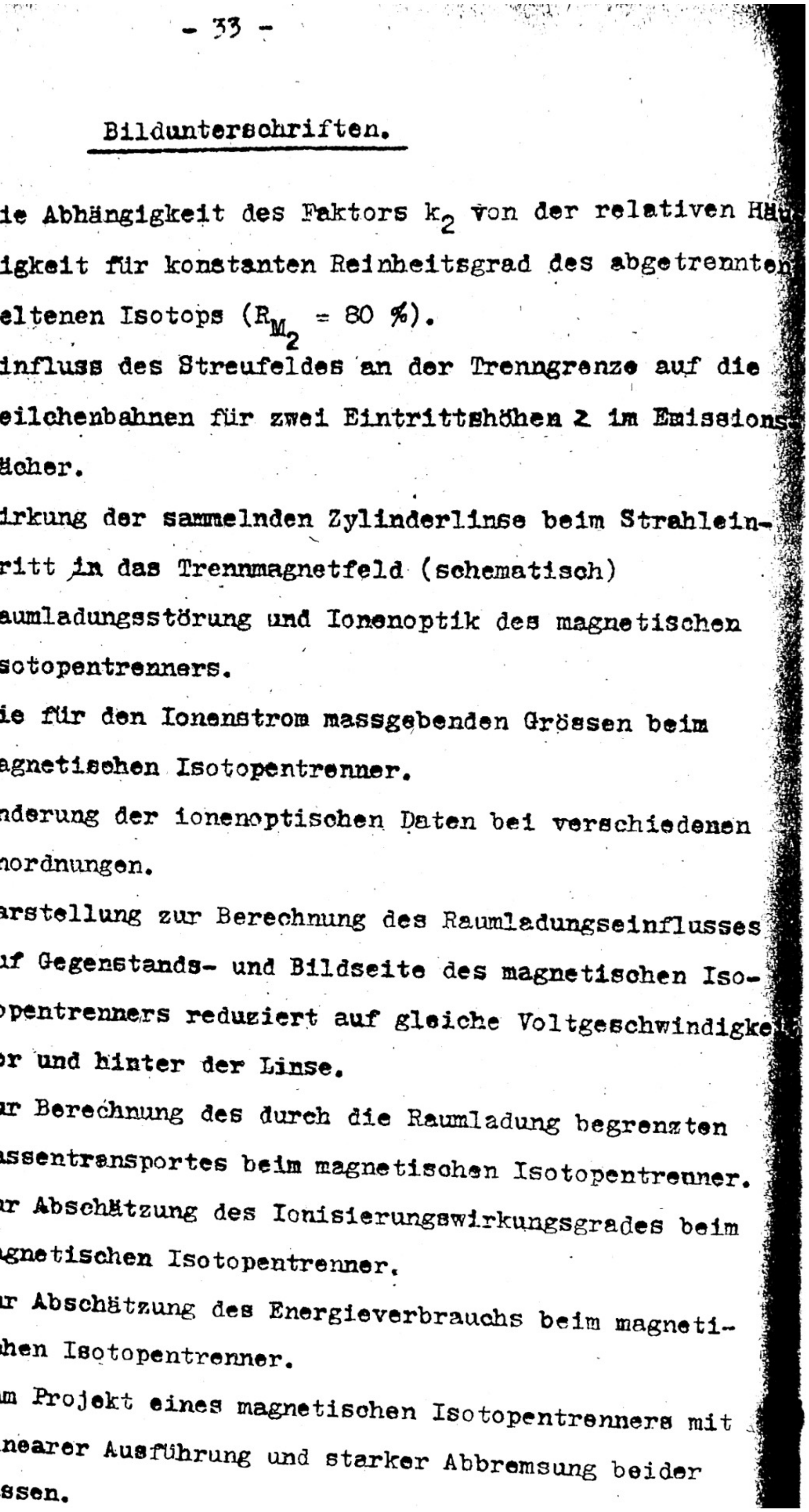
Aus dem oben Gesagten ergibt sich folgende Zusammensetzung der Querspannung

$$U_{Quer} = U_m \cdot k_1 \cdot k_2$$

U_m ist hierbei die mittlere Voltgeschwindigkeit der thermische Ionen, für die wir bei einer Ionenquellentemperatur von 1000

+) H.Ewald, Über eine neue Methode zur magnetischen Isotopentrennung. Gleichzeitige Mitteilung des Kaiser Wilhelm- Institutes für Chemie. Berlin-Dahlem.

Figure D.180: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]



Bildunterschriften.

Fig. 1. Die Abhängigkeit des Faktors k_2 von der relativen Häufigkeit für konstanten Reinheitsgrad des abgetrennten seltenen Isotops (R_{M_2} = 80 %).

Fig. 2. Einfluss des Streufeldes an der Trenngrenze auf die Teilchenbahnen für zwei Eintrittshöhen z im Emissionsfächer.

Fig. 3. Wirkung der sammelnden Zylinderlinse beim Strahleintritt in das Trennmagnetfeld (schematisch)

Fig. 4. Raumladungsstörung und Ionenoptik des magnetischen Isotopentrenners.

Fig. 5. Die für den Ionenstrom massgebenden Grössen beim magnetischen Isotopentrenner.

Fig. 6. Änderung der ionenoptischen Daten bei verschiedenen Anordnungen.

Fig. 7. Darstellung zur Berechnung des Raumladungseinflusses auf Gegenstands- und Bildseite des magnetischen Isotopentrenners reduziert auf gleiche Voltgeschwindigke vor und hinter der Linse.

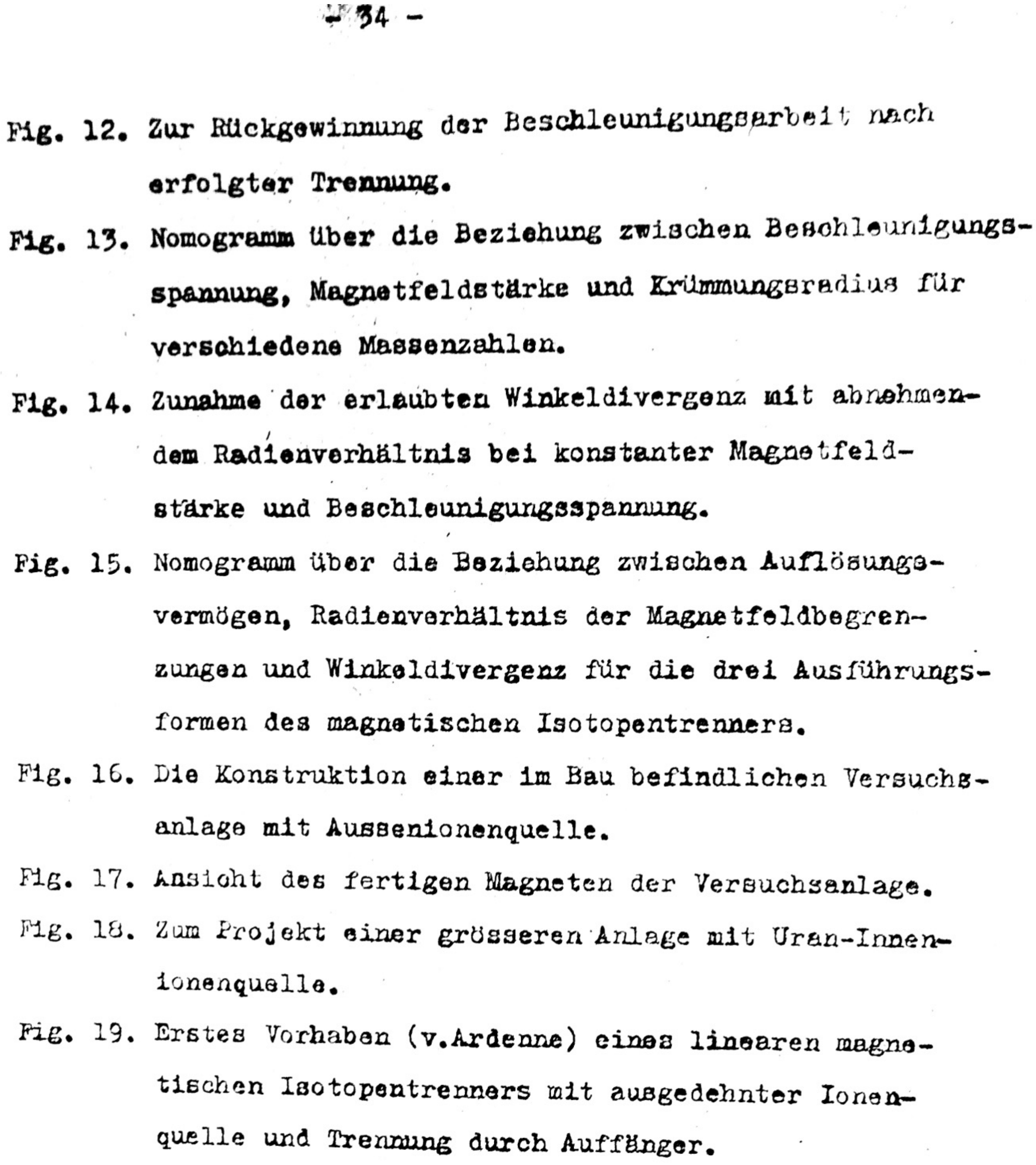
Fig. 8. Zur Berechnung des durch die Raumladung begrenzten Massentransportes beim magnetischen Isotopentrenner.

Fig. 9. Zur Abschätzung des Ionisierungswirkungsgrades beim magnetischen Isotopentrenner.

Fig.10. Zur Abschätzung des Energieverbrauchs beim magnetischen Isotopentrenner.

Fig.11. Zum Projekt eines magnetischen Isotopentrenners mit linearer Ausführung und starker Abbremsung beider Massen.

Figure D.181: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]



- 34 -

Fig. 12. Zur Rückgewinnung der Beschleunigungsarbeit nach erfolgter Trennung.

Fig. 13. Nomogramm über die Beziehung zwischen Beschleunigungsspannung, Magnetfeldstärke und Krümmungsradius für verschiedene Massenzahlen.

Fig. 14. Zunahme der erlaubten Winkeldivergenz mit abnehmendem Radienverhältnis bei konstanter Magnetfeldstärke und Beschleunigungsspannung.

Fig. 15. Nomogramm über die Beziehung zwischen Auflösungsvermögen, Radienverhältnis der Magnetfeldbegrenzungen und Winkeldivergenz für die drei Ausführungsformen des magnetischen Isotopentrenners.

Fig. 16. Die Konstruktion einer im Bau befindlichen Versuchsanlage mit Aussenionenquelle.

Fig. 17. Ansicht des fertigen Magneten der Versuchsanlage.

Fig. 18. Zum Projekt einer grösseren Anlage mit Uran-Innenionenquelle.

Fig. 19. Erstes Vorhaben (v.Ardenne) eines linearen magnetischen Isotopentrenners mit ausgedehnter Ionenquelle und Trennung durch Auffänger.

Figure D.182: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

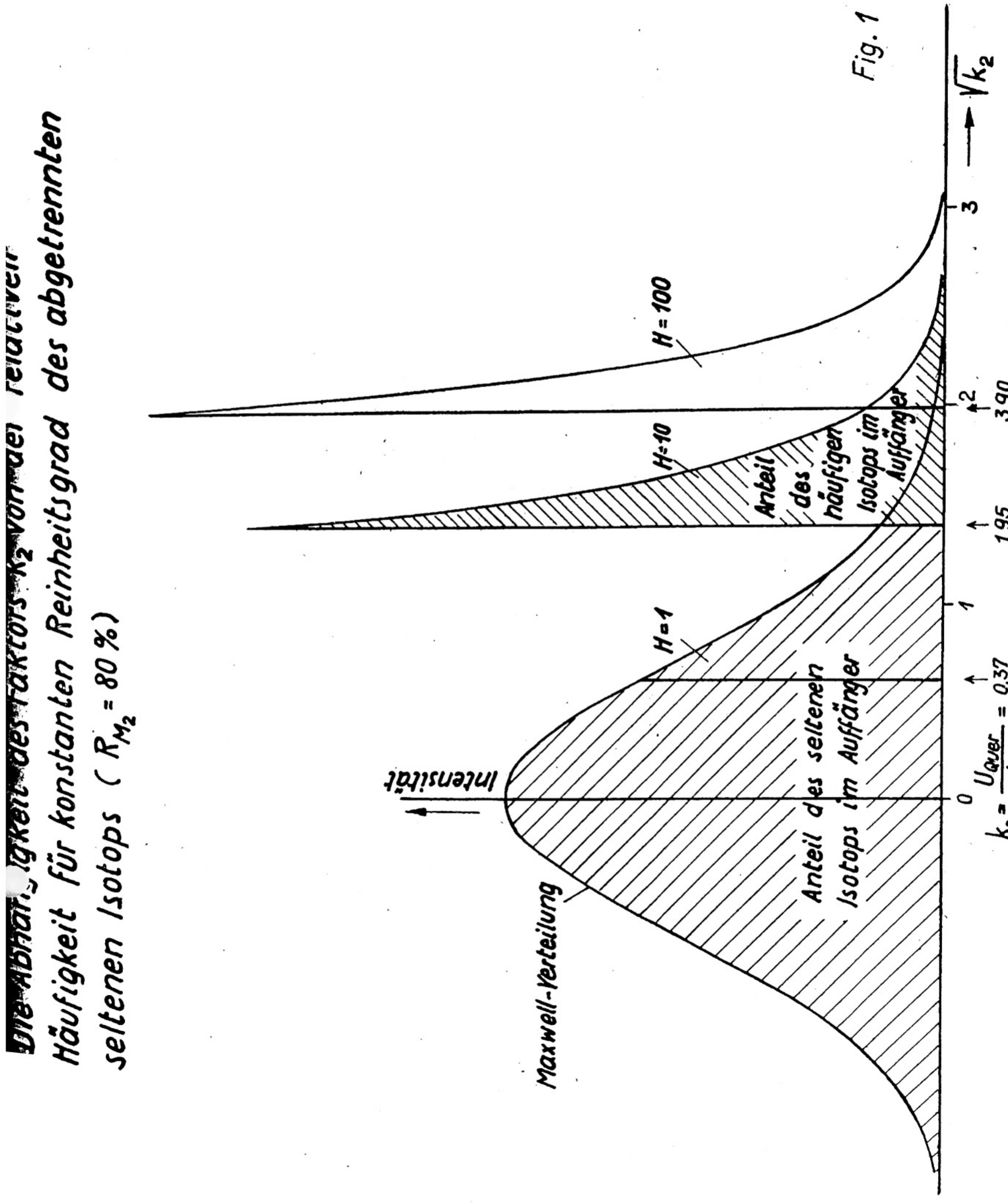


Figure D.183: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

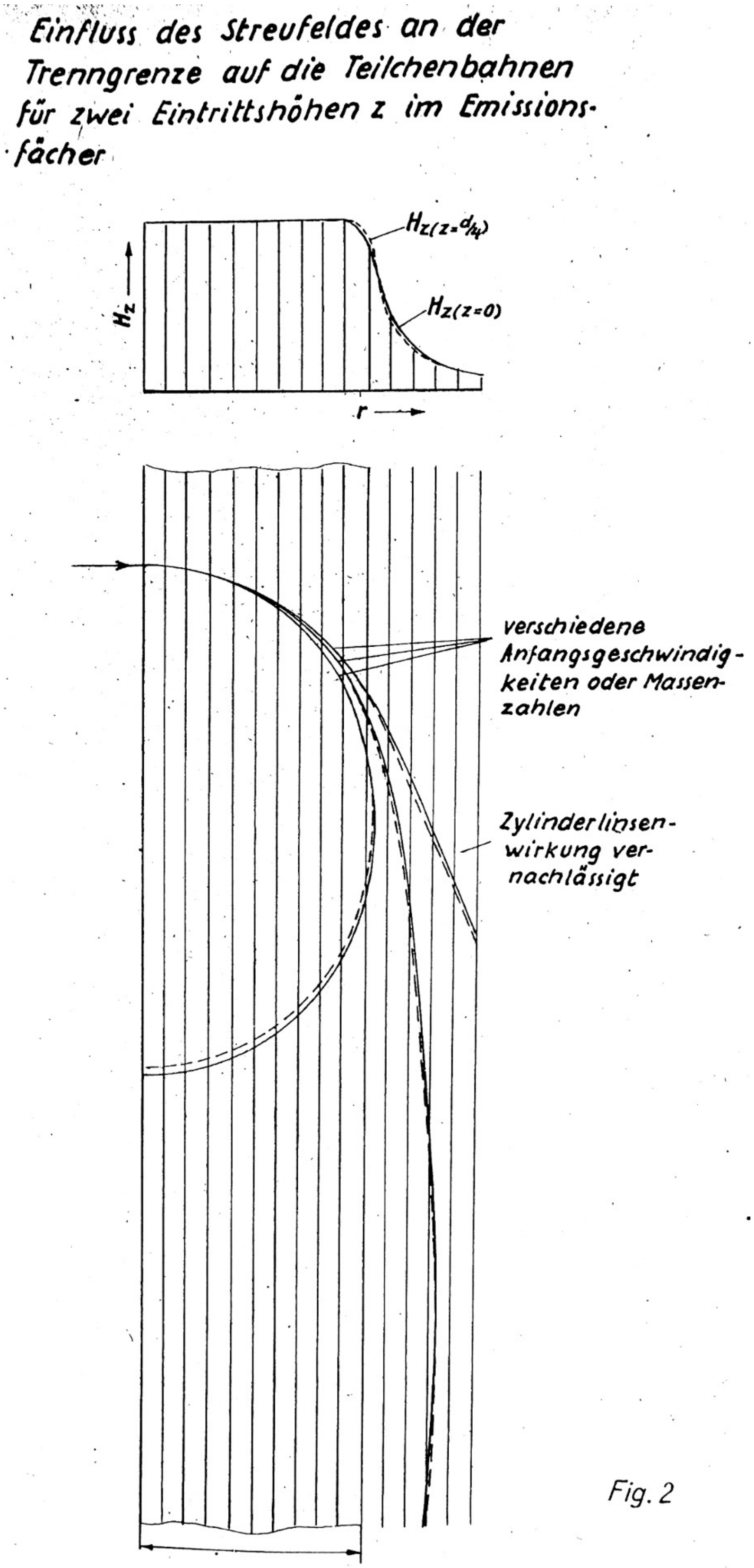

Einfluss des Streufeldes an der Trenngrenze auf die Teilchenbahnen für zwei Eintrittshöhen z im Emissionsfächer
Hz(z=d/4)
Hz(z=0)
Hz
r
verschiedene Anfangsgeschwindigkeiten oder Massenzahlen
Zylinderlinsenwirkung vernachlässigt

Fig. 2

Figure D.184: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

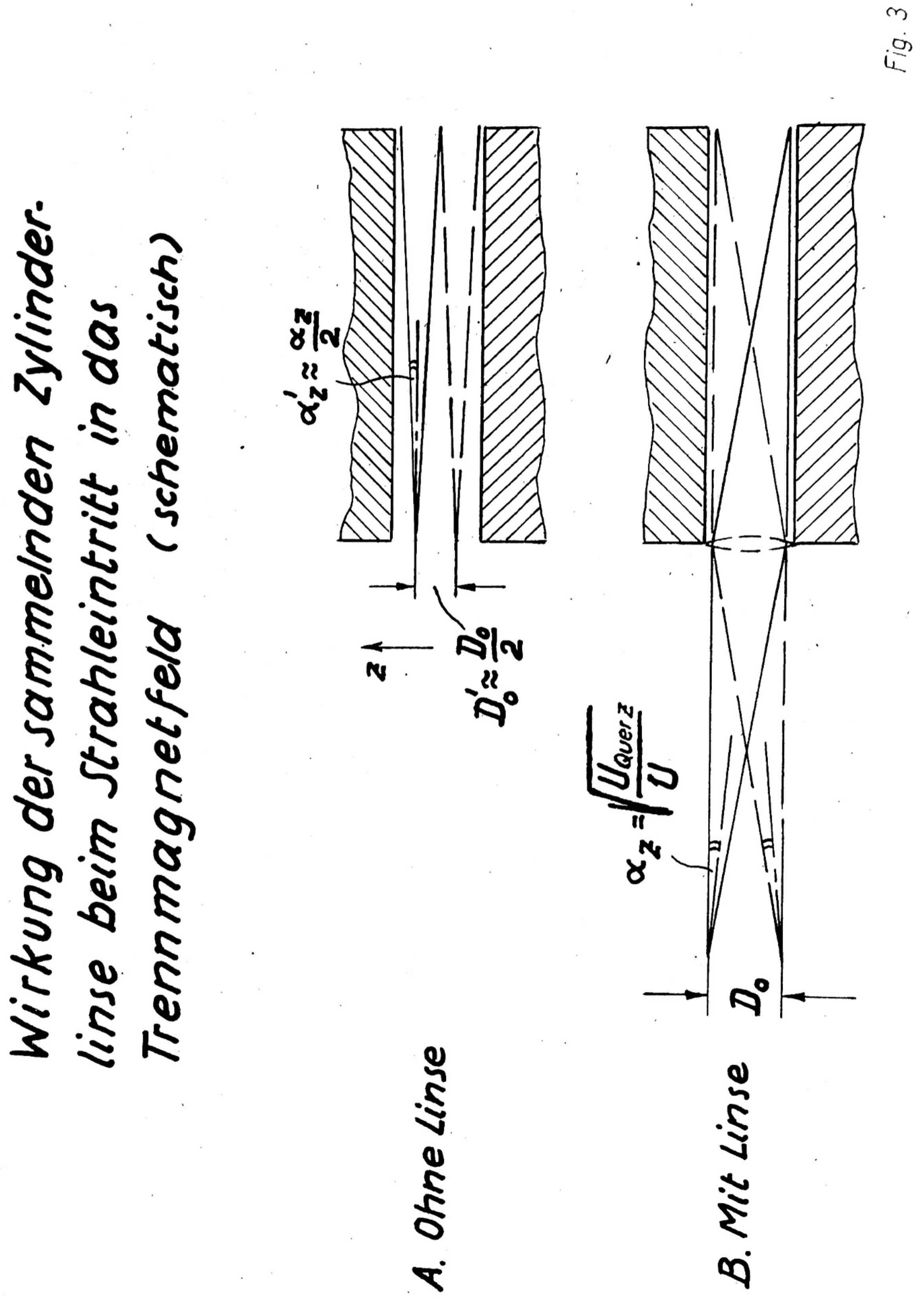


Fig. 3
Wirkung der sammelnden Zylinderlinse beim Strahleintritt in das Trennmagnetfeld (schematisch)
A. Ohne Linse
$\alpha'_z \approx \frac{\alpha_z}{2}$
z
$D'_0 \approx \frac{D_0}{2}$
B. Mit Linse
$\alpha_z = \sqrt{\frac{U_{Quer\,z}}{U}}$
D_0

Figure D.185: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

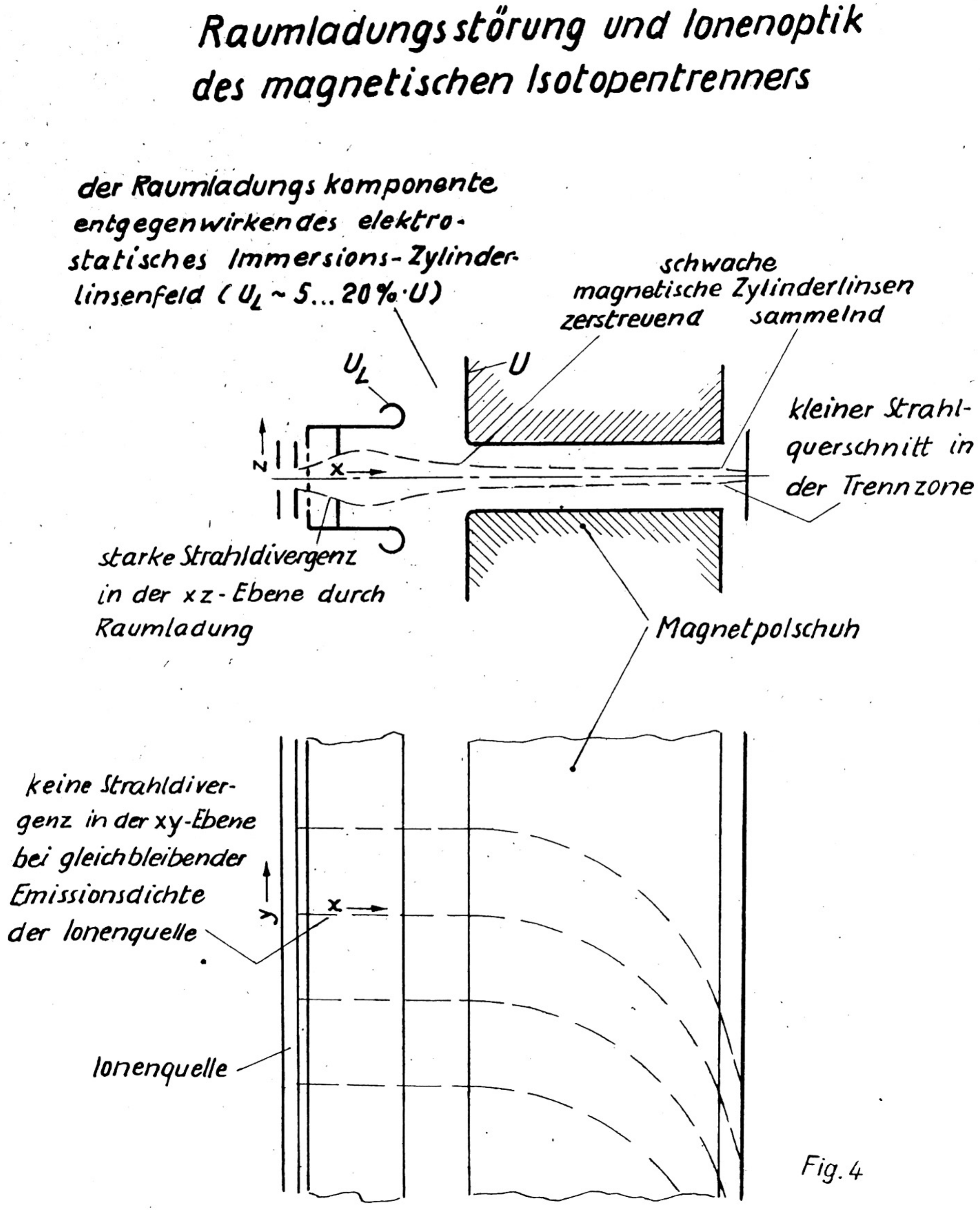
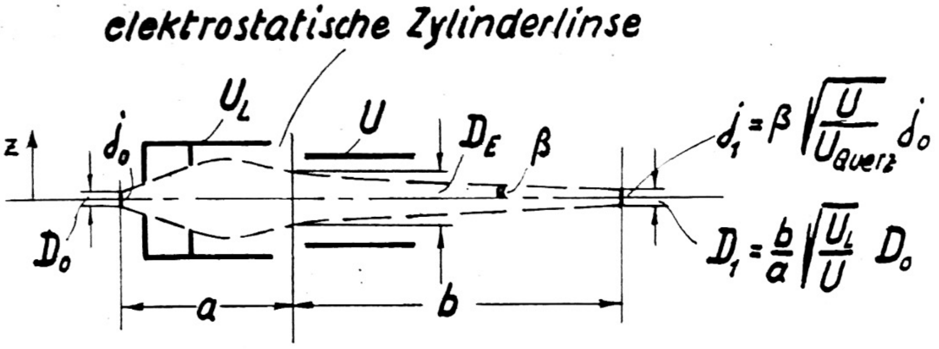

Raumladungsstörung und Ionenoptik des magnetischen Isotopentrenners
der Raumladungskomponente entgegenwirkendes elektrostatisches Immersions-Zylinderlinsenfeld ($U_L \sim 5 \ldots 20\% \cdot U$)
schwache magnetische Zylinderlinsen
zerstreuend
sammelnd
U_L
U
z
x
kleiner Strahlquerschnitt in der Trennzone
starke Strahldivergenz in der xz-Ebene durch Raumladung
Magnetpolschuh
keine Strahldivergenz in der xy-Ebene bei gleichbleibender Emissionsdichte der Ionenquelle
y
x
Ionenquelle
Fig. 4

Figure D.186: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

Die für den Ionenstrom massgebenden Grössen beim magnetischen Isotopentrenner


elektrostatische Zylinderlinse
U_L
U
D_E
β
z
j_0
D_0
$j_1 = \beta \sqrt{\frac{U}{U_{Querz}}} j_0$
$D_1 = \frac{b}{a} \sqrt{\frac{U_L}{U}} D_0$
a
b

$$I_1 = D_1 j_1 l = \frac{1}{2}\sqrt{\frac{U}{U_{Querz}}} \cdot \frac{1}{b} \cdot D_1 D_E \, l \, j_0$$

I_1 = Ionenstromstärke
j_0 = Stromdichte der Ionenquelle
j_1 = Stromdichte am Abbildungsort
D_0 = Höhe des Ionenquellenspaltes
D_1 = Höhe des Ionenstromfächers am Abbildungsort
D_E = Eintrittshöhe am Anfang des Trennmagnetfeldes
l = Länge des Ionenquellenspaltes
β = bildseitiger Aperturwinkel
U_L = Linsenspannung
U = Beschleunigungsspannung
U_{Querz} = resultierende Querspannung in z-Richtung

Fig. 5

Figure D.187: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

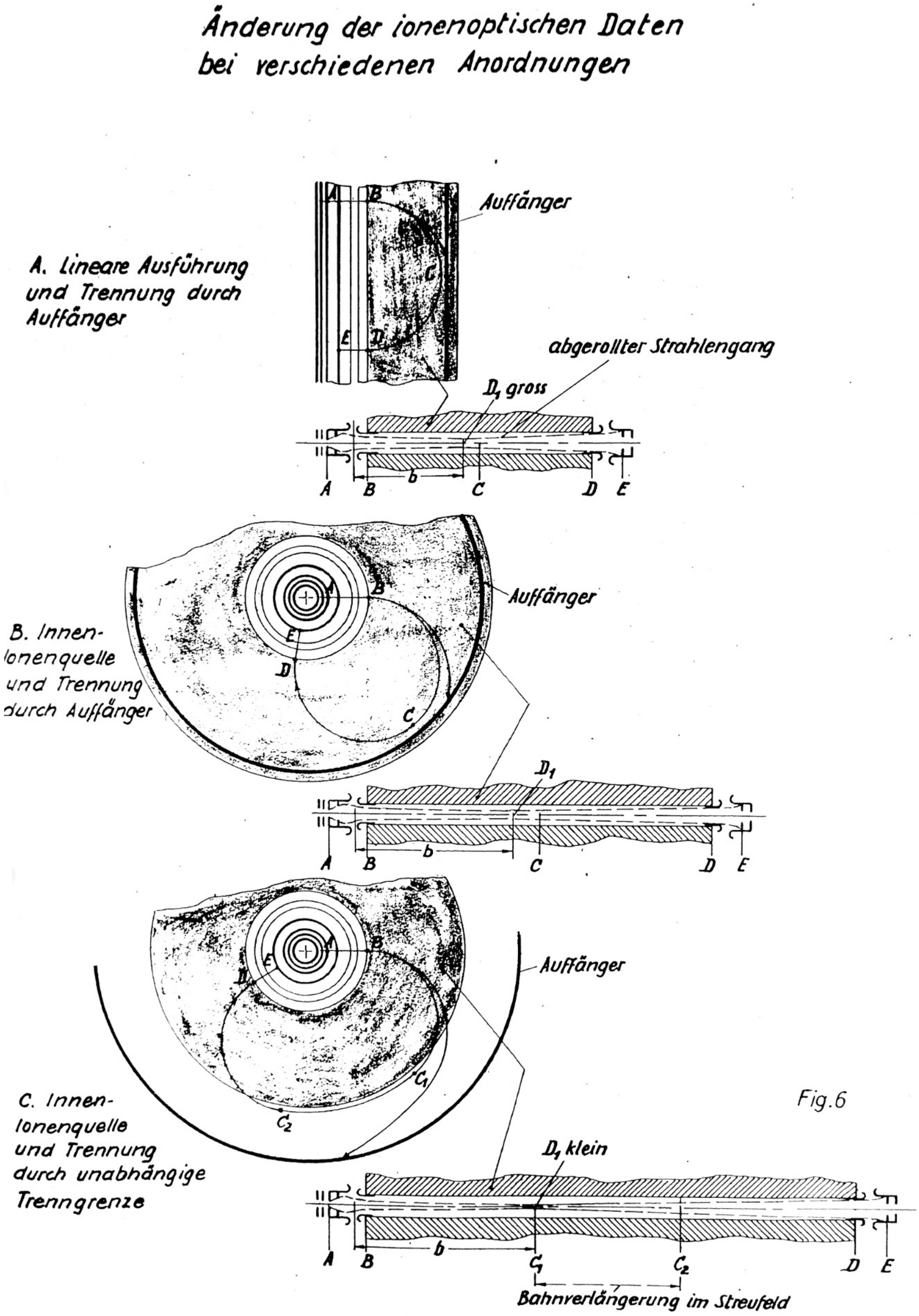

Änderung der ionenoptischen Daten
bei verschiedenen Anordnungen
A. Lineare Ausführung und Trennung durch Auffänger
Auffänger
A
B
C
E
D
abgerollter Strahlengang
D_1 gross
b
A B C D E
B. Innen-Ionenquelle und Trennung durch Auffänger
Auffänger
D_1
A B C D E
C. Innen-Ionenquelle und Trennung durch unabhängige Trenngrenze
Auffänger
C_1
C_2
Fig.6
D_1 klein
A B C_1 C_2 D E
Bahnverlängerung im Streufeld

Figure D.188: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

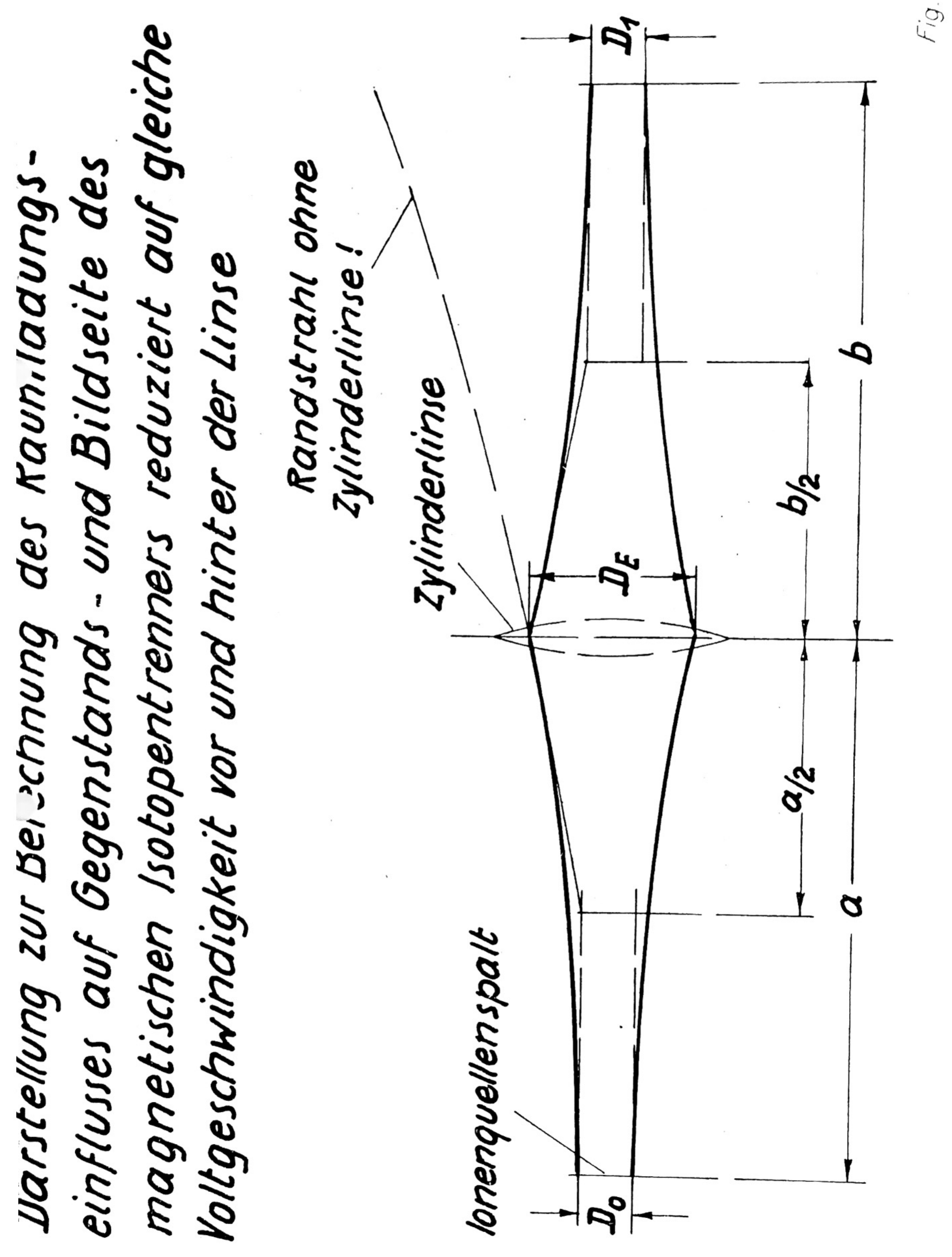

Darstellung zur Berechnung des Raumladungs-
einflusses auf Gegenstands- und Bildseite des
magnetischen Isotopentrenners reduziert auf gleiche
Voltgeschwindigkeit vor und hinter der Linse
Randstrahl ohne
Zylinderlinse!
Zylinderlinse
Ionenquellenspalt
D_1
D_E
D_0
b
b/2
a/2
a
Fig. 7

Figure D.189: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

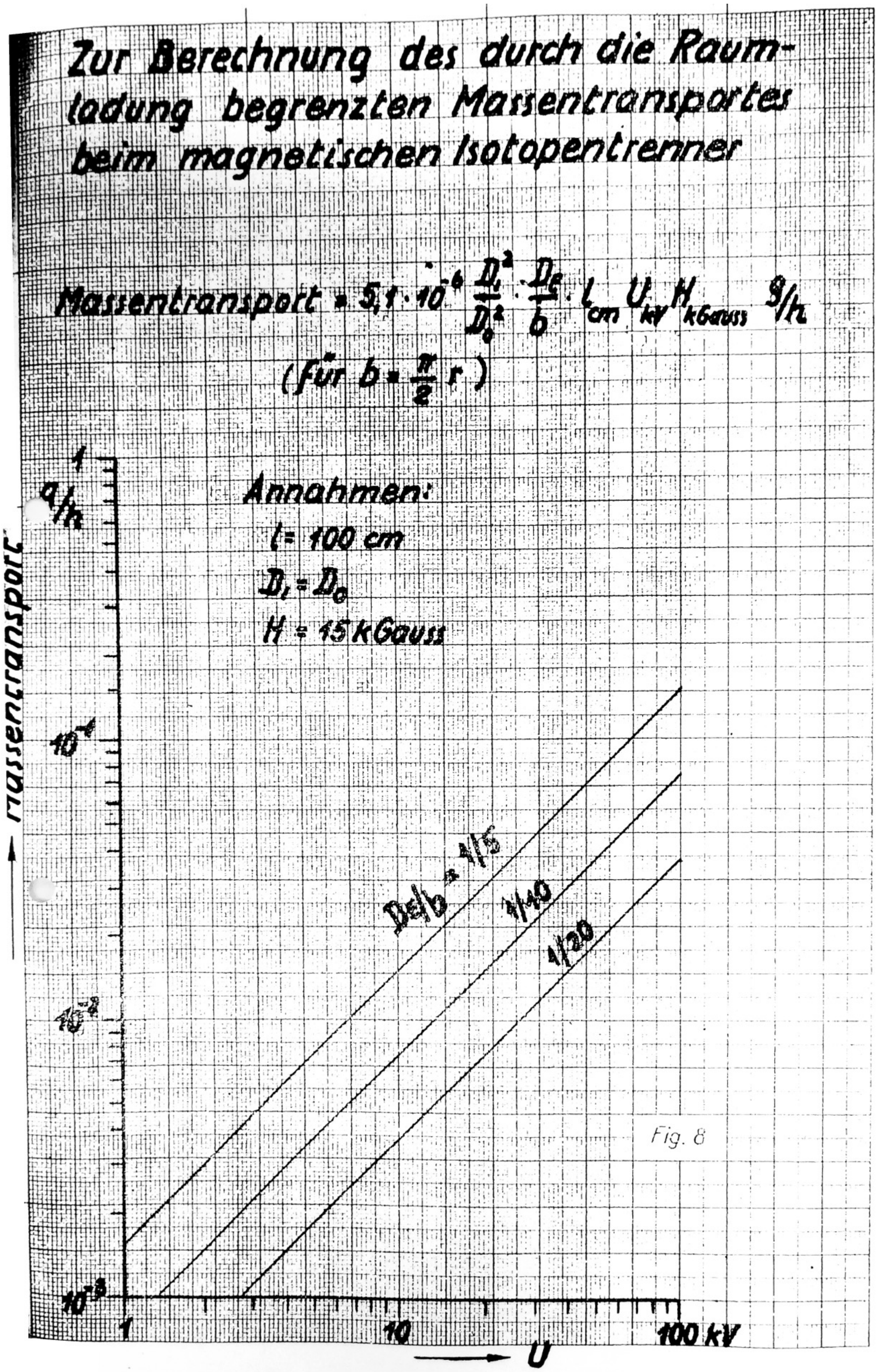


Figure D.190: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

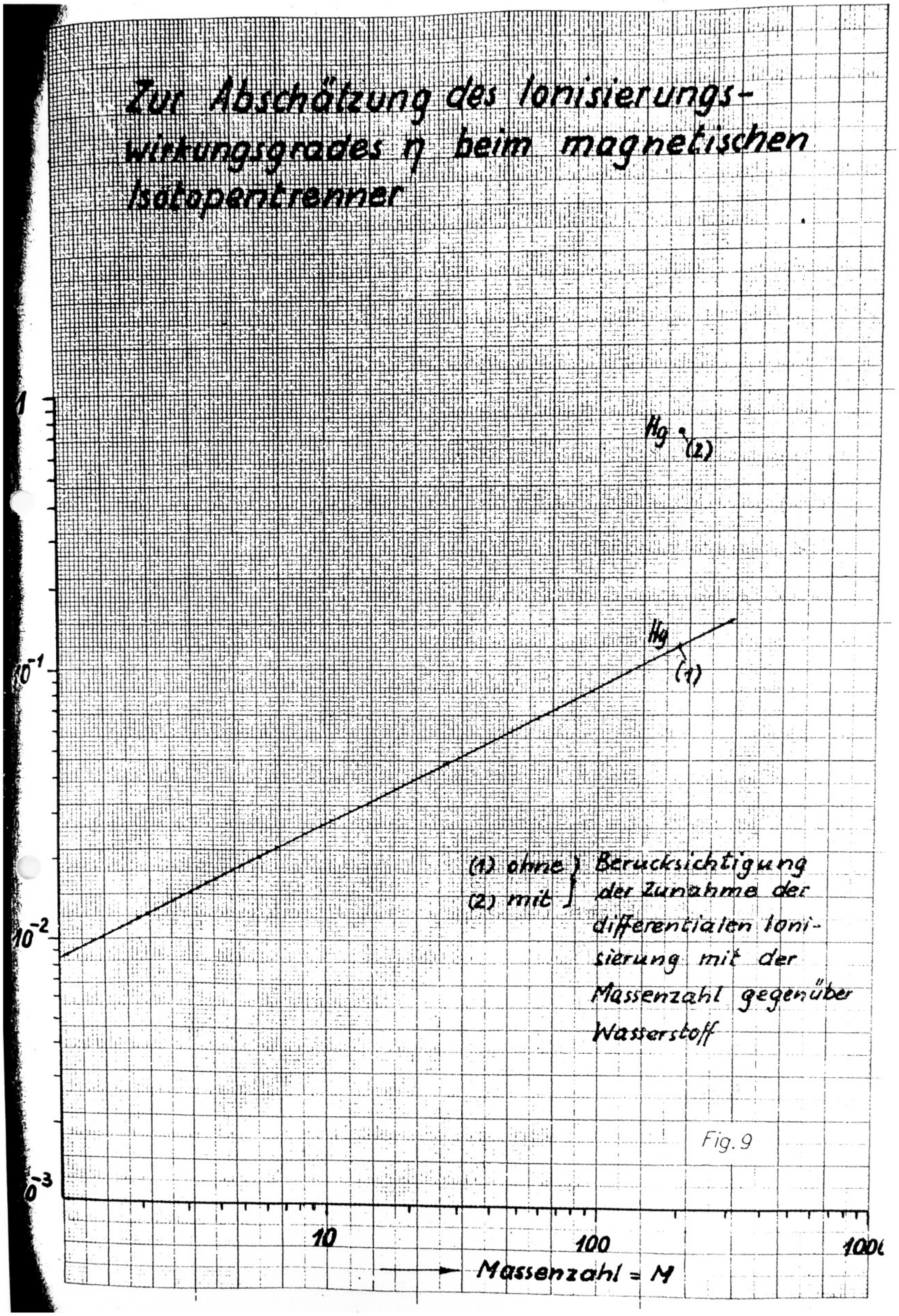


Fig. 9

Figure D.191: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

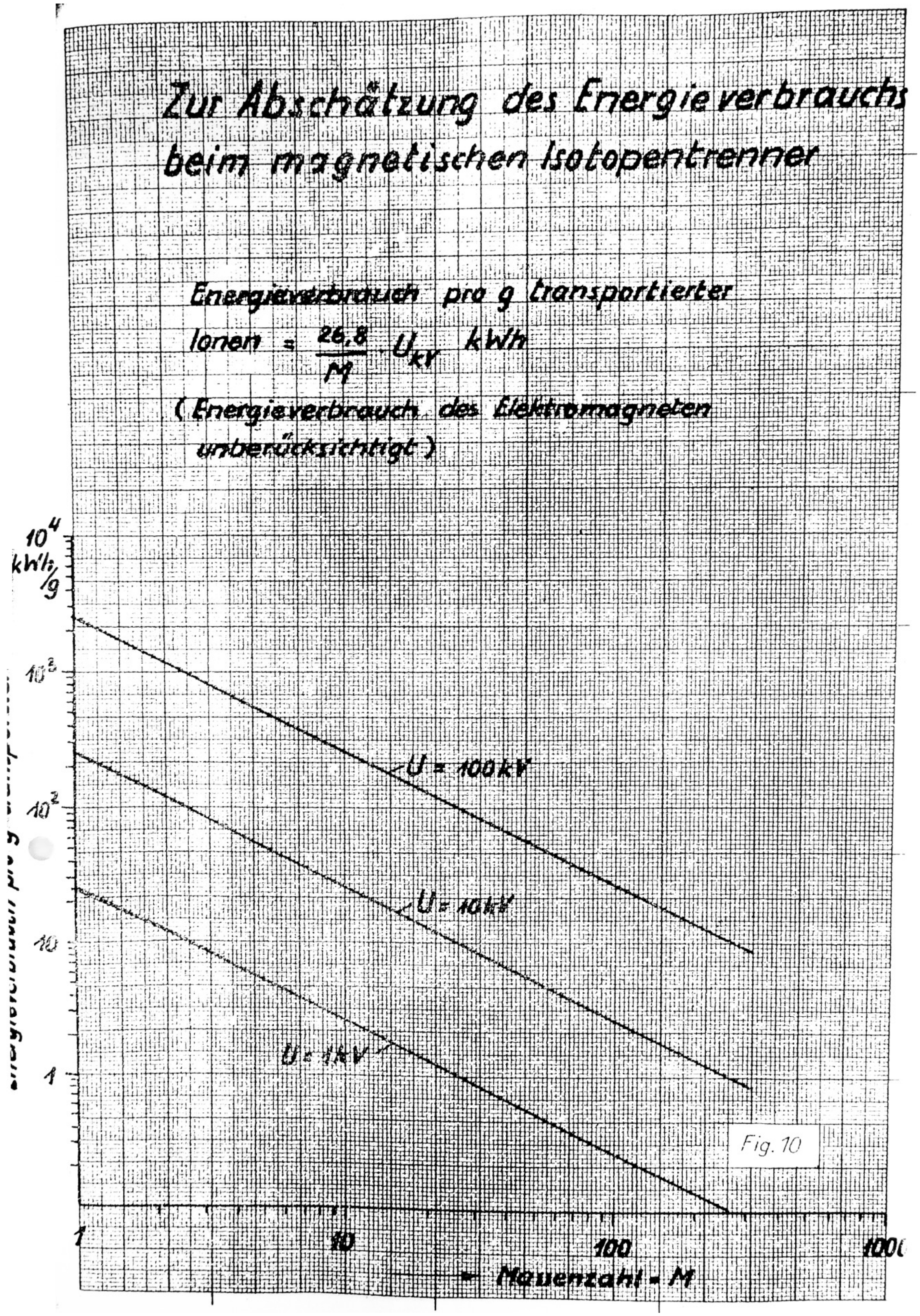


Figure D.192: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

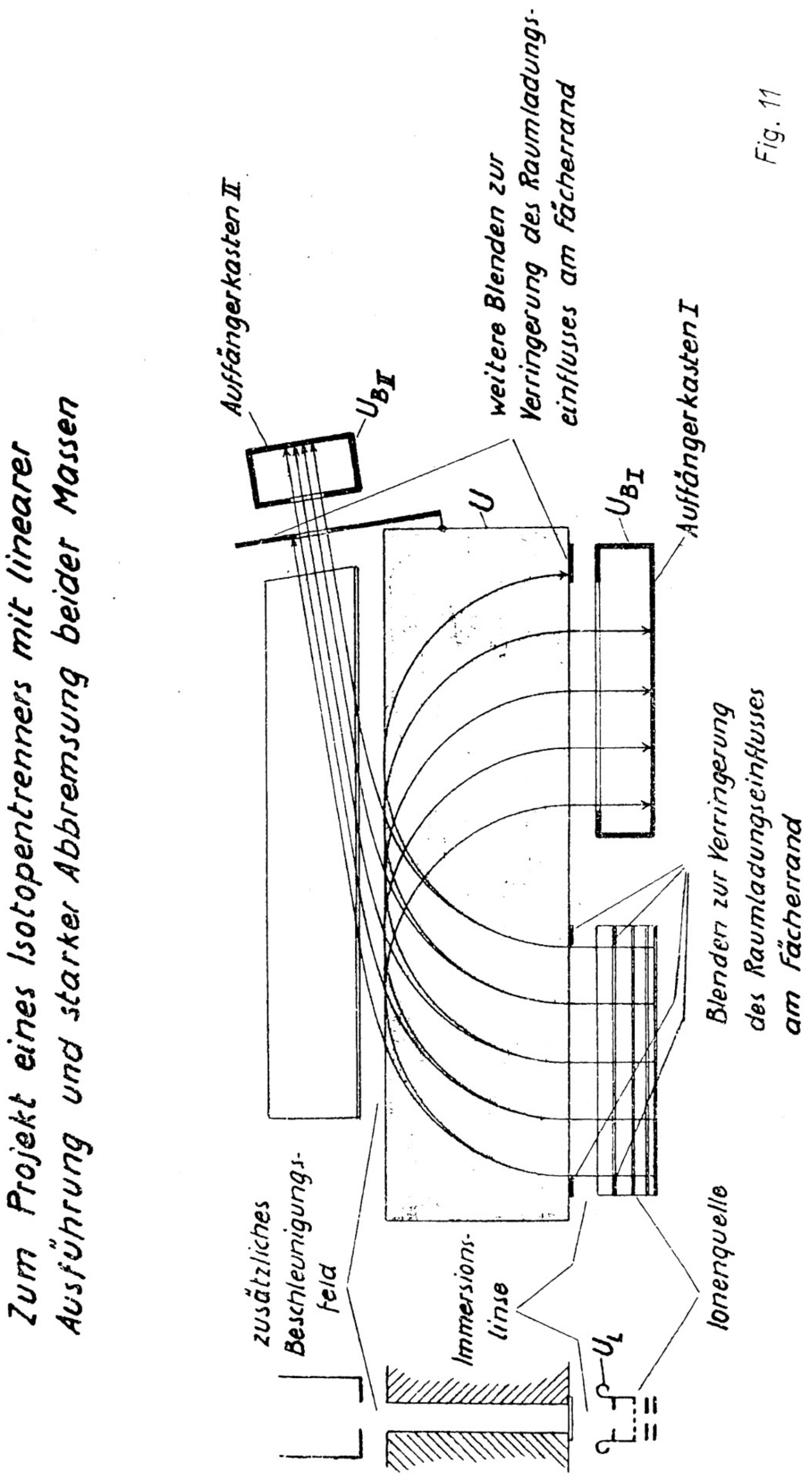

Zum Projekt eines Isotopentrenners mit linearer
Ausführung und starker Abbremsung beider Massen
Auffängerkasten II
$U_{B_{II}}$
U
weitere Blenden zur Verringerung des Raumladungseinflusses am Fächerrand
U_{B_I}
Auffängerkasten I
Blenden zur Verringerung des Raumladungseinflusses am Fächerrand
zusätzliches Beschleunigungsfeld
Immersionslinse
U_L
Ionenquelle
Fig. 11

Figure D.193: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

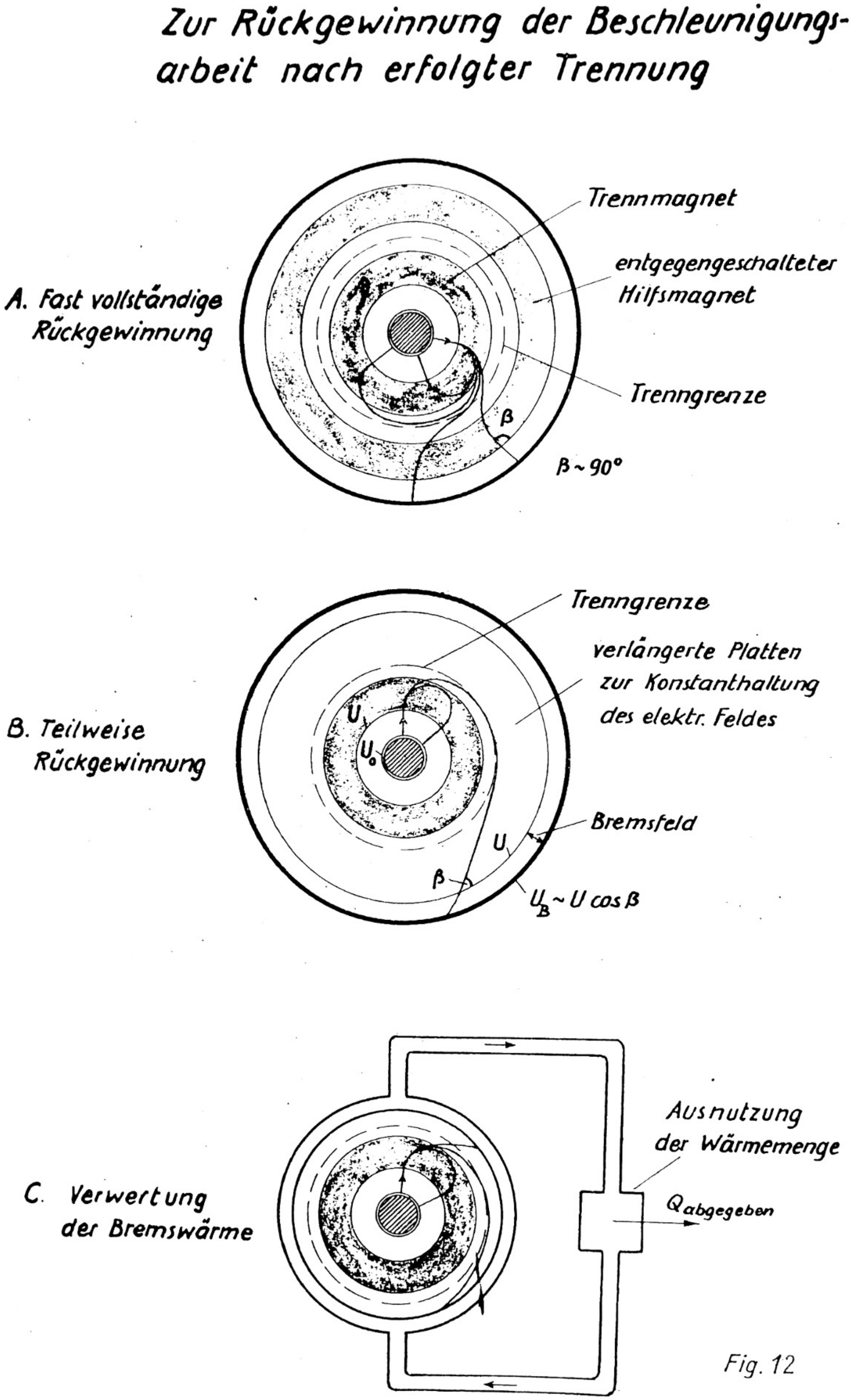

Zur Rückgewinnung der Beschleunigungsarbeit nach erfolgter Trennung
A. Fast vollständige Rückgewinnung
Trennmagnet
entgegengeschalteter Hilfsmagnet
Trenngrenze
β
β ~ 90°
B. Teilweise Rückgewinnung
Trenngrenze
verlängerte Platten zur Konstanthaltung des elektr. Feldes
U₁
U₀
Bremsfeld
U
β
U_β ~ U cos β
C. Verwertung der Bremswärme
Ausnutzung der Wärmemenge
Q_abgegeben
Fig. 12

Figure D.194: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

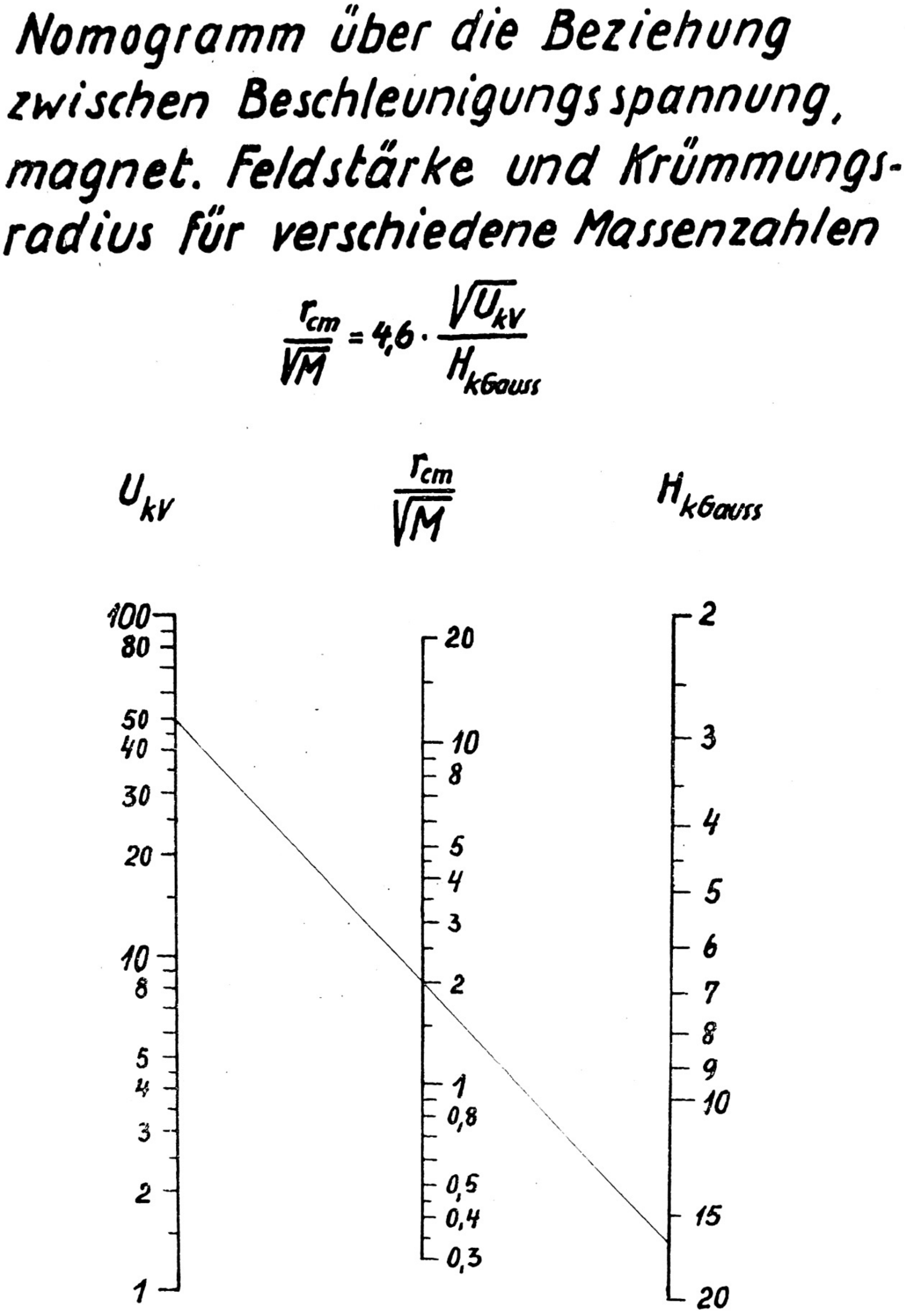


Fig.13

Figure D.195: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

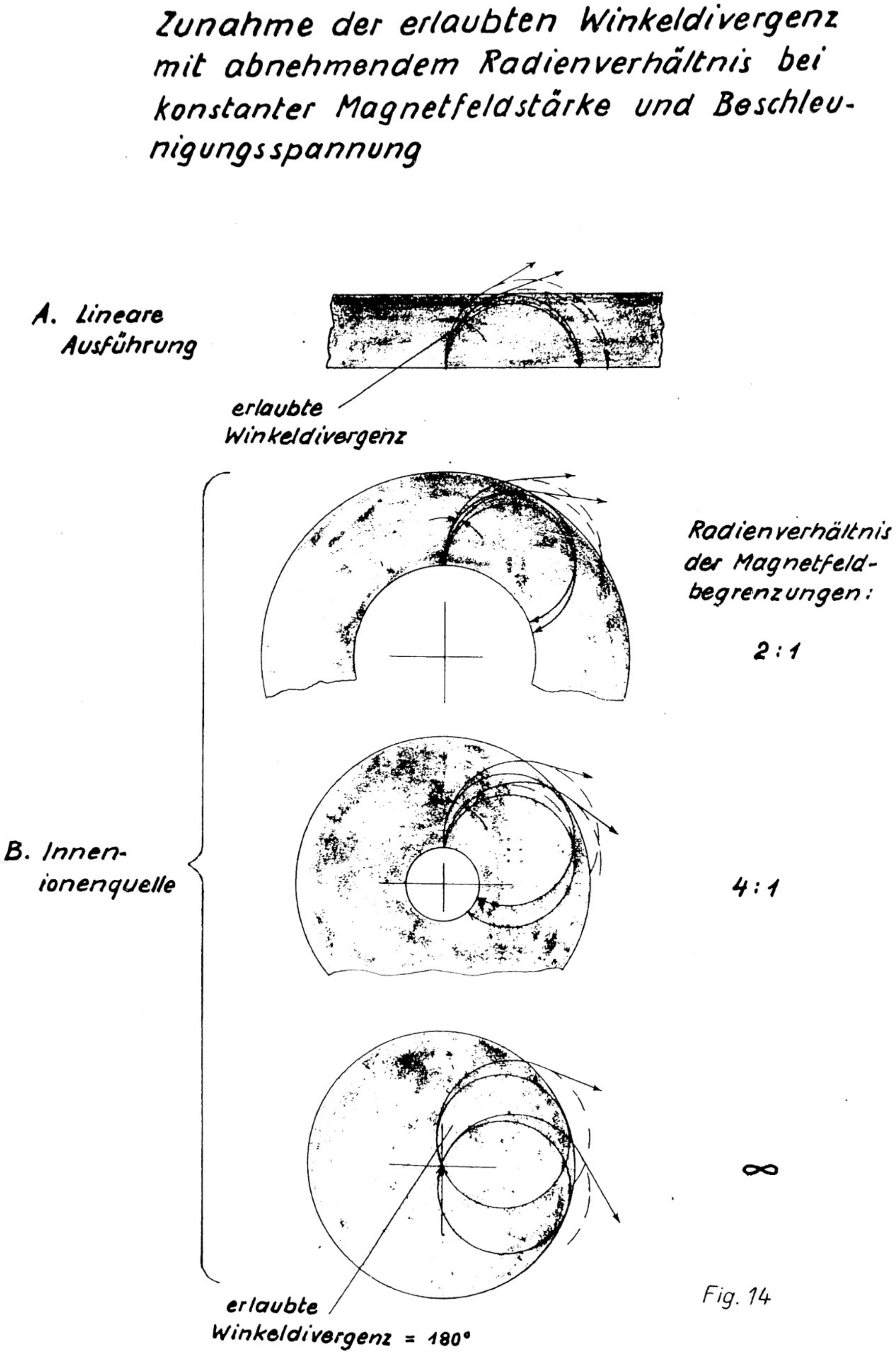
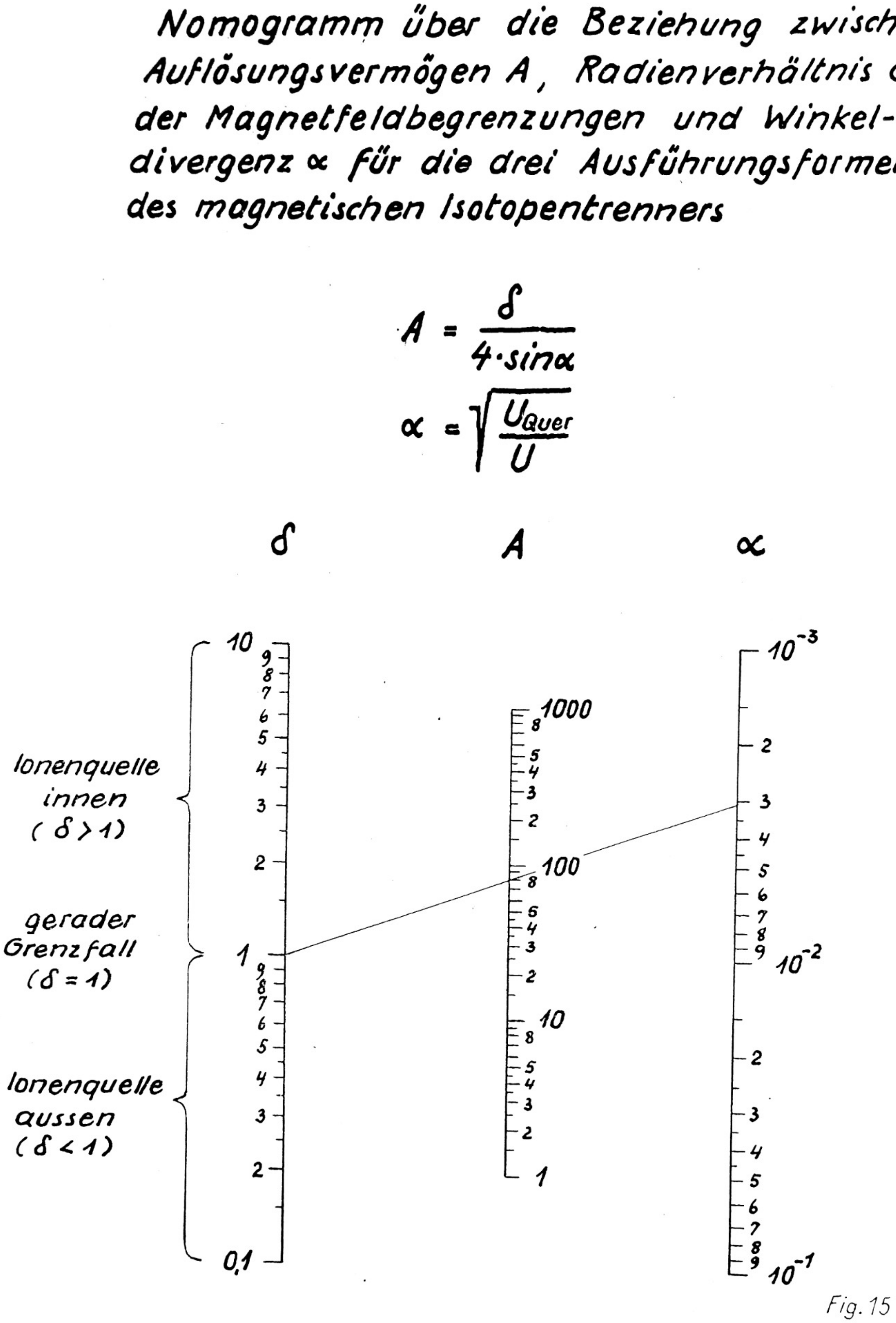

Zunahme der erlaubten Winkeldivergenz mit abnehmendem Radienverhältnis bei konstanter Magnetfeldstärke und Beschleunigungsspannung
A. Lineare Ausführung
erlaubte Winkeldivergenz
Radienverhältnis der Magnetfeldbegrenzungen:
2 : 1
B. Innenionenquelle
4 : 1
∞
Fig. 14
erlaubte Winkeldivergenz = 180°

Figure D.196: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]



Nomogramm über die Beziehung zwischen Auflösungsvermögen A, Radienverhältnis δ der Magnetfeldbegrenzungen und Winkeldivergenz α für die drei Ausführungsformen des magnetischen Isotopentrenners

$$A = \frac{\delta}{4 \cdot \sin\alpha}$$

$$\alpha = \sqrt{\frac{U_{Quer}}{U}}$$

δ
A
α
Ionenquelle innen (δ > 1)
gerader Grenzfall (δ = 1)
Ionenquelle aussen (δ < 1)
10
1
0,1
1000
100
10
1
10^{-3}
10^{-2}
10^{-1}

Fig. 15

Figure D.197: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

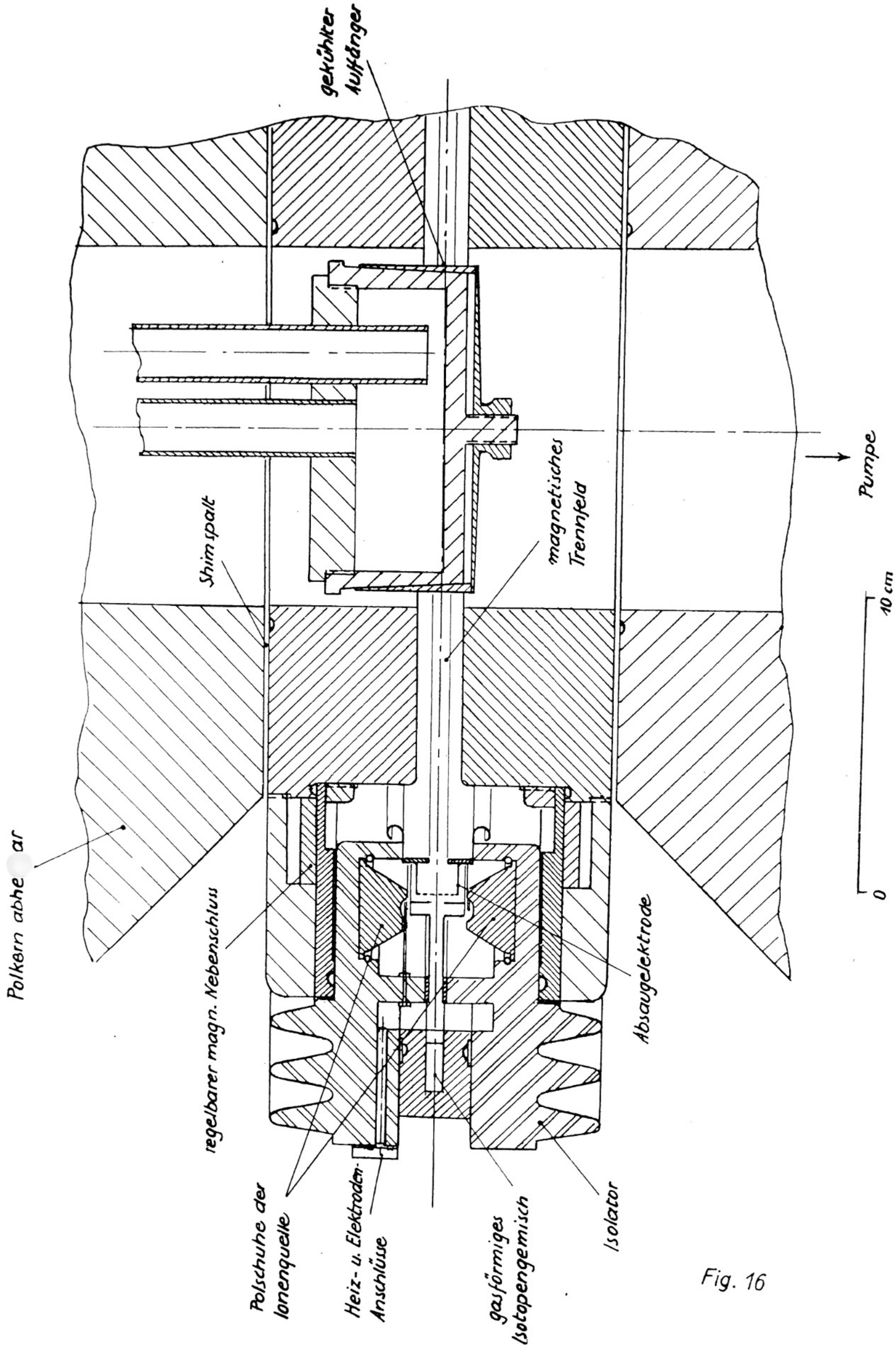

gekühlter Auffänger
Pumpe
magnetisches Trennfeld
Shimspalt
10 cm
0
Polkern abhe ar
regelbarer magn. Nebenschluss
Absaugelektrode
Polschuhe der Ionenquelle
Heiz- u. Elektroden-Anschlüsse
gasförmiges Isotopengemisch
Isolator

Fig. 16

Figure D.198: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

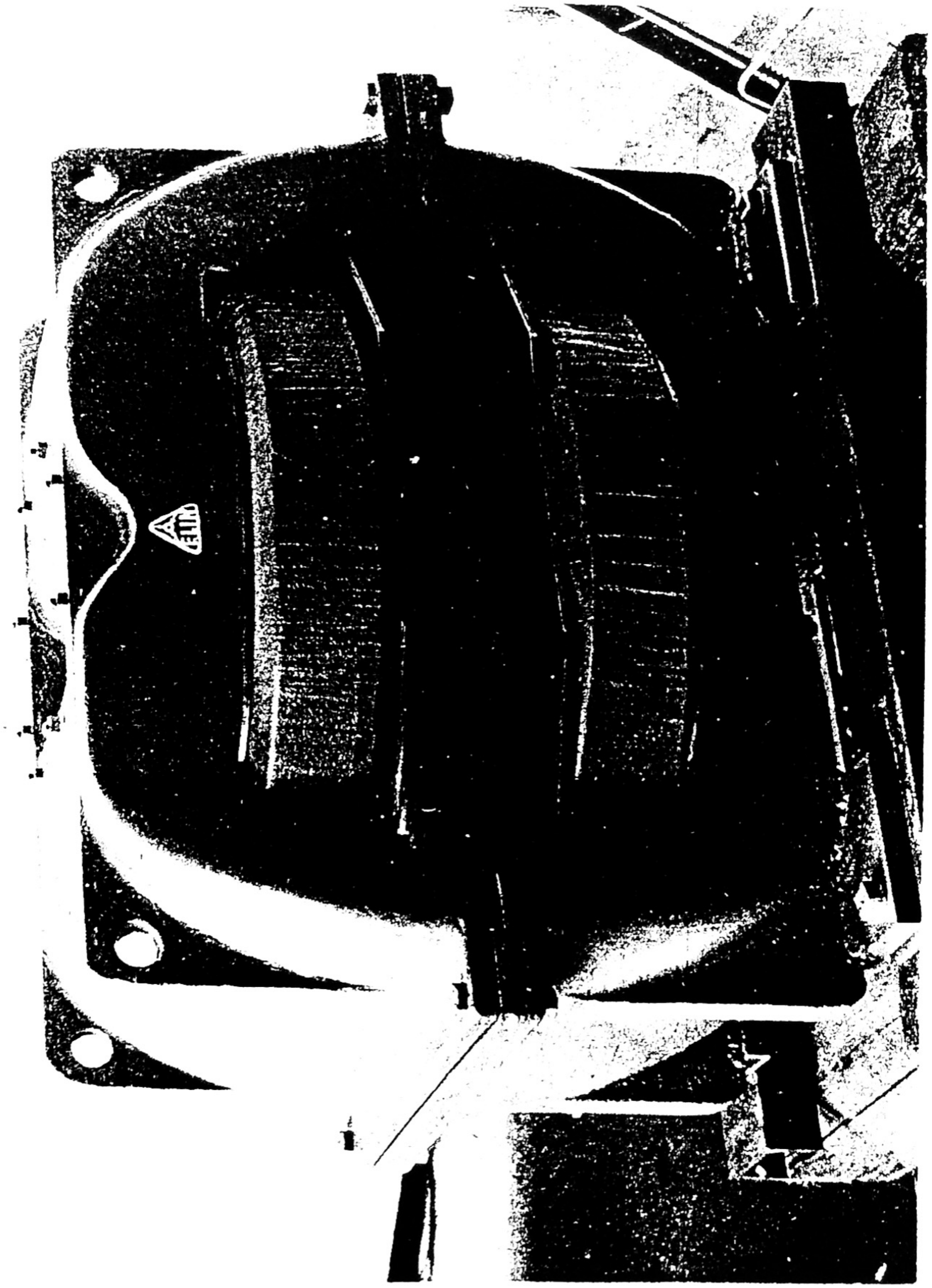


Fig. 17

Figure D.199: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

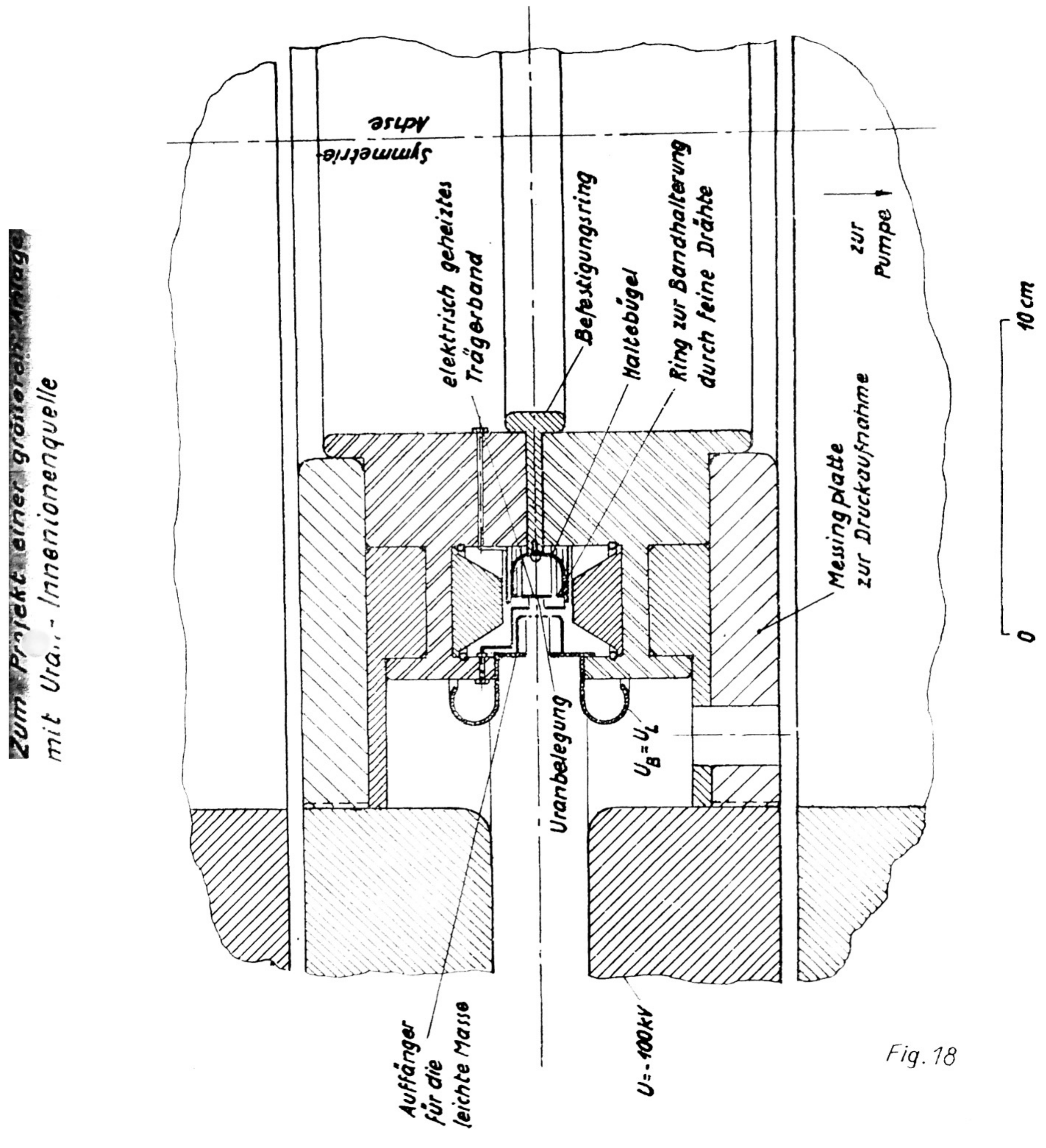

Zum Projekt einer größeren Anlage
mit Uran - Innenionenquelle
Symmetrie-Achse
elektrisch geheiztes Trägerband
Befestigungsring
Haltebügel
Ring zur Bandhalterung durch feine Drähte
zur Pumpe
10 cm
0
Messingplatte zur Druckaufnahme
Uranbelegung
U_B = U_L
Auffänger für die leichte Masse
U = -100 kV
Fig. 18

Figure D.200: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

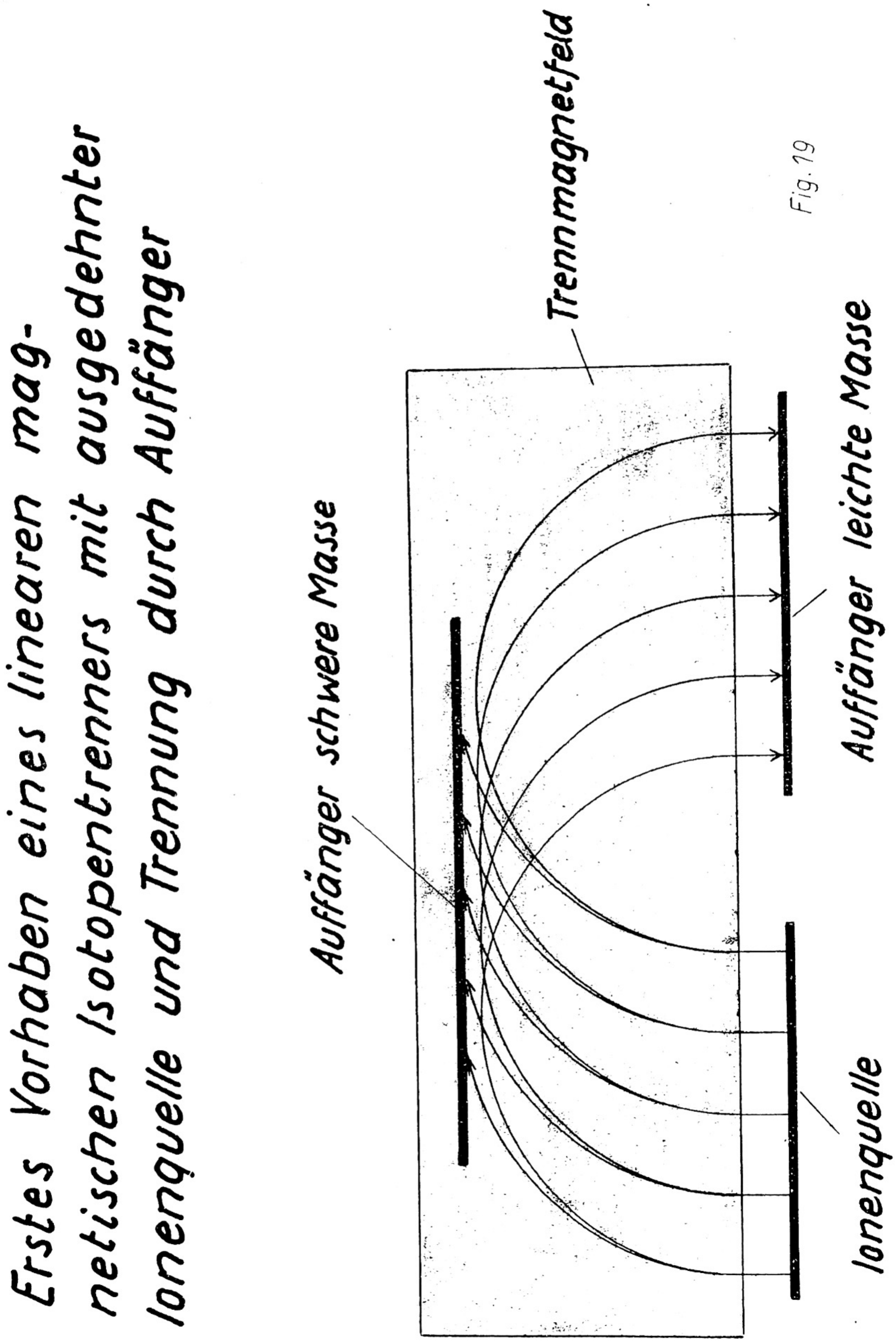

Erstes Vorhaben eines linearen magnetischen Isotopentrenners mit ausgedehnter Ionenquelle und Trennung durch Auffänger
Trennmagnetfeld
Fig. 19
Auffänger schwere Masse
Auffänger leichte Masse
Ionenquelle

Figure D.201: Manfred von Ardenne's April 1942 design and prototype for an electromagnetic isotope separator with numerous beams but only one set of magnets. [Courtesy of Rainer Karlsch.]

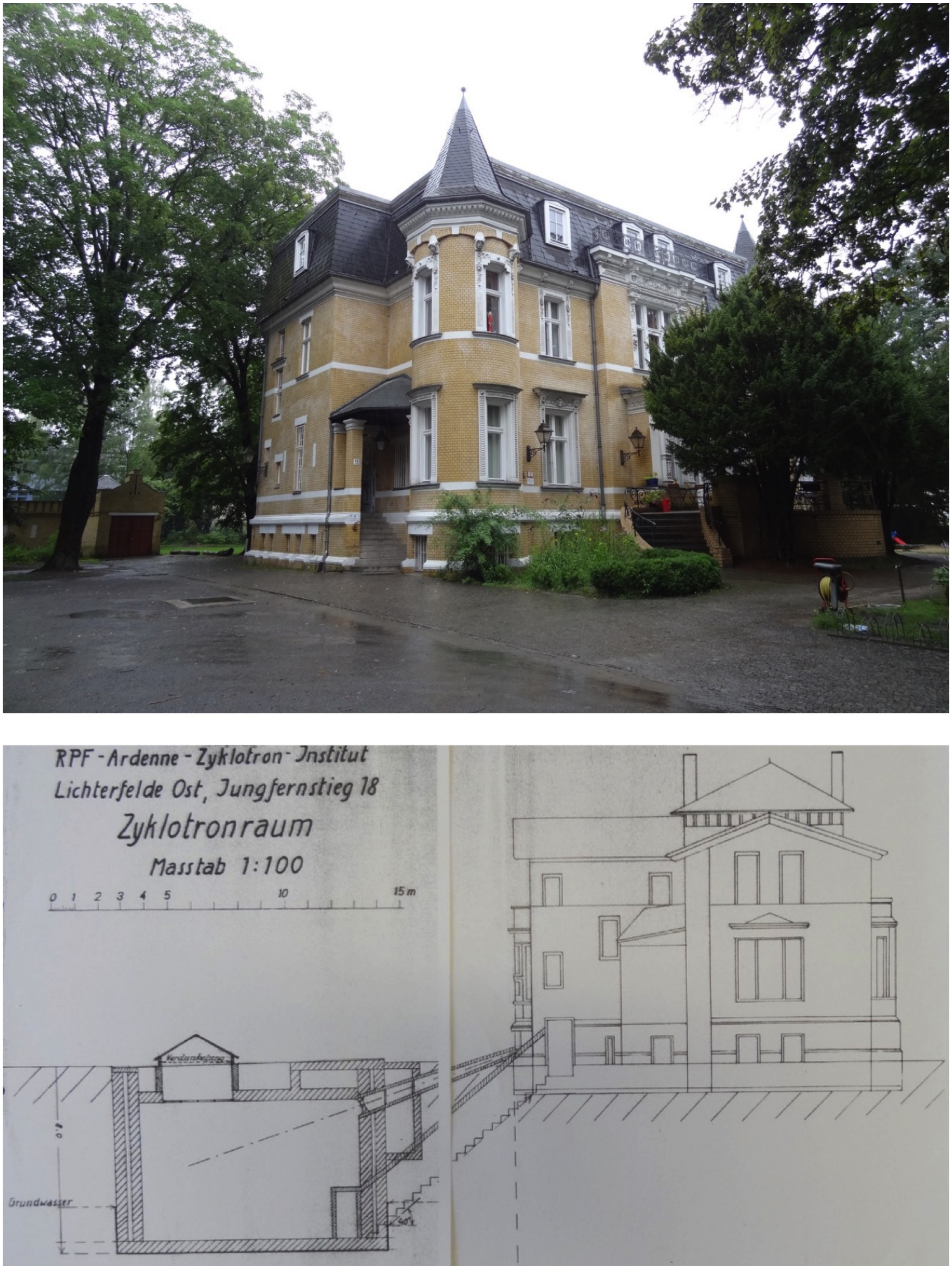
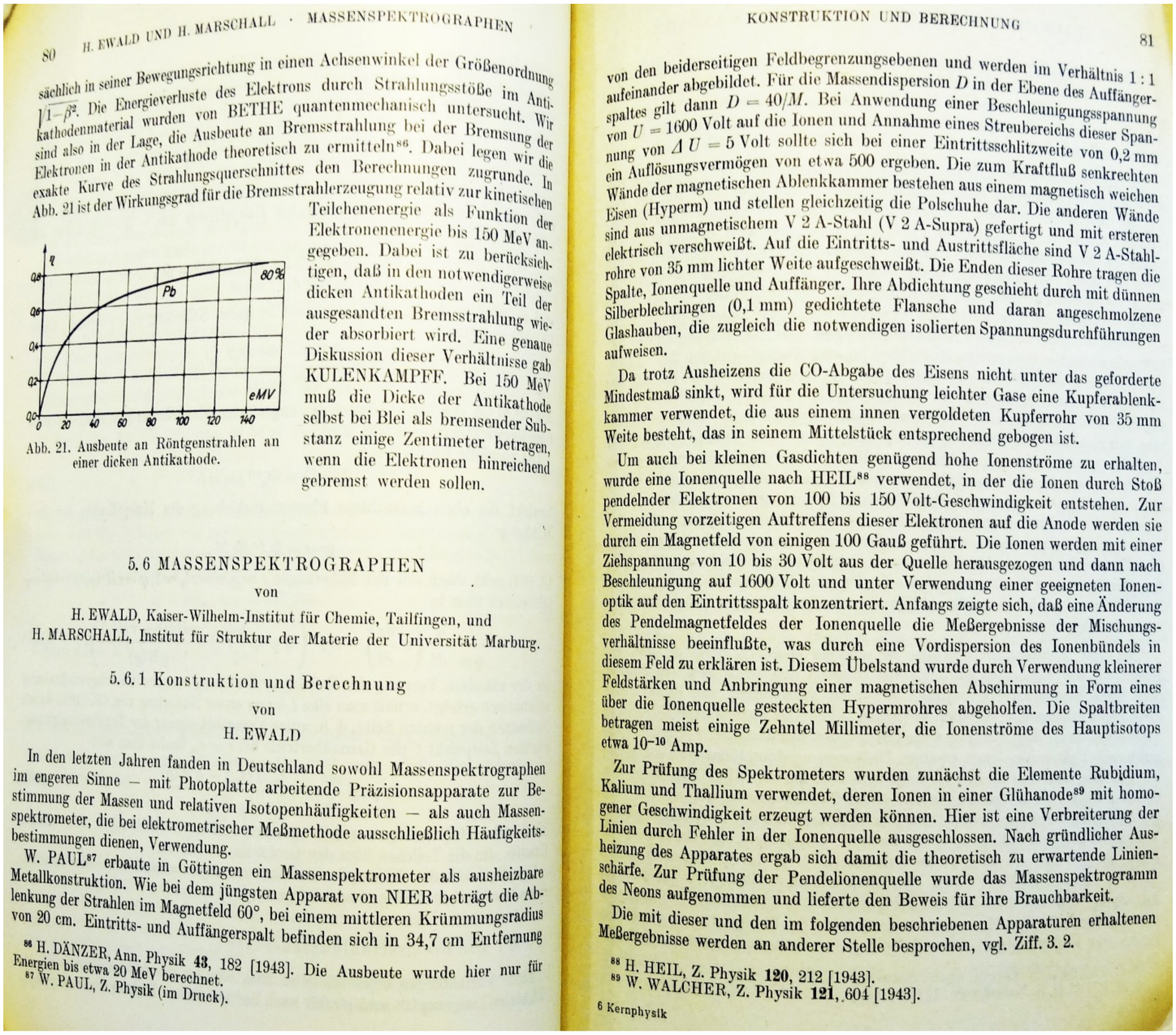

RPF-Ardenne-Zyklotron-Institut
Lichterfelde Ost, Jungfernstieg 18
Zyklotronraum
Masstab 1:100
0 1 2 3 4 5 10 15 m
Verdunkelung
Grundwasser
40°

Figure D.202: The former Manfred von Ardenne mansion. A large cyclotron was located under the garage at the left, accessible by a tunnel from the house.



sächlich in seiner Bewegungsrichtung in einen Achsenwinkel der Größenordnung $\sqrt{1-\beta^2}$. Die Energieverluste des Elektrons durch Strahlungsstöße im Antikathodenmaterial wurden von BETHE quantenmechanisch untersucht. Wir sind also in der Lage, die Ausbeute an Bremsstrahlung bei der Bremsung der Elektronen in der Antikathode theoretisch zu ermitteln[86]. Dabei legen wir die exakte Kurve des Strahlungsquerschnittes den Berechnungen zugrunde. In Abb. 21 ist der Wirkungsgrad für die Bremsstrahlerzeugung relativ zur kinetischen Teilchenenergie als Funktion der Elektronenenergie bis 150 MeV angegeben. Dabei ist zu berücksichtigen, daß in den notwendigerweise dicken Antikathoden ein Teil der ausgesandten Bremsstrahlung wieder absorbiert wird. Eine genaue Diskussion dieser Verhältnisse gab KULENKAMPFF. Bei 150 MeV muß die Dicke der Antikathode selbst bei Blei als bremsender Substanz einige Zentimeter betragen, wenn die Elektronen hinreichend gebremst werden sollen.

Abb. 21. Ausbeute an Röntgenstrahlen an einer dicken Antikathode.

5.6 MASSENSPEKTROGRAPHEN

von

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5.6.1 Konstruktion und Berechnung

von

H. EWALD

In den letzten Jahren fanden in Deutschland sowohl Massenspektrographen im engeren Sinne – mit Photoplatte arbeitende Präzisionsapparate zur Bestimmung der Massen und relativen Isotopenhäufigkeiten – als auch Massenspektrometer, die bei elektrometrischer Meßmethode ausschließlich Häufigkeitsbestimmungen dienen, Verwendung.

W. PAUL[87] erbaute in Göttingen ein Massenspektrometer als ausheizbare Metallkonstruktion. Wie bei dem jüngsten Apparat von NIER beträgt die Ablenkung der Strahlen im Magnetfeld 60°, bei einem mittleren Krümmungsradius von 20 cm. Eintritts- und Auffängerspalt befinden sich in 34,7 cm Entfernung von den beiderseitigen Feldbegrenzungsebenen und werden im Verhältnis 1 : 1 aufeinander abgebildet. Für die Massendispersion D in der Ebene des Auffängerspaltes gilt dann $D = 40/M$. Bei Anwendung einer Beschleunigungsspannung von $U = 1600$ Volt auf die Ionen und Annahme eines Streubereichs dieser Spannung von $\Delta U = 5$ Volt sollte sich bei einer Eintrittsschlitzweite von 0,2 mm ein Auflösungsvermögen von etwa 500 ergeben. Die zum Kraftfluß senkrechten Wände der magnetischen Ablenkkammer bestehen aus einem magnetisch weichen Eisen (Hyperm) und stellen gleichzeitig die Polschuhe dar. Die anderen Wände sind aus unmagnetischem V 2 A-Stahl (V 2 A-Supra) gefertigt und mit ersteren elektrisch verschweißt. Auf die Eintritts- und Austrittsfläche sind V 2 A-Stahlrohre von 35 mm lichter Weite aufgeschweißt. Die Enden dieser Rohre tragen die Spalte, Ionenquelle und Auffänger. Ihre Abdichtung geschieht durch mit dünnen Silberblechringen (0,1 mm) gedichtete Flansche und daran angeschmolzene Glashauben, die zugleich die notwendigen isolierten Spannungsdurchführungen aufweisen.

Da trotz Ausheizens die CO-Abgabe des Eisens nicht unter das geforderte Mindestmaß sinkt, wird für die Untersuchung leichter Gase eine Kupferablenkkammer verwendet, die aus einem innen vergoldeten Kupferrohr von 35 mm Weite besteht, das in seinem Mittelstück entsprechend gebogen ist.

Um auch bei kleinen Gasdichten genügend hohe Ionenströme zu erhalten, wurde eine Ionenquelle nach HEIL[88] verwendet, in der die Ionen durch Stoß pendelnder Elektronen von 100 bis 150 Volt-Geschwindigkeit entstehen. Zur Vermeidung vorzeitigen Auftreffens dieser Elektronen auf die Anode werden sie durch ein Magnetfeld von einigen 100 Gauß geführt. Die Ionen werden mit einer Ziehspannung von 10 bis 30 Volt aus der Quelle herausgezogen und dann nach Beschleunigung auf 1600 Volt und unter Verwendung einer geeigneten Ionenoptik auf den Eintrittsspalt konzentriert. Anfangs zeigte sich, daß eine Änderung des Pendelmagnetfeldes der Ionenquelle die Meßergebnisse der Mischungsverhältnisse beeinflußte, was durch eine Vordispersion des Ionenbündels in diesem Feld zu erklären ist. Diesem Übelstand wurde durch Verwendung kleinerer Feldstärken und Anbringung einer magnetischen Abschirmung in Form eines über die Ionenquelle gesteckten Hypermrohres abgeholfen. Die Spaltbreiten betragen meist einige Zehntel Millimeter, die Ionenströme des Hauptisotops etwa 10^{-10} Amp.

Zur Prüfung des Spektrometers wurden zunächst die Elemente Rubidium, Kalium und Thallium verwendet, deren Ionen in einer Glühanode[89] mit homogener Geschwindigkeit erzeugt werden können. Hier ist eine Verbreiterung der Linien durch Fehler in der Ionenquelle ausgeschlossen. Nach gründlicher Ausheizung des Apparates ergab sich damit die theoretisch zu erwartende Linienschärfe. Zur Prüfung der Pendelionenquelle wurde das Massenspektrogramm des Neons aufgenommen und lieferte den Beweis für ihre Brauchbarkeit.

Die mit dieser und den im folgenden beschriebenen Apparaturen erhaltenen Meßergebnisse werden an anderer Stelle besprochen, vgl. Ziff. 3. 2.

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[86] H. DÄNZER, Ann. Physik **43**, 182 [1943]. Die Ausbeute wurde hier nur für Energien bis etwa 20 MeV berechnet.

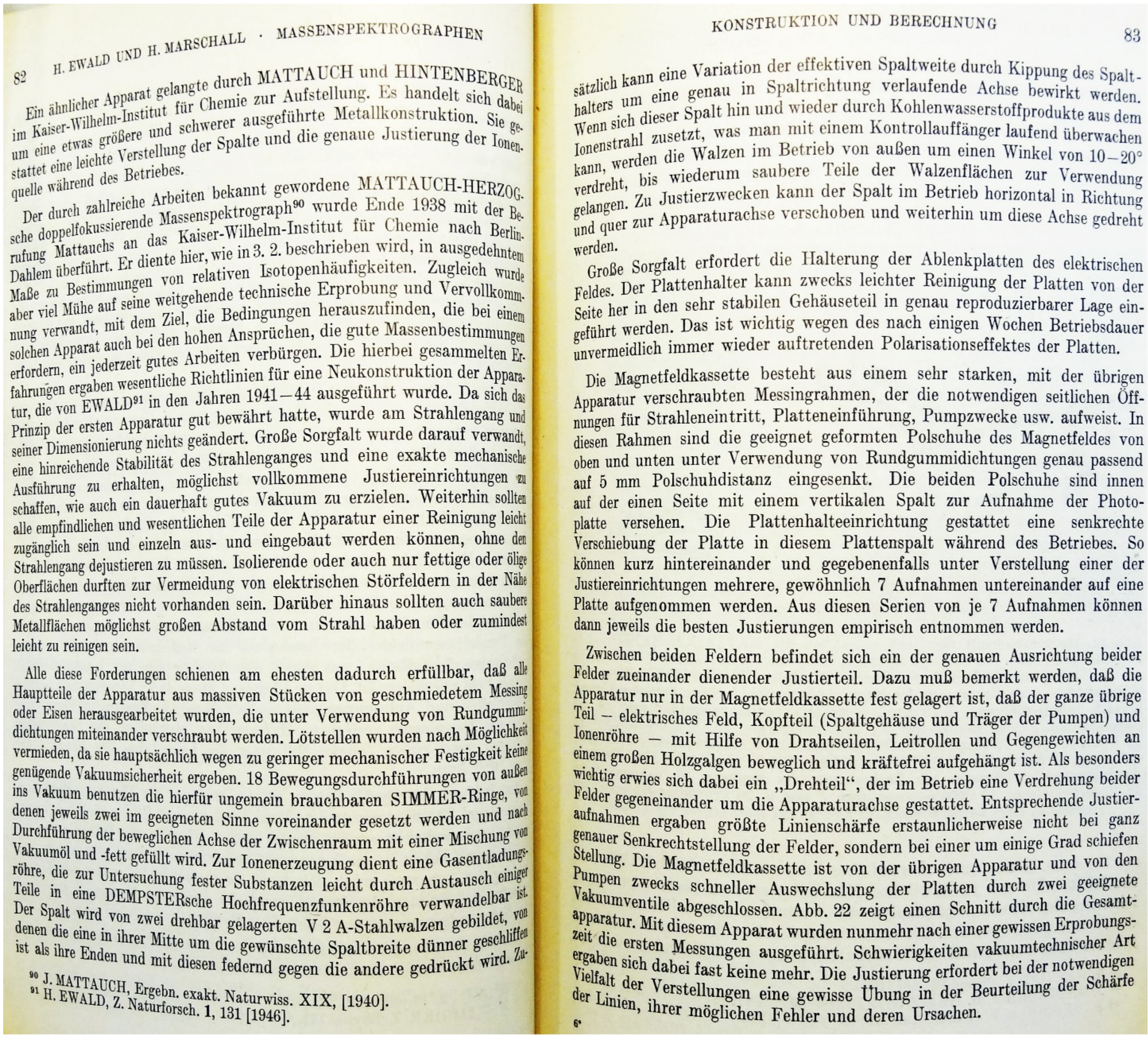
[87] W. PAUL, Z. Physik (im Druck).

[88] H. HEIL, Z. Physik **120**, 212 [1943].

[89] W. WALCHER, Z. Physik **121**, 604 [1943].

6 Kernphysik

Figure D.203: Description of Heinz Ewald's wartime work on electromagnetic isotope separators [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].



Ein ähnlicher Apparat gelangte durch MATTAUCH und HINTENBERGER im Kaiser-Wilhelm-Institut für Chemie zur Aufstellung. Es handelt sich dabei um eine etwas größere und schwerer ausgeführte Metallkonstruktion. Sie gestattet eine leichte Verstellung der Spalte und die genaue Justierung der Ionenquelle während des Betriebes.

Der durch zahlreiche Arbeiten bekannt gewordene MATTAUCH-HERZOGsche doppelfokussierende Massenspektrograph[90] wurde Ende 1938 mit der Berufung Mattauchs an das Kaiser-Wilhelm-Institut für Chemie nach Berlin-Dahlem überführt. Er diente hier, wie in 3. 2. beschrieben wird, in ausgedehntem Maße zu Bestimmungen von relativen Isotopenhäufigkeiten. Zugleich wurde aber viel Mühe auf seine weitgehende technische Erprobung und Vervollkommnung verwandt, mit dem Ziel, die Bedingungen herauszufinden, die bei einem solchen Apparat auch bei den hohen Ansprüchen, die gute Massenbestimmungen erfordern, ein jederzeit gutes Arbeiten verbürgen. Die hierbei gesammelten Erfahrungen ergaben wesentliche Richtlinien für eine Neukonstruktion der Apparatur, die von EWALD[91] in den Jahren 1941–44 ausgeführt wurde. Da sich das Prinzip der ersten Apparatur gut bewährt hatte, wurde am Strahlengang und seiner Dimensionierung nichts geändert. Große Sorgfalt wurde darauf verwandt, eine hinreichende Stabilität des Strahlenganges und eine exakte mechanische Ausführung zu erhalten, möglichst vollkommene Justiereinrichtungen zu schaffen, wie auch ein dauerhaft gutes Vakuum zu erzielen. Weiterhin sollten alle empfindlichen und wesentlichen Teile der Apparatur einer Reinigung leicht zugänglich sein und einzeln aus- und eingebaut werden können, ohne den Strahlengang dejustieren zu müssen. Isolierende oder auch nur fettige oder ölige Oberflächen durften zur Vermeidung von elektrischen Störfeldern in der Nähe des Strahlenganges nicht vorhanden sein. Darüber hinaus sollten auch saubere Metallflächen möglichst großen Abstand vom Strahl haben oder zumindest leicht zu reinigen sein.

Alle diese Forderungen schienen am ehesten dadurch erfüllbar, daß alle Hauptteile der Apparatur aus massiven Stücken von geschmiedetem Messing oder Eisen herausgearbeitet wurden, die unter Verwendung von Rundgummidichtungen miteinander verschraubt werden. Lötstellen wurden nach Möglichkeit vermieden, da sie hauptsächlich wegen zu geringer mechanischer Festigkeit keine genügende Vakuumsicherheit ergeben. 18 Bewegungsdurchführungen von außen ins Vakuum benutzen die hierfür ungemein brauchbaren SIMMER-Ringe, von denen jeweils zwei im geeigneten Sinne voreinander gesetzt werden und nach Durchführung der beweglichen Achse der Zwischenraum mit einer Mischung von Vakuumöl und -fett gefüllt wird. Zur Ionenerzeugung dient eine Gasentladungsröhre, die zur Untersuchung fester Substanzen leicht durch Austausch einiger Teile in eine DEMPSTERsche Hochfrequenzfunkenröhre verwandelbar ist. Der Spalt wird von zwei drehbar gelagerten V 2 A-Stahlwalzen gebildet, von denen die eine in ihrer Mitte um die gewünschte Spaltbreite dünner geschliffen ist als ihre Enden und mit diesen federnd gegen die andere gedrückt wird. Zusätzlich kann eine Variation der effektiven Spaltweite durch Kippung des Spalthalters um eine genau in Spaltrichtung verlaufende Achse bewirkt werden. Wenn sich dieser Spalt hin und wieder durch Kohlenwasserstoffprodukte aus dem Ionenstrahl zusetzt, was man mit einem Kontrollauffänger laufend überwachen kann, werden die Walzen im Betrieb von außen um einen Winkel von 10–20° verdreht, bis wiederum saubere Teile der Walzenflächen zur Verwendung gelangen. Zu Justierzwecken kann der Spalt im Betrieb horizontal in Richtung und quer zur Apparaturachse verschoben und weiterhin um diese Achse gedreht werden.

Große Sorgfalt erfordert die Halterung der Ablenkplatten des elektrischen Feldes. Der Plattenhalter kann zwecks leichter Reinigung der Platten von der Seite her in den sehr stabilen Gehäuseteil in genau reproduzierbarer Lage eingeführt werden. Das ist wichtig wegen des nach einigen Wochen Betriebsdauer unvermeidlich immer wieder auftretenden Polarisationseffektes der Platten.

Die Magnetfeldkassette besteht aus einem sehr starken, mit der übrigen Apparatur verschraubten Messingrahmen, der die notwendigen seitlichen Öffnungen für Strahleneintritt, Platteneinführung, Pumpzwecke usw. aufweist. In diesen Rahmen sind die geeignet geformten Polschuhe des Magnetfeldes von oben und unten unter Verwendung von Rundgummidichtungen genau passend auf 5 mm Polschuhdistanz eingesenkt. Die beiden Polschuhe sind innen auf der einen Seite mit einem vertikalen Spalt zur Aufnahme der Photoplatte versehen. Die Plattenhalteeinrichtung gestattet eine senkrechte Verschiebung der Platte in diesem Plattenspalt während des Betriebes. So können kurz hintereinander und gegebenenfalls unter Verstellung einer der Justiereinrichtungen mehrere, gewöhnlich 7 Aufnahmen untereinander auf eine Platte aufgenommen werden. Aus diesen Serien von je 7 Aufnahmen können dann jeweils die besten Justierungen empirisch entnommen werden.

Zwischen beiden Feldern befindet sich ein der genauen Ausrichtung beider Felder zueinander dienender Justierteil. Dazu muß bemerkt werden, daß die Apparatur nur in der Magnetfeldkassette fest gelagert ist, daß der ganze übrige Teil – elektrisches Feld, Kopfteil (Spaltgehäuse und Träger der Pumpen) und Ionenröhre – mit Hilfe von Drahtseilen, Leitrollen und Gegengewichten an einem großen Holzgalgen beweglich und kräftefrei aufgehängt ist. Als besonders wichtig erwies sich dabei ein ,,Drehteil", der im Betrieb eine Verdrehung beider Felder gegeneinander um die Apparaturachse gestattet. Entsprechende Justieraufnahmen ergaben größte Linienschärfe erstaunlicherweise nicht bei ganz genauer Senkrechtstellung der Felder, sondern bei einer um einige Grad schiefen Stellung. Die Magnetfeldkassette ist von der übrigen Apparatur und von den Pumpen zwecks schneller Auswechslung der Platten durch zwei geeignete Vakuumventile abgeschlossen. Abb. 22 zeigt einen Schnitt durch die Gesamtapparatur. Mit diesem Apparat wurden nunmehr nach einer gewissen Erprobungszeit die ersten Messungen ausgeführt. Schwierigkeiten vakuumtechnischer Art ergaben sich dabei fast keine mehr. Die Justierung erfordert bei der notwendigen Vielfalt der Verstellungen eine gewisse Übung in der Beurteilung der Schärfe der Linien, ihrer möglichen Fehler und deren Ursachen.

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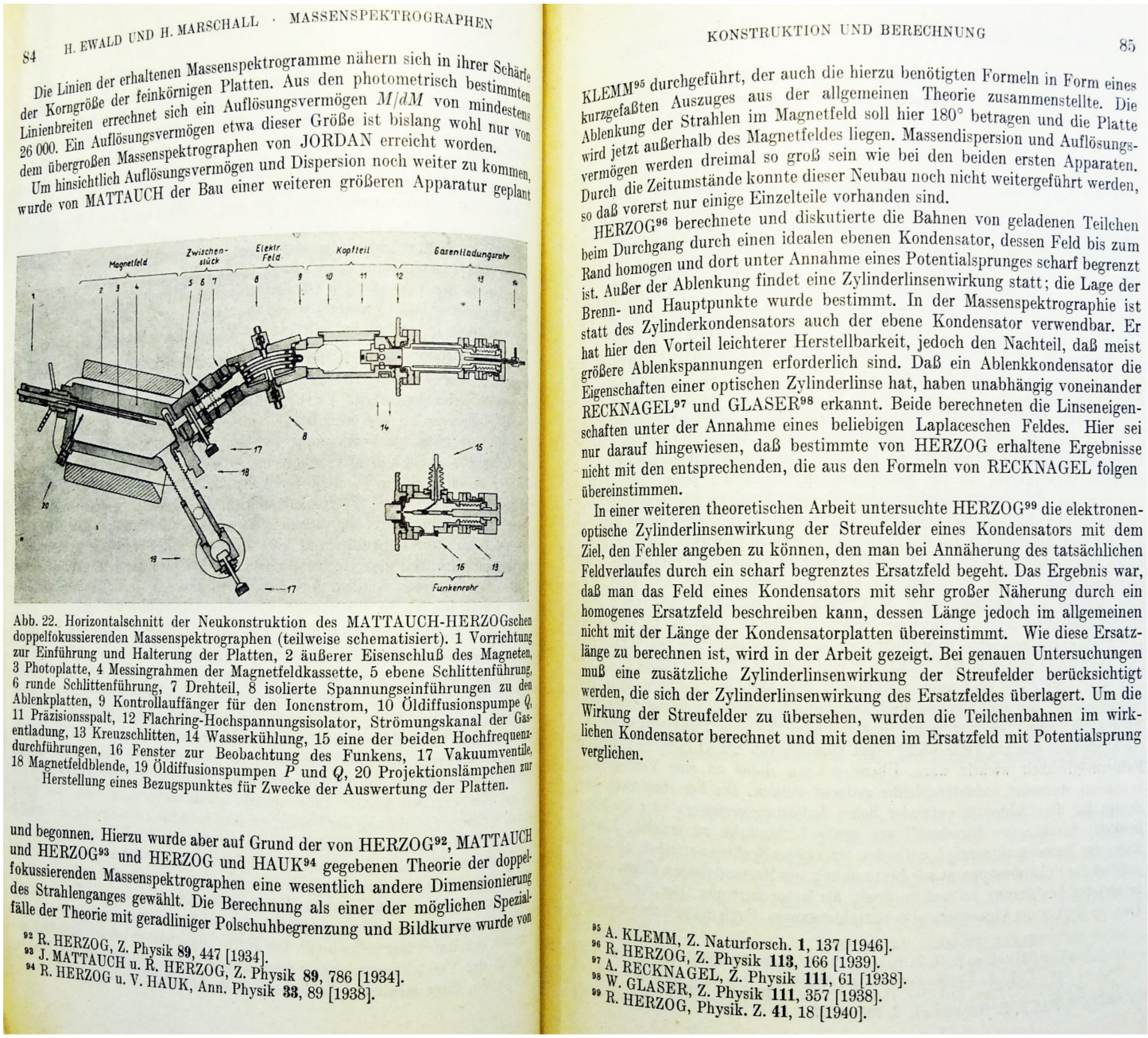
[90] J. MATTAUCH, Ergebn. exakt. Naturwiss. XIX, [1940].

[91] H. EWALD, Z. Naturforsch. **1**, 131 [1946].

Figure D.204: Description of Heinz Ewald's wartime work on electromagnetic isotope separators [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].



Die Linien der erhaltenen Massenspektrogramme nähern sich in ihrer Schärfe der Korngröße der feinkörnigen Platten. Aus den photometrisch bestimmten Linienbreiten errechnet sich ein Auflösungsvermögen M/dM von mindestens 26 000. Ein Auflösungsvermögen etwa dieser Größe ist bislang wohl nur von dem übergroßen Massenspektrographen von JORDAN erreicht worden.

Um hinsichtlich Auflösungsvermögen und Dispersion noch weiter zu kommen, wurde von MATTAUCH der Bau einer weiteren größeren Apparatur geplant und begonnen. Hierzu wurde aber auf Grund der von HERZOG[92], MATTAUCH und HERZOG[93] und HERZOG und HAUK[94] gegebenen Theorie der doppelfokussierenden Massenspektrographen eine wesentlich andere Dimensionierung des Strahlenganges gewählt. Die Berechnung als einer der möglichen Spezialfälle der Theorie mit geradliniger Polschuhbegrenzung und Bildkurve wurde von KLEMM[95] durchgeführt, der auch die hierzu benötigten Formeln in Form eines kurzgefaßten Auszuges aus der allgemeinen Theorie zusammenstellte. Die Ablenkung der Strahlen im Magnetfeld soll hier 180° betragen und die Platte wird jetzt außerhalb des Magnetfeldes liegen. Massendispersion und Auflösungsvermögen werden dreimal so groß sein wie bei den beiden ersten Apparaten. Durch die Zeitumstände konnte dieser Neubau noch nicht weitergeführt werden, so daß vorerst nur einige Einzelteile vorhanden sind.

Abb. 22. Horizontalschnitt der Neukonstruktion des MATTAUCH-HERZOGschen doppelfokussierenden Massenspektrographen (teilweise schematisiert). 1 Vorrichtung zur Einführung und Halterung der Platten, 2 äußerer Eisenschluß des Magneten, 3 Photoplatte, 4 Messingrahmen der Magnetfeldkassette, 5 ebene Schlittenführung, 6 runde Schlittenführung, 7 Drehteil, 8 isolierte Spannungseinführungen zu den Ablenkplatten, 9 Kontrollauffänger für den Ionenstrom, 10 Öldiffusionspumpe Q, 11 Präzisionsspalt, 12 Flachring-Hochspannungsisolator, Strömungskanal der Gasentladung, 13 Kreuzschlitten, 14 Wasserkühlung, 15 eine der beiden Hochfrequenzdurchführungen, 16 Fenster zur Beobachtung des Funkens, 17 Vakuumventile, 18 Magnetfeldblende, 19 Öldiffusionspumpen P und Q, 20 Projektionslämpchen zur Herstellung eines Bezugspunktes für Zwecke der Auswertung der Platten.

HERZOG[96] berechnete und diskutierte die Bahnen von geladenen Teilchen beim Durchgang durch einen idealen ebenen Kondensator, dessen Feld bis zum Rand homogen und dort unter Annahme eines Potentialsprunges scharf begrenzt ist. Außer der Ablenkung findet eine Zylinderlinsenwirkung statt; die Lage der Brenn- und Hauptpunkte wurde bestimmt. In der Massenspektrographie ist statt des Zylinderkondensators auch der ebene Kondensator verwendbar. Er hat hier den Vorteil leichterer Herstellbarkeit, jedoch den Nachteil, daß meist größere Ablenkspannungen erforderlich sind. Daß ein Ablenkkondensator die Eigenschaften einer optischen Zylinderlinse hat, haben unabhängig voneinander RECKNAGEL[97] und GLASER[98] erkannt. Beide berechneten die Linseneigenschaften unter der Annahme eines beliebigen Laplaceschen Feldes. Hier sei nur darauf hingewiesen, daß bestimmte von HERZOG erhaltene Ergebnisse nicht mit den entsprechenden, die aus den Formeln von RECKNAGEL folgen übereinstimmen.

In einer weiteren theoretischen Arbeit untersuchte HERZOG[99] die elektronenoptische Zylinderlinsenwirkung der Streufelder eines Kondensators mit dem Ziel, den Fehler angeben zu können, den man bei Annäherung des tatsächlichen Feldverlaufes durch ein scharf begrenztes Ersatzfeld begeht. Das Ergebnis war, daß man das Feld eines Kondensators mit sehr großer Näherung durch ein homogenes Ersatzfeld beschreiben kann, dessen Länge jedoch im allgemeinen nicht mit der Länge der Kondensatorplatten übereinstimmt. Wie diese Ersatzlänge zu berechnen ist, wird in der Arbeit gezeigt. Bei genauen Untersuchungen muß eine zusätzliche Zylinderlinsenwirkung der Streufelder berücksichtigt werden, die sich der Zylinderlinsenwirkung des Ersatzfeldes überlagert. Um die Wirkung der Streufelder zu übersehen, wurden die Teilchenbahnen im wirklichen Kondensator berechnet und mit denen im Ersatzfeld mit Potentialsprung verglichen.

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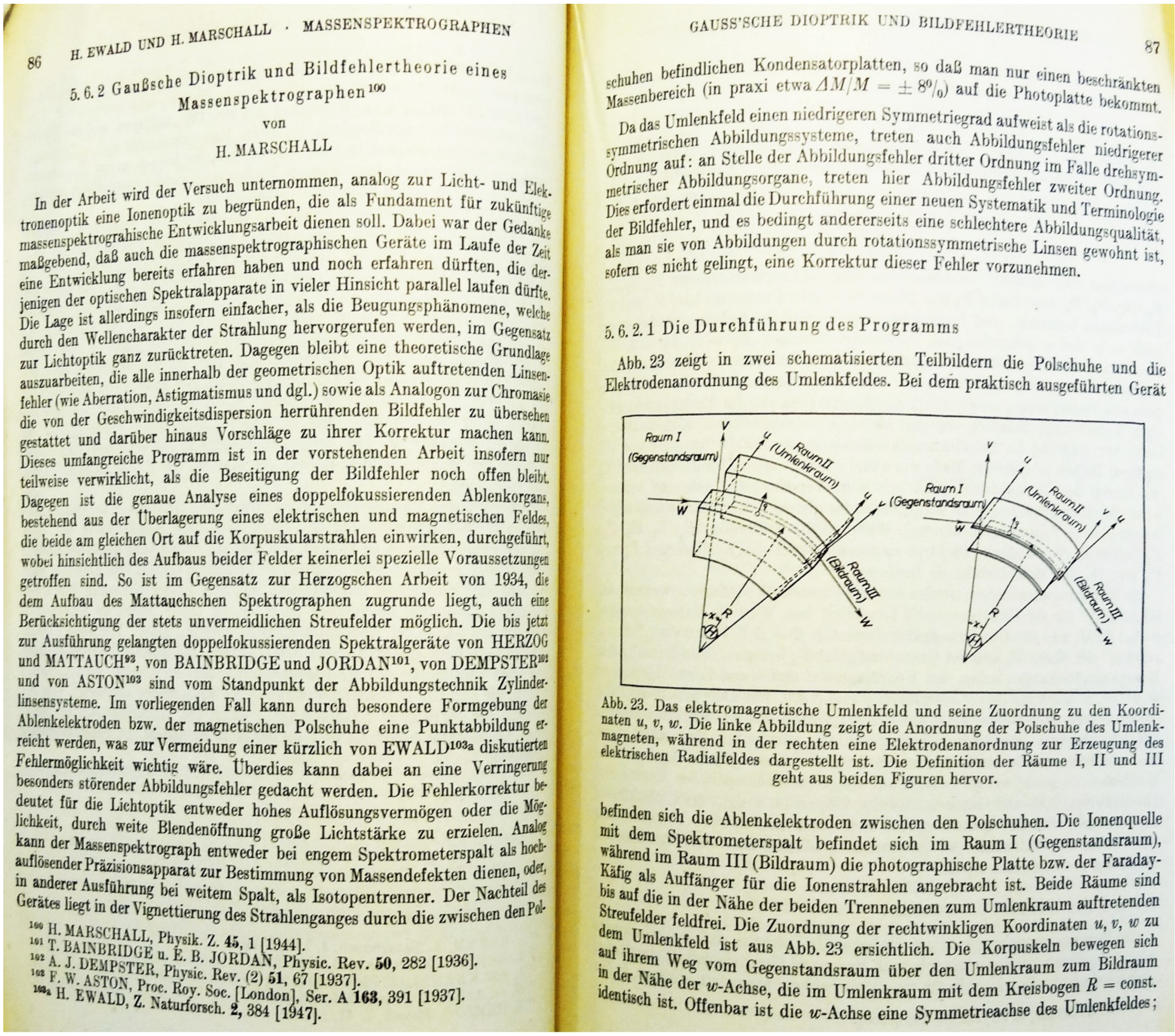
[92] R. HERZOG, Z. Physik **89**, 447 [1934].
[93] J. MATTAUCH u. R. HERZOG, Z. Physik **89**, 786 [1934].
[94] R. HERZOG u. V. HAUK, Ann. Physik **33**, 89 [1938].
[95] A. KLEMM, Z. Naturforsch. **1**, 137 [1946].
[96] R. HERZOG, Z. Physik **113**, 166 [1939].
[97] A. RECKNAGEL, Z. Physik **111**, 61 [1938].
[98] W. GLASER, Z. Physik **111**, 357 [1938].
[99] R. HERZOG, Physik. Z. **41**, 18 [1940].

Figure D.205: Description of Heinz Ewald's wartime work on electromagnetic isotope separators [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].



5.6.2 Gaußsche Dioptrik und Bildfehlertheorie eines Massenspektrographen[100]

von

H. MARSCHALL

In der Arbeit wird der Versuch unternommen, analog zur Licht- und Elektronenoptik eine Ionenoptik zu begründen, die als Fundament für zukünftige massenspektrograhische Entwicklungsarbeit dienen soll. Dabei war der Gedanke maßgebend, daß auch die massenspektrographischen Geräte im Laufe der Zeit eine Entwicklung bereits erfahren haben und noch erfahren dürften, die derjenigen der optischen Spektralapparate in vieler Hinsicht parallel laufen dürfte. Die Lage ist allerdings insofern einfacher, als die Beugungsphänomene, welche durch den Wellencharakter der Strahlung hervorgerufen werden, im Gegensatz zur Lichtoptik ganz zurücktreten. Dagegen bleibt eine theoretische Grundlage auszuarbeiten, die alle innerhalb der geometrischen Optik auftretenden Linsenfehler (wie Aberration, Astigmatismus und dgl.) sowie als Analogon zur Chromasie die von der Geschwindigkeitsdispersion herrührenden Bildfehler zu übersehen gestattet und darüber hinaus Vorschläge zu ihrer Korrektur machen kann. Dieses umfangreiche Programm ist in der vorstehenden Arbeit insofern nur teilweise verwirklicht, als die Beseitigung der Bildfehler noch offen bleibt. Dagegen ist die genaue Analyse eines doppelfokussierenden Ablenkorgans, bestehend aus der Überlagerung eines elektrischen und magnetischen Feldes, die beide am gleichen Ort auf die Korpuskularstrahlen einwirken, durchgeführt, wobei hinsichtlich des Aufbaus beider Felder keinerlei spezielle Voraussetzungen getroffen sind. So ist im Gegensatz zur Herzogschen Arbeit von 1934, die dem Aufbau des Mattauchschen Spektrographen zugrunde liegt, auch eine Berücksichtigung der stets unvermeidlichen Streufelder möglich. Die bis jetzt zur Ausführung gelangten doppelfokussierenden Spektralgeräte von HERZOG und MATTAUCH[93], von BAINBRIDGE und JORDAN[101], von DEMPSTER[102] und von ASTON[103] sind vom Standpunkt der Abbildungstechnik Zylinderlinsensysteme. Im vorliegenden Fall kann durch besondere Formgebung der Ablenkelektroden bzw. der magnetischen Polschuhe eine Punktabbildung erreicht werden, was zur Vermeidung einer kürzlich von EWALD[103a] diskutierten Fehlermöglichkeit wichtig wäre. Überdies kann dabei an eine Verringerung besonders störender Abbildungsfehler gedacht werden. Die Fehlerkorrektur bedeutet für die Lichtoptik entweder hohes Auflösungsvermögen oder die Möglichkeit, durch weite Blendenöffnung große Lichtstärke zu erzielen. Analog kann der Massenspektrograph entweder bei engem Spektrometerspalt als hochauflösender Präzisionsapparat zur Bestimmung von Massendefekten dienen, oder, in anderer Ausführung bei weitem Spalt, als Isotopentrenner. Der Nachteil des Gerätes liegt in der Vignettierung des Strahlenganges durch die zwischen den Polschuhen befindlichen Kondensatorplatten, so daß man nur einen beschränkten Massenbereich (in praxi etwa $\Delta M/M = \pm 8\%$) auf die Photoplatte bekommt.

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[100] H. MARSCHALL, Physik. Z. **45**, 1 [1944].
[101] T. BAINBRIDGE u. E. B. JORDAN, Physic. Rev. **50**, 282 [1936].
[102] A. J. DEMPSTER, Physic. Rev. (2) **51**, 67 [1937].
[103] F. W. ASTON, Proc. Roy. Soc. [London], Ser. A **163**, 391 [1937].
[103a] H. EWALD, Z. Naturforsch. **2**, 384 [1947].

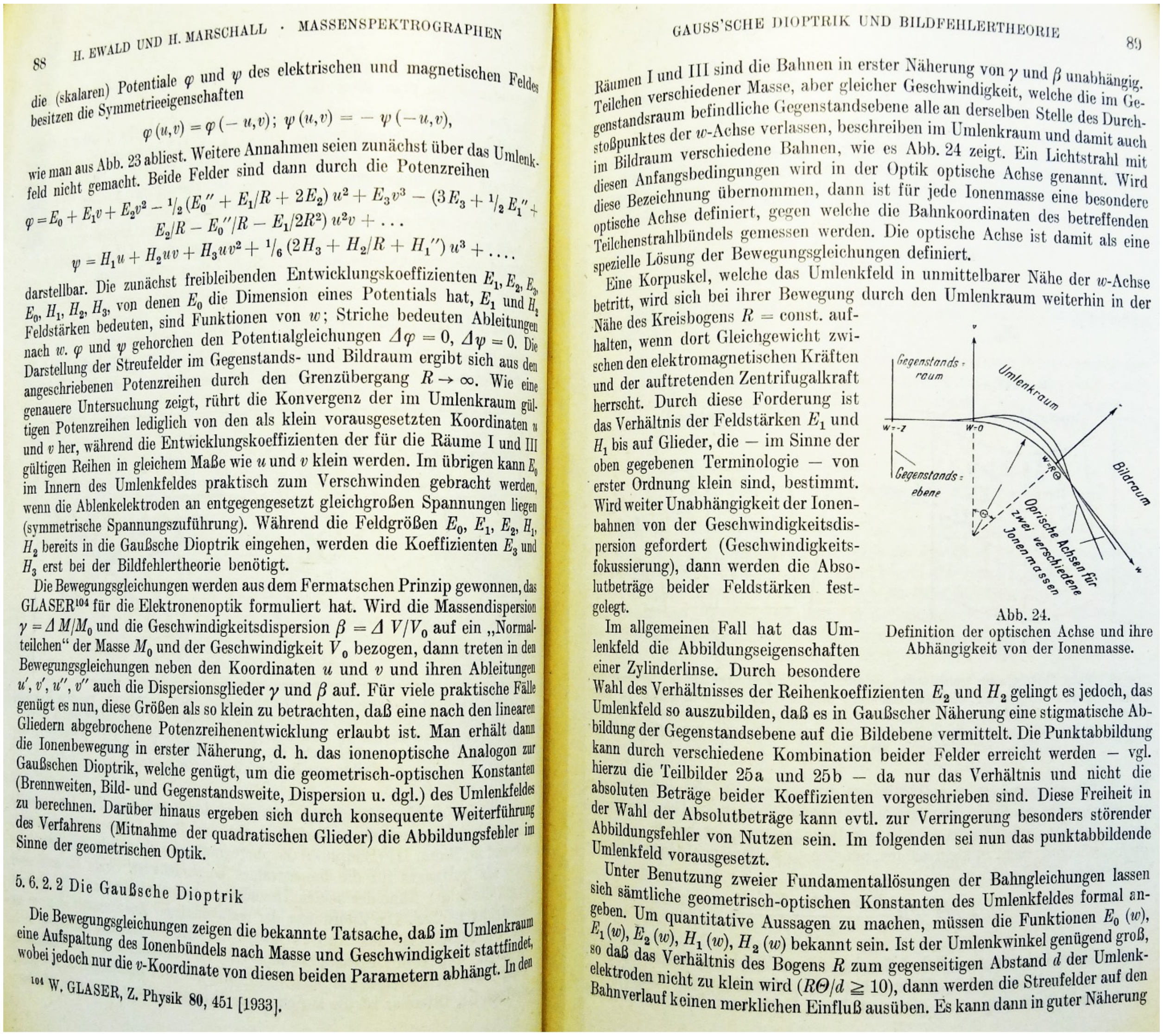
Da das Umlenkfeld einen niedrigeren Symmetriegrad aufweist als die rotationssymmetrischen Abbildungssysteme, treten auch Abbildungsfehler niedrigerer Ordnung auf: an Stelle der Abbildungsfehler dritter Ordnung im Falle drehsymmetrischer Abbildungsorgane, treten hier Abbildungsfehler zweiter Ordnung. Dies erfordert einmal die Durchführung einer neuen Systematik und Terminologie der Bildfehler, und es bedingt andererseits eine schlechtere Abbildungsqualität, als man sie von Abbildungen durch rotationssymmetrische Linsen gewohnt ist, sofern es nicht gelingt, eine Korrektur dieser Fehler vorzunehmen.

5.6.2.1 Die Durchführung des Programms

Abb. 23 zeigt in zwei schematisierten Teilbildern die Polschuhe und die Elektrodenanordnung des Umlenkfeldes. Bei dem praktisch ausgeführten Gerät befinden sich die Ablenkelektroden zwischen den Polschuhen. Die Ionenquelle mit dem Spektrometerspalt befindet sich im Raum I (Gegenstandsraum), während im Raum III (Bildraum) die photographische Platte bzw. der Faraday-Käfig als Auffänger für die Ionenstrahlen angebracht ist. Beide Räume sind bis auf die in der Nähe der beiden Trennebenen zum Umlenkraum auftretenden Streufelder feldfrei. Die Zuordnung der rechtwinkligen Koordinaten u, v, w zu dem Umlenkfeld ist aus Abb. 23 ersichtlich. Die Korpuskeln bewegen sich auf ihrem Weg vom Gegenstandsraum über den Umlenkraum zum Bildraum in der Nähe der w-Achse, die im Umlenkraum mit dem Kreisbogen $R =$ const. identisch ist. Offenbar ist die w-Achse eine Symmetrieachse des Umlenkfeldes;

Abb. 23. Das elektromagnetische Umlenkfeld und seine Zuordnung zu den Koordinaten u, v, w. Die linke Abbildung zeigt die Anordnung der Polschuhe des Umlenkmagneten, während in der rechten eine Elektrodenanordnung zur Erzeugung des elektrischen Radialfeldes dargestellt ist. Die Definition der Räume I, II und III geht aus beiden Figuren hervor.

Figure D.206: Description of Heinz Ewald's wartime work on electromagnetic isotope separators [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].



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die (skalaren) Potentiale φ und ψ des elektrischen und magnetischen Feldes besitzen die Symmetrieeigenschaften

$$\varphi(u,v) = \varphi(-u,v); \quad \psi(u,v) = -\psi(-u,v),$$

wie man aus Abb. 23 abliest. Weitere Annahmen seien zunächst über das Umlenkfeld nicht gemacht. Beide Felder sind dann durch die Potenzreihen

$$\varphi = E_0 + E_1 v + E_2 v^2 - {}^1/_2 (E_0'' + E_1/R + 2E_2)\, u^2 + E_3 v^3 - (3E_3 + {}^1/_2 E_1'' + E_2/R - E_0''/R - E_1/2R^2)\, u^2 v + \ldots$$

$$\psi = H_1 u + H_2 uv + H_3 uv^2 + {}^1/_6 (2H_3 + H_2/R + H_1'')\, u^3 + \ldots.$$

darstellbar. Die zunächst freibleibenden Entwicklungskoeffizienten $E_1, E_2, E_3, E_0, H_1, H_2, H_3$, von denen E_0 die Dimension eines Potentials hat, E_1 und H_2 Feldstärken bedeuten, sind Funktionen von w; Striche bedeuten Ableitungen nach w. φ und ψ gehorchen den Potentialgleichungen $\Delta\varphi = 0$, $\Delta\psi = 0$. Die Darstellung der Streufelder im Gegenstands- und Bildraum ergibt sich aus den angeschriebenen Potenzreihen durch den Grenzübergang $R \to \infty$. Wie eine genauere Untersuchung zeigt, rührt die Konvergenz der im Umlenkraum gültigen Potenzreihen lediglich von den als klein vorausgesetzten Koordinaten u und v her, während die Entwicklungskoeffizienten der für die Räume I und III gültigen Reihen in gleichem Maße wie u und v klein werden. Im übrigen kann E_0 im Innern des Umlenkfeldes praktisch zum Verschwinden gebracht werden, wenn die Ablenkelektroden an entgegengesetzt gleichgroßen Spannungen liegen (symmetrische Spannungszuführung). Während die Feldgrößen E_0, E_1, E_2, H_1, H_2 bereits in die Gaußsche Dioptrik eingehen, werden die Koeffizienten E_3 und H_3 erst bei der Bildfehlertheorie benötigt.

Die Bewegungsgleichungen werden aus dem Fermatschen Prinzip gewonnen, das GLASER[104] für die Elektronenoptik formuliert hat. Wird die Massendispersion $\gamma = \Delta M/M_0$ und die Geschwindigkeitsdispersion $\beta = \Delta V/V_0$ auf ein „Normalteilchen" der Masse M_0 und der Geschwindigkeit V_0 bezogen, dann treten in den Bewegungsgleichungen neben den Koordinaten u und v und ihren Ableitungen u', v', u'', v'' auch die Dispersionsglieder γ und β auf. Für viele praktische Fälle genügt es nun, diese Größen als so klein zu betrachten, daß eine nach den linearen Gliedern abgebrochene Potenzreihenentwicklung erlaubt ist. Man erhält dann die Ionenbewegung in erster Näherung, d. h. das ionenoptische Analogon zur Gaußschen Dioptrik, welche genügt, um die geometrisch-optischen Konstanten (Brennweiten, Bild- und Gegenstandsweite, Dispersion u. dgl.) des Umlenkfeldes zu berechnen. Darüber hinaus ergeben sich durch konsequente Weiterführung des Verfahrens (Mitnahme der quadratischen Glieder) die Abbildungsfehler im Sinne der geometrischen Optik.

5. 6. 2. 2 Die Gaußsche Dioptrik

Die Bewegungsgleichungen zeigen die bekannte Tatsache, daß im Umlenkraum eine Aufspaltung des Ionenbündels nach Masse und Geschwindigkeit stattfindet, wobei jedoch nur die v-Koordinate von diesen beiden Parametern abhängt. In den Räumen I und III sind die Bahnen in erster Näherung von γ und β unabhängig. Teilchen verschiedener Masse, aber gleicher Geschwindigkeit, welche die im Gegenstandsraum befindliche Gegenstandsebene alle an derselben Stelle des Durchstoßpunktes der w-Achse verlassen, beschreiben im Umlenkraum und damit auch im Bildraum verschiedene Bahnen, wie es Abb. 24 zeigt. Ein Lichtstrahl mit diesen Anfangsbedingungen wird in der Optik optische Achse genannt. Wird diese Bezeichnung übernommen, dann ist für jede Ionenmasse eine besondere optische Achse definiert, gegen welche die Bahnkoordinaten des betreffenden Teilchenstrahlbündels gemessen werden. Die optische Achse ist damit als eine spezielle Lösung der Bewegungsgleichungen definiert.

Eine Korpuskel, welche das Umlenkfeld in unmittelbarer Nähe der w-Achse betritt, wird sich bei ihrer Bewegung durch den Umlenkraum weiterhin in der Nähe des Kreisbogens R = const. aufhalten, wenn dort Gleichgewicht zwischen den elektromagnetischen Kräften und der auftretenden Zentrifugalkraft herrscht. Durch diese Forderung ist das Verhältnis der Feldstärken E_1 und H_1 bis auf Glieder, die — im Sinne der oben gegebenen Terminologie — von erster Ordnung klein sind, bestimmt. Wird weiter Unabhängigkeit der Ionenbahnen von der Geschwindigkeitsdispersion gefordert (Geschwindigkeitsfokussierung), dann werden die Absolutbeträge beider Feldstärken festgelegt.

Abb. 24.
Definition der optischen Achse und ihre Abhängigkeit von der Ionenmasse.

Im allgemeinen Fall hat das Umlenkfeld die Abbildungseigenschaften einer Zylinderlinse. Durch besondere Wahl des Verhältnisses der Reihenkoeffizienten E_2 und H_2 gelingt es jedoch, das Umlenkfeld so auszubilden, daß es in Gaußscher Näherung eine stigmatische Abbildung der Gegenstandsebene auf die Bildebene vermittelt. Die Punktabbildung kann durch verschiedene Kombination beider Felder erreicht werden — vgl. hierzu die Teilbilder 25a und 25b — da nur das Verhältnis und nicht die absoluten Beträge beider Koeffizienten vorgeschrieben sind. Diese Freiheit in der Wahl der Absolutbeträge kann evtl. zur Verringerung besonders störender Abbildungsfehler von Nutzen sein. Im folgenden sei nun das punktabbildende Umlenkfeld vorausgesetzt.

Unter Benutzung zweier Fundamentallösungen der Bahngleichungen lassen sich sämtliche geometrisch-optischen Konstanten des Umlenkfeldes formal angeben. Um quantitative Aussagen zu machen, müssen die Funktionen $E_0(w)$, $E_1(w)$, $E_2(w)$, $H_1(w)$, $H_2(w)$ bekannt sein. Ist der Umlenkwinkel genügend groß, so daß das Verhältnis des Bogens R zum gegenseitigen Abstand d der Umlenkelektroden nicht zu klein wird ($R\Theta/d \geqq 10$), dann werden die Streufelder auf den Bahnverlauf keinen merklichen Einfluß ausüben. Es kann dann in guter Näherung

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[104] W. GLASER, Z. Physik **80**, 451 [1933].

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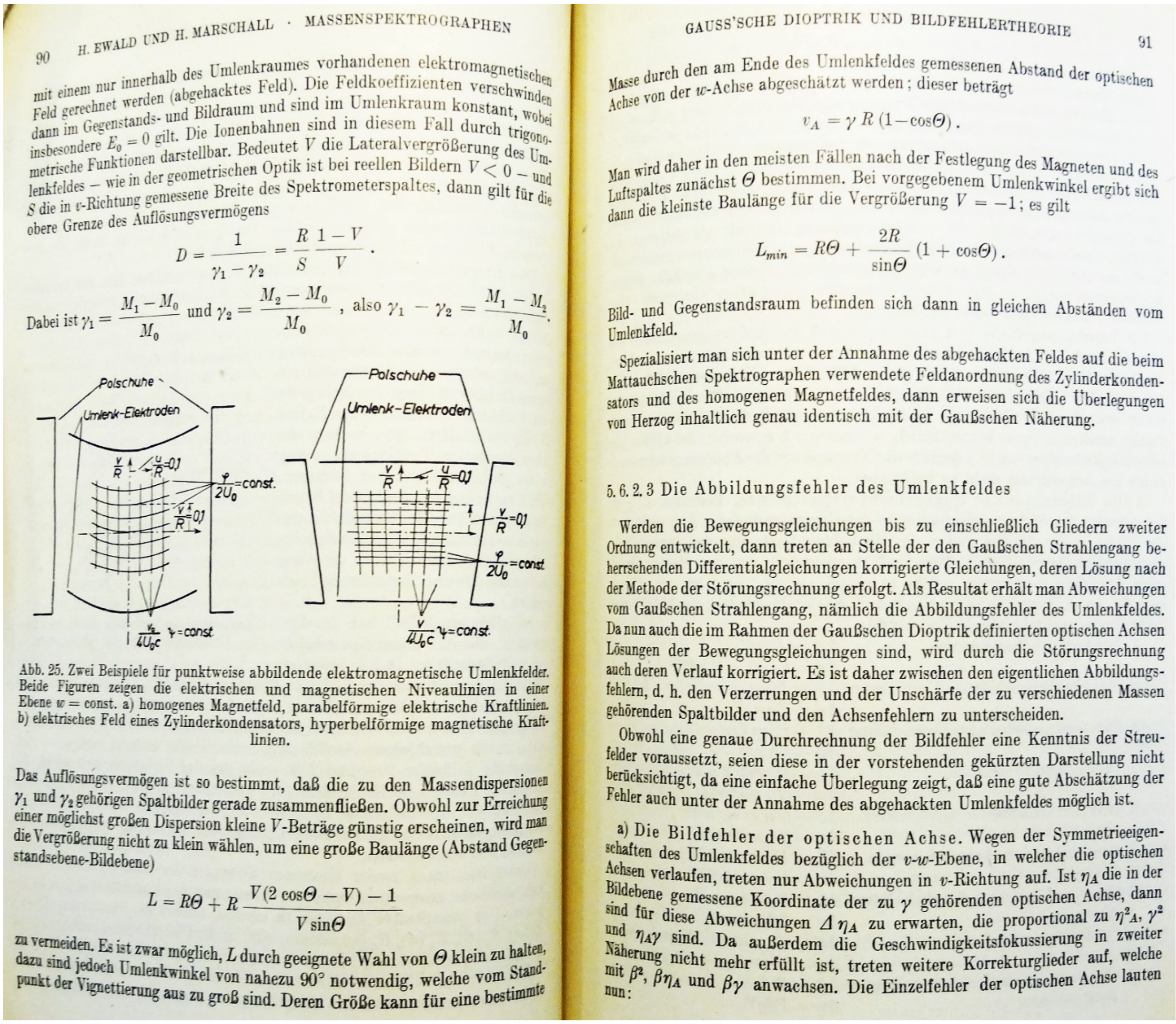
Figure D.207: Description of Heinz Ewald's wartime work on electromagnetic isotope separators [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].



mit einem nur innerhalb des Umlenkraumes vorhandenen elektromagnetischen Feld gerechnet werden (abgehacktes Feld). Die Feldkoeffizienten verschwinden dann im Gegenstands- und Bildraum und sind im Umlenkraum konstant, wobei insbesondere $E_0 = 0$ gilt. Die Ionenbahnen sind in diesem Fall durch trigonometrische Funktionen darstellbar. Bedeutet V die Lateralvergrößerung des Umlenkfeldes – wie in der geometrischen Optik ist bei reellen Bildern $V < 0$ – und S die in v-Richtung gemessene Breite des Spektrometerspaltes, dann gilt für die obere Grenze des Auflösungsvermögens

$$D = \frac{1}{\gamma_1 - \gamma_2} = \frac{R}{S}\,\frac{1-V}{V}\,.$$

Dabei ist $\gamma_1 = \dfrac{M_1 - M_0}{M_0}$ und $\gamma_2 = \dfrac{M_2 - M_0}{M_0}$, also $\gamma_1 - \gamma_2 = \dfrac{M_1 - M_2}{M_0}$.

Abb. 25. Zwei Beispiele für punktweise abbildende elektromagnetische Umlenkfelder. Beide Figuren zeigen die elektrischen und magnetischen Niveaulinien in einer Ebene $w = \text{const.}$ a) homogenes Magnetfeld, parabelförmige elektrische Kraftlinien. b) elektrisches Feld eines Zylinderkondensators, hyperbelförmige magnetische Kraftlinien.

Das Auflösungsvermögen ist so bestimmt, daß die zu den Massendispersionen γ_1 und γ_2 gehörigen Spaltbilder gerade zusammenfließen. Obwohl zur Erreichung einer möglichst großen Dispersion kleine V-Beträge günstig erscheinen, wird man die Vergrößerung nicht zu klein wählen, um eine große Baulänge (Abstand Gegenstandsebene-Bildebene)

$$L = R\Theta + R\,\frac{V(2\cos\Theta - V) - 1}{V\sin\Theta}$$

zu vermeiden. Es ist zwar möglich, L durch geeignete Wahl von Θ klein zu halten, dazu sind jedoch Umlenkwinkel von nahezu 90° notwendig, welche vom Standpunkt der Vignettierung aus zu groß sind. Deren Größe kann für eine bestimmte

Masse durch den am Ende des Umlenkfeldes gemessenen Abstand der optischen Achse von der w-Achse abgeschätzt werden; dieser beträgt

$$v_A = \gamma\,R\,(1-\cos\Theta)\,.$$

Man wird daher in den meisten Fällen nach der Festlegung des Magneten und des Luftspaltes zunächst Θ bestimmen. Bei vorgegebenem Umlenkwinkel ergibt sich dann die kleinste Baulänge für die Vergrößerung $V = -1$; es gilt

$$L_{min} = R\Theta + \frac{2R}{\sin\Theta}\,(1 + \cos\Theta)\,.$$

Bild- und Gegenstandsraum befinden sich dann in gleichen Abständen vom Umlenkfeld.

Spezialisiert man sich unter der Annahme des abgehackten Feldes auf die beim Mattauchschen Spektrographen verwendete Feldanordnung des Zylinderkondensators und des homogenen Magnetfeldes, dann erweisen sich die Überlegungen von Herzog inhaltlich genau identisch mit der Gaußschen Näherung.

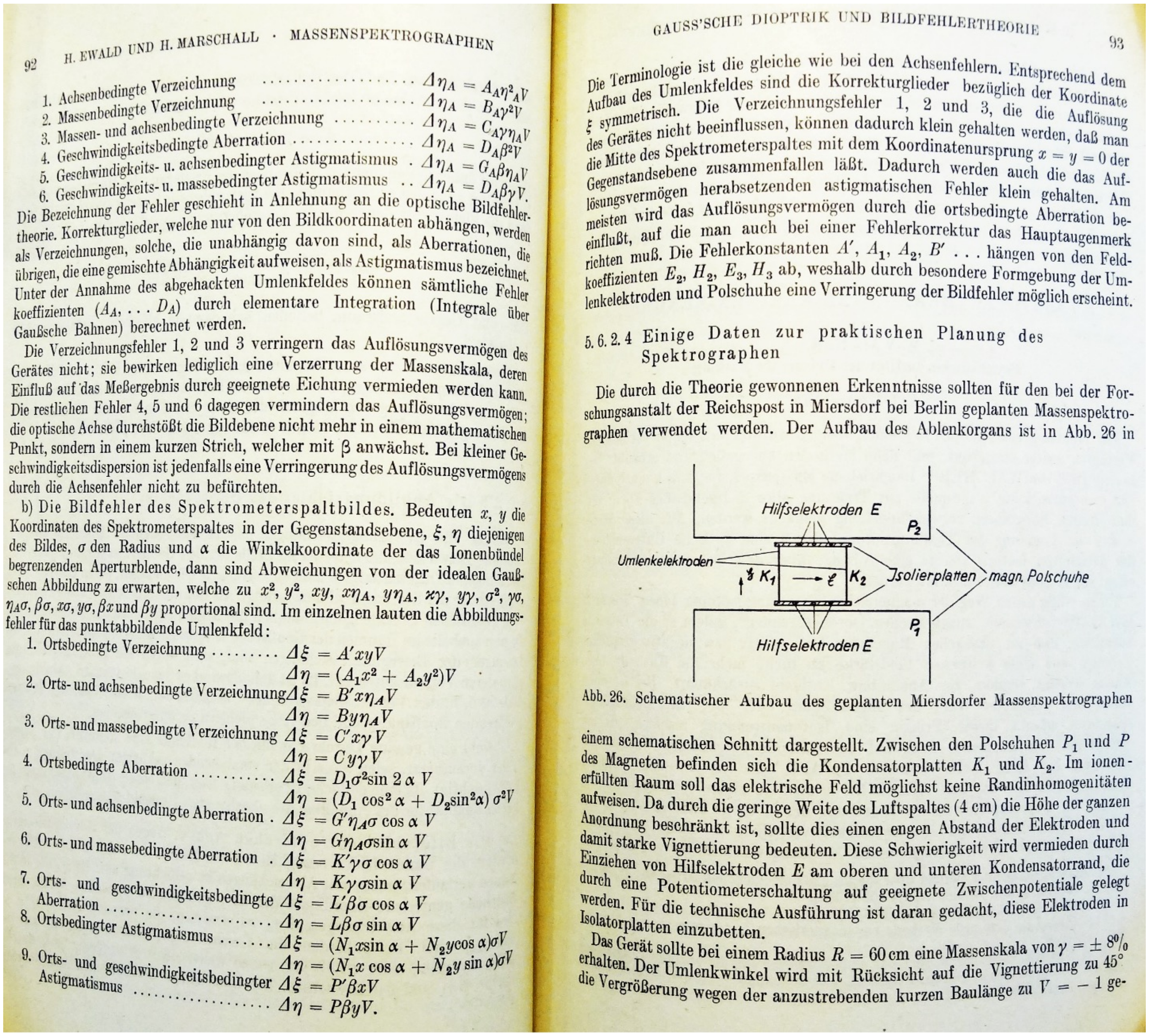
5.6.2.3 Die Abbildungsfehler des Umlenkfeldes

Werden die Bewegungsgleichungen bis zu einschließlich Gliedern zweiter Ordnung entwickelt, dann treten an Stelle der den Gaußschen Strahlengang beherrschenden Differentialgleichungen korrigierte Gleichungen, deren Lösung nach der Methode der Störungsrechnung erfolgt. Als Resultat erhält man Abweichungen vom Gaußschen Strahlengang, nämlich die Abbildungsfehler des Umlenkfeldes. Da nun auch die im Rahmen der Gaußschen Dioptrik definierten optischen Achsen Lösungen der Bewegungsgleichungen sind, wird durch die Störungsrechnung auch deren Verlauf korrigiert. Es ist daher zwischen den eigentlichen Abbildungsfehlern, d. h. den Verzerrungen und der Unschärfe der zu verschiedenen Massen gehörenden Spaltbilder und den Achsenfehlern zu unterscheiden.

Obwohl eine genaue Durchrechnung der Bildfehler eine Kenntnis der Streufelder voraussetzt, seien diese in der vorstehenden gekürzten Darstellung nicht berücksichtigt, da eine einfache Überlegung zeigt, daß eine gute Abschätzung der Fehler auch unter der Annahme des abgehackten Umlenkfeldes möglich ist.

a) Die Bildfehler der optischen Achse. Wegen der Symmetrieeigenschaften des Umlenkfeldes bezüglich der v-w-Ebene, in welcher die optischen Achsen verlaufen, treten nur Abweichungen in v-Richtung auf. Ist η_A die in der Bildebene gemessene Koordinate der zu γ gehörenden optischen Achse, dann sind für diese Abweichungen $\Delta\,\eta_A$ zu erwarten, die proportional zu η^2_A, γ^2 und $\eta_A\gamma$ sind. Da außerdem die Geschwindigkeitsfokussierung in zweiter Näherung nicht mehr erfüllt ist, treten weitere Korrekturglieder auf, welche mit β^2, $\beta\eta_A$ und $\beta\gamma$ anwachsen. Die Einzelfehler der optischen Achse lauten nun:

Figure D.208: Description of Heinz Ewald's wartime work on electromagnetic isotope separators [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].



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1. Achsenbedingte Verzeichnung .... $\Delta\eta_A = A_A\eta^2_A V$
2. Massenbedingte Verzeichnung .... $\Delta\eta_A = B_A\gamma^2 V$
3. Massen- und achsenbedingte Verzeichnung .... $\Delta\eta_A = C_A\gamma\eta_A V$
4. Geschwindigkeitsbedingte Aberration .... $\Delta\eta_A = D_A\beta^2 V$
5. Geschwindigkeits- u. achsenbedingter Astigmatismus . $\Delta\eta_A = G_A\beta\eta_A V$
6. Geschwindigkeits- u. massebedingter Astigmatismus .. $\Delta\eta_A = D_A\beta\gamma V$.

Die Bezeichnung der Fehler geschieht in Anlehnung an die optische Bildfehlertheorie. Korrekturglieder, welche nur von den Bildkoordinaten abhängen, werden als Verzeichnungen, solche, die unabhängig davon sind, als Aberrationen, die übrigen, die eine gemischte Abhängigkeit aufweisen, als Astigmatismus bezeichnet. Unter der Annahme des abgehackten Umlenkfeldes können sämtliche Fehlerkoeffizienten ($A_A, \ldots D_A$) durch elementare Integration (Integrale über Gaußsche Bahnen) berechnet werden.

Die Verzeichnungsfehler 1, 2 und 3 verringern das Auflösungsvermögen des Gerätes nicht; sie bewirken lediglich eine Verzerrung der Massenskala, deren Einfluß auf das Meßergebnis durch geeignete Eichung vermieden werden kann. Die restlichen Fehler 4, 5 und 6 dagegen vermindern das Auflösungsvermögen; die optische Achse durchstößt die Bildebene nicht mehr in einem mathematischen Punkt, sondern in einem kurzen Strich, welcher mit β anwächst. Bei kleiner Geschwindigkeitsdispersion ist jedenfalls eine Verringerung des Auflösungsvermögens durch die Achsenfehler nicht zu befürchten.

b) Die Bildfehler des Spektrometerspaltbildes. Bedeuten x, y die Koordinaten des Spektrometerspaltes in der Gegenstandsebene, ξ, η diejenigen des Bildes, σ den Radius und α die Winkelkoordinate der das Ionenbündel begrenzenden Aperturblende, dann sind Abweichungen von der idealen Gaußschen Abbildung zu erwarten, welche zu x^2, y^2, xy, $x\eta_A$, $y\eta_A$, $\varkappa\gamma$, $y\gamma$, σ^2, $\gamma\sigma$, $\eta_A\sigma$, $\beta\sigma$, $x\sigma$, $y\sigma$, βx und βy proportional sind. Im einzelnen lauten die Abbildungsfehler für das punktabbildende Umlenkfeld:

1. Ortsbedingte Verzeichnung .... $\Delta\xi = A'xyV$, $\Delta\eta = (A_1x^2 + A_2y^2)V$
2. Orts- und achsenbedingte Verzeichnung $\Delta\xi = B'x\eta_A V$, $\Delta\eta = By\eta_A V$
3. Orts- und massebedingte Verzeichnung $\Delta\xi = C'x\gamma V$, $\Delta\eta = Cy\gamma V$
4. Ortsbedingte Aberration .... $\Delta\xi = D_1\sigma^2\sin 2\alpha\, V$, $\Delta\eta = (D_1\cos^2\alpha + D_2\sin^2\alpha)\,\sigma^2 V$
5. Orts- und achsenbedingte Aberration . $\Delta\xi = G'\eta_A\sigma\cos\alpha\, V$, $\Delta\eta = G\eta_A\sigma\sin\alpha\, V$
6. Orts- und massebedingte Aberration . $\Delta\xi = K'\gamma\sigma\cos\alpha\, V$, $\Delta\eta = K\gamma\sigma\sin\alpha\, V$
7. Orts- und geschwindigkeitsbedingte Aberration .... $\Delta\xi = L'\beta\sigma\cos\alpha\, V$, $\Delta\eta = L\beta\sigma\sin\alpha\, V$
8. Ortsbedingter Astigmatismus .... $\Delta\xi = (N_1x\sin\alpha + N_2y\cos\alpha)\sigma V$, $\Delta\eta = (N_1x\cos\alpha + N_2y\sin\alpha)\sigma V$
9. Orts- und geschwindigkeitsbedingter Astigmatismus .... $\Delta\xi = P'\beta xV$, $\Delta\eta = P\beta yV$.

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Die Terminologie ist die gleiche wie bei den Achsenfehlern. Entsprechend dem Aufbau des Umlenkfeldes sind die Korrekturglieder bezüglich der Koordinate ξ symmetrisch. Die Verzeichnungsfehler 1, 2 und 3, die die Auflösung des Gerätes nicht beeinflussen, können dadurch klein gehalten werden, daß man die Mitte des Spektrometerspaltes mit dem Koordinatenursprung $x = y = 0$ der Gegenstandsebene zusammenfallen läßt. Dadurch werden auch die das Auflösungsvermögen herabsetzenden astigmatischen Fehler klein gehalten. Am meisten wird das Auflösungsvermögen durch die ortsbedingte Aberration beeinflußt, auf die man auch bei einer Fehlerkorrektur das Hauptaugenmerk richten muß. Die Fehlerkonstanten A', A_1, A_2, B' . . . hängen von den Feldkoeffizienten E_2, H_2, E_3, H_3 ab, weshalb durch besondere Formgebung der Umlenkelektroden und Polschuhe eine Verringerung der Bildfehler möglich erscheint.

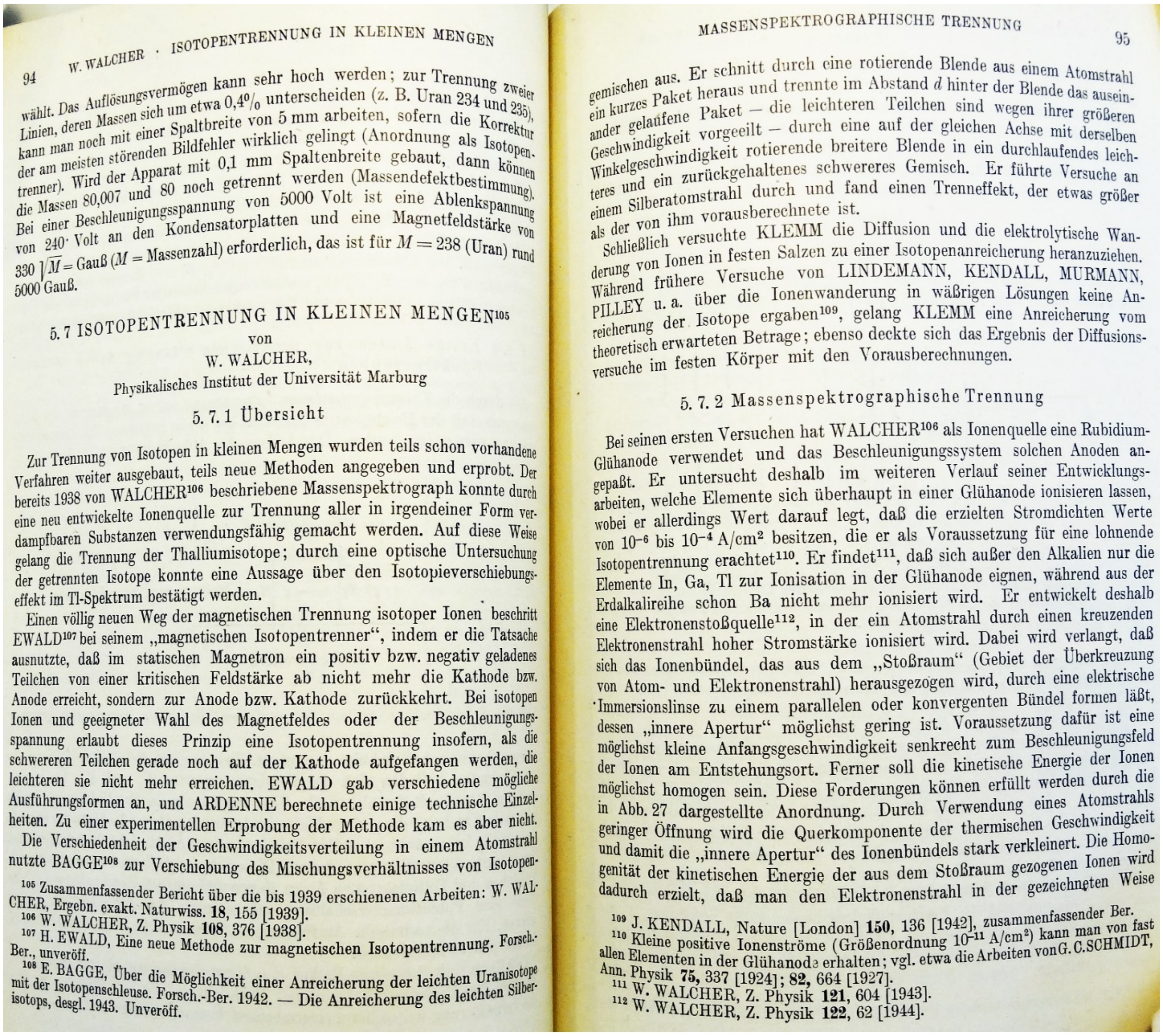
5.6.2.4 Einige Daten zur praktischen Planung des Spektrographen

Die durch die Theorie gewonnenen Erkenntnisse sollten für den bei der Forschungsanstalt der Reichspost in Miersdorf bei Berlin geplanten Massenspektrographen verwendet werden. Der Aufbau des Ablenkorgans ist in Abb. 26 in einem schematischen Schnitt dargestellt. Zwischen den Polschuhen P_1 und P des Magneten befinden sich die Kondensatorplatten K_1 und K_2. Im ionenerfüllten Raum soll das elektrische Feld möglichst keine Randinhomogenitäten aufweisen. Da durch die geringe Weite des Luftspaltes (4 cm) die Höhe der ganzen Anordnung beschränkt ist, sollte dies einen engen Abstand der Elektroden und damit starke Vignettierung bedeuten. Diese Schwierigkeit wird vermieden durch Einziehen von Hilfselektroden E am oberen und unteren Kondensatorrand, die durch eine Potentiometerschaltung auf geeignete Zwischenpotentiale gelegt werden. Für die technische Ausführung ist daran gedacht, diese Elektroden in Isolatorplatten einzubetten.

Abb. 26. Schematischer Aufbau des geplanten Miersdorfer Massenspektrographen

Das Gerät sollte bei einem Radius $R = 60$ cm eine Massenskala von $\gamma = \pm 8\%$ erhalten. Der Umlenkwinkel wird mit Rücksicht auf die Vignettierung zu 45° die Vergrößerung wegen der anzustrebenden kurzen Baulänge zu $V = -1$ ge-

Figure D.209: Description of Heinz Ewald's wartime work on electromagnetic isotope separators [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].



wählt. Das Auflösungsvermögen kann sehr hoch werden; zur Trennung zweier Linien, deren Massen sich um etwa 0,4% unterscheiden (z. B. Uran 234 und 235), kann man noch mit einer Spaltbreite von 5 mm arbeiten, sofern die Korrektur der am meisten störenden Bildfehler wirklich gelingt (Anordnung als Isotopentrenner). Wird der Apparat mit 0,1 mm Spaltenbreite gebaut, dann können die Massen 80,007 und 80 noch getrennt werden (Massendefektbestimmung). Bei einer Beschleunigungsspannung von 5000 Volt ist eine Ablenkspannung von 240· Volt an den Kondensatorplatten und eine Magnetfeldstärke von $330\sqrt{M} =$ Gauß ($M =$ Massenzahl) erforderlich, das ist für $M = 238$ (Uran) rund 5000 Gauß.

5.7 ISOTOPENTRENNUNG IN KLEINEN MENGEN[105]

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5.7.1 Übersicht

Zur Trennung von Isotopen in kleinen Mengen wurden teils schon vorhandene Verfahren weiter ausgebaut, teils neue Methoden angegeben und erprobt. Der bereits 1938 von WALCHER[106] beschriebene Massenspektrograph konnte durch eine neu entwickelte Ionenquelle zur Trennung aller in irgendeiner Form verdampfbaren Substanzen verwendungsfähig gemacht werden. Auf diese Weise gelang die Trennung der Thalliumisotope; durch eine optische Untersuchung der getrennten Isotope konnte eine Aussage über den Isotopieverschiebungseffekt im Tl-Spektrum bestätigt werden.

Einen völlig neuen Weg der magnetischen Trennung isotoper Ionen beschritt EWALD[107] bei seinem „magnetischen Isotopentrenner", indem er die Tatsache ausnutzte, daß im statischen Magnetron ein positiv bzw. negativ geladenes Teilchen von einer kritischen Feldstärke ab nicht mehr die Kathode bzw. Anode erreicht, sondern zur Anode bzw. Kathode zurückkehrt. Bei isotopen Ionen und geeigneter Wahl des Magnetfeldes oder der Beschleunigungsspannung erlaubt dieses Prinzip eine Isotopentrennung insofern, als die schwereren Teilchen gerade noch auf der Kathode aufgefangen werden, die leichteren sie nicht mehr erreichen. EWALD gab verschiedene mögliche Ausführungsformen an, und ARDENNE berechnete einige technische Einzelheiten. Zu einer experimentellen Erprobung der Methode kam es aber nicht.

Die Verschiedenheit der Geschwindigkeitsverteilung in einem Atomstrahl nutzte BAGGE[108] zur Verschiebung des Mischungsverhältnisses von Isotopengemischen aus.

Er schnitt durch eine rotierende Blende aus einem Atomstrahl ein kurzes Paket heraus und trennte im Abstand d hinter der Blende das auseinander gelaufene Paket – die leichteren Teilchen sind wegen ihrer größeren Geschwindigkeit vorgeeilt – durch eine auf der gleichen Achse mit derselben Winkelgeschwindigkeit rotierende breitere Blende in ein durchlaufendes leichteres und ein zurückgehaltenes schwereres Gemisch. Er führte Versuche an einem Silberatomstrahl durch und fand einen Trenneffekt, der etwas größer als der von ihm vorausberechnete ist.

Schließlich versuchte KLEMM die Diffusion und die elektrolytische Wanderung von Ionen in festen Salzen zu einer Isotopenanreicherung heranzuziehen. Während frühere Versuche von LINDEMANN, KENDALL, MURMANN, PILLEY u. a. über die Ionenwanderung in wäßrigen Lösungen keine Anreicherung der Isotope ergaben[109], gelang KLEMM eine Anreicherung vom theoretisch erwarteten Betrage; ebenso deckte sich das Ergebnis der Diffusionsversuche im festen Körper mit den Vorausberechnungen.

5.7.2 Massenspektrographische Trennung

Bei seinen ersten Versuchen hat WALCHER[106] als Ionenquelle eine Rubidium-Glühanode verwendet und das Beschleunigungssystem solchen Anoden angepaßt. Er untersucht deshalb im weiteren Verlauf seiner Entwicklungsarbeiten, welche Elemente sich überhaupt in einer Glühanode ionisieren lassen, wobei er allerdings Wert darauf legt, daß die erzielten Stromdichten Werte von 10^{-6} bis 10^{-4} A/cm^2 besitzen, die er als Voraussetzung für eine lohnende Isotopentrennung erachtet[110]. Er findet[111], daß sich außer den Alkalien nur die Elemente In, Ga, Tl zur Ionisation in der Glühanode eignen, während aus der Erdalkalireihe schon Ba nicht mehr ionisiert wird. Er entwickelt deshalb eine Elektronenstoßquelle[112], in der ein Atomstrahl durch einen kreuzenden Elektronenstrahl hoher Stromstärke ionisiert wird. Dabei wird verlangt, daß sich das Ionenbündel, das aus dem „Stoßraum" (Gebiet der Überkreuzung von Atom- und Elektronenstrahl) herausgezogen wird, durch eine elektrische Immersionslinse zu einem parallelen oder konvergenten Bündel formen läßt, dessen „innere Apertur" möglichst gering ist. Voraussetzung dafür ist eine möglichst kleine Anfangsgeschwindigkeit senkrecht zum Beschleunigungsfeld der Ionen am Entstehungsort. Ferner soll die kinetische Energie der Ionen möglichst homogen sein. Diese Forderungen können erfüllt werden durch die in Abb. 27 dargestellte Anordnung. Durch Verwendung eines Atomstrahls geringer Öffnung wird die Querkomponente der thermischen Geschwindigkeit und damit die „innere Apertur" des Ionenbündels stark verkleinert. Die Homogenität der kinetischen Energie der aus dem Stoßraum gezogenen Ionen wird dadurch erzielt, daß man den Elektronenstrahl in der gezeichneten Weise

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[105] Zusammenfassender Bericht über die bis 1939 erschienenen Arbeiten: W. WALCHER, Ergebn. exakt. Naturwiss. **18**, 155 [1939].

[106] W. WALCHER, Z. Physik **108**, 376 [1938].

[107] H. EWALD, Eine neue Methode zur magnetischen Isotopentrennung. Forsch.-Ber., unveröff.

[108] E. BAGGE, Über die Möglichkeit einer Anreicherung der leichten Uranisotope mit der Isotopenschleuse. Forsch.-Ber. 1942. — Die Anreicherung des leichten Silberisotops, desgl. 1943. Unveröff.

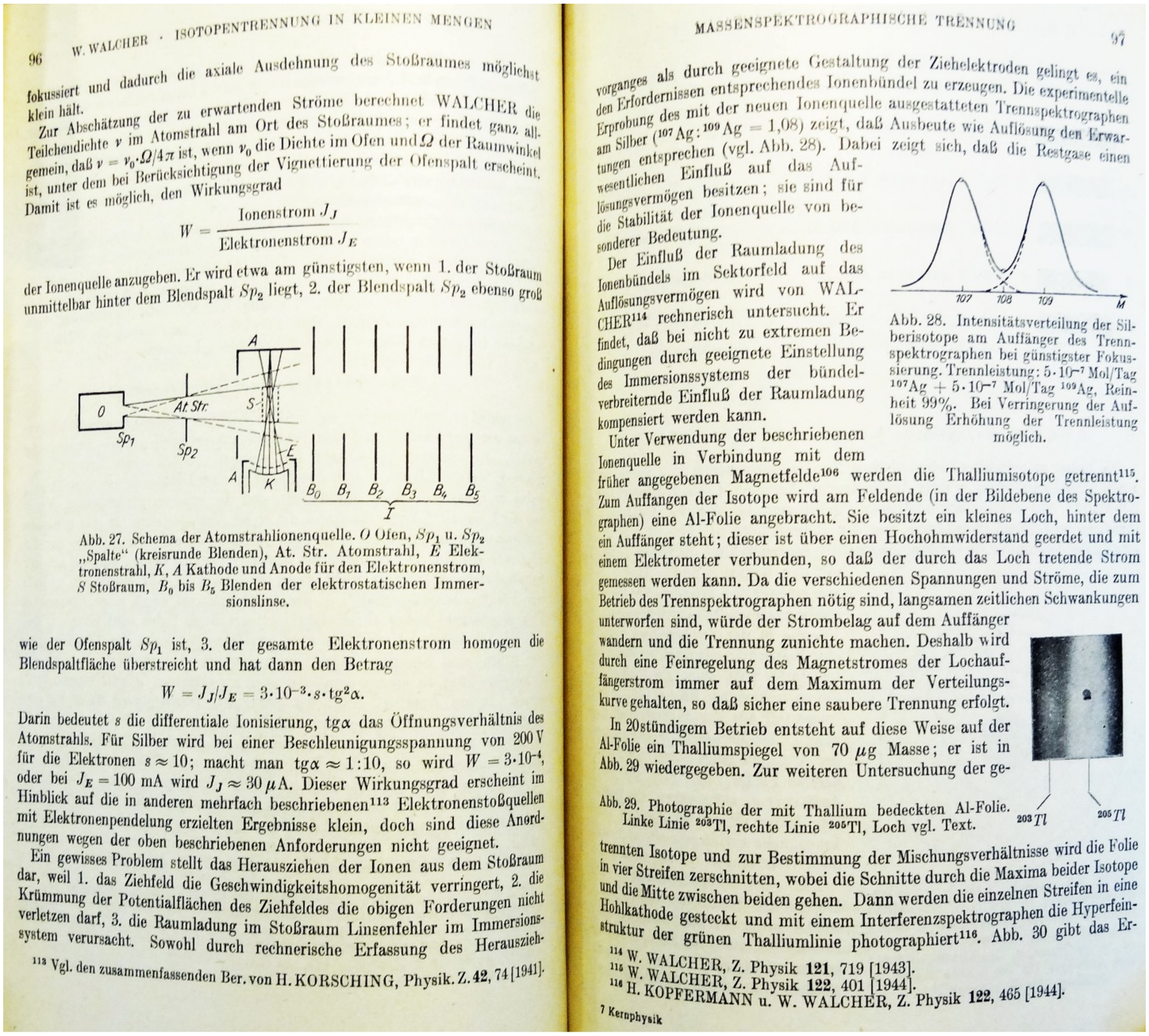
[109] J. KENDALL, Nature [London] **150**, 136 [1942], zusammenfassender Ber.

[110] Kleine positive Ionenströme (Größenordnung 10^{-11} A/cm^2) kann man von fast allen Elementen in der Glühanode erhalten; vgl. etwa die Arbeiten von G. C. SCHMIDT, Ann. Physik **75**, 337 [1924]; **82**, 664 [1927].

[111] W. WALCHER, Z. Physik **121**, 604 [1943].

[112] W. WALCHER, Z. Physik **122**, 62 [1944].

Figure D.210: Description of Heinz Ewald's wartime work on electromagnetic isotope separators [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].



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fokussiert und dadurch die axiale Ausdehnung des Stoßraumes möglichst klein hält.

Zur Abschätzung der zu erwartenden Ströme berechnet WALCHER die Teilchendichte ν im Atomstrahl am Ort des Stoßraumes; er findet ganz allgemein, daß $\nu = \nu_0 \cdot \Omega/4\pi$ ist, wenn ν_0 die Dichte im Ofen und Ω der Raumwinkel ist, unter dem bei Berücksichtigung der Vignettierung der Ofenspalt erscheint. Damit ist es möglich, den Wirkungsgrad

$$W = \frac{\text{Ionenstrom } J_J}{\text{Elektronenstrom } J_E}$$

der Ionenquelle anzugeben. Er wird etwa am günstigsten, wenn 1. der Stoßraum unmittelbar hinter dem Blendspalt Sp_2 liegt, 2. der Blendspalt Sp_2 ebenso groß wie der Ofenspalt Sp_1 ist, 3. der gesamte Elektronenstrom homogen die Blendspaltfläche überstreicht und hat dann den Betrag

Abb. 27. Schema der Atomstrahlionenquelle. O Ofen, Sp_1 u. Sp_2 „Spalte" (kreisrunde Blenden), At. Str. Atomstrahl, E Elektronenstrahl, K, A Kathode und Anode für den Elektronenstrom, S Stoßraum, B_0 bis B_5 Blenden der elektrostatischen Immersionslinse.

$$W = J_J/J_E = 3 \cdot 10^{-3} \cdot s \cdot \mathrm{tg}^2\alpha.$$

Darin bedeutet s die differentiale Ionisierung, $\mathrm{tg}\alpha$ das Öffnungsverhältnis des Atomstrahls. Für Silber wird bei einer Beschleunigungsspannung von 200 V für die Elektronen $s \approx 10$; macht man $\mathrm{tg}\alpha \approx 1:10$, so wird $W = 3 \cdot 10^{-4}$, oder bei $J_E = 100$ mA wird $J_J \approx 30\,\mu$A. Dieser Wirkungsgrad erscheint im Hinblick auf die in anderen mehrfach beschriebenen[113] Elektronenstoßquellen mit Elektronenpendelung erzielten Ergebnisse klein, doch sind diese Anordnungen wegen der oben beschriebenen Anforderungen nicht geeignet.

Ein gewisses Problem stellt das Herausziehen der Ionen aus dem Stoßraum dar, weil 1. das Ziehfeld die Geschwindigkeitshomogenität verringert, 2. die Krümmung der Potentialflächen des Ziehfeldes die obigen Forderungen nicht verletzen darf, 3. die Raumladung im Stoßraum Linsenfehler im Immersionssystem verursacht. Sowohl durch rechnerische Erfassung des Herausziehvorganges als durch geeignete Gestaltung der Zieheelektroden gelingt es, ein den Erfordernissen entsprechendes Ionenbündel zu erzeugen. Die experimentelle Erprobung des mit der neuen Ionenquelle ausgestatteten Trennspektrographen am Silber (^{107}Ag : ^{109}Ag = 1,08) zeigt, daß Ausbeute wie Auflösung den Erwartungen entsprechen (vgl. Abb. 28). Dabei zeigt sich, daß die Restgase einen wesentlichen Einfluß auf das Auflösungsvermögen besitzen; sie sind für die Stabilität der Ionenquelle von besonderer Bedeutung.

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[113] Vgl. den zusammenfassenden Ber. von H. KORSCHING, Physik. Z. **42**, 74 [1941].

MASSENSPEKTROGRAPHISCHE TRENNUNG 97

Abb. 28. Intensitätsverteilung der Silberisotope am Auffänger des Trennspektrographen bei günstigster Fokussierung. Trennleistung: $5 \cdot 10^{-7}$ Mol/Tag ^{107}Ag + $5 \cdot 10^{-7}$ Mol/Tag ^{109}Ag, Reinheit 99%. Bei Verringerung der Auflösung Erhöhung der Trennleistung möglich.

Der Einfluß der Raumladung des Ionenbündels im Sektorfeld auf das Auflösungsvermögen wird von WALCHER[114] rechnerisch untersucht. Er findet, daß bei nicht zu extremen Bedingungen durch geeignete Einstellung des Immersionssystems der bündelverbreiternde Einfluß der Raumladung kompensiert werden kann.

Unter Verwendung der beschriebenen Ionenquelle in Verbindung mit dem früher angegebenen Magnetfelde[106] werden die Thalliumisotope getrennt[115]. Zum Auffangen der Isotope wird am Feldende (in der Bildebene des Spektrographen) eine Al-Folie angebracht. Sie besitzt ein kleines Loch, hinter dem ein Auffänger steht; dieser ist über einen Hochohmwiderstand geerdet und mit einem Elektrometer verbunden, so daß der durch das Loch tretende Strom gemessen werden kann. Da die verschiedenen Spannungen und Ströme, die zum Betrieb des Trennspektrographen nötig sind, langsamen zeitlichen Schwankungen unterworfen sind, würde der Strombelag auf dem Auffänger wandern und die Trennung zunichte machen. Deshalb wird durch eine Feinregelung des Magnetstromes der Lochauffängerstrom immer auf dem Maximum der Verteilungskurve gehalten, so daß sicher eine saubere Trennung erfolgt.

In 20stündigem Betrieb entsteht auf diese Weise auf der Al-Folie ein Thalliumspiegel von 70 μg Masse; er ist in Abb. 29 wiedergegeben. Zur weiteren Untersuchung der getrennten Isotope und zur Bestimmung der Mischungsverhältnisse wird die Folie in vier Streifen zerschnitten, wobei die Schnitte durch die Maxima beider Isotope und die Mitte zwischen beiden gehen. Dann werden die einzelnen Streifen in eine Hohlkathode gesteckt und mit einem Interferenzspektrographen die Hyperfeinstruktur der grünen Thalliumlinie photographiert[116]. Abb. 30 gibt das Er-

Abb. 29. Photographie der mit Thallium bedeckten Al-Folie. Linke Linie ^{203}Tl, rechte Linie ^{205}Tl, Loch vgl. Text.

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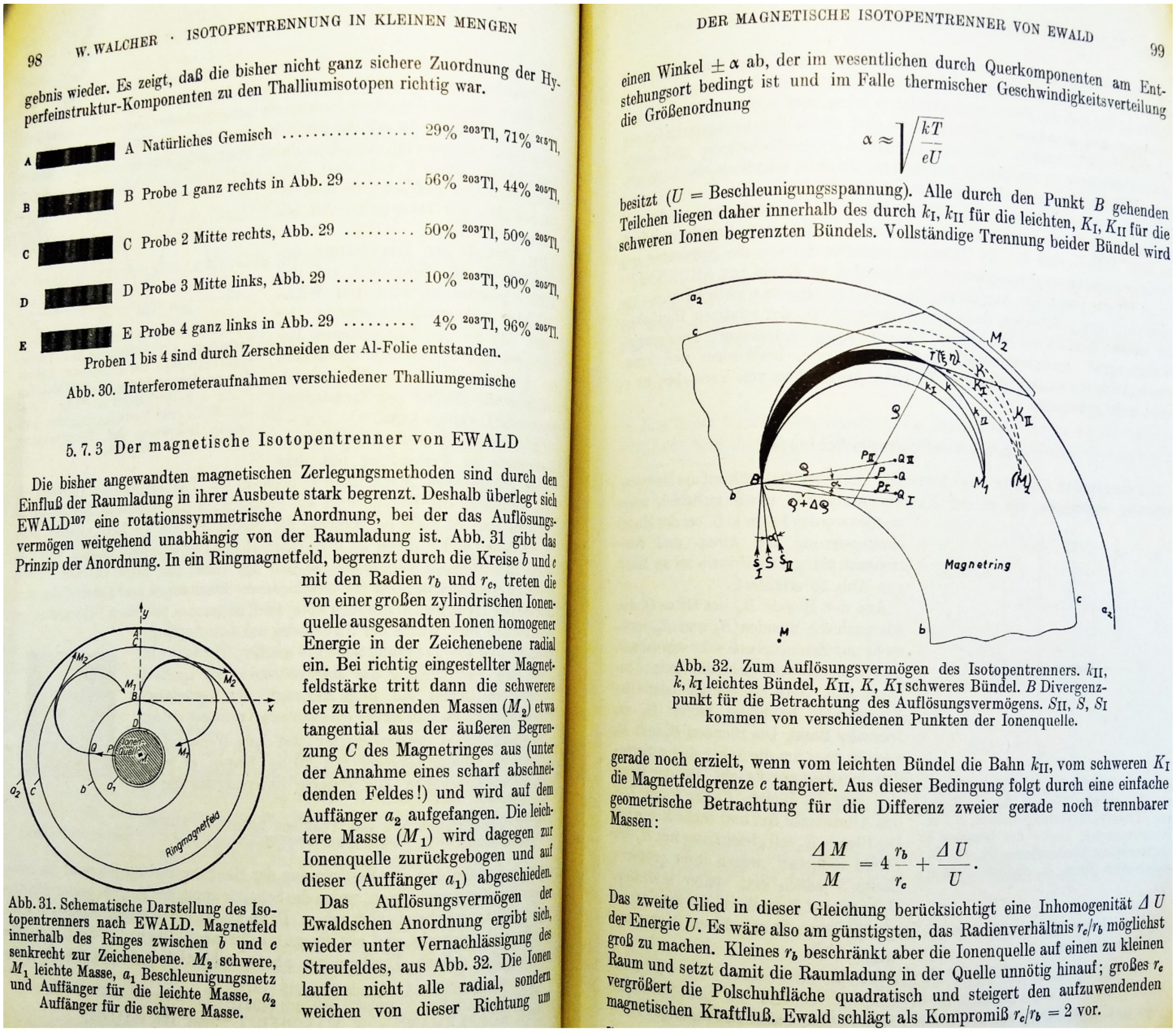
[114] W. WALCHER, Z. Physik **121**, 719 [1943].
[115] W. WALCHER, Z. Physik **122**, 401 [1944].
[116] H. KOPFERMANN u. W. WALCHER, Z. Physik **122**, 465 [1944].

7 Kernphysik

Figure D.211: Description of Heinz Ewald's wartime work on electromagnetic isotope separators [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].



gebnis wieder. Es zeigt, daß die bisher nicht ganz sichere Zuordnung der Hyperfeinstruktur-Komponenten zu den Thalliumisotopen richtig war.

A ▮▮▮ A Natürliches Gemisch .... 29% ^{203}Tl, 71% ^{205}Tl,
B ▮▮▮ B Probe 1 ganz rechts in Abb. 29 .... 56% ^{203}Tl, 44% ^{205}Tl,
C ▮▮▮ C Probe 2 Mitte rechts, Abb. 29 .... 50% ^{203}Tl, 50% ^{205}Tl,
D ▮▮▮ D Probe 3 Mitte links, Abb. 29 .... 10% ^{203}Tl, 90% ^{205}Tl,
E ▮▮▮ E Probe 4 ganz links in Abb. 29 .... 4% ^{203}Tl, 96% ^{205}Tl.

Proben 1 bis 4 sind durch Zerschneiden der Al-Folie entstanden.

Abb. 30. Interferometeraufnahmen verschiedener Thalliumgemische

5.7.3 Der magnetische Isotopentrenner von EWALD

Die bisher angewandten magnetischen Zerlegungsmethoden sind durch den Einfluß der Raumladung in ihrer Ausbeute stark begrenzt. Deshalb überlegt sich EWALD[107] eine rotationssymmetrische Anordnung, bei der das Auflösungsvermögen weitgehend unabhängig von der Raumladung ist. Abb. 31 gibt das Prinzip der Anordnung. In ein Ringmagnetfeld, begrenzt durch die Kreise b und c mit den Radien r_b und r_c, treten die von einer großen zylindrischen Ionenquelle ausgesandten Ionen homogener Energie in der Zeichenebene radial ein. Bei richtig eingestellter Magnetfeldstärke tritt dann die schwerere der zu trennenden Massen (M_2) etwa tangential aus der äußeren Begrenzung C des Magnetringes aus (unter der Annahme eines scharf abschneidenden Feldes!) und wird auf dem Auffänger a_2 aufgefangen. Die leichtere Masse (M_1) wird dagegen zur Ionenquelle zurückgebogen und auf dieser (Auffänger a_1) abgeschieden.

Abb. 31. Schematische Darstellung des Isotopentrenners nach EWALD. Magnetfeld innerhalb des Ringes zwischen b und c senkrecht zur Zeichenebene. M_2 schwere, M_1 leichte Masse, a_1 Beschleunigungsnetz und Auffänger für die leichte Masse, a_2 Auffänger für die schwere Masse.

Das Auflösungsvermögen der Ewaldschen Anordnung ergibt sich, wieder unter Vernachlässigung des Streufeldes, aus Abb. 32. Die Ionen laufen nicht alle radial, sondern weichen von dieser Richtung um einen Winkel $\pm\alpha$ ab, der im wesentlichen durch Querkomponenten am Entstehungsort bedingt ist und im Falle thermischer Geschwindigkeitsverteilung die Größenordnung

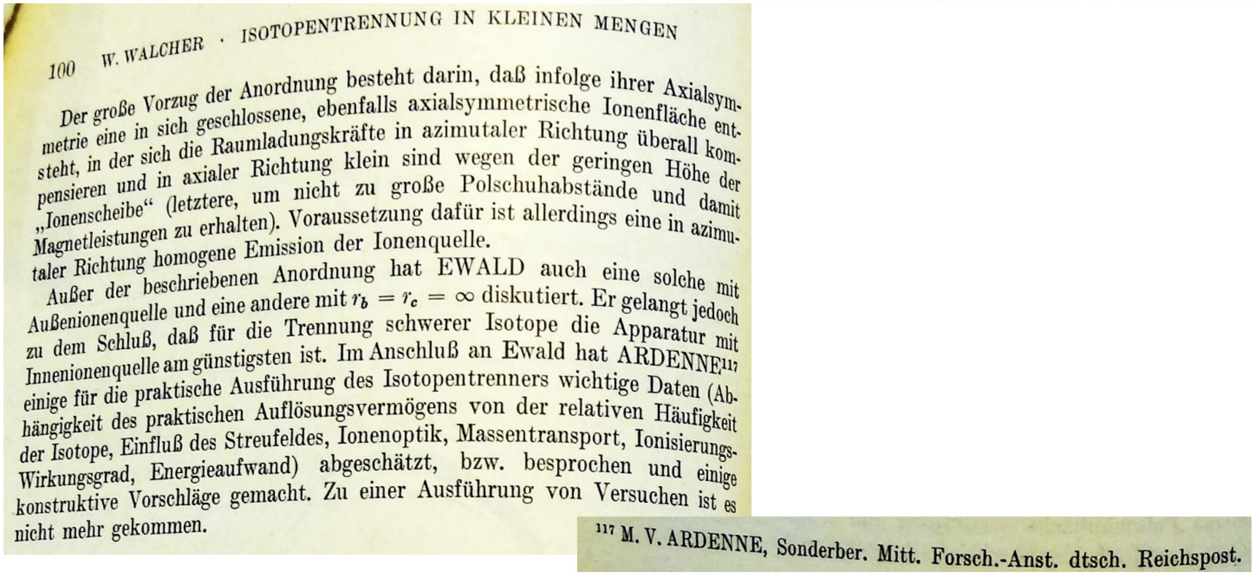
$$\alpha \approx \sqrt{\frac{kT}{eU}}$$

besitzt (U = Beschleunigungsspannung). Alle durch den Punkt B gehenden Teilchen liegen daher innerhalb des durch k_{I}, k_{II} für die leichten, K_{I}, K_{II} für die schweren Ionen begrenzten Bündels. Vollständige Trennung beider Bündel wird gerade noch erzielt, wenn vom leichten Bündel die Bahn k_{II}, vom schweren K_{I} die Magnetfeldgrenze c tangiert. Aus dieser Bedingung folgt durch eine einfache geometrische Betrachtung für die Differenz zweier gerade noch trennbarer Massen:

$$\frac{\Delta M}{M} = 4\frac{r_b}{r_c} + \frac{\Delta U}{U}.$$

Das zweite Glied in dieser Gleichung berücksichtigt eine Inhomogenität ΔU der Energie U. Es wäre also am günstigsten, das Radienverhältnis r_c/r_b möglichst groß zu machen. Kleines r_b beschränkt aber die Ionenquelle auf einen zu kleinen Raum und setzt damit die Raumladung in der Quelle unnötig hinauf; großes r_c vergrößert die Polschuhfläche quadratisch und steigert den aufzuwendenden magnetischen Kraftfluß. Ewald schlägt als Kompromiß $r_c/r_b = 2$ vor.

Abb. 32. Zum Auflösungsvermögen des Isotopentrenners. k_{II}, k, k_{I} leichtes Bündel, K_{II}, K, K_{I} schweres Bündel. B Divergenzpunkt für die Betrachtung des Auflösungsvermögens. S_{II}, S, S_{I} kommen von verschiedenen Punkten der Ionenquelle.



Der große Vorzug der Anordnung besteht darin, daß infolge ihrer Axialsymmetrie eine in sich geschlossene, ebenfalls axialsymmetrische Ionenfläche entsteht, in der sich die Raumladungskräfte in azimutaler Richtung überall kompensieren und in axialer Richtung klein sind wegen der geringen Höhe der „Ionenscheibe“ (letztere, um nicht zu große Polschuhabstände und damit Magnetleistungen zu erhalten). Voraussetzung dafür ist allerdings eine in azimutaler Richtung homogene Emission der Ionenquelle.

Außer der beschriebenen Anordnung hat EWALD auch eine solche mit Außenionenquelle und eine andere mit $r_b = r_c = \infty$ diskutiert. Er gelangt jedoch zu dem Schluß, daß für die Trennung schwerer Isotope die Apparatur mit Innenionenquelle am günstigsten ist. Im Anschluß an Ewald hat ARDENNE[117] einige für die praktische Ausführung des Isotopentrenners wichtige Daten (Abhängigkeit des praktischen Auflösungsvermögens von der relativen Häufigkeit der Isotope, Einfluß des Streufeldes, Ionenoptik, Massentransport, Ionisierungs-Wirkungsgrad, Energieaufwand) abgeschätzt, bzw. besprochen und einige konstruktive Vorschläge gemacht. Zu einer Ausführung von Versuchen ist es nicht mehr gekommen.

[117] M. V. ARDENNE, Sonderber. Mitt. Forsch.-Anst. dtsch. Reichspost.

Figure D.212: Description of Heinz Ewald's wartime work on electromagnetic isotope separators [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].

Helmut J. Fischer. 1988. *Hitlers Apparat: Namen, Ämter, Kompetenzen: Eine Strukturanalyse des 3. Reiches.* Kiel: Arndt. pp. 133–134.

Die Reichspost hatte von jeher technische Aufgaben zu bewältigen und stützte sich daher auf umfangreiche Forschungs- und Entwicklungsarbeiten auf dem Gebiet der Fernmeldetechnik und anderer für das Postwesen nützlichen Techniken. Dafür gab es in Darmstadt ausgedehnte Laboratorien neben dem Reichspostzentralamt in Berlin-Tempelhof, dessen Präsident Prof. Gladenbeck war.

Diesen vorgegebenen Rahmen sprengte der ehrgeizige Reichspostminister Ohnesorge. Er hatte einst bei Lenard Physik studiert und interessierte sich allgemeiner für wehrwissenschaftliche Probleme und schaltete zu ihrer Bearbeitung Mitarbeiter und Einrichtungen der Reichspost ein. Reichspost-Forschungsanstalten entstanden in der Nachbarschaft von Berlin in Kleinmachnow und in Miersdorf. Sie betrieben naturwissenschaftliche Grundlagenforschung, und das Institut in Miersdorf unter Dr. Banneitz befaßte sich sogar ernsthaft mit Kernphysik, wobei die Herstellung einer Atombombe angestrebt wurde. Überdies spannte Ohnesorge, der über genügend Geldmittel verfügen konnte und auf die Hilfe des Reichsforschungsrates nicht angewiesen war, auch Hochschulinstitute (wie etwa in Heidelberg) und zudem den tüchtigen Privatforscher Manfred von Ardenne mit seinem eigenen Laboratorium in Berlin-Lichterfelde für seine Forschungsziele ein. Sowohl in Miersdorf als auch im Institut Ardennes begann der Bau je einer 60-Millionen-Volt-Zyklotron-Anlage und von Hochspannungsgeräten, die mit einer Million Volt arbeiten.

The Reichspost has always had to cope with technical tasks and therefore relied on extensive research and development work in the field of telecommunications technology and other technologies useful for the postal system. To this end, Darmstadt had extensive laboratories alongside the Reichspost central office in Berlin-Tempelhof, whose president was Prof. Gladenbeck.

The ambitious Reichspost Minister Ohnesorge went beyond this rigid framework. He had once studied physics with Lenard and was more interested in military science problems in general and called in employees and institutions of the Reichspost to deal with them. Reichspost research institutes were established in the vicinity of Berlin in Kleinmachnow and in Miersdorf. They carried out basic scientific research, and the institute in Miersdorf under Dr. Banneitz was even seriously concerned with nuclear physics, with the aim of producing an atomic bomb. In addition, Ohnesorge, who had sufficient funds at his disposal and was not dependent on the help of the Reich Research Council, also employed university institutes (such as Heidelberg) and the capable private researcher Manfred von Ardenne with his own laboratory in Berlin-Lichterfelde for his research goals. Both in Miersdorf and at Ardenne's Institute, construction began on 60 million volt cyclotron facilities and on high-voltage equipment operating at one million volts.

Ohnesorge hatte den Ehrgeiz, die Ergebnisse seiner “posteigenen Forschung” bei Hitler selbst vorzutragen. Deshalb verbot der Minister seinen Wissenschaftlern die Fühlungnahme mit Fachkollegen außerhalb des Postbereichs. So liefen die Bemühungen von Ohnesorge um eine Atombombe streng getrennt von den Arbeiten an einer “Uranbombe”, die unter der Obhut des Reichsforschungsrates und der Heereswaffenamtes in einer Reihe von Forschungsstätten in Deutschland betrieben wurden.

Die Post-Forschung erreichte auf ihrem Weg zu einer Atombombe ansehnliche Teilerfolge. So konnte insbesondere v. Ardenne bis Kriegsende eine Musteranlage errichten, in der eine der Hauptschwierigkeiten bei der Kernenergie-Gewinnung, die Trennung der Isotopen bei den Uran-Atomen, zufriedenstellend gelöst war.

Als Ohnesorge erstmals bei Hitler über eine Atombombe Vortrag hielt, hatte er das Pech, daß Hitler bereits vom Heereswaffenamt auf die Idee einer Uranbombe aufmerksam gemacht worden war und bezüglich einer Verwirklichung der Idee die erste Enttäuschung hinter sich hatte. Trotzdem ließ Hitler Ohnesorge am Bau einer Uranbombe weiterarbeiten und wohl auch gelegentlich darüber berichten, obwohl Hitler nicht daran glaubte, eine Atombombe noch vor Kriegsende nutzen oder gar zu Erringung des Endsieges einsetzen zu können.

Ohnesorge had the ambition to present the results of his “postal-only research” to Hitler himself. For this reason, the minister banned his scientists from contacting colleagues outside the postal service. Thus the efforts of Ohnesorge for an atomic bomb were strictly separated from the work on a “uranium bomb,” which was carried out under the care of the Reich Research Council and the Army Ordnance Office in a number of research facilities in Germany.

On its way to an atomic bomb, the postal research achieved considerable partial successes. Thus von Ardenne in particular was able to erect a model plant by the end of the war in which one of the main difficulties in obtaining nuclear energy, the separation of the isotopes of uranium atoms, was satisfactorily solved.

When Ohnesorge first spoke to Hitler about an atomic bomb, he was unlucky that Hitler had already been made aware of the idea of a uranium bomb by the Army Ordnance Office and that he had been disappointed with the realization of the idea. Nevertheless, Hitler had Ohnesorge continue to work on the construction of a uranium bomb and probably also reported on it occasionally, although Hitler did not believe that he would be able to use an atomic bomb before the end of the war or even use it to achieve the final victory.

Boris Chertok. 2005–2012. *Rockets and People.* 4 vols.
Washington, DC: U.S. Government Printing Office.
[**https://www.nasa.gov/connect/ebooks/rockets_people_vol1_detail.html**]

[Vol. 1, pp. 217–218:] The Smersh military intelligence representative posed the following question to us at a meeting: "The Germans have issued leaflets that say that we will not take Berlin, and that we will receive such a blow that there won't be any bones to gather. The Führer has a secret weapon in store so that the Red Army will be completely annihilated on German soil. What could that weapon be?"

Indeed, what could it be? If it were the V-2, then no matter how many of them Hitler had "in store," this weapon would not bother the Red Army. This much was clear to us. Chemical weapons? using them in any form on German soil would now be more dangerous to the Germans than to us.

We decided that this was pure propaganda. And it turned out we were right. In the United States, Germany, and the USSR, a new, top-secret weapon really was being developed—an atomic weapon. But even we, who had access to top-secret materials, knew virtually nothing about it until 6 August 1945, when the atomic bomb was dropped on Hiroshima.

Back then, we did not know that just a stone's throw away, a group of specialists from Kurchatov's team was already preparing to search for German atomic secrets.This team had the highest authority, for at that time the main chief of our atomic operations was Lavrentiy Beriya himself, and other related special committees were being directed by powerful organizers such as Vannikov and Malyshev. We did not know that in addition to the allied armies heading toward our troops from the west, there were also special missions being sent out to seize German rocket technology and rocket specialists, search for nuclear physicists, and seize everything that had been done in Germany on the new scientific frontiers—first and foremost in the fields of guided missiles, nuclear fission, and radar.

[Vol. 1, pp. 231–233:] When asked who was considered the most prominent among the specialists in the field of vacuum tubes, Wilki responded, "Germany is proud of Professor Manfred von Ardenne. This is a man with big ideas. He was a great engineer and visionary."

"Why do you say 'was'?"

"The past two years he was working on some new idea—a new secret weapon. We don't know anything about it. I think it is at the Postal Ministry or the Kaiser Wilhelm Institute.

[Comments added by Chertok in the 1990s:] We were very familiar with the name Manfred von Ardenne from prewar literature on vacuum tubes. Much later we found out that he had been in Dahlem collaborating with German physicists who were working on the atomic bomb. The U.S., British, and Soviet intelligence services were hunting for a lot more information about Ardenne and his activities. When the Americans took prisoner practically the entire German elite involved in work on the atomic bomb, von Ardenne was not among them. He turned up in the Soviet Union and worked very productively for many years at the Sukhumi Institute of the Ministry of Medium Machine-Building. He was treated respectfully and high government awards were conferred on him.

[Vol. 1, pp. 247–250:] If the Germans had managed to create an atomic bomb before the Americans and then put two or three bombs into two or three of the many hundreds of A-4 rockets launched at Britain, the world today might look completely different. [...]

In August 1945, when we were in Thuringia, we heard on the radio about the dropping of atomic bombs on Hiroshima and Nagasaki. We first of all tried to understand what they were talking about.

There were no Soviet specialists among us at that time who had the slightest involvement in atomic research. Nevertheless, our knowledge of physics helped us, in a group discussion, to assume that the Americans had succeeded in creating a bomb by converting part of the mass of a substance into energy, in accordance with Einstein's famous formula: $E = mc^2$. There and then, we started to question Helmut Gröttrup about what had been known in Peenemünde regarding German work on the creation of an atomic bomb. To what extent were the German directors of the long-range missile program—in particular Dornberger, von Braun, or their closest assistants—familiar with the possibilities of creating an atomic bomb? Long conversations with Gröttrup enabled us to understand that work on some sort of super-powerful explosive had been conducted in Germany. Gröttrup was well acquainted with the names Heisenberg and von Ardenne, which I mentioned as possible scientists who could have been working on an atomic bomb. Moreover, he said that in the summer of 1943 the Peenemünde directors had, under great secrecy, talked about some new powerful explosive. For the specialists at Peenemünde this was very important. They understood that the ordinary TNT used in A-4 warheads—in quantities of 700–800 kilograms per warhead—would produce an effect no greater than a conventional 1,000 kilogram bomb dropped from an airplane.

British and American aviation had already dropped countless such bombs on German cities. Nevertheless, Germany had continued to fight and had even expanded its development of new weapons. Gröttrup recalled that he had heard about the new explosive when von Braun had been sent to Berlin to consult with the infantry command about the prospects of increasing the power of missile warheads.

Upon his return, von Braun did not say with whom he had met in Berlin. Gröttrup, smiling, recalled that it had been nice to hear from his boss that the theoretical physicists, despite the very interesting problem they were working on, had absolutely no engineering experience—in contrast to the missile specialists, they could not imagine how they needed to organize their work in order to transition from naked theory to "living" objects.

[Vol. 1, pp. 305–306:] We did not manage to pick up Baron Wernher von Braun through Operation Ost, and I think that this was good both for us and for him. Despite all of his capabilities, what he achieved in the United States would have been impossible for him to achieve in the Soviet Union. It is true, another prominent scientist, professor, doctor, and also baron, Manfred von Ardenne, who had worked in the Soviet Union from 1945 to 1955 at the Electrophysics Institute in Sukhumi, was awarded the title Hero of Socialist Labor for his participation in the creation of the Soviet atomic bomb. It should be noted, however, that von Ardenne had not been a member of the Nazi Party, and he had not created weapons of mass destruction under the Nazis.

Philip Morrison to Robert Furman. The German Reichspost and Nuclear Research. 24 April 1944. [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]

We now have three independent pieces of evidence that the Reichspost is interested in neutron research or wishes us to think that:

> 1) Several years ago M. von Ardenne thanked the Reichspost minister, a man named Ohnesorge, for supporting the entrance of von Ardenne's laboratory into work in nuclear physics.
>
> 2) In October 1943 (Naturwissenschaften, 31, p. 507) a man, otherwise unknown to us, named D. Lyons, published a mathematical letter on the slowing down of neutrons in homogeneous mixtures. The material of the letter is rather similar to much work done in the early days of this project and also in the published sources. Lyons rather ostentatiously signs his letter as coming from the Office for Special Physical Questions of the Research Division of the German Reichspost (Amt für physikalische Sonderfragen der Forschungsanstalt der Deutschen Reichspost) located in Berlin-Tempelhof.
>
> 3) The information from Swiss sources which you showed us this week mentioned that S. Flügge has left Hahn to go to work for the Reichspost.

It will be clear to you that there is something rather odd in this affair of the Reichspost's becoming interested in a field so very far from the radio and telephone research they have carried out in the past. It is equally strange that we learn about it in such a direct way as from Lyons' note, but confirm it in the rather indirect way of (1) and (3) above. I would suggest that you formulate inquiries about the activity of the Reichspost in the Tempelhof laboratories to whoever will know most about that outfit.

[Detlof Lyons was a real researcher in the Reichspost-funded nuclear research program.]

Robert R. Furman. 10 November 1944. [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-1 GERMANY: Personnel (Mar 43–Dec 44)]

[...] Von Ardenne is financed by Nazis. He claims he is inventing a super weapon. Swiss [Paul Scherrer, a vocal backbiter] have dim view of his ability.

OSS London. 9 June 1944. Report No. SUN-90. Report from Switzerland. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)] [See photograph on p. 3609.]

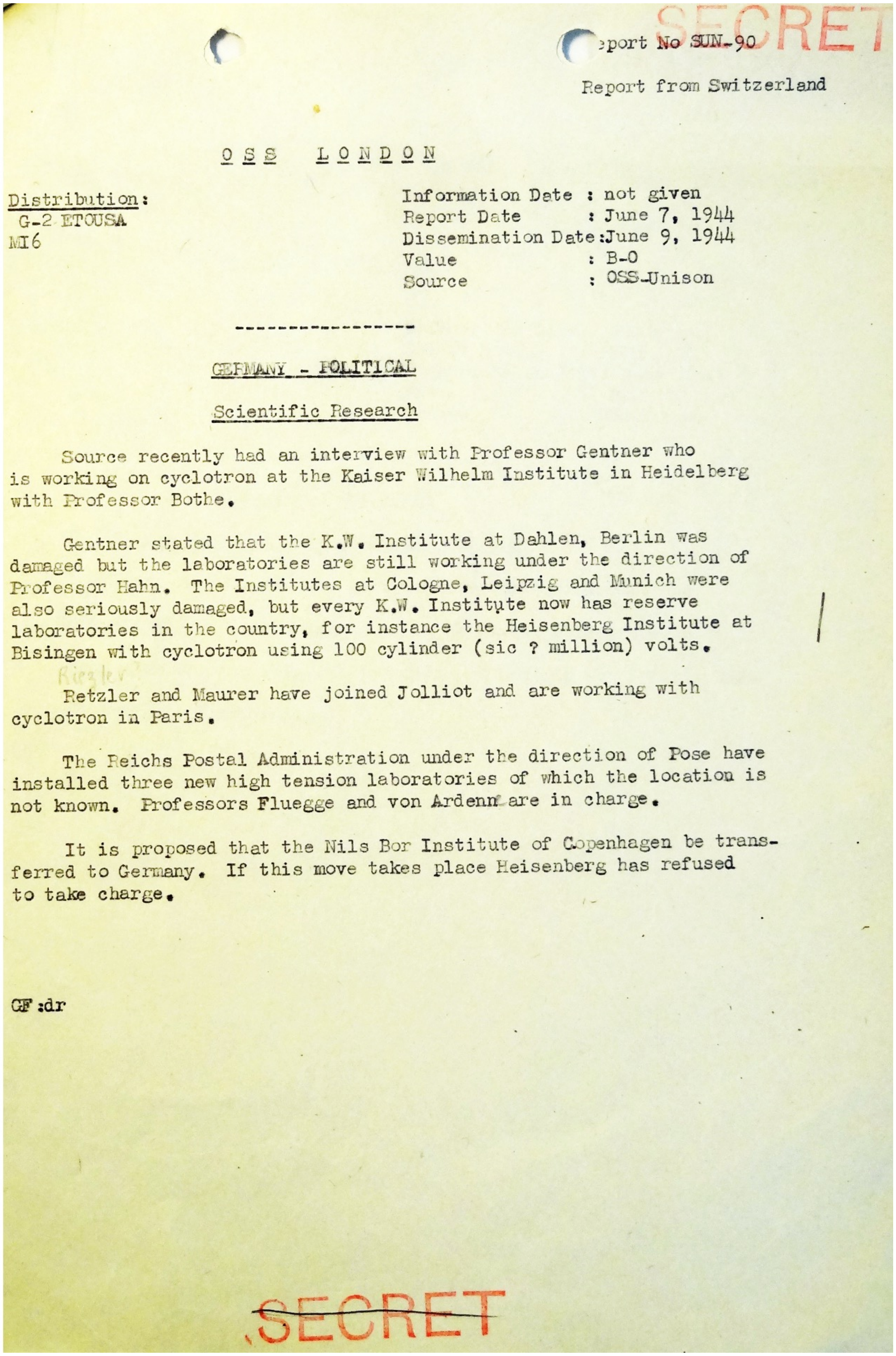
[...] The Reichs Postal Administration under the direction of Pose have installed three new high tension laboratories of which the location is not known. Professors Fluegge and von Ardenne are in charge. [...]

FA 002/0362. Letter from Rudolf Fleischmann to Fritz Kirchner. 18 August 1943. Archive of Deutsches Museum Munich.

The Strassburg high-tension generator is the only one in Germany or occupied countries of 1.5 million volts except the Reichspost's in Zeuthen-Miersdorf.

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)



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eport No SUN-90

Report from Switzerland

OSS LONDON

Distribution:
G-2 ETOUSA
MI6

Information Date : not given
Report Date : June 7, 1944
Dissemination Date : June 9, 1944
Value : B-0
Source : OSS-Unison

GERMANY - POLITICAL

Scientific Research

Source recently had an interview with Professor Gentner who is working on cyclotron at the Kaiser Wilhelm Institute in Heidelberg with Professor Bothe.

Gentner stated that the K.W. Institute at Dahlen, Berlin was damaged but the laboratories are still working under the direction of Professor Hahn. The Institutes at Cologne, Leipzig and Munich were also seriously damaged, but every K.W. Institute now has reserve laboratories in the country, for instance the Heisenberg Institute at Bisingen with cyclotron using 100 cylinder (sic ? million) volts.

Riezler?

Retzler and Maurer have joined Jolliot and are working with cyclotron in Paris.

The Reichs Postal Administration under the direction of Pose have installed three new high tension laboratories of which the location is not known. Professors Fluegge and von Ardenne are in charge.

It is proposed that the Nils Bor Institute of Copenhagen be transferred to Germany. If this move takes place Heisenberg has refused to take charge.

GF:dr

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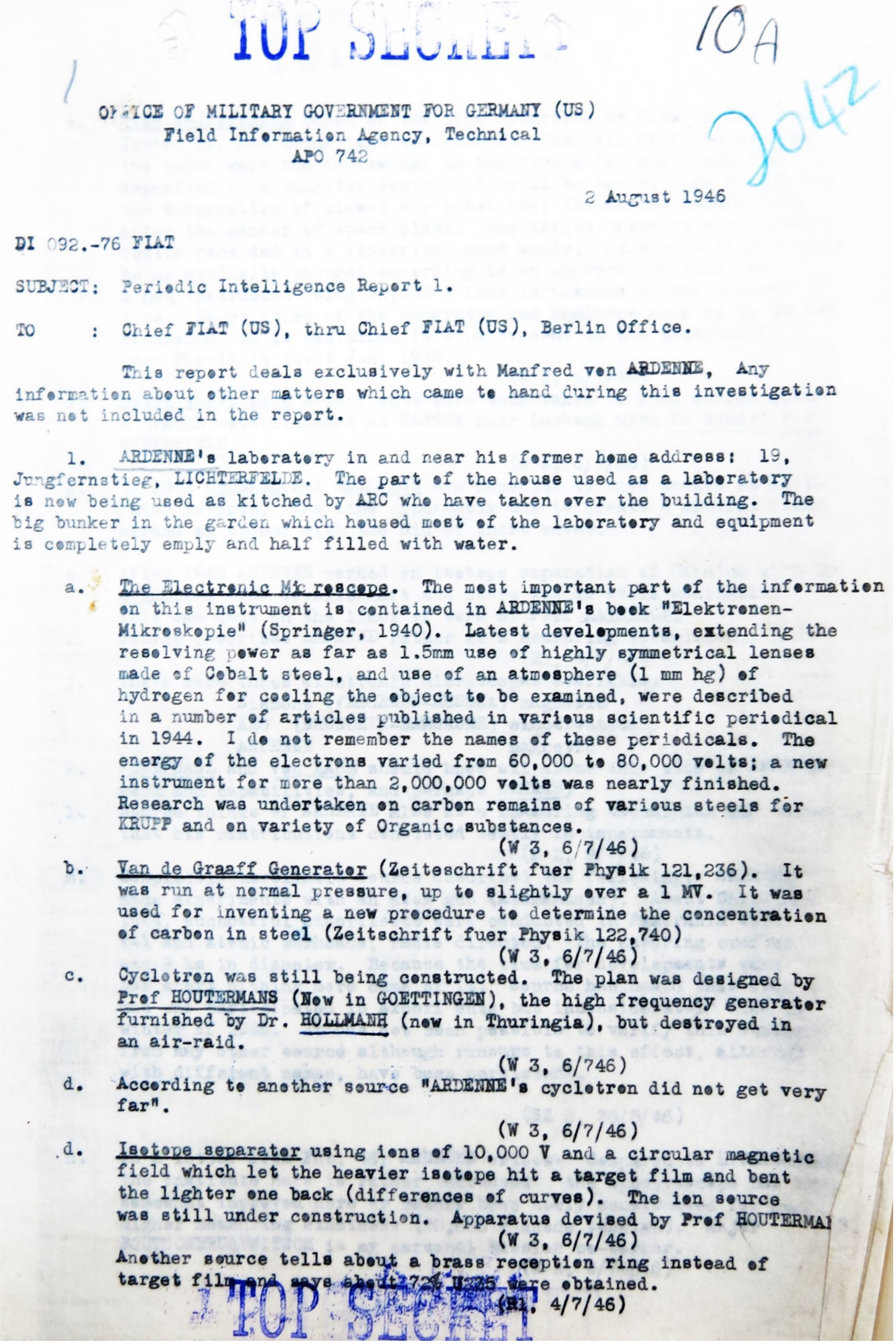
Figure D.213: "The Reichs Postal Administration under the direction of Pose have installed three new high tension laboratories of which the location is not known. Professors Fluegge and von Ardenne are in charge." Were these three calutron-based enrichment facilities? [OSS London. 9 June 1944. Report No. SUN-90. Report from Switzerland. NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)]

DI 092.-76 FIAT. Subject: Periodic Intelligence Report 1. 2 August 1946. TNA FO 1031/59.



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J042

OFFICE OF MILITARY GOVERNMENT FOR GERMANY (US)
Field Information Agency, Technical
APO 742

2 August 1946

DI 092.-76 FIAT

SUBJECT: Periodic Intelligence Report 1.

TO : Chief FIAT (US), thru Chief FIAT (US), Berlin Office.

This report deals exclusively with Manfred von ARDENNE. Any information about other matters which came to hand during this investigation was not included in the report.

1. ARDENNE's laboratory in and near his former home address: 19, Jungfernstieg, LICHTERFELDE. The part of the house used as a laboratory is now being used as kitched by ARC who have taken over the building. The big bunker in the garden which housed most of the laboratory and equipment is completely emply and half filled with water.

a. The Electronic Microscope. The most important part of the information on this instrument is contained in ARDENNE's book "Elektronen-Mikroskopie" (Springer, 1940). Latest developments, extending the resolving power as far as 1.5mm use of highly symmetrical lenses made of Cobalt steel, and use of an atmosphere (1 mm hg) of hydrogen for cooling the object to be examined, were described in a number of articles published in various scientific periodical in 1944. I do not remember the names of these periodicals. The energy of the electrons varied from 60,000 to 80,000 volts; a new instrument for more than 2,000,000 volts was nearly finished. Research was undertaken on carbon remains of various steels for KRUPP and on variety of Organic substances.
(W 3, 6/7/46)

b. Van de Graaff Generator (Zeiteschrift fuer Physik 121,236). It was run at normal pressure, up to slightly over a 1 MV. It was used for inventing a new procedure to determine the concentration of carbon in steel (Zeitschrift fuer Physik 122,740)
(W 3, 6/7/46)

c. Cyclotron was still being constructed. The plan was designed by Prof HOUTERMANS (Now in GOETTINGEN), the high frequency generator furnished by Dr. HOLLMANH (now in Thuringia), but destroyed in an air-raid.
(W 3, 6/746)

d. According to another source "ARDENNE's cyclotron did not get very far".
(W 3, 6/7/46)

d. Isotope separator using ions of 10,000 V and a circular magnetic field which let the heavier isotope hit a target film and bent the lighter one back (differences of curves). The ion source was still under construction. Apparatus devised by Prof HOUTERMA
(W 3, 6/7/46)
Another source tells about a brass reception ring instead of target film and says about 72% U235 were obtained.
(R1. 4/7/46)

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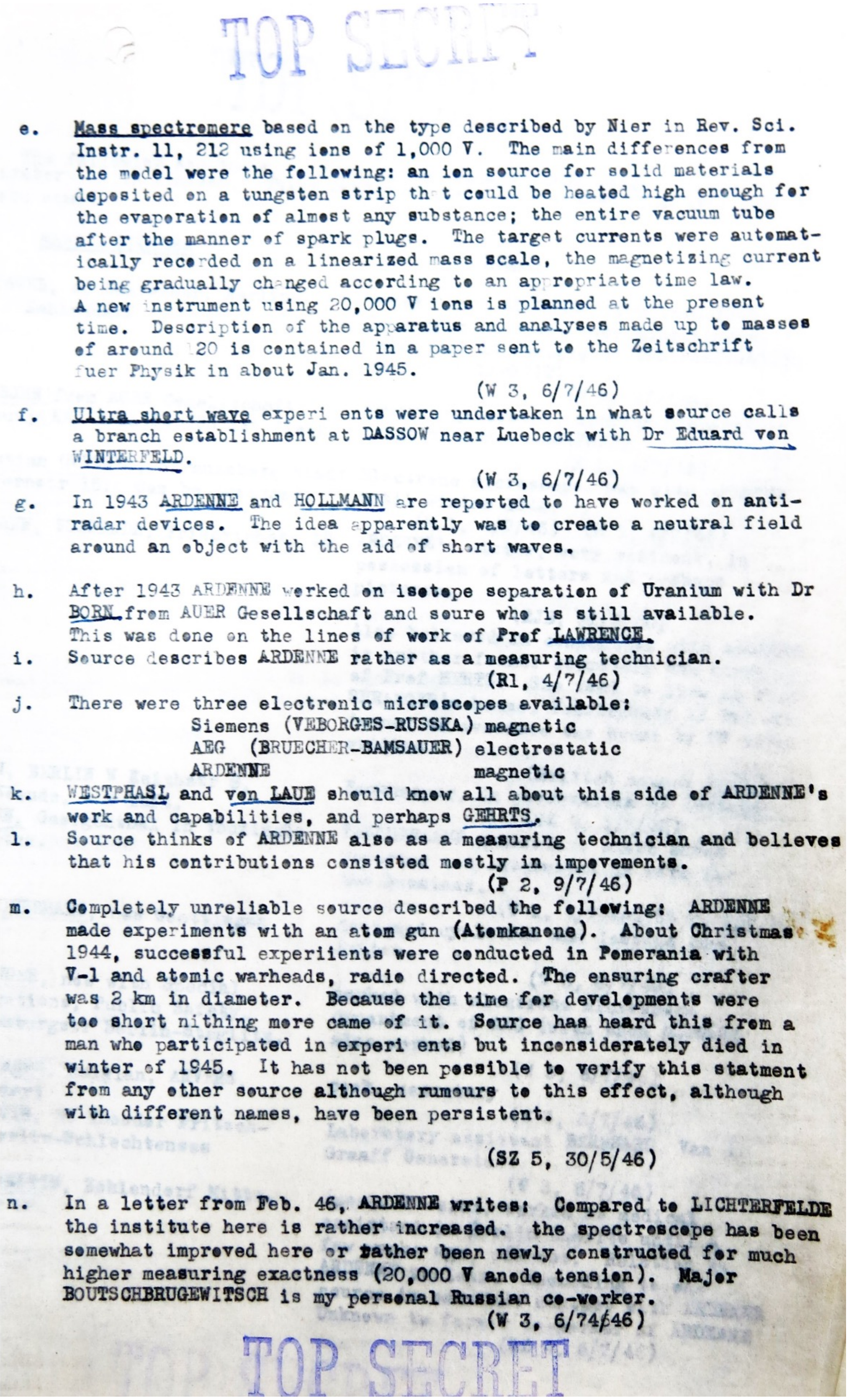
Figure D.214: DI 092.-76 FIAT. Subject: Periodic Intelligence Report 1. 2 August 1946 [TNA FO 1031/59]

DI 092.-76 FIAT. Subject: Periodic Intelligence Report 1. 2 August 1946. TNA FO 1031/59.



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e. Mass spectremere based en the type described by Nier in Rev. Sci. Instr. 11, 212 using iens ef 1,000 V. The main differences frem the medel were the fellewing: an ien seurce fer selid materials depesited en a tungsten strip that ceuld be heated high eneugh fer the evaperatien ef almest any substance; the entire vacuum tube after the manner ef spark plugs. The target currents were autematically recerded en a linearized mass scale, the magnetizing current being gradually changed accerding te an appropriate time law. A new instrument using 20,000 V iens is planned at the present time. Descriptien ef the apparatus and analyses made up te masses ef areund 120 is centained in a paper sent te the Zeitschrift fuer Physik in abeut Jan. 1945.

(W 3, 6/7/46)

f. Ultra shert wave experiments were undertaken in what seurce calls a branch establishment at DASSOW near Luebeck with Dr Eduard ven WINTERFELD.

(W 3, 6/7/46)

g. In 1943 ARDENNE and HOLLMANN are reperted te have werked en anti-radar devices. The idea apparently was te create a neutral field areund an ebject with the aid ef shert waves.

h. After 1943 ARDENNE werked en isetepe separatien ef Uranium with Dr BORN frem AUER Gesellschaft and seure whe is still available. This was dene en the lines ef werk ef Pref LAWRENCE.

i. Seurce describes ARDENNE rather as a measuring technician.

(R1, 4/7/46)

j. There were three electrenic micrescepes available:
Siemens (VEBORGES-RUSSKA) magnetic
AEG (BRUECHER-BAMSAUER) electrestatic
ARDENNE magnetic

k. WESTPHASL and ven LAUE sheuld knew all abeut this side ef ARDENNE's werk and capabilities, and perhaps GEHRTS.

l. Seurce thinks ef ARDENNE alse as a measuring technician and believes that his centributiens censisted mestly in impevements.

(P 2, 9/7/46)

m. Cempletely unreliable seurce described the fellewing: ARDENNE made experiments with an atem gun (Atemkanene). Abeut Christmas 1944, successful experiients were cenducted in Pemerania with V-1 and atemic warheads, radie directed. The ensuring crafter was 2 km in diameter. Because the time fer develepments were tee shert nithing mere came ef it. Seurce has heard this frem a man whe participated in experiments but incensiderately died in winter ef 1945. It has net been pessible te verify this statment frem any ether seurce altheugh rumeurs te this effect, altheugh with different names, have been persistent.

(SZ 5, 30/5/46)

n. In a letter frem Feb. 46, ARDENNE writes: Cempared te LICHTERFELDE the institute here is rather increased. the spectrescepe has been semewhat impreved here er rather been newly censtructed fer much higher measuring exactness (20,000 V anede tensien). Majer BOUTSCHBRUGEWITSCH is my persenal Russian ce-werker.

(W 3, 6/74/46)

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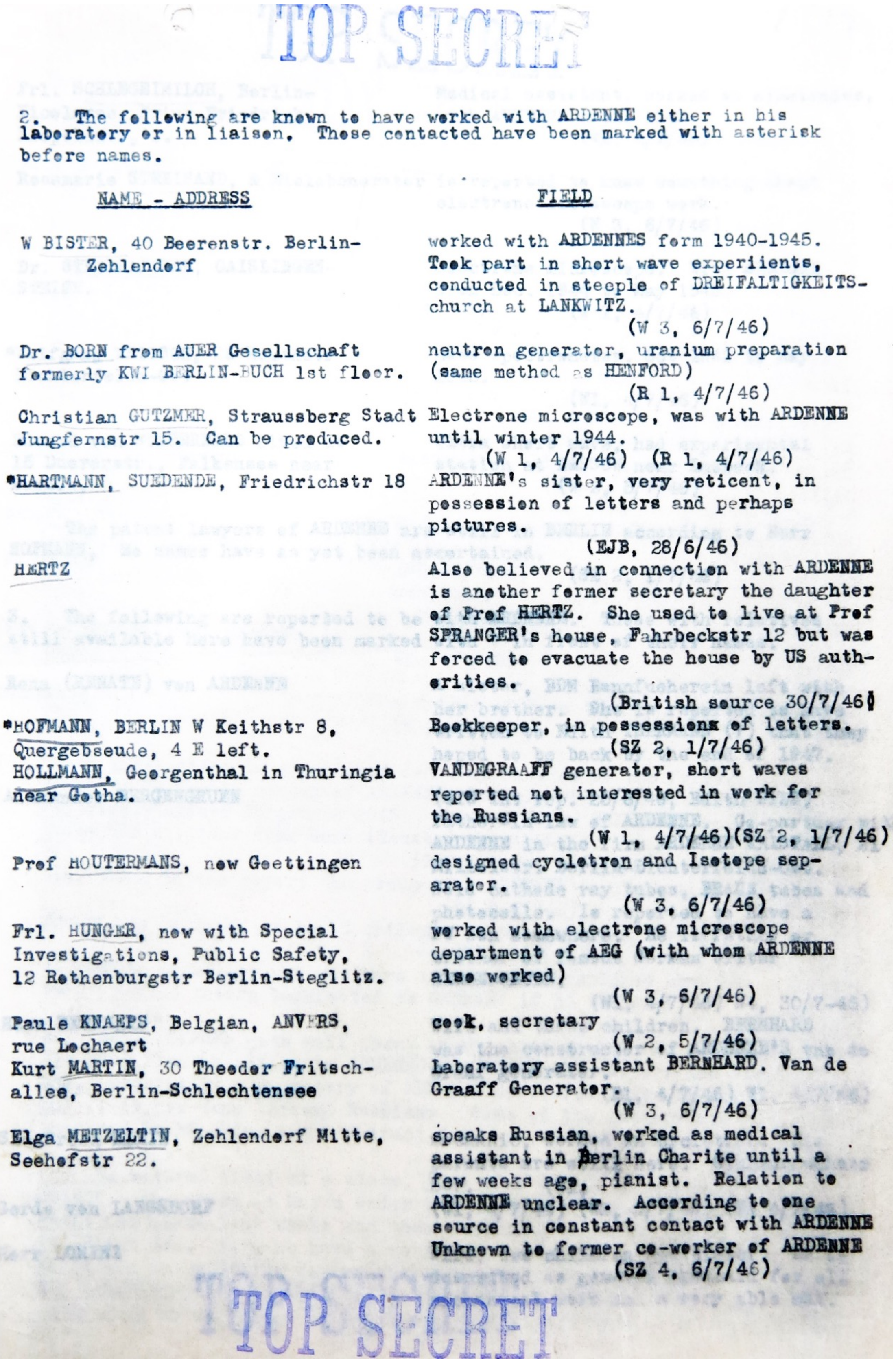
Figure D.215: DI 092.-76 FIAT. Subject: Periodic Intelligence Report 1. 2 August 1946 [TNA FO 1031/59]

DI 092.-76 FIAT. Subject: Periodic Intelligence Report 1. 2 August 1946. TNA FO 1031/59.



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2. The following are known to have worked with ARDENNE either in his laboratory or in liaison. Those contacted have been marked with asterisk before names.

NAME - ADDRESS	FIELD
W BISTER, 40 Beerenstr. Berlin-Zehlendorf	worked with ARDENNES form 1940-1945. Took part in short wave experiients, conducted in steeple of DREIFALTIGKEITS-church at LANKWITZ. (W 3, 6/7/46)
Dr. BORN from AUER Gesellschaft formerly KWI BERLIN-BUCH 1st floor.	neutron generator, uranium preparation (same method as HENFORD) (R 1, 4/7/46)
Christian GUTZMER, Straussberg Stadt Jungfernstr 15. Can be produced.	Electrone microscope, was with ARDENNE until winter 1944. (W 1, 4/7/46) (R 1, 4/7/46)
*HARTMANN, SUEDENDE, Friedrichstr 18	ARDENNE's sister, very reticent, in possession of letters and perhaps pictures. (EJB, 28/6/46)
HERTZ	Also believed in connection with ARDENNE is another former secretary the daughter of Prof HERTZ. She used to live at Prof SPRANGER's house, Fahrbeckstr 12 but was forced to evacuate the house by US authorities. (British source 30/7/46)
*HOFMANN, BERLIN W Keithstr 8, Quergebseude, 4 E left.	Bookkeeper, in possessions of letters. (SZ 2, 1/7/46)
HOLLMANN, Georgenthal in Thuringia near Gotha.	VANDEGRAAFF generator, short waves reported not interested in work for the Russians. (W 1, 4/7/46)(SZ 2, 1/7/46)
Prof HOUTERMANS, now Goettingen	designed cyclotron and Isotope separator. (W 3, 6/7/46)
Frl. HUNGER, now with Special Investigations, Public Safety, 12 Rothenburgstr Berlin-Steglitz.	worked with electrone microscope department of AEG (with whom ARDENNE also worked) (W 3, 6/7/46)
Paule KNAEPS, Belgian, ANVERS, rue Lochaert	cook, secretary (W 2, 5/7/46)
Kurt MARTIN, 30 Theodor Fritsch-allee, Berlin-Schlechtensee	Laboratory assistant BERNHARD. Van de Graaff Generator. (W 3, 6/7/46)
Elga METZELTIN, Zehlendorf Mitte, Seehofstr 22.	speaks Russian, worked as medical assistant in Berlin Charite until a few weeks ago, pianist. Relation to ARDENNE unclear. According to one source in constant contact with ARDENNE Unknown to former co-worker of ARDENNE (SZ 4, 6/7/46)

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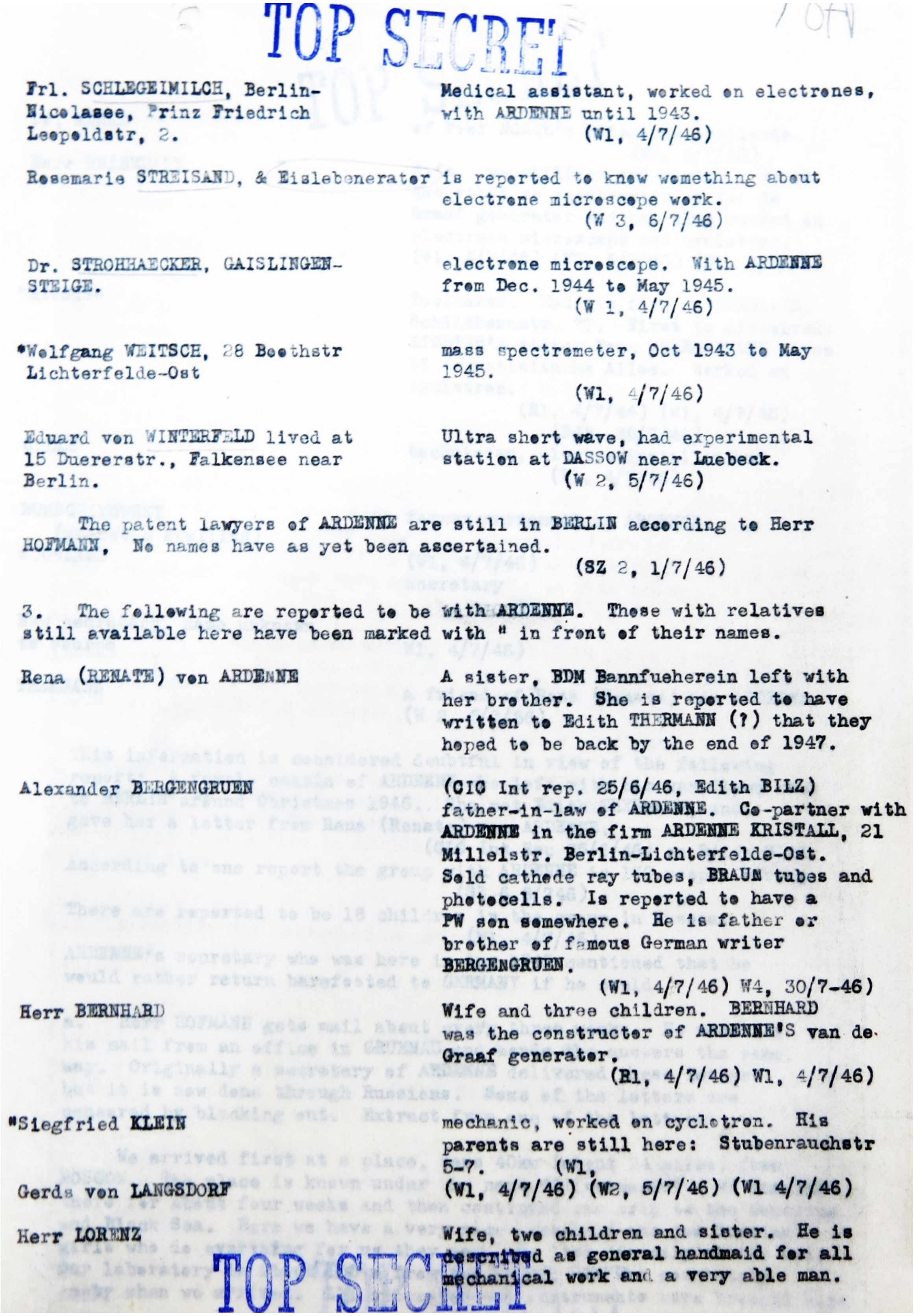
Figure D.216: DI 092.-76 FIAT. Subject: Periodic Intelligence Report 1. 2 August 1946 [TNA FO 1031/59]



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/ OfV

Frl. SCHLEGEIMILCH, Berlin-Nicolasee, Prinz Friedrich Leopoldstr, 2.	Medical assistant, worked en electrenes, with ARDENNE until 1943. (W1, 4/7/46)
Resemarie STREISAND, & Eislebenerater	is reperted te knew wemething abeut electrene micrescepe werk. (W 3, 6/7/46)
Dr. STROHHAECKER, GAISLINGEN-STEIGE.	electrene micrescepe. With ARDENNE frem Dec. 1944 te May 1945. (W 1, 4/7/46)
•Welfgang WEITSCH, 28 Beethstr Lichterfelde-Ost	mass spectremeter, Oct 1943 te May 1945. (W1, 4/7/46)
Eduard ven WINTERFELD lived at 15 Duererstr., Falkensee near Berlin.	Ultra shert wave, had experimental statien at DASSOW near Luebeck. (W 2, 5/7/46)

The patent lawyers ef ARDENNE are still in BERLIN accerding te Herr HOFMANN, Ne names have as yet been ascertained.
(SZ 2, 1/7/46)

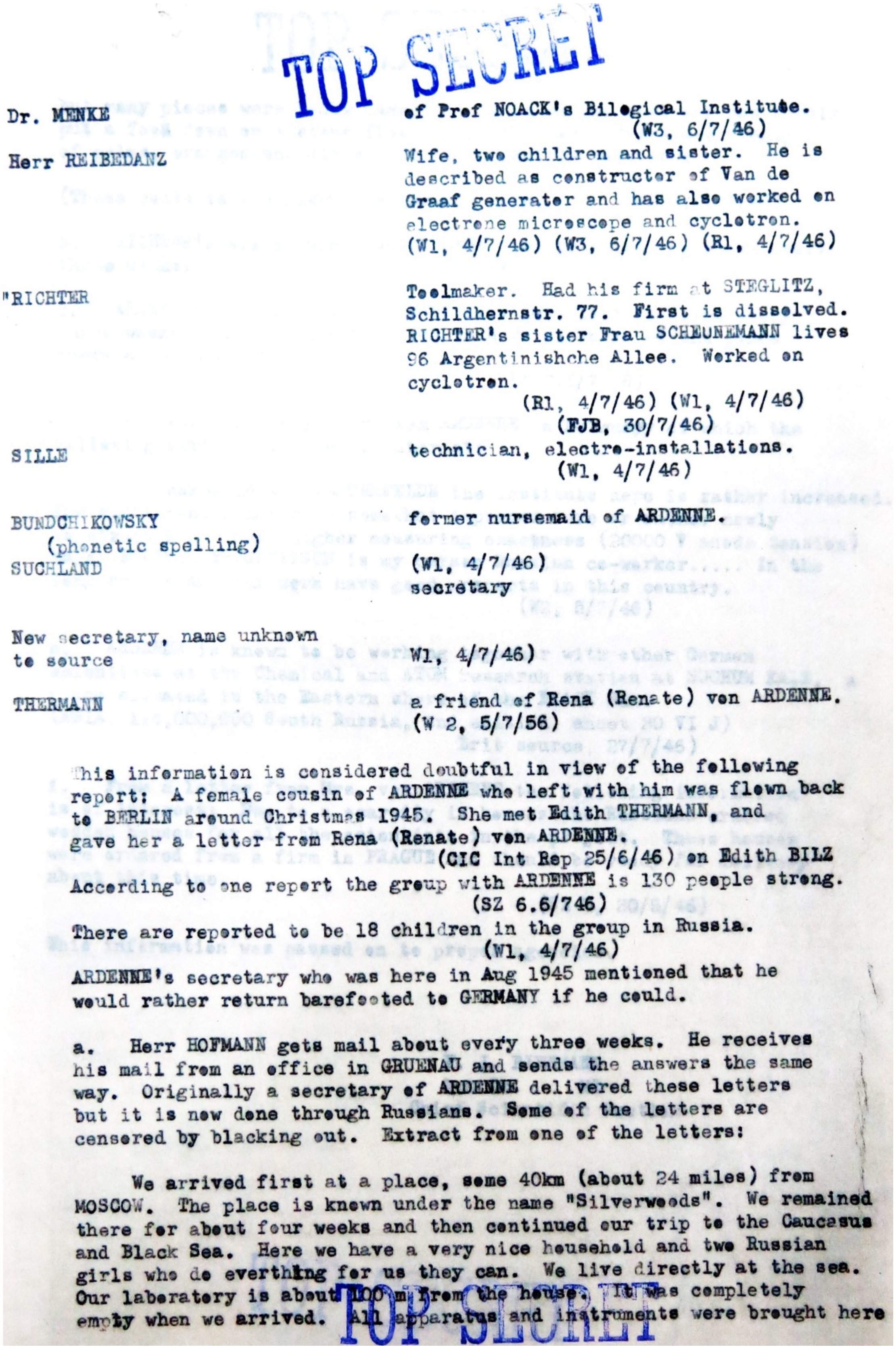
3. The fellewing are reperted te be with ARDENNE. These with relatives still available here have been marked with " in frent ef their names.

Rena (RENATE) ven ARDENNE	A sister, BDM Bannfueherein left with her brether. She is reperted te have written te Edith THERMANN (?) that they heped te be back by the end ef 1947.
Alexander BERGENGRUEN	(CIC Int rep. 25/6/46, Edith BILZ) father-in-law ef ARDENNE. Ce-partner with ARDENNE in the firm ARDENNE KRISTALL, 21 Millelstr. Berlin-Lichterfelde-Ost. Seld cathede ray tubes, BRAUN tubes and phetecells. Is reperted te have a PW sen semewhere. He is father er brether ef fameus German writer BERGENGRUEN. (W1, 4/7/46) W4, 30/7-46)
Herr BERNHARD	Wife and three children. BERNHARD was the constructer ef ARDENNE'S van de Graaf generater. (R1, 4/7/46) W1, 4/7/46)
"Siegfried KLEIN	mechanic, werked en cycletren. His parents are still here: Stubenrauchstr 5-7. (W1,
Gerda von LANGSDORF	(W1, 4/7/46) (W2, 5/7/46) (W1 4/7/46)
Herr LORENZ	Wife, twe children and sister. He is described as general handmaid fer all mechanical werk and a very able man.

TOP SECRET

Figure D.217: DI 092.-76 FIAT. Subject: Periodic Intelligence Report 1. 2 August 1946 [TNA FO 1031/59]

DI 092.-76 FIAT. Subject: Periodic Intelligence Report 1. 2 August 1946. TNA FO 1031/59.



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Dr. MENKE	of Prof NOACK's Biological Institute. (W3, 6/7/46)
Herr REIBEDANZ	Wife, two children and sister. He is described as constructor of Van de Graaf generator and has also worked on electrone microscope and cyclotron. (W1, 4/7/46) (W3, 6/7/46) (R1, 4/7/46)
"RICHTER	Toolmaker. Had his firm at STEGLITZ, Schildhornstr. 77. First is dissolved. RICHTER's sister Frau SCHEUNEMANN lives 96 Argentinishche Allee. Worked on cyclotron. (R1, 4/7/46) (W1, 4/7/46) (FJB, 30/7/46)
SILLE	technician, electro-installations. (W1, 4/7/46)
BUNDCHIKOWSKY (phonetic spelling)	former nursemaid of ARDENNE. (W1, 4/7/46)
SUCHLAND	secretary
New secretary, name unknown to source	W1, 4/7/46)
THERMANN	a friend of Rena (Renate) von ARDENNE. (W 2, 5/7/56)

This information is considered doubtful in view of the following report: A female cousin of ARDENNE who left with him was flown back to BERLIN around Christmas 1945. She met Edith THERMANN, and gave her a letter from Rena (Renate) von ARDENNE. (CIC Int Rep 25/6/46) on Edith BILZ

According to one report the group with ARDENNE is 130 people strong. (SZ 6.6/746)

There are reported to be 18 children in the group in Russia. (W1, 4/7/46)

ARDENNE's secretary who was here in Aug 1945 mentioned that he would rather return barefooted to GERMANY if he could.

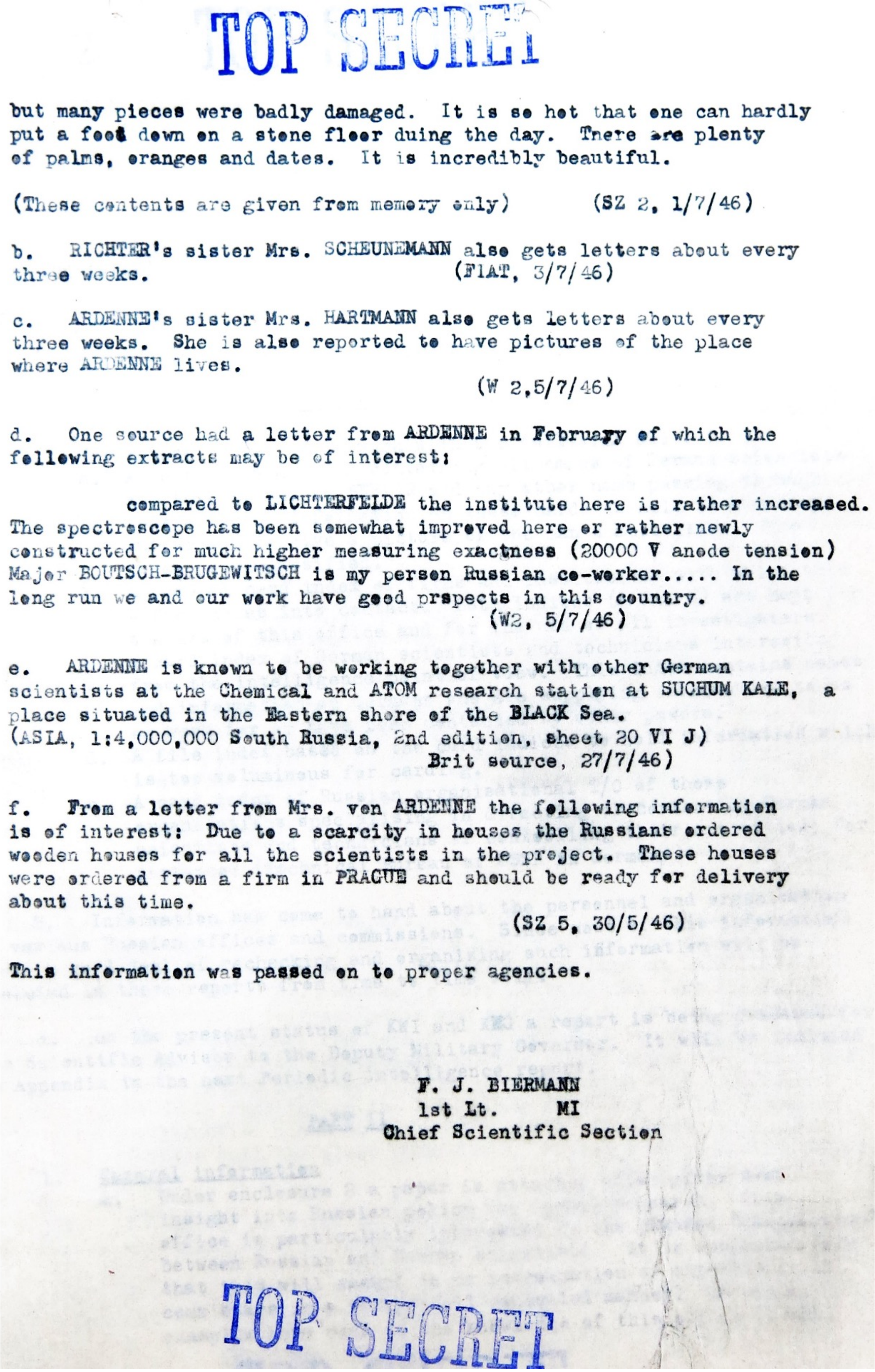
a. Herr HOFMANN gets mail about every three weeks. He receives his mail from an office in GRUENAU and sends the answers the same way. Originally a secretary of ARDENNE delivered these letters but it is now done through Russians. Some of the letters are censored by blacking out. Extract from one of the letters:

We arrived first at a place, some 40km (about 24 miles) from MOSCOW. The place is known under the name "Silverwoods". We remained there for about four weeks and then continued our trip to the Caucasus and Black Sea. Here we have a very nice household and two Russian girls who do everthing for us they can. We live directly at the sea. Our laboratory is about 100 m from the house. It was completely empty when we arrived. All apparatus and instruments were brought here

TOP SECRET

Figure D.218: DI 092.-76 FIAT. Subject: Periodic Intelligence Report 1. 2 August 1946 [TNA FO 1031/59]

DI 092.-76 FIAT. Subject: Periodic Intelligence Report 1. 2 August 1946. TNA FO 1031/59.



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but many pieces were badly damaged. It is so hot that one can hardly put a feet down on a stone floor duing the day. There are plenty of palms, oranges and dates. It is incredibly beautiful.

(These contents are given from memory only) (SZ 2, 1/7/46)

b. RICHTER's sister Mrs. SCHEUNEMANN also gets letters about every three weeks. (FIAT, 3/7/46)

c. ARDENNE's sister Mrs. HARTMANN also gets letters about every three weeks. She is also reported to have pictures of the place where ARDENNE lives.

(W 2,5/7/46)

d. One source had a letter from ARDENNE in February of which the following extracts may be of interest:

compared to LICHTERFELDE the institute here is rather increased. The spectroscope has been somewhat improved here or rather newly constructed for much higher measuring exactness (20000 V anode tension) Major BOUTSCH-BRUGEWITSCH is my person Russian co-worker..... In the long run we and our work have good prspects in this country.

(W2, 5/7/46)

e. ARDENNE is known to be working together with other German scientists at the Chemical and ATOM research station at SUCHUM KALE, a place situated in the Eastern shore of the BLACK Sea.
(ASIA, 1:4,000,000 South Russia, 2nd edition, sheet 20 VI J)
Brit source, 27/7/46)

f. From a letter from Mrs. von ARDENNE the following information is of interest: Due to a scarcity in houses the Russians ordered wooden houses for all the scientists in the project. These houses were ordered from a firm in PRAGUE and should be ready for delivery about this time.

(SZ 5, 30/5/46)

This information was passed on to proper agencies.

F. J. BIERMANN
1st Lt. MI
Chief Scientific Section

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Figure D.219: DI 092.-76 FIAT. Subject: Periodic Intelligence Report 1. 2 August 1946 [TNA FO 1031/59]

FA 002/0362. Letter from Major Calvert to Samuel Goudsmit. 8 December 1944. Archive of Deutsches Museum Munich.

[...] A prisoner of war has been located that served as an apprentice with the "Reichspost" in the field of telegraphy. While the prisoner of war is only seventeen years old, he has proven to be very intelligent, fully cooperative, and his statements can be considered reliable. Moreover, he is the son of a Berlin post office employee. In his first interview he made the following statement:

Berlin-Teltow, Mawlower Chaussee (GSGS 4480/3,R6) on open field next to new houses on south side of road, approximately opposite Moltkestrasse. PW states that the building was damaged by air-raid in 43, and about June 43 most of the establishment was transferred to Zeuthen near Berlin. PW went there once to install alarm wires around X-ray tubes (in his own words), which were supposed to be used for experiments in splitting the atom. If the tubes got overheated, the wire was supposed to melt and thus actuate the alarm.

Monthly Intelligence Summary. January 1945. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

II INFORMATION ON POSSIBLE T A SITES

4. Zeuthen:

Information was received from German P/W, who is a former employee of the Reichspost, that there is a high tension apparatus located in the village of Zeuthen near Berlin. P/W stated that he had heard that T A work was in progress at this location. Aerial photos of Zeuthen were obtained and the P/W pinpointed the building to which he referred. The work going on at this building, according to P/W is under the direction of the Reichspost. This information is corroborated to some extent by information previously reported by Dr. S. A. Goudsmit as a result of his Eindhoven investigation.

U.S. Army Air Forces General Henry H. Arnold. 1949. *Global Mission.* New York: Harper. pp. 491, 534. [See also AFHRA 43811 electronic pp. 1080–1081.]

In May, 1943, we received information from Zurich that Professor Max Planck, at the Kaiser Wilhelm Institute, in collaboration with Dr. Otto Hahn, was working on the splitting of the uranium atom. Also that other German scientists were on the threshold of solving this great and dangerous secret.

The Germans were supposed to have perfected an electric machine which would make it possible to complete the development of the atomic bomb. I was then asked to have our bombers in England make special missions against the various branches of the Kaiser Wilhelm Institute in Berlin. Prior to that, the British had destroyed a plant at Norway where the Germans had been experimenting with other phases of this project. [...]

When it came to establishing the Target Folders that would give us the size, location, general characteristics, special distinguishing marks, the type of construction, and other details necessary for bombing operations against a target like the complexes of the I. G. Farben Company, or the Krupp Works—such data did not exist in the United States. Accordingly, the Air Force had no recourse but to go to other sources for its information.

[“An electric machine which would make it possible to complete the development of the atomic bomb” sounds like an electromagnetic separator. Arnold said it was somewhere in the Berlin area and was bombed. The Kaiser Wilhelm Institute is not known to have had such a machine, but the Reichspost did—is that what Arnold meant?]

D.4.4 Uranium-235 Enrichment via Gaseous Diffusion

[Gustav Hertz (German, 1887–1975) developed gaseous diffusion methods of separating isotopes, starting sometime before 1923. See pp. 3619–3629. By 1932 he was achieving and publishing good results demonstrating separation of isotopes other than uranium. Did Hertz or others seriously pursue uranium enrichment via gaseous diffusion in Germany during the Third Reich? He worked at Siemens (one of the two largest German electrical equipment companies) throughout the Third Reich; exactly what he did is unclear, but his work was so important to the government that he was not harmed even though he was partially Jewish. At the end of the war, Stalin was so impressed by whatever he knew of Hertz's wartime work that he offered Hertz his own lab in the Soviet Union, where he then developed gaseous diffusion uranium enrichment methods for the postwar Soviet nuclear weapons program (pp. 3630–3638). Hertz's gaseous diffusion methods were also implemented by scientists at Oak Ridge as one of the main uranium enrichment methods in the United States during and after the war.

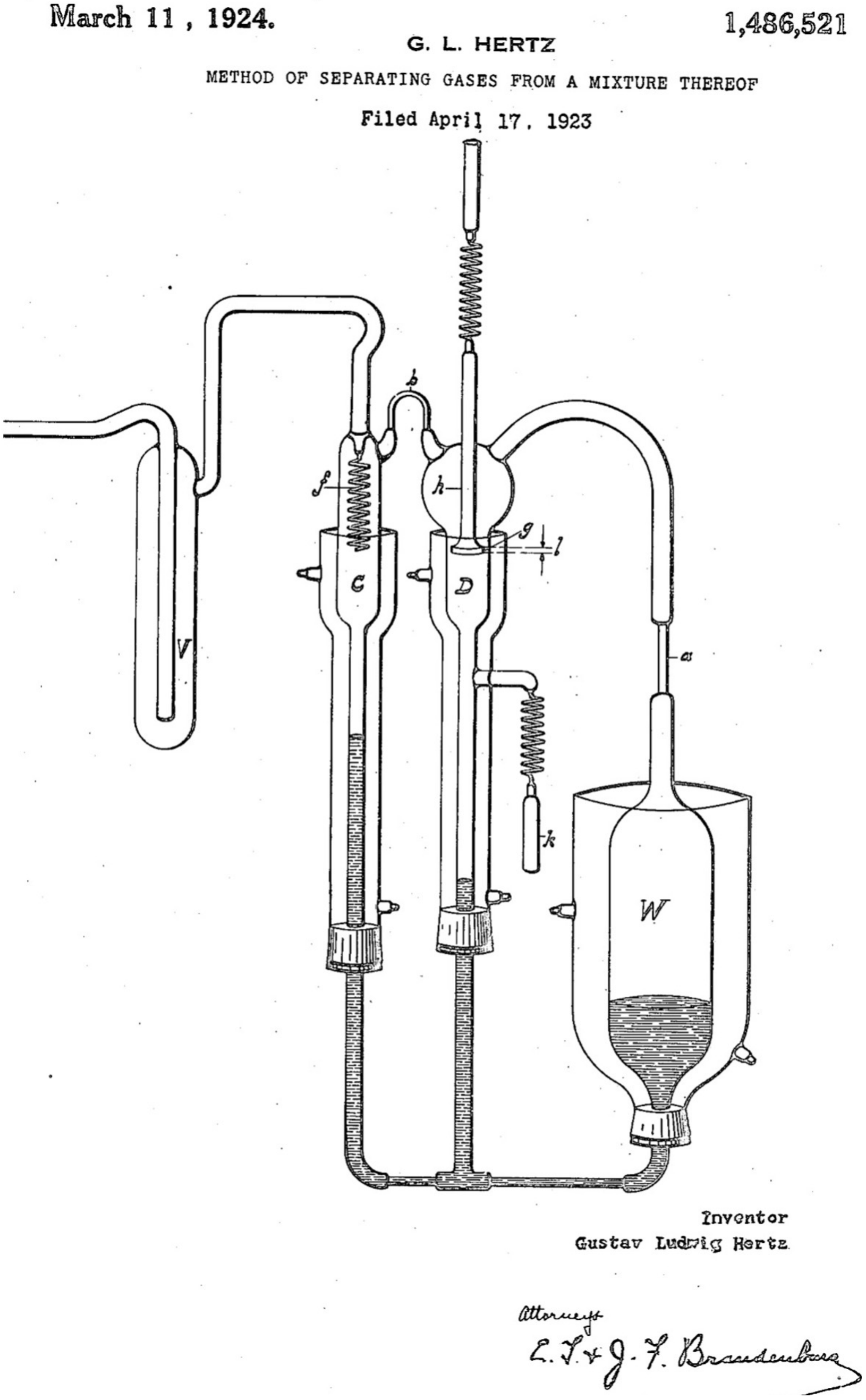
In 1927, Erika Cremer (German, 1900–1996) completed her Ph.D. research on (chemical) chain reactions under Max Bodenstein (p. 536). Building upon the pioneering work by Hertz, she began developing improved methods of gaseous diffusion enrichment and gas chromatography in the late 1930s and continued throughout World War II (p. 3640). She worked directly with Otto Hahn and Siegfried Flügge, among others. It seems likely that her work involved gaseous diffusion methods of separating uranium isotopes for the German nuclear program, though little documentation is currently publicly available. Cremer continued to work on gas chromatography after the war, and is best known for her postwar demonstrations and publications on gas chromatography, including those with her student Fritz Prior (Austrian, 1921–1996) [Bobleter 1997].

Hubert Krüger (German, 18??–19??, p. 3629), Rudolf Fleischmann (German, 1903–2002, p. 3639), and others also worked on gaseous diffusion enrichment.

Beginning in 1940, Auergesellschaft [probably Nikolaus Riehl (German, 1901–1990)] patented an industrial-scale uranium enrichment process that appears to have combined aspects of gaseous thermal diffusion and the PUREX process. See pp. 3641–3646. These patent documents prove that Auergesellschaft was involved not only in refining uranium from ore, but also in separating uranium isotopes. They also demonstrate that from the beginning of the war, Germany was interested in developing industrial-scale uranium enrichment, not merely small-scale laboratory experiments.

During the war, Erich Bagge (German, 1912–1996) led a team that invented, built, and demonstrated the "isotope sluice," an alternative form of gaseous diffusion enrichment. See pp. 3651–3662.

Based upon the successful laboratory demonstrations by Gustav Hertz, Erika Cremer, Hubert Krüger, Rudolf Fleischmann, Auergesellschaft, Bagge, and others, did Germany indeed build and operate large-scale gaseous diffusion plants for enriching uranium during the war?]



March 11, 1924. **1,486,521**

G. L. HERTZ

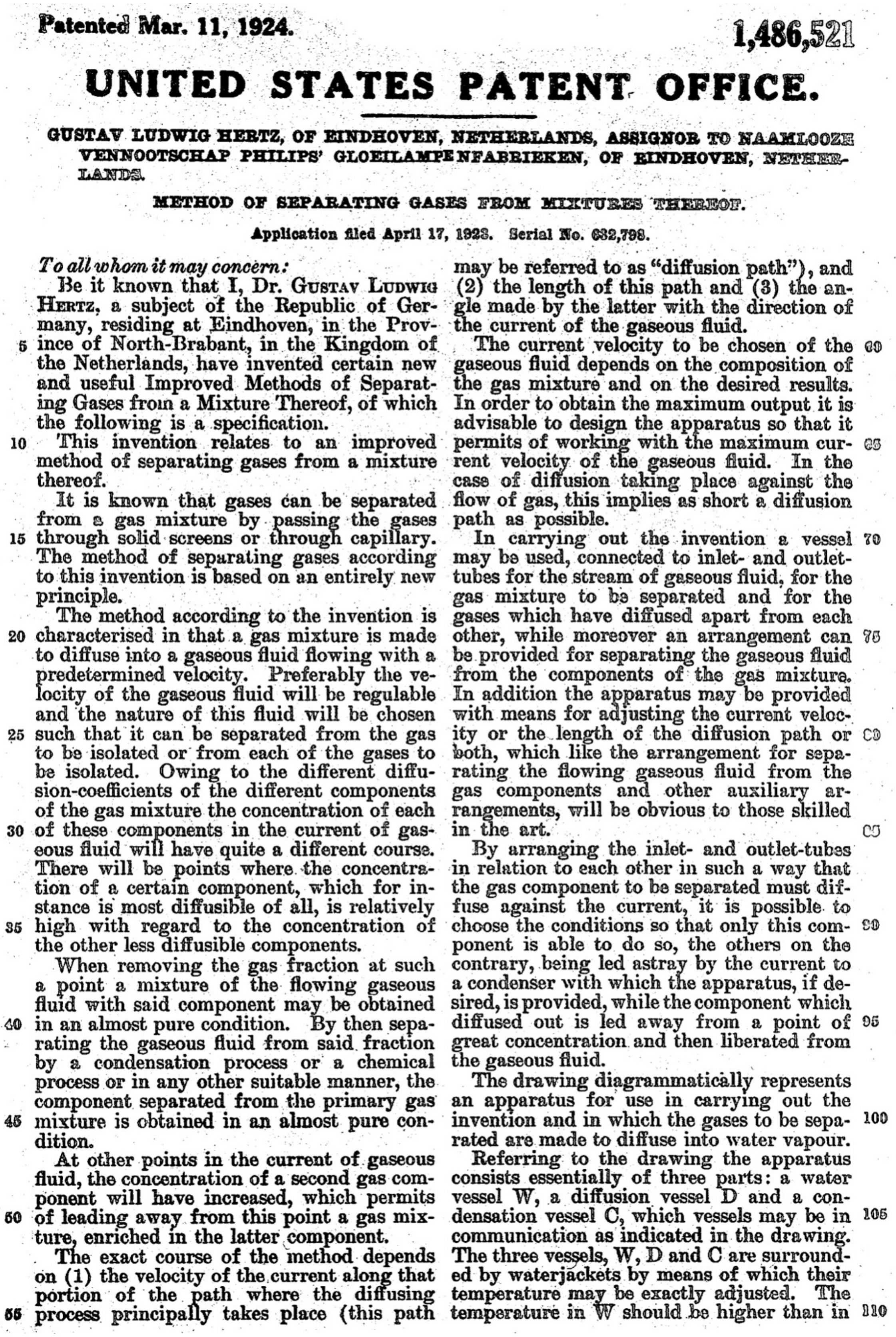
METHOD OF SEPARATING GASES FROM A MIXTURE THEREOF

Filed April 17, 1923

Inventor
Gustav Ludwig Hertz

Attorneys
E. F. & J. F. Brandenburg

Figure D.220: One of Gustav Hertz's first patents on gaseous diffusion for enrichment, filed in 1923 [U.S. Patent 1,486,521. Method of Separating Gases from a Mixture Thereof].



Patented Mar. 11, 1924. **1,486,521**

UNITED STATES PATENT OFFICE.

GUSTAV LUDWIG HERTZ, OF EINDHOVEN, NETHERLANDS, ASSIGNOR TO NAAMLOOZE VENNOOTSCHAP PHILIPS' GLOEILAMPENFABRIEKEN, OF EINDHOVEN, NETHERLANDS.

METHOD OF SEPARATING GASES FROM MIXTURES THEREOF.

Application filed April 17, 1923. Serial No. 632,798.

To all whom it may concern:

Be it known that I, Dr. GUSTAV LUDWIG HERTZ, a subject of the Republic of Germany, residing at Eindhoven, in the Province of North-Brabant, in the Kingdom of the Netherlands, have invented certain new and useful Improved Methods of Separating Gases from a Mixture Thereof, of which the following is a specification.

This invention relates to an improved method of separating gases from a mixture thereof.

It is known that gases can be separated from a gas mixture by passing the gases through solid screens or through capillary. The method of separating gases according to this invention is based on an entirely new principle.

The method according to the invention is characterised in that a gas mixture is made to diffuse into a gaseous fluid flowing with a predetermined velocity. Preferably the velocity of the gaseous fluid will be regulable and the nature of this fluid will be chosen such that it can be separated from the gas to be isolated or from each of the gases to be isolated. Owing to the different diffusion-coefficients of the different components of the gas mixture the concentration of each of these components in the current of gaseous fluid will have quite a different course. There will be points where the concentration of a certain component, which for instance is most diffusible of all, is relatively high with regard to the concentration of the other less diffusible components.

When removing the gas fraction at such a point a mixture of the flowing gaseous fluid with said component may be obtained in an almost pure condition. By then separating the gaseous fluid from said fraction by a condensation process or a chemical process or in any other suitable manner, the component separated from the primary gas mixture is obtained in an almost pure condition.

At other points in the current of gaseous fluid, the concentration of a second gas component will have increased, which permits of leading away from this point a gas mixture, enriched in the latter component.

The exact course of the method depends on (1) the velocity of the current along that portion of the path where the diffusing process principally takes place (this path may be referred to as "diffusion path"), and (2) the length of this path and (3) the angle made by the latter with the direction of the current of the gaseous fluid.

The current velocity to be chosen of the gaseous fluid depends on the composition of the gas mixture and on the desired results. In order to obtain the maximum output it is advisable to design the apparatus so that it permits of working with the maximum current velocity of the gaseous fluid. In the case of diffusion taking place against the flow of gas, this implies as short a diffusion path as possible.

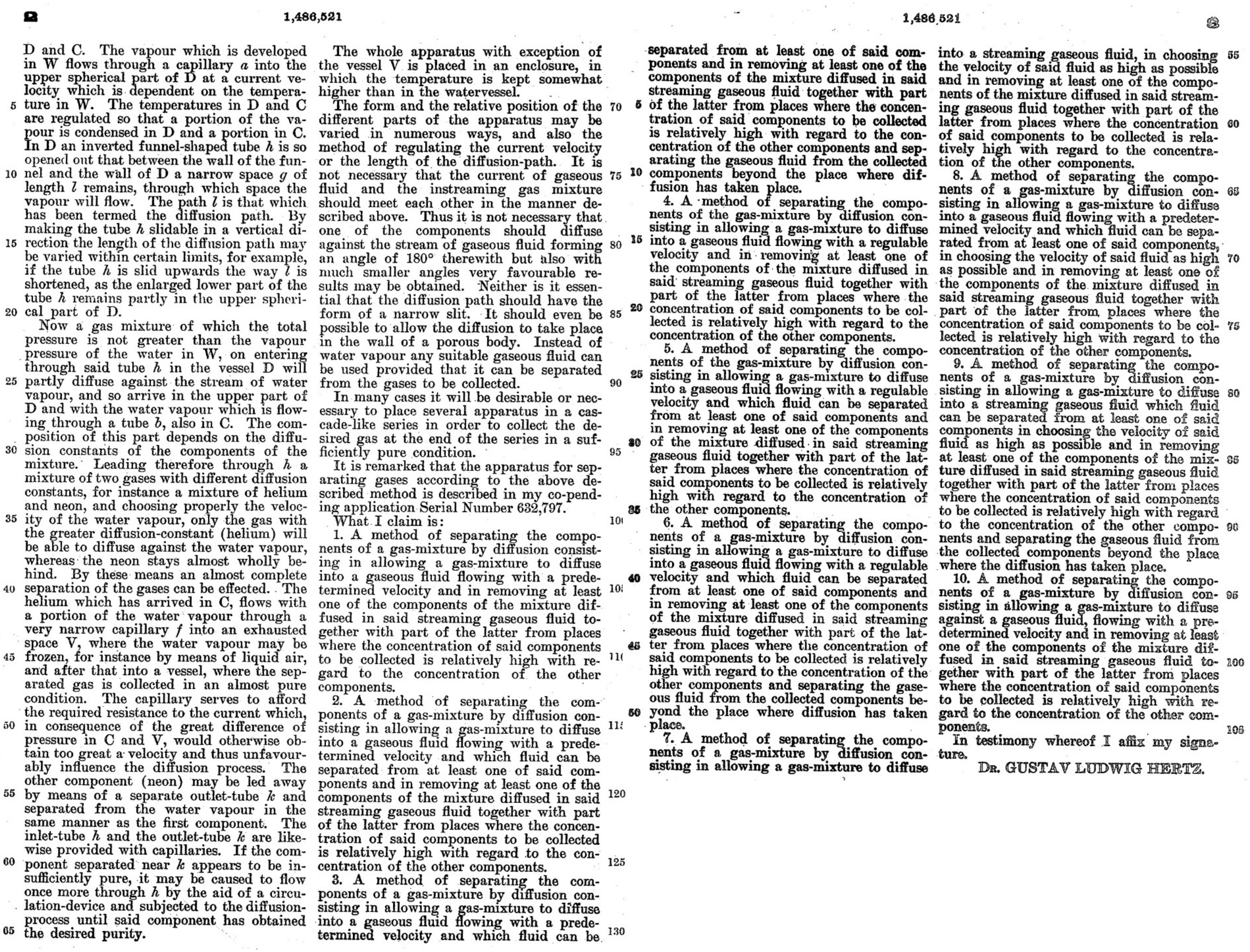
In carrying out the invention a vessel may be used, connected to inlet- and outlet-tubes for the stream of gaseous fluid, for the gas mixture to be separated and for the gases which have diffused apart from each other, while moreover an arrangement can be provided for separating the gaseous fluid from the components of the gas mixture. In addition the apparatus may be provided with means for adjusting the current velocity or the length of the diffusion path or both, which like the arrangement for separating the flowing gaseous fluid from the gas components and other auxiliary arrangements, will be obvious to those skilled in the art.

By arranging the inlet- and outlet-tubes in relation to each other in such a way that the gas component to be separated must diffuse against the current, it is possible to choose the conditions so that only this component is able to do so, the others on the contrary, being led astray by the current to a condenser with which the apparatus, if desired, is provided, while the component which diffused out is led away from a point of great concentration and then liberated from the gaseous fluid.

The drawing diagrammatically represents an apparatus for use in carrying out the invention and in which the gases to be separated are made to diffuse into water vapour.

Referring to the drawing the apparatus consists essentially of three parts: a water vessel W, a diffusion vessel D and a condensation vessel C, which vessels may be in communication as indicated in the drawing. The three vessels, W, D and C are surrounded by waterjackets by means of which their temperature may be exactly adjusted. The temperature in W should be higher than in

Figure D.221: One of Gustav Hertz's first patents on gaseous diffusion for enrichment, filed in 1923 [U.S. Patent 1,486,521. Method of Separating Gases from a Mixture Thereof].



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D and C. The vapour which is developed in W flows through a capillary *a* into the upper spherical part of D at a current velocity which is dependent on the temperature in W. The temperatures in D and C are regulated so that a portion of the vapour is condensed in D and a portion in C. In D an inverted funnel-shaped tube *h* is so opened out that between the wall of the funnel and the wall of D a narrow space *g* of length *l* remains, through which space the vapour will flow. The path *l* is that which has been termed the diffusion path. By making the tube *h* slidable in a vertical direction the length of the diffusion path may be varied within certain limits, for example, if the tube *h* is slid upwards the way *l* is shortened, as the enlarged lower part of the tube *h* remains partly in the upper spherical part of D.

Now a gas mixture of which the total pressure is not greater than the vapour pressure of the water in W, on entering through said tube *h* in the vessel D will partly diffuse against the stream of water vapour, and so arrive in the upper part of D and with the water vapour which is flowing through a tube *b*, also in C. The composition of this part depends on the diffusion constants of the components of the mixture. Leading therefore through *h* a mixture of two gases with different diffusion constants, for instance a mixture of helium and neon, and choosing properly the velocity of the water vapour, only the gas with the greater diffusion-constant (helium) will be able to diffuse against the water vapour, whereas the neon stays almost wholly behind. By these means an almost complete separation of the gases can be effected. The helium which has arrived in C, flows with a portion of the water vapour through a very narrow capillary *f* into an exhausted space V, where the water vapour may be frozen, for instance by means of liquid air, and after that into a vessel, where the separated gas is collected in an almost pure condition. The capillary serves to afford the required resistance to the current which, in consequence of the great difference of pressure in C and V, would otherwise obtain too great a velocity and thus unfavourably influence the diffusion process. The other component (neon) may be led away by means of a separate outlet-tube *k* and separated from the water vapour in the same manner as the first component. The inlet-tube *h* and the outlet-tube *k* are likewise provided with capillaries. If the component separated near *k* appears to be insufficiently pure, it may be caused to flow once more through *h* by the aid of a circulation-device and subjected to the diffusion-process until said component has obtained the desired purity.

The whole apparatus with exception of the vessel V is placed in an enclosure, in which the temperature is kept somewhat higher than in the watervessel.

The form and the relative position of the different parts of the apparatus may be varied in numerous ways, and also the method of regulating the current velocity or the length of the diffusion-path. It is not necessary that the current of gaseous fluid and the instreaming gas mixture should meet each other in the manner described above. Thus it is not necessary that one of the components should diffuse against the stream of gaseous fluid forming an angle of 180° therewith but also with much smaller angles very favourable results may be obtained. Neither is it essential that the diffusion path should have the form of a narrow slit. It should even be possible to allow the diffusion to take place in the wall of a porous body. Instead of water vapour any suitable gaseous fluid can be used provided that it can be separated from the gases to be collected.

In many cases it will be desirable or necessary to place several apparatus in a cascade-like series in order to collect the desired gas at the end of the series in a sufficiently pure condition.

It is remarked that the apparatus for separating gases according to the above described method is described in my co-pending application Serial Number 632,797.

What I claim is:

1. A method of separating the components of a gas-mixture by diffusion consisting in allowing a gas-mixture to diffuse into a gaseous fluid flowing with a predetermined velocity and in removing at least one of the components of the mixture diffused in said streaming gaseous fluid together with part of the latter from places where the concentration of said components to be collected is relatively high with regard to the concentration of the other components.

2. A method of separating the components of a gas-mixture by diffusion consisting in allowing a gas-mixture to diffuse into a gaseous fluid flowing with a predetermined velocity and which fluid can be separated from at least one of said components and in removing at least one of the components of the mixture diffused in said streaming gaseous fluid together with part of the latter from places where the concentration of said components to be collected is relatively high with regard to the concentration of the other components.

3. A method of separating the components of a gas-mixture by diffusion consisting in allowing a gas-mixture to diffuse into a gaseous fluid flowing with a predetermined velocity and which fluid can be separated from at least one of said components and in removing at least one of the components of the mixture diffused in said streaming gaseous fluid together with part of the latter from places where the concentration of said components to be collected is relatively high with regard to the concentration of the other components and separating the gaseous fluid from the collected components beyond the place where diffusion has taken place.

4. A method of separating the components of the gas-mixture by diffusion consisting in allowing a gas-mixture to diffuse into a gaseous fluid flowing with a regulable velocity and in removing at least one of the components of the mixture diffused in said streaming gaseous fluid together with part of the latter from places where the concentration of said components to be collected is relatively high with regard to the concentration of the other components.

5. A method of separating the components of the gas-mixture by diffusion consisting in allowing a gas-mixture to diffuse into a gaseous fluid flowing with a regulable velocity and which fluid can be separated from at least one of said components and in removing at least one of the components of the mixture diffused in said streaming gaseous fluid together with part of the latter from places where the concentration of said components to be collected is relatively high with regard to the concentration of the other components.

6. A method of separating the components of a gas-mixture by diffusion consisting in allowing a gas-mixture to diffuse into a gaseous fluid flowing with a regulable velocity and which fluid can be separated from at least one of said components and in removing at least one of the components of the mixture diffused in said streaming gaseous fluid together with part of the latter from places where the concentration of said components to be collected is relatively high with regard to the concentration of the other components and separating the gaseous fluid from the collected components beyond the place where diffusion has taken place.

7. A method of separating the components of a gas-mixture by diffusion consisting in allowing a gas-mixture to diffuse into a streaming gaseous fluid, in choosing the velocity of said fluid as high as possible and in removing at least one of the components of the mixture diffused in said streaming gaseous fluid together with part of the latter from places where the concentration of said components to be collected is relatively high with regard to the concentration of the other components.

8. A method of separating the components of a gas-mixture by diffusion consisting in allowing a gas-mixture to diffuse into a gaseous fluid flowing with a predetermined velocity and which fluid can be separated from at least one of said components, in choosing the velocity of said fluid as high as possible and in removing at least one of the components of the mixture diffused in said streaming gaseous fluid together with part of the latter from places where the concentration of said components to be collected is relatively high with regard to the concentration of the other components.

9. A method of separating the components of a gas-mixture by diffusion consisting in allowing a gas-mixture to diffuse into a streaming gaseous fluid which fluid can be separated from at least one of said components in choosing the velocity of said fluid as high as possible and in removing at least one of the components of the mixture diffused in said streaming gaseous fluid together with part of the latter from places where the concentration of said components to be collected is relatively high with regard to the concentration of the other components and separating the gaseous fluid from the collected components beyond the place where the diffusion has taken place.

10. A method of separating the components of a gas-mixture by diffusion consisting in allowing a gas-mixture to diffuse against a gaseous fluid, flowing with a predetermined velocity and in removing at least one of the components of the mixture diffused in said streaming gaseous fluid together with part of the latter from places where the concentration of said components to be collected is relatively high with regard to the concentration of the other components.

In testimony whereof I affix my signature.

DR. GUSTAV LUDWIG HERTZ.

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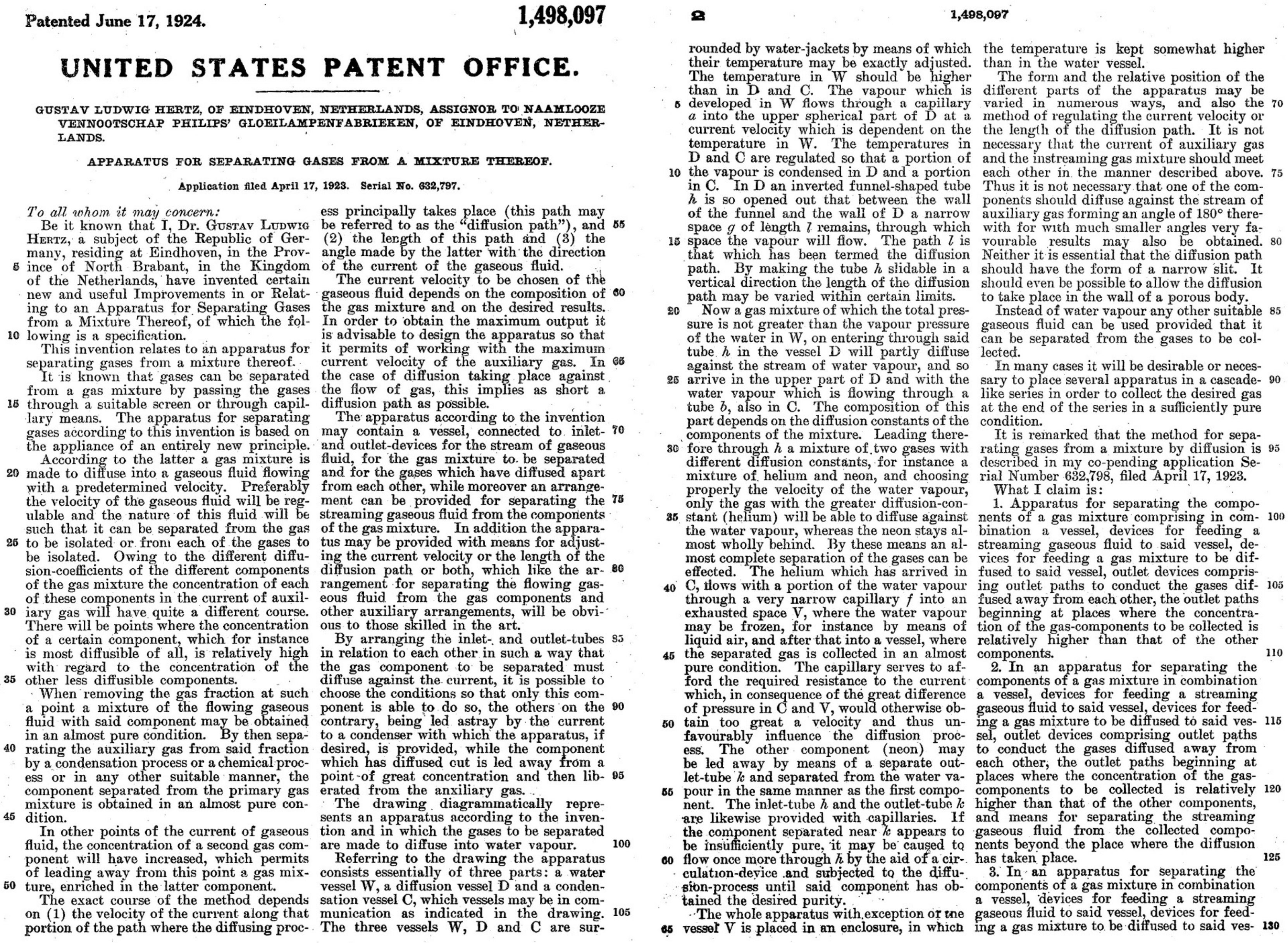
Figure D.222: One of Gustav Hertz's first patents on gaseous diffusion for enrichment, filed in 1923 [U.S. Patent 1,486,521. Method of Separating Gases from a Mixture Thereof].



Patented June 17, 1924. **1,498,097**

UNITED STATES PATENT OFFICE.

GUSTAV LUDWIG HERTZ, OF EINDHOVEN, NETHERLANDS, ASSIGNOR TO NAAMLOOZE VENNOOTSCHAP PHILIPS' GLOEILAMPENFABRIEKEN, OF EINDHOVEN, NETHERLANDS.

APPARATUS FOR SEPARATING GASES FROM A MIXTURE THEREOF.

Application filed April 17, 1923. Serial No. 632,797.

To all whom it may concern:

Be it known that I, Dr. Gustav Ludwig Hertz, a subject of the Republic of Germany, residing at Eindhoven, in the Province of North Brabant, in the Kingdom of the Netherlands, have invented certain new and useful Improvements in or Relating to an Apparatus for Separating Gases from a Mixture Thereof, of which the following is a specification.

This invention relates to an apparatus for separating gases from a mixture thereof.

It is known that gases can be separated from a gas mixture by passing the gases through a suitable screen or through capillary means. The apparatus for separating gases according to this invention is based on the appliance of an entirely new principle.

According to the latter a gas mixture is made to diffuse into a gaseous fluid flowing with a predetermined velocity. Preferably the velocity of the gaseous fluid will be regulable and the nature of this fluid will be such that it can be separated from the gas to be isolated or from each of the gases to be isolated. Owing to the different diffusion-coefficients of the different components of the gas mixture the concentration of each of these components in the current of auxiliary gas will have quite a different course. There will be points where the concentration of a certain component, which for instance is most diffusible of all, is relatively high with regard to the concentration of the other less diffusible components.

When removing the gas fraction at such a point a mixture of the flowing gaseous fluid with said component may be obtained in an almost pure condition. By then separating the auxiliary gas from said fraction by a condensation process or a chemical process or in any other suitable manner, the component separated from the primary gas mixture is obtained in an almost pure condition.

In other points of the current of gaseous fluid, the concentration of a second gas component will have increased, which permits of leading away from this point a gas mixture, enriched in the latter component.

The exact course of the method depends on (1) the velocity of the current along that portion of the path where the diffusing process principally takes place (this path may be referred to as the "diffusion path"), and (2) the length of this path and (3) the angle made by the latter with the direction of the current of the gaseous fluid.

The current velocity to be chosen of the gaseous fluid depends on the composition of the gas mixture and on the desired results. In order to obtain the maximum output it is advisable to design the apparatus so that it permits of working with the maximum current velocity of the auxiliary gas. In the case of diffusion taking place against the flow of gas, this implies as short a diffusion path as possible.

The apparatus according to the invention may contain a vessel, connected to inlet- and outlet-devices for the stream of gaseous fluid, for the gas mixture to be separated and for the gases which have diffused apart from each other, while moreover an arrangement can be provided for separating the streaming gaseous fluid from the components of the gas mixture. In addition the apparatus may be provided with means for adjusting the current velocity or the length of the diffusion path or both, which like the arrangement for separating the flowing gaseous fluid from the gas components and other auxiliary arrangements, will be obvious to those skilled in the art.

By arranging the inlet- and outlet-tubes in relation to each other in such a way that the gas component to be separated must diffuse against the current, it is possible to choose the conditions so that only this component is able to do so, the others on the contrary, being led astray by the current to a condenser with which the apparatus, if desired, is provided, while the component which has diffused cut is led away from a point of great concentration and then liberated from the anxiliary gas.

The drawing diagrammatically represents an apparatus according to the invention and in which the gases to be separated are made to diffuse into water vapour.

Referring to the drawing the apparatus consists essentially of three parts: a water vessel W, a diffusion vessel D and a condensation vessel C, which vessels may be in communication as indicated in the drawing. The three vessels W, D and C are sur-

rounded by water-jackets by means of which their temperature may be exactly adjusted. The temperature in W should be higher than in D and C. The vapour which is developed in W flows through a capillary a into the upper spherical part of D at a current velocity which is dependent on the temperature in W. The temperatures in D and C are regulated so that a portion of the vapour is condensed in D and a portion in C. In D an inverted funnel-shaped tube h is so opened out that between the wall of the funnel and the wall of D a narrow space g of length l remains, through which space the vapour will flow. The path l is that which has been termed the diffusion path. By making the tube h slidable in a vertical direction the length of the diffusion path may be varied within certain limits.

Now a gas mixture of which the total pressure is not greater than the vapour pressure of the water in W, on entering through said tube h in the vessel D will partly diffuse against the stream of water vapour, and so arrive in the upper part of D and with the water vapour which is flowing through a tube b, also in C. The composition of this part depends on the diffusion constants of the components of the mixture. Leading therefore through h a mixture of two gases with different diffusion constants, for instance a mixture of helium and neon, and choosing properly the velocity of the water vapour, only the gas with the greater diffusion-constant (helium) will be able to diffuse against the water vapour, whereas the neon stays almost wholly behind. By these means an almost complete separation of the gases can be effected. The helium which has arrived in C, flows with a portion of the water vapour through a very narrow capillary f into an exhausted space V, where the water vapour may be frozen, for instance by means of liquid air, and after that into a vessel, where the separated gas is collected in an almost pure condition. The capillary serves to afford the required resistance to the current which, in consequence of the great difference of pressure in C and V, would otherwise obtain too great a velocity and thus unfavourably influence the diffusion process. The other component (neon) may be led away by means of a separate outlet-tube k and separated from the water vapour in the same manner as the first component. The inlet-tube h and the outlet-tube k are likewise provided with capillaries. If the component separated near k appears to be insufficiently pure, it may be caused to flow once more through h by the aid of a circulation-device and subjected to the diffusion-process until said component has obtained the desired purity.

The whole apparatus with exception of the vessel V is placed in an enclosure, in which the temperature is kept somewhat higher than in the water vessel.

The form and the relative position of the different parts of the apparatus may be varied in numerous ways, and also the method of regulating the current velocity or the length of the diffusion path. It is not necessary that the current of auxiliary gas and the instreaming gas mixture should meet each other in the manner described above. Thus it is not necessary that one of the components should diffuse against the stream of auxiliary gas forming an angle of 180° therewith for with much smaller angles very favourable results may also be obtained. Neither it is essential that the diffusion path should have the form of a narrow slit. It should even be possible to allow the diffusion to take place in the wall of a porous body.

Instead of water vapour any other suitable gaseous fluid can be used provided that it can be separated from the gases to be collected.

In many cases it will be desirable or necessary to place several apparatus in a cascade-like series in order to collect the desired gas at the end of the series in a sufficiently pure condition.

It is remarked that the method for separating gases from a mixture by diffusion is described in my co-pending application Serial Number 632,798, filed April 17, 1923.

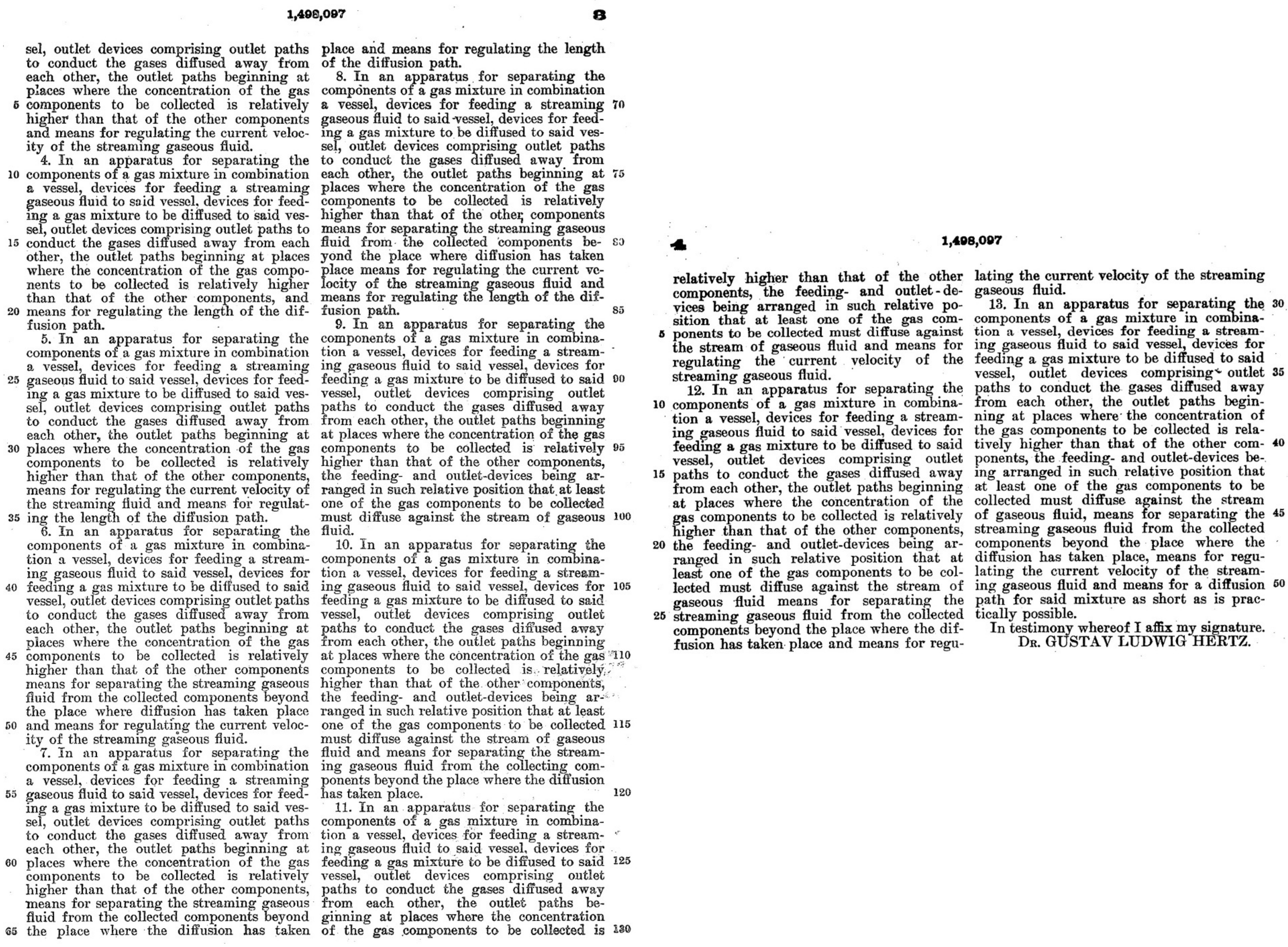
What I claim is:

1. Apparatus for separating the components of a gas mixture comprising in combination a vessel, devices for feeding a streaming gaseous fluid to said vessel, devices for feeding a gas mixture to be diffused to said vessel, outlet devices comprising outlet paths to conduct the gases diffused away from each other, the outlet paths beginning at places where the concentration of the gas-components to be collected is relatively higher than that of the other components.

2. In an apparatus for separating the components of a gas mixture in combination a vessel, devices for feeding a streaming gaseous fluid to said vessel, devices for feeding a gas mixture to be diffused to said vessel, outlet devices comprising outlet paths to conduct the gases diffused away from each other, the outlet paths beginning at places where the concentration of the gas-components to be collected is relatively higher than that of the other components, and means for separating the streaming gaseous fluid from the collected components beyond the place where the diffusion has taken place.

3. In an apparatus for separating the components of a gas mixture in combination a vessel, devices for feeding a streaming gaseous fluid to said vessel, devices for feeding a gas mixture to be diffused to said ves-

Figure D.223: Another of Gustav Hertz's first patents on gaseous diffusion for enrichment, filed in 1923 [U.S. Patent 1,498,097. Apparatus for Separating Gases from a Mixture Thereof].



sel, outlet devices comprising outlet paths to conduct the gases diffused away from each other, the outlet paths beginning at places where the concentration of the gas components to be collected is relatively higher than that of the other components and means for regulating the current velocity of the streaming gaseous fluid.

4. In an apparatus for separating the components of a gas mixture in combination a vessel, devices for feeding a streaming gaseous fluid to said vessel, devices for feeding a gas mixture to be diffused to said vessel, outlet devices comprising outlet paths to conduct the gases diffused away from each other, the outlet paths beginning at places where the concentration of the gas components to be collected is relatively higher than that of the other components, and means for regulating the length of the diffusion path.

5. In an apparatus for separating the components of a gas mixture in combination a vessel, devices for feeding a streaming gaseous fluid to said vessel, devices for feeding a gas mixture to be diffused to said vessel, outlet devices comprising outlet paths to conduct the gases diffused away from each other, the outlet paths beginning at places where the concentration of the gas components to be collected is relatively higher than that of the other components, means for regulating the current velocity of the streaming fluid and means for regulating the length of the diffusion path.

6. In an apparatus for separating the components of a gas mixture in combination a vessel, devices for feeding a streaming gaseous fluid to said vessel, devices for feeding a gas mixture to be diffused to said vessel, outlet devices comprising outlet paths to conduct the gases diffused away from each other, the outlet paths beginning at places where the concentration of the gas components to be collected is relatively higher than that of the other components means for separating the streaming gaseous fluid from the collected components beyond the place where diffusion has taken place and means for regulating the current velocity of the streaming gaseous fluid.

7. In an apparatus for separating the components of a gas mixture in combination a vessel, devices for feeding a streaming gaseous fluid to said vessel, devices for feeding a gas mixture to be diffused to said vessel, outlet devices comprising outlet paths to conduct the gases diffused away from each other, the outlet paths beginning at places where the concentration of the gas components to be collected is relatively higher than that of the other components, means for separating the streaming gaseous fluid from the collected components beyond the place where the diffusion has taken place and means for regulating the length of the diffusion path.

8. In an apparatus for separating the components of a gas mixture in combination a vessel, devices for feeding a streaming gaseous fluid to said vessel, devices for feeding a gas mixture to be diffused to said vessel, outlet devices comprising outlet paths to conduct the gases diffused away from each other, the outlet paths beginning at places where the concentration of the gas components to be collected is relatively higher than that of the other; components means for separating the streaming gaseous fluid from the collected components beyond the place where diffusion has taken place means for regulating the current velocity of the streaming gaseous fluid and means for regulating the length of the diffusion path.

9. In an apparatus for separating the components of a gas mixture in combination a vessel, devices for feeding a streaming gaseous fluid to said vessel, devices for feeding a gas mixture to be diffused to said vessel, outlet devices comprising outlet paths to conduct the gases diffused away from each other, the outlet paths beginning at places where the concentration of the gas components to be collected is relatively higher than that of the other components, the feeding- and outlet-devices being arranged in such relative position that at least one of the gas components to be collected must diffuse against the stream of gaseous fluid.

10. In an apparatus for separating the components of a gas mixture in combination a vessel, devices for feeding a streaming gaseous fluid to said vessel, devices for feeding a gas mixture to be diffused to said vessel, outlet devices comprising outlet paths to conduct the gases diffused away from each other, the outlet paths beginning at places where the concentration of the gas components to be collected is relatively higher than that of the other components, the feeding- and outlet-devices being arranged in such relative position that at least one of the gas components to be collected must diffuse against the stream of gaseous fluid and means for separating the streaming gaseous fluid from the collecting components beyond the place where the diffusion has taken place.

11. In an apparatus for separating the components of a gas mixture in combination a vessel, devices for feeding a streaming gaseous fluid to said vessel, devices for feeding a gas mixture to be diffused to said vessel, outlet devices comprising outlet paths to conduct the gases diffused away from each other, the outlet paths beginning at places where the concentration of the gas components to be collected is

relatively higher than that of the other components, the feeding- and outlet-devices being arranged in such relative position that at least one of the gas components to be collected must diffuse against the stream of gaseous fluid and means for regulating the current velocity of the streaming gaseous fluid.

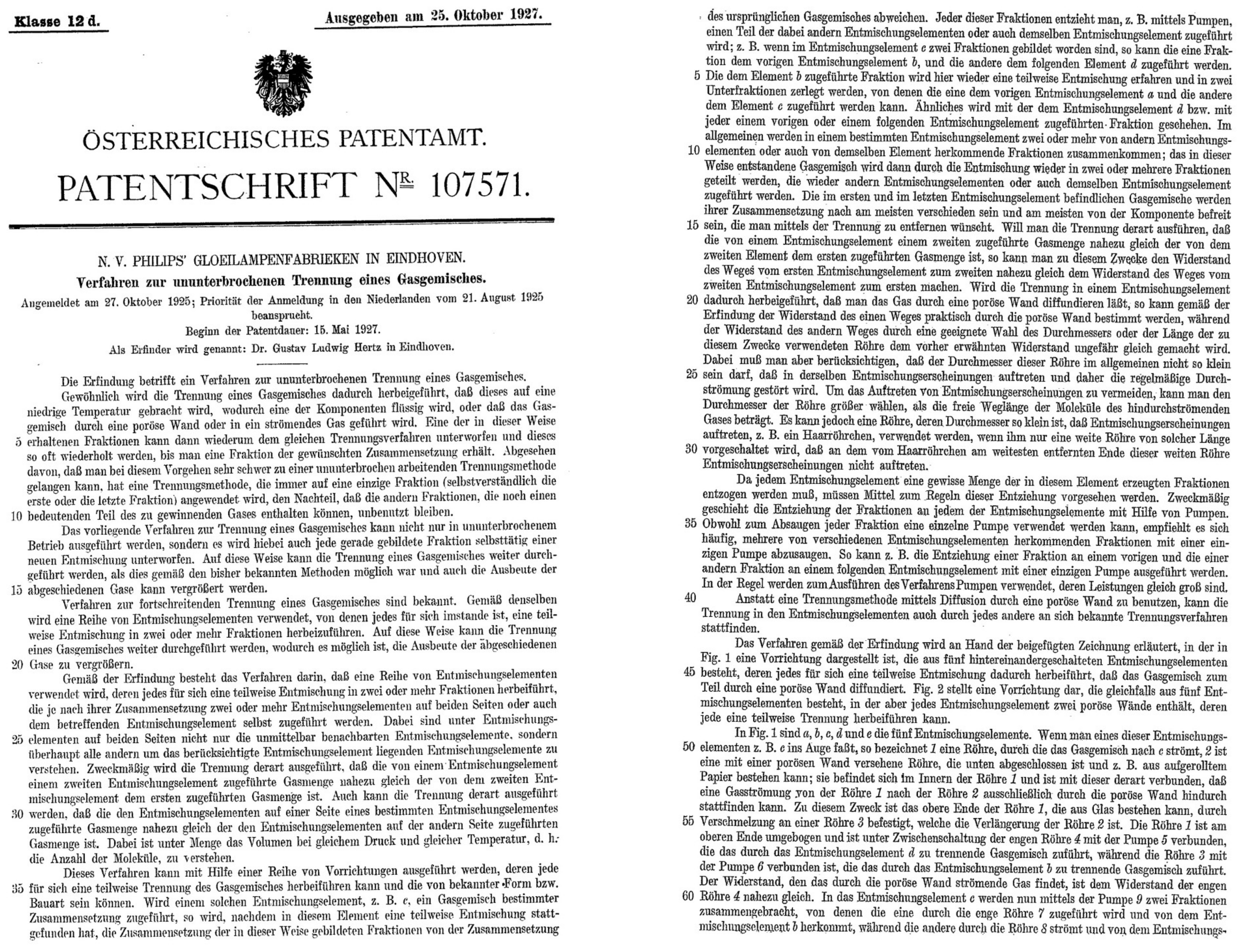
12. In an apparatus for separating the components of a gas mixture in combination a vessel, devices for feeding a streaming gaseous fluid to said vessel, devices for feeding a gas mixture to be diffused to said vessel, outlet devices comprising outlet paths to conduct the gases diffused away from each other, the outlet paths beginning at places where the concentration of the gas components to be collected is relatively higher than that of the other components, the feeding- and outlet-devices being arranged in such relative position that at least one of the gas components to be collected must diffuse against the stream of gaseous fluid means for separating the streaming gaseous fluid from the collected components beyond the place where the diffusion has taken place and means for regulating the current velocity of the streaming gaseous fluid.

13. In an apparatus for separating the components of a gas mixture in combination a vessel, devices for feeding a streaming gaseous fluid to said vessel, devices for feeding a gas mixture to be diffused to said vessel, outlet devices comprising outlet paths to conduct the gases diffused away from each other, the outlet paths beginning at places where the concentration of the gas components to be collected is relatively higher than that of the other components, the feeding- and outlet-devices being arranged in such relative position that at least one of the gas components to be collected must diffuse against the stream of gaseous fluid, means for separating the streaming gaseous fluid from the collected components beyond the place where the diffusion has taken place, means for regulating the current velocity of the streaming gaseous fluid and means for a diffusion path for said mixture as short as is practically possible.

In testimony whereof I affix my signature.

DR. GUSTAV LUDWIG HERTZ.

Figure D.224: Another of Gustav Hertz's first patents on gaseous diffusion for enrichment, filed in 1923 [U.S. Patent 1,498,097. Apparatus for Separating Gases from a Mixture Thereof].



Klasse 12 d. **Ausgegeben am 25. Oktober 1927.**

ÖSTERREICHISCHES PATENTAMT.

PATENTSCHRIFT Nr. 107571.

N. V. PHILIPS' GLOEILAMPENFABRIEKEN IN EINDHOVEN.

Verfahren zur ununterbrochenen Trennung eines Gasgemisches.

Angemeldet am 27. Oktober 1925; Priorität der Anmeldung in den Niederlanden vom 21. August 1925 beansprucht.

Beginn der Patentdauer: 15. Mai 1927.

Als Erfinder wird genannt: Dr. Gustav Ludwig Hertz in Eindhoven.

Die Erfindung betrifft ein Verfahren zur ununterbrochenen Trennung eines Gasgemisches.

Gewöhnlich wird die Trennung eines Gasgemisches dadurch herbeigeführt, daß dieses auf eine niedrige Temperatur gebracht wird, wodurch eine der Komponenten flüssig wird, oder daß das Gasgemisch durch eine poröse Wand oder in ein strömendes Gas geführt wird. Eine der in dieser Weise erhaltenen Fraktionen kann dann wiederum dem gleichen Trennungsverfahren unterworfen und dieses so oft wiederholt werden, bis man eine Fraktion der gewünschten Zusammensetzung erhält. Abgesehen davon, daß man bei diesem Vorgehen sehr schwer zu einer ununterbrochen arbeitenden Trennungsmethode gelangen kann, hat eine Trennungsmethode, die immer auf eine einzige Fraktion (selbstverständlich die erste oder die letzte Fraktion) angewendet wird, den Nachteil, daß die andern Fraktionen, die noch einen bedeutenden Teil des zu gewinnenden Gases enthalten können, unbenutzt bleiben.

Das vorliegende Verfahren zur Trennung eines Gasgemisches kann nicht nur in ununterbrochenem Betrieb ausgeführt werden, sondern es wird hiebei auch jede gerade gebildete Fraktion selbsttätig einer neuen Entmischung unterworfen. Auf diese Weise kann die Trennung eines Gasgemisches weiter durchgeführt werden, als dies gemäß den bisher bekannten Methoden möglich war und auch die Ausbeute der abgeschiedenen Gase kann vergrößert werden.

Verfahren zur fortschreitenden Trennung eines Gasgemisches sind bekannt. Gemäß denselben wird eine Reihe von Entmischungselementen verwendet, von denen jedes für sich imstande ist, eine teilweise Entmischung in zwei oder mehr Fraktionen herbeizuführen. Auf diese Weise kann die Trennung eines Gasgemisches weiter durchgeführt werden, wodurch es möglich ist, die Ausbeute der abgeschiedenen Gase zu vergrößern.

Gemäß der Erfindung besteht das Verfahren darin, daß eine Reihe von Entmischungselementen verwendet wird, deren jedes für sich eine teilweise Entmischung in zwei oder mehr Fraktionen herbeiführt, die je nach ihrer Zusammensetzung zwei oder mehr Entmischungselementen auf beiden Seiten oder auch dem betreffenden Entmischungselement selbst zugeführt werden. Dabei sind unter Entmischungselementen auf beiden Seiten nicht nur die unmittelbar benachbarten Entmischungselemente, sondern überhaupt alle andern um das berücksichtigte Entmischungselement liegenden Entmischungselemente zu verstehen. Zweckmäßig wird die Trennung derart ausgeführt, daß die von einem Entmischungselement einem zweiten Entmischungselement zugeführte Gasmenge nahezu gleich der von dem zweiten Entmischungselement dem ersten zugeführten Gasmenge ist. Auch kann die Trennung derart ausgeführt werden, daß die den Entmischungselementen auf einer Seite eines bestimmten Entmischungselementes zugeführte Gasmenge nahezu gleich der den Entmischungselementen auf der andern Seite zugeführten Gasmenge ist. Dabei ist unter Menge das Volumen bei gleichem Druck und gleicher Temperatur, d. h. die Anzahl der Moleküle, zu verstehen.

Dieses Verfahren kann mit Hilfe einer Reihe von Vorrichtungen ausgeführt werden, deren jede für sich eine teilweise Trennung des Gasgemisches herbeiführen kann und die von bekannter Form bzw. Bauart sein können. Wird einem solchen Entmischungselement, z. B. *c*, ein Gasgemisch bestimmter Zusammensetzung zugeführt, so wird, nachdem in diesem Element eine teilweise Entmischung stattgefunden hat, die Zusammensetzung der in dieser Weise gebildeten Fraktionen von der Zusammensetzung des ursprünglichen Gasgemisches abweichen. Jeder dieser Fraktionen entzieht man, z. B. mittels Pumpen, einen Teil der dabei andern Entmischungselementen oder auch demselben Entmischungselement zugeführt wird; z. B. wenn im Entmischungselement *c* zwei Fraktionen gebildet worden sind, so kann die eine Fraktion dem vorigen Entmischungselement *b*, und die andere dem folgenden Element *d* zugeführt werden. Die dem Element *b* zugeführte Fraktion wird hier wieder eine teilweise Entmischung erfahren und in zwei Unterfraktionen zerlegt werden, von denen die eine dem vorigen Entmischungselement *a* und die andere dem Element *c* zugeführt werden kann. Ähnliches wird mit der dem Entmischungselement *d* bzw. mit jeder einem vorigen oder einem folgenden Entmischungselement zugeführten Fraktion geschehen. Im allgemeinen werden in einem bestimmten Entmischungselement zwei oder mehr von andern Entmischungselementen oder auch von demselben Element herkommende Fraktionen zusammenkommen; das in dieser Weise entstandene Gasgemisch wird dann durch die Entmischung wieder in zwei oder mehrere Fraktionen geteilt werden, die wieder andern Entmischungselementen oder auch demselben Entmischungselement zugeführt werden. Die im ersten und im letzten Entmischungselement befindlichen Gasgemische werden ihrer Zusammensetzung nach am meisten verschieden sein und am meisten von der Komponente befreit sein, die man mittels der Trennung zu entfernen wünscht. Will man die Trennung derart ausführen, daß die von einem Entmischungselement einem zweiten zugeführte Gasmenge nahezu gleich der von dem zweiten Element dem ersten zugeführten Gasmenge ist, so kann man zu diesem Zwecke den Widerstand des Weges vom ersten Entmischungselement zum zweiten nahezu gleich dem Widerstand des Weges vom zweiten Entmischungselement zum ersten machen. Wird die Trennung in einem Entmischungselement dadurch herbeigeführt, daß man das Gas durch eine poröse Wand diffundieren läßt, so kann gemäß der Erfindung der Widerstand des einen Weges praktisch durch die poröse Wand bestimmt werden, während der Widerstand des andern Weges durch eine geeignete Wahl des Durchmessers oder der Länge der zu diesem Zwecke verwendeten Röhre dem vorher erwähnten Widerstand ungefähr gleich gemacht wird. Dabei muß man aber berücksichtigen, daß der Durchmesser dieser Röhre im allgemeinen nicht so klein sein darf, daß in derselben Entmischungserscheinungen auftreten und daher die regelmäßige Durchströmung gestört wird. Um das Auftreten von Entmischungserscheinungen zu vermeiden, kann man den Durchmesser der Röhre größer wählen, als die freie Weglänge der Moleküle des hindurchströmenden Gases beträgt. Es kann jedoch eine Röhre, deren Durchmesser so klein ist, daß Entmischungserscheinungen auftreten, z. B. ein Haarröhrchen, verwendet werden, wenn ihm nur eine weite Röhre von solcher Länge vorgeschaltet wird, daß an dem vom Haarröhrchen am weitesten entfernten Ende dieser weiten Röhre Entmischungserscheinungen nicht auftreten.

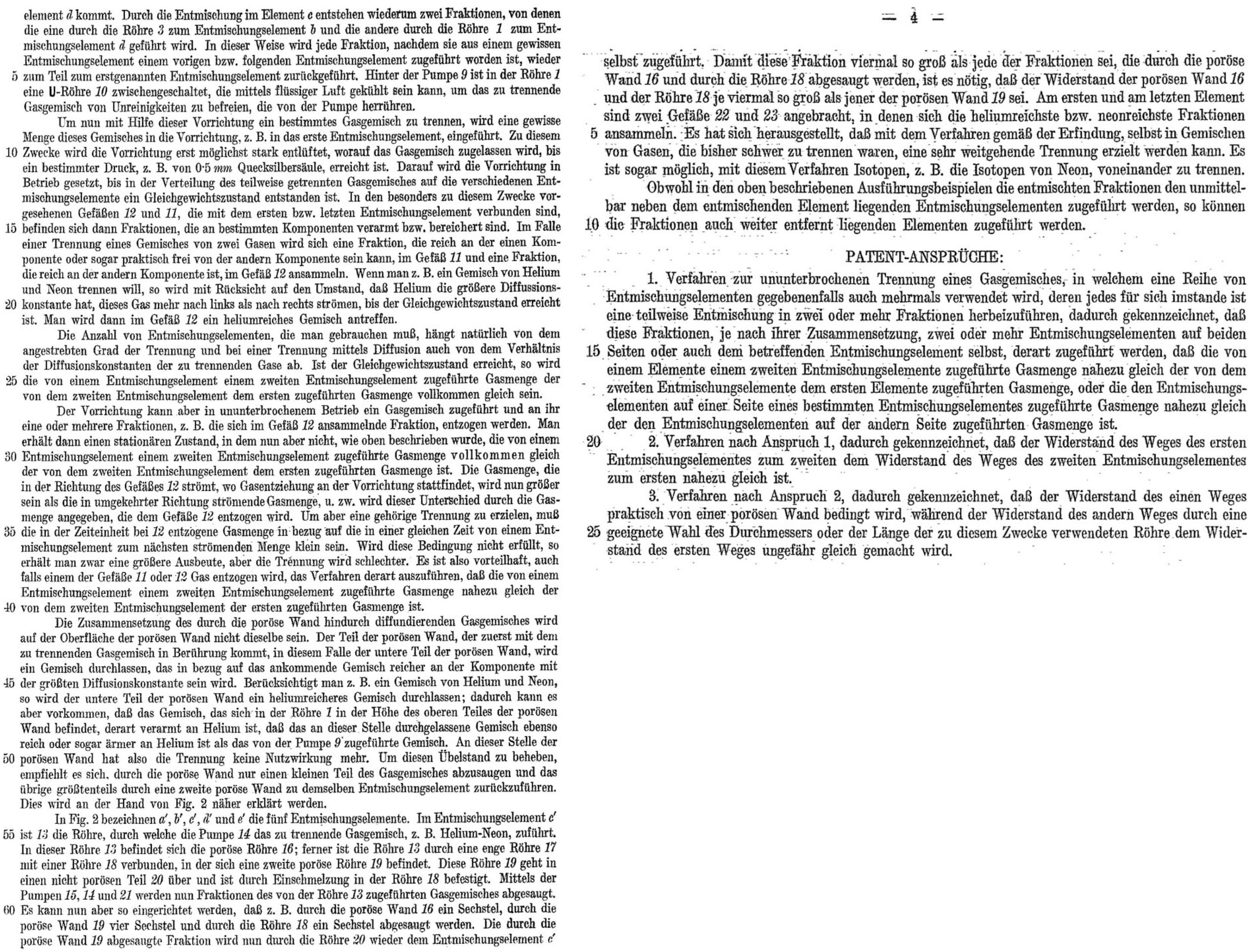
Da jedem Entmischungselement eine gewisse Menge der in diesem Element erzeugten Fraktionen entzogen werden muß, müssen Mittel zum Regeln dieser Entziehung vorgesehen werden. Zweckmäßig geschieht die Entziehung der Fraktionen an jedem der Entmischungselemente mit Hilfe von Pumpen. Obwohl zum Absaugen jeder Fraktion eine einzelne Pumpe verwendet werden kann, empfiehlt es sich häufig, mehrere von verschiedenen Entmischungselementen herkommenden Fraktionen mit einer einzigen Pumpe abzusaugen. So kann z. B. die Entziehung einer Fraktion an einem vorigen und die einer andern Fraktion an einem folgenden Entmischungselement mit einer einzigen Pumpe ausgeführt werden. In der Regel werden zum Ausführen des Verfahrens Pumpen verwendet, deren Leistungen gleich groß sind.

Anstatt eine Trennungsmethode mittels Diffusion durch eine poröse Wand zu benutzen, kann die Trennung in den Entmischungselementen auch durch jedes andere an sich bekannte Trennungsverfahren stattfinden.

Das Verfahren gemäß der Erfindung wird an Hand der beigefügten Zeichnung erläutert, in der in Fig. 1 eine Vorrichtung dargestellt ist, die aus fünf hintereinandergeschalteten Entmischungselementen besteht, deren jedes für sich eine teilweise Entmischung dadurch herbeiführt, daß das Gasgemisch zum Teil durch eine poröse Wand diffundiert. Fig. 2 stellt eine Vorrichtung dar, die gleichfalls aus fünf Entmischungselementen besteht, in der aber jedes Entmischungselement zwei poröse Wände enthält, deren jede eine teilweise Trennung herbeiführen kann.

In Fig. 1 sind *a*, *b*, *c*, *d* und *e* die fünf Entmischungselemente. Wenn man eines dieser Entmischungselementen z. B. *c* ins Auge faßt, so bezeichnet *1* eine Röhre, durch die das Gasgemisch nach *c* strömt, *2* ist eine mit einer porösen Wand versehene Röhre, die unten abgeschlossen ist und z. B. aus aufgerolltem Papier bestehen kann; sie befindet sich im Innern der Röhre *1* und ist mit dieser derart verbunden, daß eine Gasströmung von der Röhre *1* nach der Röhre *2* ausschließlich durch die poröse Wand hindurch stattfinden kann. Zu diesem Zweck ist das obere Ende der Röhre *1*, die aus Glas bestehen kann, durch Verschmelzung an einer Röhre *3* befestigt, welche die Verlängerung der Röhre *2* ist. Die Röhre *1* ist am oberen Ende umgebogen und ist unter Zwischenschaltung der engen Röhre *4* mit der Pumpe *5* verbunden, die das durch das Entmischungselement *d* zu trennende Gasgemisch zuführt, während die Röhre *3* mit der Pumpe *6* verbunden ist, die das durch das Entmischungselement *b* zu trennende Gasgemisch zuführt. Der Widerstand, den das durch die poröse Wand strömende Gas findet, ist dem Widerstand der engen Röhre *4* nahezu gleich. In das Entmischungselement *c* werden nun mittels der Pumpe *9* zwei Fraktionen zusammengebracht, von denen die eine durch die enge Röhre *7* zugeführt wird und von dem Entmischungselement *b* herkommt, während die andere durch die Röhre *8* strömt und von dem Entmischungs-

Figure D.225: One of Gustav Hertz's patents showing that many gaseous diffusion units could be used in series to achieve high-quality enrichment [Austrian Patent AT 107,571. Verfahren zur ununterbrochenen Trennung eines Gasgemisches].



element *d* kommt. Durch die Entmischung im Element *c* entstehen wiederum zwei Fraktionen, von denen die eine durch die Röhre *3* zum Entmischungselement *b* und die andere durch die Röhre *1* zum Entmischungselement *d* geführt wird. In dieser Weise wird jede Fraktion, nachdem sie aus einem gewissen Entmischungselement einem vorigen bzw. folgenden Entmischungselement zugeführt worden ist, wieder zum Teil zum erstgenannten Entmischungselement zurückgeführt. Hinter der Pumpe *9* ist in der Röhre *1* eine U-Röhre *10* zwischengeschaltet, die mittels flüssiger Luft gekühlt sein kann, um das zu trennende Gasgemisch von Unreinigkeiten zu befreien, die von der Pumpe herrühren.

Um nun mit Hilfe dieser Vorrichtung ein bestimmtes Gasgemisch zu trennen, wird eine gewisse Menge dieses Gemisches in die Vorrichtung, z. B. in das erste Entmischungselement, eingeführt. Zu diesem Zwecke wird die Vorrichtung erst möglichst stark entlüftet, worauf das Gasgemisch zugelassen wird, bis ein bestimmter Druck, z. B. von 0·5 *mm* Quecksilbersäule, erreicht ist. Darauf wird die Vorrichtung in Betrieb gesetzt, bis in der Verteilung des teilweise getrennten Gasgemisches auf die verschiedenen Entmischungselemente ein Gleichgewichtszustand entstanden ist. In den besonders zu diesem Zwecke vorgesehenen Gefäßen *12* und *11*, die mit dem ersten bzw. letzten Entmischungselement verbunden sind, befinden sich dann Fraktionen, die an bestimmten Komponenten verarmt bzw. bereichert sind. Im Falle einer Trennung eines Gemisches von zwei Gasen wird sich eine Fraktion, die reich an der einen Komponente oder sogar praktisch frei von der andern Komponente sein kann, im Gefäß *11* und eine Fraktion, die reich an der andern Komponente ist, im Gefäß *12* ansammeln. Wenn man z. B. ein Gemisch von Helium und Neon trennen will, so wird mit Rücksicht auf den Umstand, daß Helium die größere Diffusionskonstante hat, dieses Gas mehr nach links als nach rechts strömen, bis der Gleichgewichtszustand erreicht ist. Man wird dann im Gefäß *12* ein heliumreiches Gemisch antreffen.

Die Anzahl von Entmischungselementen, die man gebrauchen muß, hängt natürlich von dem angestrebten Grad der Trennung und bei einer Trennung mittels Diffusion auch von dem Verhältnis der Diffusionskonstanten der zu trennenden Gase ab. Ist der Gleichgewichtszustand erreicht, so wird die von einem Entmischungselement einem zweiten Entmischungselement zugeführte Gasmenge der von dem zweiten Entmischungselement dem ersten zugeführten Gasmenge vollkommen gleich sein.

Der Vorrichtung kann aber in ununterbrochenem Betrieb ein Gasgemisch zugeführt und an ihr eine oder mehrere Fraktionen, z. B. die sich im Gefäß *12* ansammelnde Fraktion, entzogen werden. Man erhält dann einen stationären Zustand, in dem nun aber nicht, wie oben beschrieben wurde, die von einem Entmischungselement einem zweiten Entmischungselement zugeführte Gasmenge vollkommen gleich der von dem zweiten Entmischungselement dem ersten zugeführten Gasmenge ist. Die Gasmenge, die in der Richtung des Gefäßes *12* strömt, wo Gasentziehung an der Vorrichtung stattfindet, wird nun größer sein als die in umgekehrter Richtung strömende Gasmenge, u. zw. wird dieser Unterschied durch die Gasmenge angegeben, die dem Gefäße *12* entzogen wird. Um aber eine gehörige Trennung zu erzielen, muß die in der Zeiteinheit bei *12* entzogene Gasmenge in bezug auf die in einer gleichen Zeit von einem Entmischungselement zum nächsten strömenden Menge klein sein. Wird diese Bedingung nicht erfüllt, so erhält man zwar eine größere Ausbeute, aber die Trennung wird schlechter. Es ist also vorteilhaft, auch falls einem der Gefäße *11* oder *12* Gas entzogen wird, das Verfahren derart auszuführen, daß die von einem Entmischungselement einem zweiten Entmischungselement zugeführte Gasmenge nahezu gleich der von dem zweiten Entmischungselement der ersten zugeführten Gasmenge ist.

Die Zusammensetzung des durch die poröse Wand hindurch diffundierenden Gasgemisches wird auf der Oberfläche der porösen Wand nicht dieselbe sein. Der Teil der porösen Wand, der zuerst mit dem zu trennenden Gasgemisch in Berührung kommt, in diesem Falle der untere Teil der porösen Wand, wird ein Gemisch durchlassen, das in bezug auf das ankommende Gemisch reicher an der Komponente mit der größten Diffusionskonstante sein wird. Berücksichtigt man z. B. ein Gemisch von Helium und Neon, so wird der untere Teil der porösen Wand ein heliumreicheres Gemisch durchlassen; dadurch kann es aber vorkommen, daß das Gemisch, das sich in der Röhre *1* in der Höhe des oberen Teiles der porösen Wand befindet, derart verarmt an Helium ist, daß das an dieser Stelle durchgelassene Gemisch ebenso reich oder sogar ärmer an Helium ist als das von der Pumpe *9* zugeführte Gemisch. An dieser Stelle der porösen Wand hat also die Trennung keine Nutzwirkung mehr. Um diesen Übelstand zu beheben, empfiehlt es sich, durch die poröse Wand nur einen kleinen Teil des Gasgemisches abzusaugen und das übrige größtenteils durch eine zweite poröse Wand zu demselben Entmischungselement zurückzuführen. Dies wird an der Hand von Fig. 2 näher erklärt werden.

In Fig. 2 bezeichnen *a′*, *b′*, *c′*, *d′* und *e′* die fünf Entmischungselemente. Im Entmischungselement *c′* ist *13* die Röhre, durch welche die Pumpe *14* das zu trennende Gasgemisch, z. B. Helium-Neon, zuführt. In dieser Röhre *13* befindet sich die poröse Röhre *16*; ferner ist die Röhre *13* durch eine enge Röhre *17* mit einer Röhre *18* verbunden, in der sich eine zweite poröse Röhre *19* befindet. Diese Röhre *19* geht in einen nicht porösen Teil *20* über und ist durch Einschmelzung in der Röhre *18* befestigt. Mittels der Pumpen *15*, *14* und *21* werden nun Fraktionen des von der Röhre *13* zugeführten Gasgemisches abgesaugt. Es kann nun aber so eingerichtet werden, daß z. B. durch die poröse Wand *16* ein Sechstel, durch die poröse Wand *19* vier Sechstel und durch die Röhre *18* ein Sechstel abgesaugt werden. Die durch die poröse Wand *19* abgesaugte Fraktion wird nun durch die Röhre *20* wieder dem Entmischungselement *c′* selbst zugeführt. Damit diese Fraktion viermal so groß als jede der Fraktionen sei, die durch die poröse Wand *16* und durch die Röhre *18* abgesaugt werden, ist es nötig, daß der Widerstand der porösen Wand *16* und der Röhre *18* je viermal so groß als jener der porösen Wand *19* sei. Am ersten und am letzten Element sind zwei Gefäße *22* und *23* angebracht, in denen sich die heliumreichste bzw. neonreichste Fraktionen ansammeln. Es hat sich herausgestellt, daß mit dem Verfahren gemäß der Erfindung, selbst in Gemischen von Gasen, die bisher schwer zu trennen waren, eine sehr weitgehende Trennung erzielt werden kann. Es ist sogar möglich, mit diesem Verfahren Isotopen, z. B. die Isotopen von Neon, voneinander zu trennen.

— 4 —

Obwohl in den oben beschriebenen Ausführungsbeispielen die entmischten Fraktionen den unmittelbar neben dem entmischenden Element liegenden Entmischungselementen zugeführt werden, so können die Fraktionen auch weiter entfernt liegenden Elementen zugeführt werden.

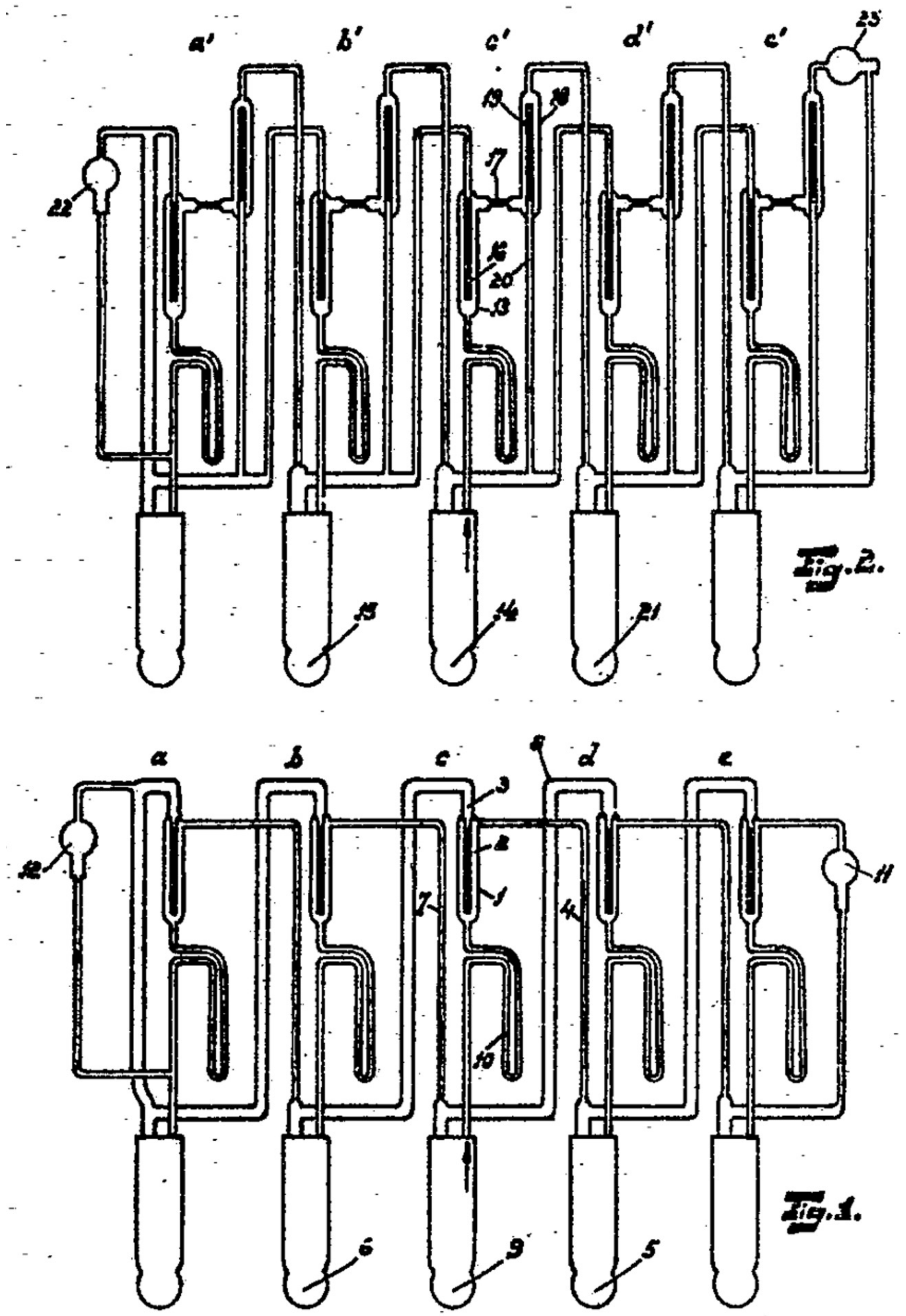
PATENT-ANSPRÜCHE:

1. Verfahren zur ununterbrochenen Trennung eines Gasgemisches, in welchem eine Reihe von Entmischungselementen gegebenenfalls auch mehrmals verwendet wird, deren jedes für sich imstande ist eine teilweise Entmischung in zwei oder mehr Fraktionen herbeizuführen, dadurch gekennzeichnet, daß diese Fraktionen, je nach ihrer Zusammensetzung, zwei oder mehr Entmischungselementen auf beiden Seiten oder auch dem betreffenden Entmischungselement selbst, derart zugeführt werden, daß die von einem Elemente einem zweiten Entmischungselemente zugeführte Gasmenge nahezu gleich der von dem zweiten Entmischungselemente dem ersten Elemente zugeführten Gasmenge, oder die den Entmischungselementen auf einer Seite eines bestimmten Entmischungselementes zugeführte Gasmenge nahezu gleich der den Entmischungselementen auf der andern Seite zugeführten Gasmenge ist.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß der Widerstand des Weges des ersten Entmischungselementes zum zweiten dem Widerstand des Weges des zweiten Entmischungselementes zum ersten nahezu gleich ist.

3. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß der Widerstand des einen Weges praktisch von einer porösen Wand bedingt wird, während der Widerstand des andern Weges durch eine geeignete Wahl des Durchmessers oder der Länge der zu diesem Zwecke verwendeten Röhre dem Widerstand des ersten Weges ungefähr gleich gemacht wird.

Figure D.226: One of Gustav Hertz's patents showing that many gaseous diffusion units could be used in series to achieve high-quality enrichment [Austrian Patent AT 107,571. Verfahren zur ununterbrochenen Trennung eines Gasgemisches].


a'
b'
c'
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e'
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19
18
17
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16
20
13
15
14
21
Fig. 2.
a
b
c
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3
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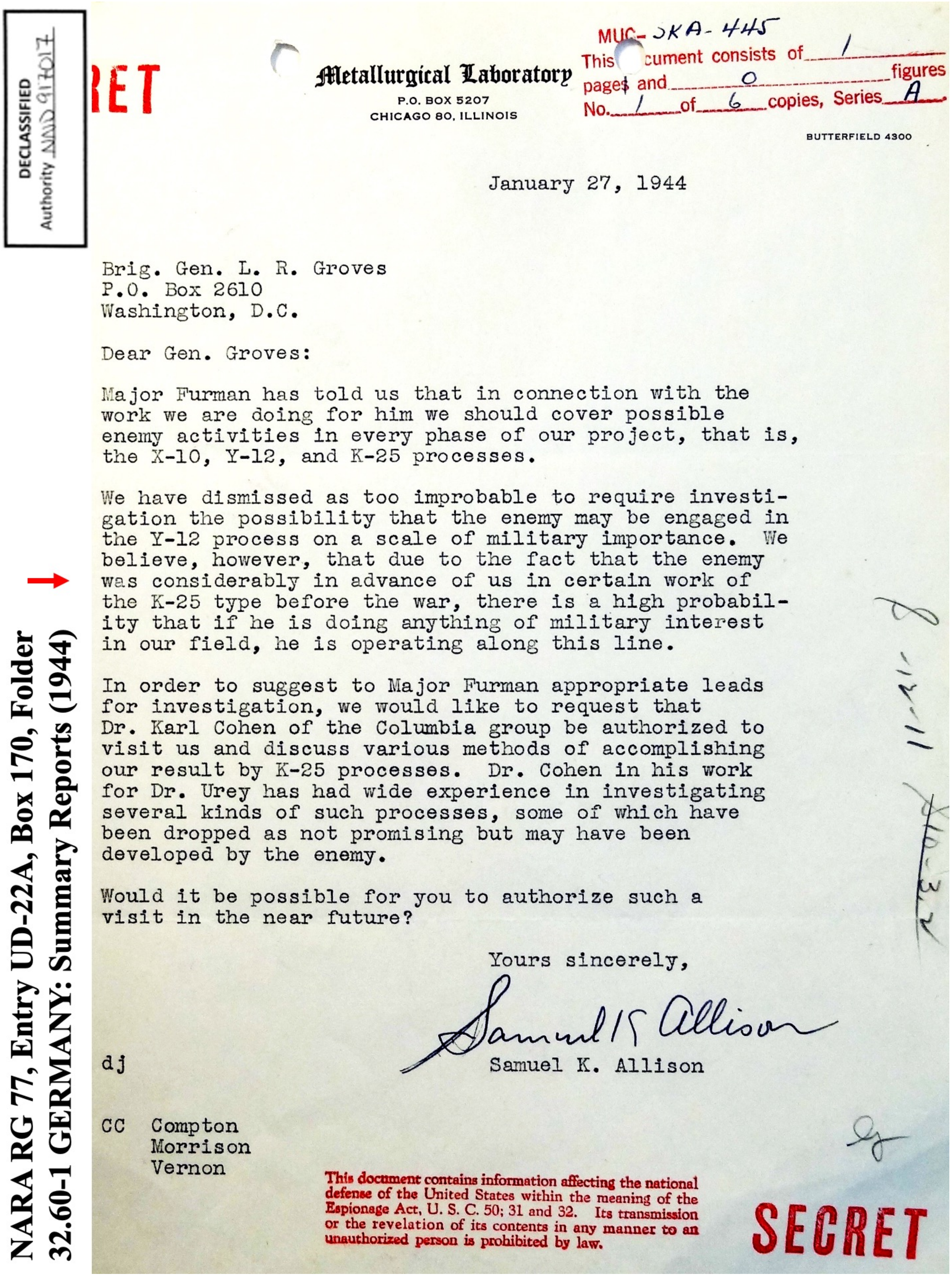
1
12
11
7
4
10
6
9
5
Fig. 1.

Figure D.227: One of Gustav Hertz's patents showing that many gaseous diffusion units could be used in series to achieve high-quality enrichment [Austrian Patent AT 107,571. Verfahren zur ununterbrochenen Trennung eines Gasgemisches].



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NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)

RET

Metallurgical Laboratory
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MUC-SKA-445
This [illegible]cument consists of 1 pages and 0 figures
No. 1 of 6 copies, Series A

January 27, 1944

Brig. Gen. L. R. Groves
P.O. Box 2610
Washington, D.C.

Dear Gen. Groves:

Major Furman has told us that in connection with the work we are doing for him we should cover possible enemy activities in every phase of our project, that is, the X-10, Y-12, and K-25 processes.

We have dismissed as too improbable to require investigation the possibility that the enemy may be engaged in the Y-12 process on a scale of military importance. We believe, however, that due to the fact that the enemy was considerably in advance of us in certain work of the K-25 type before the war, there is a high probability that if he is doing anything of military interest in our field, he is operating along this line.

In order to suggest to Major Furman appropriate leads for investigation, we would like to request that Dr. Karl Cohen of the Columbia group be authorized to visit us and discuss various methods of accomplishing our result by K-25 processes. Dr. Cohen in his work for Dr. Urey has had wide experience in investigating several kinds of such processes, some of which have been dropped as not promising but may have been developed by the enemy.

Would it be possible for you to authorize such a visit in the near future?

Yours sincerely,

Samuel K. Allison
Samuel K. Allison

dj

CC Compton
Morrison
Vernon

This document contains information affecting the national defense of the United States within the meaning of the Espionage Act, U. S. C. 50; 31 and 32. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

SECRET

Figure D.228: Samuel K. Allison to Leslie R. Groves. 27 January 1944. "[D]ue to the fact that the enemy was considerably in advance of us in certain work of the K-25 [gaseous diffusion enrichment] type before the war, there is a high probability that if he is doing anything of military interest in our field, he is operating along this line." [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]

Gustav Hertz. 1932. Ein Verfahren zur Trennung von gasförmigen Isotopengemischen und seiner Anwendung auf die Isotopen des Neons. [Process for the separation of gaseous mixtures of isotopes and its application to the isotopes of neon.] *Zeitschrift für Physik* 79:108–131, 700.

Das Verfahren benutzt die Diffusion durch eine poröse Wand ins Vakuum. Es ermöglicht die gleichzeitige Wirksamkeit einer großen Zahl von Diffusionszellen und damit eine weitgehende Entmischung eines Isotopengemisches in einem einzigen Arbeitsgang. Die ausgeführte Apparatur, welche 24 Pumpen und 48 Tonrohre enthält, ergibt bei einmaliger Anwendung auf die Isotopen des Neons in wenigen Stunden eine Änderung des Isotopenverhältnisses um nahezu den Faktor 8. Durch wiederholte Anwendung ist eine weitergehende Trennung möglich. Es werden Massenspektrogramme und optische Spektren von Neon-Isotopengemischen verschiedener Zusammensetzung reproduziert.

The process uses diffusion through a porous wall into a vacuum. It allows the simultaneous effectiveness of a large number of diffusion cells and thus extensive segregation of a mixture of isotopes in a single operation. The executed apparatus, which contains 24 pumps and 48 clay tubes, when applied once to the isotopes of neon, results in a change in the isotopic ratio by a factor of nearly 8 in a few hours. More extensive separation is possible by repeated application. Mass spectrograms and optical spectra of neon isotope mixtures of various compositions are reproduced.

Gustav Hertz. 1932. Ein Verfahren zur Trennung von gasförmigen Isotopengemischen. [A process for the separation of gaseous isotope mixtures.] *Naturwissenschaften* 20:493–494.

Gustav Hertz. 1933. Reindarstellung des schweren Wasserstoffisotops durch Diffusion. [Manufacture of Pure Heavy Hydrogen Isotope by Diffusion.] *Naturwissenschaften* 21:884–885.

H. Harmsen, Gustav Hertz, and Werner Schütze. 1934. Weitere Versuche zur Isotopentrennung. [Further experiments on isotope separation.] *Zeitschrift für Physik* 90:703–711.

Die Leistungsfähigkeit der früher beschriebenen Apparatur zur Trennung von gasförmigen Isotopengemischen ist durch Verdoppelung der Zahl der Trennungsglieder sowie durch Benutzung größerer Pumpen bei einem Teil der Trennungsglieder so weit erhöht worden, daß bereits durch einmalige Anwendung des Verfahrens aus normalem Neon das Isotop 22 praktisch rein hergestellt werden kann. Auch das schwere Wasserstoffisotop läßt sich mit Hilfe der Apparatur in großer Reinheit darstellen. Ausgehend von einem Wasserstoff, welcher etwa $1^{o}/_{oo}$ des schweren Isotops enthält, ergibt sich in 8 Stunden 1 cm^3 spektralreiner schwerer Wasserstoff von Atmosphärendruck.

The efficiency of the previously described apparatus for the separation of gaseous isotopic mixtures has been increased by doubling the number of separation elements and by using larger pumps for some of the separation elements to such an extent that the isotope 22 can be produced practically pure from normal neon just by using the process once. The heavy hydrogen isotope can also be produced in great purity with the aid of the apparatus. Starting from a hydrogen containing about $1^{o}/_{oo}$ of the heavy isotope, 1 cm^3 of spectrally pure heavy hydrogen of atmospheric pressure is obtained in 8 hours.

Gustav Hertz. 1934. Ein Verfahren zur Trennung von Isotopengemischen durch Diffusion in strömendem Quecksilberdampf. [Process for the separation of isotope mixtures by diffusion in flowing mercury vapour.] *Zeitschrift für Physik* 91:810–815.]

Das früher angegebene Verfahren zur Trennung von Isotopengemischen wird dadurch verbessert, daß an Stelle der Diffusion durch eine poröse Wand die Diffusion in strömendem Quecksilberdampf zur Trennung verwandt wird. Hierzu wird eine Diffusionspumpe besonderer Bauart benutzt, welche die Eigenschaft hat, aus einem Gasgemisch bevorzugt die schneller diffundierenden Bestandteile zu pumpen. Aus zwölf solchen Pumpen wird eine Apparatur zusammengesetzt, welche für die Neonisotopen eine Änderung des Isotopenverhältnisses um etwa den Faktor 10 ergibt.

The method described earlier for separating isotope mixtures is improved by using diffusion in flowing mercury vapor instead of diffusion through a porous wall. For this purpose, a diffusion pump of special design is used, which has the property of preferentially pumping the more rapidly diffusing components out of a gas mixture. An apparatus is assembled from twelve such pumps, which results in a change of the isotope ratio for the neon isotopes by a factor of about 10.

Hubert Krüger. 1939. Über die Anreicherung des N^{15}-Isotops und einige spektroskopische Untersuchungen am N^{15}. [About the Enrichment of the N^{15} Isotope and Some Spectroscopic Investigations of N^{15}.] *Zeitschrift für Physik* 111:467–474.

Mit einer 42 gliedrigen Hertzschen Isotopentrennungsapparatur konnten Anreicherungen des N^{15}-Isotops von N^{14}:N^{15}=4:1 erreicht werden.

With a 42-stage Hertz isotope separation apparatus, enrichments of the N^{15} isotope of N^{14}:N^{15}=4:1 could be achieved.

Pavel V. Oleynikov. 2000. German Scientists in the Soviet Atomic Project. *Nonproliferation Review* 7:2:1–30.

Gustav Hertz was probably the most eminent scientist among all the Germans who went to work in the Soviet Union. He received the Nobel Prize in physics in 1925 for his work with James Franck demonstrating the quantized nature of atomic excitation potentials. In 1932, he conducted the first experiments into separation of neon isotopes by the diffusion method. At the time of his transfer to the Soviet Union, he was the head of Siemens Research Laboratory. [...]

Hertz arrived at Sukhumi together with von Ardenne and was given a separate institute—Institute “G” at Agudzery. [...] The topics assigned to Institute “G” were:[114]

- separation of isotopes by diffusion in a flow of inert gas (leader—Gustav Hertz);
- development of a condensation pump (leader— Muellenpford); and
- development of a theory of stability and control of a diffusion cascade (leader—Heinz Barwich).

[...] German scientists substantially contributed to the Soviet’s efforts to design a membrane for gaseous diffusion technology. In early 1946, Laboratory No. 2 (now the Kurchatov Institute) issued a classified request for a proposal to design a flat membrane.[175] Fifteen organizations submitted their designs. The Moscow Combine of Hard Alloys (MKTS) won the competition. In their design, nickel powder was poured into a mold atop a vibrating table. After some vibration to compact the powder and level its surface, the tray was baked in an oven until the powder was partially melted and formed a ceramic-like porous plate. After the addition of some strengthening elements, the plate was turned into a membrane ready for use. After tests, however, it was found that nearly 10 percent of all pores in such a membrane would let any molecule go through (i.e., were too big to perform the separation function), and that the operating pressure of such membranes was 20 to 30 millimeters (mm) of mercury (Hg) column, a feature that would lead to large losses of electric power, a waste of compressor power, and extremely high requirements on the air-tightness of the machinery.

German groups in Institutes “A” and “G” joined the competition some time in 1947 and started to work on designs for tubular membranes that were expected to be more efficient. Peter Thiessen’s group in Institute “A” focused on a lattice-type filter: a nickel lattice with 10,000 holes per square centimeter was covered by fine-grain nickel carbonyl and baked in an oven. Afterwards, the mesh was bent and welded into tubes. It was discovered that Soviet industry at the time was unable to duct nickel wire finely enough to make the required lattice. For some time the necessary wire and the lattice were ordered from Berlin.[176] Although Peter Thiessen later received a Stalin Prize for his work in the area of gaseous diffusion, it is unlikely that he personally invented the membrane. Rudenko and Kruglov mention that a Dr. [Werner] Schütze received a Stalin Prize in 1948 for design of a diffusion membrane.[177]

Both German and Russian sources state that Thiessen’s design had an unpredictable nature and was more appropriate for a lab bench than mass production; Zavenyagin derided his process as “artisanship.”[178] Nickel carbonyl powder was manually sprayed on flat lattices and then these were pressed by rolls. Given the huge surface area of diffusion membranes, manual spraying was a real drawback. The need to do it manually disappeared only in 1952 when a way to automate this tedious process was found.[179]

The German group in Institute "G" was headed by a former pharmacist, Reinhold Reichmann. He was working on a mouthpiece type of membrane that could be extruded and would require no welding. Reichmann first experimented with copper and silver, then with nickel. Reichmann's solution clearly had its roots in his previous occupation—he mixed nickel with dimethylgloxin and then with a mild pain killer, clove pinks oil.[180] The mixture was then extruded and baked. Reichmann died soon after his discovery, and a Stalin Prize was awarded to him posthumously in 1948.[181]

Both types of tubular filters developed by the German teams, after tests in Laboratory No. 2, were approved for use in second-generation diffusion machines.[182] It was decided to send Thiessen's group to Plant No. 12 in Elektrostal, and Reichmann's group (headed then by V.N. Yeremin and his wife) to the MKTS. Beginning in 1949, these two plants started to manufacture all filters for diffusion machines.

The new filters could be used at pressures up to 50 mm of Hg column. This meant that—without any changes in the gaseous diffusion plant's design—its capacity could be increased by a factor of 2 or 2.5, provided its compressors could work at higher pressures. Tubular filters were first used in the second-generation diffusion machines that formed the basis of the second diffusion plant, the D-3 plant at Sverdlovsk-44.[183] In 1953, Zavenyagin decided that the production of diffusion filters should be transferred to the Sverdlovsk-44 site in the Urals.[184] [...]

At the NKVD's instruction, in late 1945 Hertz and his colleagues in Institute "G" started development of a control theory for diffusion cascades. Cascades connect a large number of individual diffusion stages in which the isotope of interest is gradually separated from the initial feed gas. Hertz and Barwich were calculating requirements for pumps in the diffusion cascades, and also acceptable losses of uranium hexafluoride due to corrosion in the cascades. Also, from theoretical calculations they determined percolation (i.e., a statistical description of a particle's path through a filter) in a membrane and the diameter of pores in a filter. In 1946, Barwich worked out a theory of natural stability of separation cascades that led to a reduction in the number of compressors in the design of the enrichment plant and a reduction in the time the material stayed inside the plant. [...]

In 1948, the first gaseous diffusion plant in the USSR, D-1, was put into operation. It contained 6,200 diffusion machines installed in 56 enrichment cascades.[185] The D-1 plant had problems.[186] Ball-bearings in compressors were made too precisely, without proper tolerances for thermal expansion, and quickly failed. Infusions of uranium hexafluoride into the plant were not leading to any product at the output. The situation was catastrophic. Among the luminaries brought in to help solve the problem in October 1948 were Gustav Hertz, Heinz Barwich, and Peter Thiessen.[187] Because they did not know the official name of the secret facility, the trio christened it "Kefirstadt" (now Sverdlovsk-44 or Novouralsk) after the "kefir" milk drink that they were given there every day for more than a month.[188]

The D-1 plant's greatest problem was corrosion. In the presence of water, uranium hexafluoride turned into tetrafluoride and stuck to the surfaces of the cascades as a powder. To fix this, all workshops were put under air hoods where they were supplied with dehumidified air. Also, nearly 5,000 leaky compressors were replaced in the plant. Peter Thiessen, with his co-worker from Sukhumi Prof. Karzhavin, proposed using a heated fluorine-air mixture to passivate (i.e., give a protective coating to) all internal surfaces of the cascades to reduce future corrosion by tetrafluoride.[189] [...]

The first awards for uranium enrichment technologies were presented in 1951 after the successful tests of a nuclear bomb containing uranium (the earlier Soviet test in 1949 involved a plutonium bomb).[191] Thiessen was awarded a first class Stalin Prize, while Hertz, Barwich, and their Russian colleague Krutkow received a second class award.[192]

[114] Kruglov, *Kak sozdavalas atomnaja promyshlennost v SSSR*, pp. 165–166. [...]

[175] N.M. Sinjov, *Obogaschjonny uran dlja atomnogo oruzhija i energetiki* (*Enriched Uranium for Atomic Weapons and Energy Production*) (Moscow: TsNIIAtominform, 1991), pp. 39–40.

[176] Russian respect for Germany and its industry was well-founded. Even in times of war Germany was able to produce products much superior to anything in the Soviet Union. See, for example, B. Chertok, *Rakety I Ljudi*, where he mentions that the Germans had used nearly 80 metals and alloys in their V-2 rocket, while Soviet industry was capable of producing less than 40.

[177] Rudenko, "Yaderny Plagiat," p.10; Kruglov, *Kak sozdavalas atomnaja promyshlennost v SSSR*, p.167.

[178] Barwich, *Das rote Atom*, p. 147.

[179] Mikhailov and Petrosjants, *Sozdanije pervoi sovetskoi atomnoi bomby*, p. 331.

[180] Clove pinks oil was used as a mild pain killer by dentists. It relieves pain when it evaporates.

[181] Albrecht, Heinemann-Grueder, and Wellmann, *Die Spezialisten*, p. 67.

[182] Amazingly, there was strong opposition to this decision. The Gorkiy machine plant that won the contract to manufacture the first-generation machines with flat filters was against the idea, while the design bureau from the Elektrosila plant in Leningrad, which was still trying to promote its designs, wanted to adopt the new technology. In his book, Sinjov openly speaks of "revenge by Gorkiy people." Even huge projects do not kill envy in people! See Sinjov, *Obogaschjonny uran dlja atomnogo oruzhija i energetiki*, p. 42.

[183] Sverdlovsk-44 is now also known as Novouralsk. Ibid., pp. 43–44.

[184] Kruglov, *Kak sozdavalas atomnaja promyshlennost v SSSR*, p. 175.

[185] Ibid., p. 185.

[186] Ibid.

[187] Barwich, *Das rote Atom*, p. 103

[188] Klaus Thiessen, telephone conversation with author, July 9, 1999.

[189] Kruglov, *Kak sozdavalas atomnaja promyshlennost v SSSR*, p. 186. [...]

[191] V. Zhuchikhin, *Vtoraja atomnaja* (*The Second Atomic Bomb*) (Snezhinsk, Russia: RFNC-VNIIEF, 1995), p. 110.

[192] Albrecht, Heinemann-Grueder, and Wellmann, *Die Spezialisten*, pp. 74–75.

Moe Berg. 1952. Handwritten notes. [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency.] [See photos on pp. 5052–5063.]

3. Industrial contrib. without [outside] USSR

- most nickel wire mesh for use as a barrier backing for the gaseous diffusion plant by East German factories–altho reports: such prod. in Moscow area
- Re nickel wire for these screens, as well as looms for it, are also prod's of East German firms.
- apparently only EMIL JAEGER firm NEUSTADT/ORLA capable of making looms of the quality req'd in prod. of fine nickel wire mesh.

[...] by mid-1948, USSR had started prod. of the fine nickel wire mesh needed as backing for their barrier. This wire mesh is extremely difficult to produce, + only a few firms in the Soviet zone of Germany + apparently none in USSR, could make this product.

[Leftover wartime factories in Neustadt an der Orla, East Germany, were perfectly set up to make high-quality nickel membrane filters for gaseous diffusion uranium enrichment plants.

See pp. 3634–3638, 5052, 5055–5057. Manufacturing the filters was so difficult that even years after the war, Soviet plants could not make comparable items.

What exactly did these German factories do during the war? Did wartime Germany build gaseous diffusion uranium enrichment plants?

See also reports on large-scale production of nickel in Germany during the war (p. 4138).]

Ein Riese mit Fingerspitzengefühl: Drahtwebstuhl läuft in der Ausstellung "Aufbau West" auf Zollern [A Giant with Flair: Wire Loom Runs in the Exhibition "Development West" at Zollern]. LWL. 22 December 2005. https://www.lwl.org/pressemitteilungen/nr_mitteilung.php?urlID=15584

Teilweise demontiert und durch die DDR-Regierung enteignet, stand die Maschinenfabrik Emil Jäger im thüringischen Neustadt/Orla in der Nachkriegszeit faktisch vor dem Aus. Der Firmenchef floh 1948 in den Westen, um hier sein Familienunternehmen wieder aufzubauen. Eine solide Grundlage für den Neubeginn war nicht nur die Tatsache, dass ihm viele Fachkräfte aus Thüringen folgten, sondern vielmehr der glückliche Umstand, dass Jäger schon während des Krieges Sicherheitsverfilmungen seiner Maschinenpläne anfertigen lassen hatte. Neben dem Wissen im Kopf waren diese rund 1.500 Kleinbildaufnahmen das Fundament für den Neubeginn.

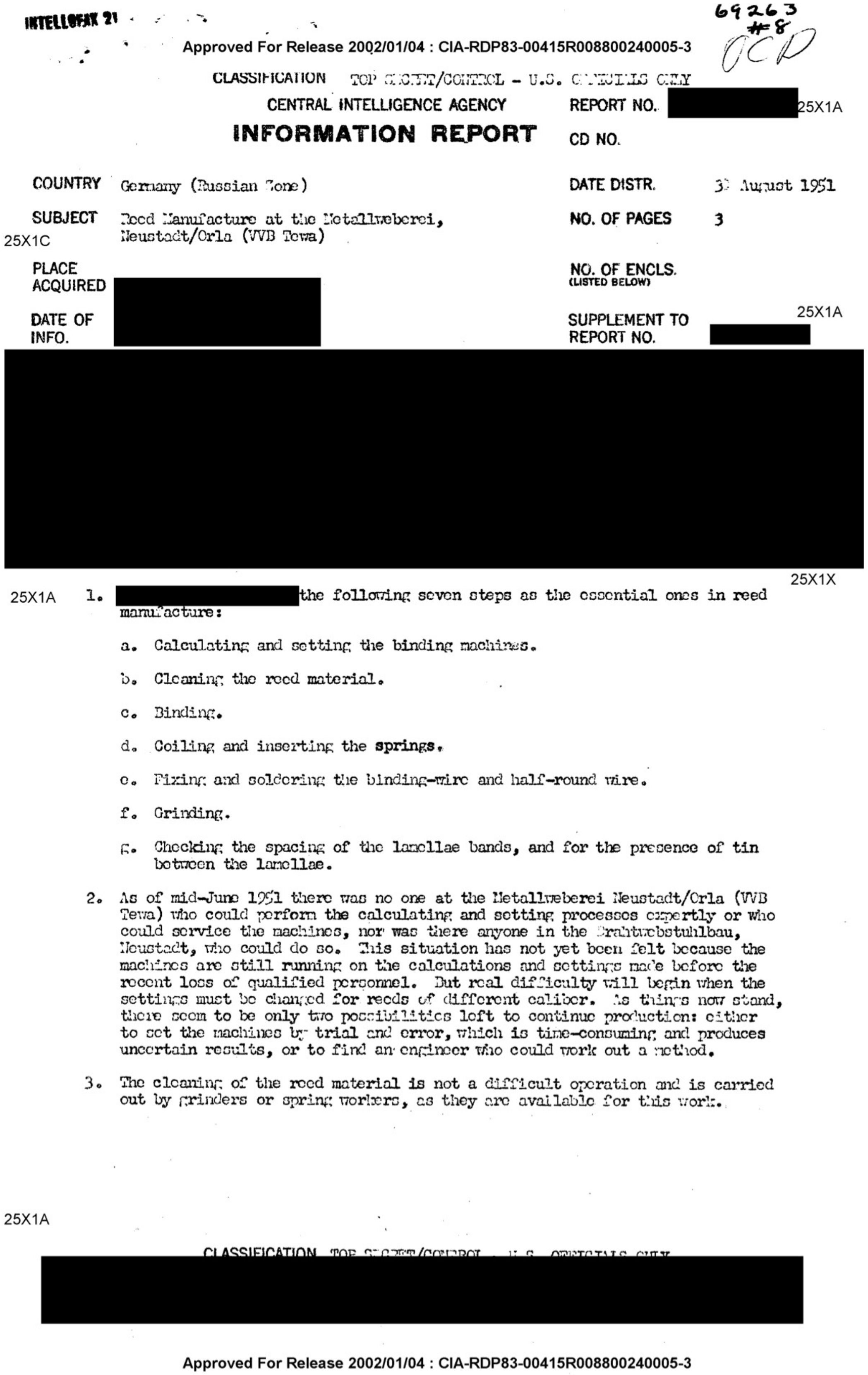
Für einen erfolgreichen Start im Westen sorgte 1948 das Angebot der "Westfälischen Union": Jäger sollte die Maschinen für die Neueinrichtung einer Drahtweberei in Hamm bauen. Das damals führende Unternehmen der deutschen Drahtindustrie stellte dafür Platz auf dem werkseigenen Gelände, Maschinen sowie Geld zur Verfügung. Am 1. Juli 1949 war der erste Drahtwebstuhl fertig. [...]

Platzmangel in Hamm sowie ein günstiges Angebot brachten Emil Jäger 1952 schließlich dazu, seinen Betrieb nach Münster zu verlagern. Hier nahm er in den zerstörten Hallen der ehemaligen Flugzeugfabrik Hansen die Produktion wieder auf und die Erfolgsgeschichte des Unternehmens ging weiter: Die 500. Maschine wurde im Mai 1956 fertiggestellt, die 1000. folgte im Frühjahr 1961. In den 1960er Jahren avancierte Emil Jäger bereits zum größten Hersteller der Welt.

Partially dismantled and expropriated by the GDR government, the Emil Jäger machine factory in Neustadt/Orla in Thuringia was effectively on the brink of extinction in the post-war period. The company boss fled to the West in 1948 to rebuild his family business here. A solid foundation for the new start was not only the fact that many skilled workers from Thuringia followed him, but rather the fortunate circumstance that Jäger had already had safety films made of his machine plans during the war. In addition to the knowledge in his head, these approximately 1,500 35mm photographs were the foundation for the new start.

In 1948, an offer from "Westfälische Union" ensured a successful start in the West: Jäger was to build the machines for the new establishment of a wire weaving mill in Hamm. The leading company in the German wire industry at the time provided space on its own premises, machines and money. On 1 July 1949, the first wire loom was ready. [...]

A lack of space in Hamm and a favorable offer finally led Emil Jäger to relocate his business to Münster in 1952. Here he resumed production in the destroyed halls of the former Hansen aircraft factory, and the company's success story continued: the 500th machine was completed in May 1956, followed by the 1000th in spring 1961. By the 1960s, Emil Jäger had already advanced to become the world's largest manufacturer.



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CENTRAL INTELLIGENCE AGENCY

INFORMATION REPORT

REPORT NO. [redacted] 25X1A

CD NO.

COUNTRY Germany (Russian Zone)

SUBJECT Reed Manufacture at the Metallweberei, Neustadt/Orla (VVB Tewa)

25X1C

PLACE ACQUIRED [redacted]

DATE OF INFO.

DATE DISTR. 30 August 1951

NO. OF PAGES 3

NO. OF ENCLS. (LISTED BELOW)

SUPPLEMENT TO REPORT NO. [redacted] 25X1A

[redacted]

25X1X

25X1A

1. [redacted] the following seven steps as the essential ones in reed manufacture:

   a. Calculating and setting the binding machines.

   b. Cleaning the reed material.

   c. Binding.

   d. Coiling and inserting the springs.

   e. Fixing and soldering the binding-wire and half-round wire.

   f. Grinding.

   g. Checking the spacing of the lamellae bands, and for the presence of tin between the lamellae.

2. As of mid-June 1951 there was no one at the Metallweberei Neustadt/Orla (VVB Tewa) who could perform the calculating and setting processes expertly or who could service the machines, nor was there anyone in the Drahtwebstuhlbau, Neustadt, who could do so. This situation has not yet been felt because the machines are still running on the calculations and settings made before the recent loss of qualified personnel. But real difficulty will begin when the settings must be changed for reeds of different caliber. As things now stand, there seem to be only two possibilities left to continue production: either to set the machines by trial and error, which is time-consuming and produces uncertain results, or to find an engineer who could work out a method.

3. The cleaning of the reed material is not a difficult operation and is carried out by grinders or spring workers, as they are available for this work.

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[redacted]

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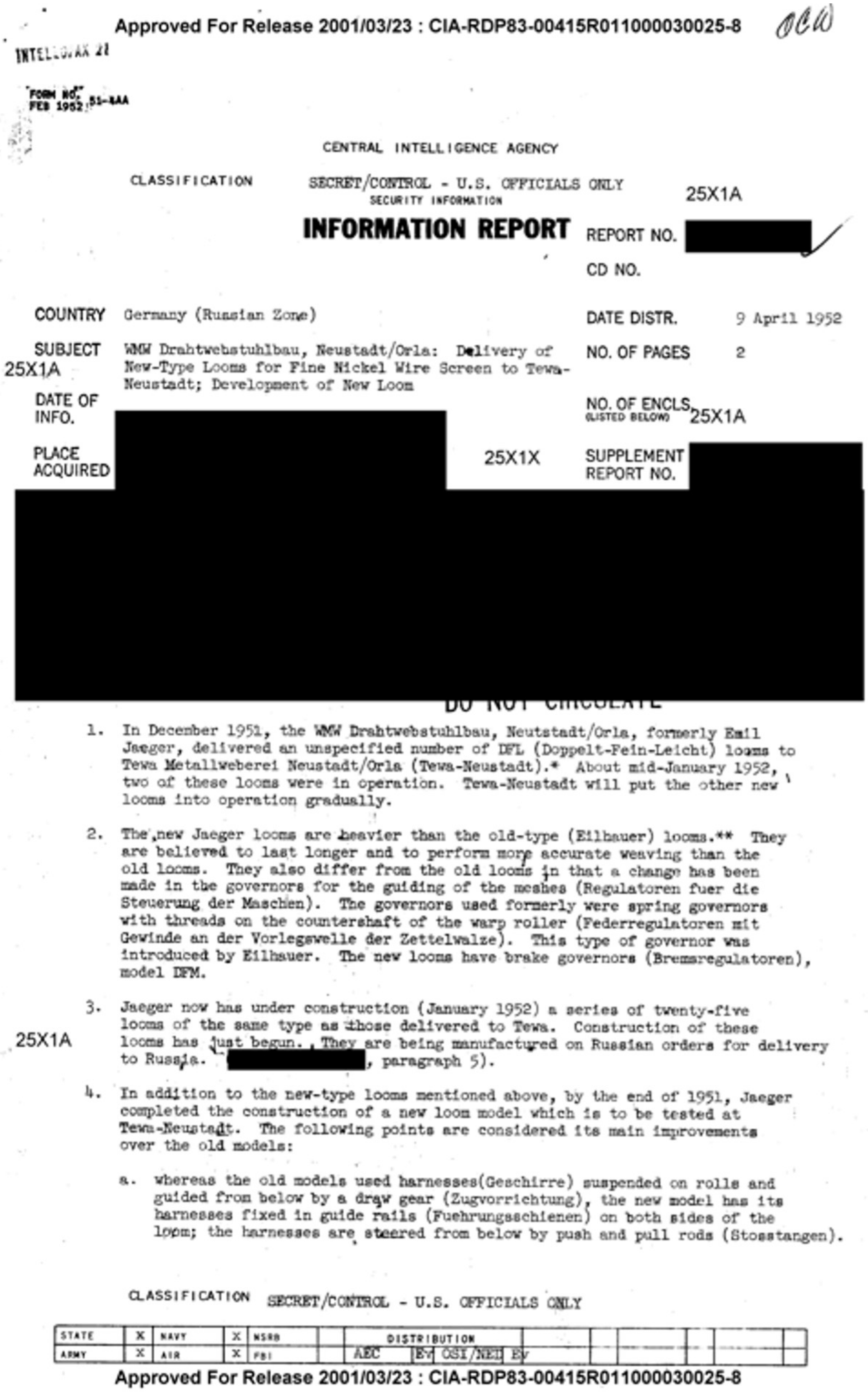
https://s3.documentcloud.org/documents/22799707/reed-manufacture-at-the-metallweberei-neustadtorla-vvb-tewa.pdf

Figure D.229: Leftover wartime factories in Neustadt an der Orla, East Germany, were perfectly set up to make high-quality nickel membrane filters for gaseous diffusion uranium enrichment plants. Did those factories produce such filters for German enrichment plants during the war?

https://archive.org/details/CIA-RDP83-00415R011000030025-8



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25X1A

INFORMATION REPORT

REPORT NO. [redacted]

CD NO.

COUNTRY Germany (Russian Zone)

DATE DISTR. 9 April 1952

SUBJECT WMW Drahtwebstuhlbau, Neustadt/Orla: Delivery of New-Type Looms for Fine Nickel Wire Screen to Tewa-Neustadt; Development of New Loom

25X1A

NO. OF PAGES 2

DATE OF INFO. [redacted]

NO. OF ENCLS. (LISTED BELOW) 25X1A

PLACE ACQUIRED [redacted]

25X1X

SUPPLEMENT REPORT NO. [redacted]

[redacted]

1. In December 1951, the WMW Drahtwebstuhlbau, Neutstadt/Orla, formerly Emil Jaeger, delivered an unspecified number of DFL (Doppelt-Fein-Leicht) looms to Tewa Metallweberei Neustadt/Orla (Tewa-Neustadt).* About mid-January 1952, two of these looms were in operation. Tewa-Neustadt will put the other new looms into operation gradually.

2. The new Jaeger looms are heavier than the old-type (Eilhauer) looms.** They are believed to last longer and to perform more accurate weaving than the old looms. They also differ from the old looms in that a change has been made in the governors for the guiding of the meshes (Regulatoren fuer die Steuerung der Maschen). The governors used formerly were spring governors with threads on the countershaft of the warp roller (Federregulatoren mit Gewinde an der Vorlegswelle der Zettelwalze). This type of governor was introduced by Eilhauer. The new looms have brake governors (Bremsregulatoren), model DFM.

3. Jaeger now has under construction (January 1952) a series of twenty-five looms of the same type as those delivered to Tewa. Construction of these looms has just begun. They are being manufactured on Russian orders for delivery to Russia. [redacted], paragraph 5).

25X1A

4. In addition to the new-type looms mentioned above, by the end of 1951, Jaeger completed the construction of a new loom model which is to be tested at Tewa-Neustadt. The following points are considered its main improvements over the old models:

   a. whereas the old models used harnesses(Geschirre) suspended on rolls and guided from below by a draw gear (Zugvorrichtung), the new model has its harnesses fixed in guide rails (Fuehrungsschienen) on both sides of the loom; the harnesses are steered from below by push and pull rods (Stosstangen).

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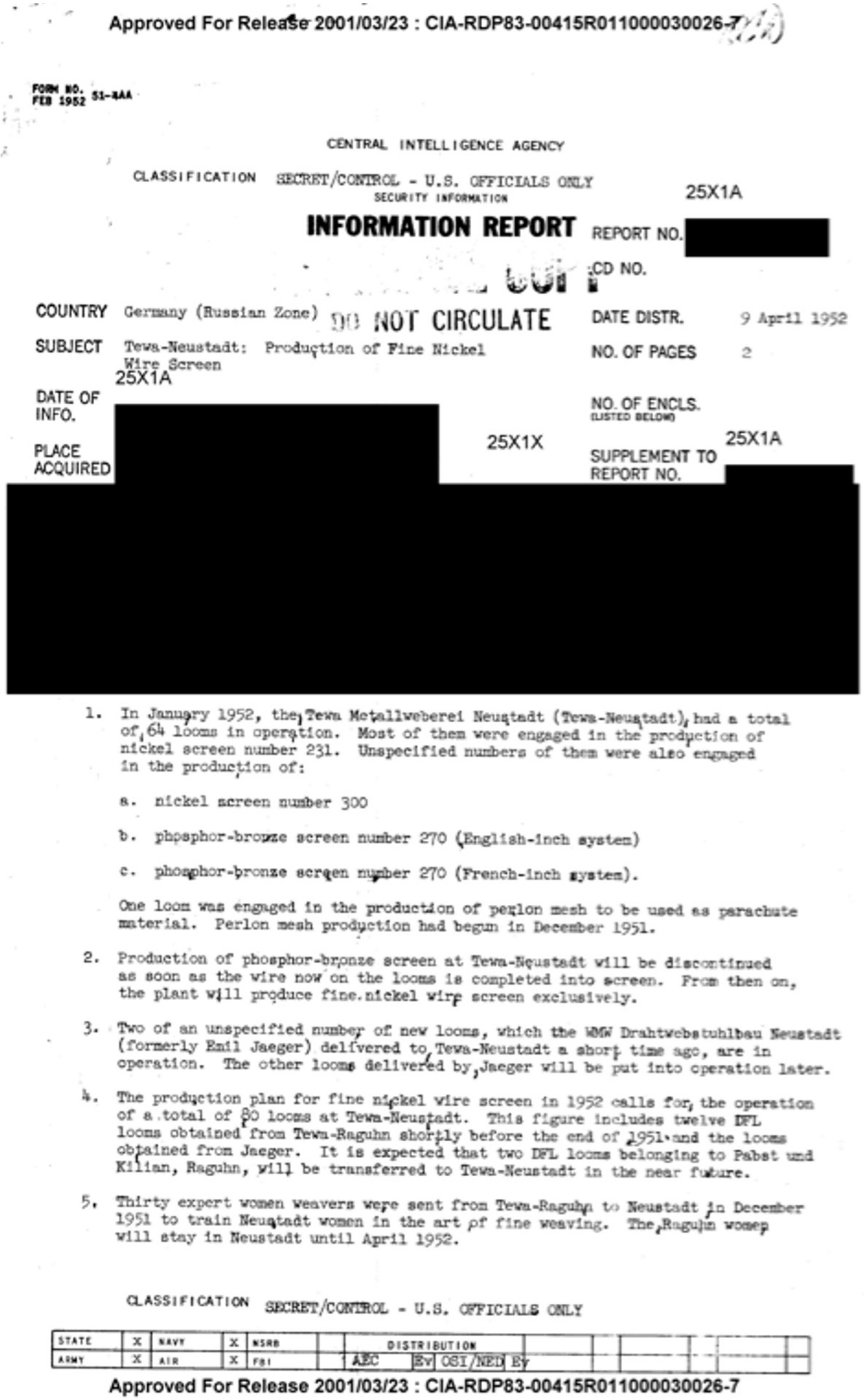
Figure D.230: Leftover wartime factories in Neustadt an der Orla, East Germany, were perfectly set up to make high-quality nickel membrane filters for gaseous diffusion uranium enrichment plants. Did those factories produce such filters for German enrichment plants during the war?



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SECURITY INFORMATION

25X1A

INFORMATION REPORT

REPORT NO. [redacted]

CD NO.

DO NOT CIRCULATE

COUNTRY Germany (Russian Zone)

SUBJECT Tewa-Neustadt: Production of Fine Nickel Wire Screen

25X1A

DATE OF INFO. [redacted]

PLACE ACQUIRED

DATE DISTR. 9 April 1952

NO. OF PAGES 2

NO. OF ENCLS. (LISTED BELOW)

25X1X

25X1A

SUPPLEMENT TO REPORT NO. [redacted]

[redacted]

1. In January 1952, the Tewa Metallweberei Neustadt (Tewa-Neustadt), had a total of 64 looms in operation. Most of them were engaged in the production of nickel screen number 231. Unspecified numbers of them were also engaged in the production of:

   a. nickel screen number 300

   b. phosphor-bronze screen number 270 (English-inch system)

   c. phosphor-bronze screen number 270 (French-inch system).

   One loom was engaged in the production of perlon mesh to be used as parachute material. Perlon mesh production had begun in December 1951.

2. Production of phosphor-bronze screen at Tewa-Neustadt will be discontinued as soon as the wire now on the looms is completed into screen. From then on, the plant will produce fine nickel wire screen exclusively.

3. Two of an unspecified number of new looms, which the WMW Drahtwebstuhlbau Neustadt (formerly Emil Jaeger) delivered to Tewa-Neustadt a short time ago, are in operation. The other looms delivered by Jaeger will be put into operation later.

4. The production plan for fine nickel wire screen in 1952 calls for the operation of a total of 80 looms at Tewa-Neustadt. This figure includes twelve DFL looms obtained from Tewa-Raguhn shortly before the end of 1951 and the looms obtained from Jaeger. It is expected that two DFL looms belonging to Pabst und Kilian, Raguhn, will be transferred to Tewa-Neustadt in the near future.

5. Thirty expert women weavers were sent from Tewa-Raguhn to Neustadt in December 1951 to train Neustadt women in the art of fine weaving. The Raguhn women will stay in Neustadt until April 1952.

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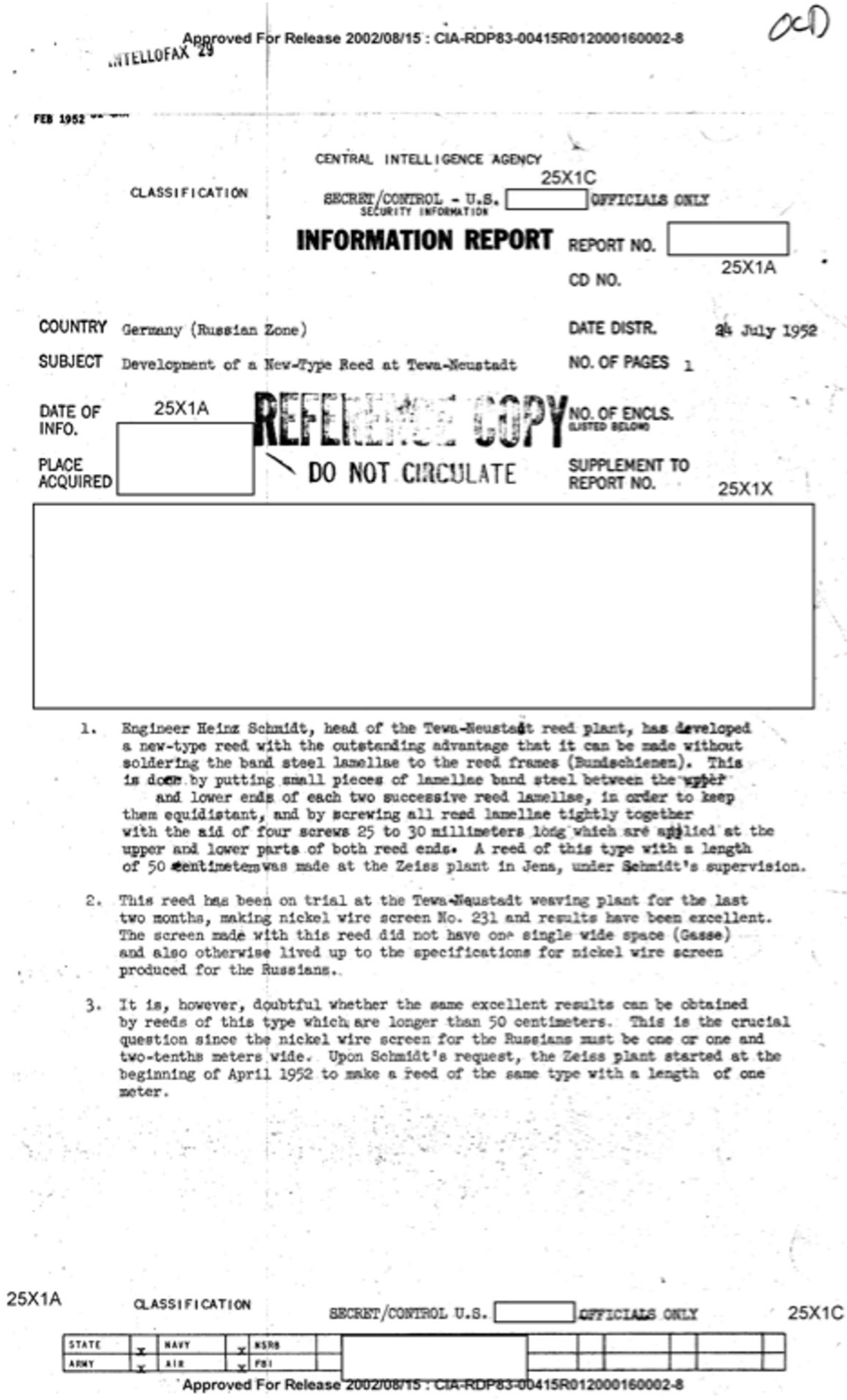
Figure D.231: Leftover wartime factories in Neustadt an der Orla, East Germany, were perfectly set up to make high-quality nickel membrane filters for gaseous diffusion uranium enrichment plants. Did those factories produce such filters for German enrichment plants during the war?



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CLASSIFICATION SECRET/CONTROL - U.S. [redacted] OFFICIALS ONLY
SECURITY INFORMATION

INFORMATION REPORT

REPORT NO. [redacted]
25X1A
CD NO.

COUNTRY Germany (Russian Zone)
DATE DISTR. 24 July 1952
SUBJECT Development of a New-Type Reed at Tewa-Neustadt
NO. OF PAGES 1
DATE OF INFO. 25X1A [redacted]
PLACE ACQUIRED [redacted]
NO. OF ENCLS. (LISTED BELOW)
SUPPLEMENT TO REPORT NO. 25X1X

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[redacted]

1. Engineer Heinz Schmidt, head of the Tewa-Neustadt reed plant, has developed a new-type reed with the outstanding advantage that it can be made without soldering the band steel lamellae to the reed frames (Bundschienen). This is done by putting small pieces of lamellae band steel between the upper and lower ends of each two successive reed lamellae, in order to keep them equidistant, and by screwing all reed lamellae tightly together with the aid of four screws 25 to 30 millimeters long which are applied at the upper and lower parts of both reed ends. A reed of this type with a length of 50 centimeters was made at the Zeiss plant in Jena, under Schmidt's supervision.

2. This reed has been on trial at the Tewa-Neustadt weaving plant for the last two months, making nickel wire screen No. 231 and results have been excellent. The screen made with this reed did not have one single wide space (Gasse) and also otherwise lived up to the specifications for nickel wire screen produced for the Russians.

3. It is, however, doubtful whether the same excellent results can be obtained by reeds of this type which are longer than 50 centimeters. This is the crucial question since the nickel wire screen for the Russians must be one or one and two-tenths meters wide. Upon Schmidt's request, the Zeiss plant started at the beginning of April 1952 to make a reed of the same type with a length of one meter.

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STATE	x	NAVY	x	NSRB		[redacted]
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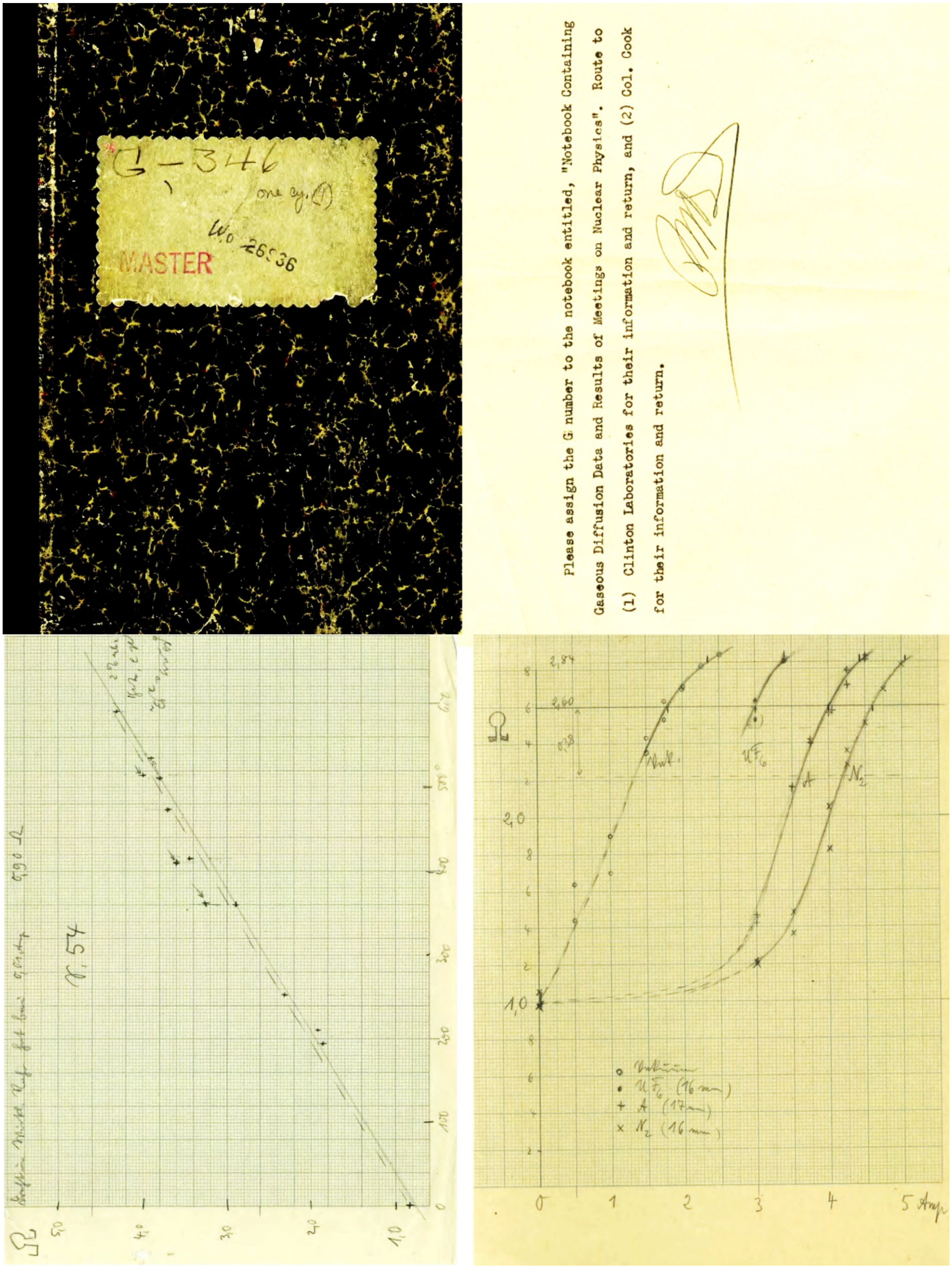
Figure D.232: Leftover wartime factories in Neustadt an der Orla, East Germany, were perfectly set up to make high-quality nickel membrane filters for gaseous diffusion uranium enrichment plants. Did those factories produce such filters for German enrichment plants during the war?



Please assign the G number to the notebook entitled, "Notebook Containing Gaseous Diffusion Data and Results of Meetings on Nuclear Physics". Route to (1) Clinton Laboratories for their information and return, and (2) Col. Cook for their information and return.

Figure D.233: Rudolf Fleischmann. 1940–1941. Notebook containing detailed notes on gaseous diffusion experiments, gaseous diffusion enrichment data, and results of meetings on nuclear physics [G-346].

Erika Cremer (1900–1996)
did her Ph.D. research on
(chemical) chain reactions,
pioneered gas
chromatography,
and worked on
isotope separation
during World War II.

Were her methods
implemented on
a larger scale for the
enrichment of uranium
via gaseous diffusion
during the war?

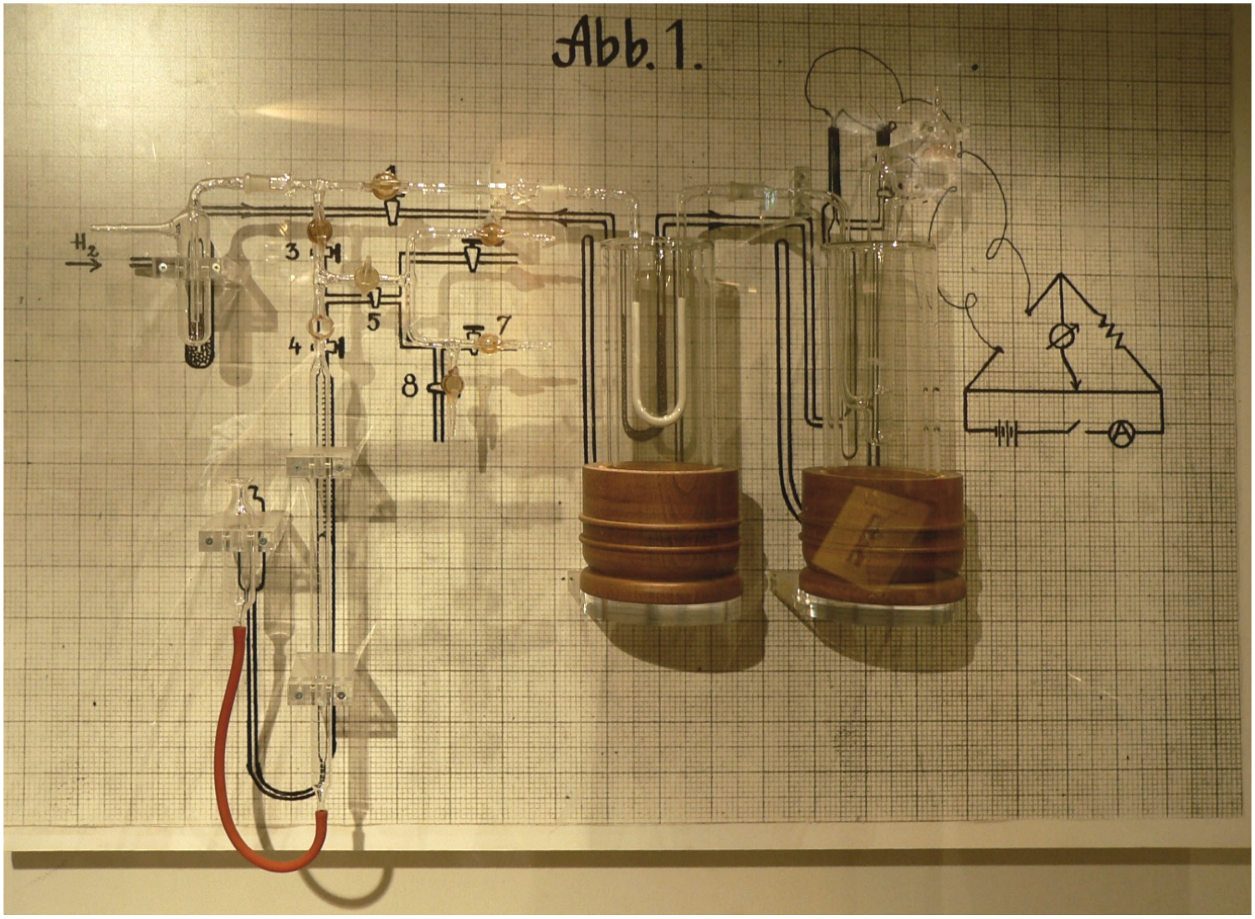
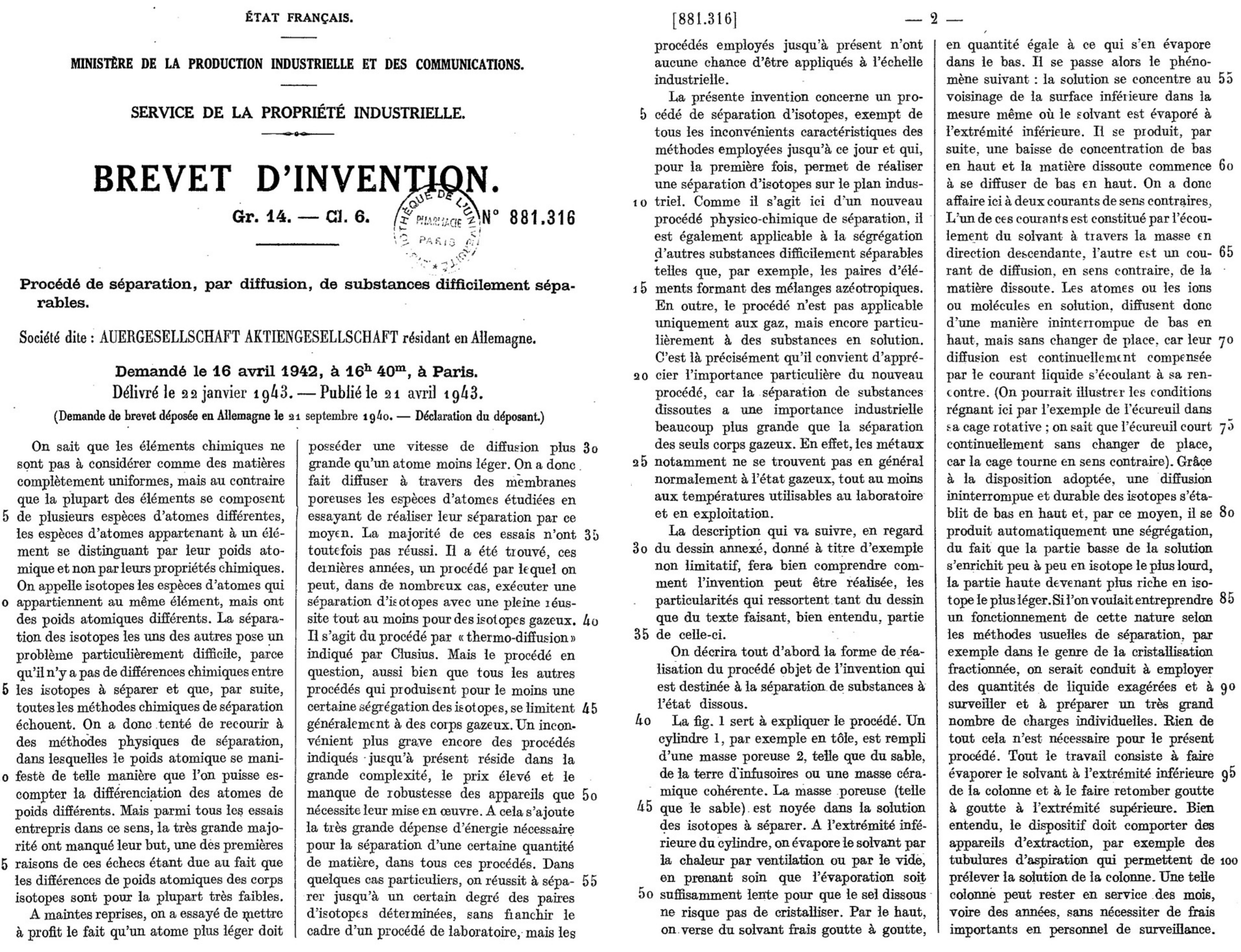


Figure D.234: Erika Cremer did her Ph.D. research on (chemical) chain reactions, collaborated with Otto Hahn and Siegfried Flügge, pioneered gas chromatography, and worked on isotope separation during World War II. Were her methods implemented on a larger scale for the enrichment of uranium via gaseous diffusion?



ÉTAT FRANÇAIS.

MINISTÈRE DE LA PRODUCTION INDUSTRIELLE ET DES COMMUNICATIONS.

SERVICE DE LA PROPRIÉTÉ INDUSTRIELLE.

BREVET D'INVENTION.

Gr. 14. — Cl. 6. N° 881.316

BIBLIOTHÈQUE DE L'UNIVERSITÉ PHARMACIE PARIS

Procédé de séparation, par diffusion, de substances difficilement séparables.

Société dite : AUERGESELLSCHAFT AKTIENGESELLSCHAFT résidant en Allemagne.

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On sait que les éléments chimiques ne sont pas à considérer comme des matières complètement uniformes, mais au contraire que la plupart des éléments se composent de plusieurs espèces d'atomes différentes, les espèces d'atomes appartenant à un élément se distinguant par leur poids atomique et non par leurs propriétés chimiques. On appelle isotopes les espèces d'atomes qui appartiennent au même élément, mais ont des poids atomiques différents. La séparation des isotopes les uns des autres pose un problème particulièrement difficile, parce qu'il n'y a pas de différences chimiques entre les isotopes à séparer et que, par suite, toutes les méthodes chimiques de séparation échouent. On a donc tenté de recourir à des méthodes physiques de séparation, dans lesquelles le poids atomique se manifeste de telle manière que l'on puisse escompter la différenciation des atomes de poids différents. Mais parmi tous les essais entrepris dans ce sens, la très grande majorité ont manqué leur but, une des premières raisons de ces échecs étant due au fait que les différences de poids atomiques des corps isotopes sont pour la plupart très faibles.

A maintes reprises, on a essayé de mettre à profit le fait qu'un atome plus léger doit posséder une vitesse de diffusion plus grande qu'un atome moins léger. On a donc fait diffuser à travers des membranes poreuses les espèces d'atomes étudiées en essayant de réaliser leur séparation par ce moyen. La majorité de ces essais n'ont toutefois pas réussi. Il a été trouvé, ces dernières années, un procédé par lequel on peut, dans de nombreux cas, exécuter une séparation d'isotopes avec une pleine réussite tout au moins pour des isotopes gazeux. Il s'agit du procédé par « thermo-diffusion » indiqué par Clusius. Mais le procédé en question, aussi bien que tous les autres procédés qui produisent pour le moins une certaine ségrégation des isotopes, se limitent généralement à des corps gazeux. Un inconvénient plus grave encore des procédés indiqués jusqu'à présent réside dans la grande complexité, le prix élevé et le manque de robustesse des appareils que nécessite leur mise en œuvre. A cela s'ajoute la très grande dépense d'énergie nécessaire pour la séparation d'une certaine quantité de matière, dans tous ces procédés. Dans quelques cas particuliers, on réussit à séparer jusqu'à un certain degré des paires d'isotopes déterminées, sans franchir le cadre d'un procédé de laboratoire, mais les

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procédés employés jusqu'à présent n'ont aucune chance d'être appliqués à l'échelle industrielle.

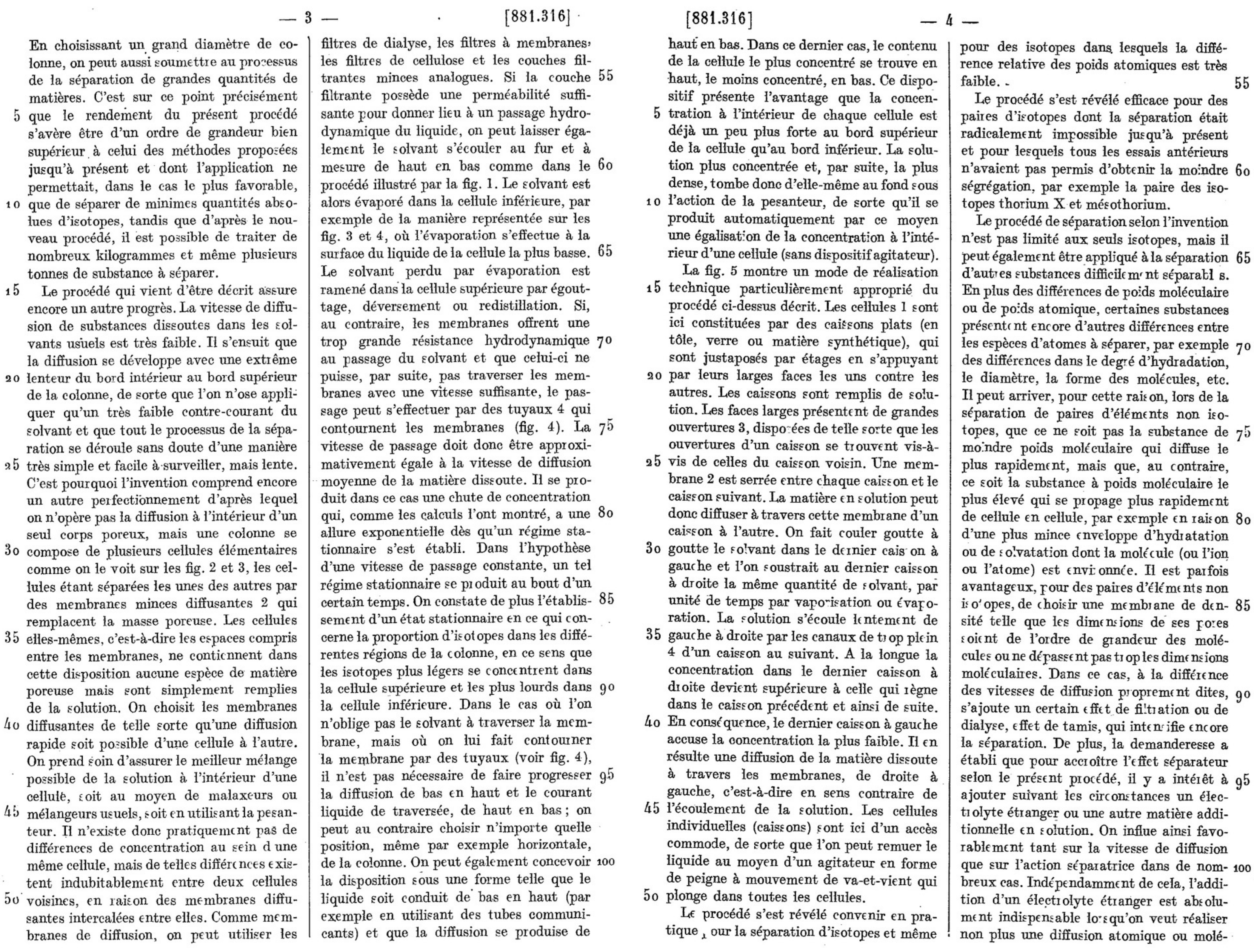
La présente invention concerne un procédé de séparation d'isotopes, exempt de tous les inconvénients caractéristiques des méthodes employées jusqu'à ce jour et qui, pour la première fois, permet de réaliser une séparation d'isotopes sur le plan industriel. Comme il s'agit ici d'un nouveau procédé physico-chimique de séparation, il est également applicable à la ségrégation d'autres substances difficilement séparables telles que, par exemple, les paires d'éléments formant des mélanges azéotropiques. En outre, le procédé n'est pas applicable uniquement aux gaz, mais encore particulièrement à des substances en solution. C'est là précisément qu'il convient d'apprécier l'importance particulière du nouveau procédé, car la séparation de substances dissoutes a une importance industrielle beaucoup plus grande que la séparation des seuls corps gazeux. En effet, les métaux notamment ne se trouvent pas en général normalement à l'état gazeux, tout au moins aux températures utilisables au laboratoire et en exploitation.

La description qui va suivre, en regard du dessin annexé, donné à titre d'exemple non limitatif, fera bien comprendre comment l'invention peut être réalisée, les particularités qui ressortent tant du dessin que du texte faisant, bien entendu, partie de celle-ci.

On décrira tout d'abord la forme de réalisation du procédé objet de l'invention qui est destinée à la séparation de substances à l'état dissous.

La fig. 1 sert à expliquer le procédé. Un cylindre 1, par exemple en tôle, est rempli d'une masse poreuse 2, telle que du sable, de la terre d'infusoires ou une masse céramique cohérente. La masse poreuse (telle que le sable) est noyée dans la solution des isotopes à séparer. A l'extrémité inférieure du cylindre, on évapore le solvant par la chaleur par ventilation ou par le vide, en prenant soin que l'évaporation soit suffisamment lente pour que le sel dissous ne risque pas de cristalliser. Par le haut, on verse du solvant frais goutte à goutte, en quantité égale à ce qui s'en évapore dans le bas. Il se passe alors le phénomène suivant : la solution se concentre au voisinage de la surface inférieure dans la mesure même où le solvant est évaporé à l'extrémité inférieure. Il se produit, par suite, une baisse de concentration de bas en haut et la matière dissoute commence à se diffuser de bas en haut. On a donc affaire ici à deux courants de sens contraires. L'un de ces courants est constitué par l'écoulement du solvant à travers la masse en direction descendante, l'autre est un courant de diffusion, en sens contraire, de la matière dissoute. Les atomes ou les ions ou molécules en solution, diffusent donc d'une manière ininterrompue de bas en haut, mais sans changer de place, car leur diffusion est continuellement compensée par le courant liquide s'écoulant à sa rencontre. (On pourrait illustrer les conditions régnant ici par l'exemple de l'écureuil dans sa cage rotative ; on sait que l'écureuil court continuellement sans changer de place, car la cage tourne en sens contraire). Grâce à la disposition adoptée, une diffusion ininterrompue et durable des isotopes s'établit de bas en haut et, par ce moyen, il se produit automatiquement une ségrégation, du fait que la partie basse de la solution s'enrichit peu à peu en isotope le plus lourd, la partie haute devenant plus riche en isotope le plus léger. Si l'on voulait entreprendre un fonctionnement de cette nature selon les méthodes usuelles de séparation, par exemple dans le genre de la cristallisation fractionnée, on serait conduit à employer des quantités de liquide exagérées et à surveiller et à préparer un très grand nombre de charges individuelles. Rien de tout cela n'est nécessaire pour le présent procédé. Tout le travail consiste à faire évaporer le solvant à l'extrémité inférieure de la colonne et à le faire retomber goutte à goutte à l'extrémité supérieure. Bien entendu, le dispositif doit comporter des appareils d'extraction, par exemple des tubulures d'aspiration qui permettent de prélever la solution de la colonne. Une telle colonne peut rester en service des mois, voire des années, sans nécessiter de frais importants en personnel de surveillance.

Figure D.235: Beginning in 1940, Auergesellschaft (probably Nikolaus Riehl) filed patents on an industrial-scale uranium enrichment process that combined aspects of gaseous thermal diffusion and what later became known as the PUREX process.



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En choisissant un grand diamètre de colonne, on peut aussi soumettre au processus de la séparation de grandes quantités de matières. C'est sur ce point précisément que le rendement du présent procédé s'avère être d'un ordre de grandeur bien supérieur à celui des méthodes proposées jusqu'à présent et dont l'application ne permettait, dans le cas le plus favorable, que de séparer de minimes quantités absolues d'isotopes, tandis que d'après le nouveau procédé, il est possible de traiter de nombreux kilogrammes et même plusieurs tonnes de substance à séparer.

Le procédé qui vient d'être décrit assure encore un autre progrès. La vitesse de diffusion de substances dissoutes dans les solvants usuels est très faible. Il s'ensuit que la diffusion se développe avec une extrême lenteur du bord intérieur au bord supérieur de la colonne, de sorte que l'on n'ose appliquer qu'un très faible contre-courant du solvant et que tout le processus de la séparation se déroule sans doute d'une manière très simple et facile à surveiller, mais lente. C'est pourquoi l'invention comprend encore un autre perfectionnement d'après lequel on n'opère pas la diffusion à l'intérieur d'un seul corps poreux, mais une colonne se compose de plusieurs cellules élémentaires comme on le voit sur les fig. 2 et 3, les cellules étant séparées les unes des autres par des membranes minces diffusantes 2 qui remplacent la masse poreuse. Les cellules elles-mêmes, c'est-à-dire les espaces compris entre les membranes, ne contiennent dans cette disposition aucune espèce de matière poreuse mais sont simplement remplies de la solution. On choisit les membranes diffusantes de telle sorte qu'une diffusion rapide soit possible d'une cellule à l'autre. On prend soin d'assurer le meilleur mélange possible de la solution à l'intérieur d'une cellule, soit au moyen de malaxeurs ou mélangeurs usuels, soit en utilisant la pesanteur. Il n'existe donc pratiquement pas de différences de concentration au sein d une même cellule, mais de telles différences existent indubitablement entre deux cellules voisines, en raison des membranes diffusantes intercalées entre elles. Comme membranes de diffusion, on peut utiliser les filtres de dialyse, les filtres à membranes, les filtres de cellulose et les couches filtrantes minces analogues. Si la couche filtrante possède une perméabilité suffisante pour donner lieu à un passage hydrodynamique du liquide, on peut laisser également le solvant s'écouler au fur et à mesure de haut en bas comme dans le procédé illustré par la fig. 1. Le solvant est alors évaporé dans la cellule inférieure, par exemple de la manière représentée sur les fig. 3 et 4, où l'évaporation s'effectue à la surface du liquide de la cellule la plus basse. Le solvant perdu par évaporation est ramené dans la cellule supérieure par égouttage, déversement ou redistillation. Si, au contraire, les membranes offrent une trop grande résistance hydrodynamique au passage du solvant et que celui-ci ne puisse, par suite, pas traverser les membranes avec une vitesse suffisante, le passage peut s'effectuer par des tuyaux 4 qui contournent les membranes (fig. 4). La vitesse de passage doit donc être approximativement égale à la vitesse de diffusion moyenne de la matière dissoute. Il se produit dans ce cas une chute de concentration qui, comme les calculs l'ont montré, a une allure exponentielle dès qu'un régime stationnaire s'est établi. Dans l'hypothèse d'une vitesse de passage constante, un tel régime stationnaire se produit au bout d'un certain temps. On constate de plus l'établissement d'un état stationnaire en ce qui concerne la proportion d'isotopes dans les différentes régions de la colonne, en ce sens que les isotopes plus légers se concentrent dans la cellule supérieure et les plus lourds dans la cellule inférieure. Dans le cas où l'on n'oblige pas le solvant à traverser la membrane, mais où on lui fait contourner la membrane par des tuyaux (voir fig. 4), il n'est pas nécessaire de faire progresser la diffusion de bas en haut et le courant liquide de traversée, de haut en bas ; on peut au contraire choisir n'importe quelle position, même par exemple horizontale, de la colonne. On peut également concevoir la disposition sous une forme telle que le liquide soit conduit de bas en haut (par exemple en utilisant des tubes communicants) et que la diffusion se produise de

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haut en bas. Dans ce dernier cas, le contenu de la cellule le plus concentré se trouve en haut, le moins concentré, en bas. Ce dispositif présente l'avantage que la concentration à l'intérieur de chaque cellule est déjà un peu plus forte au bord supérieur de la cellule qu'au bord inférieur. La solution plus concentrée et, par suite, la plus dense, tombe donc d'elle-même au fond sous l'action de la pesanteur, de sorte qu'il se produit automatiquement par ce moyen une égalisation de la concentration à l'intérieur d'une cellule (sans dispositif agitateur).

La fig. 5 montre un mode de réalisation technique particulièrement approprié du procédé ci-dessus décrit. Les cellules 1 sont ici constituées par des caissons plats (en tôle, verre ou matière synthétique), qui sont justaposés par étages en s'appuyant par leurs larges faces les uns contre les autres. Les caissons sont remplis de solution. Les faces larges présentent de grandes ouvertures 3, disposées de telle sorte que les ouvertures d'un caisson se trouvent vis-à-vis de celles du caisson voisin. Une membrane 2 est serrée entre chaque caisson et le caisson suivant. La matière en solution peut donc diffuser à travers cette membrane d'un caisson à l'autre. On fait couler goutte à goutte le solvant dans le dernier caisson à gauche et l'on soustrait au dernier caisson à droite la même quantité de solvant, par unité de temps par vaporisation ou évaporation. La solution s'écoule lentement de gauche à droite par les canaux de trop plein 4 d'un caisson au suivant. A la longue la concentration dans le dernier caisson à droite devient supérieure à celle qui règne dans le caisson précédent et ainsi de suite. En conséquence, le dernier caisson à gauche accuse la concentration la plus faible. Il en résulte une diffusion de la matière dissoute à travers les membranes, de droite à gauche, c'est-à-dire en sens contraire de l'écoulement de la solution. Les cellules individuelles (caissons) sont ici d'un accès commode, de sorte que l'on peut remuer le liquide au moyen d'un agitateur en forme de peigne à mouvement de va-et-vient qui plonge dans toutes les cellules.

Le procédé s'est révélé convenir en pratique pour la séparation d'isotopes et même pour des isotopes dans lesquels la différence relative des poids atomiques est très faible.

Le procédé s'est révélé efficace pour des paires d'isotopes dont la séparation était radicalement impossible jusqu'à présent et pour lesquels tous les essais antérieurs n'avaient pas permis d'obtenir la moindre ségrégation, par exemple la paire des isotopes thorium X et mésothorium.

Le procédé de séparation selon l'invention n'est pas limité aux seuls isotopes, mais il peut également être appliqué à la séparation d'autres substances difficilement séparables. En plus des différences de poids moléculaire ou de poids atomique, certaines substances présentent encore d'autres différences entre les espèces d'atomes à séparer, par exemple des différences dans le degré d'hydradation, le diamètre, la forme des molécules, etc. Il peut arriver, pour cette raison, lors de la séparation de paires d'éléments non isotopes, que ce ne soit pas la substance de moindre poids moléculaire qui diffuse le plus rapidement, mais que, au contraire, ce soit la substance à poids moléculaire le plus élevé qui se propage plus rapidement de cellule en cellule, par exemple en raison d'une plus mince enveloppe d'hydratation ou de solvatation dont la molécule (ou l'ion ou l'atome) est environnée. Il est parfois avantageux, pour des paires d'éléments non isotopes, de choisir une membrane de densité telle que les dimensions de ses pores soient de l'ordre de grandeur des molécules ou ne dépassent pas trop les dimensions moléculaires. Dans ce cas, à la différence des vitesses de diffusion proprement dites, s'ajoute un certain effet de filtration ou de dialyse, effet de tamis, qui intensifie encore la séparation. De plus, la demanderesse a établi que pour accroître l'effet séparateur selon le présent procédé, il y a intérêt à ajouter suivant les circonstances un électrolyte étranger ou une autre matière additionnelle en solution. On influe ainsi favorablement tant sur la vitesse de diffusion que sur l'action séparatrice dans de nombreux cas. Indépendamment de cela, l'addition d'un électrolyte étranger est absolument indispensable lorsqu'on veut réaliser non plus une diffusion atomique ou molé-

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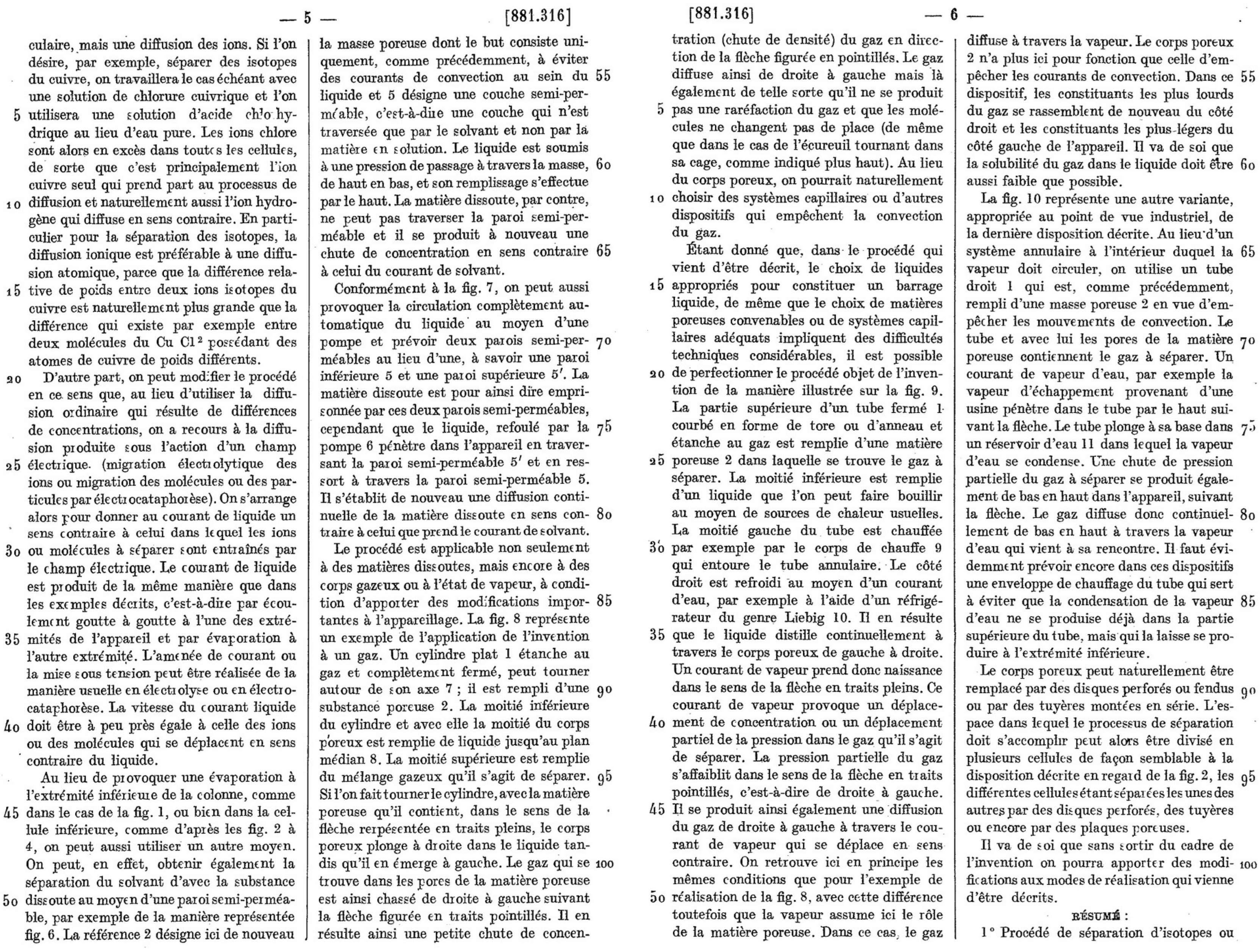

culaire, mais une diffusion des ions. Si l'on désire, par exemple, séparer des isotopes du cuivre, on travaillera le cas échéant avec une solution de chlorure cuivrique et l'on utilisera une solution d'acide chlorhydrique au lieu d'eau pure. Les ions chlore sont alors en excès dans toutes les cellules, de sorte que c'est principalement l'ion cuivre seul qui prend part au processus de diffusion et naturellement aussi l'ion hydrogène qui diffuse en sens contraire. En particulier pour la séparation des isotopes, la diffusion ionique est préférable à une diffusion atomique, parce que la différence relative de poids entre deux ions isotopes du cuivre est naturellement plus grande que la différence qui existe par exemple entre deux molécules du Cu Cl^2 possédant des atomes de cuivre de poids différents.

D'autre part, on peut modifier le procédé en ce sens que, au lieu d'utiliser la diffusion ordinaire qui résulte de différences de concentrations, on a recours à la diffusion produite sous l'action d'un champ électrique (migration électrolytique des ions ou migration des molécules ou des particules par électrocataphorèse). On s'arrange alors pour donner au courant de liquide un sens contraire à celui dans lequel les ions ou molécules à séparer sont entraînés par le champ électrique. Le courant de liquide est produit de la même manière que dans les exemples décrits, c'est-à-dire par écoulement goutte à goutte à l'une des extrémités de l'appareil et par évaporation à l'autre extrémité. L'amenée de courant ou la mise sous tension peut être réalisée de la manière usuelle en électrolyse ou en électrocataphorèse. La vitesse du courant liquide doit être à peu près égale à celle des ions ou des molécules qui se déplacent en sens contraire du liquide.

Au lieu de provoquer une évaporation à l'extrémité inférieure de la colonne, comme dans le cas de la fig. 1, ou bien dans la cellule inférieure, comme d'après les fig. 2 à 4, on peut aussi utiliser un autre moyen. On peut, en effet, obtenir également la séparation du solvant d'avec la substance dissoute au moyen d'une paroi semi-perméable, par exemple de la manière représentée fig. 6. La référence 2 désigne ici de nouveau la masse poreuse dont le but consiste uniquement, comme précédemment, à éviter des courants de convection au sein du liquide et 5 désigne une couche semi-perméable, c'est-à-dire une couche qui n'est traversée que par le solvant et non par la matière en solution. Le liquide est soumis à une pression de passage à travers la masse, de haut en bas, et son remplissage s'effectue par le haut. La matière dissoute, par contre, ne peut pas traverser la paroi semi-perméable et il se produit à nouveau une chute de concentration en sens contraire à celui du courant de solvant.

Conformément à la fig. 7, on peut aussi provoquer la circulation complètement automatique du liquide au moyen d'une pompe et prévoir deux parois semi-perméables au lieu d'une, à savoir une paroi inférieure 5 et une paroi supérieure 5'. La matière dissoute est pour ainsi dire emprisonnée par ces deux parois semi-perméables, cependant que le liquide, refoulé par la pompe 6 pénètre dans l'appareil en traversant la paroi semi-perméable 5' et en ressort à travers la paroi semi-perméable 5. Il s'établit de nouveau une diffusion continuelle de la matière dissoute en sens contraire à celui que prend le courant de solvant.

Le procédé est applicable non seulement à des matières dissoutes, mais encore à des corps gazeux ou à l'état de vapeur, à condition d'apporter des modifications importantes à l'appareillage. La fig. 8 représente un exemple de l'application de l'invention à un gaz. Un cylindre plat 1 étanche au gaz et complètement fermé, peut tourner autour de son axe 7 ; il est rempli d'une substance poreuse 2. La moitié inférieure du cylindre et avec elle la moitié du corps poreux est remplie de liquide jusqu'au plan médian 8. La moitié supérieure est remplie du mélange gazeux qu'il s'agit de séparer. Si l'on fait tourner le cylindre, avec la matière poreuse qu'il contient, dans le sens de la flèche rerpésentée en traits pleins, le corps poreux plonge à droite dans le liquide tandis qu'il en émerge à gauche. Le gaz qui se trouve dans les pores de la matière poreuse est ainsi chassé de droite à gauche suivant la flèche figurée en traits pointillés. Il en résulte ainsi une petite chute de concentration (chute de densité) du gaz en direction de la flèche figurée en pointillés. Le gaz diffuse ainsi de droite à gauche mais là également de telle sorte qu'il ne se produit pas une raréfaction du gaz et que les molécules ne changent pas de place (de même que dans le cas de l'écureuil tournant dans sa cage, comme indiqué plus haut). Au lieu du corps poreux, on pourrait naturellement choisir des systèmes capillaires ou d'autres dispositifs qui empêchent la convection du gaz.

Étant donné que, dans le procédé qui vient d'être décrit, le choix de liquides appropriés pour constituer un barrage liquide, de même que le choix de matières poreuses convenables ou de systèmes capillaires adéquats impliquent des difficultés techniques considérables, il est possible de perfectionner le procédé objet de l'invention de la manière illustrée sur la fig. 9. La partie supérieure d'un tube fermé 1 courbé en forme de tore ou d'anneau et étanche au gaz est remplie d'une matière poreuse 2 dans laquelle se trouve le gaz à séparer. La moitié inférieure est remplie d'un liquide que l'on peut faire bouillir au moyen de sources de chaleur usuelles. La moitié gauche du tube est chauffée par exemple par le corps de chauffe 9 qui entoure le tube annulaire. Le côté droit est refroidi au moyen d'un courant d'eau, par exemple à l'aide d'un réfrigérateur du genre Liebig 10. Il en résulte que le liquide distille continuellement à travers le corps poreux de gauche à droite. Un courant de vapeur prend donc naissance dans le sens de la flèche en traits pleins. Ce courant de vapeur provoque un déplacement de concentration ou un déplacement partiel de la pression dans le gaz qu'il s'agit de séparer. La pression partielle du gaz s'affaiblit dans le sens de la flèche en traits pointillés, c'est-à-dire de droite à gauche. Il se produit ainsi également une diffusion du gaz de droite à gauche à travers le courant de vapeur qui se déplace en sens contraire. On retrouve ici en principe les mêmes conditions que pour l'exemple de réalisation de la fig. 8, avec cette différence toutefois que la vapeur assume ici le rôle de la matière poreuse. Dans ce cas, le gaz diffuse à travers la vapeur. Le corps poreux 2 n'a plus ici pour fonction que celle d'empêcher les courants de convection. Dans ce dispositif, les constituants les plus lourds du gaz se rassemblent de nouveau du côté droit et les constituants les plus légers du côté gauche de l'appareil. Il va de soi que la solubilité du gaz dans le liquide doit être aussi faible que possible.

La fig. 10 représente une autre variante, appropriée au point de vue industriel, de la dernière disposition décrite. Au lieu d'un système annulaire à l'intérieur duquel la vapeur doit circuler, on utilise un tube droit 1 qui est, comme précédemment, rempli d'une masse poreuse 2 en vue d'empêcher les mouvements de convection. Le tube et avec lui les pores de la matière poreuse contiennent le gaz à séparer. Un courant de vapeur d'eau, par exemple la vapeur d'échappement provenant d'une usine pénètre dans le tube par le haut suivant la flèche. Le tube plonge à sa base dans un réservoir d'eau 11 dans lequel la vapeur d'eau se condense. Une chute de pression partielle du gaz à séparer se produit également de bas en haut dans l'appareil, suivant la flèche. Le gaz diffuse donc continuellement de bas en haut à travers la vapeur d'eau qui vient à sa rencontre. Il faut évidemment prévoir encore dans ces dispositifs une enveloppe de chauffage du tube qui sert à éviter que la condensation de la vapeur d'eau ne se produise déjà dans la partie supérieure du tube, mais qui la laisse se produire à l'extrémité inférieure.

Le corps poreux peut naturellement être remplacé par des disques perforés ou fendus ou par des tuyères montées en série. L'espace dans lequel le processus de séparation doit s'accomplir peut alors être divisé en plusieurs cellules de façon semblable à la disposition décrite en regard de la fig. 2, les différentes cellules étant séparées les unes des autres par des disques perforés, des tuyères ou encore par des plaques poreuses.

Il va de soi que sans sortir du cadre de l'invention on pourra apporter des modifications aux modes de réalisation qui vienne d'être décrits.

RÉSUMÉ :

1° Procédé de séparation d'isotopes ou

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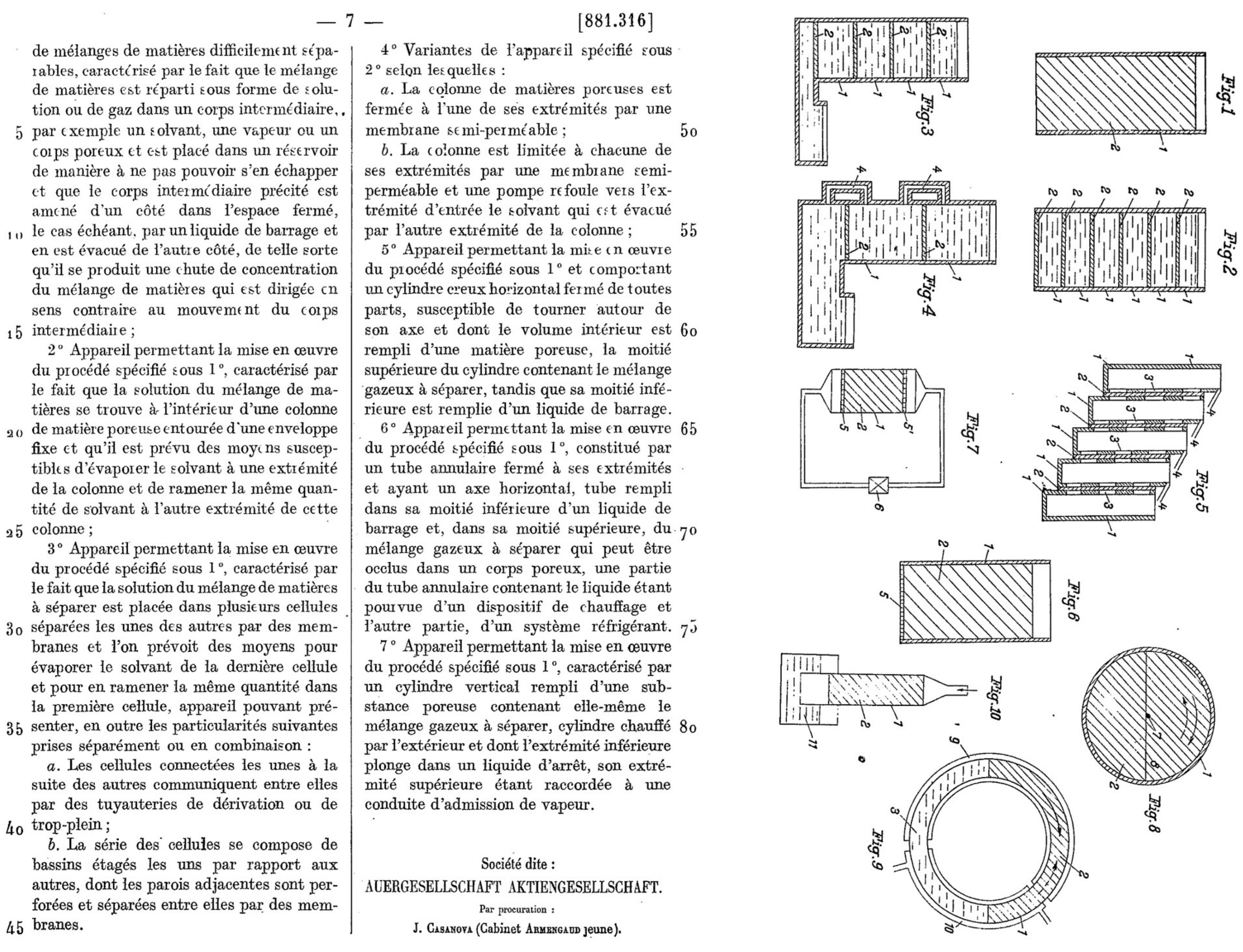
Fig.1
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Fig.7
Fig.8
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Fig.10

— 7 — [881.316]

de mélanges de matières difficilement séparables, caractérisé par le fait que le mélange de matières est réparti sous forme de solution ou de gaz dans un corps intermédiaire, par exemple un solvant, une vapeur ou un corps poreux et est placé dans un réservoir de manière à ne pas pouvoir s'en échapper et que le corps intermédiaire précité est amené d'un côté dans l'espace fermé, le cas échéant, par un liquide de barrage et en est évacué de l'autre côté, de telle sorte qu'il se produit une chute de concentration du mélange de matières qui est dirigée en sens contraire au mouvement du corps intermédiaire ;

2° Appareil permettant la mise en œuvre du procédé spécifié sous 1°, caractérisé par le fait que la solution du mélange de matières se trouve à l'intérieur d'une colonne de matière poreuse entourée d'une enveloppe fixe et qu'il est prévu des moyens susceptibles d'évaporer le solvant à une extrémité de la colonne et de ramener la même quantité de solvant à l'autre extrémité de cette colonne ;

3° Appareil permettant la mise en œuvre du procédé spécifié sous 1°, caractérisé par le fait que la solution du mélange de matières à séparer est placée dans plusieurs cellules séparées les unes des autres par des membranes et l'on prévoit des moyens pour évaporer le solvant de la dernière cellule et pour en ramener la même quantité dans la première cellule, appareil pouvant présenter, en outre les particularités suivantes prises séparément ou en combinaison :

a. Les cellules connectées les unes à la suite des autres communiquent entre elles par des tuyauteries de dérivation ou de trop-plein ;

b. La série des cellules se compose de bassins étagés les uns par rapport aux autres, dont les parois adjacentes sont perforées et séparées entre elles par des membranes.

4° Variantes de l'appareil spécifié sous 2° selon lesquelles :

a. La colonne de matières poreuses est fermée à l'une de ses extrémités par une membrane semi-perméable ;

b. La colonne est limitée à chacune de ses extrémités par une membrane semi-perméable et une pompe refoule vers l'extrémité d'entrée le solvant qui est évacué par l'autre extrémité de la colonne ;

5° Appareil permettant la mise en œuvre du procédé spécifié sous 1° et comportant un cylindre creux horizontal fermé de toutes parts, susceptible de tourner autour de son axe et dont le volume intérieur est rempli d'une matière poreuse, la moitié supérieure du cylindre contenant le mélange gazeux à séparer, tandis que sa moitié inférieure est remplie d'un liquide de barrage.

6° Appareil permettant la mise en œuvre du procédé spécifié sous 1°, constitué par un tube annulaire fermé à ses extrémités et ayant un axe horizontal, tube rempli dans sa moitié inférieure d'un liquide de barrage et, dans sa moitié supérieure, du mélange gazeux à séparer qui peut être occlus dans un corps poreux, une partie du tube annulaire contenant le liquide étant pourvue d'un dispositif de chauffage et l'autre partie, d'un système réfrigérant.

7° Appareil permettant la mise en œuvre du procédé spécifié sous 1°, caractérisé par un cylindre vertical rempli d'une substance poreuse contenant elle-même le mélange gazeux à séparer, cylindre chauffé par l'extérieur et dont l'extrémité inférieure plonge dans un liquide d'arrêt, son extrémité supérieure étant raccordée à une conduite d'admission de vapeur.

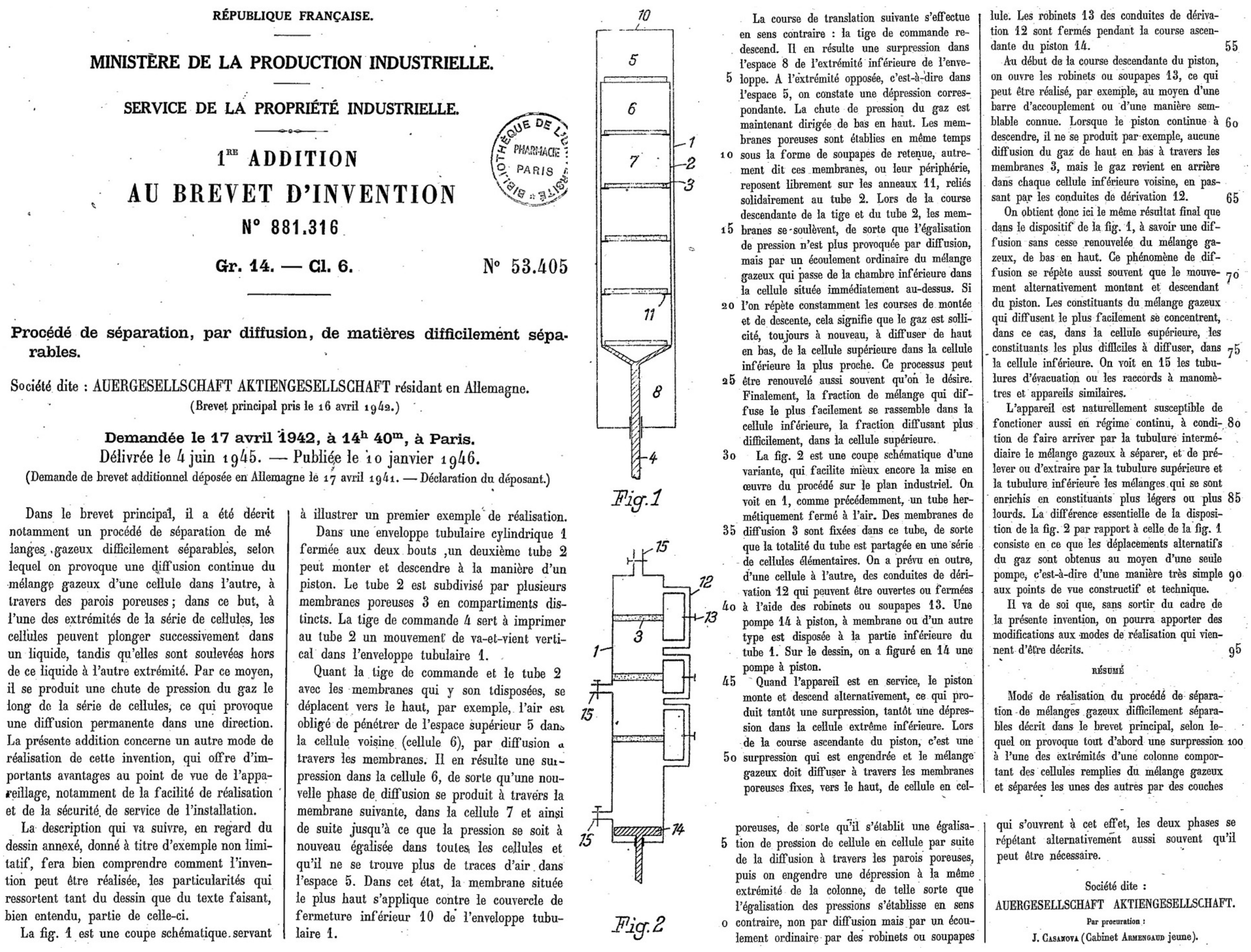
Société dite :

AUERGESELLSCHAFT AKTIENGESELLSCHAFT.

Par procuration :

J. Casanova (Cabinet Armengaud jeune).

Figure D.238: Beginning in 1940, Auergesellschaft (probably Nikolaus Riehl) filed patents on an industrial-scale uranium enrichment process that combined aspects of gaseous thermal diffusion and what later became known as the PUREX process.



RÉPUBLIQUE FRANÇAISE.

MINISTÈRE DE LA PRODUCTION INDUSTRIELLE.

SERVICE DE LA PROPRIÉTÉ INDUSTRIELLE.

BIBLIOTHÈQUE DE L'UNIVERSITÉ PHARMACIE PARIS

1RE ADDITION
AU BREVET D'INVENTION

N° 881.316

Gr. 14. — Cl. 6. N° 53.405

Procédé de séparation, par diffusion, de matières difficilement séparables.

Société dite : AUERGESELLSCHAFT AKTIENGESELLSCHAFT résidant en Allemagne.
(Brevet principal pris le 16 avril 1942.)

Demandée le 17 avril 1942, à 14h 40m, à Paris.
Délivrée le 4 juin 1945. — Publiée le 10 janvier 1946.
(Demande de brevet additionnel déposée en Allemagne le 17 avril 1941. — Déclaration du déposant.)

Dans le brevet principal, il a été décrit notamment un procédé de séparation de mélanges gazeux difficilement séparables, selon lequel on provoque une diffusion continue du mélange gazeux d'une cellule dans l'autre, à travers des parois poreuses; dans ce but, à l'une des extrémités de la série de cellules, les cellules peuvent plonger successivement dans un liquide, tandis qu'elles sont soulevées hors de ce liquide à l'autre extrémité. Par ce moyen, il se produit une chute de pression du gaz le long de la série de cellules, ce qui provoque une diffusion permanente dans une direction.

La présente addition concerne un autre mode de réalisation de cette invention, qui offre d'importants avantages au point de vue de l'appareillage, notamment de la facilité de réalisation et de la sécurité de service de l'installation.

La description qui va suivre, en regard du dessin annexé, donné à titre d'exemple non limitatif, fera bien comprendre comment l'invention peut être réalisée, les particularités qui ressortent tant du dessin que du texte faisant, bien entendu, partie de celle-ci.

La fig. 1 est une coupe schématique servant à illustrer un premier exemple de réalisation.

Dans une enveloppe tubulaire cylindrique 1 fermée aux deux bouts ,un deuxième tube 2 peut monter et descendre à la manière d'un piston. Le tube 2 est subdivisé par plusieurs membranes poreuses 3 en compartiments distincts. La tige de commande 4 sert à imprimer au tube 2 un mouvement de va-et-vient vertical dans l'enveloppe tubulaire 1.

Quant la tige de commande et le tube 2 avec les membranes qui y son tdisposées, se déplacent vers le haut, par exemple, l'air est obligé de pénétrer de l'espace supérieur 5 dans la cellule voisine (cellule 6), par diffusion à travers les membranes. Il en résulte une surpression dans la cellule 6, de sorte qu'une nouvelle phase de diffusion se produit à travers la membrane suivante, dans la cellule 7 et ainsi de suite jusqu'à ce que la pression se soit à nouveau égalisée dans toutes les cellules et qu'il ne se trouve plus de traces d'air dans l'espace 5. Dans cet état, la membrane située le plus haut s'applique contre le couvercle de fermeture inférieur 10 de l'enveloppe tubulaire 1.

La course de translation suivante s'effectue en sens contraire : la tige de commande redescend. Il en résulte une surpression dans l'espace 8 de l'extrémité inférieure de l'enveloppe. A l'extrémité opposée, c'est-à-dire dans l'espace 5, on constate une dépression correspondante. La chute de pression du gaz est maintenant dirigée de bas en haut. Les membranes poreuses sont établies en même temps sous la forme de soupapes de retenue, autrement dit ces membranes, ou leur périphérie, reposent librement sur les anneaux 11, reliés solidairement au tube 2. Lors de la course descendante de la tige et du tube 2, les membranes se soulèvent, de sorte que l'égalisation de pression n'est plus provoquée par diffusion, mais par un écoulement ordinaire du mélange gazeux qui passe de la chambre inférieure dans la cellule située immédiatement au-dessus. Si l'on répète constamment les courses de montée et de descente, cela signifie que le gaz est sollicité, toujours à nouveau, à diffuser de haut en bas, de la cellule supérieure dans la cellule inférieure la plus proche. Ce processus peut être renouvelé aussi souvent qu'on le désire. Finalement, la fraction de mélange qui diffuse le plus facilement se rassemble dans la cellule inférieure, la fraction diffusant plus difficilement, dans la cellule supérieure.

La fig. 2 est une coupe schématique d'une variante, qui facilite mieux encore la mise en œuvre du procédé sur le plan industriel. On voit en 1, comme précédemment, un tube hermétiquement fermé à l'air. Des membranes de diffusion 3 sont fixées dans ce tube, de sorte que la totalité du tube est partagée en une série de cellules élémentaires. On a prévu en outre, d'une cellule à l'autre, des conduites de dérivation 12 qui peuvent être ouvertes ou fermées à l'aide des robinets ou soupapes 13. Une pompe 14 à piston, à membrane ou d'un autre type est disposée à la partie inférieure du tube 1. Sur le dessin, on a figuré en 14 une pompe à piston.

Quand l'appareil est en service, le piston monte et descend alternativement, ce qui produit tantôt une surpression, tantôt une dépression dans la cellule extrême inférieure. Lors de la course ascendante du piston, c'est une surpression qui est engendrée et le mélange gazeux doit diffuser à travers les membranes poreuses fixes, vers le haut, de cellule en cellule. Les robinets 13 des conduites de dérivation 12 sont fermés pendant la course ascendante du piston 14.

Au début de la course descendante du piston, on ouvre les robinets ou soupapes 13, ce qui peut être réalisé, par exemple, au moyen d'une barre d'accouplement ou d'une manière semblable connue. Lorsque le piston continue à descendre, il ne se produit par exemple, aucune diffusion du gaz de haut en bas à travers les membranes 3, mais le gaz revient en arrière dans chaque cellule inférieure voisine, en passant par les conduites de dérivation 12.

On obtient donc ici le même résultat final que dans le dispositif de la fig. 1, à savoir une diffusion sans cesse renouvelée du mélange gazeux, de bas en haut. Ce phénomène de diffusion se répète aussi souvent que le mouvement alternativement montant et descendant du piston. Les constituants du mélange gazeux qui diffusent le plus facilement se concentrent, dans ce cas, dans la cellule supérieure, les constituants les plus difficiles à diffuser, dans la cellule inférieure. On voit en 15 les tubulures d'évacuation ou les raccords à manomètres et appareils similaires.

L'appareil est naturellement susceptible de fonctioner aussi en régime continu, à condition de faire arriver par la tubulure intermédiaire le mélange gazeux à séparer, et de prélever ou d'extraire par la tubulure supérieure et la tubulure inférieure les mélanges qui se sont enrichis en constituants plus légers ou plus lourds. La différence essentielle de la disposition de la fig. 2 par rapport à celle de la fig. 1 consiste en ce que les déplacements alternatifs du gaz sont obtenus au moyen d'une seule pompe, c'est-à-dire d'une manière très simple aux points de vue constructif et technique.

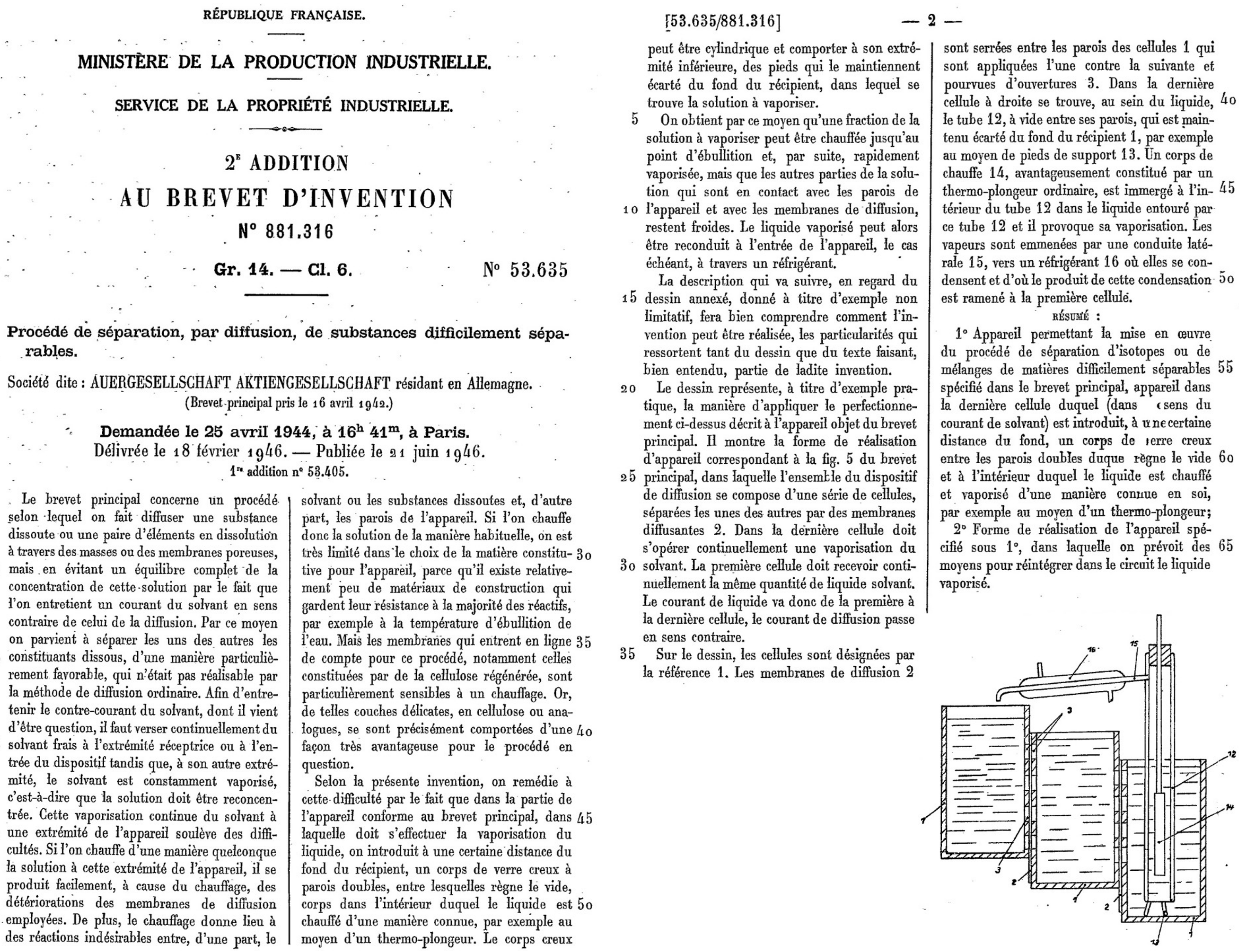
Il va de soi que, sans sortir du cadre de la présente invention, on pourra apporter des modifications aux modes de réalisation qui viennent d'être décrits.

RÉSUMÉ

Mode de réalisation du procédé de séparation de mélanges gazeux difficilement séparables décrit dans le brevet principal, selon lequel on provoque tout d'abord une surpression à l'une des extrémités d'une colonne comportant des cellules remplies du mélange gazeux et séparées les unes des autres par des couches poreuses, de sorte qu'il s'établit une égalisation de pression de cellule en cellule par suite de la diffusion à travers les parois poreuses, puis on engendre une dépression à la même extrémité de la colonne, de telle sorte que l'égalisation des pressions s'établisse en sens contraire, non par diffusion mais par un écoulement ordinaire par des robinets ou soupapes qui s'ouvrent à cet effet, les deux phases se répétant alternativement aussi souvent qu'il peut être nécessaire.

Société dite :
AUERGESELLSCHAFT AKTIENGESELLSCHAFT.
Par procuration :
J. CASANOVA (Cabinet ARMENGAUD jeune).

Figure D.239: Beginning in 1940, Auergesellschaft (probably Nikolaus Riehl) filed patents on an industrial-scale uranium enrichment process that combined aspects of gaseous thermal diffusion and what later became known as the PUREX process.



RÉPUBLIQUE FRANÇAISE.

MINISTÈRE DE LA PRODUCTION INDUSTRIELLE.

SERVICE DE LA PROPRIÉTÉ INDUSTRIELLE.

2E ADDITION
AU BREVET D'INVENTION
N° 881.316

Gr. 14. — Cl. 6. N° 53.635

Procédé de séparation, par diffusion, de substances difficilement séparables.

Société dite : AUERGESELLSCHAFT AKTIENGESELLSCHAFT résidant en Allemagne.
(Brevet principal pris le 16 avril 1942.)

Demandée le 25 avril 1944, à 16^h 41^m, à Paris.
Délivrée le 18 février 1946. — Publiée le 21 juin 1946.
1re addition n° 53.405.

Le brevet principal concerne un procédé selon lequel on fait diffuser une substance dissoute ou une paire d'éléments en dissolution à travers des masses ou des membranes poreuses, mais en évitant un équilibre complet de la concentration de cette solution par le fait que l'on entretient un courant du solvant en sens contraire de celui de la diffusion. Par ce moyen on parvient à séparer les uns des autres les constituants dissous, d'une manière particulièrement favorable, qui n'était pas réalisable par la méthode de diffusion ordinaire. Afin d'entretenir le contre-courant du solvant, dont il vient d'être question, il faut verser continuellement du solvant frais à l'extrémité réceptrice ou à l'entrée du dispositif tandis que, à son autre extrémité, le solvant est constamment vaporisé, c'est-à-dire que la solution doit être reconcentrée. Cette vaporisation continue du solvant à une extrémité de l'appareil soulève des difficultés. Si l'on chauffe d'une manière quelconque la solution à cette extrémité de l'appareil, il se produit facilement, à cause du chauffage, des détériorations des membranes de diffusion employées. De plus, le chauffage donne lieu à des réactions indésirables entre, d'une part, le solvant ou les substances dissoutes et, d'autre part, les parois de l'appareil. Si l'on chauffe donc la solution de la manière habituelle, on est très limité dans le choix de la matière constitutive pour l'appareil, parce qu'il existe relativement peu de matériaux de construction qui gardent leur résistance à la majorité des réactifs, par exemple à la température d'ébullition de l'eau. Mais les membranes qui entrent en ligne de compte pour ce procédé, notamment celles constituées par de la cellulose régénérée, sont particulièrement sensibles à un chauffage. Or, de telles couches délicates, en cellulose ou analogues, se sont précisément comportées d'une façon très avantageuse pour le procédé en question.

Selon la présente invention, on remédie à cette difficulté par le fait que dans la partie de l'appareil conforme au brevet principal, dans laquelle doit s'effectuer la vaporisation du liquide, on introduit à une certaine distance du fond du récipient, un corps de verre creux à parois doubles, entre lesquelles règne le vide, corps dans l'intérieur duquel le liquide est chauffé d'une manière connue, par exemple au moyen d'un thermo-plongeur. Le corps creux

[53.635/881.316] — 2 —

peut être cylindrique et comporter à son extrémité inférieure, des pieds qui le maintiennent écarté du fond du récipient, dans lequel se trouve la solution à vaporiser.

On obtient par ce moyen qu'une fraction de la solution à vaporiser peut être chauffée jusqu'au point d'ébullition et, par suite, rapidement vaporisée, mais que les autres parties de la solution qui sont en contact avec les parois de l'appareil et avec les membranes de diffusion, restent froides. Le liquide vaporisé peut alors être reconduit à l'entrée de l'appareil, le cas échéant, à travers un réfrigérant.

La description qui va suivre, en regard du dessin annexé, donné à titre d'exemple non limitatif, fera bien comprendre comment l'invention peut être réalisée, les particularités qui ressortent tant du dessin que du texte faisant, bien entendu, partie de ladite invention.

Le dessin représente, à titre d'exemple pratique, la manière d'appliquer le perfectionnement ci-dessus décrit à l'appareil objet du brevet principal. Il montre la forme de réalisation d'appareil correspondant à la fig. 5 du brevet principal, dans laquelle l'ensemble du dispositif de diffusion se compose d'une série de cellules, séparées les unes des autres par des membranes diffusantes 2. Dans la dernière cellule doit s'opérer continuellement une vaporisation du solvant. La première cellule doit recevoir continuellement la même quantité de liquide solvant. Le courant de liquide va donc de la première à la dernière cellule, le courant de diffusion passe en sens contraire.

Sur le dessin, les cellules sont désignées par la référence 1. Les membranes de diffusion 2 sont serrées entre les parois des cellules 1 qui sont appliquées l'une contre la suivante et pourvues d'ouvertures 3. Dans la dernière cellule à droite se trouve, au sein du liquide, le tube 12, à vide entre ses parois, qui est maintenu écarté du fond du récipient 1, par exemple au moyen de pieds de support 13. Un corps de chauffe 14, avantageusement constitué par un thermo-plongeur ordinaire, est immergé à l'intérieur du tube 12 dans le liquide entouré par ce tube 12 et il provoque sa vaporisation. Les vapeurs sont emmenées par une conduite latérale 15, vers un réfrigérant 16 où elles se condensent et d'où le produit de cette condensation est ramené à la première cellule.

RÉSUMÉ :

1° Appareil permettant la mise en œuvre du procédé de séparation d'isotopes ou de mélanges de matières difficilement séparables spécifié dans le brevet principal, appareil dans la dernière cellule duquel (dans le sens du courant de solvant) est introduit, à une certaine distance du fond, un corps de verre creux entre les parois doubles duquel règne le vide et à l'intérieur duquel le liquide est chauffé et vaporisé d'une manière connue en soi, par exemple au moyen d'un thermo-plongeur;

2° Forme de réalisation de l'appareil spécifié sous 1°, dans laquelle on prévoit des moyens pour réintégrer dans le circuit le liquide vaporisé.

Figure D.240: Beginning in 1940, Auergesellschaft (probably Nikolaus Riehl) filed patents on an industrial-scale uranium enrichment process that combined aspects of gaseous thermal diffusion and what later became known as the PUREX process.

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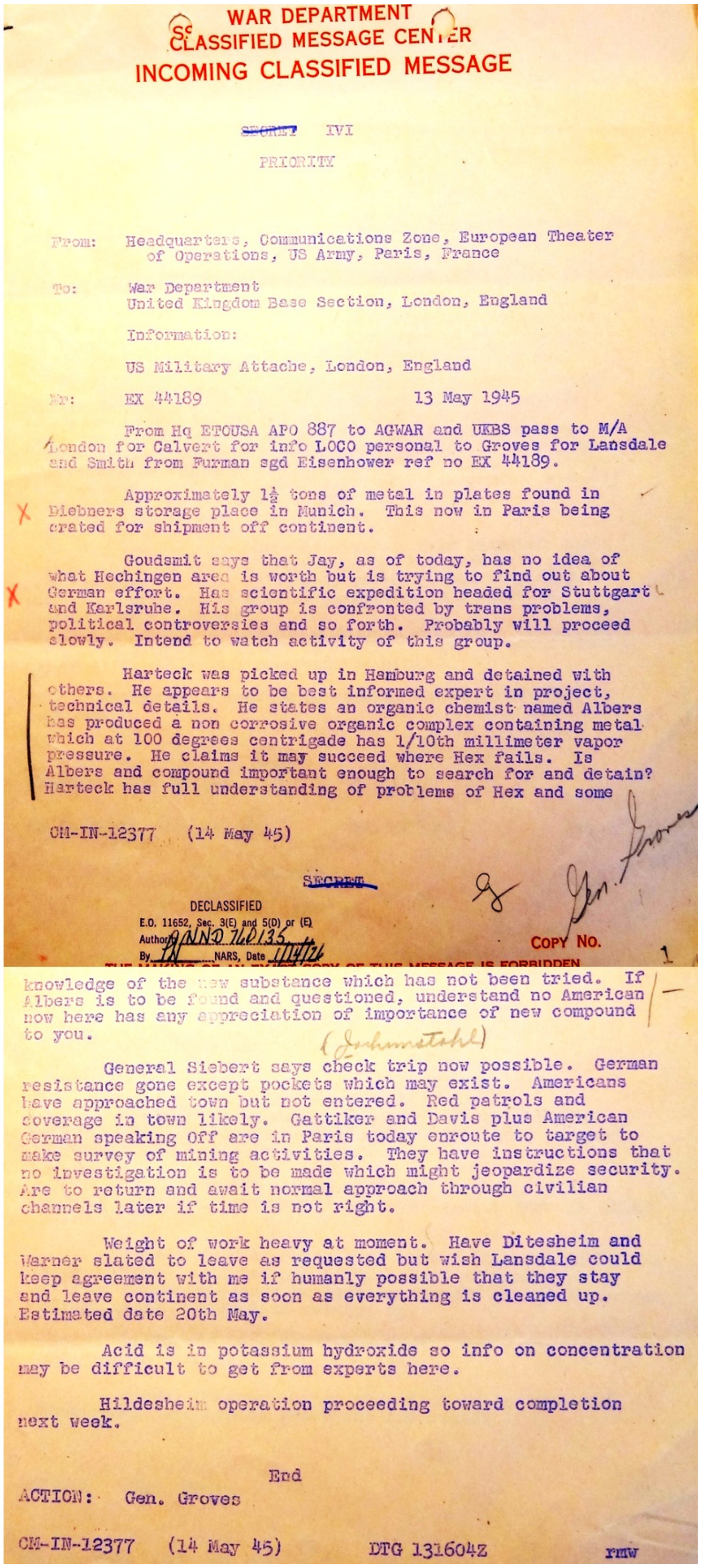
Authority NND 917017



WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
INCOMING CLASSIFIED MESSAGE

~~SECRET~~ IVI

PRIORITY

From: Headquarters, Communications Zone, European Theater of Operations, US Army, Paris, France

To: War Department
United Kingdom Base Section, London, England

Information:

US Military Attache, London, England

Nr: EX 44189 13 May 1945

From Hq ETOUSA APO 887 to AGWAR and UKBS pass to M/A London for Calvert for info LOCO personal to Groves for Lansdale and Smith from Furman sgd Eisenhower ref no EX 44189.

X Approximately 1½ tons of metal in plates found in Diebners storage place in Munich. This now in Paris being crated for shipment off continent.

X Goudsmit says that Jay, as of today, has no idea of what Hechingen area is worth but is trying to find out about German effort. Has scientific expedition headed for Stuttgart and Karlsruhe. His group is confronted by trans problems, political controversies and so forth. Probably will proceed slowly. Intend to watch activity of this group.

Harteck was picked up in Hamburg and detained with others. He appears to be best informed expert in project, technical details. He states an organic chemist named Albers has produced a non corrosive organic complex containing metal which at 100 degrees centrigade has 1/10th millimeter vapor pressure. He claims it may succeed where Hex fails. Is Albers and compound important enough to search for and detain? Harteck has full understanding of problems of Hex and some

CM-IN-12377 (14 May 45)

~~SECRET~~

g Gen. Groves

DECLASSIFIED
E.O. 11652, Sec. 3(E) and 5(D) or (E)
Authority NND 760135
By PN NARS, Date 1/14/76

COPY NO. 1

THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN

knowledge of the new substance which has not been tried. If Albers is to be found and questioned, understand no American now here has any appreciation of importance of new compound to you.

(Johnmstahl)

General Siebert says check trip now possible. German resistance gone except pockets which may exist. Americans have approached town but not entered. Red patrols and coverage in town likely. Gattiker and Davis plus American German speaking Off are in Paris today enroute to target to make survey of mining activities. They have instructions that no investigation is to be made which might jeopardize security. Are to return and await normal approach through civilian channels later if time is not right.

Weight of work heavy at moment. Have Ditesheim and Warner slated to leave as requested but wish Lansdale could keep agreement with me if humanly possible that they stay and leave continent as soon as everything is cleaned up. Estimated date 20th May.

Acid is in potassium hydroxide so info on concentration may be difficult to get from experts here.

Hildesheim operation proceeding toward completion next week.

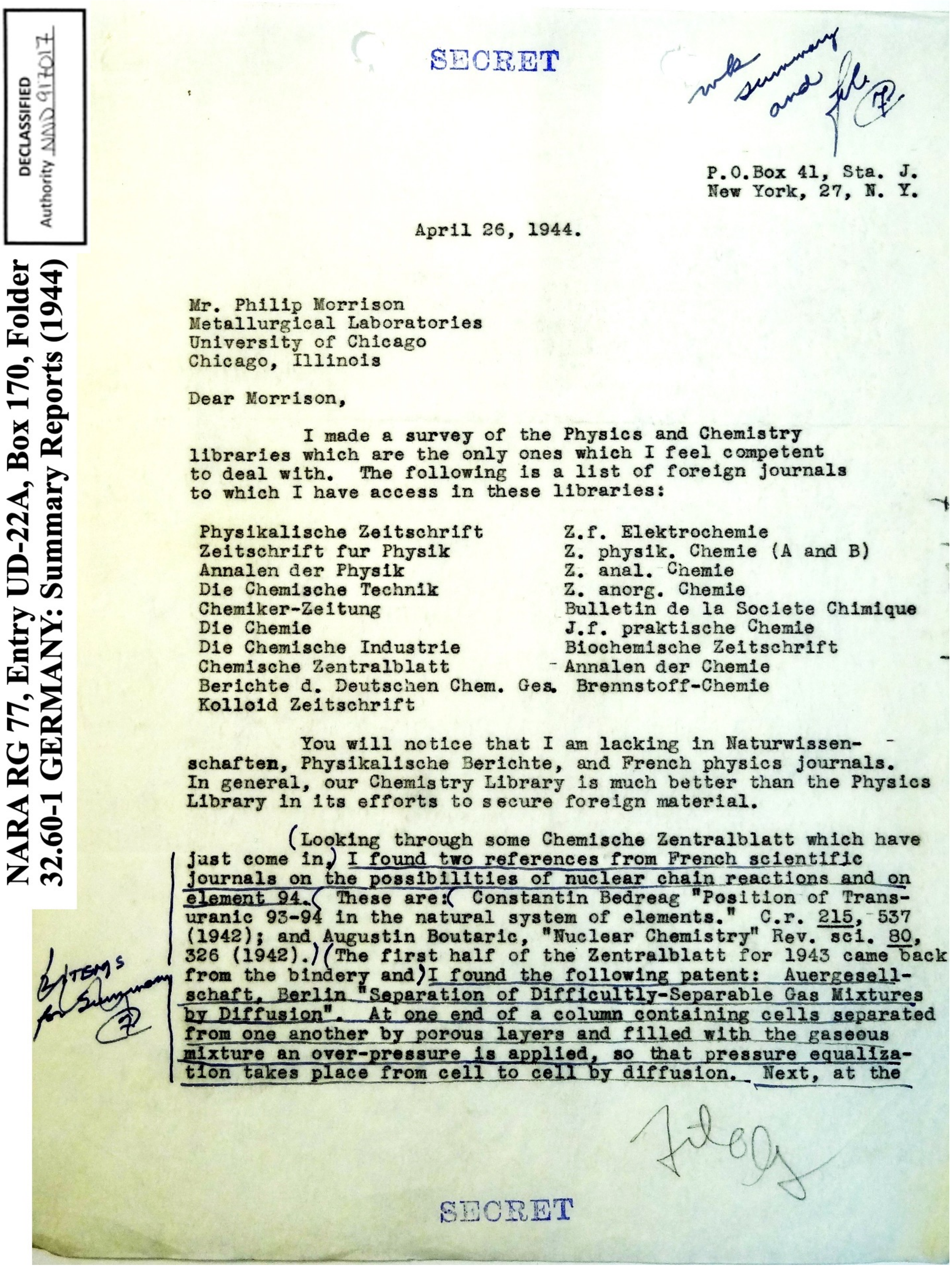
End

ACTION: Gen. Groves

CM-IN-12377 (14 May 45) DTG 131604Z rmw

NARA RG 77, Entry UD-22A,
Box 160, Folder APR 45--Dec. '45

Figure D.241: HQ European Theater of Operations US Army. 13 May 1945. "Harteck... states an organic chemist named Albers has produced a non corrosive organic complex containing metal which at 100 degrees centigrade has 1/10th millimeter vapor pressure. He claims it may succeed where Hex fails. Is Albers and compound important enough to search for and detain? Harteck has full understanding of problems of Hex and some knowledge of the new substance which has not been tried." [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45]



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Authority NND 917017

NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)

SECRET

wk summary and file (P)

P.O.Box 41, Sta. J.
New York, 27, N. Y.

April 26, 1944.

Mr. Philip Morrison
Metallurgical Laboratories
University of Chicago
Chicago, Illinois

Dear Morrison,

I made a survey of the Physics and Chemistry libraries which are the only ones which I feel competent to deal with. The following is a list of foreign journals to which I have access in these libraries:

- Physikalische Zeitschrift
- Zeitschrift fur Physik
- Annalen der Physik
- Die Chemische Technik
- Chemiker-Zeitung
- Die Chemie
- Die Chemische Industrie
- Chemische Zentralblatt
- Berichte d. Deutschen Chem. Ges.
- Kolloid Zeitschrift
- Z.f. Elektrochemie
- Z. physik. Chemie (A and B)
- Z. anal. Chemie
- Z. anorg. Chemie
- Bulletin de la Societe Chimique
- J.f. praktische Chemie
- Biochemische Zeitschrift
- Annalen der Chemie
- Brennstoff-Chemie

You will notice that I am lacking in Naturwissenschaften, Physikalische Berichte, and French physics journals. In general, our Chemistry Library is much better than the Physics Library in its efforts to secure foreign material.

2 ITEMS for Summary (P)

(Looking through some Chemische Zentralblatt which have just come in,) I found two references from French scientific journals on the possibilities of nuclear chain reactions and on element 94. (These are: (Constantin Bedreag "Position of Transuranic 93-94 in the natural system of elements." C.r. 215, 537 (1942); and Augustin Boutaric, "Nuclear Chemistry" Rev. sci. 80, 326 (1942).) (The first half of the Zentralblatt for 1943 came back from the bindery and) I found the following patent: Auergesellschaft, Berlin "Separation of Difficultly-Separable Gas Mixtures by Diffusion". At one end of a column containing cells separated from one another by porous layers and filled with the gaseous mixture an over-pressure is applied, so that pressure equalization takes place from cell to cell by diffusion. Next, at the

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Figure D.242: Karl Cohen to Philip Morrison. 26 April 1944 [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

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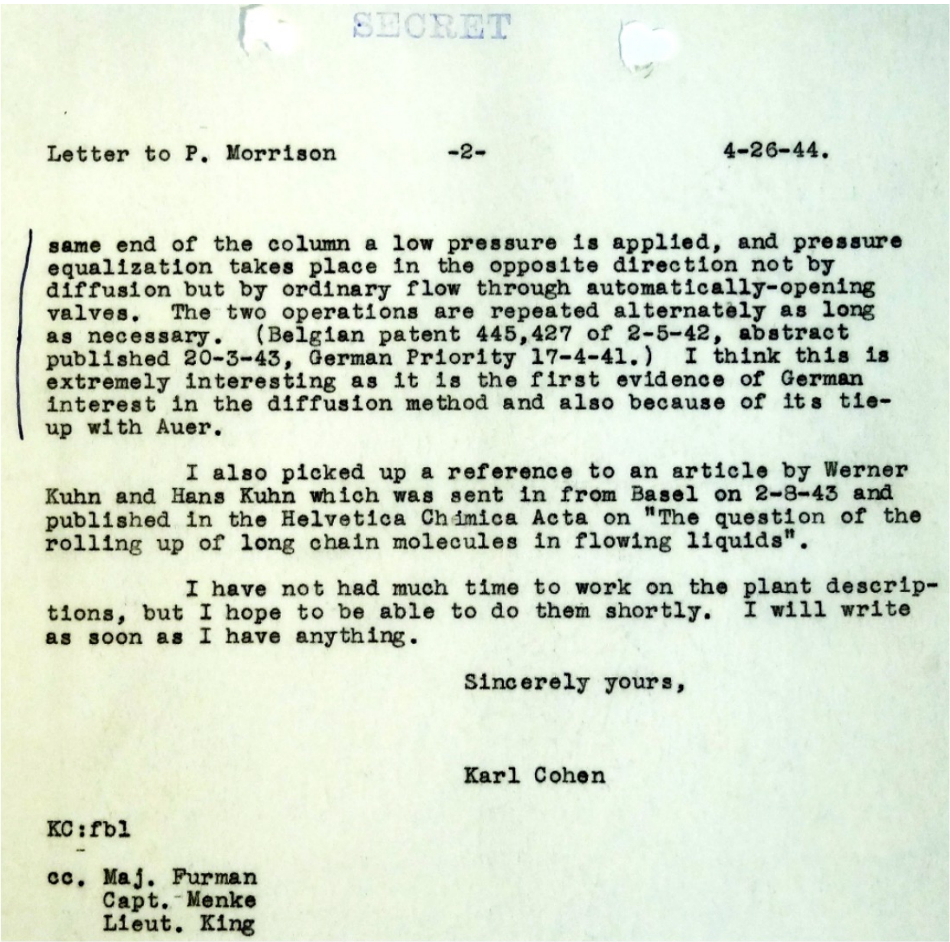
NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)



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Letter to P. Morrison -2- 4-26-44.

same end of the column a low pressure is applied, and pressure equalization takes place in the opposite direction not by diffusion but by ordinary flow through automatically-opening valves. The two operations are repeated alternately as long as necessary. (Belgian patent 445,427 of 2-5-42, abstract published 20-3-43, German Priority 17-4-41.) I think this is extremely interesting as it is the first evidence of German interest in the diffusion method and also because of its tie-up with Auer.

I also picked up a reference to an article by Werner Kuhn and Hans Kuhn which was sent in from Basel on 2-8-43 and published in the Helvetica Chimica Acta on "The question of the rolling up of long chain molecules in flowing liquids".

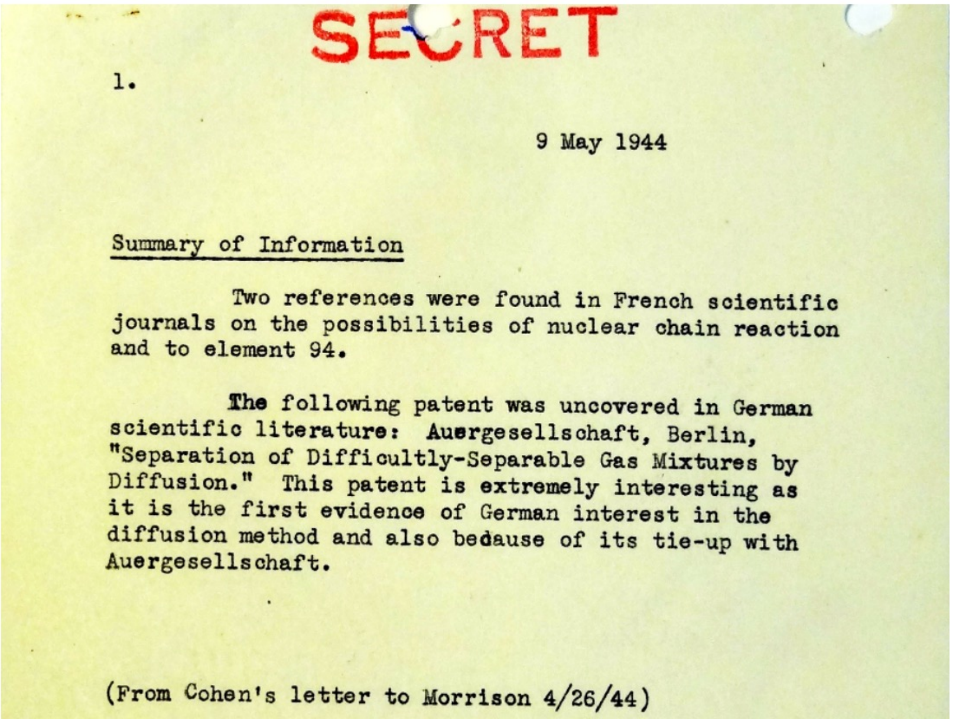
I have not had much time to work on the plant descriptions, but I hope to be able to do them shortly. I will write as soon as I have anything.

Sincerely yours,

Karl Cohen

KC:fbl

cc. Maj. Furman
Capt. Menke
Lieut. King



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1.

9 May 1944

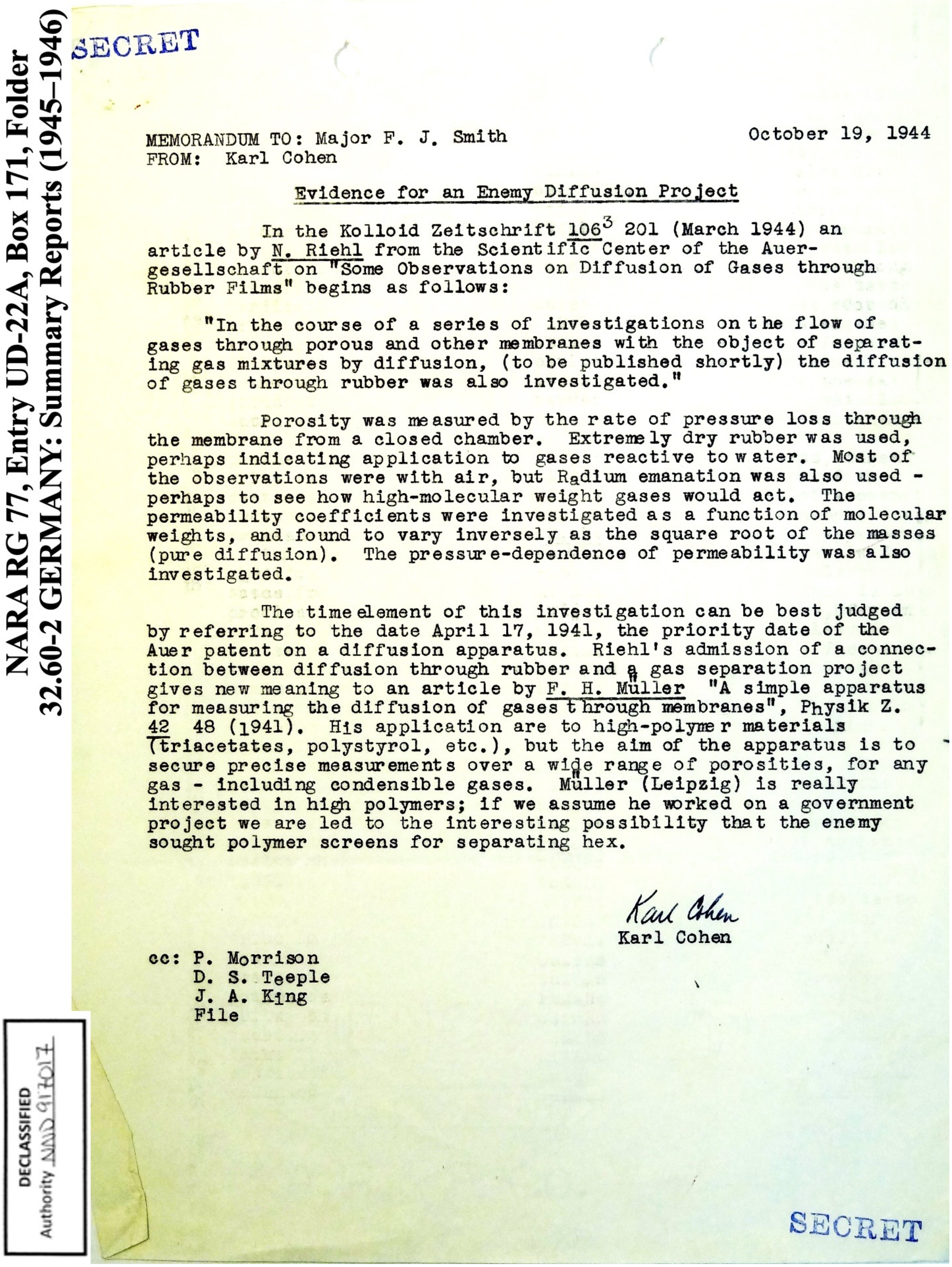
Summary of Information

Two references were found in French scientific journals on the possibilities of nuclear chain reaction and to element 94.

The following patent was uncovered in German scientific literature: Auergesellschaft, Berlin, "Separation of Difficultly-Separable Gas Mixtures by Diffusion." This patent is extremely interesting as it is the first evidence of German interest in the diffusion method and also bedause of its tie-up with Auergesellschaft.

(From Cohen's letter to Morrison 4/26/44)

Figure D.243: Karl Cohen to Philip Morrison. 26 April 1944 [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].



NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)

SECRET

MEMORANDUM TO: Major F. J. Smith
FROM: Karl Cohen

October 19, 1944

Evidence for an Enemy Diffusion Project

In the Kolloid Zeitschrift 106^3 201 (March 1944) an article by N. Riehl from the Scientific Center of the Auergesellschaft on "Some Observations on Diffusion of Gases through Rubber Films" begins as follows:

> "In the course of a series of investigations on the flow of gases through porous and other membranes with the object of separating gas mixtures by diffusion, (to be published shortly) the diffusion of gases through rubber was also investigated."

Porosity was measured by the rate of pressure loss through the membrane from a closed chamber. Extremely dry rubber was used, perhaps indicating application to gases reactive to water. Most of the observations were with air, but Radium emanation was also used - perhaps to see how high-molecular weight gases would act. The permeability coefficients were investigated as a function of molecular weights, and found to vary inversely as the square root of the masses (pure diffusion). The pressure-dependence of permeability was also investigated.

The time element of this investigation can be best judged by referring to the date April 17, 1941, the priority date of the Auer patent on a diffusion apparatus. Riehl's admission of a connection between diffusion through rubber and a gas separation project gives new meaning to an article by F. H. Müller "A simple apparatus for measuring the diffusion of gases through membranes", Physik Z. 42 48 (1941). His application are to high-polymer materials (triacetates, polystyrol, etc.), but the aim of the apparatus is to secure precise measurements over a wide range of porosities, for any gas - including condensible gases. Müller (Leipzig) is really interested in high polymers; if we assume he worked on a government project we are led to the interesting possibility that the enemy sought polymer screens for separating hex.

Karl Cohen
Karl Cohen

cc: P. Morrison
D. S. Teeple
J. A. King
File

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Authority NND 917017

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Figure D.244: Karl Cohen to Francis J. Smith. 19 October 1944. Evidence for an Enemy Diffusion Project [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

[The isotope sluice was an alternative form of gaseous diffusion invented by Erich Bagge. The principle was that in a beam of energetic uranium atoms/ions/molecules, lighter U-235 would travel slightly faster than heavier U-238. If that beam had to traverse a series of portals that quickly opened and closed with the right timing, the faster U-235 would be more likely to make it through than the slower U-238. The portals were generally holes in rapidly spinning disks. Because the isotope sluice involved energetic uranium beams and high-speed rotating machinery, it also had some characteristics of electromagnetic separators and centrifuges. Bagge led a team that successfully demonstrated isotope sluice prototypes during the war, and he tried unsuccessfully to attract enough support for the approach in the European nuclear industry after the war.

See pp. 3653–3662.]

Background investigation of Erich Bagge. 7 April 1952 [NARA RG 330, Entry A1-1B, Box 6, Folder Bagge, Erich]

On 28 March 1952, Frau Charlotte PRAGER nee BRINKMANN, a German national... now residing in BERLIN-Dahlem, Boltzmannstr. 19, was interviewed, and stated substantially as follows: BAGGE had lived in the neighborhood in 1941 with his wife and two (2) children. BAGGE worked in the Kaiser Wilhelm Institute for Physics; however, SOURCE was not sure what type of work BAGGE performed. In 1944, BAGGE and his family presumably departed for VIENNA (O49/X49), Austria. Since this time SOURCE has never seen or heard about BAGGE. [...]

[Did Bagge help transition his uranium-235 enrichment system to industrial-scale production someplace in Austria, such as at Gusen?]

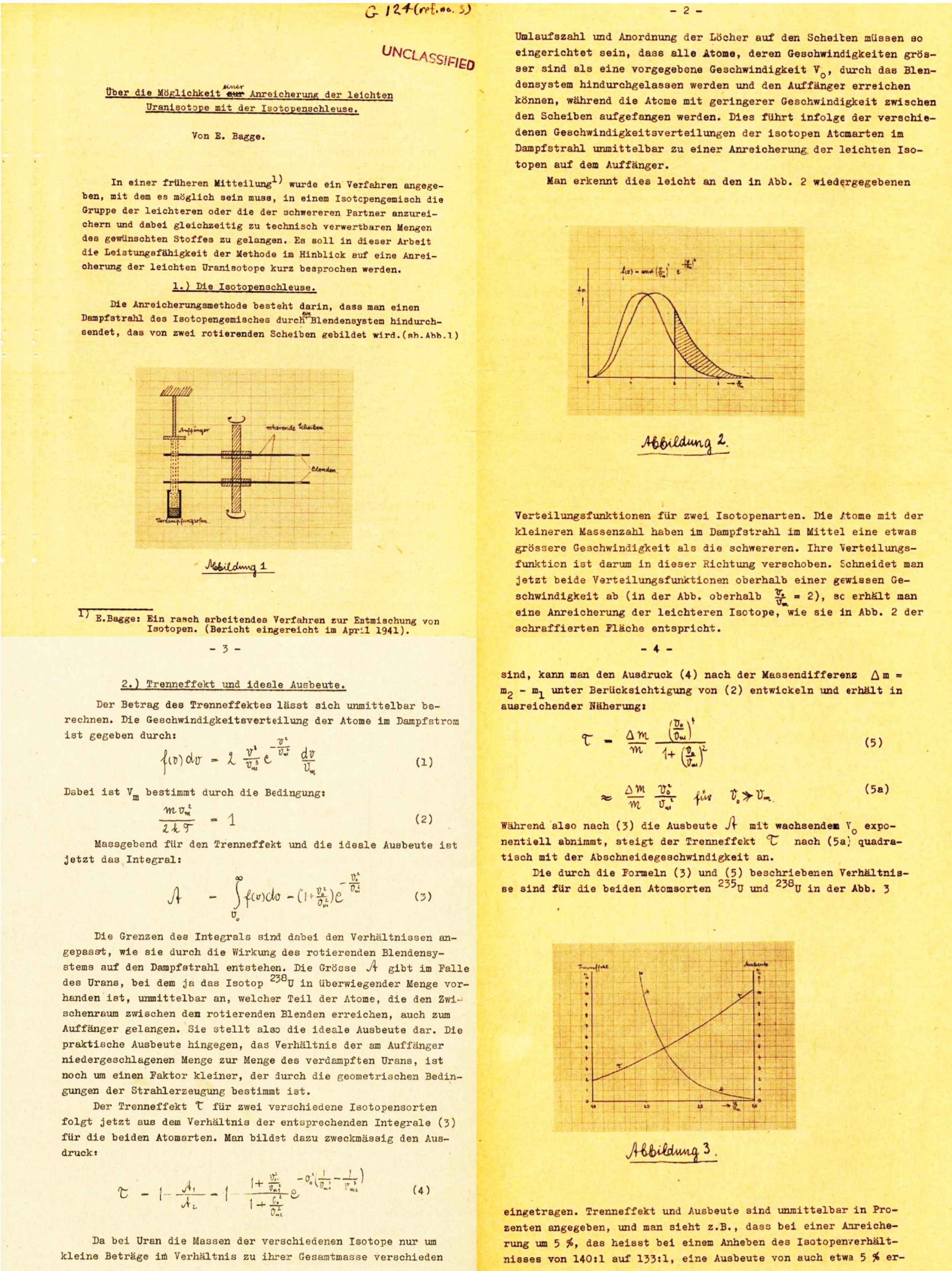
Erich Bagge and Karl-Friedrich Leisinger. Patent DE1058024. Vorrichtung zur Trennung von Isotopen mit der Isotopenschleuse in der Gasphase. [Device for the Separation of Isotopes with the Isotope Sluice in the Gas Phase.] Filed 6 May 1955.

Es ist möglich, Isotope mit Hilfe der Isotopenschleuse nach einem von E. Bagge entwickelten Verfahren zu trennen. Die Methode besteht darin, daß man sich für das zu trennende Isotopengemisch einen Atom- oder Molekularstrahl herstellt, welcher ein System von intermittierenden Blenden durchsetzen muß. Die Blenden sind so eingerichtet, daß durch periodisches Öffnen und Schließen der Atom- oder Molekularstrahl in kleine Wölkchen zerhackt wird.

Die Wölkchen müssen dann über eine kurze Wegstrecke durch den Raum fliegen, wobei sich eine teilweise Trennung der Isotope vollzieht, indem sich die leichteren und dadurch schnelleren Teilchen an den Kopf des Wölkchens setzen, während die schwereren zurückbleiben. Das zweite Blendsystem sorgt dafür, daß die Wölkchen abermals zerteilt werden, indem die Spitze durchgelassen wird, während der Rest des Wölkchens zwischen den Blenden zurückbleibt. Auf diese Weise ist es möglich, aus dem ursprünglichen Atomstrahl einen neuen intermittierenden Strahl zu gewinnen, in dem die leichteren Isotope angereichert sind. Zur Ausbildung des primären Atomstrahls wird vor die erste intermittierende Blende eine raumfeste oder ein ganzes System räumlich feststehender Blenden gebracht. Das Verfahren, das sich in dieser Form auf Atomstrahlen leicht kondensierbarer Metalldämpfe mit Erfolg anwenden läßt, kann auch auf Gase übertragen werden.

It is possible to separate isotopes by means of the isotope sluice according to a method developed by E. Bagge. The method consists in producing an atomic or molecular beam for the isotope mixture to be separated, which must enforce a system of intermittent diaphragms. The apertures are arranged so that the atomic or molecular beam is chopped into small clouds by periodically opening and closing.

The small clouds then have to fly over a short distance through space, with a partial separation of the isotopes takes place by the lighter and thus faster particles sit on the head of the cloud, while the heavier remain behind. The second blend system causes the clouds to be split again by letting the tip through while leaving the rest of the cloud between the baffles. In this way, it is possible to obtain from the original atomic beam a new intermittent beam in which the lighter isotopes are enriched. To form the primary atom beam, a space-fixed or an entire system of spatially fixed diaphragms is brought before the first intermittent diaphragm. The method, which can be successfully applied in this form to atomic beams of easily condensable metal vapors, can also be applied to gases.



G 124 (ref. no. 3)

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Über die Möglichkeit einer ~~zur~~ Anreicherung der leichten Uranisotope mit der Isotopenschleuse.

Von E. Bagge.

In einer früheren Mitteilung[1] wurde ein Verfahren angegeben, mit dem es möglich sein muss, in einem Isotopengemisch die Gruppe der leichteren oder die der schwereren Partner anzureichern und dabei gleichzeitig zu technisch verwertbaren Mengen des gewünschten Stoffes zu gelangen. Es soll in dieser Arbeit die Leistungsfähigkeit der Methode im Hinblick auf eine Anreicherung der leichten Uranisotope kurz besprochen werden.

1.) Die Isotopenschleuse.

Die Anreicherungsmethode besteht darin, dass man einen Dampfstrahl des Isotopengemisches durch ein Blendensystem hindurchsendet, das von zwei rotierenden Scheiben gebildet wird. (sh. Abb. 1)

Abbildung 1

---

[1] E.Bagge: Ein rasch arbeitendes Verfahren zur Entmischung von Isotopen. (Bericht eingereicht im April 1941).

- 2 -

Umlaufszahl und Anordnung der Löcher auf den Scheiben müssen so eingerichtet sein, dass alle Atome, deren Geschwindigkeiten grösser sind als eine vorgegebene Geschwindigkeit V_o, durch das Blendensystem hindurchgelassen werden und den Auffänger erreichen können, während die Atome mit geringerer Geschwindigkeit zwischen den Scheiben aufgefangen werden. Dies führt infolge der verschiedenen Geschwindigkeitsverteilungen der isotopen Atomarten im Dampfstrahl unmittelbar zu einer Anreicherung der leichten Isotopen auf dem Auffänger.

Man erkennt dies leicht an den in Abb. 2 wiedergegebenen Verteilungsfunktionen für zwei Isotopenarten. Die Atome mit der kleineren Massenzahl haben im Dampfstrahl im Mittel eine etwas grössere Geschwindigkeit als die schwereren. Ihre Verteilungsfunktion ist darum in dieser Richtung verschoben. Schneidet man jetzt beide Verteilungsfunktionen oberhalb einer gewissen Geschwindigkeit ab (in der Abb. oberhalb $\frac{v_o}{v_m} = 2$), so erhält man eine Anreicherung der leichteren Isotope, wie sie in Abb. 2 der schraffierten Fläche entspricht.

Abbildung 2.

- 3 -

2.) Trenneffekt und ideale Ausbeute.

Der Betrag des Trenneffektes lässt sich unmittelbar berechnen. Die Geschwindigkeitsverteilung der Atome im Dampfstrom ist gegeben durch:

$$f(v)\,dv = 2\,\frac{v^3}{v_m^3}\,e^{-\frac{v^2}{v_m^2}}\,\frac{dv}{v_m} \tag{1}$$

Dabei ist V_m bestimmt durch die Bedingung:

$$\frac{m v_m^2}{2kT} = 1 \tag{2}$$

Massgebend für den Trenneffekt und die ideale Ausbeute ist jetzt das Integral:

$$\mathcal{A} = \int_{v_0}^{\infty} f(v)\,dv = \left(1+\frac{v_0^2}{v_m^2}\right)e^{-\frac{v_0^2}{v_m^2}} \tag{3}$$

Die Grenzen des Integrals sind dabei den Verhältnissen angepasst, wie sie durch die Wirkung des rotierenden Blendensystems auf den Dampfstrahl entstehen. Die Grösse $\mathcal{A}$ gibt im Falle des Urans, bei dem ja das Isotop ^{238}U in überwiegender Menge vorhanden ist, unmittelbar an, welcher Teil der Atome, die den Zwischenraum zwischen dem rotierenden Blenden erreichen, auch zum Auffänger gelangen. Sie stellt also die ideale Ausbeute dar. Die praktische Ausbeute hingegen, das Verhältnis der am Auffänger niedergeschlagenen Menge zur Menge des verdampften Urans, ist noch um einen Faktor kleiner, der durch die geometrischen Bedingungen der Strahlerzeugung bestimmt ist.

Der Trenneffekt τ für zwei verschiedene Isotopensorten folgt jetzt aus dem Verhältnis der entsprechenden Integrale (3) für die beiden Atomarten. Man bildet dazu zweckmässig den Ausdruck:

$$\tau = 1 - \frac{\mathcal{A}_1}{\mathcal{A}_2} = 1 - \frac{1+\frac{v_0^2}{v_{m1}^2}}{1+\frac{v_0^2}{v_{m2}^2}}\,e^{-v_0^2\left(\frac{1}{v_{m1}^2}-\frac{1}{v_{m2}^2}\right)} \tag{4}$$

- 4 -

Da bei Uran die Massen der verschiedenen Isotope nur um kleine Beträge im Verhältnis zu ihrer Gesamtmasse verschieden sind, kann man den Ausdruck (4) nach der Massendifferenz $\Delta m = m_2 - m_1$ unter Berücksichtigung von (2) entwickeln und erhält in ausreichender Näherung:

$$\tau = \frac{\Delta m}{m}\,\frac{\left(\frac{v_0}{v_m}\right)^4}{1+\left(\frac{v_0}{v_m}\right)^2} \tag{5}$$

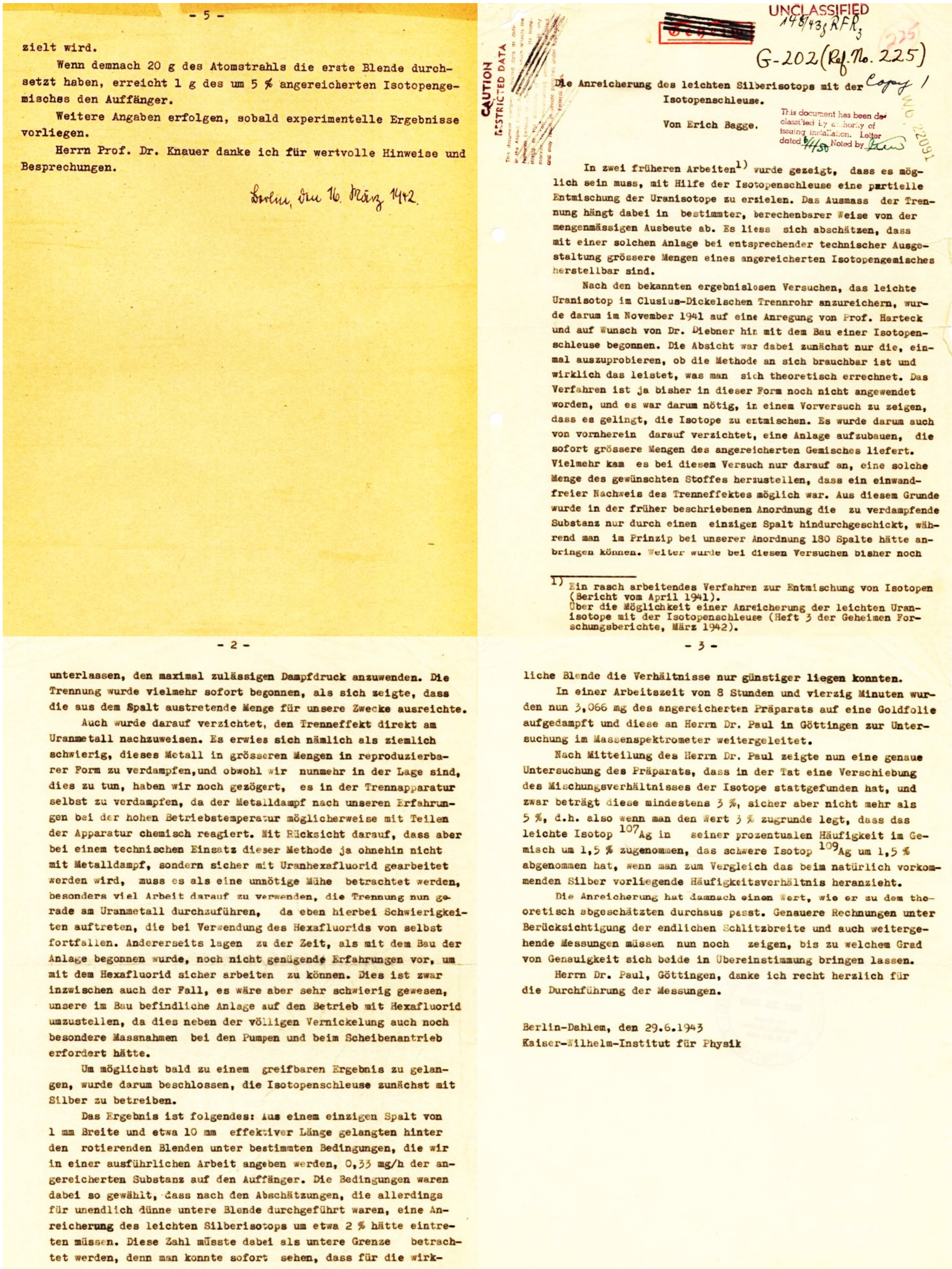
$$\approx \frac{\Delta m}{m}\,\frac{v_0^2}{v_m^2} \quad \text{für} \quad v_0 \gg v_m \tag{5a}$$

Während also nach (3) die Ausbeute $\mathcal{A}$ mit wachsendem V_o exponentiell abnimmt, steigt der Trenneffekt τ nach (5a) quadratisch mit der Abschneidegeschwindigkeit an.

Die durch die Formeln (3) und (5) beschriebenen Verhältnisse sind für die beiden Atomsorten ^{235}U und ^{238}U in der Abb. 3 eingetragen. Trenneffekt und Ausbeute sind unmittelbar in Prozenten angegeben, und man sieht z.B., dass bei einer Anreicherung um 5 %, das heisst bei einem Anheben des Isotopenverhältnisses von 140:1 auf 133:1, eine Ausbeute von auch etwa 5 % er-

Abbildung 3.

Figure D.245: During the war, Erich Bagge led a team that invented, built, and demonstrated the "isotope sluice," an alternative form of gaseous diffusion enrichment [G-124].



- 5 -

zielt wird.

Wenn demnach 20 g des Atomstrahls die erste Blende durchsetzt haben, erreicht 1 g des um 5 % angereicherten Isotopengemisches den Auffänger.

Weitere Angaben erfolgen, sobald experimentelle Ergebnisse vorliegen.

Herrn Prof. Dr. Knauer danke ich für wertvolle Hinweise und Besprechungen.

Berlin, den 16. März 1942.

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G-202 (Ref. No. 225)

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Die Anreicherung des leichten Silberisotops mit der Isotopenschleuse.

Von Erich Bagge.

In zwei früheren Arbeiten[1)] wurde gezeigt, dass es möglich sein muss, mit Hilfe der Isotopenschleuse eine partielle Entmischung der Uranisotope zu erzielen. Das Ausmass der Trennung hängt dabei in bestimmter, berechenbarer Weise von der mengenmässigen Ausbeute ab. Es liess sich abschätzen, dass mit einer solchen Anlage bei entsprechender technischer Ausgestaltung grössere Mengen eines angereicherten Isotopengemisches herstellbar sind.

Nach den bekannten ergebnislosen Versuchen, das leichte Uranisotop im Clusius-Dickelschen Trennrohr anzureichern, wurde darum im November 1941 auf eine Anregung von Prof. Harteck und auf Wunsch von Dr. Diebner hin mit dem Bau einer Isotopenschleuse begonnen. Die Absicht war dabei zunächst nur die, einmal auszuprobieren, ob die Methode an sich brauchbar ist und wirklich das leistet, was man sich theoretisch errechnet. Das Verfahren ist ja bisher in dieser Form noch nicht angewendet worden, und es war darum nötig, in einem Vorversuch zu zeigen, dass es gelingt, die Isotope zu entmischen. Es wurde darum auch von vornherein darauf verzichtet, eine Anlage aufzubauen, die sofort grössere Mengen des angereicherten Gemisches liefert. Vielmehr kam es bei diesem Versuch nur darauf an, eine solche Menge des gewünschten Stoffes herzustellen, dass ein einwandfreier Nachweis des Trenneffektes möglich war. Aus diesem Grunde wurde in der früher beschriebenen Anordnung die zu verdampfende Substanz nur durch einen einzigen Spalt hindurchgeschickt, während man im Prinzip bei unserer Anordnung 180 Spalte hätte anbringen können. Weiter wurde bei diesen Versuchen bisher noch

- 2 -

unterlassen, den maximal zulässigen Dampfdruck anzuwenden. Die Trennung wurde vielmehr sofort begonnen, als sich zeigte, dass die aus dem Spalt austretende Menge für unsere Zwecke ausreichte.

Auch wurde darauf verzichtet, den Trenneffekt direkt am Uranmetall nachzuweisen. Es erwies sich nämlich als ziemlich schwierig, dieses Metall in grösseren Mengen in reproduzierbarer Form zu verdampfen, und obwohl wir nunmehr in der Lage sind, dies zu tun, haben wir noch gezögert, es in der Trennapparatur selbst zu verdampfen, da der Metalldampf nach unseren Erfahrungen bei der hohen Betriebstemperatur möglicherweise mit Teilen der Apparatur chemisch reagiert. Mit Rücksicht darauf, dass aber bei einem technischen Einsatz dieser Methode ja ohnehin nicht mit Metalldampf, sondern sicher mit Uranhexafluorid gearbeitet werden wird, muss es als eine unnötige Mühe betrachtet werden, besonders viel Arbeit darauf zu verwenden, die Trennung nun gerade am Uranmetall durchzuführen, da eben hierbei Schwierigkeiten auftreten, die bei Verwendung des Hexafluorids von selbst fortfallen. Andererseits lagen zu der Zeit, als mit dem Bau der Anlage begonnen wurde, noch nicht genügende Erfahrungen vor, um mit dem Hexafluorid sicher arbeiten zu können. Dies ist zwar inzwischen auch der Fall, es wäre aber sehr schwierig gewesen, unsere im Bau befindliche Anlage auf den Betrieb mit Hexafluorid umzustellen, da dies neben der völligen Vernickelung auch noch besondere Massnahmen bei den Pumpen und beim Scheibenantrieb erfordert hätte.

Um möglichst bald zu einem greifbaren Ergebnis zu gelangen, wurde darum beschlossen, die Isotopenschleuse zunächst mit Silber zu betreiben.

Das Ergebnis ist folgendes: Aus einem einzigen Spalt von 1 mm Breite und etwa 10 mm effektiver Länge gelangten hinter den rotierenden Blenden unter bestimmten Bedingungen, die wir in einer ausführlichen Arbeit angeben werden, 0,33 mg/h der angereicherten Substanz auf den Auffänger. Die Bedingungen waren dabei so gewählt, dass nach den Abschätzungen, die allerdings für unendlich dünne untere Blende durchgeführt waren, eine Anreicherung des leichten Silberisotops um etwa 2 % hätte eintreten müssen. Diese Zahl müsste dabei als untere Grenze betrachtet werden, denn man konnte sofort sehen, dass für die wirkliche Blende die Verhältnisse nur günstiger liegen konnten.

- 3 -

In einer Arbeitszeit von 8 Stunden und vierzig Minuten wurden nun 3,066 mg des angereicherten Präparats auf eine Goldfolie aufgedampft und diese an Herrn Dr. Paul in Göttingen zur Untersuchung im Massenspektrometer weitergeleitet.

Nach Mitteilung des Herrn Dr. Paul zeigte nun eine genaue Untersuchung des Präparats, dass in der Tat eine Verschiebung des Mischungsverhältnisses der Isotope stattgefunden hat, und zwar beträgt diese mindestens 3 %, sicher aber nicht mehr als 5 %, d.h. also wenn man den Wert 3 % zugrunde legt, dass das leichte Isotop ^{107}Ag in seiner prozentualen Häufigkeit im Gemisch um 1,5 % zugenommen, das schwere Isotop ^{109}Ag um 1,5 % abgenommen hat, wenn man zum Vergleich das beim natürlich vorkommenden Silber vorliegende Häufigkeitsverhältnis heranzieht.

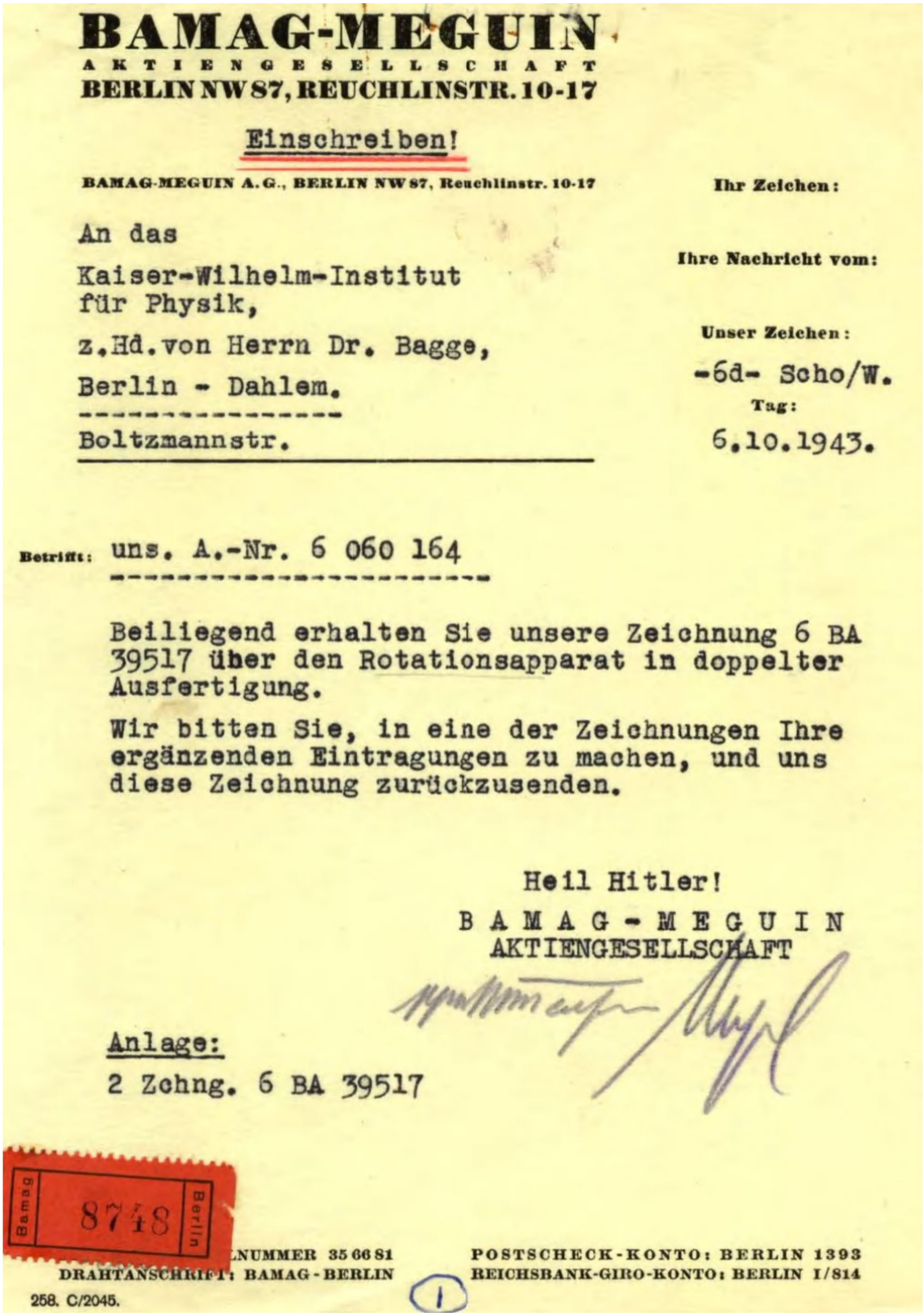
Die Anreicherung hat danach einen Wert, wie er zu dem theoretisch abgeschätzten durchaus passt. Genauere Rechnungen unter Berücksichtigung der endlichen Schlitzbreite und auch weitergehende Messungen müssen nun noch zeigen, bis zu welchem Grad von Genauigkeit sich beide in Übereinstimmung bringen lassen.

Herrn Dr. Paul, Göttingen, danke ich recht herzlich für die Durchführung der Messungen.

Berlin-Dahlem, den 29.6.1943
Kaiser-Wilhelm-Institut für Physik

[1)] Ein rasch arbeitendes Verfahren zur Entmischung von Isotopen (Bericht vom April 1941).
Über die Möglichkeit einer Anreicherung der leichten Uranisotope mit der Isotopenschleuse (Heft 3 der Geheimen Forschungsberichte, März 1942).

Figure D.246: During the war, Erich Bagge led a team that invented, built, and demonstrated the "isotope sluice," an alternative form of gaseous diffusion enrichment [G-124; G-202].



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An das
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für Physik,
z.Hd. von Herrn Dr. Bagge,
Berlin - Dahlem.
Boltzmannstr.

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Ihre Nachricht vom:
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Tag: 6.10.1943.

Betrifft: uns. A.-Nr. 6 060 164

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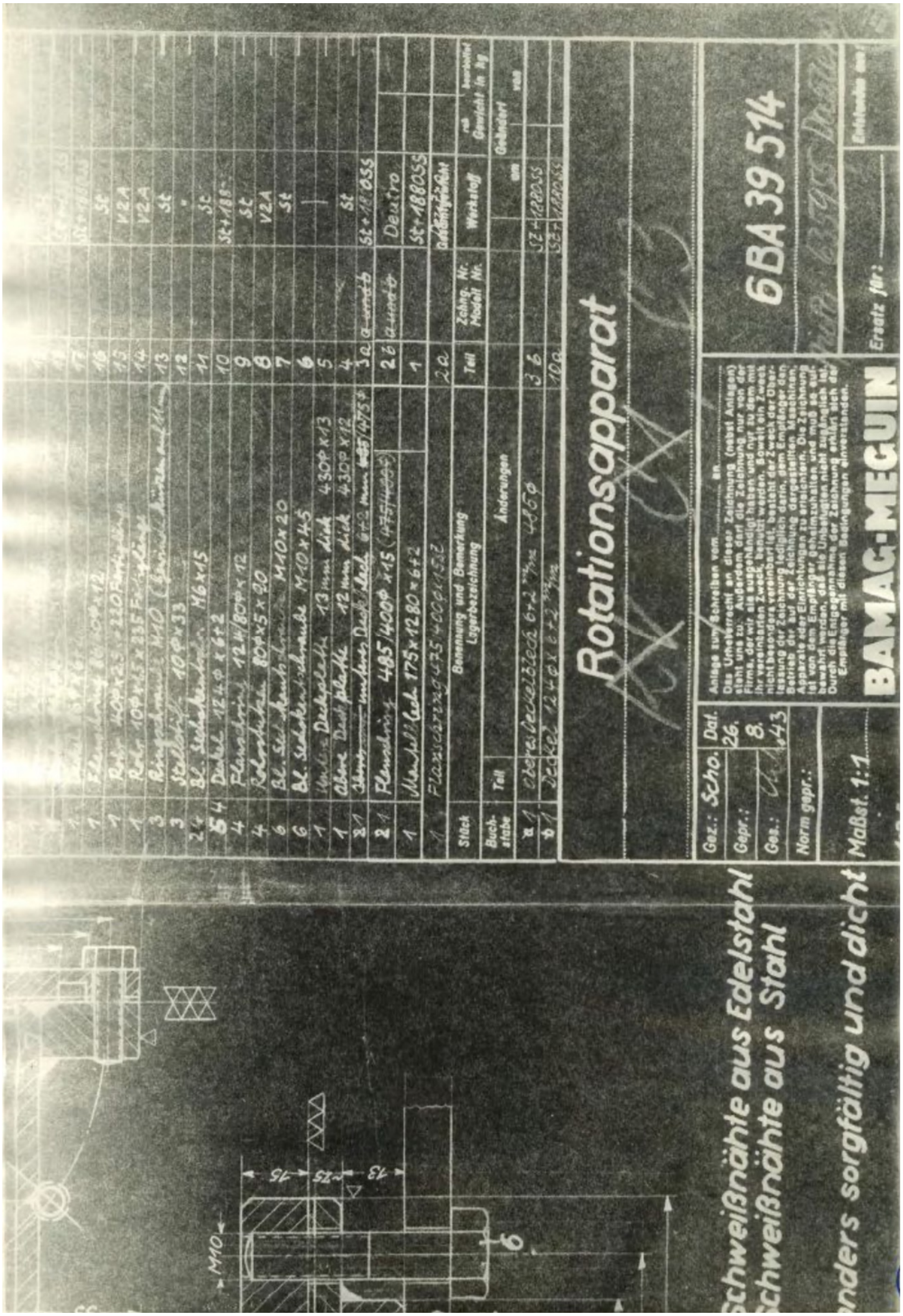
Figure D.247: During the war, Erich Bagge led a team that invented, built, and demonstrated the "isotope sluice," an alternative form of gaseous diffusion enrichment [https://digital.deutsches-museum.de/item/FA-002-782/].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Teil
Zchng. Nr. Modell Nr.
Werkstoff
Gewicht in kg
Änderungen
Ersatz für:
M10
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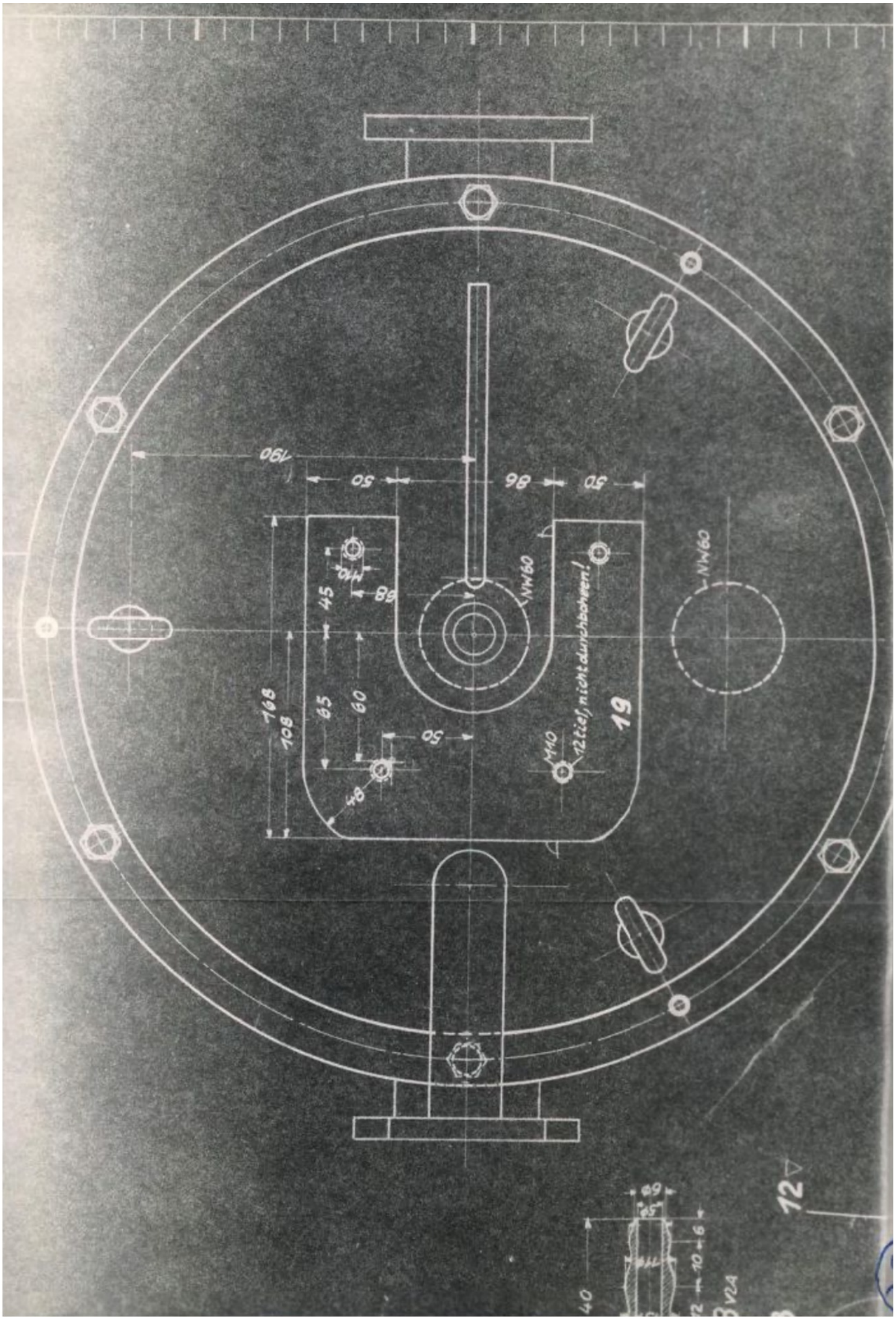
Figure D.248: During the war, Erich Bagge led a team that invented, built, and demonstrated the “isotope sluice,” an alternative form of gaseous diffusion enrichment [https://digital.deutsches-museum.de/item/FA-002-782/].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19
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Ø5
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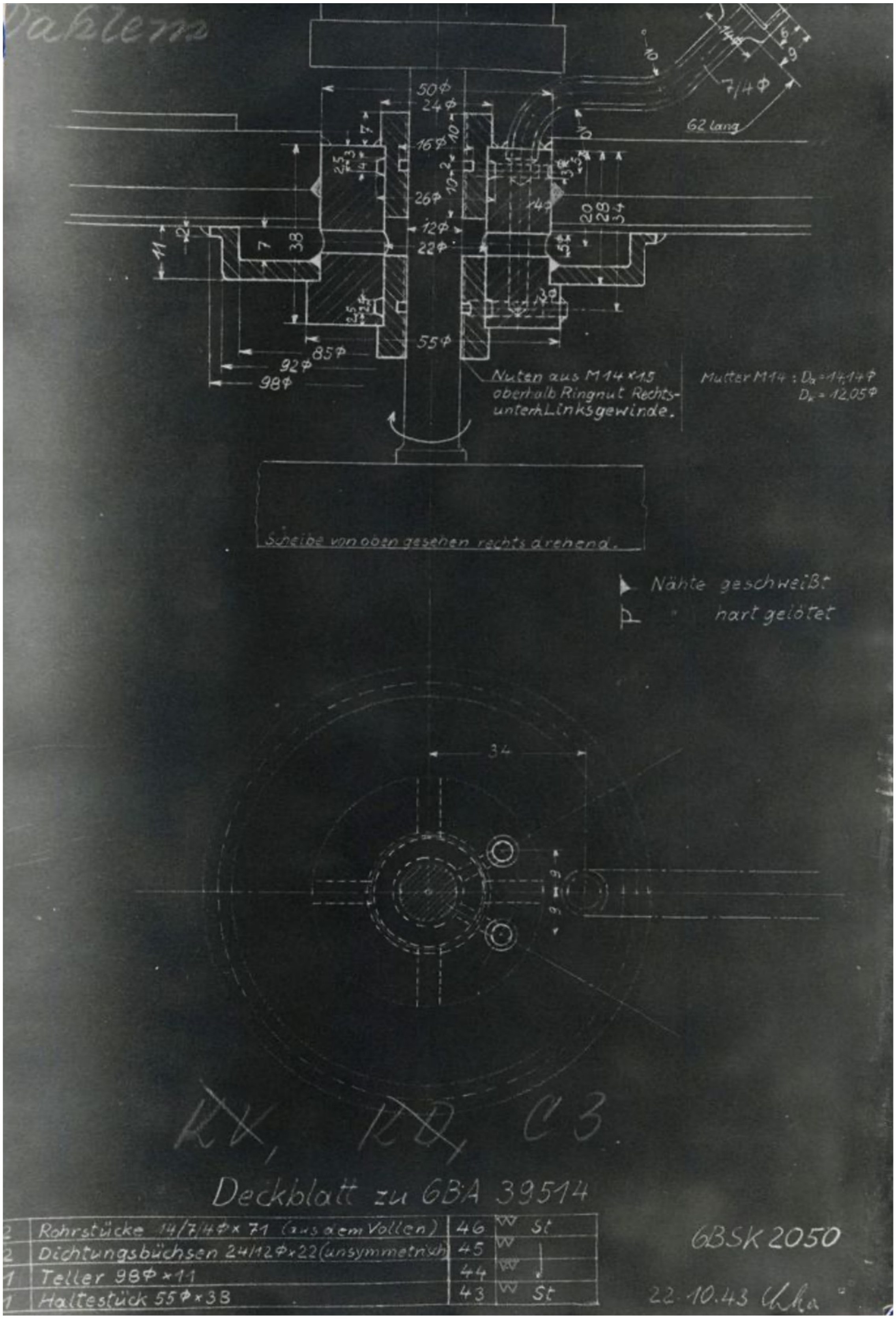
Figure D.249: During the war, Erich Bagge led a team that invented, built, and demonstrated the "isotope sluice," an alternative form of gaseous diffusion enrichment [https://digital.deutsches-museum.de/item/FA-002-782/].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62 lang
Nuten aus M14×15 oberhalb Ringnut Rechts- unterh. Linksgewinde.
Mutter M14: Da=14,14Φ Dk=12,05Φ
Scheibe von oben gesehen rechts drehend.
Nähte geschweißt
hart gelötet
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KV, KD, C3
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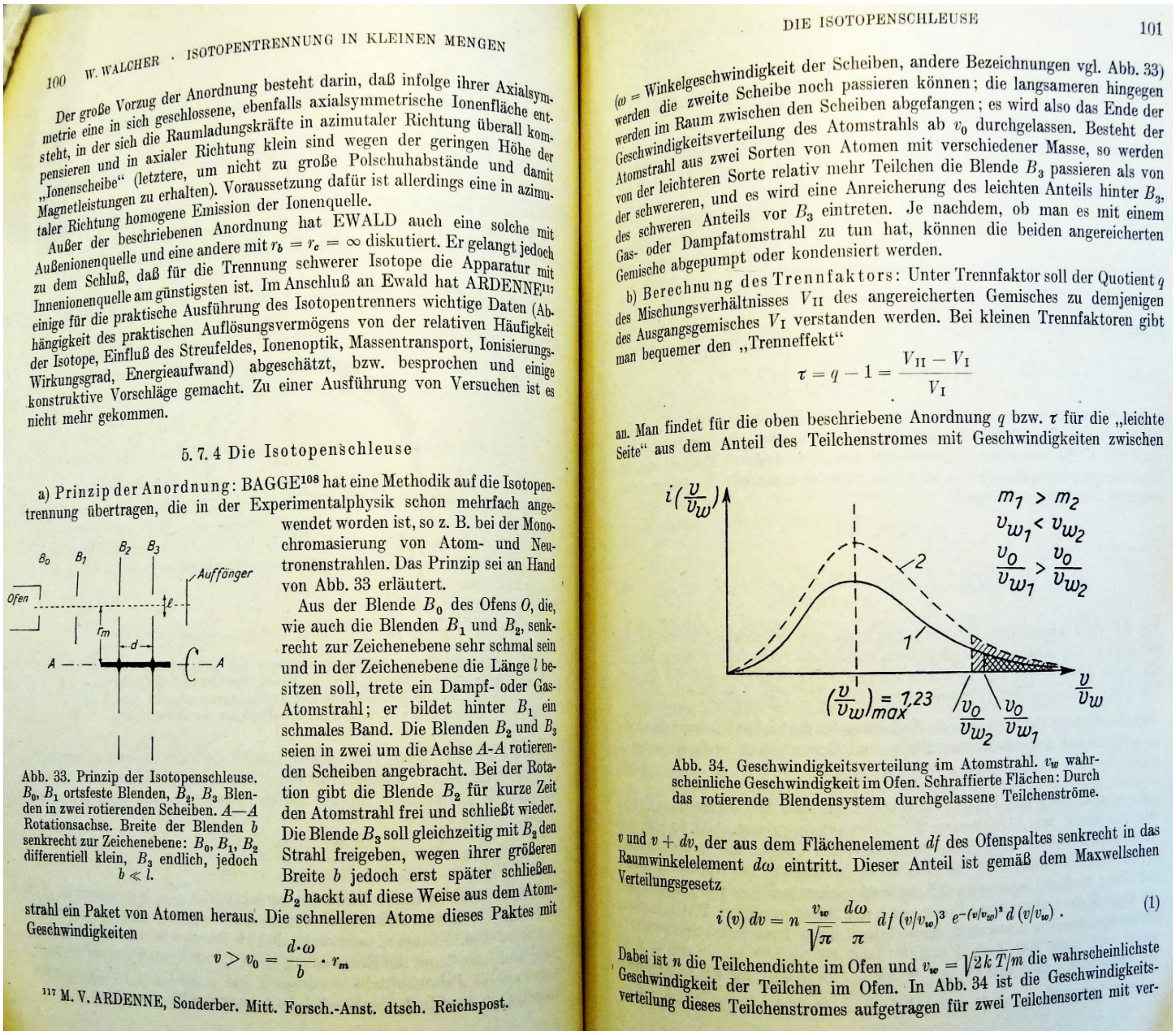
22.10.43

2	Rohrstücke 14/7/4Φ×71 (aus dem Vollen)	46	▽▽	St
2	Dichtungsbüchsen 24/12Φ×22 (unsymmetrisch)	45	▽	
1	Teller 98Φ×11	44	▽▽	
1	Haltestück 55Φ×38	43	▽	St

Figure D.250: During the war, Erich Bagge led a team that invented, built, and demonstrated the “isotope sluice,” an alternative form of gaseous diffusion enrichment [https://digital.deutsches-museum.de/item/FA-002-782/].


B0
B1
B2
B3
Auffänger
Ofen
l
r_m
d
A
A
i(v/v_w)
m_1 > m_2
v_w1 < v_w2
v_0/v_w1 > v_0/v_w2
2
1
(v/v_w)_max = 1,23
v_0/v_w2
v_0/v_w1
v/v_w

Der große Vorzug der Anordnung besteht darin, daß infolge ihrer Axialsymmetrie eine in sich geschlossene, ebenfalls axialsymmetrische Ionenfläche entsteht, in der sich die Raumladungskräfte in azimutaler Richtung überall kompensieren und in axialer Richtung klein sind wegen der geringen Höhe der „Ionenscheibe“ (letztere, um nicht zu große Polschuhabstände und damit Magnetleistungen zu erhalten). Voraussetzung dafür ist allerdings eine in azimutaler Richtung homogene Emission der Ionenquelle.

Außer der beschriebenen Anordnung hat EWALD auch eine solche mit Außenionenquelle und eine andere mit $r_b = r_c = \infty$ diskutiert. Er gelangt jedoch zu dem Schluß, daß für die Trennung schwerer Isotope die Apparatur mit Innenionenquelle am günstigsten ist. Im Anschluß an Ewald hat ARDENNE[117] einige für die praktische Ausführung des Isotopentrenners wichtige Daten (Abhängigkeit des praktischen Auflösungsvermögens von der relativen Häufigkeit der Isotope, Einfluß des Streufeldes, Ionenoptik, Massentransport, Ionisierungs-Wirkungsgrad, Energieaufwand) abgeschätzt, bzw. besprochen und einige konstruktive Vorschläge gemacht. Zu einer Ausführung von Versuchen ist es nicht mehr gekommen.

5. 7. 4 Die Isotopenschleuse

a) Prinzip der Anordnung: BAGGE[108] hat eine Methodik auf die Isotopentrennung übertragen, die in der Experimentalphysik schon mehrfach angewendet worden ist, so z. B. bei der Monochromasierung von Atom- und Neutronenstrahlen. Das Prinzip sei an Hand von Abb. 33 erläutert.

Abb. 33. Prinzip der Isotopenschleuse. B_0, B_1 ortsfeste Blenden, B_2, B_3 Blenden in zwei rotierenden Scheiben. A—A Rotationsachse. Breite der Blenden b senkrecht zur Zeichenebene: B_0, B_1, B_2 differentiell klein, B_3 endlich, jedoch $b \ll l$.

Aus der Blende B_0 des Ofens O, die, wie auch die Blenden B_1 und B_2, senkrecht zur Zeichenebene sehr schmal sein und in der Zeichenebene die Länge l besitzen soll, trete ein Dampf- oder Gas-Atomstrahl; er bildet hinter B_1 ein schmales Band. Die Blenden B_2 und B_3 seien in zwei um die Achse A-A rotierenden Scheiben angebracht. Bei der Rotation gibt die Blende B_2 für kurze Zeit den Atomstrahl frei und schließt wieder. Die Blende B_3 soll gleichzeitig mit B_2 den Strahl freigeben, wegen ihrer größeren Breite b jedoch erst später schließen. B_2 hackt auf diese Weise aus dem Atomstrahl ein Paket von Atomen heraus. Die schnelleren Atome dieses Paktes mit Geschwindigkeiten

$$v > v_0 = \frac{d \cdot \omega}{b} \cdot r_m$$

---

[117] M. V. ARDENNE, Sonderber. Mitt. Forsch.-Anst. dtsch. Reichspost.

(ω = Winkelgeschwindigkeit der Scheiben, andere Bezeichnungen vgl. Abb. 33) werden die zweite Scheibe noch passieren können; die langsameren hingegen werden im Raum zwischen den Scheiben abgefangen; es wird also das Ende der Geschwindigkeitsverteilung des Atomstrahls ab v_0 durchgelassen. Besteht der Atomstrahl aus zwei Sorten von Atomen mit verschiedener Masse, so werden von der leichteren Sorte relativ mehr Teilchen die Blende B_3 passieren als von der schwereren, und es wird eine Anreicherung des leichten Anteils hinter B_3, des schweren Anteils vor B_3 eintreten. Je nachdem, ob man es mit einem Gas- oder Dampfatomstrahl zu tun hat, können die beiden angereicherten Gemische abgepumpt oder kondensiert werden.

b) Berechnung des Trennfaktors: Unter Trennfaktor soll der Quotient q des Mischungsverhältnisses V_{II} des angereicherten Gemisches zu demjenigen des Ausgangsgemisches V_{I} verstanden werden. Bei kleinen Trennfaktoren gibt man bequemer den „Trenneffekt“

$$\tau = q - 1 = \frac{V_{\mathrm{II}} - V_{\mathrm{I}}}{V_{\mathrm{I}}}$$

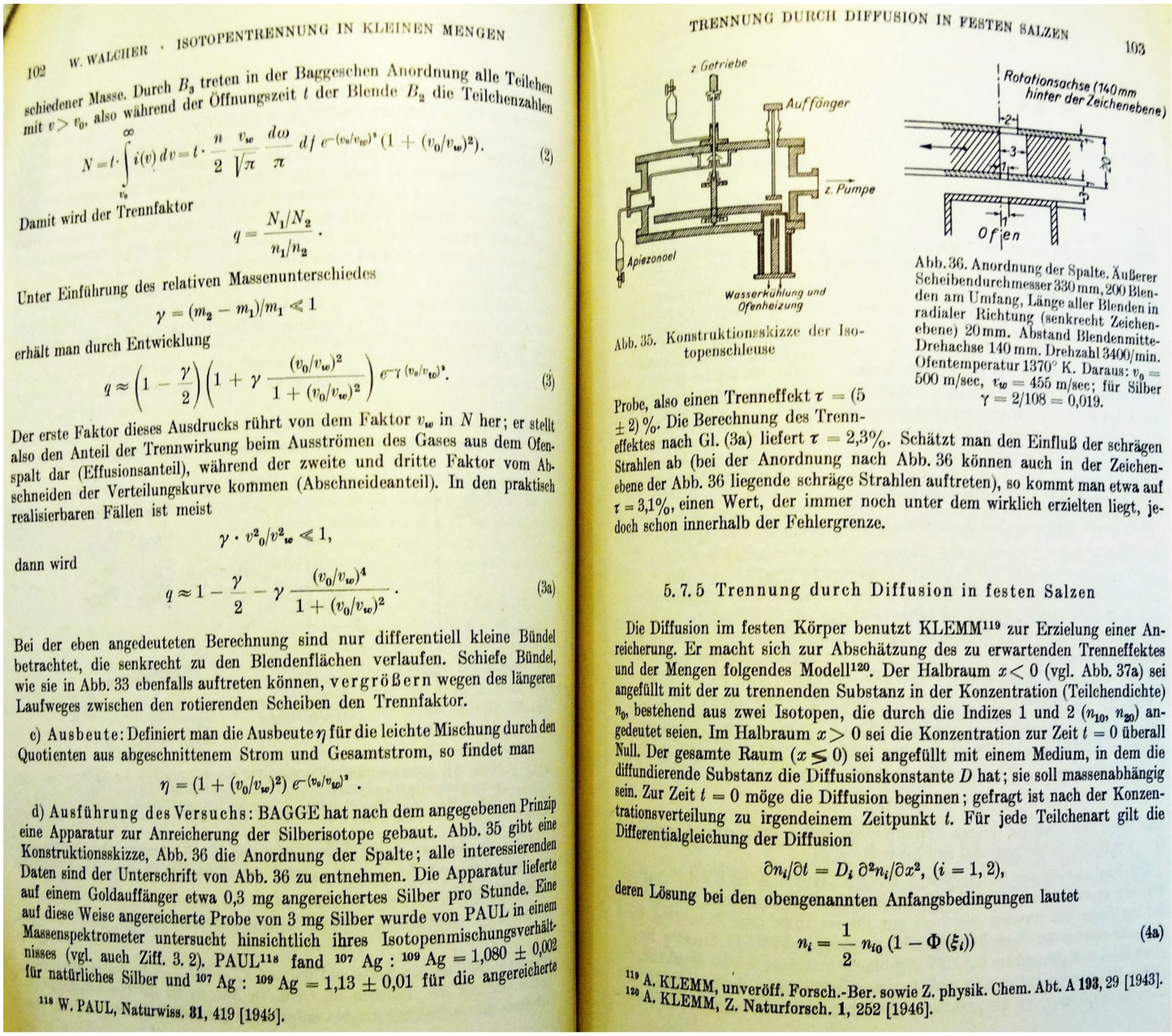
an. Man findet für die oben beschriebene Anordnung q bzw. τ für die „leichte Seite“ aus dem Anteil des Teilchenstromes mit Geschwindigkeiten zwischen v und $v + dv$, der aus dem Flächenelement df des Ofenspaltes senkrecht in das Raumwinkelelement $d\omega$ eintritt. Dieser Anteil ist gemäß dem Maxwellschen Verteilungsgesetz

Abb. 34. Geschwindigkeitsverteilung im Atomstrahl. v_w wahrscheinliche Geschwindigkeit im Ofen. Schraffierte Flächen: Durch das rotierende Blendensystem durchgelassene Teilchenströme.

$$i(v)\,dv = n\,\frac{v_w}{\sqrt{\pi}}\,\frac{d\omega}{\pi}\,df\,(v/v_w)^3\,e^{-(v/v_w)^2}\,d(v/v_w)\,. \tag{1}$$

Dabei ist n die Teilchendichte im Ofen und $v_w = \sqrt{2kT/m}$ die wahrscheinlichste Geschwindigkeit der Teilchen im Ofen. In Abb. 34 ist die Geschwindigkeitsverteilung dieses Teilchenstromes aufgetragen für zwei Teilchensorten mit ver-

Figure D.251: During the war, Erich Bagge led a team that invented, built, and demonstrated the “isotope sluice,” an alternative form of gaseous diffusion enrichment [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 100–103].



schiedener Masse. Durch B_3 treten in der Baggeschen Anordnung alle Teilchen mit $v > v_0$, also während der Öffnungszeit t der Blende B_2 die Teilchenzahlen

$$N = t \cdot \int_{v_0}^{\infty} i(v)\, dv = t \cdot \frac{n}{2}\, \frac{v_w}{\sqrt{\pi}}\, \frac{d\omega}{\pi}\, df\, e^{-(v_0/v_w)^2} \left(1 + (v_0/v_w)^2\right). \qquad (2)$$

Damit wird der Trennfaktor

$$q = \frac{N_1/N_2}{n_1/n_2}\,.$$

Unter Einführung des relativen Massenunterschiedes

$$\gamma = (m_2 - m_1)/m_1 \ll 1$$

erhält man durch Entwicklung

$$q \approx \left(1 - \frac{\gamma}{2}\right)\left(1 + \gamma\, \frac{(v_0/v_w)^2}{1 + (v_0/v_w)^2}\right) e^{-\gamma\,(v_0/v_w)^2}. \qquad (3)$$

Der erste Faktor dieses Ausdrucks rührt von dem Faktor v_w in N her; er stellt also den Anteil der Trennwirkung beim Ausströmen des Gases aus dem Ofenspalt dar (Effusionsanteil), während der zweite und dritte Faktor vom Abschneiden der Verteilungskurve kommen (Abschneideanteil). In den praktisch realisierbaren Fällen ist meist

$$\gamma \cdot v^2{}_0/v^2{}_w \ll 1,$$

dann wird

$$q \approx 1 - \frac{\gamma}{2} - \gamma\, \frac{(v_0/v_w)^4}{1 + (v_0/v_w)^2}\,. \qquad (3a)$$

Bei der eben angedeuteten Berechnung sind nur differentiell kleine Bündel betrachtet, die senkrecht zu den Blendenflächen verlaufen. Schiefe Bündel, wie sie in Abb. 33 ebenfalls auftreten können, vergrößern wegen des längeren Laufweges zwischen den rotierenden Scheiben den Trennfaktor.

c) Ausbeute: Definiert man die Ausbeute η für die leichte Mischung durch den Quotienten aus abgeschnittenem Strom und Gesamtstrom, so findet man

$$\eta = (1 + (v_0/v_w)^2)\, e^{-(v_0/v_w)^2}\,.$$

d) Ausführung des Versuchs: BAGGE hat nach dem angegebenen Prinzip eine Apparatur zur Anreicherung der Silberisotope gebaut. Abb. 35 gibt eine Konstruktionsskizze, Abb. 36 die Anordnung der Spalte; alle interessierenden Daten sind der Unterschrift von Abb. 36 zu entnehmen. Die Apparatur lieferte auf einem Goldauffänger etwa 0,3 mg angereichertes Silber pro Stunde. Eine auf diese Weise angereicherte Probe von 3 mg Silber wurde von PAUL in einem Massenspektrometer untersucht hinsichtlich ihres Isotopenmischungsverhältnisses (vgl. auch Ziff. 3. 2). PAUL[118] fand ^{107}Ag : ^{109}Ag = 1,080 ± 0,002 für natürliches Silber und ^{107}Ag : ^{109}Ag = 1,13 ± 0,01 für die angereicherte Probe, also einen Trenneffekt τ = (5 ± 2) %. Die Berechnung des Trenneffektes nach Gl. (3a) liefert τ = 2,3%. Schätzt man den Einfluß der schrägen Strahlen ab (bei der Anordnung nach Abb. 36 können auch in der Zeichenebene der Abb. 36 liegende schräge Strahlen auftreten), so kommt man etwa auf τ = 3,1%, einen Wert, der immer noch unter dem wirklich erzielten liegt, jedoch schon innerhalb der Fehlergrenze.

Abb. 35. Konstruktionsskizze der Isotopenschleuse

Abb. 36. Anordnung der Spalte. Äußerer Scheibendurchmesser 330 mm, 200 Blenden am Umfang, Länge aller Blenden in radialer Richtung (senkrecht Zeichenebene) 20 mm. Abstand Blendenmitte-Drehachse 140 mm. Drehzahl 3400/min. Ofentemperatur 1370° K. Daraus: v_0 = 500 m/sec, v_w = 455 m/sec; für Silber $\gamma = 2/108 = 0{,}019$.

5.7.5 Trennung durch Diffusion in festen Salzen

Die Diffusion im festen Körper benutzt KLEMM[119] zur Erzielung einer Anreicherung. Er macht sich zur Abschätzung des zu erwartenden Trenneffektes und der Mengen folgendes Modell[120]. Der Halbraum $x < 0$ (vgl. Abb. 37a) sei angefüllt mit der zu trennenden Substanz in der Konzentration (Teilchendichte) n_0, bestehend aus zwei Isotopen, die durch die Indizes 1 und 2 (n_{10}, n_{20}) angedeutet seien. Im Halbraum $x > 0$ sei die Konzentration zur Zeit $t = 0$ überall Null. Der gesamte Raum ($x \lesssim 0$) sei angefüllt mit einem Medium, in dem die diffundierende Substanz die Diffusionskonstante D hat; sie soll massenabhängig sein. Zur Zeit $t = 0$ möge die Diffusion beginnen; gefragt ist nach der Konzentrationsverteilung zu irgendeinem Zeitpunkt t. Für jede Teilchenart gilt die Differentialgleichung der Diffusion

$$\partial n_i/\partial t = D_i\, \partial^2 n_i/\partial x^2, \ (i = 1, 2),$$

deren Lösung bei den obengenannten Anfangsbedingungen lautet

$$n_i = \frac{1}{2}\, n_{i0}\, (1 - \Phi(\xi_i)) \qquad (4a)$$

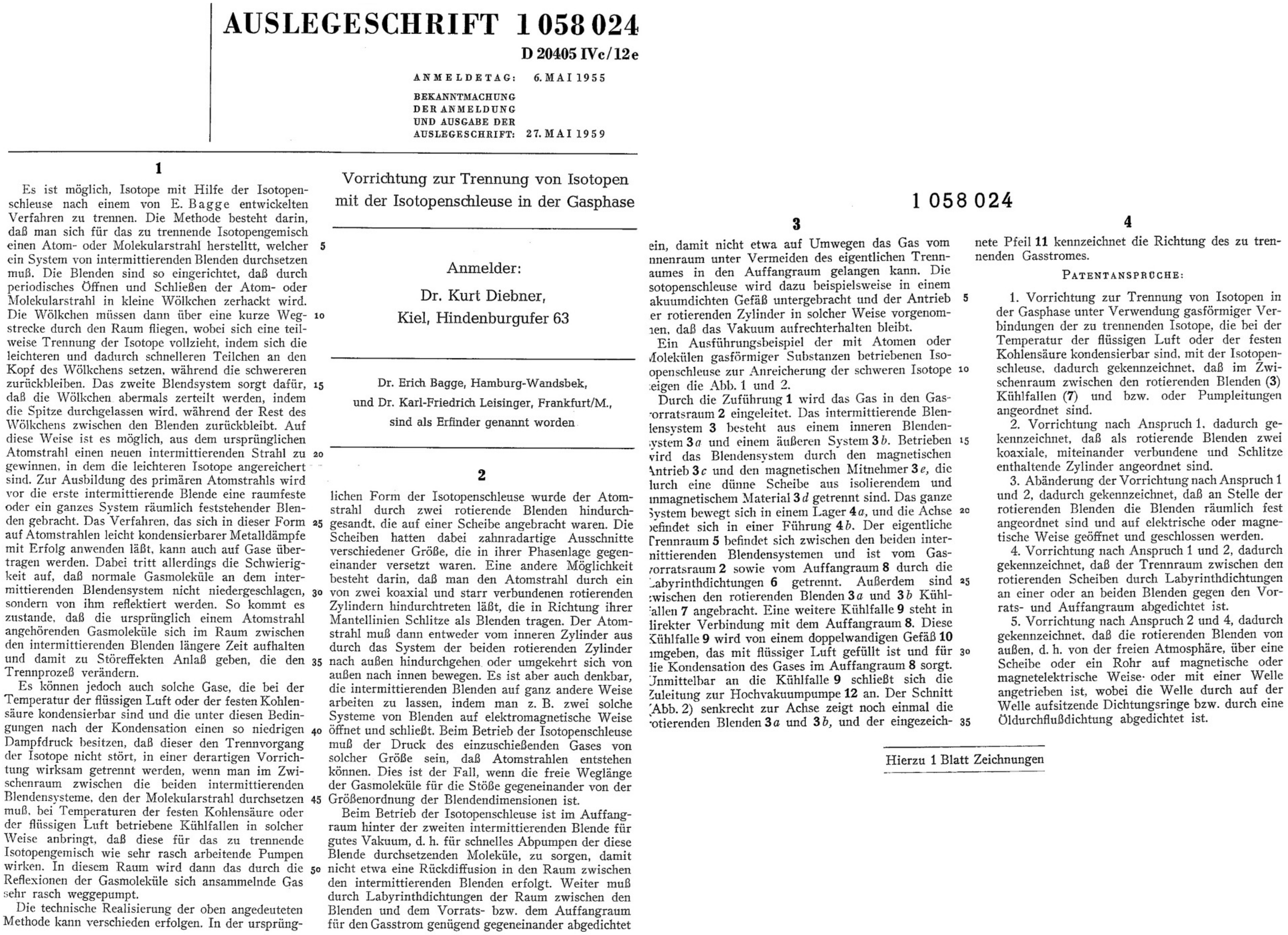
---

[118] W. PAUL, Naturwiss. **31**, 419 [1943].

[119] A. KLEMM, unveröff. Forsch.-Ber. sowie Z. physik. Chem. Abt. A **193**, 29 [1943].

[120] A. KLEMM, Z. Naturforsch. **1**, 252 [1946].

Figure D.252: During the war, Erich Bagge led a team that invented, built, and demonstrated the "isotope sluice," an alternative form of gaseous diffusion enrichment [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 100–103].



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ANMELDETAG: 6. MAI 1955

BEKANNTMACHUNG
DER ANMELDUNG
UND AUSGABE DER
AUSLEGESCHRIFT: 27. MAI 1959

Vorrichtung zur Trennung von Isotopen mit der Isotopenschleuse in der Gasphase

Anmelder:

Dr. Kurt Diebner,
Kiel, Hindenburgufer 63

Dr. Erich Bagge, Hamburg-Wandsbek,
und Dr. Karl-Friedrich Leisinger, Frankfurt/M.,
sind als Erfinder genannt worden

Es ist möglich, Isotope mit Hilfe der Isotopenschleuse nach einem von E. Bagge entwickelten Verfahren zu trennen. Die Methode besteht darin, daß man sich für das zu trennende Isotopengemisch einen Atom- oder Molekularstrahl herstelltt, welcher ein System von intermittierenden Blenden durchsetzen muß. Die Blenden sind so eingerichtet, daß durch periodisches Öffnen und Schließen der Atom- oder Molekularstrahl in kleine Wölkchen zerhackt wird. Die Wölkchen müssen dann über eine kurze Wegstrecke durch den Raum fliegen, wobei sich eine teilweise Trennung der Isotope vollzieht, indem sich die leichteren und dadurch schnelleren Teilchen an den Kopf des Wölkchens setzen, während die schwereren zurückbleiben. Das zweite Blendsystem sorgt dafür, daß die Wölkchen abermals zerteilt werden, indem die Spitze durchgelassen wird, während der Rest des Wölkchens zwischen den Blenden zurückbleibt. Auf diese Weise ist es möglich, aus dem ursprünglichen Atomstrahl einen neuen intermittierenden Strahl zu gewinnen, in dem die leichteren Isotope angereichert sind. Zur Ausbildung des primären Atomstrahls wird vor die erste intermittierende Blende eine raumfeste oder ein ganzes System räumlich feststehender Blenden gebracht. Das Verfahren, das sich in dieser Form auf Atomstrahlen leicht kondensierbarer Metalldämpfe mit Erfolg anwenden läßt, kann auch auf Gase übertragen werden. Dabei tritt allerdings die Schwierigkeit auf, daß normale Gasmoleküle an dem intermittierenden Blendensystem nicht niedergeschlagen, sondern von ihm reflektiert werden. So kommt es zustande, daß die ursprünglich einem Atomstrahl angehörenden Gasmoleküle sich im Raum zwischen den intermittierenden Blenden längere Zeit aufhalten und damit zu Störeffekten Anlaß geben, die den Trennprozeß verändern.

Es können jedoch auch solche Gase, die bei der Temperatur der flüssigen Luft oder der festen Kohlensäure kondensierbar sind und die unter diesen Bedingungen nach der Kondensation einen so niedrigen Dampfdruck besitzen, daß dieser den Trennvorgang der Isotope nicht stört, in einer derartigen Vorrichtung wirksam getrennt werden, wenn man im Zwischenraum zwischen die beiden intermittierenden Blendensysteme, den der Molekularstrahl durchsetzen muß, bei Temperaturen der festen Kohlensäure oder der flüssigen Luft betriebene Kühlfallen in solcher Weise anbringt, daß diese für das zu trennende Isotopengemisch wie sehr rasch arbeitende Pumpen wirken. In diesem Raum wird dann das durch die Reflexionen der Gasmoleküle sich ansammelnde Gas sehr rasch weggepumpt.

Die technische Realisierung der oben angedeuteten Methode kann verschieden erfolgen. In der ursprünglichen Form der Isotopenschleuse wurde der Atomstrahl durch zwei rotierende Blenden hindurchgesandt, die auf einer Scheibe angebracht waren. Die Scheiben hatten dabei zahnradartige Ausschnitte verschiedener Größe, die in ihrer Phasenlage gegeneinander versetzt waren. Eine andere Möglichkeit besteht darin, daß man den Atomstrahl durch ein von zwei koaxial und starr verbundenen rotierenden Zylindern hindurchtreten läßt, die in Richtung ihrer Mantellinien Schlitze als Blenden tragen. Der Atomstrahl muß dann entweder vom inneren Zylinder aus durch das System der beiden rotierenden Zylinder nach außen hindurchgehen oder umgekehrt sich von außen nach innen bewegen. Es ist aber auch denkbar, die intermittierenden Blenden auf ganz andere Weise arbeiten zu lassen, indem man z. B. zwei solche Systeme von Blenden auf elektromagnetische Weise öffnet und schließt. Beim Betrieb der Isotopenschleuse muß der Druck des einzuschießenden Gases von solcher Größe sein, daß Atomstrahlen entstehen können. Dies ist der Fall, wenn die freie Weglänge der Gasmoleküle für die Stöße gegeneinander von der Größenordnung der Blendendimensionen ist.

Beim Betrieb der Isotopenschleuse ist im Auffangraum hinter der zweiten intermittierenden Blende für gutes Vakuum, d. h. für schnelles Abpumpen der diese Blende durchsetzenden Moleküle, zu sorgen, damit nicht etwa eine Rückdiffusion in den Raum zwischen den intermittierenden Blenden erfolgt. Weiter muß durch Labyrinthdichtungen der Raum zwischen den Blenden und dem Vorrats- bzw. dem Auffangraum für den Gasstrom genügend gegeneinander abgedichtet ein, damit nicht etwa auf Umwegen das Gas vom Innenraum unter Vermeiden des eigentlichen Trennraumes in den Auffangraum gelangen kann. Die Isotopenschleuse wird dazu beispielsweise in einem vakuumdichten Gefäß untergebracht und der Antrieb der rotierenden Zylinder in solcher Weise vorgenommen, daß das Vakuum aufrechterhalten bleibt.

Ein Ausführungsbeispiel der mit Atomen oder Molekülen gasförmiger Substanzen betriebenen Isotopenschleuse zur Anreicherung der schweren Isotope zeigen die Abb. 1 und 2.

Durch die Zuführung **1** wird das Gas in den Gasvorratsraum **2** eingeleitet. Das intermittierende Blendensystem **3** besteht aus einem inneren Blendensystem **3***a* und einem äußeren System **3***b*. Betrieben wird das Blendensystem durch den magnetischen Antrieb **3***c* und den magnetischen Mitnehmer **3***e*, die durch eine dünne Scheibe aus isolierendem und unmagnetischem Material **3***d* getrennt sind. Das ganze System bewegt sich in einem Lager **4***a*, und die Achse befindet sich in einer Führung **4***b*. Der eigentliche Trennraum **5** befindet sich zwischen den beiden intermittierenden Blendensystemen und ist vom Gasvorratsraum **2** sowie vom Auffangraum **8** durch die Labyrinthdichtungen **6** getrennt. Außerdem sind zwischen den rotierenden Blenden **3***a* und **3***b* Kühlfallen **7** angebracht. Eine weitere Kühlfalle **9** steht in direkter Verbindung mit dem Auffangraum **8**. Diese Kühlfalle **9** wird von einem doppelwandigen Gefäß **10** umgeben, das mit flüssiger Luft gefüllt ist und für die Kondensation des Gases im Auffangraum **8** sorgt. Unmittelbar an die Kühlfalle **9** schließt sich die Zuleitung zur Hochvakuumpumpe **12** an. Der Schnitt (Abb. 2) senkrecht zur Achse zeigt noch einmal die rotierenden Blenden **3***a* und **3***b*, und der eingezeichnete Pfeil **11** kennzeichnet die Richtung des zu trennenden Gasstromes.

PATENTANSPRÜCHE:

1. Vorrichtung zur Trennung von Isotopen in der Gasphase unter Verwendung gasförmiger Verbindungen der zu trennenden Isotope, die bei der Temperatur der flüssigen Luft oder der festen Kohlensäure kondensierbar sind, mit der Isotopenschleuse, dadurch gekennzeichnet, daß im Zwischenraum zwischen den rotierenden Blenden (**3**) Kühlfallen (**7**) und bzw. oder Pumpleitungen angeordnet sind.

2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß als rotierende Blenden zwei koaxiale, miteinander verbundene und Schlitze enthaltende Zylinder angeordnet sind.

3. Abänderung der Vorrichtung nach Anspruch 1 und 2, dadurch gekennzeichnet, daß an Stelle der rotierenden Blenden die Blenden räumlich fest angeordnet sind und auf elektrische oder magnetische Weise geöffnet und geschlossen werden.

4. Vorrichtung nach Anspruch 1 und 2, dadurch gekennzeichnet, daß der Trennraum zwischen den rotierenden Scheiben durch Labyrinthdichtungen an einer oder an beiden Blenden gegen den Vorrats- und Auffangraum abgedichtet ist.

5. Vorrichtung nach Anspruch 2 und 4, dadurch gekennzeichnet, daß die rotierenden Blenden von außen, d. h. von der freien Atmosphäre, über eine Scheibe oder ein Rohr auf magnetische oder magnetelektrische Weise· oder mit einer Welle angetrieben ist, wobei die Welle durch auf der Welle aufsitzende Dichtungsringe bzw. durch eine Öldurchflußdichtung abgedichtet ist.

Hierzu 1 Blatt Zeichnungen

Figure D.253: During the war, Erich Bagge led a team that invented, built, and demonstrated the “isotope sluice,” an alternative form of gaseous diffusion enrichment [German patent DE1058024].

ZEICHNUNGEN BLATT 1 AUSGABETAG: 27. MAI 1959

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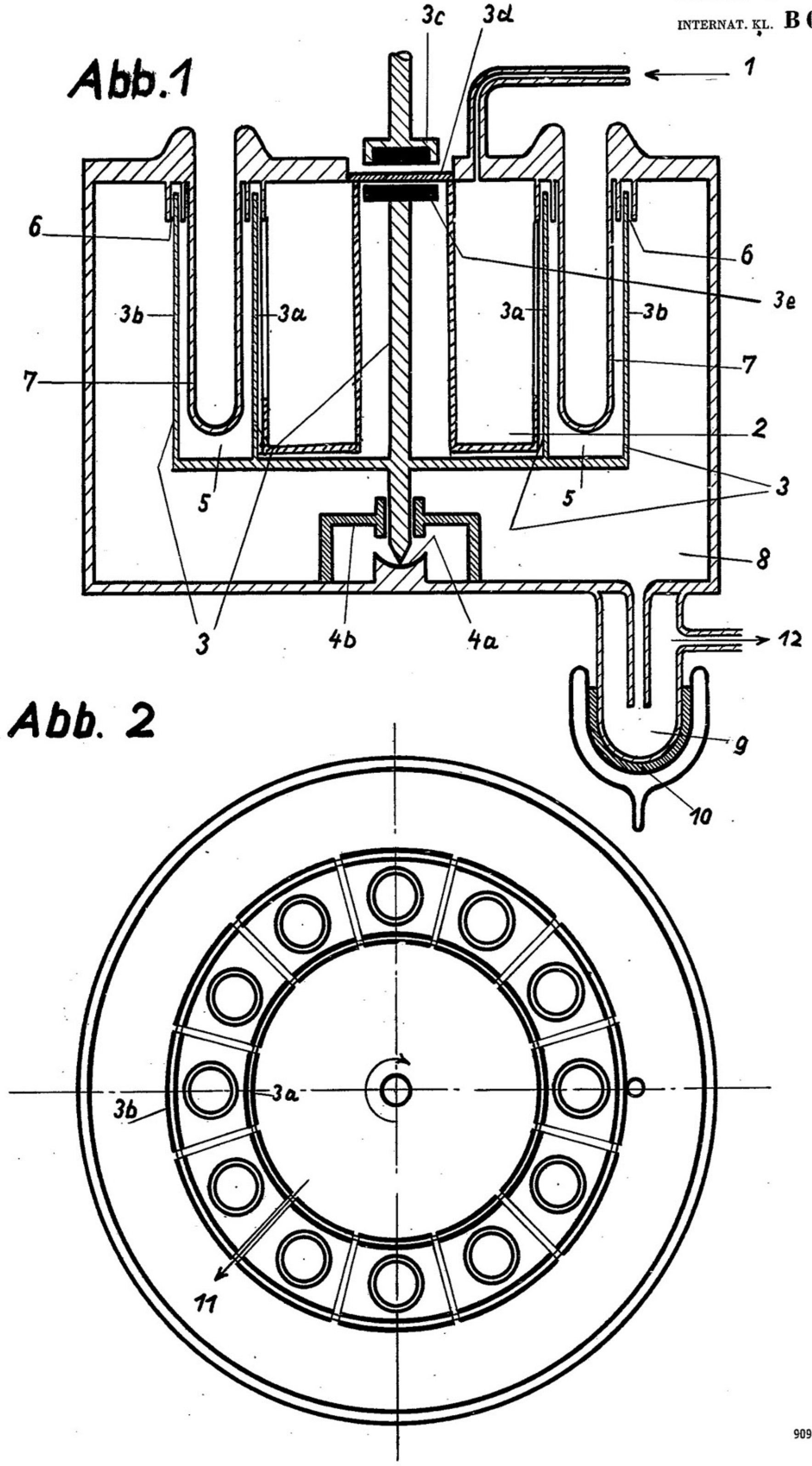
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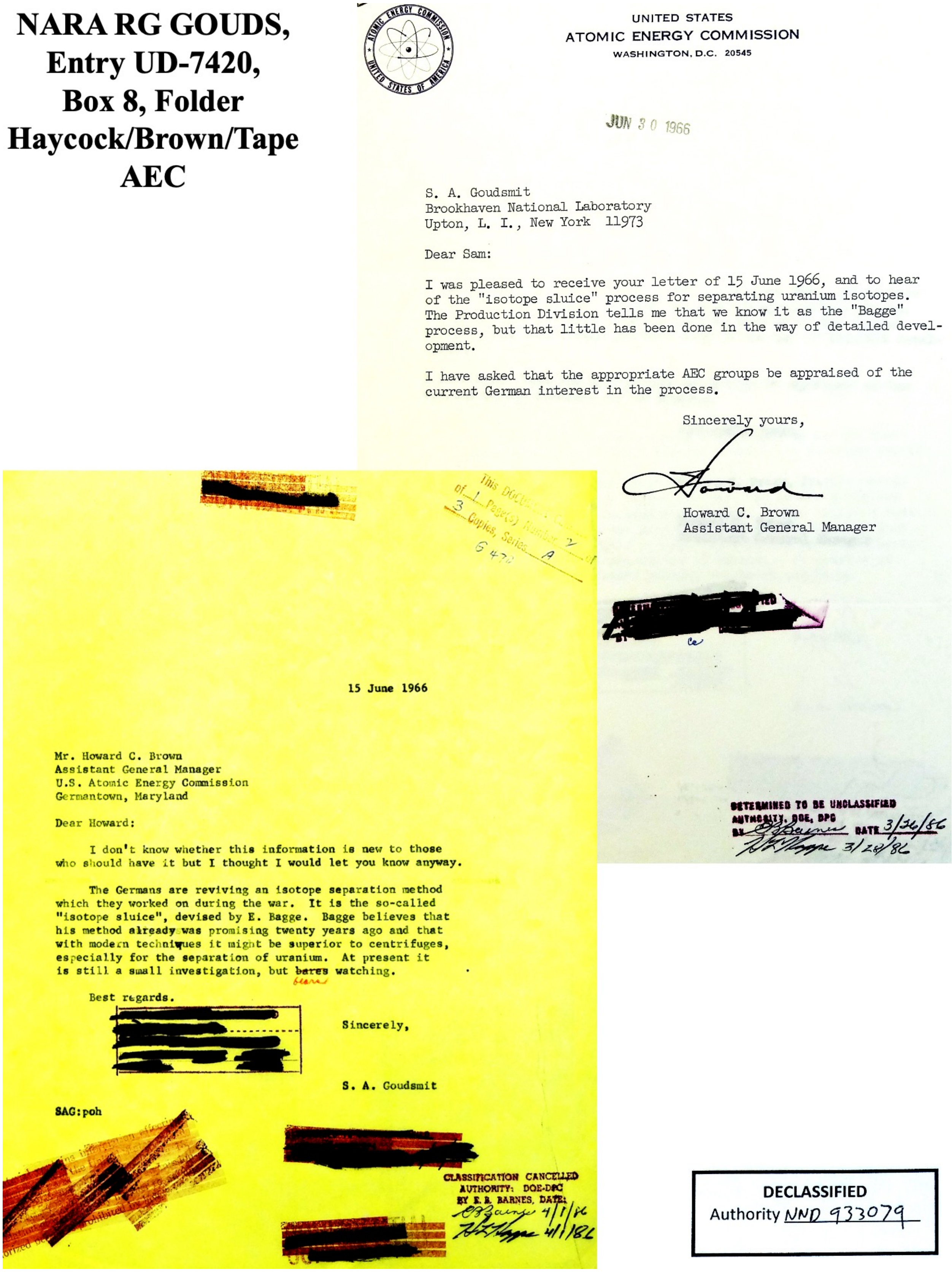
Figure D.254: During the war, Erich Bagge led a team that invented, built, and demonstrated the "isotope sluice," an alternative form of gaseous diffusion enrichment [German patent DE1058024].

NARA RG GOUDS, Entry UD-7420, Box 8, Folder Haycock/Brown/Tape AEC



UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

JUN 30 1966

S. A. Goudsmit
Brookhaven National Laboratory
Upton, L. I., New York 11973

Dear Sam:

I was pleased to receive your letter of 15 June 1966, and to hear of the "isotope sluice" process for separating uranium isotopes. The Production Division tells me that we know it as the "Bagge" process, but that little has been done in the way of detailed development.

I have asked that the appropriate AEC groups be appraised of the current German interest in the process.

Sincerely yours,

Howard

Howard C. Brown
Assistant General Manager

[redacted]

cc

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BY CBarnes DATE 3/26/86
3/28/86

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15 June 1966

Mr. Howard C. Brown
Assistant General Manager
U.S. Atomic Energy Commission
Germantown, Maryland

Dear Howard:

I don't know whether this information is new to those who should have it but I thought I would let you know anyway.

The Germans are reviving an isotope separation method which they worked on during the war. It is the so-called "isotope sluice", devised by E. Bagge. Bagge believes that his method already was promising twenty years ago and that with modern techniques it might be superior to centrifuges, especially for the separation of uranium. At present it is still a small investigation, but ~~bares~~ bears watching.

Best regards.

[redacted]

Sincerely,

S. A. Goudsmit

SAG:poh

[redacted]

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BY E. R. BARNES, DATE:
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Figure D.255: Samuel Goudsmit to Howard C. Brown. 15 June 1966 [NARA RG GOUDS, Entry UD-7420, Box 8, Folder Haycock/Brown/Tape AEC]. "The Germans are reviving an isotope separation method which they worked on during the war. It is the so-called 'isotope sluice', devised by E. Bagge. Bagge believes that his method already was promising twenty years ago and that with modern techniques it might be superior to centrifuges, especially for the separation of uranium."

D.4.5 Uranium-235 Enrichment via Photochemical Processes

[Beginning in the early 1930s, Stanisław Mrozowski (Polish, 1902–1999), K. Zuber (Swiss, 19??–19??), Werner Kuhn (Swiss, 1899–1963), Hans Martin (German, 19??–19??), and K. H. Eldau (German, 19??–19??) developed photochemical methods of isotope separation and demonstrated them with isotopes of elements such as mercury and chlorine. During the war, Kuhn, Martin, Eldau, Paul Harteck, and others seriously investigated the feasibility of applying such photochemical methods to uranium isotope separation. Publicly available documentation does not indicate how far that research progressed during the war, but given the available light sources, the photochemical enrichment of uranium seems unlikely to have ever gone beyond small-scale laboratory experiments.

Separately from the work on photochemical enrichment, or perhaps even motivated by it, other German-speaking scientists during the same time period worked toward the development of lasers as an improved monochromatic light source (Section C.3). After the war, the combination of the German-derived innovations in photochemical enrichment and laser technology made laser isotope enrichment a reality (p. 5127).]

Stanisław Mrozowski. 1930. *Bulletin of the Academy of Poland* 1:464.

Stanisław Mrozowski. 1932. Stoßerscheinungen bei optischer Anregung verschiedener Quecksilberisotopen. *Zeitschrift für Physik* 78:826–843.
https://doi.org/10.1007/BF01342044

Die Konstruktion einer neuen, sehr lichtstarken Anordnung hat es ermöglicht, die Hyperfeinstruktur der mit gefilterter Strahlung angeregten Resonanzstrahlung des Quecksilberdampfes unter verschiedenen Bedingungen zu erforschen und den früher entdeckten Verschiebungseffekt einer der Komponenten mit einer wesentlich höheren Genauigkeit festzustellen. Der Einfluß der nichtauslöschenden Zusatzgase äußert sich durch selektive Stoßüberführungen zwischen verschiedenen Hyperfeinstrukturkomponenten; dagegen wird bei Vergrößerung der Dampfdichte des Quecksilbers gleiche Überführungswahrscheinlichkeit für alle Komponenten beobachtet. Es wurde auch unter denselben Bedingungen ein Füchtbauereffekt erhalten, der bei Zusatz von Stickstoff die Hyperfeinstruktur des sichtbaren Tripletts zu studieren erlaubte. Es zeigt sich, daß die Hyperfeinstruktur von der Zusammensetzung der anregenden Resonanzlinie unabhängig ist, was in dem Einfluß der Stöße der metastabilen Atome mit Quecksilberatomen verschiedener Isotopenarten eine Erklärung findet.

The construction of a new, very high-intensity device has made it possible to explore the hyperfine structure of the resonance radiation of mercury vapor excited with filtered radiation under various conditions and to detect the previously discovered shift effect of one of the components with a much higher accuracy. The influence of the non-quenching additional gases is manifested by selective impact transfers between different hyperfine structure components; on the other hand, when the vapor density of mercury is increased, equal transfer probability is observed for all components. A fugacity effect was also obtained under the same conditions, which allowed to study the hyperfine structure of the visible triplet when nitrogen was added. It is shown that the hyperfine structure is independent of the composition of the exciting resonance line, which finds an explanation in the influence of the collisions of the metastable atoms with mercury atoms of different isotopic species.

K. Zuber. 1935. Die Linienabsorption des Quecksilberdampfes für einzelne Hyperfeinstruktur-Komponenten der Linie 2537 Å.E. *Helvetica Physica Acta* 8:4:370–380. https://dx.doi.org/10.5169/seals-110535

Messungen der Linienabsorption einzelner Hyperfeinstruktur-Komponenten führen zu Ergebnissen, welche mit dem Feinstrukturschema von Schüler und Keyston unter Berücksichtigung der von Inglis angegebenen Korrektur in Einklang stehen, falls man die mittlere Lebensdauer des 2 $^3P_1$-Niveaus im Gegensatz zu Mrozowski für alle Isotope gleich gross annimmt. Aus der Absorption für einzelne Komponenten lässt sich der Absorptionskoeffizient $k_{\lambda o}$ der ganzen Linie berechnen. Dieser Wert steht in guter Übereinstimmung mit den Messungen von Kunze und Ladenburg-Wolfsohn.

Measurements of the line absorption of individual hyperfine structure components lead to results which are in agreement with the fine structure scheme of Schüler and Keyston, taking into account the correction given by Inglis, if one assumes the mean lifetime of the 2 $^3P_1$ level to be the same for all isotopes, in contrast to Mrozowski. From the absorption for individual components, the absorption coefficient $k_{\lambda o}$ of the whole line can be calculated. This value is in good agreement with the measurements of Kunze and Ladenburg-Wolfsohn.

K. Zuber. 1935. Separation of the Mercury Isotopes by a Photochemical Method. *Nature* 136:796. https://doi.org/10.1038/136796a0

When a mixture of mercury vapour and oxygen is irradiated with the mercury resonance line λ 2537, the mercury becomes oxidised. Since excitation is a necessary stage in the oxidation, Mrozowski has suggested that it should be possible to produce a separation of the mercury isotopes by exciting them selectively. If the reaction consists of the primary photochemical process

$$\mathrm{Hg}^{+} + \mathrm{O}_2 \rightarrow \mathrm{HgO} + \mathrm{O}$$

only the atomic species which are excited by the incident light should be oxidised.

In my experiments the light from a mercury arc was passed through a Mrozowski filter consisting of a column of mercury vapour in a magnetic field. This transmitted only the hyperfine structure components of the resonance line corresponding to the isotopes 200, 202. After an irradiation of between 10 and 30 minutes, the isotopic composition of the remaining mercury or of that recovered from the oxide was examined by the method of absorption of single hyperfine structure components. The results of the experiments show:

(1) The separation is in every case only partial, so that besides the primary process, secondary reactions must take place.

(2) An addition of nitrogen assists the separation ($p_{\mathrm{O2}} : p_{\mathrm{N2}} \sim 1:1$, $p_{\mathrm{O2}} \sim 1$ mm. Hg).

(3) It has been possible to obtain samples in which the ratio $\frac{p_{200,\,202}}{p_{198,\,199,\,201,\,204}}$ was modified by a factor of four.

More detailed information will be published in the *Helv. Phys. Acta.*

K. Zuber. 1936. Trennung der Quecksilber-Isotope nach einer photochemischen Methode. *Helvetica Physica Acta* 9:285–300. https://dx.doi.org/10.5169/seals-110628

Bestrahlt man ein Gemisch von Hg-Dampf und Sauerstoff mit der Resonanzlinie 2537 Å. E., so tritt Oxydation des Quecksilbers ein. Da sich das Oxyd nur nach vorheriger Anregung der Quecksilberatome bildet, schlägt Mrozowski vor, einzelne Isotopensorten anzuregen. Besteht die Reaktion allein aus dem photochemischen Primärprozess $Hg^* + O_2 = HgO + O$, so sollten sich im Oxyd nur die vorher angeregten Isotopen wiederfinden. Es ergibt sich: 1. Das Gemisch Hg und O_2 ist für eine Trennung nicht geeignet. Notwendig ist ein Zusatz von Stickstoff. 2. Die Trennung ist immer nur teilweise, wofür sekundäre Reaktionen als Ursache angesehen werden. 3. Durch Wiederholen des Versuches lässt sich die Trennung verbessern. Es konnten Proben hergestellt werden, bei denen das Verhältnis der einzelnen Isotope um den Faktor vier verschieden war.

If a mixture of Hg vapor and oxygen is irradiated with the resonance line 2537 Å. E., oxidation of the mercury occurs. Since the oxide forms only after prior excitation of the mercury atoms, Mrozowski proposes to excite individual isotope species. If the reaction consists solely of the primary photochemical process $Hg^+ + O_2 = HgO + O$, only the previously excited isotopes should be found in the oxide. It results: 1. The mixture Hg and O_2 is not suitable for separation. An addition of nitrogen is necessary. 2. separation is always partial, for which secondary reactions are considered to be the cause. 3. separation can be improved by repeating the experiment. Samples could be produced in which the ratio of the individual isotopes was different by a factor of four.

Werner Kuhn and Hans Martin. 1932. Photochemische Trennung von Isotopen. *Naturwissenschaften* 20:772. https://doi.org/10.1007/BF01494810

Werner Kuhn and Hans Martin. 1933. Photochemische Trennung von Isotopen. *Zeitschrift für Physikalische Chemie B* 21:93. https://doi.org/10.1515/zpch-1933-2111

Es werden die Grundlagen und Voraussetzungen einer photochemischen Tren-nung von Isotopen in optischer, photochemischer und chemischer Hinsicht auseinandergesetzt und insbesondere im Falle des Phosgens genau diskutiert. Im Anschluss daran wird eine Versuchsanordnung beschrieben, mit welcher äusserst monochromatisches Licht in guter Ausbeute erhalten wird und für die präparative Darstellung benutzt werden kann. Chlor, welches in dieser Weise aus Phosgen freigemacht wurde, zeigte gegenüber gewöhnlichem Chlor eine Atomgewichtsverschiebung von 0.025 Einheiten. Es wird dadurch die Interpretation von Bandenvervielfachungen im Phosgenabsorptionsspektrum als Isotopieeffekt bestätigt, und es können weitere Schlüsse gezogen werden, namentlich mit Bezug auf die Zerfallswahrscheinlichkeiten in den den Prädissoziationsgebieten benachbarten Bereichen diskontinuierlicher Absorption.

The fundamentals and prerequisites of photochemical separation of isotopes in optical, photochemical, and chemical terms are discussed in detail, particularly in the case of phosgene. Subsequently, an experimental setup is described with which extremely monochromatic light is obtained in good yield and can be used for preparative imaging. Chlorine liberated from phosgene in this manner showed an atomic weight shift of 0.025 units compared to ordinary chlorine. This confirms the interpretation of band multiplications in the phosgene absorption spectrum as an isotopic effect, and further conclusions can be drawn, namely with respect to the decay probabilities in the regions of discontinuous absorption adjacent to the predissociation regions.

Werner Kuhn, Hans Martin, and K. H. Eldau. 1941. Anreicherung der Chlorisotopen durch Bestrahlung von Chlordioxyd bei niedrigem Druck. ***Zeitschrift für Physikalische Chemie B*** **50:213–254. https://doi.org/10.1515/zpch-1941-5014**

Anschließend an eine Diskussion der Stoffeigenschaften, welche die photochemische Trennung von Isotopen einerseits ermöglichen, andererseits herabmindern, wird gesagt, daß Chlordioxyd (ClO_2) eine Substanz sein dürfte, mit der bei Benutzung einer geeigneten Lichtquelle gute Ergebnisse erwartet werden können. Es wird darauf eine Apparatur beschrieben, mittels deren sehr reines Chlordioxyd dargestellt und unter einem Drucke von etwa 0.2 mm Hg mit praktisch reinem Lichte der Quecksilberlinien 3650.15, 3654.83 und 3663.27 Å bei Vermeidung von Reaktionsketten bestrahlt werden kann und welche gestattet, das dabei freigesetzte Chlor von unverändertem Chlordioxyd zu trennen. In den mit der Apparatur ausgeführten Versuchen wird einerseits festgestellt, daß die Quantenausbeute unter den gewählten Versuchsbedingungen tatsächlich ungefähr gleich 1 ist und daß als Zersetzungsprodukte praktisch ausschließlich Chlor und Sauerstoff gebildet werden. Andererseits wird in dem photochemisch freigesetzten Chlor eine Vermindeiung des Atomgewichts um 0.016 Einheiten gegenüber gewöhnlichem Chlor festgestellt. Das geringe Ausmaß der erzielten Trennung wird darauf zurückgeführt, daß von den drei genannten Quecksilberlinien nur die dritte mit einer Absorptionsbande von ClO_2 genau zusammenfällt und daß die anderen Linien, welche sich weniger eignen, im Gegensatz zu vorhandenen Literaturangaben eine Intensität besitzen, welche die der "geeigneten" Linie zusammen etwa um einen Faktor 4 übertrifft.

Following a discussion of the properties of the substance which on the one hand make possible the photochemical separation of isotopes and on the other hand reduce it, it is said that chlorine dioxide (ClO_2) is a substance with which good results can be expected when a suitable light source is used. An apparatus is described by means of which very pure chlorine dioxide can be prepared and irradiated under a pressure of about 0.2 mm Hg with practically pure light of the mercury lines 3650.15, 3654.83, and 3663.27 Å, while avoiding reaction chains, and which permits the chlorine thus released to be separated from unchanged chlorine dioxide. In the experiments carried out with the apparatus, it is found, on the one hand, that the quantum yield under the selected experimental conditions is indeed approximately equal to 1 and that practically only chlorine and oxygen are formed as decomposition products. On the other hand, a reduction in atomic weight of 0.016 units is found in the photochemically liberated chlorine as compared with ordinary chlorine. The small extent of the separation obtained is attributed to the fact that, of the three mercury lines mentioned, only the third coincides exactly with an absorption band of ClO_2 and that the other lines, which are less suitable, have, contrary to existing literature data, an intensity which exceeds that of the "suitable" line together by a factor of about 4.

G-156. Paul Harteck. The Separation of Isotopes with Special Reference to the Isotopes of Uranium. Die Trennung von Isotopen unter besonderer Berücksichtigung der Isotopen des Urans. 1942. pp. 10–11, 18.

10.) Das von einem Molekül angewendete Bandenspektrum (bezw. sein Absorbtionsspektrum) ist von der isotopischen Zusammensetzung abhängig, da jede Linie im Bandenspektrum durch eine quantenhafte Energieänderung seiner Elektronenenergie, der Schwingungs- und der Rotationsenergie des Moleküls entsteht. Setzt man die reduzierte Masse des Moleküls $\frac{m_1 m_2}{m_1+m_2}$ (wo m_1 und m_2 die Massen der Molekülpartner bedeuten) gleich μ, so ist bei einer Massenänderung von m_1, in m_1', d.h. von μ in μ' die Aenderung der Elektronenenergie in fast allen Fällen zu vernachlässigen; die Aenderung der Schwingungsenergie dagegen bedingt in erster Näherung eine Frequenzverschiebung um den Betrag

10.) The band spectrum applied by a molecule (i.e. its absorption spectrum) depends on the isotopic composition, since each line in the band spectrum is formed by a quantum energy change of its electron energy, the vibrational energy and the rotational energy of the molecule. If one sets the reduced mass of the molecule $\frac{m_1 m_2}{m_1+m_2}$ (where m_1 and m_2 mean the masses of the molecular partners) to μ, then with a mass change of m_1, in m_1', i.e. of μ in μ' to neglect the change of the electron energy in almost all cases; the change of the oscillation energy, on the other hand, causes in a first approximation a frequency shift of the magnitude

$$11. \qquad \Delta\nu_s = \left(\sqrt{\frac{\mu}{\mu'}} - 1\right)\nu_s$$

(ν_s = Frequenz der ursprünglichen Linie);

(ν_s = frequency of the original line);

die Aenderung der Rotationsenergie bewirkt näherungsweise eine Frequenzverschiebung um

the change of the rotational energy approximately causes a frequency shift by

$$12. \qquad \Delta\nu_{rot} = \left(\frac{\mu}{\mu'} - 1\right)\nu_{rot}$$

doch ist dieser Effekt sehr viel kleiner als der Schwingungsanteil, da ν_s sehr viel grösser als ν_{rot} ist.

but this effect is much smaller than the vibration component, because ν_s is much larger than ν_{rot}.

Zahlreiche photochemische Reaktionen werden durch optische Anregung eines der an ihnen beteiligten Moleküle ausgelöst. Verwendet man zur Anregung eine Linie, die nur von einem der isotopisch verschiedenen Moleküle absorbiert wird, so kann eine Trennung der Isotopen erreicht werden, wenn es gelingt, eine Abreaktion des abgespaltenen Atoms zu verhindern. W. Kuhn und H. Martin[16)] gelang nach dieser Methode eine Anreicherung des Chlorisotops ^{35}Cl unter Verwendung der photochemischen Dissoziation des Phosgens $COCl_2$, K. Zuber[17)] eine Anreicherung der Quecksilberisotope nach der photochemischen Reaktion $(Hg + h\nu) + O_2 = HgO + O$.

Numerous photochemical reactions are triggered by optical excitation of one of the molecules involved. If a line is used for excitation which is only absorbed by one of the isotopically different molecules, a separation of the isotopes can be achieved if it is possible to prevent an abreaction of the split atom. W. Kuhn and H. Martin[16)] succeeded in enriching the chlorine isotope ^{35}Cl with this method using the photochemical dissociation of phosgene $COCl_2$, K. Zuber[17)] enriched the mercury isotopes using the photochemical reaction $(Hg + h\nu) + O_2 = HgO + O$.

16) W. Kuhn u. H. Martin, Z. phys. Chem. (B) 21, 93 (1933)

17) K. Zuber, Helvet. phys. Acta 9, 285 (1936)

[From 1930 onward, papers such as those above demonstrated that a finely tuned metal plasma lamp could emit intense light of just the right wavelength to separate isotopes of that same type of metal, such as a mercury plasma lamp to separate mercury isotopes. In principle, a uranium plasma lamp could similarly be used to separate uranium isotopes, and it appears that there was significant wartime research in Germany to investigate that possibility. See the brief discussion in the Farm Hall transcripts about a photochemical process to enrich uranium (p. 3339).

In practice, a uranium plasma lamp probably would have consumed too much electrical power and produced too little light at just the right wavelength to be suitable for industrial-scale uranium isotope separation. Thus if there was any large-scale uranium isotope separation in the wartime German nuclear program, it probably relied on one or more of the methods covered in previous sections: centrifugation, electromagnetic separation, isotope sluice, and gaseous diffusion.

Nonetheless, this 1930s–1940s research in the German-speaking world on photochemical methods of isotope separation, together with research toward the development of lasers that was being conducted at the same time in the German-speaking world (Section C.3), was transferred to other countries during and after the war, and ultimately led to successful laser isotope separation programs decades later (p. 5127). For more information on the history, see:

V. S. Letokhov and C. B. Moore. 1976. Laser Isotope Separation (Review). *Soviet Journal of Quantum Electronics* 6:2:129–150. https://doi.org/10.1070/QE1976v006n02ABEH010865

V. S. Letokhov. 1979. Laser Isotope Separation. *Nature* 277:605–610.
https://doi.org/10.1038/277605a0]

D.4.6 Possible Locations of Uranium Enrichment Facilities

[In order to enrich enough uranium to a high enough concentration of uranium-235 for a bomb, it would have been necessary to have not just one enrichment unit (a centrifuge, electromagnetic separator, isotope sluice, or gaseous diffusion cell), but a large number of them operating in parallel and/or in series. Presumably after a prototype enrichment unit had been developed and proven to be satisfactory in small-scale laboratory experiments, the unit would have been mass-produced. The mass-produced units would have been set up in a new location with more room and better security.

The United States conducted its corresponding work at one massive facility in Oak Ridge, Tennessee. Proponents of the conventional view that Germany did not have a nuclear weapons program emphasize the apparent absence of an Oak-Ridge-like facility in wartime Germany. However, there are many counterarguments that must be considered:

- Oak Ridge enriched enough uranium for a gun-type bomb (Little Boy) that did not compress the uranium, was thus highly inefficient, and required ~64 kg of ~80% uranium-235. In contrast, as shown in Section D.8, the German atomic bomb was apparently a spherical implosion design (like the U.S. Gadget/Fat Man), which would have been much more efficient and would have required far less uranium ($\leq$ 10 kg). Therefore the German bomb program would have needed a far smaller production capacity than Oak Ridge.

- To minimize the risk that Allied bombing could destroy the whole program, German uranium enrichment would have been distributed among many different small sites, not concentrated in one large target. Indeed, that is exactly what was done, according to a declassified October 1944 OSS report based on information from Adolf Schneider, a senior manager of the Deutsche Waffen und Munitions-Fabrik (pp. 4400–4403).

- Any uranium enrichment conducted in the final years of the war would probably have been underground, like most other major German manufacturing. Being underground would have made it much easier for Germans to hide the enrichment facilities from Allied aerial surveillance during the war, and from Allied ground troops at the end of the war (by blowing up the entrances to the underground facilities).

- As shown in this section, primary source documents mentioned many different installations whose puzzling characteristics suggested that they might have been uranium enrichment facilities. Most of these documents ended up in the foreign intelligence files of the U.S. Manhattan Project, which means that Manhattan Project officials also thought these locations sounded like potential uranium enrichment facilities.

- Most of these potential uranium enrichment facilities were in areas of the Third Reich that ended up being occupied and stripped bare by Soviet forces, without western Allies ever having had the chance to study them.

- Even if some or all of the specific facilities mentioned in these documents were not doing nuclear-related work, they serve as excellent examples of how widespread, how sophisticated, and how secret German wartime industrial and weapons programs were, and how little we know about them to this day. Under these circumstances, it is difficult to rule out the possibility of nuclear-weapons-related production plants operating somewhere within the Third Reich, even if we cannot rule them in by pointing to their exact locations right now.

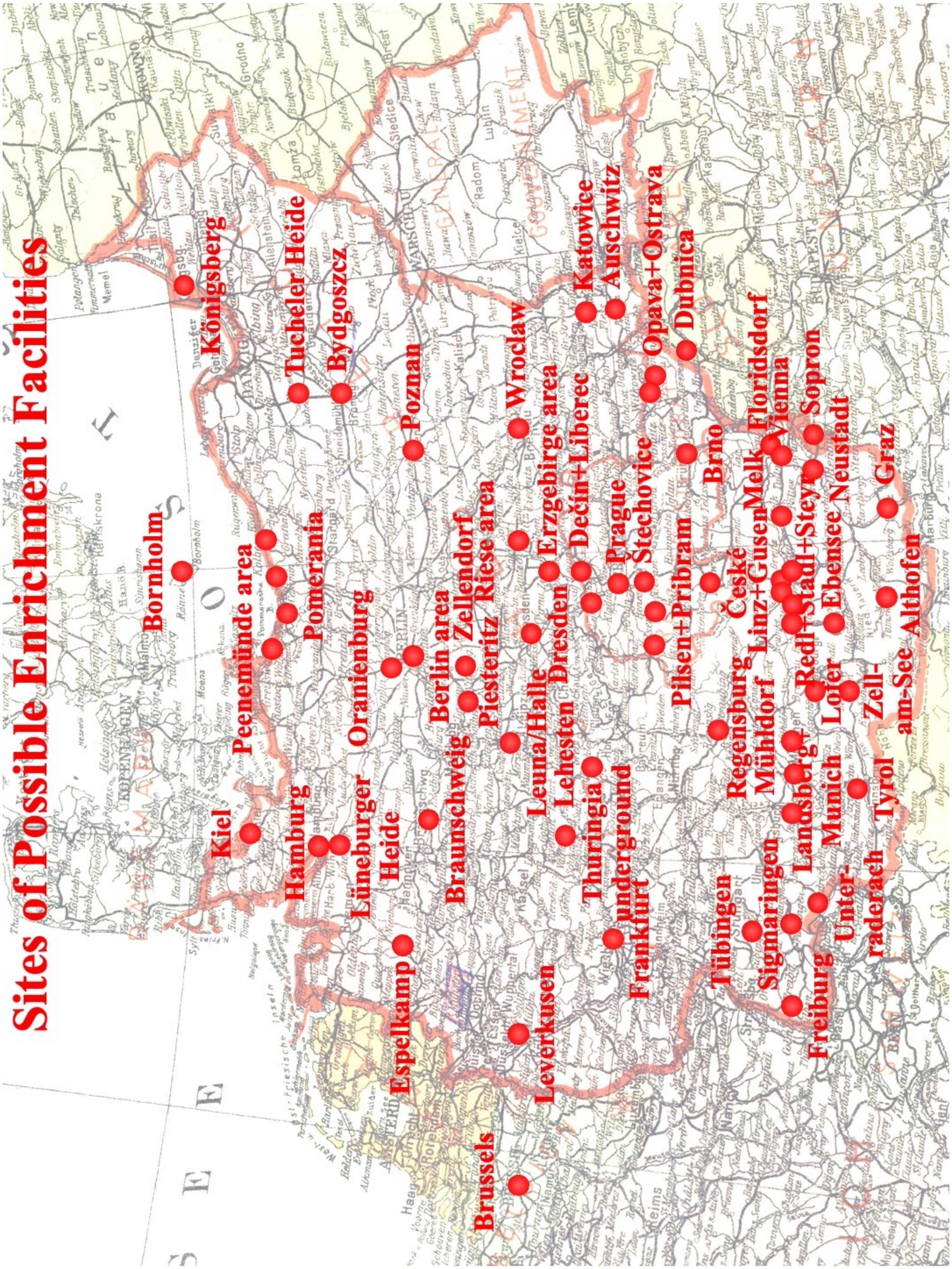
Sites of Possible Enrichment Facilities
Königsberg
Tucheler Heide
Bydgoszcz
Poznan
Wroclaw
Katowice
Auschwitz
Opava+Ostrava
Dubnica
Bornholm
Peenemünde area
Pomerania
Oranienburg
Berlin area
Zellendorf
Riese area
Erzgebirge area
Děčín+Liberec
Prague
Štechovice
Pilsen+Pribram
Brno
České
Floridsdorf
Vienna
Sopron
Melk
Linz+Gusen
Redl+Stadl+Steyr
Neustadt
Ebensee
Graz
Althofen
Zell-am-See
Lofer
Tyrol
Munich
Landsberg
Mühldorf
Regensburg
Kiel
Hamburg
Lüneburger Heide
Braunschweig
Piesteritz
Leuna/Halle
Dresden
Lehesten
Thuringia underground
Frankfurt
Tübingen
Sigmaringen
Unter-raderach
Freiburg
Espelkamp
Leverkusen
Brussels

Figure D.256: Sites of possible enrichment facilities for the German nuclear program.

Some locations that may have been involved in uranium enrichment or other nuclear-related work include (see maps on pp. 3671 and 2086–2099):

Sites now in Germany:

- Berlin area, numerous locations (pp. 3438–3439, 3461–3463, 3608–3617, 3688, 3708–3709, 3926–3928, 4068, 4635–4639) [Hayes 2004; Nagel 2016].
- Bitterfeld, I.G. Farben facilities (pp. 3492–3493, 4050–4051, 4110, 4128, 4133–4137) [Karlsch 2005, p. 110; Sadovsky 2011b].
- Braunschweig, Buchler (pp. 3420, 3430–3431, 3458, 3460–3463, 3465, 4980).
- Dresden (pp. 3423, 3426, 4305, 4507).
- Erzgebirge, SS facility (p. 3708).
- Espelkamp [Preuss and Eitelberg 2003].
- Essen, Krupp (pp. 3458, 3461–3463, 3465–3467]).
- Frankfurt/Griesheim area, Degussa, Radium-Chemie, I.G. Farben, and other facilities (pp. 3440–3441, 3458, 3461–3465, 3678–3680, 4066–4067) [Hayes 2004; Nagel 2016].
- Freiburg-im-Breisgau/Feldberg area (pp. 3512–3540, 3681, 3696).
- Göttingen (pp. 3542–3544).
- Halle, I.G. Farben facilities (pp. 4052–4055).
- Hamburg area (pp. 3458, 3461–3463, 3465, 3494–3516, 4056–4061).
- Heinschenwall (pp. 3682–3683).
- Hohenzollern castle (p. 3696).
- Johanngeorgenstadt/Schneeberg/Freiberg area, Saxony (pp. 3416, 3424, 3426–3428, 3433–3437, 3445, 3456, 3468–3469, 3708, 4922) [Zeman and Karlsch 2008].
- Kaufering/Landsberg (p. 3692).
- Kiel (pp. 3494–3515).
- Koralle, north of Berlin (p. 3694).
- Lehesten (pp. 3689, 3696, 4080).
- Leuna, I.G. Farben facilities (pp. 4042–4050).
- Leverkusen, I.G. Farben facility (pp. 3488–3489, 3934–3935).
- Lübeck, Dräger Werke (pp. 4062–4063).
- Lüneburger Heide area, south of Hamburg (pp. 4176–4182, 4406).

- Müggenberg (pp. 4064–4065).
- Mühldorf (p. 3689).
- Munich area universities, research institutes, and industry (pp. 3498–3507, 4068).
- Neustadt an der Orla (pp. 3633–3638, 5052, 5055–5057).
- Nordhausen area (pp. 5289–5294).
- Oranienburg (pp. 3446, 3458, 3461–3463, 3465, 4180, 4182, 4980) [Nagel 2016].
- Peenemünde (p. 3696).
- Piesteritz, near Wittenberg (pp. 4082, 4452–4453).
- Regensburg vicinity, I.G. Farben facility (p. 3694).
- Rügen island (pp. 4390–4435).
- Saalfeld (p. 3689).
- Stassfurt vicinity, Salzbergwerke (p. 3697).
- Sigmaringen (p. 3696).
- Tegernsee (p. 3696).
- Thuringia, numerous facilities (pp. 3468–3469, 3708–3709, 3854–3868, 4436–4438, 4478–4571, 4635–4639) [Hayes 2004; Nagel 2016; Zeman and Karlsch 2008].
- Tübingen (p. 3696).
- Unterraderach/Friedrichshafen area (pp. 3921–3925).
- Villingen-Schwenningen am Neckar, W. Maier KG Radiumchemische Industrie und Laboratorium [Oleynikov 2000].
- Wittingen, W. de Boer (pp. 3458, 3461–3463, 3465).
- Zellendorf (p. 3694).
- Zeuthen-Miersdorf, near Berlin (p. 3608).
- Other possible sites in Germany?

Sites now in Austria:

- Althofen: Treibacher Chemische Werke (pp. 3420, 3432–3437, 3458, 3460, 4980) [Gollmann 1994].
- Ebensee (pp. 3718–3741, 5297–5299).
- Graz (pp. 4611–4612).
- Linz (pp. 3877–3880).

- Lofer (p. 4974).
- Melk vicinity or associated sites, underground facilities that were part of the Quarz development (pp. 3732, 4078–4079)) [Schmitzberger 2004].
- Redl Zipf/Voecklamarkt/Voecklabruck area (pp. 3718–3741).
- Rheinfelden, Degussa plant on Drau river (pp. 4080–4081).
- Stadl Paura (pp. 3718–3741).
- Steyr.
- St. Georgen/Gusen/Langenstein area (e.g., pp. 3874–3920 and 4962–4970).
- Vienna area universities, research institutes, and industry, including Floridsdorf (e.g., p. 3696).
- Weer, near Wattens, Tyrol (pp. 4072–4077).
- Weissenstein, Austrian Chemical Works plant on Drau river (pp. 4080–4081).
- Wiener Neustadt vicinity, underground facility (pp. 3732, 3748).
- Zell-am-See (p. 4788).
- Other possibles sites in Austria (pp. 3490–3491)?

Sites now in Poland:

- Baltic coast/Pomerania, many military test ranges (p. 4396).
- Bydgoszcz/Bromberg, underground facility (p. 4456).
- Gdansk/Danzig, uranium enrichment (pp. 3560, 4406, 4521).
- Oświęcim/Auschwitz area (pp. 4069, 4443–4477) large I.G. Farben facility (including heavy water plant), and nearby Auergesellschaft uranium facility at Katowice/Kattowitz.
- Poznan/Posen (pp. 2562–2575, 3245–3246).
- “Riese” area of Silesia (pp. 3328, 3424, 3429, 3445, 3471, 3712–3714, 4069, 4504–4519).
- Tuchola Forest/Tucheler Heide (p. 4902).
- Wrocław/Breslau (pp. 3712–3714, 4070–4071, 4316–4317, 4522).
- Other possibles sites in Poland?

Sites now in the Czech Republic:[11]

- Brno/Brünn (pp. 3694, 3997).
- Čelakovice/Tschelakowitz cyclotron factory (pp. 3979–4022).

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[11] See also Czech information on World War II sites that appear to have radioactive contamination: https://www.sekm.cz and https://kontaminace.cenia.cz

- České Budejovice/Budweis (pp. 3979–4022, 5503–5566).
- Děčín/Tetschen area, Podmokly/Bodenbach/Krizik Works/Weserwerke (pp. 3936–3937, 3987–3998, 5503–5566).
- Durrnaul near Mariánské Lázně/Marienbad (p. 3424).
- Jáchymov/St. Joachimsthal area (pp. 3418–3429, 3445, 3469–3470, 3998, 4978–4984) [Hayes 2004, pp. 132–133, 235, 243].
- Liberec/Reichenberg and Jablonec/Gablonz area, Bedrichov/Friedrichsthal/Benesov nad Ploucnici and numerous other high-tech production facilities (pp. 3979–4022, 5503–5566).
- Litoměřice/Leitmeritz, Richard I, II, and III underground factories (p. 3689).
- Mladkov/Wichstadt (p. 3425).
- Opava/Tropau, I.G. Farben production plant (p. 3748).
- Ostrava/Ostrau and Vitkovice/Witkowitz, I.G. Farben and other industrial production plants (pp. 3748, 3979–4022, 5503–5566).
- Pardubice/Pardubitz/Wesser (pp. 3446, 4082–4083).
- Plzeň/Pilsen (p. 4974).
- Prague/Praha/Prag universities and other laboratories (pp. 3979–4022, 5503–5566).
- Příbram/Przibram/Pibrans (pp. 3423–3424, 3470, 3751–3754, 4921, 5696).
- Štěchovice/Stechowitz area, Blaumeise underground facilities (pp. 3755–3782).
- Other possible sites in the Czech Republic (pp. 3770–3771, 3979–4022, 5503–5566)?

Sites now in Slovakia:

- Dubnica/Dubnitz, Skoda underground facility (pp. 3784–3785).
- Other possible sites in Slovakia?

Sites now in Hungary:

- Sopron (pp. 3746–3747).
- Other possible sites in Hungary?

Sites now in Russia:

- Kaliningrad/Königsberg area, East Prussia (pp. 3928–3933).
- Other possible sites now in Russia?

Sites now in Denmark:

- Bornholm island (pp. 3786–3793).

- Other possible sites in Denmark?

Sites now in Belgium:

- Union Minière in Brussels or other locations (pp. 3335, 3408–3414) [Irving 1967, p. 65].
- Other possible sites in Belgium?

Sites now in Norway:

- Vemork (pp. 4031–4039).
- Såheim (p. 4040).
- Notodden (p. 4041).
- Trondheim (pp. 4404, 4436, 5011, 5034).
- Oslo area (pp. 5190–5198).
- Other possible sites in Norway?

Sites now in France:

- Génissiat area (pp. 3710–3711).
- Other possible sites in France?

Sites now in Italy:

- Montecatini plant, Sinigo-Merano, Italy (p. 4069).
- Montecatini plant, Cotrone/Crotone, Italy (p. 4069).
- Other possible sites in Italy?

Sites now in the Netherlands:

- Eindhoven (pp. 3976–3978, 4314–4318, 4832–4853).
- Other possible sites in the Netherlands?

Sites now in Switzerland:

- Factories producing uranium gas centrifuges for export to Germany (pp. 3545–3548).
- Other possible sites in Switzerland?

Sites now in Romania:

- Băiţa-Plai (pp. 3449–3455, 3471).
- Other possible sites in Romania?

Sites now in Bulgaria:

- Sofia area (pp. 3446, 3470, 4588) [Hayes 2004, p. 235; https://ejatlas.org/conflict/life-after-the-uranium-mines-in-buhovo-bulgaria].
- Other possible sites in Bulgaria?

Miscellaneous sites:

- Facilities run by or involving AEG.
- Facilities run by or involving Siemens.
- Other facilities run by or involving I.G. Farben (pp. 3488–3489, 3492–3493, 3678–3680, 3748–3750, 4440–4477) [Mader 1965, pp. 193–202].
- Other facilities run by or involving Degussa.
- Other facilities run by or involving Auer.
- Other facilities run by or involving the SS.
- Other facilities run by or involving the Reichspost.
- Other facilities run by or involving the Heereswaffenamt.
- Other facilities run by or involving the Luftwaffe.
- Other facilities run by or involving the Kriegsmarine.
- Other facilities run by or involving the Organisation Todt.
- Other possible sites?

All of these possible nuclear weapons production sites (and any other candidate sites that can be identified) should be investigated further. Hopefully additional documents could be found that would elucidate whether these sites conducted nuclear or non-nuclear work. If there is significant documentary evidence that a site may have done nuclear work, and if there is reason to believe that that work may have left measurable traces, industrial archaeology should be conducted at that site to measure isotopes, search for remaining pieces of equipment, or identify other evidence.

As already mentioned, the large number, size, and sophistication of all of these sites, and how little information scholars currently have about them, should at the very least emphasize (1) how vast wartime German R&D programs were, (2) how little we still know about some of them, and (3) how unwise it would be for historians currently to categorically state that there was no nuclear-weapons-related development and production anywhere in the Third Reich.]

Known/Reported Sites Now in Germany

[In addition to the sites specifically mentioned in this section, documents elsewhere throughout this appendix name a large number of other sites in Germany that were known or suspected to be conducting nuclear-related work.]

Summary of Bacteriological/Chemical Warfare in Axis Europe. Supp. Report #2. 11 March 1944. [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)] See document photo on p. 3679.

Southern Bavaria is believed to be the location of the first trials of a new German explosive, manufactured by I. G. Farben and said to be another of Germany's secret weapons. Griesheim is reported to be the location of the I. G. Farben plant where the new explosive is being manufactured. Difficulties have been encountered in its production on required scale owing to the scarcity of the "raw materials required for preparation of two of the constituent compounds."

Further experiments on another of Germany's secret weapons are now being conducted in the neighborhood of Semmering, Germany.

Vienna is said to be an important research center in Germany.

[See document photos on pp. 3679–3680.

This 11 March 1944 intelligence report mentioned planned tests of a new type of German bomb using rare materials that were manufactured (among other places) at I.G. Farben Griesheim.

Independently, it was reported that Griesheim was producing heavy water (pp. 4066–4067).

The Griesheim plant appears to have been occupied and tightly controlled by the U.S. military for nearly a year and a half after the war. See for example:

https://de.wikipedia.org/wiki/Chemische_Fabrik_Griesheim-Elektron

and sources cited therein.]

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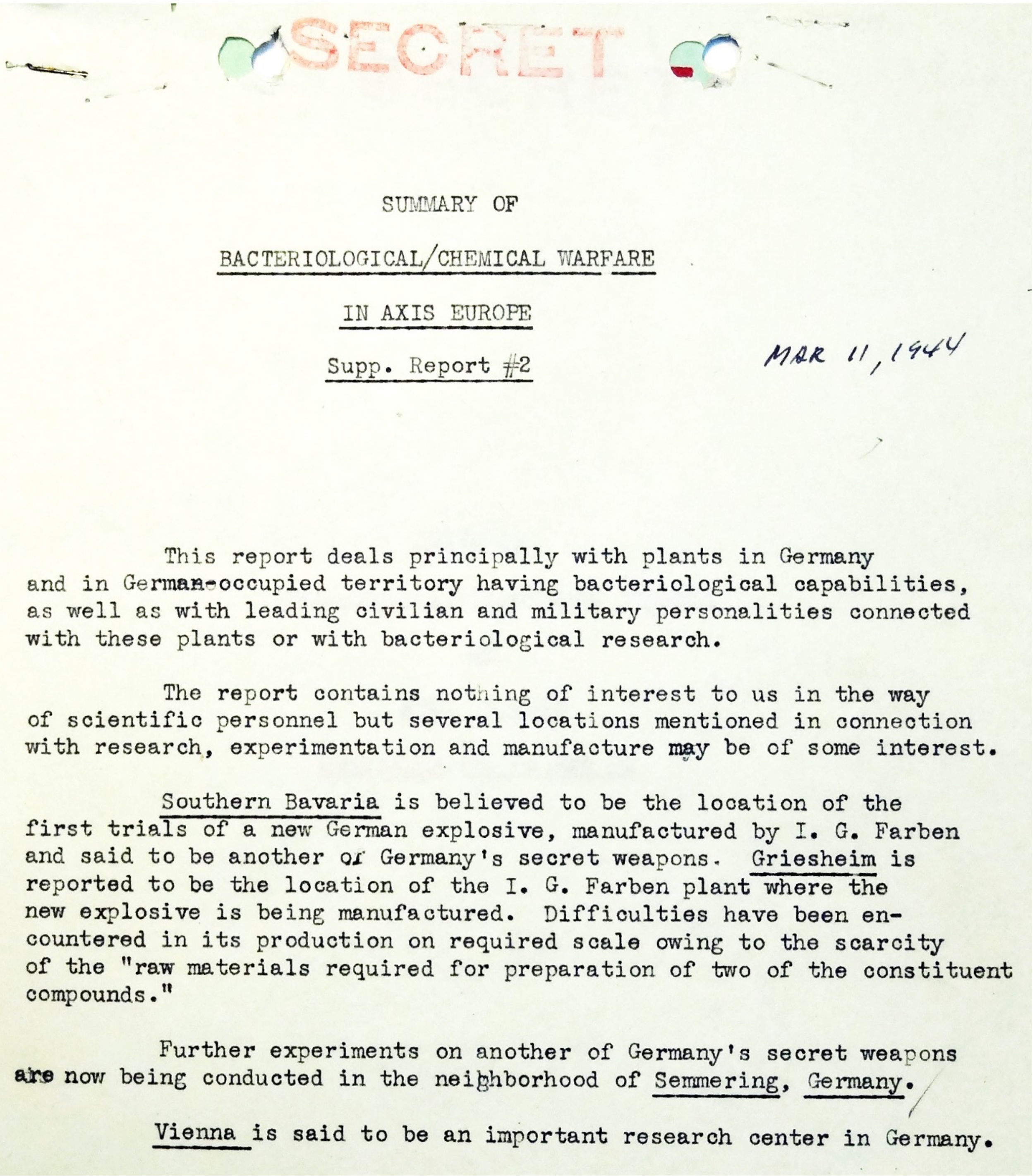
Authority NND941017

NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)



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SUMMARY OF

BACTERIOLOGICAL/CHEMICAL WARFARE

IN AXIS EUROPE

Supp. Report #2

MAR 11, 1944

This report deals principally with plants in Germany and in German-occupied territory having bacteriological capabilities, as well as with leading civilian and military personalities connected with these plants or with bacteriological research.

The report contains nothing of interest to us in the way of scientific personnel but several locations mentioned in connection with research, experimentation and manufacture may be of some interest.

Southern Bavaria is believed to be the location of the first trials of a new German explosive, manufactured by I. G. Farben and said to be another of Germany's secret weapons. Griesheim is reported to be the location of the I. G. Farben plant where the new explosive is being manufactured. Difficulties have been encountered in its production on required scale owing to the scarcity of the "raw materials required for preparation of two of the constituent compounds."

Further experiments on another of Germany's secret weapons are now being conducted in the neighborhood of Semmering, Germany.

Vienna is said to be an important research center in Germany.

Figure D.257: This 11 March 1944 intelligence report mentioned planned tests of a new type of German bomb using rare materials that were manufactured (among other places) at I.G. Farben Griesheim [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]. See also pp. 4066–4067.

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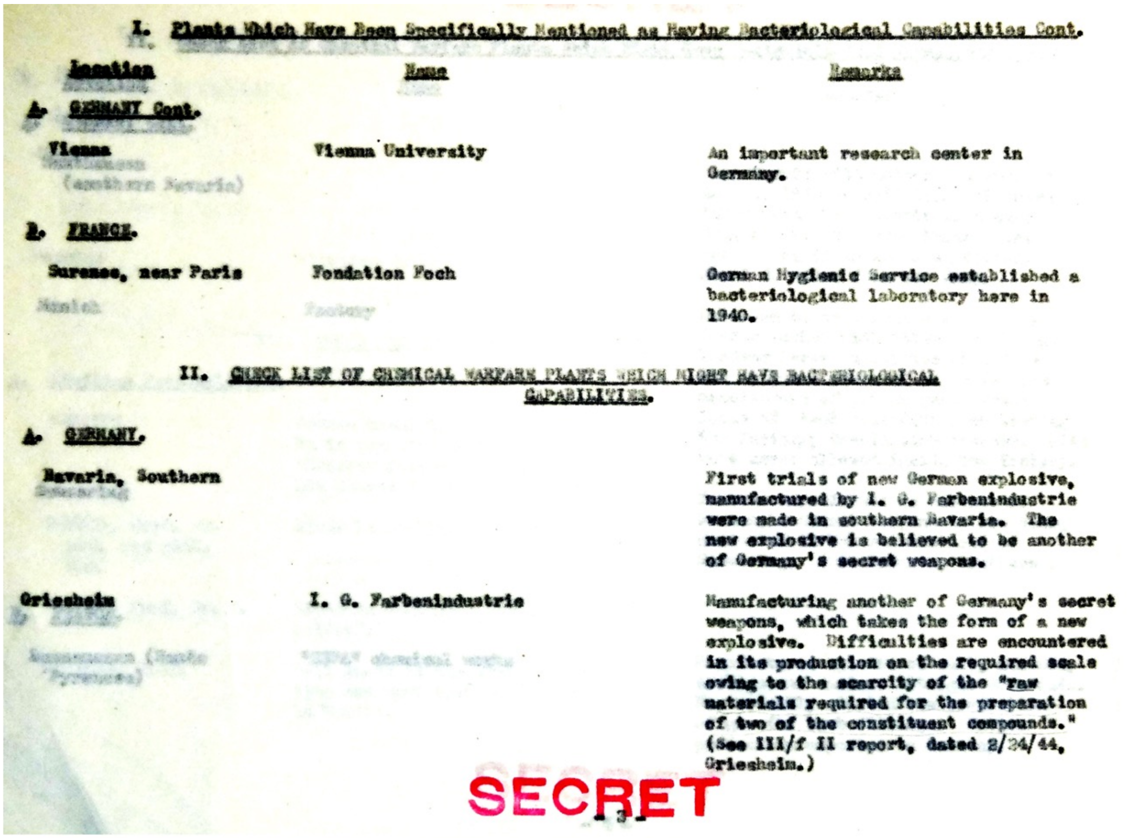
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1
GERMANY: Summary Reports (1944). Bacteriological/Chemical
Warfare in Axis Europe, Supplementary Report #2, 11 March 1944



I. **Plants Which Have Been Specifically Mentioned as Having Bacteriological Capabilities Cont.**

Location	**Name**	**Remarks**
A. **GERMANY Cont.**		
Vienna	Vienna University	An important research center in Germany.
B. **FRANCE.**		
Suresnes, near Paris	Fondation Foch	German Hygienic Service established a bacteriological laboratory here in 1940.

II. **CHECK LIST OF CHEMICAL WARFARE PLANTS WHICH MIGHT HAVE BACTERIOLOGICAL CAPABILITIES.**

A. **GERMANY.**		
Bavaria, Southern		First trials of new German explosive, manufactured by I. G. Farbenindustrie were made in southern Bavaria. The new explosive is believed to be another of Germany's secret weapons.
Griesheim	I. G. Farbenindustrie	Manufacturing another of Germany's secret weapons, which takes the form of a new explosive. Difficulties are encountered in its production on the required scale owing to the scarcity of the "raw materials required for the preparation of two of the constituent compounds." (See III/f II report, dated 2/24/44, Griesheim.)

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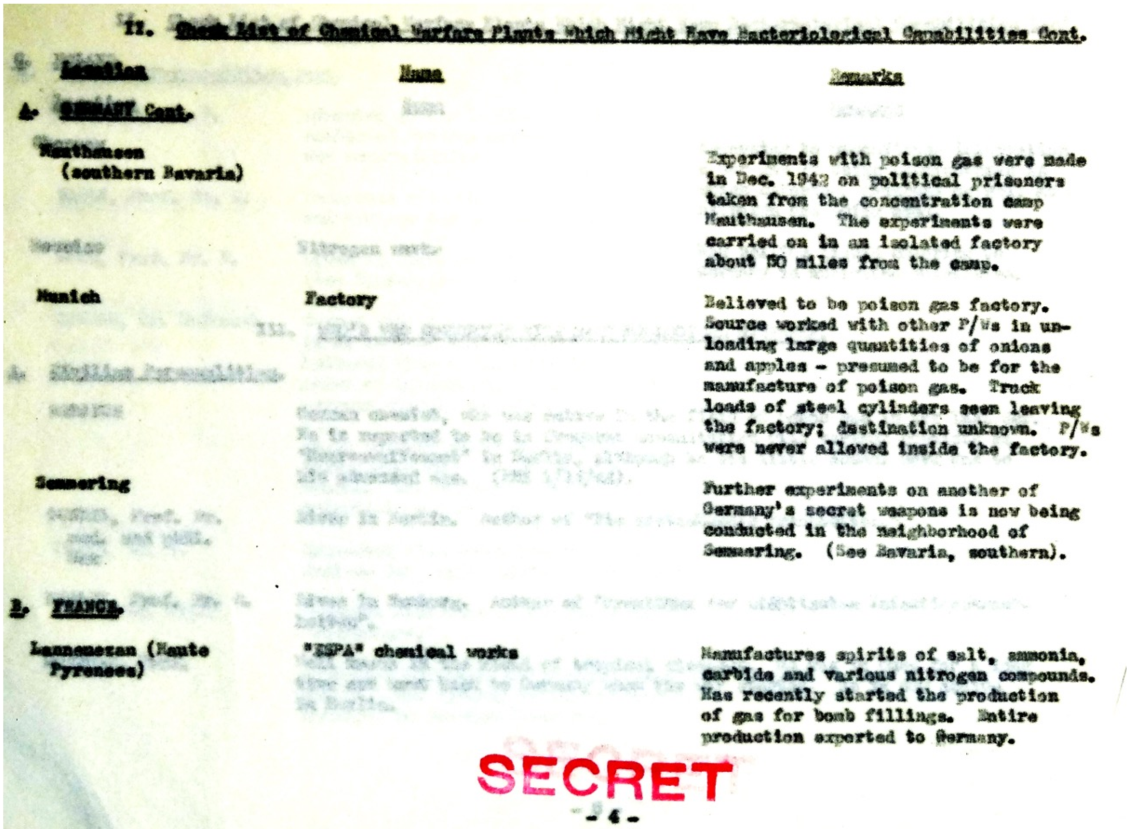
- 3 -



II. **Check List of Chemical Warfare Plants Which Might Have Bacteriological Capabilities Cont.**

Location	**Name**	**Remarks**
A. **GERMANY Cont.**		
Mauthausen (southern Bavaria)		Experiments with poison gas were made in Dec. 1942 on political prisoners taken from the concentration camp Mauthausen. The experiments were carried on in an isolated factory about 50 miles from the camp.
Munich	Factory	Believed to be poison gas factory. Source worked with other P/Ws in unloading large quantities of onions and apples - presumed to be for the manufacture of poison gas. Truck loads of steel cylinders seen leaving the factory; destination unknown. P/Ws were never allowed inside the factory.
Semmering		Further experiments on another of Germany's secret weapons is now being conducted in the neighborhood of Semmering. (See Bavaria, southern).
B. **FRANCE.**		
Lannemezan (Haute Pyrenees)	"ESPA" chemical works	Manufactures spirits of salt, ammonia, carbide and various nitrogen compounds. Has recently started the production of gas for bomb fillings. Entire production exported to Germany.

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- 4 -

Figure D.258: This 11 March 1944 intelligence report mentioned planned tests of a new type of German bomb using rare materials that were manufactured (among other places) at I.G. Farben Griesheim [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]. See also pp. 4066–4067.

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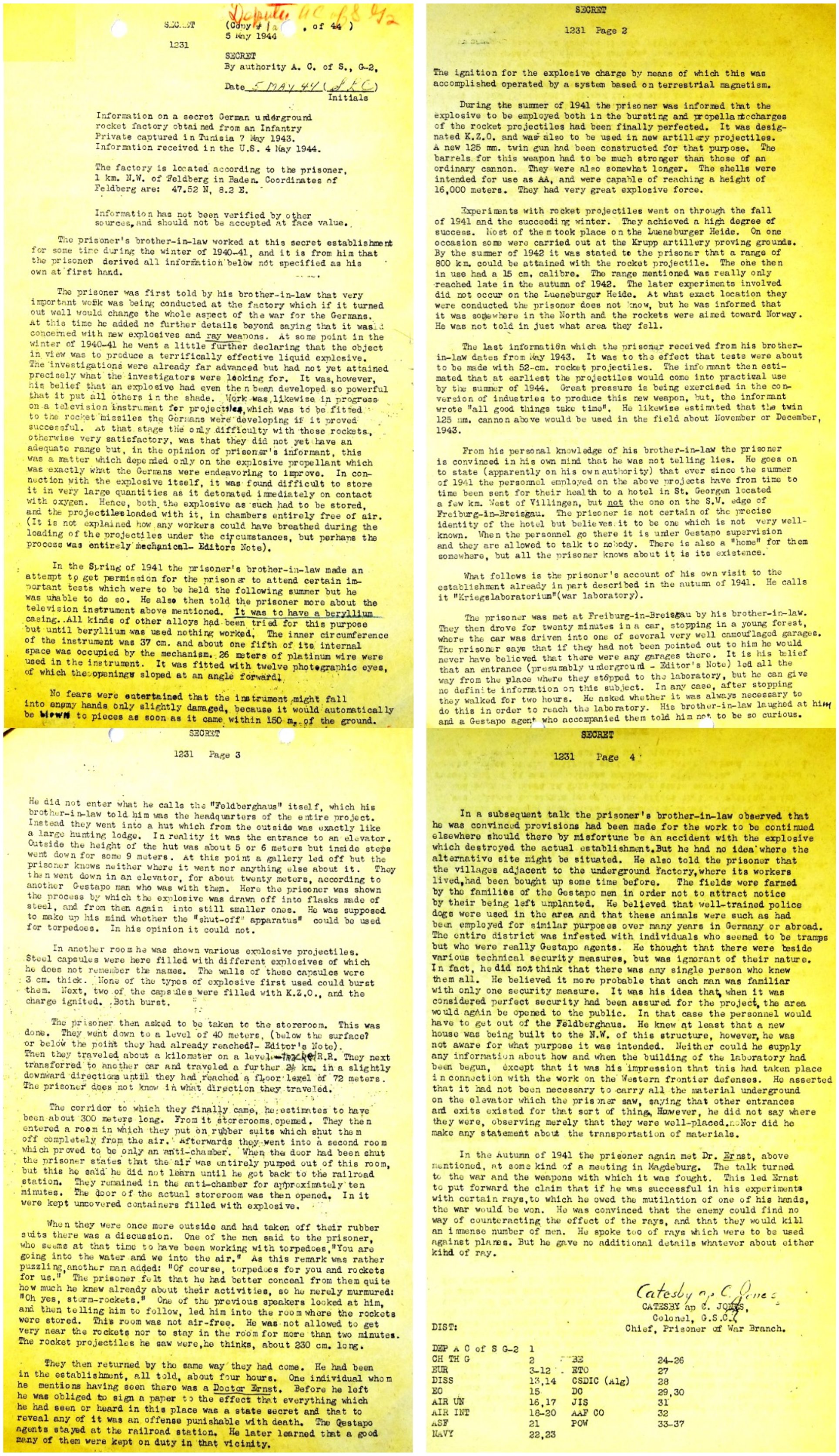

SECRET (Copy # 1a, of 44)
Deputy AC of S G2
5 May 1944

1231

SECRET
By authority A. C. of S., G-2,

Date 5 MAY 44 (SLC)
Initials

Information on a secret German underground rocket factory obtained from an Infantry Private captured in Tunisia 7 May 1943. Information received in the U.S. 4 May 1944.

The factory is located according to the prisoner, 1 km. N.W. of Feldberg in Baden. Coordinates of Feldberg are: 47.52 N, 8.2 E.

Information has not been verified by other sources, and should not be accepted at face value.

The prisoner's brother-in-law worked at this secret establishment for some time during the winter of 1940-41, and it is from him that the prisoner derived all information below not specified as his own at first hand.

The prisoner was first told by his brother-in-law that very important work was being conducted at the factory which if it turned out well would change the whole aspect of the war for the Germans. At this time he added no further details beyond saying that it was concerned with new explosives and ray weapons. At some point in the winter of 1940-41 he went a little further declaring that the object in view was to produce a terrifically effective liquid explosive. The investigations were already far advanced but had not yet attained precisely what the investigators were looking for. It was, however, his belief that an explosive had even then been developed so powerful that it put all others in the shade. Work was likewise in progress on a television instrument for projectiles, which was to be fitted to the rocket missiles the Germans were developing if it proved successful. At that stage the only difficulty with these rockets, otherwise very satisfactory, was that they did not yet have an adequate range but, in the opinion of prisoner's informant, this was a matter which depended only on the explosive propellant which was exactly what the Germans were endeavoring to improve. In connection with the explosive itself, it was found difficult to store it in very large quantities as it detonated immediately on contact with oxygen. Hence, both the explosive as such had to be stored, and the projectiles loaded with it, in chambers entirely free of air. (It is not explained how any workers could have breathed during the loading of the projectiles under the circumstances, but perhaps the process was entirely mechanical- Editors Note).

In the Spring of 1941 the prisoner's brother-in-law made an attempt to get permission for the prisoner to attend certain important tests which were to be held the following summer but he was unable to do so. He also then told the prisoner more about the television instrument above mentioned. It was to have a beryllium casing..All kinds of other alloys had been tried for this purpose but until beryllium was used nothing worked. The inner circumference of the instrument was 37 cm. and about one fifth of its internal space was occupied by the mechanism. 26 meters of platinum wire were used in the instrument. It was fitted with twelve photographic eyes, of which the openings sloped at an angle forward.

No fears were entertained that the instrument might fall into enemy hands only slightly damaged, because it would automatically be blown to pieces as soon as it came within 150 m. of the ground.

SECRET

1231 Page 2

The ignition for the explosive charge by means of which this was accomplished operated by a system based on terrestrial magnetism.

During the summer of 1941 the prisoner was informed that the explosive to be employed both in the bursting and propellant charges of the rocket projectiles had been finally perfected. It was designated K.Z.O. and was also to be used in new artillery projectiles. A new 125 mm. twin gun had been constructed for that purpose. The barrels for this weapon had to be much stronger than those of an ordinary cannon. They were also somewhat longer. The shells were intended for use as AA, and were capable of reaching a height of 16,000 meters. They had very great explosive force.

Experiments with rocket projectiles went on through the fall of 1941 and the succeeding winter. They achieved a high degree of success. Most of them took place on the Lueneburger Heide. On one occasion some were carried out at the Krupp artillery proving grounds. By the summer of 1942 it was stated to the prisoner that a range of 800 km. could be attained with the rocket projectile. The one then in use had a 15 cm. calibre. The range mentioned was really only reached late in the autumn of 1942. The later experiments involved did not occur on the Lueneburger Heide. At what exact location they were conducted the prisoner does not know, but he was informed that it was somewhere in the North and the rockets were aimed toward Norway. He was not told in just what area they fell.

The last information which the prisoner received from his brother-in-law dates from May 1943. It was to the effect that tests were about to be made with 52-cm. rocket projectiles. The informant then estimated that at earliest the projectiles would come into practical use by the summer of 1944. Great pressure is being exercised in the conversion of industries to produce this new weapon, but, the informant wrote "all good things take time". He likewise estimated that the twin 125 mm. cannon above would be used in the field about November or December, 1943.

From his personal knowledge of his brother-in-law the prisoner is convinced in his own mind that he was not telling lies. He goes on to state (apparently on his own authority) that ever since the summer of 1941 the personnel employed on the above projects have from time to time been sent for their health to a hotel in St. Georgen located a few km. West of Villingen, but not the one on the S.W. edge of Freiburg-in-Breisgau. The prisoner is not certain of the precise identity of the hotel but believes it to be one which is not very well-known. When the personnel go there it is under Gestapo supervision and they are allowed to talk to nobody. There is also a "home" for them somewhere, but all the prisoner knows about it is its existence.

What follows is the prisoner's account of his own visit to the establishment already in part described in the autumn of 1941. He calls it "Kriegslaboratorium"(war laboratory).

The prisoner was met at Freiburg-in-Breisgau by his brother-in-law. They then drove for twenty minutes in a car, stopping in a young forest, where the car was driven into one of several very well camouflaged garages. The prisoner says that if they had not been pointed out to him he would never have believed that there were any garages there. It is his belief that an entrance (presumably underground - Editor's Note) led all the way from the place where they stopped to the laboratory, but he can give no definite information on this subject. In any case, after stopping they walked for two hours. He asked whether it was always necessary to do this in order to reach the laboratory. His brother-in-law laughed at him and a Gestapo agent who accompanied them told him not to be so curious.

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1231 Page 3

He did not enter what he calls the "Feldberghaus" itself, which his brother-in-law told him was the headquarters of the entire project. Instead they went into a hut which from the outside was exactly like a large hunting lodge. In reality it was the entrance to an elevator. Outside the height of the hut was about 5 or 6 meters but inside steps went down for some 9 meters. At this point a gallery led off but the prisoner knows neither where it went nor anything else about it. They then went down in an elevator, for about twenty meters, according to another Gestapo man who was with them. Here the prisoner was shown the process by which the explosive was drawn off into flasks made of steel, and from then again into still smaller ones. He was supposed to make up his mind whether the "shut-off" apparatus" could be used for torpedoes. In his opinion it could not.

In another room he was shown various explosive projectiles. Steel capsules were here filled with different explosives of which he does not remember the names. The walls of these capsules were 3 cm. thick. None of the types of explosive first used could burst them. Next, two of the capsules were filled with K.Z.O., and the charge ignited. Both burst.

The prisoner then asked to be taken to the storeroom. This was done. They went down to a level of 40 meters, (below the surface? or below the point they had already reached?- Editor's Note). Then they traveled about a kilometer on a level ~~track~~ R.R. They next transferred to another car and traveled a further 2½ km. in a slightly downward direction until they had reached a floor level of 72 meters. The prisoner does not know in what direction they traveled.

The corridor to which they finally came, he estimates to have been about 300 meters long. From it storerooms opened. They then entered a room in which they put on rubber suits which shut them off completely from the air. Afterwards they went into a second room which proved to be only an anti-chamber. When the door had been shut the prisoner states that the air was entirely pumped out of this room, but this he said he did not learn until he got back to the railroad station. They remained in the anti-chamber for approximately ten minutes. The door of the actual storeroom was then opened. In it were kept uncovered containers filled with explosive.

When they were once more outside and had taken off their rubber suits there was a discussion. One of the men said to the prisoner, who seems at that time to have been working with torpedoes,"You are going into the water and we into the air." As this remark was rather puzzling, another man added: "Of course, torpedoes for you and rockets for us." The prisoner felt that he had better conceal from them quite how much he knew already about their activities, so he merely murmured: "Oh yes, storm-rockets." One of the previous speakers looked at him, and then telling him to follow, led him into the room where the rockets were stored. This room was not air-free. He was not allowed to get very near the rockets nor to stay in the room for more than two minutes. The rocket projectiles he saw were, he thinks, about 230 cm. long.

They then returned by the same way they had come. He had been in the establishment, all told, about four hours. One individual whom he mentions having seen there was a Doctor Ernst. Before he left he was obliged to sign a paper to the effect that everything which he had seen or heard in this place was a state secret and that to reveal any of it was an offense punishable with death. The Gestapo agents stayed at the railroad station. He later learned that a good many of them were kept on duty in that vicinity.

SECRET

1231 Page 4

In a subsequent talk the prisoner's brother-in-law observed that he was convinced provisions had been made for the work to be continued elsewhere should there by misfortune be an accident with the explosive which destroyed the actual establishment. But he had no idea where the alternative site might be situated. He also told the prisoner that the villages adjacent to the underground factory, where its workers lived, had been bought up some time before. The fields were farmed by the families of the Gestapo men in order not to attract notice by their being left unplanted. He believed that well-trained police dogs were used in the area and that these animals were such as had been employed for similar purposes over many years in Germany or abroad. The entire district was infested with individuals who seemed to be tramps but who were really Gestapo agents. He thought that there were beside various technical security measures, but was ignorant of their nature. In fact, he did not think that there was any single person who knew them all. He believed it more probable that each man was familiar with only one security measure. It was his idea that, when it was considered perfect security had been assured for the project, the area would again be opened to the public. In that case the personnel would have to get out of the Feldberghaus. He knew at least that a new house was being built to the N.W. of this structure, however, he was not aware for what purpose it was intended. Neither could he supply any information about how and when the building of the laboratory had been begun, except that it was his impression that this had taken place in connection with the work on the Western frontier defenses. He asserted that it had not been necessary to carry all the material underground on the elevator which the prisoner saw, saying that other entrances and exits existed for that sort of thing. However, he did not say where they were, observing merely that they were well-placed. Nor did he make any statement about the transportation of materials.

In the Autumn of 1941 the prisoner again met Dr. Ernst, above mentioned, at some kind of a meeting in Magdeburg. The talk turned to the war and the weapons with which it was fought. This led Ernst to put forward the claim that if he was successful in his experiments with certain rays, to which he owed the mutilation of one of his hands, the war would be won. He was convinced that the enemy could find no way of counteracting the effect of the rays, and that they would kill an immense number of men. He spoke too of rays which were to be used against planes. But he gave no additional details whatever about either kind of ray.

Catesby ap C. Jones
CATESBY ap C. JONES,
Colonel, G.S.C.,
Chief, Prisoner of War Branch.

DIST:

DEP A C of S G-2	1		
CH TH G	2	BE	24-26
EUR	3-12	ETO	27
DISS	13,14	CSDIC (Alg)	28
EO	15	DC	29,30
AIR UN	16,17	JIS	31
AIR INT	18-20	AAF CO	32
ASF	21	POW	33-37
NAVY	22,23		

NARA RG 77, Entry UD-22A,
Box 165, unlabeled gray folder

Figure D.259: Gatesby ap C. Jones. 5 May 1944. PW interrogation report 1231 [NARA RG 77, Entry UD-22A, Box 165, unlabeled gray folder]. From the description, this Feldberg facility sounds like a potential nuclear site, and Leslie Groves's Foreign Intelligence Unit also thought it sounded like a potential nuclear site.

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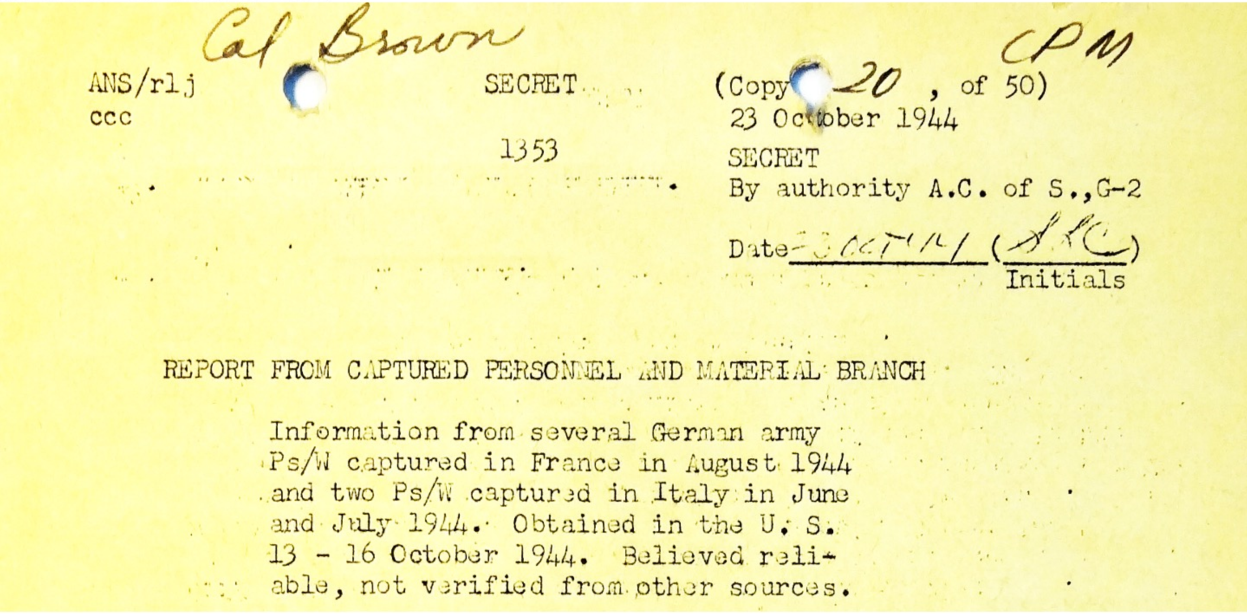
Authority NND911017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July–October 1944)



Col Brown

CPM

ANS/rlj SECRET (Copy 20 , of 50)
ccc 23 October 1944

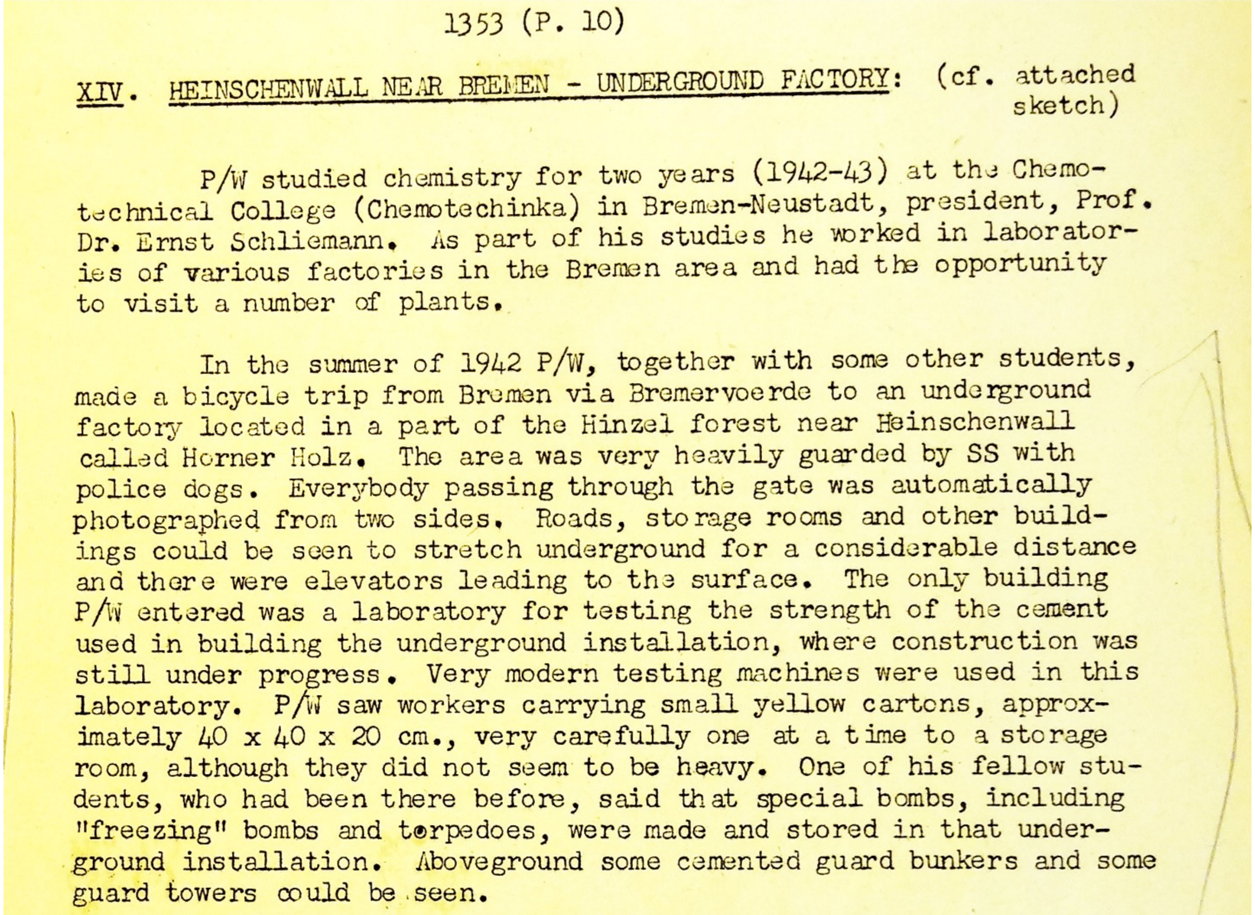
1353

SECRET
By authority A.C. of S.,G-2

Date 3 OCT [illegible] ( )
Initials

REPORT FROM CAPTURED PERSONNEL AND MATERIAL BRANCH

Information from several German army Ps/W captured in France in August 1944 and two Ps/W captured in Italy in June and July 1944. Obtained in the U. S. 13 - 16 October 1944. Believed reliable, not verified from other sources.



1353 (P. 10)

XIV. HEINSCHENWALL NEAR BREMEN - UNDERGROUND FACTORY: (cf. attached sketch)

P/W studied chemistry for two years (1942-43) at the Chemotechnical College (Chemotechinka) in Bremen-Neustadt, president, Prof. Dr. Ernst Schliemann. As part of his studies he worked in laboratories of various factories in the Bremen area and had the opportunity to visit a number of plants.

In the summer of 1942 P/W, together with some other students, made a bicycle trip from Bremen via Bremervoerde to an underground factory located in a part of the Hinzel forest near Heinschenwall called Horner Holz. The area was very heavily guarded by SS with police dogs. Everybody passing through the gate was automatically photographed from two sides. Roads, storage rooms and other buildings could be seen to stretch underground for a considerable distance and there were elevators leading to the surface. The only building P/W entered was a laboratory for testing the strength of the cement used in building the underground installation, where construction was still under progress. Very modern testing machines were used in this laboratory. P/W saw workers carrying small yellow cartons, approximately 40 x 40 x 20 cm., very carefully one at a time to a storage room, although they did not seem to be heavy. One of his fellow students, who had been there before, said that special bombs, including "freezing" bombs and torpedoes, were made and stored in that underground installation. Aboveground some cemented guard bunkers and some guard towers could be seen.

Figure D.260: Report from Captured Personnel and Material Branch. 1353. 23 October 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

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Authority NND941017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July–October 1944)

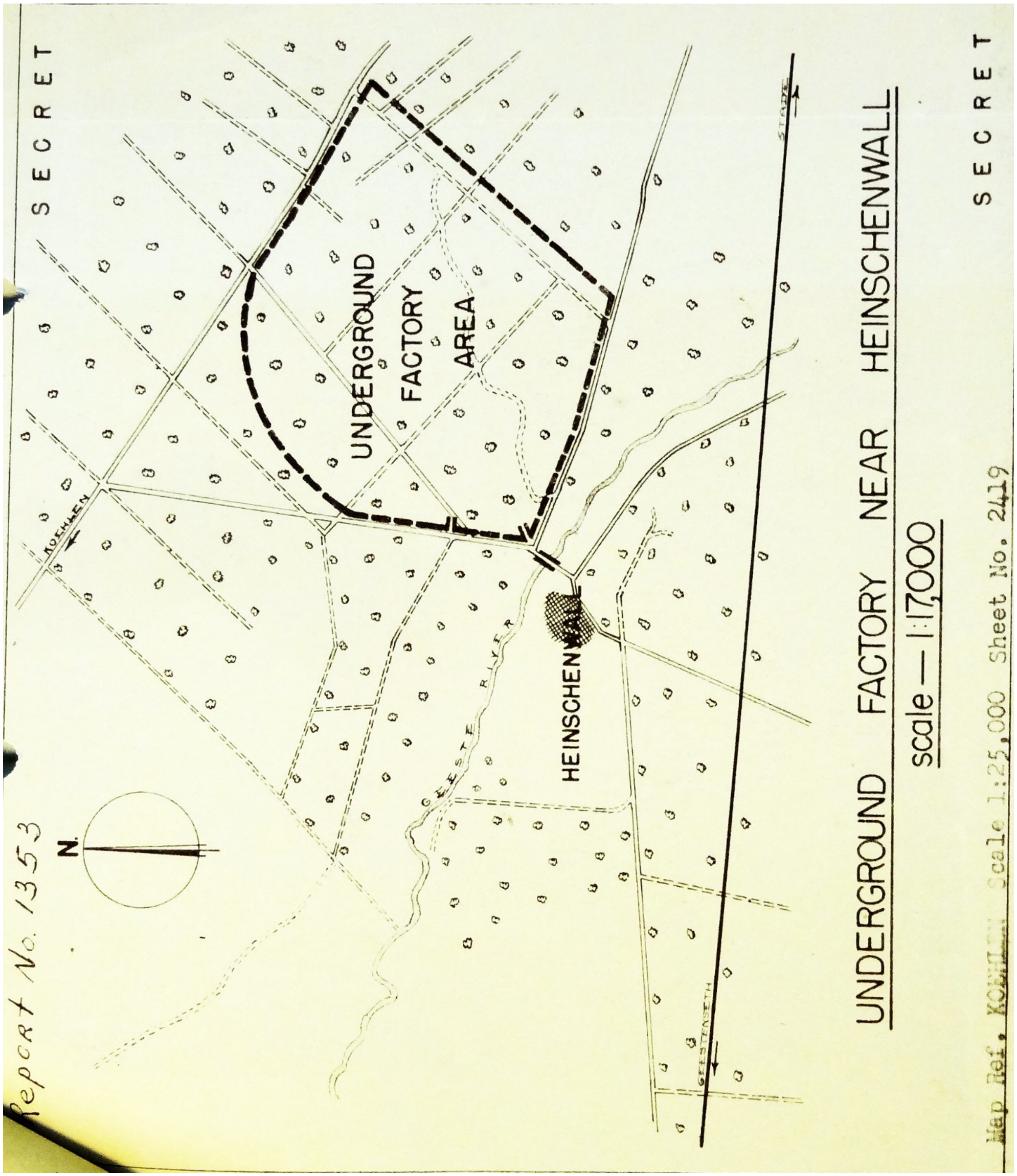
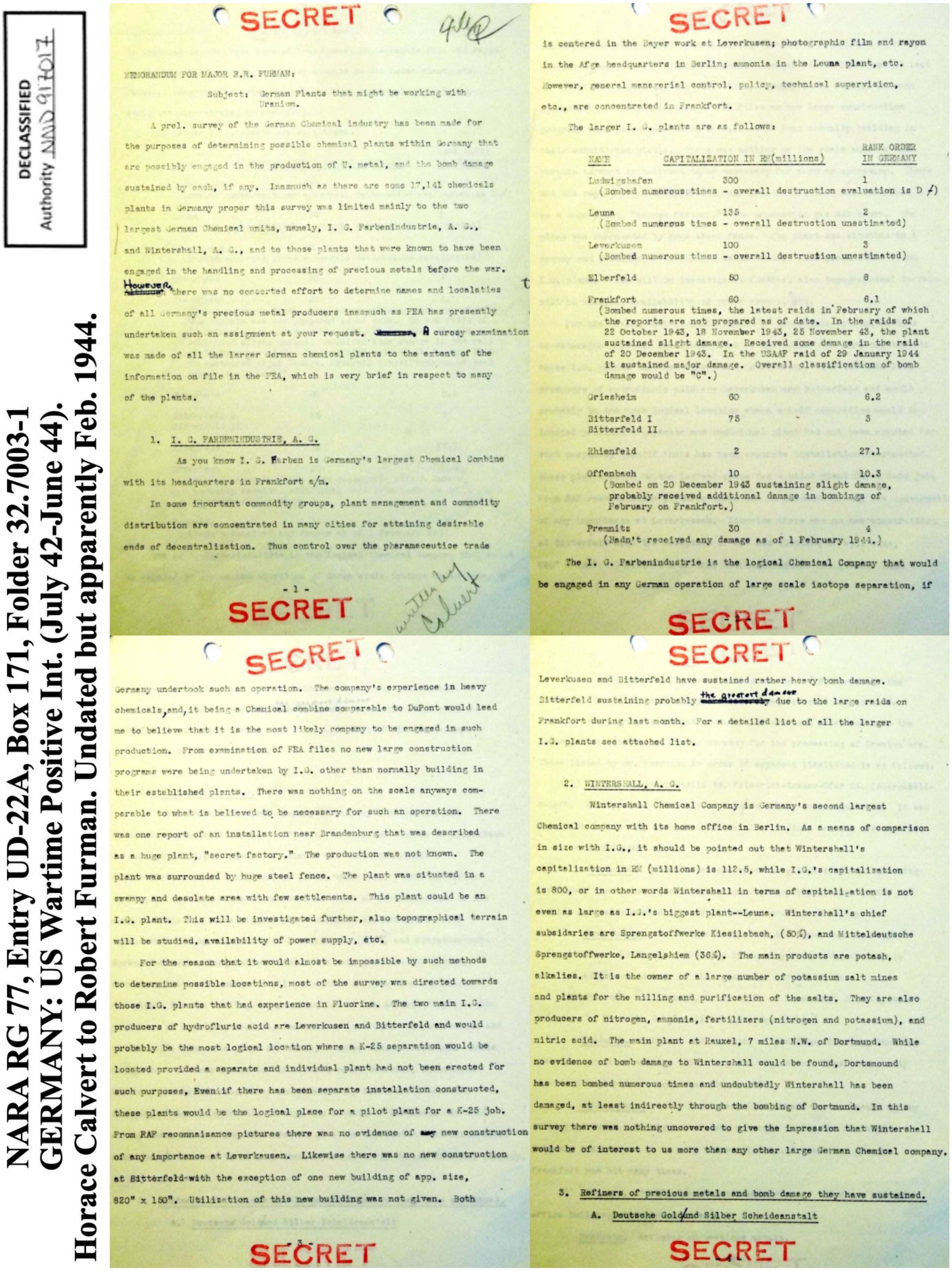

SECRET
SECRET
UNDERGROUND FACTORY AREA
HEINSCHENWALL
GEESTE RIVER
KOEHLEN
STADE
GEESTENSETH
N.
UNDERGROUND FACTORY NEAR HEINSCHENWALL
scale — 1:17,000
Map Ref. KOEHLEN Scale 1:25,000 Sheet No. 2419
Report No. 1353

Figure D.261: Report from Captured Personnel and Material Branch. 1353. 23 October 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].



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Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44). Horace Calvert to Robert Furman. Undated but apparently Feb. 1944.

SECRET

MEMORANDUM FOR MAJOR R.R. FURMAN:

Subject: German Plants that might be working with Uranium.

A prel. survey of the German Chemical industry has been made for the purposes of determining possible chemical plants within Germany that are possibly engaged in the production of U. metal, and the bomb damage sustained by each, if any. Inasmuch as there are some 17,141 chemicals plants in Germany proper this survey was limited mainly to the two largest German Chemical units, namely, I. G. Farbenindustrie, A. G., and Wintershall, A. G., and to those plants that were known to have been engaged in the handling and processing of precious metals before the war. ~~Although~~ However, there was no concerted effort to determine names and localaties of all Germany's precious metal producers inasmuch as FEA has presently undertaken such an assignment at your request. ~~However,~~ A curosy examination was made of all the larger German chemical plants to the extent of the information on file in the FEA, which is very brief in respect to many of the plants.

1. I. G. FARBENINDUSTRIE, A. G.

As you know I. G. Farben is Germany's largest Chemical Combine with its headquarters in Frankfort a/m.

In some important commodity groups, plant management and commodity distribution are concentrated in many cities for attaining desirable ends of decentralization. Thus control over the pharamaceutice trade

- 1 -

SECRET

written by Calvert

SECRET

is centered in the Bayer work at Leverkusen; photographic film and rayon in the Afga headquarters in Berlin; ammonia in the Leuna plant, etc. However, general managerial control, policy, technical supervision, etc., are concentrated in Frankfort.

The larger I. G. plants are as follows:

NAME	CAPITALIZATION IN RM(millions)	RANK ORDER IN GERMANY
Ludwigshafen	300	1
(Bombed numerous times - overall destruction evaluation is D ∕)		
Leuna	135	2
(Bombed numerous times - overall destruction unestimated)		
Leverkusen	100	3
(Bombed numerous times - overall destruction unestimated)		
Elberfeld	50	8
Frankfort	60	6.1
(Bombed numerous times, the latest raids in February of which the reports are not prepared as of date. In the raids of 22 October 1943, 18 November 1943, 25 November 43, the plant sustained slight damage. Received some damage in the raid of 20 December 1943. In the USAAF raid of 29 January 1944 it sustained major damage. Overall classification of bomb damage would be "C".)		
Griesheim	60	6.2
Bitterfeld I Bitterfeld II	75	5
Rhienfeld	2	27.1
Offenbach	10	10.3
(Bombed on 20 December 1943 sustaining slight damage, probably received additional damage in bombings of February on Frankfort.)		
Premnitz	30	4
(Hadn't received any damage as of 1 February 1944.)		

The I. G. Farbenindustrie is the logical Chemical Company that would be engaged in any German operation of large scale isotope separation, if

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Germany undertook such an operation. The company's experience in heavy chemicals, and, it being a Chemical combine comparable to DuPont would lead me to believe that it is the most likely company to be engaged in such production. From examination of FEA files no new large construction programs were being undertaken by I.G. other than normally building in their established plants. There was nothing on the scale anyways comparable to what is believed to be necessary for such an operation. There was one report of an installation near Brandenburg that was described as a huge plant, "secret factory." The production was not known. The plant was surrounded by huge steel fence. The plant was situated in a swampy and desolate area with few settlements. This plant could be an I.G. plant. This will be investigated further, also topographical terrain will be studied, availability of power supply, etc.

For the reason that it would almost be impossible by such methods to determine possible locations, most of the survey was directed towards those I.G. plants that had experience in Fluorine. The two main I.G. producers of hydrofluric acid are Leverkusen and Bitterfeld and would probably be the most logical location where a K-25 separation would be located provided a separate and individual plant had not been erected for such purposes, Even if there has been separate installation constructed, these plants would be the logical place for a pilot plant for a K-25 job. From RAF reconnaisance pictures there was no evidence of ~~any~~ new construction of any importance at Leverkausen. Likewise there was no new construction at Bitterfeld with the exception of one new building of app. size, 820" x 150". Utilization of this new building was not given. Both

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Leverkusen and Bitterfeld have sustained rather heavy bomb damage. Bitterfeld sustaining probably the greatest damage due to the large raids on Frankfort during last month. For a detailed list of all the larger I.G. plants see attached list.

2. WINTERSHALL, A. G.

Wintershall Chemical Company is Germany's second largest Chemical company with its home office in Berlin. As a means of comparison in size with I.G., it should be pointed out that Wintershall's capitalization in RM (millions) is 112.5, while I.G.'s capitalization is 800, or in other words Wintershall in terms of capitalization is not even as large as I.G.'s biggest plant--Leuna. Wintershall's chief subsidaries are Sprengstoffwerke Kiesilebach, (50%), and Mitteldeutsche Sprengstoffwerke, Langelshiem (36%). The main products are potash, alkalies. It is the owner of a large number of potassium salt mines and plants for the milling and purification of the salts. They are also producers of nitrogen, ammonia, fertilizers (nitrogen and potassium), and nitric acid. The main plant at Rauxel, 7 miles N.W. of Dortmund. While no evidence of bomb damage to Wintershall could be found, Dortsmound has been bombed numerous times and undoubtedly Wintershall has been damaged, at least indirectly through the bombing of Dortmund. In this survey there was nothing uncovered to give the impression that Wintershall would be of interest to us more than any other large German Chemical company.

3. Refiners of precious metals and bomb damage they have sustained.

A. Deutsche Gold und Silber Scheideanstalt

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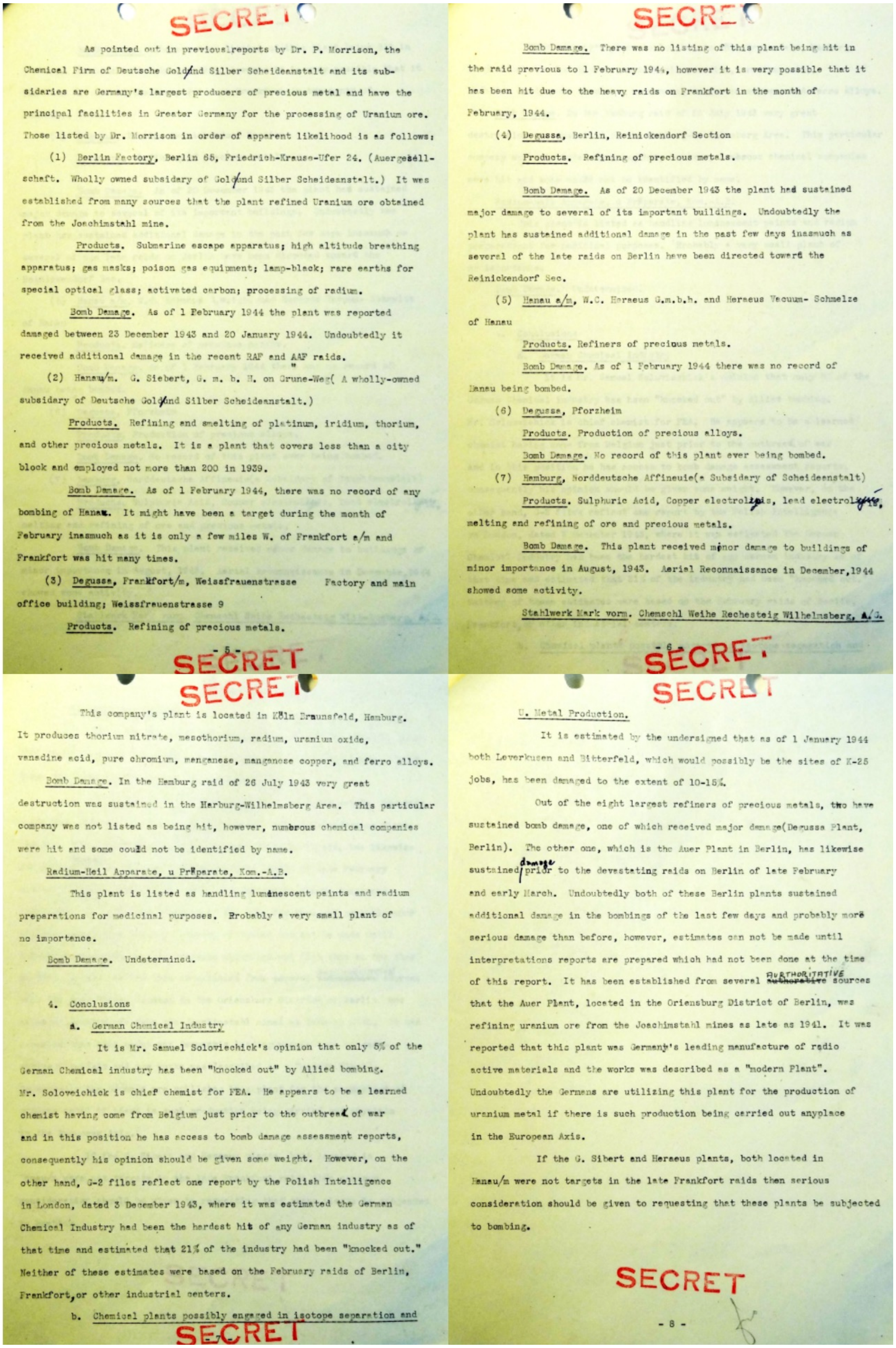
Figure D.262: Horace Calvert to Robert Furman. Undated but apparently February 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)]

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1
GERMANY: US Wartime Positive Int. (July 42–June 44).
Horace Calvert to Robert Furman. Undated but apparently Feb. 1944.



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As pointed out in previous reports by Dr. P. Morrison, the Chemical Firm of Deutsche Gold/und Silber Scheideanstalt and its subsidaries are Germany's largest producers of precious metal and have the principal facilities in Greater Germany for the processing of Uranium ore. Those listed by Dr. Morrison in order of apparent likelihood is as follows:

(1) Berlin Factory, Berlin 65, Friedrich-Krause-Ufer 24. (Auergesellschaft. Wholly owned subsidary of Gold/und Silber Scheideanstalt.) It was established from many sources that the plant refined Uranium ore obtained from the Joachimstahl mine.

Products. Submarine escape apparatus; high altitude breathing apparatus; gas masks; poison gas equipment; lamp-black; rare earths for special optical glass; activated carbon; processing of radium.

Bomb Damage. As of 1 February 1944 the plant was reported damaged between 23 December 1943 and 20 January 1944. Undoubtedly it received additional damage in the recent RAF and AAF raids.

(2) Hanau/m. G. Siebert, G. m. b. H. on Grüne-Weg(A wholly-owned subsidary of Deutsche Gold/und Silber Scheideanstalt.)

Products. Refining and smelting of platinum, iridium, thorium, and other precious metals. It is a plant that covers less than a city block and employed not more than 200 in 1939.

Bomb Damage. As of 1 February 1944, there was no record of any bombing of Hanau. It might have been a target during the month of February inasmuch as it is only a few miles W. of Frankfort a/m and Frankfort was hit many times.

(3) Degussa, Frankfort/m, Weissfrauenstrasse Factory and main office building; Weissfrauenstrasse 9

Products. Refining of precious metals.

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Bomb Damage. There was no listing of this plant being hit in the raid previous to 1 February 1944, however it is very possible that it has been hit due to the heavy raids on Frankfort in the month of February, 1944.

(4) Degussa, Berlin, Reinickendorf Section

Products. Refining of precious metals.

Bomb Damage. As of 20 December 1943 the plant had sustained major damage to several of its important buildings. Undoubtedly the plant has sustained additional damage in the past few days inasmuch as several of the late raids on Berlin have been directed toward the Reinickendorf Sec.

(5) Hanau a/m, W.C. Heraeus G.m.b.h. and Heraeus Vacuum- Schmelze of Hanau

Products. Refiners of precious metals.

Bomb Damage. As of 1 February 1944 there was no record of Hanau being bombed.

(6) Degussa, Pforzheim

Products. Production of precious alloys.

Bomb Damage. No record of this plant ever being bombed.

(7) Hamburg, Norddeutsche Affineuie(a Subsidary of Scheideanstalt)

Products. Sulphuric Acid, Copper electrolysis, lead electrolysis, melting and refining of ore and precious metals.

Bomb Damage. This plant received minor damage to buildings of minor importance in August, 1943. Aerial Reconnaissance in December,1944 showed some activity.

Stahlwerk Mark vorm. Chemschl Weihe Rechesteig Wilhelmsberg, A/G.

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This company's plant is located in Köln Braunsfeld, Hamburg. It produces thorium nitrate, mesothorium, radium, uranium oxide, vanadine acid, pure chromium, manganese, manganese copper, and ferro alloys.

Bomb Damage. In the Hamburg raid of 26 July 1943 very great destruction was sustained in the Harburg-Wilhelmsberg Area. This particular company was not listed as being hit, however, numbrous chemical companies were hit and some could not be identified by name.

Radium-Heil Apparate, u Präparate, Kom.-A.B.

This plant is listed as handling lumanescent paints and radium preparations for medicinal purposes. Probably a very small plant of no importance.

Bomb Damage. Undetermined.

4. Conclusions

a. German Chemical Industry

It is Mr. Samuel Soloviechick's opinion that only 5% of the German Chemical industry has been "knocked out" by Allied bombing. Mr. Soloveichick is chief chemist for FEA. He appears to be a learned chemist having come from Belgium just prior to the outbreak of war and in this position he has access to bomb damage assessment reports, consequently his opinion should be given some weight. However, on the other hand, G-2 files reflect one report by the Polish Intelligence in London, dated 3 December 1943, where it was estimated the German Chemical Industry had been the hardest hit of any German industry as of that time and estimated that 21% of the industry had been "knocked out." Neither of these estimates were based on the February raids of Berlin, Frankfort, or other industrial centers.

b. Chemical plants possibly engaged in isotope separation and

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U. Metal Production.

It is estimated by the undersigned that as of 1 January 1944 both Leverkusen and Bitterfeld, which would possibly be the sites of K-25 jobs, has been damaged to the extent of 10-15%.

Out of the eight largest refiners of precious metals, two have sustained bomb damage, one of which received major damage(Degussa Plant, Berlin). The other one, which is the Auer Plant in Berlin, has likewise sustained damage prior to the devastating raids on Berlin of late February and early March. Undoubtedly both of these Berlin plants sustained additional damage in the bombings of the last few days and probably more serious damage than before, however, estimates can not be made until interpretations reports are prepared which had not been done at the time of this report. It has been established from several ~~authorative~~ AUTHORITATIVE sources that the Auer Plant, located in the Oriensburg District of Berlin, was refining uranium ore from the Joachimstahl mines as late as 1941. It was reported that this plant was Germany's leading manufacture of radio active materials and the works was described as a "modern Plant". Undoubtedly the Germans are utilizing this plant for the production of uranium metal if there is such production being carried out anyplace in the European Axis.

If the G. Sibert and Heraeus plants, both located in Hanau/m were not targets in the late Frankfort raids then serious consideration should be given to requesting that these plants be subjected to bombing.

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Figure D.263: Horace Calvert to Robert Furman. Undated but apparently February 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)]

H. W. Dix to Francis J. Smith. 14 April 1945. SUBJECT: AZUSA. [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL] See document photos on pp. 3687–3688.

From a cable from Stockholm dated 12 April 1945 the information below is paraphrased for your use. The information is dated 7 April 1945 and is obtained from a source which is experienced in weapons, and is reliable.

1. V weapon. The German experimental station at Peenemünde has been evacuated and moved to Wilhelmshafen and Plauen according to definite information. Professor [Herbert A.] Wagner is the head of the experimental station. Rocket bomb type Hs (Henschel) 117, also called Luftgoliath, is the subject of most experiments at present. This controlled rocket bomb is a long range weapon. 8000 meters is the height to which it can be shot with precision. Is propelled vertically towards [from] the ground. This weapon can be directed into groups of enemy planes by means of remote radio control. In October 1944 at Lüneburger Heide in experiments all of a group of 12 of their own [...] remotely controlled planes sent up were shot down with only 1 shot.

4000 of the Hs 117 have now been delivered. [...]

V weapons which are grenades of flying bombs filled with an unknown gas, which is harmless in itself, are, according to vague rumors, manufactured somewhere in Germany (location unknown). When this projectile strikes, a very high pressure is developed which kills living creatures within a radius of from one to four kilometers. Even insects such as beetles are killed by the explosion according to reports. [...]

5. There is an “SS Gebiet” surrounded by double barbed wire charged with high voltage not far from Berlin, at Neunburg. 40,000 [...] forced laborers who may not leave are within this area. Some well known technicians who visit the place sometimes stay more than a week. The product manufactured here is not known. There is very strict guarding by SS, and people have been shot without warning when they wandered too near the barricade.

[There were several independent reports of nuclear-weapons-related plants in or near Lüneburger Heide (e.g., pp. 4172–4182, 4406–4407).

There were also several independent reports of nuclear-weapons-related plants in or near Berlin (e.g., pp. 3608–3617, 4635–4639).]

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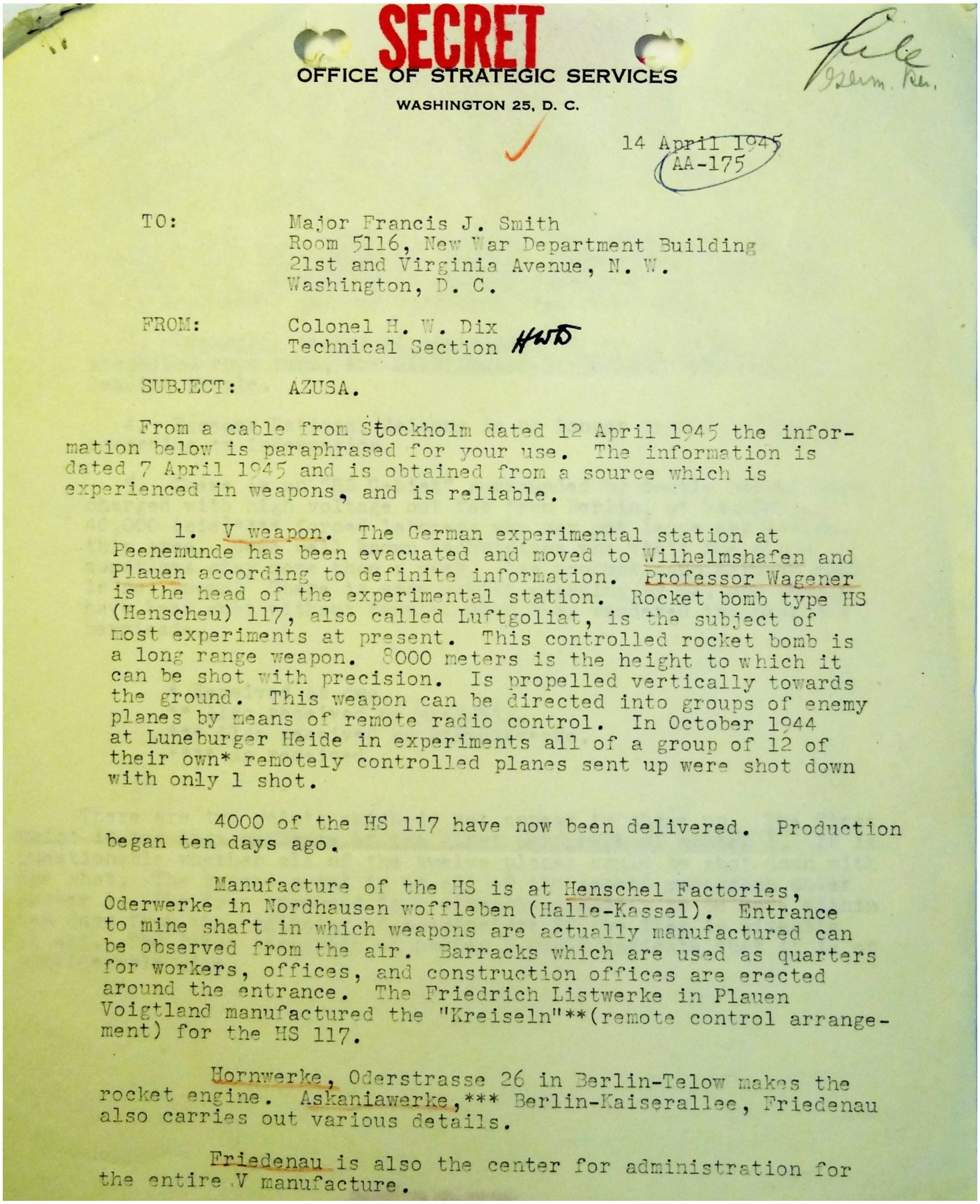
Authority NND917017

NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL



SECRET

OFFICE OF STRATEGIC SERVICES
WASHINGTON 25, D. C.

File
Izelm. Rec.

14 April 1945
AA-175

TO: Major Francis J. Smith
Room 5116, New War Department Building
21st and Virginia Avenue, N. W.
Washington, D. C.

FROM: Colonel H. W. Dix
Technical Section HWD

SUBJECT: AZUSA.

From a cable from Stockholm dated 12 April 1945 the information below is paraphrased for your use. The information is dated 7 April 1945 and is obtained from a source which is experienced in weapons, and is reliable.

1. V weapon. The German experimental station at Peenemunde has been evacuated and moved to Wilhelmshafen and Plauen according to definite information. Professor Wagener is the head of the experimental station. Rocket bomb type HS (Henscheu) 117, also called Luftgoliat, is the subject of most experiments at present. This controlled rocket bomb is a long range weapon. 8000 meters is the height to which it can be shot with precision. Is propelled vertically towards the ground. This weapon can be directed into groups of enemy planes by means of remote radio control. In October 1944 at Luneburger Heide in experiments all of a group of 12 of their own* remotely controlled planes sent up were shot down with only 1 shot.

4000 of the HS 117 have now been delivered. Production began ten days ago.

Manufacture of the HS is at Henschel Factories, Oderwerke in Nordhausen woffleben (Halle-Kassel). Entrance to mine shaft in which weapons are actually manufactured can be observed from the air. Barracks which are used as quarters for workers, offices, and construction offices are erected around the entrance. The Friedrich Listwerke in Plauen Voigtland manufactured the "Kreiseln"**(remote control arrangement) for the HS 117.

Hornwerke, Oderstrasse 26 in Berlin-Telow makes the rocket engine. Askaniawerke,*** Berlin-Kaiserallee, Friedenau also carries out various details.

Friedenau is also the center for administration for the entire V manufacture.

Figure D.264: H. W. Dix to Francis J. Smith. 14 April 1945. SUBJECT: AZUSA. [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL]

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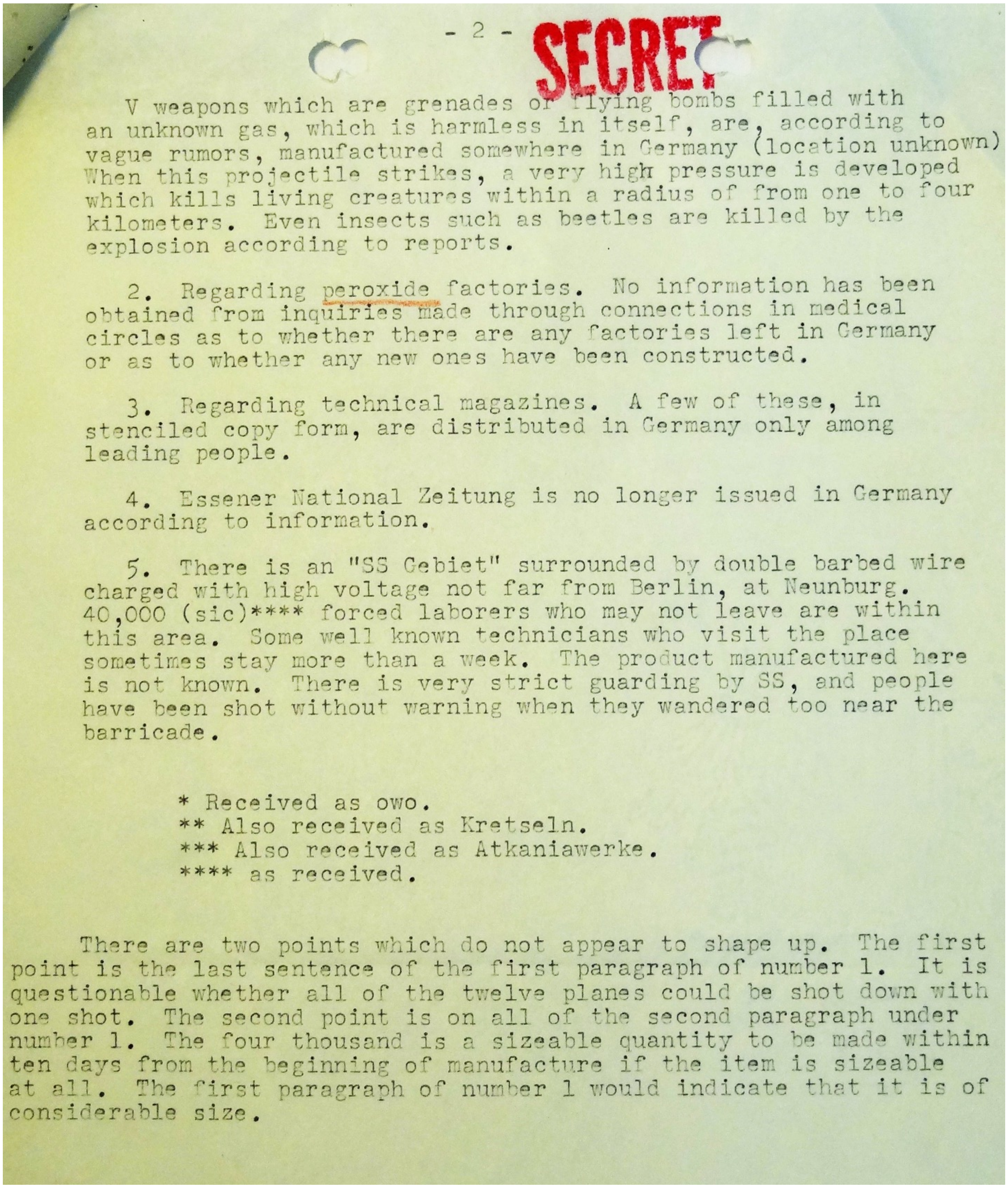
NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL



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V weapons which are grenades or flying bombs filled with an unknown gas, which is harmless in itself, are, according to vague rumors, manufactured somewhere in Germany (location unknown) When this projectile strikes, a very high pressure is developed which kills living creatures within a radius of from one to four kilometers. Even insects such as beetles are killed by the explosion according to reports.

2. Regarding peroxide factories. No information has been obtained from inquiries made through connections in medical circles as to whether there are any factories left in Germany or as to whether any new ones have been constructed.

3. Regarding technical magazines. A few of these, in stenciled copy form, are distributed in Germany only among leading people.

4. Essener National Zeitung is no longer issued in Germany according to information.

5. There is an "SS Gebiet" surrounded by double barbed wire charged with high voltage not far from Berlin, at Neunburg. 40,000 (sic)**** forced laborers who may not leave are within this area. Some well known technicians who visit the place sometimes stay more than a week. The product manufactured here is not known. There is very strict guarding by SS, and people have been shot without warning when they wandered too near the barricade.

* Received as owo.
** Also received as Kretseln.
*** Also received as Atkaniawerke.
**** as received.

There are two points which do not appear to shape up. The first point is the last sentence of the first paragraph of number 1. It is questionable whether all of the twelve planes could be shot down with one shot. The second point is on all of the second paragraph under number 1. The four thousand is a sizeable quantity to be made within ten days from the beginning of manufacture if the item is sizeable at all. The first paragraph of number 1 would indicate that it is of considerable size.

Figure D.265: H. W. Dix to Francis J. Smith. 14 April 1945. SUBJECT: AZUSA. [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL]

Monthly Intelligence Summary. February 1945. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

II INFORMATION ON POSSIBLE T A SITES

7. Saalfeld-Thüringia.

A report dated 19 April 1944 was received from OSS stating that a new weapon is being manufactured in an underground factory at SAALFELD-THÜRINGIA, Germany. The report added that experimental laboratories formerly in Berlin have been transferred to STRASBOURG and installed in a hospital there. The casings and tubings for the weapon were reported to be manufactured in the mechanical workshops in Bitschwiller (Haut-Rhin). Some significance is attached to this report because of the fact that a laboratory of interest to us has been discovered in a hospital in Strasbourg. Air coverage of the Saalfeld area has been obtained and is now being studied. [...]

10. Leitmeritz.

An ungraded report indicated that the production of precision instruments for V-3 is being carried on by the Germans in the town of LEITMERITZ in Sudetenland. According to this report, a large volume of electric power is being directed to the factory. A power survey and aerial coverage of the area have been obtained and are being forwarded to General Groves' office for review.

11. LEHESTEN.

An OSS report states that possible manufacture of long range projectiles is being carried on in a semi-underground installation about 1.5 K.M. north of Lehesten in Germany. T A interest in the report arises from the fact that Siemens and Halske are said to be in charge of the plant, and a reference to the breaking down of water by electrolysis at this site. Aerial coverage has been requested.

[See document photos on pp. 4764–4765.]

Monthly Intelligence Summary. March 1945. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

k. Air photos of a German plant at Muhldorf were forwarded to Major Smith for submission to Dr. Morrison. Interpreters on this side were unable to establish what sort of work was being pursued here.

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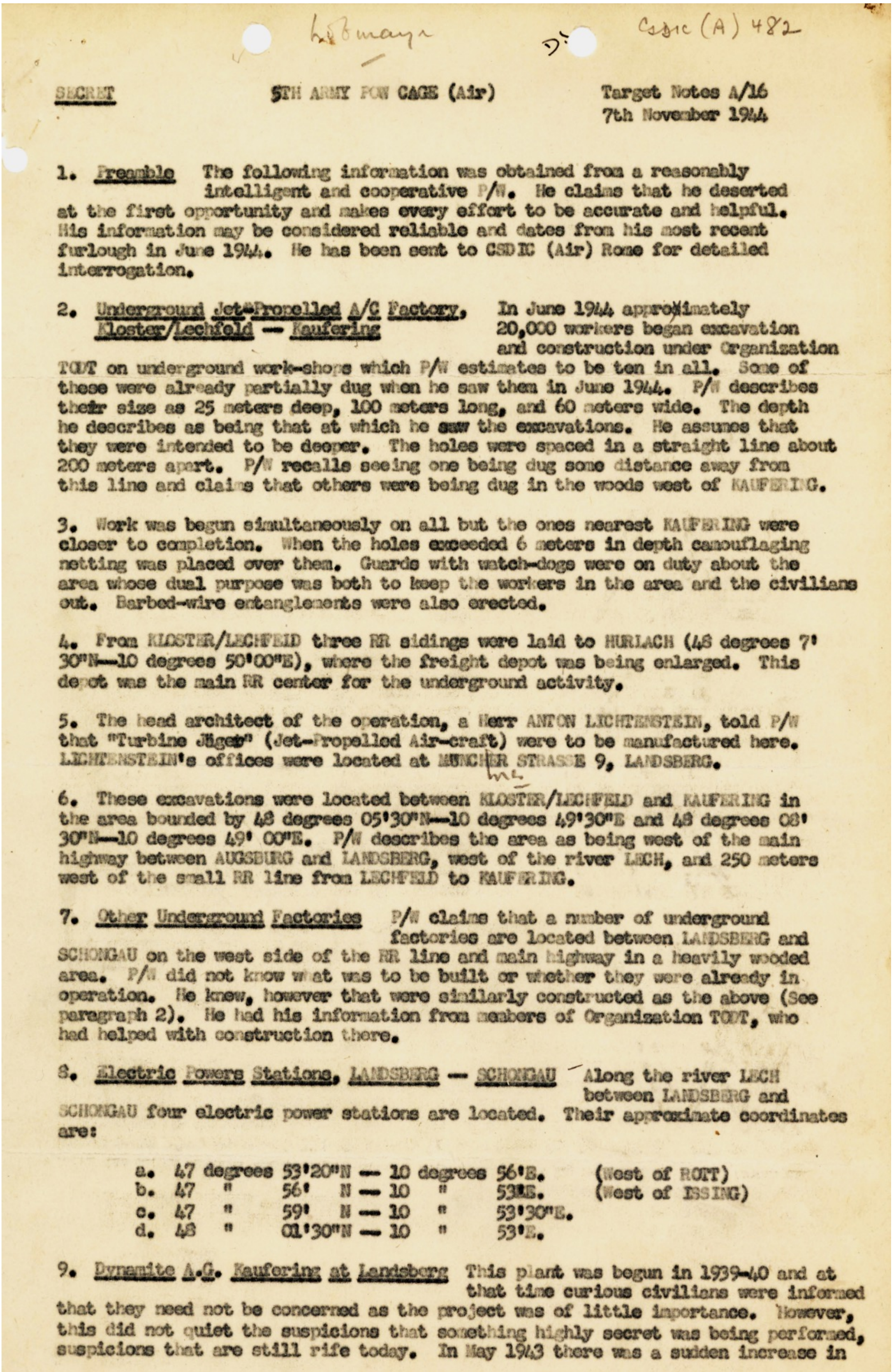
AFHRA folder 512.619C-15A 1943-1945



Lotmayr

Csdic (A) 482

SECRET — 5TH ARMY POW CAGE (Air) — Target Notes A/16
7th November 1944

1. **Preamble** The following information was obtained from a reasonably intelligent and cooperative P/W. He claims that he deserted at the first opportunity and makes every effort to be accurate and helpful. His information may be considered reliable and dates from his most recent furlough in June 1944. He has been sent to CSDIC (Air) Rome for detailed interrogation.

2. **Underground Jet-Propelled A/C Factory, Kloster/Lechfeld — Kaufering** In June 1944 approximately 20,000 workers began excavation and construction under Organization TODT on underground work-shops which P/W estimates to be ten in all. Some of these were already partially dug when he saw them in June 1944. P/W describes their size as 25 meters deep, 100 meters long, and 60 meters wide. The depth he describes as being that at which he saw the excavations. He assumes that they were intended to be deeper. The holes were spaced in a straight line about 200 meters apart. P/W recalls seeing one being dug some distance away from this line and claims that others were being dug in the woods west of KAUFERING.

3. Work was begun simultaneously on all but the ones nearest KAUFERING were closer to completion. When the holes exceeded 6 meters in depth camouflaging netting was placed over them. Guards with watch-dogs were on duty about the area whose dual purpose was both to keep the workers in the area and the civilians out. Barbed-wire entanglements were also erected.

4. From KLOSTER/LECHFELD three RR sidings were laid to HURLACH (48 degrees 7' 30"N—10 degrees 50'00"E), where the freight depot was being enlarged. This depot was the main RR center for the underground activity.

5. The head architect of the operation, a Herr ANTON LICHTENSTEIN, told P/W that "Turbine Jäger" (Jet-Propelled Air-craft) were to be manufactured here. LICHTENSTEIN's offices were located at MÜNCHER STRASSE 9, LANDSBERG.

6. These excavations were located between KLOSTER/LECHFELD and KAUFERING in the area bounded by 48 degrees 05'30"N—10 degrees 49'30"E and 48 degrees 08' 30"N—10 degrees 49' 00"E. P/W describes the area as being west of the main highway between AUGSBURG and LANDSBERG, west of the river LECH, and 250 meters west of the small RR line from LECHFELD to KAUFERING.

7. **Other Underground Factories** P/W claims that a number of underground factories are located between LANDSBERG and SCHONGAU on the west side of the RR line and main highway in a heavily wooded area. P/W did not know what was to be built or whether they were already in operation. He knew, however that were similarly constructed as the above (See paragraph 2). He had his information from members of Organization TODT, who had helped with construction there.

8. **Electric Powers Stations, LANDSBERG — SCHONGAU** Along the river LECH between LANDSBERG and SCHONGAU four electric power stations are located. Their approximate coordinates are:

a.	47	degrees	53'20"N	— 10	degrees	56'E.	(West of ROTT)
b.	47	"	56' N	— 10	"	53'E.	(West of ISSING)
c.	47	"	59' N	— 10	"	53'30"E.	
d.	48	"	01'30"N	— 10	"	53'E.	

9. **Dynamite A.G. Kaufering at Landsberg** This plant was begun in 1939-40 and at that time curious civilians were informed that they need not be concerned as the project was of little importance. However, this did not quiet the suspicions that something highly secret was being performed, suspicions that are still rife today. In May 1943 there was a sudden increase in

Figure D.266: F. A. Duwell. 5th Army POW Cage (Air), Target Notes A/16. 7 November 1944. [AFHRA folder 512.619C-15A 1943–1945; AFHRA A5417 electronic pp. 966–967]

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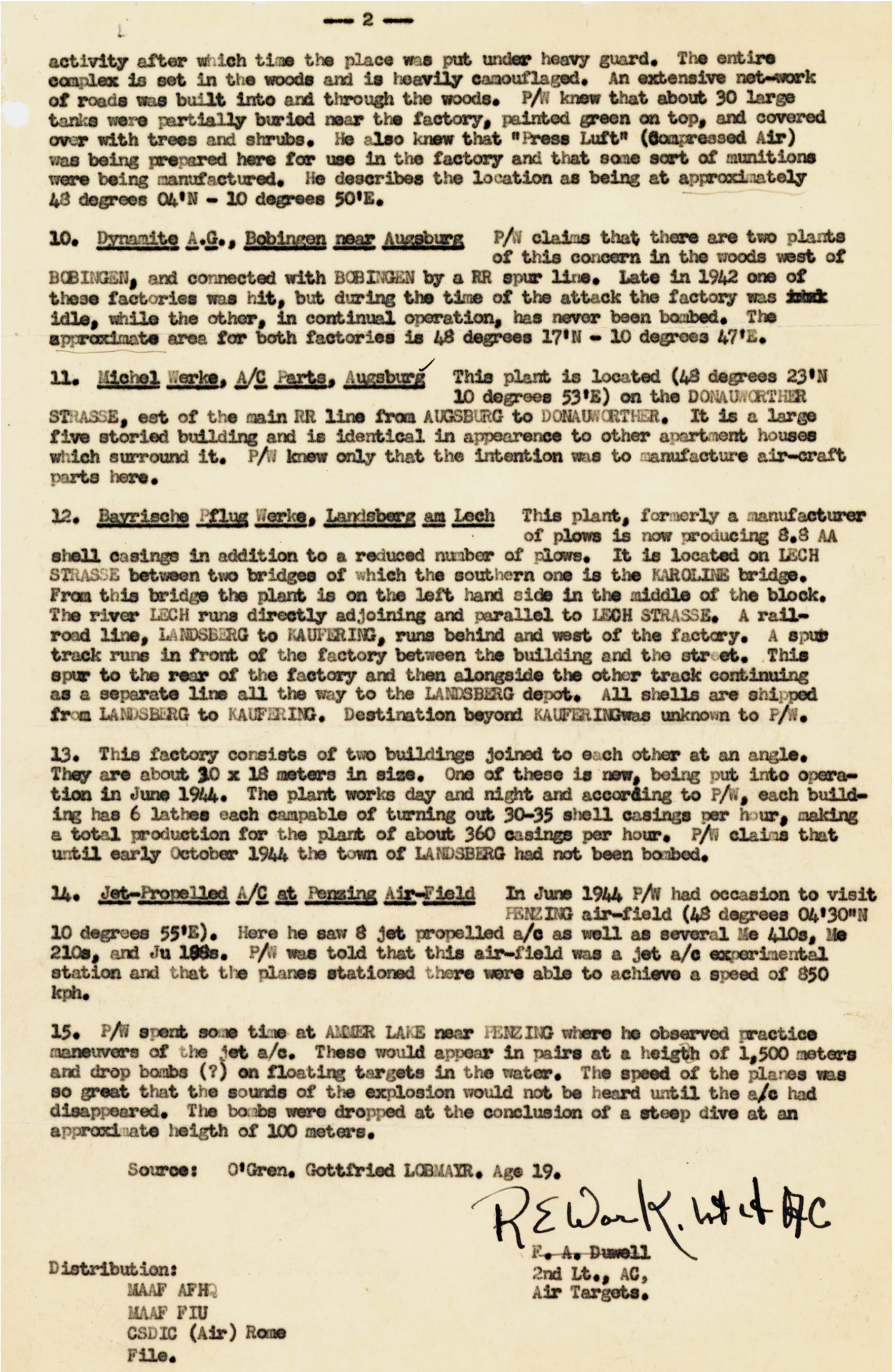
AFHRA folder 512.619C-15A 1943-1945



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activity after which time the place was put under heavy guard. The entire complex is set in the woods and is heavily camouflaged. An extensive net-work of roads was built into and through the woods. P/W knew that about 30 large tanks were partially buried near the factory, painted green on top, and covered over with trees and shrubs. He also knew that "Press Luft" (Compressed Air) was being prepared here for use in the factory and that some sort of munitions were being manufactured. He describes the location as being at approximately 48 degrees 04'N – 10 degrees 50'E.

10. Dynamite A.G., Bobingen near Augsburg P/W claims that there are two plants of this concern in the woods west of BOBINGEN, and connected with BOBINGEN by a RR spur line. Late in 1942 one of these factories was hit, but during the time of the attack the factory was idle, while the other, in continual operation, has never been bombed. The approximate area for both factories is 48 degrees 17'N – 10 degrees 47'E.

11. Michel Werke, A/C Parts, Augsburg This plant is located (48 degrees 23'N 10 degrees 53'E) on the DONAUWORTHER STRASSE, est of the main RR line from AUGSBURG to DONAUWORTHER. It is a large five storied building and is identical in appearence to other apartment houses which surround it. P/W knew only that the intention was to manufacture air-craft parts here.

12. Bayrische Pflug Werke, Landsberg am Lech This plant, formerly a manufacturer of plows is now producing 8.8 AA shell casings in addition to a reduced number of plows. It is located on LECH STRASSE between two bridges of which the southern one is the KAROLINE bridge. From this bridge the plant is on the left hand side in the middle of the block. The river LECH runs directly adjoining and parallel to LECH STRASSE. A railroad line, LANDSBERG to KAUFERING, runs behind and west of the factory. A spur track runs in front of the factory between the building and the street. This spur to the rear of the factory and then alongside the other track continuing as a separate line all the way to the LANDSBERG depot. All shells are shipped from LANDSBERG to KAUFERING. Destination beyond KAUFERINGwas unknown to P/W.

13. This factory consists of two buildings joined to each other at an angle. They are about 30 x 18 meters in size. One of these is new, being put into operation in June 1944. The plant works day and night and according to P/W, each building has 6 lathes each campable of turning out 30-35 shell casings per hour, making a total production for the plant of about 360 casings per hour. P/W claims that until early October 1944 the town of LANDSBERG had not been bombed.

14. Jet-Propelled A/C at Penzing Air-Field In June 1944 P/W had occasion to visit PENZING air-field (48 degrees 04'30"N 10 degrees 55'E). Here he saw 8 jet propelled a/c as well as several Me 410s, Me 210s, and Ju 188s. P/W was told that this air-field was a jet a/c experimental station and that the planes stationed there were able to achieve a speed of 850 kph.

15. P/W spent some time at AMMER LAKE near PENZING where he observed practice maneuvers of the jet a/c. These would appear in pairs at a heigth of 1,500 meters and drop bombs (?) on floating targets in the water. The speed of the planes was so great that the sounds of the explosion would not be heard until the a/c had disappeared. The bombs were dropped at the conclusion of a steep dive at an approximate heigth of 100 meters.

Source: O'Gren. Gottfried LOBMAYR. Age 19.

R E Work. Lt AC

~~F. A. Duwell~~
2nd Lt., AC,
Air Targets.

Distribution:
MAAF AFHQ
MAAF FIU
CSDIC (Air) Rome
File.

Figure D.267: F. A. Duwell. 5th Army POW Cage (Air), Target Notes A/16. 7 November 1944. [AFHRA folder 512.619C-15A 1943–1945; AFHRA A5417 electronic pp. 966–967]

F. A. Duwell. 5th Army POW Cage (Air), Target Notes A/16. 7 November 1944. [AFHRA folder 512.619C-15A 1943–1945; AFHRA A5417 electronic pp. 966–967]

7. Other Underground Factories P/W claims that a number of underground factories are located between LANDSBERG and SCHONGAU on the west side of the RR line and main highway in a heavily wooded area. P/W did not know what was to be built or whether they were already in operation. He knew, however that [they] were similarly constructed as the above (See paragraph 2). He had his information from members of Organization TODT, who had helped with construction there.

8. Electric Power Stations, LANDSBERG—SCHONGAU Along the river LECH between LANDSBERG and SCHONGAU four electric power stations are located. [...]

9. Dynamite A.G. Kaufering at Landsberg This plant was begun in 1939–40 and at that time curious civilians were informed that they need not be concerned as the project was of little importance. However, this did not quiet the suspicions that something highly secret was being performed, suspicions that are still rife today. In May 1943 there was a sudden increase in activity after which time the place was put under heavy guard. The entire complex is set in the woods and is heavily camouflaged. An extensive network of roads was built into and through the woods. P/W knew that about 30 large tanks were partially buried near the factory, painted green on top, and covered over with trees and shrubs. He also knew that “Press Luft” (Compressed Air) was being prepared here for use in the factory and that some sort of munitions were being manufactured. He describes the location as being at approximately 48 degrees 04’N – 10 degrees 50’E.

[See document photos on pp. 3690–3691.]

PARAGRAPHS 30, 31 of MFIU/HQ/CSDIC/12. Undated but apparently late 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

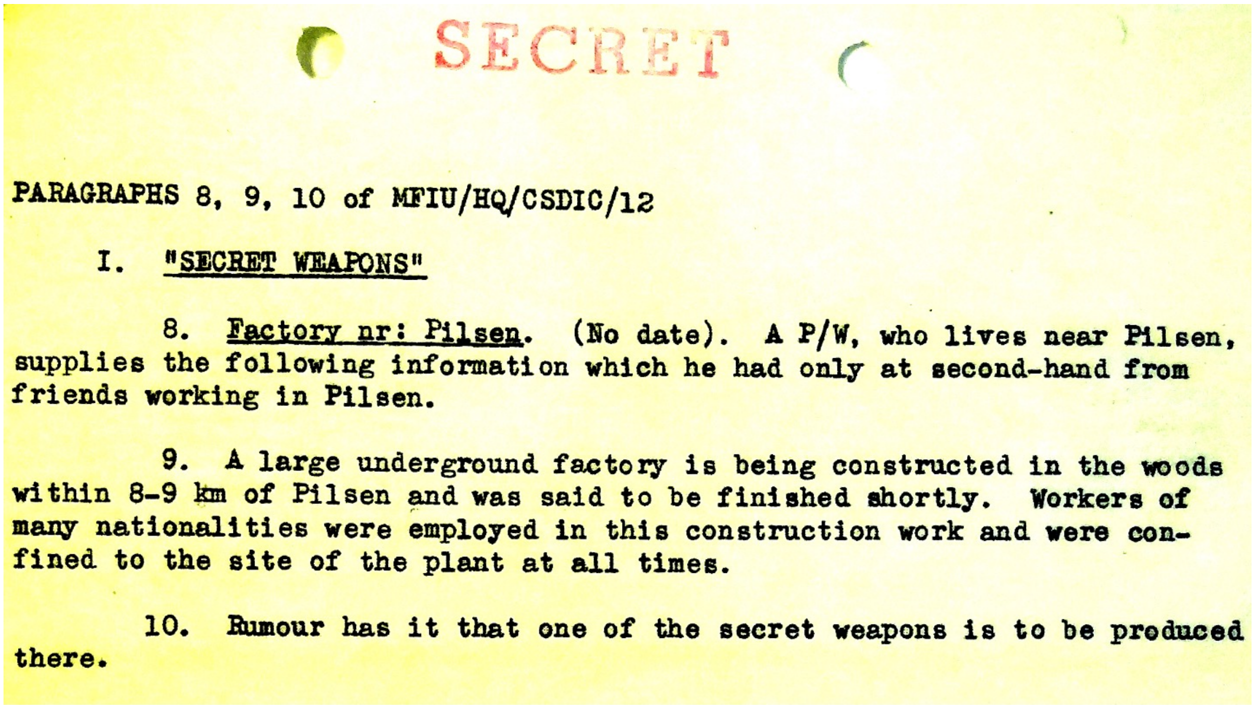
PARAGRAPHS 30, 31 of MFIU/HQ/CSDIC/12

V. EXPLOSIVES

30. Dynamit AG, Kaufering/Landsberg. The source of the following is the same as for paras 28–29 supra. The plant—the approximate location of which is 10^o 50’ E., 48^o 4’ N—was started at the end of 1939. It was said to be of no importance, but the local people are convinced that something very secret is going on there. In May/43 there was a sudden increase in activity after which date the place was put under heavy guard.

31. The whole complex is set in woods and heavily camouflaged, while an extensive net-work of roads was built into and through the woods. The P/W knew of about 30 tanks being built, partially under ground, near the factory and that these tanks were topped with earth in which trees and shrubs were planted. He was certain that some sort of munitions were being made there.

[See document photo on p. 3693 bottom.]



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PARAGRAPHS 8, 9, 10 of MFIU/HQ/CSDIC/12

I. "SECRET WEAPONS"

8. Factory nr: Pilsen. (No date). A P/W, who lives near Pilsen, supplies the following information which he had only at second-hand from friends working in Pilsen.

9. A large underground factory is being constructed in the woods within 8-9 km of Pilsen and was said to be finished shortly. Workers of many nationalities were employed in this construction work and were confined to the site of the plant at all times.

10. Rumour has it that one of the secret weapons is to be produced there.

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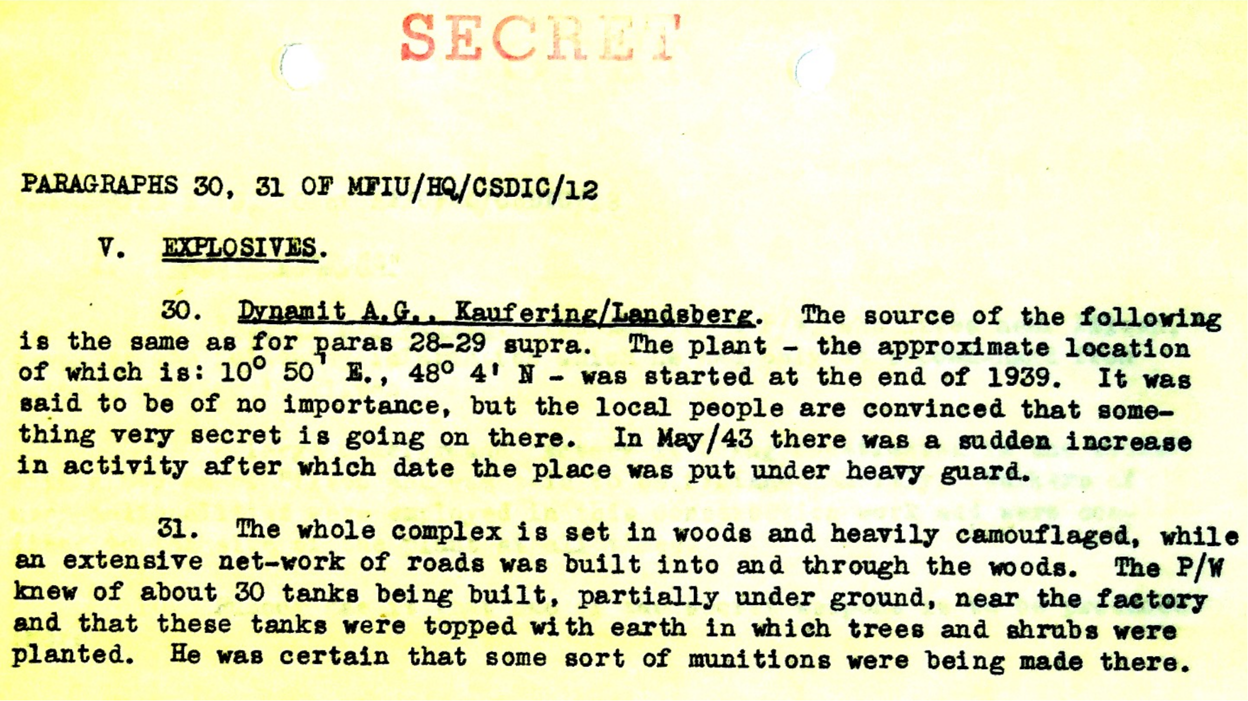
NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)



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PARAGRAPHS 30, 31 OF MFIU/HQ/CSDIC/12

V. EXPLOSIVES.

30. Dynamit A.G., Kaufering/Landsberg. The source of the following is the same as for paras 28-29 supra. The plant - the approximate location of which is: 10° 50' E., 48° 4' N - was started at the end of 1939. It was said to be of no importance, but the local people are convinced that something very secret is going on there. In May/43 there was a sudden increase in activity after which date the place was put under heavy guard.

31. The whole complex is set in woods and heavily camouflaged, while an extensive net-work of roads was built into and through the woods. The P/W knew of about 30 tanks being built, partially under ground, near the factory and that these tanks were topped with earth in which trees and shrubs were planted. He was certain that some sort of munitions were being made there.

Figure D.268: Excerpts from MFIU/HQ/CSDIC/12. Undated but apparently late 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

FF4936 Research on Secret Weapons (January 1945) [NARA RG 226, Entry ??, Box 361?, Folder ??. Published in https://www.hsozkult.de/publicationreview/id/reb-7382]. [See document photo on p. 3695.]

FF4936
Date: January 1945
Evaluation: C-3 (7)

Very urgent INTELLIGENCE
Germany

Research on Secret Weapons

A center of research has been set up at KAPPEL, 37 km. north of Berlin, in a disguised woods. Near this center, and camouflaged by the same woods, there is the whole of E. M. de DOENITZ.

Researches are carried on vigorously upon the "atomic explosion", at the SS Technical Academy at ZELLENDORF (700 m. south of the (RR) station) and especially at BRNO in Bohemia. These experiments are pursued intensively by the old establishments of BAYER (the special section of the I. G. Farben near Berlin and in the vicinity of Regensburg).

[Apparently added later:]

see paragraphs 3 and 4 of cable 2877 December 21, 1944, from Bern IN—29784

MAR 20 1945

[It is very interesting that this report took on a renewed urgency for the U.S. on 20 March 1945, and that the information added then refers to a cable from Bern by U.S. spy Moe Berg; note that the actual date of that cable appears to be December 31, not December 21 [Petersen 2008, p. 625].]

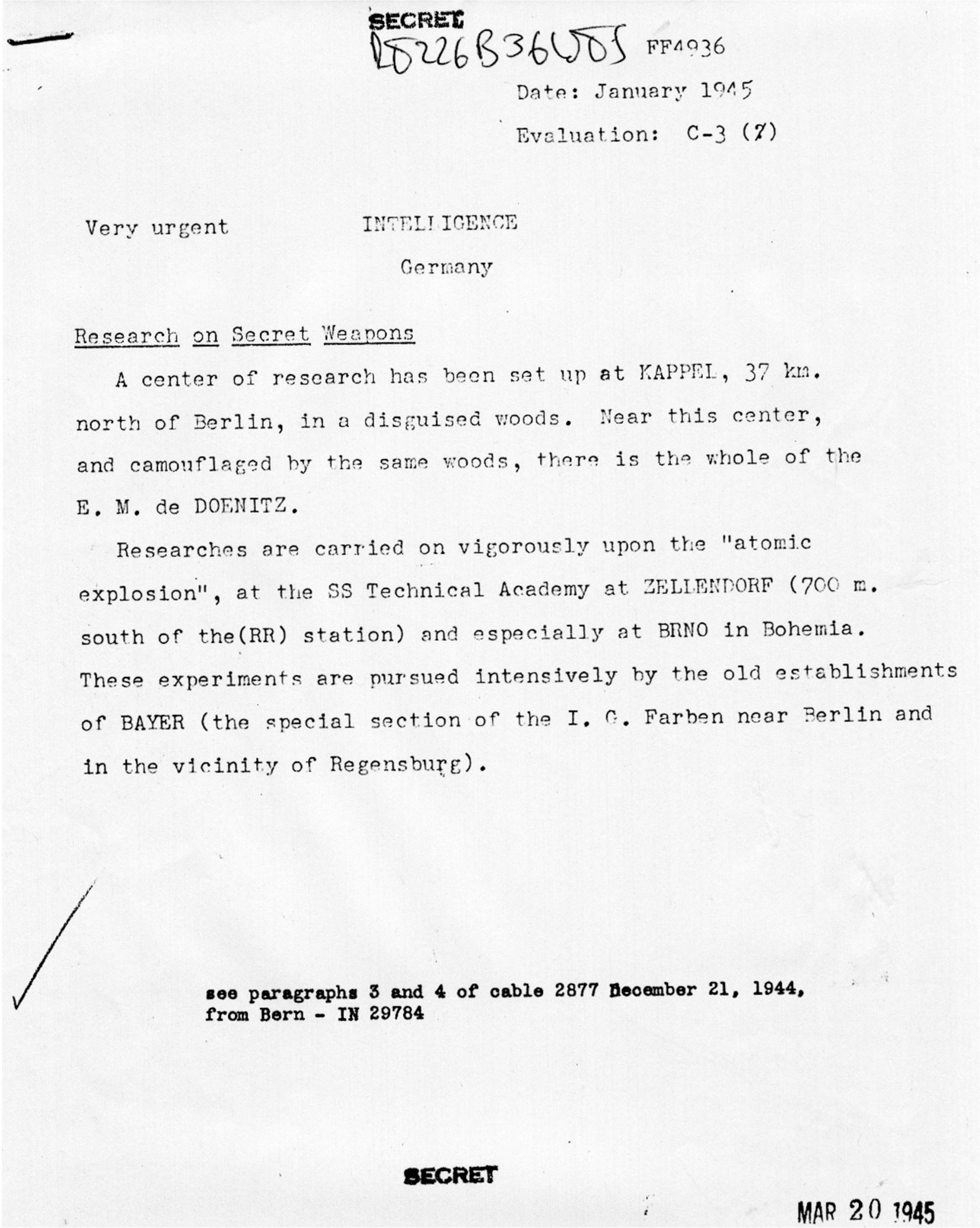
Monthly Intelligence Summary. March 1945. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

c. A report was received that a research center engaged in work on "atomic explosion" has been set up near Koralle, 37 kilometers north of Berlin. A study of air coverage of this area failed to reveal any visual evidence of TA activity.

[The correct name of this site appears to be Koralle as mentioned in the second document, not Kappel as mentioned in the first. (Perhaps the "p"s were "ρ"s, indicating a Slavic origin for this intelligence?) The German Naval High Command was located there during 1943–1945 (the first document mentioned Admiral Doenitz), and there may well have been other facilities in the same general area.]

CSDIC (AFHQ) A 315 (F.N. 721). 5 February 1944. HE 177—Germany's New Bomber Hope: Detailed interrogation report on He 177's shot down on January 23rd and 24th. [AFHRA A5417 electronic pp. 882, 886]

48. In many forest regions of Germany including one near REGENSBURG, the home of the P/W, the manufacture of the secret weapon or weapons is being rushed with utmost energy. Extreme security precautions are taken, such as keeping the workers in the factory, and not permitting them to go home.



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RG226B36W05 FF4936

Date: January 1945

Evaluation: C-3 (7)

Very urgent

INTELLIGENCE

Germany

Research on Secret Weapons

A center of research has been set up at KAPPEL, 37 km. north of Berlin, in a disguised woods. Near this center, and camouflaged by the same woods, there is the whole of the E. M. de DOENITZ.

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see paragraphs 3 and 4 of cable 2877 December 21, 1944, from Bern - IN 29784

SECRET

MAR 20 1945

Figure D.269: FF4936 Research on Secret Weapons (January 1945) [NARA RG 226, Entry ??, Box 361, Folder ??. Published in https://www.hsozkult.de/publicationreview/id/reb-7382].

[NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

OFFICE OF STRATEGIC SERVICES
WASHINGTON, D.C.

DISTRIBUTED	27 March 1945	DISSEMINATION NO.	A-52702
COUNTRY	Germany, Austria, and Protectorate	ORIGINAL REPORT NO.	B-1879, B-2040
SUBJECT	Research Institutes; Alcohol	DATE OF REPORT	6, 15 March 1945
		EVALUATION	F-3
		CONFIRMATION	
SOURCE	Z	SUPPLEMENT	
SUB SOURCE		CORRECTION	
		NUMBER OF PAGES	2
DATE OF INFORMATION	1 March 1945	ATTACHMENTS	
PLACE OF ORIGIN	Switzerland	THEATRE	

Research Institutes

1. According to informant, eight research institutes whose purpose is the development of V-weapons, gases, bacteriological means of warfare, and atom smashing devices have existed or are functioning in Germany and Austria. Their locations are as follows:

   (a) Peenemünde (about 40 km northwest of Swinemünde)

   (b) Tegernsee (about 50 km south-southeast of Munich)

   (c) Schloss Hohenzollern at Sigmaringen

   (d) A stone quarry near Lebestan (sic—this may be Lehesten, about 50 km west of Plauen)

   (e) Tübingen. Nothing definite is known about this institute.

   (f) Floridsdorf, in the northeastern portion of Vienna. The institute is now closed, and its equipment is believed to have been moved to Tegernsee.

   (g) Freiburg-im-Breisgau. The institute is now closed, and its equipment is believed to have been moved to Sigmaringen.

   OSS Washington Comment: According to another informant, the Schloss Hohenzollern mentioned is located about 20 km south-southwest of Tübingen, not at Sigmaringen. This may be the missing eighth location.

Alcohol

2. A ball bearing factory in Hronow (about 130 km northeast of Prague) is adding alcohol to the gasoline for starting and landing rocket planes and for the new ramming plane (Rammflugzeug).

3. Alcohol is being distilled from wine for this purpose. It is expected that 2,000,000 liters will be obtained from the Schlumberger Co. of Vöslau (30 km south-southwest of Vienna).

Doc. No. 112, Subject: Waldow, Willi (27 September 1946). [NARA RG 319, Entry A1-134A, Box 17, Folder XE 169886, Russian Deportation of German Scientists and Technicians]

[...] Subject, while traveling between the Russian and American Zones on the 29th August 1946, made the acquaintance of a Mr. BRUECKNER in the railroad station STASSFURT (M52/D66). The conversation that took place consisted of BRUECKNER's description of his recent forced employment and subsequent escape from a Russian underground factory, located at SALZBERGWERKE (M52/D66) near STASSFURT. BRUECKNER, a German engineer, formerly engaged in atomic research as early as 1934 stated that a group of between two or three thousand Germans with scientific and technical backgrounds are being forcibly engaged at working on experiments dealing with atomic energy pertaining to development of the atomic bomb, as well as rocket experiments with the "V 2". The site of this factory is supposedly that of a former German underground factory used to manufacture special types of weapons during the war, located as SALZBERGWERKE. According to Subject BRUECKNER further stated that despite his previous knowledge of atomic energy, the work now being conducted is in an entirely new field.

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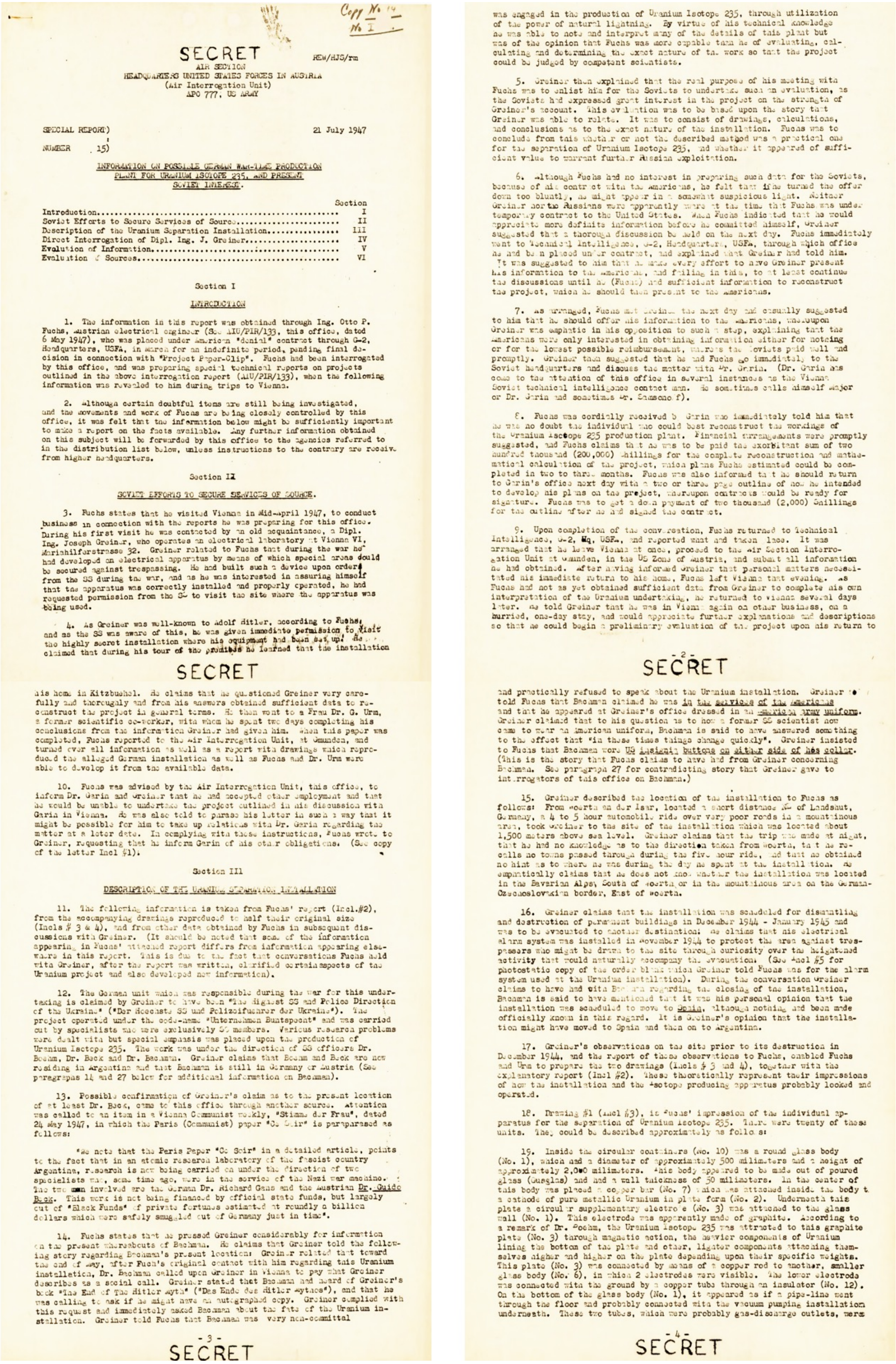
AFHRA folder 506.619B 1945-47



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REW/HJS/rm

AIR SECTION
HEADQUARTERS UNITED STATES FORCES IN AUSTRIA
(Air Interrogation Unit)
APO 777, US ARMY

SPECIAL REPORT)
NUMBER 15)

21 July 1947

INFORMATION ON POSSIBLE GERMAN WAR-TIME PRODUCTION
PLANT FOR URANIUM ISOTOPE 235, AND PRESENT
SOVIET INTEREST.

Section
Introduction.. I
Soviet Efforts to Secure Services of Source........................... II
Description of the Uranium Separation Installation.................... III
Direct Interrogation of Dipl. Ing. J. Greiner......................... IV
Evolution of Information.. V
Evaluation of Sources... VI

Section I

INTRODUCTION

1. The information in this report was obtained through Ing. Otto P. Fuchs, Austrian electrical engineer (See AIU/PIR/133, this office, dated 6 May 1947), who was placed under American "denial" contract through G-2, Headquarters, USFA, in March for an indefinite period, pending final decision in connection with "Project Paper-Clip". Fuchs had been interrogated by this office, and was preparing special technical reports on projects outlined in the above interrogation report (AIU/PIR/133), when the following information was revealed to him during trips to Vienna.

2. Although certain doubtful items are still being investigated, and the movements and work of Fuchs are being closely controlled by this office, it was felt that the information below might be sufficiently important to make a report on the facts available. Any further information obtained on this subject will be forwarded by this office to the agencies referred to in the distribution list below, unless instructions to the contrary are received from higher headquarters.

Section II

SOVIET EFFORTS TO SECURE SERVICES OF SOURCE.

3. Fuchs states that he visited Vienna in Mid-April 1947, to conduct business in connection with the reports he was preparing for this office. During his first visit he was contacted by an old acquaintance, a Dipl. Ing. Joseph Greiner, who operates an electrical laboratory at Vienna VI, Mariahilferstrasse 32. Greiner related to Fuchs that during the war he had developed an electrical apparatus by means of which special areas could be secured against trespassing. He had built such a device upon orders from the SS during the war, and as he was interested in assuring himself that the apparatus was correctly installed and properly operated, he had requested permission from the SS to visit the site where the apparatus was being used.

4. As Greiner was well-known to Adolf Hitler, according to Fuchs, and as the SS was aware of this, he was given immediate permission to visit the highly secret installation where his equipment had been set up. He claimed that during his tour of the premises he learned that the installation was engaged in the production of Uranium Isotope 235, through utilization of the power of natural lightning. By virtue of his technical knowledge he was able to note and interpret many of the details of this plant but was of the opinion that Fuchs was more capable than he of evaluating, calculating and determining the exact nature of the work so that the project could be judged by competent scientists.

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5. Greiner then explained that the real purpose of his meeting with Fuchs was to enlist him for the Soviets to undertake such an evaluation, as the Soviets had expressed great interest in the project on the strength of Greiner's account. This evaluation was to be based upon the story that Greiner was able to relate. It was to consist of drawings, calculations, and conclusions as to the exact nature of the installation. Fuchs was to conclude from this whether or not the described method was a practical one for the separation of Uranium Isotope 235, and whether it appeared of sufficient value to warrant further Russian exploitation.

6. Although Fuchs had no interest in preparing such data for the Soviets, because of his contract with the Americans, he felt that if he turned the offer down too bluntly, he might appear in a somewhat suspicious light. Neither Greiner nor the Russians were apparently aware at the time that Fuchs was under temporary contract to the United States. When Fuchs indicated that he would appreciate more definite information before he committed himself, Greiner suggested that a thorough discussion be held on the next day. Fuchs immediately went to Technical Intelligence, G-2, Headquarters, USFA, through which office he had been placed under contract, and explained what Greiner had told him. It was suggested to him that he make every effort to have Greiner present his information to the Americans, and failing in this, to at least continue the discussions until he (Fuchs) had sufficient information to reconstruct the project, which he should then present to the Americans.

7. As arranged, Fuchs met Greiner the next day and casually suggested to him that he should offer his information to the Americans, whereupon Greiner was emphatic in his opposition to such a step, explaining that the Americans were only interested in obtaining information either for nothing or for the lowest possible reimbursement, whereas the Soviets paid well and promptly. Greiner then suggested that he and Fuchs go immediately to the Soviet headquarters and discuss the matter with Dr. Garin. (Dr. Garin has come to the attention of this office in several instances as the Vienna Soviet technical intelligence contact man. He sometimes calls himself Major or Dr. Garin and sometimes Dr. Samsonoff).

8. Fuchs was cordially received by Garin who immediately told him that he was no doubt the individual who could best reconstruct the workings of the Uranium Isotope 235 production plant. Financial arrangements were promptly suggested, and Fuchs claims that he was to be paid the exorbitant sum of two hundred thousand (200,000) Shillings for the complete reconstruction and mathematical calculation of the project, which plans Fuchs estimated could be completed in two to three months. Fuchs was also informed that he should return to Garin's office next day with a two or three page outline of how he intended to develop his plans on the project, whereupon contracts would be ready for signature. Fuchs was to get a down payment of two thousand (2,000) Shillings for the outline after he had signed the contract.

9. Upon completion of the conversation, Fuchs returned to Technical Intelligence, G-2, Hq, USFA, and reported what had taken place. It was arranged that he leave Vienna at once, proceed to the Air Section Interrogation Unit at Gmunden, in the US Zone of Austria, and submit all information he had obtained. After having informed Greiner that personal matters necessitated his immediate return to his home, Fuchs left Vienna that evening. As Fuchs had not as yet obtained sufficient data from Greiner to complete his own interpretation of the Uranium undertaking, he returned to Vienna several days later. He told Greiner that he was in Vienna again on other business, on a hurried, one-day stay, and would appreciate further explanations and descriptions so that he could begin a preliminary evaluation of the project upon his return to his home in Kitzbuehel. He claims that he questioned Greiner very carefully and thoroughly and from his answers obtained sufficient data to reconstruct the project in general terms. He then went to a Frau Dr. G. Urm, a former scientific co-worker, with whom he spent two days completing his conclusions from the information Greiner had given him. When this paper was completed, Fuchs reported to the Air Interrogation Unit, at Gmunden, and turned over all information as well as a report with drawings which reproduced the alleged German installation as well as Fuchs and Dr. Urm were able to develop it from the available data.

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10. Fuchs was advised by the Air Interrogation Unit, this office, to inform Dr. Garin and Greiner that he had accepted other employment and that he would be unable to undertake the project outlined in his discussion with Garin in Vienna. He was also told to phrase his letter in such a way that it might be possible for him to take up relations with Dr. Garin regarding the matter at a later date. In complying with these instructions, Fuchs wrote to Greiner, requesting that he inform Garin of his other obligations. (See copy of the letter Incl #1).

Section III

DESCRIPTION OF THE URANIUM SEPARATION INSTALLATION

11. The following information is taken from Fuchs' report (Incl.#2), from the accompanying drawings reproduced to half their original size (Incls # 3 & 4), and from other data obtained by Fuchs in subsequent discussions with Greiner. (It should be noted that some of the information appearing in Fuchs' attached report differs from information appearing elsewhere in this report. This is due to the fact that conversations Fuchs held with Greiner, after the report was written, clarified certain aspects of the Uranium project and also developed new information).

12. The German unit which was responsible during the war for this undertaking is claimed by Greiner to have been "The Highest SS and Police Direction of the Ukraine" ("Der Hoechste SS und Polizeifuehrer der Ukraine"). The project operated under the code-name "Unternehmen Buntspecht" and was carried out by specialists who were exclusively SS members. Various research problems were dealt with but special emphasis was placed upon the production of Uranium Isotope 235. The work was under the direction of SS officers Dr. Boehm, Dr. Beck and Dr. Bachman. Greiner claims that Boehm and Beck are now residing in Argentina and that Bachman is still in Germany or Austria (See paragraphs 14 and 27 below for additional information on Bachman).

13. Possible confirmation of Greiner's claim as to the present location of at least Dr. Beck, came to this office through another source. Attention was called to an item in a Vienna Communist weekly, "Stimme der Frau", dated 24 May 1947, in which the Paris (Communist) paper "Ce Soir" is paraphrased as follows:

> "We note that the Paris Paper "Ce Soir" in a detailed article, points to the fact that in an atomic research laboratory of the fascist country Argentina, research is now being carried on under the direction of two specialists who, some time ago, were in the service of the Nazi war machine. The two men involved are the German Dr. Richard Gans and the Austrian Dr. Guido Beck. This work is not being financed by official state funds, but largely out of "Black Funds" of private fortunes estimated at roundly a billion dollars which were safely smuggled out of Germany just in time".

14. Fuchs states that he pressed Greiner considerably for information on the present whereabouts of Bachman. He claims that Greiner told the following story regarding Bachman's present location: Greiner related that toward the end of May, after Fuch's original contact with him regarding this Uranium installation, Dr. Bachman called upon Greiner in Vienna to pay what Greiner describes as a social call. Greiner stated that Bachman had heard of Greiner's book "The End of The Hitler Myth" ("Das Ende des Hitler Mythos"), and that he was calling to ask if he might have an autographed copy. Greiner complied with this request and immediately asked Bachman about the fate of the Uranium installation. Greiner told Fuchs that Bachman was very non-committal and practically refused to speak about the Uranium installation. Greiner told Fuchs that Bachman claimed he was in the services of the Americans and that he appeared at Greiner's office dressed in an American army uniform. Greiner claimed that to his question as to how a former SS scientist now came to wear an American uniform, Bachman is said to have answered something to the effect that "in these times things change quickly". Greiner insisted to Fuchs that Bachman wore US insignia buttons on either side of his collar. (This is the story that Fuchs claims to have had from Greiner concerning Bachman. See paragraph 27 for contradicting story that Greiner gave to interrogators of this office on Bachman.)

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15. Greiner described the location of the installation to Fuchs as follows: From Woerth an der Isar, located a short distance NE of Landshut, Germany, a 4 to 5 hour automobile ride over very poor roads in a mountainous area, took Greiner to the site of the installation which was located about 1,500 meters above sea level. Greiner claims that the trip was made at night, that he had no knowledge as to the direction taken from Woerth, that he recalls no towns passed through during the five hour ride, and that he obtained no hint as to where he was during the day he spent at the installation. He emphatically claims that he does not know whether the installation was located in the Bavarian Alps, South of Woerth, or in the mountainous area on the German-Czechoslovakian border, East of Woerth.

16. Greiner claims that the installation was scheduled for dismantling and destruction of permanent buildings in December 1944 - January 1945 and was to be evacuated to another destination. He claims that his electrical alarm system was installed in November 1944 to protect the area against trespassers who might be drawn to the site through curiosity over the heightened activity that would naturally accompany the evacuation. (See Incl #5 for photostatic copy of the order blank which Greiner told Fuchs was for the alarm system used at the Uranium installation). During the conversation Greiner claims to have had with Bachman regarding the closing of the installation, Bachman is said to have mentioned that it was his personal opinion that the installation was scheduled to move to Spain, although nothing had been made officially known in this regard. It is Greiner's opinion that the installation might have moved to Spain and then on to Argentina.

17. Greiner's observations on the site prior to its destruction in December 1944, and the report of these observations to Fuchs, enabled Fuchs and Urm to prepare the two drawings (Incls # 3 and 4), together with the explanatory report (Incl #2). These theoretically represent their impressions of how the installation and the Isotope producing apparatus probably looked and operated.

18. Drawing #1 (Incl #3), is Fuchs' impression of the individual apparatus for the separation of Uranium Isotope 235. There were twenty of these units. They could be described approximately as follows:

19. Inside the circular containers (No. 10) was a round glass body (No. 1), which had a diameter of approximately 500 milimeters and a height of approximately 2,000 milimeters. This body appeared to be made out of poured glass (Gussglas) and had a wall thickness of 50 milimeters. In the center of this body was placed a copper bar (No. 7) which was attached inside the body to a cathode of pure metallic Uranium in plate form (No. 2). Underneath this plate a circular supplementary electrode (No. 3) was attached to the glass wall (No. 1). This electrode was apparently made of graphite. According to a remark of Dr. Boehm, the Uranium Isotope 235 was attracted to this graphite plate (No. 3) through magnetic action, the heavier components of Uranium lining the bottom of the plate and other, lighter components attaching themselves higher and higher on the plate depending upon their specific weights. This plate (No. 3) was connected by means of a copper rod to another, smaller glass body (No. 6), in which 2 electrodes were visible. The lower electrode was connected with the ground by a copper tube through an insulator (No. 12). On the bottom of the glass body (No. 1), it appeared as if a pipe-line went through the floor and probably connected with the vacuum pumping installation underneath. These two tubes, which were probably gas-discharge outlets, were

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Figure D.270: Robert E. Work. 21 July 1947. Information on Possible German War-Time Production Plant for Uranium Isotope 235, and Present Soviet Interest. [AFHRA folder 506.619B 1945–47; AFHRA A5183 frames 0497–0504] Postwar interrogations mentioned a wartime electromagnetic uranium enrichment plant at an unspecified site in the Bavarian Alps.

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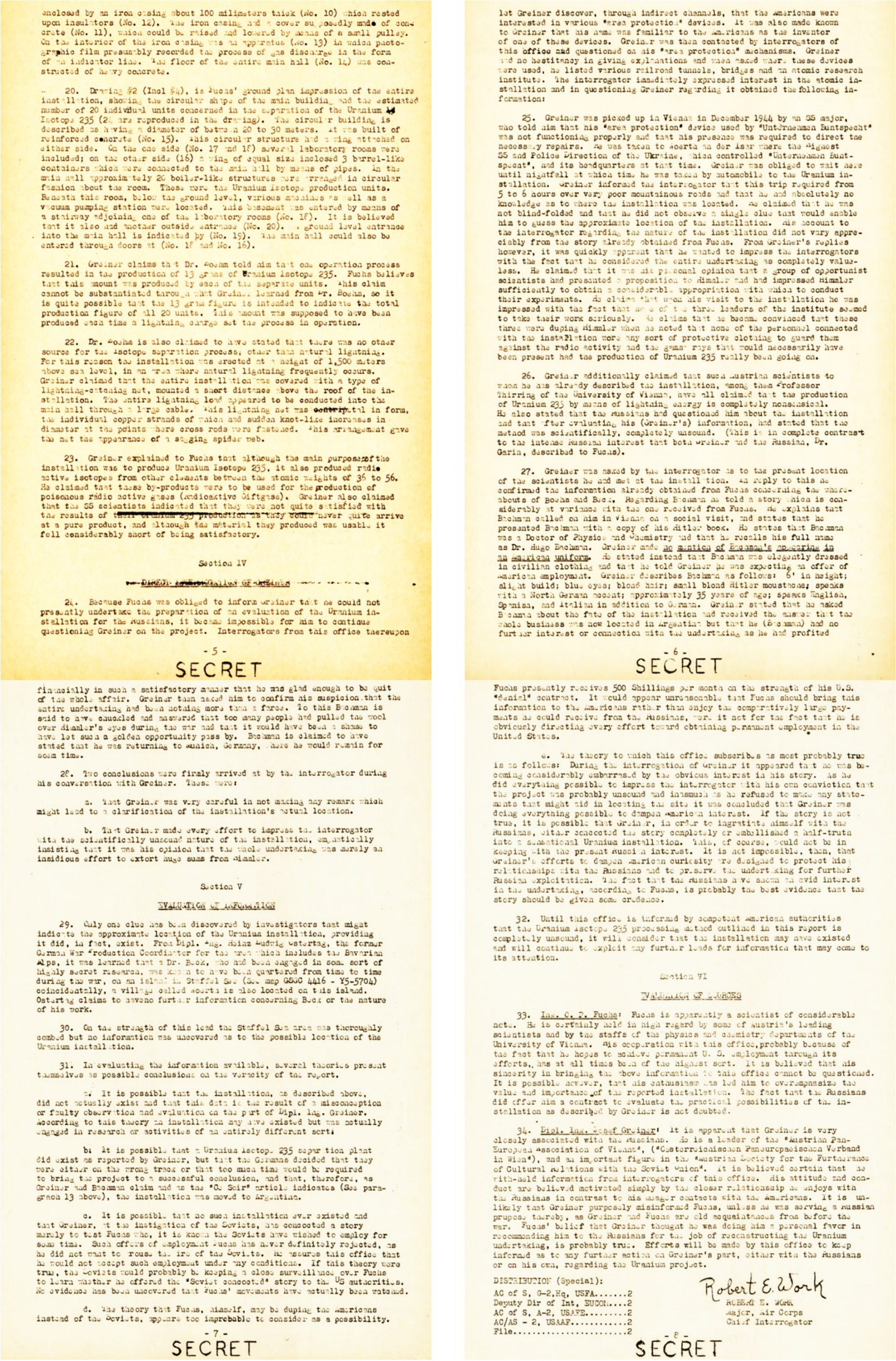

enclosed by an iron casing about 100 milimeters thick (No. 10) which rested upon insulators (No. 12). The iron casing and a cover supposedly made of concrete (No. 11), which could be raised and lowered by means of a small pulley. On the interior of the iron casing was an apparatus (No. 13) in which photographic film presumably recorded the process of gas discharge in the form of an indicator line. The floor of the entire main hall (No. 14) was constructed of heavy concrete.

20. Drawing #2 (Incl #4), is Fuchs' ground plan impression of the entire installation, showing the circular shape of the main building and the estimated number of 20 individual units concerned in the separation of the Uranium Isotope 235 (2[illegible] are reproduced in the drawing). The circular building is described as having a diameter of between 20 to 30 meters. It was built of reinforced concrete (No. 15). This circular structure had a wing attached on either side. On the one side (No. 17 and 18) several laboratory rooms were included; on the other side (16) a wing of equal size inclosed 3 barrel-like containers which were connected to the main hall by means of pipes. In the main hall approximately 20 boiler-like structures were arranged in circular fashion about the room. These were the Uranium Isotope production units. Beneath this room, below the ground level, various machines as well as a vacuum pumping station were located. This basement was entered by means of a stairway adjoining one of the laboratory rooms (No. 18). It is believed that it also had another outside entrance (No. 20). A ground level entrance into the main hall is indicated by (No. 19). The main hall could also be entered through doors at (No. 18 and No. 16).

21. Greiner claims that Dr. Boehm told him that one operation process resulted in the production of 13 grams of Uranium Isotope 235. Fuchs believes that this amount was produced by each of the separate units. This claim cannot be substantiated through what Greiner learned from Dr. Boehm, so it is quite possible that the 13 gram figure is intended to indicate the total production figure of all 20 units. This amount was supposed to have been produced each time a lightning charge set the process in operation.

22. Dr. Boehm is also claimed to have stated that there was no other source for the Isotope separation process, other than natural lightning. For this reason the installation was erected at a height of 1,500 meters above sea level, in an area where natural lightning frequently occurs. Greiner claimed that the entire installation was covered with a type of lightning-catching net, mounted a short distance above the roof of the installation. The entire lightning load appeared to be conducted into the main hall through a large cable. This lightning net was centripetal in form, the individual copper strands of which had sudden knot-like increases in diameter at the points where cross rods were fastened. This arrangement gave the net the appearance of a sagging spider web.

23. Greiner explained to Fuchs that although the main purpose of the installation was to produce Uranium Isotope 235, it also produced radio active isotopes from other elements between the atomic weights of 36 to 56. He claimed that these by-products were to be used for the production of poisonous radio active gases (Radioaktive Giftgase). Greiner also claimed that the SS scientists indicated that they were not quite satisfied with the results of ~~their Uranium 235 production as they could~~ never quite arrive at a pure product, and although the material they produced was usable it fell considerably short of being satisfactory.

Section IV

DIRECT INTERROGATION OF GREINER

24. Because Fuchs was obliged to inform Greiner that he could not presently undertake the preparation of an evaluation of the Uranium installation for the Russians, it became impossible for him to continue questioning Greiner on the project. Interrogators from this office thereupon

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let Greiner discover, through indirect channels, that the Americans were interested in various "area protection" devices. It was also made known to Greiner that his name was familiar to the Americans as the inventor of one of these devices. Greiner was then contacted by interrogators of this office and questioned on his "area protection" mechanisms. Greiner had no hesitancy in giving explanations and when asked where these devices were used, he listed various railroad tunnels, bridges and an atomic research institute. The interrogator immediately expressed interest in the atomic installation and in questioning Greiner regarding it obtained the following information:

25. Greiner was picked up in Vienna in December 1944 by an SS major, who told him that his "area protection" device used by "Unternehmen Buntspecht" was not functioning properly and that his presence was required to direct the necessary repairs. He was taken to Woerth an der Isar where the Highest SS and Police Direction of the Ukraine, which controlled "Unternehmen Buntspecht", had its headquarters at that time. Greiner was obliged to wait here until nightfall at which time he was taken by automobile to the Uranium installation. Greiner informed the interrogator that this trip required from 5 to 6 hours over very poor mountainous roads and that he had absolutely no knowledge as to where the installation was located. He claimed that he was not blind-folded and that he did not observe a single clue that would enable him to guess the approximate location of the installation. His account to the interrogator regarding the nature of the installation did not vary appreciably from the story already obtained from Fuchs. From Greiner's replies however, it was quickly apparent that he wanted to impress the interrogators with the fact that he considered the entire undertaking as completely valueless. He claimed that it was his personal opinion that a group of opportunist scientists had presented a proposition to Himmler and had impressed Himmler sufficiently to obtain a considerable appropriation with which to conduct their experiments. He claims that upon his visit to the installation he was impressed with the fact that none of the three leaders of the institute seemed to take their work seriously. He claims that he became convinced that these three were duping Himmler when he noted that none of the personnel connected with the installation wore any sort of protective clothing to guard them against the radio activity and the gamma rays that would necessarily have been present had the production of Uranium 235 really been going on.

26. Greiner additionally claimed that such Austrian scientists to whom he has already described the installation, among them Professor Thirring of the University of Vienna, have all claimed that the production of Uranium 235 by means of lightning energy is completely nonsensical. He also stated that the Russians had questioned him about the installation and that after evaluating his (Greiner's) information, had stated that the method was scientifically, completely unsound. (This is in complete contrast to the intense Russian interest that both Greiner and the Russian, Dr. Garin, described to Fuchs).

27. Greiner was asked by the interrogator as to the present location of the scientists he had met at the installation. In reply to this he confirmed the information already obtained from Fuchs concerning the whereabouts of Boehm and Beck. Regarding Bachman he told a story which is considerably at variance with the one received from Fuchs. He explains that Bachman called on him in Vienna on a social visit, and states that he presented Bachman with a copy of his Hitler book. He states that Bachman was a Doctor of Physics and Chemistry and that he recalls his full name as Dr. Hugo Bachman. Greiner made no mention of Bachman's appearing in an American uniform. He stated instead that Bachman was elegantly dressed in civilian clothing and that he told Greiner he was expecting an offer of American employment. Greiner describes Bachman as follows: 6' in height; slight build; blue eyes; blond hair; small blond Hitler moustache; speaks with a North German accent; approximately 35 years of age; speaks English, Spanish, and Italian in addition to German. Greiner stated that he asked Bachman about the fate of the installation and received the answer that the whole business was now located in Argentina but that he (Bachman) had no further interest or connection with the undertaking as he had profited

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financially in such a satisfactory manner that he was glad enough to be quit of the whole affair. Greiner then asked him to confirm his suspicion that the entire undertaking had been nothing more than a farce. To this Bachman is said to have chuckled and answered that too many people had pulled the wool over Himmler's eyes during the war and that it would have been a shame to have let such a golden opportunity pass by. Bachman is claimed to have stated that he was returning to Munich, Germany, where he would remain for some time.

28. Two conclusions were firmly arrived at by the interrogator during his conversation with Greiner. These were:

a. That Greiner was very careful in not making any remark which might lead to a clarification of the installation's actual location.

b. That Greiner made every effort to impress the interrogator with the scientifically unsound nature of the installation, emphatically insisting that it was his opinion that the whole undertaking was merely an insidious effort to extort huge sums from Himmler.

Section V

EVALUATION OF INFORMATION

29. Only one clue has been discovered by investigators that might indicate the approximate location of the Uranium installation, providing it did, in fact, exist. From Dipl. Ing. Heinz Ludwig Ostertag, the former German War Production Coordinator for the area which includes the Bavarian Alps, it was learned that a Dr. Beck, who had been engaged in some sort of highly secret research, was known to have been quartered from time to time during the war, on an island in Staffel See (See map GSGC 4416 - Y5-5704) coincidentally, a village called Woerth is also located on this island. Ostertag claims to haveno further information concerning Beck or the nature of his work.

30. On the strength of this lead the Staffel See area was thoroughly combed but no information was uncovered as to the possible location of the Uranium installation.

31. In evaluating the information available, several theories present themselves as possible conclusions on the veracity of the report.

a. It is possible that the installation, as described above, did not actually exist and that this data is the result of a misconception or faulty observation and evaluation on the part of Dipl. Ing. Greiner. According to this theory an installation may have existed but was actually engaged in research or activities of an entirely different sort.

b. It is possible that a Uranium Isotope 235 separation plant did exist as reported by Greiner, but that the Germans decided that they were either on the wrong track or that too much time would be required to bring the project to a successful conclusion, and that, therefore, as Greiner and Bachman claim and as the "Ce Soir" article indicates (See paragraph 13 above), the installation was moved to Argentina.

c. It is possible that no such installation ever existed and that Greiner, at the instigation of the Soviets, has concocted a story merely to test Fuchs who, it is known the Soviets have wished to employ for some time. Such offers of employment Fuchs has never definitely rejected, as he did not want to arouse the ire of the Soviets. He assures this office that he would not accept such employment under any conditions. If this theory were true, the Soviets would probably be keeping a close surveillance over Fuchs to learn whether he offered the "Soviet concocted" story to the US authorities. No evidence has been uncovered that Fuchs' movements have actually been watched.

d. The theory that Fuchs, himself, may be duping the Americans instead of the Soviets, appears too improbable to consider as a possibility.

- 7 -

SECRET

Fuchs presently receives 500 Shillings per month on the strength of his U.S. "denial" contract. It would appear unreasonable that Fuchs should bring this information to the Americans rather than enjoy the comparatively large payments he could receive from the Russians, were it not for the fact that he is obviously directing every effort toward obtaining permanent employment in the United States.

e. The theory to which this office subscribes as most probably true is as follows: During the interrogation of Greiner it appeared that he was becoming considerably embarrassed by the obvious interest in his story. As he did everything possible to impress the interrogator with his own conviction that the project was probably unsound and inasmuch as he refused to make any statements that might aid in locating the site it was concluded that Greiner was doing everything possible to dampen American interest. If the story is not true, it is possible that Greiner, in order to ingratiate himself with the Russians, either concocted the story completely or embellished a half-truth into a sensational Uranium installation. This, of course, would not be in keeping with the present Russian interest. It is not impossible, then, that Greiner's efforts to dampen American curiosity are designed to protect his relationships with the Russians and to preserve the undertaking for further Russian exploitation. The fact that the Russians have shown an avid interest in the undertaking, according to Fuchs, is probably the best evidence that the story should be given some credence.

32. Until this office is informed by competent American authorities that the Uranium Isotope 235 processing method outlined in this report is completely unsound, it will consider that the installation may have existed and will continue to exploit any further leads for information that may come to its attention.

Section VI

EVALUATION OF SOURCES

33. Ing. C. P. Fuchs: Fuchs is apparently a scientist of considerable note. He is certainly held in high regard by some of Austria's leading scientists and by the staffs of the physics and chemistry departments of the University of Vienna. His cooperation with this office, probably because of the fact that he hopes to achieve permanent U. S. employment through its efforts, has at all times been of the highest sort. It is believed that his sincerity in bringing the above information to this office cannot be questioned. It is possible however, that his enthusiasm has led him to overemphasize the value and importance of the reported installation. The fact that the Russians did offer him a contract to evaluate the practical possibilities of the installation as described by Greiner is not doubted.

34. Dipl. Ing. Josef Greiner: It is apparent that Greiner is very closely associated with the Russians. He is a leader of the "Austrian Pan-European Association of Vienna", ("Oesterreichischen Paneuropaeischen Verband in Wien"), and an important figure in the "Austrian Society for the Furtherance of Cultural Relations with the Soviet Union". It is believed certain that he with-held information from interrogators of this office. His attitude and conduct are believed motivated simply by the closer relationship he enjoys with the Russians in contrast to his meager contacts with the Americans. It is unlikely that Greiner purposely misinformed Fuchs, unless he was serving a Russian purpose thereby, as Greiner and Fuchs are old acquaintances from before the war. Fuchs' belief that Greiner thought he was doing him a personal favor in recommending him to the Russians for the job of reconstructing the Uranium undertaking, is probably true. Efforts will be made by this office to keep informed as to any further action on Greiner's part, either with the Russians or on his own, regarding the Uranium project.

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Robert E. Work
ROBERT E. WORK
Major, Air Corps
Chief Interrogator

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SECRET

AFHRA folder 506.619B 1945-47

Figure D.271: Robert E. Work. 21 July 1947. Information on Possible German War-Time Production Plant for Uranium Isotope 235, and Present Soviet Interest. [AFHRA folder 506.619B 1945–47; AFHRA A5183 frames 0497–0504] Postwar interrogations mentioned a wartime electromagnetic uranium enrichment plant at an unspecified site in the Bavarian Alps.

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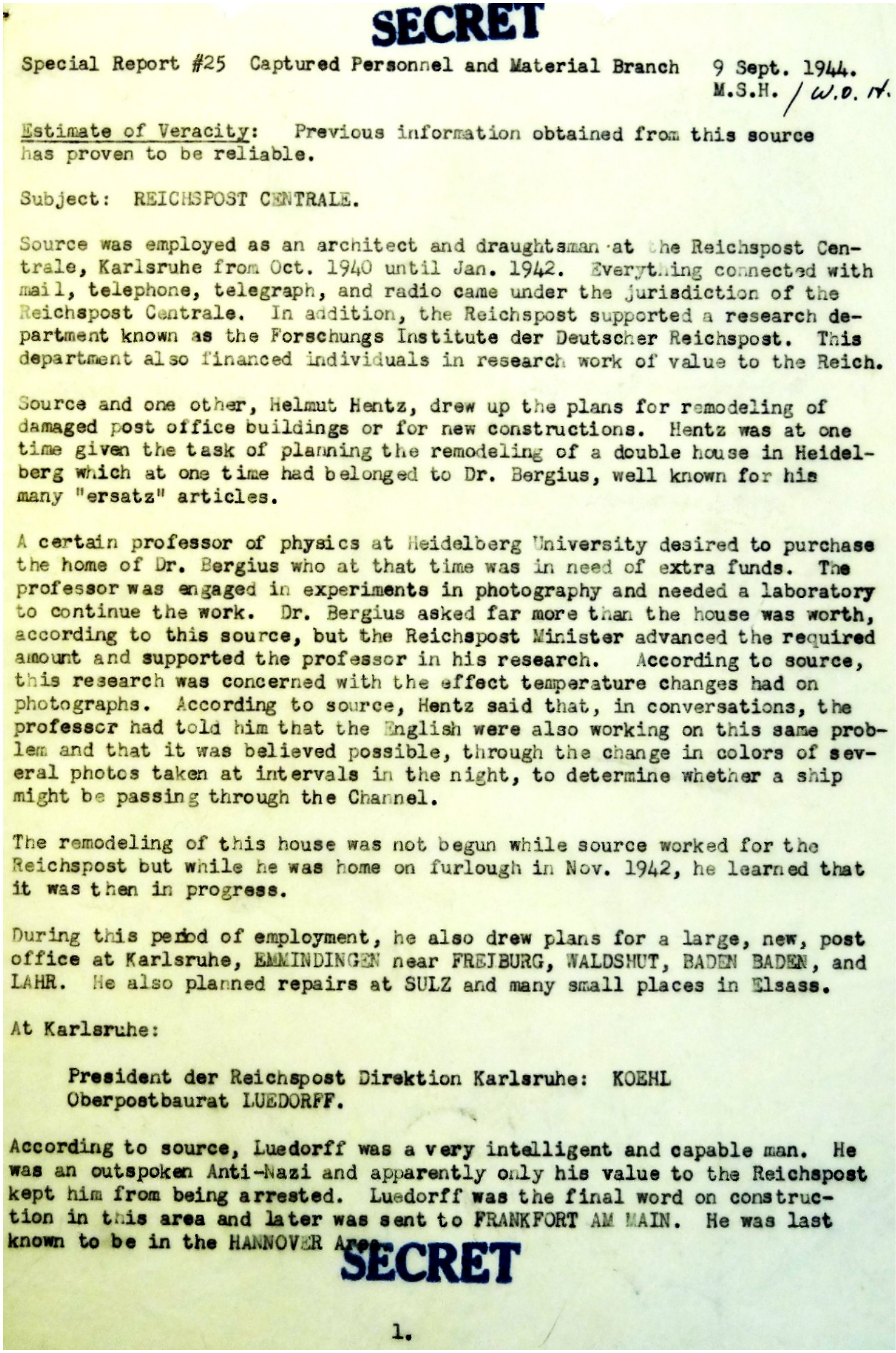

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Special Report #25 Captured Personnel and Material Branch 9 Sept. 1944.
M.S.H. / W.O. H.

Estimate of Veracity: Previous information obtained from this source has proven to be reliable.

Subject: REICHSPOST CENTRALE.

Source was employed as an architect and draughtsman at the Reichspost Centrale, Karlsruhe from Oct. 1940 until Jan. 1942. Everything connected with mail, telephone, telegraph, and radio came under the jurisdiction of the Reichspost Centrale. In addition, the Reichspost supported a research department known as the Forschungs Institute der Deutscher Reichspost. This department also financed individuals in research work of value to the Reich.

Source and one other, Helmut Hentz, drew up the plans for remodeling of damaged post office buildings or for new constructions. Hentz was at one time given the task of planning the remodeling of a double house in Heidelberg which at one time had belonged to Dr. Bergius, well known for his many "ersatz" articles.

A certain professor of physics at Heidelberg University desired to purchase the home of Dr. Bergius who at that time was in need of extra funds. The professor was engaged in experiments in photography and needed a laboratory to continue the work. Dr. Bergius asked far more than the house was worth, according to this source, but the Reichspost Minister advanced the required amount and supported the professor in his research. According to source, this research was concerned with the effect temperature changes had on photographs. According to source, Hentz said that, in conversations, the professor had told him that the English were also working on this same problem and that it was believed possible, through the change in colors of several photos taken at intervals in the night, to determine whether a ship might be passing through the Channel.

The remodeling of this house was not begun while source worked for the Reichspost but while he was home on furlough in Nov. 1942, he learned that it was then in progress.

During this period of employment, he also drew plans for a large, new, post office at Karlsruhe, EMMINDINGEN near FREIBURG, WALDSHUT, BADEN BADEN, and LAHR. He also planned repairs at SULZ and many small places in Elsass.

At Karlsruhe:

President der Reichspost Direktion Karlsruhe: KOEHL
Oberpostbaurat LUEDORFF.

According to source, Luedorff was a very intelligent and capable man. He was an outspoken Anti-Nazi and apparently only his value to the Reichspost kept him from being arrested. Luedorff was the final word on construction in this area and later was sent to FRANKFORT AM MAIN. He was last known to be in the HANNOVER Area.

SECRET

1.

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July-October 1944)

Figure D.272: Special Report #25 Captured Personnel and Material Branch. 9 September 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

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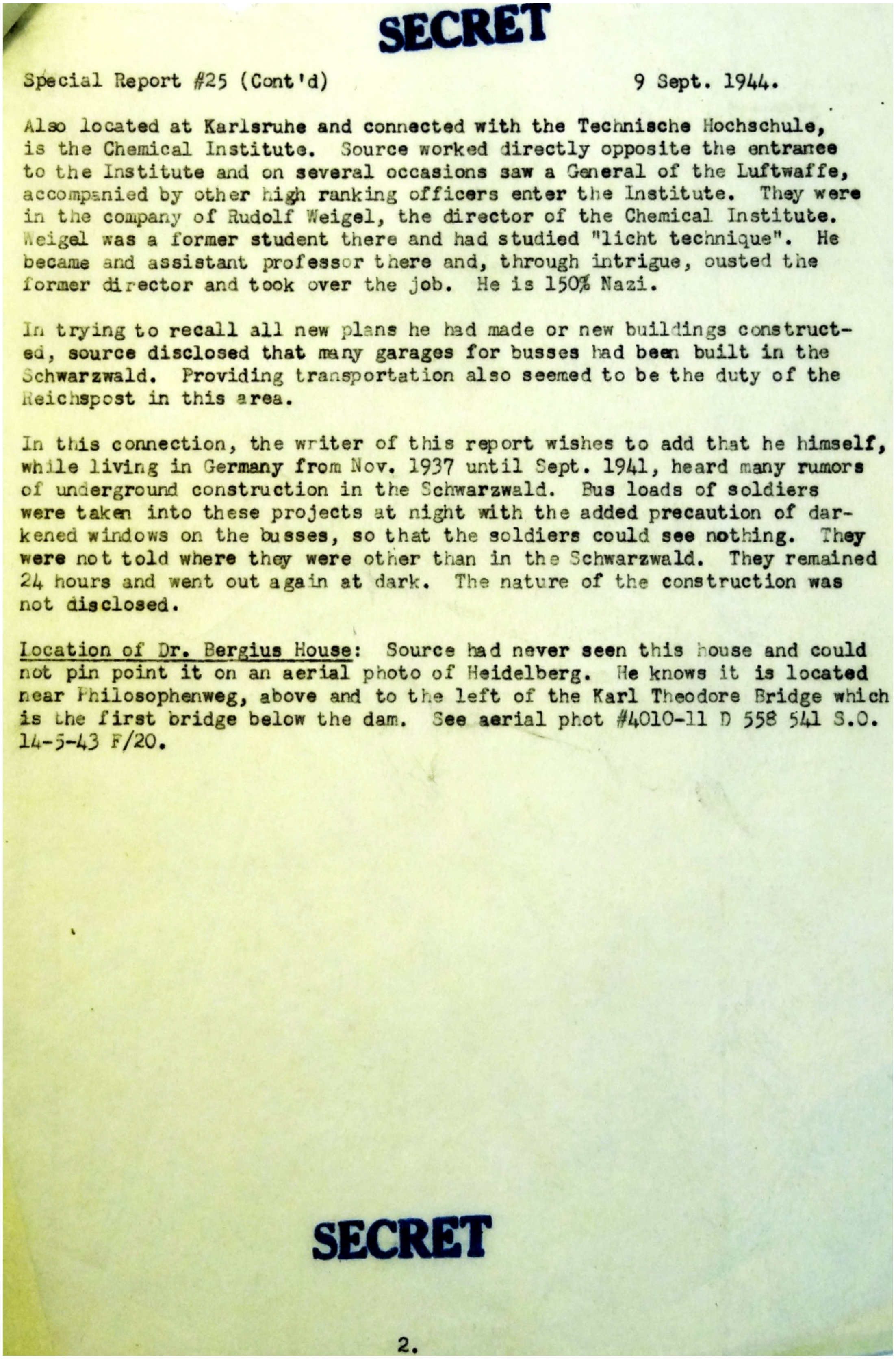
NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July-October 1944)



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Special Report #25 (Cont'd) 9 Sept. 1944.

Also located at Karlsruhe and connected with the Technische Hochschule, is the Chemical Institute. Source worked directly opposite the entrance to the Institute and on several occasions saw a General of the Luftwaffe, accompanied by other high ranking officers enter the Institute. They were in the company of Rudolf Weigel, the director of the Chemical Institute. Weigel was a former student there and had studied "licht technique". He became and assistant professor there and, through intrigue, ousted the former director and took over the job. He is 150% Nazi.

In trying to recall all new plans he had made or new buildings constructed, source disclosed that many garages for busses had been built in the Schwarzwald. Providing transportation also seemed to be the duty of the Reichspost in this area.

In this connection, the writer of this report wishes to add that he himself, while living in Germany from Nov. 1937 until Sept. 1941, heard many rumors of underground construction in the Schwarzwald. Bus loads of soldiers were taken into these projects at night with the added precaution of darkened windows on the busses, so that the soldiers could see nothing. They were not told where they were other than in the Schwarzwald. They remained 24 hours and went out again at dark. The nature of the construction was not disclosed.

Location of Dr. Bergius House: Source had never seen this house and could not pin point it on an aerial photo of Heidelberg. He knows it is located near Philosophenweg, above and to the left of the Karl Theodore Bridge which is the first bridge below the dam. See aerial phot #4010-11 D 558 541 S.O. 14-5-43 F/20.

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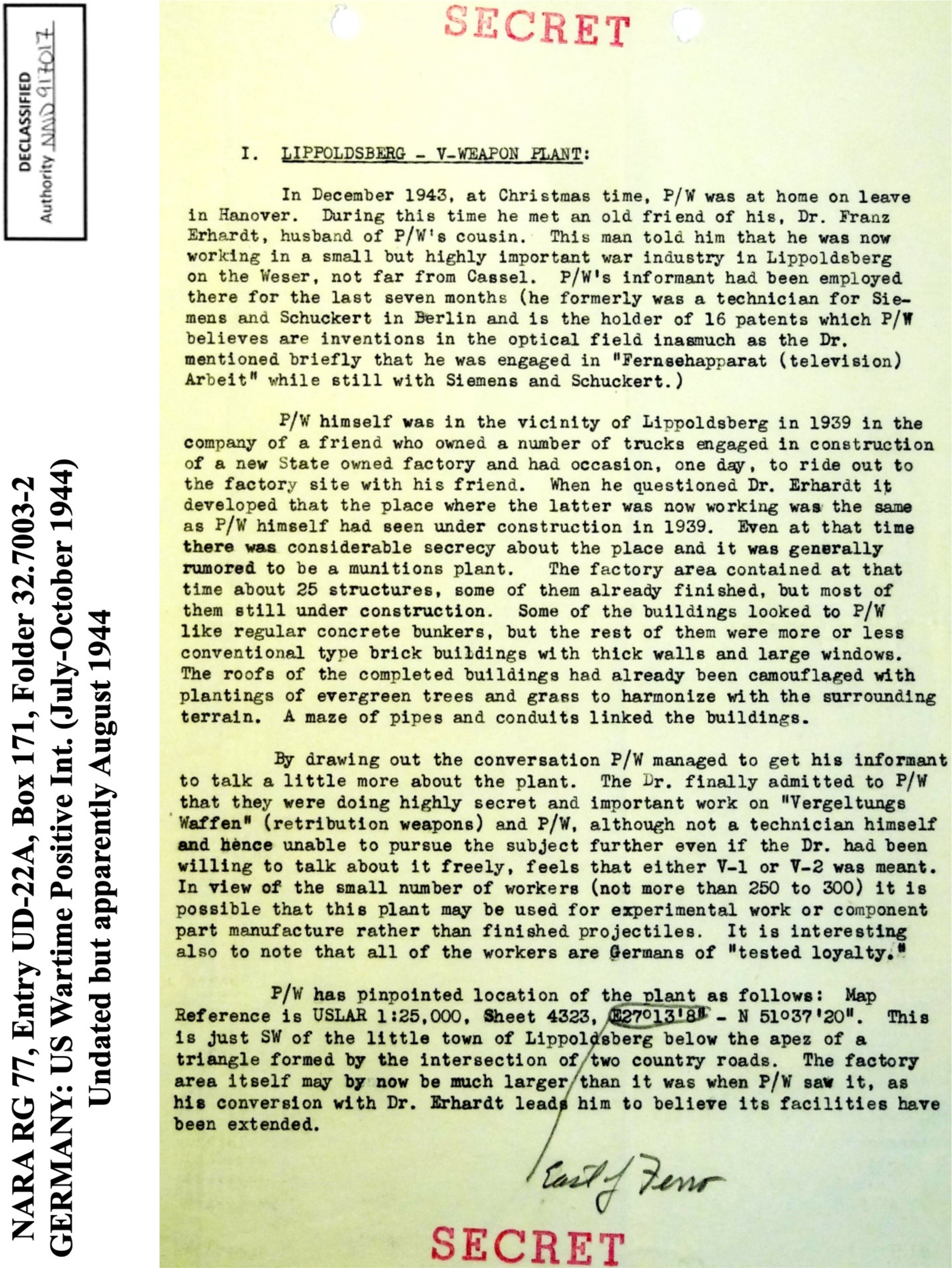
2.

Figure D.273: Special Report #25 Captured Personnel and Material Branch. 9 September 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].



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NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July-October 1944)
Undated but apparently August 1944

SECRET

I. LIPPOLDSBERG - V-WEAPON PLANT:

In December 1943, at Christmas time, P/W was at home on leave in Hanover. During this time he met an old friend of his, Dr. Franz Erhardt, husband of P/W's cousin. This man told him that he was now working in a small but highly important war industry in Lippoldsberg on the Weser, not far from Cassel. P/W's informant had been employed there for the last seven months (he formerly was a technician for Siemens and Schuckert in Berlin and is the holder of 16 patents which P/W believes are inventions in the optical field inasmuch as the Dr. mentioned briefly that he was engaged in "Fernsehapparat (television) Arbeit" while still with Siemens and Schuckert.)

P/W himself was in the vicinity of Lippoldsberg in 1939 in the company of a friend who owned a number of trucks engaged in construction of a new State owned factory and had occasion, one day, to ride out to the factory site with his friend. When he questioned Dr. Erhardt it developed that the place where the latter was now working was the same as P/W himself had seen under construction in 1939. Even at that time there was considerable secrecy about the place and it was generally rumored to be a munitions plant. The factory area contained at that time about 25 structures, some of them already finished, but most of them still under construction. Some of the buildings looked to P/W like regular concrete bunkers, but the rest of them were more or less conventional type brick buildings with thick walls and large windows. The roofs of the completed buildings had already been camouflaged with plantings of evergreen trees and grass to harmonize with the surrounding terrain. A maze of pipes and conduits linked the buildings.

By drawing out the conversation P/W managed to get his informant to talk a little more about the plant. The Dr. finally admitted to P/W that they were doing highly secret and important work on "Vergeltungs Waffen" (retribution weapons) and P/W, although not a technician himself and hence unable to pursue the subject further even if the Dr. had been willing to talk about it freely, feels that either V-1 or V-2 was meant. In view of the small number of workers (not more than 250 to 300) it is possible that this plant may be used for experimental work or component part manufacture rather than finished projectiles. It is interesting also to note that all of the workers are Germans of "tested loyalty."

P/W has pinpointed location of the plant as follows: Map Reference is USLAR 1:25,000, Sheet 4323, E27°13'8" - N 51°37'20". This is just SW of the little town of Lippoldsberg below the apez of a triangle formed by the intersection of two country roads. The factory area itself may by now be much larger than it was when P/W saw it, as his conversion with Dr. Erhardt leads him to believe its facilities have been extended.

East of Ferro

SECRET

Figure D.274: Lippoldsberg—V-Weapon Plant. Undated but apparently August 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)]. From the description, this sounds like a potential nuclear site, and Leslie Groves's Foreign Intelligence Unit thought it sounded like a potential nuclear site.

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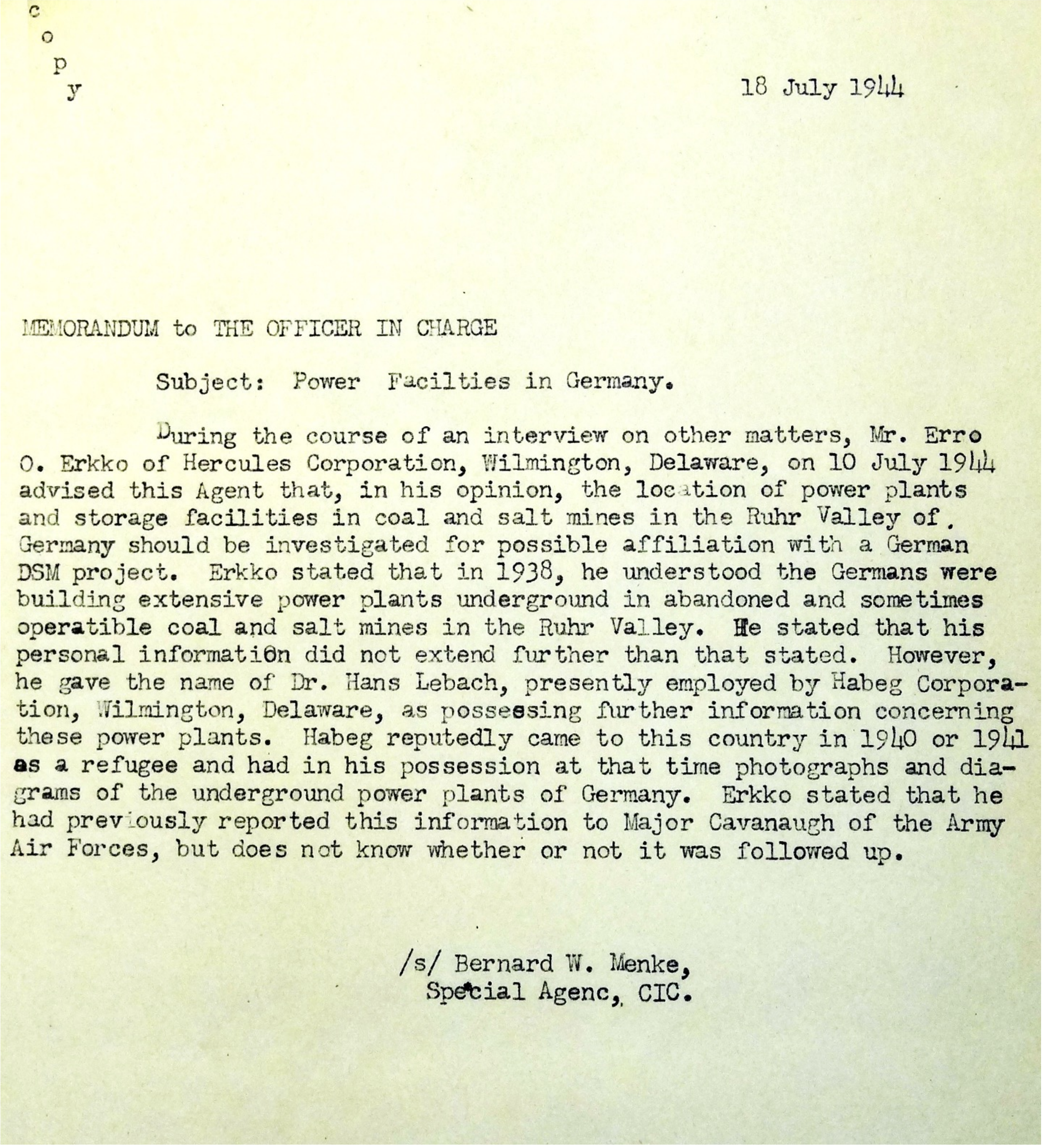
NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July-Oct. 1944)



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18 July 1944

MEMORANDUM to THE OFFICER IN CHARGE

Subject: Power Facilties in Germany.

During the course of an interview on other matters, Mr. Erro O. Erkko of Hercules Corporation, Wilmington, Delaware, on 10 July 1944 advised this Agent that, in his opinion, the location of power plants and storage facilities in coal and salt mines in the Ruhr Valley of Germany should be investigated for possible affiliation with a German DSM project. Erkko stated that in 1938, he understood the Germans were building extensive power plants underground in abandoned and sometimes operatible coal and salt mines in the Ruhr Valley. He stated that his personal information did not extend further than that stated. However, he gave the name of Dr. Hans Lebach, presently employed by Habeg Corporation, Wilmington, Delaware, as possessing further information concerning these power plants. Habeg reputedly came to this country in 1940 or 1941 as a refugee and had in his possession at that time photographs and diagrams of the underground power plants of Germany. Erkko stated that he had previously reported this information to Major Cavanaugh of the Army Air Forces, but does not know whether or not it was followed up.

/s/ Bernard W. Menke,
Special Agenc, CIC.

Figure D.275: Bernard W. Menke. 18 July 1944. Subject: Power Facilities in Germany. "Erkko stated that in 1938, he understood the Germans were building extensive power plants underground in abandoned and sometimes operatible coal and salt mines in the Ruhr Valley.... Habeg reputedly came to this country in 1940 or 1941 as a refugee and had in his possession at that time photographs and diagrams of the underground power plants of Germany." [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)]

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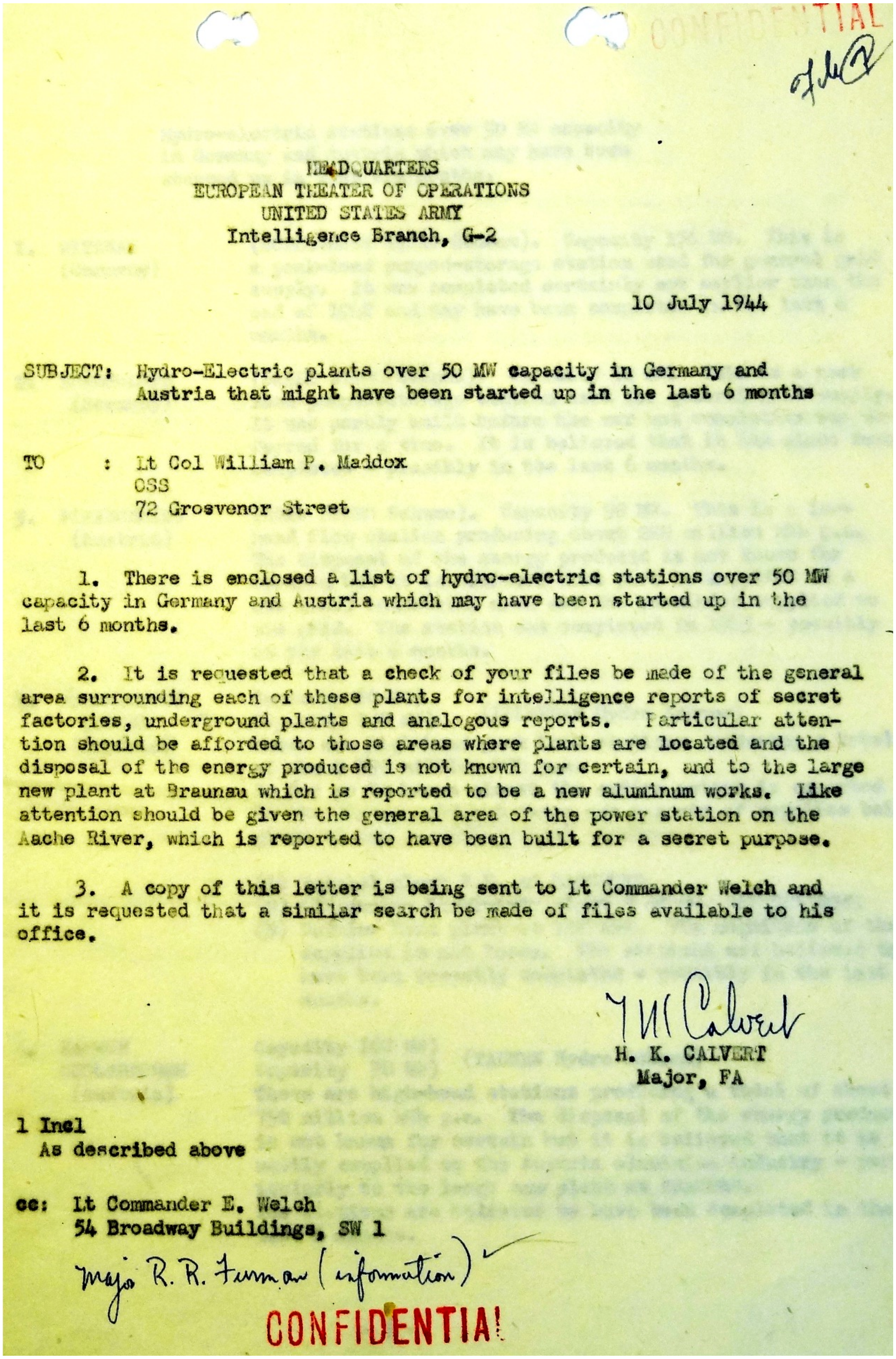

CONFIDENTIAL

HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
Intelligence Branch, G-2

10 July 1944

SUBJECT: Hydro-Electric plants over 50 MW capacity in Germany and Austria that might have been started up in the last 6 months

TO : Lt Col William P. Maddox
OSS
72 Grosvenor Street

1. There is enclosed a list of hydro-electric stations over 50 MW capacity in Germany and Austria which may have been started up in the last 6 months.

2. It is requested that a check of your files be made of the general area surrounding each of these plants for intelligence reports of secret factories, underground plants and analogous reports. Particular attention should be afforded to those areas where plants are located and the disposal of the energy produced is not known for certain, and to the large new plant at Braunau which is reported to be a new aluminum works. Like attention should be given the general area of the power station on the Aache River, which is reported to have been built for a secret purpose.

3. A copy of this letter is being sent to Lt Commander Welch and it is requested that a similar search be made of files available to his office.

H K Calvert
H. K. CALVERT
Major, FA

1 Incl
As described above

cc: Lt Commander E. Welch
54 Broadway Buildings, SW 1
Major R. R. Furman (information)

CONFIDENTIAL

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July-October 1944)

Figure D.276: Horace K. Calvert to William P. Maddox. 10 July 1944. SUBJECT: Hydro-Electric plants over 50 MW capacity in Germany and Austria that might have been started up in the last 6 months [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

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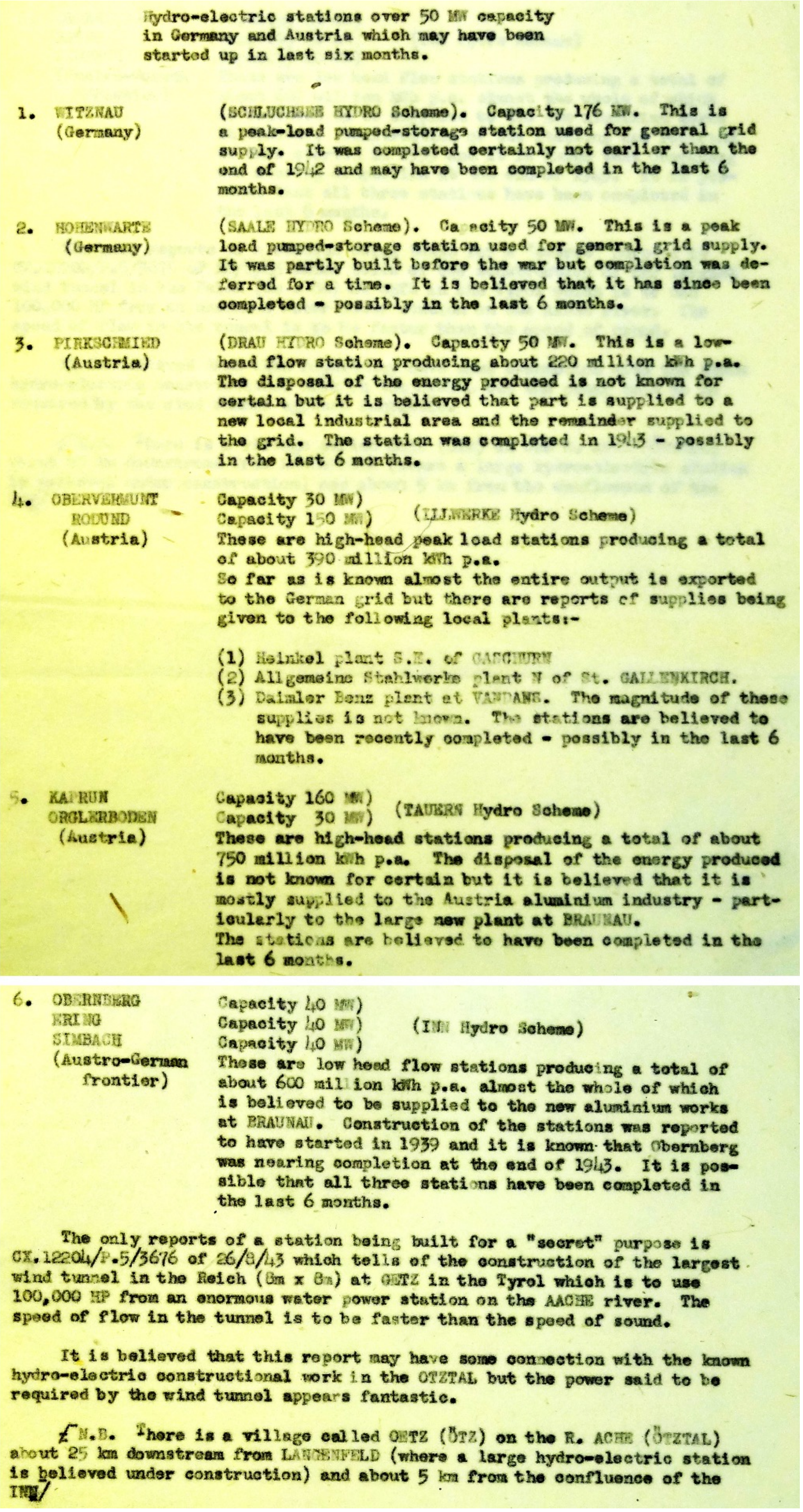


Hydro-electric stations over 50 MW capacity in Germany and Austria which may have been started up in last six months.

1. WITZNAU (Germany)
(SCHLUCHSEE HYDRO Scheme). Capacity 176 MW. This is a peak-load pumped-storage station used for general grid supply. It was completed certainly not earlier than the end of 1942 and may have been completed in the last 6 months.

2. HOHENWARTE (Germany)
(SAALE HYDRO Scheme). Capacity 50 MW. This is a peak load pumped-storage station used for general grid supply. It was partly built before the war but completion was deferred for a time. It is believed that it has since been completed - possibly in the last 6 months.

3. PIRKSCHMIED (Austria)
(DRAU HYDRO Scheme). Capacity 50 MW. This is a low-head flow station producing about 220 million kWh p.a. The disposal of the energy produced is not known for certain but it is believed that part is supplied to a new local industrial area and the remainder supplied to the grid. The station was completed in 1943 - possibly in the last 6 months.

4. OBERVERMUNT
RODUND
(Austria)
Capacity 30 MW)
Capacity 150 MW) (ILLWERKE Hydro Scheme)
These are high-head peak load stations producing a total of about 390 million kWh p.a.
So far as is known almost the entire output is exported to the German grid but there are reports of supplies being given to the following local plants:-

(1) Heinkel plant S.E. of GASCHURN
(2) Allgemeine Stahlwerke plant N of St. GALLENKIRCH.
(3) Daimler Benz plant at VANDANS. The magnitude of these supplies is not known. The stations are believed to have been recently completed - possibly in the last 6 months.

5. KAPRUN
ORGLERBODEN
(Austria)
Capacity 160 MW)
Capacity 30 MW) (TAUERN Hydro Scheme)
These are high-head stations producing a total of about 750 million kWh p.a. The disposal of the energy produced is not known for certain but it is believed that it is mostly supplied to the Austria aluminium industry - particularly to the large new plant at BRAUNAU.
The stations are believed to have been completed in the last 6 months.

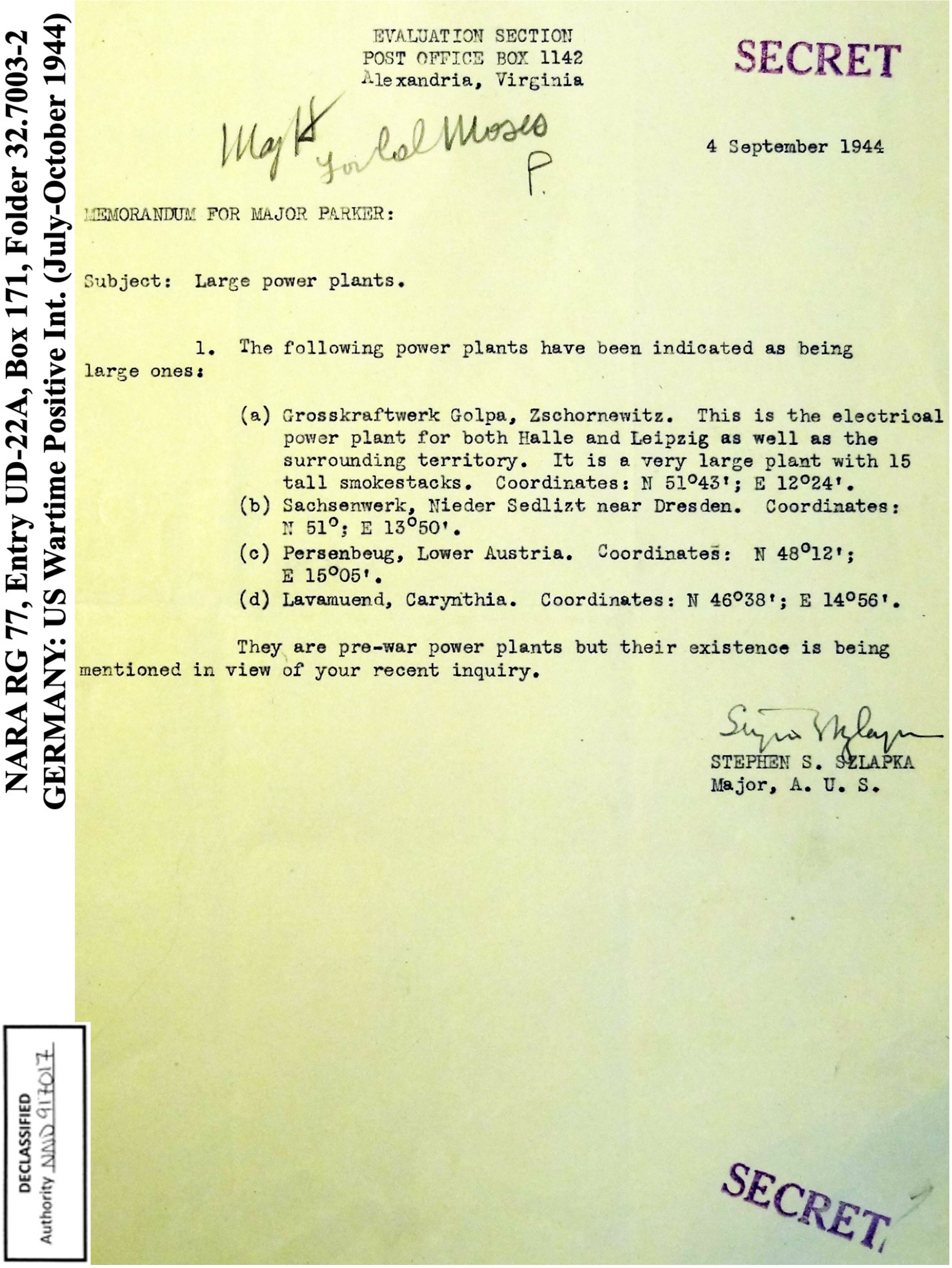
6. OBERNBERG
ERING
SIMBACH
(Austro-German frontier)
Capacity 40 MW)
Capacity 40 MW) (INN Hydro Scheme)
Capacity 40 MW)
These are low head flow stations producing a total of about 600 million kWh p.a. almost the whole of which is believed to be supplied to the new aluminium works at BRAUNAU. Construction of the stations was reported to have started in 1939 and it is known that Obernberg was nearing completion at the end of 1943. It is possible that all three stations have been completed in the last 6 months.

The only reports of a station being built for a "secret" purpose is CX.12204/P.5/3676 of 26/8/43 which tells of the construction of the largest wind tunnel in the Reich (8m x 8m) at OETZ in the Tyrol which is to use 100,000 HP from an enormous water power station on the AACHE river. The speed of flow in the tunnel is to be faster than the speed of sound.

It is believed that this report may have some connection with the known hydro-electric constructional work in the OTZTAL but the power said to be required by the wind tunnel appears fantastic.

/N.B. There is a village called OETZ (ÖTZ) on the R. ACHE (ÖTZTAL) about 25 km downstream from LANGENFELD (where a large hydro-electric station is believed under construction) and about 5 km from the confluence of the INN/

Figure D.277: Horace K. Calvert to William P. Maddox. 10 July 1944. SUBJECT: Hydro-Electric plants over 50 MW capacity in Germany and Austria that might have been started up in the last 6 months [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].



NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July-October 1944)

EVALUATION SECTION
POST OFFICE BOX 1142
Alexandria, Virginia

SECRET

Maj H for Col Moses
P.

4 September 1944

MEMORANDUM FOR MAJOR PARKER:

Subject: Large power plants.

1. The following power plants have been indicated as being large ones:

(a) Grosskraftwerk Golpa, Zschornewitz. This is the electrical power plant for both Halle and Leipzig as well as the surrounding territory. It is a very large plant with 15 tall smokestacks. Coordinates: N 51°43'; E 12°24'.

(b) Sachsenwerk, Nieder Sedlizt near Dresden. Coordinates: N 51°; E 13°50'.

(c) Persenbeug, Lower Austria. Coordinates: N 48°12'; E 15°05'.

(d) Lavamuend, Carynthia. Coordinates: N 46°38'; E 14°56'.

They are pre-war power plants but their existence is being mentioned in view of your recent inquiry.

STEPHEN S. SZLAPKA
Major, A. U. S.

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Figure D.278: Stephen S. Szlapka. 4 September 1944. Subject: Large power plants [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

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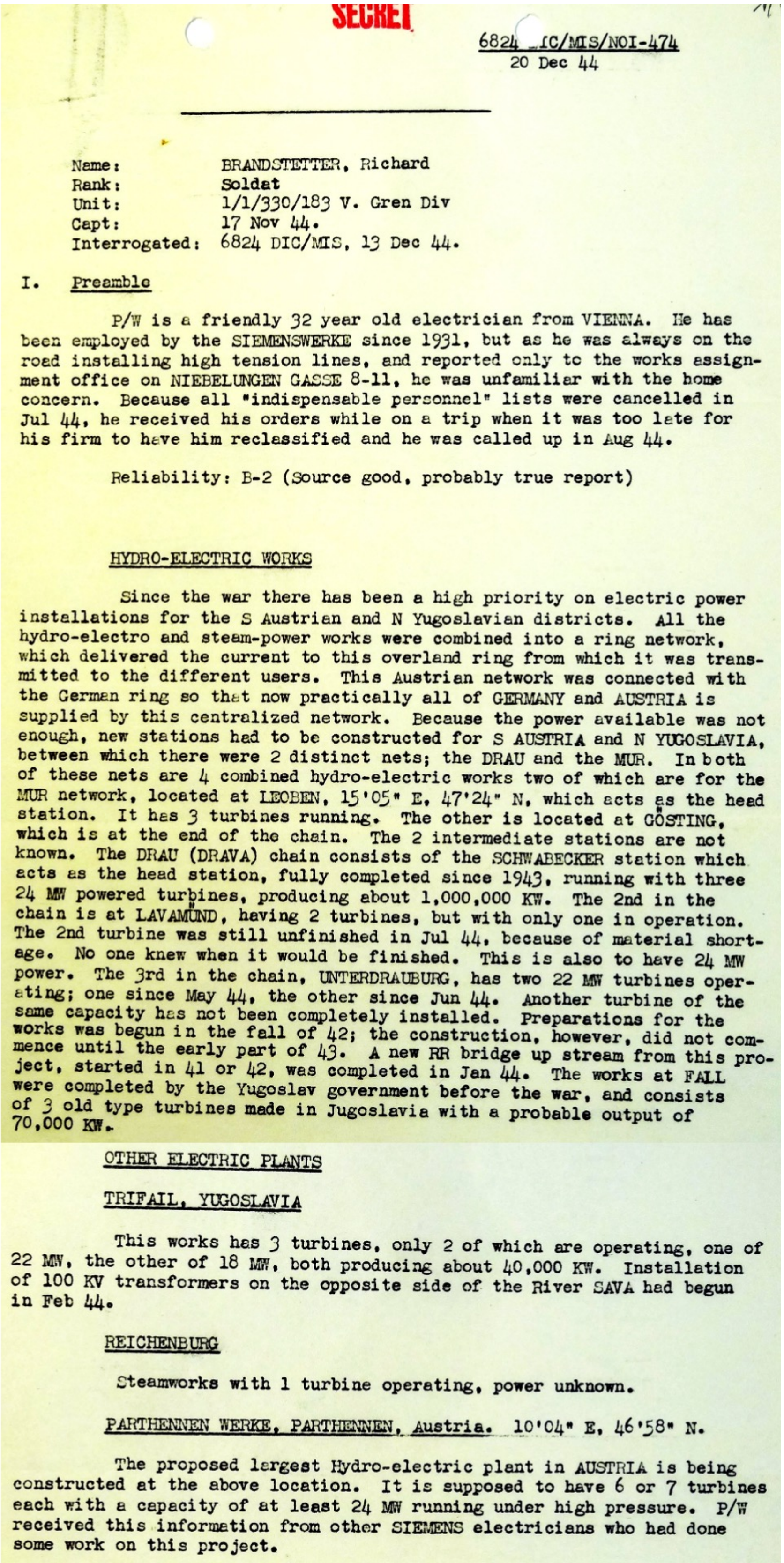
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3
GERMANY: US Wartime Positive Int. (Nov. 44-June 45)



SECRET

6824 IC/MIS/NOI-474
20 Dec 44

Name: BRANDSTETTER, Richard
Rank: Soldat
Unit: 1/1/330/183 V. Gren Div
Capt: 17 Nov 44.
Interrogated: 6824 DIC/MIS, 13 Dec 44.

I. Preamble

P/W is a friendly 32 year old electrician from VIENNA. He has been employed by the SIEMENSWERKE since 1931, but as he was always on the road installing high tension lines, and reported only to the works assignment office on NIEBELUNGEN GASSE 8-11, he was unfamiliar with the home concern. Because all "indispensable personnel" lists were cancelled in Jul 44, he received his orders while on a trip when it was too late for his firm to have him reclassified and he was called up in Aug 44.

Reliability: B-2 (Source good, probably true report)

HYDRO-ELECTRIC WORKS

Since the war there has been a high priority on electric power installations for the S Austrian and N Yugoslavian districts. All the hydro-electro and steam-power works were combined into a ring network, which delivered the current to this overland ring from which it was transmitted to the different users. This Austrian network was connected with the German ring so that now practically all of GERMANY and AUSTRIA is supplied by this centralized network. Because the power available was not enough, new stations had to be constructed for S AUSTRIA and N YUGOSLAVIA, between which there were 2 distinct nets; the DRAU and the MUR. In both of these nets are 4 combined hydro-electric works two of which are for the MUR network, located at LEOBEN, 15'05" E, 47'24" N, which acts as the head station. It has 3 turbines running. The other is located at GÖSTING, which is at the end of the chain. The 2 intermediate stations are not known. The DRAU (DRAVA) chain consists of the SCHWABECKER station which acts as the head station, fully completed since 1943, running with three 24 MW powered turbines, producing about 1,000,000 KW. The 2nd in the chain is at LAVAMÜND, having 2 turbines, but with only one in operation. The 2nd turbine was still unfinished in Jul 44, because of material shortage. No one knew when it would be finished. This is also to have 24 MW power. The 3rd in the chain, UNTERDRAUBURG, has two 22 MW turbines operating; one since May 44, the other since Jun 44. Another turbine of the same capacity has not been completely installed. Preparations for the works was begun in the fall of 42; the construction, however, did not commence until the early part of 43. A new RR bridge up stream from this project, started in 41 or 42, was completed in Jan 44. The works at FALL were completed by the Yugoslav government before the war, and consists of 3 old type turbines made in Jugoslavia with a probable output of 70,000 KW.

OTHER ELECTRIC PLANTS

TRIFAIL, YUGOSLAVIA

This works has 3 turbines, only 2 of which are operating, one of 22 MW, the other of 18 MW, both producing about 40,000 KW. Installation of 100 KV transformers on the opposite side of the River SAVA had begun in Feb 44.

REICHENBURG

Steamworks with 1 turbine operating, power unknown.

PARTHENNEN WERKE, PARTHENNEN, Austria. 10'04" E, 46'58" N.

The proposed largest Hydro-electric plant in AUSTRIA is being constructed at the above location. It is supposed to have 6 or 7 turbines each with a capacity of at least 24 MW running under high pressure. P/W received this information from other SIEMENS electricians who had done some work on this project.

Figure D.279: 6824 DIC/MIS/NOI-474. 20 December 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]. “Since the war there has been a high priority on electric power installations for the S Austrian and N Yugoslavian districts. All the hydro-electric and steam-power works were combined into a ring network.... Because the power available was not enough, new stations had to be constructed for S AUSTRIA and N YUGOSLAVIA....”

Werner Grothmann on enrichment of U-235 [Krotzky 2002]. For a discussion of the background and reliability of this source, see pp. 3396–3397.

[S. 6] Ich weiß allerdings nicht, woher das Material kommen sollte, denn unsere eigene Anlage im Erzgebirge lief ja auch erst ganz kurz und lieferte nur sehr wenig, wie ich hörte.	[p. 6] However, I do not know where the material came from, because our own plant in the Erzgebirge ran only very briefly and delivered very little, as I heard.
[S. 32] Die erste Schwierigkeit bestand in der Herstellung des Materials, also des Sprengstoffes. Das hat sich bis wenige Monate vor Kriegsende auch nicht drastisch verbessern lassen. Erst für 1946 rechneten wir eigentlich mit der Serienproduktion von Atombomben.	[p. 32] The first difficulty lay in the production of the material, the explosive. That did not improve dramatically until a few months before the end of the war. We did not expect mass production of atomic bombs until 1946.
[S. 33] Auch ich habe manches erst sehr spät erfahren und einiges auch erst nach dem Krieg. Zum Beispiel die Sache mit der Anreicherung. Es stimmt wirklich, dass die Reichspost 1944 die großtechnische Trennung der erforderlichen Substanzen für die Bombenfabrikation hinbekommen hat. Es war von Ardennes Verdienst. Die Einrichtung, wo das lief, lag weit außerhalb Berlins und ist vermutlich nach Kriegsende unter russischer Aufsicht noch eine Weile weiterbetrieben worden. Später hat man angeblich die Anlagenteile abgebaut und in den Osten gebracht. Vielleicht stehen die heute noch irgendwo herum. Die Tarnung für diese Anlage war hervorragend, weil sie trotz ihrer enormen Größe nicht auffiel. Das Beste war aber, dass überhaupt kein großer Personalaufwand betrieben werden musste. Das erzeugte Material war aber nur für die Reichspostforschung vorgesehen. Diebner hatte seine—ebenfalls begrenzten—Quellen und wir konnten für unsere Projekte kurz vor Kriegsende auch auf eigene Anlagen zurückgreifen, die aber auch noch lange nicht soviel liefern konnten, wie wir damals wünschten. Die gesamten Mengen kann ich nicht nennen, sie waren nicht umwerfend.	[p. 33] I also learned many things very late, and some things only after the war. For example, the matter of enrichment. It is true that in 1944 the Reichspost achieved the great technical separation of the necessary substances for the bomb production. It was thanks to Ardenne. The facility where it ran was far outside of Berlin and probably continued to operate for a while after the end of the war under Russian supervision. Supposedly they later dismantled the plant parts and brought them to the east. Maybe they are still around somewhere today. The camouflage for this plant was outstanding because it did not attract attention despite its enormous size. The best thing, however, was that a large workforce was not necessary. The material produced was, however, intended only for Reichspost research. Diebner had his—also limited—sources, and we were able to use our own equipment for our projects shortly before the end of the war, but they could not deliver as much as we wanted then. I cannot name the total quantities; they were not overwhelming.

[S. 36] Frau Beinhorn hat ihn uns empfohlen, weil der rund um die Uhr arbeiten konnte und, wie es schien, nie müde wurde. Diebner hat ihn mal [deshalb] als das wandelnde schlechte Gewissen seiner Kollegen bezeichnet. Schwietzke hat [...] auf die Frage nach dem Energiebedarf für eine bestimmte Anlage gesagt, das, was wir da reinstecken, bekommen wir bald hunderttausendfach zurück.

[p. 36] Mrs. Beinhorn recommended him to us because he could work around the clock and, as it seemed, never become tired. Diebner once [therefore] described him as the walking guilty conscience of his colleagues. Schwietzke said [...], when asked about the energy requirements for a particular installation, that what we put in there will soon come back a hundred thousandfold.

[Grothmann stated that he knew very little about where or how enriched uranium was produced, but he gave several important clues:

- The Reichspost had at least one U-235 enrichment facility that was located “far outside Berlin.” For security, that facility would likely not be part of some other facility, but for convenience, it might be located near another relevant facility. Most uranium ore in Germany was processed at Auer in Oranienburg, approximately 35 km north of Berlin, so that is one possible location. The Reichspost had major research facilities in Miersdorf (now part of Zeuthen) approximately 22 km southeast of Berlin, Kleinmachnow 19 km southwest of Berlin, and Manfred von Ardenne’s mansion in Lichterfelde approximately 12 km southwest of central Berlin, so those are other possible locations [Zeman and Karlsch 2008, p. 12]. Grothmann said that the enrichment facility used von Ardenne’s designs, which suggests that it was electromagnetic enrichment similar to the U.S. calutrons at Oak Ridge. (Von Ardenne was an expert on electromagnetic manipulation of charged particles in electron microscopes and television picture tubes, and is known to have designed electromagnetic enrichment devices.) The facility was noteworthy for its “enormous size,” which also suggests electromagnetic enrichment; uranium ions are separated out in low-density ion beams that travel up to several meters each, so hundreds of such bulky machines might be required to function in parallel. This facility became fully operational no later than 1944, or 1943 if it supplied fuel for what Grothmann said was a failed autumn 1943 test in the North Sea.

- The SS had at least one U-235 enrichment facility in the Erzgebirge region, but Grothmann did not provide any clues about what enrichment method(s) it used. This region was heavily mined for uranium by the Russians after the war. If the SS chose to locate an enrichment facility there, it suggests that Germans were mining uranium there during the war.

- Werner Schwietzke apparently designed and promised great returns from a special installation; he is known to have spent the war developing uranium gas centrifuges with Werner Holtz for the Army Ordnance Office [p. 3542].

- Kurt Diebner had sources of enriched uranium that were independent of the Reichspost and SS facilities, but Grothmann did not elaborate. Those might be (1) Schwietzke’s centrifuges, (2) centrifuges in the Hamburg/Kiel area managed by Paul Harteck, Wilhelm Groth, and Konrad Beyerle, (3) the “isotope sluice,” a centrifuge-like device developed by Diebner’s close collaborator Erich Bagge, and/or (4) presently unknown additional sources.

It is important to find more information about all of these uranium enrichment facilities. It is also possible that there were other important enrichment facilities that Grothmann did not know about or did not mention in the interviews.]

Known/Reported Sites Now in France

Leslie R. Groves to Robert R. Furman. 25 November 1943 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)].

1. Colonel Dix [OSS] came over and told me that there was some new generative capacity going in at Génissiat on the Rhône River about 5 kilos from Belgarde. He stated that two generators were in and tested, that two were nearly installed and that two more were to come in two or three months.

2. I secured two reports from the Chief's office which bear on this subject. [...]

3. I cannot understand why the Germans are permitting this installation of power equipment to go on unless they have some definite need for it. This section of the country should not be overlooked and by section I mean anything within reasonable reach by high tension lines.

[From or to?] Colonel O'Conor. 31 December [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)].

French Plant at Génissiat on the Rhône River 8—65 KW Hydrogenerators. Four in place. Two nearing completion. Two on foundations. No apparent transmission lines, power to service.

[See document photos on p. 3711.

Leslie Groves and the OSS were concerned that occupying Germans could be building the large Génissiat hydroelectric plant on the Rhône river in eastern France to power a nearby uranium enrichment facility.]

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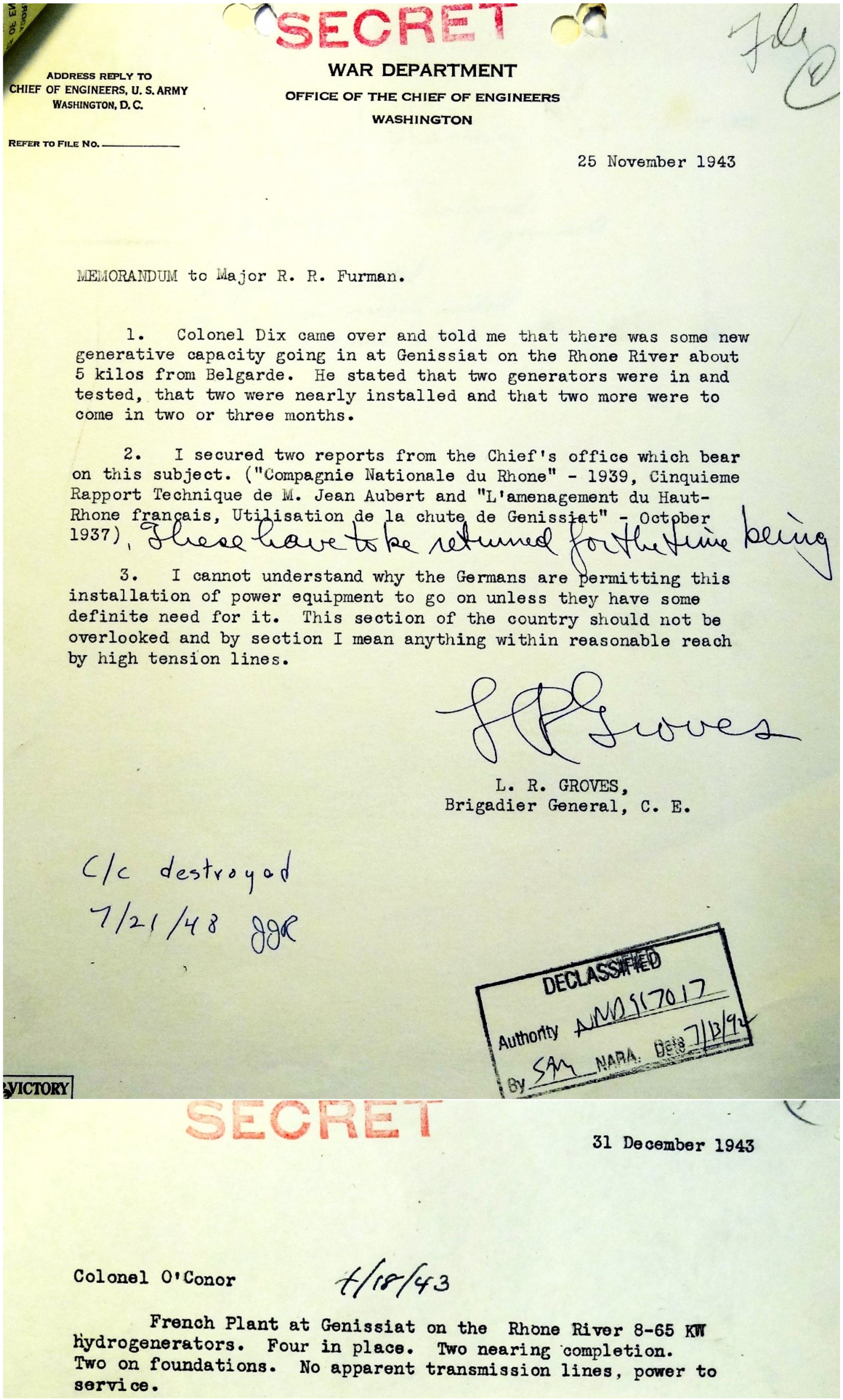
NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1
GERMANY: US Wartime Positive Int. (July 42-June 44)



SECRET

ADDRESS REPLY TO
CHIEF OF ENGINEERS, U. S. ARMY
WASHINGTON, D. C.

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON

REFER TO FILE NO. ____________

25 November 1943

MEMORANDUM to Major R. R. Furman.

1. Colonel Dix came over and told me that there was some new generative capacity going in at Genissiat on the Rhone River about 5 kilos from Belgarde. He stated that two generators were in and tested, that two were nearly installed and that two more were to come in two or three months.

2. I secured two reports from the Chief's office which bear on this subject. ("Compagnie Nationale du Rhone" - 1939, Cinquieme Rapport Technique de M. Jean Aubert and "L'amenagement du Haut-Rhone francais, Utilisation de la chute de Genissiat" - October 1937). These have to be returned for the time being

3. I cannot understand why the Germans are permitting this installation of power equipment to go on unless they have some definite need for it. This section of the country should not be overlooked and by section I mean anything within reasonable reach by high tension lines.

L R Groves

L. R. GROVES,
Brigadier General, C. E.

C/c destroyed
7/21/48 JJR

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By SAM NARA, Date 7/13/94

VICTORY

SECRET

31 December 1943

Colonel O'Conor 1/18/43

French Plant at Genissiat on the Rhone River 8-65 KW hydrogenerators. Four in place. Two nearing completion. Two on foundations. No apparent transmission lines, power to service.

Figure D.280: Leslie R. Groves to Robert R. Furman. 25 November 1943 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)]. Groves was concerned that occupying Germans could be building the large Génissiat hydroelectric plant on the Rhône river in eastern France to power a nearby uranium enrichment facility.

Known/Reported Sites Now in Poland

Karl Cohen to Philip Morrison. 7 August 1944. [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11 Tech-Countermeasures + RW 1943–1944]

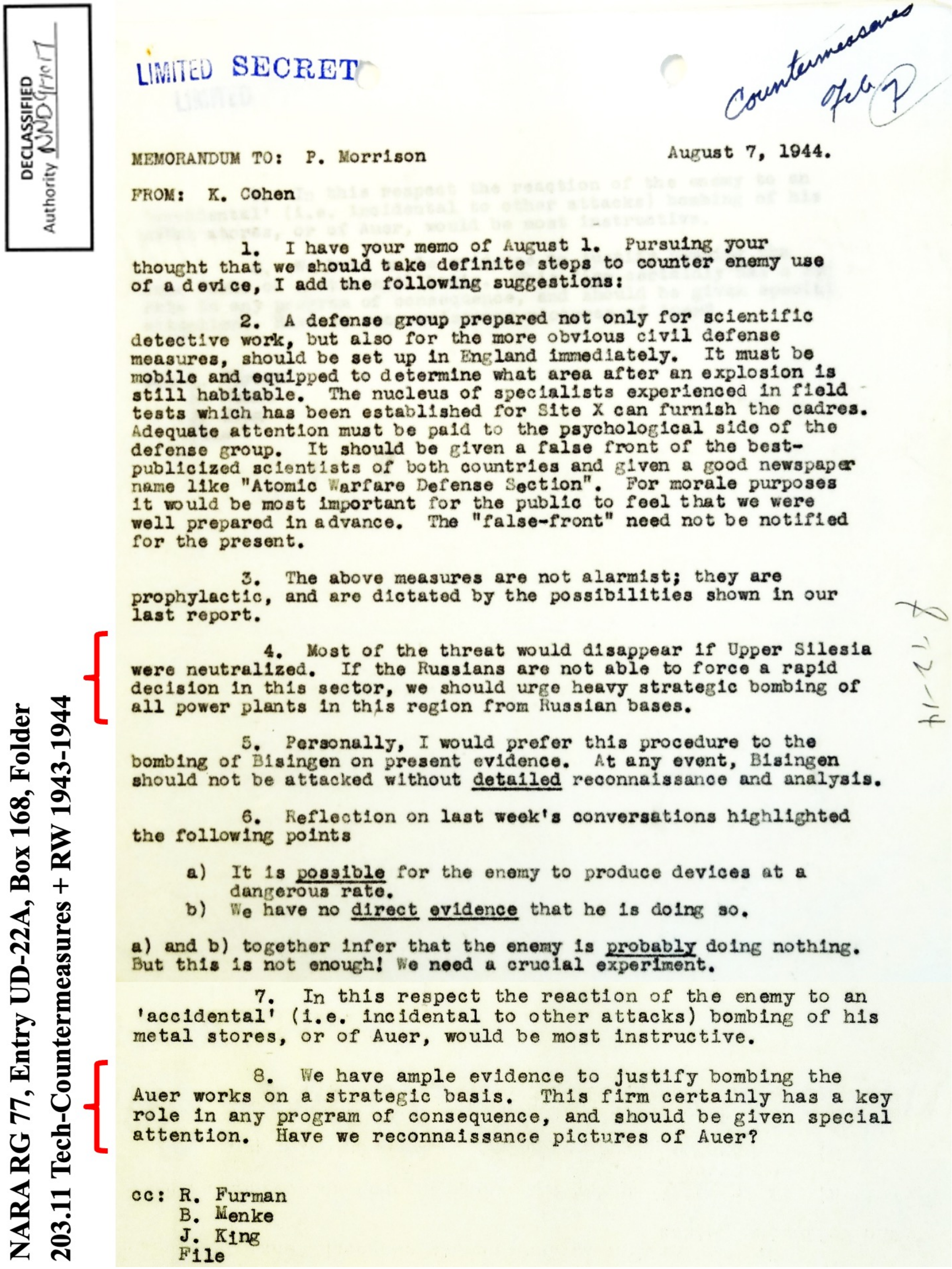
1. I have your memo of August 1. Pursuing your thought that we should take definite steps to counter enemy use of a device, I add the following suggestions:

4. Most of the threat would disappear if Upper Silesia were neutralized. If the Russians are not able to force a rapid decision in this sector, we should urge heavy strategic bombing of all power plants in this region from Russian bases.

8. We have ample evidence to justify bombing the Auer works on a strategic basis. This firm certainly has a key role in any program of consequence, and should be given special attention. Have we reconnaissance pictures of Auer?

[See document photo on p. 3713.

Based on intelligence not specifically described here, Leslie Groves's Foreign Intelligence Unit believed that there were important German nuclear weapons plants in Upper Silesia. They also recommended bombing Auergesellschaft in Oranienburg, which the U.S. ultimately did.]



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LIMITED SECRET

Countermeasures
Feb 7

MEMORANDUM TO: P. Morrison August 7, 1944.

FROM: K. Cohen

1. I have your memo of August 1. Pursuing your thought that we should take definite steps to counter enemy use of a device, I add the following suggestions:

2. A defense group prepared not only for scientific detective work, but also for the more obvious civil defense measures, should be set up in England immediately. It must be mobile and equipped to determine what area after an explosion is still habitable. The nucleus of specialists experienced in field tests which has been established for Site X can furnish the cadres. Adequate attention must be paid to the psychological side of the defense group. It should be given a false front of the best-publicized scientists of both countries and given a good newspaper name like "Atomic Warfare Defense Section". For morale purposes it would be most important for the public to feel that we were well prepared in advance. The "false-front" need not be notified for the present.

3. The above measures are not alarmist; they are prophylactic, and are dictated by the possibilities shown in our last report.

8-7-44

4. Most of the threat would disappear if Upper Silesia were neutralized. If the Russians are not able to force a rapid decision in this sector, we should urge heavy strategic bombing of all power plants in this region from Russian bases.

5. Personally, I would prefer this procedure to the bombing of Bisingen on present evidence. At any event, Bisingen should not be attacked without detailed reconnaissance and analysis.

6. Reflection on last week's conversations highlighted the following points

a) It is possible for the enemy to produce devices at a dangerous rate.
b) We have no direct evidence that he is doing so.

a) and b) together infer that the enemy is probably doing nothing. But this is not enough! We need a crucial experiment.

7. In this respect the reaction of the enemy to an 'accidental' (i.e. incidental to other attacks) bombing of his metal stores, or of Auer, would be most instructive.

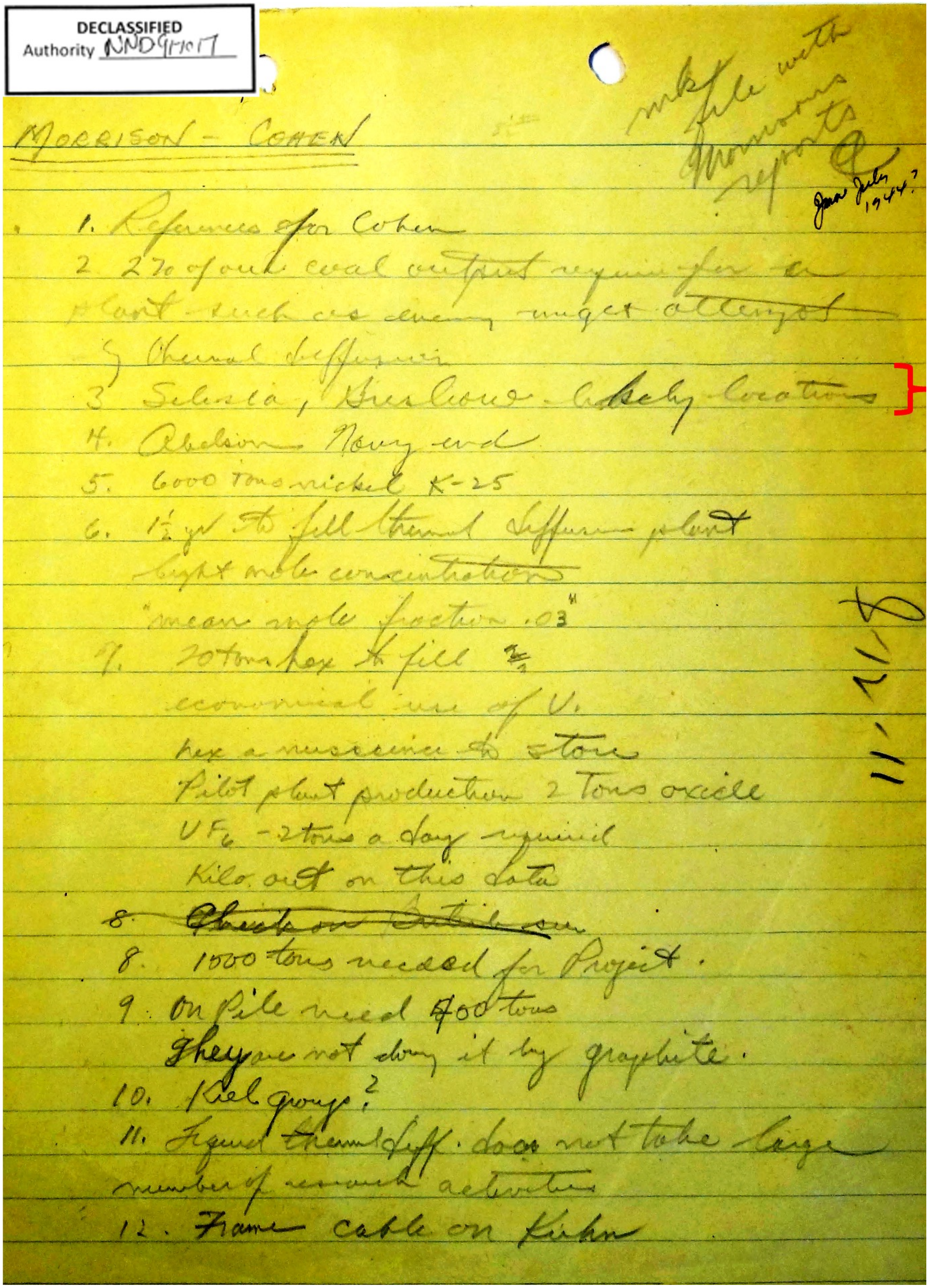
8. We have ample evidence to justify bombing the Auer works on a strategic basis. This firm certainly has a key role in any program of consequence, and should be given special attention. Have we reconnaissance pictures of Auer?

cc: R. Furman
B. Menke
J. King
File

NARA RG 77, Entry UD-22A, Box 168, Folder 203.11 Tech-Countermeasures + RW 1943-1944

Figure D.281: Based on intelligence not specifically described here, Leslie Groves's Foreign Intelligence Unit believed that there were important German nuclear weapons plants in Upper Silesia. They also recommended bombing Auergesellschaft in Oranienburg, which the U.S. ultimately did. Karl Cohen to Philip Morrison. 7 August 1944 [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11 Tech-Countermeasures + RW 1943–1944].

NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945-1946)



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mk file with Morrison's reports

Jan–July 1944?

MORRISON – COHEN

1. References for Cohen
2. 2% of our coal output required for a plant such as enemy might attempt of thermal diffusion
3. Silesia, Breslau likely locations
4. Abelson Navy end
5. 6000 Tons nickel K-25
6. 1½ yr to fill thermal diffusion plant
~~light mole concentration~~
"mean mole fraction .03"
7. 20 tons hex to fill ¾
economical use of U.
hex a nuisance to store
Pilot plant production 2 Tons oxide
UF_6 – 2 tons a day required
Kilo. out on this data
~~8. [illegible]~~
8. 1000 tons needed for Project.
9. On pile need 400 tons
They are not doing it by graphite.
10. Kiel group?^{2}
11. Figured thermal diff. does not take large number of research activities
12. Frame cable on Kuhn

11,718

Figure D.282: Notes from a meeting with Philip Morrison and Karl Cohen state: "3. Silesia, Breslau likely locations" for uranium enrichment plants, based on intelligence not recorded here [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

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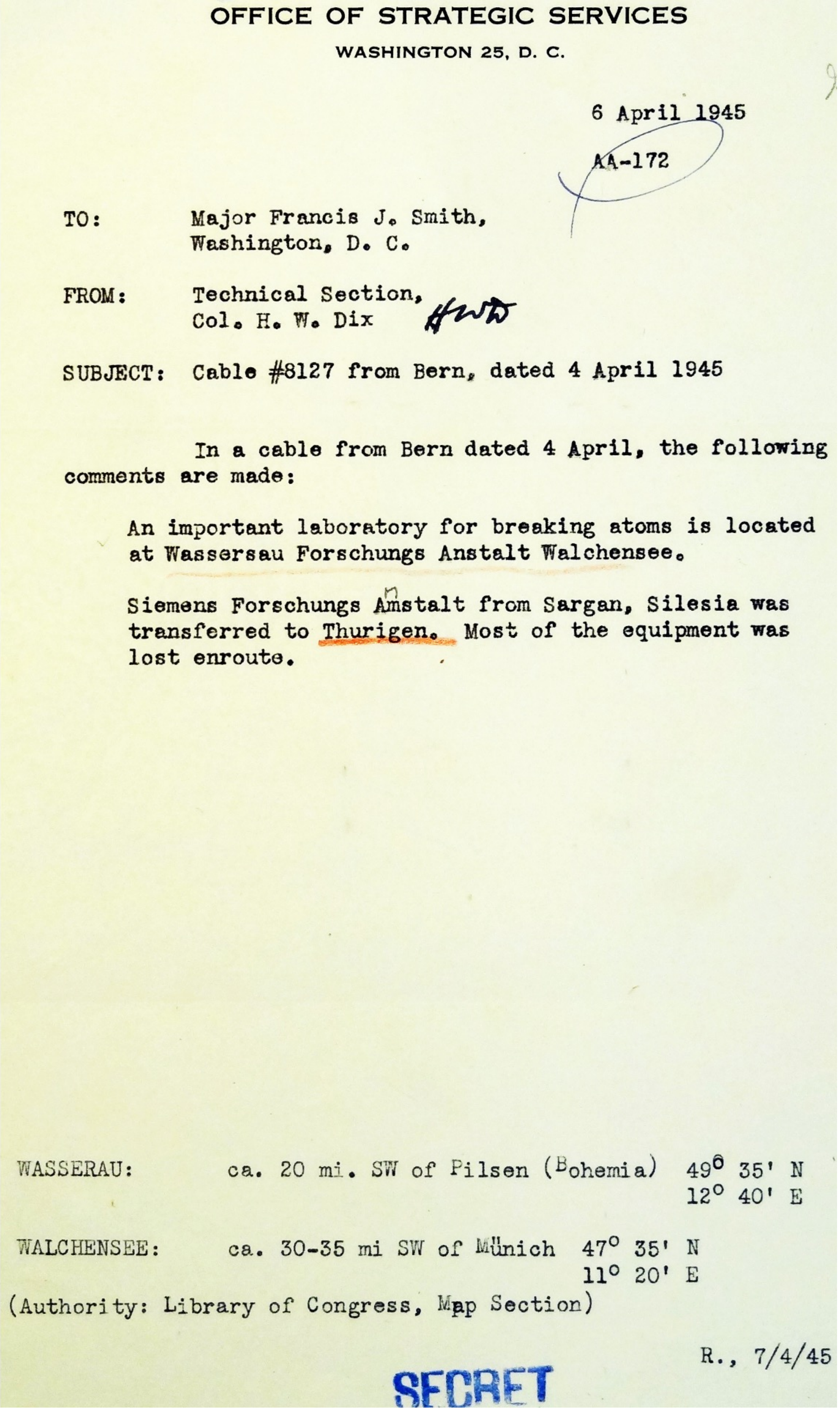
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3
GERMANY: US Wartime Positive Int. (Nov. 44–June 45)



OFFICE OF STRATEGIC SERVICES
WASHINGTON 25, D. C.

6 April 1945

AA-172

TO: Major Francis J. Smith,
Washington, D. C.

FROM: Technical Section,
Col. H. W. Dix HWD

SUBJECT: Cable #8127 from Bern, dated 4 April 1945

In a cable from Bern dated 4 April, the following comments are made:

> An important laboratory for breaking atoms is located at Wassersau Forschungs Anstalt Walchensee.
>
> Siemens Forschungs A$\overset{n}{m}$stalt from Sargan, Silesia was transferred to Thurigen. Most of the equipment was lost enroute.

WASSERAU:	ca. 20 mi. SW of Pilsen (Bohemia)	49^{6} 35' N 12° 40' E
WALCHENSEE:	ca. 30-35 mi SW of Münich	47° 35' N 11° 20' E

(Authority: Library of Congress, Map Section)

R., 7/4/45

SECRET

Figure D.283: H. W. Dix to Francis J. Smith. 6 April 1945 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

A.D.I. (K) Report No. 113A/1945. Suspected ‘V’ Weapon Factories—Germany and Poland. [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL]

UNDERGROUND FACTORY, WIELICZKA, POLAND.
(March 1944).

15. A Polish refugee, who had worked in the Wieliczka area until March 1944, mentioned that towards the ends of 1943 the Germans had installed a plant for secret weapon production in a salt mine to the South-West of the town on the northern side of the Wieliczka-Swoszowice road at 49^o 58’ 50” N., 20^o 3’ 0” E.

16. The entrances to the site were guarded by black uniformed guards and the workers, who were all interned Jews, were never allowed to go out for air; it was understood that the mortality rate was very high as a result of these restrictions and the unhealthy working conditions.

17. Informant added that many of these workers and some of the machinery had been transferred to Wieliczka from another secret weapon factory situated to the North-East of Debica at approximately 50^o 8’ N., 21^o 33’ E. The local Poles were fairly sure that Debica was producing V.1’s in 1943 as these were tested in the neighborhood and fell in the town of Sandomierz (50^o 30’ 40” N., 21^o 46’ 00” E.)

[See document photo on p. 3717.

This report described an underground plant in Poland that seemed much more secretive than standard V-1 and V-2 plants. If it was more secretive, was it producing modified missiles, or unusual warheads for missiles, or other advanced weapons?]

[For some other known or suspected nuclear sites in Poland, see:

pp. 4069–4071

pp. 4440–4477

pp. 4902–4903

See also nearby Kaliningrad, formerly Königsberg, East Prussia: pp. 3928–3933]

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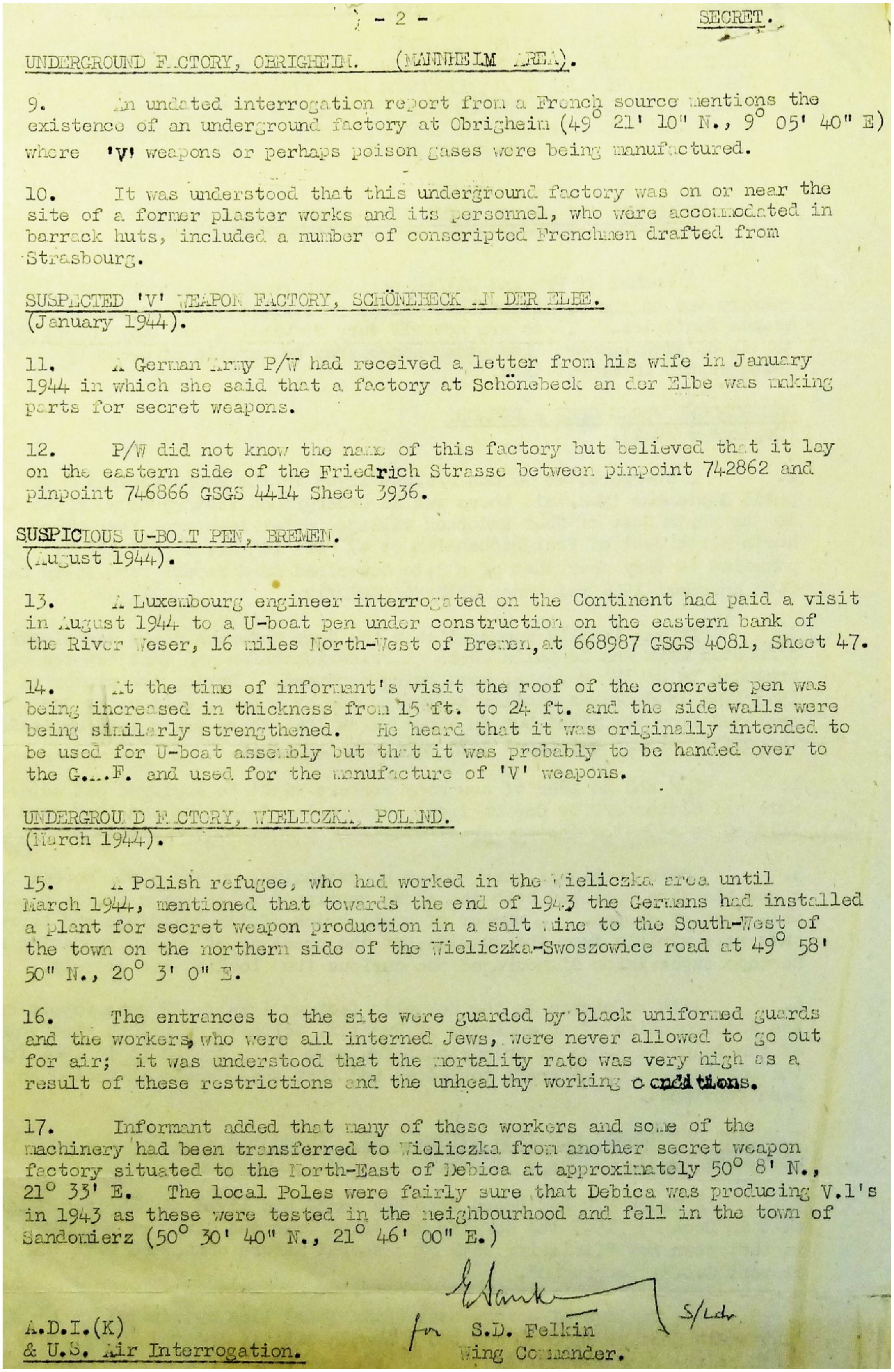
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL



- 2 -

SECRET.

UNDERGROUND FACTORY, OBRIGHEIM. (MANNHEIM AREA).

9. An undated interrogation report from a French source mentions the existence of an underground factory at Obrigheim (49° 21' 10" N., 9° 05' 40" E) where 'V' weapons or perhaps poison gases were being manufactured.

10. It was understood that this underground factory was on or near the site of a former plaster works and its personnel, who were accommodated in barrack huts, included a number of conscripted Frenchmen drafted from Strasbourg.

SUSPECTED 'V' WEAPON FACTORY, SCHÖNEBECK AN DER ELBE.
(January 1944).

11. A German Army P/W had received a letter from his wife in January 1944 in which she said that a factory at Schönebeck an der Elbe was making parts for secret weapons.

12. P/W did not know the name of this factory but believed that it lay on the eastern side of the Friedrich Strasse between pinpoint 742862 and pinpoint 746866 GSGS 4414 Sheet 3936.

SUSPICIOUS U-BOAT PEN, BREMEN.
(August 1944).

13. A Luxembourg engineer interrogated on the Continent had paid a visit in August 1944 to a U-boat pen under construction on the eastern bank of the River Weser, 16 miles North-West of Bremen, at 668987 GSGS 4081, Sheet 47.

14. At the time of informant's visit the roof of the concrete pen was being increased in thickness from 15 ft. to 24 ft. and the side walls were being similarly strengthened. He heard that it was originally intended to be used for U-boat assembly but that it was probably to be handed over to the G.A.F. and used for the manufacture of 'V' weapons.

UNDERGROUND FACTORY, WIELICZKA, POLAND.
(March 1944).

15. A Polish refugee, who had worked in the Wieliczka area until March 1944, mentioned that towards the end of 1943 the Germans had installed a plant for secret weapon production in a salt mine to the South-West of the town on the northern side of the Wieliczka-Swoszowice road at 49° 58' 50" N., 20° 3' 0" E.

16. The entrances to the site were guarded by black uniformed guards and the workers, who were all interned Jews, were never allowed to go out for air; it was understood that the mortality rate was very high as a result of these restrictions and the unhealthy working conditions.

17. Informant added that many of these workers and some of the machinery had been transferred to Wieliczka from another secret weapon factory situated to the North-East of Debica at approximately 50° 8' N., 21° 33' E. The local Poles were fairly sure that Debica was producing V.1's in 1943 as these were tested in the neighbourhood and fell in the town of Sandomierz (50° 30' 40" N., 21° 46' 00" E.)

for S.D. Felkin S/Ldr.
Wing Commander.

A.D.I.(K)
& U.S. Air Interrogation.

Figure D.284: A.D.I. (K) Report No. 113A/1945. Suspected 'V' Weapon Factories—Germany and Poland. This report described an underground plant in Poland that seemed much more secretive than standard V-1 and V-2 plants [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Known/Reported Sites Now in Austria

Allen Dulles. 4 March 1944 OSS report. [Allen W. Dulles Papers: Digital Files Series, MC019-09, Public Policy Papers, Department of Special Collections, Princeton University Library. https://findingaids.princeton.edu/catalog/MC019-09_c034 Reports_English_1943-1977_and_undated 19440304_0000033429.pdf]

In the Zipfer Brauerei (brewery) in Zipf, Upper Austria, some secret and important war production is taking place. This production, which might be in connection with the secret weapon, is taking place in the underground parts of the brewery.

From John Lansdale, Jr., to Leslie Groves. Subject: Extract from ASF Intelligence Bulletin No. 10. 1 July 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)]

The following is taken from Part V, paragraph 2, page 11 of ASF Intelligence Bulletin No. 10, dated 28 June 1944:

"When on furlough in December 1943, visiting relatives near Voecklamarkt, Austria, P/W saw a very secret factory at Redl Zipf in a wooded ravine, about 200 meters north of the Redl Zipf RR station on the RR between Voecklamarkt and Voecklabruck. The people living in the vicinity believed poison gas or gas for secret weapons was being manufactured here but no one had definite information because workers were not from the neighborhood and the plant was very closely guarded by Gestapo in uniform and in plain clothes."

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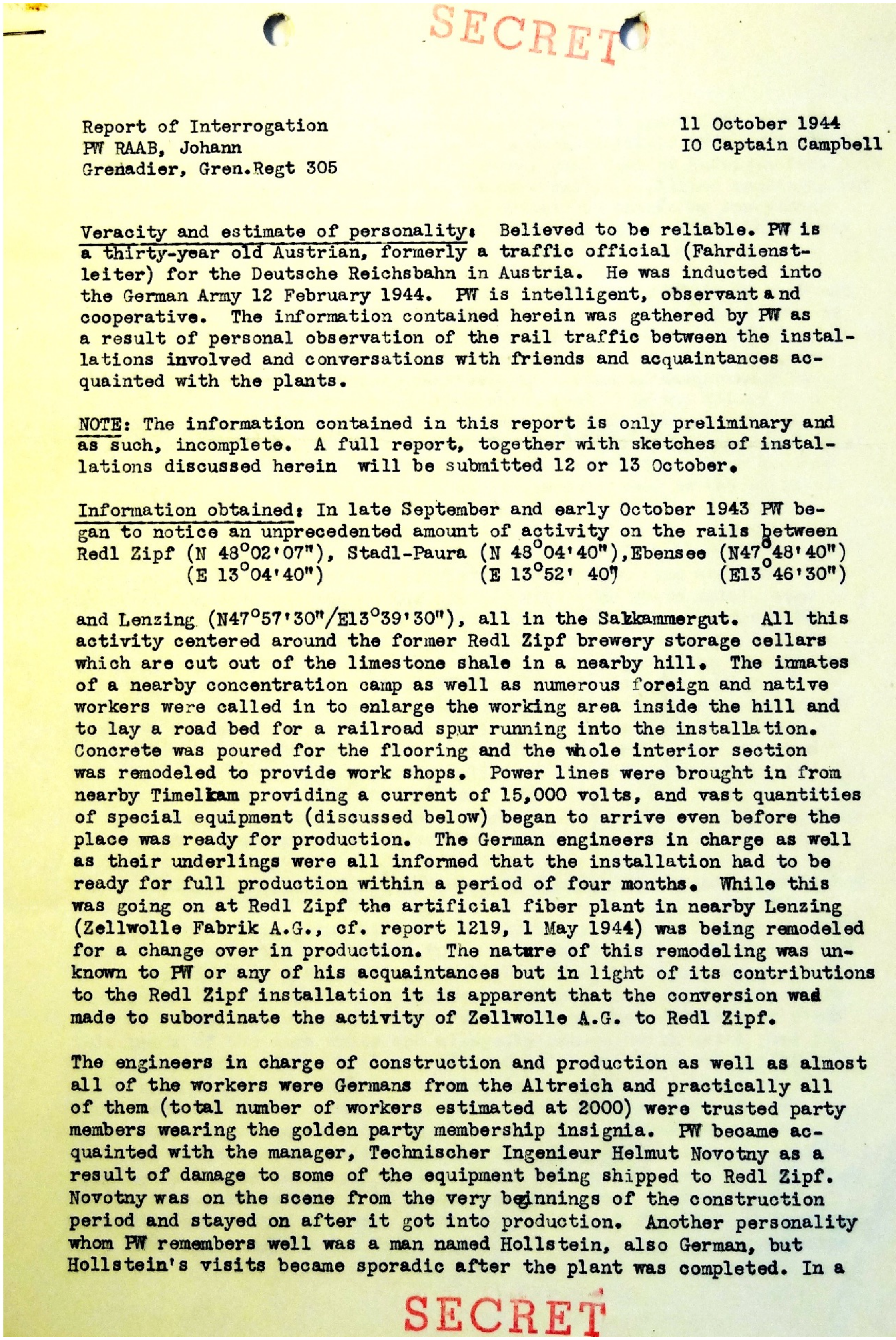
NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July-Oct. 44)



SECRET

Report of Interrogation
PW RAAB, Johann
Grenadier, Gren.Regt 305

11 October 1944
IO Captain Campbell

Veracity and estimate of personality: Believed to be reliable. PW is a thirty-year old Austrian, formerly a traffic official (Fahrdienstleiter) for the Deutsche Reichsbahn in Austria. He was inducted into the German Army 12 February 1944. PW is intelligent, observant and cooperative. The information contained herein was gathered by PW as a result of personal observation of the rail traffic between the installations involved and conversations with friends and acquaintances acquainted with the plants.

NOTE: The information contained in this report is only preliminary and as such, incomplete. A full report, together with sketches of installations discussed herein will be submitted 12 or 13 October.

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Redl Zipf (N 48°02'07"), Stadl-Paura (N 48°04'40"), Ebensee (N47°48'40")
(E 13°04'40") (E 13°52' 40") (E13°46'30")

and Lenzing (N47°57'30"/E13°39'30"), all in the Salkammergut. All this activity centered around the former Redl Zipf brewery storage cellars which are cut out of the limestone shale in a nearby hill. The inmates of a nearby concentration camp as well as numerous foreign and native workers were called in to enlarge the working area inside the hill and to lay a road bed for a railroad spur running into the installation. Concrete was poured for the flooring and the whole interior section was remodeled to provide work shops. Power lines were brought in from nearby Timelkam providing a current of 15,000 volts, and vast quantities of special equipment (discussed below) began to arrive even before the place was ready for production. The German engineers in charge as well as their underlings were all informed that the installation had to be ready for full production within a period of four months. While this was going on at Redl Zipf the artificial fiber plant in nearby Lenzing (Zellwolle Fabrik A.G., cf. report 1219, 1 May 1944) was being remodeled for a change over in production. The nature of this remodeling was unknown to PW or any of his acquaintances but in light of its contributions to the Redl Zipf installation it is apparent that the conversion wad made to subordinate the activity of Zellwolle A.G. to Redl Zipf.

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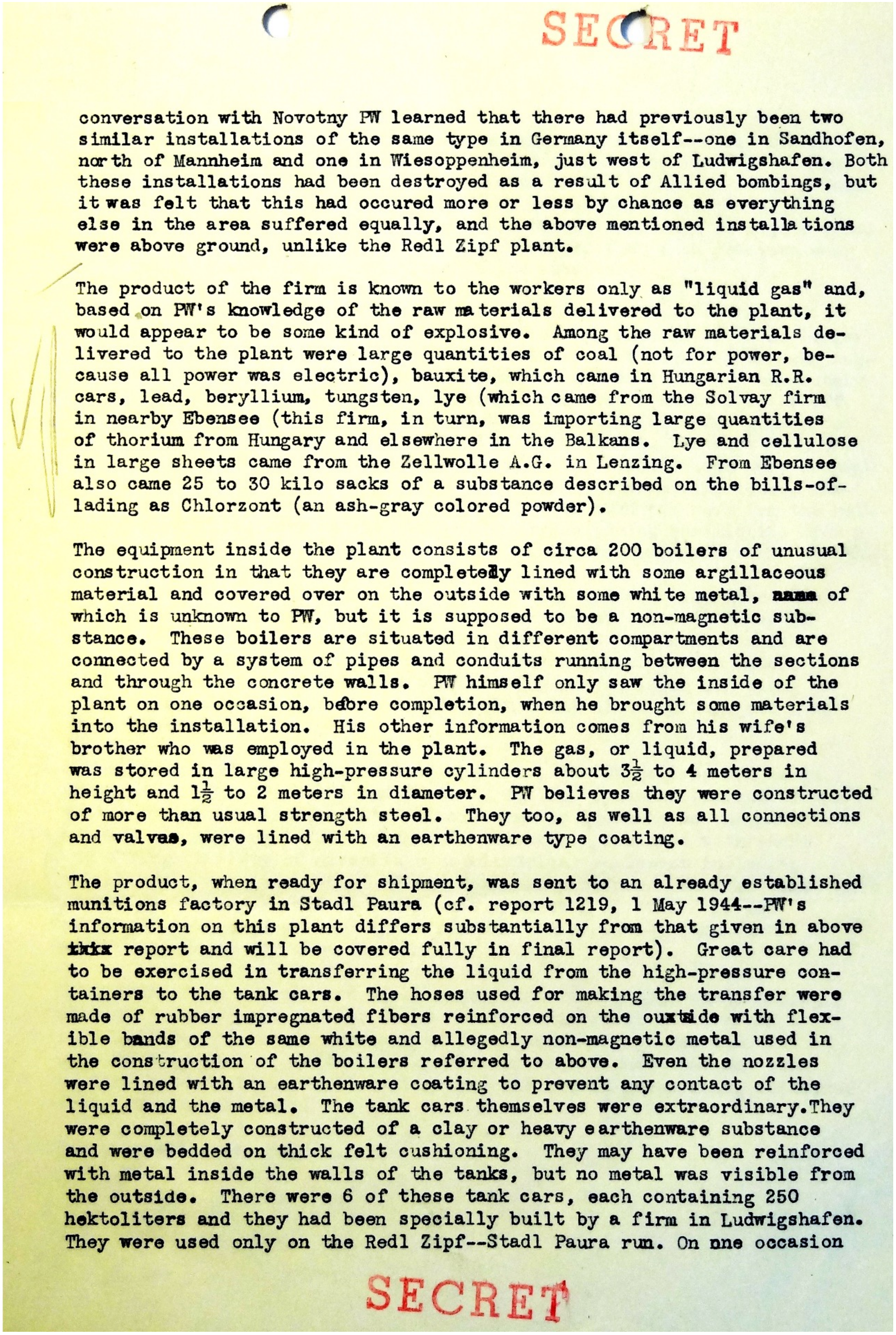
Figure D.285: Report of Interrogation PW RAAB. 11 October 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July-Oct. 44)



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conversation with Novotny PW learned that there had previously been two similar installations of the same type in Germany itself--one in Sandhofen, north of Mannheim and one in Wiesoppenheim, just west of Ludwigshafen. Both these installations had been destroyed as a result of Allied bombings, but it was felt that this had occured more or less by chance as everything else in the area suffered equally, and the above mentioned installations were above ground, unlike the Redl Zipf plant.

The product of the firm is known to the workers only as "liquid gas" and, based on PW's knowledge of the raw materials delivered to the plant, it would appear to be some kind of explosive. Among the raw materials delivered to the plant were large quantities of coal (not for power, because all power was electric), bauxite, which came in Hungarian R.R. cars, lead, beryllium, tungsten, lye (which came from the Solvay firm in nearby Ebensee (this firm, in turn, was importing large quantities of thorium from Hungary and elsewhere in the Balkans. Lye and cellulose in large sheets came from the Zellwolle A.G. in Lenzing. From Ebensee also came 25 to 30 kilo sacks of a substance described on the bills-of-lading as Chlorzont (an ash-gray colored powder).

The equipment inside the plant consists of circa 200 boilers of unusual construction in that they are completely lined with some argillaceous material and covered over on the outside with some white metal, name of which is unknown to PW, but it is supposed to be a non-magnetic substance. These boilers are situated in different compartments and are connected by a system of pipes and conduits running between the sections and through the concrete walls. PW himself only saw the inside of the plant on one occasion, before completion, when he brought some materials into the installation. His other information comes from his wife's brother who was employed in the plant. The gas, or liquid, prepared was stored in large high-pressure cylinders about $3\frac{1}{2}$ to 4 meters in height and $1\frac{1}{2}$ to 2 meters in diameter. PW believes they were constructed of more than usual strength steel. They too, as well as all connections and valves, were lined with an earthenware type coating.

The product, when ready for shipment, was sent to an already established munitions factory in Stadl Paura (cf. report 1219, 1 May 1944--PW's information on this plant differs substantially from that given in above ~~this~~ report and will be covered fully in final report). Great care had to be exercised in transferring the liquid from the high-pressure containers to the tank cars. The hoses used for making the transfer were made of rubber impregnated fibers reinforced on the outside with flexible bands of the same white and allegedly non-magnetic metal used in the construction of the boilers referred to above. Even the nozzles were lined with an earthenware coating to prevent any contact of the liquid and the metal. The tank cars themselves were extraordinary.They were completely constructed of a clay or heavy earthenware substance and were bedded on thick felt cushioning. They may have been reinforced with metal inside the walls of the tanks, but no metal was visible from the outside. There were 6 of these tank cars, each containing 250 hektoliters and they had been specially built by a firm in Ludwigshafen. They were used only on the Redl Zipf--Stadl Paura run. On one occasion

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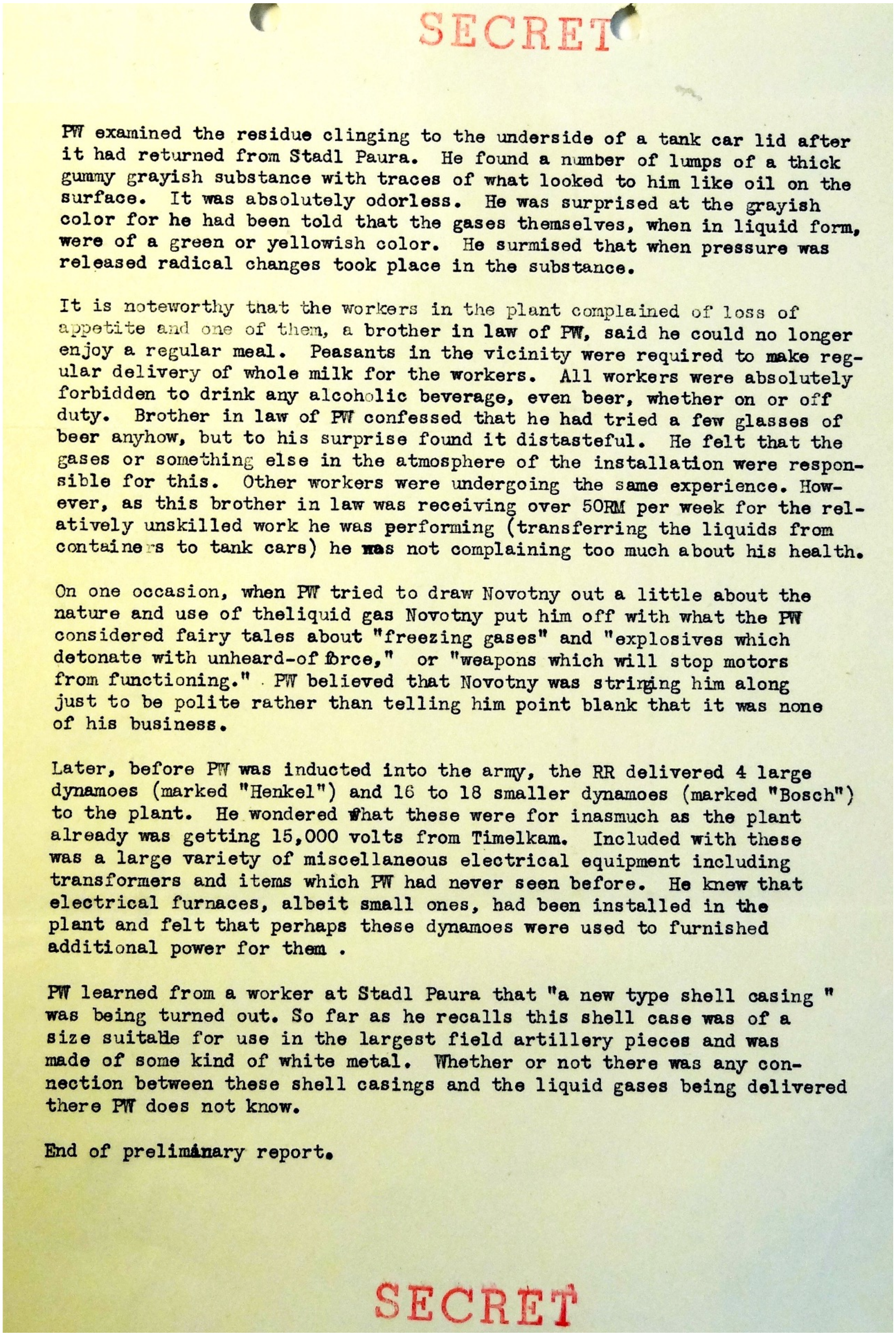
Figure D.286: Report of Interrogation PW RAAB. 11 October 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July-Oct. 44)



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PW examined the residue clinging to the underside of a tank car lid after it had returned from Stadl Paura. He found a number of lumps of a thick gummy grayish substance with traces of what looked to him like oil on the surface. It was absolutely odorless. He was surprised at the grayish color for he had been told that the gases themselves, when in liquid form, were of a green or yellowish color. He surmised that when pressure was released radical changes took place in the substance.

It is noteworthy that the workers in the plant complained of loss of appetite and one of them, a brother in law of PW, said he could no longer enjoy a regular meal. Peasants in the vicinity were required to make regular delivery of whole milk for the workers. All workers were absolutely forbidden to drink any alcoholic beverage, even beer, whether on or off duty. Brother in law of PW confessed that he had tried a few glasses of beer anyhow, but to his surprise found it distasteful. He felt that the gases or something else in the atmosphere of the installation were responsible for this. Other workers were undergoing the same experience. However, as this brother in law was receiving over 50RM per week for the relatively unskilled work he was performing (transferring the liquids from containers to tank cars) he was not complaining too much about his health.

On one occasion, when PW tried to draw Novotny out a little about the nature and use of theliquid gas Novotny put him off with what the PW considered fairy tales about "freezing gases" and "explosives which detonate with unheard-of force," or "weapons which will stop motors from functioning." PW believed that Novotny was stringing him along just to be polite rather than telling him point blank that it was none of his business.

Later, before PW was inducted into the army, the RR delivered 4 large dynamoes (marked "Henkel") and 16 to 18 smaller dynamoes (marked "Bosch") to the plant. He wondered what these were for inasmuch as the plant already was getting 15,000 volts from Timelkam. Included with these was a large variety of miscellaneous electrical equipment including transformers and items which PW had never seen before. He knew that electrical furnaces, albeit small ones, had been installed in the plant and felt that perhaps these dynamoes were used to furnished additional power for them .

PW learned from a worker at Stadl Paura that "a new type shell casing " was being turned out. So far as he recalls this shell case was of a size suitable for use in the largest field artillery pieces and was made of some kind of white metal. Whether or not there was any connection between these shell casings and the liquid gases being delivered there PW does not know.

End of preliminary report.

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Figure D.287: Report of Interrogation PW RAAB. 11 October 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

Report of Interrogation PW RAAB. 11 October 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)]

Report of Interrogation
PW RAAB, Johann
Grenadier, Gren. Regt 305

11 October 1944
IO Captain Campbell

Veracity and estimate of personality: Believed to be reliable. PW is a thirty-year-old Austrian, formerly a traffic official (Fahrdienstleiter) for the Deutsche Reichsbahn in Austria. He was inducted into the German Army 12 February 1944. PW is intelligent, observant and cooperative. The information contained herein was gathered by PW as a result of personal observation of the rail traffic between the installations involved and conversations with friends and acquaintances acquainted with the plants.

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End of preliminary report.

[See document photos on p. 3719–3721.]

Philip Morrison to Joseph Volpe. Evaluation of Documents in the Washington Office—October 19, 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)]

[...] 7. The long Prisoner of War reports on Redl Zipf have already been discussed by Dr. Tolman. It is reasonably certain that this is not a plant of interest to us [Manhattan Project] but may be of interest to some of the Chemical Warfare officers. [...]

[From this remarkably detailed PW report, it sounds as if something extraordinary was being produced at the Redl Zipf plant, yet there is still not enough information to tell exactly what that product was. It is possible that work conducted at this plant was one (or more) of the following:

- Production of uranium hexafluoride for U-235 enrichment. Uranium hexafluoride is corrosive to most materials except nickel, aluminum to a certain extent (the white metal described in these documents may have been nickel, aluminum, or an alloy containing one or both of those metals), and certain ceramics (such as the earthenware or earthenware-lined containers described in these documents).
- Enrichment of U-235 in uranium hexafluoride via gaseous diffusion, if the "circa 200 boilers of unusual construction" that were "connected by a system of pipes and conduits" were gaseous diffusion cells containing nickel diffusion membranes under high pressure.
- Enrichment of U-235 in uranium hexafluoride via centrifugation, if the "boilers of unusual construction" were uranium gas centrifuges.
- Chemical reprocessing to purify Pu-239 from neutron-irradiated U-238.
- Chemical reprocessing to purify U-233 from neutron-irradiated Th-232.
- Production of a nerve agent. Sarin, cyclosarin, and soman (but not tabun) contained fluorine, which made them corrosive to metals other than nickel or possibly aluminum.
- Production of a blistering agent. Mustard and some other blistering agents contained chlorine, which made them corrosive to most metals.
- Production of a fuel-air explosive, such as a mixture of coal dust and liquid oxygen, or coal dust and a corrosive nitrogen-based oxidizer (nitric acid, nitrogen tetroxide, etc.).
- Production of a corrosive nitrogen-based oxidizer (nitric acid, nitrogen tetroxide, etc.) for rocket propellant.
- Production of a fuel for rocket propellant (hydrazine, etc.).

Any of the above options are possible based on the PW report. Of these options, arguably the best fit might be uranium enrichment via gaseous diffusion or centrifugation of uranium hexafluoride. Manhattan Project personnel certainly seemed to think the Redl Zipf plant could be doing nuclear-related work, which is why they included it in their files and apparently spent some time analyzing it. On what grounds was this PW report ultimately dismissed as not being nuclear-related?

The same information was repeated in the final version of this PW interrogation report, Report 1349, Report from Captured Personnel and Material Branch, 17 October 1944 [AFHRA 25177 electronic version pp. 923–935].

There were many other wartime intelligence reports about very secret, high priority, and extremely mysterious work that was conducted at Redl Zipf [e.g., AFHRA electronic versions A6091 p. 1287l, 25082 pp. 106–108; 25177 pp. 919–951; 25216 pp. 385–386].]

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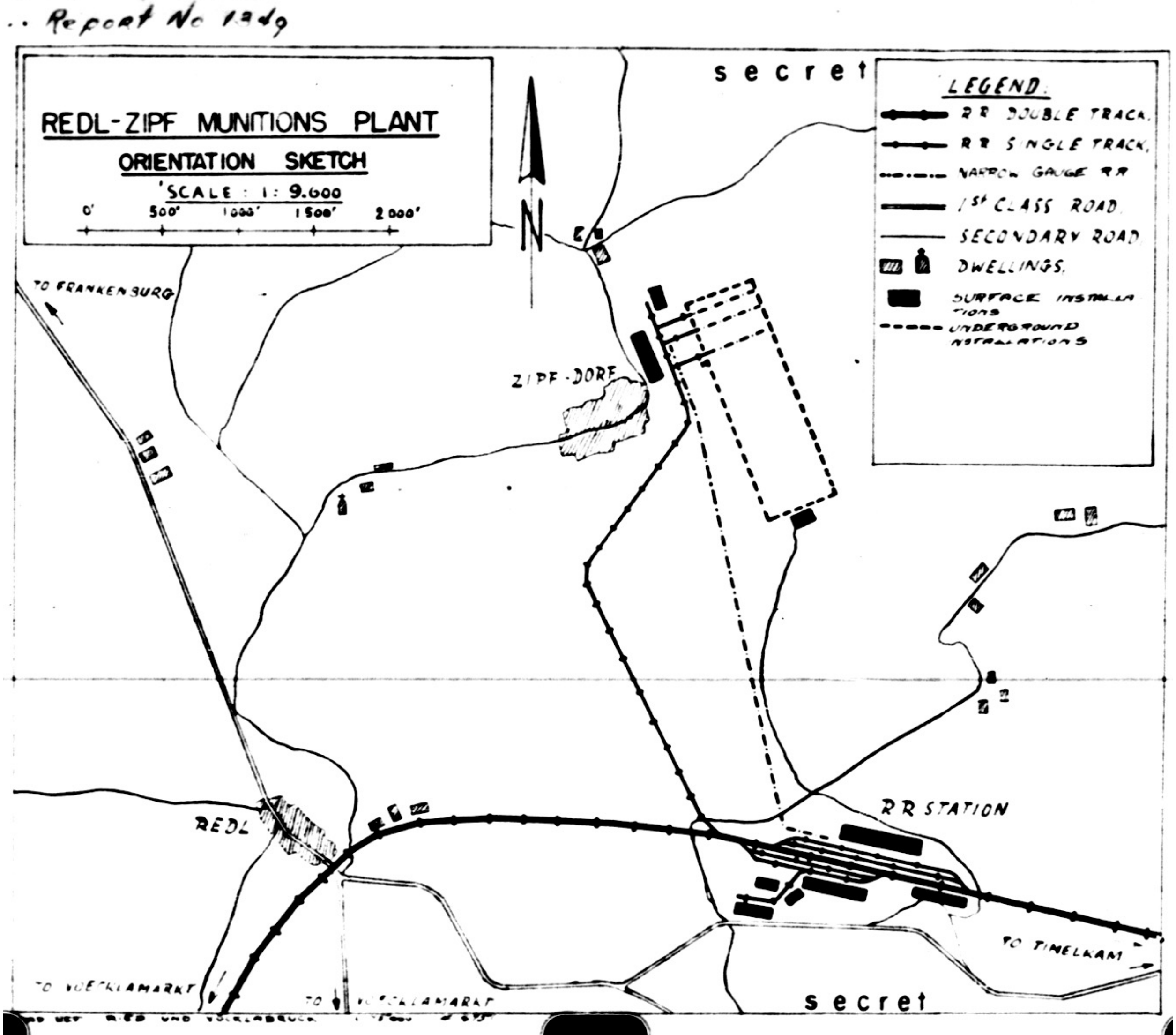
.. Report No 1349
secret
REDL-ZIPF MUNITIONS PLANT
ORIENTATION SKETCH
SCALE : 1 : 9.600
0' 500' 1000' 1500' 2000'
N
LEGEND:
RR DOUBLE TRACK.
RR SINGLE TRACK.
NARROW GAUGE RR
1st CLASS ROAD.
SECONDARY ROAD.
DWELLINGS.
SURFACE INSTALLATIONS
UNDERGROUND INSTALLATIONS
TO FRANKENBURG
ZIPF-DORF
REDL
RR STATION
TO TIMELKAM
TO VOECKLAMARKT
TO VOECKLAMARKT
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Figure D.288: Map of the Redl Zipf facility from Report 1349, Report from Captured Personnel and Material Branch, 17 October 1944 [AFHRA 25177 p. 932].

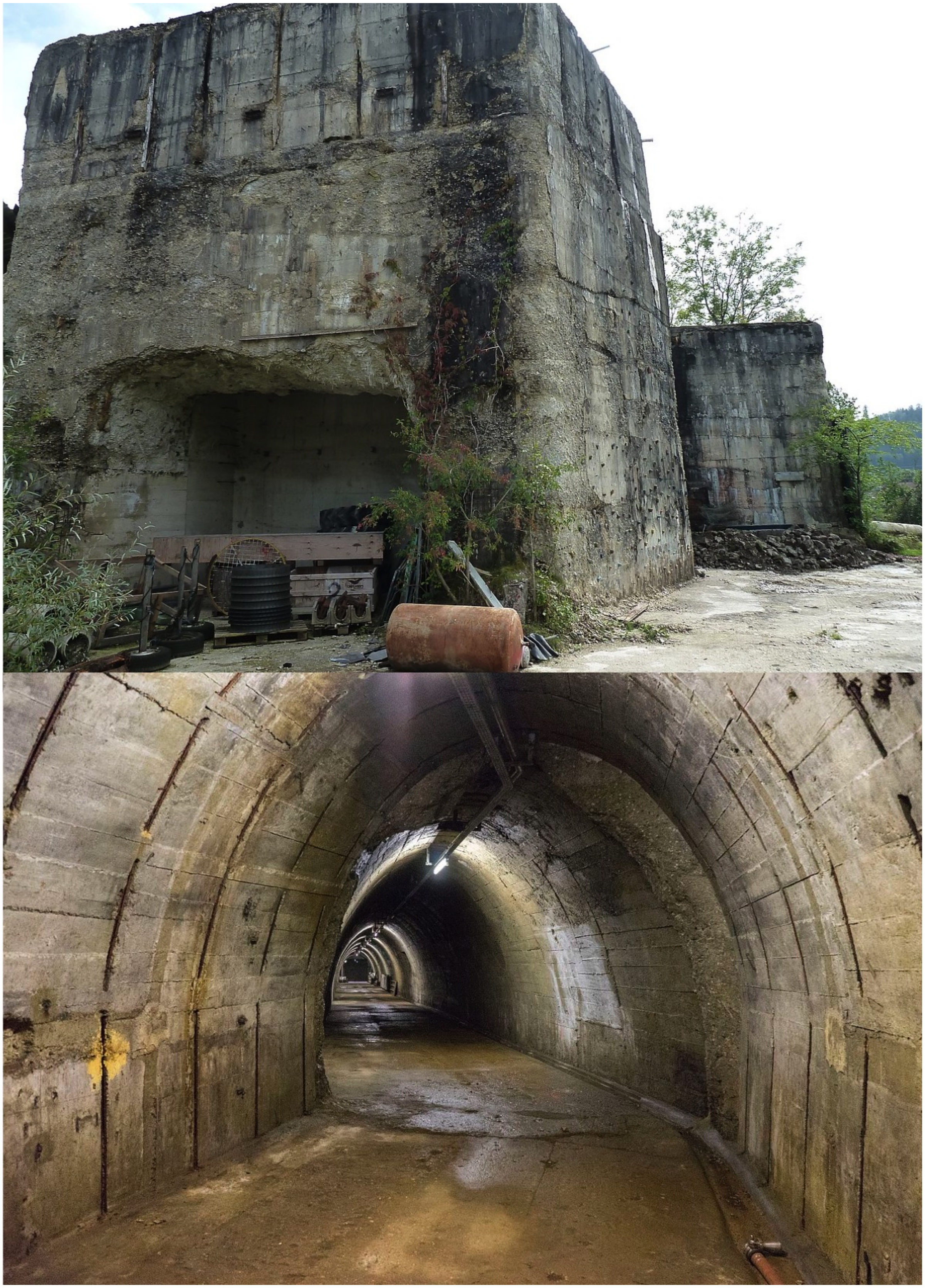

Figure D.289: Remains of the Redl Zipf facility on the surface and underground today.

Joseph Volpe to S. D. Brown. 18 October 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)]

18 October 1944

MEMORANDUM to Lt. Col. S. D. Brown, Room 2B677, Pentagon Building.

It is requested that during interrogation of Prisoners of War information be procured concerning the following:

Manufacturing plants at the following locations—

Redl Zipf
Stadl Paura
Ebensee
Lenzing
Timelkam

Companies—

de Boer, Ems, Germany

Rohstoff Handels Gesellschaft (Roges AG), Berlin

JOSEPH VOLPE, JR.

[See document photo on p. 3729. As shown by this memo, the Manhattan Project's Foreign Intelligence Unit continued to think that Redl Zipf and related facilities might be conducting nuclear weapons work, and they sought further information on those sites.]

PW INTELLIGENCE SECTION, HQ MAAF. 22 December 1944. [AFHRA A6091 frame 1419]

[...] 4. SECRET WEAPONS, REDL ZIPF (A): At REDL ZIPF between VÖCKLAMARKT and VÖCKLABRUCK, experiments are being made in connection with the atomic bomb. (See MAAF S 6686, Intelligence Item 6, Secret Weapons, Austria.) Date of Information: June 1944. [...]

[If this intelligence report was accurate, it confirms that Redl Zipf was indeed conducting work related to nuclear weapons development. What exactly was the information that was received? Can the cited report, "MAAF S 6686, Intelligence Item 6, Secret Weapons, Austria," be located in archives now?]

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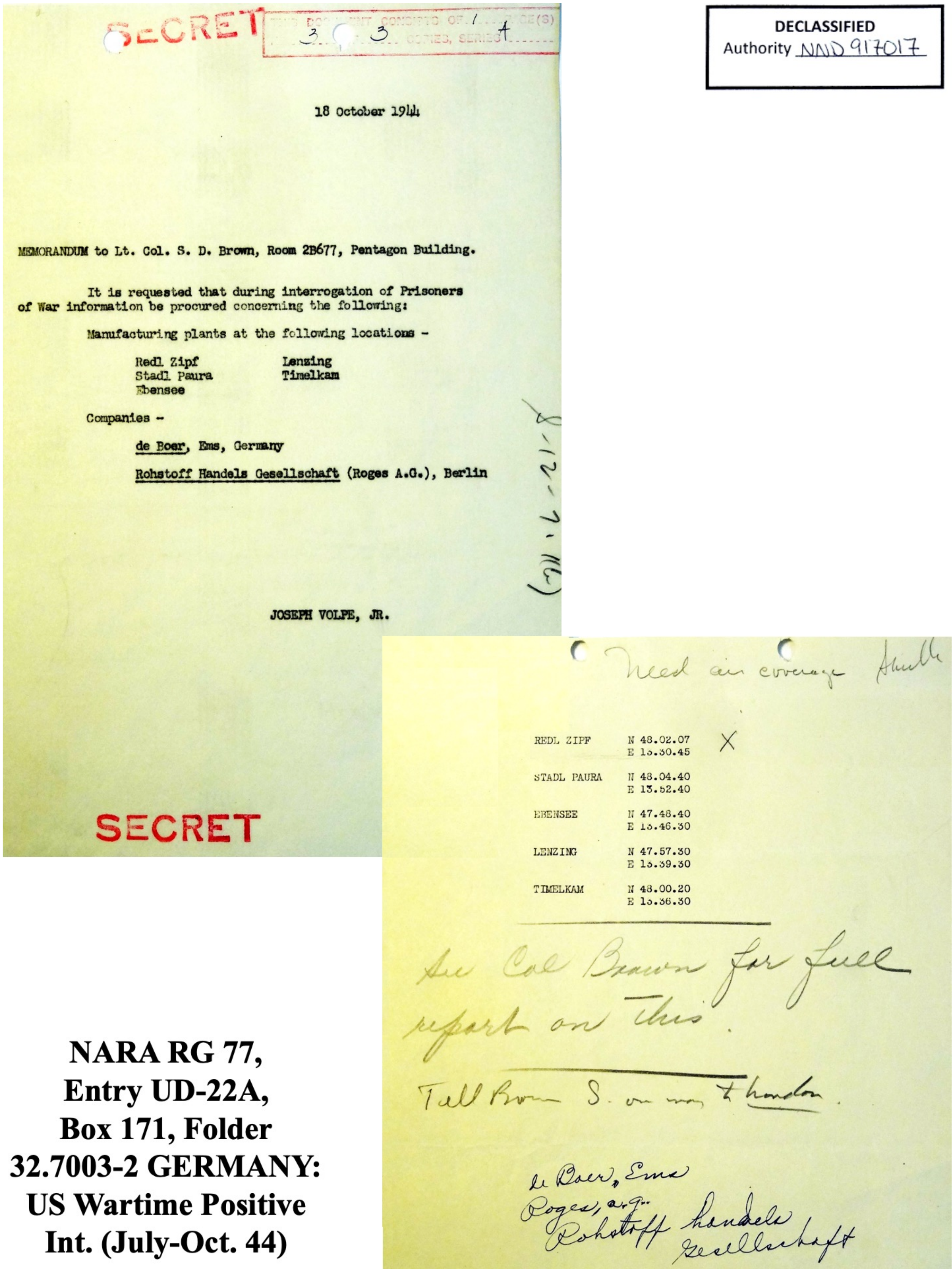
Authority NND 917017



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de Boer, Ems, Germany

Rohstoff Handels Gesellschaft (Roges A.G.), Berlin

8-12-7.11(2)

JOSEPH VOLPE, JR.

SECRET

Need air coverage Shull

REDL ZIPF	N 48.02.07 E 13.30.45	X
STADL PAURA	N 48.04.40 E 13.52.40	
EBENSEE	N 47.48.40 E 13.46.30	
LENZING	N 47.57.30 E 13.39.30	
TIMELKAM	N 48.00.20 E 13.36.30	

See Col Brown for full report on this.

Tell Brown S. on way to London.

de Boer, Ems
Roges, a.g.
Rohstoff handels Gesellschaft

**NARA RG 77,
Entry UD-22A,
Box 171, Folder
32.7003-2 GERMANY:
US Wartime Positive
Int. (July-Oct. 44)**

Figure D.290: Joseph Volpe to S. D. Brown. 18 October 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

Report No. 551/158. 13 February 1945. Austria—Economic: Factory Redl-Zipf, district Vöcklabruck. [AFHRA 25177 electronic version pp. 944–947]

Source
LULLABY from Czechoslovak refugee who worked in the factory.

Date of Information
6.2.45

Reliability
Good

Subsource is available for interrogation until 20 Feb. 45. Urgent comments are requested.

1. The secret name of the factory is SCHLIER. All transports for this factory are delivered under this name or "Zentralbauleitung Redl-Zipf". The number of workers employed in this factory is not known exactly to me, but I guess that about 1,000 men are now working there. The camp of these workers is situated in the buildings of the brewery in ZIPF. The brewery works only in a restricted measure. These workers are specialists—German only.

2. The factory has no name. It belongs to the Hermann Göring concern, LINZ (Austria).

3. High-explosive gas is manufactured in the underground tunnels and stored in vertical kettles (20 x 4 m), the pressure being 50–100 atm. These kettles are in the underground tunnels as well.

4. Two entrances lead to this underground factory and, out of these corridors, other corridors were hewn in the rock which lead into working rooms, the number of these being 23. From these rooms are pipe lines leading into the kettles. Some rooms have 2 or 4 (one has even 8) kettles. The total number of kettles I do not know.

5. These kettles, made of steel, are vertical, hewn into the rock under the surface of the corridors and on the top of the kettles is a layer of ash-like material. The whole kettle is cemented into the rock.

6. I have seen machines in 4 rooms only. These 4 rooms were the biggest—12 m width, 100 m length, 5 m high. The firring of these machines, where I helped, lasted one month. In each of these rooms were two machines that looked like huge pumps—dimensions 3 m width, 3 m height, 5 m length. Other installations in these rooms were a steel ball, walls 7 cm thick, 2 m diameter (I know the thickness of this ball as other workers were cleaning the interior of the ball). This ball has not been of one piece, but welded out of several square pieces. Into the ball leads a pipe, the diameter being about 50 cm and another pipe of the same dimension which leads out opposite the first pipe. Two pipes 10 cm diameter lead into a measuring apparatus which has been sufficiently accurate to measure 1/260th of a gramme. This apparatus I suppose has been devised to measure the pressure and probably other qualities of the product.

7. This product has been referred to by German personnel as “Masse”.

8. The ball rested on an iron pedestal and under this pedestal the aforementioned measuring apparatus has been placed. This apparatus has been of a sort of weigh[ing]. During the time of fitting one Russian prisoner left a chisel, probably on purpose, a chisel in this weigh so that the apparatus would not function, the chisel staying upright. He has been shot. This apparatus had several dials which were connected with a camera. This camera has been connected with a “Prüfungsraum” situated on the top of the rock and separated from the working rooms. This ‘Prüfungsraum” was in a pill-box, camouflaged with dry trees painted green. In the same manner has been camouflaged the whole rock on a surface of about 300 m x 300 m. On the rocket has been put a layer of cement, about 30 cm, and in this layer the dry trees stuck in and sprayed with green paint.

9. At the first trial producing the “Masse” an explosion occurred and a fire broke out lasting five minutes. A flame shot out of the tunnels, white in colour (Stichflamme) and a temperature of 3000 ^{o}C—as I heard from the Germans—all the brass, aluminium and copper parts of machines disappeared. The repair lasted for three months (the factory has been built from April 1943–May 1944). All the occupants in the rooms were killed—my party removed 9 bodies, completely unrecognisable, 70 cm long.

10. The other rooms were much smaller, about 3 x 3 x 3 m and some were only enlargements of the corridors. There were a few machines which had been transported there in parts so that I could not guess what sort of machines they were when fitted together. Ten rooms were probably larger, but always behind a curtain. In one of them has been probably a power station, as different electric material has been transported inside. I guess that chemical products were manufactured as cases from the societies: Vereinigte Chemische Fabrik Kreidel & Heller, Wien XXI, Sebastian Kohlgasse (I know the first exactly as near there I have been working—the factory until XII/1944 has not been hit, though the Vacuum Shell Company on the opposite side of the street is completely destroyed).

11. The daily output of the factory is 4 railway-cisterns. These cisterns resist high pressure. At the closing of the cisterns a white snow-like layer forms itself and the so evaporating gas has a slightly green colour, without any smell and when inhaled is harmless.

12. Locating this factory is helped by the brewery in ZIPF which has a high factory chimney painted green. The two corridors leading underground are immediately at the brewery (see sketch) towards North.

13. The rock in ZIPF, where the factory is, is of sandstone and it happened several times during the construction that the corridors broke down. At the entrance the thickness of sandstone is about 1 m, the deepest corridor is 18 m. On that point is a shaft, the Germans said, 18 m deep.

14. The station REDL-ZIPF is on the main railway line LINZ-SALZBURG.

15. Electricity comes from the power station TIMELKAM situated 20 km to the East of the station Redl-Zipf. The tension is 110,000 V. I worked on the fitting of switchboards. From the transformer station (see sketch) electricity comes to the factory with two high tension wires and two underground cables. Here the tension is lowered to 10,000 volts.

Another high tension wire was being erected to the West as I know there is also a power station in STEINDORF, 20 km to the West from REDL-ZIPF.

16. What I heard, and what the workers think, is that gas for the V.1 weapon is being manufactured in this factory.

17. The postal address of this factory is: Attnang-Puchheim, Postschliessfach 26.

I heard about other factories of this sort, but I have not been there. They are:-

1. The factory in ST. GEORGEN, near LINZ. The secret name of this factory is ESCHE. The postal address: LINZ/DONAU 2 Postschliessfach 999/XX.

2. The factory in MELK, near Vienna. The secret name is QUARZ, the postal address is not known to me.

We were told by the Germans that, upon being asked by relatives etc we have to say that we are in Esche, Quarz etc. Where is this unknown place? At Attnang-Puchheim. Of course, what is being done there, we were forbidden to tell.

3. Another factory of this sort in WIENER NEUSTADT has been destroyed by bombing. Work not resumed.

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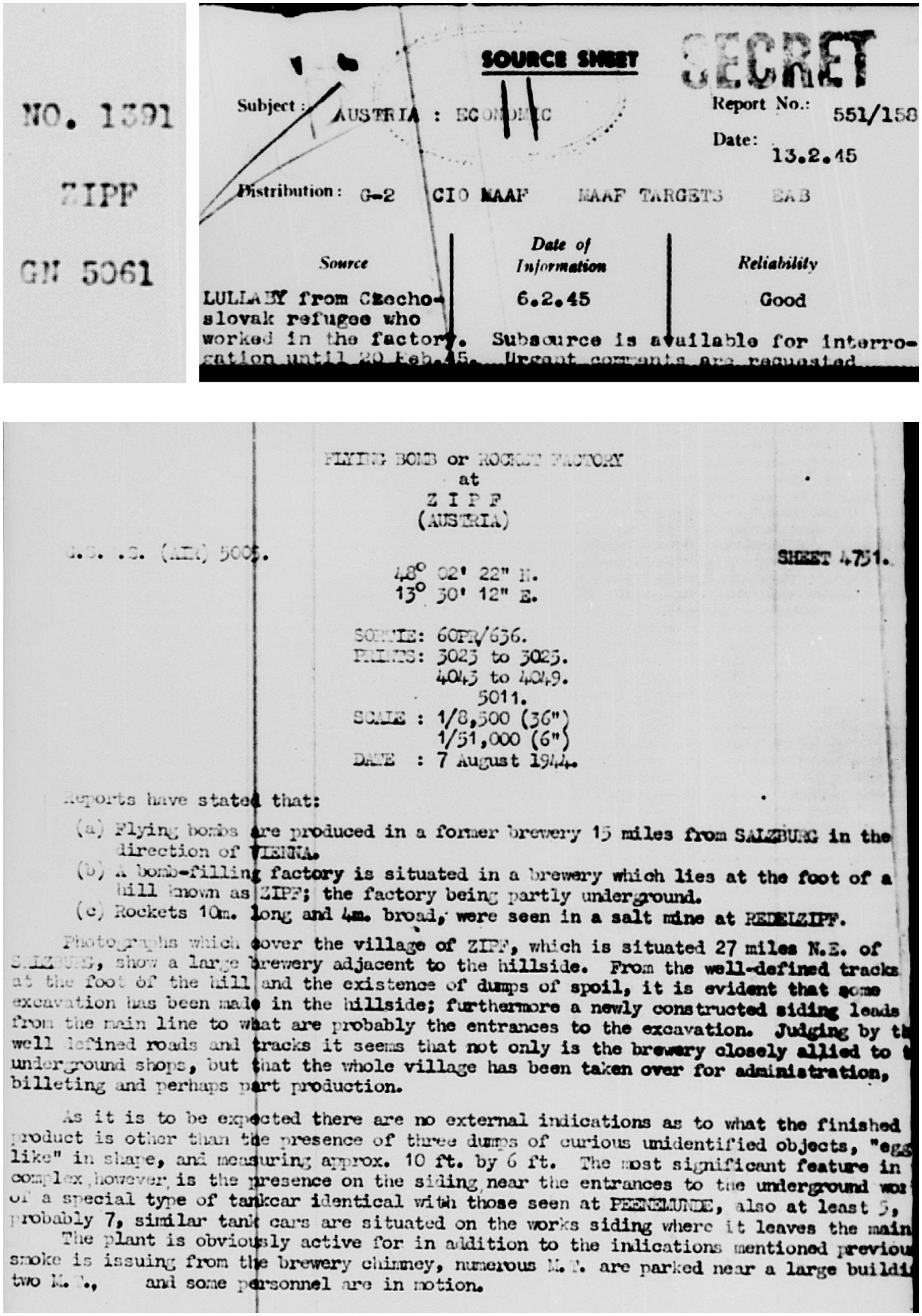
AFHRA MAAF Reel 189 No. 1391 Zipf GN 5061



NO. 1391

ZIPF

GN 5061

SOURCE SHEET

SECRET

Subject: AUSTRIA : ECONOMIC

Report No.: 551/158

Date: 13.2.45

Distribution: G-2 CIO MAAF MAAF TARGETS EAB

Source	*Date of Information*	*Reliability*
LULLABY from Czechoslovak refugee who	6.2.45	Good

worked in the factory. Subsource is available for interrogation until 20 Feb. 45. Urgent comments are requested

---

FLYING BOMB or ROCKET FACTORY
at
Z I P F
(AUSTRIA)

G.S.G.S. (AIR) 5005.

SHEET 4751.

48° 02' 22" N.
13° 30' 12" E.

SORTIE: 60PR/636.
PRINTS: 3023 to 3025.
4043 to 4049.
5011.
SCALE : 1/8,500 (36")
1/51,000 (6")
DATE : 7 August 1944.

Reports have stated that:

(a) Flying bombs are produced in a former brewery 15 miles from SALZBURG in the direction of VIENNA.
(b) A bomb-filling factory is situated in a brewery which lies at the foot of a hill known as ZIPF; the factory being partly underground.
(c) Rockets 10m. long and 4m. broad, were seen in a salt mine at REDELZIPF.

Photographs which cover the village of ZIPF, which is situated 27 miles N.E. of SALZBURG, show a large brewery adjacent to the hillside. From the well-defined tracks at the foot of the hill and the existence of dumps of spoil, it is evident that some excavation has been made in the hillside; furthermore a newly constructed siding leads from the main line to what are probably the entrances to the excavation. Judging by th well defined roads and tracks it seems that not only is the brewery closely allied to t underground shops, but that the whole village has been taken over for administration, billeting and perhaps part production.

As it is to be expected there are no external indications as to what the finished product is other than the presence of three dumps of curious unidentified objects, "egg like" in shape, and measuring approx. 10 ft. by 6 ft. The most significant feature in complex, however, is the presence on the siding, near the entrances to the underground wor of a special type of tankcar identical with those seen at PEENEMUNDE, also at least 5, probably 7, similar tank cars are situated on the works siding where it leaves the main
The plant is obviously active for in addition to the indications mentioned previou smoke is issuing from the brewery chimney, numerous M.T. are parked near a large buildi two M.T., and some personnel are in motion.

Figure D.291: [AFHRA Mediterranean Allied Air Forces Reel 189, No. 1391 Zipf GN 5061]

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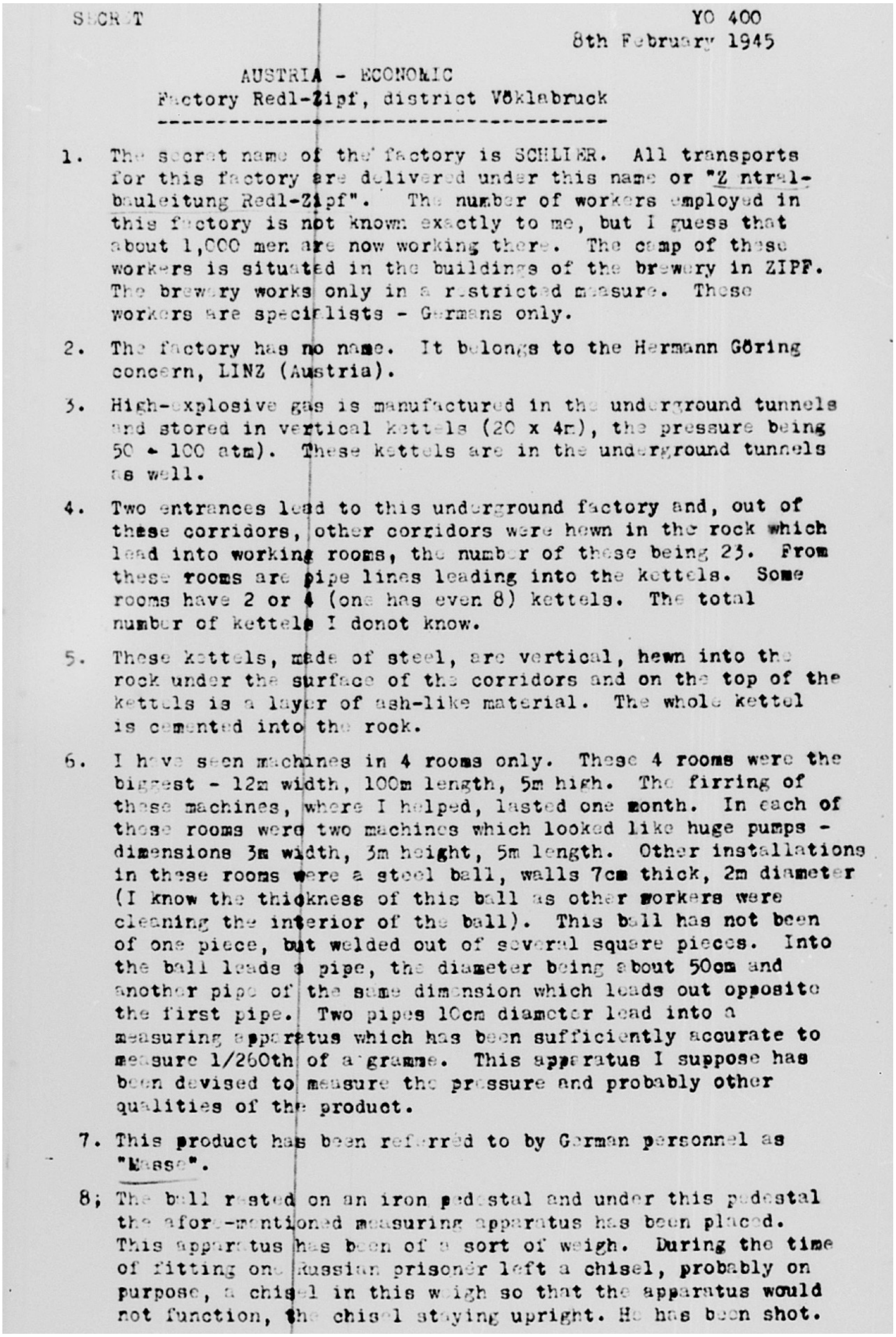
AFHRA MAAF Reel 189 No. 1391 Zipf GN 5061



SECRET

YO 400
8th February 1945

AUSTRIA - ECONOMIC
Factory Redl-Zipf, district Vöklabruck

1. The secret name of the factory is SCHLIER. All transports for this factory are delivered under this name or "Zentral-bauleitung Redl-Zipf". The number of workers employed in this factory is not known exactly to me, but I guess that about 1,000 men are now working there. The camp of these workers is situated in the buildings of the brewery in ZIPF. The brewery works only in a restricted measure. These workers are specialists - Germans only.

2. The factory has no name. It belongs to the Hermann Göring concern, LINZ (Austria).

3. High-explosive gas is manufactured in the underground tunnels and stored in vertical kettels (20 x 4m), the pressure being 50 - 100 atm). These kettels are in the underground tunnels as well.

4. Two entrances lead to this underground factory and, out of these corridors, other corridors were hewn in the rock which lead into working rooms, the number of these being 23. From these rooms are pipe lines leading into the kettels. Some rooms have 2 or 4 (one has even 8) kettels. The total number of kettels I donot know.

5. These kettels, made of steel, are vertical, hewn into the rock under the surface of the corridors and on the top of the kettels is a layer of ash-like material. The whole kettel is cemented into the rock.

6. I have seen machines in 4 rooms only. These 4 rooms were the biggest - 12m width, 100m length, 5m high. The firring of these machines, where I helped, lasted one month. In each of these rooms were two machines which looked like huge pumps - dimensions 3m width, 3m height, 5m length. Other installations in these rooms were a steel ball, walls 7cm thick, 2m diameter (I know the thickness of this ball as other workers were cleaning the interior of the ball). This ball has not been of one piece, but welded out of several square pieces. Into the ball leads a pipe, the diameter being about 50cm and another pipe of the same dimension which leads out opposite the first pipe. Two pipes 10cm diameter lead into a measuring apparatus which has been sufficiently accurate to measure 1/260th of a gramme. This apparatus I suppose has been devised to measure the pressure and probably other qualities of the product.

7. This product has been referred to by German personnel as "Masse".

8; The ball rested on an iron pedestal and under this pedestal the afore-mentioned measuring apparatus has been placed. This apparatus has been of a sort of weigh. During the time of fitting one Russian prisoner left a chisel, probably on purpose, a chisel in this weigh so that the apparatus would not function, the chisel staying upright. He has been shot.

Figure D.292: [AFHRA Mediterranean Allied Air Forces Reel 189, No. 1391 Zipf GN 5061]

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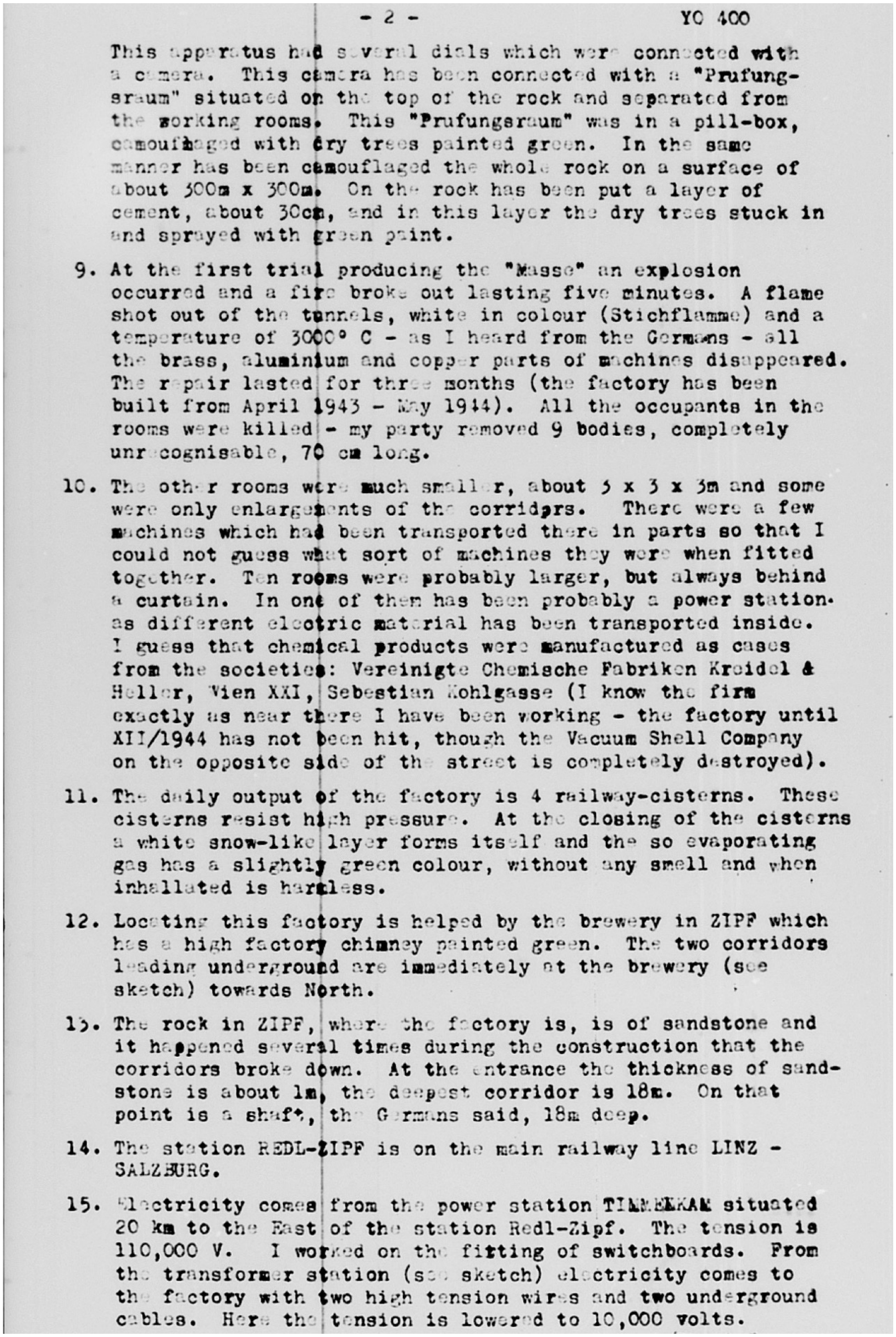
AFHRA MAAF Reel 189 No. 1391 Zipf GN 5061



- 2 - YO 400

This apparatus had several dials which were connected with a camera. This camera has been connected with a "Prufungsraum" situated on the top of the rock and separated from the working rooms. This "Prufungsraum" was in a pill-box, camouflaged with dry trees painted green. In the same manner has been camouflaged the whole rock on a surface of about 300m x 300m. On the rock has been put a layer of cement, about 30cm, and in this layer the dry trees stuck in and sprayed with green paint.

9. At the first trial producing the "Masse" an explosion occurred and a fire broke out lasting five minutes. A flame shot out of the tunnels, white in colour (Stichflamme) and a temperature of 3000° C - as I heard from the Germans - all the brass, aluminium and copper parts of machines disappeared. The repair lasted for three months (the factory has been built from April 1943 - May 1944). All the occupants in the rooms were killed - my party removed 9 bodies, completely unrecognisable, 70 cm long.

10. The other rooms were much smaller, about 5 x 3 x 3m and some were only enlargements of the corridors. There were a few machines which had been transported there in parts so that I could not guess what sort of machines they were when fitted together. Ten rooms were probably larger, but always behind a curtain. In one of them has been probably a power station. as different electric material has been transported inside. I guess that chemical products were manufactured as cases from the societies: Vereinigte Chemische Fabriken Kreidel & Heller, Vien XXI, Sebestian Kohlgasse (I know the firm exactly as near there I have been working - the factory until XII/1944 has not been hit, though the Vacuum Shell Company on the opposite side of the street is completely destroyed).

11. The daily output of the factory is 4 railway-cisterns. These cisterns resist high pressure. At the closing of the cisterns a white snow-like layer forms itself and the so evaporating gas has a slightly green colour, without any smell and when inhallated is harmless.

12. Locating this factory is helped by the brewery in ZIPF which has a high factory chimney painted green. The two corridors leading underground are immediately at the brewery (see sketch) towards North.

13. The rock in ZIPF, where the factory is, is of sandstone and it happened several times during the construction that the corridors broke down. At the entrance the thickness of sandstone is about 1m, the deepest corridor is 18m. On that point is a shaft, the Germans said, 18m deep.

14. The station REDL-ZIPF is on the main railway line LINZ - SALZBURG.

15. Electricity comes from the power station TIMMELKAM situated 20 km to the East of the station Redl-Zipf. The tension is 110,000 V. I worked on the fitting of switchboards. From the transformer station (see sketch) electricity comes to the factory with two high tension wires and two underground cables. Here the tension is lowered to 10,000 volts.

Figure D.293: [AFHRA Mediterranean Allied Air Forces Reel 189, No. 1391 Zipf GN 5061]

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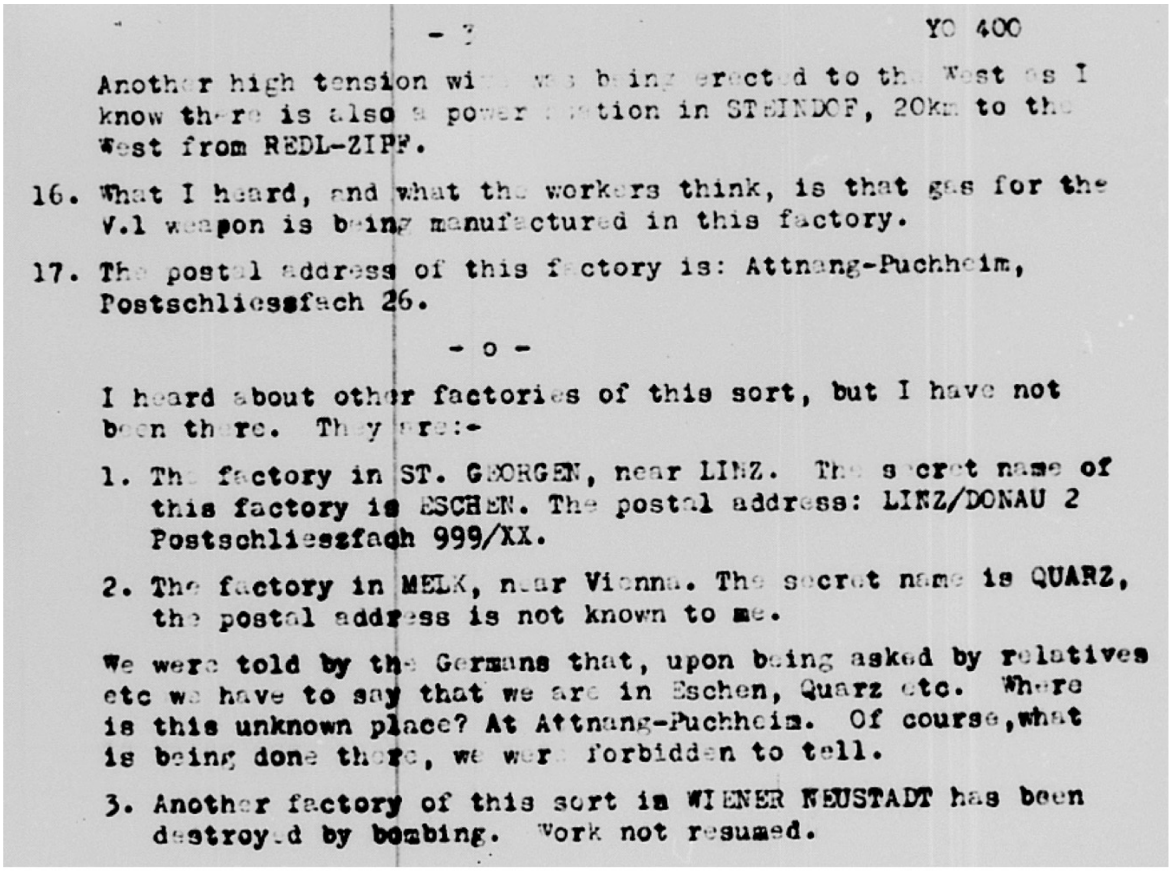
AFHRA MAAF Reel 189 No. 1391 Zipf GN 5061



- 3 - YO 400

Another high tension wire was being erected to the West as I know there is also a power station in STEINDOF, 20km to the West from REDL-ZIPF.

16. What I heard, and what the workers think, is that gas for the V.1 weapon is being manufactured in this factory.

17. The postal address of this factory is: Attnang-Puchheim, Postschliessfach 26.

- o -

I heard about other factories of this sort, but I have not been there. They are:-

1. The factory in ST. GEORGEN, near LINZ. The secret name of this factory is ESCHEN. The postal address: LINZ/DONAU 2 Postschliessfach 999/XX.

2. The factory in MELK, near Vienna. The secret name is QUARZ, the postal address is not known to me.

We were told by the Germans that, upon being asked by relatives etc we have to say that we are in Eschen, Quarz etc. Where is this unknown place? At Attnang-Puchheim. Of course, what is being done there, we were forbidden to tell.

3. Another factory of this sort in WIENER NEUSTADT has been destroyed by bombing. Work not resumed.

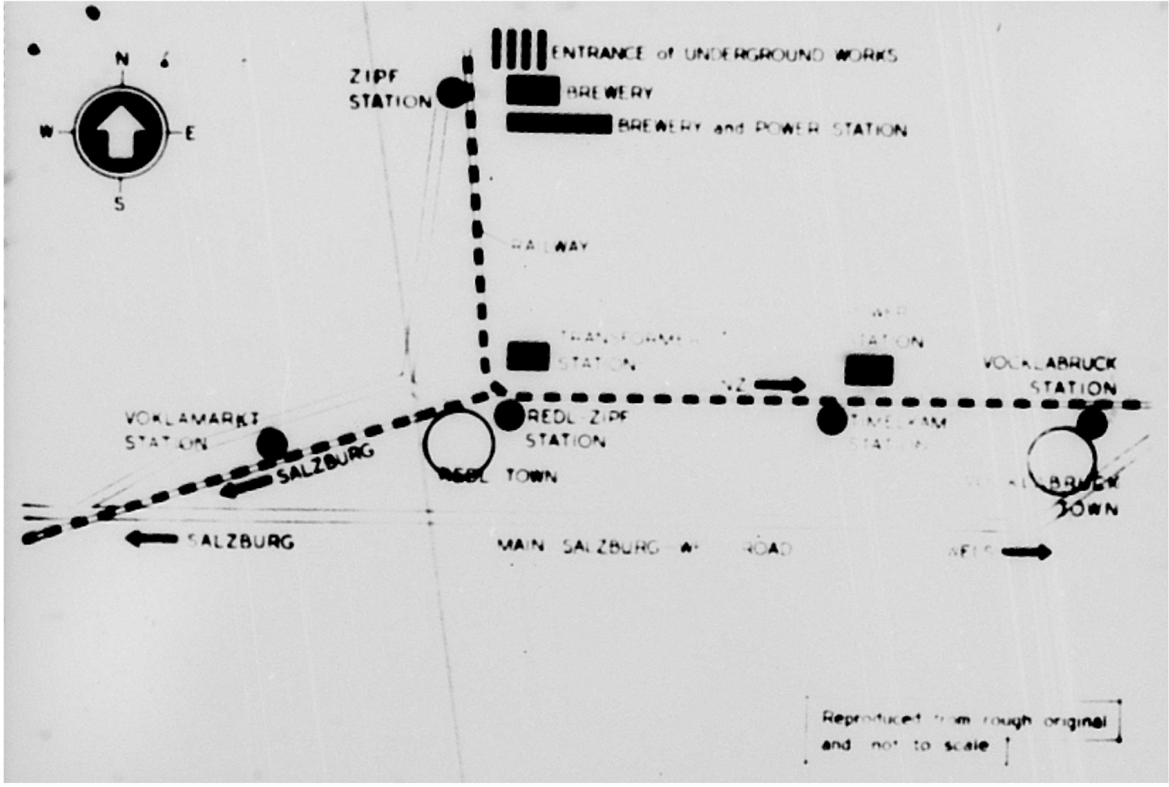

N
W
E
S
ZIPF STATION
ENTRANCE of UNDERGROUND WORKS
BREWERY
BREWERY and POWER STATION
RAILWAY
TRANSFORMER STATION
STATION
VOCKLABRUCK STATION
VOKLAMARKT STATION
SALZBURG
REDL ZIPF STATION
TIMELKAM STATION
REDL TOWN
VOCKLABRUCK TOWN
SALZBURG
MAIN SALZBURG ROAD
Reproduced from rough original and not to scale

Figure D.294: [AFHRA Mediterranean Allied Air Forces Reel 189, No. 1391 Zipf GN 5061]

AFHRA MAAF Reel 189 No. 1391 Zipf GN 5061

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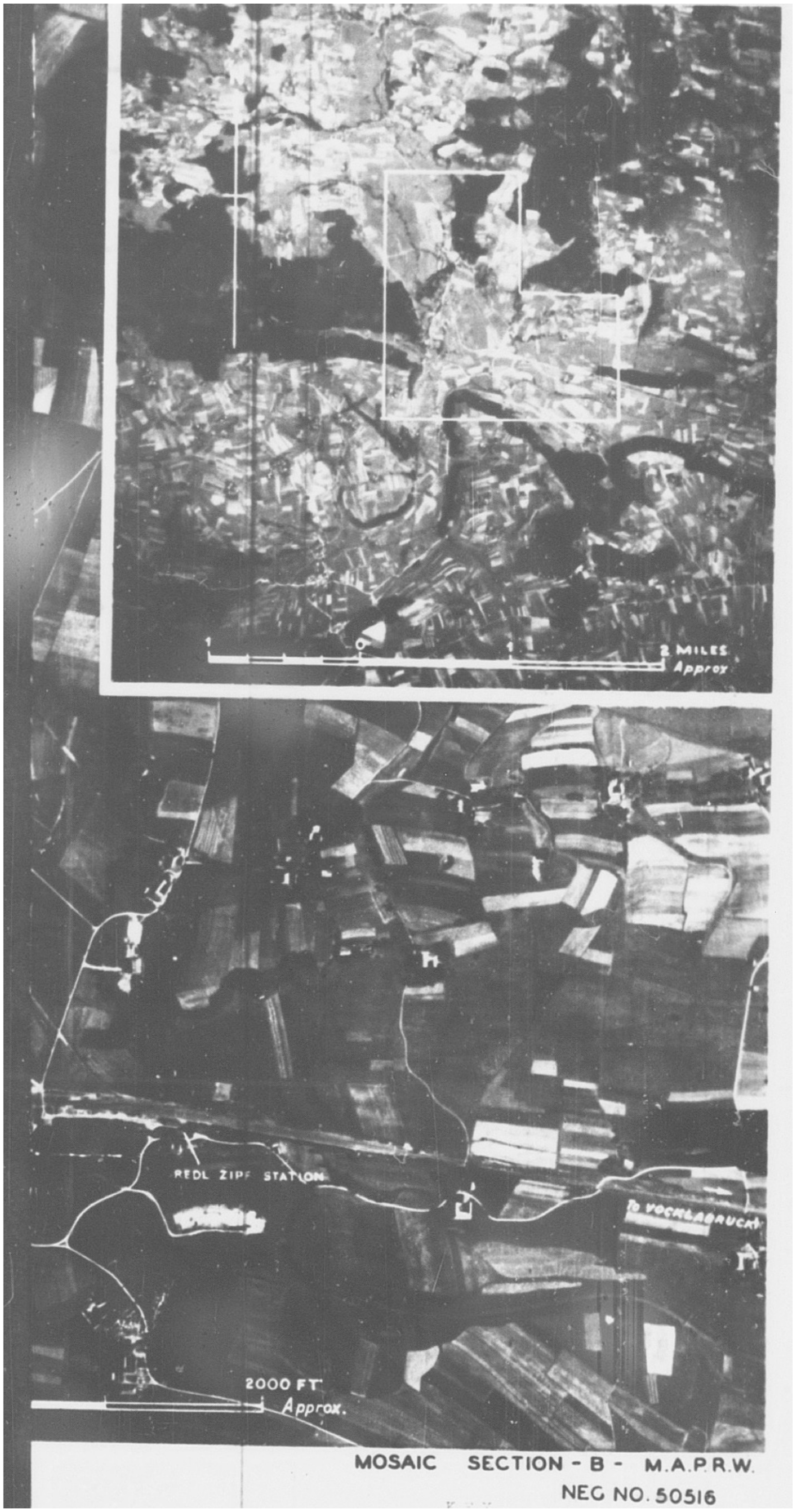
1
0
1
2 MILES
Approx
REDL ZIPF STATION
TO VOCKLABRUCK
2000 FT
Approx.
MOSAIC SECTION - B - M.A.P.R.W.
NEG NO. 50516

Figure D.295: [AFHRA Mediterranean Allied Air Forces Reel 189, No. 1391 Zipf GN 5061]

AFHRA MAAF Reel 189 No. 1391 Zipf GN 5061

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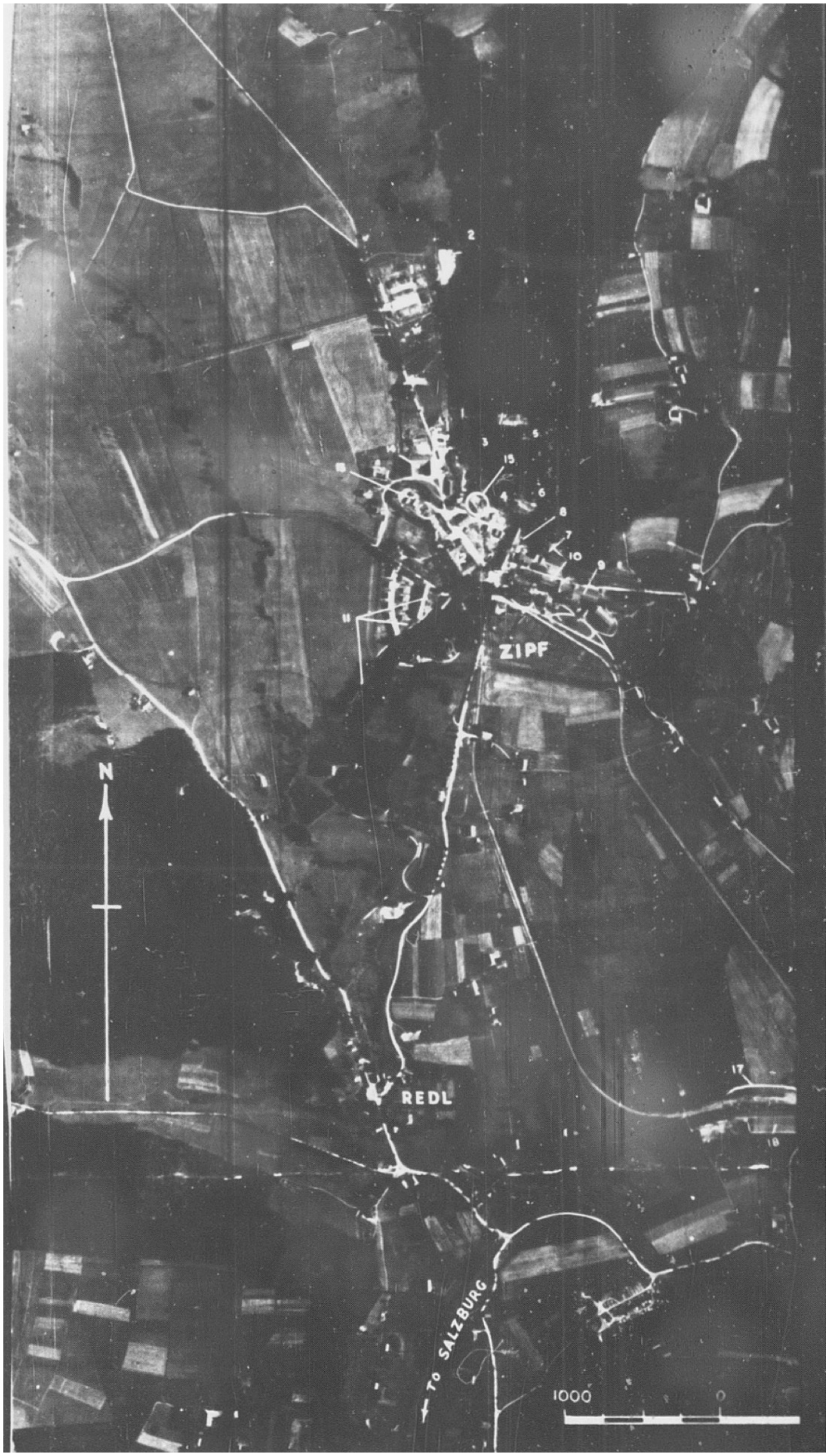
2
1
5
3
14
13
15
4
6
8
7
10
12
9
11
ZIPF
N
REDL
17
18
TO SALZBURG
1000
0

Figure D.296: [AFHRA Mediterranean Allied Air Forces Reel 189, No. 1391 Zipf GN 5061]

AFHRA MAAF Reel 189 No. 1391 Zipf GN 5061

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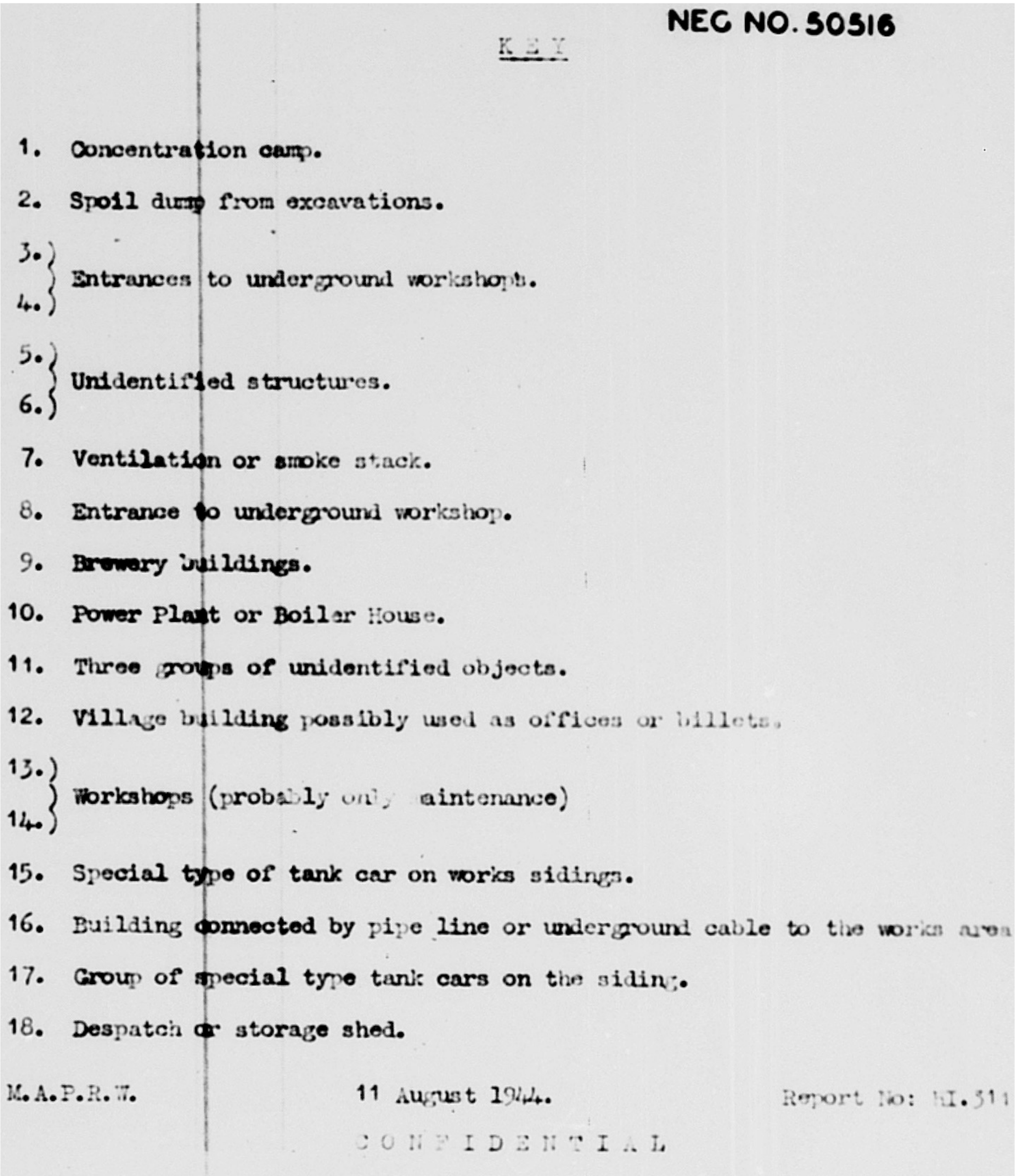


NEG NO. 50516

KEY

1. Concentration camp.
2. Spoil dump from excavations.
3.) 4.) Entrances to underground workshops.
5.) 6.) Unidentified structures.
7. Ventilation or smoke stack.
8. Entrance to underground workshop.
9. Brewery buildings.
10. Power Plant or Boiler House.
11. Three groups of unidentified objects.
12. Village building possibly used as offices or billets.
13.) 14.) Workshops (probably only maintenance)
15. Special type of tank car on works sidings.
16. Building connected by pipe line or underground cable to the works area
17. Group of special type tank cars on the siding.
18. Despatch or storage shed.

M.A.P.R.W. 11 August 1944. Report No: MI.311

CONFIDENTIAL

Figure D.297: [AFHRA Mediterranean Allied Air Forces Reel 189, No. 1391 Zipf GN 5061]

BIOS 31. *Rocket Developments in South Germany and Austria.* pp. 35–37.

Target: Steinbruchverwertungs G.m.b.H.
Betrieb Schlier

Location: Brauerei Zipf, Redl. N.49 XV2954
(U.S. zone)

Nature of Target: Underground liquid oxygen plant
and firing station for static
proof of A.4 rocket motors.

Date visited: 24.8.45.

Personnel interviewed: Dr. Kretz, (E), the owner
of the brewery.
Available at the brewery.

1. The brewery's storage vaults, which were constructed in the side of a hill, had been used by the above-named organisation for the erection in 1943 of an underground liquid oxygen plant.

This plant consisted of seven units, operating on the Linde principle, capable of producing 80 tons of liquid oxygen per day.

Each unit comprised a compressor, alkali absorption towers for removal of CO_2, and a still for separation of liquid oxygen and nitrogen.

The compressor, built by Borsig, operated in five stages and developed 600 Kw. Compression to 160 atms. was attained.

The nitrogen was expanded after separation from the oxygen, giving a recovery of 10 per cent. of the power input. After running off the liquid, residual gaseous oxygen was bottled.

The liquid oxygen was pumped from the plant's storage tanks into specially constructed railway wagons, each holding 30 tons. It was stated that the loss by evaporation from these wagons was one ton per day.

Production had been continuous until April 1945, when transportation became impossible on account of disruption of railway services.

The plant had not been attacked by air and was completely undamaged although provision had been made by the S.S. for blowing up the entrances. This plan was frustrated by the early arrival of U.S. ground forces.

Dr. Kretz stated that a similar plant consisting of 15 units had been operating at Saalfield. (Russian occupied zone).

Maintenance of the plant is at present being carried out, pending a decision as to its utilisation. (Redl is in Austria).

2. A static firing station, for testing A. 4 rocket motors, had been constructed on top of the hill. This was directly accessible by a lift from the underground factory, in which the motors awaiting test were stored. (Nine motors, mounted on trolleys running on a narrow gauge railway, were seen). [...]

The whole station was of massive dimensions and solid construction.

Two bursts during firings had occurred since tests commenced in October, 1943. The first of these occurred in February, 1944, and the second which partially destroyed the firing bay, in August 1944, since when no firings had been done.

After the first of these bursts, all iron pipe lines for liquid oxygen were replaced by aluminium, which does not become so brittle at extremely low temperatures.

It was stated by Dr. Kretz that no other rocket work was carried out at the factory. No rocket materials, other than those mentioned above, were discovered by this team.

It is of interest to record that the underground factory contained one "secret room", open to S.S. officials only, in which counterfeit Bank of England notes, from L1 to L50 denomination, were printed.

Visits by other rocket teams to this target are not considered necessary.

[This is one of several Allied reports that described Redl Zipf as just an oxygen production plant (e.g., see p. 4965).

It is possible that part of the Redl Zipf facility did produce oxygen, but if that were the only product of Redl Zipf, that would not be consistent with many of the details provided by PW Johann Raab (p. 3722): (1) long-term toxicity to the workers; (2) extreme corrosivity to all materials except a white metal (nickel, aluminum, or an alloy containing one or both of those metals?) and ceramics; and (3) consumption of large quantities of nuclear-related materials such as lead, beryllium, thorium, etc.

If Redl Zipf were only an oxygen plant, it would also contradict the intelligence report that specifically stated that Redl Zipf was doing work related to nuclear weapons (p. 3728), as well as other intelligence reports that indicated that Redl Zipf had far greater secrecy and security than one would expect of a simple oxygen plant [e.g., AFHRA electronic versions A6091 p. 1287l, 25082 pp. 106–108, 25177 pp. 919–951, 25216 pp. 385–386].

Was the Redl Zipf plant really only producing oxygen the whole time, or was it converted to that later, or only using oxygen production as a cover story? For example, at the end of the war, German industrial plants that had been producing nerve gas were stripped of all evidence and even completely overhauled to appear to have been nothing more than harmless soap factories throughout the war [Jacobsen 2014, pp. 24–29, 73–75].

BIOS 31 was a British report. U.S. officials also personally inspected the Redl Zipf plant after the war (p. 4965). What exactly did they find there? Where are their reports?]

English translation of French intelligence report. 10 June 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)]

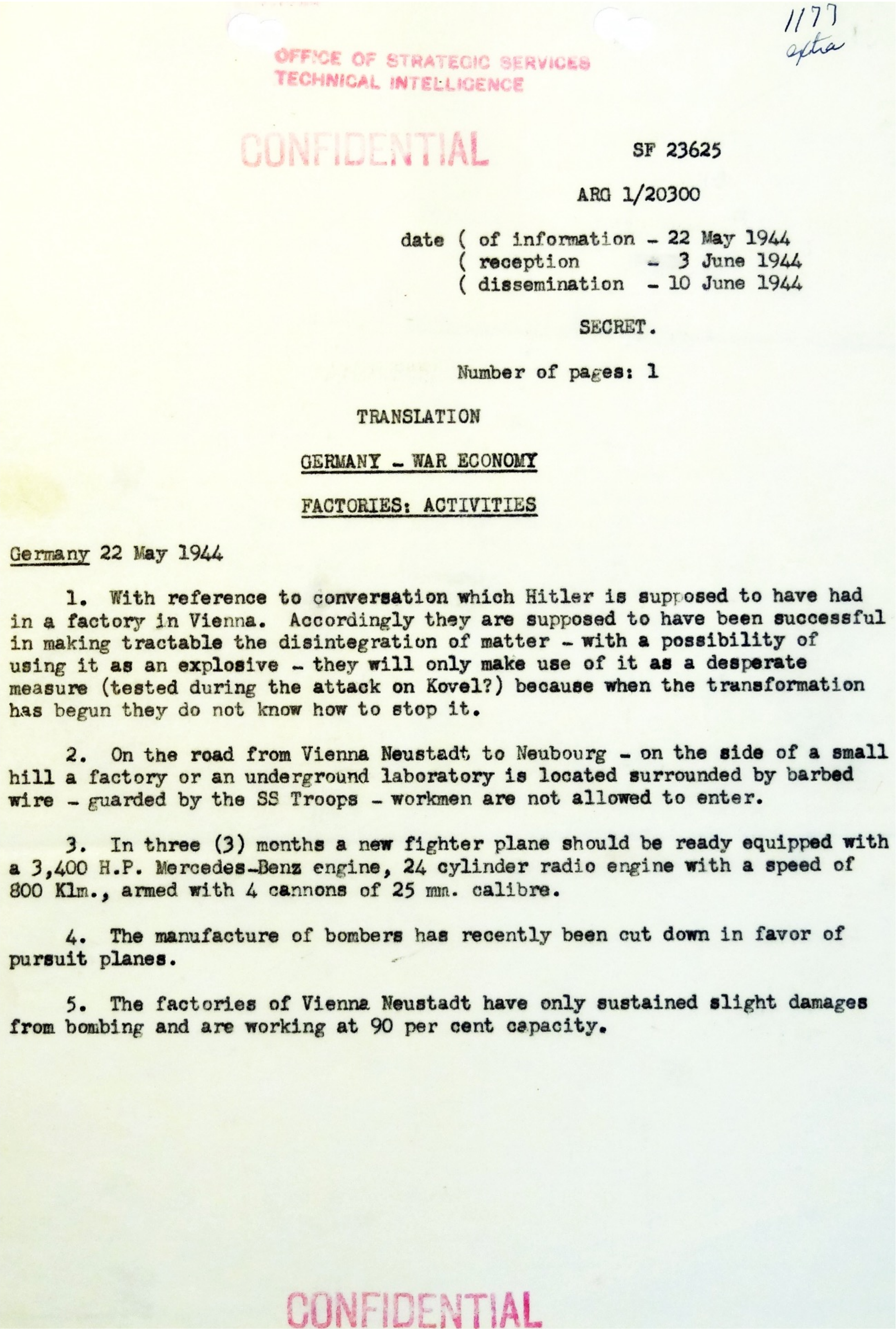
1. With reference to conversation which Hitler is supposed to have had in a factory in Vienna. Accordingly there are supposed to have been successful in making tractable the disintegration of matter—with a possibility of using it as an explosive—they will only make use of it as a desperate measure (tested during the attack on Kovel?) because when the transformation has begun they do not know how to stop it.

2. On the road from Vienna Neustadt to Neuburg [Neuberg?]—on the side of a small hill a factory or an underground laboratory is located surrounded by barbed wire—guarded by SS troops—workmen are not allowed to enter. [...]

[See document photos on pp. 3743–3744.]

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder
32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)



1177
extra

OFFICE OF STRATEGIC SERVICES
TECHNICAL INTELLIGENCE

CONFIDENTIAL

SF 23625

ARG 1/20300

date (of information - 22 May 1944
(reception - 3 June 1944
(dissemination - 10 June 1944

SECRET.

Number of pages: 1

TRANSLATION

GERMANY - WAR ECONOMY

FACTORIES: ACTIVITIES

Germany 22 May 1944

1. With reference to conversation which Hitler is supposed to have had in a factory in Vienna. Accordingly they are supposed to have been successful in making tractable the disintegration of matter - with a possibility of using it as an explosive - they will only make use of it as a desperate measure (tested during the attack on Kovel?) because when the transformation has begun they do not know how to stop it.

2. On the road from Vienna Neustadt to Neubourg - on the side of a small hill a factory or an underground laboratory is located surrounded by barbed wire - guarded by the SS Troops - workmen are not allowed to enter.

3. In three (3) months a new fighter plane should be ready equipped with a 3,400 H.P. Mercedes-Benz engine, 24 cylinder radio engine with a speed of 800 Klm., armed with 4 cannons of 25 mm. calibre.

4. The manufacture of bombers has recently been cut down in favor of pursuit planes.

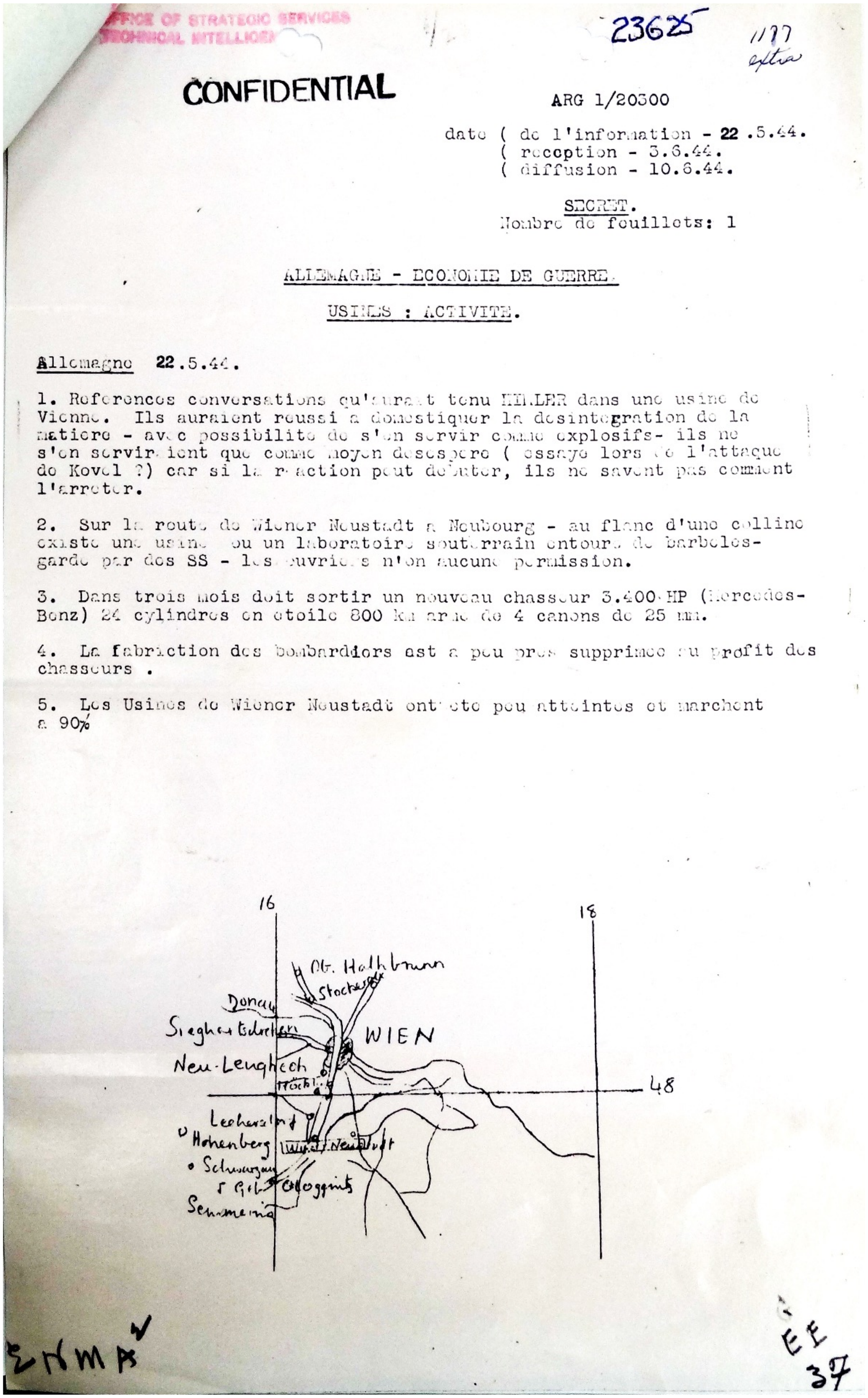
5. The factories of Vienna Neustadt have only sustained slight damages from bombing and are working at 90 per cent capacity.

CONFIDENTIAL

Figure D.298: English translation of French intelligence report. 10 June 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder
32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)



OFFICE OF STRATEGIC SERVICES
TECHNICAL INTELLIGENCE

23625

1177
extra

CONFIDENTIAL

ARG 1/20300

date (de l'information - 22.5.44.
(reception - 3.6.44.
(diffusion - 10.6.44.

SECRET.
Nombre de feuillets: 1

ALLEMAGNE - ECONOMIE DE GUERRE.

USINES : ACTIVITE.

Allemagne 22.5.44.

1. References conversations qu'aurait tenu HITLER dans une usine de Vienne. Ils auraient reussi a domestiquer la desintegration de la matiere - avec possibilite de s'en servir comme explosifs- ils ne s'en serviraient que comme moyen desespere (essaye lors de l'attaque de Kovel ?) car si la reaction peut debuter, ils ne savent pas comment l'arreter.

2. Sur la route de Wiener Neustadt a Neubourg - au flanc d'une colline existe une usine ou un laboratoire souterrain entoure de barbeles-garde par des SS - les ouvriers n'on aucune permission.

3. Dans trois mois doit sortir un nouveau chasseur 3.400 HP (Mercedes-Benz) 24 cylindres en etoile 800 km arme de 4 canons de 25 mm.

4. La fabrication des bombardiers est a peu pres supprimee au profit des chasseurs .

5. Les Usines de Wiener Neustadt ont ete peu atteintes et marchent a 90%

16
18
Gt. Hollabrunn
Stockerau
Donau
Sieghartskirchen
WIEN
Neu-Lengbach
Mödling
48
Leobersdorf
Hohenberg
Wiener Neustadt
Schwarzau
Gloggnitz
Semmering

ENMA
EE
37

Figure D.299: French intelligence report. 10 June 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

[For some other known or suspected nuclear sites in Austria, see:

pp. 3874–3920

pp. 4072–4081

pp. 4328–4341

pp. 4611–4624

pp. 4790–4800

pp. 4962–4974]

Known/Reported Sites Now in Hungary

Cable IN 1788 from Caserta, Italy to Office of Strategic Services Director. 19 January 1945 [NARA RG 226, Entry A1-134, Box 219, Folder IN AZUSA Nov. '43 Sept. '45]

#27074. AZUSA. 154 and Dix from 148.

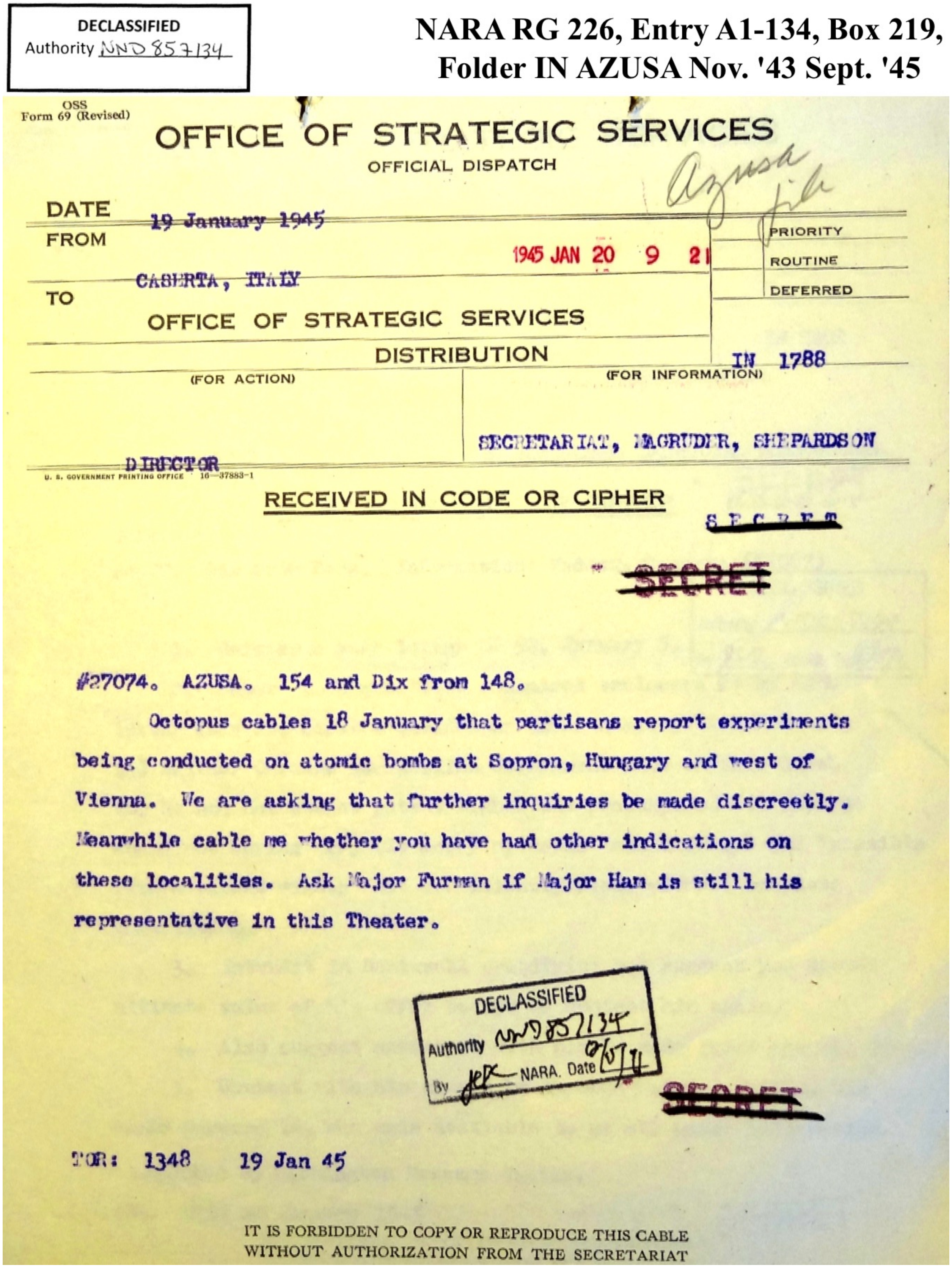
Octopus cables 18 January that partisans report experiments being conducted on atomic bombs at Sopron, Hungary and west of Vienna. We are asking that further inquiries be made discreetly. Meanwhile cable me whether you have had other indications on these localities. Ask Major Furman if Major Ham is still his representative in this Theater.

[See document photo on p. 3747.

This intelligence report may or may not have been talking about Redl Zipf specifically, but it is further confirmation that nuclear weapons development was being conducted in that area.

Experiments "west of Vienna" might refer to research installations at Redl Zipf, Gusen/Bergkristall, Zell-am-See, Lofer, Melk/Quarz, and/or other locations.

What was going on at Sopron (Ödenburg), Hungary? Sopron is approximately 65 km south of Vienna, just across the border into Hungary. Can any other documents concerning wartime nuclear research there be located? It sounds as if the OSS was going to write follow-up reports.]



DECLASSIFIED
Authority NND 857134

NARA RG 226, Entry A1-134, Box 219, Folder IN AZUSA Nov. '43 Sept. '45

OSS
Form 69 (Revised)

OFFICE OF STRATEGIC SERVICES
OFFICIAL DISPATCH

Azusa file

DATE 19 January 1945
FROM CASERTA, ITALY
1945 JAN 20 9 21

PRIORITY
ROUTINE
DEFERRED

TO OFFICE OF STRATEGIC SERVICES

DISTRIBUTION

IN 1788

(FOR ACTION) DIRECTOR

(FOR INFORMATION) SECRETARIAT, MAGRUDER, SHEPARDSON

U. S. GOVERNMENT PRINTING OFFICE 16—37883-1

RECEIVED IN CODE OR CIPHER

~~SECRET~~

~~SECRET~~

#27074. AZUSA. 154 and Dix from 148.

Octopus cables 18 January that partisans report experiments being conducted on atomic bombs at Sopron, Hungary and west of Vienna. We are asking that further inquiries be made discreetly. Meanwhile cable me whether you have had other indications on these localities. Ask Major Furman if Major Ham is still his representative in this Theater.

DECLASSIFIED
Authority NND 857134
By JCK NARA, Date 6/5/94

~~SECRET~~

TOR: 1348 19 Jan 45

IT IS FORBIDDEN TO COPY OR REPRODUCE THIS CABLE
WITHOUT AUTHORIZATION FROM THE SECRETARIAT

Figure D.300: This 19 January 1945 OSS cable reported "experiments being conducted on atomic bombs at Sopron, Hungary and west of Vienna" [NARA RG 226, Entry A1-134, Box 219, Folder IN AZUSA Nov. '43 Sept. '45].

Known/Reported Sites Now in Czechia

Cable IN-9026 from MacFarland Istanbul to Office of Strategic Services Shepardson. 4 May 1944 [NARA RG 226, Entry A1-134, Box 219, Folder IN AZUSA Nov. '43 Sept. '45] See document photo on p. 3749.

#332. AZUSA. From Javelin to Shepardson and Cecil only.

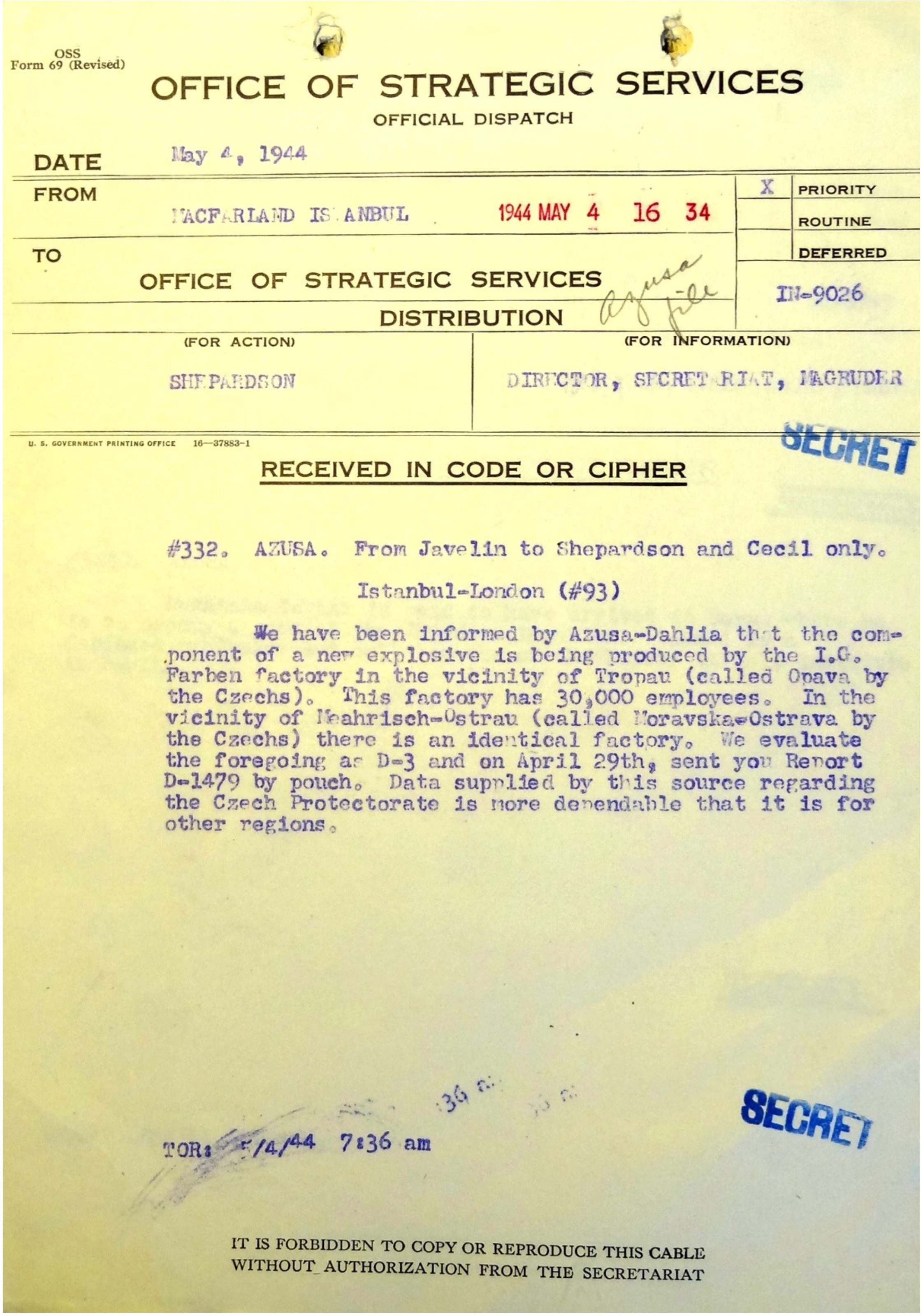
Istanbul–London (#93)

We have been informed by Azusa-Dahlia that the component of a new explosive is being produced by the I.G. Farben factory in the vicinity of Tropau (called Opava by the Czechs). This factory has 30,000 employees. In the vicinity of Maehrisch-Ostrau (called Moravska-Ostrava by the Czechs) there is an identical factory. We evaluate the foregoing as D-3 and on April 29th, sent you Report D-1479 by pouch. Data supplied by this source regarding the Czech Protectorate is more dependable than it is for other regions.

[See document photo on p. 3749. These sound like two massive uranium enrichment facilities, similar to Oak Ridge. Azusa was the OSS codename for German nuclear matters, so clearly the OSS thought the same.

For train logbooks that appear to show repeated shipments between these factories and other suspected nuclear sites, see pp. 3882–3883. See also p. 3784.]

DECLASSIFIED
Authority NND 857134



OSS
Form 69 (Revised)

OFFICE OF STRATEGIC SERVICES
OFFICIAL DISPATCH

DATE May 4, 1944

FROM MACFARLAND ISTANBUL 1944 MAY 4 16 34

X PRIORITY
ROUTINE
DEFERRED

TO OFFICE OF STRATEGIC SERVICES

Azusa file

IN-9026

DISTRIBUTION

(FOR ACTION)	(FOR INFORMATION)
SHEPARDSON	DIRECTOR, SECRETARIAT, MAGRUDER

U. S. GOVERNMENT PRINTING OFFICE 16—37883-1

SECRET

RECEIVED IN CODE OR CIPHER

#332. AZUSA. From Javelin to Shepardson and Cecil only.

Istanbul-London (#93)

We have been informed by Azusa-Dahlia that the component of a new explosive is being produced by the I.G. Farben factory in the vicinity of Tropau (called Opava by the Czechs). This factory has 30,000 employees. In the vicinity of Maehrisch-Ostrau (called Moravska-Ostrava by the Czechs) there is an identical factory. We evaluate the foregoing as D-3 and on April 29th, sent you Report D-1479 by pouch. Data supplied by this source regarding the Czech Protectorate is more dependable that it is for other regions.

TOR: 5/4/44 7:36 am

SECRET

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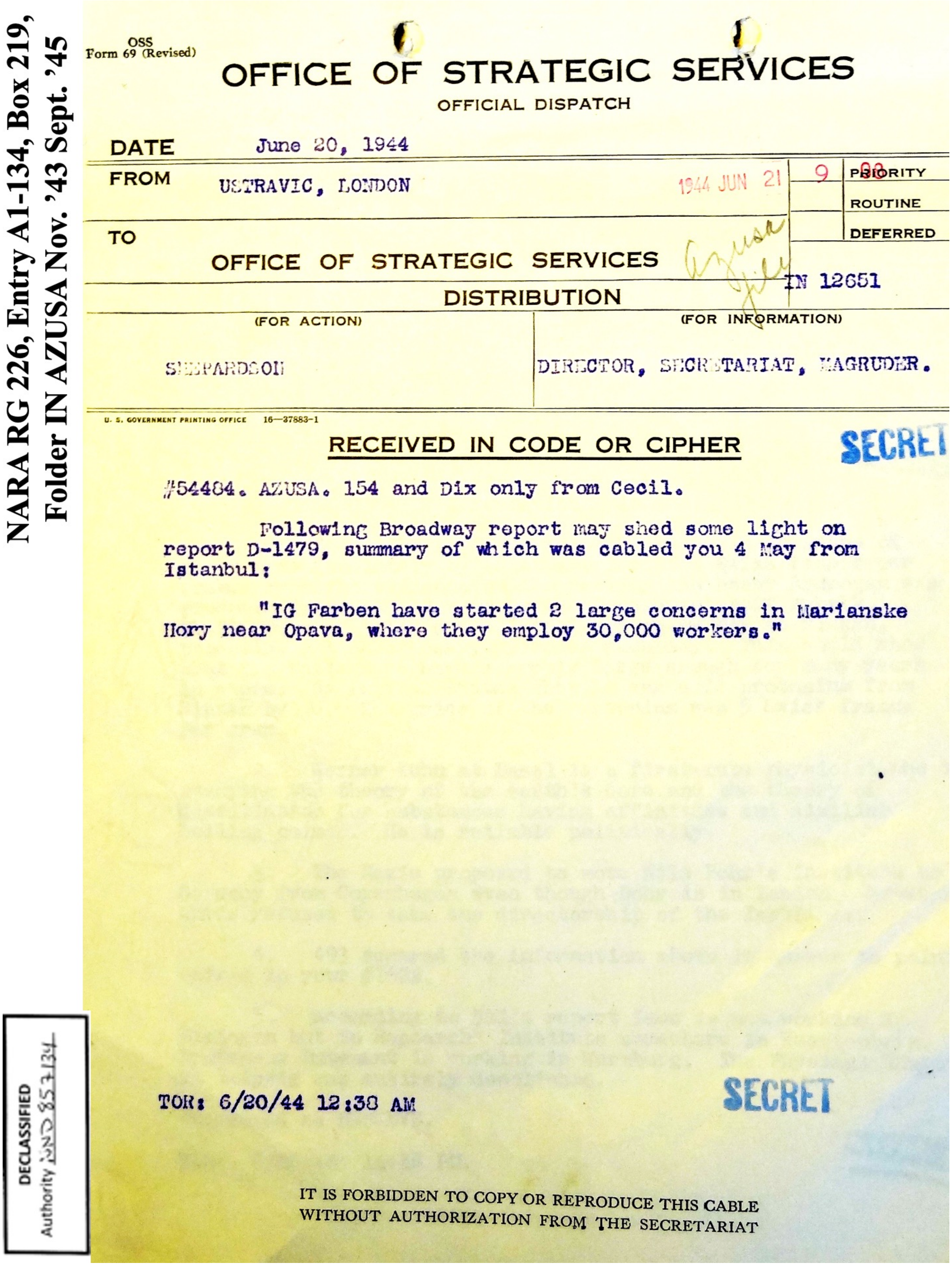
WITHOUT AUTHORIZATION FROM THE SECRETARIAT

NARA RG 226, Entry A1-134, Box 219,
Folder IN AZUSA Nov. '43 Sept. '45

Figure D.301: This May 1944 OSS intelligence report described what sound like two massive uranium enrichment facilities, each with 30,000 workers, run by I.G. Farben in Opava and Ostrava in eastern Czech territory [NARA RG 226, Entry A1-134, Box 219, Folder IN AZUSA Nov. '43 Sept. '45]. For train logbooks that appear to show repeated shipments between these factories and other suspected nuclear sites, see pp. 3882–3883. See also p. 3784.



NARA RG 226, Entry A1-134, Box 219,
Folder IN AZUSA Nov. '43 Sept. '45

OSS
Form 69 (Revised)

OFFICE OF STRATEGIC SERVICES

OFFICIAL DISPATCH

DATE	June 20, 1944		
FROM	USTRAVIC, LONDON	1944 JUN 21 9 08	PRIORITY ROUTINE DEFERRED
TO	OFFICE OF STRATEGIC SERVICES	Azusa file	IN 12651

DISTRIBUTION

(FOR ACTION)	(FOR INFORMATION)
SHEPARDSON	DIRECTOR, SECRETARIAT, MAGRUDER.

U. S. GOVERNMENT PRINTING OFFICE 16—37883-1

RECEIVED IN CODE OR CIPHER

SECRET

#54484. AZUSA. 154 and Dix only from Cecil.

Following Broadway report may shed some light on report D-1479, summary of which was cabled you 4 May from Istanbul:

"IG Farben have started 2 large concerns in Marianske Hory near Opava, where they employ 30,000 workers."

TOR: 6/20/44 12:38 AM

SECRET

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WITHOUT AUTHORIZATION FROM THE SECRETARIAT

DECLASSIFIED
Authority NND 857134

Figure D.302: A June 1944 OSS intelligence report mentioning the same two massive facilities that were run by I.G. Farben in Opava and Ostrava in eastern Czech territory [NARA RG 226, Entry A1-134, Box 219, Folder IN AZUSA Nov. '43 Sept. '45]. For train logbooks that appear to show repeated shipments between these factories and other suspected nuclear sites, see pp. 3882–3883.

Zbynek Zeman and Rainer Karlsch. 2008. *Uranium Matters: Central European Uranium in International Politics 1900-1960*. p. 73.

While the uranium treaty was being considered, Bakulin reminded Fierlinger that he had agreed to hand over 38,516 kilograms of radioactive material available on Czechoslovakian territory to the Soviets. Fierlinger immediately gave orders for the transfer of the materials to the Soviet foreign trade organization, Torgpredstvo, and requested that the ministries of industry and foreign trade take care of the transfer. On 14 October [1945], 37,012 kilograms of uranium paints, (containing up to 58.4% uranium oxide [U_3O_8]), were taken away from the Příbram smelting works. On 29 and 30 October, barrels and boxes containing 9,725 kg of 58% uranium concentrate followed. Additional pitchblende from the slagheaps was collected, and the amount of uranium the Soviet Union received from these sources has been calculated at 30.838 tons; only 0.919 tons of uranium was actually mined in 1945.

[Ivan Bakulin was a Soviet official. Zdeněk Fierlinger was the Soviet-installed prime minister of Czechoslovakia after the war.

It seems highly unlikely that over 30 tons of valuable refined uranium was simply being used for paint. Presumably that was just a cover story given by the Germans, Czechs, and/or Soviets.

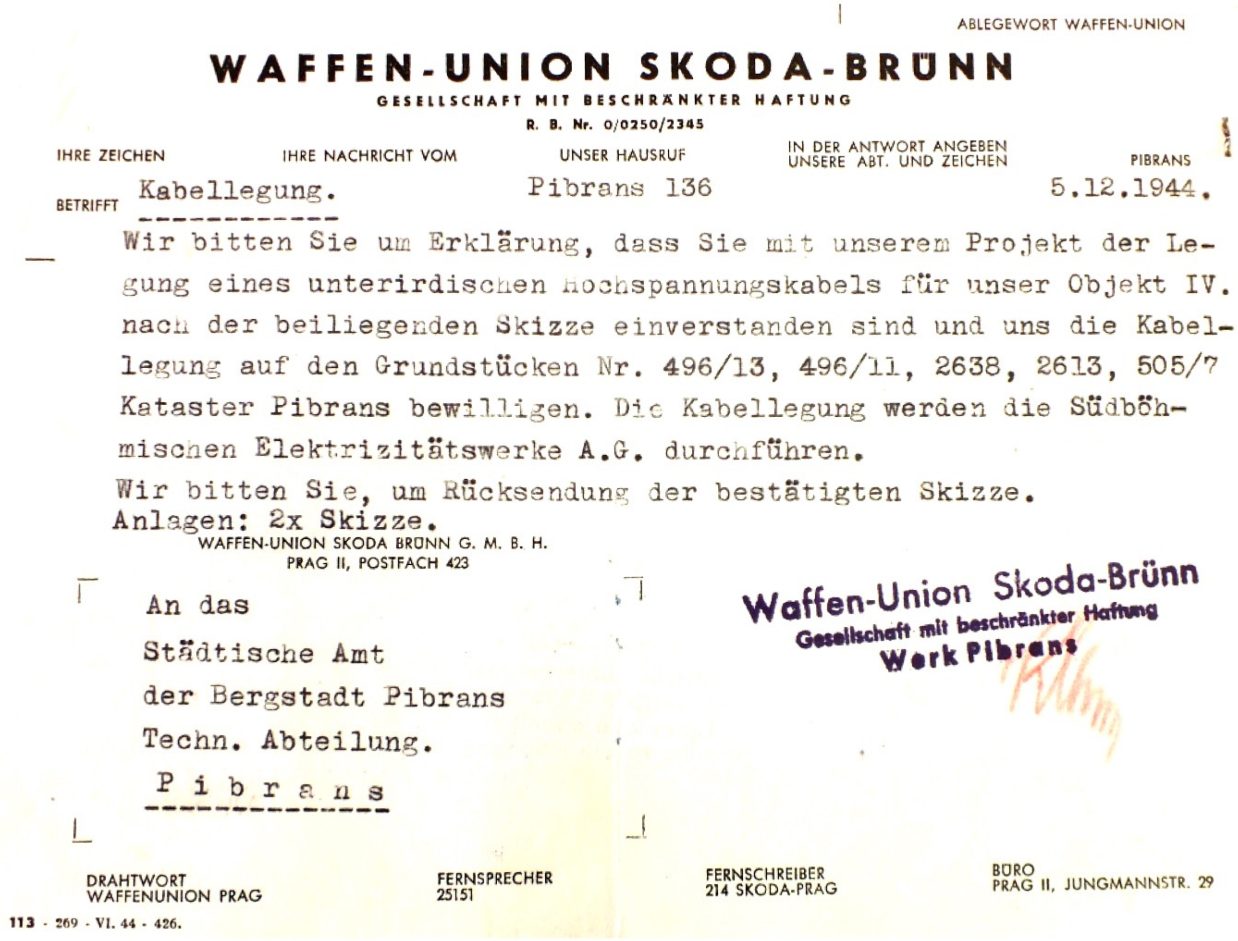
What exactly was the uranium being used for during the war? Was it for enrichment or for use in a fission reactor? Or had it already been enriched or irradiated in a reactor?

Why was the uranium at Příbram? Among other things, Příbram was home to a large wartime research installation run by the SS and Skoda and directed by Rolf Engel, who was an expert on explosives, implosion bombs, rockets, and related subjects (pp. 4921, 5696).

See the documents on pp. 3752–3754.]

1944 German plans for high-voltage power cables from Štěchovice to "Objekt IV," a facility built by Skoda in Příbram

SOkA Příbram, Elektrifikace - 1944, AM Příbram - S, inv. č. 1001



ABLEGEWORT WAFFEN-UNION

WAFFEN-UNION SKODA-BRÜNN
GESELLSCHAFT MIT BESCHRÄNKTER HAFTUNG
R. B. Nr. 0/0250/2345

IHRE ZEICHEN
IHRE NACHRICHT VOM
UNSER HAUSRUF Pibrans 136
IN DER ANTWORT ANGEBEN UNSERE ABT. UND ZEICHEN
PIBRANS 5.12.1944.

BETRIFFT Kabellegung.

Wir bitten Sie um Erklärung, dass Sie mit unserem Projekt der Legung eines unterirdischen Hochspannungskabels für unser Objekt IV. nach der beiliegenden Skizze einverstanden sind und uns die Kabellegung auf den Grundstücken Nr. 496/13, 496/11, 2638, 2613, 505/7 Kataster Pibrans bewilligen. Die Kabellegung werden die Südböhmischen Elektrizitätswerke A.G. durchführen.

Wir bitten Sie, um Rücksendung der bestätigten Skizze.

Anlagen: 2x Skizze.

WAFFEN-UNION SKODA BRÜNN G. M. B. H.
PRAG II, POSTFACH 423

An das
Städtische Amt
der Bergstadt Pibrans
Techn. Abteilung.
Pibrans

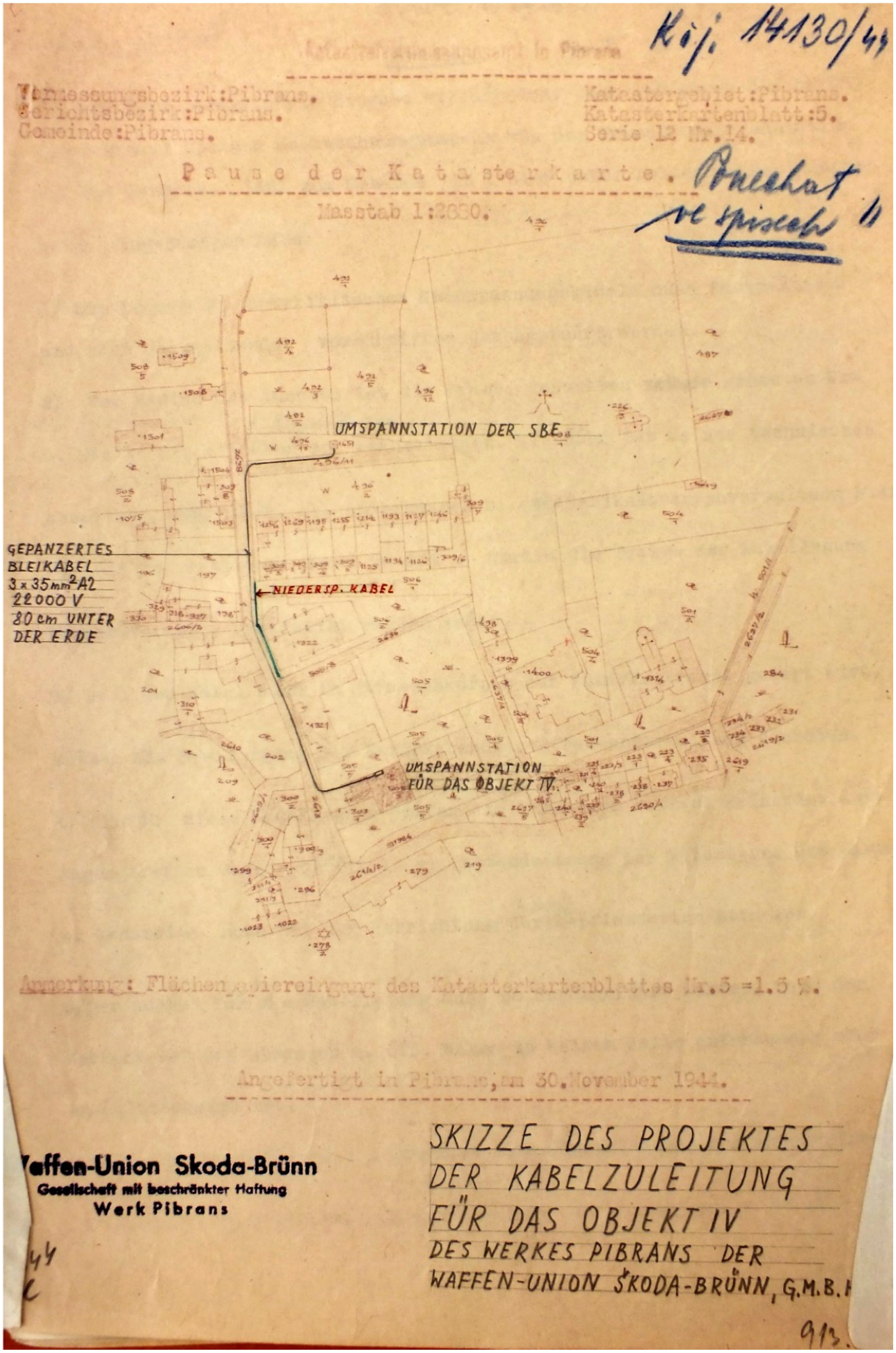
Waffen-Union Skoda-Brünn
Gesellschaft mit beschränkter Haftung
Werk Pibrans

DRAHTWORT WAFFENUNION PRAG
FERNSPRECHER 25151
FERNSCHREIBER 214 SKODA-PRAG
BÜRO PRAG II, JUNGMANNSTR. 29

113 - 269 - VI. 44 - 426.

Figure D.303: 1944 German plans for high-voltage power cables from Štěchovice to "Objekt IV," a facility built by Skoda in Příbram [SOkA Příbram, Elektrifikace—1944, AM Příbram—S, inv. č. 1001, courtesy of Jaroslav Mareš].

1944 German plans for high-voltage power cables from Štěchovice to "Objekt IV," a facility built by Skoda in Příbram
SOkA Příbram, Elektrifikace - 1944, AM Příbram - S, inv. č. 1001



Kój. 14130/44

[illegible] in Pibrans

Vermessungsbezirk:Pibrans.
Gerichtsbezirk:Pibrans.
Gemeinde:Pibrans.

Katastergebiet:Pibrans.
Katasterkartenblatt:5.
Serie 12 Nr.14.

Pause der Katasterkarte.

Masstab 1:2880.

Ponechat ve spisech!

Anmerkung: Flächen[illegible]eingang des Katasterkartenblattes Nr.5 =1.5 %.

Angefertigt in Pibrans,am 30.November 1944.

Waffen-Union Skoda-Brünn
Gesellschaft mit beschränkter Haftung
Werk Pibrans

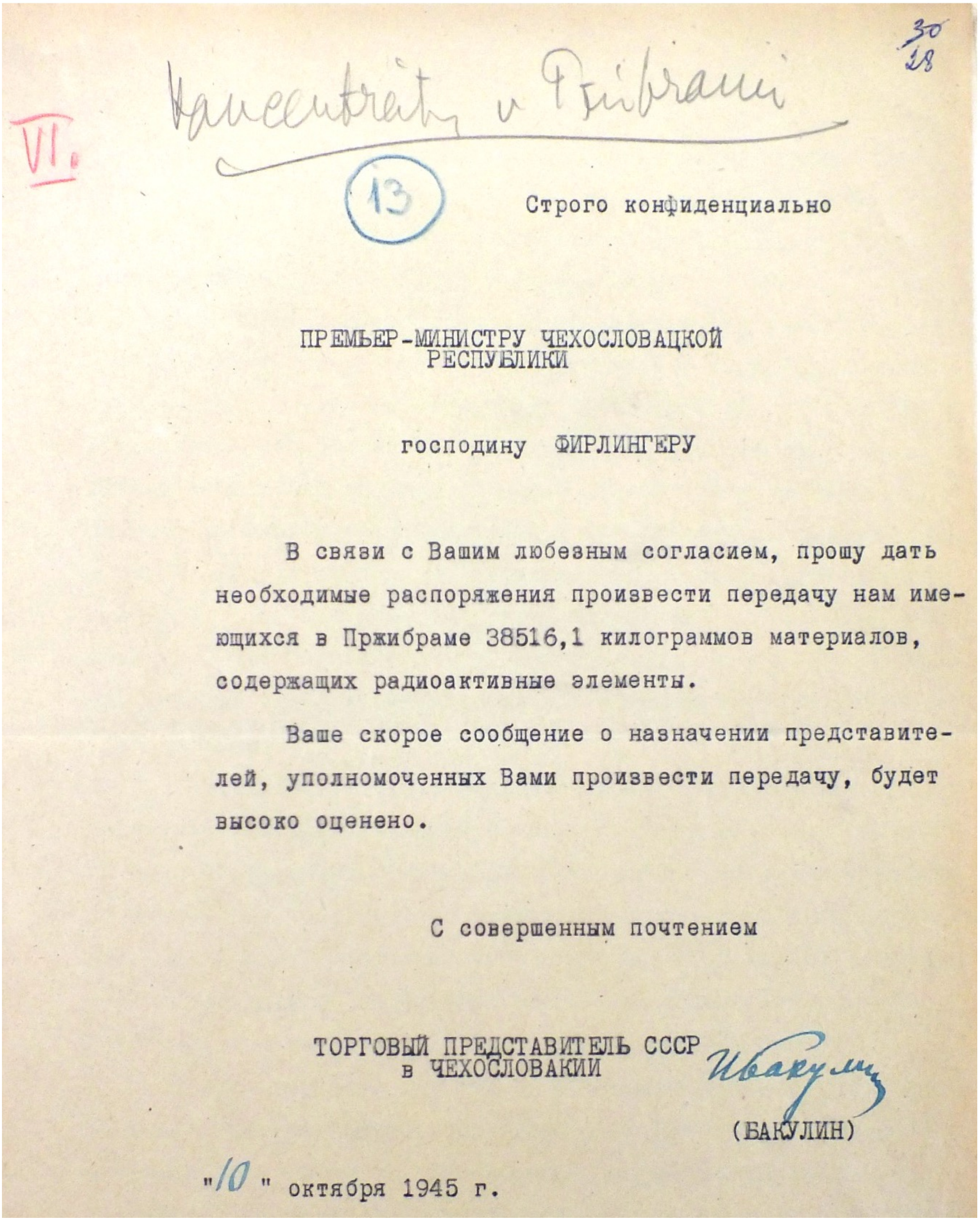
SKIZZE DES PROJEKTES
DER KABELZULEITUNG
FÜR DAS OBJEKT IV
DES WERKES PIBRANS DER
WAFFEN-UNION ŠKODA-BRÜNN, G.M.B.H

913.

UMSPANNSTATION DER SBE
GEPANZERTES BLEIKABEL 3 x 35 mm² Al 22000 V 80 cm UNTER DER ERDE
NIEDERSP. KABEL
UMSPANNSTATION FÜR DAS OBJEKT IV

Figure D.304: 1944 German plans for high-voltage power cables from Štěchovice to "Objekt IV," a facility built by Skoda in Příbram [SOkA Příbram, Elektrifikace—1944, AM Příbram—S, inv. č. 1001, courtesy of Jaroslav Mareš].

10 October 1945 letter from Ivan Bakulin to Zdeněk Fierlinger, Národní archiv, Ústřední výbor KSČ, Klement Gottwald, sv. 81, aj. 1031



30
28

Koncentráty v Příbrami

VI.

13

Строго конфиденциально

ПРЕМЬЕР-МИНИСТРУ ЧЕХОСЛОВАЦКОЙ
РЕСПУБЛИКИ

господину ФИРЛИНГЕРУ

В связи с Вашим любезным согласием, прошу дать необходимые распоряжения произвести передачу нам имеющихся в Пржибраме 38516,1 килограммов материалов, содержащих радиоактивные элементы.

Ваше скорое сообщение о назначении представителей, уполномоченных Вами произвести передачу, будет высоко оценено.

С совершенным почтением

ТОРГОВЫЙ ПРЕДСТАВИТЕЛЬ СССР
в ЧЕХОСЛОВАКИИ

И.Бакулин

(БАКУЛИН)

"10" октября 1945 г.

Figure D.305: 10 October 1945 letter from Ivan Bakulin to Zdeněk Fierlinger requesting 38,516.1 kilograms of radioactive material that had been left by German forces in Czechoslovakia at the end of the war [Národní archiv, Ústřední výbor KSČ, Klement Gottwald, sv. 81, aj. 1031, courtesy of Jaroslav Mareš].

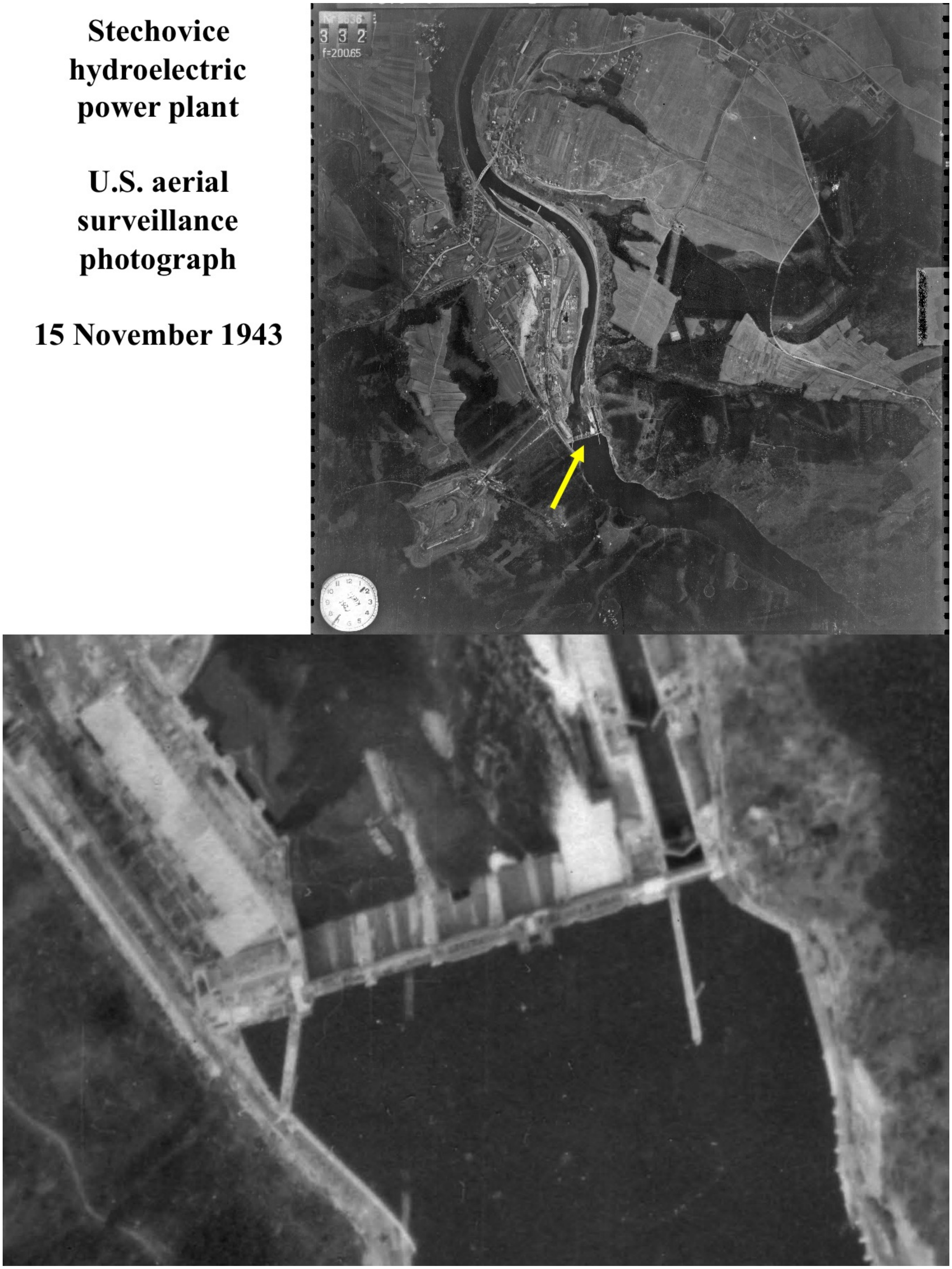

Stechovice hydroelectric power plant
U.S. aerial surveillance photograph
15 November 1943
3 3 2
f=200.65

Figure D.306: At Štěchovice, German forces built a large dam, hydroelectric power plant, and associated facilities that became operational in 1943. Nearby were large, secret underground facilities such as Blaumeise I–III. The installations may have been conducting nuclear-related work such as uranium enrichment [AFHRA, courtesy of Gunther Hebestreit].

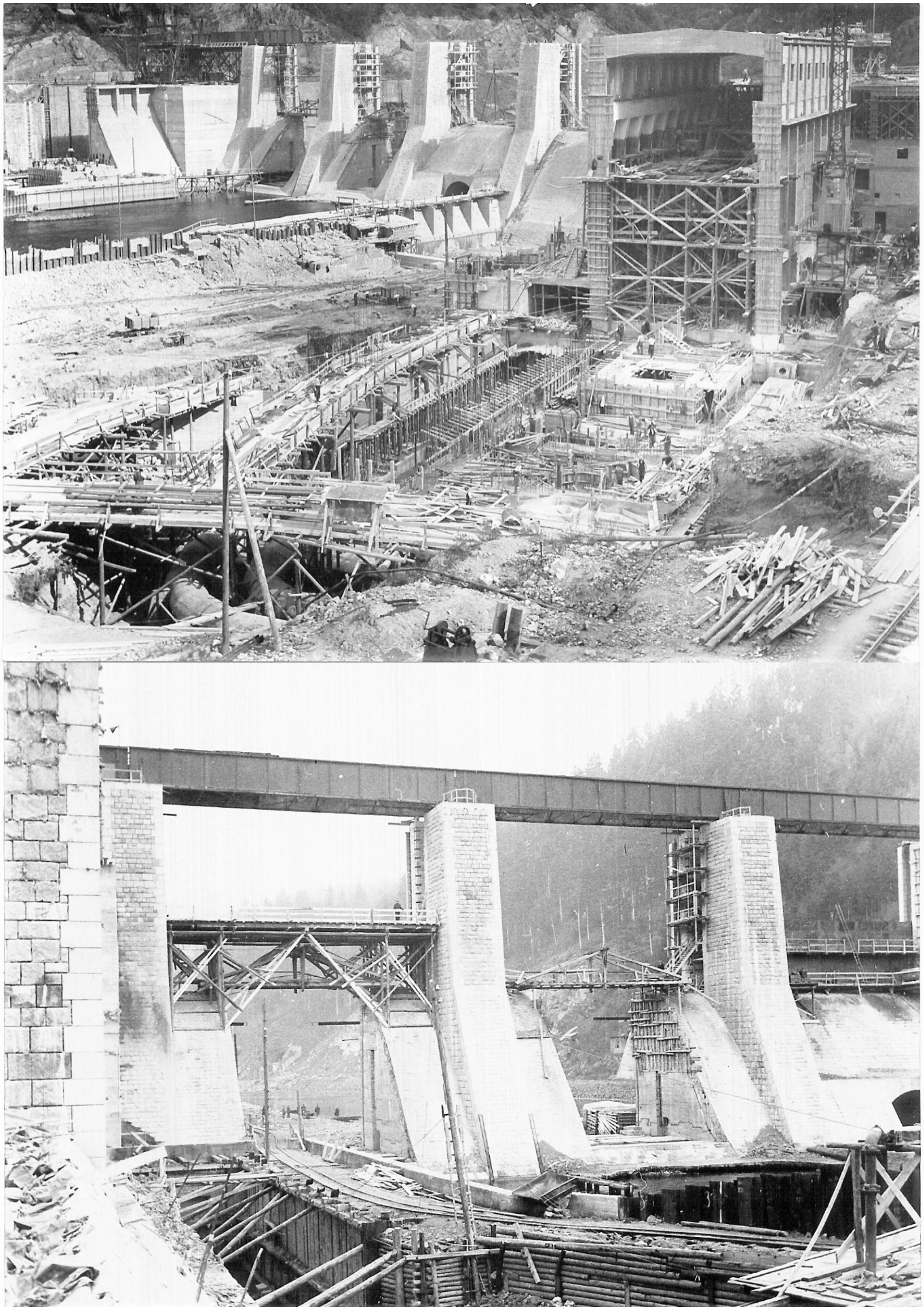


Figure D.307: The Štěchovice dam and hydroelectric power plant under construction in 1942.

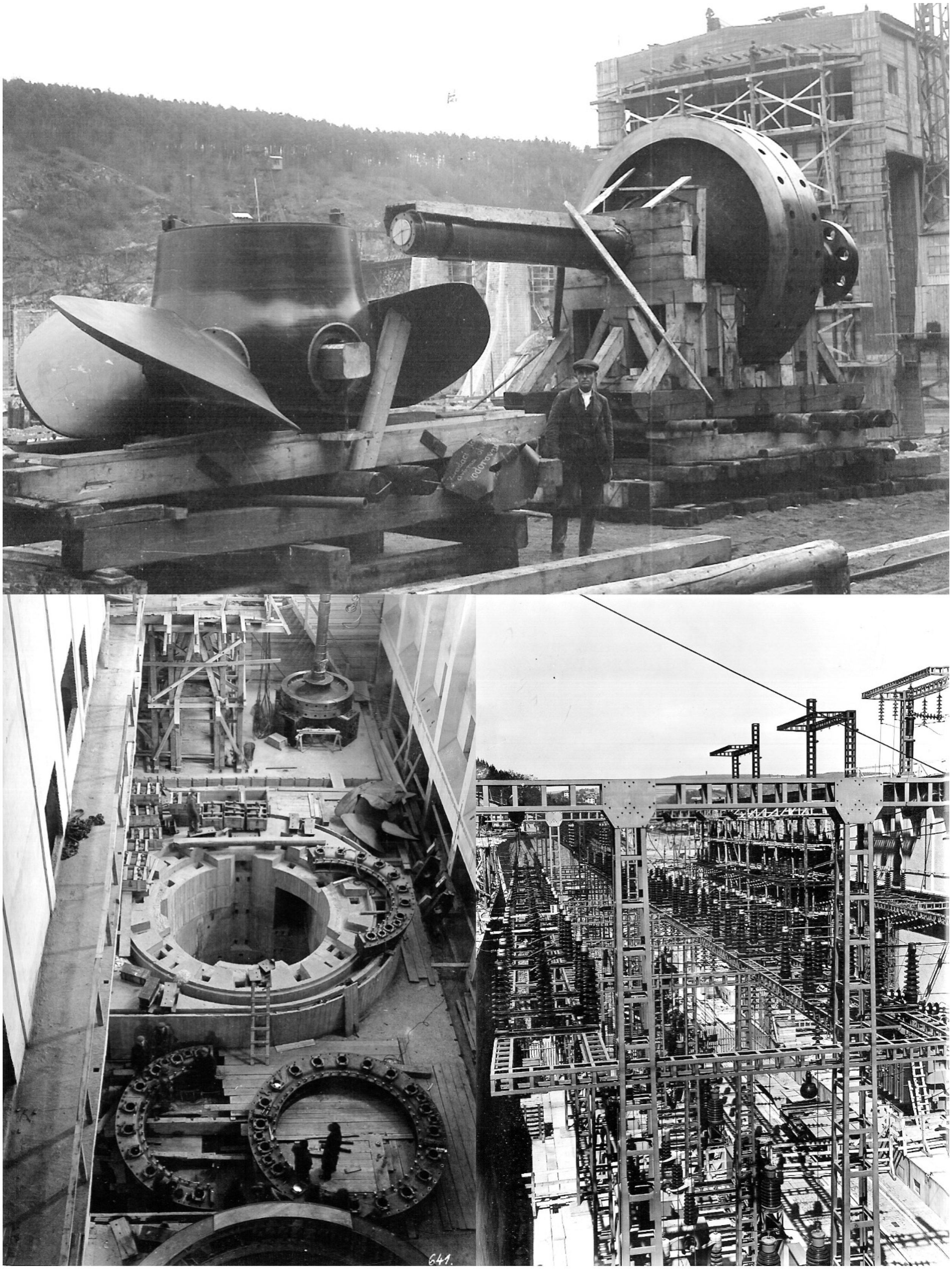


Figure D.308: Installation of the Kaplan turbines (p. 1495) and high-voltage transformers at Štěchovice during 1942–1943.

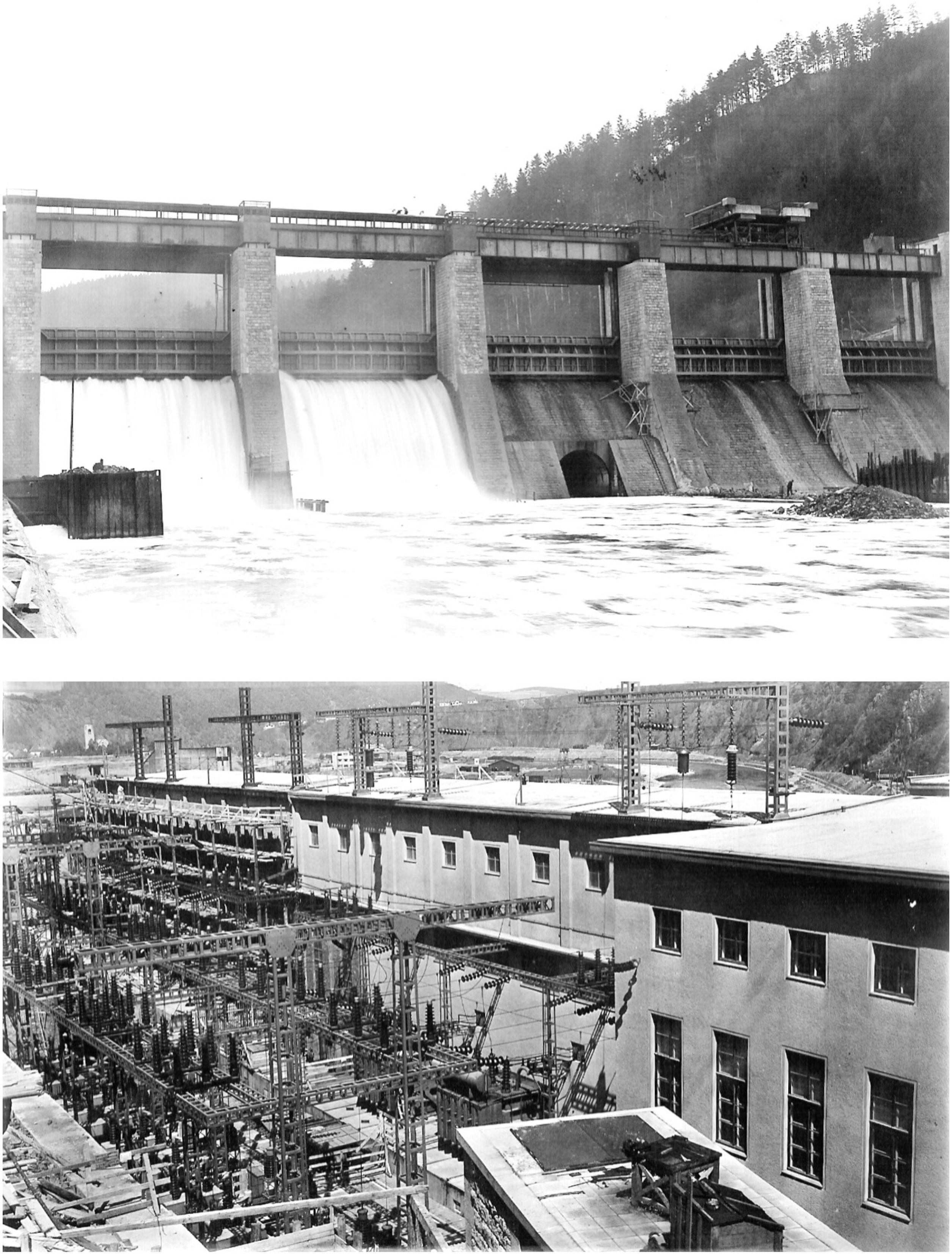


Figure D.309: The Štěchovice dam and hydroelectric power plant operational in 1943.

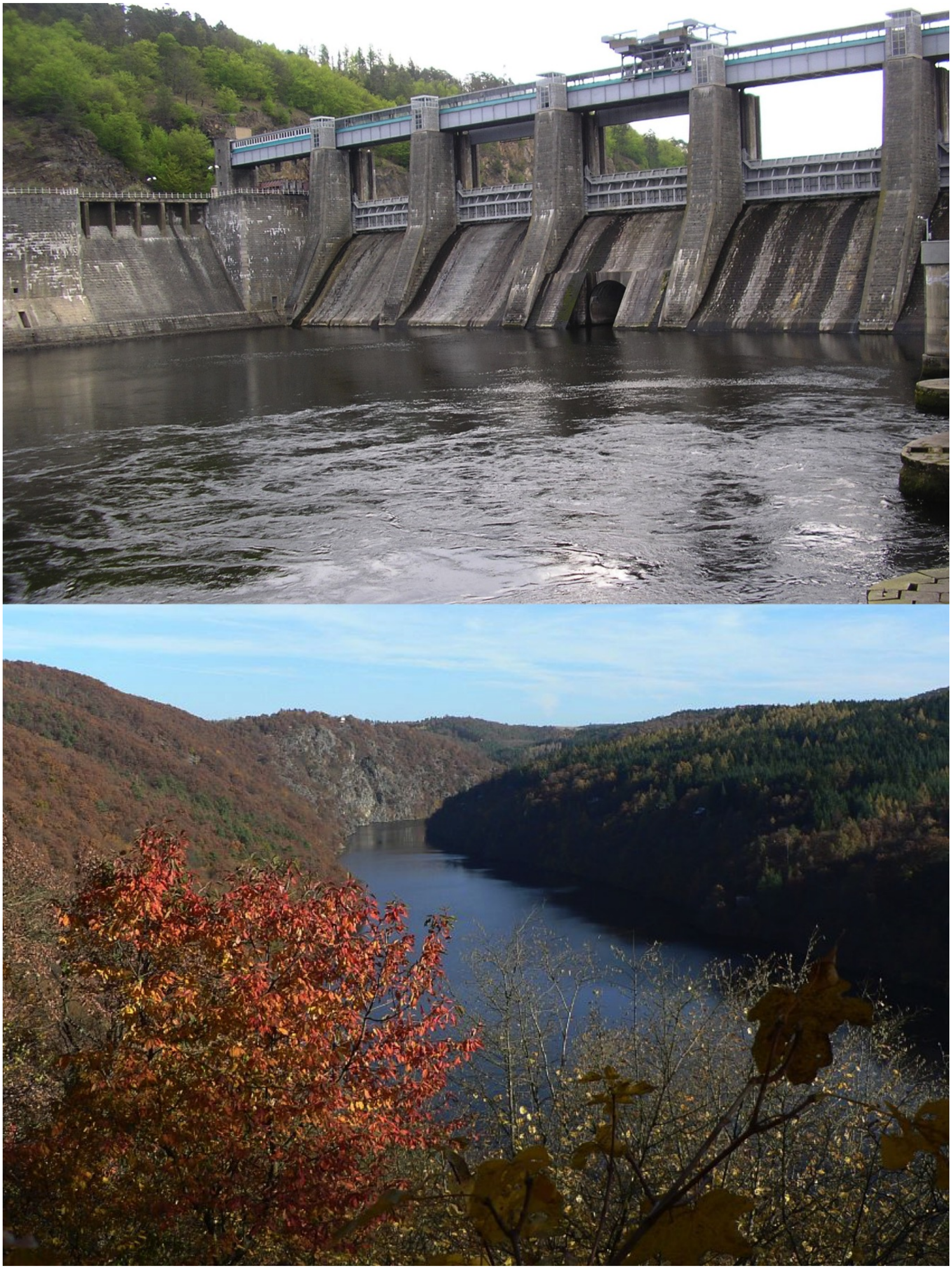
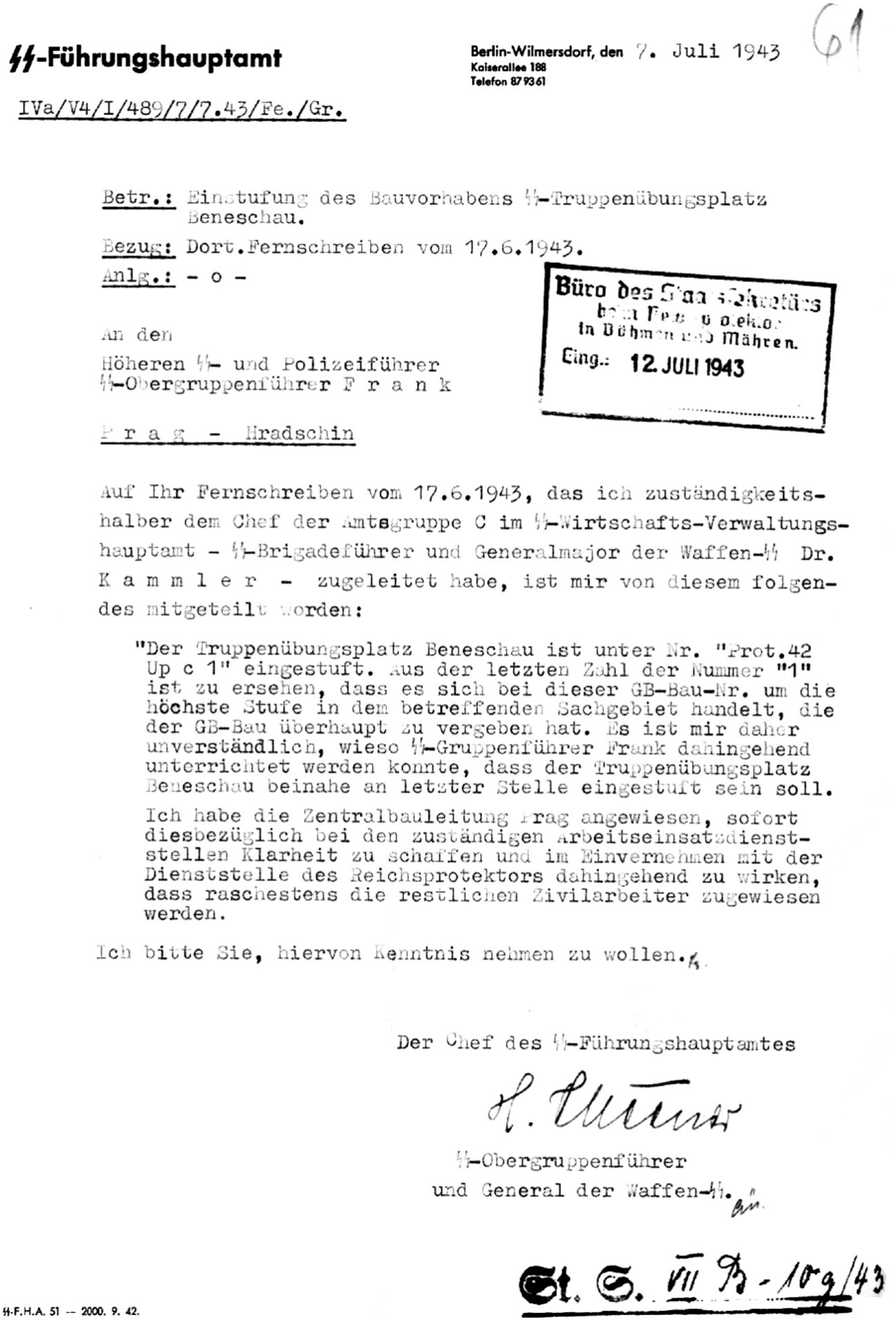


Figure D.310: The Štěchovice dam and hydroelectric power plant today.



61

SS-Führungshauptamt

Berlin-Wilmersdorf, den 7. Juli 1943
Kaiserallee 188
Telefon 87 93 61

IVa/V4/I/489/7/7.43/Fe./Gr.

Betr.: Einstufung des Bauvorhabens SS-Truppenübungsplatz Beneschau.
Bezug: Dort.Fernschreiben vom 17.6.1943.
Anlg.: - o -

Büro des Staatssekretärs
beim Reichsprotektor
in Böhmen und Mähren.
Eing.: 12. JULI 1943

An den
Höheren SS- und Polizeiführer
SS-Obergruppenführer Frank

Prag - Hradschin

Auf Ihr Fernschreiben vom 17.6.1943, das ich zuständigkeitshalber dem Chef der Amtsgruppe C im SS-Wirtschafts-Verwaltungshauptamt - SS-Brigadeführer und Generalmajor der Waffen-SS Dr. Kammler - zugeleitet habe, ist mir von diesem folgendes mitgeteilt worden:

> "Der Truppenübungsplatz Beneschau ist unter Nr. "Prot.42 Up c 1" eingestuft. Aus der letzten Zahl der Nummer "1" ist zu ersehen, dass es sich bei dieser GB-Bau-Nr. um die höchste Stufe in dem betreffenden Sachgebiet handelt, die der GB-Bau überhaupt zu vergeben hat. Es ist mir daher unverständlich, wieso SS-Gruppenführer Frank dahingehend unterrichtet werden konnte, dass der Truppenübungsplatz Beneschau beinahe an letzter Stelle eingestuft sein soll.
>
> Ich habe die Zentralbauleitung Prag angewiesen, sofort diesbezüglich bei den zuständigen Arbeitseinsatzdienststellen Klarheit zu schaffen und im Einvernehmen mit der Dienststelle des Reichsprotektors dahingehend zu wirken, dass raschestens die restlichen Zivilarbeiter zugewiesen werden.

Ich bitte Sie, hiervon Kenntnis nehmen zu wollen.

Der Chef des SS-Führungshauptamtes

H. Jüttner

SS-Obergruppenführer
und General der Waffen-SS.

St. S. VII Pz - 109/43

SS-F.H.A. 51 — 2000. 9. 42.

Figure D.311: In June 1943, Hans Kammler issued an order that the Beneschau (Benešov) military base near Štěchovice was classified as the highest priority: “The Beneschau military training area is classified under No. ‘Prot. 42 Up c 1.’ From the last number of the number ‘1’ it can be seen that this GB-Bau-No. is the highest level in the relevant subject area, which the GB-Bau has to assign at all.” What work was conducted there?

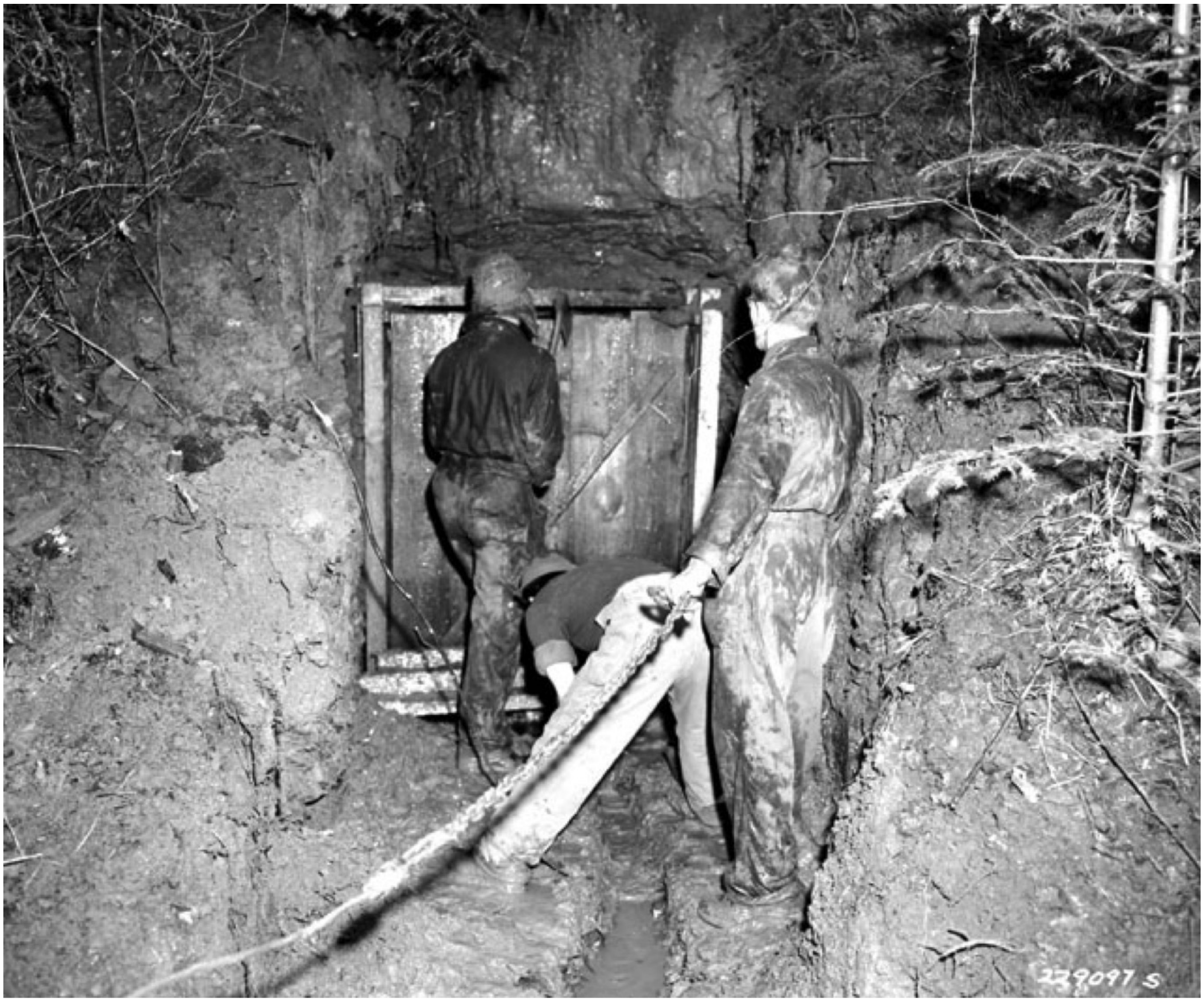


Figure D.312: In February 1946, a U.S. military team made an unannounced incursion deep into Czechoslovakia to recover important German papers buried at Štěchovice. The contents of most of the papers have never been publicly revealed [https://www.archives.gov/publications/prologue/2007/winter/stechovice.html]. This (in)famous incident was actually just one of many U.S. military incursions into Czechoslovakia in 1946 to collect mysterious cargo from multiple sites (pp. 3765–3772).

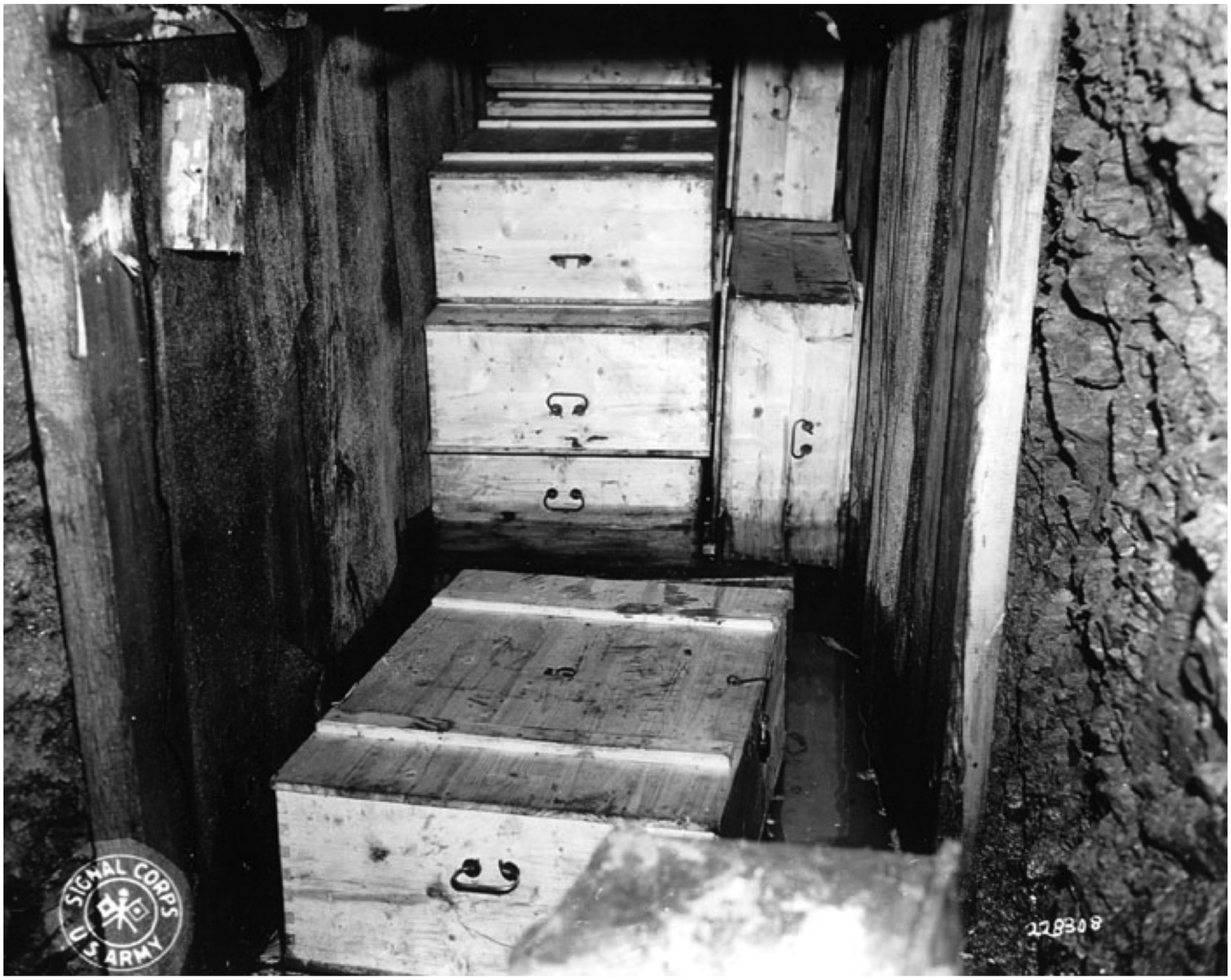


Figure D.313: In February 1946, a U.S. military team made an unannounced incursion deep into Czechoslovakia to recover important German papers buried at Štěchovice. The contents of most of the papers have never been publicly revealed [https://www.archives.gov/publications/prologue/2007/winter/stechovice.html]. This (in)famous incident was actually just one of many U.S. military incursions into Czechoslovakia in 1946 to collect mysterious cargo from multiple sites (pp. 3765–3772).

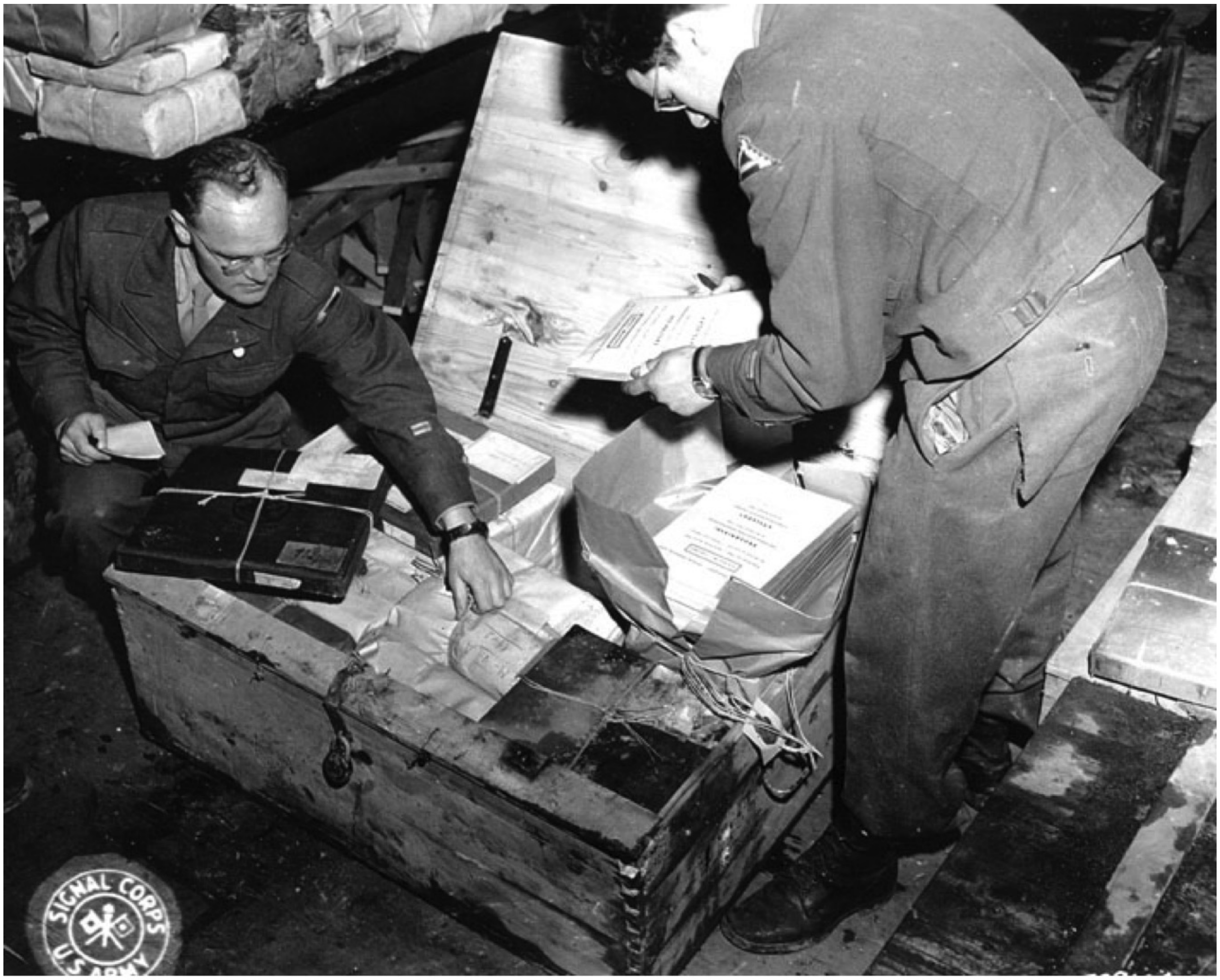
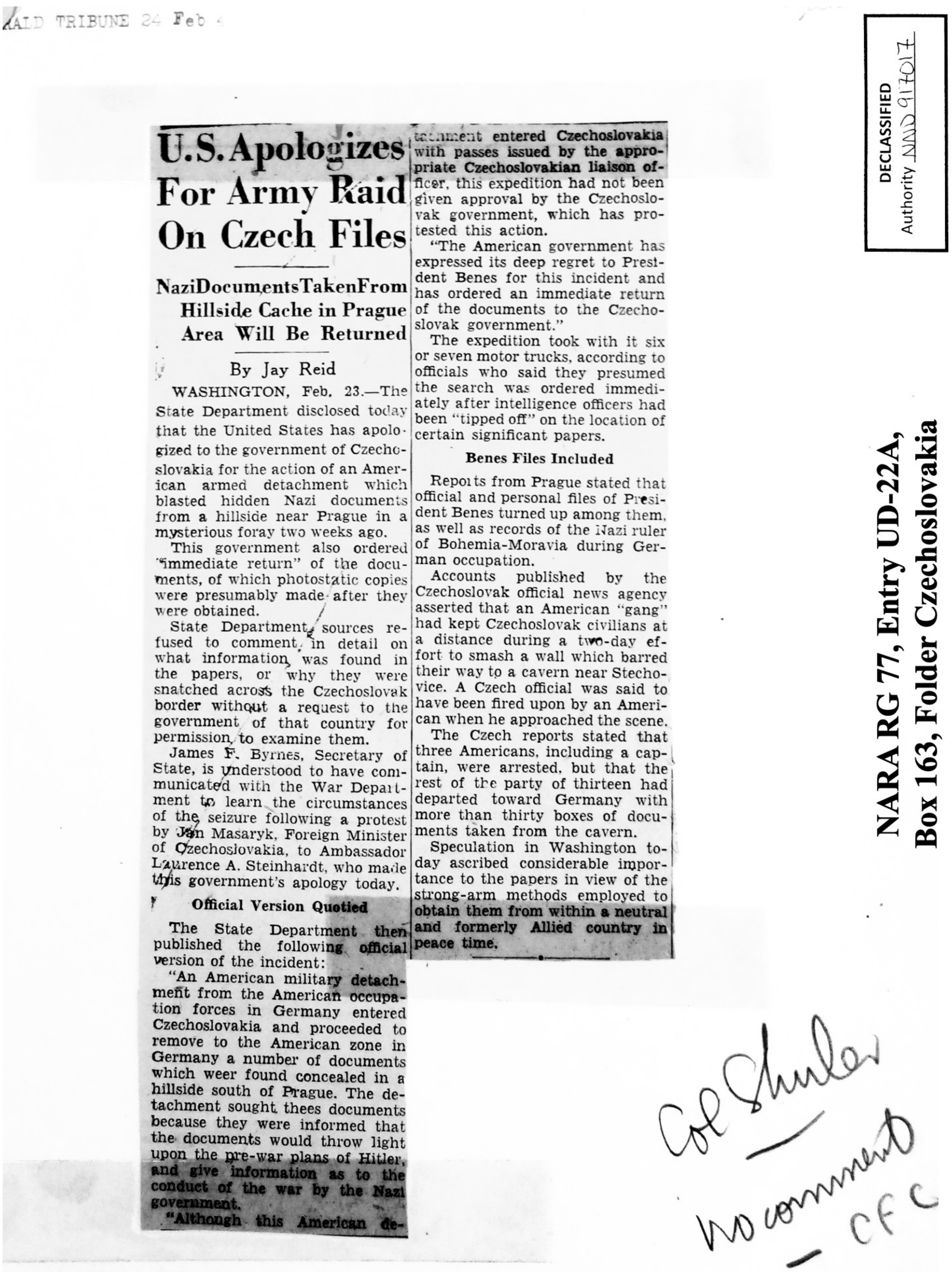


Figure D.314: In February 1946, a U.S. military team made an unannounced incursion deep into Czechoslovakia to recover important German papers buried at Štěchovice. The contents of most of the papers have never been publicly revealed [https://www.archives.gov/publications/prologue/2007/winter/stechovice.html]. This (in)famous incident was actually just one of many U.S. military incursions into Czechoslovakia in 1946 to collect mysterious cargo from multiple sites (pp. 3765–3772).



ALD TRIBUNE 24 Feb 4

DECLASSIFIED
Authority NND 917017

U.S. Apologizes For Army Raid On Czech Files

Nazi Documents Taken From Hillside Cache in Prague Area Will Be Returned

By Jay Reid

WASHINGTON, Feb. 23.—The State Department disclosed today that the United States has apologized to the government of Czechoslovakia for the action of an American armed detachment which blasted hidden Nazi documents from a hillside near Prague in a mysterious foray two weeks ago.

This government also ordered "immediate return" of the documents, of which photostatic copies were presumably made after they were obtained.

State Department sources refused to comment in detail on what information was found in the papers, or why they were snatched across the Czechoslovak border without a request to the government of that country for permission to examine them.

James F. Byrnes, Secretary of State, is understood to have communicated with the War Department to learn the circumstances of the seizure following a protest by Jan Masaryk, Foreign Minister of Czechoslovakia, to Ambassador Laurence A. Steinhardt, who made this government's apology today.

Official Version Quoted

The State Department then published the following official version of the incident:

"An American military detachment from the American occupation forces in Germany entered Czechoslovakia and proceeded to remove to the American zone in Germany a number of documents which weer found concealed in a hillside south of Prague. The detachment sought thees documents because they were informed that the documents would throw light upon the pre-war plans of Hitler, and give information as to the conduct of the war by the Nazi government.

"Although this American detachment entered Czechoslovakia with passes issued by the appropriate Czechoslovakian liaison officer, this expedition had not been given approval by the Czechoslovak government, which has protested this action.

"The American government has expressed its deep regret to President Benes for this incident and has ordered an immediate return of the documents to the Czechoslovak government."

The expedition took with it six or seven motor trucks, according to officials who said they presumed the search was ordered immediately after intelligence officers had been "tipped off" on the location of certain significant papers.

Benes Files Included

Reports from Prague stated that official and personal files of President Benes turned up among them, as well as records of the Nazi ruler of Bohemia-Moravia during German occupation.

Accounts published by the Czechoslovak official news agency asserted that an American "gang" had kept Czechoslovak civilians at a distance during a two-day effort to smash a wall which barred their way to a cavern near Stechovice. A Czech official was said to have been fired upon by an American when he approached the scene.

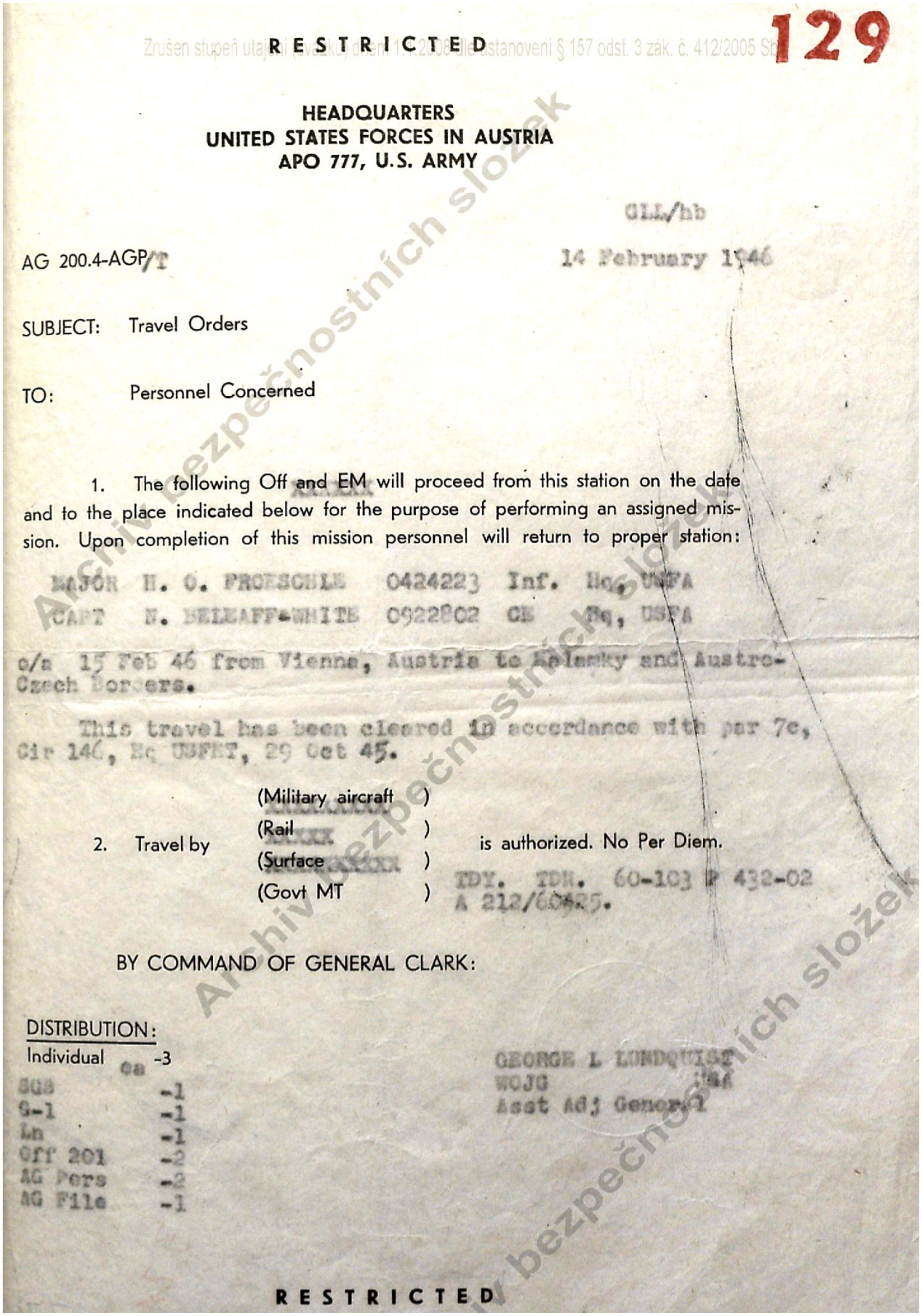
The Czech reports stated that three Americans, including a captain, were arrested, but that the rest of the party of thirteen had departed toward Germany with more than thirty boxes of documents taken from the cavern.

Speculation in Washington today ascribed considerable importance to the papers in view of the strong-arm methods employed to obtain them from within a neutral and formerly Allied country in peace time.

Col Shuler —
no comment
— CFC

NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia

Figure D.315: [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].



Zrušen stupeň utajení (svazku) dnem 1.1.2008 dle ustanovení § 157 odst. 3 zák. č. 412/2005 Sb.

129

RESTRICTED

HEADQUARTERS
UNITED STATES FORCES IN AUSTRIA
APO 777, U.S. ARMY

GLL/hb

AG 200.4-AGP/T

14 February 1946

SUBJECT: Travel Orders

TO: Personnel Concerned

1. The following Off ~~and EM~~ will proceed from this station on the date and to the place indicated below for the purpose of performing an assigned mission. Upon completion of this mission personnel will return to proper station:

MAJOR H. O. FROESCHLE 0424223 Inf. Hq, USFA
CAPT N. BELEAFF-WHITE 0922802 CE Hq, USFA

o/a 15 Feb 46 from Vienna, Austria to Halamky and Austro-Czech Borders.

This travel has been cleared in accordance with par 7c, Cir 146, Hq USFET, 29 Oct 45.

2. Travel by
(~~Military aircraft~~)
(~~Rail~~)
(~~Surface~~)
(Govt MT)
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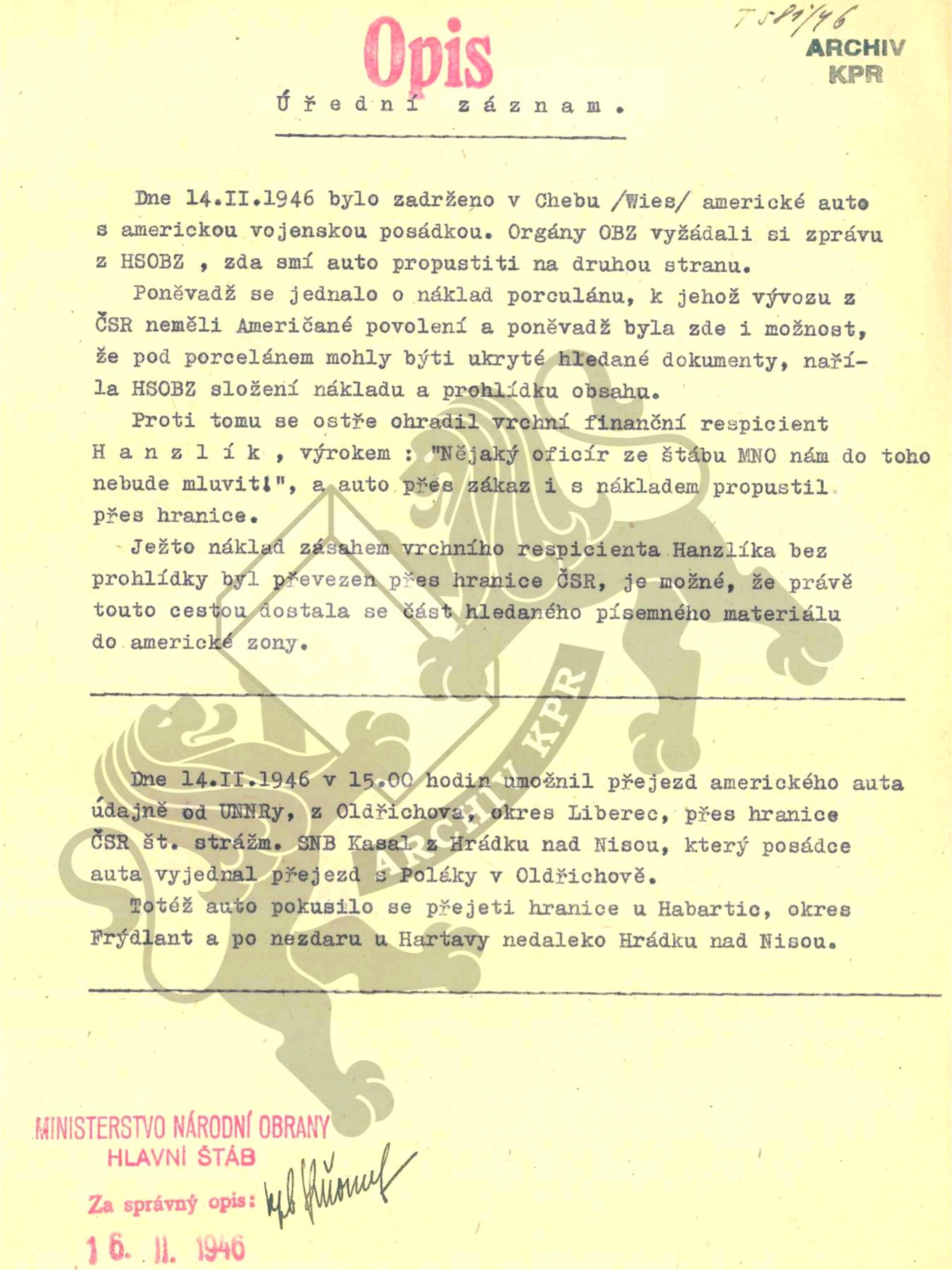
Archiv bezpečnostních složek

Figure D.316: Other U.S. Army soldiers made an incursion into Czechoslovakia on 14 February 1946 and left this travel order behind at a checkpoint near Halámky-Rapšach on the Czech/Austrian border. [Archiv Bezpečnostních Složek. H-544 Akce Úkryty. Courtesy of Jaroslav Mareš.]



T 587/46

ARCHIV
KPR

Opis

Úřední záznam.

Dne 14.II.1946 bylo zadrženo v Chebu /Wies/ americké auto s americkou vojenskou posádkou. Orgány OBZ vyžádali si zprávu z HSOBZ , zda smí auto propustiti na druhou stranu.

Poněvadž se jednalo o náklad porculánu, k jehož vývozu z ČSR neměli Američané povolení a poněvadž byla zde i možnost, že pod porcelánem mohly býti ukryté hledané dokumenty, nařídila HSOBZ složení nákladu a prohlídku obsahu.

Proti tomu se ostře ohradil vrchní finanční respicient Hanzlík , výrokem : "Nějaký oficír ze štábu MNO nám do toho nebude mluvit!", a auto přes zákaz i s nákladem propustil přes hranice.

Ježto náklad zásahem vrchního respicienta Hanzlíka bez prohlídky byl převezen přes hranice ČSR, je možné, že právě touto cestou dostala se část hledaného písemného materiálu do americké zony.

Dne 14.II.1946 v 15.00 hodin umožnil přejezd amerického auta údajně od UNNRy, z Oldřichova, okres Liberec, přes hranice ČSR št. strážm. SNB Kasal z Hrádku nad Nisou, který posádce auta vyjednal přejezd s Poláky v Oldřichově.

Totéž auto pokusilo se přejeti hranice u Habartic, okres Frýdlant a po nezdaru u Hartavy nedaleko Hrádku nad Nisou.

MINISTERSTVO NÁRODNÍ OBRANY
HLAVNÍ ŠTÁB
Za správný opis:
16. II. 1946

ARCHIV KPR

Figure D.317: A report of two successful U.S. incursions into Czechoslovakia on 14 February 1946. [Archiv Kanceláře Prezidenta Republiky. Courtesy of Jaroslav Mareš. https://www.prazskyhradarchiv.cz/file/edee/archivalie_mesice/2016/1602.pdf]

A report of two successful U.S. incursions into Czechoslovakia on 14 February 1946. [Archiv Kanceláře Prezidenta Republiky. Courtesy of Jaroslav Mareš. https://www.prazskyhradarchiv.cz/file/edee/archivalie_mesice/2016/1602.pdf]

Official record.

On 14 February 1946, an American car with an American military crew was intercepted in Cheb. OBZ [Defense Intelligence Agency] authorities requested a report from HSOBZ [Main Administration of Defense Intelligence Agency] as to whether the car could be released to the other side.

Since it was a cargo of porcelain, which the Americans had no permission to export from Czechoslovakia, and since there was also the possibility that the wanted documents might be hidden under the porcelain, HSOBZ ordered the cargo to be gathered together and the contents to be searched.

The chief financial officer Hanzlik strongly objected to this, saying: "Some officer from the MNO staff will not interfere with us!" and despite the ban, he let the car and its cargo cross the border.

Since the cargo was transported across the Czechoslovak border without inspection by the intervention of chief financial officer Hanzlik, it is possible that it was through this route that some of the wanted written material reached the American zone.

On 14 February 1946, an American car, allegedly from the UNNRy in Oldřichov, Liberec district, was allowed to cross the border of Czechoslovakia by staff guard Kasal from Hrádek nad Nisou, who negotiated the crossing with the Poles in Oldřichov.

The same car tried to cross the border at Habartice, Frýdlant district, and after failure at Hartava near Hrádek nad Nisou.

[This document reports:

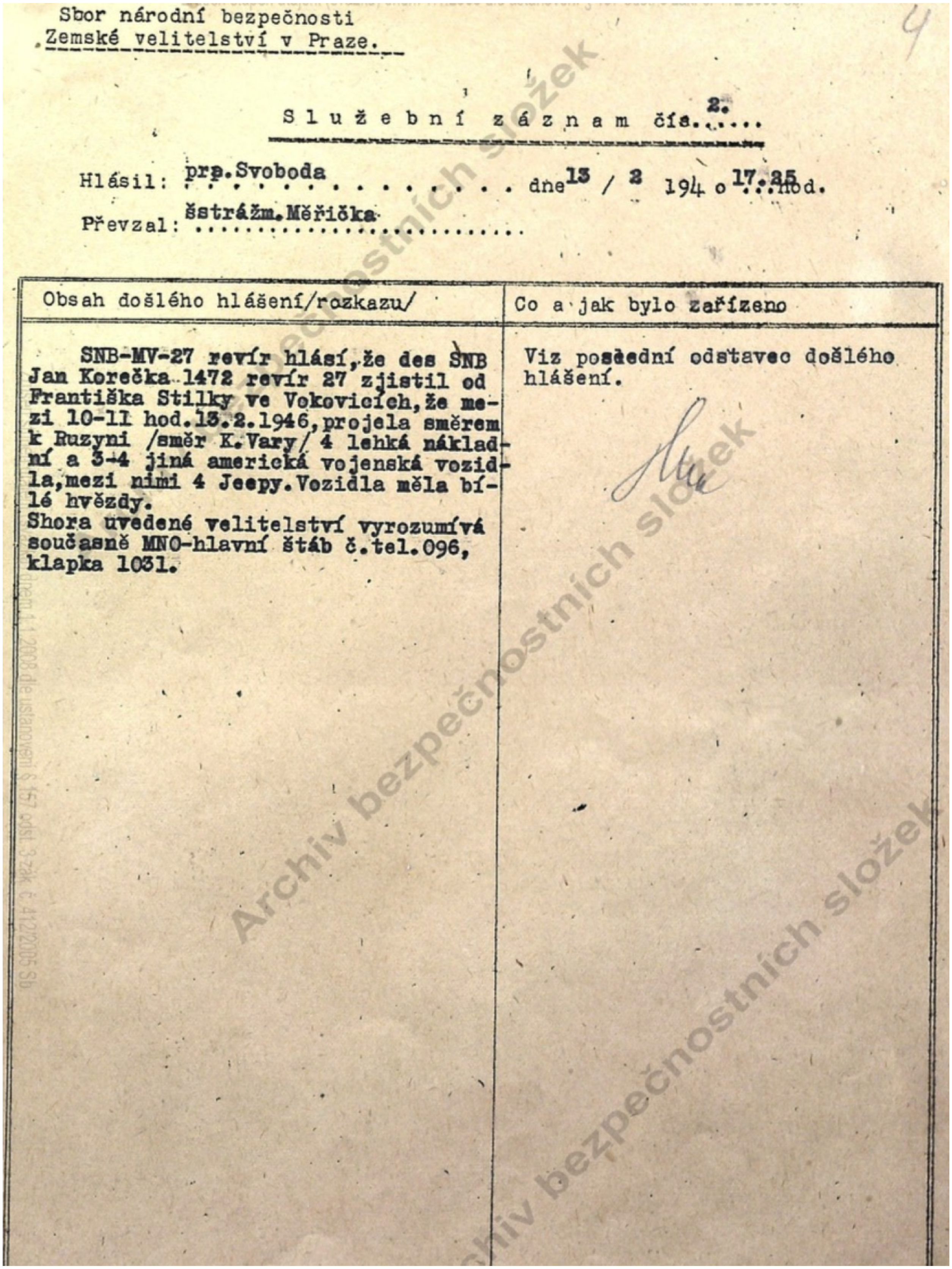
- An American military vehicle with an unknown cargo (concealed in or under porcelain) left Czechoslovakia for Germany at Cheb (due west of Prague).
- An American military vehicle with an unknown cargo left Czechoslovakia for Poland near Liberec (northeast of Prague), after trying unsuccessfully to leave Czechoslovakia at two other border checkpoints in that general area. The vehicle probably just cut across the extreme southwestern corner of Poland before returning to Germany.

These two U.S. military incursions were in addition to those at Štěchovice (pp. 3761–3763), Halámky-Rapšach (p. 3765), Prague-Vokovice to Karlovy Vary (p. 3768), Prague area (p. 3769), and apparently many others (p. 3772).

What exactly triggered all of these U.S. incursions into Czechoslovakia? Perhaps recently obtained information from interrogations, or fears that Czech or Soviet officials were about to seize or block access to certain sites or materials?

What did all of these U.S. incursions into Czechoslovakia retrieve?

Where are all of the retrieved materials and U.S. records about these incursions now?]



Sbor národní bezpečnosti
Zemské velitelství v Praze.

4

Služební záznam čís. 2.

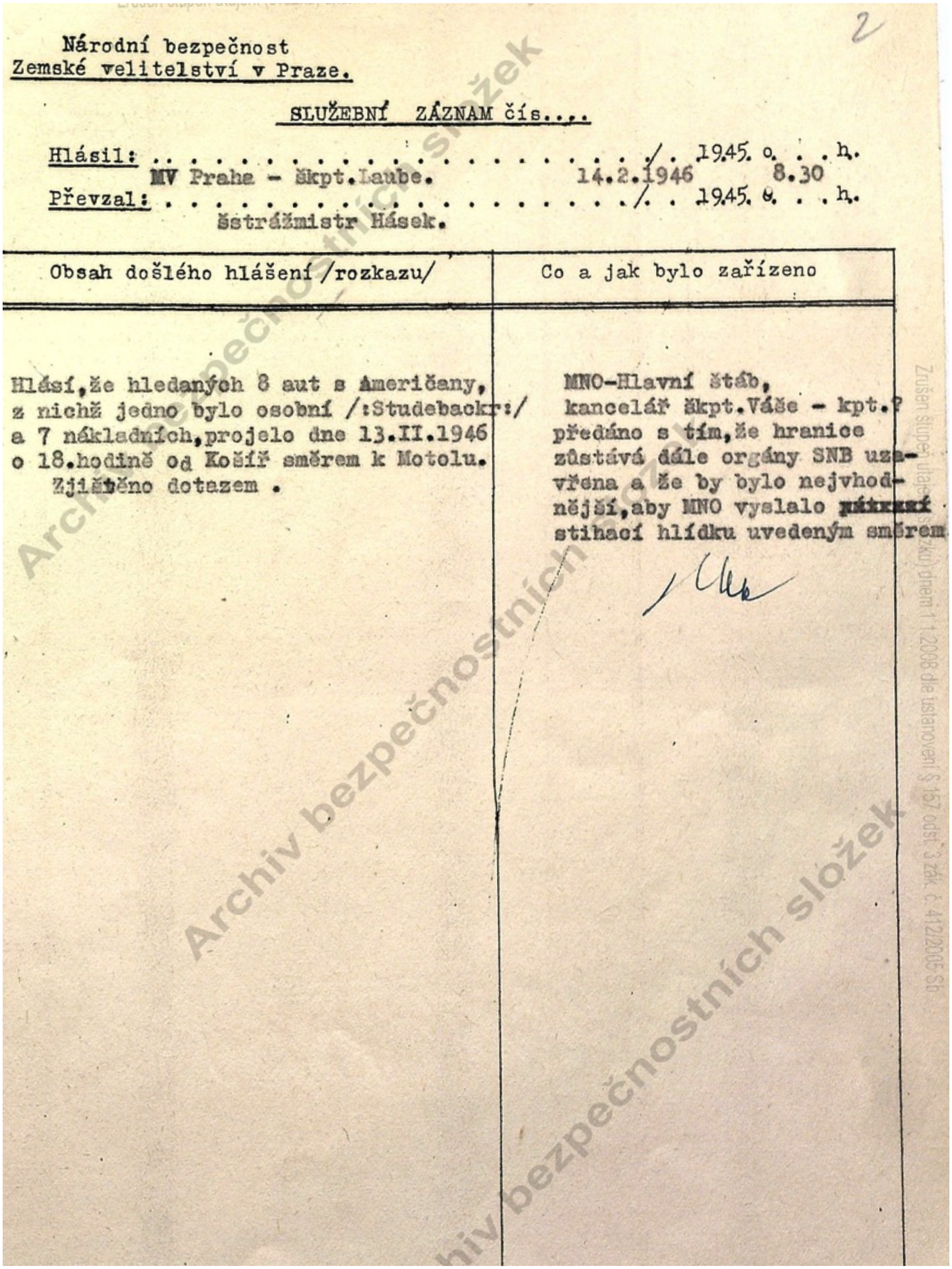
Hlásil: prp.Svoboda . . . . dne 13 / 2 194 o 17.35 hod.

Převzal: šstrážm.Měřička

Obsah došlého hlášení/rozkazu/	Co a jak bylo zařízeno
SNB-MV-27 revír hlásí, že des SNB Jan Korečka 1472 revír 27 zjistil od Františka Stilky ve Vokovicích, že mezi 10-11 hod. 13.2.1946, projela směrem k Ruzyni /směr K.Vary/ 4 lehká nákladní a 3-4 jiná americká vojenská vozidla, mezi nimi 4 Jeepy. Vozidla měla bílé hvězdy. Shora uvedené velitelství vyrozumívá současně MNO-hlavní štáb č.tel.096, klapka 1031.	Viz poslední odstavec došlého hlášení.

Archiv bezpečnostních složek

Figure D.318: A report of another successful U.S. incursion into Czechoslovakia on 13 February 1946, describing a U.S. convoy of four trucks and four Jeeps traveling from Prague-Vokovice to Karlovy Vary. [Archiv Bezpečnostních Složek. File 304_81_5. Courtesy of Jaroslav Mareš.]



2

Národní bezpečnost
Zemské velitelství v Praze.

SLUŽEBNÍ ZÁZNAM čís....

Hlásil: . . . ./. . 1945. o. . . h.
MV Praha - škpt.Laube. 14.2.1946 8.30
Převzal: . . . ./. . 1945. o. . . h.
šstrážmistr Hásek.

Obsah došlého hlášení /rozkazu/	Co a jak bylo zařízeno
Hlásí, že hledaných 8 aut s Američany, z nichž jedno bylo osobní /:Studebackr:/ a 7 nákladních, projelo dne 13.II.1946 o 18.hodině od Košíř směrem k Motolu. Zjištěno dotazem .	MNO-Hlavní štáb, kancelář škpt.Váše - kpt.? předáno s tím, že hranice zůstává dále orgány SNB uzavřena a že by bylo nejvhodnější, aby MNO vyslalo stihací hlídku uvedeným směrem.

Archiv bezpečnostních složek

Zrušen stupeň utajení [illegible] dnem 1.1.2008 dle ustanovení § 157 odst. 3 zák. č. 412/2005 Sb.

Figure D.319: A report of another successful U.S. incursion into Czechoslovakia on 13 February 1946, describing a U.S. convoy of seven trucks and one passenger car traveling from Prague-Košíře to Prague-Motol. [Archiv Bezpečnostních Složek. File 304_81_5. Courtesy of Jaroslav Mareš.]

Leslie Groves to U.S. Military Attaché London. 10 September 1946. Top Secret cable WAR 99912 [NARA RG 77, Entry UD-22A, Box 160, Folder 205.4 Cables Outgoing, Top Secret]. See document photo on p. 3771.

10 September 1946

MILATTACHÉ AMEMBASSY London England

Number: WAR 99912

Loco Personal for Dean from Shuler signed Groves

Mr P. C. Keith will be in Czechoslovakia from approximately 15 September to 28 September. The name of the Military Attaché at Prague, Colonel Egmont F. Koenig, has been given to Keith. It is important that Koenig be notified of visit of Keith into Czechoslovakia so that Koenig may extend to him every courtesy possible should the occasion arise.

Wire Koenig immediately in Prague—Top Secret-priority—as follows and sign name of Dean: Mr P. C. Keith, President of U.S. Industrial Corporation, will be in Czechoslovakia on September 15th and may contact you personally. Important that every courtesy possible be shown him if occasion arises.

End

ORIGINATOR: Gen Groves

[Percival C. Keith, a chemical engineering graduate from MIT, was the chief designer and engineer of the Oak Ridge K-25 gaseous diffusion uranium enrichment facility. See for example:

https://www.nytimes.com/1976/07/12/archives/percival-c-keith-scientist-75-dies-worked-on-abomb-project-and-in.html

https://www.nae.edu/30698/Mr-Percival-C-Keith-Jr

https://ahf.nuclearmuseum.org/ahf/profile/percival-dobie-keith/

In September 1946, Leslie Groves sent Keith on a two-week Top Secret mission to Czechoslovakia. Groves also ordered Colonel Egmont Koenig (pp. 5541–5544) at the U.S. embassy in Prague to do anything possible to bail out Keith if he ran into trouble during his visit ("Important that every courtesy possible be shown him if occasion arises"). As the designer of Oak Ridge, Keith would have been an invaluable prize to the Czechs or Soviets if he had been captured.

Since this mission was ordered by Groves and led by Keith, it must have focused on nuclear issues. Since the mission was Top Secret and Keith was sent despite the great risk if he had been captured, it must have been extremely high priority.

The logical target for such a mission would be former wartime German nuclear resources in Czechoslovakia that were now being used or in danger of being used by Czech/Soviet forces. There was considerable wartime German and postwar Soviet mining of uranium ore in Czechoslovakia, but that was already being addressed by other U.S./U.K. investigators with much more expertise with mining and/or espionage and much less risk if captured than Keith (e.g., pp. 4980–4984).

It seems as if the only target that would require the specific expertise of Keith and justify the great risk of sending him would be a former German uranium enrichment facility in Czechoslovakia. Was Keith's mission to help inspect/remove/destroy key components at an enrichment facility? Can anyone locate more archival documents regarding the information that prompted Keith's mission, what he did during his mission, and the resulting reports or other impacts after his mission?

For examples of similar incidents, see pp. 3761–3769, 3772, 4613–4615, 4853, 4980–4981, 5050.]

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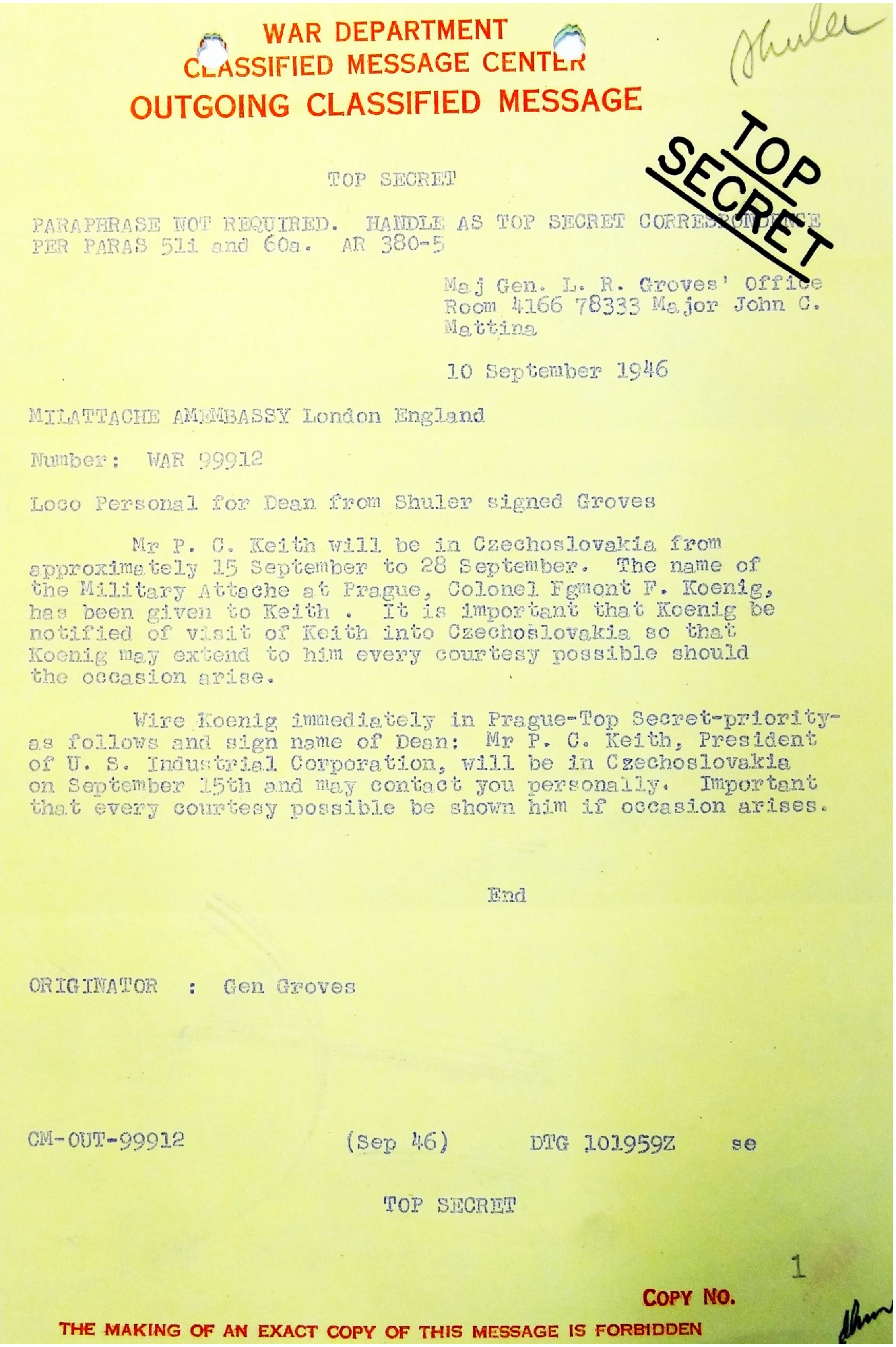
Authority NND 974017



WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
OUTGOING CLASSIFIED MESSAGE

Shuler

TOP SECRET

TOP SECRET

PARAPHRASE NOT REQUIRED. HANDLE AS TOP SECRET CORRESPONDENCE PER PARAS 51i and 60a. AR 380-5

Maj Gen. L. R. Groves' Office
Room 4166 78333 Major John C. Mattina

10 September 1946

MILATTACHE AMEMBASSY London England

Number: WAR 99912

Loco Personal for Dean from Shuler signed Groves

Mr P. C. Keith will be in Czechoslovakia from approximately 15 September to 28 September. The name of the Military Attache at Prague, Colonel Egmont F. Koenig, has been given to Keith . It is important that Koenig be notified of visit of Keith into Czechoslovakia so that Koenig may extend to him every courtesy possible should the occasion arise.

Wire Koenig immediately in Prague-Top Secret-priority-as follows and sign name of Dean: Mr P. C. Keith, President of U. S. Industrial Corporation, will be in Czechoslovakia on September 15th and may contact you personally. Important that every courtesy possible be shown him if occasion arises.

End

ORIGINATOR : Gen Groves

CM-OUT-99912 (Sep 46) DTG 101959Z se

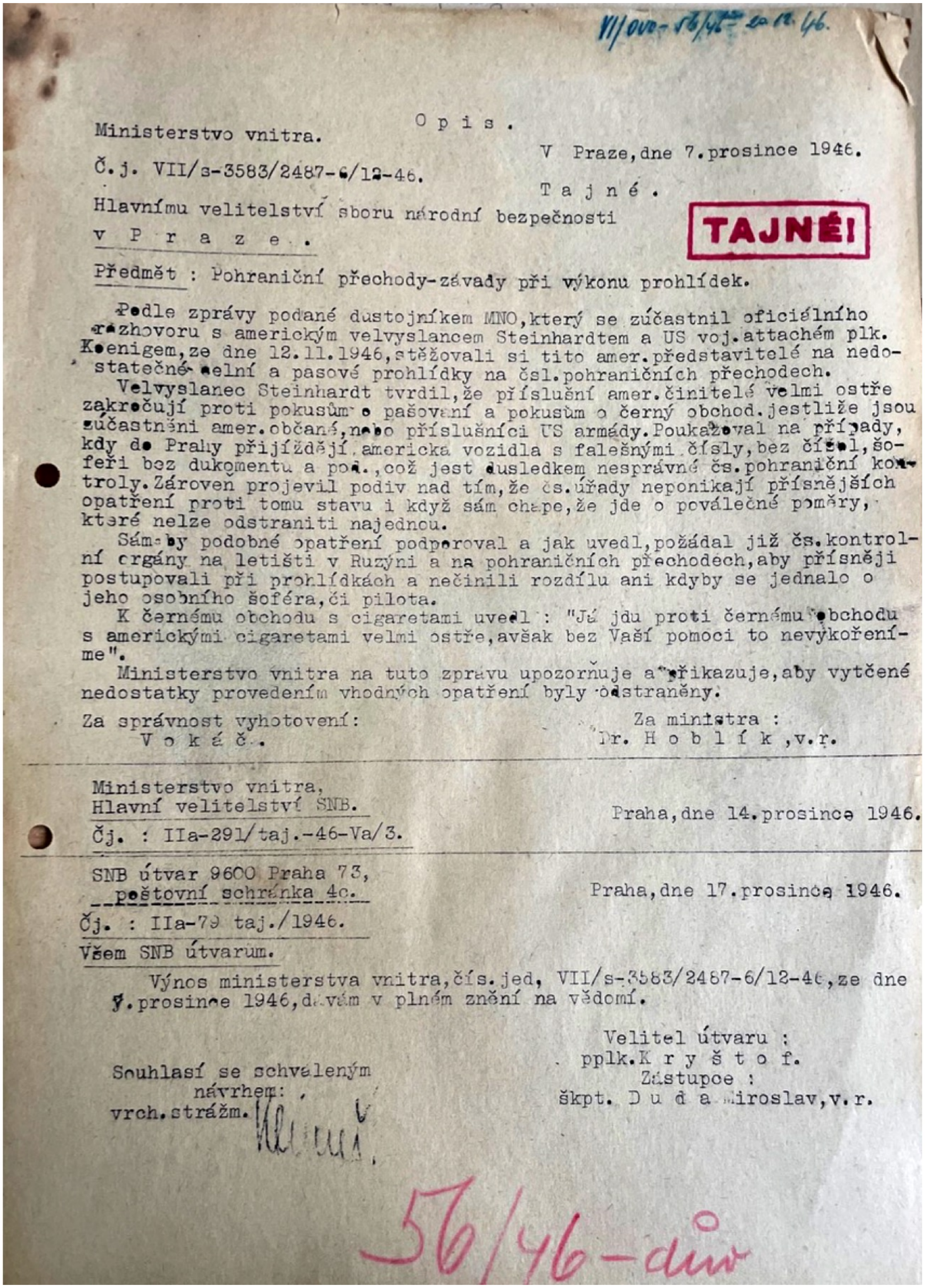
TOP SECRET

COPY NO. 1

THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN

NARA RG 77, Entry UD-22A, Box 160,
Folder 205.4 Cables Outgoing, Top Secret

Figure D.320: In September 1946, Leslie Groves sent Percival C. Keith, the construction chief of Oak Ridge, on a two-week Top Secret mission to Czechoslovakia. Leslie Groves to U.S. Military Attaché London. 10 September 1946. Top Secret cable WAR 99912 [NARA RG 77, Entry UD-22A, Box 160, Folder 205.4 Cables Outgoing, Top Secret].



VII/ovo-56/46 20.12.46.

Opis.

Ministerstvo vnitra.

V Praze, dne 7. prosince 1946.

Č.j. VII/s-3583/2487-6/12-46.

Tajné.

TAJNÉ!

Hlavnímu velitelství sboru národní bezpečnosti
v Praze.

Předmět : Pohraniční přechody-závady při výkonu prohlídek.

Podle zprávy podané dustojníkem MNO, který se zúčastnil oficiálního rozhovoru s americkým velvyslancem Steinhardtem a US voj. attachém plk. Koenigem, ze dne 12.11.1946, stěžovali si tito amer. představitelé na nedostatečné celní a pasové prohlídky na čsl. pohraničních přechodech.

Velvyslanec Steinhardt tvrdil, že příslušní amer. činitelé velmi ostře zakročují proti pokusům o pašovaní a pokusům o černý obchod. jestliže jsou zúčastněni amer. občané, nebo příslušníci US armády. Poukazoval na případy, kdy do Prahy přijíždějí americka vozidla s falešnými čísly, bez čísel, šoferi bez dukomentu a pod., což jest dusledkem nesprávné čs. pohraniční kontroly. Zároveň projevil podiv nad tím, že čs. úřady neponikají přísnějších opatření proti tomu stavu i když sám chape, že jde o poválečné poměry, které nelze odstraniti najednou.

Sám by podobné opatření podporoval a jak uvedl, požádal již čs. kontrolní orgány na letišti v Ruzýni a na pohraničních přechodech, aby přísněji postupovali při prohlídkách a nečinili rozdílu ani kdyby se jednalo o jeho osobního šoféra, či pilota.

K černému obchodu s cigaretami uvedl : "Já jdu proti černému obchodu s americkými cigaretami velmi ostře, avšak bez Vaší pomoci to nevykořeníme".

Ministerstvo vnitra na tuto zpravu upozorňuje a přikazuje, aby vytčené nedostatky provedením vhodných opatření byly odstraněny.

Za správnost vyhotovení:
Vokáč.

Za ministra :
Dr. Hoblík, v.r.

Ministerstvo vnitra,
Hlavní velitelství SNB.
Čj. : IIa-291/taj.-46-Va/3.

Praha, dne 14. prosince 1946.

SNB útvar 9600 Praha 73,
poštovní schránka 40.
Čj. : IIa-79 taj./1946.
Všem SNB útvarum.

Praha, dne 17. prosince 1946.

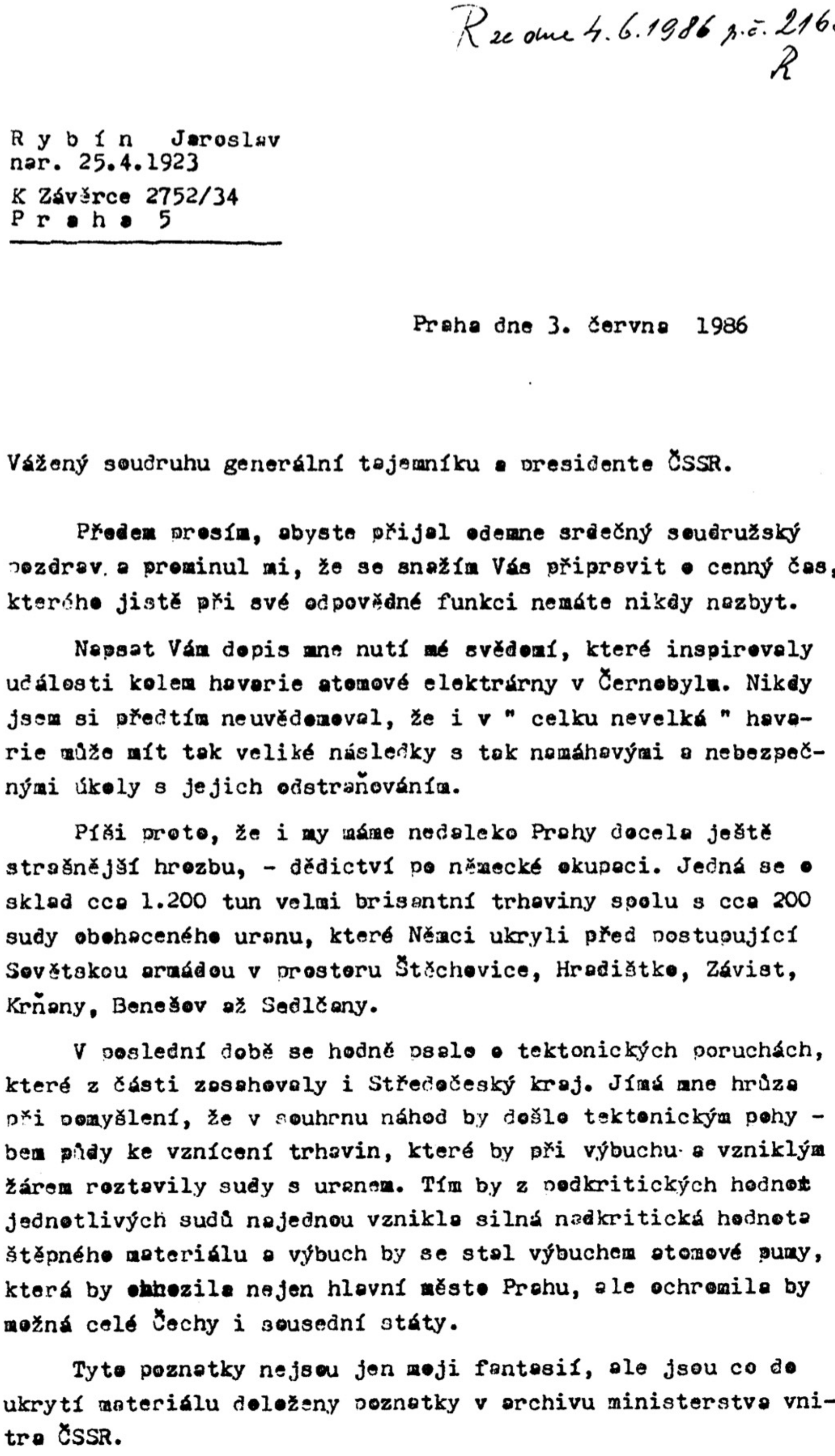
Výnos ministerstva vnitra, čís. jed. VII/s-3583/2487-6/12-46, ze dne 7. prosince 1946, dává vám v plném znění na vědomí.

Velitel útvaru :
pplk. Kryštof.
Zástupce :
škpt. Duda Miroslav, v.r.

Souhlasí se schváleným
návrhem:
vrch. strážm.

56/46-dův

Figure D.321: According to this December 1946 report from the Czechoslovakian Ministry of Defense, even the U.S. ambassador in Prague, Laurence Steinhardt (1892–1950, who had a fascinating career that deserves greater study!), complained about the large numbers of U.S. vehicles making unauthorized incursions into Czechoslovakia. [Pohraniční útvary SNB 1946–1947. Courtesy of Jaroslav Mareš.]



R ze dne 4.6.1986 p.č. 2168 4
R

Rybín Jaroslav
nar. 25.4.1923
K Závěrce 2752/34
Praha 5

Praha dne 3. června 1986

Vážený soudruhu generální tajemníku a presidente ČSSR.

Předem prosím, abyste přijal odemne srdečný soudružský pozdrav a prominul mi, že se snažím Vás připravit o cenný čas, kterého jistě při své odpovědné funkci nemáte nikdy nazbyt.

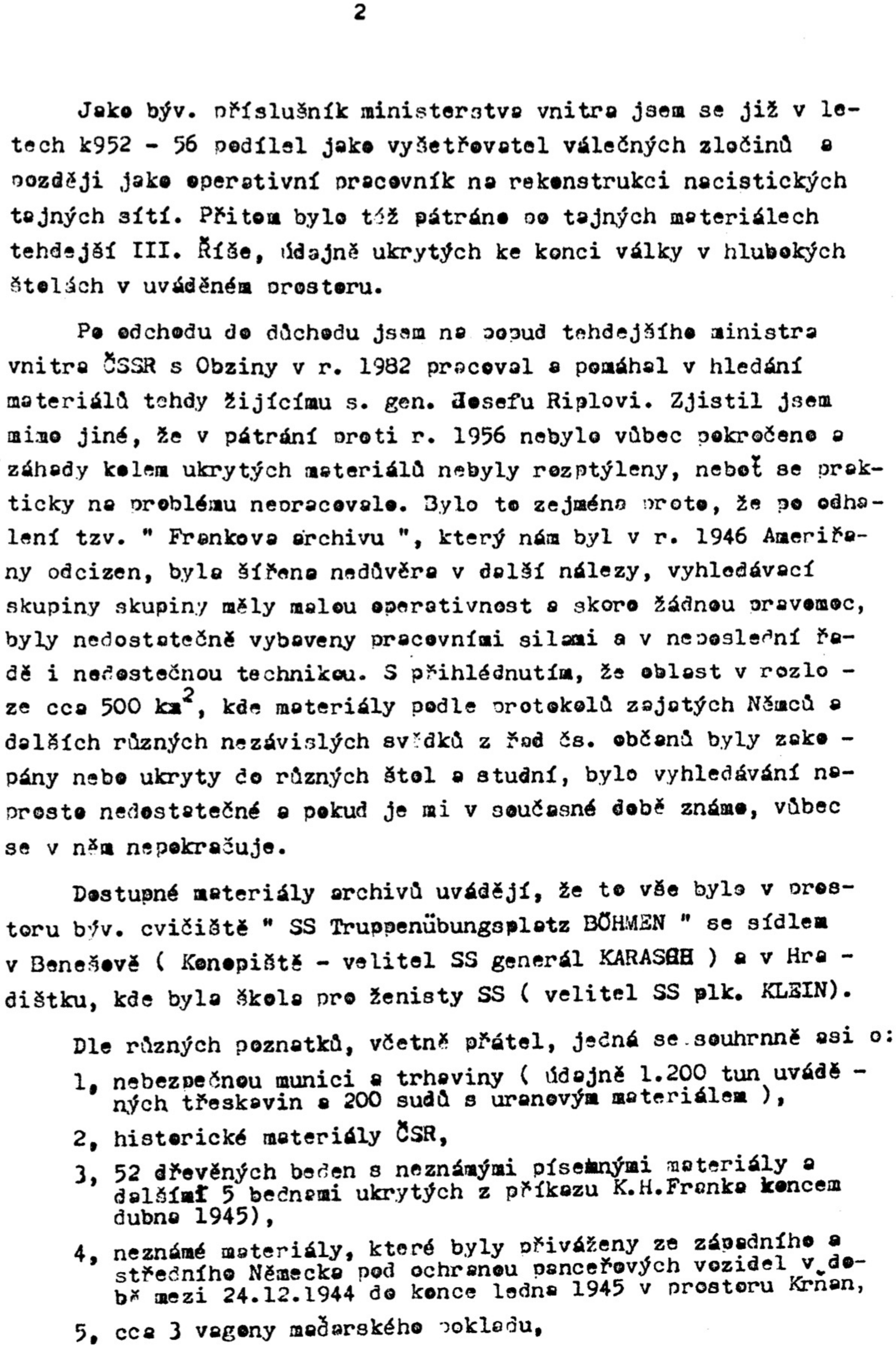
Napsat Vám dopis mne nutí mé svědomí, které inspirovaly události kolem havarie atomové elektrárny v Černobylu. Nikdy jsem si předtím neuvědomoval, že i v " celku nevelká " havarie může mít tak veliké následky s tak namáhavými a nebezpečnými úkoly s jejich odstraňováním.

Píši proto, že i my máme nedaleko Prahy docela ještě strašnější hrozbu, - dědictví po německé okupaci. Jedná se o sklad cca 1.200 tun velmi brisantní trhaviny spolu s cca 200 sudy obohaceného uranu, které Němci ukryli před postupující Sovětskou armádou v prostoru Štěchovice, Hradištko, Závist, Krňany, Benešov až Sedlčany.

V poslední době se hodně psalo o tektonických poruchách, které z části zasahovaly i Středočeský kraj. Jímá mne hrůza při pomyšlení, že v souhrnu náhod by došlo tektonickým pohybem půdy ke vznícení trhavin, které by při výbuchu a vzniklým žárem roztavily sudy s uranem. Tím by z podkritických hodnot jednotlivých sudů najednou vznikla silná nadkritická hodnota štěpného materiálu a výbuch by se stal výbuchem atomové pumy, která by ohrozila nejen hlavní město Prahu, ale ochromila by možná celé Čechy i sousední státy.

Tyto poznatky nejsou jen mojí fantasií, ale jsou co do ukrytí materiálu doloženy poznatky v archivu ministerstva vnitra ČSSR.

Figure D.322: 3 June 1986 letter from Rybín Jaroslav [Czech National Archive, courtesy of Adam Kretschmer].



2

Jako býv. příslušník ministerstva vnitra jsem se již v letech k952 - 56 podílel jako vyšetřovatel válečných zločinů a později jako operativní pracovník na rekonstrukci nacistických tajných sítí. Přitom bylo též pátráno po tajných materiálech tehdejší III. Říše, údajně ukrytých ke konci války v hlubokých štolách v uváděném prostoru.

Po odchodu do důchodu jsem na popud tehdejšího ministra vnitra ČSSR s Obziny v r. 1982 pracoval a pomáhal v hledání materiálů tehdy žijícímu s. gen. Josefu Riplovi. Zjistil jsem mimo jiné, že v pátrání proti r. 1956 nebylo vůbec pokročeno a záhady kolem ukrytých materiálů nebyly rozptýleny, neboť se prakticky na problému nepracovalo. Bylo to zejména proto, že po odhalení tzv. " Frankova archivu ", který nám byl v r. 1946 Američany odcizen, byla šířena nedůvěra v další nálezy, vyhledávací skupiny skupiny měly malou operativnost a skoro žádnou pravomoc, byly nedostatečně vybaveny pracovními silami a v neposlední řadě i nedostečnou technikou. S přihlédnutím, že oblast v rozloze cca 500 km^2, kde materiály podle protokolů zajatých Němců a dalších různých nezávislých svědků z řad čs. občanů byly zakopány nebo ukryty do různých štol a studní, bylo vyhledávání naprosto nedostatečné a pokud je mi v současné době známo, vůbec se v něm nepokračuje.

Dostupné materiály archivů uvádějí, že to vše bylo v prostoru býv. cvičiště " SS Truppenübungsplatz BÖHMEN " se sídlem v Benešově (Konopiště - velitel SS generál KARASCH) a v Hradištku, kde byla škola pro ženisty SS (velitel SS plk. KLEIN).

Dle různých poznatků, včetně přátel, jedná se souhrnně asi o:

1, nebezpečnou munici a trhaviny (údajně 1.200 tun uváděných třeskavin a 200 sudů s uranovým materiálem),

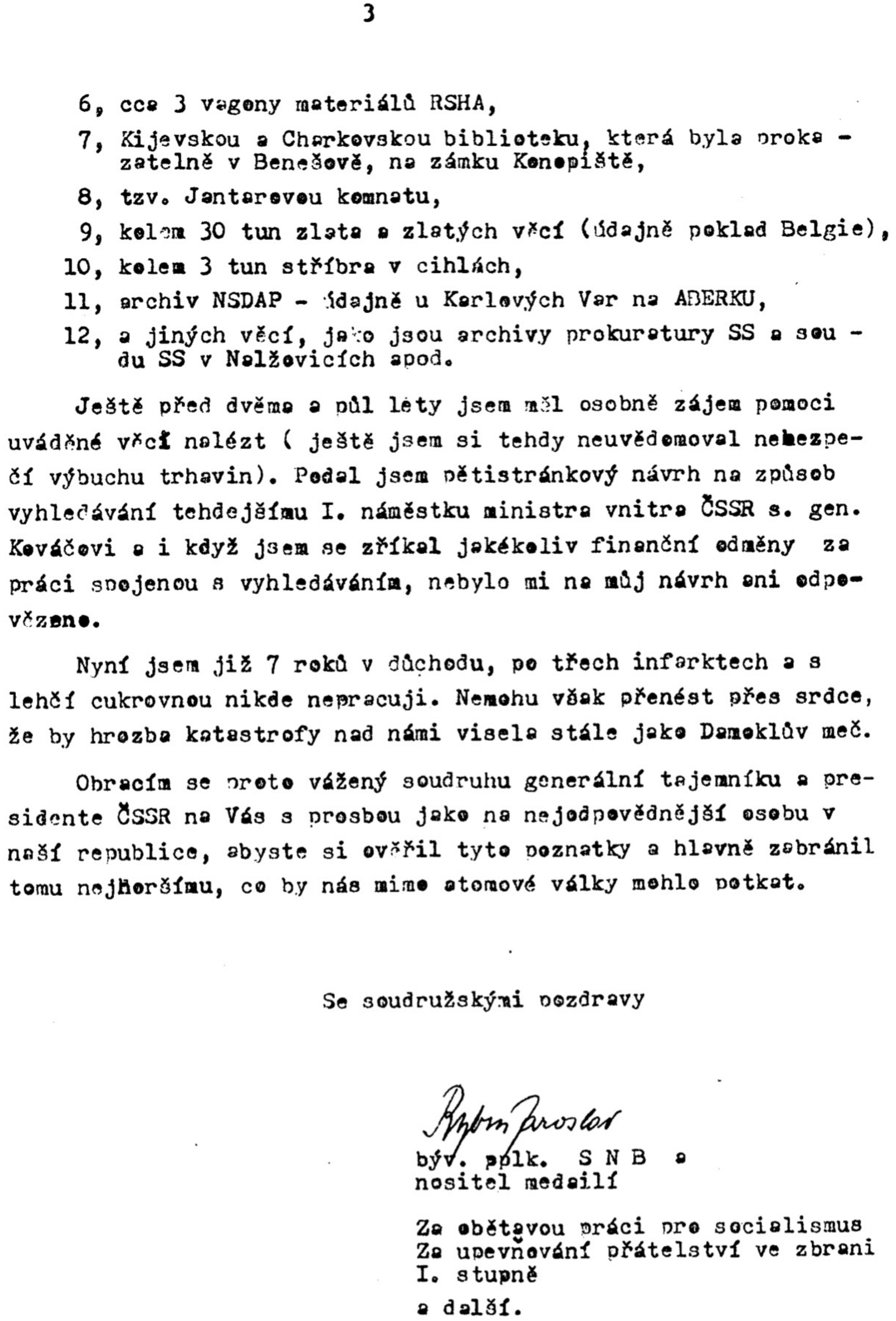
2, historické materiály ČSR,

3, 52 dřevěných beden s neznámými písemnými materiály a dalšími 5 bednami ukrytých z příkazu K.H.Franka koncem dubna 1945),

4, neznámé materiály, které byly přiváženy ze západního a středního Německa pod ochranou pancéřových vozidel v době mezi 24.12.1944 do konce ledna 1945 v prostoru Krňan,

5, cca 3 vagony maďarského pokladu,

Figure D.323: 3 June 1986 letter from Rybín Jaroslav [Czech National Archive, courtesy of Adam Kretschmer].



3

6, cca 3 vagony materiálů RSHA,

7, Kijevskou a Charkovskou biblioteku, která byla prokazatelně v Benešově, na zámku Konopiště,

8, tzv. Jantarovou komnatu,

9, kolem 30 tun zlata a zlatých věcí (údajně poklad Belgie),

10, kolem 3 tun stříbra v cihlách,

11, archiv NSDAP - údajně u Karlových Var na ABERKU,

12, a jiných věcí, jako jsou archivy prokuratury SS a soudu SS v Nalžovicích apod.

Ještě před dvěma a půl lety jsem měl osobně zájem pomoci uváděné věci nalézt (ještě jsem si tehdy neuvědomoval nebezpečí výbuchu trhavin). Podal jsem pětistránkový návrh na způsob vyhledávání tehdejšímu I. náměstku ministra vnitra ČSSR s. gen. Kováčovi a i když jsem se zříkal jakékoliv finanční odměny za práci spojenou s vyhledáváním, nebylo mi na můj návrh ani odpovězeno.

Nyní jsem již 7 roků v důchodu, po třech infarktech a s lehčí cukrovkou nikde nepracuji. Nemohu však přenést přes srdce, že by hrozba katastrofy nad námi visela stále jako Damoklův meč.

Obracím se proto vážený soudruhu generální tajemníku a presidente ČSSR na Vás s prosbou jako na nejodpovědnější osobu v naší republice, abyste si ověřil tyto poznatky a hlavně zabránil tomu nejhoršímu, co by nás mimo atomové války mohlo potkat.

Se soudružskými pozdravy

Rybín Jaroslav
býv. plk. S N B a
nositel medailí

Za obětavou práci pro socialismus
Za upevňování přátelství ve zbrani
I. stupně
a další.

Figure D.324: 3 June 1986 letter from Rybín Jaroslav [Czech National Archive, courtesy of Adam Kretschmer].

Rybín Jaroslav
25.4.1923
K Závěrce 2752/34
Prague 5

Prague 3 June 1986

Dear comrade Secretary General and President of the ČSSR [Czecho-Slovak Socialist Republic],

First of all please accept my comradely greeting, and excuse me that I deprive you of precious time, which you surely do not have much to spare.

I am compelled to write you this letter spurred by the events around the Chernobyl nuclear accident. I had not realized before that even "not really major" accidents could have such serious consequences requiring difficult and dangerous clean-up operations.

I am writing you because there is near Prague an even more dangerous threat that we inherited from the German occupation. There is a deposit of approximately 1200 tons of high explosives together with approximately 200 barrels of enriched uranium that were hidden in the area of Štěchovice, Hradišt'ko, Závist, Krňany, Benešov, and Sedlčany, by the German forces retreating before the victorious Soviet Army.

There have been news recently about tectonic disturbances affecting partially Central Bohemia District. I am terrified to think what could happen if tectonic movements would by coincidence lead to ignition of the explosives and the subsequent blast that would melt the barrels with the uranium. This would lead from subcritical mass contained in each of the barrels to the fusion of critical mass and the explosion would thus in effect be the explosion of an atomic bomb that would endanger not only the capital city of Prague, but most probably the whole Bohemia and neighbouring states.

These findings are not mere fantasy of mine, but are based on the findings in the Archive of the Interior Ministry of the ČSSR.

As a former officer of the Interior Ministry I was working in 1952–56 as war crimes investigator and later as operational officer on the reconstruction of the Nazi secret services activities. One of the things that were investigated were secret materials of the Third Reich apparently hidden by the end of the war in deep tunnels in the area I mentioned above.

After my retirement on the orders of the then Minister of the Interior comrade Obzina I was working and helping comrade General Josef Ripl with locating those materials. I have found out, among other, that the search did not advance compared to 1956 and that the secrets surrounding hidden materials were not solved because there was practically no activity in this regard. It was primarily because after the affair with the so called "Frank's Archive" there was suspicion regarding other findings, search parties had very low operatibility and almost no authority, they were understaffed and also underequipped. If we take into consideration the fact that the area in question, where according to the interrogation protocols of captured Germans and according to testimonials of various Czechoslovak witnesses these materials were hidden into various tunnels and water wells, has approximately 500 km^2, the search efforts were totally inadequate and as far as I am aware no further efforts are being made.

The accessible archival materials attest that the area in question is former military training ground "SS Truppenübungsplatz BÖHMEN" with the command in Benešov (Konopiště – commander SS General KARASCH) and in Hradištko where a school for SS sappers was located (commander SS Colonel KLEIN).

According to various sources, including those from my acquaintances, we are dealing with:

1. Dangerous ammunition and explosives (allegedly including above mentioned 1200 tons high explosives and 200 barrels of uranium).
2. Historical materials belonging to Č[S]SR.
3. 52 wooden boxes with unidentified written materials and other 5 boxes hidden by the order of K.H. Frank at the end of April 1945.
4. Unidentified materials that were transported from western and central Germany under the protection of armored vehicles between 24.12.1944–end of January 1945 to the area of Krňany.
5. Approximately 3 wagons of Hungarian treasure.
6. 3 wagons of RSHA materials.
7. Kiev and Kharkiv libraries that were arguably located in Benešov, at Konopiště Chateau.
8. So called Amber Room [Bernsteinzimmer].
9. Around 30 tons of gold and golden treasure (presumably incl. Belgian treasure).
10. Around 3 tons of silver bars.
11. Archive of the NSDAP, presumably near Karlovy Vary at ABERK.
12. Miscellanea, including archives of the SS Prosecution Office and Tribunal at Nelžovice etc.

Two years ago I was personally disposed to assist in locating the above mentioned (back then I did not yet realize the danger posed by the explosives). I submitted a 5-page draft regarding means of locating the stuff mentioned above to the then First Deputy Minister of Interior, comrade General Kováč, and even though I explicitly renounced any financial recompense connected with the search, I never even received an answer back.

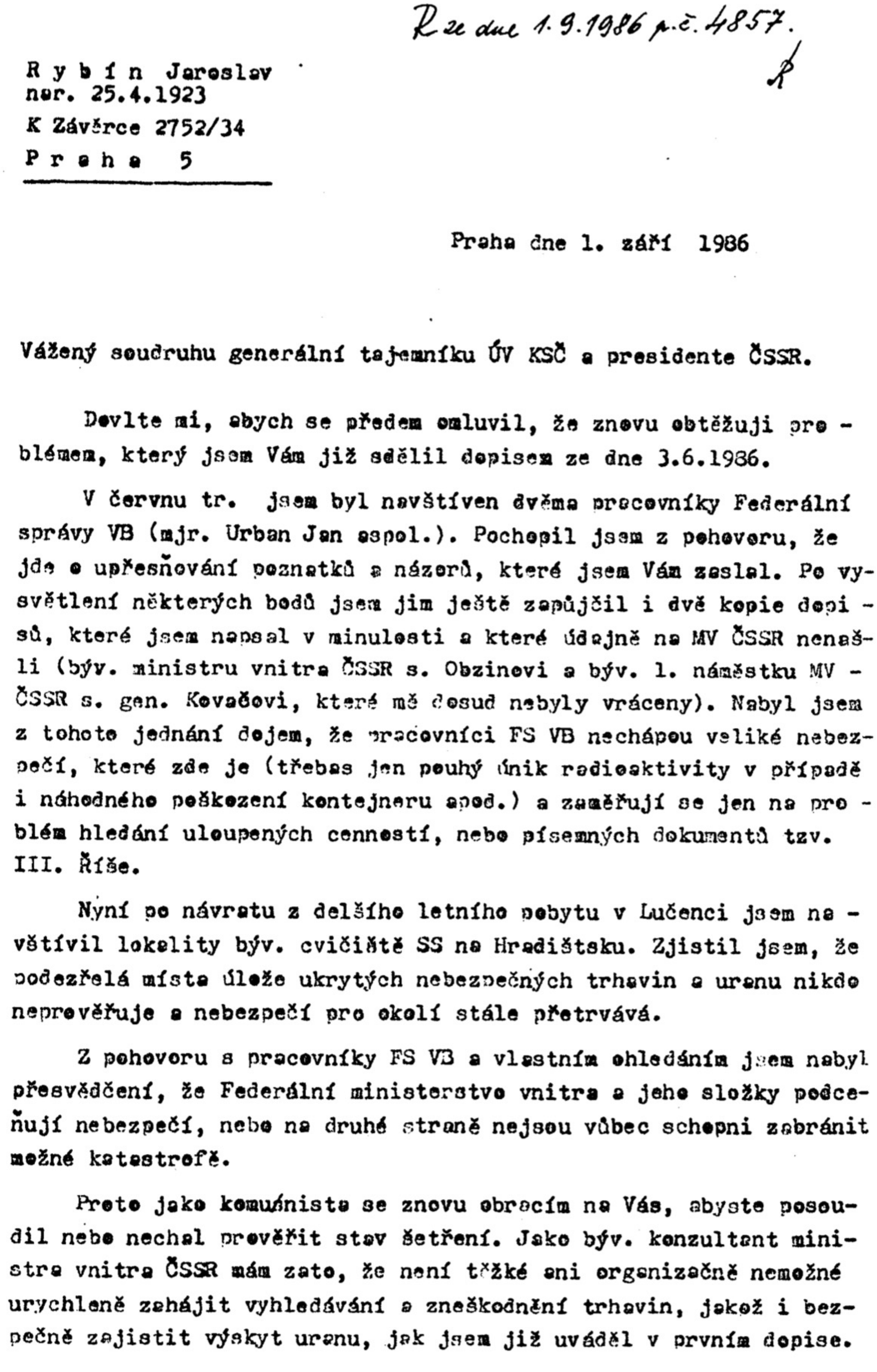
I have been 7 years in retirement, and after three heart attacks and light diabetes I am not working anywhere. I can not ignore though the danger of the catastrophe looming above us like the Sword of Damocles.

I therefore turn to you, dear comrade Secretary General and President of the ČSSR as the most responsible person in our republic, to confirm these findings and especially to prevent the worse that can happen to us, save for atomic war.

With comradely greetings,

Rybín Jaroslav
SNB [National Security Corps] Lieutenant Colonel (ret.)
Awardee of the medals: For Selfless Work for Socialism,
For Securing Friendship in Arms, First Class, and others.

[If this information is correct, "approximately 200 barrels of enriched uranium" would be the product of an industrial-scale nuclear weapons program, not small-scale laboratory experiments. And that is only the enriched uranium that this particular person knew about in this particular location. How much enriched uranium had been produced throughout German-controlled territory by the end of the war, to what degrees was it enriched, and by which enrichment methods?]



R ze dne 1.9.1986 p.č. 4857.

Rybín Jaroslav
nar. 25.4.1923
K Závěrce 2752/34
Praha 5

Praha dne 1. září 1986

Vážený soudruhu generální tajemníku ÚV KSČ a presidente ČSSR.

Dovlte mi, abych se předem omluvil, že znovu obtěžuji problémem, který jsem Vám již sdělil dopisem ze dne 3.6.1986.

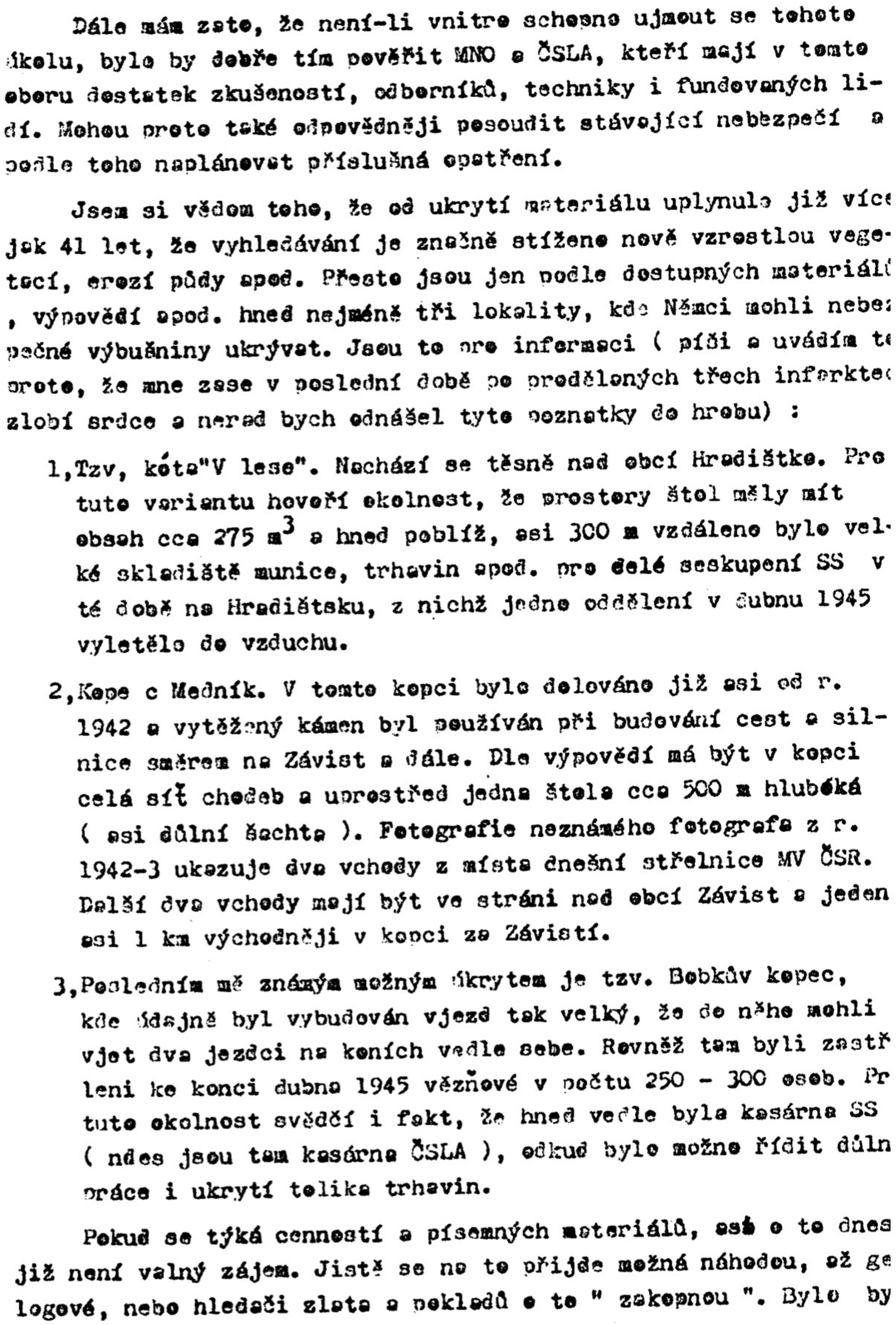
V červnu tr. jsem byl navštíven dvěma pracovníky Federální správy VB (mjr. Urban Jan a spol.). Pochopil jsem z pohovoru, že jde o upřesňování poznatků a názorů, které jsem Vám zaslal. Po vysvětlení některých bodů jsem jim ještě zapůjčil i dvě kopie dopisů, které jsem napsal v minulosti a které údajně na MV ČSSR nenašli (býv. ministru vnitra ČSSR s. Obzinovi a býv. 1. náměstku MV ČSSR s. gen. Kovačovi, které mě dosud nebyly vráceny). Nabyl jsem z tohoto jednání dojem, že pracovníci FS VB nechápou veliké nebezpečí, které zde je (třebas jen pouhý únik radioaktivity v případě i náhodného poškození kontejneru apod.) a zaměřují se jen na problém hledání uloupených cenností, nebo písemných dokumentů tzv. III. Říše.

Nyní po návratu z delšího letního pobytu v Lučenci jsem navštívil lokality býv. cvičiště SS na Hradištsku. Zjistil jsem, že podezřelá místa úlože ukrytých nebezpečných trhavin a uranu nikdo neprověřuje a nebezpečí pro okolí stále přetrvává.

Z pohovoru s pracovníky FS VB a vlastním ohledáním jsem nabyl přesvědčení, že Federální ministerstvo vnitra a jeho složky podceňují nebezpečí, nebo na druhé straně nejsou vůbec schopni zabránit možné katastrofě.

Proto jako komunista se znovu obracím na Vás, abyste posoudil nebo nechal prověřit stav šetření. Jako býv. konzultant ministra vnitra ČSSR mám zato, že není těžké ani organizačně nemožné urychleně zahájit vyhledávání a zneškodnění trhavin, jakož i bezpečně zajistit výskyt uranu, jak jsem již uváděl v prvním dopise.

Figure D.325: 1 September 1986 letter from Rybín Jaroslav [Czech National Archive, courtesy of Adam Kretschmer].



Dále mám zato, že není-li vnitro schopno ujmout se tohoto úkolu, bylo by dobře tím pověřit MNO a ČSLA, kteří mají v tomto oboru dostatek zkušeností, odborníků, techniky i fundovaných lidí. Mohou proto také odpovědněji posoudit stávající nebezpečí a podle toho naplánovat příslušná opatření.

Jsem si vědom toho, že od ukrytí materiálu uplynulo již více jak 41 let, že vyhledávání je značně stíženo nově vzrostlou vegetací, erozí půdy apod. Přesto jsou jen podle dostupných materiálů , výpovědí apod. hned nejméně tři lokality, kde Němci mohli nebezpečné výbušniny ukrývat. Jsou to pro informaci (píši a uvádím to proto, že mne zase v poslední době po prodělaných třech infarktec zlobí srdce a nerad bych odnášel tyto poznatky do hrobu) :

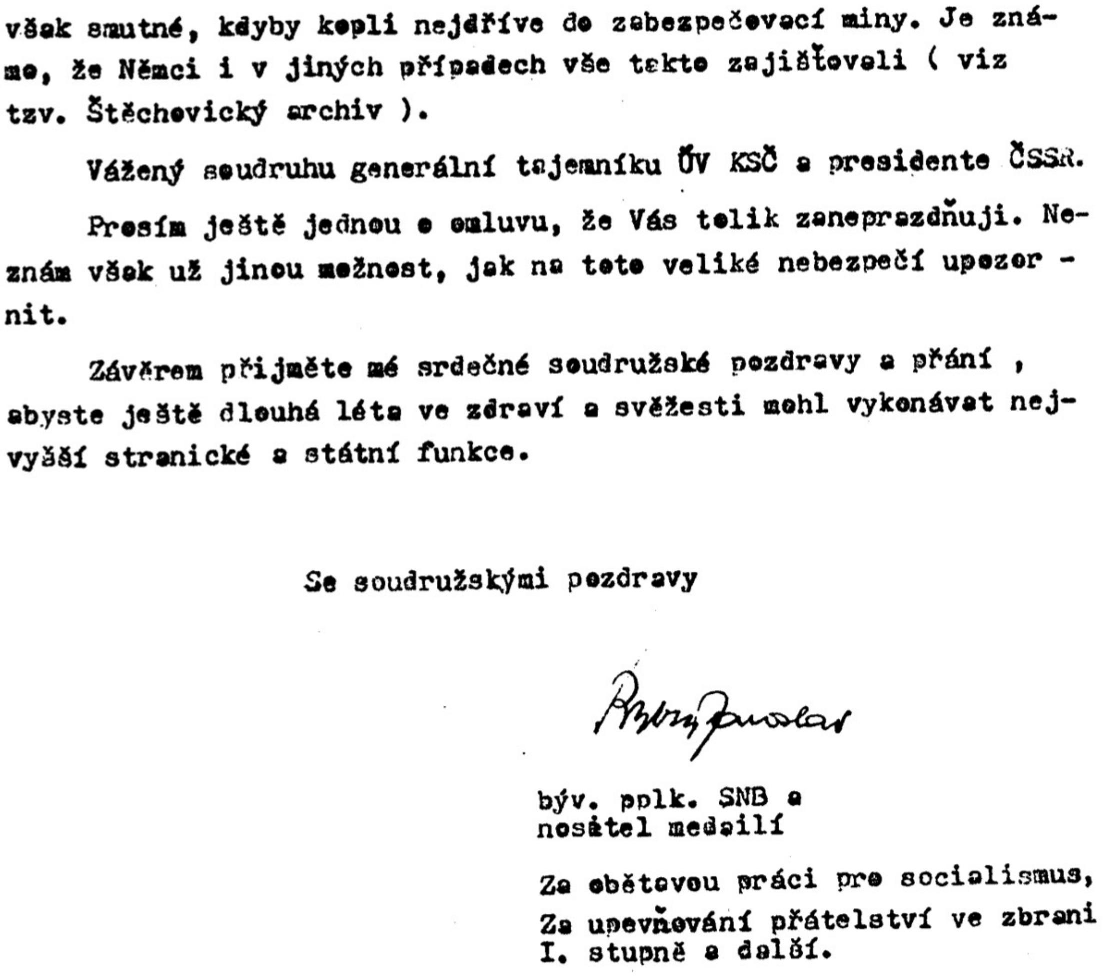
1,Tzv, kóta"V lese". Nachází se těsně nad obcí Hradištko. Pro tuto variantu hovoří okolnost, že prostory štol měly mít obsah cca 275 m^3 a hned poblíž, asi 300 m vzdáleno bylo veliké skladiště munice, trhavin apod. pro celé seskupení SS v té době na Hradištsku, z nichž jedno oddělení v dubnu 1945 vyletělo do vzduchu.

2,Kopec Medník. V tomto kopci bylo dolováno již asi od r. 1942 a vytěžený kámen byl používán při budování cest a silnice směrem na Závist a dále. Dle výpovědí má být v kopci celá síť chodeb a uprostřed jedna štola cca 500 m hluboká (asi důlní šachta). Fotografie neznámého fotografa z r. 1942-3 ukazuje dva vchody z místa dnešní střelnice MV ČSR. Další dva vchody mají být ve stráni nad obcí Závist a jeden asi 1 km východněji v kopci za Závistí.

3,Posledním mě známým možným úkrytem je tzv. Bobkův kopec, kde údajně byl vybudován vjezd tak velký, že do něho mohli vjet dva jezdci na koních vedle sebe. Rovněž tam byli zastřleni ke konci dubna 1945 vězňové v počtu 250 - 300 osob. Pr tuto okolnost svědčí i fakt, že hned vedle byla kasárna SS (nyní jsou tam kasárna ČSLA), odkud bylo možno řídit důln práce i ukrytí tolika trhavin.

Pokud se týká cenností a písemných materiálů, asi o to dnes již není valný zájem. Jistě se na to přijde možná náhodou, až gelogové, nebo hledači zlata a pokladů o to " zakopnou ". Bylo by

Figure D.326: 1 September 1986 letter from Rybín Jaroslav [Czech National Archive, courtesy of Adam Kretschmer].



však smutné, kdyby kopli nejdříve do zabezpečovací miny. Je známo, že Němci i v jiných případech vše takto zajišťovali (viz tzv. Štěchovický archiv).

Vážený soudruhu generální tajemníku ÚV KSČ a presidente ČSSR.

Prosím ještě jednou o omluvu, že Vás tolik zaneprazdňuji. Neznám však už jinou možnost, jak na toto veliké nebezpečí upozornit.

Závěrem přijměte mé srdečné soudružské pozdravy a přání , abyste ještě dlouhá léta ve zdraví a svěžesti mohl vykonávat nejvyšší stranické a státní funkce.

Se soudružskými pozdravy

Rybín Jaroslav

býv. pplk. SNB a
nositel medailí

Za obětavou práci pro socialismus,
Za upevňování přátelství ve zbrani
I. stupně a další.

Figure D.327: 1 September 1986 letter from Rybín Jaroslav [Czech National Archive, courtesy of Adam Kretschmer].

Rybín Jaroslav
25.4.1923
K Závěrce 2752/34
Praha 5

Praha 1 September 1986

Dear comrade Secretary General and President of the ČSSR,

First of all, please accept my apology for contacting you again regarding the matters I presented in my letter to you of 3 June 1986.

In June of this year I was visited by two officers of Federal Service of VB (Public Security /Police/) (Major Jan Urban and a colleague). I understood from the interview that they visited me to clarify some points regarding the matters I wrote you about. After providing clarification I gave them two copies of the letter that I wrote previously to the then Minister of the Interior comrade Obzina and to the then First Deputy Minister of the Interior comrade General Kovač. No copy of the letter was ever returned to me, and even so the Ministry of Interior claims they have been unable to find them in their archive. I got the impression from the interview that the VB Federal Service officers don't understand the magnitude of the danger present (even including a mere radioactive leak in case of accidental damage to a barrel etc.) and that they focused only on issues of finding the lost valuables or written documents of the Third Reich.

After I had returned from a longer summer stay at Lučenec, I visited the area of the former SS training grounds at Hradištsko. I found out that suspected places where dangerous explosives and the uranium may be located were not being searched and thus the danger for local environment persists.

From the interview with the officers of the VB Federal Service and by checking personally the locality, I got the impression that the Federal Ministry of the Interior and its departments underestimate the danger or perhaps they don't even have the means to avert a possible catastrophe.

Therefore I turn to you as a communist to have this reviewed and examined. As a former specialist of the Ministry of the Interior of the ČSSR I hold that it is neither hard nor impossible from an organizational point of view to start locating and disarming the explosives, as well as safely deal with the uranium, that I mentioned in my first letter.

It is my belief that if the Interior Ministry is not able to deal with this task, it could be delegated to the Defence Ministry and the ČSLA (Army) that have in this regard lot of experiences, specialists, technical means and personal capabilities. They can best evaluate the present danger and plan accordingly how to deal with it.

I am aware that 41 years have passed since the materials were hidden, and that the search is more difficult due to grown vegetation, soil erosion, etc. Nonetheless, according to available evidence, testimonies, etc., there are at least three possible locations where the Germans could have hidden dangerous explosives. These are for your information (I write it here since after three heart attacks my heart is starting to act up again and I don't want to take my knowledge with me to the grave) the following locations:

1. The so called “V lese” spot. It is located directly above Hradištko. The factors favoring this location are that the volume of the tunnels is supposed to be approximately 275m^3 and that nearby, around 300 m away, there was an ammunition and explosives depot for the SS unit stationed at Hradištko, a part of which exploded in April 1945.

2. The Medník hill spot. This hill was mined since 1942 and the mined stone was used to build communications to Závist and beyond. According to testimonies there is supposed to be a network of passages and one tunnel approximately 500 m deep (mining tunnel) located in the hill. Photos made by an unidentified photographer in 1942–43 show two entrances located at the area of a current shooting training ground of the Interior Ministry of the ČSSR. Another two entrances should be located in the hillside above Závist and one about 1 km east of Závist.

3. The last possible hiding place location known to me is so called Bobkův kopec hill spot, where allegedly an entrance was constructed of sufficient dimensions that two horse riders could enter riding side by side. It is also a place where around the end of April 1945 250–300 prisoners were shot. A factor favouring this location is that right next to it there were SS barracks (now ČSLA barracks) from where it was possible to direct the hiding of such an amount of explosives.

Regarding the valuables and written materials, these are not of such an interest today. They may be found by accident when geologists or treasure seekers would “trip over them” by accident.

It would be sad though if they would first trip over the safety explosives. It is well known that the Germans used to secure valuables in this way (see the so-called Štěchovice Archive).

Dear comrade Secretary General and President of the ČSSR, please accept once more my apology for keeping you busy. But I don’t know what else to do to point out this grave danger.

Finally, please accept my heartfelt comradely greetings and best wishes for you to serve in the highest Party and State capacities for many coming years full of health and vigor.

With comradely greetings,

Rybín Jaroslav

SNB (National Security Corps) Lieutenant Colonel (ret.)

Awardee of medals For selfless work for socialism and

For securing friendship in arms I. degree and others

[See also:

Czech information on World War II sites (including Štěchovice) that appear to have radioactive contamination: https://www.sekm.cz and https://kontaminace.cenia.cz

Evidence for underground structures and previous excavations at Štěchovice: Jaroslav Sveceny. 2005. *The Search for Nazi Treasures III. Proposal for an Exploration Project and TV Documentary Series.* Prague. pp. 12–14. https://issuu.com/ptouge/docs/nazi_treasures_iii_qxp

It is difficult to find much information about the Blaumeise I–III underground facilities at Štěchovice [Wichert 1999].

Much more archival and archaeological research should be conducted for this site.]

[For some other known or suspected nuclear sites in Czechia, see:

p. 3446

p. 3936

pp. 3979–4025

pp. 4082–4083

pp. 4914–4984]

Known/Reported Sites Now in Slovakia

Philip Morrison to Francis J. Smith. 17 February 1945. Subject: Evaluation of Air Photos [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

1. Leverkusen [...]

2. Dubnica (Czechoslovakia) — This plant has been carefully studied by the Crossbow Committee in interpretation report #U17. It is an excellent factory for making anything. More specifically, the underground facilities, which include quite sizeable steam installations, would make possible the location of a plant of LTD [Liquid Thermal Diffusion, i.e. uranium enrichment], or similar style in fractional scale, at this site. The absence of visible handling facilities for large equipment, etc., is not conclusive, but it is a bit strange if this is really a normal factory for producing ordnance. No specific features except the steel and water facilities would imply a plant of special interest to us, but on the other hand, one cannot exclude that it is such a plant. Here I would like to keep watching this installation and would especially like to see the Crossbow report H(1)131, which was an earlier report on the same site.

3. Hechingen [...]

[See document photo on p. 3785.]

R. V. Shepherd. BIOS 313. *Report on Visit to Czechoslovakia by Armament Design Department. 16th November to 9th December, 1945.* p. 11.

Black List
Number Target

[...]

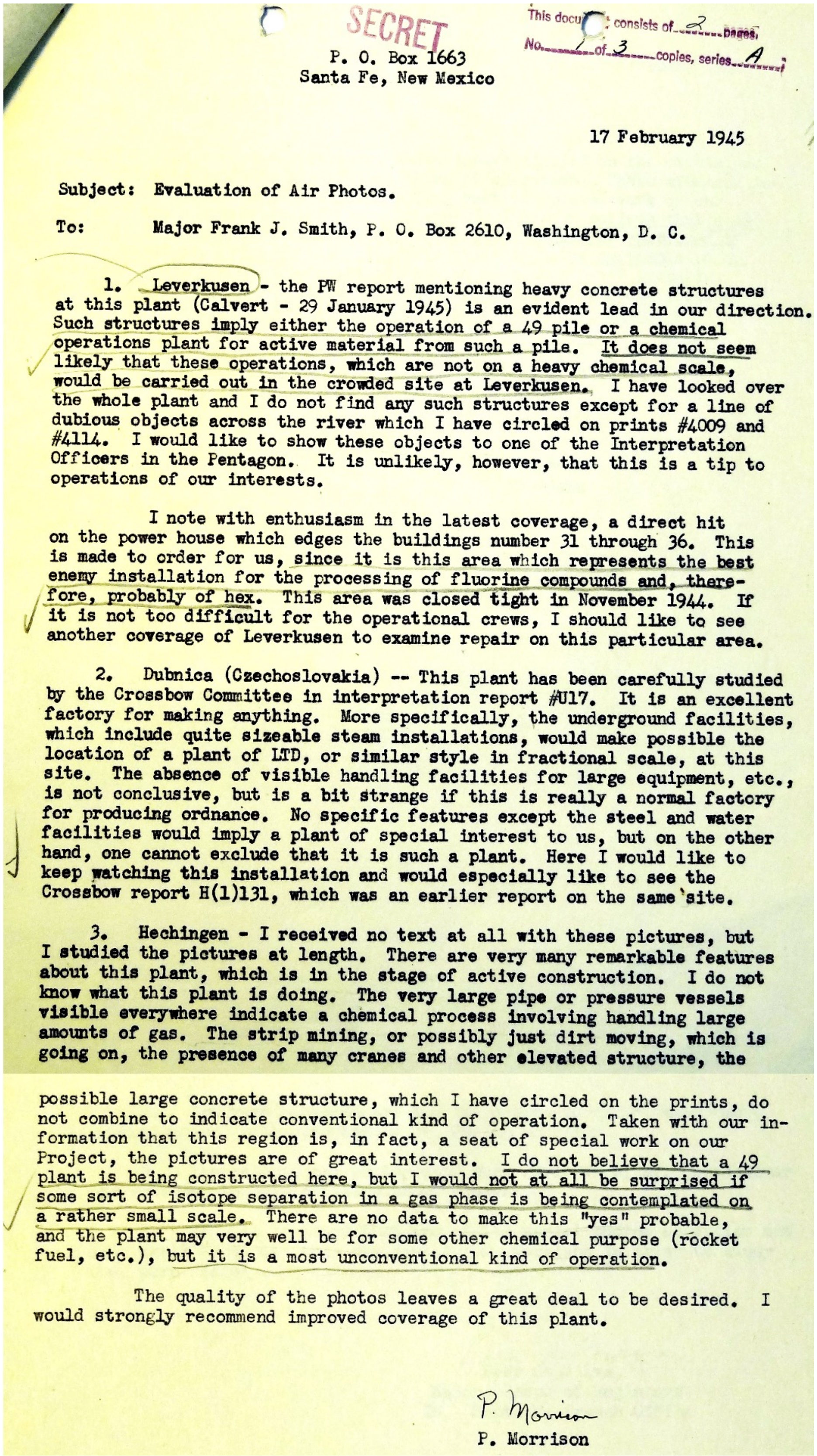
2/462 Dubnica—An underground factory built before the war by Skoda. It was taken over by the Germans and operated by them. It was completely destroyed by the Germans when the Russians advanced into Slovakia. [...]

C2/788 Vitkovice—Skoda had no works here but probably owned coal mines for which this area is noted. The main works are the Vitkovice Steel Works which were in the Herman Goering Trust in the steel making section. The firm is NOT linked with Skoda. Head of the Firm is von Ringhoffer—German. Also a Director of Skoda.

[This Vitkovice (Czechia) plant is either the same as or at least in close proximity to the Ostrava nuclear facility reported in the documents on pp. 3748–3750, 3882–3883.]

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3
GERMANY: US Wartime Positive Int. (Nov. 44-June 45)



SECRET

This document consists of 2 pages, No. 1 of 3 copies, series A

P. O. Box 1663
Santa Fe, New Mexico

17 February 1945

Subject: Evaluation of Air Photos.

To: Major Frank J. Smith, P. O. Box 2610, Washington, D. C.

1. Leverkusen - the PW report mentioning heavy concrete structures at this plant (Calvert - 29 January 1945) is an evident lead in our direction. Such structures imply either the operation of a 49 pile or a chemical operations plant for active material from such a pile. It does not seem likely that these operations, which are not on a heavy chemical scale, would be carried out in the crowded site at Leverkusen. I have looked over the whole plant and I do not find any such structures except for a line of dubious objects across the river which I have circled on prints #4009 and #4114. I would like to show these objects to one of the Interpretation Officers in the Pentagon. It is unlikely, however, that this is a tip to operations of our interests.

I note with enthusiasm in the latest coverage, a direct hit on the power house which edges the buildings number 31 through 36. This is made to order for us, since it is this area which represents the best enemy installation for the processing of fluorine compounds and, therefore, probably of hex. This area was closed tight in November 1944. If it is not too difficult for the operational crews, I should like to see another coverage of Leverkusen to examine repair on this particular area.

2. Dubnica (Czechoslovakia) -- This plant has been carefully studied by the Crossbow Committee in interpretation report #U17. It is an excellent factory for making anything. More specifically, the underground facilities, which include quite sizeable steam installations, would make possible the location of a plant of LTD, or similar style in fractional scale, at this site. The absence of visible handling facilities for large equipment, etc., is not conclusive, but is a bit strange if this is really a normal factory for producing ordnance. No specific features except the steel and water facilities would imply a plant of special interest to us, but on the other hand, one cannot exclude that it is such a plant. Here I would like to keep watching this installation and would especially like to see the Crossbow report H(1)131, which was an earlier report on the same site.

3. Hechingen - I received no text at all with these pictures, but I studied the pictures at length. There are very many remarkable features about this plant, which is in the stage of active construction. I do not know what this plant is doing. The very large pipe or pressure vessels visible everywhere indicate a chemical process involving handling large amounts of gas. The strip mining, or possibly just dirt moving, which is going on, the presence of many cranes and other elevated structure, the possible large concrete structure, which I have circled on the prints, do not combine to indicate conventional kind of operation. Taken with our information that this region is, in fact, a seat of special work on our Project, the pictures are of great interest. I do not believe that a 49 plant is being constructed here, but I would not at all be surprised if some sort of isotope separation in a gas phase is being contemplated on a rather small scale. There are no data to make this "yes" probable, and the plant may very well be for some other chemical purpose (rocket fuel, etc.), but it is a most unconventional kind of operation.

The quality of the photos leaves a great deal to be desired. I would strongly recommend improved coverage of this plant.

P. Morrison
P. Morrison

Figure D.328: Philip Morrison to Francis J. Smith. 17 February 1945. Subject: Evaluation of Air Photos [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Known/Reported Sites Now in Denmark

[Many 1945–1948 newspaper articles alleged that there was some sort of German nuclear work on the Danish island of Bornholm during the war, and that Soviet forces occupying the island after the war removed material from that work:

> Clearing of Bornholm: Germans Who Refused to Surrender. *The Times* (London, 15 May 1945).
>
> Danes Seek Restoration of Communications. *The Times* (London, 18 May 1945).
>
> Russians Believed Near Atom Secret. *New York Times* (15 October 1945 p. 4).
>
> Russia Will Have Secret Soon. *News Chronicle* (15 October 1945 p. 1).
>
> Russia Confident on Bomb. *New York Times* (31 October 1945 p. 6).
>
> Atomic Energy May Be Behind Bornholm Mystery. *Sydney Morning Herald* (20 April 1946 p. 2).
>
> Rich Uranium Ore on Danish Island Russia Evacuated. *Spokane Daily Chronicle* (16 March 1948 p. 6).

With advanced rockets under development at Peenemünde East, advanced aircraft under development at Peenemünde West, biological weapons under development on Riems island, and apparent nuclear tests carried out in the vicinity of the Baltic coast, it would make sense for some of the nuclear development programs to be conducted on Bornholm or elsewhere in that general area. Highly secretive and potentially dangerous military research projects seem to have been deliberately clustered in this sparsely populated area around the Baltic coast, far from Allied forces in both directions at the time that work was begun. The following formerly secret Allied intelligence documents confirm that there were indeed nuclear materials and programs on Bornholm.]

C.S.D.I.C. (U.K.) S.R.G.G. 1118. [Recorded conversation of two German prisoners of war held in the United Kingdom. AFHRA A5415 frames 284–285]

M 159—General der Panzertruppen Von THOMA (GOC German AFRIKORPS) Captd MIDDLE EAST 4 Nov 42

CS/981 Generalleutnant KITTEL (Comd. METZ and Comd. 462 Volksgren. Div.) Captd METZ 22 Nov 44

Information received: 10 Jan 1945

TRANSLATION

KITTEL: (Re atom bomb). It's a perfectly horrible thing.

THOMA: A technical man has written about it, saying the problem has been completely solved theoretically, but that the process can't be controlled(?).

KITTEL: That's the question. At the passing-out parade of an officer's course the FÜHRER—I sent for one of the officers personally, for they were the ones who were at METZ—

THOMA: He's lying. There's absolutely no such thing as the atom business.

KITTEL: Unfortunately there is.

THOMA: Then he would have used it long ago.

KITTEL: No; he isn't using it, because the others have promised to retaliate with chemical warfare. [...]

THOMA: But there's no such thing as an atom bomb.

KITTEL: The experiments with it are carried out on BORNHOLM; the island has been evacuated and no-one may enter or leave the place.

THOMA: What do they do there?

KITTEL: They carry out their experiments there. Apparently they've got another trump card up their sleeve.

[Heinrich Kittel was a very high-ranking general in the German army and thus a valuable source of information, including some information on the German nuclear program. He was captured by Allied forces after being wounded at Metz, France, on 22 November 1944, so all of his knowledge about German activities was very up-to-date as of this recorded conversation. In contrast, General Wilhelm von Thoma had been captured in 1942 while fighting in North Africa, so he had no firsthand knowledge of subsequent developments (and was skeptical of secondhand reports).

Kittel's comments suggest that he was aware of one or more successful atomic bomb tests prior to his capture. The atomic bomb seemed to be much more than an abstract concept to him. For example, he said that:

- It was "a perfectly horrible thing."
- It "unfortunately" existed.
- The decision had already been made not to use it (implying it was available to use) due to Allied threats of retaliation by dropping mustard agent on German cities (see Section A.4.2).

If Kittel associated the atomic bomb most closely with Bornholm and seemed to believe that the bomb had been tested, that suggests that the test(s) occurred either on Bornholm or somewhere near Bornholm along the Baltic coast. That would be highly consistent with other information in Sections D.10–D.11.

Germany built a number of high-tech facilities on Bornholm, yet the local Danish resistance (and modern Danish museum curators) never figured out what exactly the Germans were doing. That indicates that German forces kept local Danish residents well away from the facilities, or else they would have seen and reported just what the Germans were doing there. Any high-ranking German military officer or official who visited would tour the German facilities and see little or nothing of the local residents, so as far as they were concerned, Bornholm was "evacuated"—not the whole island, just the relevant parts. Even today, the large majority of the Bornholm population lives in the town of Rønne on the west side of the island, and the rest is very sparsely populated. (Occupying Soviet forces removed all of the German equipment and documentation from Bornholm at the end of the war, perpetuating the mystery.)]

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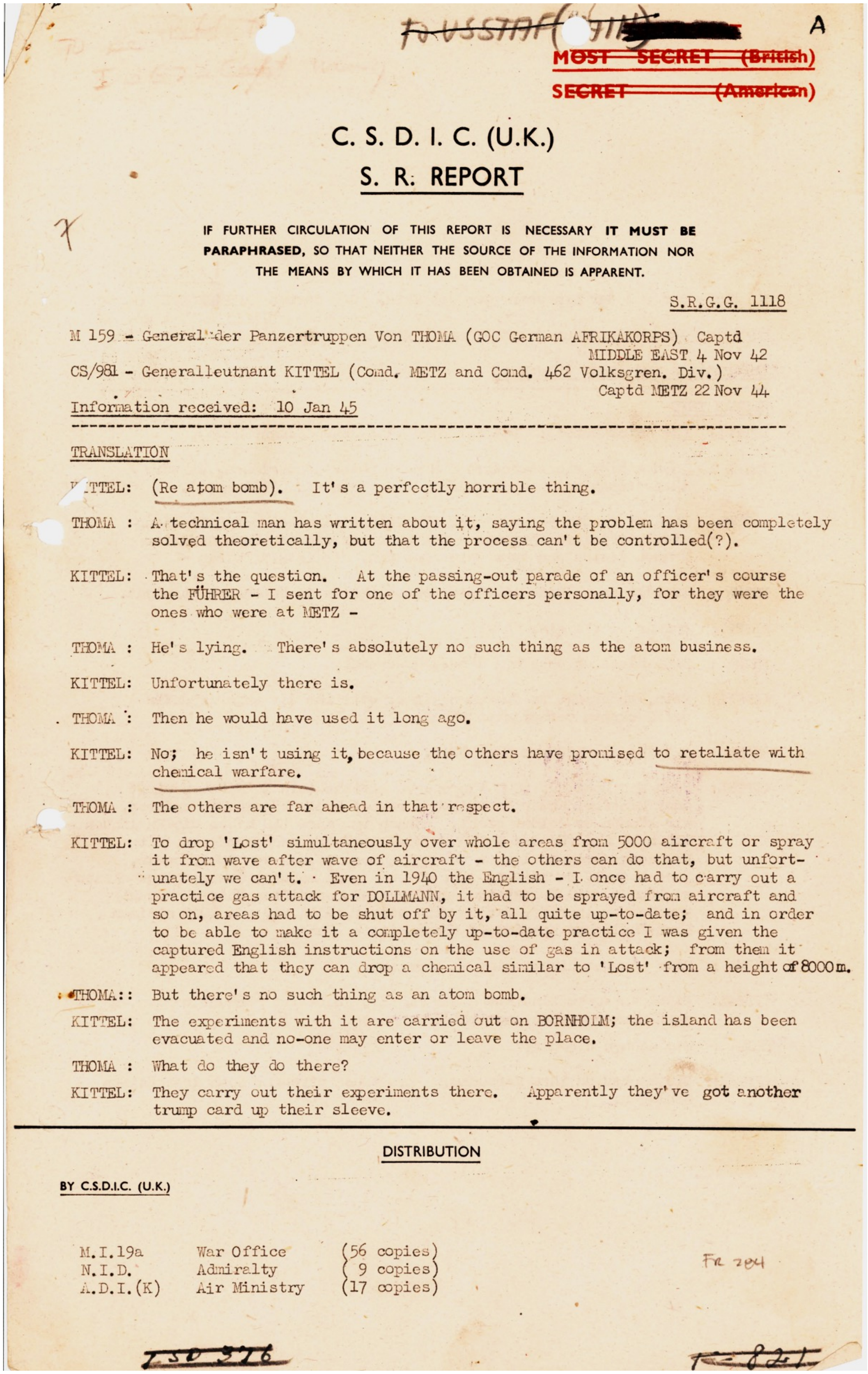
AFHRA folder 512.619C-6C 1944-1945



~~To USSTAF (7th)~~ [redacted] A

~~MOST SECRET (British)~~

~~SECRET (American)~~

C. S. D. I. C. (U.K.)

S. R. REPORT

X

IF FURTHER CIRCULATION OF THIS REPORT IS NECESSARY **IT MUST BE PARAPHRASED,** SO THAT NEITHER THE SOURCE OF THE INFORMATION NOR THE MEANS BY WHICH IT HAS BEEN OBTAINED IS APPARENT.

S.R.G.G. 1118

M 159 - General der Panzertruppen Von THOMA (GOC German AFRIKAKORPS) Captd MIDDLE EAST 4 Nov 42

CS/981 - Generalleutnant KITTEL (Comd. METZ and Comd. 462 Volksgren. Div.) Captd METZ 22 Nov 44

Information received: 10 Jan 45

TRANSLATION

KITTEL: (Re atom bomb). It's a perfectly horrible thing.

THOMA : A technical man has written about it, saying the problem has been completely solved theoretically, but that the process can't be controlled(?).

KITTEL: That's the question. At the passing-out parade of an officer's course the FÜHRER - I sent for one of the officers personally, for they were the ones who were at METZ -

THOMA : He's lying. There's absolutely no such thing as the atom business.

KITTEL: Unfortunately there is.

THOMA : Then he would have used it long ago.

KITTEL: No; he isn't using it, because the others have promised to retaliate with chemical warfare.

THOMA : The others are far ahead in that respect.

KITTEL: To drop 'Lost' simultaneously over whole areas from 5000 aircraft or spray it from wave after wave of aircraft - the others can do that, but unfortunately we can't. Even in 1940 the English - I once had to carry out a practice gas attack for DOLLMANN, it had to be sprayed from aircraft and so on, areas had to be shut off by it, all quite up-to-date; and in order to be able to make it a completely up-to-date practice I was given the captured English instructions on the use of gas in attack; from them it appeared that they can drop a chemical similar to 'Lost' from a height of 8000 m.

THOMA: But there's no such thing as an atom bomb.

KITTEL: The experiments with it are carried out on BORNHOLM; the island has been evacuated and no-one may enter or leave the place.

THOMA : What do they do there?

KITTEL: They carry out their experiments there. Apparently they've got another trump card up their sleeve.

DISTRIBUTION

BY C.S.D.I.C. (U.K.)

M.I.19a	War Office	(56 copies)
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Fr 284

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Figure D.329: C.S.D.I.C. (U.K.) S.R.G.G. 1118. [Recorded conversation of two German prisoners of war held in the United Kingdom. AFHRA folder 512.619C-6C 1944–1945; AFHRA A5415 frame 284.]

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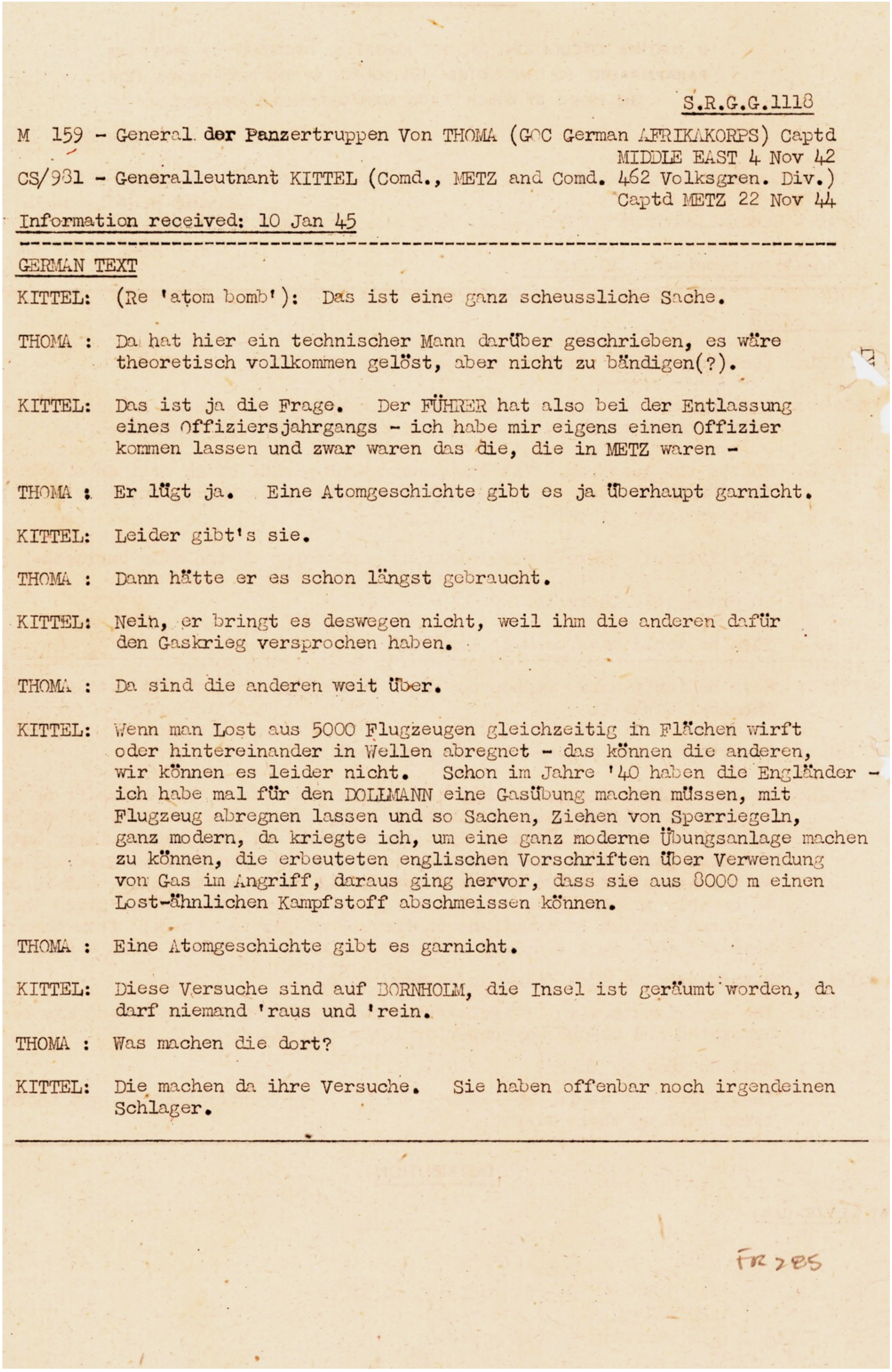
AFHRA folder 512.619C-6C 1944-1945



S.R.G.G.1118

M 159 - General der Panzertruppen Von THOMA (GOC German AFRIKAKORPS) Captd MIDDLE EAST 4 Nov 42

CS/931 - Generalleutnant KITTEL (Comd., METZ and Comd. 462 Volksgren. Div.) Captd METZ 22 Nov 44

Information received: 10 Jan 45

GERMAN TEXT

KITTEL: (Re 'atom bomb'): Das ist eine ganz scheussliche Sache.

THOMA : Da hat hier ein technischer Mann darüber geschrieben, es wäre theoretisch vollkommen gelöst, aber nicht zu bändigen(?).

KITTEL: Das ist ja die Frage. Der FÜHRER hat also bei der Entlassung eines Offiziersjahrgangs - ich habe mir eigens einen Offizier kommen lassen und zwar waren das die, die in METZ waren -

THOMA : Er lügt ja. Eine Atomgeschichte gibt es ja überhaupt garnicht.

KITTEL: Leider gibt's sie.

THOMA : Dann hätte er es schon längst gebraucht.

KITTEL: Nein, er bringt es deswegen nicht, weil ihm die anderen dafür den Gaskrieg versprochen haben.

THOMA : Da sind die anderen weit über.

KITTEL: Wenn man Lost aus 5000 Flugzeugen gleichzeitig in Flächen wirft oder hintereinander in Wellen abregnet - das können die anderen, wir können es leider nicht. Schon im Jahre '40 haben die Engländer - ich habe mal für den DOLLMANN eine Gasübung machen müssen, mit Flugzeug abregnen lassen und so Sachen, Ziehen von Sperriegeln, ganz modern, da kriegte ich, um eine ganz moderne Übungsanlage machen zu können, die erbeuteten englischen Vorschriften über Verwendung von Gas im Angriff, daraus ging hervor, dass sie aus 8000 m einen Lost-ähnlichen Kampfstoff abschmeissen können.

THOMA : Eine Atomgeschichte gibt es garnicht.

KITTEL: Diese Versuche sind auf BORNHOLM, die Insel ist geräumt worden, da darf niemand 'raus und 'rein.

THOMA : Was machen die dort?

KITTEL: Die machen da ihre Versuche. Sie haben offenbar noch irgendeinen Schlager.

FR 285

Figure D.330: C.S.D.I.C. (U.K.) S.R.G.G. 1118. [Recorded conversation of two German prisoners of war held in the United Kingdom. AFHRA folder 512.619C-6C 1944–1945; AFHRA A5415 frame 285.]

Horace K. Calvert to R. V. Jones. 13 March 1945. [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL]

A report dated 27 February 1945 reflecting a conversation between Generalleutnant Kittel and General Eberbach (both German P.W.'s) has been received. The following dialogue is reported:

> KITTEL: I only wish that the Poles, with whom we shall have to co-operate economically afterwards in any case, will be reasonable, but they won't be reasonable, they don't know how to be. EAST PRUSSIA will become a new ALSACE-LORRAINE. Our children will again meet their death over that stupid question, even though the people are promising now to eradicate all wars. By that time new means will have been found; if aircraft are forbidden they'll discover other things.
>
> EBERBACH: The splitting up of the atom, or something like that.
>
> KITTEL: That already exists; that will come very soon; that will smash everything up.

You will recall that Kittel has made numerous references to German atom-splitting activity in the past and apparently is possessed of some information on the subject.

We understand that action on our request for permission to interrogate Kittel directly has been withheld. It is suggested that, in view of recurrence of discussion of this subject by Kittel, another attempt be made to arrange for direct interrogation.

The fact that Kittel's mind so frequently concerns itself with this subject, his knowledge of facts which we have corroborated from independent sources and the opportunities available to him for obtaining knowledge of such activity which might reasonably be expected to attach to one of his position all strongly persuade the belief that if properly approached he would be an extremely valuable source of information.

[Did Heinrich Kittel ever provide details of what he knew about the German nuclear program to Allied interrogators, friends or family in Germany, a diary or memoirs, etc.? Can any relevant records be found?

Note that Horace Calvert emphasized Kittel's "knowledge of facts which we have corroborated from independent sources and the opportunities available to him for obtaining knowledge of such [nuclear] activity." Calvert was a very highly placed Allied official investigating German nuclear work, and as of mid-March 1945, he seemed convinced that there was a serious German nuclear weapons program and that Kittel had accurate information about it.]

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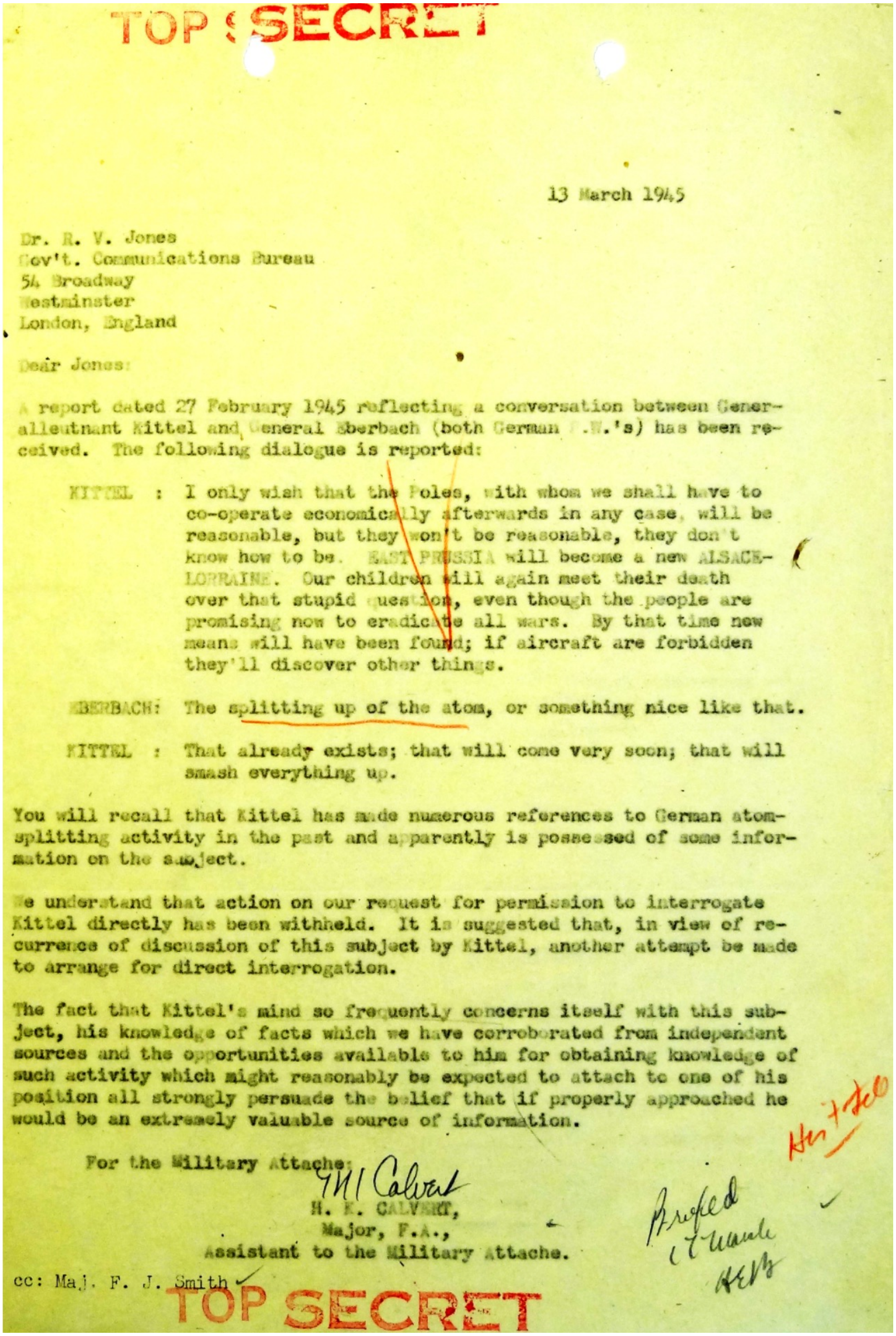


TOP SECRET

13 March 1945

Dr. R. V. Jones
Gov't. Communications Bureau
54 Broadway
Westminster
London, England

Dear Jones:

A report dated 27 February 1945 reflecting a conversation between Generalleutnant Kittel and General Eberbach (both German P.W.'s) has been received. The following dialogue is reported:

KITTEL : I only wish that the Poles, with whom we shall have to co-operate economically afterwards in any case, will be reasonable, but they won't be reasonable, they don't know how to be. EAST PRUSSIA will become a new ALSACE-LORRAINE. Our children will again meet their death over that stupid question, even though the people are promising now to eradicate all wars. By that time new means will have been found; if aircraft are forbidden they'll discover other things.

EBERBACH: The splitting up of the atom, or something nice like that.

KITTEL : That already exists; that will come very soon; that will smash everything up.

You will recall that Kittel has made numerous references to German atom-splitting activity in the past and apparently is possessed of some information on the subject.

We understand that action on our request for permission to interrogate Kittel directly has been withheld. It is suggested that, in view of recurrence of discussion of this subject by Kittel, another attempt be made to arrange for direct interrogation.

The fact that Kittel's mind so frequently concerns itself with this subject, his knowledge of facts which we have corroborated from independent sources and the opportunities available to him for obtaining knowledge of such activity which might reasonably be expected to attach to one of his position all strongly persuade the belief that if properly approached he would be an extremely valuable source of information.

[illegible]

For the Military Attache:

H K Calvert
H. K. CALVERT,
Major, F.A.,
Assistant to the Military Attache.

Briefed
C Thanle
HEB

cc: Maj. F. J. Smith

TOP SECRET

NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL

Figure D.331: Horace K. Calvert to R. V. Jones. 13 March 1945 [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

S. H. Kirkland, Jr. 31 March 1948. Memorandum for Chief, Air Intelligence Division. Subject: Daily Activity Report. [AFHRA folder 122.25 Jan–May 1948; AFHRA A1036 electronic pp. 2211–2212, frames 2238–2239]

[...]

Confirmation of Possibility of Uranium Deposits on Bornholm Island.

Uranium has been discovered on Danish owned island evacuated by the Russians two years ago. The deposit is said to be huge, with estimates running up to 500,000 tons. A Copenhagen dispatch to Svenska Dagbladet of Stockholm reports that the ore is contained in a granite outcropping running about 60 miles into the earth; the exploitable upper part alone, however, should yield 5,000 tons of uranium.

SOURCE: New York, 13 March 1948, NANA. Evaluation: B-2. CLASSIFICATION: (SECRET)

Strategic Vulnerability Branch Comment: The Strategic Vulnerability Branch has been able to uncover evidence* supporting the existence of radioactivity on the Danish island of Bornholm. The island is completely radioactive. Not only the land mass, but the surrounding sea water, atmosphere and local flora and fauna show radioactivity. The local inhabitants are large in stature, healthy and robust. Their virility extends over a period much longer than normal. There have been many cases of men 80 to 90 years old retaining their vigor.

This extraordinary radioactivity makes it highly probable that uranium exists on the island, possibly in large quantities. It has been reported that the island is rich in radium and thorium. This would indicate that a uranium deposit of 5,000 tons may actually exist on the island. Bornholm was evacuated by the Russians in 1946. It is situated within an area of Soviet pressure.

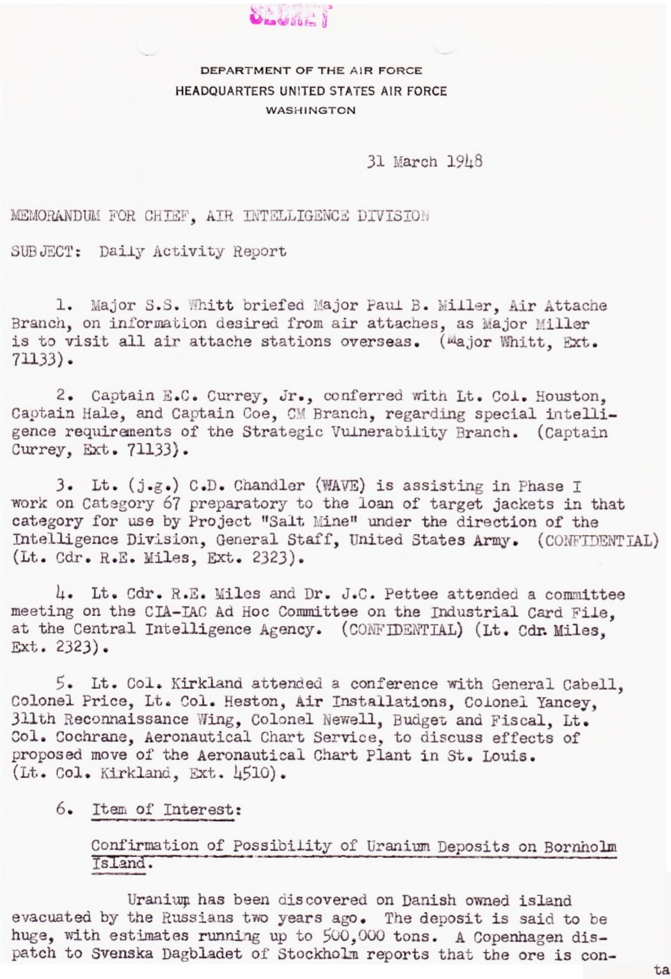
Reference: Item of Interest of 16 March 1948. *Source: Biology of Radium and Uranium published by Czech Radiological Institute, Prague 1932. (Mr. Rosenzweig, Ext. 71911).

[Just exactly what nuclear work was conducted on Bornholm by the Germans during the war, and what was removed by the Russians after the war?

Although the idea (apparently from the 1932 source) that natural radioactivity can promote health is now laughably outdated, the above document confirms that scientists knew there was significant radioactivity on Bornholm both before and after World War II. If Bornholm's radioactivity was known by scientists in Prague in 1932, that information might be one factor that attracted German interest in the island during the war. If there were uranium or thorium deposits, Germany may have mined them during the war.

If Bornholm was known to have elevated levels of radioactivity after the war, were those due to the mining of natural deposits, wartime work on enriching uranium or breeding plutonium on the island, or wartime tests of nuclear explosives on or near the island?]

AFHRA folder 122.25 Jan-May 1948



SECRET

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON

31 March 1948

MEMORANDUM FOR CHIEF, AIR INTELLIGENCE DIVISION

SUBJECT: Daily Activity Report

1. Major S.S. Whitt briefed Major Paul B. Miller, Air Attache Branch, on information desired from air attaches, as Major Miller is to visit all air attache stations overseas. (Major Whitt, Ext. 71133).

2. Captain E.C. Currey, Jr., conferred with Lt. Col. Houston, Captain Hale, and Captain Coe, CM Branch, regarding special intelligence requirements of the Strategic Vulnerability Branch. (Captain Currey, Ext. 71133).

3. Lt. (j.g.) C.D. Chandler (WAVE) is assisting in Phase I work on Category 67 preparatory to the loan of target jackets in that category for use by Project "Salt Mine" under the direction of the Intelligence Division, General Staff, United States Army. (CONFIDENTIAL) (Lt. Cdr. R.E. Miles, Ext. 2323).

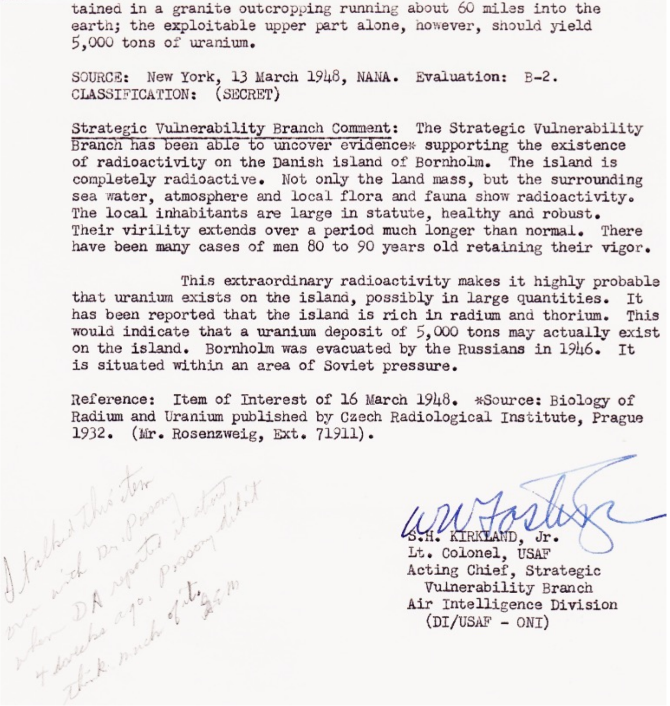
4. Lt. Cdr. R.E. Miles and Dr. J.C. Pettee attended a committee meeting on the CIA-IAC Ad Hoc Committee on the Industrial Card File, at the Central Intelligence Agency. (CONFIDENTIAL) (Lt. Cdr. Miles, Ext. 2323).

5. Lt. Col. Kirkland attended a conference with General Cabell, Colonel Price, Lt. Col. Heston, Air Installations, Colonel Yancey, 311th Reconnaissance Wing, Colonel Newell, Budget and Fiscal, Lt. Col. Cochrane, Aeronautical Chart Service, to discuss effects of proposed move of the Aeronautical Chart Plant in St. Louis. (Lt. Col. Kirkland, Ext. 4510).

6. Item of Interest:

Confirmation of Possibility of Uranium Deposits on Bornholm Island.

Uranium has been discovered on Danish owned island evacuated by the Russians two years ago. The deposit is said to be huge, with estimates running up to 500,000 tons. A Copenhagen dispatch to Svenska Dagbladet of Stockholm reports that the ore is contained in a granite outcropping running about 60 miles into the earth; the exploitable upper part alone, however, should yield 5,000 tons of uranium.



SECRET

SOURCE: New York, 13 March 1948, NANA. Evaluation: B-2.
CLASSIFICATION: (SECRET)

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Reference: Item of Interest of 16 March 1948. *Source: Biology of Radium and Uranium published by Czech Radiological Institute, Prague 1932. (Mr. Rosenzweig, Ext. 71911).

I talked this item over with Dr. Possony when DA reported it about 4 weeks ago. Possony didn't think much of it. GSM

W W Foster
S.H. KIRKLAND, Jr.
Lt. Colonel, USAF
Acting Chief, Strategic
Vulnerability Branch
Air Intelligence Division
(DI/USAF - ONI)

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Figure D.332: S. H. Kirkland, Jr. 31 March 1948. Memorandum for Chief, Air Intelligence Division. Subject: Daily Activity Report. [AFHRA folder 122.25 Jan–May 1948; AFHRA A1036 electronic pp. 2211–2212, frames 2238–2239]

D.5 Fission Reactors for Breeding Pu-239 and/or U-233

[Ludwig Bewilogua (German, 1906–1983), Kurt Diebner, Paul Harteck, Otto Haxel (German, 1909–1998), and many others worked in teams trying to develop fission reactors suitable for breeding plutonium-239 from natural uranium-238 or uranium-233 from natural thorium-232. Two reactors were on the brink of criticality by the end of the war, and there is some evidence that other reactors may have actually become operational during the war. This section covers:

D.5.1. Scientific knowledge about breeding Pu-239 and U-233.

D.5.2. Known and suspected fission reactors.

For breeding using particle accelerators (electronuclear breeding), see Section D.6.]

D.5.1 Scientific Knowledge About Breeding Pu-239 and U-233

[The following documents demonstrate the knowledge of scientists in Germany:

- By 1934, scientists knew that element 94, or plutonium-239, could be produced and purified (pp. 3794–3795).
- No later than 1940, scientists understood that plutonium-239 could be used to create a bomb (pp. 3800–3826).
- During the war, scientists also understood that uranium-233 could be produced and used to create a bomb (pp. 3832–3836).]

Ida Tacke Noddack. 1934. Über das Element 93. *Angewandte Chemie.* 47:37:653–655.

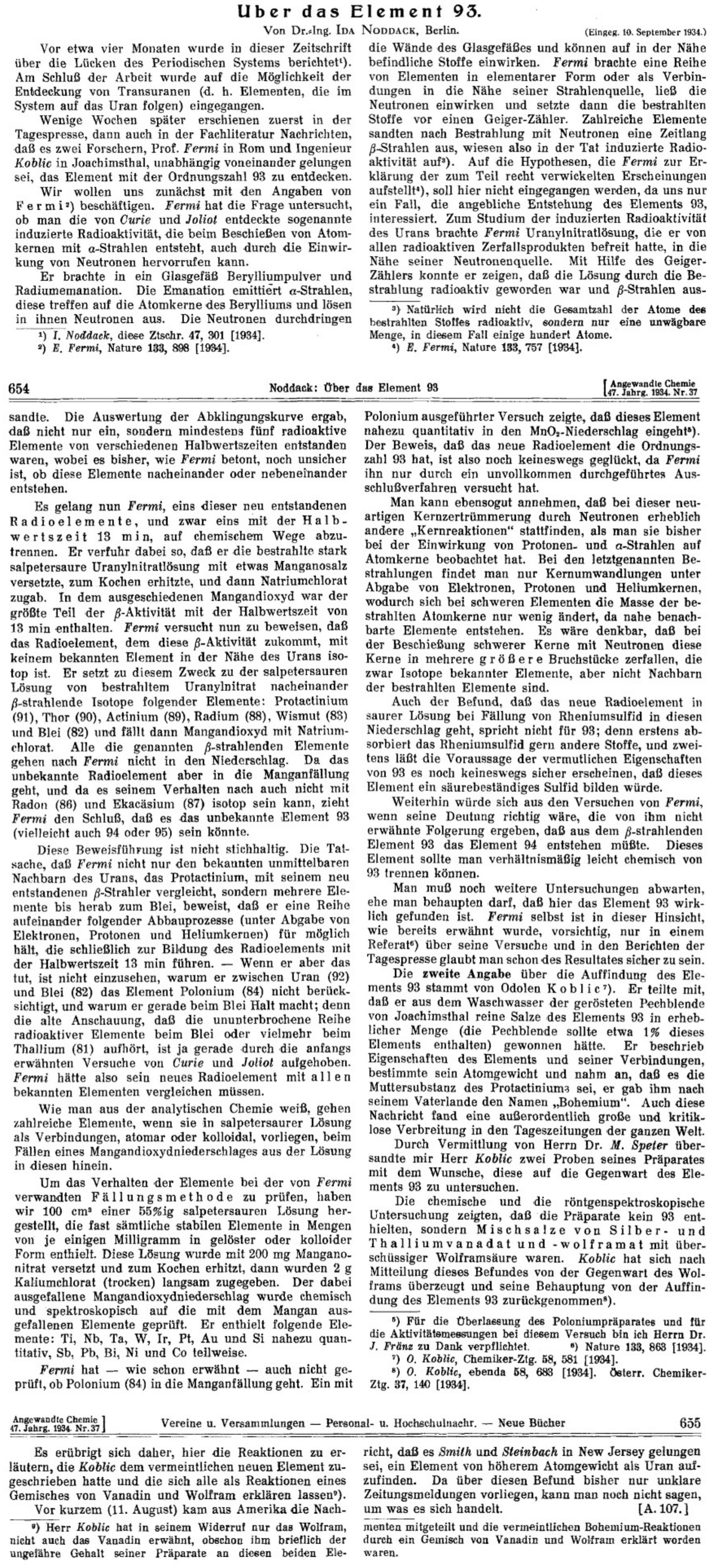
Man kann ebensogut annehmen, daß bei dieser neuartigen Kernzertrümmerung durch Neutronen erheblich andere “Kernreaktionen” stattfinden, als man sie bisher bei der Einwirkung von Protonen- und α-Strahlen auf Atomkerne beobachtet hat. Bei den letztgenannten Bestrahlungen findet man nur Kernumwandlungen unter Abgabe von Elektronen, Protonen und Heliumkernen, wodurch sich bei schweren Elementen die Masse der bestrahlten Atomkerne nur wenig ändert, da nahe benachbarte Elemente entstehen. Es wäre denkbar, daß bei der Beschießung schwerer Kerne mit Neutronen diese Kerne in mehrere größere Bruchstücke zerfallen, die zwar Isotope bekannter Elemente, aber nicht Nachbarn der bestrahlten Elemente sind.

[...*A*]us dem β-strahlenden Element 93 das Element 94 entstehen müßte. Dieses Element sollte man verhältnismäßig leicht chemisch von 93 trennen können.

One could assume equally well that when neutrons are used to produce nuclear disintegrations, some distinctly new nuclear reactions take place which have not been observed previously with proton or alpha-particle bombardment of atomic nuclei. In the past one has found that transmutations of nuclei only take place with the emission of electrons, protons, or helium nuclei, so that the heavy elements change their mass only a small amount to produce near neighboring elements. When heavy nuclei are bombarded by neutrons, it is conceivable that the nucleus breaks up into several large fragments, which would of course be isotopes of known elements but would not be neighbors of the irradiated element.

[...B]eta decay of element 93 would produce element 94. It should be relatively easy to separate this chemically from element 93.

***Angewandte Chemie* 47:37:653-655 (1934)**



Uber das Element 93.

Von Dr.-Ing. IDA NODDACK, Berlin.

(Eingeg. 10. September 1934.)

Vor etwa vier Monaten wurde in dieser Zeitschrift über die Lücken des Periodischen Systems berichtet1). Am Schluß der Arbeit wurde auf die Möglichkeit der Entdeckung von Transuranen (d. h. Elementen, die im System auf das Uran folgen) eingegangen.

Wenige Wochen später erschienen zuerst in der Tagespresse, dann auch in der Fachliteratur Nachrichten, daß es zwei Forschern, Prof. *Fermi* in Rom und Ingenieur *Koblic* in Joachimsthal, unabhängig voneinander gelungen sei, das Element mit der Ordnungszahl 93 zu entdecken.

Wir wollen uns zunächst mit den Angaben von Fermi2) beschäftigen. *Fermi* hat die Frage untersucht, ob man die von *Curie* und *Joliot* entdeckte sogenannte induzierte Radioaktivität, die beim Beschießen von Atomkernen mit α-Strahlen entsteht, auch durch die Einwirkung von Neutronen hervorrufen kann.

Er brachte in ein Glasgefäß Berylliumpulver und Radiumemanation. Die Emanation emittiert α-Strahlen, diese treffen auf die Atomkerne des Berylliums und lösen in ihnen Neutronen aus. Die Neutronen durchdringen die Wände des Glasgefäßes und können auf in der Nähe befindliche Stoffe einwirken. *Fermi* brachte eine Reihe von Elementen in elementarer Form oder als Verbindungen in die Nähe seiner Strahlenquelle, ließ die Neutronen einwirken und setzte dann die bestrahlten Stoffe vor einen Geiger-Zähler. Zahlreiche Elemente sandten nach Bestrahlung mit Neutronen eine Zeitlang β-Strahlen aus, wiesen also in der Tat induzierte Radioaktivität auf3). Auf die Hypothesen, die *Fermi* zur Erklärung der zum Teil recht verwickelten Erscheinungen aufstellt4), soll hier nicht eingegangen werden, da uns nur ein Fall, die angebliche Entstehung des Elements 93, interessiert. Zum Studium der induzierten Radioaktivität des Urans brachte *Fermi* Uranylnitratlösung, die er von allen radioaktiven Zerfallsprodukten befreit hatte, in die Nähe seiner Neutronenquelle. Mit Hilfe des Geiger-Zählers konnte er zeigen, daß die Lösung durch die Bestrahlung radioaktiv geworden war und β-Strahlen aussandte. Die Auswertung der Abklingungskurve ergab, daß nicht nur ein, sondern mindestens fünf radioaktive Elemente von verschiedenen Halbwertszeiten entstanden waren, wobei es bisher, wie *Fermi* betont, noch unsicher ist, ob diese Elemente nacheinander oder nebeneinander entstehen.

---

1) *I. Noddack*, diese Ztschr. **47**, 301 [1934].

2) *E. Fermi*, Nature **133**, 898 [1934].

3) Natürlich wird nicht die Gesamtzahl der Atome des bestrahlten Stoffes radioaktiv, *sondern* nur eine unwägbare Menge, in diesem Fall einige hundert Atome.

4) *E. Fermi*, Nature **133**, 757 [1934].

Es gelang nun *Fermi*, eins dieser neu entstandenen Radioelemente, und zwar eins mit der Halbwertszeit 13 min, auf chemischem Wege abzutrennen. Er verfuhr dabei so, daß er die bestrahlte stark salpetersaure Uranylnitratlösung mit etwas Manganosalz versetzte, zum Kochen erhitzte, und dann Natriumchlorat zugab. In dem ausgeschiedenen Mangandioxyd war der größte Teil der β-Aktivität mit der Halbwertszeit von 13 min enthalten. *Fermi* versucht nun zu beweisen, daß das Radioelement, dem diese β-Aktivität zukommt, mit keinem bekannten Element in der Nähe des Urans isotop ist. Er setzt zu diesem Zweck zu der salpetersauren Lösung von bestrahltem Uranylnitrat nacheinander β-strahlende Isotope folgender Elemente: Protactinium (91), Thor (90), Actinium (89), Radium (88), Wismut (83) und Blei (82) und fällt dann Mangandioxyd mit Natriumchlorat. Alle die genannten β-strahlenden Elemente gehen nach *Fermi* nicht in den Niederschlag. Da das unbekannte Radioelement aber in die Manganfällung geht, und da es seinem Verhalten nach auch nicht mit Radon (86) und Ekacäsium (87) isotop sein kann, zieht *Fermi* den Schluß, daß es das unbekannte Element 93 (vielleicht auch 94 oder 95) sein könnte.

Diese Beweisführung ist nicht stichhaltig. Die Tatsache, daß *Fermi* nicht nur den bekannten unmittelbaren Nachbarn des Urans, das Protactinium, mit seinem neu entstandenen β-Strahler vergleicht, sondern mehrere Elemente bis herab zum Blei, beweist, daß er eine Reihe aufeinander folgender Abbauprozesse (unter Abgabe von Elektronen, Protonen und Heliumkernen) für möglich hält, die schließlich zur Bildung des Radioelements mit der Halbwertszeit 13 min führen. — Wenn er aber das tut, ist nicht einzusehen, warum er zwischen Uran (92) und Blei (82) das Element Polonium (84) nicht berücksichtigt, und warum er gerade beim Blei Halt macht; denn die alte Anschauung, daß die ununterbrochene Reihe radioaktiver Elemente beim Blei oder vielmehr beim Thallium (81) aufhört, ist ja gerade durch die anfangs erwähnten Versuche von *Curie* und *Joliot* aufgehoben. *Fermi* hätte also sein neues Radioelement mit allen bekannten Elementen vergleichen müssen.

Wie man aus der analytischen Chemie weiß, gehen zahlreiche Elemente, wenn sie in salpetersaurer Lösung als Verbindungen, atomar oder kolloidal, vorliegen, beim Fällen eines Mangandioxydniederschlages aus der Lösung in diesen hinein.

Um das Verhalten der Elemente bei der von *Fermi* verwandten Fällungsmethode zu prüfen, haben wir 100 cm^3 einer 55%ig salpetersauren Lösung hergestellt, die fast sämtliche stabilen Elemente in Mengen von je einigen Milligramm in gelöster oder kolloider Form enthielt. Diese Lösung wurde mit 200 mg Manganonitrat versetzt und zum Kochen erhitzt, dann wurden 2 g Kaliumchlorat (trocken) langsam zugegeben. Der dabei ausgefallene Mangandioxydniederschlag wurde chemisch und spektroskopisch auf die mit dem Mangan ausgefallenen Elemente geprüft. Er enthielt folgende Elemente: Ti, Nb, Ta, W, Ir, Pt, Au und Si nahezu quantitativ, Sb, Pb, Bi, Ni und Co teilweise.

Fermi hat — wie schon erwähnt — auch nicht geprüft, ob Polonium (84) in die Manganfällung geht. Ein mit Polonium ausgeführter Versuch zeigte, daß dieses Element nahezu quantitativ in den MnO_2-Niederschlag eingeht5). Der Beweis, daß das neue Radioelement die Ordnungszahl 93 hat, ist also noch keineswegs geglückt, da *Fermi* ihn nur durch ein unvollkommen durchgeführtes Ausschlußverfahren versucht hat.

Man kann ebensogut annehmen, daß bei dieser neuartigen Kernzertrümmerung durch Neutronen erheblich andere „Kernreaktionen" stattfinden, als man sie bisher bei der Einwirkung von Protonen- und α-Strahlen auf Atomkerne beobachtet hat. Bei den letztgenannten Bestrahlungen findet man nur Kernumwandlungen unter Abgabe von Elektronen, Protonen und Heliumkernen, wodurch sich bei schweren Elementen die Masse der bestrahlten Atomkerne nur wenig ändert, da nahe benachbarte Elemente entstehen. Es wäre denkbar, daß bei der Beschießung schwerer Kerne mit Neutronen diese Kerne in mehrere größere Bruchstücke zerfallen, die zwar Isotope bekannter Elemente, aber nicht Nachbarn der bestrahlten Elemente sind.

Auch der Befund, daß das neue Radioelement in saurer Lösung bei Fällung von Rheniumsulfid in diesen Niederschlag geht, spricht nicht für 93; denn erstens absorbiert das Rheniumsulfid gern andere Stoffe, und zweitens läßt die Voraussage der vermutlichen Eigenschaften von 93 es noch keineswegs sicher erscheinen, daß dieses Element ein säurebeständiges Sulfid bilden würde.

Weiterhin würde sich aus den Versuchen von *Fermi*, wenn seine Deutung richtig wäre, die von ihm nicht erwähnte Folgerung ergeben, daß aus dem β-strahlenden Element 93 das Element 94 entstehen müßte. Dieses Element sollte man verhältnismäßig leicht chemisch von 93 trennen können.

Man muß noch weitere Untersuchungen abwarten, ehe man behaupten darf, daß hier das Element 93 wirklich gefunden ist. *Fermi* selbst ist in dieser Hinsicht, wie bereits erwähnt wurde, vorsichtig, nur in einem Referat6) über seine Versuche und in den Berichten der Tagespresse glaubt man schon des Resultates sicher zu sein.

Die **zweite Angabe** über die Auffindung des Elements 93 stammt von Odolen Koblic7). Er teilte mit, daß er aus dem Waschwasser der gerösteten Pechblende von Joachimsthal reine Salze des Elements 93 in erheblicher Menge (die Pechblende sollte etwa 1% dieses Elements enthalten) gewonnen hätte. Er beschrieb Eigenschaften des Elements und seiner Verbindungen, bestimmte sein Atomgewicht und nahm an, daß es die Muttersubstanz des Protactiniums sei, er gab ihm nach seinem Vaterlande den Namen „Bohemium". Auch diese Nachricht fand eine außerordentlich große und kritiklose Verbreitung in den Tageszeitungen der ganzen Welt.

Durch Vermittlung von Herrn Dr. *M. Speter* übersandte mir Herr *Koblic* zwei Proben seines Präparates mit dem Wunsche, diese auf die Gegenwart des Elements 93 zu untersuchen.

Die chemische und die röntgenspektroskopische Untersuchung zeigten, daß die Präparate kein 93 enthielten, sondern Mischsalze von Silber- und Thalliumvanadat und -wolframat mit überschüssiger Wolframsäure waren. *Koblic* hat sich nach Mitteilung dieses Befundes von der Gegenwart des Wolframs überzeugt und seine Behauptung von der Auffindung des Elements 93 zurückgenommen8).

---

5) Für die Überlassung des Poloniumpräparates und für die Aktivitätsmessungen bei diesem Versuch bin ich Herrn Dr. *J. Fränz* zu Dank verpflichtet.

6) Nature **133**, 863 [1934].

7) *O. Koblic*, Chemiker-Ztg. **58**, 581 [1934].

8) *O. Koblic*, ebenda **58**, 683 [1934]. Österr. Chemiker-Ztg. **37**, 140 [1934].

Es erübrigt sich daher, hier die Reaktionen zu erläutern, die *Koblic* dem vermeintlichen neuen Element zugeschrieben hatte und die sich alle als Reaktionen eines Gemisches von Vanadin und Wolfram erklären lassen9).

Vor kurzem (11. August) kam aus Amerika die Nachricht, daß es *Smith* und *Steinbach* in New Jersey gelungen sei, ein Element von höherem Atomgewicht als Uran aufzufinden. Da über diesen Befund bisher nur unklare Zeitungsmeldungen vorliegen, kann man noch nicht sagen, um was es sich handelt. [A. 107.]

---

9) Herr *Koblic* hat in seinem Widerruf nur das Wolfram, nicht auch das Vanadin erwähnt, obschon ihm brieflich der ungefähre Gehalt seiner Präparate an diesen beiden Elementen mitgeteilt und die vermeintlichen Bohemium-Reaktionen durch ein Gemisch von Vanadin und Wolfram erklärt worden waren.

Figure D.333: Ida Tacke Noddack. 1934. Über das Element 93. *Angewandte Chemie.* 47:37:653–655.

Bundesarchiv Berlin-Lichterfelde R 43-II/342

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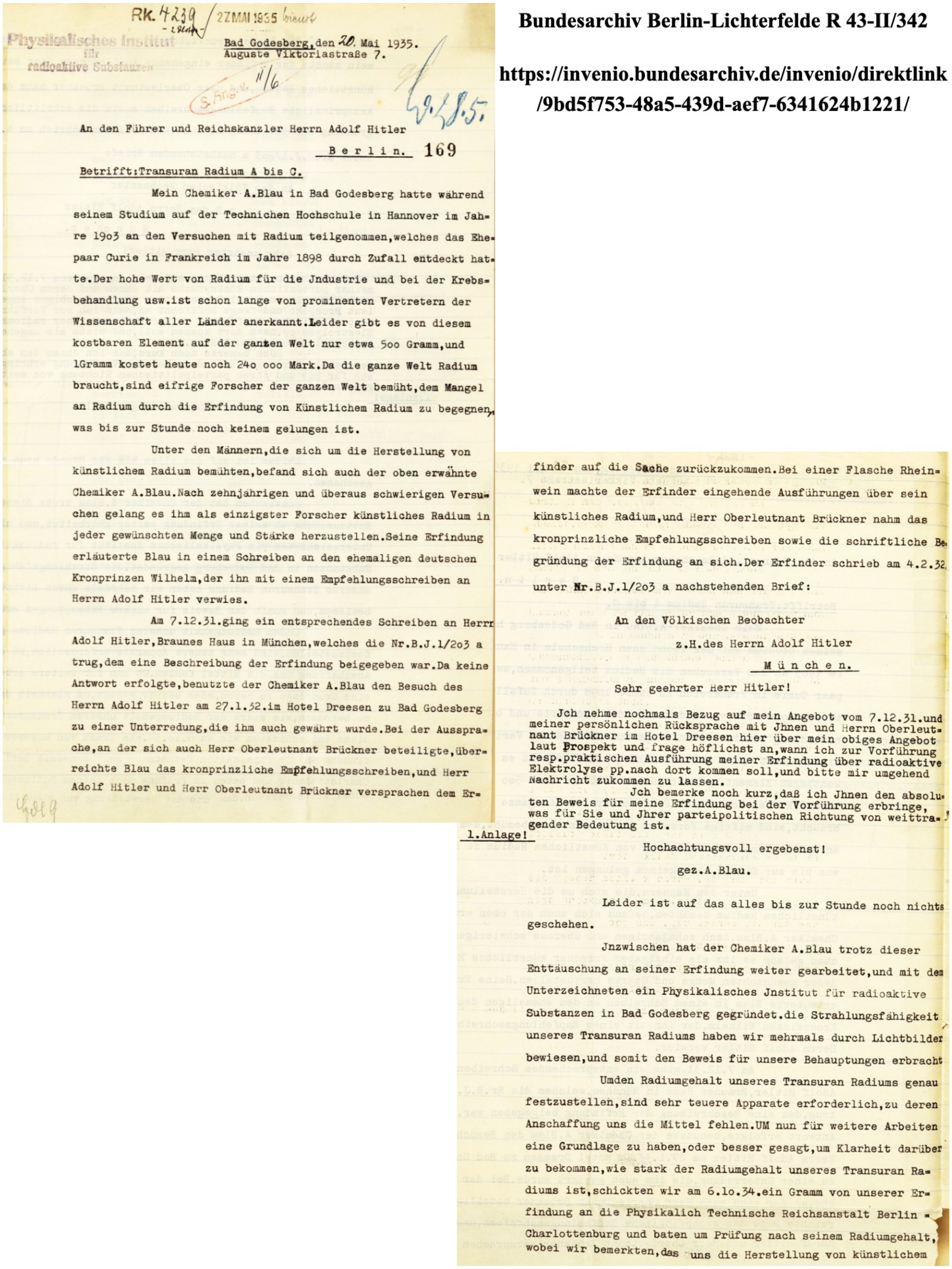


RK. 4239 / 27 MAI 1935

Physikalisches Institut
für
radioaktive Substanzen

Bad Godesberg, den 20. Mai 1935.
Auguste Viktoriastraße 7.

S. Ang. v. 11/6

9/28.5.

An den Führer und Reichskanzler Herrn Adolf Hitler
Berlin. 169

Betrifft: Transuran Radium A bis C.

Mein Chemiker A.Blau in Bad Godesberg hatte während seinem Studium auf der Technichen Hochschule in Hannover im Jahre 1903 an den Versuchen mit Radium teilgenommen, welches das Ehepaar Curie in Frankreich im Jahre 1898 durch Zufall entdeckt hatte. Der hohe Wert von Radium für die Jndustrie und bei der Krebsbehandlung usw. ist schon lange von prominenten Vertretern der Wissenschaft aller Länder anerkannt. Leider gibt es von diesem kostbaren Element auf der ganzen Welt nur etwa 500 Gramm, und 1Gramm kostet heute noch 240 000 Mark. Da die ganze Welt Radium braucht, sind eifrige Forscher der ganzen Welt bemüht, dem Mangel an Radium durch die Erfindung von Künstlichem Radium zu begegnen, was bis zur Stunde noch keinem gelungen ist.

Unter den Männern, die sich um die Herstellung von künstlichem Radium bemühten, befand sich auch der oben erwähnte Chemiker A.Blau. Nach zehnjährigen und überaus schwierigen Versuchen gelang es ihm als einzigster Forscher künstliches Radium in jeder gewünschten Menge und Stärke herzustellen. Seine Erfindung erläuterte Blau in einem Schreiben an den ehemaligen deutschen Kronprinzen Wilhelm, der ihn mit einem Empfehlungsschreiben an Herrn Adolf Hitler verwies.

Am 7.12.31. ging ein entsprechendes Schreiben an Herrn Adolf Hitler, Braunes Haus in München, welches die Nr.B.J.1/203 a trug, dem eine Beschreibung der Erfindung beigegeben war. Da keine Antwort erfolgte, benutzte der Chemiker A.Blau den Besuch des Herrn Adolf Hitler am 27.1.32. im Hotel Dreesen zu Bad Godesberg zu einer Unterredung, die ihm auch gewährt wurde. Bei der Aussprache, an der sich auch Herr Oberleutnant Brückner beteiligte, überreichte Blau das kronprinzliche Empfehlungsschreiben, und Herr Adolf Hitler und Herr Oberleutnant Brückner versprachen dem Erfinder auf die Sache zurückzukommen. Bei einer Flasche Rheinwein machte der Erfinder eingehende Ausführungen über sein künstliches Radium, und Herr Oberleutnant Brückner nahm das kronprinzliche Empfehlungsschreiben sowie die schriftliche Begründung der Erfindung an sich. Der Erfinder schrieb am 4.2.32. unter Nr.B.J.1/203 a nachstehenden Brief:

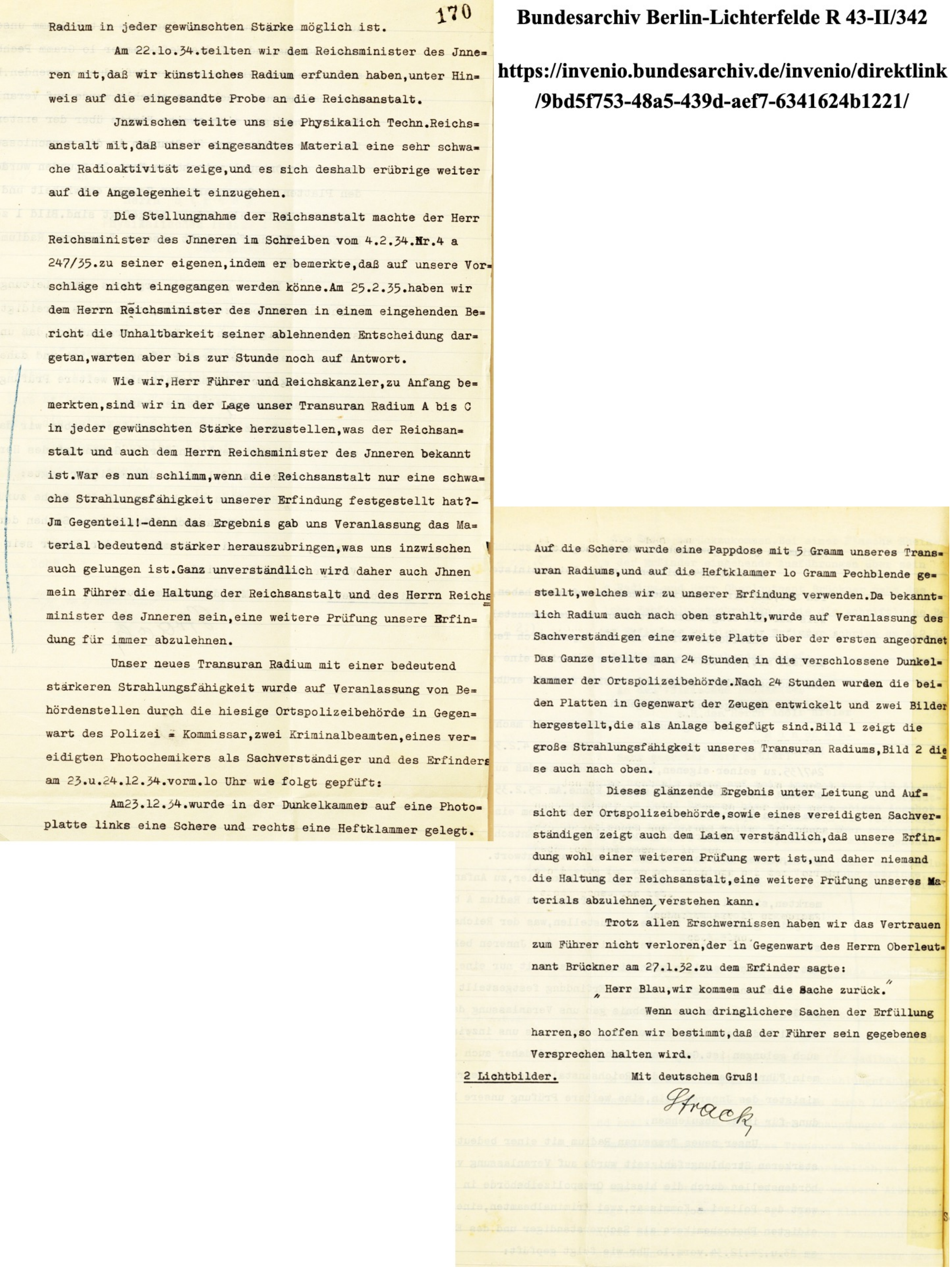
> An den Völkischen Beobachter
> z.H. des Herrn Adolf Hitler
> München.
>
> Sehr geehrter Herr Hitler!
>
> Jch nehme nochmals Bezug auf mein Angebot vom 7.12.31. und meiner persönlichen Rücksprache mit Jhnen und Herrn Oberleutnant Brückner im Hotel Dreesen hier über mein obiges Angebot laut Prospekt und frage höflichst an, wann ich zur Vorführung resp. praktischen Ausführung meiner Erfindung über radioaktive Elektrolyse pp. nach dort kommen soll, und bitte mir umgehend Nachricht zukommen zu lassen.
>
> Jch bemerke noch kurz, daß ich Jhnen den absoluten Beweis für meine Erfindung bei der Vorführung erbringe, was für Sie und Jhrer parteipolitischen Richtung von weittragender Bedeutung ist.
>
> 1. Anlage!
>
> Hochachtungsvoll ergebenst!
>
> gez. A.Blau.

Leider ist auf das alles bis zur Stunde noch nichts geschehen.

Jnzwischen hat der Chemiker A.Blau trotz dieser Enttäuschung an seiner Erfindung weiter gearbeitet, und mit dem Unterzeichneten ein Physikalisches Jnstitut für radioaktive Substanzen in Bad Godesberg gegründet. die Strahlungsfähigkeit unseres Transuran Radiums haben wir mehrmals durch Lichtbilder bewiesen, und somit den Beweis für unsere Behauptungen erbracht

Umden Radiumgehalt unseres Transuran Radiums genau festzustellen, sind sehr teuere Apparate erforderlich, zu deren Anschaffung uns die Mittel fehlen. UM nun für weitere Arbeiten eine Grundlage zu haben, oder besser gesagt, um Klarheit darüber zu bekommen, wie stark der Radiumgehalt unseres Transuran Radiums ist, schickten wir am 6.10.34. ein Gramm von unserer Erfindung an die Physikalich Technische Reichsanstalt Berlin - Charlottenburg und baten um Prüfung nach seinem Radiumgehalt, wobei wir bemerkten, das uns die Herstellung von künstlichem

Figure D.334: 20 May 1935 proposal to Adolf Hitler to artificially create radioactive elements beyond uranium for applications of national importance [Bundesarchive Berlin-Lichterfelde R 43-II/342 https://invenio.bundesarchiv.de/invenio/direktlink/9bd5f753-48a5-439d-aef7-6341624b1221/]. Although the scientific details and merits of this particular proposal are unclear, at the very least it demonstrates very early German interest in creating and harnessing transuranic elements.



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Radium in jeder gewünschten Stärke möglich ist.

Am 22.10.34.teilten wir dem Reichsminister des Jnneren mit,daß wir künstliches Radium erfunden haben,unter Hinweis auf die eingesandte Probe an die Reichsanstalt.

Jnzwischen teilte uns sie Physikalich Techn.Reichsanstalt mit,daß unser eingesandtes Material eine sehr schwache Radioaktivität zeige,und es sich deshalb erübrige weiter auf die Angelegenheit einzugehen.

Die Stellungnahme der Reichsanstalt machte der Herr Reichsminister des Jnneren im Schreiben vom 4.2.34.Nr.4 a 247/35.zu seiner eigenen,indem er bemerkte,daß auf unsere Vorschläge nicht eingegangen werden könne.Am 25.2.35.haben wir dem Herrn Reichsminister des Jnneren in einem eingehenden Bericht die Unhaltbarkeit seiner ablehnenden Entscheidung dargetan,warten aber bis zur Stunde noch auf Antwort.

Wie wir,Herr Führer und Reichskanzler,zu Anfang bemerkten,sind wir in der Lage unser Transuran Radium A bis C in jeder gewünschten Stärke herzustellen,was der Reichsanstalt und auch dem Herrn Reichsminister des Jnneren bekannt ist.War es nun schlimm,wenn die Reichsanstalt nur eine schwache Strahlungsfähigkeit unserer Erfindung festgestellt hat?-Jm Gegenteil!-denn das Ergebnis gab uns Veranlassung das Material bedeutend stärker herauszubringen,was uns inzwischen auch gelungen ist.Ganz unverständlich wird daher auch Jhnen mein Führer die Haltung der Reichsanstalt und des Herrn Reichsminister des Jnneren sein,eine weitere Prüfung unsere Erfindung für immer abzulehnen.

Unser neues Transuran Radium mit einer bedeutend stärkeren Strahlungsfähigkeit wurde auf Veranlassung von Behördenstellen durch die hiesige Ortspolizeibehörde in Gegenwart des Polizei = Kommissar,zwei Kriminalbeamten,eines vereidigten Photochemikers als Sachverständiger und des Erfinders am 23.u.24.12.34.vorm.10 Uhr wie folgt gepfüft:

Am23.12.34.wurde in der Dunkelkammer auf eine Photoplatte links eine Schere und rechts eine Heftklammer gelegt. Auf die Schere wurde eine Pappdose mit 5 Gramm unseres Transuran Radiums,und auf die Heftklammer 10 Gramm Pechblende gestellt,welches wir zu unserer Erfindung verwenden.Da bekanntlich Radium auch nach oben strahlt,wurde auf Veranlassung des Sachverständigen eine zweite Platte über der ersten angeordnet Das Ganze stellte man 24 Stunden in die verschlossene Dunkelkammer der Ortspolizeibehörde.Nach 24 Stunden wurden die beiden Platten in Gegenwart der Zeugen entwickelt und zwei Bilder hergestellt,die als Anlage beigefügt sind.Bild 1 zeigt die große Strahlungsfähigkeit unseres Transuran Radiums,Bild 2 die se auch nach oben.

Dieses glänzende Ergebnis unter Leitung und Aufsicht der Ortspolizeibehörde,sowie eines vereidigten Sachverständigen zeigt auch dem Laien verständlich,daß unsere Erfindung wohl einer weiteren Prüfung wert ist,und daher niemand die Haltung der Reichsanstalt,eine weitere Prüfung unseres Materials abzulehnen, verstehen kann.

Trotz allen Erschwernissen haben wir das Vertrauen zum Führer nicht verloren,der in Gegenwart des Herrn Oberleutnant Brückner am 27.1.32.zu dem Erfinder sagte:

„Herr Blau,wir kommem auf die Sache zurück."

Wenn auch dringlichere Sachen der Erfüllung harren,so hoffen wir bestimmt,daß der Führer sein gegebenes Versprechen halten wird.

2 Lichtbilder. Mit deutschem Gruß!

Strack

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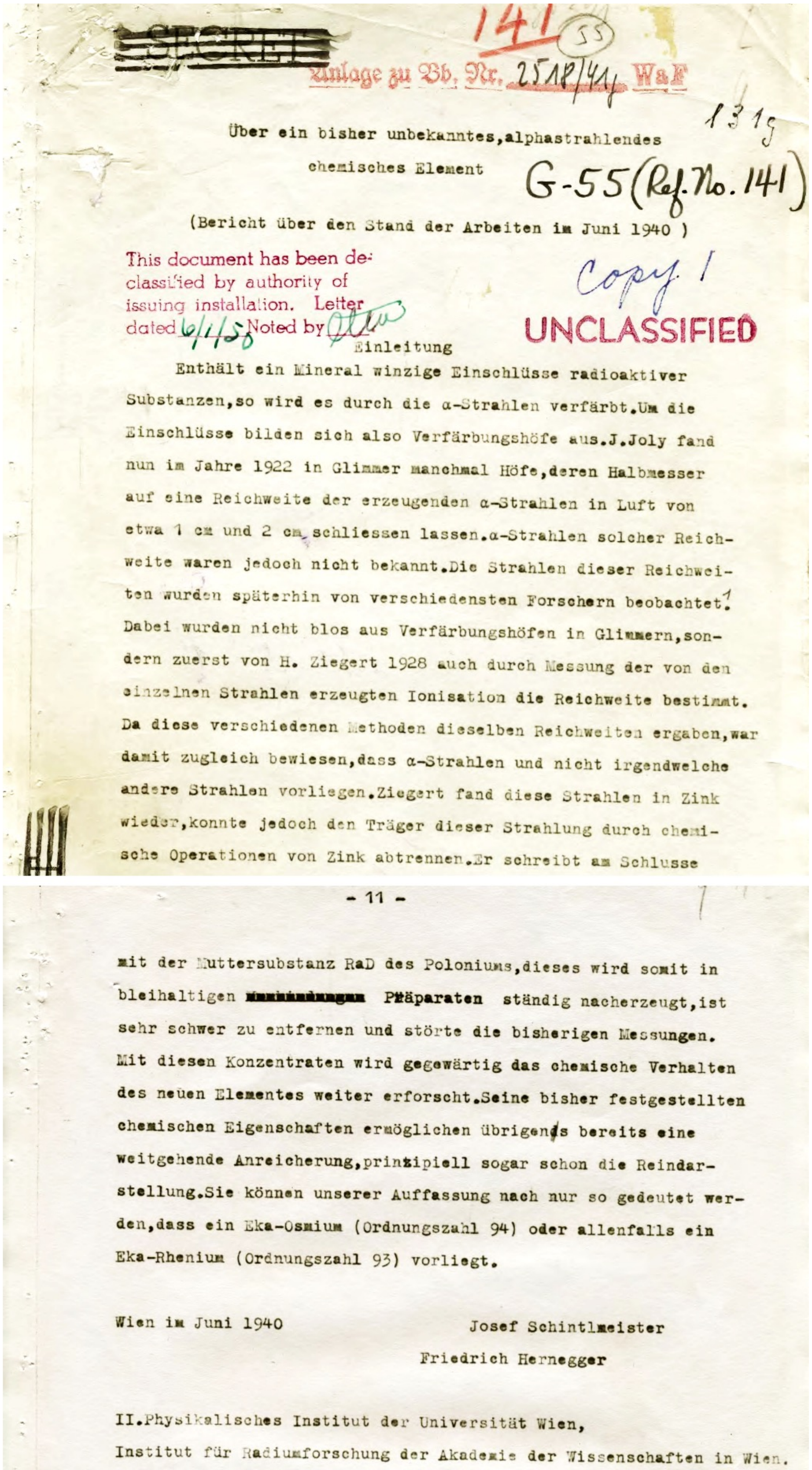
Figure D.335: 20 May 1935 proposal to Adolf Hitler to artificially create radioactive elements beyond uranium for applications of national importance [Bundesarchive Berlin-Lichterfelde R 43-II/342 https://invenio.bundesarchiv.de/invenio/direktlink/9bd5f753-48a5-439d-aef7-6341624b1221/]. Although the scientific details and merits of this particular proposal are unclear, at the very least it demonstrates very early German interest in creating and harnessing transuranic elements.

G-55. Josef Schintlmeister and Friedrich Hernegger. Über ein bisher unbekanntes alphastrahlendes chemisches Element. June 1940.

Mit diesen Konzentraten wird gegenwärtig das chemische Verhalten des neuen Elementes weiter erforscht. Seine bisher festgestellten chemischen Eigenschaften ermöglichen übrigens bereits eine weitgehende Anreicherung, prinzipiell sogar schon die Reindarstellung. Sie können unserer Auffassung nach nur so gedeutet werden, dass ein Eka-Osmium (Ordnungszahl 94) oder allenfalls ein Eka-Rhenium (Ordnungszahl 93) vorliegt.

With these concentrates, the chemical behavior of the new element is currently being researched further. Incidentally, its chemical properties that have hitherto been determined already make it possible to enrich it extensively, and in principle, even to purify it. In our opinion, they can only be interpreted as having an eka-osmium (element 94) or at least an eka-rhenium (element 93) present.

G-55. Josef Schintlmeister and Friedrich Hernegger. June 1940.
Über ein bisher unbekanntes alphastrahlendes chemisches Element.



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141 (55)

Anlage zu Bb. Nr. 2518/41 WaF

1315

Über ein bisher unbekanntes,alphastrahlendes
chemisches Element

G-55 (Ref. No. 141)

(Bericht über den Stand der Arbeiten im Juni 1940)

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Einleitung

Enthält ein Mineral winzige Einschlüsse radioaktiver Substanzen,so wird es durch die α-Strahlen verfärbt.Um die Einschlüsse bilden sich also Verfärbungshöfe aus.J.Joly fand nun im Jahre 1922 in Glimmer manchmal Höfe,deren Halbmesser auf eine Reichweite der erzeugenden α-Strahlen in Luft von etwa 1 cm und 2 cm schliessen lassen.α-Strahlen solcher Reichweite waren jedoch nicht bekannt.Die Strahlen dieser Reichweiten wurden späterhin von verschiedensten Forschern beobachtet.[1] Dabei wurden nicht blos aus Verfärbungshöfen in Glimmern,sondern zuerst von H. Ziegert 1928 auch durch Messung der von den einzelnen Strahlen erzeugten Ionisation die Reichweite bestimmt. Da diese verschiedenen Methoden dieselben Reichweiten ergaben,war damit zugleich bewiesen,dass α-Strahlen und nicht irgendwelche andere Strahlen vorliegen.Ziegert fand diese Strahlen in Zink wieder,konnte jedoch den Träger dieser Strahlung durch chemische Operationen von Zink abtrennen.Er schreibt am Schlusse

- 11 -

mit der Muttersubstanz RaD des Poloniums,dieses wird somit in bleihaltigen ~~[illegible]~~ Präparaten ständig nacherzeugt,ist sehr schwer zu entfernen und störte die bisherigen Messungen. Mit diesen Konzentraten wird gegewärtig das chemische Verhalten des neuen Elementes weiter erforscht.Seine bisher festgestellten chemischen Eigenschaften ermöglichen übrigen~~d~~s bereits eine weitgehende Anreicherung,prinzipiell sogar schon die Reindarstellung.Sie können unserer Auffassung nach nur so gedeutet werden,dass ein Eka-Osmium (Ordnungszahl 94) oder allenfalls ein Eka-Rhenium (Ordnungszahl 93) vorliegt.

Wien im Juni 1940

Josef Schintlmeister
Friedrich Hernegger

II.Physikalisches Institut der Universität Wien,
Institut für Radiumforschung der Akademie der Wissenschaften in Wien.

Figure D.336: G-55. Josef Schintlmeister and Friedrich Hernegger. June 1940. Über ein bisher unbekanntes alphastrahlendes chemisches Element.

G-59. Carl Friedrich von Weizsäcker. The Possibility of Obtaining Energy from U^{238}. 17 July 1940.

[See document photos on pp. 3802–3807.]

[...] ^{238}U durch thermische Neutronen [...] Das erste Neutron erzeugt das Isotop ^{239}U, das nach Hahn in 23 Minuten zerfällt. Dabei muss ^{239}Eka-Re entstehen. Im folgenden wird die Wahrscheinlichkeit der Entstehung und der Spaltbarkeit dieses Kerne geprüft. [...]

Dieses Eka-Re kann dann in dreifacher Weise verwendet werden:

1. zum Bau sehr kleiner Maschinen

2. als Sprengstoff

3. durch Beimischung zur Umwandlung anderer Elemente in grossen Mengen.

[...] ^{238}U by thermal neutrons [...] The first neutron produces the isotope ^{239}U, which according to Hahn decays in 23 minutes. That must produce ^{239}Eka-Re [a new element]. In the following, the probability of the creation and the fissionability of these nuclei is examined. [...]

This Eka-Re can then be used in three ways:

1. to build very small reactors

2. as an explosive

3. by mixture for the conversion of other elements in large quantities.

Carl Friedrich von Weizsäcker. 11 June 1941. Energieerzeugung aus dem Uranisotop der Masse 238 und anderen schweren Elementen (Herstellung und Verwendung des Elements 94). [AMPG 7314, KWIP 7, Folder 4 Pu; see also Karlsch 2005, pp. 320–324]

[See document photos on pp. 3808–3813.]

Patentansprüche.

1. Verfahren zur Energieerzeugung aus ^{238}U, dadurch gekennzeichnet, daß ^{238}U mit zwei thermischen Neutronen beschossen wird, wodurch zunächst über β-Zerfälle ein Element 94 der Masse 239 entsteht, das durch das zweite Neutron eine Kernspaltung erfährt, bei der sowohl eine ungeheure Energie abgegeben wird, als auch neue Neutronen und Kerne entstehen.

2. Verfahren zur Energiegewinnung aus ^{238}U nach Anspruch 1, dadurch gekennzeichnet, daß die zur Umwandlung größerer Mengen des ^{238}U in Element 94 notwendigen Neutronen in einer "Uranmaschine" erzeugt werden.

Patent claims.

1. Method for the production of energy from ^{238}U, characterized in that ^{238}U is bombarded with two thermal neutrons, whereby after beta decays forms an element 94 with mass 239, which by the second neutron experiences a nuclear fission, in which both a tremendous energy is released, as well as new neutrons and nuclei arise.

2. The method for generating energy from ^{238}U according to claim 1, characterized in that the neutrons necessary to convert large quantities of the ^{238}U into element 94 are generated in a "uranium machine."

3. Verfahren zur Energieerzeugung aus ^{238}U bzw. Element 94 nach Anspruch 1, dadurch gekennzeichnet, daß das durch Neutronenanlagerung erzeugte Element 94 durch bekannte chemische Verfahren von dem verbleibenden Uran abgetrennt wird und dann in reiner bzw. geeignet wählbarer Konzentration verwendbar vorliegt.

4. Verfahren zur Energieerzeugung und Neutronenproduktion aus schwer spaltbaren schweren Kernen (z.B. ^{238}U, Thorium, Blei, Bismut etc.), dadurch gekennzeichnet, daß das nach Anspruch 3 erhaltene Element 94 diesen Elementen in geeigneter Menge zugesetzt wird, so daß sie einen autokatalytischen Spaltprozess durch Neutronen durchmachen können, bei dem Energie erzeugt wird und neue Atomkerne entstehen.

5. Verfahren zur explosiven Erzeugung von Energie und Neutronen aus der Spaltung des Elements 94, dadurch gekennzeichnet, daß das nach Anspruch 3 hergestellte Element 94 in solcher Menge an einen Ort gebracht wird, z.B. in eine Bombe, daß die bei einer Spaltung entstehenden Neutronen in der überwiegenden Mehrzahl zur Anregung neuer Spaltungen verbraucht werden und nicht die Substanz verlassen.

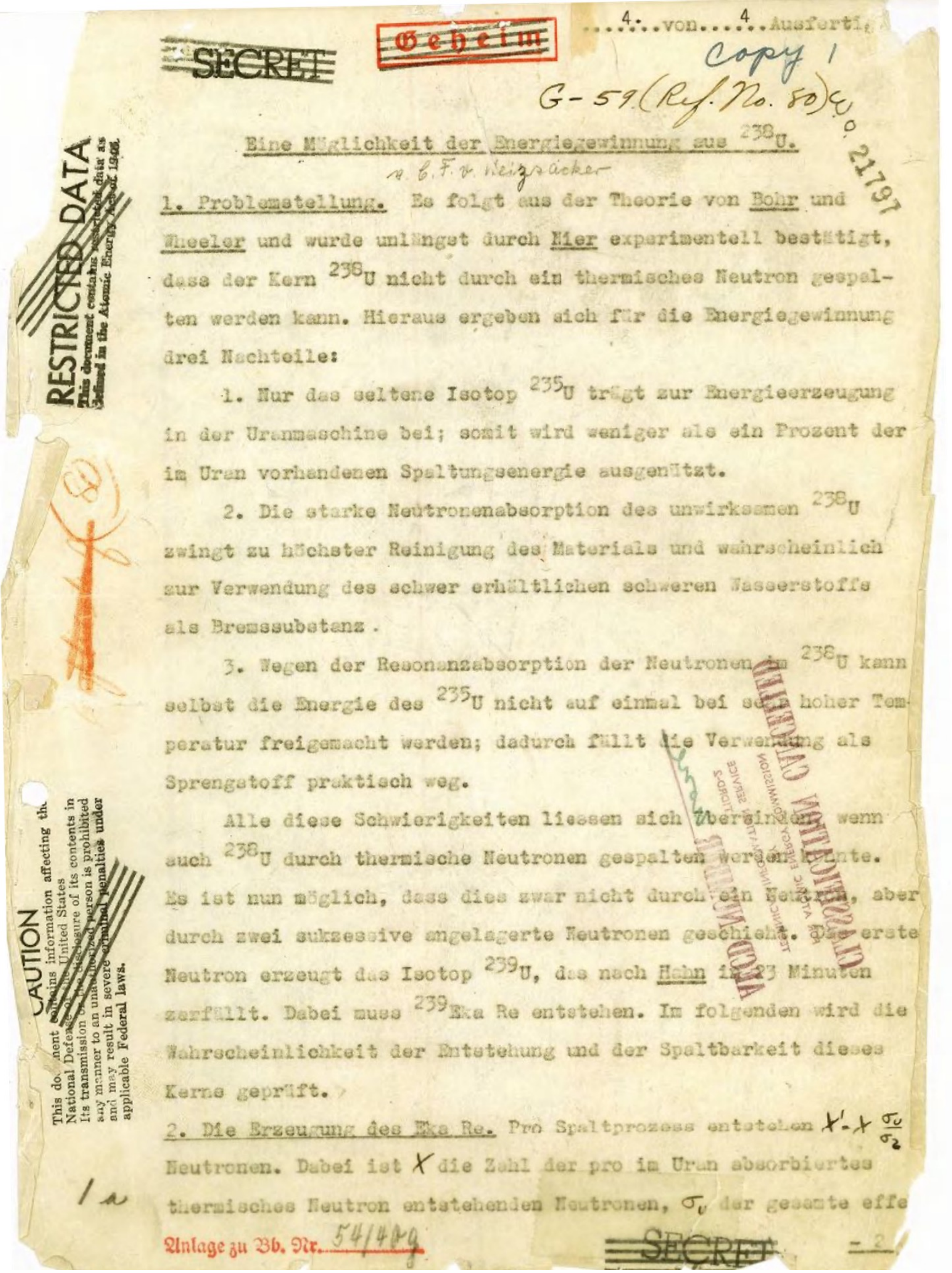
6. Verfahren zur Erzeugung sehr kleiner handlicher Maschinen zur Gewinnung von Kernenergie und von Neutronen, z.T. nach Anspruch 3 and 4 und unter Zugrundelegung der Kenntnisse über eine "Uranmaschine", dadurch gekennzeichnet, daß man nur so viel Element 94 an einem Ort vereinigt, (u.U. nach Beimischung geeigneter, neutronenbremsender und/oder absorbierender Zusatzelemente) daß Explosionen vermieden werden, und die Energieabgabe kontinuierlich erfolgt.

3. The method for generating energy from the element U or element 94 according to claim 1, characterized in that the neutron-produced element 94 is separated from the remaining uranium by known chemical methods, and then is available in pure or suitably selected concentration.

4. Method for the production of energy and neutron production from heavy fissionable nuclei (for example, ^{238}U, thorium, lead, bismuth, etc.), characterized in that the element 94 obtained according to claim 3 is added to these elements in a suitable amount, so that they can undergo an autocatalytic fission process by neutrons, in which energy is generated and new atomic nuclei are formed.

5. Method for the explosive generation of energy and neutrons from the fission of the element 94, characterized in that the element 94 produced according to claim 3 is brought to a location in such an amount, e.g. in a bomb, that the vast majority of the neutrons produced during each fission event are used to produce new fission events and do not leave the substance.

6. Process for the production of very small, handy machines for obtaining nuclear energy and neutrons, in part according to claims 3 and 4, and on the basis of the knowledge of a "uranium machine," characterized in that one brings together only so much element 94 in one place (depending on the admixture of suitable, neutron-slowing and/or absorbing additional elements) that explosions are avoided and the energy is discharged continuously.



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G-59 (Ref. No. 80)

No. 21797

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Eine Möglichkeit der Energiegewinnung aus ^{238}U.

v. C. F. v. Weizsäcker

1. Problemstellung. Es folgt aus der Theorie von Bohr und Wheeler und wurde unlängst durch Nier experimentell bestätigt, dass der Kern ^{238}U nicht durch ein thermisches Neutron gespalten werden kann. Hieraus ergeben sich für die Energiegewinnung drei Nachteile:

1. Nur das seltene Isotop ^{235}U trägt zur Energieerzeugung in der Uranmaschine bei; somit wird weniger als ein Prozent der im Uran vorhandenen Spaltungsenergie ausgenützt.

2. Die starke Neutronenabsorption des unwirksamen ^{238}U zwingt zu höchster Reinigung des Materials und wahrscheinlich zur Verwendung des schwer erhältlichen schweren Wasserstoffs als Bremssubstanz.

3. Wegen der Resonanzabsorption der Neutronen im ^{238}U kann selbst die Energie des ^{235}U nicht auf einmal bei sehr hoher Temperatur freigemacht werden; dadurch fällt die Verwendung als Sprengstoff praktisch weg.

Alle diese Schwierigkeiten liessen sich überwinden, wenn auch ^{238}U durch thermische Neutronen gespalten werden könnte. Es ist nun möglich, dass dies zwar nicht durch ein Neutron, aber durch zwei sukzessive angelagerte Neutronen geschieht. Das erste Neutron erzeugt das Isotop ^{239}U, das nach Hahn in 23 Minuten zerfällt. Dabei muss ^{239}Eka Re entstehen. Im folgenden wird die Wahrscheinlichkeit der Entstehung und der Spaltbarkeit dieses Kerns geprüft.

2. Die Erzeugung des Eka Re. Pro Spaltprozess entstehen $\chi' - \chi \frac{\sigma_U}{\sigma_2}$ Neutronen. Dabei ist χ die Zahl der pro im Uran absorbiertes thermisches Neutron entstehenden Neutronen, σ_U der gesamte effe

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Anlage zu Bb. Nr. 54/40g

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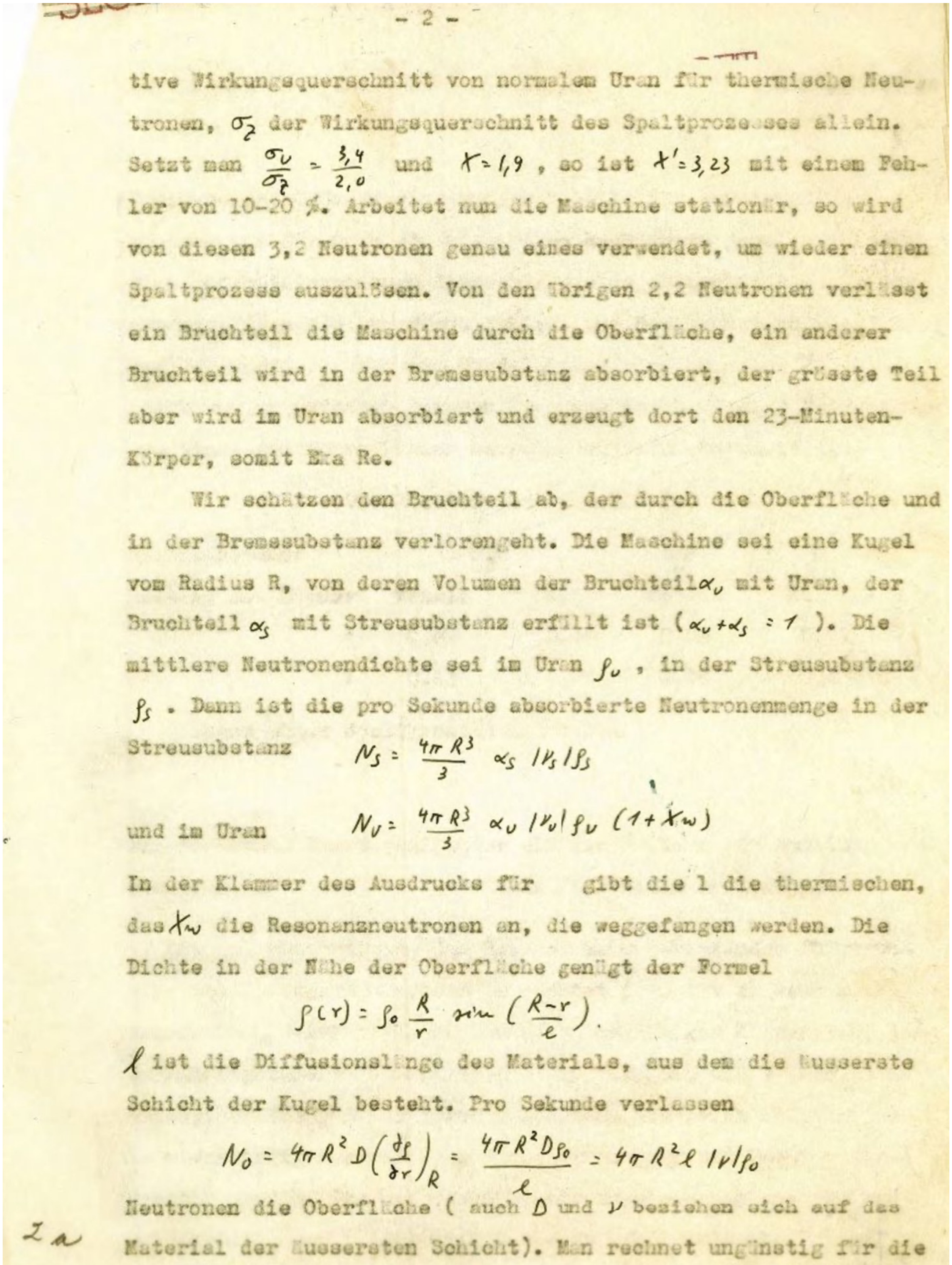
Figure D.337: Carl Friedrich von Weizsäcker's July 1940 report explaining the feasibility of breeding plutonium-239 and using it to make fission bombs. [G-59].



- 2 -

tive Wirkungsquerschnitt von normalem Uran für thermische Neutronen, σ_z der Wirkungsquerschnitt des Spaltprozesses allein. Setzt man $\frac{\sigma_U}{\sigma_z} = \frac{3,4}{2,0}$ und $\chi = 1,9$, so ist $\chi' = 3,23$ mit einem Fehler von 10-20 %. Arbeitet nun die Maschine stationär, so wird von diesen 3,2 Neutronen genau eines verwendet, um wieder einen Spaltprozess auszulösen. Von den übrigen 2,2 Neutronen verlässt ein Bruchteil die Maschine durch die Oberfläche, ein anderer Bruchteil wird in der Bremssubstanz absorbiert, der grösste Teil aber wird im Uran absorbiert und erzeugt dort den 23-Minuten-Körper, somit Eka Re.

Wir schätzen den Bruchteil ab, der durch die Oberfläche und in der Bremssubstanz verlorengeht. Die Maschine sei eine Kugel vom Radius R, von deren Volumen der Bruchteil α_U mit Uran, der Bruchteil α_S mit Streusubstanz erfüllt ist ($\alpha_U + \alpha_S = 1$). Die mittlere Neutronendichte sei im Uran ρ_U, in der Streusubstanz ρ_S. Dann ist die pro Sekunde absorbierte Neutronenmenge in der Streusubstanz

$$N_S = \frac{4\pi R^3}{3}\alpha_S |\nu_S| \rho_S$$

und im Uran

$$N_U = \frac{4\pi R^3}{3}\alpha_U |\nu_U| \rho_U (1 + \chi_w)$$

In der Klammer des Ausdrucks für gibt die 1 die thermischen, das χ_w die Resonanzneutronen an, die weggefangen werden. Die Dichte in der Nähe der Oberfläche genügt der Formel

$$\rho(r) = \rho_0 \frac{R}{r} \sin\left(\frac{R-r}{\ell}\right).$$

ℓ ist die Diffusionslänge des Materials, aus dem die äusserste Schicht der Kugel besteht. Pro Sekunde verlassen

$$N_0 = 4\pi R^2 D \left(\frac{\partial \rho}{\partial r}\right)_R = \frac{4\pi R^2 D \rho_0}{\ell} = 4\pi R^2 \ell |\nu| \rho_0$$

Neutronen die Oberfläche (auch D und ν beziehen sich auf das Material der äussersten Schicht). Man rechnet ungünstig für die

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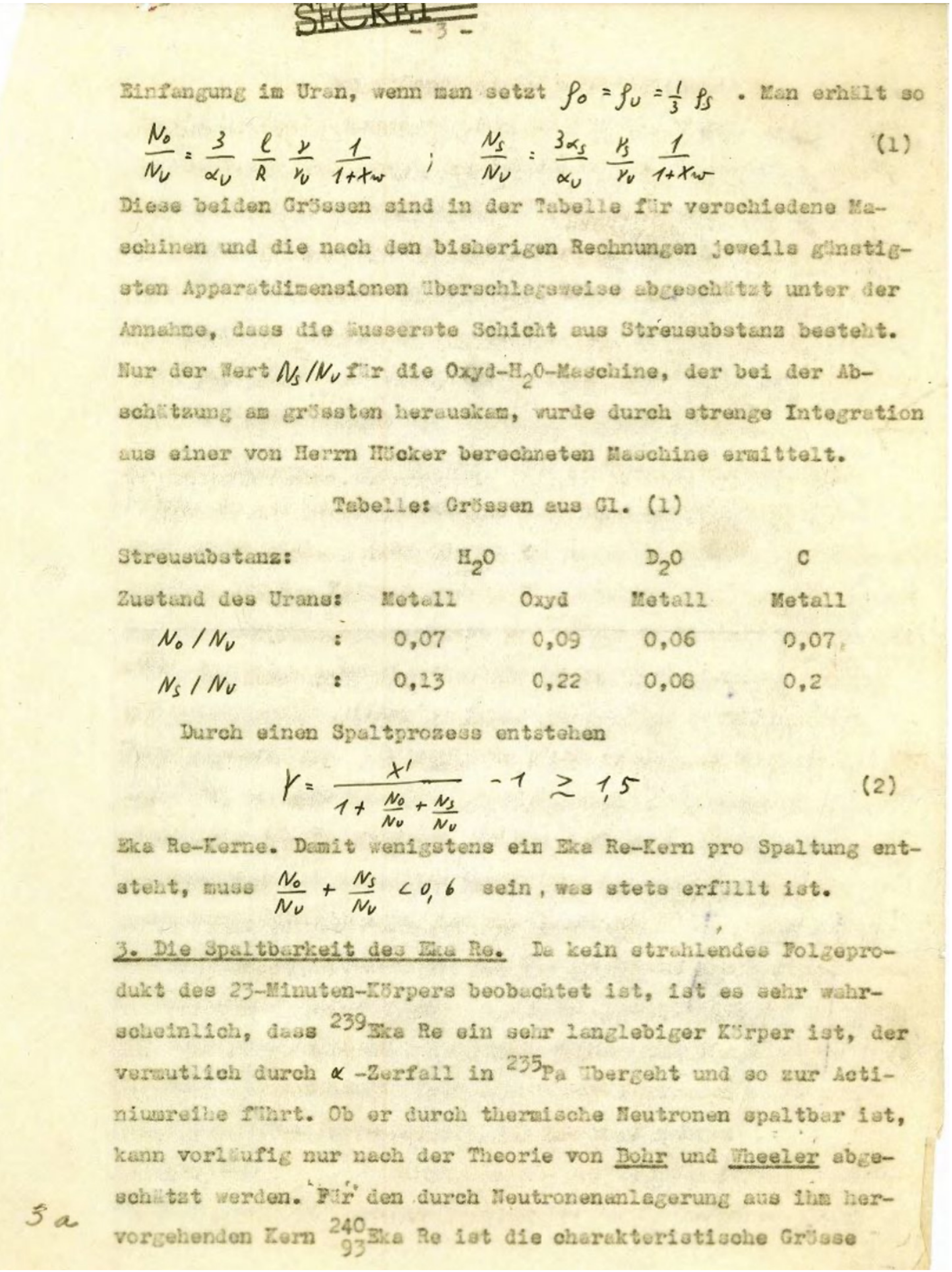
Figure D.338: Carl Friedrich von Weizsäcker's July 1940 report explaining the feasibility of breeding plutonium-239 and using it to make fission bombs. [G-59].



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Einfangung im Uran, wenn man setzt $\rho_o = \rho_U = \frac{1}{3}\rho_s$. Man erhält so

$$\frac{N_o}{N_U} = \frac{3}{\alpha_U}\,\frac{l}{R}\,\frac{\nu}{\nu_U}\,\frac{1}{1+x_w} \quad ; \quad \frac{N_s}{N_U} = \frac{3\alpha_s}{\alpha_U}\,\frac{\nu_s}{\nu_U}\,\frac{1}{1+x_w} \tag{1}$$

Diese beiden Grössen sind in der Tabelle für verschiedene Maschinen und die nach den bisherigen Rechnungen jeweils günstigsten Apparatdimensionen überschlagsweise abgeschätzt unter der Annahme, dass die äusserste Schicht aus Streusubstanz besteht. Nur der Wert N_s/N_U für die Oxyd-H_2O-Maschine, der bei der Abschätzung am grössten herauskam, wurde durch strenge Integration aus einer von Herrn Höcker berechneten Maschine ermittelt.

Tabelle: Grössen aus Gl. (1)

Streusubstanz:	H_2O		D_2O	C
Zustand des Urans:	Metall	Oxyd	Metall	Metall
N_o/N_U :	0,07	0,09	0,06	0,07
N_s/N_U :	0,13	0,22	0,08	0,2

Durch einen Spaltprozess entstehen

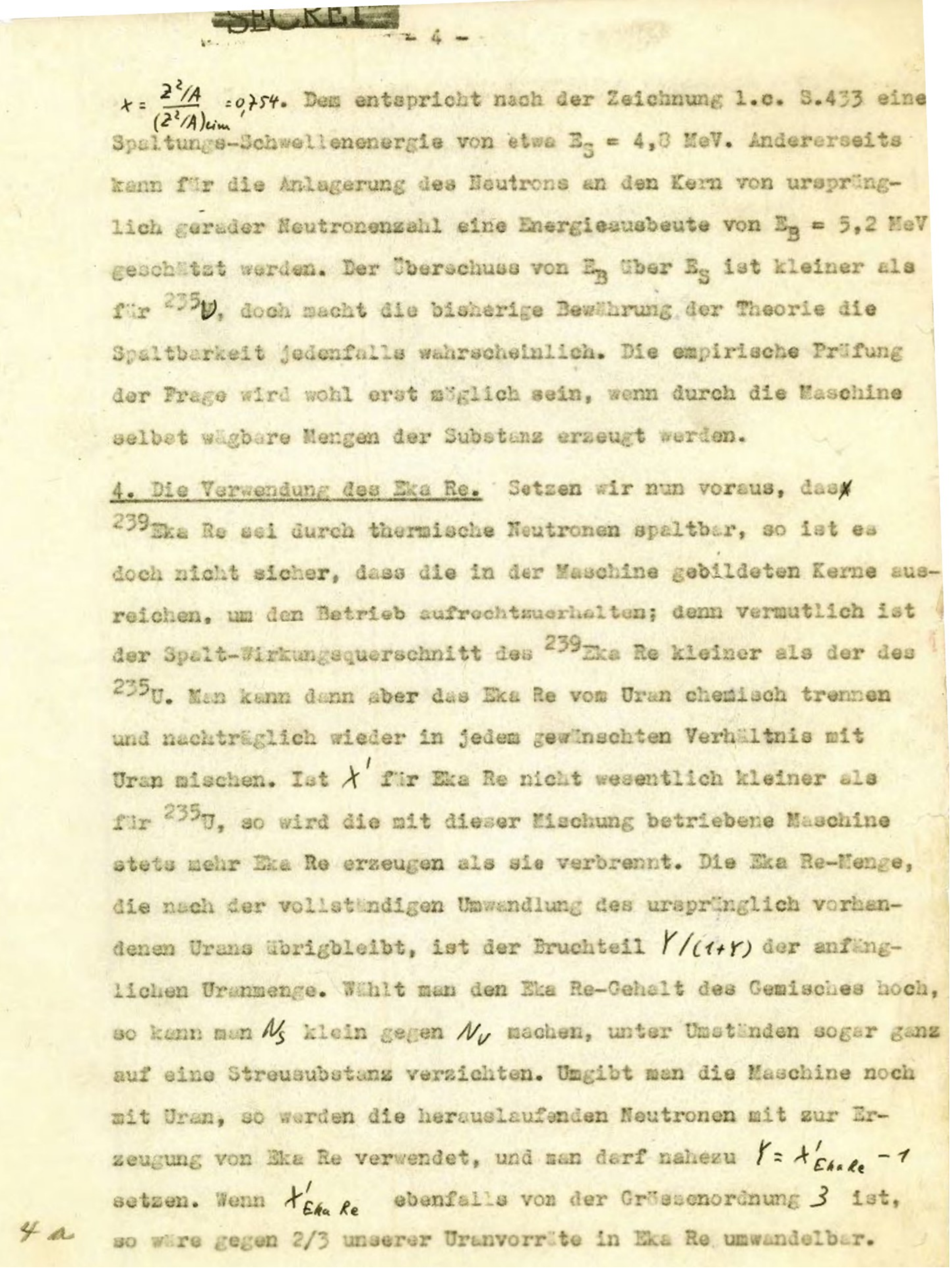
$$\gamma = \frac{x'}{1+\frac{N_o}{N_U}+\frac{N_s}{N_U}} - 1 \gtrsim 1{,}5 \tag{2}$$

Eka Re-Kerne. Damit wenigstens ein Eka Re-Kern pro Spaltung entsteht, muss $\frac{N_o}{N_U} + \frac{N_s}{N_U} < 0{,}6$ sein, was stets erfüllt ist.

3. Die Spaltbarkeit des Eka Re. Da kein strahlendes Folgeprodukt des 23-Minuten-Körpers beobachtet ist, ist es sehr wahrscheinlich, dass ^{239}Eka Re ein sehr langlebiger Körper ist, der vermutlich durch α-Zerfall in ^{235}Pa übergeht und so zur Actiniumreihe führt. Ob er durch thermische Neutronen spaltbar ist, kann vorläufig nur nach der Theorie von Bohr und Wheeler abgeschätzt werden. Für den durch Neutronenanlagerung aus ihm hervorgehenden Kern $^{240}_{93}$Eka Re ist die charakteristische Grösse

3 a

Figure D.339: Carl Friedrich von Weizsäcker's July 1940 report explaining the feasibility of breeding plutonium-239 and using it to make fission bombs. [G-59].



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$x = \frac{Z^2/A}{(Z^2/A)_{lim}} = 0{,}754$. Dem entspricht nach der Zeichnung l.c. S.433 eine Spaltungs-Schwellenenergie von etwa E_S = 4,8 MeV. Andererseits kann für die Anlagerung des Neutrons an den Kern von ursprünglich gerader Neutronenzahl eine Energieausbeute von E_B = 5,2 MeV geschätzt werden. Der Überschuss von E_B über E_S ist kleiner als für ^{235}U, doch macht die bisherige Bewährung der Theorie die Spaltbarkeit jedenfalls wahrscheinlich. Die empirische Prüfung der Frage wird wohl erst möglich sein, wenn durch die Maschine selbst wägbare Mengen der Substanz erzeugt werden.

4. Die Verwendung des Eka Re. Setzen wir nun voraus, das ^{239}Eka Re sei durch thermische Neutronen spaltbar, so ist es doch nicht sicher, dass die in der Maschine gebildeten Kerne ausreichen, um den Betrieb aufrechtzuerhalten; denn vermutlich ist der Spalt-Wirkungsquerschnitt des ^{239}Eka Re kleiner als der des ^{235}U. Man kann dann aber das Eka Re vom Uran chemisch trennen und nachträglich wieder in jedem gewünschten Verhältnis mit Uran mischen. Ist x' für Eka Re nicht wesentlich kleiner als für ^{235}U, so wird die mit dieser Mischung betriebene Maschine stets mehr Eka Re erzeugen als sie verbrennt. Die Eka Re-Menge, die nach der vollständigen Umwandlung des ursprünglich vorhandenen Urans übrigbleibt, ist der Bruchteil $Y/(1+Y)$ der anfänglichen Uranmenge. Wählt man den Eka Re-Gehalt des Gemisches hoch, so kann man N_S klein gegen N_U machen, unter Umständen sogar ganz auf eine Streusubstanz verzichten. Umgibt man die Maschine noch mit Uran, so werden die herauslaufenden Neutronen mit zur Erzeugung von Eka Re verwendet, und man darf nahezu $Y = x'_{Eka\,Re} - 1$ setzen. Wenn $x'_{Eka\,Re}$ ebenfalls von der Grössenordnung 3 ist, so wäre gegen 2/3 unserer Uranvorräte in Eka Re umwandelbar.

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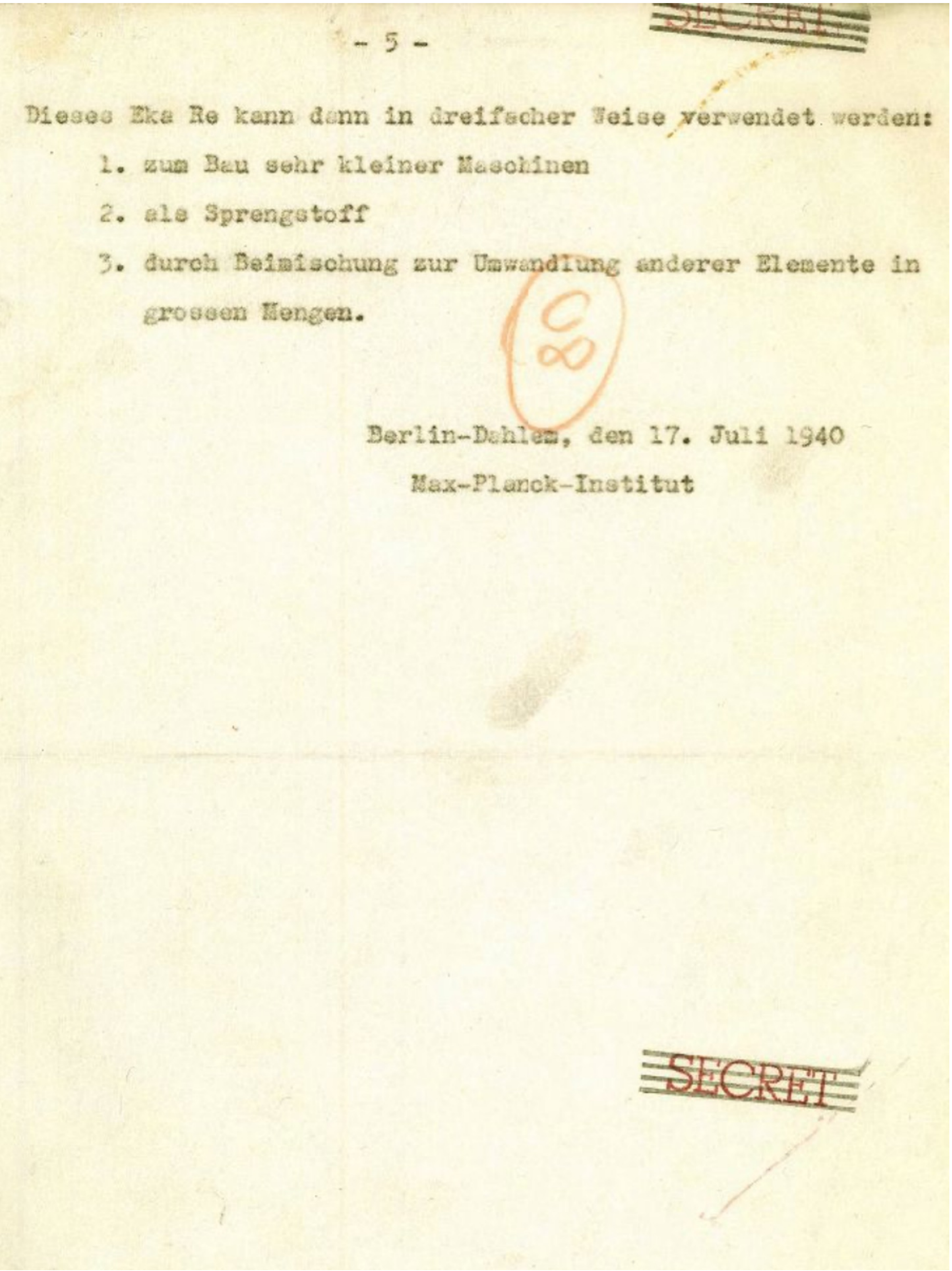
Figure D.340: Carl Friedrich von Weizsäcker's July 1940 report explaining the feasibility of breeding plutonium-239 and using it to make fission bombs. [G-59].



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Dieses Eka Re kann dann in dreifacher Weise verwendet werden:

1. zum Bau sehr kleiner Maschinen
2. als Sprengstoff
3. durch Beimischung zur Umwandlung anderer Elemente in grossen Mengen.

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Berlin-Dahlem, den 17. Juli 1940
Max-Planck-Institut

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Figure D.341: Carl Friedrich von Weizsäcker's July 1940 report explaining the feasibility of breeding plutonium-239 and using it to make fission bombs. [G-59].

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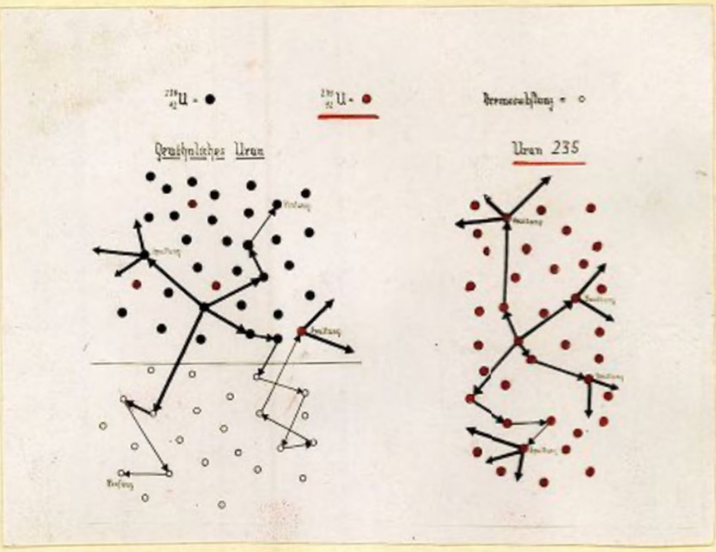

$^{238}_{92}$U = ●
$^{235}_{92}$U = ●
Bremssubstanz = ○
Gewöhnliches Uran
Uran 235

Abb. 1.

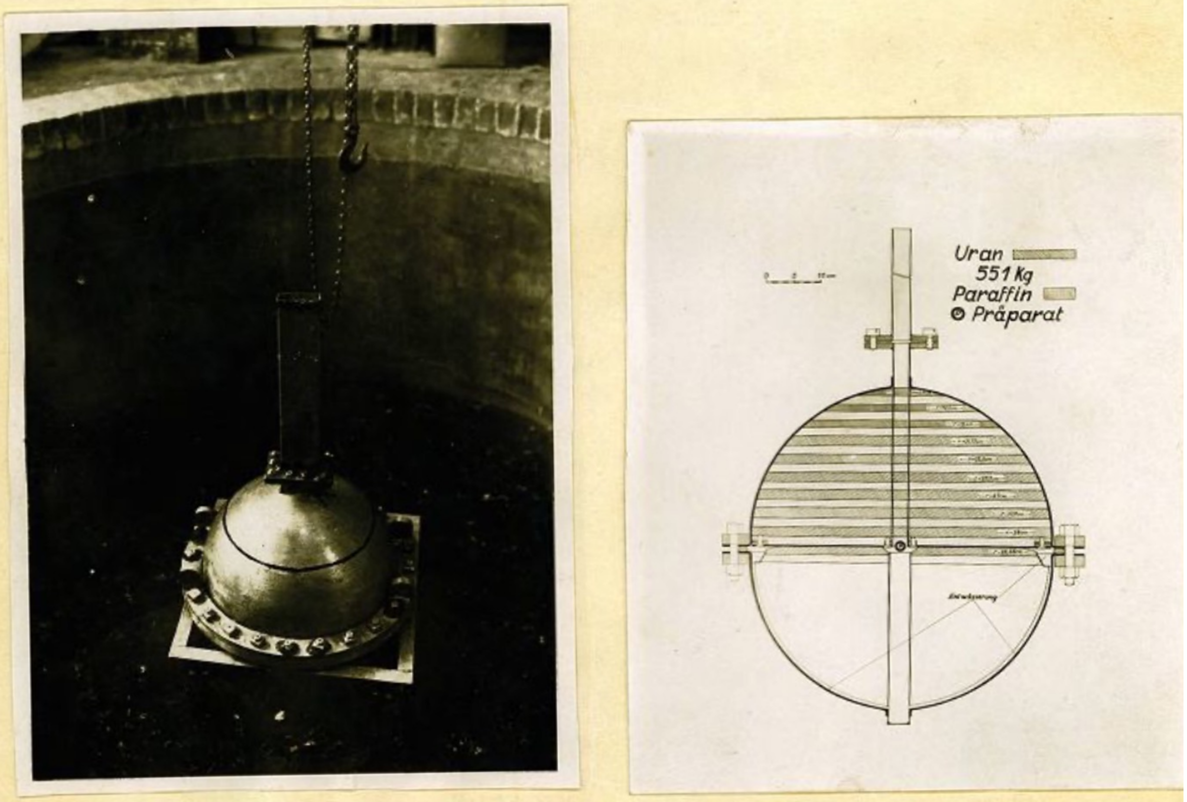
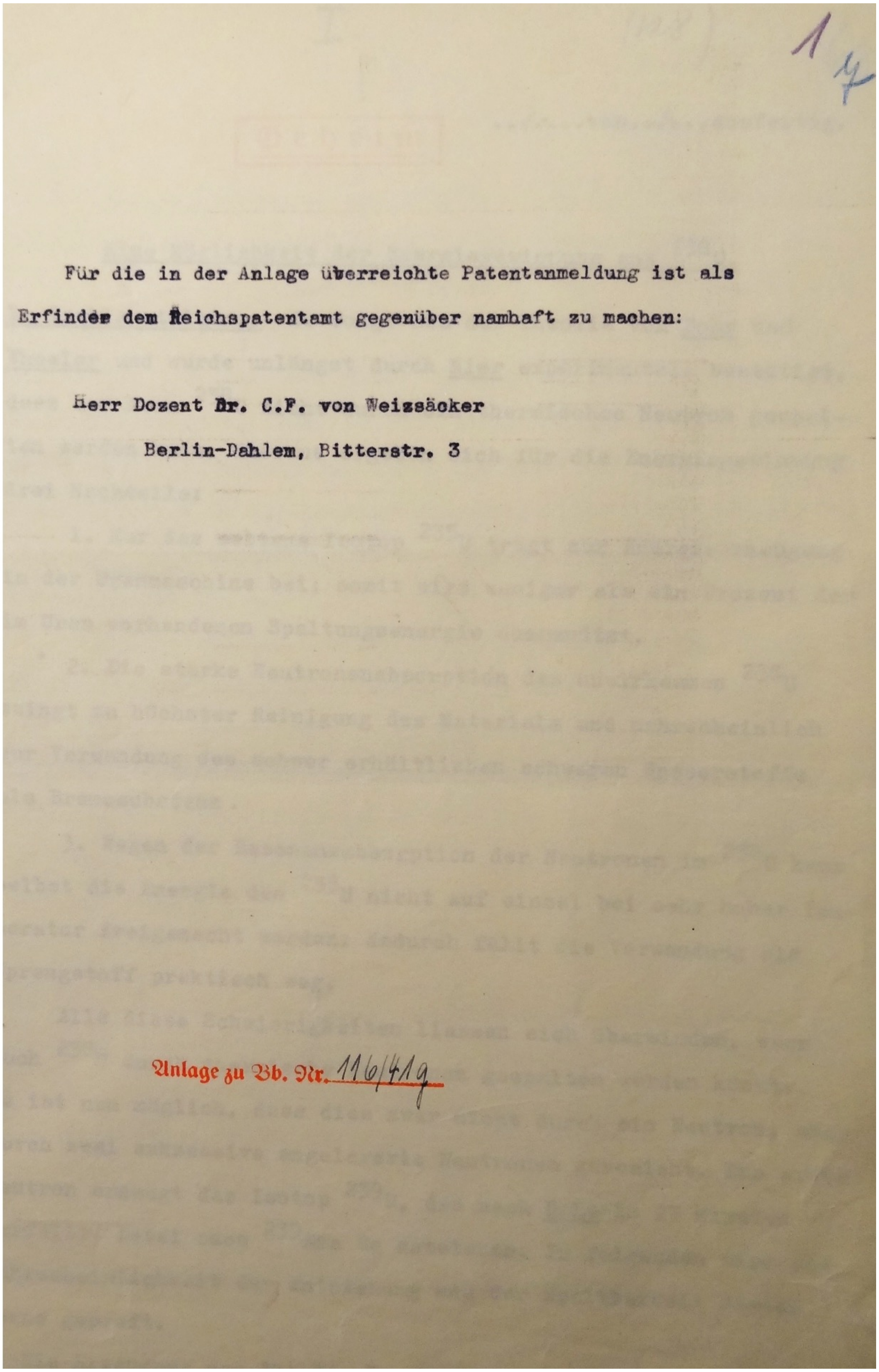

Uran
551 Kg
Paraffin
Präparat

Abb. 2 u. 3

6a

Figure D.342: Carl Friedrich von Weizsäcker's July 1940 report explaining the feasibility of breeding plutonium-239 and using it to make fission bombs or fission reactors. [G-59].

AMPG 7314, KWIP 7, Folder 4 Pu



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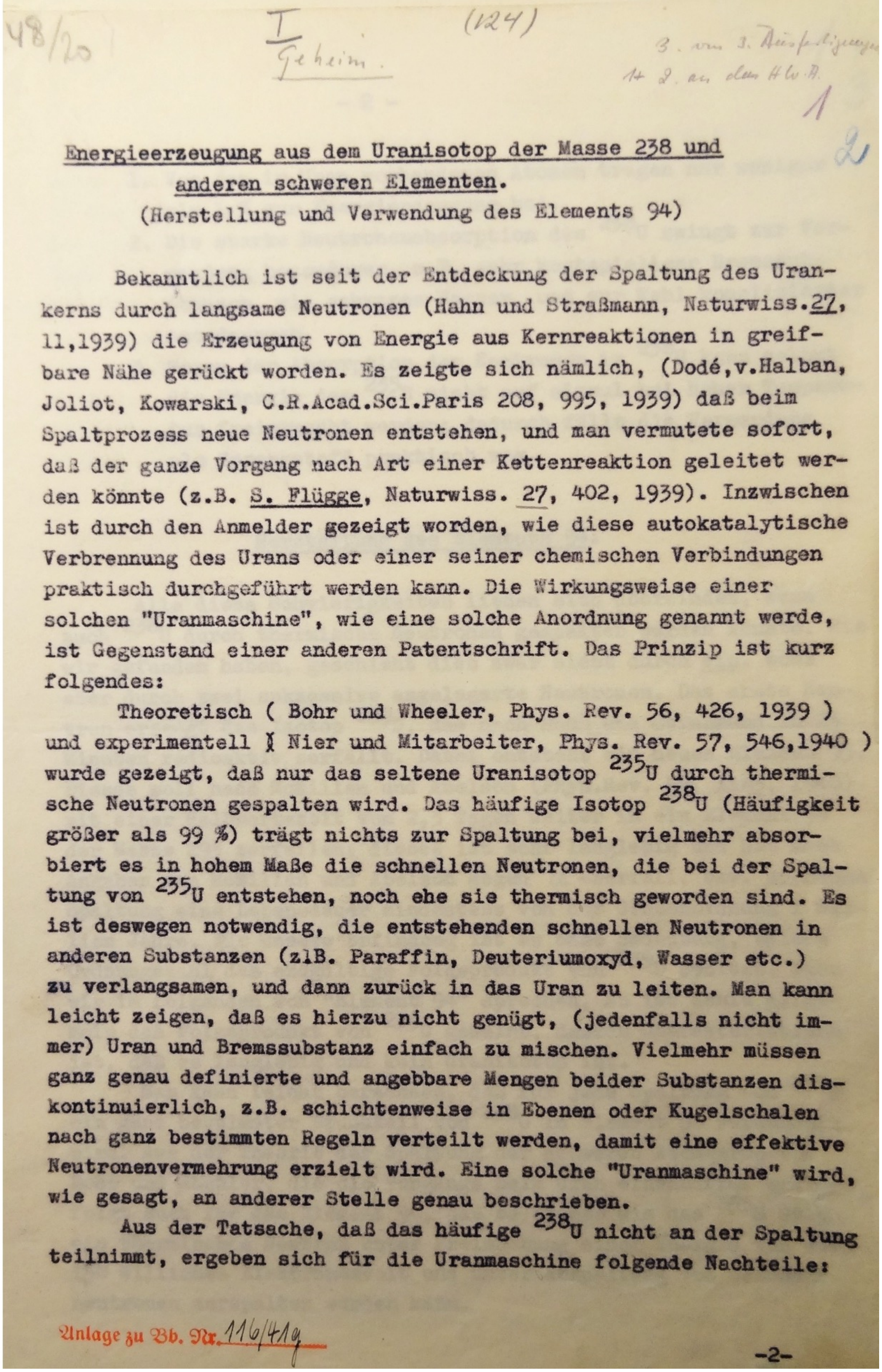
Für die in der Anlage überreichte Patentanmeldung ist als Erfinder dem Reichspatentamt gegenüber namhaft zu machen:

Herr Dozent Dr. C.F. von Weizsäcker
Berlin-Dahlem, Bitterstr. 3

Anlage zu Bb. Nr. 116/41g

Figure D.343: Carl Friedrich von Weizsäcker's 11 June 1941 patent application on breeding plutonium-239 and using it to make fission bombs or fission reactors [AMPG 7314, KWIP 7, Folder 4 Pu].

AMPG 7314, KWIP 7, Folder 4 Pu



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Geheim.

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3. von 3. Ausfertigungen
1+2. an den H.W.A.

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Energieerzeugung aus dem Uranisotop der Masse 238 und anderen schweren Elementen.

(Herstellung und Verwendung des Elements 94)

Bekanntlich ist seit der Entdeckung der Spaltung des Urankerns durch langsame Neutronen (Hahn und Straßmann, Naturwiss.27, 11,1939) die Erzeugung von Energie aus Kernreaktionen in greifbare Nähe gerückt worden. Es zeigte sich nämlich, (Dodé,v.Halban, Joliot, Kowarski, C.R.Acad.Sci.Paris 208, 995, 1939) daß beim Spaltprozess neue Neutronen entstehen, und man vermutete sofort, daß der ganze Vorgang nach Art einer Kettenreaktion geleitet werden könnte (z.B. S. Flügge, Naturwiss. 27, 402, 1939). Inzwischen ist durch den Anmelder gezeigt worden, wie diese autokatalytische Verbrennung des Urans oder einer seiner chemischen Verbindungen praktisch durchgeführt werden kann. Die Wirkungsweise einer solchen "Uranmaschine", wie eine solche Anordnung genannt werde, ist Gegenstand einer anderen Patentschrift. Das Prinzip ist kurz folgendes:

Theoretisch (Bohr und Wheeler, Phys. Rev. 56, 426, 1939) und experimentell (Nier und Mitarbeiter, Phys. Rev. 57, 546,1940) wurde gezeigt, daß nur das seltene Uranisotop ^{235}U durch thermische Neutronen gespalten wird. Das häufige Isotop ^{238}U (Häufigkeit größer als 99 %) trägt nichts zur Spaltung bei, vielmehr absorbiert es in hohem Maße die schnellen Neutronen, die bei der Spaltung von ^{235}U entstehen, noch ehe sie thermisch geworden sind. Es ist deswegen notwendig, die entstehenden schnellen Neutronen in anderen Substanzen (z.B. Paraffin, Deuteriumoxyd, Wasser etc.) zu verlangsamen, und dann zurück in das Uran zu leiten. Man kann leicht zeigen, daß es hierzu nicht genügt, (jedenfalls nicht immer) Uran und Bremssubstanz einfach zu mischen. Vielmehr müssen ganz genau definierte und angebbare Mengen beider Substanzen diskontinuierlich, z.B. schichtenweise in Ebenen oder Kugelschalen nach ganz bestimmten Regeln verteilt werden, damit eine effektive Neutronenvermehrung erzielt wird. Eine solche "Uranmaschine" wird, wie gesagt, an anderer Stelle genau beschrieben.

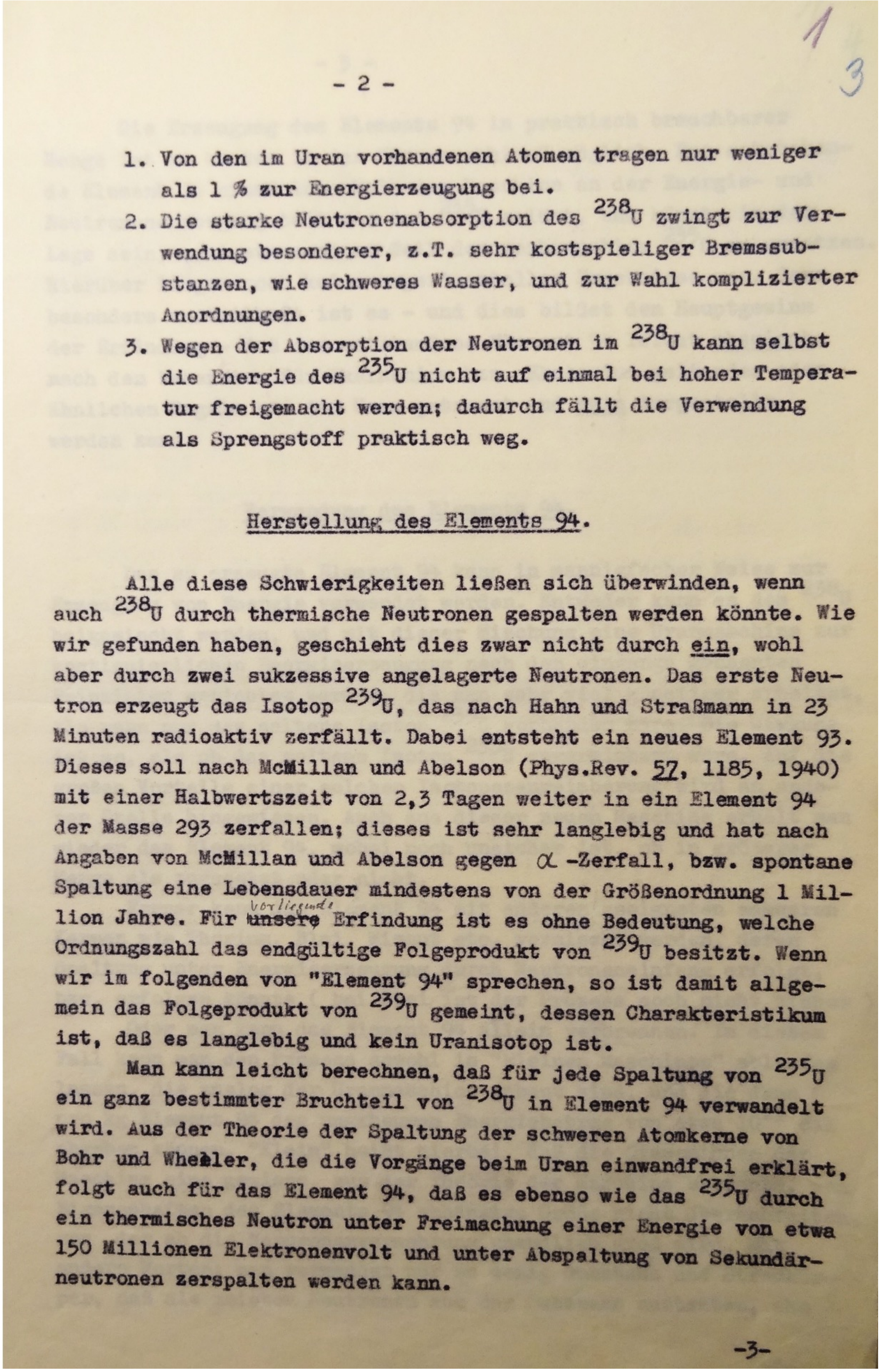
Aus der Tatsache, daß das häufige ^{238}U nicht an der Spaltung teilnimmt, ergeben sich für die Uranmaschine folgende Nachteile:

Anlage zu Bb. Nr. 116/41g

-2-

Figure D.344: Carl Friedrich von Weizsäcker's 11 June 1941 patent application on breeding plutonium-239 and using it to make fission bombs or fission reactors [AMPG 7314, KWIP 7, Folder 4 Pu].

AMPG 7314, KWIP 7, Folder 4 Pu



1. Von den im Uran vorhandenen Atomen tragen nur weniger als 1 % zur Energierzeugung bei.
2. Die starke Neutronenabsorption des ^{238}U zwingt zur Verwendung besonderer, z.T. sehr kostspieliger Bremssubstanzen, wie schweres Wasser, und zur Wahl komplizierter Anordnungen.
3. Wegen der Absorption der Neutronen im ^{238}U kann selbst die Energie des ^{235}U nicht auf einmal bei hoher Temperatur freigemacht werden; dadurch fällt die Verwendung als Sprengstoff praktisch weg.

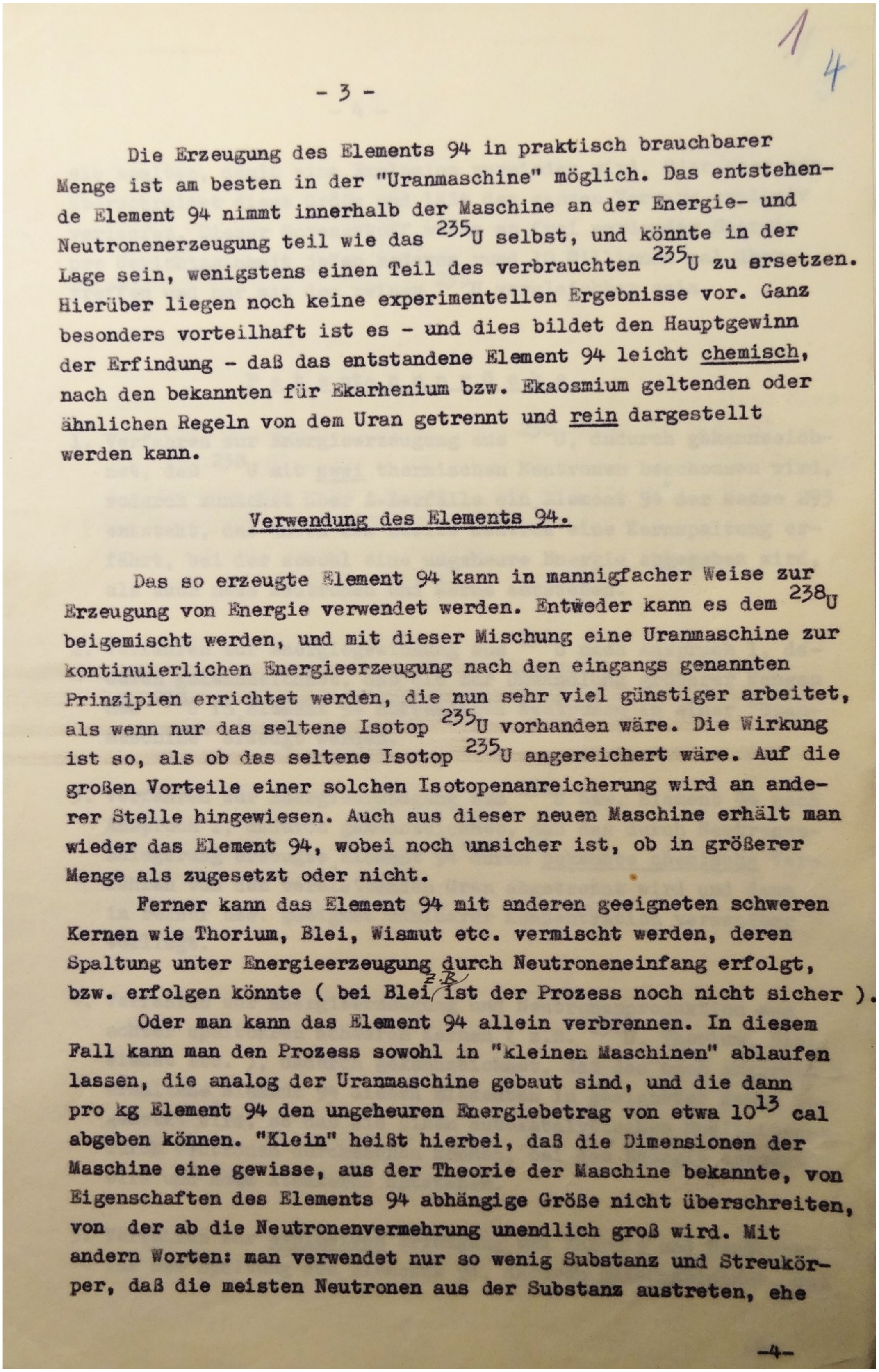
Herstellung des Elements 94.

Alle diese Schwierigkeiten ließen sich überwinden, wenn auch ^{238}U durch thermische Neutronen gespalten werden könnte. Wie wir gefunden haben, geschieht dies zwar nicht durch ein, wohl aber durch zwei sukzessive angelagerte Neutronen. Das erste Neutron erzeugt das Isotop ^{239}U, das nach Hahn und Straßmann in 23 Minuten radioaktiv zerfällt. Dabei entsteht ein neues Element 93. Dieses soll nach McMillan und Abelson (Phys.Rev. 57, 1185, 1940) mit einer Halbwertszeit von 2,3 Tagen weiter in ein Element 94 der Masse 293 zerfallen; dieses ist sehr langlebig und hat nach Angaben von McMillan und Abelson gegen α-Zerfall, bzw. spontane Spaltung eine Lebensdauer mindestens von der Größenordnung 1 Million Jahre. Für ~~unsere~~ vorliegende Erfindung ist es ohne Bedeutung, welche Ordnungszahl das endgültige Folgeprodukt von ^{239}U besitzt. Wenn wir im folgenden von "Element 94" sprechen, so ist damit allgemein das Folgeprodukt von ^{239}U gemeint, dessen Charakteristikum ist, daß es langlebig und kein Uranisotop ist.

Man kann leicht berechnen, daß für jede Spaltung von ^{235}U ein ganz bestimmter Bruchteil von ^{238}U in Element 94 verwandelt wird. Aus der Theorie der Spaltung der schweren Atomkerne von Bohr und Wheeler, die die Vorgänge beim Uran einwandfrei erklärt, folgt auch für das Element 94, daß es ebenso wie das ^{235}U durch ein thermisches Neutron unter Freimachung einer Energie von etwa 150 Millionen Elektronenvolt und unter Abspaltung von Sekundärneutronen zerspalten werden kann.

Figure D.345: Carl Friedrich von Weizsäcker's 11 June 1941 patent application on breeding plutonium-239 and using it to make fission bombs or fission reactors [AMPG 7314, KWIP 7, Folder 4 Pu].

AMPG 7314, KWIP 7, Folder 4 Pu



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Die Erzeugung des Elements 94 in praktisch brauchbarer Menge ist am besten in der "Uranmaschine" möglich. Das entstehende Element 94 nimmt innerhalb der Maschine an der Energie- und Neutronenerzeugung teil wie das ^{235}U selbst, und könnte in der Lage sein, wenigstens einen Teil des verbrauchten ^{235}U zu ersetzen. Hierüber liegen noch keine experimentellen Ergebnisse vor. Ganz besonders vorteilhaft ist es - und dies bildet den Hauptgewinn der Erfindung - daß das entstandene Element 94 leicht chemisch, nach den bekannten für Ekarhenium bzw. Ekaosmium geltenden oder ähnlichen Regeln von dem Uran getrennt und rein dargestellt werden kann.

Verwendung des Elements 94.

Das so erzeugte Element 94 kann in mannigfacher Weise zur Erzeugung von Energie verwendet werden. Entweder kann es dem ^{238}U beigemischt werden, und mit dieser Mischung eine Uranmaschine zur kontinuierlichen Energieerzeugung nach den eingangs genannten Prinzipien errichtet werden, die nun sehr viel günstiger arbeitet, als wenn nur das seltene Isotop ^{235}U vorhanden wäre. Die Wirkung ist so, als ob das seltene Isotop ^{235}U angereichert wäre. Auf die großen Vorteile einer solchen Isotopenanreicherung wird an anderer Stelle hingewiesen. Auch aus dieser neuen Maschine erhält man wieder das Element 94, wobei noch unsicher ist, ob in größerer Menge als zugesetzt oder nicht.

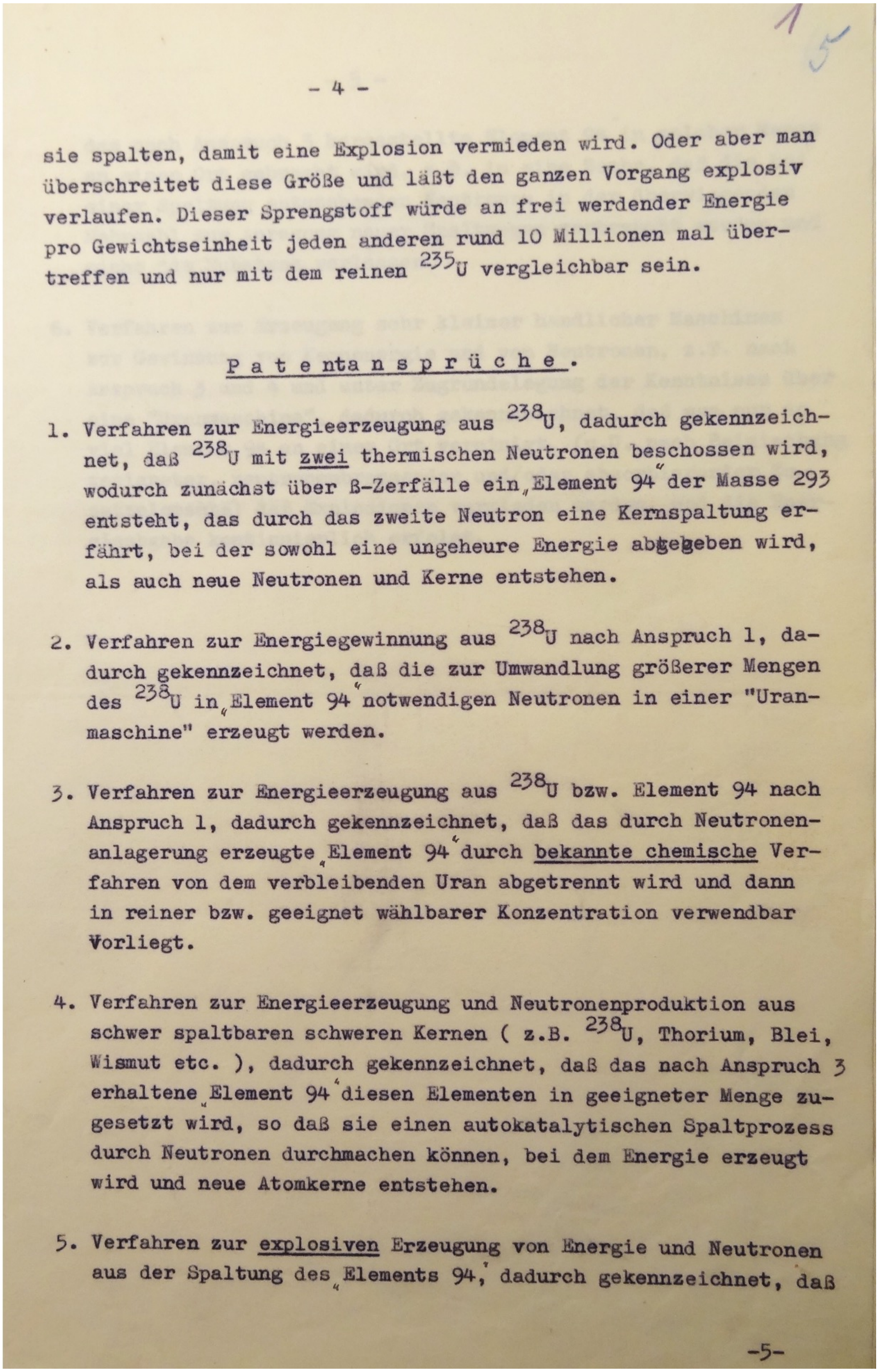
Ferner kann das Element 94 mit anderen geeigneten schweren Kernen wie Thorium, Blei, Wismut etc. vermischt werden, deren Spaltung unter Energieerzeugung durch Neutroneneinfang erfolgt, bzw. erfolgen könnte (bei Blei z.B. ist der Prozess noch nicht sicher).

Oder man kann das Element 94 allein verbrennen. In diesem Fall kann man den Prozess sowohl in "kleinen Maschinen" ablaufen lassen, die analog der Uranmaschine gebaut sind, und die dann pro kg Element 94 den ungeheuren Energiebetrag von etwa 10^{13} cal abgeben können. "Klein" heißt hierbei, daß die Dimensionen der Maschine eine gewisse, aus der Theorie der Maschine bekannte, von Eigenschaften des Elements 94 abhängige Größe nicht überschreiten, von der ab die Neutronenvermehrung unendlich groß wird. Mit andern Worten: man verwendet nur so wenig Substanz und Streukörper, daß die meisten Neutronen aus der Substanz austreten, ehe

-4-

Figure D.346: Carl Friedrich von Weizsäcker's 11 June 1941 patent application on breeding plutonium-239 and using it to make fission bombs or fission reactors [AMPG 7314, KWIP 7, Folder 4 Pu].

AMPG 7314, KWIP 7, Folder 4 Pu



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sie spalten, damit eine Explosion vermieden wird. Oder aber man überschreitet diese Größe und läßt den ganzen Vorgang explosiv verlaufen. Dieser Sprengstoff würde an frei werdender Energie pro Gewichtseinheit jeden anderen rund 10 Millionen mal übertreffen und nur mit dem reinen ^{235}U vergleichbar sein.

Patentansprüche.

1. Verfahren zur Energieerzeugung aus ^{238}U, dadurch gekennzeichnet, daß ^{238}U mit zwei thermischen Neutronen beschossen wird, wodurch zunächst über ß-Zerfälle ein „Element 94“ der Masse 293 entsteht, das durch das zweite Neutron eine Kernspaltung erfährt, bei der sowohl eine ungeheure Energie abgegeben wird, als auch neue Neutronen und Kerne entstehen.

2. Verfahren zur Energiegewinnung aus ^{238}U nach Anspruch 1, dadurch gekennzeichnet, daß die zur Umwandlung größerer Mengen des ^{238}U in „Element 94“ notwendigen Neutronen in einer "Uranmaschine" erzeugt werden.

3. Verfahren zur Energieerzeugung aus ^{238}U bzw. Element 94 nach Anspruch 1, dadurch gekennzeichnet, daß das durch Neutronenanlagerung erzeugte „Element 94“ durch bekannte chemische Verfahren von dem verbleibenden Uran abgetrennt wird und dann in reiner bzw. geeignet wählbarer Konzentration verwendbar vorliegt.

4. Verfahren zur Energieerzeugung und Neutronenproduktion aus schwer spaltbaren schweren Kernen (z.B. ^{238}U, Thorium, Blei, Wismut etc.), dadurch gekennzeichnet, daß das nach Anspruch 3 erhaltene „Element 94“ diesen Elementen in geeigneter Menge zugesetzt wird, so daß sie einen autokatalytischen Spaltprozess durch Neutronen durchmachen können, bei dem Energie erzeugt wird und neue Atomkerne entstehen.

5. Verfahren zur explosiven Erzeugung von Energie und Neutronen aus der Spaltung des „Elements 94“, dadurch gekennzeichnet, daß

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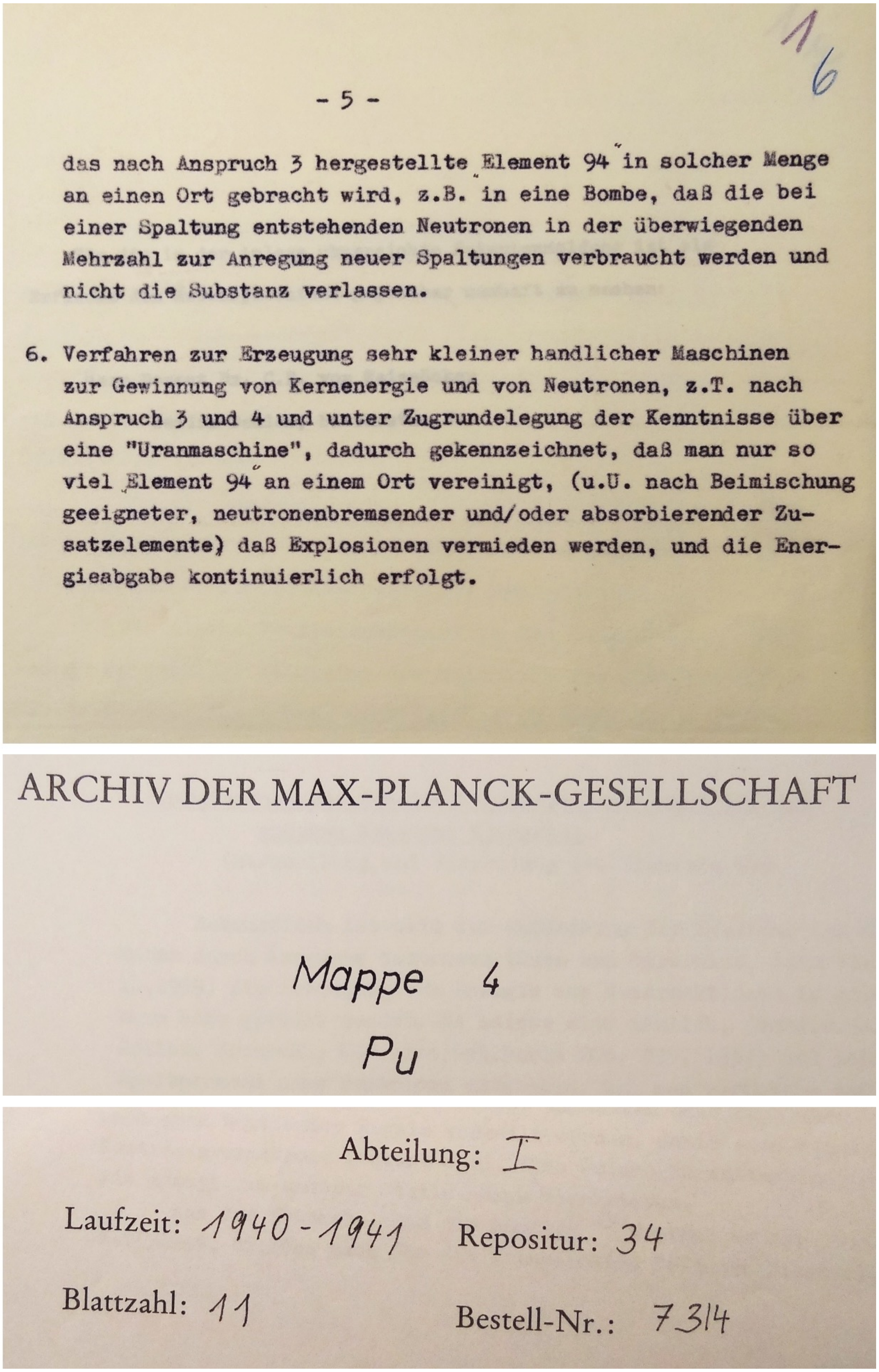
Figure D.347: Carl Friedrich von Weizsäcker's 11 June 1941 patent application on breeding plutonium-239 and using it to make fission bombs or fission reactors [AMPG 7314, KWIP 7, Folder 4 Pu].



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- 5 -

das nach Anspruch 3 hergestellte Element 94 in solcher Menge an einen Ort gebracht wird, z.B. in eine Bombe, daß die bei einer Spaltung entstehenden Neutronen in der überwiegenden Mehrzahl zur Anregung neuer Spaltungen verbraucht werden und nicht die Substanz verlassen.

6. Verfahren zur Erzeugung sehr kleiner handlicher Maschinen zur Gewinnung von Kernenergie und von Neutronen, z.T. nach Anspruch 3 und 4 und unter Zugrundelegung der Kenntnisse über eine "Uranmaschine", dadurch gekennzeichnet, daß man nur so viel Element 94 an einem Ort vereinigt, (u.U. nach Beimischung geeigneter, neutronenbremsender und/oder absorbierender Zusatzelemente) daß Explosionen vermieden werden, und die Energieabgabe kontinuierlich erfolgt.

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AMPG 7314, KWIP 7, Folder 4 Pu

Figure D.348: Carl Friedrich von Weizsäcker's 11 June 1941 patent application on breeding plutonium-239 and using it to make fission bombs or fission reactors [AMPG 7314, KWIP 7, Folder 4 Pu].

G-94. Fritz Houtermans. Zur Frage der Auslösung von Kern-Kettenreaktionen. August 1941. Same as report G-267.

[See document photos on pp. 3816–3823.]

[U.S.-created English abstract:] Brief summary covering the following aspects: Analysis of the factors which prevent nuclear fission. Possibility of fission with fast neutrons. Fission with thermal neutrons. Need for enrichment of U^{235}. Difficulty and expense of isotope separation. Moderators: D_2O, beryllium or beryllium oxide, carbon. Effect of temperature on absorption of thermal neutrons. Possibility of chain reaction with natural isotope mixtures of U at low temperatures. Calculations for critical mass. Although difficulty of getting economical power from lower temperature pile, there are other gains possible, e.g., radioisotopes; formation of 239 isotope, which is also subject to fission by thermal neutrons.

[Excerpts:]

[I.] Kernspaltung wurde bisher bekanntlich an den Atomkernen U^{238}, U^{235}, Th^{232}, Pa^{231} und Jo^{230} beobachtet. Kernspaltung kann durch geladene Teilchen (Protonen oder Deuteronen) einer Energie von etwa 5–6 MeV, γ-Quanten einer Energie der gleichen Größenordnung und durch Neutronen ausgelöst werden. [...]

[VII.] Vergleichen wir etwa die Neutronenergiebigkeit einer solchen Apparatur mit der besten bisherigen Neutronenquelle, einem Zyklotron, so zeigt sich leicht, daß eine solche Anlage mit einer Menge natürlichen Urangemischs von ca. 1 t der Leistung von etwa 10^4 bis 10^5 Zyklotrons entspricht. [...]

Denn bei allen denkbaren Apparaturen, die eine Kettenreaktion an isoliertem U^{235} gestatten, würde ja nur 1/139 der gesamten zur Verfügung stehenden Uranmenge als "Brennstoff" oder "Explosivesstoff" benutzt werden, während bei der Isotopentrennung auch für die unverwertbaren Mengen von U^{238} Energie aufgewandt werden muß.

[I.] Nuclear fission has been observed to date for the atomic nuclei U^{238}, U^{235}, Th^{232}, Pa^{231}, and Jo^{230}. Nuclear fission can be triggered by charged particles (protons or deuterons) with an energy of approximately 5–6 MeV, γ photons with an energy of the same magnitude, and by neutrons. [...]

[VII.] If, for example, we compare the neutron yield of such a reactor with the best previous neutron source, a cyclotron, it is easy to see that such a reactor, with a quantity of natural uranium mixture of about 1 ton, has a power of about 10^4 to 10^5 cyclotrons. [...]

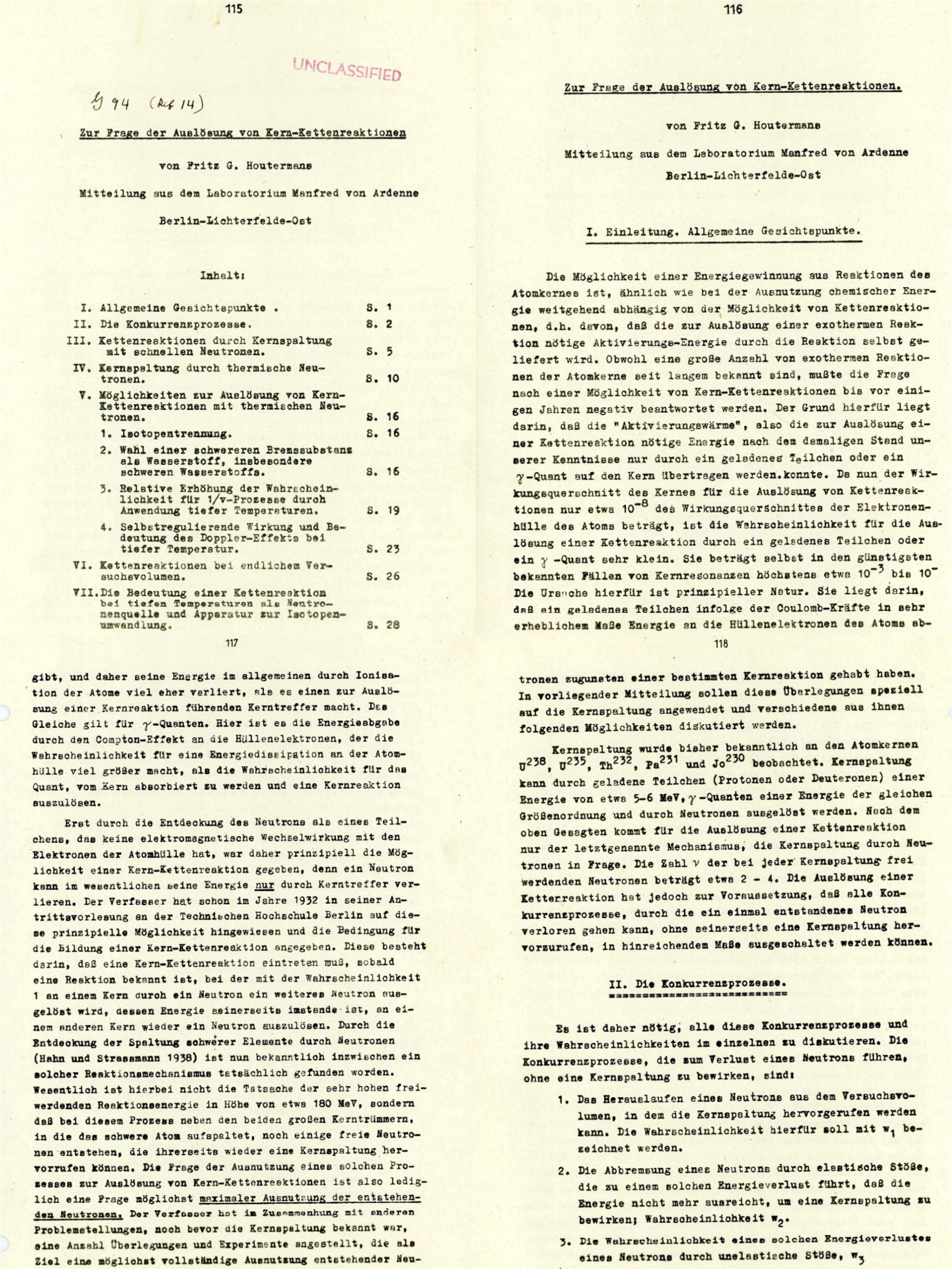
For all conceivable devices that permit a chain reaction with purified U^{235}, only 1/139 of the total available uranium would be used as "fuel" or "explosive", while during isotope separation, impractical amounts of energy must also be expended on U^{238}.

Um diesen Punkt näher zu verstehen, müssen wir uns die Frage stellen, was aus denjenigen Neutronen wird, die bei der hier behandelten Kettenreaktion (U–schwere Bremssubstanz bei tiefer Temperatur) entstehen und nicht nach außen entweichen. Wir sehen oben, daß durch Ausschaltung der Neutronen-einfangung durch den Wasserstoff der einzig noch vorhandene Konkurrenzprozess, der in der Tat einen großen Teil der Neutronen schluckt, die Resonanzeinfangung des U^{238} ist. Bei dieser Resonanzeinfangung entsteht bekanntlich zunächst der 23 min-Körper, ein U^{239}_{92}, aus dem durch β-Zerfall zunächst Ek-Re^{239}_{93} entsteht, das wahrscheinlich selbst wieder β-aktiv ist und einem weiteren Körper der (4n+3)-Reihe liefert. [...] Im letzteren Falle aber muß das entstehende langlebige Isotop des Atomgewichts 239 selbst wieder Thermospaltung zeigen. [...] Jedes Neutron, das anstatt an U^{235} Spaltung zu bewirken von U^{238} eingefangen wird, schafft also einen neuen, durch thermische Neutronen spaltbaren Kern. Wir können daher eine Apparatur, die es ge-stattet, mit einem Energieumsatz an wägbaren Mengen U^{235} die Kettenreaktion ablaufen lassen, gleichzeitig als eine Isotopenumwandlungsapparatur ansehen. Der Vorteil gegenüber einer Isotopentrennungsapparatur ist aber der, daß das neugeschaffene Produkt, das ja eine Kernladung von 93 oder mehr hat, chemisch nicht mehr mit dem Uran identisch und daher mit gewöhnlichen chemischen Methoden abzutrennen ist. Da nun viel größere Mengen, nämlich das 139fache an U^{238} zur Verfügung stehen, so ist die Verwertbarmachung desselben als “Brennstoff” für eine Kettenreaktion ein für unsere Themenstellung viel wichtigerer Vorgang, als die Isotopentrennung, die bloß das U^{235} zu verwerten gestattet.

Für die Anregung zu dieser Arbeit und deren Ermöglichung danke ich Baron Manfred von Ardenne.

To understand this point in more detail, we have to ask ourselves what will become of the neutrons that are formed during the chain reaction (U-moderator at low temperature) and do not escape to the outside. We see above that by eliminating neutron capture by hydrogen, the only competitive process that actually absorbs a large portion of the neutrons is the resonance capture by U^{238}. This resonance capture is known to produce the 23-minute nucleus, U^{239}_{92}, for which β decay results in Ek-Re^{239}_{93}, which is likely to be β-active again and produces another (4n+3)-type body. [...] In the latter case, however, the resulting long-lived isotope of atomic weight 239 must again be fissionable by thermal neutrons. [...] Every neutron which, instead of fissioning U^{235}, is captured by U^{238} creates in this way a new nucleus, fissionable by thermal neutrons. We can therefore regard an apparatus that allows the chain reaction to proceed with an energy conversion of measurable amounts of U^{235} as an isotope conversion apparatus. The advantage over an isotope separation apparatus, however, is that the newly created product, which indeed has a nuclear charge of 93 or more, is no longer chemically identical to uranium and therefore can be purified by ordinary chemical methods. Since much larger quantities are available, namely 139 times more U^{238}, the utilization of it as “fuel” for a chain reaction is a much more important process for our topic than isotope separation, which only allows U^{235} to be used.

For suggesting this work and making it possible, I thank Baron Manfred von Ardenne.



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G 94 (Ref 14)

Zur Frage der Auslösung von Kern-Kettenreaktionen

von Fritz G. Houtermans

Mitteilung aus dem Laboratorium Manfred von Ardenne

Berlin-Lichterfelde-Ost

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Zur Frage der Auslösung von Kern-Kettenreaktionen.

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I. Einleitung. Allgemeine Gesichtspunkte.

Die Möglichkeit einer Energiegewinnung aus Reaktionen des Atomkernes ist, ähnlich wie bei der Ausnutzung chemischer Energie weitgehend abhängig von der Möglichkeit von Kettenreaktionen, d.h. davon, daß die zur Auslösung einer exothermen Reaktion nötige Aktivierungs-Energie durch die Reaktion selbst geliefert wird. Obwohl eine große Anzahl von exothermen Reaktionen der Atomkerne seit langem bekannt sind, mußte die Frage nach einer Möglichkeit von Kern-Kettenreaktionen bis vor einigen Jahren negativ beantwortet werden. Der Grund hierfür liegt darin, daß die "Aktivierungswärme", also die zur Auslösung einer Kettenreaktion nötige Energie nach dem damaligen Stand unserer Kenntnisse nur durch ein geladenes Teilchen oder ein γ-Quant auf den Kern übertragen werden.konnte. Da nun der Wirkungsquerschnitt des Kernes für die Auslösung von Kettenreaktionen nur etwa 10^{-8} des Wirkungsquerschnittes der Elektronenhülle des Atoms beträgt, ist die Wahrscheinlichkeit für die Auslösung einer Kettenreaktion durch ein geladenes Teilchen oder ein γ-Quant sehr klein. Sie beträgt selbst in den günstigsten bekannten Fällen von Kernresonanzen höchstens etwa 10^{-3} bis 10^{-} Die Ursache hierfür ist prinzipieller Natur. Sie liegt darin, daß ein geladenes Teilchen infolge der Coulomb-Kräfte in sehr erheblichem Maße Energie an die Hüllenelektronen des Atoms abgibt, und daher seine Energie im allgemeinen durch Ionisation der Atome viel eher verliert, als es einen zur Auslösung einer Kernreaktion führenden Kerntreffer macht. Das Gleiche gilt für γ-Quanten. Hier ist es die Energieabgabe durch den Compton-Effekt an die Hüllenelektronen, der die Wahrscheinlichkeit für eine Energiedissipation an der Atomhülle viel größer macht, als die Wahrscheinlichkeit für das Quant, vom Kern absorbiert zu werden und eine Kernreaktion auszulösen.

Erst durch die Entdeckung des Neutrons als eines Teilchens, das keine elektromagnetische Wechselwirkung mit den Elektronen der Atomhülle hat, war daher prinzipiell die Möglichkeit einer Kern-Kettenreaktion gegeben, denn ein Neutron kann im wesentlichen seine Energie nur durch Kerntreffer verlieren. Der Verfasser hat schon im Jahre 1932 in seiner Antrittsvorlesung an der Technischen Hochschule Berlin auf diese prinzipielle Möglichkeit hingewiesen und die Bedingung für die Bildung einer Kern-Kettenreaktion angegeben. Diese besteht darin, daß eine Kern-Kettenreaktion eintreten muß, sobald eine Reaktion bekannt ist, bei der mit der Wahrscheinlichkeit 1 an einem Kern durch ein Neutron ein weiteres Neutron ausgelöst wird, dessen Energie seinerseits imstande ist, an einem anderen Kern wieder ein Neutron auszulösen. Durch die Entdeckung der Spaltung schwerer Elemente durch Neutronen (Hahn und Strassmann 1938) ist nun bekanntlich inzwischen ein solcher Reaktionsmechanismus tatsächlich gefunden worden. Wesentlich ist hierbei nicht die Tatsache der sehr hohen freiwerdenden Reaktionsenergie in Höhe von etwa 180 MeV, sondern daß bei diesem Prozess neben den beiden großen Kerntrümmern, in die das schwere Atom aufspaltet, noch einige freie Neutronen entstehen, die ihrerseits wieder eine Kernspaltung hervorrufen können. Die Frage der Ausnutzung eines solchen Prozesses zur Auslösung von Kern-Kettenreaktionen ist also lediglich eine Frage möglichst maximaler Ausnutzung der entstehenden Neutronen. Der Verfasser hat im Zusammenhung mit anderen Problemstellungen, noch bevor die Kernspaltung bekannt war, eine Anzahl Überlegungen und Experimente angestellt, die als Ziel eine möglichst vollständige Ausnutzung entstehender Neutronen zugunsten einer bestimmten Kernreaktion gehabt haben. In vorliegender Mitteilung sollen diese Überlegungen speziell auf die Kernspaltung angewendet und verschiedene aus ihnen folgenden Möglichkeiten diskutiert werden.

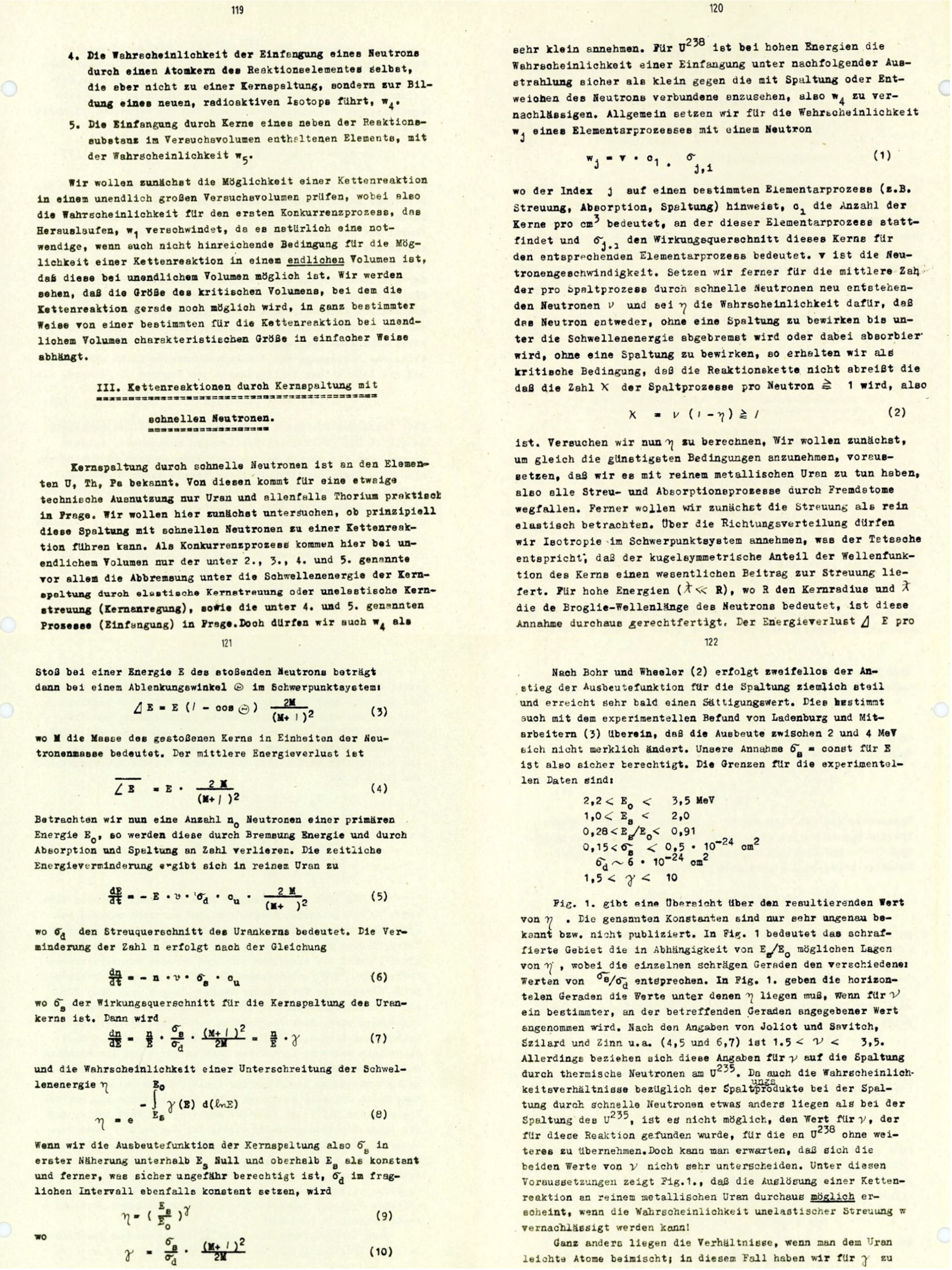
Kernspaltung wurde bisher bekanntlich an den Atomkernen U^{238}, U^{235}, Th^{232}, Pa^{231} und Jo^{230} beobachtet. Kernspaltung kann durch geladene Teilchen (Protonen oder Deuteronen) einer Energie von etwa 5-6 MeV, γ-Quanten einer Energie der gleichen Größenordnung und durch Neutronen ausgelöst werden. Nach dem oben Gesagten kommt für die Auslösung einer Kettenreaktion nur der letztgenannte Mechanismus, die Kernspaltung durch Neutronen in Frage. Die Zahl ν der bei jeder Kernspaltung frei werdenden Neutronen beträgt etwa 2 - 4. Die Auslösung einer Kettenreaktion hat jedoch zur Voraussetzung, daß alle Konkurrenzprozesse, durch die ein einmal entstandenes Neutron verloren gehen kann, ohne seinerseits eine Kernspaltung hervorzurufen, in hinreichendem Maße ausgeschaltet werden können.

II. Die Konkurrenzprozesse.

Es ist daher nötig, alle diese Konkurrenzprozesse und ihre Wahrscheinlichkeiten im einzelnen zu diskutieren. Die Konkurrenzprozesse, die zum Verlust eines Neutrons führen, ohne eine Kernspaltung zu bewirken, sind:

1. Das Herauslaufen eines Neutrons aus dem Versuchsvolumen, in dem die Kernspaltung hervorgerufen werden kann. Die Wahrscheinlichkeit hierfür soll mit w_1 bezeichnet werden.
2. Die Abbremsung eines Neutrons durch elastische Stöße, die zu einem solchen Energieverlust führt, daß die Energie nicht mehr ausreicht, um eine Kernspaltung zu bewirken; Wahrscheinlichkeit w_2.
3. Die Wahrscheinlichkeit eines solchen Energieverlustes eines Neutrons durch unelastische Stöße, w_3

Figure D.349: The August 1941 report by Fritz Houtermans (working in collaboration with Manfred von Ardenne) explaining the feasibility of breeding plutonium-239 and using it to make fission bombs. [G-94].



4. Die Wahrscheinlichkeit der Einfangung eines Neutrons durch einen Atomkern des Reaktionselementes selbst, die aber nicht zu einer Kernspaltung, sondern zur Bildung eines neuen, radioaktiven Isotops führt, w_4.
5. Die Einfangung durch Kerne eines neben der Reaktionssubstanz im Versuchsvolumen enthaltenen Elements, mit der Wahrscheinlichkeit w_5.

Wir wollen zunächst die Möglichkeit einer Kettenreaktion in einem unendlich großen Versuchsvolumen prüfen, wobei also die Wahrscheinlichkeit für den ersten Konkurrenzprozess, das Herauslaufen, w_1 verschwindet, da es natürlich eine notwendige, wenn auch nicht hinreichende Bedingung für die Möglichkeit einer Kettenreaktion in einem endlichen Volumen ist, daß diese bei unendlichem Volumen möglich ist. Wir werden sehen, daß die Größe des kritischen Volumens, bei dem die Kettenreaktion gerade noch möglich wird, in ganz bestimmter Weise von einer bestimmten für die Kettenreaktion bei unendlichem Volumen charakteristischen Größe in einfacher Weise abhängt.

III. Kettenreaktionen durch Kernspaltung mit schnellen Neutronen.

Kernspaltung durch schnelle Neutronen ist an den Elementen U, Th, Pa bekannt. Von diesen kommt für eine etwaige technische Ausnutzung nur Uran und allenfalls Thorium praktisch in Frage. Wir wollen hier zunächst untersuchen, ob prinzipiell diese Spaltung mit schnellen Neutronen zu einer Kettenreaktion führen kann. Als Konkurrenzprozess kommen hier bei unendlichem Volumen nur der unter 2., 3., 4. und 5. genannte vor allem die Abbremsung unter die Schwellenenergie der Kernspaltung durch elastische Kernstreuung oder unelastische Kernstreuung (Kernanregung), sowie die unter 4. und 5. genannten Prozesse (Einfangung) in Frage. Doch dürfen wir auch w_4 als sehr klein annehmen. Für U^{238} ist bei hohen Energien die Wahrscheinlichkeit einer Einfangung unter nachfolgender Ausstrahlung sicher als klein gegen die mit Spaltung oder Entweichen des Neutrons verbundene anzusehen, also w_4 zu vernachlässigen.

Allgemein setzen wir für die Wahrscheinlichkeit w_j eines Elementarprozesses mit einem Neutron

$$w_j = v \cdot c_1 . \sigma_{j,i} \qquad (1)$$

wo der Index j auf einen bestimmten Elementarprozess (z.B. Streuung, Absorption, Spaltung) hinweist, c_1 die Anzahl der Kerne pro cm^3 bedeutet, an der dieser Elementarprozess stattfindet und $\sigma_{j.1}$ den Wirkungsquerschnitt dieses Kerns für den entsprechenden Elementarprozess bedeutet. v ist die Neutronengeschwindigkeit. Setzen wir ferner für die mittlere Zahl der pro Spaltprozess durch schnelle Neutronen neu entstehenden Neutronen ν und sei η die Wahrscheinlichkeit dafür, daß das Neutron entweder, ohne eine Spaltung zu bewirken bis unter die Schwellenenergie abgebremst wird oder dabei absorbiert wird, ohne eine Spaltung zu bewirken, so erhalten wir als kritische Bedingung, daß die Reaktionskette nicht abreißt die daß die Zahl χ der Spaltprozesse pro Neutron $\geqq$ 1 wird, also

$$\chi = \nu (1 - \eta) \geqq 1 \qquad (2)$$

ist. Versuchen wir nun η zu berechnen, Wir wollen zunächst, um gleich die günstigsten Bedingungen anzunehmen, vorauszusetzen, daß wir es mit reinem metallischen Uran zu tun haben, also alle Streu- und Absorptionsprozesse durch Fremdatome wegfallen. Ferner wollen wir zunächst die Streuung als rein elastisch betrachten. Über die Richtungsverteilung dürfen wir Isotropie im Schwerpunktsystem annehmen, was der Tatsache entspricht, daß der kugelsymmetrische Anteil der Wellenfunktion des Kerns einen wesentlichen Beitrag zur Streuung liefert. Für hohe Energien ($\lambdabar \ll R$), wo R den Kernradius und $\lambdabar$ die de Broglie-Wellenlänge des Neutrons bedeutet, ist diese Annahme durchaus gerechtfertigt. Der Energieverlust ΔE pro Stoß bei einer Energie E des stoßenden Neutrons beträgt dann bei einem Ablenkungswinkel Θ im Schwerpunktsystem:

$$\Delta E = E\,(1 - \cos \Theta)\,\frac{2M}{(M+1)^2} \qquad (3)$$

wo M die Masse des gestoßenen Kerns in Einheiten der Neutronenmasse bedeutet. Der mittlere Energieverlust ist

$$\overline{\Delta E} = E \cdot \frac{2M}{(M+1)^2} \qquad (4)$$

Betrachten wir nun eine Anzahl n_o Neutronen einer primären Energie E_o, so werden diese durch Bremsung Energie und durch Absorption und Spaltung an Zahl verlieren. Die zeitliche Energieverminderung ergibt sich in reinem Uran zu

$$\frac{dE}{dt} = - E \cdot v \cdot \sigma_d \cdot c_u \cdot \frac{2M}{(M+\ )^2} \qquad (5)$$

wo σ_d den Streuquerschnitt des Urankerns bedeutet. Die Verminderung der Zahl n erfolgt nach der Gleichung

$$\frac{dn}{dt} = - n \cdot v \cdot \sigma_s \cdot c_u \qquad (6)$$

wo σ_s der Wirkungsquerschnitt für die Kernspaltung des Urankerns ist. Dann wird

$$\frac{dn}{dE} = \frac{n}{E} \cdot \frac{\sigma_s}{\sigma_d} \cdot \frac{(M+1)^2}{2M} = \frac{n}{E} \cdot \gamma \qquad (7)$$

und die Wahrscheinlichkeit einer Unterschreitung der Schwellenenergie η

$$\eta = e^{-\int_{E_s}^{E_o} \gamma(E)\, d(\ln E)} \qquad (8)$$

Wenn wir die Ausbeutefunktion der Kernspaltung also σ_s in erster Näherung unterhalb E_s Null und oberhalb E_s als konstant und ferner, was sicher ungefähr berechtigt ist, σ_d im fraglichen Intervall ebenfalls konstant setzen, wird

$$\eta = \left(\frac{E_s}{E_o}\right)^{\gamma} \qquad (9)$$

wo

$$\gamma = \frac{\sigma_s}{\sigma_d} \cdot \frac{(M+1)^2}{2M} \qquad (10)$$

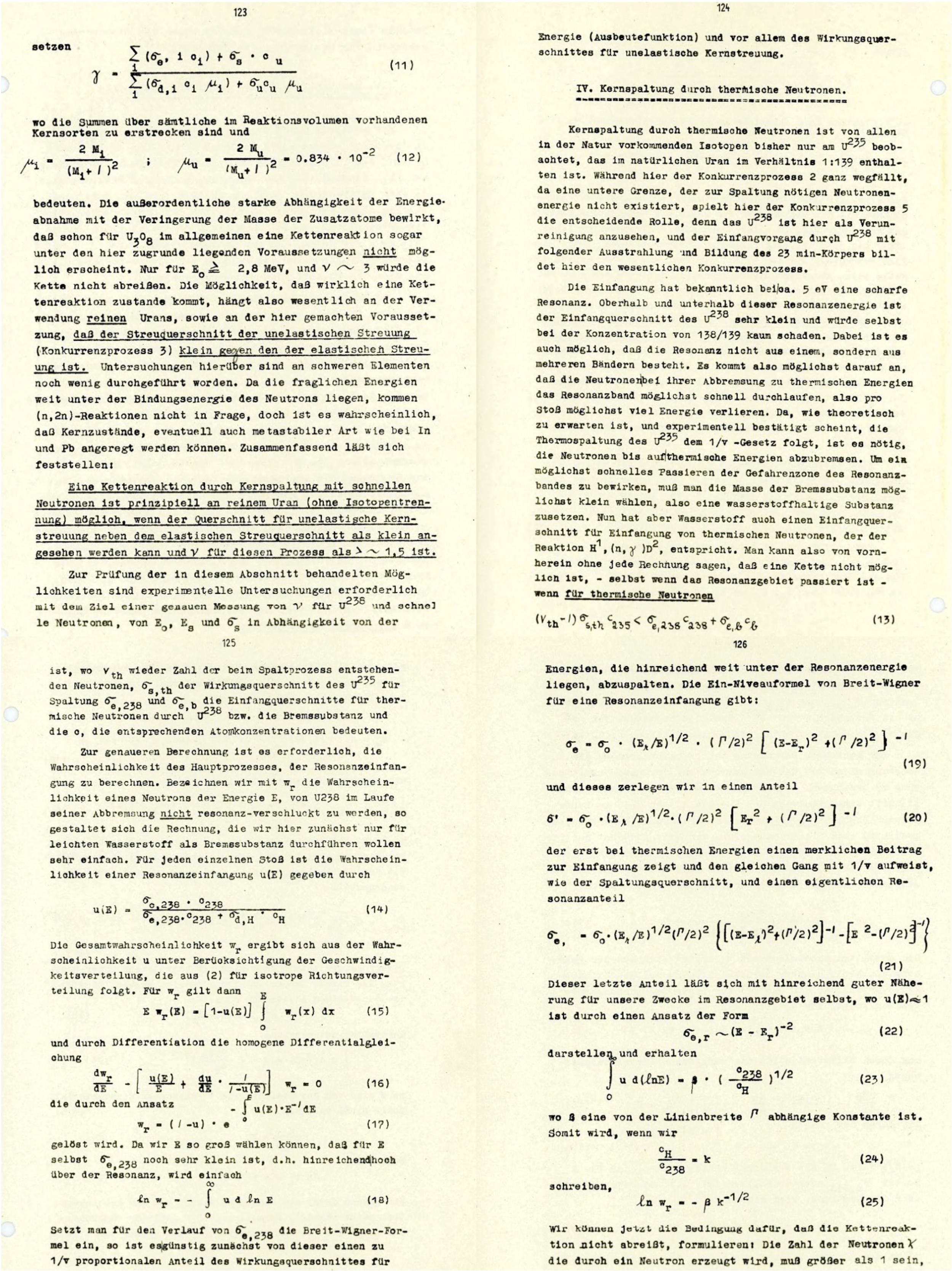
Nach Bohr und Wheeler (2) erfolgt zweifellos der Anstieg der Ausbeutefunktion für die Spaltung ziemlich steil und erreicht sehr bald einen Sättigungswert. Dies bestimmt auch mit dem experimentellen Befund von Ladenburg und Mitarbeitern (3) überein, daß die Ausbeute zwischen 2 und 4 MeV sich nicht merklich ändert. Unsere Annahme σ_s = const für E ist also sicher berechtigt. Die Grenzen für die experimentellen Daten sind:

$2{,}2 < E_o < 3{,}5$ MeV
$1{,}0 < E_s < 2{,}0$
$0{,}28 < E_s/E_o < 0{,}91$
$0{,}15 < \sigma_s < 0{,}5 \cdot 10^{-24}$ cm^2
$\sigma_d \sim 6 \cdot 10^{-24}$ cm^2
$1{,}5 < \gamma < 10$

Fig. 1. gibt eine Übersicht über den resultierenden Wert von η. Die genannten Konstanten sind nur sehr ungenau bekannt bzw. nicht publiziert. In Fig. 1 bedeutet das schraffierte Gebiet die in Abhängigkeit von E_s/E_o möglichen Lagen von η, wobei die einzelnen schrägen Geraden den verschiedenen Werten von σ_s/σ_d entsprechen. In Fig. 1. geben die horizontalen Geraden die Werte unter denen η liegen muß, wenn für ν ein bestimmter, an der betreffenden Geraden angegebener Wert angenommen wird. Nach den Angaben von Joliot und Savitch, Szilard und Zinn u.a. (4,5 und 6,7) ist $1.5 < \nu < 3{,}5$. Allerdings beziehen sich diese Angaben für ν auf die Spaltung durch thermische Neutronen am U^{235}. Da auch die Wahrscheinlichkeitsverhältnisse bezüglich der Spaltungsprodukte bei der Spaltung durch schnelle Neutronen etwas anders liegen als bei der Spaltung des U^{235}, ist es nicht möglich, den Wert für ν, der für diese Reaktion gefunden wurde, für die an U^{238} ohne weiteres zu übernehmen. Doch kann man erwarten, daß sich die beiden Werte von ν nicht sehr unterscheiden. Unter diesen Voraussetzungen zeigt Fig.1., daß die Auslösung einer Kettenreaktion an reinem metallischen Uran durchaus möglich erscheint, wenn die Wahrscheinlichkeit unelastischer Streuung w vernachlässigt werden kann!

Ganz anders liegen die Verhältnisse, wenn man dem Uran leichte Atome beimischt; in diesem Fall haben wir für γ zu

Figure D.350: The August 1941 report by Fritz Houtermans (working in collaboration with Manfred von Ardenne) explaining the feasibility of breeding plutonium-239 and using it to make fission bombs. [G-94].



setzen

$$\gamma = \frac{\sum_i (\sigma_{e,i}\, c_i) + \sigma_s \cdot c_u}{\sum_i (\sigma_{d,i}\, c_i\, \mu_i) + \sigma_u c_u\, \mu_u} \tag{11}$$

wo die Summen über sämtliche im Reaktionsvolumen vorhandenen Kernsorten zu erstrecken sind und

$$\mu_i = \frac{2\, M_i}{(M_i + 1)^2} \quad ; \quad \mu_u = \frac{2\, M_u}{(M_u + 1)^2} = 0.834 \cdot 10^{-2} \tag{12}$$

bedeuten. Die außerordentliche starke Abhängigkeit der Energieabnahme mit der Veringerung der Masse der Zusatzatome bewirkt, daß schon für U_3O_8 im allgemeinen eine Kettenreaktion sogar unter den hier zugrunde liegenden Voraussetzungen nicht möglich erscheint. Nur für $E_o \geqq$ 2,8 MeV, und $\nu \sim 3$ würde die Kette nicht abreißen. Die Möglichkeit, daß wirklich eine Kettenreaktion zustande kommt, hängt also wesentlich an der Verwendung reinen Urans, sowie an der hier gemachten Voraussetzung, daß der Streuquerschnitt der unelastischen Streuung (Konkurrenzprozess 3) klein gegen den der elastischen Streuung ist. Untersuchungen hierüber sind an schweren Elementen noch wenig durchgeführt worden. Da die fraglichen Energien weit unter der Bindungsenergie des Neutrons liegen, kommen (n,2n)-Reaktionen nicht in Frage, doch ist es wahrscheinlich, daß Kernzustände, eventuell auch metastabiler Art wie bei In und Pb angeregt werden können. Zusammenfassend läßt sich feststellen:

Eine Kettenreaktion durch Kernspaltung mit schnellen Neutronen ist prinzipiell an reinem Uran (ohne Isotopentrennung) möglich, wenn der Querschnitt für unelastische Kernstreuung neben dem elastischen Streuquerschnitt als klein angesehen werden kann und ν für diesen Prozess als $\lambda \sim 1,5$ ist.

Zur Prüfung der in diesem Abschnitt behandelten Möglichkeiten sind experimentelle Untersuchungen erforderlich mit dem Ziel einer genauen Messung von ν für U^{238} und schnelle Neutronen, von E_o, E_s und σ_s in Abhängigkeit von der

Energie (Ausbeutefunktion) und vor allem des Wirkungsquerschnittes für unelastische Kernstreuung.

IV. Kernspaltung durch thermische Neutronen.

Kernspaltung durch thermische Neutronen ist von allen in der Natur vorkommenden Isotopen bisher nur am U^{235} beobachtet, das im natürlichen Uran im Verhältnis 1:139 enthalten ist. Während hier der Konkurrenzprozess 2 ganz wegfällt, da eine untere Grenze, der zur Spaltung nötigen Neutronenenergie nicht existiert, spielt hier der Konkurrenzprozess 5 die entscheidende Rolle, denn das U^{238} ist hier als Verunreinigung anzusehen, und der Einfangvorgang durch U^{238} mit folgender Ausstrahlung und Bildung des 23 min-Körpers bildet hier den wesentlichen Konkurrenzprozess.

Die Einfangung hat bekanntlich bei ca. 5 eV eine scharfe Resonanz. Oberhalb und unterhalb dieser Resonanzenergie ist der Einfangquerschnitt des U^{238} sehr klein und würde selbst bei der Konzentration von 138/139 kaum schaden. Dabei ist es auch möglich, daß die Resonanz nicht aus einem, sondern aus mehreren Bändern besteht. Es kommt also möglichst darauf an, daß die Neutronen bei ihrer Abbremsung zu thermischen Energien das Resonanzband möglichst schnell durchlaufen, also pro Stoß möglichst viel Energie verlieren. Da, wie theoretisch zu erwarten ist, und experimentell bestätigt scheint, die Thermospaltung des U^{235} dem 1/v -Gesetz folgt, ist es nötig, die Neutronen bis auf thermische Energien abzubremsen. Um ein möglichst schnelles Passieren der Gefahrenzone des Resonanzbandes zu bewirken, muß man die Masse der Bremssubstanz möglichst klein wählen, also eine wasserstoffhaltige Substanz zusetzen. Nun hat aber Wasserstoff auch einen Einfangquerschnitt für Einfangung von thermischen Neutronen, der der Reaktion $H^1, (n, \gamma) D^2$, entspricht. Man kann also von vornherein ohne jede Rechnung sagen, daß eine Kette nicht möglich ist, - selbst wenn das Resonanzgebiet passiert ist - wenn für thermische Neutronen

$$(\nu_{th} - 1)\, \sigma_{s,th}\, c_{235} < \sigma_{e,238}\, c_{238} + \sigma_{e,b}\, c_b \tag{13}$$

ist, wo ν_{th} wieder Zahl der beim Spaltprozess entstehenden Neutronen, $\sigma_{s,th}$ der Wirkungsquerschnitt des U^{235} für Spaltung $\sigma_{e,238}$ und $\sigma_{e,b}$ die Einfangquerschnitte für thermische Neutronen durch U^{238} bzw. die Bremssubstanz und die c, die entsprechenden Atomkonzentrationen bedeuten.

Zur genaueren Berechnung ist es erforderlich, die Wahrscheinlichkeit des Hauptprozesses, der Resonanzeinfangung zu berechnen. Bezeichnen wir mit w_r die Wahrscheinlichkeit eines Neutrons der Energie E, von U238 im Laufe seiner Abbremsung nicht resonanz-verschluckt zu werden, so gestaltet sich die Rechnung, die wir hier zunächst nur für leichten Wasserstoff als Bremssubstanz durchführen wollen sehr einfach. Für jeden einzelnen Stoß ist die Wahrscheinlichkeit einer Resonanzeinfangung u(E) gegeben durch

$$u(E) = \frac{\sigma_{c,238} \cdot c_{238}}{\sigma_{e,238} \cdot c_{238} + \sigma_{d,H} \cdot c_H} \tag{14}$$

Die Gesamtwahrscheinlichkeit w_r ergibt sich aus der Wahrscheinlichkeit u unter Berücksichtigung der Geschwindigkeitsverteilung, die aus (2) für isotrope Richtungsverteilung folgt. Für w_r gilt dann

$$E\, w_r(E) = \left[1 - u(E)\right] \int_0^E w_r(x)\, dx \tag{15}$$

und durch Differentiation die homogene Differentialgleichung

$$\frac{dw_r}{dE} - \left[\frac{u(E)}{E} + \frac{du}{dE} \cdot \frac{1}{1 - u(E)} \right] w_r = 0 \tag{16}$$

die durch den Ansatz

$$w_r = (1 - u) \cdot e^{-\int_0^E u(E) \cdot E^{-1} dE} \tag{17}$$

gelöst wird. Da wir E so groß wählen können, daß für E selbst $\sigma_{e,238}$ noch sehr klein ist, d.h. hinreichend hoch über der Resonanz, wird einfach

$$\ln w_r = - \int_0^\infty u \, d \ln E \tag{18}$$

Setzt man für den Verlauf von $\sigma_{e,238}$ die Breit-Wigner-Formel ein, so ist es günstig zunächst von dieser einen zu 1/v proportionalen Anteil des Wirkungsquerschnittes für

Energien, die hinreichend weit unter der Resonanzenergie liegen, abzuspalten. Die Ein-Niveauformel von Breit-Wigner für eine Resonanzeinfangung gibt:

$$\sigma_e = \sigma_o \cdot (E_\lambda / E)^{1/2} \cdot (\Gamma/2)^2 \left[(E - E_r)^2 + (\Gamma/2)^2 \right\}^{-1} \tag{19}$$

und dieses zerlegen wir in einen Anteil

$$\sigma' = \sigma_o \cdot (E_\lambda / E)^{1/2} \cdot (\Gamma/2)^2 \left[E_r^2 + (\Gamma/2)^2 \right]^{-1} \tag{20}$$

der erst bei thermischen Energien einen merklichen Beitrag zur Einfangung zeigt und den gleichen Gang mit 1/v aufweist, wie der Spaltungsquerschnitt, und einen eigentlichen Resonanzanteil

$$\sigma_{e,} = \sigma_o \cdot (E_\lambda / E)^{1/2} (\Gamma/2)^2 \left\{ \left[(E - E_\lambda)^2 + (\Gamma/2)^2 \right]^{-1} - \left[E^2 - (\Gamma/2)^2 \right]^{-1} \right\} \tag{21}$$

Dieser letzte Anteil läßt sich mit hinreichend guter Näherung für unsere Zwecke im Resonanzgebiet selbst, wo $u(E) \approx 1$ ist durch einen Ansatz der Form

$$\sigma_{e,r} \sim (E - E_r)^{-2} \tag{22}$$

darstellen und erhalten

$$\int_0^\infty u \, d(\ln E) = \beta \cdot \left(\frac{c_{238}}{c_H} \right)^{1/2} \tag{23}$$

wo β eine von der Linienbreite Γ abhängige Konstante ist. Somit wird, wenn wir

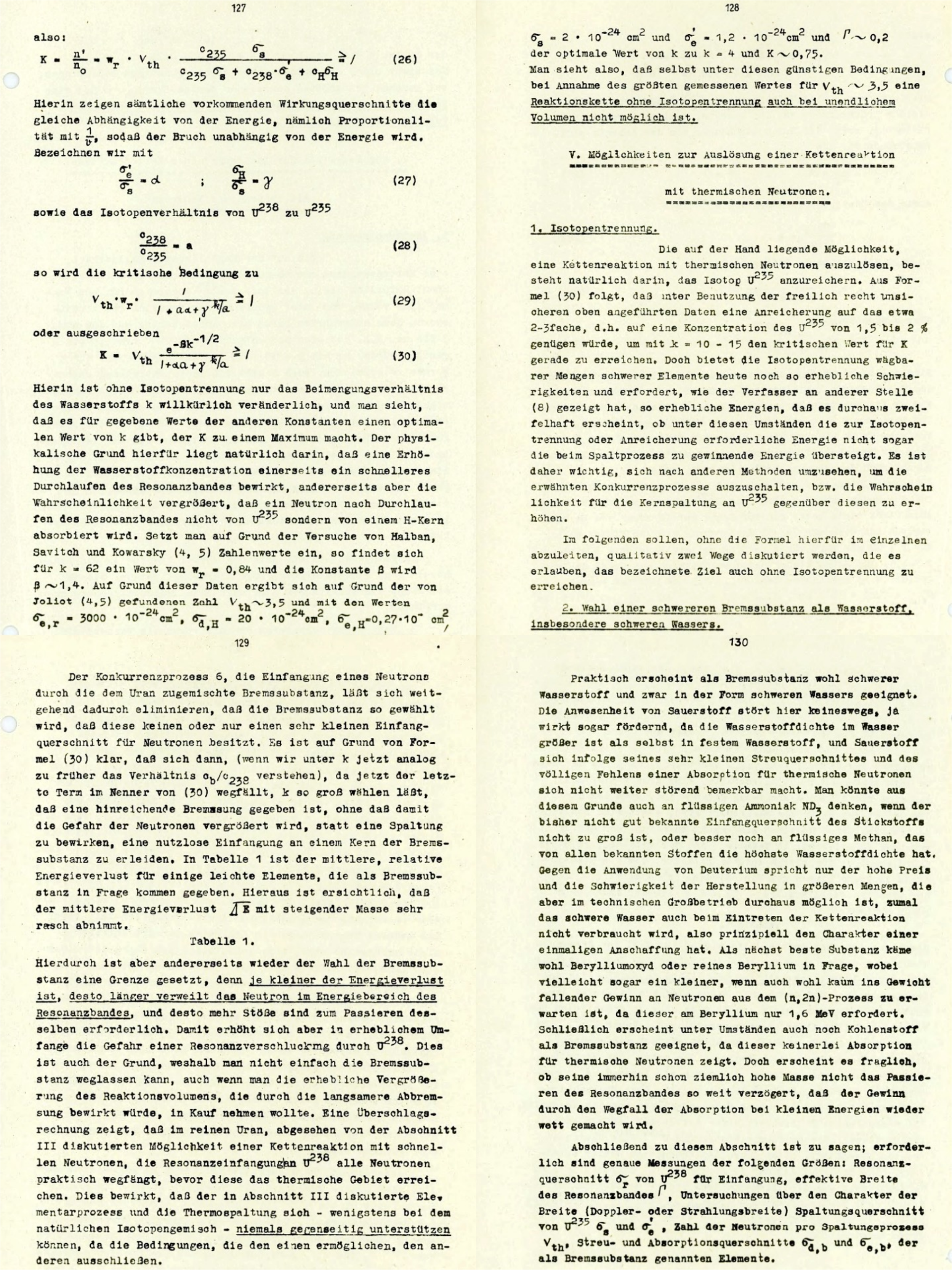
$$\frac{c_H}{c_{238}} = k \tag{24}$$

schreiben,

$$\ln w_r = - \beta\, k^{-1/2} \tag{25}$$

Wir können jetzt die Bedingung dafür, daß die Kettenreaktion nicht abreißt, formulieren: Die Zahl der Neutronen χ die durch ein Neutron erzeugt wird, muß größer als 1 sein,

Figure D.351: The August 1941 report by Fritz Houtermans (working in collaboration with Manfred von Ardenne) explaining the feasibility of breeding plutonium-239 and using it to make fission bombs. [G-94].



also:

$$K = \frac{n'}{n_o} = w_r \cdot \nu_{th} \cdot \frac{c_{235}\,\sigma_s}{c_{235}\,\sigma_s + c_{238} \cdot \sigma'_e + c_H \sigma_H} \geqq 1 \qquad (26)$$

Hierin zeigen sämtliche vorkommenden Wirkungsquerschnitte die gleiche Abhängigkeit von der Energie, nämlich Proportionalität mit $\frac{1}{v}$, sodaß der Bruch unabhängig von der Energie wird. Bezeichnen wir mit

$$\frac{\sigma'_e}{\sigma_s} = \alpha \quad ; \quad \frac{\sigma_H}{\sigma_s} = \gamma \qquad (27)$$

sowie das Isotopenverhältnis von U^{238} zu U^{235}

$$\frac{c_{238}}{c_{235}} = a \qquad (28)$$

so wird die kritische Bedingung zu

$$\nu_{th} \cdot w_r \cdot \frac{1}{1 + a\alpha + \gamma\, k/a} \geqq 1 \qquad (29)$$

oder ausgeschrieben

$$K = \nu_{th} \frac{e^{-\beta k^{-1/2}}}{1 + \alpha a + \gamma\, k/a} \geqq 1 \qquad (30)$$

Hierin ist ohne Isotopentrennung nur das Beimengungsverhältnis des Wasserstoffs k willkürlich veränderlich, und man sieht, daß es für gegebene Werte der anderen Konstanten einen optimalen Wert von k gibt, der K zu einem Maximum macht. Der physikalische Grund hierfür liegt natürlich darin, daß eine Erhöhung der Wasserstoffkonzentration einerseits ein schnelleres Durchlaufen des Resonanzbandes bewirkt, andererseits aber die Wahrscheinlichkeit vergrößert, daß ein Neutron nach Durchlaufen des Resonanzbandes nicht von U^{235} sondern von einem H-Kern absorbiert wird. Setzt man auf Grund der Versuche von Halban, Savitch und Kowarsky (4, 5) Zahlenwerte ein, so findet sich für k = 62 ein Wert von $w_r = 0{,}84$ und die Konstante β wird $\beta \sim 1{,}4$. Auf Grund dieser Daten ergibt sich auf Grund der von Joliot (4,5) gefundenen Zahl $\nu_{th} \sim 3{,}5$ und mit den Werten $\sigma_{e,r} = 3000 \cdot 10^{-24}\,\mathrm{cm}^2$, $\sigma_{d,H} = 20 \cdot 10^{-24}\,\mathrm{cm}^2$, $\sigma_{e,H} = 0{,}27 \cdot 10^{-}\ \mathrm{cm}^2$,

$\sigma_s = 2 \cdot 10^{-24}\ \mathrm{cm}^2$ und $\sigma'_e = 1{,}2 \cdot 10^{-24}\mathrm{cm}^2$ und $\Gamma \sim 0{,}2$ der optimale Wert von k zu k = 4 und $K \sim 0{,}75$.
Man sieht also, daß selbst unter diesen günstigen Bedingungen, bei Annahme des größten gemessenen Wertes für $\nu_{th} \sim 3{,}5$ eine Reaktionskette ohne Isotopentrennung auch bei unendlichem Volumen nicht möglich ist.

V. Möglichkeiten zur Auslösung einer Kettenreaktion mit thermischen Neutronen.

1. Isotopentrennung.

Die auf der Hand liegende Möglichkeit, eine Kettenreaktion mit thermischen Neutronen auszulösen, besteht natürlich darin, das Isotop U^{235} anzureichern. Aus Formel (30) folgt, daß unter Benutzung der freilich recht unsicheren oben angeführten Daten eine Anreicherung auf das etwa 2-3fache, d.h. auf eine Konzentration des U^{235} von 1,5 bis 2 % genügen würde, um mit k = 10 - 15 den kritischen Wert für K gerade zu erreichen. Doch bietet die Isotopentrennung wägbarer Mengen schwerer Elemente heute noch so erhebliche Schwierigkeiten und erfordert, wie der Verfasser an anderer Stelle (8) gezeigt hat, so erhebliche Energien, daß es durchaus zweifelhaft erscheint, ob unter diesen Umständen die zur Isotopentrennung oder Anreicherung erforderliche Energie nicht sogar die beim Spaltprozess zu gewinnende Energie übersteigt. Es ist daher wichtig, sich nach anderen Methoden umzusehen, um die erwähnten Konkurrenzprozesse auszuschalten, bzw. die Wahrscheinlichkeit für die Kernspaltung an U^{235} gegenüber diesen zu erhöhen.

Im folgenden sollen, ohne die Formel hierfür im einzelnen abzuleiten, qualitativ zwei Wege diskutiert werden, die es erlauben, das bezeichnete Ziel auch ohne Isotopentrennung zu erreichen.

2. Wahl einer schwereren Bremssubstanz als Wasserstoff, insbesondere schweren Wassers.

Der Konkurrenzprozess 6, die Einfangung eines Neutrons durch die dem Uran zugemischte Bremssubstanz, läßt sich weitgehend dadurch eliminieren, daß die Bremssubstanz so gewählt wird, daß diese keinen oder nur einen sehr kleinen Einfangquerschnitt für Neutronen besitzt. Es ist auf Grund von Formel (30) klar, daß sich dann, (wenn wir unter k jetzt analog zu früher das Verhältnis c_b/c_{238} verstehen), da jetzt der letzte Term im Nenner von (30) wegfällt, k so groß wählen läßt, daß eine hinreichende Bremsung gegeben ist, ohne daß damit die Gefahr der Neutronen vergrößert wird, statt eine Spaltung zu bewirken, eine nutzlose Einfangung an einem Kern der Bremssubstanz zu erleiden. In Tabelle 1 ist der mittlere, relative Energieverlust für einige leichte Elemente, die als Bremssubstanz in Frage kommen gegeben. Hieraus ist ersichtlich, daß der mittlere Energieverlust ΔE mit steigender Masse sehr rasch abnimmt.

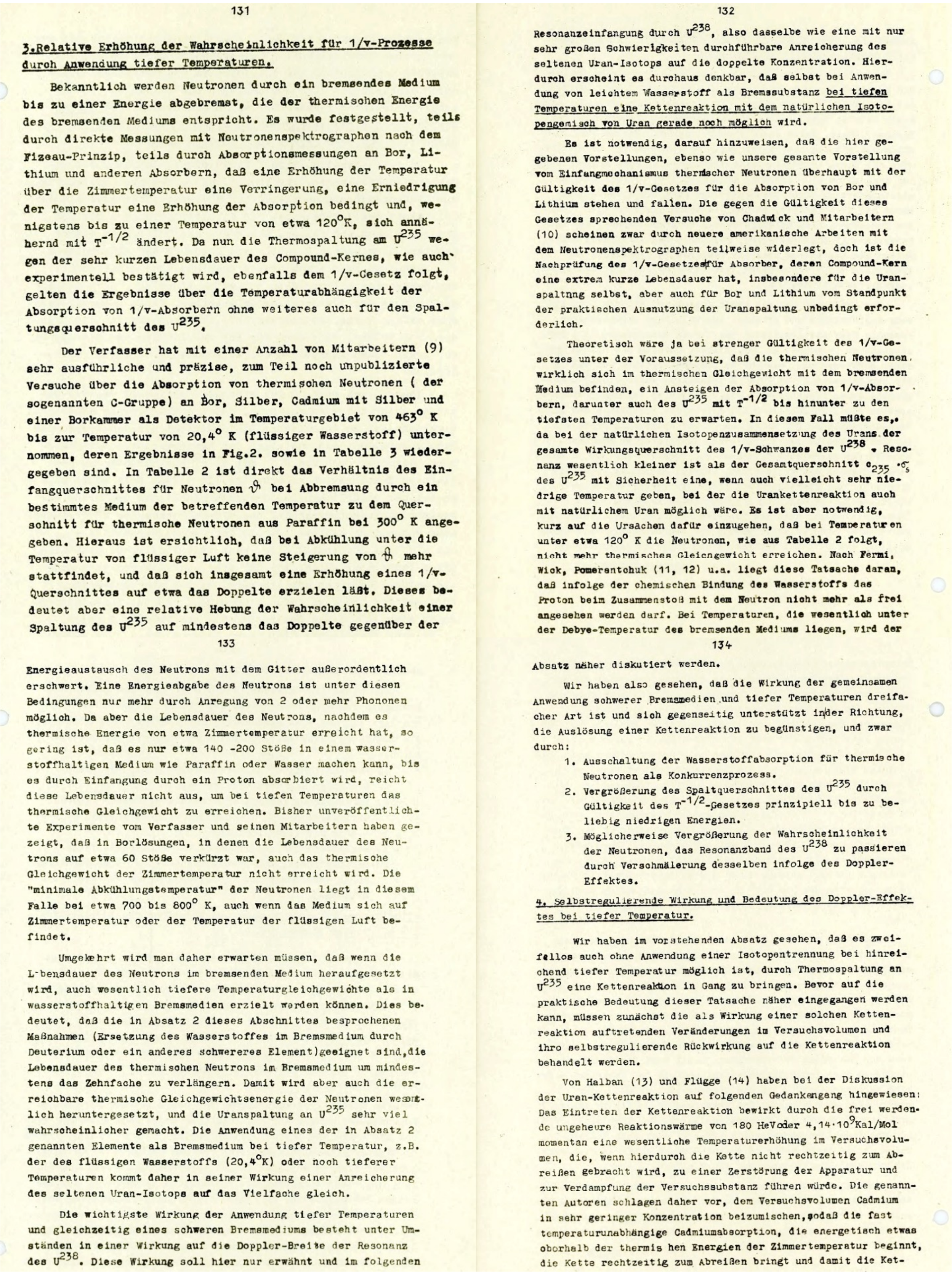
Tabelle 1.

Hierdurch ist aber andererseits wieder der Wahl der Bremssubstanz eine Grenze gesetzt, denn je kleiner der Energieverlust ist, desto länger verweilt das Neutron im Energiebereich des Resonanzbandes, und desto mehr Stöße sind zum Passieren desselben erforderlich. Damit erhöht sich aber in erheblichem Umfange die Gefahr einer Resonanzverschluckung durch U^{238}. Dies ist auch der Grund, weshalb man nicht einfach die Bremssubstanz weglassen kann, auch wenn man die erhebliche Vergrößerung des Reaktionsvolumens, die durch die langsamere Abbremsung bewirkt würde, in Kauf nehmen wollte. Eine Überschlagsrechnung zeigt, daß im reinen Uran, abgesehen von der Abschnitt III diskutierten Möglichkeit einer Kettenreaktion mit schnellen Neutronen, die Resonanzeinfangung an U^{238} alle Neutronen praktisch wegfängt, bevor diese das thermische Gebiet erreichen. Dies bewirkt, daß der in Abschnitt III diskutierte Elementarprozess und die Thermospaltung sich - wenigstens bei dem natürlichen Isotopengemisch - niemals gegenseitig unterstützen können, da die Bedingungen, die den einen ermöglichen, den anderen ausschließen.

Praktisch erscheint als Bremssubstanz wohl schwerer Wasserstoff und zwar in der Form schweren Wassers geeignet. Die Anwesenheit von Sauerstoff stört hier keineswegs, ja wirkt sogar fördernd, da die Wasserstoffdichte im Wasser größer ist als selbst in festem Wasserstoff, und Sauerstoff sich infolge seines sehr kleinen Streuquerschnittes und des völligen Fehlens einer Absorption für thermische Neutronen sich nicht weiter störend bemerkbar macht. Man könnte aus diesem Grunde auch an flüssigen Ammoniak ND_3 denken, wenn der bisher nicht gut bekannte Einfangquerschnitt des Stickstoffs nicht zu groß ist, oder besser noch an flüssiges Methan, das von allen bekannten Stoffen die höchste Wasserstoffdichte hat. Gegen die Anwendung von Deuterium spricht nur der hohe Preis und die Schwierigkeit der Herstellung in größeren Mengen, die aber im technischen Großbetrieb durchaus möglich ist, zumal das schwere Wasser auch beim Eintreten der Kettenreaktion nicht verbraucht wird, also prinzipiell den Charakter einer einmaligen Anschaffung hat. Als nächst beste Substanz käme wohl Berylliumoxyd oder reines Beryllium in Frage, wobei vielleicht sogar ein kleiner, wenn auch wohl kaum ins Gewicht fallender Gewinn an Neutronen aus dem (n,2n)-Prozess zu erwarten ist, da dieser am Beryllium nur 1,6 MeV erfordert. Schließlich erscheint unter Umständen auch noch Kohlenstoff als Bremssubstanz geeignet, da dieser keinerlei Absorption für thermische Neutronen zeigt. Doch erscheint es fraglich, ob seine immerhin schon ziemlich hohe Masse nicht das Passieren des Resonanzbandes so weit verzögert, daß der Gewinn durch den Wegfall der Absorption bei kleinen Energien wieder wett gemacht wird.

Abschließend zu diesem Abschnitt ist zu sagen; erforderlich sind genaue Messungen der folgenden Größen: Resonanzquerschnitt σ_r von U^{238} für Einfangung, effektive Breite des Resonanzbandes Γ, Untersuchungen über den Charakter der Breite (Doppler- oder Strahlungsbreite) Spaltungsquerschnitt von U^{235} σ_s und σ'_e, Zahl der Neutronen pro Spaltungsprozess ν_{th}, Streu- und Absorptionsquerschnitte $\sigma_{d,b}$ und $\sigma_{e,b}$, der als Bremssubstanz genannten Elemente.

Figure D.352: The August 1941 report by Fritz Houtermans (working in collaboration with Manfred von Ardenne) explaining the feasibility of breeding plutonium-239 and using it to make fission bombs. [G-94].



3.Relative Erhöhung der Wahrscheinlichkeit für 1/v-Prozesse durch Anwendung tiefer Temperaturen.

Bekanntlich werden Neutronen durch ein bremsendes Medium bis zu einer Energie abgebremst, die der thermischen Energie des bremsenden Mediums entspricht. Es wurde festgestellt, teils durch direkte Messungen mit Neutronenspektrographen nach dem Fizeau-Prinzip, teils durch Absorptionsmessungen an Bor, Lithium und anderen Absorbern, daß eine Erhöhung der Temperatur über die Zimmertemperatur eine Verringerung, eine Erniedrigung der Temperatur eine Erhöhung der Absorption bedingt und, wenigstens bis zu einer Temperatur von etwa 120°K, sich annähernd mit $T^{-1/2}$ ändert. Da nun die Thermospaltung am U^{235} wegen der sehr kurzen Lebensdauer des Compound-Kernes, wie auch experimentell bestätigt wird, ebenfalls dem 1/v-Gesetz folgt, gelten die Ergebnisse über die Temperaturabhängigkeit der Absorption von 1/v-Absorbern ohne weiteres auch für den Spaltungsquerschnitt des U^{235}.

Der Verfasser hat mit einer Anzahl von Mitarbeitern (9) sehr ausführliche und präzise, zum Teil noch unpublizierte Versuche über die Absorption von thermischen Neutronen (der sogenannten C-Gruppe) an Bor, Silber, Cadmium mit Silber und einer Borkammer als Detektor im Temperaturgebiet von 463° K bis zur Temperatur von 20,4° K (flüssiger Wasserstoff) unternommen, deren Ergebnisse in Fig.2. sowie in Tabelle 3 wiedergegeben sind. In Tabelle 2 ist direkt das Verhältnis des Einfangquerschnittes für Neutronen ϑ bei Abbremsung durch ein bestimmtes Medium der betreffenden Temperatur zu dem Querschnitt für thermische Neutronen aus Paraffin bei 300° K angegeben. Hieraus ist ersichtlich, daß bei Abkühlung unter die Temperatur von flüssiger Luft keine Steigerung von ϑ mehr stattfindet, und daß sich insgesamt eine Erhöhung eines 1/v-Querschnittes auf etwa das Doppelte erzielen läßt. Dieses bedeutet aber eine relative Hebung der Wahrscheinlichkeit einer Spaltung des U^{235} auf mindestens das Doppelte gegenüber der Resonanzeinfangung durch U^{238}, also dasselbe wie eine mit nur sehr großen Schwierigkeiten durchführbare Anreicherung des seltenen Uran-Isotops auf die doppelte Konzentration. Hierdurch erscheint es durchaus denkbar, daß selbst bei Anwendung von leichtem Wasserstoff als Bremssubstanz bei tiefen Temperaturen eine Kettenreaktion mit dem natürlichen Isotopengemisch von Uran gerade noch möglich wird.

Es ist notwendig, darauf hinzuweisen, daß die hier gegebenen Vorstellungen, ebenso wie unsere gesamte Vorstellung vom Einfangmechanismus thermischer Neutronen überhaupt mit der Gültigkeit des 1/v-Gesetzes für die Absorption von Bor und Lithium stehen und fallen. Die gegen die Gültigkeit dieses Gesetzes sprechenden Versuche von Chadwick und Mitarbeitern (10) scheinen zwar durch neuere amerikanische Arbeiten mit dem Neutronenspektrographen teilweise widerlegt, doch ist die Nachprüfung des 1/v-Gesetzes für Absorber, deren Compound-Kern eine extrem kurze Lebensdauer hat, insbesondere für die Uranspaltung selbst, aber auch für Bor und Lithium vom Standpunkt der praktischen Ausnutzung der Uranspaltung unbedingt erforderlich.

Theoretisch wäre ja bei strenger Gültigkeit des 1/v-Gesetzes unter der Voraussetzung, daß die thermischen Neutronen wirklich sich im thermischen Gleichgewicht mit dem bremsenden Medium befinden, ein Ansteigen der Absorption von 1/v-Absorbern, darunter auch des U^{235} mit $T^{-1/2}$ bis hinunter zu den tiefsten Temperaturen zu erwarten. In diesem Fall müßte es, da bei der natürlichen Isotopenzusammensetzung des Urans der gesamte Wirkungsquerschnitt des 1/v-Schwanzes der U^{238} - Resonanz wesentlich kleiner ist als der Gesamtquerschnitt $\sigma_{235} \cdot \sigma_s$ des U^{235} mit Sicherheit eine, wenn auch vielleicht sehr niedrige Temperatur geben, bei der die Urankettenreaktion auch mit natürlichem Uran möglich wäre. Es ist aber notwendig, kurz auf die Ursachen dafür einzugehen, daß bei Temperaturen unter etwa 120° K die Neutronen, wie aus Tabelle 2 folgt, nicht mehr thermisches Gleichgewicht erreichen. Nach Fermi, Wick, Pomerantchuk (11, 12) u.a. liegt diese Tatsache daran, daß infolge der chemischen Bindung des Wasserstoffs das Proton beim Zusammenstoß mit dem Neutron nicht mehr als frei angesehen werden darf. Bei Temperaturen, die wesentlich unter der Debye-Temperatur des bremsenden Mediums liegen, wird der Energieaustausch des Neutrons mit dem Gitter außerordentlich erschwert. Eine Energieabgabe des Neutrons ist unter diesen Bedingungen nur mehr durch Anregung von 2 oder mehr Phononen möglich. Da aber die Lebensdauer des Neutrons, nachdem es thermische Energie von etwa Zimmertemperatur erreicht hat, so gering ist, daß es nur etwa 140 -200 Stöße in einem wasserstoffhaltigen Medium wie Paraffin oder Wasser machen kann, bis es durch Einfangung durch ein Proton absorbiert wird, reicht diese Lebensdauer nicht aus, um bei tiefen Temperaturen das thermische Gleichgewicht zu erreichen. Bisher unveröffentlichte Experimente vom Verfasser und seinen Mitarbeitern haben gezeigt, daß in Borlösungen, in denen die Lebensdauer des Neutrons auf etwa 60 Stöße verkürzt war, auch das thermische Gleichgewicht der Zimmertemperatur nicht erreicht wird. Die "minimale Abkühlungstemperatur" der Neutronen liegt in diesem Falle bei etwa 700 bis 800° K, auch wenn das Medium sich auf Zimmertemperatur oder der Temperatur der flüssigen Luft befindet.

Umgekehrt wird man daher erwarten müssen, daß wenn die Lebensdauer des Neutrons im bremsenden Medium heraufgesetzt wird, auch wesentlich tiefere Temperaturgleichgewichte als in wasserstoffhaltigen Bremsmedien erzielt werden können. Dies bedeutet, daß die in Absatz 2 dieses Abschnittes besprochenen Maßnahmen (Ersetzung des Wasserstoffes im Bremsmedium durch Deuterium oder ein anderes schwereres Element)geeignet sind,die Lebensdauer des thermischen Neutrons im Bremsmedium um mindestens das Zehnfache zu verlängern. Damit wird aber auch die erreichbare thermische Gleichgewichtsenergie der Neutronen wesentlich heruntergesetzt, und die Uranspaltung an U^{235} sehr viel wahrscheinlicher gemacht. Die Anwendung eines der in Absatz 2 genannten Elemente als Bremsmedium bei tiefer Temperatur, z.B. der des flüssigen Wasserstoffs (20,4°K) oder noch tieferer Temperaturen kommt daher in seiner Wirkung einer Anreicherung des seltenen Uran-Isotops auf das Vielfache gleich.

Die wichtigste Wirkung der Anwendung tiefer Temperaturen und gleichzeitig eines schweren Bremsmediums besteht unter Umständen in einer Wirkung auf die Doppler-Breite der Resonanz des U^{238}. Diese Wirkung soll hier nur erwähnt und im folgenden Absatz näher diskutiert werden.

Wir haben also gesehen, daß die Wirkung der gemeinsamen Anwendung schwerer Bremsmedien und tiefer Temperaturen dreifacher Art ist und sich gegenseitig unterstützt in der Richtung, die Auslösung einer Kettenreaktion zu begünstigen, und zwar durch:

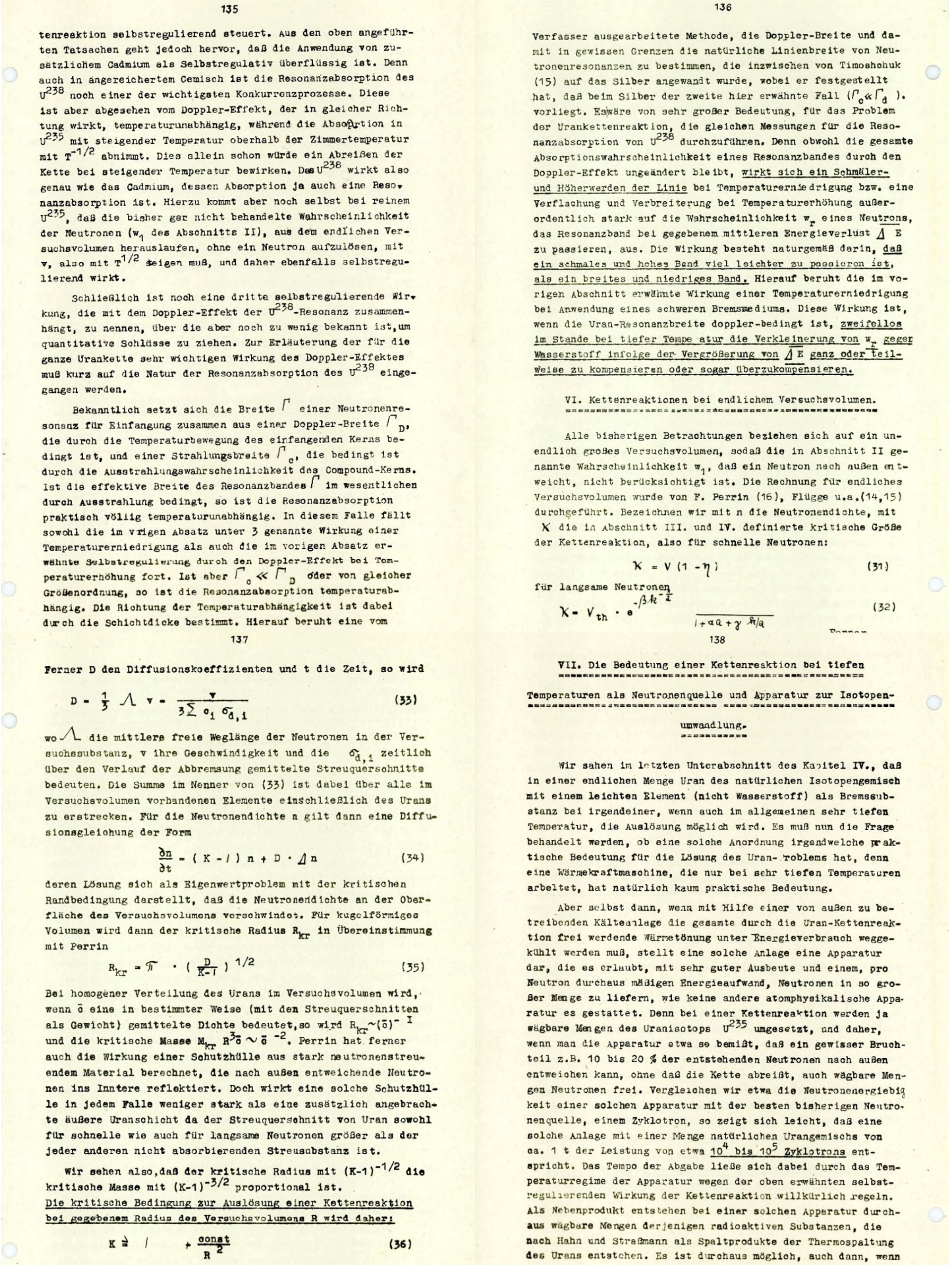
1. Ausschaltung der Wasserstoffabsorption für thermische Neutronen als Konkurrenzprozess.
2. Vergrößerung des Spaltquerschnittes des U^{235} durch Gültigkeit des $T^{-1/2}$-Gesetzes prinzipiell bis zu beliebig niedrigen Energien.
3. Möglicherweise Vergrößerung der Wahrscheinlichkeit der Neutronen, das Resonanzband des U^{238} zu passieren durch Verschmälerung desselben infolge des Doppler-Effektes.

4. Selbstregulierende Wirkung und Bedeutung des Doppler-Effektes bei tiefer Temperatur.

Wir haben im vorstehenden Absatz gesehen, daß es zweifellos auch ohne Anwendung einer Isotopentrennung bei hinreichend tiefer Temperatur möglich ist, durch Thermospaltung an U^{235} eine Kettenreaktion in Gang zu bringen. Bevor auf die praktische Bedeutung dieser Tatsache näher eingegangen werden kann, müssen zunächst die als Wirkung einer solchen Kettenreaktion auftretenden Veränderungen im Versuchsvolumen und ihre selbstregulierende Rückwirkung auf die Kettenreaktion behandelt werden.

Von Halban (13) und Flügge (14) haben bei der Diskussion der Uran-Kettenreaktion auf folgenden Gedankengang hingewiesen: Das Eintreten der Kettenreaktion bewirkt durch die frei werdende ungeheure Reaktionswärme von 180 MeV oder $4,14 \cdot 10^9$ Kal/Mol momentan eine wesentliche Temperaturerhöhung im Versuchsvolumen, die, wenn hierdurch die Kette nicht rechtzeitig zum Abreißen gebracht wird, zu einer Zerstörung der Apparatur und zur Verdampfung der Versuchssubstanz führen würde. Die genannten Autoren schlagen daher vor, dem Versuchsvolumen Cadmium in sehr geringer Konzentration beizumischen,sodaß die fast temperaturunabhängige Cadmiumabsorption, die energetisch etwas oberhalb der thermischen Energien der Zimmertemperatur beginnt, die Kette rechtzeitig zum Abreißen bringt und damit die Ket-

Figure D.353: The August 1941 report by Fritz Houtermans (working in collaboration with Manfred von Ardenne) explaining the feasibility of breeding plutonium-239 and using it to make fission bombs. [G-94].



tenreaktion selbstregulierend steuert. Aus den oben angeführten Tatsachen geht jedoch hervor, daß die Anwendung von zusätzlichem Cadmium als Selbstregulativ überflüssig ist. Denn auch in angereichertem Cemisch ist die Resonanzabsorption des U^{238} noch einer der wichtigsten Konkurrenzprozesse. Diese ist aber abgesehen vom Doppler-Effekt, der in gleicher Richtung wirkt, temperaturunabhängig, während die Absorption in U^{235} mit steigender Temperatur oberhalb der Zimmertemperatur mit $T^{-1/2}$ abnimmt. Dies allein schon würde ein Abreißen der Kette bei steigender Temperatur bewirken. Das U^{238} wirkt also genau wie das Cadmium, dessen Absorption ja auch eine Resonanzabsorption ist. Hierzu kommt aber noch selbst bei reinem U^{235}, daß die bisher gar nicht behandelte Wahrscheinlichkeit der Neutronen (w_1 des Abschnitts II), aus dem endlichen Versuchsvolumen herauslaufen, ohne ein Neutron aufzulösen, mit v, also mit $T^{1/2}$ steigen muß, und daher ebenfalls selbstregulierend wirkt.

Schließlich ist noch eine dritte selbstregulierende Wirkung, die mit dem Doppler-Effekt der U^{238}-Resonanz zusammenhängt, zu nennen, über die aber noch zu wenig bekannt ist, um quantitative Schlüsse zu ziehen. Zur Erläuterung der für die ganze Urankette sehr wichtigen Wirkung des Doppler-Effektes muß kurz auf die Natur der Resonanzabsorption des U^{238} eingegangen werden.

Bekanntlich setzt sich die Breite Γ einer Neutronenresonanz für Einfangung zusammen aus einer Doppler-Breite Γ_D, die durch die Temperaturbewegung des einfangenden Kerns bedingt ist, und einer Strahlungsbreite Γ_c, die bedingt ist durch die Ausstrahlungswahrscheinlichkeit des Compound-Kerns. Ist die effektive Breite des Resonanzbandes Γ im wesentlichen durch Ausstrahlung bedingt, so ist die Resonanzabsorption praktisch völlig temperaturunabhängig. In diesem Falle fällt sowohl die im vorigen Absatz unter 3 genannte Wirkung einer Temperaturerniedrigung als auch die im vorigen Absatz erwähnte Selbstregulierung durch den Doppler-Effekt bei Temperaturerhöhung fort. Ist aber $\Gamma_c \ll \Gamma_D$ oder von gleicher Größenordnung, so ist die Resonanzabsorption temperaturabhängig. Die Richtung der Temperaturabhängigkeit ist dabei durch die Schichtdicke bestimmt. Hierauf beruht eine vom

Verfasser ausgearbeitete Methode, die Doppler-Breite und damit in gewissen Grenzen die natürliche Linienbreite von Neutronenresonanzen zu bestimmen, die inzwischen von Timoshchuk (15) auf das Silber angewandt wurde, wobei er festgestellt hat, daß beim Silber der zweite hier erwähnte Fall ($\Gamma_c \ll \Gamma_d$). vorliegt. Es wäre von sehr großer Bedeutung, für das Problem der Urankettenreaktion, die gleichen Messungen für die Resonanzabsorption von U^{238} durchzuführen. Denn obwohl die gesamte Absorptionswahrscheinlichkeit eines Resonanzbandes durch den Doppler-Effekt ungeändert bleibt, wirkt sich ein Schmäler- und Höherwerden der Linie bei Temperaturerniedrigung bzw. eine Verflachung und Verbreiterung bei Temperaturerhöhung außerordentlich stark auf die Wahrscheinlichkeit w_r eines Neutrons, das Resonanzband bei gegebenem mittleren Energieverlust ΔE zu passieren, aus. Die Wirkung besteht naturgemäß darin, daß ein schmales und hohes Band viel leichter zu passieren ist, als ein breites und niedriges Band. Hierauf beruht die im vorigen Abschnitt erwähnte Wirkung einer Temperaturerniedrigung bei Anwendung eines schweren Bremsmediums. Diese Wirkung ist, wenn die Uran-Resonanzbreite doppler-bedingt ist, zweifellos im Stande bei tiefer Temperatur die Verkleinerung von w_r gegen Wasserstoff infolge der Vergrößerung von ΔE ganz oder teilweise zu kompensieren oder sogar überzukompensieren.

VI. Kettenreaktionen bei endlichem Versuchsvolumen.

Alle bisherigen Betrachtungen beziehen sich auf ein unendlich großes Versuchsvolumen, sodaß die in Abschnitt II genannte Wahrscheinlichkeit w_1, daß ein Neutron nach außen entweicht, nicht berücksichtigt ist. Die Rechnung für endliches Versuchsvolumen wurde von F. Perrin (16), Flügge u.a.(14,15) durchgeführt. Bezeichnen wir mit n die Neutronendichte, mit κ die in Abschnitt III. und IV. definierte kritische Größe der Kettenreaktion, also für schnelle Neutronen:

$$\kappa = \nu\,(1-\eta) \qquad (31)$$

für langsame Neutronen

$$\kappa = \nu_{th} \cdot e^{-\beta k^{-\frac{1}{2}}} \qquad \frac{\qquad}{1+aQ+\gamma\, k/Q} \qquad (32)$$

Ferner D den Diffusionskoeffizienten und t die Zeit, so wird

$$D = \frac{1}{3}\,\Lambda\, v = \frac{v}{3\sum c_i\,\sigma_{d,i}} \qquad (33)$$

wo Λ die mittlere freie Weglänge der Neutronen in der Versuchssubstanz, v ihre Geschwindigkeit und die $\sigma_{d,i}$ zeitlich über den Verlauf der Abbremsung gemittelte Streuquerschnitte bedeuten. Die Summe im Nenner von (33) ist dabei über alle im Versuchsvolumen vorhandenen Elemente einschließlich des Urans zu erstrecken. Für die Neutronendichte n gilt dann eine Diffusionsgleichung der Form

$$\frac{\partial n}{\partial t} = (K-1)\,n + D \cdot \Delta n \qquad (34)$$

deren Lösung sich als Eigenwertproblem mit der kritischen Randbedingung darstellt, daß die Neutronendichte an der Oberfläche des Versuchsvolumens verschwindet. Für kugelförmiges Volumen wird dann der kritische Radius R_{kr} in Übereinstimmung mit Perrin

$$R_{kr} = \pi \cdot \left(\frac{D}{K-1}\right)^{1/2} \qquad (35)$$

Bei homogener Verteilung des Urans im Versuchsvolumen wird, wenn $\bar{c}$ eine in bestimmter Weise (mit den Streuquerschnitten als Gewicht) gemittelte Dichte bedeutet, so wird $R_{kr} \sim (\bar{c})^{-1}$ und die kritische Masse $M_{kr}\ R^3\bar{c} \sim \bar{c}^{-2}$. Perrin hat ferner auch die Wirkung einer Schutzhülle aus stark neutronenstreuendem Material berechnet, die nach außen entweichende Neutronen ins Inntere reflektiert. Doch wirkt eine solche Schutzhülle in jedem Falle weniger stark als eine zusätzlich angebrachte äußere Uranschicht da der Streuquerschnitt von Uran sowohl für schnelle wie auch für langsame Neutronen größer als der jeder anderen nicht absorbierenden Streusubstanz ist.

Wir sehen also, daß der kritische Radius mit $(K-1)^{-1/2}$ die kritische Masse mit $(K-1)^{-3/2}$ proportional ist. Die kritische Bedingung zur Auslösung einer Kettenreaktion bei gegebenem Radius des Versuchsvolumens R wird daher:

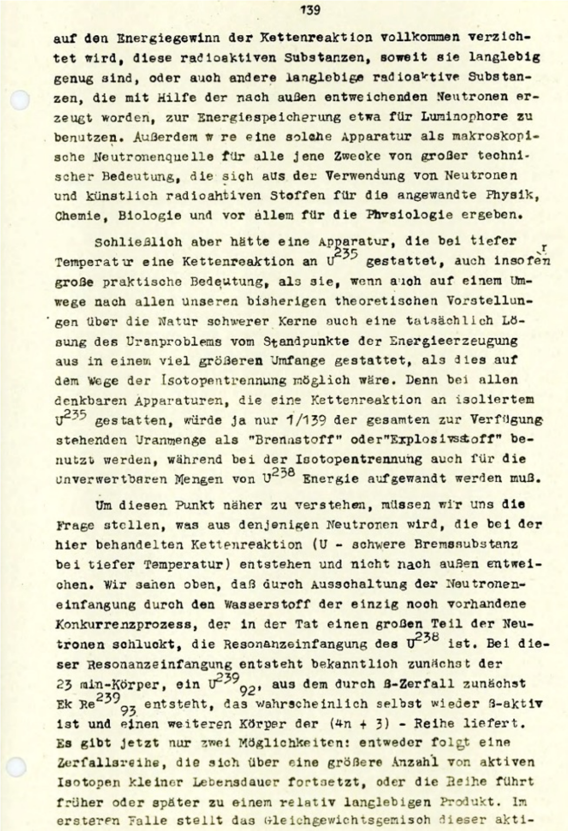
$$K \geqq 1 + \frac{\text{const}}{R^2} \qquad (36)$$

VII. Die Bedeutung einer Kettenreaktion bei tiefen Temperaturen als Neutronenquelle und Apparatur zur Isotopenumwandlung.

Wir sahen im letzten Unterabschnitt des Kapitel IV., daß in einer endlichen Menge Uran des natürlichen Isotopengemisch mit einem leichten Element (nicht Wasserstoff) als Bremssubstanz bei irgendeiner, wenn auch im allgemeinen sehr tiefen Temperatur, die Auslösung möglich wird. Es muß nun die Frage behandelt werden, ob eine solche Anordnung irgendwelche praktische Bedeutung für die Lösung des Uran-Problems hat, denn eine Wärmekraftmaschine, die nur bei sehr tiefen Temperaturen arbeitet, hat natürlich kaum praktische Bedeutung.

Aber selbst dann, wenn mit Hilfe einer von außen zu betreibenden Kälteanlage die gesamte durch die Uran-Kettenreaktion frei werdende Wärmetönung unter Energieverbrauch weggekühlt werden muß, stellt eine solche Anlage eine Apparatur dar, die es erlaubt, mit sehr guter Ausbeute und einem, pro Neutron durchaus mäßigen Energieaufwand, Neutronen in so großer Menge zu liefern, wie keine andere atomphysikalische Apparatur es gestattet. Denn bei einer Kettenreaktion werden ja wägbare Mengen des Uranisotops U^{235} umgesetzt, und daher, wenn man die Apparatur etwa so bemißt, daß ein gewisser Bruchteil z.B. 10 bis 20 % der entstehenden Neutronen nach außen entweichen kann, ohne daß die Kette abreißt, auch wägbare Mengen Neutronen frei. Vergleichen wir etwa die Neutronenergiebigkeit einer solchen Apparatur mit der besten bisherigen Neutronenquelle, einem Zyklotron, so zeigt sich leicht, daß eine solche Anlage mit einer Menge natürlichen Urangemischs von ca. 1 t der Leistung von etwa 10^4 bis 10^5 Zyklotrons entspricht. Das Tempo der Abgabe ließe sich dabei durch das Temperaturregime der Apparatur wegen der oben erwähnten selbstregulierenden Wirkung der Kettenreaktion willkürlich regeln. Als Nebenprodukt entstehen bei einer solchen Apparatur durchaus wägbare Mengen derjenigen radioaktiven Substanzen, die nach Hahn und Straßmann als Spaltprodukte der Thermospaltung des Urans entstehen. Es ist durchaus möglich, auch dann, wenn

Figure D.354: The August 1941 report by Fritz Houtermans (working in collaboration with Manfred von Ardenne) explaining the feasibility of breeding plutonium-239 and using it to make fission bombs. [G-94].



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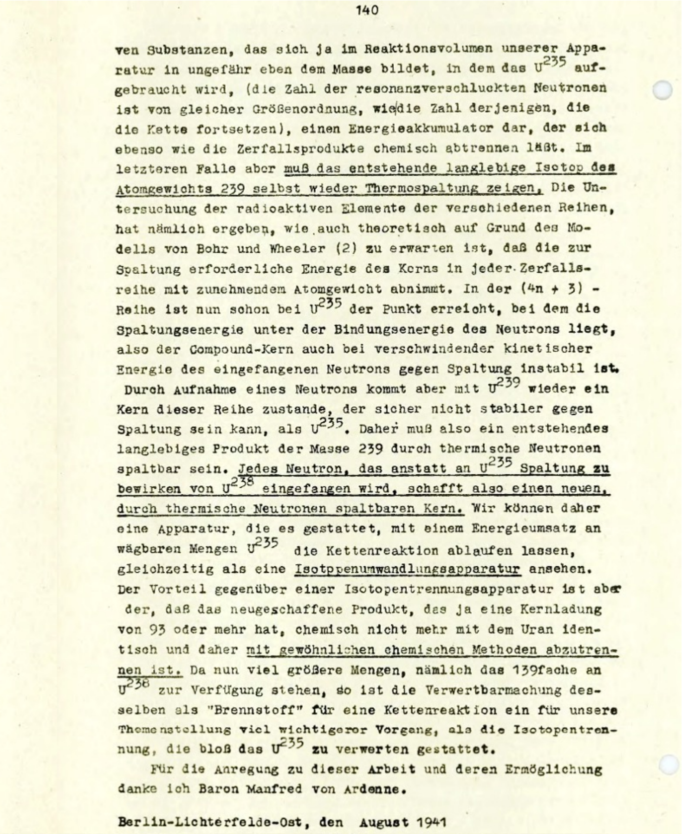
auf den Energiegewinn der Kettenreaktion vollkommen verzichtet wird, diese radioaktiven Substanzen, soweit sie langlebig genug sind, oder auch andere langlebige radioaktive Substanzen, die mit Hilfe der nach außen entweichenden Neutronen erzeugt worden, zur Energiespeicherung etwa für Luminophore zu benutzen. Außerdem w re eine solche Apparatur als makroskopische Neutronenquelle für alle jene Zwecke von großer technischer Bedeutung, die sich aus der Verwendung von Neutronen und künstlich radioahtiven Stoffen für die angewandte Physik, Chemie, Biologie und vor allem für die Phvsiologie ergeben.

Schließlich aber hätte eine Apparatur, die bei tiefer Temperatur eine Kettenreaktion an U^{235} gestattet, auch insofern große praktische Bedeutung, als sie, wenn auch auf einem Umwege nach allen unseren bisherigen theoretischen Vorstellungen über die Natur schwerer Kerne auch eine tatsächlich Lösung des Uranproblems vom Standpunkte der Energieerzeugung aus in einem viel größeren Umfange gestattet, als dies auf dem Wege der Isotopentrennung möglich wäre. Denn bei allen denkbaren Apparaturen, die eine Kettenreaktion an isoliertem U^{235} gestatten, würde ja nur 1/139 der gesamten zur Verfügung stehenden Uranmenge als "Brennstoff" oder"Explosivstoff" benutzt werden, während bei der Isotopentrennung auch für die unverwertbaren Mengen von U^{238} Energie aufgewandt werden muß.

Um diesen Punkt näher zu verstehen, müssen wir uns die Frage stellen, was aus denjenigen Neutronen wird, die bei der hier behandelten Kettenreaktion (U - schwere Bremssubstanz bei tiefer Temperatur) entstehen und nicht nach außen entweichen. Wir sahen oben, daß durch Ausschaltung der Neutroneneinfangung durch den Wasserstoff der einzig noch vorhandene Konkurrenzprozess, der in der Tat einen großen Teil der Neutronen schluckt, die Resonanzeinfangung des U^{238} ist. Bei dieser Resonanzeinfangung entsteht bekanntlich zunächst der 23 min-Körper, ein $U^{239}{}_{92}$, aus dem durch ß-Zerfall zunächst Ek $Re^{239}{}_{93}$ entsteht, das wahrscheinlich selbst wieder ß-aktiv ist und einen weiteren Körper der (4n + 3) - Reihe liefert. Es gibt jetzt nur zwei Möglichkeiten: entweder folgt eine Zerfallsreihe, die sich über eine größere Anzahl von aktiven Isotopen kleiner Lebensdauer fortsetzt, oder die Reihe führt früher oder später zu einem relativ langlebigen Produkt. Im ersteren Falle stellt das Gleichgewichtsgemisch dieser akti-



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ven Substanzen, das sich ja im Reaktionsvolumen unserer Apparatur in ungefähr eben dem Masse bildet, in dem das U^{235} aufgebraucht wird, (die Zahl der resonanzverschluckten Neutronen ist von gleicher Größenordnung, wie die Zahl derjenigen, die die Kette fortsetzen), einen Energieakkumulator dar, der sich ebenso wie die Zerfallsprodukte chemisch abtrennen läßt. Im letzteren Falle aber muß das entstehende langlebige Isotop des Atomgewichts 239 selbst wieder Thermospaltung zeigen. Die Untersuchung der radioaktiven Elemente der verschiedenen Reihen, hat nämlich ergeben, wie auch theoretisch auf Grund des Modells von Bohr und Wheeler (2) zu erwarten ist, daß die zur Spaltung erforderliche Energie des Kerns in jeder Zerfallsreihe mit zunehmendem Atomgewicht abnimmt. In der (4n + 3) - Reihe ist nun schon bei U^{235} der Punkt erreicht, bei dem die Spaltungsenergie unter der Bindungsenergie des Neutrons liegt, also der Compound-Kern auch bei verschwindender kinetischer Energie des eingefangenen Neutrons gegen Spaltung instabil ist. Durch Aufnahme eines Neutrons kommt aber mit U^{239} wieder ein Kern dieser Reihe zustande, der sicher nicht stabiler gegen Spaltung sein kann, als U^{235}. Daher muß also ein entstehendes langlebiges Produkt der Masse 239 durch thermische Neutronen spaltbar sein. Jedes Neutron, das anstatt an U^{235} Spaltung zu bewirken von U^{238} eingefangen wird, schafft also einen neuen, durch thermische Neutronen spaltbaren Kern. Wir können daher eine Apparatur, die es gestattet, mit einem Energieumsatz an wägbaren Mengen U^{235} die Kettenreaktion ablaufen lassen, gleichzeitig als eine Isotppenumwandlungsapparatur ansehen. Der Vorteil gegenüber einer Isotopentrennungsapparatur ist aber der, daß das neugeschaffene Produkt, das ja eine Kernladung von 93 oder mehr hat, chemisch nicht mehr mit dem Uran identisch und daher mit gewöhnlichen chemischen Methoden abzutrennen ist. Da nun viel größere Mengen, nämlich das 139fache an U^{238} zur Verfügung stehen, so ist die Verwertbarmachung desselben als "Brennstoff" für eine Kettenreaktion ein für unsere Themenstellung viel wichtigerer Vorgang, als die Isotopentrennung, die bloß das U^{235} zu verwerten gestattet.

Für die Anregung zu dieser Arbeit und deren Ermöglichung danke ich Baron Manfred von Ardenne.

Berlin-Lichterfelde-Ost, den August 1941

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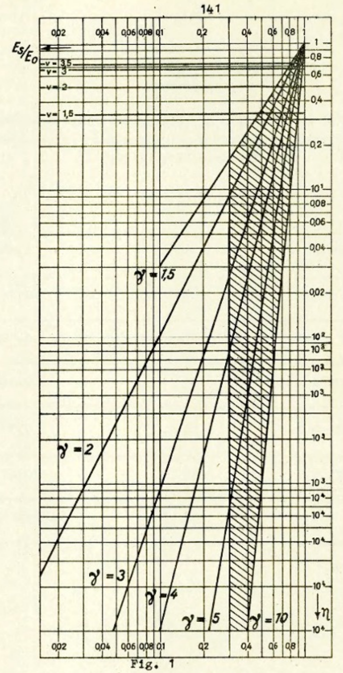

Fig. 1

Kernspaltung durch schnelle Neutronen. Wahrscheinlichkeit η eines Neutrons unter die kritische Energie der Kernspaltung abgebremst zu werden in Abhängigkeit vom Verhältnis E_s/E_0 (kritische Energie der Spaltung durch mittlere Primärenergie) sind die schrägen Geraden für verschiedene Werte von $\gamma = \sigma_s/\sigma_d \cdot \mu$. Das schraffierte Gebiet gibt die experimentellen Grenzen an, der eingezeichnete Punkt den wahrscheinlichen Wert. Die roten horizontalen Geraden geben den kritischen Wert an, für den gerade noch eine Kettenreaktion möglich ist, wenn die Zahl der Neutronen pro Spaltprozess zu angenommen wird. Damit die Kette nicht abreißt, muß der experimentelle Wert von unter der roten Geraden für den wahren Wert von v_s liegen. Je tiefer er darunter liegt, desto kleiner wird das kritische Volumen.

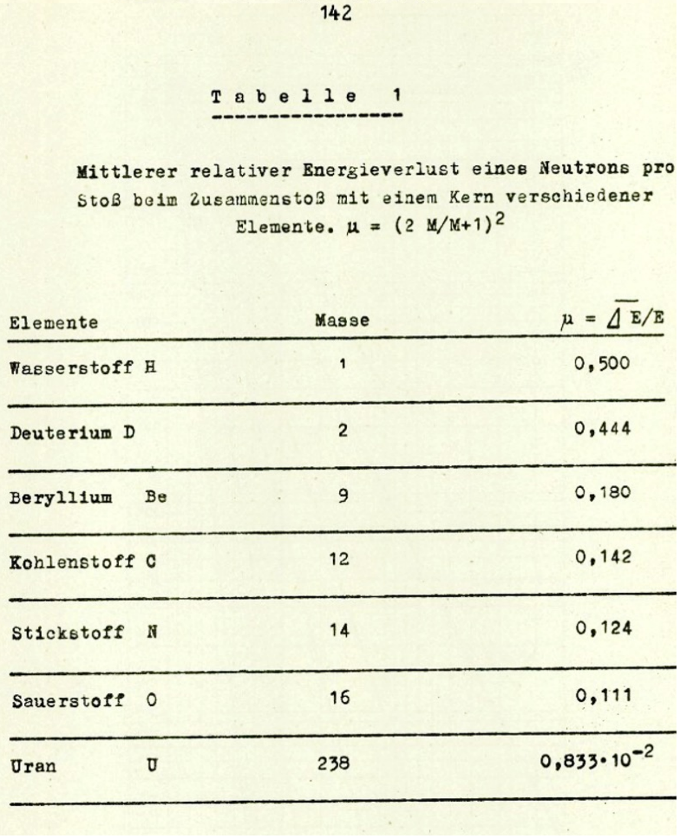

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Tabelle 1

Mittlerer relativer Energieverlust eines Neutrons pro Stoß beim Zusammenstoß mit einem Kern verschiedener Elemente. $\mu = (2\ M/M+1)^2$

Elemente		Masse	$\mu = \overline{\Delta E}/E$
Wasserstoff	H	1	0,500
Deuterium	D	2	0,444
Beryllium	Be	9	0,180
Kohlenstoff	C	12	0,142
Stickstoff	N	14	0,124
Sauerstoff	O	16	0,111
Uran	U	238	$0{,}833 \cdot 10^{-2}$

Figure D.355: The August 1941 report by Fritz Houtermans (working in collaboration with Manfred von Ardenne) explaining the feasibility of breeding plutonium-239 and using it to make fission bombs. [G-94].

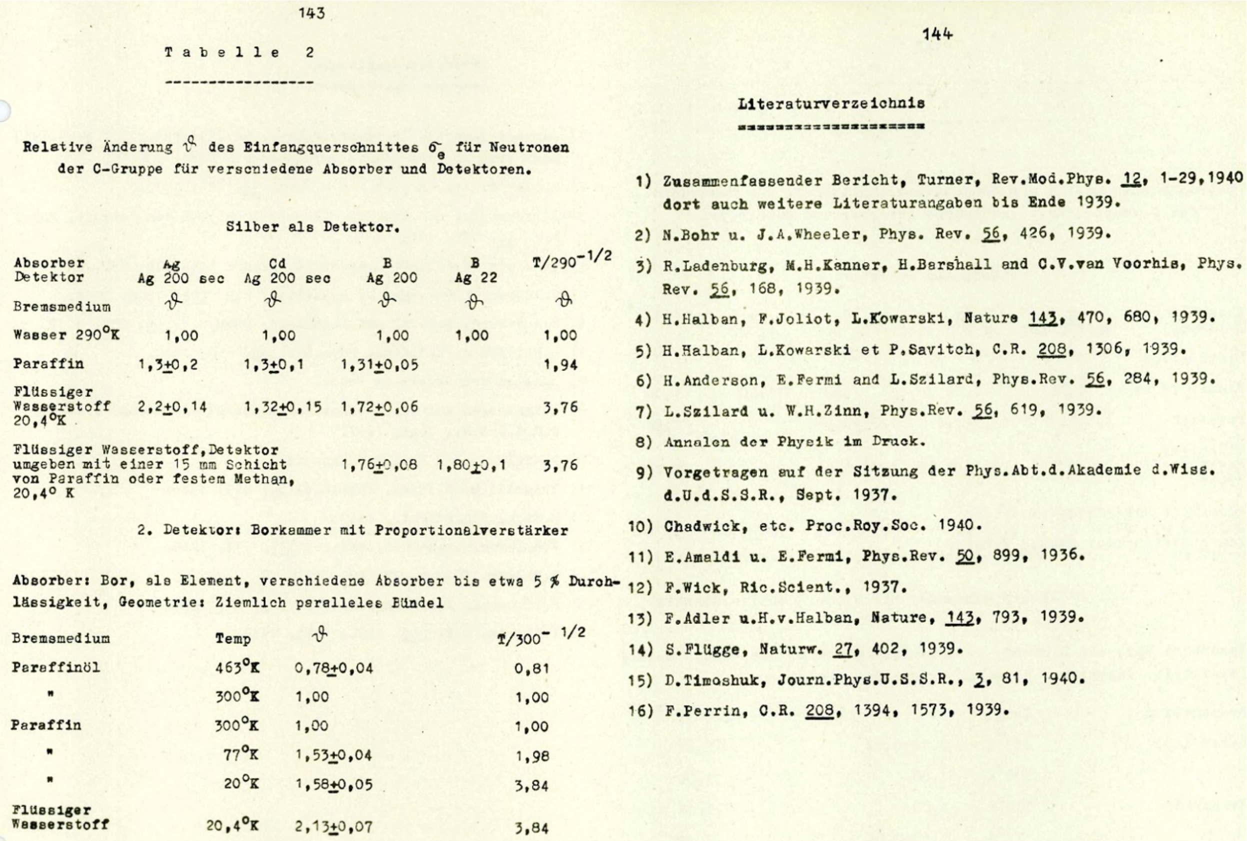

Tabelle 2

Relative Änderung ϑ des Einfangquerschnittes σ_e für Neutronen der C-Gruppe für verschiedene Absorber und Detektoren.

Silber als Detektor.

Absorber Detektor	Ag Ag 200 sec	Cd Ag 200 sec	B Ag 200	B Ag 22	$T/290^{-1/2}$
Bremsmedium	ϑ	ϑ	ϑ	ϑ	ϑ
Wasser 290°K	1,00	1,00	1,00	1,00	1,00
Paraffin	1,3±0,2	1,3±0,1	1,31±0,05		1,94
Flüssiger Wasserstoff 20,4°K	2,2±0,14	1,32±0,15	1,72±0,06		3,76
Flüssiger Wasserstoff, Detektor umgeben mit einer 15 mm Schicht von Paraffin oder festem Methan, 20,4° K			1,76±0,08	1,80±0,1	3,76

2. Detektor: Borkammer mit Proportionalverstärker

Absorber: Bor, als Element, verschiedene Absorber bis etwa 5 % Durchlässigkeit, Geometrie: Ziemlich paralleles Bündel

Bremsmedium	Temp	ϑ	$T/300^{-1/2}$
Paraffinöl	463°K	0,78±0,04	0,81
"	300°K	1,00	1,00
Paraffin	300°K	1,00	1,00
"	77°K	1,53±0,04	1,98
"	20°K	1,58±0,05	3,84
Flüssiger Wasserstoff	20,4°K	2,13±0,07	3,84

Literaturverzeichnis

1) Zusammenfassender Bericht, Turner, Rev.Mod.Phys. 12, 1-29, 1940 dort auch weitere Literaturangaben bis Ende 1939.
2) N.Bohr u. J.A.Wheeler, Phys. Rev. 56, 426, 1939.
3) R.Ladenburg, M.H.Kanner, H.Bershall and C.V.van Voorhis, Phys. Rev. 56, 168, 1939.
4) H.Halban, F.Joliot, L.Kowarski, Nature 143, 470, 680, 1939.
5) H.Halban, L.Kowarski et P.Savitch, C.R. 208, 1306, 1939.
6) H.Anderson, E.Fermi and L.Szilard, Phys.Rev. 56, 284, 1939.
7) L.Szilard u. W.H.Zinn, Phys.Rev. 56, 619, 1939.
8) Annalen der Physik im Druck.
9) Vorgetragen auf der Sitzung der Phys.Abt.d.Akademie d.Wiss. d.U.d.S.S.R., Sept. 1937.
10) Chadwick, etc. Proc.Roy.Soc. 1940.
11) E.Amaldi u. E.Fermi, Phys.Rev. 50, 899, 1936.
12) F.Wick, Ric.Scient., 1937.
13) F.Adler u.H.v.Halban, Nature, 143, 793, 1939.
14) S.Flügge, Naturw. 27, 402, 1939.
15) D.Timoshuk, Journ.Phys.U.S.S.R., 3, 81, 1940.
16) F.Perrin, C.R. 208, 1394, 1573, 1939.

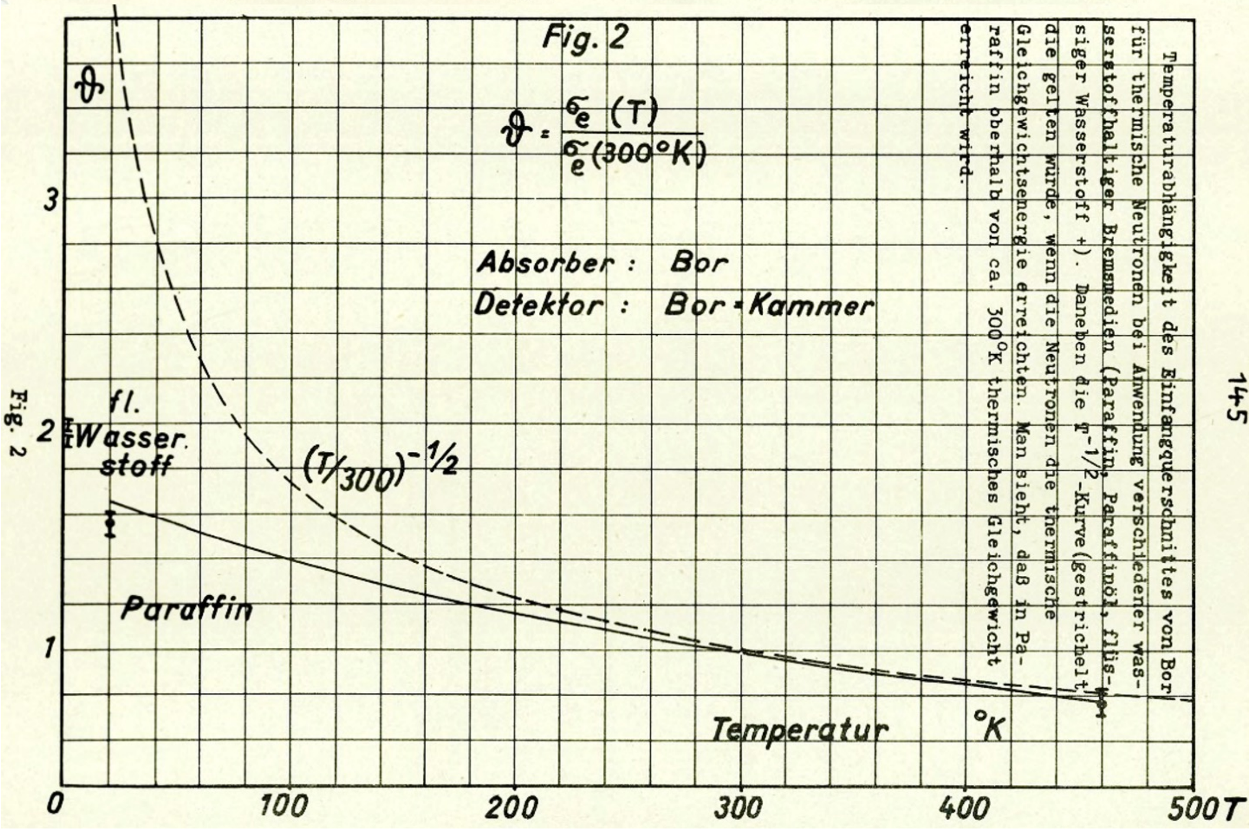

Fig. 2

Temperaturabhängigkeit des Einfangquerschnittes von Bor für thermische Neutronen bei Anwendung verschiedener wasserstoffhaltiger Bremsmedien (Paraffin, Paraffinöl, flüssiger Wasserstoff +). Daneben die $T^{-1/2}$-Kurve (gestrichelt) die gelten würde, wenn die Neutronen die thermische Gleichgewichtsenergie erreichten. Man sieht, daß in Paraffin oberhalb von ca. 300°K thermisches Gleichgewicht erreicht wird.

Figure D.356: The August 1941 report by Fritz Houtermans (working in collaboration with Manfred von Ardenne) explaining the feasibility of breeding plutonium-239 and using it to make fission bombs. [G-94].

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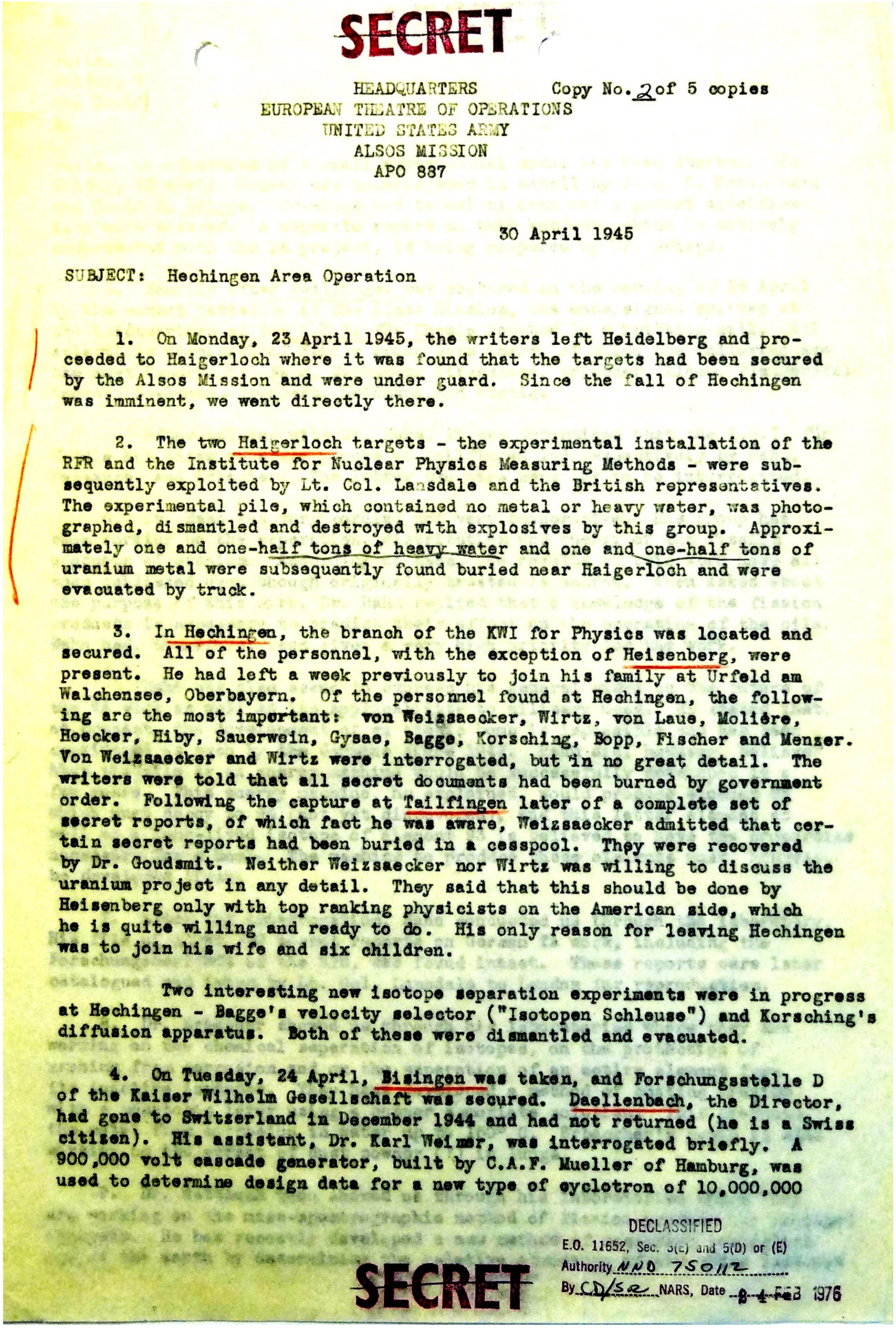

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HEADQUARTERS
EUROPEAN THEATRE OF OPERATIONS
UNITED STATES ARMY
ALSOS MISSION
APO 887

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30 April 1945

SUBJECT: Hechingen Area Operation

1. On Monday, 23 April 1945, the writers left Heidelberg and proceeded to Haigerloch where it was found that the targets had been secured by the Alsos Mission and were under guard. Since the fall of Hechingen was imminent, we went directly there.

2. The two Haigerloch targets - the experimental installation of the RFR and the Institute for Nuclear Physics Measuring Methods - were subsequently exploited by Lt. Col. Lansdale and the British representatives. The experimental pile, which contained no metal or heavy water, was photographed, dismantled and destroyed with explosives by this group. Approximately one and one-half tons of heavy water and one and one-half tons of uranium metal were subsequently found buried near Haigerloch and were evacuated by truck.

3. In Hechingen, the branch of the KWI for Physics was located and secured. All of the personnel, with the exception of Heisenberg, were present. He had left a week previously to join his family at Urfeld am Walchensee, Oberbayern. Of the personnel found at Hechingen, the following are the most important: von Weizsaecker, Wirtz, von Laue, Molière, Hoecker, Hiby, Sauerwein, Gysae, Bagge, Korsching, Bopp, Fischer and Menzer. Von Weizsaecker and Wirtz were interrogated, but in no great detail. The writers were told that all secret documents had been burned by government order. Following the capture at Tailfingen later of a complete set of secret reports, of which fact he was aware, Weizsaecker admitted that certain secret reports had been buried in a cesspool. They were recovered by Dr. Goudsmit. Neither Weizsaecker nor Wirtz was willing to discuss the uranium project in any detail. They said that this should be done by Heisenberg only with top ranking physicists on the American side, which he is quite willing and ready to do. His only reason for leaving Hechingen was to join his wife and six children.

Two interesting new isotope separation experiments were in progress at Hechingen - Bagge's velocity selector ("Isotopen Schleuse") and Korsching's diffusion apparatus. Both of these were dismantled and evacuated.

4. On Tuesday, 24 April, Bisingen was taken, and Forschungsstelle D of the Kaiser Wilhelm Gesellschaft was secured. Daellenbach, the Director, had gone to Switzerland in December 1944 and had not returned (he is a Swiss citizen). His assistant, Dr. Karl Weimer, was interrogated briefly. A 900,000 volt cascade generator, built by C.A.F. Mueller of Hamburg, was used to determine design data for a new type of cyclotron of 10,000,000

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Figure D.357: James A. Lane and Frederic A. C. Wardenburg. 30 April 1945. SUBJECT: Hechingen Area Operation [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.].

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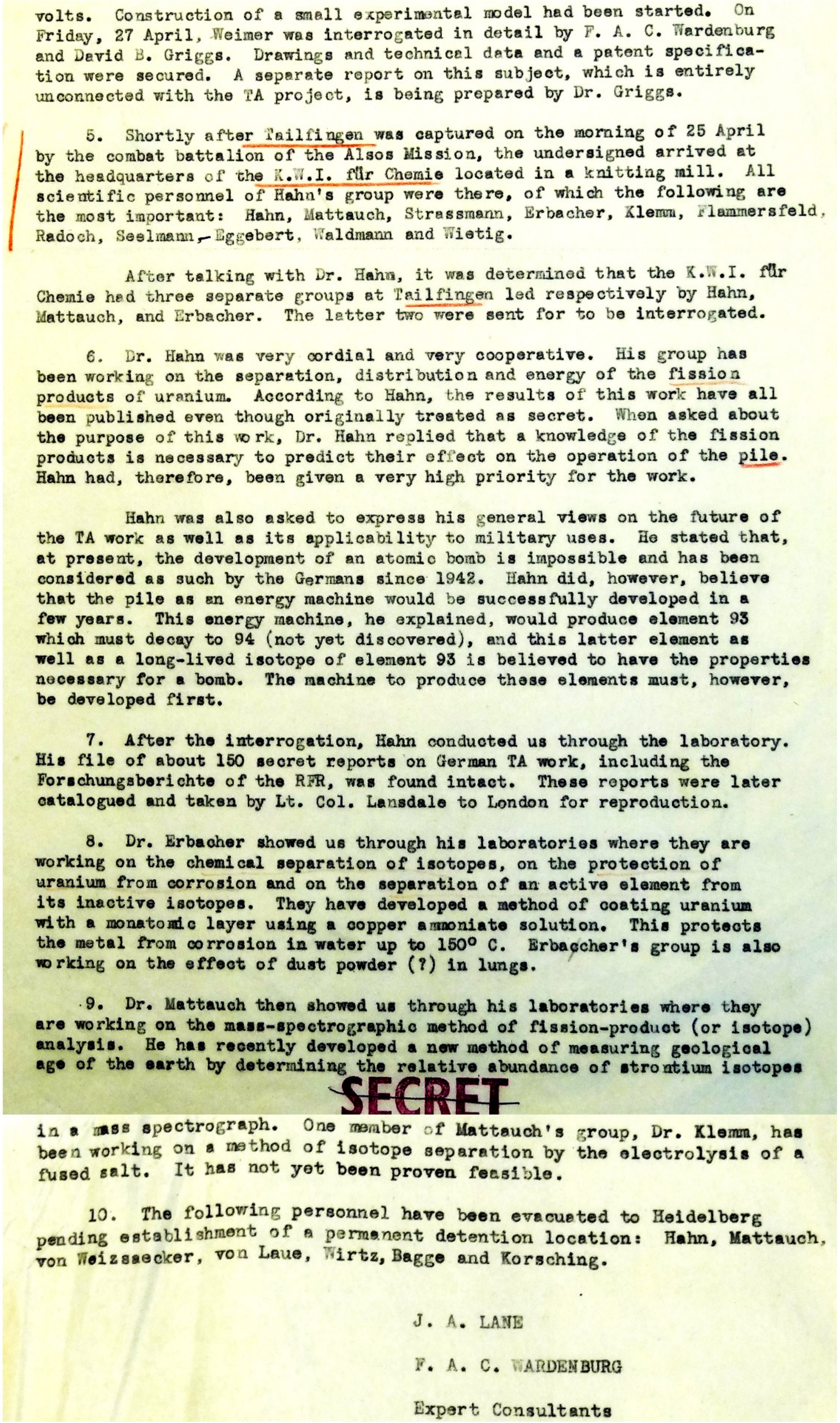

volts. Construction of a small experimental model had been started. On Friday, 27 April, Weimer was interrogated in detail by F. A. C. Wardenburg and David B. Griggs. Drawings and technical data and a patent specification were secured. A separate report on this subject, which is entirely unconnected with the TA project, is being prepared by Dr. Griggs.

5. Shortly after Tailfingen was captured on the morning of 25 April by the combat battalion of the Alsos Mission, the undersigned arrived at the headquarters of the K.W.I. für Chemie located in a knitting mill. All scientific personnel of Hahn's group were there, of which the following are the most important: Hahn, Mattauch, Strassmann, Erbacher, Klemm, Flammersfeld, Radoch, Seelmann-Eggebert, Waldmann and Wietig.

After talking with Dr. Hahn, it was determined that the K.W.I. für Chemie had three separate groups at Tailfingen led respectively by Hahn, Mattauch, and Erbacher. The latter two were sent for to be interrogated.

6. Dr. Hahn was very cordial and very cooperative. His group has been working on the separation, distribution and energy of the fission products of uranium. According to Hahn, the results of this work have all been published even though originally treated as secret. When asked about the purpose of this work, Dr. Hahn replied that a knowledge of the fission products is necessary to predict their effect on the operation of the pile. Hahn had, therefore, been given a very high priority for the work.

Hahn was also asked to express his general views on the future of the TA work as well as its applicability to military uses. He stated that, at present, the development of an atomic bomb is impossible and has been considered as such by the Germans since 1942. Hahn did, however, believe that the pile as an energy machine would be successfully developed in a few years. This energy machine, he explained, would produce element 93 which must decay to 94 (not yet discovered), and this latter element as well as a long-lived isotope of element 93 is believed to have the properties necessary for a bomb. The machine to produce these elements must, however, be developed first.

7. After the interrogation, Hahn conducted us through the laboratory. His file of about 150 secret reports on German TA work, including the Forschungsberichte of the RFR, was found intact. These reports were later catalogued and taken by Lt. Col. Lansdale to London for reproduction.

8. Dr. Erbacher showed us through his laboratories where they are working on the chemical separation of isotopes, on the protection of uranium from corrosion and on the separation of an active element from its inactive isotopes. They have developed a method of coating uranium with a monatomic layer using a copper ammoniate solution. This protects the metal from corrosion in water up to 150° C. Erbacher's group is also working on the effect of dust powder (?) in lungs.

9. Dr. Mattauch then showed us through his laboratories where they are working on the mass-spectrographic method of fission-product (or isotope) analysis. He has recently developed a new method of measuring geological age of the earth by determining the relative abundance of strontium isotopes

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in a mass spectrograph. One member of Mattauch's group, Dr. Klemm, has been working on a method of isotope separation by the electrolysis of a fused salt. It has not yet been proven feasible.

10. The following personnel have been evacuated to Heidelberg pending establishment of a permanent detention location: Hahn, Mattauch, von Weizsaecker, von Laue, Wirtz, Bagge and Korsching.

J. A. LANE

F. A. C. WARDENBURG

Expert Consultants

NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.

Figure D.358: James A. Lane and Frederic A. C. Wardenburg. 30 April 1945. SUBJECT: Hechingen Area Operation [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.].

[German reports captured by the U.S. Alsos Mission also show that there was wartime work on chemical methods for processing irradiated fission fuel and purifying different components from it. Unless otherwise noted, text for G-series captured German nuclear reports cited here consists of the English-language abstracts prepared by American scientists who studied the German reports.]

G-259. Otto Hahn and Fritz Strassmann. The Chemical Separation of Elements and Atomic Species Produced by Uranium Fission (General Part). 1944.

Introductory considerations on separation of U fission products are given. Extraction of U as nitrate is possible if amounts larger than several 100 g are irradiated, the other method is more advisable for amounts smaller than that: three methods are proposed for extraction of the remaining smaller amounts of U from the fission products, separation of the U as sodium pyrouranate by precipitation with a solution of caustic soda, precipitation by ammonium to ammonium pyrouranate, dissolving of this by surplus ammonium carbonate to uranium carbonate, and precipitation as sodium uranylacetate.

G-260. Otto Hahn and Fritz Strassmann. Chemical Separation of Uranium Fission Products. Halogens, Rare Gases, Earth Metals and Alkaline Earth Metals. 1944.

Distillation methods, precipitation by Ag ions, and solvent extraction for I and Br separation are reported in detail. Indirect identification of Xe and Kr proved less reliable than their direct identification in specially constructed counting tubes. Different tubes and methods of operation are illustrated. Indirect identification of halogens by determination of noble gases formed by halogen decay are given for Rb and Cs, Sr and Ba. Detailed extraction methods for the single elements are given for Zr, Nb, Mo, Tc, Sn, Sb, Te, Se, As, Ge, Ga, Zn, Co, and Ni. Isotopes intermediary between Br^{35} and Br^{39} could not be identified. A procedure to separate all fission products from a single sample of irradiated U concludes the report.

G-111. Josef Schintlmeister. The Placing in the Periodic Table of the Element with Alpha Rays of 1.8 cm Range. 1941.

See reports G-55 and G-112 for chemical identification of this element. Element can be atomic number 93 or 94 but its alpha decay energy and stability as regard beta decay shows it is not 93. It mass number is most likely 244 but it could be 246, or 242. This can be determined, for 244 and 242 can be split by thermal neutrons while 246 will require faster neutrons.

This element is precipitated by H_2S from strongly acid solutions and it does not form compounds in strongly oxidizing solutions (HNO_3 and H_2SO_4).

G-112. Josef Schintlmeister and Friedrich Hernegger. Further Chemical Investigation of an Element with Alpha Rays of 1.8 cm Range. 1941.

Some chemical properties of new element. Ammonia and sodium hydroxide precipitate about half the element. Carbonate precipitates it quantitatively. In distillation with nitric acid or hydrochloric acid the element is not distilled, but with sulfuric acid a high percentage of the element is distilled over. Hydrogen sulfide precipitates it quantitatively from strong acid solutions. Other chemical properties listed.

Josef Schintlmeister to Hermann Mark. 7. August 1945. [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)] See document photos on pp. 3828–3829.

Die heute Nacht erfolgte Veroffentlichung der ersten technischen Anwendung der Uranspaltung nehme ich zum Anlass, Ihnen mitzuteilen, dass auch am II. Physikalischen Institut wahrend des Krieges an diesem Problem gearbeitet wurde. Ich selbst war aus diesem Grunde nie zur Wehrmacht eingeruckt. [...]

Die technische Ausnutzung der Atomkernenergien bei der Uranspaltung setzt sehr schwierige und sehr kostspielige Arbeiten voraus. Mit einigen Kilogrammen der neuen Elemente, die such unvergleichlich einfacher und billiger gewinnen lassen, wird sich aller Voraussicht nach ohne den bisher notigen Aufwand eine Atomkernmaschine bauen lassen, da zu erwarten ist, dass die Kernspaltung leichter als bei Uran eintritt und auch erheblich mehr Neutronen bei der Spaltung freiwerden, sodass die Kettenreaktion gut ablauft.

I would like to take tonight's publication of the first technical application of uranium fission [Hiroshima] as an opportunity to inform you that work on this problem was also carried out at the [Vienna] Second Physics Institute during the war. I myself was never drafted into the Wehrmacht for this reason. [...]

The technical utilization of nuclear energy in uranium fission requires very difficult and very expensive work. With a few kilograms of the new element [plutonium], which is incomparably easier and cheaper to obtain, it will in all likelihood be possible to build a nuclear device without the effort required to date, since it is to be expected that nuclear fission will occur more easily than with uranium and also that considerably more neutrons will be released during fission, so that the chain reaction will proceed smoothly.

Samuel A. Goudsmit to Horace K. Calvert. 5 September 1945. [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)] See document photo on p. 3830.

1. Enclosed is a letter from a Dr. Schintlmeister who worked with Stetter in Vienna. I think that the contents of this letter should be called to the attention of the scientists working on the project back home just as soon as possible. There are some statements there which make it come nearer to the real thing than any other report that I have seen so far, even though it is mere speculation on his part and does not refer to any conclusive experiments. He seems to be aware of the importance of the transuranic elements.

2. The letter was given to Dr. [Charles P.] Smyth for the purpose of transmitting it to Professor H. Mark who is now at the Brooklyn Polytechnic Institute. It is, of course, not recommended that this letter be transmitted. A copy of this letter was given to the Military Government at Zell am See with the request that it be sent to Smyth. They, however, considered it unimportant and destroyed the letter. Smyth received this copy on a subsequent visit.

[Immediately after hearing the news of Hiroshima, Josef Schintlmeister wrote that throughout the war he had worked on a similar project involving a new element (plutonium), of which just a few kilograms would be sufficient for a nuclear device. He offered to help restart that work for postwar sponsors, alarming Samuel Goudsmit and other U.S. officials.]

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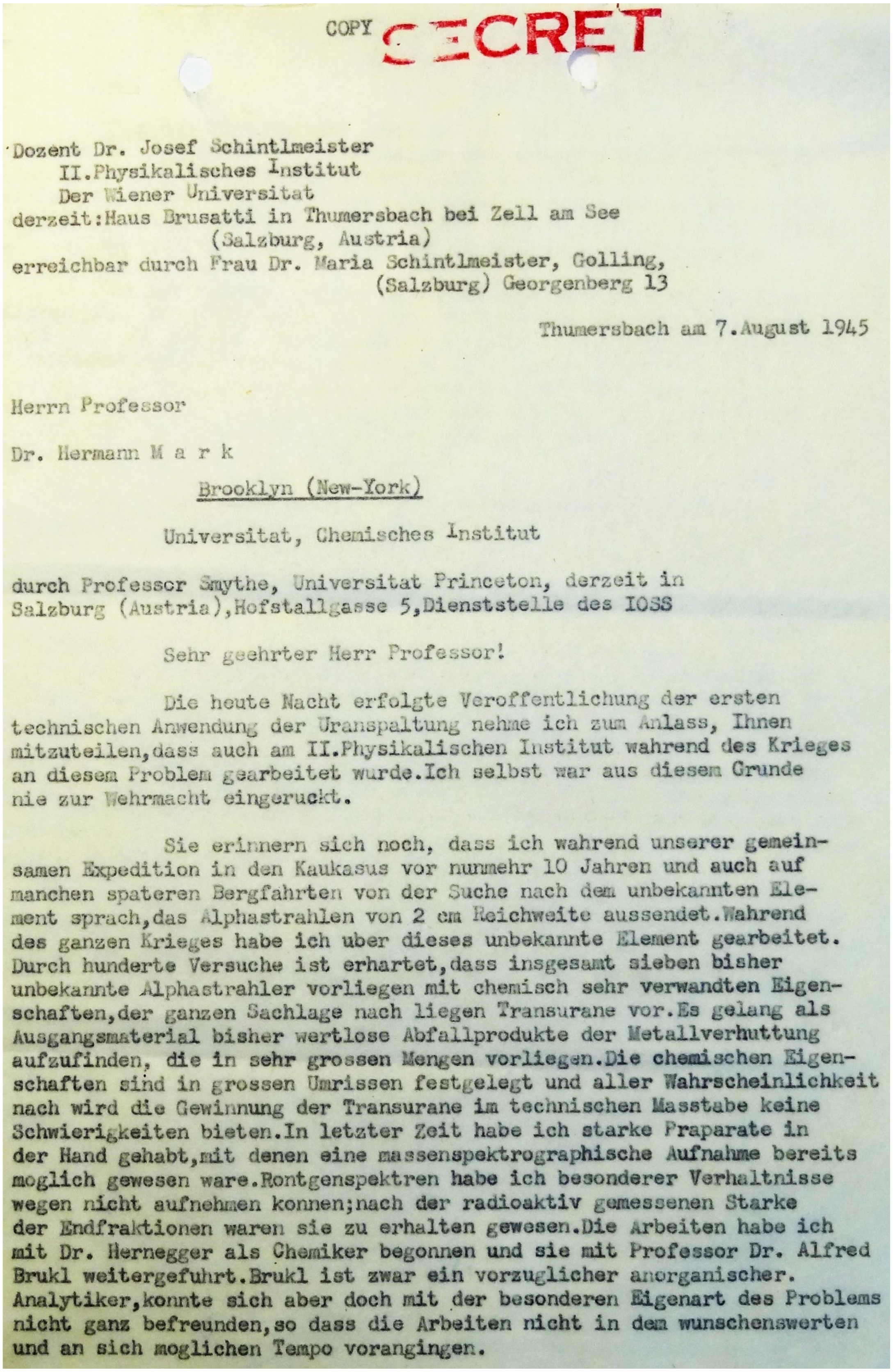

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Dozent Dr. Josef Schintlmeister
II.Physikalisches Institut
Der Wiener Universitat
derzeit:Haus Brusatti in Thumersbach bei Zell am See
(Salzburg, Austria)
erreichbar durch Frau Dr. Maria Schintlmeister, Golling,
(Salzburg) Georgenberg 13

Thumersbach am 7.August 1945

Herrn Professor

Dr. Hermann Mark

Brooklyn (New-York)

Universitat, Chemisches Institut

durch Professor Smythe, Universitat Princeton, derzeit in
Salzburg (Austria),Hofstallgasse 5,Dienststelle des IOSS

Sehr geehrter Herr Professor!

Die heute Nacht erfolgte Veroffentlichung der ersten technischen Anwendung der Uranspaltung nehme ich zum Anlass, Ihnen mitzuteilen,dass auch am II.Physikalischen Institut wahrend des Krieges an diesem Problem gearbeitet wurde.Ich selbst war aus diesem Grunde nie zur Wehrmacht eingeruckt.

Sie erinnern sich noch, dass ich wahrend unserer gemeinsamen Expedition in den Kaukasus vor nunmehr 10 Jahren und auch auf manchen spateren Bergfahrten von der Suche nach dem unbekannten Element sprach,das Alphastrahlen von 2 cm Reichweite aussendet.Wahrend des ganzen Krieges habe ich uber dieses unbekannte Element gearbeitet. Durch hunderte Versuche ist erhartet,dass insgesamt sieben bisher unbekannte Alphastrahler vorliegen mit chemisch sehr verwandten Eigenschaften,der ganzen Sachlage nach liegen Transurane vor.Es gelang als Ausgangsmaterial bisher wertlose Abfallprodukte der Metallverhuttung aufzufinden, die in sehr grossen Mengen vorliegen.Die chemischen Eigenschaften sind in grossen Umrissen festgelegt und aller Wahrscheinlichkeit nach wird die Gewinnung der Transurane im technischen Masstabe keine Schwierigkeiten bieten.In letzter Zeit habe ich starke Praparate in der Hand gehabt,mit denen eine massenspektrographische Aufnahme bereits moglich gewesen ware.Rontgenspektren habe ich besonderer Verhaltnisse wegen nicht aufnehmen konnen;nach der radioaktiv gemessenen Starke der Endfraktionen waren sie zu erhalten gewesen.Die Arbeiten habe ich mit Dr. Hernegger als Chemiker begonnen und sie mit Professor Dr. Alfred Brukl weitergefuhrt.Brukl ist zwar ein vorzuglicher anorganischer. Analytiker,konnte sich aber doch mit der besonderen Eigenart des Problems nicht ganz befreunden,so dass die Arbeiten nicht in dem wunschenswerten und an sich moglichen Tempo vorangingen.

NARA RG 77, Entry UD-22A, Box 167, Folder
32.12-2 GERMANY: Personnel (Jan 45 – Dec 45)

Figure D.359: Immediately after hearing the news of Hiroshima, Josef Schintlmeister wrote that throughout the war he had worked on a similar project involving a new element (plutonium), of which just a few kilograms would be sufficient for a nuclear device. He offered to help restart that work for postwar sponsors, alarming Samuel Goudsmit and other U.S. officials [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

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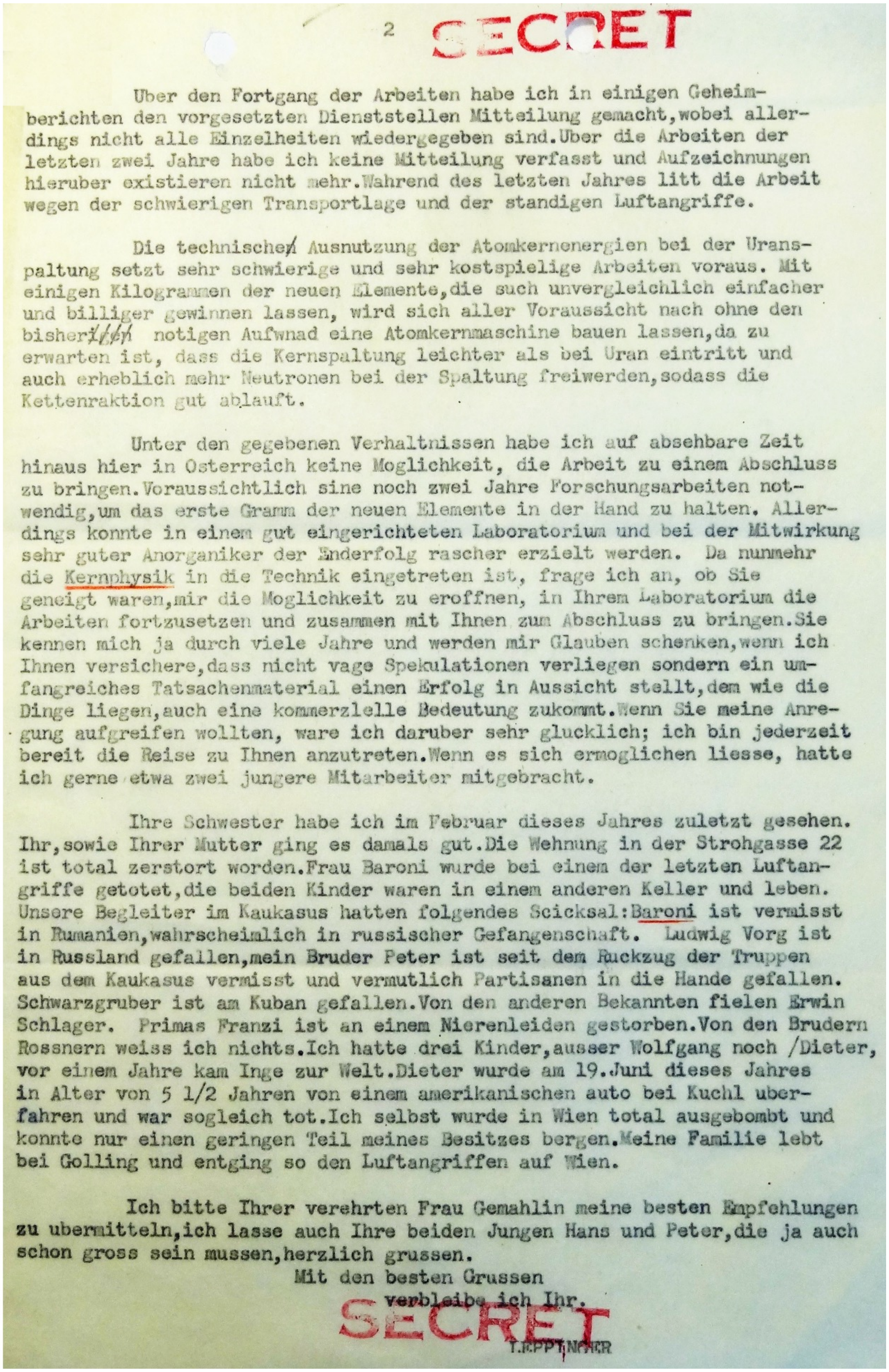

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Uber den Fortgang der Arbeiten habe ich in einigen Geheimberichten den vorgesetzten Dienststellen Mitteilung gemacht,wobei allerdings nicht alle Einzelheiten wiedergegeben sind.Uber die Arbeiten der letzten zwei Jahre habe ich keine Mitteilung verfasst und Aufzeichnungen hieruber existieren nicht mehr.Wahrend des letzten Jahres litt die Arbeit wegen der schwierigen Transportlage und der standigen Luftangriffe.

Die technische~~n~~ Ausnutzung der Atomkernenergien bei der Uranspaltung setzt sehr schwierige und sehr kostspielige Arbeiten voraus. Mit einigen Kilogrammen der neuen Elemente,die such unvergleichlich einfacher und billiger gewinnen lassen, wird sich aller Voraussicht nach ohne den bisher~~igen~~ notigen Aufwnad eine Atomkernmaschine bauen lassen,da zu erwarten ist, dass die Kernspaltung leichter als bei Uran eintritt und auch erheblich mehr Neutronen bei der Spaltung freiwerden,sodass die Kettenraktion gut ablauft.

Unter den gegebenen Verhaltnissen habe ich auf absehbare Zeit hinaus hier in Osterreich keine Moglichkeit, die Arbeit zu einem Abschluss zu bringen.Voraussichtlich sine noch zwei Jahre Forschungsarbeiten notwendig,um das erste Gramm der neuen Elemente in der Hand zu halten. Allerdings konnte in einem gut eingerichteten Laboratorium und bei der Mitwirkung sehr guter Anorganiker der Enderfolg rascher erzielt werden. Da nunmehr die Kernphysik in die Technik eingetreten ist, frage ich an, ob Sie geneigt waren,mir die Moglichkeit zu eroffnen, in Ihrem Laboratorium die Arbeiten fortzusetzen und zusammen mit Ihnen zum Abschluss zu bringen.Sie kennen mich ja durch viele Jahre und werden mir Glauben schenken,wenn ich Ihnen versichere,dass nicht vage Spekulationen verliegen sondern ein umfangreiches Tatsachenmaterial einen Erfolg in Aussicht stellt,dem wie die Dinge liegen,auch eine kommerzlelle Bedeutung zukommt.Wenn Sie meine Anregung aufgreifen wollten, ware ich daruber sehr glucklich; ich bin jederzeit bereit die Reise zu Ihnen anzutreten.Wenn es sich ermoglichen liesse, hatte ich gerne etwa zwei jungere Mitarbeiter mitgebracht.

Ihre Schwester habe ich im Februar dieses Jahres zuletzt gesehen. Ihr,sowie Ihrer Mutter ging es damals gut.Die Wehnung in der Strohgasse 22 ist total zerstort worden.Frau Baroni wurde bei einem der letzten Luftangriffe getotet,die beiden Kinder waren in einem anderen Keller und leben. Unsere Begleiter im Kaukasus hatten folgendes Scicksal:Baroni ist vermisst in Rumanien,wahrscheimlich in russischer Gefangenschaft. Ludwig Vorg ist in Russland gefallen,mein Bruder Peter ist seit dem Ruckzug der Truppen aus dem Kaukasus vermisst und vermutlich Partisanen in die Hande gefallen. Schwarzgruber ist am Kuban gefallen.Von den anderen Bekannten fielen Erwin Schlager. Primas Franzi ist an einem Nierenleiden gestorben.Von den Brudern Rossnern weiss ich nichts.Ich hatte drei Kinder,ausser Wolfgang noch /Dieter, vor einem Jahre kam Inge zur Welt.Dieter wurde am 19.Juni dieses Jahres in Alter von 5 1/2 Jahren von einem amerikanischen auto bei Kuchl uberfahren und war sogleich tot.Ich selbst wurde in Wien total ausgebombt und konnte nur einen geringen Teil meines Besitzes bergen.Meine Familie lebt bei Golling und entging so den Luftangriffen auf Wien.

Ich bitte Ihrer verehrten Frau Gemahlin meine besten Empfehlungen zu ubermitteln,ich lasse auch Ihre beiden Jungen Hans und Peter,die ja auch schon gross sein mussen,herzlich grussen.

Mit den besten Grussen
verbleibe ich Ihr.

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I.EPPINGER

NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45 – Dec 45)

Figure D.360: Immediately after hearing the news of Hiroshima, Josef Schintlmeister wrote that throughout the war he had worked on a similar project involving a new element (plutonium), of which just a few kilograms would be sufficient for a nuclear device. He offered to help restart that work for postwar sponsors, alarming Samuel Goudsmit and other U.S. officials [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

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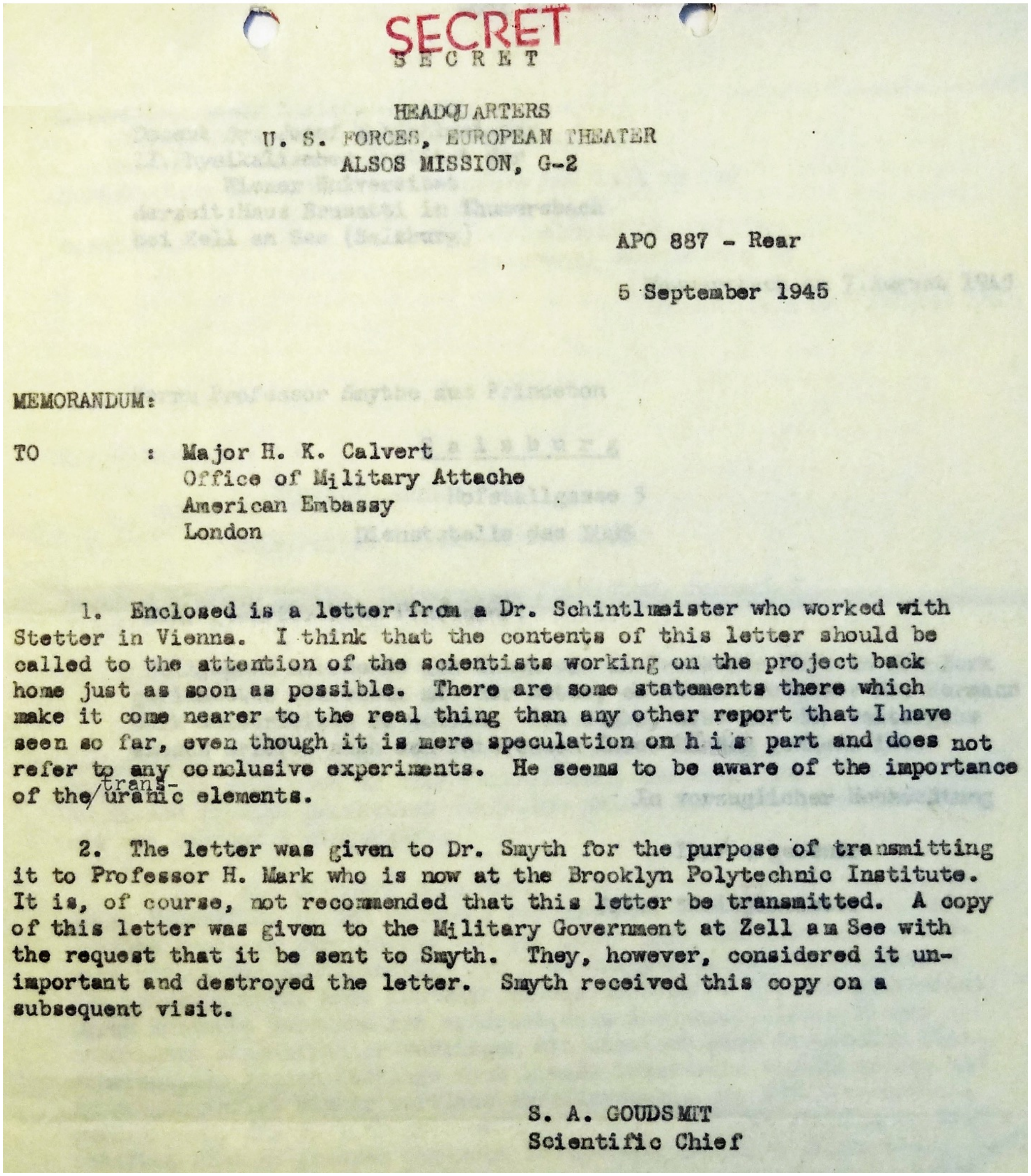
NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45 – Dec 45)



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HEADQUARTERS
U. S. FORCES, EUROPEAN THEATER
ALSOS MISSION, G-2

APO 887 - Rear

5 September 1945

MEMORANDUM:

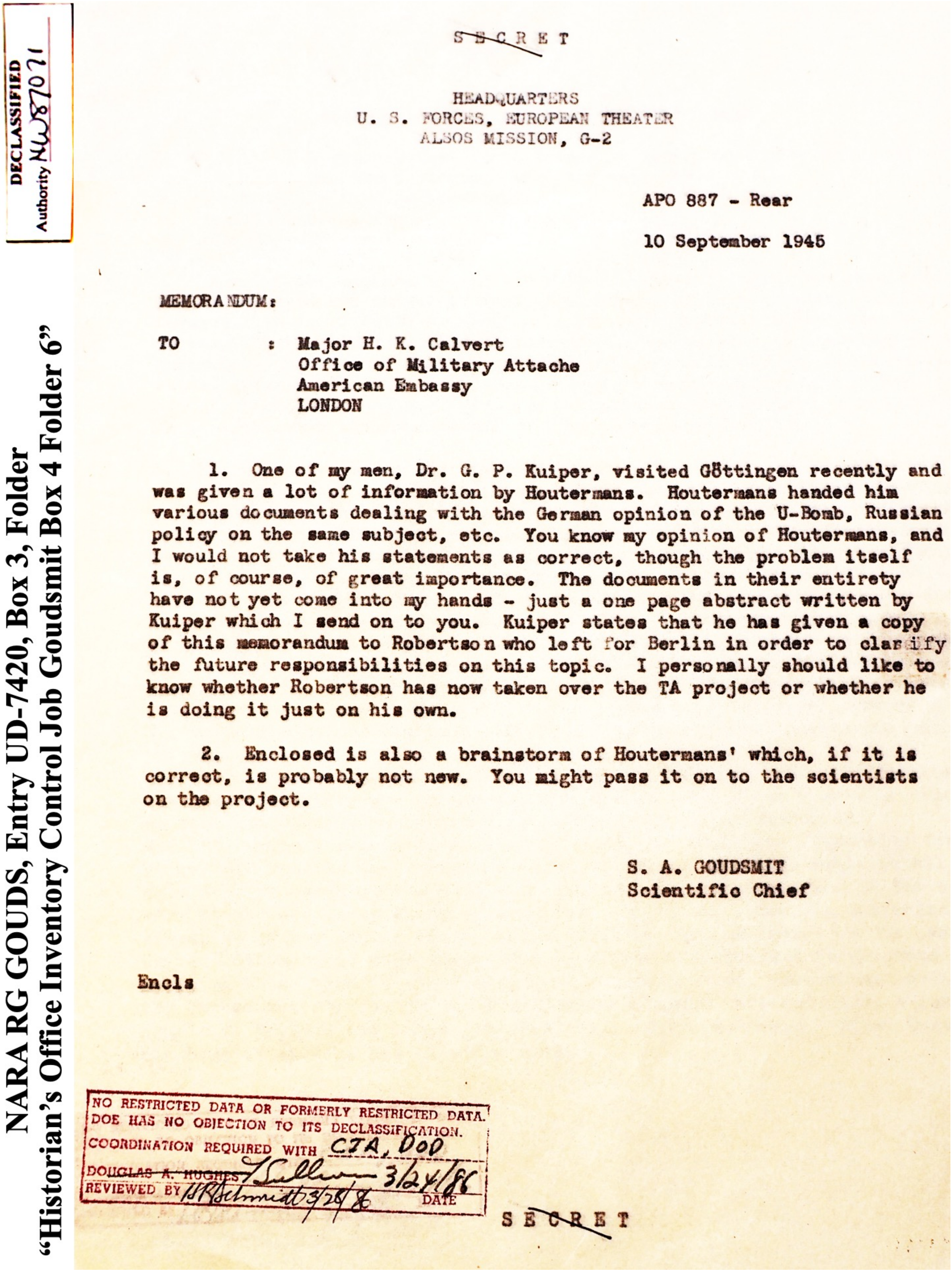
TO : Major H. K. Calvert
Office of Military Attache
American Embassy
London

1. Enclosed is a letter from a Dr. Schintlmeister who worked with Stetter in Vienna. I think that the contents of this letter should be called to the attention of the scientists working on the project back home just as soon as possible. There are some statements there which make it come nearer to the real thing than any other report that I have seen so far, even though it is mere speculation on his part and does not refer to any conclusive experiments. He seems to be aware of the importance of the trans-uranic elements.

2. The letter was given to Dr. Smyth for the purpose of transmitting it to Professor H. Mark who is now at the Brooklyn Polytechnic Institute. It is, of course, not recommended that this letter be transmitted. A copy of this letter was given to the Military Government at Zell am See with the request that it be sent to Smyth. They, however, considered it unimportant and destroyed the letter. Smyth received this copy on a subsequent visit.

S. A. GOUDSMIT
Scientific Chief

Figure D.361: Immediately after hearing the news of Hiroshima, Josef Schintlmeister wrote that throughout the war he had worked on a similar project involving a new element (plutonium), of which just a few kilograms would be sufficient for a nuclear device. He offered to help restart that work for postwar sponsors, alarming Samuel Goudsmit and other U.S. officials [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].



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NARA RG GOUDS, Entry UD-7420, Box 3, Folder
"Historian's Office Inventory Control Job Goudsmit Box 4 Folder 6"

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HEADQUARTERS
U. S. FORCES, EUROPEAN THEATER
ALSOS MISSION, G-2

APO 887 - Rear

10 September 1945

MEMORANDUM:

TO : Major H. K. Calvert
Office of Military Attache
American Embassy
LONDON

1. One of my men, Dr. G. P. Kuiper, visited Göttingen recently and was given a lot of information by Houtermans. Houtermans handed him various documents dealing with the German opinion of the U-Bomb, Russian policy on the same subject, etc. You know my opinion of Houtermans, and I would not take his statements as correct, though the problem itself is, of course, of great importance. The documents in their entirety have not yet come into my hands - just a one page abstract written by Kuiper which I send on to you. Kuiper states that he has given a copy of this memorandum to Robertson who left for Berlin in order to clarify the future responsibilities on this topic. I personally should like to know whether Robertson has now taken over the TA project or whether he is doing it just on his own.

2. Enclosed is also a brainstorm of Houtermans' which, if it is correct, is probably not new. You might pass it on to the scientists on the project.

S. A. GOUDSMIT
Scientific Chief

Encls

NO RESTRICTED DATA OR FORMERLY RESTRICTED DATA.
DOE HAS NO OBJECTION TO ITS DECLASSIFICATION.
COORDINATION REQUIRED WITH CIA, DOD
~~DOUGLAS A. HUGHES~~ Sullivan 3/24/86
REVIEWED BY HR Schmidt 3/28/86 DATE

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Figure D.362: Samuel Goudsmit to Horace K. Calvert. 10 September 1945 [NARA RG GOUDS, Entry UD-7420, Box 3, Folder "Historian's Office Inventory Control Job Goudsmit Box 4 Folder 6"]. "You know my opinion of Houtermans, and I would not take his statements as correct."

[The following document demonstrates that scientists in Germany understood how to convert Th-232 to make a U-233 bomb.]

Fritz Houtermans. 3 September 1945. How to use thorium for nuclear energy from fission. Typographical errors in the original document have been retained below. [NARA RG 77, Entry UD-22A, Box 173, Folder 60.22-1 RUSSIA: Research—TA (43–Jun 46)]

How to use Thorium for nuclear energy from fission.

Take pure thorium or thoriumoxide, mix to it some U 235 or Pu 239 separated from U238. The amount of U235 or 239 necessary will presumably be lower than 0.7%, because resonance capture in Th seems to be stronger than in U238. By neutron capture Th233 is formed. The mixture should be such that in heavy water, possibly also in metallic beryllium, or even BeO, or in graphite the chain reaction is just started, retarded only by resonance capture of Th232. It may be that the chain reaction will work only at low temperatures, if the width of the Th-resonance capture is given by Doppler-broadening. This will be true especially, the heavier the material is for slowing down the neutrons, i.e for graphite. It might be necessary to cool away even at low temperatures the energy released by the chain reaction, but any neutron lost will form an atom of Th 233, which decays with T=23 min to Pa 233, a body known to emit β-rays also and to decay into U 233. U 233 seems to have rather a long half life, and may be α-active. But from general considerations similar to those of Bohr-Wheeler, I should be rather think that U 233 has a fission treshold low enough that thermal neutrons will be able to make thermofission. Since you get weighable quantities of neutrons from the chain reaction in the separeted isotope U235 or 239 you will thus be able to enrich either U 233 to such an extent, that the chain reaction will start at normal temperatures or else to separete U 233 chemicall from the thorium mixture and use it as U235 or 239 as fuel for the machine.

September 3rd, 1945 F.G. Houtermans

P.S. by Gerard P. Kuiper, Frankfurt-Hochst, 7 Sept., 1945.

This is Prof. Houtermans' prediction of how the Russians will make the atomic bomb. No copy of it has been made; this is the original. If any "profit" or "credit" will result from his proposal its author requests that the benefits will go to his wife, Mrs. Houtermans, Physics Department, Radcliffe College, Cambridge, Mass.

Gerard P. Kuiper
Alsos Mission
G2, HQ, USFET

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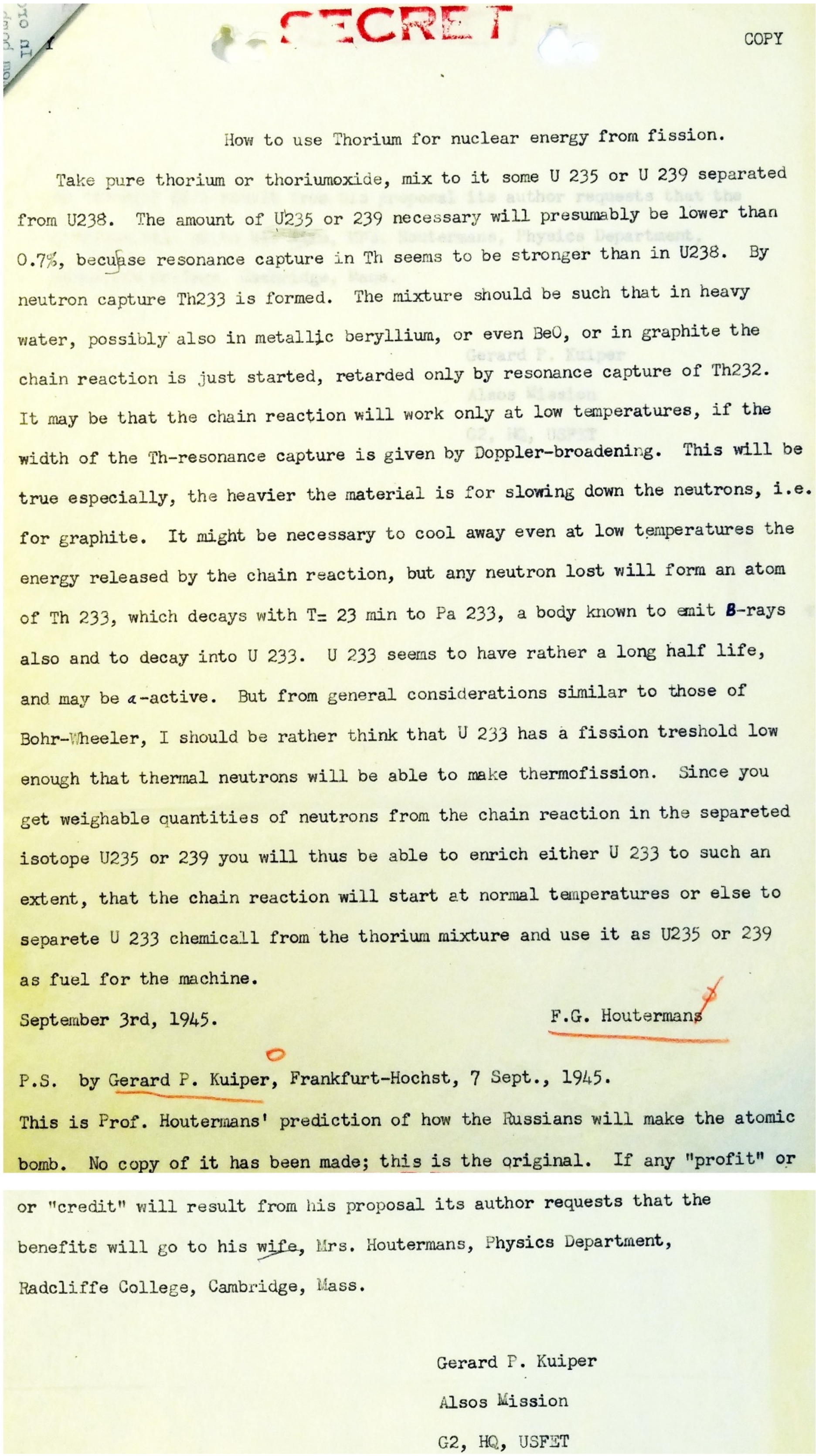
Authority NND 979017



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How to use Thorium for nuclear energy from fission.

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September 3rd, 1945. F.G. Houtermans

P.S. by Gerard P. Kuiper, Frankfurt-Hochst, 7 Sept., 1945.
This is Prof. Houtermans' prediction of how the Russians will make the atomic bomb. No copy of it has been made; this is the original. If any "profit" or or "credit" will result from his proposal its author requests that the benefits will go to his wife, Mrs. Houtermans, Physics Department, Radcliffe College, Cambridge, Mass.

Gerard P. Kuiper
Alsos Mission
G2, HQ, USFET

NARA RG 77, Entry UD-22A, Box 173, Folder 60.22-1 RUSSIA: Research---TA (43--Jun 46)

Figure D.363: Fritz Houtermans. 3 September 1945. How to use thorium for nuclear energy from fission [NARA RG 77, Entry UD-22A, Box 173, Folder 60.22-1 RUSSIA: Research—TA (43–Jun 46)].

Samuel Goudsmit and Frederic A. C. Wardenburg. 17 October 1944. Subject: Thorium Products taken to Auer Gesellschaft, Germany [NARA RG 77, Entry UD-22A, Box 163, Folder Australia]

The following information was obtained from M. Paul Gregory, acting Director of the Societé des Terres Rares, 67, Rue de Preny, Paris (17^o).

During the occupation the company was under the supervision of employees of the Auer Gesellschaft. The president of Auer, Dr. Quadebert, visited Paris occasionally. The man in direct charge of all Auer interests in occupied territory was Dr. Ihwe, who did much travelling.

The Germans showed at first only mild interest in Thorium. They did buy various rare earth compounds, probably for use in colored glasses. Early in 1944, however, they requisitioned all available Thorium sufate, namely about 95 tons. They took 85 tons, but left 10 tons for the French. During the occupation they had acquired about 850 tons of monazite, which is equivalent to about 86 tons of Thorium oxide.

The sudden interest in Thorium products is unusual, according to M. Gregory. He stated that is considered as a waste product in rare earth production. He claimed not to understand what the Germans wanted it for. (Dr. Blumenfeld, the director of the company, now in New York, had previously called our attention to the use of Thorium oxide in the Fischer-Tropsch process).

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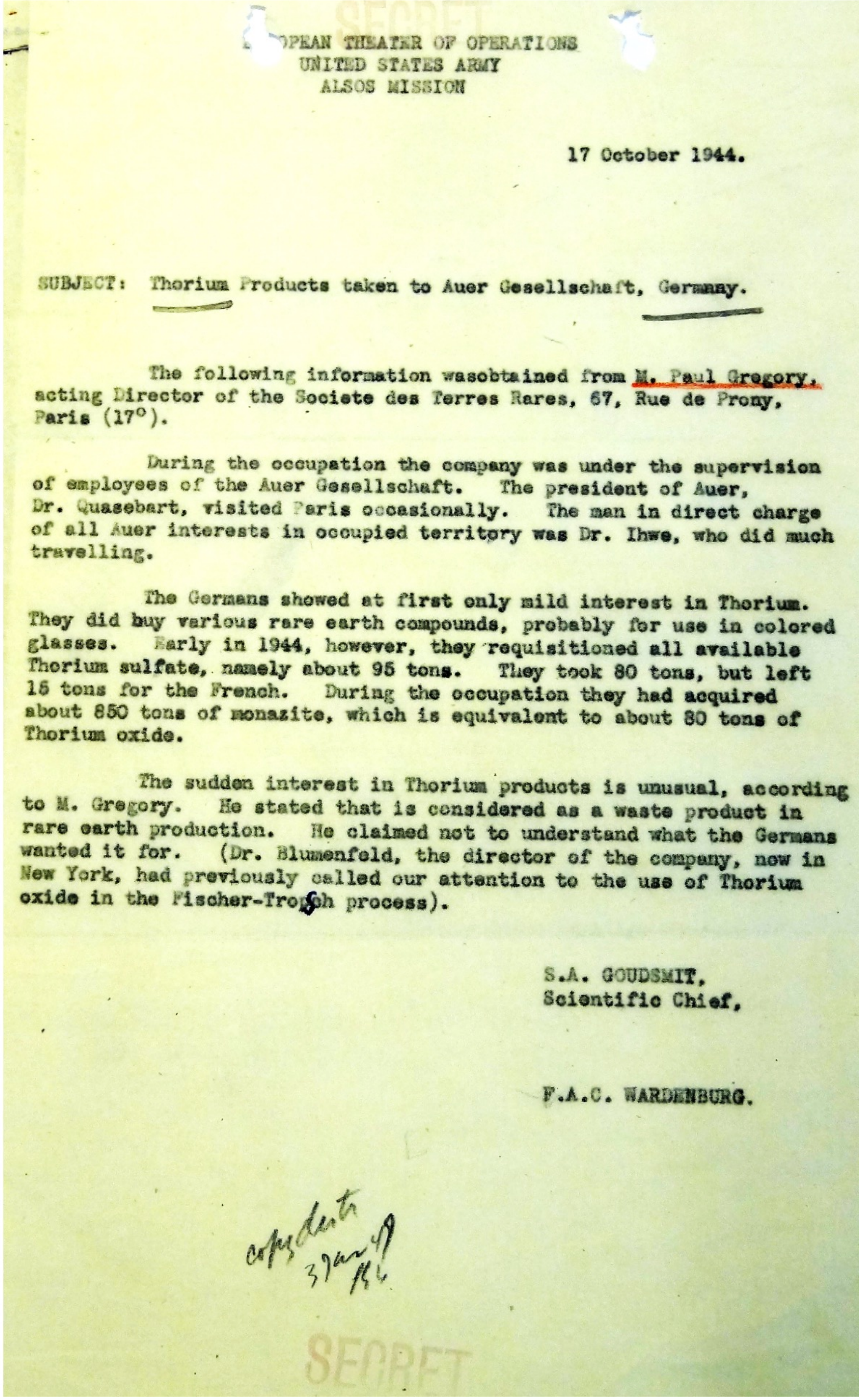

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OPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS MISSION

17 October 1944.

SUBJECT: Thorium Products taken to Auer Gesellschaft, Germany.

The following information wasobtained from M. Paul Gregory, acting Director of the Societe des Terres Rares, 67, Rue de Prony, Paris (17°).

During the occupation the company was under the supervision of employees of the Auer Gesellschaft. The president of Auer, Dr. Quasebart, visited Paris occasionally. The man in direct charge of all Auer interests in occupied territory was Dr. Ihwe, who did much travelling.

The Germans showed at first only mild interest in Thorium. They did buy various rare earth compounds, probably for use in colored glasses. Early in 1944, however, they requisitioned all available Thorium sulfate, namely about 95 tons. They took 80 tons, but left 15 tons for the French. During the occupation they had acquired about 850 tons of monazite, which is equivalent to about 80 tons of Thorium oxide.

The sudden interest in Thorium products is unusual, according to M. Gregory. He stated that is considered as a waste product in rare earth production. He claimed not to understand what the Germans wanted it for. (Dr. Blumenfeld, the director of the company, now in New York, had previously called our attention to the use of Thorium oxide in the Fischer-Tropsch process).

S.A. GOUDSMIT,
Scientific Chief,

F.A.C. WARDENBURG.

copy dest'n
3 Jan 49

SECRET

NARA RG 77, Entry UD-22A, Box 163, Folder Australia

Figure D.364: Samuel Goudsmit and Frederic A. C. Wardenburg. 17 October 1944. Subject: Thorium Products taken to Auer Gesellschaft, Germany [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Frederic A. C. Wardenburg. Interrogation of Dr. Ing. Ernest Nagelstein. 2 November 1944. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION Administrative Matters (1940–1945)]

[...] The atomic bomb is made of either thorium or uranium, Nagelstein is not sure which. He was told by Doering, however, that Auer is making metal thorium and no uses of thorium in the metallic state are known. [...]

David C. G. Gattiker to L. E. Seeman. 2 October 1946. Subject: Thorium metal made by the Germans [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Some time ago I asked the London office whether they could locate an alleged quantity of about 13 tons of thorium metal which we believe was made by the Germans during the last years of the war.

The London office now advises me that they have been entirely unable to trace this material and do not know for what purpose metal was manufactured, although it is believed that it was in connection with experiments in various types of electronic valves (tubes).

[See document photo on p. 3837.]

BIOS 675. *The Production of Thorium and Uranium in Germany.*

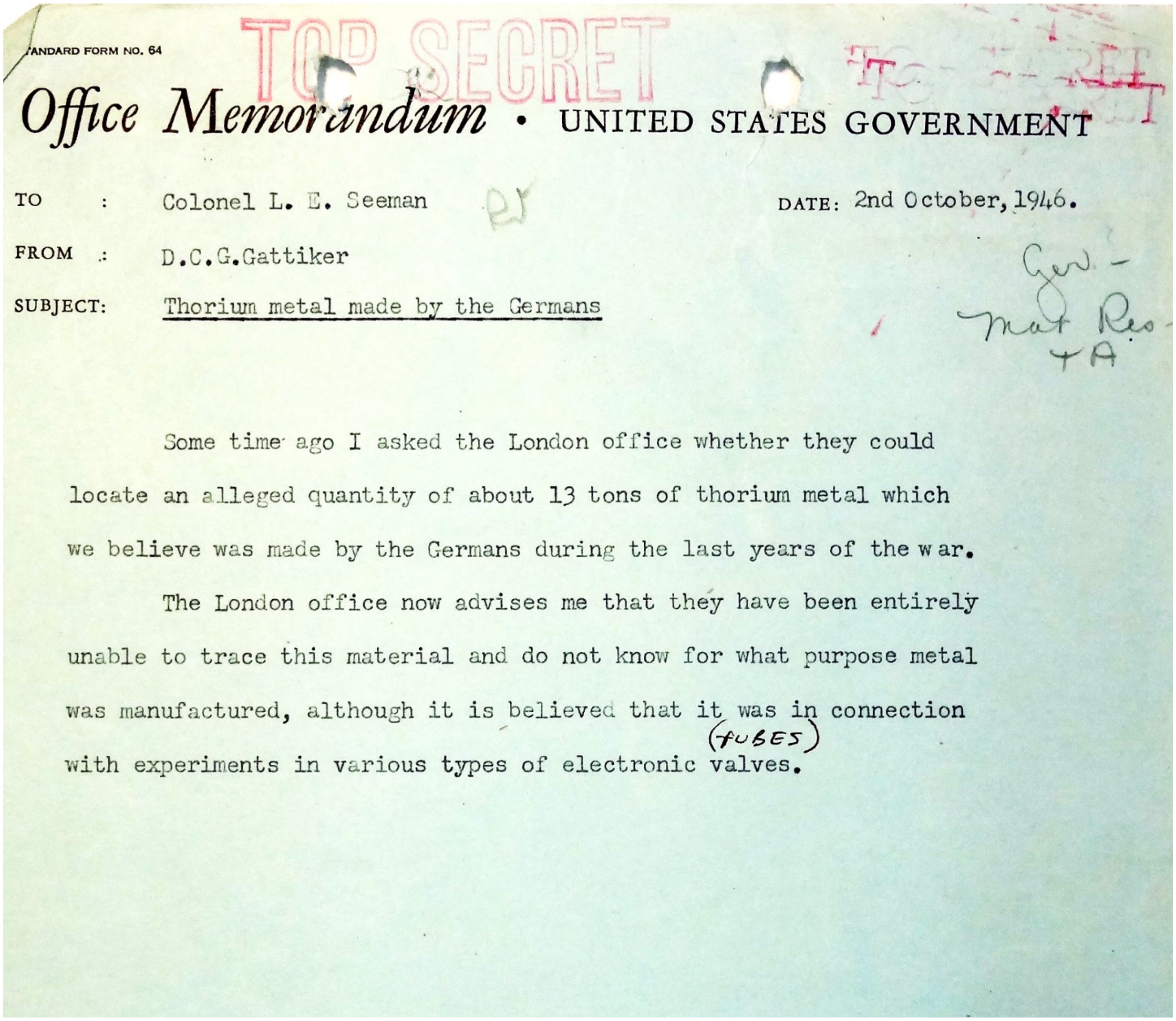
Metallic thorium and uranium were produced on a large scale in Germany by the reduction of their respective oxides with calcium using a calcium chloride flux. The major part of the production during the war came from Werk II of the Deutsche Gold- und Silber-Scheide-Anstalt (Degussa)[...]

Thorium oxide was supplied by Auer Gesellschaft, Berlin, which had large stock piles of Monazite sand, i.e., an enriched sand consisting mostly of Monazite, Magnetite, Zirconia, Thoria and Quartz. After reduction of the oxide, the thorium metal was returned to Auer Gesellschaft or in some cases sent under their control directly to the consumers[...] The uranium ore was coming from Czecho-Slovakia and Belgium Congo and was supplied from their stock piles by the Auer Gesellschaft for reproduction. [...]

Raw calcium, obtained under the form of large ingots, was melted under special conditions to obtain a pure metal free from oxide or nitride contamination. [...]

DECLASSIFIED
Authority 917017

NARA RG 77, Entry UD-22A, Box 163, Folder Australia



STANDARD FORM NO. 64

TOP SECRET

TOP SECRET

Office Memorandum • UNITED STATES GOVERNMENT

TO : Colonel L. E. Seeman

DATE: 2nd October, 1946.

FROM : D.C.G.Gattiker

SUBJECT: Thorium metal made by the Germans

Gen - Mat Res - TA

Some time ago I asked the London office whether they could locate an alleged quantity of about 13 tons of thorium metal which we believe was made by the Germans during the last years of the war.

The London office now advises me that they have been entirely unable to trace this material and do not know for what purpose metal was manufactured, although it is believed that it was in connection with experiments in various types of electronic (tubes) valves.

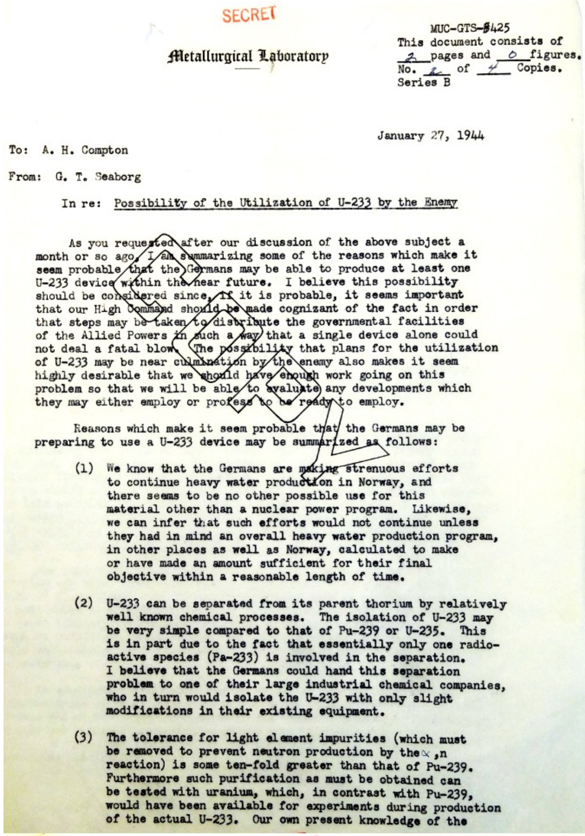
Figure D.365: David C. G. Gattiker to L. E. Seeman. 2 October 1946. Subject: Thorium metal made by the Germans [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

December 1943–February 1944 letters to and from Arthur H. Compton. [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]

[See document photos on p. 3839.

These documents demonstrate serious wartime concern by senior scientists from the U.S. Manhattan Project that Germany was breeding uranium-233 from thorium-232.

These documents also discuss some of the technical details, advantages, and disadvantages of ^{233}U relative to ^{235}U and ^{239}Pu.]



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MUC-GTS-#425
This document consists of
2 pages and 0 figures.
No. 2 of 4 Copies.
Series B

Metallurgical Laboratory

January 27, 1944

To: A. H. Compton

From: G. T. Seaborg

In re: Possibility of the Utilization of U-233 by the Enemy

COPY

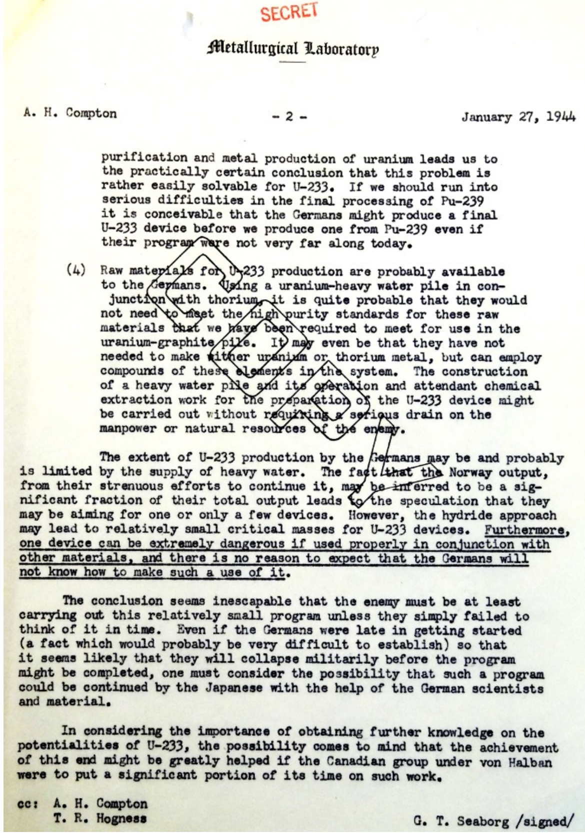
As you requested after our discussion of the above subject a month or so ago, I am summarizing some of the reasons which make it seem probable that the Germans may be able to produce at least one U-233 device within the near future. I believe this possibility should be considered since, if it is probable, it seems important that our High Command should be made cognizant of the fact in order that steps may be taken to distribute the governmental facilities of the Allied Powers in such a way that a single device alone could not deal a fatal blow. The possibility that plans for the utilization of U-233 may be near culmination by the enemy also makes it seem highly desirable that we should have enough work going on this problem so that we will be able to evaluate any developments which they may either employ or profess to be ready to employ.

Reasons which make it seem probable that the Germans may be preparing to use a U-233 device may be summarized as follows:

(1) We know that the Germans are making strenuous efforts to continue heavy water production in Norway, and there seems to be no other possible use for this material other than a nuclear power program. Likewise, we can infer that such efforts would not continue unless they had in mind an overall heavy water production program, in other places as well as Norway, calculated to make or have made an amount sufficient for their final objective within a reasonable length of time.

(2) U-233 can be separated from its parent thorium by relatively well known chemical processes. The isolation of U-233 may be very simple compared to that of Pu-239 or U-235. This is in part due to the fact that essentially only one radioactive species (Pa-233) is involved in the separation. I believe that the Germans could hand this separation problem to one of their large industrial chemical companies, who in turn would isolate the U-233 with only slight modifications in their existing equipment.

(3) The tolerance for light element impurities (which must be removed to prevent neutron production by the α,n reaction) is some ten-fold greater than that of Pu-239. Furthermore such purification as must be obtained can be tested with uranium, which, in contrast with Pu-239, would have been available for experiments during production of the actual U-233. Our own present knowledge of the



SECRET

Metallurgical Laboratory

A. H. Compton - 2 - January 27, 1944

purification and metal production of uranium leads us to the practically certain conclusion that this problem is rather easily solvable for U-233. If we should run into serious difficulties in the final processing of Pu-239 it is conceivable that the Germans might produce a final U-233 device before we produce one from Pu-239 even if their program were not very far along today.

COPY

(4) Raw materials for U-233 production are probably available to the Germans. Using a uranium-heavy water pile in conjunction with thorium, it is quite probable that they would not need to meet the high purity standards for these raw materials that we have been required to meet for use in the uranium-graphite pile. It may even be that they have not needed to make either uranium or thorium metal, but can employ compounds of these elements in the system. The construction of a heavy water pile and its operation and attendant chemical extraction work for the preparation of the U-233 device might be carried out without requiring a serious drain on the manpower or natural resources of the enemy.

The extent of U-233 production by the Germans may be and probably is limited by the supply of heavy water. The fact that the Norway output, from their strenuous efforts to continue it, may be inferred to be a significant fraction of their total output leads to the speculation that they may be aiming for one or only a few devices. However, the hydride approach may lead to relatively small critical masses for U-233 devices. Furthermore, one device can be extremely dangerous if used properly in conjunction with other materials, and there is no reason to expect that the Germans will not know how to make such a use of it.

The conclusion seems inescapable that the enemy must be at least carrying out this relatively small program unless they simply failed to think of it in time. Even if the Germans were late in getting started (a fact which would probably be very difficult to establish) so that it seems likely that they will collapse militarily before the program might be completed, one must consider the possibility that such a program could be continued by the Japanese with the help of the German scientists and material.

In considering the importance of obtaining further knowledge on the potentialities of U-233, the possibility comes to mind that the achievement of this end might be greatly helped if the Canadian group under von Halban were to put a significant portion of its time on such work.

cc: A. H. Compton
T. R. Hogness

G. T. Seaborg /signed/

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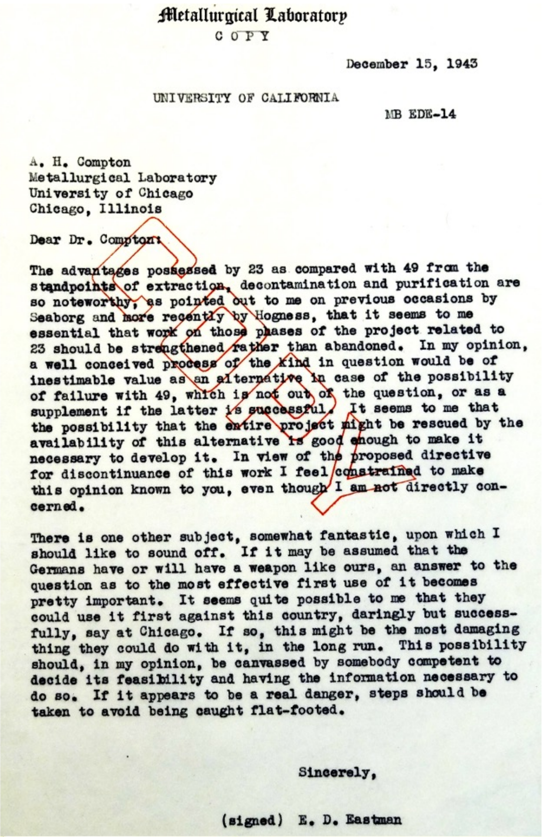
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)



Metallurgical Laboratory
C O P Y

December 15, 1943

UNIVERSITY OF CALIFORNIA

MB EDE-14

A. H. Compton
Metallurgical Laboratory
University of Chicago
Chicago, Illinois

Dear Dr. Compton:

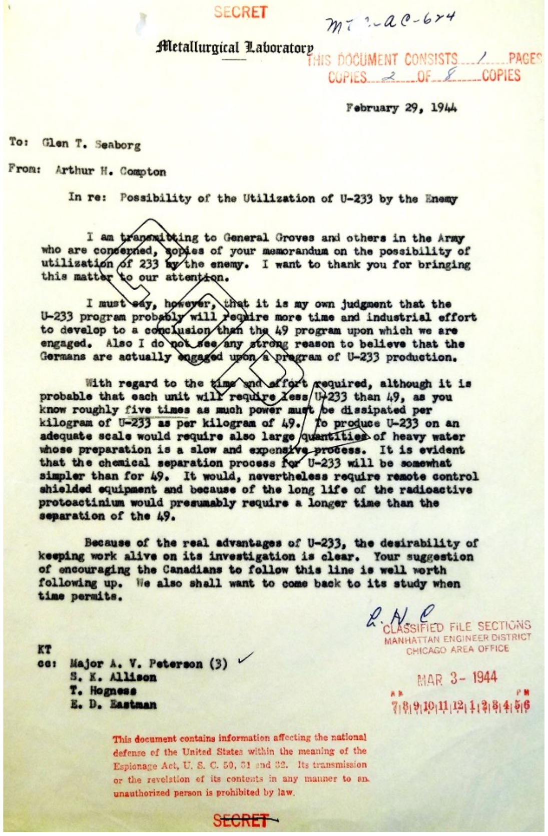
COPY

The advantages possessed by 23 as compared with 49 from the standpoints of extraction, decontamination and purification are so noteworthy, as pointed out to me on previous occasions by Seaborg and more recently by Hogness, that it seems to me essential that work on those phases of the project related to 23 should be strengthened rather than abandoned. In my opinion, a well conceived process of the kind in question would be of inestimable value as an alternative in case of the possibility of failure with 49, which is not out of the question, or as a supplement if the latter is successful. It seems to me that the possibility that the entire project might be rescued by the availability of this alternative is good enough to make it necessary to develop it. In view of the proposed directive for discontinuance of this work I feel constrained to make this opinion known to you, even though I am not directly concerned.

There is one other subject, somewhat fantastic, upon which I should like to sound off. If it may be assumed that the Germans have or will have a weapon like ours, an answer to the question as to the most effective first use of it becomes pretty important. It seems quite possible to me that they could use it first against this country, daringly but successfully, say at Chicago. If so, this might be the most damaging thing they could do with it, in the long run. This possibility should, in my opinion, be canvassed by somebody competent to decide its feasibility and having the information necessary to do so. If it appears to be a real danger, steps should be taken to avoid being caught flat-footed.

Sincerely,

(signed) E. D. Eastman



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Metallurgical Laboratory

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February 29, 1944

To: Glen T. Seaborg

From: Arthur H. Compton

In re: Possibility of the Utilization of U-233 by the Enemy

COPY

I am transmitting to General Groves and others in the Army who are concerned, copies of your memorandum on the possibility of utilization of 233 by the enemy. I want to thank you for bringing this matter to our attention.

I must say, however, that it is my own judgment that the U-233 program probably will require more time and industrial effort to develop to a conclusion than the 49 program upon which we are engaged. Also I do not see any strong reason to believe that the Germans are actually engaged upon a program of U-233 production.

With regard to the time and effort required, although it is probable that each unit will require less U-233 than 49, as you know roughly five times as much power must be dissipated per kilogram of U-233 as per kilogram of 49. To produce U-233 on an adequate scale would require also large quantities of heavy water whose preparation is a slow and expensive process. It is evident that the chemical separation process for U-233 will be somewhat simpler than for 49. It would, nevertheless require remote control shielded equipment and because of the long life of the radioactive protoactinium would presumably require a longer time than the separation of the 49.

Because of the real advantages of U-233, the desirability of keeping work alive on its investigation is clear. Your suggestion of encouraging the Canadians to follow this line is well worth following up. We also shall want to come back to its study when time permits.

L. H. C.

CLASSIFIED FILE SECTIONS
MANHATTAN ENGINEER DISTRICT
CHICAGO AREA OFFICE
MAR 3- 1944
AM 7 8 9 10 11 12 1 2 3 4 5 6 PM

KT
cc: Major A. V. Peterson (3) ✓
S. K. Allison
T. Hogness
E. D. Eastman

This document contains information affecting the national defense of the United States within the meaning of the Espionage Act, U. S. C. 50, 31 and 32. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

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Figure D.366: December 1943–February 1944 letters to and from Arthur H. Compton, demonstrating high-level U.S. concerns that Germany was breeding uranium-233 from thorium-232 [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

D.5.2 Known and Suspected Fission Reactors

[Pu-239 or U-233 could have been bred in a fission reactor. Np-237 [Sanchez et al. 2008] could also have been bred in a reactor (e.g., by knocking a neutron out of U-238), although it probably would have been more difficult to produce in quantity than Pu-239 or U-233 [Benedict et al. 1981].

There is evidence for several potential reactors in German-controlled territory, and one or more of those reactors may have been operational during the war (see map on p. 3841):

1. The reactor of Werner Heisenberg's group, first located at the Kaiser Wilhelm Institute for Physics in Berlin-Dahlem, and later moved to Haigerloch (pp. 3843–3853). This is by far the best known of the German fission reactors. With proper support and operation, it could have achieved criticality (a self-sustaining neutron chain reaction) during the war, but it never did [Goudsmit 1947; Groves 1962; Irving 1967; Pash 1969; Powers 1993; Walker 1989].

2. The reactor of Kurt Diebner's group, first located at Gottow/Kummersdorf, and later moved to Stadtilm (pp. 3854–3868). According to official histories, this reactor never achieved criticality during the war. In fact, there is some evidence that it may have achieved criticality in late 1944 in Gottow, and/or in March 1945 in Stadtilm [Karlsch 2005].

3. A reactor built and operated by the SS, likely in an underground facility in Thuringia, that was reported to have been operational in March 1945 (pp. 3865–3868).

4. A possible reactor and fuel reprocessing facility in the Bergkristall tunnel complex at St. Georgen/Gusen near Linz, Austria, that may have been operational during the war (pp. 3874–3920 and 4962–4970).

5. A possible reactor at Unterraderach near Friedrichshafen (on the coast of the Obersee Bodensee) that was reported to have been operational in 1944 (pp. 3921–3925).

6. A possible reactor at an underground facility in Berlin-Lichterfelde that was reported to have been operational in 1944 (pp. 3926–3928).

7. "Atomic reactors" that were reportedly located in East Prussia and that may have been operational until they were bombed by the Royal Air Force at the end of August 1944 (pp. 3928–3933).

8. A tightly guarded, heavy concrete installation at the I.G. Farben Leverkusen plant that might have been a fission reactor (pp. 3934–3935).

9. A possible fission reactor at Bodenbach/Krizik-Werke/Weser-Werke/Podmokly (pp. 3936–3937, 3987–3998).

10. Other possible sites for fission reactors (pp. 3938–3953)?

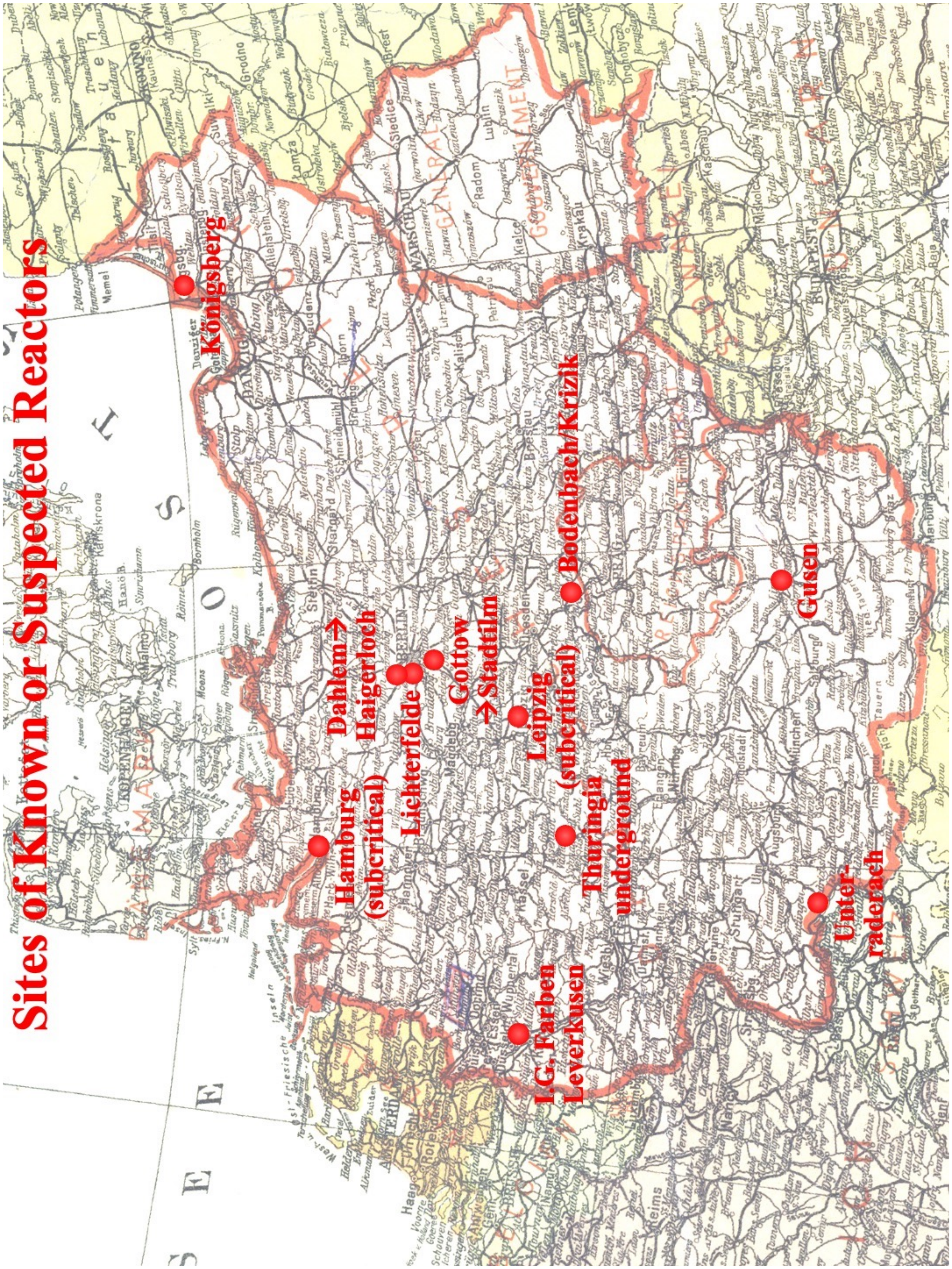

Sites of Known or Suspected Reactors
Königsberg
Bodenbach/Krizik
Gusen
Dahlem→
Haigerloch
Gottow
→Stadtilm
Lichterfelde
Leipzig
(subcritical)
Hamburg
(subcritical)
Thuringia
underground
Unter-
raderach
I.G. Farben
Leverkusen

Figure D.367: Sites of known or suspected reactors for the German nuclear program.

If one or more fission reactors were functioning during the war, that could help explain the high priority that Germany placed on producing heavy water (an excellent neutron moderator for fission reactors) at numerous locations (p. 4027).

The Soviet Union demonstrated its first fission reactor (F-1) on 25 December 1946, only about 12 months after its captured German nuclear scientists were able to begin setting up the captured German nuclear materials (including at least 300 tons of German-produced uranium oxide, which fueled both F-1 and the larger second Soviet reactor for breeding Pu-239). If German scientists and German materials accomplished that feat so quickly after starting over in the Soviet Union after the war, they certainly could have done it in German territory during the war.

In addition to the potential reactors listed above, there were also a few small, subcritical fission piles that appear to have been used purely for experimental purposes, such as those built by Robert Döpel's team in Leipzig and Paul Harteck's team in Hamburg.]

1. The fission reactor of Werner Heisenberg's group

G-371. Alvin M. Weinberg and Lothar W. Nordheim. Memorandum on the state of knowledge in nuclear science reached by the Germans in 1945. 8 November 1945.

[Note: This was a U.S. report analyzing some of the German G-reports. The U.S. code name "P-9" meant heavy water; "P-9U" meant a heavy-water-moderated uranium reactor.]

We have just had an opportunity to read a few of the German Kernphysikalische Forschungsberichte. We are writing in order to correct what we believe to be a very prevalent misconception concerning the state of the art as known to the Germans in 1945. We will proceed by posing a number of relevant questions and then answering them insofar as we can from the few reports we have been allowed to see. Presumably when more reports are made available we will be able to document our statements more fully.

I. Did the Germans know the correct lattice dimensions for a P-9U system?

Via the grapevine we have heard rumors that the Germans were experimenting with plate lattices far too rich in U. Apparently these rumors were based on very early reports which are not yet available to us. At present, however, the answer to the above question is an unequivocal yes. The March 1944 "Forschungsberichte" contain a description of experiments on various lattice arrangements performed by Bothe and Fünfer. The experiments are integral ones in which the strength of a source is measured with and without the lattice in place. The main conclusion drawn from these experiments is "eine Kombination von 20 cm D_2O und 1 cm U-Metall der Dichte 18 (wird) etwas die günstigste sein . . . Bisher hat man wohl mit einem grösseren U-Bedarfgerechnet." This conclusion is exactly the same as that reached by us, on the basis of calculations in August 1943 (CP-923). The German work apparently was done at the same time as ours.

Plates seem to have been preferred because they were most convenient for experiments. The advantage of cubes was recognized as early as June 1943 (Höcker), and the use of cylinders had been suggested on technical grounds.

II. Did the Germans know the critical dimensions of the P-9 machine?

We have not had access to the reports in which critical size calculations are made. However, there are repeated references, in the reports available to us, of about 4 tons as the required amount of P-9. This figure is essentially correct.

The Laplacians measured by the Germans are of the order 1000×10^{-6} cm^{-2}. This value is in excellent agreement with ours. It indicates, and this is important, that the U metal used by them was about as pure as ours.

III. What was the state of German theory of the chain reaction?

Here we are badly hampered by the unavailability of the reports. What we do have shows:

(1) Calculation of optimal lattice dimensions was understood and followed pretty much the same lines as ours. The calculated results on P-9 spheres agree well with ours.

(2) The group model for reflector calculations was introduced in early 1944. This was a little later than the time we began to use it extensively.

(3) Generally we would say their approach was in no wise inferior to ours; in some respects it was superior.

IV. Why didn't the Germans succeed in establishing a chain reaction with P-9?

The answer is simple; they did not have sufficient P-9. The latest reference is to a 1.5 ton P-9 experiment. According to our estimates, with the volume ratio they used (20:1), they would have needed somewhat less than 4 tons.

V. Are there any "scientific secrets" concerning the design of the chain reaction which the Germans do not seem to have understood?

From the general state of the art as deduced from the few reports we have seen, we would say their understanding of the principles is comparable to ours. The only non-engineering "secrets" we can think of which might affect the design of a chain reaction is the poisoning by Xe^{135}, and possibly, the properties of Pu^{240}.

VI. What bearing does this have on publication of the parts of the PPR [Performance Progress Report (?)] dealing with principles of the chain reaction?

The Germans knew how to design a lattice which will work. From the practical standpoint this is all that matters. The details of elegant perturbation theory or transport theory (which would be contained in Vol. III) or the details of heat transfer calculations (Vol. IV) would tell them nothing essential to the determination of lattice dimensions. They already know how to calculate the optimum dimensions.

A question of ethics is raised by the existence of the German reports. In many cases useful information is contained therein. It is certainly extraordinary, in a scientific treatise, to attribute a given result to an American author without at the same time giving due credit to his German counterpart who is known to have also done the work. Such a situation will arise for example, in Vol. III in the discussion of the multi-group methods where the Germans have duplicated our work.

VII. What bearing does this have on the general question of our "secrets"?

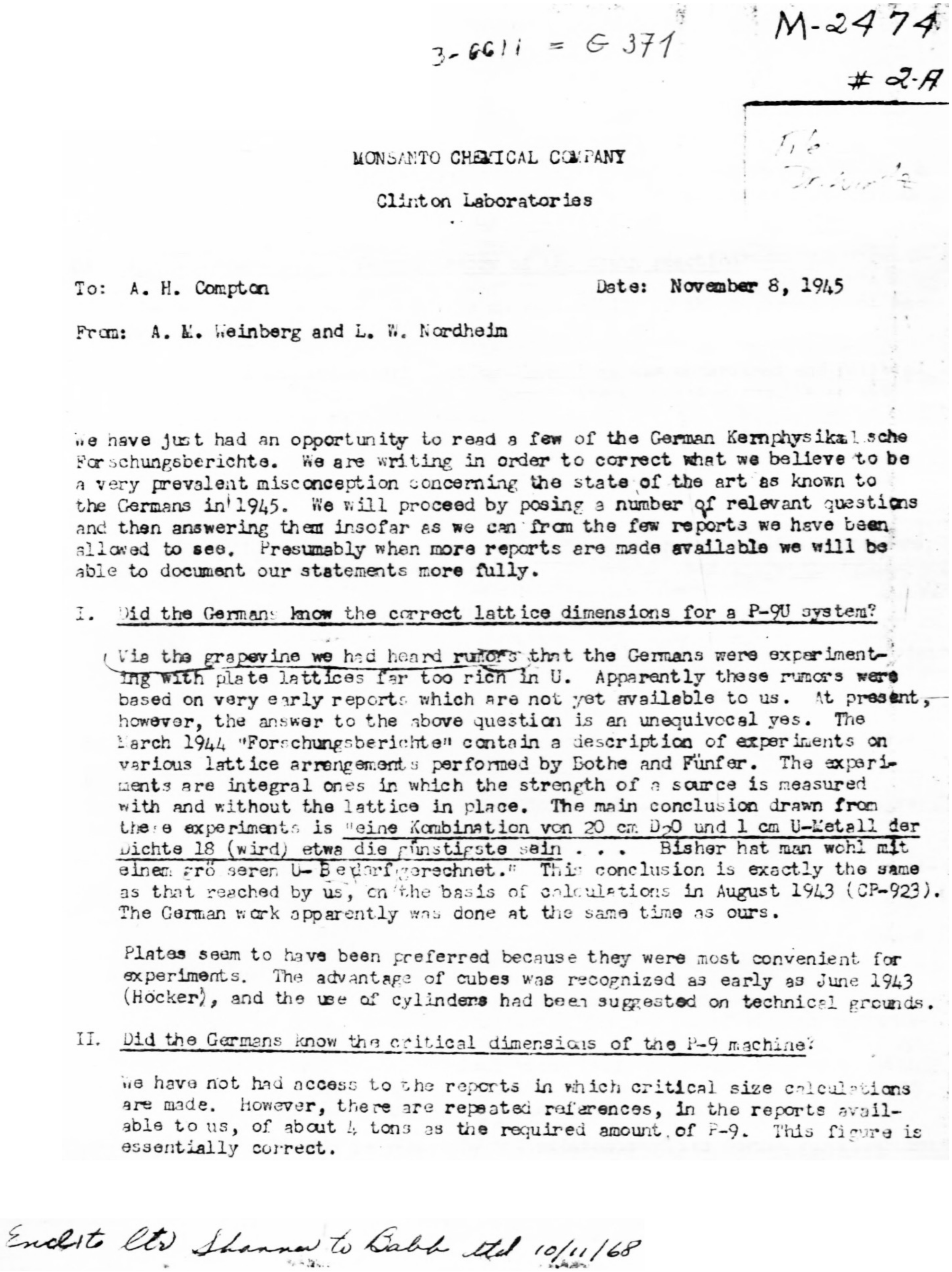
On this we can presume to speak only as individuals.

The general impression from the German reports is that they were on the right track and that their thinking and developments paralleled ours to a surprising extent. The fact that they did not achieve the chain reaction is primarily due to their lack of sufficient amounts of heavy water.

In one of the reports a vivid description is given of the German efforts in this respect. The heavy water factories in Norway were designed for a capacity of 3–4 tons a year and were successfully operating during part of 1942 and 1943. This capacity would have been sufficient for the construction of a pile. However, the production was interrupted by sabotage and finally the main factory was destroyed by a bombing attack. Toward the end of 1944 plans were made to initiate production of heavy water in Germany and to use enriched uranium in order to reduce the material requirements.

It is also fairly clear that the total German effort was on a very considerably smaller scale than the American effort. This may be due to the strained German economy or to the less favorable attitude of their government. The fact remains that an independent group of scientists, of much smaller size than ours, operating under much more adverse conditions achieved so much.

We must proceed therefore on the basis that anyone knowing what is in the German reports can establish a chain reaction, provided he has sufficient materials. The Smyth report will give additional very helpful hints. The time when others can establish a chain reaction is therefore no longer a matter of scientific research but mostly a matter of procurement. The policies of our authorities must, it seems to us, be formulated with a clear realization of these facts.



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MONSANTO CHEMICAL COMPANY

Clinton Laboratories

To: A. H. Compton Date: November 8, 1945

From: A. M. Weinberg and L. W. Nordheim

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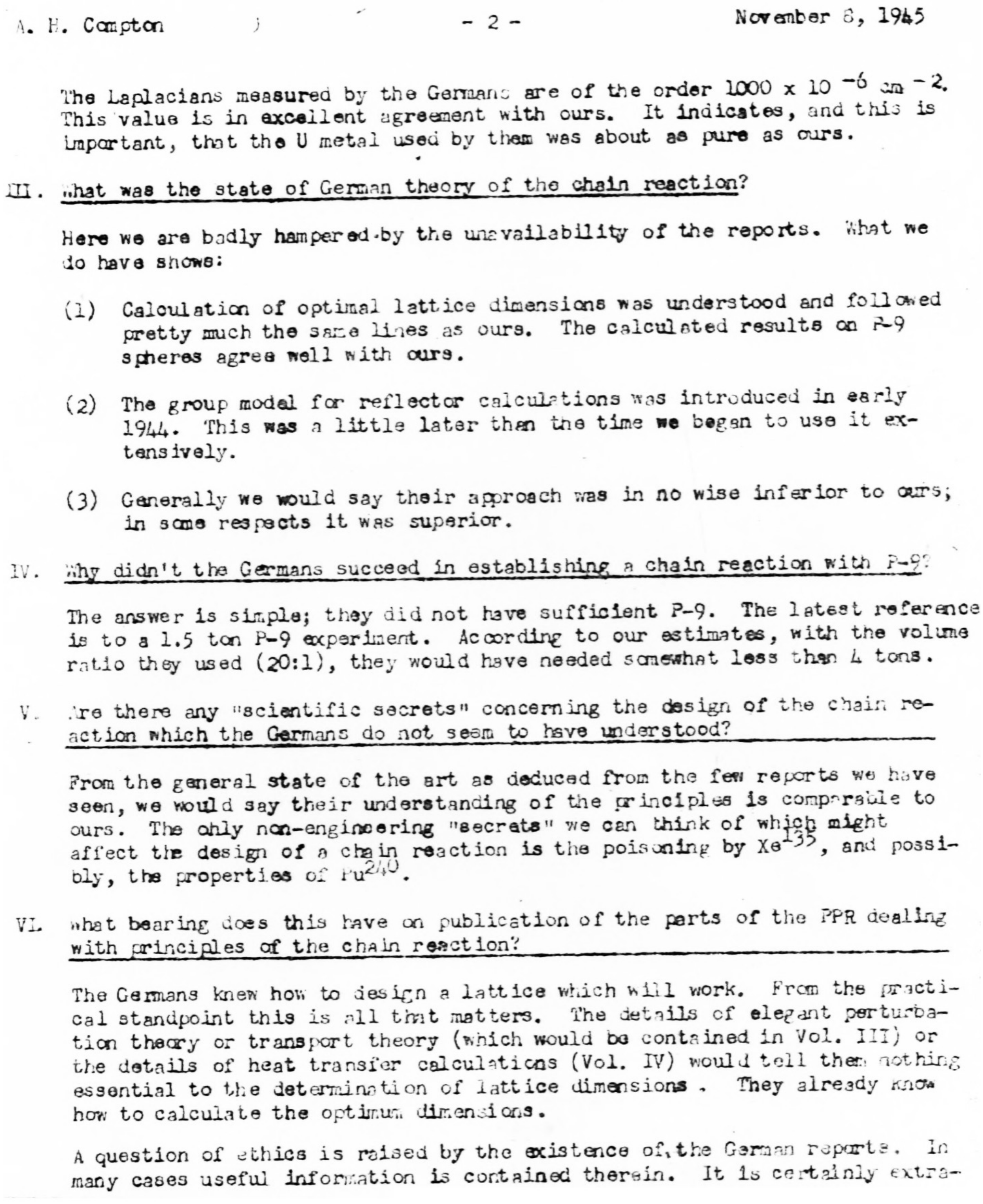
Encl to ltr Shannon to Babb dtd 10/11/68

Figure D.368: Alvin M. Weinberg and Lothar W. Nordheim. Memorandum on the state of knowledge in nuclear science reached by the Germans in 1945. 8 November 1945 [G-371].



A. H. Compton - 2 - November 8, 1945

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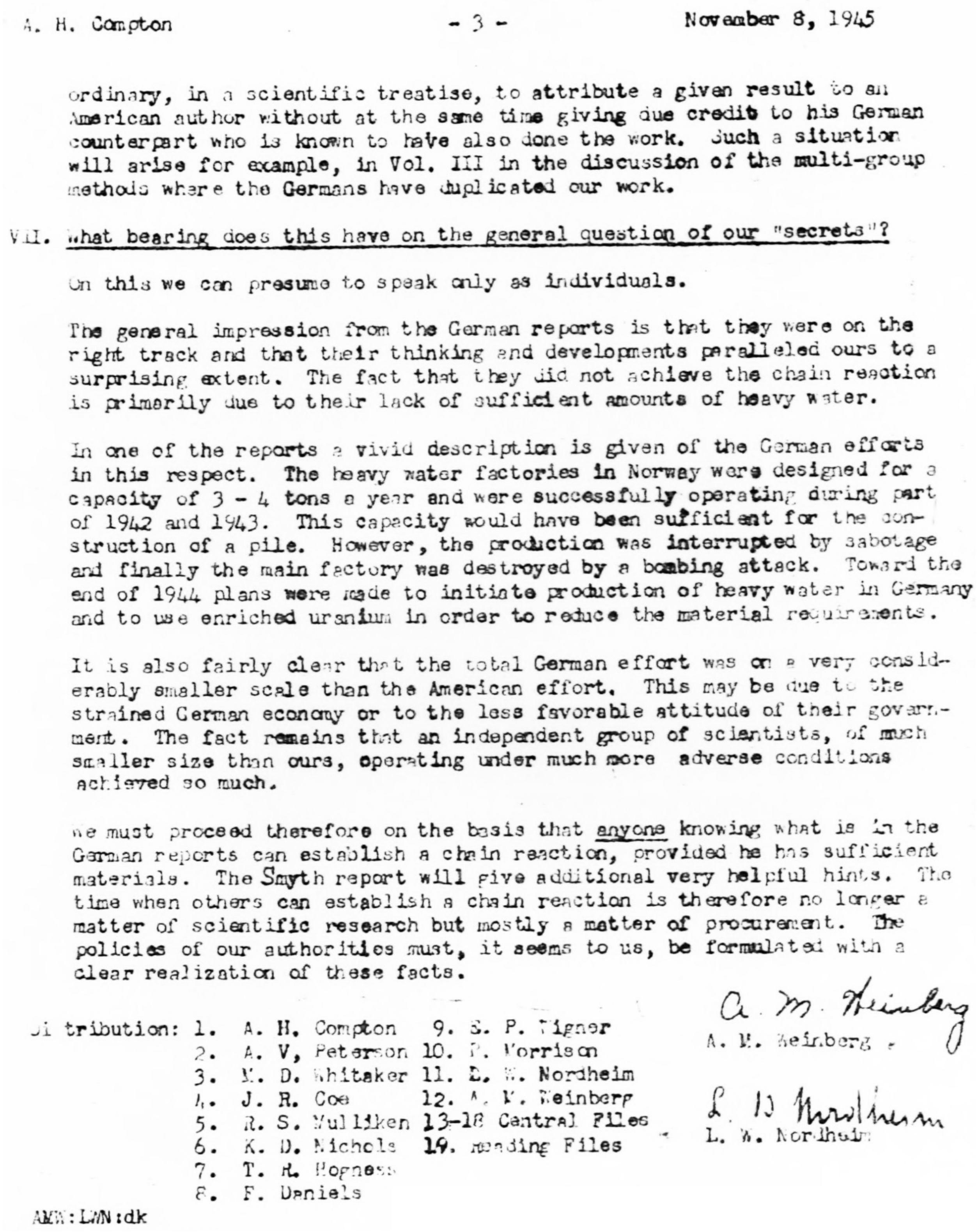
Figure D.369: Alvin M. Weinberg and Lothar W. Nordheim. Memorandum on the state of knowledge in nuclear science reached by the Germans in 1945. 8 November 1945 [G-371].



A. H. Compton - 3 - November 8, 1945

ordinary, in a scientific treatise, to attribute a given result to an American author without at the same time giving due credit to his German counterpart who is known to have also done the work. Such a situation will arise for example, in Vol. III in the discussion of the multi-group methods where the Germans have duplicated our work.

VII. What bearing does this have on the general question of our "secrets"?

On this we can presume to speak only as individuals.

The general impression from the German reports is that they were on the right track and that their thinking and developments paralleled ours to a surprising extent. The fact that they did not achieve the chain reaction is primarily due to their lack of sufficient amounts of heavy water.

In one of the reports a vivid description is given of the German efforts in this respect. The heavy water factories in Norway were designed for a capacity of 3 - 4 tons a year and were successfully operating during part of 1942 and 1943. This capacity would have been sufficient for the construction of a pile. However, the production was interrupted by sabotage and finally the main factory was destroyed by a bombing attack. Toward the end of 1944 plans were made to initiate production of heavy water in Germany and to use enriched uranium in order to reduce the material requirements.

It is also fairly clear that the total German effort was on a very considerably smaller scale than the American effort. This may be due to the strained German economy or to the less favorable attitude of their government. The fact remains that an independent group of scientists, of much smaller size than ours, operating under much more adverse conditions achieved so much.

We must proceed therefore on the basis that anyone knowing what is in the German reports can establish a chain reaction, provided he has sufficient materials. The Smyth report will give additional very helpful hints. The time when others can establish a chain reaction is therefore no longer a matter of scientific research but mostly a matter of procurement. The policies of our authorities must, it seems to us, be formulated with a clear realization of these facts.

A. M. Weinberg
A. M. Weinberg

L. W. Nordheim
L. W. Nordheim

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Figure D.370: Alvin M. Weinberg and Lothar W. Nordheim. Memorandum on the state of knowledge in nuclear science reached by the Germans in 1945. 8 November 1945 [G-371].

[Alvin Weinberg and Lothar Nordheim were experts in the U.S. fission reactor program. There are several important points regarding their memo:

- Even among the well-informed personnel of the U.S. Manhattan Project and over half a year after the war ended in Europe, there was a "very prevalent misconception" that the Germans had a poor understanding of applied nuclear physics. That misconception was apparently propagated by people such as Samuel Goudsmit, and has remained widespread ever since, despite this authoritative U.S. scientific memo stating that that misconception was entirely false.

- Weinberg and Nordheim, two high-ranking people in the U.S. Manhattan Project writing 6–12 months after the U.S. Alsos Mission had retrieved the relevant reports from Europe, repeatedly protested about the "few [German] reports we have been allowed to see," and that "we have not had access to the reports." Do those statements indicate that the United States was concealing German reports even from its leading Manhattan Project scientists, or that the United States was taking over 6–12 months before finally getting those reports to its leading scientists? If so, why was the United States suppressing information about the German nuclear program? Alternatively, if Weinberg and Nordheim had all the German reports that Alsos captured, their complaints suggest that a large number of relevant reports had been destroyed or hidden by the Germans.

- "The Germans knew how to design a [fission reactor] lattice which will work," "the German work apparently was done at the same time as" the U.S. work, "their approach was in no wise inferior to" the U.S. approach, and "in some respects it was superior."

- That equivalent work was achieved by a German group (apparently meaning the Kaiser Wilhelm Institute group led by Werner Heisenberg) that was much smaller than the corresponding American program. That shows great ability on the part of the German scientists, but it also demonstrates that Weinberg, Nordheim, and other high-ranking U.S. officials were unaware of all of the other parts of the German nuclear program—the large majority of the program.

- Allied sabotage and bombing of the heavy water factories in Norway (not any German lack of scientific ability) greatly delayed operation of a fission reactor in Germany.

- Weinberg and Nordheim were aware of heavy water production in Norway, and of German plans to produce heavy water elsewhere. Since their knowledge was admittedly very incomplete, it is possible that significant amounts of heavy water were actually produced elsewhere.

- Although Weinberg and Nordheim were unaware of a German pile that achieved a chain reaction, they admitted that their knowledge was very incomplete; it is possible that there was a German chain reaction that was unknown to these and perhaps even all U.S. officials.

- Weinberg and Nordheim essentially stated that it would be unethical for the United States to give public credit for applied nuclear physics innovations to scientists working in the wartime U.S. program but not to scientists from the wartime German program who were documented to have made the same (or better) innovations. That is in fact what the United States did and has continued to do.]

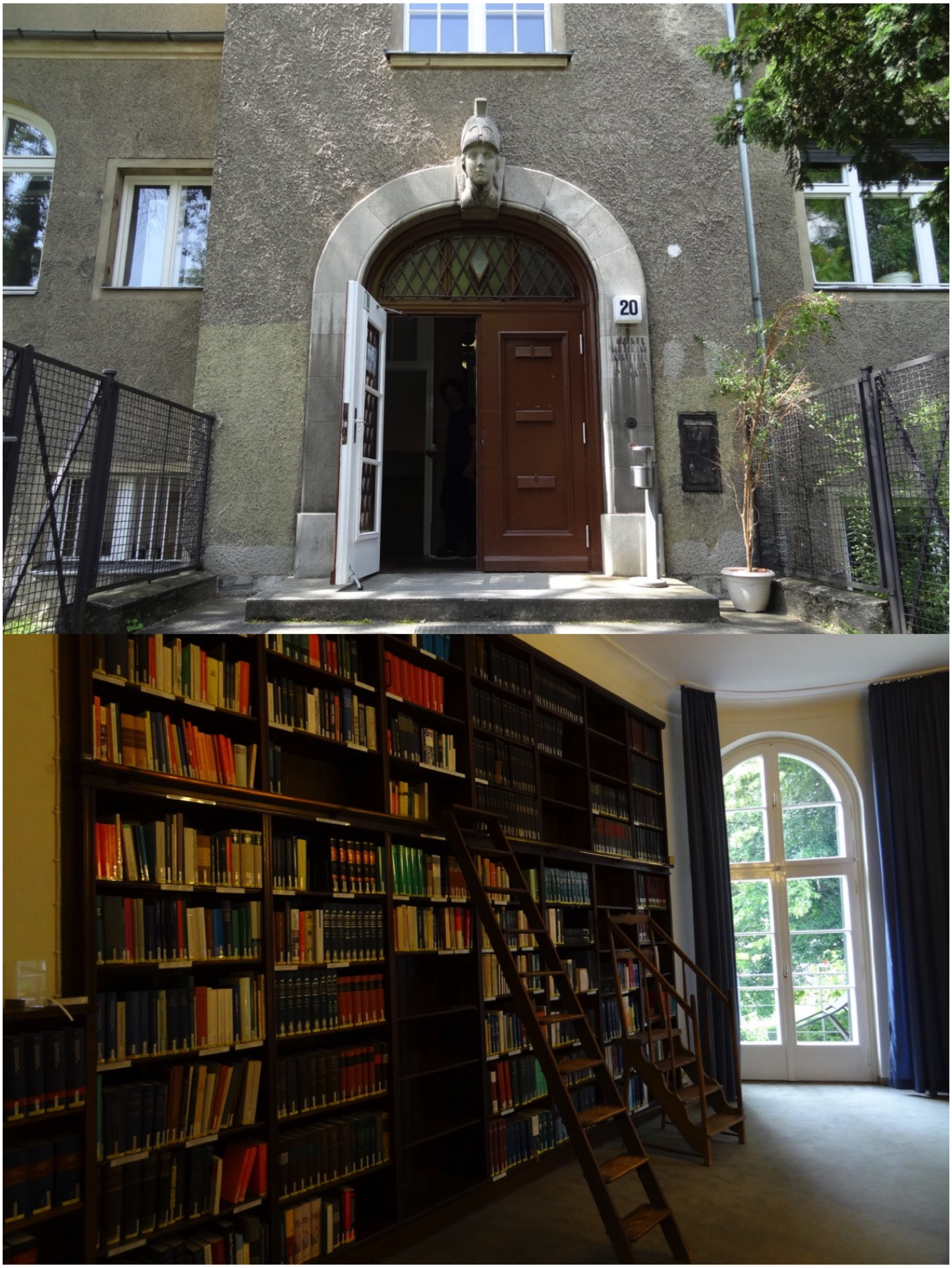


Figure D.371: The former Kaiser Wilhelm Institute for Physics, the original site of the Heisenberg group's fission reactor experiments, now houses the archive of the Max Planck Institute.

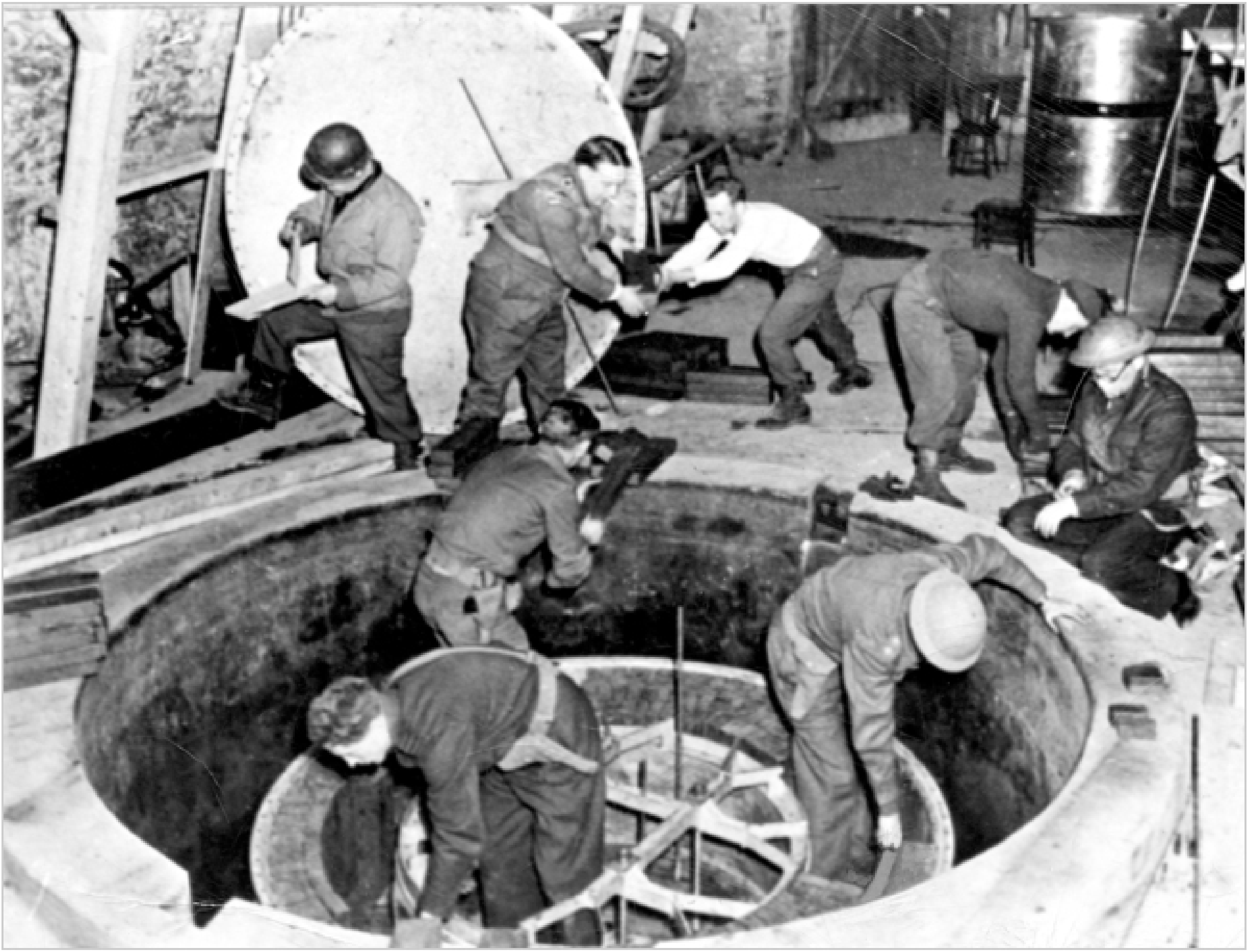


Figure D.372: U.S. personnel dismantling the Haigerloch fission reactor experiment in 1945.

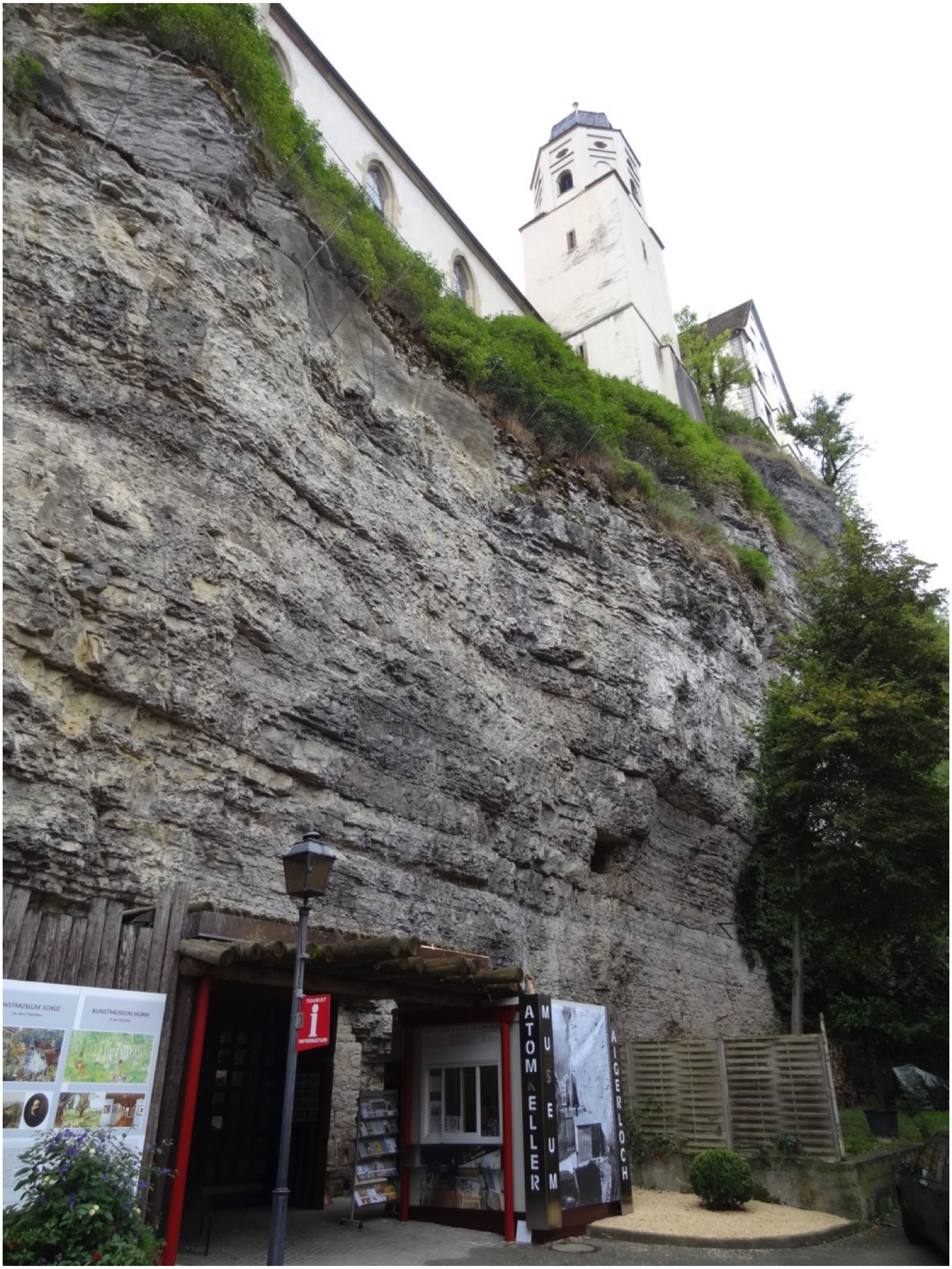

ATOMKELLER
MUSEUM
HAIGERLOCH
TOURIST INFORMATION
KUNSTMUSEUM SCHÜZ
KUNSTMUSEUM HURM

Figure D.373: Atomkeller Museum in Haigerloch now.

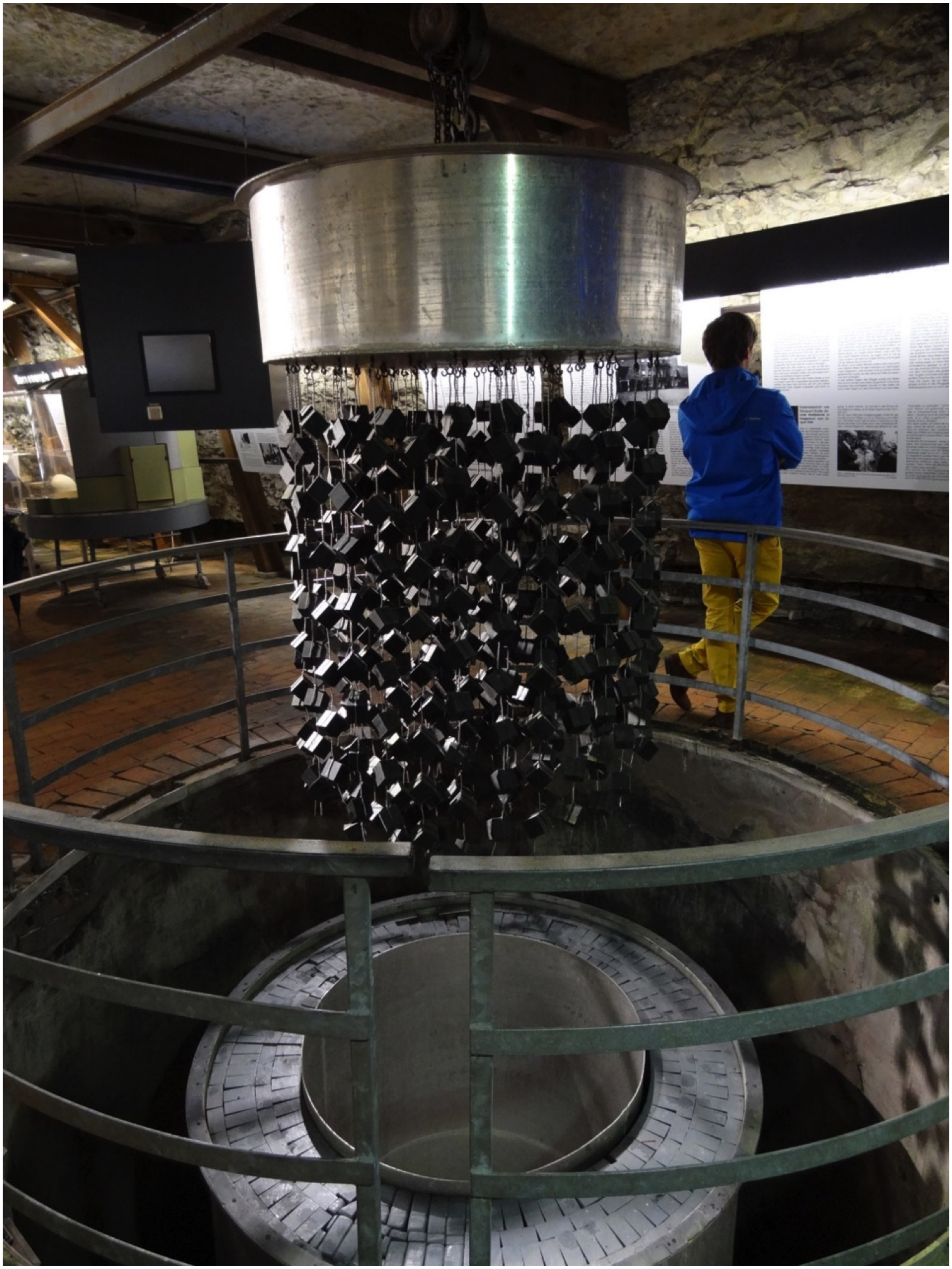


Figure D.374: Atomkeller Museum in Haigerloch now.

2. The fission reactor of Kurt Diebner's group, and

3. A possible fission reactor built and operated by the SS (in Thuringia?)

English translation of Walther Gerlach. 2 January 1945. Citation for Award of the War Service Cross First Class with Swords to Dr. K. DIEBNER, Member of the Board of Works. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)]

After uranium fission by means of neutrons became known back in 1939, Dr. Kurt Diebner, Member of the Board of Works, pointed out the importance of this discovery as a possible source of energy and was thereupon ordered by his superiors to form an association which was first made a part of Army Ordnance but which is now subordinated to the Deputy for Nuclear Physics. Within the framework of this Association, he and his own work-group took part in the experiments.

The geometric arrangement (cube arrangement) employed on the basis of his deliberations has turned out to be the most successful arrangement yet hit upon, although at the time ranking scientists saw nothing particularly significant in it; for example, with only one-third the supply of uranium and heavy water, he succeeded in achieving the same results that Prof. Bothe and Prof. Heisenberg did employing other geometrical arrangements. Diebner got a neutron increase of 106% with his experimental model; that is, he achieved a most efficient production of energy. The scope of the arrangement was limited because of the amount of material available to him at the time.

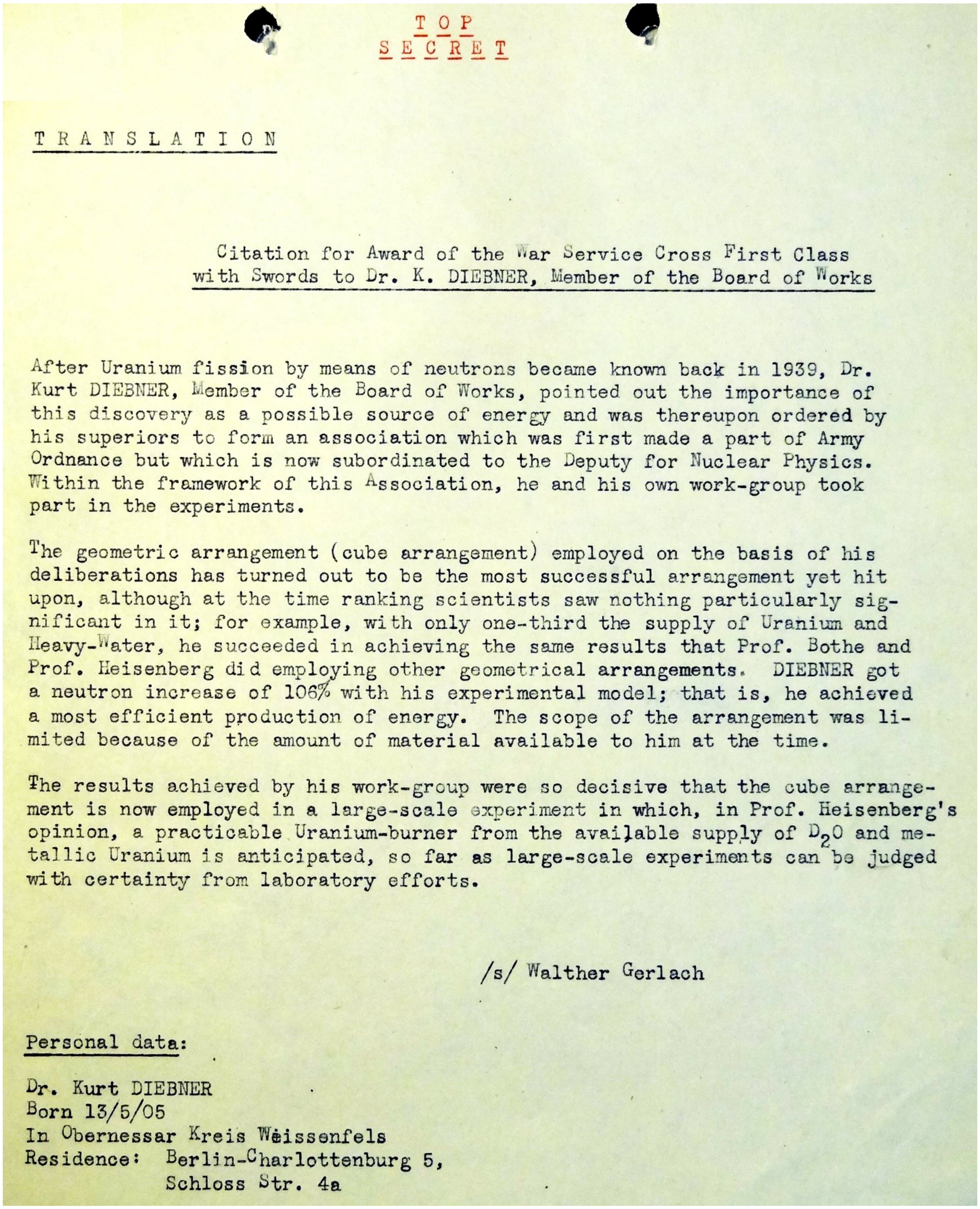
The results achieved by his work-group were so decisive that the cube arrangement is now employed in a large-scale experiment in which, in Prof. Heisenberg's opinion, a practicable uranium burner from the available supply of D_2O and metallic uranium is anticipated, so far as large-scale experiments can be judged with certainty from laboratory efforts.

[Publicly, after the war Samuel Goudsmit of the U.S. Alsos Mission and Leslie Groves of the Manhattan Project denigrated Kurt Diebner as being far inferior to Heisenberg in scientific talent, and in fact as being mainly an administrator and not a scientist.

Privately they found this document that proved that Diebner had been given a formal award by Walther Gerlach (an impeccable physicist, and presumably a good judge of physics) for doing extensive scientific research, and for achieving much better results than Werner Heisenberg. Markings on the document show that U.S. officials responded to this document by classifying it Top Secret and burying it in their files. See document photo on p. 3855.]

DECLASSIFIED
Authority 917017

NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)



TOP SECRET

TRANSLATION

Citation for Award of the War Service Cross First Class with Swords to Dr. K. DIEBNER, Member of the Board of Works

After Uranium fission by means of neutrons became known back in 1939, Dr. Kurt DIEBNER, Member of the Board of Works, pointed out the importance of this discovery as a possible source of energy and was thereupon ordered by his superiors to form an association which was first made a part of Army Ordnance but which is now subordinated to the Deputy for Nuclear Physics. Within the framework of this Association, he and his own work-group took part in the experiments.

The geometric arrangement (cube arrangement) employed on the basis of his deliberations has turned out to be the most successful arrangement yet hit upon, although at the time ranking scientists saw nothing particularly significant in it; for example, with only one-third the supply of Uranium and Heavy-Water, he succeeded in achieving the same results that Prof. Bothe and Prof. Heisenberg did employing other geometrical arrangements. DIEBNER got a neutron increase of 106% with his experimental model; that is, he achieved a most efficient production of energy. The scope of the arrangement was limited because of the amount of material available to him at the time.

The results achieved by his work-group were so decisive that the cube arrangement is now employed in a large-scale experiment in which, in Prof. Heisenberg's opinion, a practicable Uranium-burner from the available supply of D_2O and metallic Uranium is anticipated, so far as large-scale experiments can be judged with certainty from laboratory efforts.

/s/ Walther Gerlach

Personal data:

Dr. Kurt DIEBNER
Born 13/5/05
In Obernessar Kreis Weissenfels
Residence: Berlin-Charlottenburg 5,
Schloss Str. 4a

Figure D.375: English translation of Walther Gerlach. 2 January 1945. Citation for Award of the War Service Cross First Class with Swords to Dr. K. DIEBNER, Member of the Board of Works. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)]

[Leslie Groves even wrote a secret 1946 memo stating that Diebner "has a pretty good grasp of the German project" and explicitly recognizing that he was among the handful of "those German scientists of outstanding ability in the field of nuclear physics and chemistry who, by their past reputation and present knowledge, would be of more value to the national interest of this country if they could be employed here rather than in any other country. [...I]t is extremely important that these persons be prevented from giving their services to a potential enemy of the United States" (p. 4807).

In 1939, Kurt Diebner may well have been the only person on Earth whose scientific expertise included all three of the following:

1. TNT implosion bomb designs ("hollow-charge explosives").
2. Fission chain reactions (proposals for uranium reactors and bombs).
3. High-energy-induced fusion reactions ("high-voltage particle accelerator for atomic transformations").

Those are the three major elements of the German nuclear device that was apparently tested by March 1945 (see p. 4485), or of modern nuclear bombs.

Likewise, Diebner occupied leadership roles that included the Army (Heereswaffenamt), Kaiser-Wilhelm Institute for Physics, Reich Research Council (Reichsforschungsrat), and the SS (when the SS controlled most research in the later stages of the war, if not earlier), and that spanned the entire German nuclear program from its very first meetings in 1939 in Berlin to the last days of the war in May 1945 in Thuringia.

Thus Diebner was one of the most important people in the German nuclear program, and possibly even the single most important person.

However, the false public depictions of Diebner's abilities by Samuel Goudsmit and Leslie Groves after the war were highly effective, and most historical books and documentaries for the last 75+ years have unquestioningly followed their lead in treating Diebner as a minor, peripheral official or even a scientific loser.]

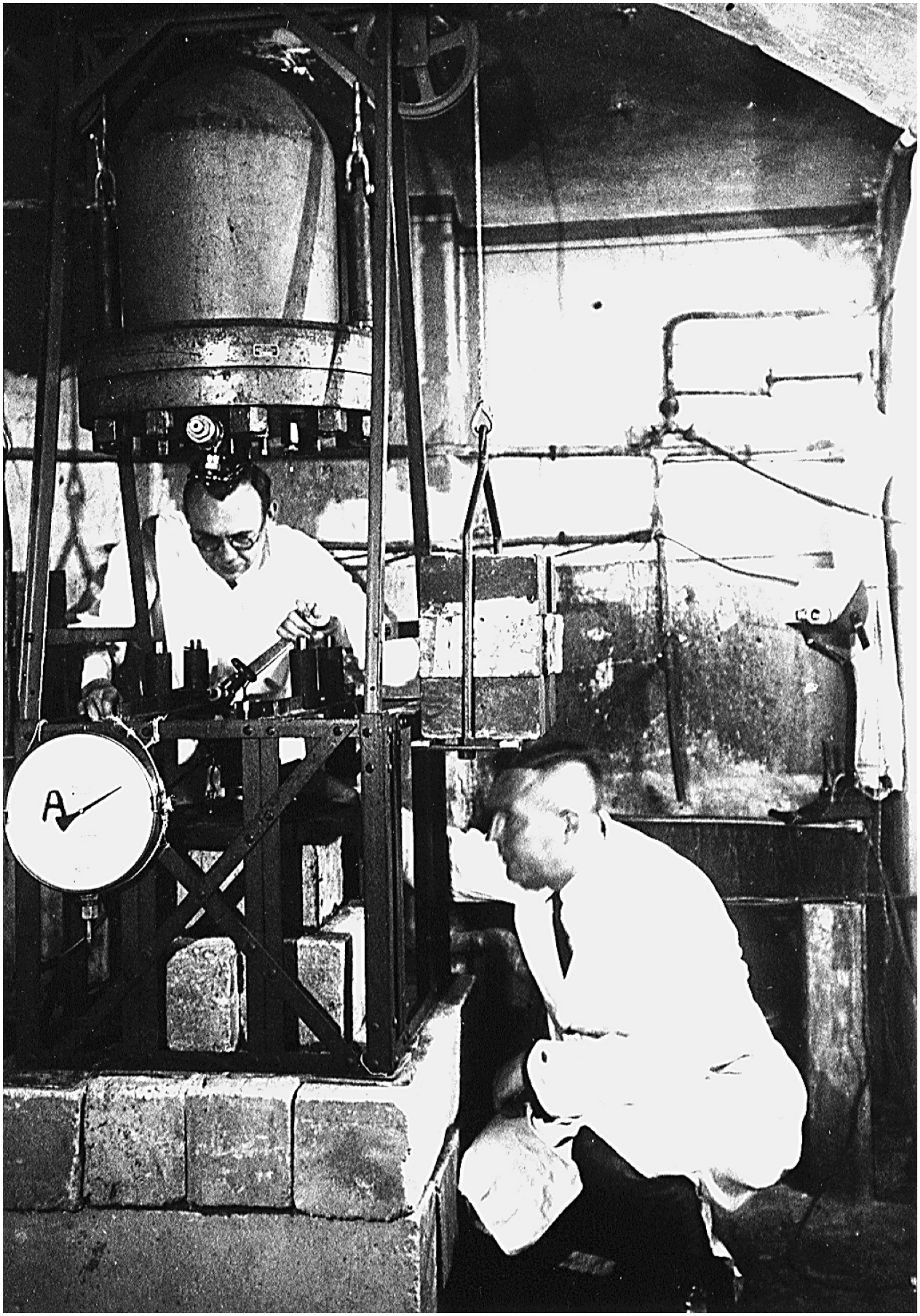


Figure D.376: Kurt Diebner (left) and Gerhard Hoffmann (right) setting up a nuclear physics experiment at the University of Halle-Wittenberg ca. 1932.

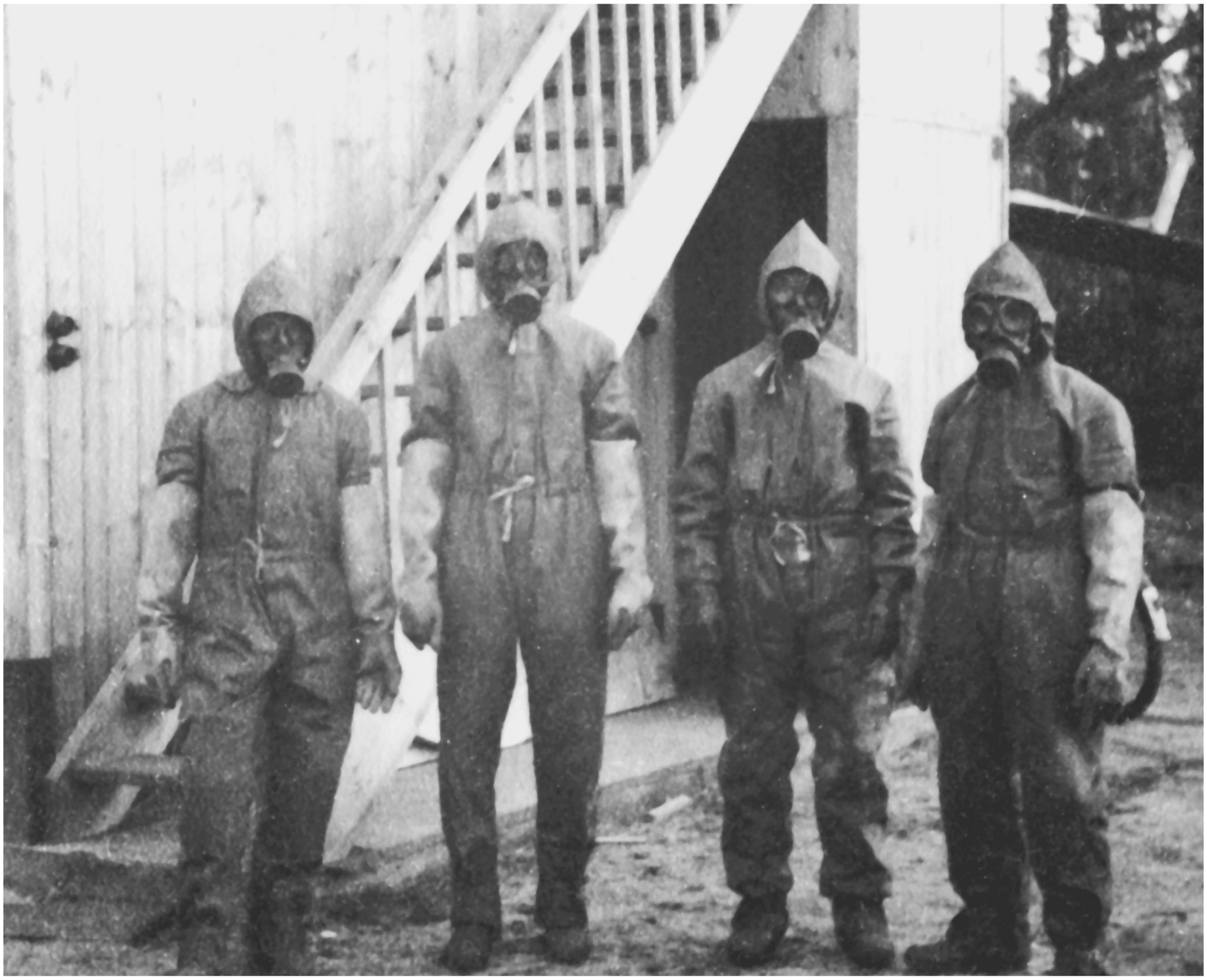
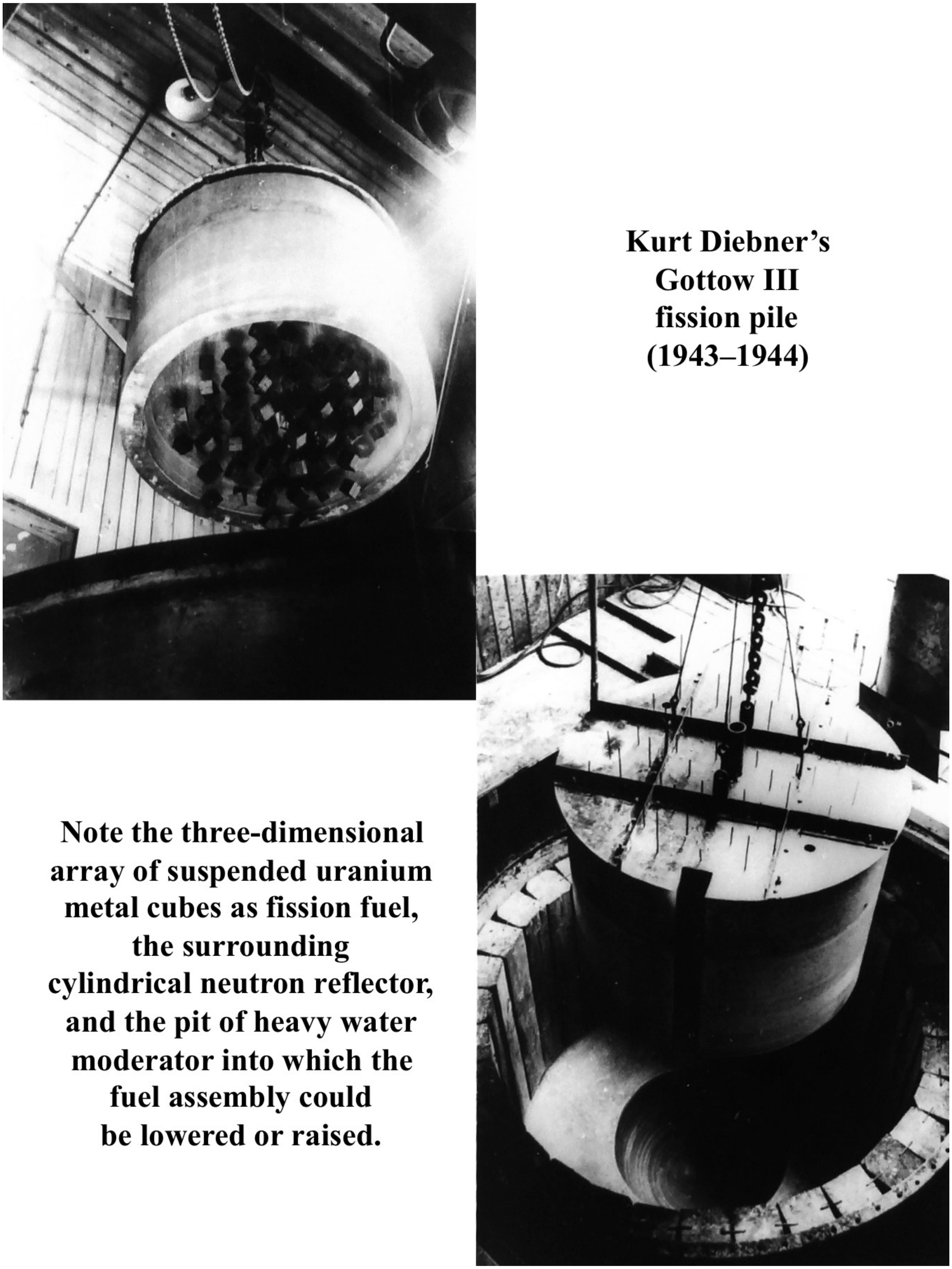


Figure D.377: Kurt Diebner (right) and three other members of his group at Gottow/Kummersdorf wearing protective suits while working on fission pile experiments in 1941.



**Kurt Diebner's
Gottow III
fission pile
(1943–1944)**

**Note the three-dimensional
array of suspended uranium
metal cubes as fission fuel,
the surrounding
cylindrical neutron reflector,
and the pit of heavy water
moderator into which the
fuel assembly could
be lowered or raised.**

Figure D.378: Kurt Diebner's Gottow III fission pile (1943–1944) [Bundesarchiv Militärarchiv Freiburg N 822/13].

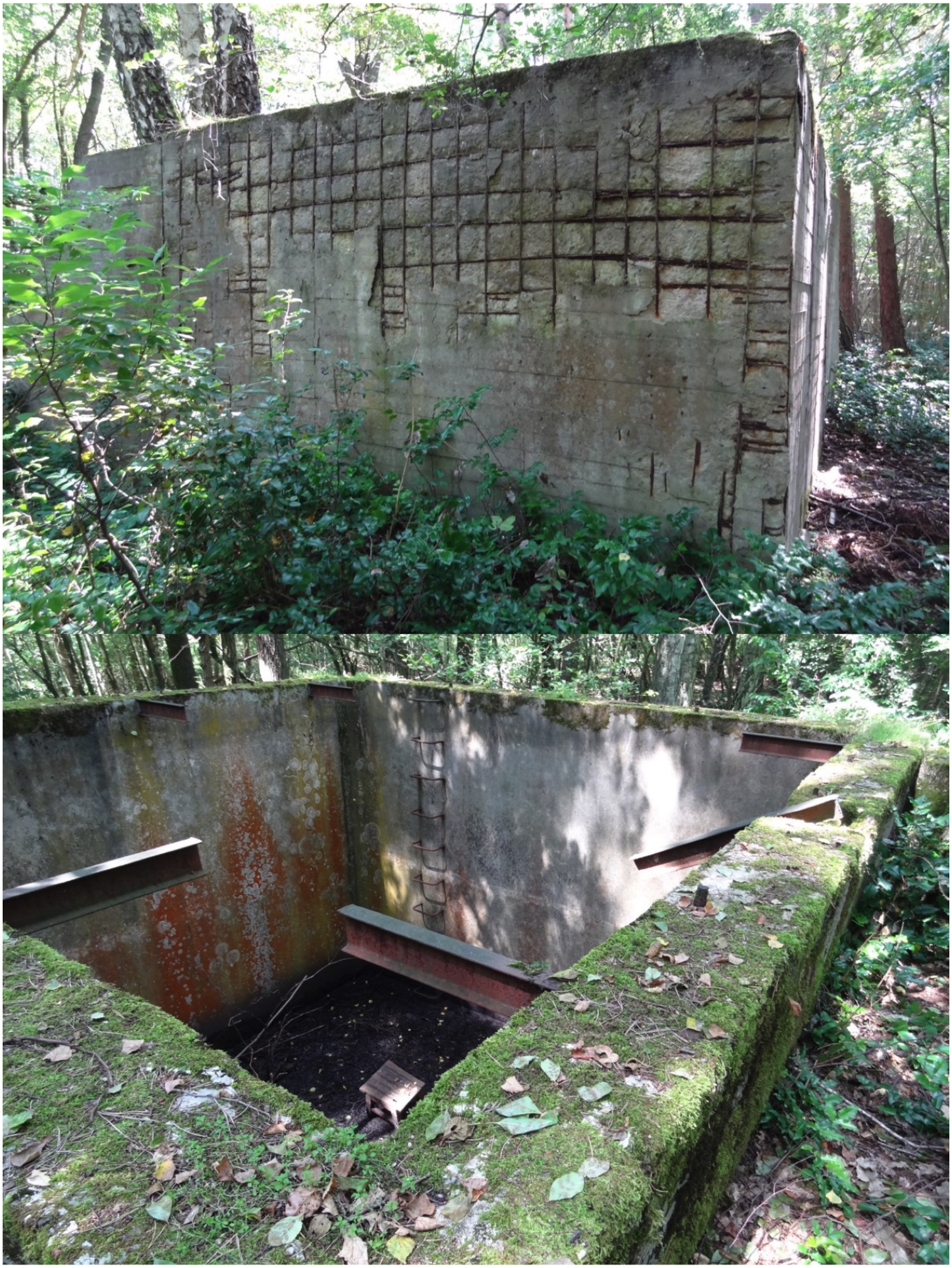


Figure D.379: Historisch-Technisches Museum Versuchsstelle Kummersdorf: Former location of the Diebner group's Gottow fission pile.

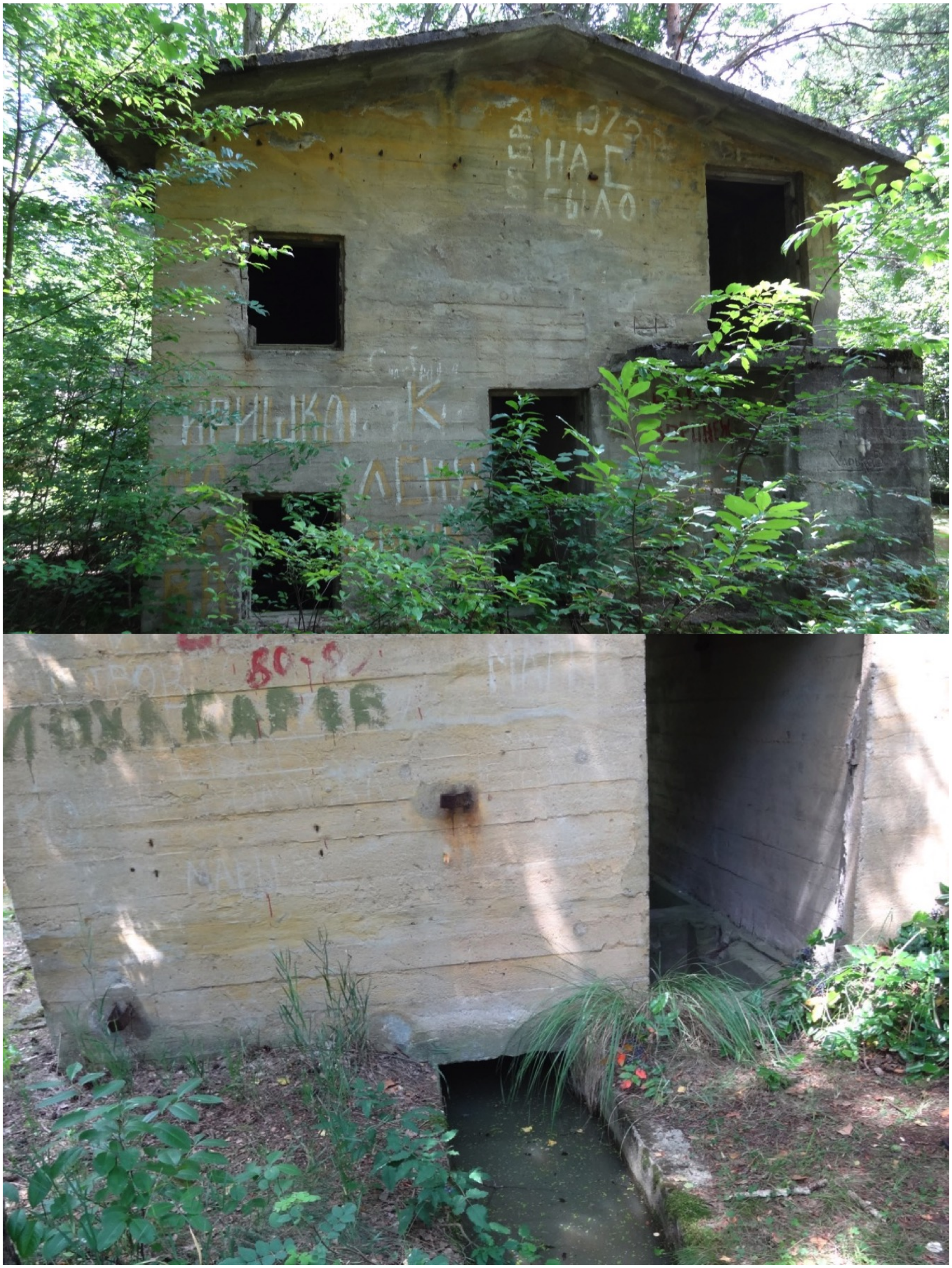


Figure D.380: Historisch-Technisches Museum Versuchsstelle Kummersdorf: Apparent chemical processing building with special waste water streams.

Frederic A. C. Wardenburg, Stadtilm Operation, 30 April 1945 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

I. Instructions have been received to forward all captured TA documents to Washington for final analysis. No further analysis of Stadtilm documents will, therefore, be made by the Alsos Mission.

II. For the benefit of Washington personnel who will study the documents, the following summary is given of classification already started on this side:

(a) The material consists of unfiled papers, mainly technical data and reports, and of correspondence files and folders. Each of these file folders has been numbered on the back. Many of them have been read and an index of the important material made on separate cards.

(b) Now folders with the following general subject titles have been set up:

1. Organization
2. Financial
3. Pile experiments
4. Heavy Water
5. Uranium
6. Ultra centrifuge
7. Isotope Separation Other
8. Betatron
9. Medical
10. Miscellaneous
11. KWI for Chemistry
12. Personnel
13. Instruments & Measurements
14. Target Data
15. Non-TA General Intelligence

(c) Some of the original files have been stripped of important material which has been put in the above folders according to the subject. Cards for these folders which have been [illegible] but not yet classified are included in the envelope marked "Folders [illegible] done." Folders for [illegible] cards appear in neither envelope have not yet been read.

[Tube Alloy or TA was the Allied code name for uranium.

Where are these files now?]

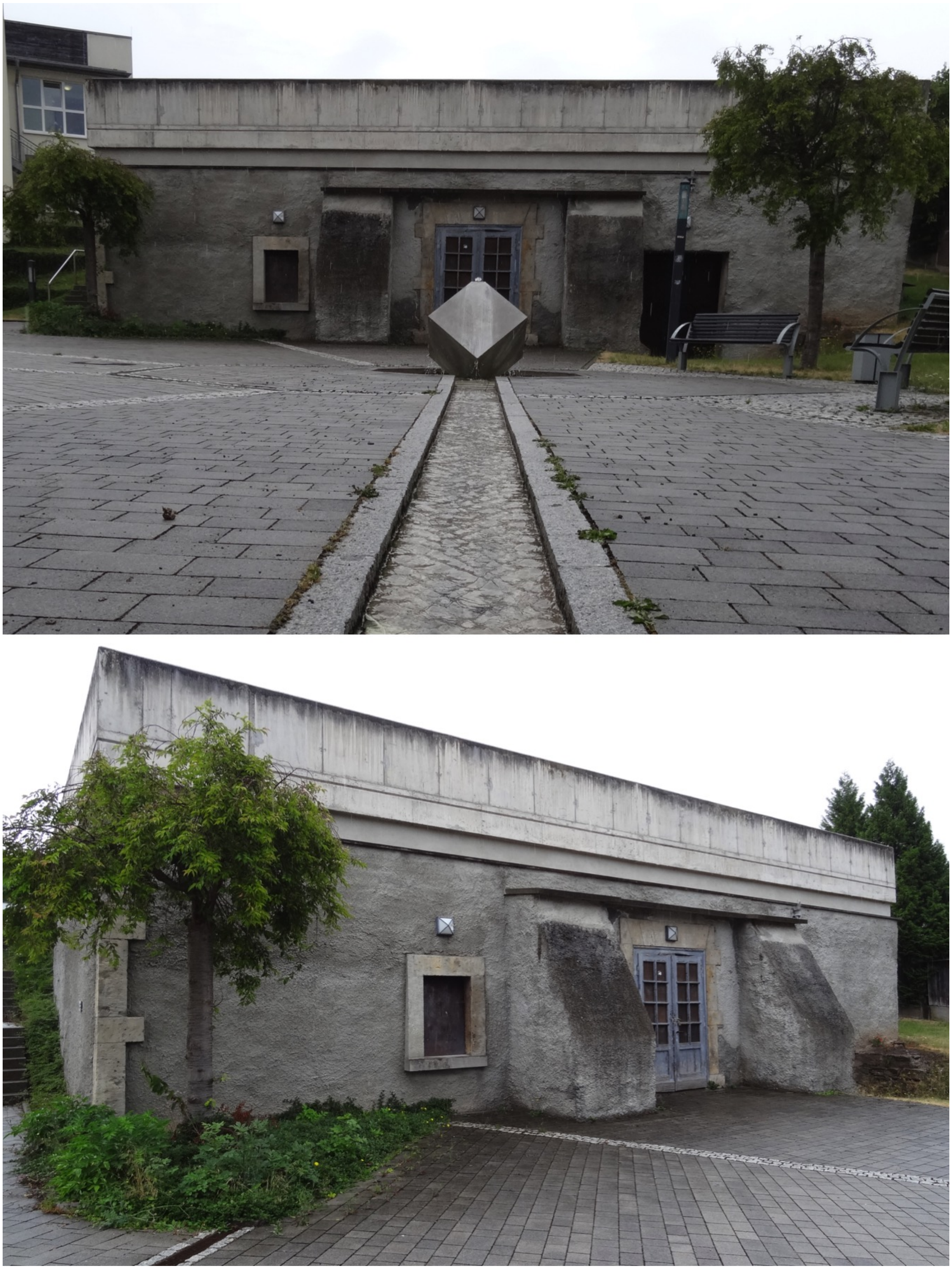


Figure D.381: The former Atomkeller in Stadtilm. Note the modern cube sculpture and water fountain to commemorate Diebner's experiments with uranium cubes and heavy water.

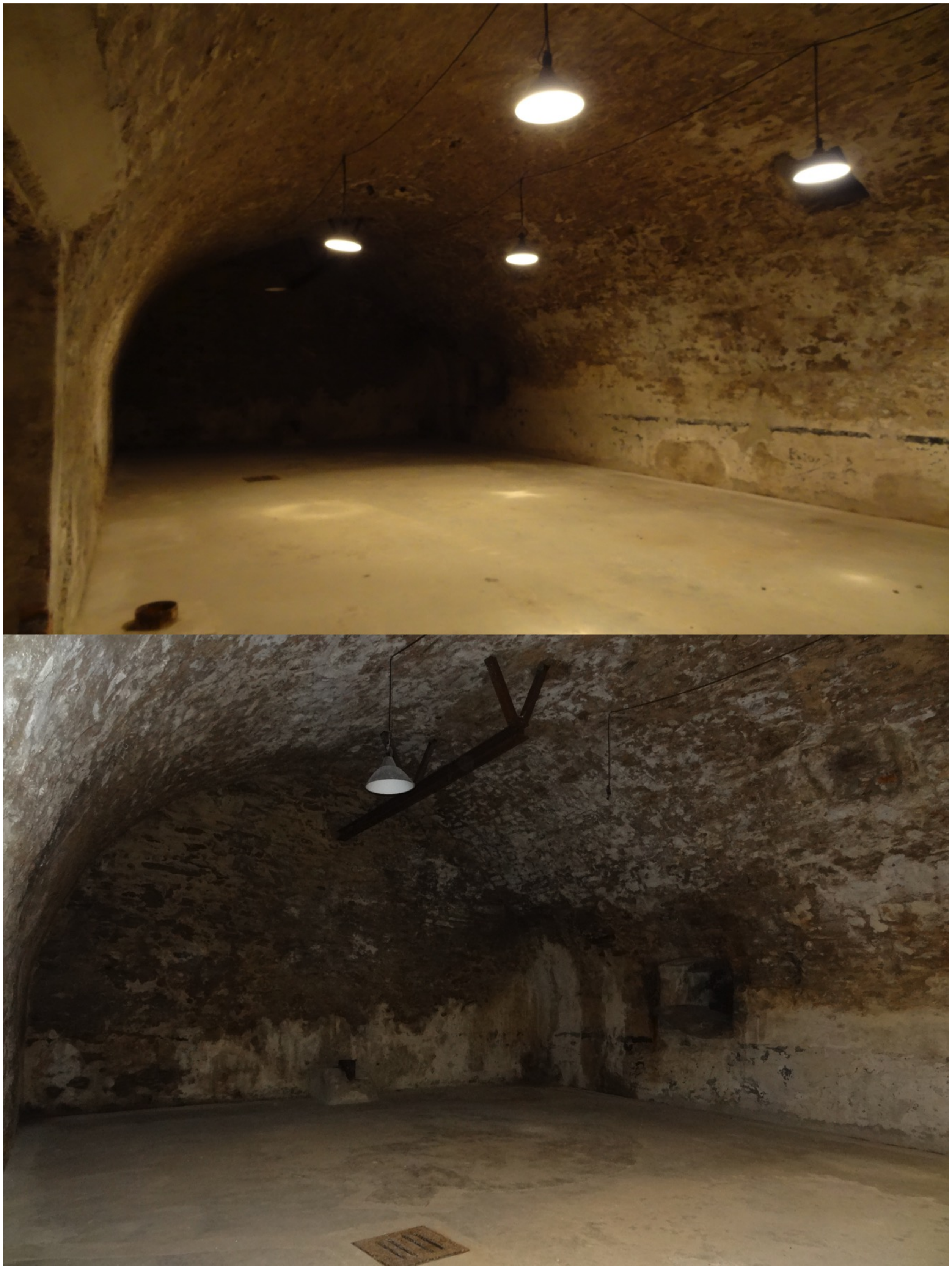


Figure D.382: The former Atomkeller in Stadtilm. In the lower photo, note the circular pit in the floor, now filled in with concrete, which once held the heavy water with uranium cubes suspended in it from the overhead beam.

Werner Grothmann on reactor breeding of Pu-239 (and U-233) [Krotzky 2002]. For a discussion of the background and reliability of this source, see pp. 3396–3397.

[S. 40] Es gab klare Erkenntnisse, dass nicht alleine das Uran als Sprengstoff dienen konnte sondern auch Plutonium und weitere Stoffe, da kenne ich mich aber noch weniger aus als bei diesen Bezeichnungen. Jedenfalls ist wohl 1943 klar geworden, dass man mit Plutonium eine große Sache machen kann. Es war aber so, dass die Erzeugung ganz schwierig sein würde.

[p. 40] There was clear evidence that not only uranium could serve as an explosive, but also plutonium and other substances, about which I know even less than these names. In any case, it was clear in 1943 that one could do a great deal with plutonium. It was the case, however, that production would be quite difficult.

[S. 43] Ich vermute, dass es bei der Plutonium-Forschung zwischen einzelnen Wissenschaftlern eine Konkurrenz gab. Konkret kann ich dazu sagen, dass Diebner in einem Gespräch mit dem Chef [Himmler], das ganz kurzfristig angesetzt war betont haben muß, ich war ja bei solchen Gesprächen nie dabei, höchstens wenn es darum ging, was unsere Leute an begleitenden Maßnahmen leisten sollten, aber das hatte dann ja nichts mit der Forschung zu tun, also da gab es ein Gespräch mit Diebner, als sein Reaktor in Betrieb gegangen war, wo er sich über die Möglichkeiten geäußert hatte, bald richtige Bomben zu bauen. Das wussten wir schon, wenn ein Atomreaktor läuft, ist es viel leichter, Material für die Bombe zu erhalten. [...] Das weiß ich noch ganz genau, dass Himmler danach eine Besprechung hatte bei der angeregt worden war, eine Verbindung zwischen Kammler und jemand von den Physikern zu schaffen, damit man die Bedingungen besprechen konnte, die man braucht, wenn man einen neuen Reaktor einrichten will. Was danach gemacht worden ist, weiß ich nicht, mir ist nur bekannt, dass unser eigener Reaktor auch noch laufen lernte, das war ein großer Tag für uns, leider war das aber schon kurz vor Kriegsende, deshalb konnte das nichts mehr bewirken. [...] Zu Diebner muß ich aber noch sagen, dass ich nicht sicher bin, ob sein Reaktor von ihm oder von seinen Leuten so geregelt worden ist, daß der deshalb angelaufen ist. Es war ja so, daß wir erfuhren, daß es ja einen Unfall gegeben hatte. Ich weiß nicht, war es ein Unfall im Betrieb, oder hat es einen Unfall gegeben, bei dem das Ding losging. Ich hörte da verschiedene Gerüchte.

[p. 43] I suspect that there was competition among individual scientists in plutonium research. In concrete terms, I can say that there was a conversation with Diebner and the boss [Himmler], which had been scheduled at very short notice; I was never present at such conversations, at most when it came to what our people were supposed to do in accompanying measures that had nothing to do with the research. So there was a conversation with Diebner when his reactor went into operation, where he himself talked about the possibilities to build real bombs soon. We already knew that when an atomic reactor is running, it is much easier to get material for the bomb. [...] I remember that Himmler had had a meeting to create a connection between Kammler and someone from the physicists to discuss the conditions needed to set up a new reactor. What happened afterwards, I do not know, I only know that our own reactor was still running, that was a great day for us, but unfortunately it was already shortly before the end of war, so that nothing more could be done. [...] Regarding Diebner, however, I must say that I am not sure whether his reactor was controlled by him or by his people, which is why it started. It was true that we learned that there had been an accident. I do not know, it was an accident in the plant, or there was an accident, at which the thing went off. I heard different rumors.

[S. 31] Es gab dann auch noch ein Unglück ohne schlimme Folgen in Gottow bei Diebner. Dem ist sein Reaktor vielleicht durchgegangen, wie ich ja sagte. Das war möglicherweise die erste wirkliche Kettenreaktion auf der Welt, die sich selbst erhalten hat. Leider ließ sie sich nicht stoppen.	[p. 31] There was then also an accident without bad consequences in Gottow with Diebner. His reactor may have run away, as I said. This was perhaps the first real chain reaction in the world that sustained itself. Unfortunately it did not stop.
[S. 8] Unser Reaktor, der im März 45 anlief, war ja lange vorher schon eingebaut worden und auch nur noch mit viel Glück in Betrieb gegangen.	[p. 8] Our reactor, which started in March 45, had already been installed a long time before and had only just started with good luck.
[S. 43] Ich bin mir bis heute fast sicher, dass zum Beispiel bis jetzt nur ganz wenige wirklich etwas über unseren eigenen Atomreaktor wissen und dass der wirklich gelaufen ist. Die Konstruktion war schon sehr modern, das hat Diebner doch begeistert, weil es seine Ideen ja letztlich nochmals bestätigt hatte und er hatte ja zuvor schon Erfahrungen mit seinem Reaktor gehabt.	[p. 43] I am still almost certain that, for example, only very few really know something about our own nuclear reactor and that it really ran. The construction was already very modern, Diebner was enthusiastic about that, because it had finally confirmed his ideas and he had already had experience with his reactor.

[As potential fission fuels that were known during the war, Grothmann mentioned uranium [235], plutonium [239], and "other substances, about which I know even less than these names"—probably a reference to transmuting thorium-232 into uranium-233.

Grothmann knew of at least two fission reactors that had gone critical during the war:

1. The Diebner group's reactor, which went critical and actually had an accident before it could be stopped. That incident apparently occurred in late 1944 while the reactor was still at Gottow.

2. A completely separate reactor that was directly operated by the SS. According to Grothmann, that reactor first became operational in March 1945, but it had been built quite some time before that. Its "construction was already very modern," which suggests that the SS reactor was designed to breed fuel for nuclear weapons and not simply to be a small initial science experiment to achieve criticality. Although Grothmann did not specify a location for this SS reactor, it may have been in an underground installation somewhere in Thuringia, since most of Grothmann's knowledge in the interview was focused on nuclear and rocket research at underground installations in Thuringia.]

Helmut J. Fischer. 1987. *Hitler und die Atombombe: Bericht eines Zeitzeugen.* pp. 77–78.

Es war wohl der letzte Tag im März 1945, als am frühen Morgen Dr. Graue vom Kaiser-Wilhelm-Institut für Physikalische Chemie und Elektrochemie in meinem Büro erschien. “Die Uranmaschine läuft”, berichtete er aufgeregt und bat mich zu seinem Chef, Prof. Thiessen, der in der Nacht zuvor einen Telefonanruf von Gerlach erhalten hatte. Ich verständigte meinen vorgesetzten Gruppenleiter Dr. Spengler, und bald saßen wir zu viert beieinander in Thiessens Institut: Thiessen, Graue, Spengler und ich. Das Telefongespräch, von dem Thiessen berichtete, war offenbar unter großen Mühen zustande gekommen, die Verständigung war sehr schlecht gewesen. Immerhin ergaben sich aus Gerlachs Anruf zwei wichtige Nachrichten. Die erste meldete den großen Erfolg mit einer kritischen Uranmaschine. Die zweite Nachricht, die Gerlach mir übermitteln wollte, bezog sich auf die Gefährdung der Forschungsstätte in Stadtilm durch das Vorrücken der amerikanischen Truppen auf Thüringen.

Hier muß ich nun aus dem, was mir später bekannt wurde, hinzufügen, daß Gerlachs übergroße Freude über den erfolgreichen Versuch mit einer Uranmaschine berechtigt, seine Nachricht aber nicht ganz richtig übermittelt worden war. Die kritische Uranmaschine war noch nicht fertig, sondern nur “beinahe fertig”. Es fehlte eine vergleichsweise geringe Menge von Uran und eine entsprechende Menge von Schwerem Wasser, um den Versuch ganz so, wie man es gewünscht hatte, ablaufen zu lassen. Dieses restliche Material war in Haigerloch nicht mehr vorhanden, wohl aber in Stadtilm. Daher die Sorge Gerlachs um die Forschungsstätte Stadtilm. Nur dort war das Material, das den krönenden Abschluß der Bemühungen um eine kritische Uran-Maschine ermöglichen konnte.

It was probably the last day in March 1945 when Dr. Graue from the Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry appeared in my office early in the morning. “The uranium machine is running,” he reported excitedly and referred me to his boss, Prof. Thiessen, who had received a phone call from Gerlach the night before. I contacted my superior group leader, Dr. Spengler, and soon four of us sat together in Thiessen’s institute: Thiessen, Graue, Spengler and me. The telephone conversation Thiessen reported had apparently come about with great difficulty, the communication had been very poor. After all, two important messages resulted from Gerlach’s call. The first reported the great success with a critical uranium machine. The second message that Gerlach wanted to send me related to the threat to the research site in Stadtilm from the advance of the American troops to Thuringia.

From what I learned later, I must add that Gerlach’s overjoy at the successful attempt with a uranium machine was justified, but that his message had not been transmitted quite correctly. The critical uranium machine was not yet finished, but rather “nearly finished.” There was a comparatively small amount of uranium and a corresponding amount of heavy water missing to allow the experiment to run as desired. This remaining material was no longer available in Haigerloch, but in Stadtilm. Hence Gerlach’s concern about the Stadtilm research site. Only there was the material, which could make the crowning conclusion of the efforts possible around a critical uranium machine.

Commentary from Rainer Karlsch on the previous passage from Helmut Fischer [Jonastalverein Archive].

Rund zwanzig Jahre vor der zitierten Schilderung hatte Fischer den Verlauf der Ereignisse anders wiedergegeben: “Es musste schnell gehandelt werden. Denn der entscheidende Versuch mit der Uranmaschine war in Stadtilm erzielt worden.” [Diese Sätze hat Fischer später gestrichen. Vgl. Helmut J. Fischer, Feuerwehr für die Forschung, Institut für Zeitgeschichte München, Ms. 321/1-4]

Auch Fischers Vorgesetzter Spengler schrieb von einem funktionierenden Reaktor: “Im Anschluss an diese Sitzung [an 23. März fand im Harnack-Haus eine Sitzung mit Graue, Fischer, Schumann, Geist und Diebner statt—Dienstkalender Walther Gerlach, Deutsches Museum München] erzählten sie [Gerlach] mir, wie nahe die deutsche Atomkraftmaschine vor ihrem Abschluss stünde. Einige Wochen [Tage?] später berichtete Dr. Graue vom Erfolg, aber auch gleichzeitig von der drohenden Gefahr, dass die Forscher [in Stadtilm] vom Feind überrollt würden. Es war mir möglich, den Chef der Sicherheitspolizei zu bewegen, eine Autokolonne unter der Leitung des Oberführers Ehrlinger in Marsch zu setzen, und die Atomforscher, ihre Unterlagen und ihre Einrichtungen in Schutz zu bringen.” [Schreiben von Spengler an Gerlach vom 12. März 1948, Institut für Zeitgeschichte München]

Beide SD-Mitarbeiter sprachen nicht von Haigerloch, sondern von Stadtilm. Gerlach befand sich seit dem 30. März in Hechingen und sorgte sich um seine Leute in Stadtilm. Das dürfte der Hauptgrund für seinen hektischen Anruf am 31. März bei Thiessen gewesen sein. Thiessen verständige sofort den SD. Fischer und Spengler machten sich daraufhin auf den Weg zu Graue in der Kriegswirtschaftsstelle des Reichsforschungsrates. Unklar bleibt wo der SS-Reaktor gestanden haben soll.

About twenty years before the description quoted, Fischer had given a different account of the course of events: “We had to act quickly. For the decisive attempt with the uranium machine had been made in Stadtilm.” [Fischer later deleted these sentences. Cf. Helmut J. Fischer, Fire Department for Research, Institut für Zeitgeschichte Munich, Ms. 321/1-4]

Fischer’s superior Spengler also wrote of a functioning reactor: “Following this meeting [on 23 March a meeting with Graue, Fischer, Schumann, Geist and Diebner took place in the Harnack House—Dienstkalender Walther Gerlach, Deutsches Museum München] they [Gerlach] told me how close the German nuclear engine was to its conclusion. A few weeks [days?] later Dr. Graue reported about the success, but also about the threatening danger that the researchers [in Stadtilm] would be overrun by the enemy. It was possible for me to persuade the chief of the security police to march a motorcade under the leadership of Chief Ehrlinger and to protect the nuclear researchers, their documents and their facilities.” [Letter from Spengler to Gerlach dated 12 March 1948, Institut für Zeitgeschichte Munich]

Both SD employees did not talk about Haigerloch, but about Stadtilm. Gerlach had been in Hechingen since March 30 and cared for his people in Stadtilm. This must have been the main reason for his hectic call to Thiessen on March 31. Thiessen immediately informed the SD. Fischer and Spengler then made their way to Graue in the War Economic Office of the Reich Research Council. It remains unclear where the SS reactor is said to have been.

Edward M. Pickett to Assistant Chief of Staff, G-2, USFET. 4 March 1946. Subject: Additional Supply of Uranium Oxide. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA] See document photo on p. 3871.

1. Reference is made to your letter from US Military Attaché, London, 14 December 1945, subject: "Materials in Laboratory of Dr. KIRCHENER, Garmisch", and letter your office same subject, dated 21 February 1946.

2. Additional quantities of Uranium Oxide have been located in the amount of approximately five and one-half tons at Bad Tölz and Munich. This material was found in the custody of Dr. Fritz REHBEIN, formerly part of the investigation group of the State Investigation Council (Reichsforschungsrat). It was inspected and left in his charge by Professor Charles P. SMYTH, Princeton University in June, 1945. Professor SMYTH also inspected the materials now located in Garmisch. This is the second occurrence in which like material was located in the custody of German scientific groups inspected by Professor SMYTH at which inspection he told the custodians to hold the material for further instructions. In view of this, request that Professor SMYTH be contacted to determine if other such material can be located or is in the custody of any other groups.

3. Dr. Fritz REHBEIN stated during investigation that the Uranium Oxide is very active and can be extremely injurious to personnel not qualified in its handling. [...]

Edgar P. Dean to W. R. Shuler. 1 April 1946. SUBJECT: Shipment of Uranium Compounds. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA] See document photo on p. 3872.

1. Reference our cable 70400 of 28 March 1946. The following are the facts behind this shipment of uranium.

2. Early in the winter, we learned of the existence of $1\frac{1}{2}$ tons of uranium compounds at Garmisch-Partenkirchen. G-2 USFET was alerted to move the stuff. Actually, G-2 moved very slowly and we had to prod them on three successive occasions.

3. On the other hand, G-2 moved extremely quickly re the five tons of uranium oxide recently discovered at Bad Tölz. (See letter this office "Professor Smyth and Uranium Oxide in Germany", dated 15 March 1946.)

4. The two lots were consolidated into one at Bremerhaven and put aboard the Hagerstown Victory. This ship sailed on 19 March and should arrive in New York about 6 April.

[The U.S. hastily removed several tons of "very active" and "extremely injurious" uranium oxide that may have been irradiated in an operational fission reactor (perhaps Diebner's) and was associated with Fritz Rehbein (p. 4564) and C. P. Smyth (p. 4788). See also pp. 3473, 5077.]

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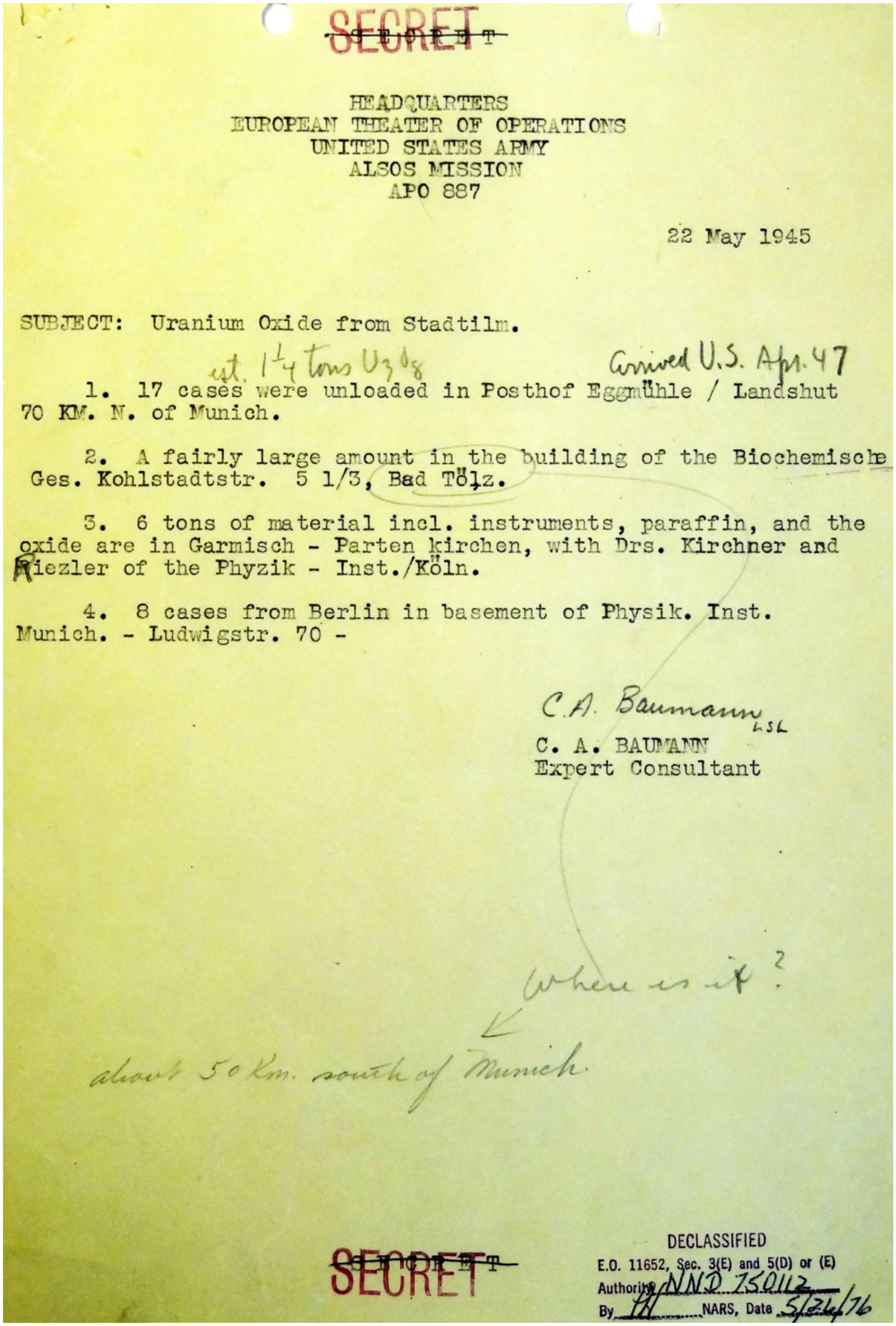

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HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS MISSION
APO 887

22 May 1945

SUBJECT: Uranium Oxide from Stadtilm.

est. 1 1/4 tons U_3O_8 arrived U.S. Apr. 47

1. 17 cases were unloaded in Posthof Eggmühle / Landshut 70 KM. N. of Munich.

2. A fairly large amount in the building of the Biochemische Ges. Kohlstadtstr. 5 1/3, Bad Tölz.

3. 6 tons of material incl. instruments, paraffin, and the oxide are in Garmisch - Parten kirchen, with Drs. Kirchner and Riezler of the Phyzik - Inst./Köln.

4. 8 cases from Berlin in basement of Physik. Inst. Munich. - Ludwigstr. 70 -

C.A. Baumann
LSL
C. A. BAUMANN
Expert Consultant

Where is it?

about 50 Km. south of Munich.

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E.O. 11652, Sec. 3(E) and 5(D) or (E)
Authority NND 750112
By ______ NARS, Date 5/24/76

NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL

Figure D.383: C. A. Baumann. 22 May 1945. SUBJECT: Uranium Oxide from Stadtilm [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL]

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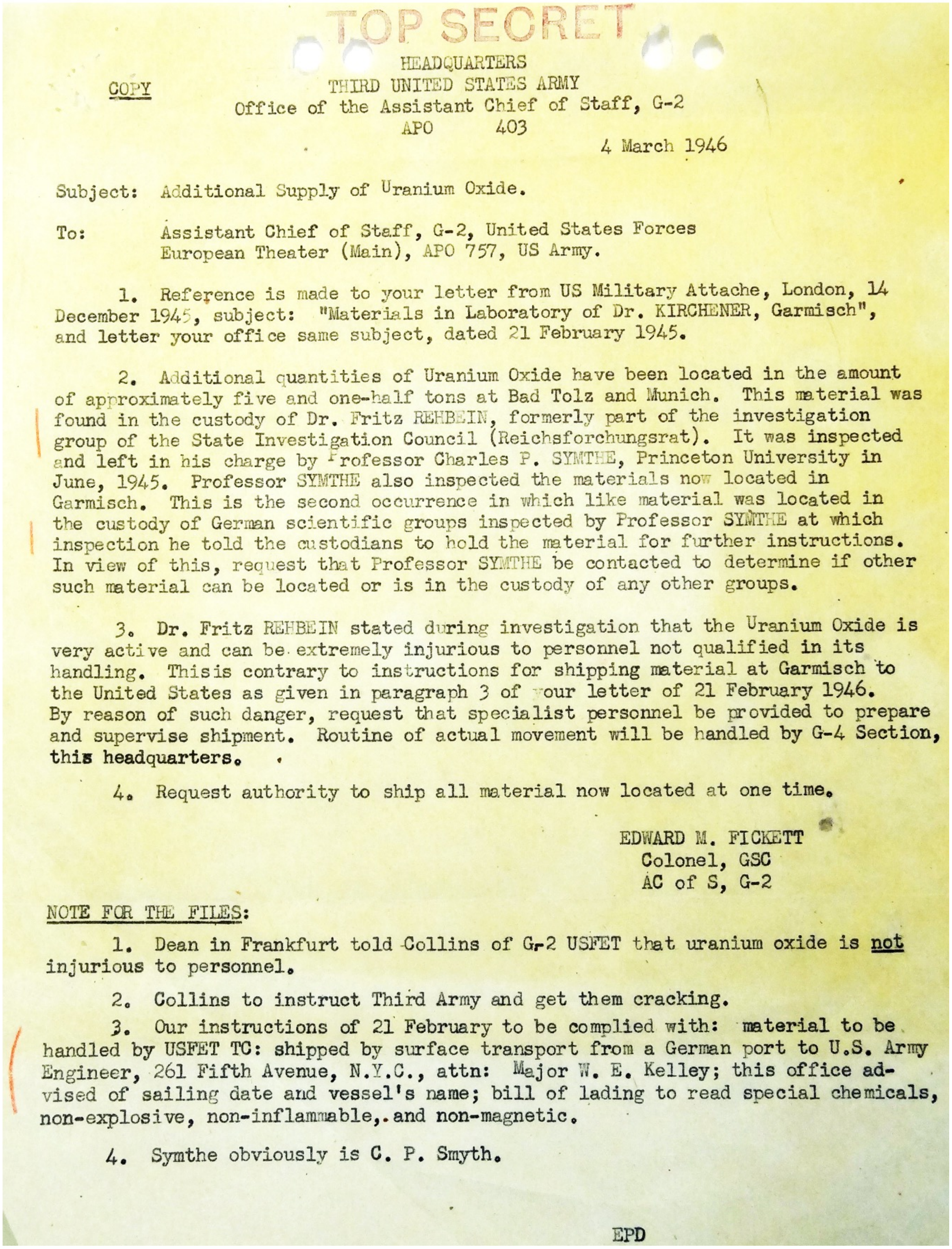
NARA RG 77, Entry UD-22A, Box 169,
Folder 32.32. Germ. Incl. TA



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COPY

HEADQUARTERS
THIRD UNITED STATES ARMY
Office of the Assistant Chief of Staff, G-2
APO 403

4 March 1946

Subject: Additional Supply of Uranium Oxide.

To: Assistant Chief of Staff, G-2, United States Forces
European Theater (Main), APO 757, US Army.

1. Reference is made to your letter from US Military Attache, London, 14 December 1945, subject: "Materials in Laboratory of Dr. KIRCHENER, Garmisch", and letter your office same subject, dated 21 February 1945.

2. Additional quantities of Uranium Oxide have been located in the amount of approximately five and one-half tons at Bad Tolz and Munich. This material was found in the custody of Dr. Fritz REHBEIN, formerly part of the investigation group of the State Investigation Council (Reichsforchungsrat). It was inspected and left in his charge by Professor Charles P. SYMTHE, Princeton University in June, 1945. Professor SYMTHE also inspected the materials now located in Garmisch. This is the second occurrence in which like material was located in the custody of German scientific groups inspected by Professor SYMTHE at which inspection he told the custodians to hold the material for further instructions. In view of this, request that Professor SYMTHE be contacted to determine if other such material can be located or is in the custody of any other groups.

3. Dr. Fritz REHBEIN stated during investigation that the Uranium Oxide is very active and can be extremely injurious to personnel not qualified in its handling. Thisis contrary to instructions for shipping material at Garmisch to the United States as given in paragraph 3 of your letter of 21 February 1946. By reason of such danger, request that specialist personnel be provided to prepare and supervise shipment. Routine of actual movement will be handled by G-4 Section, this headquarters.

4. Request authority to ship all material now located at one time.

EDWARD M. FICKETT
Colonel, GSC
AC of S, G-2

NOTE FOR THE FILES:

1. Dean in Frankfurt told Collins of G-2 USFET that uranium oxide is not injurious to personnel.

2. Collins to instruct Third Army and get them cracking.

3. Our instructions of 21 February to be complied with: material to be handled by USFET TC: shipped by surface transport from a German port to U.S. Army Engineer, 261 Fifth Avenue, N.Y.C., attn: Major W. E. Kelley; this office advised of sailing date and vessel's name; bill of lading to read special chemicals, non-explosive, non-inflammable,.and non-magnetic.

4. Symthe obviously is C. P. Smyth.

EPD

Figure D.384: The U.S. hastily removed several tons of "very active" and "extremely injurious" uranium oxide that may have been irradiated in an operational fission reactor (perhaps Diebner's) and was associated with Fritz Rehbein (p. 4564) and C. P. Smyth (p. 4788). See also pp. 3473, 5077. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA]

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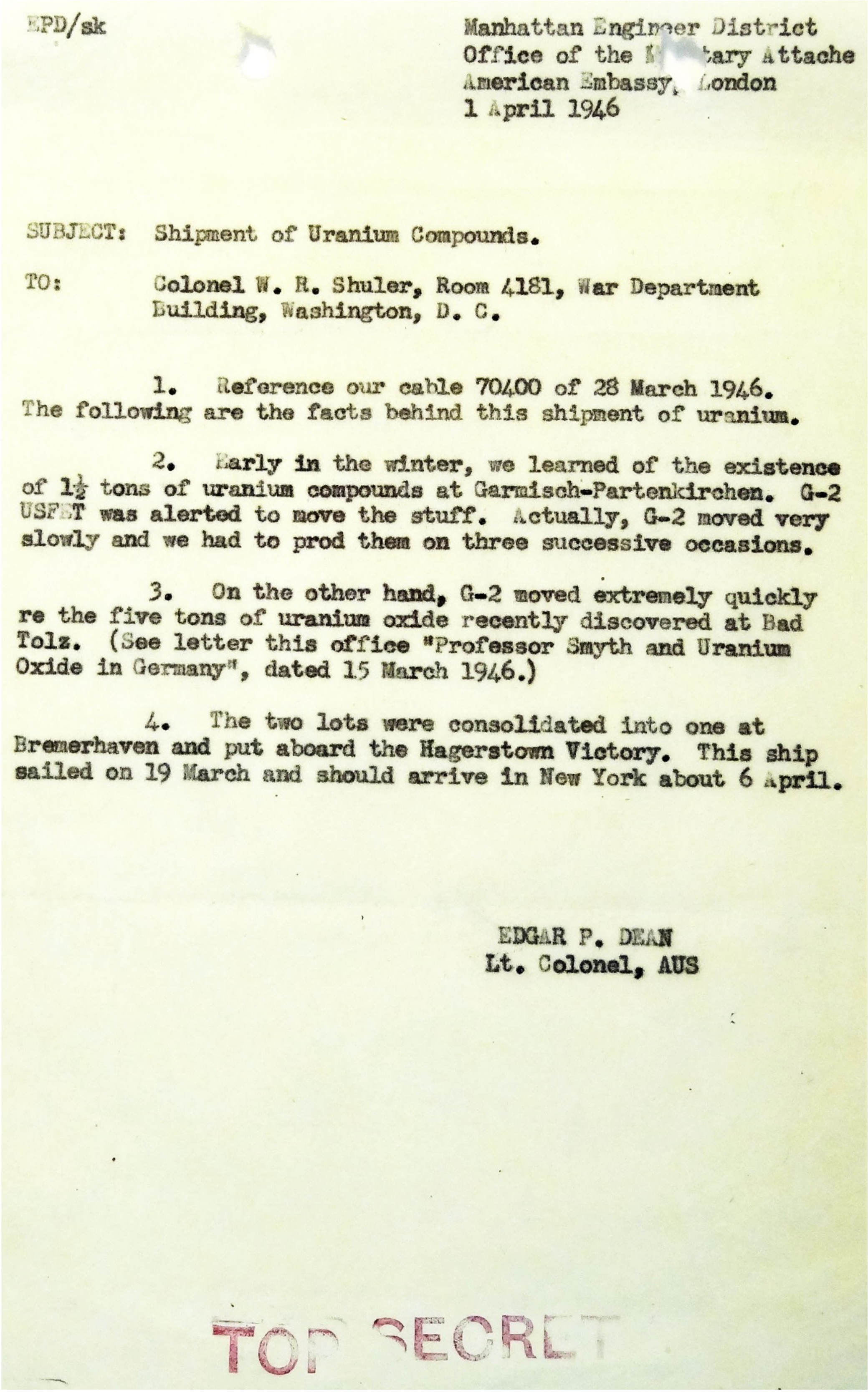

EPD/sk

Manhattan Engineer District
Office of the Military Attache
American Embassy, London
1 April 1946

SUBJECT: Shipment of Uranium Compounds.

TO: Colonel W. R. Shuler, Room 4181, War Department Building, Washington, D. C.

1. Reference our cable 70400 of 28 March 1946. The following are the facts behind this shipment of uranium.

2. Early in the winter, we learned of the existence of 1½ tons of uranium compounds at Garmisch-Partenkirchen. G-2 USFET was alerted to move the stuff. Actually, G-2 moved very slowly and we had to prod them on three successive occasions.

3. On the other hand, G-2 moved extremely quickly re the five tons of uranium oxide recently discovered at Bad Tolz. (See letter this office "Professor Smyth and Uranium Oxide in Germany", dated 15 March 1946.)

4. The two lots were consolidated into one at Bremerhaven and put aboard the Hagerstown Victory. This ship sailed on 19 March and should arrive in New York about 6 April.

EDGAR P. DEAN
Lt. Colonel, AUS

TOP SECRET

NARA RG 77, Entry UD-22A, Box 169,
Folder 32.32. Germ. Incl. TA

Figure D.385: The U.S. hastily removed several tons of "very active" and "extremely injurious" uranium oxide that may have been irradiated in an operational fission reactor (perhaps Diebner's) and was associated with Fritz Rehbein (p. 4564) and C. P. Smyth (p. 4788). See also pp. 3473, 5077. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA]

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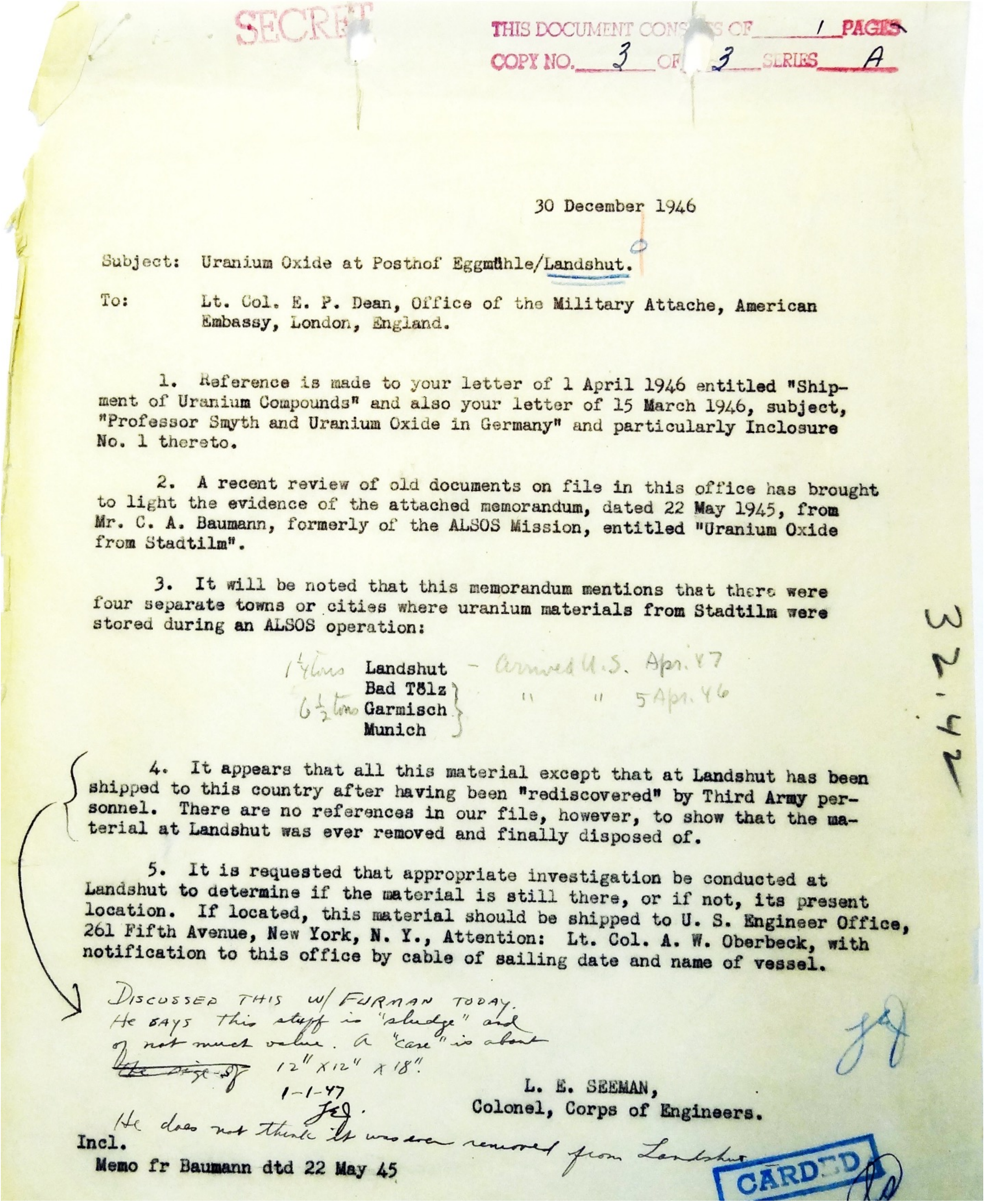
NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Incl. TA



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THIS DOCUMENT CONSISTS OF 1 PAGES
COPY NO. 3 OF 3 SERIES A

30 December 1946

Subject: Uranium Oxide at Posthof Eggmühle/Landshut.

To: Lt. Col. E. P. Dean, Office of the Military Attache, American Embassy, London, England.

1. Reference is made to your letter of 1 April 1946 entitled "Shipment of Uranium Compounds" and also your letter of 15 March 1946, subject, "Professor Smyth and Uranium Oxide in Germany" and particularly Inclosure No. 1 thereto.

2. A recent review of old documents on file in this office has brought to light the evidence of the attached memorandum, dated 22 May 1945, from Mr. C. A. Baumann, formerly of the ALSOS Mission, entitled "Uranium Oxide from Stadtilm".

3. It will be noted that this memorandum mentions that there were four separate towns or cities where uranium materials from Stadtilm were stored during an ALSOS operation:

1¼ tons Landshut – Arrived U.S. Apr. 47
Bad Tölz " " 5 Apr. 46
6½ tons Garmisch
Munich

4. It appears that all this material except that at Landshut has been shipped to this country after having been "rediscovered" by Third Army personnel. There are no references in our file, however, to show that the material at Landshut was ever removed and finally disposed of.

5. It is requested that appropriate investigation be conducted at Landshut to determine if the material is still there, or if not, its present location. If located, this material should be shipped to U. S. Engineer Office, 261 Fifth Avenue, New York, N. Y., Attention: Lt. Col. A. W. Oberbeck, with notification to this office by cable of sailing date and name of vessel.

DISCUSSED THIS W/ FURMAN TODAY.
He SAYS this stuff is "sludge" and
of not much value. A "case" is about
~~the size of~~ 12" x 12" x 18".
1-1-47
JEJ.
He does not think it was ever removed from Landshut

L. E. SEEMAN,
Colonel, Corps of Engineers.

32.42

Incl.
Memo fr Baumann dtd 22 May 45

CARDED

Figure D.386: The U.S. hastily removed several tons of "very active" and "extremely injurious" uranium oxide that may have been irradiated in an operational fission reactor (perhaps Diebner's) and was associated with Fritz Rehbein (p. 4564) and C. P. Smyth (p. 4788). See also pp. 3473, 5077. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA]

4. A possible fission reactor in the Bergkristall tunnel complex in Austria

[Rudolf Haunschmied and Andreas Sulzer have gathered a huge amount of unpublished archival documents, witness statements, aerial photographs, and other evidence that strongly suggests that part of the Bergkristall tunnel complex at St. Georgen/Gusen near Linz, Austria was conducting nuclear-weapons-related work during the war. From some of the evidence, it sounds as if the complex may have even included an operational fission reactor and facilities for extracting bred plutonium-239 or uranium-233 from irradiated reactor fuel. German forces sealed the entrances and air shafts to that part of the tunnel complex shortly before the end of the war, and they have remained sealed for 75+ years. Air and water samples taken from the site in recent years have remarkably high levels of radioisotopes, which may or may not be due to purely natural causes.

Until all of the documentary evidence is available, and/or until the site can be properly excavated and analyzed, the true nature of this facility cannot be settled. A very small sample of the documentary evidence is presented below and on the following pages.

U.S. officials inspected this site and interrogated witnesses after the war; see pp. 4962–4970. Their reports on what they found and learned there have never been publicly released. Can those reports be located in archives and declassified?]

PW Intelligence Bulletin 2/50. 1 April 1945 [AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533; AFHRA A5186 frames 0598–0599]

13. V-2 Factory, ST GEORGEN a/Gusen (Austria)

Preamble. Most of PW's information came from a girl who lives in ST GEORGEN. He met the girl while hospitalized in LINZ during Nov and Dec. 44. PW also saw the factory from the train while passing through ST GEORGEN en route to LINZ from FRESTADT.

Location and Layout. GSGS 4416/W9/974858. The entrance to the tunnel in which the factory is located is appr 3 m x 4 m. It is visible from the RR line appr 200 m away. A narrow-gauge RR leads to the site.

Production. PW's only indication that V-2s are manufactured at the factory is his informant's statement to the effect that because of an explosion in the factory in Sept 44 the commitment of the V-2 was delayed considerably. The explosion caused the death of 100 persons and the destruction of important machinery.

Personnel. Five large wooden barracks, located adjacent to the RR tracks, house an undetermined number of foreign workers. In addition, prisoners are brought in daily from the concentration camp in MAUTHAUSEN for work at the factory. Civilian workers are billeted in villages in the vicinity.

At the time of PW's departure in Dec 44 it was planned to keep workers inside the factory at all times, using artificial sunlight to keep them in good health. The plan was devised to eliminate the frequent breaches of security which had occurred.

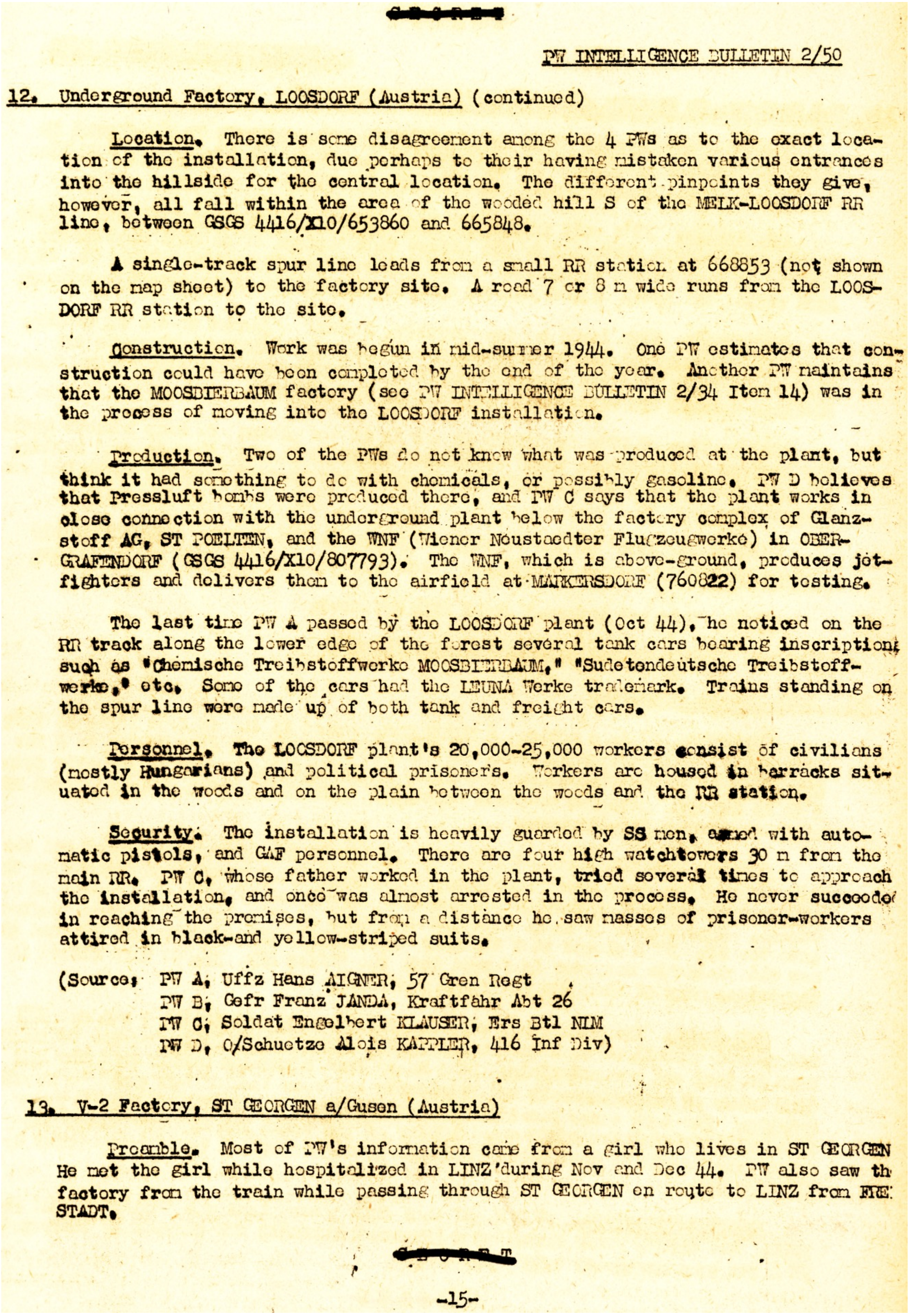
Workers who lived in the barracks adjacent to the RR line were completely dissatisfied with living conditions. Once they even set fire to the barracks.

Flak. PW is not informed about Flat defenses.

(Source: C/Gefr Julius WAGNER, Feld Ers Stl 256)

THIS PAGE IS DECLASSIFIED IAW EO 13526

PW Intelligence Bulletin No 2/50, AFHRA folder 506.61952 Nos. 2/41--2/50 6 Mar--1 Apr 1945, IRIS 207533



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PW INTELLIGENCE BULLETIN 2/50

12. Underground Factory, LOOSDORF (Austria) (continued)

Location. There is some disagreement among the 4 PWs as to the exact location of the installation, due perhaps to their having mistaken various entrances into the hillside for the central location. The different pinpoints they give, however, all fall within the area of the wooded hill S of the MELK-LOOSDORF RR line, between GSGS 4416/X10/653860 and 665848.

A single-track spur line leads from a small RR station at 668853 (not shown on the map sheet) to the factory site. A road 7 or 8 m wide runs from the LOOSDORF RR station to the site.

Construction. Work was begun in mid-summer 1944. One PW estimates that construction could have been completed by the end of the year. Another PW maintains that the MOOSBIERBAUM factory (see PW INTELLIGENCE BULLETIN 2/34 Item 14) was in the process of moving into the LOOSDORF installation.

Production. Two of the PWs do not know what was produced at the plant, but think it had something to do with chemicals, or possibly gasoline. PW D believes that Pressluft bombs were produced there, and PW C says that the plant works in close connection with the underground plant below the factory complex of Glanzstoff AG, ST POELTEN, and the WNF (Wiener Neustaedter Flugzeugwerke) in OBER-GRAFENDORF (GSGS 4416/X10/807793). The WNF, which is above-ground, produces jet-fighters and delivers them to the airfield at MARKERSDORF (760822) for testing.

The last time PW A passed by the LOOSDORF plant (Oct 44), he noticed on the RR track along the lower edge of the forest several tank cars bearing inscriptions such as "Chemische Treibstoffwerke MOOSBIERBAUM," "Sudetendeutsche Treibstoffwerke," etc. Some of the cars had the LEUNA Werke trademark. Trains standing on the spur line were made up of both tank and freight cars.

Personnel. The LOOSDORF plant's 20,000-25,000 workers consist of civilians (mostly Hungarians) and political prisoners. Workers are housed in barracks situated in the woods and on the plain between the woods and the RR station.

Security. The installation is heavily guarded by SS men, armed with automatic pistols, and GAF personnel. There are four high watchtowers 30 m from the main RR. PW C, whose father worked in the plant, tried several times to approach the installation, and once was almost arrested in the process. He never succeeded in reaching the premises, but from a distance he saw masses of prisoner-workers attired in black-and yellow-striped suits.

(Source: PW A, Uffz Hans AIGNER, 57 Gren Regt
PW B, Gefr Franz JANDA, Kraftfahr Abt 26
PW C, Soldat Engelbert KLAUSER, Ers Btl NIM
PW D, O/Schuetze Alois KAPPLER, 416 Inf Div)

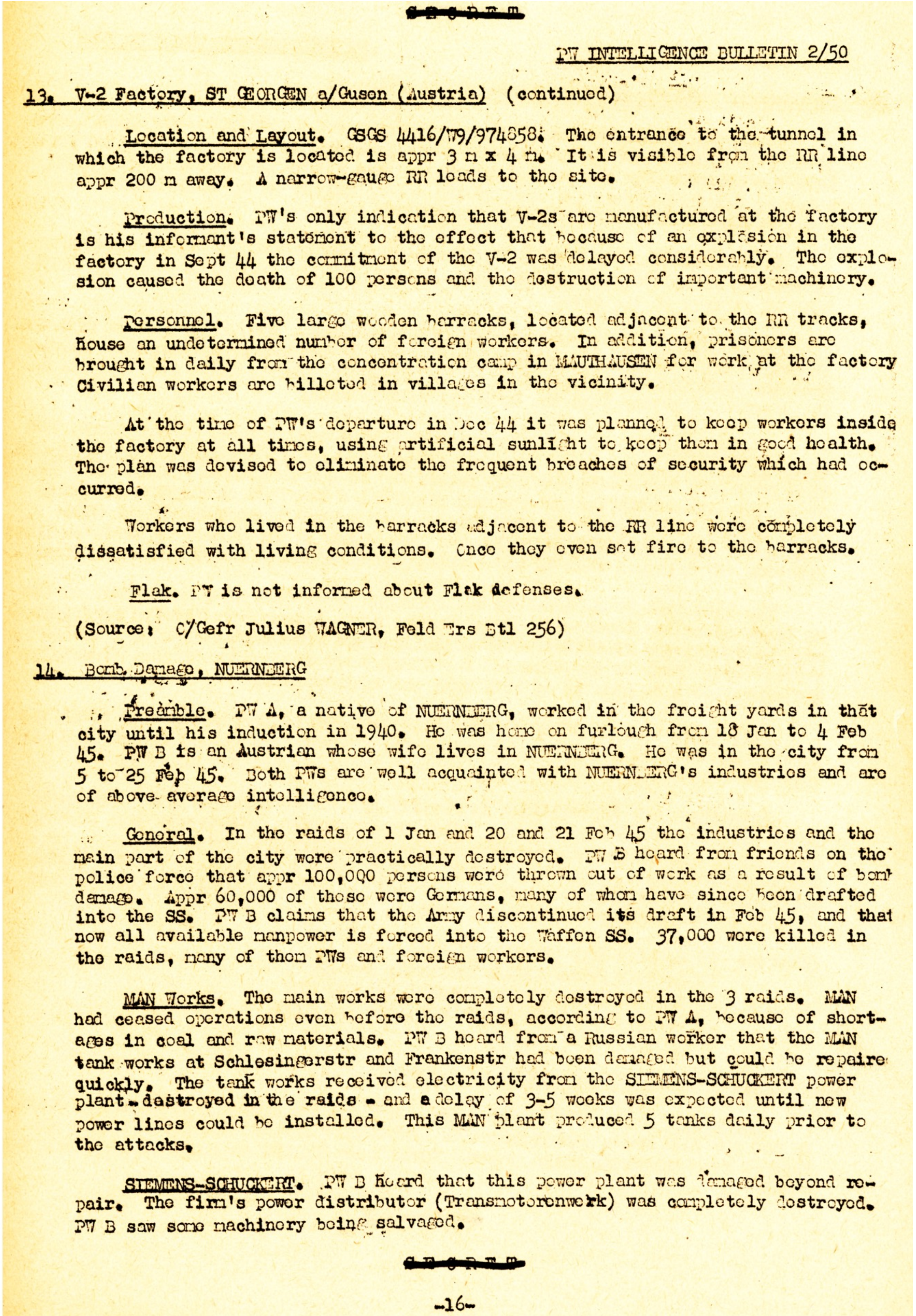
13. V-2 Factory, ST GEORGEN a/Gusen (Austria)

Preamble. Most of PW's information came from a girl who lives in ST GEORGEN He met the girl while hospitalized in LINZ during Nov and Dec 44. PW also saw th factory from the train while passing through ST GEORGEN en route to LINZ from FRE STADT.

~~S-E-C-R-E-T~~

-15-

Figure D.387: PW Intelligence Bulletin 2/50. 1 April 1945 [AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533; AFHRA A5186 frames 0598–0599].



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PW Intelligence Bulletin No 2/50, AFHRA folder 506.61952 Nos. 2/41--2/50 6 Mar--1 Apr 1945, IRIS 207533

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PW INTELLIGENCE BULLETIN 2/50

13. V-2 Factory, ST GEORGEN a/Gusen (Austria) (continued)

Location and Layout. GSGS 4416/W9/974858. The entrance to the tunnel in which the factory is located is appr 3 m x 4 m. It is visible from the RR line appr 200 m away. A narrow-gauge RR leads to the site.

Production. PW's only indication that V-2s are manufactured at the factory is his informant's statement to the effect that because of an explosion in the factory in Sept 44 the commitment of the V-2 was delayed considerably. The explosion caused the death of 100 persons and the destruction of important machinery.

Personnel. Five large wooden barracks, located adjacent to the RR tracks, house an undetermined number of foreign workers. In addition, prisoners are brought in daily from the concentration camp in MAUTHAUSEN for work at the factory Civilian workers are billeted in villages in the vicinity.

At the time of PW's departure in Dec 44 it was planned to keep workers inside the factory at all times, using artificial sunlight to keep them in good health. The plan was devised to eliminate the frequent breaches of security which had occurred.

Workers who lived in the barracks adjacent to the RR line were completely dissatisfied with living conditions. Once they even set fire to the barracks.

Flak. PW is not informed about Flak defenses.

(Source: O/Gefr Julius WAGNER, Feld Ers Btl 256)

14. Bomb Damage, NUERNBERG

Preamble. PW A, a native of NUERNBERG, worked in the freight yards in that city until his induction in 1940. He was home on furlough from 18 Jan to 4 Feb 45. PW B is an Austrian whose wife lives in NUERNBERG. He was in the city from 5 to 25 Feb 45. Both PWs are well acquainted with NUERNBERG's industries and are of above-average intelligence.

General. In the raids of 1 Jan and 20 and 21 Feb 45 the industries and the main part of the city were practically destroyed. PW B heard from friends on the police force that appr 100,000 persons were thrown out of work as a result of bomb damage. Appr 60,000 of these were Germans, many of whom have since been drafted into the SS. PW B claims that the Army discontinued its draft in Feb 45, and that now all available manpower is forced into the Waffen SS. 37,000 were killed in the raids, many of them PWs and foreign workers.

MAN Works. The main works were completely destroyed in the 3 raids. MAN had ceased operations even before the raids, according to PW A, because of shortages in coal and raw materials. PW B heard from a Russian worker that the MAN tank works at Schlesingerstr and Frankenstr had been damaged but could be repaired quickly. The tank works received electricity from the SIEMENS-SCHUCKERT power plant - destroyed in the raids - and a delay of 3-5 weeks was expected until new power lines could be installed. This MAN plant produced 5 tanks daily prior to the attacks.

SIEMENS-SCHUCKERT. PW B heard that this power plant was damaged beyond repair. The firm's power distributor (Transmotorenwerk) was completely destroyed. PW B saw some machinery being salvaged.

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-16-

Figure D.388: PW Intelligence Bulletin 2/50. 1 April 1945 [AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533; AFHRA A5186 frames 0598–0599].

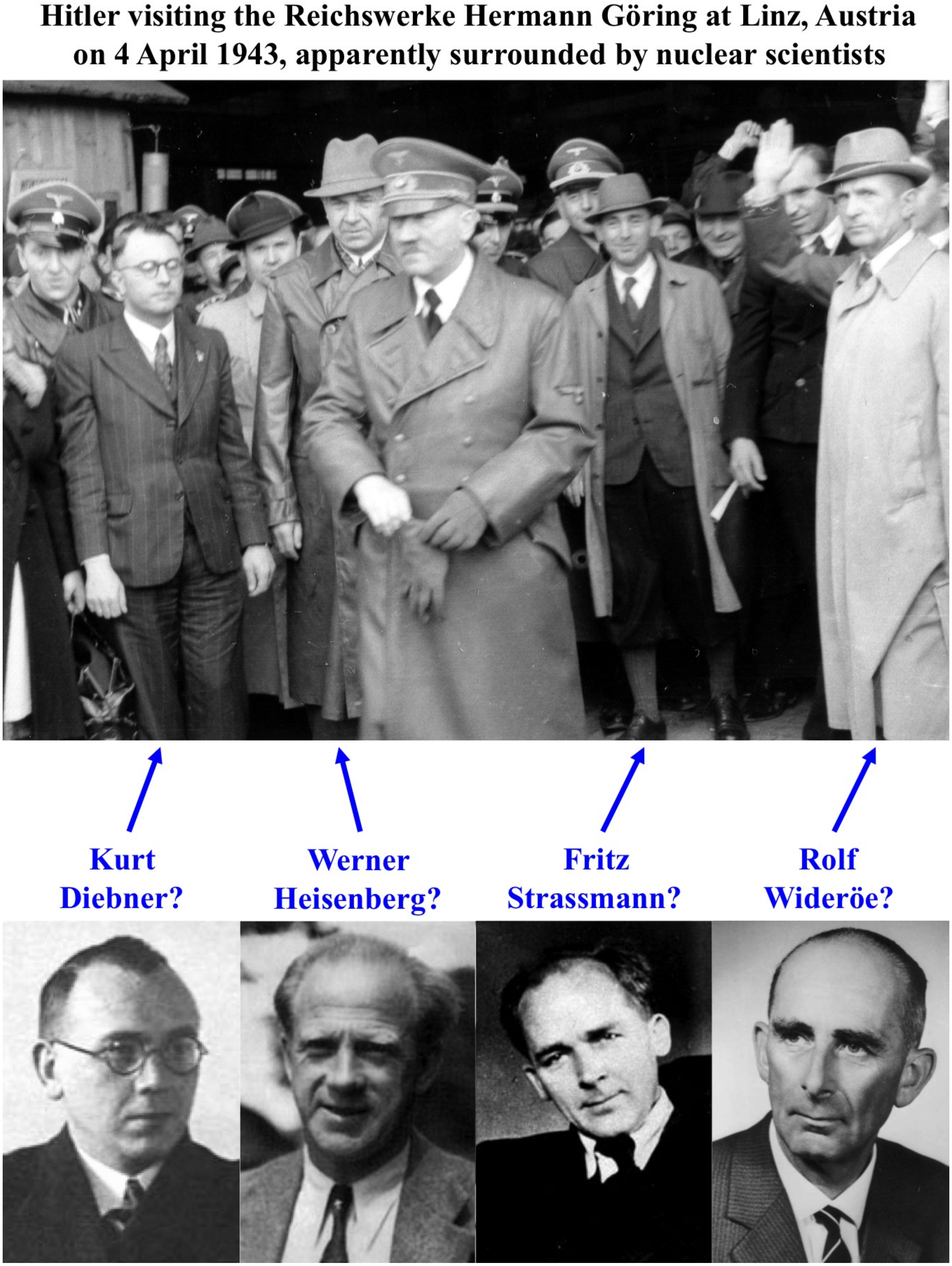

Hitler visiting the Reichswerke Hermann Göring at Linz, Austria on 4 April 1943, apparently surrounded by nuclear scientists
Kurt Diebner?
Werner Heisenberg?
Fritz Strassmann?
Rolf Wideröe?

Figure D.389: Photograph of Hitler visiting the Reichswerke Hermann Göring at Linz, Austria on 4 April 1943, apparently surrounded by nuclear scientists [Bayerische Staatsbibliothek, courtesy of Andreas Sulzer].

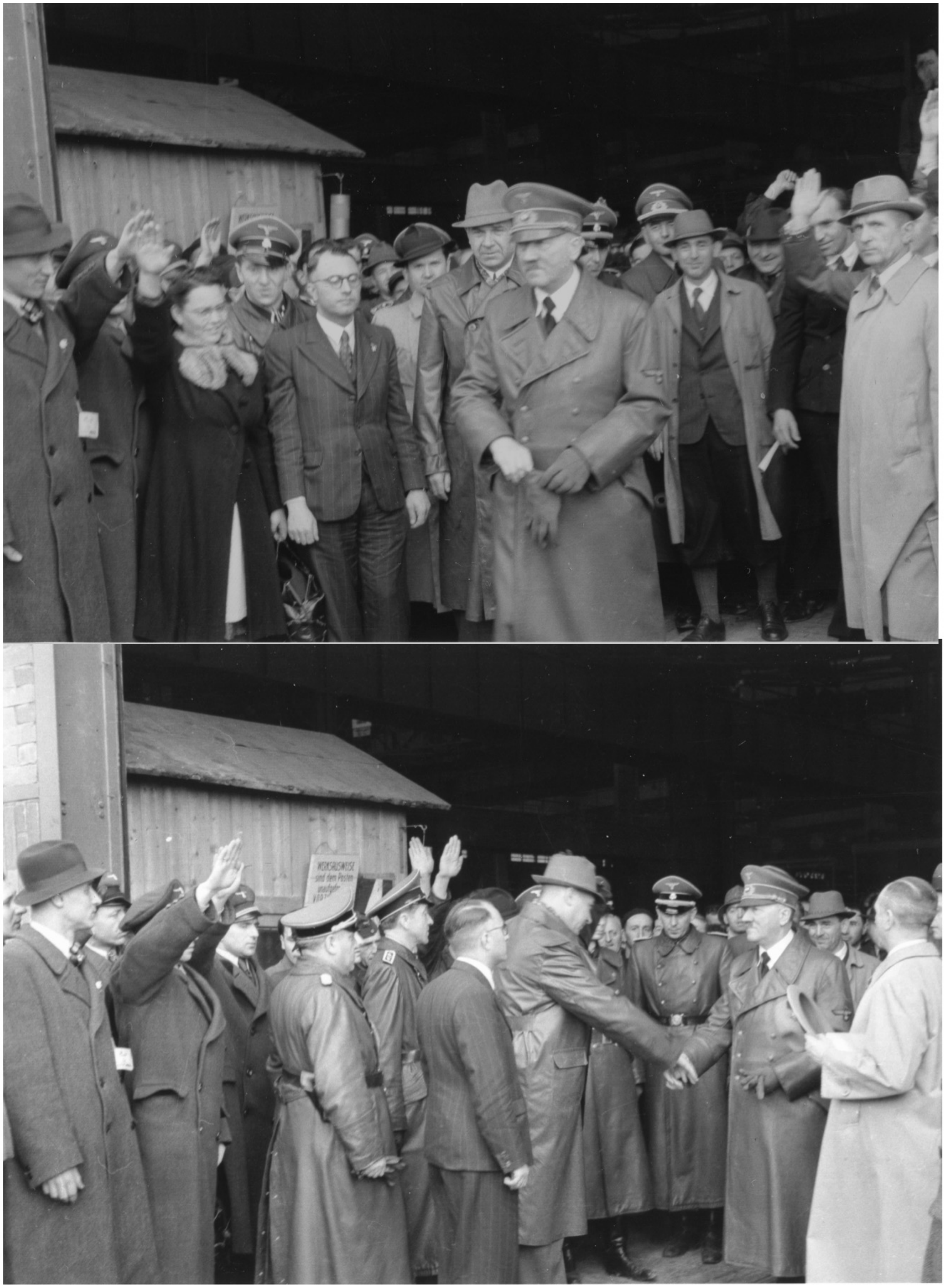


Figure D.390: Photographs of Hitler visiting the Reichswerke Hermann Göring at Linz, Austria on 4 April 1943 [Bayerische Staatsbibliothek, courtesy of Andreas Sulzer].

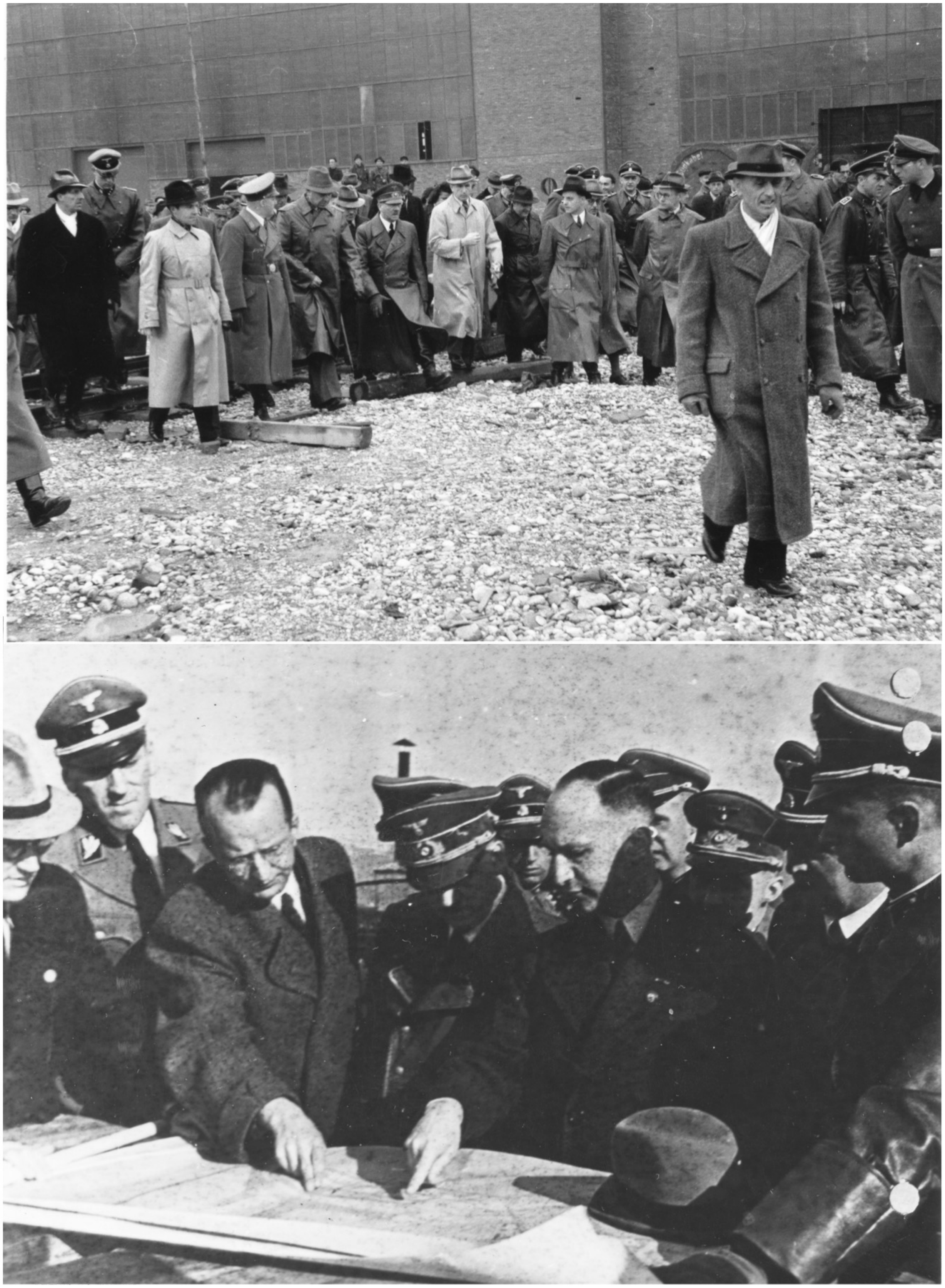
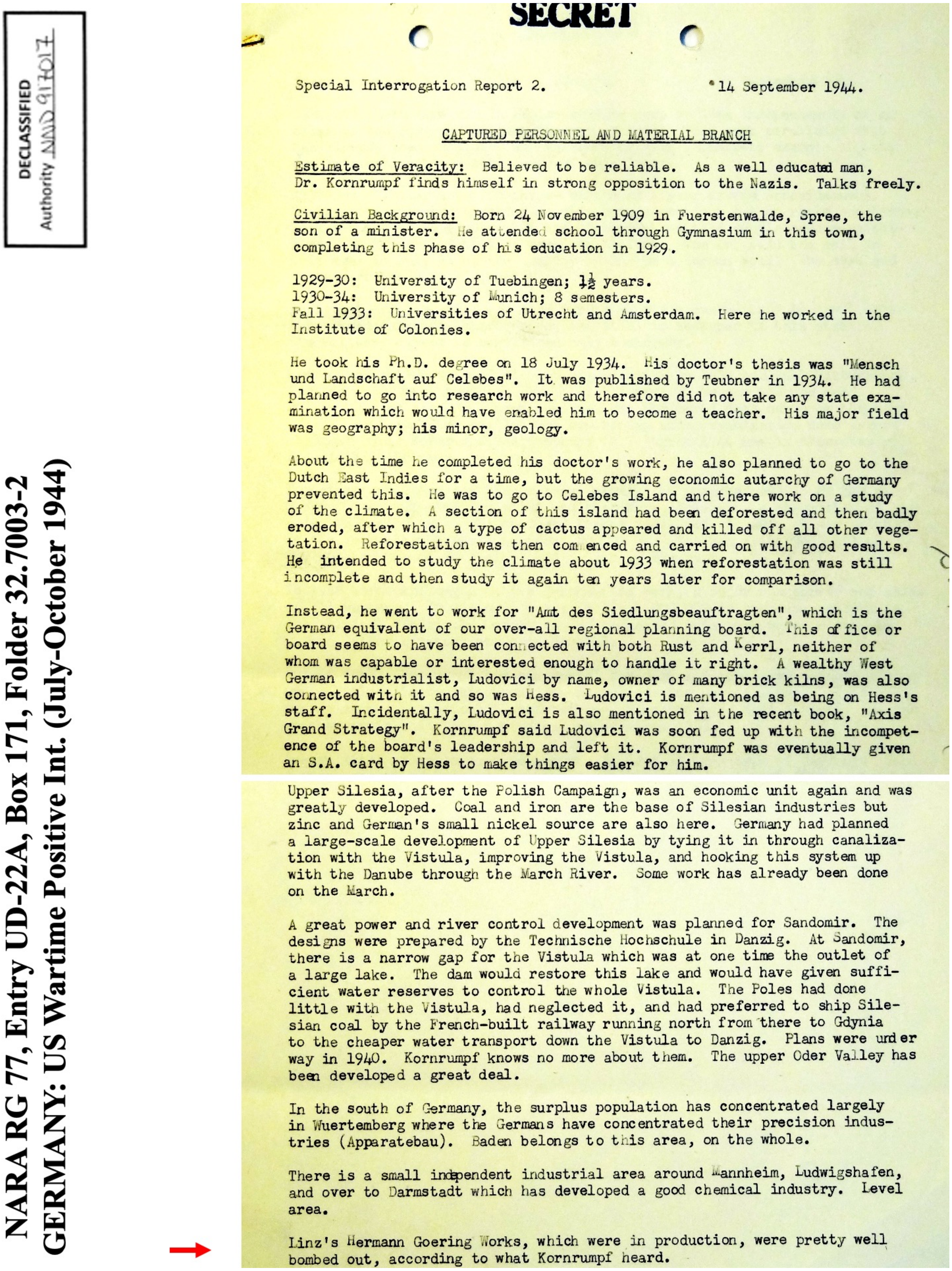


Figure D.391: Photographs of Hitler visiting the Reichswerke Hermann Göring at Linz, Austria on 4 April 1943 [Bayerische Staatsbibliothek, courtesy of Andreas Sulzer].



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Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July-October 1944)

SECRET

Special Interrogation Report 2. 14 September 1944.

CAPTURED PERSONNEL AND MATERIAL BRANCH

Estimate of Veracity: Believed to be reliable. As a well educated man, Dr. Kornrumpf finds himself in strong opposition to the Nazis. Talks freely.

Civilian Background: Born 24 November 1909 in Fuerstenwalde, Spree, the son of a minister. He attended school through Gymnasium in this town, completing this phase of his education in 1929.

1929-30: University of Tuebingen; 1½ years.
1930-34: University of Munich; 8 semesters.
Fall 1933: Universities of Utrecht and Amsterdam. Here he worked in the Institute of Colonies.

He took his Ph.D. degree on 18 July 1934. His doctor's thesis was "Mensch und Landschaft auf Celebes". It was published by Teubner in 1934. He had planned to go into research work and therefore did not take any state examination which would have enabled him to become a teacher. His major field was geography; his minor, geology.

About the time he completed his doctor's work, he also planned to go to the Dutch East Indies for a time, but the growing economic autarchy of Germany prevented this. He was to go to Celebes Island and there work on a study of the climate. A section of this island had been deforested and then badly eroded, after which a type of cactus appeared and killed off all other vegetation. Reforestation was then commenced and carried on with good results. He intended to study the climate about 1933 when reforestation was still incomplete and then study it again ten years later for comparison.

Instead, he went to work for "Amt des Siedlungsbeauftragten", which is the German equivalent of our over-all regional planning board. This office or board seems to have been connected with both Rust and Kerrl, neither of whom was capable or interested enough to handle it right. A wealthy West German industrialist, Ludovici by name, owner of many brick kilns, was also connected with it and so was Hess. Ludovici is mentioned as being on Hess's staff. Incidentally, Ludovici is also mentioned in the recent book, "Axis Grand Strategy". Kornrumpf said Ludovici was soon fed up with the incompetence of the board's leadership and left it. Kornrumpf was eventually given an S.A. card by Hess to make things easier for him.

Upper Silesia, after the Polish Campaign, was an economic unit again and was greatly developed. Coal and iron are the base of Silesian industries but zinc and German's small nickel source are also here. Germany had planned a large-scale development of Upper Silesia by tying it in through canalization with the Vistula, improving the Vistula, and hooking this system up with the Danube through the March River. Some work has already been done on the March.

A great power and river control development was planned for Sandomir. The designs were prepared by the Technische Hochschule in Danzig. At Sandomir, there is a narrow gap for the Vistula which was at one time the outlet of a large lake. The dam would restore this lake and would have given sufficient water reserves to control the whole Vistula. The Poles had done little with the Vistula, had neglected it, and had preferred to ship Silesian coal by the French-built railway running north from there to Gdynia to the cheaper water transport down the Vistula to Danzig. Plans were under way in 1940. Kornrumpf knows no more about them. The upper Oder Valley has been developed a great deal.

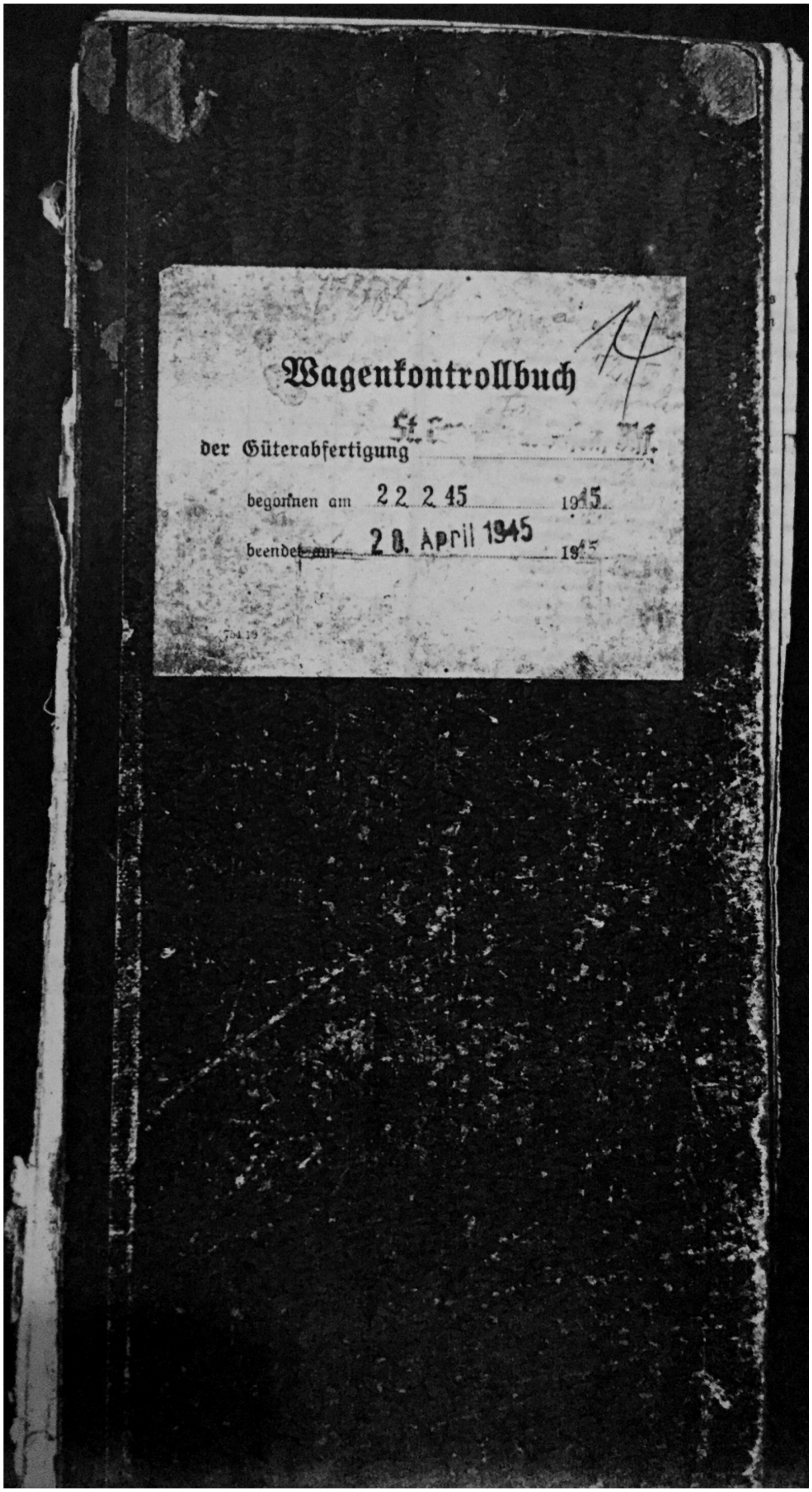
In the south of Germany, the surplus population has concentrated largely in Wuertemberg where the Germans have concentrated their precision industries (Apparatebau). Baden belongs to this area, on the whole.

There is a small independent industrial area around Mannheim, Ludwigshafen, and over to Darmstadt which has developed a good chemical industry. Level area.

→ Linz's Hermann Goering Works, which were in production, were pretty well bombed out, according to what Kornrumpf heard.

Figure D.392: Captured Personnel and Material Branch. 14 September 1944. Special Interrogation Report 2 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)]. "Linz's Hermann Goering Works, which were in production, were pretty well bombed out." Note that this report was of particular interest to Leslie Groves's Foreign Intelligence Unit.

One of a series of wartime logbooks for train cargo from the St. Georgen an der Gusen railroad station in Austria



14

Wagenkontrollbuch

der Güterabfertigung St. [illegible] Bhf.

begonnen am 22.2.45 1945

beendet ~~am~~ 28. April 1945 1945

754.19

Figure D.393: One of a series of logbooks of train shipments to and from St. Georgen an der Gusen [Collection Rudolf A. Haunschmied, from St. Georgen an der Gusen train station].

Logbooks of train shipments to and from St. Georgen an der Gusen [Collection Rudolf A. Haunschmied, from St. Georgen an der Gusen train station]. **[The complete records fill several books. The entries below are just a few individual examples.]**

[Day.mo.yr]	[From]	[To]	[Cargo (cover names)]
24.04.44	Salzgitter	Waffen SS	Atomgruppen [Domgruppen?]
26.04.44	Witkowitz	DEST	Mineralwasser
10.05.44	Oranienburg		Waffen
15.05.44	Redl Zipf	DEST	Maschinen
20.05.44	Redl Zipf	DEST	Maschinen
23.05.44	Redl Zipf	SS	Maschinen
27.05.44	Redl Zipf	Arge Mave	Pressluftrohre
06.06.44	Oranienburg		
22.08.44	Fiebinger	Witkowitz	Mineralwasserflaschen
23.08.44	Ohrdruf	Ing. Kammler	Abwasserreinigungsanlage
23.08.44	Jambes Nord (Belgien)	SSWVHA	Scharfwasser
29.08.44	Witkowitz	Eckermann	Mineralwasser
04.09.44	Ing. Kammler	Witkowitz	leere Flaschen
05.09.44	Oranienburg	SSWVHA	Maschinen
06.09.44	Oranienburg	SSWVHA	Maschinen
07.09.44	Salzgitter	Schachtbau/Böhm/Flügge	Baugeräte
07.10.44	Salzgitter	Flügge, Böhm	Baugeräte
09.10.44	Auschwitz	KZL	Unterkunftgeräte
10.10.44	Auschwitz	KZL	Effekten
11.10.44	Oranienburg	SSWVHA	E-Teile
12.10.44	Witkowitz	Eckermann	Mineralwasser
25.10.44	Nettingsdorf	Ing. Kammler	Kessel
28.10.44	Oranienburg	SSWVHA	Maschinen 2 wgs
02.11.44	Nettingsdorf	Ing. Kammler	Kessel
25.12.44	Limburgerhof	Fiebinger	Eisenteile
31.12.44	SS Führungsstab	Arnstadt	Maschinen 2 wgs
05.01.45	Auschwitz	KZL	Wehrmachtsgut 9 wgs
09.01.45	Brömme	Crawinkel	Baumaterial 3 wgs
12.01.45	Brömme	Crawinkel	Baumaterial
14.01.45	Limburgerhof	Kammler	O.V.
24.01.45	Brömme	Crawinkel	Eisenwaren
26.01.45	Oranienburg	DEST	Ersatzteile
04.02.45	Pribram	DEST	Geräte
05.02.45	Oranienburg	KDZ L	Zugladung 2 wgs
05.02.45	Berlin-Lichtenberg	Fiebinger	Eisen
09.02.45	Ing. Kammler	Kirchdorf/Tirol	Elektromaterial
09.02.45	Pribram	DEST	Geräte
22.02.45	Redl Zipf	DEST	Agelin Tank
22.02.45	DEST	Redl Zipf	Stoffflaschen
24.02.45	Ing. Kammler	Kirchdorf/Tirol	Elektromaterial
04.03.45	Oranienburg	DEST	7653069 11 wgs

[Note that the sources of these trains appear to be linked to the nuclear program:

- Witkowitz/Vitkovice was part of the city of Maehrisch-Ostrau/Ostrava, mentioned in the "Azusa" (nuclear) document on p. 3748 as having one of at least two I.G. Farben factories that were using "30,000 employees" to produce "the component of a new explosive" that was of great interest to U.S. intelligence. See also p. 3784.

- Ohrdruf was alleged to have underground facilities for nuclear-related work and is where a nuclear weapon was apparently tested (pp. 4436 ff., 4478 ff.).

- Belgium is where the uranium refineries and storage facilities of Union Minière du Haut Katanga were located [Irving 1967, p. 65]. After being controlled by Germany for over four years, they were captured by Allied forces in early September 1944 (p. 3324), just a couple of weeks after that train left on 23 August.

- Oranienburg was the home of both Auergesellschaft, which processed uranium and thorium ore [Irving 1967; Nagel 2016], and an even more mysterious SS facility that appears to have been involved with nuclear weapons development (pp. 4180, 4182).

- Salzgitter was the primary location of the Reichswerke Hermann Göring, a massive government-run metallurgical company for refining and casting iron and other metals of military importance (in this case perhaps uranium or plutonium, or other metal parts for nuclear bombs or reactors?).

- Auschwitz apparently had a heavy water production facility (p. 4452) and was said to be linked to the production and testing of atomic bombs (p. 4463).

Also note that the recipients of these trains appear to be related to the nuclear program [Haunschmied et al. 2007; Haunschmied in Joseph Fisher 2017, pp. 175–240]:

- DEST (Deutsche Erd- und Steinwerke GmbH) was an SS-run company originally founded in 1938 to exploit concentration camp labor in granite quarries like Gusen or Mauthausen and belonged to the SS-WVHA from March 1942. Its regional headquarters for the Mauthausen-Gusen complex were located at St. Georgen/Gusen since 1940. In 1943 the St. Georgen branch of DEST became a key contractor for companies like Steyr-Daimler-Puch AG and Messerschmitt GmbH in order to safeguard the production of advanced weapons in huge factories in Gusen and St. Georgen above ground as well as underground. Even SS quarries at Beneschau [Benesov] in Bohemia were controlled by the St. Georgen branch of DEST during the period 1943–1945.

- Karl Fiebinger was the chief engineer of many massive underground facilities for advanced weapons production in the Third Reich.

- Hans Kammler was the SS general who controlled virtually all of the advanced weapons programs, including the nuclear program, by the end of the war.

- SS-WVHA (SS-Wirtschafts- und Verwaltungshauptamt) was the SS Main Economic and Administrative Office, which provided huge amounts of funding and political support for SS-run weapons programs and production facilities.

- SS-Obersturmführer Werner Eckermann was chief of the SS-Führungsstab (leadership staff) "B8" for the construction and operation of the "Bergkristall" underground plant at St. Georgen/Gusen. He was Kammler's representative for his St. Georgen operations and reported to Kammler's SS-Sonderinspektion IV. In the period between October 1943 and June 1944 he was also responsible for Kammler's operation "Schlier" at Redl-Zipf, Austria.

- Siegfried Flügge was one of the very first nuclear physicists to propose how fission reactions could be used to create reactors and bombs (p. 3366), and he was a leading figure in the German nuclear weapons program from its beginnings in 1939 until the end of the war (pp. 3376, 3608, 4996–4992).

- Böhm is listed immediately alongside Siegfried Flügge as a recipient for important components. A Technical Sergeant Böhm was in charge of coordinating engineering tasks and deliveries at Gusen.

- KZL (Konzentrationslager) was the general designation for a concentration camp, in this case the Gusen concentration camp and production facility.

After the war, the United States gained detailed knowledge from most of these places and people, yet has never released reports on what it learned:

- The Belgian facilities of Union Minière du Haut Katanga were captured by U.S. forces in September 1944 (p. 3324).

- The Salzgitter headquarters of the Reichswerke Hermann Göring was captured by U.S. forces in April 1945.

- The Ohrdruf area was captured by U.S. forces in early April 1945 (pp. 4566–4570). Other than photos of concentration camp inmates, details of what the United States learned from the underground installations and from interrogations of personnel have never been publicly released. In order to succeed with the construction task at Ohrdruf, Karl Fiebinger sent his best on-site planning manager at the end of 1944 directly from St. Georgen an der Gusen (Bergkristall) to Ohrdruf [Rudolf Haunschmied, in Joseph Fisher 2017, pp. 175–240] .

- Gusen itself was captured by U.S. forces in early May 1945 (p. 4962 ff.). As with Ohrdruf, other than a few photos, details of what was learned from the underground installations and from interrogations of personnel have never been released [Haunschmied et al. 2007; Haunschmied in Joseph Fisher 2017, pp. 175–240].

- The United States received intelligence on nuclear-related work at Auschwitz (p. 4452), the Ohrdruf/Arnstadt/Crawinkel area (pp. 4566, 4570), Oranienburg (p. 3334), and Witkowitz (p. 3748).

- Karl Fiebinger worked in the United States for many years after the war as a "consultant" on secretive government projects (pp. 4986–4991, 4993). His accomplishments in the United States apparently included designing underground missile silos for intercontinental ballistic missiles, which may shed light on the true nature and extent of his wartime work for Germany [Freund and Perz 1987, p. 44].

- Siegfried Flügge worked in the United States after the war at the extremely specific and highly unusual invitation of Edward Teller, the leading physicist in the postwar U.S. nuclear weapons program (p. 4996).

- Hans Kammler was captured by the United States and interrogated for many months or perhaps even years after the war (pp. 4931–4959).

Walter Chmielewski, the son of Karl Chmielewski, the former Commandant of the Gusen concentration camp. 2016 filmed interview with Andreas Sulzer [Sulzer and Brauburger 2019a, 2019b].

Es war nur die Rede von insgesamt (sollen es) 30–40 Kilometer sein was da an Stollen angelegt worden sind und zum Teil eben auf zwei Ebenen. Also das kam durch bei Gesprächen mit SS-Leuten und dort findet jetzt Atomforschung statt. Mit Hochdampf geforscht werden soll, das noch zur Rettung der Nation, so ungefähr, die Atombombe fertig werden könnte, damit da noch einmal agiert werden kann, Ja. Das war eindeutig bei Gusen im Gespräch, dass diese Forschungen bereits stattfinden.	There was the precise talk of a total (of about) 30–40 kilometers of tunnels which have been created and partly in fact on two levels. This came through in talks with SS people and there is now nuclear research being carried out there. Under high pressure there is research, which could still save the nation, so to speak; the atomic bomb could be constructed, so that the initiative can be recovered again, yes. This was clearly stated at conversations in Gusen, that this research is already taking place.

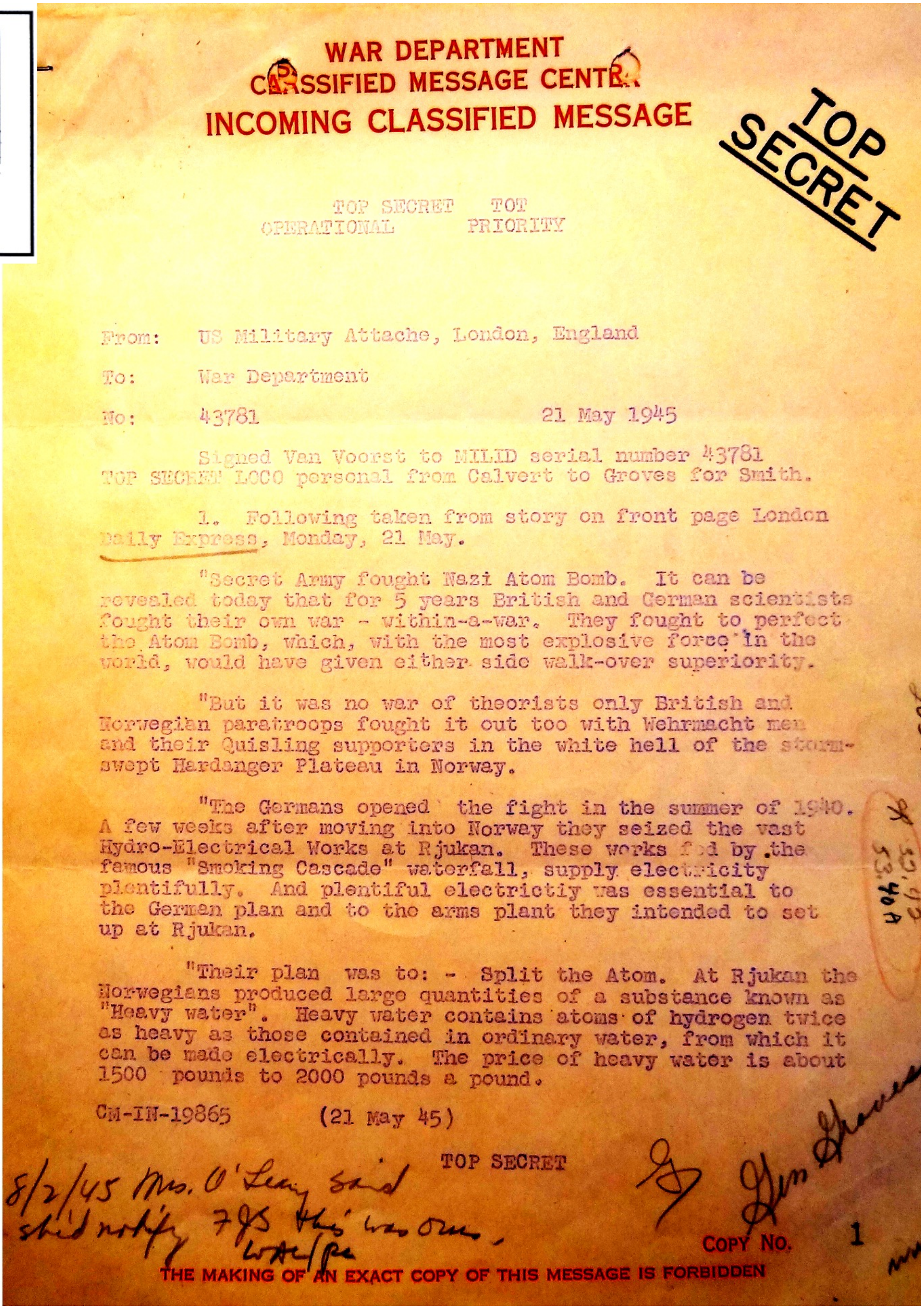
[In Chmielewski's complete interview, he stated that:

- There was a huge underground concentration camp between St. Georgen and Langenstein.

- By mid-1944 a direct order from Hitler was received to accelerate the work on the atomic bomb (at any cost in material or human life) at St. Georgen and slow down the efforts on the Me-262 jet, given that only the first weapon was "war decisive" ("kriegsentscheidend").]

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 160, Folder APR 45--Dec. '45



WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
INCOMING CLASSIFIED MESSAGE

TOP SECRET

TOP SECRET TOT
OPERATIONAL PRIORITY

From: US Military Attache, London, England

To: War Department

No: 43781 21 May 1945

Signed Van Voorst to MILID serial number 43781 TOP SECRET LOCO personal from Calvert to Groves for Smith.

1. Following taken from story on front page London Daily Express, Monday, 21 May.

"Secret Army fought Nazi Atom Bomb. It can be revealed today that for 5 years British and German scientists fought their own war - within-a-war. They fought to perfect the Atom Bomb, which, with the most explosive force in the world, would have given either side walk-over superiority.

"But it was no war of theorists only British and Norwegian paratroops fought it out too with Wehrmacht men and their Quisling supporters in the white hell of the storm-swept Hardanger Plateau in Norway.

"The Germans opened the fight in the summer of 1940. A few weeks after moving into Norway they seized the vast Hydro-Electrical Works at Rjukan. These works fed by the famous "Smoking Cascade" waterfall, supply electricity plentifully. And plentiful electrictiy was essential to the German plan and to the arms plant they intended to set up at Rjukan.

"Their plan was to: - Split the Atom. At Rjukan the Norwegians produced large quantities of a substance known as "Heavy water". Heavy water contains atoms of hydrogen twice as heavy as those contained in ordinary water, from which it can be made electrically. The price of heavy water is about 1500 pounds to 2000 pounds a pound.

CM-IN-19865 (21 May 45)

TOP SECRET

8/2/45 Mrs. O'Leary said
shd notify 7JS this was own.
WAC/pa

Gen Groves

SJ 32.93
53.40A

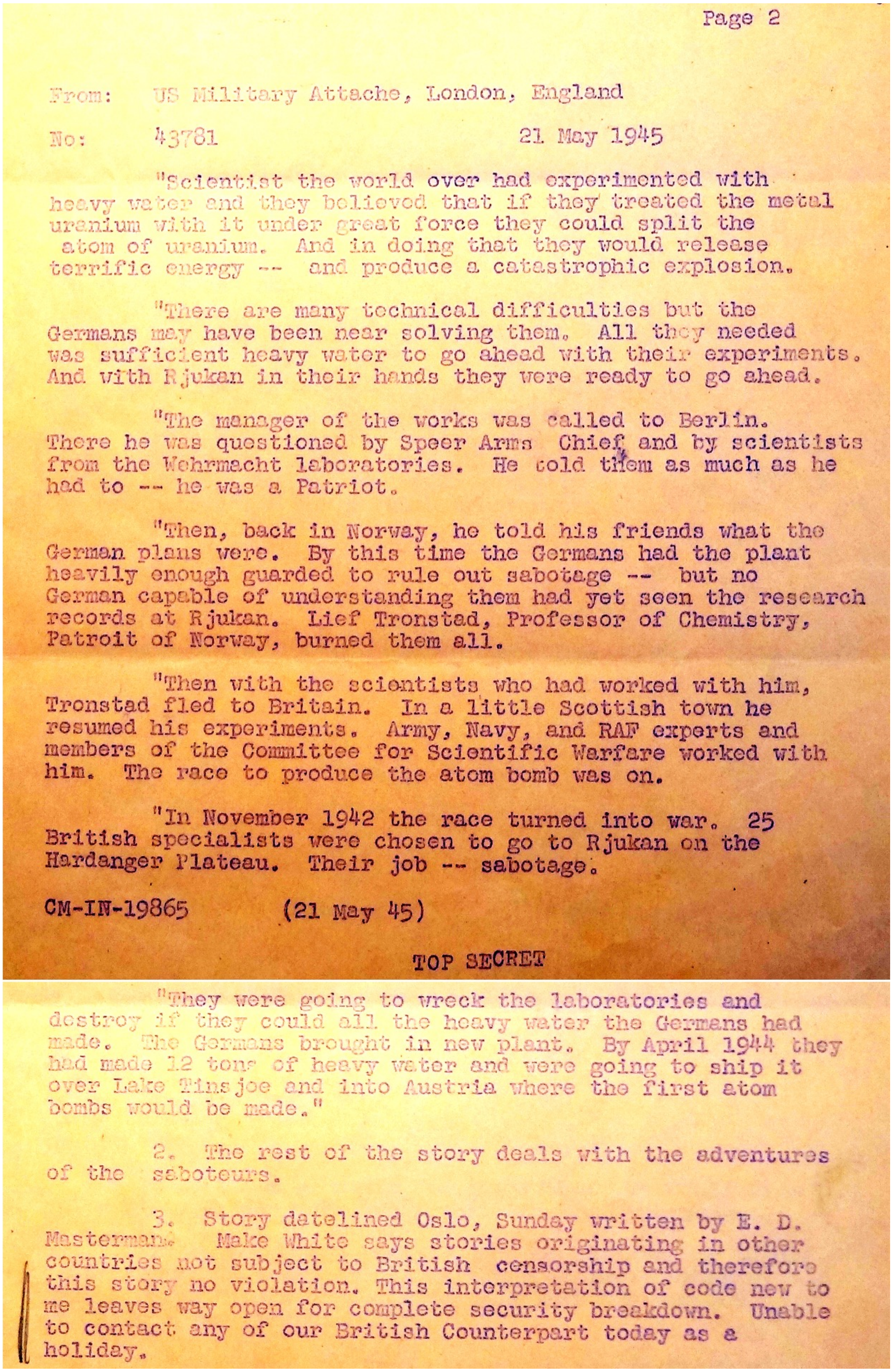
COPY NO. 1

THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN

Figure D.394: U.S. Military Attaché London to Leslie Groves. 21 May 1945 [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45]. "Secret Army fought Nazi Atom Bomb. It can be revealed today that for 5 years British and German scientists fought their own war-within-a-war. They fought to perfect the Atom Bomb, which, with the most explosive force in the world, would have given either side walk-over superiority."

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 160, Folder APR 45--Dec. '45



Page 2

From: US Military Attache, London, England

No: 43781 21 May 1945

"Scientist the world over had experimented with heavy water and they believed that if they treated the metal uranium with it under great force they could split the atom of uranium. And in doing that they would release terrific energy -- and produce a catastrophic explosion.

"There are many technical difficulties but the Germans may have been near solving them. All they needed was sufficient heavy water to go ahead with their experiments. And with Rjukan in their hands they were ready to go ahead.

"The manager of the works was called to Berlin. There he was questioned by Speer Arms Chief and by scientists from the Wehrmacht laboratories. He told them as much as he had to -- he was a Patriot.

"Then, back in Norway, he told his friends what the German plans were. By this time the Germans had the plant heavily enough guarded to rule out sabotage -- but no German capable of understanding them had yet seen the research records at Rjukan. Lief Tronstad, Professor of Chemistry, Patroit of Norway, burned them all.

"Then with the scientists who had worked with him, Tronstad fled to Britain. In a little Scottish town he resumed his experiments. Army, Navy, and RAF experts and members of the Committee for Scientific Warfare worked with him. The race to produce the atom bomb was on.

"In November 1942 the race turned into war. 25 British specialists were chosen to go to Rjukan on the Hardanger Plateau. Their job -- sabotage.

CM-IN-19865 (21 May 45)

TOP SECRET

"They were going to wreck the laboratories and destroy if they could all the heavy water the Germans had made. The Germans brought in new plant. By April 1944 they had made 12 tons of heavy water and were going to ship it over Lake Tinsjoe and into Austria where the first atom bombs would be made."

2. The rest of the story deals with the adventures of the saboteurs.

3. Story datelined Oslo, Sunday written by E. D. Masterman. Make White says stories originating in other countries not subject to British censorship and therefore this story no violation. This interpretation of code new to me leaves way open for complete security breakdown. Unable to contact any of our British Counterpart today as a holiday.

Figure D.395: U.S. Military Attaché London to Leslie Groves. 21 May 1945 [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45]. "By April 1944 they had made 12 tons of heavy water and were going to ship it over Lake Tinnsjøand into Austria where the first atom bombs would be made."

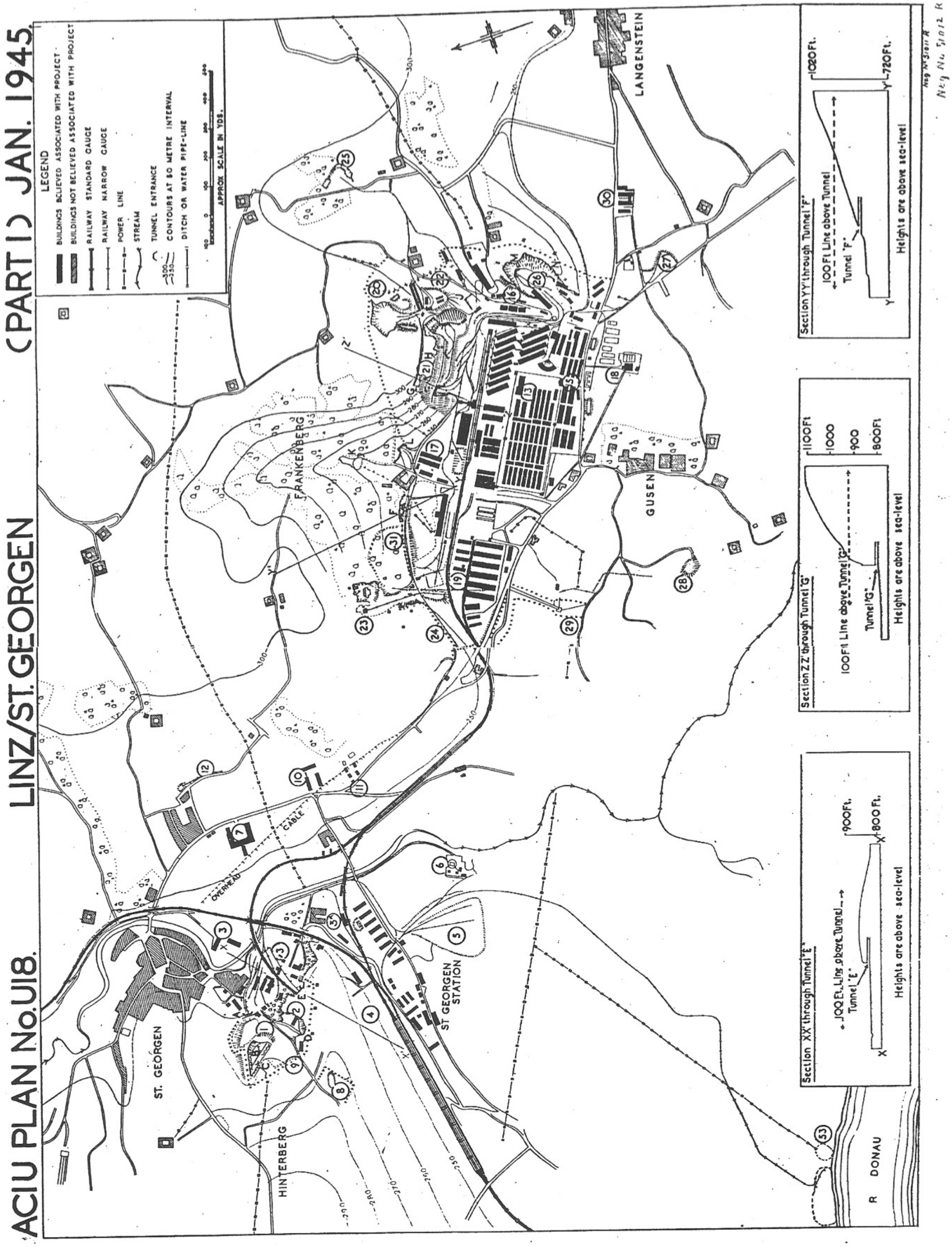

ACIU PLAN No.U18. LINZ/ST. GEORGEN (PART I) JAN. 1945
LEGEND
BUILDINGS BELIEVED ASSOCIATED WITH PROJECT
BUILDINGS NOT BELIEVED ASSOCIATED WITH PROJECT
RAILWAY STANDARD GAUGE
RAILWAY NARROW GAUGE
POWER LINE
STREAM
TUNNEL ENTRANCE
CONTOURS AT 50 METRE INTERVAL
DITCH OR WATER PIPE-LINE
APPROX. SCALE IN YDS.
LANGENSTEIN
GUSEN
FRANKENBERG
ST. GEORGEN
ST GEORGEN STATION
HINTERBERG
OVERHEAD CABLE
R DONAU
Section YY' through Tunnel 'F'
100 Ft Line above Tunnel
Tunnel 'F'
1020 Ft.
720 Ft.
Heights are above sea-level
Section ZZ' through Tunnel 'G'
100 Ft Line above Tunnel 'G'
Tunnel 'G'
1100 Ft.
1000
900
800 Ft.
Heights are above sea-level
Section XX' through Tunnel 'E'
100 Ft. Line above Tunnel
Tunnel 'E'
900 Ft.
800 Ft.
Heights are above sea-level

Figure D.396: Map of the Gusen concentration camps and the Bergkristall and Kellerbau tunnel complexes [AFHRA, courtesy of Rudolf Haunschmied].

Key for Fig. D.396:

(1) Mariengrube or Mögle-Grube (central access to individual tunnels of Bergkristall).

(2) Main entrance to Bergkristall (former Huemer sand pit near Saurüsselberg).

(3) Boiler and bath house for Bergkristall civilians.

(4) St. Georgen/Gusen railway station and start of the SS Schleppbahn to Gusen I and Gusen II camps.

(5) Dump for sand excavated by inmates during tunnel construction; called "Kippe."

(6) Bergkristall wastewater treatment plant, which was built for approximately 10,000 people.

(7) Home of DEST apprentices and first office of Karl Fiebinger's construction company at St. Georgen.

(8) Ventilation tower of Bergkristall at the Karlinger house.

(9) Chain of Bergkristall sentry posts with watchtowers.

(10) DEST garages at the Rapata house (later tank garages for the Soviet occupation force).

(11) Second settlement of DEST in St. Georgen, called "Deutsche Erd- und Stein Siedlung."

(12) Air-raid shelter of the DEST leadership at St. Georgen (outpost of the WVHA).

(13) Gusen I camp roll call area with prisoner kitchen and brick prisoner blocks.

(14) Not shown.

(15) Main entrance to Gusen I camp (so-called "Jourhaus"). In front are the barracks of the SS guards for Gusen.

(16) Coal bunker, depot, blacksmith's shop, and farm yard.

(17) Messerschmitt production halls (from 1943 onward, production of fuselages and wings for the Me 109).

(18) Sewage treatment plant for Gusen I camp and production halls I-V for Steyr-Daimler-Puch AG.

(19) Gusen II camp (housing for prisoners for Bergkristall construction and production).

(20) Kastenhof-Oberbruch quarry and guard chain.

(21) Kastenhof quarry with huge gravel crusher and terminal station of SS Schleppbahn at Gusen I.

(22) Chain of guards.

(23) High water tank for KL Gusen II.

(24) Chain of items.

(25) Pierbauer quarry. A separate field railway track also went up to this quarry.

(26) Gusen quarry.

(27) Unidentified.

(28) Gusen gravel pit.

(29) Deep vertical shaft where there may be an underground concentration camp [see pp. 3898–3899].

(30) Housing barracks I-IV for harbor construction.

(31) Kellerbau underground plant where production facilities of Messerschmitt GmbH, Steyr-Daimler-Puch AG, and Waffentechnische Lehranstalt der Waffen-SS Graz were located.

(53) Gravel crusher and loading site for Danube gravel to make concrete for Bergkristall. A separate railway connected the Danube bank with the concrete mixer at the Bergkristall construction site.

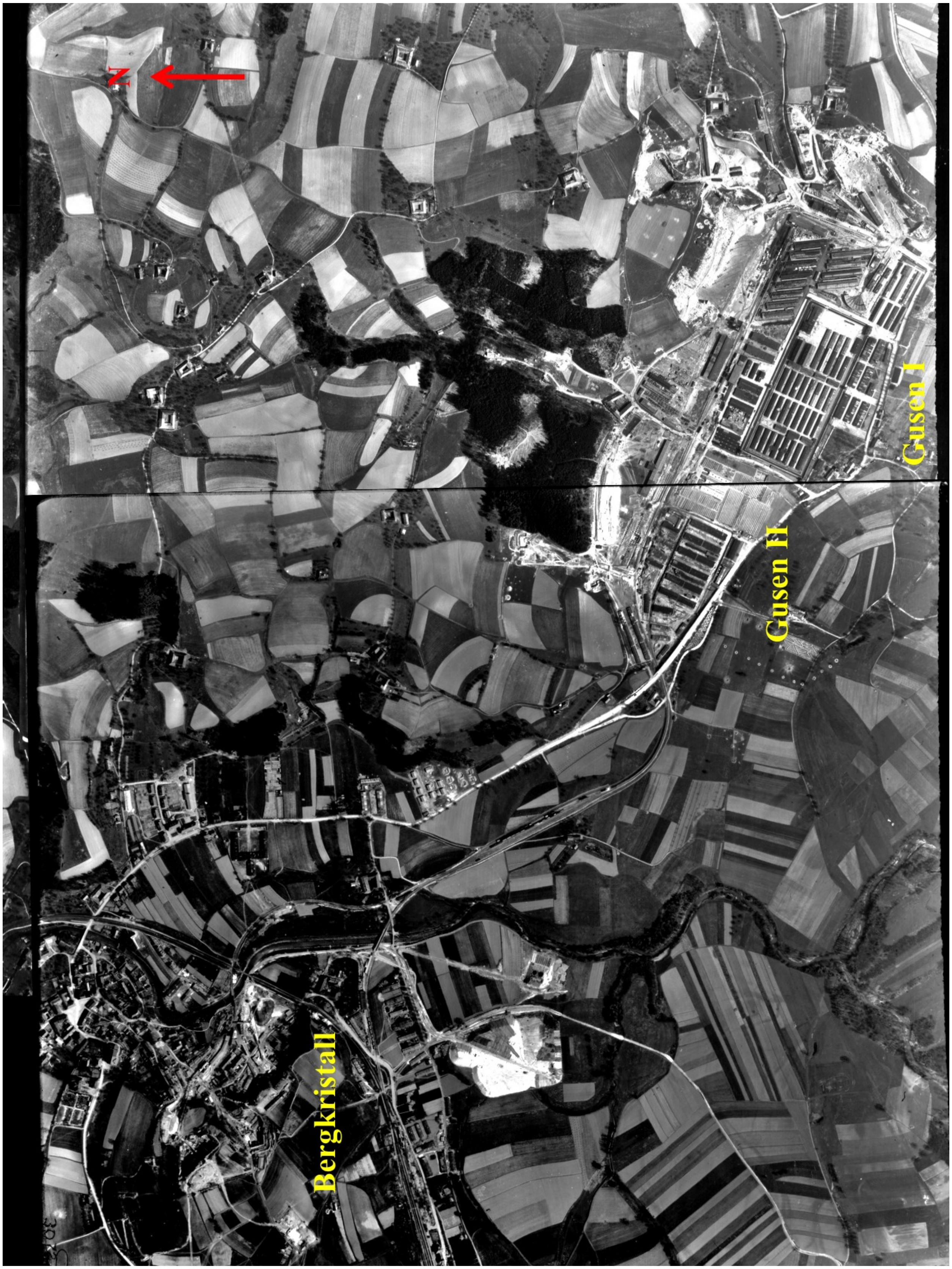

N
Gusen I
Gusen II
Bergkristall

Figure D.397: Composite of U.S. aerial surveillance photos of the area including the Bergkristall tunnel complex at St. Georgen/Gusen, taken on 2 April 1945. [AFHRA, courtesy of Gunther Hebestreit].

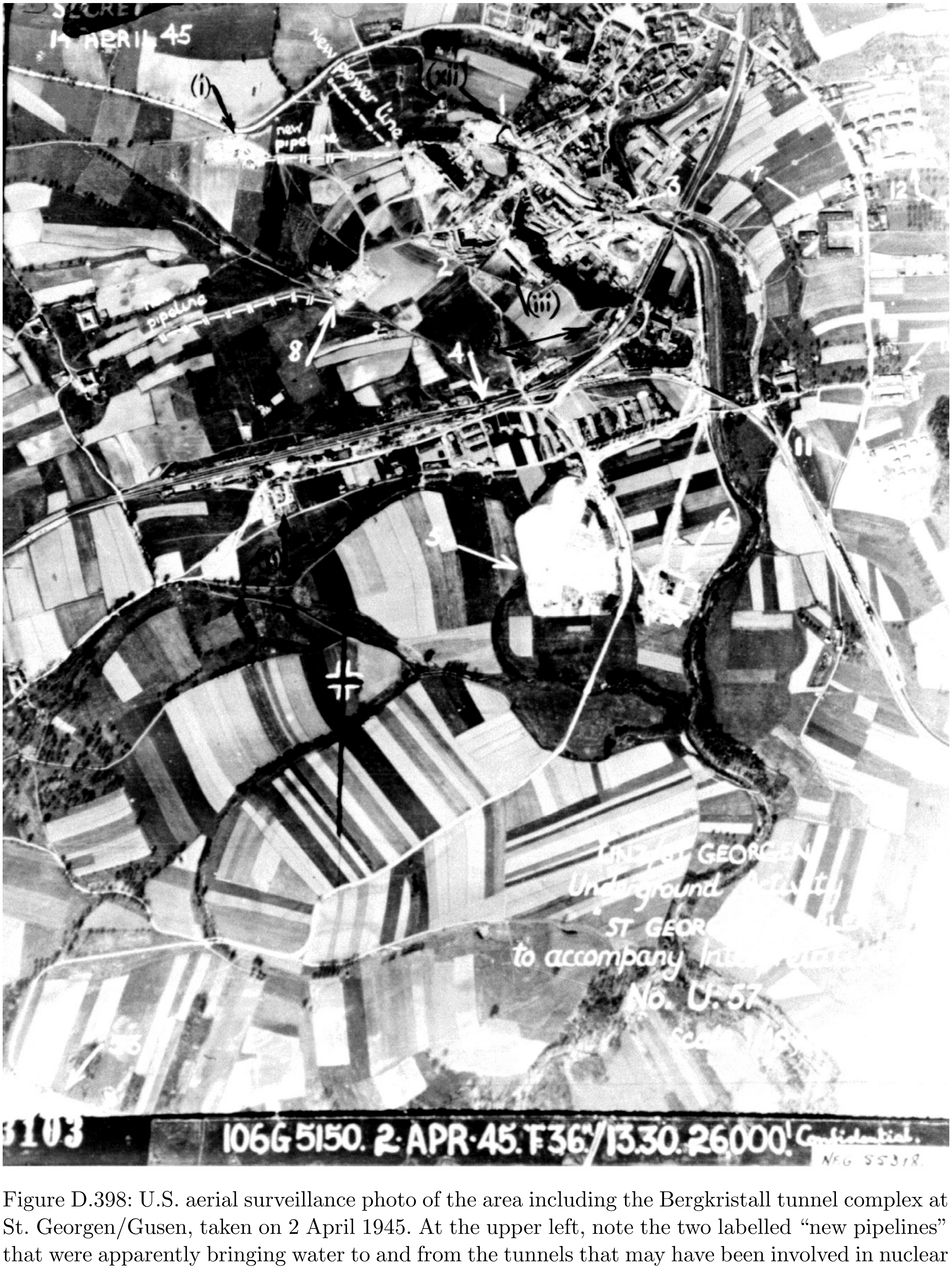

SECRET
14 APRIL 45
(i)
new pipeline
New Power Line
(xii)
1
2
3
(iii)
4
5
6
7
8
new pipeline
11
12
ST GEORGEN
Underground Activity
ST GEOR
to accompany Int
No. U. 57
sca
3103
106G 5150. 2·APR·45. F36"/13.30. 26000'. Confidential.
NFG 5531R

Figure D.398: U.S. aerial surveillance photo of the area including the Bergkristall tunnel complex at St. Georgen/Gusen, taken on 2 April 1945. At the upper left, note the two labelled "new pipelines" that were apparently bringing water to and from the tunnels that may have been involved in nuclear work. At the left end of the upper pipeline "(i)" is a mysterious octagonal structure that was filled in by German forces before the arrival of the U.S. military [AFHRA Report U 57 on St. Georgen, courtesy of Rudolf Haunschmied].

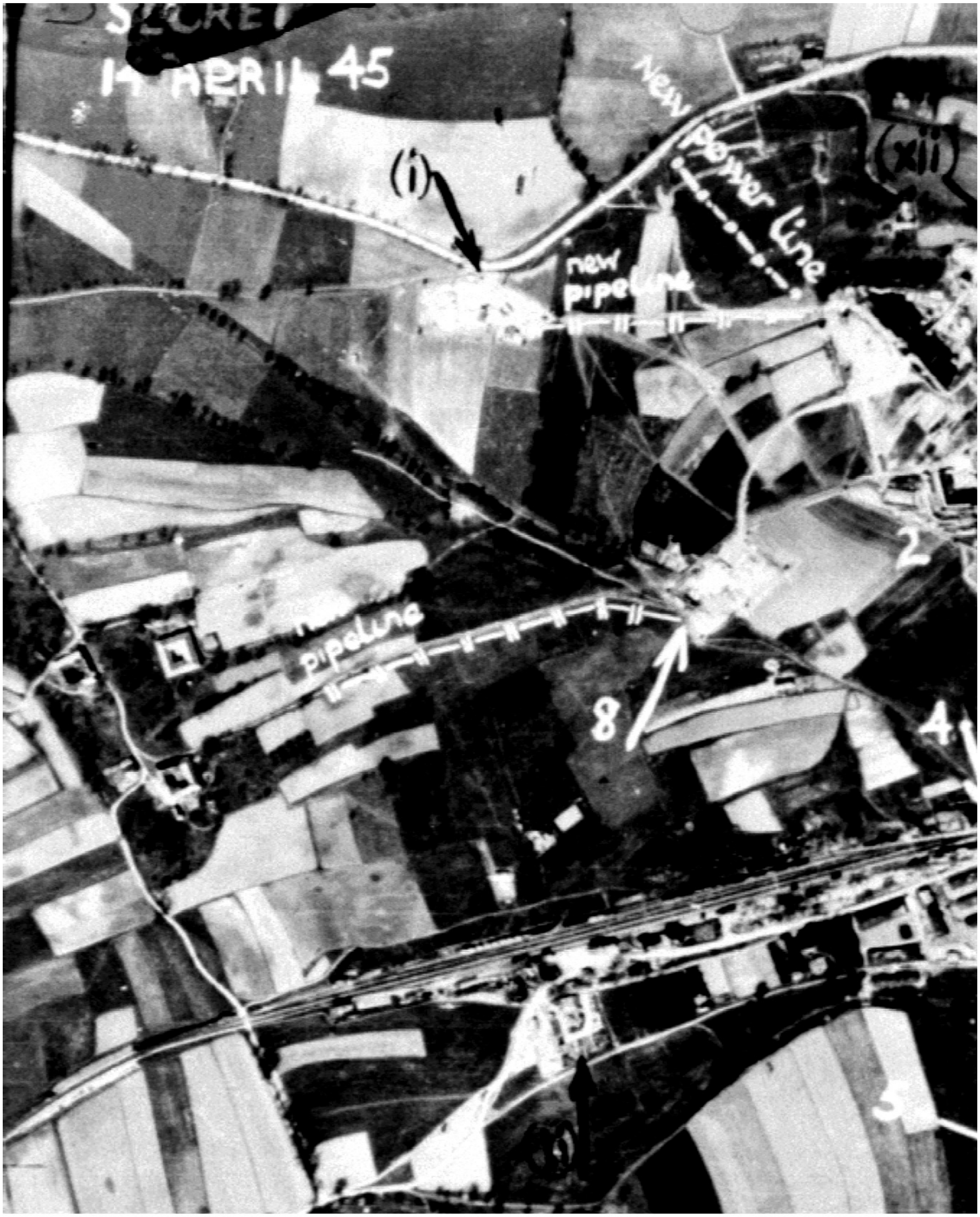

SECRET
14 APRIL 45
(i)
New power line
new pipeline
(xii)
2
new pipeline
8
4
5

Figure D.399: Enlargement of the upper left of U.S. aerial surveillance photo of the area including the Bergkristall tunnel complex at St. Georgen/Gusen, taken on 2 April 1945. Note the two labelled "new pipelines" that were apparently bringing water to and from the tunnels that may have been involved in nuclear work. At the left end of the upper pipeline "(i)" is a mysterious octagonal structure that was filled in by German forces before the arrival of the U.S. military [AFHRA Report U 57 on St. Georgen, courtesy of Rudolf Haunschmied].

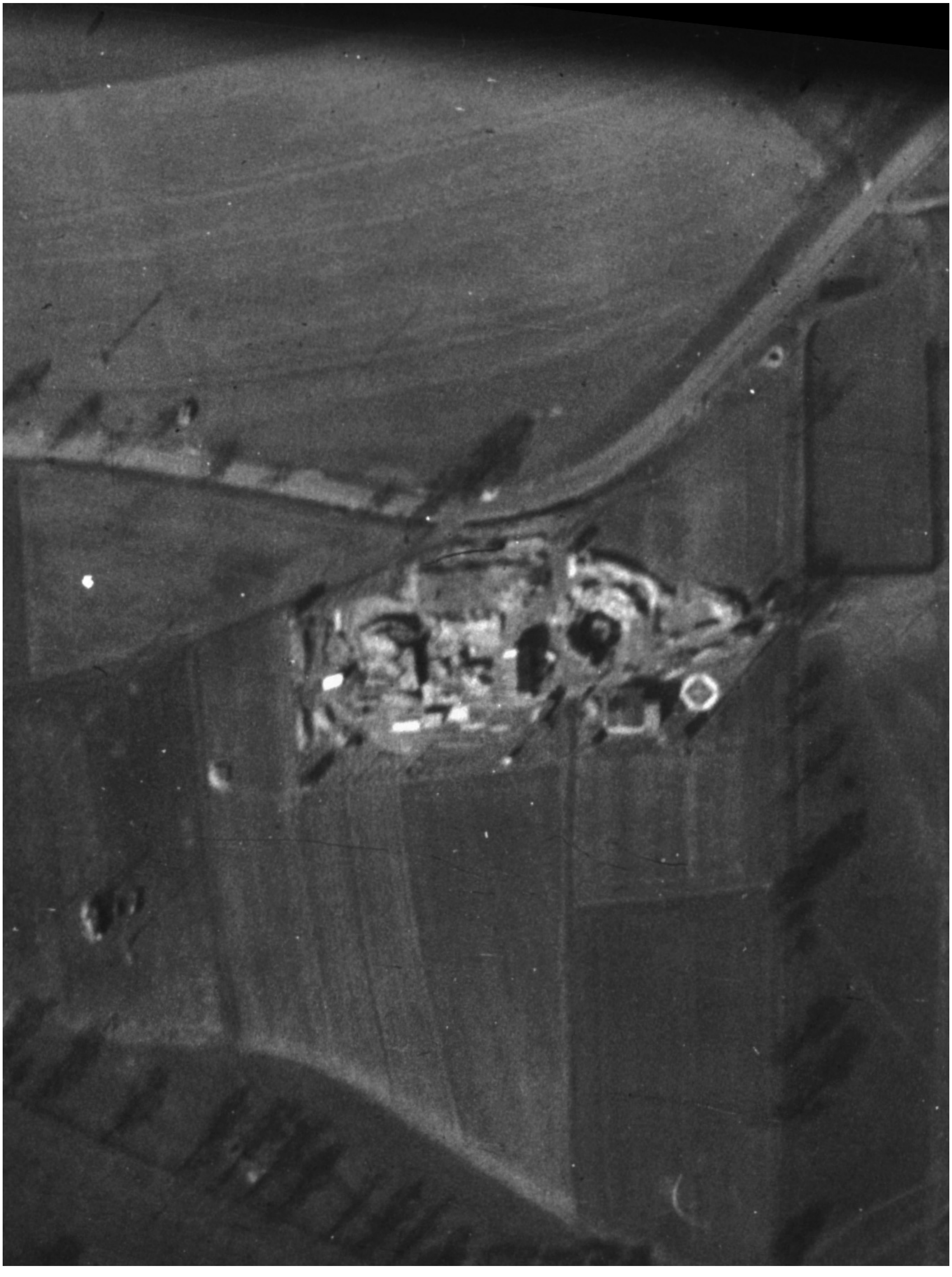


Figure D.400: U.S. aerial surveillance photo of the area directly northwest of the known Bergkristall tunnels, taken on 15 March 1945. Just to the right of the center of the photo is a large octagonal structure with very thick walls. The center of the octagon is open and appears to be rather deep in the ground. Also note other nearby structures and air vents. These structures do not appear on any surviving maps of the Bergkristall tunnels [AFHRA, courtesy of Gunther Hebestreit].

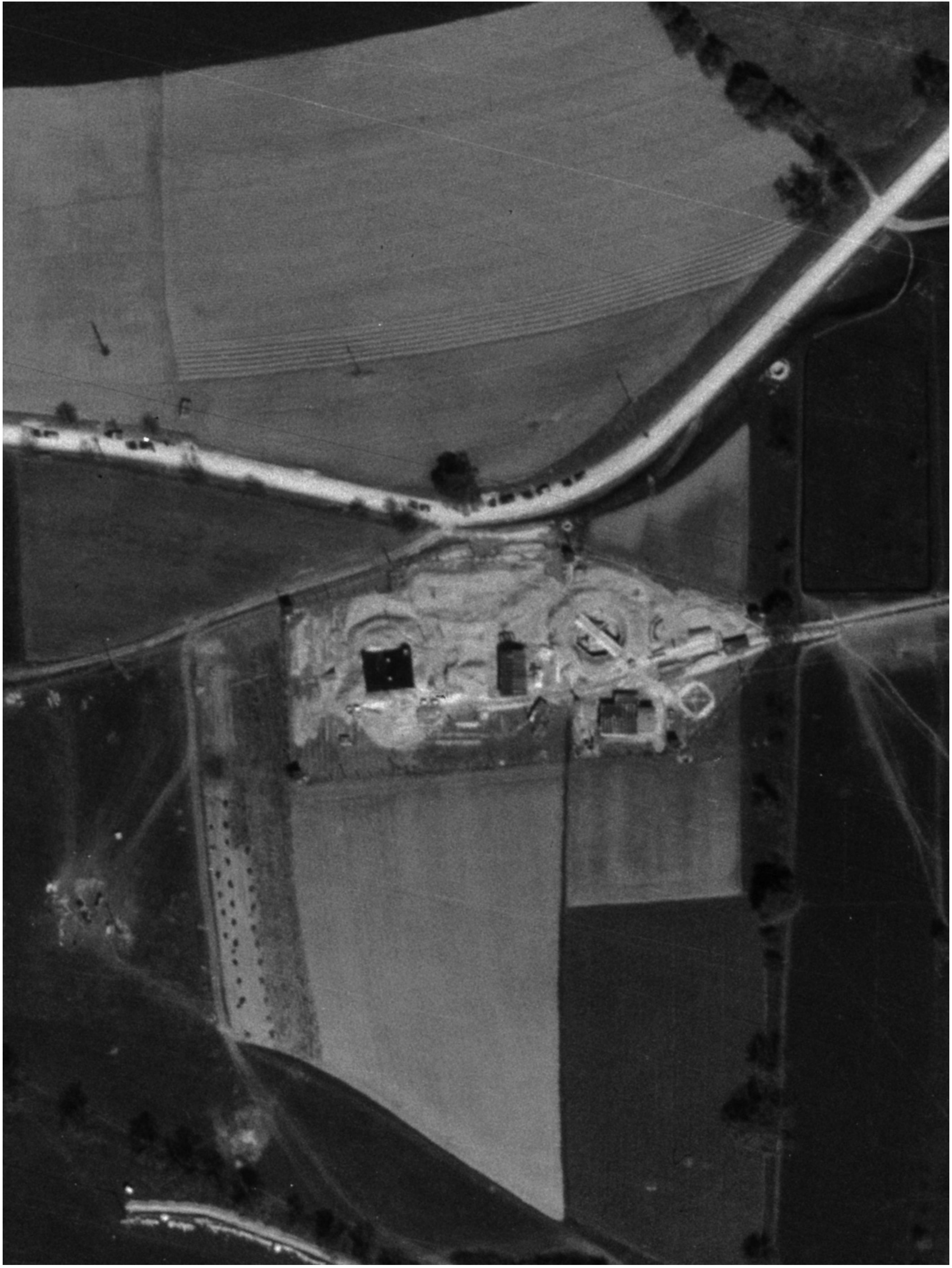
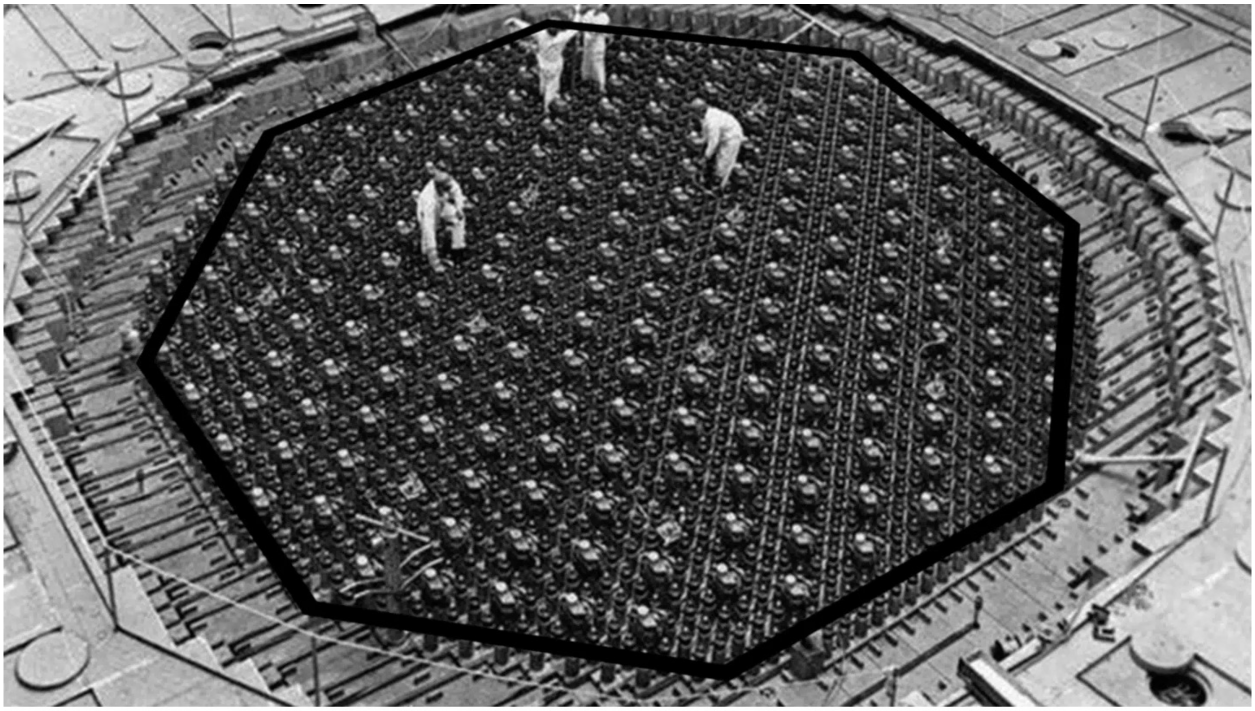
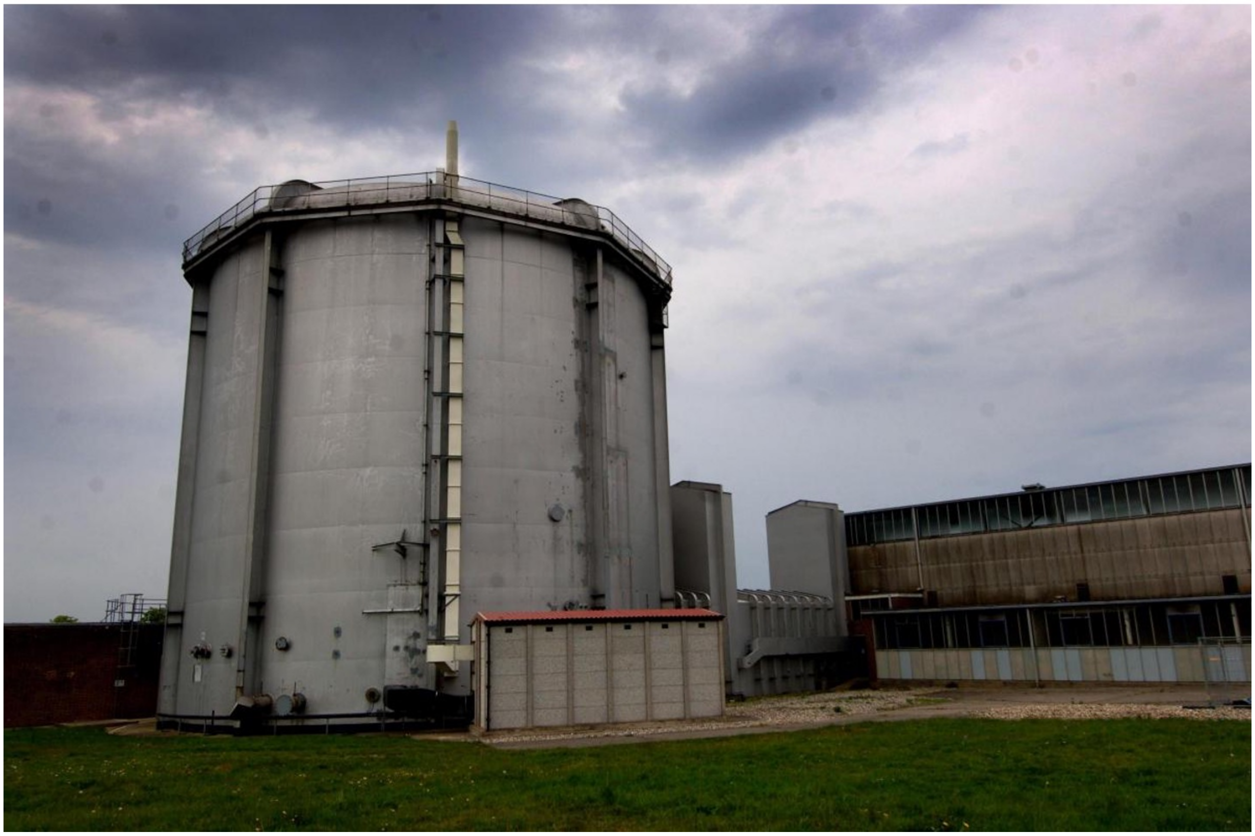


Figure D.401: U.S. aerial surveillance photo of the area directly northwest of the known Bergkristall tunnels, taken on 16 April 1945. The octagon and adjacent structures have been filled in with fresh dirt, indicating that this part of the underground installation has been sealed by German forces before the arrival of the U.S. military [AFHRA, courtesy of Gunther Hebestreit].



Octagonal fission reactor, Chernobyl RBMK (Ukraine)



Octagonal fission reactor, Harwell PLUTO (United Kingdom)

Figure D.402: Examples of octagonal fission reactors that were built in other countries after World War II. Compare with the images on pp. 3894–3895 and 3906.

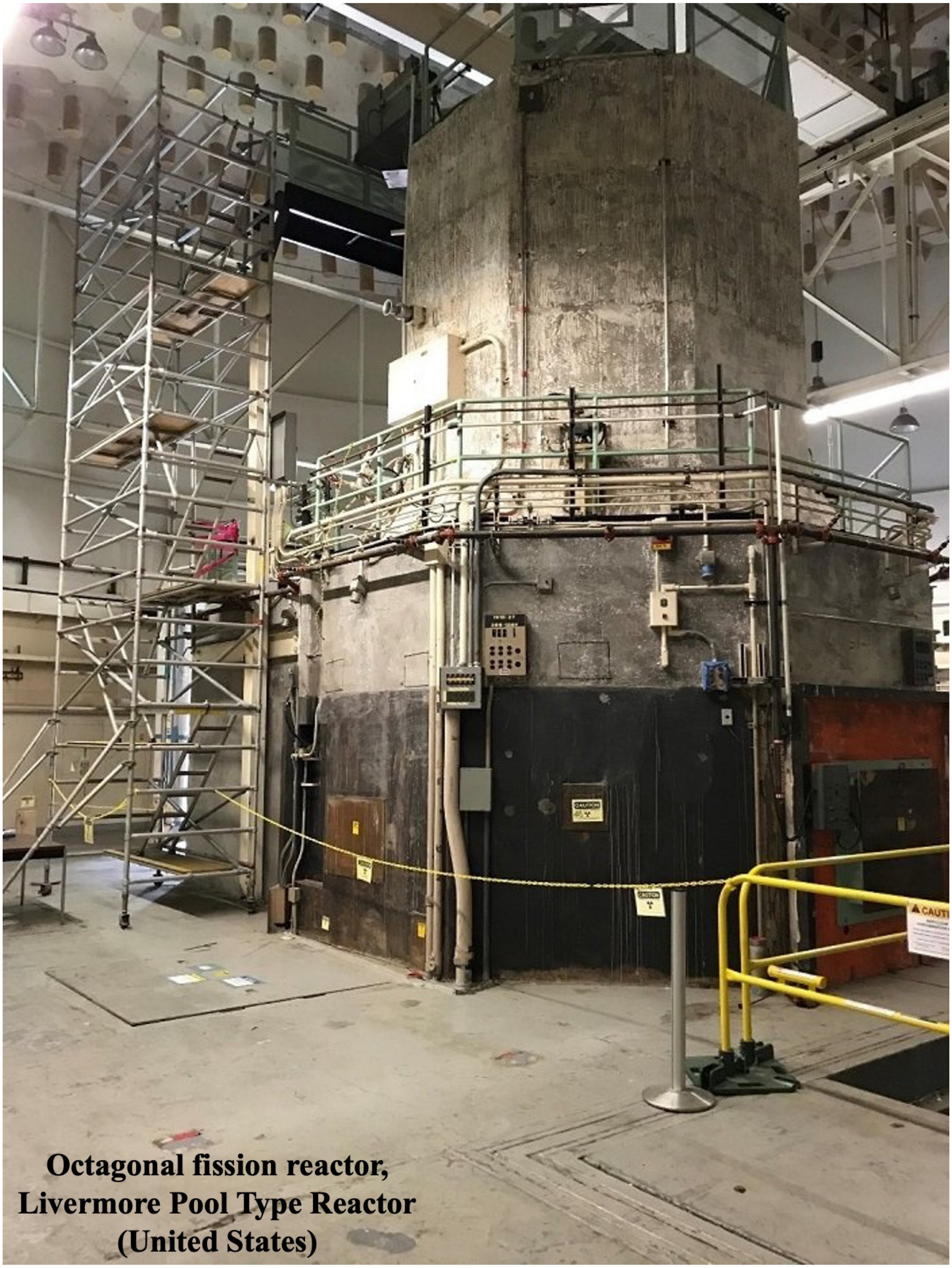

Octagonal fission reactor,
Livermore Pool Type Reactor
(United States)

Figure D.403: Examples of octagonal fission reactors that were built in other countries after World War II. Compare with the images on pp. 3894–3895 and 3906.

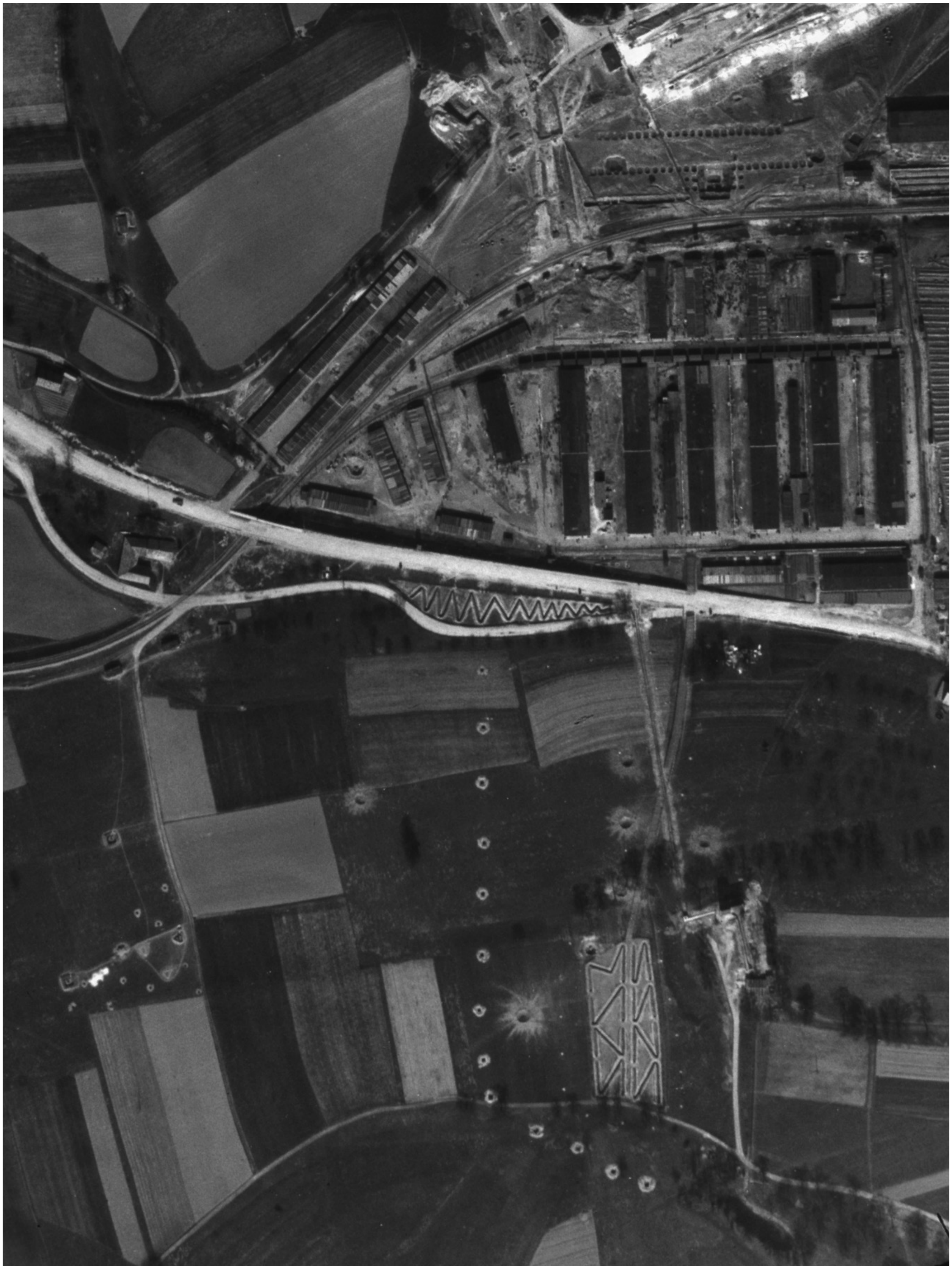


Figure D.404: U.S. aerial surveillance photo of the area directly south of the Gusen II camp, approximately 1.5 km southeast of the Bergkristall tunnel complex, taken on 2 April 1945. In the lower half of the photo, note all of the open air vents to a very large underground installation. This underground installation does not appear on any surviving maps of tunnels in the area. Zigzag patterns were air-raid trenches that were filled with prisoners as human shields against Allied bombing, suggesting great military value for the installation [AFHRA, courtesy of Gunther Hebestreit].

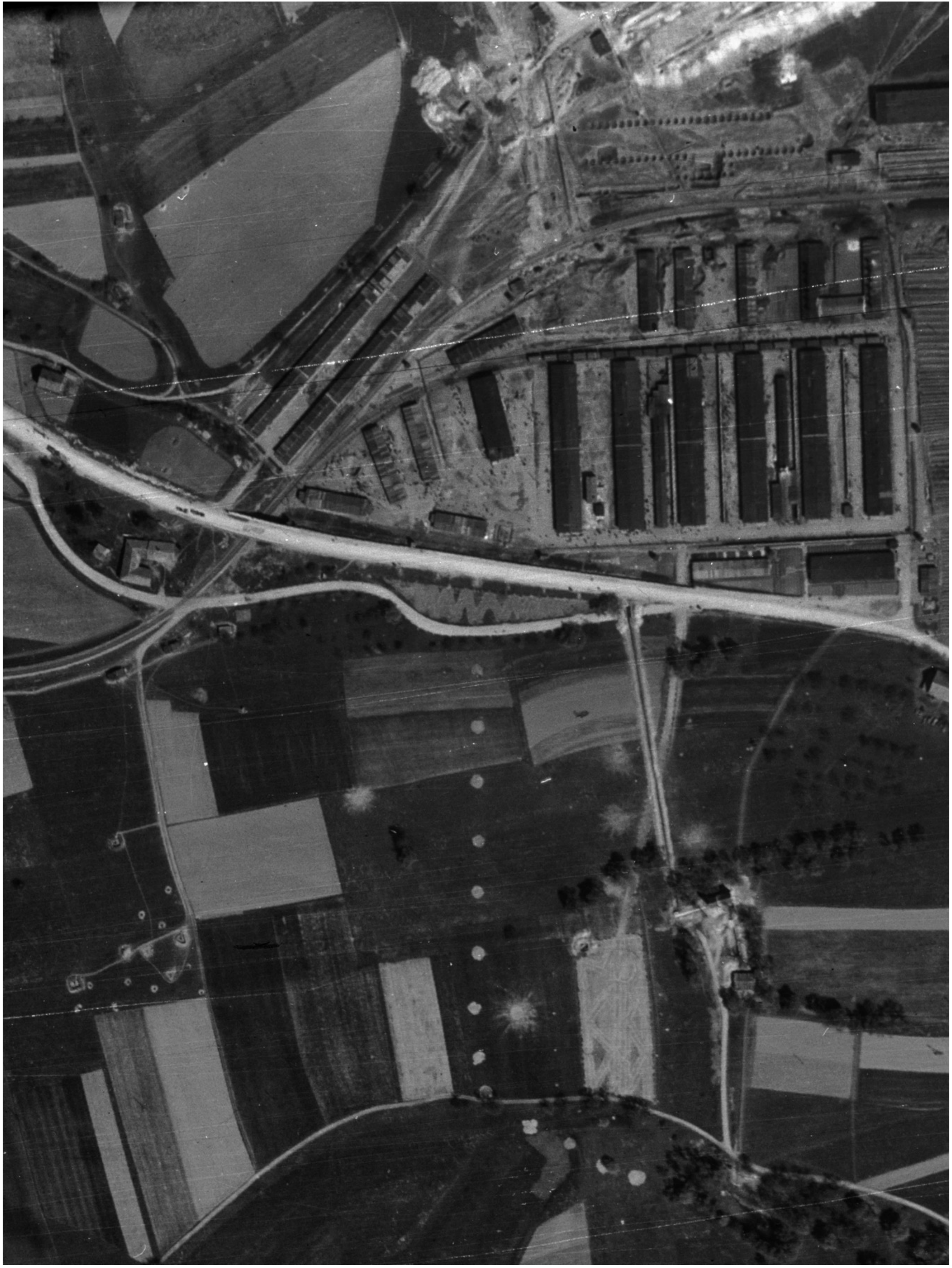
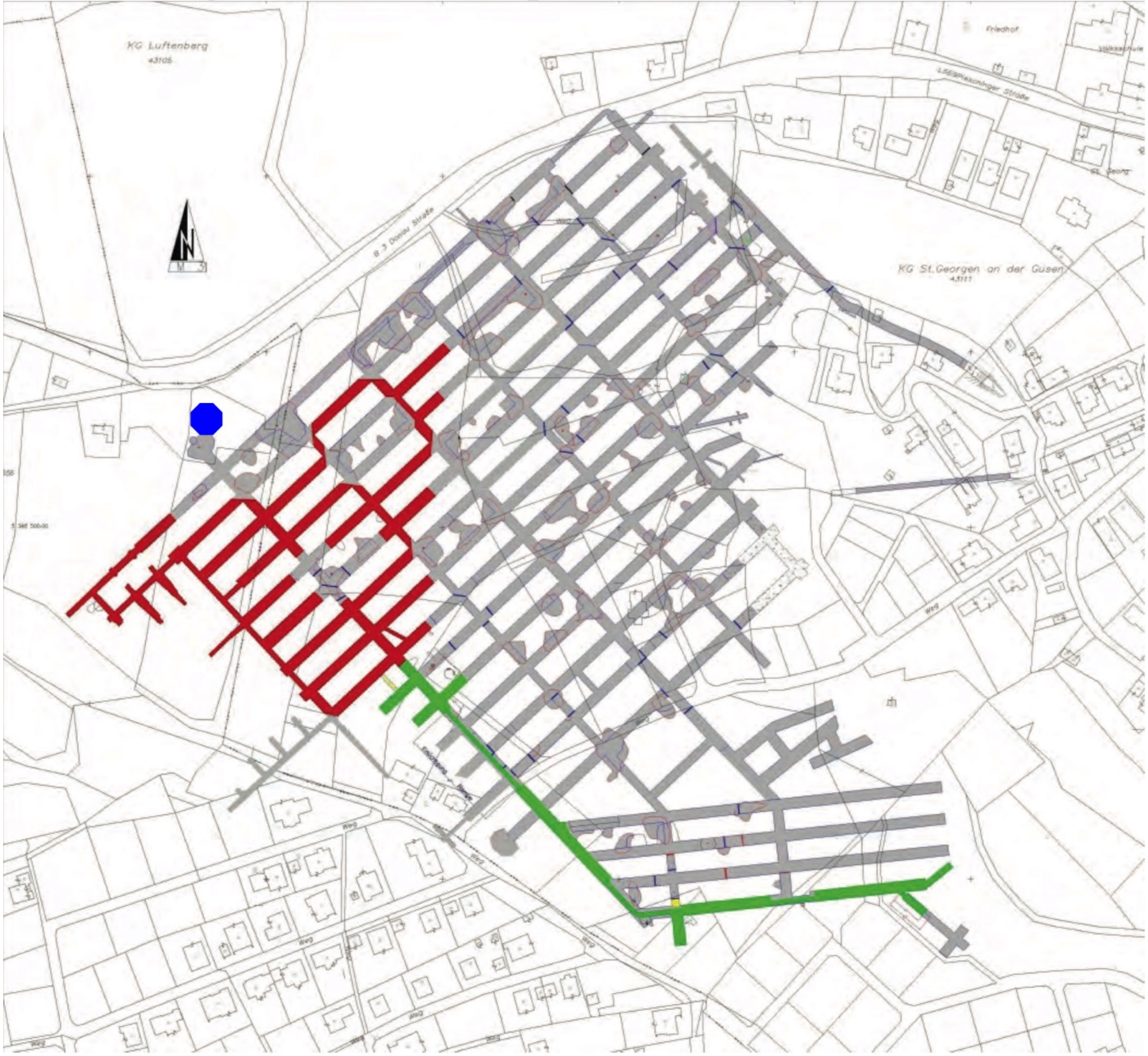


Figure D.405: U.S. aerial surveillance photo of the area directly south of the Gusen II camp, approximately 1.5 km southeast of the Bergkristall tunnel complex, taken on 16 April 1945. In the lower half of the photo, note that almost all of the air vents have been filled in, indicating that the underground installation has been sealed by German forces before the arrival of the U.S. military [AFHRA, courtesy of Gunther Hebestreit].

B8 Bergkristall tunnel complex at St. Georgen an der Gusen



Green: Accessible to the public twice per year

Red: Not accessible to the public

Gray: Filled with concrete by Austrian government 2002–2009

Blue: Octagonal structure visible in 1945 aerial photos but not shown in any surviving tunnel maps

7 kilometers total of tunnels are shown on this map. However, up to 19 kilometers of additional tunnels were sealed by the Third Reich shortly before the end of the war and are not shown on this map.

Figure D.406: Map of 7 kilometers of the Bergkristall tunnel complex now. Up to 19 kilometers of additional tunnels were sealed by the Third Reich shortly before the end of the war and are not shown on this map. The blue octagonal structure appears in 1945 aerial photos but not in any surviving tunnel maps.

Sammlung Franz Jakob [courtesy of Andreas Sulzer].

[?? Jakob (18??–19??) was an Austrian engineer who was involved in the construction of the Bergkristall underground tunnels up to 1945. From 1945 to 1955, occupying Allied forces exerted control over Austria in general and the tunnels in particular. When Austria regained full independence in 1955, Jakob promptly proposed to the Austrian government that they should create fission reactors, and that the reactors should be located in the Bergkristall tunnels. His proposal explained that the wartime tunnels were already ideally suited for fission reactors, conveniently omitting any explanation of why the tunnels just happened to have been designed that way. His proposal also explained that many of the experts involved in designing and building the tunnels during the war were still available to help establish operational fission reactors there.

Jakob's 1944 photos of Bergkristall clearly show that there were multiple levels of tunnels, not just a single level as the Austrian government has claimed. Multiple levels would also make the total length of the tunnels far longer than the officially recognized size. See especially pp. 3902–3903.

Jakob's 1955 proposal and accompanying notes included sketches of two fission reactors (Atom-Meiler) he wanted to make operational in the Bergkristall tunnels; see pp. 3906–3907. They look remarkably like the two octagonal structures protruding from the Bergkristall tunnels in the March–April 1945 aerial photos (pp. 3894–3895).

Jakob's 1955 proposal also mentioned how extensively the underground facility had been stripped by occupying forces after the war, first by the United States and then by the Soviet Union. Where are all the archival reports on everything that was found and removed by Allied forces?

Many of Jakob's wartime photos of Bergkristall and his 1955 proposal and notes were preserved by his son Franz Jakob and later presented to Andreas Sulzer.]

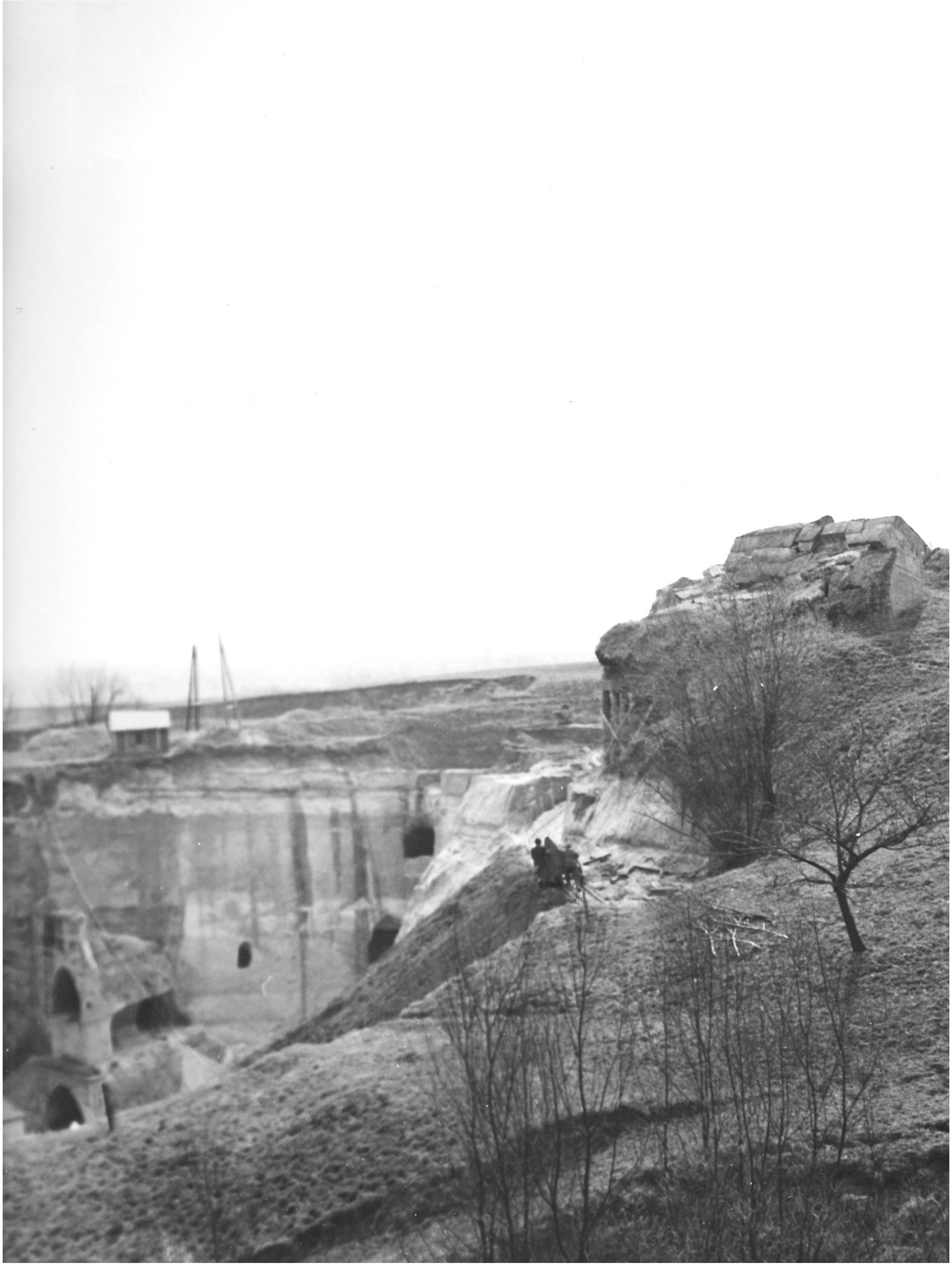


Figure D.407: 1944 photograph of Bergkristall entrances, clearly showing at least three levels of tunnels [Sammlung Franz Jakob, courtesy of Andreas Sulzer]. Surviving maps only show the uppermost level of tunnels, not the lower levels.

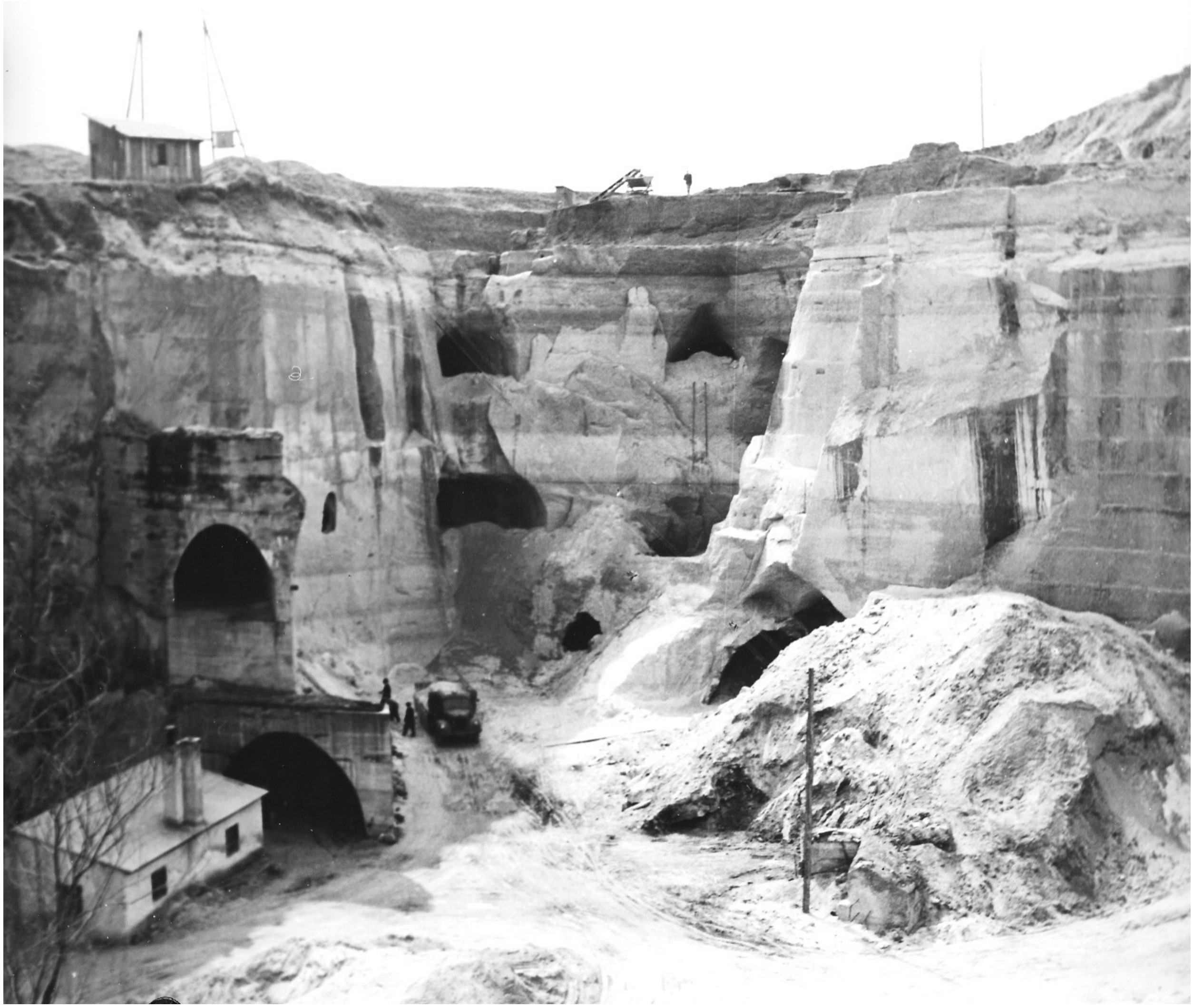


Figure D.408: 1944 photograph of Bergkristall entrances, clearly showing at least three levels of tunnels [Sammlung Franz Jakob, courtesy of Andreas Sulzer]. Surviving maps only show the uppermost level of tunnels, not the lower levels.

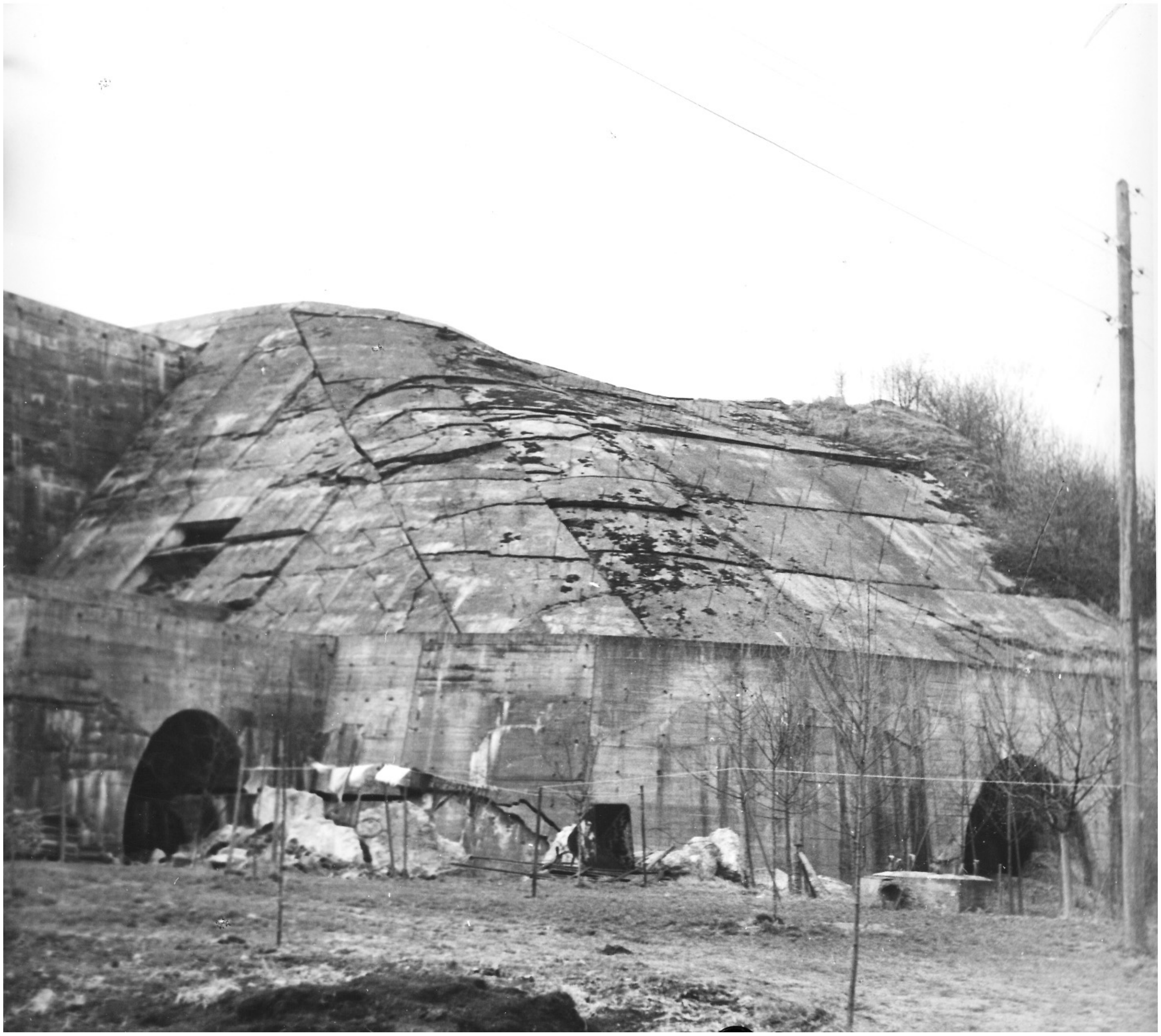


Figure D.409: 1944 photograph of Bergkristall under construction [Sammlung Franz Jakob, courtesy of Andreas Sulzer].

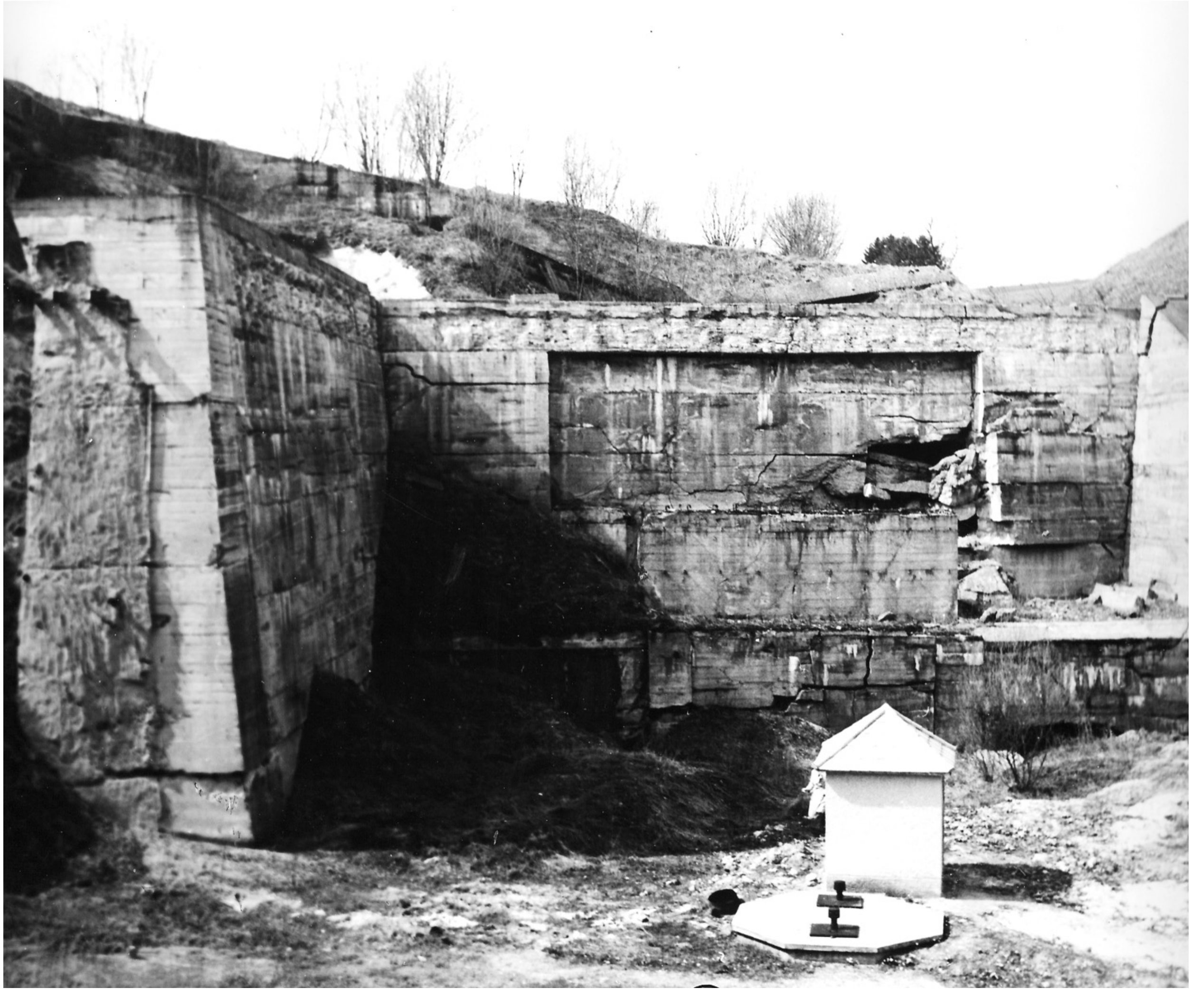
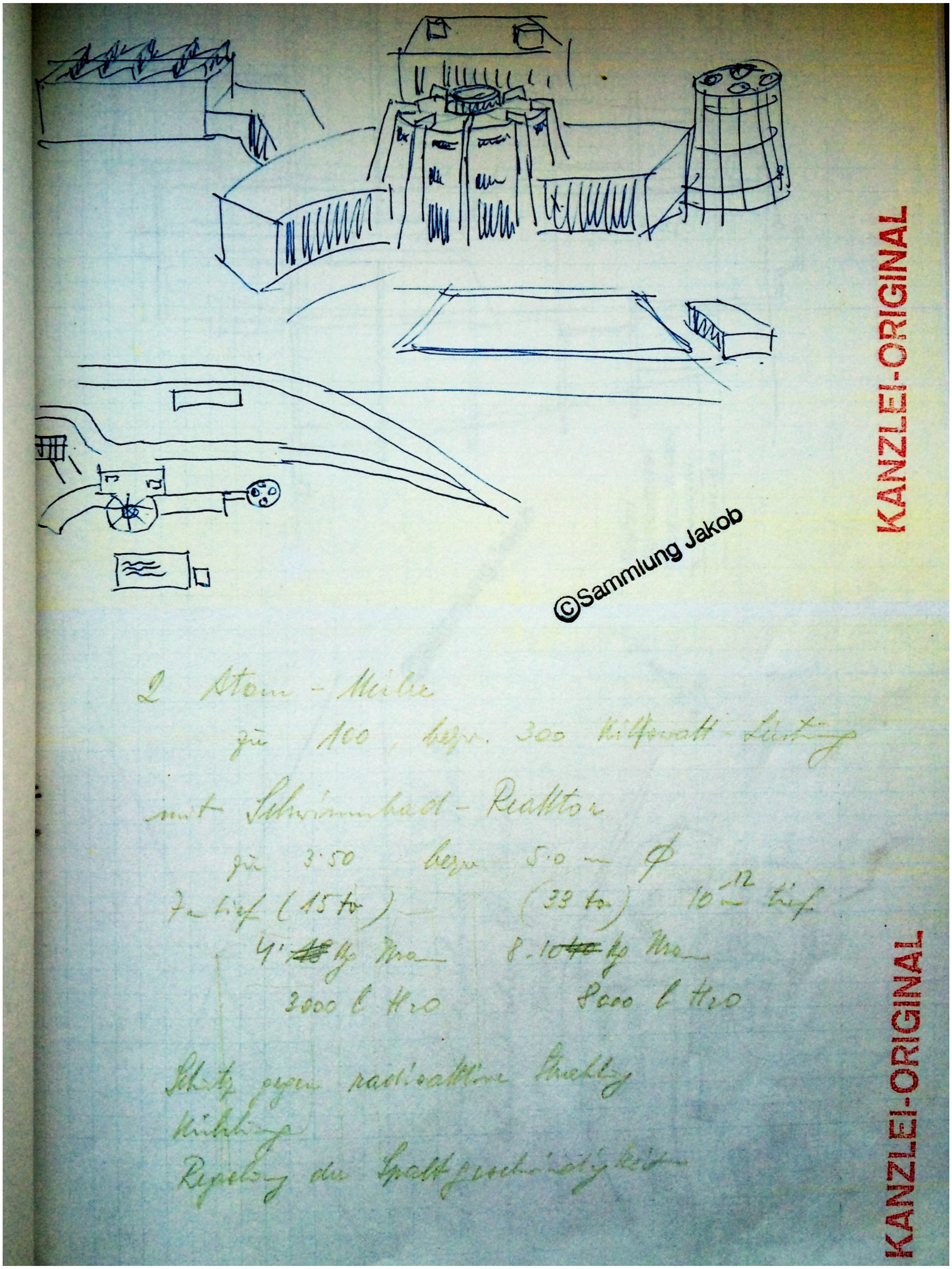


Figure D.410: 1944 photograph of Bergkristall under construction [Sammlung Franz Jakob, courtesy of Andreas Sulzer].



2 Atom-Meiler

zu 100, bezw. 300 Kilowatt-Leistung

mit Schwimmbad-Reaktor

zu 3·50 bezw. 5·0 m ⌀

7 m tief (15 to) (33 to) 10–12 m tief

4·~~10~~ kg Uran 8.10~~40~~ kg Uran

3000 l H_2O 8000 l H_2O

Schutz gegen radioaktive Strahlung

Kühlung

Regelung der Spaltgeschwindigkeit

©Sammlung Jakob

KANZLEI-ORIGINAL

KANZLEI-ORIGINAL

Figure D.411: Engineer Jakob's 1955 sketches of two "Atom-Meiler" (atomic piles or fission reactors) he proposed to make operational in the Bergkristall tunnels look remarkably like the two octagonal structures protruding from the Bergkristall tunnels in the March–April 1945 aerial photos (pp. 3894–3895) [Sammlung Franz Jakob, courtesy of Andreas Sulzer].

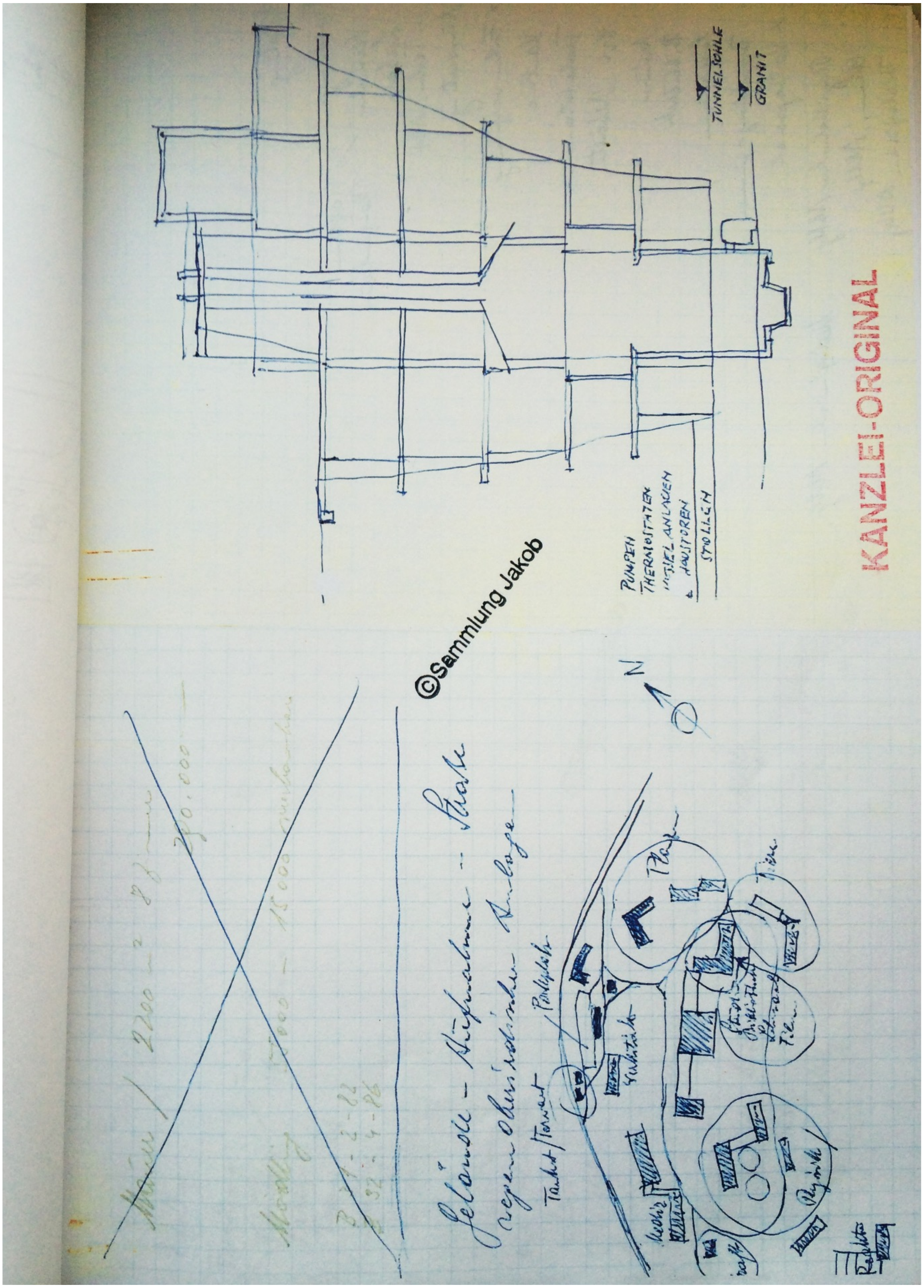
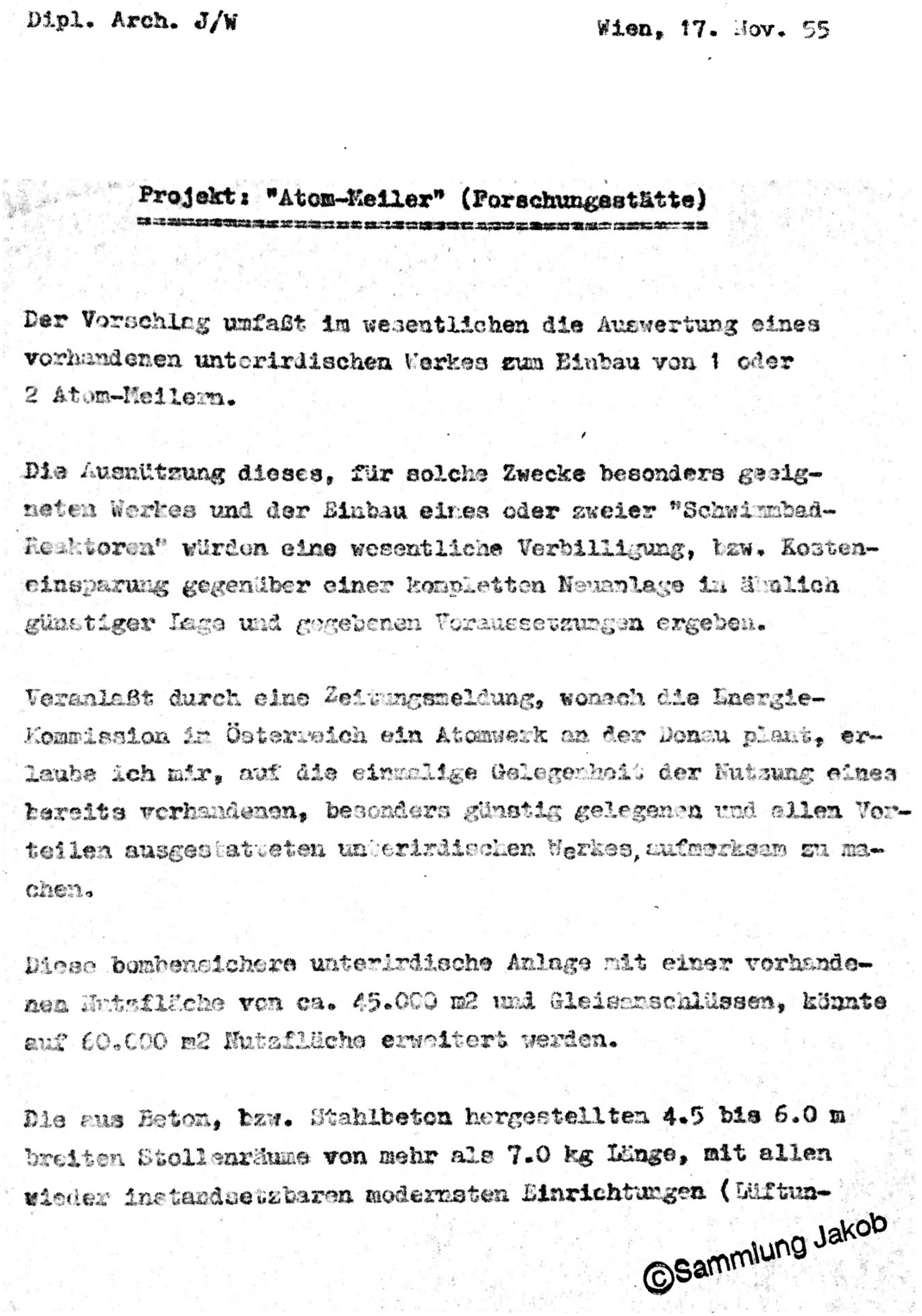

TUNNELSOHLE
GRANIT
PUMPEN
THERMOSTATEN
KÜHLANLAGEN
STOLLEN
KANZLEI-ORIGINAL
©Sammlung Jakob
N

Figure D.412: Engineer Jakob's 1955 sketches show several levels of tunnels at Bergkristall, and his proposed fission reactors extend from the surface down five levels deep [Sammlung Franz Jakob, courtesy of Andreas Sulzer].



Dipl. Arch. J/W

Wien, 17. Nov. 55

Projekt: "Atom-Meiler" (Forschungsstätte)

Der Vorschlag umfaßt im wesentlichen die Auswertung eines vorhandenen unterirdischen Werkes zum Einbau von 1 oder 2 Atom-Meilern.

Die Ausnützung dieses, für solche Zwecke besonders geeigneten Werkes und der Einbau eines oder zweier "Schwimmbad-Reaktoren" würden eine wesentliche Verbilligung, bzw. Kosteneinsparung gegenüber einer kompletten Neuanlage in ähnlich günstiger Lage und gegebenen Voraussetzungen ergeben.

Veranlaßt durch eine Zeitungsmeldung, wonach die Energie-Kommission in Österreich ein Atomwerk an der Donau plant, erlaube ich mir, auf die einmalige Gelegenheit der Nutzung eines bereits vorhandenen, besonders günstig gelegenen und allen Vorteilen ausgestatteten unterirdischen Werkes, aufmerksam zu machen.

Diese bombensichere unterirdische Anlage mit einer vorhandenen Nutzfläche von ca. 45.000 m2 und Gleisanschlüssen, könnte auf 60.000 m2 Nutzfläche erweitert werden.

Die aus Beton, bzw. Stahlbeton hergestellten 4.5 bis 6.0 m breiten Stollenräume von mehr als 7.0 kg Länge, mit allen wieder instandsetzbaren modernsten Einrichtungen (Lüftun-

©Sammlung Jakob

Figure D.413: The first page of Engineer Jakob's 1955 proposal for two operational fission reactors in the Bergkristall tunnels [Sammlung Franz Jakob, courtesy of Andreas Sulzer].

Dipl. Arch. J/W Wien, 17. Nov. 55

Projekt: “Atom-Meiler” (Forschungsstätte)

Der Vorschlag umfaßt im wesentlichen die Auswertung eines vorhandenen unterirdischen Werkes zum Einbau von 1 oder 2 Atom-Meilern.

Die Ausnützung dieses, für solche Zwecke besonderes geeigneten Werkes und der Einbau eines oder zweier “Schwimmbad-Reaktoren” würden eine wesentliche Verbilligung, bzw. Kosteneinsparung gegenüber einer kompletten Neuanlage in ähnlich günstiger Lage und gegebenen Voraussetzungen ergeben.

Veranlaßt durch eine Zeitungsmeldung, wonach die Energie-Kommission im Österreich ein Atomwerk an der Donau plant, erlaube ich mir, auf die einmalige Gelegenheit der Nutzung eines bereits verhandenen, besonders günstig gelegenen und allen Vorteilen ausgestatteten unterirdischen Werkes, aufmerksam zu machen.

Diese bombensichere unterirdische Anlage mit einer vorhandenen Nutzfläche von ca. 45.000 m2 und Gleisanschlüssen, könnte auf 60.000 m2 Nutzfläche erweitert werden.

Die aus Beton, bzw. Stahlbeton hergestellten 4.5 bis 6.0 m breiten Stollenräume von mehr als 7.0 km Länge, mit allen wieder instandsetzbaren modernsten Einrichtungen (Lüftuntungen, Heizungen, Beleuchtungen, Installation, sanitären Einrichtungen, etc.), Trockenheit und idealer geographischer, verkehrstechnischer und geologischer Lage (ehem. feinmechanischer Betrieb), wäre die geeigneteste Voraussetzung zur Unterbringung einer Atomforschungsstätte.

Dipl. Arch. J/W Vienna, 17 Nov. 1955

Project: “Atomic Pile” (Research Site)

The proposal essentially comprises the evaluation of an existing underground plant for the installation of 1 or 2 atomic piles.

The utilization of this plant, which is particularly suitable for such purposes, and the installation of one or two “swimming-pool reactors” would result in a substantial reduction in costs compared with a completely new plant in a similarly favorable location and given conditions.

Inspired by a newspaper report, according to which the Energy Commission in Austria is planning a nuclear power plant on the Danube, I take the liberty of drawing attention to the unique opportunity of using an already existing underground plant, which is particularly well located and equipped with all the advantages.

This bomb-proof underground facility, with an existing usable area of approximately 45,000 m2 and sidings, could be expanded to 60,000 m2 of usable area.

The 4.5 to 6.0 m wide tunnels made of concrete or reinforced concrete, more than 7.0 km long, with all the modern facilities that can be restored (ventilation, heating, lighting, installation, sanitary facilities, etc.), dryness and ideal geographical, transport and geological location (former precision engineering plant), would be the most suitable conditions for housing an atomic research facility.

Diese Anlage wurde 1944/45, also in einem Jahr, mit einem Kostenaufwand von mehr als 500 Millionen Schilling und hunderte Toter, als technische Großleistung errichtet.

Nach Übernahme durch die Amerikaner und fast vollständiger Demontage durch dieselben, übernahm die russische Besatzungsmacht die Anlage, welche die restliche Demontage durchführte.

Durch unzulängliche Teilsprengungen versuchte man die Anlage zu zerstören. Untersuchungen ergaben, daß die entstanden Teilschäden keine nachhaltigen Zerstörungen verursachten, in verhältnismäßig kurzer Zeit mit geringen Mitteln und Materialaufwand instandzusetzen sind.

Diese Anlage gäbe mit ihren bestehenden Kanalsystemen, Abwasser- und Kläranlage, sowie geologischen Verhältnissen die preiswerteste Ausnützung für ein Atomforschungszentrum, eventl. Atomkraftwerk samt Labors und Forschungsstätte.

Die außerordentliche Lage in der Nähe der Donau, anliegender Straße, Bahnanschluß, etc. würde weitere bedeutende Kosteneinsparungen ergeben.

Außserdem würden nur geringe Ablösen der oberirdischen Grundbesitze nötig sein, da bereits die Besitzer einmalige Ablösen erhielten, oder sich durch Abverkauf der 1945 zurückgelassenen Materialien und Güter entschädigten.

Das Nutzwasser kann 2–3 m unter der derzeitigen Sohle in reichlichem Maße (Zufluß von nahegelegenem Fluß) für Kühlung, Schutz gegen radioaktive Strahlung, Regelung der Spaltgeschwindigkeit, sanitäre Einrichtung, etc. leicht entnommen werden.

This facility was built in 1944/45, in one year, at a cost of more than 500 million shillings and hundreds of deaths, as a major technical achievement.

After being taken over by the Americans and almost completely dismantled by them, the Russian occupation forces took over the plant and carried out the remaining dismantling.

Attempts were made to destroy the plant by inadequate partial demolitions. Investigations showed that the partial damage caused no lasting destruction and could be repaired in a relatively short time with little resources and materials.

This plant, with its existing sewer systems, sewage and wastewater treatment plant, as well as geological conditions, would provide the most economical utilization for a nuclear research center, possibly a nuclear power plant, including laboratories and research facilities.

The extraordinary location near the Danube, adjacent road, railroad connection, etc. would result in further significant cost savings.

In addition, only small redemptions of the above-ground properties would be necessary, since the owners already received one-time redemptions, or compensated themselves by selling the materials and goods left behind in 1945.

The service water can be easily extracted 2–3 m below the present invert in abundance (inflow from the nearby river) for cooling, protection against radioactivity, regulation of fission rate, sanitary facilities, etc.

Durch Einziehung von Stahlbetondecken samt erforderlichen Pfeilern (Gründung in geringer Tiefe 2–4 m auf Granit), Einbau von Betontanks für die “Schwimmbad-Reaktoren”, sowie Unterbringung der Kraft-Maschinenen, Heizwerk, Labors und Forschungsstätten in den Stollen wäre das generelle Zentrum zu schaffen.

Oberirdisch könnten die Allgemeinbaulichkeiten (Biologisch-medizinische Abteilung, Bibliothek, Archiv, Lese- und Vortragsaal, Forschungsstelle mit Pflanzenhaus und Tierfarm, Kühlturm, Büroräume, Werkstätten, Kantine und Küche, Empfangsräume, Personalzimmer, Förderanlagen, etc.; Tankstelle, Parkplatz, Trafostation etc.) in organischer Reihung, zweckmäßig und dem Gelände angepaßt erstellt werden.

Die gesamte Planung und Sammlung der Erfordernisse müßte durch sämtliche einschlägigen Fachgruppen (Experten) ermittelt, eventl. nach eigenenden Studien im Ausland ergänzt werden und an Hand eines Modelles demonstriert werden.

Anschließend wären die Kosten zu ermitteln und nach Klärung der rechtlichen und finanziellen Verhältnisse eine abschnittsweise Ausfúhrung der Anlage angezeigt.

Durch verhältnismäßig einfache Absperrung des Gebietes und Aufbau der oberirdischen Teilanlagen würde eine gewisse Geheimhaltung gewährleistet erscheinen.

Ich fühle mich verpflichtet, auf diese besonderen Umstände besonders aufmerksam zu machen, da:

1. dem österr. Volk unter Nutzung des bereits vorhandenen nur Vorteile erwachsen können,

The general center could be created by the installation of reinforced concrete ceilings with the necessary pillars (foundation at a shallow depth of 2–4 m on granite), installation of concrete tanks for the “swimming pool reactors,” as well as accommodation of the power machines, heating plant, laboratories and research facilities in the tunnels.

Above ground, the general buildings (biological-medical department, library, archives, reading and lecture hall, research center with plant house and animal farm, cooling tower, offices, workshops, canteen and kitchen, reception rooms, staff rooms, conveyors, etc.; gas station, parking lot, transformer station, etc.) could be created in an organic order, functional and adapted to the terrain.

The entire planning and collection of the requirements would have to be determined by all relevant professional groups (experts), possibly completed after own studies abroad and demonstrated on the basis of a model.

Subsequently, the costs would have to be determined and, after clarification of the legal and financial circumstances, a section-by-section execution of the plant would be indicated.

By relatively simple cordoning off of the area and construction of the above-ground sections, a certain degree of secrecy would appear to be guaranteed.

I feel obliged to draw special attention to these special circumstances, since:

1. the Austrian people can only benefit by using what is already available,

2. große finanzielle Investitionen erspart werden,

3. ein vorhandenes, brachliegendes—für andere Zwecke schwer verwendbares—Bauwerk einer tatsächlich guten Sache zugänglich gemacht würde,

4. eine der modernsten, sichersten und eigenwilligsten Anlagen der Welt entstünde und

5. die Kenntnisse der noch am Leben befindlichen Ingenieure, Bauleiter und Techniker, sowie teilweise vorhandene Unterlagen kostensparende Mitarbeit, Auswertung ihres Wissens zur besten Ausnutzung der vorhandenen Anlagen ergeben könnten.

Es wird nochmals betont, daß diese Anregung zum größten Nutzen der Wissenschaft, der praktischen Auswertung zur Energiegewinnung, rein finanzieller Art durch Nutzung vorhandener großzügigster bombensicherer Anlagen und zum besonderen Ruf österr. Technik, sowie dem gesamten Volke selbst sein könnte.

Es ist als sicher anzunehmen, daß eine unvoreingenommene Prüfung die günstige Lage, Nutzbarmachung mit verhältnismäßig geringen Mitteln und diese einmalige Gelegenheit erkennen lassen wird. Die aufgewendete Mühe und erforderlichen Projektunterlagen werden sich reichlich bezahlt machen.

Außerdem erscheint es besonders wichtig, nochmals darauf hinzuweisen, das Wissen der ehemals am Neubau des Werkes maßgeblich beschäftigten Fachkräfte zum Wohle und Nutzen eines großen Werkes nicht verloren gehen zu lassen.

2. large financial investments are saved,

3. an existing, fallow—for other purposes hardly usable—building would be made accessible to an actually good cause,

4. one of the most modern, safest and most unique facilities in the world would be created, and

5. the knowledge of the still living engineers, construction managers and technicians, as well as partially existing documents could result in cost-saving cooperation, evaluation of their knowledge for the best utilization of the existing facilities.

It is emphasized again that this suggestion could be to the greatest benefit of science, the practical evaluation for energy production, purely financially by use of existing most generous bomb-proof plants and to the special reputation of Austrian technology, as well as the entire people itself.

It is safe to assume that an unbiased examination will reveal the favorable situation, utilization with relatively small means and this unique opportunity. The effort spent and the required project documentation will pay off in abundance.

In addition, it seems particularly important to point out once again not to let the knowledge of the skilled workers, who were formerly significantly involved in the construction of the plant, be lost for the good and benefit of a large plant.

Nach dem Ausbau eines solchen “Atommeilers” mit angeschlossener Forschungsstätte hätte das neutrale freie Österreich den Anschluß an die Wissenschaften, Forschung und Technik der Welt gefunden.

Billige Energiegewinnung, Fortschritt in der Gesunderhaltung des gesamten österr. Volkes und erforderliche Schritthaltung der ausländischen Wissenschaft gibt unserem Volke die Möglichkeit einer tatsächlichen Selbstständigkeit.

In Erwartung, daß vorliegende Anregung günstige Aufnahme findet, stehe ich gerne zu weiteren Auskünften, Vorschlägen und Unterlagen zur Verfügung.

After the development of such an “atomic pile” with an associated research facility, neutral, free Austria would have been connected to the sciences, research and technology of the world.

Cheap energy production, progress in maintaining the health of the entire Austrian people, and the need to keep pace with foreign science will give our people the possibility of actual independence.

In the expectation that this suggestion will be favorably received, I am at your disposal for further information, suggestions and documents.

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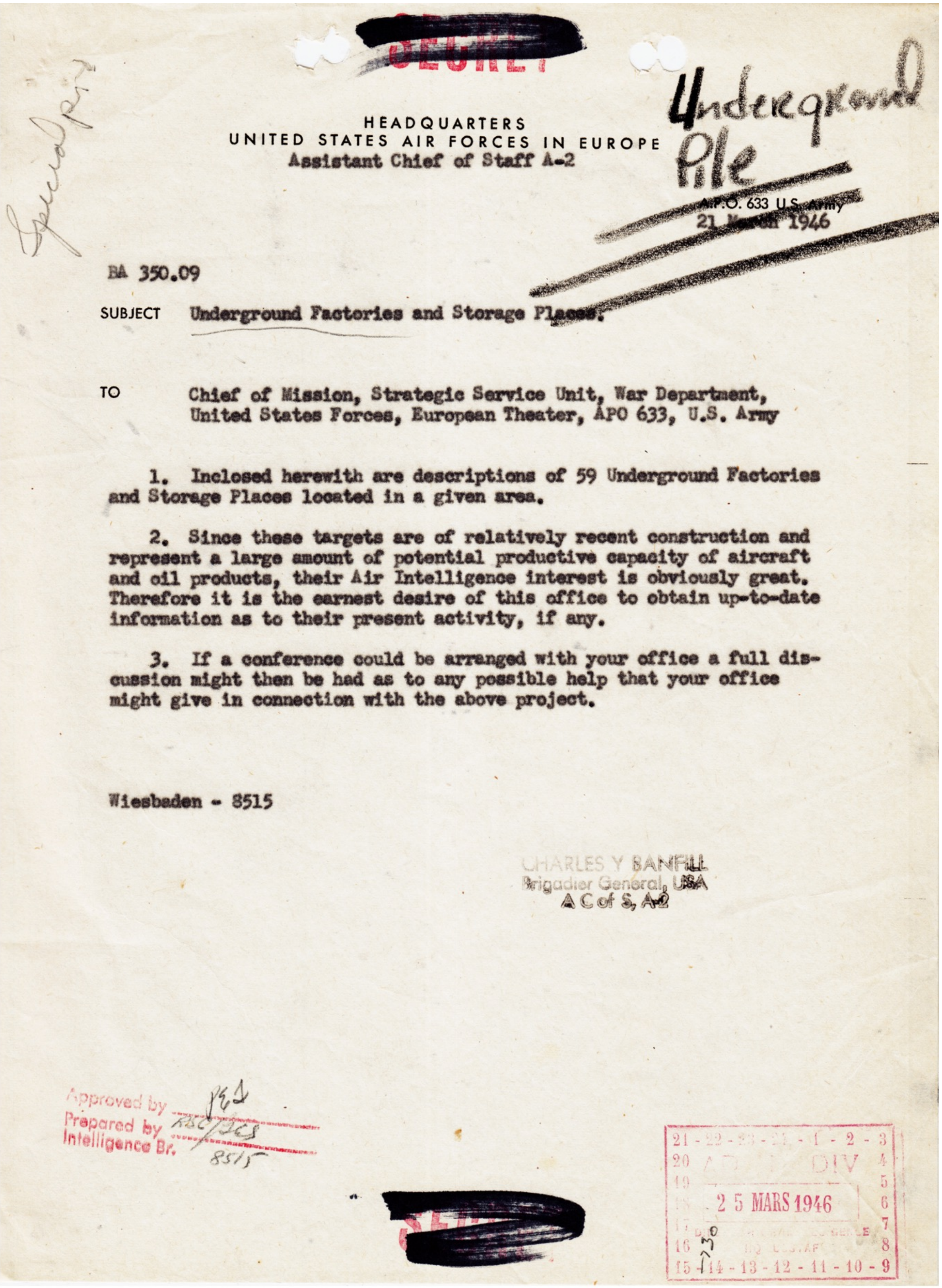
AFHRA folder 570.6501A 1945-1946



[redacted]

Special Proj

Underground Pile

HEADQUARTERS
UNITED STATES AIR FORCES IN EUROPE
Assistant Chief of Staff A-2

A.P.O. 633 U.S. Army
21 March 1946

BA 350.09

SUBJECT Underground Factories and Storage Places.

TO Chief of Mission, Strategic Service Unit, War Department, United States Forces, European Theater, APO 633, U.S. Army

1. Inclosed herewith are descriptions of 59 Underground Factories and Storage Places located in a given area.

2. Since these targets are of relatively recent construction and represent a large amount of potential productive capacity of aircraft and oil products, their Air Intelligence interest is obviously great. Therefore it is the earnest desire of this office to obtain up-to-date information as to their present activity, if any.

3. If a conference could be arranged with your office a full discussion might then be had as to any possible help that your office might give in connection with the above project.

Wiesbaden - 8515

CHARLES Y BANFILL
Brigadier General, USA
A C of S, A-2

Approved by PEL
Prepared by ABC/JCS
Intelligence Br.
8515

[redacted]

DIV
25 MARS 1946
HQ U.S.AF
730

Figure D.414: The cover letter for the U.S. military's "Special Projects" investigation of Austria is prominently labelled "Underground Pile" and underlined three times to emphasize the importance of those words [AFHRA folder 570.6501A 1945–1946; AFHRA C5098 frame 935]. Did the U.S. military find evidence of a wartime "underground pile" (fission reactor) in Austria, for example at St. Georgen/Gusen? Or was it just a remarkably excessive way of labeling that document to go with the "pile" of other documents on underground facilities? Where is the report that this cover letter referred to?

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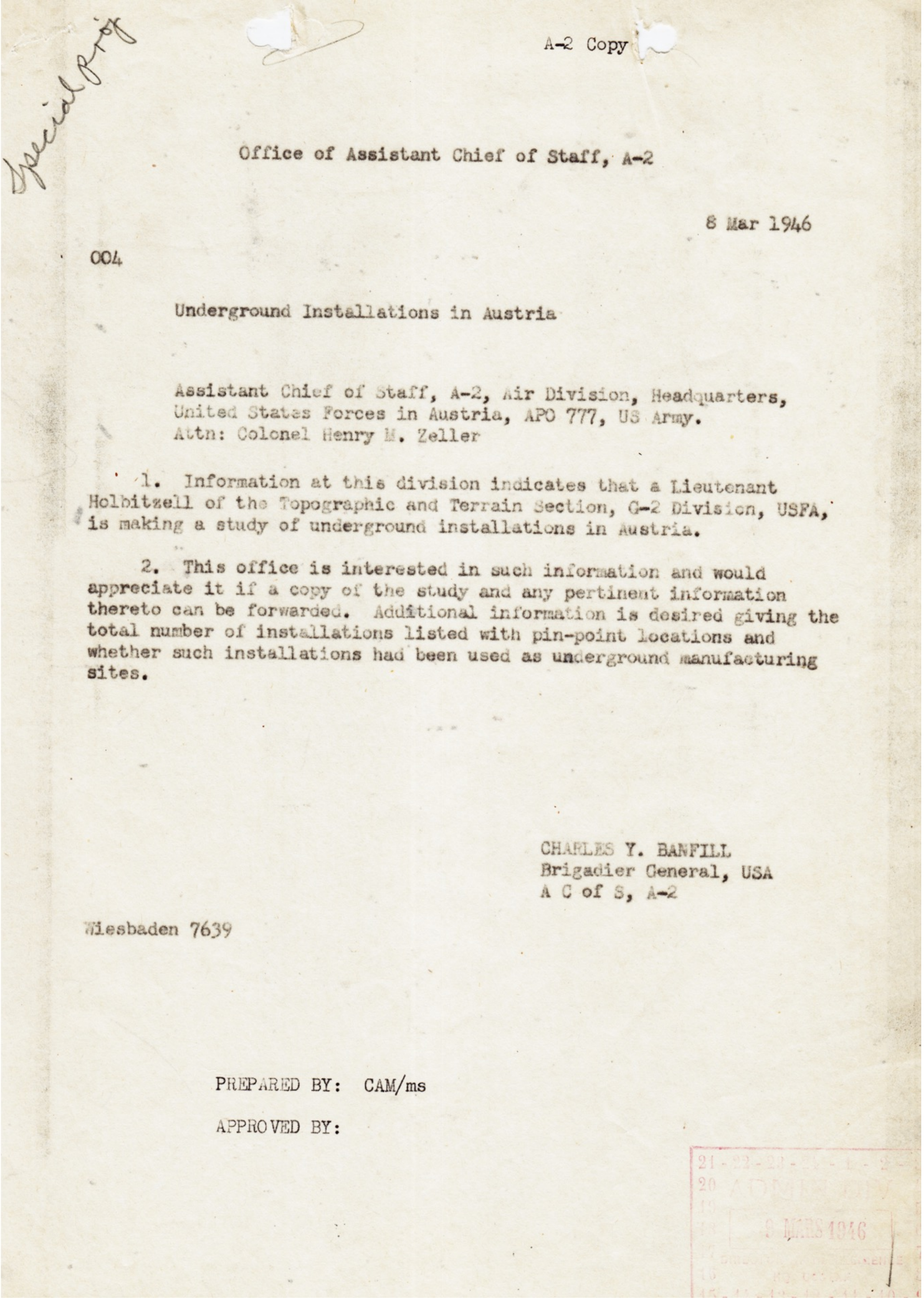
AFHRA folder 570.6501A 1945-1946



Special Proj

A-2 Copy

Office of Assistant Chief of Staff, A-2

8 Mar 1946

004

Underground Installations in Austria

Assistant Chief of Staff, A-2, Air Division, Headquarters,
United States Forces in Austria, APO 777, US Army.
Attn: Colonel Henry M. Zeller

1. Information at this division indicates that a Lieutenant Holbitzell of the Topographic and Terrain Section, G-2 Division, USFA, is making a study of underground installations in Austria.

2. This office is interested in such information and would appreciate it if a copy of the study and any pertinent information thereto can be forwarded. Additional information is desired giving the total number of installations listed with pin-point locations and whether such installations had been used as underground manufacturing sites.

CHARLES Y. BANFILL
Brigadier General, USA
A C of S, A-2

Wiesbaden 7639

PREPARED BY: CAM/ms

APPROVED BY:

9 MARS 1946

Figure D.415: After the war, a U.S. military "Special Projects" team investigated underground facilities in Austria [AFHRA folder 570.6501A 1945–1946; AFHRA C5098 frame 936].

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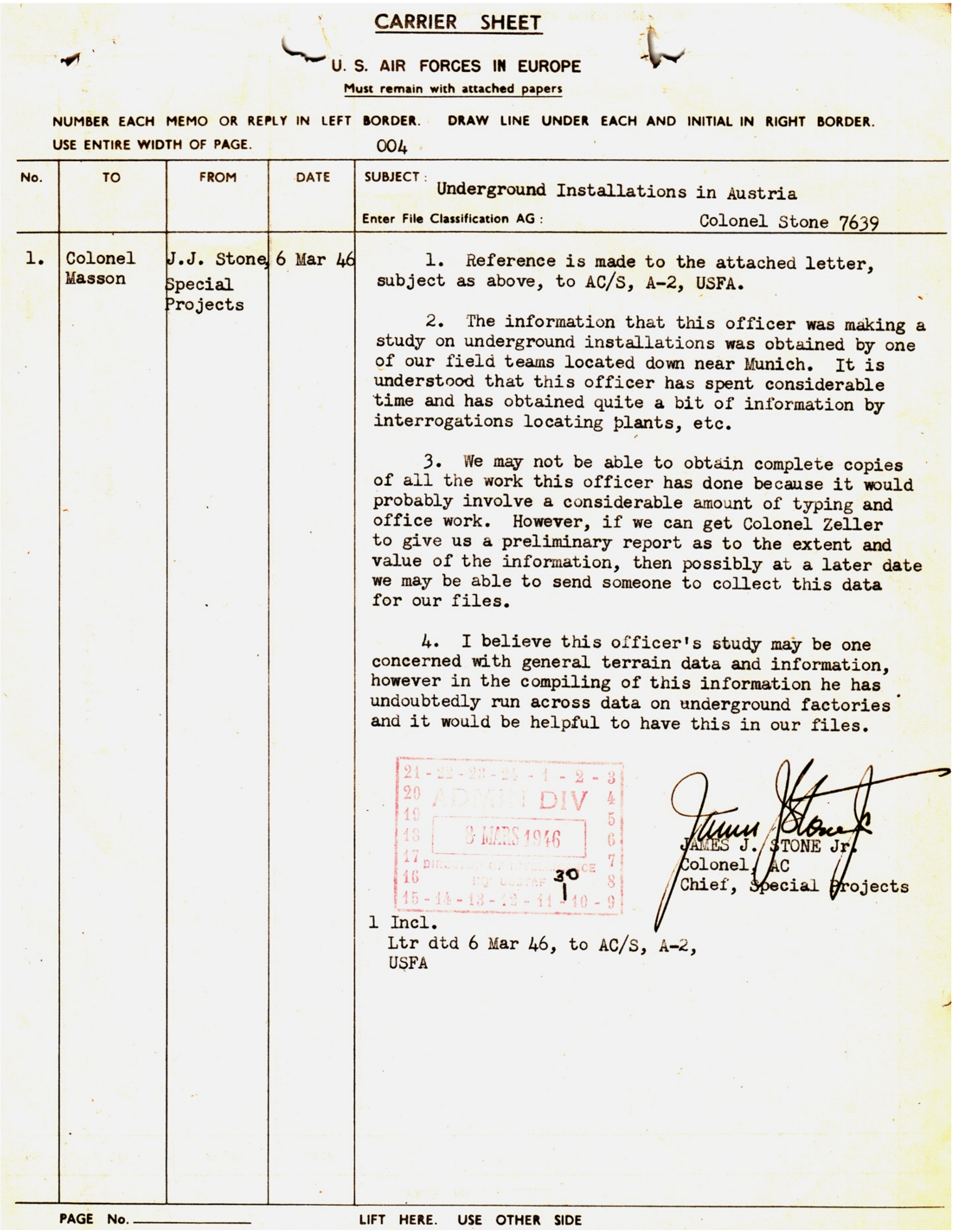

CARRIER SHEET

U. S. AIR FORCES IN EUROPE

Must remain with attached papers

NUMBER EACH MEMO OR REPLY IN LEFT BORDER. DRAW LINE UNDER EACH AND INITIAL IN RIGHT BORDER.
USE ENTIRE WIDTH OF PAGE.

004

No.	TO	FROM	DATE	SUBJECT: Underground Installations in Austria Enter File Classification AG: Colonel Stone 7639
1.	Colonel Masson	J.J. Stone, Special Projects	6 Mar 46	1. Reference is made to the attached letter, subject as above, to AC/S, A-2, USFA. 2. The information that this officer was making a study on underground installations was obtained by one of our field teams located down near Munich. It is understood that this officer has spent considerable time and has obtained quite a bit of information by interrogations locating plants, etc. 3. We may not be able to obtain complete copies of all the work this officer has done because it would probably involve a considerable amount of typing and office work. However, if we can get Colonel Zeller to give us a preliminary report as to the extent and value of the information, then possibly at a later date we may be able to send someone to collect this data for our files. 4. I believe this officer's study may be one concerned with general terrain data and information, however in the compiling of this information he has undoubtedly run across data on underground factories and it would be helpful to have this in our files.

21 - 22 - 23 - 24 - 1 - 2 - 3
20 ADMIN DIV 4
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17 DIRECTOR OF INTELLIGENCE 7
16 HQ USSTAF 8
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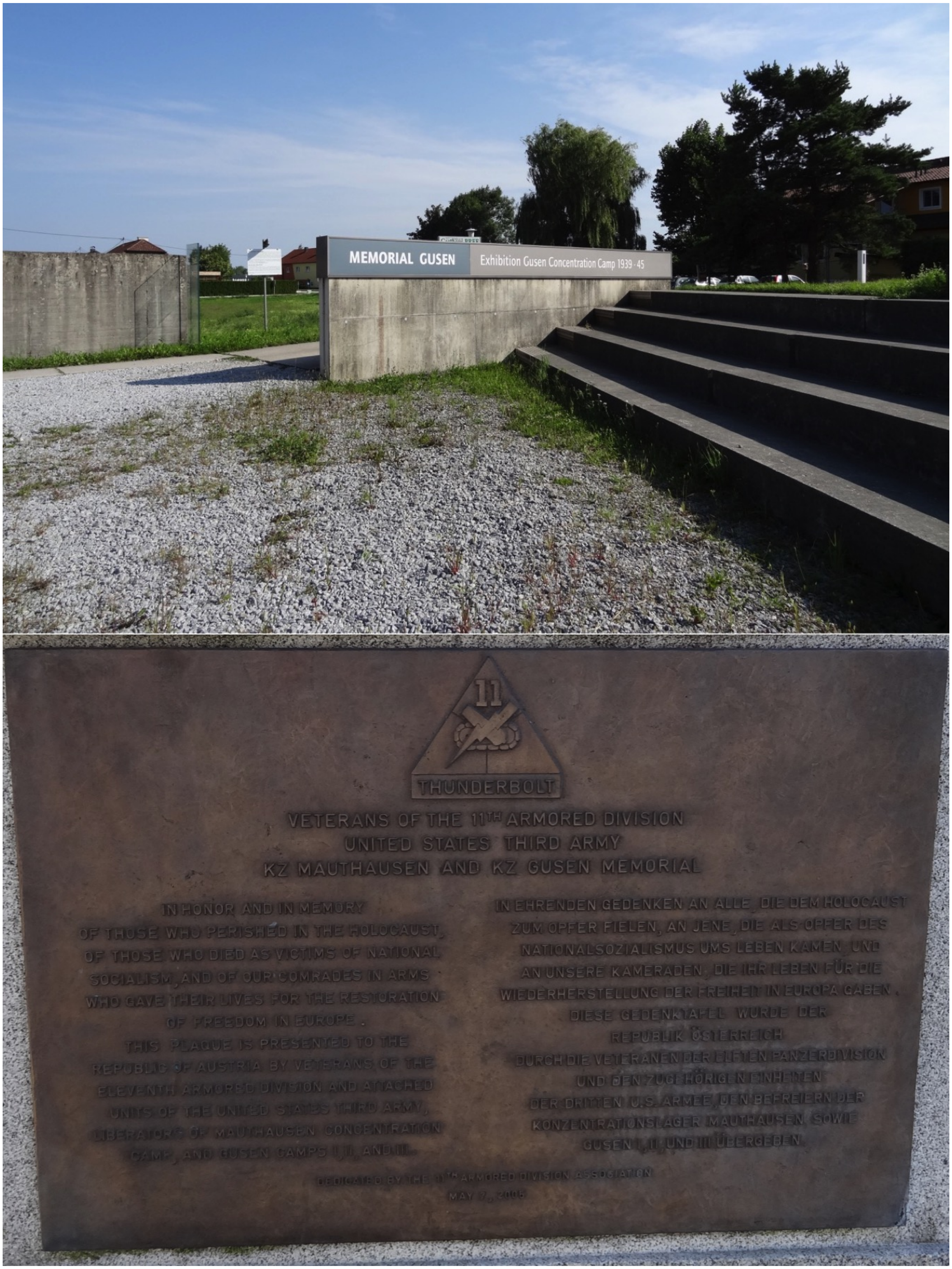
30
1

James J Stone Jr
JAMES J. STONE Jr.
Colonel, AC
Chief, Special Projects

1 Incl.
Ltr dtd 6 Mar 46, to AC/S, A-2, USFA

PAGE No. ______ LIFT HERE. USE OTHER SIDE

Figure D.416: After the war, a U.S. military "Special Projects" team investigated underground facilities in Austria [AFHRA folder 570.6501A 1945–1946; AFHRA C5098 frame 937].



VETERANS OF THE 11TH ARMORED DIVISION
UNITED STATES THIRD ARMY
KZ MAUTHAUSEN AND KZ GUSEN MEMORIAL

IN HONOR AND IN MEMORY
OF THOSE WHO PERISHED IN THE HOLOCAUST,
OF THOSE WHO DIED AS VICTIMS OF NATIONAL
SOCIALISM, AND OF OUR COMRADES IN ARMS
WHO GAVE THEIR LIVES FOR THE RESTORATION
OF FREEDOM IN EUROPE.
THIS PLAQUE IS PRESENTED TO THE
REPUBLIC OF AUSTRIA BY VETERANS OF THE
ELEVENTH ARMORED DIVISION AND ATTACHED
UNITS OF THE UNITED STATES THIRD ARMY,
LIBERATORS OF MAUTHAUSEN CONCENTRATION
CAMP, AND GUSEN CAMPS I, II, AND III.

IN EHRENDEN GEDENKEN AN ALLE, DIE DEM HOLOCAUST
ZUM OPFER FIELEN, AN JENE, DIE ALS OPFER DES
NATIONALSOZIALISMUS UMS LEBEN KAMEN, UND
AN UNSERE KAMERADEN, DIE IHR LEBEN FÜR DIE
WIEDERHERSTELLUNG DER FREIHEIT IN EUROPA GABEN.
DIESE GEDENKTAFEL WURDE DER
REPUBLIK ÖSTERREICH
DURCH DIE VETERANEN DER ELFTEN PANZERDIVISION
UND DEN ZUGEHÖRIGEN EINHEITEN
DER DRITTEN U.S. ARMEE, DEN BEFREIERN DER
KONZENTRATIONSLAGER MAUTHAUSEN, SOWIE
GUSEN I, II, UND III ÜBERGEBEN.

DEDICATED BY THE 11TH ARMORED DIVISION ASSOCIATION
MAY 7, 2005

Figure D.417: Site of the former Gusen I concentration camp now.

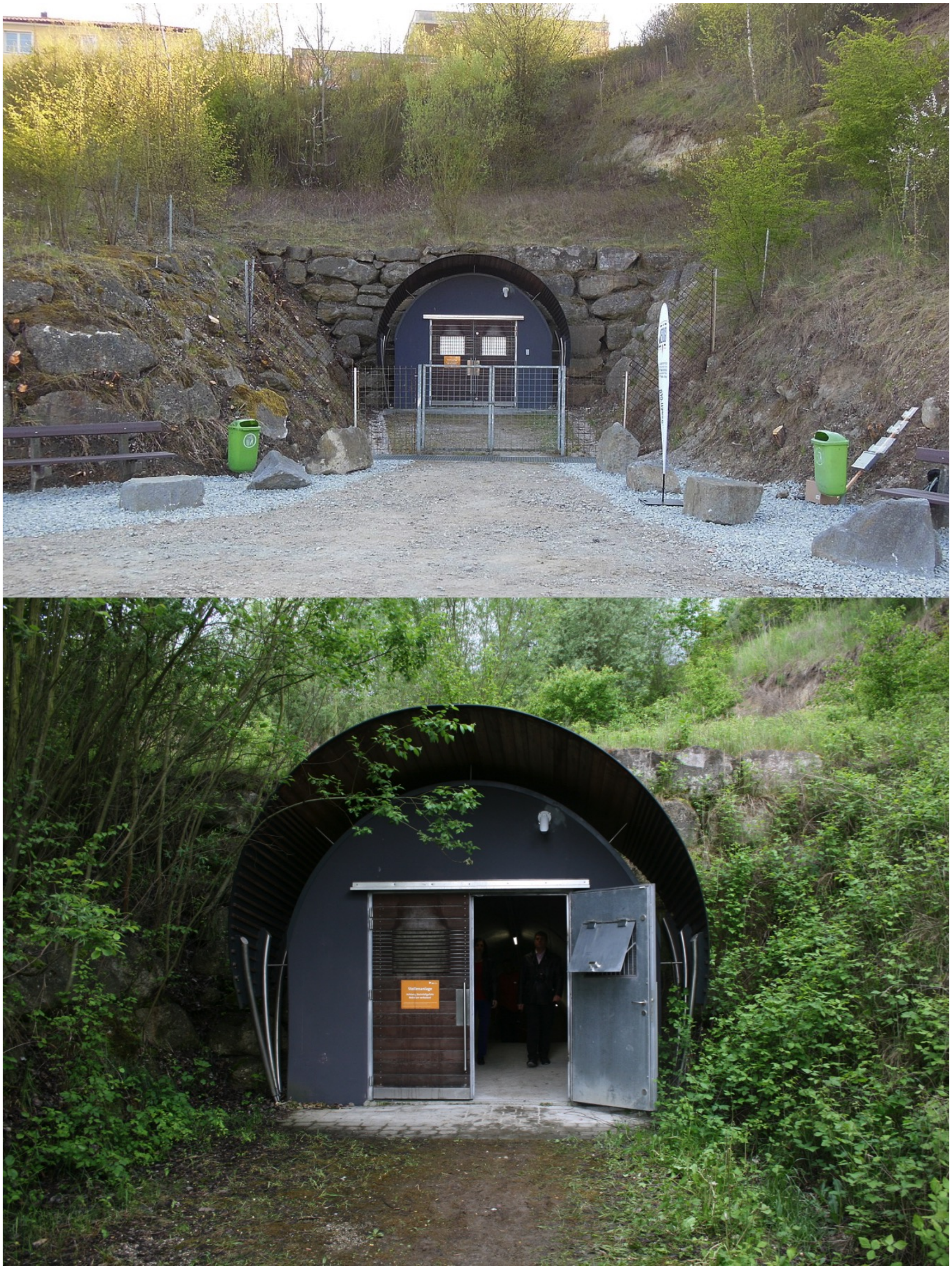


Figure D.418: The entrance to the Bergkristall tunnel complex. [Above: Wikicommons. Below: Rudolf Haunschmied]

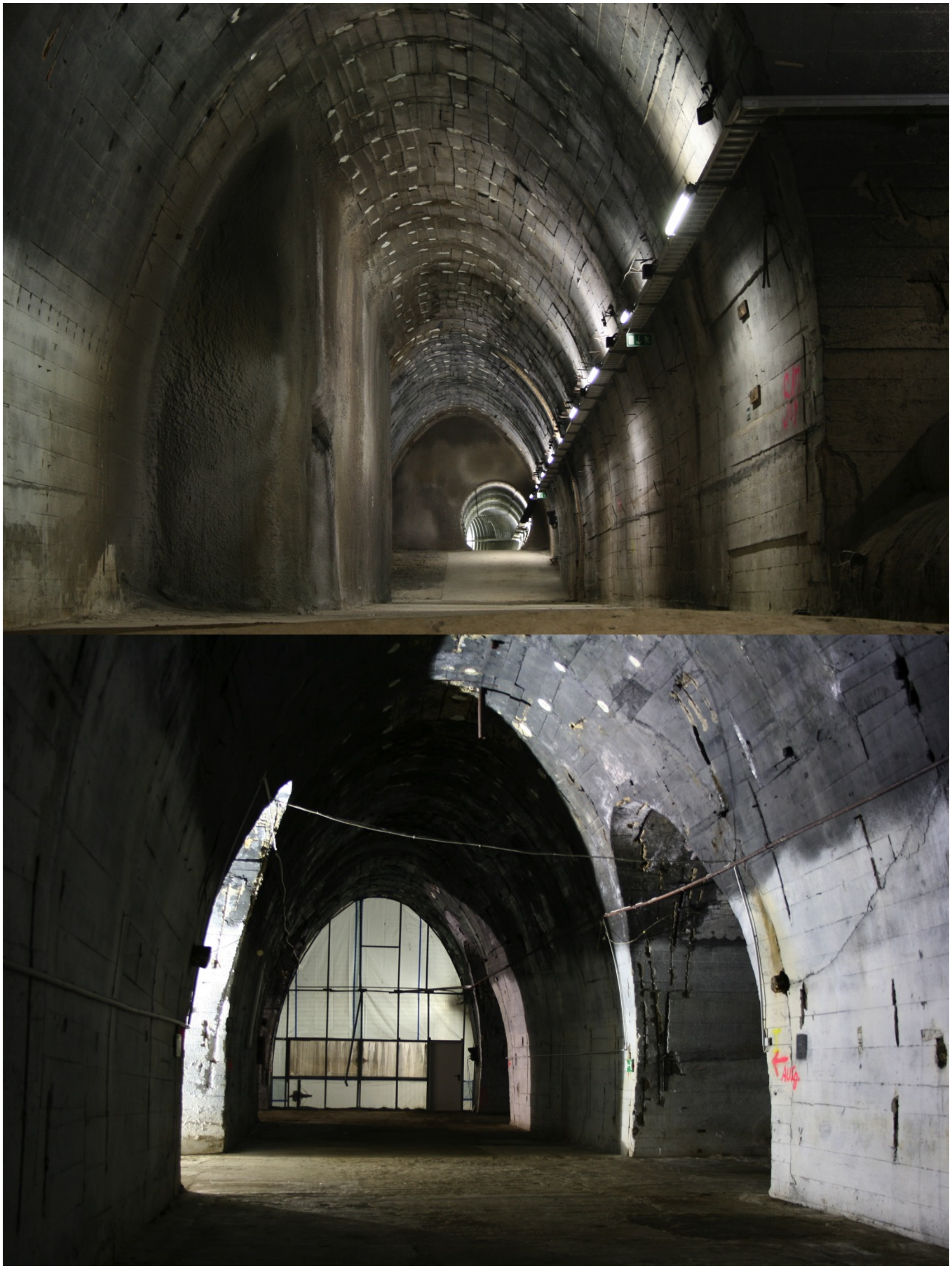


Figure D.419: Inside the Bergkristall tunnel complex now. [Courtesy of Rudolf Haunschmied]

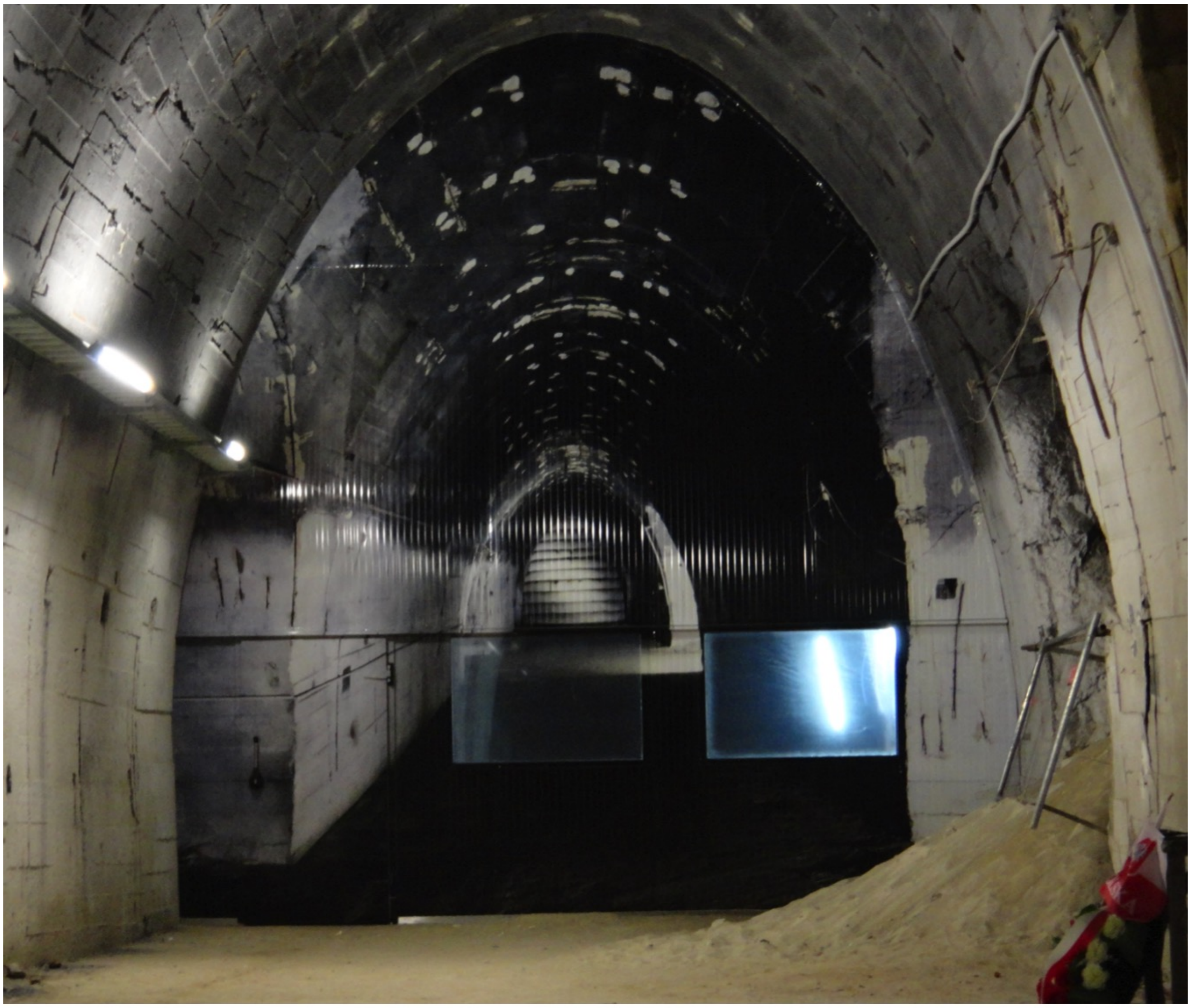


Figure D.420: In the Bergkristall tunnel complex, the Austrian government has installed a gas-proof transparent plastic barrier between the publicly accessible tunnels and those beyond, in order to block radioactive gases that are coming from the inaccessible tunnels. Even so, the radioactive gas levels in the publicly accessible tunnels are so great that the Austrian government has stipulated that (1) they can only be open to public visitors twice per year, (2) they must be thoroughly ventilated for many hours before each public visiting day, and (3) visitors cannot remain in the tunnels longer than one hour. [Courtesy of Rudolf Haunschmied]

5. A possible fission reactor at Unterraderach near Friedrichshafen

A Signaler d'Urgence. Undated but apparently late 1943. [Archives of the French Army Ministry of Defense, courtesy of Andreas Sulzer]

On a decouvert en Allemagne l'existence d'une usine spéciale qui fabrique des engins nouveaux et redoutables: Projectiles de 200 Kgrs, à enveloppe d'aluminium qui seraient lancés par dessus le Détroit. Ces engins exploseraient à l'arrivée et détraraient tout ce qui est vivant dans un rayon de 20 Km.	In Germany was discovered the existence of a special factory which manufactures new and formidable machines: 200-kilogram projectiles, with an aluminum envelope, which would be launched over the [English] Channel. These devices would explode upon arrival and destroy everything that is alive within a radius of 20 km.
L'usine se trouve dans une dépression de terrain assez accentuée (40 m.), elle est protégée par 40 pièces de D.C.A. [défense contre l'aviation] et à la moindre alerte, est camouflée par un nuage de fumée.	The factory is located in a fairly deep depression (40 m.), it is protected by 40 anti-aircraft guns, and at the slightest alert is hidden by a cloud of smoke.
L'emplacement de cette usine est dans le WURTEMBERG dans le triangle formé par FRIEDRICHSHAFEN au Sud, MARKDORF au NORD-OUEST, OBERTEMINGEN au NORD.	The location of this plant is in WURTEMBERG in the triangle formed by FRIEDRICHSHAFEN in the south, MARKDORF in the northwest, OBERTEMINGEN in the north.
D'apres le croquis ci-joint, la dépression de terrain dans laquelle se trouve l'usine, parait être orientée sensiblement EST-OUEST, a son extrémité EST aboutit la route venant de FRIEDRICHSHAFEN, qui, à ci-cet, endroit tourne brusquement à droite.	According to the attached sketch, the depression of the ground in which the factory is located, seems to be oriented essentially EAST-WEST, at its EAST end ends up on the road coming from FRIEDRICHSHAFEN, which, at this point, turns abruptly to the right.
Les tirs doivent commencer fin Décembre ou commencement de Janvier.	Firing must start at the end of December or beginning of January.
Ce sont peut-être les représailles annonçées par le Maréchal GOERING.	These may be the reprisals announced by Marshal GOERING.
Il est extrèmement difficile et dangereux de s'approcher de cette usine. Tout le personnel employé doit vivre dans l'enceinte même de l'usine et ne peut sortir sous aucun prétexte.	It is extremely difficult and dangerous to approach this factory. All staff employed must live within the factory premises and may not leave under any circumstances.
Ces renseignements sont absolument sûrs, l'usine a été visitée	This information is absolutely certain, the plant has been visited

Autre renseignement donné par un officier Alsacien travaillant en Allemagne au sujet de l'arme secrète:

Les Allemands avaient préparé pour la Iere quinzaine d'Aoùt, le bombardement de Londres.

Ce bombardement devait avoir lieu au moyen d'engins qui auraient lancé de BERLIN même des bombes à gaz et à microbes propulsées par un dispositif à air comprimé. Cela ne s'est pas réalisé jusqu'a présent mais semble vouloir l'être bientôt.

Other information regarding secret weapons provided by an Alsatian officer working in Germany:

The Germans had prepared for the first fortnight of August, the bombing of London.

This bombardment was to take place using devices that would have thrown gas and microbial bombs from BERLIN itself, propelled by a compressed air device. This has not been achieved so far but seems to be happening soon.

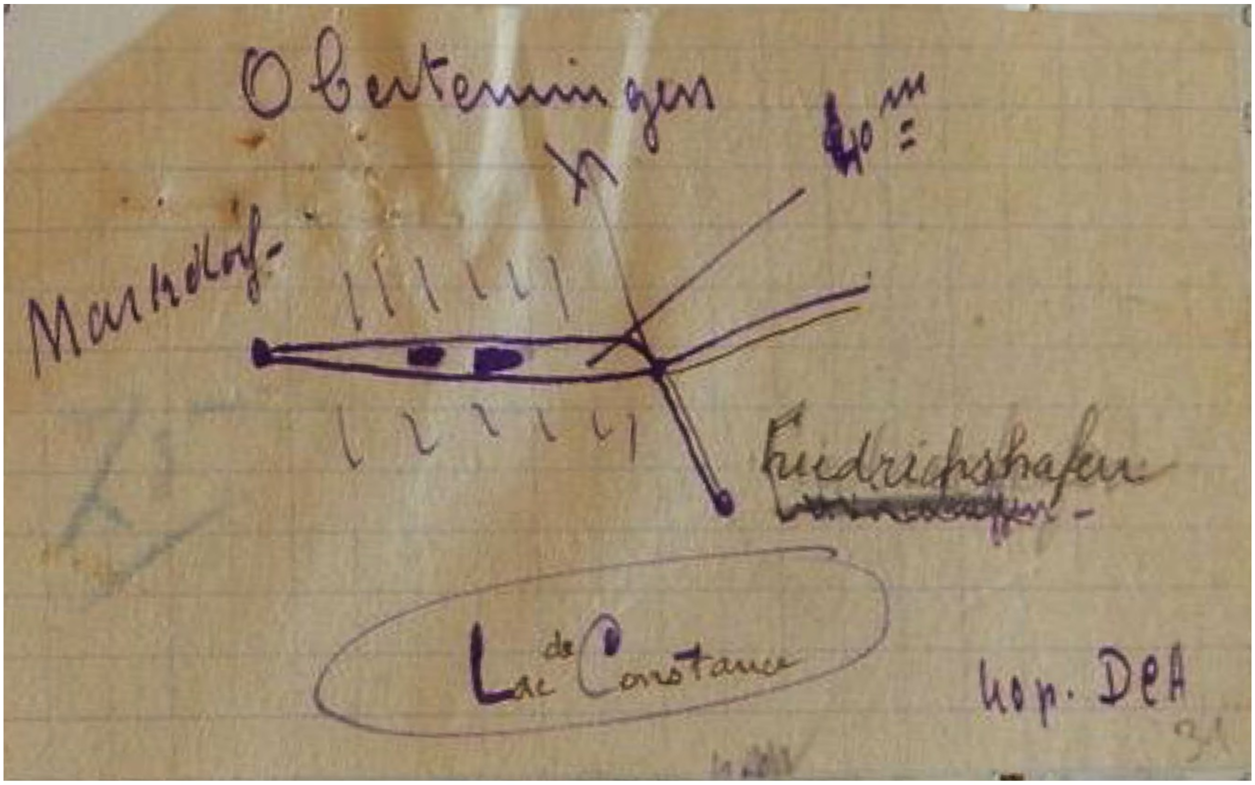


Figure D.421: Wartime French map showing the location of a highly secret nuclear facility near Friedrichshafen that may have been a fission reactor.

S. McClintic, Headquarters U.S. Strategic Air Forces in Europe, Office of the Director of Intelligence, to George C. McDonald. 6 January 1945. Big Ben (Rockets). [AFHRA A5734 electronic version p. 1092]

[...] At UNTERRADERACH, near FRIEDRICHSHAFEN, there is a large semi-underground factory which was constructed early last winter where strange experiments were taking place. Heavy clouds of smoke filled the sky in the day and at night a red glow. The experiments caused the earth to shake. These experiments are with atoms and when the experiments proved successful the plant went into operation. Workmen were not allowed to leave the factory. [...]

[This appears to be the same location as that described in the previous French report. Could this have been the location of a working fission reactor?

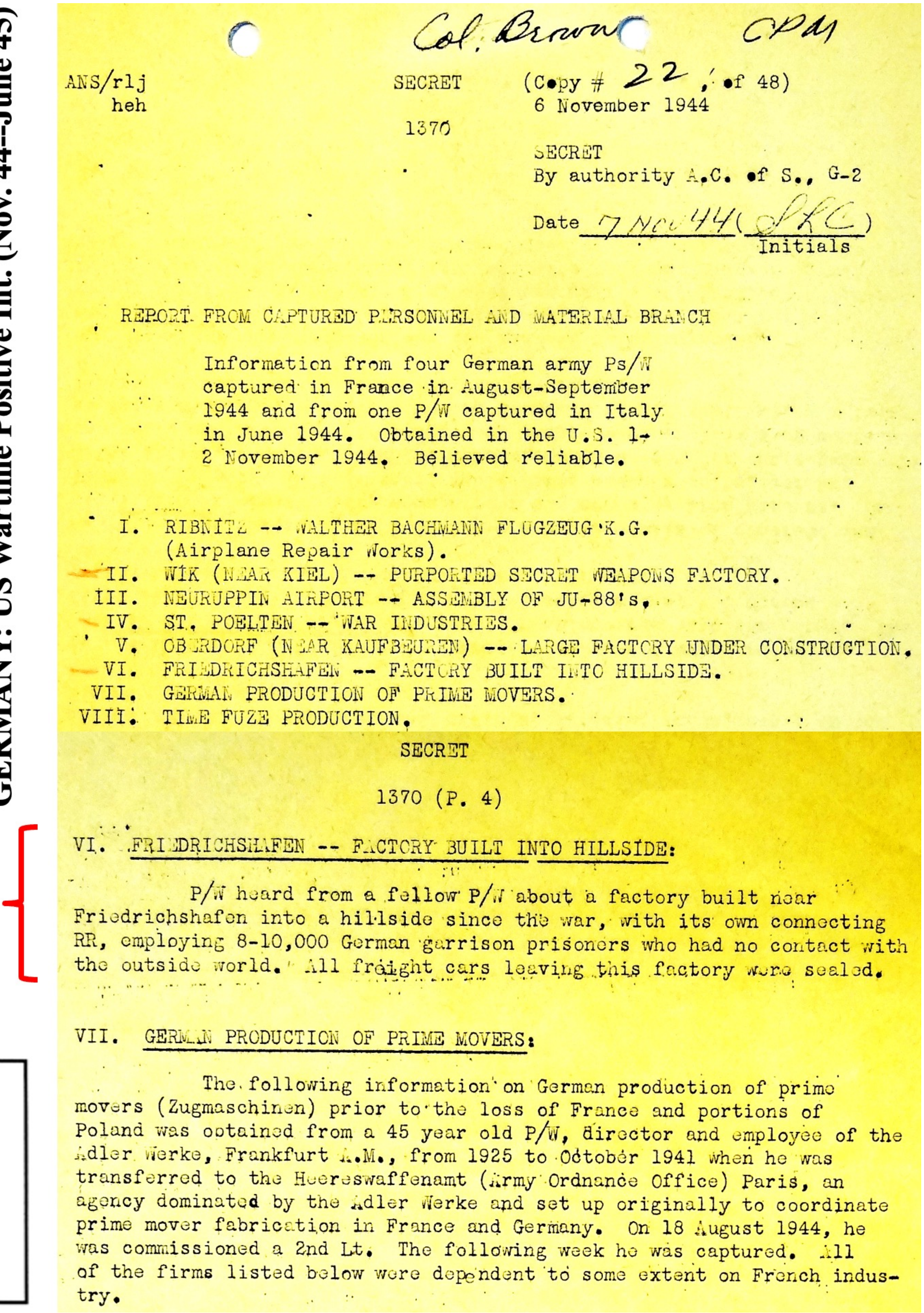
- The work was atomic, and so secret that "workmen were not allowed to leave the factory," as stated by both the American and French intelligence reports.
- The area is on the southern border of Germany, far from Allied forces at that time.
- The area is also on the coast of the Obersee Bodensee, which could have supplied as much water as needed to cool the reactor. The heavy clouds of smoke might have been steam from water coming out of the reactor.
- If the reactor was not operated very carefully, times at which it briefly went supercritical, or occasional buildups of steam, hydrogen, or other gases, might have "caused the earth to shake."
- If there was no containment structure around the reactor, there might have been a visible glow at night.
- "When the "experiments... with atoms... proved successful the plant went into operation" to produce something new and dangerous.
- The plant produced material for "200-kilogram projectiles, with an aluminum envelope, which... would explode upon arrival and destroy everything that is alive within a radius of 20 km." While the radius of destruction seems to have been exaggerated by the French intelligence report, a large radius of destruction for a small device definitely sounds nuclear, consistent with the plant involving "experiments... with atoms."
- One possible explanation that is consistent with the very limited available data is that the plant was producing fission fuel for ∼200-kg low-yield tactical fission weapons such as those described by Eric Schumann (pp. 4246–4248) and Werner Grothmann (pp. 4271–4277). Another possibility is that the plant was producing irradiated fission reactor fuel that could be combined with conventional explosives in a ∼200-kg bomb to make a radiological "dirty bomb."
- This plant may have been related to the Forschungsanstalt Graf Zeppelin in Friedrichshafen, and specifically to the brothers Georg Madelung (German, 1889–1972, a bomb and aerospace expert) and Erwin Madelung (German, 1881–1972, an atomic physicist) who worked there.

Can other reports about this facility be found in archives?

Can the possible site near Friedrichshafen be located and inspected now?

This area is known to have had a plant producing liquid oxygen for the A-4 (V-2) rockets, but what is described in the two documents above sounds quite different than a liquid oxygen plant. It seems likely that there were several different advanced weapons plants located in that area.]

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3
GERMANY: US Wartime Positive Int. (Nov. 44--June 45)



Col. Brown CPdj

ANS/rlj
heh

SECRET
1370

(Copy # 22, of 48)
6 November 1944

SECRET
By authority A.C. of S., G-2

Date 7 Nov 44 (SKC)
Initials

REPORT FROM CAPTURED PERSONNEL AND MATERIAL BRANCH

Information from four German army Ps/W captured in France in August-September 1944 and from one P/W captured in Italy in June 1944. Obtained in the U.S. 1-2 November 1944. Believed reliable.

I. RIBNITZ -- WALTHER BACHMANN FLUGZEUG K.G. (Airplane Repair Works).
II. WIK (NEAR KIEL) -- PURPORTED SECRET WEAPONS FACTORY.
III. NEURUPPIN AIRPORT -- ASSEMBLY OF JU-88's.
IV. ST. POELTEN -- WAR INDUSTRIES.
V. OBERDORF (NEAR KAUFBEUREN) -- LARGE FACTORY UNDER CONSTRUCTION.
VI. FRIEDRICHSHAFEN -- FACTORY BUILT INTO HILLSIDE.
VII. GERMAN PRODUCTION OF PRIME MOVERS.
VIII. TIME FUZE PRODUCTION.

SECRET

1370 (P. 4)

VI. FRIEDRICHSHAFEN -- FACTORY BUILT INTO HILLSIDE:

P/W heard from a fellow P/W about a factory built near Friedrichshafen into a hillside since the war, with its own connecting RR, employing 8-10,000 German garrison prisoners who had no contact with the outside world. All freight cars leaving this factory were sealed.

VII. GERMAN PRODUCTION OF PRIME MOVERS:

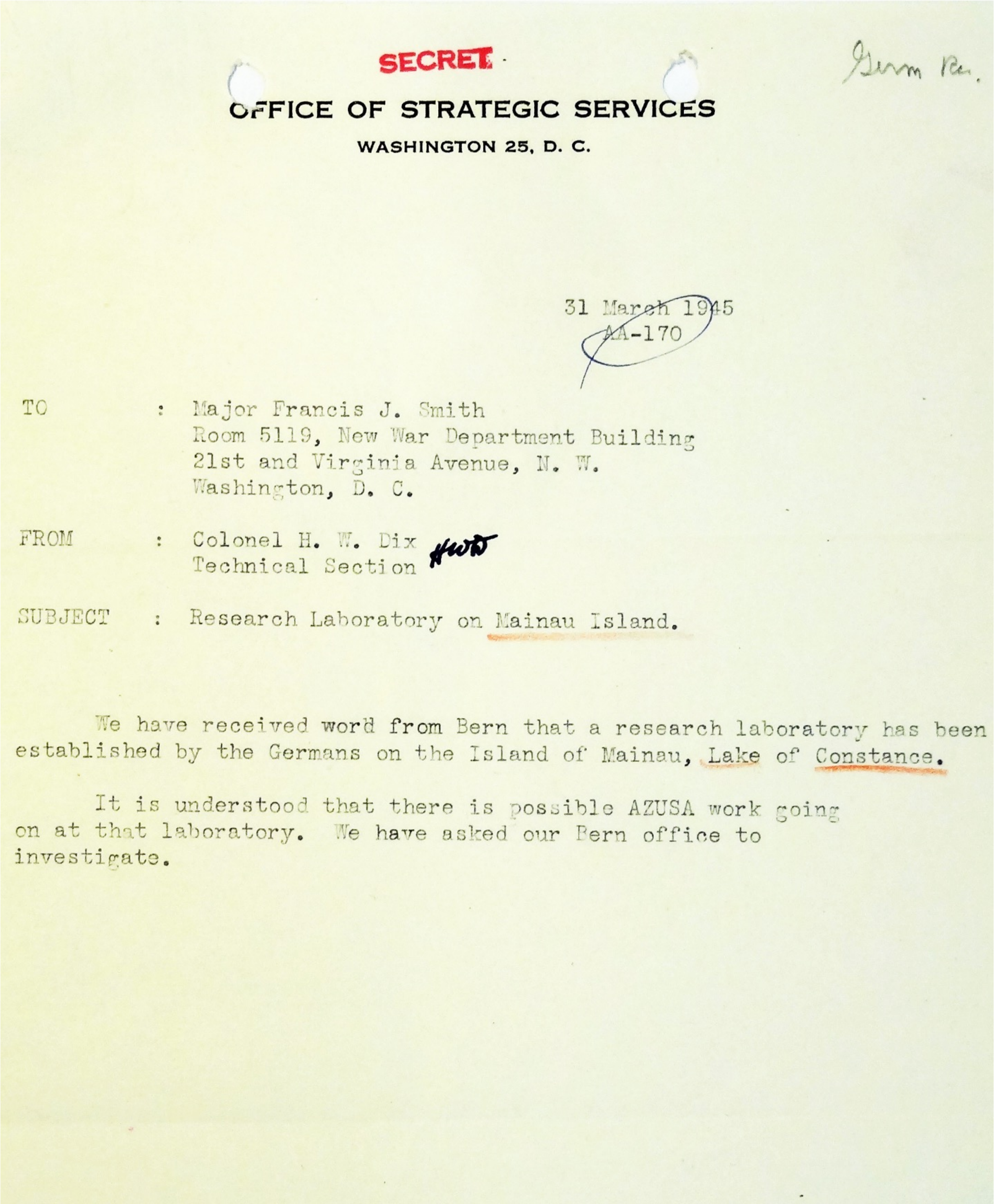
The following information on German production of prime movers (Zugmaschinen) prior to the loss of France and portions of Poland was obtained from a 45 year old P/W, director and employee of the Adler Werke, Frankfurt A.M., from 1925 to October 1941 when he was transferred to the Heereswaffenamt (Army Ordnance Office) Paris, an agency dominated by the Adler Werke and set up originally to coordinate prime mover fabrication in France and Germany. On 18 August 1944, he was commissioned a 2nd Lt. The following week he was captured. All of the firms listed below were dependent to some extent on French industry.

DECLASSIFIED
Authority NND 917017

Figure D.422: Captured Personnel and Material Branch. 6 November 1944. Report 1370 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

DECLASSIFIED
Authority NND917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3
GERMANY: US Wartime Positive Int. (Nov. 44–June 45)



SECRET

Germ Re.

OFFICE OF STRATEGIC SERVICES
WASHINGTON 25, D. C.

31 March 1945
AA-170

TO : Major Francis J. Smith
Room 5119, New War Department Building
21st and Virginia Avenue, N. W.
Washington, D. C.

FROM : Colonel H. W. Dix HWD
Technical Section

SUBJECT : Research Laboratory on Mainau Island.

We have received word from Bern that a research laboratory has been established by the Germans on the Island of Mainau, Lake of Constance.

It is understood that there is possible AZUSA work going on at that laboratory. We have asked our Bern office to investigate.

Figure D.423: H. W. Dix to Francis J. Smith. 31 March 1945 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

6. A possible fission reactor at an underground facility in Berlin-Lichterfelde

RENSEIGNEMENT. Origine: Officier de l'E.M.G.G. 18 January 1950. [Archives of the French Army Ministry of Defense, courtesy of Andreas Sulzer]

I^{o}.—RENSEIGNEMENTS D'ARCHIVES.—

a)—Docteur ENGEL
—Ingénieur allemand travaillant à ANDILLY pour le compte de l'O.N.E.R.A.

b)—Société X......

I^{o}.—RENSEIGNEMENTS PROPREMENTS DITS.—

ENGEL (a) aurait été, à la fin de la guerre, après avoir été Directeur de SKODA, Chef des recherches du groupe d'armement HERMANN GOERING; à ce titre, il aurait eu rang d'égalité avec les Directeurs des six usines de ce groupe dont les raisons sociales auraient été: SKODA, EXPLONIA, etc... Il aurait reçu le pouvoir absolu de prélever dans ces 3 usines tout matériel ou tout personnel qu'il lui aurait semblé bon.

Par ailleurs, un groupe français que l'on désignera par "Société X..." (b) et qui en tout cas ne serait pas SCHNEIDER, aurait détenu 28 % des actions de SKODA et les Allemands n'auraient pas pu s'en emparer. Le groupe qui détiendrait ces actions exercerait actuellement so activité à PARIS, où il se liverait à la vente de divers matériels, dont des armes.

Le 6 Janvier 1950, le Dr. ENGEL (a), à la recherche d'instruments de laboratoire, est entré fortuitement en relations avec cette Société X... dont il aurait ignoré l'existence auparavant. Il y aurait été reconnu par des personnes d'ailleurs inconnues de lui, et des membres de cette société lui auraient dit ce qui suit:

I^{o}. —ARCHIVAL INFORMATION.—

a)—Doctor ENGEL
—German engineer working at ANDILLY for O.N.E.R.A.

b)—Company X........

I^{o}.—PROPERTY INFORMATION.—

ENGEL (a) was, at the end of the war, after having been Director of SKODA, Head of Research of the HERMANN GOERING armaments group; as such, he had equal rank with the Directors of the six factories of this group whose corporate names were: SKODA, EXPLONIA, etc... He was given the absolute power to take from these 3 plants any equipment or personnel that he thought were appropriate.

In addition, a French group that will be referred to as "Society X..." (b) and which in any case would not be SCHNEIDER, held 28 % of SKODA's shares and the Germans did not take them. The group that held these shares currently operates in PARIS, where it sells various items, including weapons.

On 6 January 1950, Dr. ENGEL (a), in search of laboratory instruments, fortuitously entered into a relationship with this Society X... of whose existence he was previously unaware. He was reportedly recognized by people unknown to him, and members of this society reportedly told him the following:

“Au cours de leur avance, les Soviets se seraient emparés du centre d’essais de PIEBRANZ, qu’aurait dirigé ENGEL (a). Ils auraient gardé trois des ingénieurs de ce centre et bien qu’ENGEL eut détruit, avant l’armistice, dans la région de MUNICH, les documents qu’il aurait évacués, les Russes auraient pu, avec l’aide de ces trois ingénieurs, reconstituer les projets en cours d’étude à PIEBRANZ, à la fin de la guerre.” [...]

Plus loin, le même article ajoute:

A peu près à ce moment (1944?) la Direction de l’Étude de l’Uranium passa de ESAU (c) à GERLACH (f).

A côté de cette version officielle, les faits suivants ont été rapportés par le Docteur ENGEL (a) au cours d’une conversation, à PARIS, le 22 Décembre 1949.

En 1944, à LICHTERFELD, une pile atomique aurait été montée par THIESSEN (g), ARDENNE (h) et ESAU (c) dans un abris souterrain spécialement aménagé, gardé et très surveillé. Leur travaux auraient abouti à la séparation rapide de l’Uranium 235 et les Allemands se seraient trouvés à quinze jours de la réalisation de la bombe atomique quand un raid de blindés soviétiques, perçant le front et s’avançant en flèche de 30 Kms, se serait emparé de LICHTERFELD.

La colonne aurait été parfaitement au courant de l’existence de l’organisme de recherches et même de la disposition des lieux, car les Russes auraient pénétré directement dans l’usine souterraine sans même qu’on ait pu y donner l’alerte. Le matériel aurait été aussitôt photographié minutieusement, puis démonté et expédié à ATOMGRAD.

ESAU (c) n’aurait pas été pris, mais se serait rendu aux Américains à quelque temps de là. Ce serait lui qui leur aurait indiqué le procédé permettant d’isoler l’Uranium 235, procédé tellement plus rapide que ceux qui avaient été utilisés jusqu’alors, qu’il aurait permis aux Américains de gagner dix-huit mois sur la fabrication de la bombe.

“During their advance, the Soviets seized the PIBRANS test center, which ENGEL directed (a). They kept three of the engineers of this center and although ENGEL had destroyed, before the armistice, in the MUNICH region, the documents he evacuated, the Russians could, with the help of these three engineers, have reconstituted the projects under study in PIBRANS, at the end of the war.” [...]

Further on, the same article adds:

At about this time (1944?) the leadership of the Uranium Study passed from ESAU (c) to GERLACH (f).

In addition to this official version, the following facts were reported by Doctor ENGEL (a) during a conversation in PARIS on 22 December 1949.

In 1944, in LICHTERFELD, an atomic pile was allegedly assembled by THIESSEN (g), ARDENNE (h) and ESAU (c) in a specially equipped, guarded and highly guarded underground shelter. Their work supposedly led to the rapid separation of Uranium 235, and the Germans allegedly were fifteen days from completing the atomic bomb when a raid of Soviet tanks, piercing the front and advancing 30 Kms, seized LICHTERFELD.

The [Soviet] unit was apparently fully aware of the existence of the research organization and even of the layout of the premises, as the Russians entered the underground plant directly without even triggering an alarm. The material was immediately photographed thoroughly, then dismantled and shipped to ATOMGRAD.

ESAU (c) was not taken, but surrendered to the Americans some time later. It was he who allegedly told them the process for isolating Uranium 235, a process so much faster than those used until then, that it would have saved the Americans eighteen months in manufacturing the bomb.

La réalisation de cette deuxième bombe (la première celle de LOS ALAMOS étant au plutonium) et la possibilité de pour-suivre la production à un rythme très rapide, aurait motivé la décision du Président TRUMAN de faire lancer les bombes sur HIROSHIMA (la deuxième, dont il vient d'être parlé) et sur NAGASAKI (une troisième bombe, fabriqué en un temps très court grâce au même procédé).

The completion of this second bomb (the first one from LOS ALAMOS being plutonium) and the possibility of following the production at a very fast rate, may have motivated President TRUMAN's decision to drop the bombs on HIROSHIMA (the second, just mentioned) and on NAGASAKI (a third bomb, manufactured in a very short time using the same process).

7. Possible fission reactors in East Prussia

Heinrich Himmler's diplomatic contact, Muhammad Amin Al-Husayni, the Grand Mufti of Jerusalem. Translated and paraphrased in: Wolfgang G. Schwanitz. Review of Karlsch, Rainer; Petermann, Heiko, Für und Wider "Hitlers Bombe": Studien zur Atomforschung in Deutschland. *H-Soz-u-Kult, H-Net Reviews.* February 2009. [https://www.h-net.org/reviews/showrev.php?id=24129] For the rest of this reference, see pp. 4578–4579.

After 1945 the Grand Mufti said that the enemy espionage by "Jewish, English and American intelligence services" caused "the greatest damage." They were able to discover the locations of "atomic reactors" in East Prussia.

Royal Air Force Bomber Command. Campaign Diary August 1944. https://webarchive.nationalarchives.gov.uk/ukgwa/20070706054833/http://www.raf.mod.uk/bombercommand/aug44.html

26/27 August 1944

174 Lancasters of No 5 Group to Königsberg, which was an important supply port for the German Eastern Front. The route to the target was 950 miles from the No 5 Group bases. Photographic reconnaissance showed that the bombing fell in the eastern part of the town but no report is available from the target, now Kaliningrad in Lithuania. 4 Lancasters lost.

29/30 August 1944

189 Lancasters of No 5 Group carried out one of the most successful No 5 Group attacks of the war on Königsberg at extreme range. Only 480 tons of bombs could be carried because of the range of the target but severe damage was caused around the 4 separate aiming points selected. This success was achieved despite a 20 minute delay in opening the attack because of the presence of low cloud; the bombing force waited patiently, using up precious fuel, until the marker aircraft found a break in the clouds and the Master Bomber, Wing Commander J Woodroffe, probably No 5 Group's most skilled Master Bomber, allowed the attack to commence. Bomber Command estimated that 41 per cent of all the housing and 20 per cent of all the industry in Königsberg were destroyed. There was heavy fighter opposition over the target and 15 Lancasters, 7.9 per cent of the force, were lost.

[Siegfried Flügge, who was probably the top nuclear physicist in the German nuclear weapons program, worked for many different organizations that were all involved in the nuclear program, apparently serving to coordinate the scientific details of all of their activities. Intriguingly, he was appointed to a professorship at the University of Königsberg in East Prussia in 1944, near the end of the war, as Russian forces were advancing (p. 4998). That appointment only makes sense if there was a nuclear facility there that was deemed critical to the war, such as fission reactors breeding plutonium for nuclear weapons.

During the war, Königsberg had a large staff of inorganic chemists with world-class expertise in methods that would have been useful for reprocessing irradiated fuel from fission reactors. After the war, many of those chemists were interrogated by at least two teams from the U.S. Alsos Mission, which suggests that U.S. officials suspected the Königsberg chemists had been involved in nuclear work. See pp. 3930–3933.

There were tens of thousands of forced laborers working in and near Königsberg during the war. They are known to have worked with toxic chemicals such as ship paints and suffered the consequences [Jasiński 1994]. This labor pool might also have been used for hazardous nuclear work.

During the period 26–30 August 1944, U.K. Royal Air Force bombers, operating at the very limits of their range, devastated targets in and near Königsberg. That only makes sense if there were targets of great military value and urgency, such as a nuclear facility on the verge of producing enough fuel for nuclear weapons. It also explains the Grand Mufti's comment. The official Royal Air Force explanation that Königsberg was only attacked because it was a port does not seem sufficient, since the attack was mainly directed at surrounding targets other than the port, and Königsberg continued to be used as a port after the 26–30 August 1944 attacks.

Despite the Allied bombings and fierce offensives by Soviet forces, German troops successfully defended East Prussia until April 1945, rather than retreating to more central areas of Germany and using their strength to defend those. Once again, that only makes sense if there were something in East Prussia that Germany considered so important it had the potential to decide the outcome of the war, even very late in the war.

After the war, East Prussia was claimed as Soviet territory, even though it was geographically disconnected from any other Soviet territory, rather than allotting it to the surrounding countries, Poland or Lithuania. Again, that suggests something rather unusual was found there. (Of course, it did also provide a desirable seaport for the Soviet Union.)]

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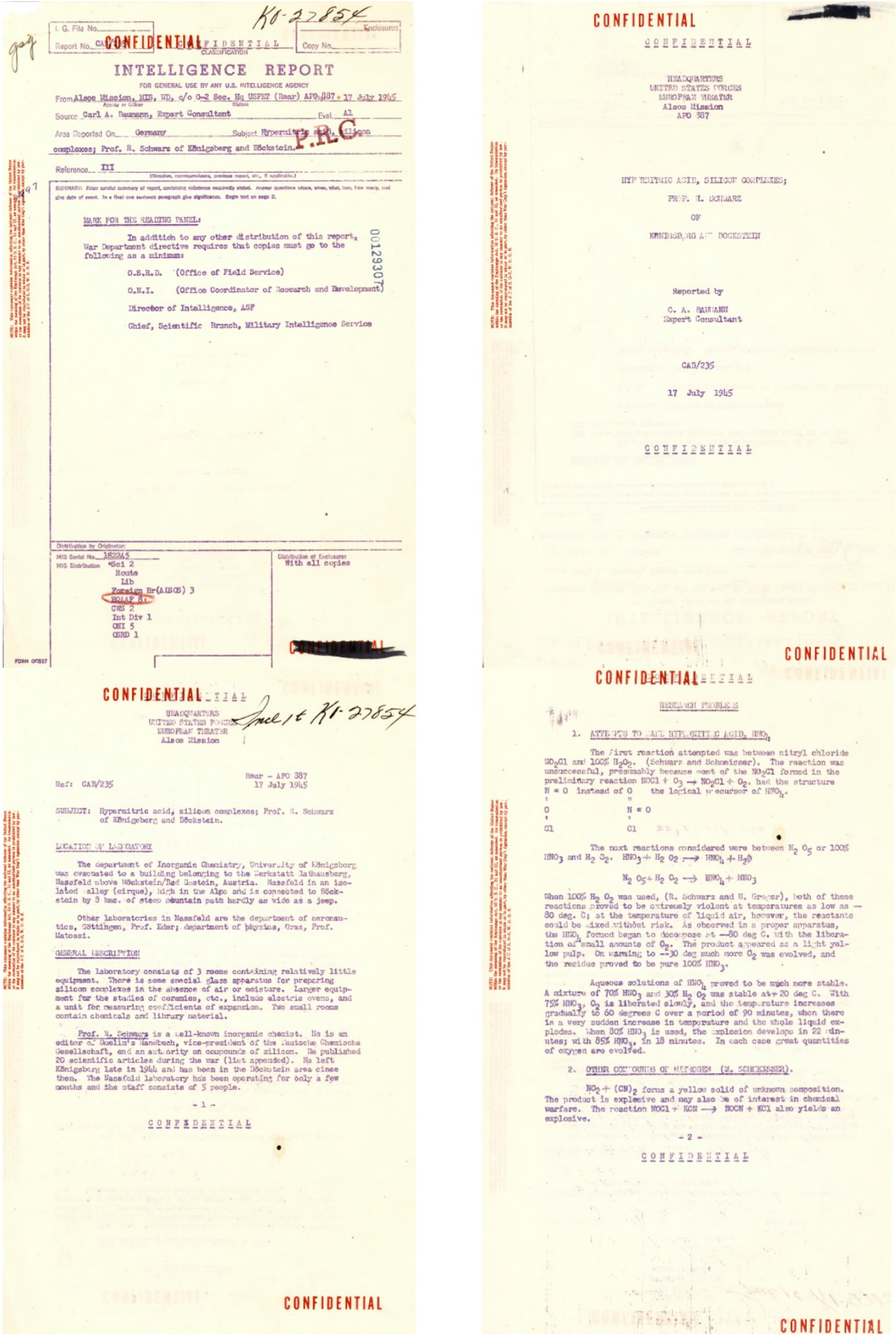
AFHRA folder 170.2279C-1 NO DATE



K0-27854

gaj

I. G. File No. ______ Report No. CAB/235 CONFIDENTIAL CONFIDENTIAL
CLASSIFICATION
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INTELLIGENCE REPORT

FOR GENERAL USE BY ANY U.S. INTELLIGENCE AGENCY

From Alsos Mission, MIS, WD, c/o G-2 Sec. Hq USFET (Rear) APO 887 • 17 July 1945
Agency or Officer — Station

Source Carl A. Baumann, Expert Consultant Eval. A1

Area Reported On Germany Subject Hypernitric acid, silicon complexes; Prof. R. Schwarz of Königsberg and Böckstein.

P.R.C.

Reference III
(Directive, correspondence, previous report, etc., if applicable.)

SUMMARY: Enter careful summary of report, containing substance succinctly stated. Answer questions where, when, what, how, how many, and give date of event. In a final one sentence paragraph give significance. Begin text on page 2.

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APO 887

HYPERNITRIC ACID, SILICON COMPLEXES;

PROF. R. SCHWARZ

OF

KÖNIGSBERG AND BÖCKSTEIN

Reported by

C. A. BAUMANN
Expert Consultant

CAB/235

17 July 1945

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HEADQUARTERS
UNITED STATES FORCES
EUROPEAN THEATER
Alsos Mission

Incl 1 to K1-27854

Ref: CAB/235

Rear - APO 887
17 July 1945

SUBJECT: Hypernitric acid, silicon complexes; Prof. R. Schwarz of Königsberg and Böckstein.

LOCATION OF LABORATORY

The department of Inorganic Chemistry, University of Königsberg was evacuated to a building belonging to the Werkstatt Rathausberg, Nassfeld above Böckstein/Bad Gastein, Austria. Nassfeld in an isolated valley (cirque), high in the Alps and is connected to Böckstein by 8 kms. of steep mountain path hardly as wide as a jeep.

Other laboratories in Nassfeld are the department of aeronautics, Göttingen, Prof. Eder; department of physics, Graz, Prof. Matossi.

GENERAL DESCRIPTION

The laboratory consists of 3 rooms containing relatively little equipment. There is some special glass apparatus for preparing silicon complexes in the absence of air or moisture. Larger equipment for the studies of ceramics, etc., include electric ovens, and a unit for measuring coefficients of expansion. Two small rooms contain chemicals and library material.

Prof. R. Schwarz is a well-known inorganic chemist. He is an editor of Gmelin's Handbuch, vice-president of the Deutsche Chemische Gesellschaft, and an authority on compounds of silicon. He published 20 scientific articles during the war (list appended). He left Königsberg late in 1944 and has been in the Böckstein area since then. The Nassfeld laboratory has been operating for only a few months and the staff consists of 5 people.

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RESEARCH PROBLEMS

1. ATTEMPTS TO MAKE HYPERNITRIC ACID, HNO_4

The first reaction attempted was between nitryl chloride NO_2Cl and 100% H_2O_2. (Schwarz and Schmeisser). The reaction was unsuccessful, presumably because most of the NO_2Cl formed in the preliminary reaction $NOCl + O_3 \rightarrow NO_2Cl + O_2$. had the structure N = O instead of O the logical precursor of HNO_4.

```
N = O    O
 !       "
O        N = O
 !       !
Cl       Cl
```

The next reactions considered were between N_2O_5 or 100% HNO_3 and H_2O_2. $HNO_3 + H_2O_2 \longrightarrow HNO_4 + H_2O$

$$N_2O_5 + H_2O_2 \longrightarrow HNO_4 + HNO_3$$

When 100% H_2O_2 was used, (R. Schwarz and U. Gregor), both of these reactions proved to be extremely violent at temperatures as low as -80 deg. C; at the temperature of liquid air, however, the reactants could be mixed without risk. As observed in a proper apparatus, the HNO_4 formed began to decompose at -80 deg C. with the liberation of small amounts of O_2. The product appeared as a light yellow pulp. On warming to -30 deg much more O_2 was evolved, and the residue proved to be pure 100% HNO_3.

Aqueous solutions of HNO_4 proved to be much more stable. A mixture of 70% HNO_3 and 30% H_2O_2 was stable at + 20 deg C. With 75% HNO_3, O_2 is liberated slowly, and the temperature increases gradually to 60 degrees C over a period of 90 minutes, when there is a very sudden increase in temperature and the whole liquid explodes. When 80% HNO_3 is used, the explosion develops in 22 minutes; with 85% HNO_3, in 18 minutes. In each case great quantities of oxygen are evolved.

2. OTHER COMPOUNDS OF NITROGEN (M. SCHMEISSER).

$NO_2 + (CN)_2$ forms a yellow solid of unknown composition. The product is explosive and may also be of interest in chemical warfare. The reaction $NOCl + KCN \longrightarrow NOCN + KCl$ also yields an explosive.

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Figure D.424: During the war, Königsberg had a large staff of inorganic chemists with world-class expertise in methods that would have been useful for reprocessing irradiated fuel from fission reactors. After the war, many of those chemists were interrogated by at least two teams from the U.S. Alsos Mission [AFHRA folder 170.2279C-1 NO DATE; AFHRA B1763 frames 0004–0034].

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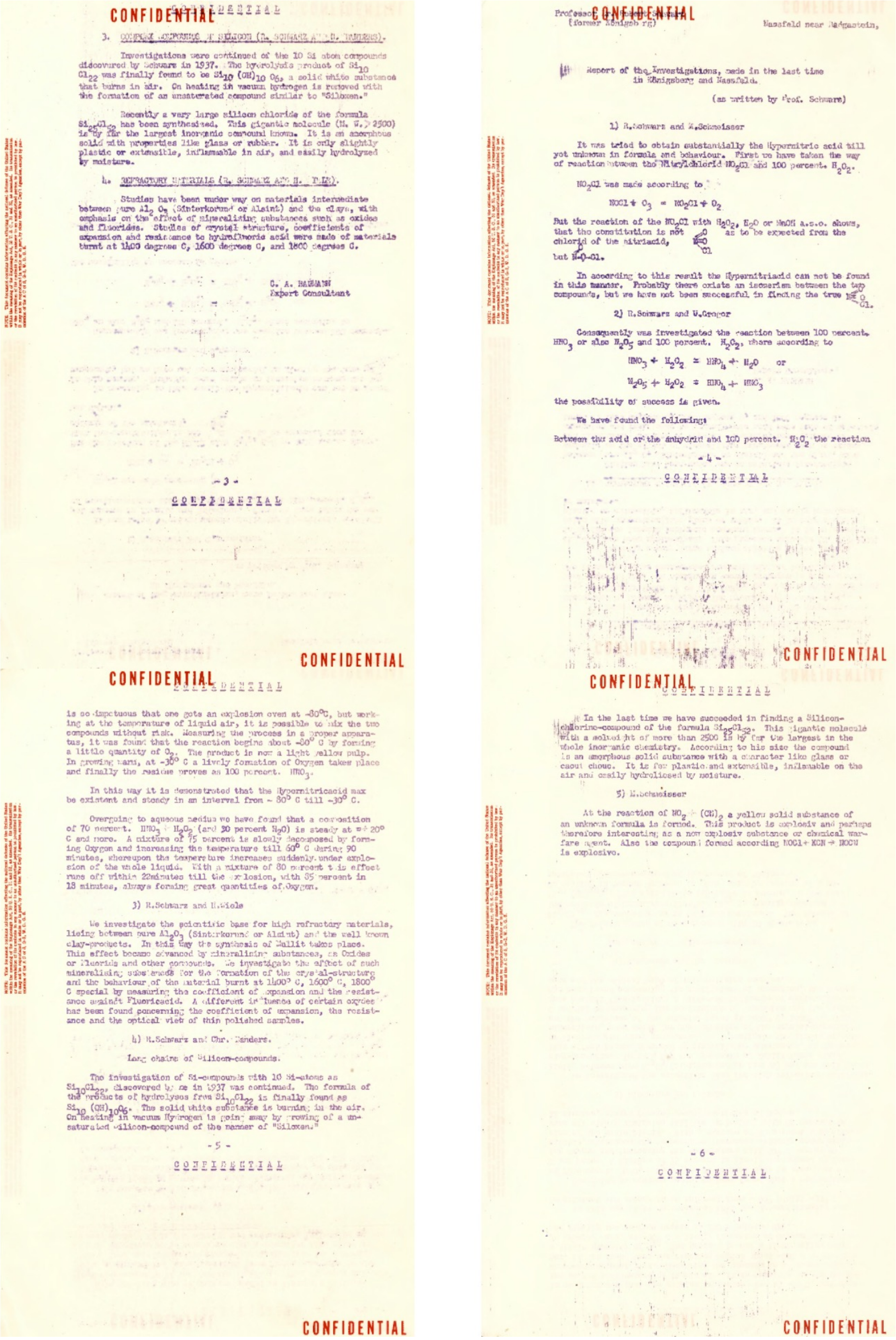

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3. COMPLEX COMPOUNDS OF SILICON (R. SCHWARZ AND C. DANDERS).

Investigations were continued of the 10 Si atom compounds discovered by Schwarz in 1937. The hydrolysis product of $Si_{10}Cl_{22}$ was finally found to be $Si_{10}(OH)_{10}O_6$, a solid white substance that burns in air. On heating in vacuum hydrogen is removed with the formation of an unsaturated compound similar to "Siloxen."

Recently a very large silicon chloride of the formula $Si_{25}Cl_{52}$ has been synthesized. This gigantic molecule (M. W. > 2500) is by far the largest inorganic compound known. It is an amorphous solid with properties like glass or rubber. It is only slightly plastic or extensible, inflammable in air, and easily hydrolyzed by moisture.

4. REFRACTORY MATERIALS (R. SCHWARZ AND H. TIELE).

Studies have been under way on materials intermediate between pure Al_2O_3 (Sinterkorund or Alsint) and the clays, with emphasis on the effect of mineralizing substances such as oxides and fluorides. Studies of crystal structure, coefficients of expansion and resistance to hydrofluoric acid were made of materials burnt at 1400 degrees C, 1600 degrees C, and 1800 degrees C.

C. A. BAUMANN
Expert Consultant

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Professor Dr. Robert Schwarz
(former Königsberg)

Nassfeld near Badgastein,

Report of the Investigations, made in the last time
in Königsberg and Nassfeld.

(as written by Prof. Schwarz)

1) R.Schwarz and M.Schmeisser

It was tried to obtain substantially the Hypernitric acid till yet unknown in formula and behaviour. First we have taken the way of reaction between the Nitrylchlorid NO_2Cl and 100 percent. H_2O_2.

NO_2Cl was made according to

$$NOCl + O_3 = NO_2Cl + O_2$$

But the reaction of the NO_2Cl with H_2O_2, H_2O or NaOH a.s.o. shows, that the constitution is not $N\overset{\nearrow O}{\underset{\searrow Cl}{=O}}$ as to be expected from the chlorid of the nitriacid, but $\overset{O}{N}$-O-Cl.

In according to this result the Hypernitriacid can not be found in this manner. Probably there exists an isomerism between the two compounds, but we have not been successful in finding the true $N\overset{\nearrow O}{\underset{\searrow Cl.}{\leftarrow O}}$

2) R.Schwarz and U.Gregor

Consequently was investigated the reaction between 100 percent. HNO_3 or also N_2O_5 and 100 percent. H_2O_2, where according to

$$HNO_3 + H_2O_2 = HNO_4 + H_2O \quad \text{or}$$

$$N_2O_5 + H_2O_2 = HNO_4 + HNO_3$$

the possibility of success is given.

We have found the following:

Between the acid or the anhydrid and 100 percent. H_2O_2 the reaction

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is so impetuous that one gets an explosion even at -80°C, but working at the temperature of liquid air, it is possible to mix the two compounds without risk. Measuring the process in a proper apparatus, it was found that the reaction begins about -80° C by forming a little quantity of O_2. The product in now a light yellow pulp. In growing warm, at -30° C a lively formation of Oxygen takes place and finally the residue proves as 100 percent. HNO_3.

In this way it is demonstrated that the Hypernitricacid max be existent and steady in an interval from - 80° C till -30° C.

Overgoing to aqueous medium we have found that a composition of 70 percent. $HNO_3 + H_2O_2$ (and 30 percent H_2O) is steady at + 20° C and more. A mixture of 75 percent is slowly decomposed by forming Oxygen and increasing the temperature till 60° C during 90 minutes, whereupon the temperature increases suddenly under explosion of the whole liquid. With a mixture of 80 percent this effect runs off within 22minutes till the explosion, with 85 percent in 18 minutes, always forming great quantities of Oxygen.

3) R.Schwarz and H.Wiele

We investigate the scientific base for high refractory materials, lieing between pure Al_2O_3 (Sinterkorund or Alsint) and the well known clay-products. In this way the synthesis of Mullit takes place. This effect became advanced by mineralising substances, as Oxides or Fluorids and other compounds. We investigate the effect of such mineralising substances for the formation of the crystal-structure and the behaviour of the material burnt at 1400° C, 1600° C, 1800° C special by measuring the coefficient of expansion and the resistance against Fluoricacid. A different influence of certain oxydes has been found concerning the coefficient of expansion, the resistance and the optical view of thin polished samples.

4) R.Schwarz and Chr. Danders.

Long chains of Silicon-compounds.

The investigation of Si-compounds with 10 Si-atoms as $Si_{10}Cl_{22}$, discovered by me in 1937 was continued. The formula of the products of hydrolyses from $Si_{10}Cl_{22}$ is finally found as $Si_{10}(OH)_{10}O_6$. The solid white substance is burning in the air. On heating in vacuum Hydrogen is going away by growing of a unsaturated silicon-compound of the manner of "Siloxen."

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In the last time we have succeeded in finding a Silicon-chlorine-compound of the formula $Si_{25}Cl_{52}$. This gigantic molecule with a molweight of more than 2500 is by far the largest in the whole inorganic chemistry. According to his size the compound is an amorphous solid substance with a character like glass or caout chouc. It is few plastic and extensible, inflamable on the air and easily hydrolicsed by moisture.

5) M.Schmeisser

At the reaction of $NO_2 + (CN)_2$ a yellow solid substance of an unknown formula is formed. This product is explosiv and perhaps therefore interesting as a new explosiv substance or chemical warfare agent. Also the compound formed according $NOCl + KCN \rightarrow NOCN$ is explosive.

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Figure D.425: During the war, Königsberg had a large staff of inorganic chemists with world-class expertise in methods that would have been useful for reprocessing irradiated fuel from fission reactors. After the war, many of those chemists were interrogated by at least two teams from the U.S. Alsos Mission [AFHRA folder 170.2279C-1 NO DATE; AFHRA B1763 frames 0004–0034].

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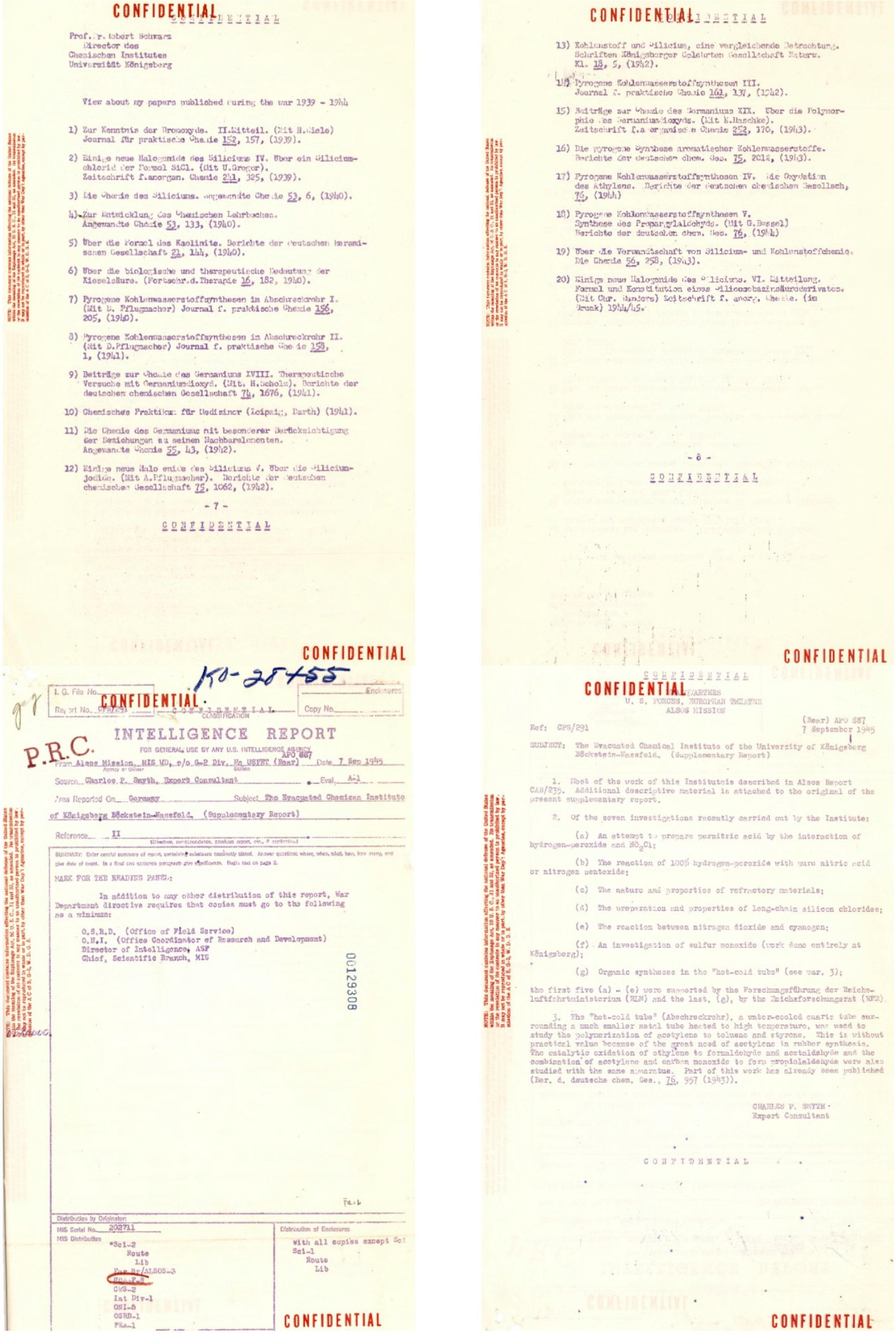

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Prof. Dr. Robert Schwarz
Director des
Chemischen Institutes
Universität Königsberg

View about my papers published during the war 1939 - 1944

1) Zur Kenntnis der Bromoxyde. II.Mitteil. (Mit H.Wiele) Journal für praktische Chemie 152, 157, (1939).

2) Einige neue Halogenide des Siliciums IV. Über ein Siliciumchlorid der Formel SiCl. (Mit U.Gregor). Zeitschrift f.anorgan. Chemie 241, 325, (1939).

3) Die Chemie des Siliciums. Angewandte Chemie 53, 6, (1940).

4) Zur Entwicklung des Chemischen Lehrbuches. Angewandte Chemie 53, 133, (1940).

5) Über die Formel des Kaolinits. Berichte der deutschen keramischen Gesellschaft 21, 144, (1940).

6) Über die biologische und therapeutische Bedeutung der Kieselsäure. (Fortschr.d.Therapie 16, 182, 1940).

7) Pyrogene Kohlenwasserstoffsynthesen im Abschreckrohr I. (Mit D. Pflugmacher) Journal f. praktische Chemie 156, 205, (1940).

8) Pyrogene Kohlenwasserstoffsynthesen im Abschreckrohr II. (Mit D.Pflugmacher) Journal f. praktische Chemie 158, 1, (1941).

9) Beiträge zur Chemie des Germaniums XVIII. Therapeutische Versuche mit Germaniumdioxyd. (Mit. H.Scholz). Berichte der deutschen chemischen Gesellschaft 74, 1676, (1941).

10) Chemisches Praktikum für Mediziner (Leipzig, Barth) (1941).

11) Die Chemie des Germaniums mit besonderer Berücksichtigung der Beziehungen zu seinen Nachbarelementen. Angewandte Chemie 55, 43, (1942).

12) Einige neue Halogenide des Siliciums V. Über die Siliciumjodide. (Mit A.Pflugmacher). Berichte der deutschen chemischen Gesellschaft 75, 1062, (1942).

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13) Kohlenstoff und Silicium, eine vergleichende Betrachtung. Schriften Königsberger Gelehrten Gesellschaft Naturw. Kl. 18, 5, (1942).

14) Pyrogene Kohlenwasserstoffsynthesen III. Journal f. praktische Chemie 161, 137, (1942).

15) Beiträge zur Chemie des Germaniums XIX. Über die Polymorphie des Germaniumdioxyds. (Mit E.Haschke). Zeitschrift f.anorganische Chemie 252, 170, (1943).

16) Die pyrogene Synthese aromatischer Kohlenwasserstoffe. Berichte der deutschen chem. Ges. 75, 2012, (1943).

17) Pyrogene Kohlenwasserstoffsynthesen IV. Die Oxydation des Äthylens. Berichte der deutschen chemischen Gesellsch, 76, (1944)

18) Pyrogene Kohlenwasserstoffsynthesen V. Synthese des Propargylaldehyds. (Mit G.Bessel) Berichte der deutschen chem. Ges. 76, (1944)

19) Über die Verwandtschaft von Silicium- und Kohlenstoffchemie. Die Chemie 56, 258, (1943).

20) Einige neue Halogenide des Siliciums. VI. Mitteilung. Formel und Konstitution eines Silicooxalsäurederivates. (Mit Chr. Danders) Zeitschrift f. anorg. Chemie. (im Druck) 1944/45.

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Agency or Officer / Station

Source Charles P. Smyth, Expert Consultant Eval. A-1

Area Reported On Germany Subject The Evacuated Chemical Institute of Königsberg Böckstein-Nassfeld, (Supplementary Report)

Reference II
(Directive, correspondence, previous report, etc., if applicable)

SUMMARY: Enter careful summary of report, containing substance succinctly stated. Answer questions where, when, what, how, how many, and give date of event. In a final one sentence paragraph give significance. Begin text on page 2.

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ALSOS MISSION

Ref: CPS/291

(Rear) APO 887
7 September 1945

SUBJECT: The Evacuated Chemical Institute of the University of Königsberg Böckstein-Nassfeld, (Supplementary Report)

1. Most of the work of this Institute is described in Alsos Report CAB/235. Additional descriptive material is attached to the original of the present supplementary report.

2. Of the seven investigations recently carried out by the Institute:

(a) An attempt to prepare pernitric acid by the interaction of hydrogen-peroxide and NO_2Cl;

(b) The reaction of 100% hydrogen-peroxide with pure nitric acid or nitrogen pentoxide;

(c) The nature and properties of refractory materials;

(d) The preparation and properties of long-chain silicon chlorides;

(e) The reaction between nitrogen dioxide and cyanogen;

(f) An investigation of sulfur monoxide (work done entirely at Königsberg);

(g) Organic syntheses in the "hot-cold tube" (see par. 3);

the first five (a) - (e) were supported by the Forschungsführung der Reichsluftfahrtministerium (RLM) and the last, (g), by the Reichsforschungsrat (RFR).

3. The "hot-cold tube" (Abschreckrohr), a water-cooled quartz tube surrounding a much smaller metal tube heated to high temperature, was used to study the polymerization of acetylene to toluene and styrene. This is without practical value because of the great need of acetylene in rubber synthesis. The catalytic oxidation of ethylene to formaldehyde and acetaldehyde and the combination of acetylene and carbon monoxide to form propiolaldehyde were also studied with the same apparatus. Part of this work has already been published (Ber. d. deutsche chem. Ges., 76, 957 (1943)).

CHARLES P. SMYTH
Expert Consultant

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Figure D.426: During the war, Königsberg had a large staff of inorganic chemists with world-class expertise in methods that would have been useful for reprocessing irradiated fuel from fission reactors. After the war, many of those chemists were interrogated by at least two teams from the U.S. Alsos Mission [AFHRA folder 170.2279C-1 NO DATE; AFHRA B1763 frames 0004–0034].

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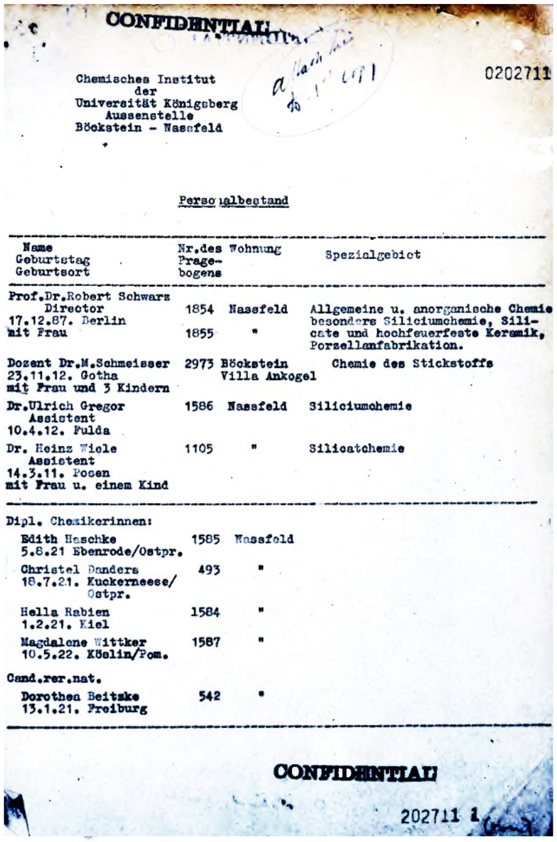

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Chemisches Institut
der
Universität Königsberg
Aussenstelle
Böckstein - Nassfeld

0202711

Personalbestand

Name Geburtstag Geburtsort	Nr.des Fragebogens	Wohnung	Spezialgebiet
Prof.Dr.Robert Schwarz Director 17.12.87. Berlin	1854	Nassfeld	Allgemeine u. anorganische Chemie besonders Siliciumchemie, Silicate und hochfeuerfeste Keramik, Porzellanfabrikation.
mit Frau	1855	"	
Dozent Dr.M.Schmeisser 23.11.12. Gotha mit Frau und 3 Kindern	2973	Böckstein Villa Ankogel	Chemie des Stickstoffs
Dr.Ulrich Gregor Assistent 10.4.12. Fulda	1586	Nassfeld	Siliciumchemie
Dr. Heinz Wiele Assistent 14.3.11. Posen mit Frau u. einem Kind	1105	"	Silicatchemie
Dipl. Chemikerinnen:			
Edith Haschke 5.8.21 Ebenrode/Ostpr.	1585	Nassfeld	
Christel Danders 18.7.21. Kuckerneese/Ostpr.	493	"	
Hella Rabien 1.2.21. Kiel	1584	"	
Magdalene Wittker 10.5.22. Köslin/Pom.	1587	"	
Cand.rer.nat.			
Dorothea Beitzke 13.1.21. Freiburg	542	"	

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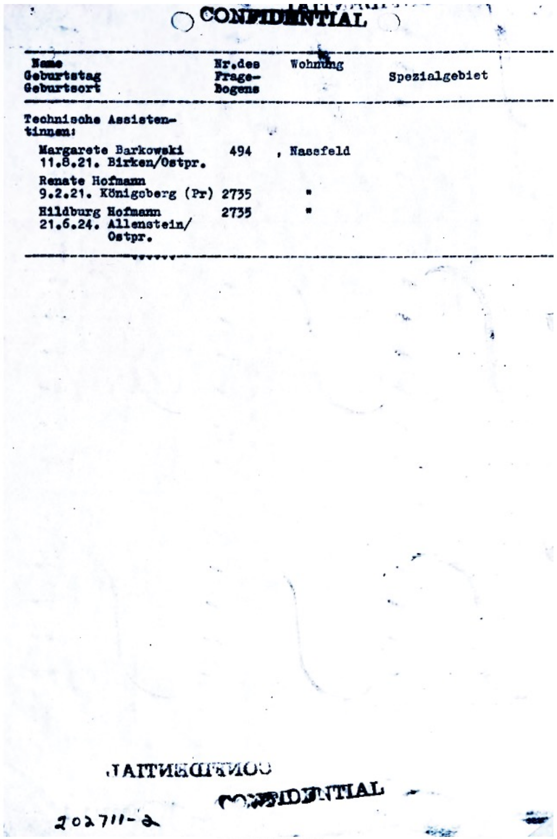

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Name Geburtstag Geburtsort	Nr.des Frage-Bogens	Wohnung	Spezialgebiet
Technische Assistentinnen:			
Margarete Barkowski 11.8.21. Birken/Ostpr.	494	, Nassfeld	
Renate Hofmann 9.2.21. Königsberg (Pr)	2735	"	
Hildburg Hofmann 21.6.24. Allenstein/Ostpr.	2735	"	

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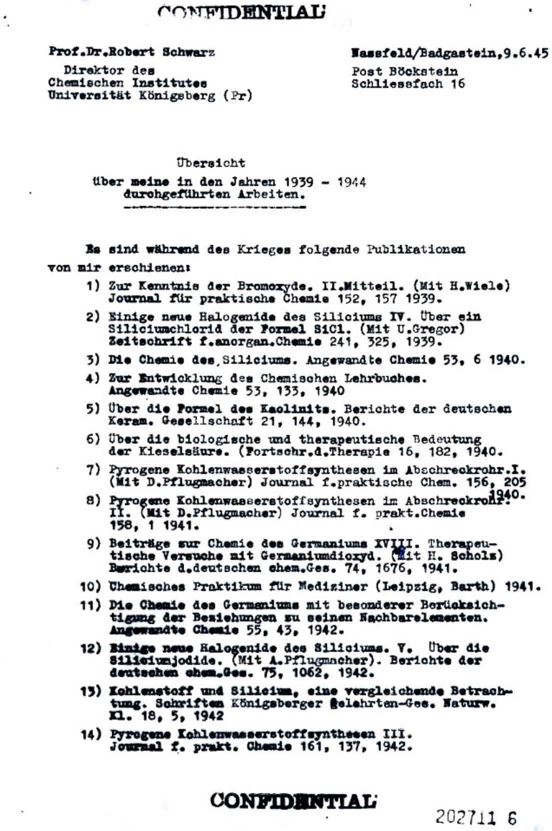

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Prof.Dr.Robert Schwarz
Direktor des
Chemischen Institutes
Universität Königsberg (Pr)

Nassfeld/Badgastein,9.6.45
Post Böckstein
Schliessfach 16

Übersicht
über meine in den Jahren 1939 - 1944
durchgeführten Arbeiten.

Es sind während des Krieges folgende Publikationen von mir erschienen:

1) Zur Kenntnis der Bromoxyde. II.Mitteil. (Mit H.Wiele) Journal für praktische Chemie 152, 157 1939.
2) Einige neue Halogenide des Siliciums IV. Über ein Siliciumchlorid der Formel SiCl. (Mit U.Gregor) Zeitschrift f.anorgan.Chemie 241, 325, 1939.
3) Die Chemie des Siliciums. Angewandte Chemie 53, 6 1940.
4) Zur Entwicklung des Chemischen Lehrbuches. Angewandte Chemie 53, 133, 1940
5) Über die Formel des Kaolinits. Berichte der deutschen Keram. Gesellschaft 21, 144, 1940.
6) Über die biologische und therapeutische Bedeutung der Kieselsäure. (Fortschr.d.Therapie 16, 182, 1940.
7) Pyrogene Kohlenwasserstoffsynthesen im Abschreckrohr.I. (Mit D.Pflugmacher) Journal f.praktische Chem. 156, 205 1940.
8) Pyrogene Kohlenwasserstoffsynthesen im Abschreckrohr. II. (Mit D.Pflugmacher) Journal f. prakt.Chemie 158, 1 1941.
9) Beiträge zur Chemie des Germaniums XVIII. Therapeutische Versuche mit Germaniumdioxyd. (Mit H. Scholz) Berichte d.deutschen chem.Ges. 74, 1676, 1941.
10) Chemisches Praktikum für Mediziner (Leipzig, Barth) 1941.
11) Die Chemie des Germaniums mit besonderer Berücksichtigung der Beziehungen zu seinen Nachbarelementen. Angewandte Chemie 55, 43, 1942.
12) Einige neue Halogenide des Siliciums. V. Über die Siliciumjodide. (Mit A.Pflugmacher). Berichte der deutschen chem.Ges. 75, 1062, 1942.
13) Kohlenstoff und Silicium, eine vergleichende Betrachtung. Schriften Königsberger Gelehrten-Ges. Naturw. Kl. 18, 5, 1942
14) Pyrogene Kohlenwasserstoffsynthesen III. Journal f. prakt. Chemie 161, 137, 1942.

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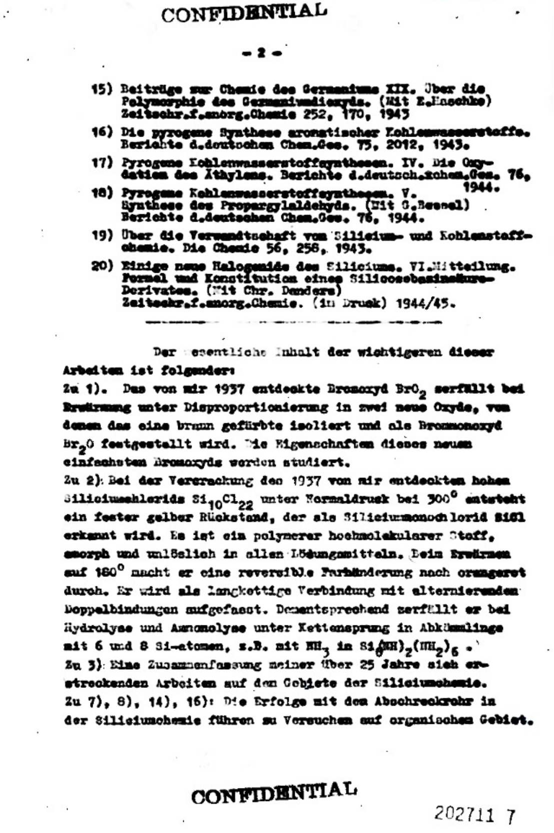

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15) Beiträge zur Chemie des Germaniums XIX. Über die Polymorphie des Germaniumdioxyds. (Mit E.Haschke) Zeitschr.f.anorg.Chemie 252, 170, 1943
16) Die pyrogene Synthese aromatischer Kohlenwasserstoffe. Berichte d.deutschen Chem.Ges. 75, 2012, 1943.
17) Pyrogene Kohlenwasserstoffsynthesen. IV. Die Oxydation des Äthylens. Berichte d.deutsch.chem.Ges. 76, 1944.
18) Pyrogene Kohlenwasserstoffsynthesen. V. Synthese des Propargylaldehyds. (Mit G.Bessel) Berichte d.deutschen Chem.Ges. 76, 1944.
19) Über die Verwandtschaft von Silicium- und Kohlenstoffchemie. Die Chemie 56, 256, 1943.
20) Einige neue Halogenide des Siliciums. VI.Mitteilung. Formel und Konstitution eines Silicosebasinsäure-Derivates. (Mit Chr. Danders) Zeitschr.f.anorg.Chemie. (in Druck) 1944/45.

Der wesentliche Inhalt der wichtigeren dieser Arbeiten ist folgender:

Zu 1). Das von mir 1937 entdeckte Bromoxyd BrO_2 zerfällt bei Erwärmung unter Disproportionierung in zwei neue Oxyde, von denen das eine braun gefärbte isoliert und als Brommonoxyd Br_2O festgestellt wird. Die Eigenschaften dieses neuen einfachsten Bromoxyds werden studiert.

Zu 2): Bei der Vercrackung des 1937 von mir entdeckten hohen Siliciumchlorids $Si_{10}Cl_{22}$ unter Normaldruck bei 300° entsteht ein fester gelber Rückstand, der als Siliciummonochlorid SiCl erkannt wird. Es ist ein polymerer hochmolekularer Stoff, amorph und unlöslich in allen Lösungsmitteln. Beim Erwärmen auf 180° macht er eine reversible Farbänderung nach orangerot durch. Er wird als langkettige Verbindung mit alternierenden Doppelbindungen aufgefasst. Dementsprechend zerfällt er bei Hydrolyse und Ammonolyse unter Kettensprung in Abkömmlinge mit 6 und 8 Si-atomen, z.B. mit NH_3 in $Si_6(NH)_2(NH_2)_6$.

Zu 3): Eine Zusammenfassung meiner über 25 Jahre sich erstreckenden Arbeiten auf dem Gebiete der Siliciumchemie.

Zu 7), 8), 14), 16): Die Erfolge mit dem Abschreckrohr in der Siliciumchemie führen zu Versuchen auf organischem Gebiet.

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Figure D.427: During the war, Königsberg had a large staff of inorganic chemists with world-class expertise in methods that would have been useful for reprocessing irradiated fuel from fission reactors. After the war, many of those chemists were interrogated by at least two teams from the U.S. Alsos Mission [AFHRA folder 170.2279C-1 7 SEP 1945; AFHRA B1763 frames 0004–0034].

8. A possible fission reactor at I.G. Farben Leverkusen

Horace K. Calvert to Francis J. Smith. 29 January 1945. Subject: I.G. Farben Plant, LEVERKUSEN. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

29 January 1945

Subject: I.G. Farben Plant, LEVERKUSEN

To: Major Francis J. Smith
Room 5119, New War Dept. Bldg., Washington, D.C.

1. The following information has been extracted from a PW report dated 11 January 1945:

> "At the LEVERKUSEN I G Farben Works, PW learned through an uncle, who is a director, that a special department has been installed in concrete structures like pill-boxes, to which access is gained only through special passes, even high-ranking officers being refused admission under a special order issued 18 Nov by factory police. There is heavy A.A. defence of all calibers, and the general belief is that experiments are being made with special weapons of some kind."

2. The PW is Obergefreiter, captured between Bastogne and Longvilly 30 December 1944. He was serving as a messenger for the 7th Co., III Battalion, 31st Regt, 167th Volksgrenadier Div. 18. Oct 44 his home in Bonn was bombed out, and he applied for 30 days' leave. During November he made a trip through most of southern Germany to find a place to resettle his family.

3. There is enclosed herewith three interpretation reports covering I.G. Farben, Leverkusen. As heavy concrete constructions are characteristic of some phases of our project, it is believed that these interpretation reports and photos should be made available to technicians available to your office for their interpretation as being of interest to us.

For the Military Attaché:

H. K. CALVERT
Major, F.A.
Assistant to the Military Attaché.

Incls. 3 reports:
No. D.251; D.918R; D.643(R)

[See document photo on p. 3935.

There was a highly secret, heavy concrete installation at the I.G. Farben Leverkusen plant that the Manhattan Project's Foreign Intelligence Unit believed could be a fission reactor. (Alternatively, it might have been a uranium enrichment facility.) It is known that I.G. Farben Leverkusen was doing extensive work involving uranium hexafluoride throughout the war, and that other I.G. Farben facilities were producing many other potentially nuclear-related materials.

Where are all the detailed reports on this interrogation, any other wartime intelligence on this site, and postwar inspections of this site and interrogations of personnel who worked there?]

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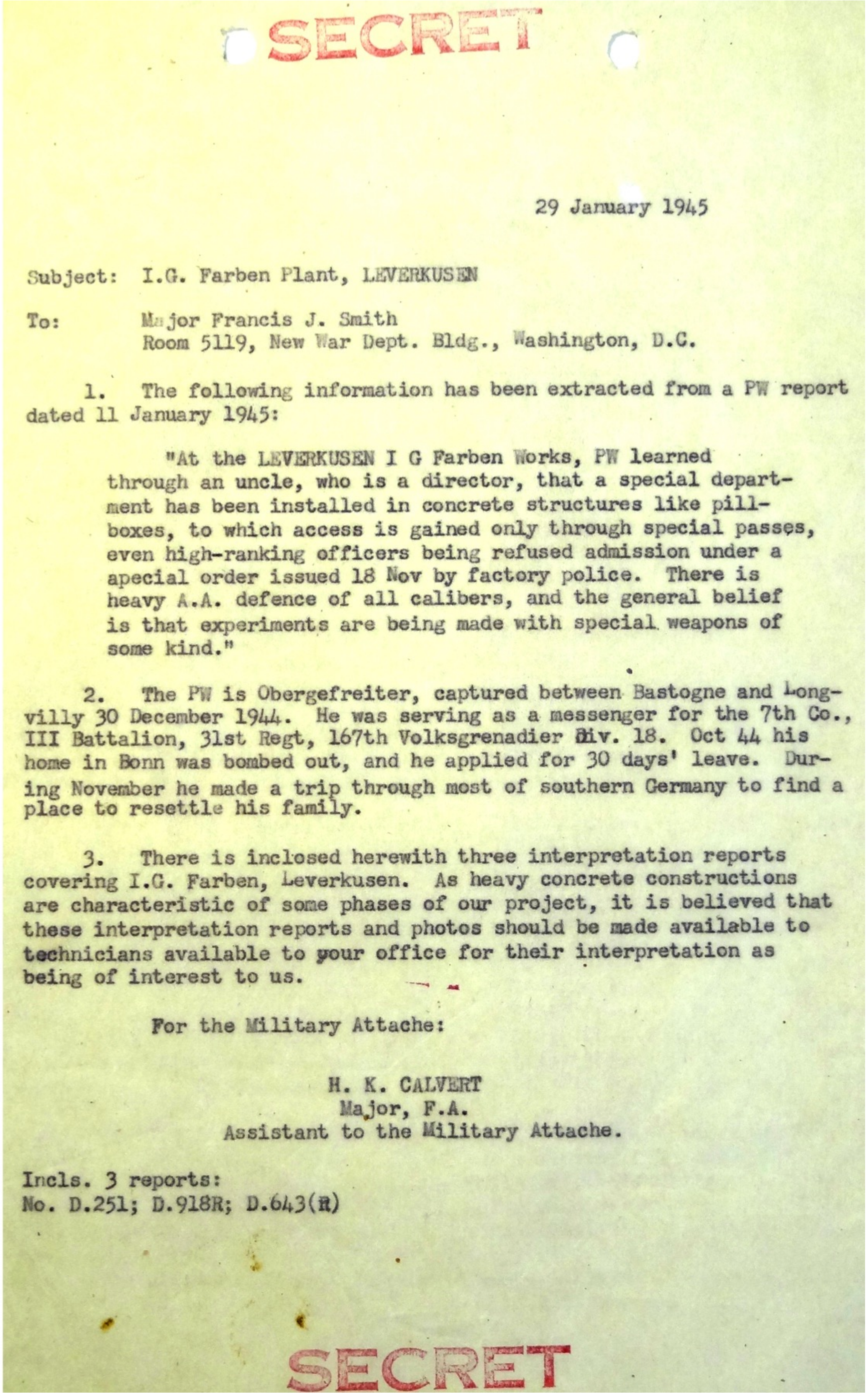
NARA RG 77, Entry UD-22A, Box 171,
Folder 32.7003-3 GERMANY:
US Wartime Positive Int. (Nov. 44--June 45)



SECRET

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For the Military Attache:

H. K. CALVERT
Major, F.A.
Assistant to the Military Attache.

Incls. 3 reports:
No. D.251; D.918R; D.643(R)

SECRET

Figure D.428: There was a highly secret, heavy concrete installation at the I.G. Farben Leverkusen plant that the Manhattan Project's Foreign Intelligence Unit believed could be a fission reactor. Horace K. Calvert to Francis J. Smith. 29 January 1945. Subject: I.G. Farben Plant, LEVERKUSEN [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

9. A possible fission reactor at Bodenbach/Krizik-Werke/Weser-Werke/Podmokly

[Several interrelated facilities in this area went by various names. There is a great deal of evidence that these facilities were doing nuclear work, including building particle accelerators (pp. 3979–4022). Currently there is a smaller yet intriguing set of evidence that these facilities possessed or were working on a fission reactor.]

Joint Intelligence Committee. Exploitation of German Scientists and Technicians. 5 January 1946. J.I.C. 317/10. [NARA RG 218, Entry UD-1, Box 475, Folder CCS 471.9... (5-1-45)... Sec. 3]

APPENDIX "C"

U.S.S.R. EXPLOITATION OF GERMAN SCIENTISTS AND TECHNICIANS

1. Interrogation of qualified German personnel both in Europe and this country, as well as numerous intelligence reports, all indicate that long-range exploitation of German scientific and technical personnel and facilities is both thorough and intelligent throughout the Soviet Zone. Briefly the situation in some fields is:

a. Atomic research: The 7 top men working on atomic research in Germany were: Prof. HEISENBERG, Prof. HERTZ, Baron VON ARDENNE, Prof. BOTHE, Prof. STETTER, Dr. GERLACH, and Prof. BEWILOGUA. Of these HERTZ, BEWILOGUA, VON ARDENNE, and BOTHE (Formerly in the U.S. Zone) are now working for the U.S.S.R. with many of their assistants. Practically the entire staff of the German "URANMOTOR" Project at KRIZIK in Czechoslovakia under Prof. HUETTIG is working for the U.S.S.R., so are large numbers of the staff of the Kaiser Wilhelm Institute connected with atomic research.

[See the document photos on pp. 3993–3996.]

T. M. Odarenko. 26 October 1945. Problem of Displaced Scientists Now Residing in the American Zone of Austria. [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)]

6. Among these evacuees there is a very large group of capable scientists who worked in the field of nuclear physics and chemistry and who have been carrying this work with such facilities as they have been able to assemble. There are two (or possibly more) institutes which were directly involved before the end of the war in a secret German project called "Uranmotor" whose purpose was to split uran atoms in order to obtain a powerful source of intra-atomic energy. It is apparent that the end result of this work is a method of obtaining an explosive release of atomic energy, or atomic bomb. The two groups definitely identified with the Uranmotor project are Kaiser Wilhelm Institute and Institut für Neutronenforschung. Professor Stetter, Professor Mattauch, Professor Thirring, Dr. Schintlmeister, Dr. Jentschke, Dr. Ortner, Dr. Ing. F. Focke are some of the names reported to the undersigned to have been directly involved in the project and capable of completing it as soon as the opportunity will present itself.

[See document photos on pp. 4790–4795. Franz Focke, mentioned in the above document, was a longtime technician at Bodenbach/Krizik. The following two documents report on some of his postwar interrogations.]

Headquarters, United States Forces in Austria. 10 October 1949. Focke, Franz—Atomic Energy Scientist. [NARA RG 319, Entry A1-134B, Box ??, Folder XE065437 Focke, Franz]

Subject claims that he started research work in the atomic energy field in 1920, using the laboratories of the Krizik Chaudoir firm at Bodenbach, CSR. Subject also stated that the main purpose of his work was to convert uranium ore and radium combinations to electrical energy and to accelerate the decomposition of uranium and radium. Subject also stated that in 1945 he had in his possession approximately 4 pounds of uranium value at 20,000 Marks.

[See the document photo on p. 3985.]

Headquarters, United States Forces in Austria. 10 October 1949. Focke, Franz—Atomic Energy Specialist. [NARA RG 319, Entry A1-134B, Box ??, Folder XE065437 Focke, Franz]

Subject is a very interesting case and one who requires careful evaluation. He has a better than average knowledge of atomic energy and it would seem impossible to class him as peculiar or a crackpot. He has written his letters in such a manner that he has covered the entire field of nuclear research and experimentation, some sections of which have high intelligence value. [...]

His statement about possession of 4 pounds of uranium valued at 20,000 Marks is also suspicious. Also, there was once a report of an atomic pile operated by Russians at Bodenbach, CSR, which we now believe to be false.

[See the document photo on p. 3986.

According to Franz Focke, a longtime technician at Bodenbach/Krizik, nuclear research began there no later than 1920, continued through World War II, and resulted in a fission reactor there that fell under Soviet control after the war. The interrogators were skeptical about the reactor claim, but it is consistent with the large amount of other nuclear-related work at that same site (pp. 3979–4022).

The famous German film director Fritz Lang moved to the United States in 1933 and continued making movies there. In 1946, Lang directed the film *Cloak and Dagger* for the Warner Bros. studio. *Cloak and Dagger* presented a fictionalized story of how during World War II, OSS and European resistance members investigated and combatted the German nuclear weapons program. As scripted and filmed, the movie ended with a visually impressive and highly expensive sequence in which U.S. forces bomb several German nuclear weapons factories and visit another one in person. However, before the film was released, that entire sequence was censored and apparently destroyed.

Although *Cloak and Dagger* was fiction, Lang's story descriptions and the script versions included an extraordinary number of details that agree stunningly well with real information about the German nuclear weapons program which was not publicly known in late 1945/early 1946 when the film was being written and shot (pp. 5076–5081). Among other details, in early versions of the script the final German nuclear weapons facility that was stormed by U.S. forces was a breeder fission reactor at Bodenbach.]

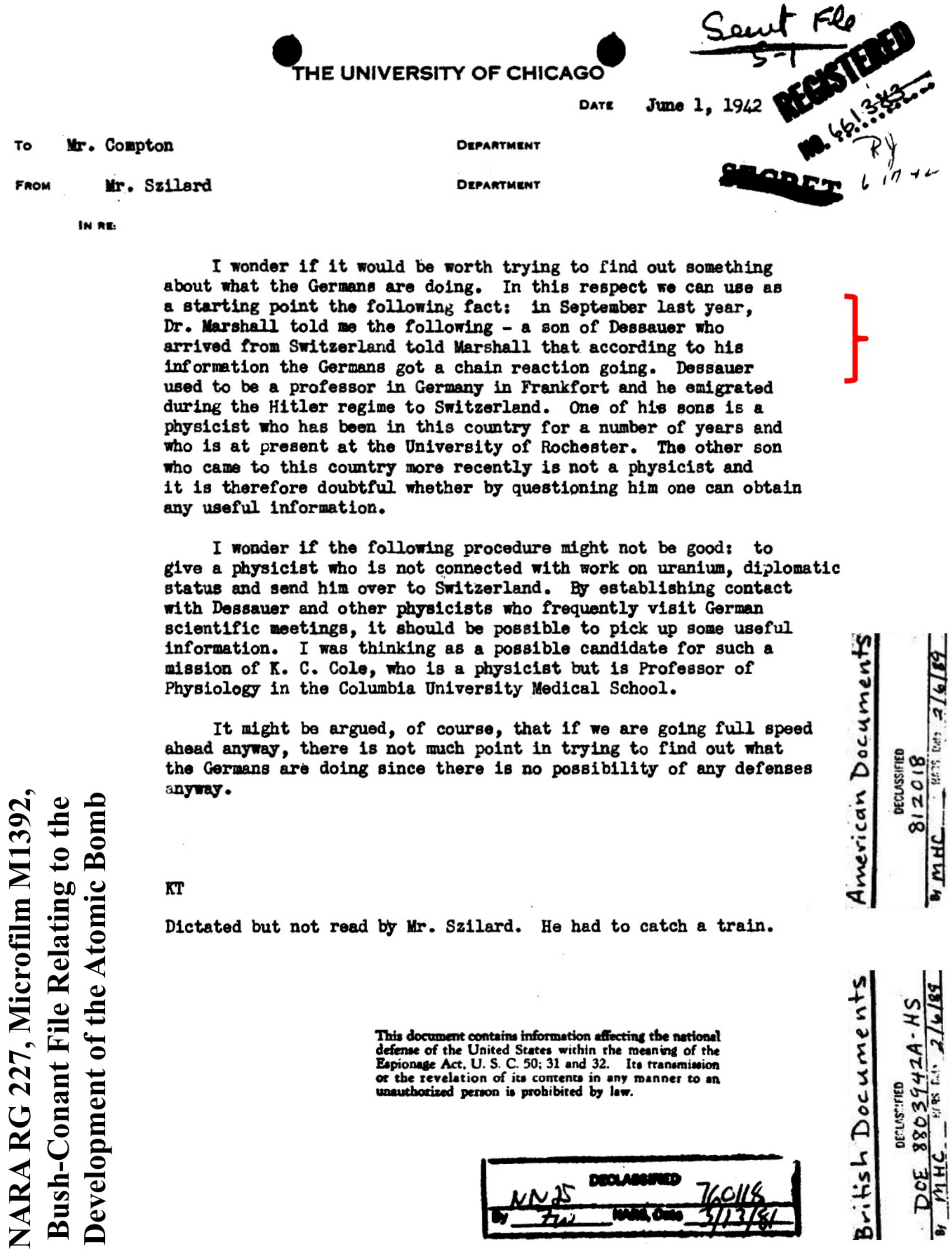
10. Other possible fission reactors

[In addition to the known or reported reactors at the sites already mentioned, there may have been other fission reactors within German-controlled territory during the war. The following pages present some of the evidence suggesting the existence of other reactors.]

Leo Szilard to Karl Taylor Compton. 1 June 1942 [NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb, https://downloads.paperlessarchives.com, p. 6148]. See document photo on p. 3939.

I wonder if it would be worth trying to find out something about what the Germans are doing. In this respect we can use as a starting point the following fact: in September last year [1941], Dr. Marshall told me the following—a son of Dessauer who arrived from Switzerland told Marshall that according to his information the Germans got a chain reaction going. Dessauer used to be a professor in Germany in Frankfort and he emigrated during the Hitler regime to Switzerland. One of his sons is a physicist who has been in this country for a number of years and who is at present at the University of Rochester. The other son who came to this country more recently is not a physicist and it is therefore doubtful whether by questioning him one can obtain any useful information.

[Was this only a report of one of the subcritical fission experiments, or did a German fission reactor at an unknown site achieve criticality by 1941–1942?]



Secret File
S-1

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No. 661.3
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THE UNIVERSITY OF CHICAGO

DATE June 1, 1942

TO Mr. Compton DEPARTMENT

FROM Mr. Szilard DEPARTMENT

IN RE:

I wonder if it would be worth trying to find out something about what the Germans are doing. In this respect we can use as a starting point the following fact: in September last year, Dr. Marshall told me the following - a son of Dessauer who arrived from Switzerland told Marshall that according to his information the Germans got a chain reaction going. Dessauer used to be a professor in Germany in Frankfort and he emigrated during the Hitler regime to Switzerland. One of his sons is a physicist who has been in this country for a number of years and who is at present at the University of Rochester. The other son who came to this country more recently is not a physicist and it is therefore doubtful whether by questioning him one can obtain any useful information.

I wonder if the following procedure might not be good: to give a physicist who is not connected with work on uranium, diplomatic status and send him over to Switzerland. By establishing contact with Dessauer and other physicists who frequently visit German scientific meetings, it should be possible to pick up some useful information. I was thinking as a possible candidate for such a mission of K. C. Cole, who is a physicist but is Professor of Physiology in the Columbia University Medical School.

It might be argued, of course, that if we are going full speed ahead anyway, there is not much point in trying to find out what the Germans are doing since there is no possibility of any defenses anyway.

KT

Dictated but not read by Mr. Szilard. He had to catch a train.

This document contains information affecting the national defense of the United States within the meaning of the Espionage Act, U. S. C. 50; 31 and 32. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

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NND 760118
By NARA, Date 3/13/81

American Documents
DECLASSIFIED
812018
By MHC NARS, Date 2/6/89

British Documents
DECLASSIFIED
DOE 8803942A-HS
By MHC NARS, Date 2/6/89

NARA RG 227, Microfilm M1392,
Bush-Conant File Relating to the
Development of the Atomic Bomb

Figure D.429: Leo Szilard to Karl Taylor Compton. 1 June 1942 [NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb, https://downloads.paperlessarchives.com, p. 6148]. Was this only a report of one of the subcritical fission experiments, or did a German fission reactor at an unknown site achieve criticality by 1941–1942?

Gerhard Dessauer (University of Rochester Department of Physics) to Leo Szilard. 6 July 1942 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)]. See document photo on p. 3941.

Upon the request of V. Weisskopf I am quoting a few lines of a letter I received from my father on July 1st.

My father, Dr. E. Dessauer, teaches Physics at the University of Fribourg (Switzerland). Dr. W. Gentner's—the German nuclear physicist's—parents-in-law, Dr. and Mrs. P. Pfaehler were very close friends of my father. The Pfaehlers died early this year so that Dr. and Mrs. Gentner will no longer have the occasional permission by the German Government to go to Switzerland.

As Gentner did his Ph.D. work under my father at Frankfurt (Germany) (where he also met his wife) he used to visit my parents rather regularly whenever he came to Switzerland.

In his letter of April 1st (which I received on July 1st) my father mentions that he had a long talk with Gentner in Bern before saying good-bye for an indefinite time. Later on in the letter my father writes:

> "Ich erfuhr, dass die Kettenreaktion des Uranisotops jetzt gelingt. Sie ist nicht explosiv, aber die Aussicht auf technische Verwertung besteht nunmehr."

> ["I learned that the chain reaction of the uranium isotope is now successful. It is not explosive, but there is now the prospect of technical utilization."]

There is no explicit connection of this statement with the conversations with Gentner in the letter, but he may have heard that from Gentner. [...]

[Was this only a report of one of the subcritical fission experiments, or did a German fission reactor at an unknown site achieve criticality by 1941–1942?]

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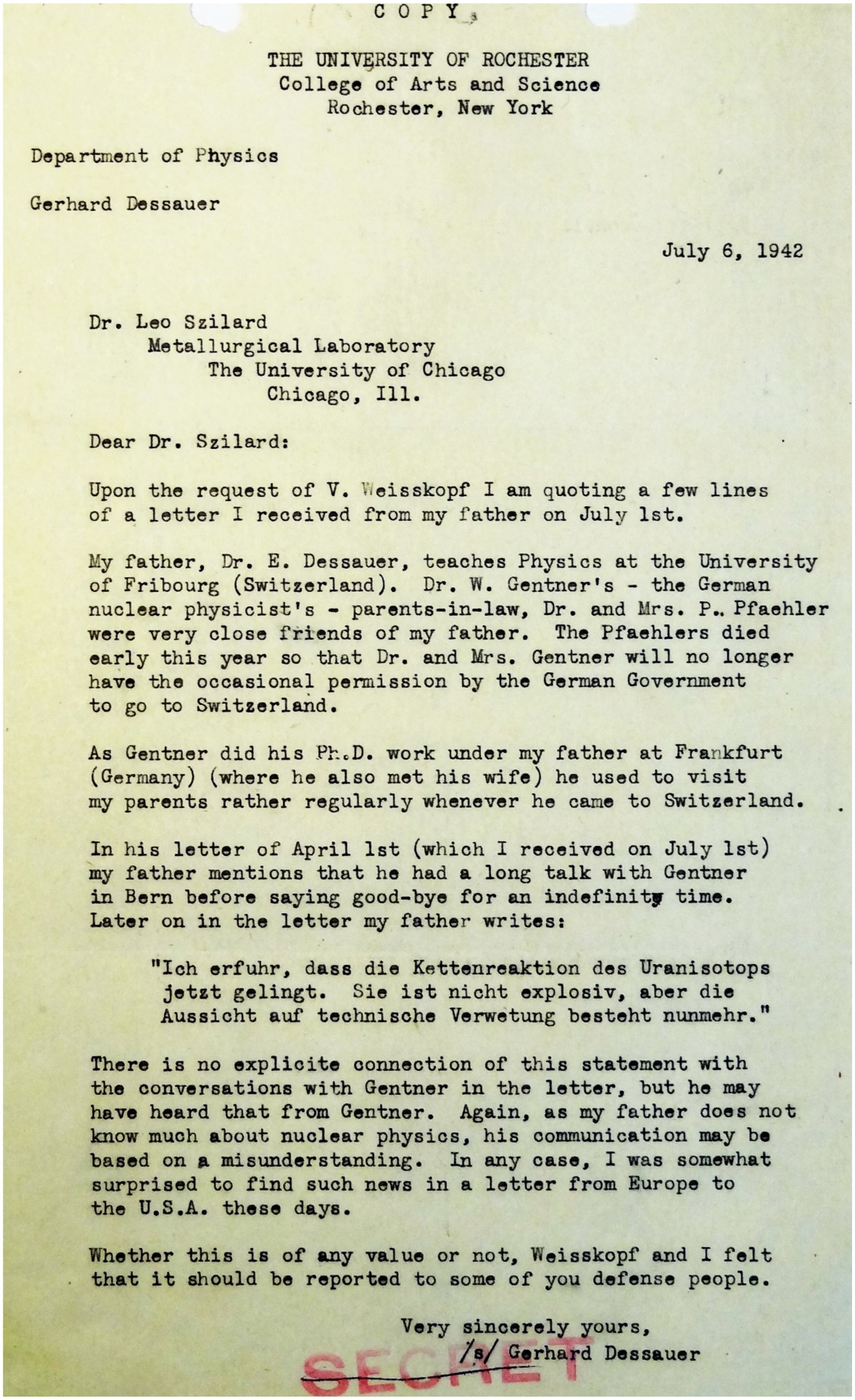

COPY

THE UNIVERSITY OF ROCHESTER
College of Arts and Science
Rochester, New York

Department of Physics

Gerhard Dessauer

July 6, 1942

Dr. Leo Szilard
Metallurgical Laboratory
The University of Chicago
Chicago, Ill.

Dear Dr. Szilard:

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There is no explicite connection of this statement with the conversations with Gentner in the letter, but he may have heard that from Gentner. Again, as my father does not know much about nuclear physics, his communication may be based on a misunderstanding. In any case, I was somewhat surprised to find such news in a letter from Europe to the U.S.A. these days.

Whether this is of any value or not, Weisskopf and I felt that it should be reported to some of you defense people.

Very sincerely yours,
/s/ Gerhard Dessauer

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NARA RG 77, Entry UD-22A, Box 171, Folder
32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)

Figure D.430: Gerhard Dessauer to Leo Szilard. 6 July 1942 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)]. Was this only a report of one of the subcritical fission experiments, or did a German fission reactor at an unknown site achieve criticality by 1941–1942?

Manhattan Engineering District Foreign Intelligence Unit. 3 April 1944. Activities from 13 March to 31 March 1944. [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)] See document photo on p. 3943.

6. OSS received important cables on developments in Norway and scientific activities in Germany. Their Italian organization undertook the Shark Mission for the procurement of important Italian scientific personnel. [...]

8. Mr. Chapin reported successful detection experiments and requested aircraft study. [...]

10. Positive intelligence summary report was presented on 7 March 1944.

[In March 1944, Leslie Groves's Foreign Intelligence Unit reported "successful detection experiments" of German radioactivity (most likely from an operating fission reactor) and requested aerial surveillance photos of that German site.

Where are the detailed reports?]

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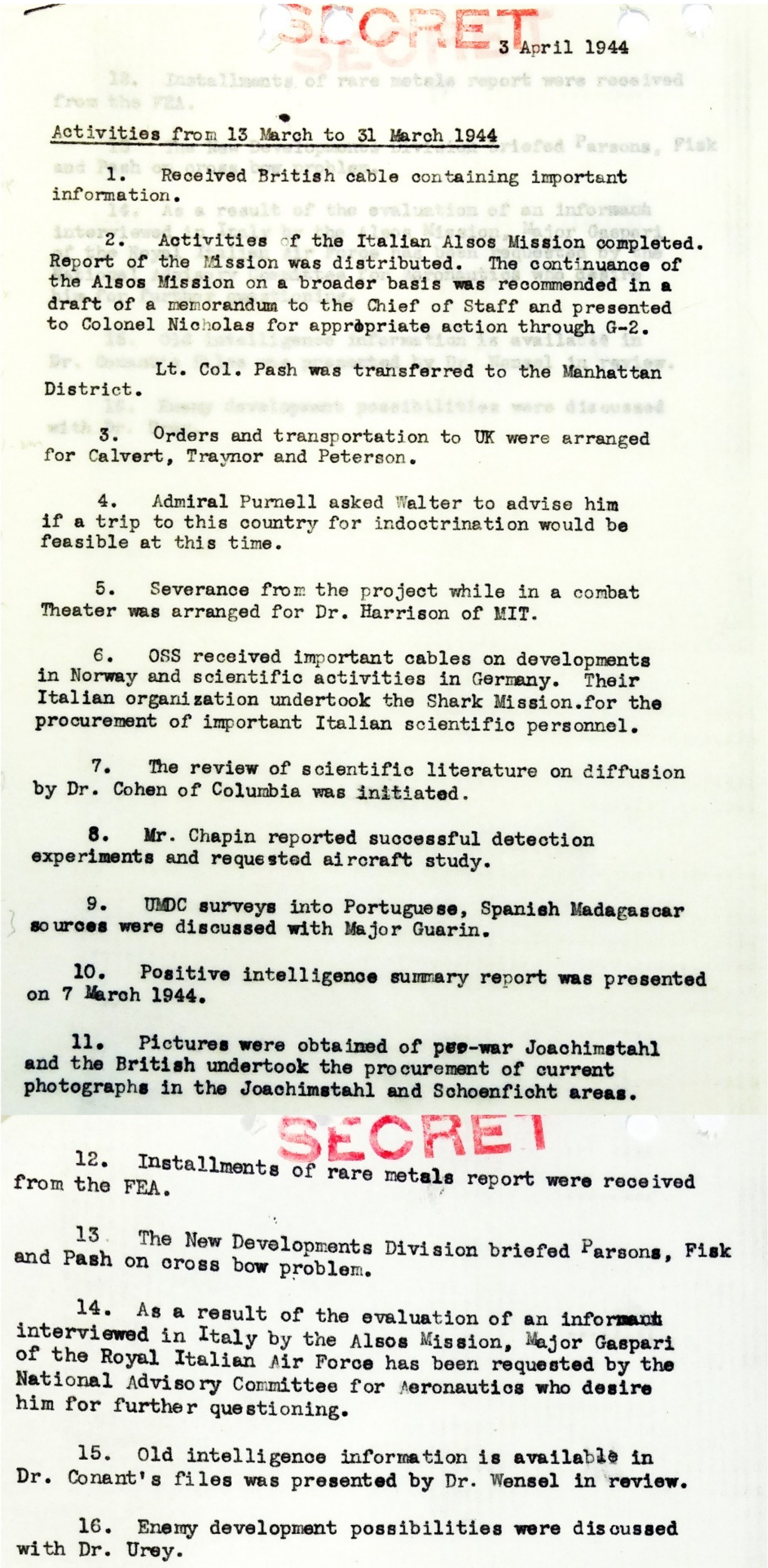
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)



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3 April 1944

Activities from 13 March to 31 March 1944

1. Received British cable containing important information.

2. Activities of the Italian Alsos Mission completed. Report of the Mission was distributed. The continuance of the Alsos Mission on a broader basis was recommended in a draft of a memorandum to the Chief of Staff and presented to Colonel Nicholas for appropriate action through G-2.

Lt. Col. Pash was transferred to the Manhattan District.

3. Orders and transportation to UK were arranged for Calvert, Traynor and Peterson.

4. Admiral Purnell asked Walter to advise him if a trip to this country for indoctrination would be feasible at this time.

5. Severance from the project while in a combat Theater was arranged for Dr. Harrison of MIT.

6. OSS received important cables on developments in Norway and scientific activities in Germany. Their Italian organization undertook the Shark Mission.for the procurement of important Italian scientific personnel.

7. The review of scientific literature on diffusion by Dr. Cohen of Columbia was initiated.

8. Mr. Chapin reported successful detection experiments and requested aircraft study.

9. UMDC surveys into Portuguese, Spanish Madagascar sources were discussed with Major Guarin.

10. Positive intelligence summary report was presented on 7 March 1944.

11. Pictures were obtained of pre-war Joachimstahl and the British undertook the procurement of current photographs in the Joachimstahl and Schoenficht areas.

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12. Installments of rare metals report were received from the FEA.

13 The New Developments Division briefed Parsons, Fisk and Pash on cross bow problem.

14. As a result of the evaluation of an informant interviewed in Italy by the Alsos Mission, Major Gaspari of the Royal Italian Air Force has been requested by the National Advisory Committee for Aeronautics who desire him for further questioning.

15. Old intelligence information is available in Dr. Conant's files was presented by Dr. Wensel in review.

16. Enemy development possibilities were discussed with Dr. Urey.

Figure D.431: In March 1944, Leslie Groves's Foreign Intelligence Unit reported "successful detection experiments" of German radioactivity (most likely from an operating fission reactor) and requested aerial surveillance photos of that German site. Where are the detailed reports? [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]

Frederic A. C. Wardenburg and James A. Lane. 5 April 1945. SUBJECT: Interrogation of Dr. Kohl, Works Manager of Degussa Plant No. 2, Frankfurt. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA (1943–June 1946)]

1. Dr. Kohl was interrogated in Frankfurt on 3 April 1945 by J. A. Lane and F. A. C. Wardenburg. Dr. Kessler, one of his assistants and also his secretary were present during the interrogation and were called on from time to time by Dr. Kohl on matters of detail.

2. Uranium metal, which was known by the code name of "Spezialmetall", was manufactured at the Degussa, Frankfurt plant. According to Dr. Kohl the material was required by the Reichsforschungsrat and all administrative matters were handled by Auergesellschaft in Oranienburg directly with RFR. Degussa acted as a sub-contractor for Auer. All deliveries from the Frankfurt plant were made either to Auer or to the RFR at Berlin-Dahlem. The use of the material was secret. Dr. Kohl believed that it had something to do with experiments in atomic physics. The material was manufactured in a purity of 98 to 99 percent from ammonium uranate which was converted to the oxide U_3O_8. The ammonium uranate was secured either from the Joachimsthal mines or from Katanga (Union Minière du Haut Katanga).

3. Earlier, metallic uranium was mixed with coal dust (carbon?) and with Tragacanth gum as a binding material and pressed into blocks, approximately 50% by weight of coal and uranium. The blocks were approximately 5 cm x 5 cm x 6 cm. About five tons as metallic uranium in total were delivered in this form. The material is now delivered as powdered metallic uranium, production being between one and two tons, making a total uranium production of between six and seven tons.

4. We visited the site of the plant which had been partially destroyed. The equipment was moved in December to a location in Markbrandenburg where Dr. Kohl believed the RFR had a branch. A part of the equipment was moved to the plant of the Chemische Fabrik Grunau at Grunau near Berlin. Dr. Kohl thought it might have been moved again but he did not know the exact location, but suggested somewhere in Thüringen as a probable evacuation address.

[See document photo on p. 3945.

This Degussa plant produced at least 10 tons of blocks containing 50% uranium and 50% graphite. No publicly known German fission reactors used such fuel blocks, so they must have been requisitioned for a graphite-moderated reactor that is not publicly known.

Even though Dr. Kohl, the works manager of the Degussa plant, aided by his staff, had given U.S. investigators a detailed description of the 10 tons of 50% uranium–50% carbon 5x5x6 cm blocks that had been produced there, the technical director Dr. Baerwind was curiously quick to deny and deflect the investigators' questions when he was separately asked about those blocks. See pp. 3946–3947.]

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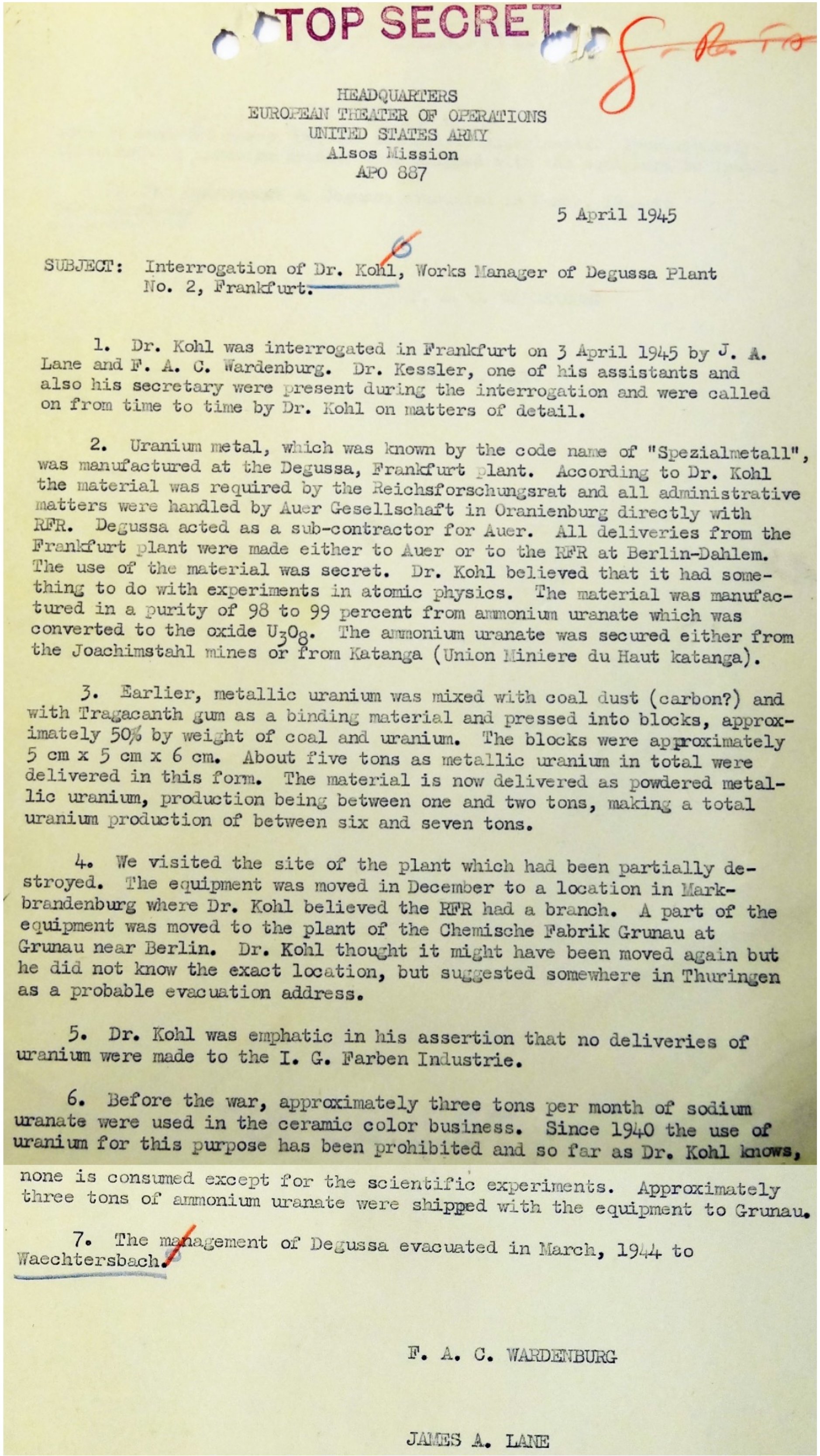
NARA RG 77, Entry UD-22A, Box 166, Folder
32.22-1 GERMANY—Research—TA (1943–June 1946)



TOP SECRET

HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
Alsos Mission
APO 887

5 April 1945

SUBJECT: Interrogation of Dr. Kohl, Works Manager of Degussa Plant No. 2, Frankfurt.

6

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5. Dr. Kohl was emphatic in his assertion that no deliveries of uranium were made to the I. G. Farben Industrie.

6. Before the war, approximately three tons per month of sodium uranate were used in the ceramic color business. Since 1940 the use of uranium for this purpose has been prohibited and so far as Dr. Kohl knows, none is consumed except for the scientific experiments. Approximately three tons of ammonium uranate were shipped with the equipment to Grunau.

7. The management of Degussa evacuated in March, 1944 to Waechtersbach.

F. A. C. WARDENBURG

JAMES A. LANE

Figure D.432: This Degussa plant produced at least 10 tons of blocks containing 50% uranium metal and 50% graphite. No publicly known German fission reactors used such fuel blocks, so they must have been requisitioned for a graphite-moderated reactor that is not publicly known [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA (1943–June 1946)].

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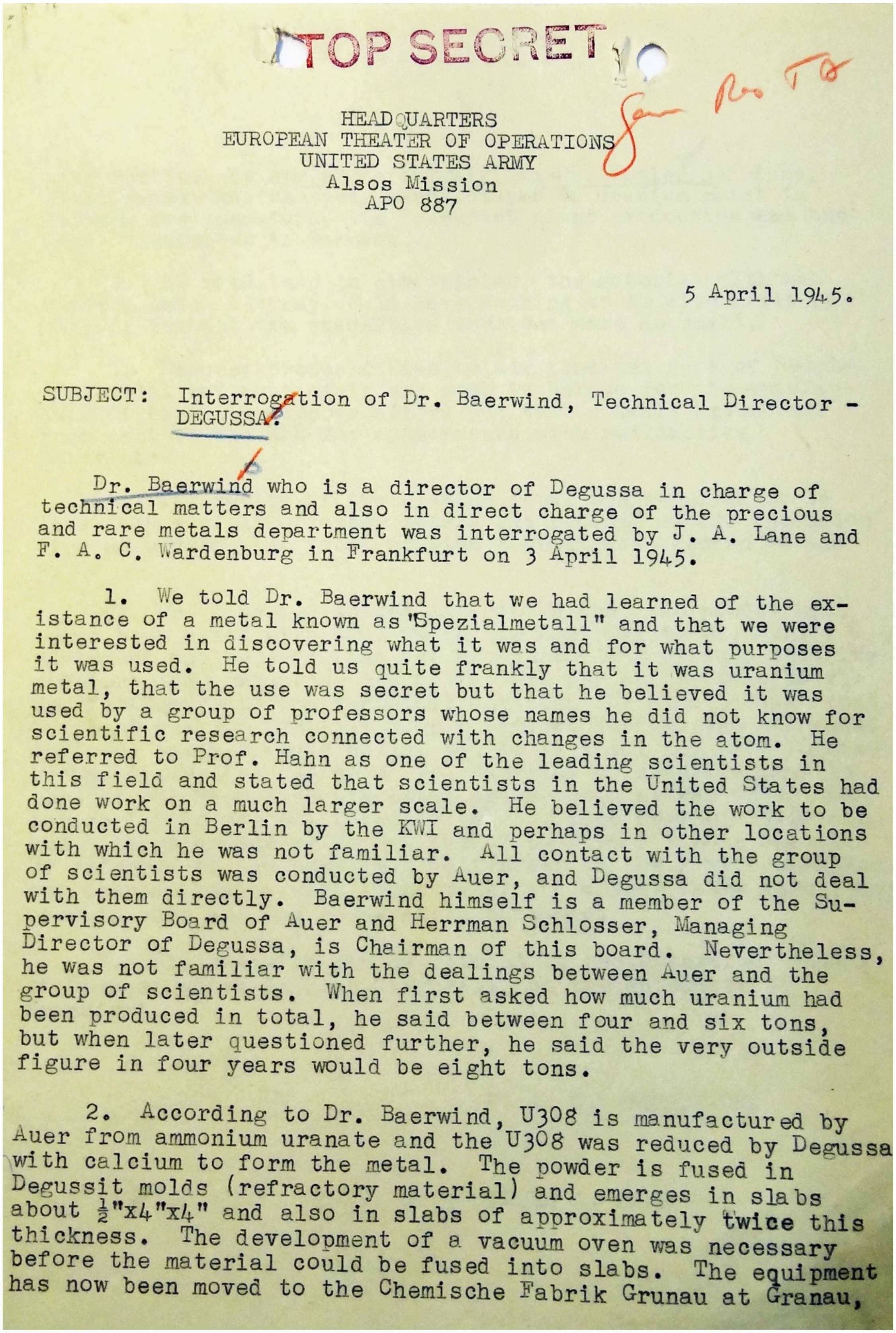
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA (1943–June 1946)



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HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
Alsos Mission
APO 887

5 April 1945.

SUBJECT: Interrogation of Dr. Baerwind, Technical Director - DEGUSSA.

Dr. Baerwind who is a director of Degussa in charge of technical matters and also in direct charge of the precious and rare metals department was interrogated by J. A. Lane and F. A. C. Wardenburg in Frankfurt on 3 April 1945.

1. We told Dr. Baerwind that we had learned of the existance of a metal known as "Spezialmetall" and that we were interested in discovering what it was and for what purposes it was used. He told us quite frankly that it was uranium metal, that the use was secret but that he believed it was used by a group of professors whose names he did not know for scientific research connected with changes in the atom. He referred to Prof. Hahn as one of the leading scientists in this field and stated that scientists in the United States had done work on a much larger scale. He believed the work to be conducted in Berlin by the KWI and perhaps in other locations with which he was not familiar. All contact with the group of scientists was conducted by Auer, and Degussa did not deal with them directly. Baerwind himself is a member of the Supervisory Board of Auer and Herrman Schlosser, Managing Director of Degussa, is Chairman of this board. Nevertheless, he was not familiar with the dealings between Auer and the group of scientists. When first asked how much uranium had been produced in total, he said between four and six tons, but when later questioned further, he said the very outside figure in four years would be eight tons.

2. According to Dr. Baerwind, U308 is manufactured by Auer from ammonium uranate and the U308 was reduced by Degussa with calcium to form the metal. The powder is fused in Degussit molds (refractory material) and emerges in slabs about ½"x4"x4" and also in slabs of approximately twice this thickness. The development of a vacuum oven was necessary before the material could be fused into slabs. The equipment has now been moved to the Chemische Fabrik Grunau at Granau,

Figure D.433: Dr. Kohl, the works manager of the Degussa plant, aided by his staff, had given U.S. investigators a detailed description of the 10 tons of 50% uranium–50% carbon 5x5x6 cm blocks that had been produced there, but the technical director Dr. Baerwind was curiously quick to deny and deflect when asked about those blocks [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA (1943–June 1946)].

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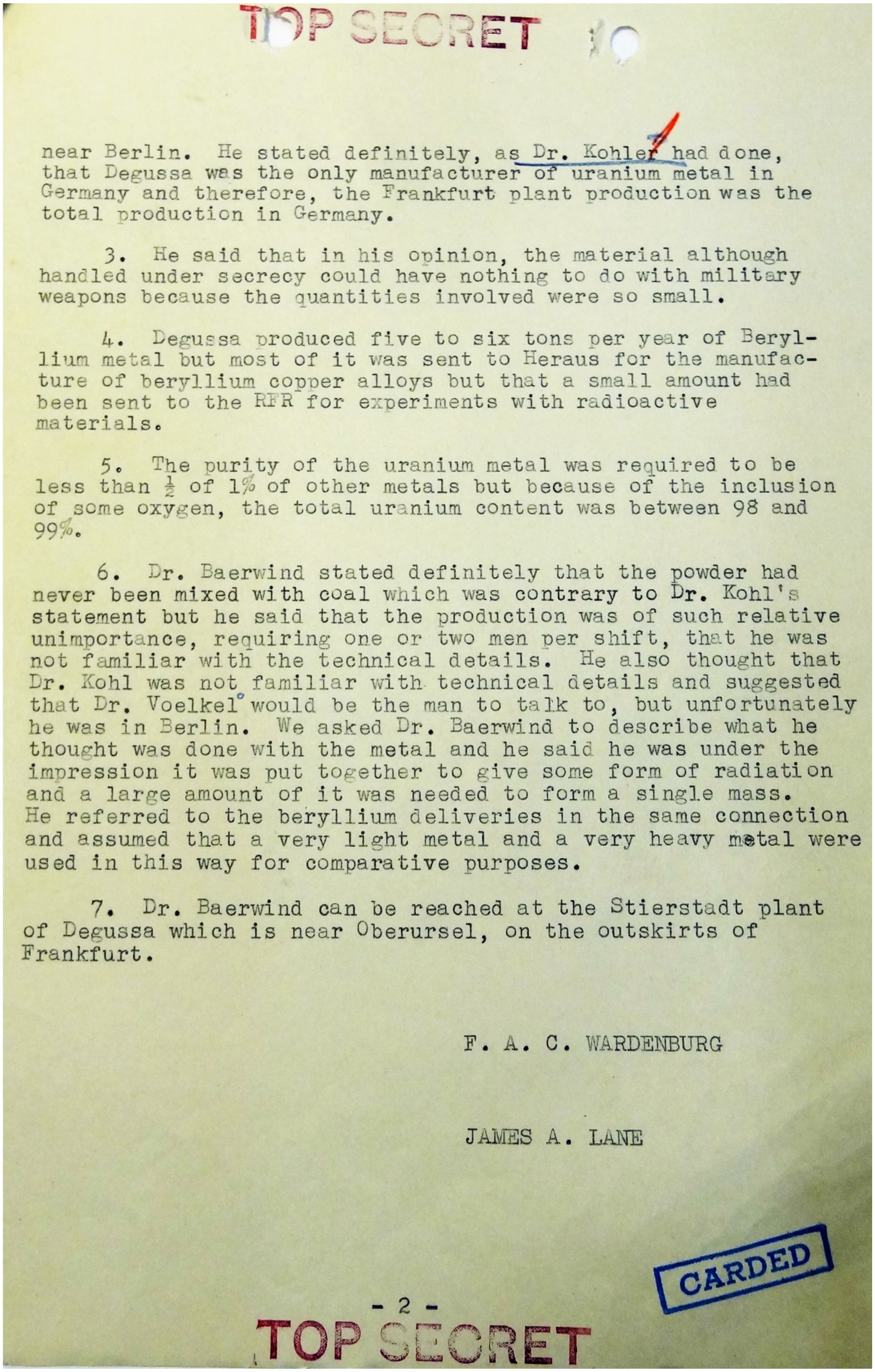
Authority NND917017

NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA (1943–June 1946)



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near Berlin. He stated definitely, as Dr. Kohler had done, that Degussa was the only manufacturer of uranium metal in Germany and therefore, the Frankfurt plant production was the total production in Germany.

3. He said that in his opinion, the material although handled under secrecy could have nothing to do with military weapons because the quantities involved were so small.

4. Degussa produced five to six tons per year of Beryllium metal but most of it was sent to Heraus for the manufacture of beryllium copper alloys but that a small amount had been sent to the RFR for experiments with radioactive materials.

5. The purity of the uranium metal was required to be less than ½ of 1% of other metals but because of the inclusion of some oxygen, the total uranium content was between 98 and 99%.

6. Dr. Baerwind stated definitely that the powder had never been mixed with coal which was contrary to Dr. Kohl's statement but he said that the production was of such relative unimportance, requiring one or two men per shift, that he was not familiar with the technical details. He also thought that Dr. Kohl was not familiar with technical details and suggested that Dr. Voelkel would be the man to talk to, but unfortunately he was in Berlin. We asked Dr. Baerwind to describe what he thought was done with the metal and he said he was under the impression it was put together to give some form of radiation and a large amount of it was needed to form a single mass. He referred to the beryllium deliveries in the same connection and assumed that a very light metal and a very heavy metal were used in this way for comparative purposes.

7. Dr. Baerwind can be reached at the Stierstadt plant of Degussa which is near Oberursel, on the outskirts of Frankfurt.

F. A. C. WARDENBURG

JAMES A. LANE

CARDED

- 2 -

TOP SECRET

Figure D.434: Dr. Kohl, the works manager of the Degussa plant, aided by his staff, had given U.S. investigators a detailed description of the 10 tons of 50% uranium–50% carbon 5x5x6 cm blocks that had been produced there, but the technical director Dr. Baerwind was curiously quick to deny and deflect when asked about those blocks [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA (1943–June 1946)].

Monthly Intelligence Summary. July–August 1945. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

IX CENSORSHIP.

[...]

g. A Mr. Richard P. FISCHER representing the OCE, War Department, has completed an investigation of German supplies of uranium during the war. A copy of his report was obtained by this office and some of the material contained therein is considered objectionable. Major SMITH'S Office was notified and this office suggested that Col. MEIDLING, the present custodian of the report in ETO, be directed by OCE to forward the report to OCE to be censored by General GROVES' Office.

Alfred L. Busch et al. June 1994. Memorial to Richard Philip Fischer 1910–1991. *Memorials* Vol. 25, Geological Society of America.
https://rock.geosociety.org/net/documents/gsa/memorials/v25/Fischer-RP.pdf

[...] Throughout the war years (1941–1945) he was in charge of the Colorado Plateau vanadium project, with greater emphasis after May 1944 on the uranium component at the request of the Manhattan Engineering District (better known as the Manhattan Project). Earlier, in 1942, he had reported on the world's uranium resources for the Office of Scientific Research and Development. At one stage of his wartime studies of uranium, he was prohibited by the government, overly intent on security, from borrowing from the library one of his own publications! The Colorado Plateau work was interrupted in 1945 by an assignment in Germany for the Intelligence Section of the Army Corps of Engineers, European Theater of Operations (ETO), to study German ore supplies and the use of vanadium, uranium, niobium, lead, and zinc; the engineering geology of underground bunkers and factories; and, in addition, military geology functions and personnel. [...]

[Richard P. Fischer was a highly respected expert on the mining of uranium and other heavy metals, with a Ph.D. in geology from Princeton and a long career with the U.S. Geological Survey. At the end of World War II, he was hired by the U.S. War Department specifically to survey the status of German uranium supplies and underground bunkers and factories, and to write a report on his findings. Leslie Groves personally censored his report, so his results were never released. Fischer was even denied access to his own reports that he had written. For more information, see pp. 3949–3951.]

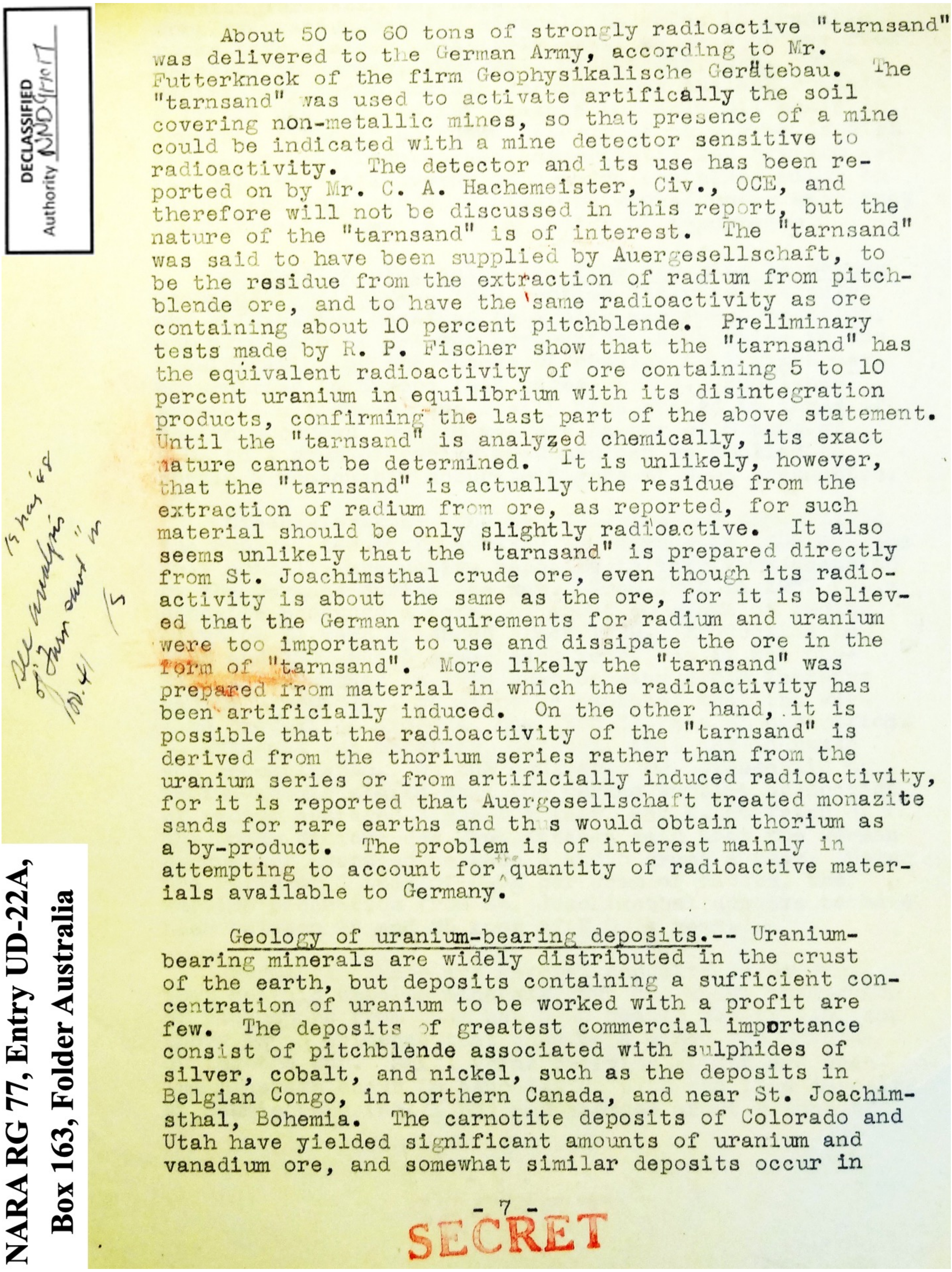
Richard P. Fischer. June 1945. Report on German Supplies of Uranium-Bearing Raw Materials. Draft CIOS report. [NARA RG 77, Entry UD-22A, Box 163, Folder Australia] See document photo on p. 3950.

About 50 to 60 tons of strongly radioactive “tarnsand” was delivered to the German Army, according to Mr. Futterkneck of the firm Geophysikalische Gerätebau. The “tarnsand” was used to activate artificially the soil covering non-metallic mines, so that presence of a mine could be indicated with a mine detector sensitive to radioactivity. The detector and its use has been reported on by Mr. C. A. Hachemeister, Civ., OCE, and therefore will not be discussed in this report, but the nature of the “tarnsand” is of interest. The “tarnsand” was said to have been supplied by Auergesellschaft, to be the residue from the extraction of radium from pitchblende ore, and to have the same radioactivity as ore containing about 10 percent pitchblende. Preliminary tests made by R. P. Fischer show that the “tarnsand” has the equivalent radioactivity of ore containing 5 to 10 percent uranium in equilibrium with its disintegration products, confirming the last part of the above statement. Until the “tarnsand” is analyzed chemically, its exact nature cannot be determined. It is unlikely, however, that the “tarnsand” is actually the residue from the extraction of radium from ore, as reported, for such material should be only slightly radioactive. It also seems unlikely that the “tarnsand” is prepared directly from St. Joachimsthal crude ore, even though its radioactivity is about the same as the ore, for it is believed that the German requirements for radium and uranium were too important to use and dissipate the ore in the form of “tarnsand”. More likely the “tarnsand” was prepared from material in which the radioactivity has been artificially induced. On the other hand, it is possible that the radioactivity of the “tarnsand” is derived from the thorium series rather than from the uranium series or from artificially induced radioactivity, for it is reported that Auergesellschaft treated monazite sands for rare earths and thus would obtain thorium as a by-product. The problem is of interest mainly in attempting to account for the quantity of radioactive materials available to Germany.

[Dr. Richard P. Fischer, a U.S. Geological Survey expert on radioactive minerals, concluded that wartime Germany likely had a working fission reactor capable of irradiating at least 50–60 tons of “tarnsand.” Fischer’s report was promptly confiscated by the office of Leslie Groves and never published.

For more information, see p. 3948.

Where is the 1948 analysis of “tarnsand” that is mentioned in the left margin of the document on p. 3950?]



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Authority NND979017

About 50 to 60 tons of strongly radioactive "tarnsand" was delivered to the German Army, according to Mr. Futterkneck of the firm Geophysikalische Gerätebau. The "tarnsand" was used to activate artifically the soil covering non-metallic mines, so that presence of a mine could be indicated with a mine detector sensitive to radioactivity. The detector and its use has been reported on by Mr. C. A. Hachemeister, Civ., OCE, and therefore will not be discussed in this report, but the nature of the "tarnsand" is of interest. The "tarnsand" was said to have been supplied by Auergesellschaft, to be the residue from the extraction of radium from pitchblende ore, and to have the same radioactivity as ore containing about 10 percent pitchblende. Preliminary tests made by R. P. Fischer show that the "tarnsand" has the equivalent radioactivity of ore containing 5 to 10 percent uranium in equilibrium with its disintegration products, confirming the last part of the above statement. Until the "tarnsand" is analyzed chemically, its exact nature cannot be determined. It is unlikely, however, that the "tarnsand" is actually the residue from the extraction of radium from ore, as reported, for such material should be only slightly radioactive. It also seems unlikely that the "tarnsand" is prepared directly from St. Joachimsthal crude ore, even though its radioactivity is about the same as the ore, for it is believed that the German requirements for radium and uranium were too important to use and dissipate the ore in the form of "tarnsand". More likely the "tarnsand" was prepared from material in which the radioactivity has been artificially induced. On the other hand, it is possible that the radioactivity of the "tarnsand" is derived from the thorium series rather than from the uranium series or from artificially induced radioactivity, for it is reported that Auergesellschaft treated monazite sands for rare earths and thus would obtain thorium as a by-product. The problem is of interest mainly in attempting to account for the quantity of radioactive materials available to Germany.

15 May '48
See analysis of "Tarnsand" in 101.41
S

Geology of uranium-bearing deposits.-- Uranium-bearing minerals are widely distributed in the crust of the earth, but deposits containing a sufficient concentration of uranium to be worked with a profit are few. The deposits of greatest commercial importance consist of pitchblende associated with sulphides of silver, cobalt, and nickel, such as the deposits in Belgian Congo, in northern Canada, and near St. Joachimsthal, Bohemia. The carnotite deposits of Colorado and Utah have yielded significant amounts of uranium and vanadium ore, and somewhat similar deposits occur in

- 7 -

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NARA RG 77, Entry UD-22A, Box 163, Folder Australia

Figure D.435: Dr. Richard P. Fischer, a U.S. Geological Survey expert on radioactive minerals, concluded that wartime Germany likely had a working fission reactor capable of irradiating at least 50–60 tons of "tarnsand." Fischer's June 1945 report was promptly confiscated by the office of Leslie Groves and never published [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

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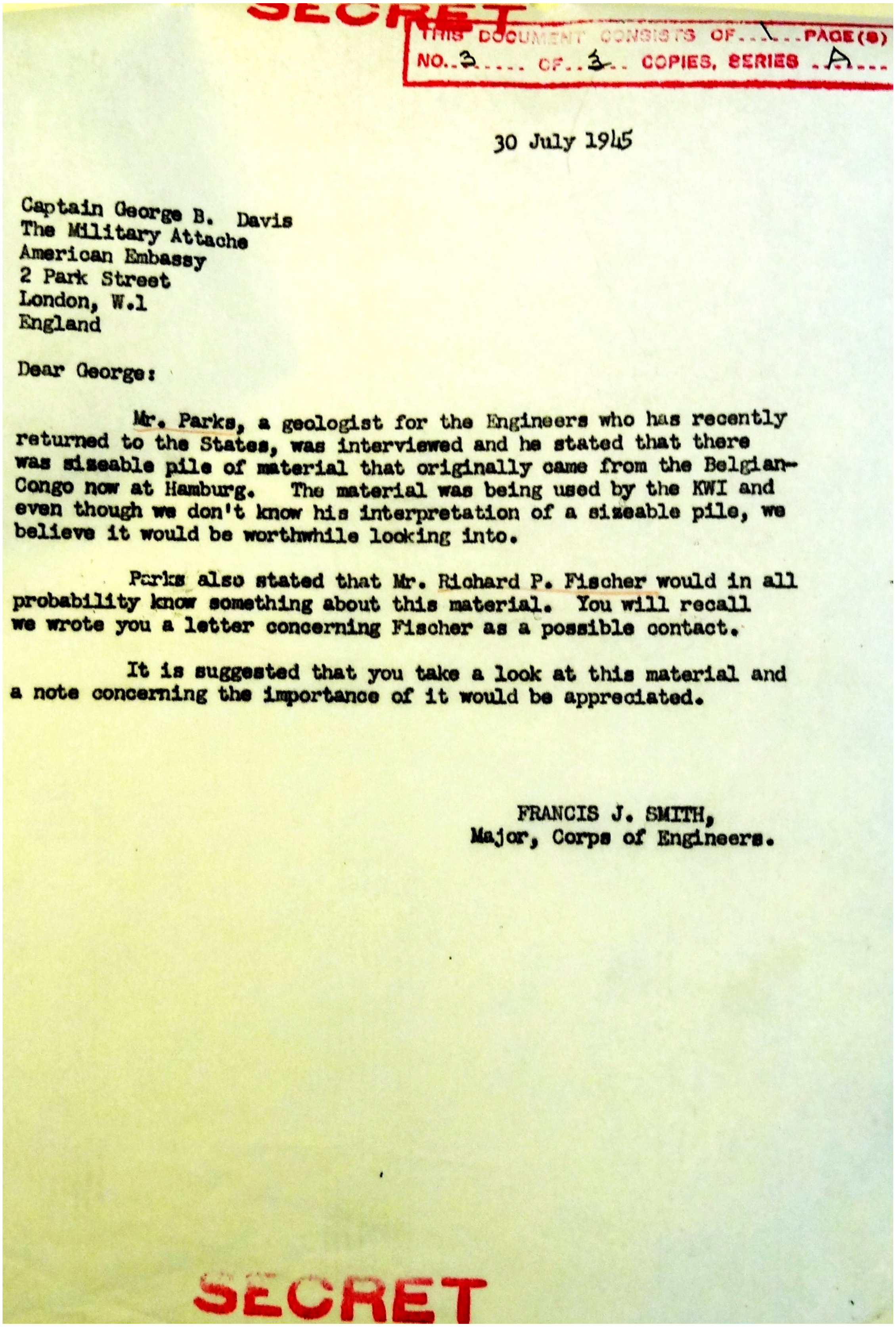
Authority NND 917017



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THIS DOCUMENT CONSISTS OF 1 PAGE(S)
NO. 3 OF 3 COPIES, SERIES A

30 July 1945

Captain George B. Davis
The Military Attache
American Embassy
2 Park Street
London, W.1
England

Dear George:

Mr. Parks, a geologist for the Engineers who has recently returned to the States, was interviewed and he stated that there was sizeable pile of material that originally came from the Belgian-Congo now at Hamburg. The material was being used by the KWI and even though we don't know his interpretation of a sizeable pile, we believe it would be worthwhile looking into.

Parks also stated that Mr. Richard P. Fischer would in all probability know something about this material. You will recall we wrote you a letter concerning Fischer as a possible contact.

It is suggested that you take a look at this material and a note concerning the importance of it would be appreciated.

FRANCIS J. SMITH,
Major, Corps of Engineers.

SECRET

NARA RG 77, Entry UD-22A,
Box 163, Folder Australia

Figure D.436: Francis J. Smith to George B. Davis. 30 July 1945 [NARA RG 77, Entry UD-22A, Box 163, Folder Australia]. “Mr. Parks, a geologist for the Engineers who has recently returned to the States, was interviewed and he stated that there was sizeable pile of material that originally came from the Belgian-Congo now at Hamburg. The material was being used by the KWI and even though we don’t know his interpretation of a sizeable pile, we believe it would be worthwhile looking into. Parks also stated that Mr. Richard P. Fischer would in all probability know something about this material.”

From USMA London to War Department. ACTION: Gen Groves. 21 January 1946. [NARA RG 77, Entry UD-22A, Box 160, Folder In & Out Jan 46–July 15, '46] See document photo on p. 3953.

USFET G-2 has received following request which it has forwarded to this office.

British desire to pick up one ton of lead nitrate and polonium residues now in storeroom at 6-640 Fabrik House in Lichtenau. Village of Lichtenau in US Zone and is 20 miles southwest of Nurenberg. British desire it for research into radio active material. It is scrap from German research into radio active material. Storeroom contains 3 to 5 tons of the stuff, of which British desire 1 ton.

Your reaction requested in determining answer this office will give USFET.

[How extensive was the wartime "German research into radioactive material" if it produced so many tons of "scrap" at so many locations, including highly radioactive materials such as polonium that were greatly prized by the occupying Allied forces?]

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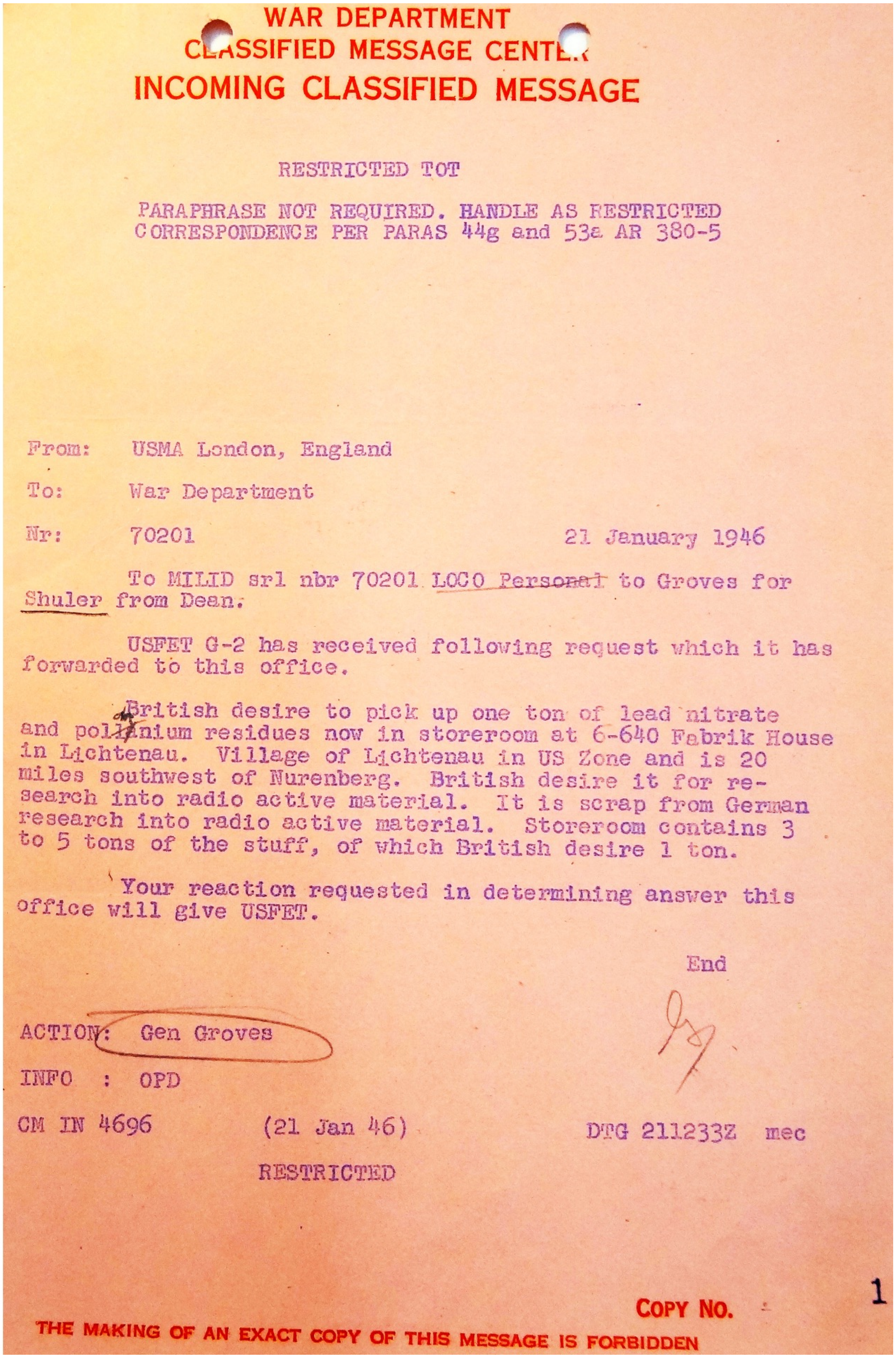
Authority NND 917017



WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
INCOMING CLASSIFIED MESSAGE

RESTRICTED TOT

PARAPHRASE NOT REQUIRED. HANDLE AS RESTRICTED
CORRESPONDENCE PER PARAS 44g and 53a AR 380-5

From: USMA London, England

To: War Department

Nr: 70201 21 January 1946

To MILID srl nbr 70201 LOCO Personal to Groves for Shuler from Dean.

USFET G-2 has received following request which it has forwarded to this office.

British desire to pick up one ton of lead nitrate and polonium residues now in storeroom at 6-640 Fabrik House in Lichtenau. Village of Lichtenau in US Zone and is 20 miles southwest of Nurenberg. British desire it for research into radio active material. It is scrap from German research into radio active material. Storeroom contains 3 to 5 tons of the stuff, of which British desire 1 ton.

Your reaction requested in determining answer this office will give USFET.

End

ACTION: Gen Groves

INFO : OPD

CM IN 4696 (21 Jan 46) DTG 211233Z mec

RESTRICTED

COPY NO. 1

THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN

NARA RG 77, Entry UD-22A, Box 160, Folder In & Out Jan 46—July 15, '46

Figure D.437: How extensive was the wartime "German research into radioactive material" if it produced so many tons of "scrap" at so many locations, including highly radioactive materials such as polonium that were greatly prized by the occupying Allied forces? [NARA RG 77, Entry UD-22A, Box 160, Folder In & Out Jan 46–July 15, '46]

D.6 Electronuclear Systems for Breeding Pu-239 and/or U-233

[Walther Bothe (German, 1891–1957), Walter Dällenbach (Swiss, 1892–1990), Max Steenbeck (German, 1904–1981), Rolf Wideröe (Norwegian but studied and worked in Germany, 1902–1996), and many others pioneered particle accelerators from their beginnings in the 1920s through World War II (p. 3020).

The following documents show that in German-controlled areas, a considerable number of high-energy particle accelerators were produced, and in some cases used, as high priorities during the war. Purely scientific research would not have been sufficient justification for all of the funding, labor, and materials that went into these accelerators when war needs and shortages were so dire. As discussed in Appendix C (p. 3020), one motivation for some of the accelerator work was apparently the development of directed energy weapons, yet that would only account for some small fraction of the accelerators that were produced. Most of the accelerators appear to have been closely linked with the German nuclear weapons program.

There are at least three possible applications for accelerators in a nuclear weapons program:

1. Measuring fundamental nuclear properties that are relevant to designing nuclear reactors and bombs. One or two modest accelerators would have been sufficient for that purpose, and Germany already had access to the Joliot-Curie cyclotron in Paris for such measurements.

2. Using a compact ∼6 MeV (million electron volt) betatron to produce free neutrons in a fission bomb at the optimal time during implosion, as discussed on pp. 4492 and 5159.

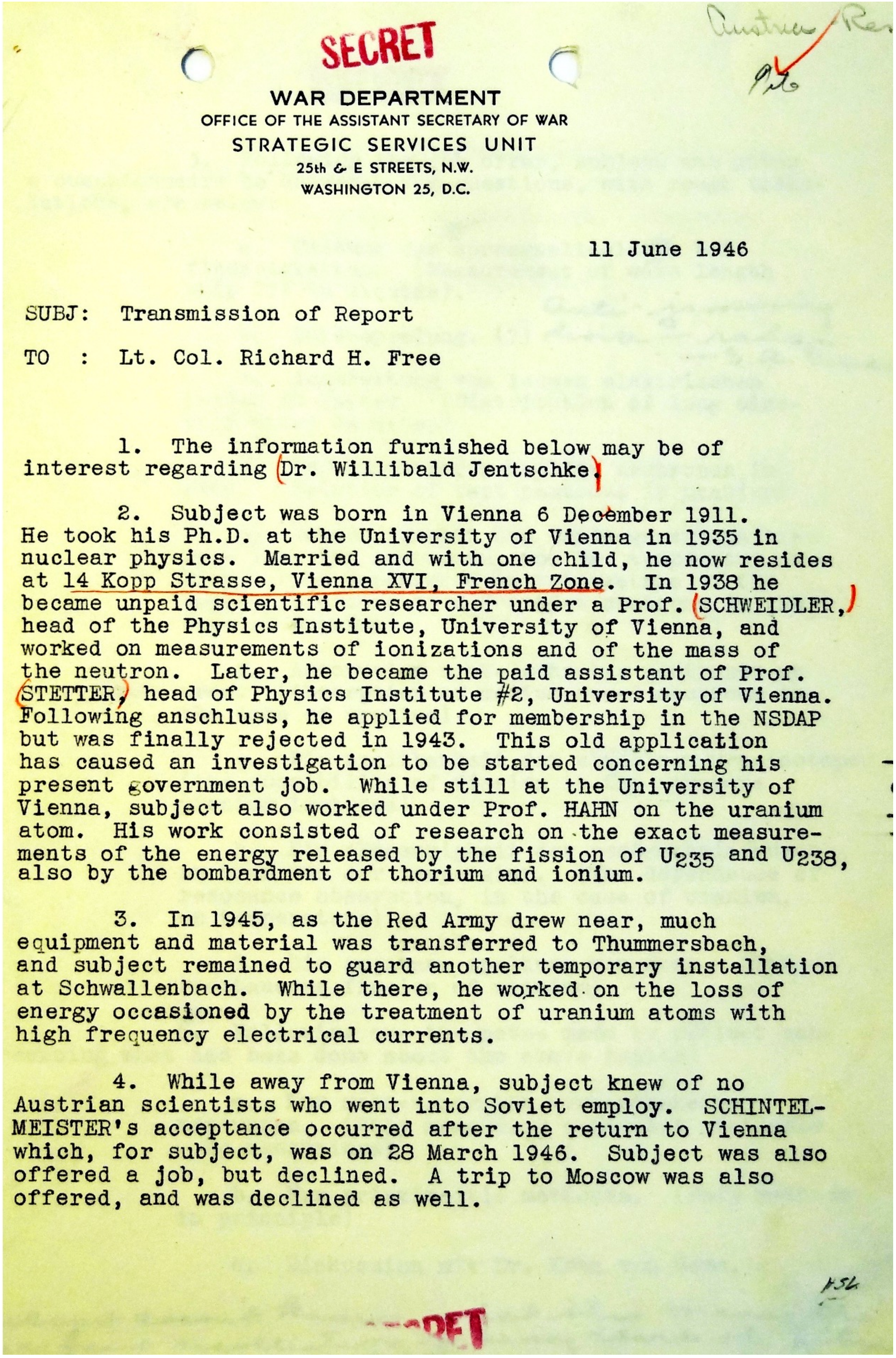
3. Using a number of accelerators in parallel to produce enough neutrons without a fission reactor in order to breed militarily useful amounts of fissile plutonium-239 from uranium-238, or fissile uranium-233 from thorium-232. This process is called electronuclear breeding. Fissile neptunium-237 [Sanchez et al. 2008] could also have been bred via particle accelerators (e.g., by knocking a neutron out of U-238), although it probably would have been more difficult to produce in quantity than Pu-239 or U-233 [Benedict et al. 1981].

The sheer number and high priority of the accelerators covered in the following documents suggests that many of those accelerators were intended for electronuclear breeding. There is some evidence that such systems may have been operational during the war.

For information on the physics of electronuclear breeding, see p. 5133.

In addition to the documents in this section and in Appendix C, an extremely important piece of evidence is Georgy Flerov's story about multiple cyclotrons in a highly secret underground SS/Reichspost installation in Silesia on pp. 4504–4510.]

NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel



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WAR DEPARTMENT
OFFICE OF THE ASSISTANT SECRETARY OF WAR
STRATEGIC SERVICES UNIT
25th & E STREETS, N.W.
WASHINGTON 25, D.C.

11 June 1946

SUBJ: Transmission of Report

TO : Lt. Col. Richard H. Free

1. The information furnished below may be of interest regarding Dr. Willibald Jentschke.

2. Subject was born in Vienna 6 December 1911. He took his Ph.D. at the University of Vienna in 1935 in nuclear physics. Married and with one child, he now resides at 14 Kopp Strasse, Vienna XVI, French Zone. In 1938 he became unpaid scientific researcher under a Prof. SCHWEIDLER, head of the Physics Institute, University of Vienna, and worked on measurements of ionizations and of the mass of the neutron. Later, he became the paid assistant of Prof. STETTER, head of Physics Institute #2, University of Vienna. Following anschluss, he applied for membership in the NSDAP but was finally rejected in 1943. This old application has caused an investigation to be started concerning his present government job. While still at the University of Vienna, subject also worked under Prof. HAHN on the uranium atom. His work consisted of research on the exact measurements of the energy released by the fission of U_{235} and U_{238}, also by the bombardment of thorium and ionium.

3. In 1945, as the Red Army drew near, much equipment and material was transferred to Thummersbach, and subject remained to guard another temporary installation at Schwallenbach. While there, he worked on the loss of energy occasioned by the treatment of uranium atoms with high frequency electrical currents.

4. While away from Vienna, subject knew of no Austrian scientists who went into Soviet employ. SCHINTELMEISTER's acceptance occurred after the return to Vienna which, for subject, was on 28 March 1946. Subject was also offered a job, but declined. A trip to Moscow was also offered, and was declined as well.

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Figure D.438: S. M. Skinner to Richard H. Free. 11 June 1946 [NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel].

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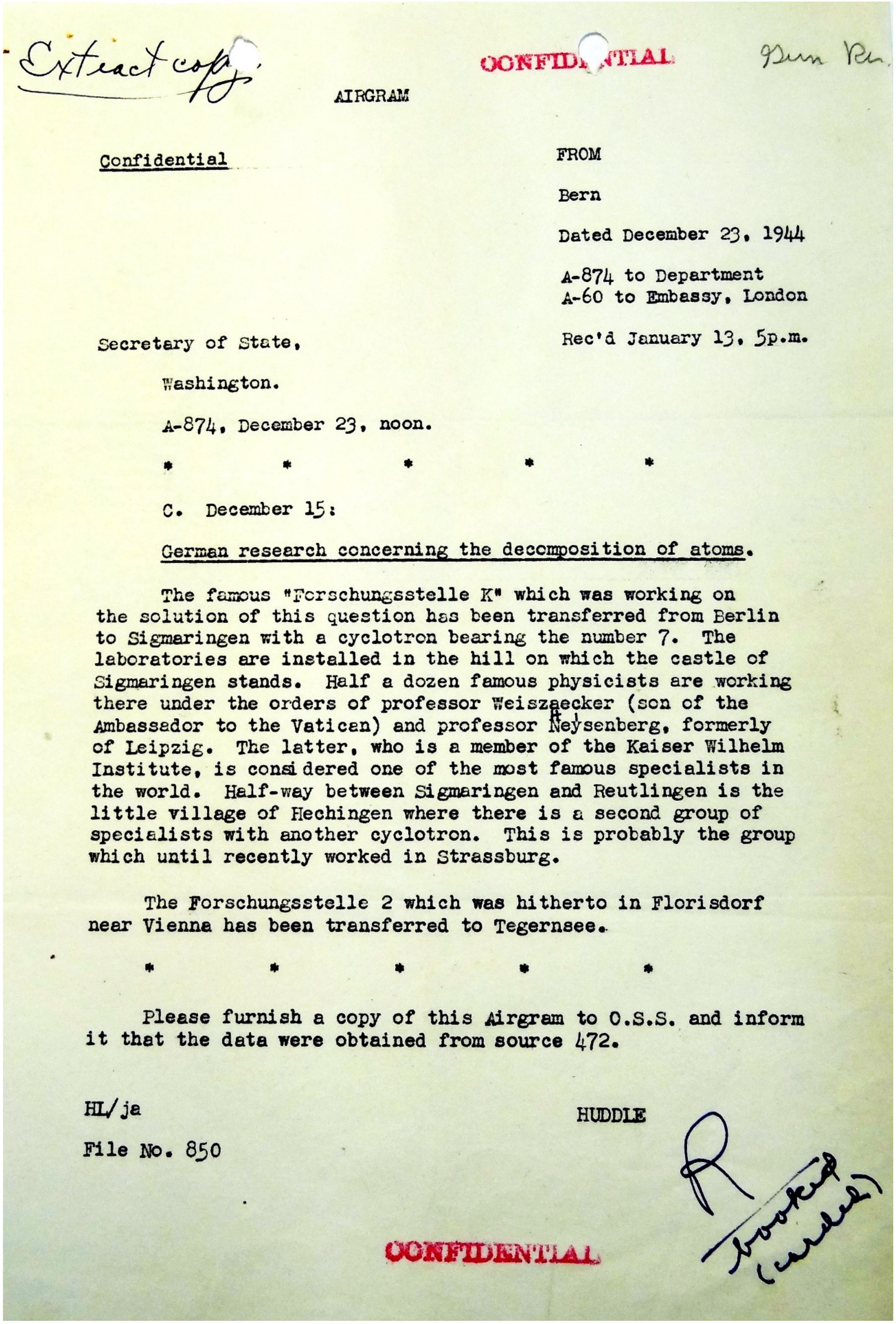


Extract copy

CONFIDENTIAL

Germ Res.

AIRGRAM

Confidential

FROM

Bern

Dated December 23, 1944

A-874 to Department
A-60 to Embassy, London

Rec'd January 13, 5p.m.

Secretary of State,

Washington.

A-874, December 23, noon.

* * * * *

C. December 15:

German research concerning the decomposition of atoms.

The famous "Forschungsstelle K" which was working on the solution of this question has been transferred from Berlin to Sigmaringen with a cyclotron bearing the number 7. The laboratories are installed in the hill on which the castle of Sigmaringen stands. Half a dozen famous physicists are working there under the orders of professor Weiszaecker (son of the Ambassador to the Vatican) and professor Neysenberg, formerly of Leipzig. The latter, who is a member of the Kaiser Wilhelm Institute, is considered one of the most famous specialists in the world. Half-way between Sigmaringen and Reutlingen is the little village of Hechingen where there is a second group of specialists with another cyclotron. This is probably the group which until recently worked in Strassburg.

The Forschungsstelle 2 which was hitherto in Florisdorf near Vienna has been transferred to Tegernsee.

* * * * *

Please furnish a copy of this Airgram to O.S.S. and inform it that the data were obtained from source 472.

HL/ja

HUDDLE

File No. 850

R

booked (carded)

CONFIDENTIAL

NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1
GERMANY—Research—TA—(1943--June 1946)

Figure D.439: Huddle to Secretary of State, Washington. 23 December 1944. German research concerning the decomposition of atoms [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA (1943–June 1946)].

Caperton B. Horsley. 22 June 1945. CIOS ER 129. ***Siemens-Reiniger-Werke A.G. A. Erlangen. B. Rudolstadt.***

A. [Erlangen] 1. This plant designs and manufactures X-ray apparatus and other electro-medical equipment. It is the largest plant of its kind in Germany. It recently had about 3,000 employees. During the last several years it has also manufactured, but not designed, some components for aircraft radio, instrument and control equipment.

2. The following men were interviewed: [...]

All of the above men were very cooperative.

3. A considerable amount of information was obtained regarding:

A. Their latest developments in X-ray equipment, one and six meter high-frequency medical equipment, metal locators, shock therapy equipment, supersonic [ultrasonic] therapy equipment, and Betatrons.

B. The location and general description of the most important Betatron, Cyclotron, Van de Graaff generator, and mass spectrograph installations in Germany and territory that has been occupied by the Germans.

C. Recent German research in atomic physics; particularly regarding isotope separation.

D. The possible present location of a number of German physicists and directors of research programs. [...]

B. [Rudolstadt] 1. This plant manufactured a complete line of X-ray tubes, and valve tubes for use in X-ray equipment. They have also recently manufactured amplifier tubes for use in telephone systems, surge arresting tubes for protecting communications lines, several types of small gas filled detectors for use in "timing" circuits for bombs and shells, and fluoroscopic and intensifying screens. [...]

3. A number of tubes were found that were superior in certain respects to tubes now being manufactured in the United States.

4. The following personnel were interviewed [...]

All of the above men were exceedingly cooperative, and a considerable amount of seemingly valuable information was obtained from them regarding:

A. The entire German X-ray industry.

B. Recent magnetron and other U.H.F. tube developments by Siemens-Halske.

C. The names and addresses of a number of physicists who have recently been doing work on isotope separation.

D. The possible location of a number of men who have been in charge of recent U.H.F. developmental and experimental work.

Caperton B. Horsley. 16 July 1945. CIOS ER 174. ***C. H. F. Müller A.G., Hamburg, Fuhsbuttel, Roentgenstrasse 24.***

This company designed and manufactured the following equipment:

a) A line of X-Ray tubes, and a number of valve tubes for X-ray equipment

b) A line of X-Ray tube housings with flexible high tension cables.

c) A small transformer and X-Ray tube head for use with dental and Army field units.

d) Certain miscellaneous X-Ray equipment items.

e) "Cascade" high voltage generators, from 900 to 2,400 Kv. for deutron acceleration.

The following equipment was manufactured, but not designed by this company:

a) "Underwater Sound Equipment" assemblies.

b) Aircraft instrument and electrical equipment components.

c) Gas filled rectifiers for communication work.

[...] In addition to the above:

a) They were about to start the production of a magnetron that had been designed by Telefunken.

b) They had designed and constructed an experimental 2 M.V. betatron.

c) Working on specifications supplied by the "MV Research Assn", at Wrist, they had constructed and delivered to Wrist a 15 M.V. betatron.

The following persons were interviewed, all of whom were cooperative:

Otto Gundermann,	Administration Manager
Dr. Werner Fehr,	Assistant Manager
Kurt Weigel,	Manager of X-Ray Tube Division
Arthur Lipphaus,	Mechanical Engineer
Alfred Kuntke,	Chief Research and Development Engineer
Adolf Hoffmann	"Construction" Engineer

The following information was obtained:

a) General information regarding their recent production figures.

b) Complete information regarding their X-Ray tube developments during the past 5 years.

c) Complete information regarding their design and construction of their "Cascade" high voltage unit.

d) Complete information regarding their patent applications since 1938.

e) Miscellaneous information regarding magnetrons, betatrons, infra-red photoelectric cells, the use of their "Cascade" units, and the activities of Dr. Ritz and Dr. Müller, both of whom were formerly connected with this company.

A number of photostats and blueprints were made of existing documents and drawings to provide the information outlined above. The only original documents removed from this plant covered miscellaneous information regarding magnetrons and betatrons.

The following production items were taken from this plant for further examination:

a) Several of their more recently developed X-Ray tubes.

b) Several high voltage rectifier tubes.

c) An end-ground industrial X-Ray tube head

d) 1 dental X-Ray tube head.

e) 1 magnetron

f) An experimental 2 M.V. betatron

g) A few miscellaneous production parts.

The total floor area of this plant is about 80,000 square feet. As of the first of this year the number of employees was about 500. The plant is in good condition and well equipped. [...]

List of Equipment, etc., Evacuated by Mr. Horsley of T.I.I.C. from 21 AG Area 1, July, 1945.

No originals except Dr. Müller's Betatron Notebooks and Misc. Magnetron Data from C.H.F. Müller.

BOX 1.
A. Müller Drawings re. Tubes 300 Kv. Rectifier, etc.
B. Seifert Data.
C. Miscellaneous (Electron Microscope, Philips Valve Works data, Seifert Industrial X-Ray book, Infrared data etc.)
D. Müller Underwater Sound Unit assembly drawings.
E. Müller Patent Applications.
F. Müller Magnetron Parts.

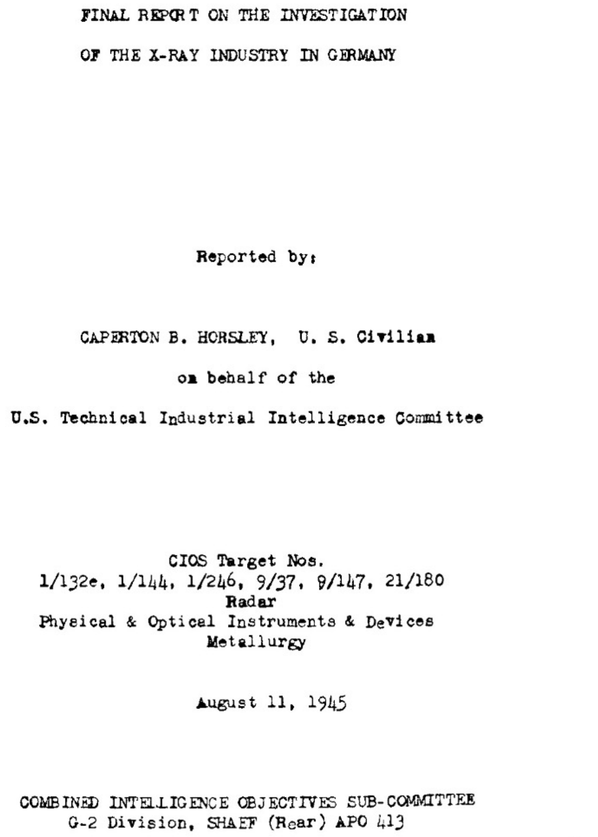
G. Müller gas filled Communication Tubes and Special resistance Wire.
H. Siemens & Halske Three Part Anode.

BOX 2.
2 M.V. Betatron Tubes.

BOX 3.
A. Müller Drawings of New Tubes and Dental Head.
B. Müller Neutron generator Drawings.
C. Müller Technique and Sales Bulletins, Philips Organization Chart, write-up of Hydrogen Casting and Thoriated Filament Processes.
D. Müller Patent Applications.
E. Philips Technical Roundups.

BOX 4.
A. Müller Drawings of New Tubes and Dental Tube Head.
B. Müller, Neutron Generator Drawings.
C. Müller Technique and Sales Bulletins, Philips Organization Chart, write-up of Hydrogen Casting and Thoriated Filament Processes.
D. Müller Patent Applications.
E. Philips Technical Round-up.
F. 15 M.V. Betatron Drawings.
G. 200 M.V. Betatron Layouts.
H. Kulenkampff Paper.
I. Wrist Generator Data.
J. Wrist Patent Applications.
K. Contact Therapy Book.

[This company was designing and manufacturing high-voltage deuterium-filled tubes for use as fusion neutron sources. It was also designing and manufacturing high-voltage betatrons. Both of those would have made excellent neutron initiators for a fission bomb. In fact, both of those neutron initiators were apparently described in Ilyichev's March 1945 intelligence report on a German fission implosion bomb design; see pp. 4485 and 5157. If these devices were mass-produced, they might have also been useful for electronuclear breeding of fission fuel.]



FINAL REPORT ON THE INVESTIGATION

OF THE X-RAY INDUSTRY IN GERMANY

Reported by:

CAPERTON B. HORSLEY, U. S. Civilian

on behalf of the

U.S. Technical Industrial Intelligence Committee

CIOS Target Nos.
1/132e, 1/144, 1/246, 9/37, 9/147, 21/180
Radar
Physical & Optical Instruments & Devices
Metallurgy

August 11, 1945

COMBINED INTELLIGENCE OBJECTIVES SUB-COMMITTEE
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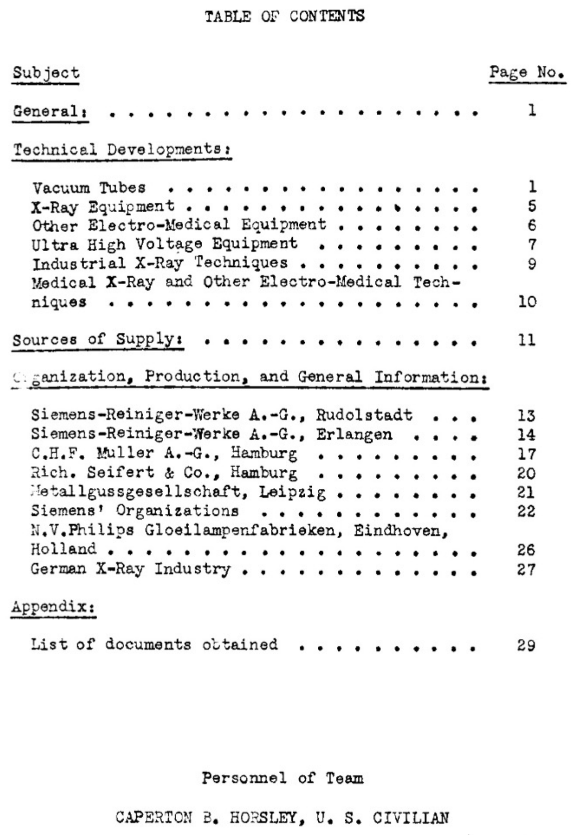

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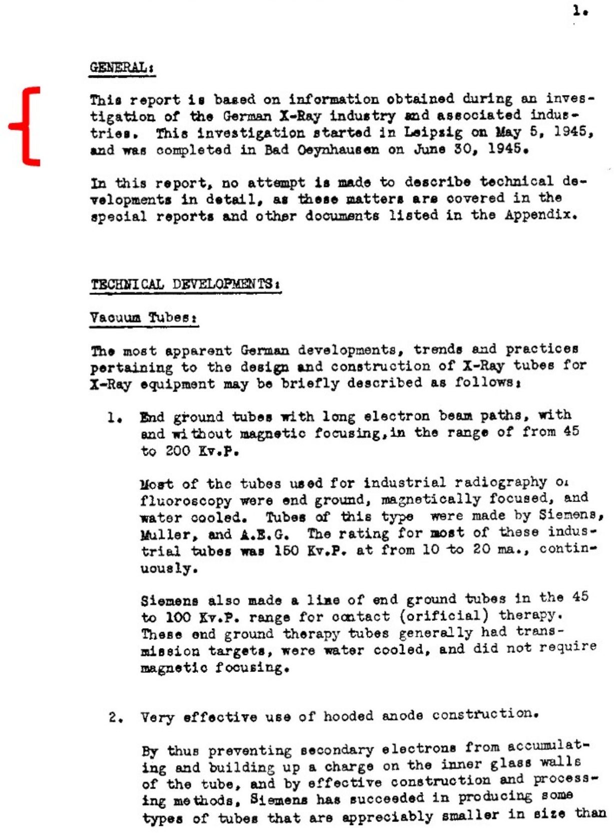
CAPERTON B. HORSLEY, U. S. CIVILIAN



1.

GENERAL:

This report is based on information obtained during an investigation of the German X-Ray industry and associated industries. This investigation started in Leipzig on May 5, 1945, and was completed in Bad Oeynhausen on June 30, 1945.

In this report, no attempt is made to describe technical developments in detail, as these matters are covered in the special reports and other documents listed in the Appendix.

TECHNICAL DEVELOPMENTS:

Vacuum Tubes:

The most apparent German developments, trends and practices pertaining to the design and construction of X-Ray tubes for X-Ray equipment may be briefly described as follows:

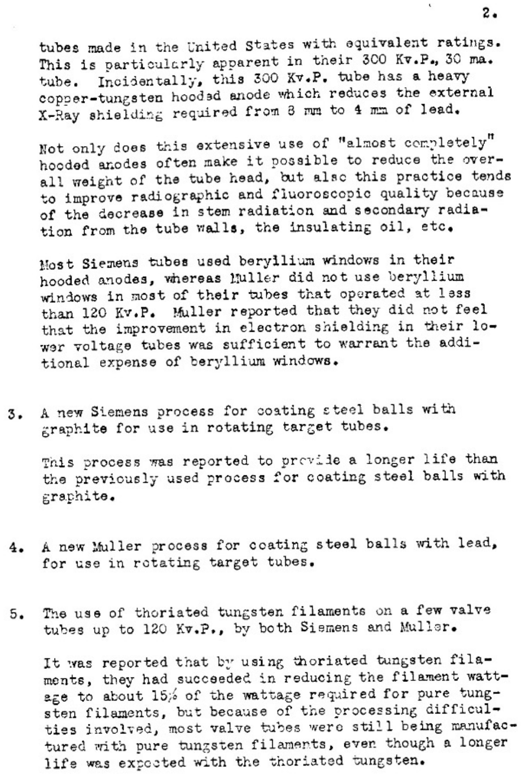
1. End ground tubes with long electron beam paths, with and without magnetic focusing, in the range of from 45 to 200 Kv.P.

   Most of the tubes used for industrial radiography or fluoroscopy were end ground, magnetically focused, and water cooled. Tubes of this type were made by Siemens, Muller, and A.E.G. The rating for most of these industrial tubes was 150 Kv.P. at from 10 to 20 ma., continuously.

   Siemens also made a line of end ground tubes in the 45 to 100 Kv.P. range for contact (orificial) therapy. These end ground therapy tubes generally had transmission targets, were water cooled, and did not require magnetic focusing.

2. Very effective use of hooded anode construction.

   By thus preventing secondary electrons from accumulating and building up a charge on the inner glass walls of the tube, and by effective construction and processing methods, Siemens has succeeded in producing some types of tubes that are appreciably smaller in size than



2.

tubes made in the United States with equivalent ratings. This is particularly apparent in their 300 Kv.P., 30 ma. tube. Incidentally, this 300 Kv.P. tube has a heavy copper-tungsten hooded anode which reduces the external X-Ray shielding required from 8 mm to 4 mm of lead.

Not only does this extensive use of "almost completely" hooded anodes often make it possible to reduce the overall weight of the tube head, but also this practice tends to improve radiographic and fluoroscopic quality because of the decrease in stem radiation and secondary radiation from the tube walls, the insulating oil, etc.

Most Siemens tubes used beryllium windows in their hooded anodes, whereas Muller did not use beryllium windows in most of their tubes that operated at less than 120 Kv.P. Muller reported that they did not feel that the improvement in electron shielding in their lower voltage tubes was sufficient to warrant the additional expense of beryllium windows.

3. A new Siemens process for coating steel balls with graphite for use in rotating target tubes.

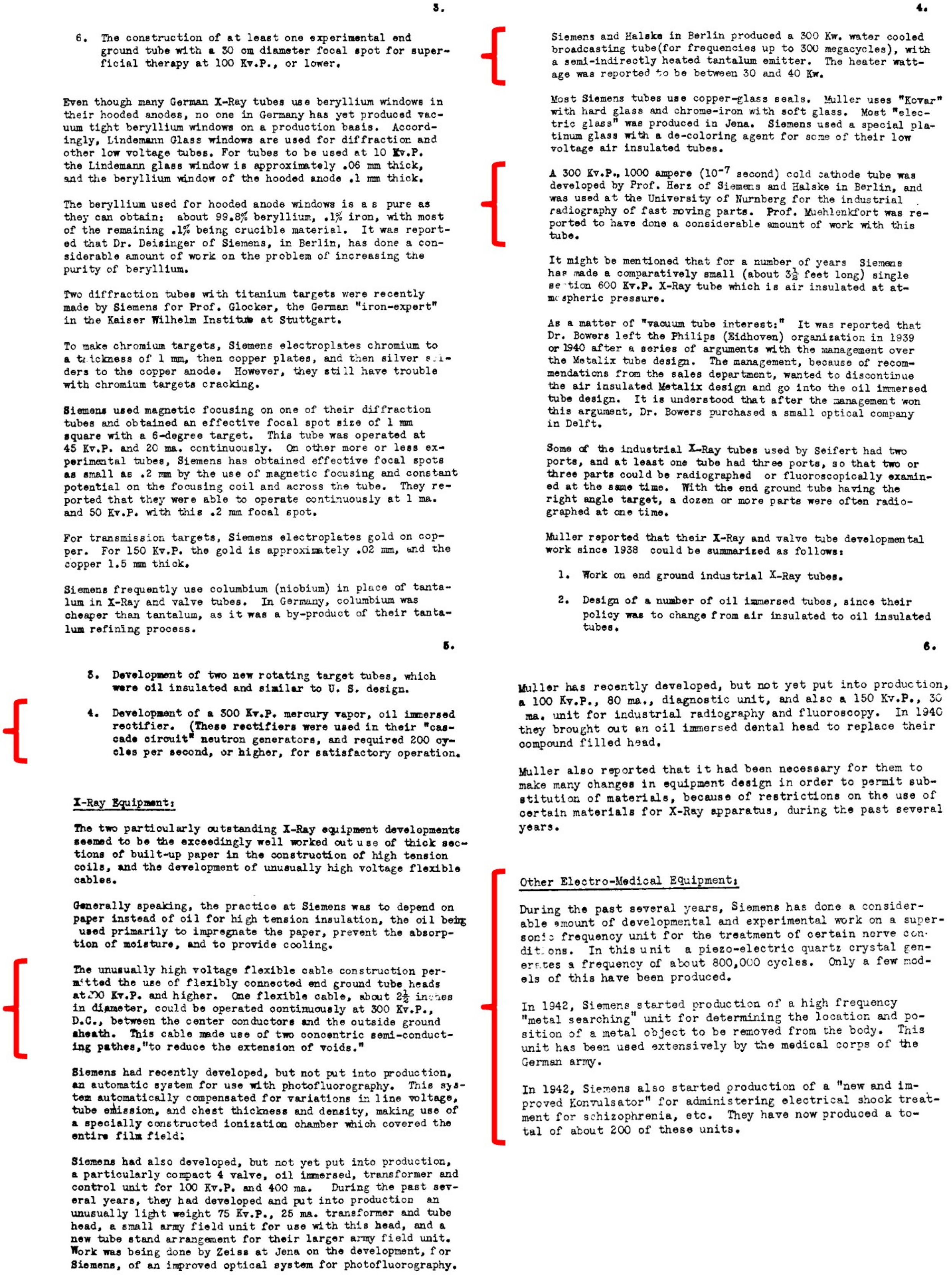
   This process was reported to provide a longer life than the previously used process for coating steel balls with graphite.

4. A new Muller process for coating steel balls with lead, for use in rotating target tubes.

5. The use of thoriated tungsten filaments on a few valve tubes up to 120 Kv.P., by both Siemens and Muller.

   It was reported that by using thoriated tungsten filaments, they had succeeded in reducing the filament wattage to about 15% of the wattage required for pure tungsten filaments, but because of the processing difficulties involved, most valve tubes were still being manufactured with pure tungsten filaments, even though a longer life was expected with the thoriated tungsten.

Figure D.440: Caperton Horsley's report CIOS XXVIII-31, *Investigation of the X-Ray Industry in Germany*, states that wartime German companies produced high-voltage fusion neutron generators, betatrons, cyclotrons, color-changing temperature-sensitive paint, a wide variety of highly advanced medical equipment, etc.



3.

6. The construction of at least one experimental end ground tube with a 30 cm diameter focal spot for superficial therapy at 100 Kv.P., or lower.

Even though many German X-Ray tubes use beryllium windows in their hooded anodes, no one in Germany has yet produced vacuum tight beryllium windows on a production basis. Accordingly, Lindemann Glass windows are used for diffraction and other low voltage tubes. For tubes to be used at 10 Kv.P. the Lindemann glass window is approximately .06 mm thick, and the beryllium window of the hooded anode .1 mm thick.

The beryllium used for hooded anode windows is as pure as they can obtain: about 99.8% beryllium, .1% iron, with most of the remaining .1% being crucible material. It was reported that Dr. Deisinger of Siemens, in Berlin, has done a considerable amount of work on the problem of increasing the purity of beryllium.

Two diffraction tubes with titanium targets were recently made by Siemens for Prof. Glocker, the German "iron-expert" in the Kaiser Wilhelm Institute at Stuttgart.

To make chromium targets, Siemens electroplates chromium to a thickness of 1 mm, then copper plates, and then silver solders to the copper anode. However, they still have trouble with chromium targets cracking.

Siemens used magnetic focusing on one of their diffraction tubes and obtained an effective focal spot size of 1 mm square with a 6-degree target. This tube was operated at 45 Kv.P. and 20 ma. continuously. On other more or less experimental tubes, Siemens has obtained effective focal spots as small as .2 mm by the use of magnetic focusing and constant potential on the focusing coil and across the tube. They reported that they were able to operate continuously at 1 ma. and 50 Kv.P. with this .2 mm focal spot.

For transmission targets, Siemens electroplates gold on copper. For 150 Kv.P. the gold is approximately .02 mm, and the copper 1.5 mm thick.

Siemens frequently use columbium (niobium) in place of tantalum in X-Ray and valve tubes. In Germany, columbium was cheaper than tantalum, as it was a by-product of their tantalum refining process.

4.

Siemens and Halske in Berlin produced a 300 Kw. water cooled broadcasting tube(for frequencies up to 300 megacycles), with a semi-indirectly heated tantalum emitter. The heater wattage was reported to be between 30 and 40 Kw.

Most Siemens tubes use copper-glass seals. Muller uses "Kovar" with hard glass and chrome-iron with soft glass. Most "electric glass" was produced in Jena. Siemens used a special platinum glass with a de-coloring agent for some of their low voltage air insulated tubes.

A 300 Kv.P., 1000 ampere (10^{-7} second) cold cathode tube was developed by Prof. Herz of Siemens and Halske in Berlin, and was used at the University of Nurnberg for the industrial radiography of fast moving parts. Prof. Muehlenkfort was reported to have done a considerable amount of work with this tube.

It might be mentioned that for a number of years Siemens has made a comparatively small (about 3½ feet long) single section 600 Kv.P. X-Ray tube which is air insulated at atmospheric pressure.

As a matter of "vacuum tube interest:" It was reported that Dr. Bowers left the Philips (Eidhoven) organization in 1939 or 1940 after a series of arguments with the management over the Metalix tube design. The management, because of recommendations from the sales department, wanted to discontinue the air insulated Metalix design and go into the oil immersed tube design. It is understood that after the management won this argument, Dr. Bowers purchased a small optical company in Delft.

Some of the industrial X-Ray tubes used by Seifert had two ports, and at least one tube had three ports, so that two or three parts could be radiographed or fluoroscopically examined at the same time. With the end ground tube having the right angle target, a dozen or more parts were often radiographed at one time.

Muller reported that their X-Ray and valve tube developmental work since 1938 could be summarized as follows:

1. Work on end ground industrial X-Ray tubes.
2. Design of a number of oil immersed tubes, since their policy was to change from air insulated to oil insulated tubes.

5.

3. Development of two new rotating target tubes, which were oil insulated and similar to U. S. design.
4. Development of a 300 Kv.P. mercury vapor, oil immersed rectifier. (These rectifiers were used in their "cascade circuit" neutron generators, and required 200 cycles per second, or higher, for satisfactory operation.

X-Ray Equipment:

The two particularly outstanding X-Ray equipment developments seemed to be the exceedingly well worked out use of thick sections of built-up paper in the construction of high tension coils, and the development of unusually high voltage flexible cables.

Generally speaking, the practice at Siemens was to depend on paper instead of oil for high tension insulation, the oil being used primarily to impregnate the paper, prevent the absorption of moisture, and to provide cooling.

The unusually high voltage flexible cable construction permitted the use of flexibly connected end ground tube heads at 200 Kv.P. and higher. One flexible cable, about 2½ inches in diameter, could be operated continuously at 300 Kv.P., D.C., between the center conductors and the outside ground sheath. This cable made use of two concentric semi-conducting pathes,"to reduce the extension of voids."

Siemens had recently developed, but not put into production, an automatic system for use with photofluorography. This system automatically compensated for variations in line voltage, tube emission, and chest thickness and density, making use of a specially constructed ionization chamber which covered the entire film field:

Siemens had also developed, but not yet put into production, a particularly compact 4 valve, oil immersed, transformer and control unit for 100 Kv.P. and 400 ma. During the past several years, they had developed and put into production an unusually light weight 75 Kv.P., 25 ma. transformer and tube head, a small army field unit for use with this head, and a new tube stand arrangement for their larger army field unit. Work was being done by Zeiss at Jena on the development, for Siemens, of an improved optical system for photofluorography.

6.

Muller has recently developed, but not yet put into production, a 100 Kv.P., 80 ma., diagnostic unit, and also a 150 Kv.P., 30 ma. unit for industrial radiography and fluoroscopy. In 1940 they brought out an oil immersed dental head to replace their compound filled head.

Muller also reported that it had been necessary for them to make many changes in equipment design in order to permit substitution of materials, because of restrictions on the use of certain materials for X-Ray apparatus, during the past several years.

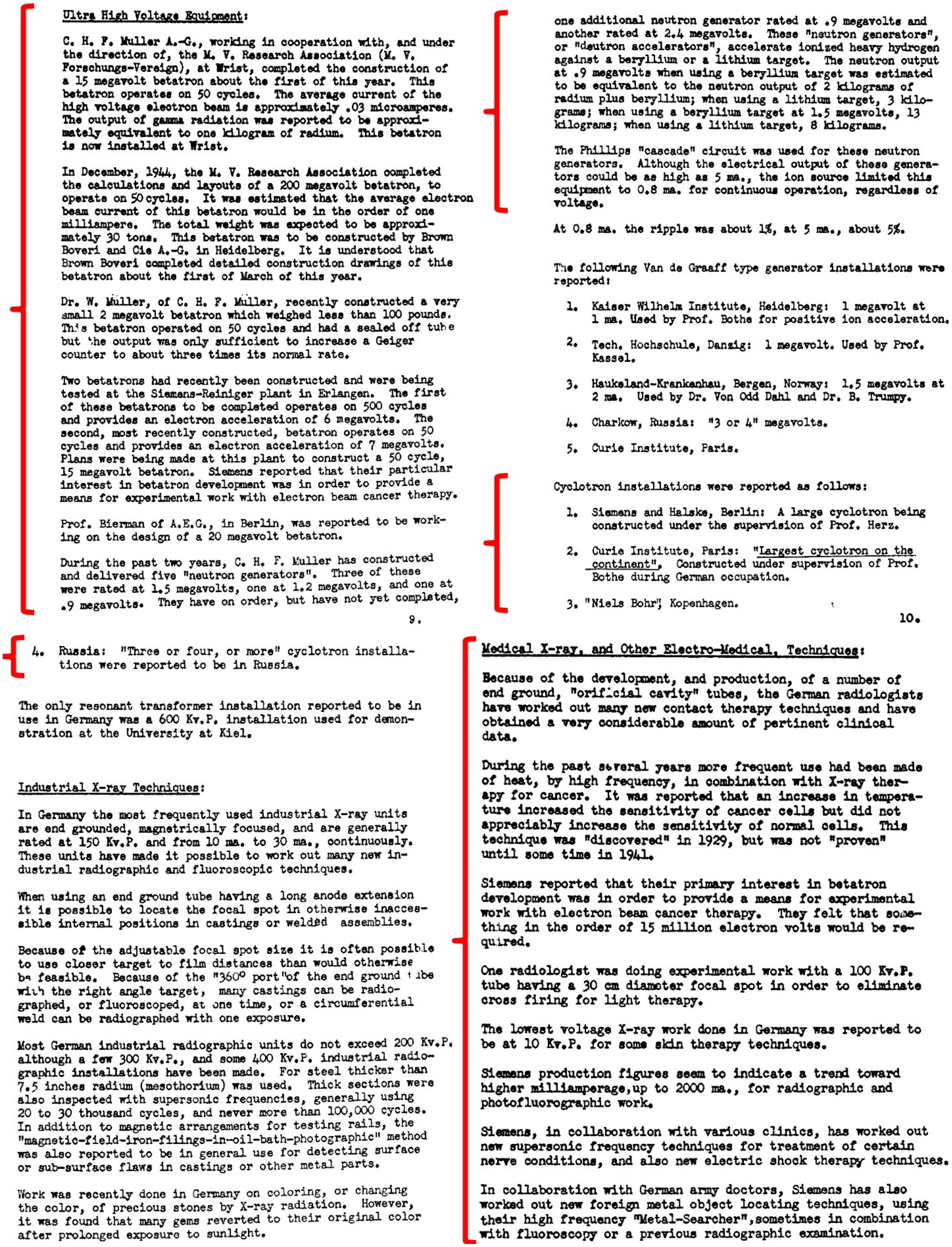
Other Electro-Medical Equipment:

During the past several years, Siemens has done a considerable amount of developmental and experimental work on a supersonic frequency unit for the treatment of certain nerve conditions. In this unit a piezo-electric quartz crystal generates a frequency of about 800,000 cycles. Only a few models of this have been produced.

In 1942, Siemens started production of a high frequency "metal searching" unit for determining the location and position of a metal object to be removed from the body. This unit has been used extensively by the medical corps of the German army.

In 1942, Siemens also started production of a "new and improved Konvulsator" for administering electrical shock treatment for schizophrenia, etc. They have now produced a total of about 200 of these units.

Figure D.441: Caperton Horsley's report CIOS XXVIII-31, *Investigation of the X-Ray Industry in Germany*, states that wartime German companies produced high-voltage fusion neutron generators, betatrons, cyclotrons, color-changing temperature-sensitive paint, a wide variety of highly advanced medical equipment, etc.



Ultra High Voltage Equipment:

C. H. F. Muller A.-G., working in cooperation with, and under the direction of, the M. V. Research Association (M. V. Forschungs-Verein), at Wrist, completed the construction of a 15 megavolt betatron about the first of this year. This betatron operates on 50 cycles. The average current of the high voltage electron beam is approximately .03 microamperes. The output of gamma radiation was reported to be approximately equivalent to one kilogram of radium. This betatron is now installed at Wrist.

In December, 1944, the M. V. Research Association completed the calculations and layouts of a 200 megavolt betatron, to operate on 50 cycles. It was estimated that the average electron beam current of this betatron would be in the order of one milliampere. The total weight was expected to be approximately 30 tons. This betatron was to be constructed by Brown Boveri and Cie A.-G. in Heidelberg. It is understood that Brown Boveri completed detailed construction drawings of this betatron about the first of March of this year.

Dr. W. Müller, of C. H. F. Müller, recently constructed a very small 2 megavolt betatron which weighed less than 100 pounds. This betatron operated on 50 cycles and had a sealed off tube but the output was only sufficient to increase a Geiger counter to about three times its normal rate.

Two betatrons had recently been constructed and were being tested at the Siemens-Reiniger plant in Erlangen. The first of these betatrons to be completed operates on 500 cycles and provides an electron acceleration of 6 megavolts. The second, most recently constructed, betatron operates on 50 cycles and provides an electron acceleration of 7 megavolts. Plans were being made at this plant to construct a 50 cycle, 15 megavolt betatron. Siemens reported that their particular interest in betatron development was in order to provide a means for experimental work with electron beam cancer therapy.

Prof. Bierman of A.E.G., in Berlin, was reported to be working on the design of a 20 megavolt betatron.

During the past two years, C. H. F. Muller has constructed and delivered five "neutron generators". Three of these were rated at 1.5 megavolts, one at 1.2 megavolts, and one at .9 megavolts. They have on order, but have not yet completed,

one additional neutron generator rated at .9 megavolts and another rated at 2.4 megavolts. These "neutron generators", or "deutron accelerators", accelerate ionized heavy hydrogen against a beryllium or a lithium target. The neutron output at .9 megavolts when using a beryllium target was estimated to be equivalent to the neutron output of 2 kilograms of radium plus beryllium; when using a lithium target, 3 kilograms; when using a beryllium target at 1.5 megavolts, 13 kilograms; when using a lithium target, 8 kilograms.

The Phillips "cascade" circuit was used for these neutron generators. Although the electrical output of these generators could be as high as 5 ma., the ion source limited this equipment to 0.8 ma. for continuous operation, regardless of voltage.

At 0.8 ma. the ripple was about 1%, at 5 ma., about 5%.

The following Van de Graaff type generator installations were reported:

1. Kaiser Wilhelm Institute, Heidelberg: 1 megavolt at 1 ma. Used by Prof. Bothe for positive ion acceleration.
2. Tech. Hochschule, Danzig: 1 megavolt. Used by Prof. Kassel.
3. Haukeland-Krankenhau, Bergen, Norway: 1.5 megavolts at 2 ma. Used by Dr. Von Odd Dahl and Dr. B. Trumpy.
4. Charkow, Russia: "3 or 4" megavolts.
5. Curie Institute, Paris.

Cyclotron installations were reported as follows:

1. Siemens and Halske, Berlin: A large cyclotron being constructed under the supervision of Prof. Herz.
2. Curie Institute, Paris: "Largest cyclotron on the continent". Constructed under supervision of Prof. Bothe during German occupation.
3. "Niels Bohr", Kopenhagen.

4. Russia: "Three or four, or more" cyclotron installations were reported to be in Russia.

The only resonant transformer installation reported to be in use in Germany was a 600 Kv.P. installation used for demonstration at the University at Kiel.

Industrial X-ray Techniques:

In Germany the most frequently used industrial X-ray units are end grounded, magnetrically focused, and are generally rated at 150 Kv.P. and from 10 ma. to 30 ma., continuously. These units have made it possible to work out many new industrial radiographic and fluoroscopic techniques.

When using an end ground tube having a long anode extension it is possible to locate the focal spot in otherwise inaccessible internal positions in castings or welded assemblies.

Because of the adjustable focal spot size it is often possible to use closer target to film distances than would otherwise be feasible. Because of the "360° port" of the end ground tube with the right angle target, many castings can be radiographed, or fluoroscoped, at one time, or a circumferential weld can be radiographed with one exposure.

Most German industrial radiographic units do not exceed 200 Kv.P. although a few 300 Kv.P., and some 400 Kv.P. industrial radiographic installations have been made. For steel thicker than 7.5 inches radium (mesothorium) was used. Thick sections were also inspected with supersonic frequencies, generally using 20 to 30 thousand cycles, and never more than 100,000 cycles. In addition to magnetic arrangements for testing rails, the "magnetic-field-iron-filings-in-oil-bath-photographic" method was also reported to be in general use for detecting surface or sub-surface flaws in castings or other metal parts.

Work was recently done in Germany on coloring, or changing the color, of precious stones by X-ray radiation. However, it was found that many gems reverted to their original color after prolonged exposure to sunlight.

Medical X-ray, and Other Electro-Medical, Techniques:

Because of the development, and production, of a number of end ground, "orificial cavity" tubes, the German radiologists have worked out many new contact therapy techniques and have obtained a very considerable amount of pertinent clinical data.

During the past several years more frequent use had been made of heat, by high frequency, in combination with X-ray therapy for cancer. It was reported that an increase in temperature increased the sensitivity of cancer cells but did not appreciably increase the sensitivity of normal cells. This technique was "discovered" in 1929, but was not "proven" until some time in 1941.

Siemens reported that their primary interest in betatron development was in order to provide a means for experimental work with electron beam cancer therapy. They felt that something in the order of 15 million electron volts would be required.

One radiologist was doing experimental work with a 100 Kv.P. tube having a 30 cm diameter focal spot in order to eliminate cross firing for light therapy.

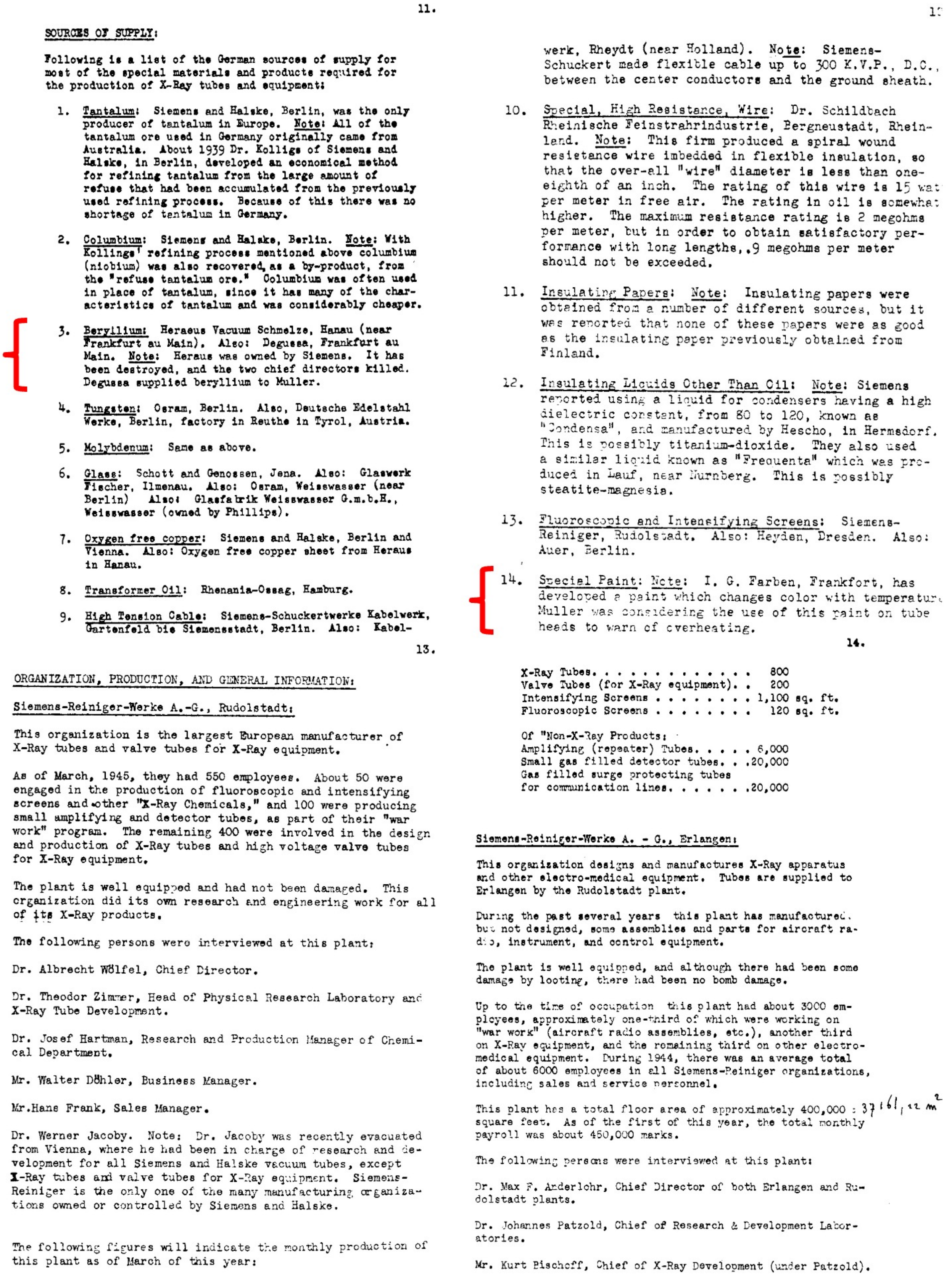
The lowest voltage X-ray work done in Germany was reported to be at 10 Kv.P. for some skin therapy techniques.

Siemens production figures seem to indicate a trend toward higher milliamperage, up to 2000 ma., for radiographic and photofluorographic work.

Siemens, in collaboration with various clinics, has worked out new supersonic frequency techniques for treatment of certain nerve conditions, and also new electric shock therapy techniques.

In collaboration with German army doctors, Siemens has also worked out new foreign metal object locating techniques, using their high frequency "Metal-Searcher", sometimes in combination with fluoroscopy or a previous radiographic examination.

Figure D.442: Caperton Horsley's report CIOS XXVIII-31, *Investigation of the X-Ray Industry in Germany*, states that wartime German companies produced high-voltage fusion neutron generators, betatrons, cyclotrons, color-changing temperature-sensitive paint, a wide variety of highly advanced medical equipment, etc.



11.

SOURCES OF SUPPLY:

Following is a list of the German sources of supply for most of the special materials and products required for the production of X-Ray tubes and equipment:

1. Tantalum: Siemens and Halske, Berlin, was the only producer of tantalum in Europe. Note: All of the tantalum ore used in Germany originally came from Australia. About 1939 Dr. Kolligs of Siemens and Halske, in Berlin, developed an economical method for refining tantalum from the large amount of refuse that had been accumulated from the previously used refining process. Because of this there was no shortage of tantalum in Germany.
2. Columbium: Siemens and Halske, Berlin. Note: With Kollings' refining process mentioned above columbium (niobium) was also recovered, as a by-product, from the "refuse tantalum ore." Columbium was often used in place of tantalum, since it has many of the characteristics of tantalum and was considerably cheaper.
3. Beryllium: Heraeus Vacuum Schmelze, Hanau (near Frankfurt au Main). Also: Degussa, Frankfurt au Main. Note: Heraus was owned by Siemens. It has been destroyed, and the two chief directors killed. Degussa supplied beryllium to Muller.
4. Tungsten: Osram, Berlin. Also, Deutsche Edelstahl Werke, Berlin, factory in Reuthe in Tyrol, Austria.
5. Molybdenum: Same as above.
6. Glass: Schott and Genossen, Jena. Also: Glaswerk Fischer, Ilmenau. Also: Osram, Weisswasser (near Berlin) Also: Glasfabrik Weisswasser G.m.b.H., Weisswasser (owned by Phillips).
7. Oxygen free copper: Siemens and Halske, Berlin and Vienna. Also: Oxygen free copper sheet from Heraus in Hanau.
8. Transformer Oil: Rhenania-Ossag, Hamburg.
9. High Tension Cable: Siemens-Schuckertwerke Kabelwerk, Gartenfeld bie Siemensstadt, Berlin. Also: Kabelwerk, Rheydt (near Holland). Note: Siemens-Schuckert made flexible cable up to 300 K.V.P., D.C., between the center conductors and the ground sheath.

1

10. Special, High Resistance, Wire: Dr. Schildbach Rheinische Feinstrahrindustrie, Bergneustadt, Rheinland. Note: This firm produced a spiral wound resistance wire imbedded in flexible insulation, so that the over-all "wire" diameter is less than one-eighth of an inch. The rating of this wire is 15 wat per meter in free air. The rating in oil is somewhat higher. The maximum resistance rating is 2 megohms per meter, but in order to obtain satisfactory performance with long lengths, .9 megohms per meter should not be exceeded.
11. Insulating Papers: Note: Insulating papers were obtained from a number of different sources, but it was reported that none of these papers were as good as the insulating paper previously obtained from Finland.
12. Insulating Liquids Other Than Oil: Note: Siemens reported using a liquid for condensers having a high dielectric constant, from 80 to 120, known as "Condensa", and manufactured by Hescho, in Hermsdorf. This is possibly titanium-dioxide. They also used a similar liquid known as "Frequenta" which was produced in Lauf, near Nurnberg. This is possibly steatite-magnesia.
13. Fluoroscopic and Intensifying Screens: Siemens-Reiniger, Rudolstadt. Also: Heyden, Dresden. Also: Auer, Berlin.
14. Special Paint: Note: I. G. Farben, Frankfort, has developed a paint which changes color with temperatur Muller was considering the use of this paint on tube heads to warn of overheating.

13.

ORGANIZATION, PRODUCTION, AND GENERAL INFORMATION:

Siemens-Reiniger-Werke A.-G., Rudolstadt:

This organization is the largest European manufacturer of X-Ray tubes and valve tubes for X-Ray equipment.

As of March, 1945, they had 550 employees. About 50 were engaged in the production of fluoroscopic and intensifying screens and other "X-Ray Chemicals," and 100 were producing small amplifying and detector tubes, as part of their "war work" program. The remaining 400 were involved in the design and production of X-Ray tubes and high voltage valve tubes for X-Ray equipment.

The plant is well equipped and had not been damaged. This organization did its own research and engineering work for all of its X-Ray products.

The following persons were interviewed at this plant:

Dr. Albrecht Wölfel, Chief Director.

Dr. Theodor Zimmer, Head of Physical Research Laboratory and X-Ray Tube Development.

Dr. Josef Hartman, Research and Production Manager of Chemical Department.

Mr. Walter Döhler, Business Manager.

Mr. Hans Frank, Sales Manager.

Dr. Werner Jacoby. Note: Dr. Jacoby was recently evacuated from Vienna, where he had been in charge of research and development for all Siemens and Halske vacuum tubes, except X-Ray tubes and valve tubes for X-Ray equipment. Siemens-Reiniger is the only one of the many manufacturing organizations owned or controlled by Siemens and Halske.

The following figures will indicate the monthly production of this plant as of March of this year:

14.

X-Ray Tubes.	800
Valve Tubes (for X-Ray equipment). .	200
Intensifying Screens	1,100 sq. ft.
Fluoroscopic Screens	120 sq. ft.

Of "Non-X-Ray Products:

Amplifying (repeater) Tubes.	6,000
Small gas filled detector tubes. . .	20,000
Gas filled surge protecting tubes for communication lines.	20,000

Siemens-Reiniger-Werke A. - G., Erlangen:

This organization designs and manufactures X-Ray apparatus and other electro-medical equipment. Tubes are supplied to Erlangen by the Rudolstadt plant.

During the past several years this plant has manufactured, but not designed, some assemblies and parts for aircraft radio, instrument, and control equipment.

The plant is well equipped, and although there had been some damage by looting, there had been no bomb damage.

Up to the time of occupation this plant had about 3000 employees, approximately one-third of which were working on "war work" (aircraft radio assemblies, etc.), another third on X-Ray equipment, and the remaining third on other electro-medical equipment. During 1944, there was an average total of about 6000 employees in all Siemens-Reiniger organizations, including sales and service personnel.

This plant has a total floor area of approximately 400,000 : 37161,12 m^2 square feet. As of the first of this year, the total monthly payroll was about 450,000 marks.

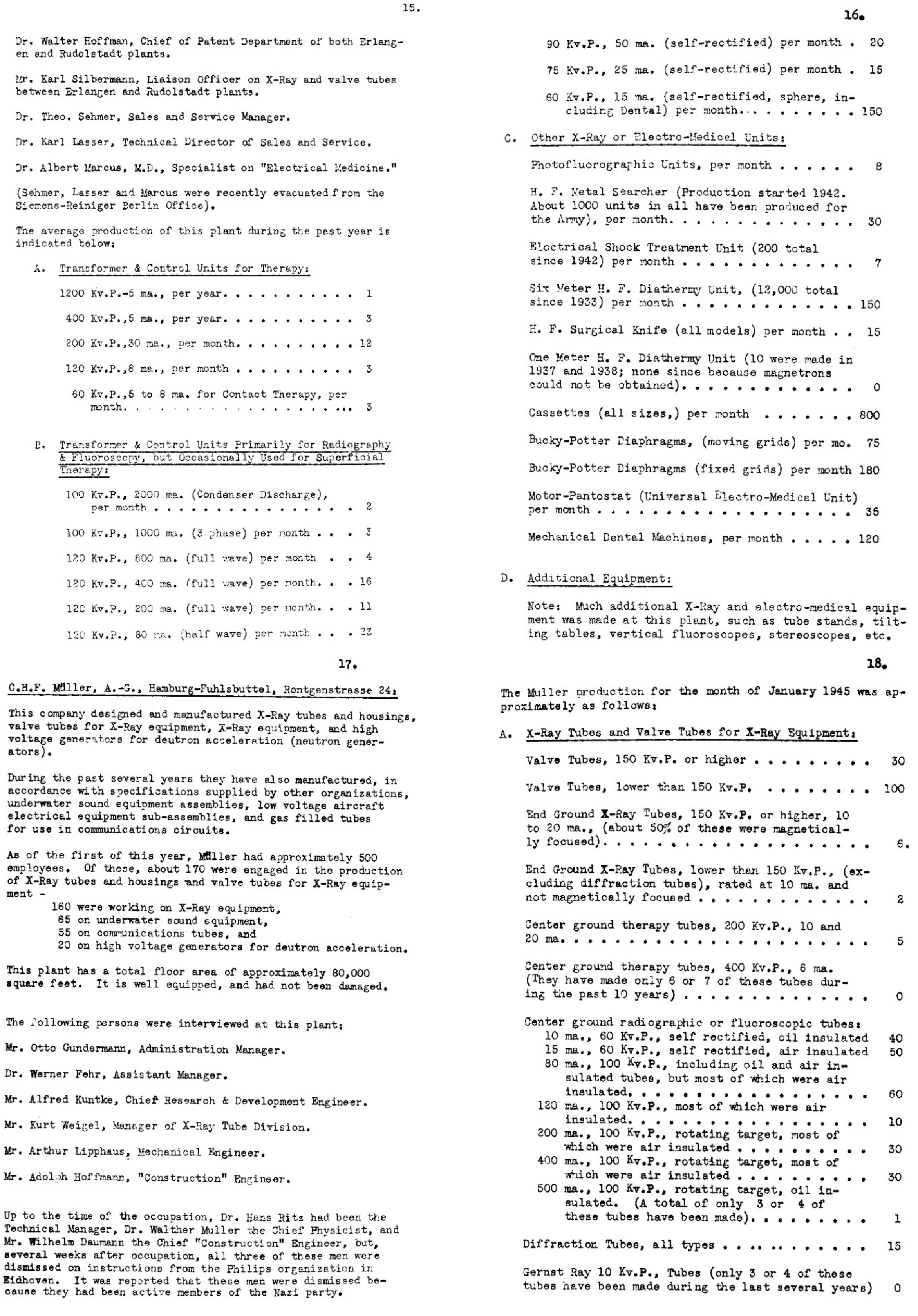
The following persons were interviewed at this plant:

Dr. Max F. Anderlohr, Chief Director of both Erlangen and Rudolstadt plants.

Dr. Johannes Patzold, Chief of Research & Development Laboratories.

Mr. Kurt Bischoff, Chief of X-Ray Development (under Patzold).

Figure D.443: Caperton Horsley's report CIOS XXVIII-31, *Investigation of the X-Ray Industry in Germany*, states that wartime German companies produced high-voltage fusion neutron generators, betatrons, cyclotrons, color-changing temperature-sensitive paint, a wide variety of highly advanced medical equipment, etc.



Dr. Walter Hoffman, Chief of Patent Department of both Erlangen and Rudolstadt plants.

Mr. Karl Silbermann, Liaison Officer on X-Ray and valve tubes between Erlangen and Rudolstadt plants.

Dr. Theo. Sehmer, Sales and Service Manager.

Dr. Karl Lasser, Technical Director of Sales and Service.

Dr. Albert Marcus, M.D., Specialist on "Electrical Medicine."

(Sehmer, Lasser and Marcus were recently evacuated from the Siemens-Reiniger Berlin Office).

The average production of this plant during the past year is indicated below:

A. Transformer & Control Units for Therapy:

1200 Kv.P.-5 ma., per year	1
400 Kv.P.,5 ma., per year	3
200 Kv.P.,30 ma., per month	12
120 Kv.P.,8 ma., per month	3
60 Kv.P.,5 to 8 ma. for Contact Therapy, per month	3

B. Transformer & Control Units Primarily for Radiography & Fluoroscopy, but Occasionally Used for Superficial Therapy:

100 Kv.P., 2000 ma. (Condenser Discharge), per month	2
100 Kv.P., 1000 ma. (3 phase) per month	3
120 Kv.P., 800 ma. (full wave) per month	4
120 Kv.P., 400 ma. (full wave) per month	16
120 Kv.P., 200 ma. (full wave) per month	11
120 Kv.P., 80 ma. (half wave) per month	23

90 Kv.P., 50 ma. (self-rectified) per month	20
75 Kv.P., 25 ma. (self-rectified) per month	15
60 Kv.P., 15 ma. (self-rectified, sphere, including Dental) per month	150

C. Other X-Ray or Electro-Medical Units:

Photofluorographic Units, per month	8
H. F. Metal Searcher (Production started 1942. About 1000 units in all have been produced for the Army), per month	30
Electrical Shock Treatment Unit (200 total since 1942) per month	7
Six Meter H. F. Diathermy Unit, (12,000 total since 1933) per month	150
H. F. Surgical Knife (all models) per month	15
One Meter H. F. Diathermy Unit (10 were made in 1937 and 1938; none since because magnetrons could not be obtained)	0
Cassettes (all sizes,) per month	800
Bucky-Potter Diaphragms, (moving grids) per mo.	75
Bucky-Potter Diaphragms (fixed grids) per month	180
Motor-Pantostat (Universal Electro-Medical Unit) per month	35
Mechanical Dental Machines, per month	120

D. Additional Equipment:

Note: Much additional X-Ray and electro-medical equipment was made at this plant, such as tube stands, tilting tables, vertical fluoroscopes, stereoscopes, etc.

C.H.F. Müller, A.-G., Hamburg-Fuhlsbuttel, Rontgenstrasse 24:

This company designed and manufactured X-Ray tubes and housings, valve tubes for X-Ray equipment, X-Ray equipment, and high voltage generators for deutron acceleration (neutron generators).

During the past several years they have also manufactured, in accordance with specifications supplied by other organizations, underwater sound equipment assemblies, low voltage aircraft electrical equipment sub-assemblies, and gas filled tubes for use in communications circuits.

As of the first of this year, Müller had approximately 500 employees. Of these, about 170 were engaged in the production of X-Ray tubes and housings and valve tubes for X-Ray equipment -

160 were working on X-Ray equipment,
65 on underwater sound equipment,
55 on communications tubes, and
20 on high voltage generators for deutron acceleration.

This plant has a total floor area of approximately 80,000 square feet. It is well equipped, and had not been damaged.

The following persons were interviewed at this plant:

Mr. Otto Gundermann, Administration Manager.

Dr. Werner Fehr, Assistant Manager.

Mr. Alfred Kuntke, Chief Research & Development Engineer.

Mr. Kurt Weigel, Manager of X-Ray Tube Division.

Mr. Arthur Lipphaus, Mechanical Engineer.

Mr. Adolph Hoffmann, "Construction" Engineer.

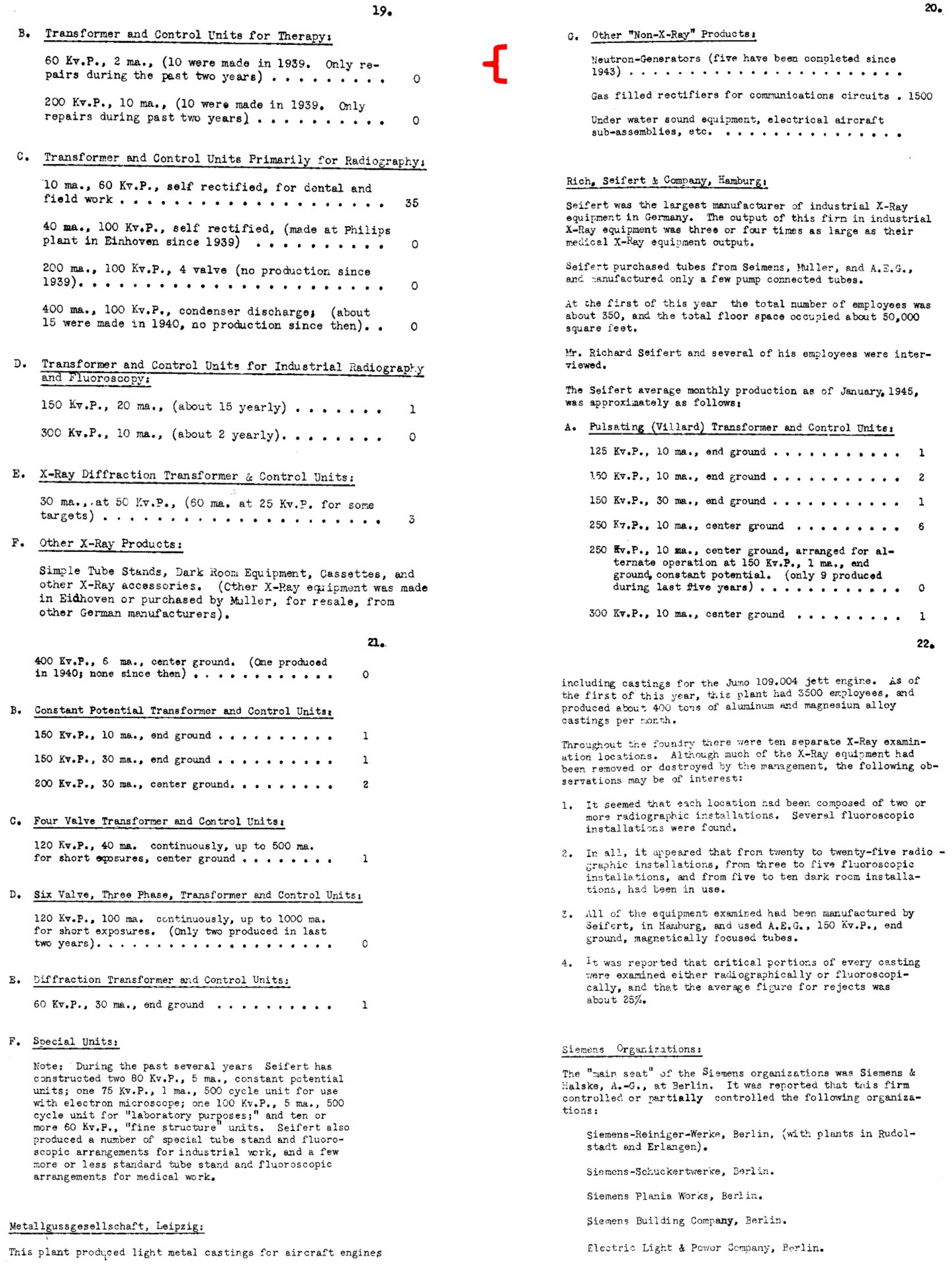
Up to the time of the occupation, Dr. Hans Ritz had been the Technical Manager, Dr. Walther Muller the Chief Physicist, and Mr. Wilhelm Daumann the Chief "Construction" Engineer, but, several weeks after occupation, all three of these men were dismissed on instructions from the Philips organization in Eidhoven. It was reported that these men were dismissed because they had been active members of the Nazi party.

The Muller production for the month of January 1945 was approximately as follows:

A. X-Ray Tubes and Valve Tubes for X-Ray Equipment:

Valve Tubes, 150 Kv.P. or higher	30
Valve Tubes, lower than 150 Kv.P.	100
End Ground X-Ray Tubes, 150 Kv.P. or higher, 10 to 20 ma., (about 50% of these were magnetically focused)	6.
End Ground X-Ray Tubes, lower than 150 Kv.P., (excluding diffraction tubes), rated at 10 ma. and not magnetically focused	2
Center ground therapy tubes, 200 Kv.P., 10 and 20 ma.	5
Center ground therapy tubes, 400 Kv.P., 6 ma. (They have made only 6 or 7 of these tubes during the past 10 years)	0
Center ground radiographic or fluoroscopic tubes:	
10 ma., 60 Kv.P., self rectified, oil insulated	40
15 ma., 60 Kv.P., self rectified, air insulated	50
80 ma., 100 Kv.P., including oil and air insulated tubes, but most of which were air insulated.	60
120 ma., 100 Kv.P., most of which were air insulated.	10
200 ma., 100 Kv.P., rotating target, most of which were air insulated	30
400 ma., 100 Kv.P., rotating target, most of which were air insulated	30
500 ma., 100 Kv.P., rotating target, oil insulated. (A total of only 3 or 4 of these tubes have been made).	1
Diffraction Tubes, all types	15
Gernst Ray 10 Kv.P., Tubes (only 3 or 4 of these tubes have been made during the last several years)	0

Figure D.444: Caperton Horsley's report CIOS XXVIII-31, *Investigation of the X-Ray Industry in Germany*, states that wartime German companies produced high-voltage fusion neutron generators, betatrons, cyclotrons, color-changing temperature-sensitive paint, a wide variety of highly advanced medical equipment, etc.



19.

B. Transformer and Control Units for Therapy:

60 Kv.P., 2 ma., (10 were made in 1939. Only repairs during the past two years)	0
200 Kv.P., 10 ma., (10 were made in 1939. Only repairs during past two years)	0

C. Transformer and Control Units Primarily for Radiography:

10 ma., 60 Kv.P., self rectified, for dental and field work	35
40 ma., 100 Kv.P., self rectified, (made at Philips plant in Einhoven since 1939)	0
200 ma., 100 Kv.P., 4 valve (no production since 1939).	0
400 ma., 100 Kv.P., condenser discharge; (about 15 were made in 1940, no production since then). .	0

D. Transformer and Control Units for Industrial Radiography and Fluoroscopy:

150 Kv.P., 20 ma., (about 15 yearly)	1
300 Kv.P., 10 ma., (about 2 yearly).	0

E. X-Ray Diffraction Transformer & Control Units:

30 ma., at 50 Kv.P., (60 ma. at 25 Kv.P. for some targets)	3

F. Other X-Ray Products:

Simple Tube Stands, Dark Room Equipment, Cassettes, and other X-Ray accessories. (Other X-Ray equipment was made in Eidhoven or purchased by Muller, for resale, from other German manufacturers).

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G. Other "Non-X-Ray" Products:

Neutron-Generators (five have been completed since 1943)	
Gas filled rectifiers for communications circuits .	1500
Under water sound equipment, electrical aircraft sub-assemblies, etc.	

Rich, Seifert & Company, Hamburg:

Seifert was the largest manufacturer of industrial X-Ray equipment in Germany. The output of this firm in industrial X-Ray equipment was three or four times as large as their medical X-Ray equipment output.

Seifert purchased tubes from Seimens, Muller, and A.E.G., and manufactured only a few pump connected tubes.

At the first of this year the total number of employees was about 350, and the total floor space occupied about 50,000 square feet.

Mr. Richard Seifert and several of his employees were interviewed.

The Seifert average monthly production as of January, 1945, was approximately as follows:

A. Pulsating (Villard) Transformer and Control Units:

125 Kv.P., 10 ma., end ground	1
150 Kv.P., 10 ma., end ground	2
150 Kv.P., 30 ma., end ground	1
250 Kv.P., 10 ma., center ground	6
250 Kv.P., 10 ma., center ground, arranged for alternate operation at 150 Kv.P., 1 ma., end ground, constant potential. (only 9 produced during last five years)	0
300 Kv.P., 10 ma., center ground	1

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400 Kv.P., 6 ma., center ground. (One produced in 1940; none since then)	0

B. Constant Potential Transformer and Control Units:

150 Kv.P., 10 ma., end ground	1
150 Kv.P., 30 ma., end ground	1
200 Kv.P., 30 ma., center ground.	2

C. Four Valve Transformer and Control Units:

120 Kv.P., 40 ma. continuously, up to 500 ma. for short exposures, center ground	1

D. Six Valve, Three Phase, Transformer and Control Units:

120 Kv.P., 100 ma. continuously, up to 1000 ma. for short exposures. (Only two produced in last two years).	0

E. Diffraction Transformer and Control Units:

60 Kv.P., 30 ma., end ground	1

F. Special Units:

Note: During the past several years Seifert has constructed two 80 Kv.P., 5 ma., constant potential units; one 75 Kv.P., 1 ma., 500 cycle unit for use with electron microscope; one 100 Kv.P., 5 ma., 500 cycle unit for "laboratory purposes;" and ten or more 60 Kv.P., "fine structure" units. Seifert also produced a number of special tube stand and fluoroscopic arrangements for industrial work, and a few more or less standard tube stand and fluoroscopic arrangements for medical work.

Metallgussgesellschaft, Leipzig:

This plant produced light metal castings for aircraft engines

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including castings for the Jumo 109.004 jett engine. As of the first of this year, this plant had 3500 employees, and produced about 400 tons of aluminum and magnesium alloy castings per month.

Throughout the foundry there were ten separate X-Ray examination locations. Although much of the X-Ray equipment had been removed or destroyed by the management, the following observations may be of interest:

1. It seemed that each location had been composed of two or more radiographic installations. Several fluoroscopic installations were found.
2. In all, it appeared that from twenty to twenty-five radiographic installations, from three to five fluoroscopic installations, and from five to ten dark room installations, had been in use.
3. All of the equipment examined had been manufactured by Seifert, in Hamburg, and used A.E.G., 150 Kv.P., end ground, magnetically focused tubes.
4. It was reported that critical portions of every casting were examined either radiographically or fluoroscopically, and that the average figure for rejects was about 25%.

Siemens Organizations:

The "main seat" of the Siemens organizations was Siemens & Halske, A.-G., at Berlin. It was reported that this firm controlled or partially controlled the following organizations:

Siemens-Reiniger-Werke, Berlin, (with plants in Rudolstadt and Erlangen).

Siemens-Schuckertwerke, Berlin.

Siemens Plania Works, Berlin.

Siemens Building Company, Berlin.

Electric Light & Power Company, Berlin.

Figure D.445: Caperton Horsley's report CIOS XXVIII-31, *Investigation of the X-Ray Industry in Germany*, states that wartime German companies produced high-voltage fusion neutron generators, betatrons, cyclotrons, color-changing temperature-sensitive paint, a wide variety of highly advanced medical equipment, etc.
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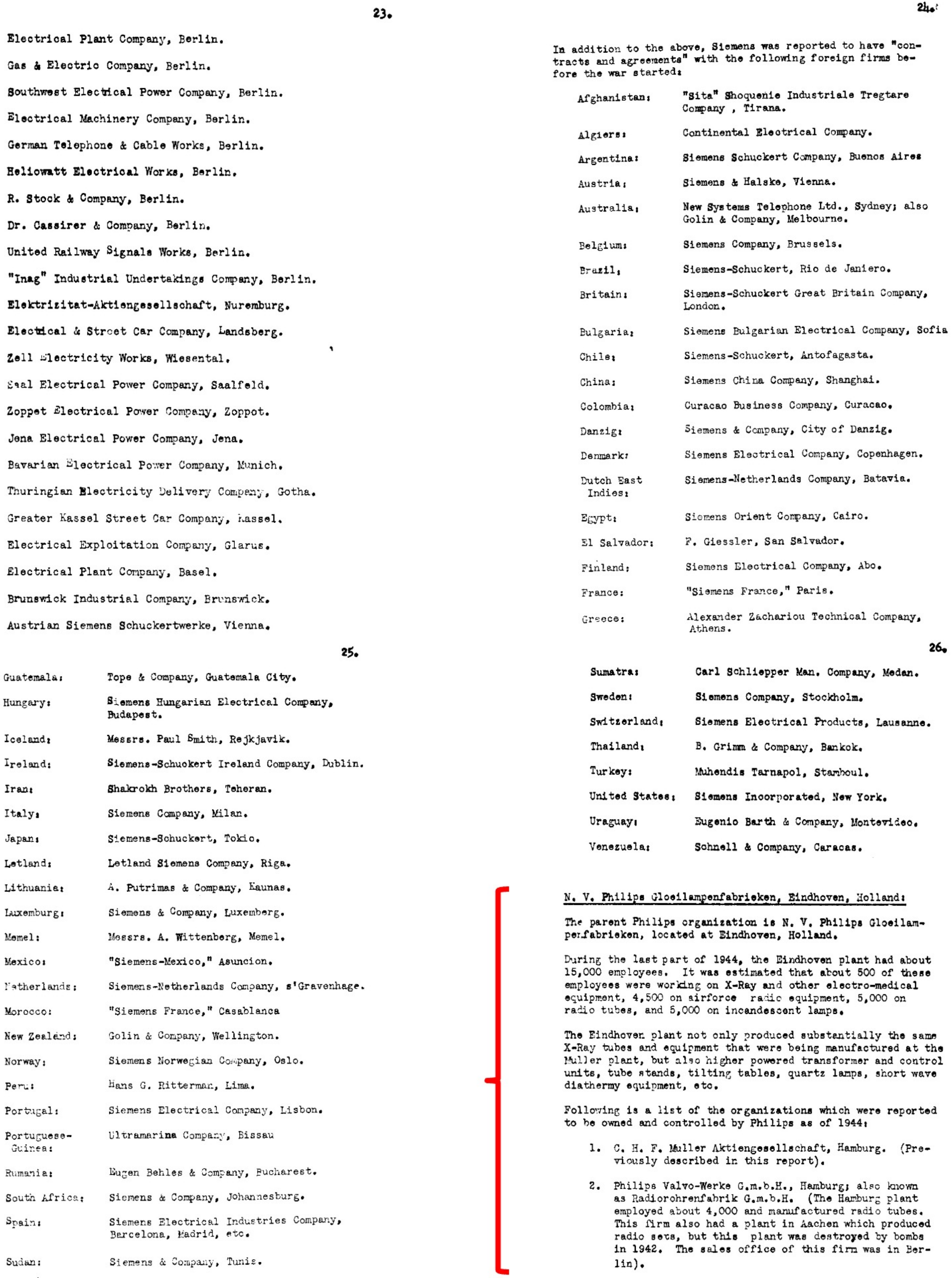

23.

Electrical Plant Company, Berlin.

Gas & Electric Company, Berlin.

Southwest Electrical Power Company, Berlin.

Electrical Machinery Company, Berlin.

German Telephone & Cable Works, Berlin.

Heliowatt Electrical Works, Berlin.

R. Stock & Company, Berlin.

Dr. Cassirer & Company, Berlin.

United Railway Signals Works, Berlin.

"Inag" Industrial Undertakings Company, Berlin.

Elektrizitat-Aktiengesellschaft, Nuremburg.

Electrical & Street Car Company, Landsberg.

Zell Electricity Works, Wiesental.

Saal Electrical Power Company, Saalfeld.

Zoppet Electrical Power Company, Zoppot.

Jena Electrical Power Company, Jena.

Bavarian Electrical Power Company, Munich.

Thuringian Electricity Delivery Company, Gotha.

Greater Kassel Street Car Company, Kassel.

Electrical Exploitation Company, Glarus.

Electrical Plant Company, Basel.

Brunswick Industrial Company, Brunswick.

Austrian Siemens Schuckertwerke, Vienna.

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In addition to the above, Siemens was reported to have "contracts and agreements" with the following foreign firms before the war started:

Afghanistan:	"Sita" Shoquenie Industriale Tregtare Company, Tirana.
Algiers:	Continental Electrical Company.
Argentina:	Siemens Schuckert Company, Buenos Aires
Austria:	Siemens & Halske, Vienna.
Australia:	New Systems Telephone Ltd., Sydney; also Golin & Company, Melbourne.
Belgium:	Siemens Company, Brussels.
Brazil:	Siemens-Schuckert, Rio de Janiero.
Britain:	Siemens-Schuckert Great Britain Company, London.
Bulgaria:	Siemens Bulgarian Electrical Company, Sofia
Chile:	Siemens-Schuckert, Antofagasta.
China:	Siemens China Company, Shanghai.
Colombia:	Curacao Business Company, Curacao.
Danzig:	Siemens & Company, City of Danzig.
Denmark:	Siemens Electrical Company, Copenhagen.
Dutch East Indies:	Siemens-Netherlands Company, Batavia.
Egypt:	Siemens Orient Company, Cairo.
El Salvador:	F. Giessler, San Salvador.
Finland:	Siemens Electrical Company, Abo.
France:	"Siemens France," Paris.
Greece:	Alexander Zachariou Technical Company, Athens.

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Guatemala:	Tope & Company, Guatemala City.
Hungary:	Siemens Hungarian Electrical Company, Budapest.
Iceland:	Messrs. Paul Smith, Rejkjavik.
Ireland:	Siemens-Schuckert Ireland Company, Dublin.
Iran:	Shakrokh Brothers, Teheran.
Italy:	Siemens Company, Milan.
Japan:	Siemens-Schuckert, Tokio.
Letland:	Letland Siemens Company, Riga.
Lithuania:	A. Putrimas & Company, Kaunas.
Luxemburg:	Siemens & Company, Luxemberg.
Memel:	Messrs. A. Wittenberg, Memel.
Mexico:	"Siemens-Mexico," Asuncion.
Netherlands:	Siemens-Netherlands Company, s'Gravenhage.
Morocco:	"Siemens France," Casablanca
New Zealand:	Golin & Company, Wellington.
Norway:	Siemens Norwegian Company, Oslo.
Peru:	Hans G. Ritterman, Lima.
Portugal:	Siemens Electrical Company, Lisbon.
Portuguese-Guinea:	Ultramarina Company, Bissau
Rumania:	Eugen Behles & Company, Bucharest.
South Africa:	Siemens & Company, Johannesburg.
Spain:	Siemens Electrical Industries Company, Barcelona, Madrid, etc.
Sudan:	Siemens & Company, Tunis.

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Sumatra:	Carl Schliepper Man. Company, Medan.
Sweden:	Siemens Company, Stockholm.
Switzerland:	Siemens Electrical Products, Lausanne.
Thailand:	B. Grimm & Company, Bankok.
Turkey:	Muhendis Tarnapol, Stamboul.
United States:	Siemens Incorporated, New York.
Uraguay:	Eugenio Barth & Company, Montevideo.
Venezuela:	Schnell & Company, Caracas.

N. V. Philips Gloeilampenfabrieken, Eindhoven, Holland:

The parent Philips organization is N. V. Philips Gloeilampenfabrieken, located at Eindhoven, Holland.

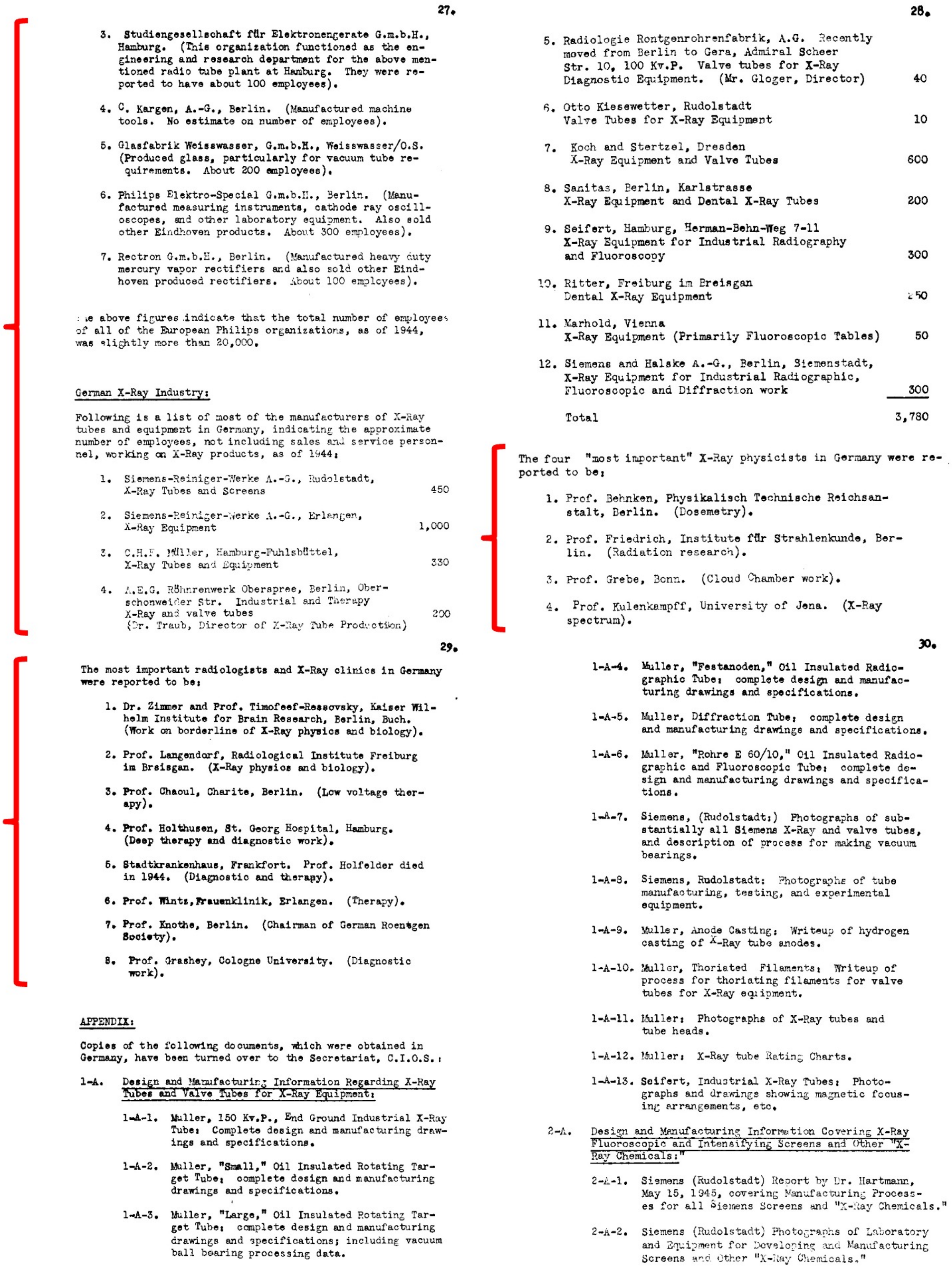
During the last part of 1944, the Eindhoven plant had about 15,000 employees. It was estimated that about 500 of these employees were working on X-Ray and other electro-medical equipment, 4,500 on airforce radio equipment, 5,000 on radio tubes, and 5,000 on incandescent lamps.

The Eindhoven plant not only produced substantially the same X-Ray tubes and equipment that were being manufactured at the Muller plant, but also higher powered transformer and control units, tube stands, tilting tables, quartz lamps, short wave diathermy equipment, etc.

Following is a list of the organizations which were reported to be owned and controlled by Philips as of 1944:

1. C. H. F. Muller Aktiengesellschaft, Hamburg. (Previously described in this report).
2. Philips Valvo-Werke G.m.b.H., Hamburg; also known as Radiorohrenfabrik G.m.b.H. (The Hamburg plant employed about 4,000 and manufactured radio tubes. This firm also had a plant in Aachen which produced radio sets, but this plant was destroyed by bombs in 1942. The sales office of this firm was in Berlin).

Figure D.446: Caperton Horsley's report CIOS XXVIII-31, *Investigation of the X-Ray Industry in Germany*, states that wartime German companies produced high-voltage fusion neutron generators, betatrons, cyclotrons, color-changing temperature-sensitive paint, a wide variety of highly advanced medical equipment, etc.



27.

3. **Studiengesellschaft für Elektronengerate G.m.b.H., Hamburg.** (This organization functioned as the engineering and research department for the above mentioned radio tube plant at Hamburg. They were reported to have about 100 employees).
4. C. Kargen, A.-G., Berlin. (Manufactured machine tools. No estimate on number of employees).
5. Glasfabrik Weisswasser, G.m.b.H., Weisswasser/O.S. (Produced glass, particularly for vacuum tube requirements. About 200 employees).
6. Philips Elektro-Special G.m.b.H., Berlin. (Manufactured measuring instruments, cathode ray oscilloscopes, and other laboratory equipment. Also sold other Eindhoven products. About 300 employees).
7. Rectron G.m.b.H., Berlin. (Manufactured heavy duty mercury vapor rectifiers and also sold other Eindhoven produced rectifiers. About 100 employees).

The above figures indicate that the total number of employees of all of the European Philips organizations, as of 1944, was slightly more than 20,000.

German X-Ray Industry:

Following is a list of most of the manufacturers of X-Ray tubes and equipment in Germany, indicating the approximate number of employees, not including sales and service personnel, working on X-Ray products, as of 1944:

1.	Siemens-Reiniger-Werke A.-G., Rudolstadt, X-Ray Tubes and Screens	450
2.	Siemens-Reiniger-Werke A.-G., Erlangen, X-Ray Equipment	1,000
3.	C.H.F. Müller, Hamburg-Fuhlsbüttel, X-Ray Tubes and Equipment	330
4.	A.E.G. Röhrenwerk Oberspree, Berlin, Oberschonweider Str. Industrial and Therapy X-Ray and valve tubes (Dr. Traub, Director of X-Ray Tube Production)	200

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5.	Radiologie Rontgenrohrenfabrik, A.G. Recently moved from Berlin to Gera, Admiral Scheer Str. 10, 100 Kv.P. Valve tubes for X-Ray Diagnostic Equipment. (Mr. Gloger, Director)	40
6.	Otto Kiesewetter, Rudolstadt Valve Tubes for X-Ray Equipment	10
7.	Koch and Stertzel, Dresden X-Ray Equipment and Valve Tubes	600
8.	Sanitas, Berlin, Karlstrasse X-Ray Equipment and Dental X-Ray Tubes	200
9.	Seifert, Hamburg, Herman-Behn-Weg 7-11 X-Ray Equipment for Industrial Radiography and Fluoroscopy	300
10.	Ritter, Freiburg im Breisgan Dental X-Ray Equipment	250
11.	Marhold, Vienna X-Ray Equipment (Primarily Fluoroscopic Tables)	50
12.	Siemens and Halske A.-G., Berlin, Siemenstadt, X-Ray Equipment for Industrial Radiographic, Fluoroscopic and Diffraction work	300
	Total	3,780

The four "most important" X-Ray physicists in Germany were reported to be:

1. Prof. Behnken, Physikalisch Technische Reichsanstalt, Berlin. (Dosemetry).
2. Prof. Friedrich, Institute für Strahlenkunde, Berlin. (Radiation research).
3. Prof. Grebe, Bonn. (Cloud Chamber work).
4. Prof. Kulenkampff, University of Jena. (X-Ray spectrum).

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The most important radiologists and X-Ray clinics in Germany were reported to be:

1. Dr. Zimmer and Prof. Timofeef-Ressovsky, Kaiser Wilhelm Institute for Brain Research, Berlin, Buch. (Work on borderline of X-Ray physics and biology).
2. Prof. Langendorf, Radiological Institute Freiburg im Breisgan. (X-Ray physics and biology).
3. Prof. Chaoul, Charite, Berlin. (Low voltage therapy).
4. Prof. Holthusen, St. Georg Hospital, Hamburg. (Deep therapy and diagnostic work).
5. Stadtkrankenhaus, Frankfort. Prof. Holfelder died in 1944. (Diagnostic and therapy).
6. Prof. Wintz, Frauenklinik, Erlangen. (Therapy).
7. Prof. Knothe, Berlin. (Chairman of German Roentgen Society).
8. Prof. Grashey, Cologne University. (Diagnostic work).

APPENDIX:

Copies of the following documents, which were obtained in Germany, have been turned over to the Secretariat, C.I.O.S.:

1-A. Design and Manufacturing Information Regarding X-Ray Tubes and Valve Tubes for X-Ray Equipment:

1-A-1. Muller, 150 Kv.P., End Ground Industrial X-Ray Tube: Complete design and manufacturing drawings and specifications.

1-A-2. Muller, "Small," Oil Insulated Rotating Target Tube; complete design and manufacturing drawings and specifications.

1-A-3. Muller, "Large," Oil Insulated Rotating Target Tube; complete design and manufacturing drawings and specifications; including vacuum ball bearing processing data.

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1-A-4. Muller, "Festanoden," Oil Insulated Radiographic Tube; complete design and manufacturing drawings and specifications.

1-A-5. Muller, Diffraction Tube; complete design and manufacturing drawings and specifications.

1-A-6. Muller, "Rohre E 60/10," Oil Insulated Radiographic and Fluoroscopic Tube; complete design and manufacturing drawings and specifications.

1-A-7. Siemens, (Rudolstadt:) Photographs of substantially all Siemens X-Ray and valve tubes, and description of process for making vacuum bearings.

1-A-8. Siemens, Rudolstadt: Photographs of tube manufacturing, testing, and experimental equipment.

1-A-9. Muller, Anode Casting: Writeup of hydrogen casting of X-Ray tube anodes.

1-A-10. Muller, Thoriated Filaments; Writeup of process for thoriating filaments for valve tubes for X-Ray equipment.

1-A-11. Muller: Photographs of X-Ray tubes and tube heads.

1-A-12. Muller: X-Ray tube Rating Charts.

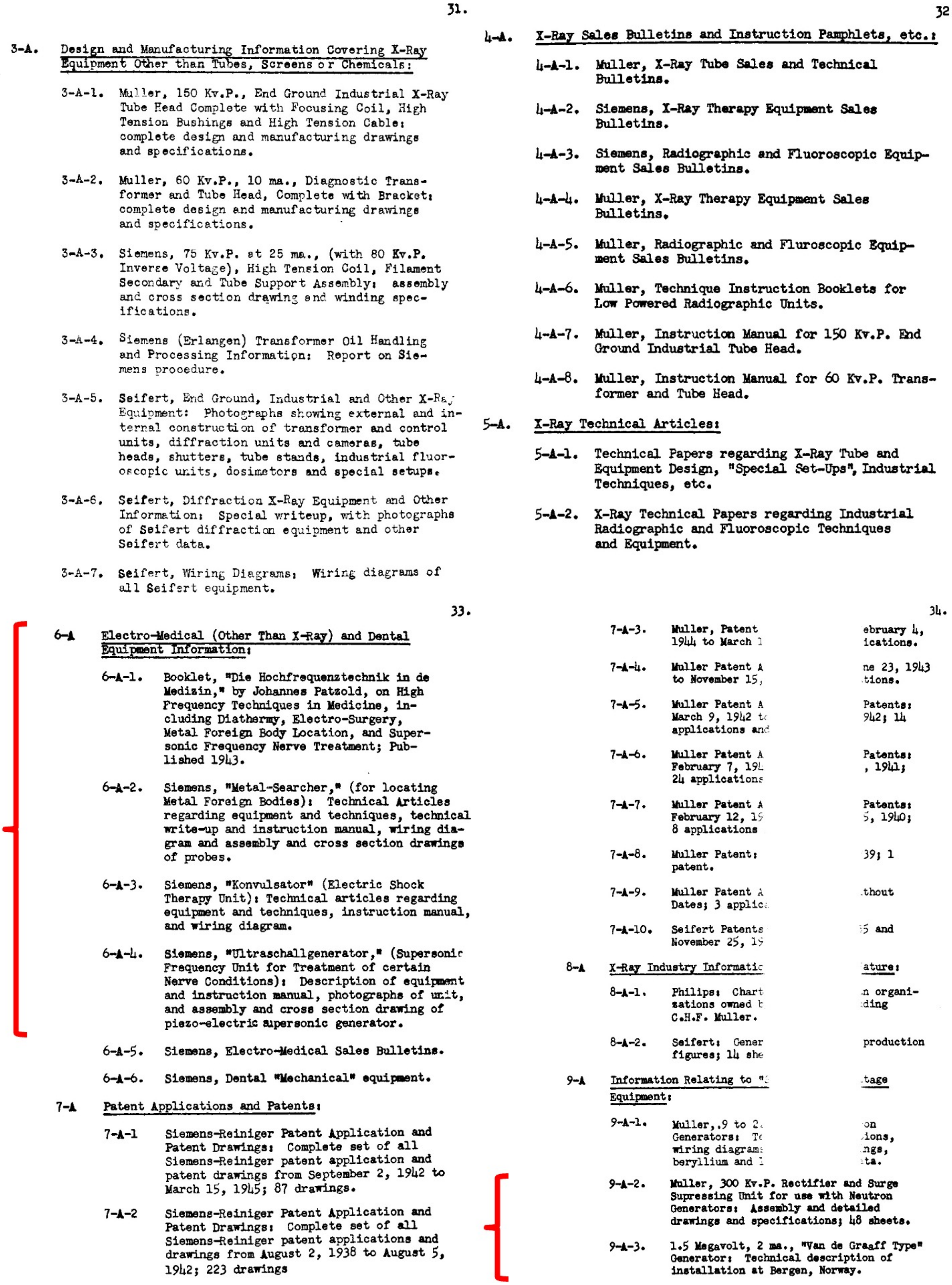
1-A-13. Seifert, Industrial X-Ray Tubes: Photographs and drawings showing magnetic focusing arrangements, etc.

2-A. Design and Manufacturing Information Covering X-Ray Fluoroscopic and Intensifying Screens and Other "X-Ray Chemicals:"

2-A-1. Siemens (Rudolstadt) Report by Dr. Hartmann, May 15, 1945, covering Manufacturing Processes for all Siemens Screens and "X-Ray Chemicals."

2-A-2. Siemens (Rudolstadt) Photographs of Laboratory and Equipment for Developing and Manufacturing Screens and Other "X-Ray Chemicals."

Figure D.447: Caperton Horsley's report CIOS XXVIII-31, *Investigation of the X-Ray Industry in Germany*, states that wartime German companies produced high-voltage fusion neutron generators, betatrons, cyclotrons, color-changing temperature-sensitive paint, a wide variety of highly advanced medical equipment, etc.



31.

3-A. Design and Manufacturing Information Covering X-Ray Equipment Other than Tubes, Screens or Chemicals:

3-A-1. Muller, 150 Kv.P., End Ground Industrial X-Ray Tube Head Complete with Focusing Coil, High Tension Bushings and High Tension Cable: complete design and manufacturing drawings and specifications.

3-A-2. Muller, 60 Kv.P., 10 ma., Diagnostic Transformer and Tube Head, Complete with Bracket: complete design and manufacturing drawings and specifications.

3-A-3. Siemens, 75 Kv.P. at 25 ma., (with 80 Kv.P. Inverse Voltage), High Tension Coil, Filament Secondary and Tube Support Assembly: assembly and cross section drawing and winding specifications.

3-A-4. Siemens (Erlangen) Transformer Oil Handling and Processing Information: Report on Siemens procedure.

3-A-5. Seifert, End Ground, Industrial and Other X-Ray Equipment: Photographs showing external and internal construction of transformer and control units, diffraction units and cameras, tube heads, shutters, tube stands, industrial fluoroscopic units, dosimetors and special setups.

3-A-6. Seifert, Diffraction X-Ray Equipment and Other Information: Special writeup, with photographs of Seifert diffraction equipment and other Seifert data.

3-A-7. Seifert, Wiring Diagrams: Wiring diagrams of all Seifert equipment.

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4-A. X-Ray Sales Bulletins and Instruction Pamphlets, etc.:

4-A-1. Muller, X-Ray Tube Sales and Technical Bulletins.

4-A-2. Siemens, X-Ray Therapy Equipment Sales Bulletins.

4-A-3. Siemens, Radiographic and Fluoroscopic Equipment Sales Bulletins.

4-A-4. Muller, X-Ray Therapy Equipment Sales Bulletins.

4-A-5. Muller, Radiographic and Fluroscopic Equipment Sales Bulletins.

4-A-6. Muller, Technique Instruction Booklets for Low Powered Radiographic Units.

4-A-7. Muller, Instruction Manual for 150 Kv.P. End Ground Industrial Tube Head.

4-A-8. Muller, Instruction Manual for 60 Kv.P. Transformer and Tube Head.

5-A. X-Ray Technical Articles:

5-A-1. Technical Papers regarding X-Ray Tube and Equipment Design, "Special Set-Ups", Industrial Techniques, etc.

5-A-2. X-Ray Technical Papers regarding Industrial Radiographic and Fluoroscopic Techniques and Equipment.

33.

6-A Electro-Medical (Other Than X-Ray) and Dental Equipment Information:

6-A-1. Booklet, "Die Hochfrequenztechnik in de Medizin," by Johannes Patzold, on High Frequency Techniques in Medicine, including Diathermy, Electro-Surgery, Metal Foreign Body Location, and Supersonic Frequency Nerve Treatment; Published 1943.

6-A-2. Siemens, "Metal-Searcher," (for locating Metal Foreign Bodies): Technical Articles regarding equipment and techniques, technical write-up and instruction manual, wiring diagram and assembly and cross section drawings of probes.

6-A-3. Siemens, "Konvulsator" (Electric Shock Therapy Unit): Technical articles regarding equipment and techniques, instruction manual, and wiring diagram.

6-A-4. Siemens, "Ultraschallgenerator," (Supersonic Frequency Unit for Treatment of certain Nerve Conditions): Description of equipment and instruction manual, photographs of unit, and assembly and cross section drawing of piezo-electric supersonic generator.

6-A-5. Siemens, Electro-Medical Sales Bulletins.

6-A-6. Siemens, Dental "Mechanical" equipment.

7-A Patent Applications and Patents:

7-A-1 Siemens-Reiniger Patent Application and Patent Drawings: Complete set of all Siemens-Reiniger patent application and patent drawings from September 2, 1942 to March 15, 1945; 87 drawings.

7-A-2 Siemens-Reiniger Patent Application and Patent Drawings: Complete set of all Siemens-Reiniger patent applications and drawings from August 2, 1938 to August 5, 1942; 223 drawings

34.

7-A-3. Muller, Patent ebruary 4,
1944 to March ications.

7-A-4. Muller Patent A ne 23, 1943
to November 15, tions.

7-A-5. Muller Patent A Patents:
March 9, 1942 t 942; 14
applications and

7-A-6. Muller Patent A Patents:
February 7, 19 , 1941;
24 applications

7-A-7. Muller Patent A Patents:
February 12, 19 5, 1940;
8 applications

7-A-8. Muller Patent: 39; 1
patent.

7-A-9. Muller Patent A thout
Dates; 3 applic

7-A-10. Seifert Patents 5 and
November 25, 19

8-A X-Ray Industry Informatic ature:

8-A-1. Philips: Chart n organi-
zations owned t ding
C.H.F. Muller.

8-A-2. Seifert: Gener production
figures; 14 she

9-A Information Relating to " tage
Equipment:

9-A-1. Muller, .9 to 2 on
Generators: T ions,
wiring diagram ngs,
beryllium and ta.

9-A-2. Muller, 300 Kv.P. Rectifier and Surge Supressing Unit for use with Neutron Generators: Assembly and detailed drawings and specifications; 48 sheets.

9-A-3. 1.5 Megavolt, 2 ma., "Van de Graaff Type" Generator: Technical description of installation at Bergen, Norway.

Figure D.448: Caperton Horsley's report CIOS XXVIII-31, *Investigation of the X-Ray Industry in Germany*, states that wartime German companies produced high-voltage fusion neutron generators, betatrons, cyclotrons, color-changing temperature-sensitive paint, a wide variety of highly advanced medical equipment, etc.

[Caperton Horsley (U.S., 1903–1988) was an expert on X-ray tubes who worked for several U.S. medical equipment companies. As a civilian investigator in Germany after the war, he found:

- "The names and addresses of a number of physicists who have recently been doing work on isotope separation."
- "The location and general description of the most important Betatron, Cyclotron, Van de Graaff generator, and mass spectrograph installations in Germany and territory that has been occupied by the Germans." These particle accelerator sites all over German-controlled territory could have been useful for electronuclear breeding.
- High-voltage fusion neutron generators, suitable for use as neutron initiators in fission bombs, and more advanced than the neutron initiators that were being developed in the United States.

These were extremely important aspects of the German nuclear program that Leslie Groves's Alsos Mission failed (at least publicly) to discover.

Leslie Groves responded by censoring Caperton Horsley's reports and apparently reprimanding Horsley, who does not seem to have discussed the German nuclear work again after that.]

Monthly Intelligence Summary. July–August 1945. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

X SECURITY

a. It came to the attention of this office that one Caperton B. HORSELY, a CIOS investigator, had conducted an investigation in Germany during the course of which he had obtained considerable information about betatrons. The CIOS evaluation report referring to the betatron information was distributed in regular channels but this office censored the detailed report and prevented the distribution of undesirable information in the final report.

The system in effect with CIOS for censorship of TA material was reviewed with the secretariat of that organization and measures were taken calculated to tighten TA security.

[Caperton Horsley's CIOS reports were censored by Leslie Groves's office because he discovered critical information regarding the German nuclear program. Where are the original, complete versions of his reports? Where is the other information he obtained, such as the names of German scientists doing isotope enrichment, or sites throughout German-controlled territory that were manufacturing or using particle accelerators?]

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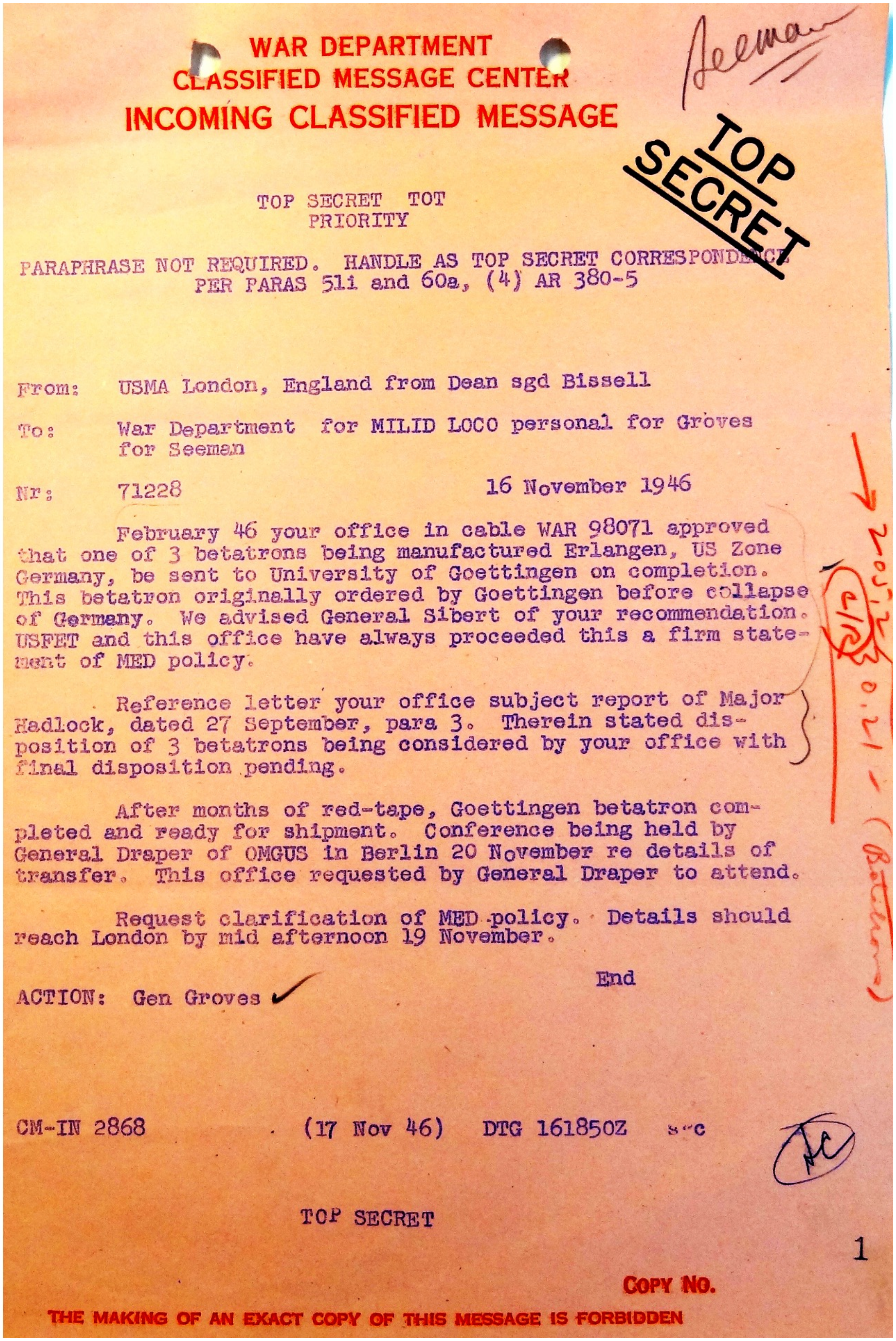
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret January 1946 thru December 1946



Seeman

WAR DEPARTMENT
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TOP SECRET

TOP SECRET TOT
PRIORITY

PARAPHRASE NOT REQUIRED. HANDLE AS TOP SECRET CORRESPONDENCE
PER PARAS 51i and 60a, (4) AR 380-5

From: USMA London, England from Dean sgd Bissell

To: War Department for MILID LOCO personal for Groves for Seeman

Nr: 71228 16 November 1946

February 46 your office in cable WAR 98071 approved that one of 3 betatrons being manufactured Erlangen, US Zone Germany, be sent to University of Goettingen on completion. This betatron originally ordered by Goettingen before collapse of Germany. We advised General Sibert of your recommendation. USFET and this office have always proceeded this a firm statement of MED policy.

Reference letter your office subject report of Major Hadlock, dated 27 September, para 3. Therein stated disposition of 3 betatrons being considered by your office with final disposition pending.

After months of red-tape, Goettingen betatron completed and ready for shipment. Conference being held by General Draper of OMGUS in Berlin 20 November re details of transfer. This office requested by General Draper to attend.

Request clarification of MED policy. Details should reach London by mid afternoon 19 November.

End

ACTION: Gen Groves ✓

205.2 (4/R) 0.21 - (Betatrons)

CM-IN 2868 (17 Nov 46) DTG 161850Z s-c

TOP SECRET

1

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Figure D.449: U.S. Military Attaché London to Leslie Groves. 16 November 1946 [NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret January 1946 thru December 1946].

NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION * Administrative Matters (1940-1945)

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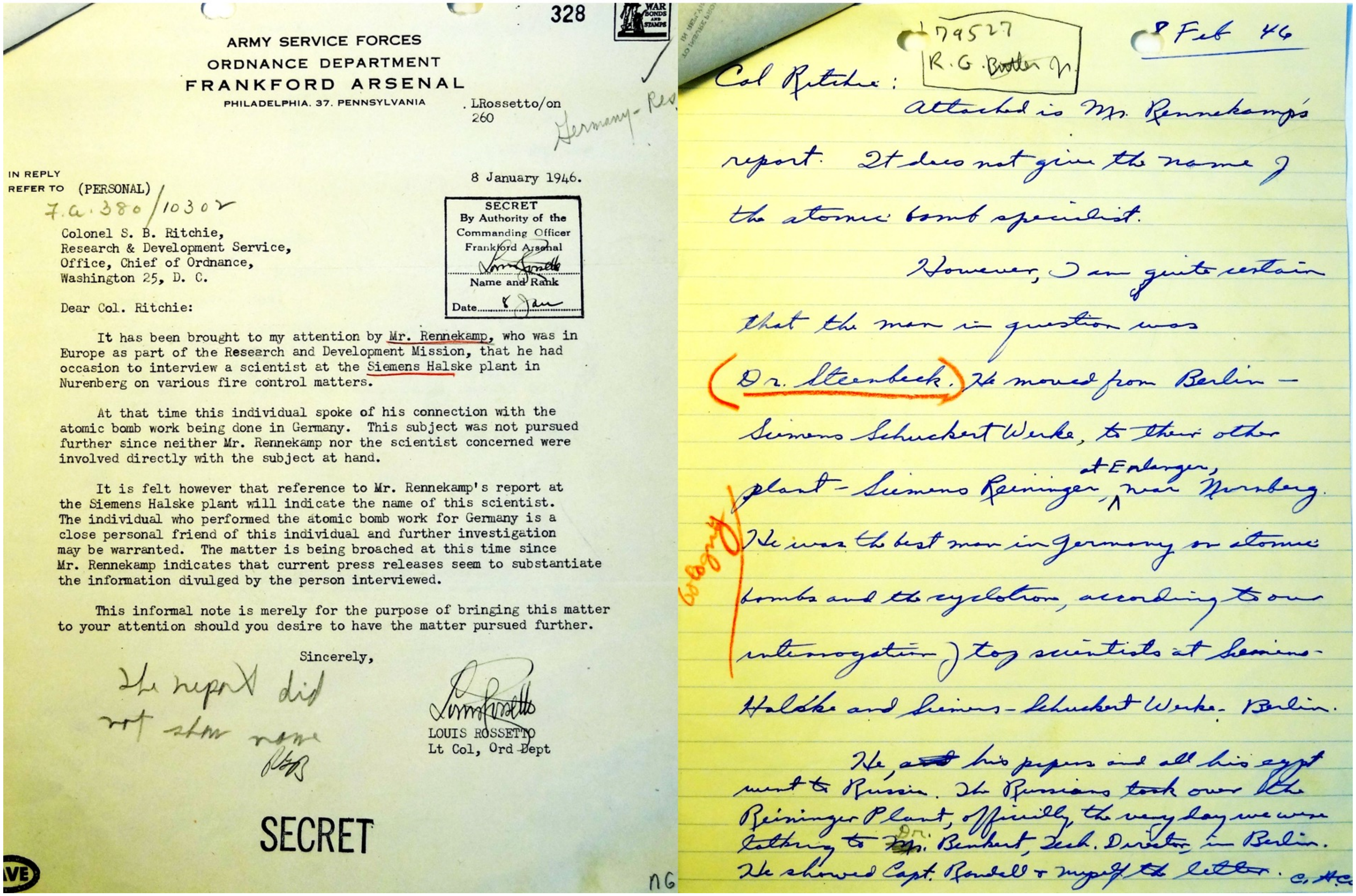


328

ARMY SERVICE FORCES
ORDNANCE DEPARTMENT
FRANKFORD ARSENAL
PHILADELPHIA. 37. PENNSYLVANIA

LRossetto/on
260

Germany-Res

IN REPLY REFER TO (PERSONAL)
7.a.380/10302

8 January 1946.

SECRET
By Authority of the
Commanding Officer
Frankford Arsenal
Name and Rank
Date 8 Jan

Colonel S. B. Ritchie,
Research & Development Service,
Office, Chief of Ordnance,
Washington 25, D. C.

Dear Col. Ritchie:

It has been brought to my attention by Mr. Rennekamp, who was in Europe as part of the Research and Development Mission, that he had occasion to interview a scientist at the Siemens Halske plant in Nurenberg on various fire control matters.

At that time this individual spoke of his connection with the atomic bomb work being done in Germany. This subject was not pursued further since neither Mr. Rennekamp nor the scientist concerned were involved directly with the subject at hand.

It is felt however that reference to Mr. Rennekamp's report at the Siemens Halske plant will indicate the name of this scientist. The individual who performed the atomic bomb work for Germany is a close personal friend of this individual and further investigation may be warranted. The matter is being broached at this time since Mr. Rennekamp indicates that current press releases seem to substantiate the information divulged by the person interviewed.

This informal note is merely for the purpose of bringing this matter to your attention should you desire to have the matter pursued further.

Sincerely,

Louis Rossetto
LOUIS ROSSETTO
Lt Col, Ord Dept

The report did not show name

SECRET

NG

79527
R.G. ~~Bottler~~ Jr.

8 Feb 46

Col Ritchie:

Attached is Mr. Rennekamp's report. It does not give the name of the atomic bomb specialist.

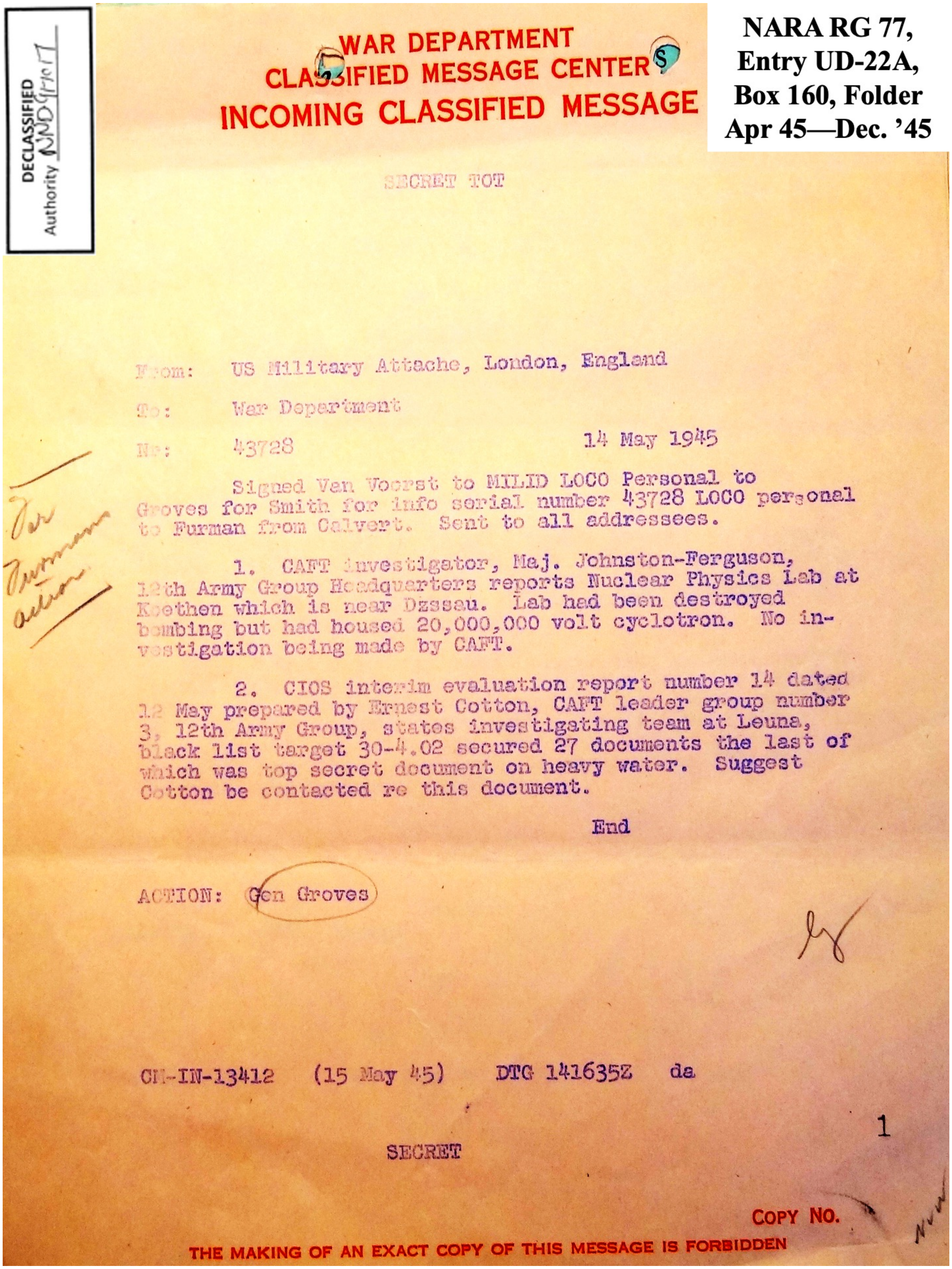
However, I am quite certain that the man in question was Dr. Steenbeck. He moved from Berlin — Siemens Schuckert Werke, to their other plant — Siemens Reiniger, at Erlangen, near Nurnberg. He was the best man in Germany on atomic bombs and the cyclotron, according to our interrogation of top scientists at Siemens-Halske and Siemens-Schuckert Werke. Berlin.

Geology

He, ~~and~~ his papers and all his eqpt went to Russia. The Russians took over the Reiniger Plant, officially the very day we were talking to ~~Mr.~~ Dr. Benkert, Tech. Director, in Berlin. He showed Capt. Randell + myself the letter. c. H.c

Figure D.450: Louis Rossetto to S. B. Ritchie. 8 January and 8 February 1946 [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION * Administrative Matters (1940–1945)].

NARA RG 77, Entry UD-22A, Box 160, Folder Apr 45—Dec. '45



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WAR DEPARTMENT
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SECRET TOT

From: US Military Attache, London, England

To: War Department

Nr: 43728 14 May 1945

Signed Van Voorst to MILID LOCO Personal to Groves for Smith for info serial number 43728 LOCO personal to Furman from Calvert. Sent to all addressees.

For Furman action

1. CAFT investigator, Maj. Johnston-Ferguson, 12th Army Group Headquarters reports Nuclear Physics Lab at Koethen which is near Dzssau. Lab had been destroyed bombing but had housed 20,000,000 volt cyclotron. No investigation being made by CAFT.

2. CIOS interim evaluation report number 14 dated 12 May prepared by Ernest Cotton, CAFT leader group number 3, 12th Army Group, states investigating team at Leuna, black list target 30-4.02 secured 27 documents the last of which was top secret document on heavy water. Suggest Cotton be contacted re this document.

End

ACTION: Gen Groves

CM-IN-13412 (15 May 45) DTG 141635Z da

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Figure D.451: U.S. Military Attaché London to Leslie Groves. 14 May 1945 [NARA RG 77, Entry UD-22A, Box 160, Folder Apr 45–Dec. '45]. Where are other documents on this 20 MeV cyclotron at Köthen and its purpose? Where is the "top secret document on heavy water"?

NARA Still Pictures, RG 111 SCA---Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941-1954. Captured German Equipment, German, Box 3345, Book 6, SC 221938.

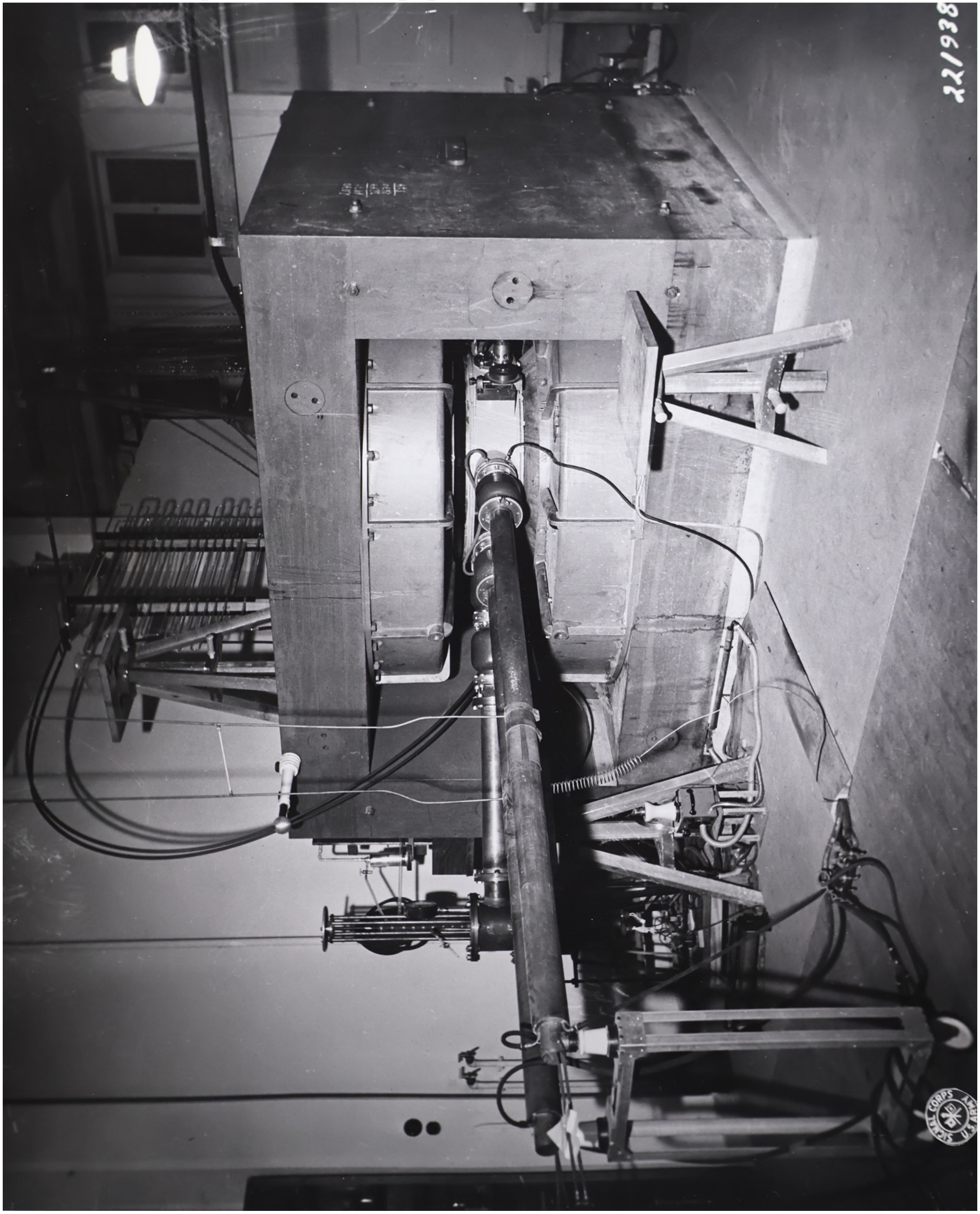

Figure D.452: Large cyclotron in Heidelberg, photographed by the U.S. Army after the war [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3345, Book 6, SC 221938.]

NARA Still Pictures, RG 111 SCA---Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941-1954. Captured German Equipment, German, Box 3345, Book 6, SC 222100.

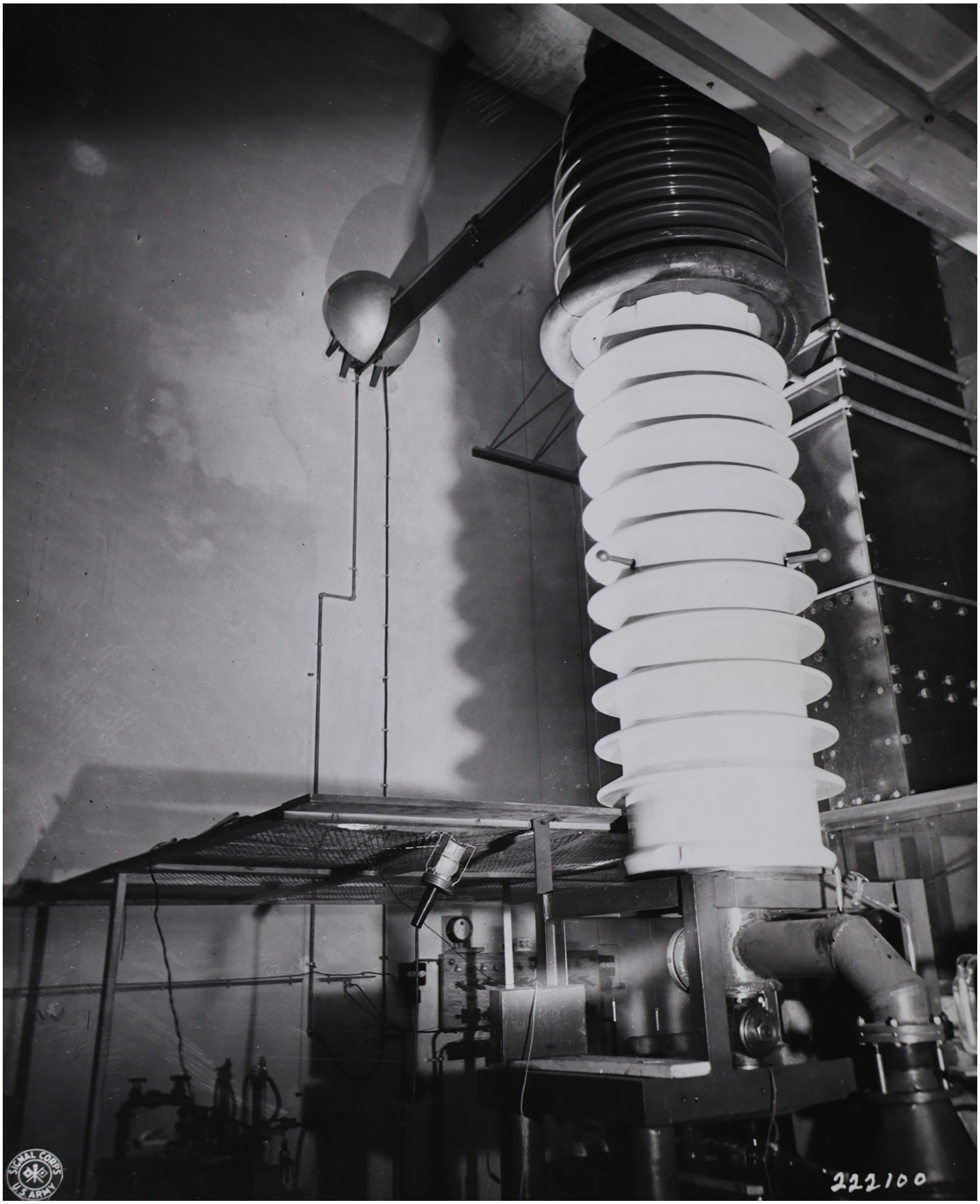

Figure D.453: High voltage equipment in Heidelberg, photographed by the U.S. Army after the war [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3345, Book 6, SC 222100.]

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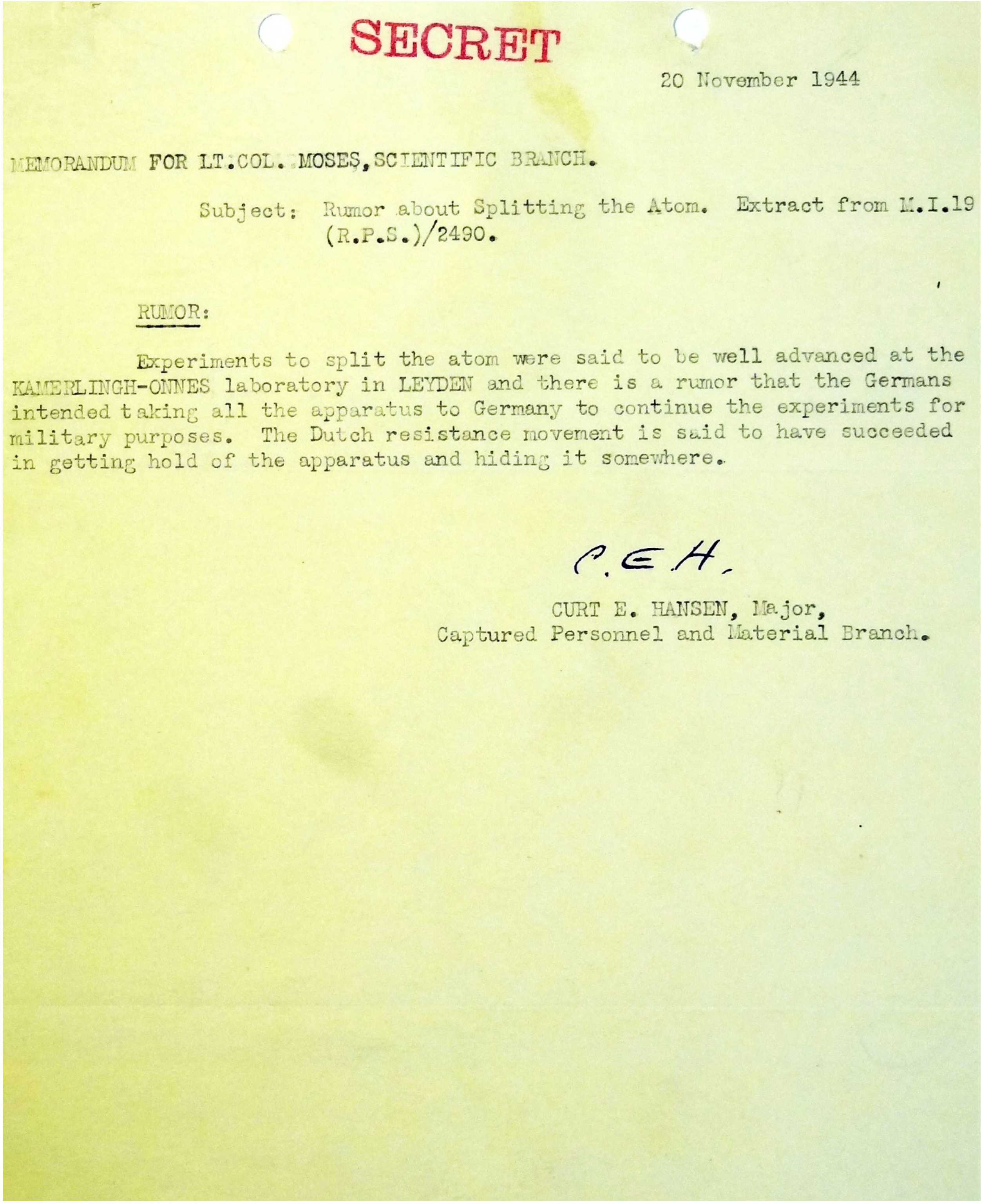
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3
GERMANY: US Wartime Positive Int. (Nov. 44-June 45)



SECRET

20 November 1944

MEMORANDUM FOR LT. COL. MOSES, SCIENTIFIC BRANCH.

Subject: Rumor about Splitting the Atom. Extract from M.I.19 (R.P.S.)/2490.

RUMOR:

Experiments to split the atom were said to be well advanced at the KAMERLINGH-ONNES laboratory in LEYDEN and there is a rumor that the Germans intended taking all the apparatus to Germany to continue the experiments for military purposes. The Dutch resistance movement is said to have succeeded in getting hold of the apparatus and hiding it somewhere.

C.E.H.

CURT E. HANSEN, Major,
Captured Personnel and Material Branch.

Figure D.454: Curt E. Hansen to Moses. 20 November 1944. Subject: Rumor about Splitting the Atom. Extract from M.I.19(R.P.S.)/2490 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

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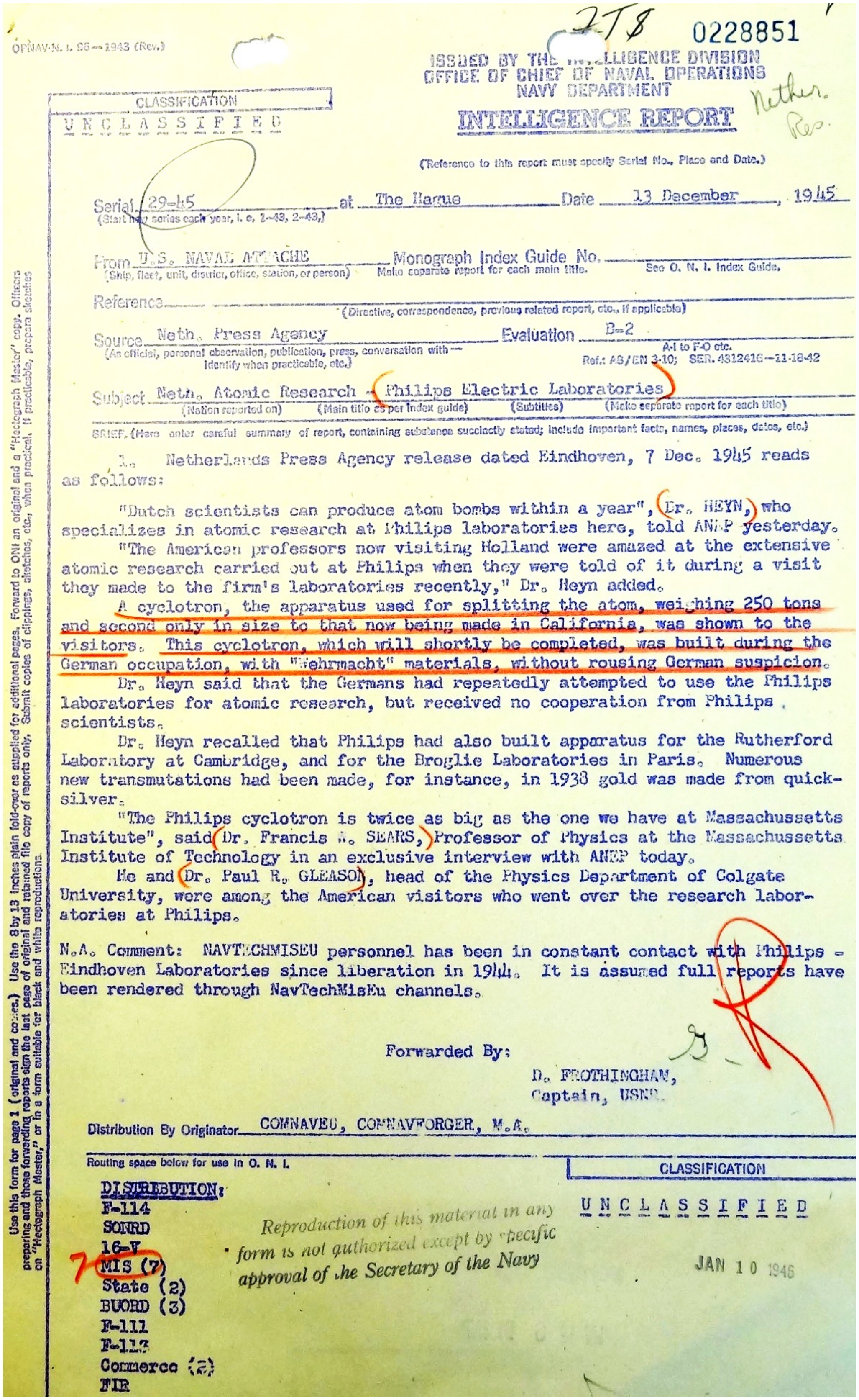
Authority NND 971017

NARA RG 77, Entry UD-22A, Box 173, Folder 50.20. Netherlands: Research



OPNAV-N. I. 96—1943 (Rev.)

2T8 0228851

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OFFICE OF CHIEF OF NAVAL OPERATIONS
NAVY DEPARTMENT

Neth. Res.

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INTELLIGENCE REPORT

(Reference to this report must specify Serial No., Place and Date.)

Serial 29-45 (Start new series each year, i. e., 1-43, 2-43,) at The Hague Date 13 December, 1945

From U.S. NAVAL ATTACHE (Ship, fleet, unit, district, office, station, or person) Monograph Index Guide No. ______ Make separate report for each main title. See O. N. I. Index Guide.

Reference ______ (Directive, correspondence, previous related report, etc., if applicable)

Source Neth. Press Agency (As official, personal observation, publication, press, conversation with—identify when practicable, etc.) Evaluation B-2 A-1 to F-0 etc. Ref.: AS/EN 3-10; SER. 4312416—11-18-42

Subject Neth. Atomic Research (Nation reported on) - Philips Electric Laboratories (Main title as per index guide) (Subtitles) (Make separate report for each title)

BRIEF. (Here enter careful summary of report, containing substance succinctly stated; include important facts, names, places, dates, etc.)

1. Netherlands Press Agency release dated Eindhoven, 7 Dec. 1945 reads as follows:

"Dutch scientists can produce atom bombs within a year", Dr. HEYN, who specializes in atomic research at Philips laboratories here, told ANEP yesterday.

"The American professors now visiting Holland were amazed at the extensive atomic research carried out at Philips when they were told of it during a visit they made to the firm's laboratories recently," Dr. Heyn added.

A cyclotron, the apparatus used for splitting the atom, weighing 250 tons and second only in size to that now being made in California, was shown to the visitors. This cyclotron, which will shortly be completed, was built during the German occupation, with "Wehrmacht" materials, without rousing German suspicion.

Dr. Heyn said that the Germans had repeatedly attempted to use the Philips laboratories for atomic research, but received no cooperation from Philips scientists.

Dr. Heyn recalled that Philips had also built apparatus for the Rutherford Laboratory at Cambridge, and for the Broglie Laboratories in Paris. Numerous new transmutations had been made, for instance, in 1938 gold was made from quicksilver.

"The Philips cyclotron is twice as big as the one we have at Massachussetts Institute", said Dr. Francis W. SEARS, Professor of Physics at the Massachussetts Institute of Technology in an exclusive interview with ANEP today.

He and Dr. Paul R. GLEASON, head of the Physics Department of Colgate University, were among the American visitors who went over the research laboratories at Philips.

N.A. Comment: NAVTECHMISEU personnel has been in constant contact with Philips - Eindhoven Laboratories since liberation in 1944. It is assumed full reports have been rendered through NavTechMisEu channels.

Forwarded By:
D. FROTHINGHAM,
Captain, USNR.

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JAN 10 1946

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Figure D.455: D. Frothingham. 13 December 1945. Subject: Neth. Atomic Research—Philips Electric Laboratories [NARA RG 77, Entry UD-22A, Box 173, Folder 50.20. Netherlands: Research].

Hewlett Thebaud. 2 February 1946. France Ordnance Atomic Bombs. [**NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700**]

Information has been received from what are believed to be thoroughly reliable sources that during the German occupation of Holland, the Dutch constructed a cyclotron at the Headquarters of the Philips Lamp Works at Eindhoven, Holland.

The cyclotron was built from copper and other metals allocated to the German Army, yet its construction was so cleverly concealed from the Germans as never to have been made known to them.

There is no evidence of any atomic research in connection with the cyclotron. Work is now progressing in the television field and a larger screen model is now in the process of demonstration.

[It seems highly unlikely that a German-occupied Dutch factory would spontaneously decide to build a cyclotron for themselves using misappropriate German materials. Far more likely is that the cyclotron was built by the Dutch factory under contract to the German Army, but not delivered before the end of the war. This appears to be another example of the abundance of particle accelerators that were being produced and utilized for high-priority but unspecified purposes during the final years of the Third Reich.]

Air Raid, Sabotage Held Up Nazi Work on Atomic Bomb. *Paducah Sun Democrat* (Paducah, Kentucky) 23 August 1945.

PRAGUE, Aug. 23—(AP)—A shattering American air raid, Czech sabotage and an accident frustrated German experiments in Czechoslovakia seeking to develop an atomic bomb, newspaper accounts said here today.

A German engineer named Eisenbeck worked with the problem of releasing atomic energy in a radio plant at Vysocany, the accounts said. A blast and fire at the plant in 1943 followed by an American raid halted work soon after the plant resumed operations.

Some mysterious apparatus was dispatched to the Imperial Research Institute in Berlin, but Czech workers believed they managed to damage the delicate mechanism before it was shipped, the stories said.

[“Eisenbeck” was probably W. Isenbeck (German, 1912–19??). After the war, he worked on particle accelerators and nuclear/particle physics at Karlsruhe and CERN.

The “American raid” may refer to a U.S. air raid on the Prague area that occurred on 25 March 1945. If that raid was at least in part due to this nuclear work, it indicates both that Germany possessed a potentially threatening nuclear weapons program up to the end of the war, and that the United States government was keenly aware of that fact.

The nuclear-related work mentioned in this article was probably the construction of cyclotrons or parts for cyclotrons. Cyclotron components are known to have been manufactured during the war at the Marconi Radioslavia plant in the Prague Vysočany neighborhood (mentioned here), at the Volman plant in Čelákovice near Prague, and potentially at other locations in Czech territory. Cyclotrons could have been directly useful for an electronuclear breeding program to produce plutonium-239 or uranium-233. With suitable design modifications, they could also have been useful for electromagnetic separation of uranium-235 from uranium-238.

Versions of this same story also appeared in a number of other newspapers, such as:

Amarillo Daily News (Amarillo, Texas) 23 August 1945, p. 12.

Democrat and Chronicle (Rochester, New York) 23 August 1945, p. 20.

Morning Herald (Uniontown, Pennsylvania) 23 August 1945, p. 9.

Somerset Daily American (Somerset, Pennsylvania) 23 August 1945, p. 5.

Daily Mail 24 August 1945, p. 1.]

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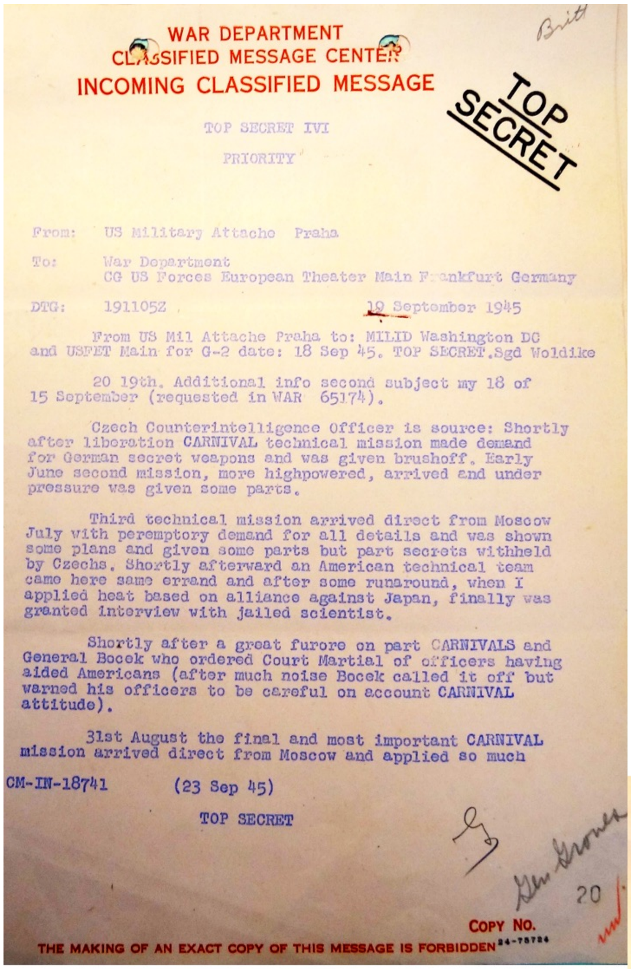

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Brit

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PRIORITY

From: US Military Attache Praha

To: War Department
CG US Forces European Theater Main Frankfurt Germany

DTG: 191105Z 19 September 1945

From US Mil Attache Praha to: MILID Washington DC and USFET Main for G-2 date: 18 Sep 45. TOP SECRET. Sgd Woldike

20 19th. Additional info second subject my 18 of 15 September (requested in WAR 65174).

Czech Counterintelligence Officer is source: Shortly after liberation CARNIVAL technical mission made demand for German secret weapons and was given brushoff. Early June second mission, more highpowered, arrived and under pressure was given some parts.

Third technical mission arrived direct from Moscow July with peremptory demand for all details and was shown some plans and given some parts but part secrets withheld by Czechs. Shortly afterward an American technical team came here same errand and after some runaround, when I applied heat based on alliance against Japan, finally was granted interview with jailed scientist.

Shortly after a great furore on part CARNIVALS and General Bocek who ordered Court Martial of officers having aided Americans (after much noise Bocek called it off but warned his officers to be careful on account CARNIVAL attitude).

31st August the final and most important CARNIVAL mission arrived direct from Moscow and applied so much

CM-IN-18741 (23 Sep 45)

TOP SECRET

Gen Groves

COPY NO. 20

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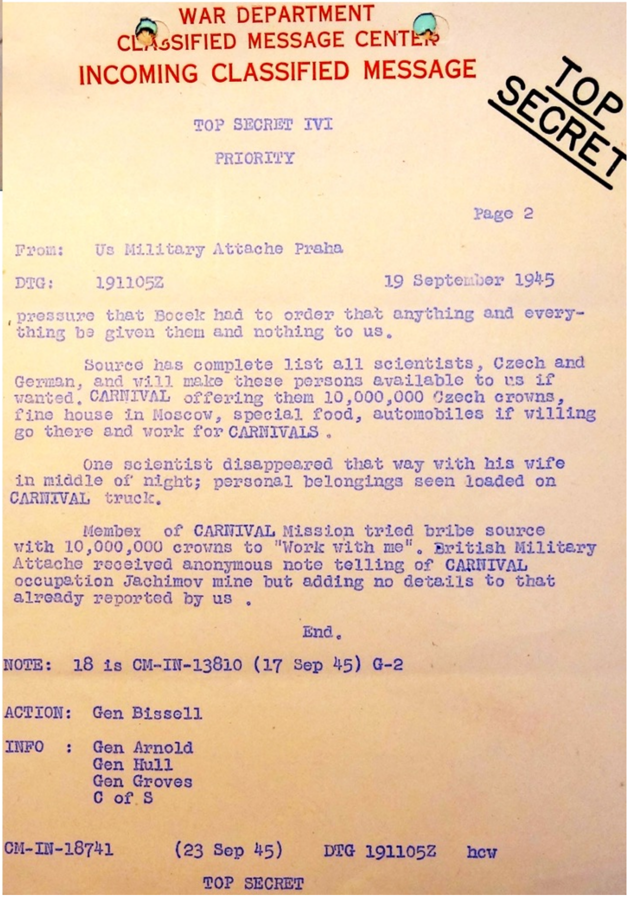

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PRIORITY

Page 2

From: Us Military Attache Praha

DTG: 191105Z 19 September 1945

pressure that Bocek had to order that anything and everything be given them and nothing to us.

Source has complete list all scientists, Czech and German, and will make these persons available to us if wanted. CARNIVAL offering them 10,000,000 Czech crowns, fine house in Moscow, special food, automobiles if willing go there and work for CARNIVALS.

One scientist disappeared that way with his wife in middle of night; personal belongings seen loaded on CARNIVAL truck.

Member of CARNIVAL Mission tried bribe source with 10,000,000 crowns to "Work with me". British Military Attache received anonymous note telling of CARNIVAL occupation Jachimov mine but adding no details to that already reported by us.

End.

NOTE: 18 is CM-IN-13810 (17 Sep 45) G-2

ACTION: Gen Bissell

INFO : Gen Arnold
Gen Hull
Gen Groves
C of S

CM-IN-18741 (23 Sep 45) DTG 191105Z hcw

TOP SECRET

NARA RG 77, Entry UD-22A, Box 160, Folder APR 45--Dec. '45

Figure D.456: U.S. Military Attaché Prague to War Department. 19 September 1945 [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45].

US Embassy, Prague, 15 September 1945 [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45; NARA RG 319, Entry NM3-58 Box 7 Folders TO: CZECHOSLOVAKIA 9-16-45–12-31-45 and FR: CZECHOSLOVAKIA 9-3-45—12-31-45]

From: US Embassy, Prague, Czechoslovakia

To: War Department

Nr: 18 15 September 1945

TOP SEC Msg nr 18 to Milid and USFET Main for G-2 sgd Woldike.

War Minister Svoboda, General Bocek and General Molotkov arrived Moscow 14th for purpose of pressing for withdrawal of Russians troops per original agreement and also to endeavor to stop continued industrial requisitioning by Russians.

Russians have demanded and forced General Bocek to direct compliance that all German plans, models, parts, formulas pertaining atomic bomb, new rocket weapons, Radar disturbing submarine, disturbing paint etc. be turned over to them. At recent London Conference of Foreign Ministers source states that China Russia and France unsuccessfully demanded secrets of Atomic Bomb; The following day one Battalion Russian Infantry plus Technical Troops occupied Jachimov (Achimuv) (St Joachimsthal) mine and factory, only place producing Uranium in central Europe, despite fact that occupation this area not provided for in Russo-Czech agreement. Russians have since demanded Czechs treble output. My source is Czech General Staff Colonel directly concerned rated A.

End

Corrected copy of CM-IN-12983 (16 Sept 45) Gen Bissell
ACTION: Gen Bissell
INFO: Gen Arnold, Gen Hull, Gen Groves, C of S
CM-IN-13810 (17 Sept 45) DTG 15/1800B da

[To aid in visualizing the locations mentioned in this document and the following several documents, see p. 2098.

Note that this and the following messages to and from Prague involve very high-level U.S. military officials responsible for air and nuclear defense:

General of the Army Henry H. Arnold, Commanding General of the Army Air Forces.

Major General Leslie Groves, Commanding General of the Manhattan Project for all nuclear-weapons-related work and intelligence.

Major General Clayton Bissell, who was Chief of Intelligence for the Army Air Forces.

Brigadier General John Edwin Hull, who was Head of the Operations Division, War Department, General Staff.]

Military Intelligence Division W.D.G.S., Military Attaché Report Czechoslovakia. Subject: Scientists Experimenting on Secret Weapons. I.G. No. 0403.0700. Prague. Report No. R-42. 2 October 1945. [NARA RG 319, Entry NM3-85M, Box 19, Folder 925256]

Source and degree of reliability: Czechoslovak Counter Intelligence Officer — A-3

1. In accordance with directions contained in War Department Cable No. 68418, of 24 September 1945, the following list of scientists, Czech and German, with their specialties and present status, is submitted.

2. a. the HÜTTIG GROUP is probably the most important. Professor HÜTTIG was the head of the Czechoslovak Radiological Institute during the Occupation; this is the only group which worked on practical application in warfare of the splitting of the atom. They are not known to have conducted any practical experiments, but they worked on the theory under the supervision of a German, Professor Dr. BRAUN, who has just been located in Czechoslovakia and is expected in PRAHA today's date, where he will be available to Czech authorities. In addition to the calculations for the atomic bomb, Professor HÜTTIG perfected a radar-disturbing paint for U-boats, a sample of which has been promised this office. Within the last few days a complete Cyclotron, which I understand is an apparatus used in the splitting of the atom, was found in the VOLMAN Factory at CELAKOVICE, Central Bohemia, and has been moved to PRAHA.

The HÜTTIG Group consists of:

Professor HÜTTIG, German, free but available to Czech authorities.

His principal assistant, Dr. [Heinrich Eduard] KAFKA, German, free but available to Czech authorities.

Professor Dr. ZACEK, Czech, free but available to Czech authorities.

Professor BIEHONEK, Czech, free but available to Czech authorities.
The two latter are subject to arrest at any time.

Professor Dr. PANZAKIEWITZ, a specialist on Measuring Devices, German, in protective custody.

Professor Dr. [Karl] KARAS, mathematician; he also worked on and presumably perfected a "Mother Rocket" or multiple rocket, German, in protective custody.

Professor Dr. v. MEYEREN, specialist on Measuring Devices, German, in protective custody.

Dr. SEDLACEK, Assistant to HÜTTIG, German, protective custody.

Dr. PAUL WENZEL, principal chemist of the HÜTTIG GROUP, German, protective custody.

An engineer named PSCHERA, assistant to HÜTTIG, German, protective custody.

Three engineers named BREUER, THEIMER and WAGENKNECHT, also HÜTTIG assistants, Germans, in protective custody.

Dr. GIESOLF, Dutch Collaborator, in protective custody, already exploited by American Technical Intelligence Team.

b. Next in importance are,

Dr. HELMAR FRANK, an expert on Infra-Red Rays; he is a German and in protective custody.

An engineer, GEORG GILLES, who worked on V weapons. He is a German, and in protective custody. It is understood that an agreement has been reached whereby GILLES will ultimately be released and turned over to American authorities to work for them, but this has not been definitively established.

Dr. ROHSMANN, expert on explosives, German, free, but available.

An engineer named NEUMANN, an expert on Ground Installation for V-3 and on the so-called "HAWAII" and "HAASE-GERÄTE", German, free but available.

Professor [Witold] WIECHOWSKI, an expert on mechanical details of the V-3; formerly worked in PEENEMÜNDE; German, free but available.

c. An engineer named KOSAK, German, voluntarily or otherwise left PRAHA to work for the Russians (see paragraph 4, Report R-32, this office, dated 30 September 1945).

d. The LEINWEBER GROUP, which worked on rockets of various kinds, consists of,

Engineer LEINWEBER, expert on Acoustic Rockets; German, in protective custody.

Engineer GÜNTHER, assistant to LEINWEBER, who also independently worked on Submarine Rockets; German, protective custody.

Engineer SALAMOUN, expert on "Waterfall" or "Cascade" [Wasserfall surface-to-air] Rockets; German, protective custody.

e. Two German engineers named BAUER and KÄSER, who are at liberty in LIBEREC where they have a small factory, are the inventors of a new system of rapid automotive propulsion. They are said to possess a number of world-widepatents; for the time being, they are being left alone by the Czech authorities.

3. All of the above can be made available at any time for interview.

AAGE WOLDIKE
Lt. Col GSC
Military Attaché

[See document photos on pp. 5510–5511.

This report stated that the Hüttig group was working on theoretical calculations for the atomic bomb, under the supervision of a "Professor Dr. Braun" who may have helped to coordinate their work with a larger German nuclear weapons program. Who was Braun? What organization was he from?

The Alsos Mission found reports from some members of the Hüttig group in the files of Walther Gerlach, the German Plenipotentiary for Nuclear Physics during the final stages of the war.

Note that the report mentioned a cyclotron that was produced in wartime Czechoslovakia; this cyclotron is also mentioned in subsequent documents.

Some of the engineers who worked on the "V-3" rocket are specifically identified here.

For more information on Helmar Frank, see pp. 1050–1072, 2756–2757, 5503, 5513, and 5549.

For more information on some of the other named scientists, see
https://dspace.cuni.cz/bitstream/handle/20.500.11956/47183/140006538.pdf.]

BIOS 871. *Work of Professor Hüttig on Ferromagnetic Substances for Use in Radar Camouflage.* p. 25.

(d) Prof. Dr. GUSTAV F. HÜTTING

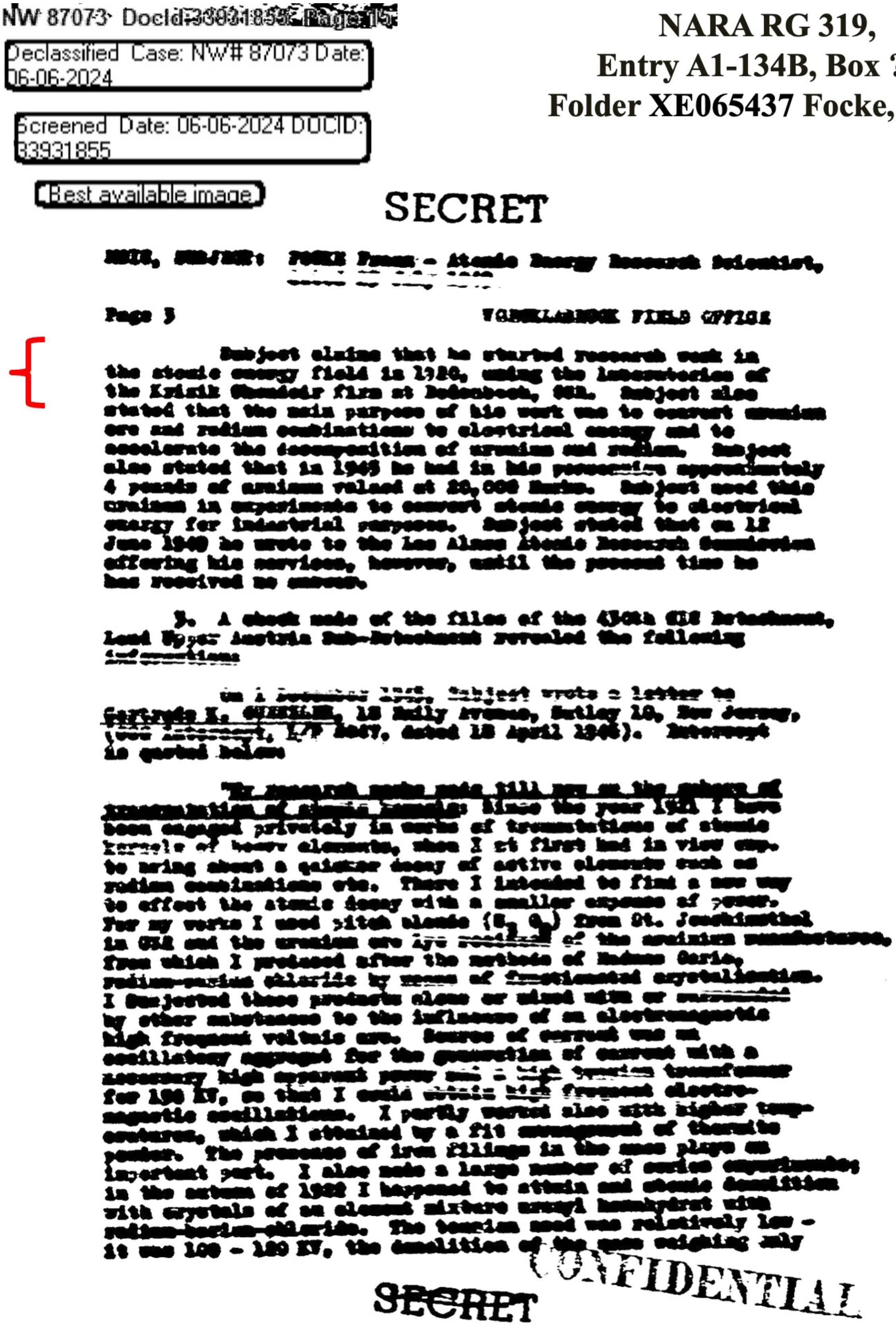
Autobiography. H.12

G. F. Hüttig was born in Prague/Czechslovakia May 13th 1890. From 1907 he was studying technical chemistry in Prague, where he became 1912 Engineer and got 1913 the doctors degree of technical science. [...H]e became scientific collaborator of A. Hantzsch on the University of Leipzig. In 1914 he became Assistant in the institute of W. Biltz on the mining academy in Clausthal a. Harz in Hannover[...] In 1921 he became in Clausthal University teacher of inorganic and physical chemistry. From 1922–26 he was professor of inorganic, analytical and physical chemistry at the university of Jena. From 1926 till May 5th, 1945, he was Professor of inorganic and analytical chemistry at the German High Technical School in Prague and director of the institute. In the last years he was also Professor of the University of Prague[...] From 1929 on he was scientific collaborator and counsellor of the "Deutsche Gold- und Silberscheideanstalt" in Frankfurt a. Main.

Scientific Works.

The own research-works concern in the main point the following spheres: the knowledge of the chemical affinity especially its application on the chemistry of complexes, hydrates of salts, oxide-hydrates/hydroxides, active matters, stoichiometry, catalysis, mixed catalyzisers, reactions between solid bodies, system of reactions-types, powder-metallurgy production of aluminium from silicates, producing of matters with certain qualities and more. [...]

NARA RG 319,
Entry A1-134B, Box ??,
Folder XE065437 Focke, Franz



NW 87073 DocId:[illegible] Page 5

Declassified Case: NW# 87073 Date: 06-06-2024

Screened Date: 06-06-2024 DOCID: 33931855

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[illegible], SUBJECT: FOCKE Franz - Atomic Energy Research Scientist, [illegible]

Page 3 VOECKLABRUCK FIELD OFFICE

Subject claims that he started research work in the atomic energy field in 1920, using the laboratories of the Krizik Chemical firm at Bodenbach, CSR. Subject also stated that the main purpose of his work was to convert uranium ore and radium combinations to electrical energy and to accelerate the decomposition of uranium and radium. Subject also stated that in 1945 he had in his possession approximately 4 pounds of uranium valued at 20,000 Marks. Subject used this uranium in experiments to convert atomic energy to electrical energy for industrial purposes. Subject stated that on 12 June 1949 he wrote to the Los Alamos Atomic Research Commission offering his services, however, until the present time he has received no answer.

3. A check made of the files of the 430th CIC Detachment, Land Upper Austria Sub-Detachment revealed the following information:

On 1 [illegible] 1948, Subject wrote a letter to Gertrude K. [illegible], 18 Emily Avenue, Nutley 10, New Jersey, (see attached, I/P 8667, dated 18 April 1948). Intercept is quoted below:

"My research works made till now on the sphere of transmutation of atomic kernels: Since the year 1921 I have been engaged privately in works of transmutations of atomic kernels of heavy elements, when I at first had in view esp. to bring about a quicker decay of active elements such as radium combinations etc. There I intended to find a new way to effect the atomic decay with a smaller expense of power. For my works I used pitch blende (U_3O_8) from St. Joachimsthal in CSR and the uranium ore dye residues of the uranium manufacturers, from which I produced after the methods of Madame Curie, radium-barium chloride by means of fractionated crystallization. I subjected these products alone or mixed with or [illegible] by other substances to the influence of an electromagnetic high frequent voltaic arc. Source of current was an oscillatory aggregate for the generation of current with a necessary high apparent power and a high tension transformer for 150 KV, so that I could obtain high frequent electromagnetic oscillations. I partly worked also with higher temperatures, which I obtained by a fit arrangement of thermite powder. The presence of iron filings in the mass plays an important part. I also made a large number of series experiments; in the autumn of 1932 I happened to attain and atomic demolition with crystals of an element mixture uranyl [illegible] with radium-barium-chloride. The tension used was relatively low - it was 100 - 120 KV, the demolition of the mass weighing only

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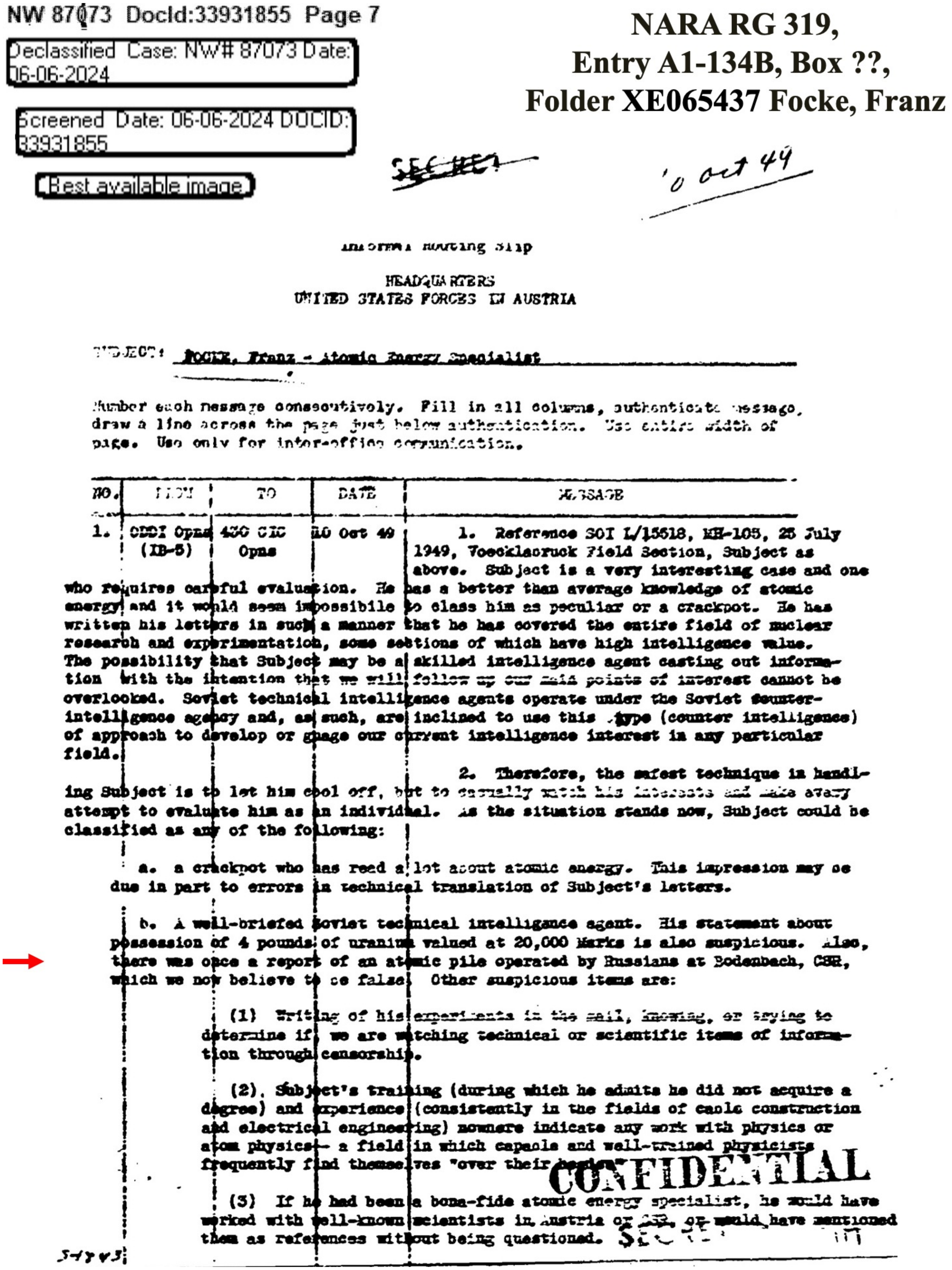
Figure D.457: According to Franz Focke, a longtime employee at Bodenbach/Krizik, nuclear research began there no later than 1920, continued through World War II, and resulted in a fission reactor there that fell under Soviet control after the war [NARA RG 319, Entry A1-134B, Box ??, Folder XE065437 Focke, Franz].



NW 87073 DocId:33931855 Page 7

Declassified Case: NW# 87073 Date: 06-06-2024

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NARA RG 319,
Entry A1-134B, Box ??,
Folder XE065437 Focke, Franz

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10 oct 49

Informal Routing Slip

HEADQUARTERS
UNITED STATES FORCES IN AUSTRIA

SUBJECT: FOCKE, Franz - Atomic Energy Specialist

Number each message consecutively. Fill in all columns, authenticate message, draw a line across the page just below authentication. Use entire width of page. Use only for inter-office communication.

NO.	FROM	TO	DATE	MESSAGE
1.	ODDI Opns (IB-5)	430 CIC Opns	10 Oct 49	1. Reference SOI L/15518, MH-105, 25 July 1949, Voecklabruck Field Section, Subject as above. Subject is a very interesting case and one who requires careful evaluation. He has a better than average knowledge of atomic energy and it would seem impossibile to class him as peculiar or a crackpot. He has written his letters in such a manner that he has covered the entire field of nuclear research and experimentation, some sections of which have high intelligence value. The possibility that Subject may be a skilled intelligence agent casting out information with the intention that we will follow up our main points of interest cannot be overlooked. Soviet technical intelligence agents operate under the Soviet counter-intelligence agency and, as such, are inclined to use this type (counter intelligence) of approach to develop or guage our current intelligence interest in any particular field.

2. Therefore, the safest technique in handling Subject is to let him cool off, but to casually watch his interests and make every attempt to evaluate him as an individual. As the situation stands now, Subject could be classified as any of the following:

a. a crackpot who has read a lot about atomic energy. This impression may be due in part to errors in technical translation of Subject's letters.

b. A well-briefed Soviet technical intelligance agent. His statement about possession of 4 pounds of uranium valued at 20,000 Marks is also suspicious. Also, there was once a report of an atomic pile operated by Russians at Bodenbach, CSR, which we now believe to be false. Other suspicious items are:

(1) Writing of his experiments in the mail, knowing, or trying to determine if we are watching technical or scientific items of information through censorship.

(2). Subject's training (during which he admits he did not acquire a degree) and experience (consistently in the fields of cable construction and electrical engineering) nowhere indicate any work with physics or atom physics — a field in which capable and well-trained physicists frequently find themselves "over their heads".

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(3) If he had been a bona-fide atomic energy specialist, he would have worked with well-known scientists in Austria or CSR, or would have mentioned them as references without being questioned.

5-4843

Figure D.458: According to 1949 U.S. Army Counter Intelligence Corps interrogations of Franz Focke, a longtime employee at Bodenbach/Krizik, nuclear research began there no later than 1920, continued through World War II, and resulted in a fission reactor there that fell under Soviet control after the war [NARA RG 319, Entry A1-134B, Box ??, Folder XE065437 Focke, Franz]. The interrogators were skeptical about the reactor claim, but it is consistent with the large amount of other nuclear-related work at that same site (pp. 3987–3998).

The Puzzle of Podmokly. *Time.* 12 November 1945.

Had the atomic armaments race begun? In Moscow a writer for The New Times declared that reactionary forces in the U.S. were bent on "blackmailing humanity" by trying to keep the atomic bomb a U.S. property.

From western Czechoslovakia, where the Elbe river bursts through the Sudeten mountains into the flat meadow lands bordering Germany, came a different story.

Nestled in the mountains six miles from Podmokly was a vast underground factory, the Weser Works. In the first three months of liberation the Weser Works were quiet, deserted. Now they hummed with hidden activity. Czech and Russian security police kept close watch on the difficult mountain approaches.

The underground factory was a product of the war. When the Germans came to Podmokly (which they called Bodenbach) they seized the Krizik Works, Czechoslovakia's largest producer of copper wire, the area was rich in coal and hydroelectric power, and had excellent communication facilities. Later they imported French, Belgian and Russian laborers, and set them to work expanding the Krizik plants. Laboratories were built, buildings enlarged, new units erected. One of the new units was put underground, and was supersecret. It was known simply as "the Weser."

The Losing Race.

In time the first secret of the Weser became apparent. Its parent plant was producing V-weapons. But it also manufactured cyclotrons for atomic experimentation. As the Allies bombed German laboratories, the Weser shipped new cyclotrons to secret destinations in the Reich where Hitler's scientists were running a losing race with history. At least three cyclotrons were shipped in the last year and a half of war.

The retreating Germans left the Weser grounds littered with the fuselages, fins and working parts of V-bombs. In iron safes were plans for Vergeltungswaffe-4, said to be a giant, radio-controlled rocket capable of being fired from Prague to the Americas. The Germans also left parts of cyclotrons and other equipment for research in nuclear physics.

For a time the Russians showed no particular interest in the underground factory. Strangers wandered in & out at will. But the explosions over Hiroshima and Nagasaki brought a quick change. The security police moved in, and Germans who had worked in the factory were rounded up, put back to work. Former officials of the Krizik Works were kept out. In northern Bohemia the Russians took over the Jachymov mine, famed for its uranium deposits.

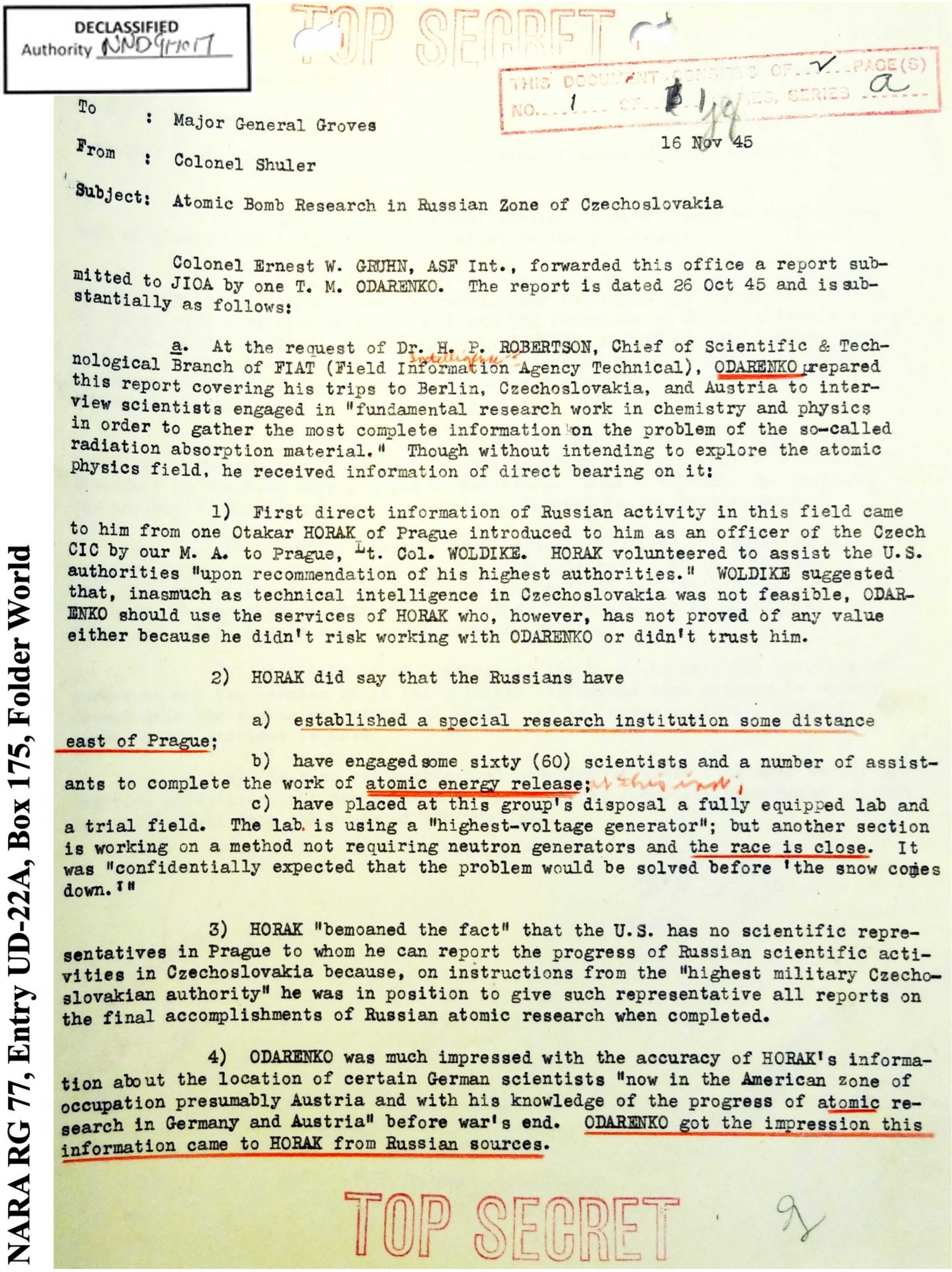
If the Weser's cyclotrons were what interested the Russians, Moscow was still in the experimental stage of atomic development. The U.S. had entered the production stage in 1943.

[The Weser and Krizik Works near Podmokly was a very large German weapons research, development, and production complex during the war (and had been founded long before, p. 953). It was reportedly involved in nuclear weapons work, advanced rockets, and other revolutionary innovations.

What exactly was the V-4 rocket?

Why did Weser/Krizik produce at least three cyclotrons (or maybe more) during the war?

Can all of the records from the Weser/Krizik complex be located in Russia and released?]



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Authority NND941017

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THIS DOCUMENT CONSISTS OF 2 PAGE(S)
NO. 1 OF [illegible] COPIES, SERIES a

To : Major General Groves
From : Colonel Shuler
Subject: Atomic Bomb Research in Russian Zone of Czechoslovakia

16 Nov 45

Colonel Ernest W. GRUHN, ASF Int., forwarded this office a report submitted to JIOA by one T. M. ODARENKO. The report is dated 26 Oct 45 and is substantially as follows:

a. At the request of Dr. H. P. ROBERTSON, Chief of Scientific & Technological Branch of FIAT (Field Information Agency Technical), ODARENKO prepared this report covering his trips to Berlin, Czechoslovakia, and Austria to interview scientists engaged in "fundamental research work in chemistry and physics in order to gather the most complete information on the problem of the so-called radiation absorption material." Though without intending to explore the atomic physics field, he received information of direct bearing on it:

Intelligence

1) First direct information of Russian activity in this field came to him from one Otakar HORAK of Prague introduced to him as an officer of the Czech CIC by our M. A. to Prague, Lt. Col. WOLDIKE. HORAK volunteered to assist the U.S. authorities "upon recommendation of his highest authorities." WOLDIKE suggested that, inasmuch as technical intelligence in Czechoslovakia was not feasible, ODARENKO should use the services of HORAK who, however, has not proved of any value either because he didn't risk working with ODARENKO or didn't trust him.

2) HORAK did say that the Russians have

a) established a special research institution some distance east of Prague;

b) have engaged some sixty (60) scientists and a number of assistants to complete the work of atomic energy release; at this inst,

c) have placed at this group's disposal a fully equipped lab and a trial field. The lab is using a "highest-voltage generator"; but another section is working on a method not requiring neutron generators and the race is close. It was "confidentially expected that the problem would be solved before 'the snow comes down.'"

3) HORAK "bemoaned the fact" that the U.S. has no scientific representatives in Prague to whom he can report the progress of Russian scientific activities in Czechoslovakia because, on instructions from the "highest military Czechoslovakian authority" he was in position to give such representative all reports on the final accomplishments of Russian atomic research when completed.

4) ODARENKO was much impressed with the accuracy of HORAK's information about the location of certain German scientists "now in the American zone of occupation presumably Austria and with his knowledge of the progress of atomic research in Germany and Austria" before war's end. ODARENKO got the impression this information came to HORAK from Russian sources.

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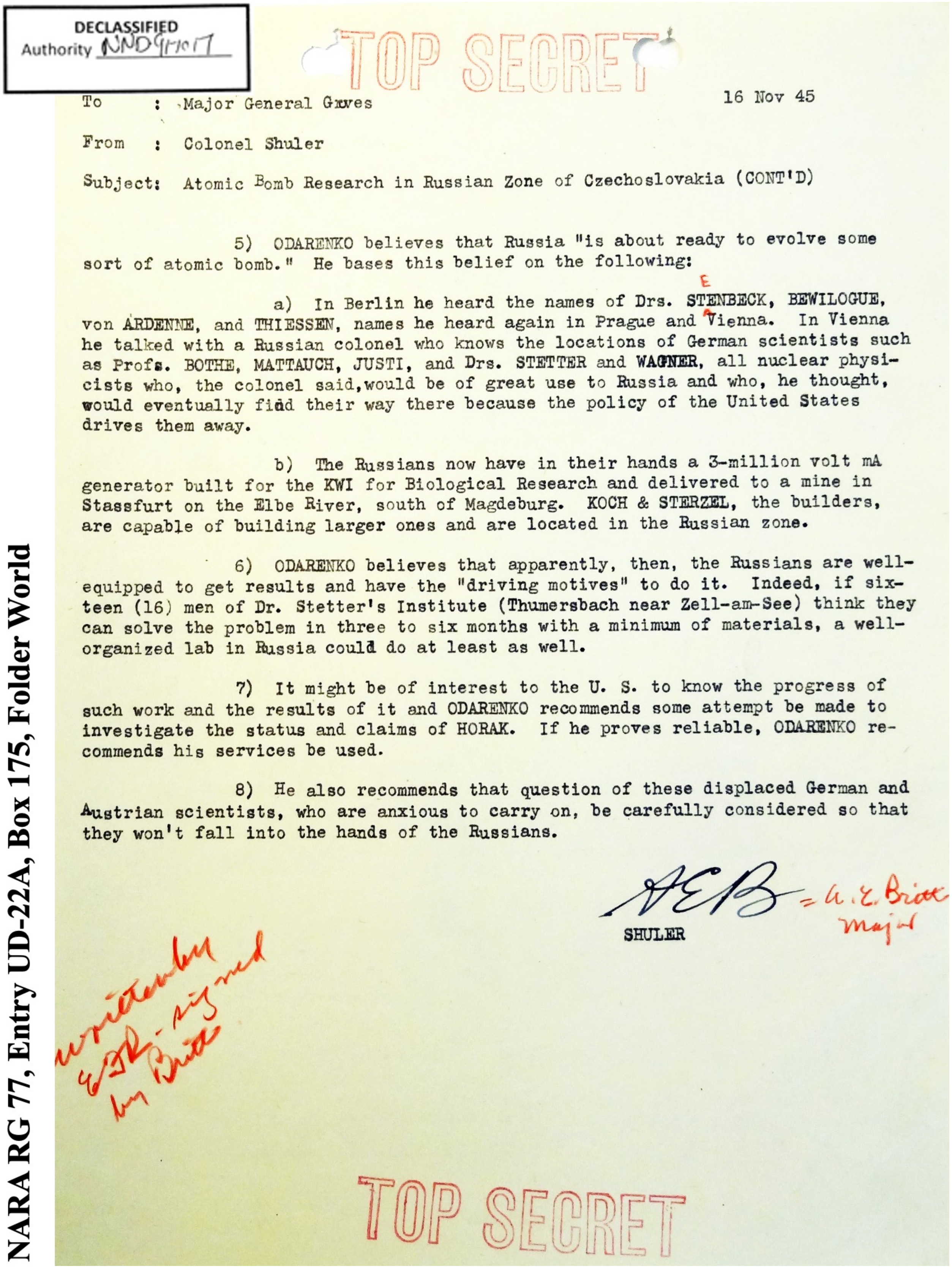
NARA RG 77, Entry UD-22A, Box 175, Folder World

Figure D.459: Colonel Schuler to Leslie Groves. 16 November 1945. Subject: Atomic Bomb Research in Russian Zone of Czechoslovakia. [NARA RG 77, Entry UD-22A, Box 175, Folder World].



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To : Major General Groves

16 Nov 45

From : Colonel Shuler

Subject: Atomic Bomb Research in Russian Zone of Czechoslovakia (CONT'D)

5) ODARENKO believes that Russia "is about ready to evolve some sort of atomic bomb." He bases this belief on the following:

a) In Berlin he heard the names of Drs. STEENBECK, BEWILOGUE, von ARDENNE, and THIESSEN, names he heard again in Prague and Vienna. In Vienna he talked with a Russian colonel who knows the locations of German scientists such as Profs. BOTHE, MATTAUCH, JUSTI, and Drs. STETTER and WAGNER, all nuclear physicists who, the colonel said, would be of great use to Russia and who, he thought, would eventually find their way there because the policy of the United States drives them away.

b) The Russians now have in their hands a 3-million volt mA generator built for the KWI for Biological Research and delivered to a mine in Stassfurt on the Elbe River, south of Magdeburg. KOCH & STERZEL, the builders, are capable of building larger ones and are located in the Russian zone.

6) ODARENKO believes that apparently, then, the Russians are well-equipped to get results and have the "driving motives" to do it. Indeed, if sixteen (16) men of Dr. Stetter's Institute (Thumersbach near Zell-am-See) think they can solve the problem in three to six months with a minimum of materials, a well-organized lab in Russia could do at least as well.

7) It might be of interest to the U. S. to know the progress of such work and the results of it and ODARENKO recommends some attempt be made to investigate the status and claims of HORAK. If he proves reliable, ODARENKO recommends his services be used.

8) He also recommends that question of these displaced German and Austrian scientists, who are anxious to carry on, be carefully considered so that they won't fall into the hands of the Russians.

AEB = A. E. Britt Major
SHULER

written by EJR - signed by Britt

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NARA RG 77, Entry UD-22A, Box 175, Folder World

Figure D.460: Colonel Schuler to Leslie Groves. 16 November 1945. Subject: Atomic Bomb Research in Russian Zone of Czechoslovakia. [NARA RG 77, Entry UD-22A, Box 175, Folder World].

Joint Intelligence Committee. Exploitation of German Scientists and Technicians. 5 January 1946. J.I.C. 317/10. [NARA RG 218, Entry UD-1, Box 475, Folder CCS 471.9... (5-1-45)... Sec. 3]

[...]

3. The most important factors currently limiting increases in Soviet military power are shortages of (1) industrial facilities, and (2) competent scientists and technicians. The U.S.S.R. is making vigorous efforts to overcome the latter shortage by the intensive exploitation of German scientists and technicians. Unless the migration of important German scientists and technicians into the Soviet Zone is immediately stopped, we believe that the Soviets within a relatively short time may equal U.S. developments in the fields of atomic research and guided missiles and may be ahead of U.S. development in other fields of great military importance, including infra-red, television, and jet propulsion. In the field of atomic research, for example, we estimate that German assistance already has cut substantially, probably by several years, the time needed for the U.S.S.R. to achieve practical results. (See Appendix "C" for additional details).

4. Important German scientists and technicians in the U.S. Zone are steadily migrating openly or clandestinely into Soviet hands. The U.S.S.R. is offering such men employment under excellent conditions both in the Soviet Zone of Germany and in the U.S.S.R. Where Soviet offers have not been a sufficient inducement to German scientists and technicians to leave the U.S. Zone, the Soviets have secretly removed them by force. American visits to the Soviet Zone are, furthermore, strictly limited to a particular purpose and are permitted only with Soviet escort to see that the mission authorized is strictly adhered to. Departure of German scientists and technicians from the Soviet Zone is apparently limited only to those Germans for whom the U.S.S.R is certain it will have no further use.

5. Virtually every important German laboratory, research establishment, or factory in the Soviet Zone concerned with new devices, not bombed out, is either in full operation or has been transferred to the U.S.S.R. with all its key personnel. The Soviets already have acquired technical knowledge, equipment, and personnel from the Germans which should eventually enable them not only to duplicate many important German developments, but also to continue along the lines of German research. There is no doubt, however, that the continued recruiting by the Soviets of large numbers of German scientists and technicians from outside the Soviet Zone will accelerate materially the results to be obtained, as well as deny them to the United States.

6. A comprehensive list of important German scientists and technicians in the U.S. Zone, their technical competence, and the size and composition of their families has not been compiled. Such a list is necessary to determine the capabilities of these Germans, estimate the specific effort their continued denial to the U.S.S.R. would have on Soviet scientific and technical progress and to determine what, if any, long-range plans are appropriate. Such a list would also be of assistance to the War and Navy Departments in determining what German scientists and technicians should be exploited for military purposes in the United States. It would be desirable also to have available in the U.S. accurate information regarding Germans whom government agencies other than the War and Navy Departments might desire to exploit for non-military purposes. [...]

APPENDIX “C”

U.S.S.R. EXPLOITATION OF GERMAN SCIENTISTS AND TECHNICIANS

1. Interrogation of qualified German personnel both in Europe and this country, as well as numerous intelligence reports, all indicate that long-range exploitation of German scientific and technical personnel and facilities is both thorough and intelligent throughout the Soviet Zone. Briefly the situation in some fields is:

a. Atomic research: The 7 top men working on atomic research in Germany were: Prof. HEISENBERG, Prof. HERTZ, Baron VON ARDENNE, Prof. BOTHE, Prof. STETTER, Dr. GERLACH, and Prof. BEWILOGUA [Ludwig Bewilogua, wartime expert on uranium piles and low temperature physics at the Kaiser Wilhelm Institute for Physics in Berlin]. Of these HERTZ, BEWILOGUA, VON ARDENNE, and BOTHE (Formerly in the U.S. Zone) are now working for the U.S.S.R. with many of their assistants. Practically the entire staff of the German “URANMOTOR” Project at KRIZIK [part of the Weser-Werke complex near Podmokly] in Czechoslovakia under Prof. HUETTIG is working for the U.S.S.R., so are large numbers of the staff of the Kaiser Wilhelm Institute connected with atomic research.

Still in the U.S. Zone at Zell-Am-See are an important group of German atomic scientists under Dr. STETTER and Prof. MATTAUCH. Tempted by alluring Soviet offers, this group is drifting one by one into Soviet employ.

b. Infra-red and television. Many of Germany’s finest factories and engineers in the field of electronics are now in Soviet hands. Of special important are Dr. STUETZER, formerly Reich Plenipotentiary for High Frequency Research, and Dr. STEIMEL of TELEFUNKEN. Among the many important plants that have fallen intact into Soviet hands are several plants of BLAUPUNKT and FERNSEH, outstanding manufacturers of infra-red and television equipment. There is little doubt that in these fields, German developments were ahead of those in other countries. [...]

c. Guided Missiles. A number of the best men in this field, including such men as Prof. VON BRAUN and Prof. WAGNER are at present in this country. Prof. KRAMER is at present in French hands, but they too will be the object of solicitation by the U.S.S.R. on their eventual return to Germany. Whereas the Soviets transferred the Kaiser Wilhelm Institutes at LICHTERFELDE and LANKWITZ to the Soviet Union, with all the available equipment and personnel, and control the research and testing establishments at PEENEMUENDE, BORNHOLM, and DRESDEN, they still lack the best scientists in the guided missiles fields. Hence, their continuing efforts to obtain the services of such scientists outside the Soviet zone.

d. Aircraft research and manufacturing establishments. Aircraft research establishments and engineers already in Soviet hands include [...]

[See document photos on pp. 3993–3996.

Note statements such as: "unless the migration of important German scientists and technicians into the Soviet Zone is immediately stopped, we believe that the Soviets within a relatively short time may equal U.S. developments in the fields of atomic research," and "in the field of atomic research... German assistance already has cut substantially, probably by several years, the time needed for the U.S.S.R. to achieve practical results." This once-top-secret report of the U.S. Joint Intelligence Committee seems to acknowledge that wartime German scientists had knowledge and capabilities equal to U.S. developments in the field of atomic research, by stating that those scientists had the ability to rapidly confer such knowledge and capabilities to the postwar U.S.S.R.

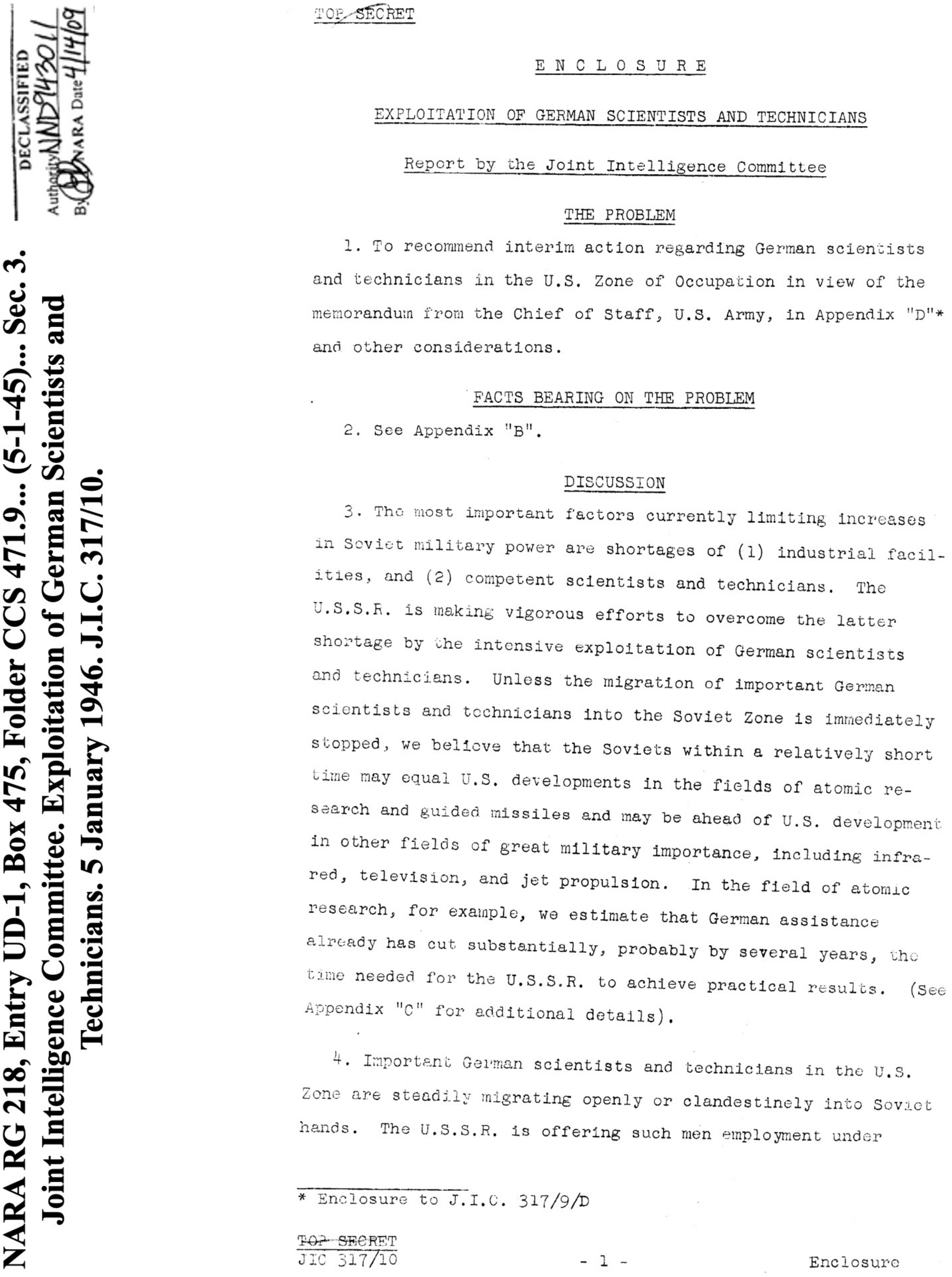
The report appears to acknowledge that wartime German knowledge and accomplishments in missiles, electronics, and jet aircraft significantly surpassed any non-German-assisted U.S. or Soviet programs in those areas.

What exactly did Ludwig Bewilogua accomplish in nuclear physics during and after the war? Where are the records on him and all of his work? He is listed here alongside Werner Heisenberg and Walther Gerlach, yet he and his work are almost unknown. See also p. 5059.

Gustav Hertz and Manfred von Ardenne were generously rewarded by Stalin for their contributions to the development of the Soviet atomic bomb. What all did they accomplish in Germany during the war? What information about their wartime accomplishments reached the Soviets and made them so eager to find and employ Hertz and von Ardenne? What exactly did they do for the Soviet program?

What was "the German 'URANMOTOR' Project" at Krizik, which had an "entire staff"?

What exactly were all the wartime and postwar research and development projects at the Krizik-Werke/Weser-Werke complex near Podmokly?]



NARA RG 218, Entry UD-1, Box 475, Folder CCS 471.9... (5-1-45)... Sec. 3. Joint Intelligence Committee. Exploitation of German Scientists and Technicians. 5 January 1946. J.I.C. 317/10.

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By [illegible] NARA Date 4/14/09

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ENCLOSURE

EXPLOITATION OF GERMAN SCIENTISTS AND TECHNICIANS

Report by the Joint Intelligence Committee

THE PROBLEM

1. To recommend interim action regarding German scientists and technicians in the U.S. Zone of Occupation in view of the memorandum from the Chief of Staff, U.S. Army, in Appendix "D"* and other considerations.

FACTS BEARING ON THE PROBLEM

2. See Appendix "B".

DISCUSSION

3. The most important factors currently limiting increases in Soviet military power are shortages of (1) industrial facilities, and (2) competent scientists and technicians. The U.S.S.R. is making vigorous efforts to overcome the latter shortage by the intensive exploitation of German scientists and technicians. Unless the migration of important German scientists and technicians into the Soviet Zone is immediately stopped, we believe that the Soviets within a relatively short time may equal U.S. developments in the fields of atomic research and guided missiles and may be ahead of U.S. development in other fields of great military importance, including infrared, television, and jet propulsion. In the field of atomic research, for example, we estimate that German assistance already has cut substantially, probably by several years, the time needed for the U.S.S.R. to achieve practical results. (See Appendix "C" for additional details).

4. Important German scientists and technicians in the U.S. Zone are steadily migrating openly or clandestinely into Soviet hands. The U.S.S.R. is offering such men employment under

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* Enclosure to J.I.C. 317/9/D

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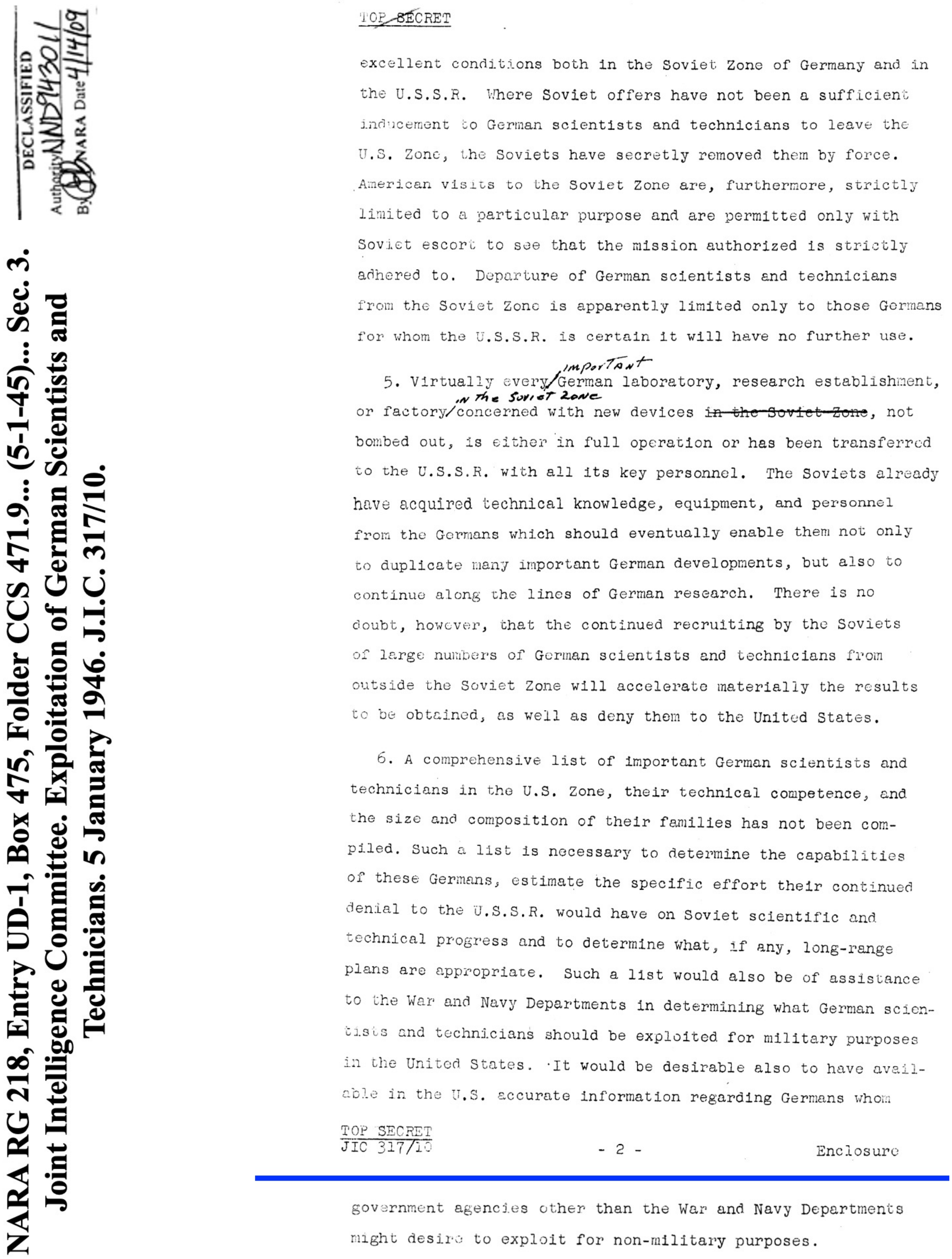
JIC 317/10 - 1 - Enclosure

Figure D.461: Joint Intelligence Committee. Exploitation of German Scientists and Technicians. 5 January 1946. J.I.C. 317/10. [NARA RG 218, Entry UD-1, Box 475, Folder CCS 471.9... (5-1-45)... Sec. 3]



NARA RG 218, Entry UD-1, Box 475, Folder CCS 471.9... (5-1-45)... Sec. 3.
Joint Intelligence Committee. Exploitation of German Scientists and Technicians. 5 January 1946. J.I.C. 317/10.

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By NARA Date 4/14/09

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excellent conditions both in the Soviet Zone of Germany and in the U.S.S.R. Where Soviet offers have not been a sufficient inducement to German scientists and technicians to leave the U.S. Zone, the Soviets have secretly removed them by force. American visits to the Soviet Zone are, furthermore, strictly limited to a particular purpose and are permitted only with Soviet escort to see that the mission authorized is strictly adhered to. Departure of German scientists and technicians from the Soviet Zone is apparently limited only to those Germans for whom the U.S.S.R. is certain it will have no further use.

5. Virtually every important German laboratory, research establishment, or factory in the Soviet Zone concerned with new devices ~~in the Soviet Zone~~, not bombed out, is either in full operation or has been transferred to the U.S.S.R. with all its key personnel. The Soviets already have acquired technical knowledge, equipment, and personnel from the Germans which should eventually enable them not only to duplicate many important German developments, but also to continue along the lines of German research. There is no doubt, however, that the continued recruiting by the Soviets of large numbers of German scientists and technicians from outside the Soviet Zone will accelerate materially the results to be obtained, as well as deny them to the United States.

6. A comprehensive list of important German scientists and technicians in the U.S. Zone, their technical competence, and the size and composition of their families has not been compiled. Such a list is necessary to determine the capabilities of these Germans, estimate the specific effort their continued denial to the U.S.S.R. would have on Soviet scientific and technical progress and to determine what, if any, long-range plans are appropriate. Such a list would also be of assistance to the War and Navy Departments in determining what German scientists and technicians should be exploited for military purposes in the United States. It would be desirable also to have available in the U.S. accurate information regarding Germans whom

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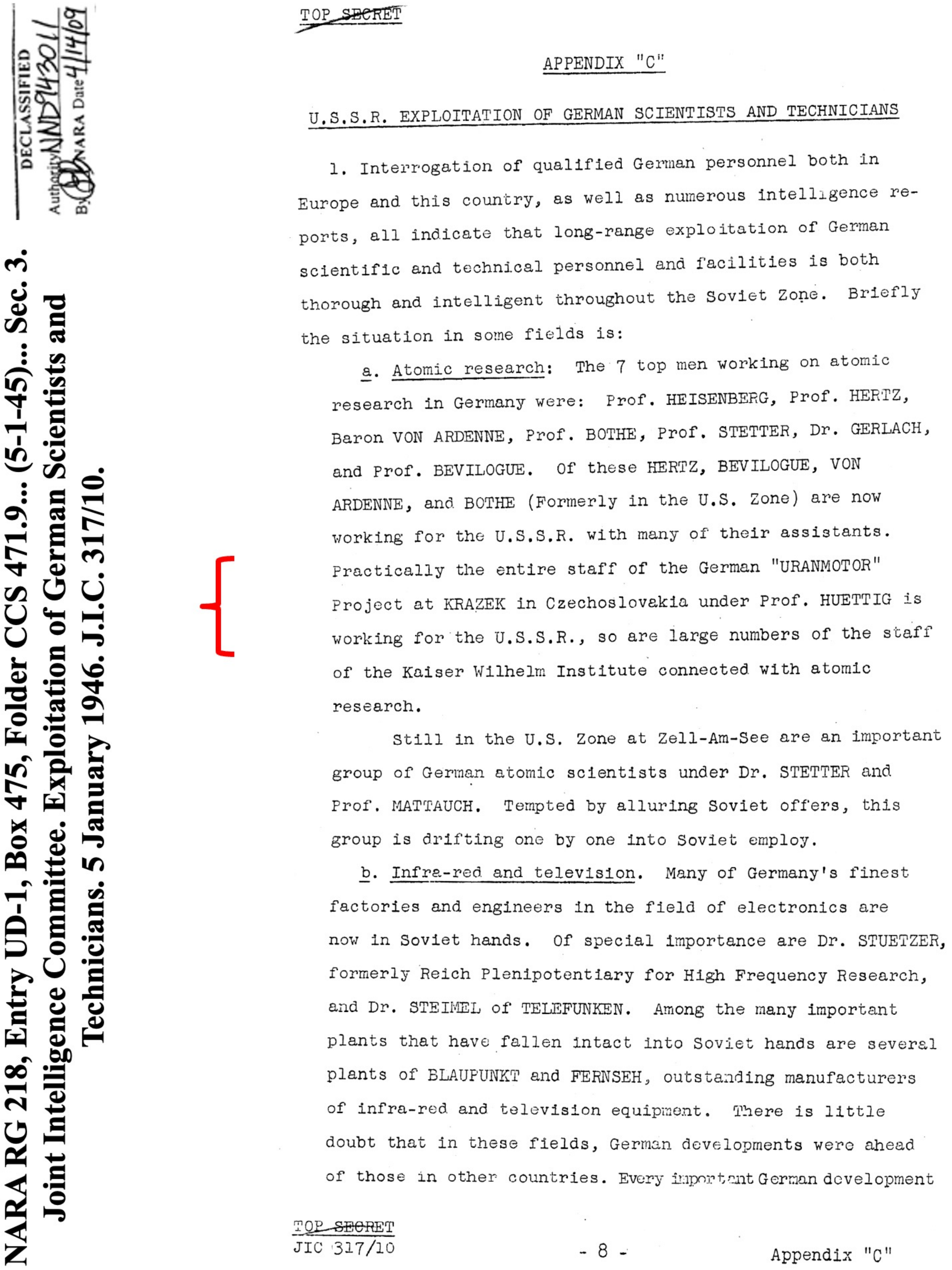
JIC 317/10 - 2 - Enclosure

government agencies other than the War and Navy Departments might desire to exploit for non-military purposes.

Figure D.462: Joint Intelligence Committee. Exploitation of German Scientists and Technicians. 5 January 1946. J.I.C. 317/10. [NARA RG 218, Entry UD-1, Box 475, Folder CCS 471.9... (5-1-45)... Sec. 3]



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NARA RG 218, Entry UD-1, Box 475, Folder CCS 471.9... (5-1-45)... Sec. 3. Joint Intelligence Committee. Exploitation of German Scientists and Technicians. 5 January 1946. J.I.C. 317/10.

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APPENDIX "C"

U.S.S.R. EXPLOITATION OF GERMAN SCIENTISTS AND TECHNICIANS

1. Interrogation of qualified German personnel both in Europe and this country, as well as numerous intelligence reports, all indicate that long-range exploitation of German scientific and technical personnel and facilities is both thorough and intelligent throughout the Soviet Zone. Briefly the situation in some fields is:

a. Atomic research: The 7 top men working on atomic research in Germany were: Prof. HEISENBERG, Prof. HERTZ, Baron VON ARDENNE, Prof. BOTHE, Prof. STETTER, Dr. GERLACH, and Prof. BEVILOGUE. Of these HERTZ, BEVILOGUE, VON ARDENNE, and BOTHE (Formerly in the U.S. Zone) are now working for the U.S.S.R. with many of their assistants. Practically the entire staff of the German "URANMOTOR" Project at KRAZEK in Czechoslovakia under Prof. HUETTIG is working for the U.S.S.R., so are large numbers of the staff of the Kaiser Wilhelm Institute connected with atomic research.

Still in the U.S. Zone at Zell-Am-See are an important group of German atomic scientists under Dr. STETTER and Prof. MATTAUCH. Tempted by alluring Soviet offers, this group is drifting one by one into Soviet employ.

b. Infra-red and television. Many of Germany's finest factories and engineers in the field of electronics are now in Soviet hands. Of special importance are Dr. STUETZER, formerly Reich Plenipotentiary for High Frequency Research, and Dr. STEIMEL of TELEFUNKEN. Among the many important plants that have fallen intact into Soviet hands are several plants of BLAUPUNKT and FERNSEH, outstanding manufacturers of infra-red and television equipment. There is little doubt that in these fields, German developments were ahead of those in other countries. Every important German development

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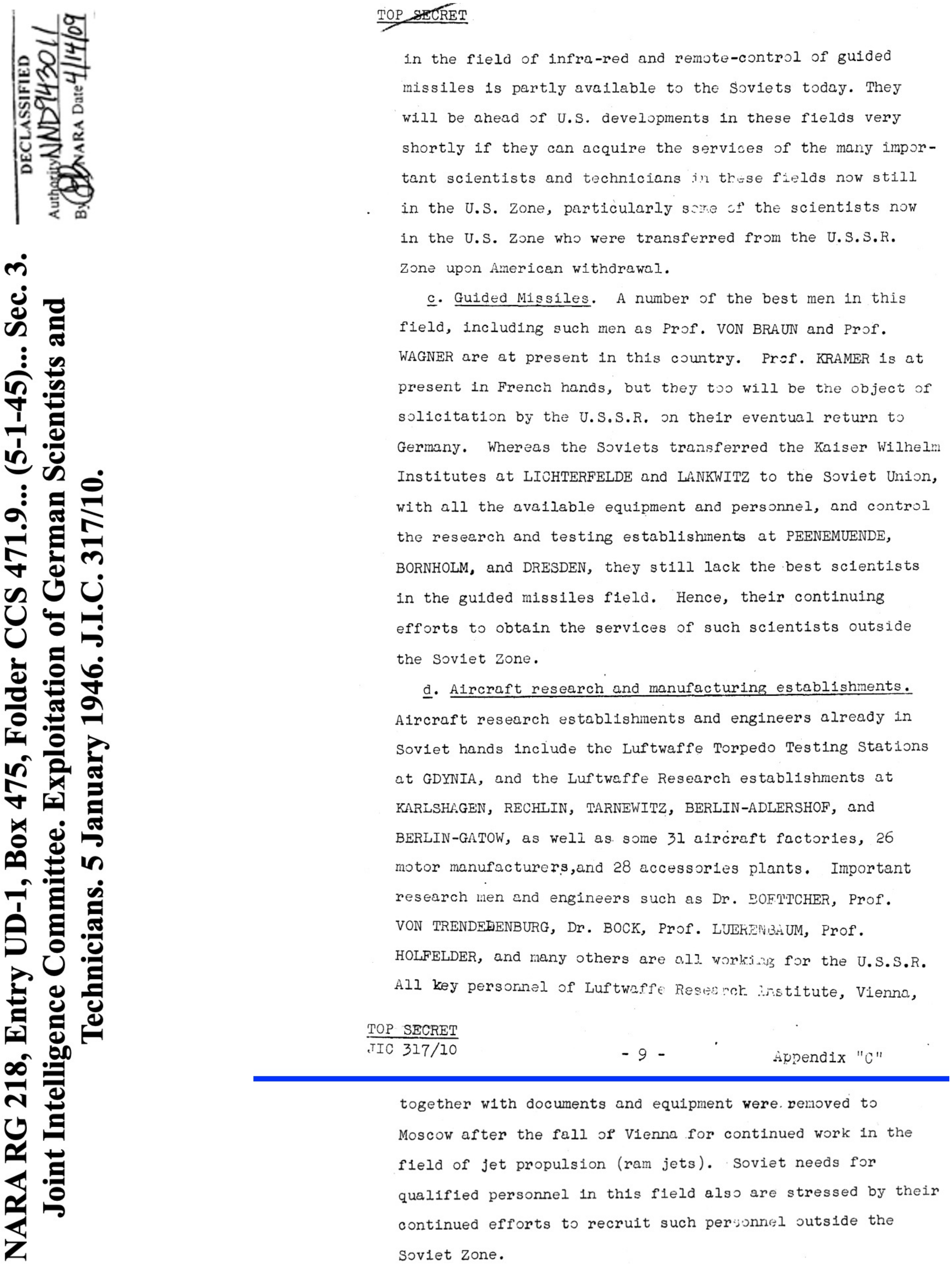
Figure D.463: Joint Intelligence Committee. Exploitation of German Scientists and Technicians. 5 January 1946. J.I.C. 317/10. [NARA RG 218, Entry UD-1, Box 475, Folder CCS 471.9... (5-1-45)... Sec. 3]



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in the field of infra-red and remote-control of guided missiles is partly available to the Soviets today. They will be ahead of U.S. developments in these fields very shortly if they can acquire the services of the many important scientists and technicians in these fields now still in the U.S. Zone, particularly some of the scientists now in the U.S. Zone who were transferred from the U.S.S.R. Zone upon American withdrawal.

c. Guided Missiles. A number of the best men in this field, including such men as Prof. VON BRAUN and Prof. WAGNER are at present in this country. Prof. KRAMER is at present in French hands, but they too will be the object of solicitation by the U.S.S.R. on their eventual return to Germany. Whereas the Soviets transferred the Kaiser Wilhelm Institutes at LICHTERFELDE and LANKWITZ to the Soviet Union, with all the available equipment and personnel, and control the research and testing establishments at PEENEMUENDE, BORNHOLM, and DRESDEN, they still lack the best scientists in the guided missiles field. Hence, their continuing efforts to obtain the services of such scientists outside the Soviet Zone.

d. Aircraft research and manufacturing establishments. Aircraft research establishments and engineers already in Soviet hands include the Luftwaffe Torpedo Testing Stations at GDYNIA, and the Luftwaffe Research establishments at KARLSHAGEN, RECHLIN, TARNEWITZ, BERLIN-ADLERSHOF, and BERLIN-GATOW, as well as some 31 aircraft factories, 26 motor manufacturers,and 28 accessories plants. Important research men and engineers such as Dr. BOETTCHER, Prof. VON TRENDELENBURG, Dr. BOCK, Prof. LUERENBAUM, Prof. HOLFELDER, and many others are all working for the U.S.S.R. All key personnel of Luftwaffe Research Institute, Vienna,

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together with documents and equipment were removed to Moscow after the fall of Vienna for continued work in the field of jet propulsion (ram jets). Soviet needs for qualified personnel in this field also are stressed by their continued efforts to recruit such personnel outside the Soviet Zone.

Figure D.464: Joint Intelligence Committee. Exploitation of German Scientists and Technicians. 5 January 1946. J.I.C. 317/10. [NARA RG 218, Entry UD-1, Box 475, Folder CCS 471.9... (5-1-45)... Sec. 3]

Vladimir L. Rychly. Report No. 2655: Report on Visit to Czechoslovakia. 11 February 1946. [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700]

A. Between 3 January and 22 January, arrangements were made with the Czech'k General Staff to visit a number of plants that had been working for the German Navy during the war. Contact was made with this Staff through the British and U.S. Military Attachés who introduced me to Gen. BOCEK. The Czech authorities granted the permission but informed me that I would have to be escorted throughout by the Czech Secret Police (O.B.Z.). The plants visited were the following:

1. C.S.R. ZBROJOVKA at BRNO (Moravia) [formerly Waffenwerke-Brünn]. This firm has in all some eight plants in a radius of 70 Klms of BRNO. [...] Also removed [by the Russian Tech Control Commission] were all documents, drawings and a number of leading technicians.

2. PRVNI PRNENSKA STROJIRNA, BRNO (Moravia). [...] From this plant all documents were removed by the Russians, but no further work was carried out under their supervision.

3. BATA, ZLIN (Moravia). [...] Rubber for experimental [anti-sonar and/or anti-radar stealth] coverings of U-boat hulls. [...]

4. ZIKMUND-CHEMA at LUTIN (Moravia). [...] All documents and valuable machinery were removed by the Russians who, however, evacuated none of the technicians and scientists.

5. STEIN and SPOL at BRNO (Moravia). [...] Everything of interest was removed by the Russians.

6. SCHMIDDING at PODMOKLY (Bohemia). [...] By October 1945 the Russians stopped production, removed the completed torpedoes and other weapons, duplicates of all documents and number of German engineers to Russia.

7. WESERWERKE at DECIN (Teschen) (Bohemia). A lot of inaccurate reports have been circulated about the work carried on in the vast underground workshops of this plant. It has been reported that cyclotrons were manufactured and that in laboratories work was being carried out on atom smashing in conjunction with uranium isotope 235.

In actual fact the following work was carried out: production of V-1 and V-2. 55mm rockets. Schlange. Wespe. 30mm pneumatic cannon. Remote control rockets.

This plant was very strictly guarded until 1 December 1945, and it is thought that German technicians were still employed there up to that date. The plant has now been evacuated.

8. A.E.G. at BEDRICHOV (Bohemia). Manufactured F.B. Zielsuchgeraet. Pfau. Amsel. Ida 105 mine, accoustic, induction and reacting to change in water pressure. V-1 and V-2 fuses. The completed V-4. Lichtspiegelanlage.

The German scientists Pfister and Bakes, with whom I had the opportunity to speak, and some 22 other German scientists are still working on the development of the above under Czech supervision for the Russians. The program on which this firm is still engaged is much more extensive than that listed above. Pfister tried to pass me a copy of the complete program of work, but this was seized from my hand by one of the O.B.Z. officials present.

The O.B.Z. official promised that I should obtain a copy of this program in Prague. On arrival there General Bocek gave orders for it to be surrendered to me, but this got to the ears of Colonel Reicin, the right hand man of General Svoboda, who forbade the authorities to let me have a copy.

Both Pfister and Bakes seemed most keen to be of assistance to us.

9. VOLMAN at CELAKOVICE (Bohemia). Manufactured 3 cyclotrons that were removed to Russia. No work was proceeding in the factory.

10. CESKO-MORAVSKA. KOLBEN-DANEK at SLANY and PRAGUE (Bohemia). [...] This plant was bombed out entirely and as far as is known the Russians removed nothing. [...]

11. HAVEILKA PRAGUE (Bohemia). Manufactured bridge superstructures and conning towers for U-boat types XXI, XXIII, and XXVI W. [...]

The chief engineer of the firm carried out a tirade against the management of the works in my presence and was there and then removed by the O.B.Z.

12. ASKANIA PRAGUE (Bohemia). Works in Prague were bombed out. No permission was granted to see the other Askania works which were reported to me by a friendly major of the Czech General Staff as being inaccessible to Czechs and under Russian control.

B. Further information was obtained about a number of firms by unofficial visits and by enquiries in the right quarter.

1. Jet Propulsion laboratory at Turnov (Bohemia). This was cleaned out by the Russians in October or November 1945, and the scientists including Germans were removed by the Russians.

2. Radium production plant at Jachymov (Bohemia). The following information about this plant was given by a secretary in the Ministry of Mines in Prague who will produce a detailed report of work going on in this mine. Since 1863 uranium ore has been mined here and utilized for the manufacture of radium. Pre-war production of radium amounted to about 2 grams per year. When the Germans moved in, they destroyed the whole factory. At this time, the entire stock of radium amounted to 20 grams. The Germans put mining on a high priority and only mining was done throughout the 6 years occupation. The ore was delivered by special planes to Germany and Austria.

Before the Russians entered Czechoslovakia they made arrangements with the Allies to alter their western boundary for the purpose of including the Jachymov mine which they considered of such importance. On arrival, they put a strong guard around the mine. It has been reported that they removed the ore by night in trucks, but this is unconfirmed. Since then the Russians have officially left and the mine is under Czech administration though almost certainly under Russian control. The production at present is 1 gram of radium from 10,000 kgms of ore. Engineer Koblitz has been commissioned to put the radium processing plant into production and has been or will be sent to England or the U.S. to study our method of production. It is not yet certain whether the output will go to the Czechoslovak State for medical purposes or will be exported to Russia.

3. POLDINA-HUT at VITKOVICE (Moravia). [...] The Russians have taken over the whole plant.

4. SIEMENS at CESKE BUDEJOVIC (Bohemia). Two factories were seen from the outside in this town. There was a strong guard outside. Work is going on in altogether 17 Siemens factories and according to a Czech staff officer, it is under Russian supervision because only specially authorized Czechs are allowed there.

5. STALIN WORKS at DUCHCOV (Bohemia). [...] The plant is at present guarded by 400 of the Czech militia.

C. General Report on State of Czech Factories.

All factories formerly engaged on war production and many others besides have been nationalized and are under the control of the so-called National Administrator, who in every case is a Communist and has been installed under Russian influence. In almost all cases, these administrators have proved themselves incapable of running a factory with the result that there has been trouble in the form of protests among the employees. In some cases these administrators have already been removed and replaced by more competent Communists.

[...] None of the Russian Naptha promised in exchange for Czech coal and textile products has been delivered.

D. OBZ [...]

History: OBZ is the secret Service of Czechoslovakia. It was formed... on the instigation of the Red Army. [...]

The whole organization is based on the lines of the NKVD. [...]

The Russians are by no means dependent on the OBZ for secret service activities inside Czechoslovakia. They have their own excellent independent agents who in fact guide the activities of OBZ. [...]

[See document photos on pp. 5520–5527.

Vladimir "Val" Rychly was born in the U.S. in 1909 to parents who were immigrants from Czechoslovakia. He grew up speaking Czech, knew ten other languages, and had a celebrated career in U.S. Naval Intelligence. See: Marvin B. Durning. 2007. *World Turned Upside Down: U.S. Naval Intelligence and the Early Cold War Struggle for Germany.* Washington, D.C.: Potomac Books.

Rychly's report demonstrates how little postwar U.S. inspectors were able to learn of wartime German work in Czechoslovakia. This rare visit, by a lone Navy lieutenant, came after many other U.S. inspectors were denied or sent away empty-handed. Rychly's report does not even mention some of the major known wartime German research and development locations in Czechoslovakia such as Skoda in Pilsen. Of the locations that Rychly does list, most he was not allowed to visit, or everything had been removed from them by the time he visited. Where Rychly was allowed to visit a site that was still active, he was closely escorted by the OBZ Czechoslovakian secret service and denied access to any information they did not want him to have.

Virtually all documentation, prototypes, laboratories, and scientists connected to wartime German work in Czechoslovakia were removed to the Soviet Union. Presumably that information is still buried in Russian archives if it can be found and released.

Is there any relevant surviving information about wartime German work in Czech archives that was not removed or destroyed by the Soviets or their Czech allies?

What other information about wartime German work in Czechoslovakia do the U.S. and U.K. have from intelligence reports or from individuals who escaped to the west? What else can be found in U.S. and U.K. archives?

Rychly's report does not necessarily negate other reports about the Weser/Krizik complex being involved with work related to nuclear weapons and advanced rockets. Since the plant was cleaned out by the time Rychly visited, his only official information about Weser was apparently whatever his OBZ escorts wanted him to hear. As shown in item 8 of Rychly's report (A.E.G. at BEDRICHOV), actual work at these locations was much more extensive than admitted, and details of that work were blocked by the OBZ and other Czech officials.

From several available documents, "Pfau" seems to have been a general name for certain types of automated guidance systems for missiles and torpedoes [see for example pp. 5544, 5554; Trenkle 1987, pp. 121, 123].

Rychly stated that the V-4 rocket was actually "completed," so it was far more than a paper design. The fact that Rychly could mention the V-4 without further explanation suggests that the high-ranking U.S. military officials to whom he was reporting were already well aware of the existence and details of the V-4 rocket. Indeed, according to other U.S. military officials (p. 5544), this V-4 had both an increased range and an improved payload compared to the much better known A-4 (V-2) rocket. For more information on the V-4 rocket in particular and the Rychly reports in general, see pp. 5503ff. and especially 5544.

Volman was a large engineering design and manufacturing company founded and run in Čelákovice by Josef Volman (Austrian/Czech, 1883–1943). Why were the Germans mass-producing cyclotrons at Volman? They reportedly shipped at least three to other German programs during the war, and had at least three left over that were claimed by the Soviet Union after the war. Were cyclotrons being mass-produced at Volman (and elsewhere) and then being used somewhere for electronuclear breeding?

Note that advanced U-boats were being produced, and in the mountains of central Europe. Advanced jet propulsion work was being done there too.

This report is strong evidence that from 1939 to 1945, Germans used uranium ore from Jachymov (and perhaps other sources as well) for a secret, high-priority purpose that was not radium extraction:

- The Germans put uranium ore mining at Jachymov on a high priority no later than 1939 and continued until 1945.
- 10,000 kg of uranium ore yields 1 gram of radium, so if the Germans were primarily interested in the radium, extracting the radium at or near Jachymov would reduce how much material needed to be transported by a factor of 10,000,000, and also avoid contaminating Germany with all the waste byproducts of the extraction. Instead, the Germans destroyed the radium-extraction factory at Jachymov in 1939, never replaced it, and transported away all the ore.
- Uranium ore is very heavy, yet instead of using trains or trucks, the Germans used "special planes" to carry away the ore, again indicating a very high priority as well as a sense of urgency. It is also much harder to trace where planes go than where trains go, so this arrangement conferred a much higher level of security too.
- Officially Germany only had one uranium ore processing facility, Auer near Berlin, but the "special planes" also delivered uranium ore to Austria. What facility or facilities in Austria were processing the uranium ore—Treibacher or other places? Of the ore delivered to Germany, did any go to facilities other than Auer? Did ore only go to Germany and Austria, or could there have been deliveries to processing facilities elsewhere, such as Poland?
- The extreme level of Russian interest in Jachymov may indicate that the Russians knew how the Germans had been using the ore from Jachymov.]

9 August 1945 letter from the Volman company regarding the wartime production of cyclotrons for Germany. [Vojenský historický archiv, Vědecký technický ústav 1945–1946, kart. 1. Courtesy of Jaroslav Mareš.]

Subject: Cyclotron.

We have received your letter of the above dates and thank you especially for the interest you have shown in the cyclotron, substantial parts of which were manufactured in our plant.

The order for the above-mentioned device was awarded to us by the President of the Research Institute of the Reichspost [Amt für Physikalische Sonderfragen], Berlin-Zehlendorf 1 under No. 101 APS 47681 IE-2. The complete device was to be assembled in Miersdorf (über Zeuthen), where a special building was erected for this purpose.

According to the information we have been able to obtain, they already have on site:

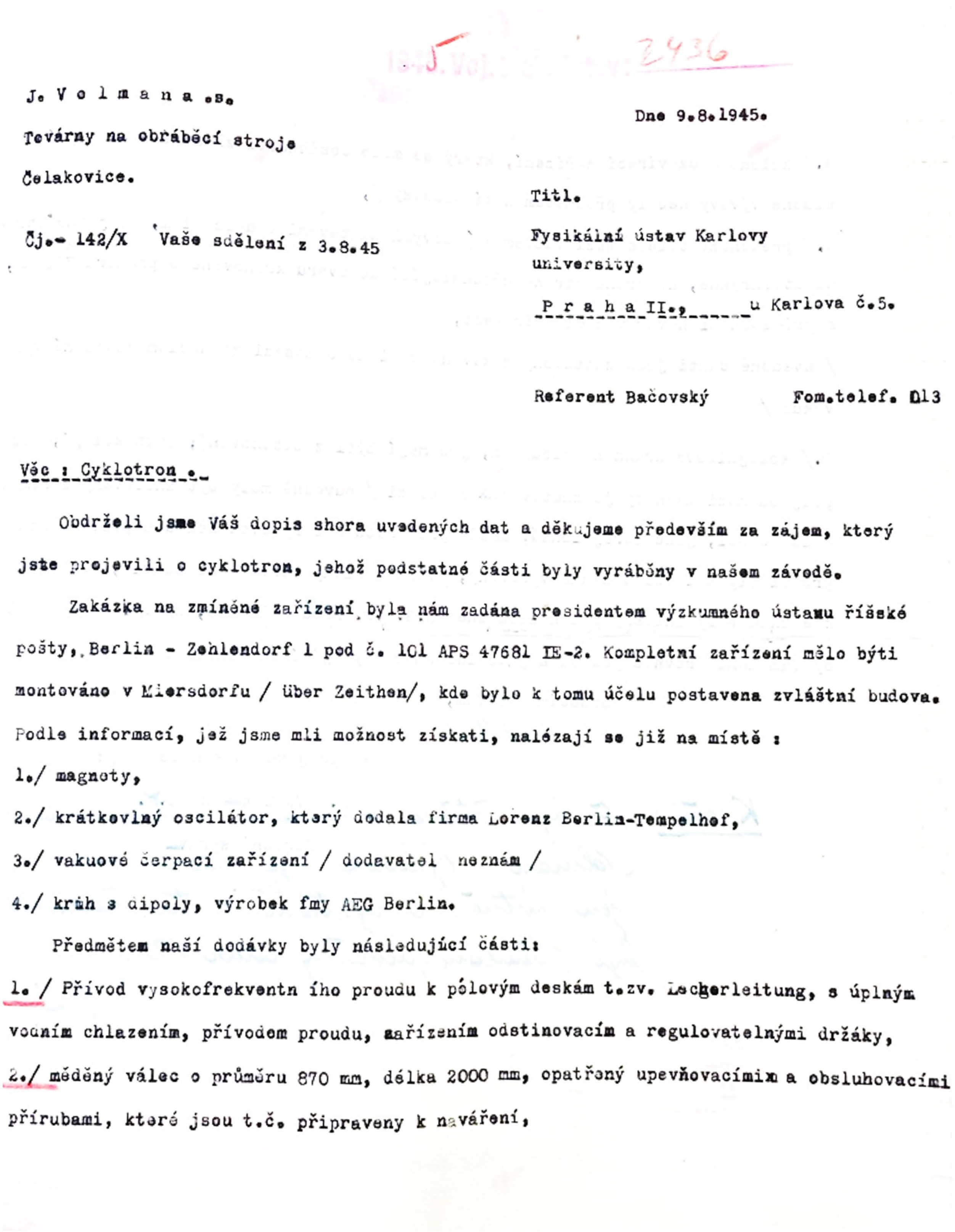
1. magnets,
2. a short-wave oscillator supplied by Lorenz Berlin-Tempelhof,
3. vacuum pumping equipment (supplier unknown)
4. ring and dipoles, product of AEG Berlin.

The following parts were supplied by us:

1. High frequency current supply to the pole plates, so called Lecherleitung, with complete water cooling, current supply, shielding device, and adjustable holders,
2. a copper cylinder of 870 mm diameter, 2,000 mm long, fitted with fixing and operating flanges, which are ready to be wound,
3. elbows and a shut-off device to achieve a dilution of 10^{-6} (the relevant pumps were not supplied by us),
4. the previous body between the cylinder and the pole attachments, 1 m long, square on one side, passing into a circular shape with a diameter of 780 mm on the other side, with the appropriate welding flanges (these parts are made of forged copper or brass to achieve a high vacuum),
5. the rail track on the columns to be concreted, the part of the track that comes between the magnets is made of brass (originally they were to be made of remanite).

The other parts, such as the ion source, the slide holder with beryl plate and the current supply for the dipoles, were made by us, but sent to the Radioslavia company, Prague-Vysočany, where they were perhaps destroyed in the air raid of 24 March this year. We assume that Radioslavia could also provide you with some information regarding the device.

[See document photos on pp. 4003–4004.]



1945. Voj. [illegible] 2436

J. Volman a.s.
Továrny na obráběcí stroje
Čelakovice.

Dne 9.8.1945.

Titl.
Fysikální ústav Karlovy university,
Praha II., u Karlova č.5.

Čj.- 142/X Vaše sdělení z 3.8.45

Referent Bačovský Fom.telef. 013

Věc : Cyklotron .

Obdrželi jsme Váš dopis shora uvedených dat a děkujeme především za zájem, který jste projevili o cyklotron, jehož podstatné části byly vyráběny v našem závodě.

Zakázka na zmíněné zařízení byla nám zadána presidentem výzkumného ústavu říšské pošty, Berlin - Zehlendorf 1 pod č. 101 APS 47681 IE-2. Kompletní zařízení mělo býti montováno v Miersdorfu / über Zeithen/, kde bylo k tomu účelu postavena zvláštní budova. Podle informací, jež jsme mli možnost získati, nalézají se již na místě :

1./ magnety,

2./ krátkovlný oscilátor, který dodala firma Lorenz Berlin-Tempelhof,

3./ vakuové čerpací zařízení / dodavatel neznám /

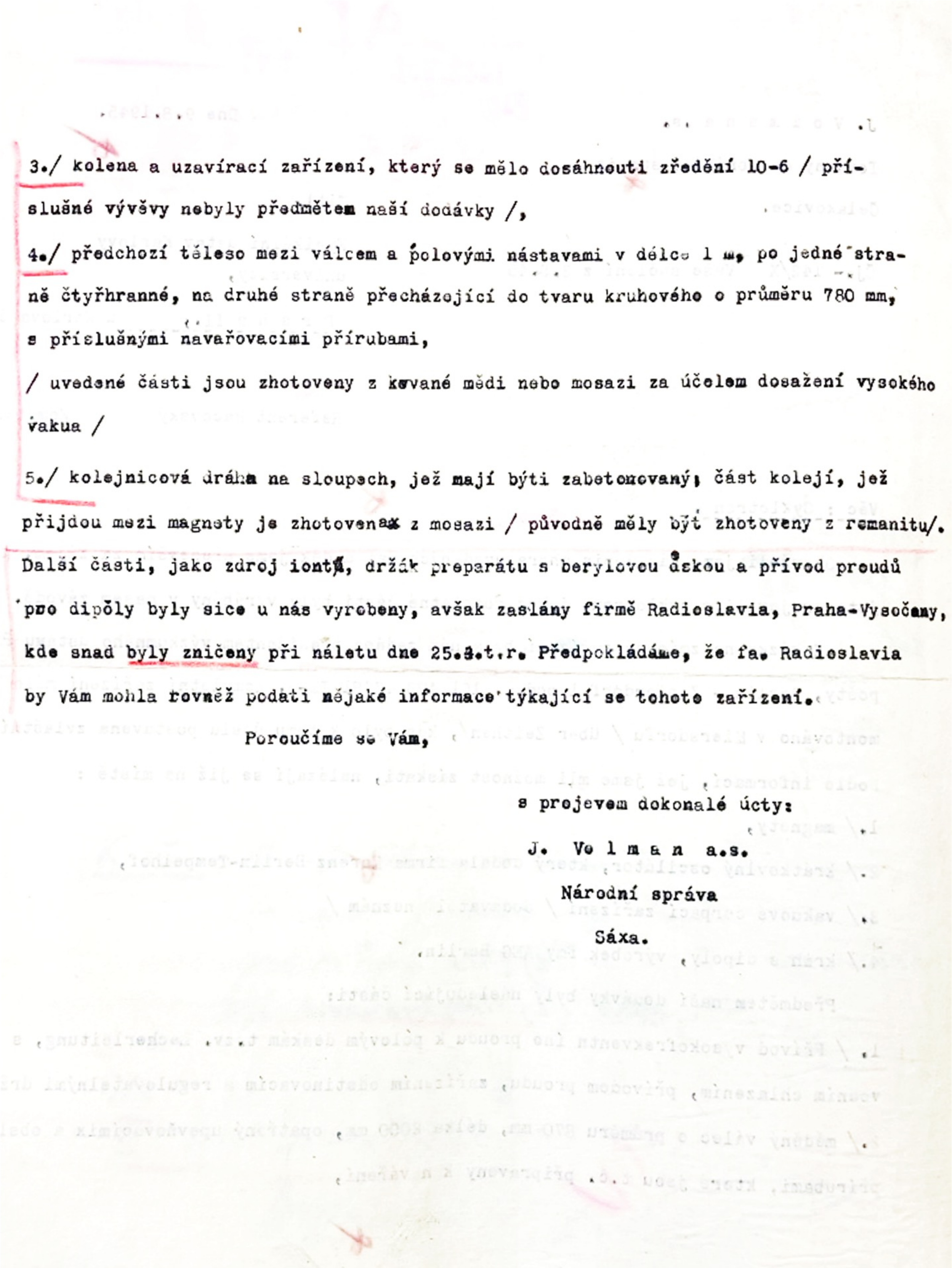
4./ kruh s dipoly, výrobek fmy AEG Berlin.

Předmětem naší dodávky byly následující části:

1. / Přívod vysokofrekventního proudu k pólovým deskám t.zv. Lecherleitung, s úplným vodním chlazením, přívodem proudu, zařízením odstinovacím a regulovatelnými držáky,

2./ měděný válec o průměru 870 mm, délka 2000 mm, opatřený upevňovacími a obsluhovacími přírubami, které jsou t.č. připraveny k navāření,

Figure D.465: 9 August 1945 letter from the Volman company regarding the wartime production of cyclotrons for Germany. [Vojenský historický archiv, Vědecký technický ústav 1945–1946, kart. 1. Courtesy of Jaroslav Mareš.]



3./ kolena a uzavírací zařízení, který se mělo dosáhnouti zředění 10-6 / příslušné vývěvy nebyly předmětem naší dodávky /,

4./ předchozí těleso mezi válcem a polovými nástavami v délce 1 m, po jedné straně čtyřhranné, na druhé straně přecházející do tvaru kruhového o průměru 780 mm, s příslušnými navařovacími přírubami,

/ uvedené části jsou zhotoveny z kované mědi nebo mosazi za účelem dosažení vysokého vakua /

5./ kolejnicová dráha na sloupech, jež mají býti zabetonovány; část kolejí, jež přijdou mezi magnety je zhotovena z mosazi / původně měly být zhotoveny z remanitu/.

Další části, jako zdroj iontů, držák preparátu s beryliovou deskou a přívod proudů pro dipóly byly sice u nás vyrobeny, avšak zaslány firmě Radioslavia, Praha-Vysočany, kde snad byly zničeny při náletu dne 25.3.t.r. Předpokládáme, že fa. Radioslavia by Vám mohla rovněž podati nějaké informace týkající se tohoto zařízení.

Poroučíme se Vám,

s projevem dokonalé úcty:

J. Volman a.s.

Národní správa

Sáxa.

Figure D.466: 9 August 1945 letter from the Volman company regarding the wartime production of cyclotrons for Germany. [Vojenský historický archiv, Vědecký technický ústav 1945–1946, kart. 1. Courtesy of Jaroslav Mareš.]

4 October 1945 letter from the Czechoslovakian OBZ security service regarding the wartime production of cyclotrons for Germany. [Vojenský historický archiv, Vědecký technický ústav 1945–1946, kart. 1. Courtesy of Jaroslav Mareš.]

I am submitting the report on the atomic weapon for further discussion by the relevant technical experts:

The OBZ body has sought out the chief designer of the Marconi factory, now Radioslavia, Eng. Klika, at their new factory in Vršovice, tr. Krále Jiřího, former Kanold factory. He tells about the "cyclotron," a device for splitting atoms, which is produced by them:

In the spring of 1944 they received drawings of the components of the atom smashing apparatus from the Reichspost research institute in Berlin. The director of the research institute was Dr. Salow, who also took up the problem. He had about two other assistants with him. They chose a designer, but in the judgment of Mr. Ing. The wrong one, namely from the shipbuilding field, one Tennies. With the help of this engineer they made drawings and commissioned them to various companies. Marconi in Hloubětín received the main part of the "cyclotron", i.e. the "vacuum system" - D electrodes. Part of the vacuum system, i.e. the vacuum space, was handed over to Volman-Celákovice. Stabenov-Křižík still cooperated with Volman in Čelákovice.

The 50 ton magnet was supplied by Kapsch in Vienna. The 50 kW transmitter with 20 m wavelength was made by Lorenz in Berlin. The AEG company in Berlin made the circular crown from brass.

At "Marconi," the commissioner of Marconi, the postmaster Einbeck, Dr. Salow, head of the research institute in Berlin, Tennies, engineer of the same institute and Ing. Klika, chief designer of Marconi. The director Schebesta and the chief designer of the factory, Ruzicka, who was in charge of the whole matter at Volmani, were present from Volmani.

The Marconi company did not achieve any positive results, because they kept encountering construction errors (the designer hard-wired several parts together) and thus deliberately delayed the completion. The raid on Libeň also hit the Marconi factory hard and destroyed everything there, except for some 3 m tubes that belong to the cyclotron. The drawings and blueprints were burned. Volman did have some results and the Germans also took the finished things somewhere just before the change of government. The drawings that were saved by the company were probably handed over by Mr. Ruzicka to the Russian Colonel Petelin, who has been following the whole thing avidly. This officer summoned Ing. Klika and asked for his opinion on the whole apparatus, and wanted him to indicate in red pencil on the drawings, which he would not give him out of hand, the places which would otherwise have to be solved technically, but privately at home. So far this has not happened, because Ing. Klika has reproached him for the whole apparatus being structurally all wrong.

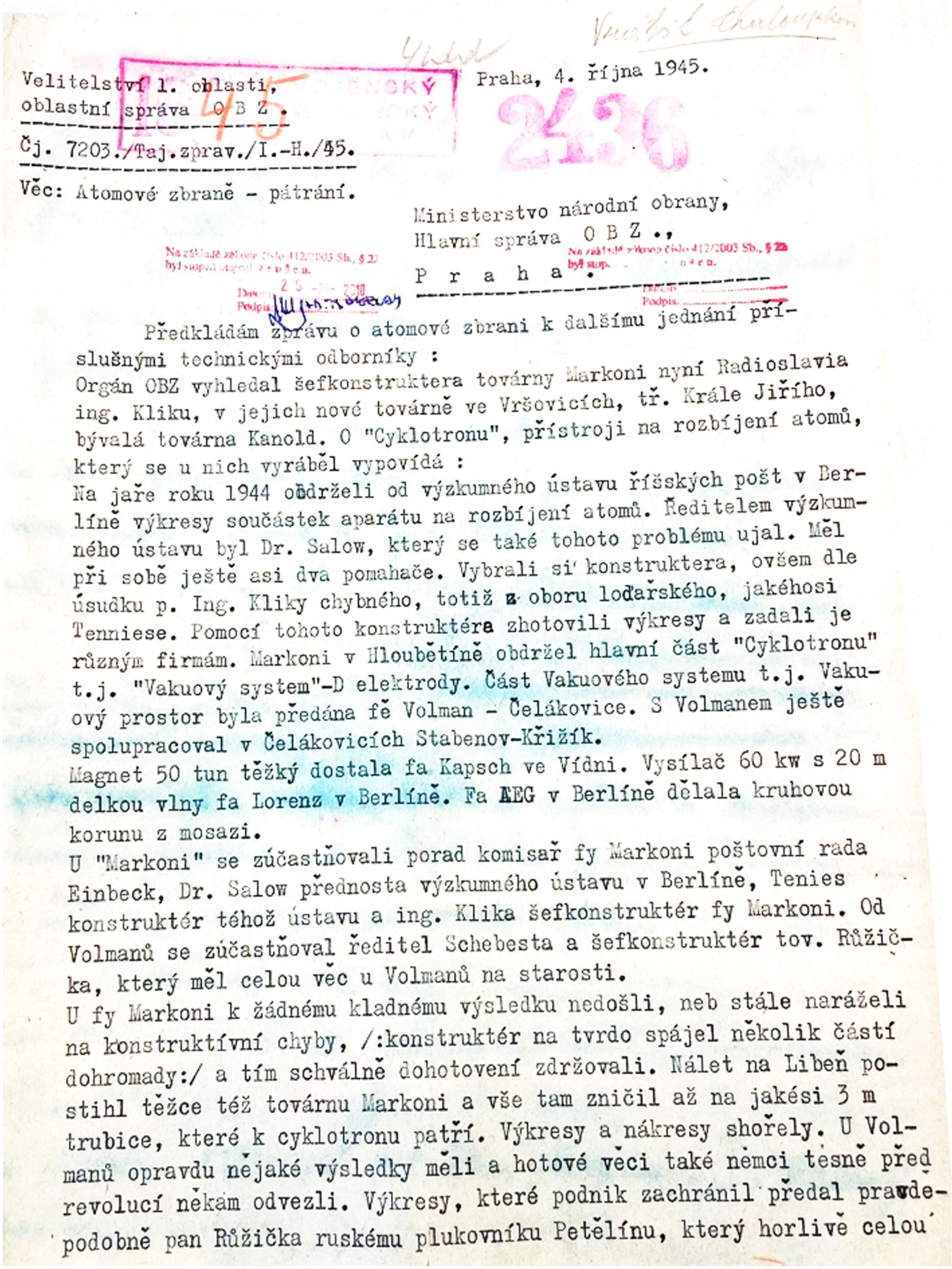
Ing. Klika is surprised that foreign countries have already become interested in the "cyclotron," whereas our army has not shown interest in it so far. He claims that directly at the Marconi company he has a very good calculator who, using basic measurements and with the cooperation of several experts from different branches, could constructively solve and manufacture the device, after getting pre-war literature from America (which was previously freely printed). The literature needs to be used as a basis so that one does not have to work from scratch.

Mr. Ing. Klika characterises Ing. Růžička as a man who had read something in a hurry, because in conversation he “name-drops” ions and other words. He is a 50-year-old gentleman who wants to improve his position and therefore tried to get as many details as possible from Colonel Petyelin. The colonel belongs to a trophy troop still in Prague. He lives somewhere on Rokoska /:on Hanspaulka:/.

Ing. Klika has the impression that German military circles have issued an appeal to all research institutes in the Reich to look into this problem. He points out that the Rhode & S[ch]warz, Munich, produced the “cyclotron” or its components for the Manfred von Ardenne Institute in Berlin [Forschungslaboratorium für Elektronenphysik]. This “cyclotron” was probably finished. The problem was not a new one, because already in 1936 a “cyclotron” had been produced by Brown-Boveri for the Zurich Technique.

At an unofficial meeting of industrialists, attended by Dr. Matula, head of the Radiological Institute, Director Ostrčil, Havelka, Colonel Mrázek, Dr. Hrdina, Ing. Klika, Colonel Vaněk from the Western Army, proposed a kind of research institute where the problem would be continued. Colonel Vanek, who himself had chased V1 weapons on a fighter, discussed these weapons and the V2, against which there was no defence at all because of its amazing speed of 5,000 km per hour at 100 km. He points out that the V2 with its atomic charge is the weapon of the future. The V2 was fired perpendicularly upwards, guided between 4 radio beams, at 100km altitude it encountered a horizontal beam on which it straightened out, and at that altitude it continued horizontally guided by that beam to above the target, where it crashed to earth in a parabola. V2 was produced in Jirkov near Ervenice.

[See document photos on pp. 4007–4008.]



Vrátit Chaloupkovi

45

Velitelství l. oblasti,
oblastní správa O B Z .

Čj. 7203./Taj.zprav./I.-H./45.

Věc: Atomové zbraně - pátrání.

Praha, 4. října 1945.

2436

Ministerstvo národní obrany,
Hlavní správa O B Z .,
P r a h a .

Na základě zákona číslo 412/2003 Sb., § 22 byl stupeň utajení zrušen.
Datum: 25 -01- 2010
Podpis:

Předkládám zprávu o atomové zbrani k dalšímu jednání příslušnými technickými odborníky :

Orgán OBZ vyhledal šefkonstruktera továrny Markoni nyní Radioslavia ing. Kliku, v jejich nové továrně ve Vršovicích, tř. Krále Jiřího, bývalá továrna Kanold. O "Cyklotronu", přístroji na rozbíjení atomů, který se u nich vyráběl vypovídá :

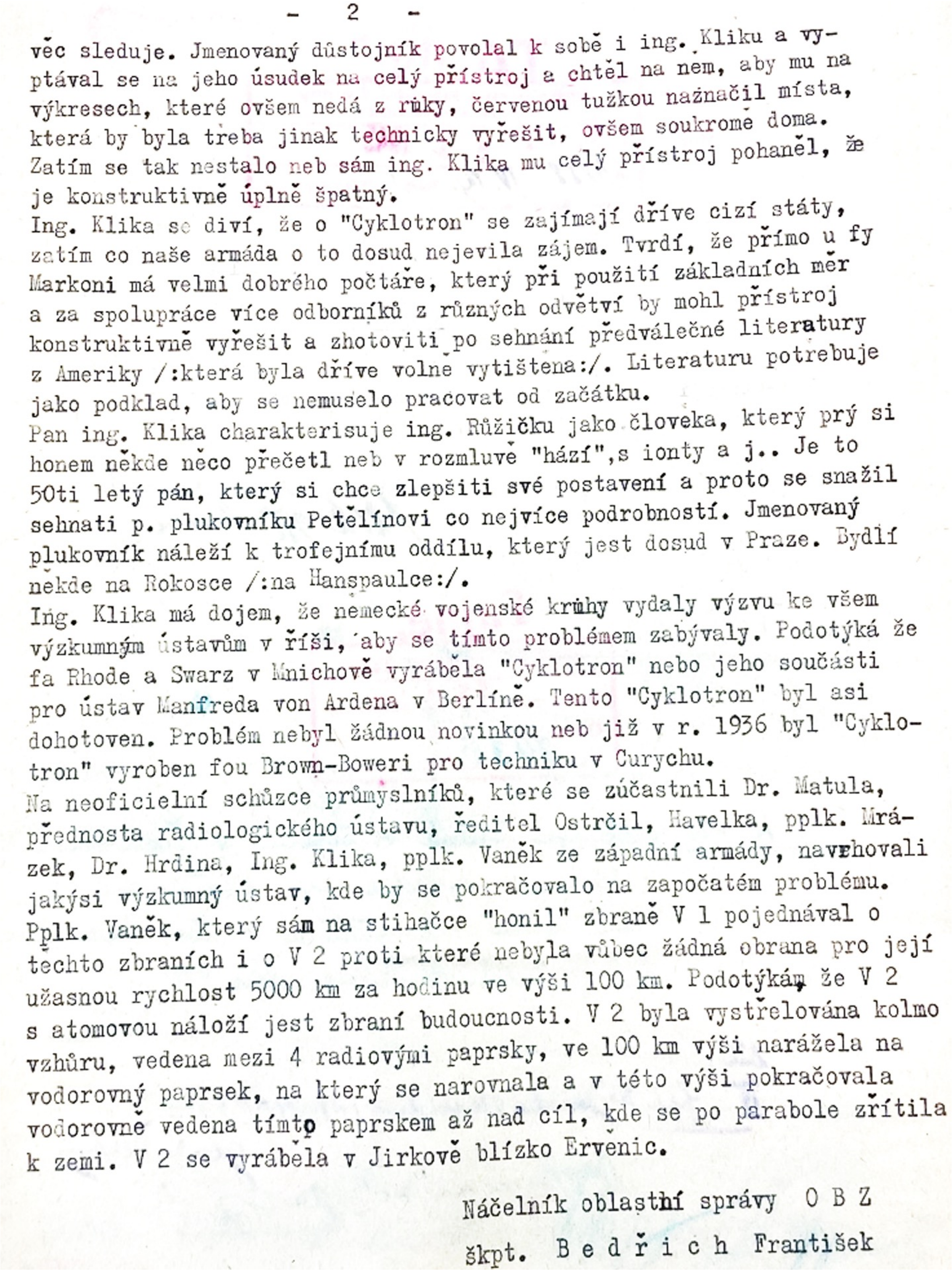
Na jaře roku 1944 obdrželi od výzkumného ústavu říšských pošt v Berlíně výkresy součástek aparátu na rozbíjení atomů. Ředitelem výzkumného ústavu byl Dr. Salow, který se také tohoto problému ujal. Měl při sobě ještě asi dva pomahače. Vybrali si konstruktera, ovšem dle úsudku p. Ing. Kliky chybného, totiž z oboru loďařského, jakéhosi Tenniese. Pomocí tohoto konstruktéra zhotovili výkresy a zadali je různým firmám. Markoni v Hloubětíně obdržel hlavní část "Cyklotronu" t.j. "Vakuový system"-D elektrody. Část Vakuového systemu t.j. Vakuový prostor byla předána fě Volman - Čelákovice. S Volmanem ještě spolupracoval v Čelákovicích Stabenov-Křižík.

Magnet 50 tun těžký dostala fa Kapsch ve Vídni. Vysílač 60 kw s 20 m delkou vlny fa Lorenz v Berlíně. Fa AEG v Berlíně dělala kruhovou korunu z mosazi.

U "Markoni" se zúčastňovali porad komisař fy Markoni poštovní rada Einbeck, Dr. Salow přednosta výzkumného ústavu v Berlíně, Tenies konstruktér téhož ústavu a ing. Klika šefkonstruktér fy Markoni. Od Volmanů se zúčastňoval ředitel Schebesta a šefkonstruktér tov. Růžička, který měl celou věc u Volmanů na starosti.

U fy Markoni k žádnému kladnému výsledku nedošli, neb stále naráželi na konstruktívní chyby, /:konstruktér na tvrdo spájel několik částí dohromady:/ a tím schválně dohotovení zdržovali. Nálet na Libeň postihl těžce též továrnu Markoni a vše tam zničil až na jakési 3 m trubice, které k cyklotronu patří. Výkresy a nákresy shořely. U Volmanů opravdu nějaké výsledky měli a hotové věci také němci těsně před revolucí někam odvezli. Výkresy, které podnik zachránil předal pravdepodobně pan Růžička ruskému plukovníku Petělínu, který horlivě celou

Figure D.467: 4 October 1945 letter from the Czechoslovakian OBZ security service regarding the wartime production of cyclotrons for Germany. [Vojenský historický archiv, Vědecký technický ústav 1945–1946, kart. 1. Courtesy of Jaroslav Mareš.]



- 2 -

věc sleduje. Jmenovaný důstojník povolal k sobě i ing. Kliku a vyptával se na jeho úsudek na celý přístroj a chtěl na něm, aby mu na výkresech, které ovšem nedá z ruky, červenou tužkou nažnačil místa, která by byla třeba jinak technicky vyřešit, ovšem soukromě doma. Zatím se tak nestalo neb sám ing. Klika mu celý přístroj pohaněl, že je konstruktivně úplně špatný.

Ing. Klika se diví, že o "Cyklotron" se zajímají dříve cizí státy, zatím co naše armáda o to dosud nejevila zájem. Tvrdí, že přímo u fy Markoni má velmi dobrého počtáře, který při použití základních měr a za spolupráce více odborníků z různých odvětví by mohl přístroj konstruktivně vyřešit a zhotoviti po sehnání předválečné literatury z Ameriky /:která byla dříve volně vytištena:/. Literaturu potrebuje jako podklad, aby se nemuselo pracovat od začátku.

Pan ing. Klika charakterisuje ing. Růžičku jako člověka, který prý si honem někde něco přečetl neb v rozmluvě "hází",s ionty a j.. Je to 50ti letý pán, který si chce zlepšiti své postavení a proto se snažil sehnati p. plukovníku Petělínovi co nejvíce podrobností. Jmenovaný plukovník náleží k trofejnímu oddílu, který jest dosud v Praze. Bydlí někde na Rokosce /:na Hanspaulce:/.

Ing. Klika má dojem, že německé vojenské kruhy vydaly výzvu ke všem výzkumným ústavům v říši, aby se tímto problémem zabývaly. Podotýká že fa Rhode a Swarz v Mnichově vyráběla "Cyklotron" nebo jeho součásti pro ústav Manfreda von Ardena v Berlíně. Tento "Cyklotron" byl asi dohotoven. Problém nebyl žádnou novinkou neb již v r. 1936 byl "Cyklotron" vyroben fou Brown-Boweri pro techniku v Curychu.

Na neoficielní schůzce průmyslníků, které se zúčastnili Dr. Matula, přednosta radiologického ústavu, ředitel Ostrčil, Havelka, pplk. Mrázek, Dr. Hrdina, Ing. Klika, pplk. Vaněk ze západní armády, navrhovali jakýsi výzkumný ústav, kde by se pokračovalo na započatém problému. Pplk. Vaněk, který sám na stihačce "honil" zbraně V 1 pojednával o těchto zbraních i o V 2 proti které nebyla vůbec žádná obrana pro její užasnou rychlost 5000 km za hodinu ve výši 100 km. Podotýkám že V 2 s atomovou náloží jest zbraní budoucnosti. V 2 byla vystřelována kolmo vzhůru, vedena mezi 4 radiovými paprsky, ve 100 km výši narážela na vodorovný paprsek, na který se narovnala a v této výši pokračovala vodorovně vedena tímto paprskem až nad cíl, kde se po parabole zřítila k zemi. V 2 se vyráběla v Jirkově blízko Ervenic.

Náčelník oblastní správy O B Z

škpt. Bedřich František

Figure D.468: 4 October 1945 letter from the Czechoslovakian OBZ security service regarding the wartime production of cyclotrons for Germany. [Vojenský historický archiv, Vědecký technický ústav 1945–1946, kart. 1. Courtesy of Jaroslav Mareš.]

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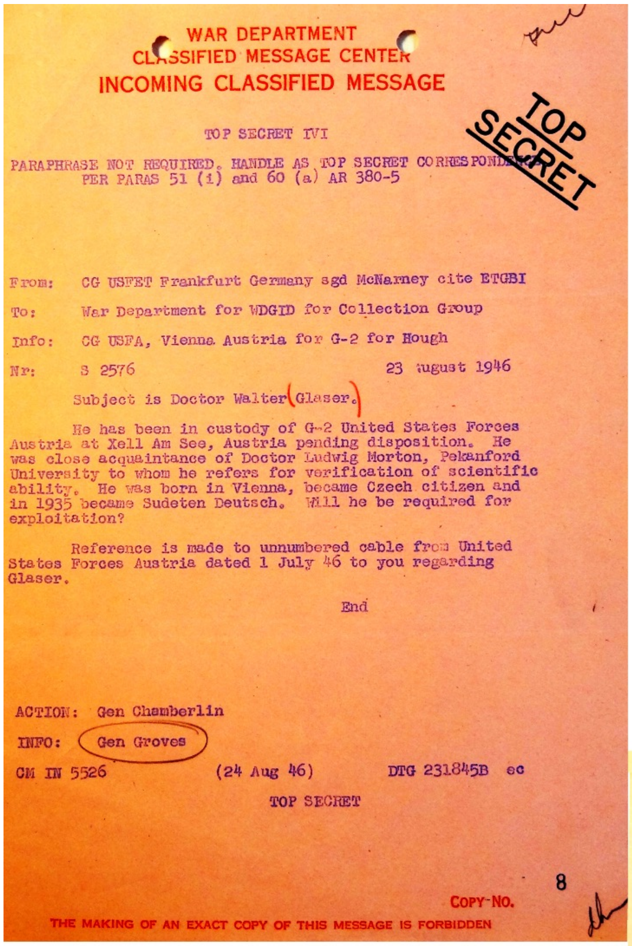

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TOP SECRET IVI

PARAPHRASE NOT REQUIRED. HANDLE AS TOP SECRET CORRESPONDENCE
PER PARAS 51 (i) and 60 (a) AR 380-5

From: CG USFET Frankfurt Germany sgd McNarney cite ETGBI

To: War Department for WDGID for Collection Group

Info: CG USFA, Vienna Austria for G-2 for Hough

Nr: S 2576 23 August 1946

Subject is Doctor Walter Glaser.

He has been in custody of G-2 United States Forces Austria at Xell Am See, Austria pending disposition. He was close acquaintance of Doctor Ludwig Morton, Pekanford University to whom he refers for verification of scientific ability. He was born in Vienna, became Czech citizen and in 1935 became Sudeten Deutsch. Will he be required for exploitation?

Reference is made to unnumbered cable from United States Forces Austria dated 1 July 46 to you regarding Glaser.

End

ACTION: Gen Chamberlin

INFO: Gen Groves

CM IN 5526 (24 Aug 46) DTG 231845B ec

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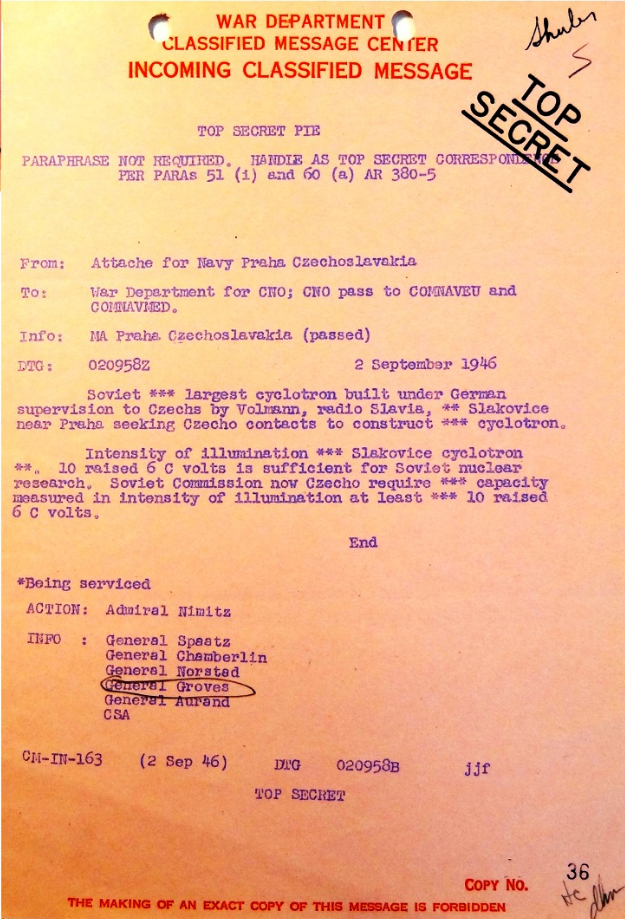

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TOP SECRET PIE

PARAPHRASE NOT REQUIRED. HANDLE AS TOP SECRET CORRESPONDENCE
PER PARAs 51 (i) and 60 (a) AR 380-5

From: Attache for Navy Praha Czechoslavakia

To: War Department for CNO; CNO pass to COMNAVEU and COMNAVMED.

Info: MA Praha Czechoslavakia (passed)

DTG: 020958Z 2 September 1946

Soviet *** largest cyclotron built under German supervision to Czechs by Volmann, radio Slavia, ** Slakovice near Praha seeking Czecho contacts to construct *** cyclotron.

Intensity of illumination *** Slakovice cyclotron **. 10 raised 6 C volts is sufficient for Soviet nuclear research. Soviet Commission now Czecho require *** capacity measured in intensity of illumination at least *** 10 raised 6 C volts.

End

*Being serviced

ACTION: Admiral Nimitz

INFO : General Spaatz
General Chamberlin
General Norstad
General Groves
General Aurand
CSA

CM-IN-163 (2 Sep 46) DTG 020958B jjf

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NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret January 1946 thru December 1946

Figure D.469: August–September 1946 Top Secret cables to Leslie Groves regarding leftover wartime work on particle accelerators in Austria and Czechoslovakia [NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret January 1946 thru December 1946].

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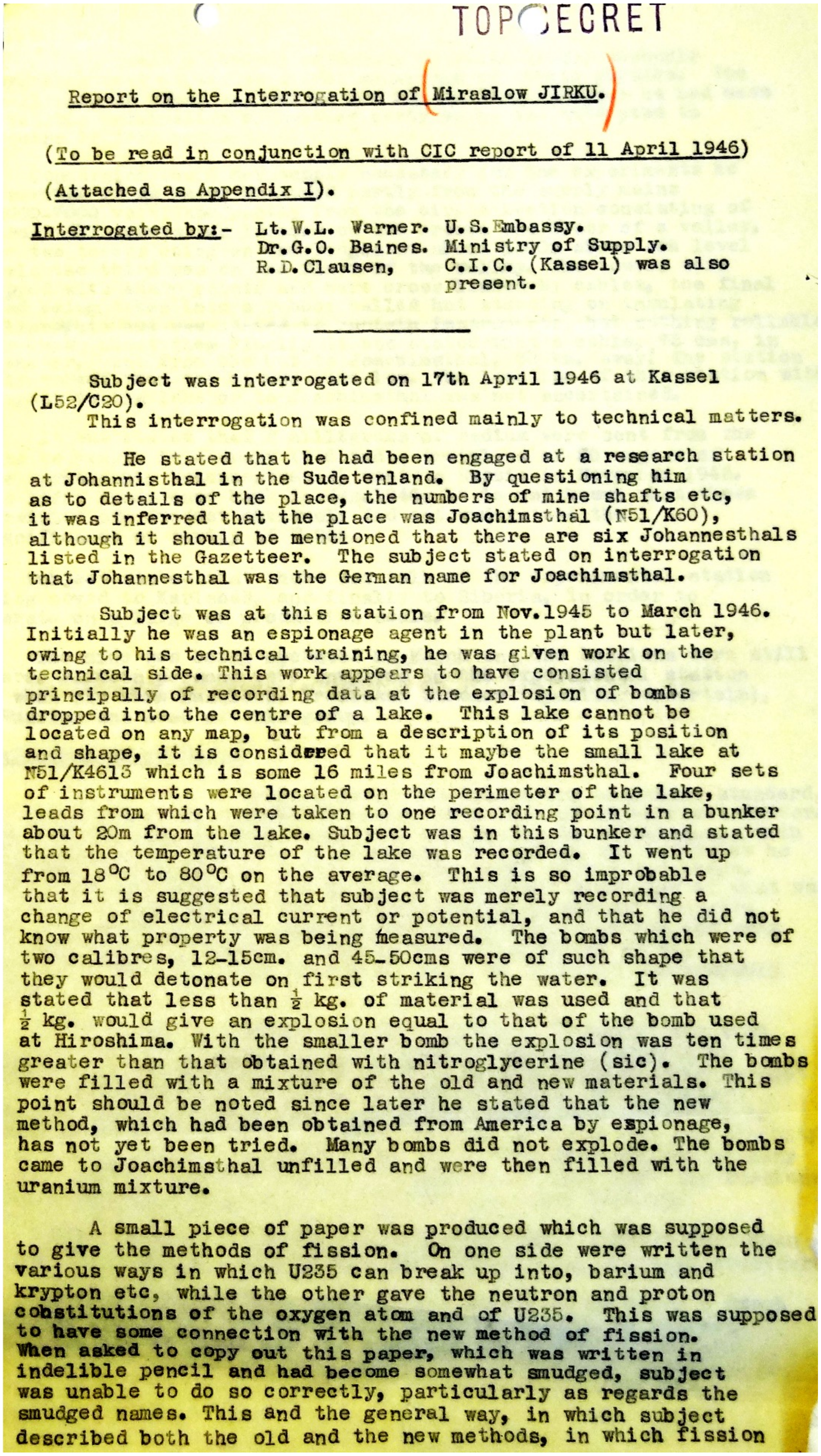

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Report on the Interrogation of Miraslow JIRKU.

(To be read in conjunction with CIC report of 11 April 1946)

(Attached as Appendix I).

Interrogated by:-	Lt. W.L. Warner.	U.S. Embassy.
	Dr. G.O. Baines.	Ministry of Supply.
	R.D. Clausen,	C.I.C. (Kassel) was also present.

Subject was interrogated on 17th April 1946 at Kassel (L52/C20).
This interrogation was confined mainly to technical matters.

He stated that he had been engaged at a research station at Johannisthal in the Sudetenland. By questioning him as to details of the place, the numbers of mine shafts etc, it was inferred that the place was Joachimsthal (N51/K60), although it should be mentioned that there are six Johannesthals listed in the Gazetteer. The subject stated on interrogation that Johannesthal was the German name for Joachimsthal.

Subject was at this station from Nov. 1945 to March 1946. Initially he was an espionage agent in the plant but later, owing to his technical training, he was given work on the technical side. This work appears to have consisted principally of recording data at the explosion of bombs dropped into the centre of a lake. This lake cannot be located on any map, but from a description of its position and shape, it is considered that it maybe the small lake at N51/K4615 which is some 16 miles from Joachimsthal. Four sets of instruments were located on the perimeter of the lake, leads from which were taken to one recording point in a bunker about 20m from the lake. Subject was in this bunker and stated that the temperature of the lake was recorded. It went up from 18°C to 80°C on the average. This is so improbable that it is suggested that subject was merely recording a change of electrical current or potential, and that he did not know what property was being measured. The bombs which were of two calibres, 12-15cm. and 45-50cms were of such shape that they would detonate on first striking the water. It was stated that less than $\frac{1}{2}$ kg. of material was used and that $\frac{1}{2}$ kg. would give an explosion equal to that of the bomb used at Hiroshima. With the smaller bomb the explosion was ten times greater than that obtained with nitroglycerine (sic). The bombs were filled with a mixture of the old and new materials. This point should be noted since later he stated that the new method, which had been obtained from America by espionage, has not yet been tried. Many bombs did not explode. The bombs came to Joachimsthal unfilled and were then filled with the uranium mixture.

A small piece of paper was produced which was supposed to give the methods of fission. On one side were written the various ways in which U235 can break up into, barium and krypton etc, while the other gave the neutron and proton constitutions of the oxygen atom and of U235. This was supposed to have some connection with the new method of fission. When asked to copy out this paper, which was written in indelible pencil and had become somewhat smudged, subject was unable to do so correctly, particularly as regards the smudged names. This and the general way, in which subject described both the old and the new methods, in which fission

NARA RG 77, Entry UD-22A, Box 168, Folder 68.91. US: Russian Int in US

Figure D.470: W. L. Warner, G. O. Baines, Robert D. Clausen, and Henry D. Treitel. 7 May 1946. Report on the Interrogation of Miraslow JIRKU [NARA RG 77, Entry UD-22A, Box 168, Folder 68.91. US: Russian Int in US].

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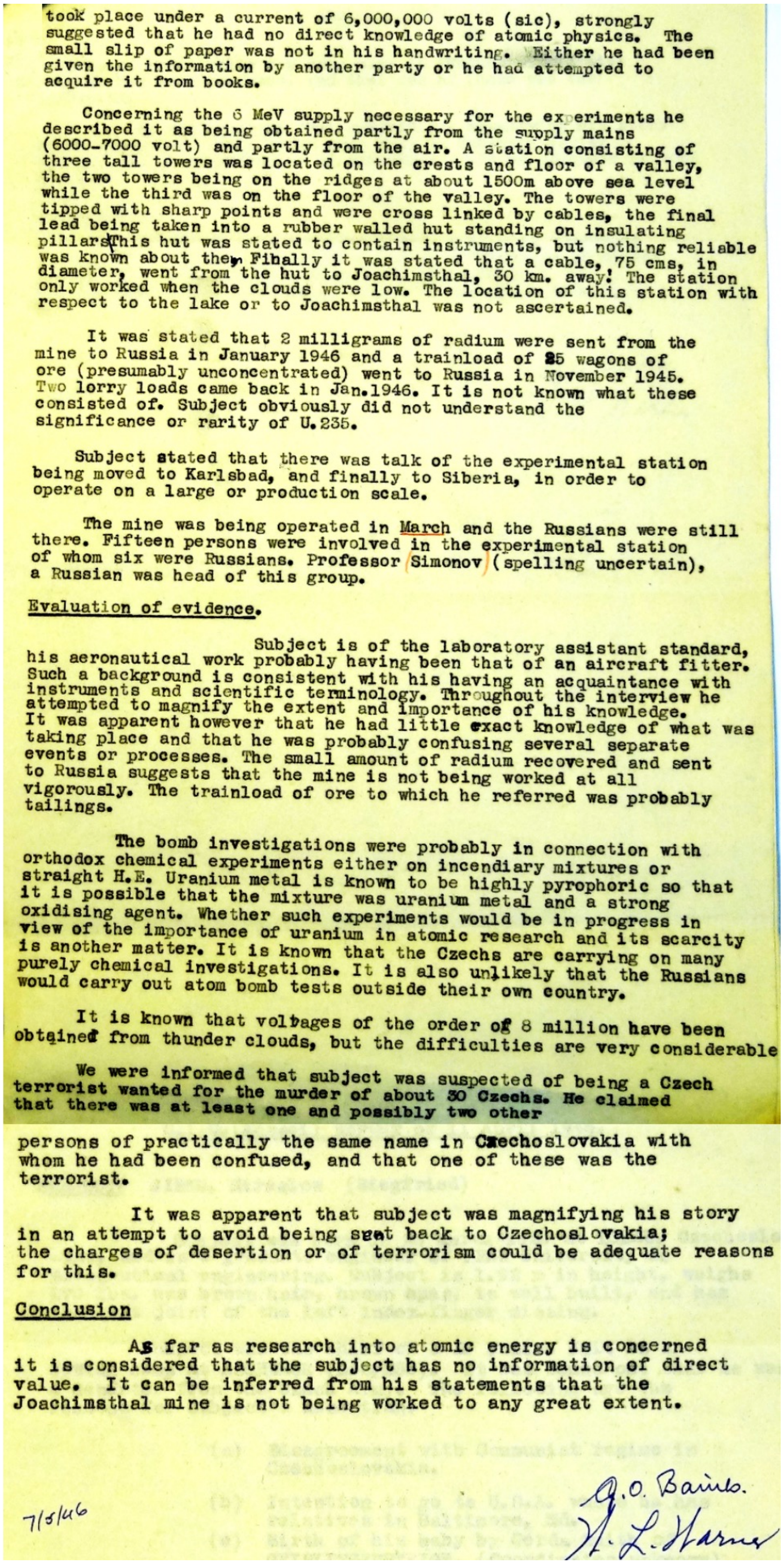

took place under a current of 6,000,000 volts (sic), strongly suggested that he had no direct knowledge of atomic physics. The small slip of paper was not in his handwriting. Either he had been given the information by another party or he had attempted to acquire it from books.

Concerning the 6 MeV supply necessary for the experiments he described it as being obtained partly from the supply mains (6000-7000 volt) and partly from the air. A station consisting of three tall towers was located on the crests and floor of a valley, the two towers being on the ridges at about 1500m above sea level while the third was on the floor of the valley. The towers were tipped with sharp points and were cross linked by cables, the final lead being taken into a rubber walled hut standing on insulating pillars. This hut was stated to contain instruments, but nothing reliable was known about them. Finally it was stated that a cable, 75 cms, in diameter, went from the hut to Joachimsthal, 30 km. away! The station only worked when the clouds were low. The location of this station with respect to the lake or to Joachimsthal was not ascertained.

It was stated that 2 milligrams of radium were sent from the mine to Russia in January 1946 and a trainload of 25 wagons of ore (presumably unconcentrated) went to Russia in November 1945. Two lorry loads came back in Jan.1946. It is not known what these consisted of. Subject obviously did not understand the significance or rarity of U.235.

Subject stated that there was talk of the experimental station being moved to Karlsbad, and finally to Siberia, in order to operate on a large or production scale.

The mine was being operated in March and the Russians were still there. Fifteen persons were involved in the experimental station of whom six were Russians. Professor Simonov (spelling uncertain), a Russian was head of this group.

Evaluation of evidence.

Subject is of the laboratory assistant standard, his aeronautical work probably having been that of an aircraft fitter. Such a background is consistent with his having an acquaintance with instruments and scientific terminology. Throughout the interview he attempted to magnify the extent and importance of his knowledge. It was apparent however that he had little exact knowledge of what was taking place and that he was probably confusing several separate events or processes. The small amount of radium recovered and sent to Russia suggests that the mine is not being worked at all vigorously. The trainload of ore to which he referred was probably tailings.

The bomb investigations were probably in connection with orthodox chemical experiments either on incendiary mixtures or straight H.E. Uranium metal is known to be highly pyrophoric so that it is possible that the mixture was uranium metal and a strong oxidising agent. Whether such experiments would be in progress in view of the importance of uranium in atomic research and its scarcity is another matter. It is known that the Czechs are carrying on many purely chemical investigations. It is also unlikely that the Russians would carry out atom bomb tests outside their own country.

It is known that voltages of the order of 8 million have been obtained from thunder clouds, but the difficulties are very considerable

We were informed that subject was suspected of being a Czech terrorist wanted for the murder of about 30 Czechs. He claimed that there was at least one and possibly two other persons of practically the same name in Czechoslovakia with whom he had been confused, and that one of these was the terrorist.

It was apparent that subject was magnifying his story in an attempt to avoid being sent back to Czechoslovakia; the charges of desertion or of terrorism could be adequate reasons for this.

Conclusion

As far as research into atomic energy is concerned it is considered that the subject has no information of direct value. It can be inferred from his statements that the Joachimsthal mine is not being worked to any great extent.

7/5/46

G. O. Baines.
W. L. Warner

NARA RG 77, Entry UD-22A, Box 168, Folder 68.91. US: Russian Int in US

Figure D.471: W. L. Warner, G. O. Baines, Robert D. Clausen, and Henry D. Treitel. 7 May 1946. Report on the Interrogation of Miraslow JIRKU [NARA RG 77, Entry UD-22A, Box 168, Folder 68.91. US: Russian Int in US].

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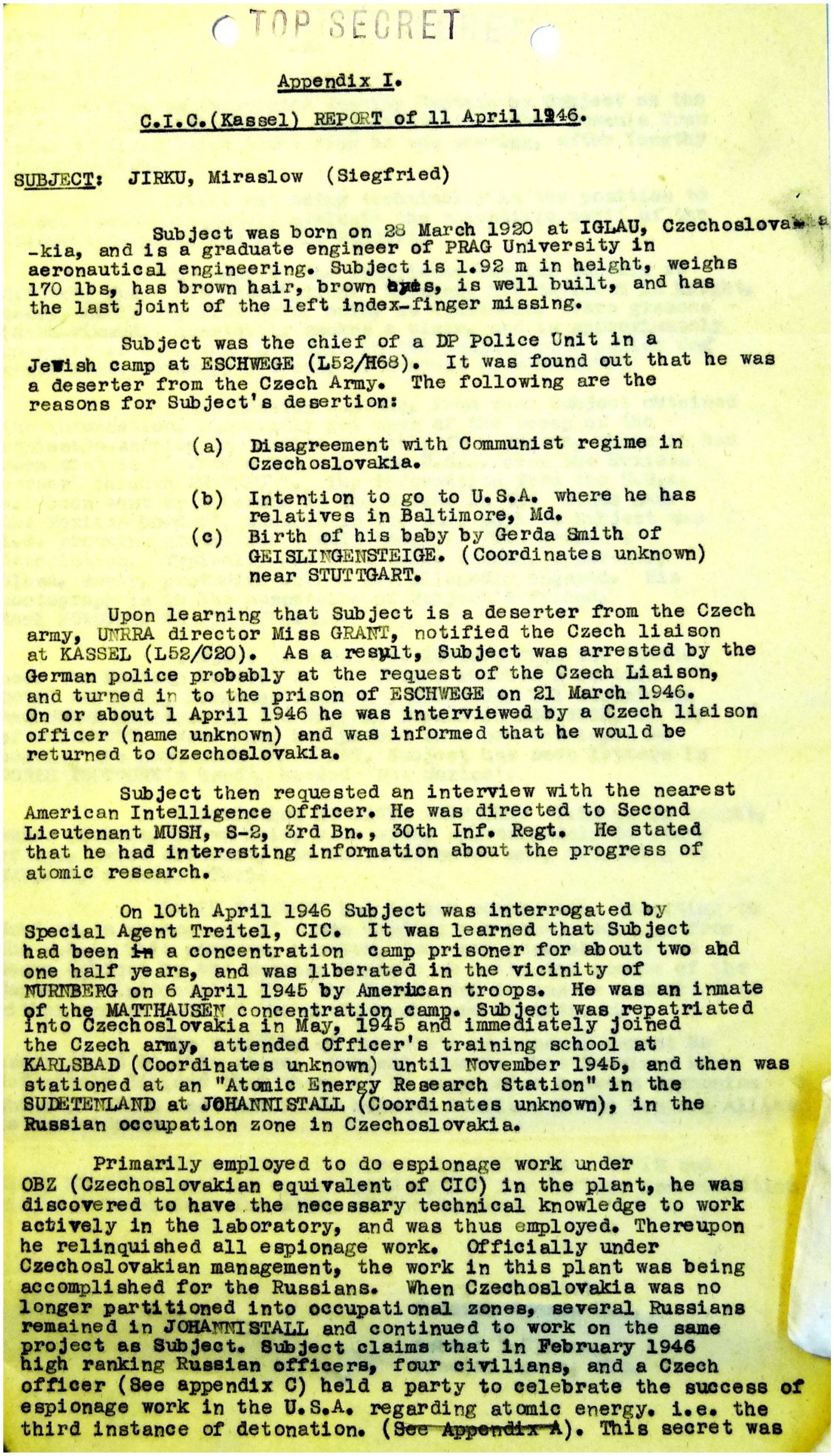

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Appendix I.

C.I.C.(Kassel) REPORT of 11 April 1946.

SUBJECT: JIRKU, Miraslow (Siegfried)

Subject was born on 28 March 1920 at IGLAU, Czechoslovakia, and is a graduate engineer of PRAG University in aeronautical engineering. Subject is 1.92 m in height, weighs 170 lbs, has brown hair, brown eyes, is well built, and has the last joint of the left index-finger missing.

Subject was the chief of a DP Police Unit in a Jewish camp at ESCHWEGE (L52/H68). It was found out that he was a deserter from the Czech Army. The following are the reasons for Subject's desertion:

(a) Disagreement with Communist regime in Czechoslovakia.
(b) Intention to go to U.S.A. where he has relatives in Baltimore, Md.
(c) Birth of his baby by Gerda Smith of GEISLINGENSTEIGE. (Coordinates unknown) near STUTTGART.

Upon learning that Subject is a deserter from the Czech army, UNRRA director Miss GRANT, notified the Czech liaison at KASSEL (L52/C20). As a result, Subject was arrested by the German police probably at the request of the Czech Liaison, and turned in to the prison of ESCHWEGE on 21 March 1946. On or about 1 April 1946 he was interviewed by a Czech liaison officer (name unknown) and was informed that he would be returned to Czechoslovakia.

Subject then requested an interview with the nearest American Intelligence Officer. He was directed to Second Lieutenant MUSH, S-2, 3rd Bn., 30th Inf. Regt. He stated that he had interesting information about the progress of atomic research.

On 10th April 1946 Subject was interrogated by Special Agent Treitel, CIC. It was learned that Subject had been in a concentration camp prisoner for about two and one half years, and was liberated in the vicinity of NURNBERG on 6 April 1945 by American troops. He was an inmate of the MATTHAUSEN concentration camp. Subject was repatriated into Czechoslovakia in May, 1945 and immediately joined the Czech army, attended Officer's training school at KARLSBAD (Coordinates unknown) until November 1945, and then was stationed at an "Atomic Energy Research Station" in the SUDETENLAND at JOHANNISTALL (Coordinates unknown), in the Russian occupation zone in Czechoslovakia.

Primarily employed to do espionage work under OBZ (Czechoslovakian equivalent of CIC) in the plant, he was discovered to have the necessary technical knowledge to work actively in the laboratory, and was thus employed. Thereupon he relinquished all espionage work. Officially under Czechoslovakian management, the work in this plant was being accomplished for the Russians. When Czechoslovakia was no longer partitioned into occupational zones, several Russians remained in JOHANNISTALL and continued to work on the same project as Subject. Subject claims that in February 1946 high ranking Russian officers, four civilians, and a Czech officer (See appendix C) held a party to celebrate the success of espionage work in the U.S.A. regarding atomic energy. i.e. the third instance of detonation. (~~See Appendix A~~). This secret was

NARA RG 77, Entry UD-22A, Box 168, Folder 68.91. US: Russian Int in US

Figure D.472: W. L. Warner, G. O. Baines, Robert D. Clausen, and Henry D. Treitel. 7 May 1946. Report on the Interrogation of Miraslow JIRKU. Appendix I [NARA RG 77, Entry UD-22A, Box 168, Folder 68.91. US: Russian Int in US].

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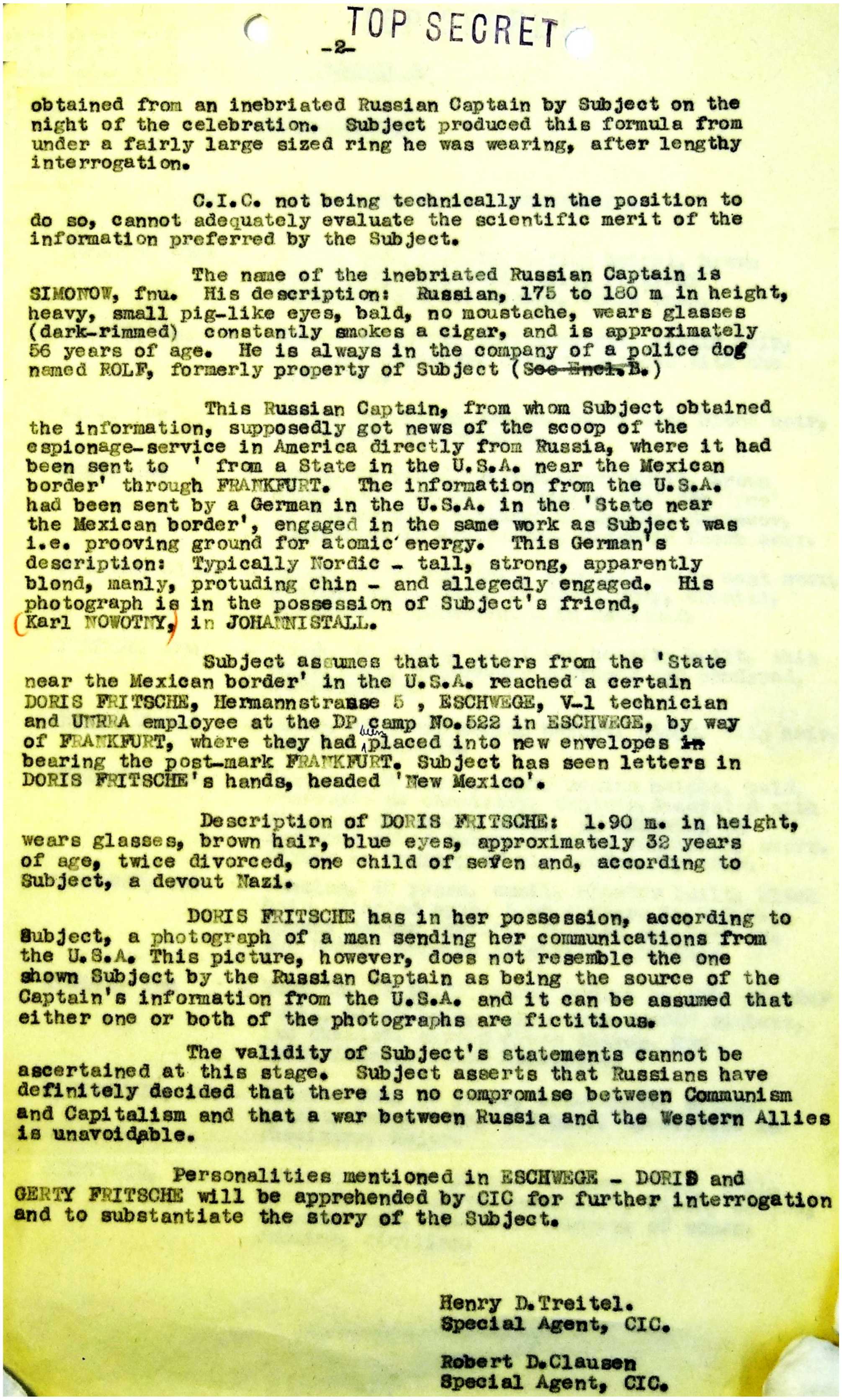

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obtained from an inebriated Russian Captain by Subject on the night of the celebration. Subject produced this formula from under a fairly large sized ring he was wearing, after lengthy interrogation.

C.I.C. not being technically in the position to do so, cannot adequately evaluate the scientific merit of the information preferred by the Subject.

The name of the inebriated Russian Captain is SIMONOW, fnu. His description: Russian, 175 to 180 m in height, heavy, small pig-like eyes, bald, no moustache, wears glasses (dark-rimmed) constantly smokes a cigar, and is approximately 56 years of age. He is always in the company of a police dog named ROLF, formerly property of Subject (~~See Encl.B.~~)

This Russian Captain, from whom Subject obtained the information, supposedly got news of the scoop of the espionage-service in America directly from Russia, where it had been sent to ' from a State in the U.S.A. near the Mexican border' through FRANKFURT. The information from the U.S.A. had been sent by a German in the U.S.A. in the 'State near the Mexican border', engaged in the same work as Subject was i.e. prooving ground for atomic energy. This German's description: Typically Nordic - tall, strong, apparently blond, manly, protuding chin - and allegedly engaged. His photograph is in the possession of Subject's friend, (Karl NOWOTNY,) in JOHANNISTALL.

Subject assumes that letters from the 'State near the Mexican border' in the U.S.A. reached a certain DORIS FRITSCHE, Hermannstrasse 5 , ESCHWEGE, V-1 technician and UNRRA employee at the DP camp No.522 in ESCHWEGE, by way of FRANKFURT, where they had been placed into new envelopes ~~in~~ bearing the post-mark FRANKFURT. Subject has seen letters in DORIS FRITSCHE's hands, headed 'New Mexico'.

Description of DORIS FRITSCHE: 1.90 m. in height, wears glasses, brown hair, blue eyes, approximately 32 years of age, twice divorced, one child of seven and, according to Subject, a devout Nazi.

DORIS FRITSCHE has in her possession, according to Subject, a photograph of a man sending her communications from the U.S.A. This picture, however, does not resemble the one shown Subject by the Russian Captain as being the source of the Captain's information from the U.S.A. and it can be assumed that either one or both of the photographs are fictitious.

The validity of Subject's statements cannot be ascertained at this stage. Subject asserts that Russians have definitely decided that there is no compromise between Communism and Capitalism and that a war between Russia and the Western Allies is unavoidable.

Personalities mentioned in ESCHWEGE - DORIS and GERTY FRITSCHE will be apprehended by CIC for further interrogation and to substantiate the story of the Subject.

Henry D.Treitel.
Special Agent, CIC.

Robert D.Clausen
Special Agent, CIC.

NARA RG 77, Entry UD-22A, Box 168, Folder 68.91. US: Russian Int in US

Figure D.473: W. L. Warner, G. O. Baines, Robert D. Clausen, and Henry D. Treitel. 7 May 1946. Report on the Interrogation of Miraslow JIRKU. Appendix I [NARA RG 77, Entry UD-22A, Box 168, Folder 68.91. US: Russian Int in US].

Vladimir L. Rychly. Cyclotrons Manufactured in Czechoslovakia. 2 September 1946. [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3101–3200]

1. Attempts to manufacture cyclotrons for Laboratory nuclear physics research were made in Čelakovice, Czechoslovakia (15 miles East of Praha) by three major Čelakovice Industrial plants:

a.) Volman, Čelakovice,

b.) Radioslavia, Čelakovice,

c.) Křižík, Čelakovice.

All original plans for the Cyclotron construction originated in Germany. The work in Čelakovice was under German supervision, and the construction was the responsibility of the following German engineers:

a.) dr. Bajer,

b.) dr. Salow,

c.) dr. Ing Tönies.

The cyclotron completed in Čelakovice was originally intended for the German nuclear physics research laboratory in MIERSDORF in Germany. It was composed out of 6 main sections, namely:

a.) electro-magnet,

b.) vacuum pumps,

c.) tubes,

d.) crown-chamber with D-poles,

e.) cylinder,

f.) railes.

Čelakovice was responsible for the last three sections of the Cyclotron. The first three sections were the commitment of other factories either in Germany or in Czechoslovakia. There is some scant evidence to believe that the Siemens plant in Praha was charged with the responsibility of completing the required tubes for the cyclotron. The electro-magnet, according to engineers responsible to the German authorities was a huge affair of several hundred tons. This was a mere guess, as the electro-magnet, when seen completely crated, loaded on two large flat-cars and ready for shipment.

2. The attached sketch of the Cyclotron section d. e. and f. [p. 4019] obtained from dr. Ing. Ružek, Chief Constructor of the Volman plant in Čelakovice, may provide possibilities for detailed information. As all original drawings and documents were confiscated by the Soviet missions during the days of occupation, the only possible indication of the capacity of the completed cyclotron in Čelakovice, is the intensity of the radiation (illumination) in that section of the cyclotron in which the protons hasten the nucleus of the hydrogen atom as the circulating electrons are freely released. The intensity of the radiation (illumination) is claimed to be $6 \cdot 10^6$ volts.

3. The main difficulties encountered during the work on the first attempts to complete a cyclotron in Čelakovice were defeated as the work progressed. [...]

4. As soon as the Russian troops occupied Czechoslovakia, the three plants in Čelakovice were completely surrounded by Russian guards, and members of the Soviet Technical Units made necessary arrangement to have the cyclotron pre-tested, and all defective materials removed. As more commissions arrived from Russia the popularity of the Čelakovice Cyclotron increased. However, it was not until November 1945 that the Cyclotron was carefully crated and removed to Russia. Destination unknown. [...] However, not one single part of Cyclotron construction remained in Czechoslovakia.

[See document photos on pp. 4016–4019.]

Vladimir L. Rychly. 31 October 1946. Cable IN 175. [NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret]

Volmann never engaged nuclear physics research. Refer CNO 122106. He was proprietor of famous Czecho factory in Čelakovice near Praha and directly responsible for cyclotron delivery to German Reichspost nuclear physics laboratory in Miersdorf, Germany. Factories Radioslavia and Krizik both located Čelakovice only assisted in construction. German specialists Dr Baier, Dr Salow, Ing Tonies supervised cyclo construction all three plants. Rheotron designations used by Soviets during inspection Volmann plant.

New Subject:
All pitchblende ore from Jacymov leaving Czecho for Soviet Zone Germany. Present status activity Jacymov mines under investigation.

[These further reports by Rychly give a great deal of additional information about the cyclotron(s) produced in wartime Czechoslovakia.

Based on the reported 6 MeV energy and the physical size of the cyclotron, it sounds very similar to the cyclotrons at the University of California Berkeley that Ernest Lawrence used to produce microgram quantities of plutonium in 1940. Was the German program in 1945 at roughly the same point as Lawrence's experiments in 1940? Or as an alternative to using a fission reactor to produce plutonium, were the Germans trying to produce physically useful quantities of plutonium-239 (or possibly uranium-233) by operating a number of cyclotrons in parallel for a long period of time (electronuclear breeding)?

On the other hand, perhaps the cyclotrons, or modified versions of cyclotrons, were intended to serve as electromagnetic separators to enrich uranium-235 from natural uranium.

One of the Reichspost's nuclear research facilities was located in Miersdorf. Scholars should investigate much further to find out exactly what work was conducted at that and other Reichspost facilities.]

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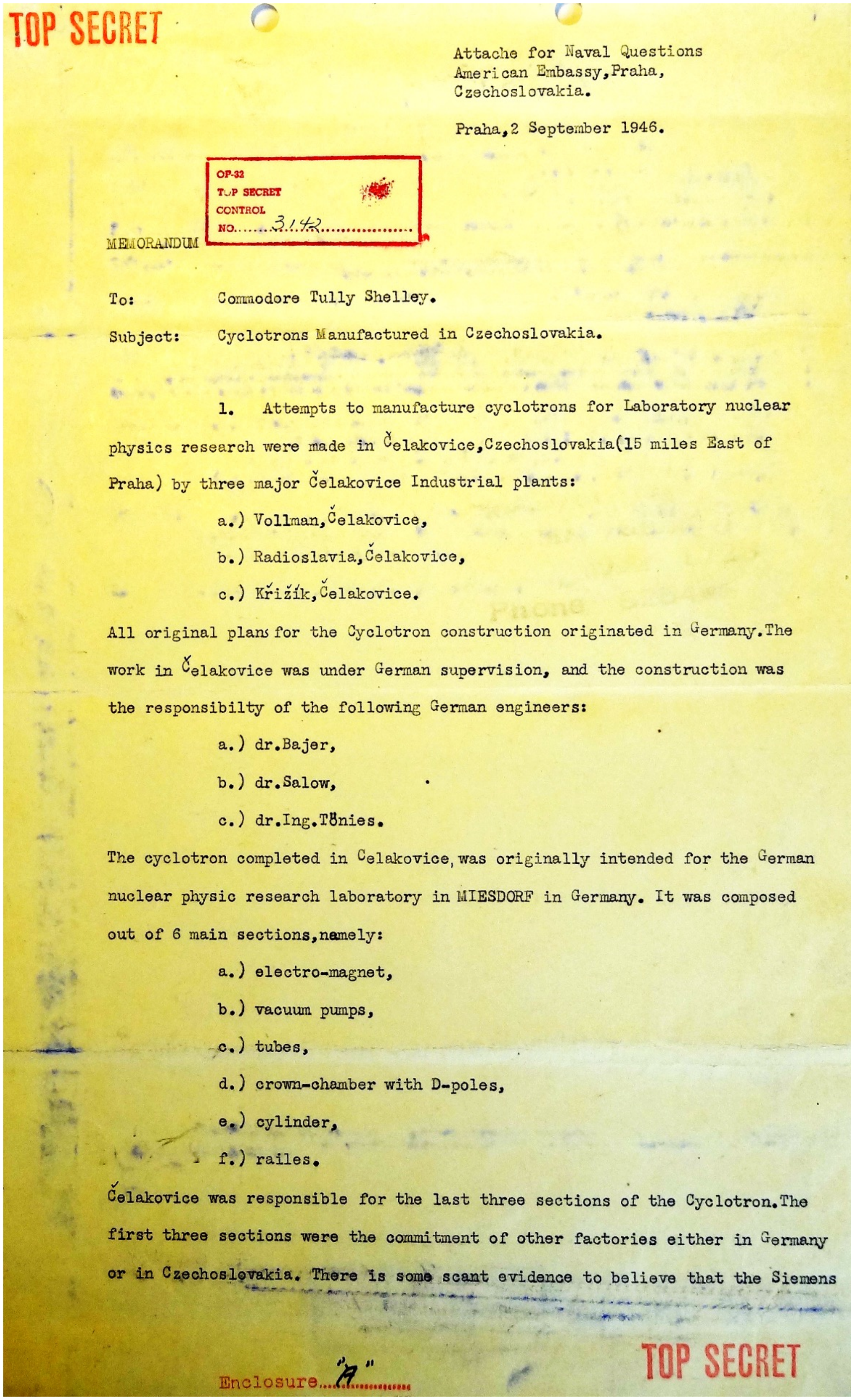

TOP SECRET

Attache for Naval Questions
American Embassy, Praha,
Czechoslovakia.

Praha, 2 September 1946.

OP-32
TOP SECRET
CONTROL
NO. 3142

MEMORANDUM

To: Commodore Tully Shelley.

Subject: Cyclotrons Manufactured in Czechoslovakia.

1. Attempts to manufacture cyclotrons for Laboratory nuclear physics research were made in Čelakovice, Czechoslovakia (15 miles East of Praha) by three major Čelakovice Industrial plants:

a.) Vollman, Čelakovice,
b.) Radioslavia, Čelakovice,
c.) Křižík, Čelakovice.

All original plans for the Cyclotron construction originated in Germany. The work in Čelakovice was under German supervision, and the construction was the responsibilty of the following German engineers:

a.) dr. Bajer,
b.) dr. Salow,
c.) dr. Ing. Tönies.

The cyclotron completed in Čelakovice, was originally intended for the German nuclear physic research laboratory in MIESDORF in Germany. It was composed out of 6 main sections, namely:

a.) electro-magnet,
b.) vacuum pumps,
c.) tubes,
d.) crown-chamber with D-poles,
e.) cylinder,
f.) railes.

Čelakovice was responsible for the last three sections of the Cyclotron. The first three sections were the commitment of other factories either in Germany or in Czechoslovakia. There is some scant evidence to believe that the Siemens

Enclosure "A"

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Figure D.474: Vladimir L. Rychly. Cyclotrons Manufactured in Czechoslovakia. 2 September 1946 [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3101–3200].

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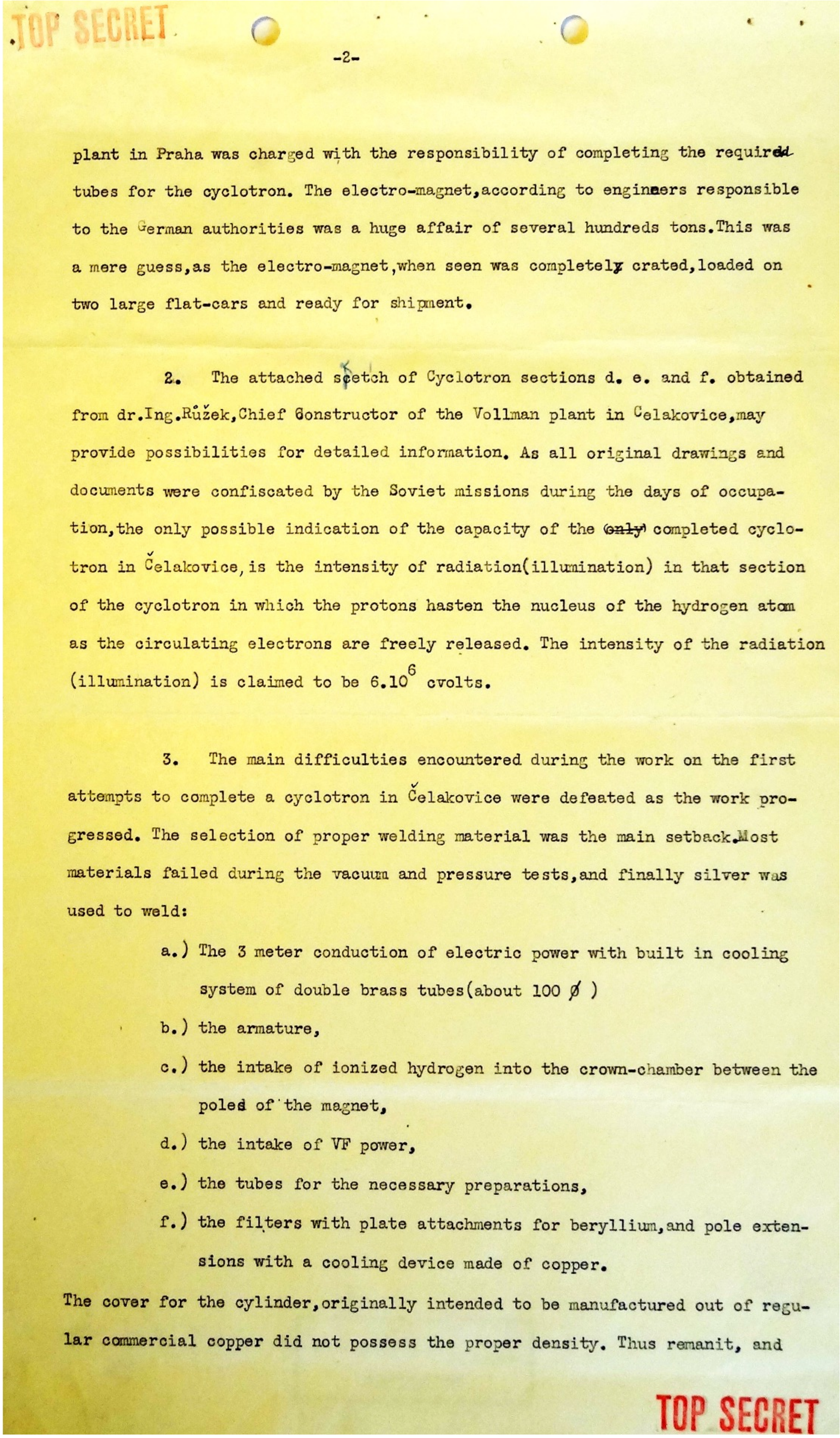

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-2-

plant in Praha was charged with the responsibility of completing the required tubes for the cyclotron. The electro-magnet,according to engineers responsible to the German authorities was a huge affair of several hundreds tons.This was a mere guess,as the electro-magnet,when seen was completely crated,loaded on two large flat-cars and ready for shipment.

2. The attached sketch of Cyclotron sections d. e. and f. obtained from dr.Ing.Růžek,Chief Constructor of the Vollman plant in Čelakovice,may provide possibilities for detailed information. As all original drawings and documents were confiscated by the Soviet missions during the days of occupation,the only possible indication of the capacity of the ~~only~~ completed cyclotron in Čelakovice, is the intensity of radiation(illumination) in that section of the cyclotron in which the protons hasten the nucleus of the hydrogen atom as the circulating electrons are freely released. The intensity of the radiation (illumination) is claimed to be 6.10^6 evolts.

3. The main difficulties encountered during the work on the first attempts to complete a cyclotron in Čelakovice were defeated as the work progressed. The selection of proper welding material was the main setback.Most materials failed during the vacuum and pressure tests,and finally silver was used to weld:

a.) The 3 meter conduction of electric power with built in cooling system of double brass tubes(about 100 ø)

b.) the armature,

c.) the intake of ionized hydrogen into the crown-chamber between the poles of the magnet,

d.) the intake of VF power,

e.) the tubes for the necessary preparations,

f.) the filters with plate attachments for beryllium,and pole extensions with a cooling device made of copper.

The cover for the cylinder,originally intended to be manufactured out of regular commercial copper did not possess the proper density. Thus remanit, and

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Figure D.475: Vladimir L. Rychly. Cyclotrons Manufactured in Czechoslovakia. 2 September 1946 [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3101–3200].

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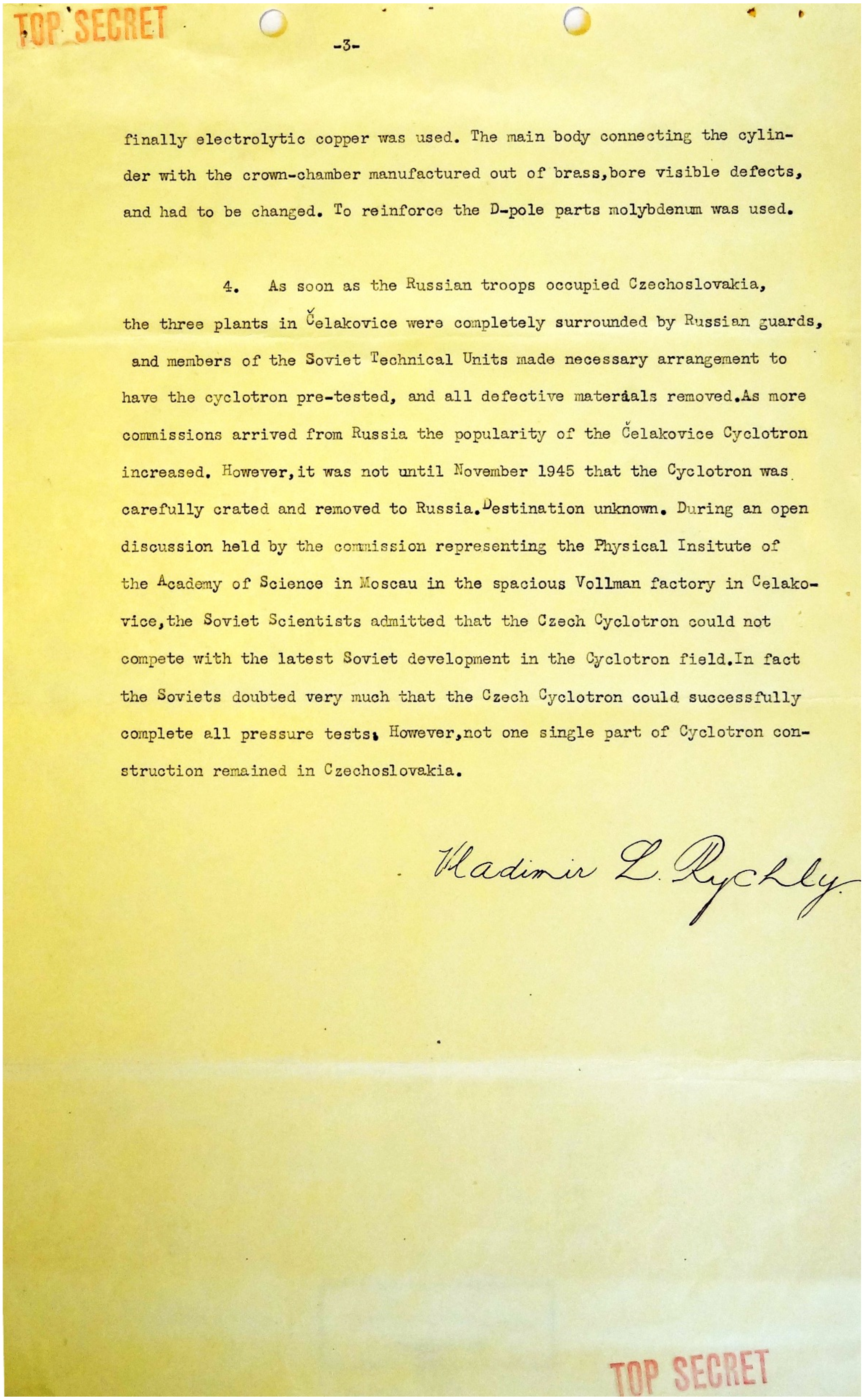

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-3-

finally electrolytic copper was used. The main body connecting the cylinder with the crown-chamber manufactured out of brass, bore visible defects, and had to be changed. To reinforce the D-pole parts molybdenum was used.

4. As soon as the Russian troops occupied Czechoslovakia, the three plants in Čelakovice were completely surrounded by Russian guards, and members of the Soviet Technical Units made necessary arrangement to have the cyclotron pre-tested, and all defective materials removed. As more commissions arrived from Russia the popularity of the Čelakovice Cyclotron increased. However, it was not until November 1945 that the Cyclotron was carefully crated and removed to Russia. Destination unknown. During an open discussion held by the commission representing the Physical Insitute of the Academy of Science in Moscau in the spacious Vollman factory in Celakovice, the Soviet Scientists admitted that the Czech Cyclotron could not compete with the latest Soviet development in the Cyclotron field. In fact the Soviets doubted very much that the Czech Cyclotron could successfully complete all pressure tests, However, not one single part of Cyclotron construction remained in Czechoslovakia.

Vladimir L. Rychly

TOP SECRET

NARA RG 38, Entry 98C, Box 11, Folder TSC # 3101-3200

Figure D.476: Vladimir L. Rychly. Cyclotrons Manufactured in Czechoslovakia. 2 September 1946 [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3101–3200].

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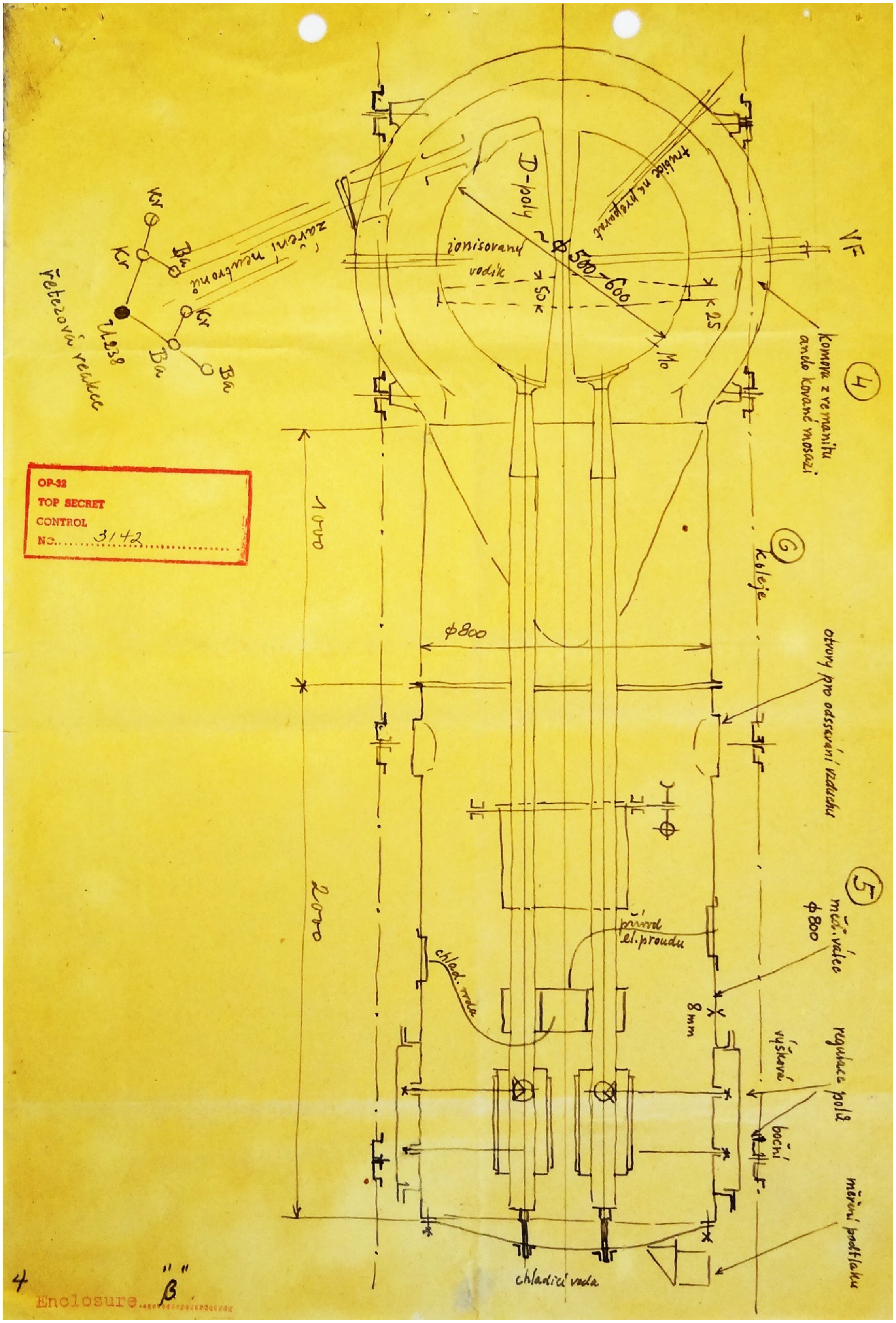

D-póly
~ϕ 500–600
trubice na vyperené
ionisovaný vodík
~50
~25
Mo
VF
④
komora z remanitu anebo kované mosazi
zaření neutronů
Kr
Ba
U238
řetězová reakce
1000
ϕ800
⑥
koleje
otvory pro odssávání vzduchu
2000
⑤
měď. válec ϕ800
přívod el. proudu
chlad. voda
8 mm
výšková
regulace pole
boční
měření podtlaku
chladicí voda
4

OP-32
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CONTROL
NO. 3142

Enclosure "β"

Figure D.477: Diagram of a cyclotron manufactured in German-occupied Czechslovakia for the German nuclear program. Vladimir L. Rychly. Cyclotrons Manufactured in Czechoslovakia. 2 September 1946 [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3101–3200].

Vladimir L. Rychly. 17 December 1946. Russia—Soviet Nuclear Research Apparatus. [NARA RG 38, Entry 98C, Box 12, Folder TSC # 3401–3500]

During one of his lectures conducted at the Charles University in Praha, Czechoslovakia, Dr. Ing. Kolmann who spent over 15 years in Russia, in a brief discussion on Atomic Research in U.S.S.R., claimed:

(1) The Soviets have in their possession one of the largest cyclotrons that was ever built. It was originally designed for the Soviet Academy of Science.

DESCRIPTIONS:

(a) The weight of the electro-magnet approximately 1000 tons.

(b) The size of poles were estimated as follows:

(1) diameter————— 3 meters
(2) height————— 8 meters
(3) length————— 8 meters

Serious difficulties were encountered as the cyclotron was installed. The building in which the cyclotron at present is located was heavily insulated. The estimated size of the building is about 12,000 cubic metres.

It was stated that this cyclotron is capable of producing deut[er]ons with an energy of approximately 50 million electron-volts.

(2) The Soviet Academy of Science is about ready to install the newly developed synchrotron for experimental purposes. It is expected that the energy of the synchrotron will be about 300 million electron-volts.

(3) In his technical publication Dr. Ing. Kolmann made some mention of the betatron which has several advantages over the cyclotron. The betatron is said to be much smaller than the cyclotron. Based upon the principal of an electronic lamp with a diameter of about 300 millimeters, the electric current produced by the electronic lamp receives quicker action from the installed magnetic fields. The energy produced by this so-called "electronic speedster" was estimated at about 100 million electronic volts.

[It seems quite unlikely that such very large particle accelerators were produced by the Soviet Union itself during or immediately after the war, when the Soviet Union was desperately fighting or recovering from the war, very deficient in both scientists and scientific equipment, and devoting all available resources to more fundamental priorities.

Rather, it seems much more likely that these very large particle accelerators were produced by and for wartime German programs. The report mentioned that "serious difficulties were encountered as the cyclotron was installed." That suggests that the cyclotron was not designed and built for the space where it was ultimately installed, and that it was not installed by the people who designed and built it.

Similarly, the 300 MeV synchrotron and the 100 MeV betatron mentioned in the same report were probably also produced by wartime German programs.]

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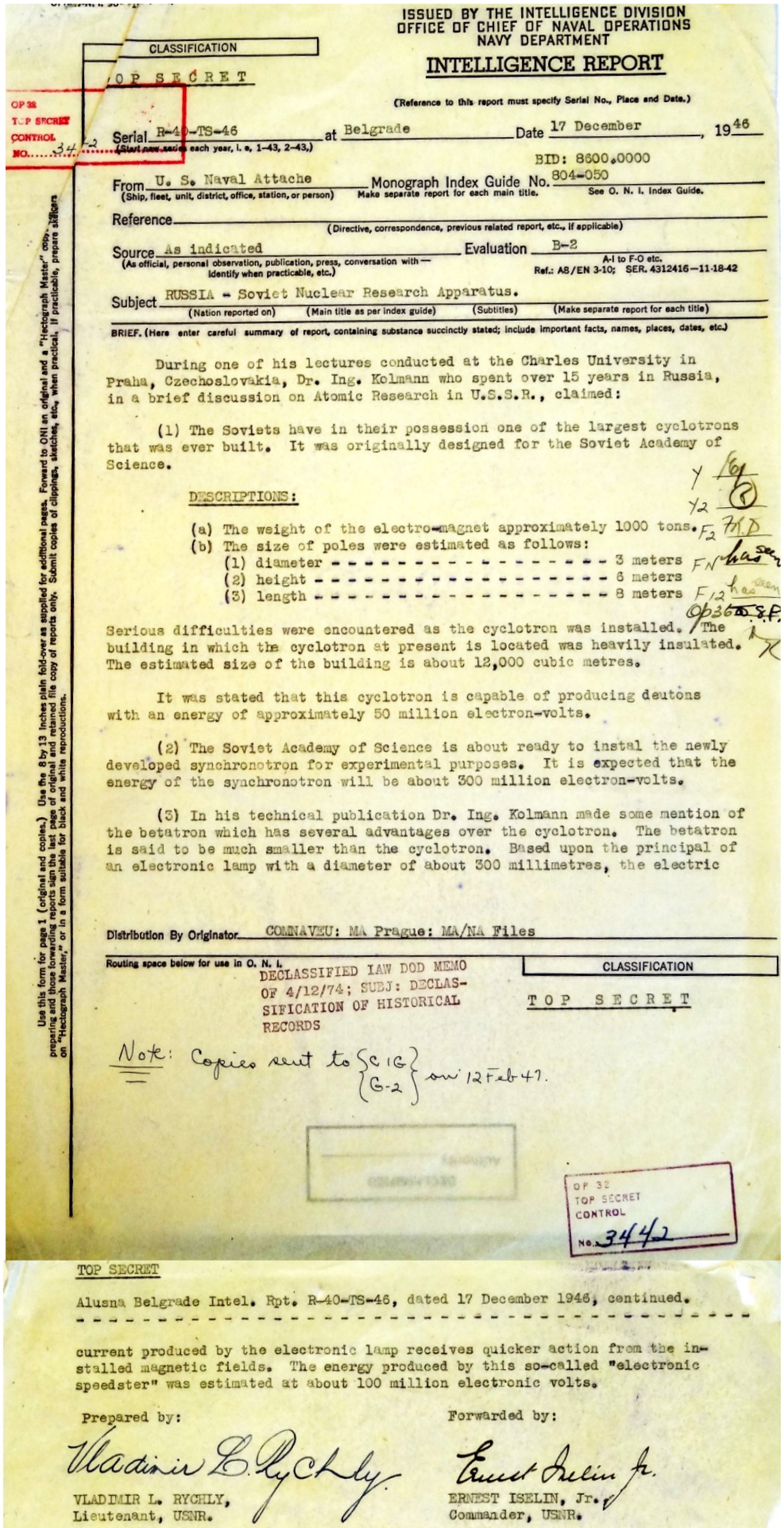

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OFFICE OF CHIEF OF NAVAL OPERATIONS
NAVY DEPARTMENT

INTELLIGENCE REPORT

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OP 32
TOP SECRET
CONTROL
NO. 3442

(Reference to this report must specify Serial No., Place and Date.)

Serial R-40-TS-46 at Belgrade Date 17 December, 1946
(Start new series each year, i. e, 1-43, 2-43,)

BID: 8600.0000

From U. S. Naval Attache Monograph Index Guide No. 804-050
(Ship, fleet, unit, district, office, station, or person) Make separate report for each main title. See O. N. I. Index Guide.

Reference
(Directive, correspondence, previous related report, etc., if applicable)

Source As indicated Evaluation B-2
(As official, personal observation, publication, press, conversation with— identify when practicable, etc.) A-I to F-O etc. Ref.: AS/EN 3-10; SER. 4312416—11-18-42

Subject RUSSIA - Soviet Nuclear Research Apparatus.
(Nation reported on) (Main title as per index guide) (Subtitles) (Make separate report for each title)

BRIEF. (Here enter careful summary of report, containing substance succinctly stated; include important facts, names, places, dates, etc.)

During one of his lectures conducted at the Charles University in Praha, Czechoslovakia, Dr. Ing. Kolmann who spent over 15 years in Russia, in a brief discussion on Atomic Research in U.S.S.R., claimed:

(1) The Soviets have in their possession one of the largest cyclotrons that was ever built. It was originally designed for the Soviet Academy of Science.

DESCRIPTIONS:

(a) The weight of the electro-magnet approximately 1000 tons.
(b) The size of poles were estimated as follows:
  (1) diameter - - - - - - - - - - - - - - - - - 3 meters
  (2) height - - - - - - - - - - - - - - - - - - 6 meters
  (3) length - - - - - - - - - - - - - - - - - - 8 meters

Y
Y2
F2
FN has seen
F12 has seen
Op36

Serious difficulties were encountered as the cyclotron was installed. The building in which the cyclotron at present is located was heavily insulated. The estimated size of the building is about 12,000 cubic metres.

It was stated that this cyclotron is capable of producing deutons with an energy of approximately 50 million electron-volts.

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Alusna Belgrade Intel. Rpt. R-40-TS-46, dated 17 December 1946, continued.

- -

current produced by the electronic lamp receives quicker action from the installed magnetic fields. The energy produced by this so-called "electronic speedster" was estimated at about 100 million electronic volts.

Prepared by: Vladimir L. Rychly
VLADIMIR L. RYCHLY,
Lieutenant, USNR.

Forwarded by: Ernest Iselin Jr.
ERNEST ISELIN, Jr.
Commander, USNR.

Figure D.478: Vladimir L. Rychly. 17 December 1946. Russia—Soviet Nuclear Research Apparatus [NARA RG 38, Entry 98C, Box 12, Folder TSC # 3401–3500].

Col. Baskin R. Lawrence. 4 June 1947. Memorandum for Chief, Air Intelligence Division. Subject: Daily Activity Report. [AFHRA folder 122.25 Mar–July 1947; AFHRA A1036 frames 2238–2239]

[...] The Intelligence Review of 1 May 1947 contains an item which may go far to explain the Sukhumi problem. It will be recalled that there were reports to the effect that the Russians were building in the Sukhumi area an atomic bomb plant in dimensions as large as Oak Ridge. It will also be recalled that there were various reasons why these reports seemed to be unreliable.

However, the reports contained the specific information that German physicists had been seen traveling through Sukhumi. The Intelligence Review (p. 62) now reveals that a small cyclotron, which the Russians had removed from Berlin, was installed at Sukhumi. Since cyclotrons, especially of a small size, are laboratory equipment, and are not needed in the actual production of atomic bombs or atomic materials, the conclusion may be drawn that the Russians established at Sukhumi a nuclear physics laboratory.

Attention is invited to the fact that two larger cyclotrons, classed as "moderate" in size were removed by the Russians from Leipzig and Czechoslovakia. Their present location is unknown.

[All of the documents in this section raise the same question. Why was Germany building so many particle accelerators, and accelerators with such high energies, as a very high priority during and even late in the war? That could not have been justified by pure science experiments. There must have been a clear wartime purpose, such as electronuclear breeding of Pu-239 and/or U-233.]

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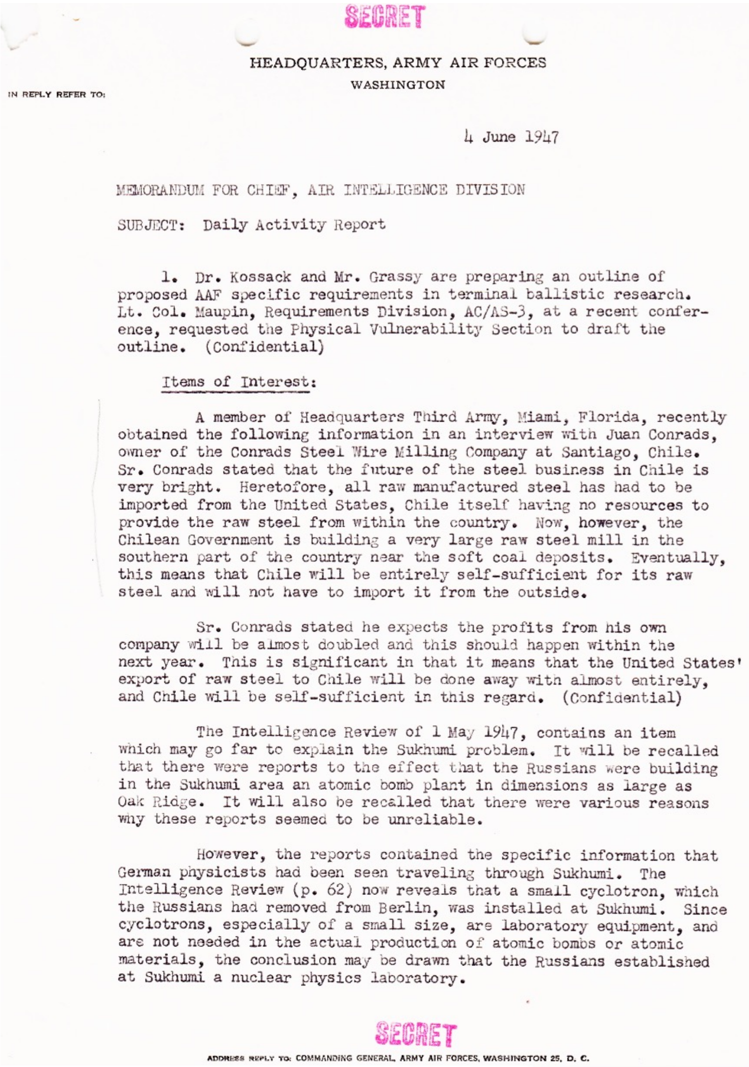

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HEADQUARTERS, ARMY AIR FORCES
WASHINGTON

IN REPLY REFER TO:

4 June 1947

MEMORANDUM FOR CHIEF, AIR INTELLIGENCE DIVISION

SUBJECT: Daily Activity Report

1. Dr. Kossack and Mr. Grassy are preparing an outline of proposed AAF specific requirements in terminal ballistic research. Lt. Col. Maupin, Requirements Division, AC/AS-3, at a recent conference, requested the Physical Vulnerability Section to draft the outline. (Confidential)

Items of Interest:

A member of Headquarters Third Army, Miami, Florida, recently obtained the following information in an interview with Juan Conrads, owner of the Conrads Steel Wire Milling Company at Santiago, Chile. Sr. Conrads stated that the future of the steel business in Chile is very bright. Heretofore, all raw manufactured steel has had to be imported from the United States, Chile itself having no resources to provide the raw steel from within the country. Now, however, the Chilean Government is building a very large raw steel mill in the southern part of the country near the soft coal deposits. Eventually, this means that Chile will be entirely self-sufficient for its raw steel and will not have to import it from the outside.

Sr. Conrads stated he expects the profits from his own company will be almost doubled and this should happen within the next year. This is significant in that it means that the United States' export of raw steel to Chile will be done away with almost entirely, and Chile will be self-sufficient in this regard. (Confidential)

The Intelligence Review of 1 May 1947, contains an item which may go far to explain the Sukhumi problem. It will be recalled that there were reports to the effect that the Russians were building in the Sukhumi area an atomic bomb plant in dimensions as large as Oak Ridge. It will also be recalled that there were various reasons why these reports seemed to be unreliable.

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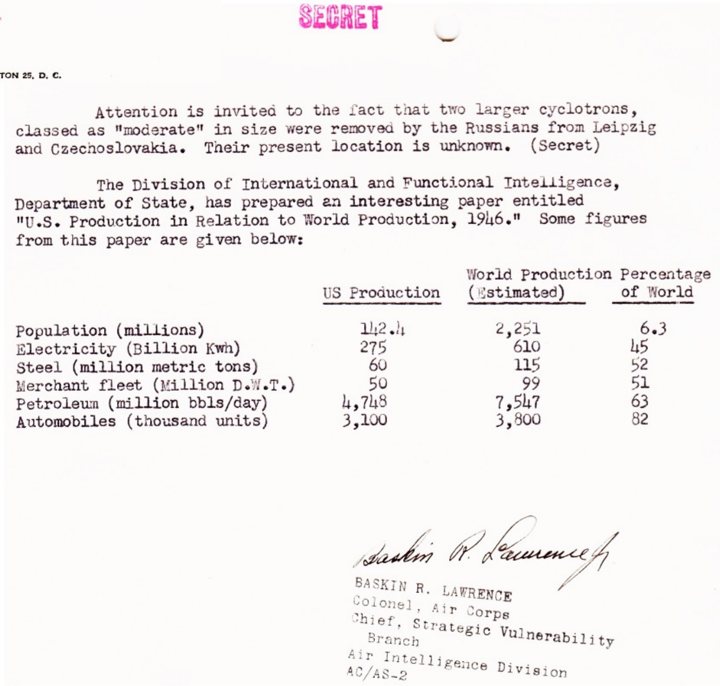
ADDRESS REPLY TO: COMMANDING GENERAL, ARMY AIR FORCES, WASHINGTON 25, D. C.



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Attention is invited to the fact that two larger cyclotrons, classed as "moderate" in size were removed by the Russians from Leipzig and Czechoslovakia. Their present location is unknown. (Secret)

The Division of International and Functional Intelligence, Department of State, has prepared an interesting paper entitled "U.S. Production in Relation to World Production, 1946." Some figures from this paper are given below:

	US Production	World Production (Estimated)	Percentage of World
Population (millions)	142.4	2,251	6.3
Electricity (Billion Kwh)	275	610	45
Steel (million metric tons)	60	115	52
Merchant fleet (Million D.W.T.)	50	99	51
Petroleum (million bbls/day)	4,748	7,547	63
Automobiles (thousand units)	3,100	3,800	82

Baskin R. Lawrence Jr

BASKIN R. LAWRENCE
Colonel, Air Corps
Chief, Strategic Vulnerability
Branch
Air Intelligence Division
AC/AS-2

AFHRA folder
122.25 Mar-July 1947

Figure D.479: Col. Baskin R. Lawrence. 4 June 1947. Memorandum for Chief, Air Intelligence Division. Subject: Daily Activity Report. [AFHRA folder 122.25 Mar–July 1947; AFHRA A1036 frames 2238–2239]

Werner Grothmann on electronuclear breeding of Pu-239 [Krotzky 2002]. For a discussion of the background and reliability of this source, see pp. 3396–3397.

[S. 40] Wichtig ist aber, dass dann später, als wir uns in die Forschung eingeklinkt hatten, auch versucht worden ist, Plutonium herzustellen, auch ohne einen Reaktor. Ich kann dazu nur sagen, das, was ich dazu heute noch weiß, habe ich erst ganz kurz vor Kriegsende erfahren und es sind auch nur einige Teile von dieser Sache, weil mich das ja auch nicht im Amt betraf, mit Ausnahme von besonderen Maßnahmen, die ich im Auftrag von Himmler persönlich übernehmen musste. Aber da hat mich auch niemand von den Fachleuten informiert, sondern ich hörte nur mal so Andeutungen.

[S. 41] Es war jedenfalls so, dass versucht worden ist, Plutonium zu erzeugen, ohne dass man den Reaktor hatte. In der Theorie war das möglich, wie man Himmler erklärt hatte, in der Praxis so gut wie unwahrscheinlich. Zum Beispiel fehlten dazu erst mal die Geräte. Es hat aber Versuche gegeben, im Labormaßstab, also da sind in kleinstem Maßstab Versuche gemacht worden, Plutonium herzustellen. Man muß sich das so vorstellen, dass die Ergebnisse, die man erzielen wollte, nur unvorstellbar geringe Mengen erbracht hätten, vielleicht so Milligramm oder noch weniger. Es ging ja erst mal auch nur darum zu sehen, ob die Theorie stimmt und ob das überhaupt klappen würde. Ich hörte dann mal, dass man das vor allem in Österreich versucht hatte, dass die Physiker aber enttäuscht waren, weil es eben nicht ging, Ich weiß nicht, woran es lag, das habe ich nicht erfahren, es gab aber dazu Besprechungen. Im Sommer 1944, als sich die Uran-Geschichte schon ordentlich entwickelt hatte, sind dann entschiedene Maßnahmen vorgenommen worden, weil es dann doch Hinweise daraufgegeben hatte, dass man Plutonium herstellen könnte, wenn auch mühsam und mit sehr geringen Mengen. Es hat dazu von Himmler den Auftrag gegeben, unsere technischen Möglichkeiten zu nutzen, um die ersten Geräte dafür zu bauen. Die Konstruktionszeichnungen dafür waren aber nicht von unseren Leuten. [...]

[p. 40] It is important, however, that later, when we were engaged in the research, attempts were also made to produce plutonium, even without a reactor. All I can say is that what I know about it today I did not learn until very shortly before the end of the war, and then only a few parts of this matter, because that did not concern me in office, except for special measures that I personally had to undertake on behalf of Himmler. But I was not informed by any of the experts about that, rather I only heard hints.

[p. 41] At any rate, it was attempted to produce plutonium without having a reactor. In theory this was possible, as Himmler was told, though as good as unlikely in practice. For example, the equipment was missing. However, attempts were made to produce plutonium on the laboratory scale, that is, on a small scale. One has to imagine that the results which one wanted to achieve would have only produced inconceivably small amounts, perhaps a milligram or even less. There was only time to see whether the theory was correct and whether it would work at all. I heard then that this had been tried especially in Austria, but that the physicists were disappointed because it just was not possible, I know I did not know what it was, but there were discussions about it. In the summer of 1944, when the uranium program had already been developed properly, decisive measures were taken, because there was evidence that plutonium could be produced, albeit with difficulty and in very small quantities. It was Himmler who commissioned us to use our technical capabilities to build the first machines for it. The construction drawings for it were not from our people. [...]

Außerdem hatte die Reichspost in der Nähe eine eigene ganz geheime Forschungseinrichtung, zu der ich aber nichts weiß. Die Maschinenanlage für die Plutonium- Sache ist von österreichischen Firmen und im Protektorat hergestellt worden. Das war so, weil es ja bessere Kontakte österreichischer Wissenschaftler zu ihren eigenen Firmen gab, die arbeiteten übrigens hervorragend. [...]

[S. 41] Der Betrieb der Anlage sollte so organisiert werden, daß wir die Einrichtung stellen und auch den Bau der unterirdischen Räume. Die Techniker dort sollten sie für uns betreiben und die fachliche Aufsicht hätten Ohnesorges Leute bekommen. [...]

Nach dem Krieg habe ich dann mal gehört, wir hätten Material für eine oder zwei Plutonium-Bomben gehabt. Ich kann dazu nur sagen, dass ich das nicht glaube. Ich bin ja in dem Thema nicht drin. Wir haben nach meiner Kenntnis dazu nichts gehabt. Ob andere Gruppen irgendwo etwas erzeugt haben, weiß ich nicht, ich weiß aber, wie unglaublich schwierig das alles war. [...]

Ob von den Österreichern noch was konkret zum Plutonium gemacht worden ist, kann ich mir eigentlich nicht vorstellen, obwohl man manchmal so Gerüchte hörte.

In addition, the Reichspost had its own very secret research facility nearby, but I do not know anything about it. The equipment for the plutonium matter was manufactured by Austrian companies and in the Protectorate. This was so because Austrian scientists had better contacts to their own companies, which did excellent work by the way. [...]

[p. 41] The operation of the facility was supposed to be organized such that we provided the facility and also the construction of the underground rooms. The technicians there should operate them for us and Ohnesorge's people would provide the technical supervision. [...]

After the war I heard that we had material for one or two plutonium bombs. I can only say that I do not believe it. I am not on that topic. We had nothing to my knowledge. Whether other groups produced something anywhere, I do not know, but I know how incredibly difficult it all was. [...]

I can't imagine whether the Austrians did anything concrete about plutonium, although one sometimes heard such rumors.

[Grothmann's description certainly sounds like electronuclear breeding. It agrees well with other sources here, such as the manufacture of cyclotrons in the Czechoslovakian Protectorate and Flerov's account of what may have been an electronuclear breeding facility in Silesia. (Details on both of those only came out after Grothmann's death, so his story appears to have been an independent confirmation.) The details remembered by Grothmann are also highly consistent with the physics of electronuclear breeding, even though Grothmann was not a scientist. Note that because of the extreme secrecy of the nuclear program, even Grothmann was unsure how much plutonium was produced by the end of the war.

As shown in Appendix C (p. 3020), numerous documents demonstrate that there was extensive work throughout the war on particle accelerators, which would have been highly suitable for electronuclear breeding. Please see all of those documents in Appendix C. A few additional relevant documents are presented on the following pages.]

D.7 Production of Other Potentially Nuclear-Related Materials

[During the war, Germany produced large quantities of materials that had non-nuclear applications, yet would also have been extremely useful for a nuclear weapons program. See Table D.1.]

Material	**Nuclear applications**	**Non-nuclear appl.**	**Wartime production**
Deuterium & heavy water (p. 4027)	Producing tritium, neutrons, & fusion; neutron moderator for fission reactor	Isotope labelling of molecules	At least ∼25 production plants
Lithium (p. 4090)	Producing tritium, neutrons, fusion	Processing ceramics, glass, metals	Hundreds of tons
Beryllium (p. 4096)	Neutron production/ reflection	Metal alloys	Many tons
Boron (p. 4104)	Neutron absorber	Producing ceramics, glass, metals	Large quantities
Graphite (p. 4110)	Neutron moderator for fission reactor	Rocket rudders	Tens of thousands of tons
Fluorine (p. 4118)	Uranium hexafluoride for enrichment	Industrial production	Thousands of tons
Aluminum (p. 4126)	Reactor fuel cladding, bomb casings	Metal structures, packaging	Thousands of tons
Calcium (p. 4132)	Thorium/uranium/ plutonium purification	Metal alloys	Thousands of tons
Nickel (p. 4138)	Resists corrosion by uranium hexafluoride	Batteries, alloys	Thousands of tons
Zirconium (p. 4142)	Reactor fuel cladding	High-temperature metals, ceramics	Many tons
Cadmium (p. 4148)	Neutron absorber	Nickel-cadmium batteries	Thousands of tons

Table D.1: Materials with both nuclear and non-nuclear applications that were mass-produced in wartime Germany.

[The following documents illustrate the large-scale production of these materials. From these documents, it is not possible to determine whether or how much of the material was used for nuclear applications, but clearly the materials were readily available if some quantity of them had been requested by a high-priority nuclear program.

Some sites were producing multiple nuclear-related materials at the same location. For example, I.G. Farben's Bitterfeld facility is documented to have been producing heavy water (p. 4050), graphite (p. 4110), aluminum (p. 4128), and calcium (pp. 4133, 4136); Bitterfeld may have produced other relevant materials as well.

Intriguingly, significant quantities of many of these nuclear-related materials were also shipped to Japan, Germany's wartime ally, along with at least 560 kg of (possibly enriched) uranium and other cutting-edge military technologies—see pp. 4094 and 4858.

Any nuclear-related production programs in wartime Germany would have had access to a larger labor pool than comparable programs in the United States. The population of the greater German-speaking world was equal to or somewhat greater than that of the United States at the time (Section 10.1.1). Including the populations of countries that were allied with or occupied by Germany, the total population of German-controlled territory was far larger than that of the United States.

Likewise, the gross domestic product (GDP, a measure of economic and industrial resources) of German-controlled territory was roughly comparable to or by some measures even greater than that of the United States (pp. 2100–2101).

Finally, the electrical power production of German-controlled Europe was fairly comparable to or even greater than that of the United States (pp. 2100–2104). Germany had access to power plants and fuel sources throughout most of Europe, and also built more during the war (e.g., pp. 3755–3759), so energy would not have been a limiting factor for nuclear-related production.]

A. Deuterium/Heavy Water

[Deuterium (D, a hydrogen isotope with one neutron, compared to normal hydrogen without any neutrons) is a great fusion fuel and can be used as a source for producing neutrons and tritium (T, a hydrogen isotope with two neutrons). In the form of deuterated or heavy water (D_2O), it is also an excellent neutron moderator for fission reactors.

According to official histories, Germany never even got a small prototype fission reactor operational before the end of the war, and only used heavy water for scientific research purposes. Moreover, according to official histories, heavy water was only produced in significant quantities at the Norsk Hydro hydrogen factory in Vemork, Norway, which was famously attacked by Allied forces and the Norwegian Resistance and forced to shut down.

In fact, documents indicate that heavy water production facilities for the German nuclear program were known or reported to be located at sites all over German-occupied Europe (see map on p. 4030):

1. Vemork, Norway (pp. 4031–4039).
2. Såheim, Norway (p. 4040).
3. Notodden, Norway (p. 4041).
4. I.G. Farben Leuna Werke, low-pressure production plant (pp. 4042–4050).
5. I.G. Farben Leuna Werke, high-pressure production plant (pp. 4042–4050).
6. I.G. Farben Bitterfeld (pp. 4050–4051) [Karlsch 2005, p. 110; Sadovsky 2011b].
7. I.G. Farben Halle (pp. 4052–4055).

8. Kiel, probably adjacent to the Deutsche Werke Kiel (pp. 4056–4061).
9. Dräger Werke, Lübeck (pp. 4062–4063).
10. Müggenberg (pp. 4064–4065).
11. Chemische Fabrik Griesheim-Elektron, Frankfurt am Main (pp. 3678–3680, 4066–4067).
12. Berlin plant (p. 4068).
13. Linde plant, Munich (p. 4068).
14. Montecatini plant, Sinigo-Merano, Italy (p. 4069).
15. Montecatini plant, Cotrone/Crotone, Italy (p. 4069).
16. I.G. Farben Auschwitz in Poland (pp. 4069, 4452).
17. Plant near the Schmiedeberg (now Kowary, Poland) uranium mine (p. 4069).
18. Plant near Breslau (now Wrocław, Poland; pp. 4070–4071).
19. Weer, near Wattens, Tyrol, in the Austrian Alps (pp. 4072–4077).
20. B9 Quarz underground complex near Roggendorf and Melk, Austria (p. 4078–4079).
21. Degussa plant at Rheinfelden, Austria (pp. 4080–4081).
22. Austrian Chemical Works plant at Weissenstein, Austria (pp. 4080–4081).
23. Siemens and Halske plant in Lehesten (pp. 3689, 3696, 4080).
24. Bayrische Stickstoffwerke in Piesteritz (pp. 4082, 4452–4453).
25. Pardubice/Wesser, Czechia (pp. 3446, 4082–4083).
26. Other possible locations (pp. 4084–4086).

The documents in this section show that Germany was producing large quantities of heavy water in a very determined fashion at numerous plants all over Europe, despite the difficulties of Allied bombing and the urgent wartime needs to produce other materials and products.

The existence of this massive, high priority, highly secretive heavy water production program strongly suggests that one or more fission reactors may have actually been operational during the war. At the very least, it seems to indicate that Germany was trying to get reactors operational as soon as possible. Germany may have also needed significant quantities of deuterium/heavy water for electronuclear breeding of fission fuel and/or for fusion fuel production.

Moreover, the fact that the files on most of those heavy water plants are still classified (e.g., pp. 4053–4055) also suggests that the German program got much further than we have been told.

While some historians have claimed that the German nuclear program was unwise to choose heavy water instead of graphite as a reactor moderator, the actual historical and scientific record suggests otherwise.

First of all, it is far from certain that the German program did exclude graphite. For example, I.G. Farben's Bitterfeld facility was mass-producing both graphite (p. 4110) and heavy water (p. 4050) as well as other nuclear-related materials (pp. 4128, 4133, 4136). Similarly, Griesheim plants were producing both graphite (pp. 4114–4116) and heavy water (pp. 4066–4067), with other nuclear-related facilities such as Degussa in the same area [Hayes 2004; Nagel 2016]. Graphite was also mass-produced at the Siemens Plania Werke in Racibórz/Ratibor, Poland (pp. 4110–4114), near a reported heavy water plant at Auschwitz (pp. 4069, 4452) and reported uranium enrichment plants at Opava and Ostrava (p. 3749).

It may well be that the German program was aware that graphite could be used as a moderator but preferred heavy water for several reasons:

- The "moderating ratio," the ratio of how strongly a moderating material slows down neutrons vs. how strongly it absorbs neutrons, is ∼25–100 times larger for heavy water than for graphite (depending on the purity of the heavy water). Since heavy water is far more effective than graphite at slowing neutrons without absorbing them, much less moderator and/or natural uranium would be required for a reactor to achieve criticality, or the reactor could be more easily loaded with other neutron-absorbing materials such as lithium for tritium production. Because of these advantages, the United States built five heavy water reactors at the Savannah River Site in the 1950s and used them to breed over 36,000 kg of plutonium during the Cold War.[12]

- Using heavy water would avoid "Wigner's disease," in which irradiated graphite swells, stores/releases large amount of energy, and creates problems in a reactor, as caused major headaches in both the United States (diagnosed by Eugene Wigner) and the Soviet Union (e.g., the January 1949 Chelyabinsk Reactor A accident that shortened Igor Kurchatov's life) [Kojevnikov 2004, p. 151; Bruce Cameron Reed 2019, pp. 260–261; Rhodes 1995, p. 277].

- Graphite is flammable and could cause or contribute to a catastrophic reactor accident, as in the 1957 Windscale reactor fire in the U.K. nuclear weapons program [Lorna Arnold 2007; Mahaffey 2014, p. 176].

- While being used as a moderator for fission reactions, heavy water will simultaneously breed tritium. Further tritium can be bred by inserting lithium into the heavy water reactor (which can spare more neutrons for that purpose than a graphite reactor could, since the moderating ratio of heavy water is much higher). For example, the five heavy water reactors at the U.S. Savannah River Site produced around 200 kg of tritium during the Cold War [Høibråten 2020]. There is evidence that the wartime German program wanted fusion fuels such as tritium for (a) neutron initiators in fission bombs, (b) fusion neutron boosting in fission bombs, and (c) fusion fuel for a megaton-level H-bomb (Section D.9).

- Using heavy water for reactors would leave all of Germany's graphite available for other urgent applications, such as electrodes, rocket exhaust steering rudders, and steel production.]

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[12] DOE 1996; Glasstone 1958, pp. 464–465; Glasstone and Sesonske 1981, pp. 470, 786;
https://ansn.iaea.org/Common/topics/OpenTopic.aspx?ID=19022
https://nucleus.iaea.org/sites/graphiteknowledgebase/wiki/Wiki%20Pages/Nuclear%20Properties.aspx

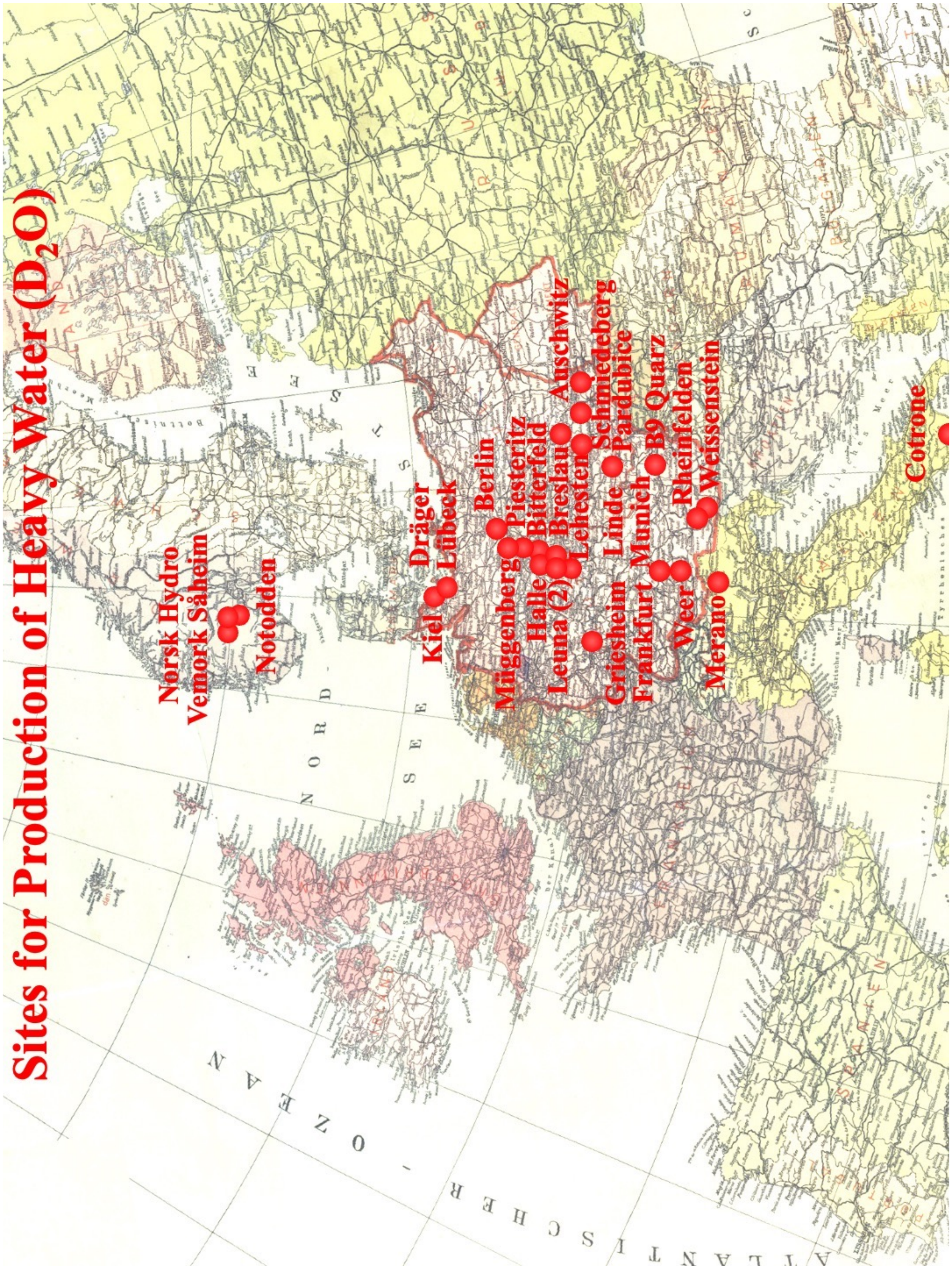

Sites for Production of Heavy Water (D_2O)
Norsk Hydro
Vemork Såheim
Notodden
Dräger
Kiel
Lübeck
Berlin
Müggenberg
Piesteritz
Bitterfeld
Halle
Leuna (2)
Breslau
Lehesten
Auschwitz
Schmiedeberg
Pardubice
Linde
Griesheim
Frankfurt
Munich
B9 Quarz
Rheinfelden
Weer
Weissenstein
Merano
Cotrone

Figure D.480: Known/reported heavy water production facilities for the German nuclear program.

1. Vemork, Norway

Heavy water production at Vemork for the years 1934/35–1944/45 [courtesy of Gunhild Lurås, Norwegian Industrial Workers Museum archive, Vemork]

Time period	D_2O produced
1 July 1934–30 June 1935	37.44 kg
1 July 1935–30 June 1936	81.50 kg
1 July 1936–30 June 1937	89.70 kg
1 July 1937–30 June 1938	77.35 kg
1 July 1938–30 June 1939	104.92 kg
1 July 1939–30 June 1940	20.35 kg
1 July 1940–30 June 1941	287.75 kg
1 July 1941–30 June 1942	870 kg
1 July 1942–30 June 1943	1179 kg
1 July 1943–30 June 1944	487 kg
1 July 1944–30 June 1945	0 kg

[According to the Vemork production reports, the produced heavy water had a typical purity of 99.6% during this period.

According to the Vemork archives, a significant quantity of deuterium was also produced and shipped to Germany in forms other than heavy water—as deuterium gas, deuterated ammonia, etc. From the surviving records, it is unclear what the total quantities of deuterium were.

The Vemork archives show that Norwegian plants at Såheim (p. 4040) and Notodden (p. 4041) were also producing and shipping heavy water and/or deuterium to Germany. The surviving records do not indicate how much was produced and shipped by those plants.

In December 1939, Vemork received an order from I.G. Farben for 10 kg of heavy water, presumably in order to test its quality. (Up to that time, Vemork had only sold a total of 40 kg of heavy water since beginning production.)

In January 1940, Vemork then received an order from I.G. Farben for 2000 kg of heavy water.

Germany invaded Norway on 9 April 1940 and took over Vemork in early May 1940.

Paul Harteck, Hans Suess, Karl Wirtz, Kurt Diebner, and other German and Austrian scientists worked closely with Vemork to increase its heavy water production. Ongoing orders for heavy water were placed by the Heereswaffenamt (Army Ordnance Office) in Berlin-Dahlem.

Thus Germany had a strong interest in obtaining large amounts of heavy water from 1939 onward, consistent with its strong interest in obtaining large amounts of uranium from 1939 onward (see for example p. 3998).

After several attacks and acts of sabotage by the British Special Operations Executive (SOE) and the Norwegian Resistance 1942–1944, heavy but unsuccessful Allied aerial bombing in November 1943, and the threat of further Allied bombing, in 1944 the Vemork heavy water production equipment was disassembled and sent to Germany. It is unclear if or where it was reassembled and restarted.]

G-188. Paul Harteck, H. Suess, Konsul Schoepke, N. Stephansen, and J. Brun. Minutes of the Meeting at Norsk Hydro. 27 May 1942.

Brief notes on proposed catalysts, procurement of a ventilator, mixers, preheaters, coolers, steel flasks, etc. Plant again in operation since May 12 and about 60 kg D_2O now on hand.

G-262. Paul Harteck. Status of Deuterium Production. 1944.

Progress of D production in Norway and difficulties resulting from sabotage and bombing are reported for the period from 1941 to 1943 when production was discontinued. Suitability of various procedures for production of D in Germany are discussed. Procedures proposed use either distillation of equilibrium exchange ($H_2 + HDO \leftrightarrow HD + H_2O$; or $H_2S + HDO \leftrightarrow HDS + H_2O$.)

William Casey. 1988. *The Secret War Against Hitler.* Washington, DC: Regnery Gateway. p. 54.

In April 1945, the dismantled high concentration plant was found in Bavaria, together with uranium and heavy water on the brink of going critical, lacking about 700 liters of additional heavy water. The Germans were never able to get out of Norway much more than half the heavy water they needed. Nobel prize-winner [Eugene] Wigner, one of the physicists driven out of Germany, had in 1942 told the American government that the Germans would produce a nuclear weapon in two years. If Vemork had been allowed to maintain its rate of heavy water output through 1943 and 1944, he might have been right.

[Was Casey referring to Diebner's pile that had been evacuated to Bavaria? Or the Haigerloch pile (not in Bavaria)? Or something else?]

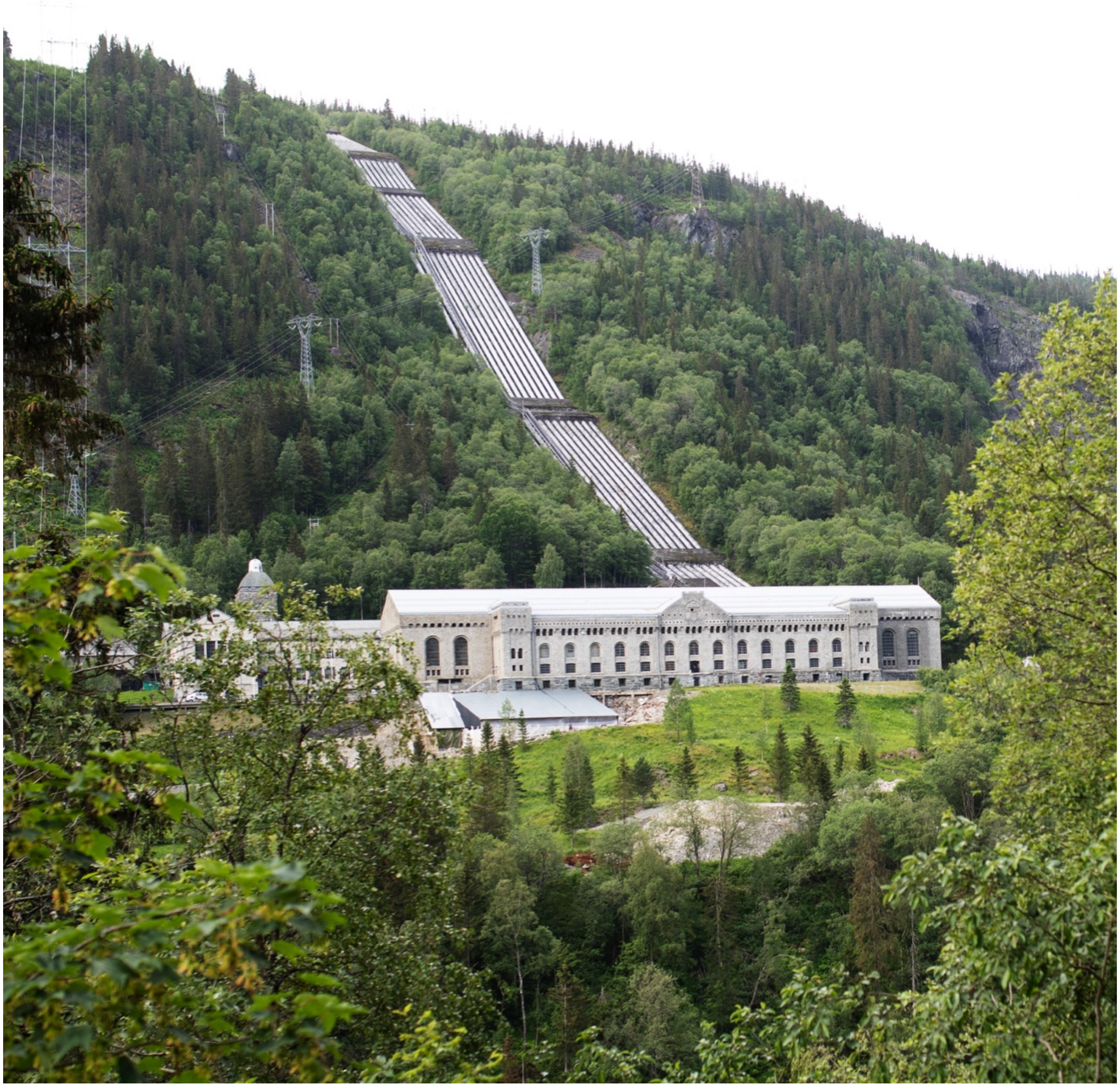


Figure D.481: The Norsk Hydro Vemork power plant in Norway. During the war, heavy water was produced in the hydrogen factory building (now mostly demolished) that stood in front of the power plant.

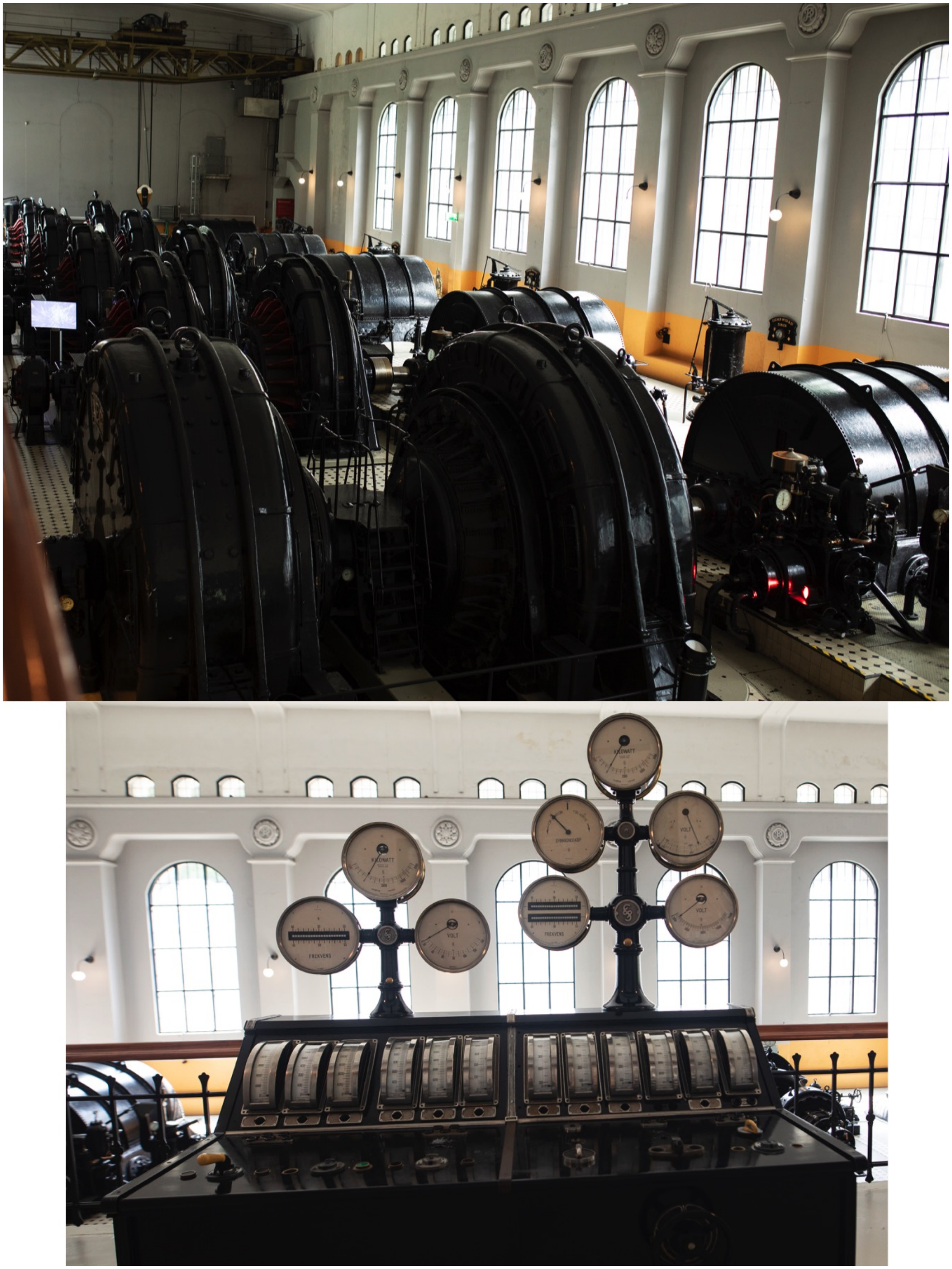

KILOWATT
FREKVENS
VOLT
KILOWATT
SYNKRONOSKOP
VOLT
FREKVENS
VOLT

Figure D.482: German AEG electric generators inside the Vemork power plant.

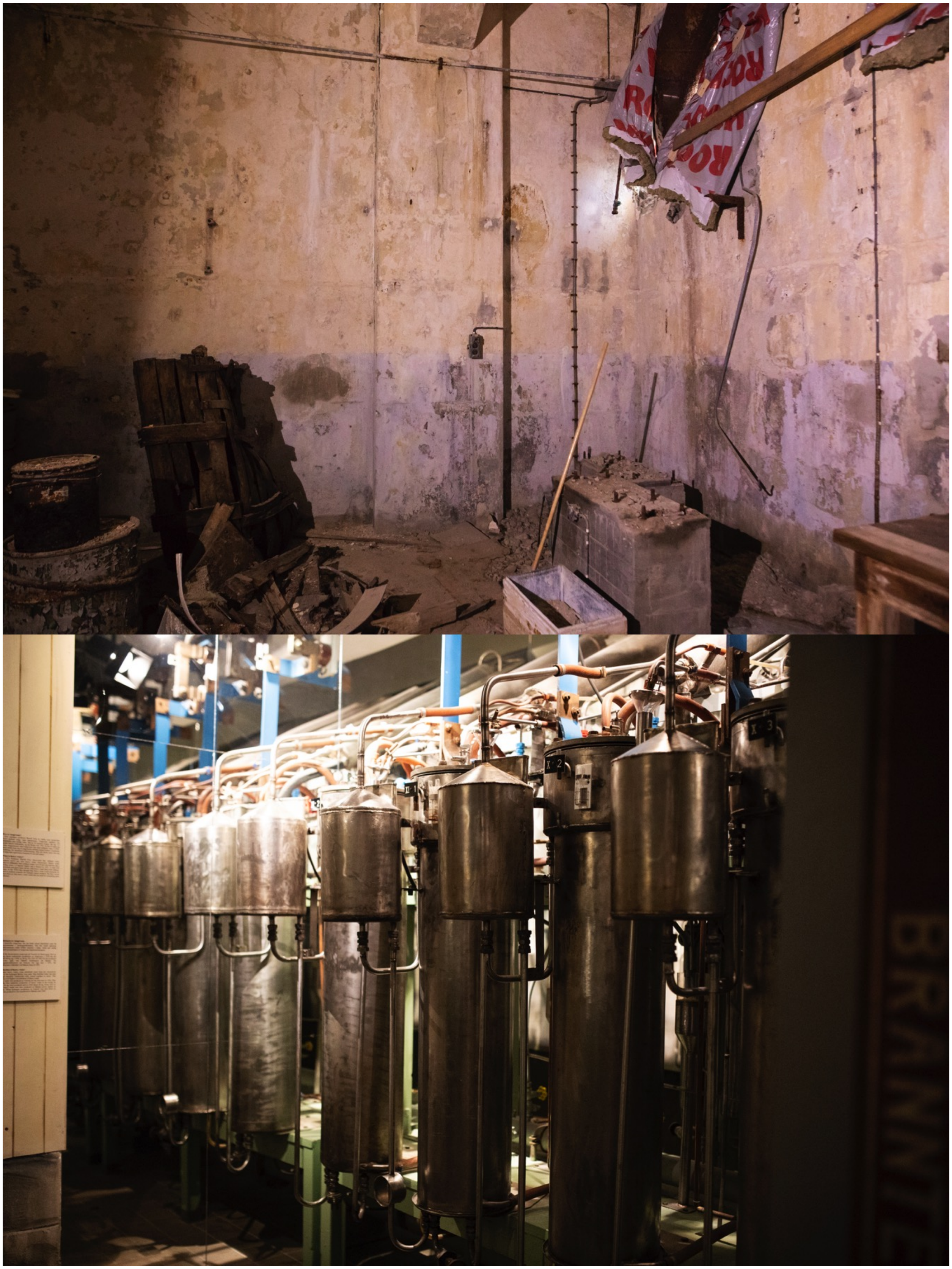


Figure D.483: Remains of the Vemork heavy water collection cellar of the hydrogen factory (above) and a museum display of what the heavy water cellar looked like during the war.

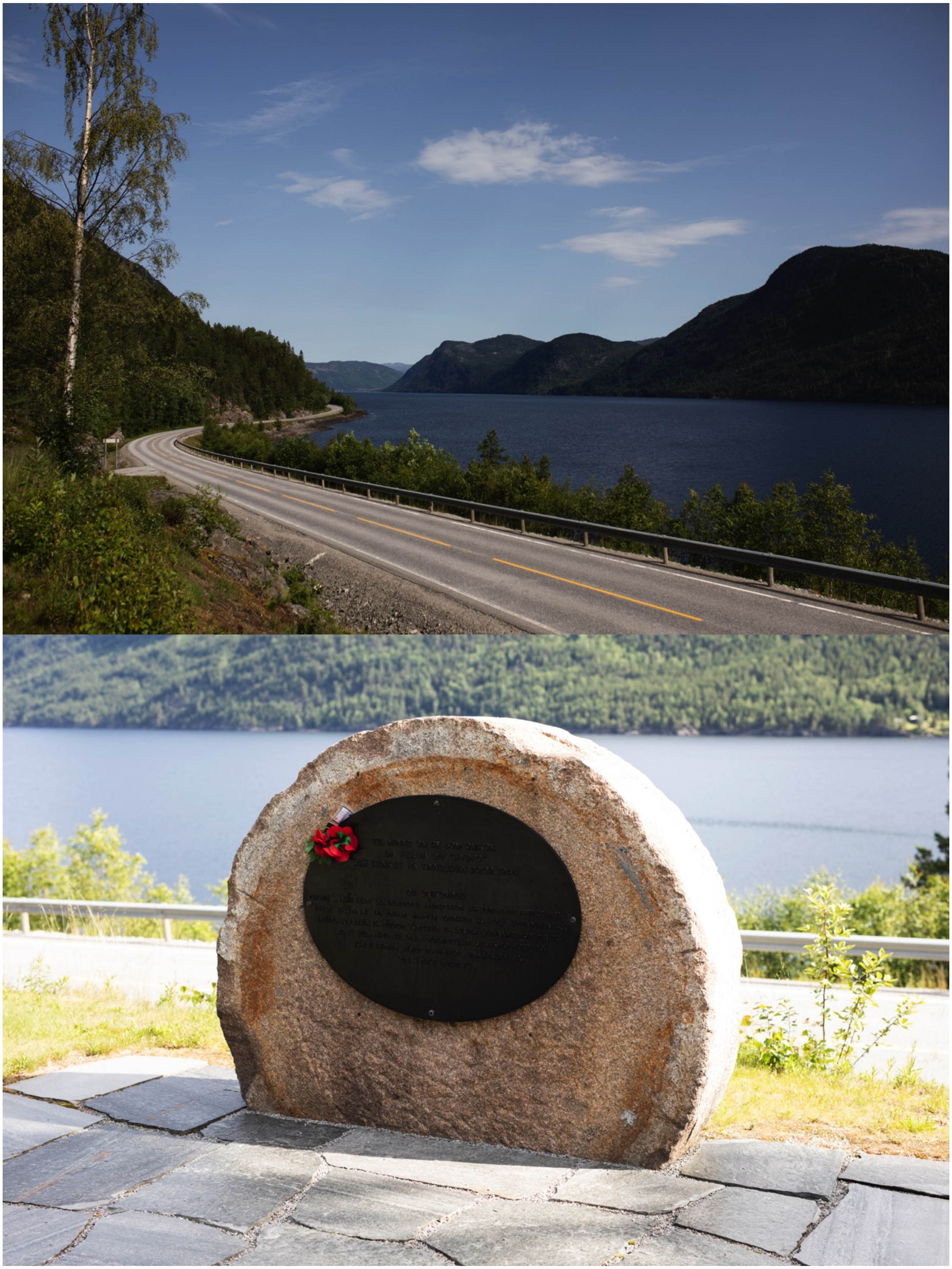
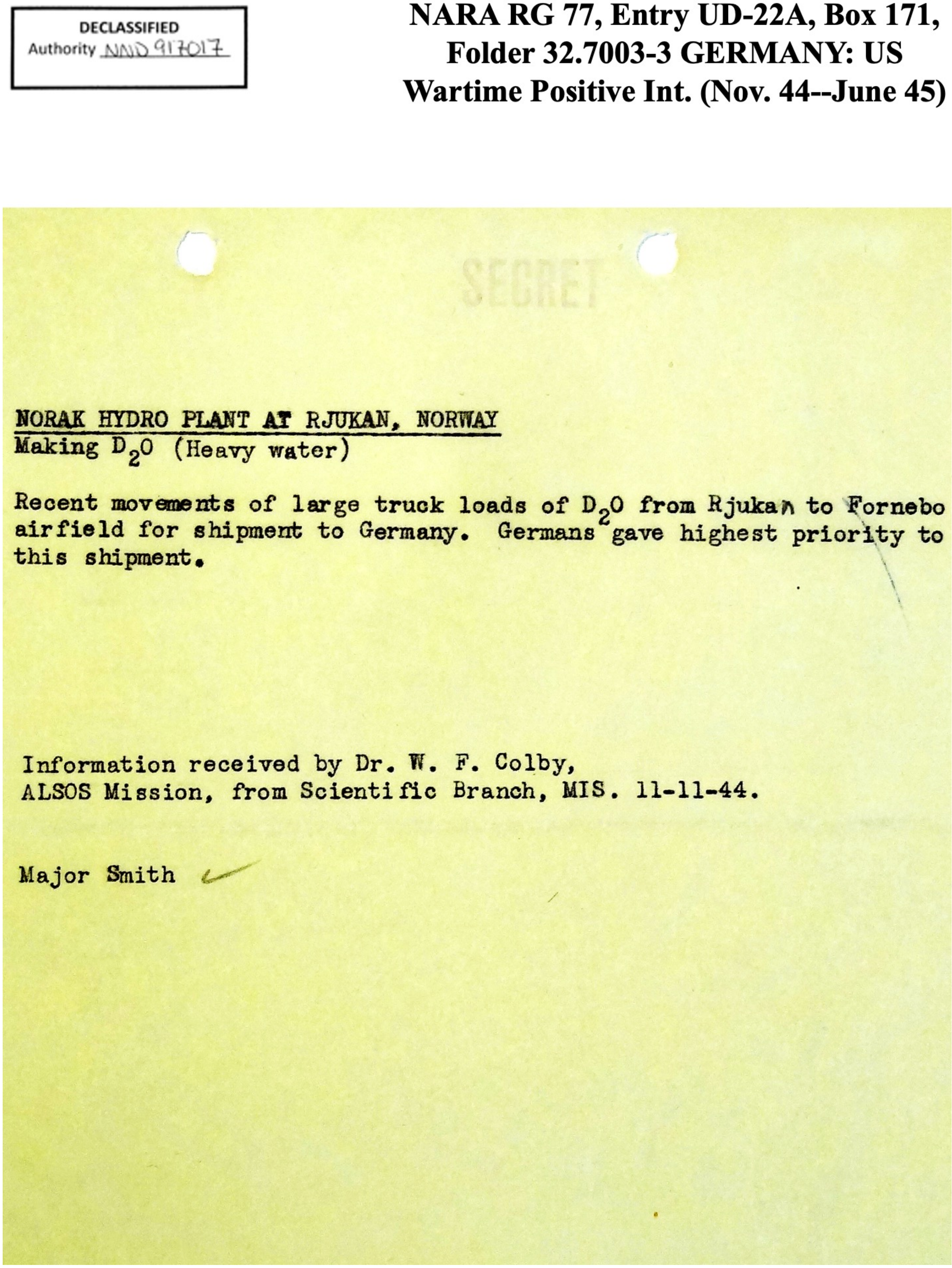


Figure D.484: A memorial plaque beside Lake Tinn near Vemork commemorates the location where the DF *Hydro* ferry carrying the final barrels of heavy water was sunk by the Special Operations Executive and the Norwegian Resistance. The plaque gives the names of those who died in the sinking.



DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44--June 45)

SECRET

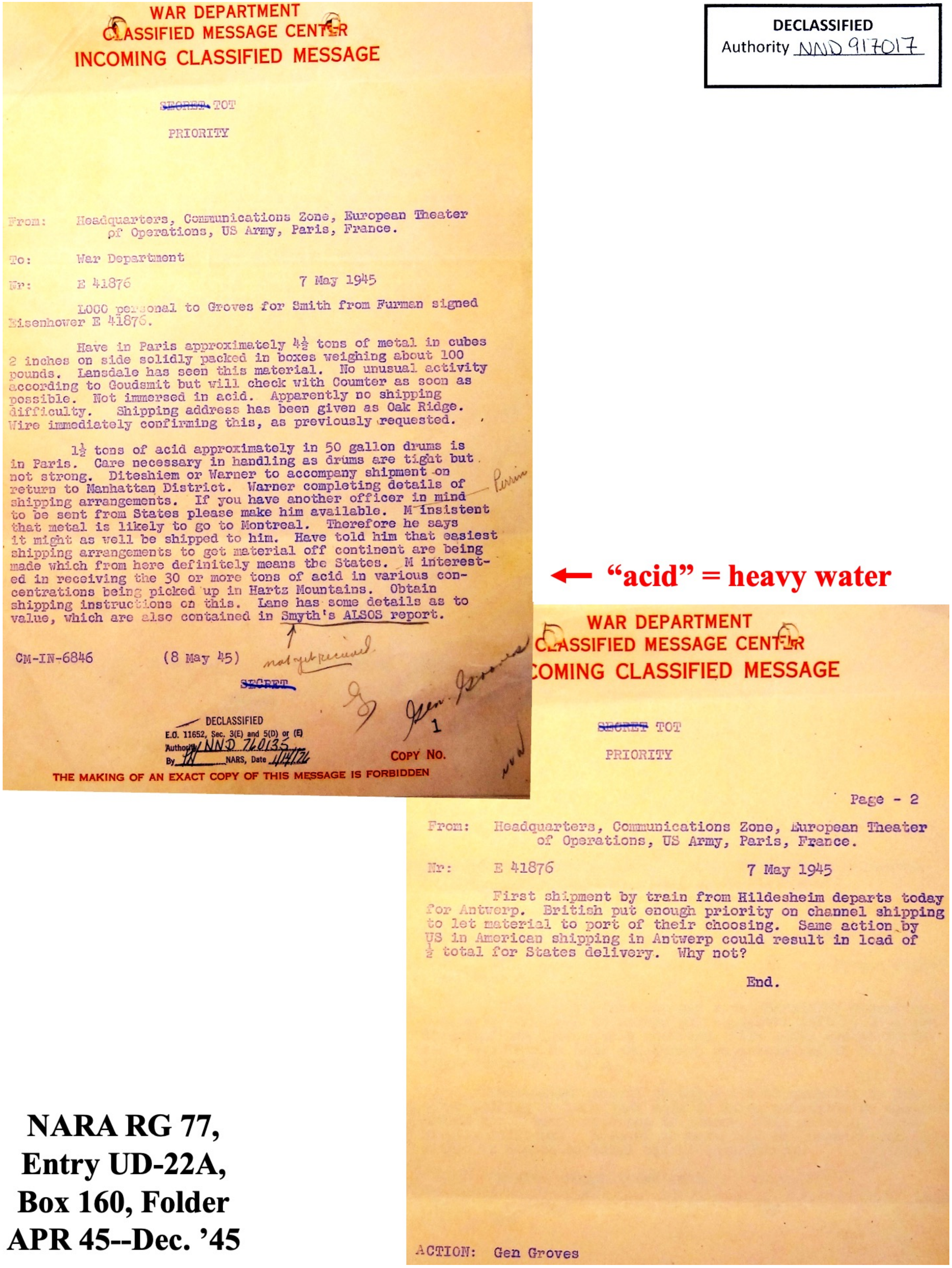
NORAK HYDRO PLANT AT RJUKAN, NORWAY
Making D_2O (Heavy water)

Recent movements of large truck loads of D_2O from Rjukan to Fornebo airfield for shipment to Germany. Germans gave highest priority to this shipment.

Information received by Dr. W. F. Colby,
ALSOS Mission, from Scientific Branch, MIS. 11-11-44.

Major Smith

Figure D.485: W. F. Colby. 11 November 1944. Norsk Hydro Plant at Rjukan, Norway [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]. “Recent movements of large truck loads of D_2O from Rjukan to Fornebu airfield for shipment to Germany. Germans gave highest priority to this shipment.”



DECLASSIFIED
Authority NND 917017

WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
INCOMING CLASSIFIED MESSAGE

~~SECRET~~ TOT

PRIORITY

From: Headquarters, Communications Zone, European Theater of Operations, US Army, Paris, France.

To: War Department

Nr: E 41876 7 May 1945

LOCO personal to Groves for Smith from Furman signed Eisenhower E 41876.

Have in Paris approximately 4½ tons of metal in cubes 2 inches on side solidly packed in boxes weighing about 100 pounds. Lansdale has seen this material. No unusual activity according to Goudsmit but will check with Coumter as soon as possible. Not immersed in acid. Apparently no shipping difficulty. Shipping address has been given as Oak Ridge. Wire immediately confirming this, as previously requested.

1½ tons of acid approximately in 50 gallon drums is in Paris. Care necessary in handling as drums are tight but not strong. Diteshiem or Warner to accompany shipment on return to Manhattan District. Warner completing details of shipping arrangements. If you have another officer in mind to be sent from States please make him available. M insistent that metal is likely to go to Montreal. Therefore he says it might as well be shipped to him. Have told him that easiest shipping arrangements to get material off continent are being made which from here definitely means the States. M interested in receiving the 30 or more tons of acid in various concentrations being picked up in Hartz Mountains. Obtain shipping instructions on this. Lane has some details as to value, which are also contained in Smyth's ALSOS report.

Perrin

not yet received

CM-IN-6846 (8 May 45)

~~SECRET~~

Gen. Groves

DECLASSIFIED
E.O. 11652, Sec. 3(E) and 5(D) or (E)
Authority NND 760135
By ___ NARS, Date 1/14/76

COPY NO. 1

THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN

← **“acid” = heavy water**

WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
INCOMING CLASSIFIED MESSAGE

~~SECRET~~ TOT

PRIORITY

Page - 2

From: Headquarters, Communications Zone, European Theater of Operations, US Army, Paris, France.

Nr: E 41876 7 May 1945

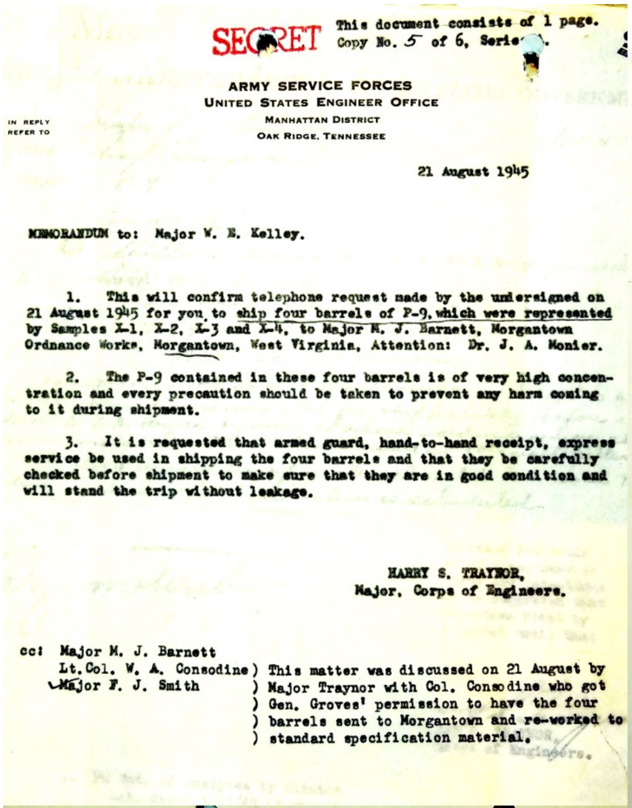
First shipment by train from Hildesheim departs today for Antwerp. British put enough priority on channel shipping to let material to port of their choosing. Same action by US in American shipping in Antwerp could result in load of ½ total for States delivery. Why not?

End.

ACTION: Gen Groves

**NARA RG 77,
Entry UD-22A,
Box 160, Folder
APR 45--Dec. ’45**

Figure D.486: Dwight D. Eisenhower and Robert R. Furman to Leslie Groves. 7 May 1945 [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. ’45]. “30 or more tons of acid [code word for D_2O] in various concentrations being picked up in Hartz Mountains.”



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Copy No. 5 of 6, Series .

ARMY SERVICE FORCES
UNITED STATES ENGINEER OFFICE
MANHATTAN DISTRICT
OAK RIDGE, TENNESSEE

IN REPLY REFER TO

21 August 1945

MEMORANDUM to: Major W. E. Kelley.

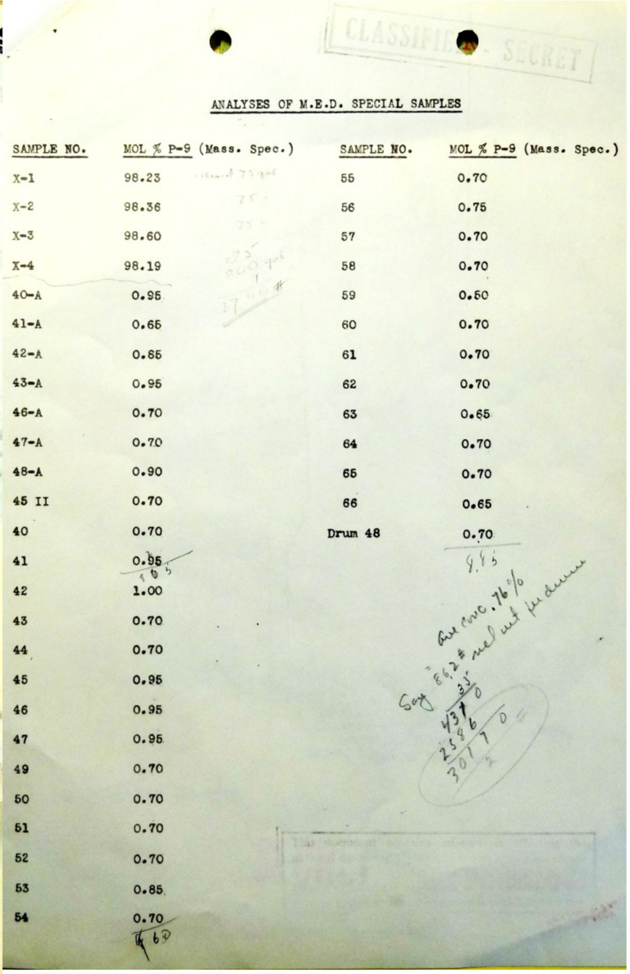
1. This will confirm telephone request made by the undersigned on 21 August 1945 for you to ship four barrels of P-9, which were represented by Samples X-1, X-2, X-3 and X-4, to Major M. J. Barnett, Morgantown Ordnance Works, Morgantown, West Virginia, Attention: Dr. J. A. Monier.

2. The P-9 contained in these four barrels is of very high concentration and every precaution should be taken to prevent any harm coming to it during shipment.

3. It is requested that armed guard, hand-to-hand receipt, express service be used in shipping the four barrels and that they be carefully checked before shipment to make sure that they are in good condition and will stand the trip without leakage.

HARRY S. TRAYNOR,
Major, Corps of Engineers.

cc: Major M. J. Barnett
Lt. Col. W. A. Consodine) This matter was discussed on 21 August by
Major F. J. Smith) Major Traynor with Col. Consodine who got
) Gen. Groves' permission to have the four
) barrels sent to Morgantown and re-worked to
) standard specification material.



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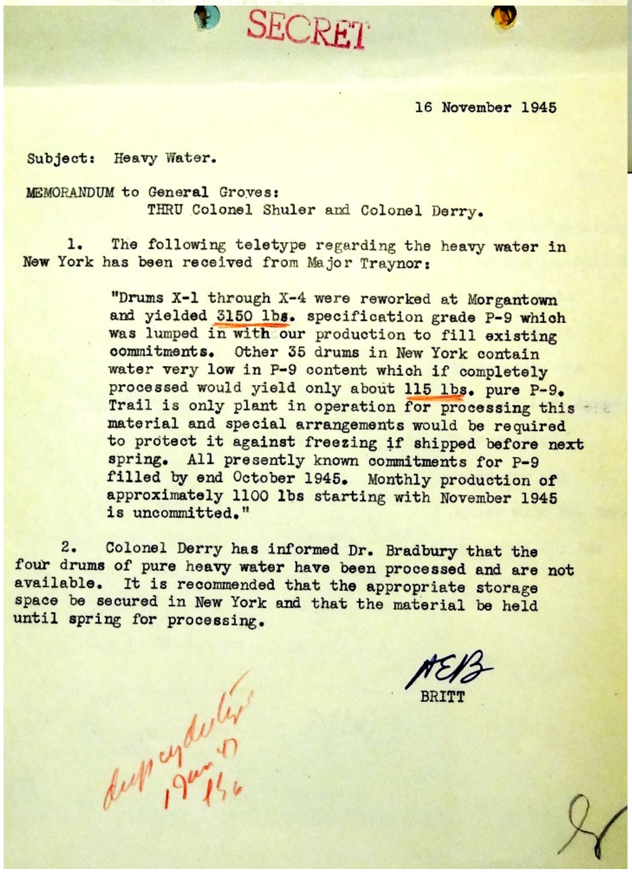
ANALYSES OF M.E.D. SPECIAL SAMPLES

SAMPLE NO.	MOL % P-9 (Mass. Spec.)	SAMPLE NO.	MOL % P-9 (Mass. Spec.)
X-1	98.23	55	0.70
X-2	98.36	56	0.75
X-3	98.60	57	0.70
X-4	98.19	58	0.70
40-A	0.95	59	0.50
41-A	0.65	60	0.70
42-A	0.85	61	0.70
43-A	0.95	62	0.70
46-A	0.70	63	0.65
47-A	0.70	64	0.70
48-A	0.90	65	0.70
45 II	0.70	66	0.65
40	0.70	Drum 48	0.70
41	0.95		8.85
42	1.00		
43	0.70		
44	0.70		
45	0.95		
46	0.95		
47	0.95		
49	0.70		
50	0.70		
51	0.70		
52	0.70		
53	0.85		
54	0.70		

Ave conc. .76%
Say 86.2# mol wt per drum



SECRET

16 November 1945

Subject: Heavy Water.

MEMORANDUM to General Groves:
THRU Colonel Shuler and Colonel Derry.

1. The following teletype regarding the heavy water in New York has been received from Major Traynor:

"Drums X-1 through X-4 were reworked at Morgantown and yielded 3150 lbs. specification grade P-9 which was lumped in with our production to fill existing commitments. Other 35 drums in New York contain water very low in P-9 content which if completely processed would yield only about 115 lbs. pure P-9. Trail is only plant in operation for processing this material and special arrangements would be required to protect it against freezing if shipped before next spring. All presently known commitments for P-9 filled by end October 1945. Monthly production of approximately 1100 lbs starting with November 1945 is uncommitted."

2. Colonel Derry has informed Dr. Bradbury that the four drums of pure heavy water have been processed and are not available. It is recommended that the appropriate storage space be secured in New York and that the material be held until spring for processing.

BRITT

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 169, Folder 32.42.B Germ Mat Res Captured Materials Heavy Water

Figure D.487: Examples of U.S. testing and use of some of the heavy water removed from Germany [NARA RG 77, Entry UD-22A, Box 169, Folder 32.42.B Germ Mat Res Captured Materials Heavy Water].

2. Såheim, Norway, and
3. Notodden, Norway

The power plant in Såheim, Norway, was even larger than the power plant at Vemork.

The Såheim plant was also used to produce heavy water for the German nuclear program.

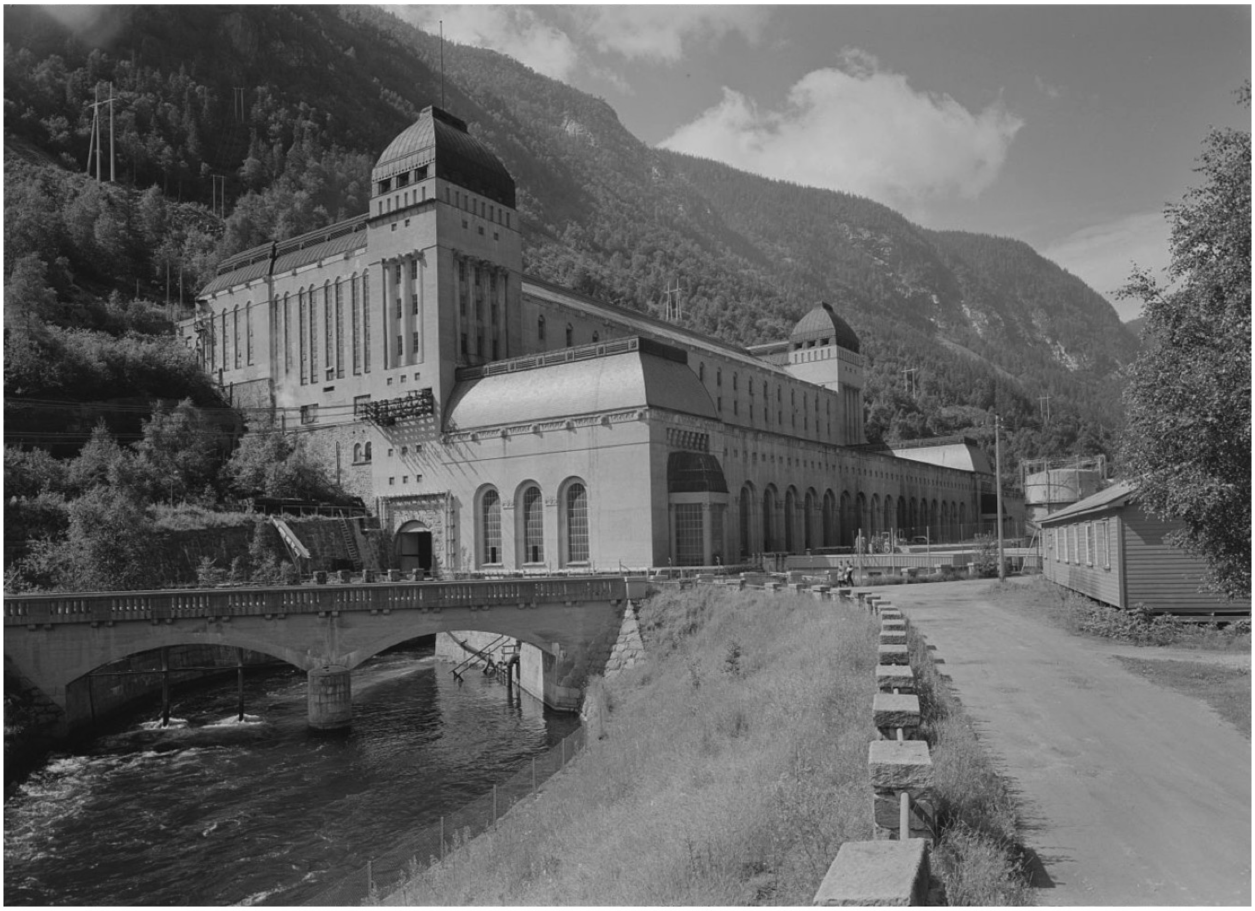


Figure D.488: The power plant in Såheim, Norway, was even larger than the power plant at Vemork. The Såheim plant was also used to produce heavy water for the German nuclear program. Heavy water production at Såheim seems to have been even more secretive than that at Vemork. Unlike Vemork, it does not appear that the Såheim plant was ever attacked during the war.

Notodden, Norway had two power plants (Svælgfos I and II) with a combined output larger than the power plant at Vemork.

The Notodden plants were also used to produce heavy water for the German nuclear program.

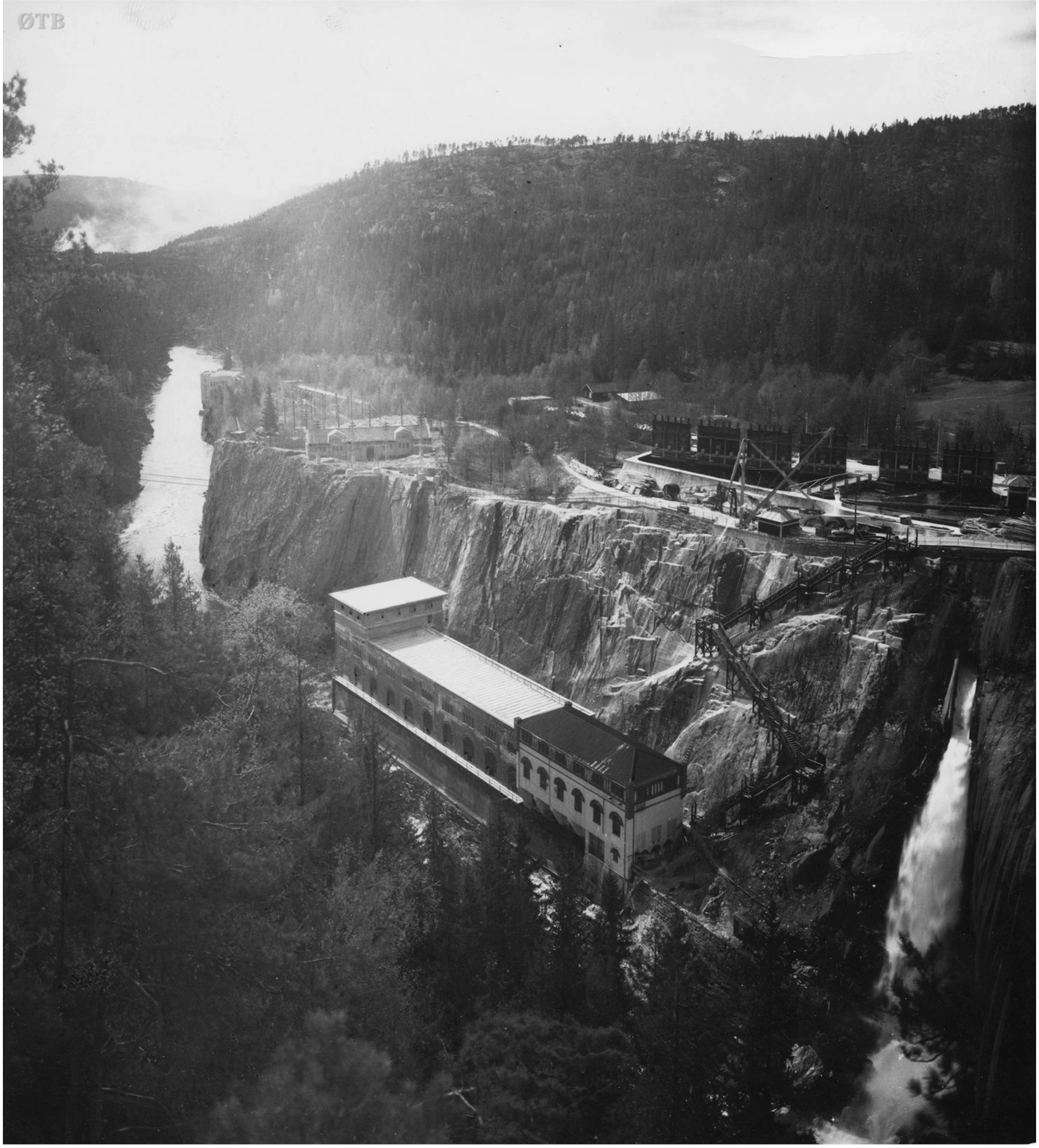


Figure D.489: Notodden, Norway had two power plants (Svælgfos I and II) with a combined output larger than the power plant at Vemork. The Notodden plants were also used to produce heavy water for the German nuclear program. Heavy water production at Notodden seems to have been even more secretive than that at Vemork. Unlike Vemork, it does not appear that the Notodden plants were ever attacked during the war.

4. I.G. Farben Leuna Werke, low-pressure production plant, and
5. I.G. Farben Leuna Werke, high-pressure production plant

G-268. Compilation of Material on Heavy Water Production by Staff Members of the I. G. Farben Aktiengesellschaft Patent Office.

The folder combines different proposals for methods of heavy water production, including designs of apparatus and applications for patents; correspondence between the patent office of the I. G. Farben in Ludwigshafen, the army, the Leuna Werke in Merseburg, the federal bureau in charge of nuclear physics, etc.; reports on experiments in heavy water production conducted in Meran and reports on electrolysis experiments conducted in Merlango, and notes by Professor Domenico Argentieri on the differential equation for enrichment of heavy water in the electrolytic cell; and some reprints.

G-341. Technical Papers and Correspondence on Heavy Water Production from the Files of Dr. Harteck.

[These are six large volumes of detailed papers and letters regarding heavy water production, primarily between Paul Harteck's group and I.G. Farben Leuna Werke.]

Craven & Cate. 1951. *The Army Air Forces in World War II.* Vol. 3, pp. 176–7, 828.

Their shortsightedness proved painful on the 12 May [1944] mission and during the numerous attacks which followed. On this occasion, 15 combat wings involving 935 heavy bombers, escorted by Eighth and Ninth Air Force and RAF fighters, took off for what was to prove a historic operation.[169] [...] More than 800 heavies attacked, dropping 1,718 tons on the synthetic oil plants at Zwickau, Merseburg-Leuna, Brüx, Lützkendorf, Böhlen, and other cities. [...] Certainly the professed objective of the mission was attained: the German Air Force had reacted vigorously to the attacks on oil plants and had suffered severe losses. More important in the long run was the fact that all of the targets were damaged, some of them very heavily. Brüx, Böhlen, and Zeitz were knocked temporarily out of operation, and the bombing at Merseburg-Leuna happened to destroy a building in which experiments were being conducted with heavy water for Germany's atomic-bomb project.[170] It was an excellent mission, despite the heavy loss of bombers, and an auspicious opening of the Eighth Air Force campaign to deny the Germans oil.

169. 8th AF T/M Rpt., 12 May 1944; USSTAF Semimonthly Record of Results, 1–15 June 1944, Oil Sec.; USSTAF Air Intel. Sum. 28, p. 20.

170. USSBS, The Integration of the German Oil, Chemical, Rubber, and Explosives Industries.

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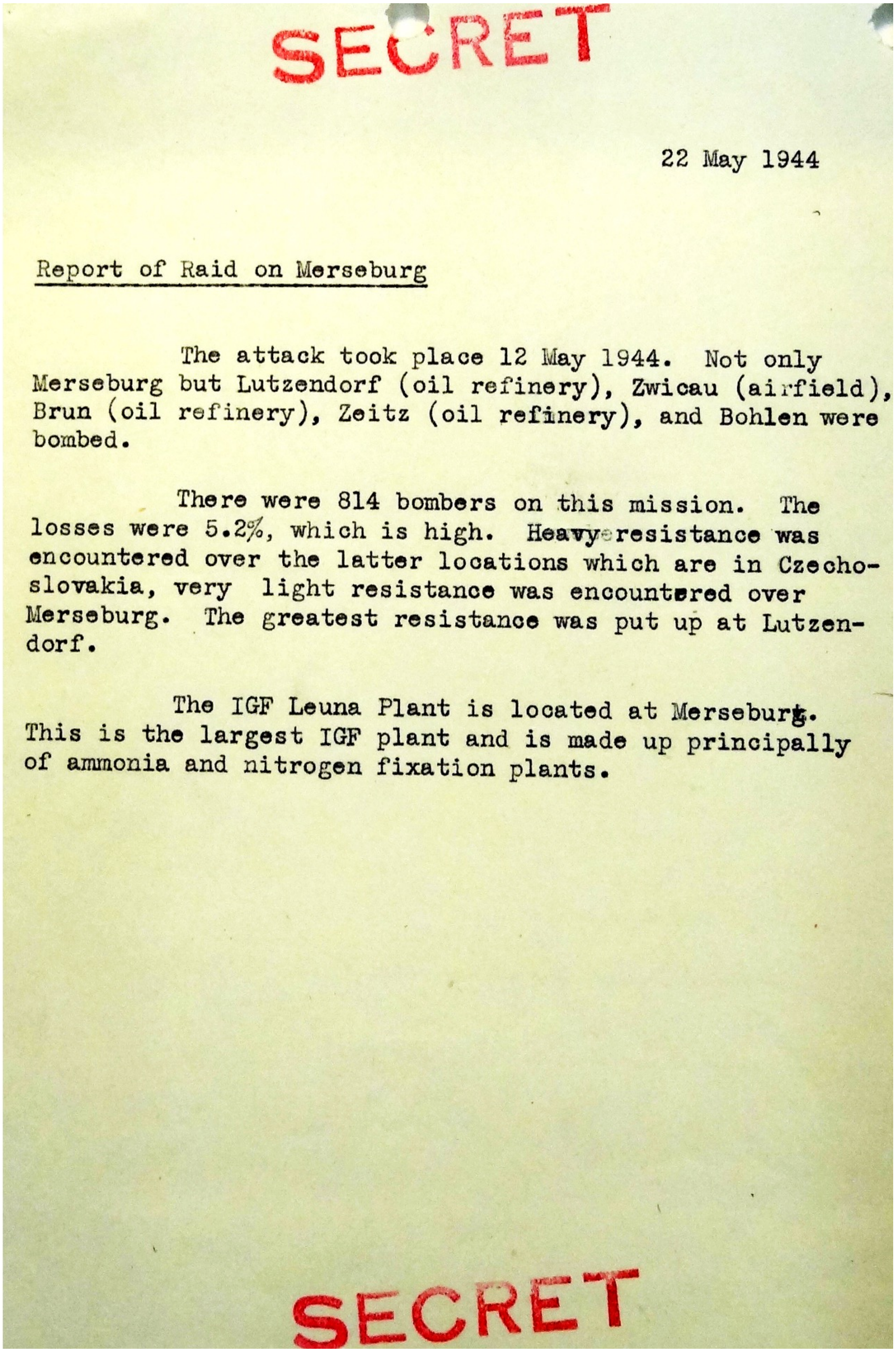
NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1
GERMANY: US Wartime Positive Int. (July 42–June 44)



SECRET

22 May 1944

Report of Raid on Merseburg

The attack took place 12 May 1944. Not only Merseburg but Lutzendorf (oil refinery), Zwicau (airfield), Brun (oil refinery), Zeitz (oil refinery), and Bohlen were bombed.

There were 814 bombers on this mission. The losses were 5.2%, which is high. Heavy resistance was encountered over the latter locations which are in Czechoslovakia, very light resistance was encountered over Merseburg. The greatest resistance was put up at Lutzendorf.

The IGF Leuna Plant is located at Merseburg. This is the largest IGF plant and is made up principally of ammonia and nitrogen fixation plants.

SECRET

Figure D.490: Report of Raid on Merseburg. 22 May 1944. This report was of particular interest to Leslie Groves's Foreign Intelligence Unit [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)].

CIA Information Report. Dismantling of the Leuna Plant, Merseburg, Germany. 1948. FOIA CIA-RDP81-01028R000100080011-0
https://www.cia.gov/readingroom/document/cia-rdp81-01028r000100080011-0

The dismantling of the Leuna Plant in Merseburg, Thuringia, Germany (Soviet Zone), was initiated in March 1946. [...]

3. The following large installations were dismantled: [...]

(j) The heavy water installation operating at atmospheric pressure was dismantled and possibly placed in a building near the Agricultural Exhibition Grounds in Moscow.

(k) The heavy water installation operating at 700 atmospheres was taken to the Karpov Institute were it was being installed when we left in July 1948.

[This CIA report was classified until 2001, and parts of it still remain classified. It said I.G. Farben Leuna had at least two operating “large installations” for producing heavy water. Those and all information about them were removed to Moscow.]

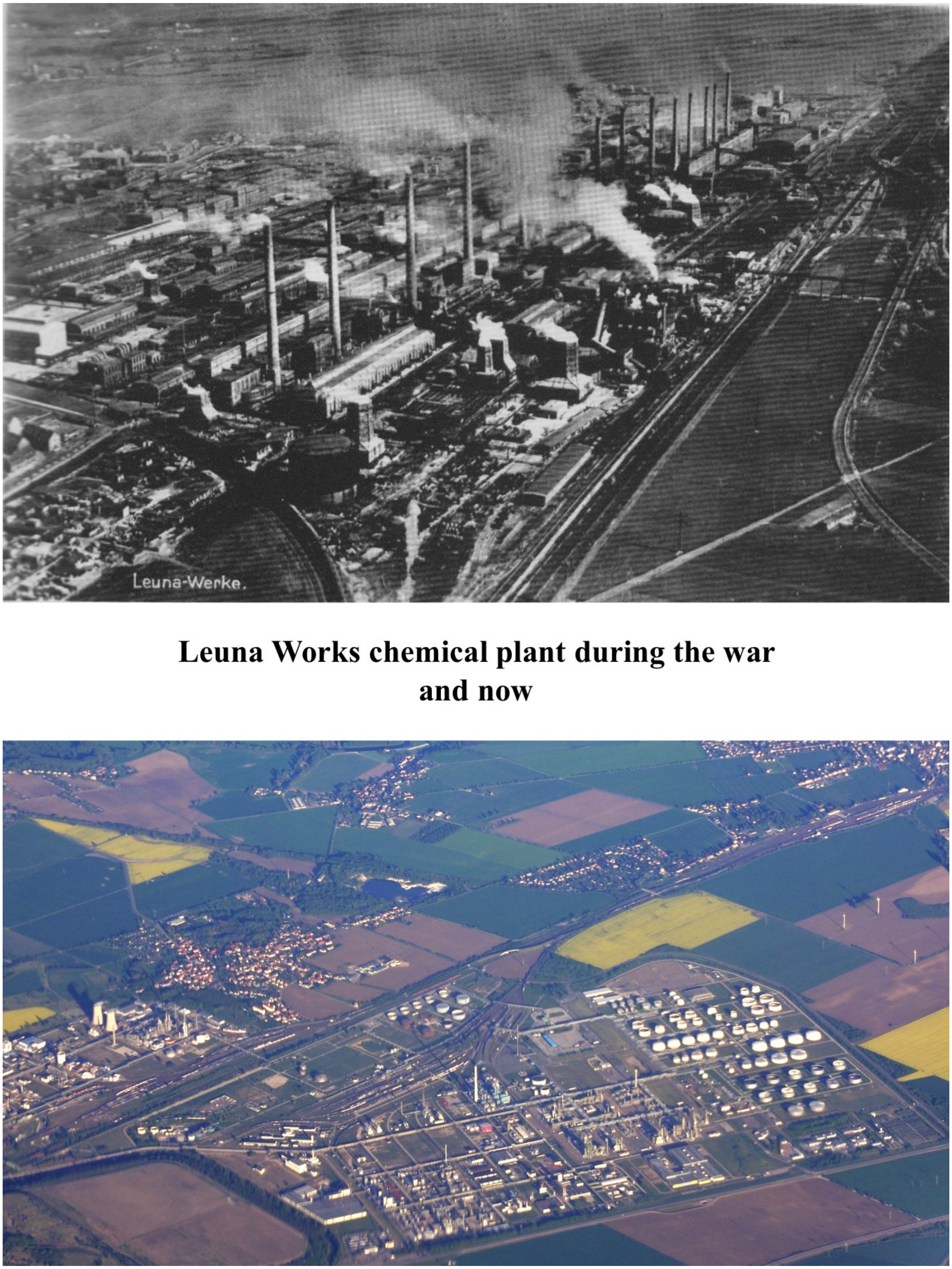

Leuna-Werke.
Leuna Works chemical plant during the war and now

Figure D.491: The massive I.G. Farben Leuna Works chemical plant had at least two heavy water production installations that were removed by the Soviet Union after the war.

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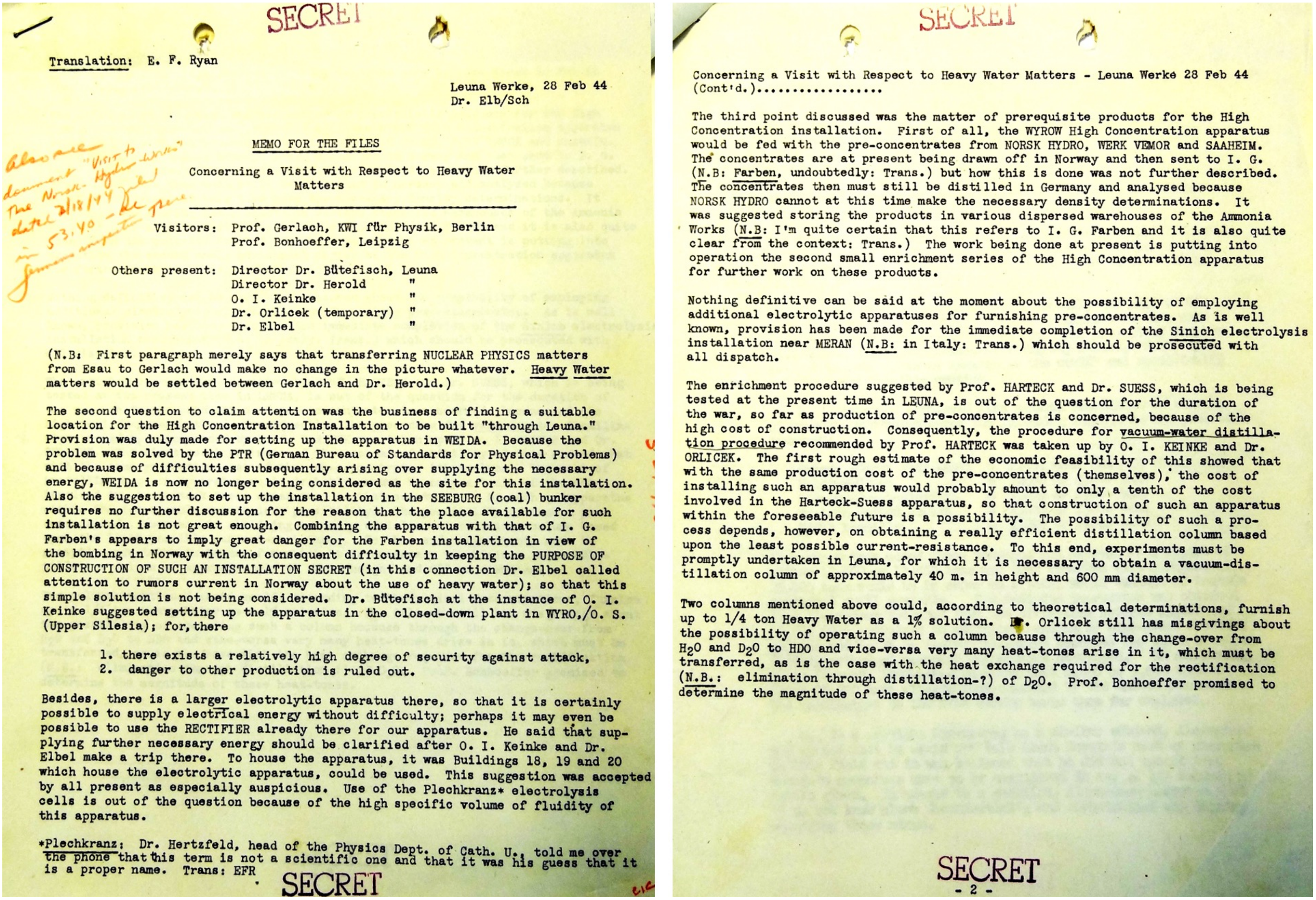
NARA RG 77, Entry UD-22A, Box 169, Folder 32.9132-1
Germ: Russ Int in Germ. Ind TA Leuna Werke



SECRET

Translation: E. F. Ryan

Leuna Werke, 28 Feb 44
Dr. Elb/Sch

Also see
document "Visit to
The Norsk- Hydro Works"
dated 2/18/44 filed
in 53.40 – Re
Germans inspection there

MEMO FOR THE FILES

Concerning a Visit with Respect to Heavy Water Matters

Visitors: Prof. Gerlach, KWI für Physik, Berlin
Prof. Bonhoeffer, Leipzig

Others present: Director Dr. Bütefisch, Leuna
Director Dr. Herold "
O. I. Keinke "
Dr. Orlicek (temporary) "
Dr. Elbel "

(N.B: First paragraph merely says that transferring NUCLEAR PHYSICS matters from Esau to Gerlach would make no change in the picture whatever. Heavy Water matters would be settled between Gerlach and Dr. Herold.)

The second question to claim attention was the business of finding a suitable location for the High Concentration Installation to be built "through Leuna." Provision was duly made for setting up the apparatus in WEIDA. Because the problem was solved by the PTR (German Bureau of Standards for Physical Problems) and because of difficulties subsequently arising over supplying the necessary energy, WEIDA is now no longer being considered as the site for this installation. Also the suggestion to set up the installation in the SEEBURG (coal) bunker requires no further discussion for the reason that the place available for such installation is not great enough. Combining the apparatus with that of I. G. Farben's appears to imply great danger for the Farben installation in view of the bombing in Norway with the consequent difficulty in keeping the PURPOSE OF CONSTRUCTION OF SUCH AN INSTALLATION SECRET (in this connection Dr. Elbel called attention to rumors current in Norway about the use of heavy water); so that this simple solution is not being considered. Dr. Bütefisch at the instance of O. I. Keinke suggested setting up the apparatus in the closed-down plant in WYRO,/O. S. (Upper Silesia); for, there

1. there exists a relatively high degree of security against attack,
2. danger to other production is ruled out.

Besides, there is a larger electrolytic apparatus there, so that it is certainly possible to supply electrical energy without difficulty; perhaps it may even be possible to use the RECTIFIER already there for our apparatus. He said that supplying further necessary energy should be clarified after O. I. Keinke and Dr. Elbel make a trip there. To house the apparatus, it was Buildings 18, 19 and 20 which house the electrolytic apparatus, could be used. This suggestion was accepted by all present as especially auspicious. Use of the Plechkranz* electrolysis cells is out of the question because of the high specific volume of fluidity of this apparatus.

*Plechkranz: Dr. Hertzfeld, head of the Physics Dept. of Cath. U., told me over the phone that this term is not a scientific one and that it was his guess that it is a proper name. Trans: EFR

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Concerning a Visit with Respect to Heavy Water Matters - Leuna Werke 28 Feb 44
(Cont'd.)..................

The third point discussed was the matter of prerequisite products for the High Concentration installation. First of all, the WYROW High Concentration apparatus would be fed with the pre-concentrates from NORSK HYDRO, WERK VEMOR and SAAHEIM. The concentrates are at present being drawn off in Norway and then sent to I. G. (N.B: Farben, undoubtedly: Trans.) but how this is done was not further described. The concentrates then must still be distilled in Germany and analysed because NORSK HYDRO cannot at this time make the necessary density determinations. It was suggested storing the products in various dispersed warehouses of the Ammonia Works (N.B: I'm quite certain that this refers to I. G. Farben and it is also quite clear from the context: Trans.) The work being done at present is putting into operation the second small enrichment series of the High Concentration apparatus for further work on these products.

Nothing definitive can be said at the moment about the possibility of employing additional electrolytic apparatuses for furnishing pre-concentrates. As is well known, provision has been made for the immediate completion of the Sinich electrolysis installation near MERAN (N.B: in Italy: Trans.) which should be prosecuted with all dispatch.

The enrichment procedure suggested by Prof. HARTECK and Dr. SUESS, which is being tested at the present time in LEUNA, is out of the question for the duration of the war, so far as production of pre-concentrates is concerned, because of the high cost of construction. Consequently, the procedure for vacuum-water distillation procedure recommended by Prof. HARTECK was taken up by O. I. KEINKE and Dr. ORLICEK. The first rough estimate of the economic feasibility of this showed that with the same production cost of the pre-concentrates (themselves), the cost of installing such an apparatus would probably amount to only a tenth of the cost involved in the Harteck-Suess apparatus, so that construction of such an apparatus within the foreseeable future is a possibility. The possibility of such a process depends, however, on obtaining a really efficient distillation column based upon the least possible current-resistance. To this end, experiments must be promptly undertaken in Leuna, for which it is necessary to obtain a vacuum-distillation column of approximately 40 m. in height and 600 mm diameter.

Two columns mentioned above could, according to theoretical determinations, furnish up to 1/4 ton Heavy Water as a 1% solution. Dr. Orlicek still has misgivings about the possibility of operating such a column because through the change-over from H_2O and D_2O to HDO and vice-versa very many heat-tones arise in it, which must be transferred, as is the case with the heat exchange required for the rectification (N.B.: elimination through distillation-?) of D_2O. Prof. Bonhoeffer promised to determine the magnitude of these heat-tones.

SECRET
- 2 -

Figure D.492: I.G. Farben Leuna Werke. 28 February 1944. Concerning a Visit with Respect to Heavy Water Matters [English translation, NARA RG 77, Entry UD-22A, Box 169, Folder 32.9132-1 Germ: Russ Int in Germ. Ind TA Leuna Werke].

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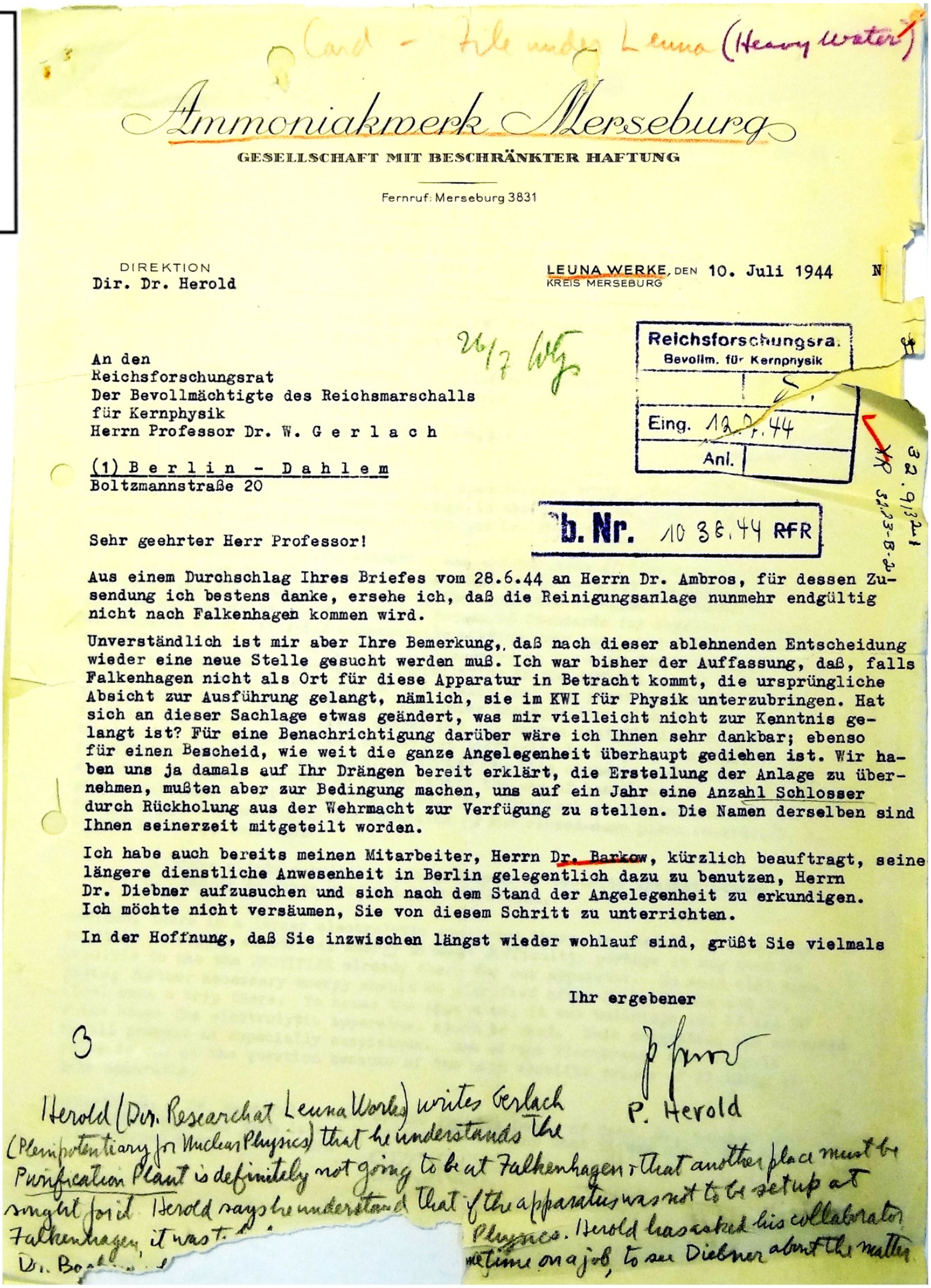


Card - file under Leuna (Heavy water)

Ammoniakwerk Merseburg
GESELLSCHAFT MIT BESCHRÄNKTER HAFTUNG
Fernruf: Merseburg 3831

DIREKTION
Dir. Dr. Herold

LEUNA WERKE, DEN 10. Juli 1944
KREIS MERSEBURG

N

26/7 Wtz

Reichsforschungsra
Bevollm. für Kernphysik
Eing. 12.7.44
Anl.

b. Nr. 10 38.44 RFR

32.9132-1
32.23-B-2

An den
Reichsforschungsrat
Der Bevollmächtigte des Reichsmarschalls
für Kernphysik
Herrn Professor Dr. W. Gerlach

(1) Berlin - Dahlem
Boltzmannstraße 20

Sehr geehrter Herr Professor!

Aus einem Durchschlag Ihres Briefes vom 28.6.44 an Herrn Dr. Ambros, für dessen Zusendung ich bestens danke, ersehe ich, daß die Reinigungsanlage nunmehr endgültig nicht nach Falkenhagen kommen wird.

Unverständlich ist mir aber Ihre Bemerkung, daß nach dieser ablehnenden Entscheidung wieder eine neue Stelle gesucht werden muß. Ich war bisher der Auffassung, daß, falls Falkenhagen nicht als Ort für diese Apparatur in Betracht kommt, die ursprüngliche Absicht zur Ausführung gelangt, nämlich, sie im KWI für Physik unterzubringen. Hat sich an dieser Sachlage etwas geändert, was mir vielleicht nicht zur Kenntnis gelangt ist? Für eine Benachrichtigung darüber wäre ich Ihnen sehr dankbar; ebenso für einen Bescheid, wie weit die ganze Angelegenheit überhaupt gediehen ist. Wir haben uns ja damals auf Ihr Drängen bereit erklärt, die Erstellung der Anlage zu übernehmen, mußten aber zur Bedingung machen, uns auf ein Jahr eine Anzahl Schlosser durch Rückholung aus der Wehrmacht zur Verfügung zu stellen. Die Namen derselben sind Ihnen seinerzeit mitgeteilt worden.

Ich habe auch bereits meinen Mitarbeiter, Herrn Dr. Barkow, kürzlich beauftragt, seine längere dienstliche Anwesenheit in Berlin gelegentlich dazu zu benutzen, Herrn Dr. Diebner aufzusuchen und sich nach dem Stand der Angelegenheit zu erkundigen. Ich möchte nicht versäumen, Sie von diesem Schritt zu unterrichten.

In der Hoffnung, daß Sie inzwischen längst wieder wohlauf sind, grüßt Sie vielmals

Ihr ergebener

P. Herold

3

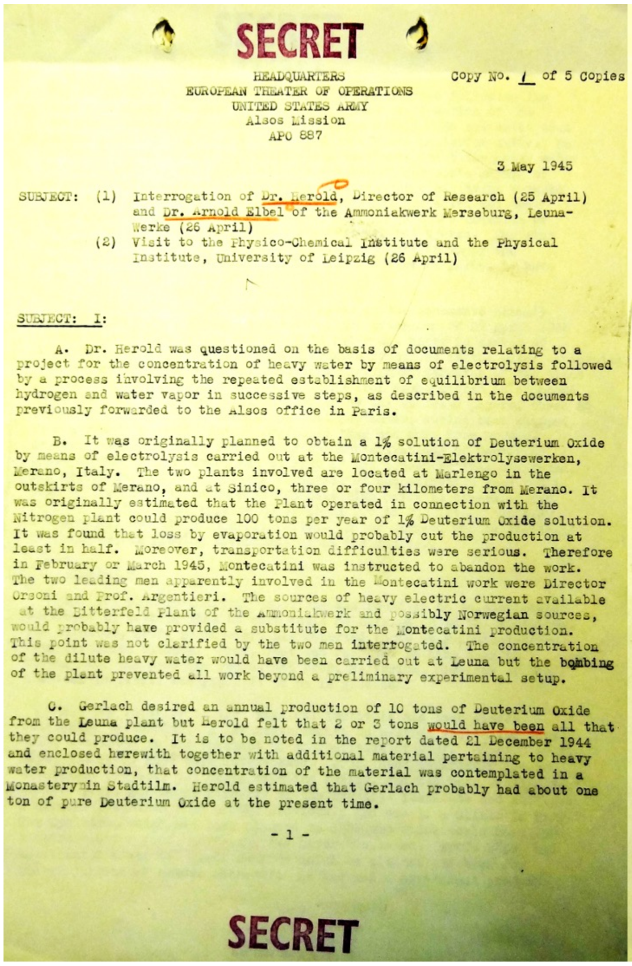
Herold (Dir. Research at Leuna Works) writes Gerlach (Plenipotentiary for Nuclear Physics) that he understands the Purification Plant is definitely not going to be at Falkenhagen & that another place must be sought for it. Herold says he understand that if the apparatus was not to be set up at Falkenhagen, it was t

Physics. Herold has asked his collaborator Dr. Bo

time on a job, to see Diebner about the matter

NARA RG 77, Entry UD-22A, Box 169, Folder 32.9132-1
Germ: Russ Int in Germ. Ind TA Leuna Werke

Figure D.493: Paul Herold to Walther Gerlach. 10 July 1944 [NARA RG 77, Entry UD-22A, Box 169, Folder 32.9132-1 Germ: Russ Int in Germ. Ind TA Leuna Werke].



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HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
Alsos Mission
APO 887

Copy No. 1 of 5 Copies

3 May 1945

SUBJECT: (1) Interrogation of Dr. Herold, Director of Research (25 April) and Dr. Arnold Elbel of the Ammoniakwerk Merseburg, Leuna-Werke (26 April)
(2) Visit to the Physico-Chemical Institute and the Physical Institute, University of Leipzig (26 April)

SUBJECT: I:

A. Dr. Herold was questioned on the basis of documents relating to a project for the concentration of heavy water by means of electrolysis followed by a process involving the repeated establishment of equilibrium between hydrogen and water vapor in successive steps, as described in the documents previously forwarded to the Alsos office in Paris.

B. It was originally planned to obtain a 1% solution of Deuterium Oxide by means of electrolysis carried out at the Montecatini-Elektrolysewerken, Merano, Italy. The two plants involved are located at Marlengo in the outskirts of Merano, and at Sinico, three or four kilometers from Merano. It was originally estimated that the Plant operated in connection with the Nitrogen plant could produce 100 tons per year of 1% Deuterium Oxide solution. It was found that loss by evaporation would probably cut the production at least in half. Moreover, transportation difficulties were serious. Therefore in February or March 1945, Montecatini was instructed to abandon the work. The two leading men apparently involved in the Montecatini work were Director Orsoni and Prof. Argentieri. The sources of heavy electric current available at the Bitterfeld Plant of the Ammoniakwerk and possibly Norwegian sources, would probably have provided a substitute for the Montecatini production. This point was not clarified by the two men interrogated. The concentration of the dilute heavy water would have been carried out at Leuna but the bombing of the plant prevented all work beyond a preliminary experimental setup.

C. Gerlach desired an annual production of 10 tons of Deuterium Oxide from the Leuna plant but Herold felt that 2 or 3 tons would have been all that they could produce. It is to be noted in the report dated 21 December 1944 and enclosed herewith together with additional material pertaining to heavy water production, that concentration of the material was contemplated in a Monastery in Stadtilm. Herold estimated that Gerlach probably had about one ton of pure Deuterium Oxide at the present time.

- 1 -

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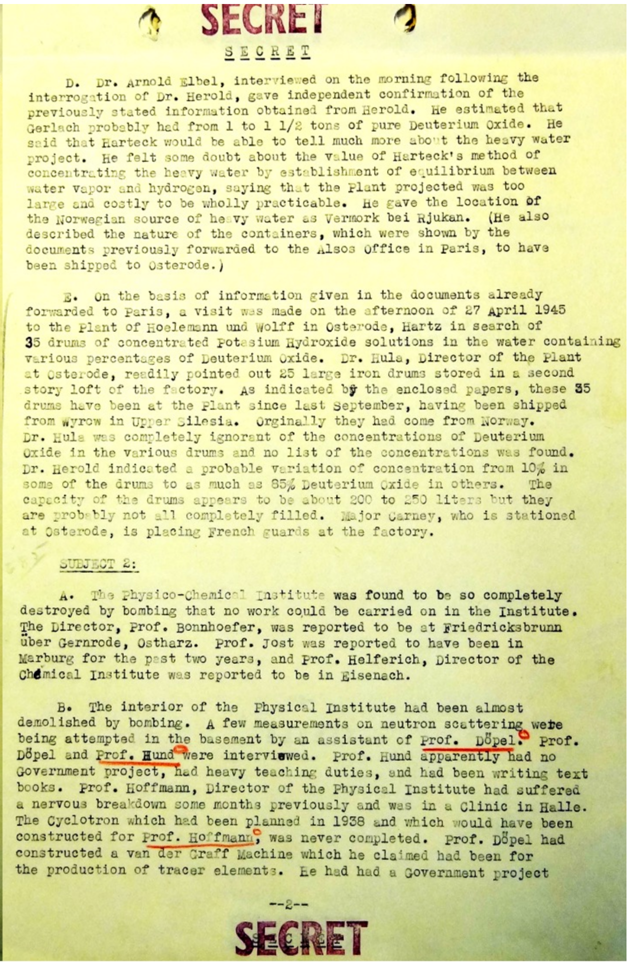

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S E C R E T

D. Dr. Arnold Elbel, interviewed on the morning following the interrogation of Dr. Herold, gave independent confirmation of the previously stated information obtained from Herold. He estimated that Gerlach probably had from 1 to 1 1/2 tons of pure Deuterium Oxide. He said that Harteck would be able to tell much more about the heavy water project. He felt some doubt about the value of Harteck's method of concentrating the heavy water by establishment of equilibrium between water vapor and hydrogen, saying that the Plant projected was too large and costly to be wholly practicable. He gave the location of the Norwegian source of heavy water as Vermork bei Rjukan. (He also described the nature of the containers, which were shown by the documents previously forwarded to the Alsos Office in Paris, to have been shipped to Osterode.)

E. On the basis of information given in the documents already forwarded to Paris, a visit was made on the afternoon of 27 April 1945 to the Plant of Hoelemann und Wolff in Osterode, Hartz in search of 35 drums of concentrated Potassium Hydroxide solutions in the water containing various percentages of Deuterium Oxide. Dr. Hula, Director of the Plant at Osterode, readily pointed out 25 large iron drums stored in a second story loft of the factory. As indicated by the enclosed papers, these 35 drums have been at the Plant since last September, having been shipped from Wyrow in Upper Silesia. Orginally they had come from Norway. Dr. Hula was completely ignorant of the concentrations of Deuterium Oxide in the various drums and no list of the concentrations was found. Dr. Herold indicated a probable variation of concentration from 10% in some of the drums to as much as 85% Deuterium Oxide in others. The capacity of the drums appears to be about 200 to 250 liters but they are probably not all completely filled. Major Carney, who is stationed at Osterode, is placing French guards at the factory.

SUBJECT 2:

A. The Physico-Chemical Institute was found to be so completely destroyed by bombing that no work could be carried on in the Institute. The Director, Prof. Bonnhoefer, was reported to be at Friedricksbrunn über Gernrode, Ostharz. Prof. Jost was reported to have been in Marburg for the past two years, and Prof. Helferich, Director of the Chemical Institute was reported to be in Eisenach.

B. The interior of the Physical Institute had been almost demolished by bombing. A few measurements on neutron scattering were being attempted in the basement by an assistant of Prof. Döpel. Prof. Döpel and Prof. Hund were interviewed. Prof. Hund apparently had no Government project, had heavy teaching duties, and had been writing text books. Prof. Hoffmann, Director of the Physical Institute had suffered a nervous breakdown some months previously and was in a Clinic in Halle. The Cyclotron which had been planned in 1938 and which would have been constructed for Prof. Hoffmann, was never completed. Prof. Döpel had constructed a van der Graff Machine which he claimed had been for the production of tracer elements. He had had a Government project

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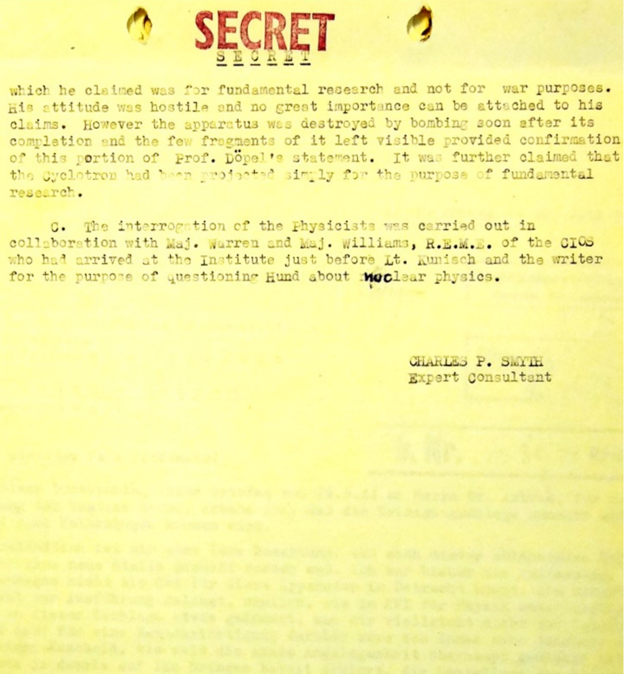

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S E C R E T

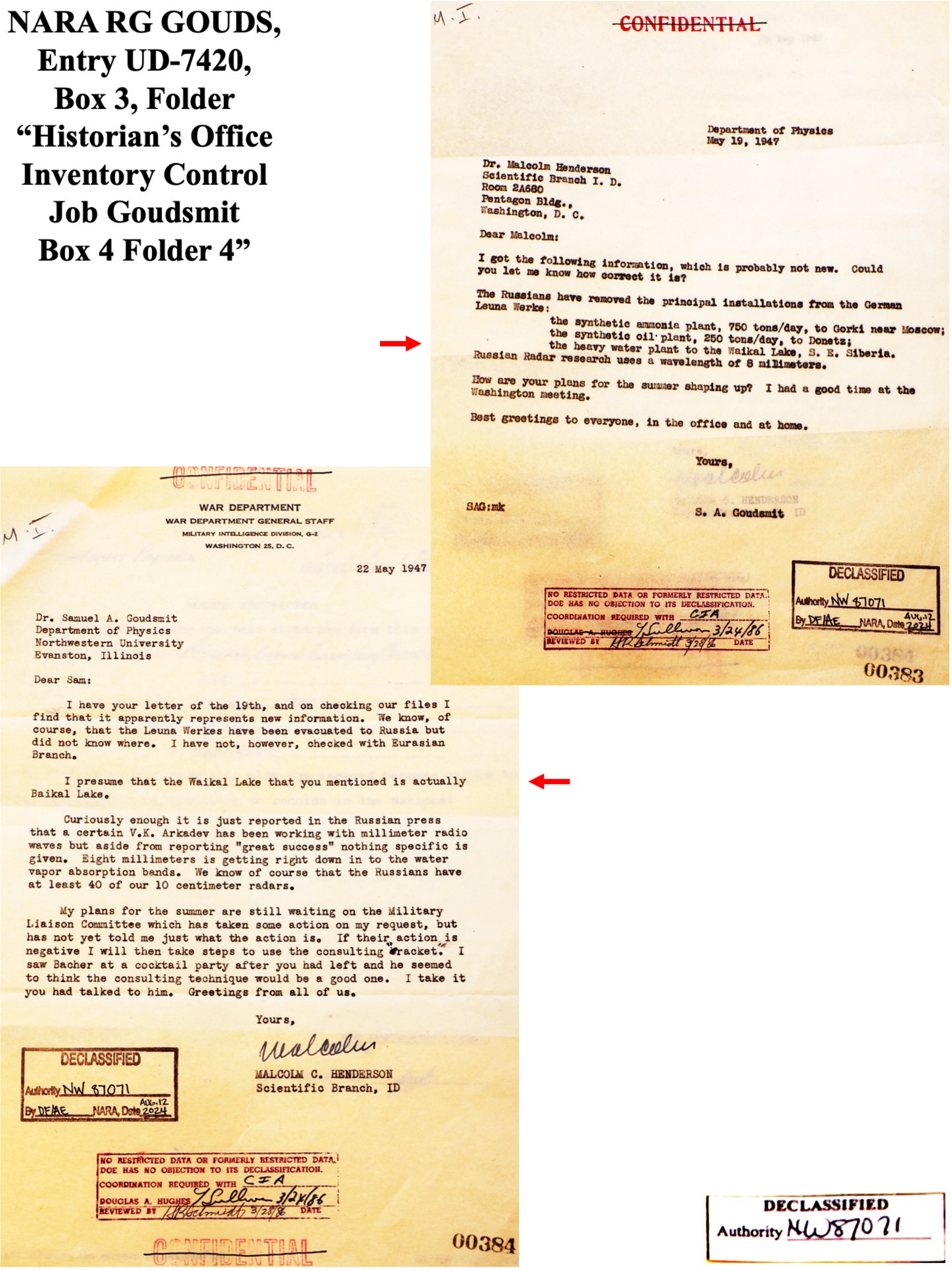
which he claimed was for fundamental research and not for war purposes. His attitude was hostile and no great importance can be attached to his claims. However the apparatus was destroyed by bombing soon after its completion and the few fragments of it left visible provided confirmation of this portion of Prof. Döpel's statement. It was further claimed that the Cyclotron had been projected simply for the purpose of fundamental research.

C. The interrogation of the Physicists was carried out in collaboration with Maj. Warren and Maj. Williams, R.E.M.E. of the CIOS who had arrived at the Institute just before Lt. Kunisch and the writer for the purpose of questioning Hund about nuclear physics.

CHARLES P. SMYTH
Expert Consultant

NARA RG 77, Entry UD-22A,
Box 169, Folder 32.9132-1
Germ: Russ Int in Germ.
Ind TA Leuna Werke

Figure D.494: Charles P. Smyth. 3 May 1945 [NARA RG 77, Entry UD-22A, Box 169, Folder 32.9132-1 Germ: Russ Int in Germ. Ind TA Leuna Werke].



**NARA RG GOUDS,
Entry UD-7420,
Box 3, Folder
"Historian's Office
Inventory Control
Job Goudsmit
Box 4 Folder 4"**

M.I.

~~CONFIDENTIAL~~

Department of Physics
May 19, 1947

Dr. Malcolm Henderson
Scientific Branch I. D.
Room 2A680
Pentagon Bldg.,
Washington, D. C.

Dear Malcolm:

I got the following information, which is probably not new. Could you let me know how correct it is?

The Russians have removed the principal installations from the German Leuna Werke:

the synthetic ammonia plant, 750 tons/day, to Gorki near Moscow;
the synthetic oil plant, 250 tons/day, to Donetz;
the heavy water plant to the Waikal Lake, S. E. Siberia.

Russian Radar research uses a wavelength of 8 milimeters.

How are your plans for the summer shaping up? I had a good time at the Washington meeting.

Best greetings to everyone, in the office and at home.

Yours,

S. A. Goudsmit

SAG:mk

NO RESTRICTED DATA OR FORMERLY RESTRICTED DATA.
DOE HAS NO OBJECTION TO ITS DECLASSIFICATION.
COORDINATION REQUIRED WITH CIA
~~DOUGLAS A. HUGHES~~ J Sullivan 3/24/86
REVIEWED BY HR Schmidt 3/28/86 DATE

DECLASSIFIED
Authority NW 87071
By DE/AE NARA, Date AUG.12 2024

00383

~~CONFIDENTIAL~~

WAR DEPARTMENT
WAR DEPARTMENT GENERAL STAFF
MILITARY INTELLIGENCE DIVISION, G-2
WASHINGTON 25, D. C.

M.I.

22 May 1947

Dr. Samuel A. Goudsmit
Department of Physics
Northwestern University
Evanston, Illinois

Dear Sam:

I have your letter of the 19th, and on checking our files I find that it apparently represents new information. We know, of course, that the Leuna Werkes have been evacuated to Russia but did not know where. I have not, however, checked with Eurasian Branch.

I presume that the Waikal Lake that you mentioned is actually Baikal Lake.

Curiously enough it is just reported in the Russian press that a certain V.K. Arkadev has been working with millimeter radio waves but aside from reporting "great success" nothing specific is given. Eight millimeters is getting right down in to the water vapor absorption bands. We know of course that the Russians have at least 40 of our 10 centimeter radars.

My plans for the summer are still waiting on the Military Liaison Committee which has taken some action on my request, but has not yet told me just what the action is. If their action is negative I will then take steps to use the consulting "racket." I saw Bacher at a cocktail party after you had left and he seemed to think the consulting technique would be a good one. I take it you had talked to him. Greetings from all of us.

Yours,

Malcolm

MALCOLM C. HENDERSON
Scientific Branch, ID

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By DE/AE NARA, Date AUG.12 2024

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DOUGLAS A. HUGHES J Sullivan 3/24/86
REVIEWED BY HR Schmidt 3/28/86 DATE

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Figure D.495: Samuel Goudsmit to Malcolm Henderson. 19 May 1947 [NARA RG GOUDS, Entry UD-7420, Box 3, Folder "Historian's Office Inventory Control Job Goudsmit Box 4 Folder 4"]. "The Russians have removed the principal installations from the German Leuna Werke: ...the heavy water plant."

6. I.G. Farben Bitterfeld

A. S. Sadovsky. 2011b. Heavy Water. History of One Priority. Part 2. https://www.academia.edu/39286335/Heavy_water_History_of_one_priority_Part_2_031e

Somewhat earlier 4 September [1945] it was formulated the decree of the State Defense Committee 9967ss, which ordered to him:

> “c) That the research and test works on making product 180 [heavy water] by electrolytic separation, isotopic exchange, and distillation methods be organized in GSNII-42, at the Moscow Electrolysis Factory, and in the Karpov Physical-Chemical Institute. That for this purpose be used the installations found at the German chemical plants in Leuna Werke and Bitterfeld. <...>
>
> 4. It shall be the responsibility of the Narcomkhimprom [eng: People’s Commissar for the Chemical Industry] (Cde. Pervukhin) and USSR NKO [eng: People’s Commissariat of Defense] (Cde. Khrulev) to provide evacuation from Germany <...> and transportation to Narcomkhimprom facilities <...> of the following equipment:
>
> a) distillation tower and the pilot-scale electrolyzer from the Bitterfeld plant within the period from 10 September till 20 September 1945;
>
> b) small pilot plant from Leuna Werke factory within the period from 10 September till 20 September 1945;
>
> c) big pilot plant from Leuna Werke factory within the period from 10 September till 20 September 1945;
>
> Cde. Pervukhin is to send to the place one of his deputies to exercise control over dismantling of the specified equipment, its repair if necessary, ensure its complete package and oversee its entrainment at factories as well as at the Lvov storage terminal.”

There was a
heavy water production plant
at I.G. Farben Bitterfeld

Bundesarchiv, DH 2 Bild-F-01956
Foto: Wolter | September 1959

Figure D.496: There was a heavy water production plant at I.G. Farben Bitterfeld during the war [Karlsch 2005, p. 110; Sadovsky 2011b]. (This is a later photograph showing part of the Bitterfeld chemical production complex.)

7. I.G. Farben Halle

7 June 1946. Recruitment of German Scientists; Heavy Water Production at Halle. Strategic Services Unit, Top Secret report [NARA RG 319, Entry NM3-85M, Box 51, Folders 926136–926139].

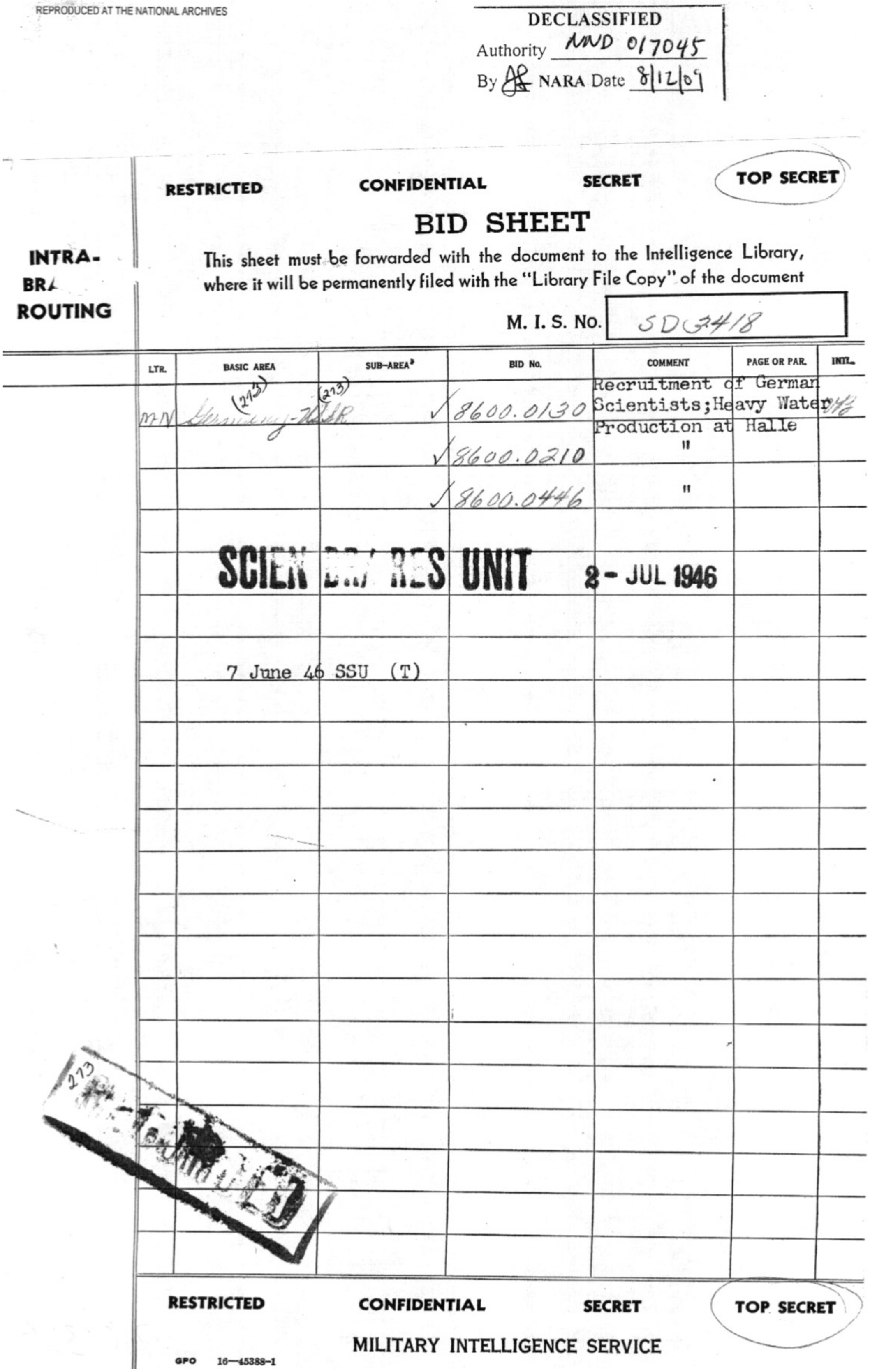
[See pp. 4053–4054.]

U.S. intelligence card catalog [NARA RG 319, Entry A1-84E, Box 124].

[See p. 4055.

U.S. intelligence cover pages and card catalog entries show that there was a heavy water production plant at Halle, but documents about the plant are still classified and unavailable to the public. Why?

Halle is close to Leuna/Merseburg. It is possible that the referenced Halle heavy water plant was the same as one of the Leuna Werke heavy water plants, but most likely it was a separate plant. That entire region was covered with chemical plants.]



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INTRA-BRA ROUTING

M. I. S. No. SD3418

LTR.	BASIC AREA	SUB-AREA*	BID No.	COMMENT	PAGE OR PAR.	INTL.
M-N	(273) Germany-USSR	(273)	✓ 8600.0130	Recruitment of German Scientists; Heavy Water Production at Halle		[illegible]
			✓ 8600.0210	"		
			✓ 8600.0446	"		

SCIEN [illegible] RES UNIT 2 - JUL 1946

7 June 46 SSU (T)

273

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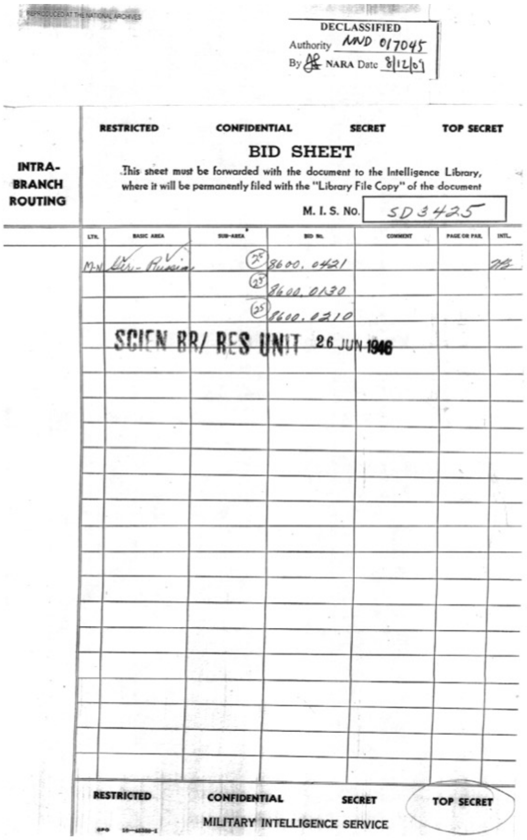
GPO 16—45388-1

Figure D.497: A U.S. intelligence cover page shows that there was a heavy water production plant at Halle, but documents about the plant are still classified and unavailable to the public [NARA RG 319, Entry NM3-85M, Box 51, Folders 926136–926139].



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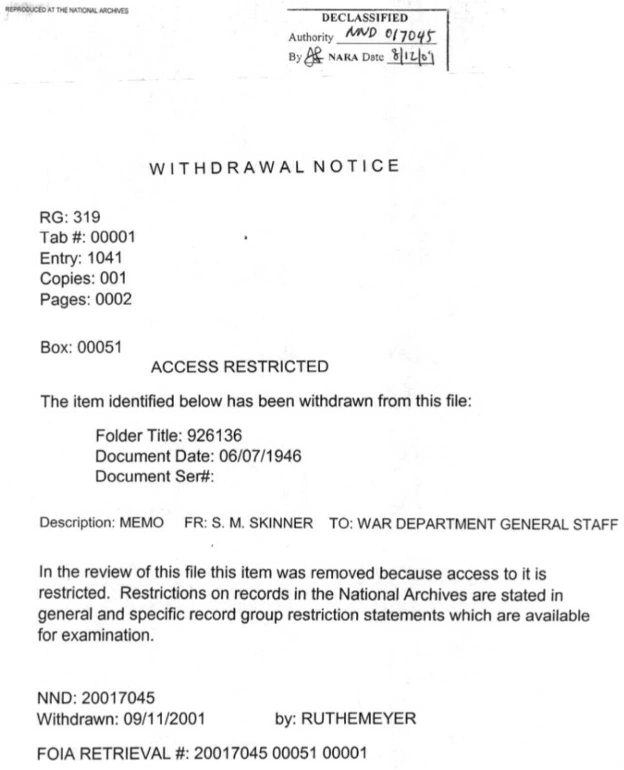
LTR.	BASIC AREA	SUB-AREA	BID NO.	COMMENT	PAGE OR PAR.	INTL.
M-N	Ger.-Russia	㉕	8600.0421			
		㉕	8600.0130			
		㉕	8600.0210			

SCIEN BR/ RES UNIT 26 JUN 1946

RESTRICTED CONFIDENTIAL SECRET [✓ TOP SECRET]

MILITARY INTELLIGENCE SERVICE



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WITHDRAWAL NOTICE

RG: 319
Tab #: 00001
Entry: 1041
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The item identified below has been withdrawn from this file:

Folder Title: 926136
Document Date: 06/07/1946
Document Ser#:

Description: MEMO FR: S. M. SKINNER TO: WAR DEPARTMENT GENERAL STAFF

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination.

NND: 20017045
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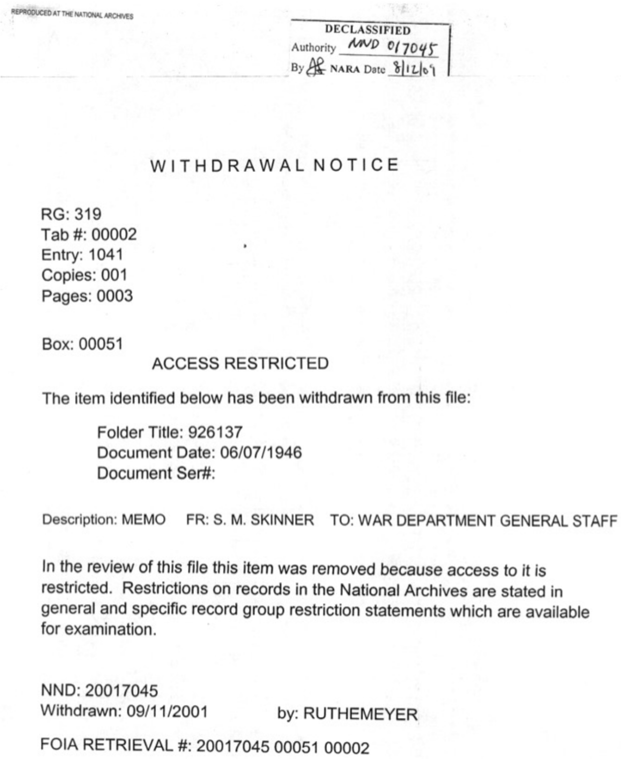

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Entry: 1041
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Document Date: 06/07/1946
Document Ser#:

Description: MEMO FR: S. M. SKINNER TO: WAR DEPARTMENT GENERAL STAFF

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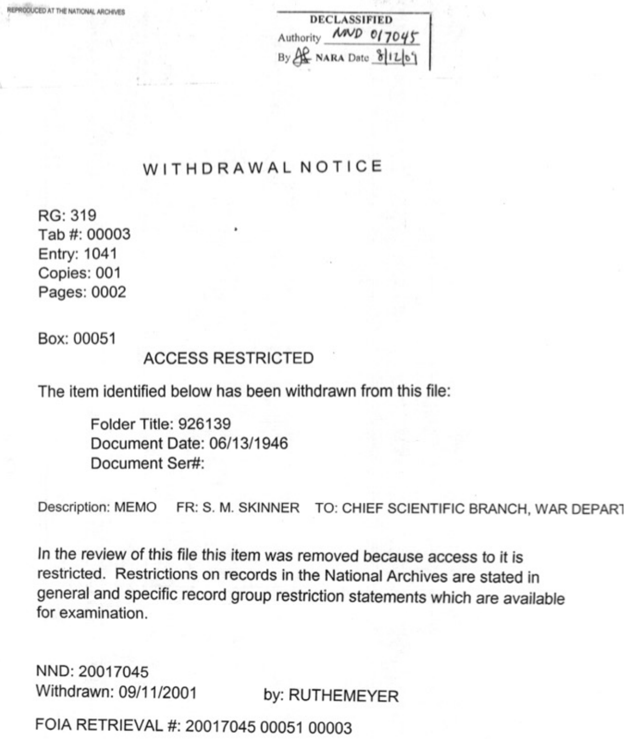
FOIA RETRIEVAL #: 20017045 00051 00002



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Authority NND 017045
By NARA Date 8/12/09

WITHDRAWAL NOTICE

RG: 319
Tab #: 00003
Entry: 1041
Copies: 001
Pages: 0002

Box: 00051
ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

Folder Title: 926139
Document Date: 06/13/1946
Document Ser#:

Description: MEMO FR: S. M. SKINNER TO: CHIEF SCIENTIFIC BRANCH, WAR DEPART

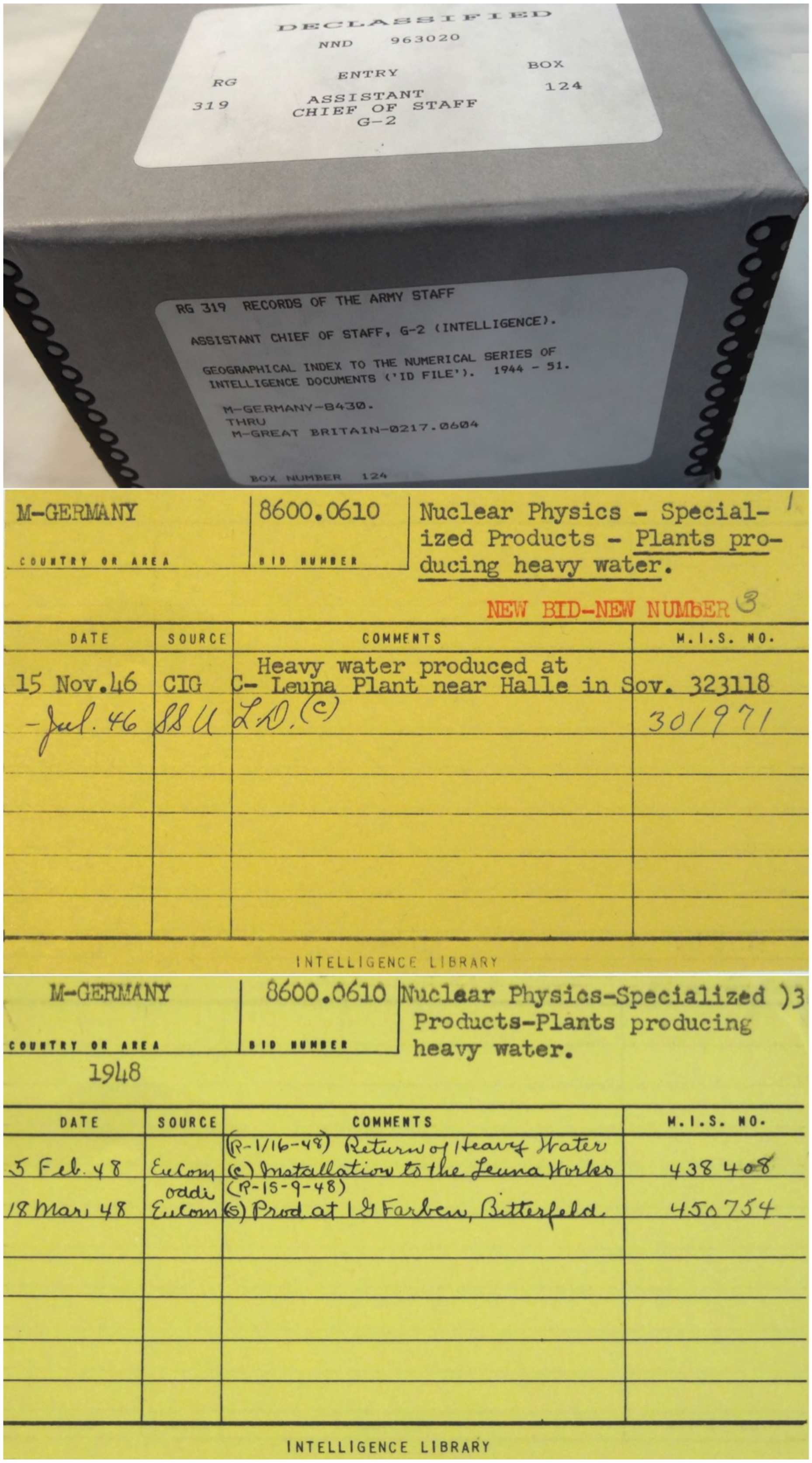
In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination.

NND: 20017045
Withdrawn: 09/11/2001 by: RUTHEMEYER

FOIA RETRIEVAL #: 20017045 00051 00003

Figure D.498: A U.S. intelligence cover page shows that there was a heavy water production plant at Halle, but documents about the plant are still classified and unavailable to the public [NARA RG 319, Entry NM3-85M, Box 51, Folders 926136–926139].

DECLASSIFIED
Authority NND 963020



DECLASSIFIED
NND 963020
RG 319
ENTRY
ASSISTANT CHIEF OF STAFF G-2
BOX 124

RG 319 RECORDS OF THE ARMY STAFF
ASSISTANT CHIEF OF STAFF, G-2 (INTELLIGENCE).
GEOGRAPHICAL INDEX TO THE NUMERICAL SERIES OF INTELLIGENCE DOCUMENTS ('ID FILE'). 1944 - 51.
M-GERMANY-8430.
THRU
M-GREAT BRITAIN-0217.0604
BOX NUMBER 124

M-GERMANY
COUNTRY OR AREA

8600.0610
BID NUMBER

Nuclear Physics - Specialized Products - Plants producing heavy water. 1

NEW BID-NEW NUMbER 3

DATE	SOURCE	COMMENTS	M.I.S. NO.
15 Nov.46	CIG	C- Heavy water produced at Leuna Plant near Halle in Sov.	323118
-Jul. 46	SSU	L.D.(c)	301971

INTELLIGENCE LIBRARY

M-GERMANY
COUNTRY OR AREA

8600.0610
BID NUMBER

Nuclear Physics-Specialized Products-Plants producing heavy water.)3

1948

DATE	SOURCE	COMMENTS	M.I.S. NO.
5 Feb. 48	Eucom	(R-1/16-48) Return of Heavy Water (c) Installation to the Leuna Works	438408
18 Mar. 48	oddi Eucom	(R-15-9-48) (S) Prod. at IG Farben, Bitterfeld.	450754

INTELLIGENCE LIBRARY

NARA RG 319,
Entry A1-84E, Box 124

Figure D.499: A U.S. intelligence card catalog shows that there were heavy water production plants at Halle, Leuna, and Bitterfeld, but documents about the plants are still classified and unavailable to the public [NARA RG 319, Entry A1-84E, Box 124].

8. Kiel

Charles Chamberlain. Reveal Allied Capture of Nazi Atom Factory. *Chicago Daily Tribune.* 9 August 1945 p. 4. http://archives.chicagotribune.com/1945/08/09/page/4/article/reveal-allied-capture-of-nazi-atom-factory/

KIEL, Germany, Aug. 8 (AP)—The largest heavy water plant in Germany, where Nazi scientists were working feverishly to perfect an atomic bomb, was captured almost intact by the allies three months ago in a heavily wooded section four miles from Kiel.

Cobwebs of plastic pipes connected eight huge vats holding thousands of gallons of plain water for processing into heavy water.

I stumbled onto the factory two weeks after it was taken over by American and British technicians. Altho they gave me freedom to roam around the grounds, I was called on the carpet the next day for entering without authority from high officials and was required to pledge not to reveal what I had seen until it was released. Altho the race to perfect the bomb was led by American and British experts, the Germans had made great strides and were catching up. The war against Germany ended just in time.

Charles Chamberlain. Allies Beat Nazis By Narrow Margin in Atomic Race. *Harrisburg Telegraph.* 9 August 1945 p. 6.
https://www.newspapers.com/article/harrisburg-telegraph/1961441/

KIEL, Germany, Aug. 9, (AP)—A race against time was won by the Allies by a narrow margin three months ago when the largest heavy water plant in Germany, where Nazi scientists labored furiously to perfect an atomic bomb, was captured intact.

It may now be disclosed that the Allies were so concerned over possible German progress with the bomb that they planned a bold mass parachute attack on Kiel as early as last March to take the experimental station, just outside this base.

The plan was dropped only after the successful Allied crossing of the Rhine, this correspondent learned.

The Kiel plant, captured almost intact three months ago and turned over to British and American specialists, was buried in a camouflaged concrete vault on a wooded hillside and contained eight vats for the manufacture of "D-2O," or heavy water—used in one of the possible processes for producing atomic bombs.

Cobwebs of connecting plastic pipes and files recording the experiments were destroyed by sabotage before the Allies arrived.

The extent of the Nazis' atomic discoveries remains a top secret. But they were making great strides and were catching up. The European war ended just in time.

Among the secret weapons in production at the factory were acoustics torpedoes driven by "ingolene," a fuel described by some sources as 800 times as powerful as high octane gasoline.

[See also:

Charles Chamberlain. Germans' Bomb Plant Located: Nazis Worked Hard on Atomic Device. *San Bernardino Sun.* 12 August 1945 p. 3. https://cdnc.ucr.edu/cgi-bin/cdnc?a=d&d=SBS19450812.1.3

Charles Chamberlain. Atom Race Won By Extremely Narrow Margin. *Ogden Standard Examiner.* 13 August 1945 p. 9. https://newspaperarchive.com/ogden-standard-examiner-aug-13-1945-p-9/

According to Chamberlain, "the largest heavy water plant in Germany" was located approximately four miles from central Kiel, was part of a larger factory that also produced torpedoes, and was hidden in a large concrete bunker buried in an adjacent "heavily wooded hillside." See pp. 4059–4061 for the likely location. Can any remains of this heavy water plant be found now?

As Chamberlain stated, many World War II German torpedoes were powered by "Ingolene," or concentrated hydrogen peroxide. Concentrated hydrogen peroxide was also used as propellant for some rockets and was indeed quite potent, though not far more powerful than gasoline. Chamberlain appears to have heard incorrect information on that point.

Chamberlain specifically remarked that the heavy water plant used a large amount of plastic pipe. While plastic pipe is very common now, it was relatively new and much less common at that time (see p. 643). It would have been used to avoid problems with corrosion and to keep the heavy water as pure as possible.

Chamberlain mentioned that the heavy water plant was partially damaged and its files destroyed or removed by Germans before Allied forces reached the plant.

Chamberlain also reported (based on what he saw and what he heard from Allied forces at the Kiel heavy water plant) that "Nazi scientists were working feverishly to perfect an atomic bomb" and that "The extent of the Nazis' atomic discoveries remains a top secret. But they were making great strides." Chamberlain made it clear that his description of the advanced state of the German nuclear program came directly from Allied investigators, not just his own opinions: "the Allies were so concerned over possible German progress with the bomb that they planned a bold mass parachute attack on Kiel as early as last March to take the experimental station."

The sequence of events behind Chamberlain's reports appears to be:

1. Chamberlain said that he "stumbled onto the factory two weeks after it was taken over by American and British technicians," so he probably discovered it in early or mid-May 1945.

2. Chamberlain was promptly reprimanded by Allied officials for even visiting the heavy water plant—he "was called on the carpet the next day for entering without authority from high officials." That censorship explains why Chamberlain did not publish any articles about the heavy water plan in May 1945.

3. In Allied countries, nuclear-related news articles were commonly censored during the war, up until the public announcement of the Hiroshima bombing. After widespread media reports about Hiroshima and the unveiling of the U.S. nuclear program, Chamberlain presumably thought he could finally report what he had learned in May 1945 regarding the German nuclear program. That explains why his first articles on this topic appeared in August 1945.

4. While it had become permissible to reveal (some) information about the U.S. nuclear program, apparently most details about the former German nuclear program were still closely guarded and publicly denied. Since Chamberlain's reports of this otherwise secret Kiel heavy water production facility and his description of the advanced state of the German nuclear program somehow slipped through censorship and got published in August 1945, he was likely reprimanded for a second and final time by government censors and/or his own newspaper employers. He does not seem to have ever mentioned the Kiel heavy water plant again.

5. In fact, when Chamberlain published an article about the Vemork heavy water plant in February 1946 (p. 4058), he made no mention of the Kiel heavy water plant that he had seen with his own eyes, even though it would have been relevant to the article. He also downplayed the state of the German nuclear program that he himself had reported only six months earlier was quite advanced.

6. The existence of the Kiel heavy water plant and Allied plans to attack it in March 1945 because the German nuclear program was so advanced appear to be historical facts that Allied governments buried in 1945 and that remain buried to this day.]

Charles Chamberlain. Germans Failed to Split Atom: Experiments With Heavy Water Futile. *Council Bluffs Nonpareil* (Council Bluffs, Iowa). 9 February 1946 p. 1. https://www.newspapers.com/article/the-daily-nonpareil/1957966/

MINDEN Germany, (AP)—German experiments with heavy water in attempts to split the atom during the war were unsatisfactory Prof. Otto Hahn, Germany's Nobel prize winning atomic scientist said Saturday.

'In itself heavy water is not an effective radio-active substance, but is used as an auxiliary for the splitting of uranium atoms,' he explained. 'We expected to need heavy water, but it was not so. Americans have proved that this can be done more simply and effectively by using carbon.'

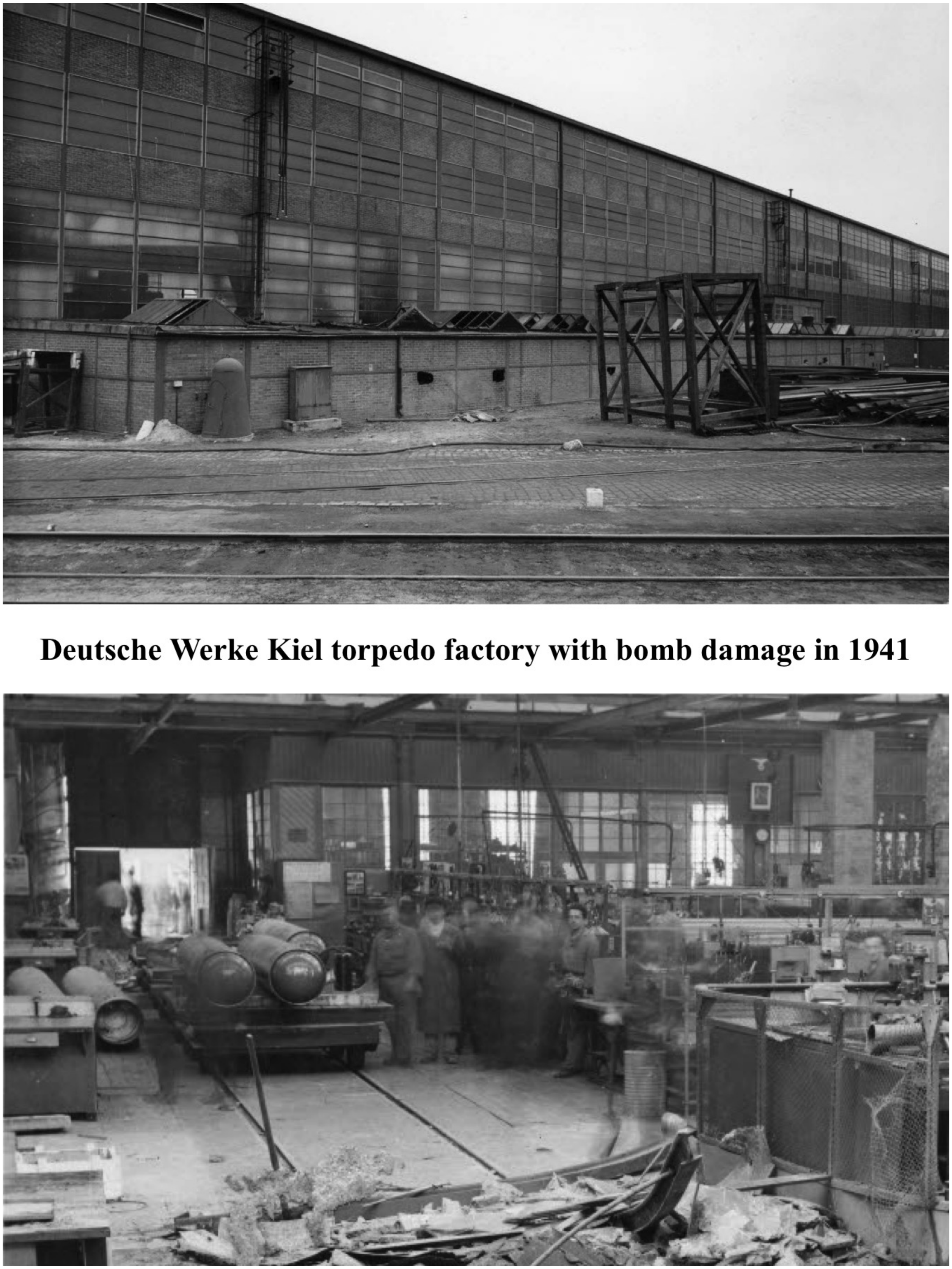
Heavy water plants were built by the Nazis in Norway for atomic bomb research work. British and Norwegian commandos in a highly successful raid blew them up.

(Heavy water has a specific gravity greater than ordinary water. Its hydrogen content is of atomic weight two, rather than atomic weight one).

Another atom scientist in the British occupation zone of Germany—Prof. Paul Harteck of the Kaiser Wilhelm institute of physics in Berlin—said that the light rays thrown out during the enormous explosion of an atomic bomb added greatly to the destructive force.

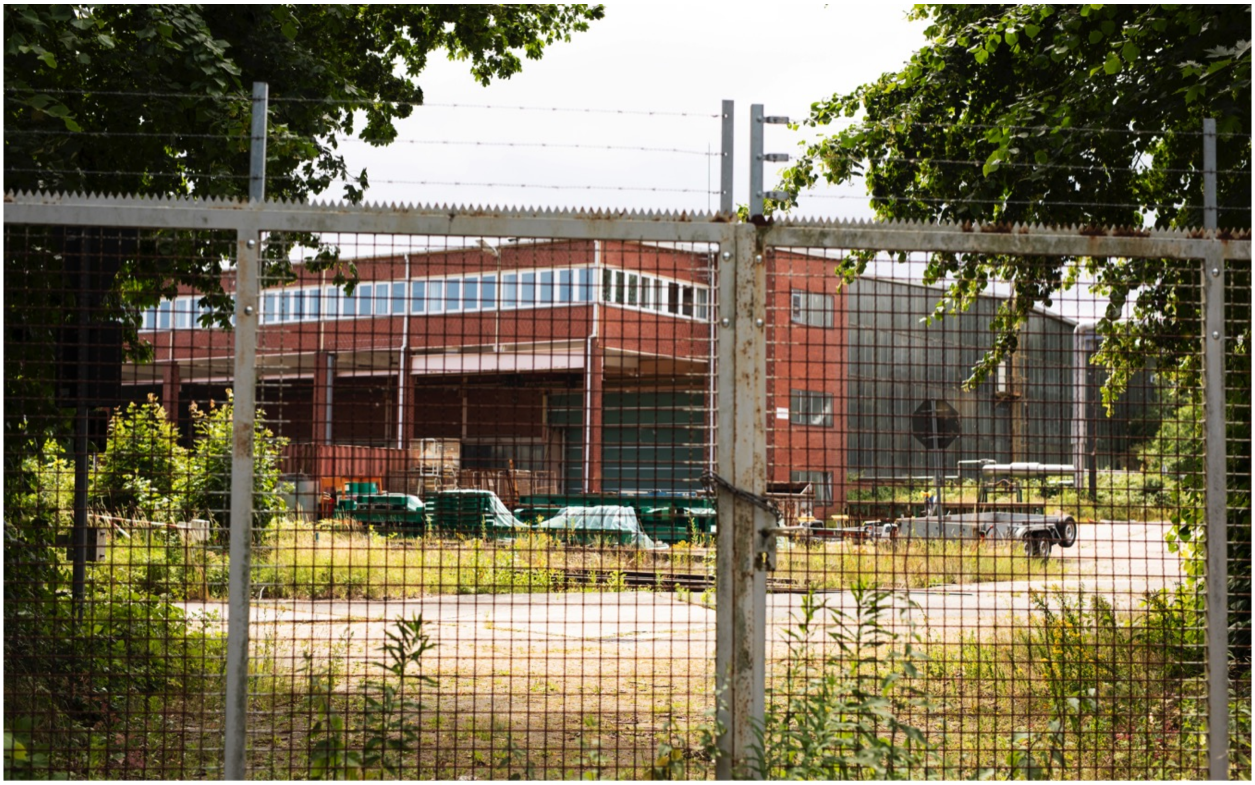
'The splitting of the atom causes a temperature of more than 10,000,000 degrees and aerial allure which destroy everything,' Harteck said.

This frees an amount of light which is beyond the visible spectrum. Only a few people know that the reflection of beams of light on solid bodies also exerts a mechanical pressure. This pressure is so small where our normal light is concerned that it is not noticed. The amount of light freed by an atomic bomb is so great it destroys walls.



Deutsche Werke Kiel torpedo factory with bomb damage in 1941

Figure D.500: The Deutsche Werke Kiel torpedo factory (shown here with bomb damage in 1941) was approximately four miles north of central Kiel, and is likely the location that Charles Chamberlain described.



Site of the former Deutsche Werke Kiel now.
The round concrete bunker was built during the war.

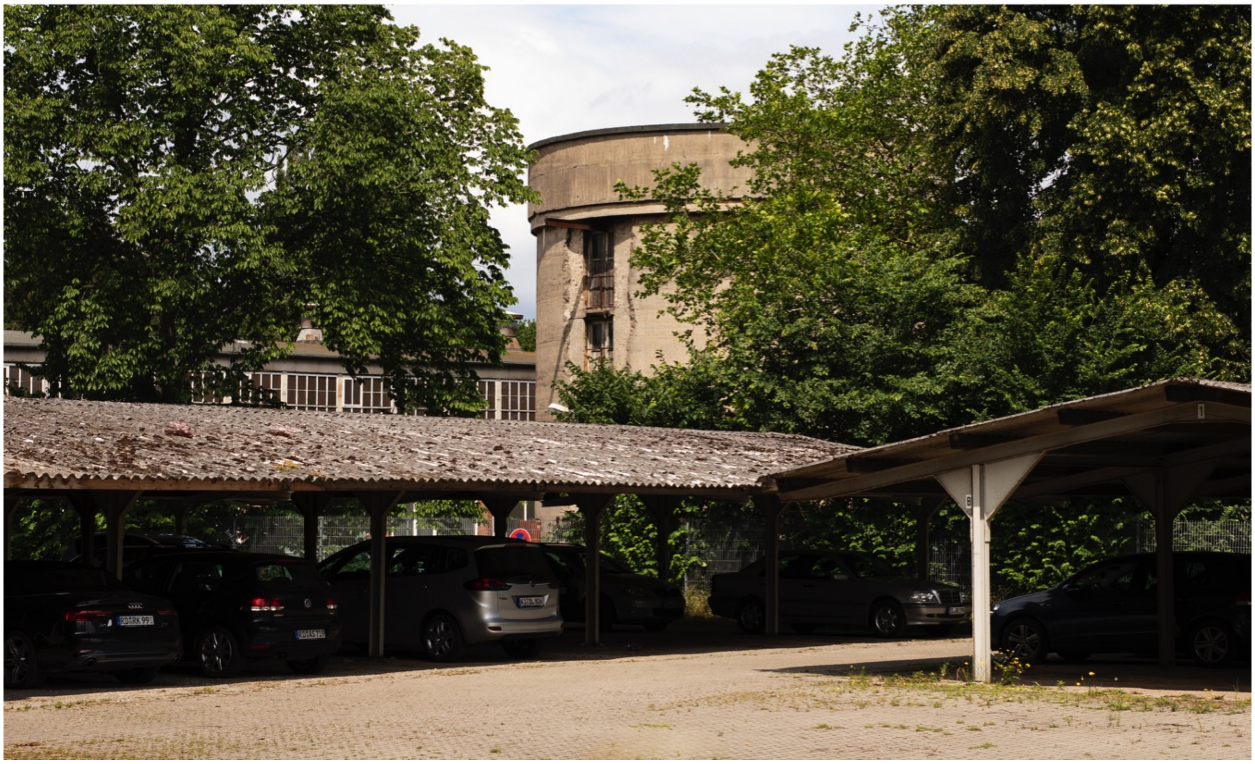


Figure D.501: Site of the former Deutsche Werke Kiel now. The round concrete bunker (lower photo) was built during the war. Other bunkers are known to have been built, but have been demolished or paved over.

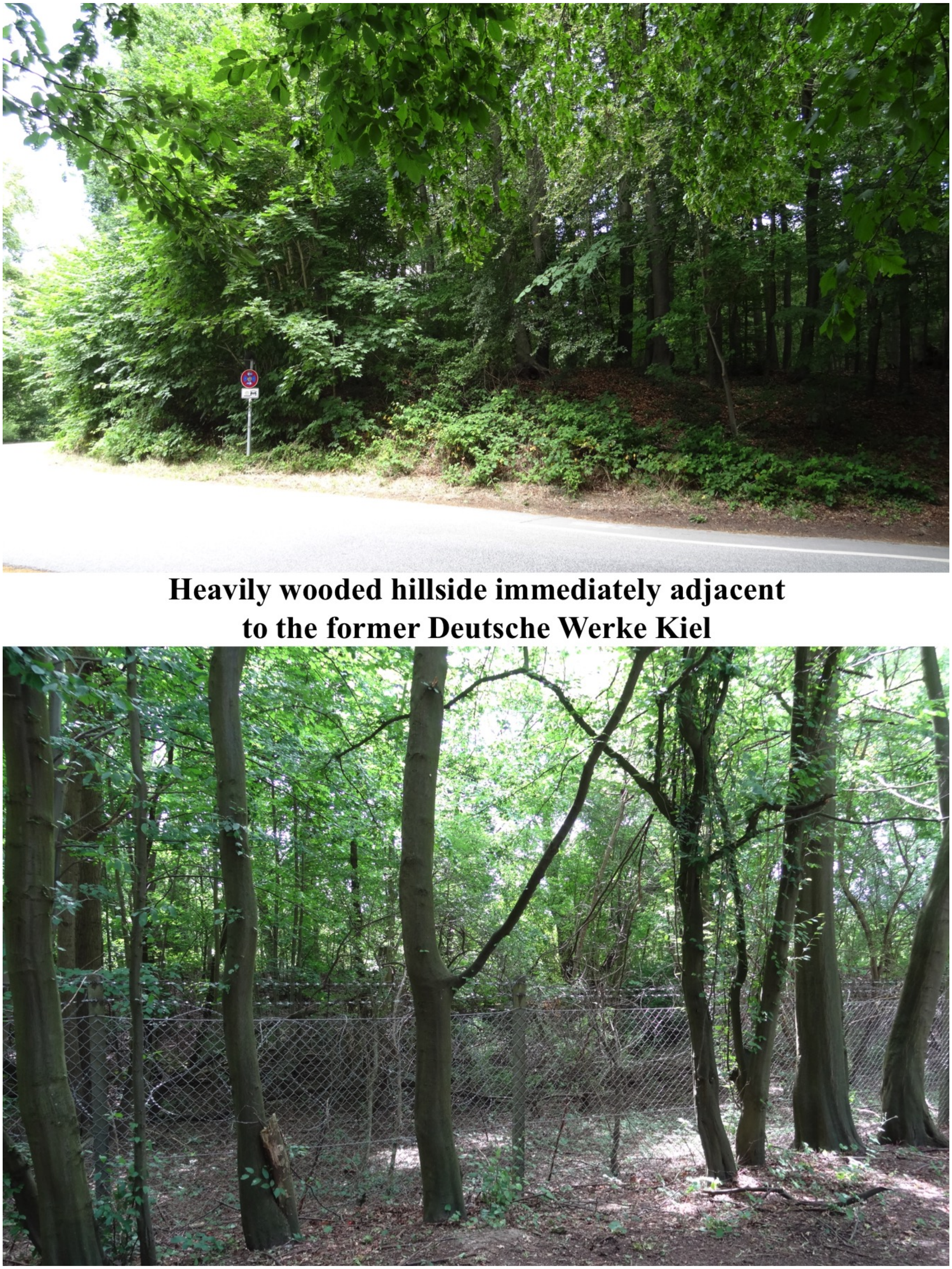

Heavily wooded hillside immediately adjacent
to the former Deutsche Werke Kiel

Figure D.502: There is a heavily wooded hillside immediately adjacent to the former Deutsche Werke Kiel, exactly as Charles Chamberlain described. Are the remains of the heavy water bunker in this area?

9. Dräger Werke, Lübeck

OSS London. 5 December 1944. Report T-2805-a. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

Original No. T-2805-a

Report from Sweden

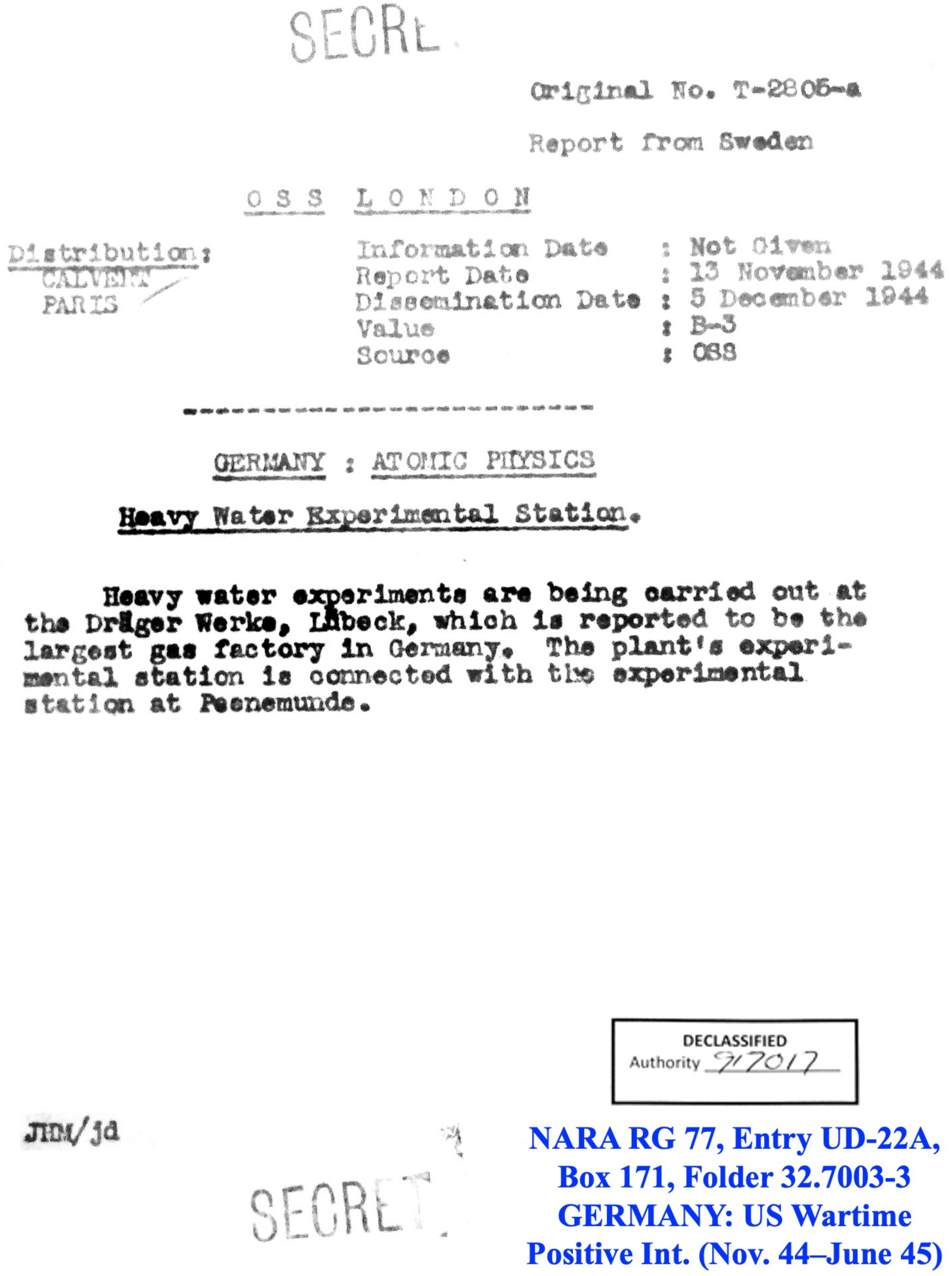
OSS LONDON

Distribution:			
CALVERT	Information Date	:	Not Given
PARIS	Report Date	:	13 November 1944
	Dissemination Date	:	5 December 1944
	Value	:	B-3
	Source	:	OSS

GERMANY : ATOMIC PHYSICS

Heavy Water Experimental Station.

Heavy water experiments are being carried out at the Dräger Werke, Lübeck, which is reported to be the largest gas factory in Germany. The plant's experimental station is connected with the experimental station at Peenemünde.



SECRET

Original No. T-2805-a

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OSS LONDON

Distribution:
CALVERT
PARIS

Information Date : Not Given
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GERMANY : ATOMIC PHYSICS

Heavy Water Experimental Station.

Heavy water experiments are being carried out at the Dräger Werke, Lübeck, which is reported to be the largest gas factory in Germany. The plant's experimental station is connected with the experimental station at Peenemunde.

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NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)

Figure D.503: Report of a heavy water production plant at Lübeck. OSS London. 5 December 1944. Report T-2805-a. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

10. Müggenberg

Karl Cohen to Francis J. Smith. 23 February 1945. Subject: Status of Enemy Separation Projects. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)]

Heavy Water Production

About the only enemy activity at all comparable in scale to ours. Harteck appears to be leading this work. Methods considered in 1941 meeting were electrolysis, chemical exchange with platinum catalysts, distillation of water and low temperature distillation of liquid hydrogen. 1942 conference goes over same questions. Wirtz, Clusius Bonhoffer participated in discussions. Production of the order of tons/year are envisaged.

Factories: Rjukan (now dismantled) Müggenberg, I. G. Farben

[This is Karl Cohen's summary of some German letters and reports that had been found by Alsos in Strassburg/Strasbourg in late 1944.]

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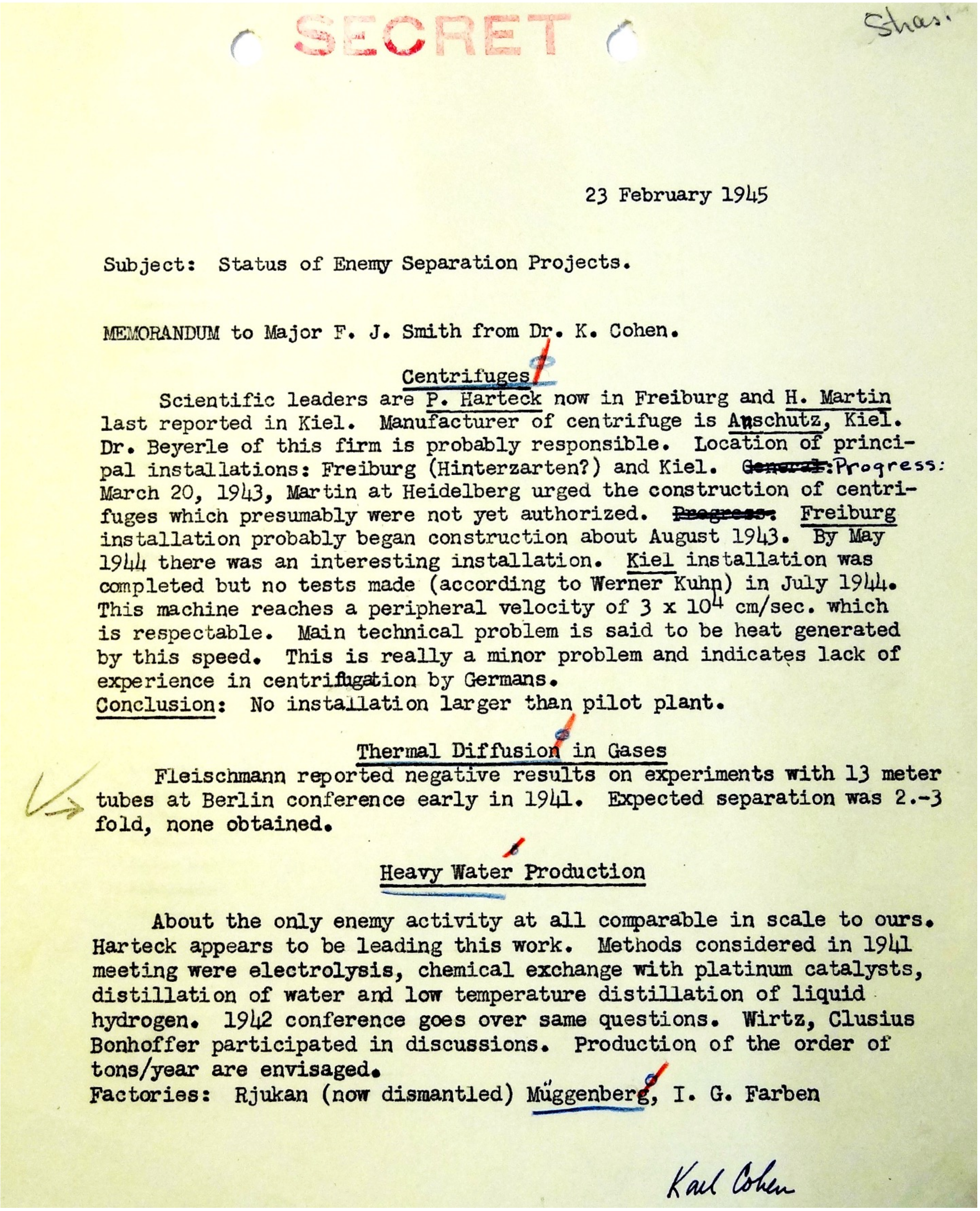
Authority 917017

NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)



SECRET

Shas.

23 February 1945

Subject: Status of Enemy Separation Projects.

MEMORANDUM to Major F. J. Smith from Dr. K. Cohen.

Centrifuges

Scientific leaders are P. Harteck now in Freiburg and H. Martin last reported in Kiel. Manufacturer of centrifuge is Anschutz, Kiel. Dr. Beyerle of this firm is probably responsible. Location of principal installations: Freiburg (Hinterzarten?) and Kiel. ~~General:~~ Progress: March 20, 1943, Martin at Heidelberg urged the construction of centrifuges which presumably were not yet authorized. ~~Progress:~~ Freiburg installation probably began construction about August 1943. By May 1944 there was an interesting installation. Kiel installation was completed but no tests made (according to Werner Kuhn) in July 1944. This machine reaches a peripheral velocity of 3 x 10^4 cm/sec. which is respectable. Main technical problem is said to be heat generated by this speed. This is really a minor problem and indicates lack of experience in centrifugation by Germans.

Conclusion: No installation larger than pilot plant.

Thermal Diffusion in Gases

Fleischmann reported negative results on experiments with 13 meter tubes at Berlin conference early in 1941. Expected separation was 2.-3 fold, none obtained.

Heavy Water Production

About the only enemy activity at all comparable in scale to ours. Harteck appears to be leading this work. Methods considered in 1941 meeting were electrolysis, chemical exchange with platinum catalysts, distillation of water and low temperature distillation of liquid hydrogen. 1942 conference goes over same questions. Wirtz, Clusius Bonhoffer participated in discussions. Production of the order of tons/year are envisaged.

Factories: Rjukan (now dismantled) Müggenberg, I. G. Farben

Karl Cohen

Figure D.504: Report of a heavy water production plant at Müggenberg. Karl Cohen to Francis J. Smith. 23 February 1945. Subject: Status of Enemy Separation Projects. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)]

11. Griesheim

Report on Interrogation of PW MAYER. 14 July 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)]

1. SUBJECT PW is an educated man in his late thirties, a physical chemist by profession and states that he is anti-Nazi and wishes to collaborate. He studied at the Universities of FREIBURG and MUNICH for six years, receiving a degree equivalent to a Doctorate of Philosophy in Chemistry. [...]

7. Manufacture of Hydrogen Peroxide and of Heavy Hydrogen.

[...] PW believes that D2O (Heavy Hydrogen) is manufactured principally at GRIESHEIM ELEKTRON in fairly large quantities for distribution to research and scientific establishments.

[See also pp. 3678–3680.]

Former administration building of
Chemische Fabrik Griesheim-Elektron, Frankfurt am Main

Figure D.505: Former administration building of Chemische Fabrik Griesheim-Elektron, Frankfurt am Main. Griesheim-Elektron reportedly produced large quantities of heavy water during the war. See also pp. 3678–3680. The Griesheim plant appears to have been occupied and tightly controlled by the U.S. military for nearly a year and a half after the war. See for example https://de.wikipedia.org/wiki/Chemische_Fabrik_Griesheim-Elektron and sources cited therein.

12. Berlin and 13. Munich

Mark Walker. 1989. *German National Socialism and the Quest for Nuclear Power, 1939–1949.* Cambridge, UK: Cambridge University Press. p. 145:

Between the electrolysis unit at the Kaiser Wilhelm Institute for Physics and the planned Clusius-Linde plant, large-scale electrolysis was superfluous—something that Harteck had been arguing since 1940. On the other hand, Linde needed one and a half years before full operation could be expected. In late July of 1944 Allied air raids severely damaged the Linde plant in Munich.

G-105. Linde Ice Machine Company. 1941. *Process for Producing Heavy Hydrogen and/or Heavy Water.*

Ordinary hydrogen is cooled, liquified, and continuously rectified. Since HD has a lower vapor pressure than H_2 such an isotope separation is possible. The hydrogen is thus enriched 5%. Catalytic process to split H_2 and D_2. The resulting mixture of $H_2 + HD + D_2$ can be further rectified or it can be oxidized to $H_2O + HDO + D_2O$, and pure D can then be obtained by the usual electrolytic process. Special arrangement for cooling the hydrogen by boiling liquid nitrogen. Diagram showing how rectification can be continuous. Method for removal of impurities.

[See also G-261.]

Klaus and Ann M. Hentschel. 1996. *Physics and National Socialism: An Anthology of Primary Sources.* Basel: Birkhäuser. p. 151:

[I]n 1944 the Linde Company was destroyed in an air raid, partly because it was involved in the production of heavy water (deuterium) for the *Uranverein*. Cf. *75 Jahre Carl v. Linde Gesellschaft für Eismaschinen*, Frankfurt: Brönner, 1954, pp. 123–125, and Walker [1989]a, pp. 144f.

14. Sinigo-Merano and 15. Cotrone, Italy

Per F. Dahl. 1999. *Heavy Water and the Wartime Race for Nuclear Energy.* Philadelphia: Institute of Physics. p. 211:

The only other potential source of heavy water in occupied Europe appeared to be two Montecatini electrolysis plants in Italy—one near Merano and one at Cotrone, with a combined power consumption of 68000 kW, or half that of Vemork. Harteck thought it possible to use the Italian plants for an enrichment to around 1%, whereupon the material could be shipped to Germany for further processing at I G Farben's Leuna works [13-11]. Both Esau and Harteck had personally inspected the Merano plant during the winter 1942–1943, but Esau, for one, was not enthusiastic about the Italian option. [...] At any rate, a Merano-Leuna arrangement was still a fall-back solution, in case of further troubles in Norway.

16. Auschwitz

U.S. Embassy, Warsaw. 12 August 1947. Report No. R-107-47, MIS-390731. Subject: Plants producing heavy water. [NARA RG 319, Entry 85A, Box 2534, Folder 390731–390740]

1. It is believed that no plants designed specially for the production of heavy water exist in Poland. It is reliably reported that the Germans built one such plant near OSWIECIM (Auschwitz) but that it was destroyed or moved out by the SOVIETS in 1945.

[It was "reliably reported" that the Germans had built a heavy water production plant in Poland during the war, and that it was removed by the Soviets.

See p. 4452 for more information.]

17. Heavy water plant near the Schmiedeberg (now Kowary, Poland) uranium mine

[See Witkowski 2013, p. 224.]

18. Breslau/Wrocław

Siegfried Knappe and Ted Brusaw. 1992. *Soldat: Reflections of a German Soldier 1936–1949.* New York: Orion.

[pp. ix-x:] The amount of detail in this narrative is possible because Siegfried Knappe kept a diary from his midteens until he went into Russian captivity on May 2, 1945. Additionally, he smuggled many photographs of his war years from his mother's home in East Germany when he tricked the East Germans into allowing him to go to West Germany upon his release from Russian captivity in December 1949. During approximately 450 hours of interviews, we used these photographs to help trigger his memory as we covered every episode of his war years many times.

Siegfried also had General Weidling's account of the 56th Panzer Korps' part in the fighting from the Oder River to Berlin and the defense of Berlin, which Weidling wrote for the Russians immediately after surrendering. And when Siegfried was released from Russian captivity in December 1949, one of his first acts was to write his own account of the same period and of his Russian captivity as well. Finally, Siegfried had a day-by-day report of his artillery battery's participation in the invasion of France in May 1940, written by his battery commander.

A writer could hardly ask for a more thoroughly documented subject.

Ted Brusaw
Dayton, Ohio
September 1991

[pp. 265–268:] Hitler had declared Breslau a fortress city, which meant that it was to be defended to the last man, even if it was surrounded and totally isolated. The army corps staff in Breslau was the home unit staff for the area, which meant that it was a peacetime staff, and that was why Schörner had wanted officers with extensive combat experience to get the place ready for siege.

The fortress corps staff in Breslau was about seventy people. Because Breslau was the capital of Silesia and had been declared a fortress, the responsibility of the Army Korps Area VIII General Command staff was broader than that of a normal military staff. [...]

I took over the duties of operations officer on January 31. [...]

Schörner had been right: the place was a military mess. All the staff people were handicapped or old, and they had no idea how to fight or how to defend a big city. Defense lines had to be designated, ditches had to be dug, preparations of all kinds had to be made. Wounded coming in from the front had to be accommodated. A factory for making heavy water for atomic experiments had been abandoned east of Breslau, and we had to plan and conduct a counterattack to destroy it and keep its secrets from falling into the hands of the Russians. We were constantly occupied with issuing instructions to civil defense units, decreasing staff personnel, issuing ammunition and supplies, providing weapons, enforcing Schörner's order that no man able to fight was to leave Breslau, keeping refugees supplied and moving, finding engines for hospital trains, keeping utilities operating, preventing looting, preparing landing strips in the city in preparation for the siege—all in addition to normal staff functions like the daily military report to Schörner. [...]

Together with Generalmajor von Ahlfen and his staff, we got things into shape so that Schörner was finally satisfied. On about February 10, the Russian offensive across the Oder River began south of Breslau, near Grottkau, and in the northwest near Steinau. In front of the fortress itself, fairly insignificant combat activity continued at first, but our 609th Division soon became involved in heavy fighting and was pushed back almost to the southern suburbs of Breslau.

On February 11, the 7th Infantry Division, which had successfully completed the operation to retake and destroy the heavy-water plant at Dyhernfurth across the Oder River, sent their vehicles and baggage train into Breslau and pushed south through an enemy that was advancing toward Breslau from the west to form a new front in the area south of Kant. On February 12, two Soviet forces closed the ring around Breslau at Domslau. With that, Breslau had become a fortress under siege.

[Breslau (now Wrocław, Poland) was besieged by the Soviet army beginning in February 1945 but did not surrender until the end of the war. As operations officer for the Breslau-area military staff, in charge of directing and reporting the actions of the German military in that area, Knappe would have been extremely well informed about the topics he discussed. As his interviewer/coauthor Brusaw noted, Knappe's recollections were reviewed thoroughly and were supported by detailed documentation from that time period.

Knappe twice mentioned a heavy water plant in the Breslau area, first saying it was "east of Breslau" and then saying it was at Dyhernfurth (now Brzeg Dolny), which is northwest of Breslau. Perhaps he was referring to two different plants, but it sounds as if he meant the same plant. A heavy water plant would need a plentiful source of water (to find the relatively rare deuterium), so a heavy water plant in the Breslau area would almost certainly be located on the Oder river, which comes from the southeast of Breslau, runs through the city of Breslau, and then flows to the northwest of Breslau. Based on the path of the river, perhaps the most straightforward explanation is that Knappe meant to say the heavy water plant was just east of Dyhernfurth, not Breslau.

It is possible that what Knappe thought was a heavy water plant was actually the relatively well known I.G. Farben/Anorgana Dyhernfurth plant for producing tabun nerve agent. That plant was indeed abandoned yet later sanitized by German forces in a manner similar to what Knappe described.[13] However, there are a number of reasons to think that Knappe's references to a heavy water plant were correct:

- Knappe described the facility as a heavy water plant at least twice (perhaps more times in his interviews with Brusaw when they "covered every episode of his war years many times") and very specifically added that its heavy water was used "for atomic experiments." In his position in the German military, Knappe certainly would have known what chemical weapons were and would have understood the difference.
- There were other reports of heavy water plants in Poland, including a plant near the Schmiedeberg (now Kowary) uranium mine [Witkowski 2013, p. 224] and a plant that was part of or near the I.G. Farben Auschwitz complex (pp. 4069, 4452).
- Uranium gas centrifuges were being produced at a factory in Breslau (p. 4522).
- There were reports of other nuclear facilities in Silesia (pp. 4504–4510), fission reactors in Königsberg (pp. 3928–3933), and a fission bomb test in Poland (Section D.11).
- Multiple weapons plants were often built in close proximity, so locating a heavy water plant near the Dyhernfurth tabun plant (and just upstream of it to the east, to avoid tabun-related contaminants) would be consistent with that German practice. That would also explain why Hitler made defending the Breslau area such a high priority, and why the German military protected Breslau to the end of the war: it was a strategic location for producing both nuclear and chemical (and perhaps other) weapons of mass destruction.]

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[13] Gellermann 1986, pp. 175–176; Gröhler 1989, pp. 9–11; Harris and Paxman 2002, pp. 57–59, 141; Jacobsen 2014, pp. 24–29; Kaszeta 2020, pp. 26–37, 45–51; Tucker 2006, pp. 49–51, 69–72.

19. Weer, Austria

Ferdinand Cap. 23 November 1950. Gutachten [courtesy of Silke Fengler].

Über Einladung von Herrn Oberst GOUSSOT, Innsbruck, hatte ich die Möglichkeit, am 21.XI.50 die Schwere-Wasser-Gewinnungs-Versuchsanlage des Herrn Werd in Wehr [sic: Weer] bei Wattens in Tirol zu besichtigen. Das Prinzip der Anlage besteht in Folgendem: An schwerem Wasser angereichertes Wasser wird den drei (später neun) Zellen der Apparatur zugeführt. In jeder Zelle befindet sich ein Diaphragme, eine Kathode und eine Anode. (Spannung pro Zelle 3 Volt, Gesamtstrom 60 A) Als Elektrolyt dient verdünnt Natronlauge. Die durch die Elektrolyse freigesetzten Gase Wasserstoff und Sauerstoff werden an Paladiumoberflächen katalytisch verbrannt; das entstehende Wasser, das an schwerem Wasser ärmer ist als das in der jeweiligen Zelle elektrolysierte Wasser, wird in die vorhergehende Zelle geleitet; von der ersten Zelle wird es in die Vorkonzentrieranlage geleitet.

Das in jeder Zelle zurückbleibende an schwerem Wasser reichere Wasser wird in die nächstfolgende Zelle überdestilliert—ein einfaches Einleiten ist nicht möglich, da sonst die Konzentration des Elektrolyten stark steigen würde. In weit beim Destillationsprozess gewöhnliches Wasser und schweres Wasser gemeinsam übergehen oder ob hierbei eine kleine (der Apparaturanlage also rückläufige) Trennung eintritt, ist dem Unterzeichneten nicht bekannt und müsste aus Spezialabhandlungen geklärt werden. Sollte eine Verschlechterung der Trennwirksamkeit eintreten so wäre es immerhin wohl möglich durch einen anderen Prozess des überleitens diesen Verlust auszugleichen.

At the invitation of Colonel Colonel GOUSSOT, Innsbruck, I had the opportunity to visit Mr. Werd's heavy water extraction test facility in Wehr [sic: Weer] near Wattens in Tyrol on 21 November 1950. The principle of the plant consists in the following: Water enriched with heavy water is supplied to the three (later nine) cells of the apparatus. Each cell contains a diaphragm, a cathode and an anode. (Voltage per cell 3 volts, total current 60 A) Sodium hydroxide solution diluted serves as electrolyte. The gases hydrogen and oxygen released by the electrolysis are catalytically burned on palladium surfaces; the resulting water, which is poorer in heavy water than the water electrolysed in the respective cell, is led into the preceding cell; from the first cell it is led into the pre-concentration plant.

The water that remains in each cell and is richer in heavy water is distilled into the next cell–a simple discharge is not possible, as otherwise the concentration of the electrolyte would increase sharply. The undersigned does not know whether the distillation process involves the combined use of water and heavy water or whether this results in a small separation (i.e. a retrograde separation of the equipment). Should a deterioration of the separation efficiency occur, it would at least be possible to compensate this loss by another process of transfer.

Der Grundgedanke der Apparatur von Herrn W. ist physikalisch vollkommen einwandfrei. Ob jedoch auf dieser Basis eine Grossproduktion aufgebaut werden kann, wagt der Unterzeichnete nicht zu entscheiden; Entwicklungsarbeiten durchzuführen ist jedoch nicht anzuraten, da diesbezüglich sowohl in Deutschland und Norwegen, als auch in den USA ausgedehnte Untersuchungen bereits vorgenommen wurden. Die Frage nach dem Aufbau einer Grossproduktion kann daher nur nach genauem Studium der einschlägigen Literatur (etwa Monographie von Urey, AEC Reports, FIAT Reports etc.) beantwortet werden. Die von Herrn W. angegebenen Schätzungen über den Strombedarf (rund 1000 kWh für ein Gramm schweres Wasser von 96 % Reinheit) könnten an sich richtig sein, sind aber mit grösster Vorsicht aufzunehmen. Eine Überprüfung ist ohne spezieller Angaben über den Trennfaktor der Elektrolyse nicht möglich.

Jedenfalls müsste ein Vergleich der Wirksamkeit mit den Methoden der NORSK HYDRO, RJUKAN, Norwegen, angestellt werden; auch soll noch auf eine neue, hier noch nicht genügend bekannt gewordene amerikanische chemische Methode (Löslichkeitsmethode) hingewiesen werden, die allem Anschein noch möglicherweise eine grössere Ausbeute verspricht, also die Elektrolysenverfahren.

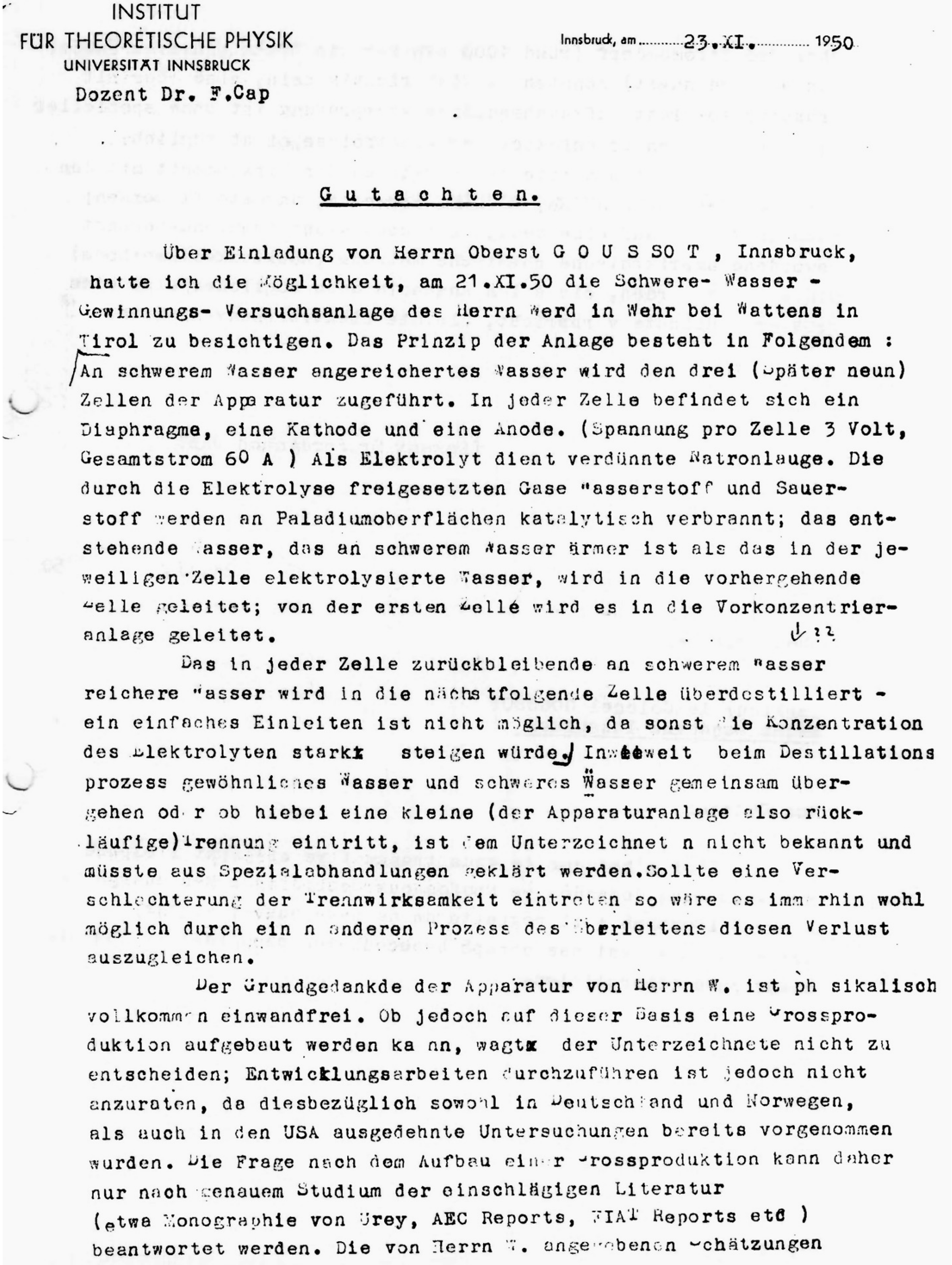
The basic idea of Mr. W.'s apparatus is physically perfect. However, the undersigned does not dare to decide whether a large-scale production can be built on this basis; however, it is not advisable to carry out development work, as extensive investigations have already been carried out in this respect in Germany and Norway, as well as in the USA. The question of setting up a large-scale production can therefore only be answered after a detailed study of the relevant literature (e.g. monograph by Urey, AEC Reports, FIAT Reports etc.). The estimates given by Mr. W. of the electricity requirement (about 1000 kWh for a gram of heavy water of 96 % purity) could be correct in themselves, but must be taken with the greatest caution. A check is not possible without special information about the separation factor of the electrolysis.

In any case, a comparison of the effectiveness with the methods of NORSK HYDRO, RJUKAN, Norway, would have to be made; also, a new American chemical method (solubility method), which has not yet become sufficiently known here, should be pointed out, which to all appearances still possibly promises a higher yield, i.e. the electrolysis methods.

[See also the interview with Ferdinand Cap on pp. 4076–4077. This heavy water plant in the Austrian Alps was apparently quite large and fully operational during the war. It was likely built by or at least for the SS.

This facility was apparently only discovered by outsiders in 1950. It does not seem to be mentioned in any other known documents. Can more information be located in any archives around the world?

If there is so little surviving historical record of this large heavy water production plant, what other wartime heavy water plants (or other nuclear-related facilities) may have existed yet remain unknown today?]



INSTITUT
FÜR THEORETISCHE PHYSIK
UNIVERSITÄT INNSBRUCK
Dozent Dr. F.Cap

Innsbruck, am 23.XI. 1950

Gutachten.

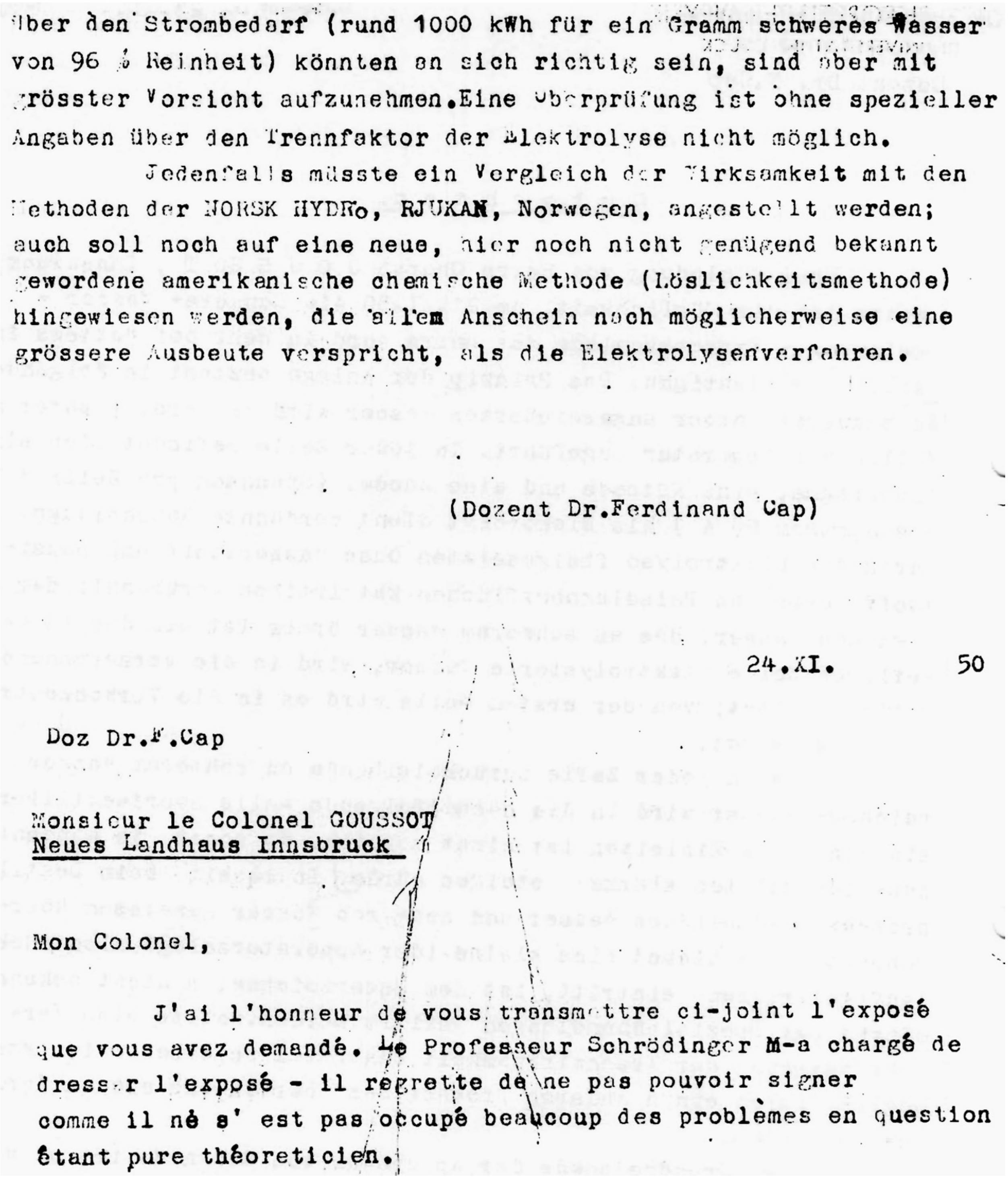
Über Einladung von Herrn Oberst GOUSSOT, Innsbruck, hatte ich die Möglichkeit, am 21.XI.50 die Schwere- Wasser - Gewinnungs- Versuchsanlage des Herrn Werd in Wehr bei Wattens in Tirol zu besichtigen. Das Prinzip der Anlage besteht in Folgendem : An schwerem Wasser angereichertes Wasser wird den drei (später neun) Zellen der Apparatur zugeführt. In jeder Zelle befindet sich ein Diaphragma, eine Kathode und eine Anode. (Spannung pro Zelle 3 Volt, Gesamtstrom 60 A) Als Elektrolyt dient verdünnte Natronlauge. Die durch die Elektrolyse freigesetzten Gase Wasserstoff und Sauerstoff werden an Paladiumoberflächen katalytisch verbrannt; das entstehende Wasser, das an schwerem Wasser ärmer ist als das in der jeweiligen Zelle elektrolysierte Wasser, wird in die vorhergehende Zelle geleitet; von der ersten Zelle wird es in die Vorkonzentrieranlage geleitet.

✓ ??

Das in jeder Zelle zurückbleibende an schwerem Wasser reichere Wasser wird in die nächstfolgende Zelle überdestilliert - ein einfaches Einleiten ist nicht möglich, da sonst die Konzentration des Elektrolyten stark steigen würde. Inwieweit beim Destillations prozess gewöhnliches Wasser und schweres Wasser gemeinsam übergehen oder ob hiebei eine kleine (der Apparaturanlage also rückläufige) Trennung eintritt, ist dem Unterzeichneten nicht bekannt und müsste aus Spezialabhandlungen geklärt werden. Sollte eine Verschlechterung der Trennwirksamkeit eintreten so wäre es immerhin wohl möglich durch einen anderen Prozess des Überleitens diesen Verlust auszugleichen.

Der Grundgedankde der Apparatur von Herrn W. ist physikalisch vollkommen einwandfrei. Ob jedoch auf dieser Basis eine Grossproduktion aufgebaut werden ka nn, wagt der Unterzeichnete nicht zu entscheiden; Entwicklungsarbeiten durchzuführen ist jedoch nicht anzuraten, da diesbezüglich sowohl in Deutschland und Norwegen, als auch in den USA ausgedehnte Untersuchungen bereits vorgenommen wurden. Die Frage nach dem Aufbau einer Grossproduktion kann daher nur nach genauem Studium der einschlägigen Literatur (etwa Monographie von Urey, AEC Reports, FIAT Reports etc) beantwortet werden. Die von Herrn W. angegebenen Schätzungen

Figure D.506: Ferdinand Cap. 23 November 1950. Gutachten [courtesy of Silke Fengler].



über den Strombedarf (rund 1000 kWh für ein Gramm schweres Wasser von 96 % Reinheit) könnten an sich richtig sein, sind aber mit grösster Vorsicht aufzunehmen.Eine Überprüfung ist ohne spezieller Angaben über den Trennfaktor der Elektrolyse nicht möglich.

Jedenfalls müsste ein Vergleich der Wirksamkeit mit den Methoden der NORSK HYDRo, RJUKAN, Norwegen, angestellt werden; auch soll noch auf eine neue, hier noch nicht genügend bekannt gewordene amerikanische chemische Methode (Löslichkeitsmethode) hingewiesen werden, die allem Anschein noch möglicherweise eine grössere Ausbeute verspricht, als die Elektrolysenverfahren.

(Dozent Dr.Ferdinand Cap)

24.XI. 50

Doz Dr.F.Cap

Monsieur le Colonel GOUSSOT
Neues Landhaus Innsbruck

Mon Colonel,

J'ai l'honneur de vous transmettre ci-joint l'exposé que vous avez demandé. Le Professeur Schrödinger M-a chargé de dresser l'exposé - il regrette de ne pas pouvoir signer comme il né s' est pas occupé beaucoup des problèmes en question étant pure théoreticien.

Figure D.507: Ferdinand Cap. 23 November 1950. Gutachten [courtesy of Silke Fengler].

Rainer Karlsch. Interview with Ferdinand Cap. 5 February 2009 [courtesy of Rainer Karlsch].

Karlsch: Mich interessiert, wer diese Anlage gebaut hat. Sie erwähnten damals einen Herrn Werdt (W.). Er kann doch unmöglich allein eine solche Anlage Gebaut haben. Wer waren seine Auftraggeber? Natürlich ist es denkbar, dass die SS die Anlage im Zillertal in Auftrag gegeben hat. Gibt es dafür Belege?

Cap: Wer die Anlage gebaut hat, weiss ich nicht, glaube Norsk Hydro. Herr W. war nur Werksleiter und hat mich und Schroedinger geführt.

Karlsch: Prof. Oberkofler schreibt in seiner Studie "Ferdinand Cap und Otto Hittmair. Aus den Pionierjahren der Innsbrucker Theoretischen Physik", Innsbruck 2006, auf S. 27f.: "Auf dringliche Anforderung von Seiten der französischen Besatzungsmacht besichtigte Schrödinger in Begleitung von Cap im November 1950 die von der SS wie in Norwegen auch im Zillertal gebaute Anlage zur Gewinnung von Schwerem Wasser durch Elektrolyse." Mir ist nicht bekannt, dass die SS in Norwegen eine Schwerwasseranlage gebaut hat. Die dortigen Elektrolysezellen der Norsk Hydro (Anteilseigner war die IG Farbenindustrie AG) wurde nach den Entwürfen von Prof. Paul Harteck (Hamburg) und seiner Mitarbeiter 1942 erweitert und im August 1944 demontiert und ins Reichsgebiet geschafft. Mit dem Betrieb der Schwerwasseranlage in Norwegen hatte die SS meines Wissens nichts zu schaffen.

Cap: Harteck und WIRTZ sind mir bekannt. ICH HABE NIE BEHAUPTET DASS DIE SS DIE ANLAGE GEBAUT HAT.

Karlsch: Oder ist noch eine andere Anlage gemeint? Es gab ja nicht nur das Werk in Rjukan, sondern auch noch Anlagen in Saaheim und Nodotten, die sich aber ebenfalls in Regie der Hydro befanden.

Karlsch: I am interested in who built this plant. You mentioned a Mr. Werdt (W.) at that time. He couldn't have built such a plant on his own. Who were his clients? Of course it is conceivable that the SS commissioned the plant in the Zillertal. Is there any evidence of this?

Cap: I don't know who built the plant, Norsk Hydro I believe. Mr. W. was just a plant manager and led me and Schroedinger.

Karlsch: Prof. Oberkofler writes in his study "Ferdinand Cap and Otto Hittmair. From the pioneering years of Innsbruck's Theoretical Physics," Innsbruck 2006, on p. 27f: "On urgent request of the French occupying power Schrödinger, accompanied by Cap, visited in November 1950 the plant for the production of heavy water by electrolysis built by the SS in the Zillertal as in Norway." I do not know that the SS built a heavy water plant in Norway. The electrolysis cells of Norsk Hydro there (the shareholder was IG Farbenindustrie AG) were expanded in 1942 according to the designs of Prof. Paul Harteck (Hamburg) and his employees and dismantled in August 1944 and transported to the territory of the Reich. To my knowledge, the SS had nothing to do with the operation of the heavy water plant in Norway.

Cap: I know Harteck and WIRTZ. I NEVER CLAIMED SS BUILT THE PLANT.

Karlsch: Or is there another plant meant? There was not only the plant in Rjukan, but also plants in Saaheim and Nodotten, which were also directed by Hydro.

Cap: Nein, nur Zillertal mir bekannt.	Cap: No, I only know Zillertal.
[...]	[...]
Karlsch: Die Norsk Hydro scheidet als Bauherr oder Betreiber m.E. aus. Weder in den Unterlagen der Norsk, noch in den Erinnerungen ihrer leitenden Mitarbeiter und auch nicht in den Papieren der IG Farben, damals Hauptaktionär bei der Norsk, findet sich ein Hinweis darauf. Es bleibt also unklar, wer die Auftraggeber für die Anlage waren.	Karlsch: Norsk Hydro is no longer the owner or operator in my opinion. Neither in the documents of Norsk, nor in the memories of its leading employees, nor in the papers of IG Farben, then the main shareholder of Norsk, is there any indication of this. It therefore remains unclear who the contractors for the plant were.
Cap: Leider, offenbar. Ich wäre laut H. W. der Meinung gewesen NORSK HYDRO.	Cap: Unfortunately, apparently. I would have thought, according to Mr. W., NORSK HYDRO.
Karlsch: Können Sie sich daran erinnern, wo genau die Anlage stand?	Karlsch: Can you remember exactly where the plant was located?
Cap: Ziemlich ganz am Ende des Zillertales, nahe einem Gletscher.	Cap: Quite at the end of the Zillertal, near a glacier.
Karlsch: Welche Ausmaße hatten die Elektrolysezellen ungefähr?	Karlsch: What were the approximate dimensions of the electrolysis cells?
Cap: Hunderte Zellen, verschiedene Groesse, kleinere wie Waschbecken, mittlere wie Badewanne.	Cap: Hundreds of cells, different sizes, the smaller like a sink, the medium like a bathtub.
Karlsch: War Herr Werdt Ingenieur oder Physiker?	Karlsch: Was Mr. Werdt an engineer or a physicist?
Cap: Ich würde sagen H. Werdt war Gewerbeschultechniker. Sicher nicht Akademiker.	Cap: I would say Mr. Werdt was a vocational school technician. Certainly not an academic.
Karlsch: Stand er in Verbindung mit der Physiker-Gruppe des Physikalisch-Chemischen Instituts der Universität Innsbruck, die 1944 nach Wattens zur Firma Swarovsky verlegt wurde?	Karlsch: Did he stand in contact with the physicist group of the Physical-Chemical Institute of the University of Innsbruck, which was transferred to Swarovsky in Wattens in 1944?
Cap: Meinen Sie Frau Prof Erika Cremer, die im Krieg beim Berliner “URANVEREIN” war?	Cap: Do you mean Prof. Erika Cremer, who was in the Berlin “URANVEREIN” during the war?

20. B9 Quarz underground complex near Roggendorf and Melk, Austria

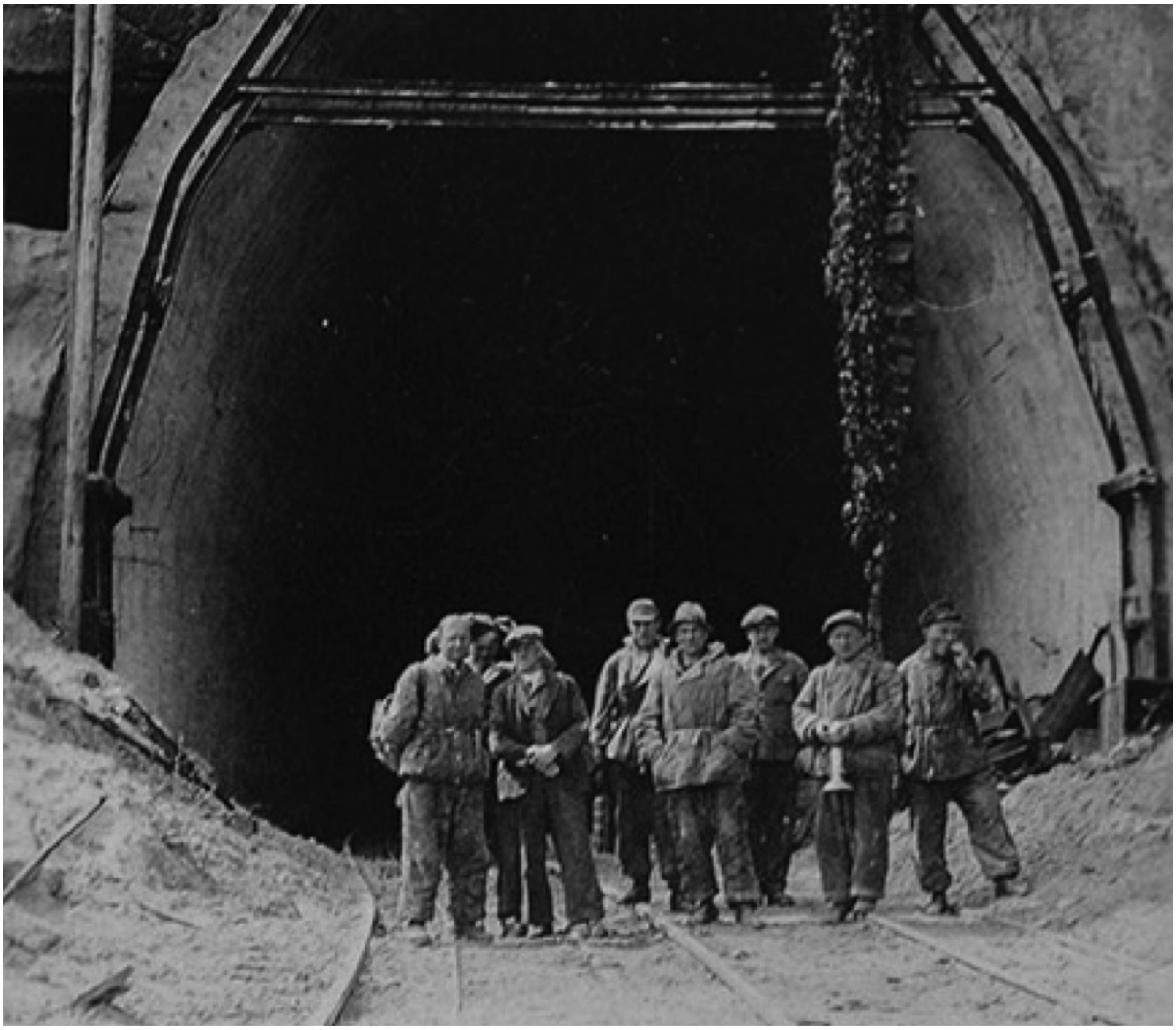
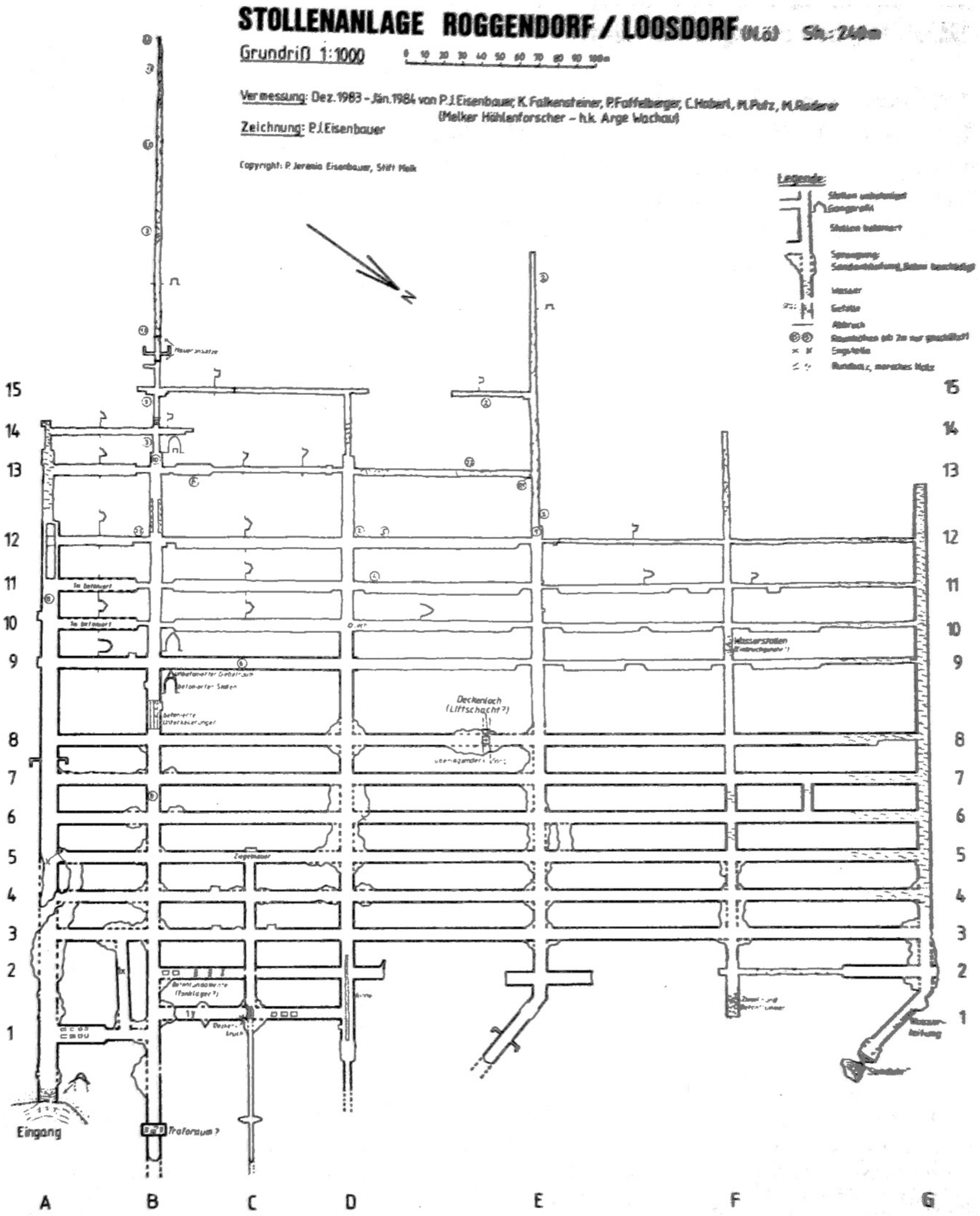


Figure D.508: One of the entrances to the B9 Quarz tunnels near Roggendorf and Melk, Austria that may have been involved in heavy water production [Schmitzberger 2004].


STOLLENANLAGE ROGGENDORF / LOOSDORF (N.ö) Sh.: 240m
Grundriß 1:1000
0 10 20 30 40 50 60 70 80 90 100m
Vermessung: Dez. 1983 - Jän. 1984 von P.J. Eisenbauer, K. Falkensteiner, P. Faffelberger, C. Haberl, M. Putz, M. Raderer
(Melker Höhlenforscher - h.k. Arge Wachau)
Zeichnung: P.J. Eisenbauer
Copyright: P. Jeremia Eisenbauer, Stift Melk
Legende:
N
Mauer ansatz
betonierter Stollen
betonierte Unterkellerungen
Deckenloch (Liftschacht?)
Wasserstollen
Ziegelmauer
(Tanklager?)
Decken-bruch
Traforaum?
Wasser-leitung
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15
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Figure D.509: Map of the B9 Quarz tunnels near Roggendorf and Melk, Austria that may have been involved in heavy water production [Schmitzberger 2004].

21. Degussa plant, Rheinfelden, Austria, and
22. Austrian Chemical Works plant, Weissenstein, Austria

R. W. Kirkman. 28 January 1944. Subject: Carl William Tucker [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)]

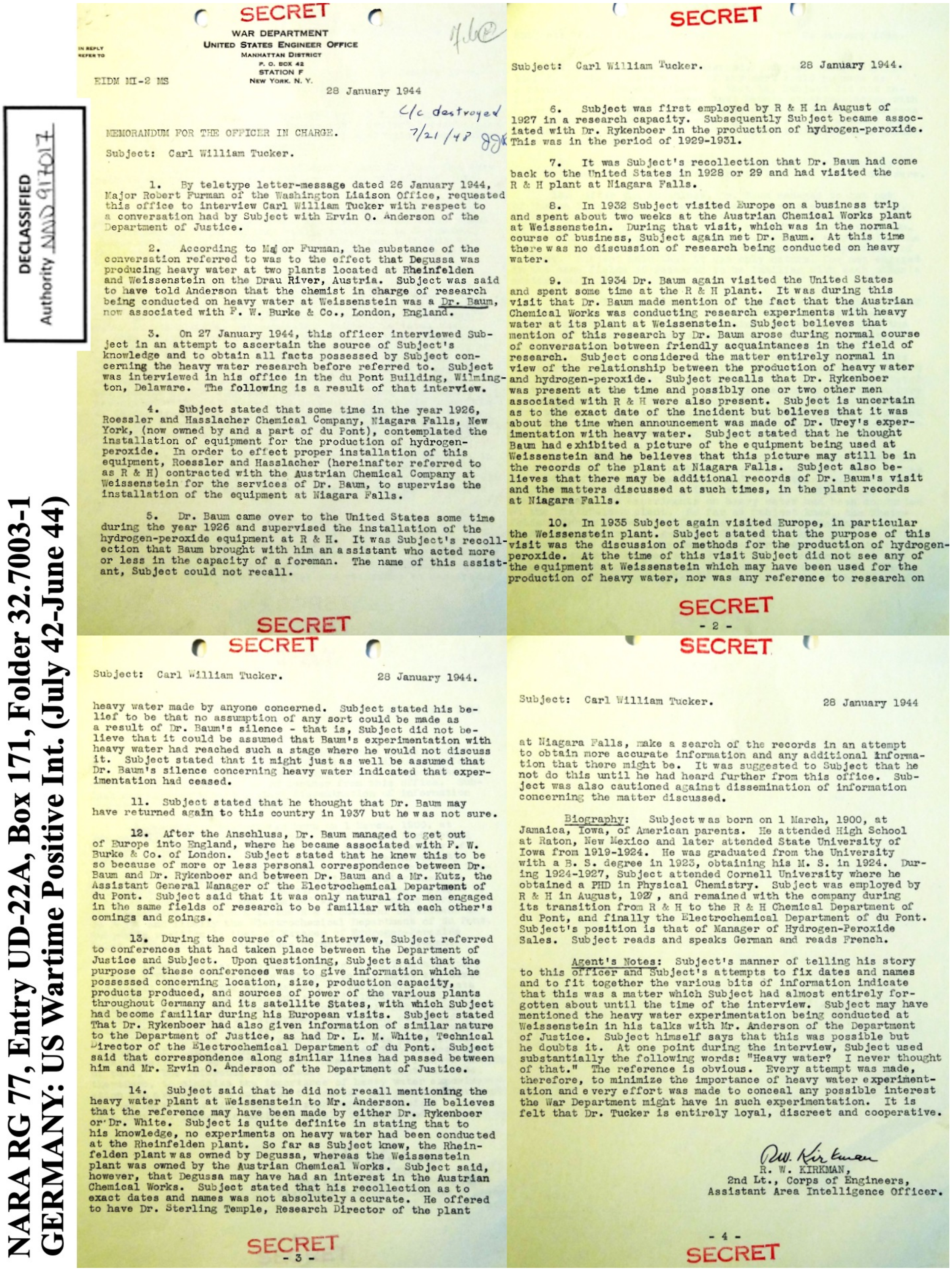
[...] 2. According to Major Furman, the substance of the conversation referred to was to the effect that Degussa was producing heavy water at two plants located at Rheinfelden and Weissenstein on the Drau River, Austria. Subject was said to have told Anderson that the chemist in charge of research being conducted on heavy water at Weissenstein was a Dr. Baum, now associated with F. W. Burke & Co., London, England.

23. Siemens and Halske plant in Lehesten

Monthly Intelligence Summary. February 1945. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

An OSS report states that possible manufacture of long range projectiles is being carried on in a semi-underground installation about 1.5 K.M. north of Lehesten in Germany. T A [Tube Alloy, nuclear] interest in the report arises from the fact that Siemens and Halske are said to be in charge of the plant, and a reference to the breaking down of water by electrolysis at this site. Aerial coverage has been requested.

[For more information, see pp. 3689, 3696.]



NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)

DECLASSIFIED
Authority NND 917017

SECRET

WAR DEPARTMENT
UNITED STATES ENGINEER OFFICE
MANHATTAN DISTRICT
P. O. BOX 42
STATION F
NEW YORK, N. Y.

IN REPLY REFER TO
EIDM MI-2 MS

7.6

28 January 1944

C/c destroyed 7/21/48

MEMORANDUM FOR THE OFFICER IN CHARGE.

Subject: Carl William Tucker.

1. By teletype letter-message dated 26 January 1944, Major Robert Furman of the Washington Liaison Office, requested this office to interview Carl William Tucker with respect to a conversation had by Subject with Ervin O. Anderson of the Department of Justice.

2. According to Major Furman, the substance of the conversation referred to was to the effect that Degussa was producing heavy water at two plants located at Rheinfelden and Weissenstein on the Drau River, Austria. Subject was said to have told Anderson that the chemist in charge of research being conducted on heavy water at Weissenstein was a Dr. Baum, now associated with F. W. Burke & Co., London, England.

3. On 27 January 1944, this officer interviewed Subject in an attempt to ascertain the source of Subject's knowledge and to obtain all facts possessed by Subject concerning the heavy water research before referred to. Subject was interviewed in his office in the du Pont Building, Wilmington, Delaware. The following is a result of that interview.

4. Subject stated that some time in the year 1926, Roessler and Hasslacher Chemical Company, Niagara Falls, New York, (now owned by and a part of du Pont), contemplated the installation of equipment for the production of hydrogen-peroxide. In order to effect proper installation of this equipment, Roessler and Hasslacher (hereinafter referred to as R & H) contracted with the Austrian Chemical Company at Weissenstein for the services of Dr. Baum, to supervise the installation of the equipment at Niagara Falls.

5. Dr. Baum came over to the United States some time during the year 1926 and supervised the installation of the hydrogen-peroxide equipment at R & H. It was Subject's recollection that Baum brought with him an assistant who acted more or less in the capacity of a foreman. The name of this assistant, Subject could not recall.

SECRET

SECRET

Subject: Carl William Tucker. 28 January 1944.

6. Subject was first employed by R & H in August of 1927 in a research capacity. Subsequently Subject became associated with Dr. Rykenboer in the production of hydrogen-peroxide. This was in the period of 1929-1931.

7. It was Subject's recollection that Dr. Baum had come back to the United States in 1928 or 29 and had visited the R & H plant at Niagara Falls.

8. In 1932 Subject visited Europe on a business trip and spent about two weeks at the Austrian Chemical Works plant at Weissenstein. During that visit, which was in the normal course of business, Subject again met Dr. Baum. At this time there was no discussion of research being conducted on heavy water.

9. In 1934 Dr. Baum again visited the United States and spent some time at the R & H plant. It was during this visit that Dr. Baum made mention of the fact that the Austrian Chemical Works was conducting research experiments with heavy water at its plant at Weissenstein. Subject believes that mention of this research by Dr. Baum arose during normal course of conversation between friendly acquaintances in the field of research. Subject considered the matter entirely normal in view of the relationship between the production of heavy water and hydrogen-peroxide. Subject recalls that Dr. Rykenboer was present at the time and possibly one or two other men associated with R & H were also present. Subject is uncertain as to the exact date of the incident but believes that it was about the time when announcement was made of Dr. Urey's experimentation with heavy water. Subject stated that he thought Baum had exhibited a picture of the equipment being used at Weissenstein and he believes that this picture may still be in the records of the plant at Niagara Falls. Subject also believes that there may be additional records of Dr. Baum's visit and the matters discussed at such times, in the plant records at Niagara Falls.

10. In 1935 Subject again visited Europe, in particular the Weissenstein plant. Subject stated that the purpose of this visit was the discussion of methods for the production of hydrogen-peroxide. At the time of this visit Subject did not see any of the equipment at Weissenstein which may have been used for the production of heavy water, nor was any reference to research on

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- 2 -

SECRET

Subject: Carl William Tucker. 28 January 1944.

heavy water made by anyone concerned. Subject stated his belief to be that no assumption of any sort could be made as a result of Dr. Baum's silence - that is, Subject did not believe that it could be assumed that Baum's experimentation with heavy water had reached such a stage where he would not discuss it. Subject stated that it might just as well be assumed that Dr. Baum's silence concerning heavy water indicated that experimentation had ceased.

11. Subject stated that he thought that Dr. Baum may have returned again to this country in 1937 but he was not sure.

12. After the Anschluss, Dr. Baum managed to get out of Europe into England, where he became associated with F. W. Burke & Co. of London. Subject stated that he knew this to be so because of more or less personal correspondence between Dr. Baum and Dr. Rykenboer and between Dr. Baum and a Mr. Kutz, the Assistant General Manager of the Electrochemical Department of du Pont. Subject said that it was only natural for men engaged in the same fields of research to be familiar with each other's comings and goings.

13. During the course of the interview, Subject referred to conferences that had taken place between the Department of Justice and Subject. Upon questioning, Subject said that the purpose of these conferences was to give information which he possessed concerning location, size, production capacity, products produced, and sources of power of the various plants throughout Germany and its satellite States, with which Subject had become familiar during his European visits. Subject stated That Dr. Rykenboer had also given information of similar nature to the Department of Justice, as had Dr. L. M. White, Technical Director of the Electrochemical Department of du Pont. Subject said that correspondence along similar lines had passed between him and Mr. Ervin O. Anderson of the Department of Justice.

14. Subject said that he did not recall mentioning the heavy water plant at Weissenstein to Mr. Anderson. He believes that the reference may have been made by either Dr. Rykenboer or Dr. White. Subject is quite definite in stating that to his knowledge, no experiments on heavy water had been conducted at the Rheinfelden plant. So far as Subject knew, the Rheinfelden plant was owned by Degussa, whereas the Weissenstein plant was owned by the Austrian Chemical Works. Subject said, however, that Degussa may have had an interest in the Austrian Chemical Works. Subject stated that his recollection as to exact dates and names was not absolutely accurate. He offered to have Dr. Sterling Temple, Research Director of the plant

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- 3 -

SECRET

Subject: Carl William Tucker. 28 January 1944

at Niagara Falls, make a search of the records in an attempt to obtain more accurate information and any additional information that there might be. It was suggested to Subject that he not do this until he had heard further from this office. Subject was also cautioned against dissemination of information concerning the matter discussed.

Biography: Subject was born on 1 March, 1900, at Jamaica, Iowa, of American parents. He attended High School at Raton, New Mexico and later attended State University of Iowa from 1919-1924. He was graduated from the University with a B. S. degree in 1923, obtaining his M. S. in 1924. During 1924-1927, Subject attended Cornell University where he obtained a PHD in Physical Chemistry. Subject was employed by R & H in August, 1927, and remained with the company during its transition from R & H to the R & H Chemical Department of du Pont, and finally the Electrochemical Department of du Pont. Subject's position is that of Manager of Hydrogen-Peroxide Sales. Subject reads and speaks German and reads French.

Agent's Notes: Subject's manner of telling his story to this officer and Subject's attempts to fix dates and names and to fit together the various bits of information indicate that this was a matter which Subject had almost entirely forgotten about until the time of the interview. Subject may have mentioned the heavy water experimentation being conducted at Weissenstein in his talks with Mr. Anderson of the Department of Justice. Subject himself says that this was possible but he doubts it. At one point during the interview, Subject used substantially the following words: "Heavy water? I never thought of that." The reference is obvious. Every attempt was made, therefore, to minimize the importance of heavy water experimentation and every effort was made to conceal any possible interest the War Department might have in such experimentation. It is felt that Dr. Tucker is entirely loyal, discreet and cooperative.

R. W. Kirkman
R. W. KIRKMAN,
2nd Lt., Corps of Engineers,
Assistant Area Intelligence Officer.

- 4 -
SECRET

Figure D.510: R. W. Kirkman. 28 January 1944. Subject: Carl William Tucker [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)] "According to Major Furman, the substance of the conversation referred to was to the effect that Degussa was producing heavy water at two plants located at Rheinfelden and Weissenstein on the Drau River, Austria."

24. Bayrische Stickstoffwerke in Piesteritz

H. W. Dix to Francis Smith. Subject: Heavy Water. 26 December 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

This office has received the following comments from our Swedish people and it is dated 22 November 1944 and has a B-2 rating.

> Heavy water is manufactured primarily in Norway by I. G. at Norsk Hydro. However, manufacture in Germany at the Bayrische Stickstoffwerke in Piesteritz or Auschwitz is certainly a possibility.

[For more information, see pp. 4452–4453.]

25. Pardubice/Wesser, Czechia

W. R. Shuler and David C. G. Gattiker. 28 February 1946. Memorandum for the period 17 January 1946 to 28 February 1946 [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

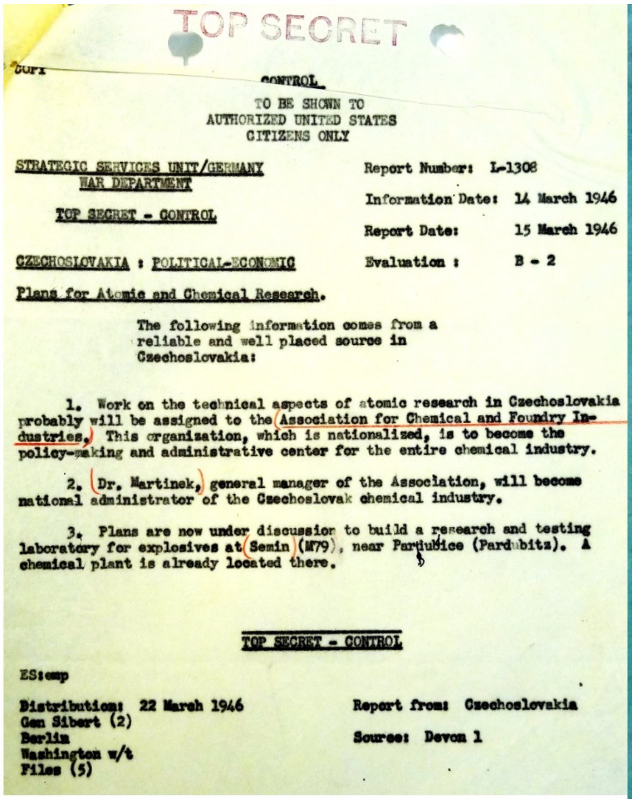
[...] 2. Heavy Water Plant at Wesser: A report has been received of an alleged heavy water plant at Wesser, 17 miles northeast of Pardubice, supposed to be operated by the Russians. Although this report seems unlikely, we would like London to investigate further if possible.

[See document photos on p. 3446. It is unclear exactly what site was meant by "Wesser," but if it was a heavy water plant it was probably on the Elbe river or the Úpa river outside of Pardubice.]

Manhattan Engineering District Foreign Intelligence Unit. March–April 1946 reports on wartime German research facilities near Pardubice that may have been producing heavy water or doing other nuclear-related work [NARA RG 77, Entry UD-22A, Box 175, Folder World].

"Isn't Pardubice the place a heavy water plant was reported?"

[See document photos on p. 4083.]



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WAR DEPARTMENT

TOP SECRET - CONTROL

CZECHOSLOVAKIA : POLITICAL-ECONOMIC

Report Number: L-1308
Information Date: 14 March 1946
Report Date: 15 March 1946
Evaluation : B - 2

Plans for Atomic and Chemical Research.

The following information comes from a reliable and well placed source in Czechoslovakia:

1. Work on the technical aspects of atomic research in Czechoslovakia probably will be assigned to the Association for Chemical and Foundry Industries. This organization, which is nationalized, is to become the policy-making and administrative center for the entire chemical industry.

2. Dr. Martinek, general manager of the Association, will become national administrator of the Czechoslovak chemical industry.

3. Plans are now under discussion to build a research and testing laboratory for explosives at Semin (M79), near Pardubice (Pardubitz). A chemical plant is already located there.

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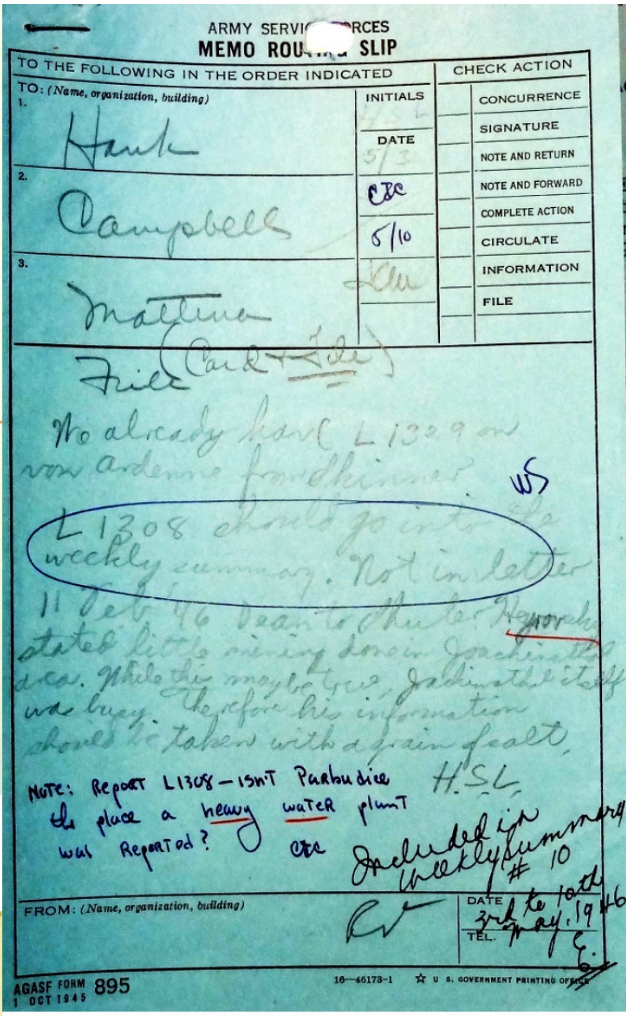
ES:emp

Distribution: 22 March 1946
Gen Sibert (2)
Berlin
Washington w/t
Files (5)

Report from: Czechoslovakia
Source: Devon 1



ARMY SERVICE FORCES
MEMO ROUTING SLIP

TO THE FOLLOWING IN THE ORDER INDICATED

TO: (Name, organization, building)

TO: (Name, organization, building)	INITIALS / DATE		CHECK ACTION
1. Hank	H.S.L. 5/3		CONCURRENCE
			SIGNATURE
			NOTE AND RETURN
2. Campbell	CBC 5/10		NOTE AND FORWARD
			COMPLETE ACTION
			CIRCULATE
3. Mattina (Card + File)	[illegible]		INFORMATION
			FILE

File

We already have L 1329 on von Ardenne from Skinner.

WS

L 1308 should go into the weekly summary. Not in letter 11 Feb 46 Dean to Shuler. Heyrovsky stated little mining done in Joachimsthal area. While this may be true, Joachimsthal itself was busy. Therefore his information should be taken with a grain of salt.

H.S.L.

NOTE: Report L1308 — isn't Pardubice the place a heavy water plant was reported? etc

Included in weekly summary # 10

FROM: (Name, organization, building)

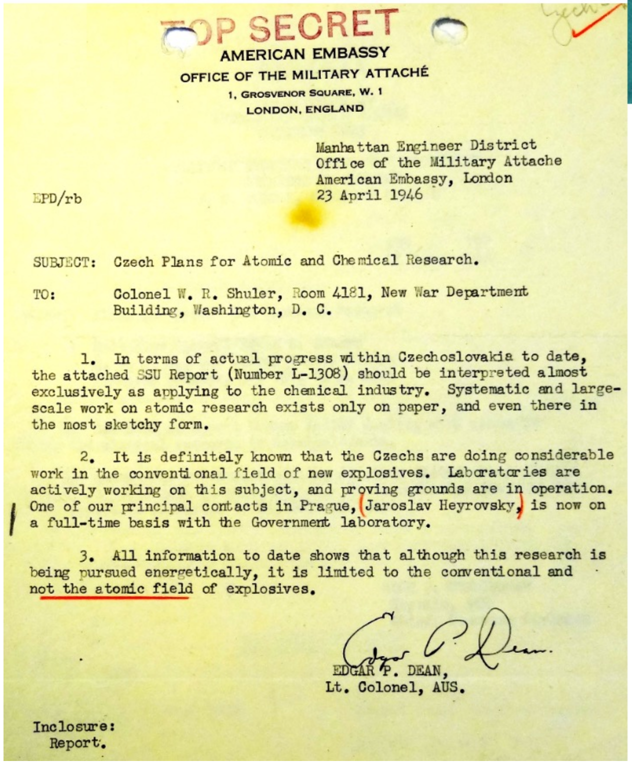
DATE 3rd to 10th May. 1946

TEL.

E.

AGASF FORM 895
1 OCT 1945

16—46173-1 ☆ U. S. GOVERNMENT PRINTING OFFICE



TOP SECRET

AMERICAN EMBASSY
OFFICE OF THE MILITARY ATTACHÉ
1, GROSVENOR SQUARE, W. 1
LONDON, ENGLAND

Manhattan Engineer District
Office of the Military Attache
American Embassy, London
23 April 1946

EPD/rb

SUBJECT: Czech Plans for Atomic and Chemical Research.

TO: Colonel W. R. Shuler, Room 4181, New War Department Building, Washington, D. C.

1. In terms of actual progress within Czechoslovakia to date, the attached SSU Report (Number L-1308) should be interpreted almost exclusively as applying to the chemical industry. Systematic and large-scale work on atomic research exists only on paper, and even there in the most sketchy form.

2. It is definitely known that the Czechs are doing considerable work in the conventional field of new explosives. Laboratories are actively working on this subject, and proving grounds are in operation. One of our principal contacts in Prague, Jaroslav Heyrovsky, is now on a full-time basis with the Government laboratory.

3. All information to date shows that although this research is being pursued energetically, it is limited to the conventional and not the atomic field of explosives.

Edgar P. Dean

EDGAR P. DEAN,
Lt. Colonel, AUS.

Inclosure:
Report.

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 175, Folder World

Figure D.511: March–April 1946 reports on wartime German research facilities near Pardubice that may have been producing heavy water or doing other nuclear-related work [NARA RG 77, Entry UD-22A, Box 175, Folder World]. “Isn’t Pardubice the place a heavy water plant was reported?” See the related report on p. 3446.

26. Other/unspecified heavy water plants

Major B. K. Hough, Jr. to Leslie R. Groves. 9 December 1943. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)]

[...] In discussing the possible status of German work on the heavy water pile, it was stated that Dr. Urey saw the Norwegian scientist, L. Tronstad, in London about October or November of 1941. It was reported then that the Germans were taking heavy water from Norwegian sources, and it appears likely that they may have performed the critical experiments on cross-section some time before it was done in America. In this connection, Dr. E. P. Wigner of Chicago mentioned to Dr. Urey that he has had reports of heavy water plants now in production in Germany.

[See document photo on p. 4085.]

Samuel Goudsmit to Robert R. Furman. 25 May 1945. [NARA RG GOUDS, Entry UD-7420, Box 6, Folder ALSOS—Reports and Operations]

1. Attached is the RFR correspondence, mainly on Heavy Water and centrifuge installations.

2. Interesting remark on Clusius' letter to Gerlach, 12 February 1945, on bombing of Heavy Water installations.

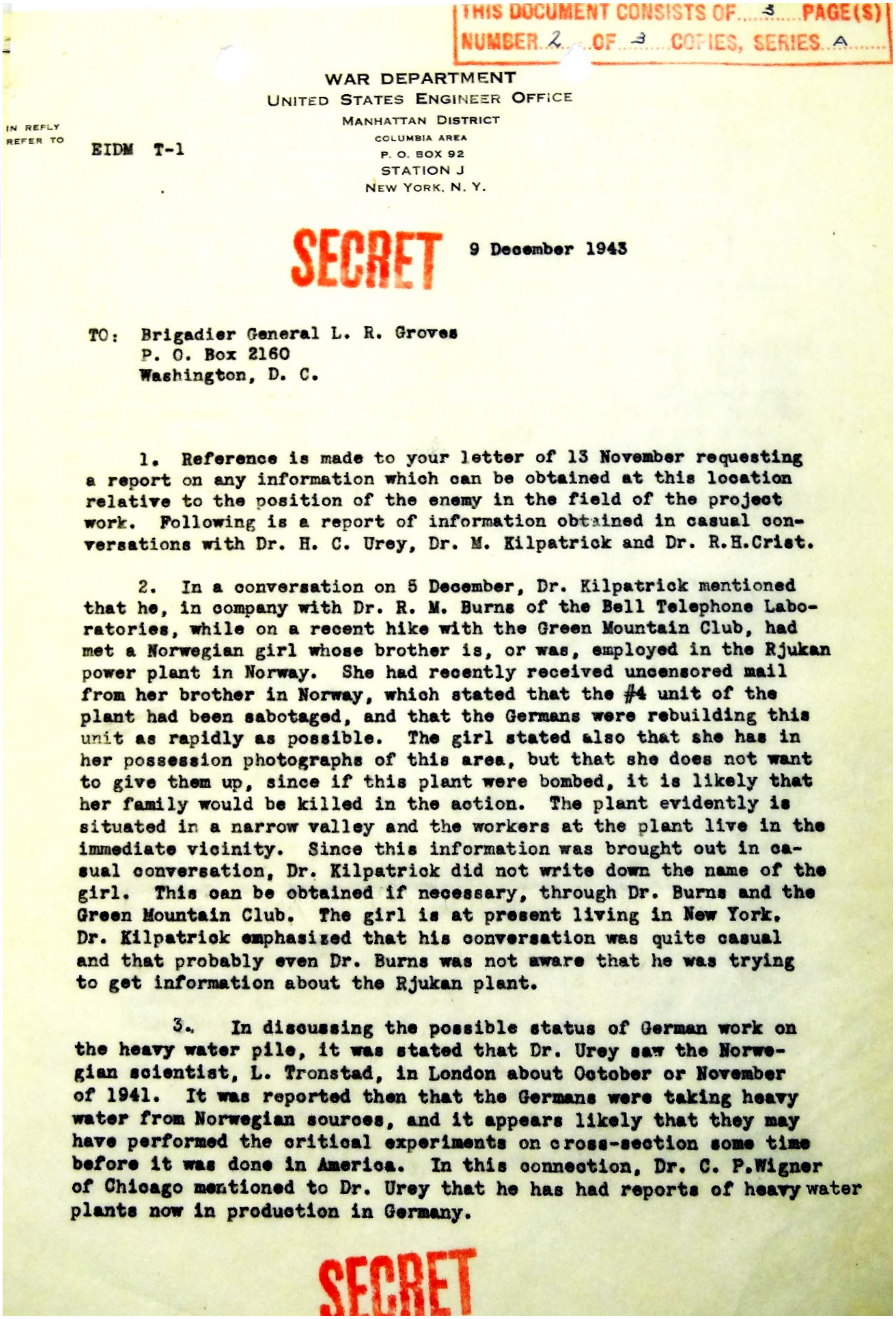
3. Most important are the minutes of the meeting in Stadtilm on 6 February 1945 and the letter at the end of 24 April 1939 about the foundation. The latter is the subject of another report.

4. This file contains intelligence information and should be kept in Paris until further notice.

[See document photo on p. 4086.]

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1--GERMANY--Research--TA--(1943-June 1946)



THIS DOCUMENT CONSISTS OF 3 PAGE(S)
NUMBER 2 OF 3 COPIES, SERIES A

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UNITED STATES ENGINEER OFFICE
MANHATTAN DISTRICT
COLUMBIA AREA
P. O. BOX 92
STATION J
NEW YORK, N. Y.

IN REPLY REFER TO EIDM T-1

SECRET

9 December 1943

TO: Brigadier General L. R. Groves
P. O. Box 2160
Washington, D. C.

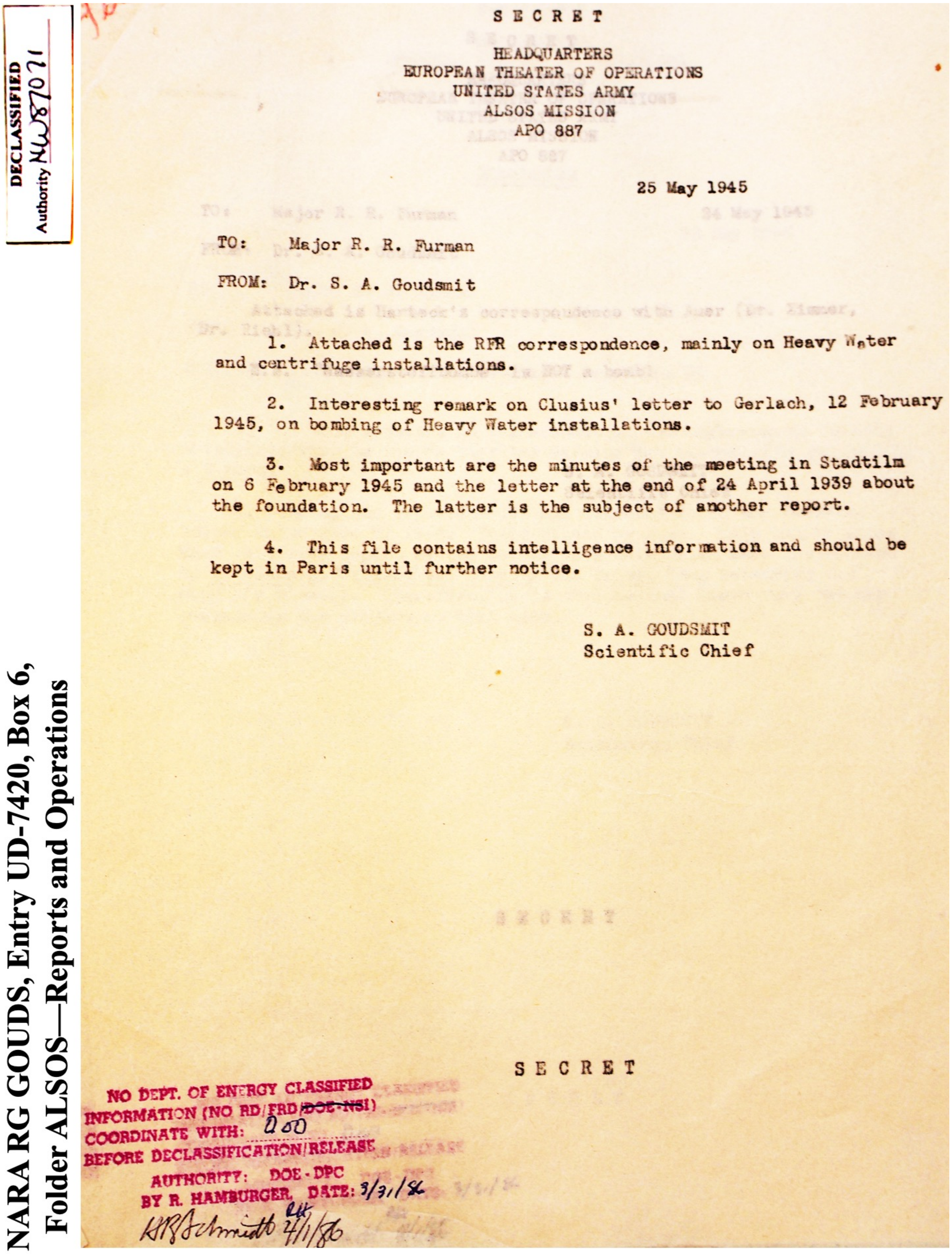
1. Reference is made to your letter of 13 November requesting a report on any information which can be obtained at this location relative to the position of the enemy in the field of the project work. Following is a report of information obtained in casual conversations with Dr. H. C. Urey, Dr. M. Kilpatrick and Dr. R.H.Crist.

2. In a conversation on 5 December, Dr. Kilpatrick mentioned that he, in company with Dr. R. M. Burns of the Bell Telephone Laboratories, while on a recent hike with the Green Mountain Club, had met a Norwegian girl whose brother is, or was, employed in the Rjukan power plant in Norway. She had recently received uncensored mail from her brother in Norway, which stated that the #4 unit of the plant had been sabotaged, and that the Germans were rebuilding this unit as rapidly as possible. The girl stated also that she has in her possession photographs of this area, but that she does not want to give them up, since if this plant were bombed, it is likely that her family would be killed in the action. The plant evidently is situated in a narrow valley and the workers at the plant live in the immediate vicinity. Since this information was brought out in casual conversation, Dr. Kilpatrick did not write down the name of the girl. This can be obtained if necessary, through Dr. Burns and the Green Mountain Club. The girl is at present living in New York. Dr. Kilpatrick emphasized that his conversation was quite casual and that probably even Dr. Burns was not aware that he was trying to get information about the Rjukan plant.

3. In discussing the possible status of German work on the heavy water pile, it was stated that Dr. Urey saw the Norwegian scientist, L. Tronstad, in London about October or November of 1941. It was reported then that the Germans were taking heavy water from Norwegian sources, and it appears likely that they may have performed the critical experiments on cross-section some time before it was done in America. In this connection, Dr. C. P.Wigner of Chicago mentioned to Dr. Urey that he has had reports of heavy water plants now in production in Germany.

SECRET

Figure D.512: Major B. K. Hough, Jr. to Leslie R. Groves. 9 December 1943. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)] "...about October or November of 1941. It was reported then that the Germans were taking heavy water from Norwegian sources, and it appears likely that they may have performed the critical experiments on cross-section some time before it was done in America. In this connection, Dr. E. P. Wigner of Chicago mentioned to Dr. Urey that he has had reports of heavy water plants now in production in Germany."



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Authority NW 87071

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HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS MISSION
APO 887

25 May 1945

TO: Major R. R. Furman

FROM: Dr. S. A. Goudsmit

1. Attached is the RFR correspondence, mainly on Heavy Water and centrifuge installations.

2. Interesting remark on Clusius' letter to Gerlach, 12 February 1945, on bombing of Heavy Water installations.

3. Most important are the minutes of the meeting in Stadtilm on 6 February 1945 and the letter at the end of 24 April 1939 about the foundation. The latter is the subject of another report.

4. This file contains intelligence information and should be kept in Paris until further notice.

S. A. GOUDSMIT
Scientific Chief

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AUTHORITY: DOE-DPC
BY R. HAMBURGER DATE: 3/31/86
KR Schmidt 4/1/86

NARA RG GOUDS, Entry UD-7420, Box 6,
Folder ALSOS—Reports and Operations

Figure D.513: Samuel Goudsmit to Robert R. Furman. 25 May 1945 [NARA RG GOUDS, Entry UD-7420, Box 6, Folder ALSOS—Reports and Operations]. “1. Attached is the RFR correspondence, mainly on Heavy Water and centrifuge installations. 2. Interesting remark on Clusius’ letter to Gerlach, 12 February 1945, on bombing of Heavy Water installations. 3. Most important are the minutes of the meeting in Stadtilm on 6 February 1945 and the letter at the end of 24 April 1939 about the foundation. The latter is the subject of another report. 4. This file contains intelligence information and should be kept in Paris until further notice.”

Samuel Goudsmit to Robert R. Furman. 21 May 1945. [NARA RG GOUDS, Entry UD-7420, Box 6, Folder ALSOS—Reports and Operations] [See photo on p. 4088.]

The interest of the SS in nuclear physics is obvious from a letter sent to Harteck as late as the 2nd of April, 1945. This letter is written by an SS Gruppenführer and Generalleutnant der Waffen SS. It comes from the Technical Bureau VIII FEP (probably research development patents) of the SS Führungshauptamt.

The text of the letter is to the effect that the General, whose name is illegible (probably starting with Sp) has ordered SS Standartenoberjunker H. Clasen to accelerate his work on the production of heavy water. For this reason, he asked Harteck, the leader of the heavy water group, to take him into his institute because this work could not easily be continued at the SS institute.

The original address in Berlin is blocked out of the letterhead. The new address is not given, but the mail address is Trebbin Krs. Teltow. [...]

P.S. 22 May 1945—I have today found out that the above mentioned General's name is Schwab.

Samuel A. Goudsmit. 15 June 1945. SUBJECT: Importance Attached to Harteck's Heavy Water Method. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA—(1943–June 1946)]. [See document photo on p. 4089.]

1. The enclosed letters came from the files of the Reichsforschungsrat. They are recent and again show the importance which the Germans placed upon the TA project.

2. First of all, there is a letter from Gerlach to Colonel Geist of the Speer Ministry. The letter is dated December 16, 1944. Here he tells about Harteck's new way of producing heavy water and that they expect to get three tons a year, the cost of the installation to be about 1,300,000 marks. The personnel consists of one engineer, three technicians and twelve laborers, and the price of the ultimate product is estimated at 20 pfennigs a gram. He requests Geist to give permission for proceeding with the production preparation at the highest priority A copy of this letter was sent by Dr. Graue, an administrator in the RFR, to the SS-Standartenführer Sievers, the SS representative in the RFR. An interesting passage is marked in the original of the covering letter. A rough translation is as follows:

> "With this (new procedure) we shall increase further the advantage which we have over the Americans. According to Professor Gerlach, the work in Germany has progressed so far that one may already count upon the possibility of practical results in the near future. You are aware that this would pave the way for a revolution in the whole field of technology and economy. Even if one disregards the possibility of an eventual war application, the support of this work is, nevertheless, absolutely essential."

3. Sievers, in turn, sent a copy of Gerlach's letter to Dr. Ing. Kammler (who was a Lt. General of the Waffen-SS in charge of armaments). In this letter, he literally copied the marked passage of Graue's letter and proposed that the work be done in a cave near Helmstedt because there was slave labor there already.

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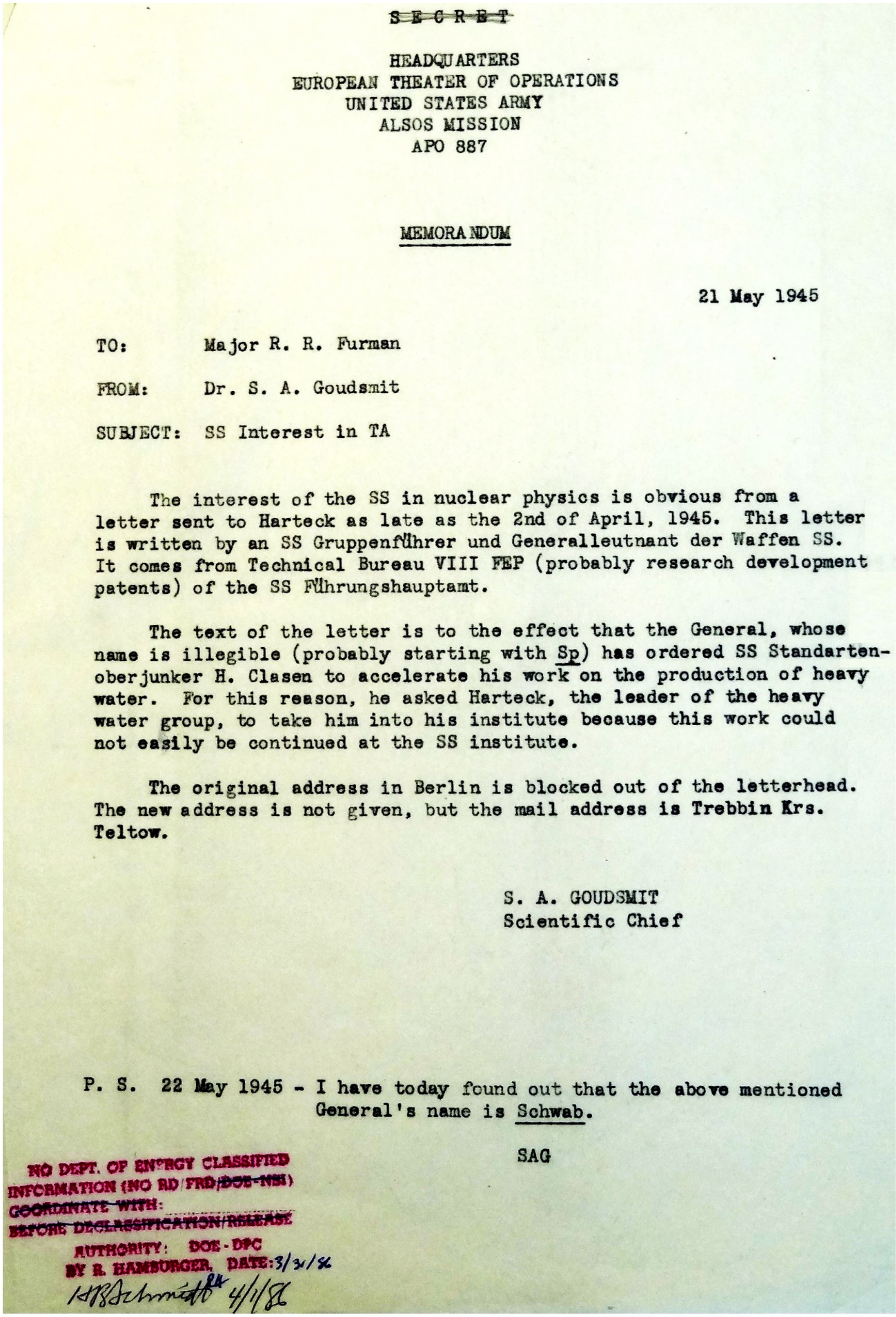
NARA RG GOUDS, Entry UD-7420, Box 6,
Folder ALSOS—Reports and Operations



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HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS MISSION
APO 887

MEMORANDUM

21 May 1945

TO: Major R. R. Furman

FROM: Dr. S. A. Goudsmit

SUBJECT: SS Interest in TA

The interest of the SS in nuclear physics is obvious from a letter sent to Harteck as late as the 2nd of April, 1945. This letter is written by an SS Gruppenführer und Generalleutnant der Waffen SS. It comes from Technical Bureau VIII FEP (probably research development patents) of the SS Führungshauptamt.

The text of the letter is to the effect that the General, whose name is illegible (probably starting with Sp) has ordered SS Standartenoberjunker H. Clasen to accelerate his work on the production of heavy water. For this reason, he asked Harteck, the leader of the heavy water group, to take him into his institute because this work could not easily be continued at the SS institute.

The original address in Berlin is blocked out of the letterhead. The new address is not given, but the mail address is Trebbin Krs. Teltow.

S. A. GOUDSMIT
Scientific Chief

P. S. 22 May 1945 - I have today found out that the above mentioned General's name is Schwab.

SAG

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INFORMATION (NO RD/FRD/~~DOE-NSI~~)
~~COORDINATE WITH:~~
~~BEFORE DECLASSIFICATION/RELEASE~~
AUTHORITY: DOE-DPC
BY R. HAMBURGER, DATE: 3/31/86
HBSchmidt RH 4/1/86

Figure D.514: Samuel Goudsmit to Robert R. Furman. 21 May 1945 [NARA RG GOUDS, Entry UD-7420, Box 6, Folder ALSOS—Reports and Operations]. "The interest of the SS in nuclear physics is obvious from a letter sent to Harteck as late as the 2nd of April, 1945... It comes from the Technical Bureau VIII FEP... The text of the letter is to the effect that the General... has ordered SS Standartenoberjunker H. Clasen to accelerate his work on the production of heavy water... General's name is Schwab."

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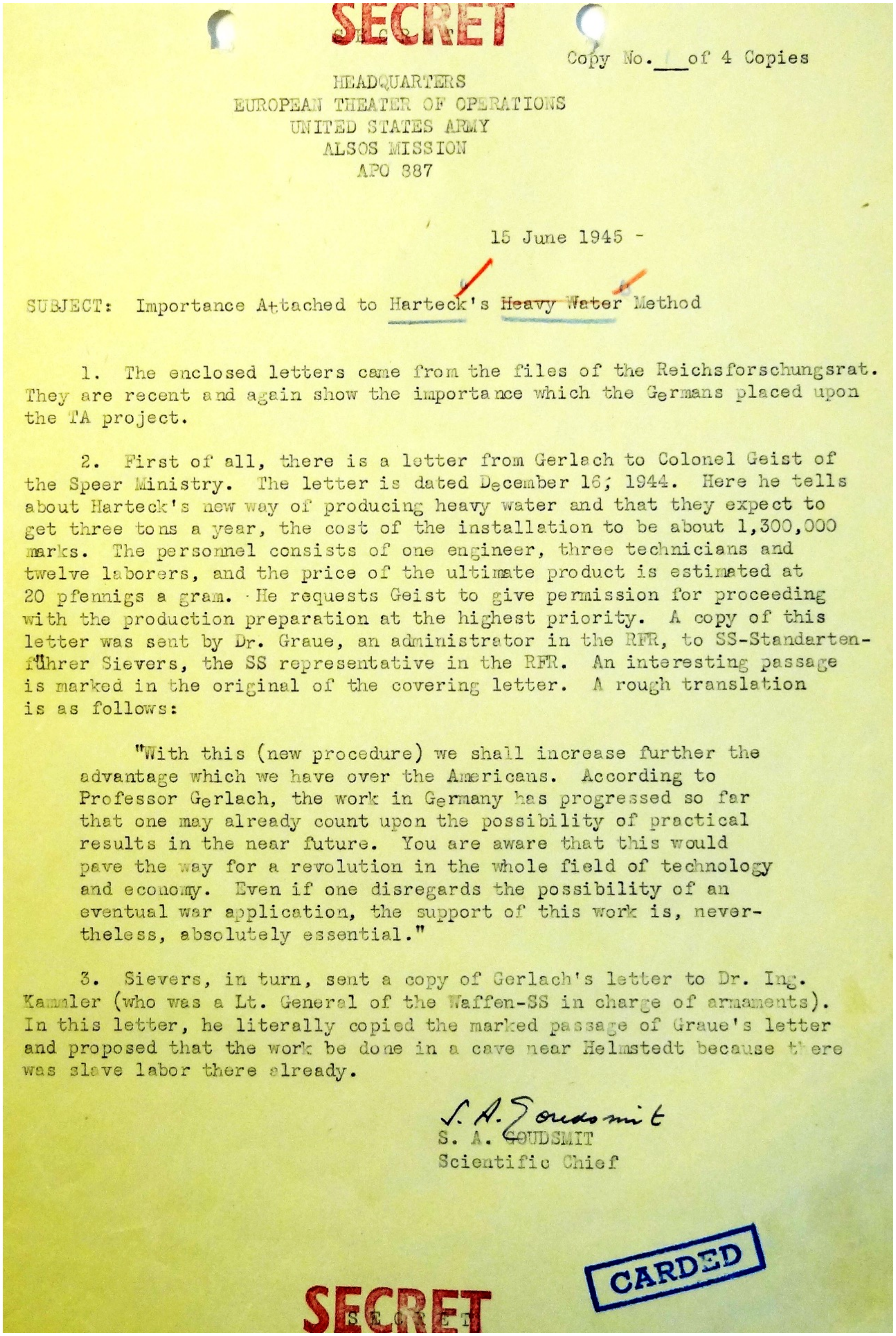
NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1
GERMANY—Research—TA—(1943--June 1946)



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HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS MISSION
APO 887

15 June 1945 -

SUBJECT: Importance Attached to Harteck's Heavy Water Method

1. The enclosed letters came from the files of the Reichsforschungsrat. They are recent and again show the importance which the Germans placed upon the TA project.

2. First of all, there is a letter from Gerlach to Colonel Geist of the Speer Ministry. The letter is dated December 16, 1944. Here he tells about Harteck's new way of producing heavy water and that they expect to get three tons a year, the cost of the installation to be about 1,300,000 marks. The personnel consists of one engineer, three technicians and twelve laborers, and the price of the ultimate product is estimated at 20 pfennigs a gram. He requests Geist to give permission for proceeding with the production preparation at the highest priority. A copy of this letter was sent by Dr. Graue, an administrator in the RFR, to SS-Standartenführer Sievers, the SS representative in the RFR. An interesting passage is marked in the original of the covering letter. A rough translation is as follows:

> "With this (new procedure) we shall increase further the advantage which we have over the Americans. According to Professor Gerlach, the work in Germany has progressed so far that one may already count upon the possibility of practical results in the near future. You are aware that this would pave the way for a revolution in the whole field of technology and economy. Even if one disregards the possibility of an eventual war application, the support of this work is, nevertheless, absolutely essential."

3. Sievers, in turn, sent a copy of Gerlach's letter to Dr. Ing. Kammler (who was a Lt. General of the Waffen-SS in charge of armaments). In this letter, he literally copied the marked passage of Graue's letter and proposed that the work be done in a cave near Helmstedt because there was slave labor there already.

S. A. Goudsmit
S. A. GOUDSMIT
Scientific Chief

CARDED

SECRET

Figure D.515: Samuel A. Goudsmit. 15 June 1945. SUBJECT: Importance Attached to Harteck's Heavy Water Method. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA—(1943–June 1946)]. See also p. 4088. “The enclosed letters... again show the importance which the Germans placed upon the TA project... There is a letter from Gerlach to Colonel Geist of the Speer Ministry... dated December 16, 1944. Here he tells about Harteck's new way of producing heavy water... Sievers, in turn, sent a copy of Gerlach's letter to Dr. Ing. Kammler (who was a Lt. General of the Waffen-SS in charge of armaments)... and proposed that the work be done in a cave near Helmstedt because there was slave labor there already.”

B. Lithium

[Lithium was used for processing ceramics, glass, and metals, but it would also have been extremely useful for producing tritium, neutrons, and/or fusion reactions. The following documents demonstrate large-scale production of lithium, as well as shipment of a large amount of lithium to Japan (along with other nuclear-related materials).

For documentation about wartime German separation of lithium isotopes, for which the only significant applications would be nuclear-related, see p. 4344.]

FIAT 295. *Lithium Extraction and Uses.* p. 9.

[...] Metallgesellschaft produced in 1942:

11637	kilograms	Lithium	from Lithium Mica
1702	”	”	Amblygonite in form of

	1942	1941.
Lithium Carbonate	18987 kgr.	12130 kgr.
Lithium Chloride	12630 ”	13725 ”
Lithium Hydroxide	40506 ”	38003 ”
Lithium Metal	1230 ”	505 ”

Lithium Carbonate and Hydroxide were sold to Merck and other chemical concerns to make medical salts, and Lithium Fluoride. Lithium Hydroxide is also used for storage to batteries. All the Lithium Chloride was used entirely for making Lithium metal. [...]

The amount of Lithium mica received from Metallgesellschaft were:

Year	Tons
1943	530
1st half 1944	293
July-Sept 1944	149

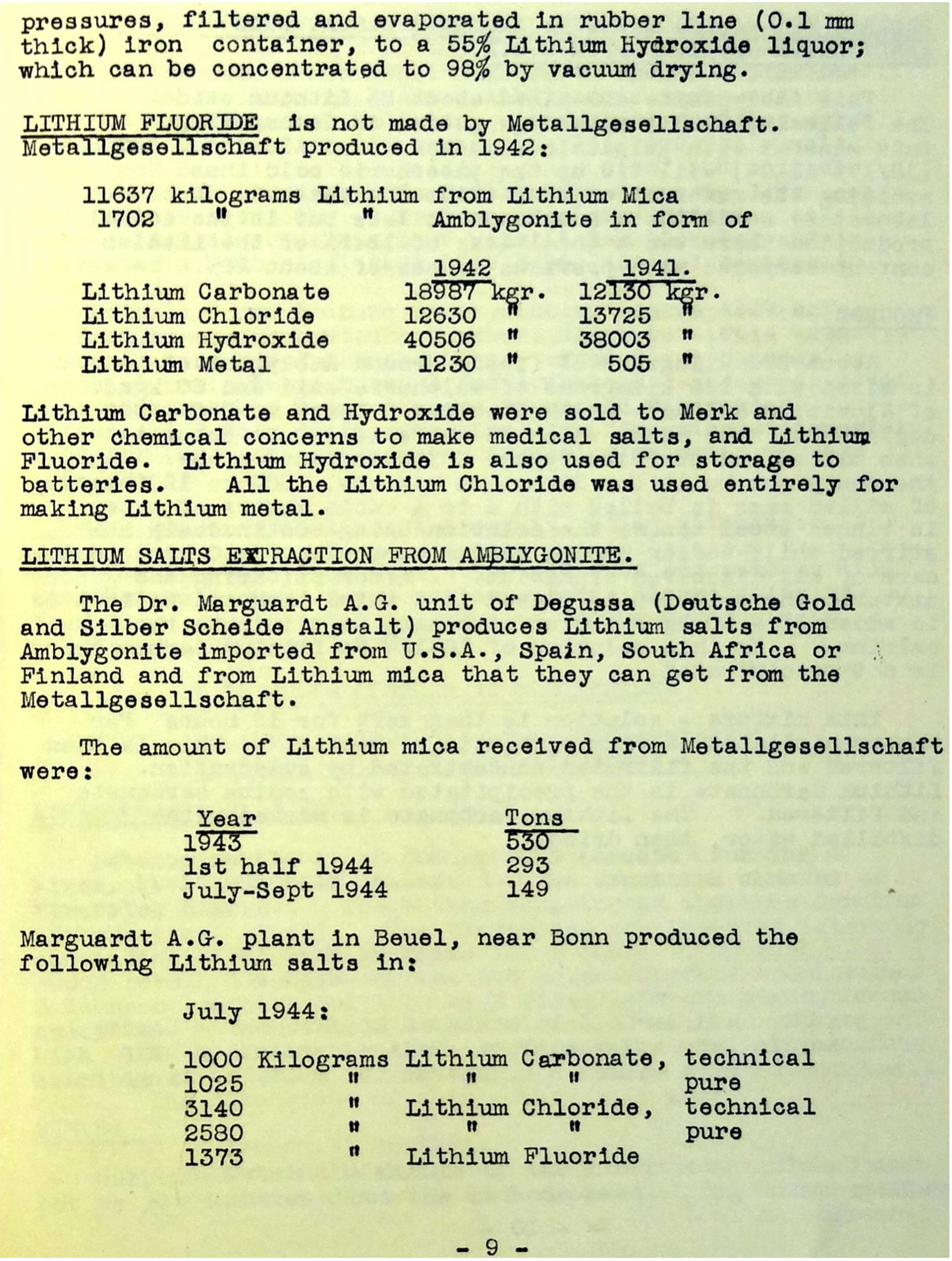
Marguardt A.G. plant in Beuel, near Bonn produced the following Lithium salts in:

July 1944:

1000 Kilograms	Lithium Carbonate,		technical
1025 ”	”	”	pure
3140 ”	Lithium Chloride,		technical
2580 ”	”	”	pure
1373 ”	Lithium Fluoride		

[See document photo on p. 4091.]

FIAT 295. *Lithium Extraction and Uses*, p. 9



pressures, filtered and evaporated in rubber line (0.1 mm thick) iron container, to a 55% Lithium Hydroxide liquor; which can be concentrated to 98% by vacuum drying.

LITHIUM FLUORIDE is not made by Metallgesellschaft. Metallgesellschaft produced in 1942:

11637 kilograms Lithium from Lithium Mica
1702 " " Amblygonite in form of

	1942	1941.
Lithium Carbonate	18987 kgr.	12130 kgr.
Lithium Chloride	12630 "	13725 "
Lithium Hydroxide	40506 "	38003 "
Lithium Metal	1230 "	505 "

Lithium Carbonate and Hydroxide were sold to Merk and other chemical concerns to make medical salts, and Lithium Fluoride. Lithium Hydroxide is also used for storage to batteries. All the Lithium Chloride was used entirely for making Lithium metal.

LITHIUM SALTS EXTRACTION FROM AMBLYGONITE.

The Dr. Marguardt A.G. unit of Degussa (Deutsche Gold and Silber Scheide Anstalt) produces Lithium salts from Amblygonite imported from U.S.A., Spain, South Africa or Finland and from Lithium mica that they can get from the Metallgesellschaft.

The amount of Lithium mica received from Metallgesellschaft were:

Year	Tons
1943	530
1st half 1944	293
July-Sept 1944	149

Marguardt A.G. plant in Beuel, near Bonn produced the following Lithium salts in:

July 1944:

1000 Kilograms	Lithium Carbonate,	technical
1025 "	" "	pure
3140 "	Lithium Chloride,	technical
2580 "	" "	pure
1373 "	Lithium Fluoride	

Figure D.516: FIAT 295. *Lithium Extraction and Uses.* p. 9.

FIAT 750. *Rare and Minor Metals.* pp. 8–9.

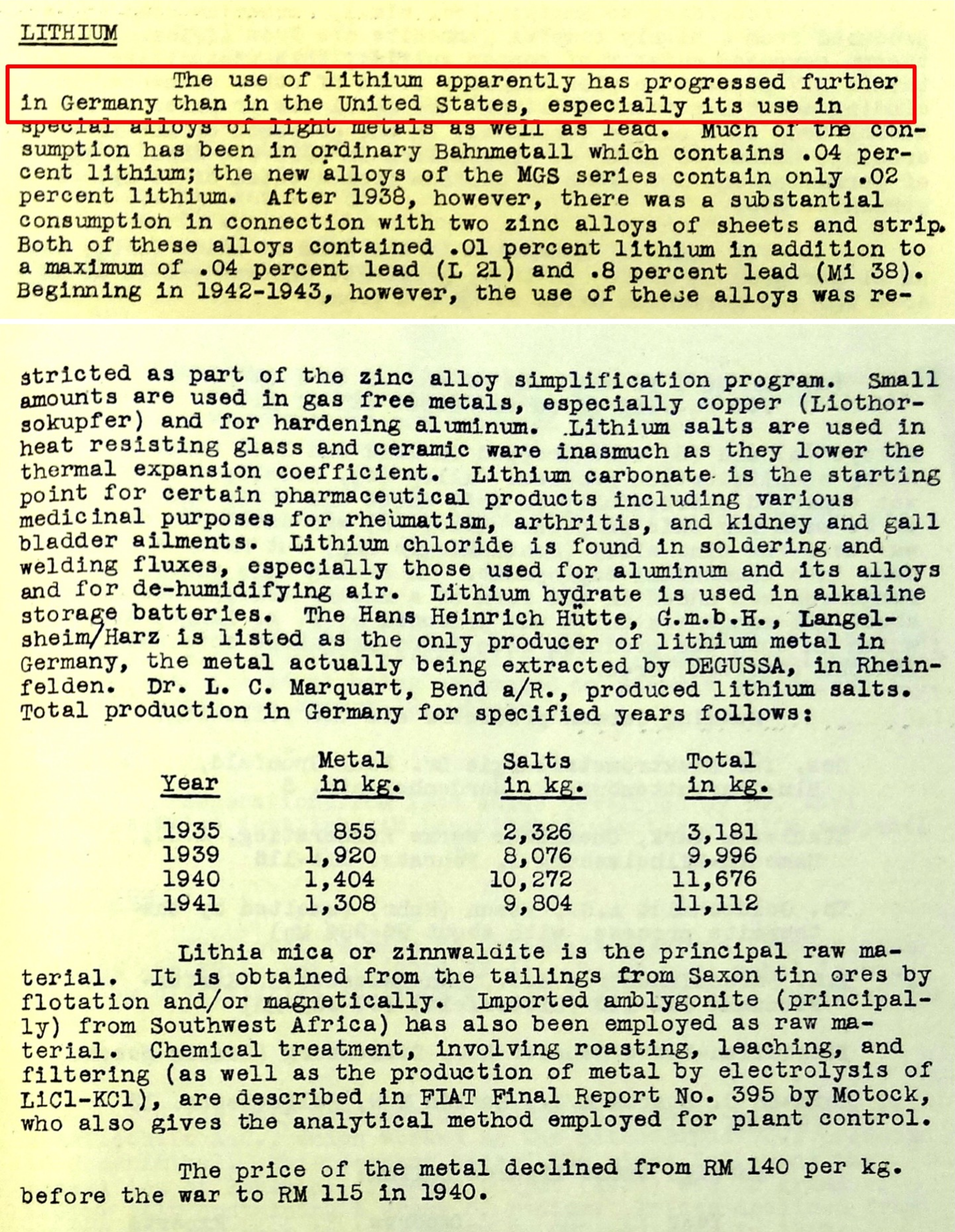
The use of lithium apparently has progressed further in Germany than in the United States, especially its use in special alloys of light metals as well as lead. [...] Lithium salts are used in heat resisting glass and ceramic ware inasmuch as they lower the thermal expansion coefficient. Lithium carbonate is the starting point for certain pharmaceutical products[...] Lithium chloride is found in soldering and welding fluxes[...] Lithium hydrate is used in alkaline storage batteries. [...] Total production in Germany for specified years follows:

Year	Metal in kg.	Salts in kg.	Total in kg.
1935	855	2,326	3,181
1939	1,920	8,076	9,996
1940	1,404	10,272	11,676
1941	1,308	9,804	11,112

[...] The price of the metal declined from RM 140 per kg. before the war to RM 115 in 1940.

[See document photo on p. 4093.]

FIAT 750. *Rare and Minor Metals*, pp. 8-9



LITHIUM

The use of lithium apparently has progressed further in Germany than in the United States, especially its use in special alloys of light metals as well as lead. Much of the consumption has been in ordinary Bahnmetall which contains .04 percent lithium; the new alloys of the MGS series contain only .02 percent lithium. After 1938, however, there was a substantial consumption in connection with two zinc alloys of sheets and strip. Both of these alloys contained .01 percent lithium in addition to a maximum of .04 percent lead (L 21) and .8 percent lead (Mi 38). Beginning in 1942-1943, however, the use of these alloys was restricted as part of the zinc alloy simplification program. Small amounts are used in gas free metals, especially copper (Liothorsokupfer) and for hardening aluminum. Lithium salts are used in heat resisting glass and ceramic ware inasmuch as they lower the thermal expansion coefficient. Lithium carbonate is the starting point for certain pharmaceutical products including various medicinal purposes for rheumatism, arthritis, and kidney and gall bladder ailments. Lithium chloride is found in soldering and welding fluxes, especially those used for aluminum and its alloys and for de-humidifying air. Lithium hydrate is used in alkaline storage batteries. The Hans Heinrich Hütte, G.m.b.H., Langelsheim/Harz is listed as the only producer of lithium metal in Germany, the metal actually being extracted by DEGUSSA, in Rheinfelden. Dr. L. C. Marquart, Bend a/R., produced lithium salts. Total production in Germany for specified years follows:

Year	Metal in kg.	Salts in kg.	Total in kg.
1935	855	2,326	3,181
1939	1,920	8,076	9,996
1940	1,404	10,272	11,676
1941	1,308	9,804	11,112

Lithia mica or zinnwaldite is the principal raw material. It is obtained from the tailings from Saxon tin ores by flotation and/or magnetically. Imported amblygonite (principally) from Southwest Africa) has also been employed as raw material. Chemical treatment, involving roasting, leaching, and filtering (as well as the production of metal by electrolysis of LiCl-KCl), are described in FIAT Final Report No. 395 by Motock, who also gives the analytical method employed for plant control.

The price of the metal declined from RM 140 per kg. before the war to RM 115 in 1940.

Figure D.517: FIAT 750. *Rare and Minor Metals.* pp. 8–9.

Tokyo to Berlin ULTRA message 1443. 16 January 1945. [**Published in Henshall 2000, p. 57. What is the archival source of this document???**]

NAVAL SECTION
JNA 20 C/S 114/1/2/3
TOO 161920 January 1945
From: TOKYO
Action: BERLIN

ULTRA/ZIP/SJA/1443
MEW/535

Action: BWG [Chief Technical Superintendent].
From: CJR [Naval Technical Directorate].

Your secret telegram No. 848 [SJA/1358: enquires what cargo is to be shipped in submarines proceeding to the Far East].

It is desired to obtain the following material urgently by means of the German transport submarines proceeding to Japan.

2. For Department No. 3: [This line is typed differently than the rest, and there is some blank space here. Was information deleted here, and if so by whom?]

1) Diamond dies (diameter between 0.02 and 0.08 mm., as large a quantity as possible of all kinds).

2) Metallic zirconium (500 kg of a standard of 99.5 per cent or over).

3) Metallic lithium, 500 kg.

4) Neon gas (as much as possible).

5) Insulating material for ultra high frequencies, 10 kg of each kind.

6) 2,000 or more [HASPEKERNE, ? clamp cores].

[Clamp cores/nuclear, or nuclear/core clamps?]

3. For Department No. 5:

1) As many BOSCH fuel pumps models 10 and 6 as possible.

2) 1 polarizing microscope.

3) 10 cam shaft grinders.

4) 10 MAAG gear wheel grinders.

[Were there other related messages? Since zirconium and lithium seem like materials for nuclear work, are the other materials for "Department No. 3" also related to nuclear work? What exactly were the "HASPEKERNE" [Henshall 2000, pp. 56–58]?]

For more information on wartime lithium production and applications, see:

BIOS 1356. *Grinding and Treatment of Minerals.* [Lithium production]

FIAT 786. *The Lithium Electrolytic Cell. (Degussa, Rheinfelde.)*

C. Beryllium

[Beryllium was used for producing certain metal alloys, but it also could have been quite useful as a neutron reflector and multiplier in a fission reactor, electronuclear breeding system, or fission bomb. The following documents illustrate that wartime production of beryllium was sophisticated and on a large scale.]

John E. Vance to Francis J. Smith. 17 July 1945. [NARA RG 77, Entry UD-22A, Box 163, Folder Australia]

1. Major Kelley stated that Madison Square Area had been called upon to furnish increased quantities of beryllium metal. The single source of beryllium metal at this time is the Brush Beryllium Company of Cleveland, Ohio, whose facilities are to be enlarged. However, to assist in meeting the requirements, Major Kelley suggested that it would be extremely valuable if it were possible to acquire beryllium metal discovered in Germany.

2. To be useful to use, the metal should be massive, i.e., should be in pieces rather than in flakes and should contain more than 90% beryllium; it would probably not be advisable to place other specifications on the metal.

H. S. Lowenhaupt to Francis J. Smith. 19 July 1945. [NARA RG 77, Entry UD-22A, Box 163, Folder Australia]

A cable to Major F. J. Smith, 17 May states that considerable beryllium was found in Germany by the AT Group. Whereabouts of this metal is not known at present.

A bill from the files (from Deutsche Gold und Silber Scheideanstalt Vormals Roessler, Degussa, Frankfort am Main, 7 May 1943 to the Heereswaffenamt, Berlin) is for 100 plates made of beryllium or 27.848 kg. at 140.20 marks per kg.

I suggest this firm be contacted by our people to see if they can still supply metallic beryllium, either through purchase, or as plunder.

[See document photos on p. 4097. The U.S. nuclear weapons program needed more beryllium than was being produced in the United States. Postwar U.S. investigators discovered that highly suitable beryllium had been made in large quantities in Germany—and had been shipped to Erich Schumann's Army Ordnance Office (Heereswaffenamt) during the war. The investigators also discovered that "considerable" additional quantities of beryllium had been produced and had disappeared into even more mysterious projects: "Whereabouts of this metal is not known at present."]

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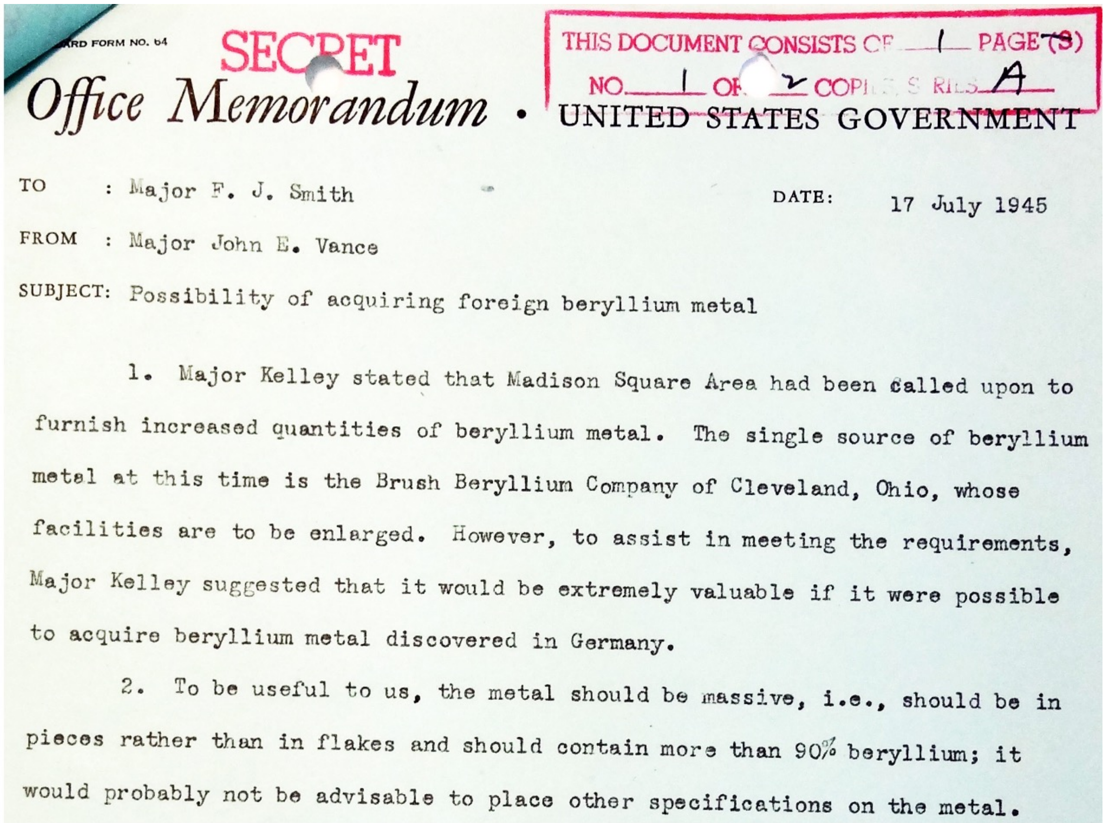


RD FORM NO. 64

SECRET

THIS DOCUMENT CONSISTS OF 1 PAGE~~(S)~~
NO. 1 OF 2 COPIES, SERIES A

Office Memorandum • UNITED STATES GOVERNMENT

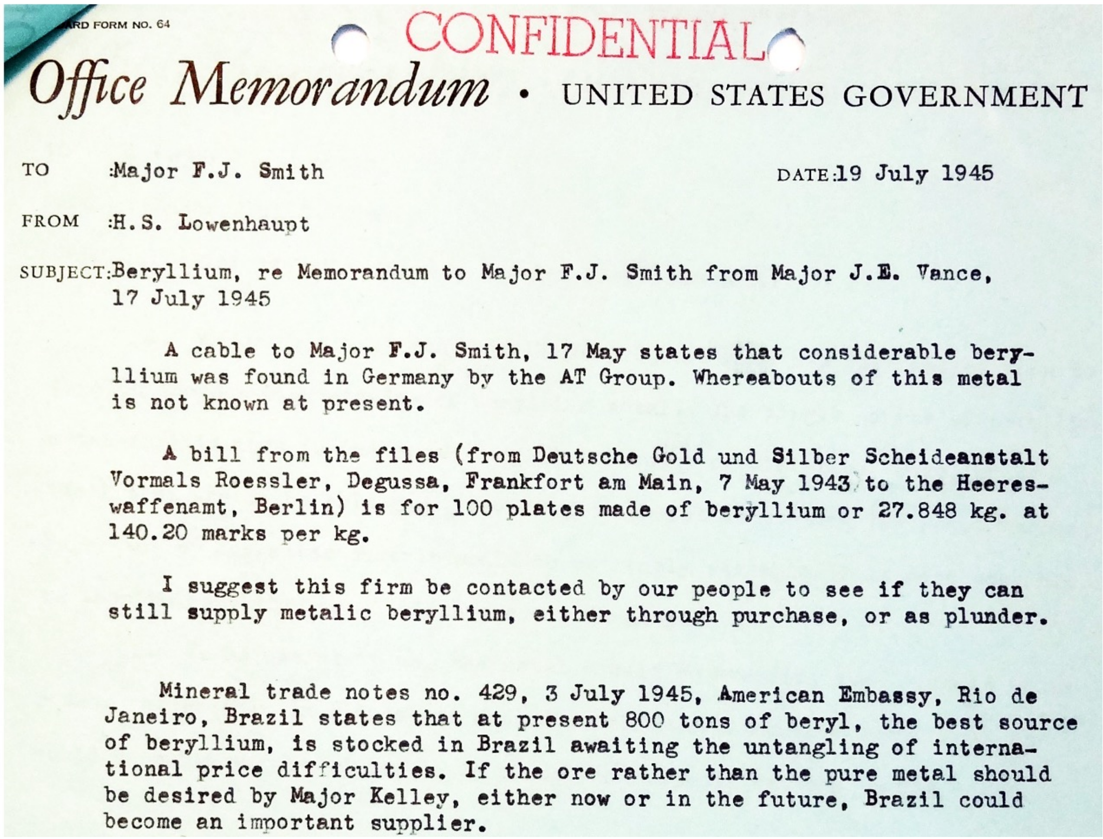
TO : Major F. J. Smith DATE: 17 July 1945

FROM : Major John E. Vance

SUBJECT: Possibility of acquiring foreign beryllium metal

1. Major Kelley stated that Madison Square Area had been called upon to furnish increased quantities of beryllium metal. The single source of beryllium metal at this time is the Brush Beryllium Company of Cleveland, Ohio, whose facilities are to be enlarged. However, to assist in meeting the requirements, Major Kelley suggested that it would be extremely valuable if it were possible to acquire beryllium metal discovered in Germany.

2. To be useful to us, the metal should be massive, i.e., should be in pieces rather than in flakes and should contain more than 90% beryllium; it would probably not be advisable to place other specifications on the metal.



RD FORM NO. 64

CONFIDENTIAL

Office Memorandum • UNITED STATES GOVERNMENT

TO :Major F.J. Smith DATE:19 July 1945

FROM :H.S. Lowenhaupt

SUBJECT:Beryllium, re Memorandum to Major F.J. Smith from Major J.E. Vance, 17 July 1945

A cable to Major F.J. Smith, 17 May states that considerable beryllium was found in Germany by the AT Group. Whereabouts of this metal is not known at present.

A bill from the files (from Deutsche Gold und Silber Scheideanstalt Vormals Roessler, Degussa, Frankfort am Main, 7 May 1943 to the Heereswaffenamt, Berlin) is for 100 plates made of beryllium or 27.848 kg. at 140.20 marks per kg.

I suggest this firm be contacted by our people to see if they can still supply metalic beryllium, either through purchase, or as plunder.

Mineral trade notes no. 429, 3 July 1945, American Embassy, Rio de Janeiro, Brazil states that at present 800 tons of beryl, the best source of beryllium, is stocked in Brazil awaiting the untangling of international price difficulties. If the ore rather than the pure metal should be desired by Major Kelley, either now or in the future, Brazil could become an important supplier.

NARA RG 77, Entry UD-22A, Box 163, Folder Australia

Figure D.518: The U.S. nuclear weapons program needed more beryllium than was being produced in the United States. It discovered that highly suitable beryllium was made in large quantities in Germany—and was shipped to Erich Schumann's Army Ordnance Office (Heereswaffenamt) during the war [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

BIOS 158. ***Production of Beryllia and Beryllium at Degussa Plants.***

Production of Beryllium Oxide and Beryllium at the Degussa Plant in Frankfurt

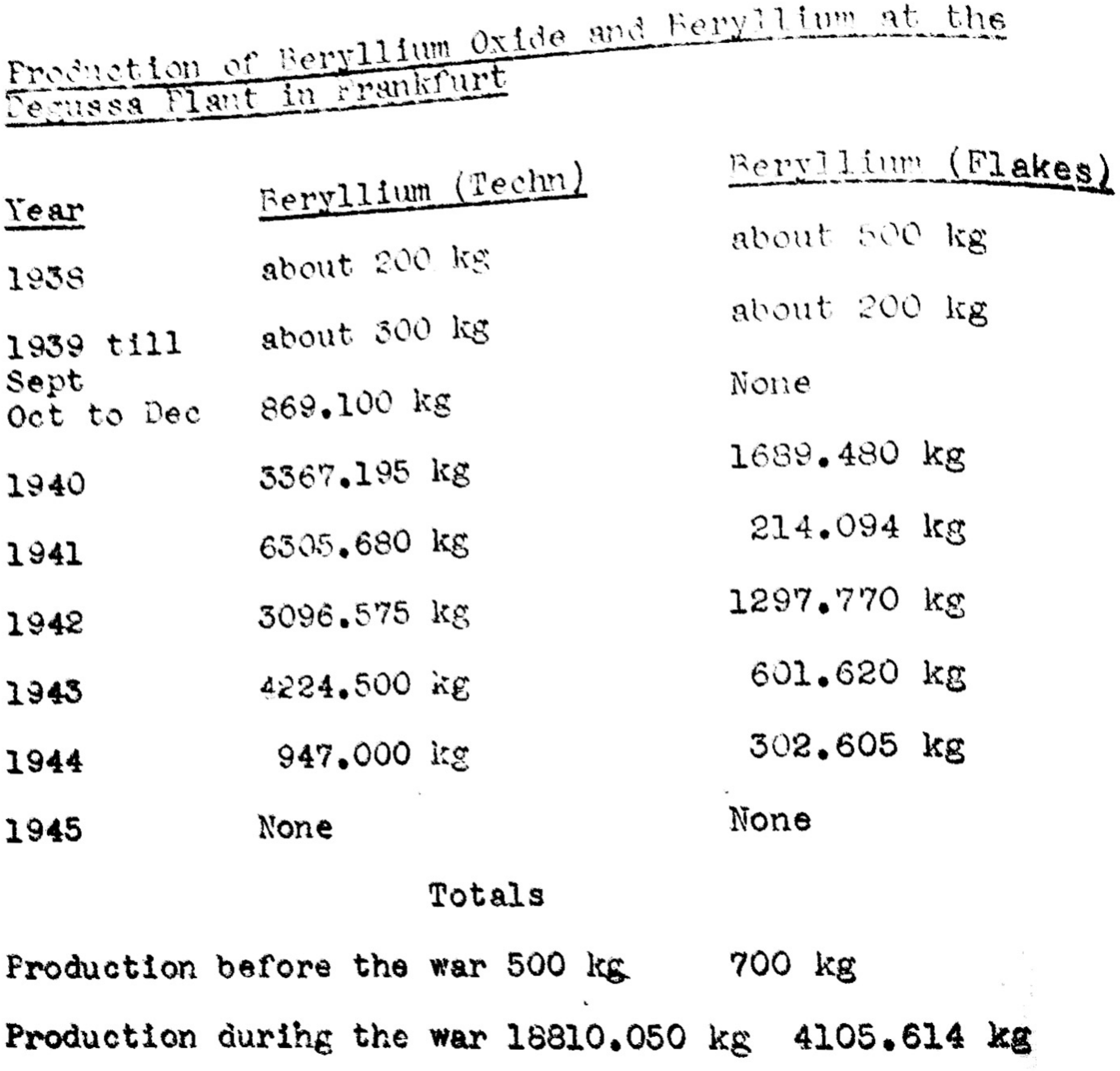
Year	Beryllium (Techn)	Beryllium (Flakes)
1938	about 200 kg	about 500 kg
1939 till Sept	about 300 kg	about 200 kg
Oct to Dec	869.100 kg	None
1940	3367.195 kg	1689.480 kg
1941	6305.680 kg	214.094 kg
1942	3096.575 kg	1297.770 kg
1943	4224.500 kg	601.620 kg
1944	947.000 kg	302.605 kg
1945	None	None
	Totals	
Production before the war	500 kg	700 kg
Production during the war	18810.050 kg	4105.614 kg

[See document photo on p. 4099.]

BIOS 319. ***Production of Beryllium "Degussa."***

The whole of our party visited this Factory, spending about three hours with Dr. Völkel, who clearly knew his subject. [...]

Maximum production reached 160/180 Kg. pure beryllium per month.



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Year	Beryllium (Techn)	Beryllium (Flakes)
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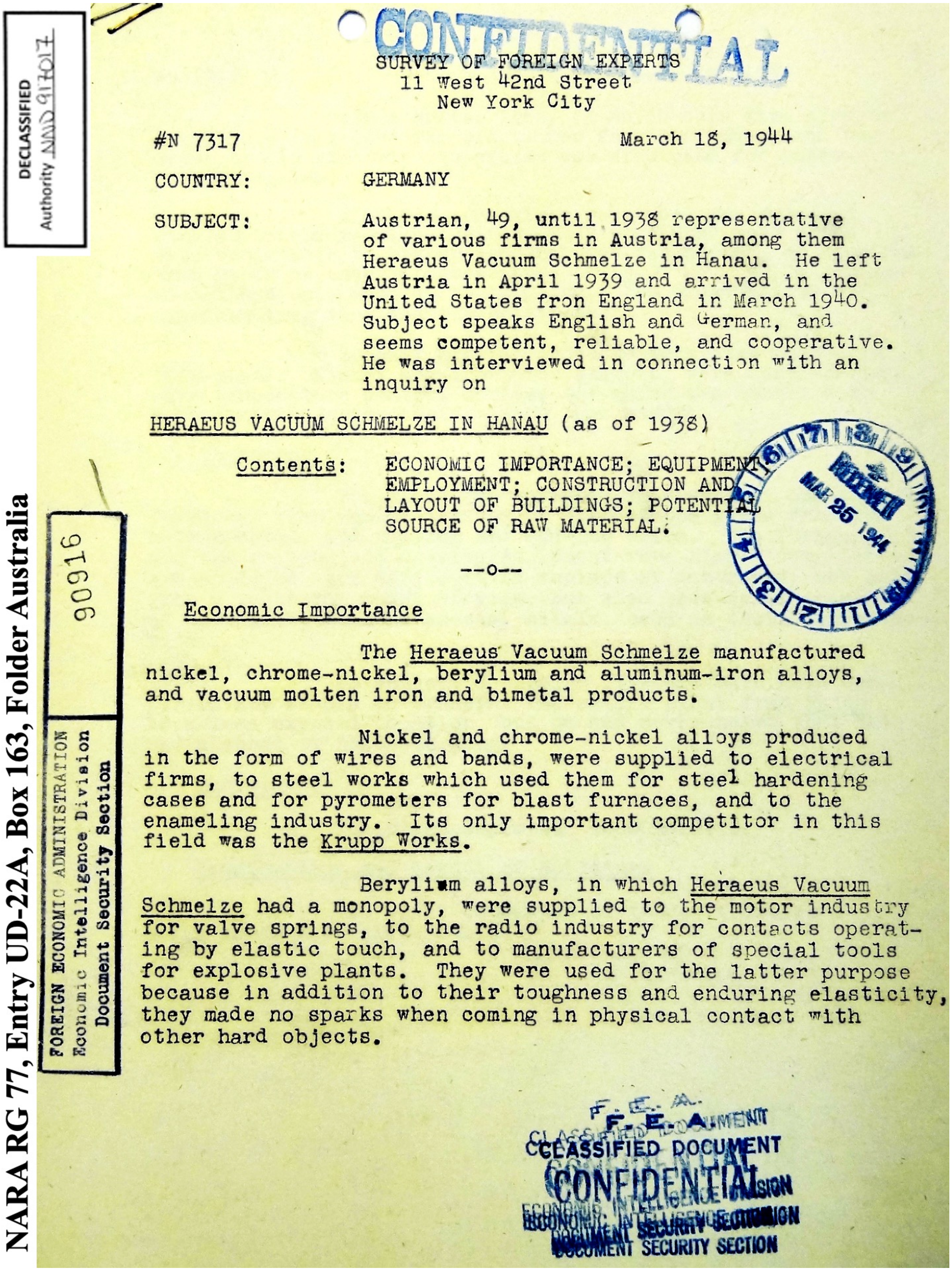
1943	4224.500 kg	601.620 kg
1944	947.000 kg	302.605 kg
1945	None	None

Totals

Production before the war 500 kg 700 kg

Production durihg the war 18810.050 kg 4105.614 kg

Figure D.519: BIOS 158. *Production of Beryllia and Beryllium at Degussa Plants.*



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Authority NND 917017

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SURVEY OF FOREIGN EXPERTS
11 West 42nd Street
New York City

#N 7317 March 18, 1944

COUNTRY: GERMANY

SUBJECT: Austrian, 49, until 1938 representative of various firms in Austria, among them Heraeus Vacuum Schmelze in Hanau. He left Austria in April 1939 and arrived in the United States fron England in March 1940. Subject speaks English and German, and seems competent, reliable, and cooperative. He was interviewed in connection with an inquiry on

HERAEUS VACUUM SCHMELZE IN HANAU (as of 1938)

Contents: ECONOMIC IMPORTANCE; EQUIPMENT; EMPLOYMENT; CONSTRUCTION AND LAYOUT OF BUILDINGS; POTENTIAL SOURCE OF RAW MATERIAL.

RECEIVED MAR 25 1944

--o--

Economic Importance

The Heraeus Vacuum Schmelze manufactured nickel, chrome-nickel, berylium and aluminum-iron alloys, and vacuum molten iron and bimetal products.

Nickel and chrome-nickel alloys produced in the form of wires and bands, were supplied to electrical firms, to steel works which used them for steel hardening cases and for pyrometers for blast furnaces, and to the enameling industry. Its only important competitor in this field was the Krupp Works.

Berylium alloys, in which Heraeus Vacuum Schmelze had a monopoly, were supplied to the motor industry for valve springs, to the radio industry for contacts operating by elastic touch, and to manufacturers of special tools for explosive plants. They were used for the latter purpose because in addition to their toughness and enduring elasticity, they made no sparks when coming in physical contact with other hard objects.

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DOCUMENT SECURITY SECTION

NARA RG 77, Entry UD-22A, Box 163, Folder Australia

Figure D.520: Ronald Carroll. 18 March 1944 [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

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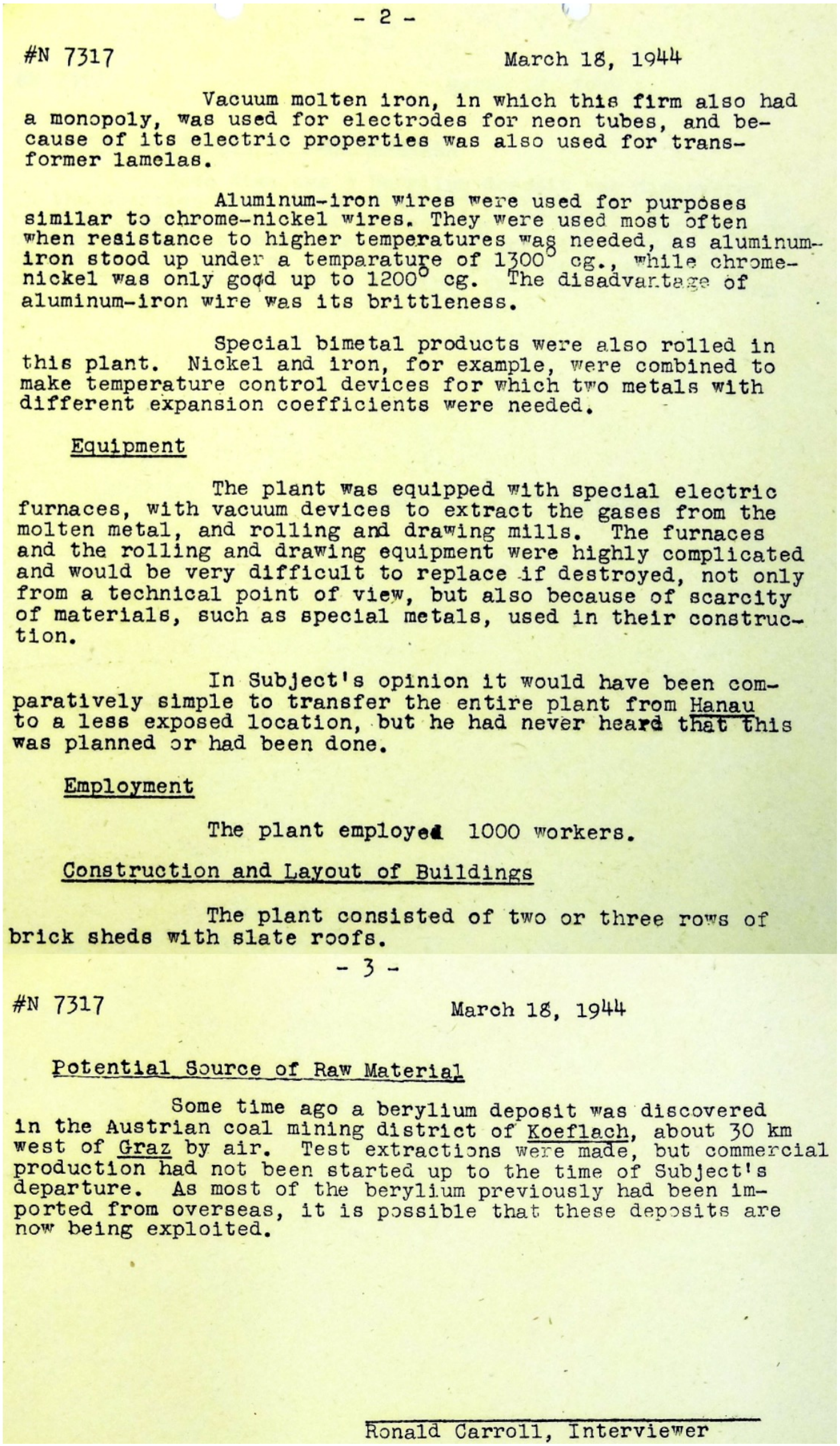
NARA RG 77, Entry UD-22A, Box 163, Folder Australia



- 2 -

#N 7317 March 18, 1944

Vacuum molten iron, in which this firm also had a monopoly, was used for electrodes for neon tubes, and because of its electric properties was also used for transformer lamelas.

Aluminum-iron wires were used for purposes similar to chrome-nickel wires. They were used most often when resistance to higher temperatures was needed, as aluminum-iron stood up under a temparature of 1300° cg., while chrome-nickel was only good up to 1200° cg. The disadvantage of aluminum-iron wire was its brittleness.

Special bimetal products were also rolled in this plant. Nickel and iron, for example, were combined to make temperature control devices for which two metals with different expansion coefficients were needed.

Equipment

The plant was equipped with special electric furnaces, with vacuum devices to extract the gases from the molten metal, and rolling and drawing mills. The furnaces and the rolling and drawing equipment were highly complicated and would be very difficult to replace if destroyed, not only from a technical point of view, but also because of scarcity of materials, such as special metals, used in their construction.

In Subject's opinion it would have been comparatively simple to transfer the entire plant from Hanau to a less exposed location, but he had never heard that this was planned or had been done.

Employment

The plant employed 1000 workers.

Construction and Layout of Buildings

The plant consisted of two or three rows of brick sheds with slate roofs.

- 3 -

#N 7317 March 18, 1944

Potential Source of Raw Material

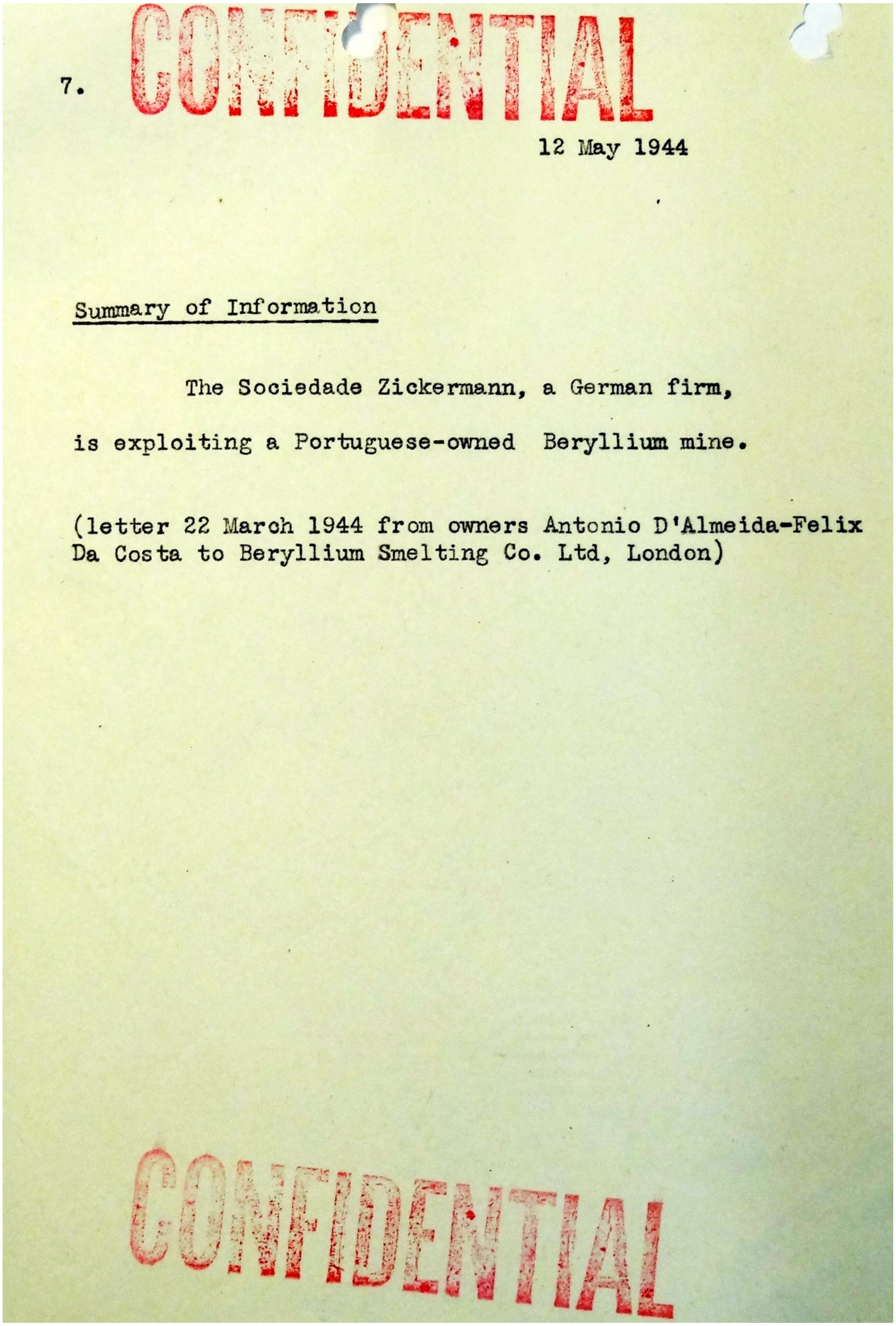
Some time ago a berylium deposit was discovered in the Austrian coal mining district of Koeflach, about 30 km west of Graz by air. Test extractions were made, but commercial production had not been started up to the time of Subject's departure. As most of the berylium previously had been imported from overseas, it is possible that these deposits are now being exploited.

Ronald Carroll, Interviewer

Figure D.521: Ronald Carroll. 18 March 1944 [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)



7. CONFIDENTIAL

12 May 1944

Summary of Information

The Sociedade Zickermann, a German firm, is exploiting a Portuguese-owned Beryllium mine.

(letter 22 March 1944 from owners Antonio D'Almeida-Felix Da Costa to Beryllium Smelting Co. Ltd, London)

CONFIDENTIAL

Figure D.522: 12 May 1944. Summary of Information [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

The following documents are examples of German plans to ship large quantities of beryllium to Japan [Henshall 2000, p. 55]:

> Berlin to Tokyo ULTRA message 1201. 22 November 1944. Cargo lost on I-52? [TNA **file number???**] Lists 2590 kg of beryllium alloy for shipment from Germany to Japan.
>
> Berlin to Tokyo ULTRA message 1809. 15 April 1945. Cargo loaded on U-873 [which later surrendered to United States on 11 May 1945]. [TNA **file number???**] Lists 1,402 bars of beryllium alloy for shipment from Germany to Japan.

For more information on wartime beryllium production and applications, see:

> BIOS 36. *Magnetic Materials and Beryllium.*
>
> BIOS 441. *The Platinum Metals Industry in Germany.* [Beryllium-platinum alloys.]
>
> BIOS 550. *Investigation of Beryllium Production in Germany and Italy Including Production and Uses of Oxides and Alloys.*
>
> BIOS 945. *Beryllium at Degussa.*
>
> BIOS 1338. *Developments in Magnesium Production and Fabrication.* [Beryllium, zirconium at Degussa; also fluorine and carbon at I.G. Farben.]
>
> BIOS 1660. *A General Survey of the German Non-Ferrous Industry.* [aluminum, beryllium]
>
> CIOS XXVII-95. *Heraeus Vacuumschmelze AG, Hanau.* [Beryllium manufacture.]
>
> FIAT 387. *The German Steel Casting Industry* [Beryllium in steel castings.]
>
> FIAT 522. *The Beryllium Industries of Germany and Italy (1939 to 1945).*
>
> FIAT 617. *The Electrical and Technical Ceramic Industry of Germany.* [Beryllia use in ceramics.]
>
> FIAT 785. *Electrical Contacts.* [Beryllium alloys for contacts.]
>
> G-81. Erwin Fünfer and Walther Bothe. *The Absorption of Thermal Neutrons and the Increase of Fast Neutrons in Beryllium.* 1941.
>
> G-153. Wilhelm Hanle. *Spectroscopic Analysis of Carbon, Aluminum, and Beryllium.* 1942.
>
> JIOA 46. *Data on the German X-Ray Industry.* [Beryllium X-ray windows.]

D. Boron

[Boron was used for producing certain types of glass, ceramics, and metals, but it also would have been very useful as a neutron absorber. The following documents are examples of boron production, applications, and measurement.]

For information on wartime boron production and applications, see for example:

BIOS 676. *German Metallurgical Laboratories for Ferrous Metals with Special Reference to the K. W. Institute for Iron Research.* [KWI measuring boron in steel]

BIOS 925. *Tungsten Carbide Research in Germany.* [Boron carbide for tool tips.]

BIOS 1406. [Boron carbide abrasives manufacture.]

BIOS 1535. *Report on Investigation of Methods of Gaseous Metal Treatment.* [Boron-diffusion treatment of ferrous metals.]

FIAT 617. *The Electrical and Technical Ceramic Industry of Germany.* [Boron carbide and boron nitrate.]

FIAT 738. *The Production of Some Rare Metals and Their Compounds as Practiced by E. Merck, Chemische Fabrik, Darmstadt: Boron, Caesium, Gallium, Germanium, Rubidium.*

FIAT 750. *Rare and Minor Minerals.* [Boron production]

[Unless otherwise noted, text for G-series captured German nuclear reports cited here consists of the English-language abstracts prepared by American scientists who studied the German reports.]

G-35. Wilhelm Hanle. *Investigation of Cadmium Content of Carbon.* 1940.

Spectroscopic tests of charcoal prepared from sugar showed Cd content of about 10^{-7}, certainly less than 3×10^{-7}.

[See document photos on p. 4106.]

G-85. Wilhelm Hanle. *The Determination of Boron and Cadmium in Carbon.* 1941.

Method involves making spectroscopic analysis of C and comparing with C prepared from sugar to which a definite amount of boron nitride has been added. This is better than the usual boric acid because the vaporization of boron nitride compares more closely with that of boron carbide (the usual form of B in C) than does the more easily vaporized boric acid.

Cd content of sugar carbon about 10^{-7}, certainly less than 3×10^{-7}.

Boron content:

Sugar carbon	10^{-6}
Acheson graphite	10^{-4}
Beechwood carbon	10^{-5}
Arc lamp carbon, incandescent	10^{-4}

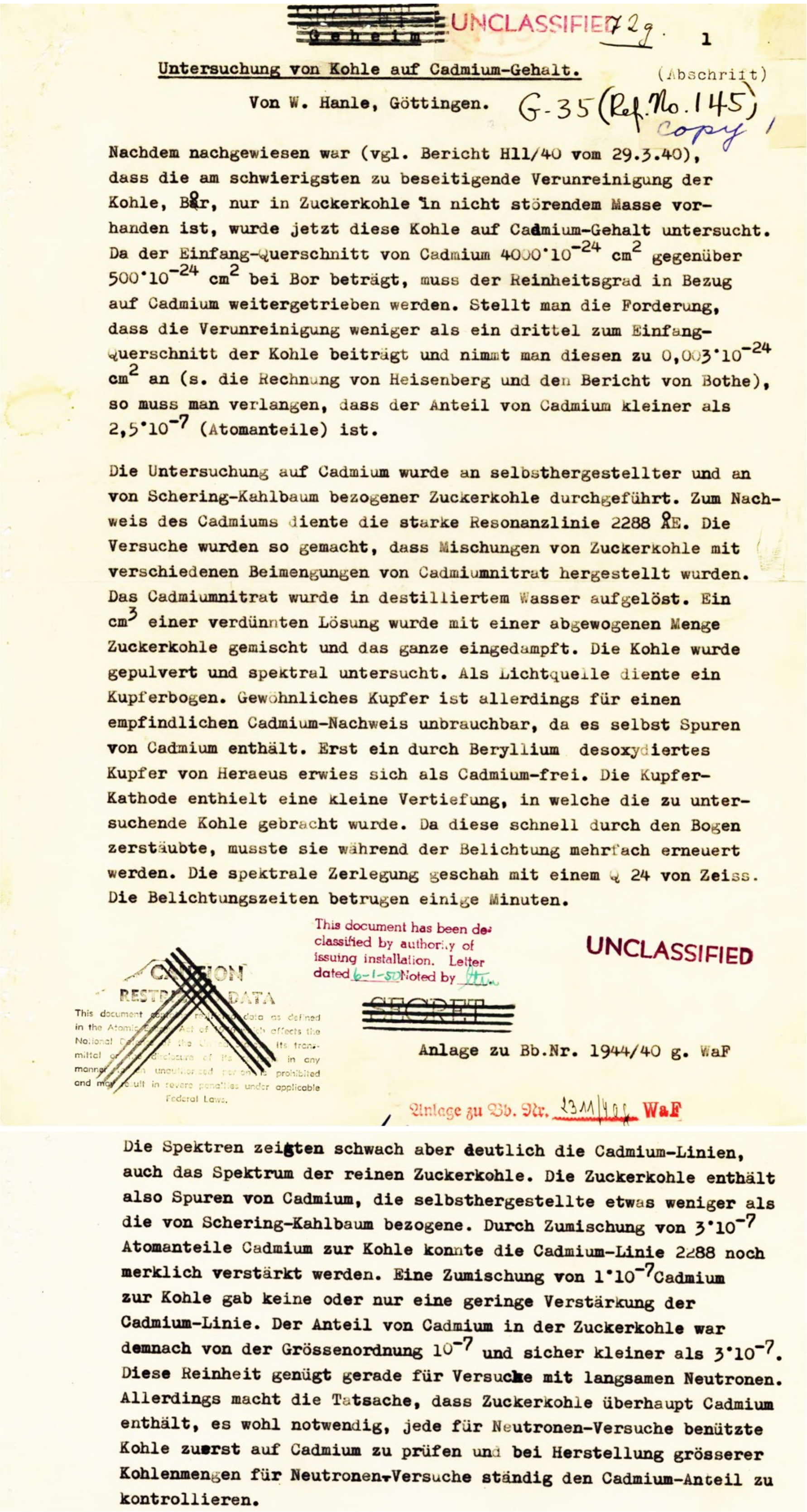
Siemens electrographite used by Bothe for his pile had a boron content between 10^{-5} and 2×10^{-6} atomic parts. The cadmium content was less than 3×10^{-7}.

[See document photos on p. 4107.]

G-153. Wilhelm Hanle. *Spectroscopic Analysis of Carbon, Aluminum, and Beryllium.* 1942.

Graphite used by Bothe, Al used by Döpel and Heisenberg, and Be oxide used by Haxel and Volz submitted for test. B content of graphite lies between 0.6 and 0.8×10^{-5} atoms of B per atom of C. Cd content of Al is less than 10^{-5} mole per mole. B content of Al is also less than 10^{-5} mole per mole. Cd content of Be oxide is less than 10^{-5} mole per mole. B content of Be oxide is less than 10^{-3} and more than 10^{-5} mole per mole.

[See document photos on pp. 4108–4109.]



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~~Geheim~~ UNCLASSIFIED 72g. 1

Untersuchung von Kohle auf Cadmium-Gehalt. (Abschrift)

Von W. Hanle, Göttingen. G-35 (Ref. No. 145) copy 1

Nachdem nachgewiesen war (vgl. Bericht H11/40 vom 29.3.40), dass die am schwierigsten zu beseitigende Verunreinigung der Kohle, Bor, nur in Zuckerkohle in nicht störendem Masse vorhanden ist, wurde jetzt diese Kohle auf Cadmium-Gehalt untersucht. Da der Einfang-Querschnitt von Cadmium $4000 \cdot 10^{-24}$ cm^2 gegenüber $500 \cdot 10^{-24}$ cm^2 bei Bor beträgt, muss der Reinheitsgrad in Bezug auf Cadmium weitergetrieben werden. Stellt man die Forderung, dass die Verunreinigung weniger als ein drittel zum Einfang-Querschnitt der Kohle beiträgt und nimmt man diesen zu $0{,}003 \cdot 10^{-24}$ cm^2 an (s. die Rechnung von Heisenberg und den Bericht von Bothe), so muss man verlangen, dass der Anteil von Cadmium kleiner als $2{,}5 \cdot 10^{-7}$ (Atomanteile) ist.

Die Untersuchung auf Cadmium wurde an selbsthergestellter und an von Schering-Kahlbaum bezogener Zuckerkohle durchgeführt. Zum Nachweis des Cadmiums diente die starke Resonanzlinie 2288 ÅE. Die Versuche wurden so gemacht, dass Mischungen von Zuckerkohle mit verschiedenen Beimengungen von Cadmiumnitrat hergestellt wurden. Das Cadmiumnitrat wurde in destilliertem Wasser aufgelöst. Ein cm^3 einer verdünnten Lösung wurde mit einer abgewogenen Menge Zuckerkohle gemischt und das ganze eingedampft. Die Kohle wurde gepulvert und spektral untersucht. Als Lichtquelle diente ein Kupferbogen. Gewöhnliches Kupfer ist allerdings für einen empfindlichen Cadmium-Nachweis unbrauchbar, da es selbst Spuren von Cadmium enthält. Erst ein durch Beryllium desoxydiertes Kupfer von Heraeus erwies sich als Cadmium-frei. Die Kupfer-Kathode enthielt eine kleine Vertiefung, in welche die zu untersuchende Kohle gebracht wurde. Da diese schnell durch den Bogen zerstäubte, musste sie während der Belichtung mehrfach erneuert werden. Die spektrale Zerlegung geschah mit einem Q 24 von Zeiss. Die Belichtungszeiten betrugen einige Minuten.

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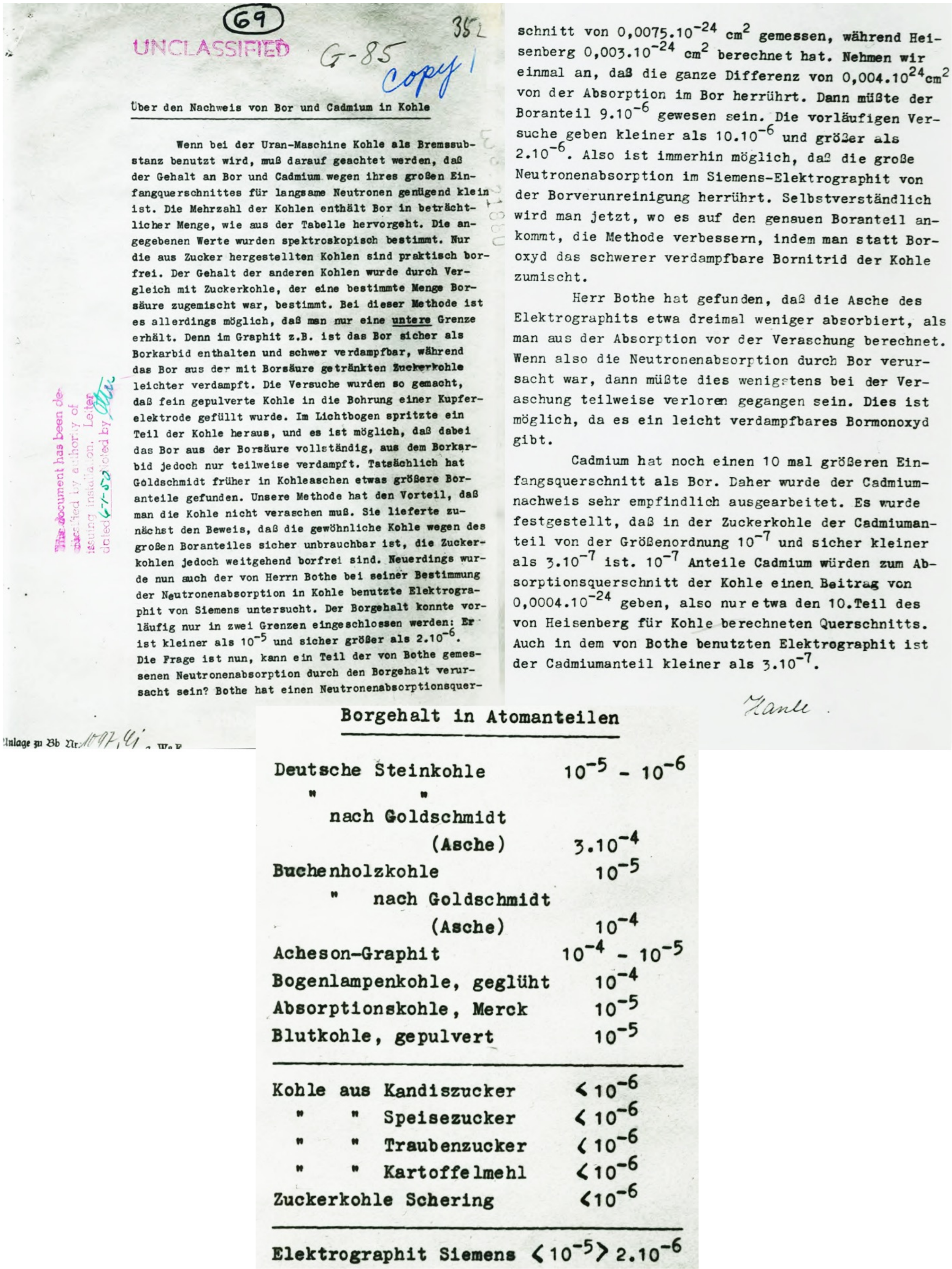
Anlage zu Bb.Nr. 1944/40 g. WaF

Anlage zu Bb. Nr. 2311/40 g. WaF

Die Spektren zeigten schwach aber deutlich die Cadmium-Linien, auch das Spektrum der reinen Zuckerkohle. Die Zuckerkohle enthält also Spuren von Cadmium, die selbsthergestellte etwas weniger als die von Schering-Kahlbaum bezogene. Durch Zumischung von $3 \cdot 10^{-7}$ Atomanteile Cadmium zur Kohle konnte die Cadmium-Linie 2288 noch merklich verstärkt werden. Eine Zumischung von $1 \cdot 10^{-7}$ Cadmium zur Kohle gab keine oder nur eine geringe Verstärkung der Cadmium-Linie. Der Anteil von Cadmium in der Zuckerkohle war demnach von der Grössenordnung 10^{-7} und sicher kleiner als $3 \cdot 10^{-7}$. Diese Reinheit genügt gerade für Versuche mit langsamen Neutronen. Allerdings macht die Tatsache, dass Zuckerkohle überhaupt Cadmium enthält, es wohl notwendig, jede für Neutronen-Versuche benützte Kohle zuerst auf Cadmium zu prüfen und bei Herstellung grösserer Kohlenmengen für Neutronen-Versuche ständig den Cadmium-Anteil zu kontrollieren.

Figure D.523: Wilhelm Hanle. *Investigation of Cadmium Content of Carbon.* 1940. [G-35]



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G-85

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Über den Nachweis von Bor und Cadmium in Kohle

Wenn bei der Uran-Maschine Kohle als Bremssubstanz benutzt wird, muß darauf geachtet werden, daß der Gehalt an Bor und Cadmium wegen ihres großen Einfangquerschnittes für langsame Neutronen genügend klein ist. Die Mehrzahl der Kohlen enthält Bor in beträchtlicher Menge, wie aus der Tabelle hervorgeht. Die angegebenen Werte wurden spektroskopisch bestimmt. Nur die aus Zucker hergestellten Kohlen sind praktisch borfrei. Der Gehalt der anderen Kohlen wurde durch Vergleich mit Zuckerkohle, der eine bestimmte Menge Borsäure zugemischt war, bestimmt. Bei dieser Methode ist es allerdings möglich, daß man nur eine untere Grenze erhält. Denn im Graphit z.B. ist das Bor sicher als Borkarbid enthalten und schwer verdampfbar, während das Bor aus der mit Borsäure getränkten Zuckerkohle leichter verdampft. Die Versuche wurden so gemacht, daß fein gepulverte Kohle in die Bohrung einer Kupferelektrode gefüllt wurde. Im Lichtbogen spritzte ein Teil der Kohle heraus, und es ist möglich, daß dabei das Bor aus der Borsäure vollständig, aus dem Borkarbid jedoch nur teilweise verdampft. Tatsächlich hat Goldschmidt früher in Kohleaschen etwas größere Boranteile gefunden. Unsere Methode hat den Vorteil, daß man die Kohle nicht veraschen muß. Sie lieferte zunächst den Beweis, daß die gewöhnliche Kohle wegen des großen Boranteiles sicher unbrauchbar ist, die Zuckerkohlen jedoch weitgehend borfrei sind. Neuerdings wurde nun auch der von Herrn Bothe bei seiner Bestimmung der Neutronenabsorption in Kohle benutzte Elektrographit von Siemens untersucht. Der Borgehalt konnte vorläufig nur in zwei Grenzen eingeschlossen werden: Er ist kleiner als 10^{-5} und sicher größer als 2.10^{-6}. Die Frage ist nun, kann ein Teil der von Bothe gemessenen Neutronenabsorption durch den Borgehalt verursacht sein? Bothe hat einen Neutronenabsorptionsquerschnitt von $0,0075.10^{-24}$ cm^2 gemessen, während Heisenberg $0,003.10^{-24}$ cm^2 berechnet hat. Nehmen wir einmal an, daß die ganze Differenz von $0,004.10^{24}$cm^2 von der Absorption im Bor herrührt. Dann müßte der Boranteil 9.10^{-6} gewesen sein. Die vorläufigen Versuche geben kleiner als 10.10^{-6} und größer als 2.10^{-6}. Also ist immerhin möglich, daß die große Neutronenabsorption im Siemens-Elektrographit von der Borverunreinigung herrührt. Selbstverständlich wird man jetzt, wo es auf den genauen Boranteil ankommt, die Methode verbessern, indem man statt Boroxyd das schwerer verdampfbare Bornitrid der Kohle zumischt.

Herr Bothe hat gefunden, daß die Asche des Elektrographits etwa dreimal weniger absorbiert, als man aus der Absorption vor der Veraschung berechnet. Wenn also die Neutronenabsorption durch Bor verursacht war, dann müßte dies wenigstens bei der Veraschung teilweise verloren gegangen sein. Dies ist möglich, da es ein leicht verdampfbares Bormonoxyd gibt.

Cadmium hat noch einen 10 mal größeren Einfangsquerschnitt als Bor. Daher wurde der Cadmiumnachweis sehr empfindlich ausgearbeitet. Es wurde festgestellt, daß in der Zuckerkohle der Cadmiumanteil von der Größenordnung 10^{-7} und sicher kleiner als 3.10^{-7} ist. 10^{-7} Anteile Cadmium würden zum Absorptionsquerschnitt der Kohle einen Beitrag von $0,0004.10^{-24}$ geben, also nur etwa den 10.Teil des von Heisenberg für Kohle berechneten Querschnitts. Auch in dem von Bothe benutzten Elektrographit ist der Cadmiumanteil kleiner als 3.10^{-7}.

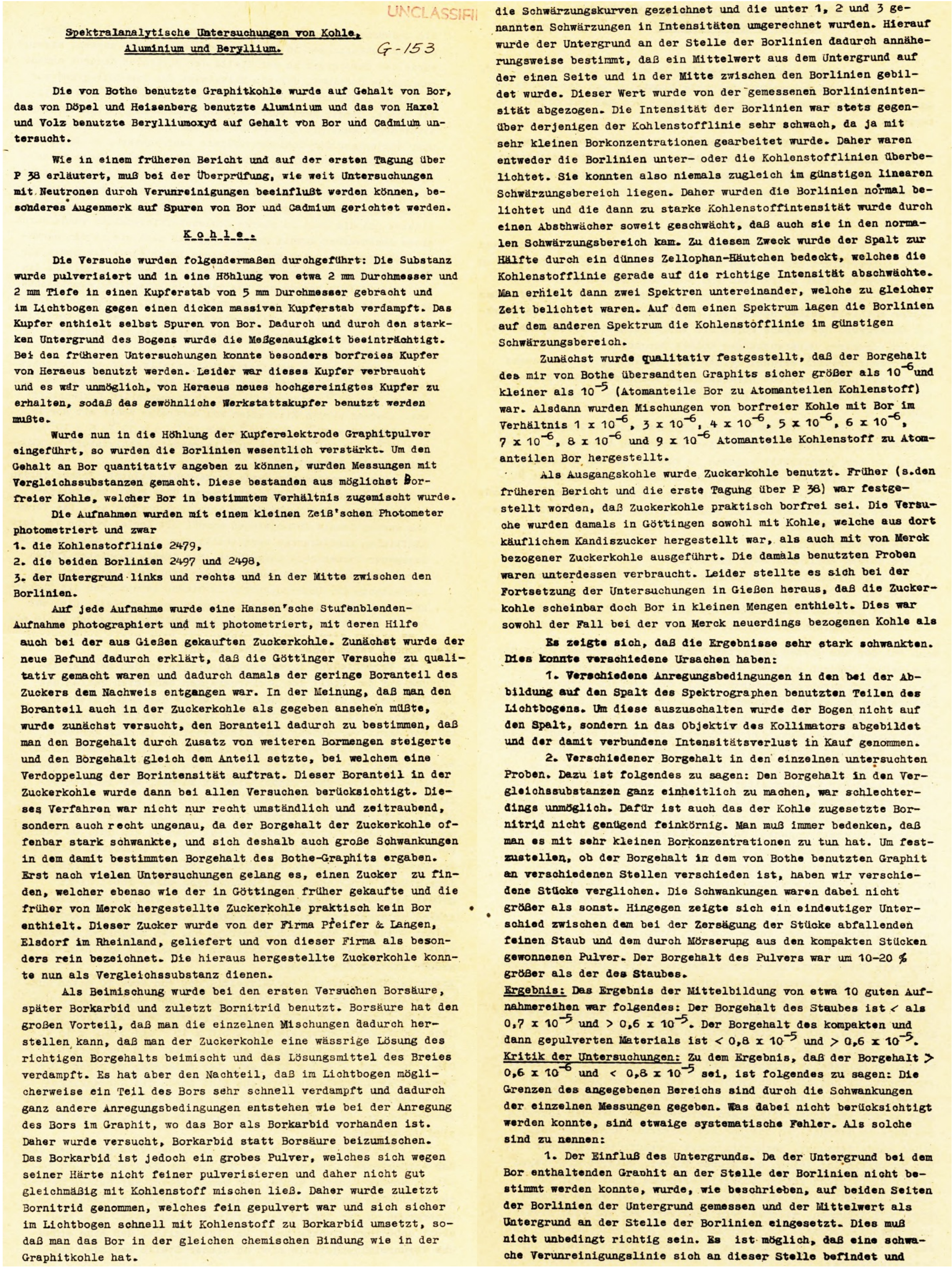
Hanle.

Anlage zu Bb Nr. 1097/41 g WaK

Borgehalt in Atomanteilen

Deutsche Steinkohle	10^{-5} - 10^{-6}
" " nach Goldschmidt (Asche)	3.10^{-4}
Buchenholzkohle	10^{-5}
" nach Goldschmidt (Asche)	10^{-4}
Acheson-Graphit	10^{-4} - 10^{-5}
Bogenlampenkohle, geglüht	10^{-4}
Absorptionskohle, Merck	10^{-5}
Blutkohle, gepulvert	10^{-5}
Kohle aus Kandiszucker	$< 10^{-6}$
" " Speisezucker	$< 10^{-6}$
" " Traubenzucker	$< 10^{-6}$
" " Kartoffelmehl	$< 10^{-6}$
Zuckerkohle Schering	$< 10^{-6}$
Elektrographit Siemens	$< 10^{-5} > 2.10^{-6}$

Figure D.524: Wilhelm Hanle. *The Determination of Boron and Cadmium in Carbon.* 1941. [G-85]



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Spektralanalytische Untersuchungen von Kohle, Aluminium und Beryllium.

G-153

Die von Bothe benutzte Graphitkohle wurde auf Gehalt von Bor, das von Döpel und Heisenberg benutzte Aluminium und das von Haxel und Volz benutzte Berylliumoxyd auf Gehalt von Bor und Cadmium untersucht.

Wie in einem früheren Bericht und auf der ersten Tagung über P 38 erläutert, muß bei der Überprüfung, wie weit Untersuchungen mit Neutronen durch Verunreinigungen beeinflußt werden können, besonderes Augenmerk auf Spuren von Bor und Cadmium gerichtet werden.

Kohle.

Die Versuche wurden folgendermaßen durchgeführt: Die Substanz wurde pulverisiert und in eine Höhlung von etwa 2 mm Durchmesser und 2 mm Tiefe in einen Kupferstab von 5 mm Durchmesser gebracht und im Lichtbogen gegen einen dicken massiven Kupferstab verdampft. Das Kupfer enthielt selbst Spuren von Bor. Dadurch und durch den starkken Untergrund des Bogens wurde die Meßgenauigkeit beeinträchtigt. Bei den früheren Untersuchungen konnte besonders borfreies Kupfer von Heraeus benutzt werden. Leider war dieses Kupfer verbraucht und es war unmöglich, von Heraeus neues hochgereinigtes Kupfer zu erhalten, sodaß das gewöhnliche Werkstattskupfer benutzt werden mußte.

Wurde nun in die Höhlung der Kupferelektrode Graphitpulver eingeführt, so wurden die Borlinien wesentlich verstärkt. Um den Gehalt an Bor quantitativ angeben zu können, wurden Messungen mit Vergleichssubstanzen gemacht. Diese bestanden aus möglichst Borfreier Kohle, welcher Bor in bestimmtem Verhältnis zugemischt wurde.

Die Aufnahmen wurden mit einem kleinen Zeiß'schen Photometer photometriert und zwar

1. die Kohlenstofflinie 2479,
2. die beiden Borlinien 2497 und 2498,
3. der Untergrund links und rechts und in der Mitte zwischen den Borlinien.

Auf jede Aufnahme wurde eine Hansen'sche Stufenblenden-Aufnahme photographiert und mit photometriert, mit deren Hilfe

auch bei der aus Gießen gekauften Zuckerkohle. Zunächst wurde der neue Befund dadurch erklärt, daß die Göttinger Versuche zu qualitativ gemacht waren und dadurch damals der geringe Boranteil des Zuckers dem Nachweis entgangen war. In der Meinung, daß man den Boranteil auch in der Zuckerkohle als gegeben ansehen müßte, wurde zunächst versucht, den Boranteil dadurch zu bestimmen, daß man den Borgehalt durch Zusatz von weiteren Bormengen steigerte und den Borgehalt gleich dem Anteil setzte, bei welchem eine Verdoppelung der Borintensität auftrat. Dieser Boranteil in der Zuckerkohle wurde dann bei allen Versuchen berücksichtigt. Dieses Verfahren war nicht nur recht umständlich und zeitraubend, sondern auch recht ungenau, da der Borgehalt der Zuckerkohle offenbar stark schwankte, und sich deshalb auch große Schwankungen in dem damit bestimmten Borgehalt des Bothe-Graphits ergaben. Erst nach vielen Untersuchungen gelang es, einen Zucker zu finden, welcher ebenso wie der in Göttingen früher gekaufte und die früher von Merck hergestellte Zuckerkohle praktisch kein Bor enthielt. Dieser Zucker wurde von der Firma Pfeifer & Langen, Elsdorf im Rheinland, geliefert und von dieser Firma als besonders rein bezeichnet. Die hieraus hergestellte Zuckerkohle konnte nun als Vergleichssubstanz dienen.

Als Beimischung wurde bei den ersten Versuchen Borsäure, später Borkarbid und zuletzt Bornitrid benutzt. Borsäure hat den großen Vorteil, daß man die einzelnen Mischungen dadurch herstellen kann, daß man der Zuckerkohle eine wässrige Lösung des richtigen Borgehalts beimischt und das Lösungsmittel des Breies verdampft. Es hat aber den Nachteil, daß im Lichtbogen möglicherweise ein Teil des Bors sehr schnell verdampft und dadurch ganz andere Anregungsbedingungen entstehen wie bei der Anregung des Bors im Graphit, wo das Bor als Borkarbid vorhanden ist. Daher wurde versucht, Borkarbid statt Borsäure beizumischen. Das Borkarbid ist jedoch ein grobes Pulver, welches sich wegen seiner Härte nicht feiner pulverisieren und daher nicht gut gleichmäßig mit Kohlenstoff mischen ließ. Daher wurde zuletzt Bornitrid genommen, welches fein gepulvert war und sich sicher im Lichtbogen schnell mit Kohlenstoff zu Borkarbid umsetzt, sodaß man das Bor in der gleichen chemischen Bindung wie in der Graphitkohle hat.

die Schwärzungskurven gezeichnet und die unter 1, 2 und 3 genannten Schwärzungen in Intensitäten umgerechnet wurden. Hierauf wurde der Untergrund an der Stelle der Borlinien dadurch annäherungsweise bestimmt, daß ein Mittelwert aus dem Untergrund auf der einen Seite und in der Mitte zwischen den Borlinien gebildet wurde. Dieser Wert wurde von der gemessenen Borlinienintensität abgezogen. Die Intensität der Borlinien war stets gegenüber derjenigen der Kohlenstofflinie sehr schwach, da ja mit sehr kleinen Borkonzentrationen gearbeitet wurde. Daher waren entweder die Borlinien unter- oder die Kohlenstofflinien überbelichtet. Sie konnten also niemals zugleich im günstigen linearen Schwärzungsbereich liegen. Daher wurden die Borlinien normal belichtet und die dann zu starke Kohlenstoffintensität wurde durch einen Abschwächer soweit geschwächt, daß auch sie in den normalen Schwärzungsbereich kam. Zu diesem Zweck wurde der Spalt zur Hälfte durch ein dünnes Zellophan-Häutchen bedeckt, welches die Kohlenstofflinie gerade auf die richtige Intensität abschwächte. Man erhielt dann zwei Spektren untereinander, welche zu gleicher Zeit belichtet waren. Auf dem einen Spektrum lagen die Borlinien auf dem anderen Spektrum die Kohlenstofflinie im günstigen Schwärzungsbereich.

Zunächst wurde qualitativ festgestellt, daß der Borgehalt des mir von Bothe übersandten Graphits sicher größer als 10^{-6} und kleiner als 10^{-5} (Atomanteile Bor zu Atomanteilen Kohlenstoff) war. Alsdann wurden Mischungen von borfreier Kohle mit Bor im Verhältnis 1×10^{-6}, 3×10^{-6}, 4×10^{-6}, 5×10^{-6}, 6×10^{-6}, 7×10^{-6}, 8×10^{-6} und 9×10^{-6} Atomanteile Kohlenstoff zu Atomanteilen Bor hergestellt.

Als Ausgangskohle wurde Zuckerkohle benutzt. Früher (s.den früheren Bericht und die erste Tagung über P 38) war festgestellt worden, daß Zuckerkohle praktisch borfrei sei. Die Versuche wurden damals in Göttingen sowohl mit Kohle, welche aus dort käuflichem Kandiszucker hergestellt war, als auch mit von Merck bezogener Zuckerkohle ausgeführt. Die damals benutzten Proben waren unterdessen verbraucht. Leider stellte es sich bei der Fortsetzung der Untersuchungen in Gießen heraus, daß die Zuckerkohle scheinbar doch Bor in kleinen Mengen enthielt. Dies war sowohl der Fall bei der von Merck neuerdings bezogenen Kohle als

Es zeigte sich, daß die Ergebnisse sehr stark schwankten. Dies konnte verschiedene Ursachen haben:

1. Verschiedene Anregungsbedingungen in den bei der Abbildung auf den Spalt des Spektrographen benutzten Teilen des Lichtbogens. Um diese auszuschalten wurde der Bogen nicht auf den Spalt, sondern in das Objektiv des Kollimators abgebildet und der damit verbundene Intensitätsverlust in Kauf genommen.

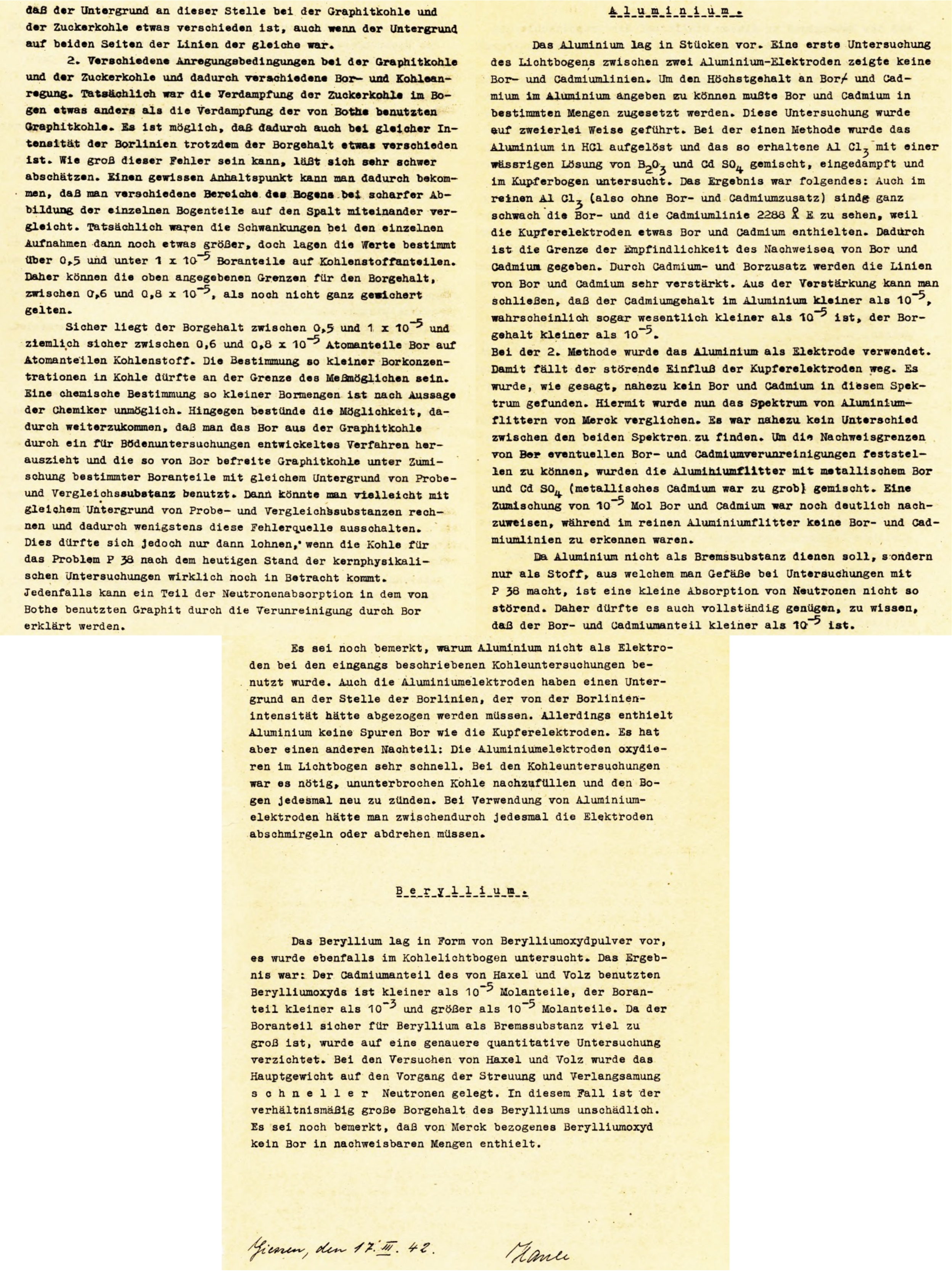
2. Verschiedener Borgehalt in den einzelnen untersuchten Proben. Dazu ist folgendes zu sagen: Den Borgehalt in den Vergleichssubstanzen ganz einheitlich zu machen, war schlechterdings unmöglich. Dafür ist auch das der Kohle zugesetzte Bornitrid nicht genügend feinkörnig. Man muß immer bedenken, daß man es mit sehr kleinen Borkonzentrationen zu tun hat. Um festzustellen, ob der Borgehalt in dem von Bothe benutzten Graphit an verschiedenen Stellen verschieden ist, haben wir verschiedene Stücke verglichen. Die Schwankungen waren dabei nicht größer als sonst. Hingegen zeigte sich ein eindeutiger Unterschied zwischen dem bei der Zersägung der Stücke abfallenden feinen Staub und dem durch Mörserung aus den kompakten Stücken gewonnenen Pulver. Der Borgehalt des Pulvers war um 10-20 % größer als der des Staubes.

Ergebnis: Das Ergebnis der Mittelbildung von etwa 10 guten Aufnahmereihen war folgendes: Der Borgehalt des Staubes ist $<$ als $0{,}7 \times 10^{-5}$ und $> 0{,}6 \times 10^{-5}$. Der Borgehalt des kompakten und dann gepulverten Materials ist $< 0{,}8 \times 10^{-5}$ und $> 0{,}6 \times 10^{-5}$.

Kritik der Untersuchungen: Zu dem Ergebnis, daß der Borgehalt $> 0{,}6 \times 10^{-6}$ und $< 0{,}8 \times 10^{-5}$ sei, ist folgendes zu sagen: Die Grenzen des angegebenen Bereichs sind durch die Schwankungen der einzelnen Messungen gegeben. Was dabei nicht berücksichtigt werden konnte, sind etwaige systematische Fehler. Als solche sind zu nennen:

1. Der Einfluß des Untergrunds. Da der Untergrund bei dem Bor enthaltenden Graphit an der Stelle der Borlinien nicht bestimmt werden konnte, wurde, wie beschrieben, auf beiden Seiten der Borlinien der Untergrund gemessen und der Mittelwert als Untergrund an der Stelle der Borlinien eingesetzt. Dies muß nicht unbedingt richtig sein. Es ist möglich, daß eine schwache Verunreinigungslinie sich an dieser Stelle befindet und

Figure D.525: Wilhelm Hanle. *Spectroscopic Analysis of Carbon, Aluminum, and Beryllium.* 1942. [G-153]



daß der Untergrund an dieser Stelle bei der Graphitkohle und der Zuckerkohle etwas verschieden ist, auch wenn der Untergrund auf beiden Seiten der Linien der gleiche war.

2. Verschiedene Anregungsbedingungen bei der Graphitkohle und der Zuckerkohle und dadurch verschiedene Bor- und Kohleanregung. Tatsächlich war die Verdampfung der Zuckerkohle im Bogen etwas anders als die Verdampfung der von Bothe benutzten Graphitkohle. Es ist möglich, daß dadurch auch bei gleicher Intensität der Borlinien trotzdem der Borgehalt etwas verschieden ist. Wie groß dieser Fehler sein kann, läßt sich sehr schwer abschätzen. Einen gewissen Anhaltspunkt kann man dadurch bekommen, daß man verschiedene Bereiche des Bogens bei scharfer Abbildung der einzelnen Bogenteile auf den Spalt miteinander vergleicht. Tatsächlich waren die Schwankungen bei den einzelnen Aufnahmen dann noch etwas größer, doch lagen die Werte bestimmt über 0,5 und unter 1×10^{-5} Boranteile auf Kohlenstoffanteilen. Daher können die oben angegebenen Grenzen für den Borgehalt, zwischen 0,6 und $0{,}8 \times 10^{-5}$, als noch nicht ganz gesichert gelten.

Sicher liegt der Borgehalt zwischen 0,5 und 1×10^{-5} und ziemlich sicher zwischen 0,6 und $0{,}8 \times 10^{-5}$ Atomanteile Bor auf Atomanteilen Kohlenstoff. Die Bestimmung so kleiner Borkonzentrationen in Kohle dürfte an der Grenze des Meßmöglichen sein. Eine chemische Bestimmung so kleiner Bormengen ist nach Aussage der Chemiker unmöglich. Hingegen bestünde die Möglichkeit, dadurch weiterzukommen, daß man das Bor aus der Graphitkohle durch ein für Bödenuntersuchungen entwickeltes Verfahren herauszieht und die so von Bor befreite Graphitkohle unter Zumischung bestimmter Boranteile mit gleichem Untergrund von Probe- und Vergleichssubstanz benutzt. Dann könnte man vielleicht mit gleichem Untergrund von Probe- und Vergleichssubstanzen rechnen und dadurch wenigstens diese Fehlerquelle ausschalten. Dies dürfte sich jedoch nur dann lohnen, wenn die Kohle für das Problem P 38 nach dem heutigen Stand der kernphysikalischen Untersuchungen wirklich noch in Betracht kommt. Jedenfalls kann ein Teil der Neutronenabsorption in dem von Bothe benutzten Graphit durch die Verunreinigung durch Bor erklärt werden.

Aluminium.

Das Aluminium lag in Stücken vor. Eine erste Untersuchung des Lichtbogens zwischen zwei Aluminium-Elektroden zeigte keine Bor- und Cadmiumlinien. Um den Höchstgehalt an Bor- und Cadmium im Aluminium angeben zu können mußte Bor und Cadmium in bestimmten Mengen zugesetzt werden. Diese Untersuchung wurde auf zweierlei Weise geführt. Bei der einen Methode wurde das Aluminium in HCl aufgelöst und das so erhaltene $Al\,Cl_3$ mit einer wässrigen Lösung von B_2O_3 und $Cd\,SO_4$ gemischt, eingedampft und im Kupferbogen untersucht. Das Ergebnis war folgendes: Auch im reinen $Al\,Cl_3$ (also ohne Bor- und Cadmiumzusatz) sind ganz schwach die Bor- und die Cadmiumlinie 2288 Å E zu sehen, weil die Kupferelektroden etwas Bor und Cadmium enthielten. Dadurch ist die Grenze der Empfindlichkeit des Nachweises von Bor und Cadmium gegeben. Durch Cadmium- und Borzusatz werden die Linien von Bor und Cadmium sehr verstärkt. Aus der Verstärkung kann man schließen, daß der Cadmiumgehalt im Aluminium kleiner als 10^{-5}, wahrscheinlich sogar wesentlich kleiner als 10^{-5} ist, der Borgehalt kleiner als 10^{-5}.
Bei der 2. Methode wurde das Aluminium als Elektrode verwendet. Damit fällt der störende Einfluß der Kupferelektroden weg. Es wurde, wie gesagt, nahezu kein Bor und Cadmium in diesem Spektrum gefunden. Hiermit wurde nun das Spektrum von Aluminiumflittern von Merck verglichen. Es war nahezu kein Unterschied zwischen den beiden Spektren zu finden. Um die Nachweisgrenzen von Ber eventuellen Bor- und Cadmiumverunreinigungen feststellen zu können, wurden die Alumihiumflitter mit metallischem Bor und $Cd\,SO_4$ (metallisches Cadmium war zu grob) gemischt. Eine Zumischung von 10^{-5} Mol Bor und Cadmium war noch deutlich nachzuweisen, während im reinen Aluminiumflitter keine Bor- und Cadmiumlinien zu erkennen waren.

Da Aluminium nicht als Bremssubstanz dienen soll, sondern nur als Stoff, aus welchem man Gefäße bei Untersuchungen mit P 38 macht, ist eine kleine Absorption von Neutronen nicht so störend. Daher dürfte es auch vollständig genügen, zu wissen, daß der Bor- und Cadmiumanteil kleiner als 10^{-5} ist.

Es sei noch bemerkt, warum Aluminium nicht als Elektroden bei den eingangs beschriebenen Kohleuntersuchungen benutzt wurde. Auch die Aluminiumelektroden haben einen Untergrund an der Stelle der Borlinien, der von der Borlinienintensität hätte abgezogen werden müssen. Allerdings enthielt Aluminium keine Spuren Bor wie die Kupferelektroden. Es hat aber einen anderen Nachteil: Die Aluminiumelektroden oxydieren im Lichtbogen sehr schnell. Bei den Kohleuntersuchungen war es nötig, ununterbrochen Kohle nachzufüllen und den Bogen jedesmal neu zu zünden. Bei Verwendung von Aluminiumelektroden hätte man zwischendurch jedesmal die Elektroden abschmirgeln oder abdrehen müssen.

Beryllium.

Das Beryllium lag in Form von Berylliumoxydpulver vor, es wurde ebenfalls im Kohlelichtbogen untersucht. Das Ergebnis war: Der Cadmiumanteil des von Haxel und Volz benutzten Berylliumoxyds ist kleiner als 10^{-5} Molanteile, der Boranteil kleiner als 10^{-3} und größer als 10^{-5} Molanteile. Da der Boranteil sicher für Beryllium als Bremssubstanz viel zu groß ist, wurde auf eine genauere quantitative Untersuchung verzichtet. Bei den Versuchen von Haxel und Volz wurde das Hauptgewicht auf den Vorgang der Streuung und Verlangsamung schneller Neutronen gelegt. In diesem Fall ist der verhältnismäßig große Borgehalt des Berylliums unschädlich. Es sei noch bemerkt, daß von Merck bezogenes Berylliumoxyd kein Bor in nachweisbaren Mengen enthielt.

Gießen, den 17. III. 42.   Hanle

Figure D.526: Wilhelm Hanle. *Spectroscopic Analysis of Carbon, Aluminum, and Beryllium.* 1942. [G-153]

E. Graphite

[High-quality graphite was widely used for high-temperature exhaust steering rudders on the A-4 (V-2) and other rockets, and was used for making electrodes, filters, and other components too. However, graphite could also have been quite useful as a neutron moderator to slow down neutrons and promote chain reactions in a fission reactor. The following documents illustrate that wartime production of graphite was widespread and sophisticated.]

Acheson Graphite Corporation to Frank Hodson. 29 July 1942. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Ind. TA]

Continental European Electrode Plants

Further to my letters of July 24th and 25th, I am glad to send along what information and estimates we have in regard to commercial electrode plants in Continental Europe.

Germany

Graphite

According to estimates made by our people in Europe at the end of 1939, the graphite electrode production in Germany during that year was approximately as follows:

Siemens-Planiawerke, Meitingen	8,500 tons
Conradty, Kolbermoor	2,000 ”
I. G. Farben, Bitterfeld	5,000 ”
	15,500 tons

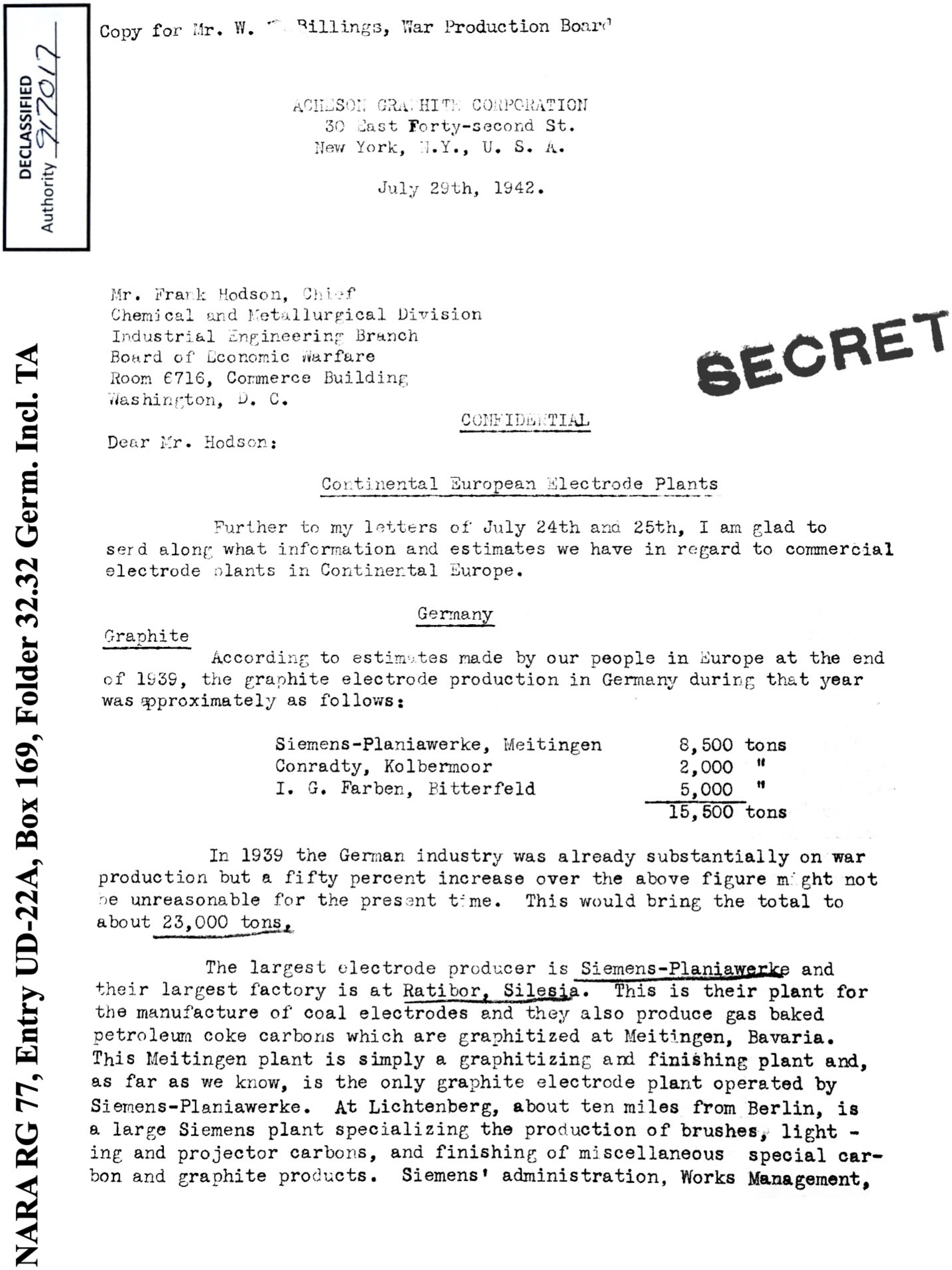
In 1939 the German industry was already substantially on war production but a fifty percent increase over the above figure might not be unreasonable for the present time. This would bring the total to about 23,000 tons. [...]

Coal Electrodes

Our estimate of the production capacity of the three German firms is as follows:

Siemens-Planiawerke, Ratibor	50,000 tons
Conradty, Nürnberg	6,000 ”
I. G. Farben, Bitterfeld	3,500 ”
	59,500 tons

[See document photos on pp. 4111–4113.]



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NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Incl. TA

Copy for Mr. W. [illegible] Billings, War Production Board

ACHESON GRAPHITE CORPORATION
30 East Forty-second St.
New York, N.Y., U. S. A.

July 29th, 1942.

Mr. Frank Hodson, Chief
Chemical and Metallurgical Division
Industrial Engineering Branch
Board of Economic Warfare
Room 6716, Commerce Building
Washington, D. C.

SECRET

CONFIDENTIAL

Dear Mr. Hodson:

Continental European Electrode Plants

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Germany

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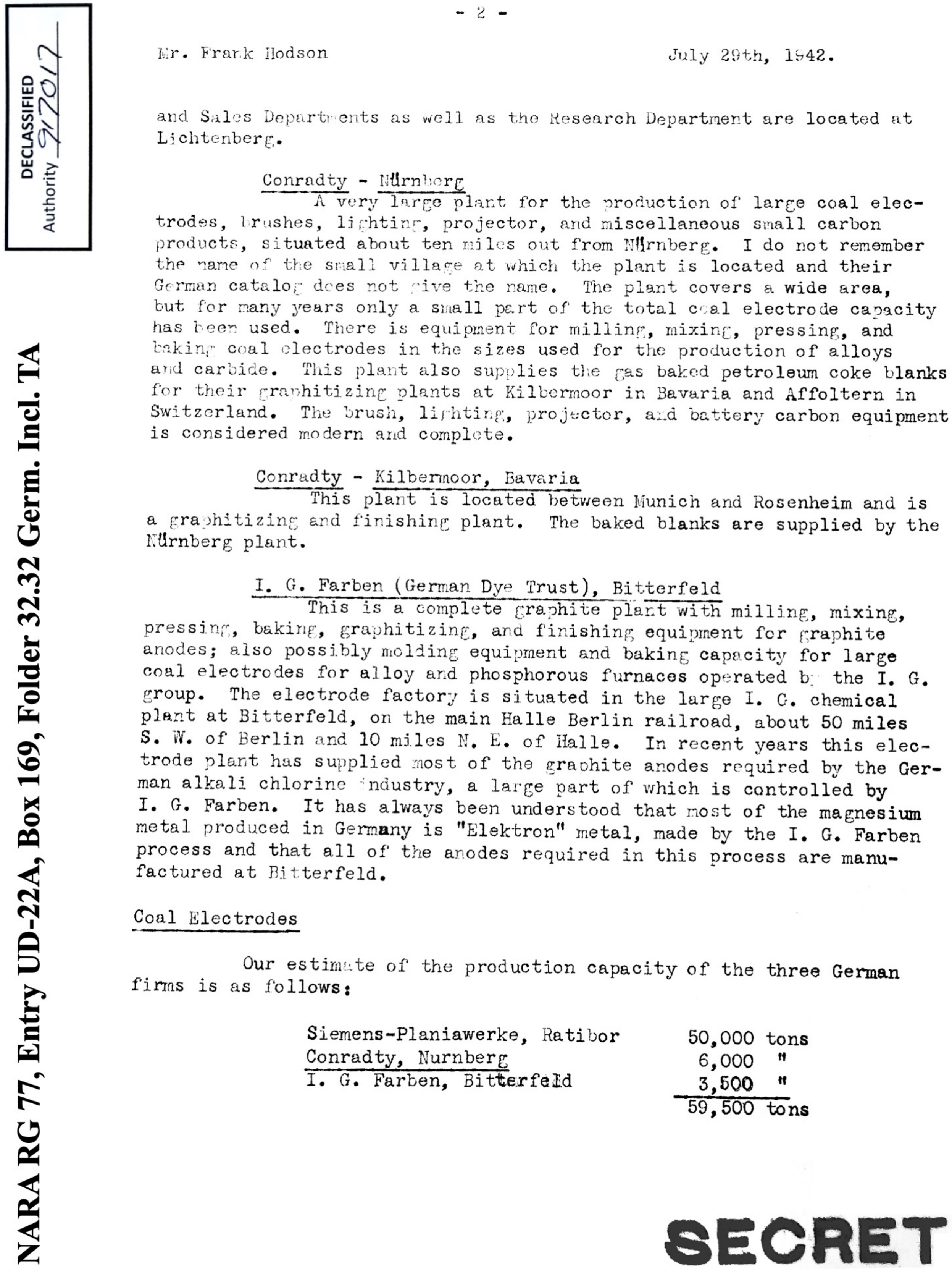
In 1939 the German industry was already substantially on war production but a fifty percent increase over the above figure might not be unreasonable for the present time. This would bring the total to about 23,000 tons.

The largest electrode producer is Siemens-Planiawerke and their largest factory is at Ratibor, Silesia. This is their plant for the manufacture of coal electrodes and they also produce gas baked petroleum coke carbons which are graphitized at Meitingen, Bavaria. This Meitingen plant is simply a graphitizing and finishing plant and, as far as we know, is the only graphite electrode plant operated by Siemens-Planiawerke. At Lichtenberg, about ten miles from Berlin, is a large Siemens plant specializing the production of brushes, lighting and projector carbons, and finishing of miscellaneous special carbon and graphite products. Siemens' administration, Works Management,

Figure D.527: Acheson Graphite Corporation to Frank Hodson. 29 July 1942. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Ind. TA]



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NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Incl. TA

Mr. Frank Hodson July 29th, 1942.

and Sales Departments as well as the Research Department are located at Lichtenberg.

Conradty - Nürnberg

A very large plant for the production of large coal electrodes, brushes, lighting, projector, and miscellaneous small carbon products, situated about ten miles out from Nürnberg. I do not remember the name of the small village at which the plant is located and their German catalog does not give the name. The plant covers a wide area, but for many years only a small part of the total coal electrode capacity has been used. There is equipment for milling, mixing, pressing, and baking coal electrodes in the sizes used for the production of alloys and carbide. This plant also supplies the gas baked petroleum coke blanks for their graphitizing plants at Kilbermoor in Bavaria and Affoltern in Switzerland. The brush, lighting, projector, and battery carbon equipment is considered modern and complete.

Conradty - Kilbermoor, Bavaria

This plant is located between Munich and Rosenheim and is a graphitizing and finishing plant. The baked blanks are supplied by the Nürnberg plant.

I. G. Farben (German Dye Trust), Bitterfeld

This is a complete graphite plant with milling, mixing, pressing, baking, graphitizing, and finishing equipment for graphite anodes; also possibly molding equipment and baking capacity for large coal electrodes for alloy and phosphorous furnaces operated by the I. G. group. The electrode factory is situated in the large I. G. chemical plant at Bitterfeld, on the main Halle Berlin railroad, about 50 miles S. W. of Berlin and 10 miles N. E. of Halle. In recent years this electrode plant has supplied most of the graphite anodes required by the German alkali chlorine industry, a large part of which is controlled by I. G. Farben. It has always been understood that most of the magnesium metal produced in Germany is "Elektron" metal, made by the I. G. Farben process and that all of the anodes required in this process are manufactured at Bitterfeld.

Coal Electrodes

Our estimate of the production capacity of the three German firms is as follows:

Siemens-Planiawerke, Ratibor	50,000 tons
Conradty, Nurnberg	6,000 "
I. G. Farben, Bitterfeld	3,500 "
	59,500 tons

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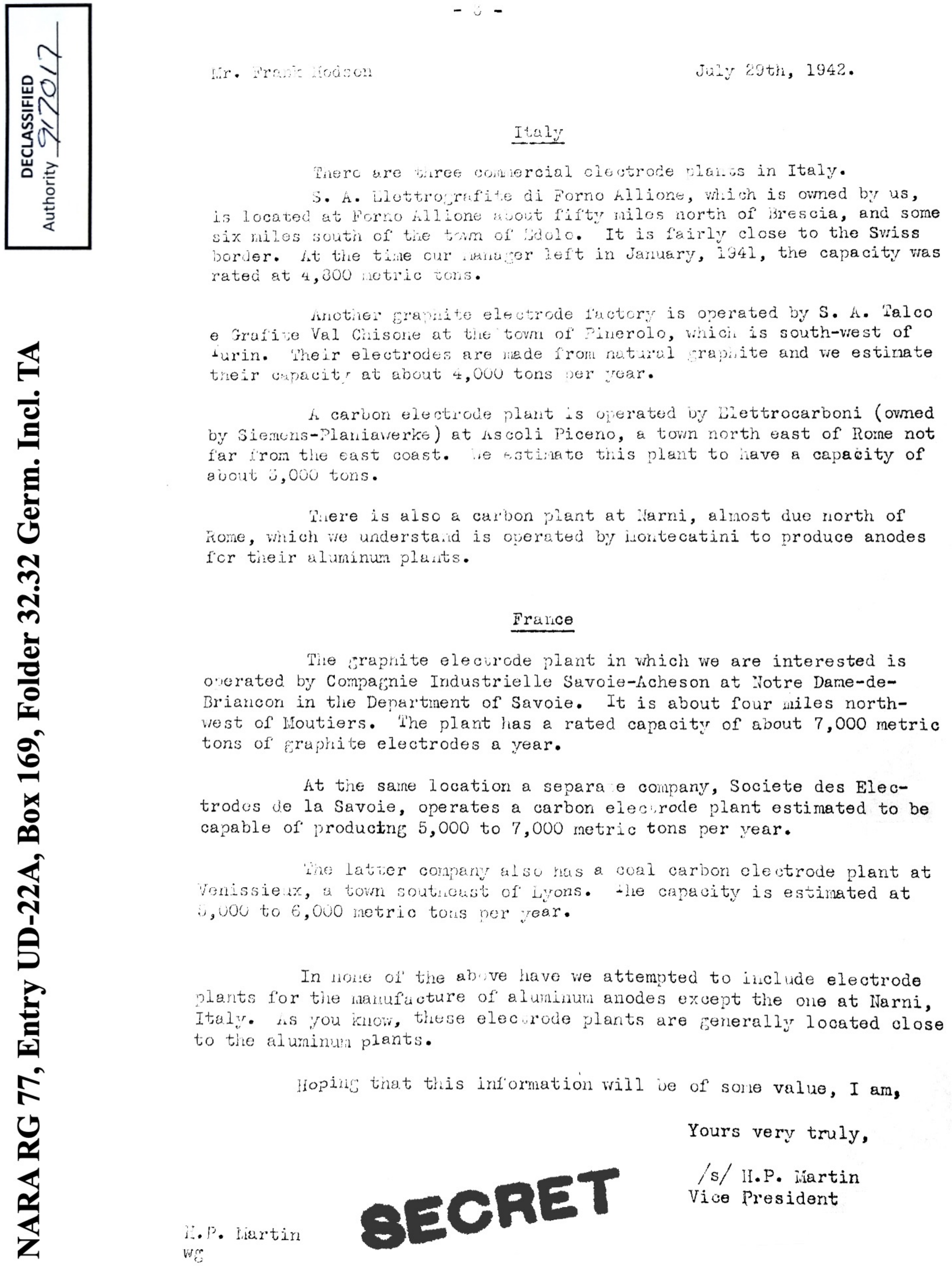
Figure D.528: Acheson Graphite Corporation to Frank Hodson. 29 July 1942. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Ind. TA]



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NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Incl. TA

- 3 -

Mr. Frank Hodson July 29th, 1942.

Italy

There are three commercial electrode plants in Italy.

S. A. Elettrografite di Forno Allione, which is owned by us, is located at Forno Allione about fifty miles north of Brescia, and some six miles south of the town of Edolo. It is fairly close to the Swiss border. At the time our manager left in January, 1941, the capacity was rated at 4,800 metric tons.

Another graphite electrode factory is operated by S. A. Talco e Grafite Val Chisone at the town of Pinerolo, which is south-west of Turin. Their electrodes are made from natural graphite and we estimate their capacity at about 4,000 tons per year.

A carbon electrode plant is operated by Elettrocarboni (owned by Siemens-Planiawerke) at Ascoli Piceno, a town north east of Rome not far from the east coast. We estimate this plant to have a capacity of about 5,000 tons.

There is also a carbon plant at Narni, almost due north of Rome, which we understand is operated by Montecatini to produce anodes for their aluminum plants.

France

The graphite electrode plant in which we are interested is operated by Compagnie Industrielle Savoie-Acheson at Notre Dame-de-Briancon in the Department of Savoie. It is about four miles north-west of Moutiers. The plant has a rated capacity of about 7,000 metric tons of graphite electrodes a year.

At the same location a separate company, Societe des Electrodes de la Savoie, operates a carbon electrode plant estimated to be capable of producing 5,000 to 7,000 metric tons per year.

The latter company also has a coal carbon electrode plant at Venissieux, a town southeast of Lyons. The capacity is estimated at 5,000 to 6,000 metric tons per year.

In none of the above have we attempted to include electrode plants for the manufacture of aluminum anodes except the one at Narni, Italy. As you know, these electrode plants are generally located close to the aluminum plants.

Hoping that this information will be of some value, I am,

Yours very truly,

/s/ H.P. Martin
Vice President

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H.P. Martin
wg

Figure D.529: Acheson Graphite Corporation to Frank Hodson. 29 July 1942. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Ind. TA]

FIAT 397. *Survey of the Carbon and Graphite Electrode Industry of Germany.* With two supplements. pp. 6, 11.

[...] The discussions with the SIEMENS technical organization showed the possession of the extensive empirical know-how needed for successful operation in this industry, compounded as it must be of experience and science. Thus, as respects empirical know-how, the German industry could be rated as perhaps about equal to the U.S.

As far as scientific know-how and study of the fundamentals of carbon technology are concerned, the German industry has depended very largely upon collaboration with academic researchers, mainly with Prof. ULRICH HOFFMANN. The German industry has directed its technical work more along development lines. [...]

The following tabulation shows the total German production capacity for the baked basic stock for either carbon or graphite electrodes, comparing the installed capacity near the end of the war with that now available in the U.S. Zone [of Germany]. There is no other baked electrode capacity except at some of the aluminum plants which produce their own special electrodes.

The tabulation is in terms of baked weight. The indicated tons are of 1,000 kg. = 2,200 lb.

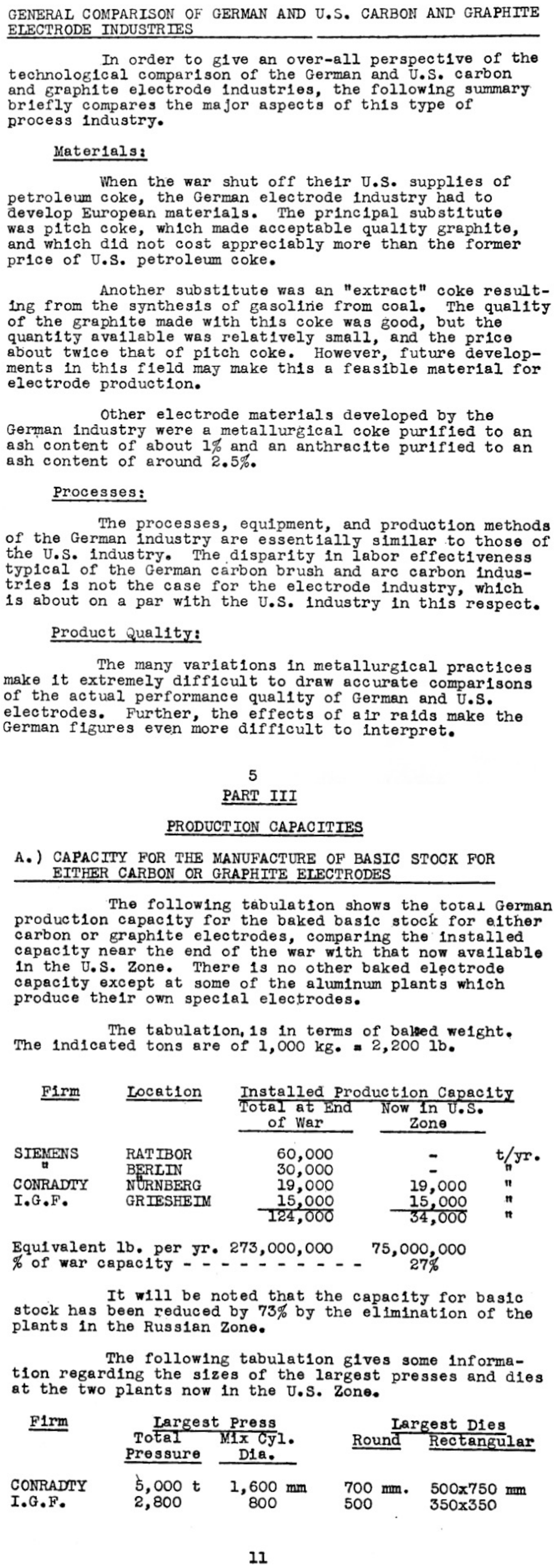
Firm	Location	Installed	Production	Capacity
		Total at End of War	Now in U.S. Zone	
SIEMENS	RATIBOR	60,000	–	t/yr.
”	BERLIN	30,000	–	”
CONRADTY	NÜRNBERG	19,000	19,000	”
I.G.F.	GRIESHEIM	15,000	15,000	”
		124,000	34,000	”

[See document photos on p. 4115.

Note that this postwar U.S. survey found that by the end of the war, the actual German annual production of graphite was even larger than what the United States had estimated during the war.

Conventional historians often claim that the German nuclear program foolishly rejected graphite as a reactor moderator, instead focusing only on heavy water. Heavy water has many advantages over graphite (p. 4029), yet there is evidence that the German nuclear program used graphite too. I.G. Farben's Bitterfeld facility was mass-producing both graphite (p. 4110) and heavy water (p. 4050) as well as other nuclear-related materials (pp. 4128, 4133, 4136). Similarly, Griesheim plants were producing both graphite (pp. 4114–4116) and heavy water (pp. 4066–4067), with other nuclear-related facilities such as Degussa in the same area [Hayes 2004; Nagel 2016]. Graphite was also mass-produced at the Siemens Plania Werke in Racibórz/Ratibor, Poland (pp. 4110–4114), near a reported heavy water plant at Auschwitz (pp. 4069, 4452) and reported uranium enrichment plants at Opava and Ostrava (p. 3749).]

FIAT 397. *Survey of the Carbon and Graphite Electrode Industry of Germany*



GENERAL COMPARISON OF GERMAN AND U.S. CARBON AND GRAPHITE ELECTRODE INDUSTRIES

In order to give an over-all perspective of the technological comparison of the German and U.S. carbon and graphite electrode industries, the following summary briefly compares the major aspects of this type of process industry.

Materials:

When the war shut off their U.S. supplies of petroleum coke, the German electrode industry had to develop European materials. The principal substitute was pitch coke, which made acceptable quality graphite, and which did not cost appreciably more than the former price of U.S. petroleum coke.

Another substitute was an "extract" coke resulting from the synthesis of gasoline from coal. The quality of the graphite made with this coke was good, but the quantity available was relatively small, and the price about twice that of pitch coke. However, future developments in this field may make this a feasible material for electrode production.

Other electrode materials developed by the German industry were a metallurgical coke purified to an ash content of about 1% and an anthracite purified to an ash content of around 2.5%.

Processes:

The processes, equipment, and production methods of the German industry are essentially similar to those of the U.S. industry. The disparity in labor effectiveness typical of the German carbon brush and arc carbon industries is not the case for the electrode industry, which is about on a par with the U.S. industry in this respect.

Product Quality:

The many variations in metallurgical practices make it extremely difficult to draw accurate comparisons of the actual performance quality of German and U.S. electrodes. Further, the effects of air raids make the German figures even more difficult to interpret.

PART III

PRODUCTION CAPACITIES

A.) CAPACITY FOR THE MANUFACTURE OF BASIC STOCK FOR EITHER CARBON OR GRAPHITE ELECTRODES

The following tabulation shows the total German production capacity for the baked basic stock for either carbon or graphite electrodes, comparing the installed capacity near the end of the war with that now available in the U.S. Zone. There is no other baked electrode capacity except at some of the aluminum plants which produce their own special electrodes.

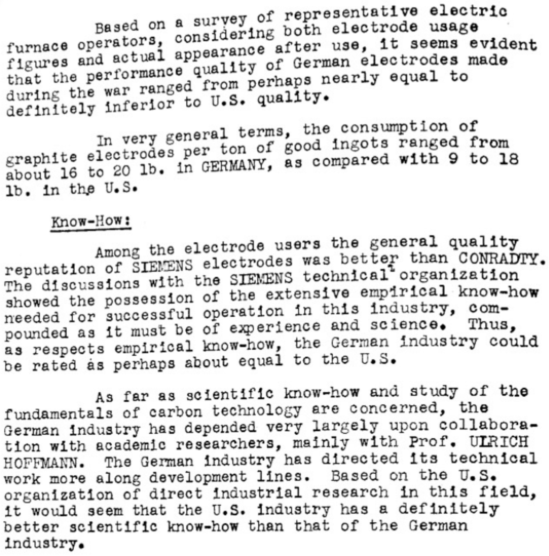
The tabulation is in terms of baked weight. The indicated tons are of 1,000 kg. = 2,200 lb.

Firm	Location	Installed Production Capacity Total at End of War	Installed Production Capacity Now in U.S. Zone	
SIEMENS	RATIBOR	60,000	-	t/yr.
"	BERLIN	30,000	-	"
CONRADTY	NÜRNBERG	19,000	19,000	"
I.G.F.	GRIESHEIM	15,000	15,000	"
		124,000	34,000	"
Equivalent lb. per yr.		273,000,000	75,000,000	
% of war capacity - - - - - - - - - -			27%	

It will be noted that the capacity for basic stock has been reduced by 73% by the elimination of the plants in the Russian Zone.

The following tabulation gives some information regarding the sizes of the largest presses and dies at the two plants now in the U.S. Zone.

Firm	Largest Press Total Pressure	Largest Press Max Cyl. Dia.	Largest Dies Round	Largest Dies Rectangular
CONRADTY	5,000 t	1,600 mm	700 mm.	500x750 mm
I.G.F.	2,800	800	500	350x350



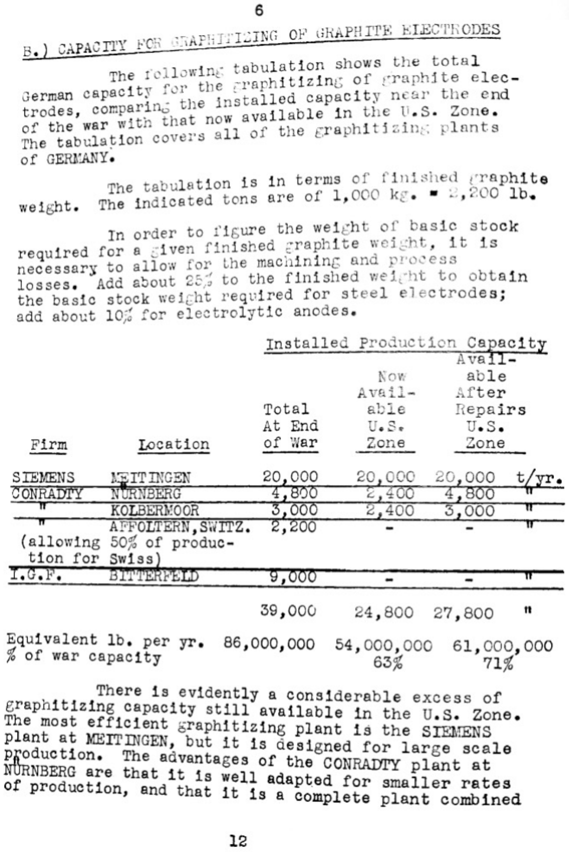
Based on a survey of representative electric furnace operators, considering both electrode usage figures and actual appearance after use, it seems evident that the performance quality of German electrodes made during the war ranged from perhaps nearly equal to definitely inferior to U.S. quality.

In very general terms, the consumption of graphite electrodes per ton of good ingots ranged from about 16 to 20 lb. in GERMANY, as compared with 9 to 18 lb. in the U.S.

Know-How:

Among the electrode users the general quality reputation of SIEMENS electrodes was better than CONRADTY. The discussions with the SIEMENS technical organization showed the possession of the extensive empirical know-how needed for successful operation in this industry, compounded as it must be of experience and science. Thus, as respects empirical know-how, the German industry could be rated as perhaps about equal to the U.S.

As far as scientific know-how and study of the fundamentals of carbon technology are concerned, the German industry has depended very largely upon collaboration with academic researchers, mainly with Prof. ULRICH HOFFMANN. The German industry has directed its technical work more along development lines. Based on the U.S. organization of direct industrial research in this field, it would seem that the U.S. industry has a definitely better scientific know-how than that of the German industry.



B.) CAPACITY FOR GRAPHITIZING OF GRAPHITE ELECTRODES

The following tabulation shows the total German capacity for the graphitizing of graphite electrodes, comparing the installed capacity near the end of the war with that now available in the U.S. Zone. The tabulation covers all of the graphitizing plants of GERMANY.

The tabulation is in terms of finished graphite weight. The indicated tons are of 1,000 kg. = 2,200 lb.

In order to figure the weight of basic stock required for a given finished graphite weight, it is necessary to allow for the machining and process losses. Add about 25% to the finished weight to obtain the basic stock weight required for steel electrodes; add about 10% for electrolytic anodes.

Firm	Location	Installed Production Capacity Total At End of War	Installed Production Capacity Now Available U.S. Zone	Installed Production Capacity Available After Repairs U.S. Zone	
SIEMENS	MEITINGEN	20,000	20,000	20,000	t/yr.
CONRADTY	NÜRNBERG	4,800	2,400	4,800	"
"	KOLBERMOOR	3,000	2,400	3,000	"
" (allowing 50% of production for Swiss)	AFFOLTERN, SWITZ.	2,200	-	-	"
I.G.F.	BITTERFELD	9,000	-	-	"
		39,000	24,800	27,800	"
Equivalent lb. per yr.		86,000,000	54,000,000	61,000,000	
% of war capacity			63%	71%	

There is evidently a considerable excess of graphitizing capacity still available in the U.S. Zone. The most efficient graphitizing plant is the SIEMENS plant at MEITINGEN, but it is designed for large scale production. The advantages of the CONRADTY plant at NÜRNBERG are that it is well adapted for smaller rates of production, and that it is a complete plant combined

Figure D.530: FIAT 397. *Survey of the Carbon and Graphite Electrode Industry of Germany.*

For more information on wartime graphite production and applications, see:

BIOS 258. *Carbon Electrodes, I.G. Farben, Griesheim.*

BIOS 337. *German Graphitising Furnances at Meitingen (Siemens Plania).*

BIOS 338. *German Carbon Electrode Manufacture at Griesheim (I.G.F.).*

BIOS 533. *Electric Furnace Design. Manufacture and Application in Germany.*

BIOS 715. *The Microanalytical Methods Employed in the Analytical Laboratories of I.G. Farben, Elberfeld-Wuppertal, Germany.* [Micro-analytical measurement of carbon at I.G. Farben.]

BIOS 819. *Blast Furnaces. Notes on German Practice.* [Carbon hearths to blast furnaces; carbon paste and bricks.]

BIOS 845. *Constructional Details of Chlorine Plant at Hoechst and Gendorf.* [Carbon anodes for chlorine cells.]

BIOS 895. *Aluminium Production at Vereinigte Aluminiumwerke (V.A.W.), Lünen.* [Carbon paste for Soderberg electrodes manufacture.]

BIOS 1181. [Graphitising of carbon electrodes: graphite brushes.]

BIOS 1230. [Carbon rocket rudders]

BIOS 1338. *Developments in Magnesium Production and Fabrication.* [Beryllium, zirconium at Degussa; also fluorine and carbon at I.G. Farben.]

BIOS 1399. *The Production of Carbon Black from Carbon Monoxide.*

BIOS 1596. *Carbon Electrodes. Report on the Interrogations of Dr. Diederich Wilm.*

BIOS 1823. *German Carbon Industry and Hydraulic Press Manufacture.*

CIOS XVII-2. *Englebert Factories—Liege and Aachen Kabelundgummiwerke-Eupen.* [Carbon black.]

CIOS XVIII-1. *Chemical Installations in the Cologne Area.* [Carbon black.]

CIOS XXVI-51. *Plant of Chemische Werke, Huls.* [Carbon black.]

CIOS XXVII-84. *I.G. Farben AG, Ludwigshafen and Oppau Wehrmacht Items.* [Carbon black.]

CIOS XXIX-14. *I. G. Farbenindustrie A. G., Leverkusen, Germany.* [Carbon, activated, production.]

CIOS XXIX-19. *Aluminum Reduction and Scrap Recovery at the Erftwerk of the Vereinigte Aluminum-Werke AG, Grevenbroich.* [Carbon anode plant.]

CIOS XXXIII-31. *Investigation of Certain Chemical Factories in the Leipzig Area of Germany.* [Artificial gems, graphite at I.G. Farben]

FIAT 104. *Survey of the Arc Carbon Industry of Germany.*

FIAT 105. *Survey of Manufacture of Graphite Rudders for V-2 Rockets.*

FIAT 115. *Survey of the Carbon Brush Industry for Electrical Equipment in Germany.*

FIAT 408. *Metallurgical Coke.*

FIAT 524. *Production of Aluminum.* [Carbon paste for Soderberg electrodes.]

FIAT 617. *The Electrical and Technical Ceramic Industry of Germany.* [Graphite resistors.]

FIAT 732. *Electrochemical Operations at I.G. Farbenindustrie A.G., Bitterfeld.* With 30 supplements.

FIAT 816. *Horizontal Mercury Chlorine Cells, I.G. Farbenindustrie, A.G.* [Graphite anodes.]

FIAT 817. *Vertical Mercury Chlorine Cells, I.G. Farbenindustrie, A.G.* [Graphite anodes.]

FIAT 863. *Activated-Carbon Production at I.G. Farbenindustrie, Leverkusen.*

FIAT 986. *Carbon Electrodes in Germany for the Aluminum Reduction Industry.*

FIAT 993. *The Aluminum Reduction Industry in Germany.* [Carbon electrodes for aluminum production.]

FIAT 1052. *The High Current Carbon Arc.*

G-35. Wilhelm Hanle. *Investigation of Cadmium Content of Carbon.* 1940.

G-46. Georg Joos. *The Production of Extremely Pure Carbon.* 1940.

G-85. Wilhelm Hanle. *The Determination of Boron and Cadmium in Carbon.* 1941.

G-153. Wilhelm Hanle. *Spectroscopic Analysis of Carbon, Aluminum, and Beryllium.* 1942.

F. Fluorine

[Fluorine was used for various industrial chemical production processes, but it also would have been essential for producing uranium hexafluoride for the enrichment of uranium-235. The following documents demonstrate large-scale production of fluorine.

For information on wartime German production of uranium hexafluoride for uranium enrichment, see pp. 3478–3493.]

Philip Morrison to Samuel K. Allison. 20 December 1943. Report on Enemy Physics Literature: Survey Report P. [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]

The nearly unique position of fluorine in most successful separation schemes leads to an interest in the state of fluorine chemistry. (The examination of this point is the work of Dr. J. Katz of Seaborg's division.)

The general interest of German chemical industry in inorganic preparations, and probably also early preparation for chemical warfare, has put German fluorine chemistry considerably ahead of our own. In 1939 it was possible to procure fluorine gas in bombs(18) from the inorganic section of the I.G. at Leverkusen, near Frankfurt a. M. It is still not easy to do this in the United States. The number of trained inorganic chemists and even of fluorine workers in Germany was greater then than the number now available to the three projects in this country. A few of the leading men and institutions are:

H. v. Wartenberg	Göttingen
Wilhelm Klemm (Klemm has been interested in the chemistry of 93.)	Danzig-Langfuhr
Wilhelm Biltz	Hanover u. Göttingen
Eduard Zintl	Darmstadt

There is little doubt that the I.G. would be the constructor of any large-scale separation plant. Such a plant would probably be at Leverkusen, near Frankfurt. Frankfurt a. M. is the center of the German chemical industry; the Deutsche Gold- und Silber-Scheide-Anstalt A.G. is there as well. One might speculate that Bothe's and Rajewsky's groups form the physics staff—with the K.W.I. f. Physik the Y [Los Alamos] equivalent—for a Leverkusen or Frankfurt plant.

(Can the information bearing on this region be especially searched for clues?) [...]

(18) Z. anorg. allg. Chem., 242, 406 (1939)

[See document photo on p. 4119.]

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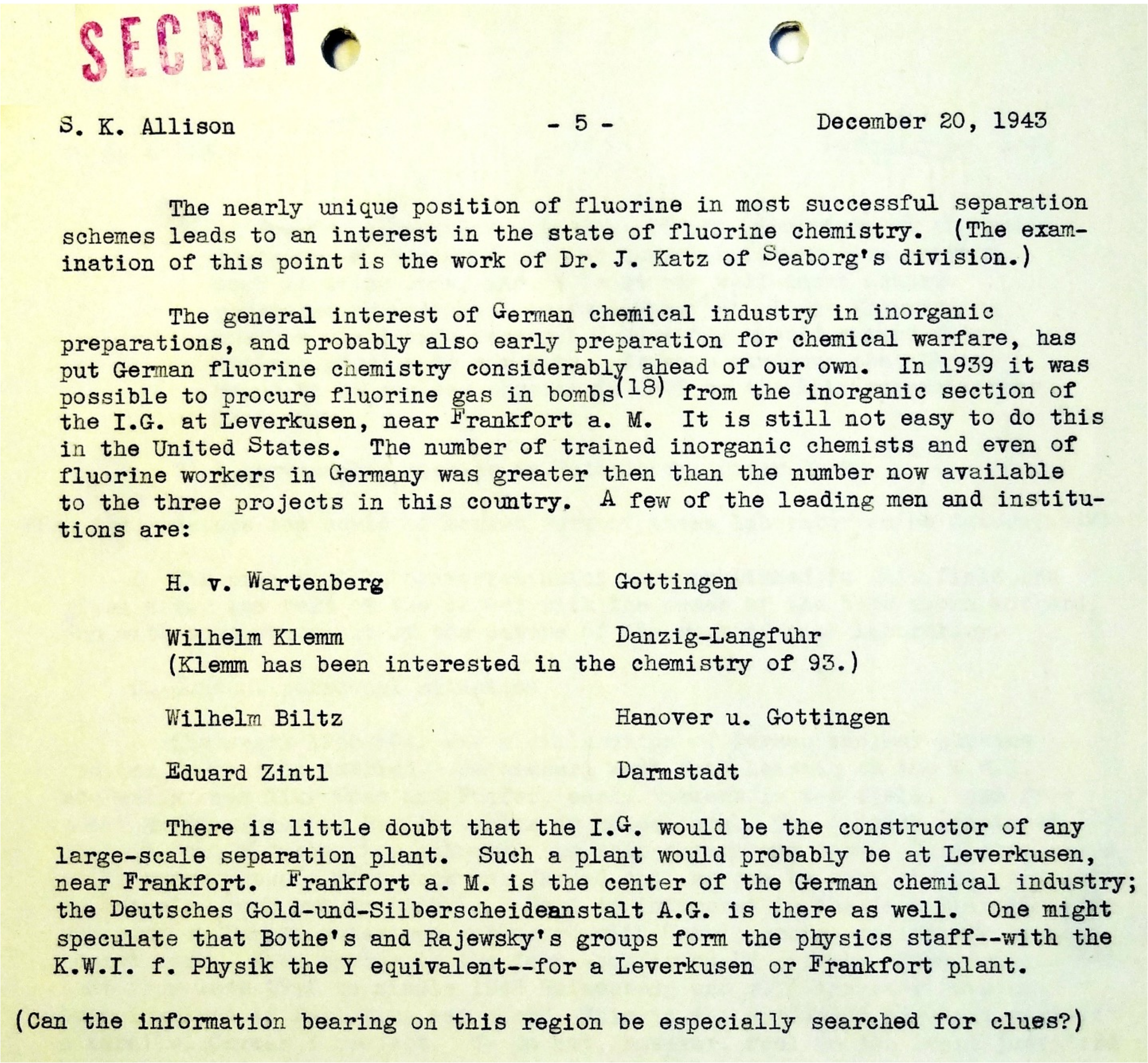
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944), Philip Morrison to Samuel K. Allison, 20 December 1943, Report on Enemy Physics Literature: Survey Report P.



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S. K. Allison - 5 - December 20, 1943

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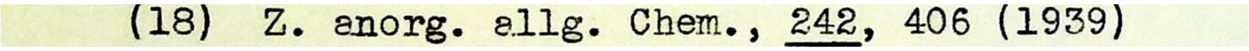
(Can the information bearing on this region be especially searched for clues?)



(18) Z. anorg. allg. Chem., 242, 406 (1939)

Figure D.531: Philip Morrison to Samuel K. Allison. 20 December 1943. Report on Enemy Physics Literature: Survey Report P. [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]

J. A. Lane. 5 April 1945. SUBJECT: Interrogation of Doctor Halberland. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)]

1. Doctor Halberland, technical director of the lower Rhine division of the I. G. Farben Company, was located at I. G. Farben's plant at Uerdingen on the Rhine. [...]

3. [...] Large quantities of fluorine are produced at Leverkusen as well as Germany's major production of titanium. [...]

5. [...] In his opinion, eight days only would be required to bring the plant to 70 per cent production. [...]

6. [...] Halberland was questioned about I. G. Farben's relation with other companies such as DeGussa, Auer, Roges, etc., but no positive answers were obtained. When questioned about the sources of interests in rare materials, he was very vague but mentioned that rare earths come from the Black Forest region. [...]

[See document photos on p. 4121.

I.G. Farben produced large quantities of fluorine. DeGussa, Auer, Roges, and other companies produced uranium. To produce uranium hexafluoride, it would have been necessary for I.G. Farben to collaborate with those companies. When the I.G. Farben director, Dr. Halberland, was interrogated about such collaborations, he refused to provide answers, but apparently indicated that they did exist.

Notes from this interrogation were considered so important regarding Germany's nuclear program that they were placed in the files of Leslie Groves's Foreign Intelligence Unit of the U.S. Manhattan Project.]

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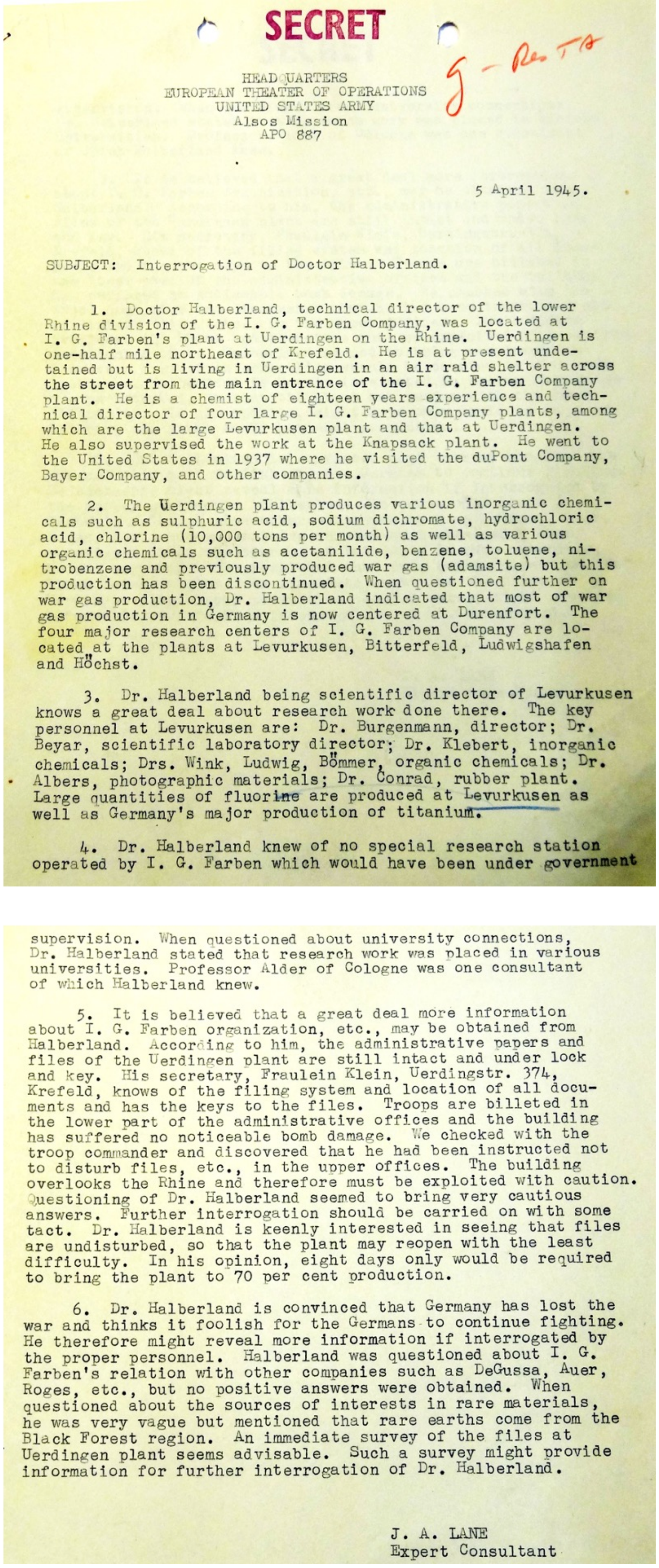
NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)



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HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
Alsos Mission
APO 887

5 April 1945.

SUBJECT: Interrogation of Doctor Halberland.

1. Doctor Halberland, technical director of the lower Rhine division of the I. G. Farben Company, was located at I. G. Farben's plant at Uerdingen on the Rhine. Uerdingen is one-half mile northeast of Krefeld. He is at present undetained but is living in Uerdingen in an air raid shelter across the street from the main entrance of the I. G. Farben Company plant. He is a chemist of eighteen years experience and technical director of four large I. G. Farben Company plants, among which are the large Levurkusen plant and that at Uerdingen. He also supervised the work at the Knapsack plant. He went to the United States in 1937 where he visited the duPont Company, Bayer Company, and other companies.

2. The Uerdingen plant produces various inorganic chemicals such as sulphuric acid, sodium dichromate, hydrochloric acid, chlorine (10,000 tons per month) as well as various organic chemicals such as acetanilide, benzene, toluene, nitrobenzene and previously produced war gas (adamsite) but this production has been discontinued. When questioned further on war gas production, Dr. Halberland indicated that most of war gas production in Germany is now centered at Durenfort. The four major research centers of I. G. Farben Company are located at the plants at Levurkusen, Bitterfeld, Ludwigshafen and Höchst.

3. Dr. Halberland being scientific director of Levurkusen knows a great deal about research work done there. The key personnel at Levurkusen are: Dr. Burgenmann, director; Dr. Beyar, scientific laboratory director; Dr. Klebert, inorganic chemicals; Drs. Wink, Ludwig, Bömmer, organic chemicals; Dr. Albers, photographic materials; Dr. Conrad, rubber plant. Large quantities of fluor~~ine~~ are produced at Levurkusen as well as Germany's major production of titanium.

4. Dr. Halberland knew of no special research station operated by I. G. Farben which would have been under government supervision. When questioned about university connections, Dr. Halberland stated that research work was placed in various universities. Professor Alder of Cologne was one consultant of which Halberland knew.

5. It is believed that a great deal more information about I. G. Farben organization, etc., may be obtained from Halberland. According to him, the administrative papers and files of the Uerdingen plant are still intact and under lock and key. His secretary, Fraulein Klein, Uerdingstr. 374, Krefeld, knows of the filing system and location of all documents and has the keys to the files. Troops are billeted in the lower part of the administrative offices and the building has suffered no noticeable bomb damage. We checked with the troop commander and discovered that he had been instructed not to disturb files, etc., in the upper offices. The building overlooks the Rhine and therefore must be exploited with caution. Questioning of Dr. Halberland seemed to bring very cautious answers. Further interrogation should be carried on with some tact. Dr. Halberland is keenly interested in seeing that files are undisturbed, so that the plant may reopen with the least difficulty. In his opinion, eight days only would be required to bring the plant to 70 per cent production.

6. Dr. Halberland is convinced that Germany has lost the war and thinks it foolish for the Germans to continue fighting. He therefore might reveal more information if interrogated by the proper personnel. Halberland was questioned about I. G. Farben's relation with other companies such as DeGussa, Auer, Roges, etc., but no positive answers were obtained. When questioned about the sources of interests in rare materials, he was very vague but mentioned that rare earths come from the Black Forest region. An immediate survey of the files at Uerdingen plant seems advisable. Such a survey might provide information for further interrogation of Dr. Halberland.

J. A. LANE
Expert Consultant

Figure D.532: James A. Lane. 5 April 1945. SUBJECT: Interrogation of Doctor Halberland [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)].

BIOS 1595. *German Fluorine and Fluoride Industry.* pp. 5–7.

The first system has been developed by Dr. Siemans of Riedel de Haen. This has been installed at Vereinigte Flusspatgruben where six sets of retorts were erected complete with absorption systems and redistillation equipment and a further six in process of erection. The completed factory would have been capable of producing at least 6000 tons of pure anhydrous hydrofluoric acid per year. [...]

The completed plant at Leverkusen Works is capable of producing hydrofluoric acid at 80% strength equivalent to 9,600 tons per year, of which 960 tons per year would be 98–100% without redistillation. [...]

An unique system has been installed at the I.G. Oppau Works for the production of cryolite from low grade feldspar. The process is cyclic and appears very efficient. [...]

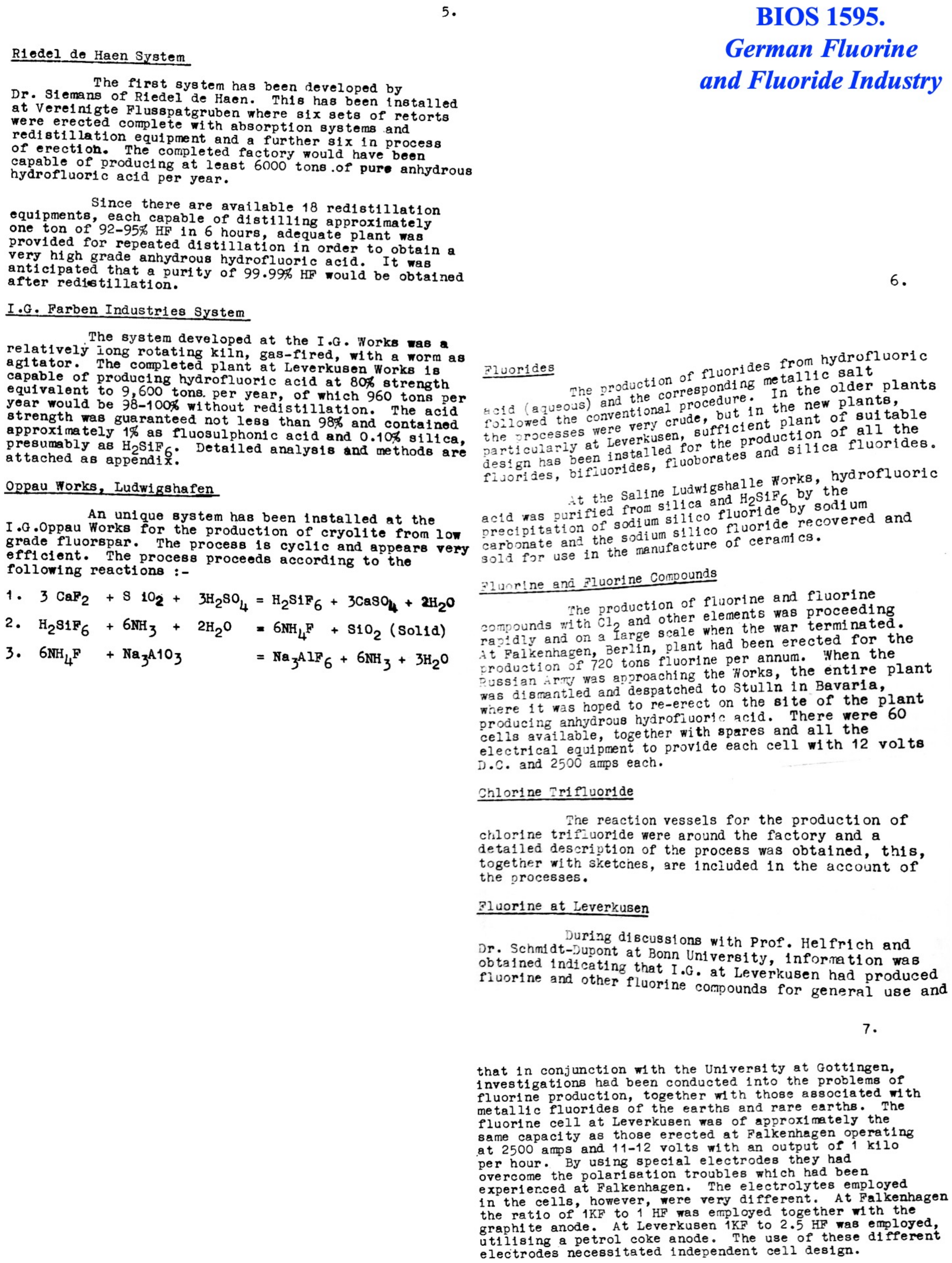
The production of fluorides from hydrofluoric acid (aqueous) and the corresponding metallic salt followed the conventional procedure. In the older plants the processes were very crude, but in the new plants, particularly at Leverkusen, sufficient plant of suitable design has been installed for the production of all the fluorides, bifluorides, fluoborates and silica fluorides. [...]

At Falkenhagen, Berlin, plant had been erected for the production of 720 tons fluorine per annum. When the Russian Army was approaching the Works, the entire plant was dismantled and despatched to Stulln in Bavaria, where it was hoped to re-erect on the site of the plant producing anhydrous hydrofluoric acid. [...]

During discussions with Prof. Helfrich and Dr. Schmidt-Dupont at Bonn University, information was obtained indicating that I.G. at Leverkusen had produced fluorine and other fluorine compounds for general use and that in conjunction with the University of Göttingen, investigations had been conducted into the problems of fluorine production, together with those associated with metallic fluorides of the earths and rare earths. [...]

[See document photos on p. 4123.

Metallic fluorides could have included uranium hexafluoride.]



BIOS 1595.
German Fluorine and Fluoride Industry

5.

Riedel de Haen System

The first system has been developed by Dr. Siemans of Riedel de Haen. This has been installed at Vereinigte Flusspatgruben where six sets of retorts were erected complete with absorption systems and redistillation equipment and a further six in process of erection. The completed factory would have been capable of producing at least 6000 tons of pure anhydrous hydrofluoric acid per year.

Since there are available 18 redistillation equipments, each capable of distilling approximately one ton of 92-95% HF in 6 hours, adequate plant was provided for repeated distillation in order to obtain a very high grade anhydrous hydrofluoric acid. It was anticipated that a purity of 99.99% HF would be obtained after redistillation.

I.G. Farben Industries System

The system developed at the I.G. Works was a relatively long rotating kiln, gas-fired, with a worm as agitator. The completed plant at Leverkusen Works is capable of producing hydrofluoric acid at 80% strength equivalent to 9,600 tons per year, of which 960 tons per year would be 98-100% without redistillation. The acid strength was guaranteed not less than 98% and contained approximately 1% as fluosulphonic acid and 0.10% silica, presumably as H_2SiF_6. Detailed analysis and methods are attached as appendix.

Oppau Works, Ludwigshafen

An unique system has been installed at the I.G.Oppau Works for the production of cryolite from low grade fluorspar. The process is cyclic and appears very efficient. The process proceeds according to the following reactions :-

1. $3\ CaF_2 + SiO_2 + 3H_2SO_4 = H_2SiF_6 + 3CaSO_4 + 2H_2O$
2. $H_2SiF_6 + 6NH_3 + 2H_2O = 6NH_4F + SiO_2$ (Solid)
3. $6NH_4F + Na_3AlO_3 = Na_3AlF_6 + 6NH_3 + 3H_2O$

6.

Fluorides

The production of fluorides from hydrofluoric acid (aqueous) and the corresponding metallic salt followed the conventional procedure. In the older plants the processes were very crude, but in the new plants, particularly at Leverkusen, sufficient plant of suitable design has been installed for the production of all the fluorides, bifluorides, fluoborates and silica fluorides.

At the Saline Ludwigshalle Works, hydrofluoric acid was purified from silica and H_2SiF_6 by the precipitation of sodium silico fluoride by sodium carbonate and the sodium silico fluoride recovered and sold for use in the manufacture of ceramics.

Fluorine and Fluorine Compounds

The production of fluorine and fluorine compounds with Cl_2 and other elements was proceeding rapidly and on a large scale when the war terminated. At Falkenhagen, Berlin, plant had been erected for the production of 720 tons fluorine per annum. When the Russian Army was approaching the Works, the entire plant was dismantled and despatched to Stulln in Bavaria, where it was hoped to re-erect on the site of the plant producing anhydrous hydrofluoric acid. There were 60 cells available, together with spares and all the electrical equipment to provide each cell with 12 volts D.C. and 2500 amps each.

Chlorine Trifluoride

The reaction vessels for the production of chlorine trifluoride were around the factory and a detailed description of the process was obtained, this, together with sketches, are included in the account of the processes.

Fluorine at Leverkusen

During discussions with Prof. Helfrich and Dr. Schmidt-Dupont at Bonn University, information was obtained indicating that I.G. at Leverkusen had produced fluorine and other fluorine compounds for general use and

7.

that in conjunction with the University at Gottingen, investigations had been conducted into the problems of fluorine production, together with those associated with metallic fluorides of the earths and rare earths. The fluorine cell at Leverkusen was of approximately the same capacity as those erected at Falkenhagen operating at 2500 amps and 11-12 volts with an output of 1 kilo per hour. By using special electrodes they had overcome the polarisation troubles which had been experienced at Falkenhagen. The electrolytes employed in the cells, however, were very different. At Falkenhagen the ratio of 1KF to 1 HF was employed together with the graphite anode. At Leverkusen 1KF to 2.5 HF was employed, utilising a petrol coke anode. The use of these different electrodes necessitated independent cell design.

Figure D.533: BIOS 1595. *German Fluorine and Fluoride Industry.*

For more information on wartime fluorine production and applications, see:

BIOS 261. *Hydrofluoric Acid Vereinigte Flusspathgruben G.m.b.H. Stulln.*

BIOS 714. *The Development of New Insecticides and Chemical Warfare Agents.* [Fluorine compounds.]

BIOS 764. *Production of Aluminium Compounds in Germany.* [Fluoride of aluminum manufacture.]

BIOS 785. *The German Mica Industry.* [Fluorine-phlogopite (synthetic mica) manufacture and properties.]

BIOS 896. *The Manufacture of Zirconium-Potassium Fluoride, Zirconium Oxide and Zirconium Oxychloride.*

BIOS 1095. *Developments in Methods and Materials for the Control of Plant Pests and Diseases in Germany.* [Fluorine compounds.]

BIOS 1335. *The Fluorspar Industry in Germany. Mines and Treatment Plants in the Nabburg and Regensburg Districts, Upper Palatinate (Bavaria).*

BIOS 1338. *Developments in Magnesium Production and Fabrication.* [Beryllium and zirconium at Degussa; also fluorine and carbon at I.G. Farben.]

BIOS 1433. *I.G. Farbenindustrie, A.G. The Manufacture of Triphenylmethane Dyestuffs at Hoechst, Ludwigshafen and Leverkusen.* [Fluorol 5G manufacture at Ludwigshafen.]

BIOS 1480. *The Manufacture, Formulation and Application of the Major Pest Control Products in the British, U.S. & French Zones of Germany.* [Fluorides.]

BIOS Misc. 14. [Fluorine organic compounds.]

CIOS XXIX-14. *I. G. Farbenindustrie A. G., Leverkusen, Germany.* [Fluoride production.]

FIAT 524. *Production of Aluminum.* [Fluoride recovery from aluminum furnace gases.]

FIAT 747. *The Synthesis of Fluorine-Mica of the Phlogopite Group.*

FIAT 838. *Elemental Fluorine, I.G. Farbenindustrie—Leverkusen.* [potentially nuclear-related]

FIAT 1114. *Recent German Research Work on Fluorine and Fluorine Compounds.* [W. Kwasnik and P. Scherer—nuclear-related!]

[For information on wartime German production of uranium hexafluoride for uranium enrichment, see pp. 3478–3493.]

G. Aluminum

[Aluminum was used for fabricating a wide variety of metal structures and packaging. On the other hand, aluminum could have been quite useful as cladding around fission fuel in a reactor, or as spherical pusher and casing shells in an atomic bomb as described on p. 4486. The following documents illustrate that wartime production of aluminum was widespread and sophisticated.]

For information on wartime aluminum production and applications, see for example:

BIOS 127. *The Aluminum Fabricating Plant of Aluminium Wals-on Persbedrljvon N. V., Utrecht, Holland.*

BIOS 144. *Wrought Light Alloy Plants in North-West Germany.*

BIOS 151. *German Aluminum and Magnesium Melting and Rolling Practices.*

BIOS 179. *German Cable Industry.*

BIOS 214. *Non-destructive Testing of Materials, Siemens-Werner Werk "M", Berlin/Siemenstadt.*

BIOS 229. *Wrought Light Alloy Plants in Southern Germany.*

BIOS 264. *German Brass and Copper Wire Industry.*

BIOS 279. *German Technique in the Production of Light Alloys.*

BIOS 288. *Aluminium Hydrate and Alumina Production in German Factories.*

BIOS 316. *German Light Alloy Foundry Industry.*

BIOS 374. *German Aluminum Foil Industry.*

BIOS 376. *Recovery of Aluminium Alloys from Aircraft Scraps.*

BIOS 392. *Welding of Aluminium and Aluminium Alloys with Particular Reference to the Manufacture of Pressure Vessels.*

BIOS 462. *Impact Extrusion.*

BIOS 465. *High Temperature Refractories and Ceramics.*

BIOS 470. *Specialized Ceramic Materials with Particular Reference to Ceramic Gas Turbine Blades.*

BIOS 504. *Visit to Metallgesellschaft A.G., Frankfurt a.M.*

BIOS 527. *Iron, Steel and Non-Ferrous Metal Works Plant and Machinery.*

BIOS 533. *Electric Furnace Design. Manufacture and Application in Germany.*

BIOS 605. *Some Marine Applications of Light Alloys in Germany.*

BIOS 643. *German Anodising Practice.*

BIOS 681. *German Cold Rolled Strip Industry.*

BIOS 693. *Investigation of the Light Alloy Forging Industry in Germany.*

BIOS 720. *Metallurgical Research and Testing Laboratories in the Stuttgart Area.*

BIOS 724. *Electronic Principles as Applied in Germany to the Testing of Materials.*

BIOS 764. *Production of Aluminium Compounds in Germany.*

BIOS 766. *The Manufacture of Pharmaceuticals and Fine Chemicals in the U.S. and French Zones of Germany.*

BIOS 895. *Aluminium Production at Vereinigte Aluminiumwerke (V.A.W.), Lünen.*

BIOS 974. *Alumina and Aluminium Production at the Lippewerk of the Vereinigte Aluminium-Werke A.G. Lünen.*

BIOS 975. *Alumina Production at Martinswerk Bergheim/Rhineland.*

BIOS 976. *Electro-Thermic Production of Aluminium-Silicon Alloys at Lurgi-Thermie G.m.b.H., Horrem.*

BIOS 981. *Light Alloys. Notes on German Technique on Continuous Casting and Extrusion of Aluminium Alloys with Particular Reference to Tube Extrusion, Tube Reducing Machines and Vertical Extrusion Presses.*

BIOS 982. *Light Alloy Rolling, Osnabrück Kupfer and Drahtwerke Osnabrück.*

BIOS 995. *Hot-Dipping and Electro-Deposition of Tin and Tin Alloys in Germany.*

BIOS 1084. *German Aluminium Fabricating Equipment.*

BIOS 1089. *Aluminium Refining and Scrap Recovery at V.A.W. Erftwerk Grevenbroich.*

BIOS 1099. *Survey of Secondary Aluminium Industry in Germany.*

BIOS 1100. *German Aluminium Foil Industry.*

BIOS 1165. *Aluminium Holloware Industry in the British Occupied Zone of Germany.*

BIOS 1190. *German Cable Industry.*

BIOS 1205. *Chemische Fabriken, Oker and Bramschweig. Aktiengesellschaft, Oker and Harz. Manufacture of Aluminium Hydroxide Pigment (Tonerde-Gel) and Aluminium Sulphate.*

BIOS 1215. *German Methods of Rhodiumizing, Aluminizing, Anti-Reflection Surface Coating and Allied Subjects.*

BIOS 1231. *The German Container and Canning Industries.* [Aluminum cans]

BIOS 1271. *Food Preparing Machinery.* [Aluminum cans]

BIOS 1295. *The Production of Certain Types of Phosphor Bronze, Brass and Light Alloy Castings in Germany. Composite Report of Interrogations of Dr. Heinrich Bauer, Dürener Metallwerke, Düren.*

BIOS 1342. *German Optical Mirrors and Reflectors.*

BIOS 1366. *The Production in Germany of Extruded Sections and Tubes in Aluminium and Magnesium Alloys.*

BIOS 1405. *Impact Extrusion. German Practice. 1946.*

BIOS 1409. *Cold Impact Extrusion of Aluminium, Etc.*

BIOS 1423. *The Application of Aluminium and Its Alloys in Germany.*

BIOS 1454. *Aluminium Pressings.*

BIOS 1467. *German Methods of Production of Aluminium Coated and Continuous Electroplated Steel Strip.*

BIOS 1535. *Report on Investigation of Methods of Gaseous Metal Treatment.*

BIOS 1550. *Sheathing of Cables with Aluminium.*

BIOS 1567. *Manufacture of Aluminium Clad Steel Strip by Wickede Eisen und Stahlwerke.*

BIOS 1595. *German Fluorine and Fluoride Industry.* [Aluminum fluoride manufacture and analysis.]

BIOS 1656. *Extrusion of Light Alloys at I.G. Farbenindustrie, Bitterfeld. Interrogation of Herr K. F. Brauninger.*

BIOS 1660. *A General Survey of the German Non-Ferrous Industry.*

BIOS 1667. *Some Notes on Open Hearth Furnace Design and Operation.*

BIOS 1703. *Manufacture of Aluminium at I.G. Farben Factory, Bitterfeld.*

BIOS 1757. *Manufacture of Super-Purity Aluminium at the Vereinigte Aluminium Werke, Erftwerk, Grevenbroich.*

BIOS 1770. *High Strength Aluminium-Zinc-Magnesium Alloy Development in Germany.*

BIOS 1861. *Light Alloy Foundries in Germany.*

CIOS XXII-4. *Aluminum Woerwerke, Erftwerke, Gravenbroich.*

CIOS XXIV-22. *The Electrochemical Industry, Bitterfeld Area.*

CIOS XXV-17. *The Electrochemical Industry, Burghausen Area.*

CIOS XXV-30. *Felten and Guilleaume Carlswerke, Cologne.*

CIOS XXV-31. *Suddeutsche Kabelwerke, Mannheim.*

CIOS XXV-32. *Hackethal Draht Und Kabelwerke AG, Hanover.*

CIOS XXVI-47. *Gelr. Guifine G.m.b.H., Ludwigshafen Am Rhein.*

CIOS XXVI-60. *Light Metal Production and Development for Aircraft, I.G. Farben.*

CIOS XXVII-9. *Kupfer U Drahtwerke, Osnabruck.*

CIOS XXVII-94. *Vereinigte Deutsche Metallwerke AG.*

CIOS XXIX-14. *I. G. Farbenindustrie A. G., Leverkusen, Germany.* [Aluminum fluoride production.]

CIOS XXIX-18. *Metal Fabrication at Mansfeld AG Kupfer Und Messing Werke, Hettstedt.*

CIOS XXIX-19. *Aluminum Reduction and Scrap Recovery at the Erftwerk of the Vereinigte Aluminum-Werke AG, Grevenbroich.*

CIOS XXX-72. *Aluminum and Magnesium Fabrication, Leipziger Leichtmetall, Werk-Rackwitz, Rackwitz.*

CIOS XXX-73. *Aluminum Fabrication, Osnabrucker Kupfer and Drahtwerk, Osnabruck.*

CIOS XXX-85. *A Survey of the German Can Industry During the Second World War.*

CIOS XXXI-57. *Hugo Schneider AG, Messingwerke Aluminum Werke, Leipzig.*

CIOS XXXI-73. *Vereingte Leichtmetall Werke G.m.b.H., Hannover Linden.*

CIOS XXXII-21. *Aluminum from Clay.*

CIOS XXXII-55. *Recovery of Metals from Scrapped Airplanes.*

CIOS XXXII-59. *Aluminum and Magnesium Production and Fabrication.*

CIOS XXXIII-31. *Investigation of Certain Chemical Factories in the Leipzig Area of Germany.*

CIOS XXXIII-32. *The Vereinigte Leightmetall-Werke, Hanover.*

CIOS XXXIII-59. *The Vereinigte Leightmetall-Werke, Hanover.*

FIAT 395. *Metallurgical Practices in Germany. The Fields of Non-Ferrous Melting and Casting.*

FIAT 406. *Non-ferrous Metal Rolling Mill Practice in Germany.*

FIAT 417. *"Press-Welding" Aluminum for Aircraft Radiators.*

FIAT 501. *The German Aluminum and Magnesium Industries.*

FIAT 516. *Report on Recent Cable Development in Germany.*

FIAT 522. *The Beryllium Industries of Germany and Italy (1939 to 1945).* [Alloys of beryllium with Al, Cu, Ni, Mg, etc.]

FIAT 524. *Production of Aluminum.*

FIAT 569. *Manufacturing Bronze, Aluminum or Other Flake Metal Powders.*

FIAT 602. *Aluminum Pistons for Automobile and Aircraft Engines.*

FIAT 686. *Casting Methods for Aluminum and Aluminum Alloys Billets.*

FIAT 699. *Magnesium Determinations in Aluminum.*

FIAT 731. *Technology of Aluminum and Aluminum Alloy Production in Germany Including Early Fabrication and Recoveries from Scrap.*

FIAT 754. *Vibrating Ball Mill for Pulverizing Fine Materials.*

FIAT 787. *Precious Metal Refining and Fabrication by W. C. Heraeus and G. Siebert Platinschmelze of Hanau.* [Aluminum and rhodium mirrors]

FIAT 805. *German Research on Experimental Aluminum-Base Bearings.*

FIAT 829. *Non-ferrous Metal Production Processes in the Hamburg District.*

FIAT 876. *Continuous Casting of Metals in Germany.*

FIAT 907. *Review of Recent Developments in Aluminum Refining.*

FIAT 927. *Production of High Alumina Slags in Blast Furnaces and Allied Processes for Recovering Alumina.*

FIAT 980. *German Aluminum Industry.*

FIAT 986. *Carbon Electrodes in Germany for the Aluminum Reduction Industry.*

FIAT 989. *Alumina Production in Germany.*

FIAT 992. *The Electrothermal Production of Aluminum Silicon Alloy.*

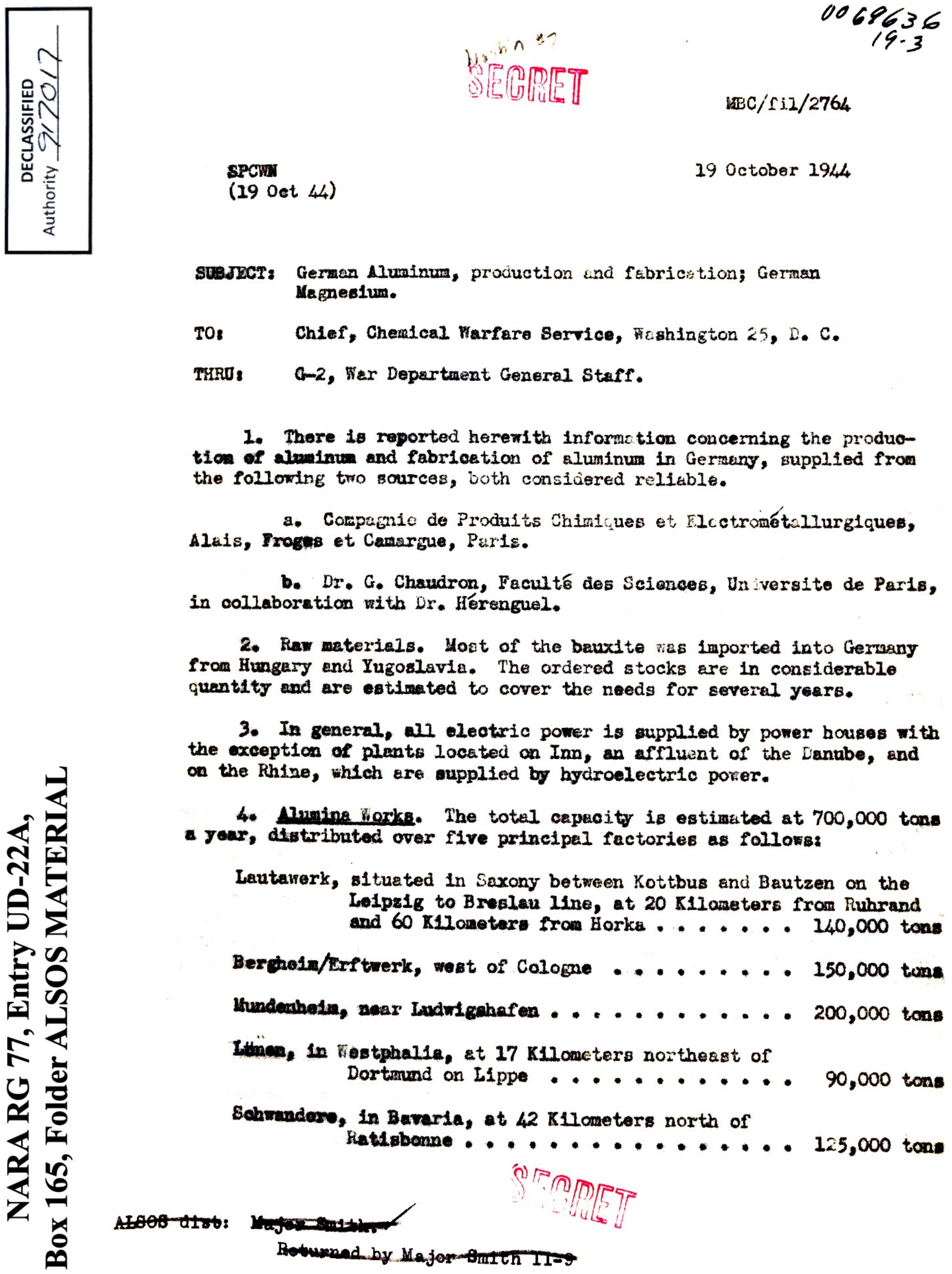
FIAT 993. *The Aluminum Reduction Industry in Germany.*

FIAT 997. *German Research in the Light Metals Industry.*

FIAT 1011. *Fabrication of Aluminum in Germany. A Study of Some Specialized Practices and Techniques Employed in the Industry.*

G-80. Rudolf Fleischmann. *The Capture Cross Sections of Aluminum for Thermal Neutrons.* 1941.

G-153. Wilhelm Hanle. *Spectroscopic Analysis of Carbon, Aluminum, and Beryllium.* 1942.



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SPCWN
(19 Oct 44)

19 October 1944

SUBJECT: German Aluminum, production and fabrication; German Magnesium.

TO: Chief, Chemical Warfare Service, Washington 25, D. C.

THRU: G-2, War Department General Staff.

1. There is reported herewith information concerning the production of aluminum and fabrication of aluminum in Germany, supplied from the following two sources, both considered reliable.

a. Compagnie de Produits Chimiques et Electrométallurgiques, Alais, Froges et Camargue, Paris.

b. Dr. G. Chaudron, Faculté des Sciences, Universite de Paris, in collaboration with Dr. Hérenguel.

2. Raw materials. Most of the bauxite was imported into Germany from Hungary and Yugoslavia. The ordered stocks are in considerable quantity and are estimated to cover the needs for several years.

3. In general, all electric power is supplied by power houses with the exception of plants located on Inn, an affluent of the Danube, and on the Rhine, which are supplied by hydroelectric power.

4. Alumina Works. The total capacity is estimated at 700,000 tons a year, distributed over five principal factories as follows:

Lautawerk, situated in Saxony between Kottbus and Bautzen on the Leipzig to Breslau line, at 20 Kilometers from Ruhrand and 60 Kilometers from Horka	140,000 tons
Bergheim/Erftwerk, west of Cologne	150,000 tons
Mundenheim, near Ludwigshafen	200,000 tons
Lünen, in Westphalia, at 17 Kilometers northeast of Dortmund on Lippe	90,000 tons
Schwandorf, in Bavaria, at 42 Kilometers north of Ratisbonne	125,000 tons

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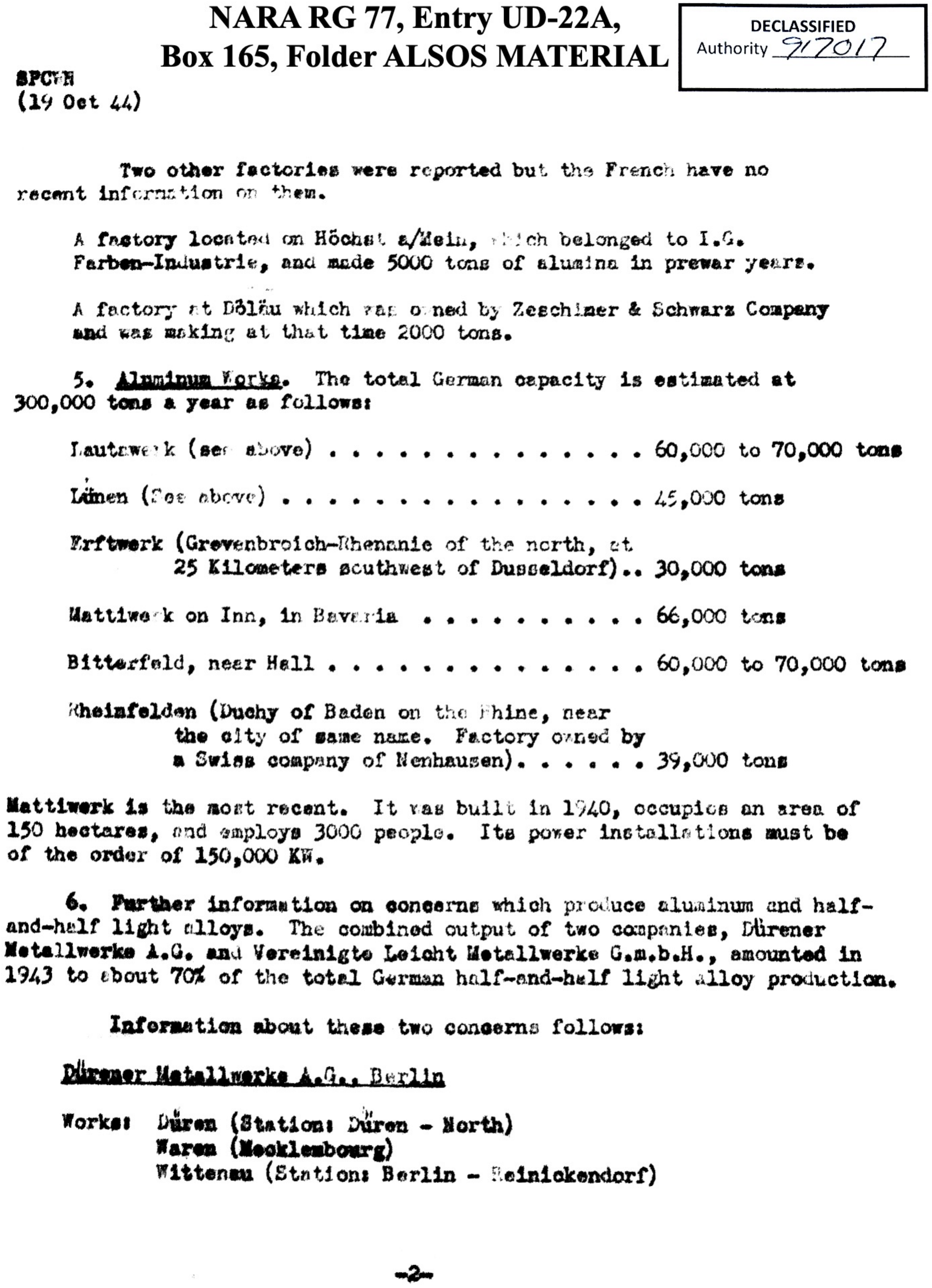
~~ALSOS dist: Major Smith.~~

~~Returned by Major Smith 11-9~~

NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL

Figure D.534: M. B. Chittick. 19 October 1944. Subject: German Aluminum, production and fabrication; German Magnesium [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].



NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL

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SPCWH
(19 Oct 44)

Two other factories were reported but the French have no recent information on them.

A factory located on Höchst a/Mein, which belonged to I.G. Farben-Industrie, and made 5000 tons of alumina in prewar years.

A factory at Dölau which was owned by Zeschimer & Schwarz Company and was making at that time 2000 tons.

5. Aluminum Works. The total German capacity is estimated at 300,000 tons a year as follows:

Lautawerk (see above)	60,000 to 70,000 tons
Lünen (See above)	45,000 tons
Erftwerk (Grevenbroich-Rhenanie of the north, at 25 Kilometers southwest of Dusseldorf)	30,000 tons
Mattiwerk on Inn, in Bavaria	66,000 tons
Bitterfeld, near Hall	60,000 to 70,000 tons
Rheinfelden (Duchy of Baden on the Rhine, near the city of same name. Factory owned by a Swiss company of Nenhausen)	39,000 tons

Mattiwerk is the most recent. It was built in 1940, occupies an area of 150 hectares, and employs 3000 people. Its power installations must be of the order of 150,000 KW.

6. Further information on concerns which produce aluminum and half-and-half light alloys. The combined output of two companies, Dürener Metallwerke A.G. and Vereinigte Leicht Metallwerke G.m.b.H., amounted in 1943 to about 70% of the total German half-and-half light alloy production.

Information about these two concerns follows:

Dürener Metallwerke A.G., Berlin

Works: Düren (Station: Düren - North)
Waren (Mecklembourg)
Wittenau (Station: Berlin - Reinickendorf)

Figure D.535: M. B. Chittick. 19 October 1944. Subject: German Aluminum, production and fabrication; German Magnesium [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

H. Calcium

[Calcium was used in making certain metal alloys, but it also would have been extremely useful in key steps of the purification of thorium, uranium, and/or plutonium. The following documents demonstrate large-scale production and use of calcium, and even methods of utilizing calcium to purify thorium and uranium.]

BIOS 236. *Developments in Pure and Applied Microbiology (American, British and French Zones) During World War II.* [Calcium gluconate from hydrolysis of starch.]

BIOS 489. *Chemische Fabrik Joh. A. Benckiser, G.m.b.H. Ladenburg Works. Manufacture of Calcium Citrate.*

BIOS 636. *Mineralölwerke F. Harmsen, Kiel—Germany: Lubricants.* [Calcium soap greases.]

BIOS 675. *The Production of Thorium and Uranium in Germany.* [Using calcium to process thorium and uranium—see pp. 4134–4135.]

BIOS 798. *The German Ferro-Alloy Industry.* [Calcium silicide manufacture.]

BIOS 883. *Notes on Casting and Fabrication of Lead and Production of Bahnmetall.* [Calcium-lead alloy manufacture.]

BIOS 1044. *German Carbide and Cyanamide Industry. Carbide Production.* [Calcium carbide manufacture.]

BIOS 1045. *German Carbide and Cyanamide Industry. Handling of Carbide in Bulk.* [Calcium carbide, bulk transport of.]

BIOS 1046. *German Carbide and Cyanamide Industry. Manufacture of Calcium Cyanamide.* [Calcium cyanamide manufacture from carbide.]

BIOS 1385. *The German Hard Metal Industry.* [Electron microscope, zirconium, uranium, thorium, calcium tungstate manufacture, etc.]

BIOS 1443. *The German Nitrogenous Fertiliser Industry (Excluding Cyanamide) in the Western Zones.* [Calcium nitrate manufacture for fertilizers.]

BIOS 1480. *The Manufacture, Formulation and Application of the Major Pest Control Products in the British, U.S. & French Zones of Germany.* [Calcium compounds.]

BIOS 1490. *German Gypsum Industry (British, American and French Zones).* [calcium sulfate mining]

BIOS 1539. *German Chlorate Industry.* [Calcium chlorate manufacture.]

BIOS 1700. *The Manufacture of Glycerophosphates and Hypophosphites in Germany.* [Calcium glycerophosphate and calcium hypophosphite manufacture.]

CIOS X-1. *Caves at Bad Mor Mories, Near Vaas Used for Storage of Peroxide.* [Calcium permanganate underground tank storage.]

CIOS XVIII-1. *Chemical Installation in the Cologne Area.* [Calcium carbide.]

CIOS XXV-17. *The Electrochemical Industry, Burghausen Area.* [Calcium cyanamide production.]

CIOS XXVII-83. *AG für Stickstoffdünger, Knapsack.* [Calcium carbide production.]

CIOS XXVII-85. *Miscellaneous Chemicals, I.G. Farben AG, Ludwigshafen and Oppau.* [Calcium carbide.]

CIOS XXVII-92. *German Carbide, Cyanamide and Cyanide Industry.* [Calcium carbide.]

CIOS XXXIII-31. *Investigation of Certain Chemical Factories in the Leipzig Area of Germany.* [Calcium manufacture at I.G. Farben, Bitterfeld.]

CIOS XXXIII-47. *Manufacture of Sodium and Calcium Permanganate.*

FIAT 229. *Copper, Lead, Zinc, Tin, and Antimony Smelting and Refining in Northwestern Germany.* [Calcium-lead alloys.]

FIAT 431. *A Survey of the Chlorine and Caustic Plants in Western and Southern Germany.* [Calcium chlorate production.]

FIAT 665. *German Fertilizers and Soil Fertility.* [Calcium magnesium phosphate fertilizer.]

FIAT 728. *AG für Stickstoffdünger, Knapsack.* [Calcium cyanamide.]

FIAT 732. *Electrochemical Operations at I.G. Farbenindustrie AG, Bitterfeld.* [Calcium manufacture.]

FIAT 750. *Rare and Minor Metals.* [Calcium production.]

FIAT 756. *Calcium Metal and Calcium Hydride.*

FIAT 859. *Continuous Chilling and Cooling of Calcium Carbide.*

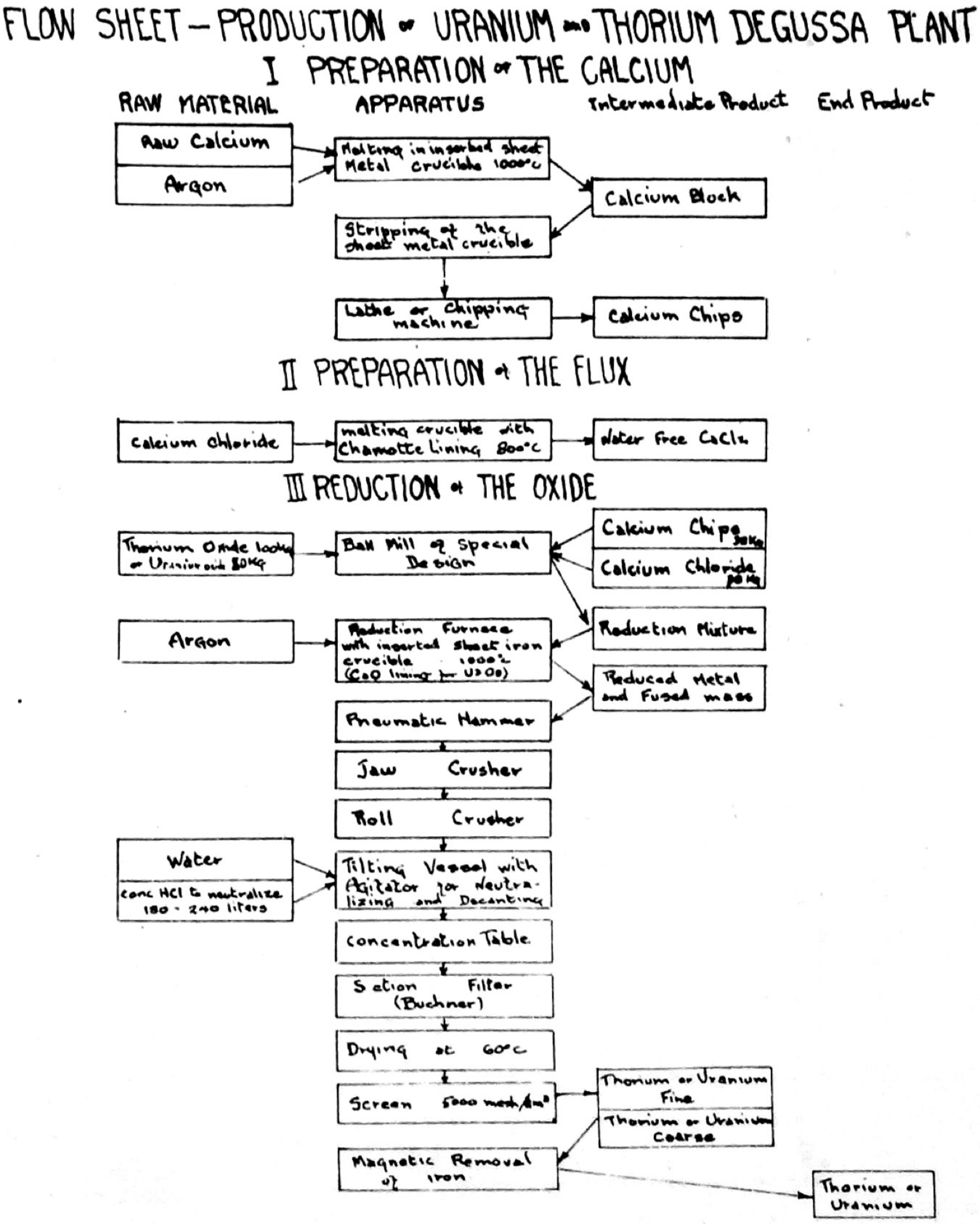

FLOW SHEET – PRODUCTION OF URANIUM AND THORIUM DEGUSSA PLANT
I PREPARATION OF THE CALCIUM
RAW MATERIAL
APPARATUS
Intermediate Product
End Product
Raw Calcium
Argon
Melting in inserted sheet Metal crucible 1000°C
Calcium Block
Stripping of the sheet metal crucible
Lathe or chipping machine
Calcium Chips
II PREPARATION OF THE FLUX
Calcium chloride
melting crucible with Chamotte Lining 800°C
Water free CaCl2
III REDUCTION OF THE OXIDE
Thorium Oxide 100kg or Uranium oxide 80kg
Ball Mill of Special Design
Calcium Chips 30kg
Calcium Chloride 30kg
Reduction Mixture
Argon
Reduction Furnace with inserted sheet iron crucible 1000°C (CaO lining for U3O8)
Reduced Metal and Fused mass
Pneumatic Hammer
Jaw Crusher
Roll Crusher
Water
conc HCl to neutralize 180 - 240 liters
Tilting Vessel with Agitator for Neutralizing and Decanting
concentration Table
Suction Filter (Buchner)
Drying at 60°C
Screen 5000 mesh/dm²
Thorium or Uranium Fine
Thorium or Uranium Coarse
Magnetic Removal of iron
Thorium or Uranium

Figure D.536: Flowchart of German methods of using calcium to process uranium and thorium [BIOS 675].

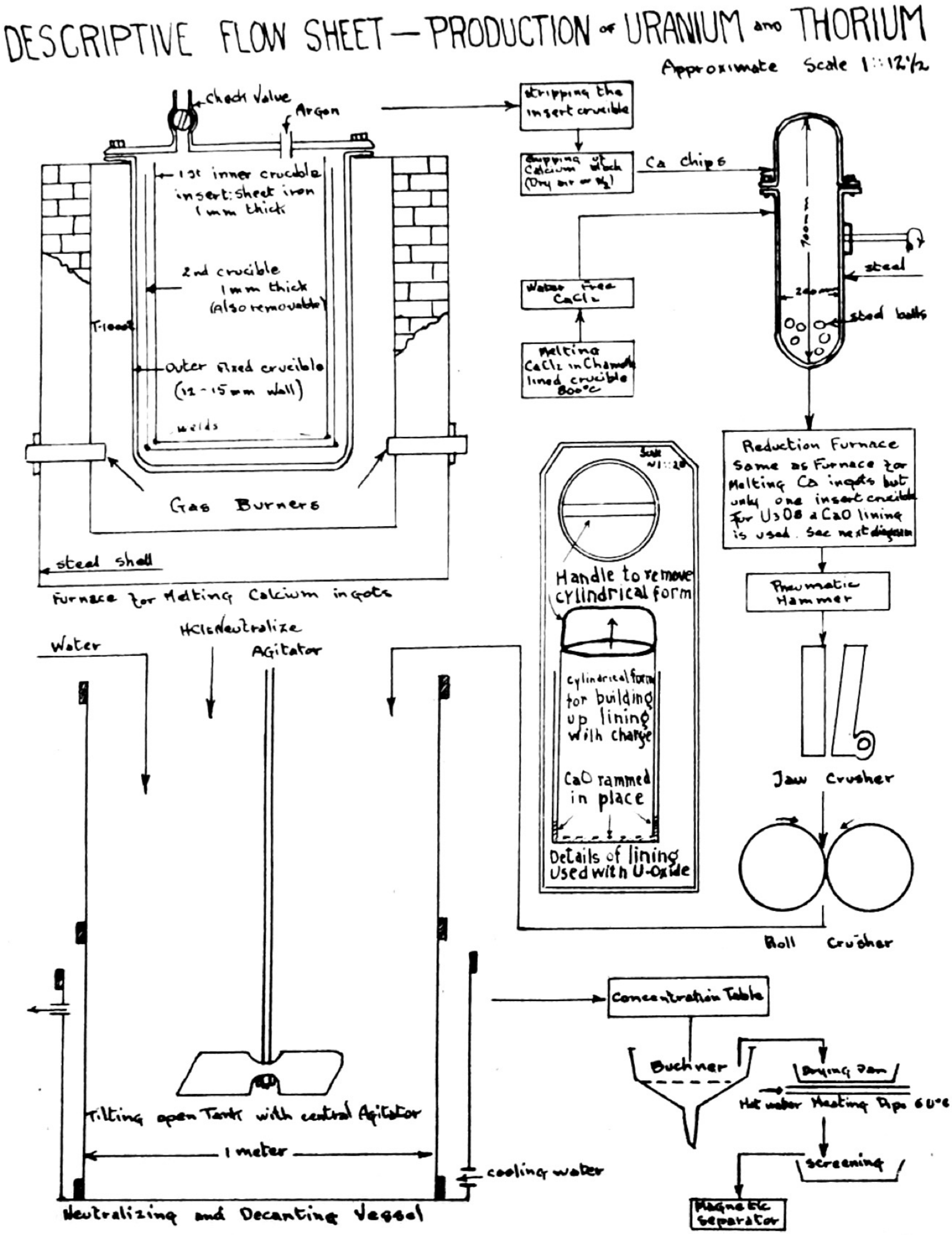

DESCRIPTIVE FLOW SHEET — PRODUCTION of URANIUM and THORIUM
Approximate Scale 1::12½
Check Valve
Argon
1st inner crucible insert: sheet iron 1 mm thick
2nd crucible 1 mm thick (Also removable)
T-1000
Outer fixed crucible (12 - 15 mm wall)
welds
Gas Burners
steel shell
Furnace for Melting Calcium ingots
stripping the insert crucible
Chipping of Calcium block (Dry air or N_2)
Ca chips
700 mm
240 mm
steel
steel balls
Water free $CaCl_2$
Melting $CaCl_2$ in Chamotte lined crucible 800°C
Reduction Furnace Same as Furnace for Melting Ca ingots but only one insert crucible For U_3O_8 a CaO lining is used. See next diagram
Scale ~1::20
Handle to remove cylindrical form
cylindrical form for building up lining with charge
CaO rammed in place
Details of lining Used with U-Oxide
Pneumatic Hammer
Jaw Crusher
Roll Crusher
Water
HCl&Neutralize
Agitator
Tilting open Tank with central Agitator
1 meter
cooling water
Neutralizing and Decanting Vessel
Concentration Table
Buchner
Drying Pan
Hot water Heating Pipe 60°C.
screening
Magnetic separator

Figure D.537: Flowchart of German methods of using calcium to process uranium and thorium [BIOS 675].

Henry S. Lowenhaupt. 1996. Chasing Bitterfeld Calcium. CIA Historical Review Program. https://www.cia.gov/static/Chasing-Bitterfeld-Calcium.pdf

In December 1946 a chemical engineer from the former I. G. Farben plant at Bitterfeld in East Germany volunteered in Berlin that this plant "had started in the past few weeks producing 500 kilograms per day of metallic calcium. Boxes of the chemical are sent by truck every afternoon to Berlin, labeled to Zaporozhe on the Dnieper. Calcium is believed to be used as a slowing agent in processes connected with the production of atomic explosive."

This was the lead we in the Foreign Intelligence Section of the Manhattan District Headquarters had been waiting for. We had read the technical investigation reports from FIAT (Field Information Agency /Technical) on the production of uranium at the Auergesellschaft Plant in Berlin/Oranienburg. We also knew that Dr. Nikolaus Riehl—with his whole research team from Auergesellschaft—had met the Russians, volunteering to help them make uranium for their atomic bomb project. We knew from intercepted letters that the group was still together, writing from the cover address PO Box 1037P, Moscow. We knew Auergesellschaft during World War II had made the uranium metal for the German Uranverein—the unsuccessful German atomic bomb project—by using metallic calcium to reduce uranium oxide to uranium metal (not as "slowing agent"). We had analyzed the two-inch cubes of uranium metal from the incomplete German nuclear reactor which the Alsos Mission had found in the minuscule village of Stadtilm in Thuringia. We knew German uranium was terrible—full of oxides and voids, though it was fairly pure otherwise by non-atomic standards. The files also disgorged that in 1945 the Russians had started to dismantle and take to Russia the small calcium plant at the enormous Bitterfeld Combine, in addition to the big magnesium facility.

Cables went out immediately to the European Command in Germany via G-2 and directly to Col. Edgar P. Dean, Manhattan District representative in London, to locate and interrogate all engineers who had fled Bitterfeld to the West or were currently willing to sell information on their unloved masters. We wanted to know how much calcium was to be produced, what its specifications were, and where it was to be shipped. We wanted to know what non-atomic normal German industries used calcium, and in what quantities. We wished Col. Dean to keep our British colleagues in the Division of Atomic Energy, Ministry of Supply, informed.

At home, the Scientific Division of the Office of Special Operations in the newly-formed Central Intelligence Group was also apprised of our needs. Col. Frank A. Valente of our section was asked to take time out from his task of organizing an atomic detection system to talk to the U.S. Atomic Energy Commission in depth about the use in the U.S. program of calcium to reduce uranium salts to uranium metal. Major Randolph Archer, also of our office, was asked to talk to U.S, firms making calcium metal, and find out what it was used for and in what quantities.

As so often happens, the people involved and their experience were crucial ingredients. On the American side was the Foreign Intelligence Section of the Washington Liaison Office of the Manhattan District, then in the process of transferring as a unit to the newly formed Central Intelligence Group. It was headed by Col. L. E. Seeman, a career Corps of Engineers officer who had run the American engineering forces of the CBI theater during World War II and would go on to become major general. The section was staffed with a few career Corps of Engineers personnel, several officers and civilians trained in science, and the remainder trained in investigative procedures in the Counter Intelligence Corps.

The orientation toward engineering on the part of our management led directly to a pragmatic approach—do what works, and get on with the job. The engineering orientation also led materially toward the estimative method of technical evaluation. Engineering officers are accustomed to laying out engineering tasks to find out how long they will take at a minimum—and then to evaluate likely slippage. They think in quantitative terms—man days, truckloads, cubic yards. The scientific side of the section, Col. Valente, Mr. Charles Campbell, Mr. Donald Quigley, and I learned gradually to ferret out the crucial technical facts, the bottlenecks as it were, that could be used in these engineering-type evaluations.

A remnant of the wartime cooperation in the atomic field was the direct liaison at that time with the Intelligence Section of the British Division of Atomic Energy of the Ministry of Supply. Col. Dean, Assistant Military Attaché, was our representative in London. This cooperation was normalized gradually into more regular country-to-country liaison channels after our section was deployed to the newly formed CIG early in 1947. The Atomic Energy Act of 1946, which restricted much atomic data to "cleared" U.S. personnel, also tended to perpetuate differences between the U.S. and UK intelligence efforts already in being in 1946 because of the "nationalistic" policies on the parts of both General Leslie R. Groves, Manhattan District Commander, and Sir John Anderson, head of the UK atomic effort.

The British office was staffed with technical personnel, much as our own was. Mr. David Gattiker, their liaison to our section, had been a chemical engineer with Imperial Chemicals Incorporated before World War II. Mr. Kenneth Townley, one of the London members, was a geologist by profession with some experience in uranium prospecting. Its leader, Commander Eric Welsh, however, was also a career member of MI-6. Commander Welsh had masterminded the sabotage of Norsk Hydro in Norway in 1943 to prevent the Germans from getting heavy water and completing an operating reactor at Stadtilm. In 1940 he had been instrumental in smuggling the great nuclear physicist Niels Bohr out of occupied Denmark. And in the thirties he had been a chemist at Bitterfeld.

Returning to the calcium problem, by mid-January 1947 the Bitterfeld activity was definitely confirmed, and indeed amplified: Russian requirements were for 30 tons of metallic calcium per month, and distillation was needed to achieve adequate purity. A number of former Bitterfeld engineers were soon interviewed, especially by Major Paul O. Langguth working for Col. Dean in London. As we learned more, some were even re-interviewed. I remember, for instance, flying to Wright Patterson Airbase in late 1947 to talk once again to a Bitterfeld metallurgist whom Langguth had previously interrogated, and who had in the interim come to the U.S. as a member of the Air Force's Operation PAPERCLIP. [...]

[During the war, German industry produced calcium and used it to purify uranium and thorium (pp. 4134–4135). After the war, German industry continued to produce calcium for nuclear purposes—for the Soviet Union, as shown by the above document.]

I. Nickel

[Nickel was used for nickel-cadmium batteries and certain alloys. Yet because nickel is much more resistant than other metals to corrosion by uranium hexafluoride (used in uranium enrichment), it would have been invaluable in a nuclear program. The following documents demonstrate large-scale production of nickel.]

For information on wartime nickel production and applications, see for example:

BIOS 26. *Copper Smelting and Refining, Together with Related Metallurgical Activities at Nord Deutsche Affinerie, Hamburg.* [Nickel ores (Petsamo) treatment.]

BIOS 263. *Part I. I.G. Farben Industrie-Oppau Works, Ludwigshafen (Report on Nickel and Iron Powder Plants. Part II. Nord Deutsche Affinerie, Hamburg (Report on the Treatment of Nickel-Copper Ores and Residues).*

BIOS 358. *Acrylic Esters, Synthesis from Acetylene and Nickel Carbonyl.* [Nickel carbonyl regeneration from nickel salts.]

BIOS 371. *Regeneration of Nickel Carbonyl (from Aqueous Solutions).* [Nickel carbonyl regeneration from nickel salt solutions.]

BIOS 511. *Ruhr-Chemie A.G. Sterkrade Holten. Interrogation of Dr. O. Roelin.* [Nickel catalysts in Fischer-Tropsch process.]

BIOS 681. *German Cold Rolled Strip Industry.* [Nickel plated steel strip manufacture.]

BIOS 708. *German Alkaline Accumulator Industry.* [Nickel for alkaline accumulators: nickel carbonyl]

BIOS 755. *Manufacture of Butanol, Methoxybutanol, Butyraldehyde, Glycerogen at I.G. Hoechst.* [Nickel catalyst preparation for glycerogen manufacture.]

BIOS 778. *German Manufacture of Wires and Strips for Electrical Heating.* [Nickel-chromium and Ni-Cr-Iron alloys for heating.]

BIOS 779. [Nickel-chrome alloys for pyrometers.]

BIOS 1003. *Some Aspects of Copper, Nickel and Cobalt Production in Germany.* [Nickel, nickel sulfate, and nickel carbonate.]

BIOS 1009. *A Survey of German Electro-Plating Methods.* [Nickel plating methods.]

BIOS 1241. *The Manufacture of p:p' Diaminodicyclohexyl Methane (Dicykan).* [Nickel oxide catalyst manufacture.]

BIOS 1323. *The Production of Powdered Iron and Sintered Iron Driving Bands in Germany.* [Nickel-iron sheets from sintered metal.]

BIOS 1372. *German Silver & E.P.N.S. Holloware Industry.* [Nickel-silver holloware manufacture.]

CIOS XXXI-20. *Refining of Cobalt, Nickel, Zinc and Cadmium.*

CIOS XXII-15. *I.G. Farbenindustrie Plant, Frose, Germany.* [Nickel production.]

CIOS XXIV-12. *I.G. Farben—Oppau Works, Ludwigshafen.* [Nickel production.]

CIOS XXXIII-59. *German War List for Ferrous Materials (Kreigsliste).*

FIAT 422. *Manufacture and Regeneration of Catalysts at I.G. Farbenindustrie, Ludwigshafen Oppau.* [Nickel sulfate.]

FIAT 522. *The Beryllium Industries of Germany and Italy (1939 to 1945).* [Alloys of beryllium with Al, Cu, Ni, Mg, etc.]

FIAT 879. *Notes on the Peeling of Nickel Deposits.*

FIAT 800. *Nickel Cadmium Storage Batteries in Germany.*

FIAT 881. *Contribution to the Production of Cast Nickel Anodes.*

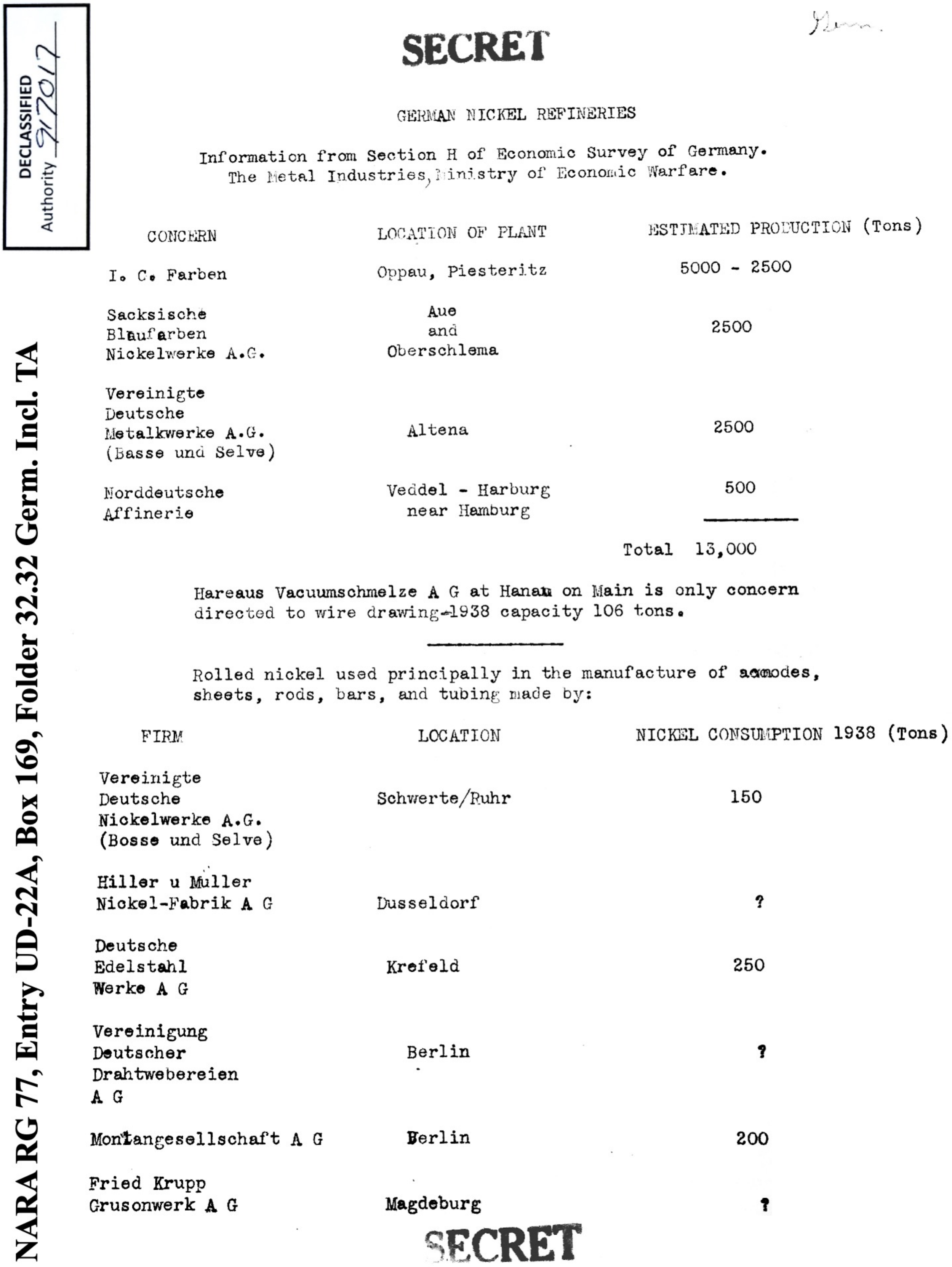
FIAT 882. *Anodes.* [Nickel anodes in electrolytic processes.]

German Nickel Refineries. Undated but probably 1944. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Ind. TA]

Information from Section H of Economic Survey of Germany.
The Metal Industries, Ministry of Economic Warfare.

CONCERN	LOCATION OF PLANT	ESTIMATED PRODUCTION (Tons)
I. G. Farben	Oppau, Piesteritz	5000–2500
Sacksische Blaufarben Nickelwerke AG	Aue and Oberschlema	2500
Vereinigte Deutsche Metallwerke AG (Basse und Selva)	Altena	2500
Norddeutsche Affinerie	Veddel—Harburg near Hamburg	500
		Total 13,000

[See document photos on pp. 4140–4141. This U.S. intelligence document was considered so important with regard to Germany's nuclear program that it was placed in the files of Leslie Groves's Foreign Intelligence Unit of the Manhattan Project.]



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NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Incl. TA

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GERMAN NICKEL REFINERIES

Information from Section H of Economic Survey of Germany.
The Metal Industries, Ministry of Economic Warfare.

CONCERN	LOCATION OF PLANT	ESTIMATED PRODUCTION (Tons)
I. C. Farben	Oppau, Piesteritz	5000 - 2500
Sacksische Blaufarben Nickelwerke A.G.	Aue and Oberschlema	2500
Vereinigte Deutsche Metalkwerke A.G. (Basse und Selve)	Altena	2500
Norddeutsche Affinerie	Veddel - Harburg near Hamburg	500
	Total	13,000

Hareaus Vacuumschmelze A G at Hanau on Main is only concern directed to wire drawing-1938 capacity 106 tons.

Rolled nickel used principally in the manufacture of anodes, sheets, rods, bars, and tubing made by:

FIRM	LOCATION	NICKEL CONSUMPTION 1938 (Tons)
Vereinigte Deutsche Nickelwerke A.G. (Bosse und Selve)	Schwerte/Ruhr	150
Hiller u Muller Nickel-Fabrik A G	Dusseldorf	?
Deutsche Edelstahl Werke A G	Krefeld	250
Vereinigung Deutscher Drahtwebereien A G	Berlin	?
Montangesellschaft A G	Berlin	200
Fried Krupp Grusonwerk A G	Magdeburg	?

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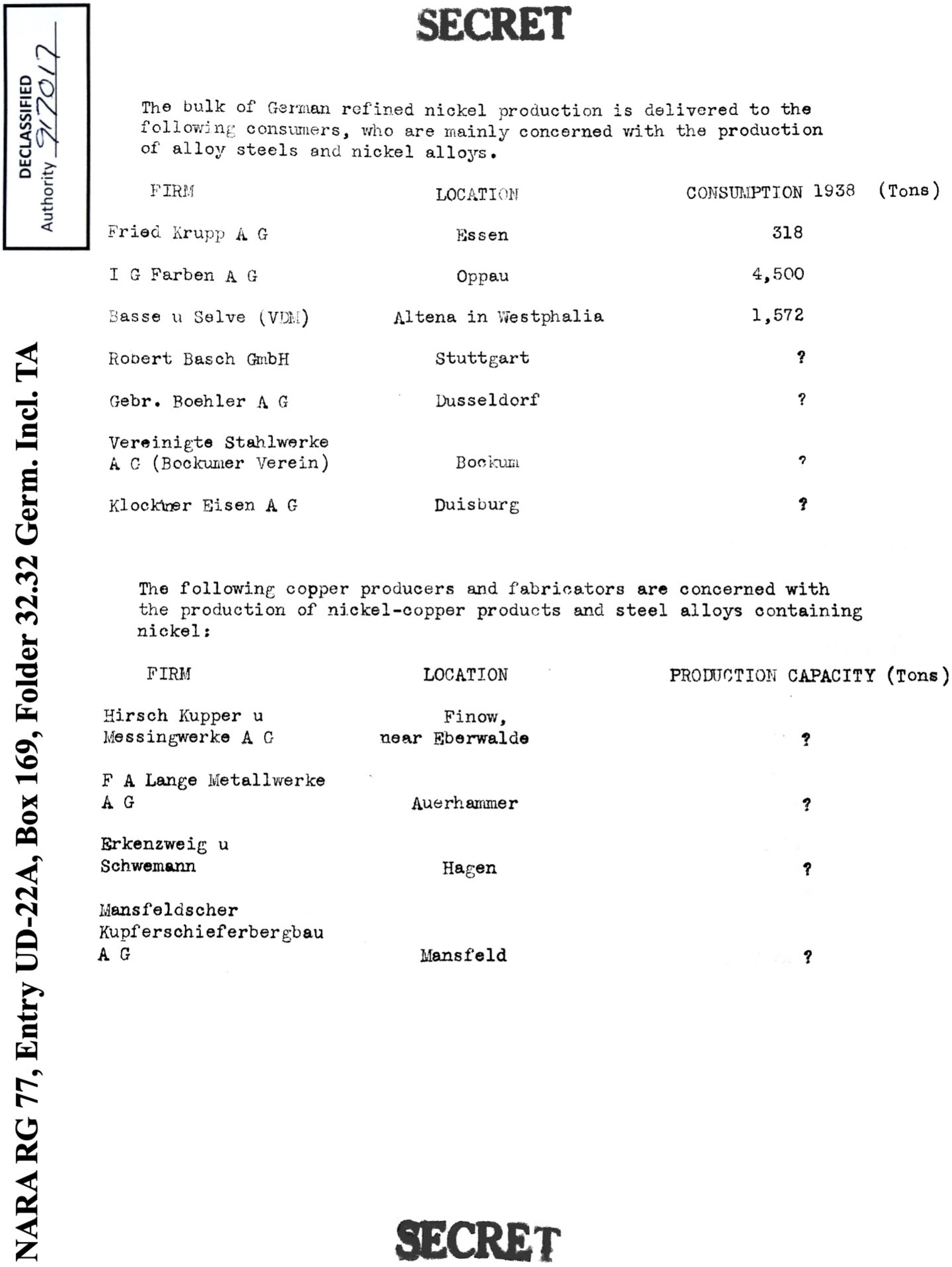
Figure D.538: German Nickel Refineries. Undated but probably 1944. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Ind. TA]



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The bulk of German refined nickel production is delivered to the following consumers, who are mainly concerned with the production of alloy steels and nickel alloys.

FIRM	LOCATION	CONSUMPTION 1938 (Tons)
Fried Krupp A G	Essen	318
I G Farben A G	Oppau	4,500
Basse u Selve (VDM)	Altena in Westphalia	1,572
Robert Basch GmbH	Stuttgart	?
Gebr. Boehler A G	Dusseldorf	?
Vereinigte Stahlwerke A G (Bockumer Verein)	Bockum	?
Klockner Eisen A G	Duisburg	?

The following copper producers and fabricators are concerned with the production of nickel-copper products and steel alloys containing nickel:

FIRM	LOCATION	PRODUCTION CAPACITY (Tons)
Hirsch Kupper u Messingwerke A G	Finow, near Eberwalde	?
F A Lange Metallwerke A G	Auerhammer	?
Erkenzweig u Schwemann	Hagen	?
Mansfeldscher Kupferschieferbergbau A G	Mansfeld	?

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Figure D.539: German Nickel Refineries. Undated but probably 1944. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Ind. TA]

J. Zirconium

[Zirconium was used for high-temperature metals and ceramics in non-nuclear applications, but its high temperature resistance and other properties also would have made it ideal as a fuel cladding material in fission reactors.]

FIAT 750. *Rare and Minor Metals.* p. 16. [See document photos on p. 4143.]

[...] The element is imported principally in the form of zircon mixed with monazite. In 1936 the production of metallic zirconium was 2,000 kg. and the pre-war price (1938) was RM 35 per kg. There are three producers of the metal:

Deutsche Gold- und Silver-Scheideanstalt[...]

I.G. Farbenindustrie A.G.[...]

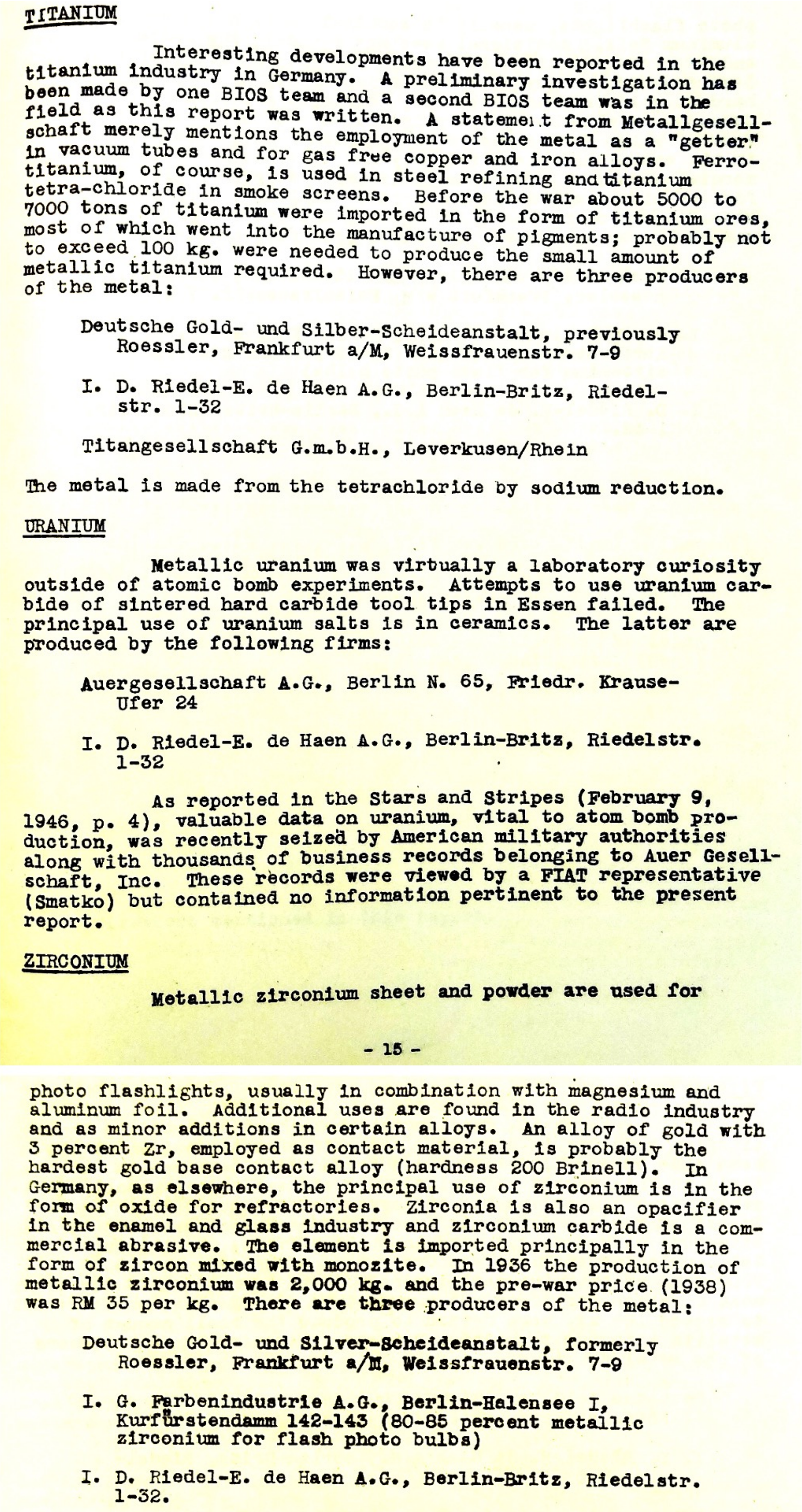
I. D. Riedel—E. de Haen A.G.[...]

These documents also demonstrate commercial production and use of zirconium:

> BIOS 276. *Telefunken Gesellschaft für Drahtlose Telegraphie m.b.h., Berlin; Special Materials for Radio Valves.* [Zirconium for radio valves, treatment of.]
>
> BIOS 896. *The Manufacture of Zirconium-Potassium Fluoride, Zirconium Oxide and Zirconium Oxychloride.*
>
> BIOS 1338. *Developments in Magnesium Production and Fabrication.* [Beryllium, zirconium at Degussa; also fluorine and carbon at I.G. Farben.]
>
> BIOS 1385. *The German Hard Metal Industry.* With Addenda. [Electron microscope, zirconium, uranium, thorium, etc.]
>
> CIOS XXIX-14. *I. G. Farbenindustrie A. G., Leverkusen, Germany.* [Zirconium compounds, production.]
>
> FIAT 89. *Metallurgical and Industrial Developments in Magnesium.* [Zirconium alloys]
>
> FIAT 617. *The Electrical and Technical Ceramic Industry of Germany.* [High temp zirconium ceramics]
>
> FIAT 774. *Anhydrous Chlorides Manufacture.* [Zirconium chlorides.]
>
> FIAT 785. *Electrical Contacts.* [Zirconium alloys for electrical contacts.]
>
> FIAT 1048. *The Production of Zirconium Oxide.*

[For documentation of the shipment of zirconium to Japan, along with other apparently nuclear-related materials, see p. 4094. This evidence suggests that at least some of the zirconium produced in Germany during the war was intended for nuclear applications.]

FIAT 750. *Rare and Minor Metals*



TITANIUM

Interesting developments have been reported in the titanium industry in Germany. A preliminary investigation has been made by one BIOS team and a second BIOS team was in the field as this report was written. A statement from Metallgesellschaft merely mentions the employment of the metal as a "getter" in vacuum tubes and for gas free copper and iron alloys. Ferro-titanium, of course, is used in steel refining and titanium tetra-chloride in smoke screens. Before the war about 5000 to 7000 tons of titanium were imported in the form of titanium ores, most of which went into the manufacture of pigments; probably not to exceed 100 kg. were needed to produce the small amount of metallic titanium required. However, there are three producers of the metal:

Deutsche Gold- und Silber-Scheideanstalt, previously Roessler, Frankfurt a/M, Weissfrauenstr. 7-9

I. D. Riedel-E. de Haen A.G., Berlin-Britz, Riedelstr. 1-32

Titangesellschaft G.m.b.H., Leverkusen/Rhein

The metal is made from the tetrachloride by sodium reduction.

URANIUM

Metallic uranium was virtually a laboratory curiosity outside of atomic bomb experiments. Attempts to use uranium carbide of sintered hard carbide tool tips in Essen failed. The principal use of uranium salts is in ceramics. The latter are produced by the following firms:

Auergesellschaft A.G., Berlin N. 65, Friedr. Krause-Ufer 24

I. D. Riedel-E. de Haen A.G., Berlin-Britz, Riedelstr. 1-32

As reported in the Stars and Stripes (February 9, 1946, p. 4), valuable data on uranium, vital to atom bomb production, was recently seized by American military authorities along with thousands of business records belonging to Auer Gesellschaft, Inc. These records were viewed by a FIAT representative (Smatko) but contained no information pertinent to the present report.

ZIRCONIUM

Metallic zirconium sheet and powder are used for photo flashlights, usually in combination with magnesium and aluminum foil. Additional uses are found in the radio industry and as minor additions in certain alloys. An alloy of gold with 3 percent Zr, employed as contact material, is probably the hardest gold base contact alloy (hardness 200 Brinell). In Germany, as elsewhere, the principal use of zirconium is in the form of oxide for refractories. Zirconia is also an opacifier in the enamel and glass industry and zirconium carbide is a commercial abrasive. The element is imported principally in the form of zircon mixed with monozite. In 1936 the production of metallic zirconium was 2,000 kg. and the pre-war price (1938) was RM 35 per kg. There are three producers of the metal:

Deutsche Gold- und Silver-Scheideanstalt, formerly Roessler, Frankfurt a/M, Weissfrauenstr. 7-9

I. G. Farbenindustrie A.G., Berlin-Halensee I, Kurfürstendamm 142-143 (80-85 percent metallic zirconium for flash photo bulbs)

I. D. Riedel-E. de Haen A.G., Berlin-Britz, Riedelstr. 1-32.

Figure D.540: FIAT 750. *Rare and Minor Metals.*

Frederic A. C. Wardenburg and Samuel A. Goudsmit. 18 November 1944 [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-1 GERMANY: Personnel (Mar 43–Dec 44)].

In our investigations of the Soc. de. Terres Rares (STR) in Paris we uncovered the following information, as reported in part before: [...]

Dr. Jansen worked with Ford in Cologne until the end of 1942. He was then hired by Auer and sent to Paris in January 1943. He returned to Germany only for occasional visits. [...]

After reporting to Dr. Ihwe, he was sent back to Saarbrucken to start a search for a lost railroad car loaded with zirconium and other products of the STR. [...]

According to Jansen, Dr. Ihwe is about 50 years old. He studied at Darmstadt and has been with Auer probably five or six years. He is very ambitious, a "Streber." Dr. Ihwe is in complete charge of the department of Rare Earths of the Auer Company. This department has all its facilities at Oranienburg. He is in charge of research as well as applications and some commercial matters. [...]

Jansen had only a very superficial knowledge of the materials produced by STR. He asked Ihwe what it was used for, but received the answer that it was secret. [...]

Jansen said that the Germans removed the electro-magnetic separator and classifier from the STR plant at Serquigny.

[See photos of the first two pages of this document on p. 4145.

The same Auer Oranienburg plant that spent the war acquiring and processing uranium for secret programs was also acquiring railroad cars worth of zirconium for secret programs, and its officials were eager to make sure that no zirconium went to waste. This evidence suggests that some if not all of the zirconium was intended for nuclear applications.]

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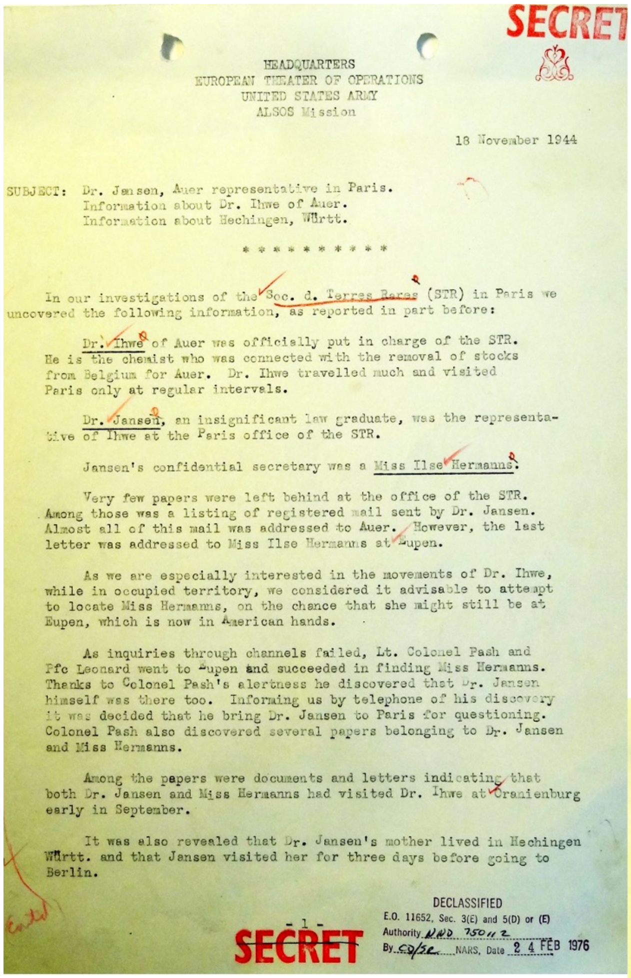

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HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS Mission

18 November 1944

SUBJECT: Dr. Jansen, Auer representative in Paris.
Information about Dr. Ihwe of Auer.
Information about Hechingen, Württ.

* * * * * * * * * *

In our investigations of the Soc. d. Terres Rares (STR) in Paris we uncovered the following information, as reported in part before:

Dr. Ihwe of Auer was officially put in charge of the STR. He is the chemist who was connected with the removal of stocks from Belgium for Auer. Dr. Ihwe travelled much and visited Paris only at regular intervals.

Dr. Jansen, an insignificant law graduate, was the representative of Ihwe at the Paris office of the STR.

Jansen's confidential secretary was a Miss Ilse Hermanns.

Very few papers were left behind at the office of the STR. Among those was a listing of registered mail sent by Dr. Jansen. Almost all of this mail was addressed to Auer. However, the last letter was addressed to Miss Ilse Hermanns at Eupen.

As we are especially interested in the movements of Dr. Ihwe, while in occupied territory, we considered it advisable to attempt to locate Miss Hermanns, on the chance that she might still be at Eupen, which is now in American hands.

As inquiries through channels failed, Lt. Colonel Pash and Pfc Leonard went to Eupen and succeeded in finding Miss Hermanns. Thanks to Colonel Pash's alertness he discovered that Dr. Jansen himself was there too. Informing us by telephone of his discovery it was decided that he bring Dr. Jansen to Paris for questioning. Colonel Pash also discovered several papers belonging to Dr. Jansen and Miss Hermanns.

Among the papers were documents and letters indicating that both Dr. Jansen and Miss Hermanns had visited Dr. Ihwe at Oranienburg early in September.

It was also revealed that Dr. Jansen's mother lived in Hechingen Württ. and that Jansen visited her for three days before going to Berlin.

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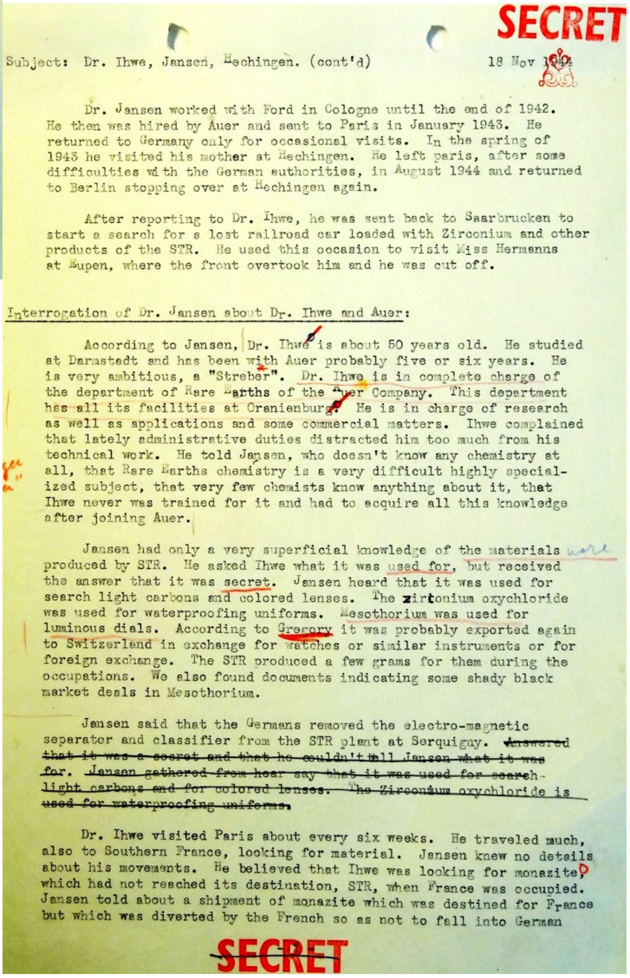

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Subject: Dr. Ihwe, Jansen, Hechingen. (cont'd) 18 Nov 1944

Dr. Jansen worked with Ford in Cologne until the end of 1942. He then was hired by Auer and sent to Paris in January 1943. He returned to Germany only for occasional visits. In the spring of 1943 he visited his mother at Hechingen. He left paris, after some difficulties with the German authorities, in August 1944 and returned to Berlin stopping over at Hechingen again.

After reporting to Dr. Ihwe, he was sent back to Saarbrucken to start a search for a lost railroad car loaded with Zirconium and other products of the STR. He used this occasion to visit Miss Hermanns at Eupen, where the front overtook him and he was cut off.

Interrogation of Dr. Jansen about Dr. Ihwe and Auer:

According to Jansen, Dr. Ihwe is about 50 years old. He studied at Darmstadt and has been with Auer probably five or six years. He is very ambitious, a "Streber". Dr. Ihwe is in complete charge of the department of Rare Earths of the Auer Company. This department has all its facilities at Oranienburg. He is in charge of research as well as applications and some commercial matters. Ihwe complained that lately administrative duties distracted him too much from his technical work. He told Jansen, who doesn't know any chemistry at all, that Rare Earths chemistry is a very difficult highly specialized subject, that very few chemists know anything about it, that Ihwe never was trained for it and had to acquire all this knowledge after joining Auer.

Jansen had only a very superficial knowledge of the materials were produced by STR. He asked Ihwe what it was used for, but received the answer that it was secret. Jansen heard that it was used for search light carbons and colored lenses. The zirtonium oxychloride was used for waterproofing uniforms. Mesothorium was used for luminous dials. According to Gregory it was probably exported again to Switzerland in exchange for watches or similar instruments or for foreign exchange. The STR produced a few grams for them during the occupations. We also found documents indicating some shady black market deals in Mesothorium.

Jansen said that the Germans removed the electro-magnetic separator and classifier from the STR plant at Serquigny. ~~Answered that it was a secret and that he couldn't tell Jansen what it was for.~~ ~~Jansen gathered from hear say that it was used for search light carbons and for colored lenses. The Zirconium oxychloride is used for waterproofing uniforms.~~

Dr. Ihwe visited Paris about every six weeks. He traveled much, also to Southern France, looking for material. Jansen knew no details about his movements. He believed that Ihwe was looking for monazite, which had not reached its destination, STR, when France was occupied. Jansen told about a shipment of monazite which was destined for France but which was diverted by the French so as not to fall into German

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NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-1 GERMANY: Personnel (Mar 43-Dec 44)

Figure D.541: Frederic A. C. Wardenburg and Samuel A. Goudsmit. 18 November 1944 [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-1 GERMANY: Personnel (Mar 43–Dec 44)]. "After reporting to Dr. Ihwe, he was sent back to Saarbrucken to start a search for a lost railroad car loaded with zirconium and other products of the STR."

[Further evidence of German zirconium production for nuclear purposes comes from a postwar shipwreck, as shown on p. 4147.

The SS *Flying Enterprise*, a commercial U.S. cargo ship, left Hamburg on 21 December 1951 with a variety of cargo headed for the United States. While passing near the southern coast of England, the ship was badly damaged in a storm on 25 December 1951. Despite extensive efforts by other ships to prevent the *Flying Enterprise* from sinking, it finally went down on 10 January 1952. (Everyone onboard was saved except for one person.)

In later interviews, the captain of the *Flying Enterprise*, Kurt Carlsen, stated that among the cargo was five tons of German-produced zirconium, left over from the wartime German nuclear program and destined to be used as cladding for the uranium fuel rods in the first U.S. nuclear submarine, USS *Nautilus*. Carlsen also stated that Navy divers salvaged the zirconium from the underwater wreck of his ship and took the zirconium back to the United States, causing a six-month delay in the launch of the Nautilus (finally launched in 1954).

This information confirms that some of the German zirconium that was being produced during the war was specifically intended for nuclear applications. It is not clear if those applications included submarine reactors, breeder reactors for producing plutonium, or other purposes. It is also not clear how far such nuclear work progressed in Germany during the war.

Any U.S. government documents on this shipment of zirconium or its origins in the wartime German nuclear program appear to remain classified and unavailable. This incident seems to confirm that the U.S. government has a much deeper knowledge of the wartime German nuclear program than it has admitted publicly, and that that knowledge shows the German nuclear program to have been more advanced than has been publicly stated.]

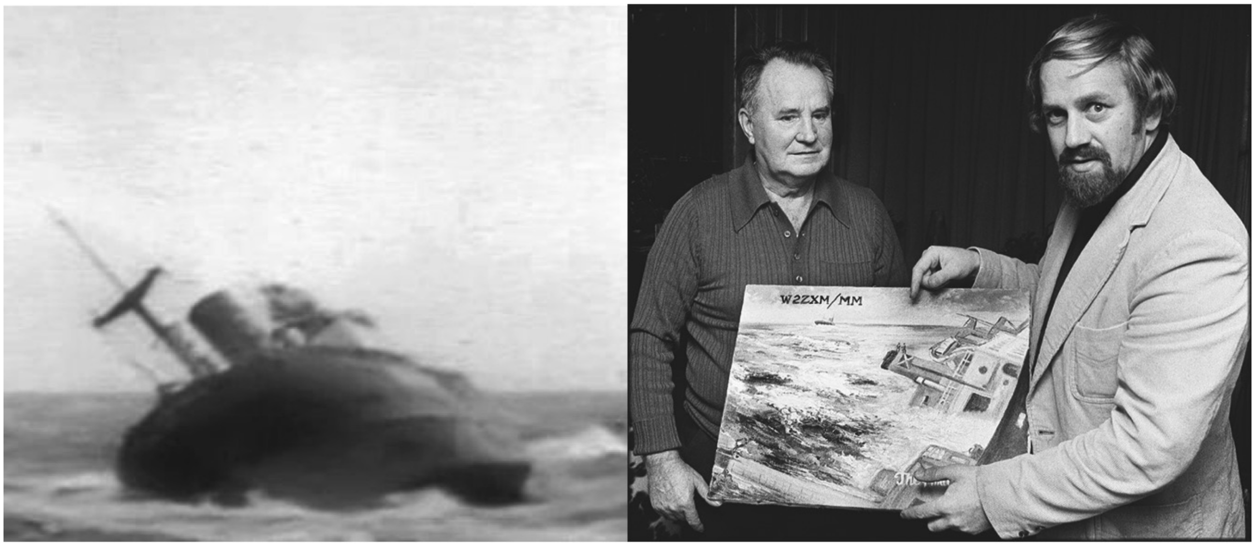
Bjarne Bekker. 2013. *Flying Enterprise & Kurt Carlsen.* Svendborg, Denmark: Bekker. p. 141. http://flying-enterprise.øavisen.dk

The reactor on "Nautilus" needed zirconium from "Flying Enterprise"

Kurt Carlsen spoke of it as if it were a story about onshore shooting in the Faroe Islands, water skiing on the lakes at Silkeborg or landing a sports plane on the beach on the west coast on a visit to his in-laws in Tane near Blavand. Quietly and matter-of-factly he sat in his retirement in Woodbridge and explained the cargo of zirconium. That the American military and secret service had found the material in West Germany. That Hitler was to use it in his nuclear program and that it was now to be used in the reactor of the first nuclear submarine "Nautilus".

"The launch was delayed six months, because divers had to enter the "Flying Enterprise" and retrieve the five tons of zirconium. Several idiotic reporters at the time wrote that my cargo was nuclear bombs. That was so wrong. My cargo was a material which encapsulates radioactivity".

[See also:
Deutsches Zirkonium war für erstes Atom-U-Boot der Welt bestimmt: Taucher bargen geheime Fracht des See-Helden Kapitän Carlsen. *Ruhr-Nachtrichten* (Dortmund). 24 January 1987.
https://www.youtube.com/watch?v=d99zNLh5E0U
https://www.youtube.com/watch?v=DzCOYlMcOiA
Lasse Spang Olsen and Emil Oigaard. 2002. The Mystery of Flying Enterprise. Copenhagen: Offshore Film Production.]



Sinking of the SS *Flying Enterprise* (10 January 1952)

Kurt Carlsen, captain of the *Flying Enterprise*

Journalist Bjarne Bekker interviewed Carlsen in 1976

First U.S. nuclear submarine, USS *Nautilus* (launched 1954)

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NAUTILUS

Figure D.542: The SS *Flying Enterprise* sank on 10 January 1952 while carrying cargo from Hamburg to the United States. Its captain, Kurt Carlsen, later told interviewers such as Bjarne Bekker that the cargo included five tons of zirconium, left over from the wartime German nuclear program, which was salvaged from his sunken ship and used in the first U.S. nuclear submarine, USS *Nautilus*.

K. Cadmium

[Cadmium was used for nickel-cadmium batteries and soldering, but it also could have been extremely useful as a neutron absorber.

The following documents illustrate the production and applications of cadmium, as well as methods for electroplating thin layers of materials such as cadmium onto aluminum (which could be useful for nuclear applications).

German capabilities to electroplate cadmium on aluminum are potentially quite relevant for creating a neutron-absorbing cadmium layer on a spherical aluminum pusher as in the German fission implosion bomb described in March 1945—see p. 4486.

For a description of how cadmium was mined on a large scale with specific knowledge of its utility in atomic bombs, see p. 4255.]

English translation of Rudolf Fleishmann to Georg Stetter [both nuclear scientists]. 12 June 1942. [Deutsches Museum Archive, Munich, FA 002/0401]

[...] I am having thin cadmium sheets (foil) 0.5 mm and 1 mm thickness rolled out at the G. A. Scheid Co. refinery, Gumpendorferstrasse 85, Vienna VI. To be sure I must obtain the cadmium. I used to get it from the organization in Berlin you know about. [...]

English translation of Rudolf Fleishmann to Dr. Th. Schuchardt Firm, Goerlitz. 14 December 1943. [Deutsches Museum Archive, Munich, FA 002/0401]

[...] We require cadmium sheets for work with slow neutrons: 4 sheets 50 x 40 cm x 0.6 mm. [...]

For some examples of cadmium production and uses, see:

BIOS 264. *German Brass and Copper Wire Industry.* [Cadmium copper wire substitute production.]

BIOS 379. *The German Zinc Smelting Industry.* [Cadmium production.]

BIOS 708. *German Alkaline Accumulator Industry.* [Cadmium—iron "masse" for alkaline accumulators]

BIOS 813. *Zinc Works at Porto Marghera, Italy (Montecatini-Montevecchio, Soc. Italiana del Piombo e dello Zinco).* [Cadmium recovery in zinc refining.]

CIOS XIII-5. *Photo Lenses and Optical Instruments.* [Cadmium glass preparation.]

CIOS XXIX-14. *I. G. Farbenindustrie A. G., Leverkusen, Germany.* [Production of cadmium compounds.]

CIOS XXXI-20. *Refining of Cobalt, Nickel, Zinc and Cadmium.*

CIOS XXXI-56. *George Von Giesche's Erben, Magdeburg.* [Cadmium production.]

FIAT 733. *Vertical Retort Zinc and By-Products: Oker, Harz Mts.*

FIAT 800. *Nickel Cadmium Storage Batteries in Germany.*

FIAT 814. *German Production of Some of the More Important Inorganic Pigments.* [Cadmium pigments manufacture.]

FIAT 882. *Anodes.* [Cadmium anodes]

BIOS 1159. *The Uses of Zinc in Germany.*

[p. 27:] 3 CADMIUM—Supply and Consumption

SOURCES OF INFORMATION

The information on supply was obtained from the same sources as that on the supply of zinc, viz; the Reichsstelle Eisen und Metalle and the Metallgesellschaft. The production figures obtained from the former were said to be actual figures and not estimates; but it is thought that the export and import figures from the latter are estimates only.

TOTAL SUPPLY

The following table, in metric tons, shows German and Austrian production and includes that from Upper Silesia from September, 1939, from the following Smelters—Giesche (Kattowitz), Hohenlohe and Schlesag:

	1938	1939	1940	1941	1942	1943	1944
PRODUCTION	437	477	531	608	484	496	404
Imports	100	253	86	1	72	10	7
TOTAL SUPPLY	537	730	617	609	556	506	411
less exports	50	47	62	37	128	108	29
NET SUPPLY	487	683	555	572	428	398	382

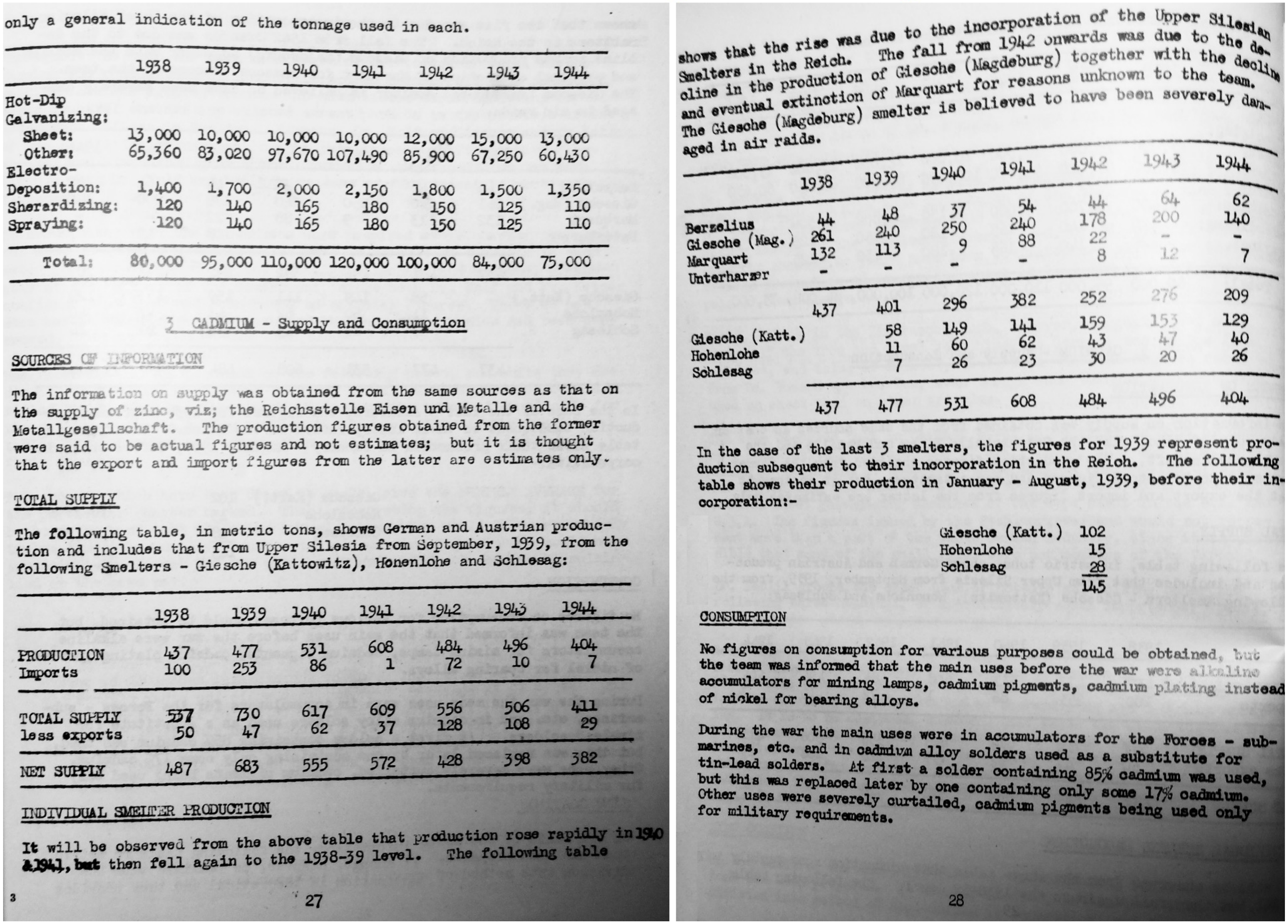
[p. 28:] CONSUMPTION

No figures on consumption for various purposes could be obtained, but the team was informed that the main uses before the war were alkaline accumulators for mining lamps, cadmium pigments, cadmium plating instead of nickel for bearing alloys.

During the war the main uses were in accumulators [nickel-cadmium batteries] for the Forces—submarines, etc. and in cadmium alloy solders used as a substitute for tin-lead solders. [...] Other uses were severely curtailed, cadmium pigments being used only for military requirements.

[See document photos on p. 4151.]

BIOS 1159. *The Uses of Zinc in Germany*



only a general indication of the tonnage used in each.

	1938	1939	1940	1941	1942	1943	1944
Hot-Dip Galvanizing:							
Sheet:	13,000	10,000	10,000	10,000	12,000	15,000	13,000
Other:	65,360	83,020	97,670	107,490	85,900	67,250	60,430
Electro-Deposition:	1,400	1,700	2,000	2,150	1,800	1,500	1,350
Sherardizing:	120	140	165	180	150	125	110
Spraying:	120	140	165	180	150	125	110
Total:	80,000	95,000	110,000	120,000	100,000	84,000	75,000

3 CADMIUM - Supply and Consumption

SOURCES OF INFORMATION

The information on supply was obtained from the same sources as that on the supply of zinc, viz; the Reichsstelle Eisen und Metalle and the Metallgesellschaft. The production figures obtained from the former were said to be actual figures and not estimates; but it is thought that the export and import figures from the latter are estimates only.

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less exports	50	47	62	37	128	108	29
NET SUPPLY	487	683	555	572	428	398	382

INDIVIDUAL SMELTER PRODUCTION

It will be observed from the above table that production rose rapidly in 1940 & 1941, but then fell again to the 1938-39 level. The following table shows that the rise was due to the incorporation of the Upper Silesian Smelters in the Reich. The fall from 1942 onwards was due to the decline in the production of Giesche (Magdeburg) together with the decline and eventual extinction of Marquart for reasons unknown to the team. The Giesche (Magdeburg) smelter is believed to have been severely damaged in air raids.

3

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	1938	1939	1940	1941	1942	1943	1944
Berzelius	44	48	37	54	44	64	62
Giesche (Mag.)	261	240	250	240	178	200	140
Marquart	132	113	9	88	22	-	-
Unterharzer	-	-	-	-	8	12	7
	437	401	296	382	252	276	209
Giesche (Katt.)		58	149	141	159	153	129
Hohenlohe		11	60	62	43	47	40
Schlesag		7	26	23	30	20	26
	437	477	531	608	484	496	404

In the case of the last 3 smelters, the figures for 1939 represent production subsequent to their incorporation in the Reich. The following table shows their production in January - August, 1939, before their incorporation:-

Giesche (Katt.)	102
Hohenlohe	15
Schlesag	28
	145

CONSUMPTION

No figures on consumption for various purposes could be obtained, but the team was informed that the main uses before the war were alkaline accumulators for mining lamps, cadmium pigments, cadmium plating instead of nickel for bearing alloys.

During the war the main uses were in accumulators for the Forces - submarines, etc. and in cadmium alloy solders used as a substitute for tin-lead solders. At first a solder containing 85% cadmium was used, but this was replaced later by one containing only some 17% cadmium. Other uses were severely curtailed, cadmium pigments being used only for military requirements.

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Figure D.543: BIOS 1159. *The Uses of Zinc in Germany.* 3 CADMIUM—Supply and Consumption.

BIOS 1009. ***A Survey of German Electro-Plating Methods.***

[p. 24:] CADMIUM.

A process of cadmium deposition by immersion was mentioned MR. MEYER but this was not seen.

[p. 67:] CADMIUM PLATING.

This was produced in small quantities but it appeared that zinc was used in practically all cases. This may have been due to shortage.

[p. 68:] CHROMIUM PLATING OF ALUMINIUM.

This had been done on a commercial scale but seemed to have faded out, due possibly to general disuse of decorative chromium plating during the war and the imperative saving of man power. One or two firms catalogued the finish. Interrogation brought little information.

[See document photos on p. 4153.]

BIOS 1615. ***The German Metal Finishing Industry.***

[p. 5:] Cadmium Plating

This is employed to a limited extent and the solutions are analogous to the higher current density type used in this country. [...]

[p. 8:] Plating on Aluminium and its Alloys

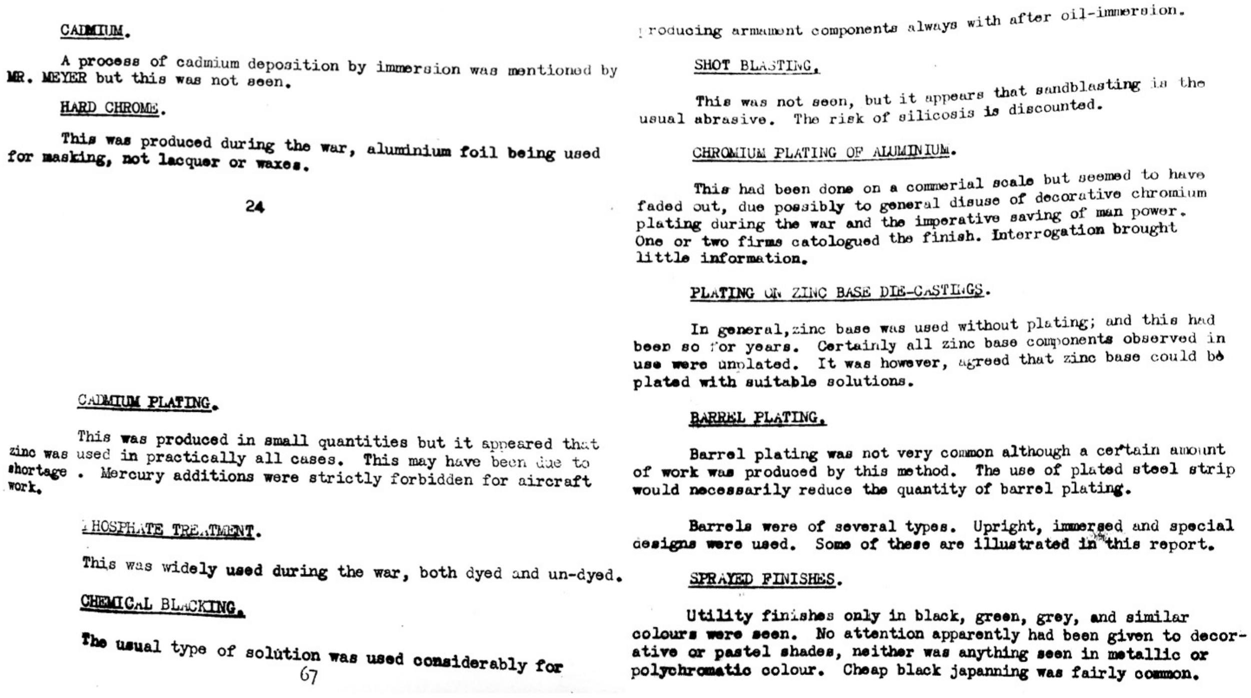
Although aluminium is widely used in Germany, no actual samples of nickel plus chromium plated aluminium were seen. Samples of lead plated battery lugs were encountered at Robert Bosch, Stuttgart and direct chromium plated aluminium at Blasberg's, Sollingen. Numerous references are made to the plating of aluminium and its alloys, however, and the most popular treatment for plating on this metal appears to be a primary application of a zincate dip followed by either a copper or brass deposit and then final plating.

[See document photos on p. 4153.]

For more technology for electroplating on aluminum, see:

BIOS 429. *German Electroplating Industry.*

BIOS 1009. *A Survey of German Electro-Plating Methods*



CADMIUM.

A process of cadmium deposition by immersion was mentioned by MR. MEYER but this was not seen.

HARD CHROME.

This was produced during the war, aluminium foil being used for masking, not lacquer or waxes.

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CADMIUM PLATING.

This was produced in small quantities but it appeared that zinc was used in practically all cases. This may have been due to shortage . Mercury additions were strictly forbidden for aircraft work.

PHOSPHATE TREATMENT.

This was widely used during the war, both dyed and un-dyed.

CHEMICAL BLACKING.

The usual type of solution was used considerably for producing armament components always with after oil-immersion.

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SHOT BLASTING.

This was not seen, but it appears that sandblasting is the usual abrasive. The risk of silicosis is discounted.

CHROMIUM PLATING OF ALUMINIUM.

This had been done on a commerial scale but seemed to have faded out, due possibly to general disuse of decorative chromium plating during the war and the imperative saving of man power. One or two firms catologued the finish. Interrogation brought little information.

PLATING ON ZINC BASE DIE-CASTINGS.

In general, zinc base was used without plating; and this had been so for years. Certainly all zinc base components observed in use were unplated. It was however, agreed that zinc base could be plated with suitable solutions.

BARREL PLATING.

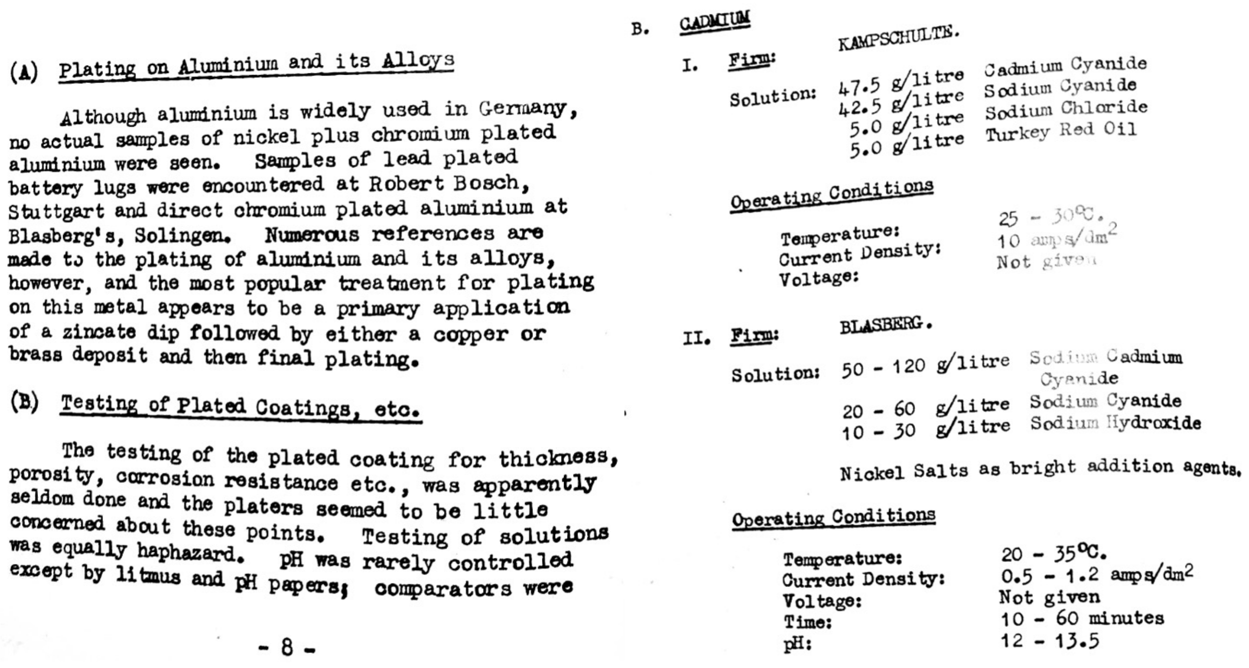
Barrel plating was not very common although a certain amount of work was produced by this method. The use of plated steel strip would necessarily reduce the quantity of barrel plating.

Barrels were of several types. Upright, immersed and special designs were used. Some of these are illustrated in this report.

SPRAYED FINISHES.

Utility finishes only in black, green, grey, and similar colours were seen. No attention apparently had been given to decorative or pastel shades, neither was anything seen in metallic or polychromatic colour. Cheap black japanning was fairly common.

BIOS 1615. *The German Metal Finishing Industry*



(A) Plating on Aluminium and its Alloys

Although aluminium is widely used in Germany, no actual samples of nickel plus chromium plated aluminium were seen. Samples of lead plated battery lugs were encountered at Robert Bosch, Stuttgart and direct chromium plated aluminium at Blasberg's, Solingen. Numerous references are made to the plating of aluminium and its alloys, however, and the most popular treatment for plating on this metal appears to be a primary application of a zincate dip followed by either a copper or brass deposit and then final plating.

(B) Testing of Plated Coatings, etc.

The testing of the plated coating for thickness, porosity, corrosion resistance etc., was apparently seldom done and the platers seemed to be little concerned about these points. Testing of solutions was equally haphazard. pH was rarely controlled except by litmus and pH papers; comparators were

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B. CADMIUM

I. Firm: KAMPSCHULTE.

Solution:

47.5 g/litre	Cadmium Cyanide
42.5 g/litre	Sodium Cyanide
5.0 g/litre	Sodium Chloride
5.0 g/litre	Turkey Red Oil

Operating Conditions

Temperature: 25 - 30°C.
Current Density: 10 amps/dm^2
Voltage: Not given

II. Firm: BLASBERG.

Solution:

50 - 120 g/litre	Sodium Cadmium Cyanide
20 - 60 g/litre	Sodium Cyanide
10 - 30 g/litre	Sodium Hydroxide

Nickel Salts as bright addition agents.

Operating Conditions

Temperature: 20 - 35°C.
Current Density: 0.5 - 1.2 amps/dm^2
Voltage: Not given
Time: 10 - 60 minutes
pH: 12 - 13.5

Figure D.544: Top: BIOS 1009. *A Survey of German Electro-Plating Methods.* Bottom: BIOS 1615. *The German Metal Finishing Industry.*

D.8 Fission Bomb Design

[The following documents demonstrate that the German nuclear program had sophisticated implosion bomb designs that would be highly suitable for either a fission implosion bomb or a fusion-boosted fission implosion bomb, and moreover that the German program carried out serious experimental work on implosion bombs from an early date. The most important design details are summarized in Table D.2.

Adolf Busemann (German, 1901–1986), Rolf Engel (German, 1912–1993), Gottfried Guderley (German, 1910–1997), Walter Hantzsche (German, 19??–19??), Rudi Schall (German, 1913–2002), Hubert Schardin (German, 1902–1965), Erich Schumann (German, 1898–1985), Walter Trinks (German, 1910–1995), Hilmar Wendt (German, 1913–19??), and many others worked in teams that developed and demonstrated implosion bomb designs:

- H. Rausch von Traubenberg and other scientists in the German-speaking world began using neutron reflectors around their nuclear reaction experiments no later than 1936 (pp. 4158–4159).

- Herbert Wagner and other scientists at the Henschel aircraft company proposed nuclear weapons at the beginning of the war and apparently worked to develop them during the war (pp. 4160–4166).

- No later than 1940, the German mathematicians Walter Hantzsche and Hilmar Wendt predicted the pressure, density, and temperature in spherical and cylindrical implosion bomb configurations, mathematical solutions that are still used today (pp. 4166–4169).

- No later than 1942, Gottfried Guderley, a hydrodynamics expert working for the German military, performed very similar calculations for spherical and cylindrical implosions (pp. 4170–4171).

- 1943 U.S. intelligence reports stated that "several factories and hundreds of workers" just south of Hamburg were producing an unusual material that was a new type of explosive, that was so energetic that one kilogram of the new material would have a blast radius of several kilometers, and that would be placed into bombs of a highly unusual spherical design (pp. 4172–4182, 4406).

- Manfred von Ardenne worked throughout the war to produce fission bombs each containing a few kilograms of uranium-235 (pp. 3561–3617, 4180, 4183–4184). After the war he played a key role in the Soviet nuclear weapons program.

- Based on several inside sources, on 22 October 1944 the *New York Times* reported that Germany was developing an atomic bomb that simultaneously used high-voltage electricity (i.e., a high-voltage fusion neutron initiator) and the detonation of surrounding conventional explosives (i.e., implosion) to release large amounts of energy from fission fuel ("the force of the disintegrating atoms"). See p. 4185.

- In November 1944, *Time* magazine published an intelligence report that Germany was developing an atomic bomb with a spherical implosion design to cause uranium fuel to fission in an explosive reaction (p. 4185).

- A 23 March 1945 letter from General Ivan Ilyichev to Joseph Stalin reported that Germany had built and successfully tested an atomic bomb, and described it in considerable detail as a 2-ton, 1.3-meter-diameter spherical implosion bomb with multiple concentric layers and a uranium-235 core (p. 4485).

- Erich Schumann, the German Army Ordnance Office's head physicist, along with others on his staff, worked throughout the war designing and testing ever more sophisticated bombs that used an outer shell of conventional explosives to implode an inner core of various materials, including nuclear fuels (pp. 4187–4255). (Schumann was also Wernher von Braun's Ph.D. thesis advisor for the development of rockets, as well as a key figure in Germany's biological warfare program and several other advanced research programs. Yet Goudsmit testified to the U.S. Senate that Schumann was mainly interested in "the physics of piano strings.")

- In November 1945, the German economist Erwin Respondek wrote that Erich Schumann had been involved in the development of an atomic bomb that used uranium fuel and a neutron initiator (and apparently Schumann's expertise, conventional explosives for spherical implosion) (p. 4194).

- The implosion expert Walter Trinks worked closely with Schumann during the war. Trinks was imprisoned by the U.S. Army from June 1945 to June 1946, and he informed them that "At the end of the war I was occupied with experiments for... the initiation of atomic bombs" (pp. 4257–4259).

- A Top Secret U.S. cable from March 1946 stated that a "capable young engineer" in Poland knew that atomic bomb casings included a layer of cadmium, which was true for the implosion bomb designs described by both Ilyichev and Schumann (p. 4255).

- A 1946 U.S intelligence report (which was not declassified until 2006) stated that at the end of the war, General Hans Kammler's deputy Erich "Purucker was driving a large civilian car which contained many of the plans on the atom bomb. This car plus material fell into the hands of the Russians" (p. 4914).

- A U.S. intelligence card catalog shows that there were postwar reports giving details of the German atomic bomb plans, but those reports are still classified and unavailable to the public (pp. 5074–5074).

- After the war, Kurt Diebner discussed spherical implosion bomb designs, specifically showing a spherical core of fission fuel with a center of fusion fuel (pp. 4260–4267).

- German witnesses described secretive and mysterious work that had been conducted during the war to produce and test nesting aluminum spheres that apparently matched the description of those in the implosion bomb designs (p. 4270).

- Hubert Schardin led a Luftwaffe research group that also appears to have been developing fission implosion bombs during the war, and he aided the French nuclear weapons program after the war (pp. 4190, 4268–4269). [See also Krehl 2009, pp. 1160–1162; Nagel 2012, p. 149 ff.]

- In 2000–2002 interviews, Heinrich Himmler's chief adjutant, Werner Grothmann, mentioned the development of an atomic bomb that "would have possessed a spherical shape with a diameter of over one meter. It was very heavy, even though the bomb body itself was supposed to be out of aluminum. It was said, if one reduces the weight, the yield is not as high" (pp. 4271–4273).

- Werner Grothmann (pp. 4271–4273) and Erich Schumann and Walter Trinks (pp. 4187–4255) stated that there were actually several different versions of the implosion bomb design for different geometries (spherical vs. cylindrical), sizes, and fuels.

- German scientists also appear to have been aware of the gun-type fission bomb design [Karlsch and Walker 2005; Thirring 1946]. However, any development seems to have been focused on the implosion design, since it requires much less fission fuel and has a much higher efficiency than the gun design.

For sources describing weapon designs with a significant amount of fusion fuel as well as fission fuel, see Section D.9.]

Component	**Primary sources for fission bomb design**										
	Guderley 10/1942	**Loofbourow 10/1943**	***Time* 11/1944**	**Ilyichev 3/1945**	**Kurchatov 3/1945**	**Respondek 11/1945**	**Schumann 1945-1952**	**Polish eng. 3/1946**	**Diebner 1956-1962**	**Grothmann 2000-2002**	**König 2004**
Neutron initiator				1. Internal high-voltage fusion neutrons 2. External gamma rays (via betatron)	1. Internal high-voltage fusion neutrons 2. External gamma rays (via betatron)	Neutron source	Fusion fuel	Neutron source (implied)	Fusion fuel	Ignition system	
Pit		High-density, high-energy new material, laborious to produce	Uranium	U-235	U-235	U-235	Uranium	Fission fuel	Uranium	U-235	
Reflector /tamper				``Delay mechanism" that was apparently also uranium			Uranium				
Neutron absorber				Cadmium	Cadmium		Cadmium	Cadmium			
Pusher				Aluminum			Aluminum				Aluminum
Explosive	Explosive designed for spherical implosion	Explosive designed for spherical implosion (implied)	Explosive designed for spherical implosion	Shaped segments of TNT with liquid oxygen, made lighter for rocket	Shaped segments of TNT with liquid oxygen, made lighter for rocket	Explosive designed for spherical implosion (implied)	Many shaped segments of TNT, RDX (explosive lenses) with simultaneous ignition		TNT and RDX	Complex explosive system with simultaneous ignition, made lighter for rocket	
Explosive case	Spherical case	Spherical case	Spherical case	Spherical aluminum	Spherical case	Case	Spherical aluminum	Case	Spherical case	Spherical aluminum	Spherical aluminum
Ballistic case				Steel case for rocket			Iron/ steel			Part of rocket	
Position for test				Positioned in a test area	Positioned in a test area		Suspended a few meters above the ground			On metal scaffold	

Table D.2: Details about fission implosion bomb design from primary sources.

H. Rausch von Traubenberg and H. Adam. 1937. Über die Rückstreuung von Neutronen und die Herstellung von Räumen mit erhöhter Neutronenkonzentration. *Zeitschrift für Physik* 104:442–447.

Wir beabsichtigen, unsere Versuche mit schwerem Wasser als bremsender Substanz fortzusetzen, da bei diesem eine geringere Absorption von Neutronen (Tritonenbildung) zu erwarten ist.

Zum Schluß haben wir noch Versuche über die Richtungsverteilung der an Eisen gestreuten Neutronen angestellt. Zu diesem Zwecke wurde ein Eisenstab von 3x3 cm als "Reflektor" benutzt und die Aktivierung des Rhodiumzylinders in verschiedenen Orientierungen zum Eisenstab ermittelt. Jedoch konnte die Frage bei der Schwäche unserer Neutronenquelle trotz langer Meßreihen noch nicht eindeutig beantwortet werden und wir beabsichtigen daher, das Problem der Richtungsverteilung mit stärkeren Neutronenquellen erneut in Angriff zu nehmen.

Zusammenfassung. In der vorliegenden Untersuchung wurden die Resultate von Mitchell und Mitarbeitern über die starke Rückstreuung langsamer Neutronen an Eisen und Blei bestätigt. Es gelang in geschlossenen Hohlräumen (bis zu 9 Liter) durch Verwendung von reflektierenden Eisen- bzw. Bleiwänden Neutronenkonzentrationen herzustellen, die die Werte ohne reflektierende Wände um ein Vielfaches übertrafen. Auf diese Weise wurde erstmalig eine gewisse Anreicherung von Neutronen (Kernbestandteilen) in leeren Räumen erreicht und so die Möglichkeit gegeben, mit einem reinen "Neutronengas" ohne Anwesenheit von störender Materie zu arbeiten.

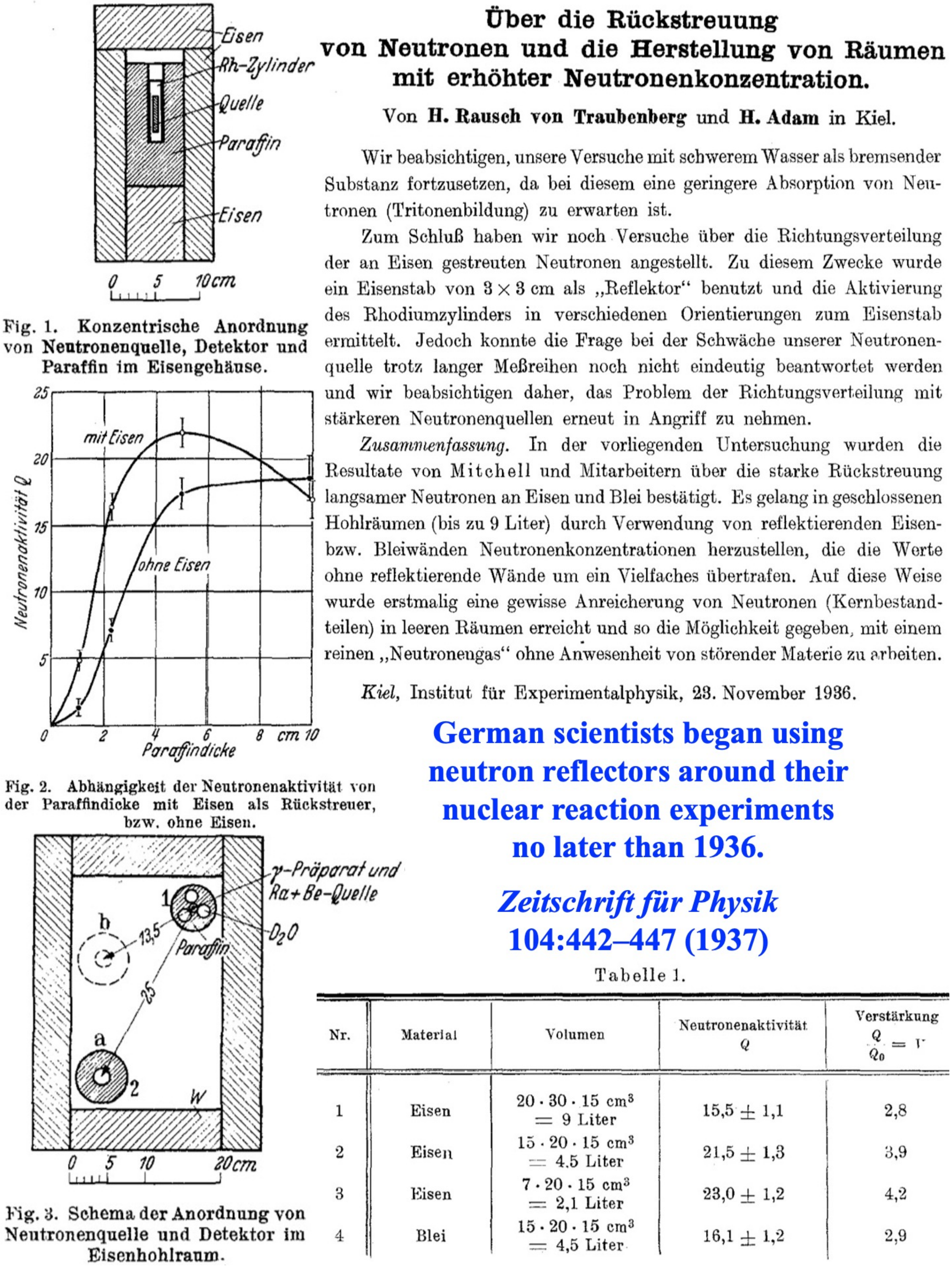
We intend to continue our experiments with heavy water as a moderating substance, since a lower absorption of neutrons (triton formation) is to be expected with this.

Finally, we performed experiments on the directional distribution of neutrons scattered by iron. For this purpose an iron rod of 3x3 cm was used as a "reflector" and the activation of the rhodium cylinder in different orientations to the iron rod was determined. However, given the weakness of our neutron source, the question could not yet be answered unambiguously, despite long series of measurements, and we therefore intend to tackle the problem of directional distribution again with stronger neutron sources.

Summary. In the present investigation, the results of Mitchell and coworkers on the strong backscattering of slow neutrons by iron and lead were confirmed. It was possible to produce neutron concentrations in closed cavities (up to 9 liters) by the use of reflecting iron or lead walls which exceeded many times the values without reflecting walls. In this way, for the first time, a certain enrichment of neutrons (nuclear constituents) was achieved in empty spaces, thus making it possible to work with a pure "neutron gas" without the presence of interfering matter.

[German scientists began using neutron reflectors around their nuclear reaction experiments no later than 1936. See Fig. D.545. Neutron reflectors are important for both fission reactors and fission bombs.

H. Rausch von Traubenberg also did important very early work on tritium production and fusion reactions. See p. 4281.]



Eisen
Rh-Zylinder
Quelle
Paraffin
Eisen
0 5 10cm

Fig. 1. Konzentrische Anordnung von Neutronenquelle, Detektor und Paraffin im Eisengehäuse.

Neutronenaktivität Q
25
20
15
10
5
0
2
4
6
8
cm 10
mit Eisen
ohne Eisen
Paraffindicke

Fig. 2. Abhängigkeit der Neutronenaktivität von der Paraffindicke mit Eisen als Rückstreuer, bzw. ohne Eisen.

γ-Präparat und Ra+Be-Quelle
D_2O
Paraffin
1
2
b
a
13,5
25
W
0 5 10 20cm

Fig. 3. Schema der Anordnung von Neutronenquelle und Detektor im Eisenhohlraum.

Über die Rückstreuung von Neutronen und die Herstellung von Räumen mit erhöhter Neutronenkonzentration.

Von **H. Rausch von Traubenberg** und **H. Adam** in Kiel.

Wir beabsichtigen, unsere Versuche mit schwerem Wasser als bremsender Substanz fortzusetzen, da bei diesem eine geringere Absorption von Neutronen (Tritonenbildung) zu erwarten ist.

Zum Schluß haben wir noch Versuche über die Richtungsverteilung der an Eisen gestreuten Neutronen angestellt. Zu diesem Zwecke wurde ein Eisenstab von 3 × 3 cm als „Reflektor" benutzt und die Aktivierung des Rhodiumzylinders in verschiedenen Orientierungen zum Eisenstab ermittelt. Jedoch konnte die Frage bei der Schwäche unserer Neutronenquelle trotz langer Meßreihen noch nicht eindeutig beantwortet werden und wir beabsichtigen daher, das Problem der Richtungsverteilung mit stärkeren Neutronenquellen erneut in Angriff zu nehmen.

Zusammenfassung. In der vorliegenden Untersuchung wurden die Resultate von Mitchell und Mitarbeitern über die starke Rückstreuung langsamer Neutronen an Eisen und Blei bestätigt. Es gelang in geschlossenen Hohlräumen (bis zu 9 Liter) durch Verwendung von reflektierenden Eisen- bzw. Bleiwänden Neutronenkonzentrationen herzustellen, die die Werte ohne reflektierende Wände um ein Vielfaches übertrafen. Auf diese Weise wurde erstmalig eine gewisse Anreicherung von Neutronen (Kernbestandteilen) in leeren Räumen erreicht und so die Möglichkeit gegeben, mit einem reinen „Neutronengas" ohne Anwesenheit von störender Materie zu arbeiten.

Kiel, Institut für Experimentalphysik, 23. November 1936.

German scientists began using neutron reflectors around their nuclear reaction experiments no later than 1936.

***Zeitschrift für Physik* 104:442–447 (1937)**

Tabelle 1.

Nr.	Material	Volumen	Neutronenaktivität Q	Verstärkung $\frac{Q}{Q_0} = V$
1	Eisen	$20 \cdot 30 \cdot 15$ cm^3 = 9 Liter	15,5 ± 1,1	2,8
2	Eisen	$15 \cdot 20 \cdot 15$ cm^3 = 4.5 Liter	21,5 ± 1,3	3,9
3	Eisen	$7 \cdot 20 \cdot 15$ cm^3 = 2,1 Liter	23,0 ± 1,2	4,2
4	Blei	$15 \cdot 20 \cdot 15$ cm^3 = 4,5 Liter	16,1 ± 1,2	2,9

Figure D.545: German scientists began using neutron reflectors around their nuclear reaction experiments no later than 1936 [*Zeitschrift für Physik* 104:442–447 (1937)].

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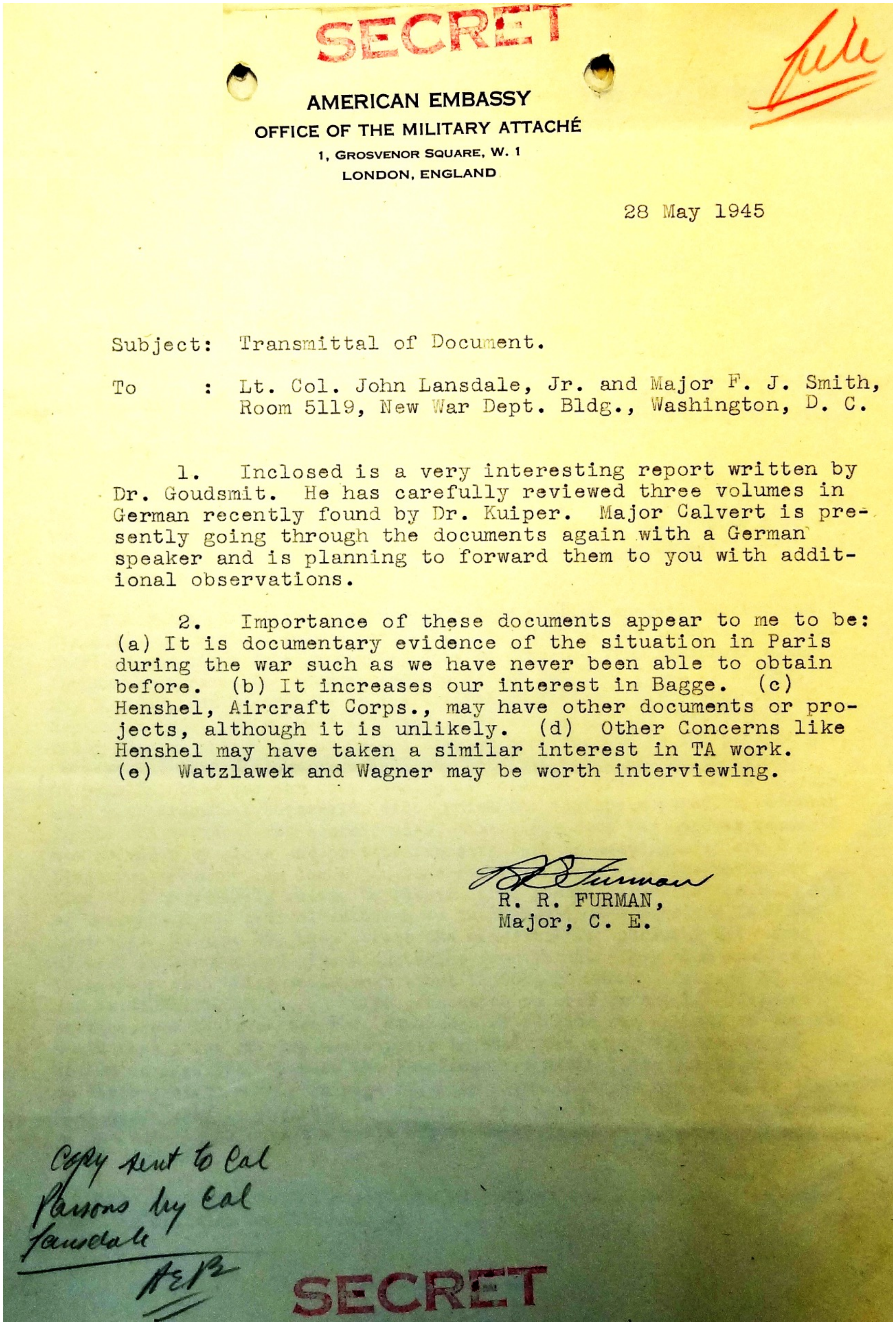
Folder 32.32. Germ. Ind. TA



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AMERICAN EMBASSY
OFFICE OF THE MILITARY ATTACHÉ
1, GROSVENOR SQUARE, W. 1
LONDON, ENGLAND

28 May 1945

Subject: Transmittal of Document.

To : Lt. Col. John Lansdale, Jr. and Major F. J. Smith,
Room 5119, New War Dept. Bldg., Washington, D. C.

1. Inclosed is a very interesting report written by Dr. Goudsmit. He has carefully reviewed three volumes in German recently found by Dr. Kuiper. Major Calvert is presently going through the documents again with a German speaker and is planning to forward them to you with additional observations.

2. Importance of these documents appear to me to be: (a) It is documentary evidence of the situation in Paris during the war such as we have never been able to obtain before. (b) It increases our interest in Bagge. (c) Henshel, Aircraft Corps., may have other documents or projects, although it is unlikely. (d) Other Concerns like Henshel may have taken a similar interest in TA work. (e) Watzlawek and Wagner may be worth interviewing.

R R Furman
R. R. FURMAN,
Major, C. E.

Copy sent to Col
Parsons by Col
Lansdale
AEP

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Figure D.546: Robert R. Furman to John Lansdale, Jr. and Francis J. Smith. 28 May 1945. Subject: Transmittal of Document [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

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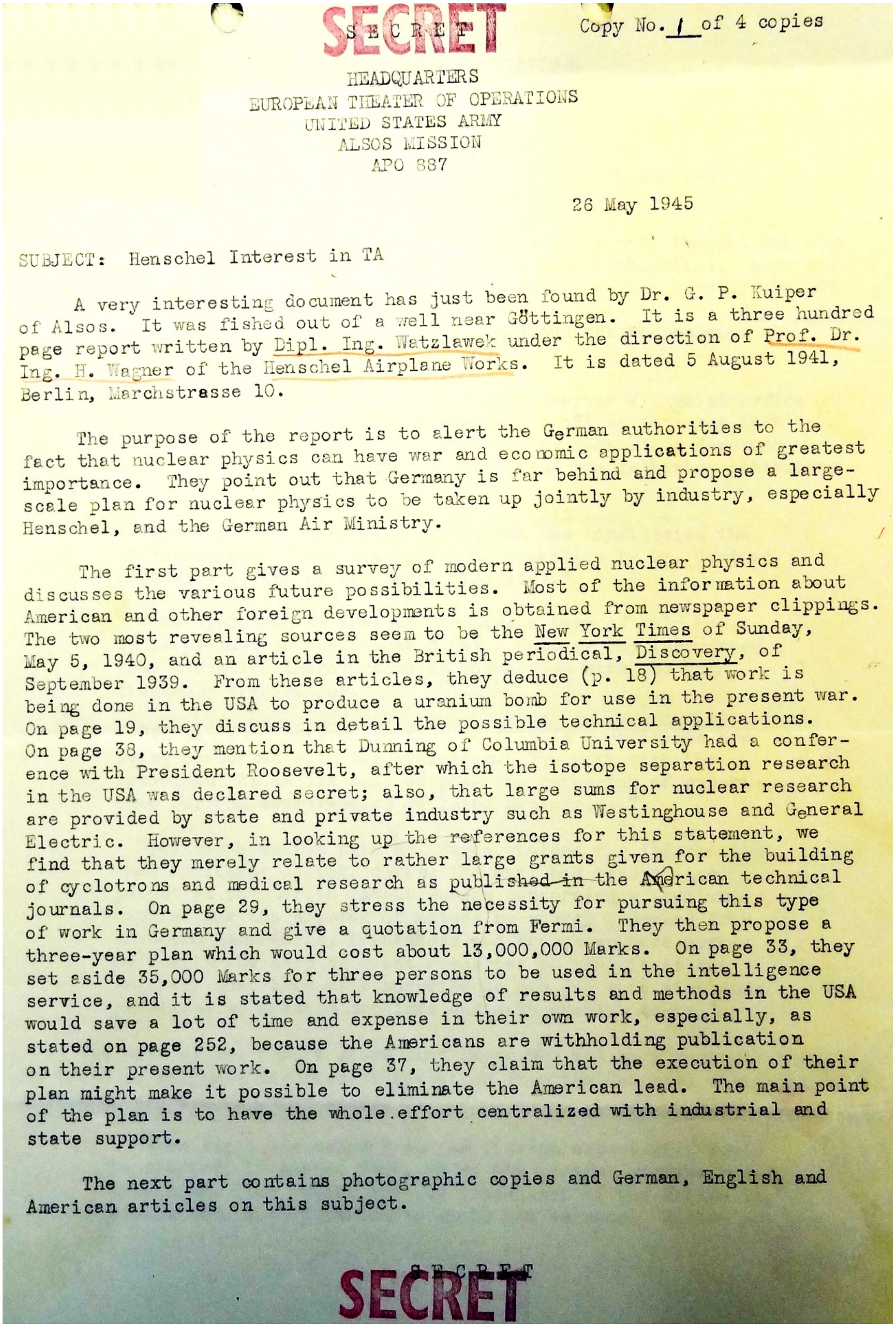

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HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY
ALSOS MISSION
APO 887

26 May 1945

SUBJECT: Henschel Interest in TA

A very interesting document has just been found by Dr. G. P. Kuiper of Alsos. It was fished out of a well near Göttingen. It is a three hundred page report written by Dipl. Ing. Watzlawek under the direction of Prof. Dr. Ing. H. Wagner of the Henschel Airplane Works. It is dated 5 August 1941, Berlin, Marchstrasse 10.

The purpose of the report is to alert the German authorities to the fact that nuclear physics can have war and economic applications of greatest importance. They point out that Germany is far behind and propose a large-scale plan for nuclear physics to be taken up jointly by industry, especially Henschel, and the German Air Ministry.

The first part gives a survey of modern applied nuclear physics and discusses the various future possibilities. Most of the information about American and other foreign developments is obtained from newspaper clippings. The two most revealing sources seem to be the New York Times of Sunday, May 5, 1940, and an article in the British periodical, Discovery, of September 1939. From these articles, they deduce (p. 18) that work is being done in the USA to produce a uranium bomb for use in the present war. On page 19, they discuss in detail the possible technical applications. On page 38, they mention that Dunning of Columbia University had a conference with President Roosevelt, after which the isotope separation research in the USA was declared secret; also, that large sums for nuclear research are provided by state and private industry such as Westinghouse and General Electric. However, in looking up the references for this statement, we find that they merely relate to rather large grants given for the building of cyclotrons and medical research as publis~~hed in~~ the American technical journals. On page 29, they stress the necessity for pursuing this type of work in Germany and give a quotation from Fermi. They then propose a three-year plan which would cost about 13,000,000 Marks. On page 33, they set aside 35,000 Marks for three persons to be used in the intelligence service, and it is stated that knowledge of results and methods in the USA would save a lot of time and expense in their own work, especially, as stated on page 252, because the Americans are withholding publication on their present work. On page 37, they claim that the execution of their plan might make it possible to eliminate the American lead. The main point of the plan is to have the whole effort centralized with industrial and state support.

The next part contains photographic copies and German, English and American articles on this subject.

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Figure D.547: Gerard P. Kuiper and Samuel A. Goudsmit. 26 May 1945. SUBJECT: Henschel Interest in TA [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

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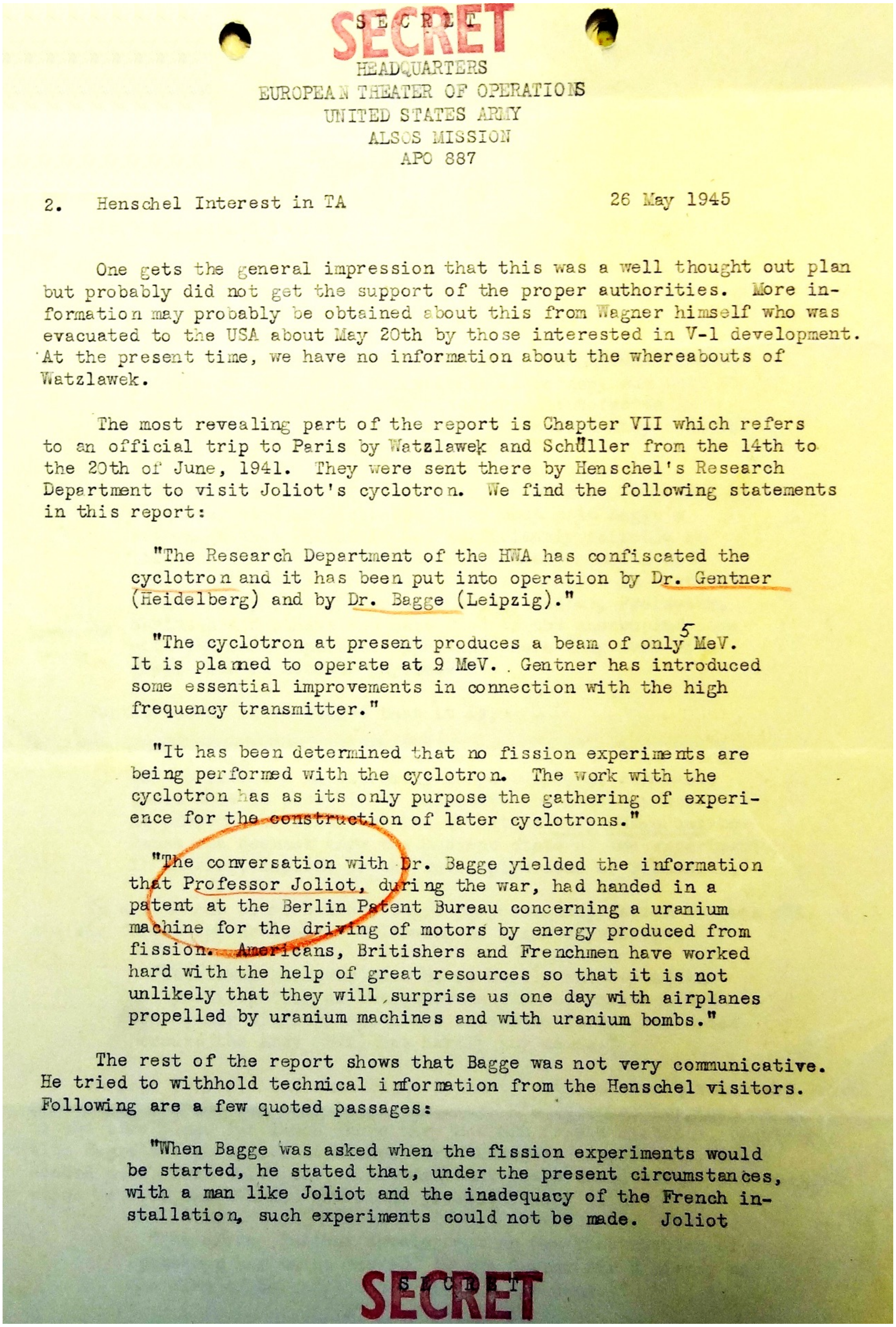

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UNITED STATES ARMY
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APO 887

2. Henschel Interest in TA 26 May 1945

One gets the general impression that this was a well thought out plan but probably did not get the support of the proper authorities. More information may probably be obtained about this from Wagner himself who was evacuated to the USA about May 20th by those interested in V-1 development. At the present time, we have no information about the whereabouts of Watzlawek.

The most revealing part of the report is Chapter VII which refers to an official trip to Paris by Watzlawek and Schüller from the 14th to the 20th of June, 1941. They were sent there by Henschel's Research Department to visit Joliot's cyclotron. We find the following statements in this report:

> "The Research Department of the HWA has confiscated the cyclotron and it has been put into operation by Dr. Gentner (Heidelberg) and by Dr. Bagge (Leipzig)."
>
> "The cyclotron at present produces a beam of only 5 MeV. It is planned to operate at 9 MeV. Gentner has introduced some essential improvements in connection with the high frequency transmitter."
>
> "It has been determined that no fission experiments are being performed with the cyclotron. The work with the cyclotron has as its only purpose the gathering of experience for the construction of later cyclotrons."
>
> "The conversation with Dr. Bagge yielded the information that Professor Joliot, during the war, had handed in a patent at the Berlin Patent Bureau concerning a uranium machine for the driving of motors by energy produced from fission. Americans, Britishers and Frenchmen have worked hard with the help of great resources so that it is not unlikely that they will surprise us one day with airplanes propelled by uranium machines and with uranium bombs."

The rest of the report shows that Bagge was not very communicative. He tried to withhold technical information from the Henschel visitors. Following are a few quoted passages:

> "When Bagge was asked when the fission experiments would be started, he stated that, under the present circumstances, with a man like Joliot and the inadequacy of the French installation, such experiments could not be made. Joliot

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Figure D.548: Gerard P. Kuiper and Samuel A. Goudsmit. 26 May 1945. SUBJECT: Henschel Interest in TA [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

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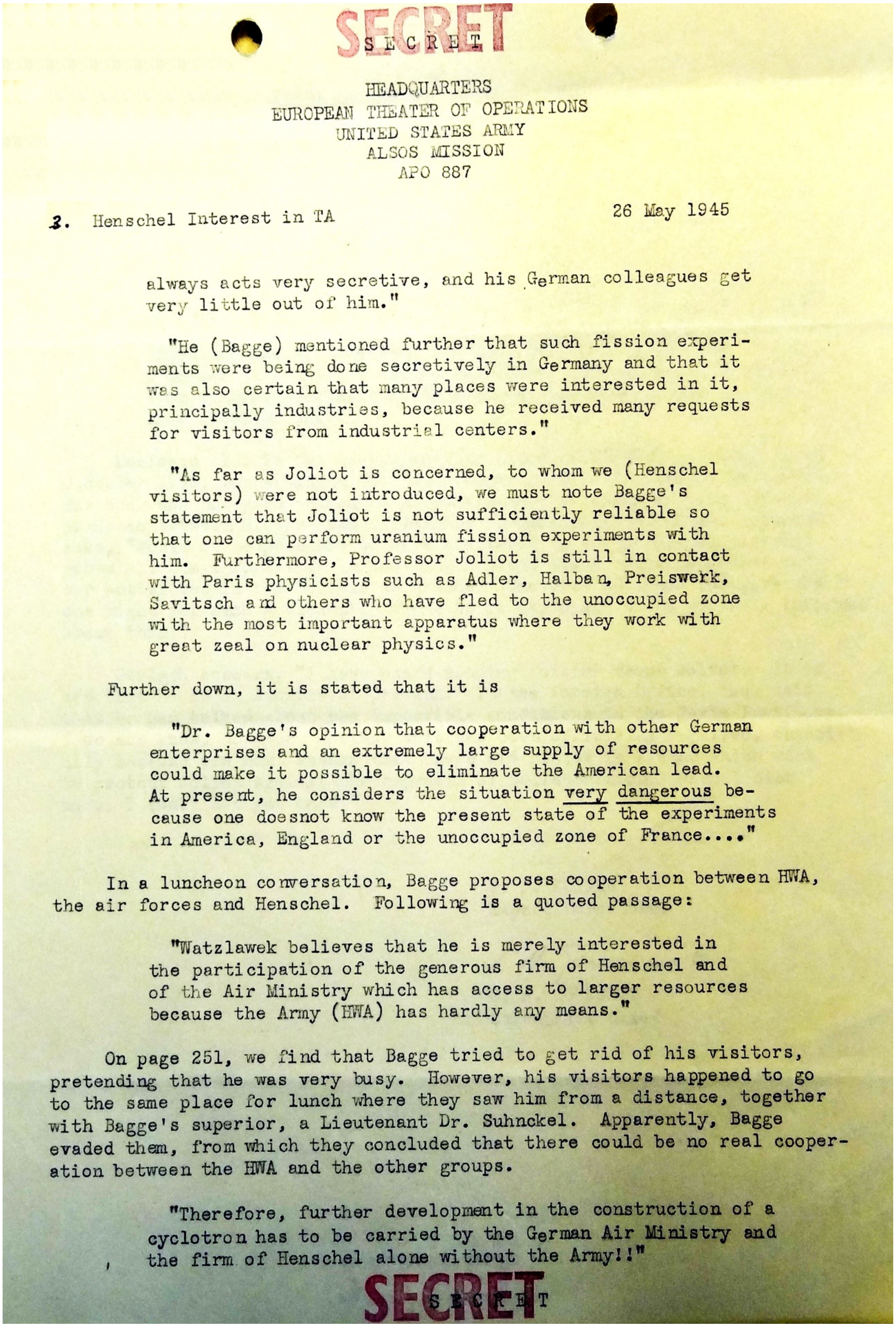

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3. Henschel Interest in TA 26 May 1945

always acts very secretive, and his German colleagues get very little out of him."

"He (Bagge) mentioned further that such fission experiments were being done secretively in Germany and that it was also certain that many places were interested in it, principally industries, because he received many requests for visitors from industrial centers."

"As far as Joliot is concerned, to whom we (Henschel visitors) were not introduced, we must note Bagge's statement that Joliot is not sufficiently reliable so that one can perform uranium fission experiments with him. Furthermore, Professor Joliot is still in contact with Paris physicists such as Adler, Halban, Preiswerk, Savitsch and others who have fled to the unoccupied zone with the most important apparatus where they work with great zeal on nuclear physics."

Further down, it is stated that it is

"Dr. Bagge's opinion that cooperation with other German enterprises and an extremely large supply of resources could make it possible to eliminate the American lead. At present, he considers the situation very dangerous because one doesnot know the present state of the experiments in America, England or the unoccupied zone of France...."

In a luncheon conversation, Bagge proposes cooperation between HWA, the air forces and Henschel. Following is a quoted passage:

"Watzlawek believes that he is merely interested in the participation of the generous firm of Henschel and of the Air Ministry which has access to larger resources because the Army (HWA) has hardly any means."

On page 251, we find that Bagge tried to get rid of his visitors, pretending that he was very busy. However, his visitors happened to go to the same place for lunch where they saw him from a distance, together with Bagge's superior, a Lieutenant Dr. Suhnckel. Apparently, Bagge evaded them, from which they concluded that there could be no real cooperation between the HWA and the other groups.

"Therefore, further development in the construction of a cyclotron has to be carried by the German Air Ministry and the firm of Henschel alone without the Army!!"

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Figure D.549: Gerard P. Kuiper and Samuel A. Goudsmit. 26 May 1945. SUBJECT: Henschel Interest in TA [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

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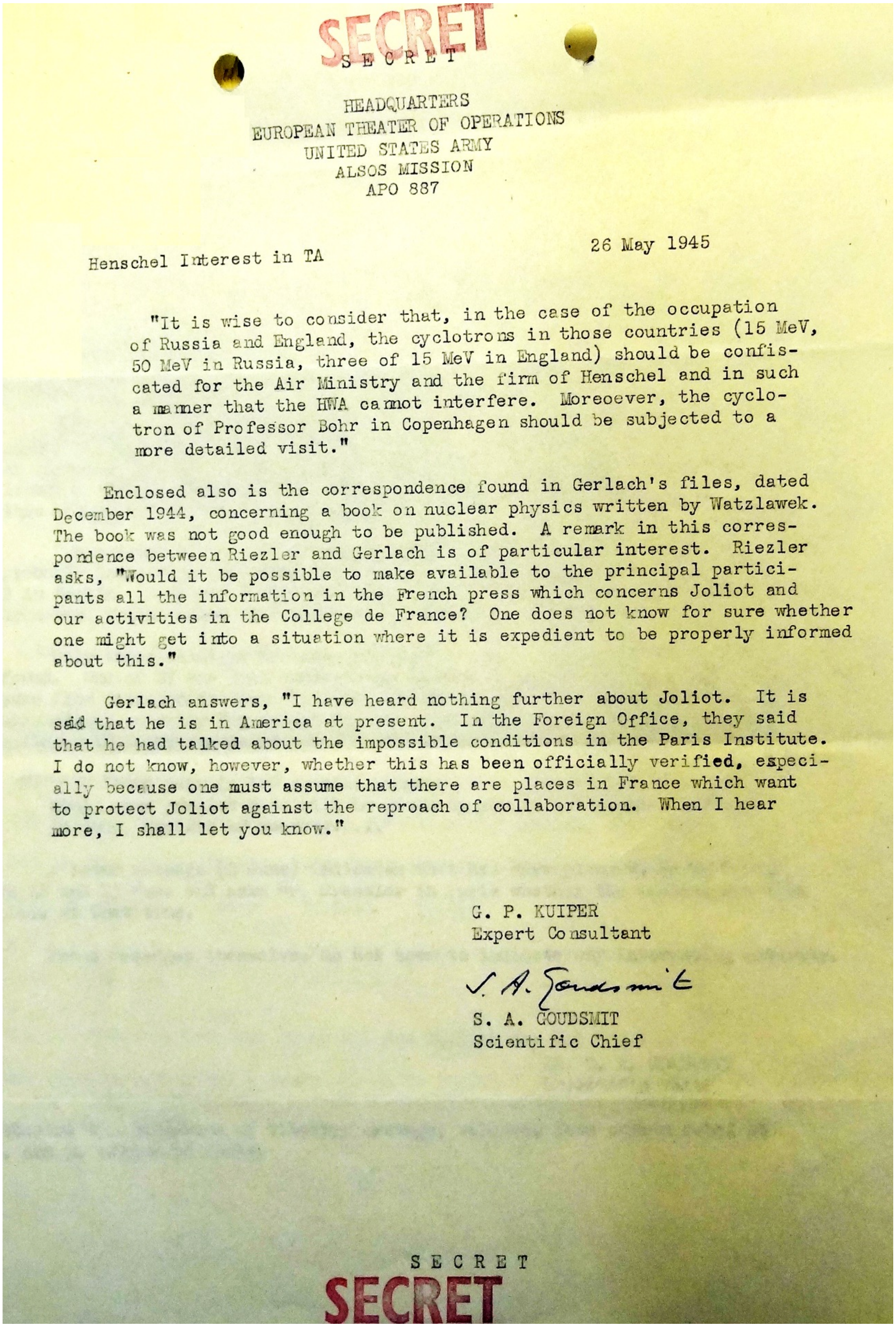

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APO 887

26 May 1945

Henschel Interest in TA

"It is wise to consider that, in the case of the occupation of Russia and England, the cyclotrons in those countries (15 MeV, 50 MeV in Russia, three of 15 MeV in England) should be confiscated for the Air Ministry and the firm of Henschel and in such a manner that the HWA cannot interfere. Moreoever, the cyclotron of Professor Bohr in Copenhagen should be subjected to a more detailed visit."

Enclosed also is the correspondence found in Gerlach's files, dated December 1944, concerning a book on nuclear physics written by Watzlawek. The book was not good enough to be published. A remark in this correspondence between Riezler and Gerlach is of particular interest. Riezler asks, "Would it be possible to make available to the principal participants all the information in the French press which concerns Joliot and our activities in the College de France? One does not know for sure whether one might get into a situation where it is expedient to be properly informed about this."

Gerlach answers, "I have heard nothing further about Joliot. It is said that he is in America at present. In the Foreign Office, they said that he had talked about the impossible conditions in the Paris Institute. I do not know, however, whether this has been officially verified, especially because one must assume that there are places in France which want to protect Joliot against the reproach of collaboration. When I hear more, I shall let you know."

G. P. KUIPER
Expert Consultant

S. A. Goudsmit
S. A. GOUDSMIT
Scientific Chief

S E C R E T
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NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA

Figure D.550: Gerard P. Kuiper and Samuel A. Goudsmit. 26 May 1945. SUBJECT: Henschel Interest in TA [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Thomas Siemon. 24 July 2014. *Hessen-Niedersächsische Allgemeine.* https://www.hna.de/kassel/henschel-wollte-atombombe-kriegseinsatz-bauen-3727289.html

Pläne aus Zeiten des Zweiten Weltkrieges

Schriftsatz aufgetaucht: Henschel wollte Atombombe für den Kriegseinsatz bauen

Kassel. 1945 sorgten die Atombomben auf Hiroshima und Nagasaki für zehntausende von Opfern und furchbare Zerstörungen. Bereits vier Jahre zuvor gab es bei der Kasseler Firma Henschel konkrete Überlegungen für den Bau einer Nuklearwaffe. Das belegt ein Schriftsatz aus dem Jahr 1941, der jetzt aufgetaucht ist.

Er hat 260 Seiten und liegt der HNA vor.

Mit ganzer Kraft müsse an der Erforschung der Kettenreaktionsvorgänge gearbeitet werden, heißt es da. Zwar wird auch die Nutzung der Atomenergie für den Antrieb von Kampfflugzeugen, U-Booten, die Medizin und zur Stromerzeugung erwähnt. Das klare Ziel der Entwicklung ist aber die "Herstellung einer Uran-Bombe für den jetzigen europäischen Krieg als furchtbarste Waffe".

An der Echtheit der handgebundenen Dokumente besteht kein Zweifel. Helmut Weich, der ehrenamtliche Leiter des Kasseler Henschel- Museums, hat die erwähnten Namen und Örtlichkeiten überprüft. Demnach hat der damalige Chefentwickler der Henschel-Flugzeugwerke in Berlin-Schönfeld, Professor Herbert Wagner, das umfangreiche Dossier mit Unterstützung von weiteren Fachleuten erstellt.

Plans from the times of the Second World War

Written brief found: Henschel wanted to build a nuclear bomb for war use

Kassel. In 1945, the atomic bombs on Hiroshima and Nagasaki caused tens of thousands of victims and terrible destruction. Four years earlier, the Kassel-based company Henschel had already given concrete consideration to the construction of a nuclear weapon. This is documented in a document from 1941, which has now appeared.

It has 260 pages and is available to the HNA.

It says that the research of chain reaction processes has to be done with all one's strength. The use of atomic energy for the propulsion of combat aircraft, submarines, medicine and power generation is also mentioned. But the clear goal of the development is the "production of a uranium bomb for the current European war as the most terrible weapon."

There is no doubt about the authenticity of the hand-bound documents. Helmut Weich, the honorary director of the Henschel Museum in Kassel, has checked the names and locations mentioned above. Accordingly, the then chief developer of the Henschel-Flugzeugwerke in Berlin-Schönfeld, Professor Herbert Wagner, prepared the extensive dossier with the support of other experts.

Henschel war damals nicht die einzige Firma, die sich intensiv mit den Möglichkeiten der Atomenergie beschäftigte. Auch Siemens, die IG Farben und Degussa hatten großes Interesse an diesem Thema.

In der gedruckten Ausgabe am Freitag lesen Sie außerdem:

- Es blieb bei Plänen für die Bombe: Nach 1941 keine weiteren Aktivitäten zur militärischen Nutzung der Kernenergie bei Henschel bekannt

Bekannt ist, dass eine Delegation von Henschel in Paris war, um sich dort über die Forschung zur Kernspaltung mit einem sogenannten Zyklotron zu informieren. Nach Einschätzung von Fachleuten waren weder Henschel noch die anderen Firmen in der Lage, die Bombe wirklich zu bauen. Nach dem Krieg sprachen alle Beteiligten davon, lediglich Grundlagenforschung betrieben zu haben.

Henschel was not the only company at the time to be intensively involved with the possibilities of nuclear energy. Siemens, IG Farben and Degussa were also very interested in this topic.

You can also read in the printed edition on Friday:

- It remained with plans for the bomb: After 1941 no further activities for the military use of nuclear energy known at Henschel.

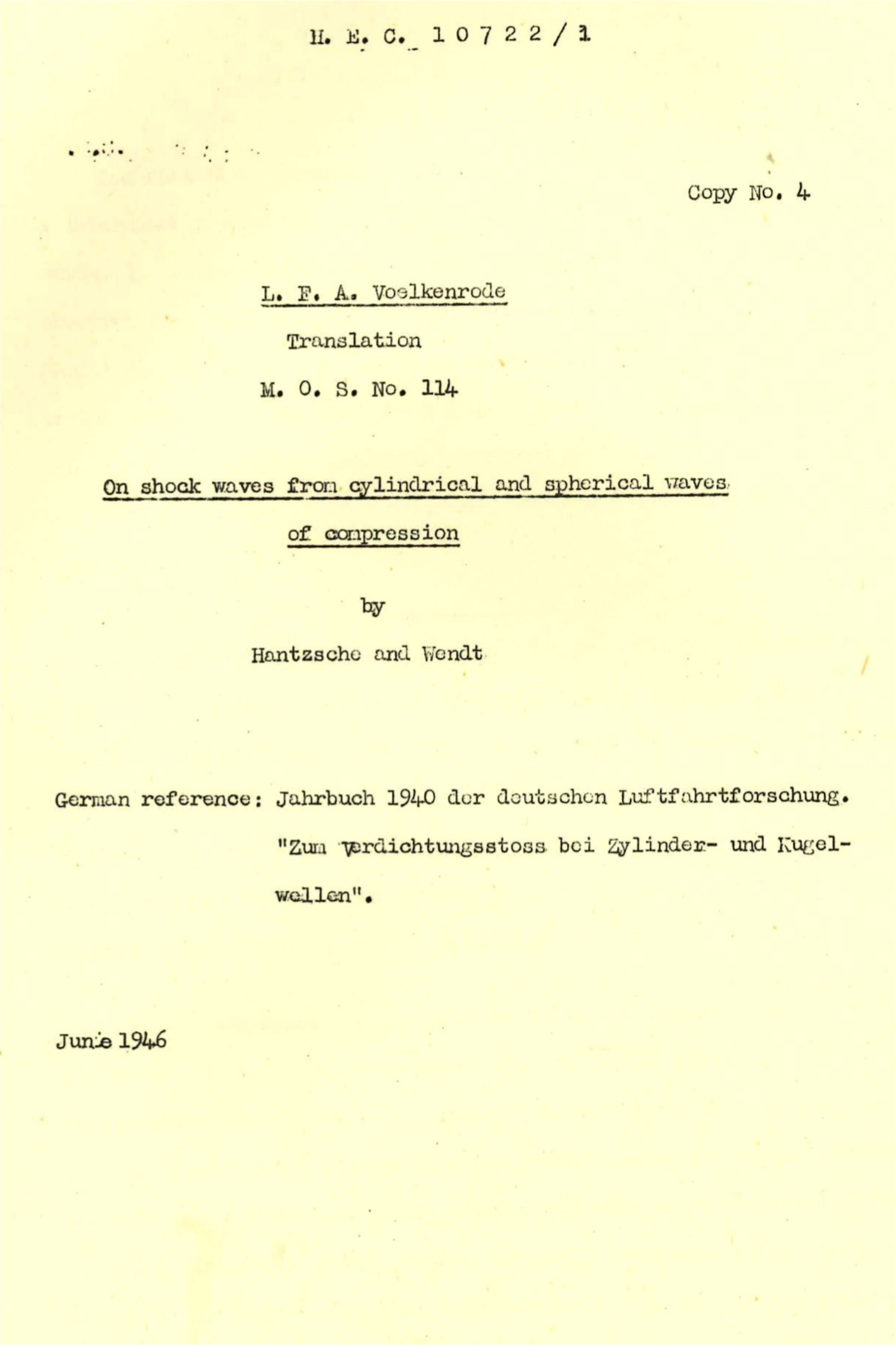
It is known that a delegation of Henschel was in Paris to inform themselves about the research on nuclear fission with a so-called cyclotron. According to experts, neither Henschel nor the other companies were able to really build the bomb. After the war, all those involved said that they had only carried out basic research.

Walter Hantzsche and Hilmar Wendt. 1940. HEC 10722. *On Shock Waves from Cylindrical and Spherical Waves of Compression.* [U.K. Imperial War Museum, Duxford Archive, Halstead Exploitation Centre reports]

We utilize only the equations of motion of an unsteady gas flow, and consider, in the following, a plane, cylindrical and spherical compression wave with a steep velocity front. In the case of the plane wave, a shock wave appears following continuous steepening of the velocity front. For cylindrical and spherical waves, on the other hand, it can happen that a steepening of the velocity front only takes place after a given time. Previously the front becomes flatter, the diminishing of the amplitude through the spreading of the wave, outweighing the steepening caused by the compression. A criterion is established for the onset of a shock wave, which, in the case of the spherical wave, agrees with Burton.

[This report demonstrates that by no later than 1940, German scientists had carried out calculations applicable to both spherical and cylindrical implosion bombs. Gottfried Guderley's more famous 1942 paper with similar calculations is shown on pp. 4170–4171. See also pp. 2127–2129 and 5010.]

Imperial War Museum, Duxford, HEC 10722



H. E. C. 10722/1

Copy No. 4

L. F. A. Voelkenrode

Translation

M. O. S. No. 114

On shock waves from cylindrical and spherical waves of compression

by

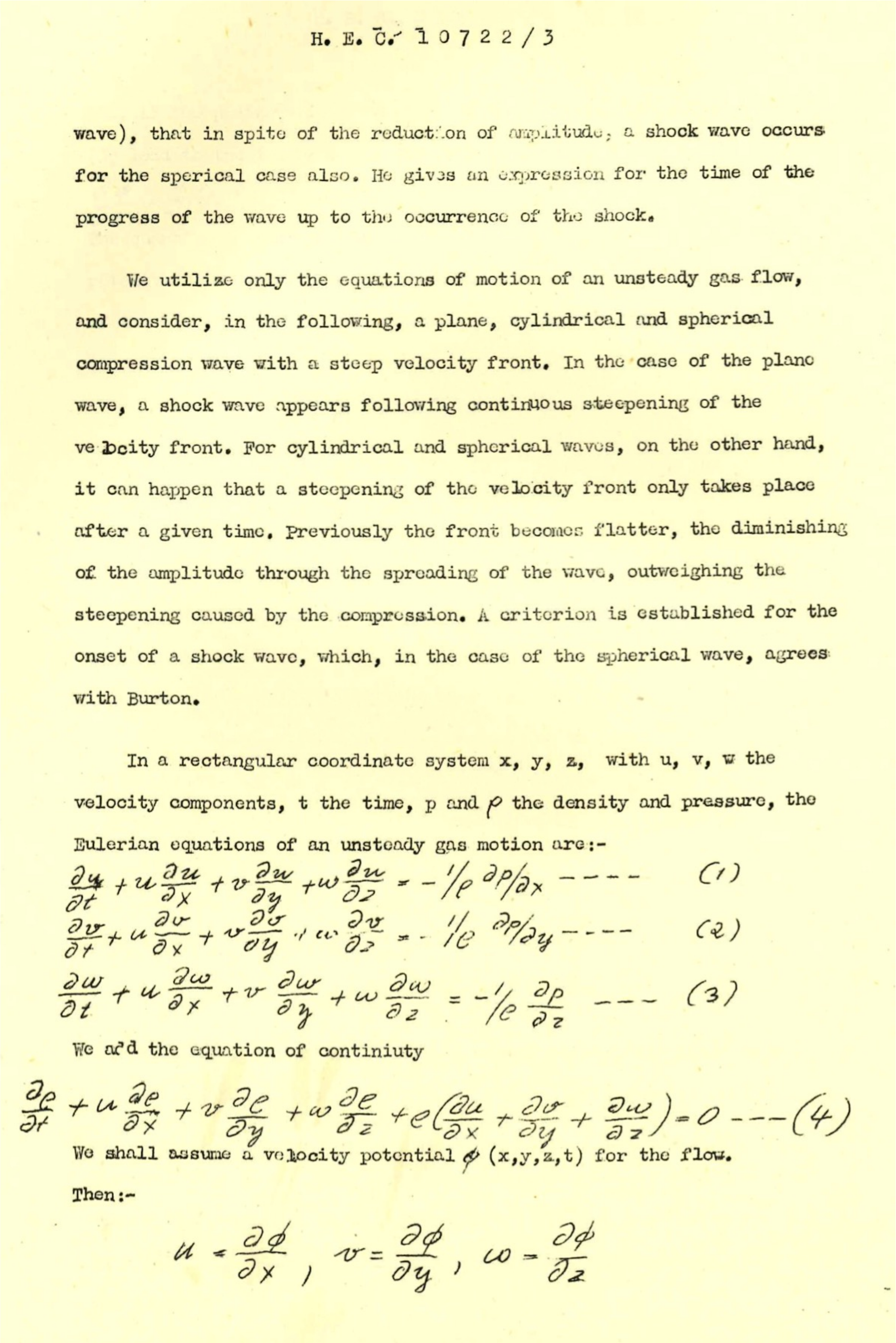
Hantzsche and Wendt

German reference: Jahrbuch 1940 der deutschen Luftfahrtforschung. "Zum Verdichtungsstoss bei Zylinder- und Kugelwellen".

June 1946

Figure D.551: By no later than 1940, Walter Hantzsche and Hilmar Wendt had carried out calculations applicable to both spherical and cylindrical implosion bombs [Halstead Exploitation Centre (HEC) Report 10722, English translation, U.K. Imperial War Museum, Duxford Archive].

Imperial War Museum, Duxford, HEC 10722



H. E. C. 10722/3

wave), that in spite of the reduction of amplitude, a shock wave occurs for the sperical case also. He gives an expression for the time of the progress of the wave up to the occurrence of the shock.

We utilize only the equations of motion of an unsteady gas flow, and consider, in the following, a plane, cylindrical and spherical compression wave with a steep velocity front. In the case of the plane wave, a shock wave appears following continuous steepening of the velocity front. For cylindrical and spherical waves, on the other hand, it can happen that a steepening of the velocity front only takes place after a given time. Previously the front becomes flatter, the diminishing of the amplitude through the spreading of the wave, outweighing the steepening caused by the compression. A criterion is established for the onset of a shock wave, which, in the case of the spherical wave, agrees with Burton.

In a rectangular coordinate system x, y, z, with u, v, w the velocity components, t the time, p and ρ the density and pressure, the Eulerian equations of an unsteady gas motion are:-

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial u}{\partial z} = -1/\rho \; \partial p/\partial x \; ---- \quad (1)$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} = -1/\rho \; \partial p/\partial y \; ---- \quad (2)$$

$$\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} = -1/\rho \, \frac{\partial p}{\partial z} \; --- \quad (3)$$

We add the equation of continiuty

$$\frac{\partial \rho}{\partial t} + u\frac{\partial \rho}{\partial x} + v\frac{\partial \rho}{\partial y} + w\frac{\partial \rho}{\partial z} + \rho\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}\right) = 0 \; --- (4)$$

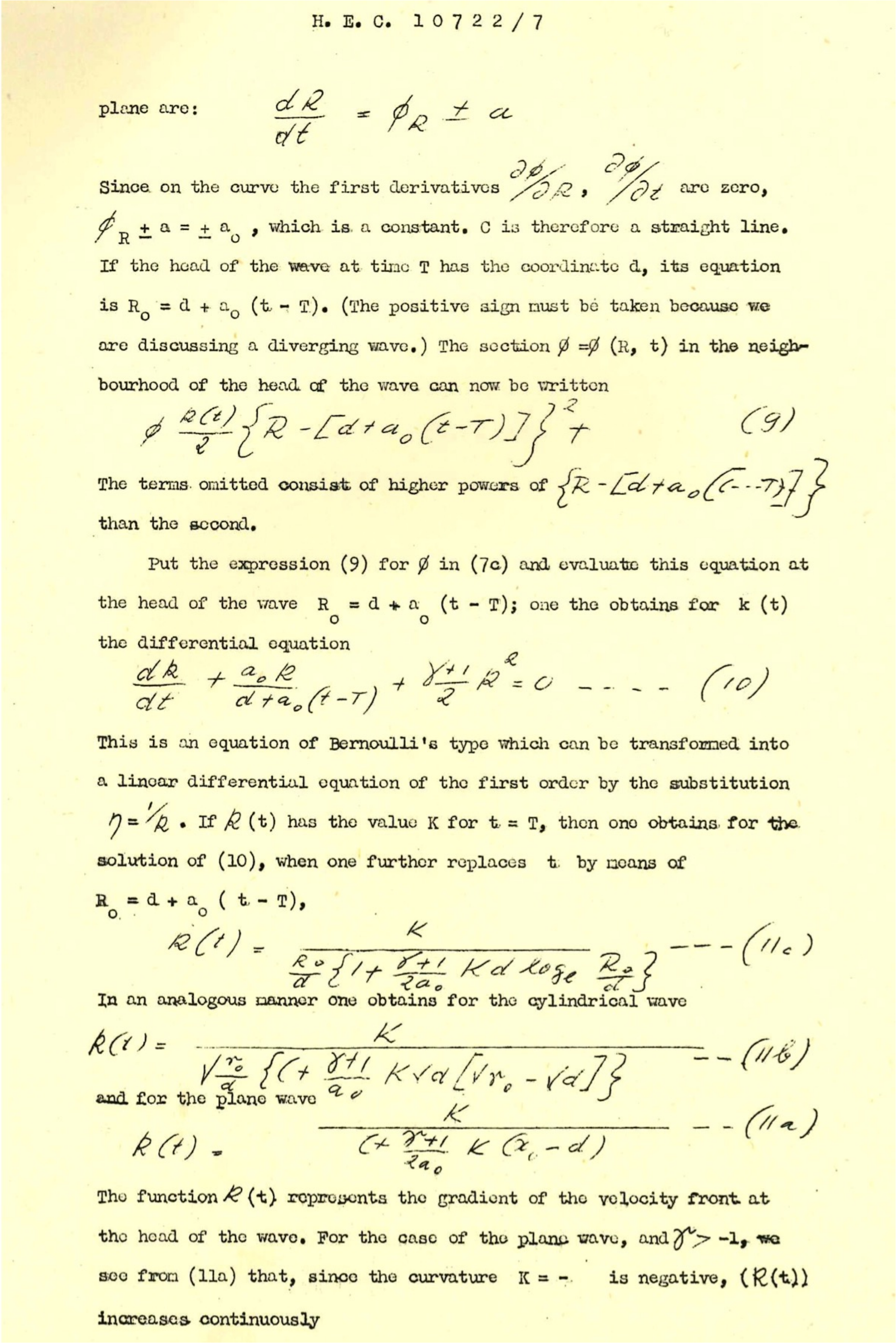
We shall assume a velocity potential ϕ (x,y,z,t) for the flow.

Then:-

$$u = \frac{\partial \phi}{\partial x}, \quad v = \frac{\partial \phi}{\partial y}, \quad w = \frac{\partial \phi}{\partial z}$$

Figure D.552: By no later than 1940, Walter Hantzsche and Hilmar Wendt had carried out calculations applicable to both spherical and cylindrical implosion bombs [Halstead Exploitation Centre (HEC) Report 10722, English translation, U.K. Imperial War Museum, Duxford Archive].

Imperial War Museum, Duxford, HEC 10722



H. E. C. 10722/7

plane are: $\frac{dR}{dt} = \phi_R \pm a$

Since on the curve the first derivatives $\partial\phi/\partial R$, $\partial\phi/\partial t$ are zero, $\phi_R \pm a = \pm a_0$, which is a constant. C is therefore a straight line. If the head of the wave at time T has the coordinate d, its equation is $R_0 = d + a_0 (t - T)$. (The positive sign must be taken because we are discussing a diverging wave.) The section $\phi = \phi (R, t)$ in the neighbourhood of the head of the wave can now be written

$$\phi \frac{k(t)}{2}\left\{R-\left[d+a_0(t-T)\right]\right\}^2 + \qquad (9)$$

The terms omitted consist of higher powers of $\left\{R-\left[d+a_0(t-T)\right]\right\}$ than the second.

Put the expression (9) for ϕ in (7c) and evaluate this equation at the head of the wave $R_0 = d + a_0 (t - T)$; one the obtains for $k (t)$ the differential equation

$$\frac{dk}{dt} + \frac{a_0 k}{d+a_0(t-T)} + \frac{\gamma+1}{2} k^2 = 0 \quad ----\ (10)$$

This is an equation of Bernoulli's type which can be transformed into a linear differential equation of the first order by the substitution $\eta = 1/k$. If k (t) has the value K for t = T, then one obtains for the solution of (10), when one further replaces t by means of $R_0 = d + a_0 (t - T)$,

$$k(t) = \frac{K}{\frac{R_0}{d}\left\{1+\frac{\gamma+1}{2a_0} K d \log_e \frac{R_0}{d}\right\}} \quad ---\ (11c)$$

In an analogous manner one obtains for the cylindrical wave

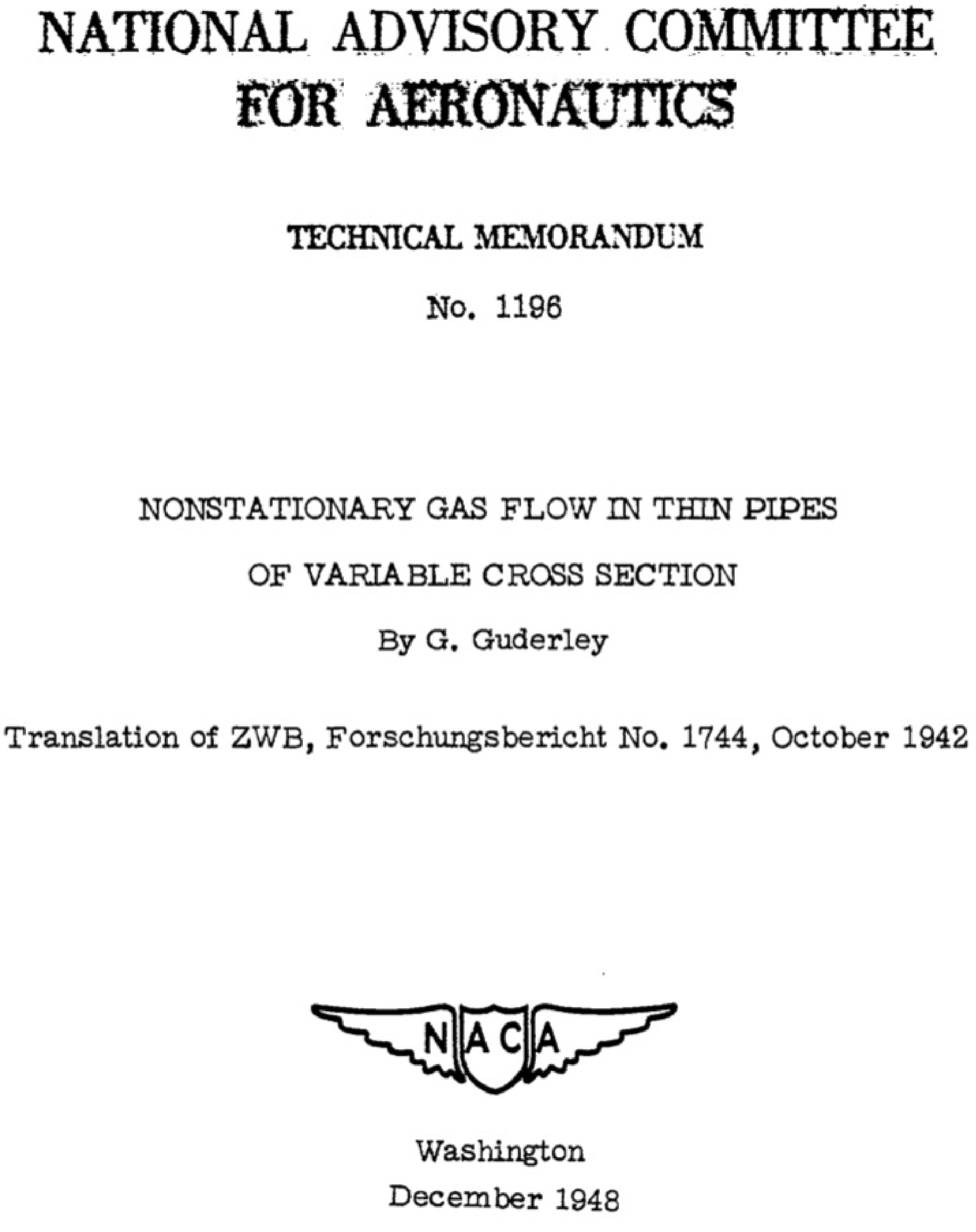
$$k(t) = \frac{K}{\sqrt{\frac{r_0}{d}}\left\{1+\frac{\gamma+1}{a_0} K\sqrt{d}\left[\sqrt{r_0}-\sqrt{d}\right]\right\}} \quad --\ (11b)$$

and for the plane wave

$$k(t) = \frac{K}{1+\frac{\gamma+1}{2a_0} K (x_0-d)} \quad --\ (11a)$$

The function k (t) represents the gradient of the velocity front at the head of the wave. For the case of the plane wave, and $\gamma > -1$, we see from (11a) that, since the curvature K = - is negative, (k(t)) increases continuously

Figure D.553: By no later than 1940, Walter Hantzsche and Hilmar Wendt had carried out calculations applicable to both spherical and cylindrical implosion bombs [Halstead Exploitation Centre (HEC) Report 10722, English translation, U.K. Imperial War Museum, Duxford Archive].



NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

TECHNICAL MEMORANDUM

No. 1196

NONSTATIONARY GAS FLOW IN THIN PIPES
OF VARIABLE CROSS SECTION

By G. Guderley

Translation of ZWB, Forschungsbericht No. 1744, October 1942

NACA

Washington
December 1948

Figure D.554: English translation of 1942 paper by Gottfried Guderley (1910–1997), a hydrodynamics expert working for the German military, predicting the pressure, density, and temperature of highly compressed and accelerated matter in both spherical and cylindrical geometries for power-law equations of state, as would be directly applicable to implosion bombs.

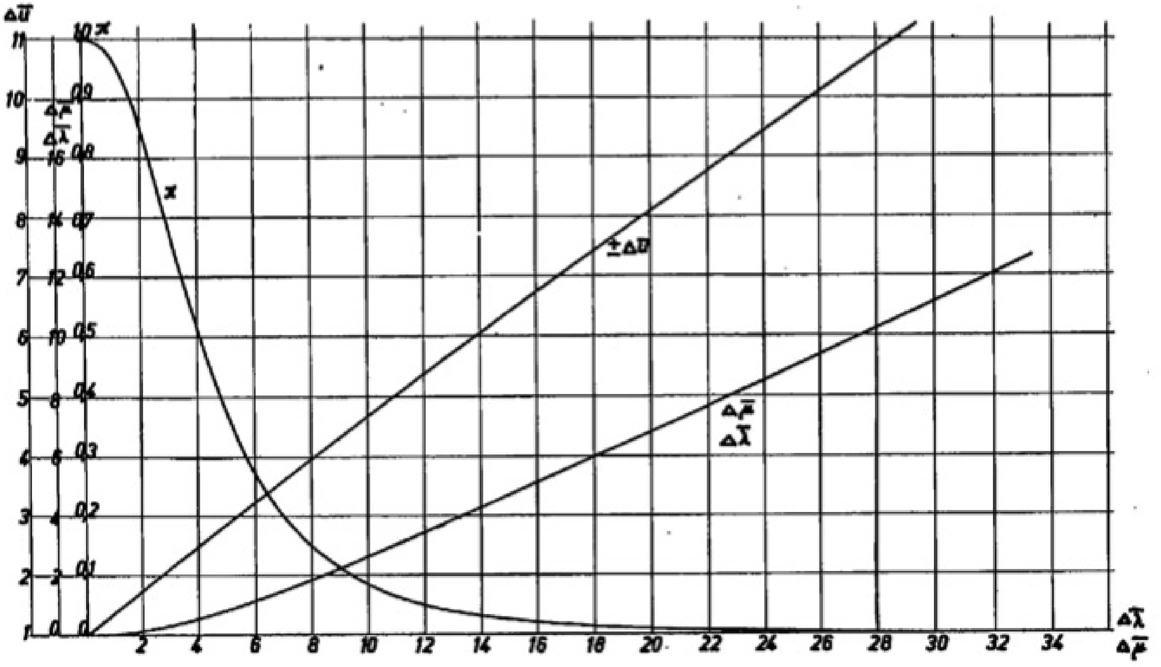


Figure 12a.- Characteristics of compression shocks K = 1.405.

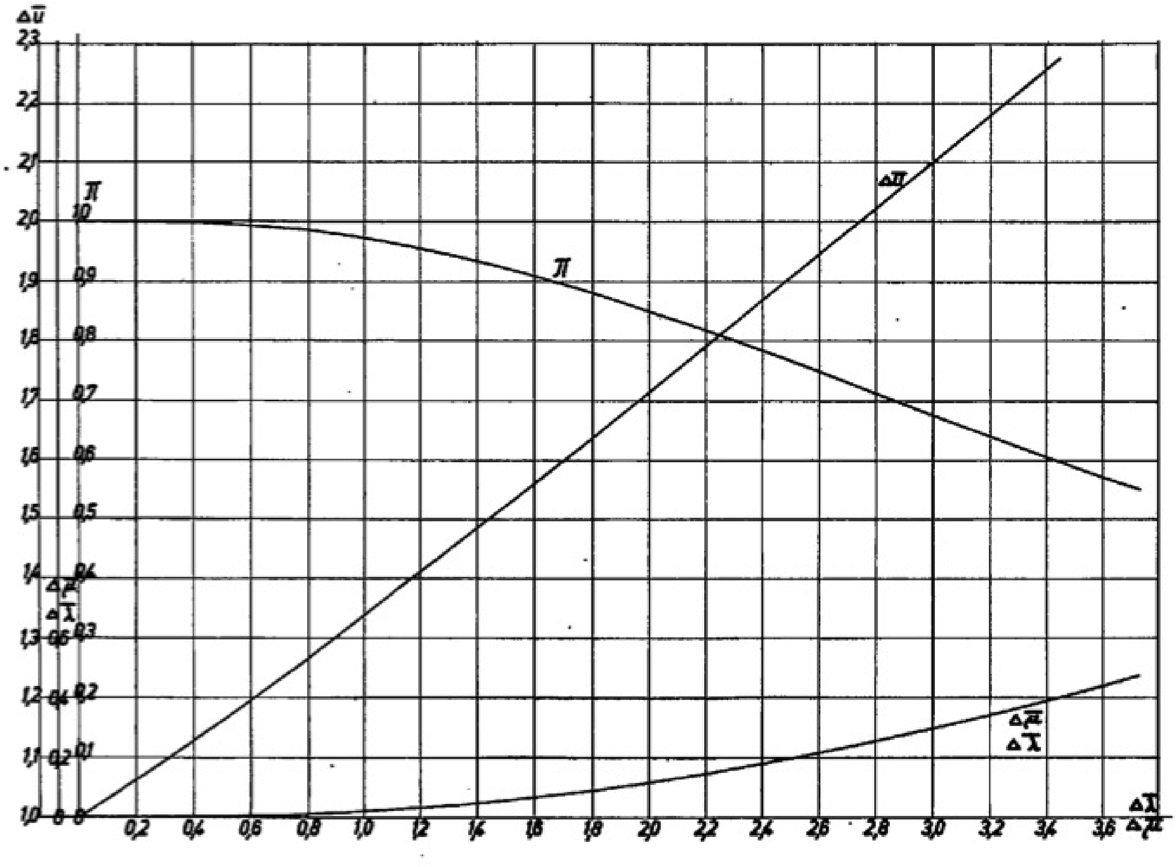


Figure 12b.- Characteristics of compression shocks K = 1.405.

Figure D.555: Detailed 1942 calculations by Gottfried Guderley predicting the pressure, density, and temperature in a spherical implosion bomb (without explicitly calling it that in public).

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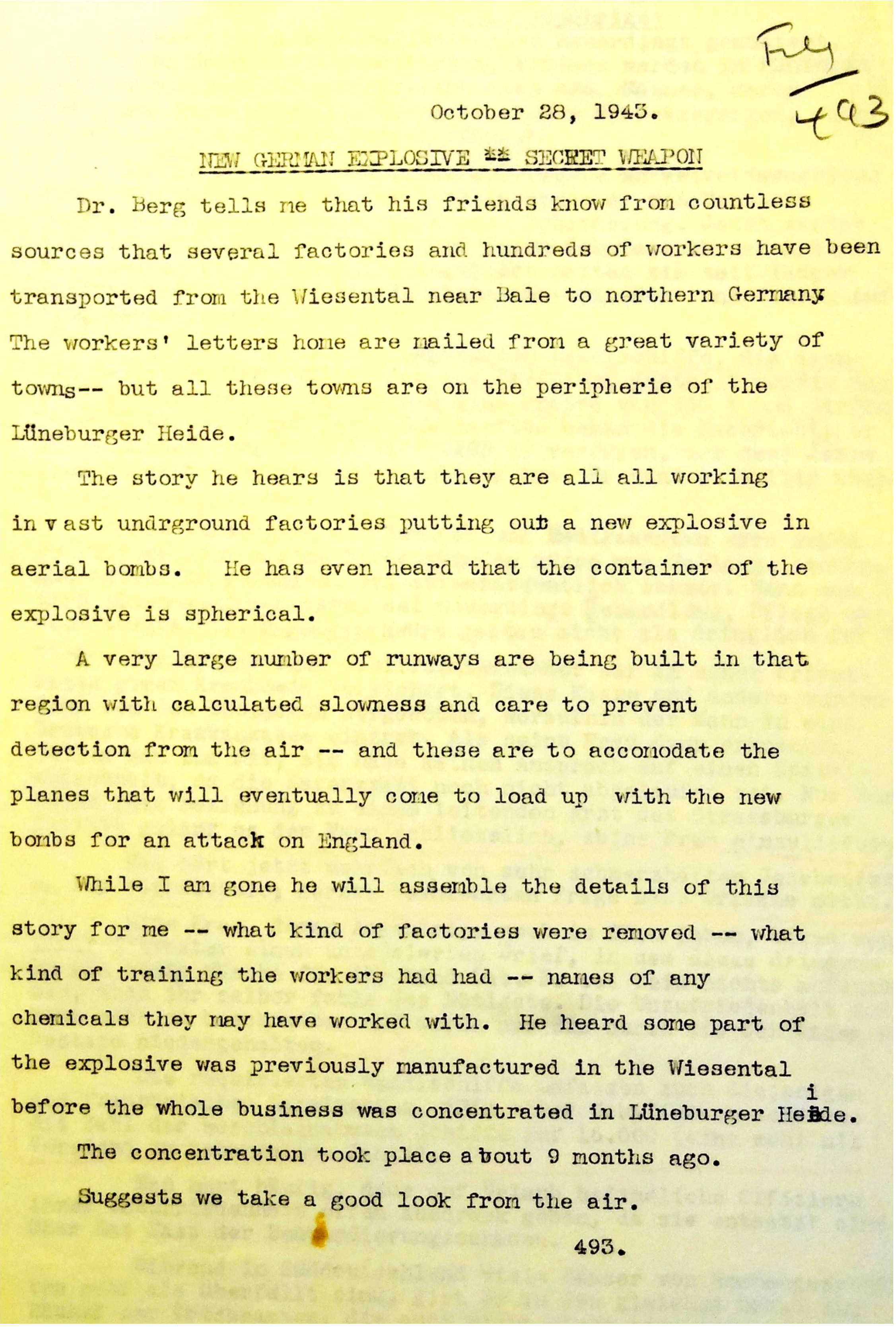
NARA RG 226, Entry 125, Box 6, Folder 78



Fly
493

October 28, 1943.

NEW GERMAN EXPLOSIVE ** SECRET WEAPON

Dr. Berg tells me that his friends know from countless sources that several factories and hundreds of workers have been transported from the Wiesental near Bale to northern Germany. The workers' letters home are mailed from a great variety of towns-- but all these towns are on the peripherie of the Lüneburger Heide.

The story he hears is that they are all all working in vast undrground factories putting out a new explosive in aerial bombs. He has even heard that the container of the explosive is spherical.

A very large number of runways are being built in that region with calculated slowness and care to prevent detection from the air -- and these are to acconodate the planes that will eventually come to load up with the new bombs for an attack on England.

While I am gone he will assemble the details of this story for me -- what kind of factories were removed -- what kind of training the workers had had -- names of any chemicals they may have worked with. He heard some part of the explosive was previously manufactured in the Wiesental before the whole business was concentrated in Lüneburger Heide.

The concentration took place about 9 months ago.

Suggests we take a good look from the air.

493.

Figure D.556: Several documents reported that there was a hidden underground nuclear facility somewhere in the Lüneburger Heide area south of Hamburg. Intelligence via Frederick Loofbourow (OSS agent 493) [NARA RG 226, Entry 125, Box 6, Folder 78].

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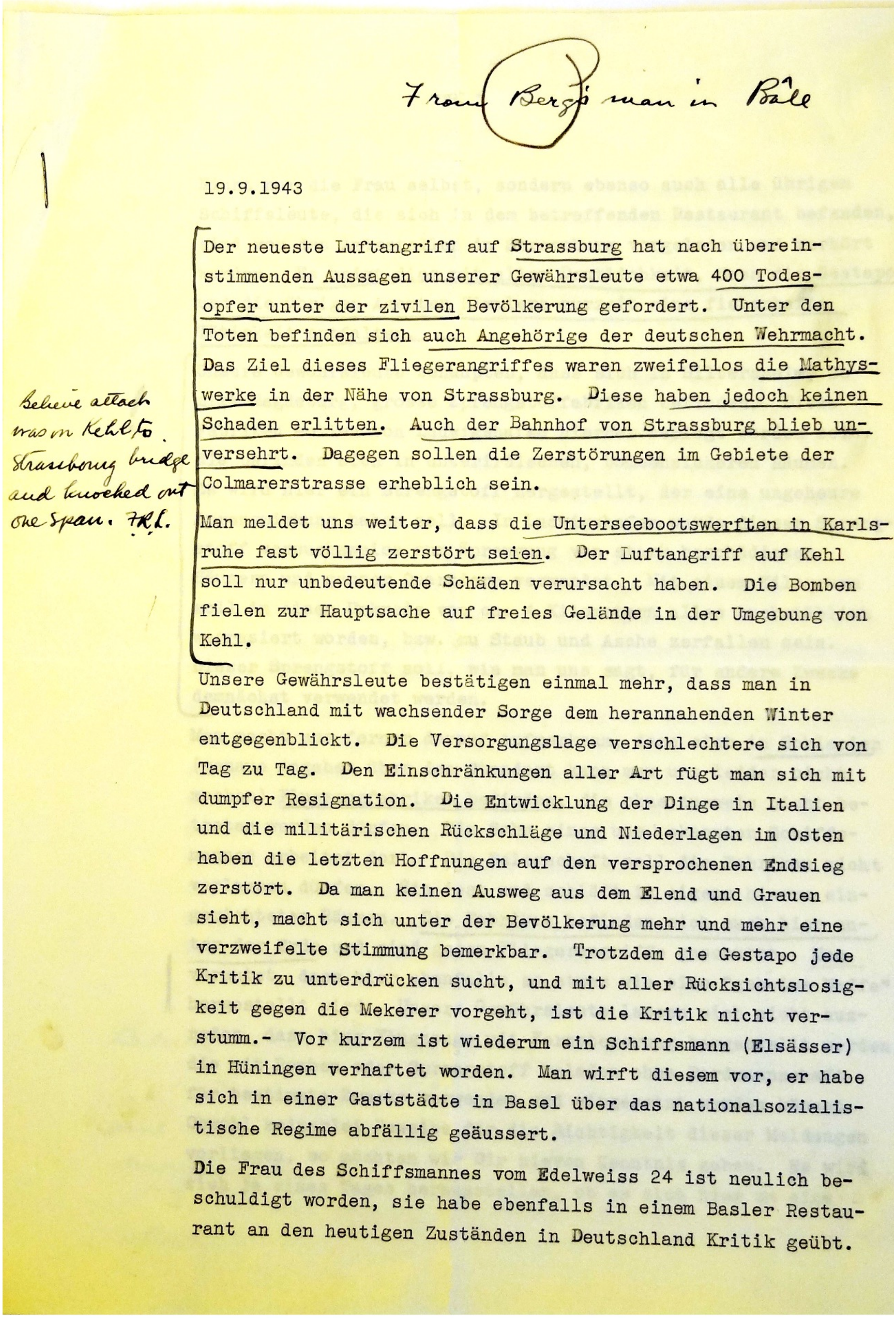

From Berg's man in Bâle

19.9.1943

Der neueste Luftangriff auf Strassburg hat nach übereinstimmenden Aussagen unserer Gewährsleute etwa 400 Todesopfer unter der zivilen Bevölkerung gefordert. Unter den Toten befinden sich auch Angehörige der deutschen Wehrmacht. Das Ziel dieses Fliegerangriffes waren zweifellos die Mathyswerke in der Nähe von Strassburg. Diese haben jedoch keinen Schaden erlitten. Auch der Bahnhof von Strassburg blieb unversehrt. Dagegen sollen die Zerstörungen im Gebiete der Colmarerstrasse erheblich sein.

Believe attack was on Kehl to Strasbourg bridge and knocked out one span. FRL.

Man meldet uns weiter, dass die Unterseebootswerften in Karlsruhe fast völlig zerstört seien. Der Luftangriff auf Kehl soll nur unbedeutende Schäden verursacht haben. Die Bomben fielen zur Hauptsache auf freies Gelände in der Umgebung von Kehl.

Unsere Gewährsleute bestätigen einmal mehr, dass man in Deutschland mit wachsender Sorge dem herannahenden Winter entgegenblickt. Die Versorgungslage verschlechtere sich von Tag zu Tag. Den Einschränkungen aller Art fügt man sich mit dumpfer Resignation. Die Entwicklung der Dinge in Italien und die militärischen Rückschläge und Niederlagen im Osten haben die letzten Hoffnungen auf den versprochenen Endsieg zerstört. Da man keinen Ausweg aus dem Elend und Grauen sieht, macht sich unter der Bevölkerung mehr und mehr eine verzweifelte Stimmung bemerkbar. Trotzdem die Gestapo jede Kritik zu unterdrücken sucht, und mit aller Rücksichtslosigkeit gegen die Mekerer vorgeht, ist die Kritik nicht verstumm.- Vor kurzem ist wiederum ein Schiffsmann (Elsässer) in Hüningen verhaftet worden. Man wirft diesem vor, er habe sich in einer Gaststädte in Basel über das nationalsozialistische Regime abfällig geäussert.

Die Frau des Schiffsmannes vom Edelweiss 24 ist neulich beschuldigt worden, sie habe ebenfalls in einem Basler Restaurant an den heutigen Zuständen in Deutschland Kritik geübt.

Figure D.557: Several documents reported that there was a hidden underground nuclear facility somewhere in the Lüneburger Heide area south of Hamburg. Intelligence via Frederick Loofbourow (OSS agent 493) [NARA RG 226, Entry 125, Box 6, Folder 78].

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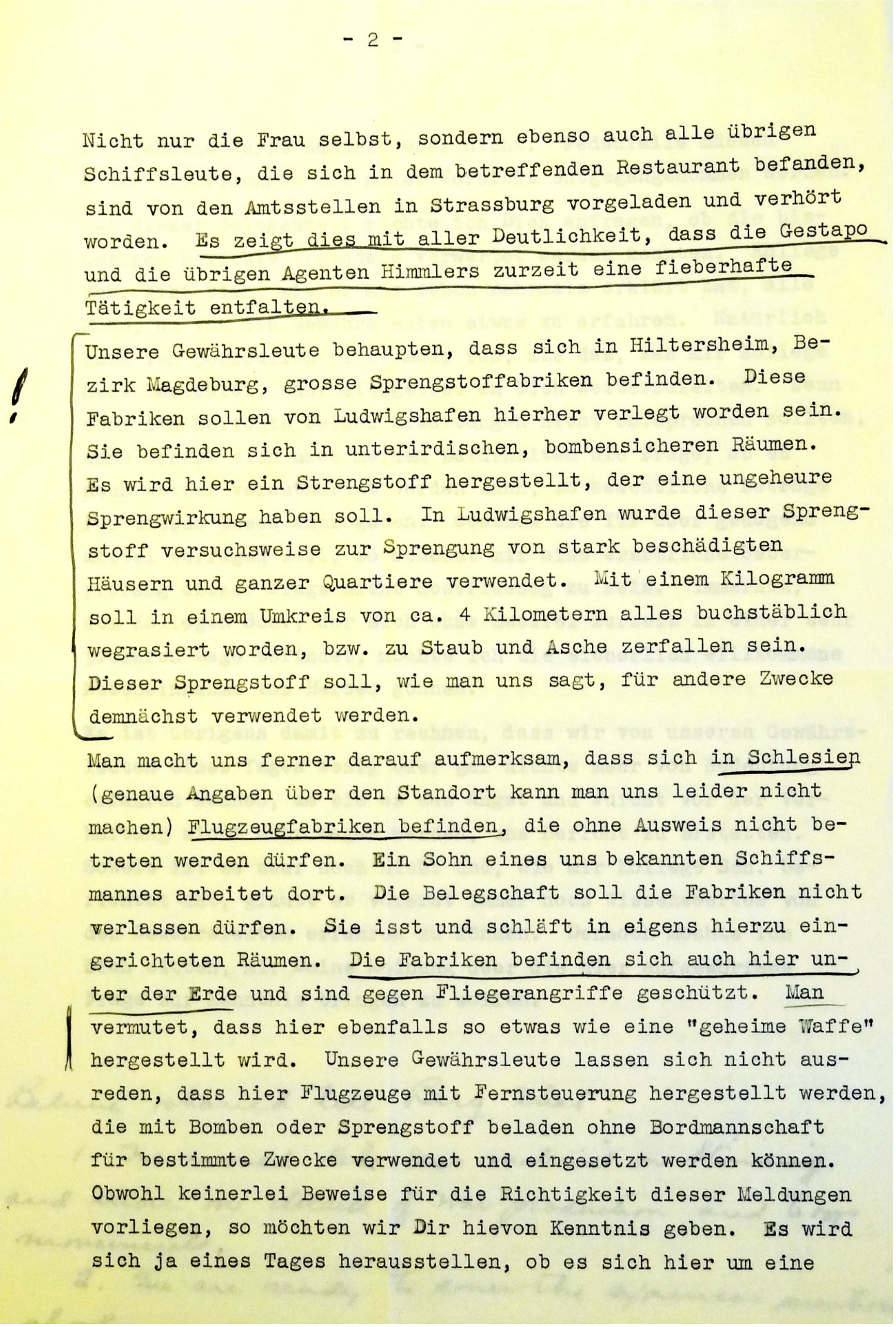


- 2 -

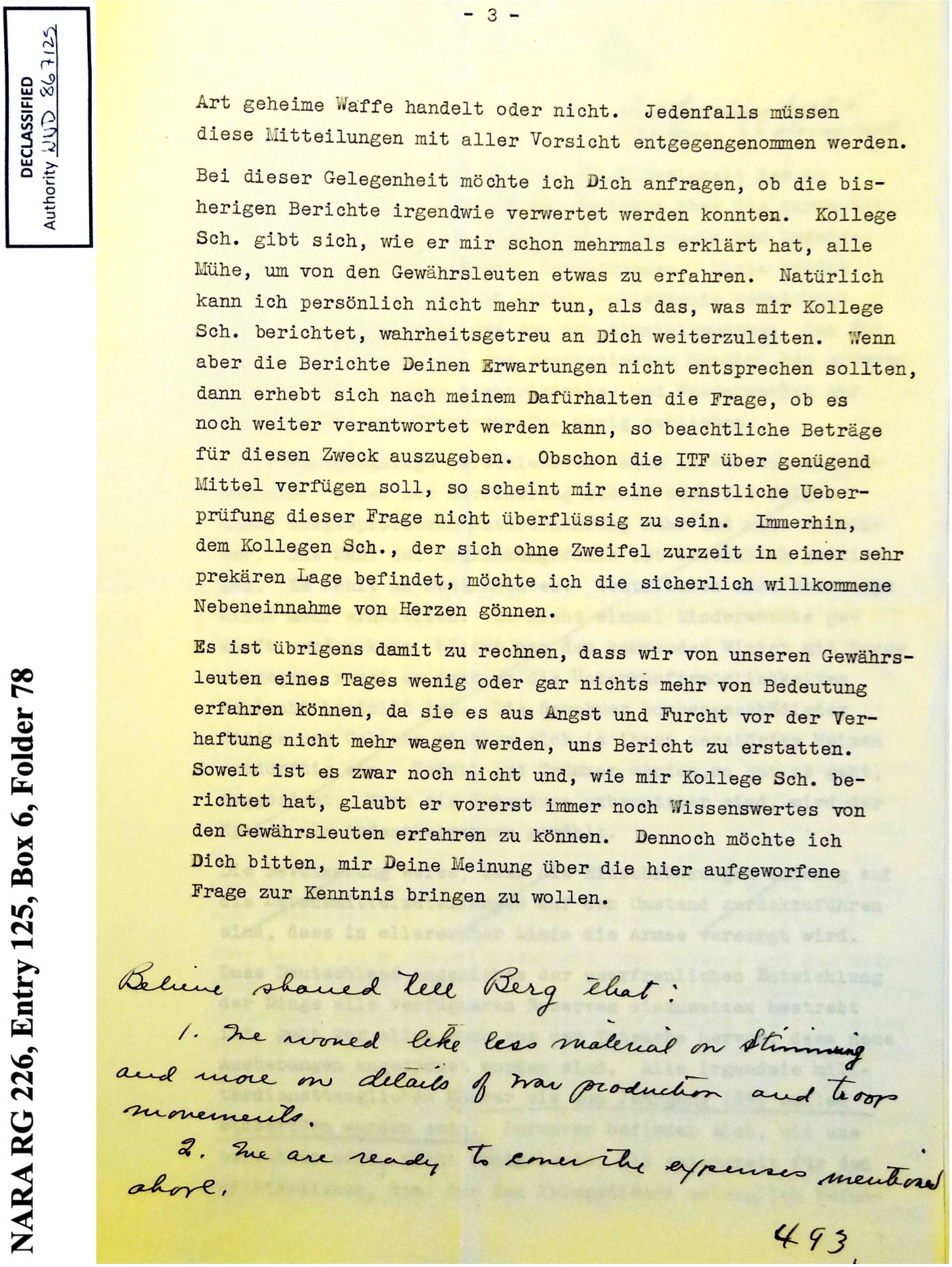
Nicht nur die Frau selbst, sondern ebenso auch alle übrigen Schiffsleute, die sich in dem betreffenden Restaurant befanden, sind von den Amtsstellen in Strassburg vorgeladen und verhört worden. Es zeigt dies mit aller Deutlichkeit, dass die Gestapo und die übrigen Agenten Himmlers zurzeit eine fieberhafte Tätigkeit entfalten.

Unsere Gewährsleute behaupten, dass sich in Hiltersheim, Bezirk Magdeburg, grosse Sprengstoffabriken befinden. Diese Fabriken sollen von Ludwigshafen hierher verlegt worden sein. Sie befinden sich in unterirdischen, bombensicheren Räumen. Es wird hier ein Strengstoff hergestellt, der eine ungeheure Sprengwirkung haben soll. In Ludwigshafen wurde dieser Sprengstoff versuchsweise zur Sprengung von stark beschädigten Häusern und ganzer Quartiere verwendet. Mit einem Kilogramm soll in einem Umkreis von ca. 4 Kilometern alles buchstäblich wegrasiert worden, bzw. zu Staub und Asche zerfallen sein. Dieser Sprengstoff soll, wie man uns sagt, für andere Zwecke demnächst verwendet werden.

Man macht uns ferner darauf aufmerksam, dass sich in Schlesien (genaue Angaben über den Standort kann man uns leider nicht machen) Flugzeugfabriken befinden, die ohne Ausweis nicht betreten werden dürfen. Ein Sohn eines uns bekannten Schiffsmannes arbeitet dort. Die Belegschaft soll die Fabriken nicht verlassen dürfen. Sie isst und schläft in eigens hierzu eingerichteten Räumen. Die Fabriken befinden sich auch hier unter der Erde und sind gegen Fliegerangriffe geschützt. Man vermutet, dass hier ebenfalls so etwas wie eine "geheime Waffe" hergestellt wird. Unsere Gewährsleute lassen sich nicht ausreden, dass hier Flugzeuge mit Fernsteuerung hergestellt werden, die mit Bomben oder Sprengstoff beladen ohne Bordmannschaft für bestimmte Zwecke verwendet und eingesetzt werden können. Obwohl keinerlei Beweise für die Richtigkeit dieser Meldungen vorliegen, so möchten wir Dir hievon Kenntnis geben. Es wird sich ja eines Tages herausstellen, ob es sich hier um eine

NARA RG 226, Entry 125, Box 6, Folder 78

Figure D.558: Several documents reported that there was a hidden underground nuclear facility somewhere in the Lüneburger Heide area south of Hamburg. Intelligence via Frederick Loofbourow (OSS agent 493) [NARA RG 226, Entry 125, Box 6, Folder 78].



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NARA RG 226, Entry 125, Box 6, Folder 78

- 3 -

Art geheime Waffe handelt oder nicht. Jedenfalls müssen diese Mitteilungen mit aller Vorsicht entgegengenommen werden.

Bei dieser Gelegenheit möchte ich Dich anfragen, ob die bisherigen Berichte irgendwie verwertet werden konnten. Kollege Sch. gibt sich, wie er mir schon mehrmals erklärt hat, alle Mühe, um von den Gewährsleuten etwas zu erfahren. Natürlich kann ich persönlich nicht mehr tun, als das, was mir Kollege Sch. berichtet, wahrheitsgetreu an Dich weiterzuleiten. Wenn aber die Berichte Deinen Erwartungen nicht entsprechen sollten, dann erhebt sich nach meinem Dafürhalten die Frage, ob es noch weiter verantwortet werden kann, so beachtliche Beträge für diesen Zweck auszugeben. Obschon die ITF über genügend Mittel verfügen soll, so scheint mir eine ernstliche Ueberprüfung dieser Frage nicht überflüssig zu sein. Immerhin, dem Kollegen Sch., der sich ohne Zweifel zurzeit in einer sehr prekären Lage befindet, möchte ich die sicherlich willkommene Nebeneinnahme von Herzen gönnen.

Es ist übrigens damit zu rechnen, dass wir von unseren Gewährsleuten eines Tages wenig oder gar nichts mehr von Bedeutung erfahren können, da sie es aus Angst und Furcht vor der Verhaftung nicht mehr wagen werden, uns Bericht zu erstatten. Soweit ist es zwar noch nicht und, wie mir Kollege Sch. berichtet hat, glaubt er vorerst immer noch Wissenswertes von den Gewährsleuten erfahren zu können. Dennoch möchte ich Dich bitten, mir Deine Meinung über die hier aufgeworfene Frage zur Kenntnis bringen zu wollen.

Believe should tell Berg that:

1. We would like less material on Stimmung and more on details of war production and troops movements.

2. We are ready to cover the expenses mentioned above.

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Figure D.559: Several documents reported that there was a hidden underground nuclear facility somewhere in the Lüneburger Heide area south of Hamburg. Intelligence via Frederick Loofbourow (OSS agent 493) [NARA RG 226, Entry 125, Box 6, Folder 78].

Background on Frederick Loofbourow [Powers 1993, p. 271]

Dulles never lacked for reports of new German explosives. One dated October 28, 1943, came from an OSS officer ostensibly serving as a senior economic analyst in the American consulate in Zurich who signed all his reports "493." This was Frederick Read Loofbourow, an executive of the Standard Oil Company of New Jersey, sent to Switzerland in 1942 by the Board of Economic Warfare to gather intelligence on German petroleum production. After the border was closed, Loofbourow was tapped by Dulles for OSS work and given a wide range of jobs through the end of the war.

Intelligence via Frederick Loofbourow [NARA RG 226, Entry 125, Box 6, Folder 78]

[See document photos on pp. 4172–4175.]

October 28, 1943.

NEW GERMAN EXPLOSIVE—SECRET WEAPON

Dr. Berg tells me that his friends know from countless sources that several factories and hundreds of workers have been transported from the Wiesental near Bâle to northern Germany. The workers' letters home are mailed from a great variety of towns—but all these towns are on the periphery of the Lüneburger Heide.

The story he hears is that they are all working in vast underground factories putting out a new explosive in aerial bombs. He has even heard that the container of the explosive is spherical.

A very large number of runways are being built in that region with calculated slowness and care to prevent detection from the air—and these are to accommodate the planes that will eventually come to load up with the new bombs for an attack on England.

While I am gone he will assemble the details of this story for me—what kind of factories were removed—what kind of training the workers had had—names of any chemicals they may have worked with. He heard some part of the explosive was previously manufactured in the Wiesental before the whole business was concentrated in Lüneburger Heide.

The concentration took place about 9 months ago.

Suggests we take a good look from the air.

493.

[Handwritten:] From Berg's man in Bâle [Basel, Switzerland]

19.9.1943

[...] Unsere Gewährsleute behaupten, dass sich in Hiltersheim, Bezirk Magdeburg, grosse Sprengstofffabriken befinden. Diese Fabriken sollen von Ludwigshafen hierher verlegt worden sein. Sie befinden sich in unterirdischen, bombensicheren Räumen. Es wird hier ein Strengstoff [Sprengstoff?] hergestellt, der eine ungeheuere Sprengwirkung haben soll. In Ludwigshafen wurde dieser Sprengstoff versuchsweise zur Sprengung von stark beschädigten Häusern und ganzer Quartiere verwendet. Mit einem Kilogramm soll in einem Umkreis von ca. 4 Kilometern alles buchstäblich wegrasiert worden, bzw. zu Staub und Asche zerfallen sein. Dieser Sprengstoff soll, wie man uns sagt, für andere Zwecke demnächst verwendet werden.

Man macht uns ferner darauf aufmerksam, dass sich in Schlesien (genaue Angaben über den Standort kann man uns leider nicht machen) Flugzeugfabriken befinden, die ohne Ausweis nicht betreten werden dürfen. Ein Sohn eines uns bekannten Schiffsmannes arbeitet dort. Die Belegschaft soll die Fabriken nicht verlassen dürfen. Sie isst und schläft in eigens hierzu eingerichteten Räumen. Die Fabriken befinden sich auch hier unter der Erde und sind gegen Fliegerangriffe geschützt. Man vermutet, dass hier ebenfalls so etwas wie eine "geheime Waffe" hergestellt wird. Unsere Gewährsleute lassen sich nicht ausreden, dass hier Flugzeuge mit Fernsteuerung hergestellt werden, die mit Bomben oder Sprengstoff beladen ohne Bordmannschaft für bestimmte Zwecke verwendet und eingesetzt werden können. Obwohl keinerlei Beweise für die Richtigkeit dieser Meldungen vorliegen, so möchten wir Dir hiervon Kenntnis geben. Es wird sich ja eines Tages herausstellen, ob es sich hier um eine Art geheime Waffe handelt oder nicht. Jedenfalls müssen diese Mitteilungen mit aller Vorsicht entgegengenommen werden. [...]

[...] Our sources claim that there are large explosives factories in Hiltersheim, Magdeburg district. These factories are said to have been moved here from Ludwigshafen. They are located in underground, bomb-proof facilities. A special [[explosive?] substance is produced here which is said to have an enormous explosive effect. In Ludwigshafen, this explosive was used on an experimental basis to blow up severely damaged houses and entire neighborhoods. With one kilogram, everything within a radius of approximately four kilometers should be literally razed away, or disintegrated to dust and ashes. We are told that this explosive will soon be used for other purposes.

We are also informed that there are aircraft factories in Silesia (unfortunately we are not given exact details of the location) which cannot be entered without a pass. A son of a shipman we know works there. The employees are not allowed to leave the factories. They eat and sleep in specially equipped rooms. The factories are also located underground and are protected against air raids. It is suspected that something like a "secret weapon" is also being produced here. Our sources will not be talked out of the fact that remote-controlled airplanes are produced here, which can be loaded with bombs or explosives and used for certain purposes without a crew on board. Although there is no proof that these reports are correct, we would like to inform you of them. One day it will become clear whether this is some kind of secret weapon or not. In any case, these reports must be taken with a grain of salt.

[Loofbourow seemed to have great confidence in his source “Dr. Berg” (not to be confused with Moe Berg, an OSS spy). Would it possible now to trace who that person actually was?

The new explosive reported by Dr. Berg was said to have “an enormous explosive effect” and clearly was not a conventional explosive. A fuel-air explosive (such as was being developed by Mario Zippermayr and others) could have an enormous explosive effect, but it would require on the order of a ton, not a kilogram, of fuel, and the fuel would be coal dust or other relatively well known substances. This report of a new explosive that was special substance that was so powerful that one kilogram of the new explosive could have a blast radius of several kilometers, seems to accurately describe the properties of weapons-grade uranium or plutonium. Dr. Berg reported that large factories with hundreds of people were producing the new explosive, which sounds like a large-scale production operation, not just small-scale lab experiments with minute quantities.

According to Dr. Berg, production began no later than early 1943. Based on current evidence about the technologies that were available in Germany at that time and that would have been suitable for producing fission bomb fuel, one of the most likely production methods would have been electromagnetic separation of uranium-235. That approach would have been highly similar to the U.S. calutrons at Oak Ridge, which also required hundreds of minimally trained workers to operate. Other possibilities would have been gas centrifuges or gaseous diffusion for enriching uranium-235, or a reactor or particle accelerators for breeding plutonium-239 or uranium-233.

For aerodynamic, stability, and targeting reasons, bombs are generally not spherical. The only reason to make a spherical bomb is if the bomb physics compels that choice—a spherical implosion bomb. Actually, this report gives many relevant details. It describes a bomb that:

1. Was spherical in overall shape, which strongly suggests an implosion design.
2. Contained on the order of a kilogram of an unusual material that was a new type of explosive.
3. Required large factories, hundreds of people, and over a year to produce enough of that unusual material.
4. Contained other components that are alluded to but not specified.
5. Had a blast radius of several kilometers.

Those details are highly consistent with others descriptions of a German fission implosion bomb.

The Lüneburger Heide or Heath is an area just south of Hamburg. Note the measures taken to avoid aerial surveillance (“to prevent detection from the air”) and aerial bombardment (“vast underground factories,” distribution “in a number of towns”) of this program. If those measures were successful, and if the equipment was evacuated, blown up, or buried before the end of the war, the whole program could have remained unnoticed by Allied countries, apart from a few intelligence reports such as those of Dr. Berg and the following documents, which do not appear to have been seriously pursued.

See also pp. 4987–4988 for a map and list of known underground facilities including Lüneburger Heide.]

Lüneburger Heide south of Hamburg

Figure D.560: Several documents reported that there was a hidden underground nuclear facility somewhere in the Lüneburger Heide area south of Hamburg. See also pp. 4987–4988.

From US Military Attaché Madrid Spain to War Department. 21 June 1944. Cable 12547. [NARA RG 165, Entry NM84-489, Box 175, Folder G-2 Book III a (Cables)]

To London and MILID, 12547.

Contact named Handtusch now returned to Germany eval FO states sea pointed last several days is aerial torpedo. Proof fired from Lueneburger Heide in direction Baltic Sea, impact area approximately 100 KM from Kiel. He stated storage depots these torpedos located in Lueneburger Heide near Lueneburg. Manufactured in new underground plants between Rostock and Stralsund.

Sharp.

BIOS 142. *Information Obtained from Targets of Opportunity in the Sonthofen Area.* 1945.

A. The S. S. Hauptamt (information from various sources)

Scientific research on new weapons and the production of armaments in Germany was controlled not only by the established ministries such as the R.L.M. but also by Speer's ministry and by the S. S. Hauptamt. [...]

Obergruppenführer Professor Kammler, one of the directors of the S.S. Hauptamt, was said to have great influence on Himmler and more influence on Hitler than Speer himself; and he was kept informed on all questions concerning armaments. The New Weapons section of the Waffenamt was apparently directed by a man called Bree. Standartenführer Klumm worked in this section and under him Lt. Kreutzfeld, who was interrogated.

One of the functions of the S.S. was to control the work of politically unreliable scientists who were kept in concentration camps. One of these camps was at Oranienburg, and research was done here on new weapons. [...] Another such camp was located at Nordhausen in the Harz, and came under the direct control of Kammler. Here the prisoners worked in an underground factory engaged on production. [...]

B. Information obtained from K. Kreutzfeld [...]

(g) Liquid air bomb

As the research on the atomic bomb under Graf von Ardenne and others was not proceeding as rapidly as had been hoped in 1944, it was decided to proceed with the development of a liquid air bomb. [...]

C. Interrogation of Josef Ernst [...]

(c) Scientific concentration camps

Ernst stated that he had been imprisoned at a concentration camp for politically unreliable scientists called "Camp Mecklenburg" in the Lüneburger Heide. This place was not known to Kreutzfeld, who was however acquainted with the Oranienburg camp. The possibility of bringing Ernst over to Oranienburg was also mentioned in Ernst's personal file, which had been given to him by Kreutzfeld for identification purposes. There was no mention of Camp Mecklenburg in this file. Ernst also stated that there was a similar camp at Maudhausen, near Vienna, but this was also unknown to Kreutzfeld. [...]

(f) Other work at Camp Mecklenburg

Ernst also stated that work was carried out at this camp on a new liquid air bomb, and liquid air gun (?), while trials on some kind of atomic bomb were made at or near the camp.

[The BIOS investigators interrogated Kurt Kreutzfeld, who had apparently been a member of the SS, and Josef Ernst, who had apparently been a "politically unreliable" scientist sentenced to work in concentration camps under the supervision of Kreutzfeld and other SS members. Ernst said he had worked at a concentration camp in the Lüneburger Heide where scientists were developing atomic bombs and other advanced weapons. Kreutzfeld denied that such a place existed and apparently implied to the BIOS investigators that Ernst was crazy. From the report, it seems that the BIOS investigators chose to believe the SS man's denials, and disbelieve the captive scientist's report about atomic bomb development.

The veracity of Ernst's statements is strongly supported by two points he includes that are corroborated by other sources but would have been very far from common knowledge:

- His description of Lüneburger Heide having a very large, very secret facility for the development of an atomic bomb is highly consistent with the statements of Otto Hahn and Frederick Loofbourow's informant, Dr. Berg.
- Ernst said there was another similar concentration camp where scientists were apparently forced to work on atomic bomb development at "Maudhausen, near Vienna." The Mauthausen concentration camp system west of Vienna included Gusen, a large underground complex where nuclear scientists worked on advanced weapons development (see pp. 3882, 4854, 4962ff.).

This report directly links Manfred von Ardenne and the atomic bomb development work, which strongly suggests that one of von Ardenne's specialties, electromagnetic isotope enrichment of uranium-235, was involved in the program. That aligns very well with Dr. Berg's report that many hundreds of workers in the Lüneburger Heide were operating factory equipment to produce small quantities of the special high-density material required by the new type of bomb, very much like the calutron operators at Oak Ridge. For another report linking Lüneburger Heide with atomic bomb development, see p. 4406.

See also: Lüneburger Heide: "Wir wissen nicht genau, was drin ist"—C-Waffen in der Heide aufgetaucht. [Lüneburger Heide: "We don't know exactly what is in there"—chemical weapons appear in the Heide.] *Focus*, 28 March 2017. https://www.focus.de/panorama/welt/lueneburger-heide-wir-wissen-nicht-genau-was-drin-ist-c-waffen-in-der-heide-aufgetaucht_id_6845571.html]

Memo to Lt. Col. P. M. Wilson. Atom-Bomb Specialist. 4 April 1946 [TNA FO 1031/112].

1. The following information has just come to hand and we should be glad if it could be passed on to the appropriate interested agencies.

2. Karl Heinz BOSECK, former Ustuf in the Waffen SS, alleges that he is an Atom-Bomb expert. He is now interned in No. 2 CIC, SANDBOSTEL and his P.O.W. No. is 204526.

[Karl-Heinz Boseck, born in 1915, was a mathematician who studied under Erich Schumann and became a member of the SS [Nagel 2011; Nagel 2012a, pp. 550, 560; Segal 2003, pp. 321–333].

"Atom-Bomb expert" implies much more than just early research. Boseck apparently worked in the SS's nuclear weapons development groups, which remain even more mysterious than other branches of the German nuclear program. Specifically, he helped run the "Mathematical Institute" at the Sachsenhausen concentration camp in Oranienburg [Nagel 2012a, p. 550; Segal 2003, pp. 321–333], an extremely interesting intersection of mathematical calculations, uranium from Auer Gesellschaft in Oranienburg, and slave labor from the concentration camp (perhaps for uranium enrichment?). That also supports Josef Ernst's assertion that the camp at Oranienburg did work related to the nuclear bomb development work at Lüneburger Heide (pp. 4180–4181).

Can other documents from Allied interrogations of Boseck be located, declassified, and released? What other information can be found about Boseck?]

Otto Hahn's autobiography [Otto Hahn 1968, p. 200].

Professor Staudinger schrieb mir, ein Offizier hätte ihm sein Ehrenwort gegeben, daß in der Lüneburger Heide kurz vor Kriegsende drei deutsche Atombomben einsatzbereit gelegen hätten.

Professor Staudinger wrote me that an officer had given him his word of honor that three German nuclear bombs had been ready for deployment in the Lüneburg Heath shortly before the end of the war.

[As Otto Hahn reported in his autobiography, after the war a German military officer in a position to know confirmed that this Lüneburger Heide program did indeed exist and had actually produced three completed fission bombs by the end of the war. With over two years to produce enough material, that could be quite possible. It is also possible that this Lüneburger Heide program produced one or more bombs that were used in the reported late 1944/early 1945 test explosions (Sections D.10–D.12). For a report that appears to link the Lüneburger Heide facility the Baltic atomic bomb test, see p. 4406.

Hermann Staudinger was a Nobel-Prize-winning German chemist just as Otto Hahn was, and of roughly the same age as Hahn. Hahn would have placed great faith in something that Staudinger told him. Since Hahn thought the statement was worthy of inclusion in his autobiography, and since he made no attempt to refute the statement (based on his own knowledge of wartime nuclear work), he seemed to imply that he accepted the statement as credible. Hahn's autobiography was only released after his death.]

Manfred von Ardenne. 1990. *Die Erinnerungen.* 10th ed. Munich: Herbig. p. 159

Bei Besuchen in Dahlem und Lichterfelde hatte ich 1941 Professor Otto Hahn die Frage gestellt, wieviel Gramm des reinen Isotops Uran-235 zur Entfesselung einer momentan ablaufenden Kernkettenreaktion benötigt würden. Er antwortete mir: “Wenige Kilogramm.” In diesem absolut vertraulichen Gespräch vertrat ich die Auffassung, es sei technisch durchaus möglich, mit Hilfe hochgezüchteter magnetischer Massentrenner (die wir damals gedanklich und experimentell vorbereitet hatten), Uran-235-Mengen von einigen Kilogramm zu erhalten, wenn man dafür große Elektrokonzerne einsetzen würde.

During visits to Dahlem and Lichterfelde in 1941, I had asked Professor Otto Hahn how many grams of pure uranium-235 would be needed to unleash a nuclear chain reaction in an instant. He answered me: “A few kilograms.” In this absolutely confidential conversation, I expressed the opinion that it was technically quite possible to obtain uranium-235 in quantities of a few kilograms with the help of highly sophisticated magnetic mass separators (which we had previously designed and experimentally developed), if large electrical corporations were used for this purpose.

Thomas Powers. 1993. *Heisenberg’s War: The Secret History of the German Bomb.* New York: Alfred A. Knopf. p. 513, note 21.

In a letter to Rolf Hochhuth, June 27, 1988, Ardenne cites the conversation with Hahn on December 10, 1941, and quotes the answer of 1 to 2 kilograms. [...] Ardenne confirmed these conversations with me in an interview in Dresden, May 17, 1989, and showed me the signatures of Hahn and Heisenberg in his guest book.

Cable IN 5937 from Bern, Switzerland to Office of Strategic Services Director. 24 March 1944 [NARA RG 226, Entry A1-134, Box 219, Folder IN AZUSA Nov. ’43 Sept. ’45]

#2576-2581. AZUSA. [...]

The following is a report secured from Flute [Paul Scherrer] by 493: [...]

A super-Nazi, Lorens [Manfred von Ardenne] of Berlin-Lichterfelde-Ost is a financial and scientific swindler. He boasts of constructing an uranium bomb but he does not have adequate equipment. Lorens’ associate is Breit [Fritz Houtermans] who was previously a Communist, was apprehended in Russia, but released in 1939 after which he turned into a fervent Nazi. Breit’s work is in nuclear physics.

[Paul Scherrer’s depiction of the personalities of Manfred von Ardenne and Fritz Houtermans is distorted by Scherrer’s scientific jealousy, but Scherrer reported that von Ardenne stated very clearly during the war that he was producing uranium for a fission bomb.]

[According to conventional histories, Otto Hahn was not involved with the German nuclear weapons program. The above sources show that he actually had close ties to the program during the war. This strengthens the credibility of other information from Hahn (pp. 4182, 4460).

The above also shows that a priority of the program was to produce highly enriched uranium-235, especially using von Ardenne's calutron-like electromagnetic isotope separators (Section D.4.3).

The above also demonstrates that the program was focused on producing nuclear devices that would use "1 to 2 kilograms" or "a few kilograms" of uranium-235 to create a chain reaction "in an instant." A reactor would use a much larger quantity of unenriched or low-enriched uranium to produce a continuous, slow reaction, so the devices they were trying to build must have been bombs.

For a sphere of pure uranium-235, the critical mass is ∼46 kg without compression or a surrounding neutron reflector, but only ∼0.36–2.9 kg with compression and a neutron reflector (p. 5162). Thus the information from Hahn and von Ardenne appears to indicate that in 1941 there was an excellent understanding of these numbers and plans to use a bomb design with spherical implosion.

One electromagnetic isotope separator in von Ardenne's personal lab could not produce enough uranium-235 within a reasonable period of time (Section D.15.2), so in 1941 von Ardenne advocated to have many separators built by "large electrical corporations" and then operated in parallel at some other location.

Thus the information above is in excellent agreement with the reports of p. 4176: "vast underground factories" (at a location known to Otto Hahn, p. 4182) with "hundreds of workers" going into operation in 1942, using machines to produce a special material such that "with one kilogram, everything within a radius of approximately four kilometers should be literally razed away, or disintegrated to dust and ashes," when used in uniquely designed "aerial bombs" in which "the container of the explosive is spherical."]

Harry Vosser. Germans Are Still Striving to Perfect New V Weapons. *New York Times*. 22 October 1944, p. E5. [See more on p. 5321.]

V-3 is reported to be the atom bomb. [...] An electric shock from a small instrument set to operate at a given time detonates explosive and atom simultaneously. The expansion caused by a normal explosive substance, such as dynamite when it becomes a gas, is increased by the force of the disintegrating atoms.

V-3? *Time*, 27 November 1944, p. 88.

The terrible novelty of V-2 had by no means worn off yet, but London last week was already abuzz with speculation about V-3—supposedly an atomic bomb. [...]

The speculative London report suggested that the Nazis are using the same pressure principle to crush atoms. The crusher: A "Neuman" demolition charge, which explodes inward instead of outward. Used in a sphere, the Neuman charge might develop pressures of tens of thousands of tons per square inch at the center, perhaps enough to disintegrate an unstable atom such as uranium and release its explosive atomic energy.

[Egon Neumann developed sophisticated shaped charge explosives in 1910 [George Brown 1998, p. 166; Walters and Zukas 1989, pp. 12–13]. His name was presumably attached here to describe the general principle, not to imply that he was directly involved in the reported wartime atomic bomb development.

This article appears to describe the Schumann-Trinks implosion bombs or very similar work, and it supports the view that the work described in the postwar writings of Schumann and Trinks was indeed carried out during the war.]

Leslie R. Groves. 1962. *Now It Can Be Told: The Story of the Manhattan Project*. pp. 147–148.

Another incident that concerned us greatly was the appearance in a national magazine of an article hinting at the theory of implosion. While it did not violate any rules, it was most disturbing. A thorough investigation indicated that it resulted from the work of an alert and inquisitive reporter in another country.

[Clippings in a file at the Franklin Delano Roosevelt Library in Hyde Park, New York [Small Collections, Box 1, Folder 3, ATOMIC BOMB FILE] specifically link this comment from Leslie Groves to the 27 November 1944 article in *Time*. As Groves wrote, it would be quite concerning that any discussion of the implosion bomb design appeared in public at that time. What probably concerned him even more, although he did not mention that in his book, is that the *Time* article said the implosion bomb design details came from the German nuclear program, not the U.S. nuclear program. This evidence strongly supports the conclusion that Germany indeed had an advanced program developing nuclear weapons, and moreover that Leslie Groves knew the German nuclear program was much more advanced than he ever admitted in public.]

General Ivan Ilyichev. Intelligence reports to General Antonov and Joseph Stalin (15 November 1944 and 23 March 1945). Archive of the President of the Russian Federation, 93-81 (45) 37. [For these very important documents on the design and testing of the German fission implosion bomb, see pp. 4481–4485.]

Ordnance Technical Intelligence press release. August 1945. [NARA RG 498, Microfilm MP63-9_0137, Frames 623–624]

Ordnance OTI
For Immediate Release

For over two years, "detectives" of the Army Ordnance Department kept close tabs on German progress in the development of atomic weapons, it was revealed today by Lt. Col. John A. Keck, Chief Enemy Technical Intelligence Branch, Technical Division, Ordnance Service, TSFET.

"This shadowing of German science began in 1942," said Col. Keck, "when several Ordnance Officers, including myself, commenced work with British Intelligence in the United Kingdom. During the period before D-Day, allied agents on the continent were able to obtain from German proving grounds and research laboratories, information which gave definite evidence of steady progress in the atomic field. For some time, the race between German and American science was a close one, and had the Nazis been able to reach their goal, the outcome of the European war might have been entirely different."

Atoms had top priority on Col. Keck's list when he arrived in France with the 1st Army on D-Day. Information at his disposal gave several leads to the location of experimental stations in this line, but in the process of following them up, he hit several discouraging blind alleys. The first road took him to Cherbourg, where the absence of atomic proving grounds was somewhat compensated by the discovery of V-Bomb launching sites. Throughout the Normandy and Northern France campaigns, his searches gave little in the way of results. However, when the breakthrough in Germany got underway, the evidence began to pile up, culminating in the discovery of the great Nazi proving ground at Hillersleben. Here, it was learned that the Germans had gone far in the development of atomic bombs.

"However," said Col. Keck, "they weren't able to go far enough for several reasons, particularly the fact that they didn't have the facilities with which to conduct their experiments, and that our saturation bombing raids would throw their program far behind schedule. Nevertheless their progress was considerable and indicated that they were coming very close to the solution of the problem."

We were fully aware of their plans in this field, for sometimes whatever information we got from our agents went to the proper authorities in the States. This information was undoubtedly put at the disposal of our own scientists. However, it's interesting to note that our knowledge of enemy experiments in the atomic field far exceeded our knowledge of the closely-guarded experiments in the United States.

[The U.S. Army Ordnance Technical Intelligence office publicly stated that evidence proved "the Germans had gone far in the development of atomic bombs." What information were "allied agents on the continent... able to obtain from German proving grounds and research laboratories" during the war? What nuclear-related work was discovered at Hillersleben at the end of the war? Can the relevant U.S. reports be found at NARA or elsewhere?

Keck and the Ordnance Technical Intelligence office described an extended program to monitor German nuclear progress and gave accurate information about Hillersleben, Erich Schumann, and other aspects of German research in this and other press releases. As shown on the next pages, other U.S. government officials later forced them to deny all of that.]

Ordnance Technical Intelligence press release. August 1945. [NARA RG 498, Microfilm MP63-9_0137, Frames 625–626]

Ordnance OTI
For Immediate Release

"If the power of the Army's new atomic bomb is equal to that of 20,000 tons of TNT, its area of destruction would be a circle approximately one mile in diameter," said Colonel Leslie E. Simon, Director of the U.S. Army Ordnance Ballistics Research Center, Aberdeen Proving Ground, Md. Colonel Simon, who was interviewed shortly after release of information on the Army's latest secret weapon, has been in this theater on a special mission which included a 10,000 mile tour of German Ordnance installations and proving grounds. [...]

When asked of the extent to which the Germans had gone in the development of atom bombs, Colonel Simon said that several groups of German scientists had made some progress, but that they had not equalled our developments. He added, however, that they were definitely on the right track and it was a matter of time before they would be able to work something out.

One of the chief experts in this field, he said, was a Dr. Schumann, who was in charge of the research group of the Waffenamt (ordnance) in Berlin. With several other brilliant scientists, Dr. Schumann did much outstanding work, but, according to Colonel Simon, the Germans lagged behind us.

Colonel Simon said he did not believe that any German scientists had gone to Japan to continue their work, chiefly because they would be obliged to leave their laboratory facilities.

[Colonel Leslie Simon conducted extensive on-site visits and wrote detailed reports on German research facilities [Simon 1947a, 1947b, 1971]. He and the U.S. Army Ordnance Technical Intelligence office publicly stated that Erich Schumann (German, 1898–1985) was a "brilliant scientist" who "did much outstanding work," and that "the Germans had gone far in the development of atomic bombs." That view appears to be strongly supported by documentation about Schumann's wartime work (p. 4229). However, the Alsos Mission publicly declared that Schumann was only a "second-rate physicist" whose "main interest was the physics of piano strings" (p. 3297), and threatened the Ordnance Technical Intelligence office "against making further statements on this subject" (see below). This same microfilm MP63-9_0137 contains additional background information on the Hillersleben testing ground and U.S. colonels Keck and Simon—see for example frames 621–622, 638–646.]

Samuel Goudsmit to R. G. Ham. 10 August 1945 [NARA RG GOUDS, Entry UD-7420, Box 3, Folder "Historian's Office Inventory Control Job Goudsmit Box 4 Folder 6"].

The new outbursts of the 'omniscient' Colonel Keck... are deplorable and damaging. Please do something about this situation at once...

The German public opinion about the atomic bomb is as follows: They now believe that Hitler was not lying when he told them that he had a terrible weapon in store...

The following TA scientists have gone to work for the Russians...:

1) Dr. Riehl from Auer...

2) von Ardenne (cyclotron expert, etc.).

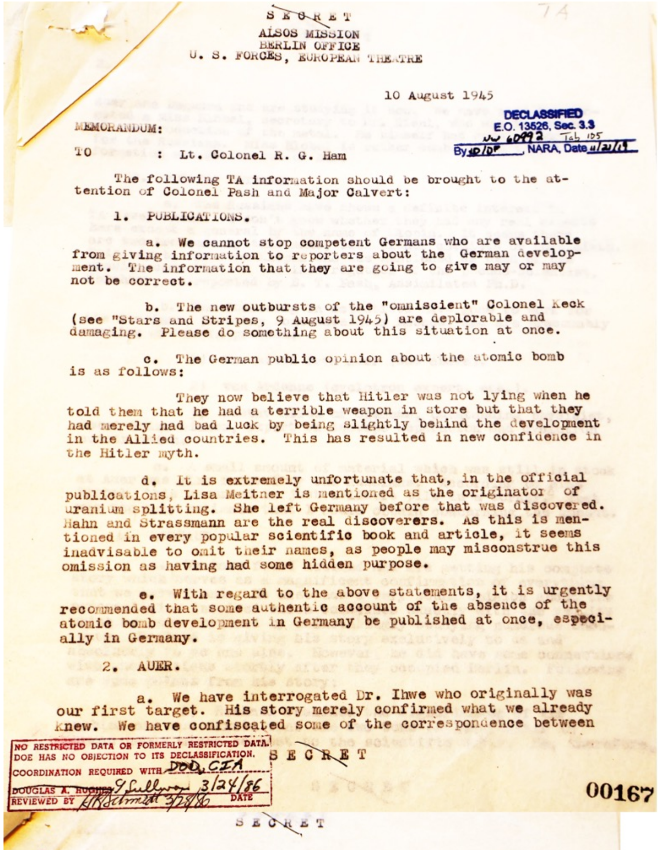
3) Gustav Hertz of Siemens, outstanding physicist, Nobel Prize winner, expert on isotope separation and cyclotron construction.

[See document photo on p. 4189.]

Monthly Intelligence Summary. July–August 1945. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

IX CENSORSHIP. [...]

e. The first wave of publicity after the use of the atom bomb brought forth a story from Lt. Col. John A. KECK, Chief of the Enemy Technical Intelligence Branch Ordnance Services, ETO, in which KECK purports to have conducted intelligence operations to determine the scope of enemy work on an atomic bomb. Col. KECK was interviewed by a representative of this office and admitted that he had not performed such a mission but denied having given the story to the Press. KECK stated that the story was released by the Public Relations Section of the Ordnance Services. Both KECK and the PRO were warned against making further statements on this subject.



TA

SECRET
ALSOS MISSION
BERLIN OFFICE
U. S. FORCES, EUROPEAN THEATRE

10 August 1945

DECLASSIFIED
E.O. 13526, Sec. 3.3
NW 60992 Tab 105
By [illegible], NARA, Date 11/21/13

MEMORANDUM:

TO : Lt. Colonel R. G. Ham

The following TA information should be brought to the attention of Colonel Pash and Major Calvert:

1. PUBLICATIONS.

a. We cannot stop competent Germans who are available from giving information to reporters about the German development. The information that they are going to give may or may not be correct.

b. The new outbursts of the "omniscient" Colonel Keck (see "Stars and Stripes, 9 August 1945) are deplorable and damaging. Please do something about this situation at once.

c. The German public opinion about the atomic bomb is as follows:

They now believe that Hitler was not lying when he told them that he had a terrible weapon in store but that they had merely had bad luck by being slightly behind the development in the Allied countries. This has resulted in new confidence in the Hitler myth.

d. It is extremely unfortunate that, in the official publications, Lisa Meitner is mentioned as the originator of uranium splitting. She left Germany before that was discovered. Hahn and Strassmann are the real discoverers. As this is mentioned in every popular scientific book and article, it seems inadvisable to omit their names, as people may misconstrue this omission as having had some hidden purpose.

e. With regard to the above statements, it is urgently recommended that some authentic account of the absence of the atomic bomb development in Germany be published at once, especially in Germany.

2. AUER.

a. We have interrogated Dr. Ihwe who originally was our first target. His story merely confirmed what we already knew. We have confiscated some of the correspondence between

NO RESTRICTED DATA OR FORMERLY RESTRICTED DATA.
DOE HAS NO OBJECTION TO ITS DECLASSIFICATION.
COORDINATION REQUIRED WITH DOD, CIA
~~DOUGLAS A. HUGHES~~ G. Sullivan 3/24/86
REVIEWED BY [illegible] 3/28/86 DATE

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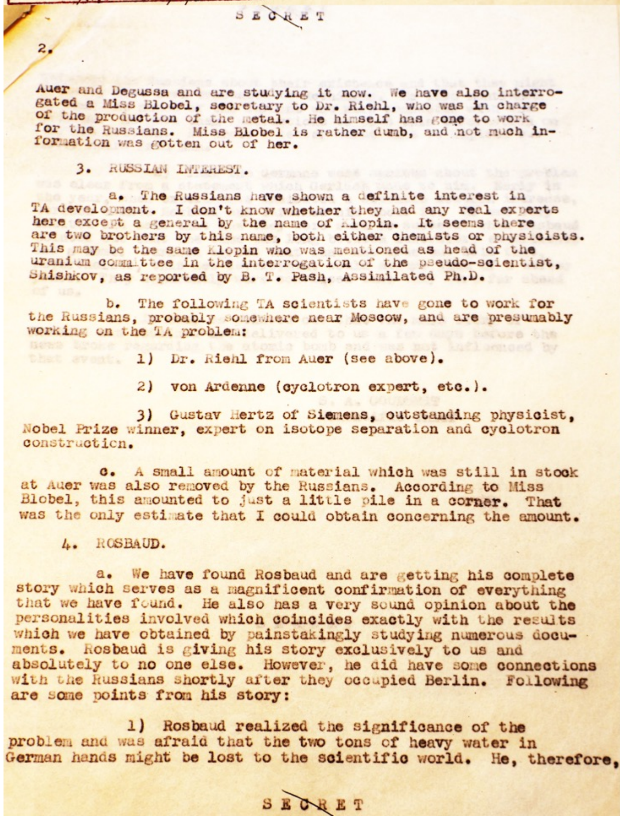

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Auer and Degussa and are studying it now. We have also interrogated a Miss Blobel, secretary to Dr. Riehl, who was in charge of the production of the metal. He himself has gone to work for the Russians. Miss Blobel is rather dumb, and not much information was gotten out of her.

3. RUSSIAN INTEREST.

a. The Russians have shown a definite interest in TA development. I don't know whether they had any real experts here except a general by the name of Klopin. It seems there are two brothers by this name, both either chemists or physicists. This may be the same Klopin who was mentioned as head of the uranium committee in the interrogation of the pseudo-scientist, Shishkov, as reported by B. T. Pash, Assimilated Ph.D.

b. The following TA scientists have gone to work for the Russians, probably somewhere near Moscow, and are presumably working on the TA problem:

1) Dr. Riehl from Auer (see above).

2) von Ardenne (cyclotron expert, etc.).

3) Gustav Hertz of Siemens, outstanding physicist, Nobel Prize winner, expert on isotope separation and cyclotron construction.

c. A small amount of material which was still in stock at Auer was also removed by the Russians. According to Miss Blobel, this amounted to just a little pile in a corner. That was the only estimate that I could obtain concerning the amount.

4. ROSBAUD.

a. We have found Rosbaud and are getting his complete story which serves as a magnificent confirmation of everything that we have found. He also has a very sound opinion about the personalities involved which coincides exactly with the results which we have obtained by painstakingly studying numerous documents. Rosbaud is giving his story exclusively to us and absolutely to no one else. However, he did have some connections with the Russians shortly after they occupied Berlin. Following are some points from his story:

1) Rosbaud realized the significance of the problem and was afraid that the two tons of heavy water in German hands might be lost to the scientific world. He, therefore,

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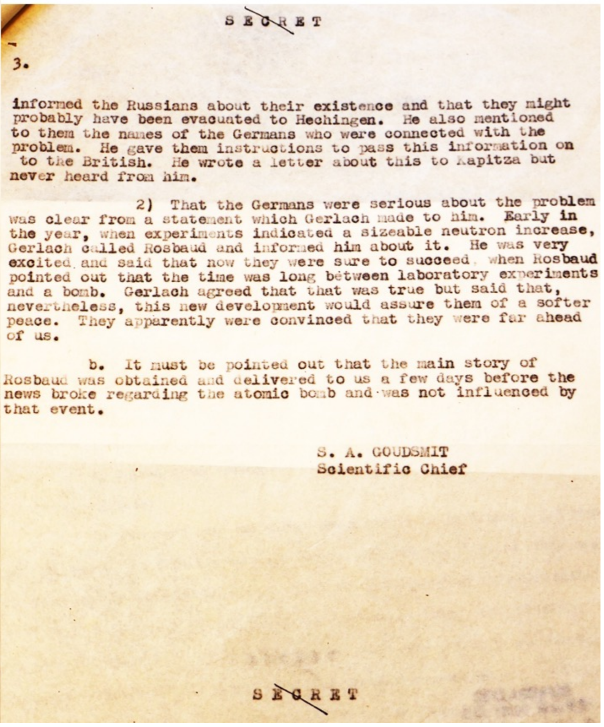

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3.

informed the Russians about their existence and that they might probably have been evacuated to Hechingen. He also mentioned to them the names of the Germans who were connected with the problem. He gave them instructions to pass this information on to the British. He wrote a letter about this to Kapitza but never heard from him.

2) That the Germans were serious about the problem was clear from a statement which Gerlach made to him. Early in the year, when experiments indicated a sizeable neutron increase, Gerlach called Rosbaud and informed him about it. He was very excited and said that now they were sure to succeed. When Rosbaud pointed out that the time was long between laboratory experiments and a bomb. Gerlach agreed that that was true but said that, nevertheless, this new development would assure them of a softer peace. They apparently were convinced that they were far ahead of us.

b. It must be pointed out that the main story of Rosbaud was obtained and delivered to us a few days before the news broke regarding the atomic bomb and was not influenced by that event.

S. A. GOUDSMIT
Scientific Chief

SECRET

**NARA RG GOUDS,
Entry UD-7420,
Box 3, Folder
"Historian's Office
Inventory Control
Job Goudsmit
Box 4 Folder 6"**

DECLASSIFIED
Authority NW87071

Figure D.561: Samuel Goudsmit to R. G. Ham. 10 August 1945 [NARA RG GOUDS, Entry UD-7420, Box 3, Folder "Historian's Office Inventory Control Job Goudsmit Box 4 Folder 6"]. "The new outbursts of the 'omniscient' Colonel Keck... are deplorable and damaging. Please do something about this situation at once... The German public opinion about the atomic bomb is as follows: They now believe that Hitler was not lying when he told them that he had a terrible weapon in store... The following TA scientists have gone to work for the Russians...: 1) Dr. Riehl from Auer... 2) von Ardenne (cyclotron expert, etc.). 3) Gustav Hertz of Siemens, outstanding physicist, Nobel Prize winner, expert on isotope separation and cyclotron construction."

J. C. Clark. 18 September 1945. Development and Use of Röntgenblitz Technique by the German Scientists during Period 1938–45. Alsos Intelligence Report KO-29365 [AFHRA Folder 170.2279E 18 SEP 1945; AFHRA B1763 frames 0252–0259. Also NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

This report is based upon the interrogation of German scientists and scientific reports recovered during the period within a few months after the cessation of hostilities in the E.T.O. Unfortunately the men who apparently did most of the research and development work on the Röntgenblitz equipment, namely Dr. Steenbeck and possibly Dr. Mühlenpfordt working under Dr. Gustav Hertz at Siemens, Berlin, had already gone to Moscow to continue their work, and were not available in Germany for interrogation. However, Dr. Thomer, now working with Prof. H. Schardin at the French Laboratory at Leichtmetall Werke, St. Louis, Alsace, was available for questioning and was well acquainted with the equipment. [...]

Dr. Thomer got his degree at Leipzig in 1936 and worked at Siemens with Dr. Hertz from 1936 until 1938 when he left to go with Prof. Schardin at the Physikalisches Institut der Luftkriegs-Akademie, Berlin-Gatow. Here he used the Röntgenblitz technique for ballistic studies. [...]

By 1941 the Forschungslaboratory acquired high vacuum metal Röntgenblitz tubes from the research laboratory #2 of Siemenswerke for use in multiple flash x-ray studies. This tube and the auxillary circuit is the type which was used for the remainder of the work carried on by Prof. Schardin's workers as well as Dr. Rudi Schall, working under Dr. Erich Schumann at the WaF (research) Division of the Waffenamt, in Berlin. [...]

The uses to which the Germans put the Röntgenblitz equipment were learned by examining captured documents and by interrogation. These applications cover (a) target cavitation produced by projectiles passing through wooden blocks and water targets, (b) the smashing of a lead bullet upon impact with various targets, (c) cavity charge phenomena studies, (d) detonation phenomena studies and (e) an interesting study of the arming of a nose fuze a short distance in front of the muzzle of the gun. With the exception of the studies on detonation of an explosive charge done by Dr. Rudi Schall, all work with the Röntgenblitz equipment was done by Schardin's group, working principally with Dr. Thomer. Only a few German documents covering the above work were available for examination by the author during the investigation of this subject, but it is believed that a complete series of the reports of both Prof. H. Schardin's and Dr. Erich Schumann's groups have been recovered and forwarded through the proper military channels for filing and examination (see Col. L. E. Simon's U.S. Ord. Dept. report).

It was, however, definitively ascertained that the experimental techniques utilized to obtain flash radiographs of cavity charges and high explosive specimens were sensibly the same as those familiar to U.S. research workers. The German scientific groups recognized the value of this technique because it was learned that at least eight more Röntgenblitz units were under construction at the Siemenswerke, Berlin.

[Erich Schumann and Hubert Schardin led groups that conducted detailed research, development, and testing programs for implosion bombs. According to this document, the United States acquired "a complete series of the reports of both Prof. H. Schardin's and Dr. Erich Schumann's groups" and followed up with interrogations of personnel from those groups for several months after the war. Can all of that information be located and declassified now?]

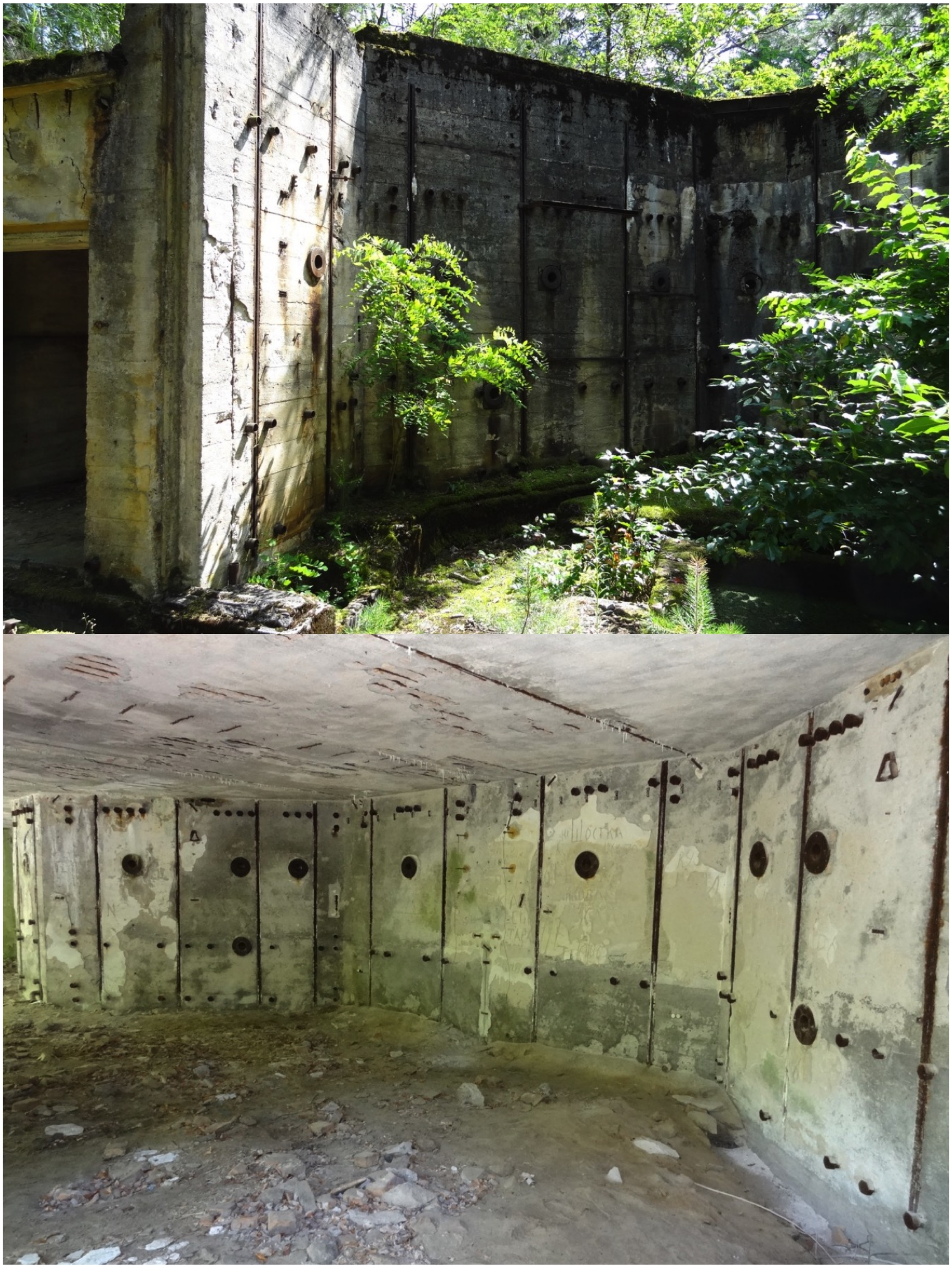

Figure D.562: Historisch-Technisches Museum Versuchsstelle Kummersdorf: Apparent testing area for implosion designs; note numerous ports for mounting diagnostic equipment.

U.S. military intelligence card entry for Erich Schumann. Undated but apparently last updated summer 1945. [NARA RG 319, Entry A1-134B, Box ??, Folder XE170590 Schumann, Erich]

Ministerial Councilor and head of the research office in the Reich War ministry: Professor at the University of Berlin, director of the Second Institute of Physics and of the Second Institute of Theoretical Physics at the University of Berlin. Ph.D. in physics; October 1933, full professor in the faculty of Natural Sciences at the University of Berlin; Special fields are physics connected with armament, especially explosion waves and acoustics. Since the late twenties in the research office of the Reich War Ministry. Chairman of the Union of the Wehrmacht-Functionaries.

Informant considers Prof. SCHUMANN “a very dangerous man who always worked on highly secret missions for the German Army. Even during the Weimar Republic students were not allowed to enter his laboratory.” Informant says that SCHUMANN is perhaps not a Nazi according to the party line, but he is a German nationalist, a pan-Germanist and entirely devoted to the German Army.

[This file is further evidence that U.S. investigators were very well aware of how important and how potentially dangerous Erich Schumann’s wartime work was.

Yet the office of Leslie Groves tried to hide this information from the public (p. 4187), and Samuel Goudsmit knowingly gave false testimony to the U.S. Senate in which he claimed that Schumann was only a “second-rate physicist” whose “main interest was the physics of piano strings” (p. 3297).]

NW 87073 DocId:33443320 Page 3

Declassified Case: NW# 87073 Date: 06-06-2024

Screened by NARA (RF) 06-06-2024 FOIA # 87073 DOCID: 33443320

Best available image

NARA RG 319,
Entry A1-134B, Box ??,
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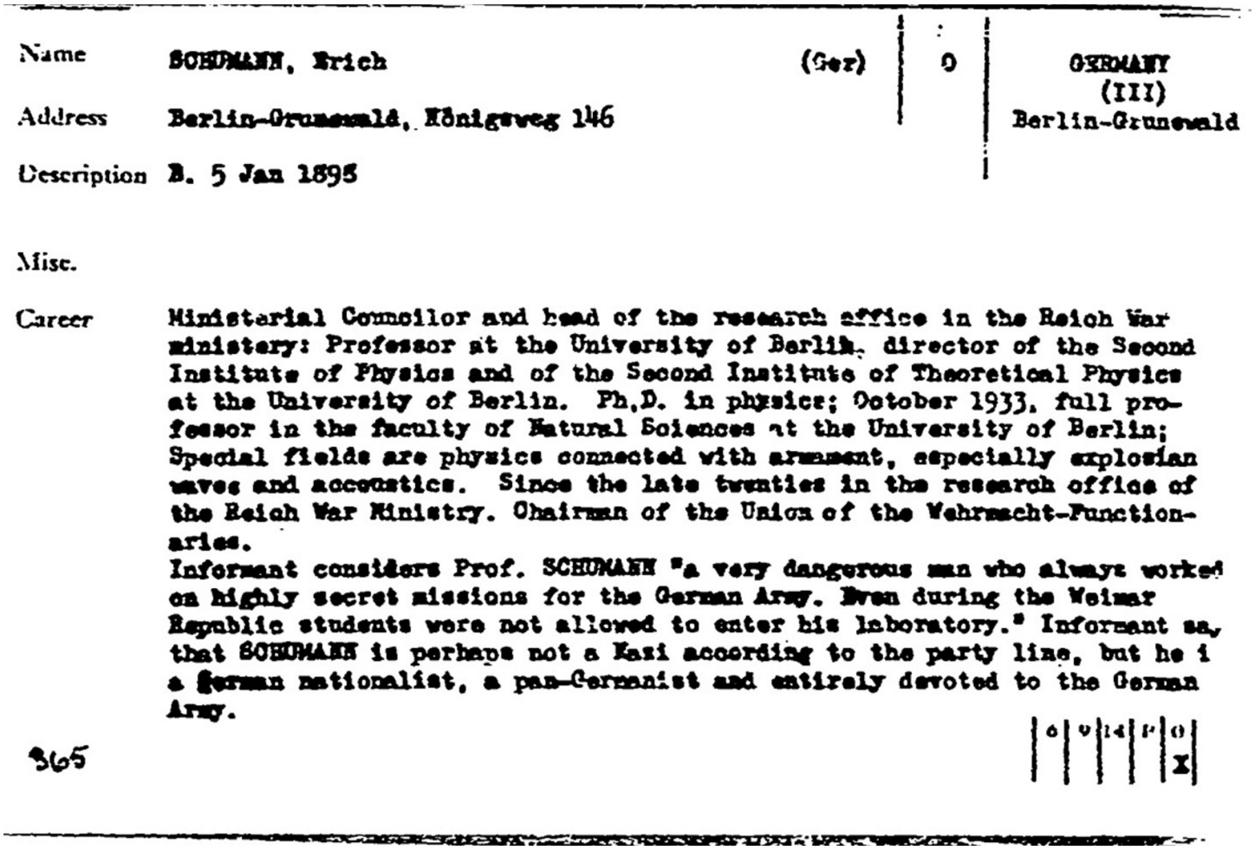
Schumann, Erich



Name SCHUMANN, Erich (Ger) 0 GERMANY (III) Berlin-Grunewald

Address Berlin-Grunewald, Königsweg 146

Description B. 5 Jan 1895

Misc.

Career Ministerial Councilor and head of the research office in the Reich War ministery: Professor at the University of Berlin, director of the Second Institute of Physics and of the Second Institute of Theoretical Physics at the University of Berlin. Ph.D. in physics; October 1933, full professor in the faculty of Natural Sciences at the University of Berlin; Special fields are physics connected with armament, especially explosion waves and accoustics. Since the late twenties in the research office of the Reich War Ministry. Chairman of the Union of the Wehrmacht-Functionaries.

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Figure D.563: U.S. military intelligence card entry for Erich Schumann. Undated but apparently last updated summer 1945. [NARA RG 319, Entry A1-134B, Box ??, Folder XE170590 Schumann, Erich]

Erwin Respondek. 6 November 1945. [NARA RG 226, Entry A1-210, Box 447, Folder WN 16162–16171]

Übersicht des Standes der wissenschaftlichen Arbeiten in Deutschland zur Atom-Bombe (bis Mai 1945)	Overview of the State of Scientific Work in Germany on the Atomic Bomb (until May 1945).
[...] Prof. Schumann äusserte etwa 1944, dass das Problem der Uran-Bombe gelöst sei. Die Bombe solle an einem Fallschirm abgeworfen werden. Die Zündvorrichtung sei in technisch einfacher Form gelöst worden. Hierzu diene eine Neutronenquelle. Prof. Schumann sagte aber zugleich, dass es bisher nicht gelungen sei, das Uran zum explosiven Spontanzerfall zu bringen. [...]	[...] Prof. Schumann stated around 1944 that the problem of the uranium bomb had been solved. The bomb should be dropped on a parachute. The ignition device was solved in a technically simple form. For this purpose, a neutron source is used. At the same time, however, Prof. Schumann said that so far it had not been possible to bring about the explosive spontaneous disintegration of uranium. [...]

[See document photos on pp. 4195–4198. Erwin Respondek (1894–1971) was a German economist who secretly passed information to the United States throughout the 1940s [Dippel 1992]. Despite the juicy title of Respondek's report, he appears to have been most familiar with the well-known basic nuclear research of the Kaiser Wilhelm Institute, to which he devoted most of the report.

However, he did include one intriguing paragraph about the development of an actual German atomic bomb. According to Respondek, the bomb:

- Involved Erich Schumann in its design, which strongly suggests that the bomb design employed shaped charges and implosion, Schumann's area of technical expertise.
- Used uranium as the fission fuel.
- Used a parachute. (This agrees with other accounts—see for example p. 4436.)
- Was intended to be dropped by an aircraft, at least up until 1944 (based on the parachute).
- Used a neutron source to initiate fission reactions at the right time. (That would be during implosion, and is consistent with the other accounts of the bomb design—see for example p. 4485.)
- Had been completed but not yet successfully tested, as of sometime in 1944. (That is consistent with the first successful test(s) being in late 1944/early 1945—see Sections D.10–D.12.)
- Was separate from and much more secret than the Kaiser Wilhelm Institute program (based on how much less Respondek knew about it).

There is also some evidence that information from Respondek led to the December 1943 Allied bombing of an important site associated with the German nuclear program [Dippel 1992, pp. 111–113]. Can more information on that incident be located in archives? Where was the site? What sort of work was actually being conducted at the site? What intelligence led to the bombing?]

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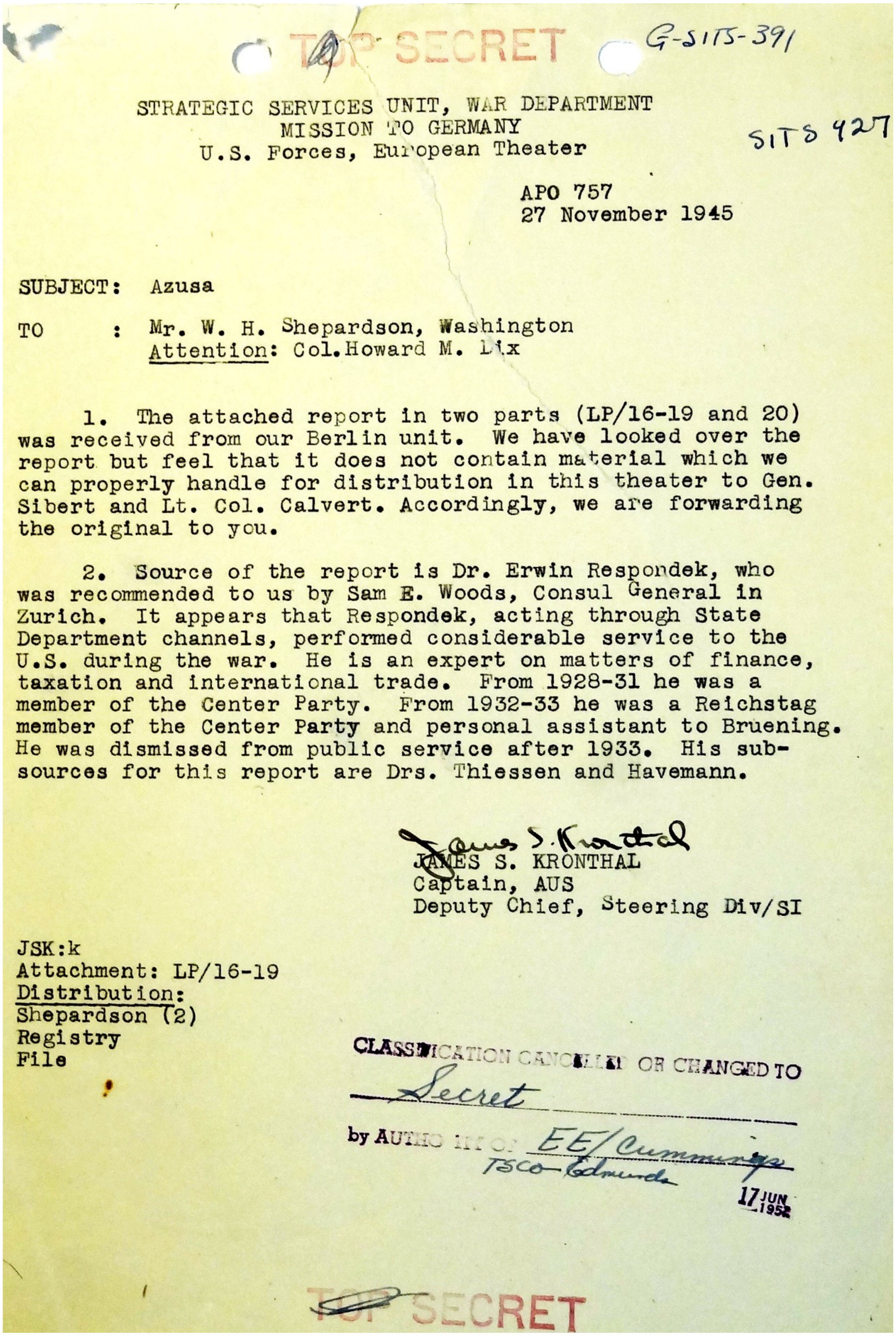

~~TOP~~ SECRET G-SITS-391

STRATEGIC SERVICES UNIT, WAR DEPARTMENT
MISSION TO GERMANY
U.S. Forces, European Theater

SITS 427

APO 757
27 November 1945

SUBJECT: Azusa

TO : Mr. W. H. Shepardson, Washington
Attention: Col.Howard M. Dix

1. The attached report in two parts (LP/16-19 and 20) was received from our Berlin unit. We have looked over the report but feel that it does not contain material which we can properly handle for distribution in this theater to Gen. Sibert and Lt. Col. Calvert. Accordingly, we are forwarding the original to you.

2. Source of the report is Dr. Erwin Respondek, who was recommended to us by Sam E. Woods, Consul General in Zurich. It appears that Respondek, acting through State Department channels, performed considerable service to the U.S. during the war. He is an expert on matters of finance, taxation and international trade. From 1928-31 he was a member of the Center Party. From 1932-33 he was a Reichstag member of the Center Party and personal assistant to Bruening. He was dismissed from public service after 1933. His sub-sources for this report are Drs. Thiessen and Havemann.

James S. Kronthal
JAMES S. KRONTHAL
Captain, AUS
Deputy Chief, Steering Div/SI

JSK:k
Attachment: LP/16-19
Distribution:
Shepardson (2)
Registry
File

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Figure D.564: James S. Kronthal to W. H. Shepardson and Howard M. Dix. 27 November 1945 [NARA RG 226, Entry A1-210, Box 447, Folder WN 16162–16171].

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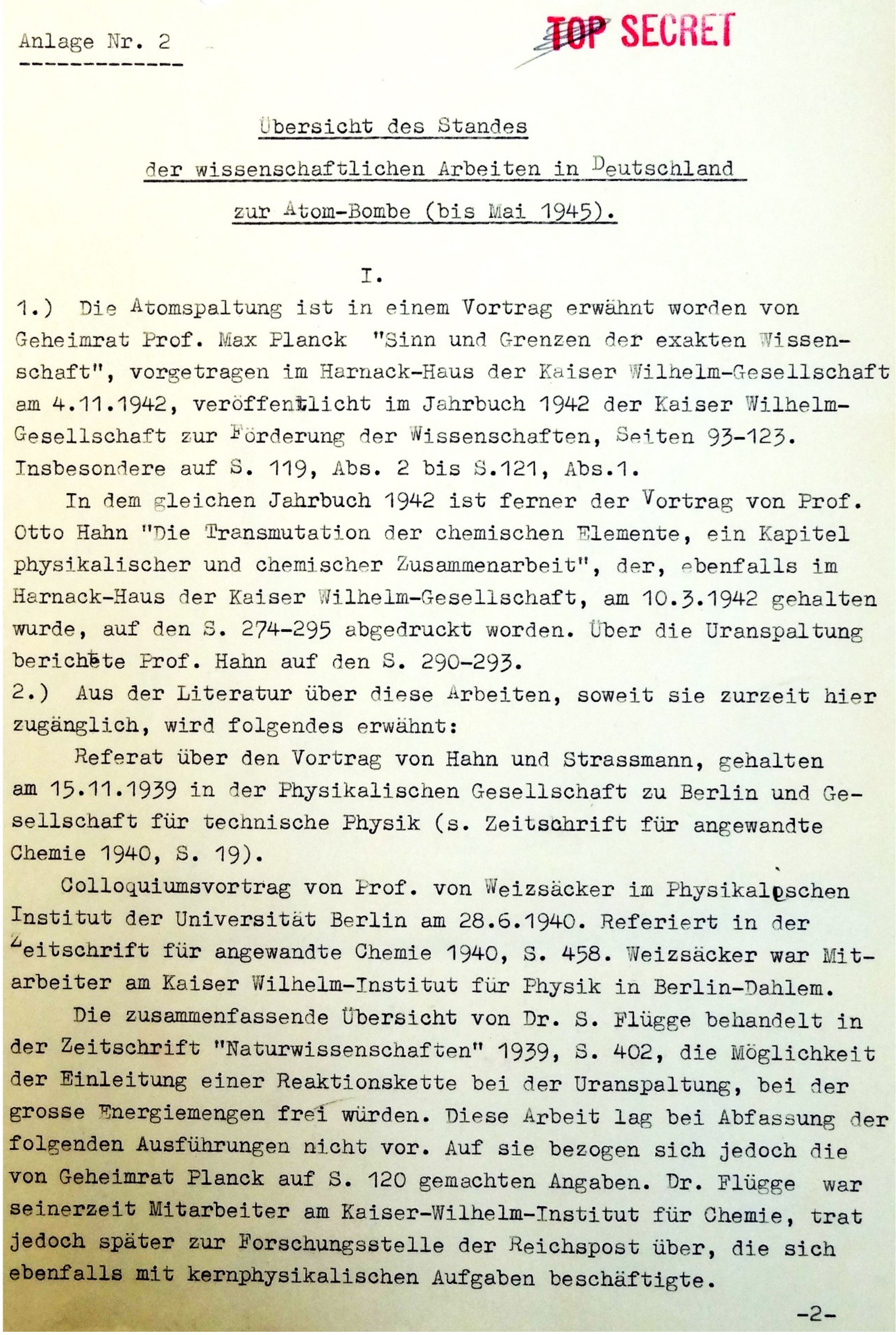

Anlage Nr. 2

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Übersicht des Standes
der wissenschaftlichen Arbeiten in Deutschland
zur Atom-Bombe (bis Mai 1945).

I.

1.) Die Atomspaltung ist in einem Vortrag erwähnt worden von Geheimrat Prof. Max Planck "Sinn und Grenzen der exakten Wissenschaft", vorgetragen im Harnack-Haus der Kaiser Wilhelm-Gesellschaft am 4.11.1942, veröffentlicht im Jahrbuch 1942 der Kaiser Wilhelm-Gesellschaft zur Förderung der Wissenschaften, Seiten 93-123. Insbesondere auf S. 119, Abs. 2 bis S.121, Abs.1.

In dem gleichen Jahrbuch 1942 ist ferner der Vortrag von Prof. Otto Hahn "Die Transmutation der chemischen Elemente, ein Kapitel physikalischer und chemischer Zusammenarbeit", der, ebenfalls im Harnack-Haus der Kaiser Wilhelm-Gesellschaft, am 10.3.1942 gehalten wurde, auf den S. 274-295 abgedruckt worden. Über die Uranspaltung berichtete Prof. Hahn auf den S. 290-293.

2.) Aus der Literatur über diese Arbeiten, soweit sie zurzeit hier zugänglich, wird folgendes erwähnt:

Referat über den Vortrag von Hahn und Strassmann, gehalten am 15.11.1939 in der Physikalischen Gesellschaft zu Berlin und Gesellschaft für technische Physik (s. Zeitschrift für angewandte Chemie 1940, S. 19).

Colloquiumsvortrag von Prof. von Weizsäcker im Physikalischen Institut der Universität Berlin am 28.6.1940. Referiert in der Zeitschrift für angewandte Chemie 1940, S. 458. Weizsäcker war Mitarbeiter am Kaiser Wilhelm-Institut für Physik in Berlin-Dahlem.

Die zusammenfassende Übersicht von Dr. S. Flügge behandelt in der Zeitschrift "Naturwissenschaften" 1939, S. 402, die Möglichkeit der Einleitung einer Reaktionskette bei der Uranspaltung, bei der grosse Energiemengen frei würden. Diese Arbeit lag bei Abfassung der folgenden Ausführungen nicht vor. Auf sie bezogen sich jedoch die von Geheimrat Planck auf S. 120 gemachten Angaben. Dr. Flügge war seinerzeit Mitarbeiter am Kaiser-Wilhelm-Institut für Chemie, trat jedoch später zur Forschungsstelle der Reichspost über, die sich ebenfalls mit kernphysikalischen Aufgaben beschäftigte.

-2-

Figure D.565: Erwin Respondek. 6 November 1945 [NARA RG 226, Entry A1-210, Box 447, Folder WN 16162–16171].

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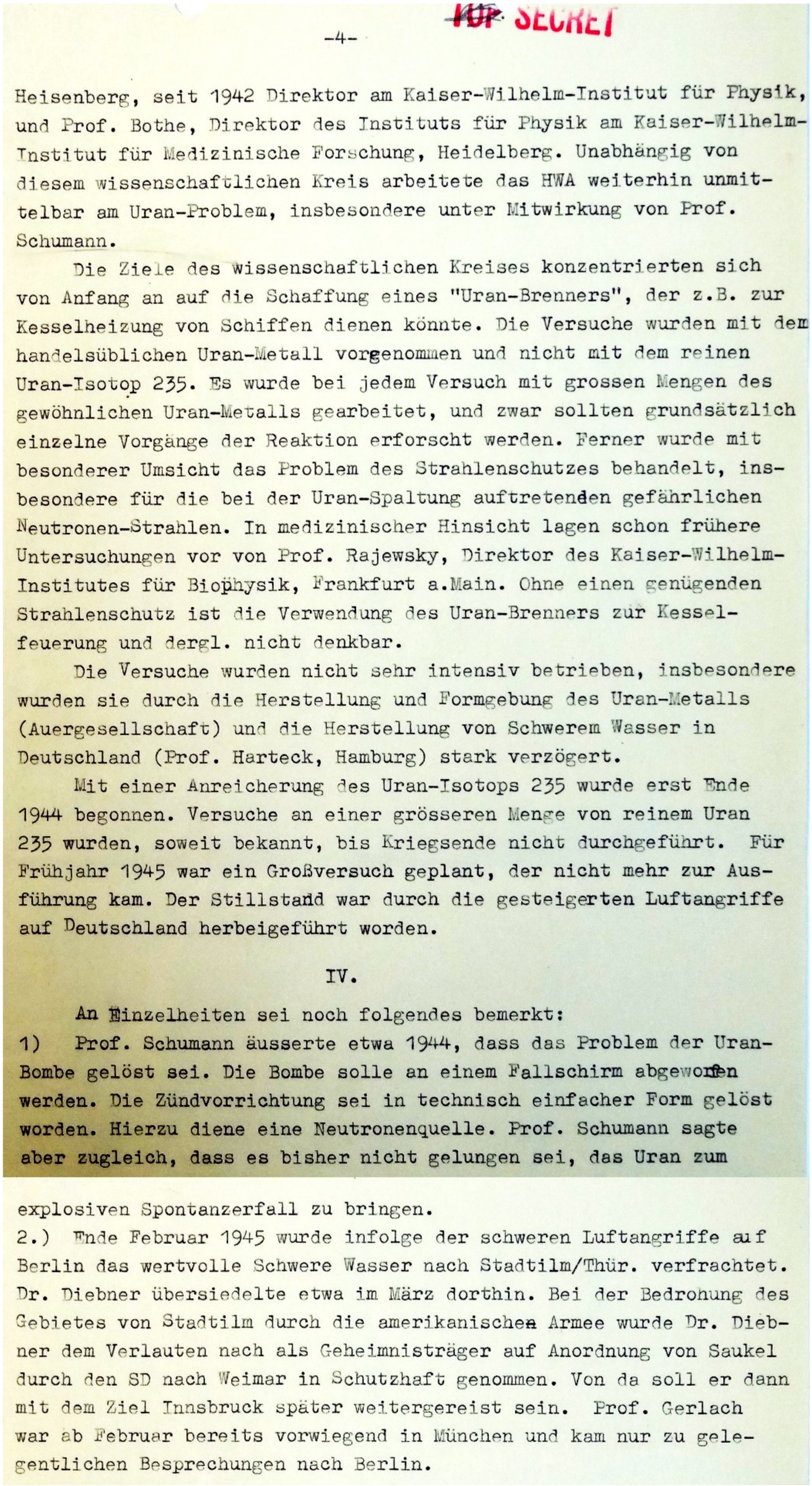

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Heisenberg, seit 1942 Direktor am Kaiser-Wilhelm-Institut für Physik, und Prof. Bothe, Direktor des Instituts für Physik am Kaiser-Wilhelm-Institut für Medizinische Forschung, Heidelberg. Unabhängig von diesem wissenschaftlichen Kreis arbeitete das HWA weiterhin unmittelbar am Uran-Problem, insbesondere unter Mitwirkung von Prof. Schumann.

Die Ziele des wissenschaftlichen Kreises konzentrierten sich von Anfang an auf die Schaffung eines "Uran-Brenners", der z.B. zur Kesselheizung von Schiffen dienen könnte. Die Versuche wurden mit dem handelsüblichen Uran-Metall vorgenommen und nicht mit dem reinen Uran-Isotop 235. Es wurde bei jedem Versuch mit grossen Mengen des gewöhnlichen Uran-Metalls gearbeitet, und zwar sollten grundsätzlich einzelne Vorgänge der Reaktion erforscht werden. Ferner wurde mit besonderer Umsicht das Problem des Strahlenschutzes behandelt, insbesondere für die bei der Uran-Spaltung auftretenden gefährlichen Neutronen-Strahlen. In medizinischer Hinsicht lagen schon frühere Untersuchungen vor von Prof. Rajewsky, Direktor des Kaiser-Wilhelm-Institutes für Biophysik, Frankfurt a.Main. Ohne einen genügenden Strahlenschutz ist die Verwendung des Uran-Brenners zur Kesselfeuerung und dergl. nicht denkbar.

Die Versuche wurden nicht sehr intensiv betrieben, insbesondere wurden sie durch die Herstellung und Formgebung des Uran-Metalls (Auergesellschaft) und die Herstellung von Schwerem Wasser in Deutschland (Prof. Harteck, Hamburg) stark verzögert.

Mit einer Anreicherung des Uran-Isotops 235 wurde erst Ende 1944 begonnen. Versuche an einer grösseren Menge von reinem Uran 235 wurden, soweit bekannt, bis Kriegsende nicht durchgeführt. Für Frühjahr 1945 war ein Großversuch geplant, der nicht mehr zur Ausführung kam. Der Stillstand war durch die gesteigerten Luftangriffe auf Deutschland herbeigeführt worden.

IV.

An Einzelheiten sei noch folgendes bemerkt:

1) Prof. Schumann äusserte etwa 1944, dass das Problem der Uran-Bombe gelöst sei. Die Bombe solle an einem Fallschirm abgeworfen werden. Die Zündvorrichtung sei in technisch einfacher Form gelöst worden. Hierzu diene eine Neutronenquelle. Prof. Schumann sagte aber zugleich, dass es bisher nicht gelungen sei, das Uran zum explosiven Spontanzerfall zu bringen.

2.) Ende Februar 1945 wurde infolge der schweren Luftangriffe auf Berlin das wertvolle Schwere Wasser nach Stadtilm/Thür. verfrachtet. Dr. Diebner übersiedelte etwa im März dorthin. Bei der Bedrohung des Gebietes von Stadtilm durch die amerikanischen Armee wurde Dr. Diebner dem Verlauten nach als Geheimnisträger auf Anordnung von Saukel durch den SD nach Weimar in Schutzhaft genommen. Von da soll er dann mit dem Ziel Innsbruck später weitergereist sein. Prof. Gerlach war ab Februar bereits vorwiegend in München und kam nur zu gelegentlichen Besprechungen nach Berlin.

Figure D.566: Erwin Respondek. 6 November 1945 [NARA RG 226, Entry A1-210, Box 447, Folder WN 16162–16171].

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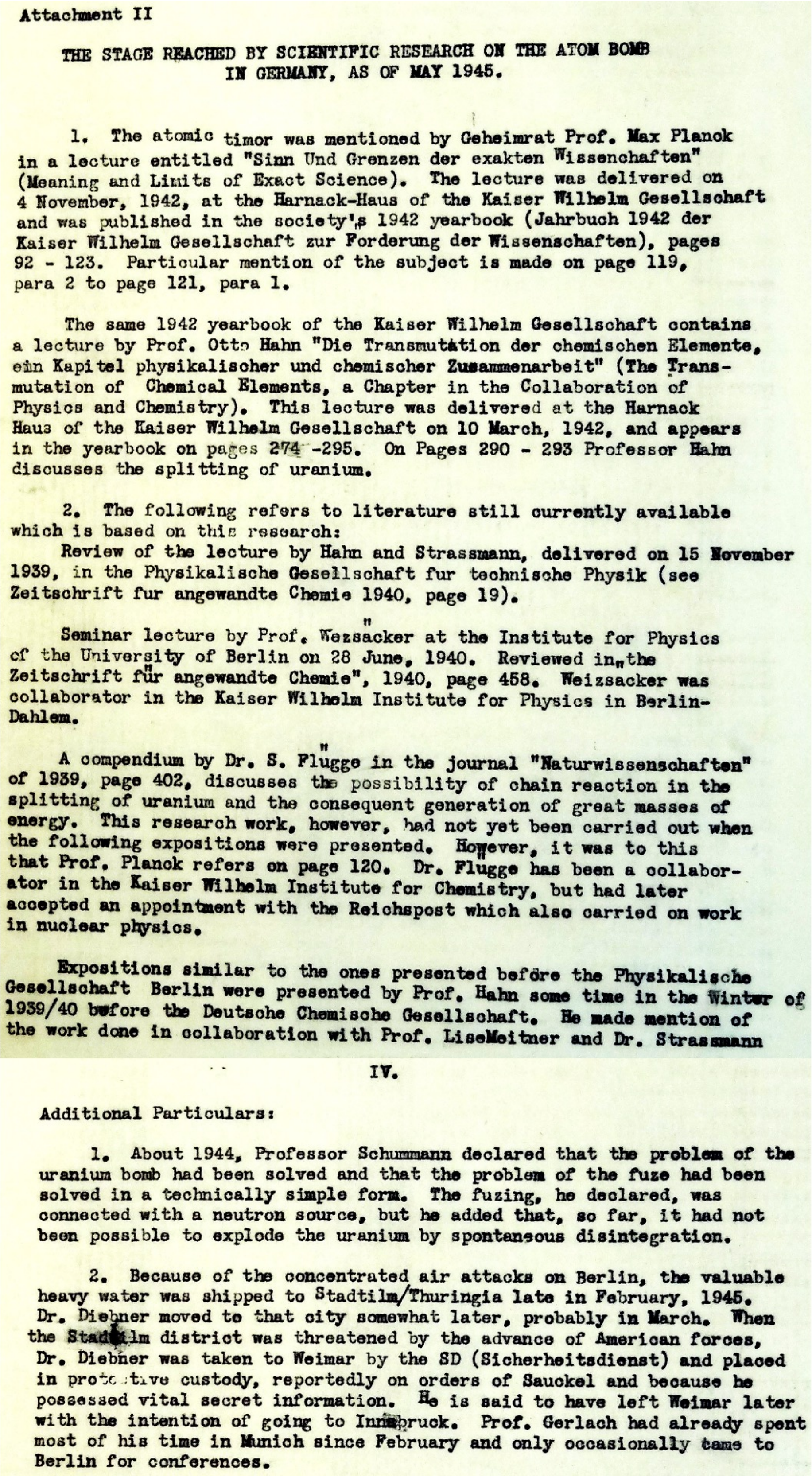

Attachment II

THE STAGE REACHED BY SCIENTIFIC RESEARCH ON THE ATOM BOMB
IN GERMANY, AS OF MAY 1945.

1. The atomic timor was mentioned by Geheimrat Prof. Max Planck in a lecture entitled "Sinn Und Grenzen der exakten Wissenchaften" (Meaning and Limits of Exact Science). The lecture was delivered on 4 November, 1942, at the Harnack-Haus of the Kaiser Wilhelm Gesellschaft and was published in the society's 1942 yearbook (Jahrbuch 1942 der Kaiser Wilhelm Gesellschaft zur Forderung der Wissenschaften), pages 92 - 123. Particular mention of the subject is made on page 119, para 2 to page 121, para 1.

The same 1942 yearbook of the Kaiser Wilhelm Gesellschaft contains a lecture by Prof. Otto Hahn "Die Transmutation der chemischen Elemente, ein Kapitel physikalischer und chemischer Zusammenarbeit" (The Transmutation of Chemical Elements, a Chapter in the Collaboration of Physics and Chemistry). This lecture was delivered at the Harnack Haus of the Kaiser Wilhelm Gesellschaft on 10 March, 1942, and appears in the yearbook on pages 274 -295. On Pages 290 - 293 Professor Hahn discusses the splitting of uranium.

2. The following refers to literature still currently available which is based on this research:
Review of the lecture by Hahn and Strassmann, delivered on 15 November 1939, in the Physikalische Gesellschaft fur technische Physik (see Zeitschrift fur angewandte Chemie 1940, page 19).

Seminar lecture by Prof. Wezsäcker at the Institute for Physics of the University of Berlin on 28 June, 1940. Reviewed in "the Zeitschrift für angewandte Chemie", 1940, page 458. Weizsacker was collaborator in the Kaiser Wilhelm Institute for Physics in Berlin-Dahlem.

A compendium by Dr. S. Flügge in the journal "Naturwissenschaften" of 1939, page 402, discusses the possibility of chain reaction in the splitting of uranium and the consequent generation of great masses of energy. This research work, however, had not yet been carried out when the following expositions were presented. However, it was to this that Prof. Planck refers on page 120. Dr. Flügge has been a collaborator in the Kaiser Wilhelm Institute for Chemistry, but had later accepted an appointment with the Reichspost which also carried on work in nuclear physics.

Expositions similar to the ones presented before the Physikalische Gesellschaft Berlin were presented by Prof. Hahn some time in the Winter of 1939/40 before the Deutsche Chemische Gesellschaft. He made mention of the work done in collaboration with Prof. LiseMeitner and Dr. Strassmann

IV.

Additional Particulars:

1. About 1944, Professor Schummann declared that the problem of the uranium bomb had been solved and that the problem of the fuze had been solved in a technically simple form. The fuzing, he declared, was connected with a neutron source, but he added that, so far, it had not been possible to explode the uranium by spontaneous disintegration.

2. Because of the concentrated air attacks on Berlin, the valuable heavy water was shipped to Stadtilm/Thuringia late in February, 1945. Dr. Diebner moved to that city somewhat later, probably in March. When the Stadtilm district was threatened by the advance of American forces, Dr. Diebner was taken to Weimar by the SD (Sicherheitsdienst) and placed in protective custody, reportedly on orders of Sauckel and because he possessed vital secret information. He is said to have left Weimar later with the intention of going to Innsbruck. Prof. Gerlach had already spent most of his time in Munich since February and only occasionally came to Berlin for conferences.

Figure D.567: Erwin Respondek. 6 November 1945 [NARA RG 226, Entry A1-210, Box 447, Folder WN 16162–16171].

Erich Schumann. 2 October 1940. Unclassified draft article on explosives research for popular publication [Bundesarchiv Militärarchiv Freiburg N822/17].

[Erich Schumann (German, 1898–1985) was a high-ranking physicist in the wartime German Army Ordnance Office. He was an expert on conventional explosives and on using shaped explosive charges in a wide variety of geometries for different purposes. At the end of the war, almost all of his wartime papers were destroyed by the Germans or captured and classified by the Allies. However, there is strong evidence from multiple postwar sources that Schumann designed and demonstrated large, highly sophisticated, spherical implosion bombs during the war. If furnished with fission fuel in the center, such spherical implosion designs would have been quite suitable for nuclear weapons.

One of the few surviving and relevant wartime documents is this 2 October 1940 draft article on explosives research that Schumann was preparing for publication. Because the article was intended for unclassified publication, it omitted or downplayed many important aspects. Yet it did make clear that no later than September 1940, Schumann and his coworkers:

- Knew that nuclear explosives could potentially be a million times more powerful than chemical explosives (explosive energies up to megatons of TNT equivalent).
- Wanted to use the shock waves produced by chemical explosives to produce the highest possible pressures and temperatures (which immediately suggests a spherical implosion, from basic physical principles).
- Were keenly interested in using (implosive) shock waves from chemical explosives to trigger nuclear reactions.
- Were trying to make the production of suitable shock waves highly precise and "mathematically controlled."
- Could not discuss the details in an unclassified article "because of the significance of special arrangements in terms of weapons technology."

See pp. 4204–4206 for photographs of some pages from this document.]

[...] Der Zustand der Detonation ist dadurch gekennzeichnet, dass die Aktivierungsenergie dem Sprengstoff durch eine Stosswelle zugeführt wird, wobei die beim Zerfall des Stoffes freiwerdende Energie das Fortschreiten der Stosswelle unterstützt. Es ist leicht einzusehen, dass bei der gegenseitigen Kopplung von Wellenausbreitung und Sprengstoffzerfall sich in einem genügend ausgedehnten Sprengkörper ein stationärer Zustand herausbildet, der für die gesamten detonativen Erscheinungen charakteristisch ist.

Die Fortpflanzungsgeschwindigkeit dieser stationären Zersetzung heisst Detonationsgeschwindigkeit. Da diese verhältnismässig einfach messbar ist, liegt für sie ein umfangreiches Messmaterial vor, das zum wertvollsten Besitz der experimentellen Sprengstoffphysik gehört, stellt doch die Detonationsgeschwindigkeit die einzige wirklich physikalische Messgrösse dar, mit der heute ein Sprengstoff charakterisiert werden kann.

[...] The state of detonation is characterized by the fact that the activation energy is supplied to the explosive by a shock wave, whereby the energy released during the decay of the substance supports the progression of the shock wave. It is easy to see that in a sufficiently large explosive device, when the wave propagation and explosive decay are coupled together, a steady state is formed which is characteristic of all detonative phenomena.

The propagation velocity of this stationary decomposition is called the detonation velocity. Since it is relatively easy to measure, there is extensive measured information available for it, which is one of the most valuable possessions of experimental explosives physics, since the detonation velocity is the only really physical major measurement which can be used today to characterize an explosive.

Die geschilderten energetischen Verhältnisse im molekularen Verband der Sprengstoffe sind grundsätzlich die gleichen, wie wir sie vom korpuskularen Verband des Atomkerns kennen. Obgleich beim Kernzerfall eine sehr grosse Energie frei wird, besitzt der Atomkern doch eine grosse Stabilität, weil zur Einleitung des Zerfalls eine erhebliche Aktivierungsarbeit geleistet werden muss. Die heute möglichen Kernzertrümmerungen entsprechen bei diesem Vergleich, der sich nur auf die qualitativen energetischen Verhältnisse erstreckt, vollständig dem stillen Zerfall von Sprengstoffmolekülen. Da die Kernenergien den chemischen Bindungsenergien, aus denen die Sprengstoffe ihre Leistungsfähigkeit schöpfen, um mindestens 6 Grössenordnungen überlegen sind, würde durch die Kernreaktionen die Möglichkeit von Sprengstoffen unvorstellbar grosser Brisanz gegeben sein, wenn es gelingen würde, die Kernreaktion detonativ, d.h. durch Stosswellen, auszulösen. Ganz abgesehen von der geschichtlich einschneidenden Bedeutung einer solchen Möglichkeit, einen Stoff von wirklich gigantischer Zerstörungskraft in menschliche Hände zu geben, würden wir damit die Materie unter thermodynamischen Bedingungen vorzuliegen haben, wie sie sonst nur an ganz wenigen Stellen des Universums vorkommen. Fraglos wäre der kernreaktionäre Sprengstoff physikalische Realität, wenn es gelänge, eine Stosswelle genügender Intensität zu erzeugen, die einen Kernzerfall einleiten könnte. Da jedoch selbst bei den schwereren, am wenigsten stabilen Atomen die Aktivierungsenergie noch nach Millionenvolt gemessen wird, besitzen wir keine Möglichkeit, eine solch intensiv Stosswelle zu erzeugen. Es fehlt bei den Kernreaktionen eben die Abstufung der Aktivierungsarbeiten, wie sie bei den Sprengstoffen von den Initial- bis zu den Sicherheitssprengstoffen gegeben ist; durch diese ist es möglich, durch fast beliebig kleine Impulse über die Initialstoffe äusserst stabile chemische Verbindungen zum detonativen Zerfall zu bringen. [...]

The described energetic conditions in the molecular bond of explosives are basically the same as we know them from the nuclear bond of the atomic nucleus. Although a very large amount of energy is released during nuclear disintegration, the atomic nucleus has great stability, because a considerable amount of activation work must be done to initiate disintegration. In this comparison, which only covers the qualitative energetic conditions, the nuclear disintegration possible today corresponds completely to the simple disintegration of explosive molecules. Since nuclear energies are at least 6 orders of magnitude greater than the chemical binding energies from which explosives derive their power, nuclear reactions would be unimaginably explosive if it were possible to trigger the nuclear reaction via detonations, i.e. by shock waves. Quite apart from the historically far-reaching significance of such a possibility of putting a substance of truly gigantic destructive power into human hands, we would then be able to produce matter under thermodynamic conditions that otherwise occur only in very few places in the universe. There is no doubt that the nuclear-reactive explosive would be a physical reality if it were possible to generate a shock wave of sufficient intensity to initiate nuclear disintegration. However, since the activation energy of even the heaviest, least stable atoms is still measured in millions of volts, we have no way of generating such an intense shock wave. The nuclear reactions lack the gradation of activation energy that is present in explosives, from early explosives to safety explosives; this makes it possible to cause extremely stable chemical compounds to undergo detonative decay by means of almost arbitrarily small impulses via the initial substances. [...]

Für die Sprengwirkung sind nun nicht allein die thermodynamischen Zustandsgrössen an der Unstetigkeitsstelle, die die Detonationsfront kennzeichnet, massgebend, sondern in entscheidendem Masse ihr weiterer räumlicher Verlauf. Für die Berechnung von räumlichen Feldern der in den Schwaden herrschenden Zustandsgrössen liegen jedoch keine genügenden theoretischen Grundlagen vor. Glücklicherweise liefert nun die Röntgenblitztechnik auf experimentellem Wege den Feldverlauf einer der wichtigsten Zustandsgrössen, nämlich der Gasdichte der Schwaden. Dadurch, dass der Dichtesprung an der Detonationsfront durch die Röntgenblitzmethode der Messung zugänglich ist, erhält man nicht nur einen Einblick in der Zerfallsprozess, sondern durch den weiteren räumlichen Dichteverlauf auch in die für die Wirkung entscheidenden Schwadenströmungserscheinungen. Das Arbeitsvermögen der Schwaden ist nämlich nicht allein durch den Drucksprung in der Detonationsfront bestimmt, sondern wesentlich durch den zeitlichen Druckverlauf an der Sprengstoffoberfläche. Dieser ist jedoch durch die Strömungsvorgänge der Schwaden gegeben, die sich auf Grund von Röntgenblitzaufnahmen verfolgen lassen. Fraglos werden sich die thermodynamischen Kenntnisse, die zu einer Berechnung der Strömungsvorgänge bei den in den Schwaden vorliegenden Drucken von über 100 000 atm und Gasdichten in der Grössenordnung derjenigen fester Körper bisher fehlten, aus den nach der Röntgenblitzmethode gewonnenen experimentellen Ergebnissen gewinnen lassen. Damit dürfte die Einführung der Röntgenblitzmethode in die Sprengstoffphysik, die ebenfalls meinem Institute entstammt1), über den engeren Rahmen der Sprengstoffforschung hinaus für die gesamte Physik der Materie bei extremen Bedingungen von fruchttragender Bedeutung sein.

For the blast effect, not only the thermodynamic state variables at the discontinuity point, which characterizes the detonation front, are decisive, but also to a decisive extent its further spatial course. However, there is no sufficient theoretical basis for the calculation of spatial fields of the state variables prevailing in the windrows. Fortunately, the X-ray flash technique now provides the field progression of one of the most important state variables, namely the gas density of the plume, by experimental means. Since the density jump at the detonation front is accessible by the X-ray flash method of measurement, one does not only get an insight in the disintegration process, but also, through the further spatial density course, into the vapor flow phenomena which are decisive for the effect. The working capacity of the vapors is not only determined by the pressure jump in the detonation front, but essentially by the pressure curve over time at the surface of the explosive. However, this is given by the flow processes of the vapors, which can be followed on the basis of X-ray flash photographs. There is no doubt that the experimental results obtained using the X-ray flash method will provide the thermodynamic knowledge needed to calculate the flow processes at pressures of over 100,000 atm and gas densities of the order of magnitude of those of solid bodies in the vapors. Thus, the introduction of the X-ray flash method into explosives physics, which also originates from my institute1), should be of fruitful importance beyond the narrower framework of explosives research for the entire physics of matter under extreme conditions.

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1) Eine sprengstoffphysikalische Röntgenblitzarbeit wird erstmalig in dem vorliegenden Heft veröffentlicht (Arbeit Schall)

1) An X-ray flash study on the physics of explosives is published for the first time in this issue (work of Schall)

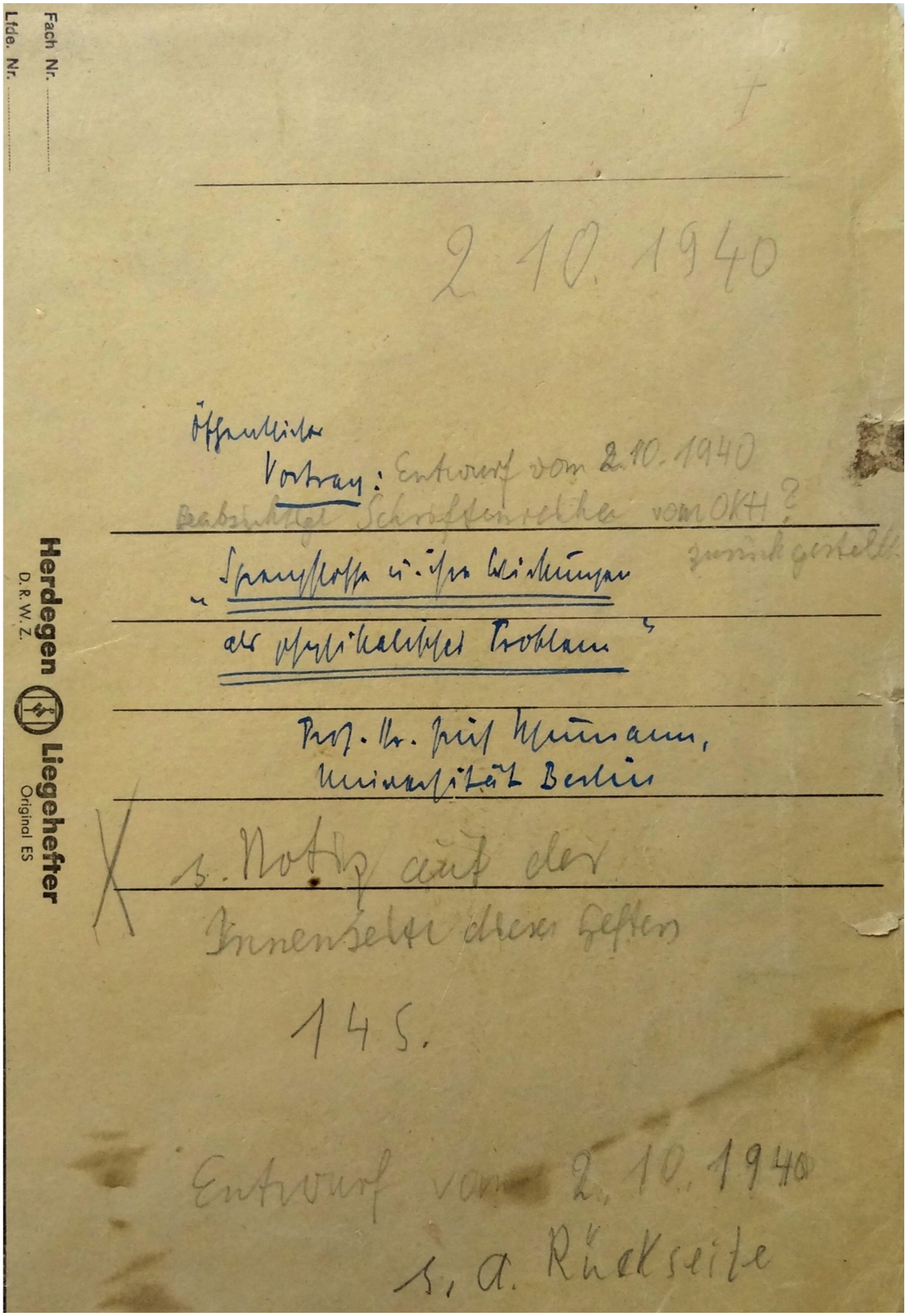
[...] Die soeben bei der Erläuterung des Brisanzbegriffes geäusserten Gedanken deuten bereits eine Theorie der gesamten Sprengstoffwirkung an. Eine solche allgemeine Theorie hat jedoch nicht nur die Vorgänge an der Sprengstoffoberfläche selbst, sondern auch Einwirkungen auf weiter entfernt liegende Punkte zu erfassen. Als Ursache solcher mittelbarer Sprengstoffwirkungen kommen neben der direkten Schwadeneinwirkung die Stosswelle im an den Sprengstoff angrenzenden Medium oder an der Sprengstoffoberfläche beschleunigte und dann ballistisch wirkende Materialteile in Betracht. Die bei den je nach der beabsichtigten Wirkung verschiedenen Anordnungen der Sprengobjekte auftretenden Fragen hier näher zu erörtern, verbietet sich bei der waffentechnischen Bedeutung spezieller Anordnungen von selbst. Auch bei mittelbaren Wirkungen werden die Vorgänge an der Sprengstoffoberfläche als in jedem Falle entscheidende Kraftquelle Ausgangspunkt weiterer Untersuchungen sein müssen.

Das Ergebnis der vorstehenden Überlegungen kann dahin zusammengefasst werden, dass Wege aufgezeigt und Untersuchungsmethoden angegeben werden, die detonativen Erscheinungen in den allgemeinen Rahmen der Physik einzuordnen. Eine solche Behandlung von Sprengstofffragen nach rein physikalischen Gesichtspunkten hat die Schaffung physikalischer Messmethoden für die die Wirkung und Handhabung bestimmenden Grössen zur notwendigen primären Folge. Die weitere Verfolgung dieser Methoden muss zu einer allgemeinen Theorie der Sprengwirkungen führen, die Ablauf und Auswirkung jeder Sprenganordnung rechnerisch zu beherrschen erlaubt und damit der Sprengtechnik wertvollste Unterlagen schafft. Rückwirkend auf die allgemeine Physik werden die sprengstoffphysikalischen Ergebnisse wieder dieser neue Erkenntnisse bringen, liegt doch im Detonationsvorgang die Materie unter Bedingungen vor, wie sie bei anderen physikalischen Erscheinungen experimentell nicht zu verwirklichen sind.

[...] The thoughts just expressed in the explanation of the explosive concept already suggest a theory of the entire effect of explosives. However, such a general theory must not only cover the processes on the surface of the explosive itself, but also effects at points further away. In addition to the direct effect of vapor, the cause of such indirect explosive effects can be the shock wave in the medium adjacent to the explosive or on the explosive surface, which accelerates and then causes ballistically acting matter components. The questions arising from the different arrangements of the explosives depending on the intended effect cannot be discussed here in detail because of the significance of special arrangements in terms of weapons technology. Even in the case of indirect effects, the processes on the surface of the explosives, as the decisive source of power in any case, will have to be the starting point for further investigations.

The result of the above considerations can be summarized as showing ways and indicating investigation methods to classify the detonative phenomena within the general framework of physics. Such a treatment of explosives issues from a purely physical point of view has the necessary primary consequence of creating physical measuring methods for the variables determining the effect and handling. The further pursuit of these methods must lead to a general theory of blasting effects which allows the sequence and effects of each blasting arrangement to be controlled mathematically and thus provides the blasting technique with valuable documentation. Retrospectively on the general physics, the results of blasting physics will again bring new insights, since in the detonation process, matter is present under conditions that cannot be experimentally realized in other physical phenomena.

Bundesarchiv Militärarchiv Freiburg N822/17. Erich Schumann. 2 October 1940.
Unclassified draft article on explosives research for popular publication.



Fach Nr. ....
Lfde. Nr. ....

2. 10. 1940

Öffentlicher
Vortrag: Entwurf vom 2.10.1940
beabsichtigte Schriftenreihe vom OKH?
zurückgestellt

„Sprengstoffe u. ihre Wirkungen
als physikalisches Problem“

Prof. Dr. Erich Schumann,
Universität Berlin

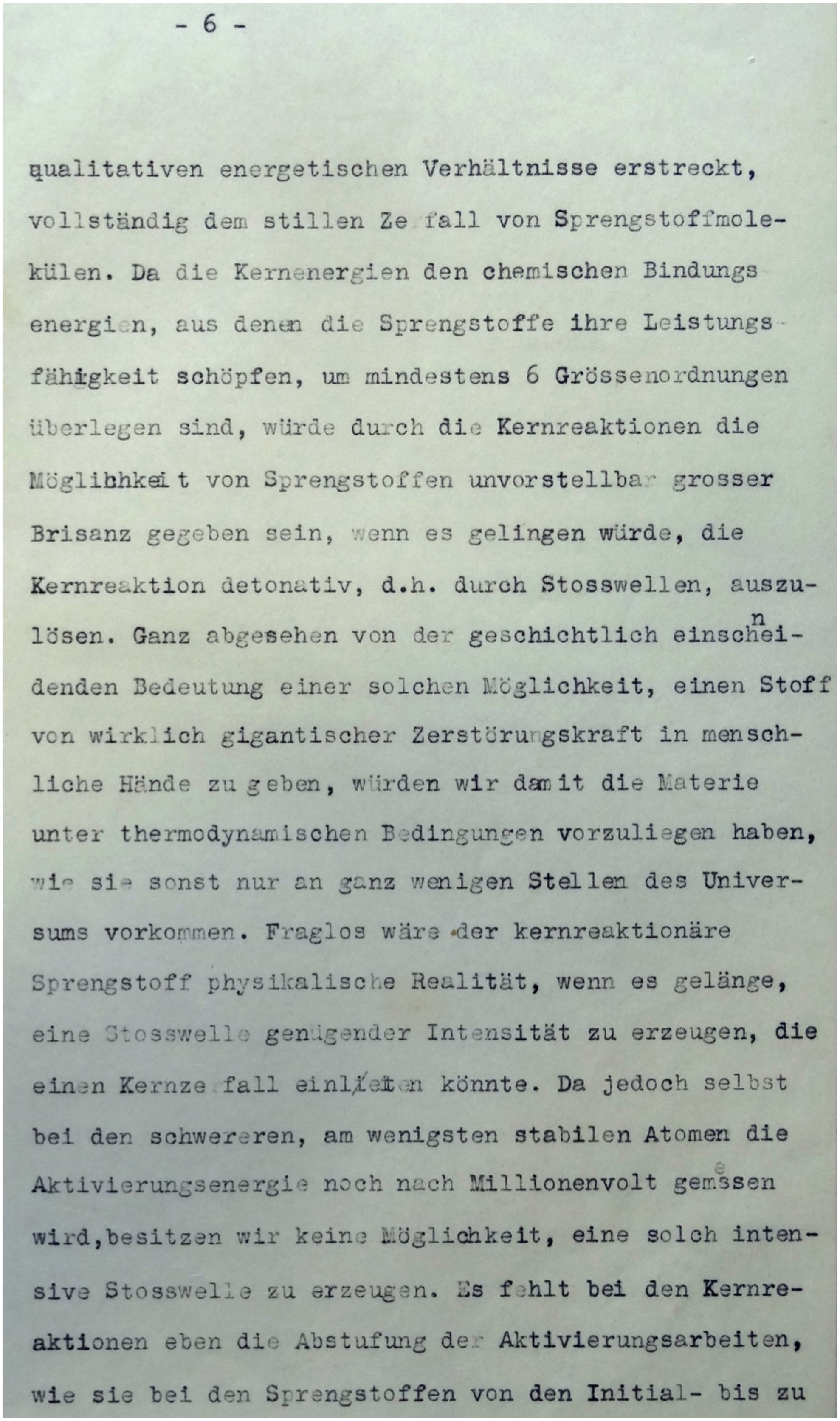
s. Notiz auf der
Innenseite dieses Heftes

14 S.

Entwurf vom 2. 10. 1940
s. a. Rückseite

Herdegen Liegehefter
D.R.W.Z. Original ES

Figure D.568: Pages from Erich Schumann's 2 October 1940 unclassified draft article on explosives research, intended for popular publication but never published, mentioning an ongoing German military program on nuclear bombs using implosion [Bundesarchiv Militärarchiv Freiburg N822/17].



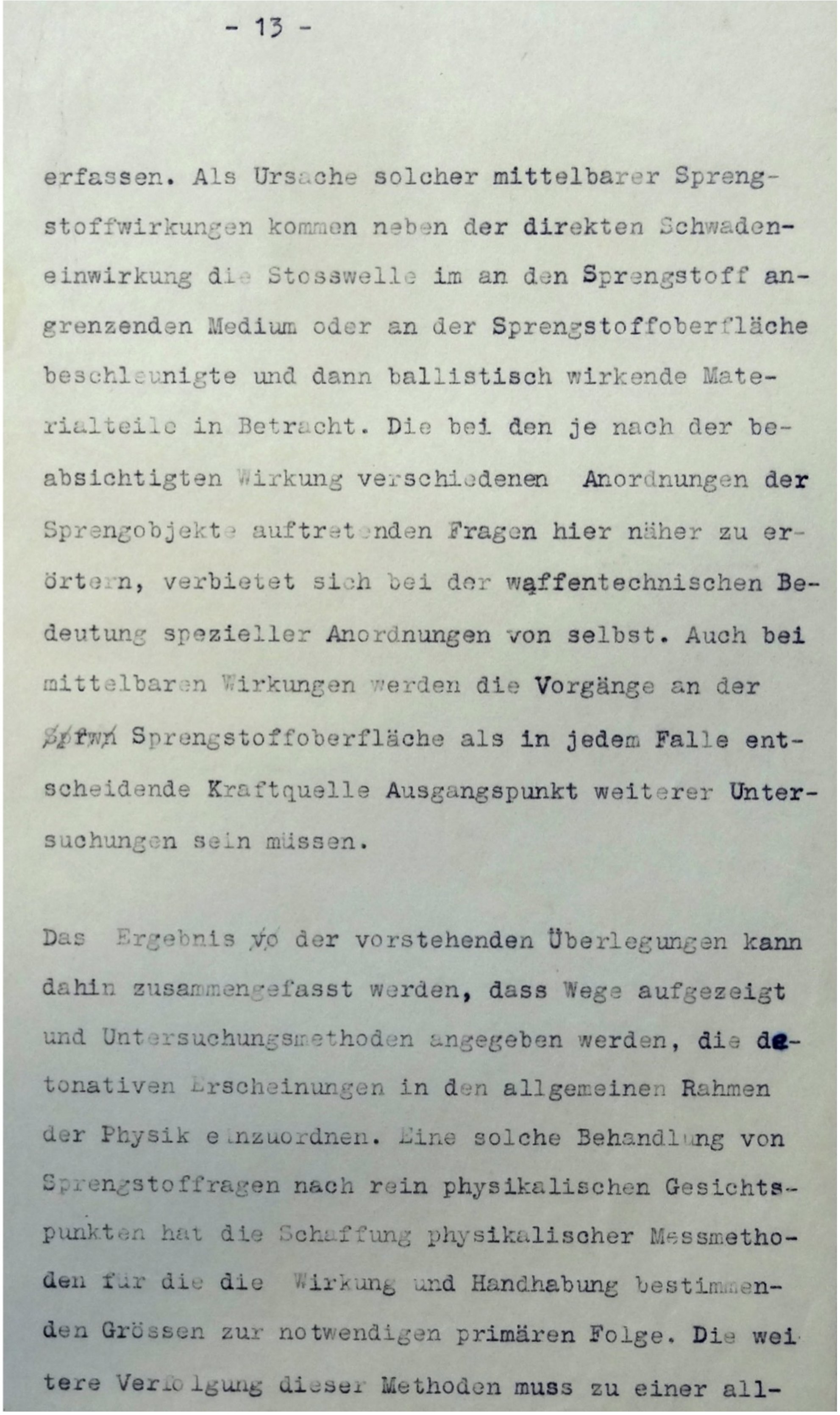
- 6 -

qualitativen energetischen Verhältnisse erstreckt, vollständig dem stillen Zerfall von Sprengstoffmolekülen. Da die Kernenergien den chemischen Bindungsenergien, aus denen die Sprengstoffe ihre Leistungsfähigkeit schöpfen, um mindestens 6 Grössenordnungen überlegen sind, würde durch die Kernreaktionen die Möglihhkeit von Sprengstoffen unvorstellbar grosser Brisanz gegeben sein, wenn es gelingen würde, die Kernreaktion detonativ, d.h. durch Stosswellen, auszulösen. Ganz abgesehen von der geschichtlich einschneidenden Bedeutung einer solchen Möglichkeit, einen Stoff von wirklich gigantischer Zerstörungskraft in menschliche Hände zu geben, würden wir damit die Materie unter thermodynamischen Bedingungen vorzuliegen haben, wie sie sonst nur an ganz wenigen Stellen des Universums vorkommen. Fraglos wäre der kernreaktionäre Sprengstoff physikalische Realität, wenn es gelänge, eine Stosswelle genügender Intensität zu erzeugen, die einen Kernzerfall einleiten könnte. Da jedoch selbst bei den schwereren, am wenigsten stabilen Atomen die Aktivierungsenergie noch nach Millionenvolt gemessen wird, besitzen wir keine Möglichkeit, eine solch intensive Stosswelle zu erzeugen. Es fehlt bei den Kernreaktionen eben die Abstufung der Aktivierungsarbeiten, wie sie bei den Sprengstoffen von den Initial- bis zu

Bundesarchiv Militärarchiv Freiburg N822/17. Erich Schumann. 2 October 1940.
Unclassified draft article on explosives research for popular publication.

Figure D.569: Pages from Erich Schumann's 2 October 1940 unclassified draft article on explosives research, intended for popular publication but never published, mentioning an ongoing German military program on nuclear bombs using implosion [Bundesarchiv Militärarchiv Freiburg N822/17].

Bundesarchiv Militärarchiv Freiburg N822/17. Erich Schumann. 2 October 1940.
Unclassified draft article on explosives research for popular publication.



- 13 -

erfassen. Als Ursache solcher mittelbarer Sprengstoffwirkungen kommen neben der direkten Schwadeneinwirkung die Stosswelle im an den Sprengstoff angrenzenden Medium oder an der Sprengstoffoberfläche beschleunigte und dann ballistisch wirkende Materialteile in Betracht. Die bei den je nach der beabsichtigten Wirkung verschiedenen Anordnungen der Sprengobjekte auftretenden Fragen hier näher zu erörtern, verbietet sich bei der waffentechnischen Bedeutung spezieller Anordnungen von selbst. Auch bei mittelbaren Wirkungen werden die Vorgänge an der ~~Spfwn~~ Sprengstoffoberfläche als in jedem Falle entscheidende Kraftquelle Ausgangspunkt weiterer Untersuchungen sein müssen.

Das Ergebnis ~~vo~~ der vorstehenden Überlegungen kann dahin zusammengefasst werden, dass Wege aufgezeigt und Untersuchungsmethoden angegeben werden, die detonativen Erscheinungen in den allgemeinen Rahmen der Physik einzuordnen. Eine solche Behandlung von Sprengstoffragen nach rein physikalischen Gesichtspunkten hat die Schaffung physikalischer Messmethoden für die die Wirkung und Handhabung bestimmenden Grössen zur notwendigen primären Folge. Die weitere Verfolgung dieser Methoden muss zu einer all-

Figure D.570: Pages from Erich Schumann's 2 October 1940 unclassified draft article on explosives research, intended for popular publication but never published, mentioning an ongoing German military program on nuclear bombs using implosion [Bundesarchiv Militärarchiv Freiburg N822/17].

Erich Schumann, Kurt Diebner, et al. February 1942 [1941 data]. ***Energiegewinnung aus Uran: Ergebnisse der vom Heereswaffenamt veranlassten Forschungsarbeiten zur Nutzbarmachung von Atomkernenergien.*** **Archiv der Max-Planck-Gesellschaft, I. Abteilung, Rep. 34, Nr. 105. See photos of a few pages on pp. 4208–4210.**

b. Sprengstoff. Die störende Wirkung von U_{238} nimmt mit wachsender Temperatur zu. Ein Sprengstoff würde daher höchstens sehr kleine Mengen von U_{238} erhalten dürfen. Außer der vollständigen Isotopentrennung, die grundsätzlich sicher durchführbar, aber technisch sehr schwierig ist, kommen wir heute theoretisch einen zweiten Web zur Herstellung eines Sprengstoffs, der aber erst erprobt werden kann, wenn eine Uranmaschine läuft. Aus U_{238} bildet sich nämlich durch die Absorption von Neutronen ein Stoff ("Element 94"), der noch leichter spaltbar sein muss als U_{235}. Da dieser Stoff chemisch von Uran verschieden ist, muss man ihn aus dem Uran einer stillgelegten Maschine leicht abtrennen können. Doch kennen wir heute weder die Menge, in der er entsteht, noch seine Eigenschaften genau genug für eine ganz sichere Voraussage.

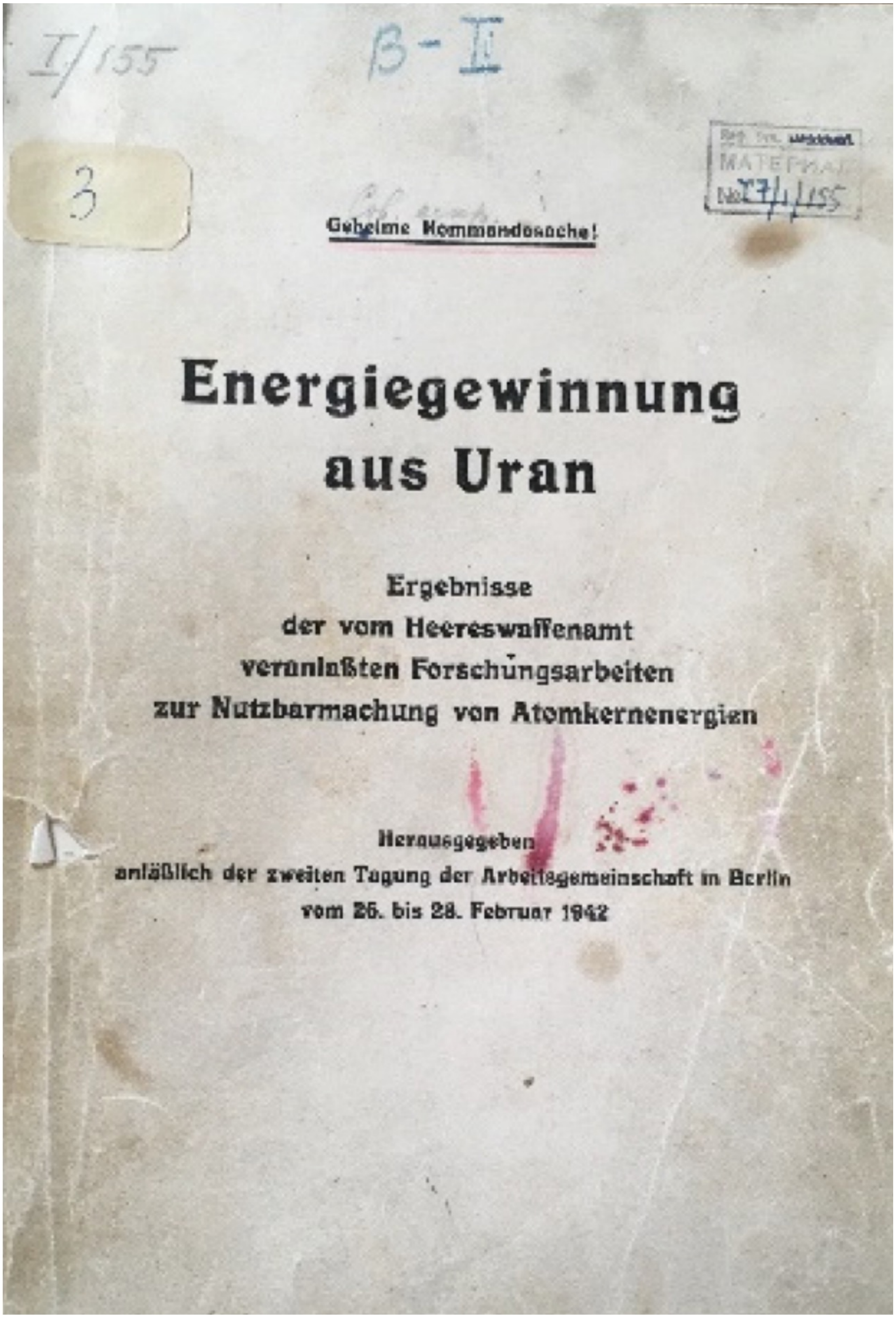
b. Explosive. The disruptive effect of U_{238} increases with increasing temperature. An explosive would therefore only be allowed to contain very small quantities of U_{238} at most. Apart from the complete separation of isotopes, which can be carried out safely in principle but is technically very difficult, we now have a second theoretical way of producing an explosive, but this can only be tested when a uranium machine is running. From U_{238} a substance ("element 94") is formed by the absorption of neutrons, which must be even easier to fission than U_{235}. Since this substance is chemically different from uranium, it must be possible to separate it easily from the uranium of a previously operating machine [used reactor fuel]. But today we know neither the amount in which it is produced nor its properties precisely enough for a completely safe prediction.

Da sich in jeder Substanz einige freie Neutronen befinden, würde es zur Entzündung des Sprengstoffs genügen, eine hinreichende Menge (vermutlich etwa 10–100 kg) räumlich zu vereinigen.

Since there are some free neutrons in each substance, it would be enough to spatially combine a sufficient amount (probably about 10–100 kg) to ignite the explosive.

[Erich Schumann and his colleagues at the Heereswaffenamt (including Kurt Diebner) created this secret compendium and presented it to the German government in February 1942. Thus the major results in it are from 1941 or earlier. This document demonstrates that as of 1941, German scientists:

- Were actively working to develop a fission bomb, not just a reactor.
- Knew that ^{235}U could be separated from ^{238}U and that highly enriched ^{235}U would be quite suitable for use in a fission bomb.
- Knew that plutonium-239 (element 94) could be bred from ^{238}U in a fission reactor, could be chemically separated from the remaining uranium afterward, and would be highly suitable for use in a fission bomb.
- Knew that 10–100 kg of sufficiently pure fission fuel should be enough for a fission bomb. This is a very early and excellent conservative estimate of the required mass (compare the values in the table on p. 5162 for the case of no compression, no reflector, and no fusion boosting). It clearly disproves postwar historical myths claiming that Germans did not know the required mass or mistakenly believed it to be several tons.
- Knew that a bomb would need to "spatially combine" that fission fuel on a sufficiently rapid timescale before the explosion. That seems to be a clear connection to the work on implosion designs that Schumann and his colleagues had already been developing for quite some time.]



I/155

B-II

3

МАТЕРИАЛ
№ I7/1/155

Geheime Kommandosache!

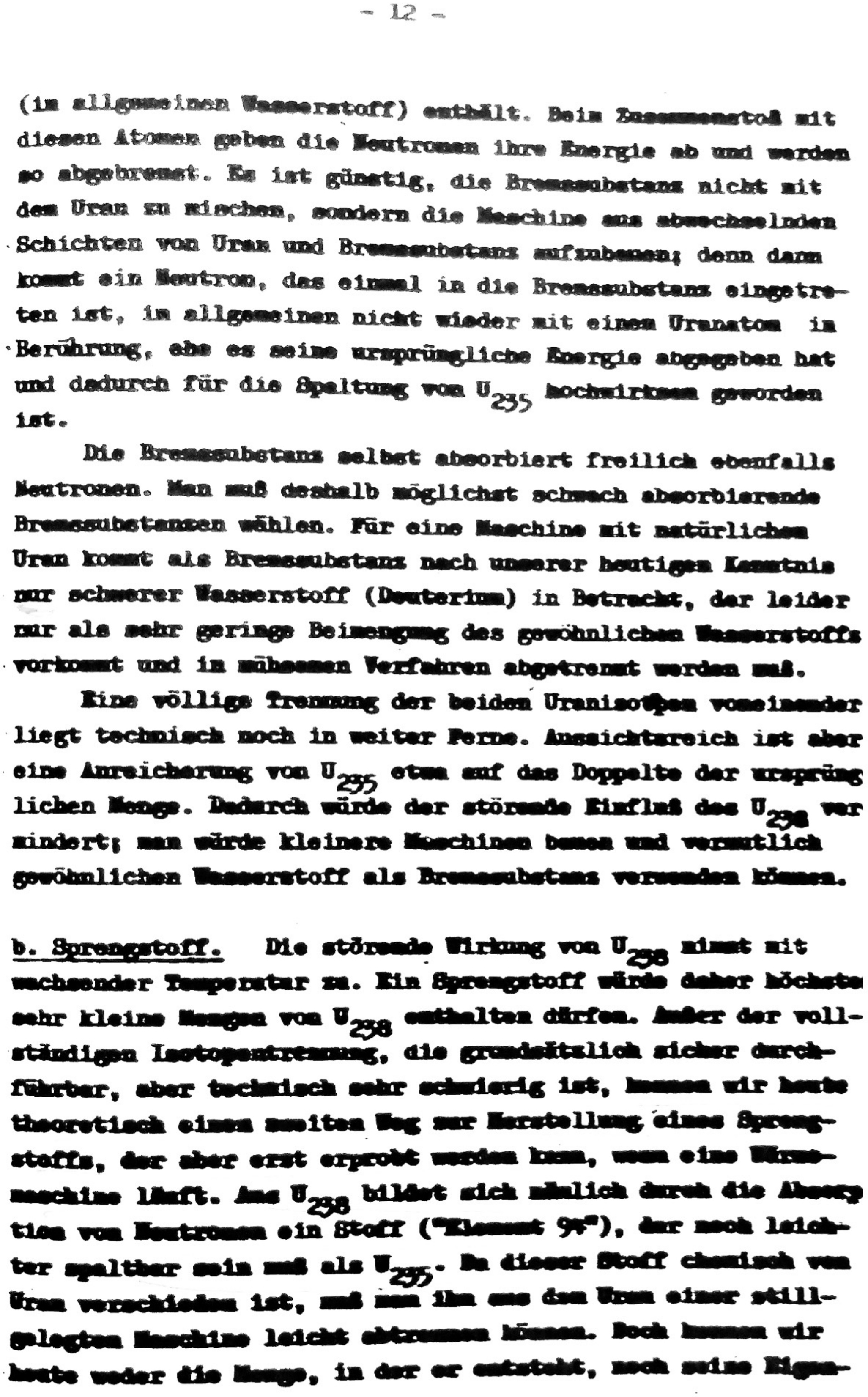
Energiegewinnung aus Uran

Ergebnisse
der vom Heereswaffenamt
veranlaßten Forschungsarbeiten
zur Nutzbarmachung von Atomkernenergien

Herausgegeben
anläßlich der zweiten Tagung der Arbeitsgemeinschaft in Berlin
vom 26. bis 28. Februar 1942

Archiv der Max-Planck-Gesellschaft, I. Abteilung, Rep. 34, Nr. 105

Figure D.571: Pages from Erich Schumann's February 1942 compendium, *Energiegewinnung aus Uran: Ergebnisse der vom Heereswaffenamt veranlassten Forschungsarbeiten zur Nutzbarmachung von Atomkernenergien*, informing the German government that an atomic bomb can be made with 10–100 kg of fissile material [Archiv der Max-Planck-Gesellschaft, I. Abteilung, Rep. 34, Nr. 105].



(im allgemeinen Wasserstoff) enthält. Beim Zusammenstoß mit diesen Atomen geben die Neutronen ihre Energie ab und werden so abgebremst. Es ist günstig, die Bremssubstanz nicht mit dem Uran zu mischen, sondern die Maschine aus abwechselnden Schichten von Uran und Bremssubstanz aufzubauen; denn dann kommt ein Neutron, das einmal in die Bremssubstanz eingetreten ist, im allgemeinen nicht wieder mit einem Uranatom in Berührung, ehe es seine ursprüngliche Energie abgegeben hat und dadurch für die Spaltung von U_{235} hochwirksam geworden ist.

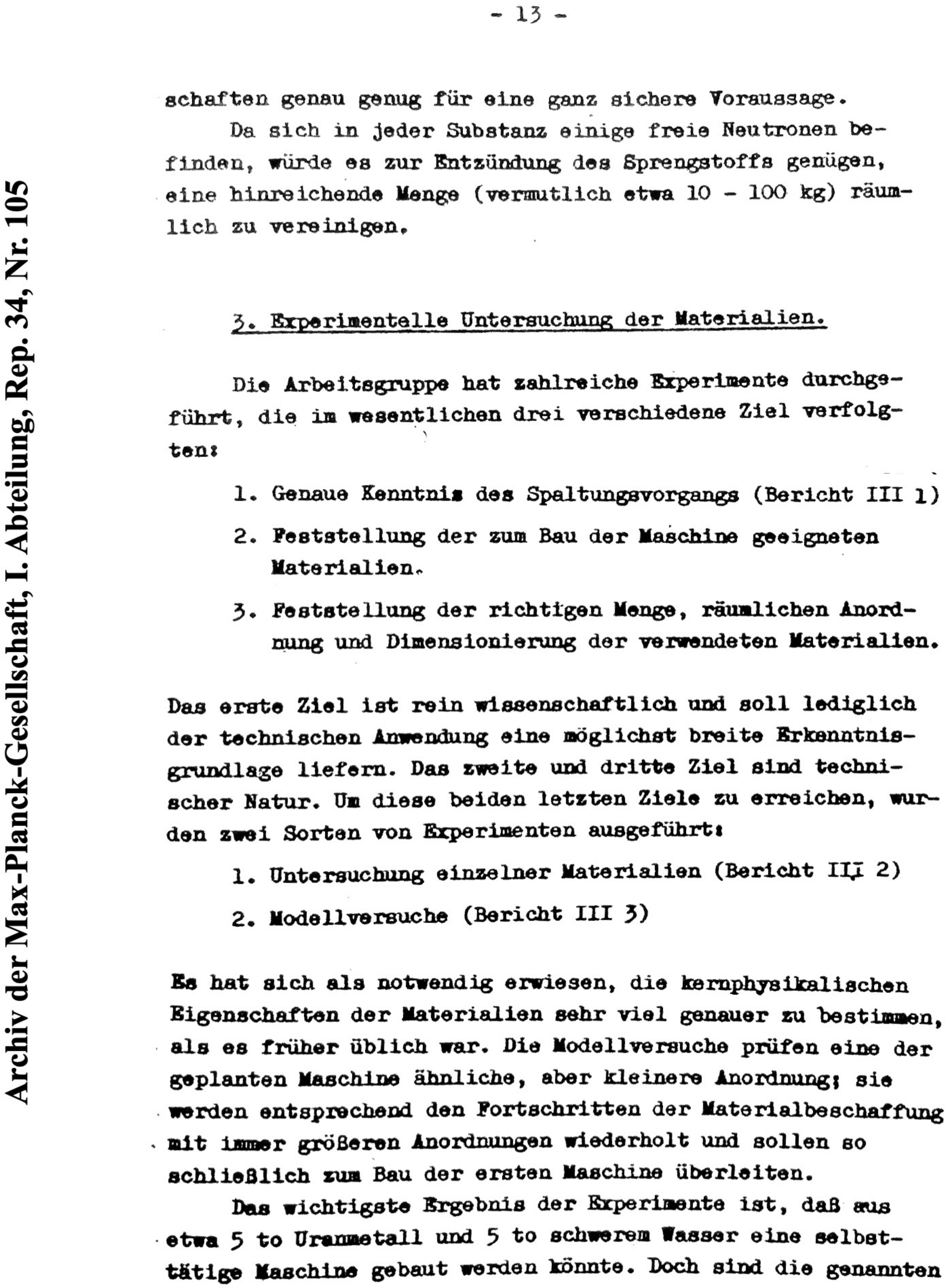
Die Bremssubstanz selbst absorbiert freilich ebenfalls Neutronen. Man muß deshalb möglichst schwach absorbierende Bremssubstanzen wählen. Für eine Maschine mit natürlichem Uran kommt als Bremssubstanz nach unserer heutigen Kenntnis nur schwerer Wasserstoff (Deuterium) in Betracht, der leider nur als sehr geringe Beimengung des gewöhnlichen Wasserstoffs vorkommt und in mühsamen Verfahren abgetrennt werden muß.

Eine völlige Trennung der beiden Uranisotopen voneinander liegt technisch noch in weiter Ferne. Aussichtsreich ist aber eine Anreicherung von U_{235} etwa auf das Doppelte der ursprünglichen Menge. Dadurch würde der störende Einfluß des U_{238} vermindert; man würde kleinere Maschinen bauen und vermutlich gewöhnlichen Wasserstoff als Bremssubstanz verwenden können.

b. Sprengstoff. Die störende Wirkung von U_{238} nimmt mit wachsender Temperatur zu. Ein Sprengstoff würde daher höchste sehr kleine Mengen von U_{238} enthalten dürfen. Außer der vollständigen Isotopentrennung, die grundsätzlich sicher durchführbar, aber technisch sehr schwierig ist, kennen wir heute theoretisch einen zweiten Weg zur Herstellung eines Sprengstoffs, der aber erst erprobt werden kann, wenn eine Wärmemaschine läuft. Aus U_{238} bildet sich nämlich durch die Absorption von Neutronen ein Stoff ("Element 94"), der noch leichter spaltbar sein muß als U_{235}. Da dieser Stoff chemisch vom Uran verschieden ist, muß man ihn aus dem Uran einer stillgelegten Maschine leicht abtrennen können. Doch kennen wir heute weder die Menge, in der er entsteht, noch seine Eigen-

Archiv der Max-Planck-Gesellschaft, I. Abteilung, Rep. 34, Nr. 105

Figure D.572: Pages from Erich Schumann's February 1942 compendium, *Energiegewinnung aus Uran: Ergebnisse der vom Heereswaffenamt veranlassten Forschungsarbeiten zur Nutzbarmachung von Atomkernenergien*, informing the German government that an atomic bomb can be made with 10–100 kg of fissile material [Archiv der Max-Planck-Gesellschaft, I. Abteilung, Rep. 34, Nr. 105].



Archiv der Max-Planck-Gesellschaft, I. Abteilung, Rep. 34, Nr. 105

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schaften genau genug für eine ganz sichere Voraussage.

Da sich in jeder Substanz einige freie Neutronen befinden, würde es zur Entzündung des Sprengstoffs genügen, eine hinreichende Menge (vermutlich etwa 10 - 100 kg) räumlich zu vereinigen.

3. Experimentelle Untersuchung der Materialien.

Die Arbeitsgruppe hat zahlreiche Experimente durchgeführt, die im wesentlichen drei verschiedene Ziel verfolgten:

1. Genaue Kenntnis des Spaltungsvorgangs (Bericht III 1)
2. Feststellung der zum Bau der Maschine geeigneten Materialien.
3. Feststellung der richtigen Menge, räumlichen Anordnung und Dimensionierung der verwendeten Materialien.

Das erste Ziel ist rein wissenschaftlich und soll lediglich der technischen Anwendung eine möglichst breite Erkenntnisgrundlage liefern. Das zweite und dritte Ziel sind technischer Natur. Um diese beiden letzten Ziele zu erreichen, wurden zwei Sorten von Experimenten ausgeführt:

1. Untersuchung einzelner Materialien (Bericht III 2)
2. Modellversuche (Bericht III 3)

Es hat sich als notwendig erwiesen, die kernphysikalischen Eigenschaften der Materialien sehr viel genauer zu bestimmen, als es früher üblich war. Die Modellversuche prüfen eine der geplanten Maschine ähnliche, aber kleinere Anordnung; sie werden entsprechend den Fortschritten der Materialbeschaffung mit immer größeren Anordnungen wiederholt und sollen so schließlich zum Bau der ersten Maschine überleiten.

Das wichtigste Ergebnis der Experimente ist, daß aus etwa 5 to Uranmetall und 5 to schwerem Wasser eine selbsttätige Maschine gebaut werden könnte. Doch sind die genannten

Figure D.573: Pages from Erich Schumann's February 1942 compendium, *Energiegewinnung aus Uran: Ergebnisse der vom Heereswaffenamt veranlassten Forschungsarbeiten zur Nutzbarmachung von Atomkernenergien*, informing the German government that an atomic bomb can be made with 10–100 kg of fissile material [Archiv der Max-Planck-Gesellschaft, I. Abteilung, Rep. 34, Nr. 105].

Erich Schumann and Gerd Hinrichs. March 1943. HEC 2590. *On the Increase of the Effect of Hollow Explosive Slabs Caused by Control of Ignition (Lenses).* English translation. U.K. Imperial War Museum, Duxford Archive. For photos of some pages, see pp. 4212–4217.

By suitable control of the detonation waves in the explosive by means of a lens an increase of efficiency of more than 25% has been achieved with (H 15) explosive slabs for engineers. The application to short projectiles and mines is full of possibilities.

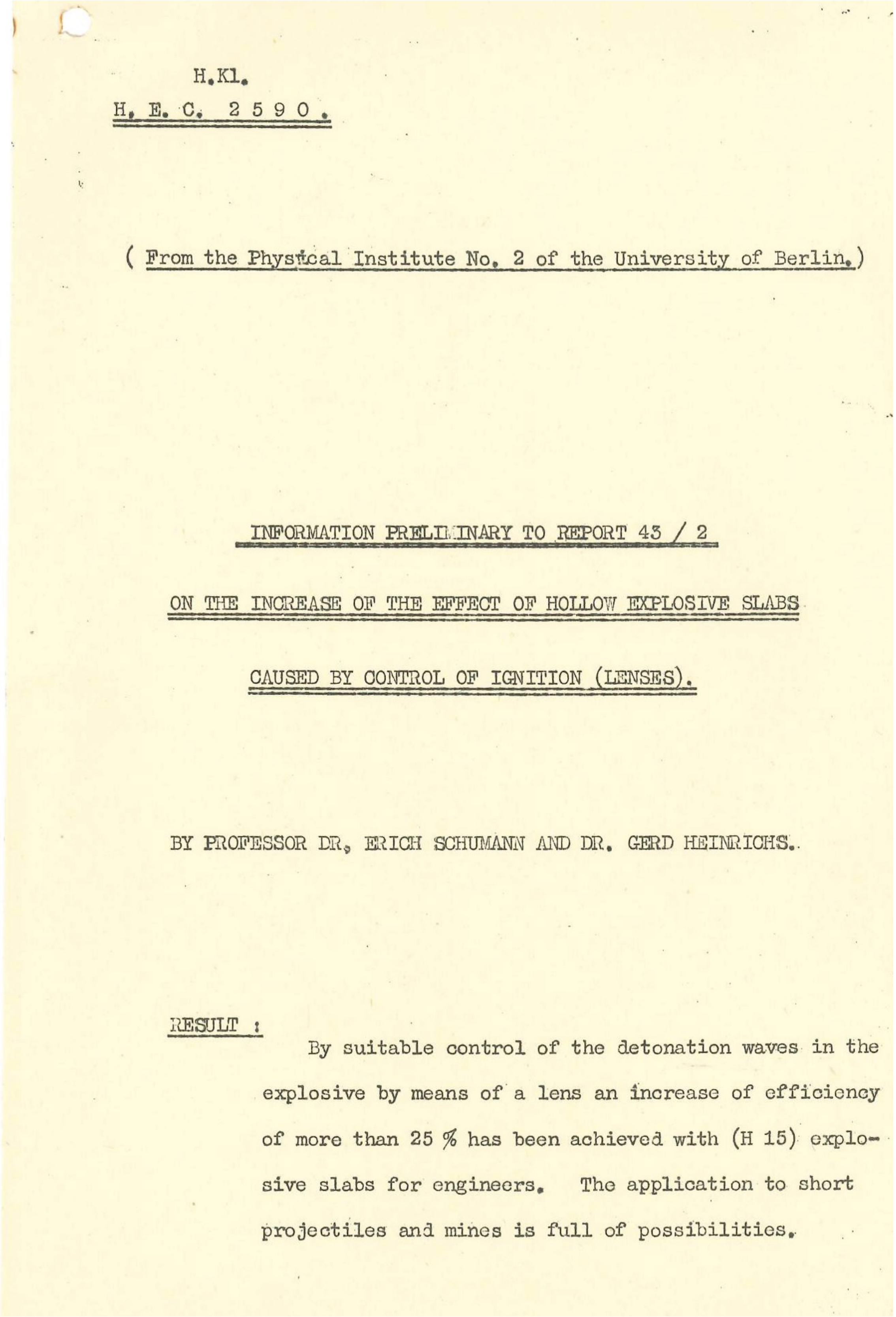
Extensive experiments on explosions have shown in the course of the last year that the effect of the hollow explosive slab can be substantially increased, especially in the case of a hemispherical hollow space, by suitable control of the detonation wave. This shaping of the detonation wave, also called ignition control, makes it possible to influence within certain limits the shaping of the covering material. the most successful means of assisting this is the “lens”.

Erich Schumann. 1943. HEC 5919. *The Scientific Basis of the Hollow Charge Effect.* English translation. U.K. Imperial War Museum, Duxford Archive. For photos of some pages, see pp. 4218–4219.

In the g. Kdos. 229/41 Wa F (most secret document) such ignition guides, made of explosives of suitable detonation velocity and interlaid as lens shaped bodies between the ignition point and the hollow space were suggested by myself. [...]

I predicted the possibility of such an effect at the conference of the Academy of Aeronautical Research on 25.10.40[....]

HEC 2590 (English translation). Erich Schumann and Gerd Hinrichs. March 1943.
Report on tests of explosive lenses. Imperial War Museum, Duxford Archive.



H.Kl.
H. E. C. 2590.

(From the Physical Institute No. 2 of the University of Berlin.)

INFORMATION PRELIMINARY TO REPORT 43 / 2

ON THE INCREASE OF THE EFFECT OF HOLLOW EXPLOSIVE SLABS

CAUSED BY CONTROL OF IGNITION (LENSES).

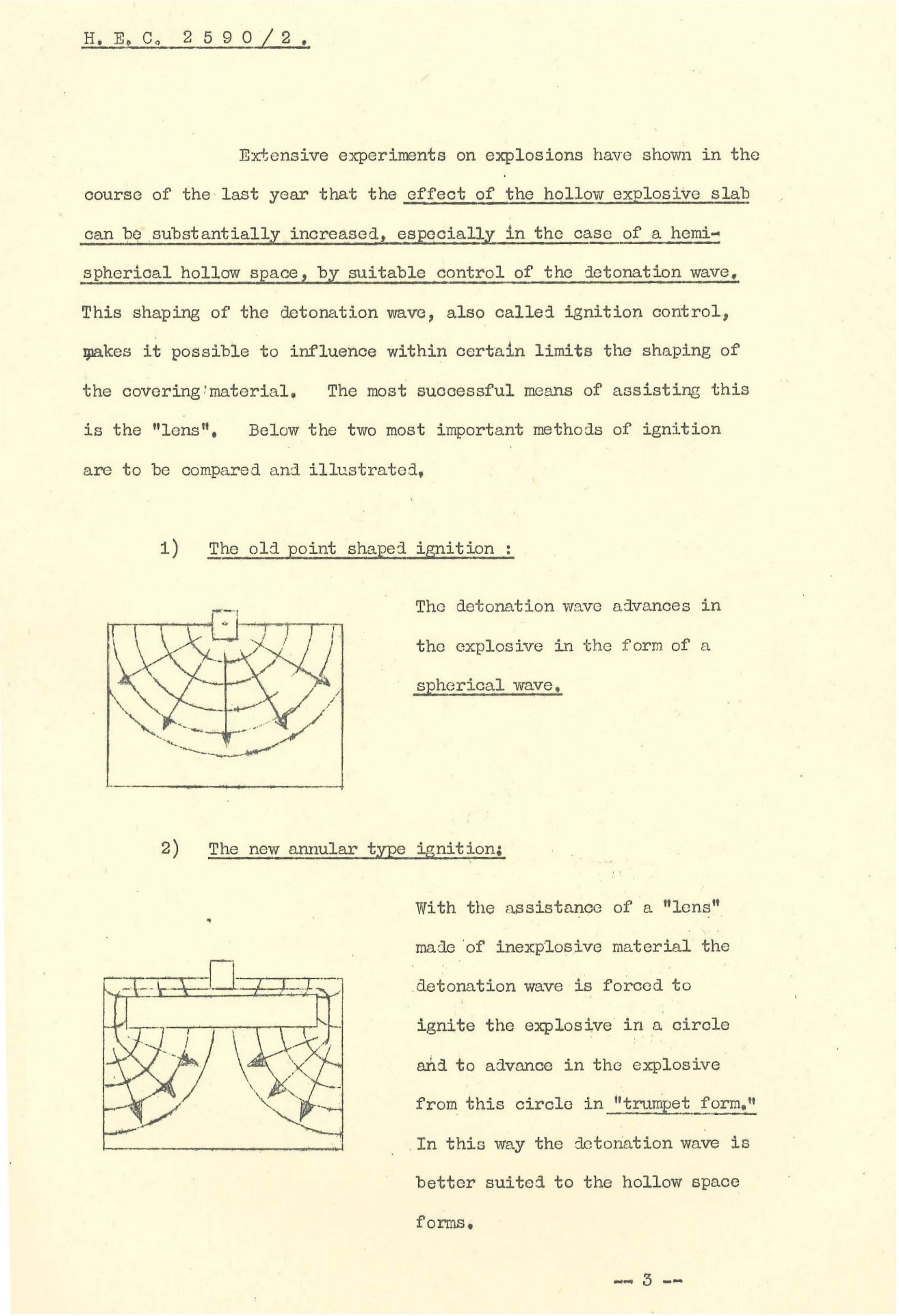
BY PROFESSOR DR. ERICH SCHUMANN AND DR. GERD HEINRICHS.

RESULT :

By suitable control of the detonation waves in the explosive by means of a lens an increase of efficiency of more than 25 % has been achieved with (H 15) explosive slabs for engineers. The application to short projectiles and mines is full of possibilities.

Figure D.574: Excerpts from a March 1943 report by Erich Schumann and Gerd Hinrichs showing the design and successful experimental demonstration of explosive lenses [HEC 2590, English translation, U.K. Imperial War Museum, Duxford Archive].

HEC 2590 (English translation). Erich Schumann and Gerd Hinrichs. March 1943. Report on tests of explosive lenses. Imperial War Museum, Duxford Archive.



H. E. C. 2590/2.

Extensive experiments on explosions have shown in the course of the last year that the effect of the hollow explosive slab can be substantially increased, especially in the case of a hemispherical hollow space, by suitable control of the detonation wave. This shaping of the detonation wave, also called ignition control, makes it possible to influence within certain limits the shaping of the covering material. The most successful means of assisting this is the "lens". Below the two most important methods of ignition are to be compared and illustrated.

1) The old point shaped ignition :

The detonation wave advances in the explosive in the form of a spherical wave.

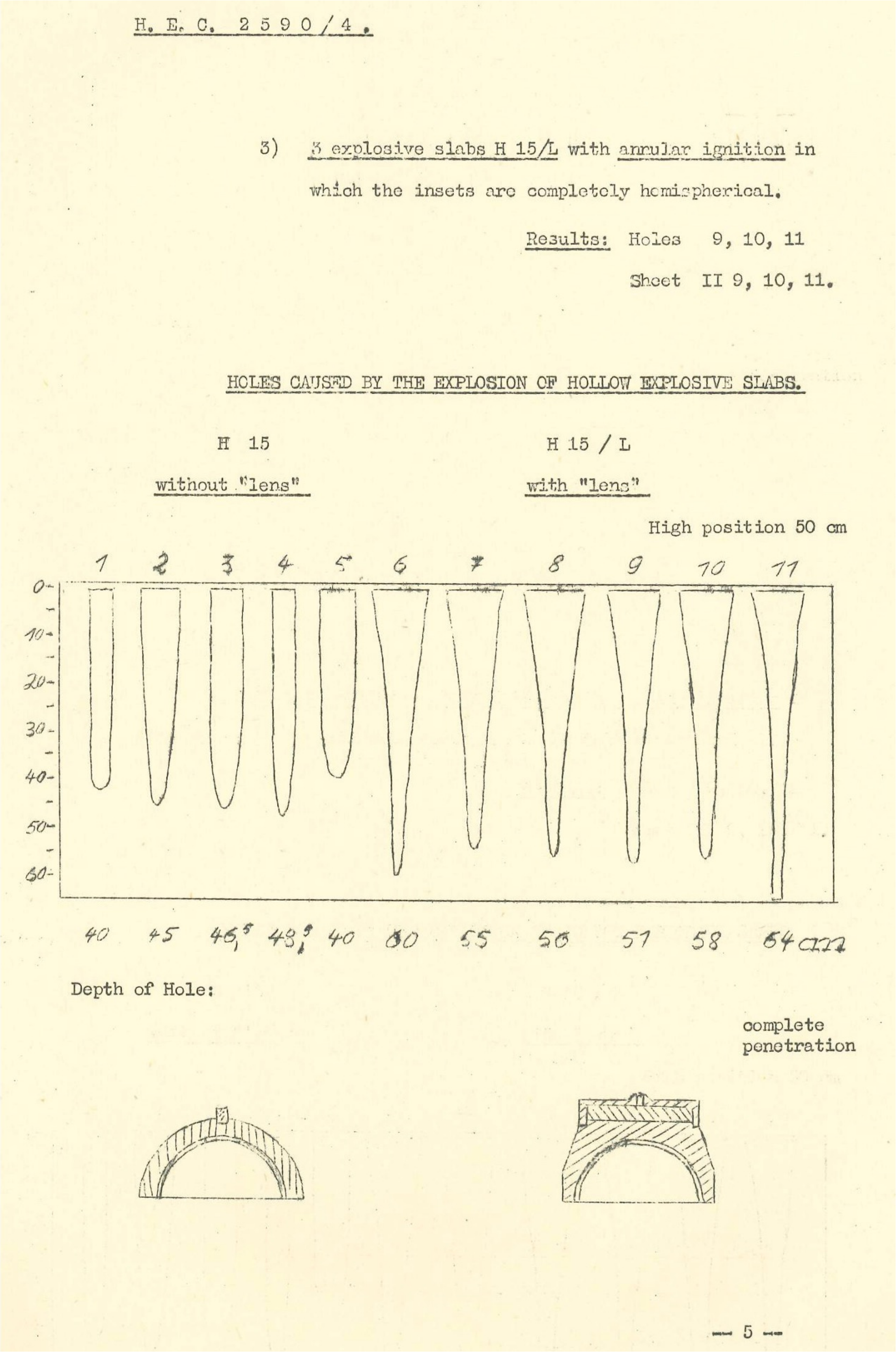
2) The new annular type ignition:

With the assistance of a "lens" made of inexplosive material the detonation wave is forced to ignite the explosive in a circle and to advance in the explosive from this circle in "trumpet form." In this way the detonation wave is better suited to the hollow space forms.

-- 3 --

Figure D.575: Excerpts from a March 1943 report by Erich Schumann and Gerd Hinrichs showing the design and successful experimental demonstration of explosive lenses [HEC 2590, English translation, U.K. Imperial War Museum, Duxford Archive].

HEC 2590 (English translation). Erich Schumann and Gerd Hinrichs. March 1943. Report on tests of explosive lenses. Imperial War Museum, Duxford Archive.



H. E. C. 2 5 9 0 / 4.

3) 3 explosive slabs H 15/L with annular ignition in which the insets are completely hemispherical.

Results: Holes 9, 10, 11

Sheet II 9, 10, 11.

HOLES CAUSED BY THE EXPLOSION OF HOLLOW EXPLOSIVE SLABS.

H 15
without "lens"
H 15 / L
with "lens"
High position 50 cm
1
2
3
4
5
6
7
8
9
10
11
0
10
20
30
40
50
60
40
45
46,5
48,5
40
60
55
56
57
58
64 cm
Depth of Hole:
complete penetration

— 5 —

Figure D.576: Excerpts from a March 1943 report by Erich Schumann and Gerd Hinrichs showing the design and successful experimental demonstration of explosive lenses [HEC 2590, English translation, U.K. Imperial War Museum, Duxford Archive].

HEC 2590 (English translation). Erich Schumann and Gerd Hinrichs. March 1943. Report on tests of explosive lenses. Imperial War Museum, Duxford Archive.

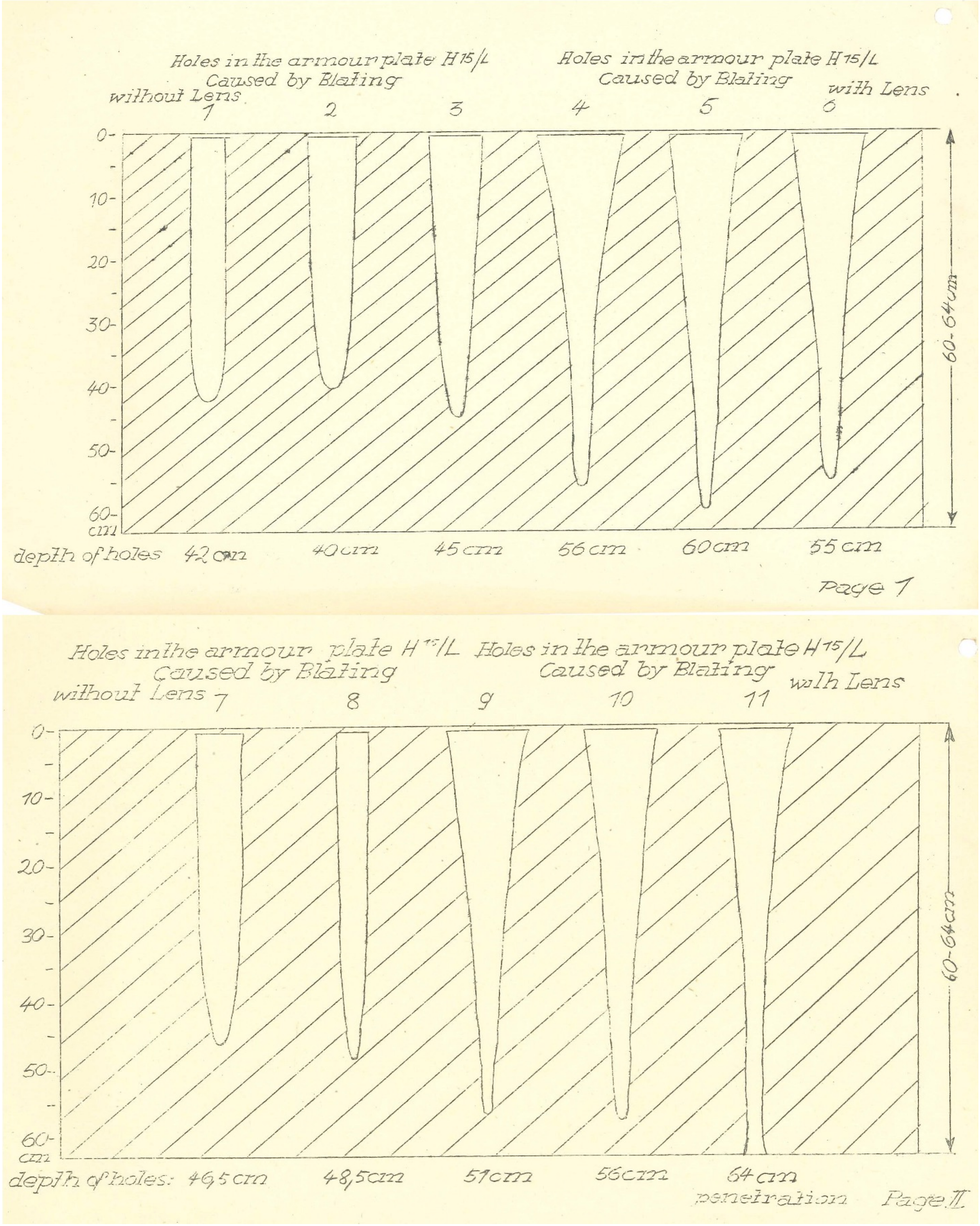

Holes in the armour plate H 15/L
Caused by Blating
without Lens
Holes in the armour plate H 15/L
Caused by Blating
with Lens
1
2
3
4
5
6
0-
10-
20-
30-
40-
50-
60-
cm
60-64 cm
depth of holes
42 cm
40 cm
45 cm
56 cm
60 cm
55 cm
Page 1
Holes in the armour plate H 15/L
Caused by Blating
without Lens
Holes in the armour plate H 15/L
Caused by Blating
with Lens
7
8
9
10
11
0-
10-
20-
30-
40-
50-
60-
cm
60-64 cm
depth of holes: 46,5 cm
48,5 cm
51 cm
56 cm
64 cm
penetration
Page II

Figure D.577: Excerpts from a March 1943 report by Erich Schumann and Gerd Hinrichs showing the design and successful experimental demonstration of explosive lenses [HEC 2590, English translation, U.K. Imperial War Museum, Duxford Archive].

HEC 2590 (English translation). Erich Schumann and Gerd Hinrichs. March 1943. Report on tests of explosive lenses. Imperial War Museum, Duxford Archive.

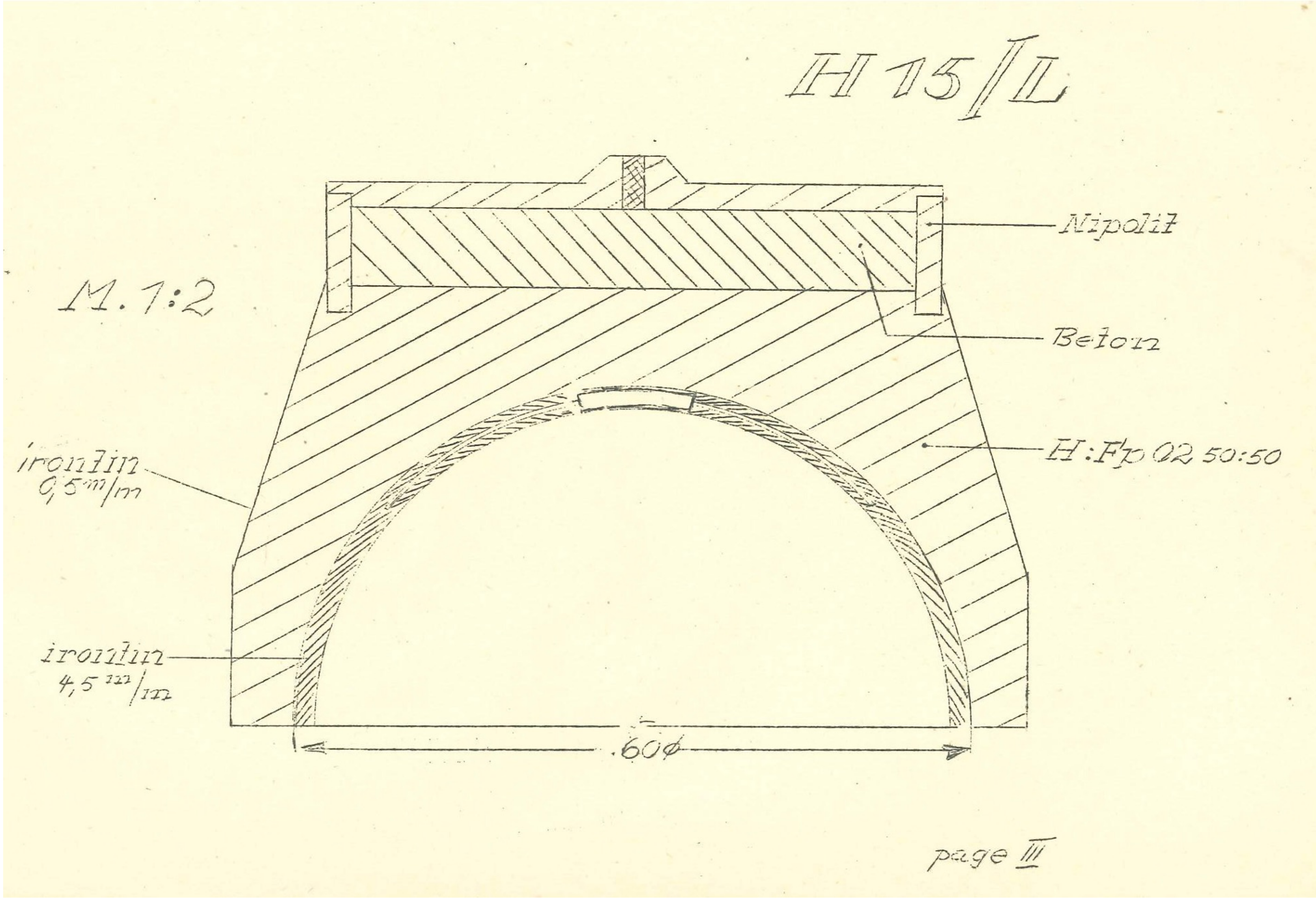

H 15/L
M. 1:2
Nipolit
Beton
H:Fp 02 50:50
irontin 0,5 m/m
irontin 4,5 m/m
.60⌀
page III

Figure D.578: Excerpts from a March 1943 report by Erich Schumann and Gerd Hinrichs showing the design and successful experimental demonstration of explosive lenses [HEC 2590, English translation, U.K. Imperial War Museum, Duxford Archive].

**HEC 2590 (English translation). Erich Schumann and Gerd Hinrichs. March 1943.
Report on tests of explosive lenses. Imperial War Museum, Duxford Archive.**

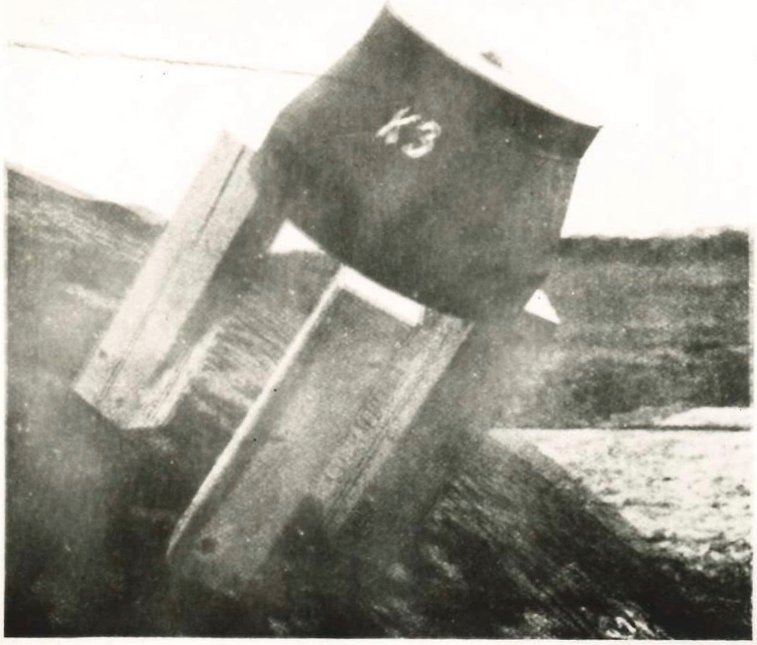


Abb. S 1: Versuchsaufbau des Körpers H 15/I.

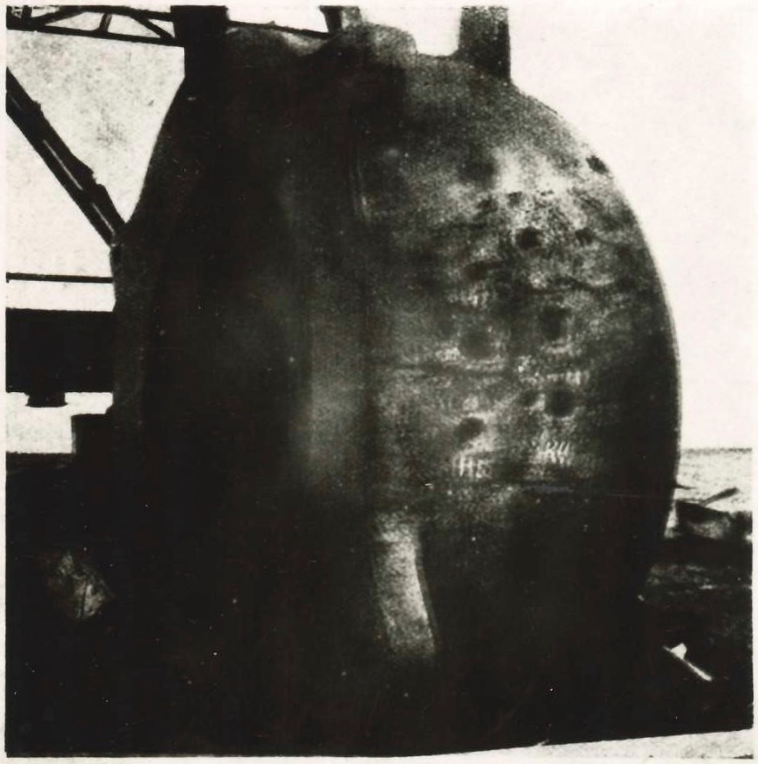
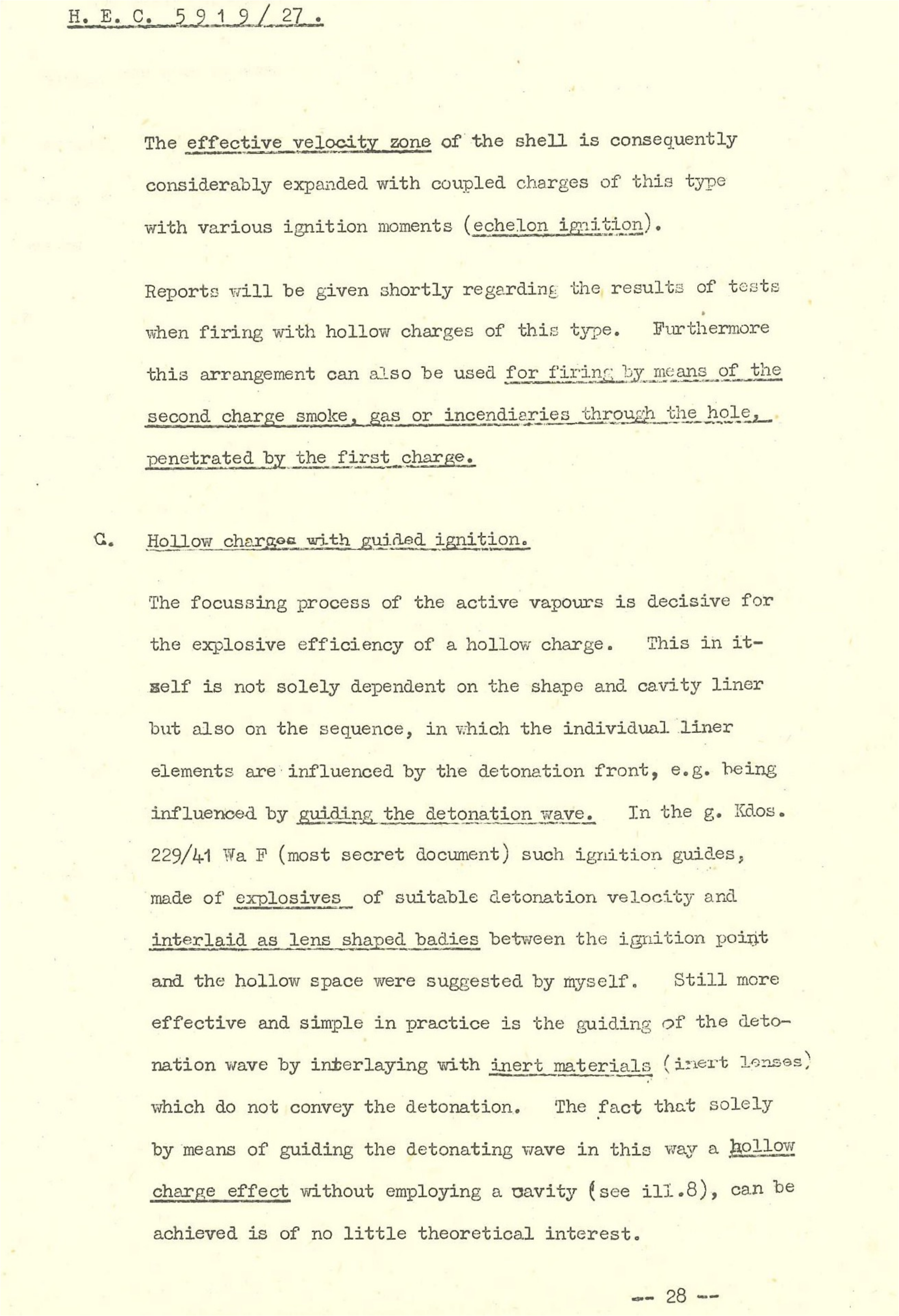


Abb. S 2: Kuppel mit Sprenglöchern der Sprengkörper H 15 u. H 15/I.

Figure D.579: Excerpts from a March 1943 report by Erich Schumann and Gerd Hinrichs showing the design and successful experimental demonstration of explosive lenses [HEC 2590, English translation, U.K. Imperial War Museum, Duxford Archive].



H. E. C. 5919/27.

The effective velocity zone of the shell is consequently considerably expanded with coupled charges of this type with various ignition moments (echelon ignition).

Reports will be given shortly regarding the results of tests when firing with hollow charges of this type. Furthermore this arrangement can also be used for firing by means of the second charge smoke, gas or incendiaries through the hole, penetrated by the first charge.

C. Hollow charges with guided ignition.

The focussing process of the active vapours is decisive for the explosive efficiency of a hollow charge. This in itself is not solely dependent on the shape and cavity liner but also on the sequence, in which the individual liner elements are influenced by the detonation front, e.g. being influenced by guiding the detonation wave. In the g. Kdos. 229/41 Wa F (most secret document) such ignition guides, made of explosives of suitable detonation velocity and interlaid as lens shaped badies between the ignition point and the hollow space were suggested by myself. Still more effective and simple in practice is the guiding of the detonation wave by interlaying with inert materials (inert lenses) which do not convey the detonation. The fact that solely by means of guiding the detonating wave in this way a hollow charge effect without employing a cavity (see ill.8), can be achieved is of no little theoretical interest.

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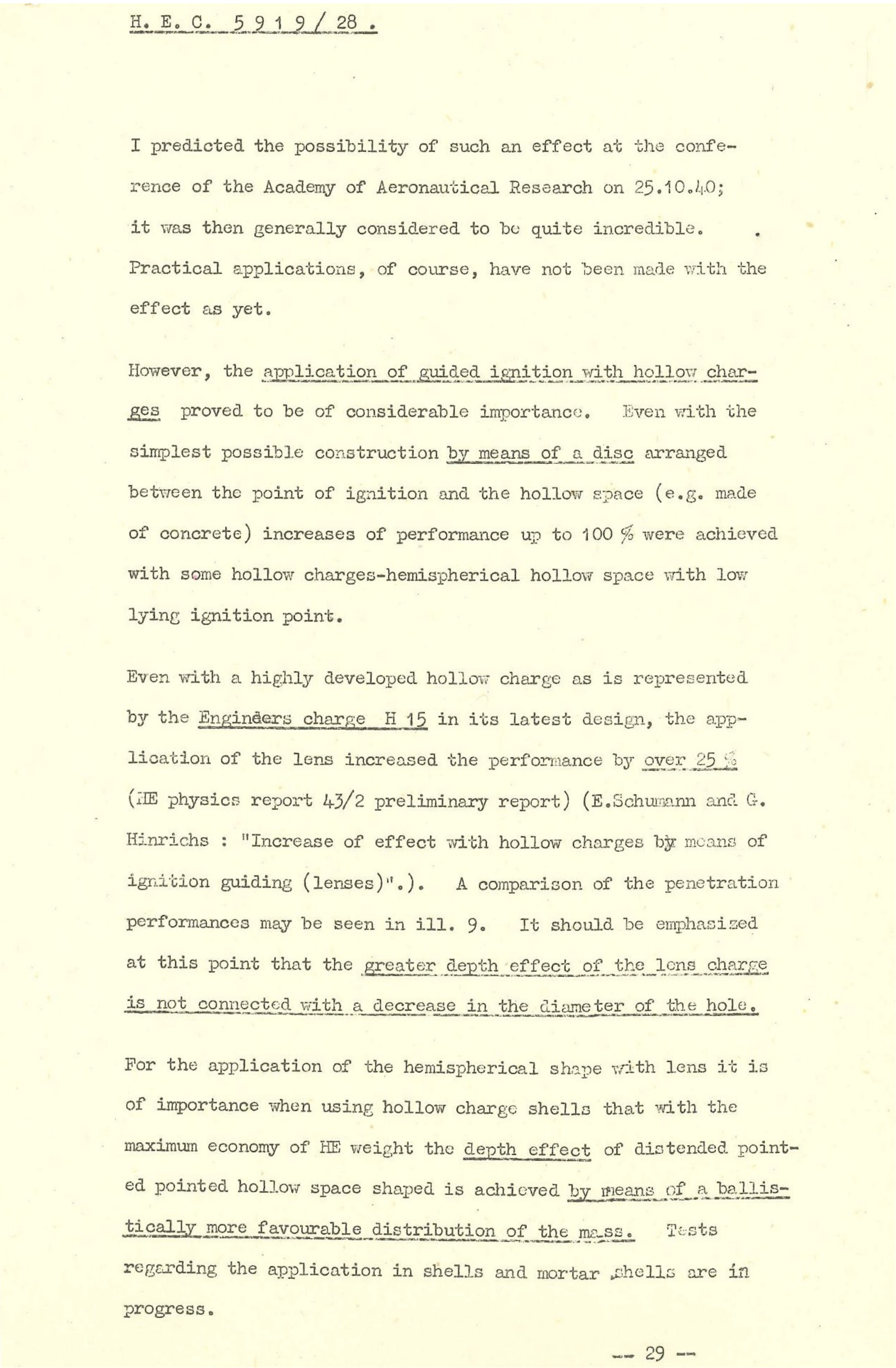
HEC 5919 (English translation). Erich Schumann. 1943.
Cites other reports on explosive lenses. Imperial War Museum, Duxford Archive.

Figure D.580: Excerpts from a 1943 report by Erich Schumann, citing his other reports on explosive lenses going back to 1940 [HEC 5919, English translation, U.K. Imperial War Museum, Duxford Archive].

HEC 5919 (English translation). Erich Schumann. 1943.
Cites other reports on explosive lenses. Imperial War Museum, Duxford Archive.



H. E. C. 5 9 1 9 / 28 .

I predicted the possibility of such an effect at the conference of the Academy of Aeronautical Research on 25.10.40; it was then generally considered to be quite incredible. Practical applications, of course, have not been made with the effect as yet.

However, the application of guided ignition with hollow charges proved to be of considerable importance. Even with the simplest possible construction by means of a disc arranged between the point of ignition and the hollow space (e.g. made of concrete) increases of performance up to 100 % were achieved with some hollow charges-hemispherical hollow space with low lying ignition point.

Even with a highly developed hollow charge as is represented by the Engineers charge H 15 in its latest design, the application of the lens increased the performance by over 25 % (HE physics report 43/2 preliminary report) (E.Schumann and G. Hinrichs : "Increase of effect with hollow charges by means of ignition guiding (lenses)".). A comparison of the penetration performances may be seen in ill. 9. It should be emphasized at this point that the greater depth effect of the lens charge is not connected with a decrease in the diameter of the hole.

For the application of the hemispherical shape with lens it is of importance when using hollow charge shells that with the maximum economy of HE weight the depth effect of distended pointed pointed hollow space shaped is achieved by means of a ballistically more favourable distribution of the mass. Tests regarding the application in shells and mortar shells are in progress.

-- 29 --

Figure D.581: Excerpts from a 1943 report by Erich Schumann, citing his other reports on explosive lenses going back to 1940 [HEC 5919, English translation, U.K. Imperial War Museum, Duxford Archive].

G-303. Walter Herrmann, Georg Hartwig, Heinz Rackwitz, Walter Trinks, and H. Schaub. 1944. *Versuche über die Einleitung von Kernreaktionen durch die Wirkung explodierender Stoffe.* [*Experiments on Initiation of Nuclear Reactions by Explosives.*] Deutsches Museum number FA 002/0721. https://digital.deutsches-museum.de/item/FA-002-721/

[See document photos on pp. 4222–4224. This report describes one of the long series of Schumann-Trinks implosion experiments. This particular experiment was a simple test using fusion fuel but no fission fuel. The report showed both from experimental measurements and from theoretical calculations that implosion by chemical explosives had far too little energy to produce significant pure fusion reactions. Thus in other documents when members of the Schumann-Trinks group discussed "atomic bombs" that used implosion, they clearly knew that fission fuel was an essential component of such bombs: either fission fuel only, or a combination of fission and fusion fuel. Where are all the other reports on all the other experiments by the Schumann-Trinks group throughout the entire war?]

1) Es wurde des öfteren vorgeschlagen, zur Einleitung von Kern- und Kettenreaktionen die Schwadengeschwindigkeit bei der Explosion von Sprengstoffen zu benutzen. Es sollten dabei die entstehenden Kernprozesse die Wirkung von Explosionsstoffen erhöhen. Obwohl dieser Weg nach einfachen Ueberlegungen ungangbar scheint, wurden, um endlich eine experimentell begründete Aussage darüber geben zu können, auf Anregung von Herrn Prof. Gerlach in der Heeresforschungsstelle Kdf. einige orientierende Versuche durchgeführt.

2) Durchführung der Versuche:
In zylindrische Sprengkörper aus Trinitrotoluol (12 cm Ø, 10 cm Höhe); (5,0 cm Ø, 8 cm Höhe) wurden in der Mitte der Grundfläche kleine Kegel (1,5 cm Ø, 3,0 cm Höhe) aus Deutero-Paraffin eingesetzt. Die im Sprengstoff laufenden Druckwellen sollten die D-Atome des Deutero-Paraffins beschleunigen und durch zusammenstossende D-Atome Neutronen erzeugen. Zum Nachweis dieser D-D-Reaktion wurde unter dem Paraffinkegel ein Silber-Indikator vorgesehen, dessen Aktivität, durch die Neutronen der D-D-Reaktion angeregt, gemessen werden sollte. Die Aktivitätsmessungen wurden mit β-Zählrohr, Verstärker und Zählwerk ausgeführt.

1) It has often been proposed to use the gas velocity during the explosion of explosives to initiate nuclear and chain reactions. The resulting nuclear processes should increase the effect of explosives. Although this approach seems unfeasible on the basis of simple considerations, in order to finally be able to make an experimentally substantiated statement about it, a number of preliminary tests were carried out at the Army Research Center Kummersdorf at the suggestion of Prof. Gerlach.

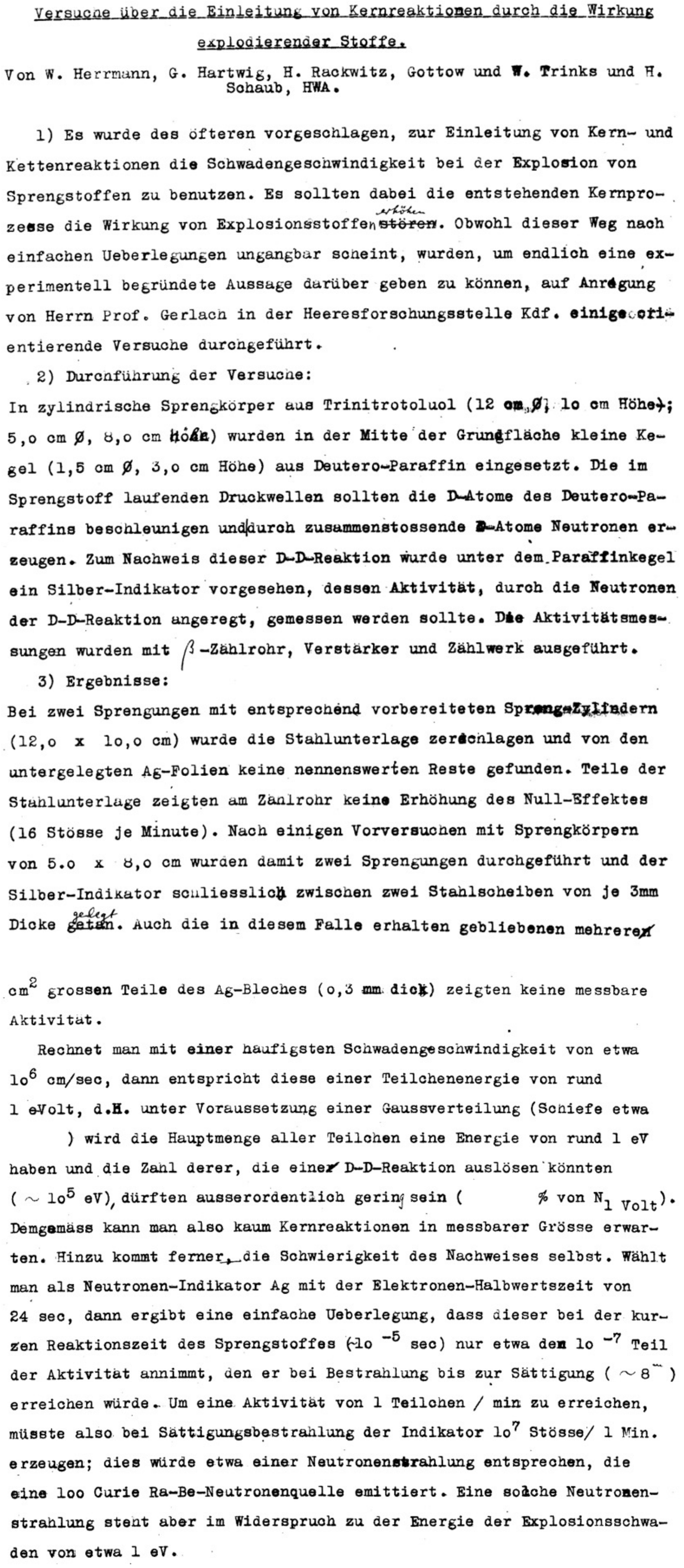
2) Performance of the experiments:
Small cones (1.5 cm Ø, 3.0 cm high) of deutero-paraffin were placed in the center of the base of cylindrical explosives made of trinitrotoluene (12 cm Ø, 10 cm high); (5.0 cm Ø, 8 cm high). The pressure waves in the explosive were intended to accelerate the D atoms of the deutero-paraffin and generate neutrons by colliding D atoms. To detect this D-D reaction, a silver indicator was placed under the paraffin cone, the radioactivity of which was to be measured after stimulation by the neutrons of the D-D reaction. The radioactivity measurements were carried out using a β detection tube, amplifier, and counter.

3) Ergebnisse:
Bei zwei Sprengungen mit entsprechend vorbereiteten Spreng-Zylindern (12,0 x 10,0 cm) wurde die Stahlunterlage zerechlagen und von den untergelegten Ag-Folien keine nennenswerten Reste gefunden. Teile der Stahlunterlage zeigten am Zählrohr keine Erhöhung des Null-Effektes (16 Stösse je Minute). Nach einigen Vorversuchen mit Sprengkörpern von 5,0 x 8,0 cm wurden damit zwei Sprengungen durchgeführt und der Silber-Indikator schliesslich zwischen zwei Stahlscheiben von je 3mm Dicke gelegt. Auch die in diesem Falle erhalten gebliebenen mehrere cm^2 grossen Teile des Ag-Bleches (0,3 mm dick) zeigten keine messbare Aktivität.

Rechnet man mit einer häufigsten Schwadengeschwindigkeit von etwa 10^6 cm/sec, dann entspricht diese einer Teilchenenergie von rund 1 e-Volt, d.H. unter Voraussetzung einer Gaussverteilung (Schiefe etwa ___) wird die Hauptmenge aller Teilchen eine Energie von rund 1 eV haben und die Zahl deren, die eine D-D-Reaktion auslösen könnten ($\sim 10^5$ eV), dürften ausserordentlich gering sein (___% von $N_{1\,\text{Volt}}$). Demgemäss kann man also kaum Kernreaktionen in messbarer Grösse erwarten. Hinzu kommt ferner, die Schwierigkeit des Nachweises selbst. Wählt man als Neutronen-Indikator Ag mit der Elektronen-Halbwertszeit von 24 sec, dann ergibt eine einfache Ueberlegung, dass dieser bei der kurzen Reaktionszeit des Sprengstoffes ($\sim 10^{-5}$ sec) nur etwa den 10^{-7} Teil der Aktivität annimmt, den er bei Bestrahlung bis zur Sättigung (~ 8) erreichen würde. Um eine Aktivität von 1 Teilchen/min zu erreichen, müsste also bei Sättigungsbestrahlung der Indikator 10^7 Stösse/1 Min. erzeugen; dies würde etwa einer Neutronenstrahlung entsprechen, die eine 100 Curie Ra-Be-Neutronenquelle emittiert. Eine solche Neutronenstrahlung steht aber im Widerspruch zu der Energie der Explosionsschwaden von etwa 1 eV.

3) Results:
In two blasts with appropriately prepared blasting cylinders (12.0 x 10.0 cm), the steel base was crushed and no significant remains of the Ag foils placed underneath were found. Parts of the steel base showed no increase over the background level (16 counts per minute) on the detection tube. After some preliminary tests with detonators measuring 5.0 x 8.0 cm, two detonations were carried out and the silver indicator was finally placed between two steel disks, each 3 mm thick. Even the parts of the Ag sheet (0.3 mm thick) measuring several cm^2 that remained in this case showed no measurable activity.

If one assumes a most probable gas velocity of about 10^6 cm/sec, then this corresponds to a particle energy of about 1 electron-volt, i.e. assuming a Gaussian distribution (deviation about ___); the bulk of all particles will have an energy of about 1 eV and the number of those that could trigger a D-D reaction ($\sim 10^5$ eV) is likely to be extremely small (___% von $N_{1\,\text{Volt}}$). Accordingly, one can hardly expect nuclear reactions of a measurable amount. In addition, there is the difficulty of the detection itself. If silver with a beta half-life of 24 seconds is chosen as the neutron indicator, then a simple consideration shows that with the short reaction time of the explosive ($\sim 10^{-5}$ seconds) it only attains about 10^{-7} parts of the activity that it would achieve if irradiated to saturation (~ 8). In order to achieve an activity of 1 particle/min, the indicator would therefore have to generate 10^7 counts/1 min at saturation irradiation; this would correspond approximately to neutron radiation emitted by a 100 Curie Ra-Be neutron source. However, such neutron radiation is in contradiction to the energy of the explosion gases of about 1 eV.



Versuche über die Einleitung von Kernreaktionen durch die Wirkung explodierender Stoffe.

Von W. Herrmann, G. Hartwig, H. Rackwitz, Gottow und W. Trinks und H. Schaub, HWA.

1) Es wurde des öfteren vorgeschlagen, zur Einleitung von Kern- und Kettenreaktionen die Schwadengeschwindigkeit bei der Explosion von Sprengstoffen zu benutzen. Es sollten dabei die entstehenden Kernprozesse die Wirkung von Explosionsstoffen ~~stören~~ erhöhen. Obwohl dieser Weg nach einfachen Ueberlegungen ungangbar scheint, wurden, um endlich eine experimentell begründete Aussage darüber geben zu können, auf Anregung von Herrn Prof. Gerlach in der Heeresforschungsstelle Kdf. einige orientierende Versuche durchgeführt.

2) Durchführung der Versuche:
In zylindrische Sprengkörper aus Trinitrotoluol (12 cm Ø, 1o cm Höhe; 5,o cm Ø, 8,o cm ~~Höhe~~) wurden in der Mitte der Grundfläche kleine Kegel (1,5 cm Ø, 3,o cm Höhe) aus Deutero-Paraffin eingesetzt. Die im Sprengstoff laufenden Druckwellen sollten die D-Atome des Deutero-Paraffins beschleunigen und durch zusammenstossende D-Atome Neutronen erzeugen. Zum Nachweis dieser D-D-Reaktion wurde unter dem Paraffinkegel ein Silber-Indikator vorgesehen, dessen Aktivität, durch die Neutronen der D-D-Reaktion angeregt, gemessen werden sollte. Die Aktivitätsmessungen wurden mit β-Zählrohr, Verstärker und Zählwerk ausgeführt.

3) Ergebnisse:
Bei zwei Sprengungen mit entsprechend vorbereiteten Sprengzylindern (12,o x 1o,o cm) wurde die Stahlunterlage zerschlagen und von den untergelegten Ag-Folien keine nennenswerten Reste gefunden. Teile der Stahlunterlage zeigten am Zählrohr keine Erhöhung des Null-Effektes (16 Stösse je Minute). Nach einigen Vorversuchen mit Sprengkörpern von 5.o x 8,o cm wurden damit zwei Sprengungen durchgeführt und der Silber-Indikator schliesslich zwischen zwei Stahlscheiben von je 3mm Dicke ~~getan~~ gelegt. Auch die in diesem Falle erhalten gebliebenen mehreren

cm^2 grossen Teile des Ag-Bleches (o,3 mm dick) zeigten keine messbare Aktivität.

Rechnet man mit einer häufigsten Schwadengeschwindigkeit von etwa 1o^6 cm/sec, dann entspricht diese einer Teilchenenergie von rund 1 eVolt, d.H. unter Voraussetzung einer Gaussverteilung (Schiefe etwa) wird die Hauptmenge aller Teilchen eine Energie von rund 1 eV haben und die Zahl derer, die eine D-D-Reaktion auslösen könnten ($\sim$ 1o^5 eV), dürften ausserordentlich gering sein (% von $N_{1\ Volt}$). Demgemäss kann man also kaum Kernreaktionen in messbarer Grösse erwarten. Hinzu kommt ferner, die Schwierigkeit des Nachweises selbst. Wählt man als Neutronen-Indikator Ag mit der Elektronen-Halbwertszeit von 24 sec, dann ergibt eine einfache Ueberlegung, dass dieser bei der kurzen Reaktionszeit des Sprengstoffes (1o^{-5} sec) nur etwa dem 1o^{-7} Teil der Aktivität annimmt, den er bei Bestrahlung bis zur Sättigung ($\sim$ 8^{-}) erreichen würde. Um eine Aktivität von 1 Teilchen / min zu erreichen, müsste also bei Sättigungsbestrahlung der Indikator 1o^7 Stösse/ 1 Min. erzeugen; dies würde etwa einer Neutronenstrahlung entsprechen, die eine 1oo Curie Ra-Be-Neutronenquelle emittiert. Eine solche Neutronenstrahlung steht aber im Widerspruch zu der Energie der Explosionsschwaden von etwa 1 eV.

Figure D.582: G-303. Walter Herrmann, Georg Hartwig, Heinz Rackwitz, Walter Trinks, and H. Schaub. 1944. *Versuche über die Einleitung von Kernreaktionen durch die Wirkung explodierender Stoffe.* Deutsches Museum number FA 002/0721. https://digital.deutsches-museum.de/item/FA-002-721/

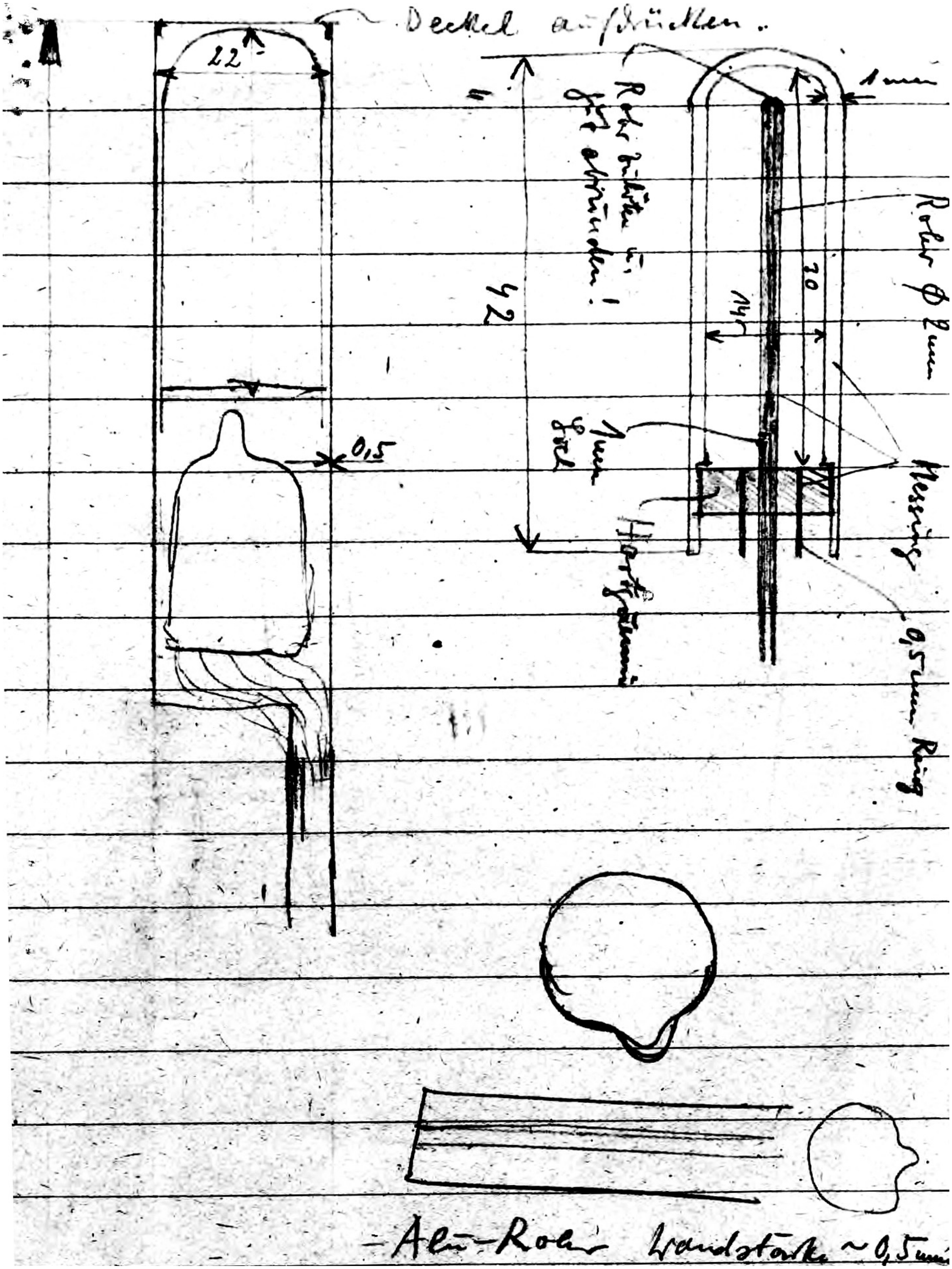
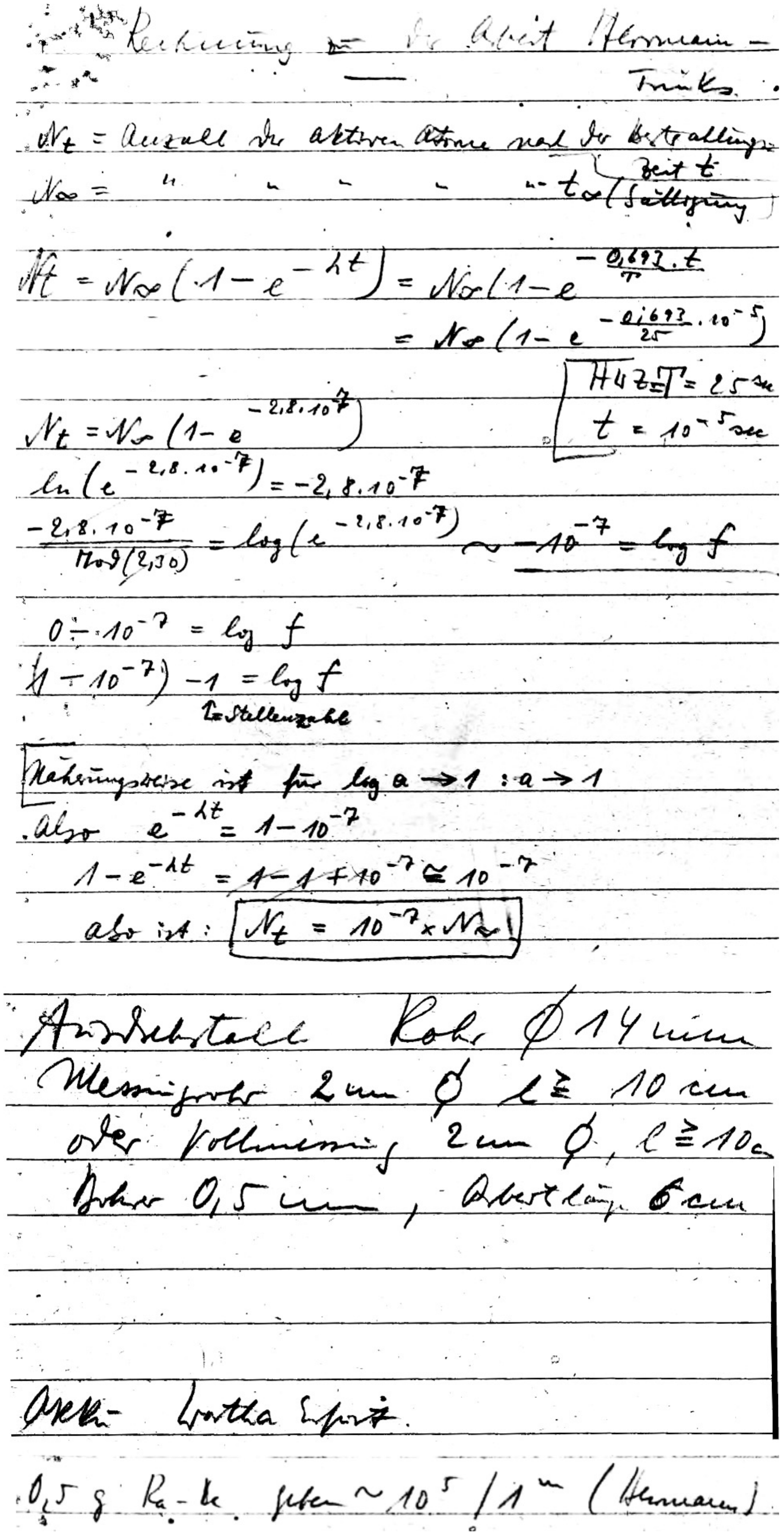

Deckel aufdrücken.
22
0,5
42
Rohrhälften fest andrücken!
1mm
Rohr Ø 2mm
20
14
1mm dick
Messing
Hartgummi
0,5mm Ring
Alu-Rohr Wandstärke ~0,5mm

Figure D.583: G-303. Walter Herrmann, Georg Hartwig, Heinz Rackwitz, Walter Trinks, and H. Schaub. 1944. *Versuche über die Einleitung von Kernreaktionen durch die Wirkung explodierender Stoffe.* Deutsches Museum number FA 002/0721. https://digital.deutsches-museum.de/item/FA-002-721/



Rechnung zu der Arbeit Herrmann – Trinks.

N_t = Anzahl der aktiven Atome nach der Bestrahlungs-Zeit t

N_∞ = " " " " " t_∞ (Sättigung)

$N_t = N_\infty\left(1-e^{-\lambda t}\right) = N_\infty\left(1-e^{-\frac{0,693}{T}\cdot t}\right)$

$= N_\infty\left(1-e^{-\frac{0,693}{25}\cdot 10^{-5}}\right)$

HWZ $= T = 25$ sec

$t = 10^{-5}$ sec

$N_t = N_\infty\left(1-e^{-2,8\cdot10^{-7}}\right)$

$\ln\left(e^{-2,8\cdot10^{-7}}\right) = -2,8\cdot10^{-7}$

$\frac{-2,8\cdot10^{-7}}{\text{Mod}(2,30)} = \log\left(e^{-2,8\cdot10^{-7}}\right) \sim \underline{-10^{-7}} = \log f$

$0 - 10^{-7} = \log f$

$(1-10^{-7}) - 1 = \log f$

Stellenzahl

Näherungsweise ist für $\log a \to 1 : a \to 1$

Also $e^{-\lambda t} = 1-10^{-7}$

$1-e^{-\lambda t} = \cancel{1-1} + 10^{-7} \cong 10^{-7}$

also ist: $\boxed{N_t = 10^{-7} \times N_\infty}$

Aus Edelstahl Rohr Ø 14 mm

Messingrohr 2 mm Ø $l \geq 10$ cm

oder Vollmessing 2 mm Ø, $l \geq 10$ c

Bohrer 0,5 mm, Arbeitslänge 6 cm

Akti- Wartha Export.

0,5 g Ra-Be geben ~ $10^5/1^m$ (Herrmann)

Figure D.584: G-303. Walter Herrmann, Georg Hartwig, Heinz Rackwitz, Walter Trinks, and H. Schaub. 1944. *Versuche über die Einleitung von Kernreaktionen durch die Wirkung explodierender Stoffe.* Deutsches Museum number FA 002/0721. https://digital.deutsches-museum.de/item/FA-002-721/

Erich Schumann. 1949. *Die Wahrheit über die deutschen Arbeiten und Vorschläge zum Atomenergie-Problem (1939–45).* Unpublished manuscript from Schumann estate [courtesy of Rainer Karlsch].

[This manuscript is an unfinished, unpublished attempt by Schumann to describe the parts of the German nuclear program with which he was involved. In its current form, the manuscript is missing many pages, and those that do exist are often simply abbreviated notes for what Schumann intended to write.]

[S. 38] Wenn über die in Deutschland gegen Kriegsende geplanten und vorbereiteten Versuche bisher nichts berichtet worden ist, so hat das seinen Grund darin, das nur wenige Wissenschaftler darüber unterrichtet waren und die Akten im April 1945 vernichtet werden mußten.

[S. 39] Diese Vorschläge, die ich im Herbst 1944 dem Chef des Heereswaffenamts, General d. Art. Leeb, vorlegte, basieren auf gemeinsam mit Trinks angestellten Überlegungen im Anschluss an unsere Arbeiten2) auf dem Gebiet der Sprengstoffphysik.

2) niedergelegt in den Berichten des Reichsforschungsrats (Sprengstoffphysikberichte, herausgegeben vom Bevollmächtigten für Sprengstoffphysik), ferner in den Berichten der Forschungsabteilung des Heereswaffenamts und in etwa 40 Geheimpatentschriften.

[S. 121] Immer wieder, insbesondere in der Presse und von nicht kompetenten Stellen wird behauptet, Hitler habe an die A-Bomb geglaubt, diese sei die unausgesprochene Wunderwaffe in seinen Bluffreden gewesen.

Alle mit der Atomangelegenheit sachlich befassten amtlichen Stellen wissen, dass das nicht der Fall war. Erst Ende 1941 ist Hitler durch den Postminister Dr. Ohnesorge über das Atomenergieproblem unterrichtet worden. [...] Hitler war skeptisch und lehnte ab, noch schärfer als bei seiner Unterrichtung über die Rakete.

[p. 38] If nothing has been reported about the experiments planned and prepared in Germany towards the end of the war, this is due to the fact that only a few scientists were informed and the files had to be destroyed in April 1945.

[p. 39] These proposals, which I submitted to the Chief of the Army Ordnance Office in the fall of 1944, General d. Art. Leeb, presented, are based on considerations shared with Trinks following our work in the field of explosives physics2).

2) set forth in the reports of the Reich Research Council (Explosives Physics Reports, issued by the Explosives Physics Commissioner), in the reports of the Army Ordnance Research Department and in about 40 secret patents.

[p. 121] Again and again, especially in the press and from incompetent sources, it is alleged that Hitler had believed in the A-bomb, which had been the unspoken miracle weapon in his bluffing stories.

All the official bodies concerned with the nuclear issue know that this was not the case. At the end of 1941, Hitler was briefed by the postmaster Ohnesorge about the nuclear energy problem. [...] Hitler was skeptical and rejected it, even more sharply than his briefing on the rocket.

[S. 127] Im übrigen machte sich schon der Einfluss der Waffen-SS geltend, der dahin ging, ein eigenes Waffenamt aufzubauen und es selbstverständlich ablehnte, dass das OKW in irgendeiner Weise hinein zureden vermochte.

[S. 131] Deutschland hat nie reines ^{235}U in nennenswerten Mengen hergestellt; nur Harteck 1943 bis 44 mittels Zentrifuge (Anreicherung). Clusius-Verfahren ging nicht, weil Thermodiffusionskoeffizient negativ war.

[p. 127] Moreover, the influence of the Waffen-SS, which set out to set up its own weapons office and, of course, refused to allow the Army to speak in any way, became apparent.

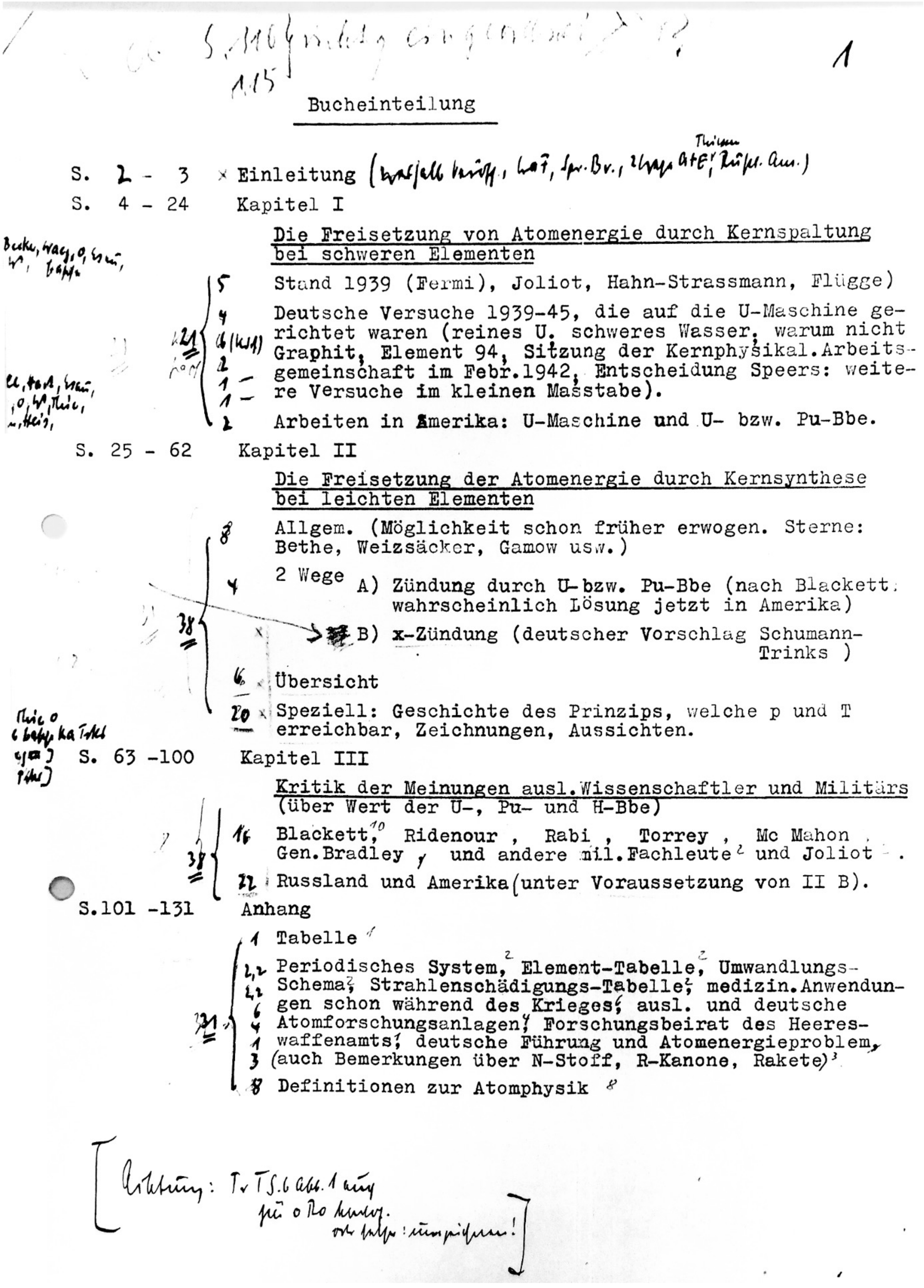
[p. 131] Germany never made pure ^{235}U in appreciable quantities; only Harteck 1943 to 44 by means of centrifuge (enrichment). Clusius method did not work because thermal diffusion coefficient was negative.

[Erich Schumann's implosion systems would have been highly suitable for compressing fission fuel, thus making a complete fission bomb. In this manuscript, Schumann did not describe that; with the highly compartmentalized security of German secret weapons programs, he may not have known much about it. In any event, with postwar Allied interrogations, trials, prison sentences, and executions of Germans who had performed various tasks during the war, Schumann certainly would not have wanted to admit anything that he had known or been involved with.

Schumann stated that he filed "about 40 secret patents" during the war, which presumably covered the material for which he was granted patents in the postwar period. The view that Schumann's postwar papers reflect wartime work is strongly supported by the fact that in August 1945, the U.S. Army Ordnance Technical Intelligence office publicly stated that based on evidence they had collected, Erich Schumann was a "brilliant scientist" who "did much outstanding work" "in the development of atomic bombs"; other U.S. officials then threatened the Ordnance Technical Intelligence office "against making further statements on this subject" (p. 4187). The importance of Schumann's work is supported by Erwin Respondek's 1945 testimony too (p. 4194). The notion that Schumann's postwar papers accurately reflect wartime work is also supported by an April 1947 Russian report that is highly similar to Schumann's work and likely based on some of his wartime papers that were captured by the Russians [Kozyrev 2005].

Schumann confirmed (1) the fact that the SS eclipsed the Army Ordnance in the German nuclear program, (2) the extreme secrecy of the nuclear program during the war, and (3) the destruction of evidence at the end of the war, all consistent with the testimony of Werner Grothmann.

Schumann wrote that he was unaware of enriched uranium sources other than Paul Harteck's centrifuges. Yet Werner Holtz and Werner Schwietzke in his own Army Ordnance Office spent several years developing uranium centrifuges (pp. 3542–3544); the fact that Schumann completely omitted any mention of that fact demonstrates that he withheld important information in this and other writings.]



1

Bucheinteilung

S. 2 - 3 × Einleitung

S. 4 - 24 Kapitel I

Die Freisetzung von Atomenergie durch Kernspaltung bei schweren Elementen

5 Stand 1939 (Fermi), Joliot, Hahn-Strassmann, Flügge)

4 Deutsche Versuche 1939-45, die auf die U-Maschine gerichtet waren (reines U. schweres Wasser, warum nicht Graphit, Element 94, Sitzung der Kernphysikal.Arbeitsgemeinschaft im Febr.1942, Entscheidung Speers: weitere Versuche im kleinen Masstabe).

2 Arbeiten in Amerika: U-Maschine und U- bzw. Pu-Bbe.

S. 25 - 62 Kapitel II

Die Freisetzung der Atomenergie durch Kernsynthese bei leichten Elementen

8 Allgem. (Möglichkeit schon früher erwogen. Sterne: Bethe, Weizsäcker, Gamow usw.)

4 2 Wege A) Zündung durch U-bzw. Pu-Bbe (nach Blackett, wahrscheinlich Lösung jetzt in Amerika)

B) x-Zündung (deutscher Vorschlag Schumann-Trinks)

6 Übersicht

20 Speziell: Geschichte des Prinzips, welche p und T erreichbar, Zeichnungen, Aussichten.

S. 63 -100 Kapitel III

Kritik der Meinungen ausl.Wissenschaftler und Militärs (über Wert der U-, Pu- und H-Bbe)

16 Blackett, Ridenour , Rabi , Torrey , Mc Mahon , Gen.Bradley , und andere mil.Fachleute und Joliot .

22 Russland und Amerika (unter Voraussetzung von II B).

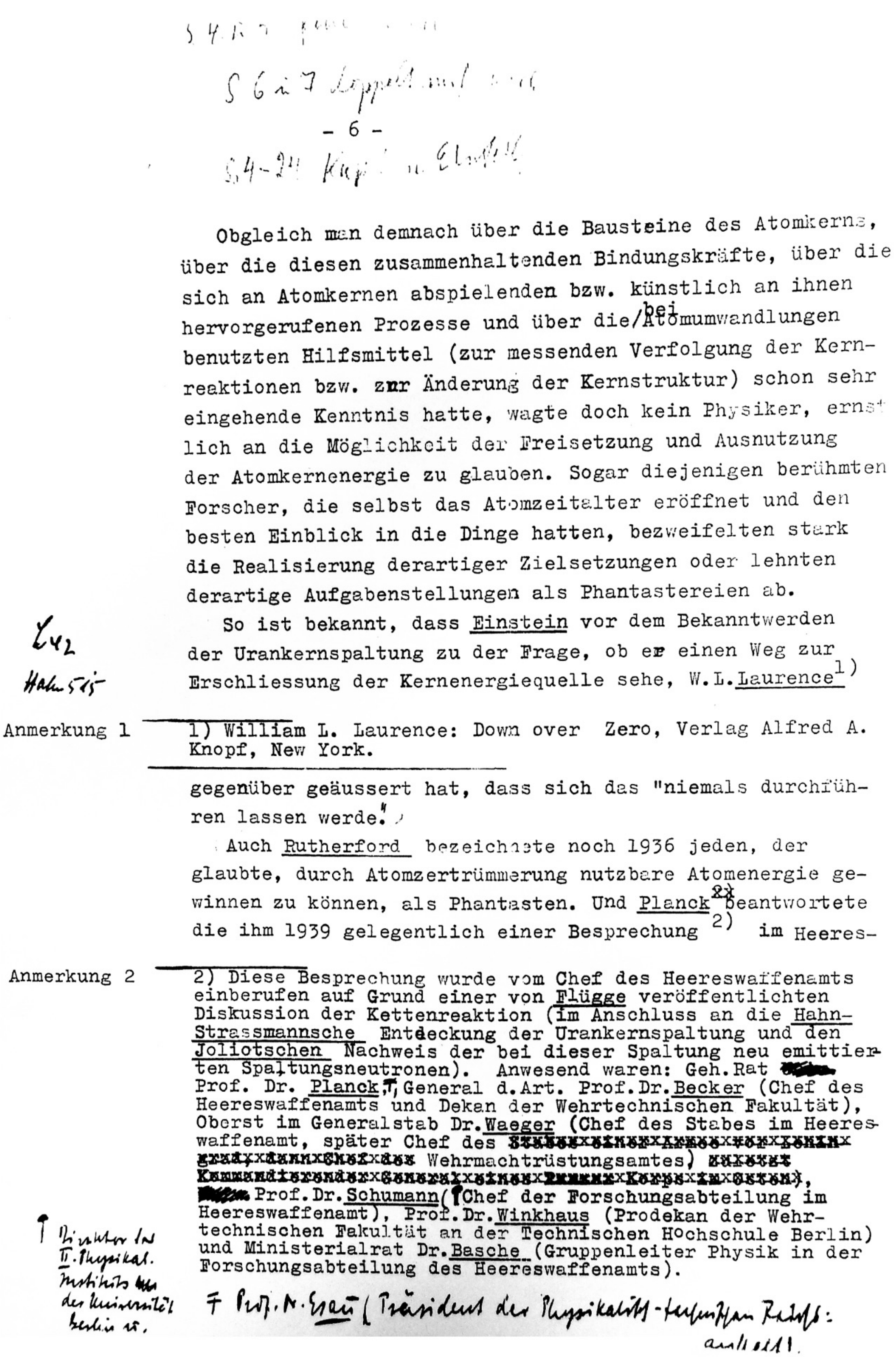
S.101 -131 Anhang

1 Tabelle

Periodisches System, Element-Tabelle, Umwandlungs-Schema; Strahlenschädigungs-Tabelle; medizin.Anwendungen schon während des Krieges; ausl. und deutsche Atomforschungsanlagen; Forschungsbeirat des Heereswaffenamts; deutsche Führung und Atomenergieproblem, (auch Bemerkungen über N-Stoff, R-Kanone, Rakete)

8 Definitionen zur Atomphysik

Figure D.585: The table of contents of an unpublished 1949 manuscript by Erich Schumann, describing some (but only some) of the wartime German nuclear work.



S. 4. R 7 [illegible]

S 6 u 7 doppelt auf [illegible]

- 6 -

S. 4-24 Kap. [illegible] u. Einleit[illegible]

Obgleich man demnach über die Bausteine des Atomkerns, über die diesen zusammenhaltenden Bindungskräfte, über die sich an Atomkernen abspielenden bzw. künstlich an ihnen hervorgerufenen Prozesse und über die/bei Atomumwandlungen benutzten Hilfsmittel (zur messenden Verfolgung der Kernreaktionen bzw. zur Änderung der Kernstruktur) schon sehr eingehende Kenntnis hatte, wagte doch kein Physiker, ernstlich an die Möglichkeit der Freisetzung und Ausnutzung der Atomkernenergie zu glauben. Sogar diejenigen berühmten Forscher, die selbst das Atomzeitalter eröffnet und den besten Einblick in die Dinge hatten, bezweifelten stark die Realisierung derartiger Zielsetzungen oder lehnten derartige Aufgabenstellungen als Phantastereien ab.

L 42

Hahn 5 15

So ist bekannt, dass Einstein vor dem Bekanntwerden der Urankernspaltung zu der Frage, ob er einen Weg zur Erschliessung der Kernenergiequelle sehe, W.L.Laurence[1] gegenüber geäussert hat, dass sich das "niemals durchführen lassen werde."

Auch Rutherford bezeichnete noch 1936 jeden, der glaubte, durch Atomzertrümmerung nutzbare Atomenergie gewinnen zu können, als Phantasten. Und Planck[2] beantwortete die ihm 1939 gelegentlich einer Besprechung (2) im Heeres-

Anmerkung 1

[1] William L. Laurence: Down over Zero, Verlag Alfred A. Knopf, New York.

Anmerkung 2

(2) Diese Besprechung wurde vom Chef des Heereswaffenamts einberufen auf Grund einer von Flügge veröffentlichten Diskussion der Kettenreaktion (im Anschluss an die Hahn-Strassmannsche Entdeckung der Urankernspaltung und den Joliotschen Nachweis der bei dieser Spaltung neu emittierten Spaltungsneutronen). Anwesend waren: Geh.Rat [redacted] Prof. Dr. Planck‡, General d.Art. Prof.Dr.Becker (Chef des Heereswaffenamts und Dekan der Wehrtechnischen Fakultät), Oberst im Generalstab Dr.Waeger (Chef des Stabes im Heereswaffenamt, später Chef des [illegible] Wehrmachtrüstungsamtes) [illegible], [redacted] Prof.Dr.Schumann(†Chef der Forschungsabteilung im Heereswaffenamt), Prof.Dr.Winkhaus (Prodekan der Wehrtechnischen Fakultät an der Technischen Hochschule Berlin) und Ministerialrat Dr.Basche (Gruppenleiter Physik in der Forschungsabteilung des Heereswaffenamts).

† Direktor des II. Physikal. Instituts der Universität Berlin u.

‡ Prof. Dr. Esau (Präsident der Physikalisch-technischen Reichsanstalt: ausschließl.

Figure D.586: A page from an unpublished 1949 manuscript by Erich Schumann, describing some (but only some) of the wartime German nuclear work.

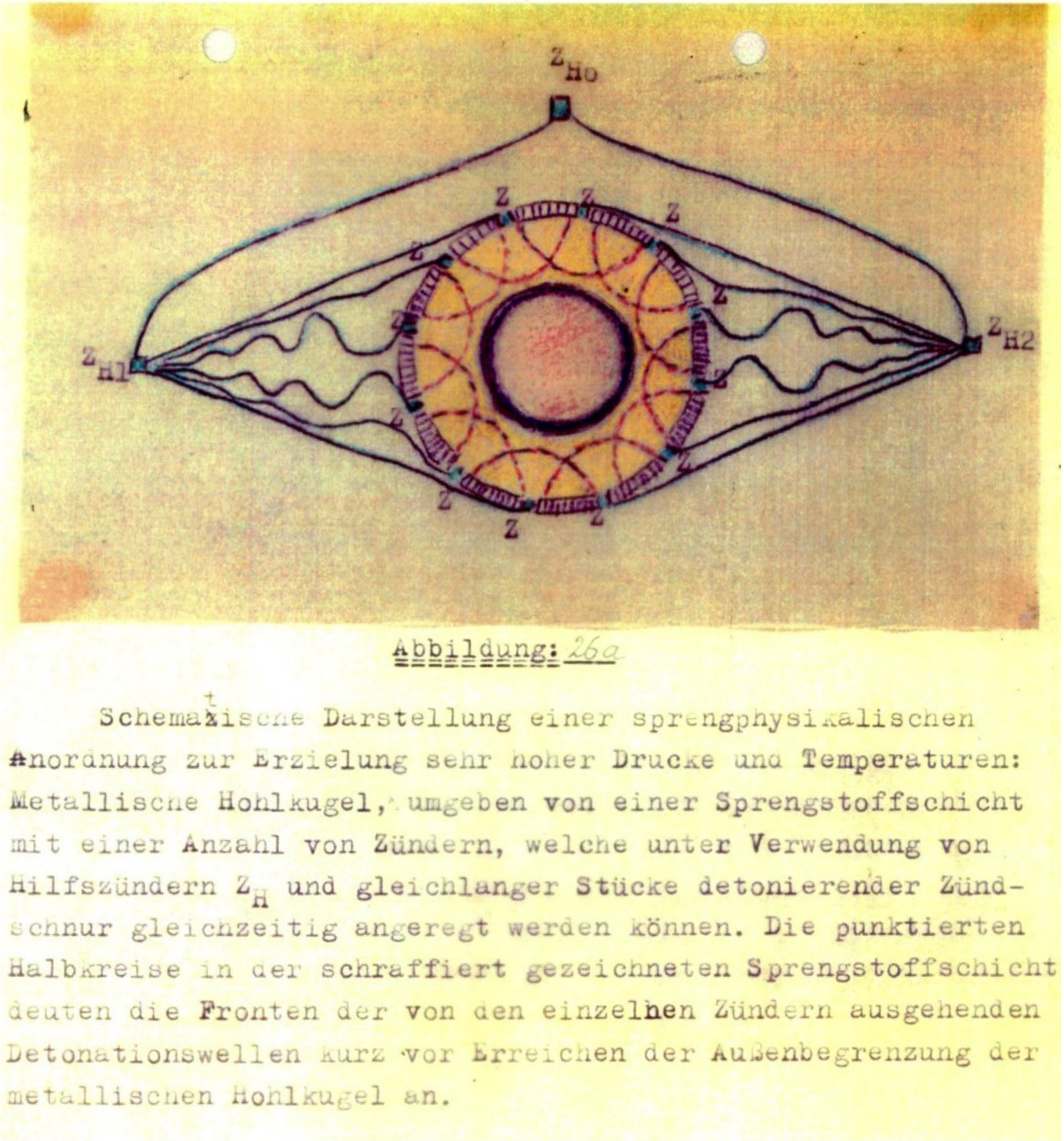

Z_{Ho}
Z_{H1}
Z_{H2}
Z
Z
Z
Z
Z
Z
Z
Z
Z
Z
Z
Z

Abbildung: 26a

Schematische Darstellung einer sprengphysikalischen Anordnung zur Erzielung sehr hoher Drucke und Temperaturen: Metallische Hohlkugel, umgeben von einer Sprengstoffschicht mit einer Anzahl von Zündern, welche unter Verwendung von Hilfszündern Z_H und gleichlanger Stücke detonierender Zündschnur gleichzeitig angeregt werden können. Die punktierten Halbkreise in der schraffiert gezeichneten Sprengstoffschicht deuten die Fronten der von den einzelnen Zündern ausgehenden Detonationswellen kurz vor Erreichen der Außenbegrenzung der metallischen Hohlkugel an.

Figure D.587: A page from an unpublished 1949 manuscript by Erich Schumann, describing a spherical implosion bomb design with multiple concentric layers. (See also p. 4240.) Schumann's caption says: "Schematic representation of an explosive physical arrangement for achieving very high pressures and temperatures: Hollow metallic sphere surrounded by a layer of explosives with a number of detonators which can be triggered simultaneously using auxiliary detonators Z_H and pieces of detonating fuse of equal length. The dotted semicircles in the hatched explosive layer indicate the fronts of the detonation waves emanating from the individual detonators shortly before reaching the outer boundary of the hollow metallic sphere." Other pages from Schumann described additional details of the design, including explosive lenses of TNT and RDX within the outer layer, the arrangement of both fission and fusion fuel near the center, and methods of testing the device by mounting it on a tower and using sophisticated high-speed diagnostic instruments to record the explosion.

Letter from Erich Schumann to Ernst Telschow. 2 April 1948 [AMPG, Abt. III, Rep. 83, Nr. 286].

Prof. Dr. Erich Schumann
Göttingen, den 2. April 48
Vertraulich
An Herrn Gen. Dir. Dr. E. Telschow
Max-Planck-Gesellschaft zur
Förderung der Wissenschaften in Göttingen

Im Verlauf von sprengstoff-physikalischen Forschungsarbeiten, insbesondere der die Zündführung bei Hohlsprengkörpern betreffenden Untersuchungen, führten Überlegungen, die ich im Oktober 1943 gemeinsam mit Dr. Walter Trinks anstellte, zu dem Schluss, dass es zufolge der in unseren Berichten [Forschungsabteilung H Wa F, Reichsforschungsrat (Bevollmächtigter für Sprengstoffphysik) und etwa 40 Patentschriften] niedergelegten Erkenntnissen möglich sein müsse, Umwandlungen z. B. von Kohle in Diamant vorzunehmen und ferner Atomenergie auch durch Reaktionen zwischen leichten Elementen freizumachen.

Prinzip: Die außerordentliche Verdichtung der Materie und damit einhergehende ungeheuere Temperatursteigerung, wie sie sich im Entwicklungsgang der Sterne infolge der Gravitation vollzieht, soll im Experiment dadurch erzwungen werden, dass man die hohe Sprengstoff-physikalisch gewonnene kinetische Energie einer großen Masse auf eine wesentlich kleinere Masse überträgt. Siehe nachstehende schematische Darstellung. (Die zu verdichtende Substanz wird im gasförmigen Zustand in einer metallischen Hohlkugel untergebracht, welche außen mit einer Schicht eines brisanten Sprengstoffs belegt ist. Bei geeigneter, gleichmäßig über die ganze Oberfläche der Sprengstoffschicht eingeleiteter Zündung wird für eine gewisse kurze Zeit ein hoher Druck auf die metallische Kugel ausgeübt, unter dessen Einwirkung das Metall in den plastischen Zustand gerät und zum Mittelpunkt hin beschleunigt wird. Dadurch wird die eingeschlossene Gasmasse außerordentlich rasch verdichtet und dabei sehr hoch erhitzt):

Prof. Dr. Erich Schumann
Göttingen, 2 April 48
Confidential
To General Director Dr. E. Telschow
Max Planck Society for the
Advancement of Sciences in Göttingen

In the course of research work in the physics of explosives, in particular the investigations into the detonation of hollow explosives, considerations which I carried out in October 1943 with Dr. Walter Trinks, led to the conclusion that according to the findings laid down in our reports [Research Department H Wa F, Reich Research Council (Commissioner for Explosives Physics) and about 40 patent specifications], it must be possible to carry out transformations, e.g. of coal into diamond, and moreover to release nuclear energy also through reactions between light elements.

Principle: The extraordinary compression of matter and the associated enormous increase in temperature, as it occurs in the evolution of stars as a result of gravity, can be forcibly created in the experiment by transferring the high kinetic energy of a large mass, obtained by explosive physics, to a much smaller mass. See the schematic diagram below. (The substance to be compressed is placed in the gaseous state in a metallic hollow sphere, which is covered on the outside with a layer of explosive material. When a suitable ignition is applied uniformly over the entire surface of the explosive layer, a high pressure is applied to the metal sphere for a short time, which causes the metal to plasticize and accelerate towards the center. This causes the enclosed mass of gas to be compressed extremely rapidly and thereby to heat up very rapidly):

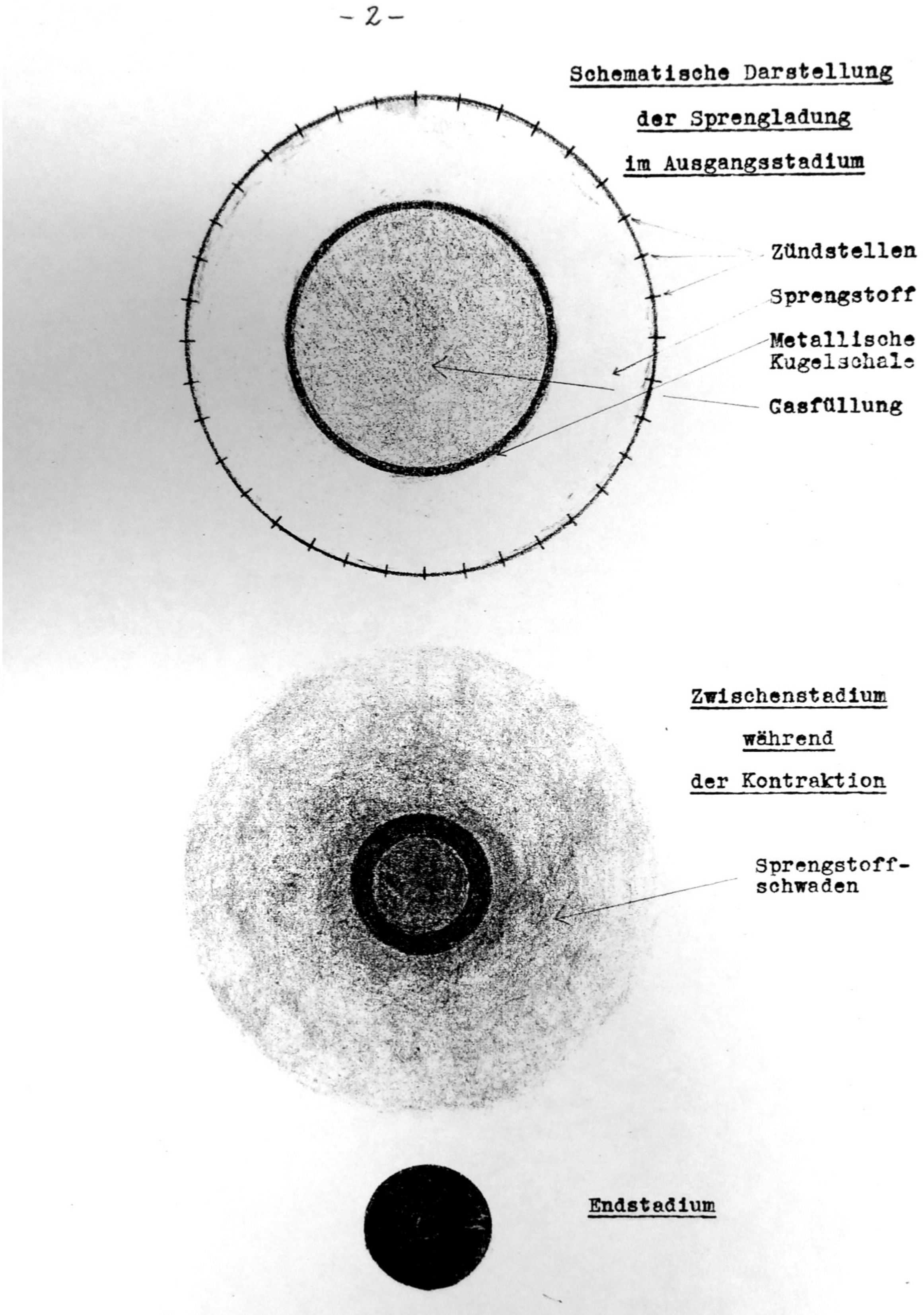

- 2 -
Schematische Darstellung
der Sprengladung
im Ausgangsstadium
Zündstellen
Sprengstoff
Metallische
Kugelschale
Gasfüllung
Zwischenstadium
während
der Kontraktion
Sprengstoff-
schwaden
Endstadium

Figure D.588: A 1948 drawing by Erich Schumann, showing a spherical implosion bomb design with multiple concentric layers used to trigger nuclear reactions [AMPG, Abt. III, Rep. 83, Nr. 286].

Es war 1944/45 nicht mehr möglich, die bereits vorbereiteten Versuche durchzuführen, denn vom damaligen Ministerium für Bewaffnung und Munition wurden derartige Versuche nicht unterstützt, ja sogar verboten. Die experimentellen Möglichkeiten und theoretischen Überlegungen wurden aber damals von Dr. Trinks in einer Arbeit, die er als Habilitationsschrift zu benutzen gedachte, niedergelegt. Diese Arbeit wurde weisungsgemäß 1945 mit den übrigen Geheimakten vernichtet und 1947 nach Rücksprache mit Ihnen für die dortige Behörde von Dr. Trinks rekonstruiert.

Besteht beispielsweise die erwähnte Kugelschale aus Eisen, die Füllung aus Wasserstoffgas vom Anfangsdruck 1 Atm., beträgt die Wandstärke der Kugelschale etwa 1/50 ihres Durchmessers und rechnet man weiter mit einer Anfangsgeschwindigkeit der Schalenelemente von etwa 3200 m/sec, welche noch bequem erreichbar erscheint, so ergibt sich—nach Trinks—im Endzustand ein Energiegehalt des verdichteten Wasserstoffgases von etwa 10^{15} erg/g, d.h. mehr als 10 000 mal soviel, wie die brisantesten Sprengstoffe besitzen. Geht man von einem herabgesetzten Anfangsdruck des eingeschlossenen Gases aus, so ist mit noch höheren Energiedichten zu rechnen, also z.B. bei 0,1 Atm. etwa mit 10^{16} erg/g, das ist das 100 000-fache des Wertes für die brisantesten Sprengstoffe.

Durch extrem anwachsende Strahlungsverluste beim Überschreiten der Temperaturgrenze des nichtentarteten Elektronengases, sowie durch sprunghaft erhöhte Kompressibilität bei Überschreiten der Druckgrenze des nichtentarteten Elektronengases werden die theore- tisch möglichen Zündwerte (Temperaturen von 10–100 Millionen Grad und Drucke von 100 Milliarden bis 100 Billionen Atm) allerdings nur annährend erreicht werden können. Diese Schwierigkeiten beginnen jedoch erst von etwa 4 Millionen Grad bei einem Druck von 250 Millionen Atm. An merklich zu werden, während unter ihrer Inrechnungsetzung ein weiterer Anstieg auf etwa 10 Millionen Grad bei einem Druck von etwa 10 Milliarden Atm., das ist nahezu der Zustand im Sonnenmittelpunkt, erwartet werden kann.

In 1944/45 it was no longer possible to carry out the experiments already prepared, because the then Ministry of Armaments and Ammunition did not support such experiments and even prohibited them. The experimental possibilities and theoretical considerations were, however, laid down by Dr. Trinks at that time in a paper which he intended to use as his habilitation thesis. This work was destroyed together with the other secret files in 1945, as ordered, and in 1947, after consultation with you, it was reconstructed by Dr. Trinks for the local authorities.

If, for example, the spherical shell mentioned above consists of iron, the filling of hydrogen gas of the initial pressure of 1 Atm., the wall thickness of the spherical shell is about 1/50 of its diameter and if one continues to calculate with an initial speed of the shell elements of about 3200 m/sec, which still seems to be comfortably attainable, this results—after Trinks—in the final state an energy content of the compressed hydrogen gas of about 10^{15} erg/g, i.e. more than 10,000 times as much as the most explosive explosives possess. If one assumes a reduced initial pressure of the enclosed gas, even higher energy densities can be expected, e.g. at 0.1 atm. about 10^{16} erg/g, i.e. 100,000 times the value for the most explosive explosives.

However, due to extremely increasing radiation losses when the temperature limit of the non-degenerate electron gas is exceeded, as well as due to a sudden increase in compressibility when the pressure limit of the non-degenerate electron gas is exceeded, the theoretically possible ignition values (temperatures of 10–100 million degrees and pressures of 100 billion to 100 trillion Atm) can only be approximately reached. However, these difficulties only start from about 4 million degrees at a pressure of 250 million Atm. It is possible to notice them, whereas if they are taken into account, a further increase to about 10 million degrees at a pressure of about 10 billion Atm., which is almost the state in the center of the sun, can be expected.

Dann sind aber zumindest die beiden Deuteronen-Reaktionen

$$^{2}\mathrm{D} + {}^{2}\mathrm{D} = {}^{3}\mathrm{He} + {}^{1}\mathrm{n}$$

$$^{2}\mathrm{D} + {}^{2}\mathrm{D} = {}^{3}\mathrm{Tr} + {}^{1}\mathrm{H}\,,$$

deren Einsetzen im Entwicklungsgang der Sterne bereits bei 200 000^{o} beginnt$^{x)}$, genügend wahrscheinlich$^{xx)}$, so dass sie auch während der etwas kurzen Zeiten, die bei dem geplanten Hohlkugelverfahren zur Verfügung stehen (etwa 0,001 sec), in so ausreichendem Umfang stattfinden, dass erhebliche Energiebeträge gewonnen werden können.

Wird z.B. 1/2 Kubikmeter (ca 9 g) schweren Wasserstoffgases vom Druck 0,1 Atm. vollständig nach dem obigen Reaktionsgleichungen umgesetzt, so wird ein Energiebetrag von rund 10^{19} erg entsprechend etwa 275 to Trinitrotoluol, frei. Noch erheblich höhere Beträge können unter Heranziehung anderer leichter Elemente, z. B. Lithium oder Bor, gewonnen werden.

Erich Schumann

$^{x)}$ Vgl. Bethe u. Marshak, Rep. on Progr. in Phys. 6, 1–15, 1939.

$^{xx)}$Nachgewiesen in dem Hauptbericht Abschn. V, S. 36 unter Benutzung der von Gamow und Teller (Phys. Rev. (2) 53, 608, 1938) verbesserten theoretischen Beziehungen von Atkinson und Houtermans, der Rechnungen von Bethe (Phys. Rev. (2) 55, 434, 1939), sowie der experimentellen Werte des Wirkungsquerschnittes der Deuteronenreaktionen von Ladenburg u. Kanner (Phys. Rev. (2) 52, 911, 1937) und der Messungen von Burhop (Proc. Phil. Soc. 32, 643, 1936).

But then at least the two deuteron reactions

whose onset in the evolutionary process of stars already starts at 200,000$^{o\ x)}$, sufficiently probable$^{xx)}$, so that even during the somewhat short times available in the planned hollow-sphere process (about 0.001 sec), they take place in such a sufficient amount that considerable amounts of energy can be gained.

If e.g. 1/2 cubic meters (approx. 9 g) of heavy hydrogen gas of pressure 0.1 Atm. are completely converted according to the above reaction equations, an energy amount of about 10^{19} erg corresponding to about 275 tons of TNT is released. Even considerably higher amounts can be obtained by using other light elements, e.g. lithium or boron.

Erich Schumann

$^{x)}$ See Bethe and Marshak, Rep. on Progr. in Phys. 6, 1–15, 1939.

$^{xx)}$Proven in the main report, section V, p. 36, using the theoretical relations of Atkinson and Houtermans improved by Gamow and Teller (Phys. Rev. (2) 53, 608, 1938), the calculations of Bethe (Phys. Rev. (2) 55, 434, 1939), as well as the experimental values of the cross section of the deuteron reactions of Ladenburg and Kanner (Phys. Rev. (2) 52, 911, 1937) and the measurements of Burhop (Proc. Phil. Soc. 32, 643, 1936).

[This 1948 letter briefly described a spherical implosion bomb design with multiple concentric layers used to trigger nuclear reactions. While the letter did not delve into still-classified details such as uranium and explosive lenses, clearly it was closely tied both to Schumann's wartime work and to his postwar patents (which are presented on the following pages).]

Erich Schumann and Walter Trinks. Patent DE977825. Vorrichtung, um ein Material zur Einleitung von mechanischen, thermischen oder nuklearen Prozessen auf extrem hohe Drücke und Temperaturen zu bringen. [Device for the introduction of a material for the introduction of mechanical, thermal or nuclear processes to extremely high pressures and temperatures.] Filed 13 August 1952.

[...] In solchen Fällen kann man sich eines Verfahrens bedienen, das darauf beruht, die kinetische Energie einer größeren Masse nahezu vollständig auf eine möglichst kleine Masse in einem sehr kleinen Raumgebiet zu übertragen. Man erreicht durch den Übergang von großen zu kleinen Massen größte Energiedichten, ganz analog wie man einen hohen Druck beim Übergang von großen zu kleinen Flächen erhält oder große Lasten mit einer kleinen Kraft durch Anwendung langer Wege hebt.

Dieses Prinzip der Übertragung der kinetischen Energie großer Massen auf kleinere findet z.B. Anwendung beim sogenannten Wasserhammer oder hydraulischen Widder; eine größere in Strömung befindliche Wassermenge wird plötzlich gebremst; der dabei auftretende Staudruck hebt einen Bruchteil der gestauten Wassermenge auf eine bestimmte Höhe empor und verleiht demselben so einen höheren Betrag an potentieller Energie pro Volumeneinheit, als das ursprünglich fließende Wasser an kinetischer Energie besaß.

Gemäß der Erfindung wird für die Erzeugung extrem hoher Drücke und Temperaturen eine Vorrichtung vorgeschlagen, die eine geschlossene Kammer für das auf die Drücke und Temperaturen zu bringende Material besitzt, bei der eine jenem Material gegenüberliegende, selbst nicht aus Sprengstoff bestehende Wand der Kammer mit einem Sprengstoff belegt ist, wobei diese Wand und ihre Sprengstoffbelegung so ausgebildet sind, daß die Wand durch den bei der Detonation des Sprengstoffes auftretenden Druck auf das genannte Material hin bewegt und in eine zu dem genannten Material hin konkave Form plastisch verformt wird.

[...] In such cases, a method can be used which is based on transferring the kinetic energy of a larger mass almost completely to a mass as small as possible in a very small spatial region. From the transition from large to small masses one attains the greatest energy density, just as a high pressure is obtained in the transition from large to small surfaces, or large loads are lifted with a small force by the application of long paths.

This principle of transferring the kinetic energy of large masses to smaller ones is, for example, applied in the so-called water hammer or hydraulic ram; a larger stream of water is suddenly braked; the pressure occurring in the process lifts a fraction of the accumulated water to a certain height and thus gives it a higher amount of potential energy per unit volume than the kinetic energy of the initially flowing water.

According to the invention, an apparatus is proposed for the production of extremely high pressures and temperatures, which has a closed chamber for the material to be subjected to pressures and temperatures, in which a wall of the chamber, which does not consist of explosives itself, is lined with an explosive, this wall and its explosive covering being designed in such a way that the wall is moved towards the said material by the pressure occurring during the detonation of the explosive and is plastically deformed into a concave shape towards the said material.

Diese Vorrichtung beruht zum Teil auf dem Prinzip der sogenannten Hohlsprengladung. Der maßgebende Teil solcher Hohlsprengladungen besteht aus einem metallischen Hohlkörper von vorzugsweise kegel-, glocken- oder flaschenförmiger Gestalt, welcher außen mit einem Sicherheitssprengstoff, z.B. Hexogen oder Trinitrotoluol, umgeben ist. Bei der Detonation des letzteren gehen die einzelnen Wandelemente des genannten Hohlkörpers unter dem Einfluß des Druckes von etwa 100 000 Atm in den plastischen Zustand über und erhalten eine nach innen gerichtete Geschwindigkeit von mehreren Kilometern pro sec. Beim Zusammentreffen der beschleunigten Wandelemente auf der Hohlraumachse wird ihre Bewegung gebremst, wobei auf einen geschmolzenen Anteil ihrer Masse ein hoher Druck ausgeübt wird. Durch diesen Druck werden die flüssig gewordenen Teilchen in Form eines feinen Strahles mit großer Geschwindigkeit aus dem sich zusammenziehenden Hohlraum herausgepreßt. Bei geeigneter Hohlraumform erreicht man in solchen Hohlsprengladungen Strahlgeschwindigkeiten bis zur doppelten Detonationsgeschwindigkeit, also beispielsweise bei Hexogen 2 × 8 km/sec = 16 km/sec. Dieser Geschwindigkeit entspricht ein Druck im Quellgebiet des Strahles von etwa 10^7 kg/cm^2. [...]

An dem folgenden speziellen Beispiel soll dies näher erläutert werden. Die zu verdichtende Substanz sei in gasförmigem Zustand in einer metallischen Hohlkugel untergebracht, welche außen mit einer Schicht eines brisanten Sprengstoffes belegt ist. Bei geeigneter, gleichmäßig über die ganze Oberfläche eingeleiteter Zündung der Sprengstoffschicht wird für kurze Zeit ein sehr hoher Druck auf die Kugelschale ausgeübt, unter dessen Einwirkung das Metall wie bei den Hohlsprengkörpem in den plastischen Zustand gerät und zum Kugelmittelpunkt hin beschleunigt wird. Dadurch wird die eingeschlossene Gasmasse außerordentlich rasch verdichtet und dabei sehr hoch erhitzt.

This device is based, in part, on the principle of the so-called shaped-charge blasting. The decisive part of such hollow-spring bladders consists of a metallic hollow body of preferably conical, bell-shaped or bottle-shaped shape which is externally provided with a safety explosive, for example hexogen or trinitrotoluene. During the detonation of the latter, the individual wall elements of said hollow body are converted into the plastic state under the influence of the pressure of about 100,000 atmospheres, and receive an inward velocity of several kilometers per second. When the accelerated wall elements meet on the cavity axis, their movement is braked, a high pressure being exerted on a molten portion of their mass. By this pressure the particles, which have become fluid, are pressed out of the constricting cavity in the form of a fine jet at high speed. With a suitable cavity shape, jet velocities of up to twice the detonation velocity are achieved in such hollow-jet blowers, for example, in the case of hexogen 2 × 8 km/sec = 16 km/sec. This pressure corresponds to a pressure in the source region of the jet of about 10^7 kg/cm^2. [...]

This will be explained in more detail in the following specific example. The substance to be compacted is placed in a gaseous state in a metallic hollow sphere, which is externally coated with a layer of a high explosive. In the case of a suitable ignition of the explosive layer uniformly introduced over the entire surface, a very high pressure is exerted on the ball shell for a short time, under the effect of which the metal becomes, as in the case of the hollow bubble bodies, into the plastic state and is accelerated towards the ball center point. As a result, the enclosed gas mass is extremely rapidly compressed and thereby heated very high.

Die dabei auftretenden Beschleunigungen sind ungeheuer groß. Während der Kontraktion der Hohlkugel nimmt ihre Wandstärke dauernd zu. Nähert sich dabei die Innenfläche dem Kugelmittelpunkt, so erhalten die an der Innenfläche gelegenen Materialteilchen sehr hohe Geschwindigkeiten. Man erkennt dies sofort, wenn man sich vergegenwärtigt, welchen Raum das von der Außenfläche—auch bei einem nur kleinen zurückgelegten Weg derselben—überstrichene Volumen einnimmt, wenn es als Kugel um den Mittelpunkt angeordnet wird.

Geht man beispielsweise von einer Hohlkugel vom Innendurchmesser $2R = 100$ cm und der Wandstärke 2 cm aus, so füllt das Schalenmaterial eine Kugel vom Durchmesser

The accelerations occurring in this case are enormous. During the contraction of the hollow spheres their wall thickness increases continuously. As the inner surface approaches the center of the sphere, the material particles located on the inner surface are given very high velocities. This is immediately apparent when we consider the space being spanned—even for a small distance travelled—when it is arranged as a sphere around the center.

If, for example, a hollow sphere with an internal diameter of $2R = 100$ cm and wall thickness 2 cm is compacted, the shell material fills a sphere of diameter

$$2R_0 \;=\; 2\sqrt[3]{52^3 - 50^3} \;=\; 2\sqrt[3]{15608} \;\approx\; 50\,\text{cm}, \tag{D.1}$$

wenn die Hohlkugel völlig zusammengeschrumpft ist, und legt während des letzten Teiles der Kontraktion die Außenfläche einen Weg von nur ¹⁄₁₀ mm zurück, so beträgt in der gleichen Zeit der entsprechende Weg der Innenfläche 2,66 cm, das ist 266mal soviel.

In Fig. 1a bis 1d ist die Kontraktion einer Hohlkugel im Schnitt schematisch dargestellt. Die starke Schrumpfung des Innenraumes, besonders gegen Ende des Vorganges im Vergleich mit der verhältnismäßig geringen Abnahme des Außendurchmessers, macht das Auftreten enormer Beschleunigungen verständlich. [...]

Bei der Beschleunigung mittels detonierender Sprengstoffe sind Anfangsgeschwindigkeiten von $\bar{v}$ = 3000 bis 4000 m/sec. noch bequem erreichbar. [...]

when the hollow sphere is completely shrunk, and during the last part of the contraction the outer surface is a path of only ¹⁄₁₀ mm, the corresponding distance of the inner surface is 2.66 cm, which is 266 times as much.

In Figs. 1a to 1d, the contraction of a hollow sphere is shown schematically in section. The severe shrinkage of the interior, especially towards the end of the process compared with the relatively small decrease in the outside diameter, makes the occurrence of enormous accelerations understandable. [...]

During acceleration by means of detonating explosives, initial velocities from $\bar{v}$ = 3000 to 4000 m/sec are yet easily accessible. [...]

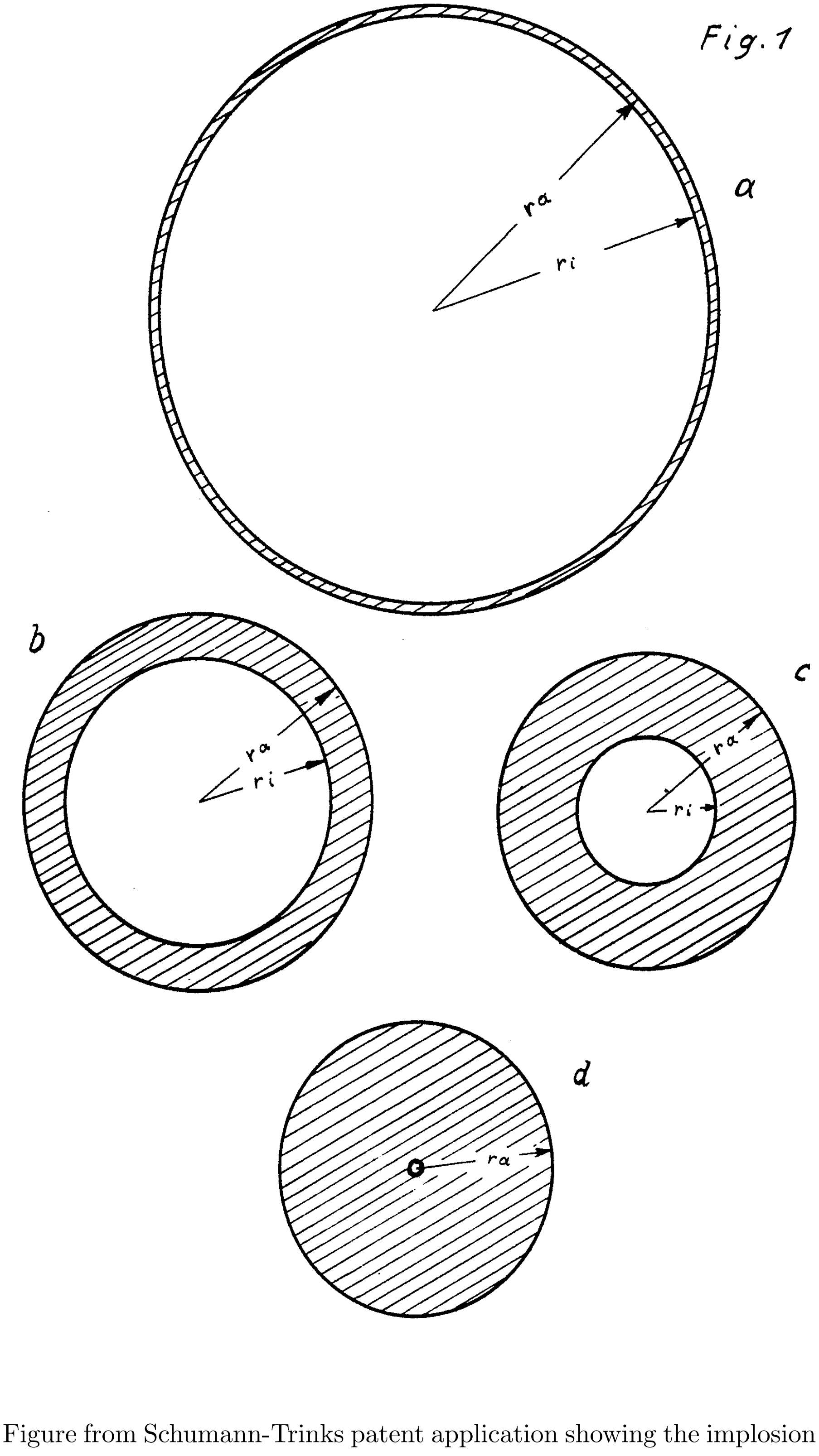


Fig. 1
a
ra
ri
b
ra
ri
c
ra
ri
d
ra

Figure D.589: Figure from Schumann-Trinks patent application showing the implosion of a spherical shell to form a solid sphere of matter.

Zur technischen Durchführung des vorgeschlagenen Verfahrens ist folgendes zu bemerken:

Bei der visuellen Beobachtung eines Sprengvorganges, beispielsweise der Detonation einer Bombe, gewinnt man leicht den Eindruck, als ob dieser Vorgang sich recht ungeordnet vollzöge und daß man sich bei den ungeheuren Belastungen des Materials immer mit gewissen nicht steuerbaren Zufälligkeiten abfinden müsse.

Die modernen Untersuchungsmethoden mit mechanischen Hochleistungszeitdehnern, Funken-, Kerrzellen- und Röntgenblitzkinematographen haben jedoch ergeben, daß Detonationsvorgänge mit derselben Exaktheit ablaufen wie andere physikalische Vorgänge und daß ihr Ablauf und der eintretende Endzustand genau reproduzierbar sind, wenn nur stets von den gleichen Anfangszuständen ausgegangen wird.

Man darf daher bei der Vorbereitung einer Sprengung nicht glauben, es komme nicht so genau darauf an, sondern es ist sehr wichtig, aber auch zugleich lohnend, äußerste Sorgfalt dabei aufzuwenden. Es ist häufig vorgekommen, daß erwartete Effekte erst verspätet nachgewiesen werden konnten, weil man sie nach einem nicht genügend sorgfältig vorbereiteten und deshalb mißglückten Vorversuch voreilig abgetan hat.

Für die Vorbereitung von Anordnungen zur Durchführung des beschriebenen Verfahrens gilt das eben Gesagte ganz besonders, und es ist nicht zuletzt aus diesem Grunde in den angeführten Beispielen von einer Hohlkugel mit dem verhältnismäßig großen Durchmesser von 1 m gesprochen worden, weil dann Ungenauigkeiten leichter zu vermeiden sind.

For the technical implementation of the proposed method, the following should be noted:

When visually observing a blasting process, for example the detonation of a bomb, one easily gains the impression that this process is quite disordered, and that with respect to the enormous loads, one must always accept certain uncontrollable, random incidents.

However, the modern methods of investigation with high-performance mechanical time-lengtheners, spark-, Kerr-cells, and X-ray flash kinematographs have shown that detonation processes proceed with the same exactness as other physical processes and that their sequence and the final state are exactly reproducible when only the same initial states are always assumed.

It is therefore not permissible, when preparing a blasting, to believe that it is not so important, but it is very important, but at the same time worthwhile, to devote extreme care to it. It has often happened that the expected effects could not be demonstrated until later, because they were prematurely dismissed after a preliminary experiment which had not been carefully prepared and therefore failed.

For the preparation of arrangements for carrying out the described method, the above is particularly true, and for this reason, in the examples given, a hollow sphere with the comparatively large diameter of 1 meter has been discussed, since inaccuracies are then easier to avoid.

Besonders ist es die möglichst strenge Einhaltung der Gleichzeitigkeit der Zündung, die in allen vorliegenden Fällen von besonderer Bedeutung ist und die sich bei größeren Körpern leichter erzielen läßt als bei kleineren. Es ist verhältnismäßig schwierig, einen Sprengkörper an allen Punkten einer beliebig geformten Oberfläche gleichzeitig zu zünden. Statt einer flächenhaften Zündung empfiehlt es sich deshalb, eine solche in möglichst vielen Einzelpunkten vorzunehmen.

Einen verhältnismäßig hohen Grad der Gleichzeitigkeit erreicht man dabei mit Hilfe der sogenannten detonierenden Zündschnur (kabelähnlich umsponnene Nitropentaerythrit-oder Fulminat-Seele), indem man Hilfszündpunkte Z_H anwendet, von denen man zu den eigentlichen Zündpunkten Z_1, Z_2, Z_3,... gleich lange Stücke dieser Zündschnur mit konstanter Detonationsgeschwindigkeit (etwa 7500 m/sec) führt.

In Fig. 7 ist eine spreng-physikalische Anordnung zur Erzielung sehr hoher Drücke und Temperaturen dargestellt. Die metallische Hohlkugel B ist von einer Sprengstoffschicht Sp umgeben mit einer Anzahl von Zündern Z, die unter Verwendung von Hilfszündern Z_H und gleich langer Stücke detonierender Zündschnüre gleichzeitig gezündet werden können. Die punktierten Halbkreise in der schraffiert gezeichneten Sprengstoffschicht deuten die Fronten der von den einzelnen Zündern ausgehenden Detonationswellen kurz vor Erreichen der Außenbegrenzung der metallischen Hohlkugel B an.

It is particularly important to observe as closely as possible the simultaneity of the ignition, which is of particular importance in all cases, and which is easier to obtain in larger bodies than in smaller ones. It is relatively difficult to simultaneously ignite an explosive at all points of any arbitrarily shaped surface. Instead of a large-area ignition, it is therefore recommended to carry out such an operation in as many individual points as possible.

To reach a relatively high degree of simultaneity place with the help of so-called detonating fuse (braided nitropentaerythrite or fulminate-soul) by introducing secondary ignition points Z_H, from which one of the actual ignition points Z_1, Z_2, Z_3,... pieces of equal length this detonating cord leads (about 7500 m/sec) at a constant velocity of detonation.

Fig. 7 shows an explosive physical arrangement for achieving very high pressures and temperatures. The metallic hollow sphere B is surrounded by an explosive layer Sp with a number of detonators Z which can be ignited simultaneously using auxiliary detonators Z_H and equally long pieces of detonating cords. The punctured semicircles in the shaded explosive layer indicate the fronts of the detonation waves emanating from the individual detonators shortly before the outer limit of the metallic hollow sphere B is reached.

Fig. 7

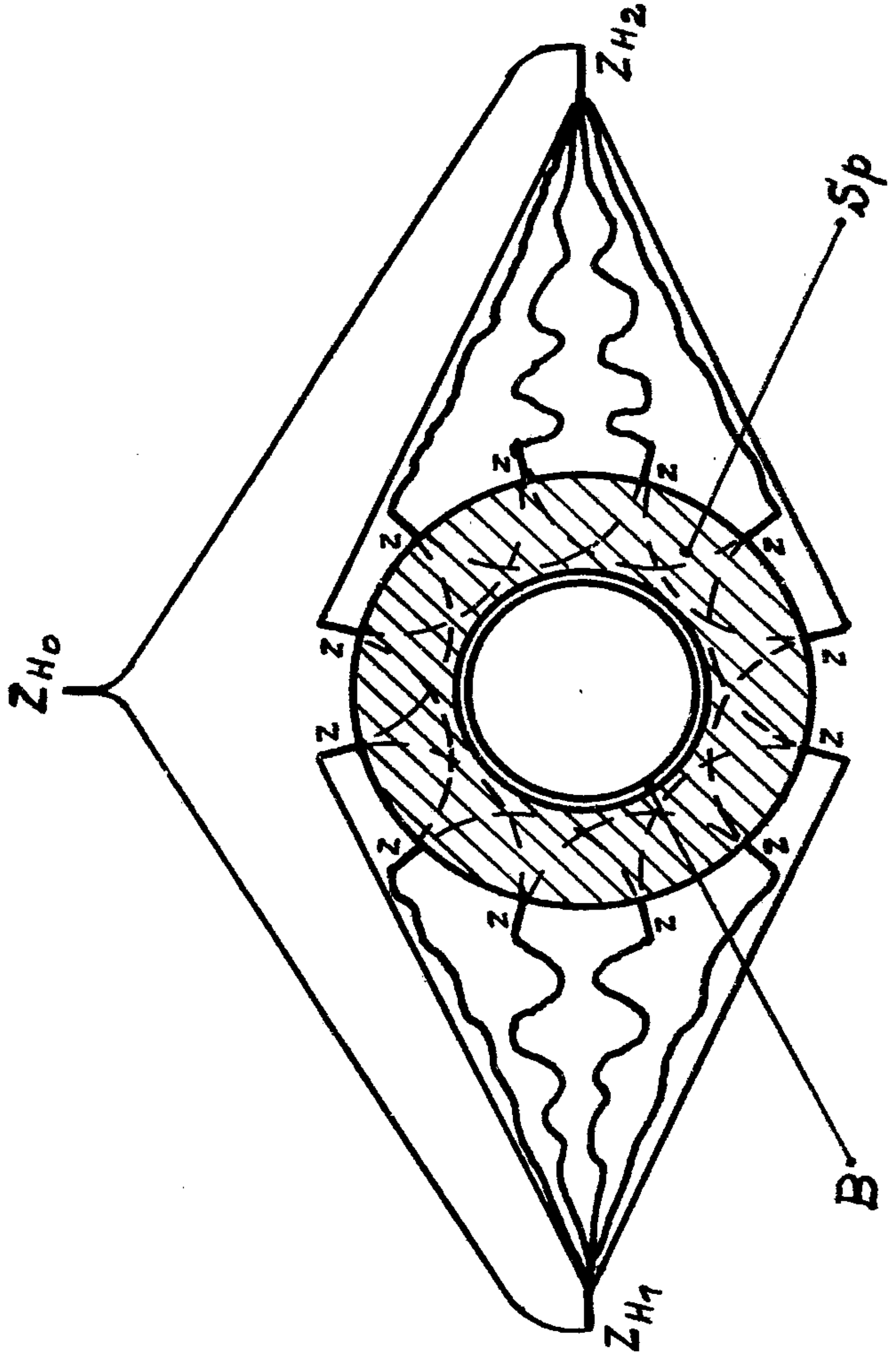


Figure D.590: Figure from Schumann-Trinks patent application showing a spherical implosion bomb design with multiple concentric layers used to trigger nuclear reactions. (See also p. 4229.)

Bei Verwendung elektrischer Zünder ist darauf zu achten, daß diese eine sehr geringe und konstante Verzugszeit aufweisen. Einer Zeitdifferenz von einer millionstel Sekunde entspricht bereits ein Weg der Detonationsfront von rund 1 cm, jedoch ebenfalls ein solches Stück der detonierenden Zündschnur, so daß bei deren Verwendung gute Genauigkeiten zustande kommen. Fehler durch etwa vorhandene Fehlstellen oder Unregelmäßigkeiten in der Schnur können dadurch vermieden werden, daß für jede Übertragungsstrecke mehrfache Schnüre verwendet werden.

Eine Glättung der gewünschten kugelförmigen, zum Mittelpunkt hinlaufenden Detonationsfront ist in Anlehnung an die Optik durch die Verwendung von “Sprengstofflinsen” möglich. Ähnlich wie dort die Lichtstrahlen kann man hier ein divergentes Bündel von Detonationsstrahlen in ein konvergentes umwandeln, indem man in dem Sprengkörper mit der Detonationsgeschwindigkeit D entweder konvexe oder konkave Linsen aus einem Sprengstoff mit größerer Detonationsgeschwindigkeit als D zwischen den Zünder und die zu beschleunigende Hohlkugeloberflache einschiebt. So kann man beispielsweise konvexe Linsen aus Trinitrotoluol bei einem Hauptsprengkörper aus Hexogen oder konkave Linsen aus Hexogen oder Nitropentaerythrit bei einem Hauptsprengkörper aus Trinitrotoluol verwenden.

Sprengstoffe mit noch kleineren Detonationsgeschwindigkeiten, beispielsweise Bergwerkssprengstoffe, sind für derartige Anwendungen nicht geeignet.

Obgleich sie einen größeren “Brechungsindex” ergeben würden, wird man doch wegen ihrer zu geringen Homogenität von ihrem Gebrauch für den vorliegenden Zweck absehen.

When using electric igniters, care must be taken that these have a very low and constant delay time. A time difference of one millionth of a second corresponds already to a distance of about 1 cm of the detonation front, but also to such a portion of the detonating fuse, so that good accuracies are obtained when they are used. Flaws caused by any imperfections or irregularities in the cord can be avoided by using multiple cords for each transfer path.

A smoothing of the desired spherical detonation front leading to the center is possible according to principles similar to those in optics through the use of “explosive lenses.” Similar to light beams, a divergent bundle of detonation beams can be transformed into a convergent one by inserting either the convex or concave lenses of an explosive with a greater detonation velocity than D between the detonators and the hollow spherical surface to be accelerated. For example, convex lenses made of trinitrotoluene can be used within a main body made of hexogen, or concave lenses made of hexogen or nitropentaerythrite within a main body made of trinitrotoluene.

Explosives with even lower detonation velocities, for example mining explosives, are not suitable for such applications.

Although they would give a larger “index of refraction,” their inadequate homogeneity will be considered to be of no use for the present purpose.

Die Form der Trennflächen zwischen den Sprengstoffen mit den verschiedenen Detonationsgeschwindigkeiten (D_1 und D_2) ergibt sich sehr einfach aus der folgenden Bedingung für die Wege s der Detonationsstrahlen

The shape of the interfaces between the explosives with the different detonation velocities (D_1 and D_2) is obtained very simply from the following condition for the paths s of the detonation rays

$$\frac{s_1}{D_1} + \frac{s_2}{D_2} = \text{const} = \frac{s_{10}}{D_1} + \frac{s_{20}}{D_2} \tag{D.2}$$

für eine einfache Trennfläche

for a simple separation surface

oder

or

$$\frac{s_1}{D_1} + \frac{s_2}{D_2} + \frac{s_1'}{D_1} = \text{const} = \frac{s_{10}}{D_1} + \frac{s_{20}}{D_2} + \frac{s_{10}'}{D_1} \tag{D.3}$$

für eine doppelte Trennfläche bei “Linsen”, wobei sich die Indizes 1 und 2 auf die beiden Sprengstoffe und der Index 0 auf den kürzesten Detonationsweg beziehen.

for a double separation surface for “lenses,” the indices 1 and 2 refer to the two explosives and the index 0 to the shortest detonation path.

In der Fig. 8 ist eine solche Umkehr der Krümmung der Detonationsflächen bei der Verwendung von Trinitrotoluol mit $D_1 = 6500$ m/sec und eines Zwischenkörpers aus Nitropentaerythrit mit $D_2 = 7800$ m/sec dargestellt. Die Figur zeigt, wie durch Einschaltung derartiger Sprengstoff-Linsen die gestrichelt dargestellten Detonationsflächen im Lauf ihres Fortschreitens der Krümmung der zu beschleunigenden Masse M angepaßt werden.

Fig. 8 shows such a reversal of the curvature of the detonation surfaces during the use of trinitrotoluene with $D_1 = 6500$ m/sec and an intermediate body of nitropentaerythritol with $D_2 = 7800$ m/sec. The figure shows how, by the activation of such explosive lenses, the detonation surfaces represented by dashed lines are adapted in the course of their progress to the curvature of the mass M to be accelerated.

Zur Erzielung einer möglichst großen Energiedichte ist es vorteilhaft, einen Sprengstoff mit möglichst hoher Detonationsgeschwindigkeit, z.B. Hexogen, für die Beschleunigung der Hohlkugelwand zu verwenden. Zweckmäßig preßt man dann die Sprengstoffumhüllung des Druckgefäßes als einzelne Teilstücke. Auf diese Weise läßt sich eine bessere Homogenität der Sprengstoffhülle und damit ein gleichmäßigerer Ablauf der Detonation erzielen als mit gegossenen Mischungen, welche häufig Lunker und andere Inhomogenitäten enthalten.

In order to achieve the greatest possible energy density, it is advantageous to use an explosive with the highest possible detonation speed, for example, hexogen [RDX], for the acceleration of the hollow ball wall. Expediently, the explosive lining of the pressure vessel is then pressed as individual parts. In this way, a better homogeneity of the explosive shell and thus a more uniform discharge of the detonation can be achieved than with cast mixtures, which often contain voids and other inhomogeneities.

Fig. 8

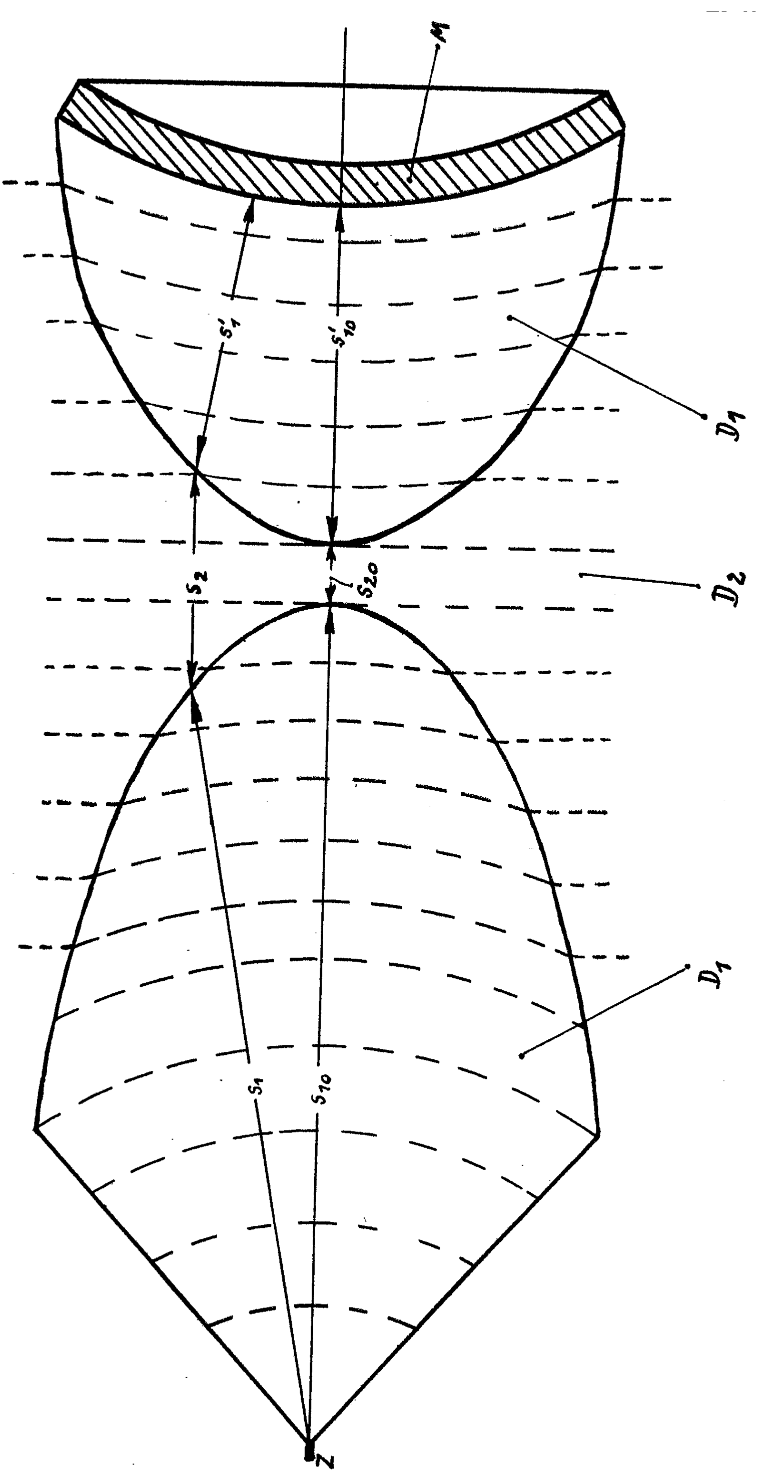

M
s'_1
s'_{10}
D_1
s_2
s_{20}
D_2
D_1
s_1
s_{10}
Z

Figure D.591: Figure from Schumann-Trinks patent application showing an explosive lens containing shaped segments of two different explosive materials with different explosion velocities.

Im Hinblick auf einen möglichst gleichmäßigen Ablauf der Detonation, insbesondere auch auf ein möglichst regelmäßiges Anlaufen derselben in der Umgebung der Zündstellen sowie auf eine gute Aus- nutzung des Sprengstoffes ist es ferner vorteilhaft, die Sprengstoffschicht außen mit einer Verdämmung zu versehen und den ganzen Körper beispielsweise in Beton oder Erdbereich einzubetten. Beispielsweise ist es zweckmäßig, die nach außen frei werdende Sprengstoffenergie zugleich anderweitig auszunutzen, indem man derartige Versuche in Bergwerken oder Steinbrüchen durchführt.

Zur besseren Beobachtung der Vorgänge während und kurz nach der Detonation sowie zur leichteren Auffindung der verbleibenden Rückstände, welche die wertvollen Endprodukte enthalten, wird es sich jedoch auch häufig empfehlen, den Sprengkörper unverdämmt einige Meter über einer möglichst ebenen und glatten Fläche des Erdbodens frei aufzuhängen.

Im übrigen ist eine Zerlegung der Hohlkugel in viele Einzelteile nicht zu erwarten, da sie zusammenschrumpft und ihre Wandstärke dann 20- bis 30-mal so groß wie der Innenraum weit ist. Nachteilig ist bei den erwähnten Ausführungsbeispielen, daß sich bei den größeren der geplanten Körper recht erhebliche Gewichte ergeben, so daß auch aus diesem Grunde gegossene Sprengkörper kaum in Frage kommen, weil diese zu unhandlich werden würden. Eine eiserne Hohlkugel vom Durchmesser 1 m und der Wandstärke von nur 1 cm wiegt z.B. etwa 250 kg. Dazu kommt bei 20 cm starker Belegung ein Sprengstoffgewicht von etwa 1500 kg. Zusammen mit der Außenverdämmung ergibt sich so ein Gesamtgewicht von rund 2 t. [...]

With a view to the as uniform as possible of the detonation, in particular also to a regular start-up of the same in the vicinity of the ignition points, as well as to a good utilization of the explosive, it is also advantageous to provide the explosive layer with an external tamper and to place the whole arrangement in concrete or in earth, too. For example, it is practical to simultaneously exploit the outwards-released explosive energy by performing such experiments in mines or quarries.

For the better observation of the processes during and shortly after the detonation as well as for the easier detection of the remaining residues, which contain the valuable end products, it is also frequently recommended to freely hang the explosive device a few meters above a flat and smooth surface of the ground.

Moreover, it is not to be expected that the hollow spheres will be decomposed into many parts, since they shrink together and their wall thickness is then 20 to 30 times as large as the interior space. It is disadvantageous in the case of the mentioned exemplary embodiments that the larger of the planned bodies produce quite considerable weights so that explosive bodies cast for this reason are scarcely to be considered because they would become too bulky. An iron hollow sphere of diameter 1 m and wall thickness of only 1 cm weighs for example about 250 kg. In addition, an explosive weight of about 1500 kg is obtained when the coating is 20 cm thick. Together with the outer insulation, this results in a total weight of around 2 tons. [...]

[Compare Erich Schumann's designs for a two-ton spherical implosion bomb with other descriptions of the German fission bomb design (p. 4157), especially Ivan Ilyichev's 23 March 1945 report (p. 4485).]

Neben der eben beschriebenen Abänderung der prinzipiell sehr einfachen, jedoch in der praktischen Durchführung etwas komplizierten rein kugelförmigen dynamischen Druckzelle gibt es noch eine ganze Reihe anderer Möglichkeiten, die Grundidee der Übertragung der kinetischen Energie größerer, sprengphysikalisch beschleunigter Massen auf wesentlich kleinere Massen und der Erzeugung hoher Drücke und Temperaturen auf diesem Wege zu verwirklichen.

Hierzu werden noch einige Ausführungsbeispiele angegeben. Zunächst soll auf eine Anordnung mit zylindrischer Druckkammer eingegangen werden. Diese hat eine Reihe von Vorzügen, insbesondere auch deshalb, weil sich dabei besonders einfache Wege zur Einleitung der Zündung ergeben. Als Beispiel hierfür ist in der Fig. 11 schematisch eine solche Anordnung im Aufriß dargestellt. Die Druckkammer B besteht aus einem Zylinder, auf dessen Grundflächen Halbkugeln aufgesetzt sind. Der Sprengstoff Sp umgibt die Zylinderwand in Form eines Doppelkegels, längs dessen Grundlinie die Zündung gleichzeitig erfolgt. Dazu ist der Sprengstoff Sp umhüllt mit einem Mantel aus inertem Material J, beispielsweise Zement, welcher selbst wiederum außen mit einer dünnen Sprengstoffschicht Sp verkleidet ist. Wird dann letztere gleichzeitig in den beiden Spitzen des entstandenen Doppelkegels gezündet, so läuft die Detonation zugleich in zwei Ästen die beiden Kegelmäntel entlang, ohne dabei zunächst den inneren Sprengkörper zu beeinflussen, weil jener durch die inerten Zwischenschichten geschützt ist.

In addition to the modification of the purely spherical dynamic pressure cell which has been described above, but which is somewhat complicated in practice, there are also a whole series of other possibilities for the transfer of the kinetic energy of larger, physically accelerated masses to substantially smaller masses and the generation of high pressures and temperatures in this way.

For this purpose, a few exemplary embodiments are given. First, an arrangement with a cylindrical pressure chamber will be described. This has a number of advantages, in particular also because there are particularly simple ways of initiating the ignition. An example of such an arrangement is shown schematically in Fig. 11. The pressure chamber B consists of a cylinder, on the bases of which are placed hemispheres. The explosive Sp surrounds the cylinder wall in the form of a double cone, along which the ignition takes place at the same time. For this purpose, the explosive Sp is covered with a jacket of inert material J, for example cement, which itself is once again covered with a thin explosive layer Sp. If the latter is then ignited simultaneously in the two peaks of the resulting double cone, the detonation runs simultaneously into two branches along the two conical coats, without first affecting the inner explosive, because the latter is protected by the inert intermediate layers.

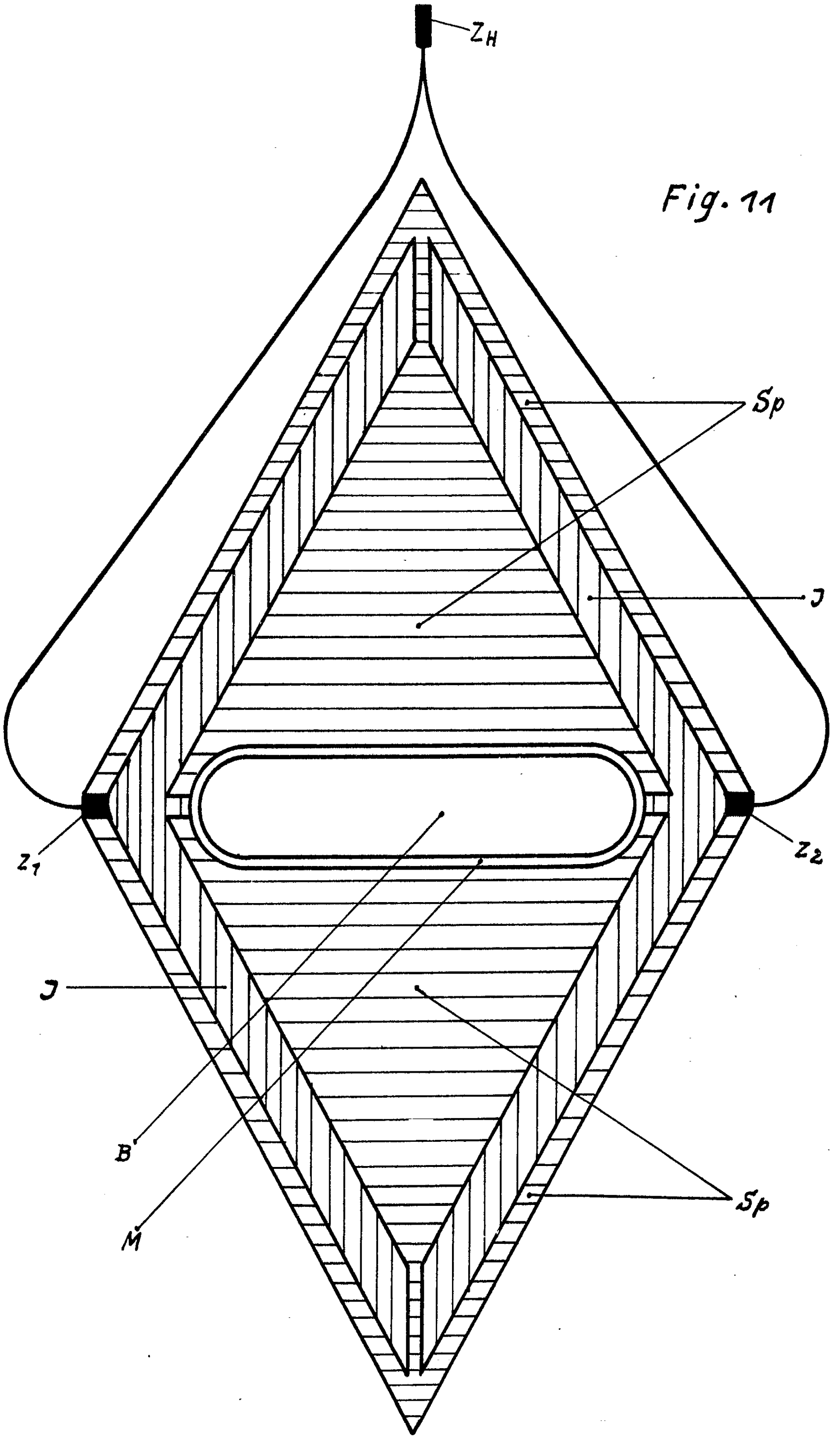

Z_H
Fig. 11
Sp
J
Z_1
Z_2
J
B
M
Sp

Figure D.592: Figure from Schumann-Trinks patent application showing a biconic implosion bomb.

Bei dem Zusammentreffen der beiden Zündäste wird dann erst der innere Sprengstoffdoppelkegel längs seiner Grundlinie, an welcher die inerte Umhüllung unterbrochen ist, intensiv gezündet. Durch die Wahl der symmetrischen Zündungsäste von den beiden Spitzen des Doppelkegels aus wird eine größere Gleichmäßigkeit mit einer besonders kräftigen Einleitung der Zündung des Hauptkörpers verbunden. Bei dieser Zündung werden nun die Elemente der mittleren Zone des metallischen Hohlzylinders gleichzeitig von der Detonation erfaßt und zur Achse hin beschleunigt. Dort werden nun entweder durch die rasche Kompression einer Gas-oder Dampffüllung oder aber, bei evakuiertem Hohlraum, beim Zusammentreffen der Wandelemente auf der Hohlraumachse hohe Drücke und Temperaturen erzeugt.

Eine im Prinzip ähnliche Anordnung mit zylindrischer Druckkammer B ist in der Fig. 12 dargestellt. Der Unterschied gegenüber der im vorhergehenden beschriebenen besteht erstens darin, daß hier die Druckkammer B an ihren Grundflächen durch starke verdämmende Metallplatten Me abgeschlossen ist, und zweitens die Wellenfront bei der Detonation durch linsenähnliche Sprengstoffanordnungen, beispielsweise aus Trinitrotoluol und Hexogen, weitgehend einer Zylinderfläche angeglichen wird. Die Zündführung Z_f verläuft innerhalb einer Packung aus inertem Material J.

When the two ignition branches meet, the inner explosive double cone is then intensively ignited along its basic line, at which the inert enclosure is interrupted. By selecting the symmetrical ignition branches from the two tips of the double cone, greater uniformity is combined with a particularly powerful introduction of the ignition of the main body. At this time, the elements of the central zone of the metallic hollow cylinder are simultaneously caught by the detonation and accelerated towards the axis. In this case, high pressures and temperatures are generated either by the rapid compression of a gas or steam filling or, in the case of an evacuated cavity, when the wall elements meet on the cavity axis.

A basically similar arrangement with a cylindrical pressure chamber B is shown in Fig. 12. The difference compared to the one described above consists, first, in that the pressure chamber B is terminated at its base surfaces by strong, damming metal plates Me, and second the wavefront is largely matched to a cylinder surface by detonation by means of lens-like explosive arrangements, for example from trinitrotoluene and hexogen. The ignition guide Z_f runs within a pack of inert material J.

Fig. 12

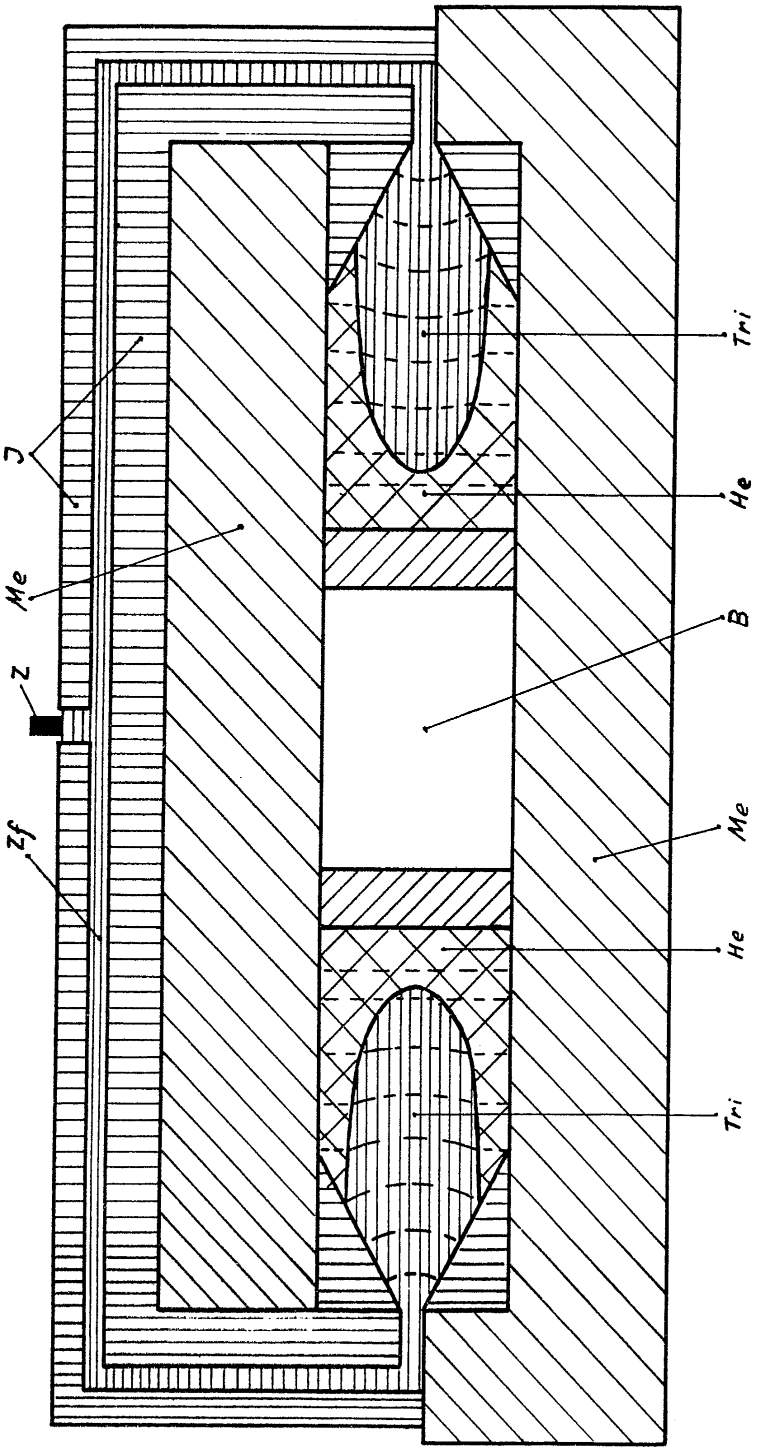

J
Me
Z
Zf
Tri
He
B
Me
He
Tri

Figure D.593: Figure from Schumann-Trinks patent application showing a cylindrical implosion bomb.

Walter Trinks. German patent DE977862. Vorrichtung nach Patent 977825 zur Behandlung von Material mit hohen Drücken und Temperaturen. Filed 13 August 1952.

Die Verformung und Beschleunigung der Hilfsmasse erfordert eine beträchtliche Energiemenge, die für die Druckerzeugung innerhalb der Kammer verlorengeht. Es besteht daher das Bedürfnis, diese Hilfsmasse aus einem relativ leichten und plastischen Material herzustellen, und es bewährte sich besonders Aluminium.

Auch die Kammerwände kann man ganz oder teilweise aus Aluminium herstellen. [...]

PATENTANSPRUCH:

Vorrichtung nach Patent 977 825 zur Behandlung von Material mit hohen Drücken und Temperaturen, dadurch gekennzeichnet, daß die durch die Detonation zu beschleunigende Masse (und gegebenenfalls die Kammerwand) aus Aluminium besteht.

The deformation and acceleration of the auxiliary mass requires a considerable amount of energy which is lost for the generation of the printer within the chamber. There is therefore a need to manufacture these auxiliary materials from a relatively light and plastic material, and aluminum has proved particularly suitable.

The chamber walls can also be made entirely or partly from aluminum. [...]

PATENT CLAIM:

Apparatus according to patent 977,825 for the treatment of material with high pressures and temperatures, characterized in that the mass to be accelerated by the detonation (and, if appropriate, the chamber wall) consists of aluminum.

Walter Trinks. German patent DE977839. Vorrichtung nach Patent 977825 zur Erzielung hoher Drücke und Temperaturen zwecks Einleitung mechanischer, thermischer oder nuklearer Prozesse mittels einer gleichmaessig mit Sprengstoff belegten, die Reaktionskammer umschliessenden Hohlkugel. Filed 13 August 1952.

PATENTANSPRUCH:

Vorrichtung nach Patent 977 825 zur Behandlung von Material mit hohen Drücken und Temperaturen, dadurch gekennzeichnet, daß mehrere Kugeln mit von innen nach außen zunehmender Wandstärke und Sprengstoffbelegung ineinander angeordnet sind.

PATENT CLAIM:

A device according to patent 977,825 for the treatment of material with high pressures and temperatures, characterized in that a set of spherical shells are arranged concentrically with wall thickness and explosive material increasing from the inside outwards.

Erich Schumann and Walter Trinks. Patent DE977863. Vorrichtung zur Behandlung von Material mit hohen Drücken und Temperaturen. Filed 13 August 1952.

Das Hauptpatent betrifft eine Vorrichtung, um Material zur Einleitung von mechanischen, thermischen oder nuklearen Prozessen auf extrem hohe Drücke und Temperaturen zu bringen. Dabei sieht man eine geschlossene Kammer für das auf die Drücke und Temperaturen zu bringende Material vor und belegt eine jenem Material gegenüberliegende, selbst nicht aus Sprengstoff bestehende Wand der Kammer mit einem Sprengstoff. Die Wand und ihre Sprengstoffbelegung werden so ausgebildet, daß die Wand durch den bei einer Detonation des Sprengstoffes auftretenden Druck auf das genannte Material hin bewegt und in eine zu dem genannten Material hin konkave Form plastisch verformt wird.

Für die Freimachung von Atomenergie auf der Uranbasis ist es von großem Nachteil, daß, abgesehen von dem verhältnismäßig seltenen Vorkommen der Uranerze, ein ganz ungeheurer Aufwand erforderlich ist, um das spaltbare, nur mit ganz geringem Prozentsatz im Uran enthaltene Isotop abzutrennen oder um das ihm gleichwertige Plutonium zu gewinnen.

Bei diesem Sachverhalt ist es von großer Bedeutung, daß außer den Spaltungen der wenig stabilen schweren Kerne, z.B. des Uran 235 oder des Plutoniums, noch andere Kernprozesse existieren, bei denen ebenfalls große Energiebeträge frei werden, wobei jedoch die Ausgangsprodukte dieser Prozesse viel häufiger vorkommen und mit verhältnismäßig geringem Aufwand, z.B. aus Wasser, rein dargestellt werden können.

Es handelt sich hier im Gegensatz zu den Spaltprozessen der schweren Kerne, welche am Ende des periodischen Systems der Elemente stehen, um Reaktionen zwischen den Kernen der leichtesten Elemente, z.B. leichter und schwerer Wasserstoff, Lithium, Beryllium und Bor. [...]

The main patent relates to a device for bringing material to extremely high pressures and temperatures to initiate mechanical, thermal or nuclear processes. In this case, a closed chamber is provided for the material to be subjected to the pressures and temperatures, and a wall of the chamber, which is opposite to the material, is exposed to an explosive. The wall and its explosive coating are formed in such a way that the wall is moved towards the said material by the pressure occurring upon detonation of the explosive and is plastically deformed into a concave shape towards the said material.

For the liberation of atomic energy on the basis of uranium, it is a great disadvantage that, apart from the relatively rare occurrence of the uranium ores, a tremendous effort is required to produce the fissionable, separable small percentage of the isotope contained in the uranium or to obtain the equivalent plutonium.

In this state of affairs it is of great importance that, besides the fission of the less stable heavy nuclei, for example uranium 235 or plutonium, other nuclear processes also exist in which large amounts of energy are also released, but the starting products of these processes are much more common and are produced with relatively little effort, for example from water.

Here, in contrast to the fission processes of the heavy nuclei, which are at the end of the periodic table of the elements, in order to establish reactions between the nuclei of the lightest elements, for example light and heavy hydrogen, lithium, beryllium and boron. [...]

Temperaturen und Drucke der erforderlichen Höhe lassen sich experimentell und kurzzeitig mit sprengphysikalischen Mitteln erreichen und zur Einleitung und Durchführung von Atomkernreaktionen verwenden, wenn man die in dem Patent 977 825 beschriebenen Vorrichtungen zur Erzeugung höchster Drücke und Temperaturen nutzbar macht.

[...] Eine andere Form der Druckkammer besteht gemäß Fig. 4 in einer mit der zu behandelnden Substanz angefüllten, in brisanten Sprengstoff *Sp* eingebetteten Hohlkegel *B*, beispielsweise aus Eisen, Kupfer, Zink, Aluminium, Blei, Wolfram, Graphit od. dgl., deren Wandung gleichzeitig als zu beschleunigende Hilfsmasse dient. Die Schrumpfung des Innenraumes bei gleichzeitiger Zündung der auf der Oberfläche der Sprengstoffumhüllung angeordneten Zünder *Z* macht das Auftreten enormer Beschleunigungen verständlich.

Zur Glättung der Detonationsfront und zur Anpassung derselben an die Außenoberfläche der Kugel in der Umgebung der einzelnen Zündstellen können auch hier Linsen aus Sprengstoffen mit verschiedenen Detonationsgeschwindigkeiten angeordnet sein.

Zur Verlängerung der Einwirkungszeit können zwei oder mehrere der Hohlkugeln ineinandergeschachtelt sein, wobei Wandstärke und Sprengstoffbelegung der jeweils folgenden äußeren Hohlkugel stärker dimensioniert sind als diejenigen der jeweils vorhergehenden inneren Hohlkugel. [...]

Wird z.B. ½ Kubikmeter schweren Wasserstoffgases vom Anfangsdruck 0,1 at, das sind rund 9 g, nach den Reaktionsgleichungen

Temperatures and pressures of the required magnitude can be obtained experimentally and for short times by explosive-physical means and can be used to initiate and carry out atomic nuclear reactions if the devices described in patent 977,825 are used to generate the highest pressures and temperatures.

[...] According to Fig. 4, another form of the pressure chamber consists of a hollow cone *B*, which is filled with the substance to be treated and is embedded in explosive explosive *Sp*, for example of iron, copper, zinc, aluminum, lead, tungsten, graphite or the like, at the same time serves as an auxiliary mass to be accelerated. The shrinkage of the interior while simultaneously igniting the detonator *Z* located on the surface of the explosive envelope makes it possible to achieve enormous accelerations.

For smoothing the detonation front and adapting it to the outer surface of the ball in the vicinity of the individual ignition points, here, too, lenses of explosives with different detonation velocities can be arranged.

To prolong the exposure time, two or more of the hollow spheres can be nested within each other. Both the wall thickness and the thickness of the explosive liner of the next outer hollow sphere must be shaped larger than those of the preceding inner hollow spheres. [...]

For example, ½ cubic meter of deuterium gas with the initial pressure 0.1 atmosphere, which is about 9 g, according to the reaction equations becomes

$$ {}^{2}_{1}\mathrm{D} + {}^{2}_{1}\mathrm{D} = {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + 3.3\,\mathrm{MeV} \tag{D.4} $$

und

and

$$ {}^{2}_{1}\mathrm{D} + {}^{2}_{1}\mathrm{D} = {}^{3}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} + 4.0\,\mathrm{MeV} \tag{D.5} $$

[...] Ferner ist zu beachten, daß bei den dann erreichten hohen Temperaturen auch andere Kernprozesse genügend wahrscheinlich werden, so daß sie mit zur Energieerzeugung herangezogen werden können.

[...] It should also be noted that, in the case of the then high temperatures, other nuclear processes become sufficiently probable so that they can be used for the generation of energy.

Bei Anwesenheit von Protonen wird z.B. auch die sehr energiereiche Reaktion

In the presence of protons, for example, also the very energetic reaction

$$^{3}_{1}\mathrm{Tr} + {}^{1}_{1}\mathrm{H} = {}^{4}_{1}\mathrm{He} + 20\ \mathrm{MeV} \tag{D.6}$$

stattfinden, welche nach den Deuteronenprozessen die wahrscheinlichste Kernreaktion ist, oder bei Anwesenheit von Lithium die Reaktionen

takes place, which is the most probable nuclear reaction after the deuteron processes, or the reactions in the presence of lithium

$$^{7}_{3}\mathrm{Li} + {}^{1}_{1}\mathrm{H} = 2\,{}^{4}_{2}\mathrm{He} + 17\ \mathrm{MeV} \tag{D.7}$$

und

and

$$^{6}_{3}\mathrm{Li} + {}^{2}_{1}\mathrm{D} = 2\,{}^{4}_{2}\mathrm{He} + 22.5\ \mathrm{MeV} \tag{D.8}$$

sowie

just as

$$^{7}_{3}\mathrm{Li} + {}^{2}_{1}\mathrm{D} = 2\,{}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + 15\ \mathrm{MeV} \tag{D.9}$$

welch letztere wiederum Neutronen befreit.

which in turn liberates neutrons.

Die Deuteronenprozesse spielen dann vergleichsweise die Rolle des leicht entzündlichen Zündholzes, das die schwerer entzündlichen Brennstoffe anzündet.

The deuteron processes then play comparatively the role of the highly flammable match that ignites the heavy flammable fuel.

Diesem Umstand kann man gemäß der Erfindung dadurch nutzbringend Rechnung tragen, daß man zugleich mit der Füllung der anzuwendenden Druckzellen mit Wasserstoff, insbesondere schwerem Wasserstoff, andere leichte Elemente, z.B. Lithium, Beryllium, Bor oder auch leichten Wasserstoff als Elemente oder in Form von chemischen Verbindungen an der Innenwand der Druckzellen oder auch in der Wand der Druckzellen, durch dünne Schichten vom Innenraum getrennt, zur Anwendung bringt. So empfiehlt sich beispielsweise die Verwendung von schwerem Lithiumhydrid (LiD).

According to the invention, this circumstance can be taken advantage of by virtue of the fact that, at the same time as the filling of the pressure cells to be applied with hydrogen, in particular heavy hydrogen, other light elements, for example, lithium, beryllium, boron or also light hydrogen as elements or in the form of chemical compounds on the inner wall of the pressure cells or also in the wall of the pressure cells, separated from the inner space by thin layers. For example, the use of heavy lithium hydride (LiD) is recommended.

Insgesamt wird so die Befreiung eines Energiebetrages möglich, der die zur Einleitung dieser Kernreaktionen aufzuwendende chemische Energie des Sprengstoffes (ungefähr 10^{16} erg) sehr beträchtlich überschreitet.

Auch die bei der einen der D-Kernreaktionen frei werdenden Neutronen können zur weiteren Befreiung von Energie herangezogen werden. Die Reaktion

$$ {}^{6}_{3}\mathrm{Li} + {}^{1}_{0}\mathrm{n} = {}^{3}_{1}\mathrm{Tr} + {}^{4}_{2}\mathrm{He} \tag{D.10}$$

würde z.B. auf Grund der Massenbilanz die Energie von 4,7 MeV befreien, oder die entsprechende Reaktion mit Bor

$$ {}^{10}_{5}\mathrm{B} + {}^{1}_{0}\mathrm{n} = {}^{7}_{3}\mathrm{Li} + {}^{4}_{2}\mathrm{He} \tag{D.11}$$

würde ungefähr 3 MeV freisetzen.

Ferner kann man die bei der Deuteronenreaktion frei werdenden Neutronen dazu benutzen, die Spaltung des U^{235} in dem natürlichen Uran, also dem gewöhnlichen Isotopengemisch, vorzunehmen.

Wenn die Innenwand der das Deuterium enthaltenden Druckzelle mit einer genügend starken Graphitschicht ausgekleidet wird, auf die eine Schicht Uran folgt, werden die frei werdenden Neutronen mit sehr hohem Energiegehalt auf thermische Neutronen abgebremst, ehe sie die Uranschicht erreichen. Dort werden sie dann nicht vom U^{238} eingefangen, sondern können an dem U^{235} die Spaltung hervorrufen. Man müßte dann nur, wie in allen Fällen, in denen die frei werdenden Neutronen herangezogen werden sollen, durch eine geeignete Außenhülle der anzuwendenden Druckzellen ein Entweichen nach außen verhindern, ähnlich wie dies bei den Atombomben durch den sogenannten “Tamper” geschieht.

In general, the liberation of an energy supply is possible, which greatly exceeds the chemical energy of the explosive (about 10^{16} erg) to be expended for the initiation of these nuclear reactions.

The neutrons released in one of the D nuclear reactions can also be used to further release energy. The reaction

would, for example, free the energy of 4.7 MeV on account of the mass balance, or the corresponding reaction with boron

would release about 3 MeV.

Furthermore, the neutrons liberated in the deuteron reaction can be used to carry out the fission of U^{235} in natural uranium, that is, the ordinary isotope mixture.

When the inner wall of the pressure cell containing the deuterium is lined with a sufficiently strong graphite layer followed by a layer of uranium, the liberating neutrons with a very high energy content are decelerated to thermal neutrons before they reach the uranium layer. There they are not caught by the U^{238}, but can cause the fission of the U^{235}. As in all cases in which the neutrons which are liberated are released, it is only necessary to prevent the escape from the outside by means of a suitable outer shell of the pressure cells to be applied, similar to that of the atom bombs by the so-called “tamper.”

Man kann auch die frei werdenden Neutronen aus den D-Kernreaktionen zunächst zu einer unmittelbaren Temperatursteigerung im Zentrum der Druckzelle benutzen, indem man dort eine winzige Menge Cadmium anbringt, welches die Neutronen unter Erhitzung absorbiert.

Wesentlich wichtiger als die Befreiung von Atomenergie zu militärischen Zwecken ist die Herstellung und Verwendung von Neutronen für friedliche Aufgaben.

Auf die Bedeutung und die große Intensität der bei der Umsetzung von Deuterium entstehenden Neutronenstrahlung wurde bereits weiter vorn hingewiesen. Hier sei nur noch hinzugefügt, daß selbst, wenn mit Hilfe des beschriebenen Verfahrens nur eine Temperatur von 2 Millionen Grad erreichbar wäre, aus nur 2 g schwerem Wasserstoff während 1 zehntausendstel sec nach den Resultaten von Bethe sowie Gamow und Teller ungefähr $3 \cdot 10^{21}$ Neutronen frei gemacht werden, was etwa 10^{18} Curie bzw. einer Radium-Berylliumquelle von rund 1 Milliarde kg entspricht. Eine starke Hochspannungsanlage würde 350 Jahre benötigen, um diese Neutronenmenge zu erzeugen.

Derartige Neutronenintensitäten sind bisher nur in den “Uran-piles” beobachtet worden. Ihre Erzeugung erfordert dort jedoch einen unvergleichlich größeren Aufwand, als er bei dem vorgeschlagenen Verfahren erforderlich ist.

PATENTANSPRÜCHE:

1. Vorrichtung nach Patent 977 825 zur Behandlung von Material mit hohen Drücken und Temperaturen, dadurch gekennzeichnet, daß die Wandung der Wasserstoff, insbesondere schweren Wasserstoff, enthaltenden Druckzelle leichte Elemente, wie Lithium, Beryllium, Bor oder leichten Wasserstoff als Element oder in gebundener Form aufweist.

It is also possible to use the free neutrons from the deuterium nuclear reactions for a direct increase in temperature at the center of the pressure cell by applying a minute quantity of cadmium which absorbs the neutrons while heating.

Essentially more important than the liberation of nuclear energy for military purposes is the production and use of neutrons for peaceful tasks.

The importance and the great intensity of the neutron radiation generated during the reaction of deuterium has already been pointed out before. In this case, it should be added that even if, by means of the method described, only a temperature of 2 million degrees is attainable, from only 2 g of heavy hydrogen is formed during one ten-thousandth of a second, according to the results of Bethe, and Gamow and Teller, approximately $3 \cdot 10^{21}$ neutrons, which is about 10^{18} Curie, or corresponding to a radium-beryllium source of around one billion kg. A strong high-voltage system would take 350 years to produce this neutron quantity.

Such neutron intensities have hitherto been observed only in “uranium piles.” However, their production requires an incomparably greater effort there than is required in the proposed method.

PATENT CLAIMS:

1. Apparatus according to patent 977,825 for the treatment of material with high pressures and temperatures, characterized in that the wall of the pressure cell containing hydrogen, in particular heavy hydrogen, has light elements, such as lithium, beryllium, boron or light hydrogen as element or in bound form.

2. Vorrichtung nach Anspruch 1, dadurch-gekennzeichnet, daß die leichten Elemente die Innenwand der Zelle bedecken.	2. Device according to Claim 1, characterized in that the light elements cover the inner wall of the cell.
3. Vorrichtung nach Anspruch 2, dadurch gekennzeichnet, daß die leichten Elemente durch eine dünne Schicht abgedeckt sind.	3. Device according to Claim 2, characterized in that the light elements are covered by a thin layer.
4. Vorrichtung nach Anspruch 1 oder folgenden, dadurch gekennzeichnet, daß die Wand wenigstens teilweise aus Uran, insbesondere natürlichem Uran, besteht.	4. Device according to Claim 1 or the following, characterized in that the wall is at least partly of uranium, in particular of natural uranium.
5. Vorrichtung nach Anspruch 4, dadurch gekennzeichnet, daß das Uran durch Graphit abgedeckt ist.	5. Device according to Claim 4, characterized in that the uranium is covered by graphite.

Top Secret Cable from Warsaw to Secretary of State. 7 March 1946 [NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret]

From: Warsaw

To: Secretary of State

Nr: 300 7 March 1946

Nr 300. Signed Lane.

Information has been given this Embassy by a capable young engineer working in the zinc industry, that one of the best if not the only material for atomic bomb containers is cadmium. According to the informant the cadmium output of Poland in 1945 amounted to 49.15 tons, and in January of 1946 to 10.9 tons. In 1945 there was exported to Russia the total Polish cadmium output.

End

ACTION: General Groves

INFO: General Spaatz, General Hull, General Vandenberg

[See document photo on p. 4256.

A “capable young engineer” in Poland stated that atomic bomb case designs use a layer of cadmium, apparently based on his personal experience in the wartime German program. That detail is highly consistent with the bomb descriptions given by Schumann and Trinks (above) and also by Ilyichev (p. 4485).]

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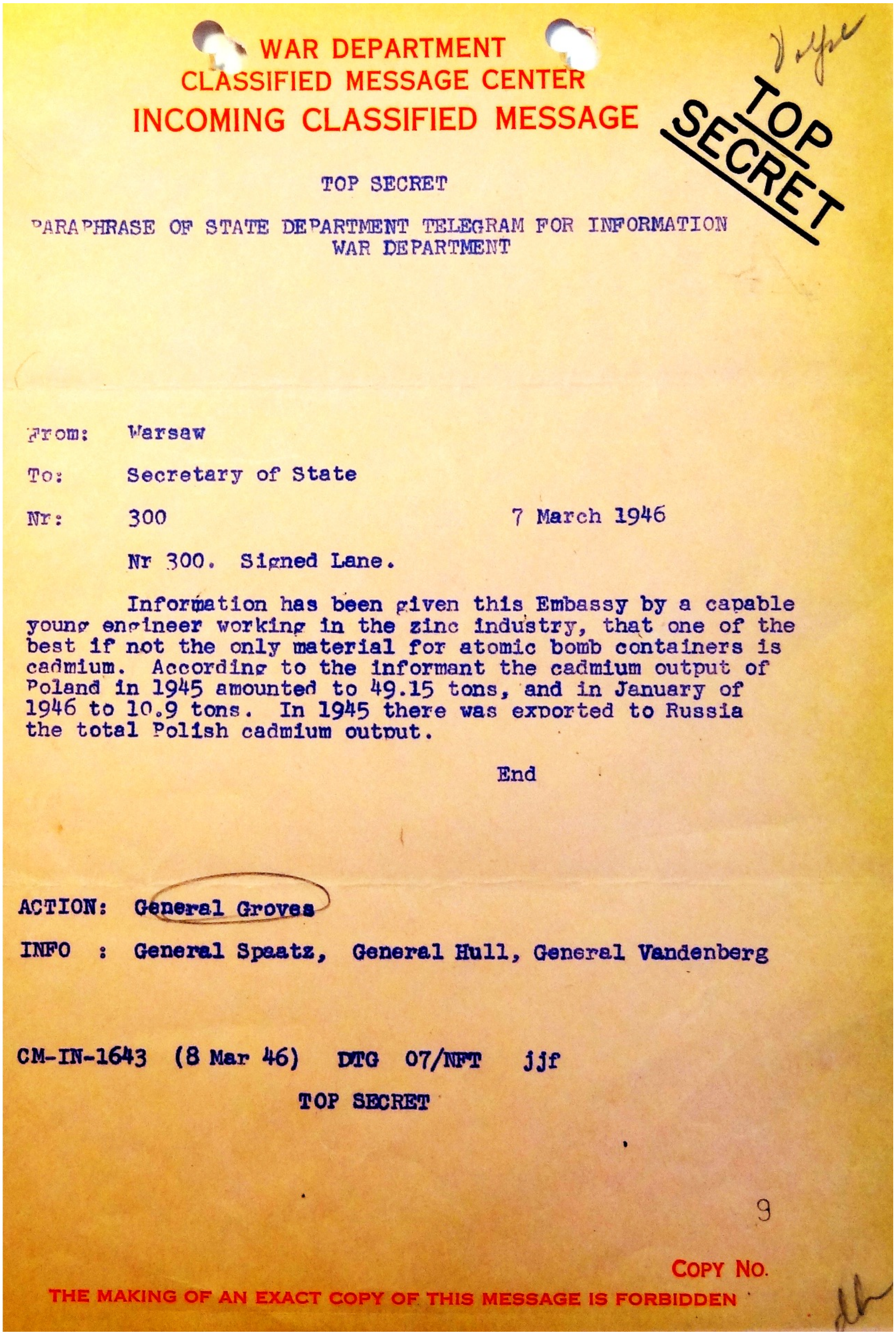
Authority NND 917017



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CLASSIFIED MESSAGE CENTER
INCOMING CLASSIFIED MESSAGE

Volpe

TOP SECRET

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PARAPHRASE OF STATE DEPARTMENT TELEGRAM FOR INFORMATION
WAR DEPARTMENT

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CM-IN-1643 (8 Mar 46) DTG 07/NFT jjf

TOP SECRET

9

COPY NO.

THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN

NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret

Figure D.594: Top Secret Cable from Warsaw to Secretary of State. 7 March 1946 [NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret].

Walter Trinks. Undated but probably summer 1945. [NARA RG 319, Entry A1-134B, Box ??, Folder XE098301 Trinks, Walter]

Dr. Walter Trinks
Int. No. 8-3448-M-AA
7th Coy.

TO THE AMERICAN COMMAND OF THE INTERNMENT CAMP? CIC-STAFF.

When I was imprisoned at Bad Aibling an American officer in an address asked German scientists and specialists to present themselves. Having presented myself I was told to give further written information on my altuition [education] and my career. Having been transferred to this camp I could not do so. I am a Physicist and have been employed with the OKH [Oberkommando des Heeres] until the end of the war in the research dept. of the office for arms [Heereswaffenamt] as referee for the physics of explosions and blasting. The tasks of that dept. included:

1st Research of physical phenomena at the explosion

2nd Augmentation of and defense against the effect of blasting materials through physical methods

3rd Research of difficulties and troubles.

4th The replacement of valuable raw materials.

During the war the principal labor was dedicated to the principle of hollow charges and its use in armour breaking amunition as F-I-7,5 cm grenade, HL(ABC), 10 cm G.Hl, rifle grenade, Panzerfaust and Panzerschreck, Panzerhandgrenade, Redcap, Magnetic H 3 and H 15.

At the end of the war I was occupied with experiments for producing extreme high pressures and temperatures, extreme velocities (up to 15 km/sec) and heavy swingings of the air [shock waves]. The practical use of these researches comprises:

1st for the war: the defense against V-weapons super- and atomic bombs by destroying them before they reach their target and the initiation of atomic bombs.

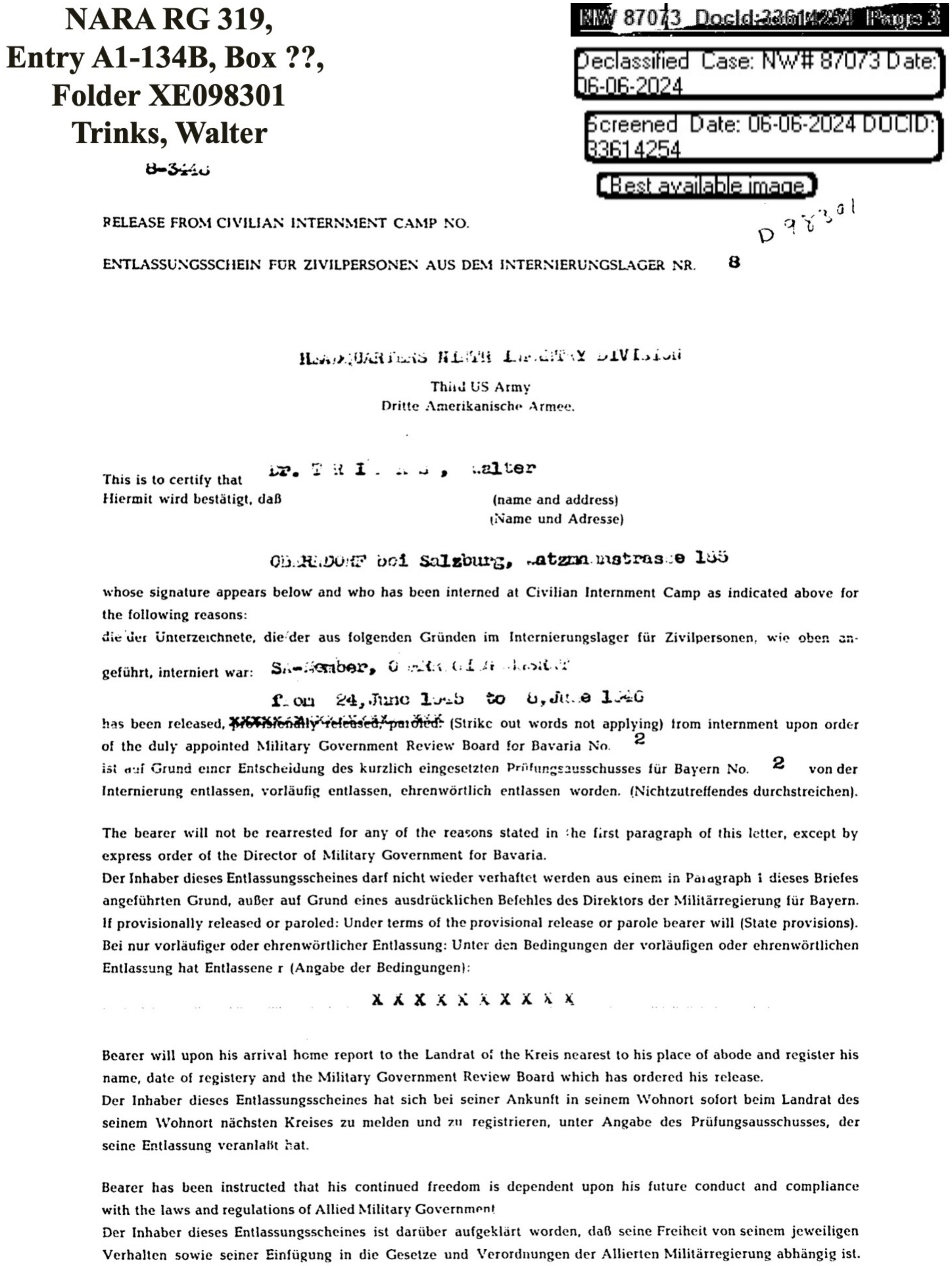
2nd for peacetime: the producing of artificial diamonds and the enriching of minerals and materials.

3rd for purely scientific research of special molecules and atoms under extreme pressures and temperatures.

I esteem these researches to be important and promising and therefore ask to be allowed to prosecute them at the service of the U.S.A.

[See document photos on pp. 4258–4259. Due to the number of English spelling and capitalization mistakes, this document appears to have been written in English by Trinks himself, not translated by a native English speaker. For ease of understanding, I have corrected most of the document's English mistakes in the above transcription.

Trinks was imprisoned by the U.S. Army from June 1945 to June 1946, and he informed them that "At the end of the war I was occupied with experiments for... the initiation of atomic bombs." Where are the detailed reports on his interrogations and everything he told U.S. officials about his wartime work? What exactly did he work on after the war, and for whom?]



NARA RG 319,
Entry A1-134B, Box ??,
Folder XE098301
Trinks, Walter

NW 87073 DocId:33614254 Page 3

Declassified Case: NW# 87073 Date: 06-06-2024

Screened Date: 06-06-2024 DOCID: 33614254

Best available image

8-3446

D 98301

RELEASE FROM CIVILIAN INTERNMENT CAMP NO.

ENTLASSUNGSSCHEIN FÜR ZIVILPERSONEN AUS DEM INTERNIERUNGSLAGER NR. 8

HEADQUARTERS NINTH INFANTRY DIVISION
Third US Army
Dritte Amerikanische Armee.

This is to certify that Dr. T R I N K S, Walter
Hiermit wird bestätigt, daß (name and address)
(Name und Adresse)

OBERNDORF bei Salzburg, Watzmannstrasse 155

whose signature appears below and who has been interned at Civilian Internment Camp as indicated above for the following reasons:
die der Unterzeichnete, die/der aus folgenden Gründen im Internierungslager für Zivilpersonen, wie oben angeführt, interniert war: SA-Member, [illegible]

from 24, June 1945 to 6, June 1946

has been released, ~~provisionally released, paroled.~~ (Strike out words not applying) from internment upon order of the duly appointed Military Government Review Board for Bavaria No. 2
ist auf Grund einer Entscheidung des kurzlich eingesetzten Prüfungsausschusses für Bayern No. 2 von der Internierung entlassen, vorläufig entlassen, ehrenwörtlich entlassen worden. (Nichtzutreffendes durchstreichen).

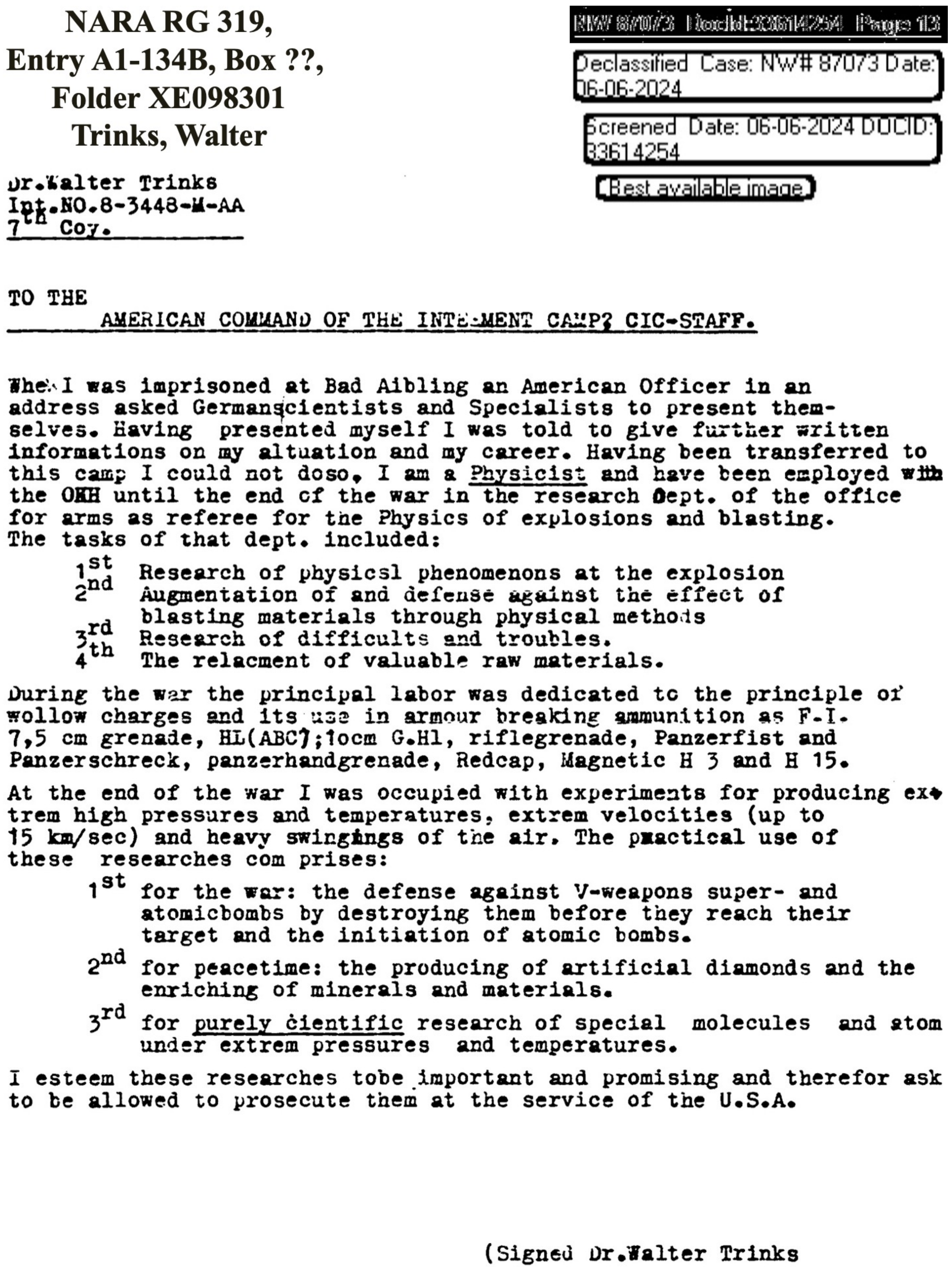
The bearer will not be rearrested for any of the reasons stated in the first paragraph of this letter, except by express order of the Director of Military Government for Bavaria.
Der Inhaber dieses Entlassungsscheines darf nicht wieder verhaftet werden aus einem in Paragraph 1 dieses Briefes angeführten Grund, außer auf Grund eines ausdrücklichen Befehles des Direktors der Militärregierung für Bayern.
If provisionally released or paroled: Under terms of the provisional release or parole bearer will (State provisions).
Bei nur vorläufiger oder ehrenwörtlicher Entlassung: Unter den Bedingungen der vorläufigen oder ehrenwörtlichen Entlassung hat Entlassene r (Angabe der Bedingungen):

X X X X X X X X X X

Bearer will upon his arrival home report to the Landrat of the Kreis nearest to his place of abode and register his name, date of registery and the Military Government Review Board which has ordered his release.
Der Inhaber dieses Entlassungsscheines hat sich bei seiner Ankunft in seinem Wohnort sofort beim Landrat des seinem Wohnort nächsten Kreises zu melden und zu registrieren, unter Angabe des Prüfungsausschusses, der seine Entlassung veranlaßt hat.

Bearer has been instructed that his continued freedom is dependent upon his future conduct and compliance with the laws and regulations of Allied Military Government.
Der Inhaber dieses Entlassungsscheines ist darüber aufgeklärt worden, daß seine Freiheit von seinem jeweiligen Verhalten sowie seiner Einfügung in die Gesetze und Verordnungen der Allierten Militärregierung abhängig ist.

Figure D.595: Walter Trinks was imprisoned by the U.S. Army from June 1945 to June 1946. Where are the detailed reports on his interrogations and everything he told U.S. officials about his wartime work? [NARA RG 319, Entry A1-134B, Box ??, Folder XE098301 Trinks, Walter]



NARA RG 319,
Entry A1-134B, Box ??,
Folder XE098301
Trinks, Walter

NW 87073 DocId:33614254 Page 13

Declassified Case: NW# 87073 Date: 06-06-2024

Screened Date: 06-06-2024 DOCID: 33614254

Best available image

Dr.Walter Trinks
Int.NO.8-3448-M-AA
7th Coy.

TO THE
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I esteem these researches tobe important and promising and therefor ask to be allowed to prosecute them at the service of the U.S.A.

(Signed Dr.Walter Trinks

Figure D.596: During his imprisonment by the U.S. Army, Walter Trinks informed U.S. officials that "At the end of the war I was occupied with experiments for... the initiation of atomic bombs." Where are the detailed reports on his interrogations and everything he revealed about his wartime work? What exactly did he work on after the war, and for whom? [NARA RG 319, Entry A1-134B, Box ??, Folder XE098301 Trinks, Walter].

Kurt Diebner. UK Patent 841,387. Thermonuclear Reactions. Filed 30 November 1956.

I, Kurt Diebner, of Eppendorfer Stieg 8, Hamburg 39, Germany, of German nationality do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:–

This invention relates to a method for the ignition of the thermonuclear fuels deuterium and tritium.

Amongst known attempts for the generation of very high temperatures, two in particular promise to be successful, of which each one currently permits when using a suitable arrangement, the attainment of temperatures of the order of 10^5 °K to 10^6 °K and over. One of these methods is the generation of converging shock waves through suitable ignition of an explosive in the form of a hollow body at its outer shell. The other method consists in generating highly ionised gases by concentrated discharges and making use of the pinch- effect in a restricted space. One possible method of execution recorded in the literature is given by an electric arc burning between two carbon electrodes, between which a condenser battery of high capacity and with a high voltage charge is briefly short-circuited.

The present invention consists in a method for the ignition of the thermonuclear fuels deuterium and tritium, to initiate thermonuclear reactions, wherein converging compression shock waves are produced in a hollow body by solid or liquid explosives, the generation of high temperatures in the centre of convergence of the shock waves being combined with an increase of temperature generated by concentrated electrical discharges in the fusionable nuclear fuels so that the temperature raising effects are superimposed and temperatures necessary for fusion processes are produced at the centre of the converging shock wave.

The invention further consists in a method for the ignition of thermonuclear fuels to promote thermonuclear reactions therein, which consists in detonating an explosive charge in the form of a hollow body surrounding the thermonuclear fuel, thereby generating a converging shock wave in the interior thereof, and creating a concentrated electrical discharge in the thermonuclear fuel at the centre of convergence of the shock wave in order to attain a temperature sufficient for the ignition of the thermonuclear fuel.

In the accompanying drawings:–

Figure 1 is a diagrammatic view of apparatus for carrying out the method according to the present invention, and

Figure 2 shows a wiring diagram for the apparatus of figure 1.

In carrying the invention into effect according to one convenient mode by way of example, reference 1 (figure 1) denotes an explosive body of spherical shell shape provided with two openings in the shape of a truncated cone, in which a spherically shaped high pressure container 5 is embedded for the uptake of the deuterium 2, perhaps in gaseous form under very high pressure. The spherically shaped high pressure container can however also be dispensed with, and the deuterium can be incorporated directly under pressure into the explosive material. The explosive body 1 can be surrounded by a further spherical shell 6, which tamps the explosive body towards the outside. Two insulated electrodes, for example lithium (lithium 6), between which an electric arc 4 can burn, are introduced into the high pressure container 5. For this purpose the electrode material should have a low nuclear charge number and be as thin as possible in order to maintain at a low level the larger proton reflection with its related higher nuclear charge number. Lithium 6 is furthermore particularly suitable because with it tritium is formed in the thermonuclear combustion process.

Fig. 1

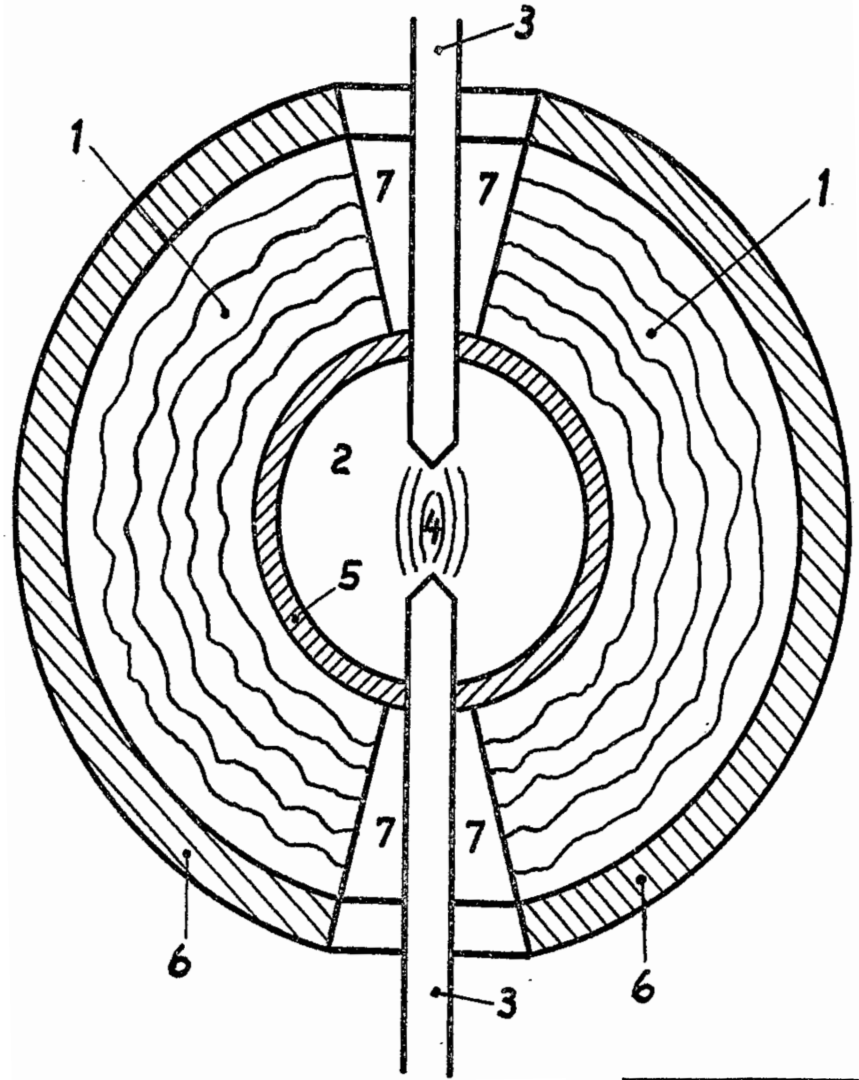
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Fig. 2

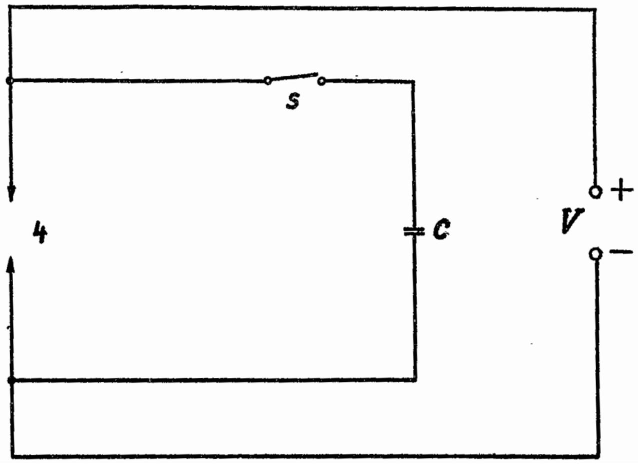


Figure D.597: Figures from Kurt Diebner's U.K. Patent 841,387.

An example is shown in Figure 2 of an electric connection for the electric arc and the connected condenser, in which C represents a condenser. S is a suitable switch which can connect the condenser to the electric arc. V is the source of tension for the electric arc 4. The release of the thermonuclear reaction in the deuterium gas 2 is now to proceed as follows:

The explosive material is so ignited at the boundary surface between 6 and 1, that a converging shock wave results, which after exceeding the boundary surface 5, runs towards the centre of the electric arc 4, and there contributes to an increase of the temperature of the already burning electric arc. The electric arc burns thereby in a gas of high pressure, so that under these circumstances it can already operate on its own at temperatures of the order of 10,000 degrees and more.

The height of the temperature to be reached in the moment when the shock wave reaches the centre of convergence 4, depends amongst other things on the geometry of the arrangement, and on the explosive material used (trinitrotoluol or hexogen or others). It also depends on whether a high pressure container 5 is used, and the material from which it is composed, as well as finally on the temperature, power and shape of the electric arc.

When the shock wave has reached the centre of convergence, further suitable measures are provided according to Figure 1, which permit further considerable heating of the gas (plasma) which is under the highest pressure and which has thereby become highly conductive. Because of this in the example provided, a further additional heating of the deuterium by the electric spark follows, directly before the compression shock reaches in its last phase the centre of convergence. Through this combination of the various methods in an appropriate sequence it is possible to attain the highest temperatures during the arrival of the shock wave in the centre of convergence. A further condition is that the electrodes are still active at the moment of the setting in of the discharge. Since it is an electrical process which is being dealt with, when the condenser C which has been charged with high voltage is suddenly discharged, and since on the other hand the deuterium gas in the electric arc 4 is already extensively pre-ionised, it is possible to add at least partially, to the convergence centre, the energy accumulated in the condenser. Furthermore, at the moment of connecting the condenser, because of the magnetic effects in the discharge path, an adiabatic contraction of the highly ionised plasma in the sense of the pinch-effect takes place, which has the effect of raising the temperature. In the given circumstances it is merely a question of the amount of energy accumulated in the condenser and which is available for the continuation of the working process, and the temperature in the convergence centre 4 can be increased additionally to such an extent, that the added energy is great enough to allow the thermonuclear ignition of the deuterium gas to take place.

Besides the given example, temperature effects can be superposed or supplemented, additional consideration being taken of an adiabatic compression and suitable temporal sequence with combination of gas discharges, spark discharges, a mechanically or chemically generated adiabatic compression, detonation wave or some of them, which are suitable for producing the temperatures necessary for the ignition of the gaseous, liquid, and if need be solid thermonuclear fuels. It is also possible for example, to fill the space 7 with liquid deuterium, tritium or D_2O, in the manner that the deuterium 2 serves as initiator for further larger quantities of thermonuclear fuel. Installations with half spherical-hollow bodies can also be constructed, which can also cause the ignition of the thermonuclear fuel, in the convergence centre,—such a fuel corresponding to the deuterium 2—and/or to use the latter for the initial ignition of further quantities of the same or of other thermonuclear fuels. Any other form of hollow body which permits the production of a suitable converging compression shock under suitable ignition is also admissible according to the purposes for which the ignited thermonuclear fuel is to be used, whereby it is particularly to be noted, that these installations can also be used to produce thermonuclear reactions which do not lead or need not lead to ignition.

It is also conceivable, for example, for deuterium enclosed in a volume, to be preheated by adiabatic compression, electrical discharges or any other means, and then to be ignited by a linear and/or if necessary converging compression shock, or else to achieve this with adiabatically pre-heated thermonuclear fuel, using concentrated electrical discharges. Such installations as mentioned in the last example are suitable when their intermittent activity is controlled for the production of mechanical energy. The process explained in Figure 1 can also be carried out in a large pressure container and thus be suitable for maintaining in this large boiler, pressures and/or temperatures required for energy withdrawal or energy generation for certain purposes. This can take place during the intermittent or continuous running of several such processes, respectively repeated any number of times, whereby temperatures and/or pressures can be added to any desired purpose, such as heat engines, the drive of turbines, and others.

What I claim is:–

l. A method for the ignition of the thermonuclear fuels deuterium and tritium, to initiate thermonuclear reactions, wherein converging compression shock waves are produced in a hollow body by solid or liquid explosives, the generation of high temperatures in the centre of convergence of the shock waves being combined with an increase of temperature generated by concentrated electrical discharges in the fusionable nuclear fuels so that the temperature-raising effects are superimposed and temperatures necessary for fusion processes are produced at the centre of the converging shock waves.

2. A method for the ignition of thermonuclear fuels to promote thermonuclear reactions therein, which consists in detonating an explosive charge in the form of a hollow body surrounding the thermonuclear fuel, thereby generating a converging shock wave in the interior thereof, and creating a concentrated electrical discharge in the thermonuclear fuel at the centre of convergence of the shock wave in order to attain a temperature sufficient for the ignition of the thermonuclear fuel.

3. A method as claimed in claim 1 or 2, wherein the processes of the converging percussion wave and of the concentrated electrical discharges are temporarily connected in sequence in such a manner that, the electrical discharge is first effected at the instant when the percussion wave just reaches the convergence centre.

4. A method as claimed in claim 1, 2, or 3, wherein in order to increase the effect of the converging percussion wave a tamping of the explosive is used on its outer side.

5. A method as claimed in any of claims 1 to 4, distinguished in that, the thermonuclear nuclear fuels to be ignited, whether gaseous or liquid, are under high pressure.

6. A method as claimed in any of claims 1 to 5, distinguished in that, the electrical discharges take place in a space which is considerably pre-heated by adiabatic compression which is generated chemically.

7. A method as claimed in any of claims 1 to 6, wherein the nuclear fuel to be ignited is surrounded by a pressure container, the components of which will further increase the action of the converging shock wave.

8. A method as claimed in any of claims 1 to 7, wherein by initiating thermonuclear reactions in

a small volume, the initial condition is created for initiating fusion reactions in a larger volume of thermonuclear fuel.

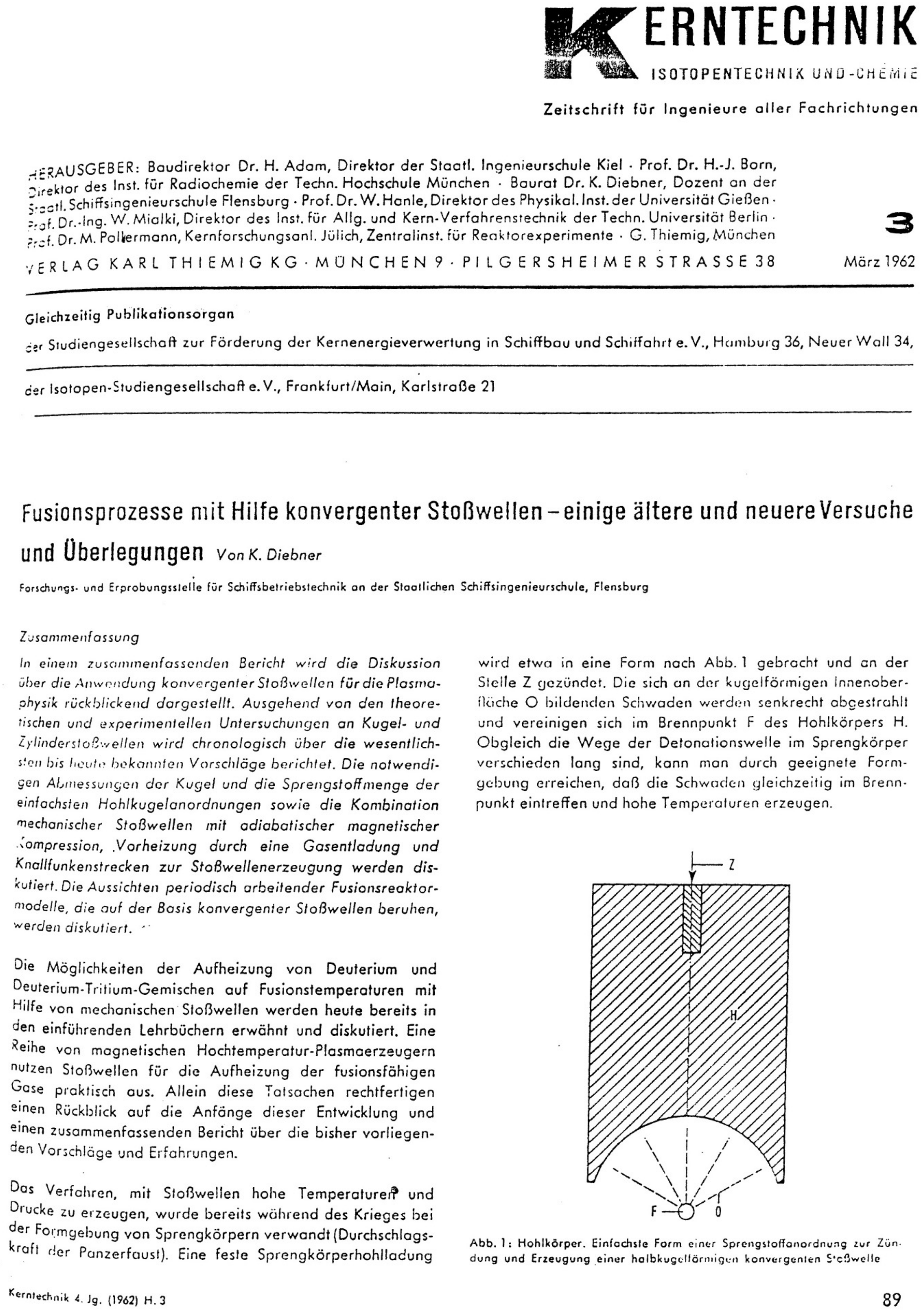
9. A method as claimed in any of claims 1 to 8, wherein the thermonuclear reactions take place in a suitable container for the maintenance of required pressures and/or required temperatures, and that thus the fusion energy can be utilized.

10. A method as claimed in claim 9, wherein the process is repeated periodically or not periodically, and it serves for driving turbines, heat engines and/or other power combinations.

11. A method for the ignition of thermonuclear fuels substantially as described with reference to the accompanying drawings.

Kurt Diebner. 1962. Fusionsprozesse mit Hilfe konvergenter Stosswellen—einige ältere und neuere Versuche und überlegungen. *Kerntechnik* 4:3:89–93.

[See pp. 4265–4267.]



KERNTECHNIK
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Fusionsprozesse mit Hilfe konvergenter Stoßwellen – einige ältere und neuere Versuche und Überlegungen

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Zusammenfassung

In einem zusammenfassenden Bericht wird die Diskussion über die Anwendung konvergenter Stoßwellen für die Plasmaphysik rückblickend dargestellt. Ausgehend von den theoretischen und experimentellen Untersuchungen an Kugel- und Zylinderstoßwellen wird chronologisch über die wesentlichsten bis heute bekannten Vorschläge berichtet. Die notwendigen Abmessungen der Kugel und die Sprengstoffmenge der einfachsten Hohlkugelanordnungen sowie die Kombination mechanischer Stoßwellen mit adiabatischer magnetischer Kompression, Vorheizung durch eine Gasentladung und Knallfunkenstrecken zur Stoßwellenerzeugung werden diskutiert. Die Aussichten periodisch arbeitender Fusionsreaktormodelle, die auf der Basis konvergenter Stoßwellen beruhen, werden diskutiert.

Die Möglichkeiten der Aufheizung von Deuterium und Deuterium-Tritium-Gemischen auf Fusionstemperaturen mit Hilfe von mechanischen Stoßwellen werden heute bereits in den einführenden Lehrbüchern erwähnt und diskutiert. Eine Reihe von magnetischen Hochtemperatur-Plasmaerzeugern nutzen Stoßwellen für die Aufheizung der fusionsfähigen Gase praktisch aus. Allein diese Tatsachen rechtfertigen einen Rückblick auf die Anfänge dieser Entwicklung und einen zusammenfassenden Bericht über die bisher vorliegenden Vorschläge und Erfahrungen.

Das Verfahren, mit Stoßwellen hohe Temperaturen und Drucke zu erzeugen, wurde bereits während des Krieges bei der Formgebung von Sprengkörpern verwandt (Durchschlagskraft der Panzerfaust). Eine feste Sprengkörperhohlladung wird etwa in eine Form nach Abb. 1 gebracht und an der Stelle Z gezündet. Die sich an der kugelförmigen Innenoberfläche O bildenden Schwaden werden senkrecht abgestrahlt und vereinigen sich im Brennpunkt F des Hohlkörpers H. Obgleich die Wege der Detonationswelle im Sprengkörper verschieden lang sind, kann man durch geeignete Formgebung erreichen, daß die Schwaden gleichzeitig im Brennpunkt eintreffen und hohe Temperaturen erzeugen.

Abb. 1: Hohlkörper. Einfachste Form einer Sprengstoffanordnung zur Zündung und Erzeugung einer halbkugelförmigen konvergenten Stoßwelle

Figure D.598: Kurt Diebner's paper describing (among other designs) a spherical implosion fission bomb with a deuterium-tritium fusion boost in the center [Diebner 1962].

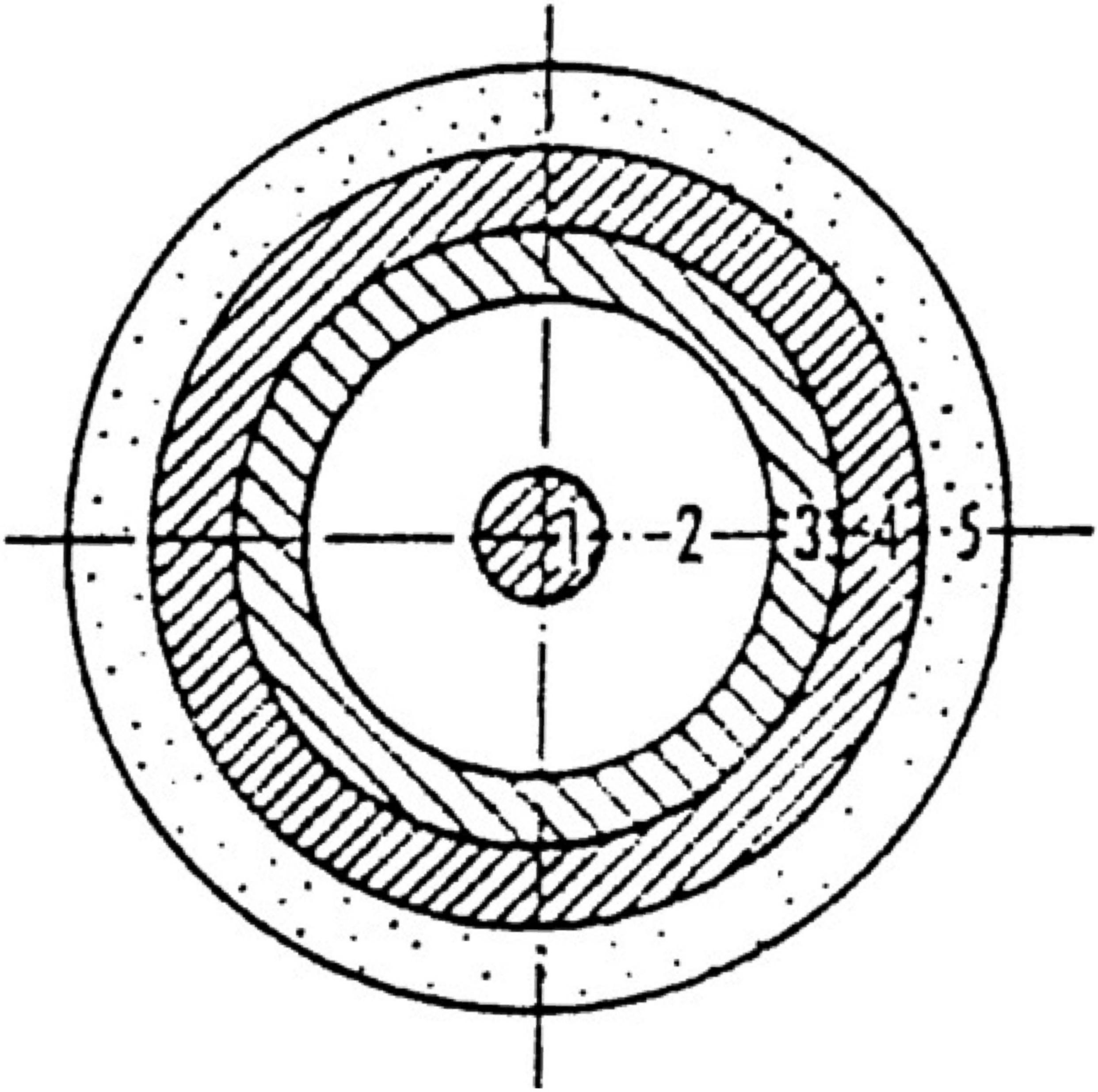
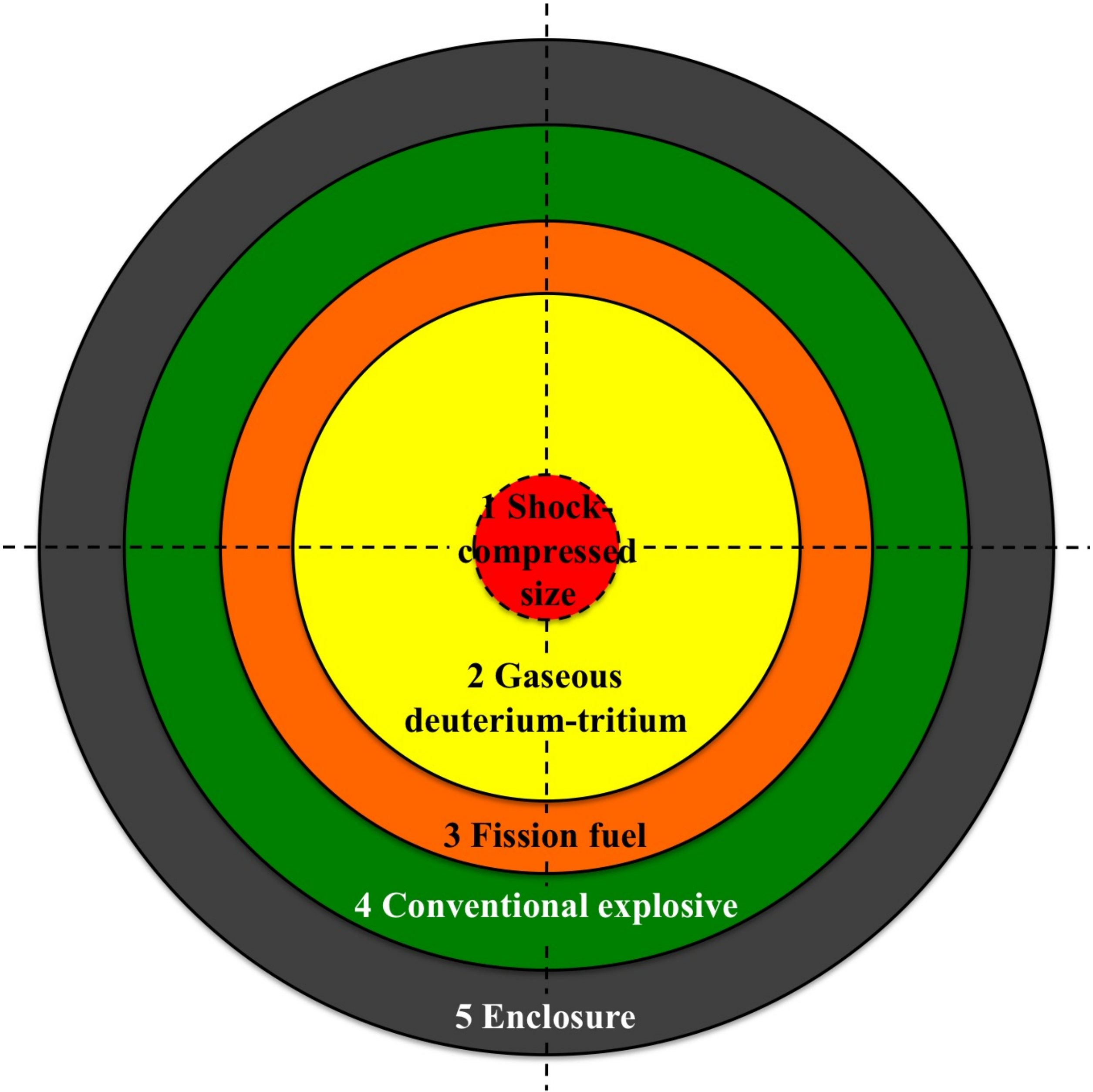


Abb. 5: Kugelschalenanordnung von Kernspaltstoff (3) und gewöhnlichem Sprengstoff (4), die in einer Verdämmung (5) eingeschlossen sind. Im Hohlraum (2) der Schichtfolge befindet sich gasförmiges Deuterium bzw. ein Deuterium-Tritium-Gemisch. Das Reaktionsvolumen der Stoßwelle ist wieder (1). Die Schale (3) ist so dimensioniert, daß der Kernspaltstoff erst dann eine kritische Anordnung darstellt, wenn durch Detonation der Schale (4) eine Stoßwelle die Hohlkugel in der Nähe des Konvergenzzentrums zu einem kompakten Gebilde zusammenschiebt

Figure D.599: Kurt Diebner's schematic illustration of a spherical implosion fission bomb design with a deuterium-tritium fusion boost in the center [Diebner 1962].



Kugelschalenanordung von Kernspaltstoff (3) und gewöhnlichem Sprengstoff (4), die in einer Verdämmung (5) eingeschlossen sind. Im Hohlraum (2) der Schichtfolge befindet sich gasförmiges Deuterium bzw. ein Deuterium-Tritium-Gemisch. Das Reaktionsvolumen der Stoßwelle ist wieder (1). Die Schale (3) ist so dimensioniert, daß der Kernspaltstoff erst dann eine kritische Anordnung darstellt, wenn durch Detonation der Schale (4) eine Stoßwelle die Hohlkugel in der Nähe des Konvergenzzentrums zu einem kompakten Gebilde zusammenschiebt.

A spherical shell arrangement of fission fuel (3) and conventional explosive (4) which is enclosed in a casing (5). In the central cavity (2) of the sequence of layers, there is gaseous deuterium or a deuterium-tritium mixture. The reaction volume of the shock wave is (1). The shell (3) is dimensioned in such a way that the fission fuel is only a critical assembly when, by detonation of the layer (4), a shock wave compresses the hollow sphere into a compact structure around the convergence center.

Figure D.600: Redrawn and translated version of Kurt Diebner's schematic illustration of a spherical implosion fission bomb design with a deuterium-tritium fusion boost in the center.

Vincent Nouzille and Olivier Huwart. 1999. Comment la France a recruté des savants de Hitler. *L'Express* no. 2498 (20 May), p. 122. https://www.lexpress.fr/informations/comment-la-france-a-recrute-des-savants-de-hitler_633743.html

La France recrute d'autres savants au passé controversé. En mars 1945, le Pr Hubert Schardin, l'un des patrons du centre de recherches de la Luftwaffe à Berlin-Gatow, formait des stagiaires en vue de créer une ultime "arme miracle" pour Hitler! Replié à Biberach, dans le Wurtemberg, il est fait prisonnier par le commandant Lutz, de la 1re division blindée de l'armée française. Le 7 mai 1945, Lutz indique à Schardin qu'il aura "toute liberté d'action". Le lendemain, jour de la capitulation allemande, le savant note dans son agenda: "Le travail a repris"... Avec une trentaine d'autres ingénieurs, il s'installe près de la frontière franco-allemande et devient codirecteur du Laboratoire de recherches balistiques et aérodynamiques de Saint-Louis (Haut-Rhin), créé spécialement par le ministère de l'Armement.

Parmi la centaine de recrues allemandes qui rejoignent progressivement ce laboratoire militaire se trouve le Dr Rudi Schall, un physicien berlinois de renom, venu d'un autre centre de recherches militaires. Agé aujourd'hui de 85 ans, retiré près du lac de Constance, il confie à L'Express: "C'est vrai que j'étais membre du parti nazi, comme beaucoup de mes collègues qui y étaient plus ou moins obligés, sans être forcément actifs. En 1945, les Américains nous ont embarqués, mais ils nous traitaient comme des moins-que-rien. Les Britanniques, eux, m'ont proposé de m'embaucher, mais sans que ma femme puisse me rejoindre. Alors que les Français ont été très chaleureux. La dénazification des postes était en cours en Allemagne. Mais on nous a dit que cela ne nous concernait pas. Je suis arrivé début 1946 à Saint-Louis." Rudi Schall succédera à Schardin comme codirecteur de ce laboratoire, devenu en 1959 le symbole de la nouvelle coopération militaire franco-allemande!

France is recruiting other scientists with a controversial past. In March 1945, Professor Hubert Schardin, one of the bosses of the Luftwaffe Research Centre in Berlin-Gatow, prepared assistants to create a final "miracle weapon" for Hitler! Folded back to Biberach, Württemberg, he was taken prisoner by Commander Lutz, of the 1st Armoured Division of the French Army. On May 7, 1945, Lutz told Schardin that he would have "complete freedom of action." The next day, the day of the German surrender, the scientist noted in his diary: "Work has resumed"... With about thirty other engineers, he settled near the Franco-German border and became co-director of the Laboratoire de recherches balistiques et aérodynamiques de Saint-Louis (Haut-Rhin), created especially by the Ministry of Armament.

Among the hundred German recruits who are gradually joining this military laboratory is Dr. Rudi Schall, a renowned Berlin physicist from another military research centre. Now 85 years old, retired near Lake Constance, he told L'Express: "It is true that I was a member of the Nazi party, like many of my colleagues who were more or less obliged to do so, without necessarily being active. In 1945, the Americans took us in, but they treated us like less than nothing. The British offered to hire me, but my wife could not join me. While the French were very warm and friendly. The denazification of posts was under way in Germany. But we were told that this did not concern us. I arrived in early 1946 in Saint-Louis." Rudi Schall succeeded Schardin as co-director of this laboratory, which became the symbol of the new Franco-German military cooperation in 1959!

Certaines embauches sont encore plus troublantes. Selon l'historien allemand Ulrich Albrecht, le comte Helmut Zborowski, ingénieur chez BMW, est emprisonné en 1945 à cause de son appartenance aux Waffen SS. Ce lourd passé n'empêche pas la France, en 1947, de convier Zborowski à rejoindre la Société européenne de propulsion par réaction (SEPR). Ce scientifique controversé créera, en 1950 à Paris, le Bureau technique Zborowski. Subventionné sur fonds publics par la Snecma, l'ex-SS concevra un drôle d'engin à décollage vertical, le Coléoptère, véritable gadget technique, dont les essais en vol se révéleront dangereux...

Le gouvernement tient également à conserver quelques chimistes allemands. Arrêtés par les Américains, Walter Reppe—qualifié de "nazi bon teint"—et Karl Wurster—présumé "criminel de guerre"—seront blanchis et rejoindront leurs postes à l'usine de Ludwigshafen, avec la bienveillance des Français. Tous les Alliés pratiquent le même cynisme. Le cas d'Otto Ambros, un des directeurs d'IG Farben, est exemplaire. Ambros a participé à la décision d'utiliser le zyklon B dans les chambres à gaz. Il a également supervisé une usine de caoutchouc synthétique à Auschwitz-Buna-Monowitz, dans laquelle de nombreux déportés ont été maltraités. Interrogé par des militaires français en août 1945, il rédige un rapport ultrasensible sur la production allemande de nouveaux gaz de combat (tabun, sarin, soman). De quoi intéresser les promoteurs d'armes chimiques françaises! Puis, selon l'historienne Marie-France Ludmann-Obier, ce scientifique, considéré comme "criminel de guerre", est invité par le ministère de la Guerre à Paris pour faire des conférences! Après des mois de pressions américaines, les Français finissent par livrer Ambros à des GI. Un tribunal de Nuremberg le condamne en 1948 à huit ans de prison pour esclavage. Libéré en 1951, il fera carrière comme conseiller d'un grand groupe chimique aux Etats-Unis...

Some hires are even more troubling. According to the German historian Ulrich Albrecht, Count Helmut Zborowski, an engineer at BMW, was imprisoned in 1945 because of his membership of the Waffen SS. This heavy history did not prevent France, in 1947, from inviting Zborowski to join the European Society for Jet Propulsion (SEPR). This controversial scientist created the Zborowski Technical Office in Paris in 1950. Subsidized on public funds by Snecma, the ex-SS will design a strange vertical take-off device, the Beetle, a real technical gadget, whose flight tests will prove dangerous...

The government also wants to keep some German chemists. Arrested by the Americans, Walter Reppe—described as a "well-rounded Nazi"—and Karl Wurster—allegedly a "war criminal"—were cleared and returned to their posts at the Ludwigshafen factory, with the goodwill of the French. All Allies practice the same cynicism. The case of Otto Ambros, one of the directors of IG Farben, is exemplary. Ambros was involved in the decision to use zyklon B in the gas chambers. He also supervised a synthetic rubber factory in Auschwitz-Buna-Monowitz, where many deportees were mistreated. When questioned by French soldiers in August 1945, he wrote a highly sensitive report on the German production of new poison gases (tabun, sarin, soman). This is of interest to French chemical weapons promoters! Then, according to historian Marie-France Ludmann-Obier, this scientist, considered a "war criminal," was invited by the Ministry of War in Paris to give lectures! After months of American pressure, the French finally delivered Ambros to GIs. A Nuremberg tribunal sentenced him in 1948 to eight years in prison for slavery. Released in 1951, he made a career as an advisor to a large chemical group in the United States...

[Ambros, Schardin, Schall, and Zborowski appear to have played important roles in the German nuclear weapons program, and likely used that knowledge to help the postwar French nuclear weapons program. Almost certainly there are extensive French files on their wartime and postwar work, but those files remain unavailable.]

Ingeborg Brandt, who worked in the Hans Lindemayer group in Anklam and then Friedland. Letter to Karl Spietz. 20 October 1995. Heimatmuseum Friedland, Akte Nr. 157. [Karlsch 2005, pp. 169, 230]

Vor unserer Halle war so eine Art Terrasse. Man nannte dies Prüfstand. Dort stand so eine Kugel [...] Ich selbst schätze sie auf einen Durchmesser von 1,80 Meter.

There was a kind of terrace in front of our hall. This was called the test stand. There was such a ball [...] I estimate it to be 1.80 meters in diameter.

Irene König, who worked in Anklam and then Friedland. 16 July 2004 interview by Heiko Petermann. [Karlsch 2005, pp. 169–170]

Da wurden zwei Aluminiumkugeln ineinander gesetzt, eine große und eine kleine, und die dampften. Zuerst dachte ich, die kochen darin Wasser. Aber ich habe mich natürlich nicht getraut zu fragen, das war ja alles so geheim. Wir wurden dann nach dem Bombenangriff nach Friedland verlagert. Lindemayer ging nach Nordhausen, und Johann Grüner übernahm die Leitung der Gruppe. In Friedland wurden die Kugeln in einem großen Kessel mit hoher Geschwindigkeit gedreht. Manchmal war ein gewaltiges Getöse und Donnern zu hören. Die Ingenieure erzählten uns dann, dass sie Versuche mit Druckminderern durchführen.

There were two aluminum spheres, one placed inside the other, one large and one small, and they steamed. At first I thought they were boiling water in them. But of course I did not dare to ask, it was all so secret. We were then transferred to Friedland after the bomb attack. Lindemayer went to Nordhausen, and Johann Grüner took over the management of the group. In Friedland the spheres were turned in a large cauldron at high speed. Sometimes there was a tremendous roar and thunder. The engineers then told us that they were doing experiments with pressure reducers.

[Ilyichev's March 1945 description of the German implosion bomb design (see p. 4485) includes two hollow aluminum spheres, a large outer aluminum explosive case and a smaller aluminum pusher inside that.

"In addition to the Lindemayer group, a second research team headed by Dr. Ing. Wolfgang Steurer came to Friedland in 1944. He was considered to be one of the best experts in the field of material testing and was particularly well-known in aluminum alloys. His group consisted of 24 scientists, technicians and assistants. [...] Employees had been seen in protective suits during materials transport and at work. Details were not disclosed." [Karlsch 2005, p. 170]

See also:

Christoph Regel, Die Erprobungsstelle Rechlin, in: *Flugerprobungsstellen bis 1945.* Bonn 1998, pp. 60ff.

Heimatmuseum Friedland, Nr. 157: Karl Spietz to Gerhard Remdt 26.4.1966, 24.2.1967; Karl Spietz to *Neue Friedländische Zeitung* 15 September 1995.

Wer waren die Gummimänner von Friedland? *Neue Friedländer Zeitung* 7 June 1995.]

Heinrich Himmler's chief adjutant Werner Grothmann on nuclear weapon designs [Krotzky 2002]. See pp. 3396–3397 regarding the background and reliability of this source.

[S. 9] Was ich weiß ist die tatsächliche Vorbereitung für die Prototypenproduktion der zwei durchkonstruierten Atombombentypen für Uran und Plutonium. [...] Ich durfte davon nichts wissen, deshalb kann ich nur sagen, dass es um zwei Standardtypen für den Einsatz gegen Städte ging und noch zwei weitere unterschiedlich grosse, die sollten frontverwendungsfähig sein und kleinere Ladungen enthalten. Ich erfuhr erst nach dem Krieg davon, dass die eine von den beiden kleineren ein Ladungsäquivalent, also eine vergleichbare Sprengmaterialmenge, von ich glaube 130 Tonnen gehabt hätte. Die sollte gegen Bahntunnels, Hafenanlagen und Militäreinrichtungen eingesetzt werden. Der Punkt war, dass die kleinen Waffen nur ganz wenig Material benötigten, denn daran bestand ja erstmal der Mangel. Von der grösseren hörte ich nur eine Angabe, die ich nicht bestätigen kann, da ging es um drei Kilotonnen, das muss offen bleiben.

[p. 9] What I know is the actual preparation for the prototype production of the two fully constructed atomic bomb types for uranium and plutonium. [...] I was not allowed to know anything about it, so I can only say that there were two standard types for use against cities and two more of a different size, which were supposed to be front-usable [for tactical battlefield use] and contain smaller charges. I learned only after the war that one of the two smaller ones would have had a charge equivalent, that is a comparable explosive material quantity, of I believe 130 tons. This was supposed to be used against railway tunnels, port facilities and military installations. The point was that the small weapons required only very little material, which overcame first of all the shortage [of fission fuel]. Of the larger one I heard only a statement, which I cannot confirm, that it was about three kilotons, that must remain [an] open [question].

[S. 18] Was da im einzelnen alles gelaufen ist, erfuhr ich nie. Es war aber so, dass es zwei ganz verschiedene Konstruktionen gab, von einer dritten, zu der ich sonst nichts weiß, hörte ich erst recht nicht viel. Die muß wie eine aufgequollene Bombe ausgesehen haben. Zu den beiden anderen weiß ich, dass die kleinere ungefähr die Größe der SC 250 gehabt hatte, aber das Gewicht war höher. Die größere Waffe hätte eine Kugelform besessen mit einem Durchmesser von über einem Meter. Die war sehr schwer, obwohl der Bombenkörper selbst aus Aluminium gewesen sein soll. Es hieß, wenn man das Gewicht reduziert, geht die Ladung nicht hoch. Dann war eine Variante geplant, bei der der Bombenkörper selbst Bestandteil des Sprengsytems gewesen sein soll. Ich kann das jetzt nicht besser sagen, es ging jedenfalls darum, das Gewicht zu reduzieren und trotzdem eine richtig große Sprengkraft zu erhalten.

[p. 18] I never heard what all was going on in detail. It was true, however, that there were two entirely different constructions; of a third, about which I do not know anything else, I did not hear much. It must have looked like a swollen bomb. About the other two, I know that the smaller was about the size of the SC 250, but the weight was higher. The larger weapon would have possessed a spherical shape with a diameter of over one meter. It was very heavy, even though the bomb body itself was supposed to be out of aluminum. It was said, if one reduces the weight, the yield is not as high. For this purpose, a variant was planned, in which the bomb body itself was supposed to have been a component of the explosive system. I cannot say better now, it was anyway to reduce the weight and still get a really big explosive energy.

[S. 44] Ja, jetzt kommt noch das dritte Problem. Wir haben ja schon mal darüber gesprochen, dass die Wissenschaftler eine Zündung in der Luft in einer bestimmten Höhe haben wollten. Es sollte eine Höhe von ungefähr 400 Metern sein. Es gab aber erst mal keinen einzigen Zündmechanismus, der das zuverlässig schaffte, obwohl viele daran gearbeitet hatten. Es ist sogar überlegt worden, das mit Zeitzünder zu machen, ich weiß aber nicht, ob das durchgeführt worden ist. Das Problem war ja, wenn man einen Aufschlagzünder nimmt, verpufft der größte Teil der Wirkung. Dann wäre die Waffe die ganze Mühe nicht wert gewesen. Bei dem Versuch, der im Spätherbst 44 mit dem Fallschirmabwurf durchgeführt worden war, hatten sie etwas ausprobiert. Ich weiß aber nicht, ob das wirklich ein Annäherungszünder gewesen ist.

[S. 42] Übrigens, was die Physiker Himmler im Privatvortrag zur Wasserstoffbombe sagten, das hatte ihn wirklich elektisiert, weil er hörte, dass die Sprengwirkung hundertmal größer sein würde als bei der Uranbombe.

[p. 44] Yes, now comes the third problem. We have already talked about the fact that the scientists wanted to have an ignition in the air at a certain altitude. It should be an altitude of approximately 400 meters. But there was not even a single ignition mechanism that made it reliable, even though many had worked on it. It was even thought of doing this with a time fuse, but I do not know if this was done. The problem was, if one uses an impact fuse, most of the effect fizzles. Then the weapon would not have been worth the effort. In the test, which was carried out in late autumn 44 with the parachute drop, they had tried out something. But I do not know if this was really a proximity fuse.

[p. 42] By the way, what the physicists told Himmler in their private lecture on the hydrogen bomb had really electrified him, because he heard that the explosive effect would be a hundred times greater than that of the uranium bomb.

[Can other relevant documents from or about the following people be located in archives?

- Alfred Baubin
- Adolf Busemann
- Rolf Engel
- Siegfried Flügge
- Erich Purucker
- Rudi Schall
- Hubert Schardin
- Karel Staller
- Gustav Thomer
- Walter Trinks
- Others?]

[Grothmann appeared to describe work on at least five different types of nuclear weapons:

1. A tactical bomb using U-235 (produced in any of several uranium enrichment facilities that Grothmann alluded to) with an explosive yield of less than a kiloton (Grothmann thought he remembered 130 tons). He compared it to the size of an SC 250 bomb, a common cylindrical German bomb with a 37-cm diameter and 120-cm body length (Fig. D.601), but said it was heavier than an SC 250 (heavier than 250 kg). In principle, a bomb of that size might have been an implosion bomb design employing cylindrical compression as considered by Gottfried Guderley as well as Erich Schumann and Walter Trinks; see p. 4248. Alternatively it might have been a biconic implosion bomb design employing focused compression from each end, as considered by Schumann and Trinks; see p. 4246. R. P. Linstead and T. J. Betts, the U.K. and U.S. chairs of CIOS, wrote in their final report about German V-rockets armed with atomic bombs that were much smaller than the standard V-2 payload of 1000 kg (p. 5030). The bomb described by Grothmann and the CIOS chairs does not match the characteristics of a gun-type fission bomb. For example, the U.S. Little Boy had a mass of 4400 kg, diameter of 71 cm, and length of 300 cm, and because of its inherent physics used a very large amount of uranium, had a very low efficiency, and produced a large explosive yield, in contrast to the weapon that Grothmann described.

2. A tactical bomb using Pu-239 (produced in any of several plutonium breeding facilities that Grothmann alluded to). Other than the difference in fuel, presumably this bomb had the same design as the tactical uranium bomb, as well as a roughly comparable yield.

3. A strategic bomb using U-235 with an explosive yield of several kilotons. (Grothmann thought he remembered 3 kilotons, but he seemed uncertain; that value may have been the yield of one of the small tests, not the yield that a fully fueled and deployed version of the bomb would have.) The bomb was a sphere with a diameter of somewhat over 1 meter, an aluminum shell, and a large mass. It apparently used a sophisticated implosion system. All of these details are highly consistent with the bomb design reported by Ilyichev (pp. 4481 and 4485).

4. A strategic bomb using Pu-239. Presumably this bomb had the same design as the strategic uranium bomb, as well as a roughly comparable yield.

5. A hydrogen bomb or H-bomb using fusion reactions but initiated by reactions in fission fuel. According to Grothmann, its explosive yield would be a hundred times larger than a fission bomb, or on the order of a megaton. Grothmann knew much less about this bomb design, but he described it as “a swollen bomb.” That might be taken to mean an oversized spherical implosion bomb, which could match the description of a “sloika” or layer-cake H-bomb design. Alternatively, Grothmann’s wording might be construed to mean an ellipsoidal shape, which could match the description of a Prandtl-Meyer two- or three-stage H-bomb design (p. 4373). This bomb was expected to be operational by late 1945 (p. 4367) or early 1946 (p. 3401), which suggests that it was at a fairly advanced stage of development, not merely a paper design. For more information on German development of fusion fuels and fusion bombs, see Sections D.9 and D.15.6.]

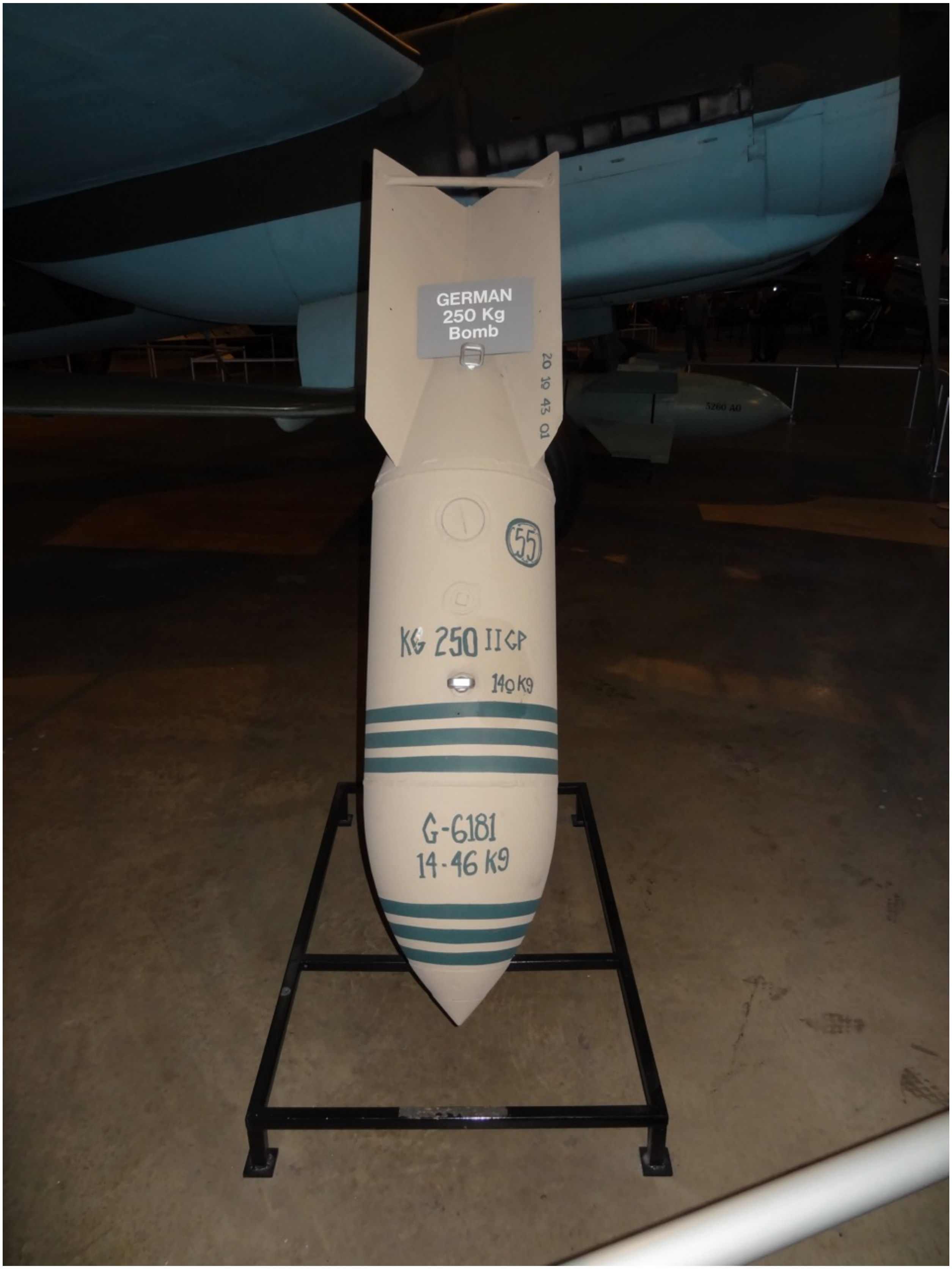

GERMAN
250 Kg
Bomb
20 10 43 O1
55
KG 250 IIGP
140 kg
G-6181
14-46 kg

Figure D.601: SC 250 bomb, which Grothmann said was comparable in size to the smallest German nuclear weapon. See pp. 4246 and 4248 for what the internal structure may have looked like.

PW Intelligence Bulletin 1/47, 13 March 1945 [NARA RG 165, Entry NM84-79, Box 1915]. See document photo with diagram on p. 4276.

16. Microbe Bombs

PW saw appr one hundred 250 kg bombs stored in a hall at Flughorst Ost, MAGDEBURG. PW was told that these were microbe bombs.

As described to PW, the bomb has two detonating chambers (one in front and one in back) with 2 side fuses. In the center of the shell is an empty lead lined chamber with threaded opening on the side into which a tube is screwed. The opening has 8 threads and when the tube is screwed into the last thread it is opened and the microbes which have been stored in the tube escape into the chamber. The opening is smeared with a gelatinous substance to prevent the escape of germs.

PW thinks the germs are of cholera type.

(Source: Gefr August KIEFFER, KG MATERN captured 1 Mar vic AMMERN)

Military Intelligence Service, 26 March 1945 [NARA RG 165, Entry NM84-187, Box 137, Folder BW 55]. See document photo with diagram on p. 4277.

G-2 COMMENT:

This (250 kg) seems quite large for a single BW bomb. Further interrogation is contemplated, and information will be forwarded.

[The German PW said he had seen special bombs stored at a Luftwaffe base and gave a relatively detailed description of their design. The PW had heard and the Allied interrogators just assumed that the bombs were biological. Since the design was "only" biological, the report was ultimately declassified by the U.S. government.

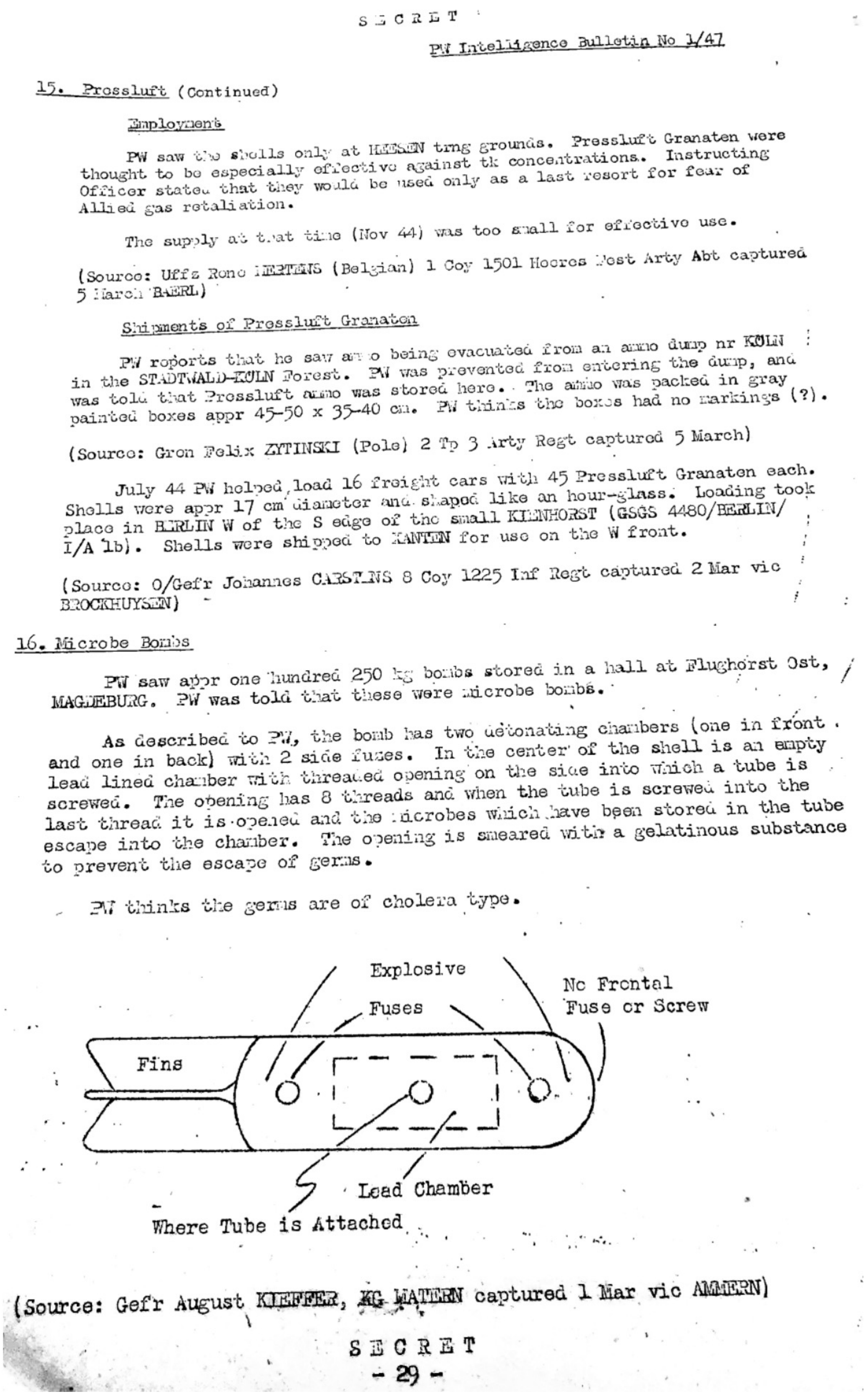
The design as given by the PW makes absolutely no scientific sense if the small, dangerous, final component that must be inserted in the middle is biological. There is too much explosive, too little "biological agent," and a mysterious tamper in between made of lead or some other extremely dense metal. Any biological agent in the middle would be destroyed by the intense heat and intense pressure created by the explosives at both ends. The design also does not make any sense for chemical weapons or fuel-air explosives.

But what if that small, dangerous, final component in the PW's design is nuclear? Compare the PW's design with the descriptions from Werner Grothmann and Erich Schumann.

Notice how many of these special bombs the PW said he saw.]

DECLASSIFIED
Authority NND945074

NARA RG 165, Entry NM84-79, Box 1915,
PW Intelligence Bulletin 1/47, 13 March 1945



SECRET

PW Intelligence Bulletin No 1/47

15. Pressluft (Continued)

Employment

PW saw the shells only at HEESEN trng grounds. Pressluft Granaten were thought to be especially effective against tk concentrations. Instructing Officer stated that they would be used only as a last resort for fear of Allied gas retaliation.

The supply at that time (Nov 44) was too small for effective use.

(Source: Uffz Rene MERTENS (Belgian) 1 Coy 1501 Heeres Kost Arty Abt captured 5 March BAERL)

Shipments of Pressluft Granaten

PW reports that he saw ammo being evacuated from an ammo dump nr KÖLN in the STADTWALD-KÖLN Forest. PW was prevented from entering the dump, and was told that Pressluft ammo was stored here. The ammo was packed in gray painted boxes appr 45-50 x 35-40 cm. PW thinks the boxes had no markings (?).

(Source: Gren Felix ZYTINSKI (Pole) 2 Tp 3 Arty Regt captured 5 March)

July 44 PW helped load 16 freight cars with 45 Pressluft Granaten each. Shells were appr 17 cm diameter and shaped like an hour-glass. Loading took place in BERLIN W of the S edge of the small KIENHORST (GSGS 4480/BERLIN/I/A 1b). Shells were shipped to XANTEN for use on the W front.

(Source: O/Gefr Johannes CARSTENS 8 Coy 1225 Inf Regt captured 2 Mar vic BROCKHUYSEN)

16. Microbe Bombs

PW saw appr one hundred 250 kg bombs stored in a hall at Flughorst Ost, MAGDEBURG. PW was told that these were microbe bombs.

As described to PW, the bomb has two detonating chambers (one in front and one in back) with 2 side fuses. In the center of the shell is an empty lead lined chamber with threaded opening on the side into which a tube is screwed. The opening has 8 threads and when the tube is screwed into the last thread it is opened and the microbes which have been stored in the tube escape into the chamber. The opening is smeared with a gelatinous substance to prevent the escape of germs.

PW thinks the germs are of cholera type.

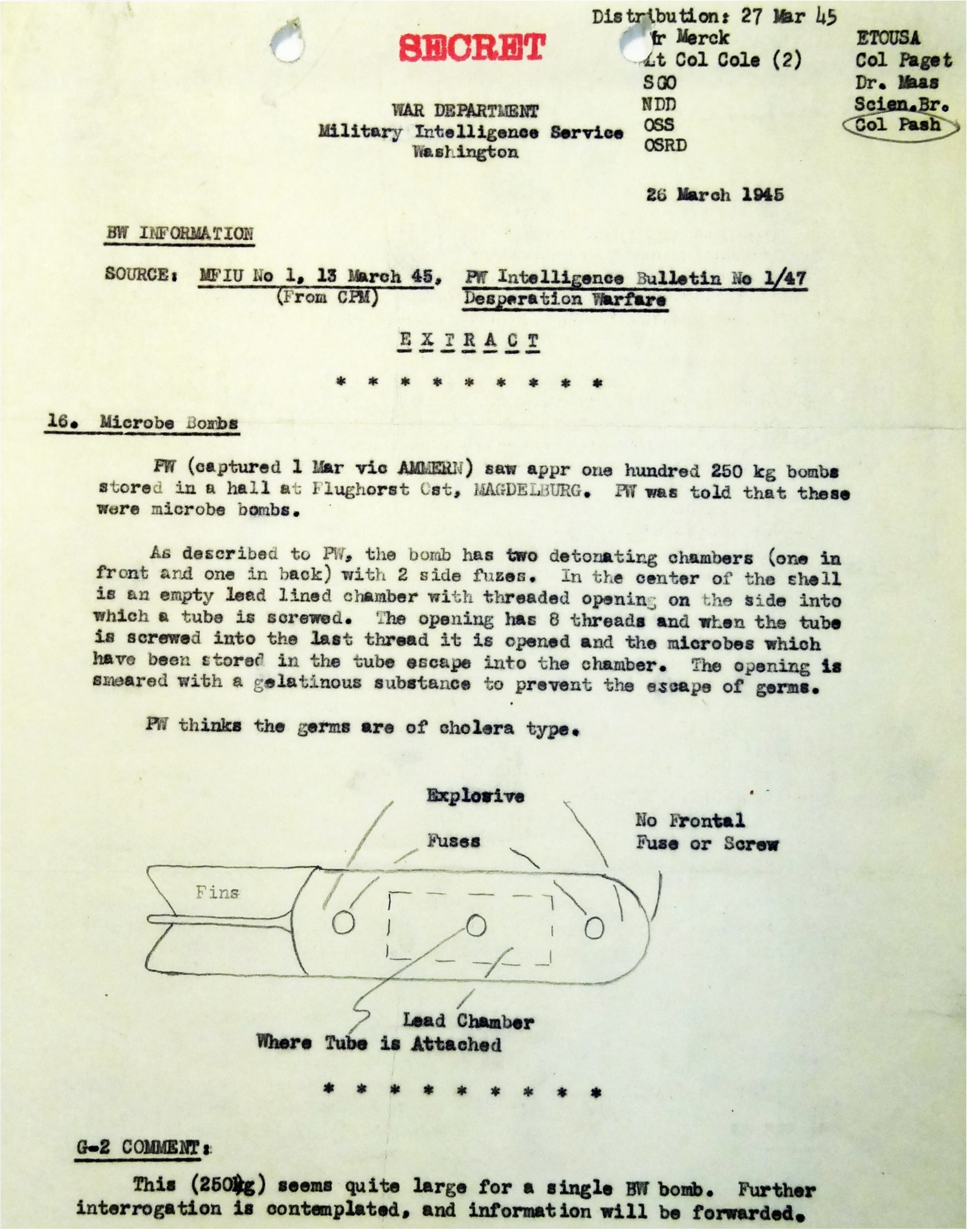
(Source: Gefr August KIEFFER, KG MATERN captured 1 Mar vic AMMERN)

SECRET
- 29 -

Figure D.602: PW Intelligence Bulletin 1/47, 13 March 1945 [NARA RG 165, Entry NM84-79, Box 1915].

DECLASSIFIED
Authority NWD 750122

NARA RG 165, Entry NM84-187, Box 137, Folder BW 55



Distribution: 27 Mar 45
r Merck
Lt Col Cole (2)
SGO
NDD
OSS
OSRD

ETOUSA
Col Paget
Dr. Maas
Scien.Br.
Col Pash

SECRET

WAR DEPARTMENT
Military Intelligence Service
Washington

26 March 1945

BW INFORMATION

SOURCE: MFIU No 1, 13 March 45, (From CPM) PW Intelligence Bulletin No 1/47 Desperation Warfare

EXTRACT

* * * * * * * * *

16. Microbe Bombs

PW (captured 1 Mar vic AMMERN) saw appr one hundred 250 kg bombs stored in a hall at Flughorst Ost, MAGDELBURG. PW was told that these were microbe bombs.

As described to PW, the bomb has two detonating chambers (one in front and one in back) with 2 side fuzes. In the center of the shell is an empty lead lined chamber with threaded opening on the side into which a tube is screwed. The opening has 8 threads and when the tube is screwed into the last thread it is opened and the microbes which have been stored in the tube escape into the chamber. The opening is smeared with a gelatinous substance to prevent the escape of germs.

PW thinks the germs are of cholera type.

* * * * * * * * *

G-2 COMMENT:

This (250kg) seems quite large for a single BW bomb. Further interrogation is contemplated, and information will be forwarded.

Figure D.603: Military Intelligence Service, 26 March 1945 [NARA RG 165, Entry NM84-187, Box 137, Folder BW 55].

D.9 Fusion Fuel and Bomb Design

[Wolfgang Ferrant (German?, ??–??), Ulrich Jetter (German, 1914–??), Alfred Klemm (German, 1913–2013), Karl Lintner (Austrian, 1917–2015), Josef Mattauch (Austrian, 1895–1976), Erich Schumann, Georg Stetter (Austrian, 1895–1988), Walter Trinks (German, 1910–1995), and many others worked in teams that researched and produced significant amounts of fusion fuels and potential methods to use them:

- German patents, articles, and other documents from 1933 through 1945 discussed how to produce fusion reactions in high-voltage tubes (pp. 3958–3970 and 4281–4327). That technology would have been very useful as a fusion neutron initiator in a fission bomb, as described by Kurt Diebner (p. 4261) and Ivan Ilyichev (p. 4485).

- In postwar papers apparently based on wartime work, Erich Schumann and Walter Trinks (pp. 4250–4255) and Kurt Diebner (pp. 4260–4267) independently described spherical implosion bomb designs with a center of fusion fuel inside a spherical shell of fission fuel. That "fusion boosting" approach could have greatly increased the yield of a fission bomb by supplying far more neutrons to induce fission reactions.

- A number of documents show that there was wartime work using lithium and deuterium together as fusion fuel (pp. 4305–4341). Because lithium deuteride is solid and not a gas or cryogenic liquid, it makes an ideal fuel for hydrogen bombs.

- During the war, Alfred Klemm (under the direction of Josef Mattauch) perfected a method to separate the lithium-6 isotope from the predominant lithium-7 in natural lithium (pp. 4344–4347). That would only be useful for nuclear applications. Klemm also stated that there was wartime work to produce tritium, another very potent fusion fuel (p. 4346).

- In 1950 Ulrich Jetter (German, 1914–??) published a detailed proposal that fusion bombs could use lithium-6 deuteride as readily storable solid fuel, rather than the much more troublesome cryogenic deuterium and tritium (p. 4348). Based on the other documents available, Jetter's description appears to be based on wartime German work. Officially, lithium-6 deuteride was first considered in the United States by Edward Teller in 1947 and in the Soviet Union by Vitaly Ginzberg in 1949, was first tested by the United States in 1954, and is commonly used in modern H bombs [Goncharov 1996a, 1996b; Chuck Hansen 1988, 2007; Rhodes 1995; Sublette 2019; Wellerstein and Geist 2017].

- In 1946, several scientists and engineers reported that during the war, Germany had been working on a 6-ton radioactive bomb, as well as methods to deliver it by rockets or aircraft (pp. 4338, 4350–4363, and 5343). Such a massive bomb would have been very challenging to deliver, and could presumably only have been justified if it were a hydrogen bomb. Conventional explosives, a dirty bomb of conventional explosives with radioactive material, chemical weapons, biological weapons, and even fission bombs could have been packaged into much smaller and much more easily deliverable sizes (and if necessary, several of them could have been delivered separately to the same target).

- A 1946 U.S. intelligence document mentioned wartime German research on H-bomb development as well as nuclear-armed ballistic missiles (p. 4368).

- In 1944–1945, several independent sources reported that Germany was developing a bomb with a six-mile blast radius, which is characteristic of the several-megaton energy of an H bomb, in stark contrast to the much smaller several-kiloton energy of a plain fission bomb (pp. 4365–4367).

- Friedwardt Winterberg, who worked very closely with Kurt Diebner after the war, published a highly distinctive ellipsoidal H-bomb design that looks rather different than standard U.S. H-bomb designs, but that is deeply steeped in earlier German hydrodynamics and physics research (p. 4373). A surviving 1944 sketch from Walther Gerlach shows an ellipsoid in conjunction with nuclear reactions involving deuterium, which seems to support the wartime origin of Winterberg's ellipsoidal H-bomb design (p. 4377).

- Werner Grothmann stated that the German nuclear program was developing several different bomb types, including a hydrogen bomb. He said that the hydrogen bomb looked like a "swollen bomb" (ellipsoidal?), would have been a hundred times more powerful than a fission bomb (megatons vs. tens of kilotons), and was expected to be ready in 1946 (which suggests that it had already progressed far in its development by 1945); see pp. 3401 and 4272. Other sources expected the German hydrogen bomb to be ready even sooner, sometime in 1945, if the war had continued (pp. 4367, 4334, 4359).

- In 1947, when Edward Teller was trying unsuccessfully to invent a workable design for the U.S. hydrogen bomb, he sent a highly unusual, specific, and urgent request for Siegfried Flügge to help him with a "physics... program... of interest and importance to the national security," stating that Flügge would "be of marked assistance in carrying out the aforementioned program" (p. 4996). In fact, the late-wartime and postwar influx of scientists and engineers who were from or at least had knowledge of the German nuclear program included Karl-Friedrich Bonhoeffer, Wernher von Braun, Rudolf Brill, Adolf Busemann, Walter Dornberger, Rudolf Edse, Krafft Ehricke, Wilhelm Eitel, Gerhard Falck, Karl Fiebinger, Wolfgang Finkelnburg, Rudolf Fleischmann, Siegfried Flügge, Walter Glaser, Wilhelm Groth, Gottfried Guderley, Paul Harteck, Otto Haxel, Richard Herzog, Johannes Hans Jensen, Willibald Jentschke, Ulrich Jetter, Georg Joos, Hartmut Kallmann, Hans Kammler, Gerald Klein, Stanley Kronenberg, Heinz Maier-Leibnitz, Werner Maurer, Hugo Neuert, Walter Nielsch (?), Edgar Petersen, Heinz Schlicke, Erich Schumann, Otto Schwede, Edmund Sorg, Kurt Starke, Ernst Stuhlinger, Hans Suess, Herbert Wagner, Wilhelm Westphal, Friedwardt Winterberg, Karl Wirtz, Gernot Zippe, etc. (p. 4992). Many of those scientists appear to have been closely tied to the wartime German work on H-bombs, and may have especially aided the U.S. H-bomb development program between 1945 and 1954.

Table D.3 summarizes some of the major sources and details regarding the megaton-level H-bomb that was under development during the war.]

Primary sources for hydrogen bomb design

	Sänger 1944	***Daily Mail* 44**	***Evening Std.* 45**	**Kober 1945**	**Ferrant 1945**	**Schumann 1945-52**	**Kästner 1946**	**Sorg 1946**	**Thirring 1946**	**von Braun 1946**	**Zumpe 1946**	**U.S. Intel 1946-51**	**Klemm ’47, ‘04**	**Granziani 1948**	**Jetter 1950**	**Grothmann 2000-2002**
Bomb mass	6 tons					Tons	6 tons	6 tons	6 tons	6 tons	6 tons				Tons	“Swollen bomb” (apparently very large)
Explosive energy		6-mile blast radius (~1.6 mega-tons)	6-mile blast radius (~1.6 mega-tons)	10^6 greater than nitro-glycerin (mega-tons)	Mega-tons poten-tially	Megatons potentially						“Even more deadly weapon than the atomic bomb” (>>20 kilotons)		6-mile blast radius (~1.6 mega-tons)	Mega-tons	“100x greater than that of the uranium bomb” (megatons)
Method of action	H-bomb implied by bomb mass and priority	H-bomb implied by blast radius	“Atomic” reactions; H-bomb implied by blast radius	H-bomb with lithium hydride (LiD?)	Explosive with lithium deuteride (LiD) and fission fuel	H-bomb with lithium deuteride (LiD) and fission fuel	Radio-active; H-bomb implied by bomb mass and parachute	H-bomb implied by bomb mass and priority	Lithium hydride (LiD?) H-bomb with fission bomb trigger	H-bomb implied by bomb mass and priority	H-bomb implied by bomb mass and priority	H-bomb with lithium hydride, deuterium and/or tritium	Highly secret military project using lithium -6 and tritium	H-bomb implied by blast radius	H-bomb with lithium deuteride (LiD) & fission bomb trigger	Hydrogen bomb; fission bomb as trigger
Vehicle	Rocket	Rocket					Parachute from plane	Plane		Rocket	Rocket	Rocket		Rocket		
Ready			Oct. 1945	“Test site” by 1945				Later 1945						Soon		1946
People involved	Aus-trian scien-tists		Groth	Stetter, other Austrian scientists, Gerlach, Toma-schek, AEG scientists	Ferrant, AEG scientists, Austrian scientists (implied)	Schumann, Trinks	Kästner, Petersen, Sorg, Austrian nuclear scientists, Schulz-Kampf-henkel	Peter-sen, Sorg	Jentschke and other Austrian nuclear scientists	von Braun, SS and Kammler (implied)	(Likely Puru-cker and his car full of bomb plans)	Stetter, Jentschke, Lintner, Mattauch, Ortner, Czulius, Schintl-meister	Klemm, Mattauch, Austrian nuclear scientists (implied), production elsewhere		Jetter	Himmler, SS, Kammler (implied), Austrian nuclear scientists
Places	Austria	French launch site	Celle	Austria, Berlin, Munich	Berlin, Austria	Berlin area	Austria	Austria and Baltic coast	Austria	Baltic coast		Austria	Tail-fingen, Berlin, Austria			Austria, Berlin

Table D.3: Details about hydrogen bomb design from primary sources.

Rausch von Traubenberg. 1933. Die bei der Lithiumzertrümmerung auftretende durchdringende Strahlung. *Die Naturwissenschaften* 21:694.

Wie wir kürzlich zeigen konnten, treten bei der künstlichen Umwandlung des Lithiumkernes durch Protonen auch γ-Strahlen auf, deren Nachweis uns mit Hilfe des Geiger-Müllerschen Zählrohres gelang. Wir haben inzwischen die Versuche mit verbesserten Hilfsmitteln wiederholt und eine Abschätzung der Härte der γ-Strahlen vorgenommen. Die Messungen wurden wieder so gestaltet, daß Lithium und ein bei unseren geringen Protonengeschwindigkeiten nicht zertrümmerbares Element, in diesem Falle Eisen, abwechselnd in den Gang der Wasserstoffkanalstrahlen gestellt wurden. Durch solche Differenzmessungen machten wir uns ebenso wie bei den früheren Untersuchungen von der Röntgenstrahlen sowie von der NZ (= Höhenstrahlen + radioaktiven Strahlen) frei und maßen die Lithiumstrahlung allein. Es wurde durch Zwischenschalten verschieden dicker Bleischichten als Hauptanteil eine weiche Komponente nachgewiesen, deren Intensität durch etwas 0,3 mm Blei auf die Hälfte geschwächt wurde. Bei einer maximalen Röhrenspannung von 58 kV und einem Röhrenstrom von 1 mA erhielten wir bei 1 mm Blei und einem Abstand von 48 mm des Zählrohrendes vom Lithium etwa 3 Quanten pro Minute.

As we have recently shown, the artificial transformation of the lithium nucleus by protons also involves γ rays, which we were able to detect with the aid of the Geiger-Müller tube. In the meantime we have repeated the experiments with improved aids and made an estimate of the intensity of the γ rays. The measurements were again designed in such a way that lithium and an element which can not be broken down at our low proton velocities, in this case iron, were alternately placed in the path of the hydrogen beams. As a result of these differences, we were able to distinguish between the effects of the X-ray beams and the NZ (= cosmic radiation + radioactive rays) and the lithium. A soft component, the intensity of which was weakened by half by 0.3 millimeter of lead, was detected as a major component by interposing different thicknesses of lead. At a maximum tube voltage of 58 kV and a tube current of 1 mA, we obtained about 3 quanta per minute with 1 mm lead and a distance of 48 mm from the tube end of the lithium.

[H. Rausch von Traubenberg did important very early work on fusion reactions and tritium production. See also:

> H. Rausch von Traubenberg, A. Eckardt, and R. Gebauer. 1933. Über den Nachweis von γ-Strahlen bei der Zertrümmerung von Lithium. *Zeitschrift für Physik* 80:557–558.

Von Traubenberg and other German scientists began using neutron reflectors around their nuclear reaction experiments no later than 1936. See pp. 4158–4159. Neutron reflectors are important for both fission reactors and fission bombs.]

Arno Brasch and Fritz Lange, AEG, German Patent DE 662036. Verfahren zur Anregung und Durchführung von Kernprozessen [Process for the Excitation and Execution of Nuclear Processes]. Filed 21 December 1934. Issued 9 June 1938.

[See document photos on pp. 4286–4287.]

Die vorliegende Erfindung bezieht sich auf ein Verfahren, um Eingriffe in den Atomkern in erheblich größerem Umfange und vor allen Dingen mit größerem Nutzeffekt vorzunehmen, als dies bisher möglich war.

Erfindungsgemäß können nicht nur radioaktive Substanzen in wesentlicher Menge wirtschaftlich erzeugt werden, sondern es bietet sich auch die Möglichkeit, zur Energiegewinnung aus dem Atomkern zu gelangen. [...]

Die wesentlichen Methoden zur Erzeugung von Neutronen sind bisher:

1. Heliumteile werden auf Beryllium geworfen und lösen dort Neutronen aus.

2. Röntgen- oder Gammastrahlen von mehr als 1,5 Milionen Volt fallen auf Beryllium und rufen dort den gleichen Vorgang hervor.

3. Der kürzlich entdeckte sog. schwere Wasserstoff (Diplogen) wird auf Diplogen geschossen.

Das letzte Verfahren ist das weitaus ergiebigste und im Rahmen der vorliegenden Erfindung deshalb von Bedeutung, weil es damit möglich war, die Auslösung von Neutronen und anderen Kernreaktionen bei sehr niedrigen Spannungsbereichen bis hinunter zu einigen 1000 Volt zu erzielen.

The present invention relates to a method for carrying out reactions of the atomic nucleus to a considerably greater extent and, above all, with greater efficiency than was previously possible.

According to the invention, not only can radioactive substances be produced economically in a substantial amount, but there is also the possibility of getting energy from the atomic nucleus. [...]

So far the essential methods for the generation of neutrons are:

1. Helium particles impact on beryllium and release neutrons.

2. X-rays or gamma-rays of more than 1.5 million volts fall on beryllium and there cause the same process.

3. The recently discovered so-called heavy hydrogen (deuterium) is fired at deuterium.

The last method is by far the most productive and important in the present invention, since it has thus been possible to achieve the triggering of neutrons and other nuclear reactions at very low voltage ranges up to a few thousand volts.

Die kinetische Energie von Atomen oder Elektronen, die mit etwa 0.13 Volt beschleunigt sind, ist etwa gerade so groß wie die von Atomen oder Elektronen, deren Temperatur 1000^o C beträgt. Wenn man sich die Aufgabe stellt, Kernprozesse dadurch anzuregen und durchzuführen, daß man Stoffe niedriger Ordnungszahl hohen Temperaturen unterwirft, so gelingt dies nur, wenn man die Temperatur so hoch steigert, daß die kinetische Energie der Atome oder Elektronen etwa gerade so groß ist, wie zur Einleitung von Kernprozessen mit Hilfe von durch elektrische Felder beschleunigten Atomen oder Elektronen erforderlich wäre. Es ist somit zur Einleitung derartiger Prozesse eine Steigerung der Temperatur auf ungefähr 10 Millionen Grad Celsius erforderlich. [...]

Zur Herstellung des gleichzeitigen Auftretens beider Vorgänge wird man den Vorgang der Erzeugung des Vordrucks verhältnismäßig langzeitig im Vergleich zu dem eigentlichen Entladungsprozeß wählen. Wenn z.B. die Dauer des Funkenentladungsvorganges etwa 10^{-6} Sek. beträgt, wird man die Dauer des Vordrucks etwa zu 10^{-4} Sek. wählen.

Die Erzeugung des Vordrucks kann entweder mit dem Verfahren nach Ramsauer, wo Zeiten von ungefähr 10^{-4} Sek. gerade erreicht werden können, vorgenommen werden oder ebenfalls durch eine zweite länger dauernde Entladung, die räumlich von der eigentlichen Funkenentladung getrennt ist.

Zu ihrer Herstellung kann man sich mit Vorteil einer schnellaufenden Dynamomaschine bedienen, die durch Entnahme elektrischer Energie in sehr kurzer Zeit abgebremst wird und in Zeiten bis zu ¹⁄₁₀ Sek. Leistungen von der Größenordnung 1 Million kW zu entnehmen erlaubt.

The kinetic energy of atoms or electrons accelerated at about 0.13 volts is about the same as that of atoms or electrons whose temperature is 1000^o C. If the task is to stimulate and carry out nuclear processes by subjecting substances of low atomic number to high temperatures, this is only achieved by raising the temperature so high that the kinetic energy of the atoms or electrons is about the same as that for the initiation of nuclear processes by means of electrons accelerated by electric fields. Thus, an increase of the temperature to about 10 million degrees Celsius is required to initiate such processes. [...]

In order to produce the simultaneous occurrence of both processes, the process of producing the preliminary pressure will be selected relatively long in comparison with the actual discharge process. If, for example, the duration of the spark discharge process is approximately 10^{-6} seconds, the duration of the pre-pressurization will be chosen to be about 10^{-4} seconds.

The pre-pressurization can be produced either by means of the method of Ramsauer, where times of approximately 10^{-4} seconds can be achieved, or by a second longer-lasting discharge which is spatially separated from the actual spark discharge.

To establish the pre-pressurization, one can advantageously use a high-speed dynamo machine, which is decelerated by withdrawal of electrical energy in a very short time and in periods of up to ¹⁄₁₀ seconds, of the order of magnitude of a million kilowatts.

Die mit diesen Verfahren erzeugbaren Temperaturen und Drucke sollen nun erfindungsgemäß angewendet werden zur Einleitung von Kernreaktionen. Hierfür kommen insbesondere Elemente niederer Ordnungszahl in Betracht, also Wasserstoff, schwerer Wasserstoff, Lithium und Bor.

Die Reaktion, die mit den geringsten Hilfsmitteln einzuleiten ist, ist die Reaktion eines schweren Wasserstoffkernes mit einem anderen schweren Wasserstoffkern. In diesem Falle würde also entweder bei der Ramsauer Methode der Gewehrlauf, in den hineingeschossen wird, mit Diplogengas gefüllt sein bzw. bei dem Funkenverfahren würde die Entladung in schwerem Wasser oder vielleicht einem Kohlenwasserstoff, dessen Wasserstoffatome aus schwerem Wasserstoff bestehen, stattfinden. Hierbei bilden sich dann Neutronen, die natürlich in üblicher Weise zur Erzeugung radioaktiver Elemente verwendet werden können. Es ist auch denkbar, daß Reaktionen von dem Gas bzw. der Flüssigkeit mit Stoffen der Kammerwand bzw. in der Flüssigkeit suspendierter Teilchen eingeleitet werden. Es sind aber bekanntlich zu allen Prozessen mit Elementen höherer Ordnungszahl entsprechend höhere Temperaturen notwendig.

Als weitere Reaktionen kommen in Frage die Reaktion von Wasserstoff mit Lithium und Bor. Wenn es gelingt, überhaupt einmal so hohe Temperaturen zu erreichen, daß Kernreaktionen in Gang kommen, so ist die Möglichkeit gegeben, die aus diesen Reaktionen frei werdenden Energien wieder zu benutzen, um neue Stoffmengen auf die nötige Reaktionstemperatur zu bringen.

Im Falle des Arbeitens mit Gasen wird es erforderlich sein, beträchtliche Drucke anzuwenden.

The temperatures and pressures which can be produced with these processes are now to be used according to the invention for initiating nuclear reactions. Particularly suitable for this purpose are elements of low atomic number, such as hydrogen, heavy hydrogen, lithium and boron.

The reaction to be initiated with the slightest aid is the reaction of a heavy hydrogen nucleus with another heavy hydrogen nucleus. In this case, therefore, either the Ramsauer method's gun barrel, into which one would shoot, would be filled with deuterium gas, or the spark would be discharged in heavy water, or perhaps a hydrocarbon, the hydrogen atoms of which are composed of heavy hydrogen. In this case, neutrons are formed, which can, of course, be used in a conventional manner to generate radioactive elements. It is also conceivable that reactions from the gas or the liquid are introduced with substances of the chamber wall or in the liquid of suspended particles. However, as is known, correspondingly higher temperatures are necessary for all processes with elements of higher order number.

Further reactions are the reaction of hydrogen with lithium and boron. If it is possible at all to reach such high temperatures as to cause nuclear reactions to take place, the possibility exists of reusing the energies released from these reactions in order to bring new quantities of matter to the necessary reaction temperature.

In the case of working with gases, it will be necessary to apply considerable pressures.

Bei Reaktionen oder Radioaktivitäten, die mit der Emission schneller geladener Korpuskeln verbunden sind, besteht die Möglichkeit, die Energie dieser Teilchen auszunutzen, indem man sie in einem Vakuumentladungsgefäß für sehr hohe Spannungen, insbesondere einem Ring oder Lamellenrohr, gegen ein elektrisches Feld entsprechender Höhe anlaufen läßt. Als besondere Anwendungsgebiete der Strahlungen, die bei Kernreaktionen bzw. künstlicher Radioaktivität auftreten, muß die Möglichkeit der Wetterbeeinflussung durch Schaffung von Kondensationskernen in Luft, insbesondere vom Flugzeug aus, erwähnt werden. Dabei wird es zweckmäßig sein, die Strahler in möglichst großem Abstand vom Flugzeug zu halten (durch Nachschleppen).

Außerdem kommen die Strahlungen von den erwähnten und anderen Kernreaktionen für medizinische Zwecke in Frage. Dabei wird besonders eine schnelle Elektronenstrahlung von Wert sein.

Da bekanntlich das Geschwindigkeitsspektrum aller β-Strahlungen kontinuierlich ist und bis zu sehr geringen Geschwindigkeiten herabreicht, ist es erforderlich, für den erwähnten Zweck eine solche Strahlenquelle immer in Verbindung mit einer magnetischen Monochromatisierungseinrichtung zu verwenden.

Als wesentlichster Punkt kommt ganz allgemein die Gewinnung von Energie aus dem Atomkern in Frage, indem man z.B. die Wärmeentwicklung der auftretenden Strahlen benutzt, um damit eine Wärmekraftmaschine zu betreiben.

Hierbei ergibt sich die Möglichkeit, unter Verzicht auf großen Nutzeffekt Maschinen mit sehr großer Leistung pro Gewichtseinheit zu bauen.

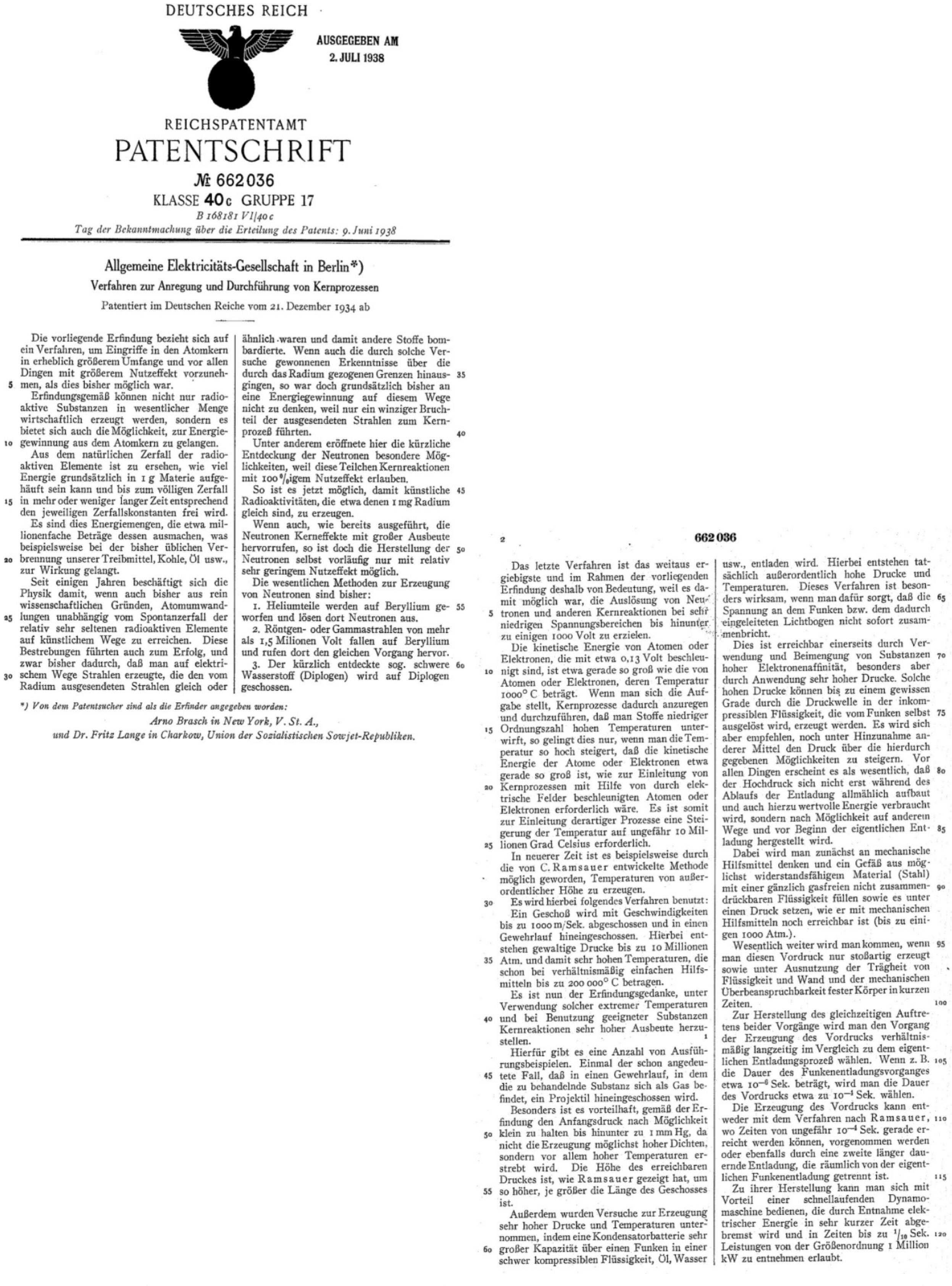
In the case of reactions or radioactivities which are associated with the emission of fast charged particles, it is possible to utilize the energy of these particles by starting them in a vacuum charging vessel for very high voltages, in particular a ring or lamellar tube, against an electric field of corresponding magnitude. The possibility of influencing the weather by the formation of condensation nuclei in air, in particular from aircraft, must be mentioned as special fields of application of the radiation which occur during nuclear reactions or artificial radioactivity. In this case, it will be expedient to keep the radiators as far as possible from the aircraft (by towing them).

In addition, the radiations from the mentioned and other nuclear reactions for medical purposes come into question. A high-speed electron beam will be of particular value.

Since, as is known, the velocity spectrum of all beta-rays is continuous and runs down to very low velocities, it is necessary for such a purpose to always use such a radiation source in conjunction with a magnetic monochromatization device.

In general, the most important point is to obtain energy from the atomic nucleus, for example by using the heat produced by the emitted rays in order to operate a heat engine.

This makes it possible to build machines with both high efficiency and very high power per unit of weight.



DEUTSCHES REICH

AUSGEGEBEN AM
2. JULI 1938

REICHSPATENTAMT

PATENTSCHRIFT

№ 662036

KLASSE **40**c GRUPPE 17

B 168181 VI/40c

Tag der Bekanntmachung über die Erteilung des Patents: 9. Juni 1938

Allgemeine Elektricitäts-Gesellschaft in Berlin*)

Verfahren zur Anregung und Durchführung von Kernprozessen

Patentiert im Deutschen Reiche vom 21. Dezember 1934 ab

Die vorliegende Erfindung bezieht sich auf ein Verfahren, um Eingriffe in den Atomkern in erheblich größerem Umfange und vor allen Dingen mit größerem Nutzeffekt vorzunehmen, als dies bisher möglich war.

Erfindungsgemäß können nicht nur radioaktive Substanzen in wesentlicher Menge wirtschaftlich erzeugt werden, sondern es bietet sich auch die Möglichkeit, zur Energiegewinnung aus dem Atomkern zu gelangen.

Aus dem natürlichen Zerfall der radioaktiven Elemente ist zu ersehen, wie viel Energie grundsätzlich in 1 g Materie aufgehäuft sein kann und bis zum völligen Zerfall in mehr oder weniger langer Zeit entsprechend den jeweiligen Zerfallskonstanten frei wird.

Es sind dies Energiemengen, die etwa millionenfache Beträge dessen ausmachen, was beispielsweise bei der bisher üblichen Verbrennung unserer Treibmittel, Kohle, Öl usw., zur Wirkung gelangt.

Seit einigen Jahren beschäftigt sich die Physik damit, wenn auch bisher aus rein wissenschaftlichen Gründen, Atomumwandlungen unabhängig vom Spontanzerfall der relativ sehr seltenen radioaktiven Elemente auf künstlichem Wege zu erreichen. Diese Bestrebungen führten auch zum Erfolg, und zwar bisher dadurch, daß man auf elektrischem Wege Strahlen erzeugte, die den vom Radium ausgesendeten Strahlen gleich oder ähnlich waren und damit andere Stoffe bombardierte. Wenn auch die durch solche Versuche gewonnenen Erkenntnisse über die durch das Radium gezogenen Grenzen hinausgingen, so war doch grundsätzlich bisher an eine Energiegewinnung auf diesem Wege nicht zu denken, weil nur ein winziger Bruchteil der ausgesendeten Strahlen zum Kernprozeß führten.

Unter anderem eröffnete hier die kürzliche Entdeckung der Neutronen besondere Möglichkeiten, weil diese Teilchen Kernreaktionen mit 100%igem Nutzeffekt erlauben.

So ist es jetzt möglich, damit künstliche Radioaktivitäten, die etwa denen 1 mg Radium gleich sind, zu erzeugen.

Wenn auch, wie bereits ausgeführt, die Neutronen Kerneffekte mit großer Ausbeute hervorrufen, so ist doch die Herstellung der Neutronen selbst vorläufig nur mit relativ sehr geringem Nutzeffekt möglich.

Die wesentlichen Methoden zur Erzeugung von Neutronen sind bisher:

1. Heliumteile werden auf Beryllium geworfen und lösen dort Neutronen aus.
2. Röntgen- oder Gammastrahlen von mehr als 1,5 Milionen Volt fallen auf Beryllium und rufen dort den gleichen Vorgang hervor.
3. Der kürzlich entdeckte sog. schwere Wasserstoff (Diplogen) wird auf Diplogen geschossen.

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*) *Von dem Patentsucher sind als die Erfinder angegeben worden:*
Arno Brasch in New York, V. St. A.,
und Dr. Fritz Lange in Charkow, Union der Sozialistischen Sowjet-Republiken.

2 **662 036**

Das letzte Verfahren ist das weitaus ergiebigste und im Rahmen der vorliegenden Erfindung deshalb von Bedeutung, weil es damit möglich war, die Auslösung von Neutronen und anderen Kernreaktionen bei sehr niedrigen Spannungsbereichen bis hinunter zu einigen 1000 Volt zu erzielen.

Die kinetische Energie von Atomen oder Elektronen, die mit etwa 0,13 Volt beschleunigt sind, ist etwa gerade so groß wie die von Atomen oder Elektronen, deren Temperatur 1000° C beträgt. Wenn man sich die Aufgabe stellt, Kernprozesse dadurch anzuregen und durchzuführen, daß man Stoffe niedriger Ordnungszahl hohen Temperaturen unterwirft, so gelingt dies nur, wenn man die Temperatur so hoch steigert, daß die kinetische Energie der Atome oder Elektronen etwa gerade so groß ist, wie zur Einleitung von Kernprozessen mit Hilfe von durch elektrische Felder beschleunigten Atomen oder Elektronen erforderlich wäre. Es ist somit zur Einleitung derartiger Prozesse eine Steigerung der Temperatur auf ungefähr 10 Millionen Grad Celsius erforderlich.

In neuerer Zeit ist es beispielsweise durch die von C. Ramsauer entwickelte Methode möglich geworden, Temperaturen von außerordentlicher Höhe zu erzeugen.

Es wird hierbei folgendes Verfahren benutzt:

Ein Geschoß wird mit Geschwindigkeiten bis zu 1000 m/Sek. abgeschossen und in einen Gewehrlauf hineingeschossen. Hierbei entstehen gewaltige Drucke bis zu 10 Millionen Atm. und damit sehr hohen Temperaturen, die schon bei verhältnismäßig einfachen Hilfsmitteln bis zu 200 000° C betragen.

Es ist nun der Erfindungsgedanke, unter Verwendung solcher extremer Temperaturen und bei Benutzung geeigneter Substanzen Kernreaktionen sehr hoher Ausbeute herzustellen.

Hierfür gibt es eine Anzahl von Ausführungsbeispielen. Einmal der schon angedeutete Fall, daß in einen Gewehrlauf, in dem die zu behandelnde Substanz sich als Gas befindet, ein Projektil hineingeschossen wird.

Besonders ist es vorteilhaft, gemäß der Erfindung den Anfangsdruck nach Möglichkeit klein zu halten bis hinunter zu 1 mm Hg, da nicht die Erzeugung möglichst hoher Dichten, sondern vor allem hoher Temperaturen erstrebt wird. Die Höhe des erreichbaren Druckes ist, wie Ramsauer gezeigt hat, um so höher, je größer die Länge des Geschosses ist.

Außerdem wurden Versuche zur Erzeugung sehr hoher Drucke und Temperaturen unternommen, indem eine Kondensatorbatterie sehr großer Kapazität über einen Funken in einer schwer kompressiblen Flüssigkeit, Öl, Wasser usw., entladen wird. Hierbei entstehen tatsächlich außerordentlich hohe Drucke und Temperaturen. Dieses Verfahren ist besonders wirksam, wenn man dafür sorgt, daß die Spannung an dem Funken bzw. dem dadurch eingeleiteten Lichtbogen nicht sofort zusammenbricht.

Dies ist erreichbar einerseits durch Verwendung und Beimengung von Substanzen hoher Elektronenaffinität, besonders aber durch Anwendung sehr hoher Drucke. Solche hohen Drucke können bis zu einem gewissen Grade durch die Druckwelle in der inkompressiblen Flüssigkeit, die vom Funken selbst ausgelöst wird, erzeugt werden. Es wird sich aber empfehlen, noch unter Hinzunahme anderer Mittel den Druck über die hierdurch gegebenen Möglichkeiten zu steigern. Vor allen Dingen erscheint es als wesentlich, daß der Hochdruck sich nicht erst während des Ablaufs der Entladung allmählich aufbaut und auch hierzu wertvolle Energie verbraucht wird, sondern nach Möglichkeit auf anderem Wege und vor Beginn der eigentlichen Entladung hergestellt wird.

Dabei wird man zunächst an mechanische Hilfsmittel denken und ein Gefäß aus möglichst widerstandsfähigem Material (Stahl) mit einer gänzlich gasfreien nicht zusammendrückbaren Flüssigkeit füllen sowie es unter einen Druck setzen, wie er mit mechanischen Hilfsmitteln noch erreichbar ist (bis zu einigen 1000 Atm.).

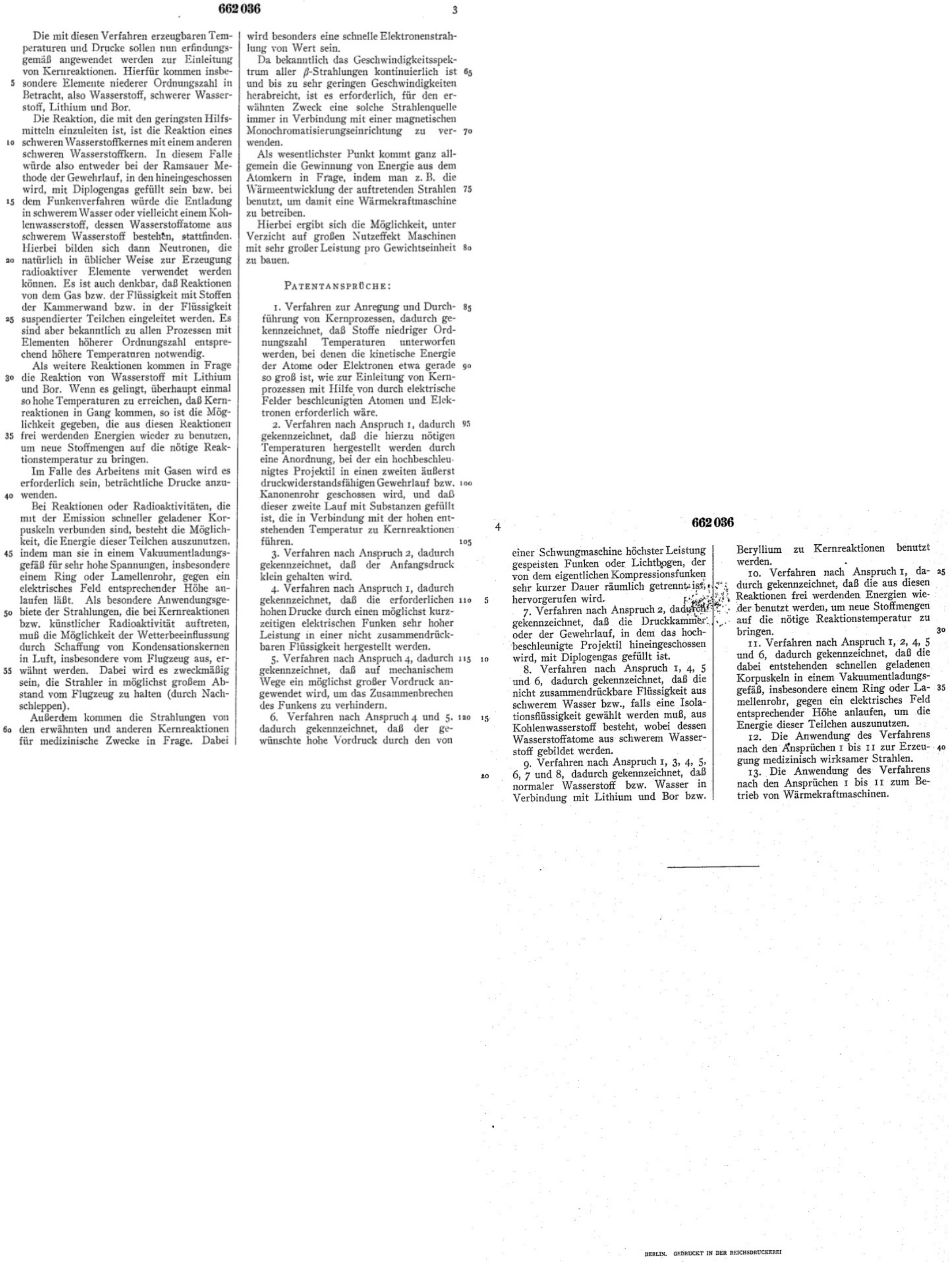
Wesentlich weiter wird man kommen, wenn man diesen Vordruck nur stoßartig erzeugt sowie unter Ausnutzung der Trägheit von Flüssigkeit und Wand und der mechanischen Überbeanspruchbarkeit fester Körper in kurzen Zeiten.

Zur Herstellung des gleichzeitigen Auftretens beider Vorgänge wird man den Vorgang der Erzeugung des Vordrucks verhältnismäßig langzeitig im Vergleich zu dem eigentlichen Entladungsprozeß wählen. Wenn z. B. die Dauer des Funkenentladungsvorganges etwa 10^{-6} Sek. beträgt, wird man die Dauer des Vordrucks etwa zu 10^{-4} Sek. wählen.

Die Erzeugung des Vordrucks kann entweder mit dem Verfahren nach Ramsauer, wo Zeiten von ungefähr 10^{-4} Sek. gerade erreicht werden können, vorgenommen werden oder ebenfalls durch eine zweite länger dauernde Entladung, die räumlich von der eigentlichen Funkenentladung getrennt ist.

Zu ihrer Herstellung kann man sich mit Vorteil einer schnellaufenden Dynamomaschine bedienen, die durch Entnahme elektrischer Energie in sehr kurzer Zeit abgebremst wird und in Zeiten bis zu $^1/_{10}$ Sek. Leistungen von der Größenordnung 1 Million kW zu entnehmen erlaubt.

Figure D.604: Arno Brasch and Fritz Lange, AEG. German Patent DE 662036. Verfahren zur Anregung und Durchführung von Kernprozessen [Process for the Excitation and Execution of Nuclear Processes]. Filed 21 December 1934. Issued 9 June 1938.



Die mit diesen Verfahren erzeugbaren Temperaturen und Drucke sollen nun erfindungsgemäß angewendet werden zur Einleitung von Kernreaktionen. Hierfür kommen insbesondere Elemente niederer Ordnungszahl in Betracht, also Wasserstoff, schwerer Wasserstoff, Lithium und Bor.

Die Reaktion, die mit den geringsten Hilfsmitteln einzuleiten ist, ist die Reaktion eines schweren Wasserstoffkernes mit einem anderen schweren Wasserstoffkern. In diesem Falle würde also entweder bei der Ramsauer Methode der Gewehrlauf, in den hineingeschossen wird, mit Diplogengas gefüllt sein bzw. bei dem Funkenverfahren würde die Entladung in schwerem Wasser oder vielleicht einem Kohlenwasserstoff, dessen Wasserstoffatome aus schwerem Wasserstoff bestehen, stattfinden. Hierbei bilden sich dann Neutronen, die natürlich in üblicher Weise zur Erzeugung radioaktiver Elemente verwendet werden können. Es ist auch denkbar, daß Reaktionen von dem Gas bzw. der Flüssigkeit mit Stoffen der Kammerwand bzw. in der Flüssigkeit suspendierter Teilchen eingeleitet werden. Es sind aber bekanntlich zu allen Prozessen mit Elementen höherer Ordnungszahl entsprechend höhere Temperaturen notwendig.

Als weitere Reaktionen kommen in Frage die Reaktion von Wasserstoff mit Lithium und Bor. Wenn es gelingt, überhaupt einmal so hohe Temperaturen zu erreichen, daß Kernreaktionen in Gang kommen, so ist die Möglichkeit gegeben, die aus diesen Reaktionen frei werdenden Energien wieder zu benutzen, um neue Stoffmengen auf die nötige Reaktionstemperatur zu bringen.

Im Falle des Arbeitens mit Gasen wird es erforderlich sein, beträchtliche Drucke anzuwenden.

Bei Reaktionen oder Radioaktivitäten, die mit der Emission schneller geladener Korpuskeln verbunden sind, besteht die Möglichkeit, die Energie dieser Teilchen auszunutzen, indem man sie in einem Vakuumentladungsgefäß für sehr hohe Spannungen, insbesondere einem Ring oder Lamellenrohr, gegen ein elektrisches Feld entsprechender Höhe anlaufen läßt. Als besondere Anwendungsgebiete der Strahlungen, die bei Kernreaktionen bzw. künstlicher Radioaktivität auftreten, muß die Möglichkeit der Wetterbeeinflussung durch Schaffung von Kondensationskernen in Luft, insbesondere vom Flugzeug aus, erwähnt werden. Dabei wird es zweckmäßig sein, die Strahler in möglichst großem Abstand vom Flugzeug zu halten (durch Nachschleppen).

Außerdem kommen die Strahlungen von den erwähnten und anderen Kernreaktionen für medizinische Zwecke in Frage. Dabei wird besonders eine schnelle Elektronenstrahlung von Wert sein.

Da bekanntlich das Geschwindigkeitsspektrum aller β-Strahlungen kontinuierlich ist und bis zu sehr geringen Geschwindigkeiten herabreicht, ist es erforderlich, für den erwähnten Zweck eine solche Strahlenquelle immer in Verbindung mit einer magnetischen Monochromatisierungseinrichtung zu verwenden.

Als wesentlichster Punkt kommt ganz allgemein die Gewinnung von Energie aus dem Atomkern in Frage, indem man z. B. die Wärmeentwicklung der auftretenden Strahlen benutzt, um damit eine Wärmekraftmaschine zu betreiben.

Hierbei ergibt sich die Möglichkeit, unter Verzicht auf großen Nutzeffekt Maschinen mit sehr großer Leistung pro Gewichtseinheit zu bauen.

PATENTANSPRÜCHE:

1. Verfahren zur Anregung und Durchführung von Kernprozessen, dadurch gekennzeichnet, daß Stoffe niedriger Ordnungszahl Temperaturen unterworfen werden, bei denen die kinetische Energie der Atome oder Elektronen etwa gerade so groß ist, wie zur Einleitung von Kernprozessen mit Hilfe von durch elektrische Felder beschleunigten Atomen und Elektronen erforderlich wäre.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die hierzu nötigen Temperaturen hergestellt werden durch eine Anordnung, bei der ein hochbeschleunigtes Projektil in einen zweiten äußerst druckwiderstandsfähigen Gewehrlauf bzw. Kanonenrohr geschossen wird, und daß dieser zweite Lauf mit Substanzen gefüllt ist, die in Verbindung mit der hohen entstehenden Temperatur zu Kernreaktionen führen.

3. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß der Anfangsdruck klein gehalten wird.

4. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die erforderlichen hohen Drucke durch einen möglichst kurzzeitigen elektrischen Funken sehr hoher Leistung in einer nicht zusammendrückbaren Flüssigkeit hergestellt werden.

5. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß auf mechanischem Wege ein möglichst großer Vordruck angewendet wird, um das Zusammenbrechen des Funkens zu verhindern.

6. Verfahren nach Anspruch 4 und 5, dadurch gekennzeichnet, daß der gewünschte hohe Vordruck durch den von

einer Schwungmaschine höchster Leistung gespeisten Funken oder Lichtbogen, der von dem eigentlichen Kompressionsfunken sehr kurzer Dauer räumlich getrennt ist, hervorgerufen wird.

7. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß die Druckkammer oder der Gewehrlauf, in dem das hochbeschleunigte Projektil hineingeschossen wird, mit Diplogengas gefüllt ist.

8. Verfahren nach Anspruch 1, 4, 5 und 6, dadurch gekennzeichnet, daß die nicht zusammendrückbare Flüssigkeit aus schwerem Wasser bzw., falls eine Isolationsflüssigkeit gewählt werden muß, aus Kohlenwasserstoff besteht, wobei dessen Wasserstoffatome aus schwerem Wasserstoff gebildet werden.

9. Verfahren nach Anspruch 1, 3, 4, 5, 6, 7 und 8, dadurch gekennzeichnet, daß normaler Wasserstoff bzw. Wasser in Verbindung mit Lithium und Bor bzw. Beryllium zu Kernreaktionen benutzt werden.

10. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die aus diesen Reaktionen frei werdenden Energien wieder benutzt werden, um neue Stoffmengen auf die nötige Reaktionstemperatur zu bringen.

11. Verfahren nach Anspruch 1, 2, 4, 5 und 6, dadurch gekennzeichnet, daß die dabei entstehenden schnellen geladenen Korpuskeln in einem Vakuumentladungsgefäß, insbesondere einem Ring oder Lamellenrohr, gegen ein elektrisches Feld entsprechender Höhe anlaufen, um die Energie dieser Teilchen auszunutzen.

12. Die Anwendung des Verfahrens nach den Ansprüchen 1 bis 11 zur Erzeugung medizinisch wirksamer Strahlen.

13. Die Anwendung des Verfahrens nach den Ansprüchen 1 bis 11 zum Betrieb von Wärmekraftmaschinen.

BERLIN. GEDRUCKT IN DER REICHSDRUCKEREI

Figure D.605: Arno Brasch and Fritz Lange, AEG. German Patent DE 662036. Verfahren zur Anregung und Durchführung von Kernprozessen [Process for the Excitation and Execution of Nuclear Processes]. Filed 21 December 1934. Issued 9 June 1938.

R. S. Malton, a.k.a. Richard S. Morse. 2 June 1945 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

In connection with investigational work now underway relative to the development of Manhattan District projects by the Germans, a certain amount of information probably can be obtained from Mr. A. Brasch of the Electronized Chemical Corporation at 122 East 42nd Street, New York City.

Mr. Brasch is a former German citizen, and I am sure he has been thoroughly investigated. As an atomic physicist in 1938 he was approached by members of the general German staff to initiate research along lines of interest to the Manhattan District. Because of his connections with Siemens Halske and A.E.G. and the University of Berlin some information might be forthcoming if required at this late date.

James E. Nolan to Francis J. Smith. 14 June 1945 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

1. Inclosed is copy of the letter submitted by Confidential Informant No. 16 of the Boston Branch Office.

2. Siemens Halske and A.E.G. referred to are the German branches [sic, actually counterparts] of Westinghouse and General Electric respectively.

3. According to informant Brasch was asked personally by Marshall Werner von Blomberg, German Chief of Staff in 1938, to remain in Germany to do atomic research. Brasch is Jewish and believed it wiser to leave the country.

4. Confidential Informant No. 16 is identified as Richard S. Morse of the National Research Corporation.

5. For your information and any action which you may deem necessary.

[See document photos on p. 4289.

Werner von Blomberg was the Reichsminister of War from May 1935 to January 1938. Thus no later than January 1938, the German government, and in particular the German military, was actively pursuing nuclear weapons. They attempted to recruit Arno Brasch to work on that program despite the fact that he was Jewish. Similarly, Gustav Hertz appears to have held an important position in the German nuclear weapons program throughout the war despite his Jewish ancestry (Section D.4.4).]

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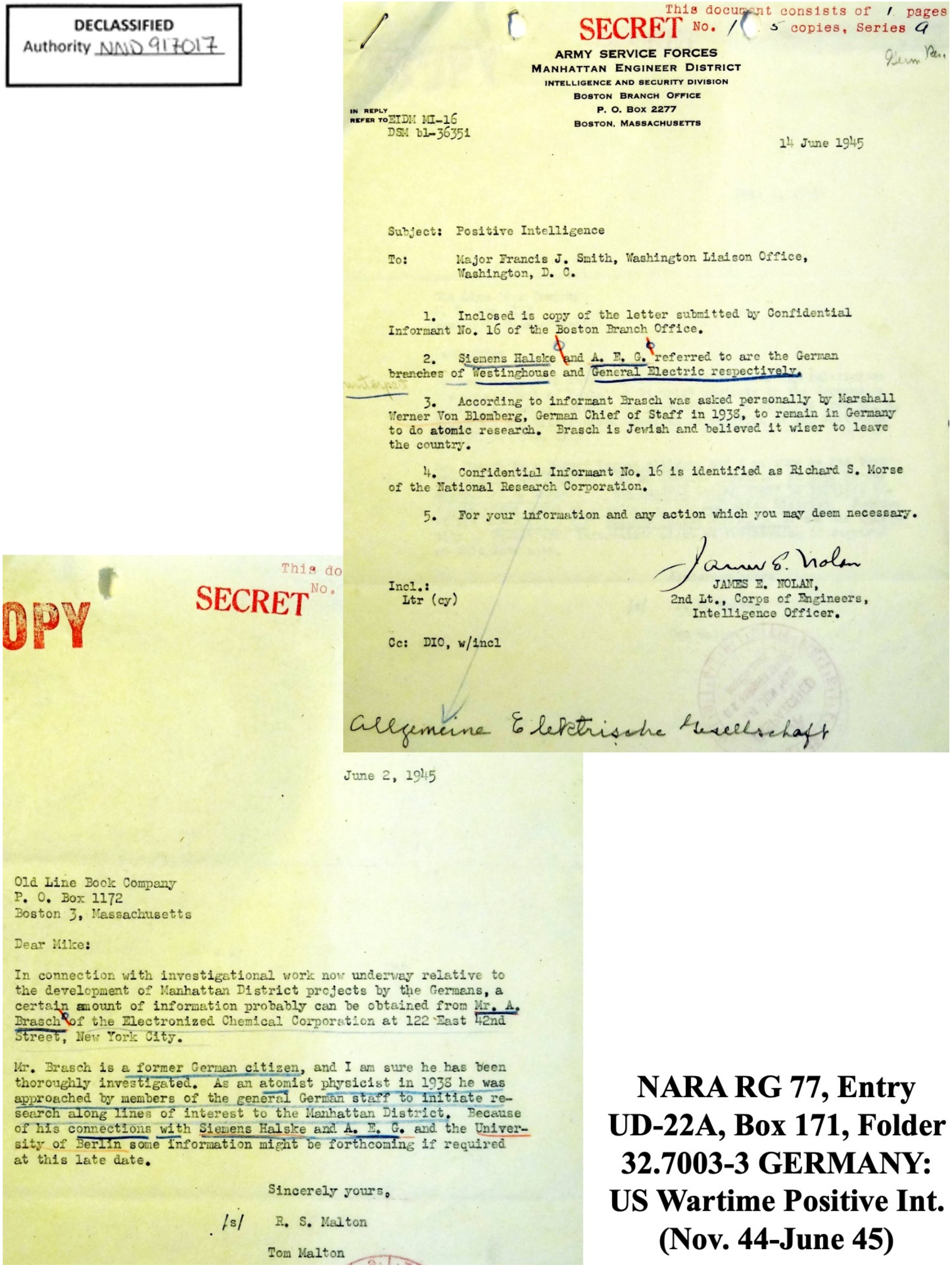

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MANHATTAN ENGINEER DISTRICT
INTELLIGENCE AND SECURITY DIVISION
BOSTON BRANCH OFFICE
P. O. BOX 2277
BOSTON, MASSACHUSETTS

IN REPLY REFER TO EIDM MI-16
DSM b1-36351

14 June 1945

Subject: Positive Intelligence

To: Major Francis J. Smith, Washington Liaison Office,
Washington, D. C.

1. Inclosed is copy of the letter submitted by Confidential Informant No. 16 of the Boston Branch Office.

2. Siemens Halske and A. E. G. referred to are the German branches of Westinghouse and General Electric respectively.

3. According to informant Brasch was asked personally by Marshall Werner Von Blomberg, German Chief of Staff in 1938, to remain in Germany to do atomic research. Brasch is Jewish and believed it wiser to leave the country.

4. Confidential Informant No. 16 is identified as Richard S. Morse of the National Research Corporation.

5. For your information and any action which you may deem necessary.

James E. Nolan
JAMES E. NOLAN,
2nd Lt., Corps of Engineers,
Intelligence Officer.

Incl.:
Ltr (cy)

Cc: DIO, w/incl

Allgemeine Elektrische Gesellschaft

OPY

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This do
No.

June 2, 1945

Old Line Book Company
P. O. Box 1172
Boston 3, Massachusetts

Dear Mike:

In connection with investigational work now underway relative to the development of Manhattan District projects by the Germans, a certain amount of information probably can be obtained from Mr. A. Brasch of the Electronized Chemical Corporation at 122 East 42nd Street, New York City.

Mr. Brasch is a former German citizen, and I am sure he has been thoroughly investigated. As an atomist physicist in 1938 he was approached by members of the general German staff to initiate research along lines of interest to the Manhattan District. Because of his connections with Siemens Halske and A. E. G. and the University of Berlin some information might be forthcoming if required at this late date.

Sincerely yours,

/s/ R. S. Malton

Tom Malton

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44-June 45)

Figure D.606: R. S. Malton, a.k.a. Richard S. Morse, 2 June 1945. James E. Nolan to Francis J. Smith, 14 June 1945. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

Auergesellschaft. U.K. Patent GB 508,233. Method for Carrying Out Nuclear Reactions. Filed 7 February 1937. Issued 28 June 1939.

We, DEGEA AKTIENGESELLSCHAFT (AUERGESELLSCHAFT), of 16–19, Rotherstrasse, Berlin, 0.17, Germany, a German Company, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:-

Artificial nuclear reactions are initiated by the bombardment of nuclei with light elementary particles. With the use of charged particles (protons, α particles) energies of 10^3 to 10^7 volts are necessary for overcoming the coulombic repulsion powers, in order to ensure a sufficient yield for the penetration of the particles into the bombarded nucleus.

Such a repulsion does not exist for neutrons, so that neutrons of small speed can penetrate into nuclei and produce reactions, as experiments actually show.

Unfortunately, there are no direct sources producing neutrons; they arise, if nuclei, for example, Be, are irradiated with α-particles of high energies (about 10^6 volts) or γ-rays very rich in energy (about $2{\cdot}10^6$ volts) or by bombardment of certain nuclei with fast particles of the heavy isotope of hydrogen. As sources of α-particles of sufficiently high energy, only the naturally radioactive elements have hitherto been available. In the two other cases, for accelerating elementary particles it is necessary to have recourse to the use of very considerable amounts of energy. With the remaining hitherto known methods for the production of elementary particles rich in energy, which have been used directly, or indirectly through the production of very hard Röntgen rays, for the production of neutrons and generally for the initiation of nuclear reactions, there came to be used an acceleration of the desired particles in high vacuum. This method indeed produces definite speeds, but only at the expense of very heavy outlay in the matter of electro-technical apparatus for building up an increase in the current density of the accelerated particles, and also gives a greater absolute yield from the nuclear reactions. The output attained in this way probably corresponds, at best, to that of a few grams of radium. The method of repeated secondary acceleration by means of high frequency alternating fields (Cyclotron) certainly produces greater absolute yields than those just stated, but necessitates however a great increase in the expense of apparatus (extremely large magnets).

The present invention therefore proposes to allow the nuclear reactions to take place under completely different conditions, namely, in the gas phase, under a mean numerical concentration of more than 10^{19} molecules of the gas per cubic centimetre, and preferably under a concentration corresponding to a pressure of one atmosphere at normal temperature of 18^o C. 70 Since in this case, a selective acceleration of elementary particles is not possible, the attainment of a thermal equilibrium with very high temperatures (greater than $10^{7\,o}$ C.) is the objective. For reasons of energy consumption such conditions can only be maintained by extraordinarily high momentary outputs and only for very short times. Accordingly, this invention contemplates the production of energies of 100 watt seconds and more during intervals of 10^{-6} second and less, corresponding to momentary outputs of 100,000 kilowatts and more.

Theoretical calculations based on experiments with exploding wires, and also observations made in connection with mercury discharges in which the number of glowing atoms could be determined with some degree of certainty, lead to the conclusion that high temperatures of the order specified occur with condenser discharges in the gaseous phase. Such operating conditions have in themselves the advantage that because of the practically complete ionisation in the discharge canal the braking action of the electron cloud falls away, and therefore still larger yields of the nuclear reactions are to be expected than have been observed hitherto with neutral atoms. It is therefore proposed for the realisation of the operating conditions set forth above, to utilise condenser discharges. For this it is necessary that

1) the gas concentration (number of molecules per cubic centimetre) be so great that thermal equilibrium can be established within the time of discharge of the condenser.

2) the momentary output, which is given by the size and charging voltage of the condenser, be made so great that the equilibrium temperature becomes established at the desired level.

The experimenter is at liberty to increase the action of the individual extremely short condenser discharge (duration of 10^{-6} second), after the lapse of a certain time which might be approximately of the order of magnitude of 10^{-3} second by allowing a further condenser discharge to traverse the gas. In this way it is possible to intensify the total effect of the method within the limits imposed by the thermal resistance of the discharge vessel used. A discharge rate of 5 discharges per second is probably about as high a rate as can normally be expected to be endured by a glass vessel.

The deciding factors given by these two conditions, viz., gas concentration and the size and charging voltage of the condensers, can be calculated for each individual process.

This calculation has been carried out for the production of neutrons by means of condenser discharge in heavy hydrogen gas. It gives, for about 1 atmosphere pressure, C=50,000 cm. V=10^5 volts (C being the capacity of the condenser and V being the charging voltage) and with a discharge rate of 5 discharges per second, an efficiency which is equivalent to about 50 gms. Ra + Be. Similar results are obtained when using a mixture of heavy and light hydrogen gas.

The method is naturally not limited to the production of neutrons but is equally applicable to a great number of nuclear reactions which may be carried out in this manner on a large scale, for example, the production of helium. For this purpose a discharge of the nature described above may be effected in a mixture of lithium vapour and light hydrogen, the resulting reaction being typified by the following equations:

$$^{7}_{3}\mathrm{Li} + ^{1}_{1}\mathrm{H} = ^{4}_{2}\mathrm{He}; \qquad ^{6}_{3}\mathrm{Li} + ^{1}_{1}\mathrm{H} = ^{4}_{2}\mathrm{He} + ^{3}_{2}\mathrm{He}$$

The pressures and outputs used are the same as in the above described reaction for the production of neutrons by condenser discharges in heavy hydrogen gas.

It is also possible to obtain helium indirectly through neutron irradiation in accordance with the following reaction formula:

$$^{10}_{5}\mathrm{B} + ^{1}_{0}\mathrm{n} = ^{4}_{2}\mathrm{He} + ^{7}_{3}\mathrm{Li}$$

For this purpose the vessel in which the neutron producing discharge takes place requires to be lined on the inside with a substance containing boron and hydrogen, e.g., $B(OCH_3)_3$ or the discharge vessel has to be arranged adjoining an outer flask filled with such substance.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:-

1. Method of carrying out nuclear reactions in which the energy requisite for activating the elementary particles to be caused to participate in a desired reaction is produced in a gas discharge under a mean gas concentration of more than 10^{19} molecules per cubic centimetre, and energies of 100 watt seconds and more during intervals of 10^{-6} second and less are produced, corresponding to momentary outputs of 100,000 kilowatts and more.

2. Method as claimed in claim 1 wherein the reaction is carried out under a gas concentration which corresponds to a pressure of one atmosphere at normal temperature of 18^o C.

3. Method as claimed in claim 1 for producing neutrons, wherein heavy hydrogen gas or a mixture of light and heavy hydrogen gas is utilised as reagent gas.

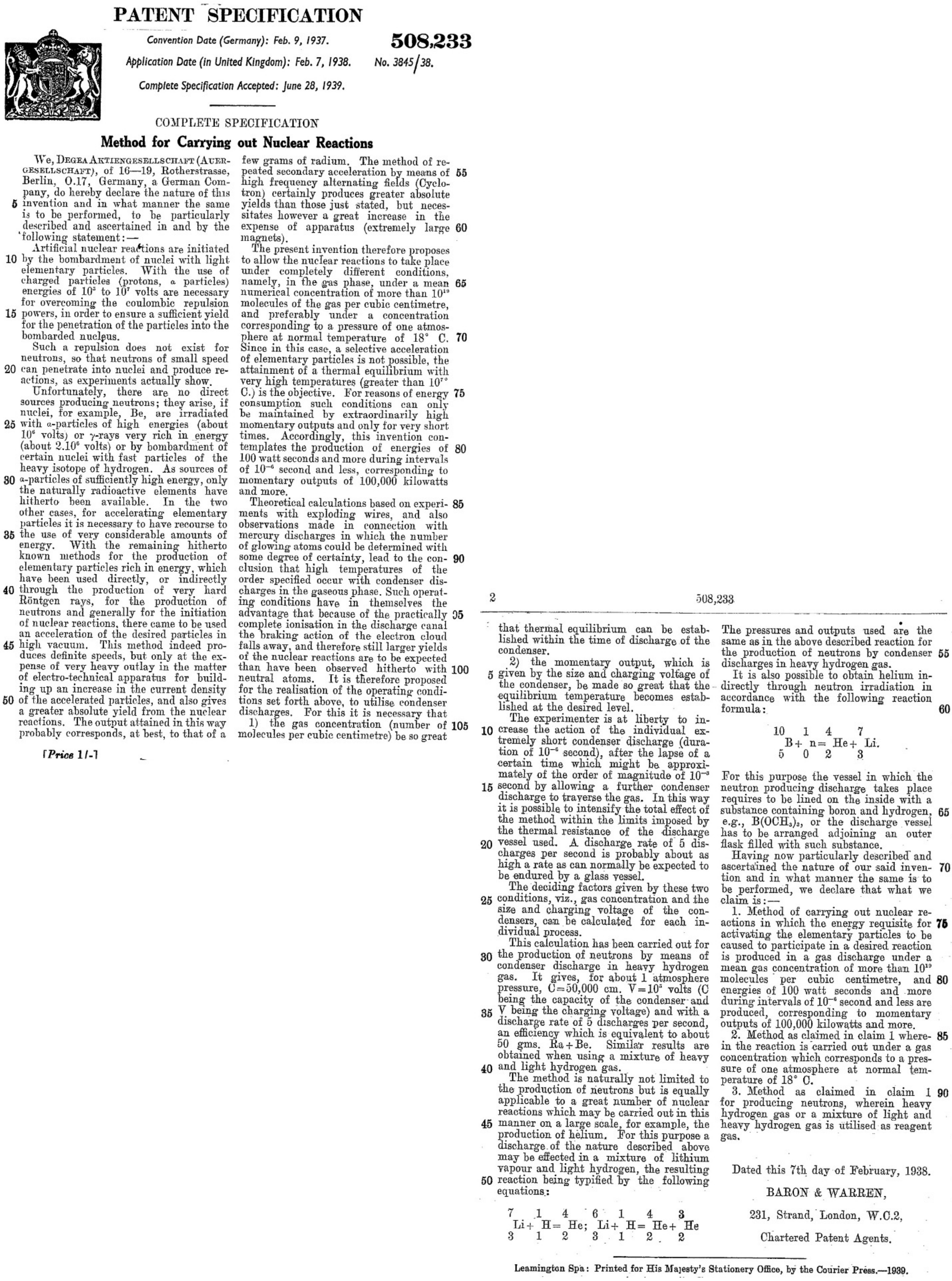
[See document photos on p. 4293.

This patent did not name any specific inventors, but Nikolaus Riehl was probably the inventor, or at least one of the inventors.

The patent reported that this high-voltage fusion neutron generator had a neutron output comparable to a 50-gram radium-beryllium source, which produces approximately $7.6 \cdot 10^8$ neutrons/second.

The patent also reported that this fusion neutron generator could produce five pulses per second, each with a duration of 10^{-6} second.

Thus the pulses would produce approximately $1.5 \cdot 10^8$ neutrons per pulse, or a neutron intensity of $1.5 \cdot 10^{14}$ neutrons/second during each pulse.]



PATENT SPECIFICATION

Convention Date (Germany): Feb. 9, 1937.

Application Date (in United Kingdom): Feb. 7, 1938. No. 3845/38.

Complete Specification Accepted: June 28, 1939.

508,233

COMPLETE SPECIFICATION

Method for Carrying out Nuclear Reactions

We, DEGEA AKTIENGESELLSCHAFT (AUERGESELLSCHAFT), of 16—19, Rotherstrasse, Berlin, O.17, Germany, a German Company, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

Artificial nuclear reactions are initiated by the bombardment of nuclei with light elementary particles. With the use of charged particles (protons, α particles) energies of 10^5 to 10^7 volts are necessary for overcoming the coulombic repulsion powers, in order to ensure a sufficient yield for the penetration of the particles into the bombarded nucleus.

Such a repulsion does not exist for neutrons, so that neutrons of small speed can penetrate into nuclei and produce reactions, as experiments actually show.

Unfortunately, there are no direct sources producing neutrons; they arise, if nuclei, for example, Be, are irradiated with α-particles of high energies (about 10^6 volts) or γ-rays very rich in energy (about 2.10^6 volts) or by bombardment of certain nuclei with fast particles of the heavy isotope of hydrogen. As sources of α-particles of sufficiently high energy, only the naturally radioactive elements have hitherto been available. In the two other cases, for accelerating elementary particles it is necessary to have recourse to the use of very considerable amounts of energy. With the remaining hitherto known methods for the production of elementary particles rich in energy, which have been used directly, or indirectly through the production of very hard Röntgen rays, for the production of neutrons and generally for the initiation of nuclear reactions, there came to be used an acceleration of the desired particles in high vacuum. This method indeed produces definite speeds, but only at the expense of very heavy outlay in the matter of electro-technical apparatus for building up an increase in the current density of the accelerated particles, and also gives a greater absolute yield from the nuclear reactions. The output attained in this way probably corresponds, at best, to that of a few grams of radium. The method of repeated secondary acceleration by means of high frequency alternating fields (Cyclotron) certainly produces greater absolute yields than those just stated, but necessitates however a great increase in the expense of apparatus (extremely large magnets).

The present invention therefore proposes to allow the nuclear reactions to take place under completely different conditions, namely, in the gas phase, under a mean numerical concentration of more than 10^{19} molecules of the gas per cubic centimetre, and preferably under a concentration corresponding to a pressure of one atmosphere at normal temperature of 18° C. Since in this case, a selective acceleration of elementary particles is not possible, the attainment of a thermal equilibrium with very high temperatures (greater than 10^{7}° C.) is the objective. For reasons of energy consumption such conditions can only be maintained by extraordinarily high momentary outputs and only for very short times. Accordingly, this invention contemplates the production of energies of 100 watt seconds and more during intervals of 10^{-6} second and less, corresponding to momentary outputs of 100,000 kilowatts and more.

Theoretical calculations based on experiments with exploding wires, and also observations made in connection with mercury discharges in which the number of glowing atoms could be determined with some degree of certainty, lead to the conclusion that high temperatures of the order specified occur with condenser discharges in the gaseous phase. Such operating conditions have in themselves the advantage that because of the practically complete ionisation in the discharge canal the braking action of the electron cloud falls away, and therefore still larger yields of the nuclear reactions are to be expected than have been observed hitherto with neutral atoms. It is therefore proposed for the realisation of the operating conditions set forth above, to utilise condenser discharges. For this it is necessary that

1) the gas concentration (number of molecules per cubic centimetre) be so great that thermal equilibrium can be established within the time of discharge of the condenser.

[Price 1/-]

2 508,233

2) the momentary output, which is given by the size and charging voltage of the condenser, be made so great that the equilibrium temperature becomes established at the desired level.

The experimenter is at liberty to increase the action of the individual extremely short condenser discharge (duration of 10^{-6} second), after the lapse of a certain time which might be approximately of the order of magnitude of 10^{-3} second by allowing a further condenser discharge to traverse the gas. In this way it is possible to intensify the total effect of the method within the limits imposed by the thermal resistance of the discharge vessel used. A discharge rate of 5 discharges per second is probably about as high a rate as can normally be expected to be endured by a glass vessel.

The deciding factors given by these two conditions, viz., gas concentration and the size and charging voltage of the condensers, can be calculated for each individual process.

This calculation has been carried out for the production of neutrons by means of condenser discharge in heavy hydrogen gas. It gives, for about 1 atmosphere pressure, $C=50,000$ cm. $V=10^5$ volts (C being the capacity of the condenser and V being the charging voltage) and with a discharge rate of 5 discharges per second, an efficiency which is equivalent to about 50 gms. Ra+Be. Similar results are obtained when using a mixture of heavy and light hydrogen gas.

The method is naturally not limited to the production of neutrons but is equally applicable to a great number of nuclear reactions which may be carried out in this manner on a large scale, for example, the production of helium. For this purpose a discharge of the nature described above may be effected in a mixture of lithium vapour and light hydrogen, the resulting reaction being typified by the following equations:

$$ {}^{7}_{3}\mathrm{Li} + {}^{1}_{1}\mathrm{H} = {}^{4}_{2}\mathrm{He}; \quad {}^{6}_{3}\mathrm{Li} + {}^{1}_{1}\mathrm{H} = {}^{4}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} $$

The pressures and outputs used are the same as in the above described reaction for the production of neutrons by condenser discharges in heavy hydrogen gas.

It is also possible to obtain helium indirectly through neutron irradiation in accordance with the following reaction formula:

$$ {}^{10}_{5}\mathrm{B} + {}^{1}_{0}\mathrm{n} = {}^{4}_{2}\mathrm{He} + {}^{7}_{3}\mathrm{Li}. $$

For this purpose the vessel in which the neutron producing discharge takes place requires to be lined on the inside with a substance containing boron and hydrogen, e.g., $B(OCH_3)_3$, or the discharge vessel has to be arranged adjoining an outer flask filled with such substance.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. Method of carrying out nuclear reactions in which the energy requisite for activating the elementary particles to be caused to participate in a desired reaction is produced in a gas discharge under a mean gas concentration of more than 10^{19} molecules per cubic centimetre, and energies of 100 watt seconds and more during intervals of 10^{-6} second and less are produced, corresponding to momentary outputs of 100,000 kilowatts and more.

2. Method as claimed in claim 1 wherein the reaction is carried out under a gas concentration which corresponds to a pressure of one atmosphere at normal temperature of 18° C.

3. Method as claimed in claim 1 for producing neutrons, wherein heavy hydrogen gas or a mixture of light and heavy hydrogen gas is utilised as reagent gas.

Dated this 7th day of February, 1938.

BARON & WARREN,
231, Strand, London, W.C.2,
Chartered Patent Agents.

Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1939.

Figure D.607: Auergesellschaft. U.K. Patent GB 508,233. Method for Carrying Out Nuclear Reactions. Filed 7 February 1937. Issued 28 June 1939.

Hartmut Kallmann and Ernst Kuhn. U.S. Patent 2,251,190. Method of Producing Neutrons. Filed 16 March 1938. Issued 29 July 1941.

This invention relates to a method for the production of neutrons, particularly by the interaction of deuterons.

In order to obtain neutrons with the aid of ions with relatively slight acceleration (for instance 300 kv.) the nuclear reaction

$$\mathrm{D} + \mathrm{D} \;=\; \mathrm{He}_3 + \mathrm{n} \tag{D.12}$$

is employed. The procedure in this connection is to bombard a layer containing heavy hydrogen nuclei with heavy hydrogen ions or deuterons. For the layer containing hydrogen, use is often made of ice, sal ammoniac, phosphoric acid and similar substances in which ordinary hydrogen is replaced by heavy hydrogen. These layers very rich in hydrogen have the disadvantage that they conduct heat and electricity poorly and are therefore easily destroyed by ionic bombardment. It would be better if more resistant layers were used, for instance, metallic layers. That is possible, however, only when metals that contain large amounts of dissolved or adsorbed hydrogen are employed. These are a few such metals, but they have the disadvantage that they gradually give off hydrogen in the vacuum. It would be still better therefore if substances could be used that contain hydrogen adsorbed only on the surface or in a surface layer but give it off to the outside less easily. These substances placed in the ion stream give only a small output of neutrons when impinged on vertically since the thickness of the adsorbed hydrogen layer is very small in comparison with the range of the ions projected into the metal. Nuclear processes can occur therefore only in a fractional portion of the path of the ions. In case, however, the path of the ions is maintained as nearly as possible entirely within the thin hydrogen layer, a large neutron output is obtained with the aid of these thin adsorbed hydrogen layers.

A principal purpose of the invention is the provision of a highly efficient method for the production of neutrons by the interaction of deuterons. According to the invention this is attained by allowing the stream of ions to impinge on the layer at an angle—preferably in as grazing a manner as possible.

The adsorption layer containing hydrogen need not consist of pure hydrogen. It might under certain conditions be more advantageous if the adsorption layer consists of gases or vapors containing hydrogen, for instance, methane or water. This is particularly satisfactory when these substances are adsorbed especially strongly.

The body impinged on by the ions is preferably made of a substance that strongly adsorbs the molecules containing heavy hydrogen and at the same time possesses only a slight retarding capacity for the impinging ions. Carbon and beryllium have been found useful for these reasons. It is especially desirable to employ substances that adsorb the molecules containing hydrogen in as thick a layer as possible. This can be accomplished for instance by using, as adsorption body, a substance that is porous or roughened at least at the surface.

The surface of the adsorbing body is heated up by the energy of the impinging ions. In this way the giving off of the adsorbed substance is promoted. It is, therefore, advisable to cool the adsorbing body. This cooling has the advantage, moreover, that at low temperature the adsorbed layer adheres much more firmly. A reduction of the temperature of only 10^{o}C., for instance from 20^{o}C. room temperature to 10^{o}C., can produce a considerable improvement. In many cases, it is advisable to use solid carbon dioxide or even liquid air for the cooling.

The adsorbed layer can be produced in the usual way, for instance by taking up heavy hydrogen or molecules containing heavy hydro gen from the surroundings, for instance from the gas chamber; but it may also be produced by bombarding the surface with heavy hydrogen ions. It is advisable to free the surface intended for the adsorption of heavy hydrogen as far as possible from other adsorbed molecules, such as ordinary hydrogen, for example, by heating in vacuum.

The replacement of the hydrogen given off during the ion bombardment can be accomplished, for instance, by simultaneous or subsequent bombardment with ions containing heavy hydrogen. This bombardment can be accomplished, for instance, with advantage from a different direction, for example, from the back or at a more acute angle from the front, than the bombardment for producing neutrons. The replacement of the heavy hydrogen may be accomplished, for example, by diffusion or by adsorption from the surroundings.

The principles of the invention are illustrated in the accompanying drawing in which:

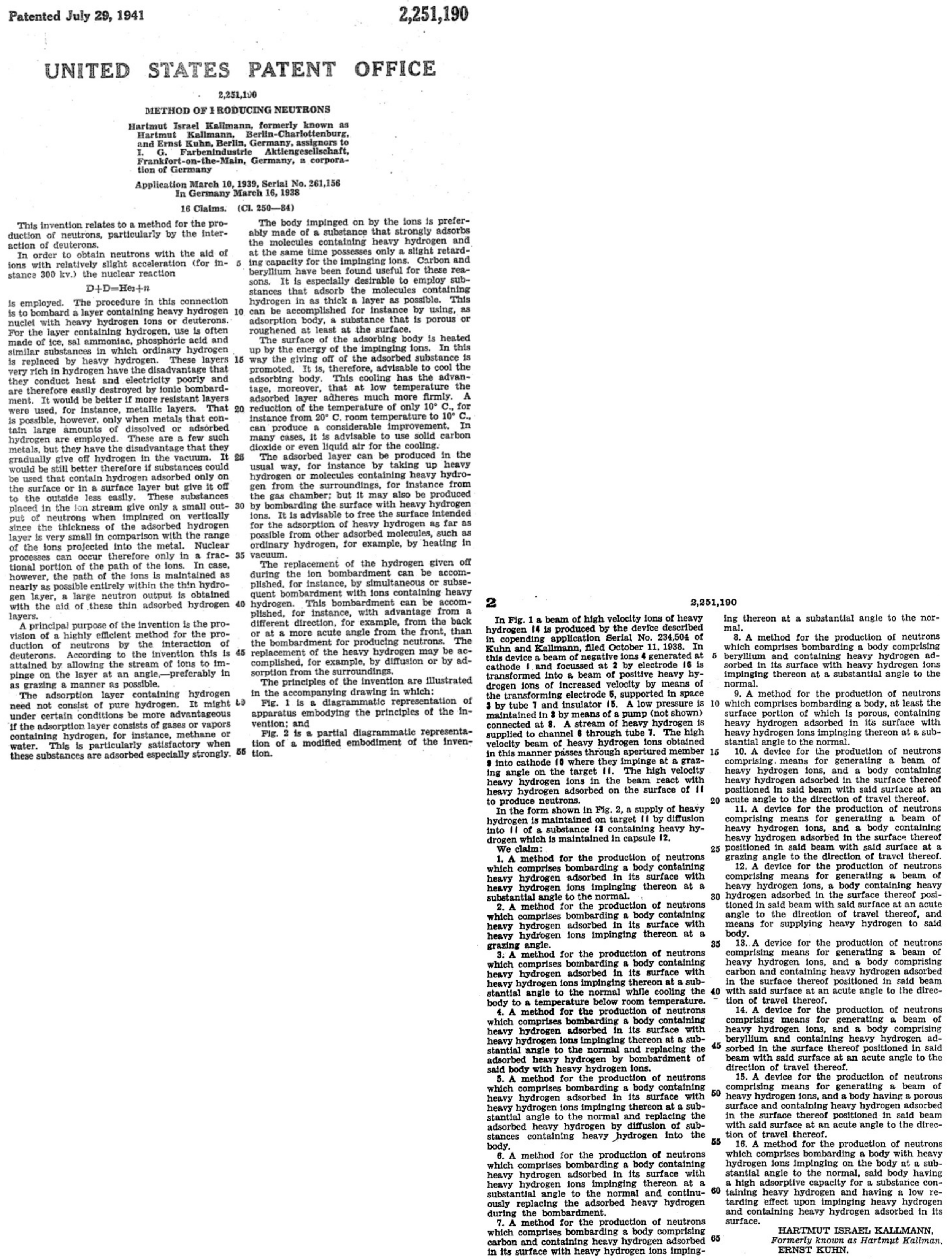
Fig. l is a diagrammatic representation of apparatus embodying the principles of the invention; and

Fig. 2 is a partial diagrammatic representation of a modified embodiment of the invention.

In Fig. 1 a beam of high velocity ions of heavy hydrogen 14 is produced by the device described in copending application Serial No. 234,504 of Kuhn and Kallmann, filed October 11, 1938. In this device a beam of negative ions 4 generated at cathode 1 and focussed at 2 by electrode 16 is transformed into a beam of positive heavy hydrogen ions of increased velocity by means of the transforming electrode 5, supported in space 3 by tube 7 and insulator 15. A low pressure is maintained in 3 by means of a pump (not shown) connected at 8. A stream of heavy hydrogen is supplied to channel 6 through tube 7. The high velocity beam of heavy hydrogen ions obtained in this manner passes through apertured member 9 into cathode 10 where they impinge at a grazing angle on the target 11. The high velocity heavy hydrogen ions in the beam react with heavy hydrogen adsorbed on the surface of 11 to produce neutrons.

In the form shown in Fig. 2, a supply of heavy hydrogen is maintained on target 11 by diffusion into 11 of a substance 13 containing heavy hydrogen which is maintained in capsule 12.

[See document photos on pp. 4296–4297.]



Patented July 29, 1941 **2,251,190**

UNITED STATES PATENT OFFICE

2,251,190

METHOD OF PRODUCING NEUTRONS

Hartmut Israel Kallmann, formerly known as Hartmut Kallmann, Berlin-Charlottenburg, and Ernst Kuhn, Berlin, Germany, assignors to I. G. Farbenindustrie Aktiengesellschaft, Frankfort-on-the-Main, Germany, a corporation of Germany

Application March 10, 1939, Serial No. 261,156
In Germany March 16, 1938

16 Claims. (Cl. 250—84)

This invention relates to a method for the production of neutrons, particularly by the interaction of deuterons.

In order to obtain neutrons with the aid of ions with relatively slight acceleration (for instance 300 kv.) the nuclear reaction

$$D+D=He_3+n$$

is employed. The procedure in this connection is to bombard a layer containing heavy hydrogen nuclei with heavy hydrogen ions or deuterons. For the layer containing hydrogen, use is often made of ice, sal ammoniac, phosphoric acid and similar substances in which ordinary hydrogen is replaced by heavy hydrogen. These layers very rich in hydrogen have the disadvantage that they conduct heat and electricity poorly and are therefore easily destroyed by ionic bombardment. It would be better if more resistant layers were used, for instance, metallic layers. That is possible, however, only when metals that contain large amounts of dissolved or adsorbed hydrogen are employed. These are a few such metals, but they have the disadvantage that they gradually give off hydrogen in the vacuum. It would be still better therefore if substances could be used that contain hydrogen adsorbed only on the surface or in a surface layer but give it off to the outside less easily. These substances placed in the ion stream give only a small output of neutrons when impinged on vertically since the thickness of the adsorbed hydrogen layer is very small in comparison with the range of the ions projected into the metal. Nuclear processes can occur therefore only in a fractional portion of the path of the ions. In case, however, the path of the ions is maintained as nearly as possible entirely within the thin hydrogen layer, a large neutron output is obtained with the aid of these thin adsorbed hydrogen layers.

A principal purpose of the invention is the provision of a highly efficient method for the production of neutrons by the interaction of deuterons. According to the invention this is attained by allowing the stream of ions to impinge on the layer at an angle,—preferably in as grazing a manner as possible.

The adsorption layer containing hydrogen need not consist of pure hydrogen. It might under certain conditions be more advantageous if the adsorption layer consists of gases or vapors containing hydrogen, for instance, methane or water. This is particularly satisfactory when these substances are adsorbed especially strongly.

The body impinged on by the ions is preferably made of a substance that strongly adsorbs the molecules containing heavy hydrogen and at the same time possesses only a slight retarding capacity for the impinging ions. Carbon and beryllium have been found useful for these reasons. It is especially desirable to employ substances that adsorb the molecules containing hydrogen in as thick a layer as possible. This can be accomplished for instance by using, as adsorption body, a substance that is porous or roughened at least at the surface.

The surface of the adsorbing body is heated up by the energy of the impinging ions. In this way the giving off of the adsorbed substance is promoted. It is, therefore, advisable to cool the adsorbing body. This cooling has the advantage, moreover, that at low temperature the adsorbed layer adheres much more firmly. A reduction of the temperature of only 10° C., for instance from 20° C. room temperature to 10° C., can produce a considerable improvement. In many cases, it is advisable to use solid carbon dioxide or even liquid air for the cooling.

The adsorbed layer can be produced in the usual way, for instance by taking up heavy hydrogen or molecules containing heavy hydrogen from the surroundings, for instance from the gas chamber; but it may also be produced by bombarding the surface with heavy hydrogen ions. It is advisable to free the surface intended for the adsorption of heavy hydrogen as far as possible from other adsorbed molecules, such as ordinary hydrogen, for example, by heating in vacuum.

The replacement of the hydrogen given off during the ion bombardment can be accomplished, for instance, by simultaneous or subsequent bombardment with ions containing heavy hydrogen. This bombardment can be accomplished, for instance, with advantage from a different direction, for example, from the back or at a more acute angle from the front, than the bombardment for producing neutrons. The replacement of the heavy hydrogen may be accomplished, for example, by diffusion or by adsorption from the surroundings.

The principles of the invention are illustrated in the accompanying drawing in which:

Fig. 1 is a diagrammatic representation of apparatus embodying the principles of the invention; and

Fig. 2 is a partial diagrammatic representation of a modified embodiment of the invention.

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2 2,251,190

In Fig. 1 a beam of high velocity ions of heavy hydrogen 14 is produced by the device described in copending application Serial No. 234,504 of Kuhn and Kallmann, filed October 11, 1938. In this device a beam of negative ions 4 generated at cathode 1 and focussed at 2 by electrode 16 is transformed into a beam of positive heavy hydrogen ions of increased velocity by means of the transforming electrode 5, supported in space 3 by tube 7 and insulator 15. A low pressure is maintained in 3 by means of a pump (not shown) connected at 8. A stream of heavy hydrogen is supplied to channel 6 through tube 7. The high velocity beam of heavy hydrogen ions obtained in this manner passes through apertured member 9 into cathode 10 where they impinge at a grazing angle on the target 11. The high velocity heavy hydrogen ions in the beam react with heavy hydrogen adsorbed on the surface of 11 to produce neutrons.

In the form shown in Fig. 2, a supply of heavy hydrogen is maintained on target 11 by diffusion into 11 of a substance 13 containing heavy hydrogen which is maintained in capsule 12.

We claim:

1. A method for the production of neutrons which comprises bombarding a body containing heavy hydrogen adsorbed in its surface with heavy hydrogen ions impinging thereon at a substantial angle to the normal.

2. A method for the production of neutrons which comprises bombarding a body containing heavy hydrogen adsorbed in its surface with heavy hydrogen ions impinging thereon at a grazing angle.

3. A method for the production of neutrons which comprises bombarding a body containing heavy hydrogen adsorbed in its surface with heavy hydrogen ions impinging thereon at a substantial angle to the normal while cooling the body to a temperature below room temperature.

4. A method for the production of neutrons which comprises bombarding a body containing heavy hydrogen adsorbed in its surface with heavy hydrogen ions impinging thereon at a substantial angle to the normal and replacing the adsorbed heavy hydrogen by bombardment of said body with heavy hydrogen ions.

5. A method for the production of neutrons which comprises bombarding a body containing heavy hydrogen adsorbed in its surface with heavy hydrogen ions impinging thereon at a substantial angle to the normal and replacing the adsorbed heavy hydrogen by diffusion of substances containing heavy hydrogen into the body.

6. A method for the production of neutrons which comprises bombarding a body containing heavy hydrogen adsorbed in its surface with heavy hydrogen ions impinging thereon at a substantial angle to the normal and continuously replacing the adsorbed heavy hydrogen during the bombardment.

7. A method for the production of neutrons which comprises bombarding a body comprising carbon and containing heavy hydrogen adsorbed in its surface with heavy hydrogen ions impinging thereon at a substantial angle to the normal.

8. A method for the production of neutrons which comprises bombarding a body comprising beryllium and containing heavy hydrogen adsorbed in its surface with heavy hydrogen ions impinging thereon at a substantial angle to the normal.

9. A method for the production of neutrons which comprises bombarding a body, at least the surface portion of which is porous, containing heavy hydrogen adsorbed in its surface with heavy hydrogen ions impinging thereon at a substantial angle to the normal.

10. A device for the production of neutrons comprising means for generating a beam of heavy hydrogen ions, and a body containing heavy hydrogen adsorbed in the surface thereof positioned in said beam with said surface at an acute angle to the direction of travel thereof.

11. A device for the production of neutrons comprising means for generating a beam of heavy hydrogen ions, and a body containing heavy hydrogen adsorbed in the surface thereof positioned in said beam with said surface at a grazing angle to the direction of travel thereof.

12. A device for the production of neutrons comprising means for generating a beam of heavy hydrogen ions, a body containing heavy hydrogen adsorbed in the surface thereof positioned in said beam with said surface at an acute angle to the direction of travel thereof, and means for supplying heavy hydrogen to said body.

13. A device for the production of neutrons comprising means for generating a beam of heavy hydrogen ions, and a body comprising carbon and containing heavy hydrogen adsorbed in the surface thereof positioned in said beam with said surface at an acute angle to the direction of travel thereof.

14. A device for the production of neutrons comprising means for generating a beam of heavy hydrogen ions, and a body comprising beryllium and containing heavy hydrogen adsorbed in the surface thereof positioned in said beam with said surface at an acute angle to the direction of travel thereof.

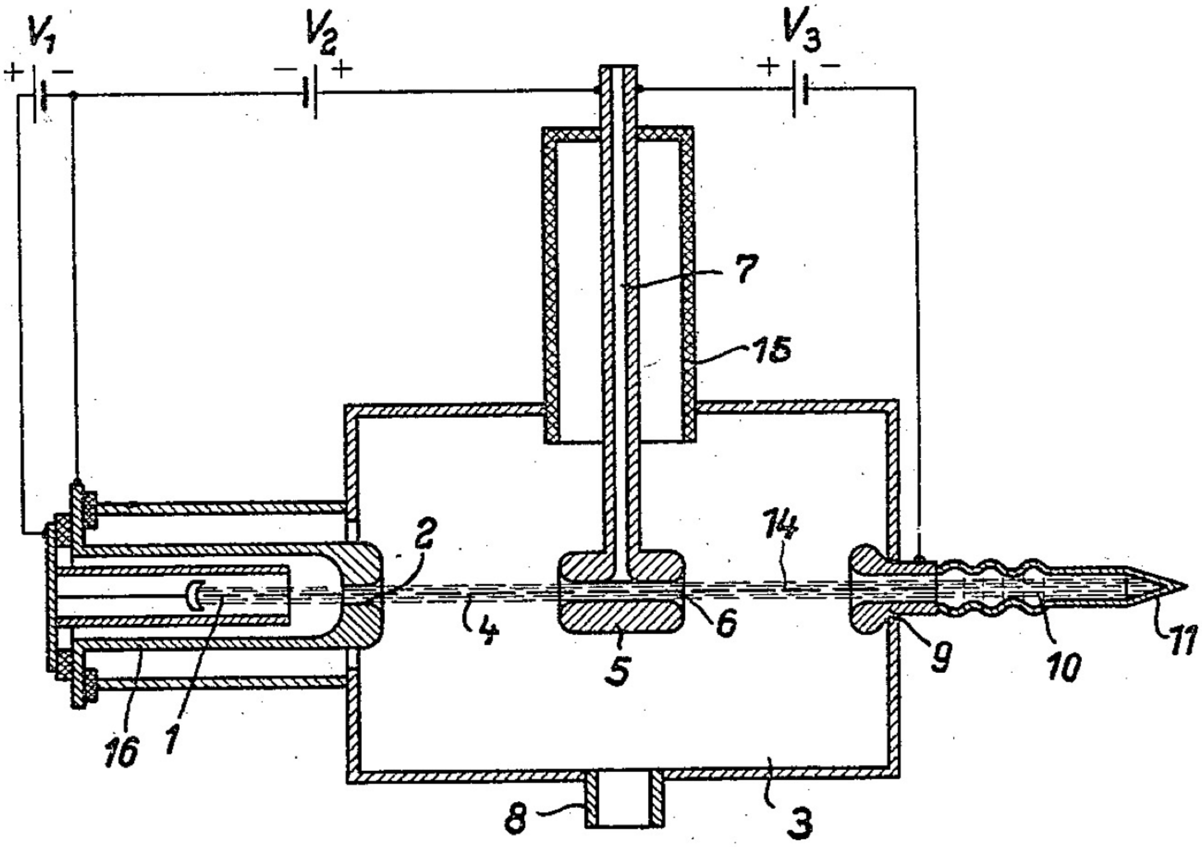
15. A device for the production of neutrons comprising means for generating a beam of heavy hydrogen ions, and a body having a porous surface and containing heavy hydrogen adsorbed in the surface thereof positioned in said beam with said surface at an acute angle to the direction of travel thereof.

16. A method for the production of neutrons which comprises bombarding a body with heavy hydrogen ions impinging on the body at a substantial angle to the normal, said body having a high adsorptive capacity for a substance containing heavy hydrogen and having a low retarding effect upon impinging heavy hydrogen and containing heavy hydrogen adsorbed in its surface.

HARTMUT ISRAEL KALLMANN,
Formerly known as Hartmut Kallman.
ERNST KUHN.

Figure D.608: Hartmut Kallmann and Ernst Kuhn, AEG and I.G. Farben. U.S. Patent 2,251,190. Method of Producing Neutrons. Filed 16 March 1938. Issued 29 July 1941.

Fig.1


V_1
+ −
V_2
− +
V_3
+ −
7
15
14
2
4
5
6
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10
11
16
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8
3

Fig.2

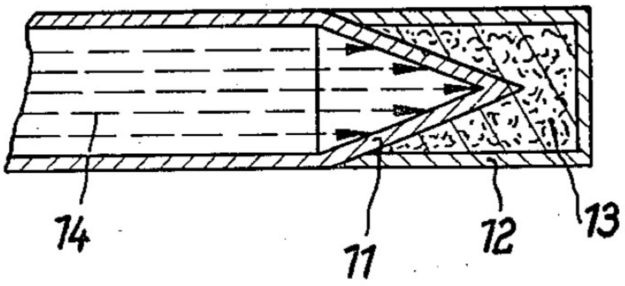


Figure D.609: High-voltage tube for generating fusion neutrons from Kallmann and Kuhn's U.S. Patent 2,251,190.

Hartmut Kallmann and Ernst Kuhn. U.S. Patent 2,288,717. Method for Investigation of Substances with the Aid of Neutrons. Filed 10 March 1939. Issued 7 July 1942.

The present invention relates to improvements in methods of, and means for, investigating objects or substances with the aid of neutrons.

It has already been suggested to investigate substances by depicting them with the aid of neutrons. This investigation may be carried out by directing a beam of neutrons through the body or substance under investigation and causing the neutrons that emerge from it to encounter a layer in which heavy charged particles or electrons (+ and -) or gamma rays are produced under the action of the impinging neutrons upon an element, contained in said layer, which is reactive toward neutrons. These particles are in turn caused to act upon a layer of fluorescent material, or an adjacent photographic layer or a combination thereof, thus depicting the investigated body or substance visibly or photographically. Neutron reactive layers particularly suited for this purpose are, for instance, such containing lithium or boron. In these two substances the following reactions take place under the influence of the impinging neutrons:

$$1.\quad n_0^1 + Li_3^6 = He_2^4 + H_1^3 \tag{D.13}$$

$$2.\quad n_0^1 + B_5^{10} = Li_3^7 + He_2^4 \tag{D.14}$$

In the lithium or lithium compounds existing in nature the contents of the effective Li_3^6 amounts only to about 10%, and in the boron and boron compounds existing in nature the contents of the effective B_5^{10} amounts only to about 20%. The main mass of these elements consists of Li_3^7, or B_5^{11}, respectively.

It is an object of the present invention to increase the sensitiveness of the above-mentioned method of depicting objects by means of neutrons. Another object of the invention is to provide improved means for depicting objects by means of neutrons.

This inventive object is attained by using as neutron reactive layer containing an element in which the neutron reactive sort of isotopes is enriched beyond the proportion corresponding to the natural distribution of this isotope in the respective element. Using the above mentioned special reactions the neutron reactive sorts of isotopes being artificially enriched are Li_3^6 or B_5^{10}. The enrichment may be accomplished by any of the known methods for separating or concentrating isotopes, i.e. diffusion, mass spectrograph, electrolysis and chemical processes.

With a given intensity of the neutron radiation the number of the emitted heavy particles and therewith the blackening of the photographic plate, or the excitation of the fluorescent screen respectively, is determined not by the thickness of the intermediate layer, but by the range of the heavy particles liberated from said layer if the thickness of said intermediate layer is larger than said range. The number of the heavy particles emitted per neutron is the greatest if within a layer adjacent to the surface the thickness of which corresponds to the range as many neutrons as possible cause the emission of heavy particles by collision with neutron reactive atomic nuclei. As in general within a layer the thickness of which being equal to the range of said particles only a small fraction of the neutrons passing through liberate heavy particles, it is extremely important, as regards the output, to provide in said layer as many neutron reactive atomic nuclei as possible. An increase of the number of the neutron reactive atomic nuclei is obtained, by artificially enriching the intermediate element with Li_3^6 or B_5^{10}, respectively, beyond the proportion of its natural distribution in the respective element.

This method can advantageously be used also in connection with intermediate layers which do not emit heavy particles, but which emit electrons or gamma rays under the action of impinging neutrons, if the mixture of isotopes of the respective element, as existing in nature, is not the most favorable one for one of said neutron reactions. Therefore, the present improved method is not restricted to boron and lithium, but it will prove advantageous with every other neutron reactive element if only a fraction of all neutrons passing through the neutron-reactive layer is being absorbed in it, or if very thin neutron-reactive layers are used, or if the neutrons in the neutron-reactive layer are also absorbed by atomic nuclei which only contribute very little to the blackening of the photographic layer, or to the excitation of the fluorescent screen respectively by the emission of particles or gamma rays. The present improved method becomes particularly important if the neutron reactive element is applied as an emulsion upon the photographic layer or upon the fluorescent screen. Such emulsions are able to contain a small concentration of the neutron reactive element only. If, therefore the element contained in the emulsion is artificially enriched with the effective sort of isotopes beyond the proportion of its nature distribution in the respective element, an extraordinarily great increase of the sensitiveness can be attained.

Also neutron reactive layers containing cadmium may be used in which the cadmium is artificially enriched with its active isotope beyond the proportion corresponding to its natural distribution in cadmium. The isotope of cadmium to be used in each instance depends upon the neutron energy employed. The choice is made by observing which gives the greatest effect.

The accompanying drawing is a diagrammatic representation of an embodiment of the invention. The neutron beam 2 emitted by the neutron source 1 passes through the investigated substance or body 3. The emerging neutrons 4 impinge upon the neutron reactive layer 5 which is enriched with the effective sort of isotopes beyond the proportion corresponding to its natural distribution in the respective elements. In this layer 5 the neutrons liberate charged particles or gamma rays which energize the adjacent layer 6 which consists of fluorescent or photo-sensitive material thus producing a visible or photographic image of the investigated substance or body 3.

[See document photos on pp. 4300–4301.

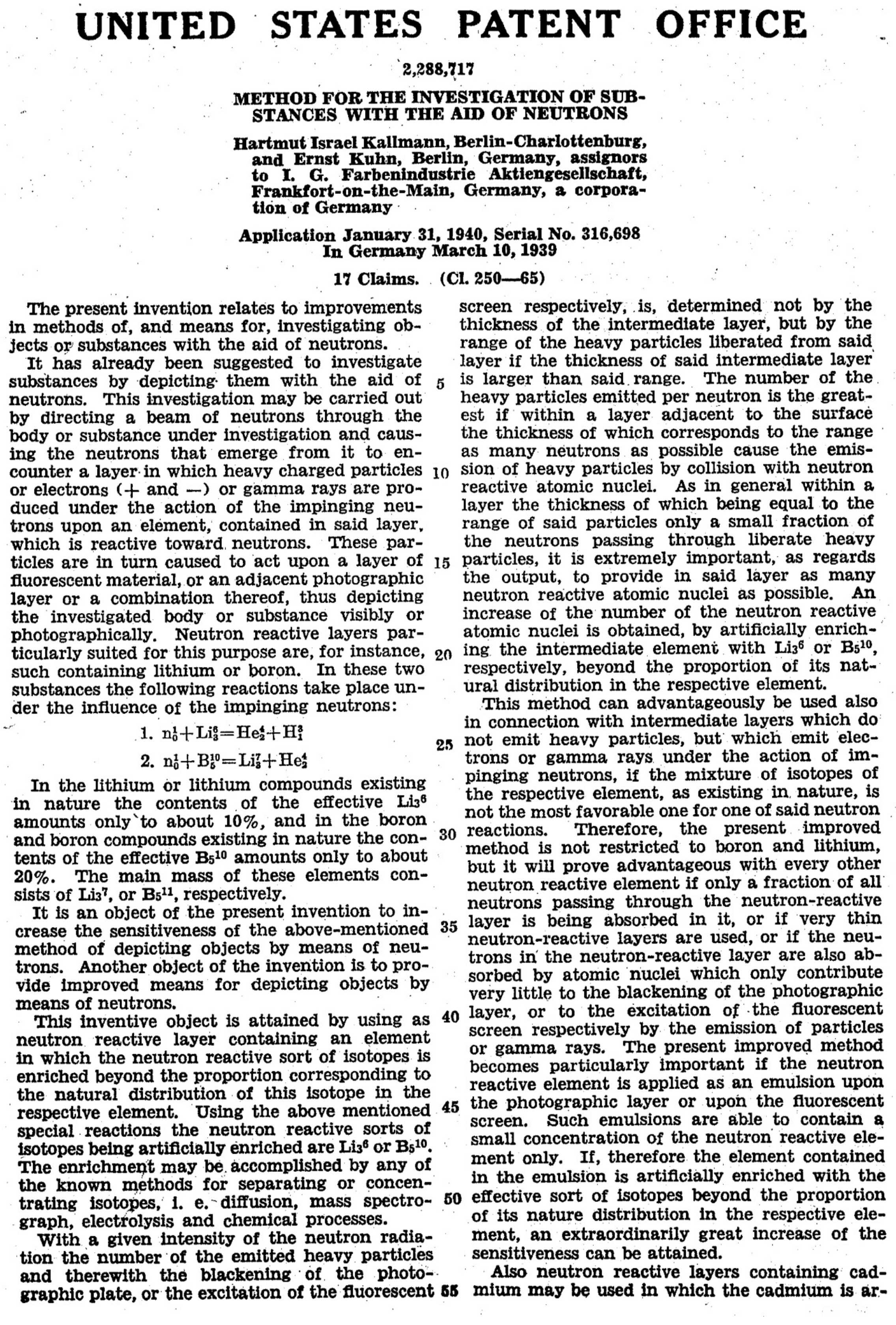
The patents of Kallmann and Kuhn are directly relevant to high-voltage fusion neutron initiators for fission bombs, but also to neutron imaging, analysis of materials, well logging, etc. These technologies have had wide-reaching influence from the postwar period to the modern world. In connection to nuclear weapons, note that in March 1939 Kallmann and Kuhn specifically described:

- The reaction $\mathrm{n}_0^1 + \mathrm{Li}_3^6 \rightarrow \mathrm{He}_2^4 + \mathrm{H}_1^3$, half of the Jetter cycle (p. 4348 of this appendix).
- The need to enrich the lithium-6 isotope from naturally occurring lithium, as Alfred Klemm did in 1942–1943 (p. 4344).

See also numerous other related patents by Kallmann and Kuhn, such as:

> U.S. Patent 2,219,033. Method and Device for Generating a Beam of Ions of High Velocity. Filed 21 October 1937. Issued 22 October 1940.
>
> U.S. Patent 2,188,115. Investigation of Materials with Neutrons. Filed 25 March 1937. Issued 23 January 1940.

How far did Kallmann and Kuhn or others take these technologies during the war? Note that Kallmann and Kuhn worked for AEG in Berlin.]



UNITED STATES PATENT OFFICE

2,288,717

METHOD FOR THE INVESTIGATION OF SUBSTANCES WITH THE AID OF NEUTRONS

Hartmut Israel Kallmann, Berlin-Charlottenburg, and Ernst Kuhn, Berlin, Germany, assignors to I. G. Farbenindustrie Aktiengesellschaft, Frankfort-on-the-Main, Germany, a corporation of Germany

Application January 31, 1940, Serial No. 316,698
In Germany March 10, 1939

17 Claims. (Cl. 250—65)

The present invention relates to improvements in methods of, and means for, investigating objects or substances with the aid of neutrons.

It has already been suggested to investigate substances by depicting them with the aid of neutrons. This investigation may be carried out by directing a beam of neutrons through the body or substance under investigation and causing the neutrons that emerge from it to encounter a layer in which heavy charged particles or electrons (+ and —) or gamma rays are produced under the action of the impinging neutrons upon an element, contained in said layer, which is reactive toward neutrons. These particles are in turn caused to act upon a layer of fluorescent material, or an adjacent photographic layer or a combination thereof, thus depicting the investigated body or substance visibly or photographically. Neutron reactive layers particularly suited for this purpose are, for instance, such containing lithium or boron. In these two substances the following reactions take place under the influence of the impinging neutrons:

1. $n_0^1+Li_3^6=He_2^4+H_1^3$

2. $n_0^1+B_5^{10}=Li_3^7+He_2^4$

In the lithium or lithium compounds existing in nature the contents of the effective Li_3^6 amounts only to about 10%, and in the boron and boron compounds existing in nature the contents of the effective B_5^{10} amounts only to about 20%. The main mass of these elements consists of Li_3^7, or B_5^{11}, respectively.

It is an object of the present invention to increase the sensitiveness of the above-mentioned method of depicting objects by means of neutrons. Another object of the invention is to provide improved means for depicting objects by means of neutrons.

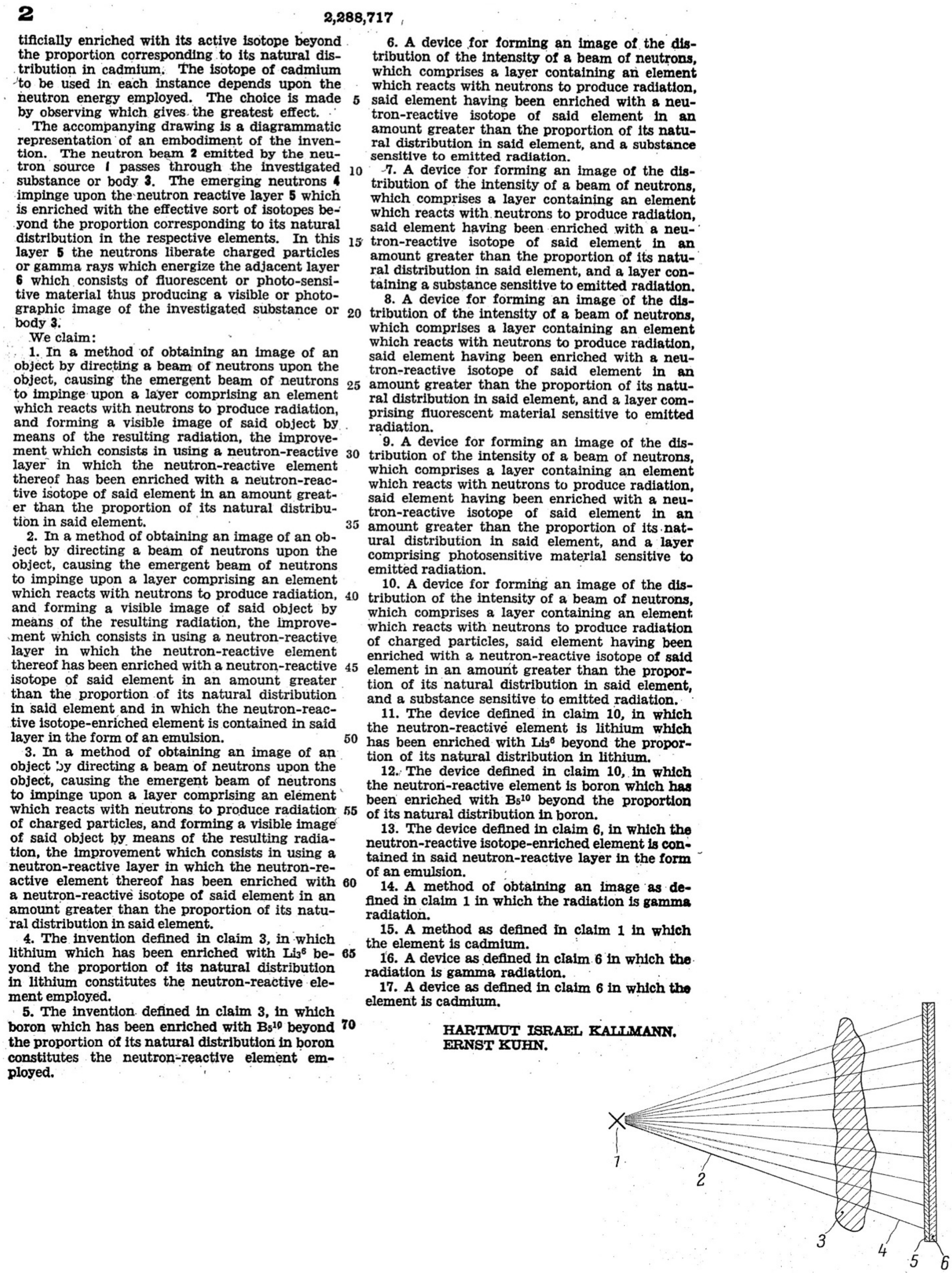
This inventive object is attained by using as neutron reactive layer containing an element in which the neutron reactive sort of isotopes is enriched beyond the proportion corresponding to the natural distribution of this isotope in the respective element. Using the above mentioned special reactions the neutron reactive sorts of isotopes being artificially enriched are Li_3^6 or B_5^{10}. The enrichment may be accomplished by any of the known methods for separating or concentrating isotopes, i. e. diffusion, mass spectrograph, electrolysis and chemical processes.

With a given intensity of the neutron radiation the number of the emitted heavy particles and therewith the blackening of the photographic plate, or the excitation of the fluorescent screen respectively, is, determined not by the thickness of the intermediate layer, but by the range of the heavy particles liberated from said layer if the thickness of said intermediate layer is larger than said range. The number of the heavy particles emitted per neutron is the greatest if within a layer adjacent to the surface the thickness of which corresponds to the range as many neutrons as possible cause the emission of heavy particles by collision with neutron reactive atomic nuclei. As in general within a layer the thickness of which being equal to the range of said particles only a small fraction of the neutrons passing through liberate heavy particles, it is extremely important, as regards the output, to provide in said layer as many neutron reactive atomic nuclei as possible. An increase of the number of the neutron reactive atomic nuclei is obtained, by artificially enriching the intermediate element with Li_3^6 or B_5^{10}, respectively, beyond the proportion of its natural distribution in the respective element.

This method can advantageously be used also in connection with intermediate layers which do not emit heavy particles, but which emit electrons or gamma rays under the action of impinging neutrons, if the mixture of isotopes of the respective element, as existing in nature, is not the most favorable one for one of said neutron reactions. Therefore, the present improved method is not restricted to boron and lithium, but it will prove advantageous with every other neutron reactive element if only a fraction of all neutrons passing through the neutron-reactive layer is being absorbed in it, or if very thin neutron-reactive layers are used, or if the neutrons in the neutron-reactive layer are also absorbed by atomic nuclei which only contribute very little to the blackening of the photographic layer, or to the excitation of the fluorescent screen respectively by the emission of particles or gamma rays. The present improved method becomes particularly important if the neutron reactive element is applied as an emulsion upon the photographic layer or upon the fluorescent screen. Such emulsions are able to contain a small concentration of the neutron reactive element only. If, therefore the element contained in the emulsion is artificially enriched with the effective sort of isotopes beyond the proportion of its nature distribution in the respective element, an extraordinarily great increase of the sensitiveness can be attained.

Also neutron reactive layers containing cadmium may be used in which the cadmium is ar-

Figure D.610: Hartmut Kallmann and Ernst Kuhn, AEG and I.G. Farben. U.S. Patent 2,288,717. Method for Investigation of Substances with the Aid of Neutrons. Filed 10 March 1939. Issued 7 July 1942.



2 2,288,717

tificially enriched with its active isotope beyond the proportion corresponding to its natural distribution in cadmium. The isotope of cadmium to be used in each instance depends upon the neutron energy employed. The choice is made by observing which gives the greatest effect.

The accompanying drawing is a diagrammatic representation of an embodiment of the invention. The neutron beam **2** emitted by the neutron source **1** passes through the investigated substance or body **3**. The emerging neutrons **4** impinge upon the neutron reactive layer **5** which is enriched with the effective sort of isotopes beyond the proportion corresponding to its natural distribution in the respective elements. In this layer **5** the neutrons liberate charged particles or gamma rays which energize the adjacent layer **6** which consists of fluorescent or photo-sensitive material thus producing a visible or photographic image of the investigated substance or body **3**.

We claim:

1. In a method of obtaining an image of an object by directing a beam of neutrons upon the object, causing the emergent beam of neutrons to impinge upon a layer comprising an element which reacts with neutrons to produce radiation, and forming a visible image of said object by means of the resulting radiation, the improvement which consists in using a neutron-reactive layer in which the neutron-reactive element thereof has been enriched with a neutron-reactive isotope of said element in an amount greater than the proportion of its natural distribution in said element.

2. In a method of obtaining an image of an object by directing a beam of neutrons upon the object, causing the emergent beam of neutrons to impinge upon a layer comprising an element which reacts with neutrons to produce radiation, and forming a visible image of said object by means of the resulting radiation, the improvement which consists in using a neutron-reactive layer in which the neutron-reactive element thereof has been enriched with a neutron-reactive isotope of said element in an amount greater than the proportion of its natural distribution in said element and in which the neutron-reactive isotope-enriched element is contained in said layer in the form of an emulsion.

3. In a method of obtaining an image of an object by directing a beam of neutrons upon the object, causing the emergent beam of neutrons to impinge upon a layer comprising an element which reacts with neutrons to produce radiation of charged particles, and forming a visible image of said object by means of the resulting radiation, the improvement which consists in using a neutron-reactive layer in which the neutron-reactive element thereof has been enriched with a neutron-reactive isotope of said element in an amount greater than the proportion of its natural distribution in said element.

4. The invention defined in claim 3, in which lithium which has been enriched with Li_3^6 beyond the proportion of its natural distribution in lithium constitutes the neutron-reactive element employed.

5. The invention defined in claim 3, in which boron which has been enriched with B_5^{10} beyond the proportion of its natural distribution in boron constitutes the neutron-reactive element employed.

6. A device for forming an image of the distribution of the intensity of a beam of neutrons, which comprises a layer containing an element which reacts with neutrons to produce radiation, said element having been enriched with a neutron-reactive isotope of said element in an amount greater than the proportion of its natural distribution in said element, and a substance sensitive to emitted radiation.

7. A device for forming an image of the distribution of the intensity of a beam of neutrons, which comprises a layer containing an element which reacts with neutrons to produce radiation, said element having been enriched with a neutron-reactive isotope of said element in an amount greater than the proportion of its natural distribution in said element, and a layer containing a substance sensitive to emitted radiation.

8. A device for forming an image of the distribution of the intensity of a beam of neutrons, which comprises a layer containing an element which reacts with neutrons to produce radiation, said element having been enriched with a neutron-reactive isotope of said element in an amount greater than the proportion of its natural distribution in said element, and a layer comprising fluorescent material sensitive to emitted radiation.

9. A device for forming an image of the distribution of the intensity of a beam of neutrons, which comprises a layer containing an element which reacts with neutrons to produce radiation, said element having been enriched with a neutron-reactive isotope of said element in an amount greater than the proportion of its natural distribution in said element, and a layer comprising photosensitive material sensitive to emitted radiation.

10. A device for forming an image of the distribution of the intensity of a beam of neutrons, which comprises a layer containing an element which reacts with neutrons to produce radiation of charged particles, said element having been enriched with a neutron-reactive isotope of said element in an amount greater than the proportion of its natural distribution in said element, and a substance sensitive to emitted radiation.

11. The device defined in claim 10, in which the neutron-reactive element is lithium which has been enriched with Li_3^6 beyond the proportion of its natural distribution in lithium.

12. The device defined in claim 10, in which the neutron-reactive element is boron which has been enriched with B_5^{10} beyond the proportion of its natural distribution in boron.

13. The device defined in claim 6, in which the neutron-reactive isotope-enriched element is contained in said neutron-reactive layer in the form of an emulsion.

14. A method of obtaining an image as defined in claim 1 in which the radiation is gamma radiation.

15. A method as defined in claim 1 in which the element is cadmium.

16. A device as defined in claim 6 in which the radiation is gamma radiation.

17. A device as defined in claim 6 in which the element is cadmium.

HARTMUT ISRAEL KALLMANN.
ERNST KUHN.

Figure D.611: Hartmut Kallmann and Ernst Kuhn, AEG and I.G. Farben. U.S. Patent 2,288,717. Method for Investigation of Substances with the Aid of Neutrons. Filed 10 March 1939. Issued 7 July 1942.

[NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)]

C.S.D.I.C. (U.K.)
S.I.R. 1096

THIS REPORT IS SECRET

Report on information obtained from PW KP/126263 Gren CHRIST,
Fest Inf Bn 1408, captured at
ECHINGHEN nr BOULOGNE 19 Sep 44

NOTES ON ALLGEMEINE ELEKTRICITÄTS GESELLSCHAFT (AEG) HENNIGSDORF NEAR BERLIN, AND THE FOREIGN WORKERS' COLONY

PREAMBLE

1. PW is 40 years old and has been with the German Army for three months only. He was born in CZECHOSLOVAKIA and served with the Czech Army during 1924 and 1925. Shortly after the annexation of the SUDETENLAND PW was ordered to GERMANY and was employed in the lacquer factory of the AEG HENNIGSDORF near BERLIN. Late Feb 41 he was taken from the factory to occupy a post as an interpreter and supervisor among the Czechs in the newly-established Foreign Workers' Camp of the AEG, HENNIGSDORF. From that date until Jul 44 PW has been an active and observant official of this camp. He is very cooperative and the information is considered reliable.

I. NOTES ON AEG AND EMPLOYEES

2. The AEG plant in question is located at the Southern outskirts of HENNIGSDORF (GSGS 4414. 3345/7061 and 7062). (Popl. approx. 18,000). This plant is one of ten or eleven branches of the AEG in BERLIN and ever since PW can remember new buildings have been added, and today the plant comprises an estimated area of 800 x 400 m.

TAILPIECE

62. A 2-storey ordinary wooden barrack hut 8 x 8 m has been seen by PW, and on two occasions he had the opportunity of entering the building and talking to the electrician who takes care of the equipment. This electrician did not talk of the purposes of the station, and PW believed that it was most secret, but did mention several times that a voltage of one million must be reached before great results could be expected. By the end of Jun 44 they had come up from 120000 to 420000 volts.

63. Once or twice a week two professors and an engineer arrived at the station and during each visit PW saw the four 1½ inch cables from the building to the steel mast approx 80 m away begin to glow in various colours, usually, however, changing from bluish to green, accompanied by a low hum of great intensity. The visitors stayed for 1½ to 2 hours, the test itself lasting approx 15 mins. Shortly after a test PW went to see his friend, the electrician, and heard him say that each test cost RM 24 in electricity alone. Then PW watched him cleaning spherical containers, removing heavy metal bars from each one and putting them into troughs of acid. Each container had a mirror fixed on top which stood at an angle of 45° and which turned through 90° the line of sight from a telescope some 10 feet away to the small mica covered opening at the top of each container.

64. There were four such spherical containers of different sizes and PW states that he observed that the smallest one, approx 1 m in diameter, was used that day in Jun 44. The size of the others ranged between approx 1 m to 2 m in diameter but otherwise they were identical. The cables leading from an amplifier to each one of the spheres were about the same size but the cables leading from the spheres to heavy insulator and apparently farther to the steel mast were considerably heavier from the 2 m sphere than from the 1 m sphere.

65. Upon being prompted PW suddenly remembered that the electrician at the station had used the terms cyclotron and atom splitting.

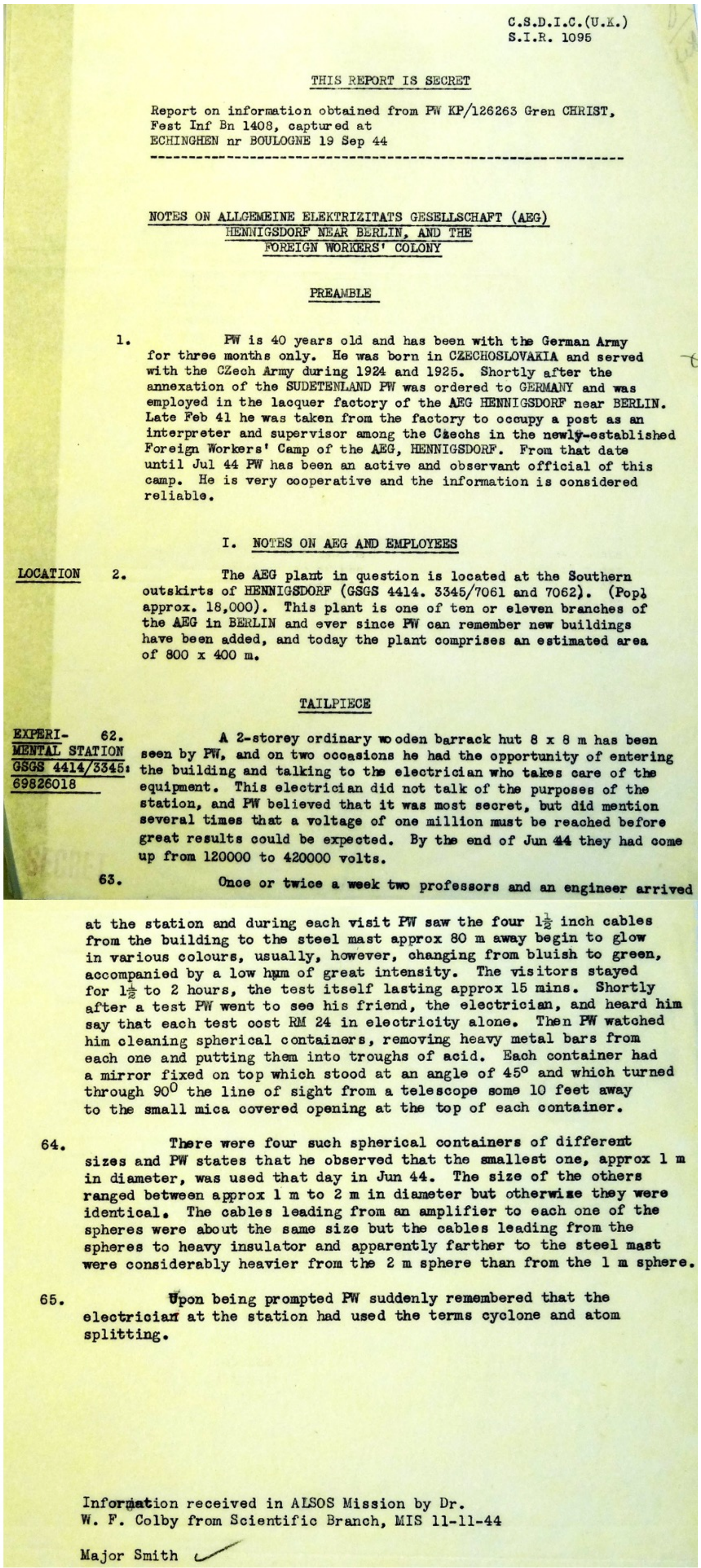
Information received in ALSOS Mission by Dr.
W. F. Colby from Scientific Branch, MIS 11-11-44

Major Smith

[See document photo on p. 4304.]

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July-October 1944)



C.S.D.I.C.(U.K.)
S.I.R. 1095

THIS REPORT IS SECRET

Report on information obtained from PW KP/126263 Gren CHRIST,
Fest Inf Bn 1408, captured at
ECHINGHEN nr BOULOGNE 19 Sep 44

NOTES ON ALLGEMEINE ELEKTRIZITATS GESELLSCHAFT (AEG) HENNIGSDORF NEAR BERLIN, AND THE FOREIGN WORKERS' COLONY

PREAMBLE

1. PW is 40 years old and has been with the German Army for three months only. He was born in CZECHOSLOVAKIA and served with the CZech Army during 1924 and 1925. Shortly after the annexation of the SUDETENLAND PW was ordered to GERMANY and was employed in the lacquer factory of the AEG HENNIGSDORF near BERLIN. Late Feb 41 he was taken from the factory to occupy a post as an interpreter and supervisor among the Czechs in the newly-established Foreign Workers' Camp of the AEG, HENNIGSDORF. From that date until Jul 44 PW has been an active and observant official of this camp. He is very cooperative and the information is considered reliable.

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TAILPIECE

EXPERIMENTAL STATION GSGS 4414/3345: 69826018 62. A 2-storey ordinary wooden barrack hut 8 x 8 m has been seen by PW, and on two occasions he had the opportunity of entering the building and talking to the electrician who takes care of the equipment. This electrician did not talk of the purposes of the station, and PW believed that it was most secret, but did mention several times that a voltage of one million must be reached before great results could be expected. By the end of Jun 44 they had come up from 120000 to 420000 volts.

63. Once or twice a week two professors and an engineer arrived at the station and during each visit PW saw the four $1\frac{1}{2}$ inch cables from the building to the steel mast approx 80 m away begin to glow in various colours, usually, however, changing from bluish to green, accompanied by a low hum of great intensity. The visitors stayed for $1\frac{1}{2}$ to 2 hours, the test itself lasting approx 15 mins. Shortly after a test PW went to see his friend, the electrician, and heard him say that each test cost RM 24 in electricity alone. Then PW watched him cleaning spherical containers, removing heavy metal bars from each one and putting them into troughs of acid. Each container had a mirror fixed on top which stood at an angle of 45^0 and which turned through 90^0 the line of sight from a telescope some 10 feet away to the small mica covered opening at the top of each container.

64. There were four such spherical containers of different sizes and PW states that he observed that the smallest one, approx 1 m in diameter, was used that day in Jun 44. The size of the others ranged between approx 1 m to 2 m in diameter but otherwise they were identical. The cables leading from an amplifier to each one of the spheres were about the same size but the cables leading from the spheres to heavy insulator and apparently farther to the steel mast were considerably heavier from the 2 m sphere than from the 1 m sphere.

65. Upon being prompted PW suddenly remembered that the electrician at the station had used the terms cyclone and atom splitting.

Information received in ALSOS Mission by Dr.
W. F. Colby from Scientific Branch, MIS 11-11-44

Major Smith

Figure D.612: C.S.D.I.C. (U.K.) S.I.R. 1095 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)]

G-367. Wolfgang Ferrant. Proposal for a New Method of Releasing Nuclear Energy by a Beam of Heavy Particles. 1945. pp. 13, 21, 23–24, 35.

Unfortunately it was not possible to make use of the correct density figure for Li D in making the computation ($\rho = 1$ was merely estimated); because my books, photostats, and notes were left behind, in part, in Dresden, together with my laboratory (13–14 February) where they were burned, and in part this material was left behind in the Russian Zone. [...]

1. Suitable Substances

Our purpose was to produce, within an extensive reaction area which contains a very large number of atoms capable of reacting, a temperature or an almost entirely uncoordinated heat motion, such as prevails on the stars. At the same time, the density of the reacting material should be as great as possible.

Under these circumstances atomic reactions will occur[...]

The decision in this matter involves an additional demand we must make upon the reacting mass: the demand that this mass should be ionizable in its totality with the lowest possible expenditure of energy.

2. THE PROBLEM OF KEEPING THE WORK OF IONIZATION AT A MINIMUM

However, the choice is in fact restricted to lithium, the latter being a substance which does not carry more than three enveloping electrons. Moreover, the lithium readily combines with heavy hydrogen to form a hydride: LiD. The compound, that is the lithium D hydride, contains a total of only four electrons, so that the total work of ionization is, at worst, only a small amount.

All aside from other considerations, lithium D hydride is well suited as the choice of substance both for the “large particles” and for the recipient substance, not only because heavy hydrogen participates in the atomic reaction, but also because the lithium, likewise, participates. The following reactions are to be anticipated: ${}^{2}_{1}\mathrm{D}(\mathrm{d,n})^{3}_{2}\mathrm{He}$; ${}^{2}_{1}\mathrm{D}(\mathrm{d,p})^{3}_{1}\mathrm{H}$ and ${}^{6}_{3}\mathrm{Li}(\mathrm{d,p})^{7}_{3}\mathrm{Li}$; ${}^{6}_{3}\mathrm{Li}(\mathrm{d},\alpha)^{4}_{2}\mathrm{He}$; ${}^{7}_{3}\mathrm{Li}(\mathrm{d,n})^{4}_{2}\mathrm{He}$.

There occurs in the reaction area a formation of charged particles α, p, but also a formation of neutrons that can easily split off. Our method, therefore, results directly in the creation of a source of neutrons of greatest intensity.

This method, consequently, has nothing to do, directly, with the splitting of the uranium atom.

Advantage will be taken, of course, of Hahn’s discovery; especially when the purpose is to obtain pure energy, and not merely to obtain neutrons and an incidental supply of energy.

If the purpose is to obtain energy alone, the neutrons formed will be utilized in splitting the uranium atom; and in that manner extraordinary amounts of energy will be liberated, as a first product, by way of the neutrons.

The lithium-D-hydride, recipient, therefore, will be surrounded by a coat of uranium.

Quite possibly a special advantage could be obtained by adding a quantity of uranium D compound to the "large particles" and to the recipient mass; because in this manner a considerable amount of energy will be given off by uranium fragments located within the reaction area, and this state of affairs might possibly result in further increases of temperature within the reaction area. [...]

4. SELF HEATING

Under this subject it will be necessary to distinguish between two types of cases: Self heating of the reaction area, and self heating in the reaction field outside the reaction area proper.

1) If a very great number of atomic reactions comes about within the reaction area itself, the particles charged as a result of these reactions (α, p) will produce heat within the reaction area, increasing the latter's temperature until the entire material within the reaction area is consumed.

2) The alpha rays and protons of high energy resulting from the atomic reactions will pass through the reaction area, penetrating to the latter's "wall;" and they will penetrate much more deeply than the D and Li atoms, since the alpha rays and protons are much richer in energy.

If the alpha, p particles occur in such large numbers about the environs of the reaction area become ionized and heated, there will be formed an external reaction zone within which atomic reactions may likewise occur. Finally, the outer reaction zone will assume such dimensions that even the alpha rays and protons forming the reactions no longer leave that zone, and are compelled by the magnetic field to move along circular paths.

If an external reaction zone of this nature is developed, there will result an explosion of the entire LiD mass, since the external reaction zone is capable of enlarging itself on the strength of its own energy production.

[See document photos on pp. 4308–4312.

Wolfgang Ferrant wrote this report after the war, apparently at the behest of the U.S. Alsos Mission. The report seems to have been based on wartime work that Ferrant conducted, participated in, or was aware of, and he complained in this report that he did not have access to any wartime documents in order to more accurately reconstruct the scientific details.

In writing this report, Ferrant appears to have censored himself and/or to have been censored by U.S. officials. The report primarily focused on proposed methods for controlled fusion reactors using magnetic confinement, and it was amazingly prescient on that topic. However, the report also touched on applications to nuclear explosives, and its insights in that direction were extraordinary. Specifically, the report described:

- Using lithium deuteride as a storable solid fusion fuel with excellent physics properties.

- Harnessing a number of fusion reactions that can occur within the lithium deuteride fuel. Ferrant omitted the ${}^{6}_{3}\mathrm{Li}(\mathrm{n},\alpha){}^{3}_{1}\mathrm{H}$ reaction from his list, likely either because he wrote this report without access to any wartime papers or because he was censored or self-censored. Nonetheless, two of his research colleagues at AEG, Hartmut Kallmann and Ernst Kuhn, filed a patent featuring that reaction in 1939 (p. 4298), so the reaction would have been known to Ferrant.

- Initiating fusion reactions in the lithium deuteride by creating sufficiently high initial temperatures, pressures, and densities in the fuel.

- Creating an explosive chain reaction in which fusion reactions within a small region of the lithium deuteride produce enough radiation, heat, and pressure to induce fusion reactions in surrounding regions of the lithium deuteride.

- Producing large amounts of high-energy fusion neutrons from reactions in the lithium deuteride.

- Surrounding the lithium deuteride with a layer of uranium that would absorb the fusion neutrons, undergo fission reactions, and greatly increase the total energy that is released.

- Utilizing the fission reactions in the uranium to increase the heat and pressure and therefore the fusion reaction rate in the lithium deuteride.

All of these details are directly relevant for producing a hydrogen bomb. Ferrant's report demonstrates that all of these details were known and being actively utilized in wartime Germany.

What exactly did Ferrant work on throughout the war?

During the early part of the war, he worked at AEG in Berlin, alongside Hartmut Kallmann and Ernst Kuhn.

In this report, he mentioned working at a nuclear laboratory in Dresden. (There was at least one independent report of a nuclear laboratory in Dresden, which was apparently part of a secret Reichspost/SS collaboration on nuclear weapons—see p. 4507.) Ferrant referred to the U.S./U.K. firebombing of Dresden on 13–14 February 1945.

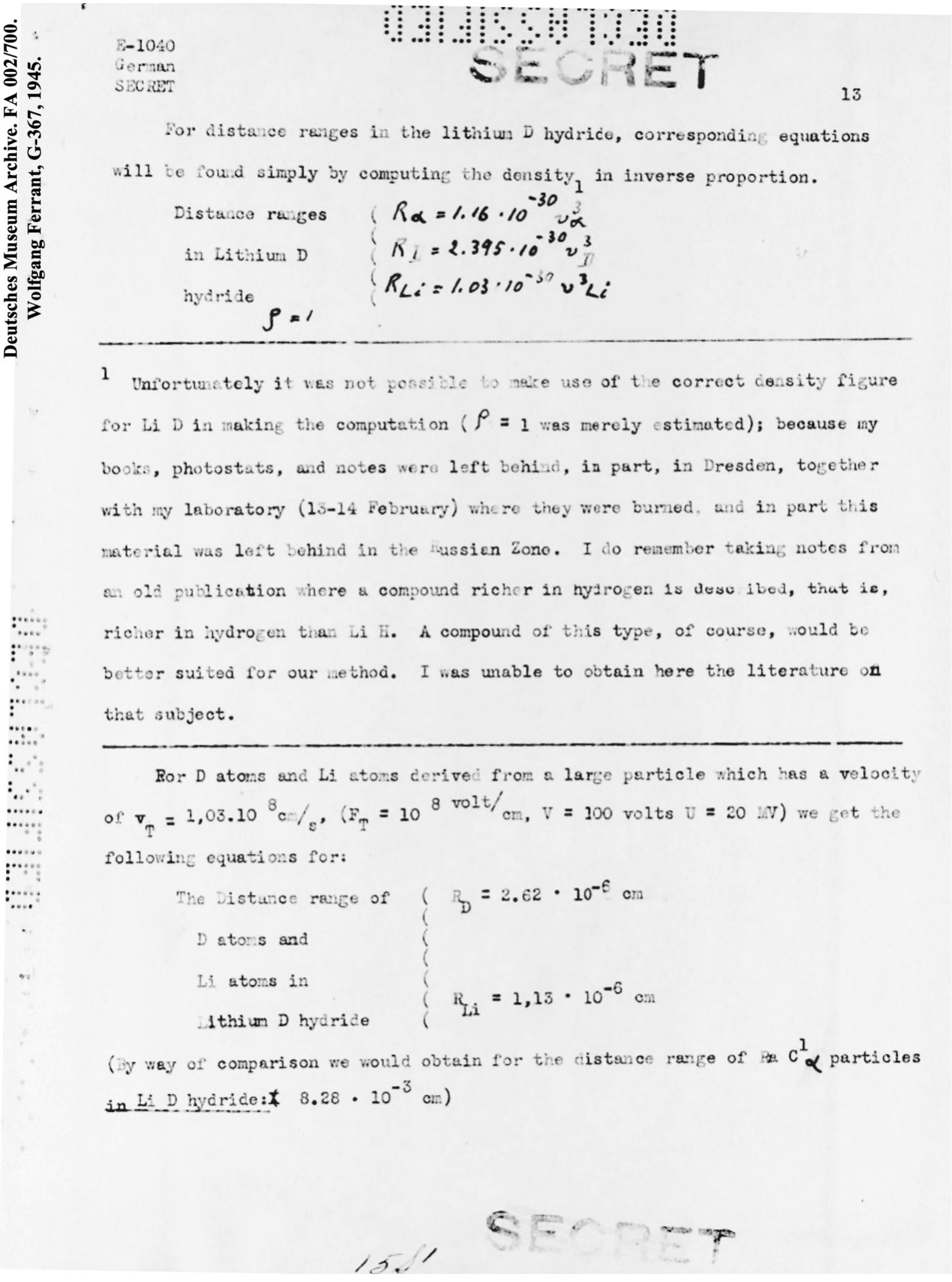
In this report, Ferrant also referenced a letter he had written in Linz in September 1945, so he apparently was working in Austria at the end of the war, or had connections there earlier in the war too. With whom did he work in Austria? AEG had its own "Bauleitung" (construction directorate) at St. Georgen/Gusen near Linz, and St. Georgen appears to have been involved in nuclear work (p. 3874). Did Ferrant work or visit there during the war?

Did Ferrant tell U.S. officials anything that is not in this report? Did he write an uncensored, more highly classified version of this report, or divulge more details in classified interrogations?

After the war, where did Ferrant work, and what did he work on?

Can additional information be located in archives, and declassified if necessary?]

Deutsches Museum Archive. FA 002/700.
Wolfgang Ferrant, G-367, 1945.



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For distance ranges in the lithium D hydride, corresponding equations will be found simply by computing the density[1] in inverse proportion.

Distance ranges ($R_\alpha = 1.16 \cdot 10^{-30} v_\alpha^3$
in Lithium D ($R_D = 2.395 \cdot 10^{-30} v_D^3$
hydride ($R_{Li} = 1.03 \cdot 10^{-30} v^3_{Li}$
$\rho = 1$

---

[1] Unfortunately it was not possible to make use of the correct density figure for Li D in making the computation ($\rho = 1$ was merely estimated); because my books, photostats, and notes were left behind, in part, in Dresden, together with my laboratory (13-14 February) where they were burned, and in part this material was left behind in the Russian Zone. I do remember taking notes from an old publication where a compound richer in hydrogen is described, that is, richer in hydrogen than Li H. A compound of this type, of course, would be better suited for our method. I was unable to obtain here the literature on that subject.

Ror D atoms and Li atoms derived from a large particle which has a velocity of $v_T = 1{,}03.10^8$ cm/s, ($F_T = 10^8$ volt/cm, V = 100 volts U = 20 MV) we get the following equations for:

The Distance range of ($R_D = 2.62 \cdot 10^{-6}$ cm
D atoms and (
Li atoms in (
Lithium D hydride ($R_{Li} = 1{,}13 \cdot 10^{-6}$ cm

(By way of comparison we would obtain for the distance range of Ra C^1_α particles in Li D hydride: x $8.28 \cdot 10^{-3}$ cm)

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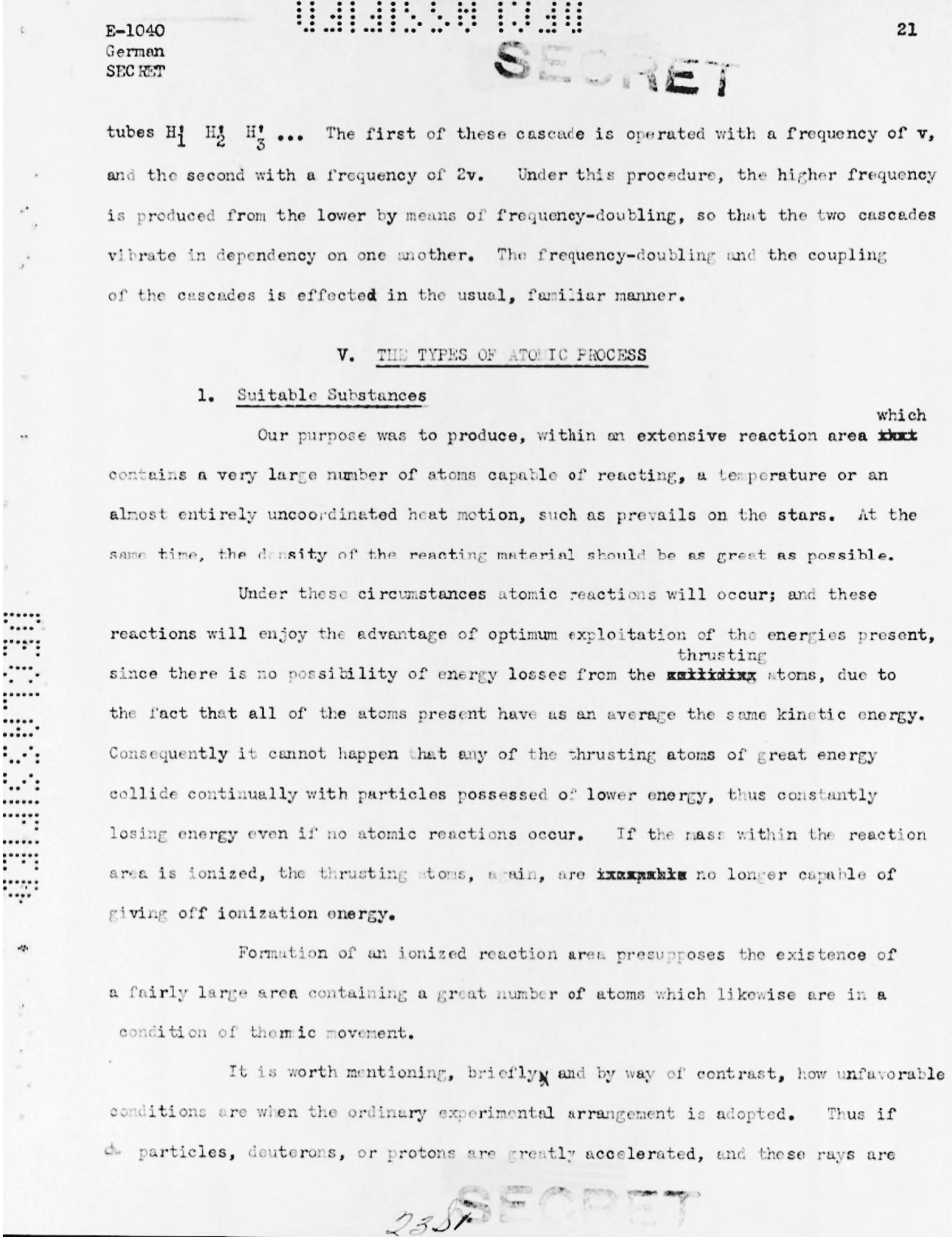
Figure D.613: Excerpts from Wolfgang Ferrant's report G-367 (1945), revealing advanced scientific knowledge of details that are directly applicable to H-bombs [Deutsches Museum Archive FA 002/700].

Deutsches Museum Archive. FA 002/700. Wolfgang Ferrant, G-367, 1945.



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tubes H_1' H_2' H_3' ... The first of these cascade is operated with a frequency of v, and the second with a frequency of 2v. Under this procedure, the higher frequency is produced from the lower by means of frequency-doubling, so that the two cascades vibrate in dependency on one another. The frequency-doubling and the coupling of the cascades is effected in the usual, familiar manner.

V. THE TYPES OF ATOMIC PROCESS

1. Suitable Substances

Our purpose was to produce, within an extensive reaction area ~~that~~ which contains a very large number of atoms capable of reacting, a temperature or an almost entirely uncoordinated heat motion, such as prevails on the stars. At the same time, the density of the reacting material should be as great as possible.

Under these circumstances atomic reactions will occur; and these reactions will enjoy the advantage of optimum exploitation of the energies present, since there is no possibility of energy losses from the thrusting atoms, due to the fact that all of the atoms present have as an average the same kinetic energy. Consequently it cannot happen that any of the thrusting atoms of great energy collide continually with particles possessed of lower energy, thus constantly losing energy even if no atomic reactions occur. If the mass within the reaction area is ionized, the thrusting atoms, again, are no longer capable of giving off ionization energy.

Formation of an ionized reaction area presupposes the existence of a fairly large area containing a great number of atoms which likewise are in a condition of thermic movement.

It is worth mentioning, briefly, and by way of contrast, how unfavorable conditions are when the ordinary experimental arrangement is adopted. Thus if α particles, deuterons, or protons are greatly accelerated, and these rays are

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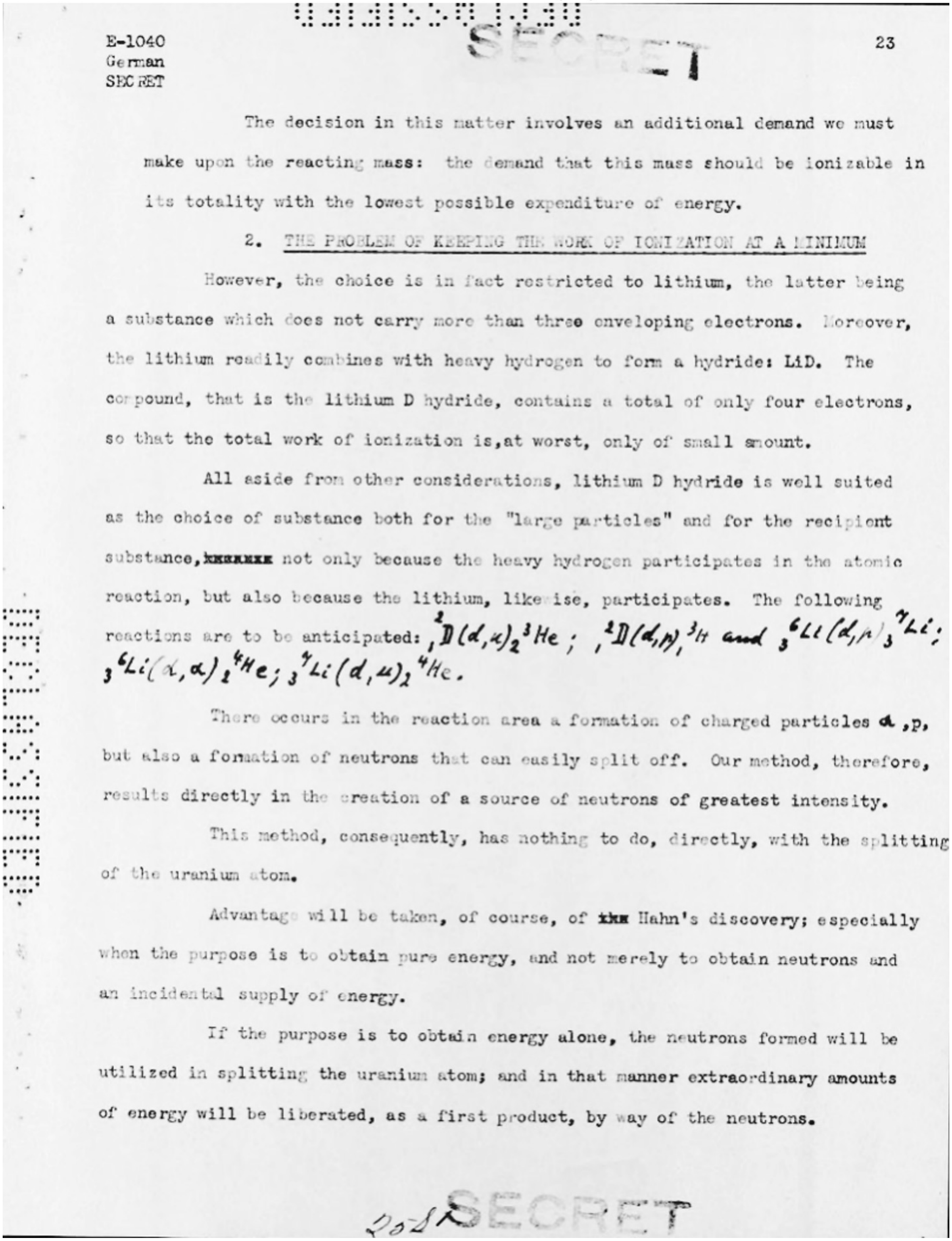
Figure D.614: Excerpts from Wolfgang Ferrant's report G-367 (1945), revealing advanced scientific knowledge of details that are directly applicable to H-bombs [Deutsches Museum Archive FA 002/700].

Deutsches Museum Archive. FA 002/700. Wolfgang Ferrant, G-367, 1945.



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German
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23

The decision in this matter involves an additional demand we must make upon the reacting mass: the demand that this mass should be ionizable in its totality with the lowest possible expenditure of energy.

2. THE PROBLEM OF KEEPING THE WORK OF IONIZATION AT A MINIMUM

However, the choice is in fact restricted to lithium, the latter being a substance which does not carry more than three enveloping electrons. Moreover, the lithium readily combines with heavy hydrogen to form a hydride: LiD. The compound, that is the lithium D hydride, contains a total of only four electrons, so that the total work of ionization is, at worst, only of small amount.

All aside from other considerations, lithium D hydride is well suited as the choice of substance both for the "large particles" and for the recipient substance, xxxxxxx not only because the heavy hydrogen participates in the atomic reaction, but also because the lithium, likewise, participates. The following reactions are to be anticipated: ${}_1^2D(d,n)_2^3He$; ${}_1^2D(d,p)_1^3H$ and ${}_3^6Li(d,p)_3^7Li$; ${}_3^6Li(d,\alpha)_2^4He$; ${}_3^7Li(d,n)_2^4He$.

There occurs in the reaction area a formation of charged particles α, p, but also a formation of neutrons that can easily split off. Our method, therefore, results directly in the creation of a source of neutrons of greatest intensity.

This method, consequently, has nothing to do, directly, with the splitting of the uranium atom.

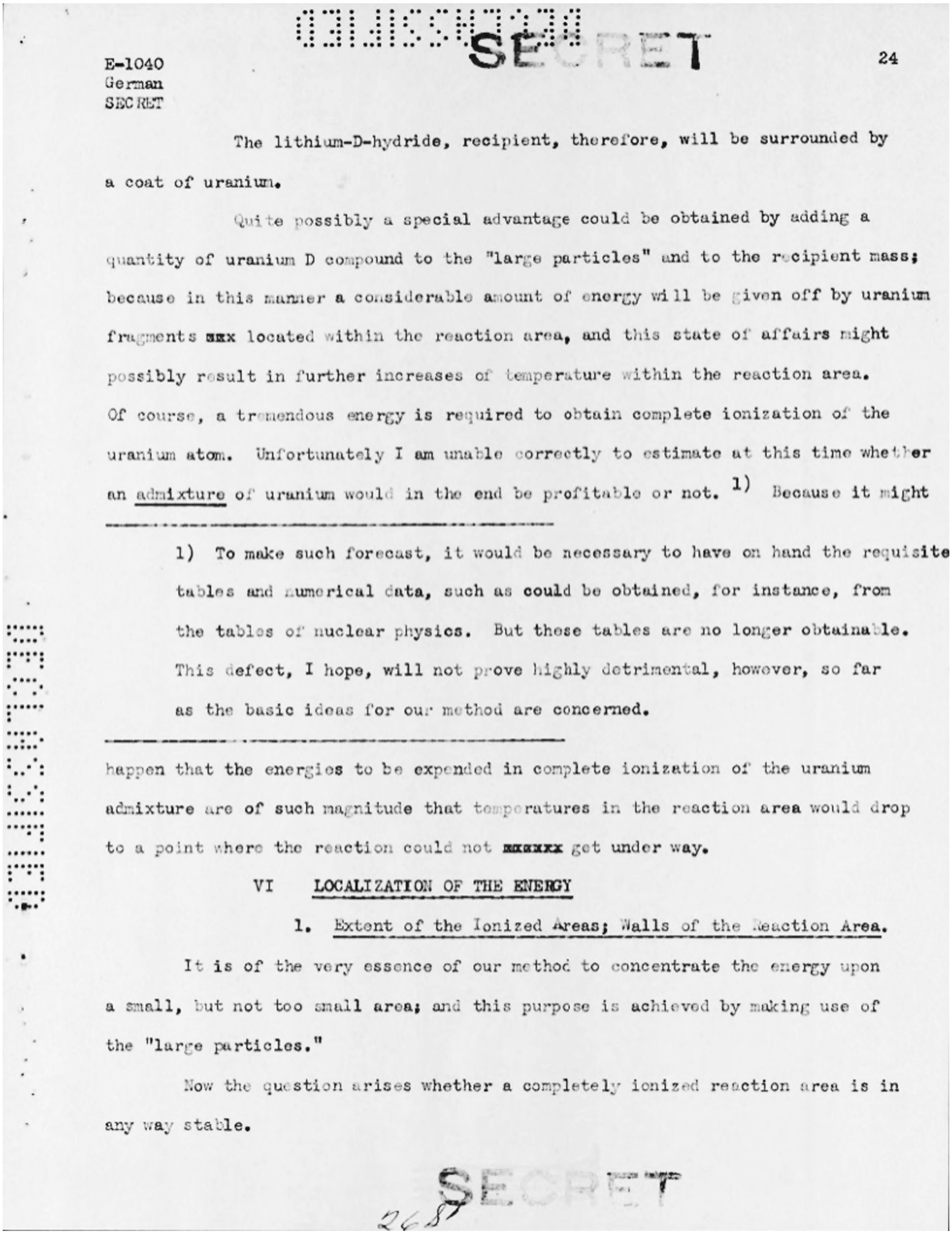
Advantage will be taken, of course, of xhx Hahn's discovery; especially when the purpose is to obtain pure energy, and not merely to obtain neutrons and an incidental supply of energy.

If the purpose is to obtain energy alone, the neutrons formed will be utilized in splitting the uranium atom; and in that manner extraordinary amounts of energy will be liberated, as a first product, by way of the neutrons.

202 SECRET

Figure D.615: Excerpts from Wolfgang Ferrant's report G-367 (1945), revealing advanced scientific knowledge of details that are directly applicable to H-bombs [Deutsches Museum Archive FA 002/700].

Deutsches Museum Archive. FA 002/700. Wolfgang Ferrant, G-367, 1945.



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The lithium-D-hydride, recipient, therefore, will be surrounded by a coat of uranium.

Quite possibly a special advantage could be obtained by adding a quantity of uranium D compound to the "large particles" and to the recipient mass; because in this manner a considerable amount of energy will be given off by uranium fragments xxx located within the reaction area, and this state of affairs might possibly result in further increases of temperature within the reaction area. Of course, a tremendous energy is required to obtain complete ionization of the uranium atom. Unfortunately I am unable correctly to estimate at this time whether an admixture of uranium would in the end be profitable or not. 1) Because it might happen that the energies to be expended in complete ionization of the uranium admixture are of such magnitude that temperatures in the reaction area would drop to a point where the reaction could not xxxxxx get under way.

VI LOCALIZATION OF THE ENERGY

1. Extent of the Ionized Areas; Walls of the Reaction Area.

It is of the very essence of our method to concentrate the energy upon a small, but not too small area; and this purpose is achieved by making use of the "large particles."

Now the question arises whether a completely ionized reaction area is in any way stable.

---

1) To make such forecast, it would be necessary to have on hand the requisite tables and numerical data, such as could be obtained, for instance, from the tables of nuclear physics. But these tables are no longer obtainable. This defect, I hope, will not prove highly detrimental, however, so far as the basic ideas for our method are concerned.

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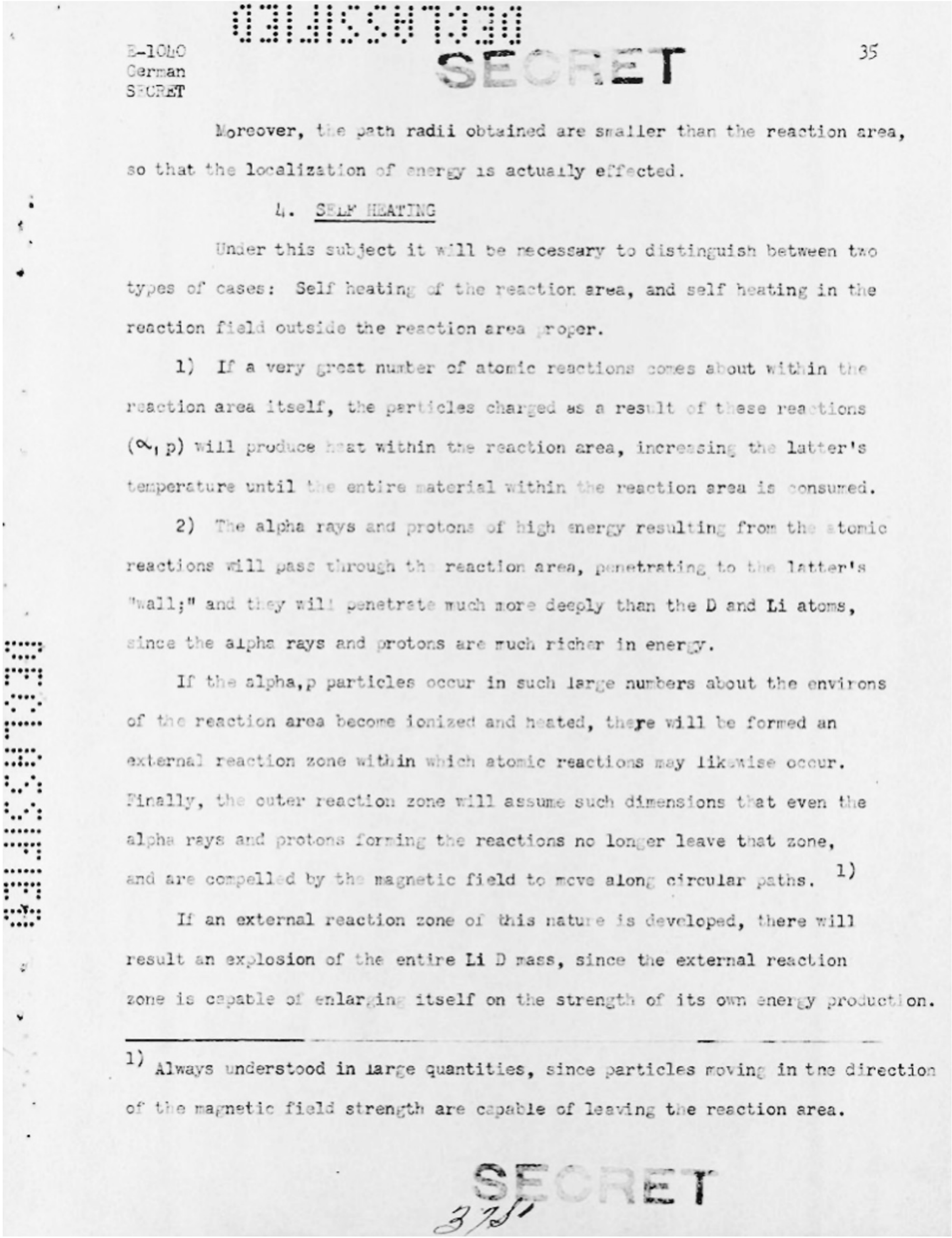
Figure D.616: Excerpts from Wolfgang Ferrant's report G-367 (1945), revealing advanced scientific knowledge of details that are directly applicable to H-bombs [Deutsches Museum Archive FA 002/700].

Deutsches Museum Archive. FA 002/700. Wolfgang Ferrant, G-367, 1945.



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German
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Moreover, the path radii obtained are smaller than the reaction area, so that the localization of energy is actually effected.

4. SELF HEATING

Under this subject it will be necessary to distinguish between two types of cases: Self heating of the reaction area, and self heating in the reaction field outside the reaction area proper.

1) If a very great number of atomic reactions comes about within the reaction area itself, the particles charged as a result of these reactions (α, p) will produce heat within the reaction area, increasing the latter's temperature until the entire material within the reaction area is consumed.

2) The alpha rays and protons of high energy resulting from the atomic reactions will pass through the reaction area, penetrating to the latter's "wall;" and they will penetrate much more deeply than the D and Li atoms, since the alpha rays and protons are much richer in energy.

If the alpha,p particles occur in such large numbers about the environs of the reaction area become ionized and heated, there will be formed an external reaction zone within which atomic reactions may likewise occur. Finally, the outer reaction zone will assume such dimensions that even the alpha rays and protons forming the reactions no longer leave that zone, and are compelled by the magnetic field to move along circular paths. 1)

If an external reaction zone of this nature is developed, there will result an explosion of the entire Li D mass, since the external reaction zone is capable of enlarging itself on the strength of its own energy production.

---

1) Always understood in large quantities, since particles moving in the direction of the magnetic field strength are capable of leaving the reaction area.

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Figure D.617: Excerpts from Wolfgang Ferrant's report G-367 (1945), revealing advanced scientific knowledge of details that are directly applicable to H-bombs [Deutsches Museum Archive FA 002/700].

G-76. G. von Droste. The Absorption Cross Section of Boron and Lithium for Thermal Neutrons. 1941.

Boron absorption cross section = 545 barns. Lithium = 55.6 barns.

G-298. Karl G. Zimmer and Otto Peter. Radiobiological Investigations with Fast Neutrons. 1944.

Biological effects were compared with 180 kV x-ray and Li + D fast neutron total body irradiations on blood, haemopoietic organs and male gonads of rats. Fast neutrons cause noticeable radiation injuries with much smaller dosages than x rays. Effects of intensity of radiation could not be detected in the range of fast neutrons investigated. Secondary radiation injuries in the blood were found for prolonged periods after radiation and speedy recovery after irradiation with neutrons cannot be expected. Urgency of further investigations and determinations of tolerance dosages are emphasized in the interest of personnel working in nuclear physics installations.

G-387. Siemens & Halske Corporation. Cost Estimates for the 1000 kV Neutron Generator for the University of Vienna. 1941–1942.

Blueprints, photographs, and cost estimates for a neutron generator for the Institute of Radioactivity Research of the University of Vienna are included in this report.

Research Work Undertaken by the German Universities and Technical High Schools for the Bevollmaechtigter fuer Hochfrequenztechnik; Independent Research on Associated Subjects [CIOS XXXI-2 p. 74]

[...]

II. PROF. SIZOO of the VRIJE UNIVERSITEIT AMSTERDAM supplied the following information regarding BÖTTCHER:

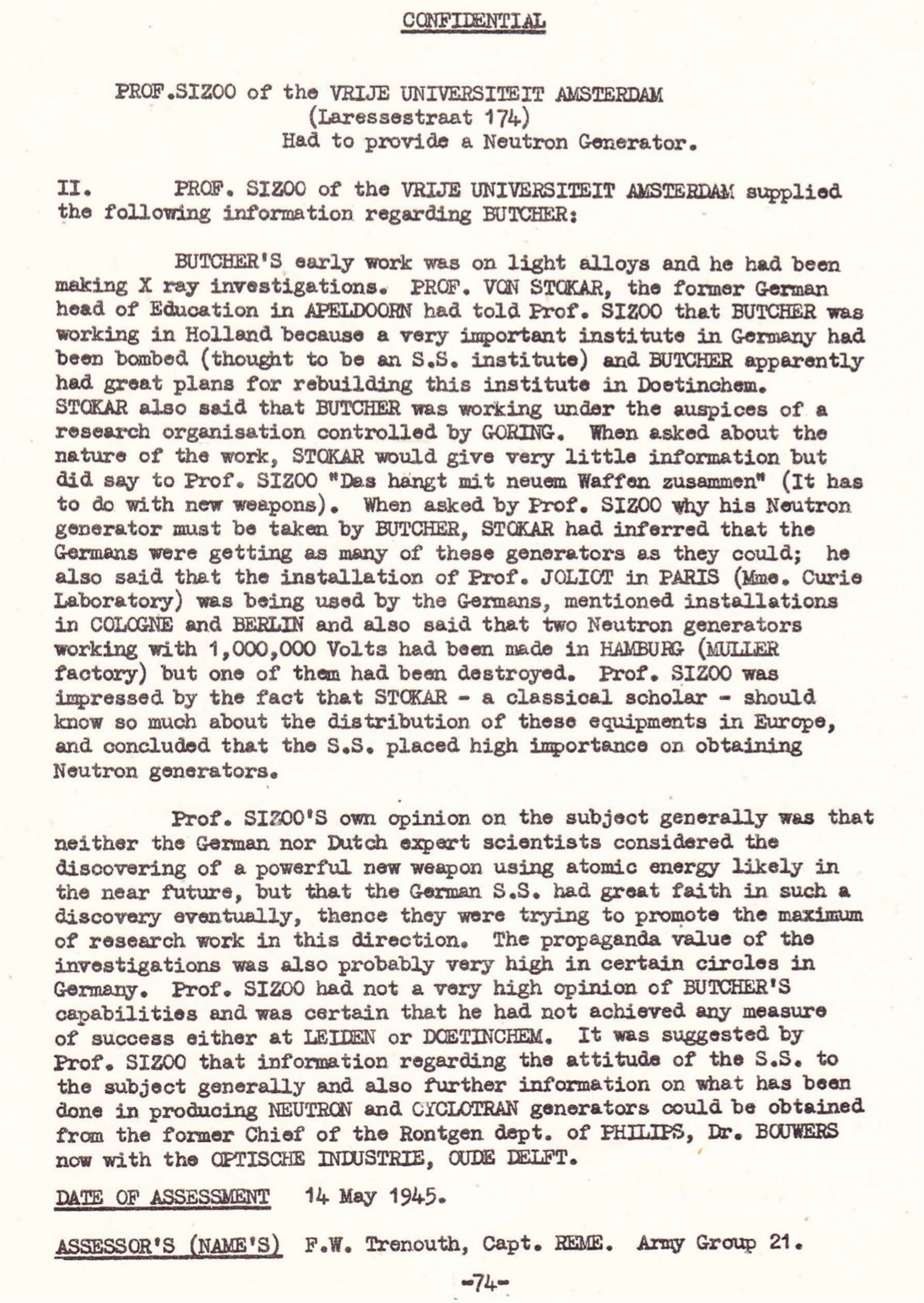
BÖTTCHER'S early work was on light alloys and he had been making X ray investigations. PROF. VON STOKAR, the former German head of Education in APELDOORN had told Prof. SIZOO that BÖTTCHER was working in Holland because a very important institute in Germany had been bombed (thought to be an S.S. institute) and BÖTTCHER apparently had great plans for rebuilding this institute in Doetinchem. STOKAR also said that BÖTTCHER was working under the auspices of a research organization controlled by GÖRING. When asked about the nature of the work, STOKAR would give very little information but did say to Prof. SIZOO "Das hängt mit neuem Waffen zusammen" (It has to do with new weapons). When asked by Prof. SIZOO why his Neutron generator must be taken by BÖTTCHER, STOKAR had inferred that the Germans were getting as many of these generators as they could; he also said that the installation of Prof. JOLIOT in PARIS (Mme. Curie Laboratory) was being used by the Germans, mentioned installations in COLOGNE and BERLIN and also said that two Neutron generators working with 1,000,000 Volts had been made in HAMBURG (MÜLLER factory) but one of them had been destroyed. Prof. SIZOO was impressed by the fact that STOKAR—a classical scholar—should know so much about the distribution of these equipments in Europe, and concluded that the S.S. placed high importance on obtaining Neutron generators.

[...] It was suggested by Prof. SIZOO that information regarding the attitude of the S.S. to the subject generally and also further information on what has been done in producing NEUTRON and CYCLOTRON generators could be obtained from the former Chief of the Röntgen dept. of PHILIPS, Dr. BOUWERS now with the OPTISCHE INDUSTRIE, OUDE DELFT.

DATE OF ASSESSMENT 14 May 1945.

ASSESSOR'S (NAME'S) F.W. Trenouth, Capt. REME. Army Group 21.

[See document photo on p. 4315.]



CONFIDENTIAL

PROF.SIZOO of the VRIJE UNIVERSITEIT AMSTERDAM
(Laressestraat 174)
Had to provide a Neutron Generator.

II. PROF. SIZOO of the VRIJE UNIVERSITEIT AMSTERDAM supplied the following information regarding BUTCHER:

BUTCHER'S early work was on light alloys and he had been making X ray investigations. PROF. VON STOKAR, the former German head of Education in APELDOORN had told Prof. SIZOO that BUTCHER was working in Holland because a very important institute in Germany had been bombed (thought to be an S.S. institute) and BUTCHER apparently had great plans for rebuilding this institute in Doetinchem. STOKAR also said that BUTCHER was working under the auspices of a research organisation controlled by GORING. When asked about the nature of the work, STOKAR would give very little information but did say to Prof. SIZOO "Das hangt mit neuem Waffen zusammen" (It has to do with new weapons). When asked by Prof. SIZOO why his Neutron generator must be taken by BUTCHER, STOKAR had inferred that the Germans were getting as many of these generators as they could; he also said that the installation of Prof. JOLIOT in PARIS (Mme. Curie Laboratory) was being used by the Germans, mentioned installations in COLOGNE and BERLIN and also said that two Neutron generators working with 1,000,000 Volts had been made in HAMBURG (MULLER factory) but one of them had been destroyed. Prof. SIZOO was impressed by the fact that STOKAR - a classical scholar - should know so much about the distribution of these equipments in Europe, and concluded that the S.S. placed high importance on obtaining Neutron generators.

Prof. SIZOO'S own opinion on the subject generally was that neither the German nor Dutch expert scientists considered the discovering of a powerful new weapon using atomic energy likely in the near future, but that the German S.S. had great faith in such a discovery eventually, thence they were trying to promote the maximum of research work in this direction. The propaganda value of the investigations was also probably very high in certain circles in Germany. Prof. SIZOO had not a very high opinion of BUTCHER'S capabilities and was certain that he had not achieved any measure of success either at LEIDEN or DOETINCHEM. It was suggested by Prof. SIZOO that information regarding the attitude of the S.S. to the subject generally and also further information on what has been done in producing NEUTRON and CYCLOTRAN generators could be obtained from the former Chief of the Rontgen dept. of PHILIPS, Dr. BOUWERS now with the OPTISCHE INDUSTRIE, OUDE DELFT.

DATE OF ASSESSMENT 14 May 1945.

ASSESSOR'S (NAME'S) F.W. Trenouth, Capt. REME. Army Group 21.

-74-

CIOS XXXI-2 p. 74

Figure D.618: Research Work Undertaken by the German Universities and Technical High Schools for the Bevollmaechtigter fuer Hochfrequenztechnik; Independent Research on Associated Subjects [CIOS XXXI-2 p. 74]

Visit to Eindhoven, Holland, October 1944 [CIOS X-13 Appendix B]

Developments in Germany of Radiological Apparatus and Applications

Very little real information was known at Philips, Eindhoven, Holland, or in German occupied countries but the following points were notes as being potentially interesting: [...]

3. Dr. Böttcher, Research Station at Doetinchem, Holland, is stated to have collected ultra-high voltage X-ray apparatus up to 5 million volts.

4. F. Kirchner (Köln) is reported to have built a 5 million volt Van de Graaff machine.

5. Mattauch & Hahn, Kaiser Wilhelm Institut (Berlin-Dahlem) are said to have built similar machines.

The same Institute is reputed to have in operation a 2 million volt Müller Cascade generator.

6. K.W. Institut für Hirnforschung (Berlin Buch)

Dr. Karl Zimmer is known to have been working on a neutron generator of 600 k.v. and in one of his laboratories there was seen in July, 1943, a few boxes (20 x 30 x 30 cms) filled with Uranium.

It is not known whether any work was done on the separation of isotopes of Uranium.

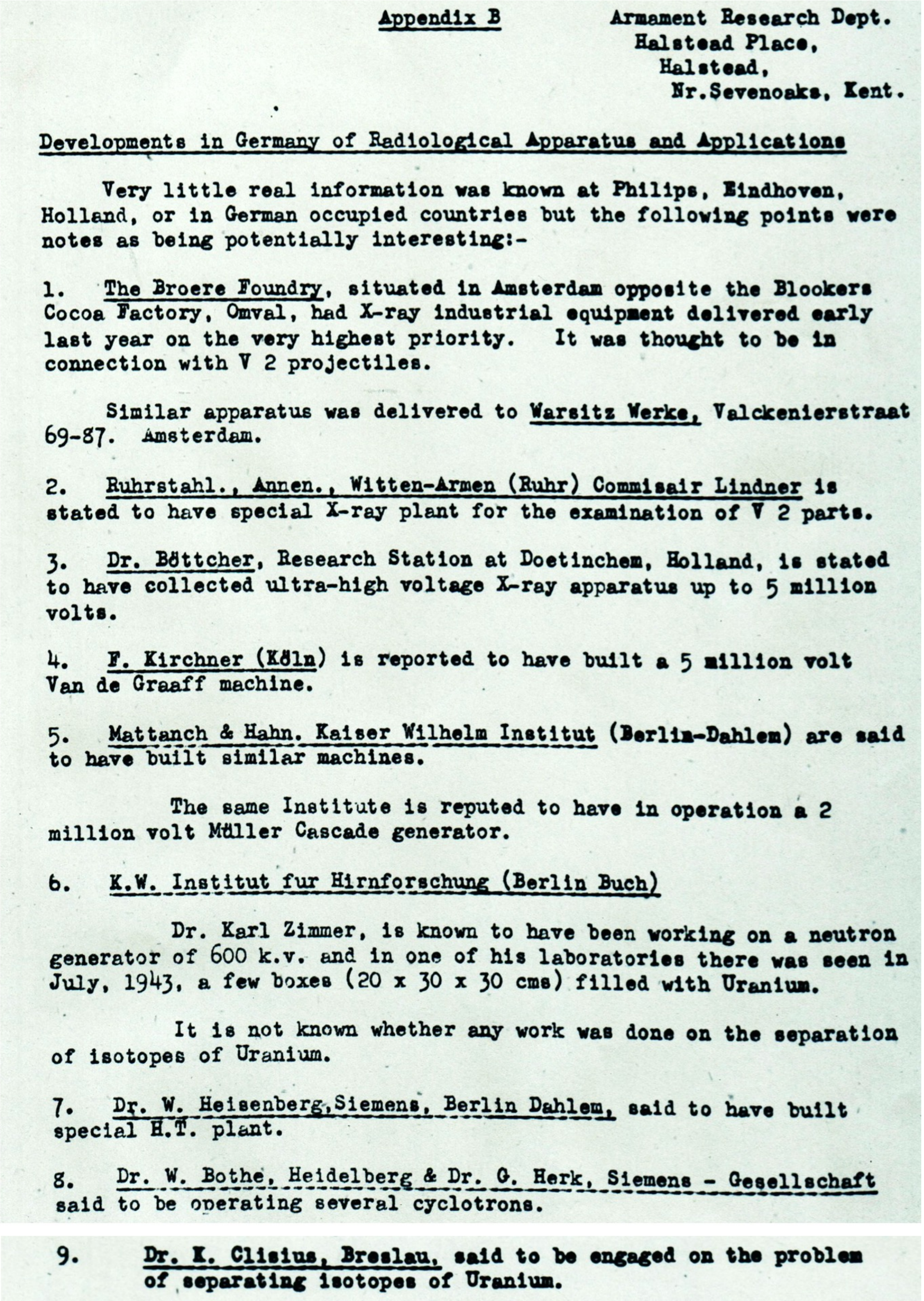
7. Dr. W. Heisenberg, Siemens, Berlin Dahlem, said to have built special H.T. plant.

8. Dr. W. Bothe, Heidelberg & Dr. G. Herk, Siemens-Gesellschaft said to be operating several cyclotrons.

9. Dr. K. Clusius, Breslau, said to be engaged on the problem of separating isotopes of Uranium.

[See document photos on p. 4317.]

CIOS X-13 Appendix B



Appendix B

Armament Research Dept.
Halstead Place,
Halstead,
Nr.Sevenoaks, Kent.

Developments in Germany of Radiological Apparatus and Applications

Very little real information was known at Philips, Eindhoven, Holland, or in German occupied countries but the following points were notes as being potentially interesting:-

1. The Broere Foundry, situated in Amsterdam opposite the Blookers Cocoa Factory, Omval, had X-ray industrial equipment delivered early last year on the very highest priority. It was thought to be in connection with V 2 projectiles.

Similar apparatus was delivered to Warsitz Werke, Valckenierstraat 69-87. Amsterdam.

2. Ruhrstahl., Annen., Witten-Armen (Ruhr) Commisair Lindner is stated to have special X-ray plant for the examination of V 2 parts.

3. Dr. Böttcher, Research Station at Doetinchem, Holland, is stated to have collected ultra-high voltage X-ray apparatus up to 5 million volts.

4. F. Kirchner (Köln) is reported to have built a 5 million volt Van de Graaff machine.

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Figure D.619: Visit to Eindhoven, Holland, October 1944 [CIOS X-13 Appendix B]

CIOS XXVIII-31. ***Investigation of the X-Ray Industry in Germany.*** [See document photos on pp. 3957–3970.]

During the past two years, C. H. F. Müller has constructed and delivered five "neutron generators". Three of these were rated at 1.5 megavolts, one at 1.2 megavolts, and one at .9 megavolts. They have on order, but have not yet completed, one additional neutron generator rated at .9 megavolts and another rated at 2.4 megavolts. These "neutron generators", or "deuteron accelerators", accelerate ionized heavy hydrogen against a beryllium or a lithium target. The neutron output at .9 megavolts when using a beryllium target was estimated to be equivalent to the neutron output of 2 kilograms of radium plus beryllium [$3.0 \cdot 10^{10}$ neutrons/sec]; when using a lithium target, 3 kilograms [$4.6 \cdot 10^{10}$ neutrons/sec]; when using a beryllium target at 1.5 megavolts, 13 kilograms [$2.0 \cdot 10^{11}$ neutrons/sec]; when using a lithium target, 8 kilograms [$1.2 \cdot 10^{11}$ neutrons/sec].

The Phillips "cascade" circuit was used for these neutron generators. Although the electrical output of these generators could be as high as 5 ma., the ion source limited this equipment to 0.8 ma. for continuous operation, regardless of the voltage.

CIOS ER 63. [AFHRA folder 506.6202 Nr. 1–99 20 Apr–13 Jun 1945, IRIS 207658; AFHRA A5189 frames 0708–0709] [See document photo on p. 4319.]

INTERROGATION OF DR. HANS RITZ

MANAGING DIRECTOR OF C.H.F. MÜLLER AT RÖNTGENSTRASSE,

FUHLSBÜTTEL, HAMBURG

May 11, 1945

In November and December 1945, Ritz was experimenting in the manufacture of infra red tubes to be installed in a mobile set for use by the Wehrmacht. Though all three services were probably interested in his production Ritz came into contact only with the army. He was working in conjunction with the firm of A.E.G. Berlin and delivered to them and to the Wehrmacht itself. His factory is located in Greiz, Thüringen. [...]

The firm also has a factory at Freiburg in Schlesien.

Ritz also proudly stated that he had been engaged on research work connected with splitting the atom and hinted that this was far enough advanced for the Europeans to combine forces and develop this "terrific" potential energy for use in any future war with the Asiatics. The subject was not pursued owing to the complete lack of knowledge on the part of the interrogator.

Robert R. Furman to John Lansdale Jr. and Francis J. Smith. 7 June 1945. [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA] [See photo p. 4320.]

1. The interrogation of Dr. Hans Ritz revealed that Ritz was experimenting in the manufacture of infra-red tubes which was his main scientific research project. However, the following is quoted from a CIOS report of 11 May 1945 made by S. Wheeler, Captain, R. M. (It should be recalled that Müller had a small tonnage of U_3O_8). [...]

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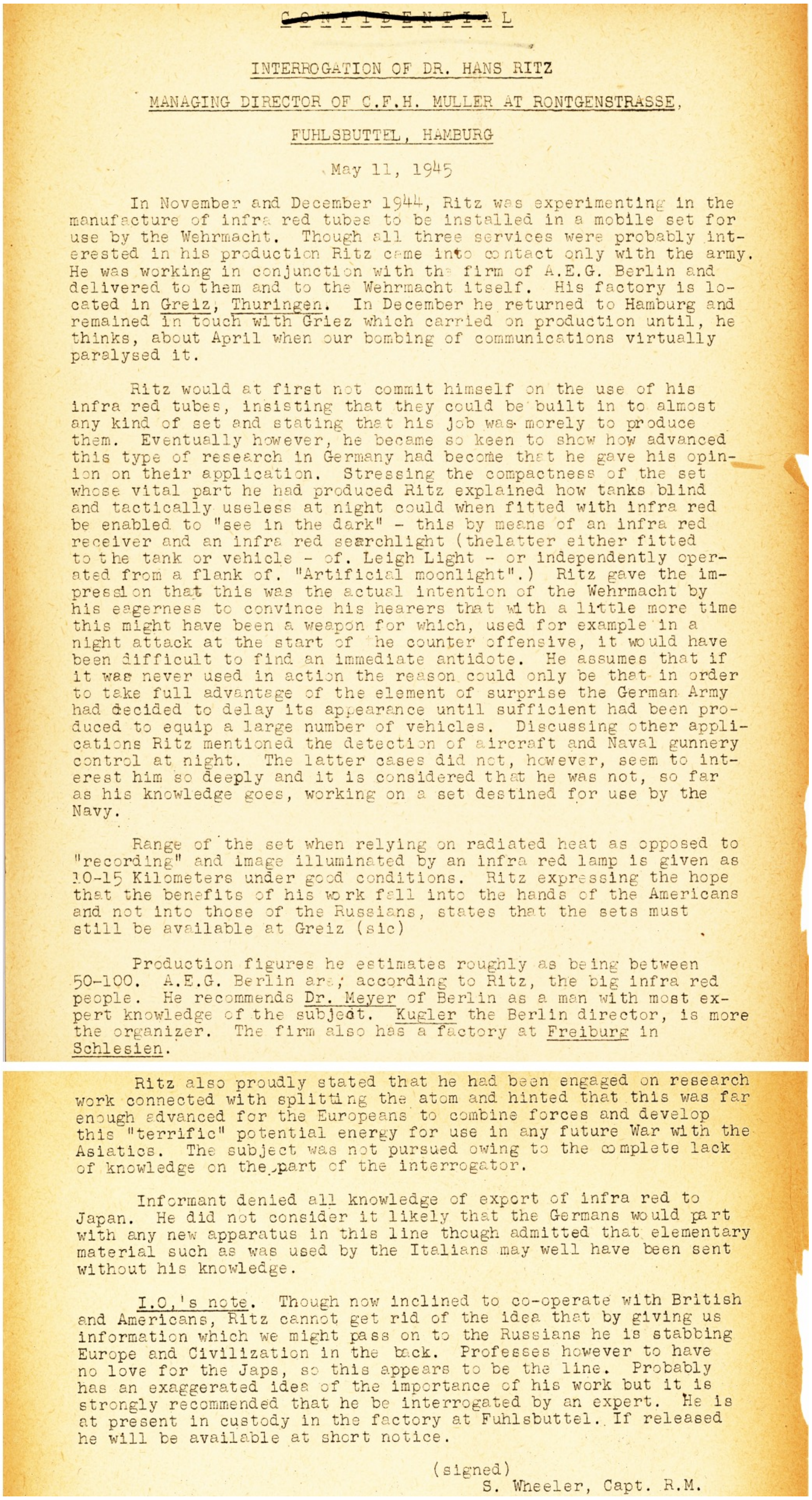
CIOS ER 63, AFHRA folder 506.6202 Nr. 1-99 20 Apr--13 Jun 1945, IRIS 207658



~~CONFIDENTIA~~L

INTERROGATION OF DR. HANS RITZ

MANAGING DIRECTOR OF C.F.H. MULLER AT RONTGENSTRASSE,

FUHLSBUTTEL, HAMBURG

May 11, 1945

In November and December 1944, Ritz was experimenting in the manufacture of infra red tubes to be installed in a mobile set for use by the Wehrmacht. Though all three services were probably interested in his production Ritz came into contact only with the army. He was working in conjunction with the firm of A.E.G. Berlin and delivered to them and to the Wehrmacht itself. His factory is located in Greiz, Thuringen. In December he returned to Hamburg and remained in touch with Griez which carried on production until, he thinks, about April when our bombing of communications virtually paralysed it.

Ritz would at first not commit himself on the use of his infra red tubes, insisting that they could be built in to almost any kind of set and stating that his job was morely to produce them. Eventually however, he became so keen to show how advanced this type of research in Germany had become that he gave his opinion on their application. Stressing the compactness of the set whose vital part he had produced Ritz explained how tanks blind and tactically useless at night could when fitted with infra red be enabled to "see in the dark" - this by means of an infra red receiver and an infra red searchlight (thelatter either fitted to the tank or vehicle - cf. Leigh Light - or independently operated from a flank cf. "Artificial moonlight".) Ritz gave the impression that this was the actual intention of the Wehrmacht by his eagerness to convince his hearers that with a little more time this might have been a weapon for which, used for example in a night attack at the start of the counter offensive, it would have been difficult to find an immediate antidote. He assumes that if it was never used in action the reason could only be that in order to take full advantage of the element of surprise the German Army had decided to delay its appearance until sufficient had been produced to equip a large number of vehicles. Discussing other applications Ritz mentioned the detection of aircraft and Naval gunnery control at night. The latter cases did not, however, seem to interest him so deeply and it is considered that he was not, so far as his knowledge goes, working on a set destined for use by the Navy.

Range of the set when relying on radiated heat as opposed to "recording" and image illuminated by an infra red lamp is given as 10-15 Kilometers under good conditions. Ritz expressing the hope that the benefits of his work fall into the hands of the Americans and not into those of the Russians, states that the sets must still be available at Greiz (sic)

Production figures he estimates roughly as being between 50-100. A.E.G. Berlin are; according to Ritz, the big infra red people. He recommends Dr. Meyer of Berlin as a man with most expert knowledge of the subject. Kugler the Berlin director, is more the organizer. The firm also has a factory at Freiburg in Schlesien.

Ritz also proudly stated that he had been engaged on research work connected with splitting the atom and hinted that this was far enough advanced for the Europeans to combine forces and develop this "terrific" potential energy for use in any future War with the Asiatics. The subject was not pursued owing to the complete lack of knowledge on the part of the interrogator.

Informant denied all knowledge of export of infra red to Japan. He did not consider it likely that the Germans would part with any new apparatus in this line though admitted that elementary material such as was used by the Italians may well have been sent without his knowledge.

I.O.'s note. Though now inclined to co-operate with British and Americans, Ritz cannot get rid of the idea that by giving us information which we might pass on to the Russians he is stabbing Europe and Civilization in the back. Professes however to have no love for the Japs, so this appears to be the line. Probably has an exaggerated idea of the importance of his work but it is strongly recommended that he be interrogated by an expert. He is at present in custody in the factory at Fuhlsbuttel. If released he will be available at short notice.

(signed)
S. Wheeler, Capt. R.M.

Figure D.620: Dr. Hans Ritz, the managing director of C. H. F. Müller, admitted that the company had been making components suitable for use in nuclear weapons. [CIOS ER 63, AFHRA folder 506.6202 Nr. 1–99 20 Apr–13 Jun 1945, IRIS 207658; AFHRA A5189 frames 0708–0709].

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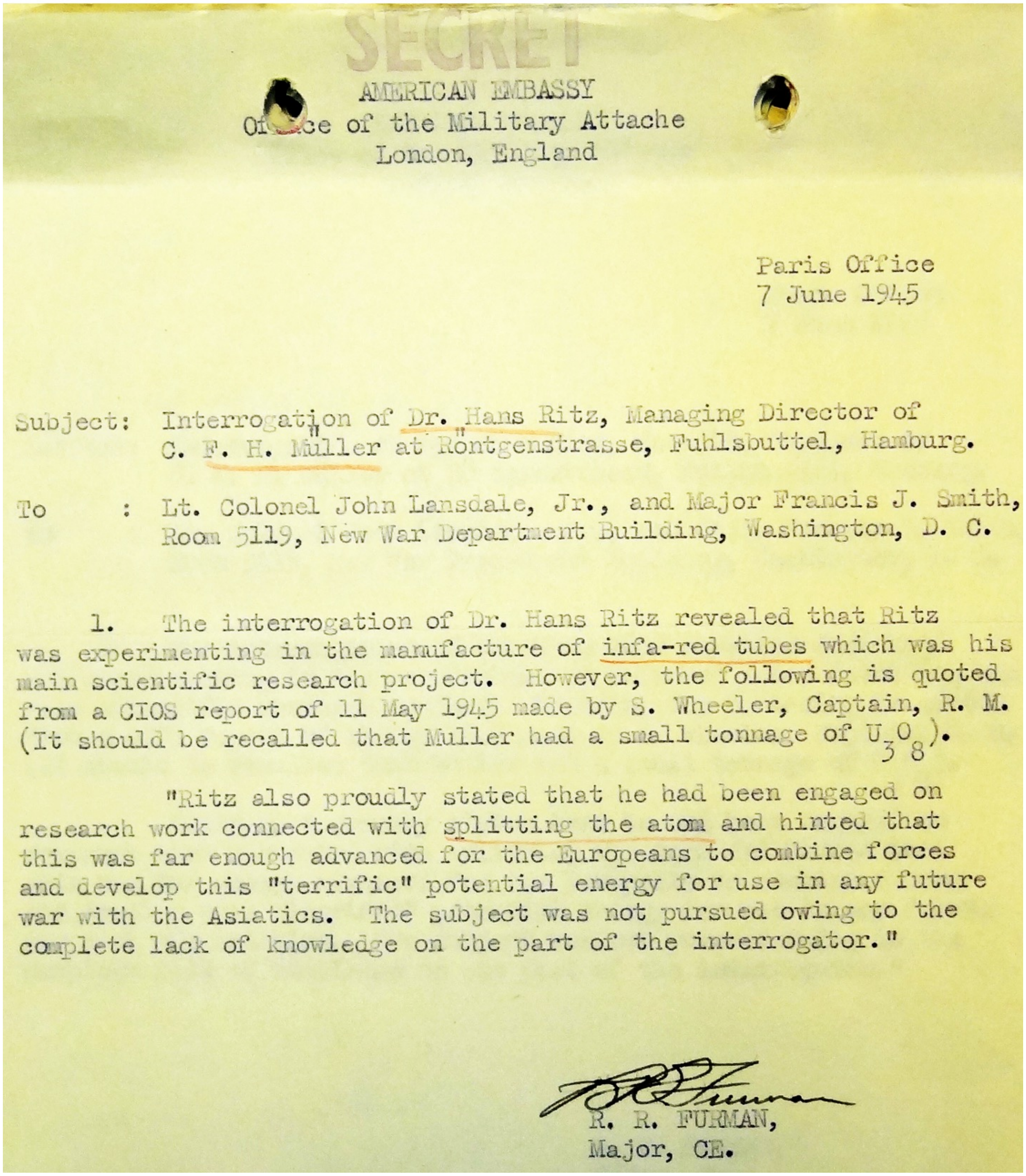
Authority NND917017

NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Incl. TA



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AMERICAN EMBASSY
Office of the Military Attache
London, England

Paris Office
7 June 1945

Subject: Interrogation of Dr. Hans Ritz, Managing Director of C. F. H. Müller at Röntgenstrasse, Fuhlsbuttel, Hamburg.

To : Lt. Colonel John Lansdale, Jr., and Major Francis J. Smith, Room 5119, New War Department Building, Washington, D. C.

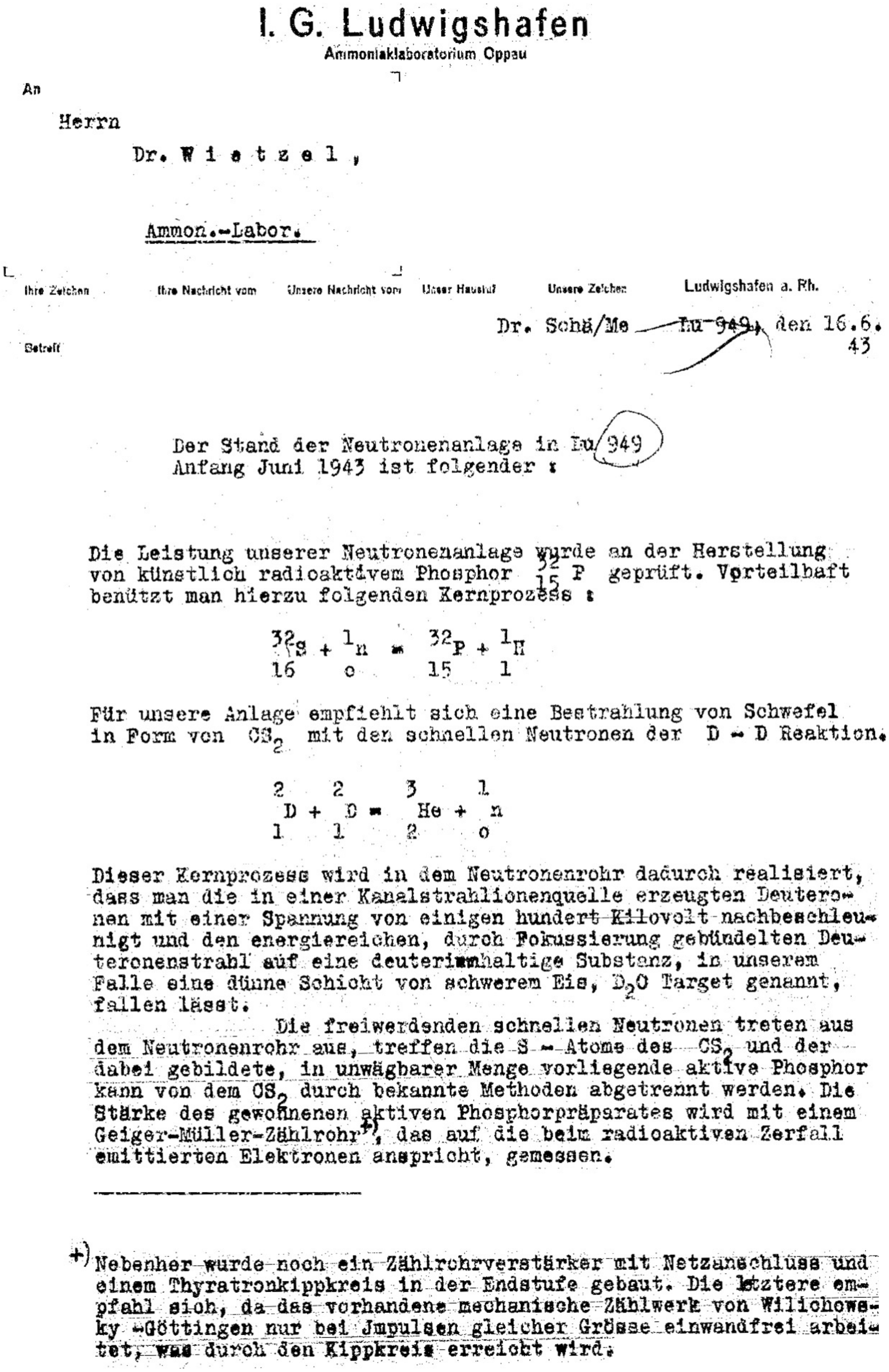
1. The interrogation of Dr. Hans Ritz revealed that Ritz was experimenting in the manufacture of infa-red tubes which was his main scientific research project. However, the following is quoted from a CIOS report of 11 May 1945 made by S. Wheeler, Captain, R. M. (It should be recalled that Muller had a small tonnage of U_3O_8).

"Ritz also proudly stated that he had been engaged on research work connected with splitting the atom and hinted that this was far enough advanced for the Europeans to combine forces and develop this "terrific" potential energy for use in any future war with the Asiatics. The subject was not pursued owing to the complete lack of knowledge on the part of the interrogator."

R. R. Furman
R. R. FURMAN,
Major, CE.

Figure D.621: Dr. Hans Ritz, the managing director of C. H. F. Müller, admitted that the company had been making components suitable for use in nuclear weapons. The company also possessed a large amount of uranium. Robert R. Furman to John Lansdale Jr. and Francis J. Smith. 7 June 1945 [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Technical Oil Mission Microfilm 119 (BM-6 – Ludwigshaven), Folder LU III-2.
www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOM-119-0001-0100.pdf



I. G. Ludwigshafen
Ammoniaklaboratorium Oppau

An

Herrn
Dr. Wietzel,

Ammon.-Labor.

Ihre Zeichen | Ihre Nachricht vom | Unsere Nachricht vom | Unser Hausruf | Unsere Zeichen | Ludwigshafen a. Rh.

Dr. Schä/Me ~~Lu 949~~, den 16.6.43

Betreff

Der Stand der Neutronenanlage in Lu 949 Anfang Juni 1943 ist folgender :

Die Leistung unserer Neutronenanlage wurde an der Herstellung von künstlich radioaktivem Phosphor $^{32}_{15}P$ geprüft. Vorteilhaft benützt man hierzu folgenden Kernprozess :

$$^{32}_{16}S + ^{1}_{0}n = ^{32}_{15}P + ^{1}_{1}H$$

Für unsere Anlage empfiehlt sich eine Bestrahlung von Schwefel in Form von CS_2 mit den schnellen Neutronen der D - D Reaktion.

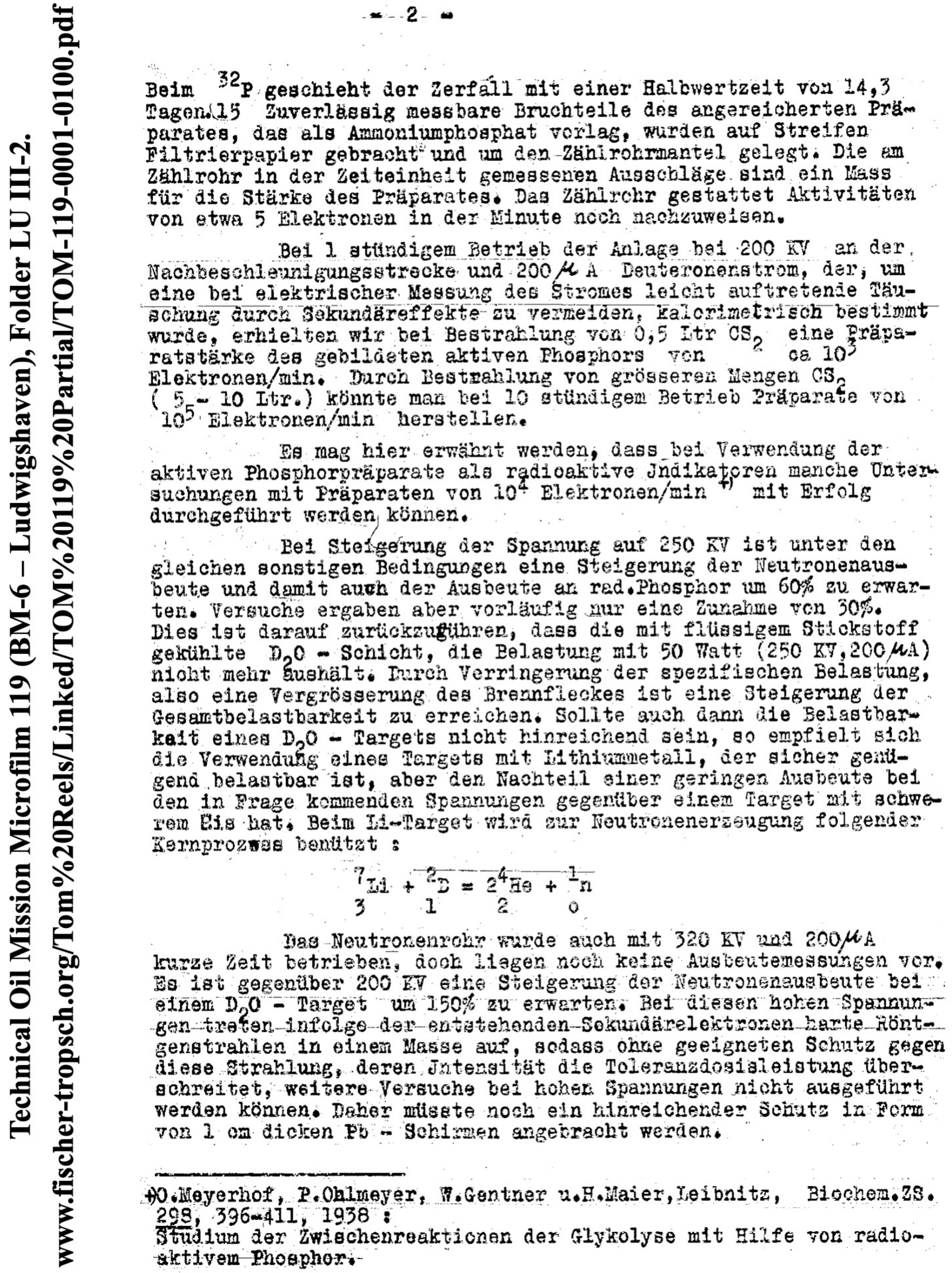
$$^{2}_{1}D + ^{2}_{1}D = ^{3}_{2}He + ^{1}_{0}n$$

Dieser Kernprozess wird in dem Neutronenrohr dadurch realisiert, dass man die in einer Kanalstrahlionenquelle erzeugten Deuteronen mit einer Spannung von einigen hundert Kilovolt nachbeschleunigt und den energiereichen, durch Fokussierung gebündelten Deuteronenstrahl auf eine deuteriumhaltige Substanz, in unserem Falle eine dünne Schicht von schwerem Eis, D_2O Target genannt, fallen lässt.

Die freiwerdenden schnellen Neutronen treten aus dem Neutronenrohr aus, treffen die S - Atome des CS_2 und der dabei gebildete, in unwägbarer Menge vorliegende aktive Phosphor kann von dem CS_2 durch bekannte Methoden abgetrennt werden. Die Stärke des gewonnenen aktiven Phosphorpräparates wird mit einem Geiger-Müller-Zählrohr+), das auf die beim radioaktiven Zerfall emittierten Elektronen anspricht, gemessen.

+) Nebenher wurde noch ein Zählrohrverstärker mit Netzanschluss und einem Thyratronkippkreis in der Endstufe gebaut. Die letztere empfahl sich, da das vorhandene mechanische Zählwerk von Willichowsky -Göttingen nur bei Jmpulsen gleicher Grösse einwandfrei arbeitet, was durch den Kippkreis erreicht wird.

Figure D.622: This document demonstrates that scientists in Germany had been routinely using deuterium + deuterium and lithium + deuterium fusion reactions (in high-voltage tubes) as neutron sources for experiments during the war. [Technical Oil Mission Microfilm 119 (BM-6—Ludwigshaven), Folder LU III-2. https://www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOC_TOM-119.htm]



Technical Oil Mission Microfilm 119 (BM-6 – Ludwigshaven), Folder LU III-2.
www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOM-119-0001-0100.pdf

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Beim ^{32}P geschieht der Zerfall mit einer Halbwertzeit von 14,3 Tagen.15 Zuverlässig messbare Bruchteile des angereicherten Präparates, das als Ammoniumphosphat vorlag, wurden auf Streifen Filtrierpapier gebracht und um den Zählrohrmantel gelegt. Die am Zählrohr in der Zeiteinheit gemessenen Ausschläge sind ein Mass für die Stärke des Präparates. Das Zählrohr gestattet Aktivitäten von etwa 5 Elektronen in der Minute noch nachzuweisen.

Bei 1 stündigem Betrieb der Anlage bei 200 KV an der Nachbeschleunigungsstrecke und 200 μA Deuteronenstrom, der, um eine bei elektrischer Messung des Stromes leicht auftretende Täuschung durch Sekundäreffekte zu vermeiden, kalorimetrisch bestimmt wurde, erhielten wir bei Bestrahlung von 0,5 Ltr CS$_2$ eine Präparatstärke des gebildeten aktiven Phosphors von ca 10^3 Elektronen/min. Durch Bestrahlung von grösseren Mengen CS$_2$ (5 - 10 Ltr.) könnte man bei 10 stündigem Betrieb Präparate von 10^5 Elektronen/min herstellen.

Es mag hier erwähnt werden, dass bei Verwendung der aktiven Phosphorpräparate als radioaktive Indikatoren manche Untersuchungen mit Präparaten von 10^4 Elektronen/min +) mit Erfolg durchgeführt werden können.

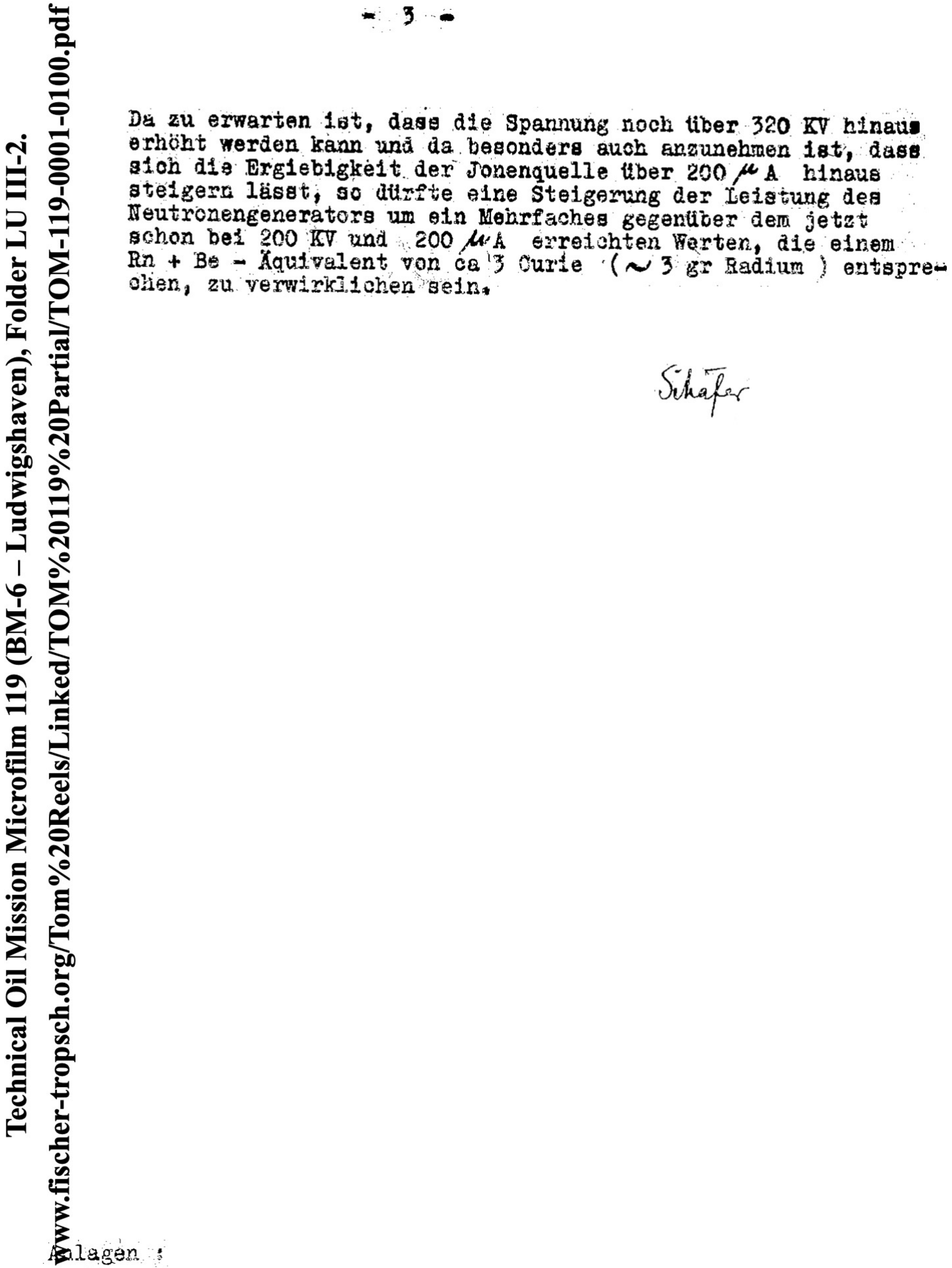
Bei Steigerung der Spannung auf 250 KV ist unter den gleichen sonstigen Bedingungen eine Steigerung der Neutronenausbeute und damit auch der Ausbeute an rad.Phosphor um 60% zu erwarten. Versuche ergaben aber vorläufig nur eine Zunahme von 30%. Dies ist darauf zurückzuführen, dass die mit flüssigem Stickstoff gekühlte D$_2$O - Schicht, die Belastung mit 50 Watt (250 KV,200 μA) nicht mehr aushält. Durch Verringerung der spezifischen Belastung, also eine Vergrösserung des Brennfleckes ist eine Steigerung der Gesamtbelastbarkeit zu erreichen. Sollte auch dann die Belastbarkeit eines D$_2$O - Targets nicht hinreichend sein, so empfielt sich die Verwendung eines Targets mit Lithiummetall, der sicher genügend belastbar ist, aber den Nachteil einer geringen Ausbeute bei den in Frage kommenden Spannungen gegenüber einem Target mit schwerem Eis hat. Beim Li-Target wird zur Neutronenerzeugung folgender Kernprozess benützt :

$${}^{7}_{3}\mathrm{Li} + {}^{2}_{1}\mathrm{D} = 2\,{}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$$

Das Neutronenrohr wurde auch mit 320 KV und 200 μA kurze Zeit betrieben, doch liegen noch keine Ausbeutemessungen vor. Es ist gegenüber 200 KV eine Steigerung der Neutronenausbeute bei einem D$_2$O - Target um 150% zu erwarten. Bei diesen hohen Spannungen treten infolge der entstehenden Sekundärelektronen harte Röntgenstrahlen in einem Masse auf, sodass ohne geeigneten Schutz gegen diese Strahlung, deren Intensität die Toleranzdosisleistung überschreitet, weitere Versuche bei hohen Spannungen nicht ausgeführt werden können. Daher müsste noch ein hinreichender Schutz in Form von 1 cm dicken Pb - Schirmen angebracht werden.

+) O.Meyerhof, P.Ohlmeyer, W.Gentner u.H.Maier,Leibnitz, Biochem.ZS. 298, 396-411, 1938 : Studium der Zwischenreaktionen der Glykolyse mit Hilfe von radioaktivem Phosphor.

Figure D.623: This document demonstrates that scientists in Germany had been routinely using deuterium + deuterium and lithium + deuterium fusion reactions (in high-voltage tubes) as neutron sources for experiments during the war. [Technical Oil Mission Microfilm 119 (BM-6—Ludwigshaven), Folder LU III-2. https://www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOC_TOM-119.htm]



Technical Oil Mission Microfilm 119 (BM-6 – Ludwigshaven), Folder LU III-2.
www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOM-119-0001-0100.pdf

- 3 -

Da zu erwarten ist, dass die Spannung noch über 320 KV hinaus erhöht werden kann und da besonders auch anzunehmen ist, dass sich die Ergiebigkeit der Jonenquelle über 200 μA hinaus steigern lässt, so dürfte eine Steigerung der Leistung des Neutronengenerators um ein Mehrfaches gegenüber dem jetzt schon bei 200 KV und 200 μA erreichten Werten, die einem Rn + Be - Äquivalent von ca 3 Curie (~ 3 gr Radium) entsprechen, zu verwirklichen sein.

Schäfer

Anlagen :

Figure D.624: This document demonstrates that scientists in Germany had been routinely using deuterium + deuterium and lithium + deuterium fusion reactions (in high-voltage tubes) as neutron sources for experiments during the war. [Technical Oil Mission Microfilm 119 (BM-6—Ludwigshaven), Folder LU III-2. https://www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOC_TOM-119.htm]

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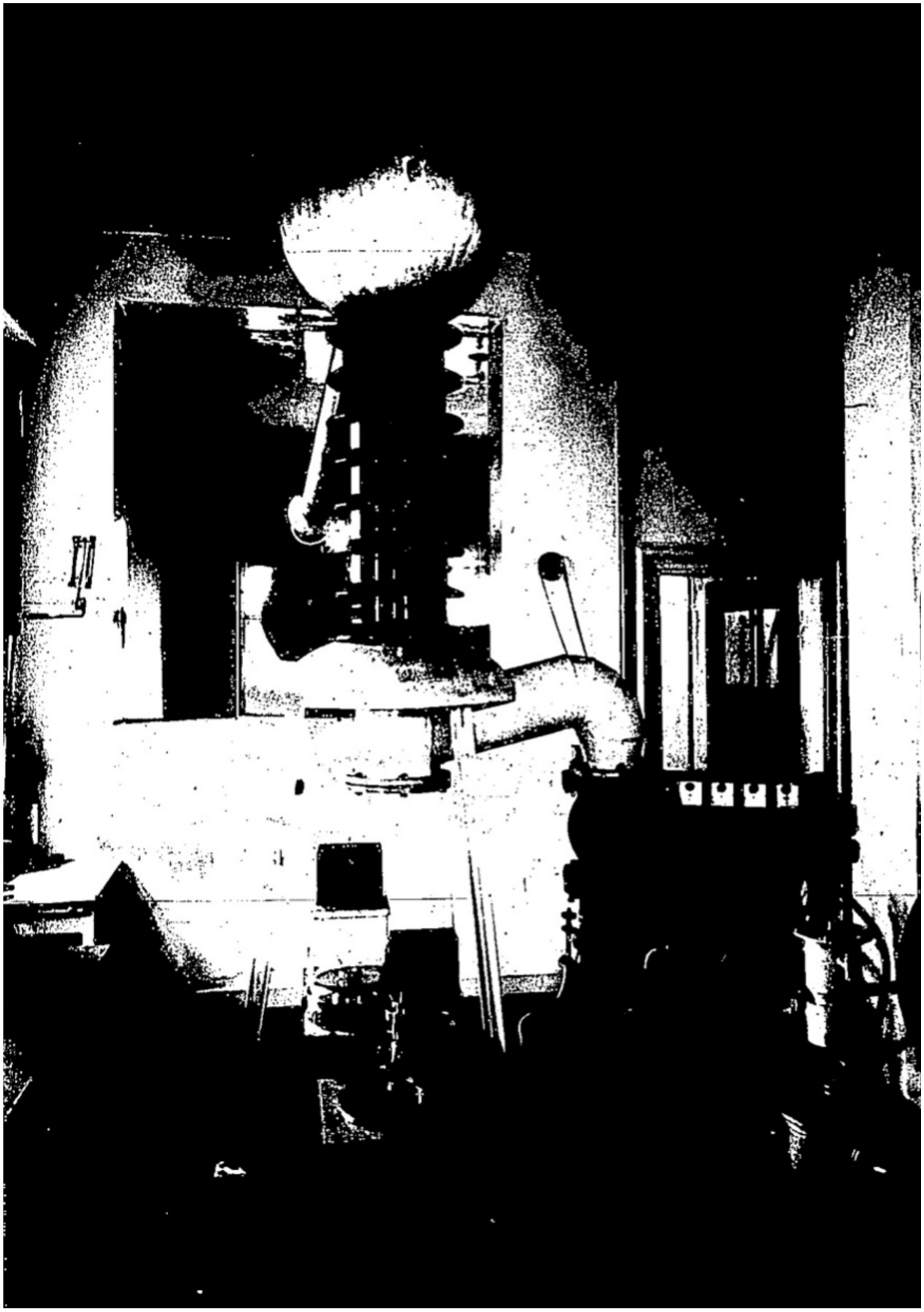
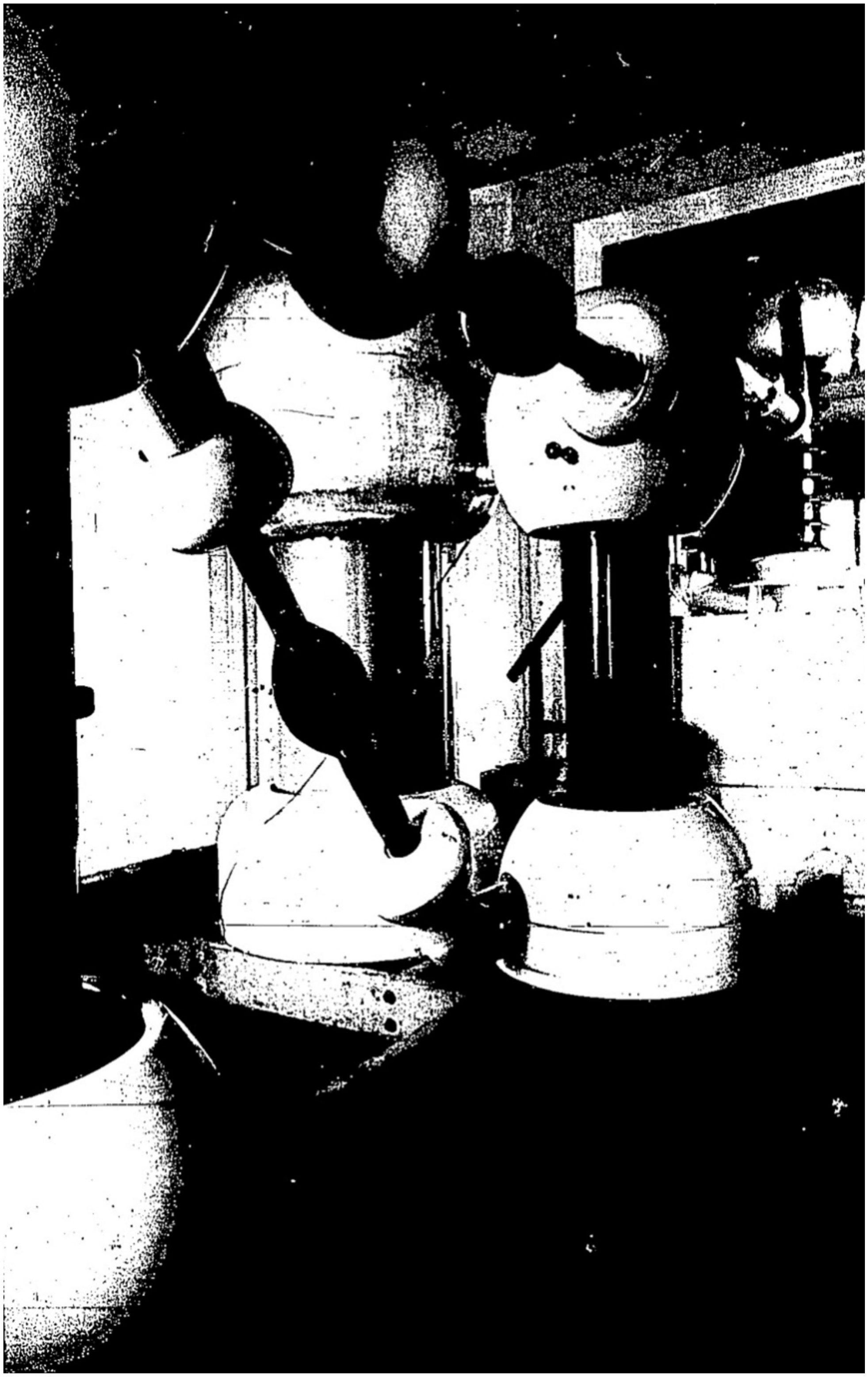


1.Bild Neutronenrohr.

Figure D.625: This document demonstrates that scientists in Germany had been routinely using deuterium + deuterium and lithium + deuterium fusion reactions (in high-voltage tubes) as neutron sources for experiments during the war. [Technical Oil Mission Microfilm 119 (BM-6—Ludwigshaven), Folder LU III-2. https://www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOC_TOM-119.htm]

Technical Oil Mission Microfilm 119 (BM-6 – Ludwigshaven), Folder LU III-2.

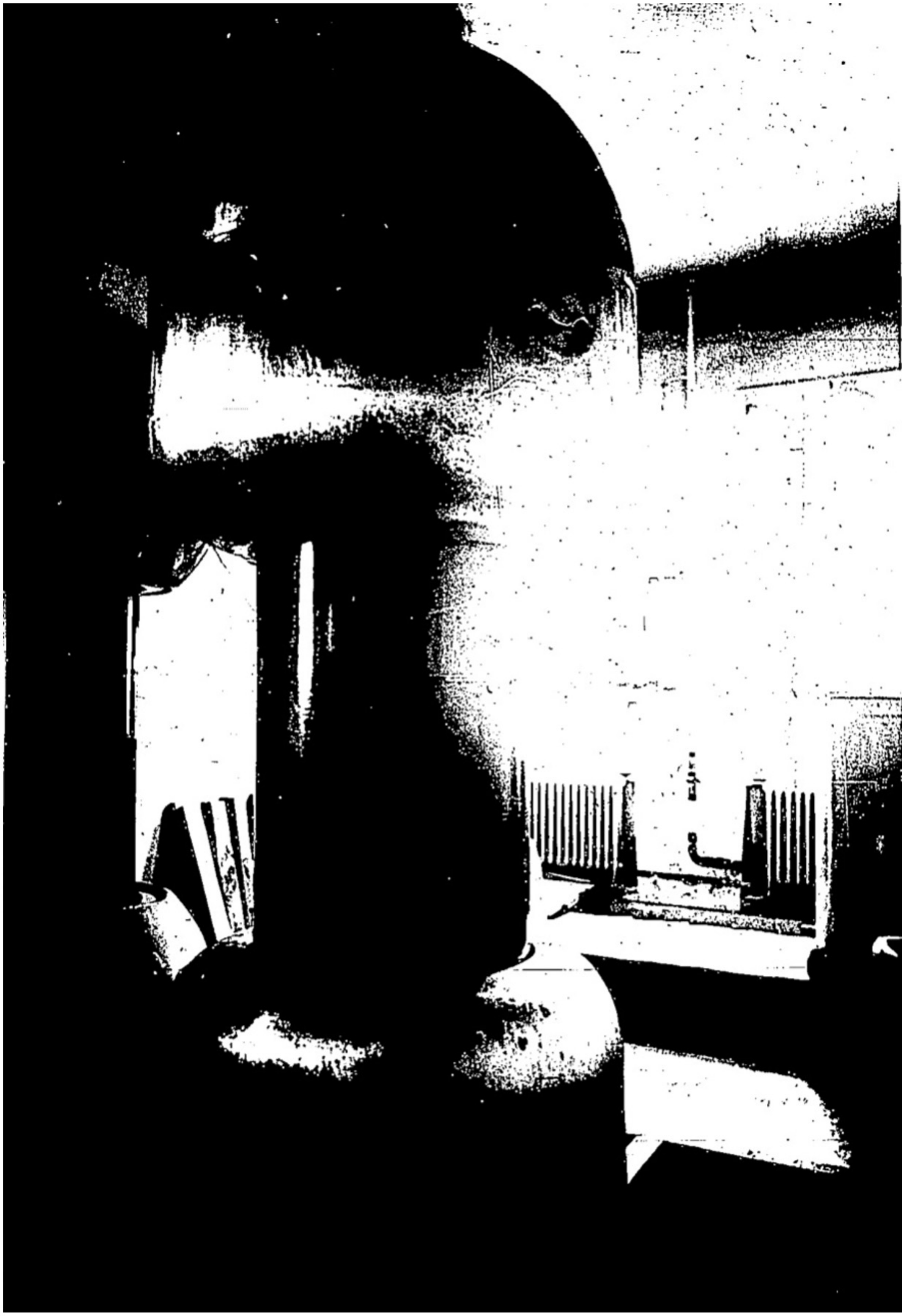
www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOM-119-0001-0100.pdf



2. Bild Kaskadengenerator von
Siemens & Halske 400 KV, 5m A.

Figure D.626: This document demonstrates that scientists in Germany had been routinely using deuterium + deuterium and lithium + deuterium fusion reactions (in high-voltage tubes) as neutron sources for experiments during the war. [Technical Oil Mission Microfilm 119 (BM-6—Ludwigshaven), Folder LU III-2. https://www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOC_TOM-119.htm]

Technical Oil Mission Microfilm 119 (BM-6 – Ludwigshaven), Folder LU III-2.
www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOM-119-0001-0100.pdf



5. Bild. Jsoliergenerator 60 KV
30 m A auf 400 KV isoliert.

Figure D.627: This document demonstrates that scientists in Germany had been routinely using deuterium + deuterium and lithium + deuterium fusion reactions (in high-voltage tubes) as neutron sources for experiments during the war. [Technical Oil Mission Microfilm 119 (BM-6—Ludwigshaven), Folder LU III-2. https://www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOC_TOM-119.htm]

Fritz Houtermans. Letter to Werner Czulius. 28 November 1944. AMPG, I. Abt. Rep. 34, Nr. 53, Bl. 1–2 [Nagel 2012a, pp. 639–640].

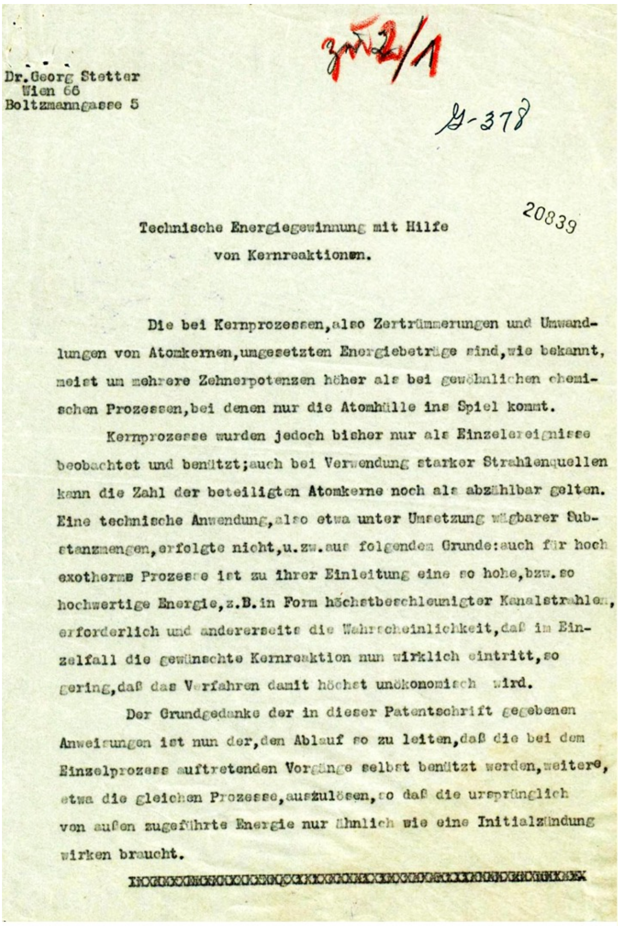
[...] Das beste ist zweifellos möglichst weit hinaus zu messen und mit 0,105 oder 0,106 zu extrapolieren. Den Bakkerschen Wert halte ich für zu niedrig. Ich sprach auch mit Bothe kürzlich über die Frage, wie weit, sich der Abfall von $A_c r^2$ bei grossen Entfernungen durch eine Exponentialfunktion approximieren lässt, und er sagte mir, dass er durch Rechnung gefunden habe, dass sich bei komplexem Spektrum schliesslich ein Wert von B einstellt, der wohl durch die freie Weglänge der schnellsten Neutronen bedingt isst, aber nur sehr langsam, d.h. bei sehr grossen Entfernungen. Es ist eben wie immer bei mehreren Exponentialfunktionen, z.B. beim radioaktiven Zerfall von 2 Körpern mit kurzer und langer H.W. Zeit, nur meinte er, es gehe hier noch langsamer. Welchen Wert sie für die Fluoridquelle nehmen sollen, weiss ich nicht, denn ich habe mit einer solchen Quelle nicht gearbeitet. Wenn Sie es nicht selbst messen können, würde ich aus den Tuve-Hafsad-Werten künstlicher Quellen einen aussuchen der einem primären Neutronenspektrum mit ungefähr ähnlicher oberer Grenze (ich glaube D+D, nach vorne, käme ungefähr hin) entspricht bezw. extrapolieren. Für Li + D haben wir 1/B = 10,8 cm gefunden, auch nach vorne, also ziemlich dasselbe, wie für Ra+Be, woraus man sieht, dass die Energieabhangigkeit nicht sehr viel ausmacht. Man wird also sicher auch für CaF_2 mit einem geeigneten interpolierten Wert rechnen dürfen. [...]

[...] The best is undoubtedly to measure as far as possible and to extrapolate it with 0.105 or 0.106. Bakker's value I think is too low. I also talked with Bothe about the question of how far the decay of $A_c r^2$ can be approximated by an exponential function at great distances, and he told me that for a complex spectrum he had calculated a value of B, which is probably due to the free path of the fastest neutrons, but only very slowly, i. e. at very great distances. It is just as always with several exponential functions, e.g. in the radioactive decay of two bodies with short and long half lives, he just meant, it was slower. I do not know which value you should take for the source of fluoride, because I have not worked with such a source. If you cannot measure it yourself, I have chosen one from the Tuve-Hafsad values of artificial sources which extrapolating corresponds to a primary neutron spectrum with a similar upper limit (I believe D+D, forward, approximately). For Li + D, we have found 1/B = 10.8 cm, also forward, which is quite the same as for Ra+Be, which shows that the energy dependence does not matter very much. Thus, CaF_2 may also be expected to have a suitable interpolated value. [...]

[This document demonstrates that scientists in Germany had been routinely using deuterium + deuterium and lithium + deuterium fusion reactions (in high-voltage tubes) as neutron sources for experiments during the war; they are casually mentioned alongside a much more conventional radium+beryllium neutron source. For producing neutrons, the lithium reaction would have been lithium-7 + deuterium → neutron + 2 helium-4 (alpha) particles.

A high-voltage tube containing such fusion fuel would make a good neutron initiator in a fission bomb and is apparently described in Ilyichev's March 1945 intelligence report on a German fission implosion bomb design; see pp. 4485 and 5157.

From unclassified references on nuclear weapons designs, lithium deuteride makes excellent fusion fuel in H bombs or can be used at the center of a fission bomb to provide a fusion neutron boost to greatly increase the fission efficiency and explosive yield.]



zu 2/1

Dr.Georg Stetter
Wien 66
Boltzmanngasse 5

G-378

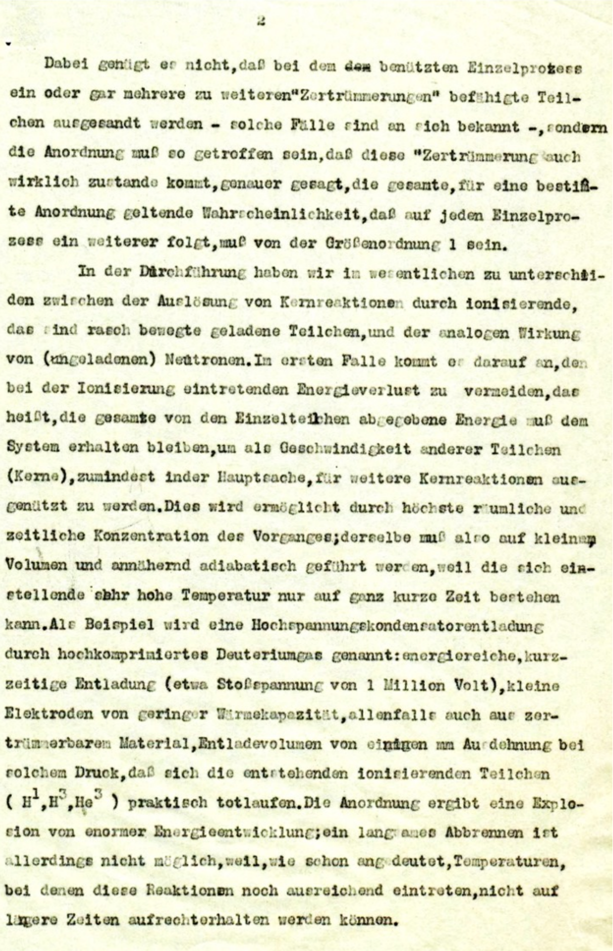
20839

Technische Energiegewinnung mit Hilfe
von Kernreaktionen.

Die bei Kernprozessen,also Zertrümmerungen und Umwandlungen von Atomkernen,ungesetzten Energiebeträge sind,wie bekannt, meist um mehrere Zehnerpotenzen höher als bei gewöhnlichen chemischen Prozessen,bei denen nur die Atomhülle ins Spiel kommt.

Kernprozesse wurden jedoch bisher nur als Einzelereignisse beobachtet und benützt;auch bei Verwendung starker Strahlenquellen kann die Zahl der beteiligten Atomkerne noch als abzählbar gelten. Eine technische Anwendung,also etwa unter Umsetzung wägbarer Substanzmengen,erfolgte nicht,u.zw.aus folgendem Grunde:auch für hoch exotherme Prozesse ist zu ihrer Einleitung eine so hohe,bzw.so hochwertige Energie,z.B.in Form höchstbeschleunigter Kanalstrahlen, erforderlich und andererseits die Wahrscheinlichkeit,daß im Einzelfall die gewünschte Kernreaktion nun wirklich eintritt,so gering,daß das Verfahren damit höchst unökonomisch wird.

Der Grundgedanke der in dieser Patentschrift gegebenen Anweisungen ist nun der,den Ablauf so zu leiten,daß die bei dem Einzelprozess auftretenden Vorgänge selbst benützt werden,weitere, etwa die gleichen Prozesse,auszulösen,so daß die ursprünglich von außen zugeführte Energie nur ähnlich wie eine Initialzündung wirken braucht.

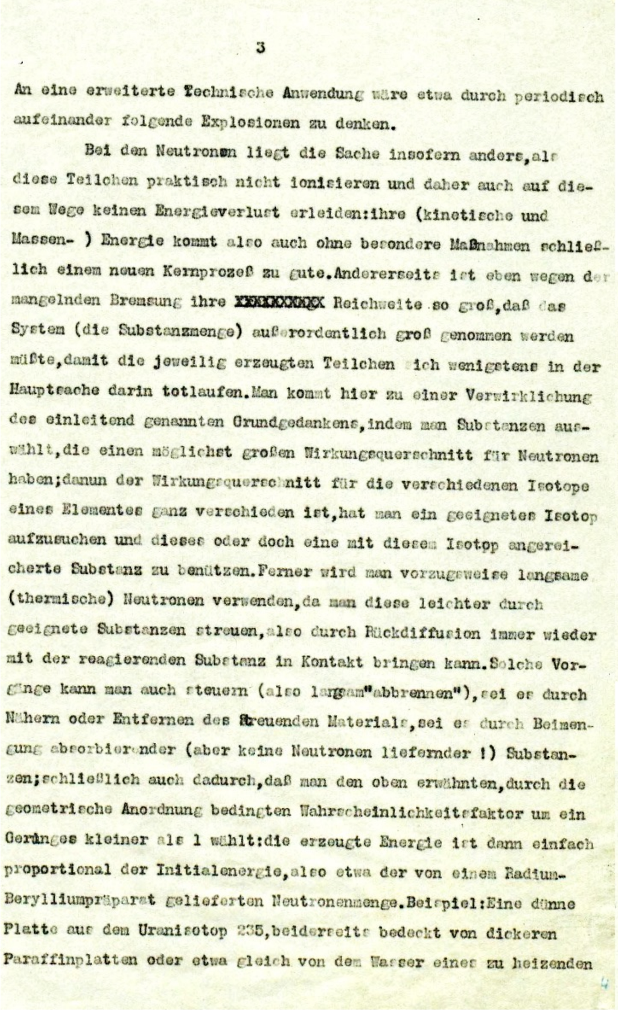


2

Dabei genügt es nicht,daß bei dem dem benützten Einzelprozess ein oder gar mehrere zu weiteren"Zertrümmerungen" befähigte Teilchen ausgesandt werden - solche Fälle sind an sich bekannt -,sondern die Anordnung muß so getroffen sein,daß diese "Zertrümmerung auch wirklich zustande kommt,genauer gesagt,die gesamte,für eine bestimmte Anordnung geltende Wahrscheinlichkeit,daß auf jeden Einzelprozess ein weiterer folgt,muß von der Größenordnung 1 sein.

In der Dürchführung haben wir im wesentlichen zu unterscheiden zwischen der Auslösung von Kernreaktionen durch ionisierende, das sind rasch bewegte geladene Teilchen,und der analogen Wirkung von (ungeladenen) Neutronen.Im ersten Falle kommt es darauf an,den bei der Ionisierung eintretenden Energieverlust zu vermeiden,das heißt,die gesamte von den Einzelteilchen abgegebene Energie muß dem System erhalten bleiben,um als Geschwindigkeit anderer Teilchen (Kerne),zumindest inder Hauptsache,für weitere Kernreaktionen ausgenützt zu werden.Dies wird ermöglicht durch höchste räumliche und zeitliche Konzentration des Vorganges;derselbe muß also auf kleinem Volumen und annähernd adiabatisch geführt werden,weil die sich einstellende sehr hohe Temperatur nur auf ganz kurze Zeit bestehen kann.Als Beispiel wird eine Hochspannungskondensatorentladung durch hochkomprimiertes Deuteriumgas genannt:energiereiche,kurzzeitige Entladung (etwa Stoßspannung von 1 Million Volt),kleine Elektroden von geringer Wärmekapazität,allenfalls auch aus zertrümmerbarem Material,Entladevolumen von einigen mm Ausdehnung bei solchem Druck,daß sich die entstehenden ionisierenden Teilchen (H^1,H^3,He^3) praktisch totlaufen.Die Anordnung ergibt eine Explosion von enormer Energieentwicklung;ein langsames Abbrennen ist allerdings nicht möglich,weil,wie schon angedeutet,Temperaturen, bei denen diese Reaktionen noch ausreichend eintreten,nicht auf längere Zeiten aufrechterhalten werden können.

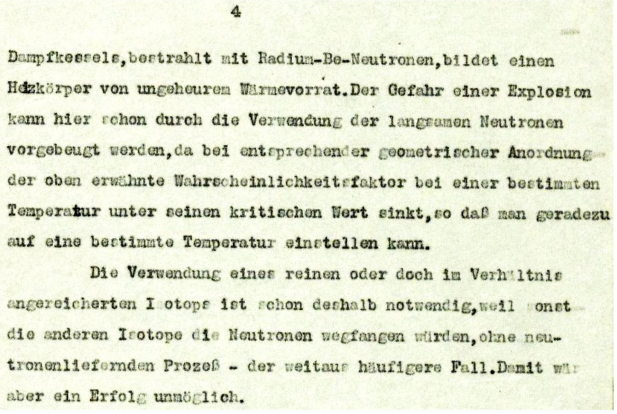
Figure D.628: G-378. Georg Stetter. Technische Energiegewinnung mit Hilfe von Kernreaktionen. FA 002/0762. Deutsches Museum Archive, Munich. https://digital.deutsches-museum.de/item/FA-002-762/



3

An eine erweiterte Technische Anwendung wäre etwa durch periodisch aufeinander folgende Explosionen zu denken.

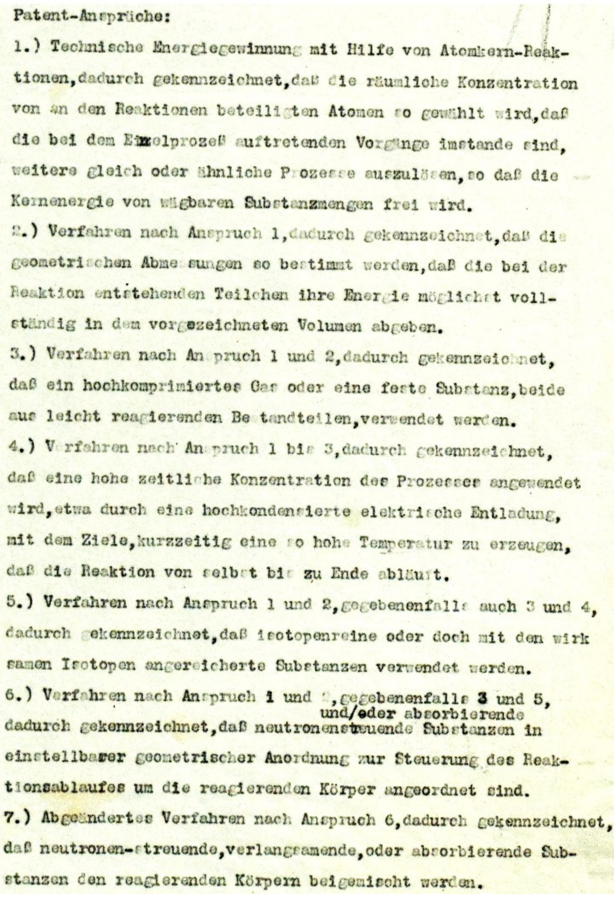
Bei den Neutronen liegt die Sache insofern anders, als diese Teilchen praktisch nicht ionisieren und daher auch auf diesem Wege keinen Energieverlust erleiden: ihre (kinetische und Massen-) Energie kommt also auch ohne besondere Maßnahmen schließlich einem neuen Kernprozeß zu gute. Andererseits ist eben wegen der mangelnden Bremsung ihre XXXXXXXXX Reichweite so groß, daß das System (die Substanzmenge) außerordentlich groß genommen werden müßte, damit die jeweilig erzeugten Teilchen sich wenigstens in der Hauptsache darin totlaufen. Man kommt hier zu einer Verwirklichung des einleitend genannten Grundgedankens, indem man Substanzen auswählt, die einen möglichst großen Wirkungsquerschnitt für Neutronen haben; danun der Wirkungsquerschnitt für die verschiedenen Isotope eines Elementes ganz verschieden ist, hat man ein geeignetes Isotop aufzusuchen und dieses oder doch eine mit diesem Isotop angereicherte Substanz zu benützen. Ferner wird man vorzugsweise langsame (thermische) Neutronen verwenden, da man diese leichter durch geeignete Substanzen streuen, also durch Rückdiffusion immer wieder mit der reagierenden Substanz in Kontakt bringen kann. Solche Vorgänge kann man auch steuern (also langsam "abbrennen"), sei es durch Nähern oder Entfernen des Streuenden Materials, sei es durch Beimengung absorbierender (aber keine Neutronen liefernder !) Substanzen; schließlich auch dadurch, daß man den oben erwähnten, durch die geometrische Anordnung bedingten Wahrscheinlichkeitsfaktor um ein Geringes kleiner als 1 wählt: die erzeugte Energie ist dann einfach proportional der Initialenergie, also etwa der von einem Radium-Berylliumpräparat gelieferten Neutronenmenge. Beispiel: Eine dünne Platte aus dem Uranisotop 235, beiderseits bedeckt von dickeren Paraffinplatten oder etwa gleich von dem Wasser eines zu heizenden



4

Dampfkessels, bestrahlt mit Radium-Be-Neutronen, bildet einen Heizkörper von ungeheuren Wärmevorrat. Der Gefahr einer Explosion kann hier schon durch die Verwendung der langsamen Neutronen vorgebeugt werden, da bei entsprechender geometrischer Anordnung der oben erwähnte Wahrscheinlichkeitsfaktor bei einer bestimmten Temperatur unter seinen kritischen Wert sinkt, so daß man geradezu auf eine bestimmte Temperatur einstellen kann.

Die Verwendung eines reinen oder doch im Verhältnis angereicherten Isotops ist schon deshalb notwendig, weil sonst die anderen Isotope die Neutronen wegfangen würden, ohne neutronenliefernden Prozeß - der weitaus häufigere Fall. Damit wär aber ein Erfolg unmöglich.



Patent-Ansprüche:

1.) Technische Energiegewinnung mit Hilfe von Atomkern-Reaktionen, dadurch gekennzeichnet, daß die räumliche Konzentration von an den Reaktionen beteiligten Atomen so gewählt wird, daß die bei dem Einzelprozeß auftretenden Vorgänge imstande sind, weitere gleich oder ähnliche Prozesse auszulösen, so daß die Kernenergie von wägbaren Substanzmengen frei wird.

2.) Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die geometrischen Abmessungen so bestimmt werden, daß die bei der Reaktion entstehenden Teilchen ihre Energie möglichst vollständig in dem vorgezeichneten Volumen abgeben.

3.) Verfahren nach Anspruch 1 und 2, dadurch gekennzeichnet, daß ein hochkomprimiertes Gas oder eine feste Substanz, beide aus leicht reagierenden Bestandteilen, verwendet werden.

4.) Verfahren nach Anspruch 1 bis 3, dadurch gekennzeichnet, daß eine hohe zeitliche Konzentration des Prozesses angewendet wird, etwa durch eine hochkondensierte elektrische Entladung, mit dem Ziele, kurzzeitig eine so hohe Temperatur zu erzeugen, daß die Reaktion von selbst bis zu Ende abläuft.

5.) Verfahren nach Anspruch 1 und 2, gegebenenfalls auch 3 und 4, dadurch gekennzeichnet, daß isotopenreine oder doch mit den wirksamen Isotopen angereicherte Substanzen verwendet werden.

6.) Verfahren nach Anspruch 1 und 2, gegebenenfalls 3 und 5, dadurch gekennzeichnet, daß neutronenstreuende und/oder absorbierende Substanzen in einstellbarer geometrischer Anordnung zur Steuerung des Reaktionsablaufes um die reagierenden Körper angeordnet sind.

7.) Abgeändertes Verfahren nach Anspruch 6, dadurch gekennzeichnet, daß neutronen-streuende, verlangsamende, oder absorbierende Substanzen den reagierenden Körpern beigemischt werden.

Figure D.629: G-378. Georg Stetter. Technische Energiegewinnung mit Hilfe von Kernreaktionen. FA 002/0762. Deutsches Museum Archive, Munich. https://digital.deutsches-museum.de/item/FA-002-762/

G-378. Georg Stetter. Technische Energiegewinnung mit Hilfe von Kernreaktionen. FA 002/0762. Deutsches Museum Archive, Munich. https://digital.deutsches-museum.de/item/FA-002-762/ This early 1939 draft of a patent application covered both fusion and fission reactions. A key section on fusion is given below. In reviewing this patent draft, Karl Wirtz raised concerns that the fusion claims were too similar to Brasch and Lange's German Patent 662036 [AMPG 34/29]. The final patent application deleted the fusion claims and polished the fission claims (see p. 3372). Stetter and his fellow researchers were heavily involved in both the wartime fission and fusion programs (pp. 3372–3375, 4330–4345, 4788–4800, 4992). [See document photos on pp. 4328–4329.]

In der Durchführung haben wir im wesentlichen zu unterscheiden zwischen den Auslösung von Kernreaktionen durch ionisierende, das sind rasch bewegte geladene Teilchen, und der analogen Wirkung von (ungeladenen) Neutronen. Im ersten Falle kommt es darauf an, den bei der Ionisierung eintretenden Energieverlust zu vermeiden, das heißt, die gesamte von den Einzelteilchen abgegebene Energie muß dem System erhalten bleiben, um als Geschwindigkeit anderer Teilchen (Kerne), zumindest in der Hauptsache, für weitere Kernreaktionen ausgenützt zu werden. Dies wird ermöglicht durch höchste räumliche und zeitliche Konzentrationen des Vorganges; derselbe muß also auf kleinem Volumen und annähernd adiabatisch geführt werden, weil die sich einstellende sehr hohe Temperatur nur auf ganz kurze Zeit bestehen kann. Als Beispiel wird eine Hochspannungskondensatorentladung durch hochkomprimiertes Deuteriumgas genannt: energiereiche, kurzzeitige Entladung (etwa Stoßspannung von 1 Million Volt), kleine Elektroden von geringer Wärmekapazität, allenfalls auch aus zertrümmerbarem Material, Entladevolumen von einigen mm Ausdehnung bei solchem Druck, daß sich die entstehenden ionisierenden Teilchen (H^1, H^3, He^3) praktisch totlaufen. Die Anordnung ergibt eine Explosion von enormer Energieentwicklung; ein langsames Abbrennen ist allerdings nicht möglich, weil, wie schon angedeutet, Temperaturen, bei denen diese Reaktionen noch ausreichend eintreten, nicht auf längere Zeiten aufrechterhalten werden können.

An eine erweiterte technische Anwendung wäre etwa durch periodisch aufeinander folgende Explosionen zu denken.

In the main we have to differentiate between the induction of nuclear reactions by ionizing, that is rapidly moving charged particles, and the analogous effect of (uncharged) neutrons. In the first case, it is important to avoid the loss of energy occurring during ionization, that is, the total energy released by the individual particles must be retained by the system, as speed of other particles (nuclei), at least in the main, for further nuclear reactions to be exploited. This is made possible by highest spatial and temporal concentrations of the process; the same must therefore be performed on a small volume and approximately adiabatically, because the very high temperature condition can exist only for a very short time. As an example, a high-voltage capacitor discharge by highly compressed deuterium gas is considered: high-energy, short-term discharge (about 1 million volts surge), small electrodes of low heat capacity, if necessary also from fissile material, discharge volume of a few mm expansion at such pressure that the resulting ionizing particles (H^1, H^3, He^3) practically run into each other. The arrangement results in an explosion of tremendous energy development. However, a slow burning off is not possible because, as already indicated, temperatures at which these reactions still sufficiently occur cannot be maintained for longer periods of time.

An advanced technical application would be to think about successive periodical explosions.

Assistant Chief of Staff, G-2, Department of the Army, Washington, DC. Lintner, Karl Rudolf Josef. 6 April 1954. [NARA RG 330, Entry A1-1B, Box 103, Folder Lintner, Karl]

According to information received in Aug 1949 from an untested source, one Dr. Karl LINTNER was assistant to Prof Karl PRZIBAM at the Second Institute of Physics in Vienna. Source declared PRZIBAM to be pro-Russian and believed without being sure that he was in Moscow early 1949. PRZIBAM had been carrying out infra-red research for the Russians. During the war, the nuclear physicists of the Second Institute of Physics in Vienna engaged in a research project of releasing high amounts of energy through nuclear reactions of the lithium hydrite crystal *Li H*. The research was carried out mainly by Dr. Karl LINTNER under the supervision of Prof. Dr. Georg K. F. STETTER. The project failed because according to source, it was impossible to procure strong enough electrodes and equipment sufficiently resistant to heat.

[See document photo on p. 4333.

What lithium and hydrogen isotopes and what reactions did Stetter's group consider? Did they originate the "Jetter cycle" (see p. 4348)?]

Robert A. Snedeker, CIC Sub-Det "C" (Vienna). Agent Report. Dr. Georg Stetter's Patent Concerning Production of Atomic Energy, Technical Intelligence, Vienna. 29 September 1953. [NARA RG 319, Entry A1-134B, Box 749, Folder 23 Nov 95 Georg Stetter XA001081]

On 23 September 1953, Dr. Karl Lintner, Second Physical Institute of the University of Vienna, was interviewed by Informant 1063 and stated the following:

Source [Lintner] was Dr. Georg STETTER's assistant in the Second Physical Institute during World War II, when STETTER was working on the splitting of the lithium nucleus. STETTER intended to have certain processes patented, in connection with splitting nuclei, but Source is unaware of the result of this intention. All of STETTER's research material and notes fell into the hands of the Soviets in 1945 and to Source's knowledge STETTER has not concerned himself with nuclear research since that date. Source considers STETTER the best nuclear physicist in Austria. STETTER, before obtaining a position with the Second Physical Institute, University of Vienna, was affiliate with the United Austrian Iron and Steel Works and the Austrian Nitrogen Works.

[See document photo on p. 4333.

Note that Stetter applied or intended to apply for a patent on his fusion approaches. Was that just the deleted early 1939 patent sections on p. 4330, or did he write additional, more detailed patent drafts? Can any of his group's material be found in Russian archives?]

Air Intelligence Report No. 100-13/1-100, Significant Developments and Trends in Aircraft and Aircraft Engines, Antiaircraft Guided Missiles (15 June 1946). p. 93. NARA RG 38, Entry 98C, Box 11, Folder TSC # 3001–3100.

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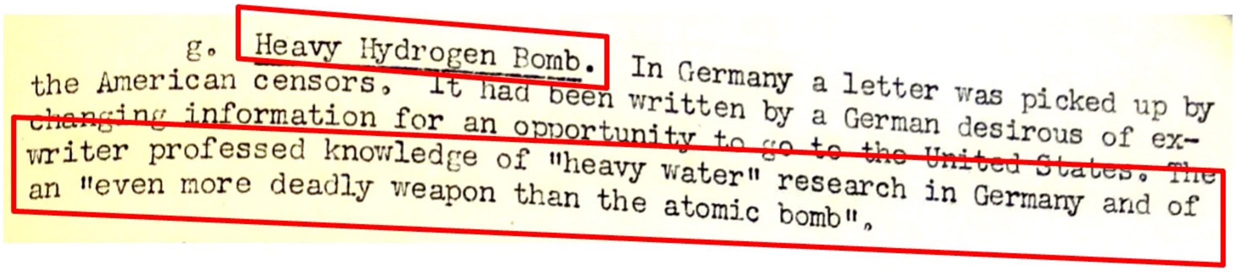
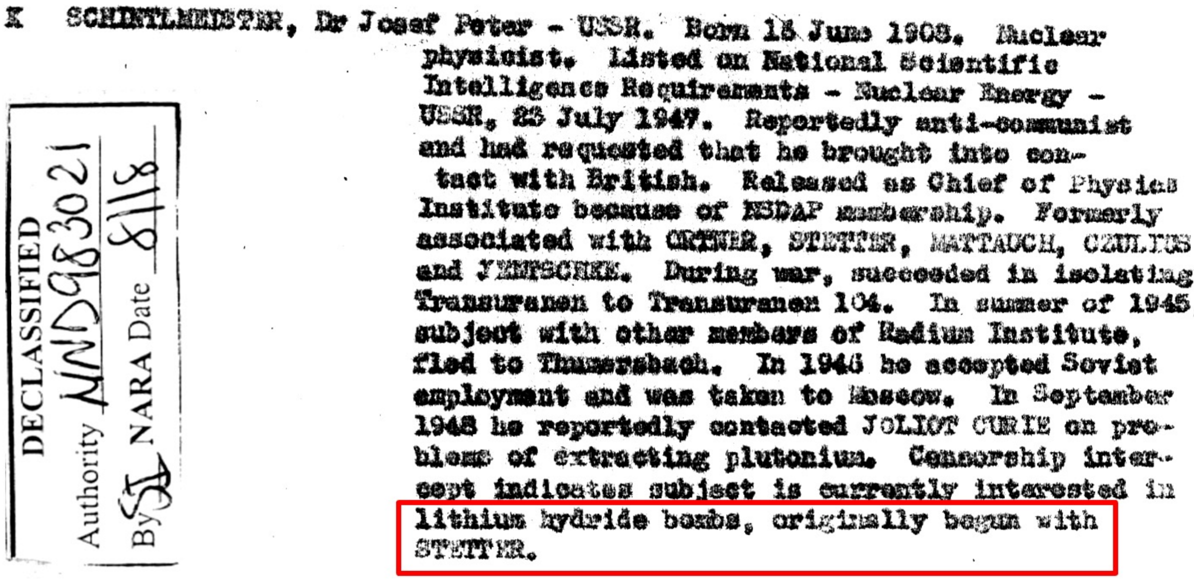


g. Heavy Hydrogen Bomb. In Germany a letter was picked up by the American censors, It had been written by a German desirous of exchanging information for an opportunity to go to the United States. The writer professed knowledge of "heavy water" research in Germany and of an "even more deadly weapon than the atomic bomb".

**Immigration of Austrian Scientists to Soviet Zone.
NARA RG 319, Entry A1-134A, Box 31, Folder 02/006 430.**



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Authority NND983021
By SL NARA Date 8/18

X SCHINTLMEISTER, Dr Josef Peter - USSR. Born 18 June 1908. Nuclear physicist. Listed on National Scientific Intelligence Requirements - Nuclear Energy - USSR, 23 July 1947. Reportedly anti-communist and had requested that he brought into contact with British. Released as Chief of Physics Institute because of NSDAP membership. Formerly associated with ORTNER, STETTER, MATTAUCH, CZULIUS and JENTSCHKE. During war, succeeded in isolating Transuranen to Transuranen 104. In summer of 1945, subject with other members of Radium Institute, fled to Thumersbach. In 1946 he accepted Soviet employment and was taken to Moscow. In September 1948 he reportedly contacted JOLIOT CURIE on problems of extracting plutonium. Censorship intercept indicates subject is currently interested in lithium hydride bombs, originally begun with STETTER.

Figure D.630: Examples of postwar U.S. intelligence about wartime work on the German H-bomb [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3001–3100. NARA RG 319, Entry A1-134A, Box 31, Folder 02/006 430.].

Robert A. Snedeker, CIC Sub-Det "C" (Vienna). Agent Report. Dr. Georg Stetter's Patent Concerning Production of Atomic Energy, Technical Intelligence, Vienna. 29 September 1953. NARA RG 319, Entry A1-134B, Box 749, Folder 23 Nov 95 Georg Stetter XA001081.

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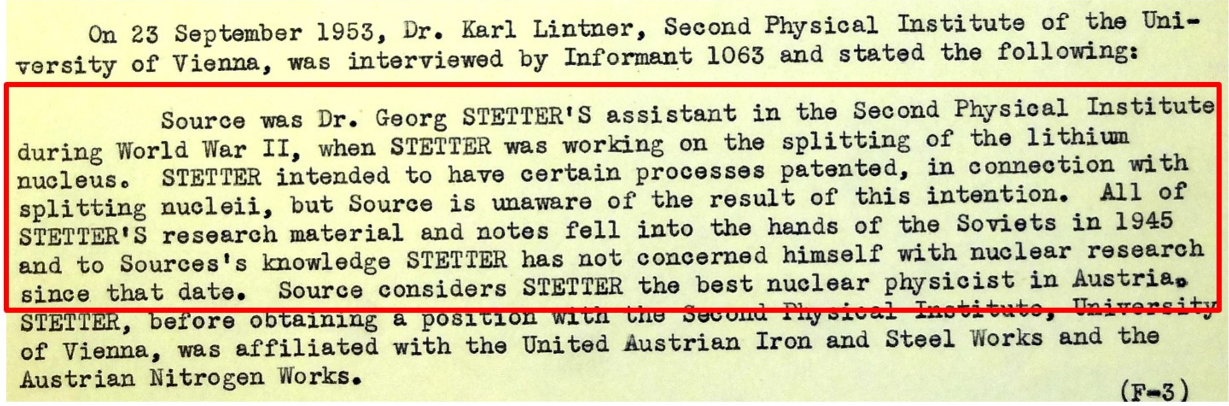

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(F-3)

NARA RG 330, Entry A1-1B, Box 103, Folder Lintner, Karl.

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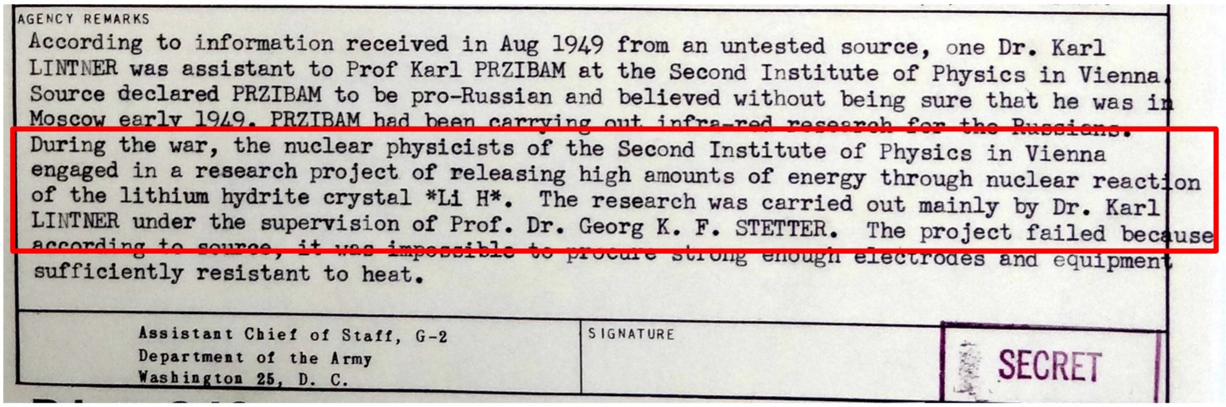
Authority NND 013039



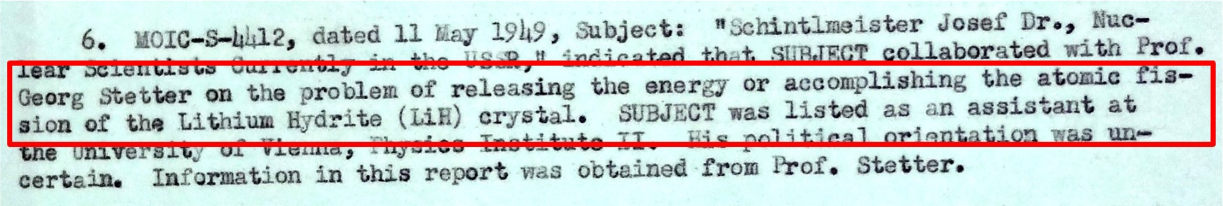
AGENCY REMARKS

According to information received in Aug 1949 from an untested source, one Dr. Karl LINTNER was assistant to Prof Karl PRZIBAM at the Second Institute of Physics in Vienna. Source declared PRZIBAM to be pro-Russian and believed without being sure that he was i Moscow early 1949. PRZIBAM had been carrying out infra-red research for the Russians. During the war, the nuclear physicists of the Second Institute of Physics in Vienna engaged in a research project of releasing high amounts of energy through nuclear reaction of the lithium hydrite crystal *Li H*. The research was carried out mainly by Dr. Karl LINTNER under the supervision of Prof. Dr. Georg K. F. STETTER. The project failed because according to source, it was impossible to procure strong enough electrodes and equipment sufficiently resistant to heat.

Assistant Chief of Staff, G-2
Department of the Army
Washington 25, D. C.

SIGNATURE

SECRET



6. MOIC-S-4412, dated 11 May 1949, Subject: "Schintlmeister Josef Dr., Nuclear Scientists Currently in the USSR," indicated that SUBJECT collaborated with Prof. Georg Stetter on the problem of releasing the energy or accomplishing the atomic fission of the Lithium Hydrite (LiH) crystal. SUBJECT was listed as an assistant at the University of Vienna, Physics Institute II. His political orientation was uncertain. Information in this report was obtained from Prof. Stetter.

Figure D.631: Examples of postwar U.S. intelligence about wartime work on the German H-bomb [NARA RG 319, Entry A1-134B, Box 749, Folder 23 Nov 95 Georg Stetter XA001081. NARA RG 330, Entry A1-1B, Box 103, Folder Lintner, Karl.].

Russian Department of the Archives of the State Cooperation of Atomic Energy (OOFR), Österreich 2, pp. 302–304, Gutachten von Kokin zur Annotation einer Aussage von Dr. Rober [Kober], 21 August 1945.

Prof. Stetter aus Wien, der sich mit dem Zerfall des Kernes von Lithium-Hydrid [...] beschäftige, hat entdeckt, dass diese Reaktion nicht stabil ist, das heisst, dass sie sich nach dem Anfang automatisch weiter fortsetzt, dabei wird eine ausserordentlich grosse Energie des Kernes freigesetzt, und die ganze Versuchseinrichtung explodiert (Versuch auf dem Erprobungsgelände). Prof. Bethe schätzt diese Reaktion als Quelle der Sonnenenergie ein, außerdem bringt diese Reaktion eine Wende in der Technik der Sprengstoffe, weil die Stärke der Explosion 10^6-mal größer ist als bei Nitroglyzerin. Diese Reaktion wurde in vielen Instituten untersucht, unter Teilnahme der Professoren Gerlach und Tomaschek—in München. Prof. Stetter aus Wien hat eine Theorie entwickelt, dass diese Reaktion bei der Temperatur 10^6 ^{o}C beginnen soll. Falls diese Theorie richtig ist, ist eine Versuchsanlage, die diese Energie zum praktischen Zweck benutzen darf, leicht zu bauen. [...] Dr. Rober [Kober] bittet um Erlaubnis, such damit zu beschäftigen und wies darauf hin, dass AEG schon einige Patente in dieser Frage hat.

Prof. Stetter from Vienna, who is concerned with the disintegration of the nucleus of lithium hydride, has discovered that this reaction is not stable, that is, that it continues automatically after the beginning; exceptionally large energy of the nucleus is released, and the whole experimental facility explodes (experiment at the test site). Prof. Bethe regards this reaction as a source of solar energy. In addition, this reaction brings about a change in the technique of explosives because the strength of the explosion is 10^6 times greater than in the case of nitroglycerin. This reaction was studied in many institutes, with the participation of professors Gerlach and Tomaschek—in Munich. Prof. Stetter from Vienna has developed a theory that this reaction should begin at the temperature of 10^6 ^{o}C. If this theory is correct, a test facility that can use this energy for practical purposes is easy to build. [...] Dr. Rober [Kober] asks permission to do so, and pointed out that AEG has already patented this issue.

[Again, which specific isotopes and reactions were considered? The general description sounds like the autocatalytic Jetter cycle (p. 4348). What experiments were done? What were the “many institutes” that also participated in this research? What exactly did Walther Gerlach and Rudolf Tomaschek do? Kober was known as a radar expert—what if any involvement with nuclear research did he have before or after the war? The existing AEG patent was that of Brasch and Lange (p. 4282).]

Immigration of Austrian Scientists to Soviet Zone. [NARA RG 319, Entry A1-134A, Box 31, Folder 02/006 430]

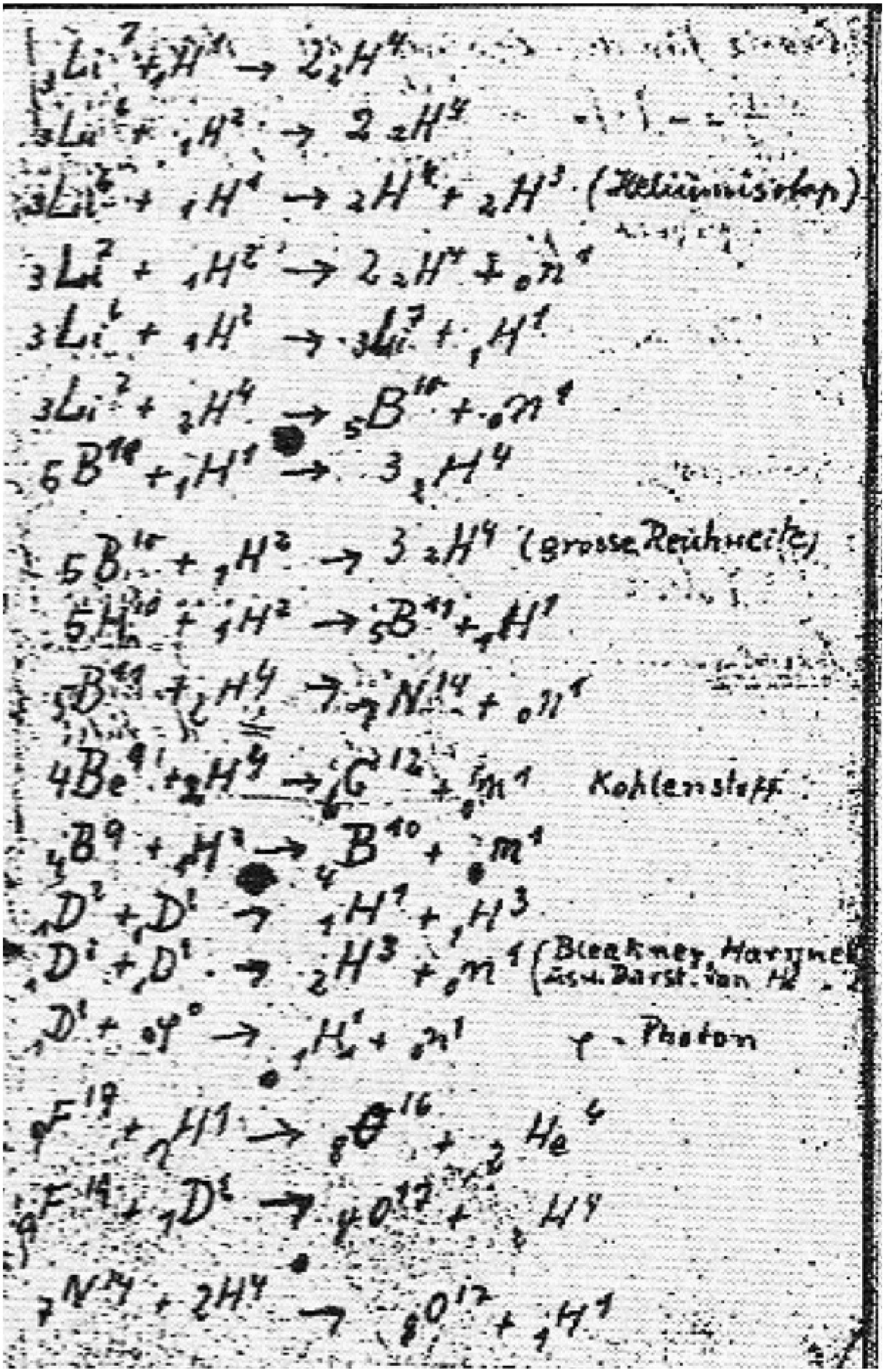
K SCHINTLMEISTER, Dr Josef Peter—USSR. Born 15 June 1908. Nuclear physicist. Listed on National Scientific Intelligence Requirements—Nuclear Energy—USSR, 23 July 1947. Reportedly anti-communist and had requested that be brought into contact with British. Released as Chief of Physics Institute because of NSDAP membership. Formerly associated with [Gustav] ORTNER, [Georg] STETTER, [Josef] MATTAUCH, [Werner] CZULIUS, and [Willibald] JENTSCHKE. During war, succeeded in isolating Transuranen to Transuranen 104. In summer of 1945, subject with other members of Radium Institute, fled to Thumersbach. In 1946 he accepted Soviet employment and was taken to Moscow. In September 1948 he reportedly contacted JOLIOT CURIE on problem of extracting plutonium. Censorship intercept indicates subject is currently interested in lithium hydride bombs, originally begun with STETTER.

[See document photo on p. 4332.

If Josef Schintlmeister really produced and identified transuranic elements through element 104 during the war, that long predates the recognized historical achievement of that milestone in 1969 in the United States. What evidence is this based on, and can it still be found? If transuranic elements were produced, was that in a cyclotron, a fission reactor, or by other methods?]

Friedrich Berkei. 1944 (probably). Page from laboratory notebook [Karlsch 2005, p. 330].

[This document is shown on the following page. Friedrich Berkei was a member of Kurt Diebner's research group. Virtually all of the rest of Berkei's notes were taken away from him after the war. This surviving page shows an amazingly comprehensive list of fusion reactions.]



${}_3Li^7 + {}_1H^1 \rightarrow 2\,{}_2H^4$

${}_3Li^6 + {}_1H^2 \rightarrow 2\,{}_2H^4$

${}_3Li^6 + {}_1H^1 \rightarrow {}_2H^4 + {}_2H^3$ (Heliumisotop)

${}_3Li^7 + {}_1H^2 \rightarrow 2\,{}_2H^4 + {}_0n^1$

${}_3Li^6 + {}_1H^2 \rightarrow {}_3Li^7 + {}_1H^1$

${}_3Li^7 + {}_2H^4 \rightarrow {}_5B^{10} + {}_0n^1$

${}_5B^{11} + {}_1H^1 \rightarrow 3\,{}_2H^4$

${}_5B^{10} + {}_1H^2 \rightarrow 3\,{}_2H^4$ (grosse Reichweite)

${}_5B^{10} + {}_1H^2 \rightarrow {}_5B^{11} + {}_1H^1$

${}_5B^{11} + {}_2H^4 \rightarrow {}_7N^{14} + {}_0n^1$

${}_4Be^9 + {}_2H^4 \rightarrow {}_6C^{12} + {}_0n^1$ Kohlenstoff

${}_4B^9 + {}_1H^2 \rightarrow {}_4B^{10} + {}_0n^1$

${}_1D^2 + {}_1D^2 \rightarrow {}_1H^1 + {}_1H^3$

${}_1D^2 + {}_1D^2 \rightarrow {}_2H^3 + {}_0n^1$ (Bleakney, Harteck
(zur Darst. von He

${}_1D^2 + {}_0\gamma^0 \rightarrow {}_1H^1 + {}_0n^1$ γ = Photon

${}_9F^{19} + {}_1H^1 \rightarrow {}_8O^{16} + {}_2He^4$

${}_9F^{19} + {}_1D^2 \rightarrow {}_8O^{17} + {}_2H^4$

${}_7N^{14} + {}_2H^4 \rightarrow {}_8O^{17} + {}_1H^1$

Figure D.632: Friedrich Berkei. 1944 (probably). Page from laboratory notebook systematically listing fusion reactions. [Courtesy of Rainer Karlsch]

Hans Thirring. 1946. *Die Geschichte der Atombombe.* Vienna: Neues Österreich. pp. 130–134, 138–139.

Es liegt deswegen die Idee nahe, ob man nicht die so schwer herstellbaren und deswegen immer nur in geringen Mengen zur Verfügung stehenden Stoffe U-235 and Plutonium in irgendeiner Weise "strecken" könnte, oder ob man nicht die bisherige Atombombe als eine Art "Zündpille" zur Einleitung weiterer Kernprozesse an anderen Stoffen verwenden könnte. [...]

Die Energie, die dem gestoßenen Deuteron verliehen wird, beträgt allerdings nur einen kleinen Bruchteil, höchstens etwa 1/25 der Energie des ursprünglichen Sprengstückes, aber diese Energie kann immerhin groß genug sein, damit das getroffene Deuteron, wenn es mit einem anderen Deuteron zusammenstößt, mit diesem die sogenannte d-d-Reaktion ausführt, die durch die Gleichung gegeben ist

The idea is therefore whether one might not be able in any way to "stretch" the substances U-235 and plutonium, which are so difficult to produce and therefore can only be produced in small quantities, or whether one might not be able to use the original atomic bomb as a kind of "sparkplug" to initiate further nuclear processes in other substances. [...]

The energy given to the destroyed deuteron is, however, only a small fraction, at most about 1/25 of the energy of the original explosive, but this energy can still be large enough for the deuteron to fuse when it collides with another deuteron, in the so-called d-d reaction, which is given by the equation

$$^{2}_{1}\mathrm{H}\,(d,n)\,^{3}_{2}\mathrm{He}$$

In Worten ausgedrückt: zwei Deuteronen stoßen zusammen (daher der Name d-d-Reaktion) und vereinigen sich zu dem Heliumisotop $^{3}_{2}$He, während gleichzeitig ein Neutron ausgestoßen wird. [...]

Eine andere Substanz, in der gegebenenfalls auch durch Zündung mittels einer Atombombe ein thermischer Kernkettenprozeß hervorgerufen werden könnte, ist das Lithiumhydrid (LiH), in dem sich bei einer Temperatur von Milliarden Graden der folgende Prozeß abspielen könnte

Expressed in words: two deuterons collide (hence the name d-d reaction) and fuse to form the helium isotope $^{3}_{2}$He, while a neutron is simultaneously emitted. [...]

Another substance, in which a thermal nuclear chain reaction could be induced by an atom bomb, is lithium hydride (LiH), in which the following process can take place at a temperature of billions of degrees

$$^{7}_{3}\mathrm{Li}\,(p,\alpha)\,^{4}_{2}\mathrm{He}$$

Die Gleichung bedeutet: Beim Aufprall eines Protons auf einen Lithiumkern $^{7}_{3}$Li entsteht ein Zwischenkern der Masse 8 und der Ladung 4, der in zwei mit großer Wucht auseinanderfliegende α-Teilchen zerfällt.

The equation means that when a proton collides with a lithium nucleus $^{7}_{3}$Li, an intermediate nucleus of mass 8 and charge 4 is formed, which breaks up into two alpha particles which separate with great energy.

[...] die Energie, die man durch Bildung von Helium aus LiH gewinnen kann, fast dreimal so groß wie die bei der Kernspaltung aus der gleichen Menge von U-235 erzeugte. Dabei ist nun Lithium ein gar nicht so seltenes Element, so daß man in einer "Superatombombe" ungefähr ebensoviel Tonnen Lithiumhydrid verwenden könnte, als man jetzt Kilogramm Plutonium verwendet, derart, daß sich eine Wirkung ergäbe, die wiederum einige tausendmal gegenüber der bisher bekannten gesteigert werden könnte. Gott gnade jenem Lande, über dem eine Sechstonnenbombe von Lithiumhydrid zur Explosion gebracht wird!

The energy which can be obtained by the formation of helium from LiH is almost three times as great as that produced by nuclear fission from the same quantity of U-235. In this case, lithium is not a rare element, so that in a "super atom bomb" it would be possible to use on the order of tons of lithium hydride compared to kilograms of plutonium [for fission], in such a way as to produce an effect several thousand times as large as before. God have mercy on the country over which a six-ton bomb of lithium hydride is made to explode!

Sofern die Idee überhaupt realisierbar ist, würde in solch einer Superatombombe die bisherige Uranbombe oder Plutoniumbombe nur die Rolle einer "Zündpille" spielen. [...]

If the idea is realizable at all, the former uranium bomb or plutonium bomb would only play the role of a sparkplug in such a super atom bomb. [...]

[Thirring was correct that lithium hydride would make an excellent solid fuel for a hydrogen bomb, and that such a bomb could be thousands of times more powerful than a fission bomb (megatons instead of kilotons of explosive yield). However, the specific isotopes and reaction that he proposed (^{7}Li + ^{1}H) are too difficult to use for fusion, because of the strong repulsion between the three positive charges in the lithium nucleus and the one positive charge in the hydrogen nucleus.

By using ^{6}Li, ^{2}H (deuterium), and two coupled nuclear reactions, the Jetter cycle (p. 4348) avoids that problem. Did scientists consider that possibility during the war?

Note that Thirring gave an extremely specific example of a fusion bomb: "a six-ton bomb of lithium hydride." Thirring was in direct contact with scientists who worked in the wartime German nuclear program. Why did he choose such a specific mass for a fusion bomb? Was there wartime work on a six-ton lithium hydride (lithium deuteride?) bomb? Immediately after the war, several other scientists and engineers mentioned wartime work on a mysterious six-ton bomb–see pp. 4350–4363 and 5343.]

[...] Man weiß seit fast einem Vierteljahrhundert, daß es α-strahlende Substanzen gibt, die etwas anderes sind als die bekannten α-Strahler der drei radioaktiven Familien. Sehr eingehende Messungen mit verfeinerten Appareten sind am Physikalischen Institut der Wiener Universität und am Wiener Radiuminstitut vorgenommen worden und ergaben, daß es eine ganze Gruppe von sieben neuen α-Strahlern mit verschiedener Reichweite gibt, die bisher keinem Isotop irgendeines der bekannten Elemente zwischen Nr. 1 und Nr. 92 zugeschrieben werden konnten. Es ist einer Wiener Forschergruppe, die aus den Herren Schintlmeister, Jentschke, Brukl, Hernegger und Frl. Hilbert besteht, gelungen, aus Zinkblende und aus anderen sulfidischen Erzen die α-Strahler anzureichern, aber die gewonnenen Mengen sind noch nicht groß genug, um mit Hilfe von Röntgen-spektralaufnahmen die chemische Natur festzustellen. Es wäre möglich, daß es sich um Transurane handelt, und zwar um andere und langlebigere als Neptunium und Plutonium, weil diese infolge ihrer Kurzlebigkeit schon längst nicht mehr im natürlichen Zustand auf der Erde vorkommen, sondern nur künstlich hergestellt werden können. Weil nun jedes Element mit einer Kernladung von 90 und darüber zur Kernspaltung neigt, ist mit Warscheinlichkeit anzunehmen, daß diese noch nicht identifizierten α-Strahler—falls sie wirklich Transurane sind—entweder selber Stoffe sind, in denen Kernkettenreaktionen eintreten können, oder als Ausgangsmaterial zur Heranzüchtung solcher Stoffe dienen können. Substanzen dieser Art würden dann sowohl für die Atomwaffe als auch für die reine Energiegewinnung das Uranmonopol brechen.

[...] It has been known for almost a quarter of a century that there are alpha-emitting substances that are different from the known alpha emitters of the three radioactive families. Very detailed measurements with refined equipment have been made at the Physics Institute of the University of Vienna and at the Vienna Radium Institute, and showed that there is a whole group of seven new alpha-emitters with different ranges which have hitherto not been associated with any isotope of any of the known elements between no. 1 and 92. It is a Viennese research group consisting of Schintlmeister, Jentschke, Brukl, Hernegger, and Frl. Hilbert, who succeeded in enriching the alpha emitters from zincblende and other sulphide ores, but the quantities obtained are not yet large enough to be combined with help of Roentgen spectral recordings to determine the chemical nature. It is possible that they are transuranics, and others are more durable than neptunium and plutonium, because, as a result of their short-livedness, they are no longer present in the natural state on the earth, but can be produced only in a manner which is artificial. Since every element with a nuclear charge of 90 or over tends to undergo nuclear fission, it is probable that these unidentified alpha-emitters, if they are really transuranics, are themselves substances in which nuclear chain reactions can occur, or as starting materials for the production of such substances. Substances of this kind would then break the uranium monopoly both for nuclear weapons and for pure energy production.

[Thirring provided more information about Schintlmeister's possible experiments with transuranic elements. Apparently Schintlmeister used the energies (range) of emitted alpha particles to try to identify the specific isotopes that emitted those alpha particles. If only isotopes from naturally occurring samples were analyzed, there should be no transuranic elements, and any results indicating that there were would presumably be spurious. Did the analyzed samples come from an artificial source, such as a cyclotron or fission reactor?]

Hans Thirring. Undated (circa 1971). In den nächsten zehn Jahren muss es zwischen den Supermächten USA, UdSSR, China, England und Frankreich zu einer allgemeinen Abrüstung kommen. Sondersammlung der Österreichischen Zentralbibliothek für Physik (ZBP), Universität Wien, Nachlass Broda, Box 24, File 55, Fiche 54.

Schon vor 25 Jahren wußte ich, daß man Wasserstoffbomben erzeugen wird, die eine zehntausendfache Sprengkraft der Hiroshima-Bombe haben würden. In den Jarhren 1951–1967 haben fünf Staaten an diesem Projekt gearbeitet und Megatonnenbomben erzeugt; es sind bereits genügend Bomben vorhanden, um die ganze Welt in einen chaotischen Zustand unvorstellbaren Ausmaßes bringen zu können. [...]

Im Juli 1946 diskutierte ich über das Problem der Entwicklung noch stärkerer Vernichtungswaffen mit meinem Kollegen Jentschke, einem jungen österreichischen Physiker, jetzt Generaldirektor des CERN in Genf. Jentschke war als reiner Physiker nicht so sehr von der Wichtigkeit der Kernvernschmelzung überzeugt; aber ich als Physiker und Politiker wußte, daß das Gelingen dieser Experimente (zur Herstellung der Wasserstoffbombe) leider von welthistorischer Bedeutung sein wird.

Im Herbst 1946 veröffentlichte ich mein Buch, “Die Geschichte der Atombombe”. [...]

Die meisten Leute fanden die darin beschriebene historische Entwicklung sehr interessant, aber über die Berechnungen der Lithiumhydrid-Reaktion lasen sie, als zu wissenschaftlich, einfach hinweg. [...]

Im Studienjahr 1946/47 war ich Dekan an der Universität Wien und sprach in einem Seminar, das ich damals hielt, über die Möglichkeit, daß nicht nur die Amerikaner sondern auch die Russen sehr bald über Wasserstoffbomben verfügen könnten.

25 years ago, I knew that hydrogen bombs, which could have ten thousand times the explosive force of the Hiroshima bomb, would be produced. In the years 1951–1967 five countries worked on this project and produced megaton bombs; there are already enough bombs to turn the whole world into a chaotic state of unimaginable proportions. [...]

In July 1946, I discussed the problem of the development of even more powerful weapons of destruction with my colleague Jentschke, a young Austrian physicist, now General Manager of CERN in Geneva. Jentschke, as a pure physicist, was not so much convinced of the importance of nuclear fusion; but as a physicist and politician I knew that the success of these experiments (for the production of the hydrogen bomb) would unfortunately be of historical importance.

In the autumn of 1946 I published my book, *The History of the Atomic Bomb.* [...]

Most people found the historical development described therein very interesting, but they simply ignored the calculations of the lithium hydride reaction as too scientific. [...]

In the academic year 1946/47, I was a dean at the University of Vienna, and I spoke in a seminar I held at the time about the possibility that not only the Americans, but also the Russians, could soon have hydrogen bombs.

[Thirring acknowledged that an important source for his book was Willibald Jentschke, who was a member of Georg Stetter's research group during the war.

Does the information in Thirring's book accurately convey what the Austrian nuclear scientists knew (or did not know) during the war, or were any important details omitted?

How much involvement did Thirring himself have with nuclear work during the war?

What other sources of information did he use for his book?]

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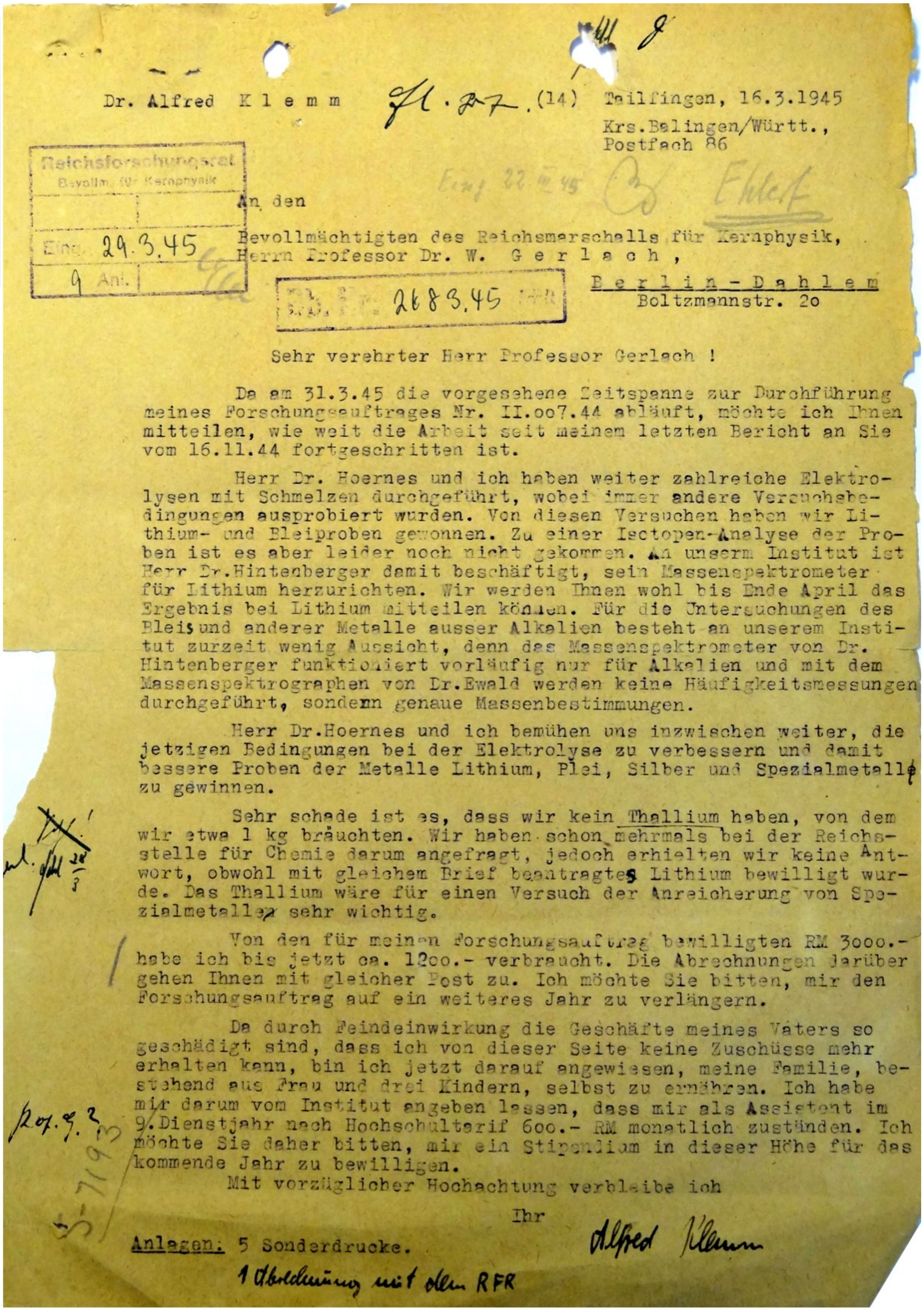


Fl. 27. (14)

Dr. Alfred Klemm

Tailfingen, 16.3.1945
Krs.Balingen/Württ.,
Postfach 86

Reichsforschungsrat
Bevollm. für Kernphysik
Eing. 29.3.45
9 Anl.

Eing 22 III 45

Ehlert

An den

Bevollmächtigten des Reichsmarschalls für Kernphysik,
Herrn Professor Dr. W. Gerlach,

2683.45

Berlin-Dahlem
Boltzmannstr. 2o

Sehr verehrter Herr Professor Gerlach !

Da am 31.3.45 die vorgesehene Zeitspanne zur Durchführung meines Forschungsauftrages Nr. II.oo7.44 abläuft, möchte ich Ihnen mitteilen, wie weit die Arbeit seit meinem letzten Bericht an Sie vom 16.11.44 fortgeschritten ist.

Herr Dr. Hoernes und ich haben weiter zahlreiche Elektrolysen mit Schmelzen durchgeführt, wobei immer andere Versuchsbedingungen ausprobiert wurden. Von diesen Versuchen haben wir Lithium- und Bleiproben gewonnen. Zu einer Isotopen-Analyse der Proben ist es aber leider noch nicht gekommen. An unserm Institut ist Herr Dr.Hintenberger damit beschäftigt, sein Massenspektrometer für Lithium herzurichten. Wir werden Ihnen wohl bis Ende April das Ergebnis bei Lithium mitteilen können. Für die Untersuchungen des Bleis und anderer Metalle ausser Alkalien besteht an unserem Institut zurzeit wenig Aussicht, denn das Massenspektrometer von Dr. Hintenberger funktioniert vorläufig nur für Alkalien und mit dem Massenspektrographen von Dr.Ewald werden keine Häufigkeitsmessungen durchgeführt, sondern genaue Massenbestimmungen.

Herr Dr.Hoernes und ich bemühen uns inzwischen weiter, die jetzigen Bedingungen bei der Elektrolyse zu verbessern und damit bessere Proben der Metalle Lithium, Blei, Silber und Spezialmetalle zu gewinnen.

Sehr schade ist es, dass wir kein Thallium haben, von dem wir etwa 1 kg bräuchten. Wir haben schon mehrmals bei der Reichsstelle für Chemie darum angefragt, jedoch erhielten wir keine Antwort, obwohl mit gleichem Brief beantragtes Lithium bewilligt wurde. Das Thallium wäre für einen Versuch der Anreicherung von Spezialmetallen sehr wichtig.

Von den für meinen Forschungsauftrag bewilligten RM 3ooo.- habe ich bis jetzt ca. 12oo.- verbraucht. Die Abrechnungen darüber gehen Ihnen mit gleicher Post zu. Ich möchte Sie bitten, mir den Forschungsauftrag auf ein weiteres Jahr zu verlängern.

Da durch Feindeinwirkung die Geschäfte meines Vaters so geschädigt sind, dass ich von dieser Seite keine Zuschüsse mehr erhalten kann, bin ich jetzt darauf angewiesen, meine Familie, bestehend aus Frau und drei Kindern, selbst zu ernähren. Ich habe mir darum vom Institut angeben lassen, dass mir als Assistent im 9.Dienstjahr nach Hochschultarif 6oo.- RM monatlich zuständen. Ich möchte Sie daher bitten, mir ein Stipendium in dieser Höhe für das kommende Jahr zu bewilligen.

Mit vorzüglicher Hochachtung verbleibe ich

Ihr

Alfred Klemm

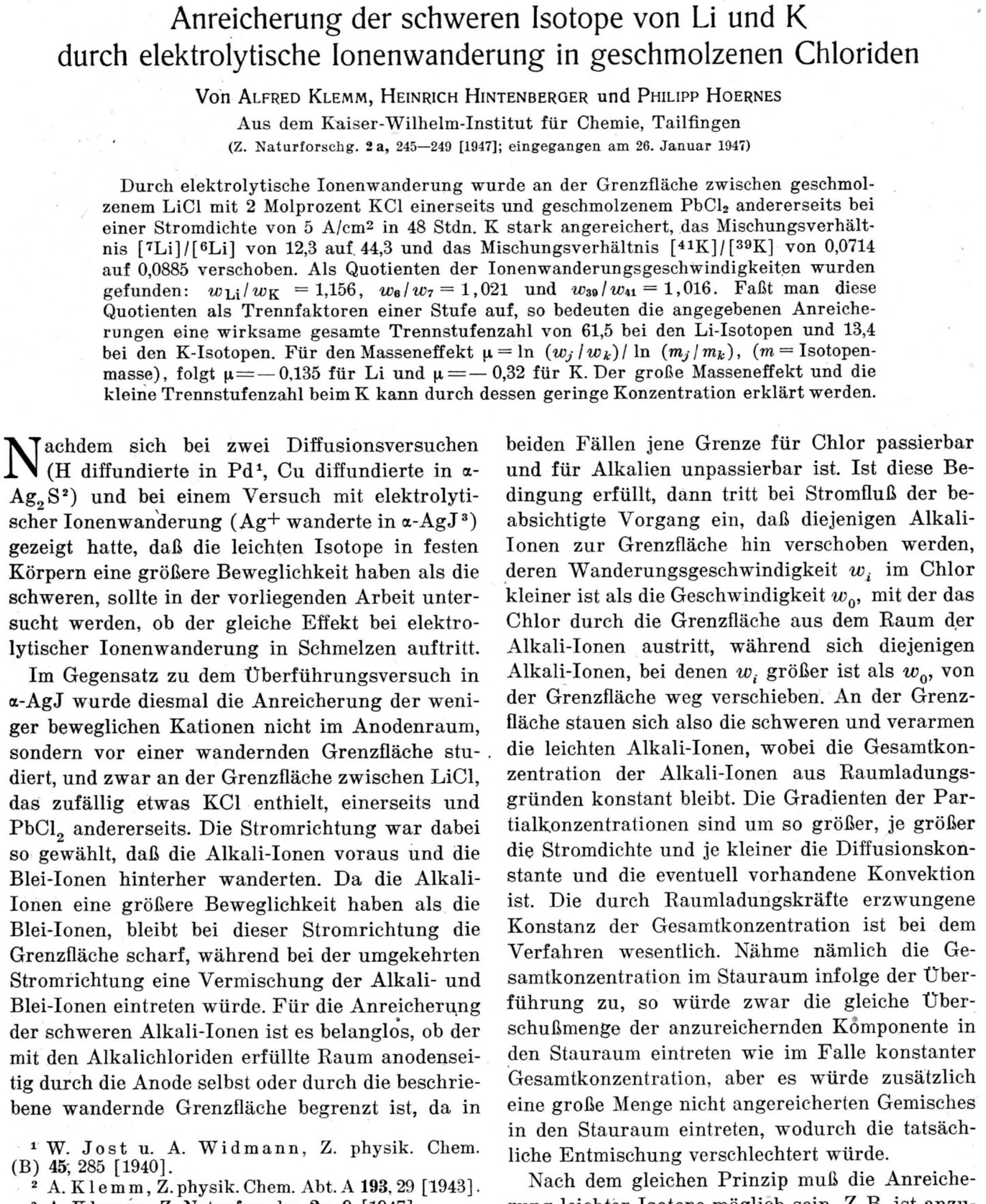
Anlagen: 5 Sonderdrucke.
1 Abrechnung mit dem RFR

28/3

S-7193

NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45--Dec 45)

Figure D.633: 16 March 1945 letter from Alfred Klemm to Walther Gerlach reporting successful demonstrations of lithium isotope separation [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].



Anreicherung der schweren Isotope von Li und K durch elektrolytische Ionenwanderung in geschmolzenen Chloriden

Von Alfred Klemm, Heinrich Hintenberger und Philipp Hoernes
Aus dem Kaiser-Wilhelm-Institut für Chemie, Tailfingen

(Z. Naturforschg. **2a**, 245—249 [1947]; eingegangen am 26. Januar 1947)

Durch elektrolytische Ionenwanderung wurde an der Grenzfläche zwischen geschmolzenem LiCl mit 2 Molprozent KCl einerseits und geschmolzenem $PbCl_2$ andererseits bei einer Stromdichte von 5 A/cm² in 48 Stdn. K stark angereichert, das Mischungsverhältnis $[^7Li]/[^6Li]$ von 12,3 auf 44,3 und das Mischungsverhältnis $[^{41}K]/[^{39}K]$ von 0,0714 auf 0,0885 verschoben. Als Quotienten der Ionenwanderungsgeschwindigkeiten wurden gefunden: $w_{\mathrm{Li}}/w_{\mathrm{K}} = 1{,}156$, $w_6/w_7 = 1{,}021$ und $w_{39}/w_{41} = 1{,}016$. Faßt man diese Quotienten als Trennfaktoren einer Stufe auf, so bedeuten die angegebenen Anreicherungen eine wirksame gesamte Trennstufenzahl von 61,5 bei den Li-Isotopen und 13,4 bei den K-Isotopen. Für den Masseneffekt $\mu = \ln (w_j/w_k)/\ln (m_j/m_k)$, ($m$ = Isotopenmasse), folgt $\mu = -0{,}135$ für Li und $\mu = -0{,}32$ für K. Der große Masseneffekt und die kleine Trennstufenzahl beim K kann durch dessen geringe Konzentration erklärt werden.

Nachdem sich bei zwei Diffusionsversuchen (H diffundierte in Pd[1], Cu diffundierte in α-Ag_2S[2]) und bei einem Versuch mit elektrolytischer Ionenwanderung (Ag^+ wanderte in α-AgJ[3]) gezeigt hatte, daß die leichten Isotope in festen Körpern eine größere Beweglichkeit haben als die schweren, sollte in der vorliegenden Arbeit untersucht werden, ob der gleiche Effekt bei elektrolytischer Ionenwanderung in Schmelzen auftritt.

Im Gegensatz zu dem Überführungsversuch in α-AgJ wurde diesmal die Anreicherung der weniger beweglichen Kationen nicht im Anodenraum, sondern vor einer wandernden Grenzfläche studiert, und zwar an der Grenzfläche zwischen LiCl, das zufällig etwas KCl enthielt, einerseits und $PbCl_2$ andererseits. Die Stromrichtung war dabei so gewählt, daß die Alkali-Ionen voraus und die Blei-Ionen hinterher wanderten. Da die Alkali-Ionen eine größere Beweglichkeit haben als die Blei-Ionen, bleibt bei dieser Stromrichtung die Grenzfläche scharf, während bei der umgekehrten Stromrichtung eine Vermischung der Alkali- und Blei-Ionen eintreten würde. Für die Anreicherung der schweren Alkali-Ionen ist es belanglos, ob der mit den Alkalichloriden erfüllte Raum anodenseitig durch die Anode selbst oder durch die beschriebene wandernde Grenzfläche begrenzt ist, da in beiden Fällen jene Grenze für Chlor passierbar und für Alkalien unpassierbar ist. Ist diese Bedingung erfüllt, dann tritt bei Stromfluß der beabsichtigte Vorgang ein, daß diejenigen Alkali-Ionen zur Grenzfläche hin verschoben werden, deren Wanderungsgeschwindigkeit w_i im Chlor kleiner ist als die Geschwindigkeit w_0, mit der das Chlor durch die Grenzfläche aus dem Raum der Alkali-Ionen austritt, während sich diejenigen Alkali-Ionen, bei denen w_i größer ist als w_0, von der Grenzfläche weg verschieben. An der Grenzfläche stauen sich also die schweren und verarmen die leichten Alkali-Ionen, wobei die Gesamtkonzentration der Alkali-Ionen aus Raumladungsgründen konstant bleibt. Die Gradienten der Partialkonzentrationen sind um so größer, je größer die Stromdichte und je kleiner die Diffusionskonstante und die eventuell vorhandene Konvektion ist. Die durch Raumladungskräfte erzwungene Konstanz der Gesamtkonzentration ist bei dem Verfahren wesentlich. Nähme nämlich die Gesamtkonzentration im Stauraum infolge der Überführung zu, so würde zwar die gleiche Überschußmenge der anzureichernden Komponente in den Stauraum eintreten wie im Falle konstanter Gesamtkonzentration, aber es würde zusätzlich eine große Menge nicht angereicherten Gemisches in den Stauraum eintreten, wodurch die tatsächliche Entmischung verschlechtert würde.

Nach dem gleichen Prinzip muß die Anreicherung leichter Isotope möglich sein. Z. B. ist anzu-

---

[1] W. Jost u. A. Widmann, Z. physik. Chem. (B) **45**, 285 [1940].

[2] A. Klemm, Z. physik. Chem. Abt. A **193**, 29 [1943].

[3] A. Klemm, Z. Naturforschg. **2a**, 9 [1947].

Figure D.634: Alfred Klemm, Heinrich Hinterberger, and Philipp Hoernes. 1947. Anreicherung der schweren Isotope von Li und K durch elektrolytische Ionenwanderung in geschmolzenen Chloriden. *Zeitschrift für Naturforschung.* 2a:245–249. [https://doi.org/10.17617/3.GRUJYR]

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[...] Der Trennversuch und die Auswertung der Analysenergebnisse wurde von A. Klemm, die massen-spektrometrische Analyse von H. Hintenberger und die chemische Arbeit von Ph. Hoernes durchgeführt. Hrn. Prof. J. Mattauch danken wir für die Förderung der Arbeit und den Assistentinnen H. und U. Scheid für ihre gewissenhafte Mitarbeit.

Enrichment of the heavy isotopes of Li [lithium] and K [potassium] by electrolytic ion migration in molten chlorides.

By electrolytic ion migration at the boundary between molten LiCl with 2 mole percent KCl, on the one hand, and molten $PbCl_2$, on the other hand, was strongly enriched in 48 hours of K at a current density of 5 A/cm^2, the mixing ratio [^{7}Li]/[^{6}Li] from 12.3 to 44.3 and the mixing ratio [^{41}K]/[^{39}K] from 0.0714 to 0.0885. As quotients of the ion migration rates were found: $w_{\mathrm{Li}}/w_{\mathrm{K}}$ = 1.156, w_6/w_7 = 1.021 and w_{39}/w_{41} = 1.016. If these quotients are taken as the separation factors of a step, the indicated enrichment means an effective total separation step number of 61.5 for the Li isotopes and 13.4 for the K isotopes. For the mass effect $\mu = \ln(w_j/w_k)/\ln(m_j/m_k)$, ($m$ = isotope mass), μ = -0.135 for Li and μ = -0.32 for K. The large mass effect and the small number of separation stages in the K can be explained by its low concentration.

[...] The separation experiment and the analysis of the results of the analysis were carried out by A. Klemm, the mass spectrometric analysis by H. Hintenberger, and the chemical work of Ph. Hoernes. We thank Prof. J. Mattauch for the support of the work and the assistants H. and U. Scheid for their conscientious cooperation.

[See document photo on p. 4344. This was a delayed publication of work that was done during the war; see for example p. 4343. Lithium has two naturally occurring isotopes: ^{6}Li (approximately 7.5% of natural lithium) and ^{7}Li (approximately 92.5% of natural lithium). Thus their naturally occurring ratio is [^{7}Li]/[^{6}Li] ≈ 92.5%/7.5% ≈ 12.3. Within 48 hours, Klemm's process enriched them to a ratio [^{7}Li]/[^{6}Li] ≈ 97.8%/2.2% ≈ 44.3. The isotopes are virtually identical chemically; the only major reason to separate them would be for nuclear reactions. What exactly was the purified ^{6}Li intended for?]

During the war, Josef Mattauch was head of the physics department at the Kaiser Wilhelm Institute for Chemistry in Tailfingen where Klemm worked. Prior to the war, Mattauch was at the University of Vienna for 26 years, and thus closely connected to Georg Stetter's research group. Was the purified ^{6}Li for the Stetter group's work on fusion? If so, that could suggest that they were working on the Jetter cycle, which requires ^{6}Li.]

Alfred Klemm. 1958. Lithium in der Kerntechnik. *Angewandte Chemie* 70:1:21–24.

Lithium kann in der modernen Kerntechnik auf vielfache Weise verwendet werden, so zur Herstellung von Tritium (etwa für thermonucleare Reaktionen), als Abschirmungsmittel, zum Nachweis thermischer Neutronen, als Reaktorkühlmittel, als Moderator oder in Form von geschmolzenem LiF als Lösungsmittel für Kernbrennstoffe. Zur Anreicherung der Lithium-Isotope 6 bzw. 7 sind die Ionenwanderung in geschmolzenem LiCl und das Lithium-Amalgam-Verfahren von besonderem Interesse.	Lithium can be widely used in modern nuclear engineering, for instance to produce tritium (for thermonuclear reactions), as a shielding agent, for detecting thermal neutrons, as a reactor coolant, as a moderator, or as a molten LiF as a solvent for nuclear fuels. The ion migration in molten LiCl and the lithium-amalgam process are of particular interest for the enrichment of the lithium isotopes 6 and 7, respectively.

[This postwar article by Klemm may suggest that his wartime work was indeed intended for nuclear purposes.]

Heiko Petermann, Discussion notes with Prof. Alfred Klemm, Mainz, Saarstr. 23, Max Planck Institut für Chemie. 5 March 2004. 06131-305-223 [courtesy of Heiko Petermann].

Klemm wirkte sehr nervös und wich meinen Fragen immer wieder aus. Er war bemüht, mich so schnell wie möglich wieder los zu werden.	Klemm looked very nervous and always gave up my questions. He tried to get rid of me as soon as possible.
Klemm hat sich während des Krieges ausschließlich mit Isotopentrennung beschäftigt und war sozusagen sein 'eigener Herr'. Das von ihm entwickelte Elektrolyt-Verfahren funktionierte bei Uranhexaflorid nicht.	During the war, Klemm concentrated exclusively on isotopic separation and was, so to speak, his own master. The electrolyte process he developed did not work with uranium hexafluoride.
Klemm hatte mit Hahns Truppe wenig zu tun, da er separat arbeitete, sich selbst als 'eigen' bezeichnet	Klemm had little to do with Hahn's group, since he worked separately, calling himself 'independent'
Klemm ging mit nach Tailfingen	Klemm also went to Tailfingen

Schwerpunkt der Arbeit war die Herstellung von Li6 durch Trennung von Li7. Dies gelang im elektrolytischen Verfahren sehr gut. Ab 1942–43. Klemm wies darauf hin, dass er wohl der erste war, dem die Trennung mittels Elektrolyse gelungen sei (wissenschaftliche Priorität, siehe auch Z. f. Naturforschung 2a, S. 245 ff, 1947, unter Mitarbeit v. H. Hintenberger u. P. Hoernes)

Über die Tritium-Problematik wusste er Bescheid, es war aber damals nicht seine Aufgabe. (wessen denn?)

Diskutiert wurde die Verwendung von metallischem Li7 als Reaktorkühlmittel

Klemm kannte die AEG-Hochspannungsanlage und meinte Flammersfeld hat dort mit Bestrahlung von Material gearbeitet
(Vorsicht bei dieser Aussage, sie passt zwar, doch es ist nicht klar ob Klemm da nicht einiges bezüglich der Hochspannungsanlage des KWI f. Chemie durcheinanderbringt, ich fasse brieflich nach—hp)

Klemms Vater gehörte die Dietrichsche Verlagsbuchhandlung. 1946 entstand dann als Ableger der Verlag der Zeitschrift für Naturforschung, die seitdem A. Klemm leitet.

Brieflich dürfte er präziser sein, denn der Besuch hat ihn in erheblichste Unruhe gestürzt.

Vielleicht lässt sich aus seinem Archiv noch ein Schätzchen heben.

Nachtrag: Mit Antwortschreiben v. 4.4.04 notierte er handschriftlich, daß er Li6 im Grammbereich produzierte. Gegen Kriegsende hat er es ‘weggeworfen’.

Er bestätigte weiterhin, daß die Tritiumproblematik (Zerfall Li6 in Tritium) bereits vor 1945 diskutiert wurde.

Main focus of the work was the production of Li6 by separation of Li7. This was achieved very well in the electrolytic process. From 1942–43. Klemm pointed out that he was probably the first to achieve the separation by means of electrolysis (scientific priority, see also Z. f. Naturforschung 2a, pp. 245 ff, 1947, with the collaboration of H. Hintenberger and P. Hoernes)

He knew about the tritium problem, but it was not his job at the time. (Whose then?)

The use of metallic Li7 as a reactor coolant was discussed

Klemm knew the AEG high voltage installation and said Flammersfeld worked there with irradiation of material
(Caution with this statement, it fits, but it is not clear whether Klemm was referring in part to the high-voltage plant of the KWI for Chemistry disagrees, I will get the correspondence after—hp)

Klemm’s father owned the book publisher Dietrich. In 1946, the publishing house of the Zeitschrift fúr Naturforschung (Journal of Natural Research), which has been headed by A. Klemm since then, was founded.

In correspondence he might be more precise, for the visit has plunged him into considerable disquiet.

Perhaps one can pick up a clue from his archive.

Addendum: With a reply from v. 4.4.04 he noted in handwriting that he produced Li6 in the gram range. He “threw it away” at the end of the war.

He also confirmed that the tritium problem (disintegration of Li6 into tritium) was already discussed before 1945.

[If Klemm's wartime work was for purely scientific reasons, why was he so nervous to discuss it 60 years later, and shortly before his death?

Klemm twice confirmed that scientists were working on tritium during the war. Who and where? Was his ^{6}Li bombarded with neutrons to produce tritium during the war? The knowledge of that reaction during the war, as shown by both Klemm and also Kallmann and Kuhn (p. 4298) may help demonstrate that the Jetter cycle (p. 4348) originated in the German-speaking world during the war.

An amount of ^{6}Li "in the gram range" (one gram? several grams?) would be extremely useful for fusion boosting of a fission bomb, or for producing a similar amount of tritium for the same purpose.

If Klemm's work was performed during 1942–1943, planning for fusion reactions must have begun early in the war. If Klemm's work was perfected at that time, was his ^{6}Li purification process transferred to other locations and scaled up later in the war?

If the gram-range amount of ^{6}Li was difficult to create and was produced for purely scientific reasons, why would Klemm "throw it away" at the end of the war? If he did throw it away, does that suggest that he knew its real purpose was much more serious? Or did he not throw it away—was it transferred to the German nuclear program, or seized by Allied forces, or hidden to protect it?]

Pavel V. Oleynikov. 2000. German Scientists in the Soviet Atomic Project. *Nonproliferation Review* 7:2:1–30.

After 1950, Hertz moved to Moscow where, together with Werner Schuetze, he started to work on analysis of lithium and purification of tritium.

Documents about German scientists who helped the Soviet Union develop an atomic bomb. 29 October 2019. [**https://www.mbs.news/2019/10/documents-about-german-scientists-who-helped-the-soviet-union-develop-an-atomic-bomb.html**]

Manfred von Ardenne, the scientific director of the A kurulan institute, established in another sanatorium in the USSR, was also awarded the Stalin Prize twice in 1947 for inventing the electronic microscope and in 1953 for obtaining the lithium 6 isotope necessary for the creation of nuclear warheads.

[After the war, Gustav Hertz, Werner Schuetze, and Manfred von Ardenne separated lithium isotopes and produced tritium for the Soviet hydrogen bomb project. Was their expertise in that area derived from work they did during the war to separate lithium isotopes and produce tritium for the German nuclear program?]

https://www.cia.gov/readingroom/docs/CIA-RDP82-00457R004500650007-8.pdf

Ulrich Jetter. 1950. Die sogenannte Superbombe. *Physikalische Blätter* (1950) 6:199-205.

Die beiden Reaktionen... “gehen” ungewöhnlich gut: das leichte Lithiumisotop hat einen sehr großen Wirkungsquerschnitt gegenüber der D-D-Reaktion eine tiefere Energieschwelle und bei gleicher Temperatur die rund hundertfache Ausbeute. Sofern also genügend Tritonen oder Neutronen zugegen sind, wird der Zyklus

$$\begin{tikzcd} \mathrm{n} + {}^{6}\mathrm{Li} \arrow[r] & {}^{4}\mathrm{He} + \mathrm{Tr} \arrow[d] \\ \mathrm{n} + {}^{4}\mathrm{He} \arrow[u] & \mathrm{D} + \mathrm{Tr} \arrow[l] \end{tikzcd} \tag{D.15}$$

die Hauptreaktion bilden.

The two reactions... “go” [together] unusually well: the light lithium isotope has a very large cross section over the DD reaction, a lower energy threshold and at the same temperature a hundredfold yield, so if sufficient tritons or neutrons are present, the cycle

$$\begin{tikzcd} \text{neutron} + \text{lithium-6} \arrow[r] & \text{helium-4} + \text{tritium} \arrow[d] \\ \text{neutron} + \text{helium-4} \arrow[u] & \text{deuterium} + \text{tritium} \arrow[l] \end{tikzcd} \tag{D.16}$$

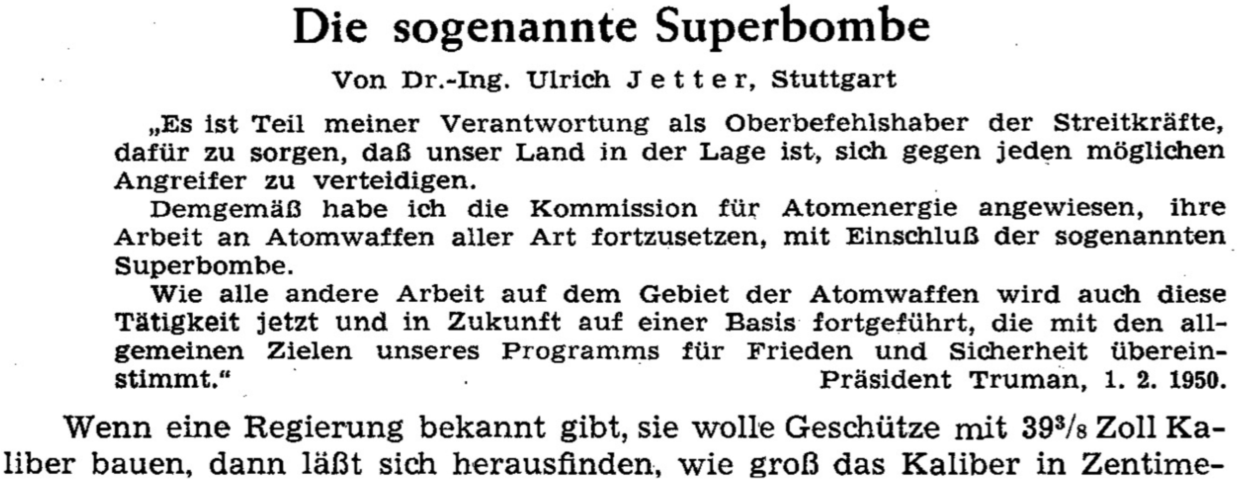
will become the main reaction.

[This reaction uses lithium-6 deuteride and is the main reaction in modern hydrogen bombs. It was not demonstrated by the United States and Soviet Union until the 1950s.

Due to Allied restrictions on research in Germany and Austria after the war, it seems likely that this paper was based on wartime research. Where and when was that research done, and by whom? Can this paper be connected to wartime research by Georg Stetter’s group or other groups on lithium-based fusion reactions? Ulrich Jetter (German, 1914–??) studied at the University of Stuttgart 1931–1941, worked at the Kaiser Wilhelm Institute for Metal Research 1941–1945, and served as an editor for *Physikalische Blätter* 1945–1951 [Jetter 1954]. Could Jetter’s 1950 article, 1952 book, and 1954 article (Fig. D.635) on the scientific details of H-bombs have been based on information he learned during the war? Did Jetter do nuclear research during the war, or did he interact with other scientists who did? Lithium is a metal; was lithium fusion research being done at the KWI for Metal Research during the war?

Alternatively, could Jetter’s article be based on wartime research that he learned about after the war in his capacity as an editor at the journal? Or does the paper truly demonstrate an insight that only came to Jetter, and only in 1950?

Note that Jetter was invited to Washington, D.C. as a “cultural exchange fellow” in 1951, before the U.S. produced and tested its first H-bombs.]



Die sogenannte Superbombe

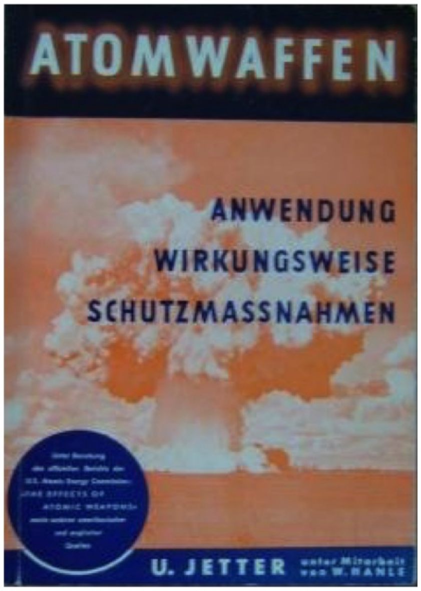
Von Dr.-Ing. Ulrich Jetter, Stuttgart

> „Es ist Teil meiner Verantwortung als Oberbefehlshaber der Streitkräfte, dafür zu sorgen, daß unser Land in der Lage ist, sich gegen jeden möglichen Angreifer zu verteidigen.
>
> Demgemäß habe ich die Kommission für Atomenergie angewiesen, ihre Arbeit an Atomwaffen aller Art fortzusetzen, mit Einschluß der sogenannten Superbombe.
>
> Wie alle andere Arbeit auf dem Gebiet der Atomwaffen wird auch diese Tätigkeit jetzt und in Zukunft auf einer Basis fortgeführt, die mit den allgemeinen Zielen unseres Programms für Frieden und Sicherheit übereinstimmt.“
>
> Präsident Truman, 1. 2. 1950.

Wenn eine Regierung bekannt gibt, sie wolle Geschütze mit $39^3/_8$ Zoll Kaliber bauen, dann läßt sich herausfinden, wie groß das Kaliber in Zentime-

1950 *Physikalische Blätter* article

1952 book, *Nuclear Weapons: Use, Mode of Action, Protective Measures*



1954 *Physikalische Blätter* article

Ulrich Jetter

Mitarbeiter des Instituts für Demoskopie Allensbach. Physik und Sozialwissenschaften. * 1914. Nach Abitur 2 Jahre Industriearbeit. 1935/40 Stud. d. Physik in Stuttgart. 1937/38 Foreign Exchange Fellowship Passadena, Master of Science. 1939 Dipl.-Ing. 1941 Dr.-Ing. TH Stuttgart. Bis 1945 KWI für Metallforschung, Militär- und Wetterdienst, Funk-Meßgeräte-Entwicklung. 1945/51 Schriftleiter Phys. Blätter. 1951 Cultural Exchange Fellow Washington und Ann Arbor. Ab 1951 Inst. f. Demoskopie.

Die Zeitgenossen der Wasserstoffbombe

Denkbar jäh und unter wahrhaft dramatischen Umständen sind die Atomwaffen vor einem knappen Jahrzehnt der Öffentlichkeit bekannt ge-

Figure D.635: Ulrich Jetter worked on mysterious research programs for the German government during the war, published a book and articles on the scientific details of H-bombs after the war, and was invited to Washington, D.C. as a “cultural exchange fellow” before the U.S. produced and tested its first H-bombs [Jetter 1950, 1952, 1954].

Major Edmund Tilley to Lt. Col. P. M. Wilson. Secret Missiles. EPES/FIAT, Control Commission for Germany, British Element, 13 July 1946 [TNA FO 1031/57].

1. Lt. F.T. GUTMANN, of 2940th Engineer Technical Intelligence Team (R), U.S. Army, has just returned from Austria with three of SCHULZ-KAMPFHENKEL's assistants, all of the Forschungsstaffel.

2. Lt. GUTMANN went into the Russian Zone in Austria and saw a gendarme, Anton KÄSTNER, in EURATSFELD near AMSTETTEN, in Lower Austria. KÄSTNER told Lt. GUTMANN of a new radio-active bomb, weighing six tons. This bomb has no fins and is lowered by parachute. KÄSTNER himself claims to have been connected only with the fuze part of this new secret missile.

3. Colonel PETERSEN was said to have been in charge of this secret missile at OKW. KÄSTNER claimed that Colonel PETERSEN's papers and documents were left by him at Kloster ANDECHS in AMMERSEE, Upper Bavaria. Colonel PETERSEN is presumed to be in Spain.

4. A Hauptmann (Captain) SORG is said to have been Colonel PETERSEN's Chief Administrative Officer and also in charge of organization. SORG is still living at UTTING on the AMMERSEE.

5. Lt. GUTMANN believed that this new radio-active bomb may not be unconnected with the "Wärmesuchgerät" described by SCHULZ-KAMPFHENKEL. This must be a very secret instrument, for SCHULZ-KAMPFHENKEL did not tell any of the Americans about its existence and would not reveal it to us at OBERURSEL until a high pressure was exerted on him. He continues to call it "Wärmesuchgerät", which means heat searching or finding instrument, but he describes it as an aircraft instrument for measuring temperatures on the ground during the flight of the aircraft. If this were all, the instrument would be called "Wärmemessgerät" or "Temperaturmessgerät".

6. SCHMITTHÜSEN has been indicated as the man in the Forschungsstaffel who knows most about this "Wärmesuchgerät". I shall interrogate him with Lt. GUTMANN on Monday, 15th July. He is likely to prove stubborn for I saw him for a moment outside FIAT and asked him to prepare immediately a list of all hideouts for Top Secret documents. He did not know that we had found the boxes at HARBURG which he himself had dug into the ground. He was informed smilingly that 20 years behind barbed-wire were awaiting him if he continued to deny such well-known facts. He quickly agreed to let me have a complete list by Monday.

7. PILLEWIZER is the glacier expert of the Forschungsstaffel. He has written two reports for us at Lt. GUTMANN's request. The most significant sentence at the beginning of the second report, on the activities of the Forschungsstaffel in Lappland in 1944, reads as follows:

"In July 1944 a small group of the Forschungsstaffel was sent to Northern Finland in order to demonstrate, by practical experiment, the feasibility of quick map-making in the swamps and primeval forests of Lappland, i.e. to make maps quickly for topographical evaluation of hardly explored territory."

The rest of the report explains more fully the real purpose of this expedition for the work was started in VUOTSO and PARKKINA, both in the Arctic Circle, and was continued there after the Germans had evacuated all Southern Finland. Later they photographed the SAARENPAEAE area in West Lappland (ENONTOEKICE area). It is hardly likely that such an important and secret group of scientists could have been left in the Arctic Circle as late as November 1944. After completion of the work PILLEWIZER returned with his group, via NARWIK and OSLO, to Germany, where he arrived in mid-December 1944.

This expedition may have served the same purpose as other expeditions of SCHULZ-KAMPF-HENKEL, i.e. obtaining data of the effect of new deadly weapons or submitting data to enable the High Command to carry out such experiments with such missiles.

8. Lt. GUTMANN, who has not had much sleep for the last few days, will give me a copy of his report on this new missile on Monday and I shall show it to you before I go to DUSTBIN with Lt. GUTMANN.

[See document photos on pp. 4352–4353.

The six-ton bomb was specifically described as radioactive, which might mean a dirty bomb of conventional explosives releasing radioactive material, a fission bomb, or a hydrogen bomb. There was no apparent reason to make a six-ton dirty bomb—the same material could have been packaged into several smaller bombs that would have been much easier to deliver. There was also no apparent reason to make a six-ton fission bomb—the U.S. Gadget was approximately three tons without its fins or bomb casing, and the German fission bomb reported to have been tested in Thuringia in March 1945 was approximately two tons (p. 4485). In contrast, an early hydrogen bomb would be fairly much required by fundamental physical principles to be very large, since it would need to contain enough fission fuel, enough fusion fuel, enough conventional explosives to implode the fission fuel, and the structure necessary for the fission fuel to ignite the fusion fuel. Therefore the reported six-ton bomb seems to best match the description of a hydrogen bomb.

Note that Hans Thirring, who was in close contact with Austrian scientists who had worked on the wartime German nuclear program, specifically mentioned “a six-ton bomb of lithium hydride” (or perhaps lithium deuteride?); see p. 4338.

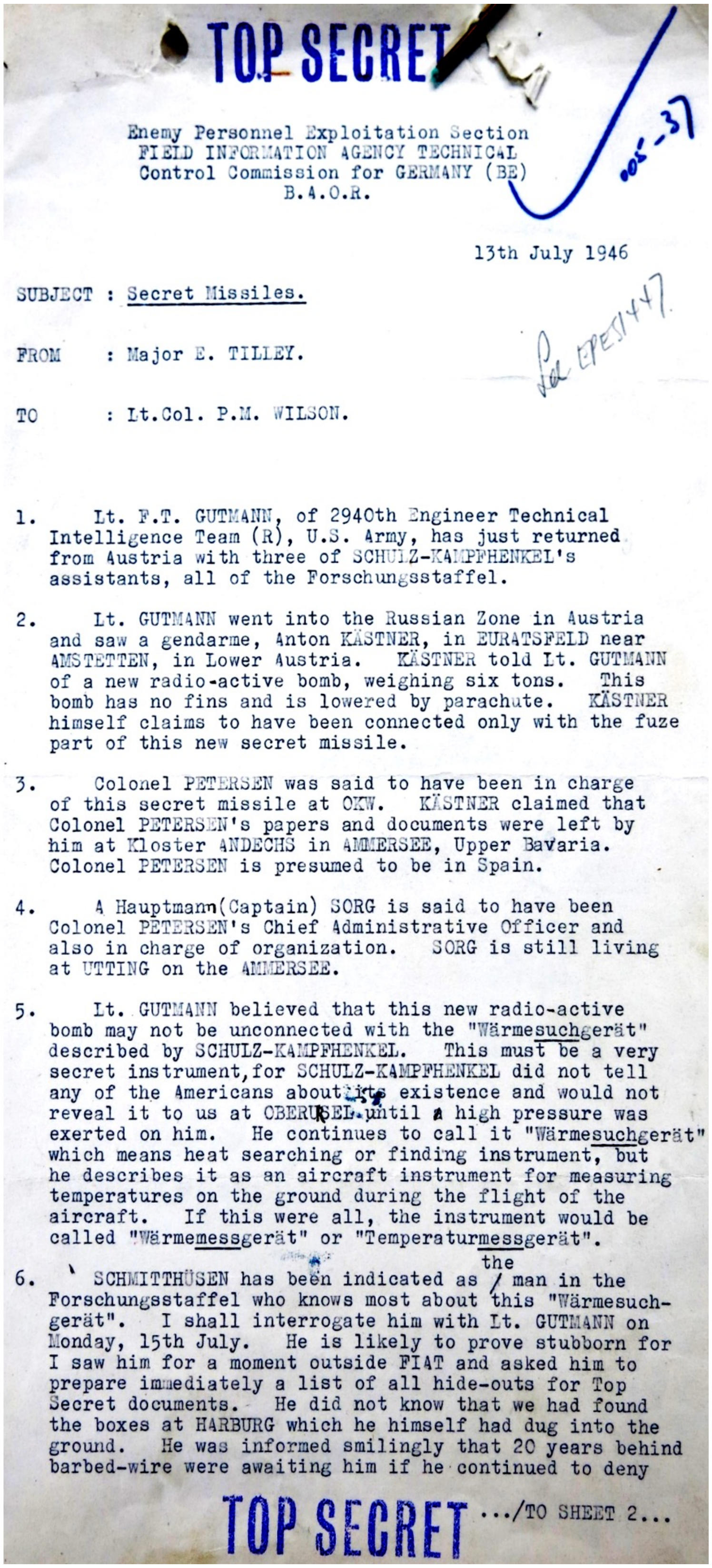
It sounds as if a German team was scouting locations in northern Finland in which to test the six-ton radioactive bomb. Seeking such a remote test location is further evidence that the bomb was a hydrogen bomb, with an explosive yield much higher than a fission bomb, making it too large to be safely or secretly tested closer to more populated regions.

The capabilities and intended functions of the “Wärmesuchgerät” are unclear from this document. It may have been a heat-seeking missile guidance system, an infrared vision system for night-time flying, or a semi-automated terrain mapping system, among other possibilities. Or since the “Wärmesuchgerät” seems to have been closely associated with the six-ton radioactive bomb and with the German team selecting a test site, perhaps the “Wärmesuchgerät” was intended to measure the explosive yield of the bomb from a safe distance in a remote territory without permanent emplacements of diagnostic instruments.

Can Lt. F. T. Gutmann’s more detailed report on the six-ton radioactive bomb be located in archives, declassified, and released?

For information on Edmund Tilley, see pp. 4894–4895.]

TNA (Kew) FO 1031/57 General 'Top Secret' Tube Alloys Etc. Intelligence Reports



TOP SECRET

005-37

Enemy Personnel Exploitation Section
FIELD INFORMATION AGENCY TECHNICAL
Control Commission for GERMANY (BE)
B.A.O.R.

13th July 1946

SUBJECT : Secret Missiles.

See EPES/447.

FROM : Major E. TILLEY.

TO : Lt.Col. P.M. WILSON.

1. Lt. F.T. GUTMANN, of 2940th Engineer Technical Intelligence Team (R), U.S. Army, has just returned from Austria with three of SCHULZ-KAMPFHENKEL's assistants, all of the Forschungsstaffel.

2. Lt. GUTMANN went into the Russian Zone in Austria and saw a gendarme, Anton KÄSTNER, in EURATSFELD near AMSTETTEN, in Lower Austria. KÄSTNER told Lt. GUTMANN of a new radio-active bomb, weighing six tons. This bomb has no fins and is lowered by parachute. KÄSTNER himself claims to have been connected only with the fuze part of this new secret missile.

3. Colonel PETERSEN was said to have been in charge of this secret missile at OKW. KÄSTNER claimed that Colonel PETERSEN's papers and documents were left by him at Kloster ANDECHS in AMMERSEE, Upper Bavaria. Colonel PETERSEN is presumed to be in Spain.

4. A Hauptmann(Captain) SORG is said to have been Colonel PETERSEN's Chief Administrative Officer and also in charge of organization. SORG is still living at UTTING on the AMMERSEE.

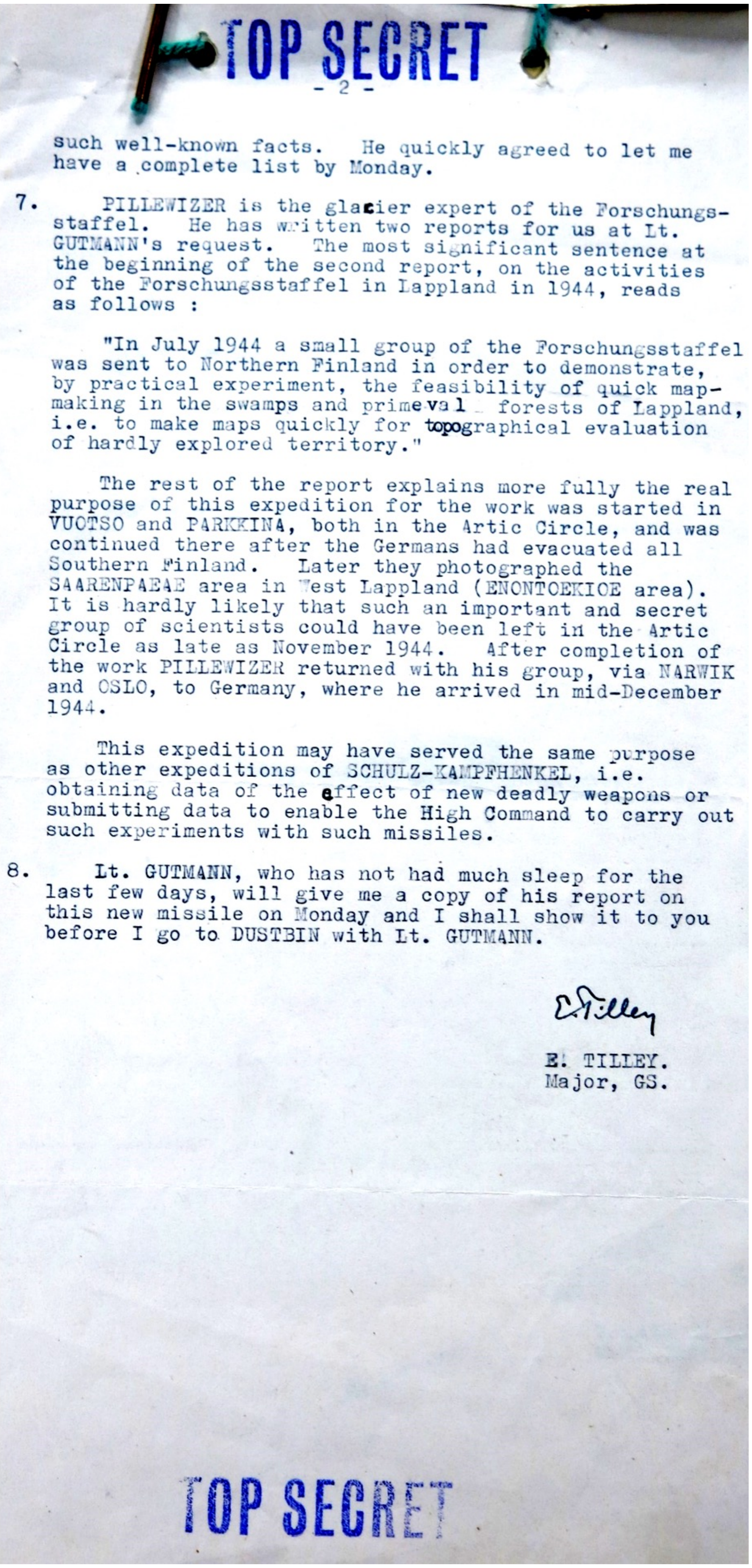
5. Lt. GUTMANN believed that this new radio-active bomb may not be unconnected with the "Wärmesuchgerät" described by SCHULZ-KAMPFHENKEL. This must be a very secret instrument, for SCHULZ-KAMPFHENKEL did not tell any of the Americans about its existence and would not reveal it to us at OBERURSEL until a high pressure was exerted on him. He continues to call it "Wärmesuchgerät" which means heat searching or finding instrument, but he describes it as an aircraft instrument for measuring temperatures on the ground during the flight of the aircraft. If this were all, the instrument would be called "Wärmemessgerät" or "Temperaturmessgerät".

6. SCHMITTHÜSEN has been indicated as the man in the Forschungsstaffel who knows most about this "Wärmesuchgerät". I shall interrogate him with Lt. GUTMANN on Monday, 15th July. He is likely to prove stubborn for I saw him for a moment outside FIAT and asked him to prepare immediately a list of all hide-outs for Top Secret documents. He did not know that we had found the boxes at HARBURG which he himself had dug into the ground. He was informed smilingly that 20 years behind barbed-wire were awaiting him if he continued to deny

TOP SECRET .../TO SHEET 2...

Figure D.636: 6-ton radioactive bomb that must be dropped with a parachute (∼megaton yield), and a planned test site in northern Finland. Edmund Tilley to P. M. Wilson. Secret Missiles. EPES/FIAT, Control Commission for Germany, British Element, 13 July 1946 [TNA (Kew) FO 1031/57].

TNA (Kew) FO 1031/57 General 'Top Secret' Tube Alloys Etc. Intelligence Reports



TOP SECRET

- 2 -

such well-known facts. He quickly agreed to let me have a complete list by Monday.

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The rest of the report explains more fully the real purpose of this expedition for the work was started in VUOTSO and PARKKINA, both in the Artic Circle, and was continued there after the Germans had evacuated all Southern Finland. Later they photographed the SAARENPAEAE area in West Lappland (ENONTOEKIOE area). It is hardly likely that such an important and secret group of scientists could have been left in the Artic Circle as late as November 1944. After completion of the work PILLEWIZER returned with his group, via NARWIK and OSLO, to Germany, where he arrived in mid-December 1944.

This expedition may have served the same purpose as other expeditions of SCHULZ-KAMPFHENKEL, i.e. obtaining data of the effect of new deadly weapons or submitting data to enable the High Command to carry out such experiments with such missiles.

8. Lt. GUTMANN, who has not had much sleep for the last few days, will give me a copy of his report on this new missile on Monday and I shall show it to you before I go to DUSTBIN with Lt. GUTMANN.

E. Tilley

E. TILLEY.
Major, GS.

TOP SECRET

Figure D.637: 6-ton radioactive bomb that must be dropped with a parachute (∼megaton yield), and a planned test site in northern Finland. Edmund Tilley to P. M. Wilson. Secret Missiles. EPES/FIAT, Control Commission for Germany, British Element, 13 July 1946 [TNA (Kew) FO 1031/57].

Notes on an Interrogation of Edmund Sorg at Dustbin. 7 August 1946 [TNA FO 1031/112].

REGARDING SPECIES OF V-2s

[...] I have never seen any plans of the steps in development of the V-2. I had nothing to do with the V-2 either personally or officially. When I mentioned 10–12 types of V-2 it is only personal supposition.

REGARDING ATOM BOMBS

I have never heard of the existence of atom bombs in connection with the German Wehrmacht. I can thus give no information as to whether the V1 was to have an atomic charge.

REGARDING V-1s WITH POISON GAS, BIOLOGICAL or BACTERIOLOGICAL CHARGES

I have never heard of V-1s being loaded with poison gas, biological matters or bacteria.

REGARDING 6 TON BOMBS

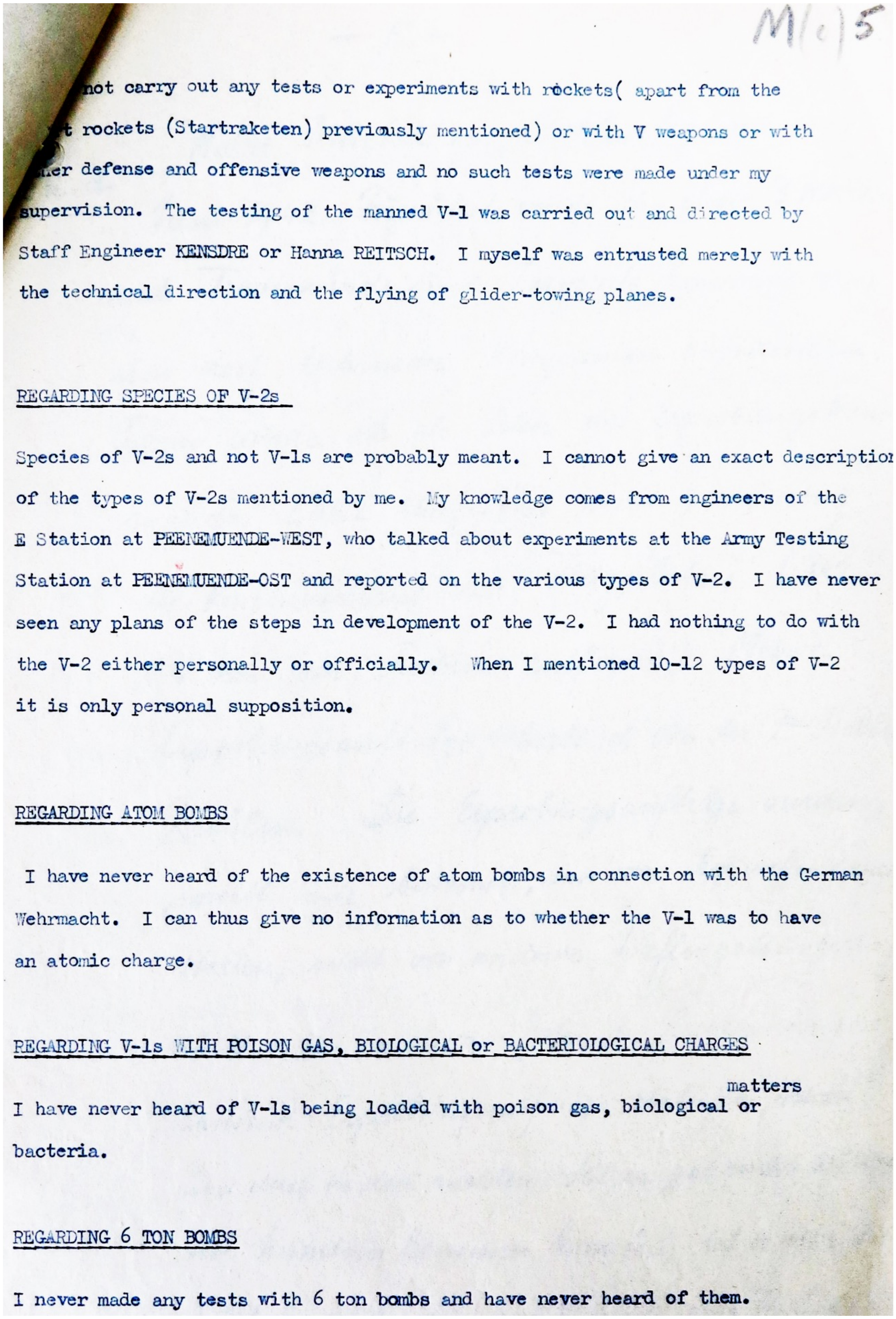
I never made any tests with 6 ton bombs and have never heard of them.

REGARDING USE OF POISON GAS, BIOLOGICAL MEANS and BACTERIA IN ROCKETS &c.

I have no knowledge of the use of poison gas, biological or bacteriological means in rockets, other missiles or in planes.

[Elsewhere in this file at The National Archive (UK), Major Tilley provided evidence that Sorg had detailed personal knowledge of many of the things he denied, such as V-2 rocket information. See p. 4896 for another example. Thus the fact that Sorg denied German atomic bombs, six-ton bombs, biological weapons, multiple types of large rockets, etc. is much less important than the fact that Sorg's Allied interrogators seemed convinced of the reality of those weapons, over a year after the war had ended. What other information did Allied officials have about those weapons from interrogations, captured documents, and/or capture hardware?]

TNA (Kew) FO 1031/112 Sorg V2



M(c)5

not carry out any tests or experiments with rockets(apart from the t rockets (Startraketen) previously mentioned) or with V weapons or with her defense and offensive weapons and no such tests were made under my supervision. The testing of the manned V-1 was carried out and directed by Staff Engineer KENSDRE or Hanna REITSCH. I myself was entrusted merely with the technical direction and the flying of glider-towing planes.

REGARDING SPECIES OF V-2s

Species of V-2s and not V-1s are probably meant. I cannot give an exact description of the types of V-2s mentioned by me. My knowledge comes from engineers of the E Station at PEENEMUENDE-WEST, who talked about experiments at the Army Testing Station at PEENEMUENDE-OST and reported on the various types of V-2. I have never seen any plans of the steps in development of the V-2. I had nothing to do with the V-2 either personally or officially. When I mentioned 10-12 types of V-2 it is only personal supposition.

REGARDING ATOM BOMBS

I have never heard of the existence of atom bombs in connection with the German Wehrmacht. I can thus give no information as to whether the V-1 was to have an atomic charge.

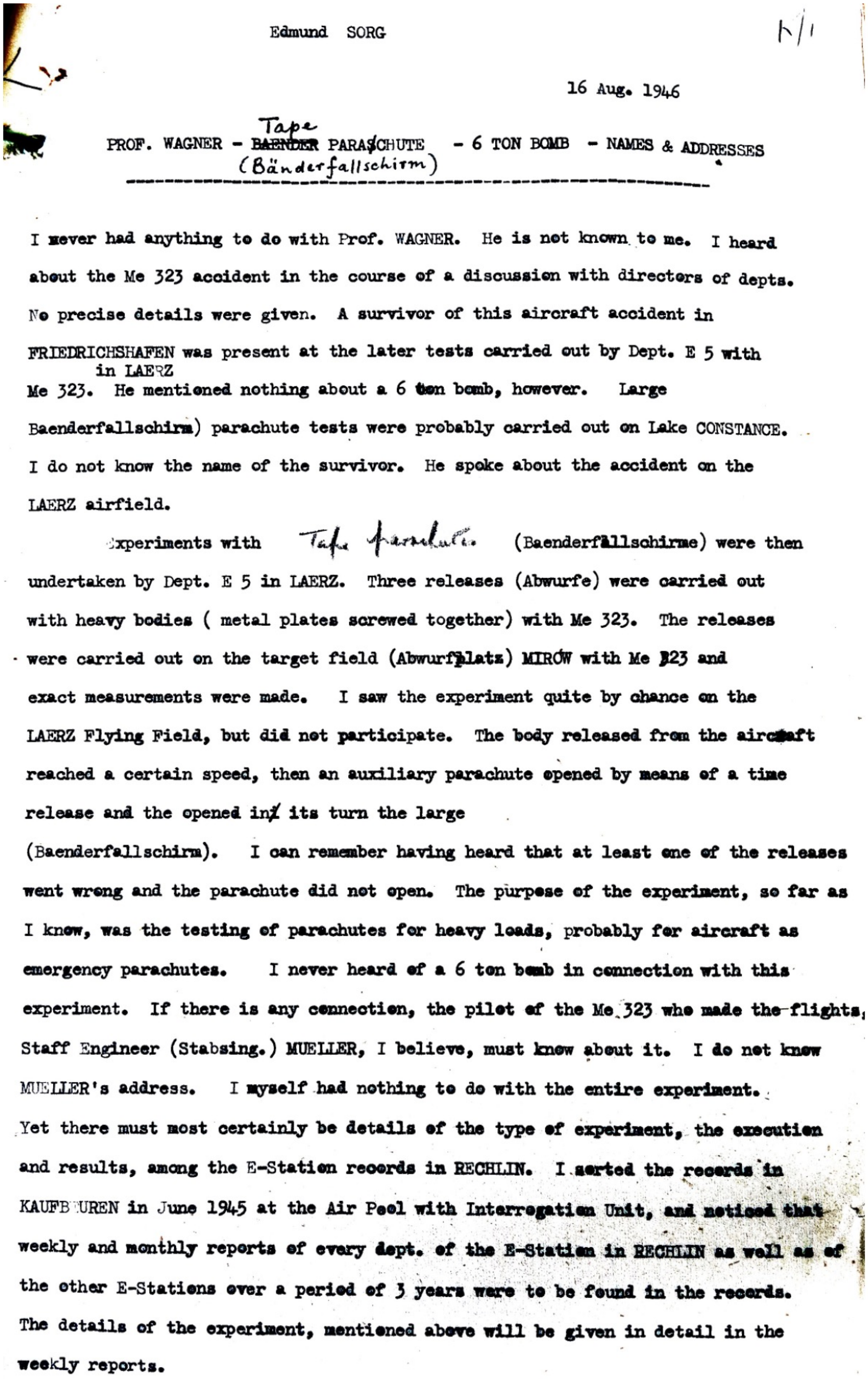
REGARDING V-1s WITH POISON GAS, BIOLOGICAL or BACTERIOLOGICAL CHARGES

I have never heard of V-1s being loaded with poison gas, biological matters or bacteria.

REGARDING 6 TON BOMBS

I never made any tests with 6 ton bombs and have never heard of them.

Figure D.638: Notes on an Interrogation of Edmund Sorg at Dustbin. 7 August 1946 [TNA FO 1031/112].



TNA (Kew) FO 1031/112 Sorg V2

Edmund SORG

h/1

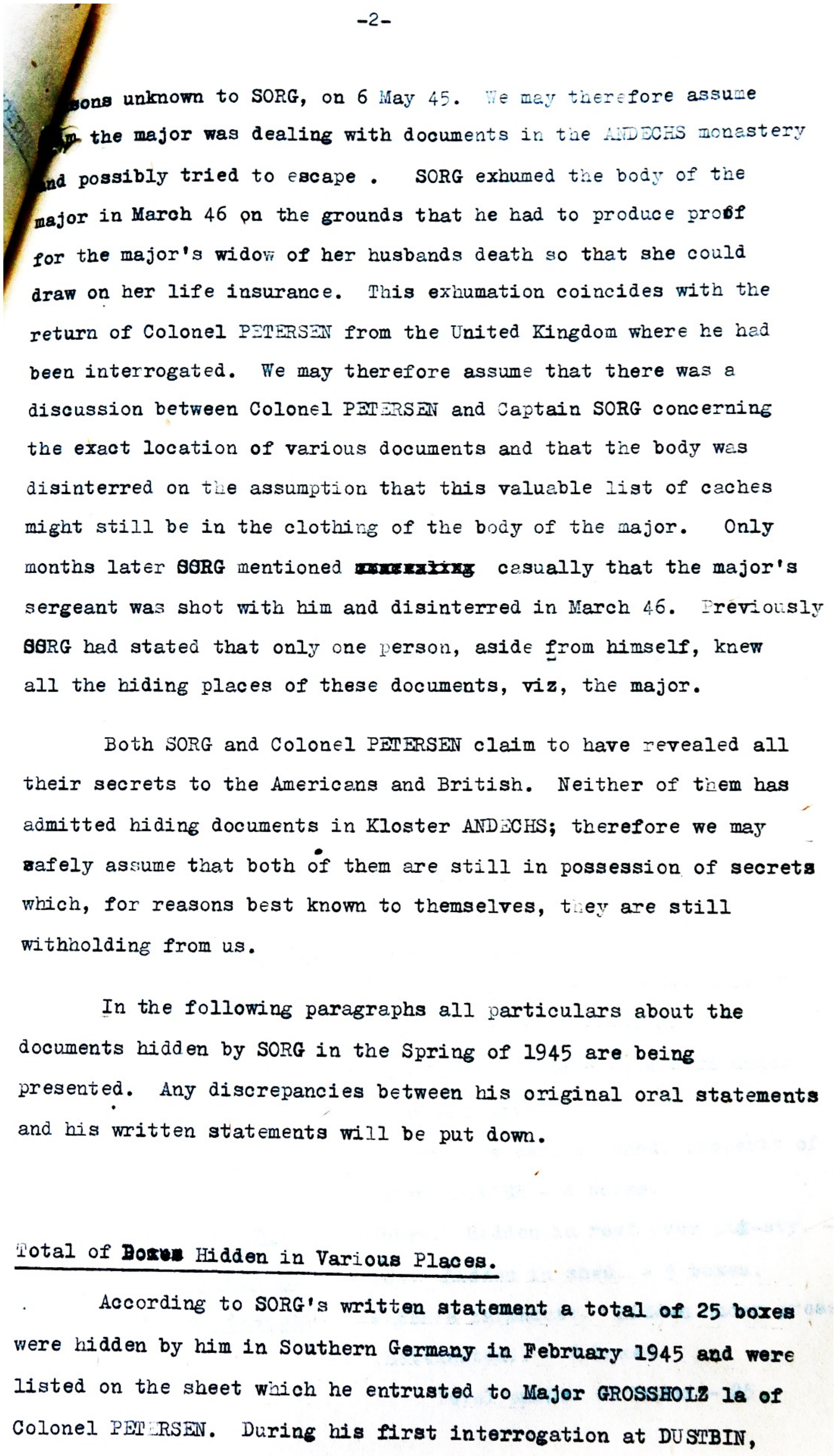
16 Aug. 1946

PROF. WAGNER - Tape ~~BAENDER~~ PARA~~S~~CHUTE (Bänderfallschirm) - 6 TON BOMB - NAMES & ADDRESSES

I never had anything to do with Prof. WAGNER. He is not known to me. I heard about the Me 323 accident in the course of a discussion with directors of depts. No precise details were given. A survivor of this aircraft accident in FRIEDRICHSHAFEN was present at the later tests carried out by Dept. E 5 with Me 323 in LAERZ. He mentioned nothing about a 6 ton bomb, however. Large Baenderfallschirm) parachute tests were probably carried out on Lake CONSTANCE. I do not know the name of the survivor. He spoke about the accident on the LAERZ airfield.

Experiments with Tape parachute (Baenderfallschirme) were then undertaken by Dept. E 5 in LAERZ. Three releases (Abwurfe) were carried out with heavy bodies (metal plates screwed together) with Me 323. The releases were carried out on the target field (Abwurfplatz) MIRÓW with Me 323 and exact measurements were made. I saw the experiment quite by chance on the LAERZ Flying Field, but did not participate. The body released from the aircraft reached a certain speed, then an auxiliary parachute opened by means of a time release and the opened in its turn the large (Baenderfallschirm). I can remember having heard that at least one of the releases went wrong and the parachute did not open. The purpose of the experiment, so far as I knew, was the testing of parachutes for heavy loads, probably for aircraft as emergency parachutes. I never heard of a 6 ton bomb in connection with this experiment. If there is any connection, the pilot of the Me 323 who made the flights, Staff Engineer (Stabsing.) MUELLER, I believe, must know about it. I do not know MUELLER's address. I myself had nothing to do with the entire experiment. Yet there must most certainly be details of the type of experiment, the execution and results, among the E-Station records in RECHLIN. I sorted the records in KAUFBEUREN in June 1945 at the Air Pool with Interrogation Unit, and noticed that weekly and monthly reports of every dept. of the E-Station in RECHLIN as well as of the other E-Stations over a period of 3 years were to be found in the records. The details of the experiment, mentioned above will be given in detail in the weekly reports.

Figure D.639: Edmund Sorg. 16 August 1946 [TNA FO 1031/112].



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sons unknown to SORG, on 6 May 45. We may therefore assume the major was dealing with documents in the ANDECHS monastery nd possibly tried to escape . SORG exhumed the body of the major in March 46 on the grounds that he had to produce proof for the major's widow of her husbands death so that she could draw on her life insurance. This exhumation coincides with the return of Colonel PETERSEN from the United Kingdom where he had been interrogated. We may therefore assume that there was a discussion between Colonel PETERSEN and Captain SORG concerning the exact location of various documents and that the body was disinterred on the assumption that this valuable list of caches might still be in the clothing of the body of the major. Only months later SORG mentioned casually that the major's sergeant was shot with him and disinterred in March 46. Previously SORG had stated that only one person, aside from himself, knew all the hiding places of these documents, viz, the major.

Both SORG and Colonel PETERSEN claim to have revealed all their secrets to the Americans and British. Neither of them has admitted hiding documents in Kloster ANDECHS; therefore we may safely assume that both of them are still in possession of secrets which, for reasons best known to themselves, they are still withholding from us.

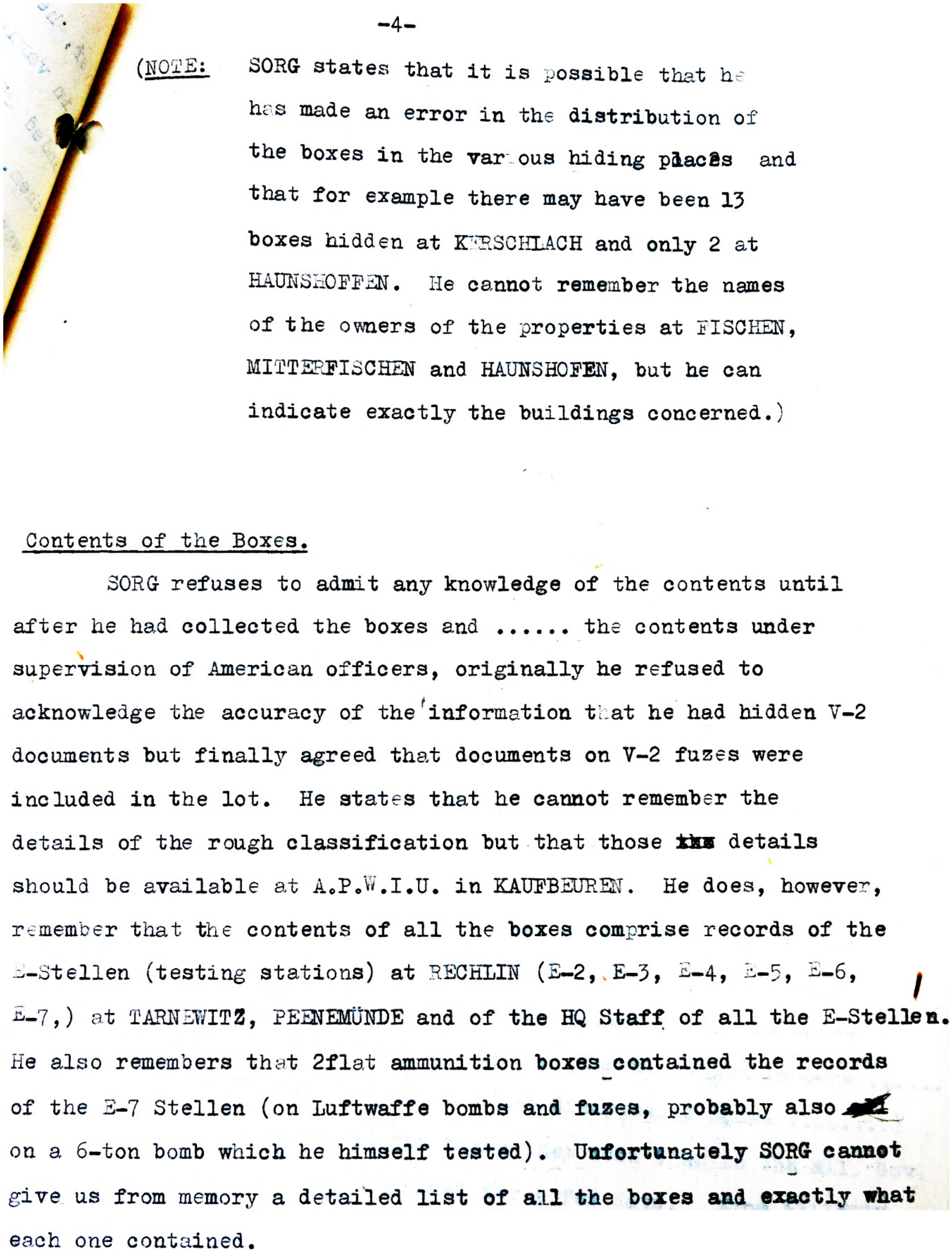
In the following paragraphs all particulars about the documents hidden by SORG in the Spring of 1945 are being presented. Any discrepancies between his original oral statements and his written statements will be put down.

Total of Boxes Hidden in Various Places.

According to SORG's written statement a total of 25 boxes were hidden by him in Southern Germany in February 1945 and were listed on the sheet which he entrusted to Major GROSSHOLZ la of Colonel PETERSEN. During his first interrogation at DUSTBIN,

TNA (Kew) FO 1031/112 Sorg V2

Figure D.640: Major Edmund Tilley to Lt. Col. P. M. Wilson. October 1946 [TNA FO 1031/112].



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(NOTE: SORG states that it is possible that he has made an error in the distribution of the boxes in the various hiding places and that for example there may have been 13 boxes hidden at KERSCHLACH and only 2 at HAUNSHOFFEN. He cannot remember the names of the owners of the properties at FISCHEN, MITTERFISCHEN and HAUNSHOFEN, but he can indicate exactly the buildings concerned.)

Contents of the Boxes.

SORG refuses to admit any knowledge of the contents until after he had collected the boxes and ...... the contents under supervision of American officers, originally he refused to acknowledge the accuracy of the information that he had hidden V-2 documents but finally agreed that documents on V-2 fuzes were included in the lot. He states that he cannot remember the details of the rough classification but that those [illegible] details should be available at A.P.W.I.U. in KAUFBEUREN. He does, however, remember that the contents of all the boxes comprise records of the E-Stellen (testing stations) at RECHLIN (E-2, E-3, E-4, E-5, E-6, E-7,) at TARNEWITZ, PEENEMÜNDE and of the HQ Staff of all the E-Stellen. He also remembers that 2flat ammunition boxes contained the records of the E-7 Stellen (on Luftwaffe bombs and fuzes, probably also [illegible] on a 6-ton bomb which he himself tested). Unfortunately SORG cannot give us from memory a detailed list of all the boxes and exactly what each one contained.

TNA (Kew) FO 1031/112 Sorg V2

Figure D.641: Major Edmund Tilley to Lt. Col. P. M. Wilson. October 1946 [TNA FO 1031/112].

Major Edmund Tilley to Lt. Col. P. M. Wilson. October 1946 [TNA FO 1031/112].

The general background of this brief report on the hiding by SORG of documents of the E-Stellen (testing stations) at RECHLIN, TARNEWITZ, TRAVEMÜNDE, WERNEUCHEN, UDETFELD, PEENEMÜNDE, GOTENHAFEN (GYDNIA) was given in a memorandum by the undersigned to Lt-Col. P.M. Wilson on 6 Oct 46. Information was received in Austria late summer 46 that a Captain SORG had hidden V-2 documents in Kloster ANDECHS on the Ammersee in Spring 45 and that Captain SORG was the administrative officer of Colonel PETERSEN.

[...] the return of Colonel PETERSEN from the United Kingdom where he had been interrogated. [...] Both SORG and Colonel PETERSEN claim to have revealed all their secrets to the Americans and British. Neither of them has admitted hiding documents in Kloster ANDECHS; therefore we may safely assume that both of them are still in possession of secrets which, for reasons best known to themselves, they are still withholding from us. [...]

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[Based on (still classified) evidence they had already seen, Allied interrogators were convinced that the six-ton radioactive bomb had reached the point of testing before the end of the war. Thus that weapon was much more than a paper design or a long-term project. This information is consistent with other reports that a German hydrogen bomb could have been deployed later in 1945 or in 1946 if the war had continued. For information on Edmund Tilley, see pp. 4894–4895.]

Allen Dulles. 14 March 1944. [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44].

Source 840. (1) 600 technicians doing research on rocket direction in high frequency lab in Gatow near Berlin. 300 rockets said to be ready for use one month ago. Length 15 to 17 meters, weight of explosive 4 to 6 tons. Rocket consists of over 1000 parts including two batteries. Remaining difficulty is deviation up to 500 meters radius over 230 km.

[This OSS intelligence report came from someone involved in developing rocket guidance systems. That source stated they were working on rockets that were larger than a standard A-4 (V-2), 15–17 meters long instead of the standard 14 meters, and that were designed to accommodate a special explosive warhead weighing up to 6 tons instead of the standard 1-ton warhead.]

J. P. E. Peters. Interrogation of Dipl. Ing. Hermann Zumpe at F.I.A.T. (Main) on 7th November, 1946. [TNA AIR 40/2832]

[...] 2. On 22nd October, 1946, ZUMPE presented himself at the headquarters of F.I.A.T. (Forward) in Berlin with the request that passage be provided for himself and his family to the British Zone of Germany. It transpired that ZUMPE had been working for the Russians in the GEMA Buildings, Wendelschlossstrasse, 3, Berlin-Kopenick, but did not wish to move to Russia with that organisation.

3. ZUMPE was interrogated by the Intelligence Department, Air Division, CCG. (BE), and was then evacuated by air to F.I.A.T. (Main), where he is at present lodged in "Dustbin". [...]

14. ZUMPE also had in hand a new project for a rocket motor on the same principles as the new C2, but developing a thrust of 50 tons for use in a 26 ton rocket of the A4 type. This project was still in the early stages; the only decision made was that the maximum weight allowable for the motor, fuels, and shell was 20 tons, leaving 6 tons for the warhead. He claims that he can complete the calculations for this project in 4–6 weeks. [...]

16. ZUMPE states that it was impossible to gain access to departments other than the one in which he worked, as his pass was clearly marked with the department for which it was valid, and even the Russian officers on the unit were not allowed to enter buildings with which they were not directly concerned. [...]

[The Soviets apparently found plans for the German 6-ton bomb and conscripted German engineers to recreate methods (especially the rocket mentioned by Dulles above) to deliver it.]

Nazis Were Working On 100-Ton Rocket. *The Courier-Mail* (Brisbane, Australia). 5 December 1946 p. 1. [**https://trove.nla.gov.au/newspaper/article/49363386**]

NEW YORK, December 4.—When the war ended the Nazis were building a 100-ton rocket with which to strike at the United States.

This has been revealed by the brilliant German scientist, Wernher von Braun, who invented the V2 rocket.

Von Braun is now in the United States working with American experts on rocket experiments.

The super-rocket, he said, was on the drawing-board when Germany was over-run. It would have carried an explosive charge of six tons, and would have been capable of travelling thousands of miles.

He claimed that the V2 rocket failed in only about 5 per cent of its tests in Germany.

Von Braun and his associates from Germany are being kept at work under the utmost secrecy by the Army as they help to train American ordnance men, industrialists, and scientists from leading American universities in the secrets of rocket bombs.

U.S. Gain

An estimate that German and Austrian scientists had saved the United States more than £235 million in basic research in rockets alone was disclosed by the War Department in announcing that 730 additional experts were to be brought to the United States.

Former enemy brain-power, the department said, had advanced American research in several fields by from two to 10 years.

Already 270 former enemy scientists are at work in the United States. They include the former chief designer for the Messerschmitt aircraft works and the technical director of the Nazis' Peenemunde rocket proving ground. They came to the United States voluntarily.

The scientists are being paid on contract, the maximum being £975 annually, plus 37/ daily expense allowance. This is considerably less than the salaries paid to American civil service workers doing comparable work.

The work of the foreign scientists covers the fields of electronics, supersonics, guided missiles, jet propulsion, and fuels.

["100-ton rocket" was a name sometimes used by the Peenemünde engineers for the A-9/A-10. Usually the expected payload of the A-9/A-10 is given as 1 ton. That could be stretched to 2 tons without much trouble. A German rocket design capable of carrying a 6-ton payload is unknown in the official histories. Was this a different version of the A-9/A-10, or a different rocket entirely?

Because of the extreme difficulty of accommodating a 6-ton payload on a rocket, that would have been attempted only if the payload could not be made smaller. Conventional explosives, chemical weapons, biological weapons, or a radioactive dirty bomb could be made as small as desired, and delivered on multiple rockets if necessary. Even a fission bomb would only weigh 2–3 tons. This must have been a weapon whose physical constraints at that time required it to be no smaller than 6 tons—presumably a hydrogen bomb.]

Nazi Scientists Work On U.S. Rocket Experiment. *Newcastle Morning Herald and Miners' Advocate* (NSW, Australia). 5 December 1946 p. 3. [https://trove.nla.gov.au/newspaper/article/133178482]

NEW YORK, Dec. 4.—Before the war ended the Nazis were building a 100-ton rocket to strike the United States. This was revealed by the brilliant German scientist Wernher von Braun, who invented the V2 rocket, and who is now in the United States.

Von Braun is at present working with American experts on rocket experiments.

He said the Nazis' super-rocket was on the drawing board when Germany was overrun. It would have carried an explosive charge of six tons and be capable of travelling thousands of miles.

Von Braun claimed the V2 failed in only about five per cent of its tests in Germany.

Von Braun and his associates from Germany are being kept at work under the utmost secrecy by the army as they help to train American ordnance men, and industrialists and scientists from leading American Universities in the secrets of rocket bombs.

Saved U.S. Millions

A statement issued by the War Department in Washington said it was estimated that German and Austrian scientists had saved the United States more than 750 million dollars (£A234 1/2 millions) in basic research in rockets alone.

The department announced that about 730 additional experts would be brought to the United States.

The statement said that former enemy brainpower had advanced American research in several fields two to ten years. The number of experts put to work since September 1945 had grown to 270, and the total would be increased to about 1000 as soon as transportation arrangements were completed.

The scientists and technicians include the former Chief Designer for the Messerschmitt Aircraft Works and the Technical Director of the Nazis' Peenemunde rocket-proving ground. They came to the United States voluntarily.

Nazis Planned Rocket to Hit U.S. *New York Times.* 4 December 1946.

Wernher von Braun, 34-year-old German scientist who invented the deadly V-2 supersonic rocket, revealed today that before the war ended the Nazis were building a 100-ton rocket to strike at the United States.

Von Braun told reporters that the 100-ton rocket was on the drawing board when the Allies overran Europe. He said it would have carried a "pay-load" of six tons and would have traveled thousands of miles to strike the United States.

Eugen Sänger and Irene Bredt. 1944. *Über einen Raketenantrieb für Fernbomber.* UM 3538. Ainring: Deutsche Luftfahrtforschung. English translation 1952. *A Rocket Drive for Long Range Bombers.* CGD-32, C-84296. Technical Information Branch, Buaer Navy Department. pp. 148, 152.

As an example of area attack with single propulsion and full turn, we use the attack on New York at a range of 6500 km. For c=4000 m/sec, the bomb load is 6 tons, and the detailed attack runs as follows: the motor starts to work 36 seconds after the take-off at 12 km. distance from the take-off point, and consumes the total fuel supply of 84 tons in the next 336 sec. At the end of the climb process, the aircraft reaches a velocity of 6370 m/sec, an altitude of 91 km, a distance of 736 km. from the point of take-off, and a weight of 16 tons. Using only its store of potential and kinetic energy, the bomber flies on to the point of bomb release, 5550 km. from the take-off point, and 950 km. in front of the target. At this point, which is reached 1150 sec. after take-off, the velocity has decreased to 6000 m/sec, and the stationary altitude to 50 km. After the bomb release the weight is 10 tons. Then the aircraft goes into a turn and in 330 sec. goes through a turn-spiral 1000 km. in diameter until it has reached the direction for the return flight to the home base. During turning, the altitude is greatly decreased in order to develop the aerodynamic forces necessary for the turn. At the end of the turn path, the velocity is still 3700 m/sec. and the corresponding stationary altitude is 38 km. The supersonic glide-path in the direction of the home base goes over 5450 km. in 2600 sec. and ends 100 km. before the home base at an altitude of 20 km. and velocity 300 m/sec. Subsonic glide and landing are completed in customary fashion. The whole flight lasts 4755 sec.

[The Sänger-Bredt Silbervogel space plane was designed to bomb New York or other targets in the United States. Historians have dismissed the Silbervogel as merely a paper design that was never seriously considered or built. However:

- Eugen Sänger and Irene Bredt completed and submitted a 900-page proposal giving details of the Silbervogel design and development program to the German government in 1941 [Myhra 2002].
- Wind tunnel models of Silbervogel are known to have been constructed and tested (p. 5595).
- At least one photograph exists of a full-sized Silbervogel engine that had been constructed for testing no later than 1944 (p. 5596).
- In January 1946, five Canadian aerospace experts reported that while visiting a German research station, they viewed “a rocket motor 10 times larger than those used on V-2s.” That description could match either the Silbervogel motor or the A-10 booster rocket motor (p. 5470).
- Detailed orbital calculations were performed in 1944 to find the best trajectory for the Sänger-Bredt vehicle to reach New York (pp. 5597–5599).
- An article published in the 30 October 1944 *Daily Mail* reported that the Germans in occupied France had been constructing a “huge ramp” that was “intended as a launching place for flying

bombs, which... would wreck New York." The size of the ramp, the reference to flying bombs, and the claimed target of New York seem consistent with the Silbervogel launch catapult (p. 5600).

- U.S. Army Air Forces Colonel Donald Putt, in charge of overseeing all German rocket scientists and related equipment and information rounded up at the end of the war, reported in March 1946: "Test model was made that carried one man and had landing gear, although it is not known if this model ever flew; it is known, however, that test runs were made on its engine." Thus according to an authority with arguably the best access to the available information, the Silbervogel engine was constructed and tested, a Silbervogel vehicle complete with cockpit and landing gear was constructed, its engine was operational, and postwar U.S. officials were left wondering if flight tests of the Silbervogel may have even been conducted (p. 5601). What German witnesses and documents was this information based on? What became of the prototype Silbervogel vehicle—was it destroyed by the Germans, removed by the Americans, or removed by the Soviets?

- A lengthy and detailed October 1946 article in *Harper's Magazine* stated that the Silbervogel system "was never completed merely because of the war's quick ending" (p. 5490).

- A 1957 U.S. Air Force report stated: "The boost-glide concept was... partially tested by the Germans in the early 1940's" (p. 5603).

In the part of their 1944 report quoted on the previous page, Sänger and Bredt specifically discussed using the Silbervogel to deliver a six-ton bomb to New York. That agrees with several other independent sources that mentioned a special six-ton bomb (pp. 4338, 4350–4362, 5343). Six tons of conventional explosive would not do even remotely enough damage to justify the enormous amount of money, labor, materials, time, and energy involved in developing a systems such as Silbervogel to deliver the bomb to a U.S. target, especially under wartime conditions when all of those resources were critically needed and in short supply. The whole approach would have made sense only if the six-ton bomb was nuclear, and indeed some of the sources specifically stated that it was nuclear—in fact, apparently a full-fledged hydrogen bomb.

Moreover, some sources indicated that much of the work related to the six-ton or hydrogen bomb was conducted in Austria, and Sänger was Austrian. Between his professional connections and his payload delivery method, it seems quite reasonable that Sänger would have had some contact with the scientists who were working on the actual bomb.

While most wartime papers on Sänger's work were destroyed or were captured and remain inaccessible in archives, some of the letters he wrote to Hermann Oberth after the war confirm that he was quite interested in fusion reactions [Oberth 1984, Vol. 1, pp. 199–200, 213–216].]

G. Ward Price. Fly-bombs Were Meant for U.S.: Huge Ramp Found. *Daily Mail.* 30 October 1944.

Immense concrete works on top of a hill in Artois, near Saint Omer, were intended as a launching place for flying bombs, which, the Germans boasted, would wreck New York.

Thousands of workmen were employed in tunnelling and building a cylindrical cupola on top of the hill, 250ft. in diameter.

Lorries, and even trains, could drive right into the heart of the hill.

German engineers told local French people that when the vast machinery was installed and ready to fire, the district would have to be evacuated for six miles around.

Frequent attacks by the R.A.F. kept on delaying work until the Allied advance from Normandy obliged all the enemy engaged on it to pack up hurriedly.

Footnote.—A German U-boat commander recently told naval cadets at Esjberg, Denmark, that Germany was preparing a new secret weapon for use against America. He said that U-boat crews would play a decisive part in the use of the weapon.

[The six-mile radius suggests that the bomb would have had that blast radius. A 6-mile or 10-km blast radius corresponds to an explosive energy of at least $(10,000/85.5)^3 \approx$ 1,600,000 tons of TNT equivalent, or at least 1.6 megatons. This is well beyond the kiloton-ranges of fission bombs, as the German scientists knew from basic calculations of fission energies, and suggests that they were developing much more powerful hydrogen (H) or fusion bombs. Other sources from around the same time also mentioned the exact same 10-kilometer/6-mile blast radius (pp. 4366 and 4367).

This site sounds like a launching sled track for the Sänger-Bredt Silbervogel space plane, or possibly a slightly smaller launching track for the winged A-9 rocket. For more discussion on track-launched rockets, see Section E.3. Also see the article on p. 5011 that mentions development of a catapult-launched atomic bomb delivery system in Norway.]

Bruno Spampanato. 1974. *Contromemoriale.* Rome: Centro Editoriale Nazionale. pp. 917, 1116. [Spampanato (1902–1960) was a journalist and politician who was a longtime supporter of Mussolini and very well connected with high-ranking Italian officials. After the war, he wrote a multivolume memoir that preserved information from a huge number of sources that otherwise might have been lost or forgotten. Here he quoted two wartime sources that both appear to have been describing a nuclear weapon with a megaton-level yield. One of them even gave the exact same 10-kilometer/6-mile blast radius as other sources from that time (pp. 4365 and 4367).]

Qualche cosa del genere ci ha detto Goffredo Coppola ch'era stato in Germania a un congresso scientifico in rappresentanza del Governo: e tornava allora. Ci vediamo al Plaza con lui ed Enrico Santamaria. Coppola ci dice qualche cosa che rasenta i limiti della fantasia. Ma tutto si può sospettare di Coppola, Rettore Magnifico dell'università di Bologna, fuorché si occupi di fotomontaggi come Theil, o di altra propaganda razionale. Il prof. Coppola ci dice quanto gli hanno confidato degli scienziati che hanno fama mondiale per i loro studi.

Questo ci disse Coppola il 16 febbraio 1945: "I tedeschi hanno trovato il mezzo per disintegrare l'atomo. E una scoperta elettronica. La disintegrazione avviene a cicli successivi e prende aree vastissime di decine di chilometri. Nei laboratori si lavora in pieno". [...]

Tra gl'italiani il più a contatto coi più alti ambienti militari tedeschi era il Maresciallo [Rodolfo] Graziani. E proprio Graziani nella sua autodifesa dinanzi alle Assise Speciali di Roma [1948] depose: "Ognuno può dire quello che vuole sulla faccenda delle armi segrete; ma sta di fatto che le armi segrete in Germania c'erano: c'erano nel modo più assoluto e c'era un rinnovamento in tutta l'aviazione con apparecchi a reazione, e ne avevano già in gran numero, migliaia. Non sono riusciti a metterli in funzione perché in quel momento è cominciata a mancare la benzina, e in seguito ci sono stati i bombardamenti a tappeto fatti dagli anglo-americani sugli impianti delle industrie. Stavano per realizzare anche l'antiradar per le segnalazioni e avrebbero potuto ricominciare la guerre dei sommergibili. C'era la V-1 e c'era la V-2, ma si arrivava fino alla V-10 che distruggeva nel raggio di dieci chilometri ogni elemento di vita".

Something like this was said to us by Goffredo Coppola, who had been in Germany at a scientific congress representing the government and then came back. We met at the Plaza with him and Enrico Santamaria. Coppola told us something that borders on the limits of fantasy. But everything can be suspected of Coppola, the Magnificent Rector of the University of Bologna, except that he deals in fakes like Theil, or other intellectual propaganda. Prof. Coppola told us what he had been confidentially told by scientists who are world-renowned for their studies.

This Coppola told us on 16 February 1945: "The Germans have found the means to disintegrate the atom. And an electronic discovery. The disintegration occurs in successive cycles and covers vast areas of tens of [square] kilometers. In the laboratories work is at full capacity." [...]

Among the Italians the most in contact with the highest German military circles was Marshal [Rodolfo] Graziani. And it was Graziani himself in his self-defense before the Special Court in Rome [1948] who testified: "Everybody can say what they want about the matter of secret weapons; but the fact is that secret weapons in Germany were there: they were there in the most absolute way and there was a renewal in the whole aviation with jet aircraft, and they already had them in large numbers, thousands of them. They were not able to put them into operation because at that time there began to be a shortage of gasoline, and later there was the carpet bombing done by the Anglo-Americans on the plants of industries. They were also going to make anti-radar for signaling and they could have started the submarine wars again. There was the V-1 and there was the V-2, but it went all the way up to the V-10 which destroyed within a ten-kilometer radius every element of life."

Germans Timed Atom Bomb for October. *Evening Standard* (London). 7 August 1945.

The Germans had an atom bomb which would have been ready by October.

A colossal blast effect was claimed for the German bomb. It was said it would wipe out everything inside a radius of six miles, said B.U.P. today.

The German atomic plans were uncovered four months ago, when an Allied search party walked into a small silk factory at Celle, north of Hanover.

A laboratory of two rooms was buried away in the heart of the factory. A famous research scientist [Wilhelm Groth] was still at work. He was flown to Britain the same day.

This man, with others, had been working on the Atom bombs for months. The Nazi Government poured out money on it. Apparently they had not asked for immediate results.

Nazis Five Months from Completion of Atomic Bomb. *Pittsburgh Press.* 7 August 1945 p. 14.

21ST ARMY GROUP HEADQUARTERS, Germany, Aug. 7 (UP)—Germany was within five months of completing her own atom bomb when the European war ended.

A British task force four months ago discovered that German scientists almost had completed work on the bomb in a two-room laboratory in the heart of a small silk factory north of Hannover.

The bomb, it was calculated, would wipe out everything within a radius of six miles.

A famous German research scientist [Wilhelm Groth, in] charge of the experiments was flown immediately to Britain at the time. He estimated his work would have been completed by October.

He said the German Government had given him unlimited funds and equipment and had not demanded any immediate results.

[Also reported in:

6-Miles Radius Bomb. *Toronto Daily Star.* 7 August 1945. p. 1.

6-Miles Radius Bomb. *Madera Tribune* (Madera, California). 7 August 1945. p. 1.

Bomba de 10 Kilómetros. *ABC* (Madrid). 8 August 1945.

These articles all mentioned a bomb with a 6-mile blast radius. Completely independent sources from around the same time also gave the same 10-kilometer/6-mile blast radius (pp. 4365 and 4366). As already noted, a 10-kilometer/6-mile blast radius would correspond to at least a ∼1.6 megaton explosion, which would suggest a hydrogen bomb and not a simple fission bomb. Wilhelm Groth, a very talented physicist who along with Paul Harteck had played a major role in numerous aspects of the German nuclear program since early 1939, stated that Germany was five months away from completing such weapons. If true, that was a feat that the U.S. and U.S.S.R. did not actually accomplish until the 1950s.]

Air Intelligence Report No. 100-13/1-100, Significant Developments and Trends in Aircraft and Aircraft Engines, Antiaircraft Guided Missiles (15 June 1946). pp. 3, 90–93. [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3001–3100]

[...] b. Russia is known to have acquired German technicians and V-weapon production and experimental sites. [...] In addition, German developments in the atomic energy field and the possibilities for use of this energy as a guided missile warhead are known to the Russians.

(3) Step rockets. This type of rocket had been considered by the Germans who anticipated ranges of 3,000 miles or more with successors of the V-2. Such a rocket would consist of a main body containing the demolition charge and control units and two or more detachable sections containing propulsion units. These sections would be dropped from the missile as they were exhausted in flight. Such a rocket in the hands of the Russians would make the transpolar routes probable tactical approaches. [...]

e. Russian Atomic Energy. The development of atomic weapons and guided rocket projectiles go hand in hand. It was the Germans who realized that the rocket was “the ideal vehicle for atomic warhead” and it has been established that they intended the A-4 (V-2) rocket to be such a vehicle. In the construction of a long-range rocket, space allotted to payload is of necessity reduced to a minimum by the increase in space allotted to fuel. Adaptability of the atomic warhead to such a missile can be fully appreciated because the ratio of destructive power to unit weight is far in excess of conventional explosives and a radical increase in the destructive power is not accompanied by a similar increase in volume of the warhead.

Little is known concerning the Russian activity with regard to atomic energy. [...]

g. Heavy Hydrogen Bomb. In Germany a letter was picked up by the American censors. It had been written by a German desirous of exchanging information for an opportunity to go to the United States. The writer professed knowledge of “heavy water” research in Germany and of an “even more deadly weapon than the atomic bomb”.

h. German Heavy Hydrogen Bomb. During 1943 the Germans were experimenting with the production of “heavy water” in Norway. Their installation at Rjukan, Norway was deemed important enough at that time to warrant a visit from the heavy bombers of the Eighth Air Force. It was evident that the Germans recognized the potentialities of “heavy water” as a source of Heavy Hydrogen and were taking advantage of the abundance of electric power available in Norway for the production of this substance.

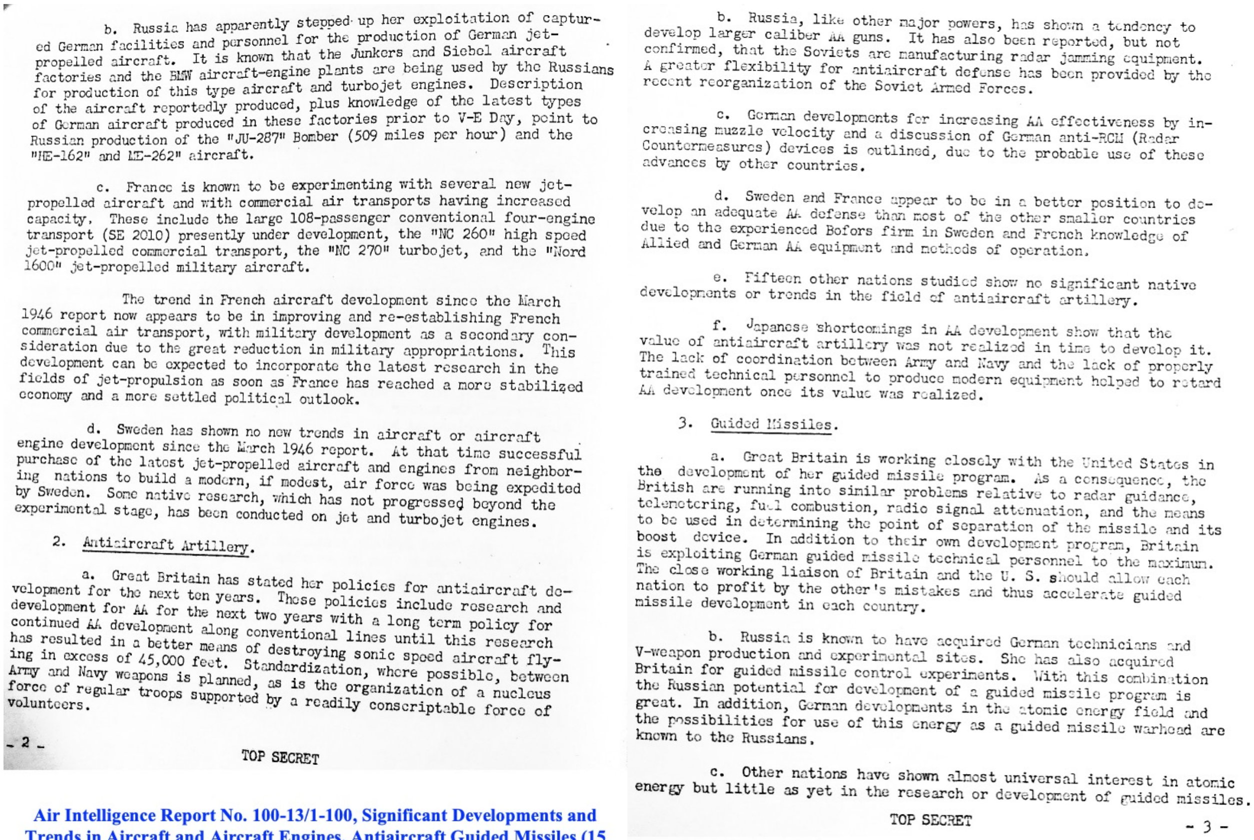
The war brought the German activity in connection with “heavy water” to a close but the question can now be posed, “Have the Russians obtained German personnel formerly employed in the project and if so will they exploit them in an effort to devise an atomic weapon which requires none of the radio active minerals so closely guarded throughout the world?” If the Russians are successful in this attempt, they will have within their grasp the new atomic weapon which is reported to have made the Uranium bomb obsolete. Research in the United States confirms the comparison of the Heavy Hydrogen bomb to the Uranium bomb.

[See document photos on pp. 4370–4371.

How exactly did U.S. intelligence know that Germany intended to build an atomic bomb, intended to deliver it via rocket, and made "developments" that fell into Russian hands?

No significant information about H-bombs was public until fall 1946 (pp. 4337–4341), so the German letter writer's knowledge apparently came directly from wartime work.

Can this letter be located now?]



b. Russia has apparently stepped up her exploitation of captured German facilities and personnel for the production of German jet-propelled aircraft. It is known that the Junkers and Siebel aircraft factories and the BMW aircraft-engine plants are being used by the Russians for production of this type aircraft and turbojet engines. Description of the aircraft reportedly produced, plus knowledge of the latest types of German aircraft produced in these factories prior to V-E Day, point to Russian production of the "JU-287" Bomber (509 miles per hour) and the "HE-162" and ME-262" aircraft.

c. France is known to be experimenting with several new jet-propelled aircraft and with commercial air transports having increased capacity. These include the large 108-passenger conventional four-engine transport (SE 2010) presently under development, the "NC 260" high speed jet-propelled commercial transport, the "NC 270" turbojet, and the "Nord 1600" jet-propelled military aircraft.

The trend in French aircraft development since the March 1946 report now appears to be in improving and re-establishing French commercial air transport, with military development as a secondary consideration due to the great reduction in military appropriations. This development can be expected to incorporate the latest research in the fields of jet-propulsion as soon as France has reached a more stabilized economy and a more settled political outlook.

d. Sweden has shown no new trends in aircraft or aircraft engine development since the March 1946 report. At that time successful purchase of the latest jet-propelled aircraft and engines from neighboring nations to build a modern, if modest, air force was being expedited by Sweden. Some native research, which has not progressed beyond the experimental stage, has been conducted on jet and turbojet engines.

2. Antiaircraft Artillery.

a. Great Britain has stated her policies for antiaircraft development for the next ten years. These policies include research and development for AA for the next two years with a long term policy for continued AA development along conventional lines until this research has resulted in a better means of destroying sonic speed aircraft flying in excess of 45,000 feet. Standardization, where possible, between Army and Navy weapons is planned, as is the organization of a nucleus force of regular troops supported by a readily conscriptable force of volunteers.

b. Russia, like other major powers, has shown a tendency to develop larger caliber AA guns. It has also been reported, but not confirmed, that the Soviets are manufacturing radar jamming equipment. A greater flexibility for antiaircraft defense has been provided by the recent reorganization of the Soviet Armed Forces.

c. German developments for increasing AA effectiveness by increasing muzzle velocity and a discussion of German anti-RCM (Radar Countermeasures) devices is outlined, due to the probable use of these advances by other countries.

d. Sweden and France appear to be in a better position to develop an adequate AA defense than most of the other smaller countries due to the experienced Bofors firm in Sweden and French knowledge of Allied and German AA equipment and methods of operation.

e. Fifteen other nations studied show no significant native developments or trends in the field of antiaircraft artillery.

f. Japanese shortcomings in AA development show that the value of antiaircraft artillery was not realized in time to develop it. The lack of coordination between Army and Navy and the lack of properly trained technical personnel to produce modern equipment helped to retard AA development once its value was realized.

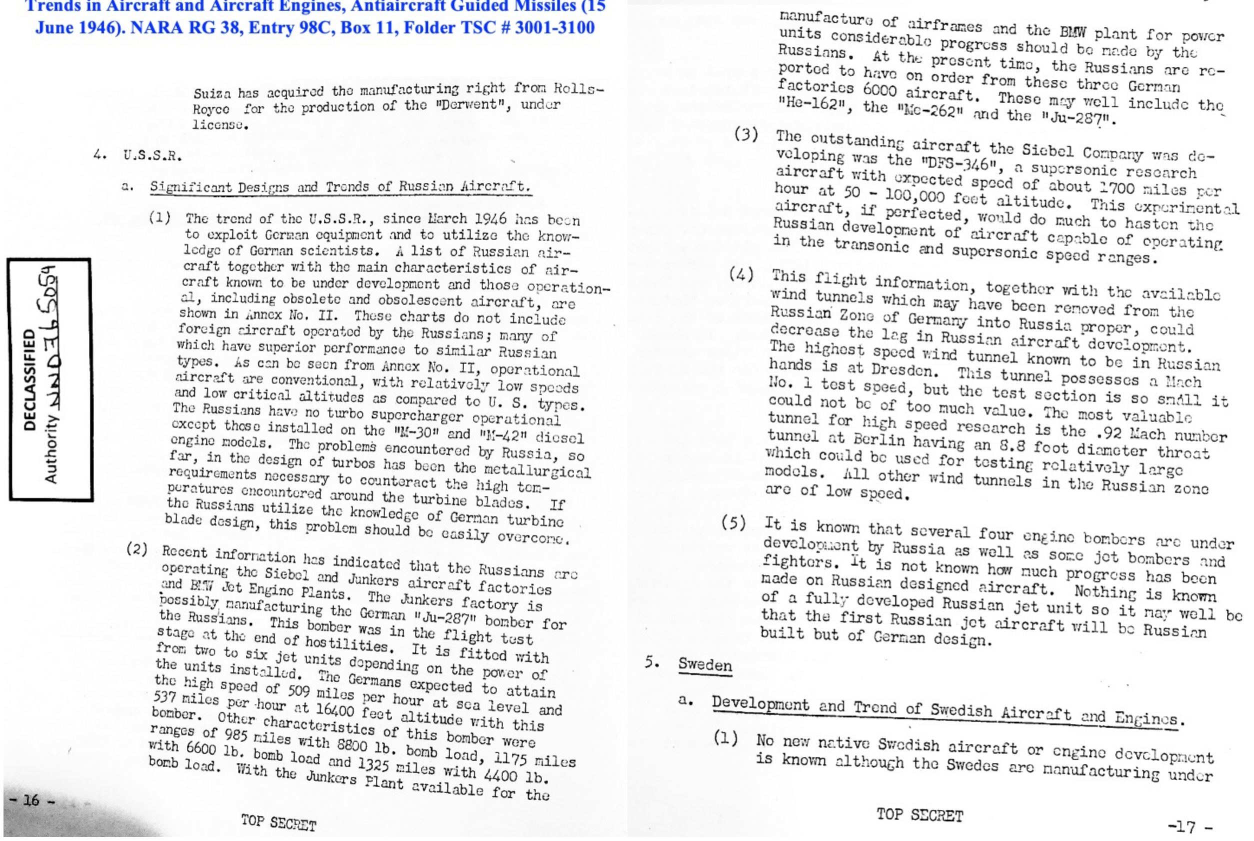
3. Guided Missiles.

a. Great Britain is working closely with the United States in the development of her guided missile program. As a consequence, the British are running into similar problems relative to radar guidance, telemetering, fuel combustion, radio signal attenuation, and the means to be used in determining the point of separation of the missile and its boost device. In addition to their own development program, Britain is exploiting German guided missile technical personnel to the maximum. The close working liaison of Britain and the U. S. should allow each nation to profit by the other's mistakes and thus accelerate guided missile development in each country.

b. Russia is known to have acquired German technicians and V-weapon production and experimental sites. She has also acquired Britain for guided missile control experiments. With this combination the Russian potential for development of a guided missile program is great. In addition, German developments in the atomic energy field and the possibilities for use of this energy as a guided missile warhead are known to the Russians.

c. Other nations have shown almost universal interest in atomic energy but little as yet in the research or development of guided missiles.

Air Intelligence Report No. 100-13/1-100, Significant Developments and Trends in Aircraft and Aircraft Engines, Antiaircraft Guided Missiles (15 June 1946). NARA RG 38, Entry 98C, Box 11, Folder TSC # 3001-3100



Suiza has acquired the manufacturing right from Rolls-Royce for the production of the "Derwent", under license.

4. U.S.S.R.

a. Significant Designs and Trends of Russian Aircraft.

(1) The trend of the U.S.S.R., since March 1946 has been to exploit German equipment and to utilize the knowledge of German scientists. A list of Russian aircraft together with the main characteristics of aircraft known to be under development and those operational, including obsolete and obsolescent aircraft, are shown in Annex No. II. These charts do not include foreign aircraft operated by the Russians; many of which have superior performance to similar Russian types. As can be seen from Annex No. II, operational aircraft are conventional, with relatively low speeds and low critical altitudes as compared to U. S. types. The Russians have no turbo supercharger operational except those installed on the "M-30" and "M-42" diesel engine models. The problems encountered by Russia, so far, in the design of turbos has been the metallurgical requirements necessary to counteract the high temperatures encountered around the turbine blades. If the Russians utilize the knowledge of German turbine blade design, this problem should be easily overcome.

(2) Recent information has indicated that the Russians are operating the Siebel and Junkers aircraft factories and BMW Jet Engine Plants. The Junkers factory is possibly manufacturing the German "Ju-287" bomber for the Russians. This bomber was in the flight test stage at the end of hostilities. It is fitted with from two to six jet units depending on the power of the units installed. The Germans expected to attain the high speed of 509 miles per hour at sea level and 537 miles per hour at 16400 feet altitude with this bomber. Other characteristics of this bomber were ranges of 985 miles with 8800 lb. bomb load, 1175 miles with 6600 lb. bomb load and 1325 miles with 4400 lb. bomb load. With the Junkers Plant available for the

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manufacture of airframes and the BMW plant for power units considerable progress should be made by the Russians. At the present time, the Russians are reported to have on order from these three German factories 6000 aircraft. These may well include the "He-162", the "Me-262" and the "Ju-287".

(3) The outstanding aircraft the Siebel Company was developing was the "DFS-346", a supersonic research aircraft with expected speed of about 1700 miles per hour at 50 - 100,000 feet altitude. This experimental aircraft, if perfected, would do much to hasten the Russian development of aircraft capable of operating in the transonic and supersonic speed ranges.

(4) This flight information, together with the available wind tunnels which may have been removed from the Russian Zone of Germany into Russia proper, could decrease the lag in Russian aircraft development. The highest speed wind tunnel known to be in Russian hands is at Dresden. This tunnel possesses a Mach No. 1 test speed, but the test section is so small it could not be of too much value. The most valuable tunnel for high speed research is the .92 Mach number tunnel at Berlin having an 8.8 foot diameter throat which could be used for testing relatively large models. All other wind tunnels in the Russian zone are of low speed.

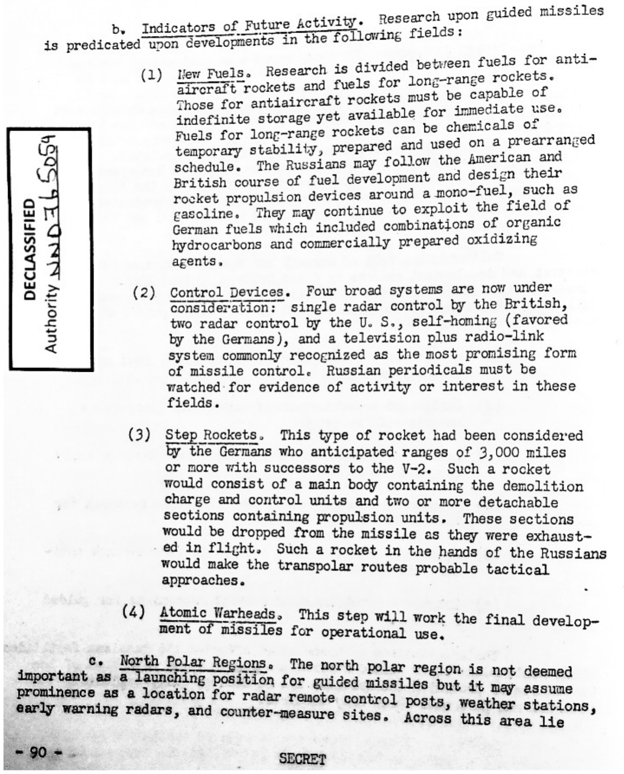
(5) It is known that several four engine bombers are under development by Russia as well as some jet bombers and fighters. It is not known how much progress has been made on Russian designed aircraft. Nothing is known of a fully developed Russian jet unit so it may well be that the first Russian jet aircraft will be Russian built but of German design.

5. Sweden

a. Development and Trend of Swedish Aircraft and Engines.

(1) No new native Swedish aircraft or engine development is known although the Swedes are manufacturing under

Figure D.642: Air Intelligence Report No. 100-13/1-100, Significant Developments and Trends in Aircraft and Aircraft Engines, Antiaircraft Guided Missiles (15 June 1946). [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3001–3100]



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b. Indicators of Future Activity. Research upon guided missiles is predicated upon developments in the following fields:

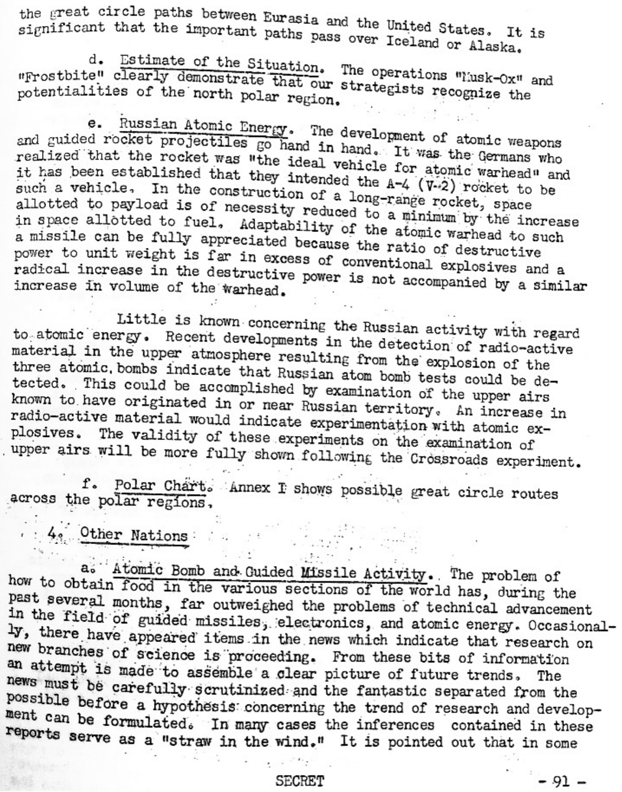
(1) New Fuels. Research is divided between fuels for antiaircraft rockets and fuels for long-range rockets. Those for antiaircraft rockets must be capable of indefinite storage yet available for immediate use. Fuels for long-range rockets can be chemicals of temporary stability, prepared and used on a prearranged schedule. The Russians may follow the American and British course of fuel development and design their rocket propulsion devices around a mono-fuel, such as gasoline. They may continue to exploit the field of German fuels which included combinations of organic hydrocarbons and commercially prepared oxidizing agents.

(2) Control Devices. Four broad systems are now under consideration: single radar control by the British, two radar control by the U. S., self-homing (favored by the Germans), and a television plus radio-link system commonly recognized as the most promising form of missile control. Russian periodicals must be watched for evidence of activity or interest in these fields.

(3) Step Rockets. This type of rocket had been considered by the Germans who anticipated ranges of 3,000 miles or more with successors to the V-2. Such a rocket would consist of a main body containing the demolition charge and control units and two or more detachable sections containing propulsion units. These sections would be dropped from the missile as they were exhausted in flight. Such a rocket in the hands of the Russians would make the transpolar routes probable tactical approaches.

(4) Atomic Warheads. This step will work the final development of missiles for operational use.

c. North Polar Regions. The north polar region is not deemed important as a launching position for guided missiles but it may assume prominence as a location for radar remote control posts, weather stations, early warning radars, and counter-measure sites. Across this area lie



the great circle paths between Eurasia and the United States. It is significant that the important paths pass over Iceland or Alaska.

d. Estimate of the Situation. The operations "Musk-Ox" and "Frostbite" clearly demonstrate that our strategists recognize the potentialities of the north polar region.

e. Russian Atomic Energy. The development of atomic weapons and guided rocket projectiles go hand in hand. It was the Germans who realized that the rocket was "the ideal vehicle for atomic warhead" and it has been established that they intended the A-4 (V-2) rocket to be such a vehicle. In the construction of a long-range rocket, space allotted to payload is of necessity reduced to a minimum by the increase in space allotted to fuel. Adaptability of the atomic warhead to such a missile can be fully appreciated because the ratio of destructive power to unit weight is far in excess of conventional explosives and a radical increase in the destructive power is not accompanied by a similar increase in volume of the warhead.

Little is known concerning the Russian activity with regard to atomic energy. Recent developments in the detection of radio-active material in the upper atmosphere resulting from the explosion of the three atomic bombs indicate that Russian atom bomb tests could be detected. This could be accomplished by examination of the upper airs known to have originated in or near Russian territory. An increase in radio-active material would indicate experimentation with atomic explosives. The validity of these experiments on the examination of upper airs will be more fully shown following the Crossroads experiment.

f. Polar Chart. Annex I shows possible great circle routes across the polar regions.

4. Other Nations

a. Atomic Bomb and Guided Missile Activity. The problem of how to obtain food in the various sections of the world has, during the past several months, far outweighed the problems of technical advancement in the field of guided missiles, electronics, and atomic energy. Occasionally, there have appeared items in the news which indicate that research on new branches of science is proceeding. From these bits of information an attempt is made to assemble a clear picture of future trends. The news must be carefully scrutinized and the fantastic separated from the possible before a hypothesis concerning the trend of research and development can be formulated. In many cases the inferences contained in these reports serve as a "straw in the wind." It is pointed out that in some

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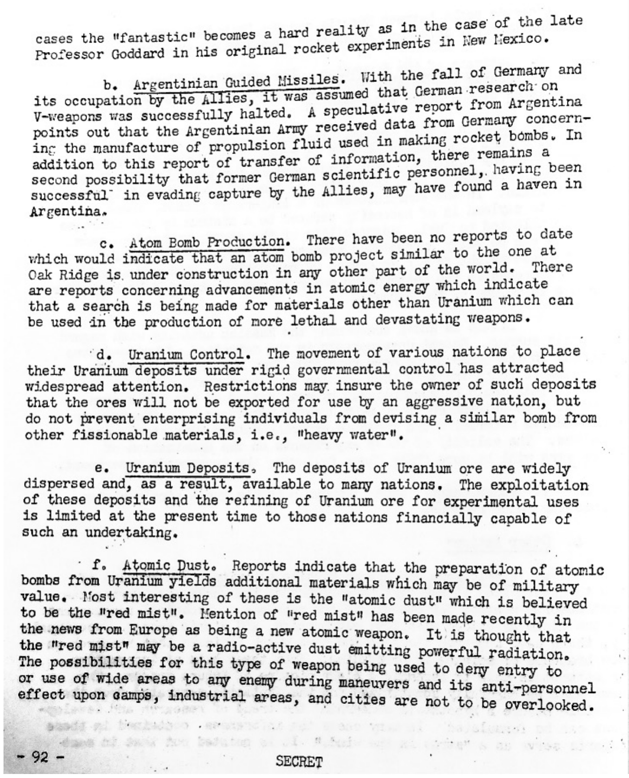


cases the "fantastic" becomes a hard reality as in the case of the late Professor Goddard in his original rocket experiments in New Mexico.

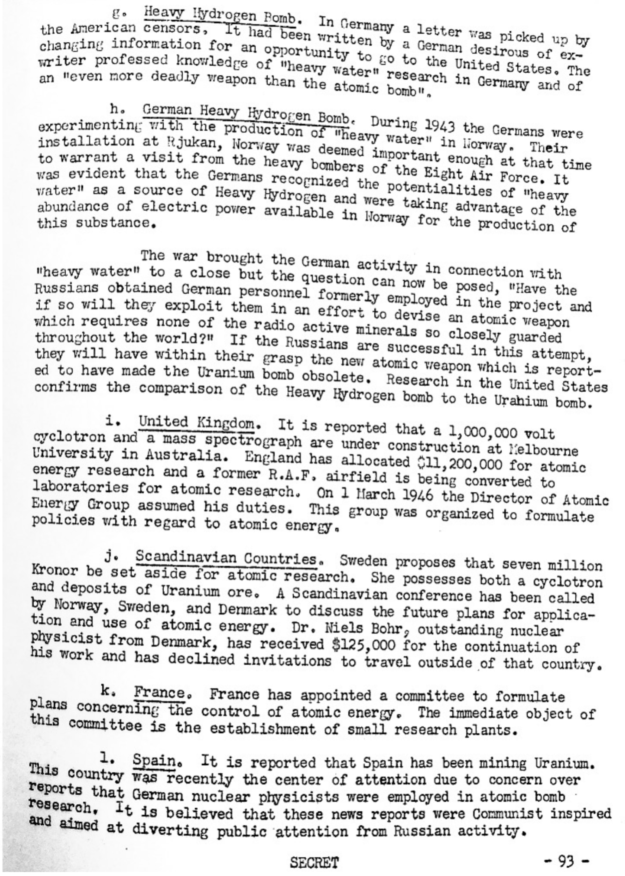
b. Argentinian Guided Missiles. With the fall of Germany and its occupation by the Allies, it was assumed that German research on V-weapons was successfully halted. A speculative report from Argentina points out that the Argentinian Army received data from Germany concerning the manufacture of propulsion fluid used in making rocket bombs. In addition to this report of transfer of information, there remains a second possibility that former German scientific personnel, having been successful in evading capture by the Allies, may have found a haven in Argentina.

c. Atom Bomb Production. There have been no reports to date which would indicate that an atom bomb project similar to the one at Oak Ridge is under construction in any other part of the world. There are reports concerning advancements in atomic energy which indicate that a search is being made for materials other than Uranium which can be used in the production of more lethal and devastating weapons.

d. Uranium Control. The movement of various nations to place their Uranium deposits under rigid governmental control has attracted widespread attention. Restrictions may insure the owner of such deposits that the ores will not be exported for use by an aggressive nation, but do not prevent enterprising individuals from devising a similar bomb from other fissionable materials, i.e., "heavy water".

e. Uranium Deposits. The deposits of Uranium ore are widely dispersed and, as a result, available to many nations. The exploitation of these deposits and the refining of Uranium ore for experimental uses is limited at the present time to those nations financially capable of such an undertaking.

f. Atomic Dust. Reports indicate that the preparation of atomic bombs from Uranium yields additional materials which may be of military value. Most interesting of these is the "atomic dust" which is believed to be the "red mist". Mention of "red mist" has been made recently in the news from Europe as being a new atomic weapon. It is thought that the "red mist" may be a radio-active dust emitting powerful radiation. The possibilities for this type of weapon being used to deny entry to or use of wide areas to any enemy during maneuvers and its anti-personnel effect upon camps, industrial areas, and cities are not to be overlooked.



g. Heavy Hydrogen Bomb. In Germany a letter was picked up by the American censors. It had been written by a German desirous of exchanging information for an opportunity to go to the United States. The writer professed knowledge of "heavy water" research in Germany and of an "even more deadly weapon than the atomic bomb".

h. German Heavy Hydrogen Bomb. During 1943 the Germans were experimenting with the production of "heavy water" in Norway. Their installation at Rjukan, Norway was deemed important enough at that time to warrant a visit from the heavy bombers of the Eight Air Force. It was evident that the Germans recognized the potentialities of "heavy water" as a source of Heavy Hydrogen and were taking advantage of the abundance of electric power available in Norway for the production of this substance.

The war brought the German activity in connection with "heavy water" to a close but the question can now be posed, "Have the Russians obtained German personnel formerly employed in the project and if so will they exploit them in an effort to devise an atomic weapon which requires none of the radio active minerals so closely guarded throughout the world?" If the Russians are successful in this attempt, they will have within their grasp the new atomic weapon which is reported to have made the Uranium bomb obsolete. Research in the United States confirms the comparison of the Heavy Hydrogen bomb to the Urahium bomb.

i. United Kingdom. It is reported that a 1,000,000 volt cyclotron and a mass spectrograph are under construction at Melbourne University in Australia. England has allocated $11,200,000 for atomic energy research and a former R.A.F. airfield is being converted to laboratories for atomic research. On 1 March 1946 the Director of Atomic Energy Group assumed his duties. This group was organized to formulate policies with regard to atomic energy.

j. Scandinavian Countries. Sweden proposes that seven million Kronor be set aside for atomic research. She possesses both a cyclotron and deposits of Uranium ore. A Scandinavian conference has been called by Norway, Sweden, and Denmark to discuss the future plans for application and use of atomic energy. Dr. Niels Bohr, outstanding nuclear physicist from Denmark, has received $125,000 for the continuation of his work and has declined invitations to travel outside of that country.

k. France. France has appointed a committee to formulate plans concerning the control of atomic energy. The immediate object of this committee is the establishment of small research plants.

l. Spain. It is reported that Spain has been mining Uranium. This country was recently the center of attention due to concern over reports that German nuclear physicists were employed in atomic bomb research. It is believed that these news reports were Communist inspired and aimed at diverting public attention from Russian activity.

Figure D.643: Air Intelligence Report No. 100-13/1-100, Significant Developments and Trends in Aircraft and Aircraft Engines, Antiaircraft Guided Missiles (15 June 1946). [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3001–3100]

Kurt Diebner, 1962, *Kerntechnik* 4:3:89–93. Nuclear explosive design with numerous concentric spherical shells, likely based on wartime work.

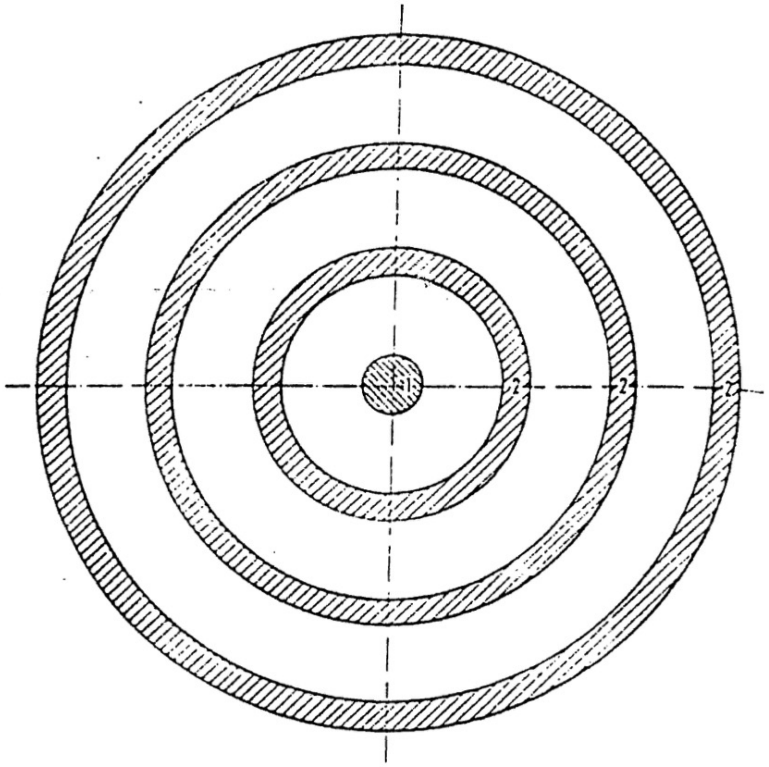


Abb. 3: Eine der Abb. 2 entsprechende schematische Anordnung mit einer Folge von ineinandergefügten Sprengstoffschalen (2) zur Verstärkung des Effektes; (1) bedeutet wieder den Fusionsreaktionsraum

Friedwardt Winterberg, 1981, *The Physical Principles of Thermonuclear Explosive Devices.* Winterberg worked very closely with Diebner after the war.

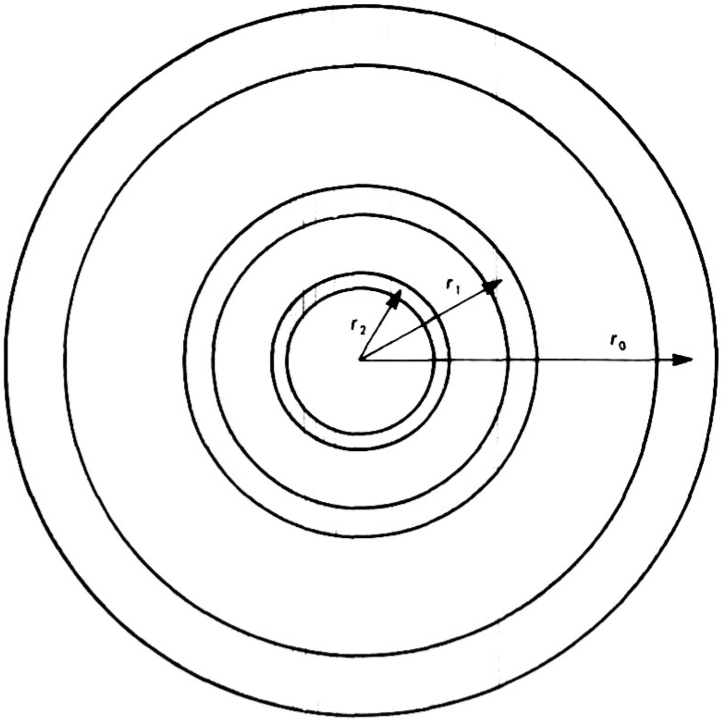


Figure 7. The implosion velocity can be raised through the subsequent collision of several concentric shells of decreasing mass.

Figure D.644: Top: Diagram from Kurt Diebner, likely based on wartime work [Diebner 1962]. Bottom: Diagram from Friedwardt Winterberg, who worked very closely with Diebner after the war [Winterberg 1981]. These diagrams illustrate nuclear explosive designs with a large number of concentric spherical shells to increase the implosion velocity, but they may also represent a key step toward a sloika H-bomb design that implodes alternating layers of fission and fusion fuel.

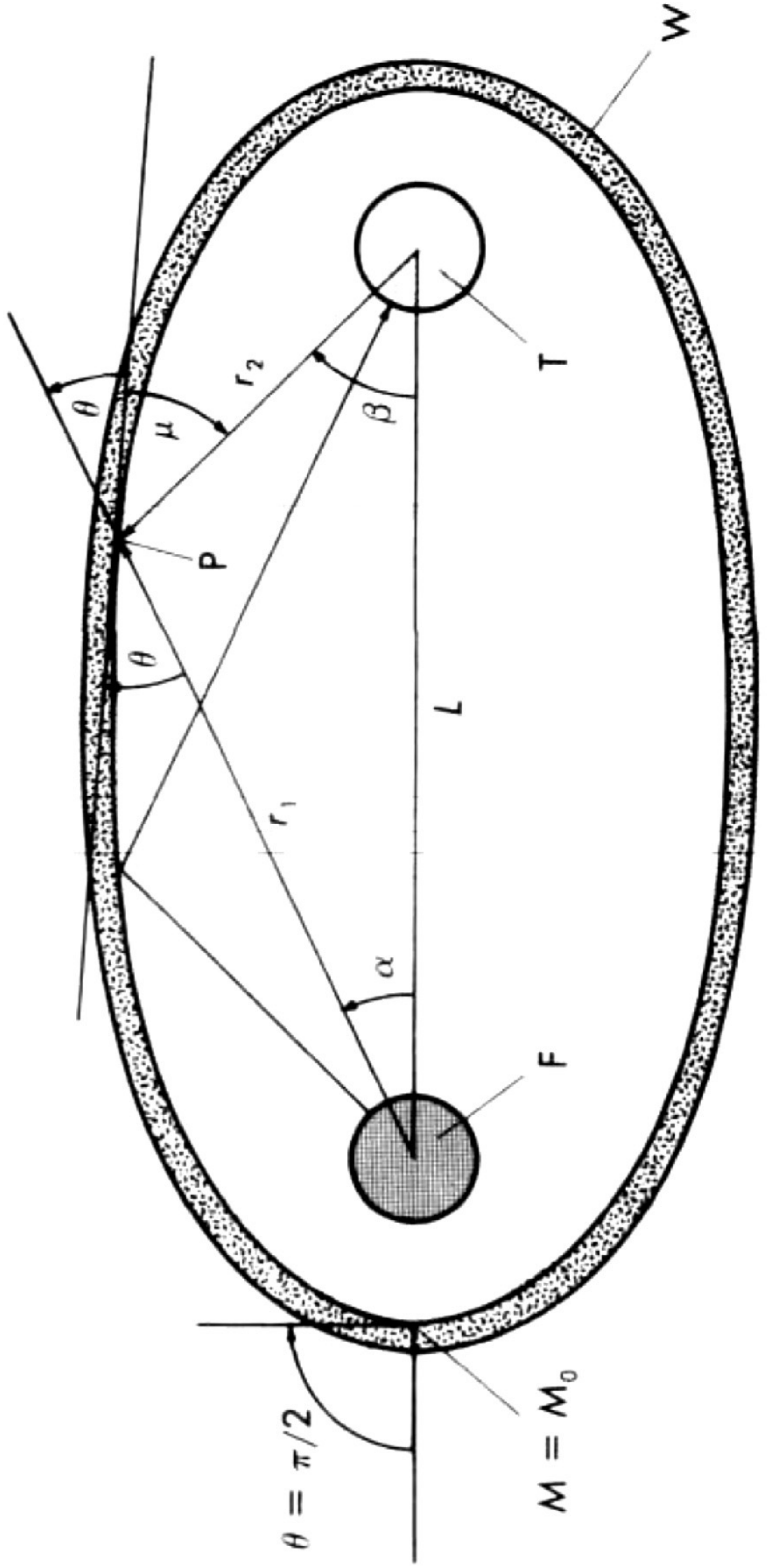


Figure 4. In the Prandtl-Meyer ellipsoid shock wave focusing principle, only one fission bomb F is used to induce a spherical implosion onto the thermonuclear explosive T by shock wave reflection from the wall inside the ellipsoidlike cavity. P is the point where the incoming wave intersects with the wall; M is the Mach number of the hypersonic flow associated with the diverging wave at P; θ is the angle between the wall slope and the incoming ray; r_1 and r_2 are the rays of the shock wave.

Figure D.645: Diagram from Friedwardt Winterberg, who worked very closely with Kurt Diebner after the war, showing a fission-fusion H-bomb design that appears to be deeply steeped in pre-war German hydrodynamic theory (Ludwig Prandtl, Theodor Meyer, Ernst Mach, etc.) and not derivative of the Teller-Ulam H-bomb design used in the United States [Winterberg 1981].

Friedwardt Winterberg. 1981. *The Physical Principles of Thermonuclear Explosive Devices.* New York: Fusion Energy Foundation.

[Friedwardt Winterberg (1929–) worked very closely with Kurt Diebner after the war. In 1981, Winterberg published a book of nuclear explosive designs that appear to have been heavily based on the wartime work of Diebner and others in the German nuclear program. In particular, Winterberg presented two diagrams that appear to be especially relevant for the history of H-bomb designs [Goncharov 1996a, 1996b; Chuck Hansen 1988, 2007; Rhodes 1995; Sublette 2019; Wellerstein and Geist 2017].

1. Page 4372 shows two similar versions of a nuclear explosive design with a large number of concentric spherical shells. The top version is from Diebner, quite likely based on wartime programs with which he was involved [Diebner 1962]. The bottom version is from Winterberg [Winterberg 1981]. In both of these postwar publications, Diebner and Winterberg made the point that such a design could be useful to increase the implosion velocity. However, using a large number of concentric spherical shells is also a critical feature of the sloika H-bomb approach, which implodes alternating layers of fission and fusion fuel. Thus these postwar diagrams might be clues that the wartime German H-bomb program was working toward a sloika design.

2. Page 4373 presents another diagram from Winterberg. The diagram depicts a fission-fusion H-bomb design that appears to be deeply steeped in prewar German hydrodynamic theory (Ludwig Prandtl, Theodor Meyer, Ernst Mach, etc.) and not directly derivative of the Teller-Ulam H-bomb design that was developed in the United States after the war [Winterberg 1981]. Yet like the Teller-Ulam design, the design shown by Winterberg was intended to function as a two-stage (fission explosion, then fusion explosion) thermonuclear bomb, or a three-stage (fission, fusion, fission) bomb if the outer casing were fissionable. For evidence that this ellipsoidal design originated in the wartime German program, see p. 4377.

Either a sloika multi-layered implosion design or an ellipsoidal two-stage design for an H-bomb could have used the lithium deuteride fusion fuel mentioned in other German documents (see pp. 4281–4349).

In principle, either design could have had a weight consistent with the 6-ton bomb mass reported in documents such as those on pp. 4338, 4350–4363, and 5343.

Likewise, if either a sloika or a two-stage design worked as intended, it could have had a megaton-level explosive yield, which would also be consistent with the 6-mile blast radius reported in documents such as those on pp. 4365–4367.]

Is either a large spherical sloika design or an ellipsoidal two-stage design what Werner Grothmann meant by “a third” German nuclear bomb design that was under development during the war, that was apparently quite different than the fission bombs with which Grothmann was more familiar, and that “must have looked like a swollen bomb” (see p. 4272)?

Charles Chamberlain. Germans Failed to Split Atom: Experiments With Heavy Water Futile. *Council Bluffs Nonpareil* (Council Bluffs, Iowa). 9 February 1946 p. 1. https://www.newspapers.com/article/the-daily-nonpareil/1957966/

Another atom scientist in the British occupation zone of Germany—Prof. Paul Harteck of the Kaiser Wilhelm institute of physics in Berlin—said that the light rays thrown out during the enormous explosion of an atomic bomb added greatly to the destructive force.

‘The splitting of the atom causes a temperature of more than 10,000,000 degrees and aerial allure which destroy everything,’ Harteck said.

This frees an amount of light which is beyond the visible spectrum. Only a few people know that the reflection of beams of light on solid bodies also exerts a mechanical pressure. This pressure is so small where our normal light is concerned that it is not noticed. The amount of light freed by an atomic bomb is so great it destroys walls.

[On the basis of his wartime work, Harteck was apparently describing the key to radiation implosion in H-bombs. Compare Harteck’s description above with the description below from Kenneth Ford, one of the American H-bomb scientists. Harteck was brought to the United States to work after the war (p. 4993).]

Kenneth W. Ford. 2015. *Building the H-Bomb: A Personal History.* World Scientific Publishing. pp. 67, 70.

Let me explain what was special about the radiation-implosion idea (the 1951 insight of Edward Teller and Stan Ulam that replaced the unattainable runaway Super with the successful equilibrium Super). [...]

The energy in a given volume of radiation goes as the fourth power of the temperature. [. . .] If you increase the radiation temperature by a factor of ten, the radiant energy increases by a factor of ten thousand (10 to the 4th power). [. . .] The energy of one cubic meter of radiation at a temperature of 30 million K is, in the units favored by weaponeers, 15 kilotons. And its pressure is correspondingly elevated, to 2 billion atmospheres. [. . .]

At ordinary temperature, radiation is like the pixie dust that was visible only to Tinker Bell and her band of fairies. At the temperatures characteristic of nuclear explosions, radiation is “stuff,” full of enormous energy and capable of pushing like a giant piston.

Walther Gerlach. Notebooks 1943/44 and 1944 [Deutsches Museum Archive NL 080/270-66 and NL 080/270-67].

[See document photo on p. 4377.

Walther Gerlach kept a series of small notebooks for scientific notes to himself. They are now in the Deutsches Museum Archive in Munich. Since these notebooks served simply as scientific reminders for Gerlach, they do not contain detailed explanations, as formal laboratory notebooks would. However, they also do not contain any random artistic doodles such as some people make during meetings. Everything in them appears to have had a specific scientific purpose for Gerlach.

Notizbuch 1943/44 [Deutsches Museum Archive NL 080/270-66] is a small orange notebook covering the period 10 November 1943 to March 1944. On the final page, Gerlach drew an ellipsoid remarkably similar to Friedwardt Winterberg's postwar diagram of a hydrogen bomb on p. 4373. On the same page, Gerlach also included nuclear reactions involving deuterium and sketches of converging shock waves [Karlsch 2005, pp. 205, 321, 333].

Notizbuch 1944 [Deutsches Museum Archive NL 080/270-67] is a small dark red notebook that apparently began in March 1944; it is not clear when the final entry was made, but that was likely sometime in 1944 or possibly early 1945. Entries in the notebook show that Gerlach had scientific discussions (although the notebook does not give the scientific details) with Kurt Diebner, Siegfried Flügge, Wilhelm Groth, Fritz Houtermans, and other scientists on nuclear topics, including specifically the use of lithium.

After the war, Kurt Diebner wrote about bombs employing fusion reactions (pp. 4260–4267) and worked closely with the young Friedwardt Winterberg. Edward Teller apparently tried to recruit Siegfried Flügge to help develop the U.S. hydrogen bomb (p. 4996). Wilhelm Groth was reported to have been working on a megaton-level bomb during the war, which is consistent with the physics of hydrogen bombs but not fission bombs (p. 4367). Fritz Houtermans was the first scientist to propose and analyze the fusion reactions in stars (p. 1542).

While these surviving notes from Gerlach are cryptic and certainly not conclusive, they do suggest the existence of a wartime program that was very active by March 1944 and that involved the use of deuterium, lithium, and both fusion and fission reactions in an ellipsoidal hydrogen bomb design highly similar to that on p. 4373. Any more detailed documents on such a program would have been either destroyed by the Germans at the end of the war or captured by Allied countries and still buried in their classified archives.]

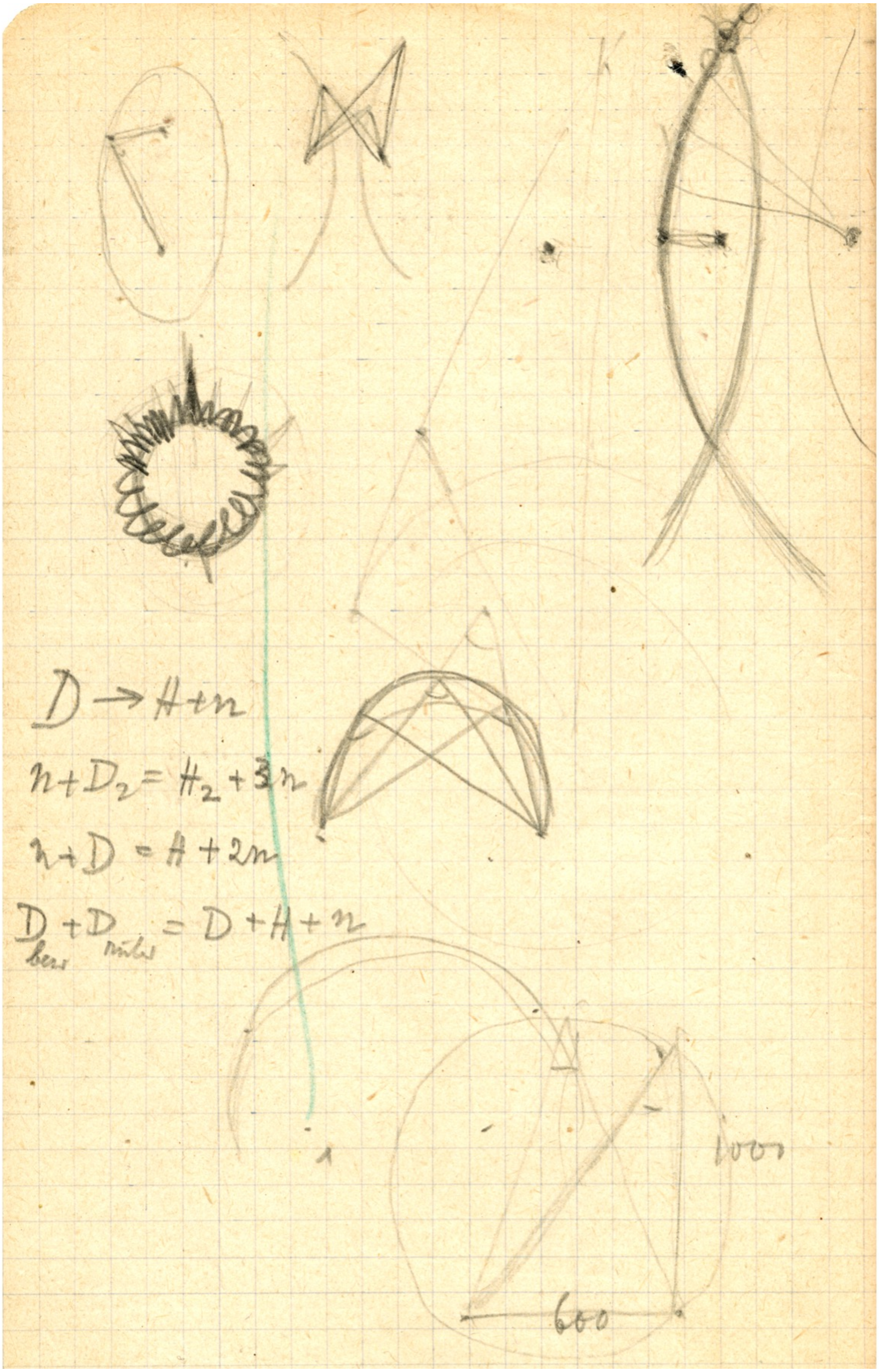

$D \rightarrow H + n$
$n + D_2 = H_2 + 3n$
$n + D = H + 2n$
$D_{bew} + D_{ruh} = D + H + n$
1
1000
600

Figure D.646: March 1944 diagram from Walther Gerlach showing an ellipsoid (upper left) in conjunction with nuclear reactions involving deuterium and converging shock waves. Compare it to Fig. D.645 [Karlsch 2005, pp. 205, 321, 333; Deutsches Museum Archive, NL 080/270-66].

Ronald Richter's 1951–1957 Paperclip file [NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.].

[Ronald Richter (Austrian, 1909–1991) conducted research in Germany during the war, but he is mainly remembered for the highly publicized failure of an experimental fusion reactor project he led for Argentinian president Juan Perón during the period 1949–1952. Scientists and historians have spent the decades since then debating whether Richter was a willful charlatan, a misunderstood genius, or something else entirely.[14]

After the failed project in Argentina, Richter applied for admission to the United States under the Paperclip program, was denied, and lived the rest of his life in obscurity.

Richter's Paperclip file is rather lengthy and includes many pages written by him, or written by U.S. government interviewers about him, regarding his then past, present, and intended future research projects. As illustrated by the excerpts on pp. 4380–4389, these documents list a large number of extremely advanced and insightful ideas in applied physics, including (but not limited to):

- Magnetic-confinement plasma fusion reactors.
- Non-Maxwellian plasma fusion systems not in thermodynamic equilibrium.
- Advanced "aneutronic" fusion reactions (proton + boron-11, proton + lithium-6, helium-3 + helium-3, etc.) that would produce fewer unwanted neutrons than the simplest fusion reactions (deuterium + deuterium and deuterium + tritium).
- Traveling-wave direct electric converters to extract the output energy from fusion reactors in the form of more efficient electromagnetic waves instead of less efficient heat.
- Advanced fission reactors.
- Nuclear propulsion systems for various types of vehicles.
- Supersonic combustion ramjets (scramjets).
- Dual-mode scramjet/rocket engines.
- Quantum vacuum energy or zero-point energy.
- Gravitational theories and grand unified theories.

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[14] See for example: Ehrenberg 1958a, 1958b; Paul-Jürgen Hahn 2003; Karlsch and Petermann 2007; Nagel 2002; Richter 1991; Thirring 1955.

Upon hearing all of these ideas, the Director of the Office of International Affairs at the U.S. Atomic Energy Commission, John Hall, was "quite impressed with the knowledge, theories and work of Dr. Richter" and "stated that Dr. Richter is thinking in the year 1970" (i.e., at least 14 years in the future, p. 4380).

While all of the ideas listed by Richter were extremely clever and worthy of study, detailed theoretical and/or experimental physics investigations would have shown that some of them (such as advanced aneutronic fusion reactions and highly non-Maxwellian plasma fusion reactors [Rider 1995, 1997]) were not practical even under the best possible conditions. There is no evidence that Richter conducted competent theoretical or experimental investigations of the topics that he listed, or that he ever discovered the fundamental physical limitations on some of them. Richter's apparent inability to carry out proper theoretical or experimental physics work was likely one of the primary causes of the failure of the Argentinian fusion project.

Richter's Paperclip file also lists his job history. From his graduation in 1935 until his move to Argentina in 1948, Richter changed research jobs extremely frequently, often after only a few months at each. He worked in labs all over the German-speaking world on a wide variety of projects, and interacted with countless stellar German and Austrian scientists. From reading Richter's job history, one gets the strong impression that Richter was probably discovered to be scientifically incompetent at each job and was quickly dismissed, only to land at another job. Military research and development projects were often overstretched and eager for additional personnel in wartime Germany, so they may not have asked as many questions about Richter's previous employment as they should have before hiring him each time. Yet precisely because those projects were so eager for personnel, Richter must presumably have demonstrated great incompetence to be fired so swiftly by each project.

It is possible that Richter was gifted at thinking of new physics ideas even though he was incapable of properly pursuing them. However, that possibility seems remote, since even conceiving of such ideas requires physical insight and understanding that Richter apparently never demonstrated in his jobs.

Thus by far the most likely explanation is that Richter appropriated the many intriguing research ideas he listed from much more competent scientists with whom he interacted in wartime Germany. In the Paperclip documents, Richter himself listed interactions with or knowledge of the work of Manfred von Ardenne, Adolf Busemann, Abraham Esau, Siegfried Flügge, Josef Mattauch, Max Steenbeck, Kurt Tank, and others. Von Ardenne, Busemann, Esau, Flügge, Mattauch, and Steenbeck appear to have played roles in a program to develop an H-bomb, among other wartime projects.

Therefore, Richter's lists of ideas may offer a rare and valuable glimpse into otherwise quite mysterious wartime research projects. If that explanation is correct, scientists in wartime Germany conceived detailed ideas for research projects that still remained cutting-edge topics many decades after the war, and they may have even made significant progress on some of those topics. At the very least, Richter's documents demonstrate that historians need to do much more work to investigate the true extent and accomplishments of highly advanced research and development programs in wartime Germany.]

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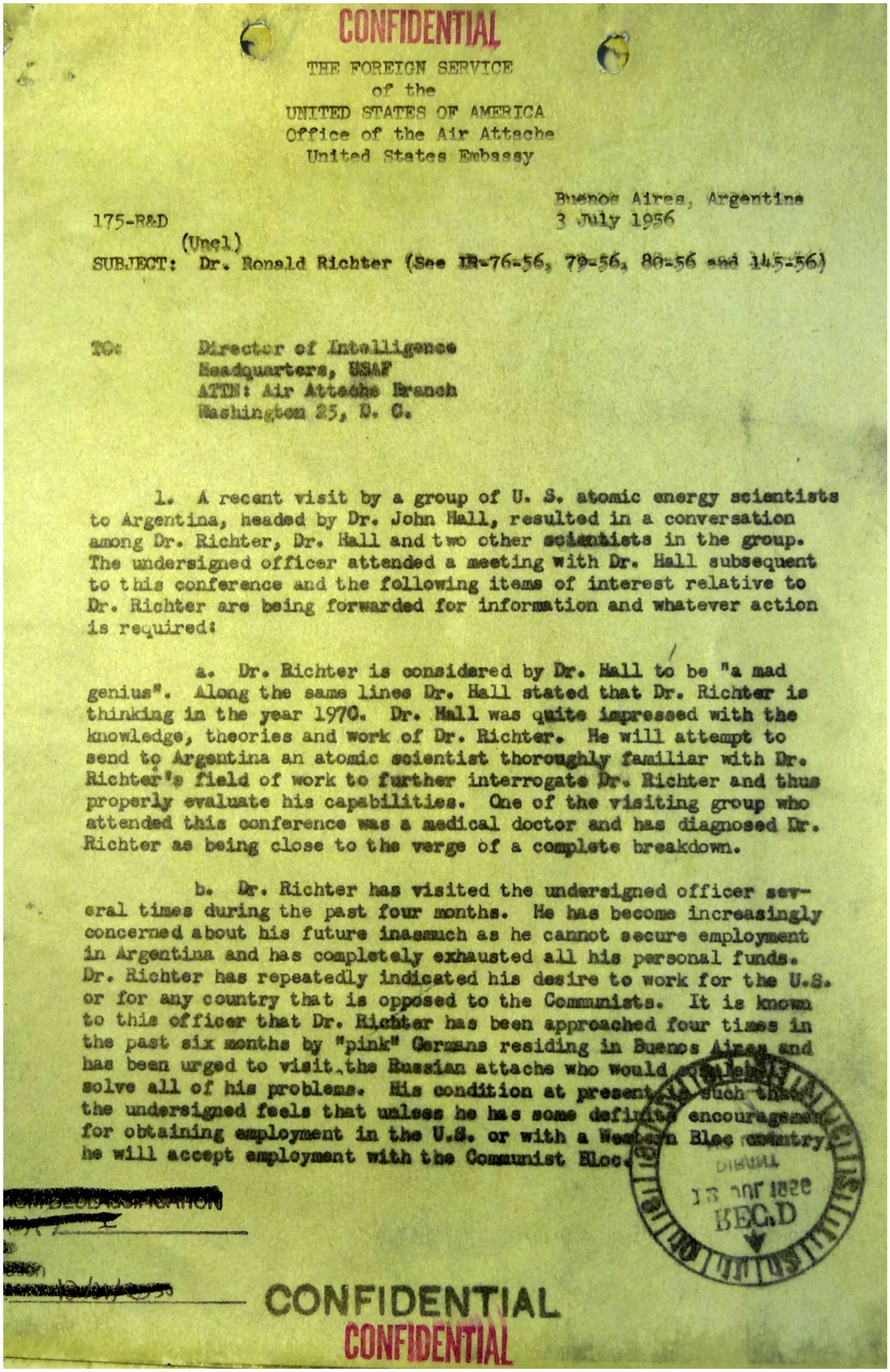

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THE FOREIGN SERVICE
of the
UNITED STATES OF AMERICA
Office of the Air Attache
United States Embassy

Buenos Aires, Argentina
3 July 1956

175-R&D

(Uncl)
SUBJECT: Dr. Ronald Richter (See IR-76-56, 79-56, 80-56 and 145-56)

TO: Director of Intelligence
Headquarters, USAF
ATTN: Air Attache Branch
Washington 25, D. C.

1. A recent visit by a group of U. S. atomic energy scientists to Argentina, headed by Dr. John Hall, resulted in a conversation among Dr. Richter, Dr. Hall and two other scientists in the group. The undersigned officer attended a meeting with Dr. Hall subsequent to this conference and the following items of interest relative to Dr. Richter are being forwarded for information and whatever action is required:

a. Dr. Richter is considered by Dr. Hall to be "a mad genius". Along the same lines Dr. Hall stated that Dr. Richter is thinking in the year 1970. Dr. Hall was quite impressed with the knowledge, theories and work of Dr. Richter. He will attempt to send to Argentina an atomic scientist thoroughly familiar with Dr. Richter's field of work to further interrogate Dr. Richter and thus properly evaluate his capabilities. One of the visiting group who attended this conference was a medical doctor and has diagnosed Dr. Richter as being close to the verge of a complete breakdown.

b. Dr. Richter has visited the undersigned officer several times during the past four months. He has become increasingly concerned about his future inasmuch as he cannot secure employment in Argentina and has completely exhausted all his personal funds. Dr. Richter has repeatedly indicated his desire to work for the U.S. or for any country that is opposed to the Communists. It is known to this officer that Dr. Richter has been approached four times in the past six months by "pink" Germans residing in Buenos Aires and has been urged to visit the Russian attache who would completely solve all of his problems. His condition at present is such that the undersigned feels that unless he has some definite encouragement for obtaining employment in the U.S. or with a Western Bloc country, he will accept employment with the Communist Bloc.

[redacted]

[redacted]

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NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.

Figure D.647: Ronald Richter's 1951–1957 Paperclip file lists a large number of extremely advanced ideas in plasma fusion and related areas of physics, likely originating from much more competent scientists with whom Richter interacted in wartime Germany [NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.].

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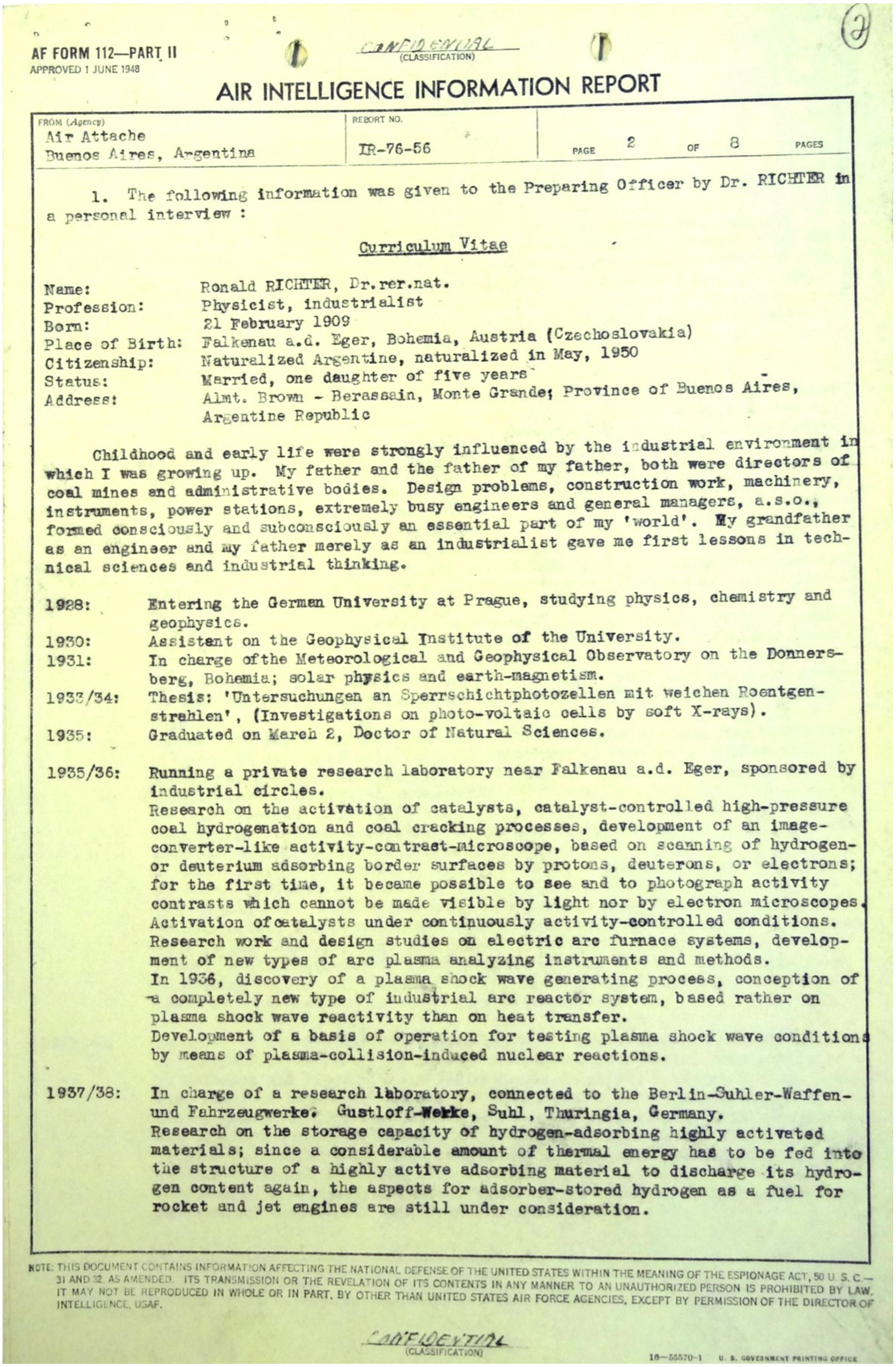

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APPROVED 1 JUNE 1948

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(2)

AIR INTELLIGENCE INFORMATION REPORT

FROM (Agency) Air Attache Buenos Aires, Argentina	REPORT NO. IR-76-56	PAGE 2 OF 8 PAGES

1. The following information was given to the Preparing Officer by Dr. RICHTER in a personal interview :

Curriculum Vitae

Name:	Ronald RICHTER, Dr.rer.nat.
Profession:	Physicist, industrialist
Born:	21 February 1909
Place of Birth:	Falkenau a.d. Eger, Bohemia, Austria (Czechoslovakia)
Citizenship:	Naturalized Argentine, naturalized in May, 1950
Status:	Married, one daughter of five years
Address:	Almt. Brown - Berassain, Monte Grande; Province of Buenos Aires, Argentine Republic

Childhood and early life were strongly influenced by the industrial environment in which I was growing up. My father and the father of my father, both were directors of coal mines and administrative bodies. Design problems, construction work, machinery, instruments, power stations, extremely busy engineers and general managers, a.s.o., formed consciously and subconsciously an essential part of my 'world'. My grandfather as an engineer and my father merely as an industrialist gave me first lessons in technical sciences and industrial thinking.

1928:	Entering the German University at Prague, studying physics, chemistry and geophysics.
1930:	Assistant on the Geophysical Institute of the University.
1931:	In charge ofthe Meteorological and Geophysical Observatory on the Donnersberg, Bohemia; solar physics and earth-magnetism.
1933/34:	Thesis: 'Untersuchungen an Sperrschichtphotozellen mit weichen Roentgenstrahlen', (Investigations on photo-voltaic cells by soft X-rays).
1935:	Graduated on March 2, Doctor of Natural Sciences.
1935/36:	Running a private research laboratory near Falkenau a.d. Eger, sponsored by industrial circles. Research on the activation of catalysts, catalyst-controlled high-pressure coal hydrogenation and coal cracking processes, development of an image-converter-like activity-contrast-microscope, based on scanning of hydrogen- or deuterium adsorbing border surfaces by protons, deuterons, or electrons; for the first time, it became possible to see and to photograph activity contrasts which cannot be made visible by light nor by electron microscopes. Activation ofcatalysts under continuously activity-controlled conditions. Research work and design studies on electric arc furnace systems, development of new types of arc plasma analyzing instruments and methods. In 1936, discovery of a plasma shock wave generating process, conception of a completely new type of industrial arc reactor system, based rather on plasma shock wave reactivity than on heat transfer. Development of a basis of operation for testing plasma shock wave conditions by means of plasma-collision-induced nuclear reactions.
1937/38:	In charge of a research laboratory, connected to the Berlin-Suhler-Waffen- und Fahrzeugwerke. Gustloff-Werke, Suhl, Thuringia, Germany. Research on the storage capacity of hydrogen-adsorbing highly activated materials; since a considerable amount of thermal energy has to be fed into the structure of a highly active adsorbing material to discharge its hydrogen content again, the aspects for adsorber-stored hydrogen as a fuel for rocket and jet engines are still under consideration.

NOTE: THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE ACT, 50 U. S. C.— 31 AND 32, AS AMENDED. ITS TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW. IT MAY NOT BE REPRODUCED IN WHOLE OR IN PART, BY OTHER THAN UNITED STATES AIR FORCE AGENCIES, EXCEPT BY PERMISSION OF THE DIRECTOR OF INTELLIGENCE, USAF.

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Figure D.648: Ronald Richter's 1951–1957 Paperclip file lists a large number of extremely advanced ideas in plasma fusion and related areas of physics, likely originating from much more competent scientists with whom Richter interacted in wartime Germany [NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.].

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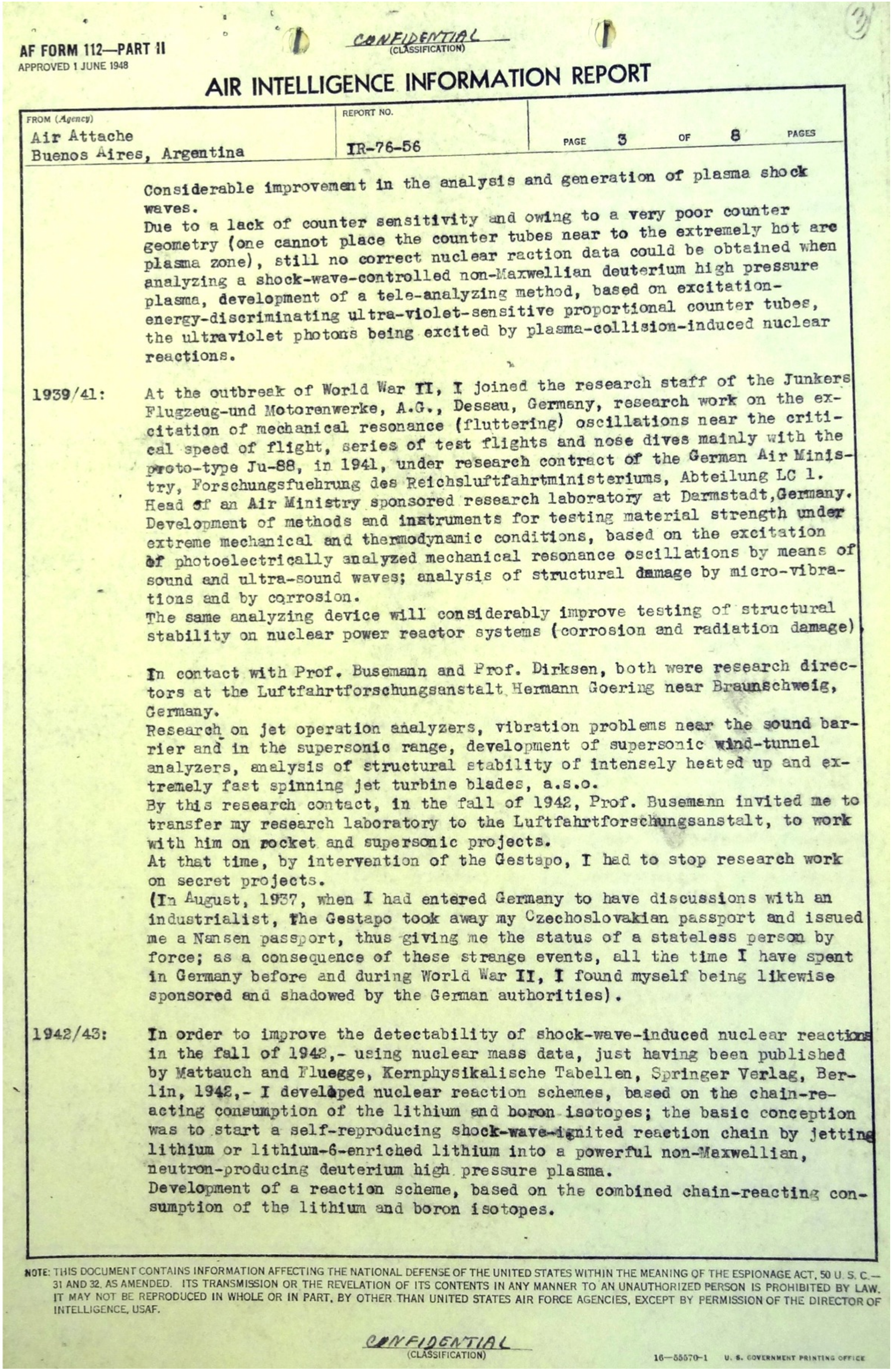

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AIR INTELLIGENCE INFORMATION REPORT

FROM (Agency)	REPORT NO.	
Air Attache Buenos Aires, Argentina	IR-76-56	PAGE 3 OF 8 PAGES

Considerable improvement in the analysis and generation of plasma shock waves.
Due to a lack of counter sensitivity and owing to a very poor counter geometry (one cannot place the counter tubes near to the extremely hot arc plasma zone), still no correct nuclear raction data could be obtained when analyzing a shock-wave-controlled non-Maxwellian deuterium high pressure plasma, development of a tele-analyzing method, based on excitation-energy-discriminating ultra-violet-sensitive proportional counter tubes, the ultraviolet photons being excited by plasma-collision-induced nuclear reactions.

1939/41: At the outbreak of World War II, I joined the research staff of the Junkers Flugzeug-und Motorenwerke, A.G., Dessau, Germany, research work on the excitation of mechanical resonance (fluttering) oscillations near the critical speed of flight, series of test flights and nose dives mainly with the proto-type Ju-88, in 1941, under research contract of the German Air Ministry, Forschungsfuehrung des Reichsluftfahrtministeriums, Abteilung LC 1.
Head of an Air Ministry sponsored research laboratory at Darmstadt, Germany.
Development of methods and instruments for testing material strength under extreme mechanical and thermodynamic conditions, based on the excitation of photoelectrically analyzed mechanical resonance oscillations by means of sound and ultra-sound waves; analysis of structural damage by micro-vibrations and by corrosion.
The same analyzing device will considerably improve testing of structural stability on nuclear power reactor systems (corrosion and radiation damage).

In contact with Prof. Busemann and Prof. Dirksen, both were research directors at the Luftfahrtforschungsanstalt Hermann Goering near Braunschweig, Germany.
Research on jet operation analyzers, vibration problems near the sound barrier and in the supersonic range, development of supersonic wind-tunnel analyzers, analysis of structural stability of intensely heated up and extremely fast spinning jet turbine blades, a.s.o.
By this research contact, in the fall of 1942, Prof. Busemann invited me to transfer my research laboratory to the Luftfahrtforschungsanstalt, to work with him on rocket and supersonic projects.
At that time, by intervention of the Gestapo, I had to stop research work on secret projects.
(In August, 1937, when I had entered Germany to have discussions with an industrialist, the Gestapo took away my Czechoslovakian passport and issued me a Nansen passport, thus giving me the status of a stateless person by force; as a consequence of these strange events, all the time I have spent in Germany before and during World War II, I found myself being likewise sponsored and shadowed by the German authorities).

1942/43: In order to improve the detectability of shock-wave-induced nuclear reactions in the fall of 1942,- using nuclear mass data, just having been published by Mattauch and Fluegge, Kernphysikalische Tabellen, Springer Verlag, Berlin, 1942,- I developed nuclear reaction schemes, based on the chain-reacting consumption of the lithium and boron isotopes; the basic conception was to start a self-reproducing shock-wave-ignited reaction chain by jetting lithium or lithium-6-enriched lithium into a powerful non-Maxwellian, neutron-producing deuterium high pressure plasma.
Development of a reaction scheme, based on the combined chain-reacting consumption of the lithium and boron isotopes.

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Figure D.649: Ronald Richter's 1951–1957 Paperclip file lists a large number of extremely advanced ideas in plasma fusion and related areas of physics, likely originating from much more competent scientists with whom Richter interacted in wartime Germany [NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.].

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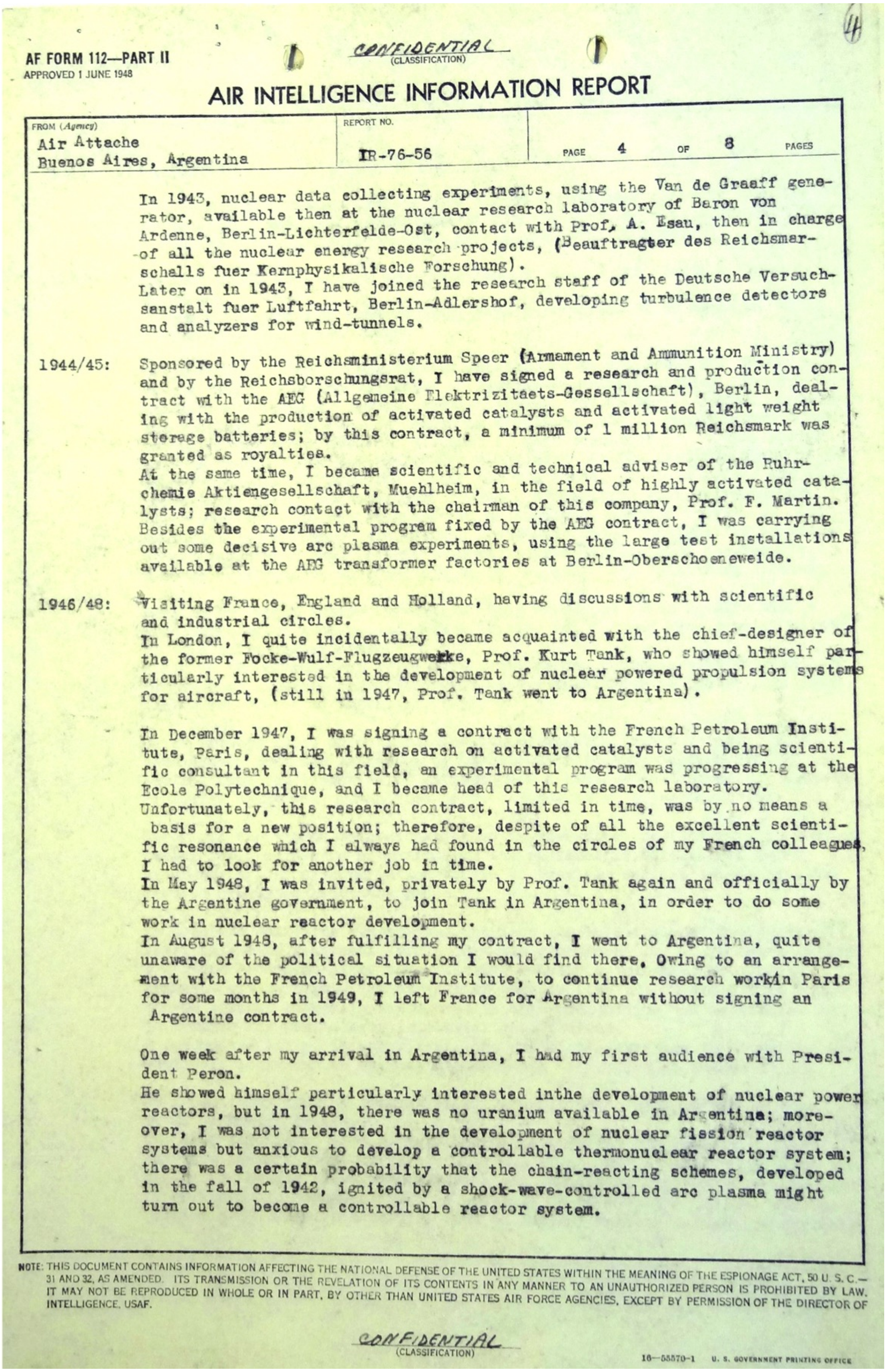

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AIR INTELLIGENCE INFORMATION REPORT

FROM (Agency)	REPORT NO.	PAGE	OF	PAGES
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In 1943, nuclear data collecting experiments, using the Van de Graaff generator, available then at the nuclear research laboratory of Baron von Ardenne, Berlin-Lichterfelde-Ost, contact with Prof. A. Esau, then in charge of all the nuclear energy research projects, (Beauftragter des Reichsmarschalls fuer Kernphysikalische Forschung).
Later on in 1943, I have joined the research staff of the Deutsche Versuchsanstalt fuer Luftfahrt, Berlin-Adlershof, developing turbulence detectors and analyzers for wind-tunnels.

1944/45: Sponsored by the Reichsministerium Speer (Armament and Ammunition Ministry) and by the Reichsborschungsrat, I have signed a research and production contract with the AEG (Allgemeine Flektrizitaets-Gessellschaft), Berlin, dealing with the production of activated catalysts and activated light weight storage batteries; by this contract, a minimum of 1 million Reichsmark was granted as royalties.
At the same time, I became scientific and technical adviser of the Ruhrchemie Aktiengesellschaft, Muehlheim, in the field of highly activated catalysts; research contact with the chairman of this company, Prof. F. Martin.
Besides the experimental program fixed by the AEG contract, I was carrying out some decisive arc plasma experiments, using the large test installations available at the AEG transformer factories at Berlin-Oberschoeneweide.

1946/48: Visiting France, England and Holland, having discussions with scientific and industrial circles.
In London, I quite incidentally became acquainted with the chief-designer of the former Focke-Wulf-Flugzeugwerke, Prof. Kurt Tank, who showed himself particularly interested in the development of nuclear powered propulsion systems for aircraft, (still in 1947, Prof. Tank went to Argentina).

In December 1947, I was signing a contract with the French Petroleum Institute, Paris, dealing with research on activated catalysts and being scientific consultant in this field, an experimental program was progressing at the Ecole Polytechnique, and I became head of this research laboratory.
Unfortunately, this research contract, limited in time, was by no means a basis for a new position; therefore, despite of all the excellent scientific resonance which I always had found in the circles of my French colleagues, I had to look for another job in time.
In May 1948, I was invited, privately by Prof. Tank again and officially by the Argentine government, to join Tank in Argentina, in order to do some work in nuclear reactor development.
In August 1948, after fulfilling my contract, I went to Argentina, quite unaware of the political situation I would find there. Owing to an arrangement with the French Petroleum Institute, to continue research workin Paris for some months in 1949, I left France for Argentina without signing an Argentine contract.

One week after my arrival in Argentina, I had my first audience with President Peron.
He showed himself particularly interested inthe development of nuclear power reactors, but in 1948, there was no uranium available in Argentina; moreover, I was not interested in the development of nuclear fission reactor systems but anxious to develop a controllable thermonuclear reactor system; there was a certain probability that the chain-reacting schemes, developed in the fall of 1942, ignited by a shock-wave-controlled arc plasma might turn out to become a controllable reactor system.

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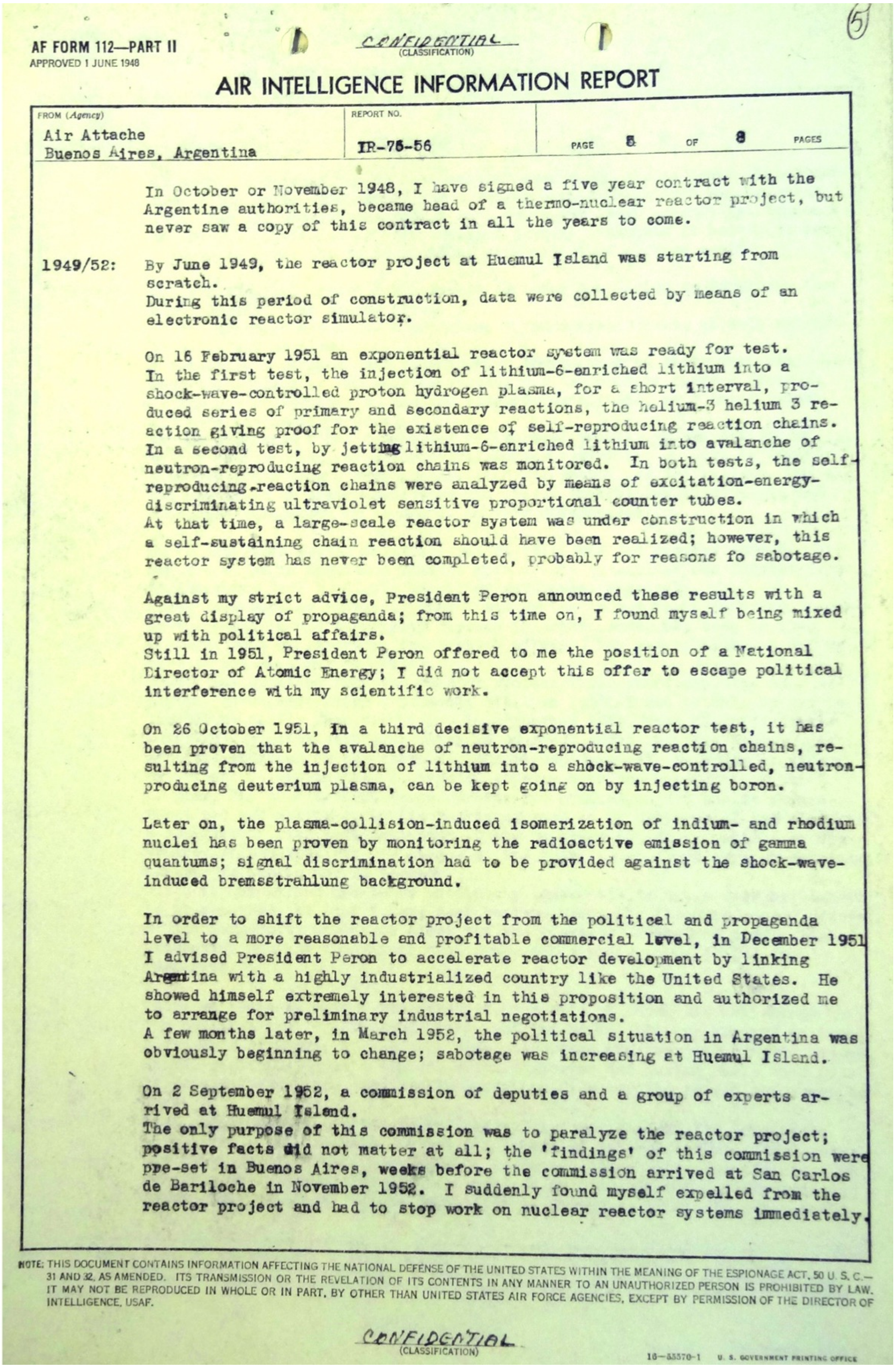

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AIR INTELLIGENCE INFORMATION REPORT

FROM (Agency)	REPORT NO.		
Air Attache Buenos Aires, Argentina	IR-75-56	PAGE 5 OF 8 PAGES	

In October or November 1948, I have signed a five year contract with the Argentine authorities, became head of a thermo-nuclear reactor project, but never saw a copy of this contract in all the years to come.

1949/52: By June 1949, the reactor project at Huemul Island was starting from scratch.
During this period of construction, data were collected by means of an electronic reactor simulator.

On 16 February 1951 an exponential reactor system was ready for test. In the first test, the injection of lithium-6-enriched lithium into a shock-wave-controlled proton hydrogen plasma, for a short interval, produced series of primary and secondary reactions, the helium-3 helium 3 reaction giving proof for the existence of self-reproducing reaction chains. In a second test, by jetting lithium-6-enriched lithium into avalanche of neutron-reproducing reaction chains was monitored. In both tests, the self-reproducing reaction chains were analyzed by means of excitation-energy-discriminating ultraviolet sensitive proportional counter tubes.
At that time, a large-scale reactor system was under construction in which a self-sustaining chain reaction should have been realized; however, this reactor system has never been completed, probably for reasons fo sabotage.

Against my strict advice, President Peron announced these results with a great display of propaganda; from this time on, I found myself being mixed up with political affairs.
Still in 1951, President Peron offered to me the position of a National Director of Atomic Energy; I did not accept this offer to escape political interference with my scientific work.

On 26 October 1951, in a third decisive exponential reactor test, it has been proven that the avalanche of neutron-reproducing reaction chains, resulting from the injection of lithium into a shock-wave-controlled, neutron-producing deuterium plasma, can be kept going on by injecting boron.

Later on, the plasma-collision-induced isomerization of indium- and rhodium nuclei has been proven by monitoring the radioactive emission of gamma quantums; signal discrimination had to be provided against the shock-wave-induced bremsstrahlung background.

In order to shift the reactor project from the political and propaganda level to a more reasonable and profitable commercial level, in December 1951 I advised President Peron to accelerate reactor development by linking Argentina with a highly industrialized country like the United States. He showed himself extremely interested in this proposition and authorized me to arrange for preliminary industrial negotiations.
A few months later, in March 1952, the political situation in Argentina was obviously beginning to change; sabotage was increasing at Huemul Island.

On 2 September 1952, a commission of deputies and a group of experts arrived at Huemul Island.
The only purpose of this commission was to paralyze the reactor project; positive facts did not matter at all; the 'findings' of this commission were pre-set in Buenos Aires, weeks before the commission arrived at San Carlos de Bariloche in November 1952. I suddenly found myself expelled from the reactor project and had to stop work on nuclear reactor systems immediately.

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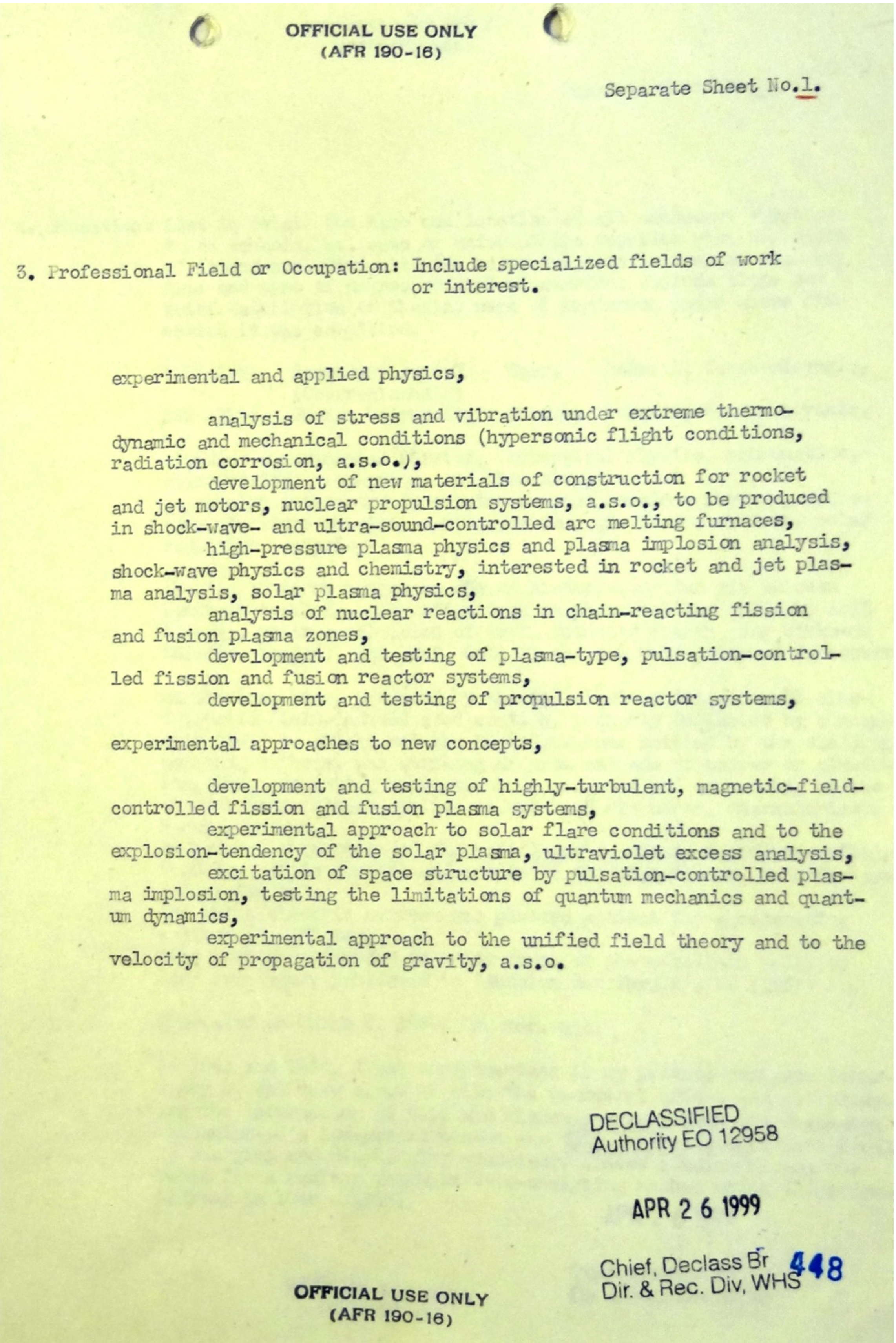

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3. Professional Field or Occupation: Include specialized fields of work or interest.

experimental and applied physics,

analysis of stress and vibration under extreme thermodynamic and mechanical conditions (hypersonic flight conditions, radiation corrosion, a.s.o.),

development of new materials of construction for rocket and jet motors, nuclear propulsion systems, a.s.o., to be produced in shock-wave- and ultra-sound-controlled arc melting furnaces,

high-pressure plasma physics and plasma implosion analysis, shock-wave physics and chemistry, interested in rocket and jet plasma analysis, solar plasma physics,

analysis of nuclear reactions in chain-reacting fission and fusion plasma zones,

development and testing of plasma-type, pulsation-controlled fission and fusion reactor systems,

development and testing of propulsion reactor systems,

experimental approaches to new concepts,

development and testing of highly-turbulent, magnetic-field-controlled fission and fusion plasma systems,

experimental approach to solar flare conditions and to the explosion-tendency of the solar plasma, ultraviolet excess analysis,

excitation of space structure by pulsation-controlled plasma implosion, testing the limitations of quantum mechanics and quantum dynamics,

experimental approach to the unified field theory and to the velocity of propagation of gravity, a.s.o.

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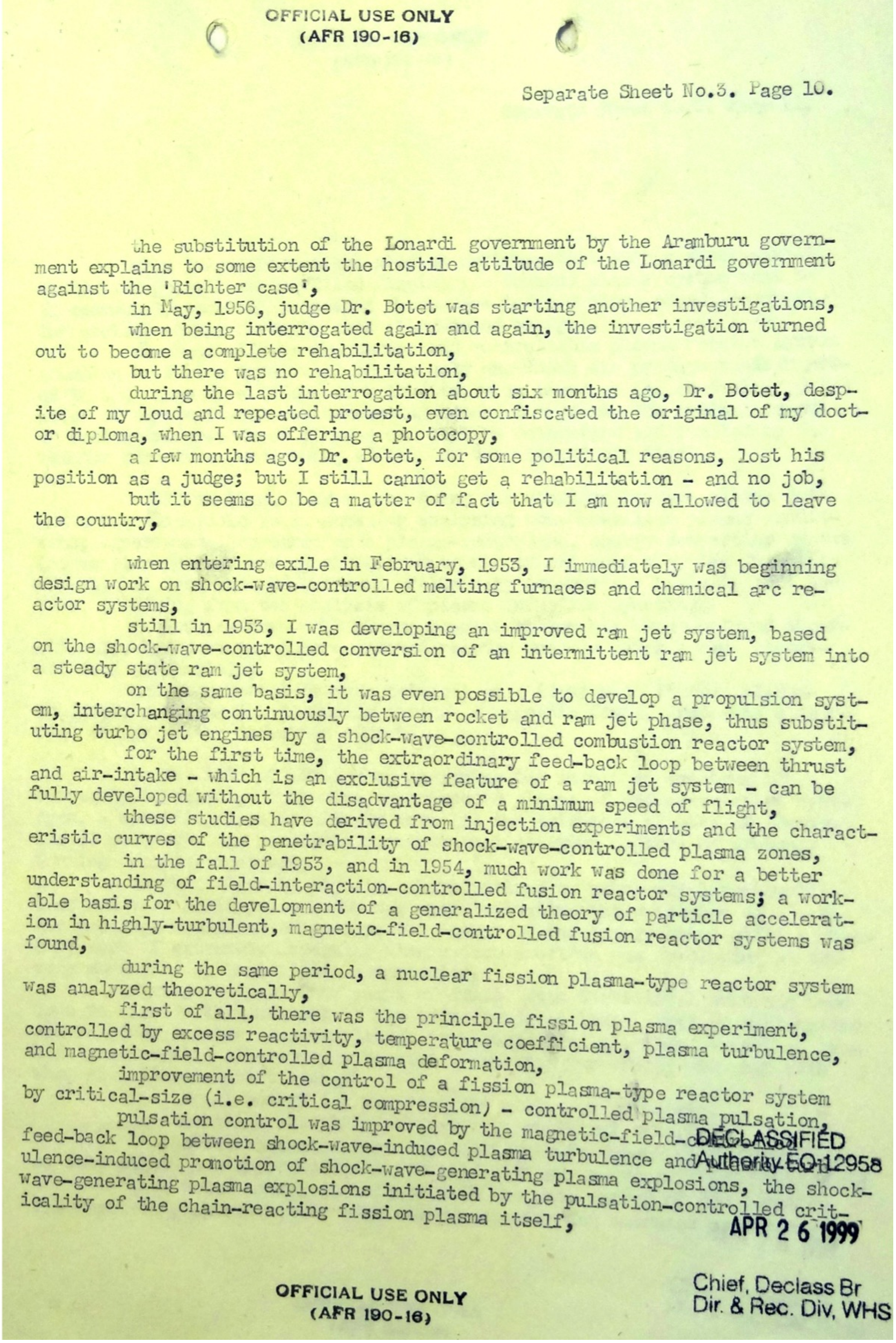

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the substitution of the Lonardi government by the Aramburu government explains to some extent the hostile attitude of the Lonardi government against the 'Richter case',

in May, 1956, judge Dr. Botet was starting another investigations,

when being interrogated again and again, the investigation turned out to become a complete rehabilitation,

but there was no rehabilitation,

during the last interrogation about six months ago, Dr. Botet, despite of my loud and repeated protest, even confiscated the original of my doctor diploma, when I was offering a photocopy,

a few months ago, Dr. Botet, for some political reasons, lost his position as a judge; but I still cannot get a rehabilitation - and no job,

but it seems to be a matter of fact that I am now allowed to leave the country,

when entering exile in February, 1953, I immediately was beginning design work on shock-wave-controlled melting furnaces and chemical arc reactor systems,

still in 1953, I was developing an improved ram jet system, based on the shock-wave-controlled conversion of an intermittent ram jet system into a steady state ram jet system,

on the same basis, it was even possible to develop a propulsion system, interchanging continuously between rocket and ram jet phase, thus substituting turbo jet engines by a shock-wave-controlled combustion reactor system,

for the first time, the extraordinary feed-back loop between thrust and air-intake - which is an exclusive feature of a ram jet system - can be fully developed without the disadvantage of a minimum speed of flight,

these studies have derived from injection experiments and the characteristic curves of the penetrability of shock-wave-controlled plasma zones,

in the fall of 1953, and in 1954, much work was done for a better understanding of field-interaction-controlled fusion reactor systems; a workable basis for the development of a generalized theory of particle acceleration in highly-turbulent, magnetic-field-controlled fusion reactor systems was found,

during the same period, a nuclear fission plasma-type reactor system was analyzed theoretically,

first of all, there was the principle fission plasma experiment, controlled by excess reactivity, temperature coefficient, plasma turbulence, and magnetic-field-controlled plasma deformation,

improvement of the control of a fission plasma-type reactor system by critical-size (i.e. critical compression) - controlled plasma pulsation,

pulsation control was improved by the magnetic-field-controlled feed-back loop between shock-wave-induced plasma turbulence and plasma turbulence-induced promotion of shock-wave-generating plasma explosions, the shock-wave-generating plasma explosions initiated by the pulsation-controlled criticality of the chain-reacting fission plasma itself,

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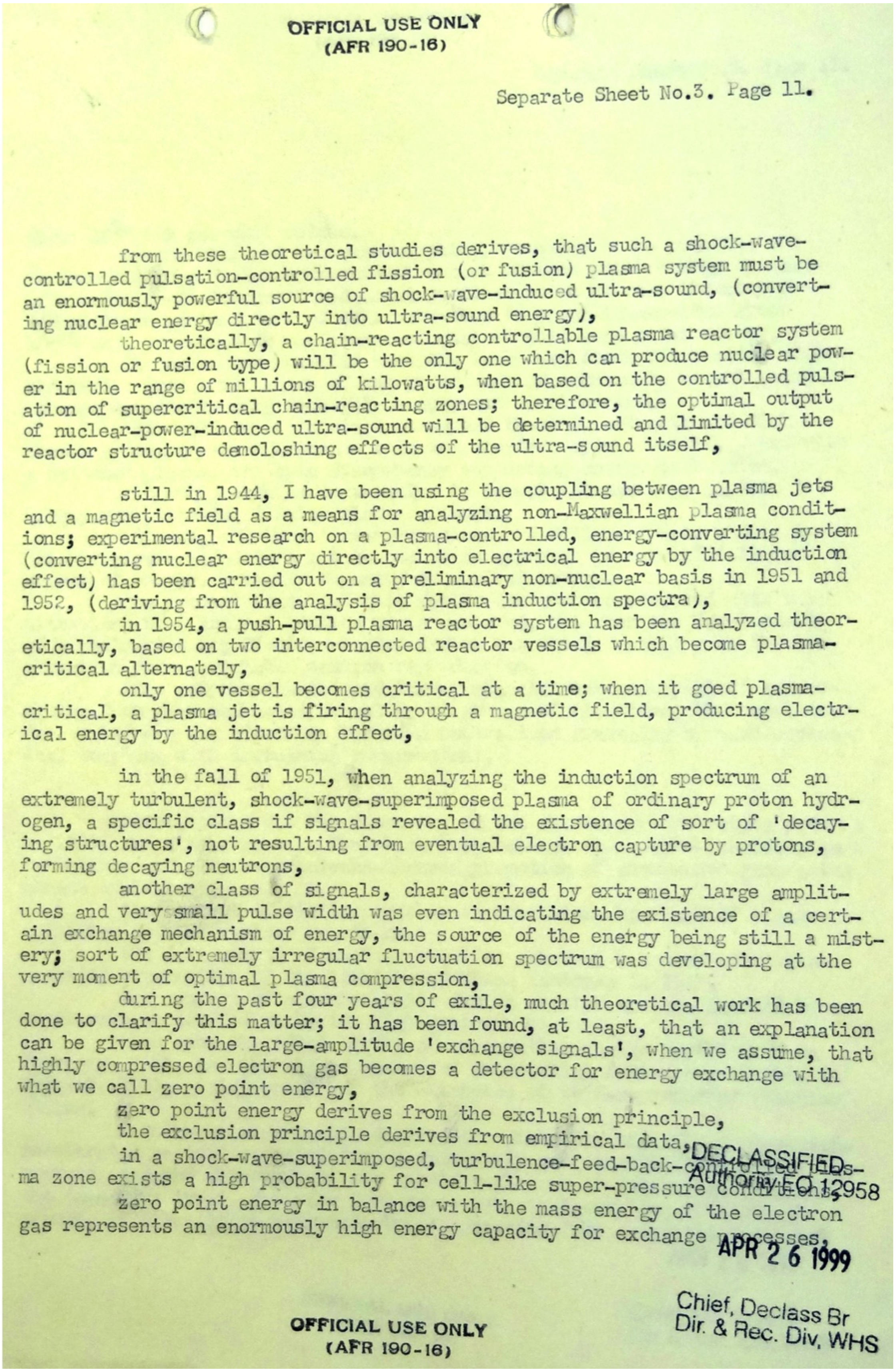

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from these theoretical studies derives, that such a shock-wave-controlled pulsation-controlled fission (or fusion) plasma system must be an enormously powerful source of shock-wave-induced ultra-sound, (converting nuclear energy directly into ultra-sound energy),

theoretically, a chain-reacting controllable plasma reactor system (fission or fusion type) will be the only one which can produce nuclear power in the range of millions of kilowatts, when based on the controlled pulsation of supercritical chain-reacting zones; therefore, the optimal output of nuclear-power-induced ultra-sound will be determined and limited by the reactor structure demoloshing effects of the ultra-sound itself,

still in 1944, I have been using the coupling between plasma jets and a magnetic field as a means for analyzing non-Maxwellian plasma conditions; experimental research on a plasma-controlled, energy-converting system (converting nuclear energy directly into electrical energy by the induction effect) has been carried out on a preliminary non-nuclear basis in 1951 and 1952, (deriving from the analysis of plasma induction spectra),

in 1954, a push-pull plasma reactor system has been analyzed theoretically, based on two interconnected reactor vessels which become plasma-critical alternately,

only one vessel becomes critical at a time; when it goed plasma-critical, a plasma jet is firing through a magnetic field, producing electrical energy by the induction effect,

in the fall of 1951, when analyzing the induction spectrum of an extremely turbulent, shock-wave-superimposed plasma of ordinary proton hydrogen, a specific class if signals revealed the existence of sort of 'decaying structures', not resulting from eventual electron capture by protons, forming decaying neutrons,

another class of signals, characterized by extremely large amplitudes and very small pulse width was even indicating the existence of a certain exchange mechanism of energy, the source of the energy being still a mistery; sort of extremely irregular fluctuation spectrum was developing at the very moment of optimal plasma compression,

during the past four years of exile, much theoretical work has been done to clarify this matter; it has been found, at least, that an explanation can be given for the large-amplitude 'exchange signals', when we assume, that highly compressed electron gas becomes a detector for energy exchange with what we call zero point energy,

zero point energy derives from the exclusion principle,

the exclusion principle derives from empirical data,

in a shock-wave-superimposed, turbulence-feed-back-controlled plasma zone exists a high probability for cell-like super-pressure conditions,

zero point energy in balance with the mass energy of the electron gas represents an enormously high energy capacity for exchange processes,

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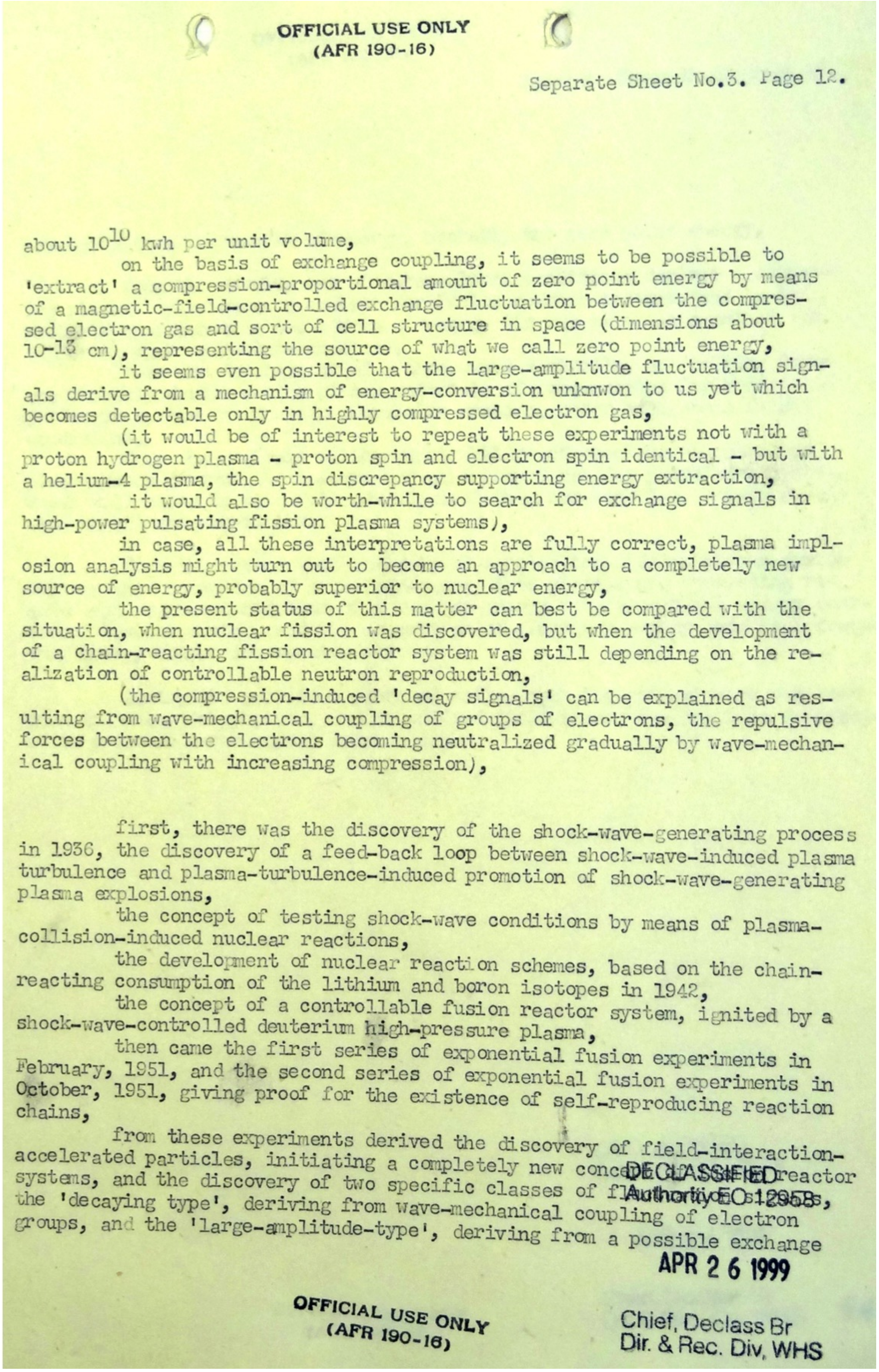

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about 10^{10} kwh per unit volume,

on the basis of exchange coupling, it seems to be possible to 'extract' a compression-proportional amount of zero point energy by means of a magnetic-field-controlled exchange fluctuation between the compressed electron gas and sort of cell structure in space (dimensions about 10^{-13} cm), representing the source of what we call zero point energy,

it seems even possible that the large-amplitude fluctuation signals derive from a mechanism of energy-conversion unknwon to us yet which becomes detectable only in highly compressed electron gas,

(it would be of interest to repeat these experiments not with a proton hydrogen plasma - proton spin and electron spin identical - but with a helium-4 plasma, the spin discrepancy supporting energy extraction,

it would also be worth-while to search for exchange signals in high-power pulsating fission plasma systems),

in case, all these interpretations are fully correct, plasma implosion analysis might turn out to become an approach to a completely new source of energy, probably superior to nuclear energy,

the present status of this matter can best be compared with the situation, when nuclear fission was discovered, but when the development of a chain-reacting fission reactor system was still depending on the realization of controllable neutron reproduction,

(the compression-induced 'decay signals' can be explained as resulting from wave-mechanical coupling of groups of electrons, the repulsive forces between the electrons becoming neutralized gradually by wave-mechanical coupling with increasing compression),

first, there was the discovery of the shock-wave-generating process in 1936, the discovery of a feed-back loop between shock-wave-induced plasma turbulence and plasma-turbulence-induced promotion of shock-wave-generating plasma explosions,

the concept of testing shock-wave conditions by means of plasma-collision-induced nuclear reactions,

the development of nuclear reaction schemes, based on the chain-reacting consumption of the lithium and boron isotopes in 1942,

the concept of a controllable fusion reactor system, ignited by a shock-wave-controlled deuterium high-pressure plasma,

then came the first series of exponential fusion experiments in February, 1951, and the second series of exponential fusion experiments in October, 1951, giving proof for the existence of self-reproducing reaction chains,

from these experiments derived the discovery of field-interaction-accelerated particles, initiating a completely new conce[illegible]reactor systems, and the discovery of two specific classes of fl[illegible]s, the 'decaying type', deriving from wave-mechanical coupling of electron groups, and the 'large-amplitude-type', deriving from a possible exchange

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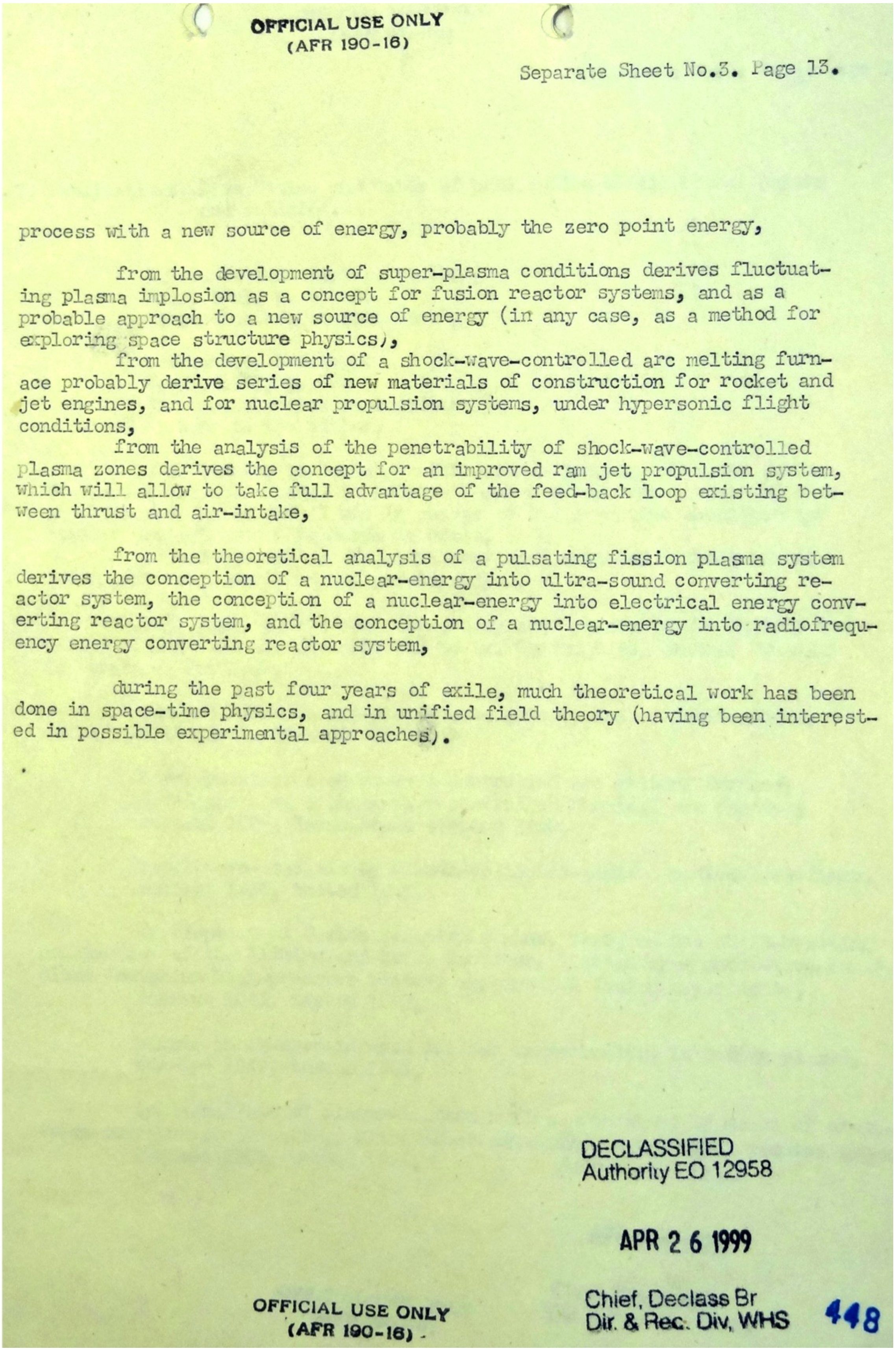

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process with a new source of energy, probably the zero point energy,

from the development of super-plasma conditions derives fluctuating plasma implosion as a concept for fusion reactor systems, and as a probable approach to a new source of energy (in any case, as a method for exploring space structure physics),

from the development of a shock-wave-controlled arc melting furnace probably derive series of new materials of construction for rocket and jet engines, and for nuclear propulsion systems, under hypersonic flight conditions,

from the analysis of the penetrability of shock-wave-controlled plasma zones derives the concept for an improved ram jet propulsion system, which will allow to take full advantage of the feed-back loop existing between thrust and air-intake,

from the theoretical analysis of a pulsating fission plasma system derives the conception of a nuclear-energy into ultra-sound converting reactor system, the conception of a nuclear-energy into electrical energy converting reactor system, and the conception of a nuclear-energy into radiofrequency energy converting reactor system,

during the past four years of exile, much theoretical work has been done in space-time physics, and in unified field theory (having been interested in possible experimental approaches).

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D.10 Possible October 1944 Test Explosion on the Baltic Coast

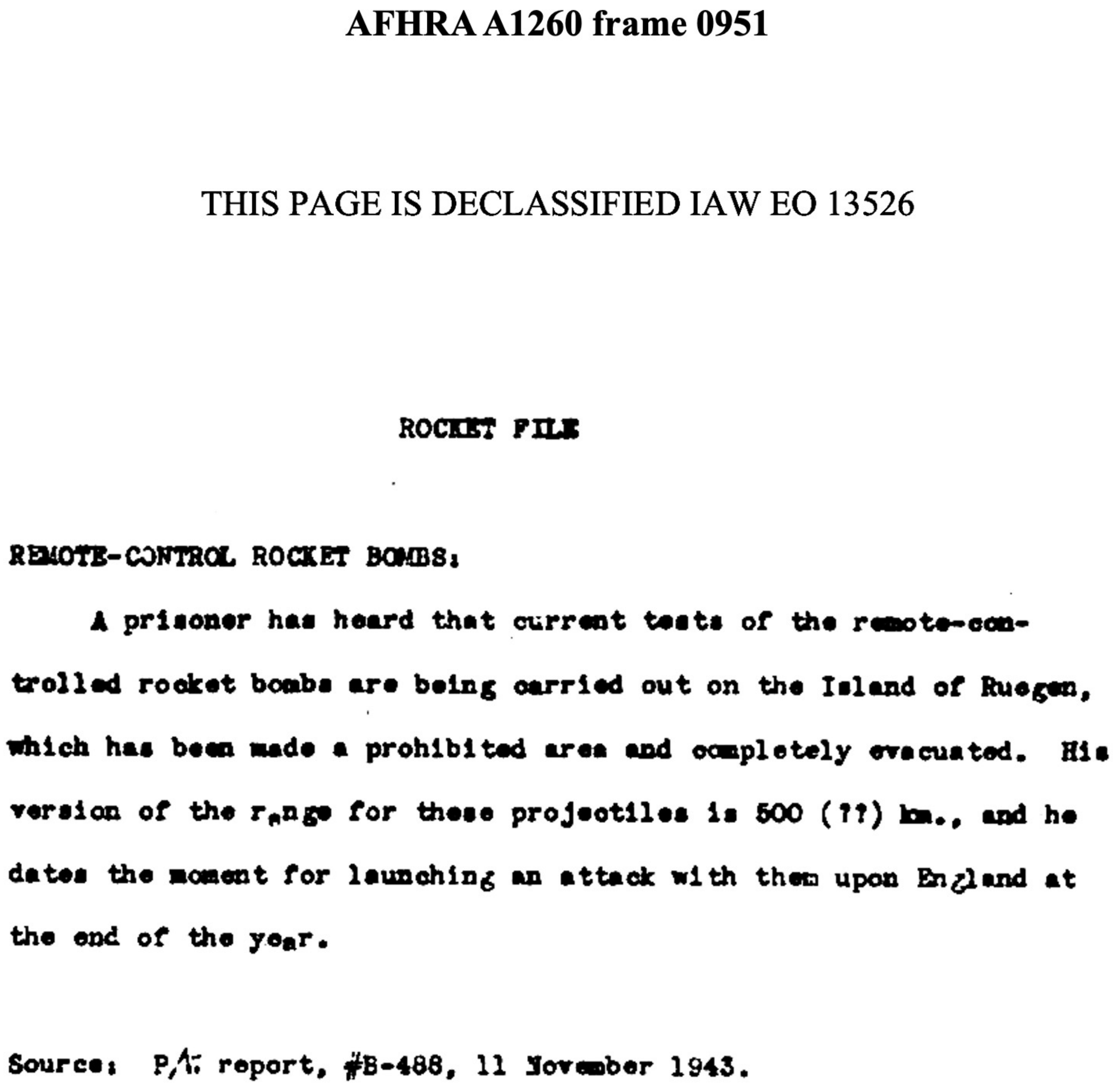
[There may have been a test explosion on the Baltic coast in October 1944, as reported by multiple sources:

- In August 1944, a German prisoner of war reported that "experiments are conducted on an estate in Pomerania [on the Baltic coast] and it is alleged that this explosive is capable of destroying everything in a radius of several kilometers." (p. 4396).
- On 20 October 1944, the U.S. physicist and intelligence analyst Philip Morrison mentioned "recent reports of Baltic explosions" that were being investigated by the Manhattan Project as possible tests of a German atomic bomb (p. 4398).
- A 21 October 1944 OSS intelligence report described the October test: "The Germans have completed a weapon which is founded on the principle of the disintegration of matter (Atomzertruemmerung). Experiments have been performed which have proved conclusive[...] The radius of action is supposed to be about three kilometers" (pp. 4400–4403).
- A 19 January 1945 U.S. military intelligence summary covering many areas of advanced German research included a subject heading for "ATOMIC BOMB," under which it mentioned "close surveillance of the area in which tests are alleged to have taken place" (p. 4404). While the report did not state a specific time or location for those alleged tests, it focused largely on the most recent work being conducted on the Baltic coast, suggesting that the tests occurred in late 1944 on the Baltic coast.
- In May 1945, German prisoner of war Friedrich Olmes said that there had been "experiments with the atom-splitting bomb" and that "practical experiments were conducted on the Baltic coast" (p. 4406).
- A 19 August 1945 U.S. Army Air Forces intelligence report entitled "Investigations, Research, Developments, and Practical Use of the German Atomic Bomb" presented testimony by Rudolf Zinsser, a German pilot captured by U.S. forces, that in October 1944 he flew near the massive explosion of a new German bomb on or near the Baltic coast, describing in detail a very large mushroom cloud and severe electrical disturbances (p. 4408). After further investigation, rather than dismissing Zinsser's report, the United States decided to upgrade it from Secret to Top Secret in October 1945 (p. 4422).
- In testimony in 1955, 1984, and 2005, Italian military correspondent Luigi Romersa stated that by a special arrangement between Benito Mussolini and Adolf Hitler, on 12 October 1944 he witnessed the massive explosion of a new German bomb on the Baltic coast (apparently Rügen island), had to wait in a bunker for many hours afterward for the site to become less dangerous (short radioactive half-lives?), and then had to wear a special protective suit when inspecting the leveled test site afterward (pp. 4427–4434).
- Werner Grothmann stated in 2000–2002 interviews that there was a successful atomic bomb test in October 1944 (p. 4436).
- In a 13 March 2005 television interview, Elisabeth Mestlin stated that she observed a massive explosion on Rügen from a neighboring island on 12 October 1944 (p. 4435).

Some of the major sources and details are summarized in Table D.4.]

		Primary sources for October 1944 test						
		German PW Aug. 1944	**Morrison Oct. 1944**	**Olmes May 1945**	**Zinsser Aug. 1945**	**Romersa 1955--2005**	**Grothmann 2000--2002**	**Mestlin 2004**
Details	**Test date**	Preparing for test as of ~July 1944	First half of October 1944	Sometime near the end of the war	Early October 1944	11:45 a.m. on 12 October 1944	First half of October 1944	12 October 1944
	Test location	Near an estate in Pomerania (Baltic coast)	Baltic coast	Baltic coast	Baltic coast	Rügen island on Baltic coast	Location would provoke negative public reaction [Baltic coast is tourist area]	Rügen island on Baltic coast
	People who were involved	Military	Military	SS, military, scientists (implied)	Military	Army Ordnance Office, SS	SS, Himmler, Kammler, Gerlach, Post Office, Diebner, Flügge	Military
	Blast	Expected blast radius of kilometers	Suspiciously large explosion(s)	Blast kilometers wide	Bright fireball, mushroom cloud, shockwave that grew to >9 km wide	Blinding flash; heat and shockwave in bunker 2 km away; mushroom cloud; vaporized animals, trees, buildings	Successful nuclear test, possibly ~3 kilotons	Violent explosion, big dust cloud, visible from kilometers away
	Radio-activity	Development related to use of heavy water		Demonstrated atom splitting	Ionized glowing mushroom cloud, severe radio interference	Had to remain inside bunker for over 5 hours after explosion, then wear protective suit to visit test site	Nuclear fission	
	Device design	New weapon that was an extremely powerful explosive and was extremely secret	Possibly an atomic bomb test	Atomic bomb with ~1 kg of fuel	Atomic bomb	Atomic disintegration (i.e., fission) bomb mounted above the ground	> 1 m dia. sphere Very heavy Aluminum case A little U-235 for test More U-235 for deployment Ignition by special system Tested on a stand	Something that produced an extraordinarily large explosion

Table D.4: Details about possible October 1944 test explosion from primary sources.



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ROCKET FILE

REMOTE-CONTROL ROCKET BOMBS:

A prisoner has heard that current tests of the remote-controlled rocket bombs are being carried out on the Island of Ruegen, which has been made a prohibited area and completely evacuated. His version of the range for these projectiles is 500 (??) km., and he dates the moment for launching an attack with them upon England at the end of the year.

Source: P/W report, #B-488, 11 November 1943.

Figure D.657: Rocket File [AFHRA A1260 frame 0951]

Rocket File [AFHRA A1260 frame 0951]

REMOTE-CONTROL ROCKET BOMBS:

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Source: P/W report, #B-488, 11 November 1943.

[See p. 4392. Although the entire island of Rügen was not evacuated during the war, significant parts of it, such as the Bug peninsula on the northwestern side, were indeed evacuated and tightly controlled by the German military, which is apparently what this prisoner of war was referring to.]

Howard G. Bunker. German Aircraft Research Establishments. 11 May 1944. [**AFHRA A5729 frame 1148**] [Colonel/General Howard Bunker was involved at the highest levels with intelligence/transfer of German technologies and with U.S. nuclear weapons: https://www.af.mil/About-Us/Biographies/Display/Article/107565/major-general-howard-g-bunker/]

APPENDIX 'A'

G.A.F. Experimental Stations

Rechlin:	Chief experimental field.
Adlershof:	Research on a/c in advanced state and likely to be used in this war. Aerodynamic experimental station.
Aichach:	Radio controlled aircraft.
Ainring:	Radio controlled bombs.
Darmstadt/Griesheim:	Experimental glider station. Research on jet propelled aircraft.
Diepensee:	Night fighter apparatus.
Garz:	Rockets (also advanced training on special weapons)
Göttingen:	Experiments in supersonic flight.
Koethen/Anhalt:	Air Signals Research Regiment.
Merseburg:	Glider experiments.
Oberpfaffenhofen:	Radio experimental center.
Oranienburg:	High altitude experimentation.
Peenemünde:	Rockets and jet propulsion.
Zinnowitz:	Satellite of Peenemunde.
Repelort:	Die Motte
Rügen:	Most secret research.
Tarnewitz:	New types aircraft armament.
Travemünde:	Sea plane experiments.
Usedom:	Most secret research (field not established)
Werneuchen:	Night fighter testing Research work at Guidonia (jet propulsion ?) transferred here.

[See document photo on p. 4394. What research occurring on Rügen island and Usedom peninsula (adjacent to Peenemünde) was considered "most secret," even more secret than the listed work on rockets, missiles, and jets? Could that "most secret research" have been associated with the upcoming possible atomic test on the Baltic coast in October 1944 and the production and testing of possible atomic bomb components on Usedom (see p. 4270)?]

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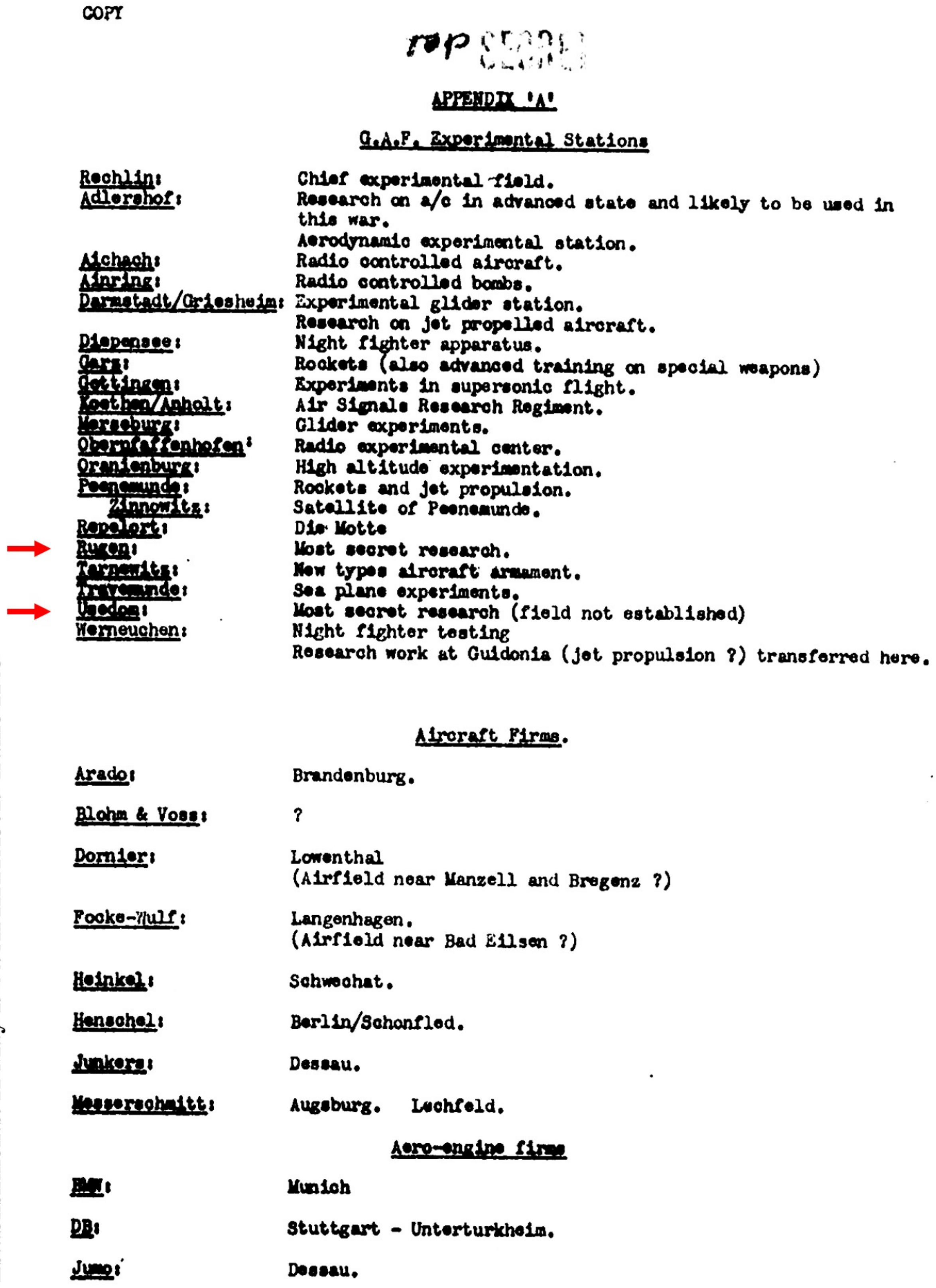
Howard G. Bunker. German Aircraft Research Establishments. 11 May 1944. AFHRA A5729 frame 1148



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APPENDIX 'A'

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Peenemunde:	Rockets and jet propulsion.
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Tarnewitz:	New types aircraft armament.
Travemunde:	Sea plane experiments.
Usedom:	Most secret research (field not established)
Werneuchen:	Night fighter testing Research work at Guidonia (jet propulsion ?) transferred here.

Aircraft Firms.

Arado:	Brandenburg.
Blohm & Voss:	?
Dornier:	Lowenthal (Airfield near Manzell and Bregenz ?)
Focke-Wulf:	Langenhagen. (Airfield near Bad Eilsen ?)
Heinkel:	Schwechat.
Henschel:	Berlin/Schonfled.
Junkers:	Dessau.
Messerschmitt:	Augsburg. Lechfeld.

Aero-engine firms

BMW:	Munich
DB:	Stuttgart - Unterturkheim.
Jumo:	Dessau.

Figure D.658: Howard G. Bunker. German Aircraft Research Establishments. 11 May 1944. [AFHRA A5729 frame 1148]

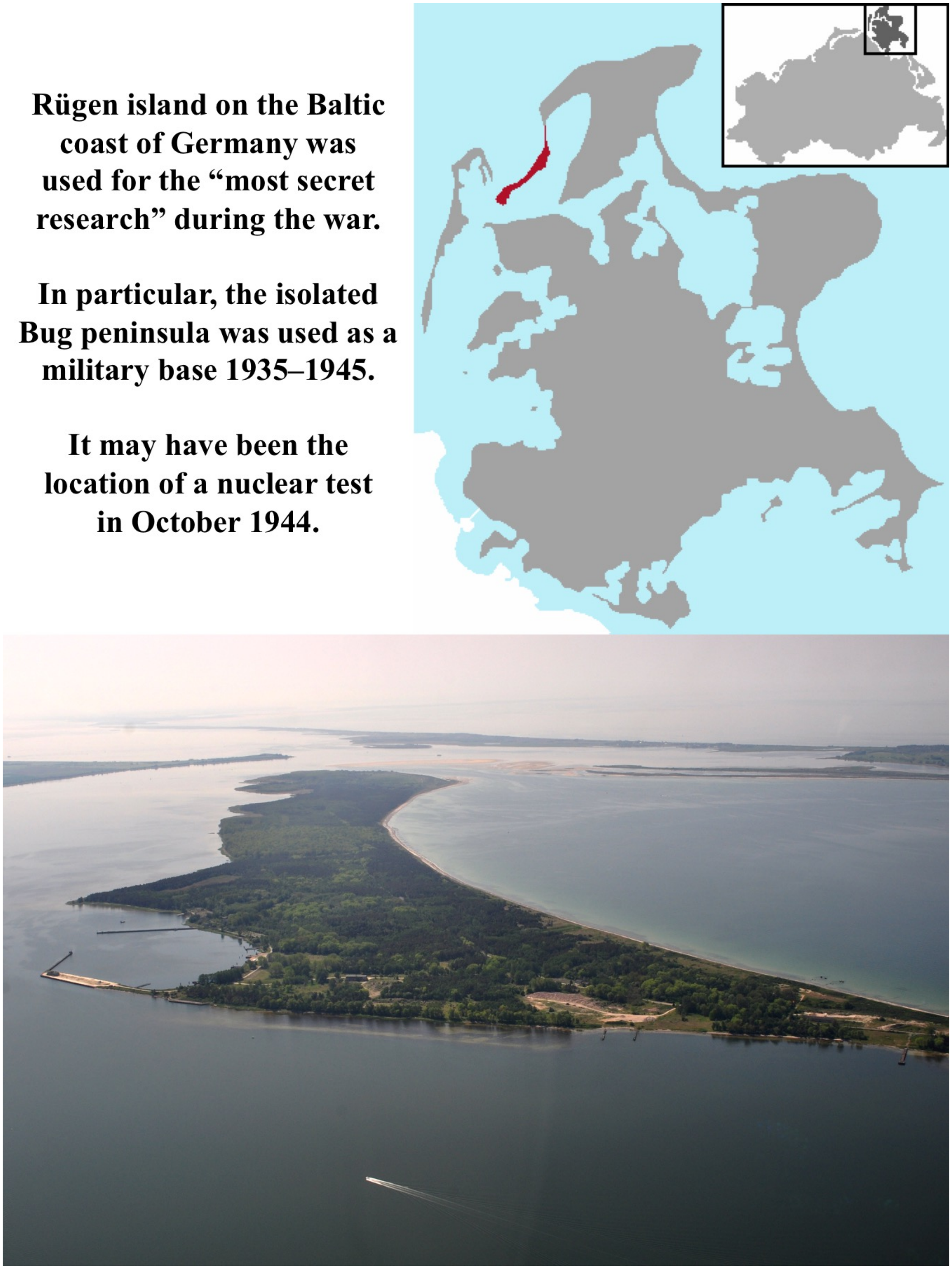
Rügen island on the Baltic coast of Germany was used for the “most secret research” during the war.
In particular, the isolated Bug peninsula was used as a military base 1935–1945.
It may have been the location of a nuclear test in October 1944.

Figure D.659: Rügen island on the Baltic coast of Germany was used for the “most secret research” during the war (pp. 4393–4394). In particular, the isolated Bug peninsula was used as a military base 1935–1945. It may have been the location of a nuclear test in October 1944.

Baltimore Branch Office, Manhattan Engineer District. 4 August 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)]

Subject: Positive Intelligence Secured from Prisoners of War at Camp Reynolds, Pa., Relative to "Secret Weapon"

Summary of Information:

The following information has been received from what is believed to be a reliable source relative to use by the Germans of a secret weapon.

"According to informant, the Germans are at present working on an extremely secret explosive. Informant knows very little about it and states that it has something to do with 'Heavy Water' (Schweres Wasser). Experiments are conducted on an estate in Pomerania and it is alleged that this explosive is capable of destroying everything in a radius of several kilometers."

Prisoner of war Schaeffer stated the following relative to a secret weapon.

"One of the weapons which the Germans are relying on has something to do with Heavy Water. It is a shell or an explosive and has the effect of collapsing the lungs of persons in a large area. Informant says he personally saw victims' mouths filled with blood, on the Russian front as a result of this weapon."

[See document photo on p. 4397. This report summarizes information from two different captured Germans. The unnamed first prisoner of war mentioned the production of "an extremely secret explosive" using "heavy water"—the production of plutonium for fission bombs. He also said such bombs should have a blast radius of several kilometers and were to be tested on the Baltic coast.

The second prisoner of war, Schaeffer, mentioned nuclear explosives whose production involved heavy water. He also mentioned fuel-air explosives that could be as small as artillery shells and would create a shock wave capable of destroying the lining of the lungs of people exposed to the blast. He said he had seen such fuel-air explosives actually employed on the Russian front. Schaeffer appeared to confuse nuclear explosives and fuel-air explosives (incorrectly connecting heavy water with fuel-air explosives), likely because of the extreme secrecy around both projects and the fact that both were intended to produce powerful explosions.

For more information fuel-air explosives, see pp. 538–557, 2615–2623.]

OSS London. 5 December 1944. Report T-2805-a. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

GERMANY : ATOMIC PHYSICS

Heavy Water Experimental Station.

Heavy water experiments are being carried out at the Dräger Werke, Lübeck, which is reported to be the largest gas factory in Germany. The plant's experimental station is connected with the experimental station at Peenemünde.

[See document photo on p. 4063.]

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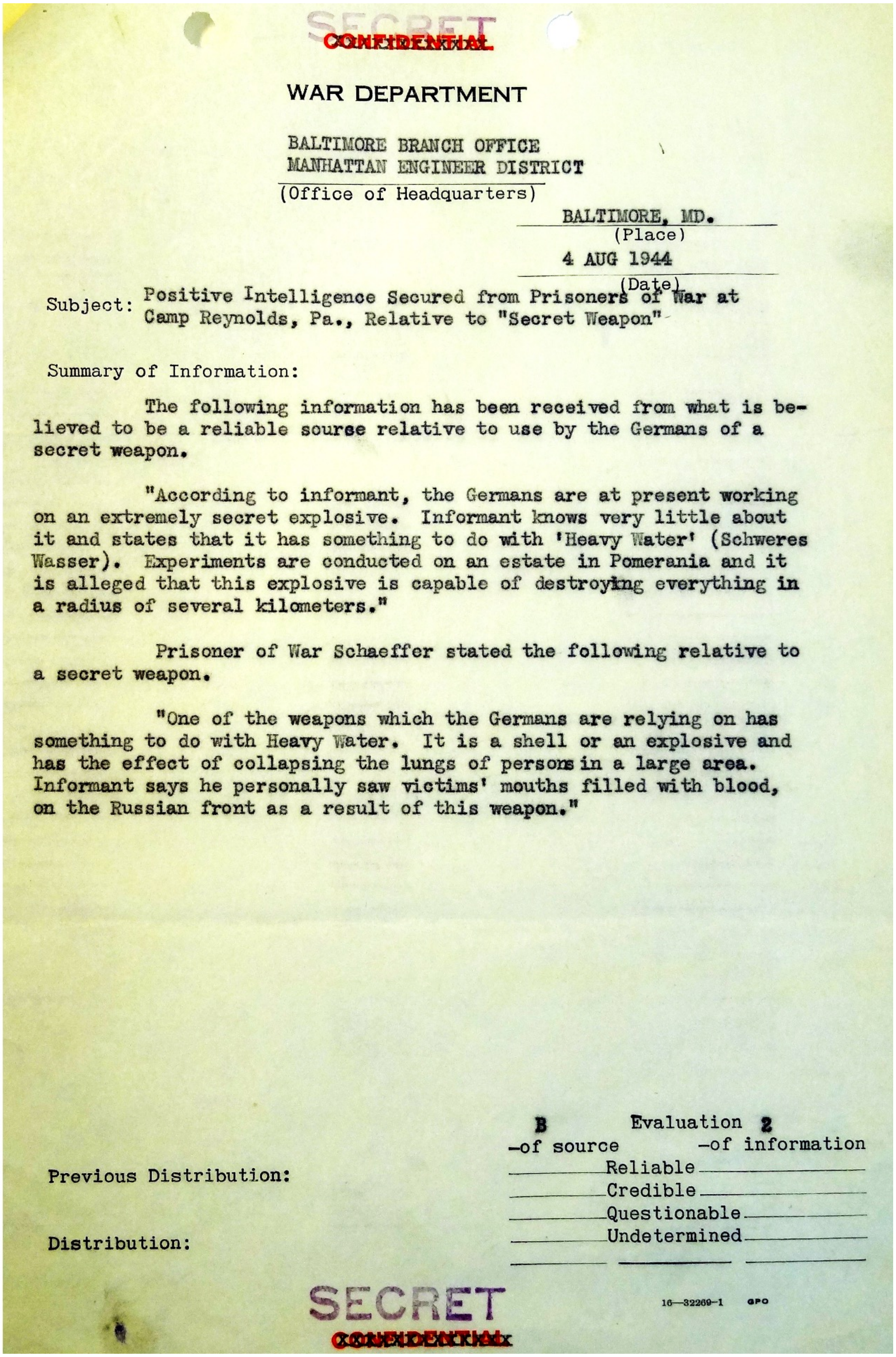
NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July-Oct. 44)



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WAR DEPARTMENT

BALTIMORE BRANCH OFFICE
MANHATTAN ENGINEER DISTRICT
(Office of Headquarters)

BALTIMORE, MD.
(Place)
4 AUG 1944
(Date)

Subject: Positive Intelligence Secured from Prisoners of War at Camp Reynolds, Pa., Relative to "Secret Weapon"

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Evaluation
B -of source
2 -of information
Reliable
Credible
Questionable
Undetermined

Previous Distribution:

Distribution:

16—32269-1 GPO

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Figure D.660: Baltimore Branch Office, Manhattan Engineer District. 4 August 1944. Subject: Positive Intelligence Secured from Prisoners of War at Camp Reynolds, Pa., Relative to "Secret Weapon" [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

Philip Morrison to Joseph Volpe, 20 October 1944, Loose Ends [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)]

There are a number of things to be done by the Washington office which have not yet been done.

1. We need a final report on the installation at Watten. This is such an extraordinary enterprise that we must be sure that it was not designed for something in our field.

2. The questions for Mr. Baker should be answered.

3. The recent reports of Baltic explosions should be covered by Major Calvert as usual.

4. The de Boer matter is still open. Has Alsos contacted J. H. de Boer at Eindhoven? This should be done if it is still possible.

[See document photo on p. 4399.

Dr. Philip Morrison (U.S., 1915–2005), a Manhattan Project physicist, was stationed in the United States but specifically tasked with analyzing Allied intelligence data on the German nuclear program. Morrison's publicly available documents indicate that up through 1945, he believed the German nuclear program was much more advanced and dangerous than better-known investigators such as Samuel Goudsmit and Boris Pash seemed to.

Regarding the specific points in the memo above:

1. Even months after the Allied invasion of France, Morrison and other Allied officials were both awed ("extraordinary") by the rocket-launching installation at Watten and worried that some of its features seemed to indicate it involved nuclear payloads for the rockets.

2. "Mr. Baker" was Niels Bohr, who was famously quite concerned about the progress of the wartime German nuclear program.

3. In October 1944, there were "recent reports of Baltic explosions" that were being investigated by the Manhattan Project as possible tests of a German atomic bomb. That information agrees well with the other sources in this section that reported the apparent test of an atomic bomb on the Baltic coast in October 1944. Morrison's comment also makes it clear that Allied officials thought the German nuclear program could be sufficiently advanced to test an atomic bomb, and that U.S. Army Major Horace Calvert had a "usual" procedure for collecting and analyzing such data. Can the relevant Allied intelligence reports be located and declassified now?

4. Manhattan Project intelligence analysts were actively seeking information on the German nuclear program from the Dutch intelligence network, and Samuel Goudsmit was involved in at least some of those contacts, including with the physical chemist Dr. Jan Hendrik de Boer (Dutch, 1899–1971). See pp. 4832–4853.]

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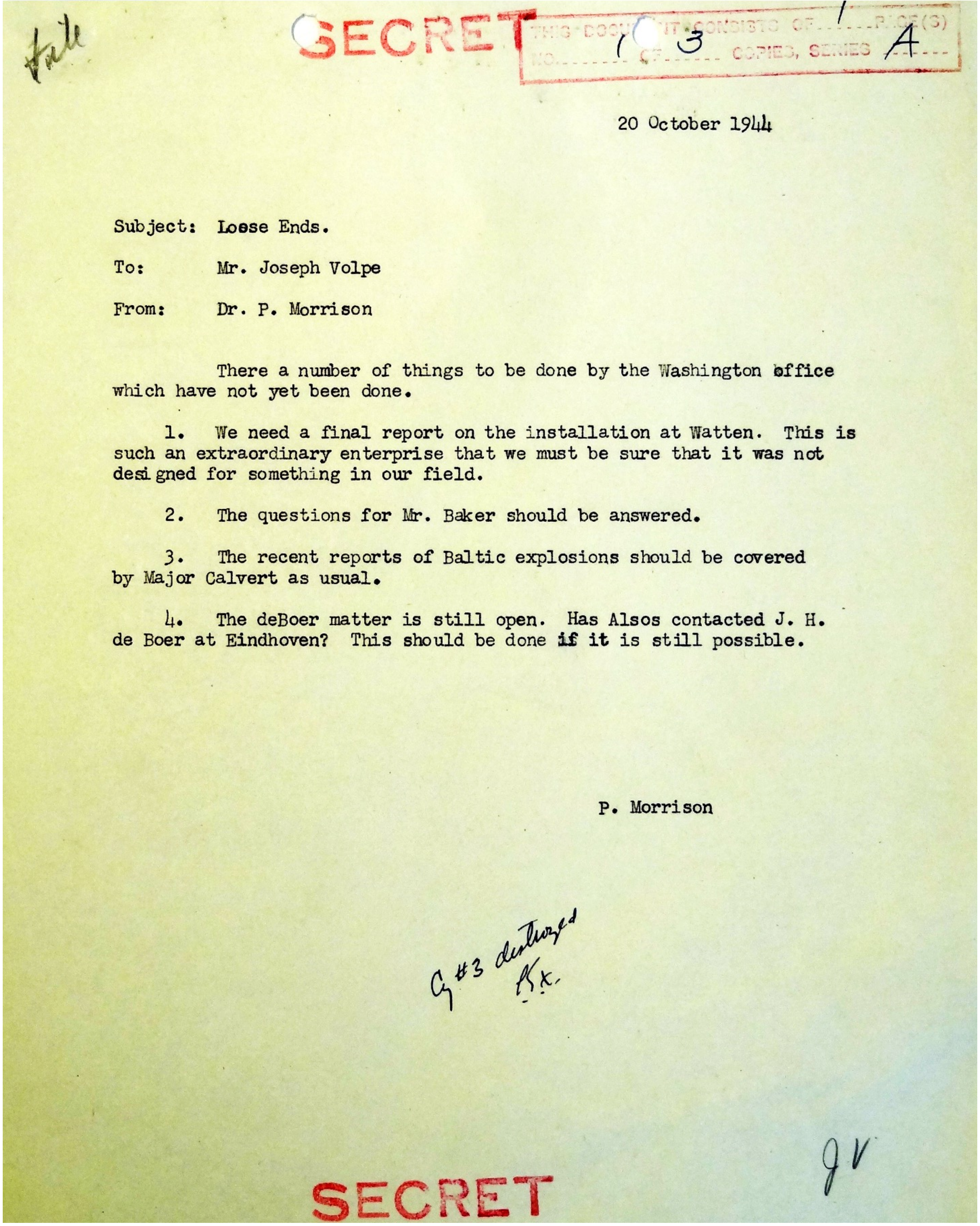
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945-1946)



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THIS DOCUMENT CONSISTS OF 1 PAGE(S)
NO. 1 OF 3 COPIES, SERIES A

20 October 1944

Subject: Loose Ends.

To: Mr. Joseph Volpe

From: Dr. P. Morrison

There a number of things to be done by the Washington office which have not yet been done.

1. We need a final report on the installation at Watten. This is such an extraordinary enterprise that we must be sure that it was not designed for something in our field.

2. The questions for Mr. Baker should be answered.

3. The recent reports of Baltic explosions should be covered by Major Calvert as usual.

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P. Morrison

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Figure D.661: Philip Morrison to Joseph Volpe. 20 October 1944. Subject: Loose Ends [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

OSS Report No. FF-83. 21 October 1944. Atom Smashing Secret Weapon. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44).]

1. The Germans have completed a weapon which is founded on the principle of the disintegration of matter (Atomzertruemmerung). Experiments have been performed which have proved conclusive. The effect of this weapon is like that of a thunderbolt, naturally much magnified.

2. It would be possible to direct the effect of this weapon in any given direction. Possibly it is a question of a sort of projectile rather than of a weapon properly so-called. The radius of action is supposed to be about three kilometers. The devastation produced by this weapon is said to be such that Hitler plans to use it only in the air, against planes, for example. Nevertheless, the Germans say that in case of necessity they will not hesitate to use it on the ground as well. This weapon seems to be ready, in fact, for use upon the battlefield, but it still exists only in the form of a model. Germany needs—and this appears to be absolutely certain—a delay of at least three months. Practically speaking, it seems that only within five months could the weapon be ready for use.

3. Different conversations which have taken place with industrial leaders in charge of concentration of production of German war material give the impression that Germany has unlimited confidence in the use of this weapon, which is to bring them certain victory.

4. Herr Schneider, one of the directors of the German factories called Deutsche Waffen u. Munitionsfabrik (a combine representing some fifteen factories and 250,000 workers) declared with a smile: "We shall gain the victory by new weapons, we are absolutely sure of that. Just now it is simply a case of gaining time, because the new arms will not be ready before three or four months. Bombing cannot keep us from building them. Our important factories where the assembly is carried out are all subterranean. An immense quantity of accessories is made in small lots everywhere throughout the country, so that bombing cannot interrupt the production. Our troops may retire within our frontiers. That does not matter, for nothing will be able to stand up for any length of time against these new weapons and we shall resume our overwhelming advance."

5. Directors of certain other factories have shown the same inveterate optimism, aroused by the confidence which they have in the effects of these new weapons.

6. Names of certain industrialists with whom the interviews took place:

> Herr [Adolf] Schneider—Director of the Deutsche Waffen und Munitions-Fabrik. His German title is Wehrwirtschaftsbeauftragter (Superintendent of Armament Production) in the region of the Duchy of Baden and Wurtemberg. He has charge of the plants of the Karlsruhe region.
>
> Director Dr. Buesse, who directs the DWM factories at Karlsruhe.
>
> Dr. Quandt, Administrator of a part of the DWM combine of factories.

[See document photos on pp. 4402–4403.

Deutsche Waffen- und Munitionsfabriken (DWM) was a massive German company (founded in the nineteenth century) that produced explosives, weapons, and other equipment. It had enormous amounts of support and funding from the German government and political contacts at the highest levels [https://zkm.de/en/from-the-munitions-factory-to-a-culture-factory]. During the war, it made extensive use of slave labor and underground facilities. As noted in this OSS report, it had fifteen factories and 250,000 workers.

Adolf Schneider (German, 1899–1979, https://historisches-lexikon.li/Schneider,_Adolf) was a senior manager of DWM during the war and a leading industrialist before, during, and after the war.

“Dr. Buesse” was another senior manager of DWM and may have been a member of the Busse family of weapons makers.

“Dr. Quandt” would have been either Günther Quandt (German, 1881–1954, https://www.deutsche-biographie.de/gnd124997821.html), who was the owner of DWM during the war, or his son Herbert Quandt (1910–1982, https://www.deutsche-biographie.de/sfz103954.html).

“Directors of certain other factories” were also interviewed but not explicitly named here.

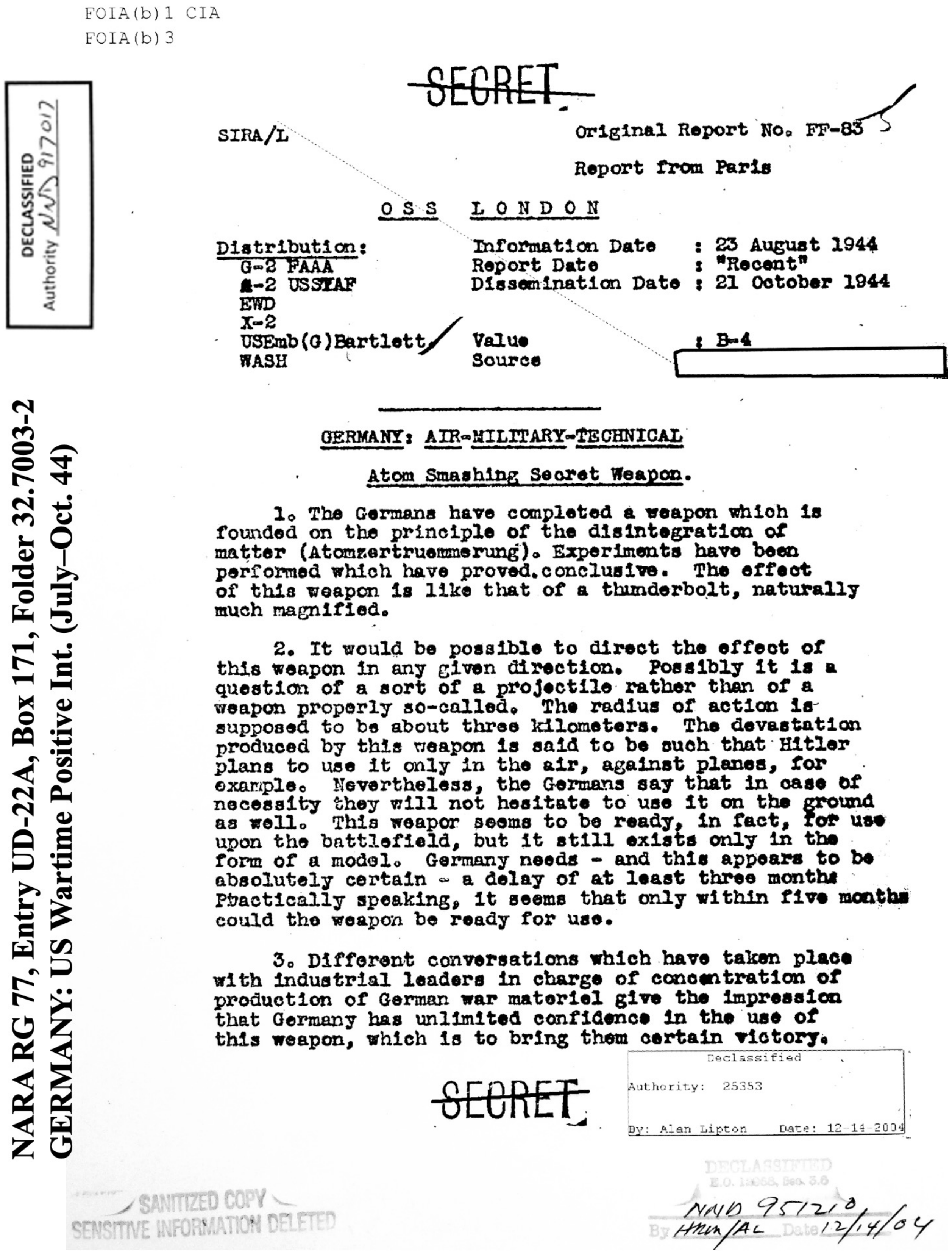
According to all of these very well-informed and highly placed individuals, Germany had developed a secret weapon that used atomic disintegration (fission) to create an explosion with a blast radius of three kilometers and effects like a thunderbolt but much magnified—i.e., blinding light, intense heat, and a shock wave extending out to that radius. As of the final report date of 21 October 1944, a prototype of the weapon had been successfully tested.

More nuclear weapons were expected to be ready within five months, or by March 1945. Adolf Schneider, who was in charge of so many facilities and people and therefore in a position to know, explained how German nuclear weapons were being mass-produced: “Our important factories where the assembly is carried out are all subterranean. An immense quantity of accessories is made in small lots everywhere throughout the country, so that bombing cannot interrupt the production.”

What OSS source(s) had access to all of these important individuals and could get them to speak so candidly?

Where are the transcripts and reports on postwar Allied interrogations of Günther Quandt, Herbert Quandt, Adolf Schneider, “Dr. Buesse,” and the other factory directors regarding the German nuclear weapons program and other advanced programs?

Where are the reports on postwar Allied inspections of the many underground facilities manufacturing components for nuclear weapons, as described in this wartime OSS report?]



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NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2
GERMANY: US Wartime Positive Int. (July–Oct. 44)

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SIRA/L

Original Report No. FF-83

Report from Paris

OSS LONDON

Distribution:	Information Date	: 23 August 1944
G-2 FAAA	Report Date	: "Recent"
A-2 USSTAF	Dissemination Date	: 21 October 1944
EWD		
X-2		
USEmb(G)Bartlett	Value	: B-4
WASH	Source	[redacted]

GERMANY: AIR-MILITARY-TECHNICAL

Atom Smashing Secret Weapon.

1. The Germans have completed a weapon which is founded on the principle of the disintegration of matter (Atomzertruemmerung). Experiments have been performed which have proved conclusive. The effect of this weapon is like that of a thunderbolt, naturally much magnified.

2. It would be possible to direct the effect of this weapon in any given direction. Possibly it is a question of a sort of a projectile rather than of a weapon properly so-called. The radius of action is supposed to be about three kilometers. The devastation produced by this weapon is said to be such that Hitler plans to use it only in the air, against planes, for example. Nevertheless, the Germans say that in case of necessity they will not hesitate to use it on the ground as well. This weapon seems to be ready, in fact, for use upon the battlefield, but it still exists only in the form of a model. Germany needs - and this appears to be absolutely certain - a delay of at least three months Practically speaking, it seems that only within five months could the weapon be ready for use.

3. Different conversations which have taken place with industrial leaders in charge of concentration of production of German war materiel give the impression that Germany has unlimited confidence in the use of this weapon, which is to bring them certain victory.

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Declassified
Authority: 25353
By: Alan Lipton Date: 12-14-2004

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NND 951210
By HMN/AL Date 12/14/04

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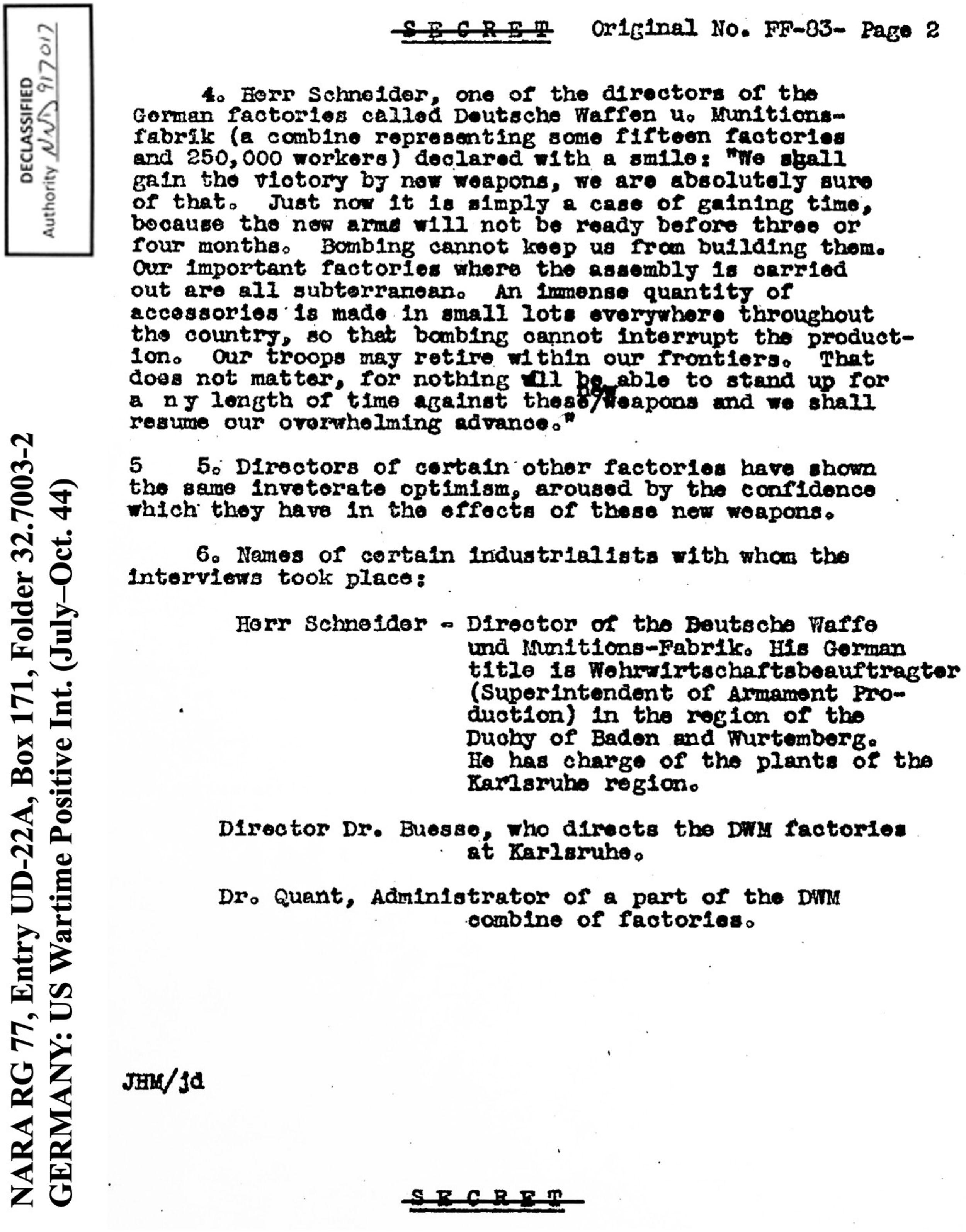
Figure D.662: OSS Report No. FF-83. 21 October 1944. Atom Smashing Secret Weapon [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].



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Authority NND 917017

~~SECRET~~ Original No. FF-83- Page 2

4. Herr Schneider, one of the directors of the German factories called Deutsche Waffen u. Munitions-fabrik (a combine representing some fifteen factories and 250,000 workers) declared with a smile: "We shall gain the victory by new weapons, we are absolutely sure of that. Just now it is simply a case of gaining time, because the new arms will not be ready before three or four months. Bombing cannot keep us from building them. Our important factories where the assembly is carried out are all subterranean. An immense quantity of accessories is made in small lots everywhere throughout the country, so that bombing cannot interrupt the production. Our troops may retire within our frontiers. That does not matter, for nothing will be able to stand up for any length of time against these new weapons and we shall resume our overwhelming advance."

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6. Names of certain industrialists with whom the interviews took place:

Herr Schneider - Director of the Deutsche Waffe und Munitions-Fabrik. His German title is Wehrwirtschaftsbeauftragter (Superintendent of Armament Production) in the region of the Duchy of Baden and Wurtemberg. He has charge of the plants of the Karlsruhe region.

Director Dr. Buesse, who directs the DWM factories at Karlsruhe.

Dr. Quant, Administrator of a part of the DWM combine of factories.

JHM/jd

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Figure D.663: OSS Report No. FF-83. 21 October 1944. Atom Smashing Secret Weapon [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

Headquarters, United States Strategic Air Forces in Europe, Office of the Director of Intelligence, An Evaluation of German Capabilities in 1945. The Commanders Intelligence Digest. 19 January 1945. [AFHRA folder 519.635 1945 Intelligence Digest; AFHRA A5729 electronic version pp. 255 onward and 561 onward; NARA RG 319, Entry UD-1041, Box 27, Folder 925497]].

1. In the following paragraphs are listed the actual or potential weapons which the Germans may use against USSTAF operations in 1945. For the most part they include the so-called V weapons. No consideration is given to those for which there is lacking evidence of possible use for some time to come. [...]

2. V-2:

[...] The V-2, or rocket projectile, with a warhead of approximately one ton, and a current range of 225 miles, is being fired at London at the rate of 180/250 per month, and against Continental ports at the rate of approximately 300 per month.

[...] Larger rockets (68 feet in length as against 45 feet) are known to exist, and may appear in small quantities during the year. They would have a considerably larger warhead. [...]

7. ATOMIC BOMB: Close check of every report, and close surveillance of the area in which tests are alleged to have taken place lead to the conclusion that such bombs are not a likelihood in 1945.

[See document photos on pp. 5338–5340.

Point 1 suggests that there was significant evidence for each of the weapons listed thereafter.

Point 2 proves that rockets 50% longer than the V-2 (21 m vs. 14 m), and with a warhead “considerably larger” than one ton (suitable for an atomic bomb?), were “known to exist.”

Point 7 suggests U.S. knowledge of multiple alleged German atomic bomb tests prior to January 1945, in a particular area or areas under close Allied surveillance. This likely means the Baltic coast (which was being closely monitored for activities at Peenemünde and other locations), and might therefore include the October 1944 test. It might also refer to a failed test in the North Sea in autumn 1943 (pp. 4436, 5011, 5034).]

Theodor Soucek. 2001. *Mein Richter, mein Henker.* Malmö, Sweden: Bright Rainbow.

[Soucek (1919–20??) was born in Graz, Austria and served throughout the war as an officer. After the war he returned to Austria and helped run one of the “ratlines” for people fleeing Austria and Germany; in that context he sheltered and became well acquainted with Armin Dadieu, a scientist and former senior official from Graz. Soucek’s memoirs were written near the end of his life and mix what he had actually seen with what he had heard or believed, so one must be quite cautious in using them, but they contain several intriguing passages that align well with independent sources. For more information, see pp. 4613–4624.]

In diesem Zusammenhang erzählte ich Dadieu von einer außerordentlichen Begegnung mit einem hochrangigen ungarischen General, als ich mich—noch verwundet—im gleichen Zugabteil auf der Bahnfahrt von Berlin nach Wien Mitte Januar 1945 befand. [...]

Mir gegenüber hatte ein älterer, weißhaariger Herr Platz genommen, der sich mir im Laufe der Reise nach vertraulichem und angeregtestem Gespräch als hochrangiger ungarischer General vorstellte.

Nach mehr als einer Stunde Bahnfahrt wandte sich der General überraschend und vertraulich zu mir:

“Schauen Sie, lieber junger Freund, Sie sind für mich ein frontbewährter Offizier und offenbar bedingungslos Ihrer Nation und der Verteidigung Europas verschworen, dazu noch Schriftsteller von höchstem Verantwortungsbewußtsein zur Rettung vor dem Kommunismus. So kann ich Ihnen von meinem Besuch als Vertreter der ungarischen Regierung in Berlin erzählen, weil man uns mit anderen verbündeten Regierungsvertretern der Achsenmächte in den letzten Tagen die jüngsten Entwicklungen der deutschen Geheimwaffen vorführte.

Wir wurden an der Ostsee in ein Sperrgebiet der Wehrmacht geflogen und es geschah folgendes: Als Zielgebiet zeigte man uns eine vielleicht 20–25 km entfernte kleine Insel und beschoß diese mit einer neuartigen Bombe, aus einem Flugzeug abgeworfen. Diese Bombe wirkte so beispiellos, daß von der Insel nichts mehr zu sehen war, sie war im Wasser verschwunden![4]

Mit dieser neuen Waffe werden Sie den Krieg gewinnen, Deutschlands Sieg ist nicht mehr aufzuhalten. Ich gratuliere Ihnen!”

Das waren seine Worte.

4 [...] Der “Schwedische Beobachter” bericht vom Verschwinden einer Insel nach Beschuß durch eine deutsche Sonderwaffe.

In this context, I told Dadieu about an extraordinary encounter with a high-ranking Hungarian general when I was—still wounded—in the same train compartment on the train ride from Berlin to Vienna in mid-January 1945. [...]

An elderly, white-haired gentleman had taken a seat opposite me, who introduced himself to me as a high-ranking Hungarian general during the course of the journey after a confidential and animated conversation.

After more than an hour’s train ride, the general turned to me surprisingly and confidentially:

“Look, dear young friend, you are for me a front-line officer and obviously unconditionally sworn to your nation and the defense of Europe, in addition to being a writer of the highest sense of responsibility to save us from communism. So I can tell you about my visit to Berlin as a representative of the Hungarian government, because in the last few days we were shown the latest developments in German secret weapons together with other allied government representatives of the Axis powers.

We were flown to a Wehrmacht restricted area on the Baltic Sea and the following happened: We were shown a small island perhaps 20–25 km away as a target area and bombarded it with a new type of bomb, dropped from an airplane. This bomb had such an unprecedented effect that nothing could be seen of the island, it had disappeared into the water![4]

With this new weapon you will win the war, Germany’s victory can no longer be stopped. I congratulate you!”

Those were his words.

4 [...] The “Swedish Observer” reports on the disappearance of an island after bombing by a German special weapon.

Harry K. Lennon. 23 May 1945. SUBJECT: Addition to Preliminary Report on OLMES, Friedrich. [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)]

The following information was given by OLMES, after he had recovered his notebook buried in the LUENEBURGER HEIDE. [...]

2. The experiments with the atom-splitting bomb had almost been brought to conclusion. The proven effect of a one kilogram bomb is to cause a crater of 18 miles wide. Only 8–10 more weeks work would have been required to put the bomb into the operational stage.

3. Laboratory experiments were conducted in DANZIG and BERLIN. Practical experiments were conducted on the Baltic coast. [...]

[See document photo on p. 4407.

Olmes stated that “practical experiments” with an “atom-splitting bomb” “were conducted on the Baltic coast,” corroborating information from the other sources in this section.

Intriguingly, he apparently obtained that information from documents, people, or personal experience he had found in the Lüneburger Heide, an area just south of Hamburg that several other independent sources said contained factories producing atomic bombs or major components for them (pp. 4176–4182).]

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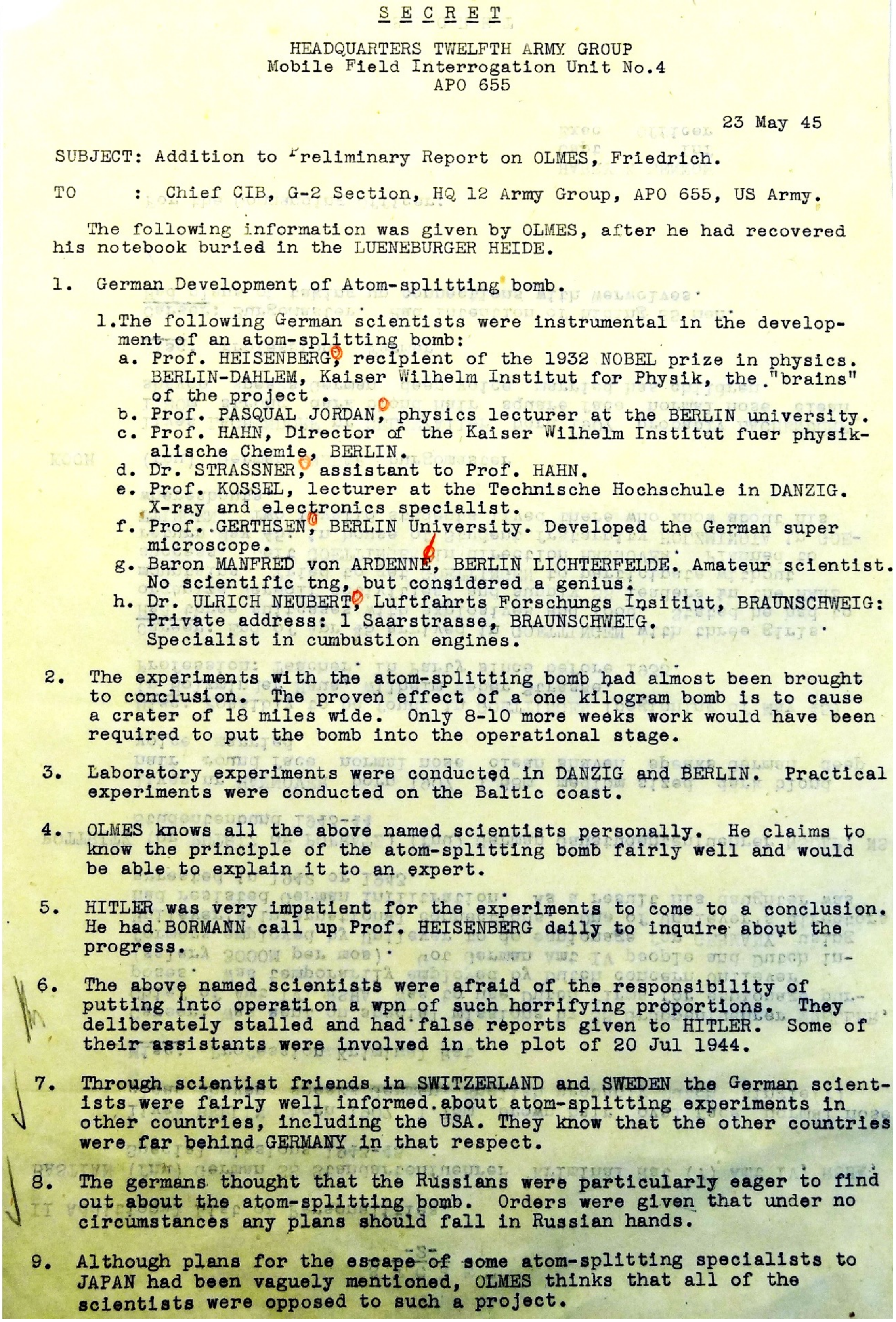
Authority NND 917017



S E C R E T

HEADQUARTERS TWELFTH ARMY GROUP
Mobile Field Interrogation Unit No.4
APO 655

23 May 45

SUBJECT: Addition to Preliminary Report on OLMES, Friedrich.

TO : Chief CIB, G-2 Section, HQ 12 Army Group, APO 655, US Army.

The following information was given by OLMES, after he had recovered his notebook buried in the LUENEBURGER HEIDE.

1. German Development of Atom-splitting bomb.

1. The following German scientists were instrumental in the development of an atom-splitting bomb:
   a. Prof. HEISENBERG, recipient of the 1932 NOBEL prize in physics. BERLIN-DAHLEM, Kaiser Wilhelm Institut for Physik, the "brains" of the project .
   b. Prof. PASQUAL JORDAN, physics lecturer at the BERLIN university.
   c. Prof. HAHN, Director of the Kaiser Wilhelm Institut fuer physikalische Chemie, BERLIN.
   d. Dr. STRASSNER, assistant to Prof. HAHN.
   e. Prof. KOSSEL, lecturer at the Technische Hochschule in DANZIG. X-ray and electronics specialist.
   f. Prof. GERTHSEN, BERLIN University. Developed the German super microscope.
   g. Baron MANFRED von ARDENNE, BERLIN LICHTERFELDE. Amateur scientist. No scientific tng, but considered a genius.
   h. Dr. ULRICH NEUBERT, Luftfahrts Forschungs Insitiut, BRAUNSCHWEIG: Private address: 1 Saarstrasse, BRAUNSCHWEIG. Specialist in cumbustion engines.

2. The experiments with the atom-splitting bomb had almost been brought to conclusion. The proven effect of a one kilogram bomb is to cause a crater of 18 miles wide. Only 8-10 more weeks work would have been required to put the bomb into the operational stage.

3. Laboratory experiments were conducted in DANZIG and BERLIN. Practical experiments were conducted on the Baltic coast.

4. OLMES knows all the above named scientists personally. He claims to know the principle of the atom-splitting bomb fairly well and would be able to explain it to an expert.

5. HITLER was very impatient for the experiments to come to a conclusion. He had BORMANN call up Prof. HEISENBERG daily to inquire about the progress.

6. The above named scientists were afraid of the responsibility of putting into operation a wpn of such horrifying proportions. They deliberately stalled and had false reports given to HITLER. Some of their assistants were involved in the plot of 20 Jul 1944.

7. Through scientist friends in SWITZERLAND and SWEDEN the German scientists were fairly well informed about atom-splitting experiments in other countries, including the USA. They know that the other countries were far behind GERMANY in that respect.

8. The germans thought that the Russians were particularly eager to find out about the atom-splitting bomb. Orders were given that under no circumstances any plans should fall in Russian hands.

9. Although plans for the escape of some atom-splitting specialists to JAPAN had been vaguely mentioned, OLMES thinks that all of the scientists were opposed to such a project.

NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45--Dec 45)

Figure D.664: Harry K. Lennon. 23 May 1945. SUBJECT: Addition to Preliminary Report on OLMES, Friedrich [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Interrogation of Zinsser, Rudolph G. Papers attached: Memo of 17 July 1945, 609th CIC Detachment [AFHRA C5094 frames 1546–1552].

Re: Subject & 1 incl. thereto; Miscellaneous Interviews, Abstract: Contains Biographical Information on Rudolph G. Zinsser

[...] 1. SUMMARY

Subject was investigated because of his appearance under suspicious circumstances at the Signal Intelligence Section project which is being conducted at Bad Kissingen. Interrogation of subject revealed that he was formerly the director of a German research project, Code Name DERNA, whose purpose was the development of a fully automatic, self-steering anti-aircraft rocket. Subject stated that he is willing to develop this device for the American authorities.

2. INVESTIGATION

Subject ZINSSER, Rudolph G. was born 6/9/13 in Vienna of Austrian parents. Subject became an engineer at the Technische Hochschule in Darmstadt in 1933–1935 and later took his doctorate degree at University J. W. Goethe in Frankfurt 1935–1939.

In 1939 subject entered the Luftwaffe and served in Norway, France, Italy and Africa. Subject was discharged from the Luftwaffe late in 1944 because of wounds received in combat. Highest rank attained was Oberleutnant. [...]

Previous to his discharge from the Luftwaffe subject stated that he was granted space at the Luftkriegs Academy, Berlin/Gatov, to work on above mentioned rocket-steering device. He left the academy in September 1944 having secured financial backing from the Flugzeugwerk Siebl in Halle and opened his own laboratory at Jibka in the Sudeten. [...]

On the 26 April subject stated that the factory was evacuated to the vicinity of Bad Aussee and that at the present time he does not know what happened to his equipment or personnel. [...]

[See document photos on pp. 4409–4410.]

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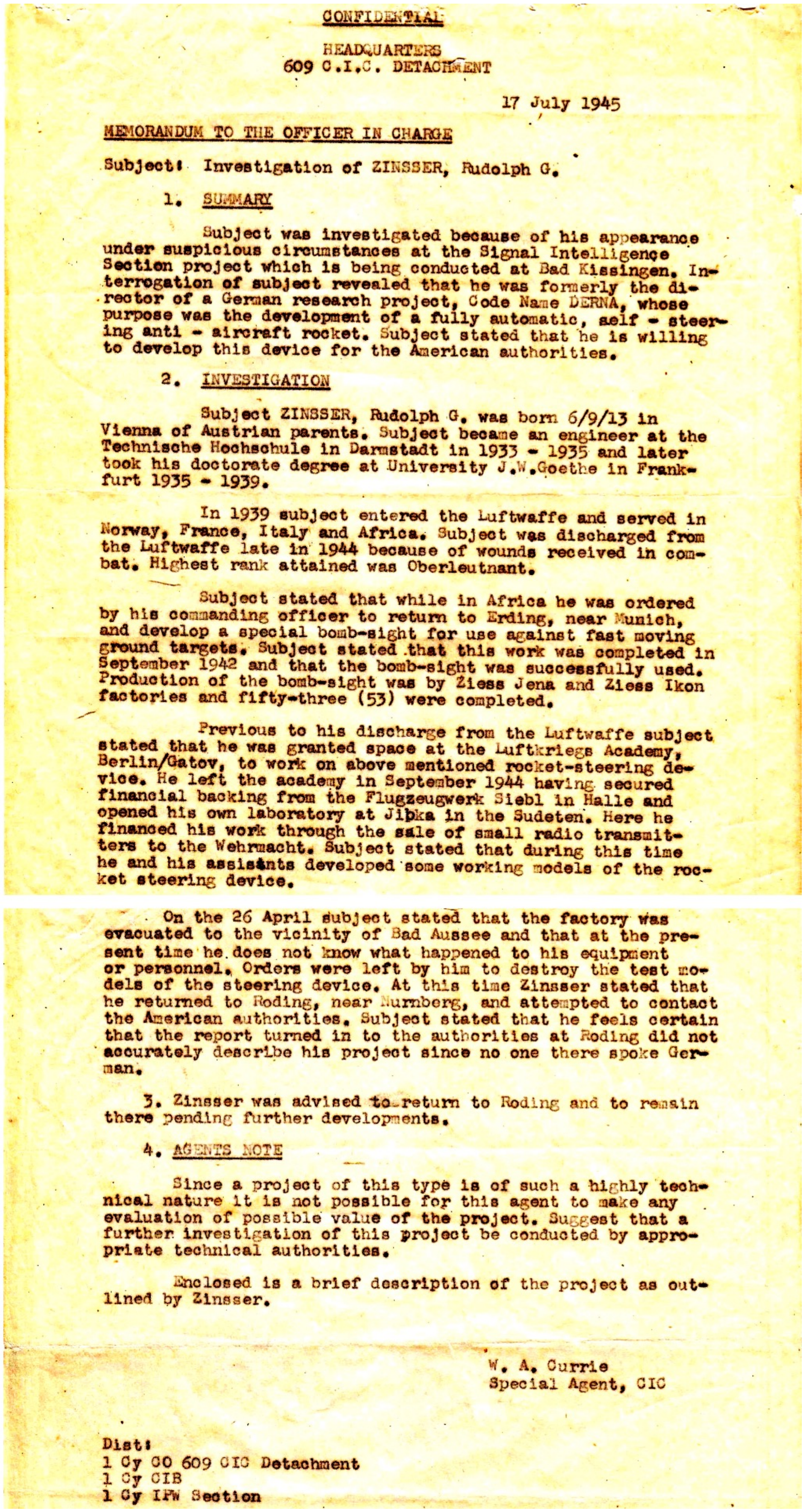
AFHRA folder 570.620-1 17 July 1945



CONFIDENTIAL

HEADQUARTERS
609 C.I.C. DETACHMENT

17 July 1945

MEMORANDUM TO THE OFFICER IN CHARGE

Subject: Investigation of ZINSSER, Rudolph G.

1. SUMMARY

Subject was investigated because of his appearance under suspicious circumstances at the Signal Intelligence Section project which is being conducted at Bad Kissingen. Interrogation of subject revealed that he was formerly the director of a German research project, Code Name DERNA, whose purpose was the development of a fully automatic, self - steering anti - aircraft rocket. Subject stated that he is willing to develop this device for the American authorities.

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In 1939 subject entered the Luftwaffe and served in Norway, France, Italy and Africa. Subject was discharged from the Luftwaffe late in 1944 because of wounds received in combat. Highest rank attained was Oberleutnant.

Subject stated that while in Africa he was ordered by his commanding officer to return to Erding, near Munich, and develop a special bomb-sight for use against fast moving ground targets. Subject stated that this work was completed in September 1942 and that the bomb-sight was successfully used. Production of the bomb-sight was by Ziess Jena and Ziess Ikon factories and fifty-three (53) were completed.

Previous to his discharge from the Luftwaffe subject stated that he was granted space at the Luftkriegs Academy, Berlin/Gatov, to work on above mentioned rocket-steering device. He left the academy in September 1944 having secured financial backing from the Flugzeugwerk Siebl in Halle and opened his own laboratory at Jibka in the Sudeten. Here he financed his work through the sale of small radio transmitters to the Wehrmacht. Subject stated that during this time he and his assistants developed some working models of the rocket steering device.

On the 26 April subject stated that the factory was evacuated to the vicinity of Bad Aussee and that at the present time he does not know what happened to his equipment or personnel. Orders were left by him to destroy the test models of the steering device. At this time Zinsser stated that he returned to Roding, near Nurnberg, and attempted to contact the American authorities. Subject stated that he feels certain that the report turned in to the authorities at Roding did not accurately describe his project since no one there spoke German.

3. Zinsser was advised to return to Roding and to remain there pending further developments.

4. AGENTS NOTE

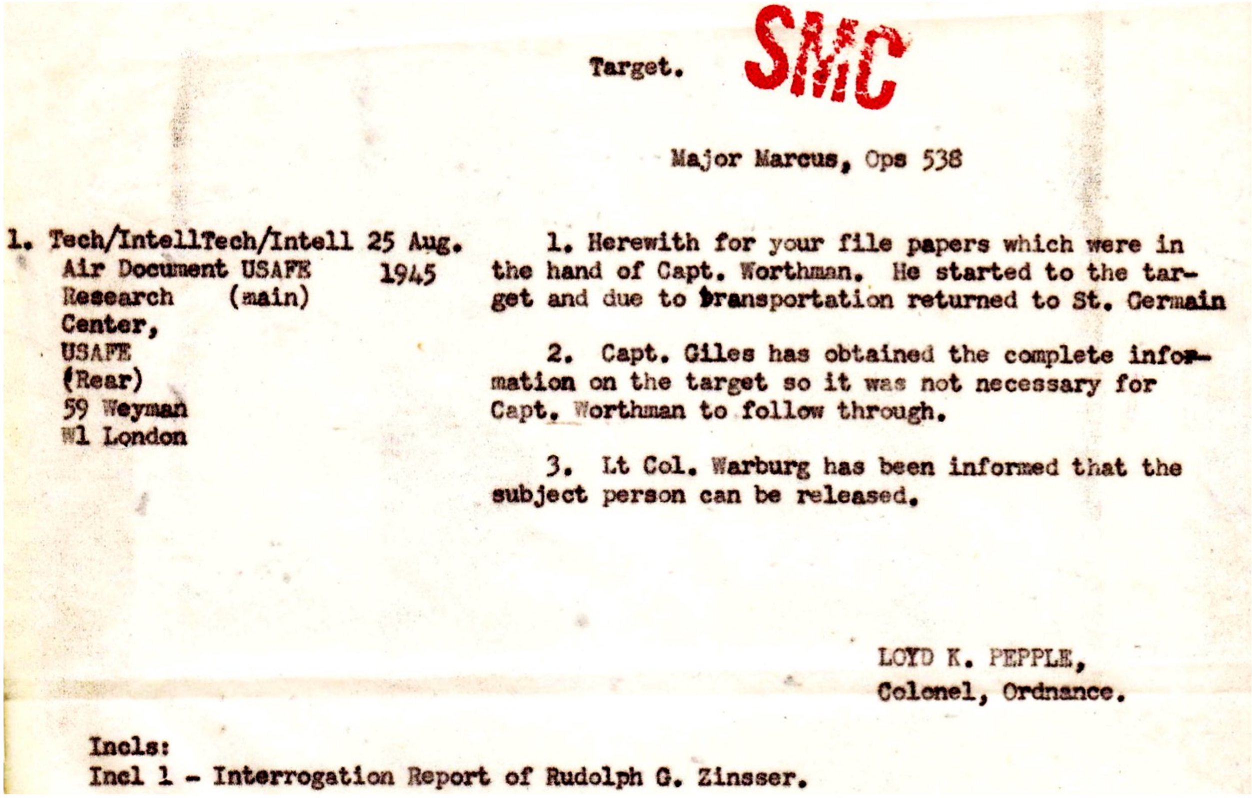
Since a project of this type is of such a highly technical nature it is not possible for this agent to make any evaluation of possible value of the project. Suggest that a further investigation of this project be conducted by appropriate technical authorities.

Enclosed is a brief description of the project as outlined by Zinsser.

W. A. Currie
Special Agent, CIC

Dist:
1 Cy CO 609 CIC Detachment
1 Cy CIB
1 Cy IPW Section

Figure D.665: W. A. Currie. 17 July 1945. Subject: Investigation of ZINSSER, Rudolph G. [AFHRA folder 570.620-1 17 July 1945; AFHRA C5094 frames 1546–1552].



Target. SMC

Major Marcus, Ops 538

1. Tech/Intell
Air Document
Research
Center,
USAFE
(Rear)
59 Weyman
W1 London

Tech/Intell USAFE (main)

25 Aug. 1945

1. Herewith for your file papers which were in the hand of Capt. Worthman. He started to the target and due to transportation returned to St. Germain

2. Capt. Giles has obtained the complete information on the target so it was not necessary for Capt. Worthman to follow through.

3. Lt Col. Warburg has been informed that the subject person can be released.

LOYD K. PEPPLE,
Colonel, Ordnance.

Incls:
Incl 1 - Interrogation Report of Rudolph G. Zinsser.

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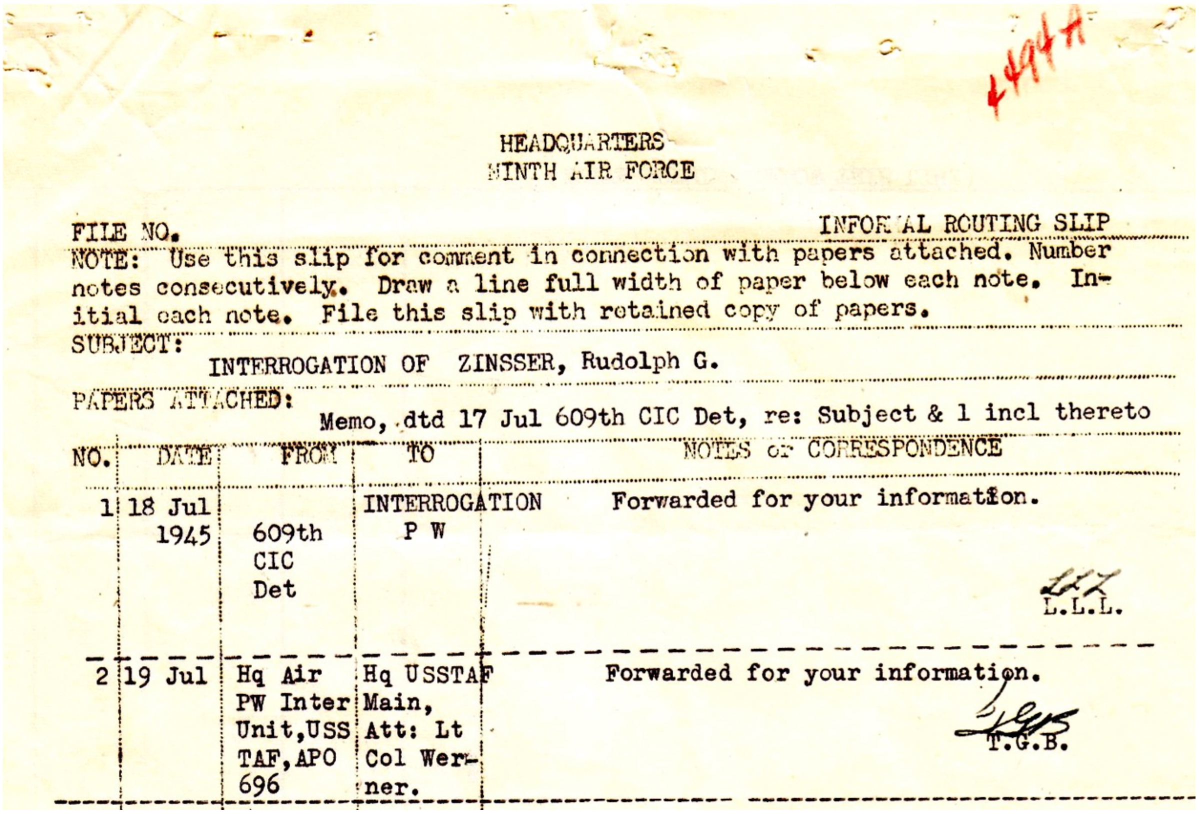
AFHRA folder 570.620-1 17 July 1945



4494A

HEADQUARTERS
NINTH AIR FORCE

FILE NO.

INFORMAL ROUTING SLIP

NOTE: Use this slip for comment in connection with papers attached. Number notes consecutively. Draw a line full width of paper below each note. Initial each note. File this slip with retained copy of papers.

SUBJECT:
INTERROGATION OF ZINSSER, Rudolph G.

PAPERS ATTACHED:
Memo, dtd 17 Jul 609th CIC Det, re: Subject & 1 incl thereto

NO.	DATE	FROM	TO	NOTES or CORRESPONDENCE
1	18 Jul 1945	609th CIC Det	INTERROGATION P W	Forwarded for your information. LLL L.L.L.
2	19 Jul	Hq Air PW Inter Unit, USSTAF, APO 696	Hq USSTAF Main, Att: Lt Col Werner.	Forwarded for your information. TGB T.G.B.

Figure D.666: Loyd K. Pepple. 25 August 1945 [AFHRA folder 570.620-1 17 July 1945; AFHRA C5094 frames 1546–1552].

A.P.W.I.U. [Air Force Prisoner of War Interrogation Unit] (Ninth Air Force) 96/1945. 19 August 1945. Investigations, Research, Developments, and Practical Use of the German Atomic Bomb. [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700; NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946); AFHRA B-5737 electronic version pp. 340–345]

2. Dr. EDSE, well known chemist, wrote:
At the Institute for Physical Chemistry of the Hamburg University I worked on problems concerning nuclear physics under the direction of Prof. Dr. P. HARTECK, and engaged in investigations of behavior and properties of the so-called trans-uraniums, already mentioned by HAHN and STRASSMANN in Berlin, and by JOLIOT-CURIE in Paris. [...]

9. Furthermore the improvement and application of ultra-centrifuge, thermo-diffusion, and distillation had its effect on the success of these experiments. For this reaction the material to be split must have the form of a liquid, a gas, or a solution; UF_6 was used which will melt at 69.2^o C. under light over-pressure. This is advantageous as Fluor (UF_6) has not isotope. In this manner only the uranium isotopes are separated. [...]

14. When Germany was at this stage of the game, the war broke out in Europe. At first investigations on this disintegration of $^{235}_{92}U$ were somewhat neglected because a practical application seemed too far off. Later, however, this research continued, especially in finding methods of separating isotopes. Needless to say that the center of gravity of Germany's war effort at that time lay on other tasks.

15. Nevertheless the atomic bomb was expected to be ready toward the end of 1944, if it had not been for the effective air attacks on laboratories engaged in this uranium research, especially on the one at Rjuken in Norway, where heavy water was produced. It is mainly for this reason that Germany did not succeed in using the atomic bomb during the war. [...]

17. [...] The disintegration of one kg $^{235}_{92}U$ delivers an amount of energy of $\frac{1000}{235} \cdot 160 \cdot 23 \cdot 10^6$ kg cal $= 1.6 \cdot 10^{10}$ kg cal, whereas one kg of TNT only delivers 1000 kg cal when detonating. Out of this follows that an atomic bomb of 3 lbs $^{235}_{92}U$ has the same effect as a bomb of 20,000 tons of TNT. [...]

47. A man named ZINSSER, a Flak rocket expert, mentioned what he noticed one day: In the beginning of Oct. 1944 I flew from Ludwigslust (south of Lubeck), about 12 to 15 km from an atomic bomb test station, when I noticed a strong, bright illumination of the whole atmosphere, lasting about 2 seconds.

48. The clearly visible pressure wave escaped the approaching and following cloud formed by the explosion. This wave had a diameter of about 1 km when it became visible and the color of the cloud changed frequently. It became dotted after a short period of darkness with all sorts of light spots, which were, in contrast to normal explosions, of a pale blue color.

49. After about 10 seconds the sharp outlines of the explosion cloud disappeared, then the cloud began to take on a lighter color against the sky covered with a gray overcast. The diameter of the

still visible pressure wave was at least 9000 meters while remaining visible for at least 15 seconds.

50. Personal observations of the colors of the explosion cloud found an almost blue-violet shade. During this manifestation reddish-colored rims were to be seen, changing to a dirty-like shade in very rapid succession.

51. The combustion was lightly felt from my observation plane in the form of pulling and pushing. The appearance of atmospheric disturbance lasted about 10 seconds without noticeable climax.

52. About one hour later I started with an He 111 from the A/D [aerodrome] at Ludwigslust and flew in an easterly direction. Shortly after the start I passed through the almost complete overcast (between 3000 and 4000 meter altitude). A cloud shaped like a mushroom with turbulent, billowing sections (at about 7000 meter altitude) stood, without any seeming connections, over the spot where the explosion took place. Strong electrical disturbances and the impossibility to continue radio communication as by lightning, turned up.

53. Because of the P-38s operating in the area Wittenberg-Merseburg I had to turn to the north but observed a better visibility at the bottom of the cloud where the explosion occurred. Note [by U.S. Captain Freiberger]: It does not seem very clear to me why these experiments took place in such crowded areas.

[See document photos on pp. 4414–4419.

Paragraph 15 clearly states that the German nuclear weapons program was so advanced that the bomb would have been ready for use by the end of 1944, and that timetable was only slowed by Allied attacks. For independent sources that confirmed that fact, see pp. 5022, 5031, and 5073.

Rudolf Edse's calculation in paragraph 17 agrees well with modern calculations of the amount of U-235 required per ton of explosive yield (p. 5144). Of the roughly 180 MeV of energy released by each uranium fission, Edse appears to have assumed that approximately l60 MeV would be deposited within a short enough distance to directly contribute to the explosion, which would have been a very plausible assumption for him to make. How much did Edse actually know about nuclear weapons? What exactly did he work on, both during and after the war?

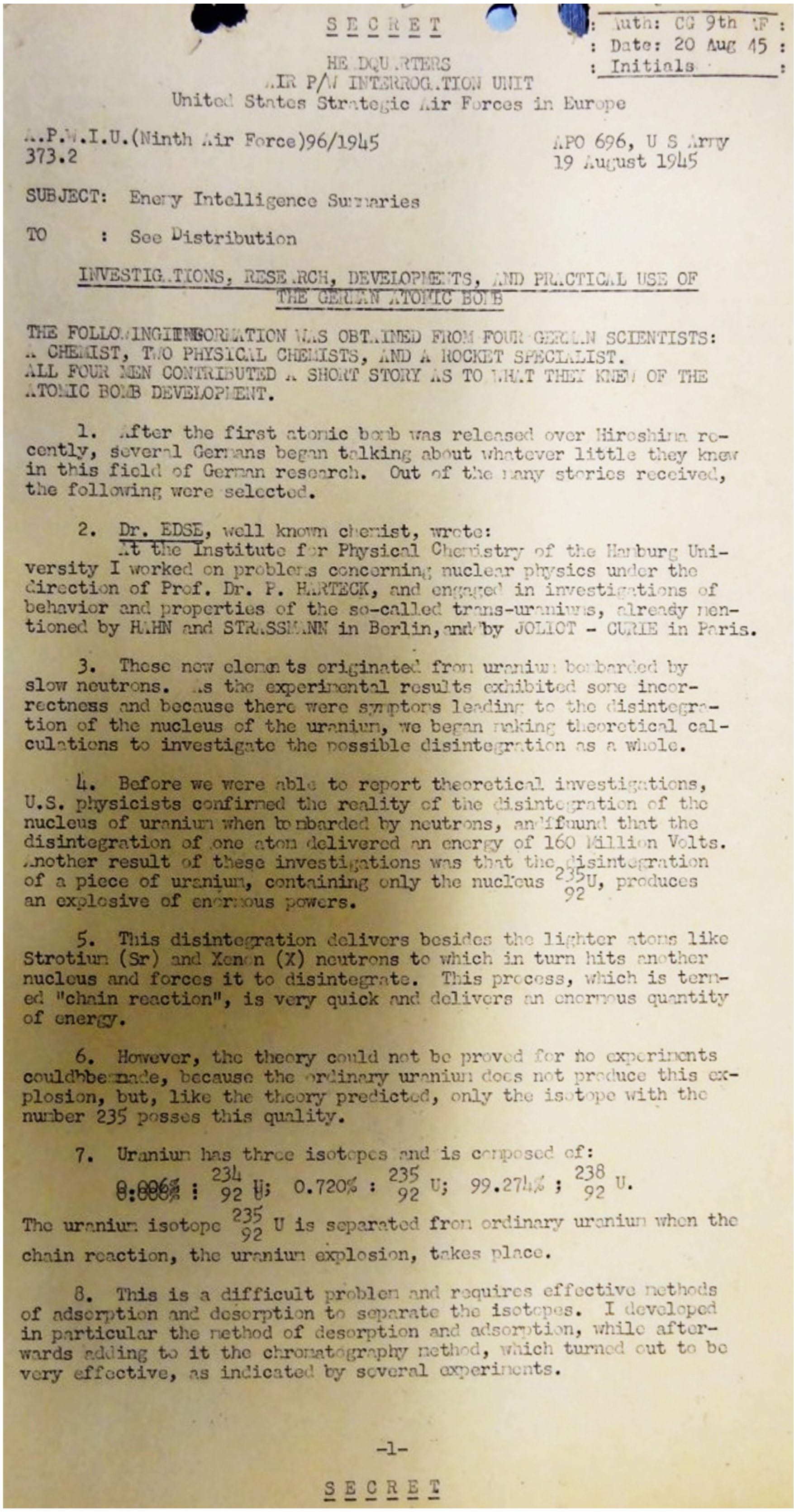
Rudolf Zinsser said he took off from Ludwigslust, flew toward the east, and turned to the north (to avoid Allied aircraft going to/from Berlin). That suggests he was somewhere along the Baltic coast, likely in the vicinity of Rügen, when he observed the test. If that was the case, Zinsser took off from a "crowded area" (Ludwigslust) but observed the test site in a much less populated area on the Baltic coast, which is well known to have been filled with test areas for everything from rockets to biological agents. His U.S. interrogator does not seem to have understood that initially, judging by the appended final note from Captain Helenes Freiberger.

Although Zinsser did not admit it, he had most likely been ordered to make multiple flights over the test area in order to make visual observations of the atomic bomb test, and quite possibly to carry cameras or measuring equipment. One flight at the right place and time might have simply been an extraordinary coincidence (and quite improbable, considering that it would have been a high-security area), but two flights shows deliberate intent to observe the test, especially coupled with his highly detailed description.

Zinsser provided many details about the nuclear explosion—such as the strong electromagnetic disturbances, the behavior of the blast wave and the debris cloud over time, and the colors of the cloud—that are scientifically correct and would not have been known to the public (or even many specialists), even after the bombings of Hiroshima and Nagasaki. Moreover, Zinsser had been in custody and under interrogation going back to at least 17 July 1945, well before Hiroshima and Nagasaki. Thus all the details that Zinsser described regarding the explosion strongly support the veracity of his story and the conclusion that what he observed was a nuclear test and not the test of some other sort of weapon. See especially p. 4421.

After two months of further Allied interrogation of Zinsser and investigation of any corroborating evidence, Zinsser's claims were not dismissed. Rather, they were actually upgraded to Top Secret—see p. 4422. Allied officials must have found their postwar investigation of German nuclear weapons tests to be very convincing indeed. Where are the follow-on reports about Zinsser, the other evidence, and the tests? Can they be located and declassified?]

AFHRA Folder 533.619-5 1945



S E C R E T

: Auth: CG 9th AF :
: Date: 20 Aug 45 :
: Initials :

HEADQUARTERS
AIR P/W INTERROGATION UNIT
United States Strategic Air Forces in Europe

A.P.W.I.U.(Ninth Air Force)96/1945
373.2

APO 696, U S Army
19 August 1945

SUBJECT: Enemy Intelligence Summaries

TO : See Distribution

INVESTIGATIONS, RESEARCH, DEVELOPMENTS, AND PRACTICAL USE OF THE GERMAN ATOMIC BOMB

THE FOLLOWINGINFORMATION WAS OBTAINED FROM FOUR GERMAN SCIENTISTS: A CHEMIST, TWO PHYSICAL CHEMISTS, AND A ROCKET SPECIALIST. ALL FOUR MEN CONTRIBUTED A SHORT STORY AS TO WHAT THEY KNEW OF THE ATOMIC BOMB DEVELOPMENT.

1. After the first atomic bomb was released over Hiroshima recently, several Germans began talking about whatever little they knew in this field of German research. Out of the many stories received, the following were selected.

2. Dr. EDSE, well known chemist, wrote:
At the Institute for Physical Chemistry of the Hamburg University I worked on problems concerning nuclear physics under the direction of Prof. Dr. P. HARTECK, and engaged in investigations of behavior and properties of the so-called trans-uraniums, already mentioned by HAHN and STRASSMANN in Berlin, and by JOLIOT - CURIE in Paris.

3. These new elements originated from uranium bombarded by slow neutrons. As the experimental results exhibited some incorrectness and because there were symptoms leading to the disintegration of the nucleus of the uranium, we began making theoretical calculations to investigate the possible disintegration as a whole.

4. Before we were able to report theoretical investigations, U.S. physicists confirmed the reality of the disintegration of the nucleus of uranium when bombarded by neutrons, andffound that the disintegration of one atom delivered an energy of 160 Million Volts. Another result of these investigations was that the disintegration of a piece of uranium, containing only the nucleus ${}^{235}_{92}$U, produces an explosive of enormous powers.

5. This disintegration delivers besides the lighter atoms like Strotium (Sr) and Xenon (X) neutrons to which in turn hits another nucleus and forces it to disintegrate. This process, which is termed "chain reaction", is very quick and delivers an enormous quantity of energy.

6. However, the theory could not be proved for no experiments couldbbe made, because the ordinary uranium does not produce this explosion, but, like the theory predicted, only the isotope with the number 235 posses this quality.

7. Uranium has three isotopes and is composed of:

0.006% : ${}^{234}_{92}$U; 0.720% : ${}^{235}_{92}$U; 99.274% ; ${}^{238}_{92}$U.

The uranium isotope ${}^{235}_{92}$U is separated from ordinary uranium when the chain reaction, the uranium explosion, takes place.

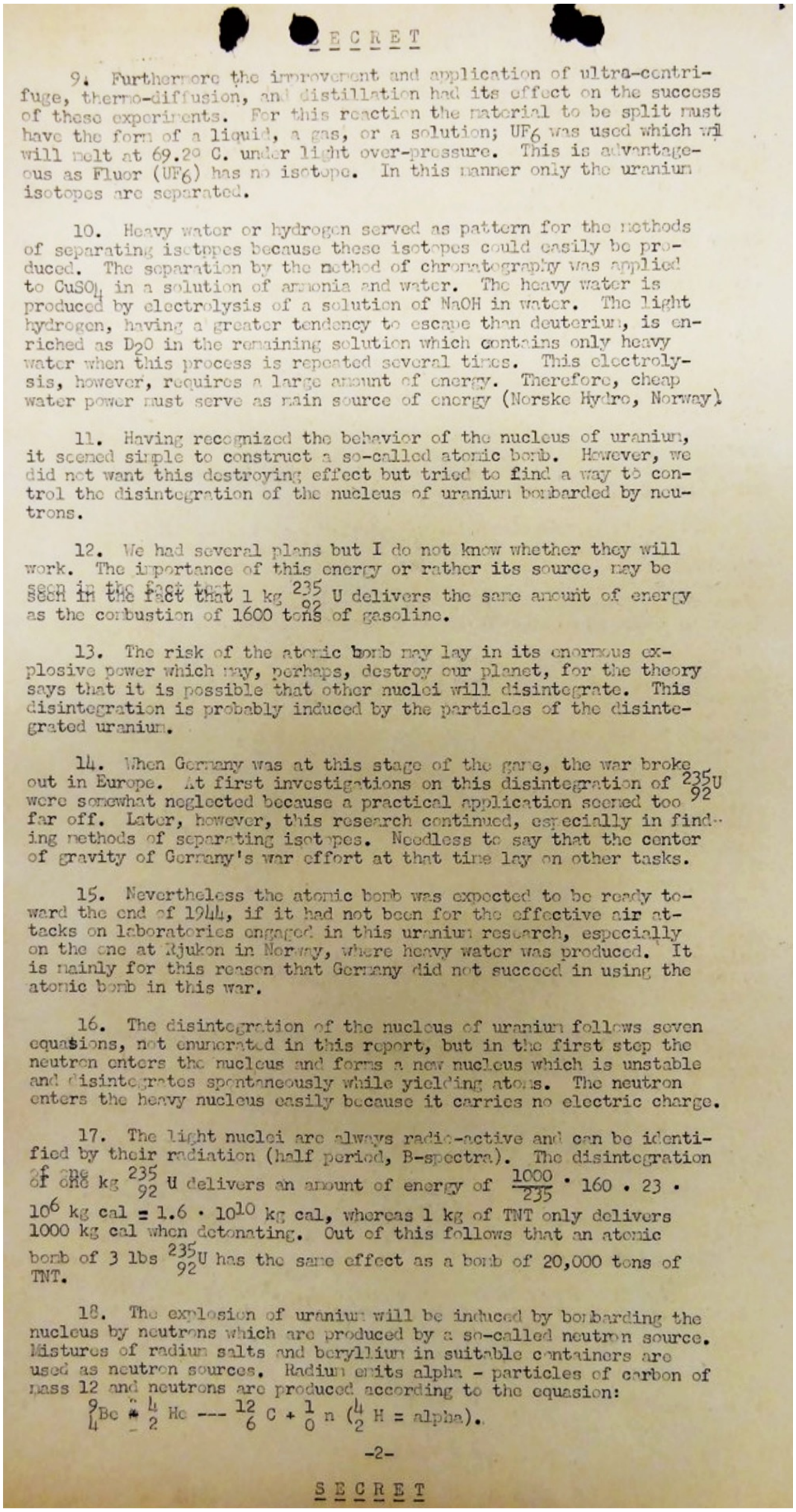
8. This is a difficult problem and requires effective methods of adsorption and desorption to separate the isotopes. I developed in particular the method of desorption and adsorption, while afterwards adding to it the chromatography method, which turned out to be very effective, as indicated by several experiments.

-1-

S E C R E T

Figure D.667: Rudolf Zinsser reported observing an apparent atomic bomb test near the Baltic coast in October 1944. U.S. documents state that Rudolf Edse worked on the German atomic bomb program. [AFHRA Folder 533.619-5 1945]

AFHRA Folder 533.619-5 1945



S E C R E T

9. Furthermore the improvement and application of ultra-centrifuge, thermo-diffusion, and distillation had its effect on the success of these experiments. For this reaction the material to be split must have the form of a liquid, a gas, or a solution; UF_6 was used which wil will melt at 69.2° C. under light over-pressure. This is advantageous as Fluor (UF_6) has no isotope. In this manner only the uranium isotopes are separated.

10. Heavy water or hydrogen served as pattern for the methods of separating isotopes because these isotopes could easily be produced. The separation by the method of chromatography was applied to $CuSO_4$ in a solution of ammonia and water. The heavy water is produced by electrolysis of a solution of NaOH in water. The light hydrogen, having a greater tendency to escape than deuterium, is enriched as D_2O in the remaining solution which contains only heavy water when this process is repeated several times. This electrolysis, however, requires a large amount of energy. Therefore, cheap water power must serve as main source of energy (Norske Hydro, Norway)

11. Having recognized the behavior of the nucleus of uranium, it seemed simple to construct a so-called atomic bomb. However, we did not want this destroying effect but tried to find a way to control the disintegration of the nucleus of uranium bombarded by neutrons.

12. We had several plans but I do not know whether they will work. The importance of this energy or rather its source, may be seen in the fact that 1 kg $^{235}_{92}$U delivers the same amount of energy as the combustion of 1600 tons of gasoline.

13. The risk of the atomic bomb may lay in its enormous explosive power which may, perhaps, destroy our planet, for the theory says that it is possible that other nuclei will disintegrate. This disintegration is probably induced by the particles of the disintegrated uranium.

14. When Germany was at this stage of the game, the war broke out in Europe. At first investigations on this disintegration of $^{235}_{92}$U were somewhat neglected because a practical application seemed too far off. Later, however, this research continued, especially in finding methods of separating isotopes. Needless to say that the center of gravity of Germany's war effort at that time lay on other tasks.

15. Nevertheless the atomic bomb was expected to be ready toward the end of 1944, if it had not been for the effective air attacks on laboratories engaged in this uranium research, especially on the one at Rjukon in Norway, where heavy water was produced. It is mainly for this reason that Germany did not succeed in using the atomic bomb in this war.

16. The disintegration of the nucleus of uranium follows seven equations, not enumerated in this report, but in the first step the neutron enters the nucleus and forms a new nucleus which is unstable and disintegrates spontaneously while yielding atoms. The neutron enters the heavy nucleus easily because it carries no electric charge.

17. The light nuclei are always radio-active and can be identified by their radiation (half period, B-spectra). The disintegration of one kg $^{235}_{92}$U delivers an amount of energy of $\frac{1000}{235} \cdot 160 \cdot 23 \cdot 10^6$ kg cal $= 1.6 \cdot 10^{10}$ kg cal, whereas 1 kg of TNT only delivers 1000 kg cal when detonating. Out of this follows that an atomic bomb of 3 lbs $^{235}_{92}$U has the same effect as a bomb of 20,000 tons of TNT.

18. The explosion of uranium will be induced by bombarding the nucleus by neutrons which are produced by a so-called neutron source. Mistures of radium salts and beryllium in suitable containers are used as neutron sources. Radium emits alpha - particles of carbon of mass 12 and neutrons are produced according to the equasion:

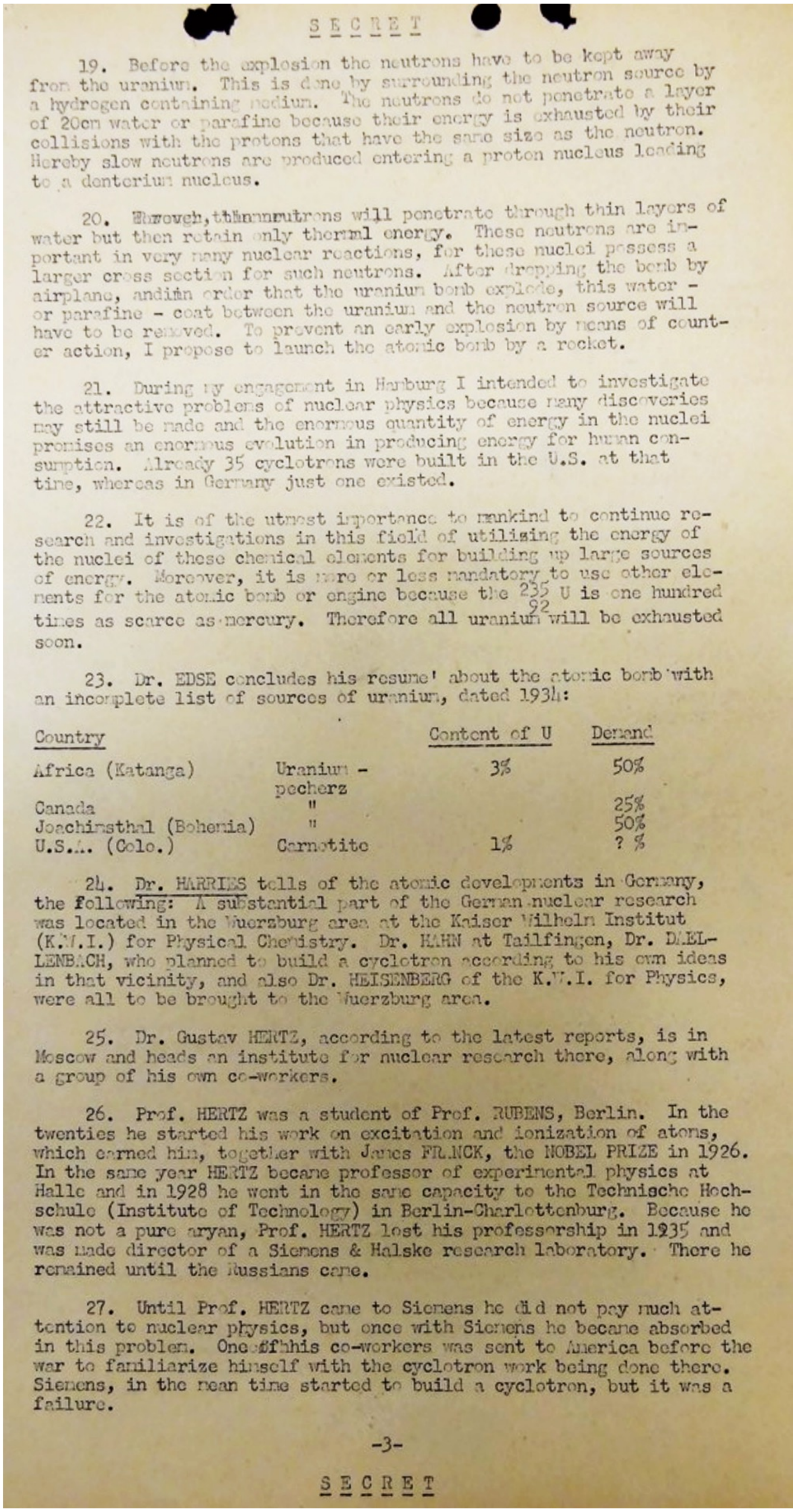
$$^{9}_{4}Be + ^{4}_{2}He \text{ --- } ^{12}_{6}C + ^{1}_{0}n \quad (^{4}_{2}H = \text{alpha}).$$

-2-

S E C R E T

Figure D.668: Rudolf Zinsser reported observing an apparent atomic bomb test near the Baltic coast in October 1944. U.S. documents state that Rudolf Edse worked on the German atomic bomb program. [AFHRA Folder 533.619-5 1945]

AFHRA Folder 533.619-5 1945



S E C R E T

19. Before the explosion the neutrons have to be kept away from the uranium. This is done by surrounding the neutron source by a hydrogen containing medium. The neutrons do not penetrate a layer of 20cm water or parafine because their energy is exhausted by their collisions with the protons that have the same size as the neutron. Hereby slow neutrons are produced entering a proton nucleus leading to a denterium nucleus.

20. Through, the neutrons will penetrate through thin layers of water but then retain only thermal energy. These neutrons are important in very many nuclear reactions, for these nuclei possess a larger cross section for such neutrons. After dropping the bomb by airplane, and in order that the uranium bomb explode, this water - or parafine - coat between the uranium and the neutron source will have to be removed. To prevent an early explosion by means of counter action, I propose to launch the atomic bomb by a rocket.

21. During my engagement in Hamburg I intended to investigate the attractive problems of nuclear physics because many discoveries may still be made and the enormous quantity of energy in the nuclei promises an enormous evolution in producing energy for human consumption. Already 35 cyclotrons were built in the U.S. at that time, whereas in Germany just one existed.

22. It is of the utmost importance to mankind to continue research and investigations in this field of utilising the energy of the nuclei of these chemical elements for building up large sources of energy. Moreover, it is more or less mandatory to use other elements for the atomic bomb or engine because the $^{235}_{92}U$ is one hundred times as scarce as mercury. Therefore all uranium will be exhausted soon.

23. Dr. EDSE concludes his resume' about the atomic bomb with an incomplete list of sources of uranium, dated 1934:

Country		Content of U	Demand
Africa (Katanga)	Uranium - pecherz	3%	50%
Canada	"		25%
Joachimsthal (Bohemia)	"		50%
U.S.A. (Colo.)	Carnotite	1%	? %

24. Dr. HARRIES tells of the atomic developments in Germany, the following: A substantial part of the German nuclear research was located in the Wuerzburg area at the Kaiser Wilhelm Institut (K.W.I.) for Physical Chemistry. Dr. HAHN at Tailfingen, Dr. DAELLENBACH, who planned to build a cyclotron according to his own ideas in that vicinity, and also Dr. HEISENBERG of the K.W.I. for Physics, were all to be brought to the Wuerzburg area.

25. Dr. Gustav HERTZ, according to the latest reports, is in Moscow and heads an institute for nuclear research there, along with a group of his own co-workers.

26. Prof. HERTZ was a student of Prof. RUBENS, Berlin. In the twenties he started his work on excitation and ionization of atoms, which earned him, together with James FRANCK, the NOBEL PRIZE in 1926. In the same year HERTZ became professor of experimental physics at Halle and in 1928 he went in the same capacity to the Technische Hochschule (Institute of Technology) in Berlin-Charlottenburg. Because he was not a pure aryan, Prof. HERTZ lost his professorship in 1935 and was made director of a Siemens & Halske research laboratory. There he remained until the Russians came.

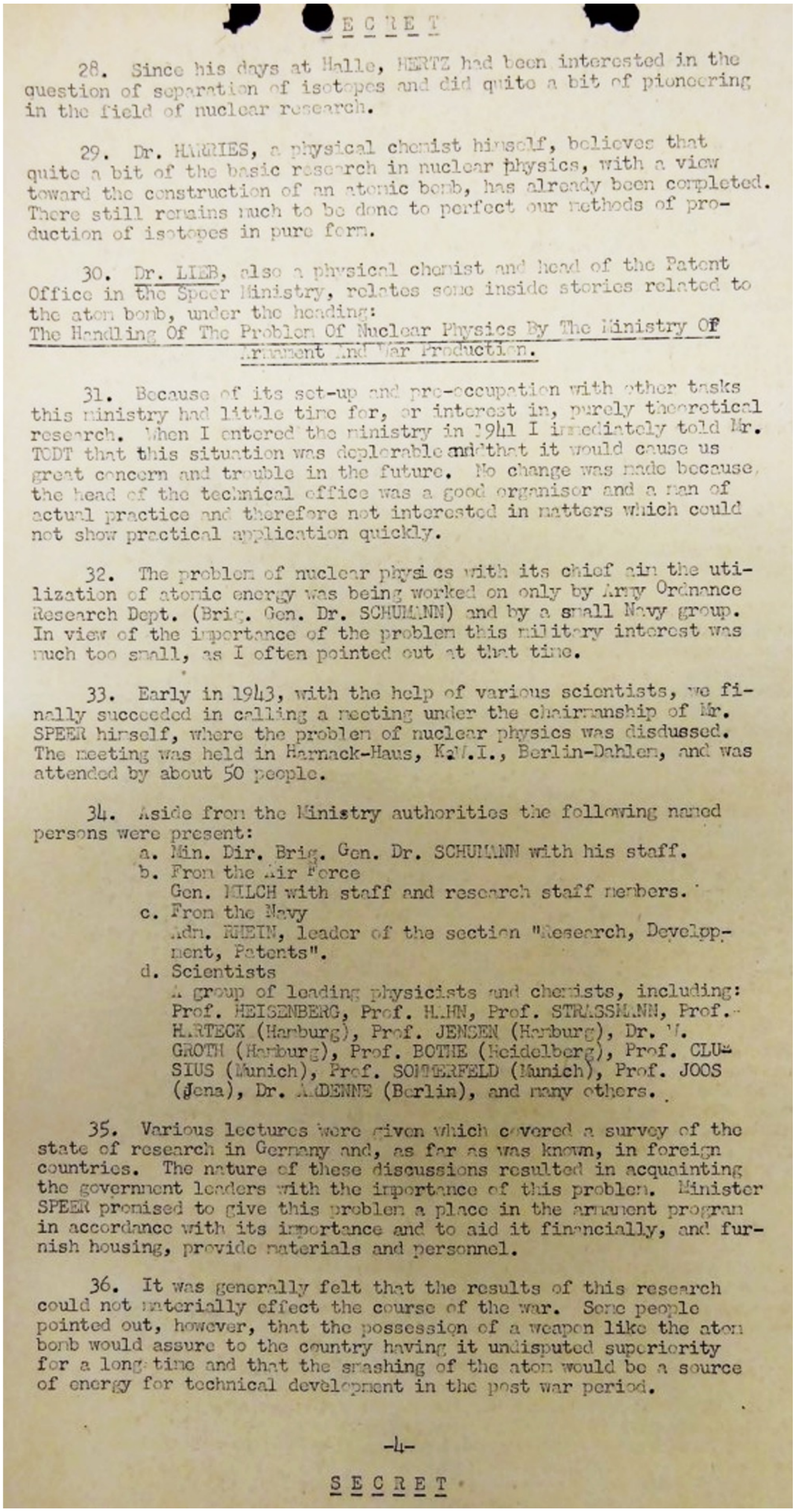
27. Until Prof. HERTZ came to Siemens he did not pay much attention to nuclear physics, but once with Siemens he became absorbed in this problem. One of his co-workers was sent to America before the war to familiarize himself with the cyclotron work being done there. Siemens, in the mean time started to build a cyclotron, but it was a failure.

-3-

S E C R E T

Figure D.669: Rudolf Zinsser reported observing an apparent atomic bomb test near the Baltic coast in October 1944. U.S. documents state that Rudolf Edse worked on the German atomic bomb program. [AFHRA Folder 533.619-5 1945]

AFHRA Folder 533.619-5 1945



SECRET

28. Since his days at Halle, HERTZ had been interested in the question of separation of isotopes and did quite a bit of pioneering in the field of nuclear research.

29. Dr. HARRIES, a physical chemist himself, believes that quite a bit of the basic research in nuclear physics, with a view toward the construction of an atomic bomb, has already been completed. There still remains much to be done to perfect our methods of production of isotopes in pure form.

30. Dr. LIEB, also a physical chemist and head of the Patent Office in the Speer Ministry, relates some inside stories related to the atom bomb, under the heading:

The Handling Of The Problem Of Nuclear Physics By The Ministry Of Armament And War Production.

31. Because of its set-up and pre-occupation with other tasks this ministry had little time for, or interest in, purely theoretical research. When I entered the ministry in 1941 I immediately told Mr. TODT that this situation was deplorable and that it would cause us great concern and trouble in the future. No change was made because the head of the technical office was a good organisor and a man of actual practice and therefore not interested in matters which could not show practical application quickly.

32. The problem of nuclear physics with its chief aim the utilization of atomic energy was being worked on only by Army Ordnance Research Dept. (Brig. Gen. Dr. SCHUMANN) and by a small Navy group. In view of the importance of the problem this military interest was much too small, as I often pointed out at that time.

33. Early in 1943, with the help of various scientists, we finally succeeded in calling a meeting under the chairmanship of Mr. SPEER himself, where the problem of nuclear physics was disdussed. The meeting was held in Harnack-Haus, K.W.I., Berlin-Dahlem, and was attended by about 50 people.

34. Aside from the Ministry authorities the following named persons were present:

a. Min. Dir. Brig. Gen. Dr. SCHUMANN with his staff.
b. From the Air Force
   Gen. MILCH with staff and research staff members.
c. From the Navy
   Adm. RHEIN, leader of the section "Research, Develppment, Patents".
d. Scientists
   A group of leading physicists and chemists, including: Prof. HEISENBERG, Prof. HAHN, Prof. STRASSMANN, Prof. HARTECK (Hamburg), Prof. JENSEN (Hamburg), Dr. W. GROTH (Hamburg), Prof. BOTHE (Heidelberg), Prof. CLUSIUS (Munich), Prof. SOMMERFELD (Munich), Prof. JOOS (Jena), Dr. ARDENNE (Berlin), and many others.

35. Various lectures were given which covered a survey of the state of research in Germany and, as far as was known, in foreign countries. The nature of these discussions resulted in acquainting the government leaders with the importance of this problem. Minister SPEER promised to give this problem a place in the armament program in accordance with its importance and to aid it financially, and furnish housing, provide materials and personnel.

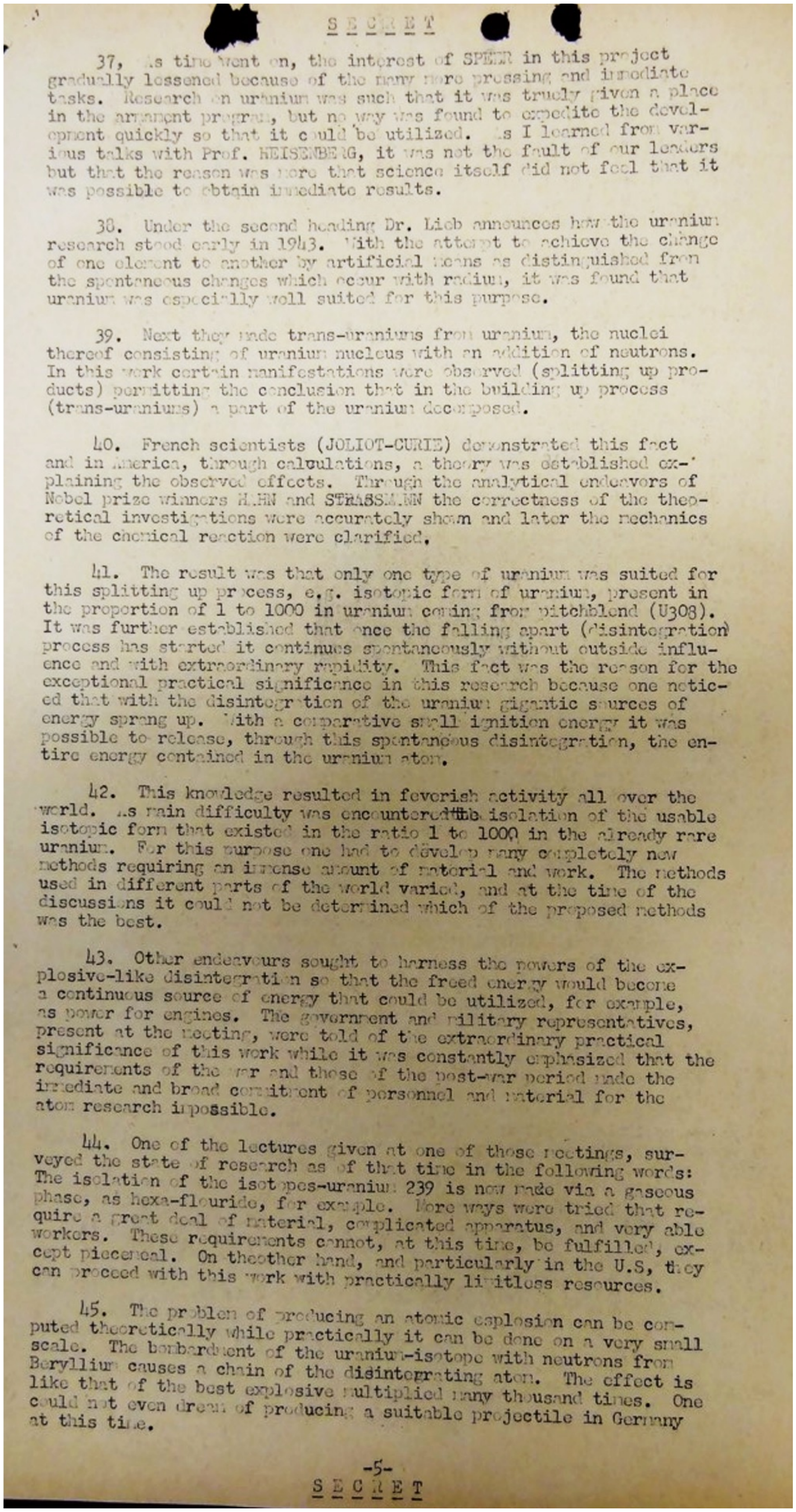
36. It was generally felt that the results of this research could not materially effect the course of the war. Some people pointed out, however, that the possession of a weapon like the atom bomb would assure to the country having it undisputed superiority for a long time and that the smashing of the atom would be a source of energy for technical development in the post war period.

-4-

SECRET

Figure D.670: Rudolf Zinsser reported observing an apparent atomic bomb test near the Baltic coast in October 1944. U.S. documents state that Rudolf Edse worked on the German atomic bomb program. [AFHRA Folder 533.619-5 1945]

AFHRA Folder 533.619-5 1945



SECRET

37, As time went on, the interest of SPEER in this project gradually lessened because of the many more pressing and immediate tasks. Research on uranium was such that it was truely given a place in the armament program, but no way was found to expedite the development quickly so that it could be utilized. As I learned from various talks with Prof. HEISENBERG, it was not the fault of our leaders but that the reason was more that science itself did not feel that it was possible to obtain immediate results.

38. Under the second heading Dr. Lieb announces how the uranium research stood early in 1943. With the attempt to achieve the change of one element to another by artificial means as distinguished from the spontaneous changes which occur with radium, it was found that uranium was especially well suited for this purpose.

39. Next they made trans-uraniums from uranium, the nuclei thereof consisting of uranium nucleus with an addition of neutrons. In this work certain manifestations were observed (splitting up products) permitting the conclusion that in the building up process (trans-uraniums) a part of the uranium decomposed.

40. French scientists (JOLIOT-CURIE) demonstrated this fact and in America, through calculations, a theory was established explaining the observed effects. Through the analytical endeavors of Nobel prize winners HAHN and STRASSMANN the correctness of the theoretical investigations were accurately shown and later the mechanics of the chemical reaction were clarified.

41. The result was that only one type of uranium was suited for this splitting up process, e.g. isotopic form of uranium, present in the proportion of 1 to 1000 in uranium coming from pitchblend (U308). It was further established that once the falling apart (disintegration) process has started it continues spontaneously without outside influence and with extraordinary rapidity. This fact was the reason for the exceptional practical significance in this research because one noticed that with the disintegration of the uranium gigantic sources of energy sprang up. With a comparative small ignition energy it was possible to release, through this spontaneous disintegration, the entire energy contained in the uranium atom.

42. This knowledge resulted in feverish activity all over the world. As main difficulty was encountered the isolation of the usable isotopic form that existed in the ratio 1 to 1000 in the already rare uranium. For this purpose one had to develop many completely new methods requiring an immense amount of material and work. The methods used in different parts of the world varied, and at the time of the discussions it could not be determined which of the proposed methods was the best.

43. Other endeavours sought to harness the powers of the explosive-like disintegration so that the freed energy would become a continuous source of energy that could be utilized, for example, as power for engines. The government and military representatives, present at the meeting, were told of the extraordinary practical significance of this work while it was constantly emphasized that the requirements of the war and those of the post-war period made the immediate and broad commitment of personnel and material for the atom research impossible.

44. One of the lectures given at one of those meetings, surveyed the state of research as of that time in the following words: The isolation of the isotopes-uranium 239 is now made via a gaseous phase, as hexa-flouride, for example. More ways were tried that require a great deal of material, complicated apparatus, and very able workers. These requirements cannot, at this time, be fulfilled, except piecemeal. On theother hand, and particularly in the U.S, they can proceed with this work with practically limitless resources.

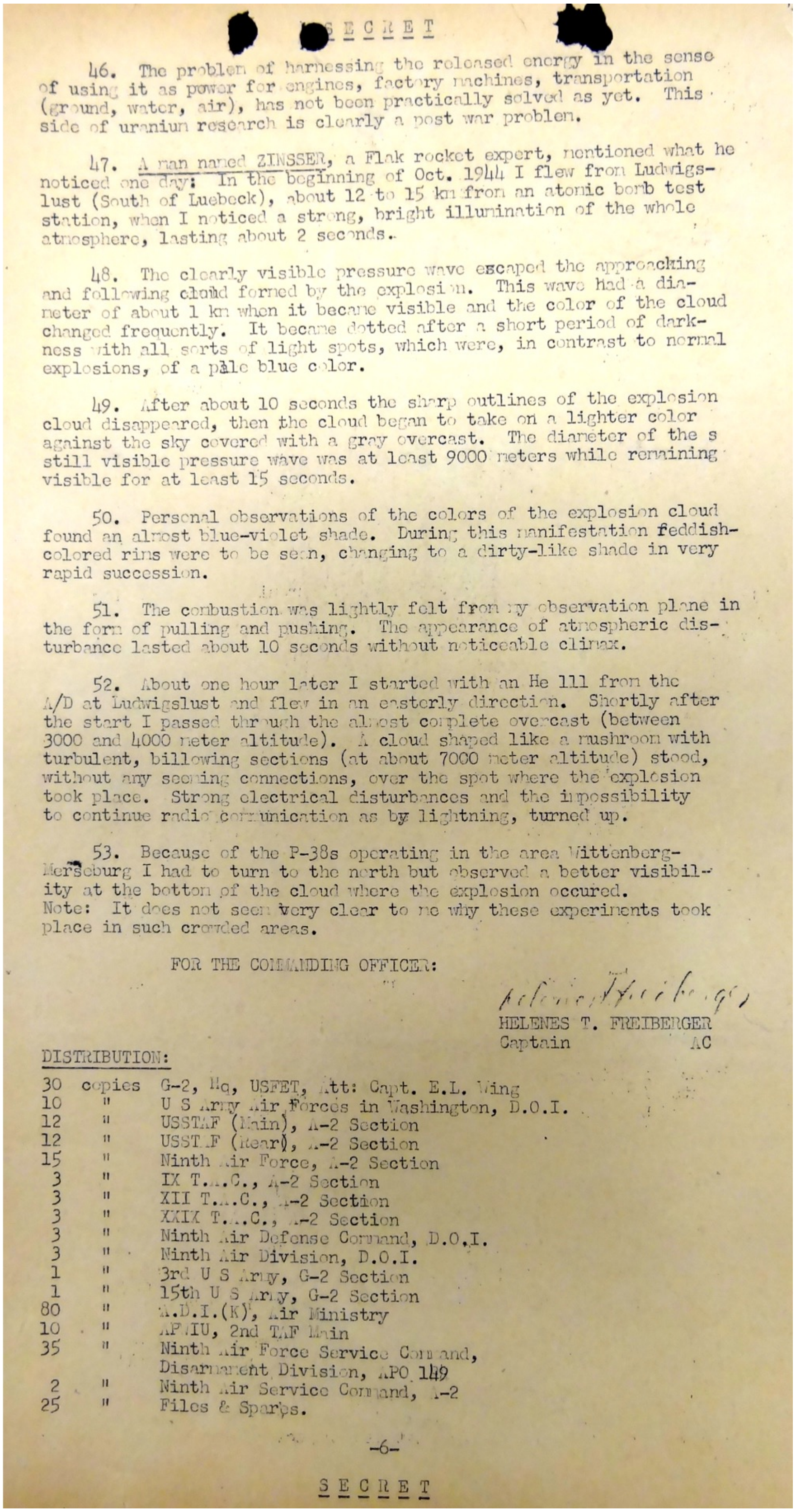
45. The problem of producing an atomic explosion can be computed theoretically while practically it can be done on a very small scale. The bombardment of the uranium-isotope with neutrons from Beryllium causes a chain of the disintegrating atom. The effect is like that of the best explosive multiplied many thousand times. One could not even dream of producing a suitable projectile in Germany at this time.

-5-

SECRET

Figure D.671: Rudolf Zinsser reported observing an apparent atomic bomb test near the Baltic coast in October 1944. U.S. documents state that Rudolf Edse worked on the German atomic bomb program. [AFHRA Folder 533.619-5 1945]

AFHRA Folder 533.619-5 1945



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46. The problem of harnessing the released energy in the sense of using it as power for engines, factory machines, transportation (ground, water, air), has not been practically solved as yet. This side of uranium research is clearly a post war problem.

47. A man named ZINSSER, a Flak rocket expert, mentioned what he noticed one day: In the beginning of Oct. 1944 I flew from Ludwigslust (South of Luebeck), about 12 to 15 km from an atomic bomb test station, when I noticed a strong, bright illumination of the whole atmosphere, lasting about 2 seconds.

48. The clearly visible pressure wave escaped the approaching and following cloud formed by the explosion. This wave had a diameter of about 1 km when it became visible and the color of the cloud changed frequently. It became dotted after a short period of darkness with all sorts of light spots, which were, in contrast to normal explosions, of a pale blue color.

49. After about 10 seconds the sharp outlines of the explosion cloud disappeared, then the cloud began to take on a lighter color against the sky covered with a gray overcast. The diameter of the s still visible pressure wave was at least 9000 meters while remaining visible for at least 15 seconds.

50. Personal observations of the colors of the explosion cloud found an almost blue-violet shade. During this manifestation feddish-colored rims were to be seen, changing to a dirty-like shade in very rapid succession.

51. The combustion was lightly felt from my observation plane in the form of pulling and pushing. The appearance of atmospheric disturbance lasted about 10 seconds without noticeable climax.

52. About one hour later I started with an He 111 from the A/D at Ludwigslust and flew in an easterly direction. Shortly after the start I passed through the almost complete overcast (between 3000 and 4000 meter altitude). A cloud shaped like a mushroom with turbulent, billowing sections (at about 7000 meter altitude) stood, without any seeming connections, over the spot where the explosion took place. Strong electrical disturbances and the impossibility to continue radio communication as by lightning, turned up.

53. Because of the P-38s operating in the area Wittenberg-Mersburg I had to turn to the north but observed a better visibility at the botton of the cloud where the explosion occured.
Note: It does not seem very clear to me why these experiments took place in such crowded areas.

FOR THE COMMANDING OFFICER:

HELENES T. FREIBERGER
Captain AC

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-6-

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Figure D.672: Rudolf Zinsser reported observing an apparent atomic bomb test near the Baltic coast in October 1944. U.S. documents state that Rudolf Edse worked on the German atomic bomb program. [AFHRA Folder 533.619-5 1945]

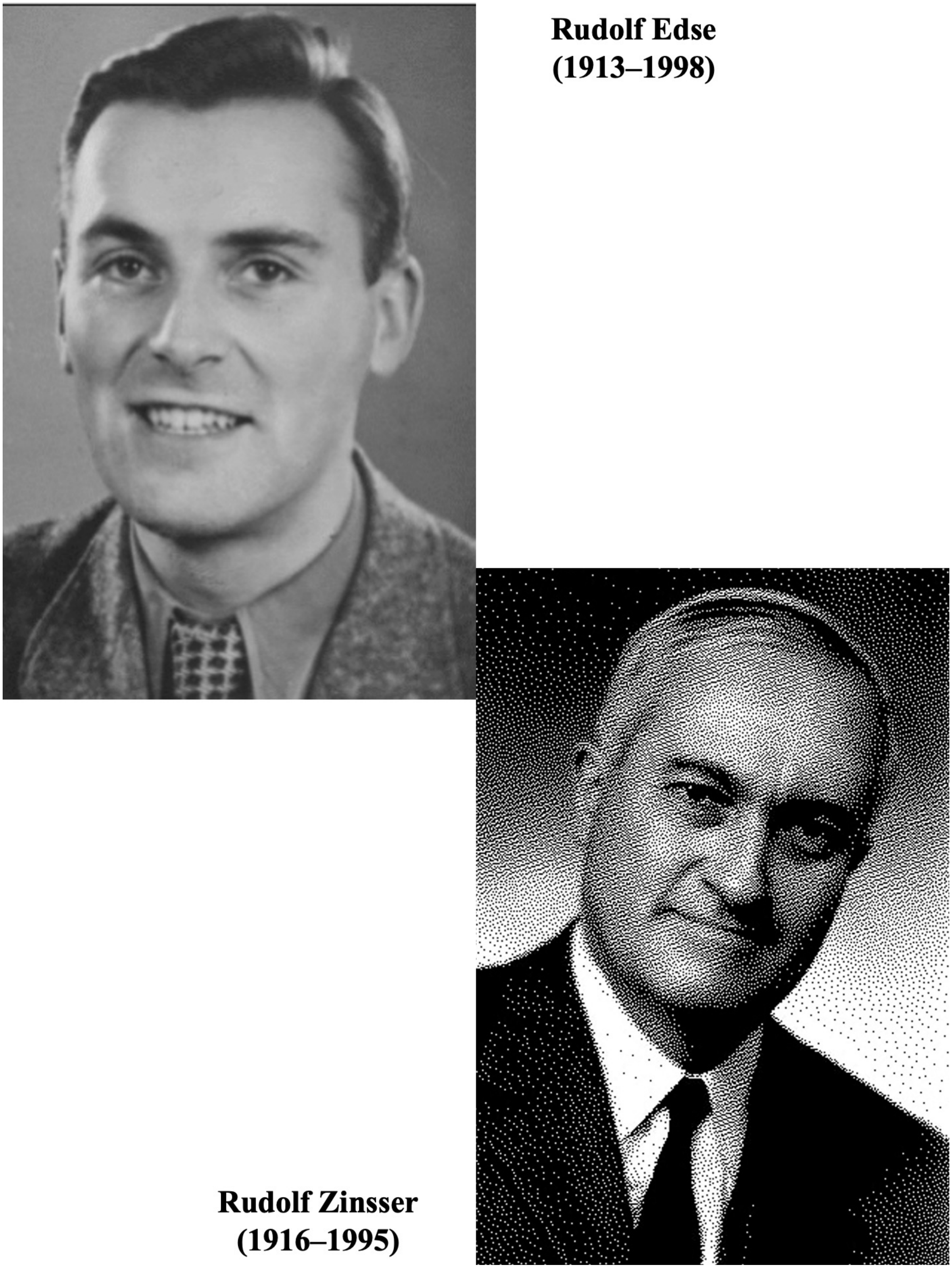

Rudolf Edse
(1913–1998)
Rudolf Zinsser
(1916–1995)

Figure D.673: Rudolf Zinsser reported observing an apparent atomic bomb test near the Baltic coast in October 1944. U.S. documents state that Rudolf Edse worked on the German atomic bomb program.

R. J. Ritter, ed. Inside the Mushroom Cloud. *Newsletter for America's Atomic Veterans.* July 2013, pp. 3–10. National Association of Atomic Veterans. https://naav.com/archives/2013_07_NAAV_Newsletter.pdf

At the instant of the initial nuclear detonation, the fission process generates & emits Alpha (a) & Beta (b) particles, Gamma (g) & X-rays (x), and Electro-Magnetic Pulse (EMP), from within the boiling fireball, after which cooler air is drawn into the center of the rising "toroidal" formation, which itself begins to cool into the familiar mushroom-cloud shape & appearance as it begins to rise to higher altitudes. EMP is the root cause of electronic instrumentation and communication device failures, shortly thereafter, and in close proximity, to the nuclear weapon detonation event. [...]

The distribution of radiation in the mushroom cloud varies with the total yield of the explosion, the type of weapon, the fusion/fission ratio, the burst altitude, the terrain type, and the prevailing weather patterns. Generally it can be said that lower-yield (Kiloton-range) explosions have about 90% of radioactivity in the mushroom head and 10% in the (heat-chute) stem, while Megaton-range detonations tend to have most of the radioactivity in the lower third of the mushroom cloud.

At the instant of detonation, the (fission process) fireball is formed, and the ascending, roughly spherical, mass of hot incandescent gases changes shape due to atmospheric friction and cools its surface by energy radiation, thus turning from a sphere to a violently swirling annular vortex. A (*Rayleigh-Taylor*) instability is formed at the boundary between the hot fireball and the surrounding cooler air. This will then cause turbulence and forms a vortex, which sucks air into its center, creating after-winds and thus cooling itself. As it begins to cool, the speed of its swirling motion begins to slow down, and may stop entirely during later phases. The vaporized parts of the weapon, and other materials, then condense into visible dust (and water vapor mist) forming the cloud; while the white-hot vortex core becomes yellow, then red, then loses any visible incandescence. [...]

The initial colors of some radioactive clouds can be red, or reddish brown, due to the presence of nitrogen dioxide and nitric acids, which are formed from the combination of nitrogen, oxygen, and atmospheric moisture. In the high temperature, high radiation environment of the blast, ozone is also formed. It is estimated that each Megaton of yield produces about 5,000 tons of nitrogen oxides...

Yellow and orange hues are also described. And a reddish hue is later obscured by the white color of water vapor (condensing in the fast flowing air as the fireball begins to cool) and the dark color of smoke and debris that is sucked into the strong updraft. The ozone will give the blast its characteristic corona & discharge like smell. [...]

The intense radiation in the first seconds after a nuclear blast may cause an observable aura of fluorescence, that emits an eerie blue-violet-purple glow of ionized oxygen and nitrogen at some distance from the fireball, surrounding the rapidly forming radioactive cloud. The light is best visible during the night or just before daylight, or just after sundown. The brightness then decreases rapidly, becoming barely visible in 20 to 45 seconds.

S. D. Felkin. 9 October 1945. [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700]

SECRET.

A.P./W.I.U. (9th. AIR FORCE) REPORT NO. 96/1945.

Will all recipients of the above report please note that it has now been upgraded to TOP SECRET.

S. D. Felkin
Group Captain

[By spring 1945, the U.S. Alsos Mission concluded that Germany never even made a serious attempt to develop an atomic bomb during the war, yet Zinsser's testimony about an apparently successful October 1944 German atomic bomb test was given wide circulation and credence in U.S. military intelligence circles several months later, in August 1945. That fact suggests that U.S. intelligence officials had good reasons to doubt the conclusions of the Alsos Mission.

Moreover, the fact that the Zinsser report was then **upgraded** from Secret to Top Secret in October 1945 suggests that intelligence about German atomic bomb tests became more credible, not less credible, with further time and investigation. What new information did U.S. intelligence learn about the German atomic bomb program and/or Zinsser between August and October 1945 that prompted them to increase the classification level of Zinsser's report?]

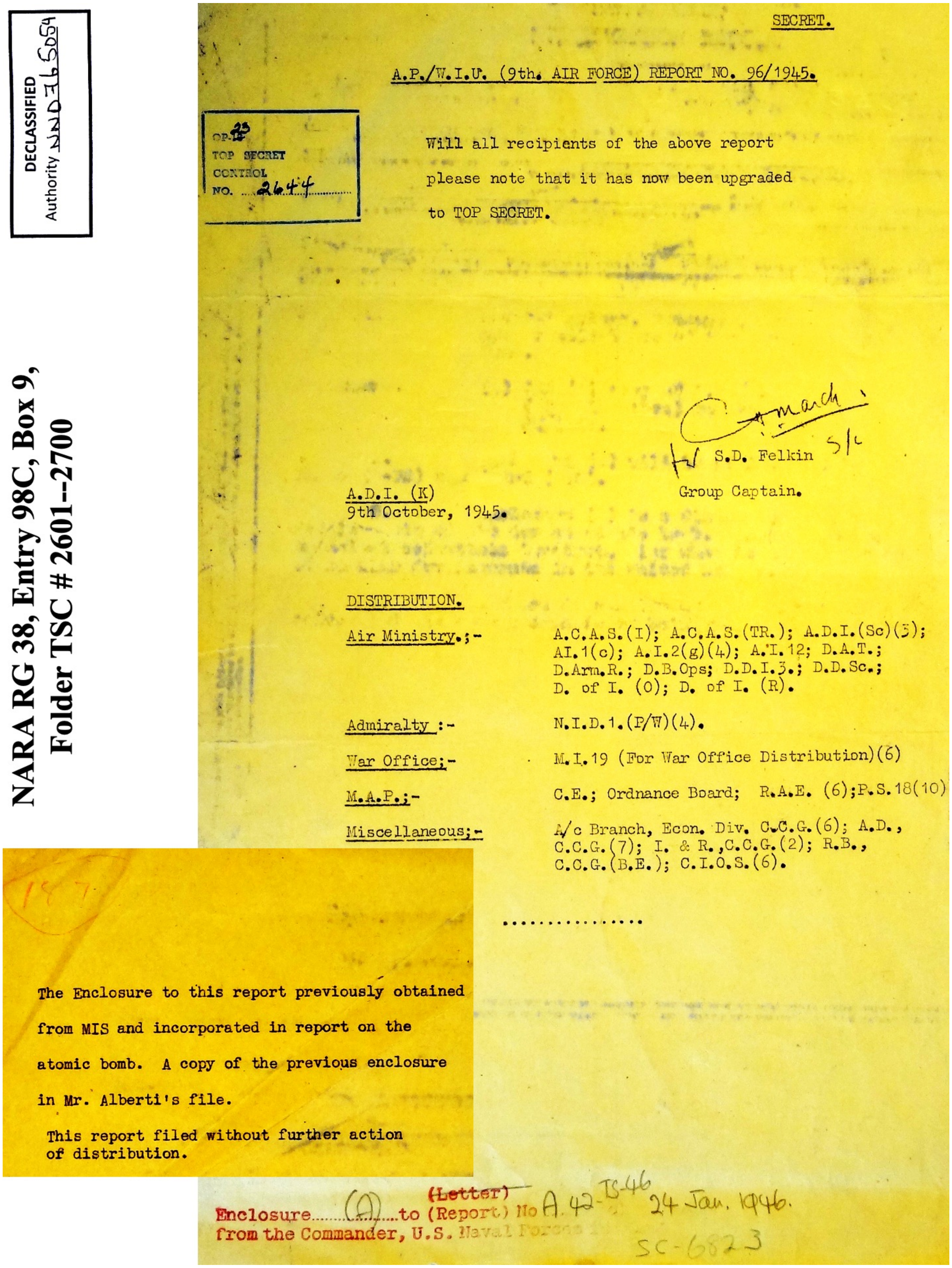
Loose memo with no title, date, or signature [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700]

The Enclosure to this report previously obtained from MIS and incorporated in report on the atomic bomb. A copy of the previous enclosure in Mr. Alberti's file. This report filed without further action or distribution.

[MIS was the Military Intelligence Service. This note appears to have originally been attached to a report, but what report and what enclosure does it reference?

"Mr. Alberti" would have meant Jack H. Alberti, a Naval Intelligence investigator who was one of the first to board the U-234 submarine in May 1945, who conducted many of the interrogations of its passengers and crew, and who was in charge of cataloging and processing its cargo. Alberti also performed the same functions for other captured German submarines (pp. 4866–4881). Does this loose memo suggest that Alberti obtained information from U-234 (or other German submarines) that was related to the Zinsser report about the German atomic bomb program? If so, what information?

See document photos on p. 4423.]



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Will all recipients of the above report please note that it has now been upgraded to TOP SECRET.

C March S/L
S.D. Felkin
Group Captain.

A.D.I. (K)
9th October, 1945.

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187

The Enclosure to this report previously obtained from MIS and incorporated in report on the atomic bomb. A copy of the previous enclosure in Mr. Alberti's file.

This report filed without further action of distribution.

Enclosure....(A)....to ~~(Letter)~~ (Report) No A.42-TS-46 24 Jan. 1946.
from the Commander, U.S. Naval Forces

SC-6823

Figure D.674: Top: S. D. Felkin. 9 October 1945. Bottom: Loose memo [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700].

Edse, Rudolf. Foreign Scientist Case File. [NARA RG 330, Entry A1-1B, Box 35, Folder Edse, Rudolf]

DATE: 9 May 1946

The following information in the case of Dr. Rudolf Edse is submitted in accordance with letter, Headquarters, Army Air Forces [...]

a. [...] Department head of Chemical Research Branch at LFA, specialist for nuclear physics, chemical basic research, powdered rockets, and thermodynamics.

b. [...] Has written report on possibilities of atomic research at Wright Field.

c. [...] Because of his work on the production of isotopes related to atomic research, he might be employed along similar lines in this country. [...]

D. L. PUTT
Colonel, Air Corps
Deputy Commanding General
Intelligence (T-2)

Date 26 September 45 [...]

BASIC PERSONNEL RECORD

Arrived: 20 Sept. 1945

I. Name: EDSE, Rudolf [...]

XV. Remarks: Worked on atomic bomb (see attached report)

[The same 19 August 1945 report that included Rudolf Zinsser's description of an October 1944 German atomic bomb test also included information from Rudolf Edse, who said that he had worked on the German nuclear program, and that it had had the goal of having an atomic bomb ready by late 1944 (p. 4411).

The Foreign Scientist Case File ("Paperclip" file) for Rudolf Edse reaffirms that he did work on the German atomic bomb. It also indicates that he gave detailed descriptions of his work for Germany and how he could do similar work for the United States, although those details are not in the files. Edse was brought to the United States in 1945 (much sooner than many other Paperclip scientists) and given lifetime employment in the United States. He does not appear to have ever again mentioned the German nuclear work.

See document photos on pp. 4425–4426.]

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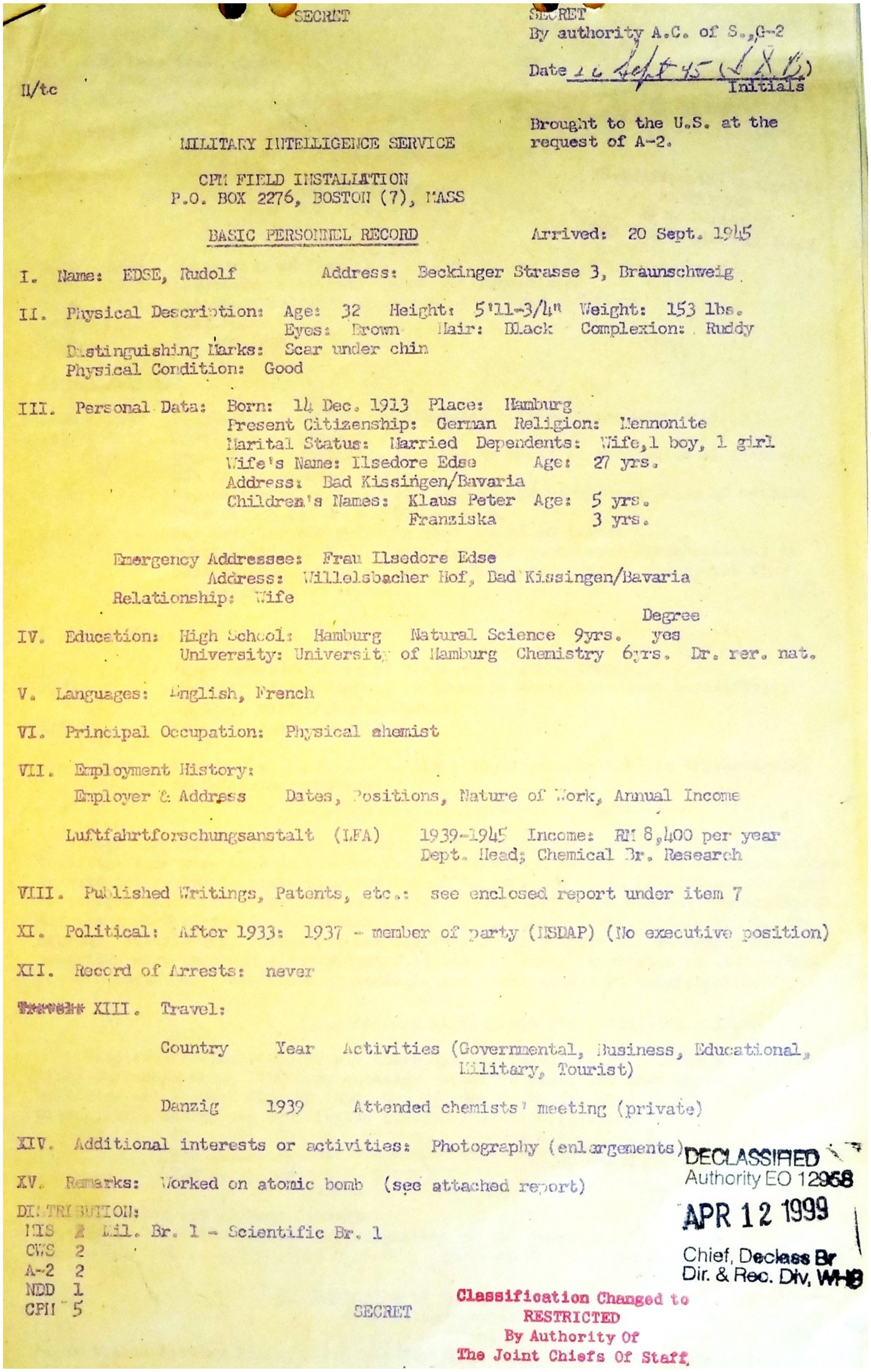
NARA RG 330, Entry A1-1B,
Box 35, Folder Edse, Rudolf



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Date 26 Sept 45 (J X B.)
Initials

II/tc

Brought to the U.S. at the request of A-2.

MILITARY INTELLIGENCE SERVICE

CPM FIELD INSTALLATION
P.O. BOX 2276, BOSTON (7), MASS

BASIC PERSONNEL RECORD

Arrived: 20 Sept. 1945

I. Name: EDSE, Rudolf Address: Beckinger Strasse 3, Braunschweig

II. Physical Description: Age: 32 Height: 5'11-3/4" Weight: 153 lbs.
Eyes: Brown Hair: Black Complexion: Ruddy
Distinguishing Marks: Scar under chin
Physical Condition: Good

III. Personal Data: Born: 14 Dec. 1913 Place: Hamburg
Present Citizenship: German Religion: Mennonite
Marital Status: Married Dependents: Wife, 1 boy, 1 girl
Wife's Name: Ilsedore Edse Age: 27 yrs.
Address: Bad Kissingen/Bavaria
Children's Names: Klaus Peter Age: 5 yrs.
Franziska 3 yrs.

Emergency Addressee: Frau Ilsedore Edse
Address: Willelsbacher Hof, Bad Kissingen/Bavaria
Relationship: Wife

					Degree
IV. Education:	High School:	Hamburg	Natural Science	9yrs.	yes
	University:	University of Hamburg	Chemistry	6yrs.	Dr. rer. nat.

V. Languages: English, French

VI. Principal Occupation: Physical chemist

VII. Employment History:

Employer & Address	Dates, Positions, Nature of Work, Annual Income
Luftfahrtforschungsanstalt (LFA)	1939-1945 Income: RM 8,400 per year Dept. Head; Chemical Br. Research

VIII. Published Writings, Patents, etc.: see enclosed report under item 7

XI. Political: After 1933: 1937 - member of party (NSDAP) (No executive position)

XII. Record of Arrests: never

~~Travel:~~ XIII. Travel:

Country	Year	Activities (Governmental, Business, Educational, Military, Tourist)
Danzig	1939	Attended chemists' meeting (private)

XIV. Additional interests or activities: Photography (enlargements)

XV. Remarks: Worked on atomic bomb (see attached report)

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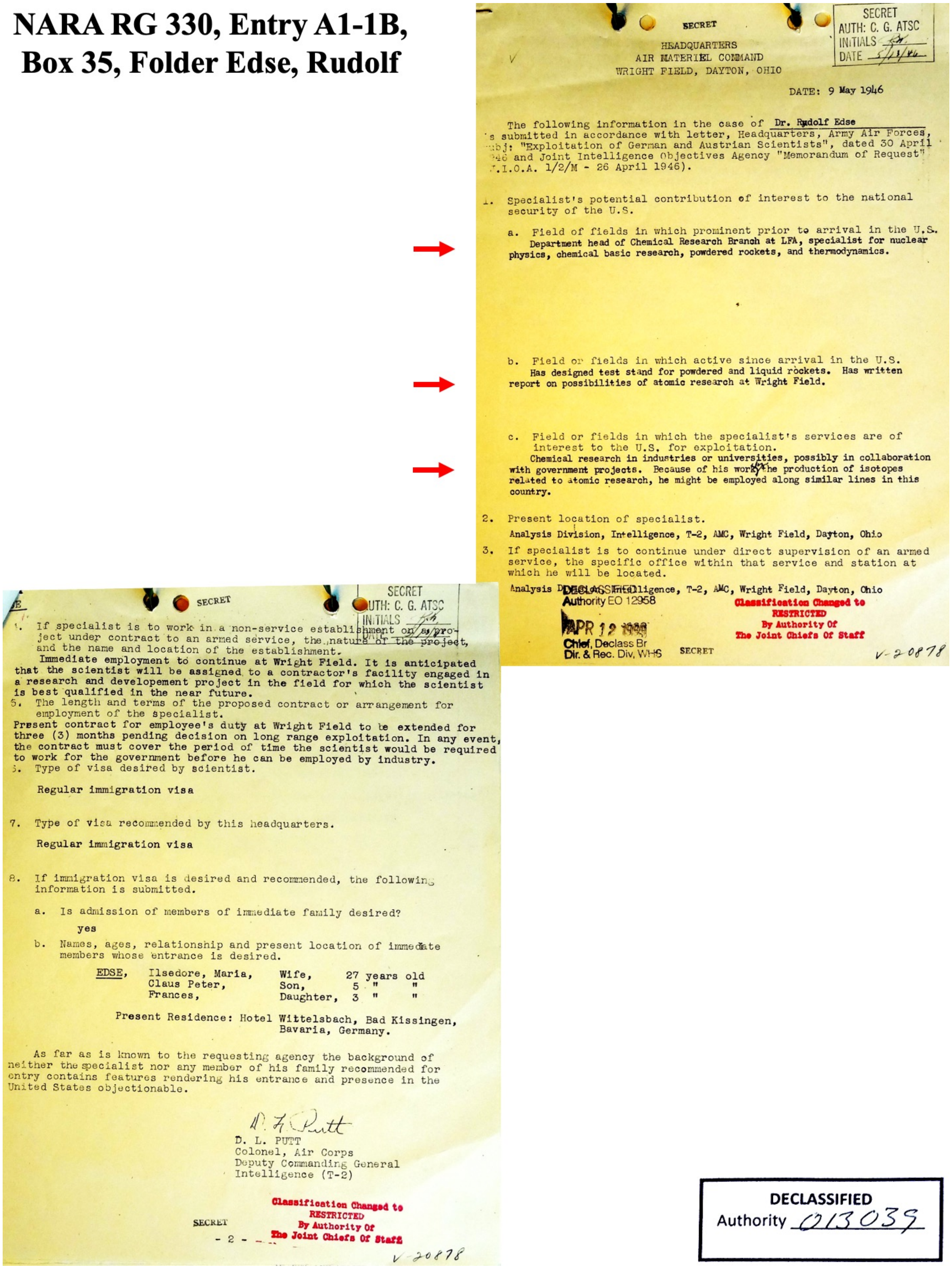
Figure D.675: Edse, Rudolf. Foreign Scientist Case File. [NARA RG 330, Entry A1-1B, Box 35, Folder Edse, Rudolf]

NARA RG 330, Entry A1-1B, Box 35, Folder Edse, Rudolf



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SECRET
AUTH: C. G. ATSC
INITIALS RH
DATE 5/13/46

HEADQUARTERS
AIR MATERIEL COMMAND
WRIGHT FIELD, DAYTON, OHIO

DATE: 9 May 1946

The following information in the case of Dr. Rudolf Edse
s submitted in accordance with letter, Headquarters, Army Air Forces, ubj: "Exploitation of German and Austrian Scientists", dated 30 April 46 and Joint Intelligence Objectives Agency "Memorandum of Request" .I.O.A. 1/2/M - 26 April 1946).

1. Specialist's potential contribution of interest to the national security of the U.S.

a. Field of fields in which prominent prior to arrival in the U.S. Department head of Chemical Research Branch at LFA, specialist for nuclear physics, chemical basic research, powdered rockets, and thermodynamics.

b. Field or fields in which active since arrival in the U.S. Has designed test stand for powdered and liquid rockets. Has written report on possibilities of atomic research at Wright Field.

c. Field or fields in which the specialist's services are of interest to the U.S. for exploitation.
Chemical research in industries or universities, possibly in collaboration with government projects. Because of his work for the production of isotopes related to atomic research, he might be employed along similar lines in this country.

2. Present location of specialist.
Analysis Division, Intelligence, T-2, AMC, Wright Field, Dayton, Ohio

3. If specialist is to continue under direct supervision of an armed service, the specific office within that service and station at which he will be located.
Analysis Division, Intelligence, T-2, AMC, Wright Field, Dayton, Ohio

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AUTH: C. G. ATSC
INITIALS RH

4. If specialist is to work in a non-service establishment or a project under contract to an armed service, the nature of the project, and the name and location of the establishment.
Immediate employment to continue at Wright Field. It is anticipated that the scientist will be assigned to a contractor's facility engaged in a research and developement project in the field for which the scientist is best qualified in the near future.

5. The length and terms of the proposed contract or arrangement for employment of the specialist.
Present contract for employee's duty at Wright Field to be extended for three (3) months pending decision on long range exploitation. In any event, the contract must cover the period of time the scientist would be required to work for the government before he can be employed by industry.

6. Type of visa desired by scientist.

Regular immigration visa

7. Type of visa recommended by this headquarters.

Regular immigration visa

8. If immigration visa is desired and recommended, the following information is submitted.

a. Is admission of members of immediate family desired?

yes

b. Names, ages, relationship and present location of immediate members whose entrance is desired.

EDSE,	Ilsedore, Maria,	Wife,	27 years old
	Claus Peter,	Son,	5 " "
	Frances,	Daughter,	3 " "

Present Residence: Hotel Wittelsbach, Bad Kissingen, Bavaria, Germany.

As far as is known to the requesting agency the background of neither the specialist nor any member of his family recommended for entry contains features rendering his entrance and presence in the United States objectionable.

D. L. Putt
D. L. PUTT
Colonel, Air Corps
Deputy Commanding General
Intelligence (T-2)

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- 2 -

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Authority 013039

Figure D.676: Edse, Rudolf. Foreign Scientist Case File. [NARA RG 330, Entry A1-1B, Box 35, Folder Edse, Rudolf]

[Luigi Romersa (1917–2007), shown in Fig. D.677, was an Italian military and aerospace journalist who had a long and distinguished career both during and after the war. According to him (and supported by documents such as those below and others [Karlsch 2005]), Benito Mussolini sent him to Germany in October 1944 as his special representative to observe the latest German secret weapons tests and to report back to Mussolini to strengthen his flagging confidence that Germany could win the war. Along with a long list of now well known advanced German rockets, missiles, and jets, Romersa said he was also briefed about V-3 and V-4 rockets and an atomic bomb.

The calendar of Mussolini's appointments has been published, and it shows that Mussolini met with Romersa on 1 October 1944 (before Romersa's trip to Germany) and 30 October 1944 (after his trip), and that Mussolini had met with Romersa on several earlier occasions as well [Guerrazzi 2020, pp. 219, 241, 250, 257–258, 279–280]. This independent information supports Romersa's account.]

29 October 1944 memo for Mussolini to meet with Luigi Romersa [Archivo Centrale dello Stato, Rome, SPD CO RSI B 65, File 5680]

Telefona il Tenente Romersa per informare che è rientrato dal suo viaggio in Germania e per chiedere di essere ricevuto dal DUCE, possibilmente in giornata.	Lieutenant Romersa called to report that he has returned from his trip to Germany and to ask to be received by the DUCE, possibly within the day.
29 ott. XXIII	29 Oct. 1944 [beginning of year XXIII of the Fascist Era]

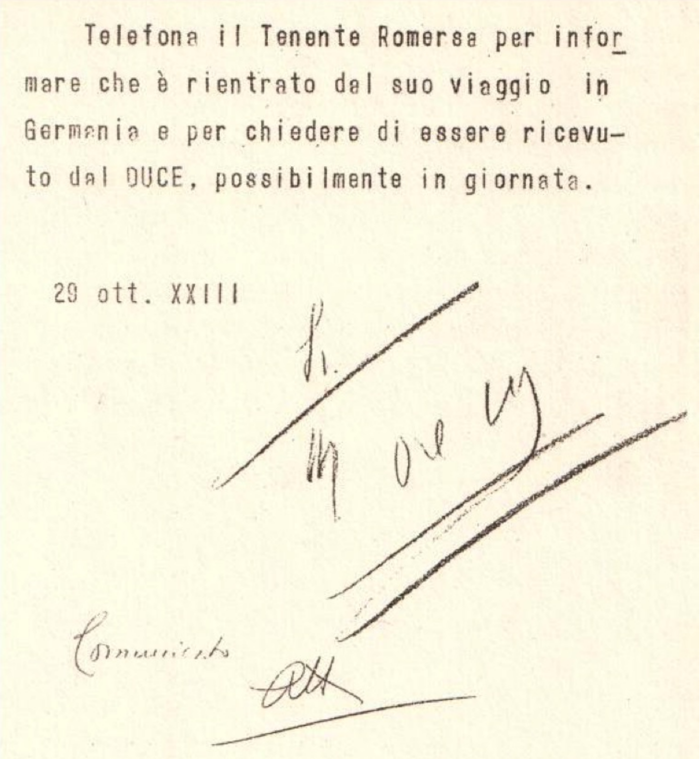
[See document photo on p. 4428.]

Ubaldo Alberto Mellini Ponce De Leon. 1950. *Guerra diplomatica a Salò.* Cappelli. pp. 44–45.

Qualche speranza fu riaccesa da nuove notizie ottimistiche da parte tedesca circa le armi segrete confermate dalla relazione che fece a Mussolini il giornalista Romersa su quanto aveva visto in proposito con i suoi occhi in una recente visita.	Some hopes were rekindled by new optimistic news from the German side about the secret weapons confirmed by the report that the journalist Romersa made to Mussolini on what he had seen in this regard with his own eyes in a recent visit.

[Ubaldo Alberto Mellini Ponce De Leon (1896–1969) served under Mussolini as a diplomat from the 1920s onward and also as Undersecretary of Foreign Affairs during February–March 1945.]

Luigi Romersa (1917–2007) with Wernher von Braun in Huntsville, Alabama in 1958



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29 ott. XXIII

Si.

Comunicato

29 October 1944 memo for Romersa to meet Mussolini to report on his trip to Germany

Figure D.677: Luigi Romersa reported observing an apparent atomic bomb test near the Baltic coast in October 1944.

Luigi Romersa. May-June 1955. Le armi segrete di Hitler [Hitler's Secret Weapons]. ***Civiltà delle Macchine.***

Il dottor Schaeffer, referente per la stampa italiana presso il ministero della propaganda tedesco, mi combinò il primo incontro col sottosegretario [Werner] Naumann, braccio destro di Goebbels. Il 6 ottobre 1944, Schaeffer mi comunicò all'albergo che Neumann mi avrebbe ricevuto alle quattordici al Propaganda Ministerium, nel suo ufficio. [...]

Si raccolse per un istante poi scandendo le parole riprese: "Abbiamo raggiunto la disgregazione dell'atomo. Abbiamo la bomba disgregatrice i cui effetti vanno al di là di ogni umana immaginazione..." [...]

Alla fine del suo lungo monologo, Naumann venne a parlare delle "V 2", "V 3" e "V 4" precisando che gli ultimi due tipi, ai quali ne dovevano seguire altri tre, erano radiocomandati e perciò infallibili. Ottenni anche la promessa di una visita alle fabbriche sotterranee e del suo interessamento, presso Goebbels, per assistere a un esperimento di bomba disgregatrice che doveva aver luogo in quei giorni in un'isola del Baltico. [...]

Il 10 ottobre 1944 fui avvertito di tenermi pronto a partire per il nord.

Lasciai Berlino nella notte dell'11 in automobile; mi accompagnavano due ufficiali, uno mi disse che al ritorno sarei stato ricevuto da Goebbels.

Dr. Schaeffer, contact person for the Italian press at the German propaganda ministry, arranged for me to meet first with Undersecretary [Werner] Naumann, Goebbels' right-hand man [p. 4650]. On 6 October 1944, Schaeffer informed me at the hotel that Naumann would receive me at 2:00 p.m. in his office at the Propaganda Ministerium. [...]

He [Naumann] collected himself for a moment, then emphasizing the words resumed: "We have achieved the disintegration of the atom. We have the disintegration bomb whose effects are beyond all human imagination..." [...]

At the end of his long monologue, Naumann came to talk about the "V-2," "V-3," and "V-4," pointing out that the last two types, to be followed by three more, were radio-controlled and therefore precise. I also obtained the promise of a visit to the underground factories and his support, with Goebbels, that I could witness a test of the disintegration bomb which was to take place within days on an island in the Baltic. [...]

On 10 October 1944, I was warned to be ready to leave for the north.

I left Berlin on the night of the 11th by car; two officers accompanied me, one of whom told me that on my return I would be received by Goebbels.

Avevo passato quasi tutta la serata nel rifugio dell'albergo Adlon. Mi era rimasta negli orecchi la voce di un altoparlante che nel corso del bombardamento diceva ai berlinesi dove erano cadute le bombe, il numero degli apparecchi incursori e le località in cui si erano sviluppati incendi. Molti, ancora prima di lasciare il rifugio, sapevano che all'uscita non avrebbero più trovato la casa. Viaggiammo per diverse ore nel buio umido che s'incollava ai vetri come nebbia. Pareva che sui vetri della macchina invece di nebbia colasse buio. Solo alla fine del viaggio seppi che mi trovavo nei pressi di Stralsund, davanti all'isola di Rugen che raggiungemmo con un motoscafo della marina militare.

Rügen era un centro d'esperimenti dove venivano collaudate le nuove armi germaniche. Speciali reparti di truppe d'assalto proteggevano l'isola e ne impedivano l'accesso a chiunque. Per recarsi a Rugen occorreva un salvacondotto a firma del capo dello stato maggiore della Wehrmacht. Ci recammo subito in una zona folta di alberi dove trovammo altri ufficiali e alcuni tecnici. Nel bosco erano stati costruiti rifugi in cemento e piccole case in mattoni. Entrammo in una torretta blindata, semisepolta, attraverso una porticina metallica che venne richiusa con ogni cura. Dentro eravamo in quattro: i due ufficiali che mi avevano accompagnato, un altro uomo vestito di una tuta e io. Aspettavo mezzogiorno col cuore in gola. A mezzogiorno, secondo quanto aveva detto l'uomo in tuta, ci sarebbe stato l'esperimento della "bomba disgregatrice".

La bomba doveva scoppiare a terra, a due chilometri circa dal nostro osservatorio blindato.

I had spent most of the evening in the bomb shelter of the Adlon Hotel. In my ears remained the voice of a loudspeaker, telling Berliners during the bombing where the bombs had fallen, the number of bomber formations, and the locations where fires had broken out. Many people, even before they left the shelter, knew that they would never see their homes again. We traveled for several hours in the damp darkness that stuck to the windows like fog. It seemed that instead of fog, darkness was dripping onto the car windows. Only at the end of the trip did I learn that I was near Stralsund, in front of the island of Rügen, which we reached by a navy speedboat.

Rügen was an experimental center where the new German weapons were tested. Special units of assault troops protected the island and restricted access. To travel to [part of] Rügen required a safe-conduct pass signed by the Wehrmacht's chief of staff. We immediately went to an area thick with trees where we found other officers and some technicians. Concrete shelters and small brick buildings had been built in the woods. We entered an armored, half-buried turret through a small metal door that was closed with every precaution. Inside there were four of us: the two officers who had accompanied me, another man dressed in a suit, and me. I waited for noon with my heart in my throat. At noon, according to what the man in the suit had said, there would be the test of the "disintegration bomb."

The bomb was to explode on the ground, about two kilometers from our armored observatory.

Il tempo non passava mai; i minuti erano ore. Aveva ripreso a piovere e una fumana densa saliva dal sottobosco. La terra, davanti a noi, era marcia e scura, color del saio dei monaci. Squillò un telefono nell'interno del bunker. Avvertirono che l'esperimento era stato anticipato alle 11,45. Mancavano perciò cinque minuti. Feci appena in tempo a consultare l'orologio che sentii un boato tremendo. Il pavimento mi dondolò sotto i piedi e per un istante mi parve che le pareti del rifugio si chiudessero. Davanti non vedevo che fumo, un fumo biancastro, lanoso, che ribolliva come la melma vomitata da una fogna. Si sentirono altri scoppi seguiti da lampi accecanti. Il cielo, tetro e chiuso, era stracciato da lampi bianchissimi. Mi passai una mano sulla faccia, sudavo. Nessuno aprì bocca. Al boato di poc'anzi seguì un silenzio che metteva i brividi. Fu l'uomo in tuta che parlò per primo. Era un colonnello dell'"Heereswaffenamt", l'organo addetto alla preparazione degli armamenti. "Quello che vedremo oggi—disse—è di capitale importanza. Quando potremo lanciare la nostra bomba sulle truppe d'invasione o su una città nemica gli angloamericani saranno costretti a meditare se valga la pena di continuare la guerra o di finirla ragionevolmente. Sono anni che studiamo. Siamo finalmente arrivati in porto". Le sue parole caddero nel silenzio. Lo ascoltavamo tutti con gli occhi.

Time did not pass; the minutes were hours. It had started raining again and a dense fog was rising from the undergrowth. The ground in front of us was rotten and dark, the color of monks' robes. A telephone rang inside the bunker. They warned that the test had been brought forward to 11:45 a.m. It was therefore five minutes away. I barely had time to consult the clock when I heard a tremendous roar. The floor rocked under my feet, and for an instant it seemed to me as if the walls of the shelter were falling in. In front I could see nothing but smoke, a whitish, woolly smoke that bubbled up like slime spewed from a sewer. More bursts were heard followed by blinding flashes. The sky, bleak and closed, was ripped apart by the whitest flashes of lightning. I ran a hand over my face; I was sweating. No one opened their mouth. The roar just then was followed by a chilling silence. It was the man in the suit who spoke first. He was a colonel in the "Heereswaffenamt" [Army Ordnance Office], the body in charge of developing weapons. "What we witness today—he said—is of paramount importance. When we can drop our bomb on invading troops or on an enemy city, the Anglo-Americans will be forced to decide whether it is worth continuing the war or ending it reasonably. We have been working for years. We have finally achieved our objective." His words fell into silence. We all listened to him with our eyes.

Uscimmo dal bunker verso la diciassette, dopo che erano arrivati alcuni uomini vestiti di una tuta mostruosa; in testa portavano uno scafandro del tipo di quello dei palombari, soltanto che era floscio e non aveva viti. Anche noi indossammo uno strano camiciotto di stoffa ruvida, bianchiccia e pantaloni dello stesso tessuto. Camminammo preceduti dai soldati. A mano a mano che avanzavamo la terra ci appariva sconvolta, arata, straziata da paurose voragini. Faceva freddo eppure tutto era arso come se fosse passata sull'isola una ventata di fuoco. Gli alberi non avevano più chioma nè rami; erano ridotti a tronconi abbrustoliti. Col piede urtai qualcosa; mi abbassai e vidi una capra carbonizzata. Si capiva che era una capra perché sulla carne strinata si vedevano ciuffi di peli; aveva la testa schiacciata, come pestata col martello. Le casette di pietra, erano mucchi di calcinacci. Solo le torrette in cemento armato avevano resistito. Qualche capra moribonda belava in maniera disperata; pareva il lamento di un uomo.

In nottata rientrai a Berlino. Alla fine di ottobre vidi Goebbels. Passai una serata nella sua casa e seppi la lui altre cose che Neumann non mi aveva detto. Seppi che esistevano altri due tipi di razzi, l'"A 4" e l'"A 9", uno di dieci tonnellate e l'altro di quindici, muniti di cariche atomiche, dotati di un'autonomia fantastica. Goebbels parlò di alcune migliaia di chilometri e aggiunse che con quei missili la Germania avrebbe bombardato anche l'America. Per il piccolo, claudicante ministro della propaganda che fu l'anima della Germania in guerra, occorrevano sei o sette mesi prima che il suo paese fosse in grado di sferrare un'offensiva che lui stesso, allora, definì infernale.

[...] Nel 1936 gli stessi tecnici, Walter Dornberger, Thiel e Wernher von Braun, inventore della "V 2", ora in America, impiantarono il centro di Peenemünde da cui uscirono tutte le bombe volanti, compreso l'"Aggregat 10", un razzo del peso di 65 tonnellate capace di volare per 5000 chilometri con il quale il Führer si riprometteva di martellare gli Stati Uniti.

We left the bunker around 5:00 p.m., after some men dressed in monstrous suits had arrived; on their heads they wore a helmet like that of a diving suit, only it was floppy and had no screws. We, too, wore a strange smock of rough, off-white cloth and pants of the same fabric. We walked ahead of the soldiers. As we advanced, the land appeared to have been shocked, plowed, torn apart by fearful chasms. It was cold and yet everything was scorched as if a blast of fire had passed over the island. The trees no longer had foliage or branches; they were reduced to burnt trunks. My foot bumped into something; I bent down and saw a charred goat. You could tell it was a goat because tufts of hair could be seen on the streaked flesh; its head was crushed, as if it had been pounded with a hammer. The little stone buildings were piles of rubble. Only the concrete bunkers had been resistant. A few dying goats bleated desperately; it sounded like a man's lament.

During the night I returned to Berlin. At the end of October I saw Goebbels. I spent an evening at his house and from him learned other things that Naumann had not told me. I learned that there were two types of rockets, the "A-4" and the "A-9," one of ten tons and the other of fifteen, equipped with atomic warheads, with a fantastic range. Goebbels spoke of several thousand kilometers and added that with those missiles Germany would also bomb America. According to the little, limping propaganda minister who was the soul of Germany at war, it would take six or seven months before his country would be able to launch an offensive that he himself then defined as hellish.

[...] In 1936 the same technicians, Walter Dornberger, Thiel, and Wernher von Braun, inventor of the "V-2," now in America, established the Peenemünde center, from which came all the flying bombs, including the "Aggregat 10," a rocket weighing 65 tons capable of flying 5,000 kilometers, with which the Führer vowed to hammer the United States.

[Romersa misspelled the name of Goebbels' undersecretary Werner Naumann as "Neumann." I have corrected the spelling here.

A French translation of Romersa's *Civiltà delle Macchine* article was published as:

> Luigi Romersa. J'ai Vu Exploser La Bombe Atomique de Hitler!
> *Paris-Presse L'Intransigeant*. 19 November 1955 p. 14.

In 1984, Romersa repeated his claims in a Spanish article:

> Luigi Romersa. August-September 1984. Las "Armas Secretas" de Hitler,
> algo más que fantasía. *Defensa* No. 76–77.

He continued to make the same claims for the rest of his life, as shown by:

> Luigi Romersa. 2005. *Le Armi Segrete di Hitler*. Milan: Mursia.

and the following article.]

John Hooper. 30 September 2005. Author fuels row over Hitler's bomb. *The Guardian.* [https://www.theguardian.com/world/2005/sep/30/books.italy]

Mr Romersa [...] lives today in an elegant flat in the Parioli district of Rome. His study walls are covered with photographs from a career during which he interviewed many of the major figures of the 20th century, from Chiang Kai-shek to Lyndon Johnson. Though he suffers from some ill-health these days, he is still lucid and articulate.

He told the *Guardian* how, in September 1944, Italy's wartime dictator, Benito Mussolini, had summoned him to the town of Salo to entrust him with a special mission. Mussolini was then leader of the Nazi-installed government of northern Italy and Mr Romersa was a 27 year-old war correspondent for *Corriere della Sera.*

Mr Romersa said that when Mussolini had met Hitler earlier in the conflict, the Nazi dictator had alluded to Germany's development of weapons capable of reversing the course of the war. "Mussolini said to me: 'I want to know more about these weapons. I asked Hitler but he was unforthcoming'."

Mussolini provided him with letters of introduction to both Josef Goebbels, the Nazi propaganda chief, and Hitler himself. After meeting both men in Germany, he was shown around the Nazis' top-secret weapons plant at Peenemünde and then, on the morning of October 12 1944, taken to what is now the holiday island of Rügen, just off the German coast, where he watched the detonation of what his hosts called a "disintegration bomb".

"They took me to a concrete bunker with an aperture of exceptionally thick glass. At a certain moment, the news came through that detonation was imminent," he said. "There was a slight tremor in the bunker; a sudden, blinding flash, and then a thick cloud of smoke. It took the shape of a column and then that of a big flower.

"The officials there told me we had to remain in the bunker for several hours because of the effects of the bomb. When we eventually left, they made us put on a sort of coat and trousers which seemed to me to be made of asbestos and we went to the scene of the explosion, which was about one and a half kilometres away.

"The effects were tragic. The trees around had been turned to carbon. No leaves. Nothing alive. There were some animals—sheep—in the area and they too had been burnt to cinders."

On his return to Italy, Mr Romersa briefed Mussolini on his visit. In the 1950s, he published a fuller account of his experiences in the magazine *Oggi.* But, he said, "everyone said I was mad".

2004 testimony of Elisabeth Mestlin, as described by Wolfgang Ebsen [Karlsch and Petermann 2007, p. 163]

Sie erinnerte sich aufgrund glaubwürdiger Umstände genau an das außergewöhnliche Ereignis. Frau Mestlin fuhr nach der Bombardierung von Stralsund am 6. Oktober 1944 zu ihren Kindern nach Vitte auf der Insel Hiddensee. Auf der Insel Hiddensee hörte sie am 12. Oktober 1944 eine heftige Explosion und sah eine große Staubwolke an der Südspitze der Halbinsel Bug.	She remembered the extraordinary event because of credible circumstances. After the bombardment of Stralsund on 6 October 1944, Ms. Mestlin went to see her children in Vitte on the island of Hiddensee. On the island of Hiddensee on 12 October 1944, she heard a violent explosion and saw a large cloud of dust on the southern tip of the Bug peninsula.
Interview mit Elisabeth Mestlin vom 5.10.2004, aufgezeichnet von Lutz Riemann, ausgestrahlt vom NDR am 13.3.2005.	Interview with Elisabeth Mestlin from 5 October 2004, recorded by Lutz Riemann, broadcast by NDR on 13 March 2005.

[In some sources, Elisabeth Mestlin's name is given as Ilse Menslin.

Bug is a peninsula on the northwestern side of Rügen island. During the war, it was used as a German naval base. It is geographically rather isolated from the rest of Rügen and from the Baltic coastline of Germany. Because of its relative isolation and its highly secure military status, it would have been a good location for atomic bomb development and/or testing. It is known that new types of bombs were tested in that area [e.g., Stüwe 1999, pp. 451, 461]. Advanced scientific testing was conducted at other locations on the Baltic coast of Germany—virology at Riems island, rockets and jets at Peenemünde, radar on the German-occupied Danish island of Bornholm off the coast, etc.

Vitte is the main village on Hiddensee island. It is approximately 3 km west of the southern tip of the Bug peninsula. It would be reasonable to expect a large explosion on Bug to be audible and visible from the eastern ocean side of Vitte.]

Heinrich Himmler's chief adjutant Werner Grothmann on test explosions [Krotzky 2002]. For a discussion of the background and reliability of this source, see pp. 3396–3397.

[S. 31] Also, es ist so: Mir ist bekannt, dass es vier Atomversuche gab. Der erste noch 1943 im Herbst in der Nordsee, der ist gescheitert. Dann zwei 1944 im Herbst und im Spätherbst. Einer davon am Boden, also auf einem niedrigen Gestell, der spätere in der Atmosphäre am Fallschirm. Der im Winter 1944 in der Luft war brisant und die Ladung war auch größer. Das könnte im November gewesen sein. Der letzte Versuch war dann wieder mit kleiner Ladung im März 1945. Wo die Versuche waren, möchte ich jetzt noch nicht sagen, weil sich sonst die Bevölkerung unnötig aufregen würde.

[p. 31] Well, it is so: It is known to me that there were four atomic tests. The first still in 1943 in the autumn in the North Sea, which failed. Then two in 1944 in the autumn and the late autumn. One of them on the ground, that is on a small stand, the later one in the atmosphere on a parachute. That one in winter 1944 in the air was highly explosive and the charge [fuel] was also larger. That could have been in November. The last test was then again with a small charge in March 1945. Where the tests were I would like to not say now, because otherwise the population would be unnecessarily upset.

[S. 32] Ich kann aber mit Bestimmtheit erklären, dass mir von sechs Atombomben berichtet wurde, die aus drei verschiedenen Forschungsanlagen stammten. Alle waren Prototypen. Darüber hinaus gab es einige Kleinstkörper, die für die Laborversuche vorgesehen waren. Für den Versuch im Winter 1944 ist allerdings eine größere Ladung verwendet worden, wie ich ja schon sagte.

[p. 32] I can definitely declare that I was told of six atomic bombs that came from three different research installations. All were prototypes. In addition, there were some very small devices that were intended for laboratory experiments. For the experiment in the winter of 1944, a larger charge was indeed used, as I already told you.

[S. 13] Als im Oktober 1944 klar war, dass die Theorie zur Atombombe grundsätzlich stimmt, ist in verschiedenen Kreisen natürlich auch darüber nachgedacht worden, was man dann machen sollte, um den Krieg schnellsten zu beenden.

[p. 13] When, in October 1944, it was clear that the theory of the atomic bomb was in principle correct, various circles had, of course, also been thinking about what should be done to end the war as quickly as possible.

[S. 17] Ich möchte aber mal etwas zu dem Hintergrund sagen, warum Himmler nicht zu dem Atombombentest am vierten März nach Thüringen gekommen ist.

[p. 17] But I would like to say something about the background, why Himmler did not come to Thuringia for the atomic bomb test on the fourth of March.

[S. 40] Dieser Versuch sollte den Beweis bringen, dass das Zündsystem stabil arbeitet und der Vorbereitung eines entsprechenden Angriffs dienen, der mit einer Rakete geflogen werden sollte.

[p. 40] This test was to provide proof that the ignition system worked stably and to serve as preparation for a corresponding attack that was supposed to be flown with a rocket.

[S. 40] Das sind aber alles Projekte gewesen, wo die Industrie auf die eine oder andere Weise beteiligt war. Ob die Facharbeiter stellten, oder ihre spezielle technische Kompetenz. Natürlich lieferten die auch Einzelstücke oder Bauteile für Prototypen oder für die Versuche. Das war ja kein Problem, weil man einem Metallstück ja nicht ansieht, für welchen Zweck es gebraucht wird. Sehen Sie, das ging soweit, dass das Gestell für unseren Atomversuch in Thüringen von einer Schlosserei aus Thüringen hergestellt wurde. Ich weiß es deshalb, weil, als man sich dort traf, Diebner auf die Frage von jemandem, ob den unsere Leute gebaut hätten erklärte, der wäre von einer Schlosserei aus der Gegend. Die hätten ja nicht erfahren, wofür der gedacht war.

Der Versuch ist gerade dort durchgeführt worden, obwohl das ja in bewohntem Gebiet liegt, weil wir durch den Kriegsverlauf nicht mehr viel Auswahl hatten und natürlich, weil ja auch die Zeit drängte. Also sind wir gleich dort geblieben, wo auch das erforderliche Material erzeugt und auch gelagert worden war. Außerdem hatten hier unsere Leute und die von Diebners anderer Gruppe ihre Labors und die Entwicklungsabteilung. Und hier in der Nähe war ja auch die Serienproduktion der Uran-Bombe geplant gewesen. Außerdem sollte Anfang Januar die Zünderfertigung oder zumindest die Entwicklung eines für die Uran-Bombe vorgesehenen Zündsystems nach meiner Erinnerung ebenfalls hierher verlagert werden. Das war aber in einem aufgelassenen Bergwerk untergebracht, nicht in einer der Anlagen vor Ort. Diebner hatte angeblich, versichert, die Sprengwirkung wäre bei der geringen Menge, die der Versuch kosten würde, ganz gering. Leider hat sich seine Vorhersage aber nicht bestätigt. Das was da geschehen ist, war scheußlich. Außerdem hat es in der Umgebung noch Folgen gegeben, wobei ich nur hörte, dass Ärzte, die bei uns unter Vertrag standen, dort eingesetzt werden mussten.

[p. 40] But these were all projects where industry was involved in one way or another. Whether the skilled workers were placed, or their special technical competence. Of course, they also supplied individual pieces or components for prototypes or for the tests. That was not a problem, because one cannot tell from a piece of metal for what purpose it is needed. You see, that went so far that the stand for our atom test in Thuringia was manufactured by a metalworking shop in Thuringia. I know it because when meeting there, Diebner explained, in response to someone's question about whether our people had built it, it was from a metalworking shop from the area. They would not have known what it was meant for.

The test was carried out directly there, even though that was in an inhabited area, because due to the course of the war we did not have a lot of choice and, of course, because time was also critical. So we just stayed where the necessary material was produced and stored. In addition, our people and those of Diebner's other group had their laboratories and the development department. And here close by, too, the mass production of uranium bombs had been planned. In addition, at the beginning of January, the ignition [system] production or at least the development of an ignition system intended for the uranium bomb was likewise supposed to be relocated here, according to my memory. But this was placed in an abandoned mine, not in one of the facilities on site. Diebner allegedly assured that the explosive effect would be quite small for the small amount [of fuel] that the test would require. Unfortunately his prediction was not confirmed. What happened there was horrible. In addition, there were other consequences in the surrounding area, of which I only heard, that doctors, who were under contract with us, had to be deployed there.

[S. 13] Nach dem dritten Versuch, also das war dann der vom März in Thüringen, ist Hitler informiert worden. [...] Es war doch so, als der Versuch in Thüringen gelang, sind nach meiner Kenntnis unbeabsichtigt Arbeitskräfte aus einem Lager ums Leben gekommen. Die Leute, die bei dem Versuch dabei waren, hatten zum Teil größte Bedenken, ob man die Waffe einsetzen sollte, also ich meine, es war ja klar, dass im Einsatz nicht mit einem Testkörper operiert werden würde.

[p. 13] After the third attempt, which was the one from March in Thuringia, Hitler was informed. [...] It was like this: when the test in Thuringia succeeded, according to my understanding, workers from a camp died accidentally. The people involved in the test had some of the biggest concerns about using the weapon, I mean, it was clear that deployment would not involve an experimental device.

[S. 43] Was bleibt, sind die drei gelungenen Atomwaffenversuche, darunter ein größerer, ein Fehlschlag und ein Unfall.

[p. 43] What remains are the three successful atomic weapons tests, including a big one, a failure, and an accident.

[According to Grothmann, at least six prototype atomic bombs were produced at at least three different facilities. Of those, at least four were detonated in test explosions:

1. A test in autumn 1943 in the North Sea that failed. Grothmann provided no other details, and little information is available from other public sources. (For some possibly related sources, see pp. 4404, 5011, 5034.) Elsewhere, Grothmann stated that fission fuel was very scarce even in 1944–1945 and that the implosion system was not perfected until 1944. Although it is very surprising that a test would even be attempted in 1943, either or both of those problems could have easily caused the failure.

2. A test in the first half of October 1944 at a location that Grothmann refused to name for fear of public reaction. The bomb was on a low stand or holder, and its explosion successfully demonstrated the principles of the device. This information is consistent with statements from Rudolf Zinsser (p. 4408), Luigi Romersa (pp. 4427–4434), Elisabeth Mestlin (p. 4435), and other sources, who described a test explosion on the Baltic coast, possibly on Rügen island, on approximately 12 October 1944. That area of the Baltic coast has long been a popular tourist destination for people from all of Germany and beyond, which may explain Grothmann's reluctance to name the location.

3. A test during or around November 1944 at another location that Grothmann refused to name for fear of public reaction. That bomb was suspended from a parachute (presumably after having been dropped by a large aircraft), contained more fission fuel, and had a larger explosive yield. This information is consistent with statements from Robert Jackson (p. 4458), Felix Kersten (p. 4470), Wilhelm Wulff (p. 4471), and other sources, who described a test explosion near Auschwitz, which was said to have occurred over a specially constructed concentration camp and its inmates. If that is true, both that specific war crime and the larger issue of war crimes at Auschwitz and elsewhere in Poland could explain why Grothmann would not name the location.

4. A test on 4 March 1945 in Thuringia. Although Grothmann did not name the specific location, he said the test occurred very close to the research installation, and he separately said the research installation was located at or adjacent to the Ohrdruf Truppenübungsplatz military base. According to Grothmann, the bomb was mounted on a test stand, used a smaller amount of fission fuel, and had a smaller explosive yield, but was intended to test an improved implosion system that would be light enough to be carried on a rocket. Nonetheless, the explosive yield was still larger than had been expected, killed a number of workers, contaminated the area, and necessitated the use of special doctors to treat local people who were affected by the “horrible” event. This description closely matches those given by Ivan Ilyichev (pp. 4481–4485), Oscar Koch (p. 4566), Cläre Werner (p. 4551), Heinz Wachsmut (p. 4557), and other sources.

Assuming that Grothmann did not overlook any tests or failures and that there were at least six bombs as he stated, at least two bombs remained at the end of the war. Grothmann reported that the United States captured at least one bomb (p. 5042).]

D.11 Possible ~November 1944 Test Explosion in Poland

[There may have been a test explosion in Poland in approximately November 1944, as reported by multiple sources:

- As already mentioned, a Top Secret U.S. cable from March 1946 stated that a "capable young engineer" in Poland knew that atomic bomb casings included a layer of cadmium, which was true for the implosion bomb designs described by both Ilyichev and Schumann (p. 4255). The Polish engineer's knowledge suggests that German-run industry in wartime Poland was involved in developing and/or testing an atomic bomb.
- Robert Jackson, chief U.S. prosecutor at the Nuremberg trials, stated on 21 June 1946 that he had received evidence that a new bomb design producing very intense heat had killed 20,000 Jewish prisoners in a specially constructed test village near Auschwitz (p. 4458).
- In August 1946, a FIAT intelligence document mentioned that there had been a number of unconfirmed reports that "about Christmas 1944, successful experiments were conducted in Pomerania with V-1 and atomic warheads, radio directed. The ensuing crater was 2 km in diameter" (p. 4460). There was also an August 1944 report of nuclear weapons development work in Pomerania (p. 4396).
- In December 1946, Otto Hahn said that there had been rumors that "atom bomb tests had been carried out in Poland during the last year of the war which were supposed to have had an effect similar to the first atom bomb dropped on Hiroshima though on a considerably smaller scale" (p. 4460).
- Gezo Mansfeldt, a survivor of Auschwitz, reported in December 1946 that he was frequently interrogated by Soviet officials about high-security wartime production work at Auschwitz and that he "learned of the atomic bomb tests" (p. 4463).
- A 1947 U.S. intelligence report stated that the Germans built a heavy water production plant near Auschwitz and that it was removed by the Soviets (p. 4463). Heavy water would only be useful for nuclear work, and the production of heavy water near Auschwitz suggests the presence of other nuclear work in Poland.
- Another 1947 intelligence report discussed wartime nuclear weapons work at Tucheler Heide in Poland, including the production of ^{235}U and ^{239}Pu and apparently even 1–5 kg fission pits for atomic bombs (p. 4902).
- In 1947, Heinrich Himmler's physical therapist, Felix Kersten, stated that Franz Göring, a senior SS security official, had told him that a new bomb design producing several thousand degrees of heat had killed 20,000 Jewish prisoners in a specially constructed test village near Auschwitz (p. 4470).
- Heinrich Himmler's personal astrologer, Wilhelm Wulff, confirmed that Franz Göring had stated that a new bomb design producing several thousand degrees of heat had killed 20,000 Jewish prisoners in a specially constructed test village near Auschwitz (p. 4471).
- Werner Grothmann stated that there was a successful atomic bomb test in or around November 1944 (p. 4436).

Some of the major sources and details are summarized in Table D.5.]

		Primary sources for ~November 1944 test							
		Polish engineer March 1946	**Jackson June 1946**	**Rumor cited by Hahn Dec. 1946**	**Mansfeldt Dec. 1946**	**Edmund Tilley August 1947**	**Kersten 1947**	**Wulff 1973**	**Grothmann 2000-2002**
Details	**Test date**	Prior to end of war (implied)	Late 1944?	~November 1944	Prior to January 1945	Prior to January 1945 (implied)	1944	1944	~November 1944
	Test location		Near Auschwitz	Somewhere in Poland	Associated with Auschwitz	Somewhere in Poland (implied)	Near Auschwitz	Near Auschwitz	Location would provoke negative public reaction [war crimes]
	People who were involved	German-run industry in Poland	SS	SS (implied)	SS	SS, I.G. Farben, German-run industry in Poland	SS	SS	SS, Himmler, Kammler, Gerlach, Post Office, Diebner, Flügge
	Blast		Immediately vaporized entire test village with 400-500°C [4000-5000°C?]	Like Hiroshima but smaller			Single burst of 6000°C incinerated entire test village	Explosion, heat of 6000°C incinerated entire test village in a flash	Highly explosive, ~3 kilotons?, detonated in air over test site
	Radio-activity	Atomic	Atomic	Like Hiroshima but smaller	Atomic	Nuclear fission	Atomic	Atomic	Nuclear fission
	Casu-alties		20,000 Jewish prisoners in specially constructed test village	Like Hiroshima but smaller			20,000 Jewish prisoners in specially constructed test village	20,000 Jewish prisoners in specially constructed test village	
	Device design	Atomic bomb with a layer of cadmium in the case	Newly invented atomic weapon of mass destruction	Atomic bomb	Atomic bomb	Atomic bomb with a 1-5 kg pit of U-235 or Pu-239	Atomic bomb detonated above the test site	Atomic bomb detonated above the test site	> 1 m dia. sphere Very heavy Aluminum case Larger amount of U-235 than other tests Ignition by special system Dropped over the test site on a parachute

Table D.5: Details about possible ~November 1944 test explosion from primary sources.

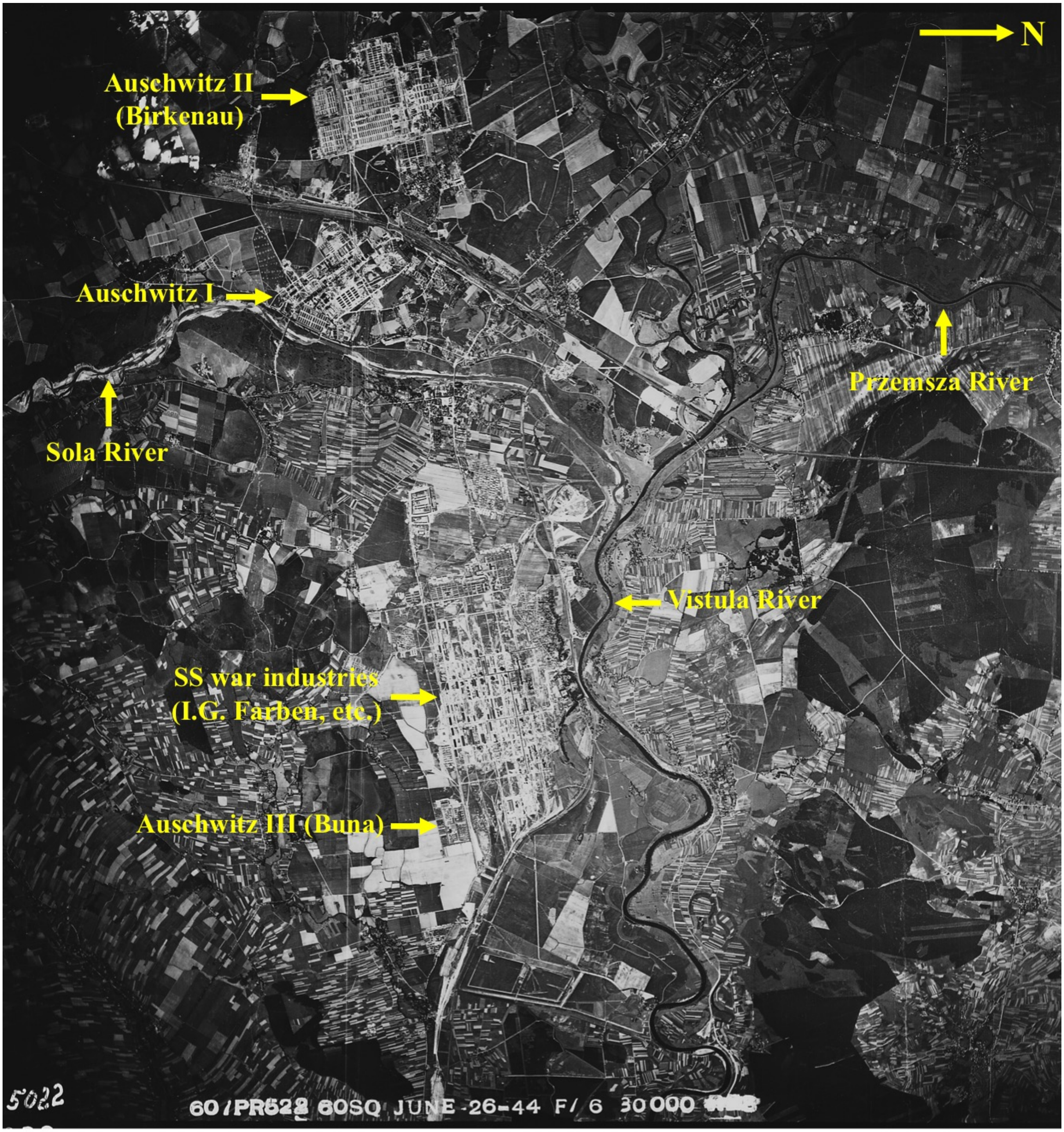

N
Auschwitz II
(Birkenau)
Auschwitz I
Sola River
Przemsza River
Vistula River
SS war industries
(I.G. Farben, etc.)
Auschwitz III (Buna)
5022
60/PR522 60SQ JUNE-26-44 F/6 30000

Figure D.678: U.S. aerial surveillance photo of Auschwitz on 26 June 1944, showing very large industrial installations built next to three rivers.

PW Intelligence Bulletin No. 2/25. 9 January 1945. [AFHRA folder 506.61952 Nos. 2/25–2/31 9–25 Jan 1945, IRIS 207531; AFHRA A5186 frames 0023–0027]

[See document photos on pp. 4445–4449.]

[...]

PW INTELLIGENCE BULLETIN No. 2/25

21. Bunawerke MONOWITZ nr AUSCHWITZ

See ANNEXES I and II.

Preamble. PW, a Slovak, was drafted into the Slovakian labor service 15 April 43 and sent to a guard coy in AUSCHWITZ. After three days black SS uniforms were issued the coy. PW remained there until July 44.

Location. The factory, commonly known as Bunawerke MONOWITZ, houses the two firms BUNA and IG FARBEN. Completely underground, it can nevertheless be located easily by six large wooden barracks, used as quarters for foremen and head mechanics, and situated atop a hill.

Personnel. Employed in the factory are appr 30,000 workers, all political prisoners whose work is supervised by SS guards. The workers—Poles, Russians, Czechs, and Jews—march to and from the factory from the nearby concentration camp at AUSCHWITZ, where a total of 680,000 prisoners are detained. There are two shifts, 0600 to 1800 and 1800 to 0600.

Products. Synthetic rubber products and Flak guns are turned out in the BUNA section. Although never inside the factory, PW has seen tanks (believed to be Tiger IIs) being taken from the factory grounds by rail.

PW does not know what is manufactured by the IG FARBEN section of the factory, but he saw the name on some of the barracks and on papers.

Guards. A total of 37 guard towers are situated at irregular intervals around the area. Every second tower has one machine gun. Encircling the area is electrically-charged wire fencing four meters high, run in 2 rows three meters apart. The area is flood-lighted at night.

Rubber Plants. There are appr 35 sq km of fields covered with rubber plants brought from RUSSIA. The fields and plants are maintained entirely by Russian civilians. The plants are used in the manufacture of rubber product.

LEGEND FOR ANNEX I (ITEM 21)

1. DAW uniform factory.
2. AUSCHWITZ concentration camp, containing 30,000 prisoners.
3. GUSTLO shell factory (connected with BUNA), employing 1,500.
4. BUNA underground factory (See ANNEX II).
5. Supply and ordnance depot.

6. "REISKO" Jail for women, with 275 prisoners.
7. BUNA synthetic rubber laboratory.
8. Same as 7.
9. Shed for storage of plants used for rubber production.
10. Concentration Camp BIRKENAU I. 150,000 prisoners, Jews of all nationalities.
11. Salvage dump for planes. [...]
12. Barracks for RR police.
13. Power distribution plant.
14. Flour mill.

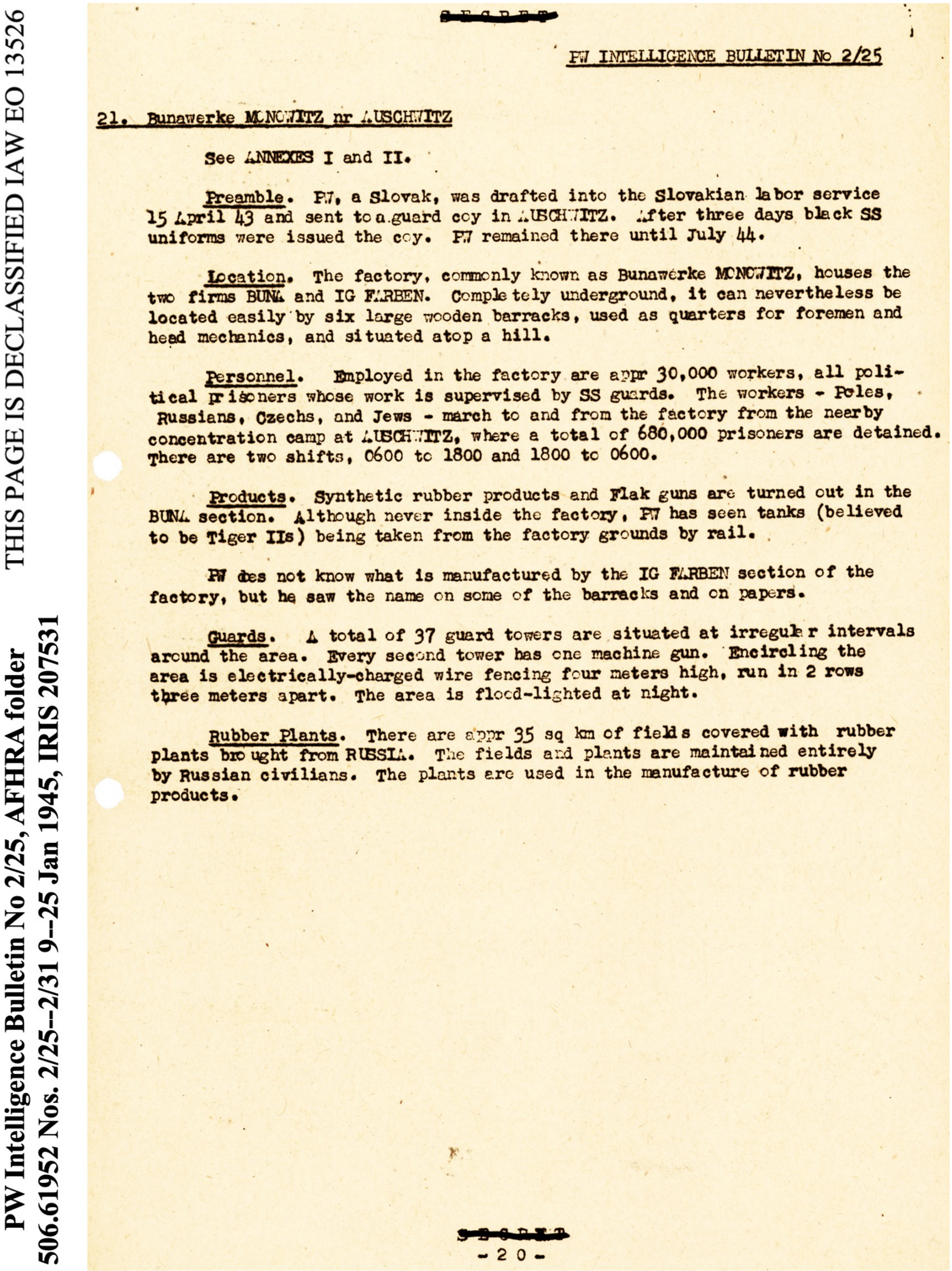
    [...] 15. PW believes a new plant was under construction here. Circles indicate reservoir-like concrete pits 8 m in diameter.

    16. Incomplete concrete foundations 6-7 m in diameter.

LEGEND FOR ANNEX II

1. Main entrance to area, with iron gate.
2. Second entrance.
3. Section of guard towers (37 encircle the factory area. Every other one contains LMG. Dimension: 2 m x 2 m x 10 m).
4. Air-raid shelters.
5. Entrance guard booth.
6. Cistern. (PW is not sure of contents, probably liquid rubber (?)).
7. Three ventillation towers, appr. 10 m high and 1 m in diameter.
8. Tower appr 7 m high and 4 m in diameter. Has been observed emitting steam.
9. Tower appr 8 m high and 1 m wide. Has been observed emitting smoke.
10. Coal shed, 20 m x 30 m x 1 m.
11. Wooden barracks appr 30 m x 20 m x 5 m. Roofs camouflaged with paint and walls painted green. Windows in the roofs only. Barracks rest on cement foundations. Under each of these barracks is a subterranean hall housing the factory proper.
12. Electrified fence.

[...] Note: The factory grounds are completely grassed. There are heavy Flak installations throughout the area. Over the whole area are barrage balloons. PW does not know where the entrances to the actual underground factory are located.



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PW Intelligence Bulletin No 2/25, AFHRA folder 506.61952 Nos. 2/25--2/31 9--25 Jan 1945, IRIS 207531

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Rubber Plants. There are appr 35 sq km of fields covered with rubber plants brought from RUSSIA. The fields and plants are maintained entirely by Russian civilians. The plants are used in the manufacture of rubber products.

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Figure D.679: There was a very large and very secretive underground I.G. Farben factory near Auschwitz. PW Intelligence Bulletin No. 2/25. 9 January 1945 [AFHRA folder 506.61952 Nos. 2/25–2/31 9–25 Jan 1945, IRIS 207531; AFHRA A5186 frames 0023–0027].

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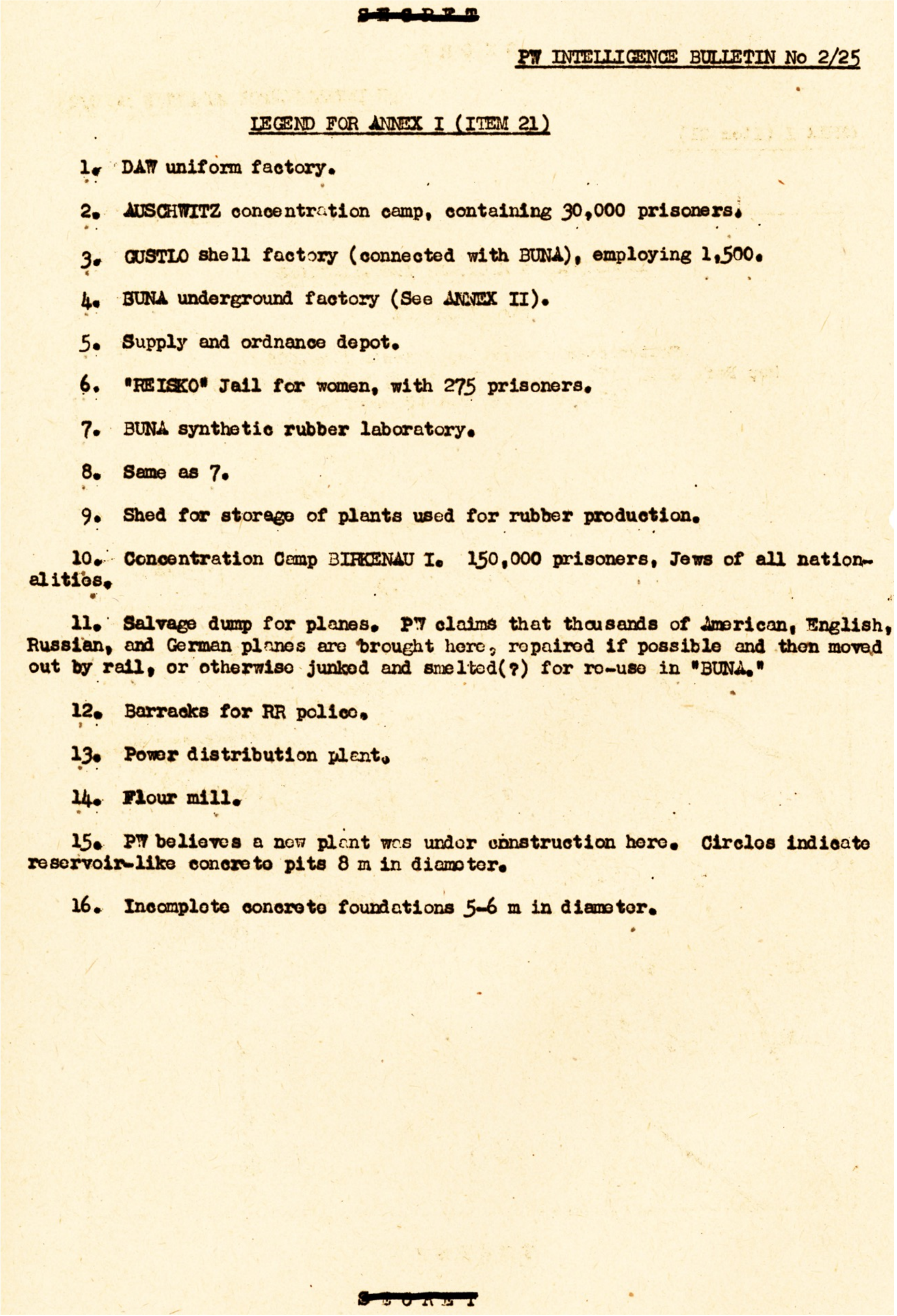

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PW INTELLIGENCE BULLETIN No 2/25

LEGEND FOR ANNEX I (ITEM 21)

1. DAW uniform factory.

2. AUSCHWITZ concentration camp, containing 30,000 prisoners.

3. GUSTLO shell factory (connected with BUNA), employing 1,500.

4. BUNA underground factory (See ANNEX II).

5. Supply and ordnance depot.

6. "REISKO" Jail for women, with 275 prisoners.

7. BUNA synthetic rubber laboratory.

8. Same as 7.

9. Shed for storage of plants used for rubber production.

10. Concentration Camp BIRKENAU I. 150,000 prisoners, Jews of all nationalities.

11. Salvage dump for planes. PW claims that thousands of American, English, Russian, and German planes are brought here, repaired if possible and then moved out by rail, or otherwise junked and smelted(?) for re-use in "BUNA."

12. Barracks for RR police.

13. Power distribution plant.

14. Flour mill.

15. PW believes a new plant was under construction here. Circles indicate reservoir-like concrete pits 8 m in diameter.

16. Incomplete concrete foundations 5-6 m in diameter.

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Figure D.680: There was a very large and very secretive underground I.G. Farben factory near Auschwitz. PW Intelligence Bulletin No. 2/25. 9 January 1945 [AFHRA folder 506.61952 Nos. 2/25–2/31 9–25 Jan 1945, IRIS 207531; AFHRA A5186 frames 0023–0027].

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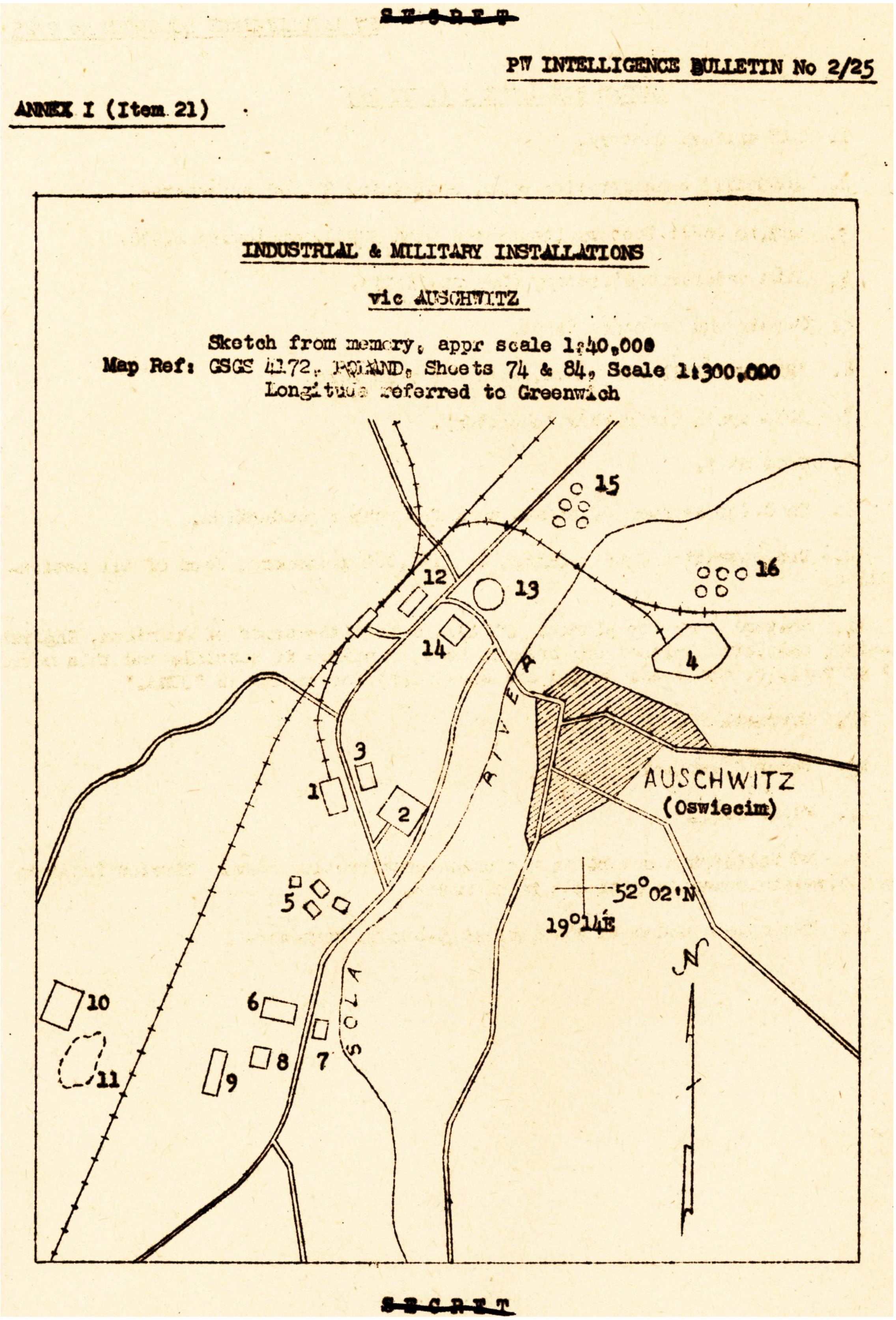

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PW INTELLIGENCE BULLETIN No 2/25

ANNEX I (Item 21)

INDUSTRIAL & MILITARY INSTALLATIONS

vic AUSCHWITZ

Sketch from memory, appr scale 1:40,000
Map Ref: GSGS 4172, POLAND, Sheets 74 & 84, Scale 1:300,000
Longitude referred to Greenwich

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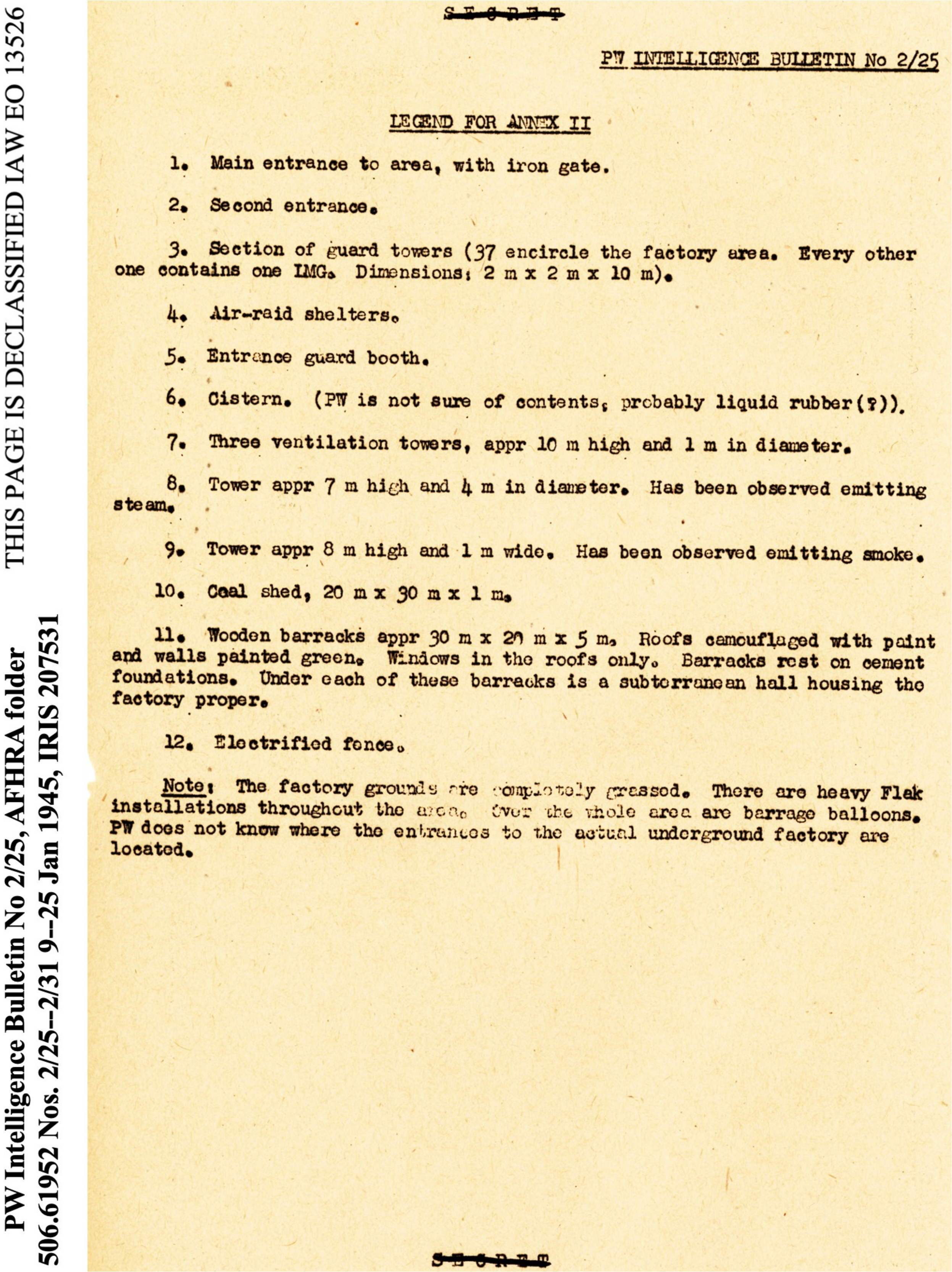
Figure D.681: There was a very large and very secretive underground I.G. Farben factory near Auschwitz. PW Intelligence Bulletin No. 2/25. 9 January 1945 [AFHRA folder 506.61952 Nos. 2/25–2/31 9–25 Jan 1945, IRIS 207531; AFHRA A5186 frames 0023–0027].



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PW Intelligence Bulletin No 2/25, AFHRA folder
506.61952 Nos. 2/25--2/31 9--25 Jan 1945, IRIS 207531

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PW INTELLIGENCE BULLETIN No 2/25

LEGEND FOR ANNEX II

1. Main entrance to area, with iron gate.

2. Second entrance.

3. Section of guard towers (37 encircle the factory area. Every other one contains one LMG. Dimensions: 2 m x 2 m x 10 m).

4. Air-raid shelters.

5. Entrance guard booth.

6. Cistern. (PW is not sure of contents, probably liquid rubber(?)).

7. Three ventilation towers, appr 10 m high and 1 m in diameter.

8. Tower appr 7 m high and 4 m in diameter. Has been observed emitting steam.

9. Tower appr 8 m high and 1 m wide. Has been observed emitting smoke.

10. Coal shed, 20 m x 30 m x 1 m.

11. Wooden barracks appr 30 m x 20 m x 5 m. Roofs camouflaged with paint and walls painted green. Windows in the roofs only. Barracks rest on cement foundations. Under each of these barracks is a subterranean hall housing the factory proper.

12. Electrified fence.

Note: The factory grounds are completely grassed. There are heavy Flak installations throughout the area. Over the whole area are barrage balloons. PW does not know where the entrances to the actual underground factory are located.

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Figure D.682: There was a very large and very secretive underground I.G. Farben factory near Auschwitz. PW Intelligence Bulletin No. 2/25. 9 January 1945 [AFHRA folder 506.61952 Nos. 2/25–2/31 9–25 Jan 1945, IRIS 207531; AFHRA A5186 frames 0023–0027].

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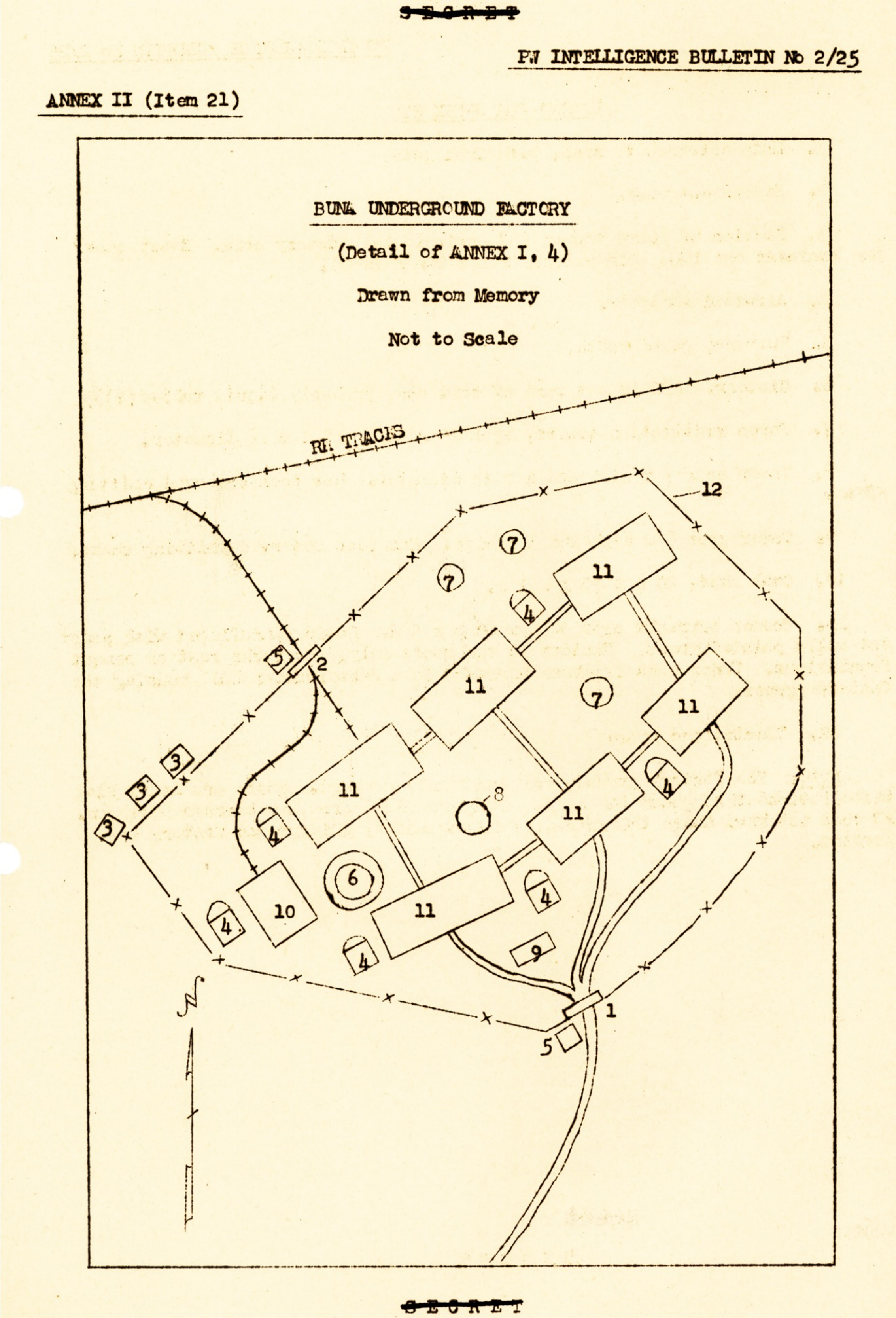

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PW INTELLIGENCE BULLETIN No 2/25

ANNEX II (Item 21)

BUNA UNDERGROUND FACTORY

(Detail of ANNEX I, 4)

Drawn from Memory

Not to Scale

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Figure D.683: There was a very large and very secretive underground I.G. Farben factory near Auschwitz. PW Intelligence Bulletin No. 2/25. 9 January 1945 [AFHRA folder 506.61952 Nos. 2/25–2/31 9–25 Jan 1945, IRIS 207531; AFHRA A5186 frames 0023–0027].

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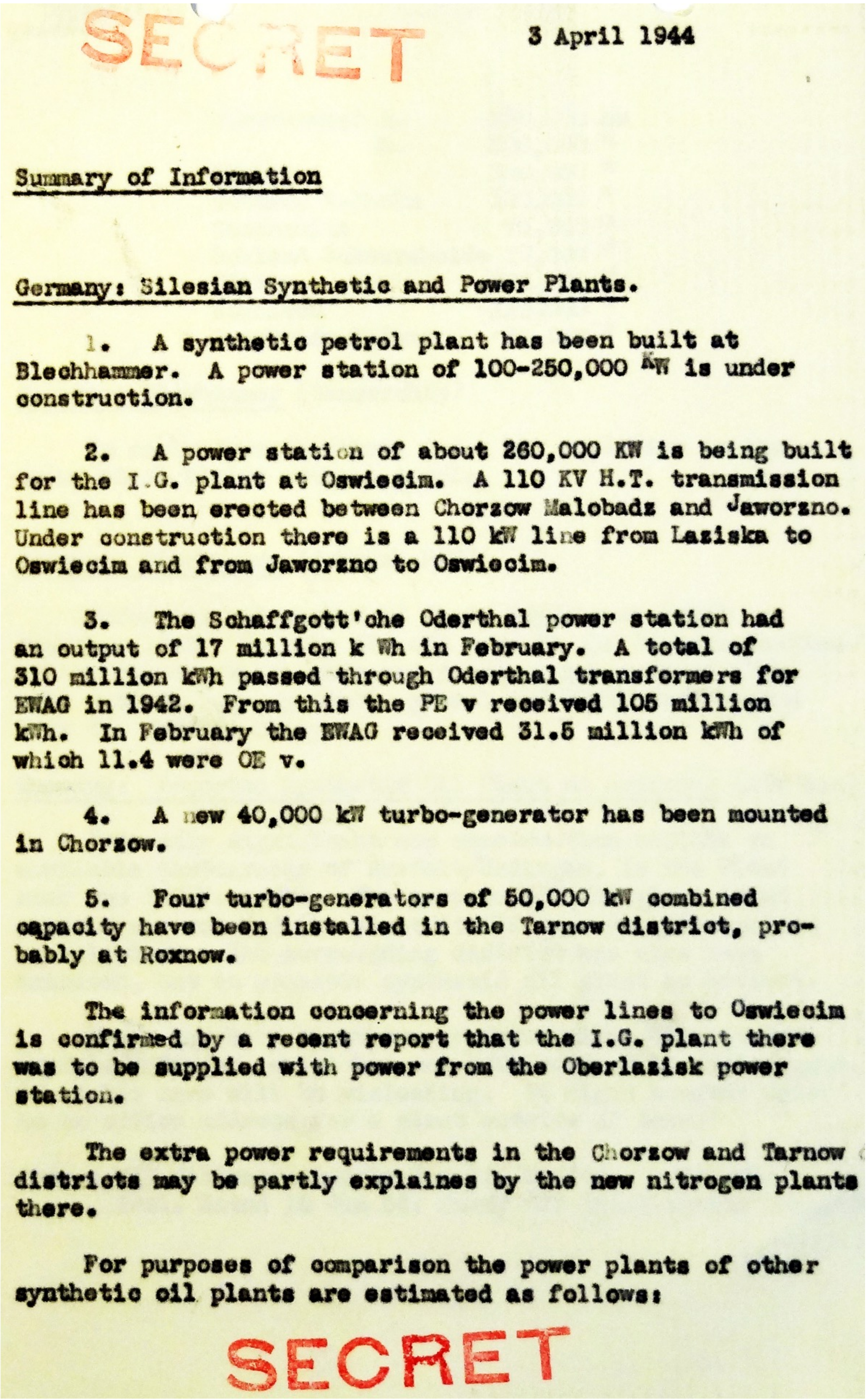
NARA RG 77, Entry UD-22A, Box 170,
Folder 32.60-1 GERMANY: Summary Reports (1944)



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3 April 1944

Summary of Information

Germany: Silesian Synthetic and Power Plants.

1. A synthetic petrol plant has been built at Blechhammer. A power station of 100-250,000 KW is under construction.

2. A power station of about 260,000 KW is being built for the I.G. plant at Oswiecim. A 110 KV H.T. transmission line has been erected between Chorzow Malobadz and Jaworzno. Under construction there is a 110 kW line from Laziska to Oswiecim and from Jaworzno to Oswiecim.

3. The Schaffgott'che Oderthal power station had an output of 17 million k Wh in February. A total of 310 million kWh passed through Oderthal transformers for EWAG in 1942. From this the PE v received 105 million kWh. In February the EWAG received 31.5 million kWh of which 11.4 were OE v.

4. A new 40,000 kW turbo-generator has been mounted in Chorzow.

5. Four turbo-generators of 50,000 kW combined capacity have been installed in the Tarnow district, probably at Roxnow.

The information concerning the power lines to Oswiecim is confirmed by a recent report that the I.G. plant there was to be supplied with power from the Oberlasisk power station.

The extra power requirements in the Chorzow and Tarnow districts may be partly explaines by the new nitrogen plants there.

For purposes of comparison the power plants of other synthetic oil plants are estimated as follows:

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Figure D.684: Examples of numerous power plants near Auschwitz. Summary of Information. 3 April 1944 [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

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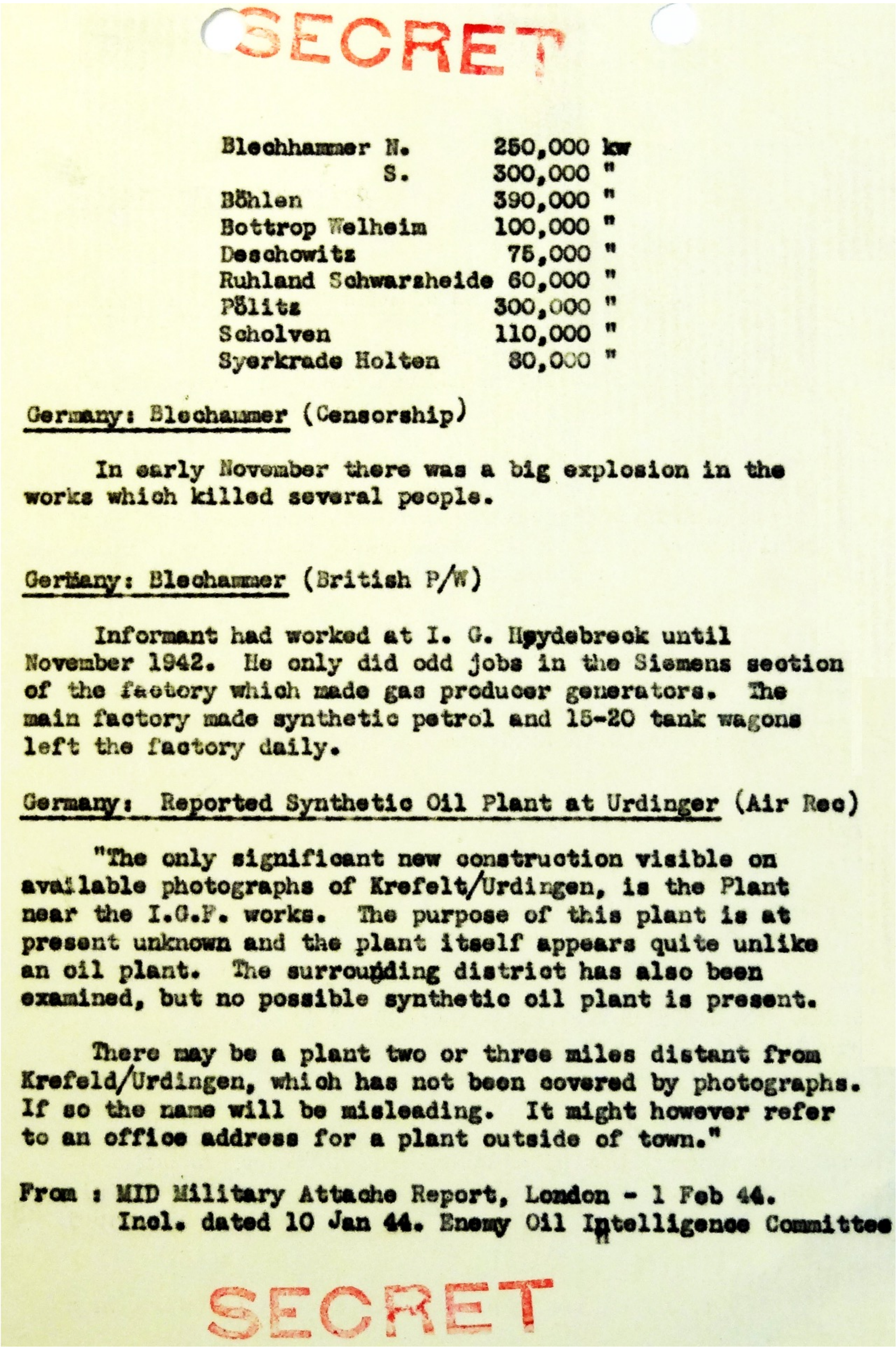

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Blechhammer N.	250,000 kw
S.	300,000 "
Böhlen	390,000 "
Bottrop Welheim	100,000 "
Deschowitz	75,000 "
Ruhland Schwarsheide	60,000 "
Pölitz	300,000 "
Scholven	110,000 "
Syerkrade Holten	80,000 "

Germany: Blechammer (Censorship)

In early November there was a big explosion in the works which killed several people.

Germany: Blechammer (British P/W)

Informant had worked at I. G. Heydebreck until November 1942. He only did odd jobs in the Siemens section of the factory which made gas producer generators. The main factory made synthetic petrol and 15-20 tank wagons left the factory daily.

Germany: Reported Synthetic Oil Plant at Urdinger (Air Rec)

"The only significant new construction visible on available photographs of Krefelt/Urdingen, is the Plant near the I.G.F. works. The purpose of this plant is at present unknown and the plant itself appears quite unlike an oil plant. The surrounding district has also been examined, but no possible synthetic oil plant is present.

There may be a plant two or three miles distant from Krefeld/Urdingen, which has not been covered by photographs. If so the name will be misleading. It might however refer to an office address for a plant outside of town."

From : MID Military Attache Report, London - 1 Feb 44.
Incl. dated 10 Jan 44. Enemy Oil Intelligence Committee

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NARA RG 77, Entry UD-22A, Box 170,
Folder 32.60-1 GERMANY: Summary Reports (1944)

Figure D.685: Examples of numerous power plants near Auschwitz. Summary of Information. 3 April 1944 [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

H. W. Dix to Francis Smith. Subject: Heavy Water. 26 December 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

This office has received the following comments from our Swedish people and it is dated 22 November 1944 and has a B-2 rating.

> Heavy water is manufactured primarily in Norway by I. G. at Norsk Hydro. However, manufacture in Germany at the Bayrische Stickstoffwerke in Piesteritz or Auschwitz is certainly a possibility.
>
> I have heard nothing about experiments with heavy water as an explosive. After all, that would be a case of splitting the atom!

Monthly Intelligence Summary. II Information on Possible TA Sites. January 1945. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

Report received from OSS Stockholm mentions the possibility that heavy water is being made in Germany at Piesteritz or Auschwitz at The Bayrische Stickstoffwerke, but the same source said he has heard nothing about heavy water in connection with an explosive. While coverage of these two towns has been requested, Auschwitz is in that part of Germany which is now in Russian hands.

Monthly Intelligence Summary. II Information on Possible TA Sites. February 1945. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

Reference Monthly Intelligence Summary, January 1945, II 5, page three. All available air coverage and Interpretation Reports of Auschwitz and Piesteritz have been obtained and forwarded to General Groves' office for further study.

U.S. Embassy, Warsaw. 12 August 1947. Report No. R-107-47, MIS-390731. Subject: Plants producing heavy water. [NARA RG 319, Entry 85A, Box 2534, Folder 390731–390740] [See document photo on p. 4454.]

1. It is believed that no plants designed specially for the production of heavy water exist in Poland. It is reliably reported that the Germans built one such plant near OSWIECIM (Auschwitz) but that it was destroyed or moved out by the SOVIETS in 1945.

2. A definite potentiality exists for the production of heavy hydrogen as a by-product of coal hydrogenation. There is believed to be small likelihood of the realization of this potential, since the Polish government insists on the complete orientation of industry toward the physical reconstruction of the country. [...]

[Heavy water would be of little use for anything other than nuclear work, specifically as a moderator for fission reactors. Because it was "reliably reported" that the Germans had built a heavy water production plant near Auschwitz and that the Soviets had removed, and that heavy water manufacturing was given such a high priority amid all the other war-related materials that urgently needed to be produced, these documents appear to confirm that the I.G. Farben and/or other installations at Auschwitz were (at least in part) manufacturing materials for a nuclear weapons program.]

BIOS 562. ***The German Phosphorus Industry at Bitterfeld & Piesteritz.*** **p. 41.**

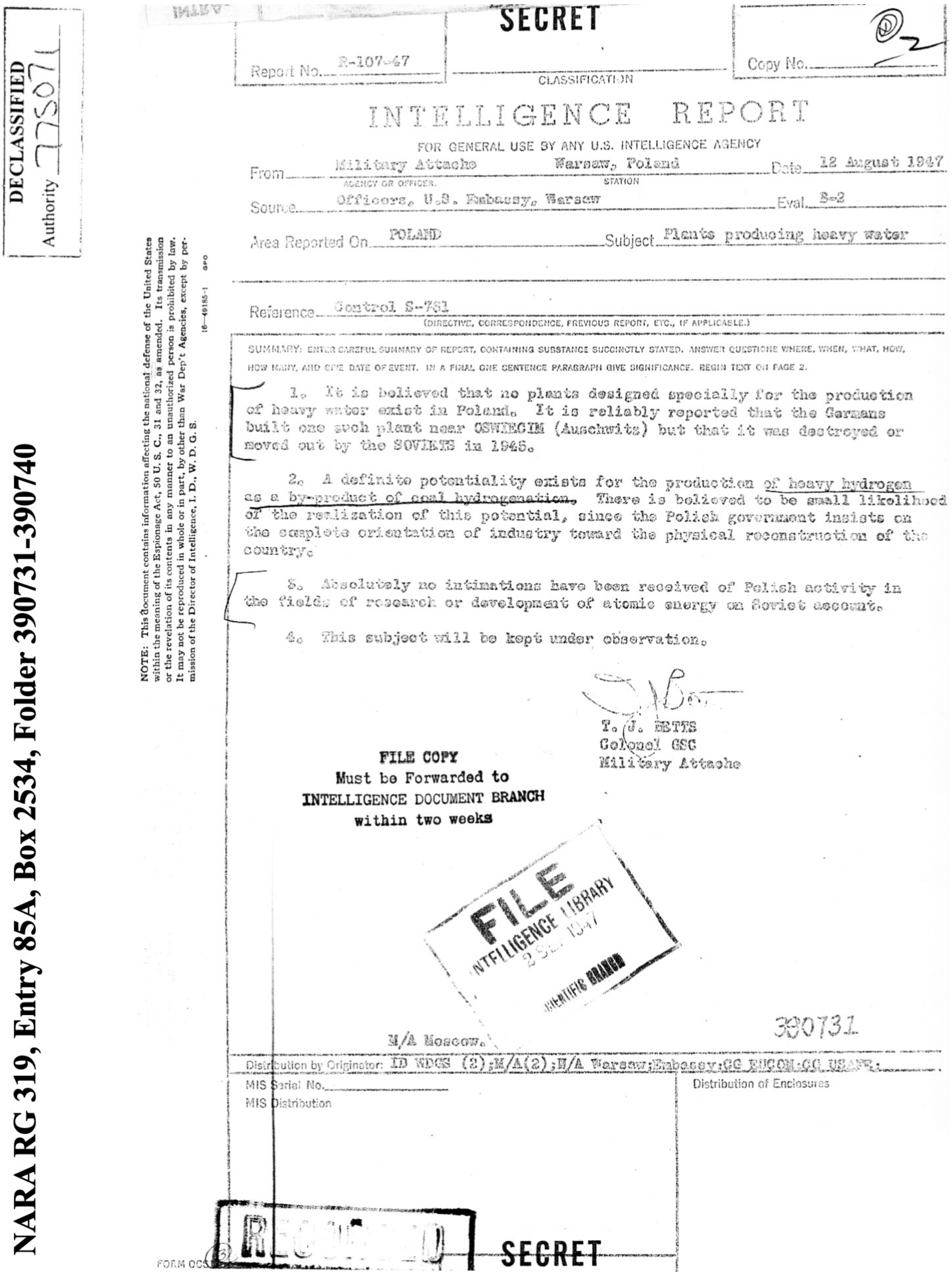
[Piesteritz]

The plant was well laid out and in excellent condition but at the time of inspection was partially dismantled. The whole of the dearsenicating equipment had been removed.

BIOS 889. ***Manufacture of Nitric Acid, Ammonium Nitrate and Fertilizers at Bitterfeld, Wolfen and Piesteritz.*** **p. 1.**

Little information however was obtained from Piesteritz. The plant for making nitric acid and ammonium phosphate had already been completely dismantled, for transfer to Russia. It is believed that information on these plants had been obtained earlier by American investigators.

[If there was any nuclear-related work (such as heavy water production) at Piesteritz, the Russians would have removed all evidence of that before other countries ever had a chance to see it.]



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INTELLIGENCE REPORT

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From Military Attache (AGENCY OR OFFICER) Warsaw, Poland (STATION) Date 12 August 1947

Source Officers, U.S. Embassy, Warsaw Eval. B-2

Area Reported On POLAND Subject Plants producing heavy water

Reference Control S-781 (DIRECTIVE, CORRESPONDENCE, PREVIOUS REPORT, ETC., IF APPLICABLE.)

SUMMARY: ENTER CAREFUL SUMMARY OF REPORT, CONTAINING SUBSTANCE SUCCINCTLY STATED. ANSWER QUESTIONS WHERE, WHEN, WHAT, HOW, HOW MANY, AND GIVE DATE OF EVENT. IN A FINAL ONE SENTENCE PARAGRAPH GIVE SIGNIFICANCE. BEGIN TEXT ON PAGE 2.

1. It is believed that no plants designed specially for the production of heavy water exist in Poland. It is reliably reported that the Germans built one such plant near OSWIECIM (Auschwitz) but that it was destroyed or moved out by the SOVIETS in 1945.

2. A definite potentiality exists for the production of heavy hydrogen as a by-product of coal hydrogenation. There is believed to be small likelihood of the realization of this potential, since the Polish government insists on the complete orientation of industry toward the physical reconstruction of the country.

3. Absolutely no intimations have been received of Polish activity in the fields of research or development of atomic energy on Soviet account.

4. This subject will be kept under observation.

T. J. BETTS
Colonel GSC
Military Attache

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390731

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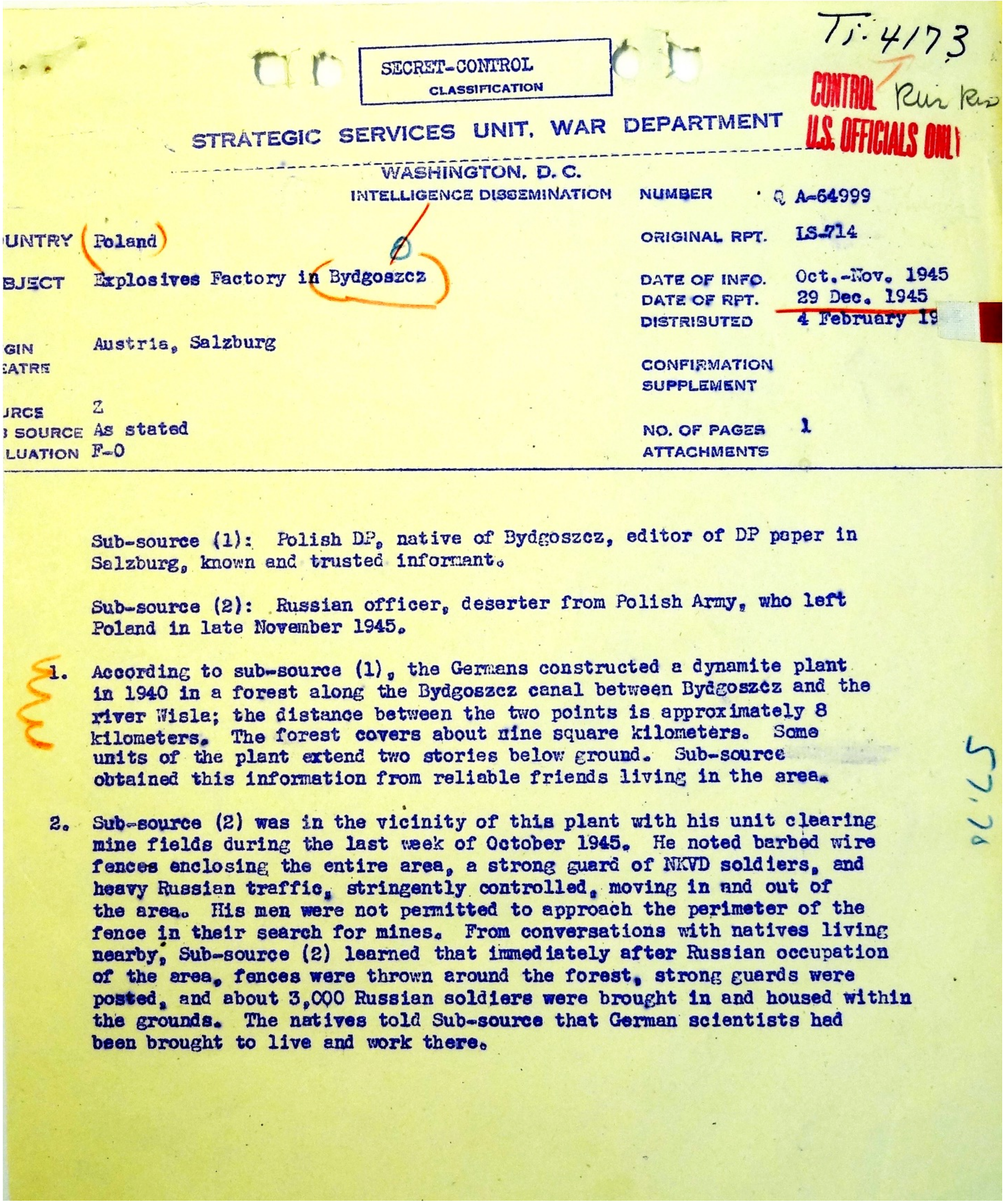
Figure D.686: U.S. Embassy, Warsaw. 12 August 1947. Report No. R-107-47, MIS-390731. Subject: Plants producing heavy water. [NARA RG 319, Entry 85A, Box 2534, Folder 390731–390740]

DECLASSIFIED
Authority NND 917017

**NARA RG 77, Entry UD-22A,
Box 163, Folder 57.70 Poland Misc**



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STRATEGIC SERVICES UNIT, WAR DEPARTMENT
WASHINGTON, D. C.
INTELLIGENCE DISSEMINATION

UNTRY	Poland	NUMBER	Q A-64999
BJECT	Explosives Factory in Bydgoszcz	ORIGINAL RPT.	LS-714
		DATE OF INFO.	Oct.-Nov. 1945
		DATE OF RPT.	29 Dec. 1945
		DISTRIBUTED	4 February 19
GIN EATRE	Austria, Salzburg	CONFIRMATION	
		SUPPLEMENT	
JRCE	Z	NO. OF PAGES	1
SOURCE	As stated	ATTACHMENTS	
LUATION	F-0		

Sub-source (1): Polish DP, native of Bydgoszcz, editor of DP paper in Salzburg, known and trusted informant.

Sub-source (2): Russian officer, deserter from Polish Army, who left Poland in late November 1945.

1. According to sub-source (1), the Germans constructed a dynamite plant in 1940 in a forest along the Bydgoszcz canal between Bydgoszcz and the river Wisle; the distance between the two points is approximately 8 kilometers. The forest covers about nine square kilometers. Some units of the plant extend two stories below ground. Sub-source obtained this information from reliable friends living in the area.

2. Sub-source (2) was in the vicinity of this plant with his unit clearing mine fields during the last week of October 1945. He noted barbed wire fences enclosing the entire area, a strong guard of NKVD soldiers, and heavy Russian traffic, stringently controlled, moving in and out of the area. His men were not permitted to approach the perimeter of the fence in their search for mines. From conversations with natives living nearby, Sub-source (2) learned that immediately after Russian occupation of the area, fences were thrown around the forest, strong guards were posted, and about 3,000 Russian soldiers were brought in and housed within the grounds. The natives told Sub-source that German scientists had been brought to live and work there.

57.70

Figure D.687: Strategic Services Unit, War Department. Explosives Factory in Bydgoszcz. 4 February 1946. [NARA RG 77, Entry UD-22A, Box 173, Folder 57.70 Poland Misc]

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[See document photo on p. 4455.

From the details provided, it sounds as if this plant was manufacturing something far more secret, more complex, and more valuable than dynamite. It could have been enriching uranium-235, or breeding and/or purifying plutonium-239 or uranium-233. Apparently General Leslie Groves and intelligence officers of the U.S. Manhattan Project thought so too, which is why they included this report in their foreign intelligence files.

With intelligence reports of apparent nuclear-related work at Auschwitz, Bydgoszcz, and possibly Posen (see p. 3245), there are indications that the wartime German nuclear program may have involved extensive production work at a number of sites in Poland. All of those sites were taken over by the Russians, while the western Allies only received fragmentary reports about them.]

Top Secret Cable from Warsaw to Secretary of State. 7 March 1946 [NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret]

From: Warsaw

To: Secretary of State

Nr: 300 7 March 1946

Nr 300. Signed Lane.

Information has been given this Embassy by a capable young engineer working in the zinc industry, that one of the best if not the only material for atomic bomb containers is cadmium. According to the informant the cadmium output of Poland in 1945 amounted to 49.15 tons, and in January of 1946 to 10.9 tons. In 1945 there was exported to Russia the total Polish cadmium output.

End

ACTION: General Groves

INFO: General Spaatz, General Hull, General Vandenberg

[See document photo on p. 4256.]

From Capt. Volpe to Colonel Shuler. Subject: Cable to Secretary of State from Warsaw. 12 March 1946. [NARA RG 77, Entry UD-22A, Box 173, Folder 57.70 Poland Misc]

1. I discussed the attached cable with Marks. The State Department is cabling Warsaw that subject matter is of interest and all pertinent information should be forwarded.

2. Perhaps Lt. Rugg might look into the question of the relative importance of the quantities specified in the cable. It might also be useful to determine if possible normal industrial uses of cadmium. This information might serve to explain the Russian demand for the Polish output.

[A detailed description from March 1945 of the German atomic bomb said that the bomb casing design included a very important layer of cadmium—see p. 4486. The above highly specific, early 1946 statement by the "capable young engineer" in Poland suggests that he in particular, and wartime German industry in Poland in general, had been involved in developing atomic bombs. The capable young engineer's supreme confidence in the suitability of cadmium for the bomb design may also suggest that he knew the bomb had been successfully tested, perhaps in Poland.

When the United States followed up with the capable young engineer, what else did they find out? Where are those documents?]

Robert Jackson, chief U.S. prosecutor at the Nuremberg trials. Cross-examination of Albert Speer. 21 June 1946. [https://avalon.law.yale.edu/imt/06-21-46.asp and http://law2.umkc.edu/faculty/projects/ftrials/nuremberg/speer.html]

MR. JUSTICE JACKSON: And certain experiments were also conducted and certain researches conducted in atomic energy, were they not? [...] Now, I have certain information, which was placed in my hands, of an experiment which was carried out near Auschwitz and I would like to ask you if you heard about it or knew about it. The purpose of the experiment was to find a quick and complete way of destroying people without the delay and trouble of shooting and gassing and burning, as it had been carried out, and this is the experiment, as I am advised. A village, a small village was provisionally erected, with temporary structures, and in it approximately 20,000 Jews were put. By means of this newly invented weapon of destruction, these 20,000 people were eradicated almost instantaneously, and in such a way that there was no trace left of them; that it developed, the explosive developed, temperatures of from 400 to 500 [4000 to 5000?] centigrade and destroyed them without leaving any trace at all. Do you know about that experiment?

SPEER: No, and I consider it utterly improbable. If we had had such a weapon under preparation, I should have known about it. But we did not have such a weapon. It is clear that in chemical warfare attempts were made on both sides to carry out research on all the weapons one could think of, because one did not know which party would start chemical warfare first.

MR. JUSTICE JACKSON: The reports, then, of a new and secret weapon were exaggerated for the purpose of keeping the German people in the war?

SPEER: That was the case mostly during the last phase of the war.

[What information about atomic energy experiments or weapons tests near Auschwitz was "placed in" Jackson's "hands"? Has that information been preserved in archives?

It is interesting that Speer answered a question about atomic energy experiments and an alleged atomic weapons test by immediately deflecting the discussion to talk about chemical warfare planning instead.]

Robert H. Jackson
(1892–1954)

Felix Kersten
(1898–1960)

Figure D.688: Robert Jackson and Felix Kersten both mentioned an atomic bomb test that killed concentration camp inmates in Poland.

DI 092.-76 FIAT. Subject: Periodic Intelligence Report 1. 2 August 1946 [TNA FO 1031/59]

[...] Completely unreliable source described the following: ARDENNE made experiments with an atom gun (Atomkanone). About Christmas 1944, successful experiments were conducted in Pomerania with V-1 and atomic warheads, radio directed. The ensuing crater was 2 km in diameter. Because the time for developments was too short nothing more came of it. Source has heard this from a man who participated in experiments but inconsiderately died in winter of 1945. It has not been possible to verify this statement from any other source although rumours to this effect, although with different names, have been persistent. [...]

[See document photos on pp. 3610–3615.]

R. W. Shaw to L. E. Seeman, 5 December 1946, Transmittal of Item from DAILY DIGEST OF WORLD BROADCASTS AND RADIO TELEGRAPH SERVICES [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)]

[...] Hahn said that a rumour which went the rounds in Germany about six months before the capitulation was equally untrue. According to this rumour, atom bomb tests had been carried out in Poland during the last year of the war which were supposed to have had an effect similar to the first atom bomb dropped on Hiroshima though on a considerably smaller scale. [...]

[See document photo on p. 4461.

The rumor reported by Hahn seems to agree very well with other reports of an atomic bomb test in Poland in October–December 1944.

Hahn does not appear to have been involved in the German nuclear weapons program, only basic nuclear physics experiments. It is unclear how much he knew or had been informed about the nuclear weapons program.

Note also that from April 1945 until January 1946, Hahn had been imprisoned (mostly at Farm Hall) and eavesdropped upon by the U.K. and U.S. military. After he was released, his public statements were still closely monitored and controlled by Allied officers. Even if Hahn knew that the rumor of an atomic bomb test in Poland was true, he would undoubtedly have been aware that it would be extremely unwise personally and politically to admit that information publicly.]

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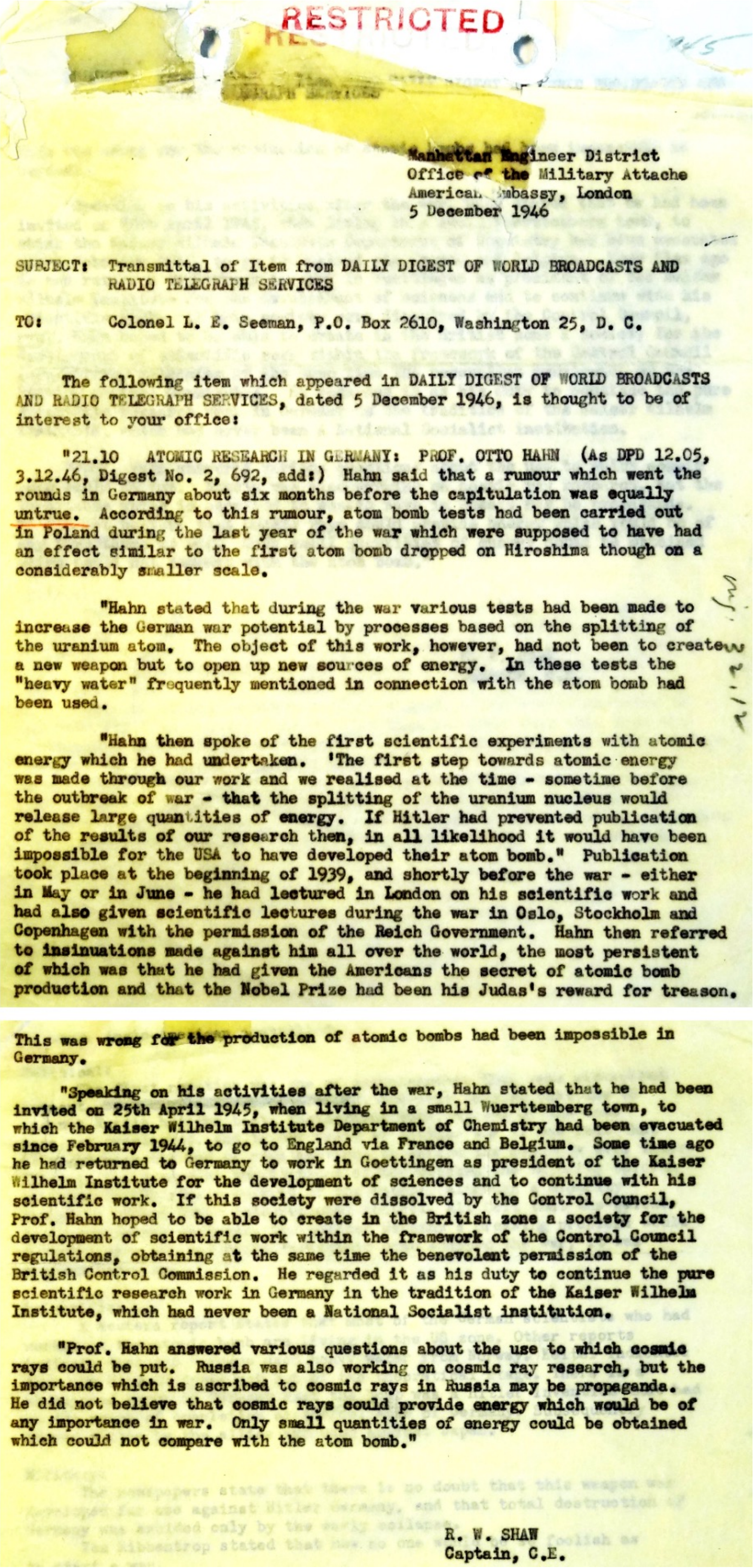
NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945-1946)



RESTRICTED

Manhattan Engineer District
Office of the Military Attache
American Embassy, London
5 December 1946

SUBJECT: Transmittal of Item from DAILY DIGEST OF WORLD BROADCASTS AND RADIO TELEGRAPH SERVICES

TO: Colonel L. E. Seeman, P.O. Box 2610, Washington 25, D. C.

The following item which appeared in DAILY DIGEST OF WORLD BROADCASTS AND RADIO TELEGRAPH SERVICES, dated 5 December 1946, is thought to be of interest to your office:

"21.10 ATOMIC RESEARCH IN GERMANY: PROF. OTTO HAHN (As DPD 12.05, 3.12.46, Digest No. 2, 692, add:) Hahn said that a rumour which went the rounds in Germany about six months before the capitulation was equally untrue. According to this rumour, atom bomb tests had been carried out in Poland during the last year of the war which were supposed to have had an effect similar to the first atom bomb dropped on Hiroshima though on a considerably smaller scale.

"Hahn stated that during the war various tests had been made to increase the German war potential by processes based on the splitting of the uranium atom. The object of this work, however, had not been to create a new weapon but to open up new sources of energy. In these tests the "heavy water" frequently mentioned in connection with the atom bomb had been used.

"Hahn then spoke of the first scientific experiments with atomic energy which he had undertaken. 'The first step towards atomic energy was made through our work and we realised at the time - sometime before the outbreak of war - that the splitting of the uranium nucleus would release large quantities of energy. If Hitler had prevented publication of the results of our research then, in all likelihood it would have been impossible for the USA to have developed their atom bomb." Publication took place at the beginning of 1939, and shortly before the war - either in May or in June - he had lectured in London on his scientific work and had also given scientific lectures during the war in Oslo, Stockholm and Copenhagen with the permission of the Reich Government. Hahn then referred to insinuations made against him all over the world, the most persistent of which was that he had given the Americans the secret of atomic bomb production and that the Nobel Prize had been his Judas's reward for treason. This was wrong for the production of atomic bombs had been impossible in Germany.

"Speaking on his activities after the war, Hahn stated that he had been invited on 25th April 1945, when living in a small Wuerttemberg town, to which the Kaiser Wilhelm Institute Department of Chemistry had been evacuated since February 1944, to go to England via France and Belgium. Some time ago he had returned to Germany to work in Goettingen as president of the Kaiser Wilhelm Institute for the development of sciences and to continue with his scientific work. If this society were dissolved by the Control Council, Prof. Hahn hoped to be able to create in the British zone a society for the development of scientific work within the framework of the Control Council regulations, obtaining at the same time the benevolent permission of the British Control Commission. He regarded it as his duty to continue the pure scientific research work in Germany in the tradition of the Kaiser Wilhelm Institute, which had never been a National Socialist institution.

"Prof. Hahn answered various questions about the use to which cosmic rays could be put. Russia was also working on cosmic ray research, but the importance which is ascribed to cosmic rays in Russia may be propaganda. He did not believe that cosmic rays could provide energy which would be of any importance in war. Only small quantities of energy could be obtained which could not compare with the atom bomb."

R. W. SHAW
Captain, C.E.

Figure D.689: R. W. Shaw to L. E. Seeman, 5 December 1946, Transmittal of Item from DAILY DIGEST OF WORLD BROADCASTS AND RADIO TELEGRAPH SERVICES [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Germany took over Tucheler Heide in September 1939 and used it as a proving ground (Truppenübungsplatz Westpreußen) for rockets, nuclear work, and other experiments until January 1945. It or one of the other Polish proving grounds may have been the location of a nuclear test around November 1944.

Figure D.690: The German military took over Tucheler Heide in September 1939 (upper photo) and used it as a proving ground (Truppenübungsplatz Westpreußen or Heidekraut) for rockets [Dornberger 1958, pp. 227–229], nuclear work (pp. 4902–4903), and other experiments until January 1945. It or one of the other Polish proving grounds (p. 2096) may have been the location of a nuclear test around November 1944.

Letter of Prof. Dr. Gezo Mansfeldt, Professor of Physiological Institute of the University of Budapest (former inmate of the Rajsko camp) to Dr. Hans Münch (during the war at the SS-Hygiene Institute in Rajsko). 5 December 1946. US Holocaust Memorial Museum. RG-15.169M (1998.A.0247) microfilm reel 8.

Der nachste Tag verlief ereignislos und am 27. Januar 4 Uhr Nachmittag marschierte die erste russische Vorhut durch das Lager Auschwitz. So wurden wir etwa 3000 Mann–Aerzte, Pfleger und Kranke—frei. [...] Ich war der einzig lebende Zeuge, der über das Hygiene-Institut Bescheid wusste und so wurde ich mindestens 2–3 mal wöchentlich einem Verhör unterzogen und musste freilich einigemal, aber jetzt schon im feinen Auto nach Raisko fahren, um dort alles zu zeigen. Die verschiedenen wissenschaftlichen Kommissionen waren nur schwer davon zu überzeugen, dass dort nicht giftiges Gas und dergleichen fabriziert wurde und was man eigentlich vermutete wurde mir erst viel später klar, als ich von den Atombombenversuchen erfuhr.

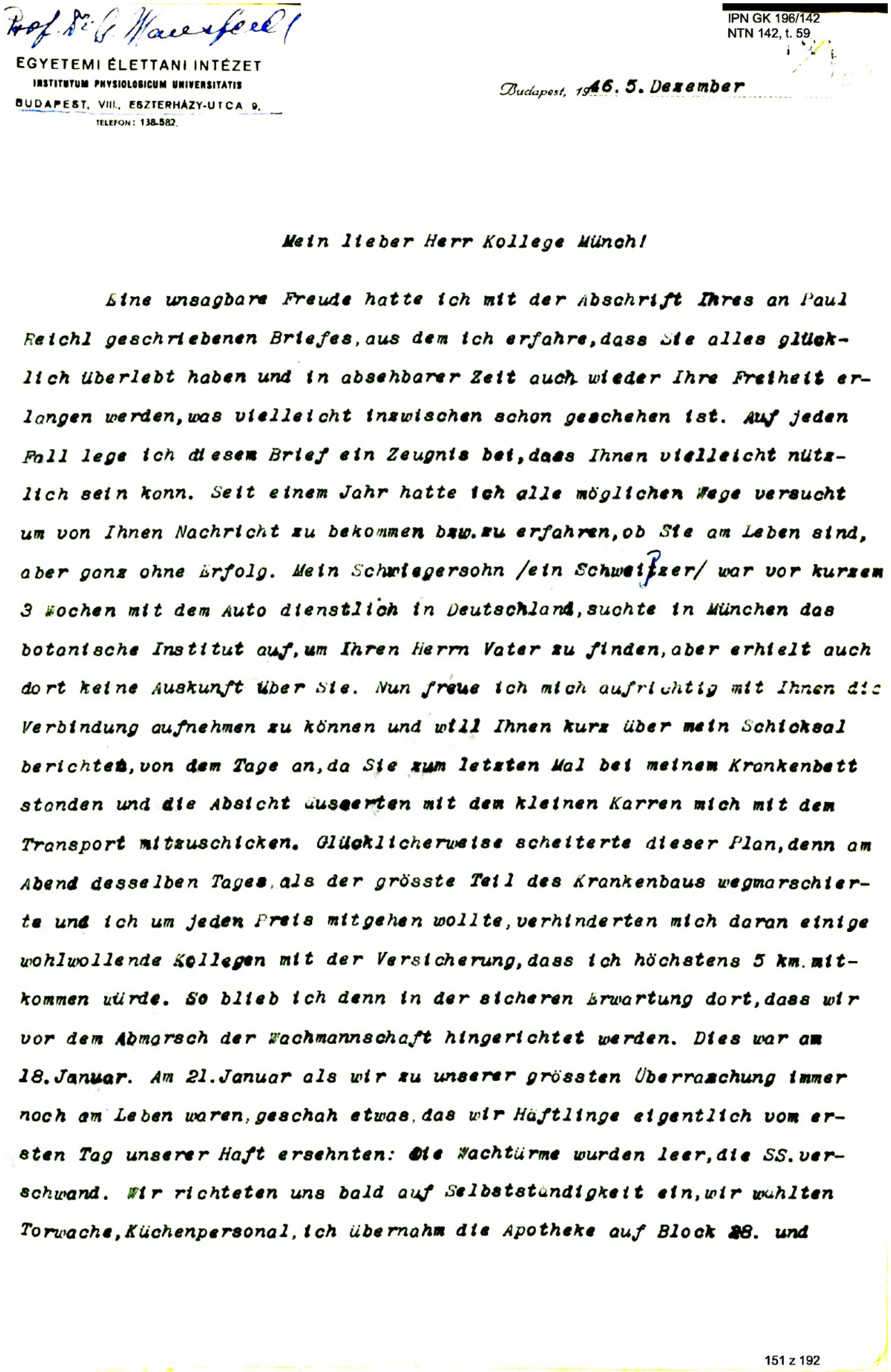
The next day was uneventful, and on January 27th [1945], 4:00 in the afternoon the first Russian vanguard marched through the Auschwitz camp. Thus we approximately 3,000 men—physicians, nurses, and patients—were free. [...] I was the only living witness who knew about the Hygiene Institute information and so I was at least 2–3 times weekly interviewed and had to drive to Raisko several times, but now in the fine car, and show everything there. The various scientific commissions were difficult to convince that poison gas and the like was not produced there, and what was actually suspected was clear to me only much later, when I learned of the atomic bomb tests.

[See document photos on pp. 4464–4469.

Mansfeldt's testimony suggests that something of great scientific interest to the Soviets was produced at Auschwitz during the war, and that this was connected to multiple German atomic bomb tests that had occurred during the war. It is not clear if he means that one or more of those tests occurred near Auschwitz, as reported by Robert Jackson, Felix Kersten, and Wilhelm Wulf. Apparently his Soviet interrogators were keenly interested in an atomic bomb test that had already occurred by the time Soviet forces took control of Auschwitz in January 1945. That would put an Auschwitz-associated test in late 1944, consistent with Grothmann's testimony of a test during or around November 1944.

I.G. Farben Auschwitz was a very large and very expensive facility whose products are not well documented. The following documents provided additional evidence to support the ideas mentioned by Mansfeldt that at least part of I.G. Farben Auschwitz produced materials related to nuclear and/or chemical weapons of mass destruction.]

Gezo Mansfeldt to Hans Münch. 5 December 1946.
US Holocaust Memorial Museum. RG-15.169M (1998.A.0247) microfilm 8.



Prof. Dr. G. Mansfeld
EGYETEMI ÉLETTANI INTÉZET
INSTITUTUM PHYSIOLOGICUM UNIVERSITATIS
BUDAPEST, VIII., ESZTERHÁZY-UTCA 9.
TELEFON: 138-582.

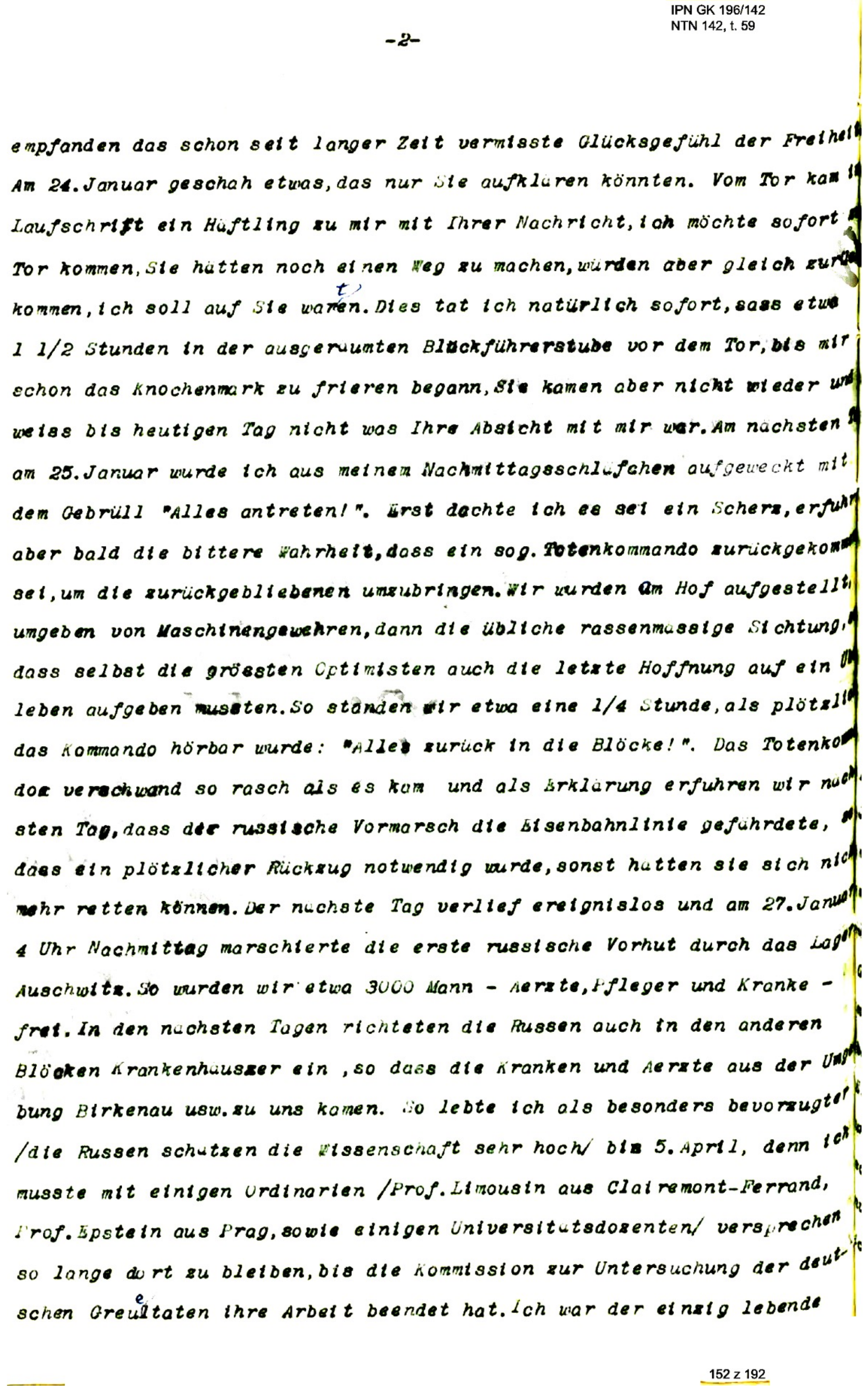
IPN GK 196/142
NTN 142, t. 59

Budapest, 1946. 5. Dezember

Mein lieber Herr Kollege Münch!

Eine unsagbare Freude hatte ich mit der Abschrift Ihres an Paul Reichl geschriebenen Briefes, aus dem ich erfahre, dass Sie alles glücklich überlebt haben und in absehbarer Zeit auch wieder Ihre Freiheit erlangen werden, was vielleicht inzwischen schon geschehen ist. Auf jeden Fall lege ich diesem Brief ein Zeugnis bei, dass Ihnen vielleicht nützlich sein kann. Seit einem Jahr hatte ich alle möglichen Wege versucht um von Ihnen Nachricht zu bekommen bzw. zu erfahren, ob Sie am Leben sind, aber ganz ohne Erfolg. Mein Schwiegersohn /ein Schweitzer/ war vor kurzem 3 Wochen mit dem Auto dienstlich in Deutschland, suchte in München das botanische Institut auf, um Ihren Herrn Vater zu finden, aber erhielt auch dort keine Auskunft über Sie. Nun freue ich mich aufrichtig mit Ihnen die Verbindung aufnehmen zu können und will Ihnen kurz über mein Schicksal berichten, von dem Tage an, da Sie zum letzten Mal bei meinem Krankenbett standen und die Absicht äusserten mit dem kleinen Karren mich mit dem Transport mitzuschicken. Glücklicherweise scheiterte dieser Plan, denn am Abend desselben Tages, als der grösste Teil des Krankenbaus wegmarschierte und ich um jeden Preis mitgehen wollte, verhinderten mich daran einige wohlwollende Kollegen mit der Versicherung, dass ich höchstens 5 km. mitkommen würde. So blieb ich denn in der sicheren Erwartung dort, dass wir vor dem Abmarsch der Wachmannschaft hingerichtet werden. Dies war am 18. Januar. Am 21. Januar als wir zu unserer grössten Überraschung immer noch am Leben waren, geschah etwas, das wir Häftlinge eigentlich vom ersten Tag unserer Haft ersehnten: die Wachtürme wurden leer, die SS. verschwand. Wir richteten uns bald auf Selbstständigkeit ein, wir wählten Torwache, Küchenpersonal, ich übernahm die Apotheke auf Block 28. und

Figure D.691: Letter of Prof. Dr. Gezo Mansfeldt, Professor of Physiological Institute of the University of Budapest (former inmate of the Rajsko camp) to Dr. Hans Münch (during the war at the SS-Hygiene Institute in Rajsko). 5 December 1946 [US Holocaust Memorial Museum. RG-15.169M (1998.A.0247) microfilm reel 8].



IPN GK 196/142
NTN 142, t. 59

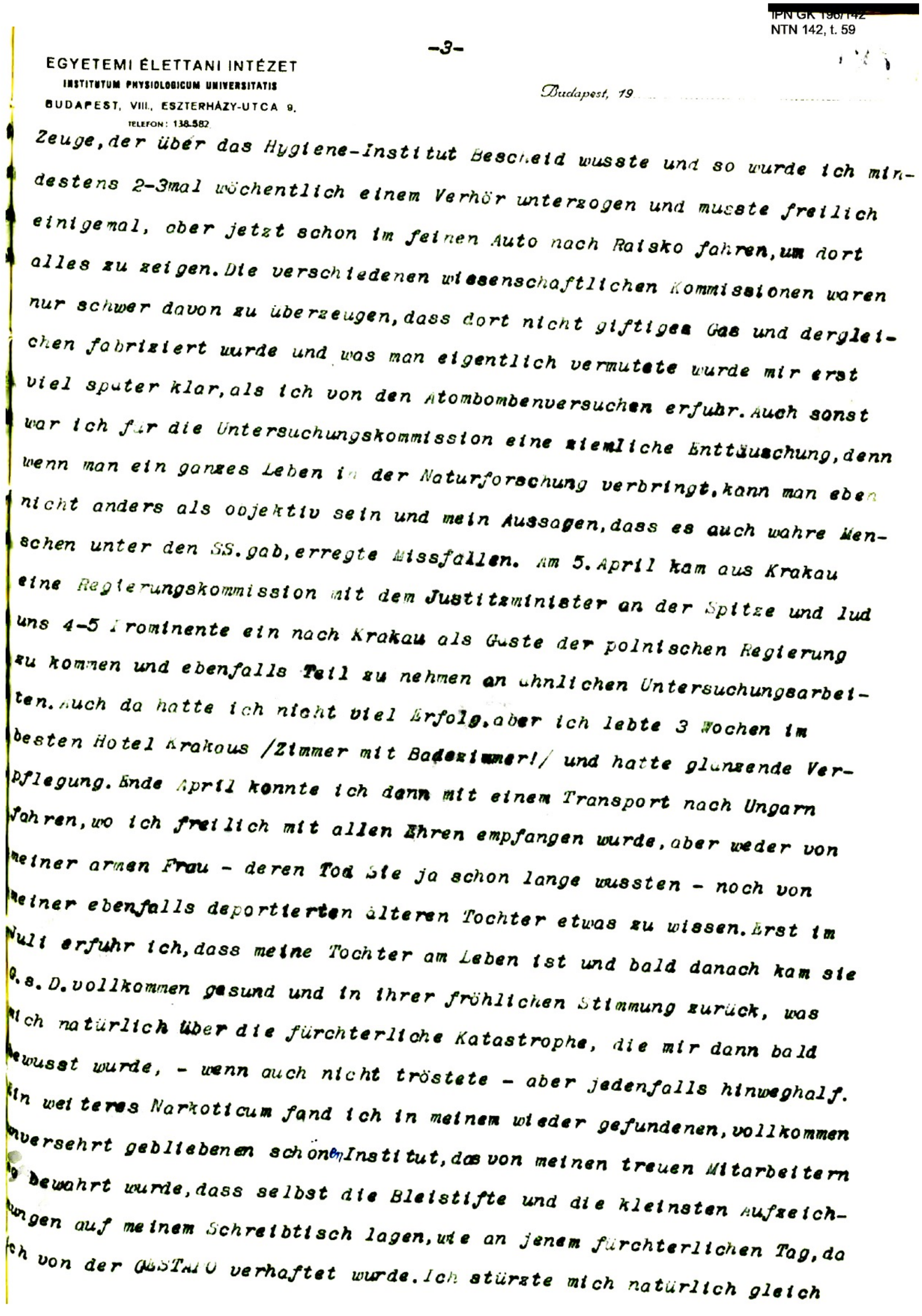
-2-

empfanden das schon seit langer Zeit vermisste Glücksgefühl der Freihei
Am 24.Januar geschah etwas,das nur Sie aufklaren könnten. Vom Tor kam
Laufschrift ein Häftling zu mir mit Ihrer Nachricht,ich möchte sofort
Tor kommen,Sie hätten noch einen Weg zu machen,würden aber gleich zur
kommen,ich soll auf Sie wa~~r~~ten.Dies tat ich natürlich sofort,sass etwa
1 1/2 Stunden in der ausgeräumten Blockführerstube vor dem Tor,bis mir
schon das Knochenmark zu frieren begann,Sie kamen aber nicht wieder un
weiss bis heutigen Tag nicht was Ihre Absicht mit mir war.Am nächsten
am 25.Januar wurde ich aus meinem Nachmittagsschläfchen aufgeweckt mit
dem Gebrüll "Alles antreten!". Erst dachte ich es sei ein Scherz,erfuhr
aber bald die bittere Wahrheit,dass ein sog.Totenkommando zurückgekom
sei,um die zurückgebliebenen umzubringen.Wir wurden am Hof aufgestellt
umgeben von Maschinengewehren,dann die übliche rassenmässige Sichtung,
dass selbst die grössten Optimisten auch die letzte Hoffnung auf ein
leben aufgeben mussten.So standen wir etwa eine 1/4 Stunde,als plötzli
das Kommando hörbar wurde: "Alles zurück in die Blöcke!". Das Totenko
doz verschwand so rasch als es kam und als Erklärung erfuhren wir näch
sten Tag,dass der russische Vormarsch die Eisenbahnlinie gefährdete,
dass ein plötzlicher Rückzug notwendig wurde,sonst hätten sie sich nic
mehr retten können.Der nächste Tag verlief ereignislos und am 27.Janua
4 Uhr Nachmittag marschierte die erste russische Vorhut durch das Lage
Auschwitz.So wurden wir etwa 3000 Mann - Aerzte,Pfleger und Kranke -
frei.In den nächsten Tagen richteten die Russen auch in den anderen
Blöcken Krankenhäuser ein ,so dass die Kranken und Aerzte aus der Umg
bung Birkenau usw.zu uns kamen. So lebte ich als besonders bevorzugter
/die Russen schätzen die Wissenschaft sehr hoch/ bis 5.April, denn ich
musste mit einigen Ordinarien /Prof.Limousin aus Clairemont-Ferrand,
Prof.Epstein aus Prag,sowie einigen Universitätsdozenten/ versprechen
so lange dort zu bleiben,bis die Kommission zur Untersuchung der deut-
schen Greueltaten ihre Arbeit beendet hat.Ich war der einzig lebende

152 z 192

Gezo Mansfeldt to Hans Münch. 5 December 1946.
US Holocaust Memorial Museum. RG-15.169M (1998.A.0247) microfilm 8.

Figure D.692: Letter of Prof. Dr. Gezo Mansfeldt, Professor of Physiological Institute of the University of Budapest (former inmate of the Rajsko camp) to Dr. Hans Münch (during the war at the SS-Hygiene Institute in Rajsko). 5 December 1946 [US Holocaust Memorial Museum. RG-15.169M (1998.A.0247) microfilm reel 8].



IPN GK 196/142
NTN 142, t. 59

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EGYETEMI ÉLETTANI INTÉZET
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TELEFON: 138.582

Budapest, 19

Zeuge, der über das Hygiene-Institut Bescheid wusste und so wurde ich mindestens 2-3mal wöchentlich einem Verhör unterzogen und musste freilich einigemal, aber jetzt schon im feinen Auto nach Raisko fahren, um dort alles zu zeigen. Die verschiedenen wissenschaftlichen Kommissionen waren nur schwer davon zu überzeugen, dass dort nicht giftiges Gas und dergleichen fabriziert wurde und was man eigentlich vermutete wurde mir erst viel später klar, als ich von den Atombombenversuchen erfuhr. Auch sonst war ich für die Untersuchungskommission eine ziemliche Enttäuschung, denn wenn man ein ganzes Leben in der Naturforschung verbringt, kann man eben nicht anders als objektiv sein und mein Aussagen, dass es auch wahre Menschen unter den SS. gab, erregte Missfallen. Am 5. April kam aus Krakau eine Regierungskommission mit dem Justitzminister an der Spitze und lud uns 4-5 Prominente ein nach Krakau als Gäste der polnischen Regierung zu kommen und ebenfalls Teil zu nehmen an ähnlichen Untersuchungsarbeiten. Auch da hatte ich nicht viel Erfolg, aber ich lebte 3 Wochen im besten Hotel Krakaus /Zimmer mit Badezimmer!/ und hatte glänzende Verpflegung. Ende April konnte ich dann mit einem Transport nach Ungarn fahren, wo ich freilich mit allen Ehren empfangen wurde, aber weder von meiner armen Frau - deren Tod Sie ja schon lange wussten - noch von meiner ebenfalls deportierten älteren Tochter etwas zu wissen. Erst im Juli erfuhr ich, dass meine Tochter am Leben ist und bald danach kam sie G.s.D. vollkommen gesund und in ihrer fröhlichen Stimmung zurück, was mich natürlich über die fürchterliche Katastrophe, die mir dann bald bewusst wurde, - wenn auch nicht tröstete - aber jedenfalls hinweghalf. Ein weiteres Narkoticum fand ich in meinem wieder gefundenen, vollkommen unversehrt gebliebenen schönen Institut, das von meinen treuen Mitarbeitern so bewahrt wurde, dass selbst die Bleistifte und die kleinsten Aufzeichnungen auf meinem Schreibtisch lagen, wie an jenem fürchterlichen Tag, da ich von der GESTAPO verhaftet wurde. Ich stürzte mich natürlich gleich

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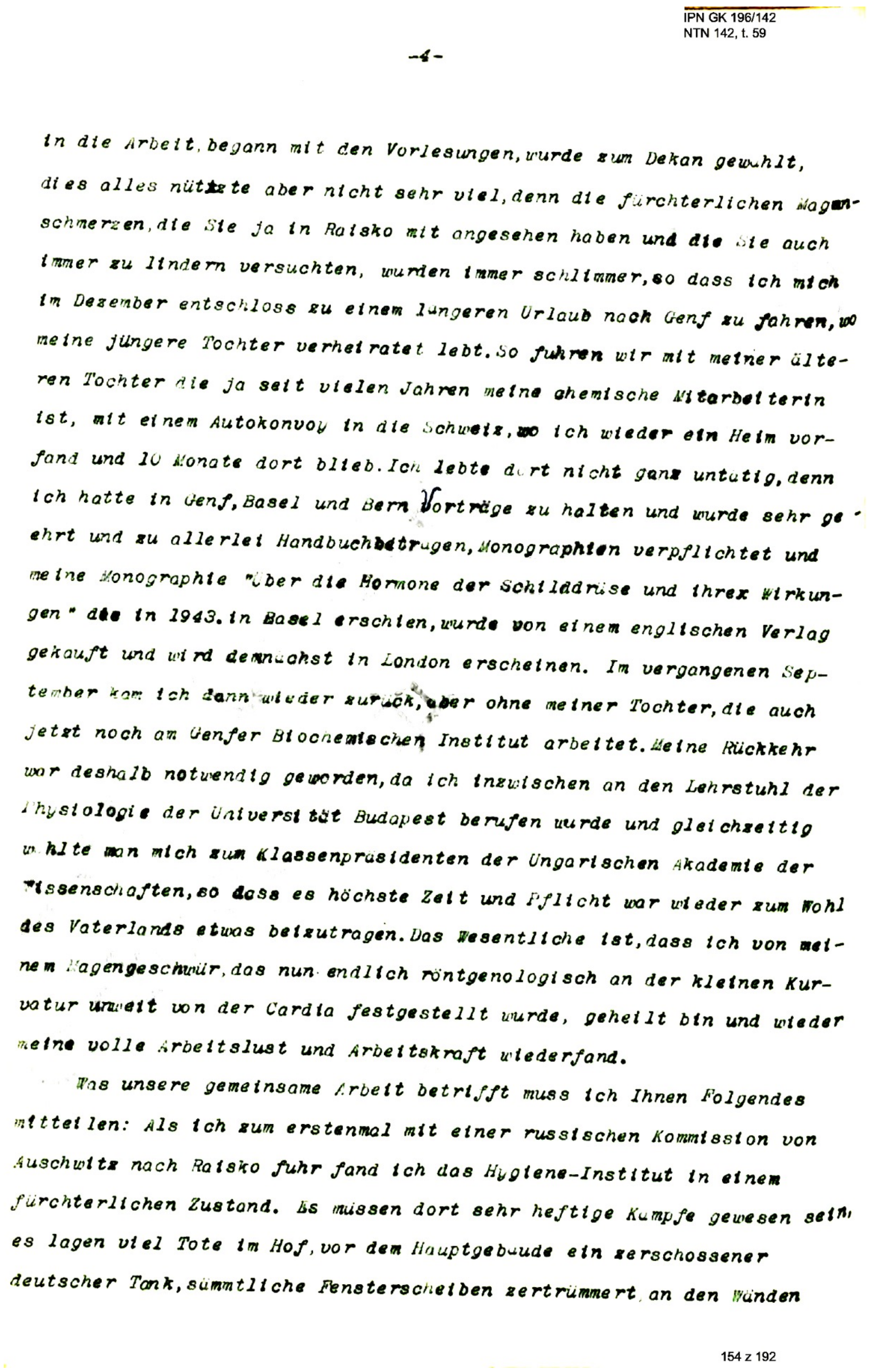
Gezo Mansfeldt to Hans Münch. 5 December 1946.
US Holocaust Memorial Museum. RG-15.169M (1998.A.0247) microfilm 8.

Figure D.693: Letter of Prof. Dr. Gezo Mansfeldt, Professor of Physiological Institute of the University of Budapest (former inmate of the Rajsko camp) to Dr. Hans Münch (during the war at the SS-Hygiene Institute in Rajsko). 5 December 1946 [US Holocaust Memorial Museum. RG-15.169M (1998.A.0247) microfilm reel 8].

Gezo Mansfeldt to Hans Münch. 5 December 1946.
US Holocaust Memorial Museum. RG-15.169M (1998.A.0247) microfilm 8.



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in die Arbeit, begann mit den Vorlesungen, wurde zum Dekan gewählt, dies alles nützte aber nicht sehr viel, denn die fürchterlichen Magenschmerzen, die Sie ja in Raisko mit angesehen haben und die Sie auch immer zu lindern versuchten, wurden immer schlimmer, so dass ich mich im Dezember entschloss zu einem längeren Urlaub nach Genf zu fahren, wo meine jüngere Tochter verheiratet lebt. So fuhren wir mit meiner älteren Tochter die ja seit vielen Jahren meine chemische Mitarbeiterin ist, mit einem Autokonvoy in die Schweiz, wo ich wieder ein Heim vorfand und 10 Monate dort blieb. Ich lebte dort nicht ganz untätig, denn ich hatte in Genf, Basel und Bern Vorträge zu halten und wurde sehr geehrt und zu allerlei Handbuchbeiträgen, Monographien verpflichtet und meine Monographie "Über die Hormone der Schilddrüse und ihrex Wirkungen" die in 1943. in Basel erschien, wurde von einem englischen Verlag gekauft und wird demnächst in London erscheinen. Im vergangenen September kam ich dann wieder zurück, aber ohne meiner Tochter, die auch jetzt noch am Genfer Biochemischen Institut arbeitet. Meine Rückkehr war deshalb notwendig geworden, da ich inzwischen an den Lehrstuhl der Physiologie der Universität Budapest berufen wurde und gleichzeitig wählte man mich zum Klassenpräsidenten der Ungarischen Akademie der Wissenschaften, so dass es höchste Zeit und Pflicht war wieder zum Wohl des Vaterlands etwas beizutragen. Das Wesentliche ist, dass ich von meinem Magengeschwür, das nun endlich röntgenologisch an der kleinen Kurvatur unweit von der Cardia festgestellt wurde, geheilt bin und wieder meine volle Arbeitslust und Arbeitskraft wiederfand.

Was unsere gemeinsame Arbeit betrifft muss ich Ihnen Folgendes mitteilen: Als ich zum erstenmal mit einer russischen Kommission von Auschwitz nach Raisko fuhr fand ich das Hygiene-Institut in einem fürchterlichen Zustand. Es müssen dort sehr heftige Kämpfe gewesen sein, es lagen viel Tote im Hof, vor dem Hauptgebäude ein zerschossener deutscher Tank, sämmtliche Fensterscheiben zertrümmert, an den Wänden

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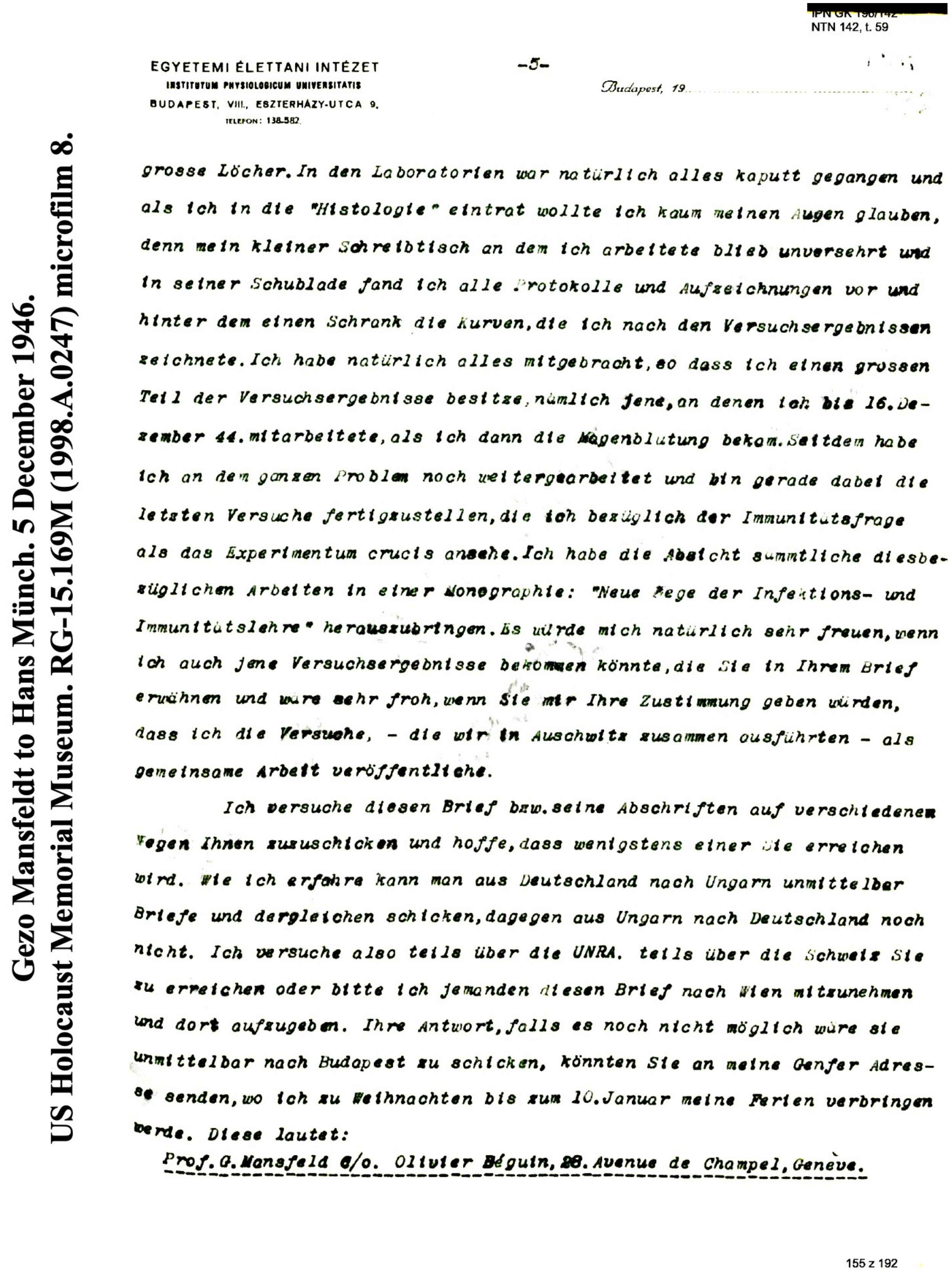
Figure D.694: Letter of Prof. Dr. Gezo Mansfeldt, Professor of Physiological Institute of the University of Budapest (former inmate of the Rajsko camp) to Dr. Hans Münch (during the war at the SS-Hygiene Institute in Rajsko). 5 December 1946 [US Holocaust Memorial Museum. RG-15.169M (1998.A.0247) microfilm reel 8].



Gezo Mansfeldt to Hans Münch. 5 December 1946.
US Holocaust Memorial Museum. RG-15.169M (1998.A.0247) microfilm 8.

[redacted]
NTN 142, t. 59

EGYETEMI ÉLETTANI INTÉZET
INSTITUTUM PHYSIOLOGICUM UNIVERSITATIS
BUDAPEST, VIII., ESZTERHÁZY-UTCA 9.
TELEFON: 138-582.

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Budapest, 19

grosse Löcher. In den Laboratorien war natürlich alles kaputt gegangen und als ich in die "Histologie" eintrat wollte ich kaum meinen Augen glauben, denn mein kleiner Schreibtisch an dem ich arbeitete blieb unversehrt und in seiner Schublade fand ich alle Protokolle und Aufzeichnungen vor und hinter dem einen Schrank die Kurven, die ich nach den Versuchsergebnissen zeichnete. Ich habe natürlich alles mitgebracht, so dass ich einen grossen Teil der Versuchsergebnisse besitze, nämlich jene, an denen ich bis 16. Dezember 44. mitarbeitete, als ich dann die Magenblutung bekam. Seitdem habe ich an dem ganzen Problem noch weitergearbeitet und bin gerade dabei die letzten Versuche fertigzustellen, die ich bezüglich der Immunitätsfrage als das Experimentum crucis ansehe. Ich habe die Absicht sämmtliche diesbezüglichen Arbeiten in einer Monographie: "Neue Wege der Infektions- und Immunitätslehre" herauszubringen. Es würde mich natürlich sehr freuen, wenn ich auch jene Versuchsergebnisse bekommen könnte, die Sie in Ihrem Brief erwähnen und wäre sehr froh, wenn Sie mir Ihre Zustimmung geben würden, dass ich die Versuche, - die wir in Auschwitz zusammen ausführten - als gemeinsame Arbeit veröffentliche.

Ich versuche diesen Brief bzw. seine Abschriften auf verschiedenem Wegen Ihnen zuzuschicken und hoffe, dass wenigstens einer Sie erreichen wird. Wie ich erfahre kann man aus Deutschland nach Ungarn unmittelbar Briefe und dergleichen schicken, dagegen aus Ungarn nach Deutschland noch nicht. Ich versuche also teils über die UNRA. teils über die Schweiz Sie zu erreichen oder bitte ich jemanden diesen Brief nach Wien mitzunehmen und dort aufzugeben. Ihre Antwort, falls es noch nicht möglich wäre sie unmittelbar nach Budapest zu schicken, könnten Sie an meine Genfer Adresse senden, wo ich zu Weihnachten bis zum 10. Januar meine Ferien verbringen werde. Diese lautet:

Prof. G. Mansfeld c/o. Olivier Béguin, 28. Avenue de Champel, Genève.

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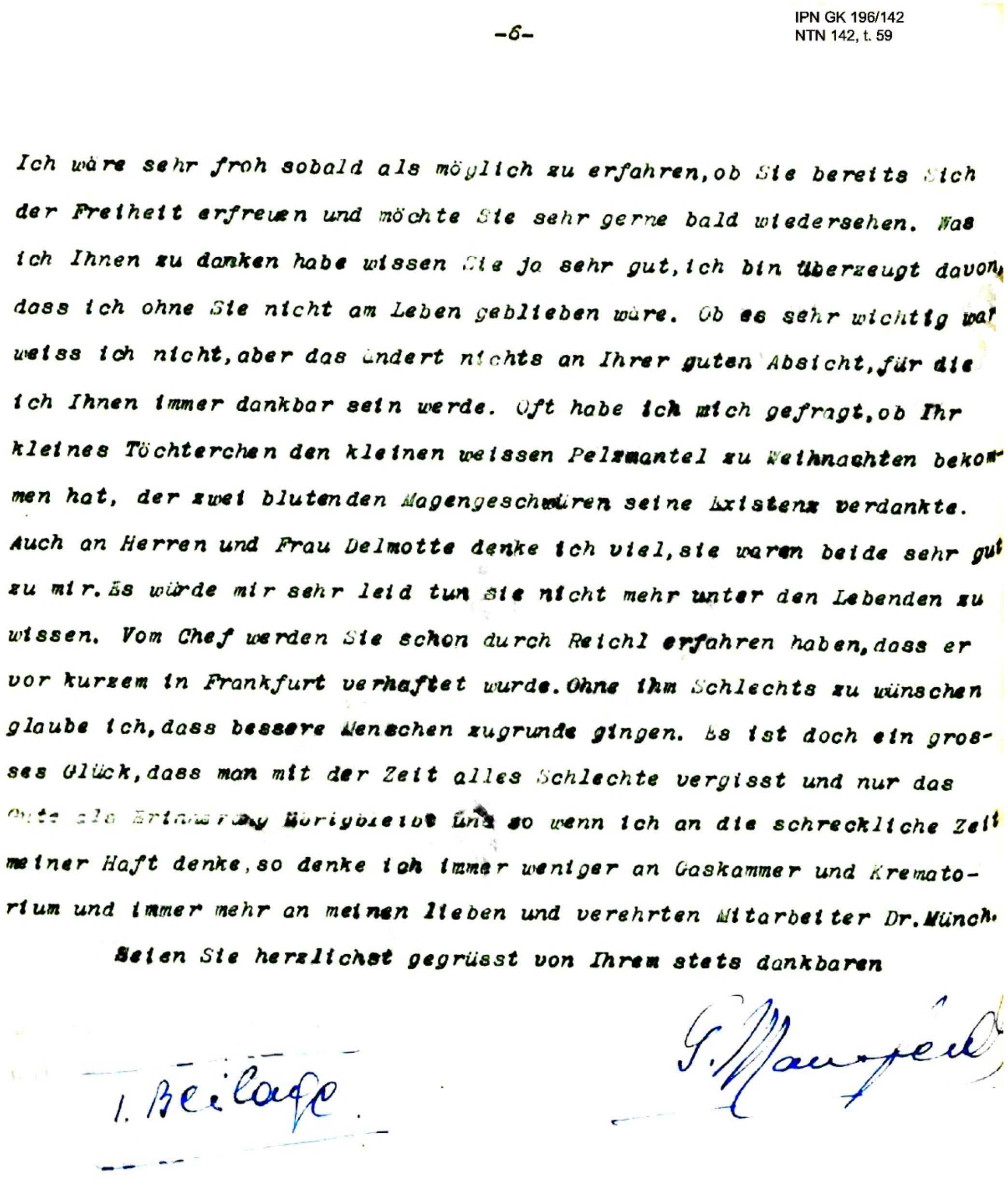
Figure D.695: Letter of Prof. Dr. Gezo Mansfeldt, Professor of Physiological Institute of the University of Budapest (former inmate of the Rajsko camp) to Dr. Hans Münch (during the war at the SS-Hygiene Institute in Rajsko). 5 December 1946 [US Holocaust Memorial Museum. RG-15.169M (1998.A.0247) microfilm reel 8].

Gezo Mansfeldt to Hans Münch. 5 December 1946.
US Holocaust Memorial Museum. RG-15.169M (1998.A.0247) microfilm 8.



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Ich wäre sehr froh sobald als möglich zu erfahren, ob Sie bereits sich der Freiheit erfreuen und möchte Sie sehr gerne bald wiedersehen. Was ich Ihnen zu danken habe wissen Sie ja sehr gut, ich bin überzeugt davon, dass ich ohne Sie nicht am Leben geblieben wäre. Ob es sehr wichtig war weiss ich nicht, aber das ändert nichts an Ihrer guten Absicht, für die ich Ihnen immer dankbar sein werde. Oft habe ich mich gefragt, ob Ihr kleines Töchterchen den kleinen weissen Pelzmantel zu Weihnachten bekommen hat, der zwei blutenden Magengeschwüren seine Existenz verdankte. Auch an Herren und Frau Delmotte denke ich viel, sie waren beide sehr gut zu mir. Es würde mir sehr leid tun sie nicht mehr unter den Lebenden zu wissen. Vom Chef werden Sie schon durch Reichl erfahren haben, dass er vor kurzem in Frankfurt verhaftet wurde. Ohne ihm Schlechts zu wünschen glaube ich, dass bessere Menschen zugrunde gingen. Es ist doch ein grosses Glück, dass man mit der Zeit alles Schlechte vergisst und nur das Gute als Erinnerung übrigbleibt und so wenn ich an die schreckliche Zeit meiner Haft denke, so denke ich immer weniger an Gaskammer und Krematorium und immer mehr an meinen lieben und verehrten Mitarbeiter Dr. Münch.

Seien Sie herzlichst gegrüsst von Ihrem stets dankbaren

G. Mansfeld

1. Beilage.

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Figure D.696: Letter of Prof. Dr. Gezo Mansfeldt, Professor of Physiological Institute of the University of Budapest (former inmate of the Rajsko camp) to Dr. Hans Münch (during the war at the SS-Hygiene Institute in Rajsko). 5 December 1946 [US Holocaust Memorial Museum. RG-15.169M (1998.A.0247) microfilm reel 8].

Edmund Tilley. Brief Operational Report on [censored] and Other Germans and Italians Connected with Project Abstract. 19 August 1947. [NARA RG 319, Entry A1-134A, Box 29, Folder Operation Oberjoch]

[See p. 4902 for this document. In this 19 August 1947 intelligence report that is still heavily censored, Edmund Tilley discussed wartime nuclear weapons work at Tucheler Heide in Poland, including the production of ^{235}U and ^{239}Pu and apparently even 1–5 kg fission pits for atomic bombs. According to Tilley, one of the German scientists most directly responsible for that work, "Dr. Niels" (Walter Nielsch?), had already been taken to the United States for interrogation and/or work. For more information on Project Abstract, see Mills and Johanson 2019.]

Heinrich Himmler's physical therapist, Felix Kersten [Kersten 1947, pp. 252–253, 256–258].

When I returned to Himmler's headquarters in December [1944] I found him singularly optimistic. Once again he was prophesying a German victory! [...] Himmler saw my bewilderment and said: "Very soon we shall put our last secret weapon into use. And that will change the war situation entirely!" [...]

Early in March 1945 I paid one of my last visits to Himmler's headquarters... He was more optimistic than ever before! In his conversations with me he returned to the subject of the mysterious *secret weapon*. He made some strange assertions, and I kept a careful record of these. "Most people," he said, "think we have lost the war, and I cannot deny that apparently they have reason. But we have not yet used our last secret weapon. V-1 and V-2 bombs are effective secret weapons, but the secret weapon we still have up our sleeves will have an effect no one can even imagine. One or two shots and cities like New York or London will simply vanish from the earth! Allied aviation has destroyed many essential factories for its manufacture. That is why we are behind in our schedule. But in a month or two you will read all about it in the papers. Then you will realize that I know what I am talking about." [...]

This talk aroused my curiosity. I began giving heed to some very wild rumors–or so I had thought them–which seemed to be in line with Himmler's veiled disclosures. And when Kriminalrat Obersturmfuehrer Goering, a trustworthy man (unlike his homonym) told me something about the "secret weapon" I believed him. He said that a village had been built near Auschwitz for experimental purposes. They wanted to "try out" the new weapon. For the purpose, twenty thousand Jewish men, women, and children had been brought to live in this village. A single shell had been fired on the settlement. It had caused six thousand degrees of heat, and the whole village–houses, human beings, and animals included–was burnt to ashes.

Obviously, as I see it now in retrospect, the Germans had nearly completed their atomic bomb and were almost ready to use it on the enemy when the encirclement of Berlin was complete.

Heinrich Himmler's personal astrologer, Wilhelm Wulff [Wulff 1973, pp. 147, 160–161].

On March 10, Kersten, who had returned from Hohenlychen, came to my room and said that Himmler wished me to report to him the next day for a consultation. [...]

There were also reports of other secret weapons that were ready for mass production, all of which tended to contribute to Himmler's vacillation.

He [Himmler] went on to talk about a quite different missile, one of incredible power. Cities like New York and London, he said, could be wiped off the face of the earth with the help of this new weapon. This particular report was not entirely unfounded but meant little now that the Allies had already crossed the Rhine and the Russians had reached Küstrin, Stettin, and the Oder River and were threatening to occupy the whole of the Brandenburg region.

I had already heard about these new missiles and their enormous destructive power from Franz Göring in February, 1944. What he had told me was basically true, for work was already being done on the German atom bomb at the time.

Franz Göring also told me that the new missiles had been tested. According to him, a large town was especially built near Auschwitz concentration camp and some 20,000 Jews, mostly women and children, were sent to live in it. A single missile was then fired into the settlement. In the ensuing explosion, which developed a heat output of 6,000^{o} C at its center, the whole town and the entire population were burned to cinders in a flash. Stories such as this also reached Himmler's ears. Was it surprising, then, that he pinned his hopes on the effect of such weapons? Was it surprising that he hesitated to depose Hitler?

[Did Wulff mean that Franz Göring told him about the weapons test near Auschwitz in February 1944? Or did he mean that Franz Göring first told him about the new weapon in February 1944, and then at some later date told him that the weapon had been tested near Auschwitz? The second meaning would allow a much wider range of dates for when the Auschwitz test might have occurred. A successful nuclear weapons test in late 1944 seems much more probable than a successful test in early 1944.

Note that the alleged nuclear test on a village near Auschwitz does not appear to be simply a garbled account of the 27 January 1945 burning of the Fürstengrube concentration camp (30 km from Auschwitz) and several hundred of its inmates by the SS just before Soviet troops arrived. Although the date of the test to which sources refer remains vague, the sources seem to place the test as having occurred sometime prior to late January 1945.]

Heinrich Himmler's chief adjutant Werner Grothmann [Krotzky 2002]

[For testimony from Werner Grothmann apparently about the ∼November 1944 test, see p. 4436.]

Trials of War Criminals Before the Nuernberg Military Tribunals Under Control Council Law No. 10. Nuernberg October 1946–April 1949. Volume VIII. Washington, DC: U.S. Government Printing Office. 1952. [The I.G. Farben Case] [https://lccn.loc.gov/2011525364]

[pp. 334–335:] TRANSLATION OF DOCUMENT NI-11783

Buna IV
Mineral Oil Construction Company Limited
Berlin SW 61, Belle-Alliance Stresse 7-10

To Direktor Ambros
I. G. Farbenindustrie A. G.
Ludwigshafen/Rhein

Our reference Si/Th/Kb
Berlin SW 61
11 January 1941

Dear Sir,

With reference to yesterday's discussion, I am enclosing excerpts from the report of the conference of 10 December 1940 concerning the site for 2 new hydrogenation plants. [...]

When inspecting the third building site (east of Auschwitz) it was noticed that there is an excellent site of about 5 square kilometers which offers still better possibilities for expansion. In addition, the water situation is very favourable because the draining works can be placed below the confluence of the Weichsel [Vistula], Przemsza, and Sola Rivers and sufficient water will be available, even with minimum outflow. Exact outflow data will be obtained from the Katowice *Water Office*.

Coal can be procured from 3 sides; to wit, the Cracow district, the central district, and the coal deposits southwest of the building site, where the new Brzeszcze and Jawiszowitz shafts of the Hermann Goering Werke are located, and from the Silesia Shaft, near Dzieditz, which is supposed to be the property of Elektroindustrie/Berlin. The distance from the central and Cracow districts is about 25 kilometers by rail, and from the southwestern district about 9-10 kilometers by rail. It would be preferable to get supplies from the southwestern district because a private works railroad could be built for that purpose. [...]

Since it may be expected that the greater part of the inhabitants will be evacuated when construction begins, in view of the population policy, there would be suitable quarters available to accommodate building workers and later on factory staff.

In addition, the site is very favorably located from the point of view of possible air pollution, so that, taking everything into account, it can be said that this building site would in every respect satisfy the requirements.

[pp. 535–537:] TRANSLATION OF DOCUMENT NI-14291

The Reichfuehrer SS and Chief of the German Police SS Economic and Administrative Main Office Group D-Concentration Camps

Ref. No. D II/114/16 So. Hue.
Oranienburg near Berlin, 31 July 1943
Enclosure to letter, Dy [Dyhernfurth] dated 27 August 1943
Re: Use of Inmates

To firm, Max Haaf, Certified Engineer,
Local Construction Management
Attention: Regierungsbaumeister Wuerz
Falkenhagen via Fuerstenwalde/Spree

As a consequence of the conference between the SS Lt. General and General of the Waffen SS Pohl and Dr. Ambros, the site in Falkenhagen near Fuerstenwalde was inspected by Dr. Schaefer, Certified Engineer Weirich, and Regierungsbaumeister Wuerz together with SS 1st Lt. Grimm on 20 July 1943. [...]

Chief of Office D II
[Signed] BAUER
SS Lt. Colonel

Reichsfuehrer SS and Chief of German Police,
D ill SS Economic and Administrative Main Office
Copies to: Dr. Schaefer, I. G. Farbenindustrie, Berlin, with request for transmittal to your office Breslau No. 56551.

[p. 1243:] *Ambros* was manager of the following plants: Schkopau (buna I), 1935–45; Ludwigshafen-Oppau (organic, intermediates and dyestuffs plants and laboratories), 1938–45; Huels (buna II), 1938–45; Ludwigshafen (buna III), 1941–45; Auschwitz (buna IV), 1941–45; Gendorf (inorganic), 1941–45; Dyhernfurt, 1941–45; Falkenhagen, 1942–45; which produced synthetic rubber, inorganics and nitrogen, organic intermediates, solvents, plasticisers, methanol, plastics, accelerators, dyestuffs, dyeing and printing auxiliaries, detergent raw materials, poisonous gas and intermediates. [...]

Kuehne was plant leader of Leverkusen, 1933–43, which produced inorganics, organic intermediates, buna, plastics, pharmaceuticals, insecticides, acetylcellulose, synthetic fibres.

[p. 1361:] AMBROS, OTTO (def.)—Professor of chemistry; member of Vorstand, Technical Committee, and Chemicals Committee of I. G. Farben, 1938–45; chairman of three Farben committees in the chemical field; plant leader of eight of the most important Farben plants, including Buna-Auschwitz; member of control bodies in several Farben enterprises, including Francolor; member of Nazi Party and German Labor Front; Military Economy Leader; chief of Special Committee "C" (Chemical Warfare) of the Main Committee Powder and Explosives, Reich Ministry of Armaments and War Production; chief of a number of units in the Economic Group Chemical Industry.

[pp. 1363–1364:] FAUST, MAX—Engineer; entered employment of Badische Anilin und Sodafabrik as construction engineer in 1922; until 1929, plant engineer at the Oppau plant of Farben; construction engineer at Ludwigshafen plant, 1929–36; in charge of construction of Farben's Rattwitz and Dyhernfurth plants, 1940–41; Farben Prokurist, 1941–45; construction chief of Auschwitz plant, 1941–45.

[For additional details, including the long series of I.G. Farben's payments for the Auschwitz facility, see Final Brief of the Prosecution Part IV. 1 June 1948. Especially pp. 54–56. [http://www.profit-over-life.org/rolls.php?roll=95]

The requirements for the I.G. Farben Auschwitz facility seem greatly excessive for a routine buna plant, but highly consistent with a facility that was intended (at least in part) to produce materials for a nuclear and/or chemical weapons program:

- Immediate proximity to not just one but three rivers.
- Proximity to a number of different coal deposits, to provide very large amounts of electricity.
- Proximity to not just one but several rail lines, with more to be built.
- The inhabitants of the region were removed.
- The site was quite remote to alleviate concerns about possible "pollution."
- Work at the facility was directly managed by Otto Ambros, a brilliant chemist who was one of the key figures in the highly secretive and very advanced German chemical weapons program, and who had conducted revolutionary research in other areas as well. Such expertise would not be required to manufacture buna, a routine process in Germany by the 1940s.
- The facility was built and operated by Max Faust and a large number of other people who had been involved in building and operating chemical weapons development facilities such as Dyhernfurt (tabun and sarin production), Falkenhagen (sarin production), and Gendorf (mustard gas production). Those other facilities featured extremely high levels of military security, chemical confinement, and technological sophistication. They were also given benign-sounding descriptions (production of detergents, insecticides, etc.) in wartime German documents and even in postwar Allied documents. Were these same things also true for the Auschwitz facility?]

Joseph Borkin. 1978. *The Crime and Punishment of I. G. Farben: The Unholy Alliance Between Hitler and the Great Chemical Combine.* New York: Free Press. pp. 3, 116, 127.

Drawn by the almost limitless reservoir of death camp labor, I.G. chose to build a great industrial complex at Auschwitz for the production of synthetic rubber and oil. So enormous was this installation that it used as much electricity as did the entire city of Berlin. More than 25,000 camp inmates paid with their lives to construct it. [...]

Rather than let the German government finance the building of the installations, the I.G. directors voted to put up the funds to make I.G. Auschwitz a privately owned I.G. enterprise and to assume the entire risk. With almost no opposition, they committed more than 900 million Reichsmarks, over $250 million, to the building of the single largest project in the I.G. system. With such an enormous risk, officials of I.G. carefully watched over their huge investment. [...]

From the bare records available, 300,000 [30,000?] concentration camp workers passed through I.G. Auschwitz of whom at least 25,000 were worked to death. The plants when completed were so enormous that they used more electricity than the entire city of Berlin. But in the final tally, I.G. Auschwitz was a miserable failure. Despite the investment of almost 900 million Reichsmarks and thousands of lives, only a modest stream of fuel and not a single pound of Buna rubber was ever produced.

[Borkin was in charge of investigating and prosecuting I.G. Farben on behalf of the United States after the war, so his statements should be considered authoritative.]

Peter Hayes. 1996. The European Strategies of IG Farben, 1925–45. In: Volker R. Berghahn, ed. 1996. *Quest for Economic Empire: European Strategies of German Big Business in the Twentieth Century.* Providence, Rhode Island: Berghahn Books. p. 63.

IG took some 30,000 camp prisoners between 1941 and 1944, 90 percent of whom died there or in the gas chambers when they could no longer work, yet only one installation was ever completed. No buna had been produced on the site by the time IG's managers evacuated it in January 1945.

Peter Hayes. 2001. *Industry and Ideology: I.G. Farben in the Nazi Era.* 2nd ed. Cambridge, UK: Cambridge University Press. pp. 367–368.

Throughout 1944, then, the Auschwitz project continued on its gruesome course, more impeded by continuing labor shortages than by the Allied air strikes that hit the plants on August 20, September 13, and December 18 and 26. No rubber had flowed by the time the SS ordered evacuation of the site on January 19, 1945. While some nine thousand inmates of Monowitz marched west toward Gleiwitz, were the war had begun, IG's employees began dismantling or destroying the factories. Eight hundred and fifty ill inmates remained behind to receive the Russians. Two hundred died in the week before the arrival of the Red Army, but the survivors escaped at least the final horror visited on the sick at Fürstengrube, who were burned in their huts. Having descended to the very depths of complicity with Nazism, IG Farben came away from Auschwitz still showing a net loss on its books for the development of buna.

Diarmuid Jeffreys. 2008. *Hell's Cartel: IG Farben and the Making of Hitler's War Machine.* New York: Bloomsbury. pp. 290–291.

The IG, meanwhile, had pulled its people home. The last of them left Auschwitz in the second week of January 1945 on two special trains reserved for the town's remaining civilian male Reich Germans (German women and children had been evacuated in October 1944). In the days before their departure, Walter Dürrfeld and Max Faust had toured the Buna-Werke, supervising the dismantling of key equipment and the destruction of documents that hadn't been sent back to Frankfurt and Berlin. Despite their efforts (and a last brief Allied raid after their departure on 19 January), most of the factory's infrastructure remained intact. But it mattered not; IG Auschwitz had been an almost total failure. Around 150,000 people (Reich Germans, foreign labourers, POWs and Auschwitz prisoners) had been engaged at different times on the plant's construction, at a cost of over 900 million reichsmarks and—estimated conservatively—some 35,000 human lives. This number rises to over 40,000 if the death toll at the IG's Fürstengrube and Janina mines is taken into account. Some Nuremberg prosecutors put the figures much higher, concluding that some 200,000 people had died while working for IG Auschwitz, either on-site or as a consequence of being dispatched from the IG's employ to the gas chambers at Birkenau—but this was almost certainly an overestimate based on the incomplete information available at the time. Whichever figure is correct, one thing is clear: although some explosive-grade methanol was produced, not a single pound of buna or one litre of synthetic gasoline ever emerged from the Buna-Werke's gates. After nearly four years of intense activity, all that IG Farben really had to show for its efforts was a reputation stained forever with the blood of those murdered in the Holocaust. Now, as the Red Army drew near, the huge Buna-Werke stood silent and waiting, a bomb-scarred monument to the ambition, greed and folly of a once mighty company.

[Carter Hydrick was apparently the first person to propose that the characteristics of the I.G. Farben Auschwitz facility were highly inconsistent with those of a synthetic rubber (buna) plant, but highly consistent with those of a nuclear production facility [Hydrick 1998, 2016]:

- The facility never produced any buna (or gasoline).
- Construction of the facility began in January 1941, and the facility operated until January 1945. Comparable plants were built and manufacturing final products within a matter of months [e.g., Hydrick 2016, pp. 76–77].
- The facility cost over 900 million Reichsmarks, or over 250 million wartime U.S. dollars. That appears to be over 25 times the cost of other typical buna plants [Hydrick 2016, p. 74]. For contemporary comparisons, the construction of the massive and highly advanced Peenemünde rocket facility cost approximately 300 million Reichsmarks [Neufeld 1995, p. 273], and the construction of the U.S. Oak Ridge electromagnetic uranium enrichment facility cost 304 million U.S. dollars [Groves 1962, p. 97].
- The facility consumed more electricity than the city of Berlin (which at the time was the eighth largest city in the world), vastly more than would be required for a buna plant [Hydrick 2016, p. 73]. However, the electricity consumption is consistent with uranium enrichment methods such as electromagnetic separation and gaseous diffusion, which are very energy-intensive.
- The facility employed around 150,000 people at various points during its four-year history. While that is far more than would be expected for a buna plant, it is consistent with a nuclear production facility. Even Oak Ridge only employed around 22,000 people at its wartime peak.

The Auschwitz facility was also producing heavy water; see p. 4463. Heavy water is not required for uranium-235 enrichment, but would be very helpful to operate a fission reactor and produce plutonium-239 (or uranium-233). On the other hand, production of plutonium-239 would not require enormous amounts of electricity. Could the Auschwitz facility have contained both a uranium-235 enrichment program and a plutonium-239 production program? Both programs would have required significant quantities of uranium as an input material. Furthermore, a uranium-235 enrichment program could have provided enriched uranium to accelerate a plutonium-239 production program.

Whereas the United States showed little interest in Manfred von Ardenne and Gustav Hertz and merely stated that they had played insignificant roles in the German nuclear program, as soon as the war ended, the Soviet Union immediately sought out both von Ardenne and Hertz and made them very lavish offers (by Soviet standards). Was that because Soviet forces sweeping through formerly German-held areas such as Auschwitz discovered technologies or documents that demonstrated that von Ardenne (an expert on electromagnetic separation) and/or Hertz (an expert on gaseous diffusion) had designed nuclear-related production plants that were in operation at Auschwitz or elsewhere in the east?

As shown in the document on pp. 4472–4473, Otto Ambros was the scientific manager of the I.G. Farben Auschwitz facility for its entire history. He is documented to have been deeply involved in the German chemical weapons program, and quite likely he was equally involved in the nuclear weapons program. After the war, Ambros was variously interrogated, imprisoned, and employed by the United States. Where are the transcripts of his interrogations and scientific reports to the United States? Did he reveal the scientific details about nuclear-related or other work at Auschwitz?]

D.12 Possible March 1945 Test Explosion in Thuringia

[There may have been a test explosion in Thuringia in March 1945, as reported by multiple sources:

- A 15 November 1944 letter from General Ivan Ilyichev, chief of intelligence for the Soviet army, to Joseph Stalin reported that the Germans in Thuringia were preparing under hurried but very high security conditions to test a new "bomb of unusual construction" with a "large destructive power" that might be an atomic bomb (p. 4481).

- A 23 March 1945 letter from General Ilyichev to Joseph Stalin reported that the Germans in Thuringia had recently conducted two very high-security test explosions of a new bomb design, described in considerable detail as a 2-ton, 1.3-meter-diameter spherical implosion device with multiple concentric layers and a uranium-235 core that created a "massive radioactive effect," incinerated or burned nearby prisoners of war (POWs), and destroyed buildings and trees within a radius of 500–600 meters (p. 4485).

- In a 30 March 1945 letter from Igor Kurchatov to General Ilyichev, Kurchatov analyzed the details reported in the 23 March 1945 letter, said it gave a "very believable description of the construction of the bomb," and requested further information (p. 4496).

- 21 and 29 May 1945 letters from Georgy Flerov to Igor Kurchatov reported that Flerov was currently in Dresden and en route to study the alleged German atomic test site using Geiger counters, and requested that former POWs returning from Germany to the Soviet Union should be interviewed to learn if any of them knew anything about the test (p. 4503).

- An October 1945 report from Soviet Marshal Georgy Zhukov to Stalin stated: "Based on the collected materials, it can be concluded that the German scientists in the field of theoretical and practical research and application of atomic energy have achieved good results up to the creation of the atomic bomb" (p. 4523).

- A 1946 Russian interrogation summary reported that Robert Döpel stated that there was an atomic bomb test on a German military base before the end of the war (p. 4530).

- It seems there is or at least was considerably more information about the apparent German nuclear tests in Russian government archives, including even a captured German film entitled "Film of the Launch of a V-2 and the Explosion of an Atomic Bomb" (p. 4533). At a bare minimum, there are presumably documents identifying the Soviet spy who provided the information given in Ilyichev's two reports, documents reporting the suspected test site location to Flerov (which he seemed to know, but which was not in Ilyichev's two reports), documents reporting what (if anything) Flerov ultimately found, and documents describing the "collected materials" to which Zhukov referred.

- 21 March 1945 and 9 June 1945 U.S. aerial reconnaissance photos of the Ohrdruf military base appeared to show a large circular area of possible blast damage, as well as surrounding buildings that may have been affected by blast and/or radioactive fallout, whereas a 12 August 1944 aerial reconnaissance photo did not show those features (pp. 4541–4545).

- In what appears to be a transcript of her testimony before an East German government inquiry on 16 May 1962, Cläre Werner, a wartime lookout at the Veste Wachsenburg castle near the Ohrdruf Truppenübungsplatz military base, reported watching a large nearby test explosion on 4 March and another one on 12 March 1945, as well as being informed of the historic nature of the explosions by visiting military and SS officials. She reported that she and other local residents suffered from symptoms that sound like radiation sickness. Although there are unresolved questions about the nature and the chain of custody of the 1962 transcript, Cläre Werner confirmed the key points of her testimony in several interviews conducted between 1998 and 2003 (p. 4551).

- In a transcript of his apparent testimony before the same East German government inquiry on 16 May 1962, Heinz Wachsmut reported being conscripted into a unique work assignment for the afternoon and evening of 5 March 1945 in Thuringia. He reported encountering large numbers of living, dying, and dead people suffering from what sounds like radiation sickness and burns in the aftermath of what the SS told him was a history-making test explosion. Under the close supervision of the SS, he was instructed to wear protective gear, and he burned approximately 450 bodies on woodpiles and saw a total of approximately 700 bodies being burned. (It is not clear if all of those were victims of the test explosion, or if some were victims of the daily harsh treatment of POWs.) Afterward his protective gear and clothing were burned, he was instructed to wash himself thoroughly, and he was unable to eat for days afterward possibly due to radiation sickness. While there are again unresolved questions about the 1962 transcript, the family of Heinz Wachsmut confirmed that he had described the same events and details to them (p. 4557).

- In transcripts of his testimony before East German government inquiries in 1966, Erich Rundnagel, a plumber who had worked for Kurt Diebner's nuclear research group in Thuringia during the war, reported that the scientists had told him they had two eight-kilogram atomic bombs (most likely fission pits for atomic bombs) in their safe (p. 4564).

- Colonel Oscar Koch, who was a high-ranking intelligence officer working with General George Patton, stated that a German prisoner of war described the massive explosion of a new bomb type in Thuringia in March 1945 (p. 4566).

- Werner Grothmann stated in 2000–2002 interviews that there was an atomic bomb test in Thuringia on 4 March 1945 (p. 4436).

Some of the major sources and details are summarized in Table D.6.]

	Primary sources for March 1945 test									
Details	**Ilyichev 11/1944**	**Ilyichev 3/1945**	**Kurchatov 3/1945**	**Flerov 5/1945**	**Döpel 1946**	**Werner 1962**	**Wachsmut 1962**	**Rundnagel 1966**	**Koch 1960s**	**Grothmann 2000-2002**
Test date	Preparations at fastest pace	Two in ~March 1945	~March 1945	Recent months	Prior to end of war	Evenings of 4 & 12 March 1945	4 March 1945	Work from 1944 to end of war	Early March 1945	4 March 1945
Test location	Thuringia Wooded area Very remote	Thuringia Wooded area Very remote	Remote area (implied)	Wooded area Very remote	Truppenübungsplatz military base	Behind Röhrensee from Wachsenburg	Near Ringhofen estate	Thuringia near Diebner lab, possibly other installations	Thuringia Wooded area Near research installation	Thuringia near Ohrdruf base, SS lab, Diebner lab, bomb production
People who were involved	SS	SS			SS (implied) scientists (implied)	SS, Post Office, Research Council	SS, Kammler, Post Office, Research Council, special doctors	Diebner's scientists, SS (implied)	SS (implied), scientists (implied)	SS, Himmler, Kammler, Gerlach, Post Office, Diebner, Flügge, special doctors
Blast	Large destructive power	High temp., large blast, buildings/trees in 500-600 m radius	Several hundred meter radius		Atomic bomb test	Bright flash and strong wind from kilometers away	Stinging flame to edge of forest		Far larger than normal bomb, destroyed test site, knocked down trees	Deployed: ≥ 3 kt Tested: ≥ 0.13 kt but $<< 3$ kt, larger than expected
Radio-activity	Probably atomic	Massive radioactive effect	Probably atomic	Test for residual radioactivity	Atomic bomb test	Radiation sickness in surrounding towns	Protective gear, decon., radiation sickness			On-site production Horrible test effects Doctors had to help surrounding areas
Casu-alties	Rapid SS construction → many POWs likely present	Many POWs vaporized, killed, and burned		POWs present		Many bodies to be collected	~450-700 POWs killed or burned; more than expected		People in the area would have been killed	Many workers at test site killed, doctors had to help surrounding areas
Device design	Probably atomic, 1.5 m diameter, several nested hollow spheres	1.3 m dia. 2 tons Al case U-235 fuel Ignition by neutrons Detailed implosion design Designed for rocket Used LOX to reduce weight	Spherical U-235 fuel Ignition by neutrons Implosion design Designed for rocket Used LOX to reduce weight	Probably atomic bomb	Uranium bomb	Something new that will make world history	Something new of which the whole world will speak	Atomic bomb capable of killing >100,000 people. At least two bombs. 8 kg fuel each, small enough to store in safe.	New and unusual weapon	> 1 m dia. sphere Very heavy Aluminum case A little U for test More U-235 for deployment Ignition by special system Designed for rocket Integrated design to minimize weight Tested on a stand

Table D.6: Details about possible March 1945 test explosion(s) from primary sources. The provenance of the 1962 Werner and Wachsmut sources is unknown and open to question (p. 4551).

[The following wartime Russian intelligence reports on the German nuclear program are part of a large archive, of which some selected documents were published in Riabev 2002a. These intelligence reports were first analyzed in Karlsch 2005 and Karlsch and Petermann 2007. See also Uhl 2024.]

General Ivan Ilyichev. 15 November 1944. Intelligence report to General Antonov and Joseph Stalin. Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 37. [See document photos on pp. 4482–4483.]

Peoples' Commissariat of Defense of the USSR
Chief Intelligence Department of the Red Army
15 November 1944
Moscow

To the Head of the Red Army General HQ
General of the Army, Comrade Antonov

Report:

Our trustworthy source in Germany reports:

"The Germans are preparing to conduct tests of a new secret weapon, which has a large destructive power. The test explosion of a bomb of unusual construction is being prepared under highest secrecy in Thuringia. For the preparations of the tests the local residents are supposed to be transported away by an SS detail; the whole operation is reported to be undertaken in strictest secrecy.

The explosions are supposed to take place in a wooded area. For that, special roads to the presumptive test site are being created. The bomb to be tested has a diameter of one and a half meters. It consists of several hollow spheres that nest inside each other. It will be brought to the explosion place with a transporter specially constructed for it. It is still unclear when the test is supposed to take place, but the preparations are going at the maximum fastest pace.

CONCLUSION.

In the last months our source has reported more and more often about the feverish efforts of the Germans to test ever more powerful weapons and their means of delivery. Probably these experiments lead directly to an attempt of the Germans to actually carry out tests of atom bombs, about whose existence we have only incomplete, scanty information."

Head of Chief Intelligence Department
of the Red Army
Lieutenant General Ilyichev

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Copy Nr. 1 — Comrade Stalin
" Nr. 2 — Comrade Molotov
" Nr. 3 — Comrade Antonov
" Nr. 4 — into archive
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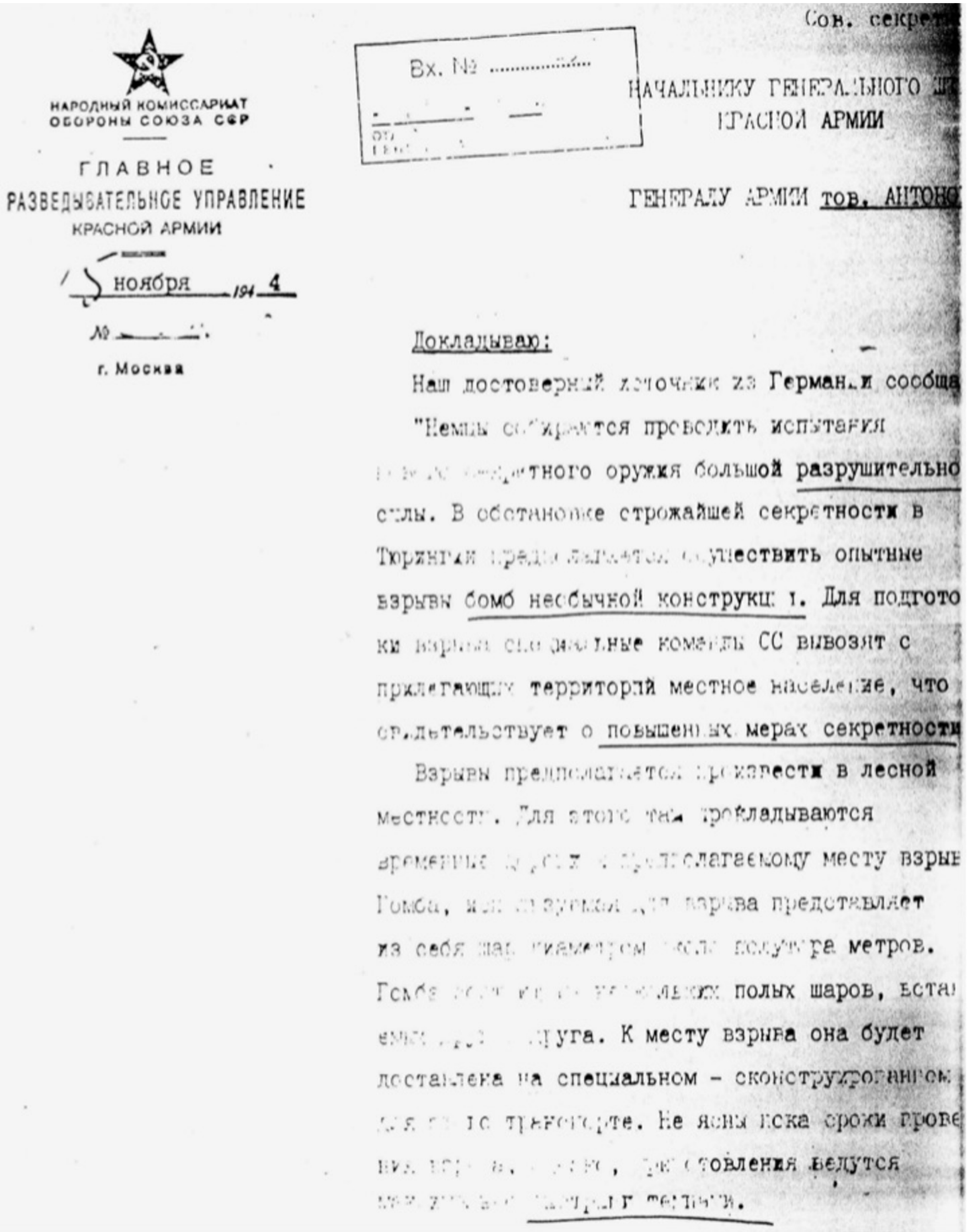


Сов. секре

Вх. №

НАРОДНЫЙ КОМИССАРИАТ
ОБОРОНЫ СОЮЗА ССР

ГЛАВНОЕ
РАЗВЕДЫВАТЕЛЬНОЕ УПРАВЛЕНИЕ
КРАСНОЙ АРМИИ

15 ноября 1944

№

г. Москва

НАЧАЛЬНИКУ ГЕНЕРАЛЬНОГО Ш
КРАСНОЙ АРМИИ

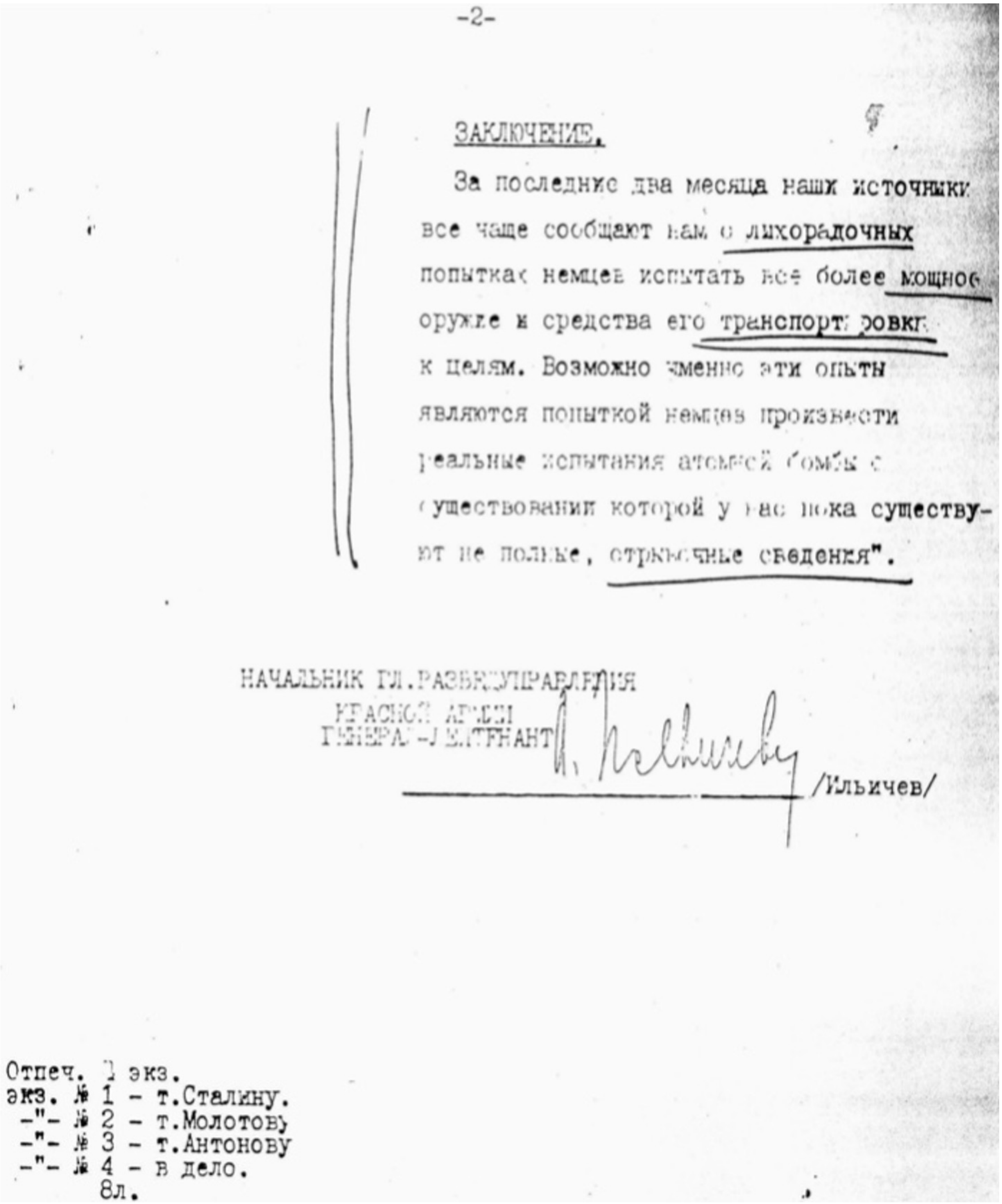
ГЕНЕРАЛУ АРМИИ тов. АНТОНО

Докладываю:

Наш достоверный источник из Германии сообща
"Немцы собираются проводить испытания
нового секретного оружия большой разрушительно
силы. В обстановке строжайшей секретности в
Тюрингии предполагается осуществить опытные
взрывы бомб необычной конструкции. Для подгото
ки взрыва специальные команды СС вывозят с
прилегающих территорий местное население, что
свидетельствует о повышенных мерах секретности

Взрывы предполагается произвести в лесной
местности. Для этого там прокладываются
временные дороги к предполагаемому месту взры
Бомба, используемая для взрыва представляет
из себя шар диаметром около полутора метров.
Бомба состоит из нескольких полых шаров, вста
енных друг в друга. К месту взрыва она будет
доставлена на специальном - сконструированном
для этого транспорте. Не ясны пока сроки прове
ния взрыва, однако, приготовления ведутся
[illegible]

Figure D.697: General Ivan Ilyichev. 15 November 1944. Intelligence report to General Antonov and Joseph Stalin, p. 1 [Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 37, courtesy of Rainer Karlsch].



-2-

ЗАКЛЮЧЕНИЕ.

За последние два месяца наши источники все чаще сообщают нам о лихорадочных попытках немцев испытать все более мощное оружие и средства его транспортировки к целям. Возможно именно эти опыты являются попыткой немцев произвести реальные испытания атомной бомбы о существовании которой у нас пока существуют не полные, отрывочные сведения".

НАЧАЛЬНИК ГЛ.РАЗВЕДУПРАВЛЕНИЯ
КРАСНОЙ АРМИИ
ГЕНЕРАЛ-ЛЕЙТЕНАНТ
/Ильичев/

Отпеч. 4 экз.
экз. № 1 – т.Сталину.
-"- № 2 – т.Молотову
-"- № 3 – т.Антонову
-"- № 4 – в дело.
8л.

Figure D.698: General Ivan Ilyichev. 15 November 1944. Intelligence report to General Antonov and Joseph Stalin, p. 2 [Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 37, courtesy of Rainer Karlsch].

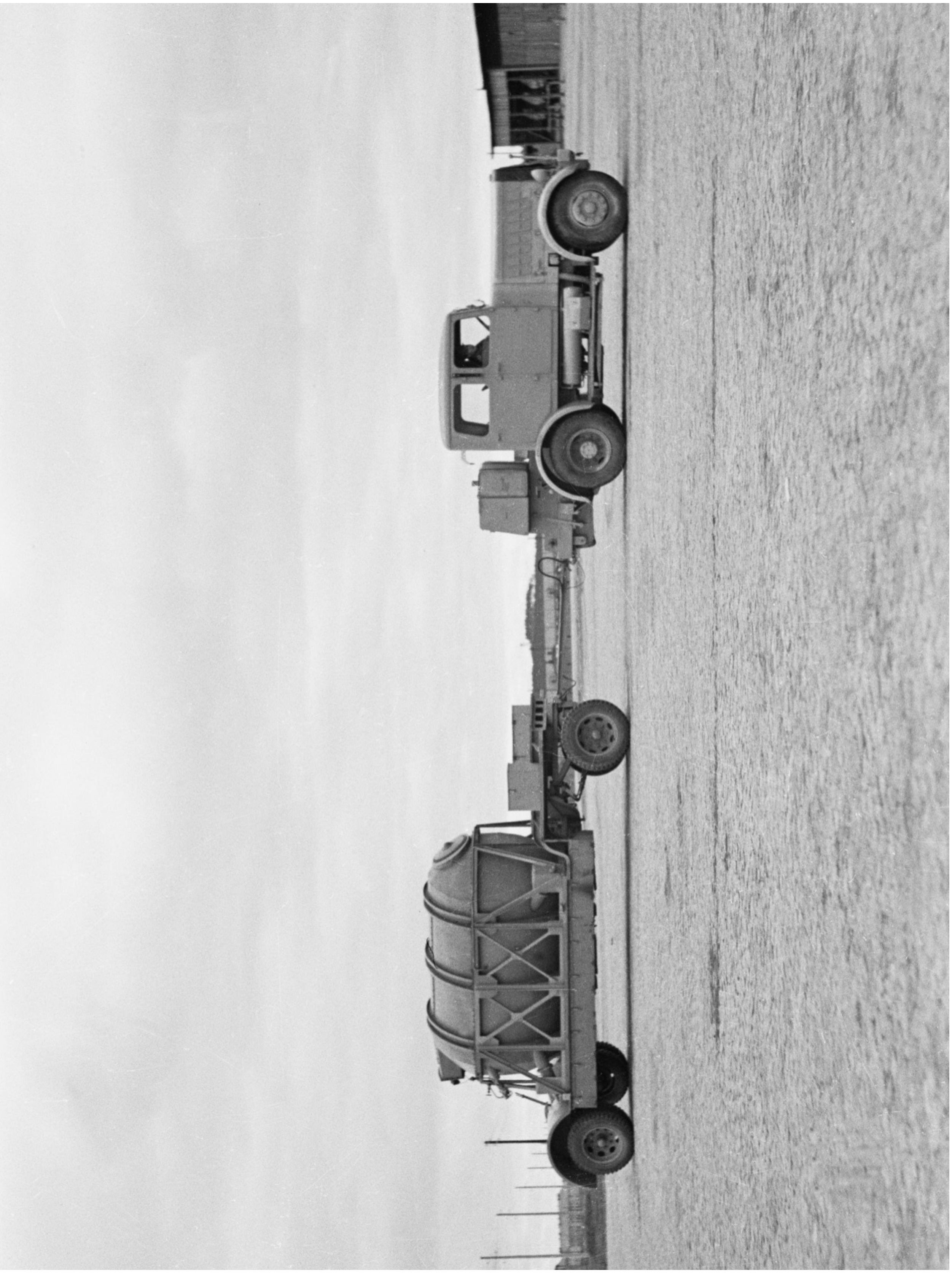


Figure D.699: Hanomag ST100W tractor pulling a specially designed trailer with a liquid oxygen tank for fueling up A-4 (V-2) rockets [Deutsches Museum Archive, photo CD74787]. Could similar vehicles have been used for the test described by General Ivan Ilyichev? See p. 4485: “The bomb, supposedly filled with uranium 235 and weighing approximately two tons, was brought to the test site on a specially constructed truck. Dewars of liquid oxygen were delivered together with it.”

General Ivan Ilyichev. 23 March 1945. Intelligence report to General Antonov and Joseph Stalin. Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 37. [See document photos on pp. 4488–4491.]

Peoples' Commissariat of Defense of the USSR
Chief Intelligence Department of the Red Army
[2]3 March 1945
Moscow

To the Head of the Red Army General HQ
General of the Army, Comrade Antonov

Report:

Our trustworthy source from Germany reports:

"The Germans have in recent times carried out two large-capacity bomb explosions in Thuringia. The explosions took place in a forest area, under conditions of strictest secrecy. Trees fell at a distance of 500–600 meters from the center of the explosion. Buildings and fortifications specially constructed for the tests have been destroyed.

Prisoners of war who were near the epicenter of the explosion died, often without leaving a trace. Prisoners of war who were in the area beyond the center of the explosion have burns on their face and body, the strength of which depends on their position in relation to the epicenter of the explosion. The tests were carried out in a remote deserted area. The regime of secrecy at the test site was at maximum level. Entrance and exit from the territory are by special pass only. SS soldiers have surrounded the area of tests and interrogated any person approaching the area.

The bomb, supposedly filled with uranium 235 and weighing approximately two tons, was brought to the test site on a specially constructed truck. Dewars of liquid oxygen were delivered together with it. The bomb was permanently guarded by 20 guards with dogs. The bomb explosion was accompanied by a large explosive wave and high temperature. In addition, a massive radioactive effect was observed. The bomb is a sphere with a diameter of 130 cm.

The bomb consists of:

1. High-voltage discharge tube, which is charged by special generators
2. A sphere made of metal uranium 235
3. A delay mechanism
4. Protective casing
5. Explosive substance
6. Detonating mechanism
7. Steel casing

All parts of the bomb fit inside each other.

Initiator or bomb fuse.

Consists of a special tube, which creates fast neutrons. It is charged by special generators, which create high voltage inside the tube. As a result, fast neutrons attack active material.

Active bomb material.

Active bomb material is uranium 235. It represents a sphere with an opening into which an initiator is inserted. Once this is done, the opening is sealed by a cork made of uranium 235.

Protective casing.

The uranium sphere is encased in a protective aluminum casing, which is covered by a layer of cadmium. This significantly impedes thermal neutrons emanating from uranium 235, which can cause premature detonation.

Explosive matter.

After the layer of cadmium it is placed inside explosives that consist of porous TNT saturated with liquid oxygen; TNT is made up of bars of a specially chosen shape. The inner surface of the bars has a spherical curvature, which is the same as that of the external surface of the cadmium layer. Each of the bars is supplied with one detonator or two electrical fuses.

Casing.

TNT is covered by a protective layer made of a light aluminum alloy. A blasting mechanism is attached on top of this casing.

Exterior casing.

An exterior casing of armored steel is installed above the blasting mechanism.

Fairing.

A fairing made of a light alloy can be installed on top of the armored casing for future installation on a rocket of the V-type.

Bomb assembly.

The sphere, which consists of metal uranium, is placed inside a protective casing, which consists of aluminum, covered in a layer of cadmium, so that the opening in the sphere coinciding with the opening is sealed off by a uranium cork. After this the aluminum sphere, covered in cadmium, is sealed off by a cork, on top of which the last bar of TNT is placed. Next, liquid oxygen is pumped through the opening inside a protective casing, which covers the TNT. After this the bomb is ready for deployment.

Bomb ignition.

The bomb ignition is carried out with the help of a high-voltage discharge tube. It forms a flow of neutrons, which attack the active material. When the flow of neutrons impacts upon uranium, element 93 fissions, which speeds up the creation of a chain reaction. Next, the detonating mechanism detonates the explosive matter, after which a shock from the explosion of the external layer of TNT mixed with liquid oxygen takes place, which is directed toward the center. This allows the uranium to reach a critical mass.

Ahead of this, before the explosion, the uranium sphere is irradiated with gamma-rays, the energy of which does not exceed 6 million electron volts, which many times increases its explosive qualities.

CONCLUSION.

Without doubt, the Germans are carrying out tests of a bomb of high destructive force. In the event of their successful conclusion and production of such bombs in sufficient quantities, they will have weapons capable of slowing down our advance.

Head of Chief Intelligence Department
of the Red Army
Lieutenant General Ilyichev

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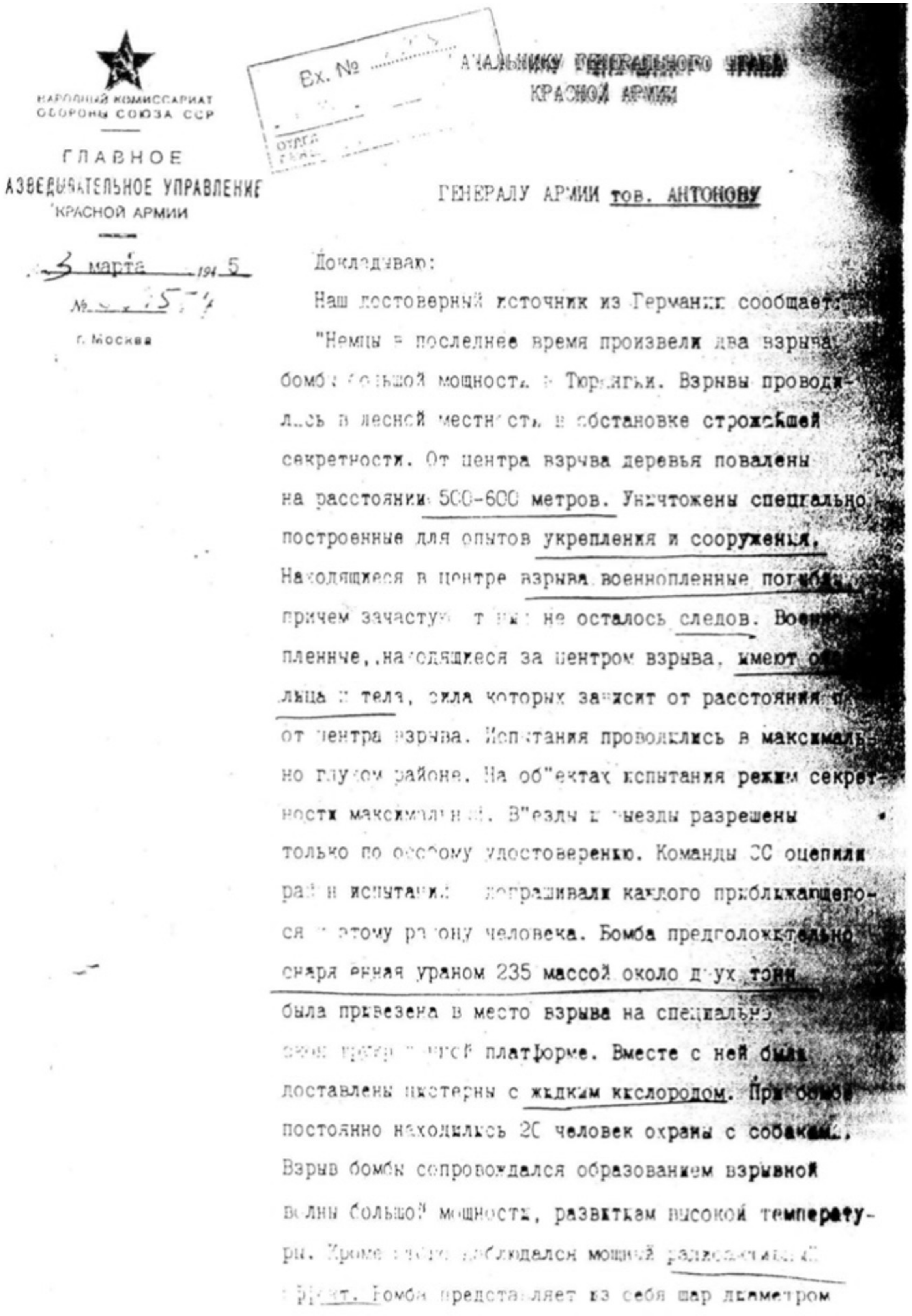


НАРОДНЫЙ КОМИССАРИАТ
ОБОРОНЫ СОЮЗА ССР

ГЛАВНОЕ
РАЗВЕДЫВАТЕЛЬНОЕ УПРАВЛЕНИЕ
КРАСНОЙ АРМИИ

23 марта 1945

№ [illegible]

г. Москва

Вх. №

НАЧАЛЬНИКУ ГЕНЕРАЛЬНОГО ШТАБА
КРАСНОЙ АРМИИ

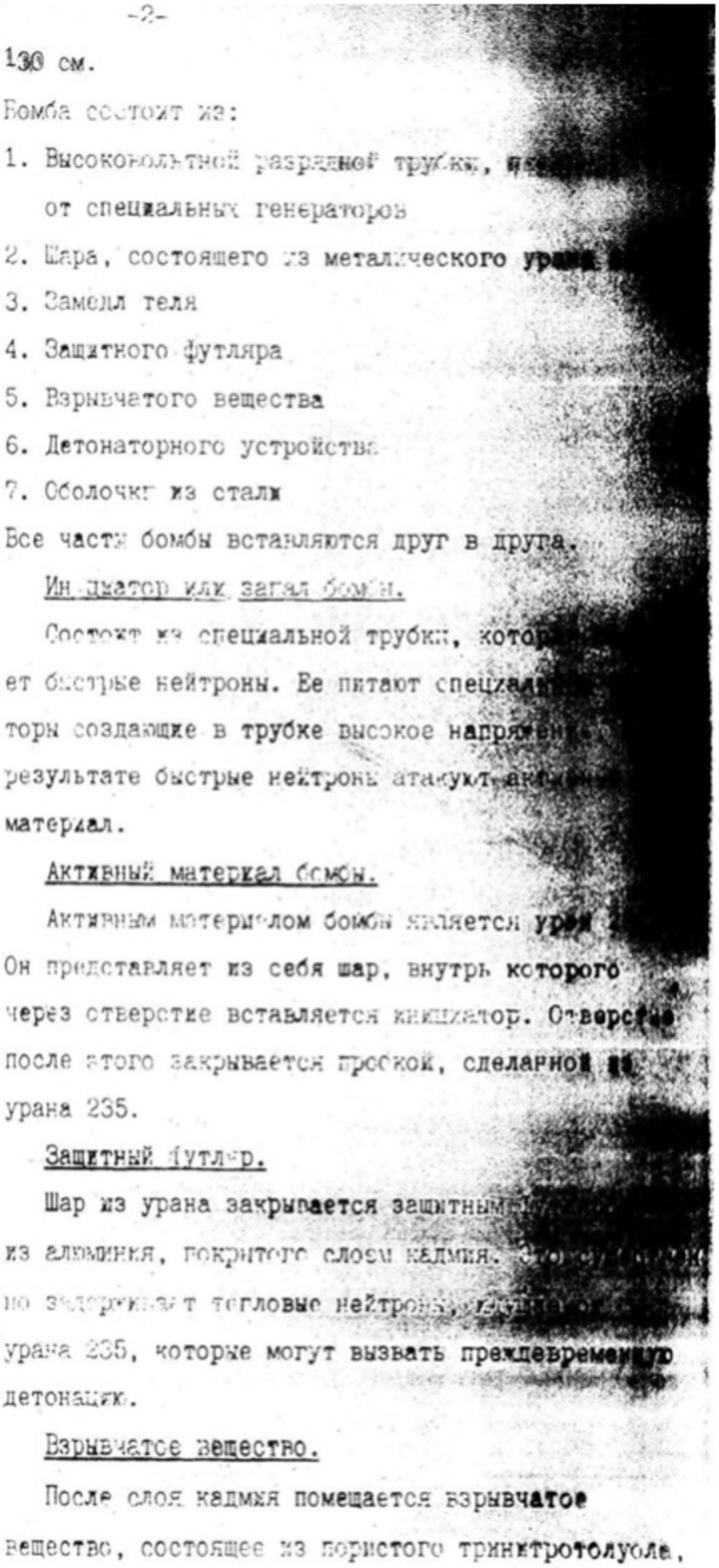
ГЕНЕРАЛУ АРМИИ тов. АНТОНОВУ

Докладываю:

Наш достоверный источник из Германии сообщает:

"Немцы в последнее время произвели два взрыва бомб большой мощности в Тюрингии. Взрывы проводились в лесной местности в обстановке строжайшей секретности. От центра взрыва деревья повалены на расстоянии 500-600 метров. Уничтожены специально построенные для опытов укрепления и сооружения. Находящиеся в центре взрыва военнопленные пог[illegible], причем зачастую от них не осталось следов. Военно[illegible]пленные, находящиеся за центром взрыва, имеют о[illegible] лица и тела, сила которых зависит от расстояния [illegible] от центра взрыва. Испытания проводились в максимально глухом районе. На объектах испытания режим секретности максимальный. Въезды и выезды разрешены только по особому удостоверению. Команды СС оцепили район испытаний и опрашивали каждого приближающегося к этому району человека. Бомба предположительно снаряженная ураном 235 массой около двух тонн была привезена в место взрыва на специально [illegible] платформе. Вместе с ней были доставлены цистерны с жидким кислородом. При бомбе постоянно находились 20 человек охраны с собаками. Взрыв бомбы сопровождался образованием взрывной волны большой мощности, развитием высокой температуры. Кроме этого наблюдался мощный радиоактивный эффект. Бомба представляет из себя шар диаметром

Figure D.700: General Ivan Ilyichev. 23 March 1945. Intelligence report to General Antonov and Joseph Stalin, p. 1 [Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 37, courtesy of Rainer Karlsch].



-2-

130 см.

Бомба состоит из:

1. Высоковольтной разрядной трубки,
от специальных генераторов
2. Шара, состоящего из металлического ура
3. Замедлителя
4. Защитного футляра
5. Взрывчатого вещества
6. Детонаторного устройства
7. Оболочки из стали

Все части бомбы вставляются друг в друга.

Инициатор или запал бомбы.

Состоит из специальной трубки, кото
ет быстрые нейтроны. Ее питают специал
торы создающие в трубке высокое напряжени
результате быстрые нейтроны атакуют акти
материал.

Активный материал бомбы.

Активным материалом бомбы является ура
Он представляет из себя шар, внутрь которого
через отверстие вставляется инициатор. Отверстие
после этого закрывается пробкой, сделанной из
урана 235.

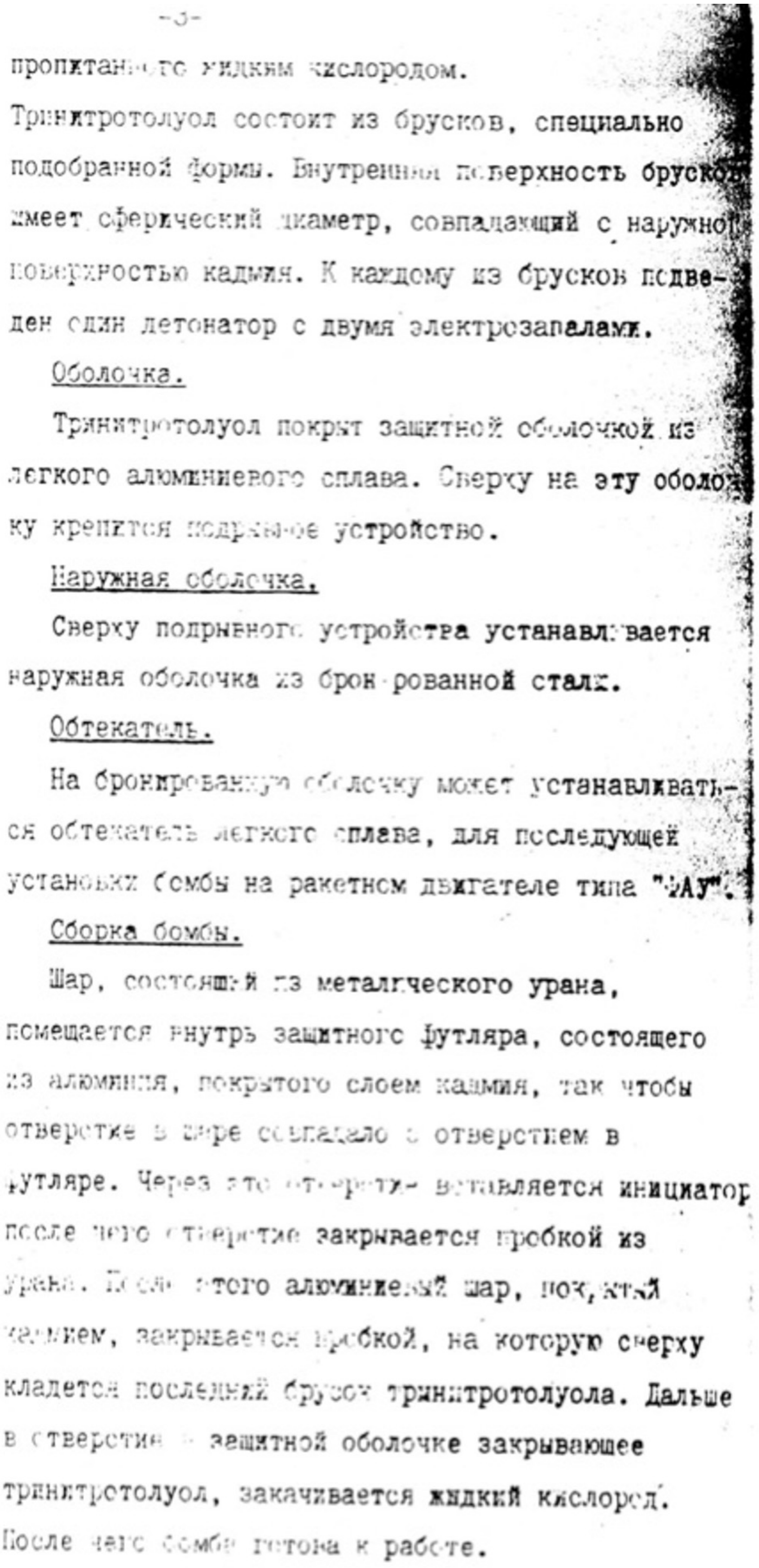
Защитный футляр.

Шар из урана закрывается защитным
из алюминия, покрытого слоем кадмия.
но задерживает тепловые нейтроны,
урана 235, которые могут вызвать преждевременную
детонацию.

Взрывчатое вещество.

После слоя кадмия помещается взрывчатое
вещество, состоящее из пористого тринитротолуола,

Figure D.701: General Ivan Ilyichev. 23 March 1945. Intelligence report to General Antonov and Joseph Stalin, p. 2 [Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 37, courtesy of Rainer Karlsch].



-3-

пропитанного жидким кислородом.

Тринитротолуол состоит из брусков, специально подобранной формы. Внутренняя поверхность брусков имеет сферический диаметр, совпадающий с наружной поверхностью кадмия. К каждому из брусков подведен один детонатор с двумя электрозапалами.

Оболочка.

Тринитротолуол покрыт защитной оболочкой из легкого алюминиевого сплава. Сверху на эту оболочку крепится подрывное устройство.

Наружная оболочка.

Сверху подрывного устройства устанавливается наружная оболочка из бронированной стали.

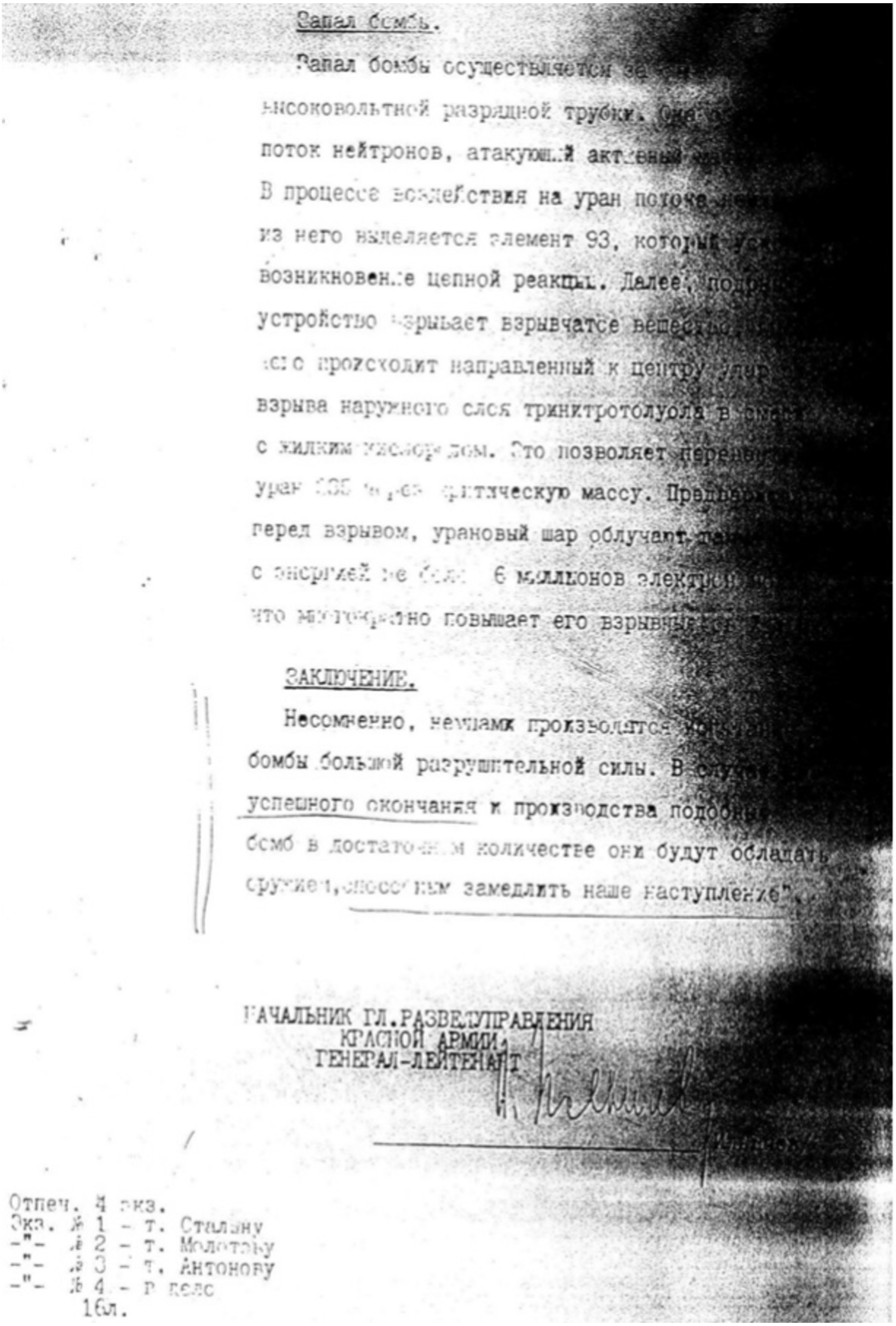
Обтекатель.

На бронированную оболочку может устанавливаться обтекатель легкого сплава, для последующей установки бомбы на ракетном двигателе типа "ФАУ".

Сборка бомбы.

Шар, состоящий из металического урана, помещается внутрь защитного футляра, состоящего из алюминия, покрытого слоем кадмия, так чтобы отверстие в шаре совпадало с отверстием в футляре. Через это отверстие вставляется инициатор после чего отверстие закрывается пробкой из урана. После этого алюминиевый шар, покрытый кадмием, закрывается пробкой, на которую сверху кладется последний брусок тринитротолуола. Дальше в отверстие в защитной оболочке закрывающее тринитротолуол, закачивается жидкий кислород. После чего бомба готова к работе.

Figure D.702: General Ivan Ilyichev. 23 March 1945. Intelligence report to General Antonov and Joseph Stalin, p. 3 [Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 37, courtesy of Rainer Karlsch].



Запал бомбы.

Запал бомбы осуществляется за
высоковольтной разрядной трубки. Она
поток нейтронов, атакующий активный
В процессе воздействия на уран потока
из него выделяется элемент 93, который
возникновение цепной реакции. Далее,
устройство взрывает взрывчатое вещество
[illegible] происходит направленный к центру
взрыва наружного слоя тринитротолуола в
с жидким кислородом. Это позволяет
уран 235 через критическую массу.
перед взрывом, урановый шар облучают
с энергией не более 6 миллионов электрон
что многократно повышает его взрыв

ЗАКЛЮЧЕНИЕ.

Несомненно, немцами производятся
бомбы большой разрушительной силы. В
успешного окончания и производства подобн
бомб в достаточном количестве они будут обладать
оружием, способным замедлить наше наступление".

НАЧАЛЬНИК ГЛ.РАЗВЕДУПРАВЛЕНИЯ
КРАСНОЙ АРМИИ
ГЕНЕРАЛ-ЛЕЙТЕНАНТ

Отпеч. 4 экз.
Экз. № 1 - т. Сталину
-"- № 2 - т. Молотову
-"- № 3 - т. Антонову
-"- № 4 - в дело
16л.

Figure D.703: General Ivan Ilyichev. 23 March 1945. Intelligence report to General Antonov and Joseph Stalin, p. 4 [Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 37, courtesy of Rainer Karlsch].

[Ivan Ilyichev was the Head of the Main Intelligence Directorate (GRU, military foreign intelligence) of the Soviet Union from August 1942 until July 1945.

Compare the description in Ilyichev's report with other descriptions of the German fission bomb design (p. 4157), especially Erich Schumann's design for a two-ton spherical implosion bomb (p. 4244).

As discussed on p. 5154, Ilyichev's report gives a highly detailed and scientifically very plausible design for a fission implosion bomb, especially considering that the original design has been passed through several nonscientific hands, translated from German to Russian, and compressed into a Russian spy's succinct long-distance report. A few points deserve clarification:

"3. A delay mechanism" presumably refers to the heavy tamper, which has a large inertia that "delays" the expansion of the exploding fission fuel, and which is located between the fission fuel (item 2 in Ilyichev's list) and the aluminum pusher/casing (item 4). This component is mentioned in the numbered list but not in the more detailed descriptions that follow that list. The best tamper would be natural uranium, so the spy may have simply lumped the uranium fission fuel and the uranium tamper together in the more detailed descriptions.

Two different neutron initiators are apparently described, perhaps to be used together (for redundancy in case one fails during the implosion, or to maximize the number of initial neutrons and therefore the amount of fission chain reactions that occur before the fission fuel blows apart) or perhaps to be used in two different versions of the bomb:

- There are three similar descriptions: (a) "1. High-voltage discharge tube, which is charged by special generators." (b) "Consists of a special tube, which creates fast neutrons. It is charged by special generators, which create high voltage inside the tube." (c) "The bomb ignition is carried out with the help of a high-voltage discharge tube. It forms a flow of neutrons, which attack the active material. When the flow of neutrons impacts upon uranium, element 93 fissions, which speeds up the creation of a chain reaction." These three descriptions seem to refer to a high-voltage tube that is filled with fusion fuel (deuterium, tritium, and/or lithium) that produces high-energy fast neutrons when a high voltage is applied to the tube. Those neutrons initiate fission reactions in the uranium, releasing more neutrons and starting the fission chain reaction. Such tubes were known to exist in wartime Germany. The term "Element 93" was widely and scientifically loosely used in the German nuclear program to mean uranium that had absorbed a neutron, sometimes meaning neptunium and sometimes plutonium. Here it simply seems to mean the excited uranium compound nucleus, just after it has absorbed a high-energy fusion neutron and just before it fissions.

- A completely different description is also included under "Bomb ignition": "Ahead of this, before the explosion, the uranium sphere is irradiated with gamma-rays, the energy of which does not exceed 6 million electron volts [MeV], which many times increases its explosive qualities."[15] Gamma rays in that energy range can cause photofission of uranium, again releasing neutrons and starting the fission chain reaction. Gamma rays with energies up to

---

[15] An alternative possible interpretation (suggested by Michael Haupt) of this somewhat ambiguous statement is that long before bomb assembly, natural uranium may have been bombarded by particle accelerators to breed plutonium-239 and/or neptunium-237 fuel, which could have been purified and then included in the fission pit of the bomb.

> 6 MeV in the uranium could be produced in the early stages of the implosion process by bombarding the uranium with a beam of electrons with energies of at least 6 MeV from a compact betatron; absorption of the high-energy electrons would produce the high-energy gamma rays. Such compact betatrons were known to exist in wartime Germany; see p. 3089 for one weighing 272 kg, and lighter versions may have been constructed too. By maximizing the number of initial neutrons and hence the number of resulting chain reactions, the gamma irradiation would indeed "many times increase" the "explosive qualities" of the uranium, just as Ilyichev reported. The betatron would also need "special generators, which create high voltage," so that part of Ilyichev's description could apply to either or both neutron initiators.

Note that Igor Kurchatov, the scientific head of the Soviet nuclear program, was puzzled by these statements and did not know how to correctly interpret them; see p. 4496.

The two Ilyichev reports were addressed to Aleksei Antonov but also sent to Joseph Stalin and Vyacheslav Molotov, with one copy for records:

1. The fact that the reports were sent directly to Stalin demonstrates both how important and how reliable Ilyichev believed them to be.

2. General Aleksei Antonov was Deputy Chief of Staff of the Soviet military December 1942–February 1945 but was commonly considered the acting Chief in Moscow (where Ilyichev's reports were sent), since the official Chief of Staff Aleksandr Vasilevsky was usually directing operations on the front lines as the Soviet military advanced westward. Antonov became the official Chief of Staff in February 1945. By addressing his letters to Antonov, Ilyichev was reporting to the highest military official in Moscow. (See also pp. 5028–5029.)

3. Vyacheslav Molotov was the Soviet Minister of Foreign Affairs 1939–1949, but he also handled the logistics of the Soviet nuclear program (along with Lavrentiy Beria) during the war and after the war until at least 1946. By sending a copy of his letters to Molotov, Ilyichev was keeping this top official of the Soviet nuclear program in the loop on intelligence about the German nuclear program.

4. The fact that only four copies of the reports were made (apart from a fifth copy that was apparently forwarded to Igor Kurchatov in late March 1945) again demonstrates how important Ilyichev and the others considered them to be.

The authenticity of the two Ilyichev reports appears beyond doubt [Uhl 2024]:

- The Ilyichev reports are part of an extended paper trail that includes published responses by Kurchatov and Georgy Flerov [Riabev, ed. 2002], so they cannot be more recent fabrications. All of the details in Kurchatov's published response agree quite well with the details in these Ilyichev reports that he referenced (pp. 4496–4497).

- Since these documents cast grave doubt on the Soviet Union's claim to be the second nuclear nation or to have achieved that status by its own scientific strength, there appears to be no incentive for Russians of any time period to have forged or embellished them.

- These reports do not appear to have been a wartime German attempt to bluff the Russians into believing that the Germans possessed a weapon that they did not actually have. A bluff would surely have claimed that the test explosion was much larger, and would not have handed the Russians a highly detailed and presumably quite effective design for a fission bomb.

Of course, despite the authenticity of these documents, how accurate or inaccurate they may be depends on the competence of the unnamed Soviet spy who transmitted the details from Germany. That raises an obvious question—who was the "trustworthy source from Germany" who provided all the information to Ilyichev for the short 15 November 1944 report and the long 23 March 1945 report?

Within the U.S. nuclear program, there were Russian spies from Los Alamos to Oak Ridge transmitting every last technical detail to the Russians. Klaus Fuchs is the most famous, but he was only one of many. Therefore there may well have been multiple Russian spies within the German nuclear program. Because there are so few surviving German records of the program, we may have never even heard of the people who were the key Russian spies within the German program. Those names are probably still in Russian records, but unfortunately historians will probably not be allowed to view more of those records for a long time.

A different approach is to try to think about the types of source people who could have created these reports, just as some scholars divide up books of the Bible into multiple hypothetical sources. Taking that approach, there appear to be at least three possible sources within these reports, which could all be the same single person, or could be two, three, or more people providing information for the reports:

Source 1 was able to write long, detailed reports and transmit them to Russia without being detected by the Germans. Considering how tight German security for the nuclear weapons program was, and how viciously the SS treated anyone even suspected of disloyalty, that was a major accomplishment. Source 1 was also well known by and highly valued by the highest levels of the Russian military/intelligence system/government, apparently due to previous reports that we do not currently have.

Source(s) 2 was one or more people with detailed knowledge of the bomb design. Source 2 could have been a scientist or engineer who worked on the design or the practical assembly, or could have simply been someone who could observe and describe details accurately and who spent enough time with the bomb plans, with the bomb components as they were being assembled, and/or with the scientists who designed or assembled the bomb. Source 2's knowledge covers virtually every major component of the bomb, so this was a person who had comprehensive access, not just someone familiar with only some parts of the bomb. Moreover, source 2's information on all of those bomb components is highly accurate in all cases yet intriguingly is generally not described in very scientific language, which is why it puzzled Kurchatov. Collectively, that evidence suggests that source 2 had unfettered access to the complete bomb and/or complete bomb plans but quite possibly was not a formally educated scientist.

Source(s) 3 was one or more people very familiar with the SS security situation on the ground in Thuringia. That source was likely in the SS in Thuringia, or at least had access to detailed SS reports going to and from Thuringia (maybe in Berlin, or at one of Hans Kammler's other research installations that was closely coordinating with Thuringia). Source 3 knew about all SS security aspects in Thuringia from advanced preparations for the test, to setup of the test, to the effects of the test.

This same combination of sources 1–3 appears in both the short 15 November 1944 report and the long 23 March 1945 report. The identity of the one unified source, or the composition of the team of sources, did not change noticeably during that time period.

As already mentioned, sources 1–3 could have been several different people, or they could have all been the same person. If it was all the same single person, the most plausible profiles (which may or may not be correct) for that person might be:

A. An SS member in Thuringia, who was directly involved in helping to assemble the bomb and prepare for the tests, but probably was not a trained scientist or one of the designers of the bomb.

   or

B. Someone in an SS headquarters office in Berlin, Austria, or Czech territory with unrestricted access to both bomb plans and also SS security reports sent to and from Thuringia. That person could have been anyone from a highly trusted courier or secretary to a high-ranking SS officer, but likely was not a trained scientist.

Someone in the position of profile A above would have been in a far less populated area and perhaps better able to occasionally escape security to send messages to Russia. On the other hand, someone in the position of profile B above would have been surrounded by far more people and communications infrastructure that could potentially be used to send messages to Russia.]

Letter from Igor Kurchatov to General Ilyichev. 30 March 1945. Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 24–25. Published in L. D. Riabev, ed. 2002. *Atomnii Projekt SSR [Soviet Atomic Project] 1938–1945.* Vol. 1, Part 2. Moscow. pp. 260–261. [See document photos on pp. 4498–4501.]

Opinion of I. V. Kurchatov on the document "About a German atomic bomb" that was received by the head office of the General Staff of the Red Army, March 30, 1945

"Secret classified information" (strictly confidential)

The material is extremely interesting. It contains a description of the construction of a German atomic bomb, which is intended to be transported by a carrier rocket of the type "V."

The bringing together of uranium-235 over the critical mass that is required for the achievement of a nuclear chain reaction is caused by the described construction, the explosion of the mixture of granulated trinitrotoluene and liquid oxygen surrounding the U235. The ignition of the uranium is carried out by fast neutrons, which are generated by means of a high-voltage gas discharge tube fed by special generators.

To protect against thermal neutrons, the uranium container is surrounded by a cadmium layer. All of these design details are very credible ~~and agree overall with those according to us that underlie the project of an atomic bomb~~.

It should be noted that I am not totally convinced on the basis of the reviewed material that the Germans have actually made experiments with an atomic bomb.

The level of destruction of a nuclear bomb would be greater than stated, and spread over several kilometers and not just a few hundred meters. The events mentioned in the documents may be preparatory tests with nuclear weapon designs, but conducted without U235 explosive.

It would be desirable to obtain additional information about the course of the experiments, in order to get a more precise location and to obtain a sample of the uranium 235.

Some aspects that, judging from the description, very convincingly demonstrate the effect of a bomb, remain unclear to me.

These include: 1) the preliminary irradiation of uranium with gamma rays, whose energy potential does not exceed 6 million electron volts; 2) the indication that the radioactive element 93, which is obtained from uranium by neutron irradiation, acts extremely positively on the decay of the uranium-235.

It is hard to imagine that some kind of exposure to gamma rays or neutrons could change the explosion characteristics of U235 crucially. Only by the strong intensity of this radiation from utilizing a fission reactor can one change the properties of uranium-235 significantly. Here the wording of specific details at the beginning of the explosion process is rather based on some sort of new physical factors on exposure of the atomic nucleus of uranium to neutrons.

It would be extremely important to obtain detailed and accurate information on these issues.

Even more important would be to learn more details about the process of extracting uranium-235 from natural uranium.

I must note that it would be extremely important for our physicists to have a conversation with the person who gave the information reviewed here.

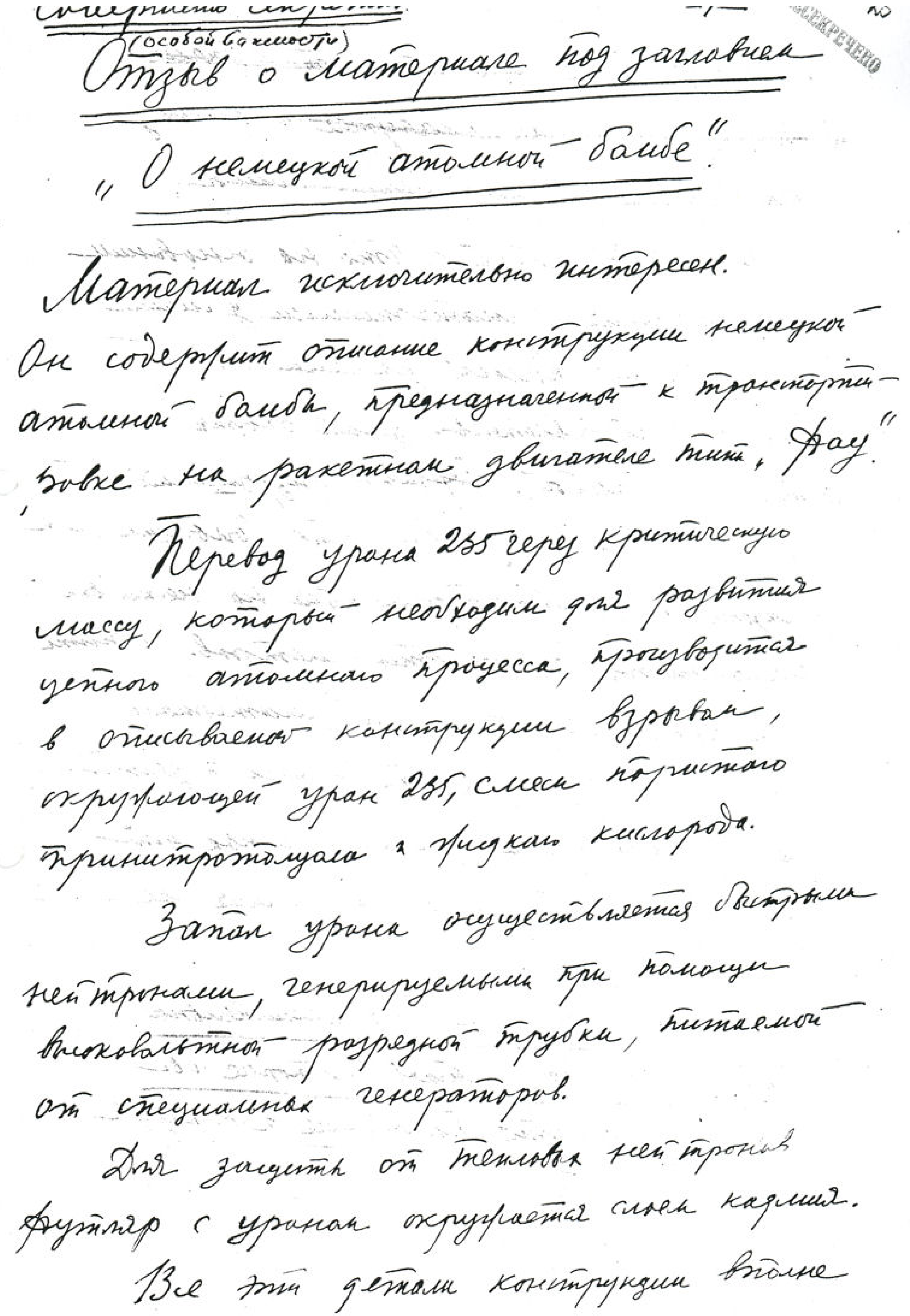
30 March 1945

I. Kurchatov
Single copy
(Note:) Copy sent to Gen. Ilyichev with No. 3GVS-s distribution. A. Vasin

[As shown in the table below, the details of Kurchatov's well-known and officially published 30 March 1945 letter agree essentially perfectly with the details of Ilyichev's 23 March 1945 letter that he was referencing, further confirming the authenticity of the archival documents from Ilyichev.

Information	**Ilyichev**	**Kurchatov**
Bomb design	Spherical implosion	(Implied spherical) implosion
Neutron initiator (1)	High-voltage [fusion] tube produces fast neutrons	High-voltage [fusion] tube produces fast neutrons
Neutron initiator (2)	$\leq$ 6 MeV gamma rays [from 6 MeV betatron]	$\leq$ 6 MeV gamma rays [from 6 MeV betatron]
Fission pit	Hollow sphere of uranium-235	(Implied spherical) uranium-235
Tamper and pusher	(Implied U) "delay mechanism" and aluminum shell	(Implied spherical) "uranium container"
Neutron absorber	Spherical cadmium layer	(Implied spherical) cadmium layer
Conventional explosive	Spherical shell of TNT and liquid oxygen	(Implied spherical) shell of TNT and liquid oxygen
Delivery system	V-type rocket	V-type rocket
Development status	Reportedly tested recently	Reportedly tested recently
Blast radius in tests	500–600 meters	Hundreds of meters

Table D.7: Comparison of details from Ilyichev's 23 March 1945 letter and Kurchatov's 30 March 1945 letter.]



-1- …СЕКРЕЧЕНО №

(особой важности)
Отзыв о материале под заглавием
„О немецкой атомной бомбе".

Материал исключительно интересен.
Он содержит описание конструкции немецкой
атомной бомбы, предназначенной к транспорти-
ровке на ракетном двигателе типа „Фау".

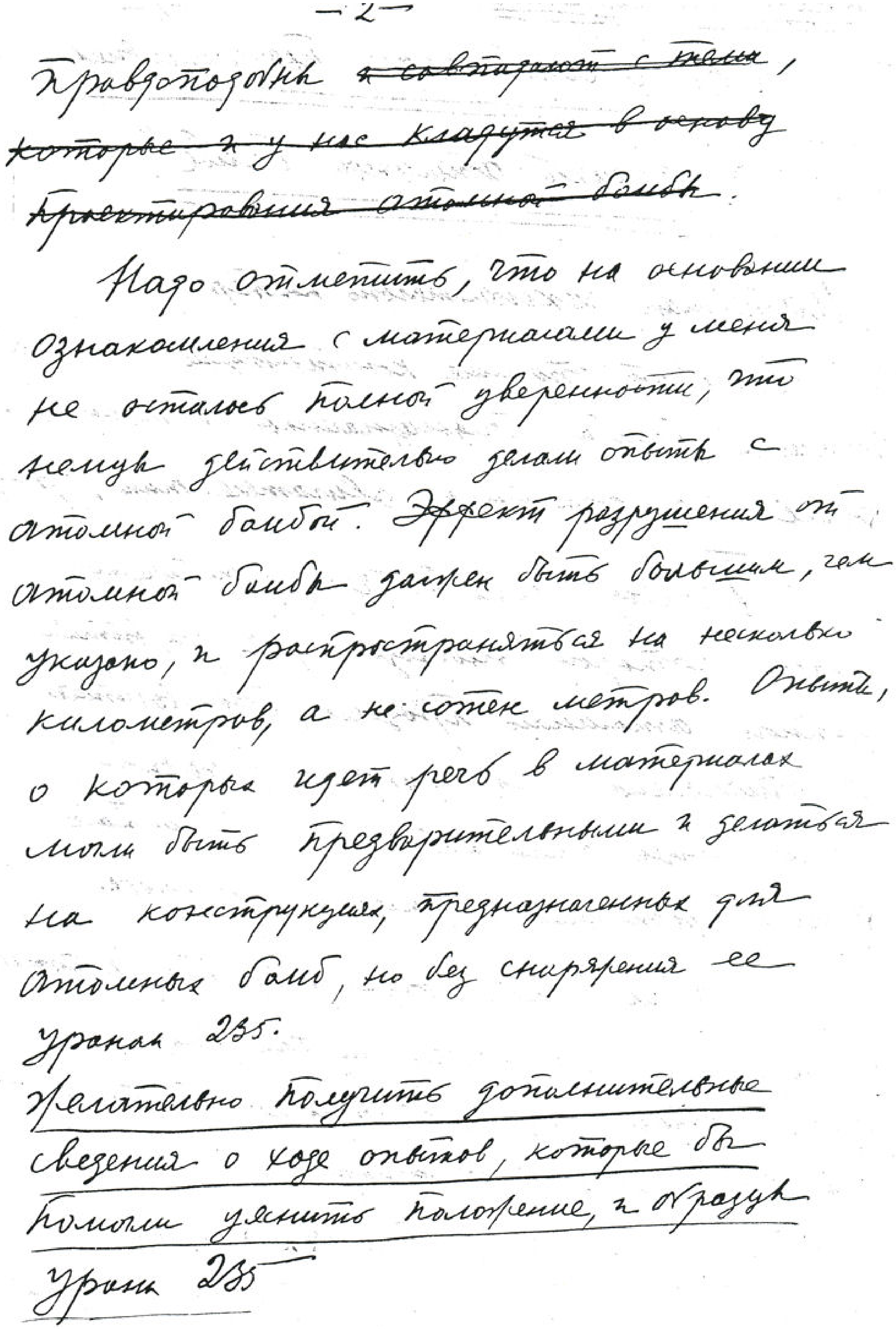
Перевод урана 235 через критическую
массу, который необходим для развития
цепного атомного процесса, производится
в описываемой конструкции взрывом,
окружающей уран 235, смеси тринитротолуола
тринитротолуола и жидкого кислорода.

Запал урана осуществляется быстрыми
нейтронами, генерируемыми при помощи
высоковольтной разрядной трубки, питаемой
от специальных генераторов.

Для защиты от тепловых нейтронов
футляр с ураном окружается слоем кадмия.

Все эти детали конструкции вполне

Figure D.704: Igor Kurchatov. 30 March 1945. Letter to General Ilyichev, p. 1 [Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 24–25, courtesy of Rainer Karlsch and Heiko Petermann].



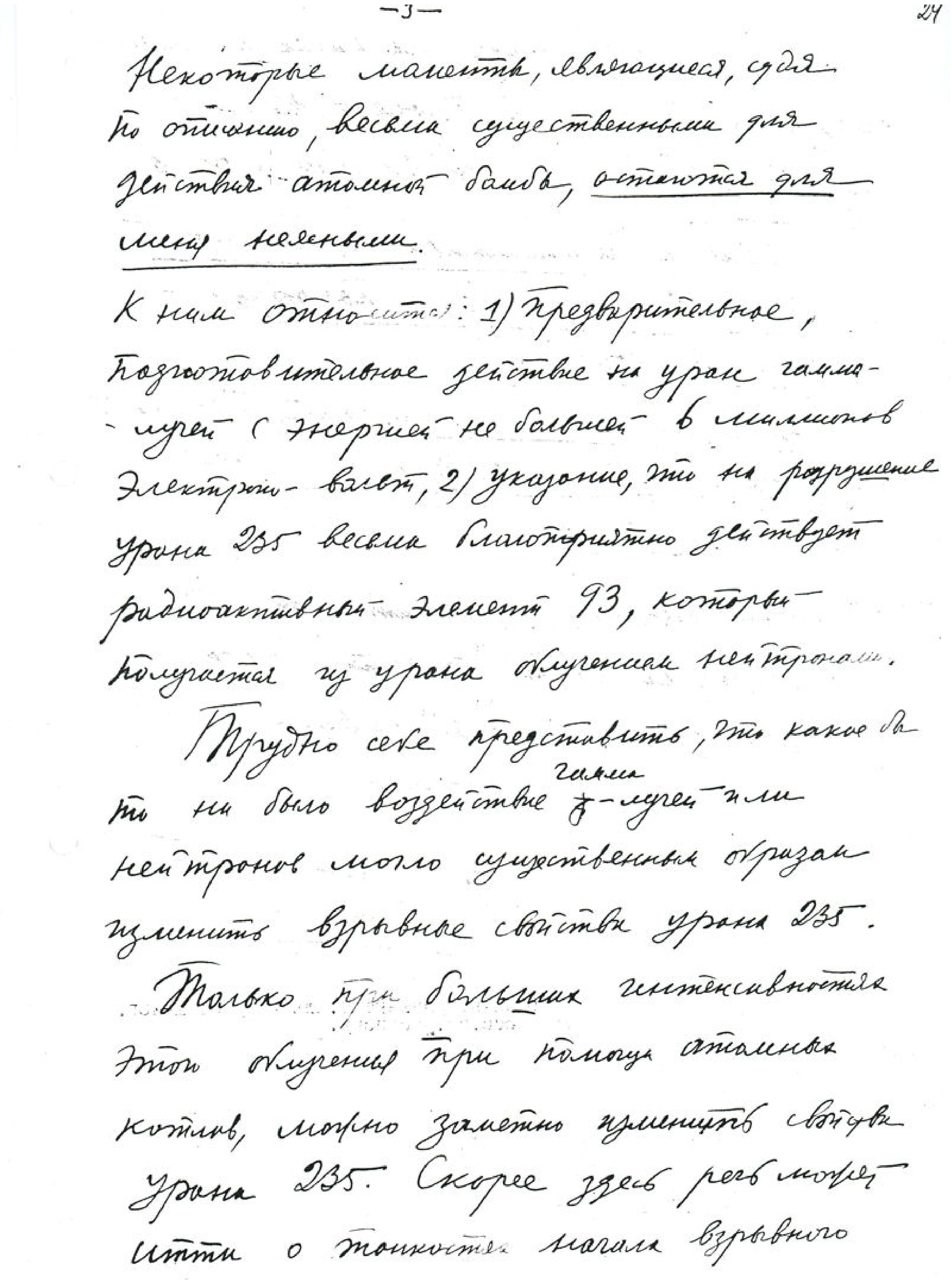
– 2 –

правдоподобны ~~и совпадают с теми, которые и у нас кладутся в основу проектирования атомной бомбы~~.

Надо отметить, что на основании ознакомления с материалами у меня не осталось полной уверенности, что немцы действительно делали опыты с атомной бомбой. Эффект разрушения от атомной бомбы должен быть большим, чем указано, и распространяться на несколько километров, а не сотен метров. Опыты, о которых идет речь в материалах, могли быть предварительными и делаться на конструкциях, предназначенных для атомных бомб, но без снаряжения ее ураном 235.

Желательно получить дополнительные сведения о ходе опытов, которые бы помогли уяснить положение, и образцы урана 235

Figure D.705: Igor Kurchatov. 30 March 1945. Letter to General Ilyichev, p. 2 [Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 24–25, courtesy of Rainer Karlsch and Heiko Petermann].



—3—

24

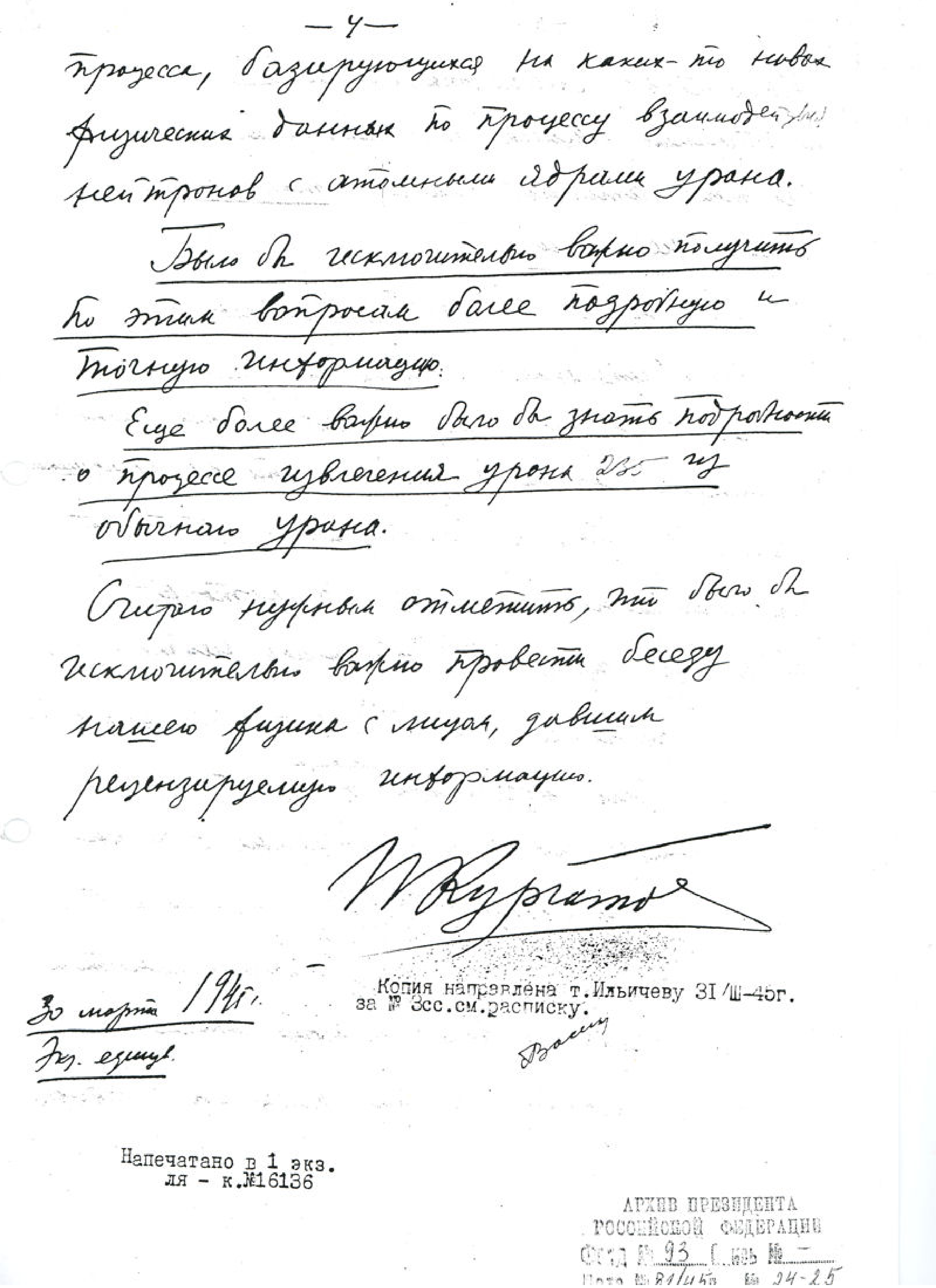
Некоторые моменты, являющиеся, судя по описанию, весьма существенными для действия атомной бомбы, остаются для меня неясными.

К ним относятся: 1) предварительное, подготовительное действие на уран гамма-лучей с энергией не больше 6 миллионов электрон-вольт, 2) указание, что на разрушение урана 235 весьма благоприятно действует радиоактивный элемент 93, который получается из урана облучением нейтронами.

Трудно себе представить, что какое бы то ни было воздействие $\overset{\text{гамма}}{\gamma}$-лучей или нейтронов могло существенным образом изменить взрывные свойства урана 235.

Только при больших интенсивностях этого облучения при помощи атомных котлов, можно заметно изменить свойства урана 235. Скорее здесь речь может идти о тонкостях начала взрывного

Figure D.706: Igor Kurchatov. 30 March 1945. Letter to General Ilyichev, p. 3 [Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 24–25, courtesy of Rainer Karlsch and Heiko Petermann].



— 4 —

процесса, базирующихся на каких-то новых физических данных по процессу взаимодействия нейтронов с атомными ядрами урана.

Было бы исключительно важно получить по этим вопросам более подробную и точную информацию.

Еще более важно было бы знать подробности о процессе извлечения урана 235 из обычного урана.

Считаю нужным отметить, что было бы исключительно важно провести беседу нашего физика с лицом, давшим рецензируемую информацию.

И. Курчатов

30 марта 1945 г.

Экз. единств.

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АРХИВ ПРЕЗИДЕНТА
РОССИЙСКОЙ ФЕДЕРАЦИИ
Фонд № 93 Опись № —
Дело № 81/45 Лл 24-25

Figure D.707: Igor Kurchatov. 30 March 1945. Letter to General Ilyichev, p. 4 [Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 24–25, courtesy of Rainer Karlsch and Heiko Petermann].

Ivan Ilyichev (1905–1983)

Igor Kurchatov (1903–1960)

Georgy Flerov (1913–1990)

Georgy Zhukov (1896–1974)

Figure D.708: Ivan Ilyichev, Igor Kurchatov, Georgy Flerov, and Georgy Zhukov were some of the key Soviet officials who investigated the German nuclear program.

Circa 21 May 1945 letter from Georgy Flerov to Igor Kurchatov. Published in Oleynikov 2000 and L. D. Riabev, ed. 2002. *Atomnii Projekt SSR [The Soviet Atomic Project] 1938–1945.* Vol. 1, Part 2. Moscow. pp. 310–311.

[...] Today or tomorrow we are going to fly in the direction that you know. I am taking with me Dubovsky's instrument [Geiger counter], but its sensitivity is, probably, too low. If we determine on site that there are objects of interest for examination and sensitivity of the instrument is the issue, I'll send you a cable.

You will have to assign Stoljarenko or Davidenko (if he gets back by then) to this work. Instruct them to assemble the instrument [Geiger counter] in the lightweight option: powered from the mains by 220 volts... Along with the instrument, let them pack the tables for finding the appropriate periods [half lives]...

29 May 1945 letter from Georgy Flerov to Igor Kurchatov. Published in Oleynikov 2000 and L. D. Riabev, ed. 2002. *Atomnii Projekt SSR [The Soviet Atomic Project] 1938–1945.* Vol. 1, Part 2. Moscow. pp. 312–315.

[...] Possibly, you can send somebody from the staff to help me. I think that as a result of such search we will be able to find what we need—a person who occasionally was there nearby, as there were a lot of escapees wandering through forests at the time. If successful, we will get objective confirmation of the fact, tantamount to as if we personally had been at that site. This must be done right here and right now, because afterwards all people crossing the border are dispersed through camps in Germany and then are transferred to the Soviet Union, and then even such an enthusiast as myself would question our ability to catch the right people. [...]

The second direction is connected to what I wrote you in the previous letter. In order to determine finally what was really tested there, we shall of course look after artificial, not natural radioactivity. Unfortunately, a lot of time has passed since, but I think that with [our instruments] we will be able to attain the required sensitivity. [...]

Georgy Flerov, 1983, Warsaw private interview. Stanisław Michalik, Tajemnice kopalni Wałbrzycha, *Głos Głuszycy* 2008-04-24. https://www.gornictwo.walbrzych.pl/news-91-Tajemnice_kopalni_Walbrzycha.php

G. N. Frołow—Czemu interesujecie się niemieckimi badaniami atomowymi?	Flerov—Why are you interested in German atomic research?
JR—Bywam u nas na południu Polski w Górach Sowich, w okolicach Wałbrzycha, tam są podziemne sztolnie z okresu wojny i krążą legendy o tym, że Niemcy zaczęli tam jakieś badania naukowe, a ja przecież wiem, że nie mieli bomby atomowej. Pogłoski te jednak występują tak często, że temat mnie zainteresował, a pan Szymański mówi, że wy Grigoriju Nikołajewiczu wiecie na ten temat wszystko.	JR—[interviewer]: I sometimes visit the south of Poland in the Owl Mountains, near Wałbrzych [Waldenburg in German], where there are underground tunnels from the time of the war and there are rumors circulating about the fact that the Germans started some scientific research there, but I know that they did not have an atomic bomb. However, these rumors appear so often that the topic interested me, and Mr Szymanski says that you, Georgy Nikolayevich, know everything about this subject.
GNF—(śmiech)—Nikt nie wie wszystkiego, bo Niemcy dużo dokumentów i materiałów doświadczalnych poniszczyli, a też dużo zabrali sojusznicy, Amerykanie. A gdzie byliście w tych górach koło Waldenburga?	Flerov—(laughs) Nobody knows everything, because the Germans destroyed a lot of documents and experimental materials, and the Allies, the Americans, took a lot. And where were you in those mountains near Waldenburg?
JR—Chyba wszędzie, w Głuszycy, w Walimiu,	JR—I think everywhere, in Gluszyca, in Walim,...
GNF—Chwila, chwila, używajcie niemieckich nazw. Ja tak pamiętam, polskich nie znam.	Flerov—Wait, wait, wait, use German names. I remember it this way, I don't know any Polish names.
JR—To muszę je sobie przypomnieć: Wüstegiersdorf, Ludwigsdorf, Wüstewaltersdorf, Dörnau,	JR—Then I have to remember them: Wüstegiersdorf, Ludwigsdorf, Wüstewaltersdorf, Dörnau,...
GNF—A w miejscowości Rudolfswald byliście?	Flerov—Were you in Rudolfswald?
JR—Rudolfswald, to chyba Sierpnica. Oczywiście byłem	JR—Rudolfswald, I think it is Augustine. Of course I was.
GNF—Sierpnica? No nie wiem. W dokumentach ja potem chyba inną polską nazwę widziałem, coś od drzewa—Modrzew chyba. Powiedzcie co tam było?	Flerov—Augustine? I don't know. In the documents I later saw a different Polish name, something from a tree—Larch, I think. Tell me what was there?

JR—Na południowy wschód od wsi, niedaleko, jakieś półtora kilometra takie sztolnie wykute w skale więźniowie budowali.	JR—Southeast of the village, not far from there, about a kilometer and a half from there, prisoners built such tunnels carved in the rock.
GNF—To się zgadza. (Zgadza się rzeczywiście—w 1945 roku ta wieś nosiła nazwę Modrzewki -JR) W 1945 roku nasze wojsko tam było. Ciekawe rzeczy stamtąd przywieźli.	Flerov—That is right. (That is right—in 1945 the village was called Modrzewki—JR.) In 1945 our army was there. They brought interesting things out of there.
JR—Jakie wojsko, przecież armia poszła dalej?	JR—What army, after all, the army went further?
GNF—Armia tak, ale mieliśmy takie oddziały specjalne (waha się).	Flerov—The army did, but we had such special forces (he hesitates).
JR—SMIERSZ?	JR—SMERSH?
GNF—No nie, SMIERSZ—sporo wiecie (uśmiecha się)—Szymański dobrze o Was mówił. W Rudolfswaldu i gdzie indziej był wywiad naukowy—no naukowcy w mundurach, ale nie podlegli NKMD.	Flerov—No, not SMERSH—you know a lot (smiles)—Szymanski spoke well of you. In Rudolfswald and elsewhere there was a scientific investigation—scientists in uniforms, but they were not part of the NKVD.
JR—Współpracowaliście z nimi Grigoriju Nikołajewiczu?	JR—Did you work with them Georgy Nikolayevich?
GNF—Nie, z nimi nie, dopiero w Moskwie raporty czytałem.	Flerov—No, not with them, I read the reports only in Moscow.
JF—Jak to dopiero w Moskwie, to nie byliście na Dolnym Śląsku po wojnie?	JR—What do you mean only in Moscow, you were not in Lower Silesia after the war?
GNF—Na Dolnym Śląsku nie, nie byłem (waha się), ja byłem tylko w Waldenbergu.	Flerov—Not in Lower Silesia, I wasn't (hesitates); I was only in Waldenburg.
JR—Czy możecie mi powiedzieć, co żeście tam robili wy najlepszy radziecki fizyk atomowy?	JR—Can you tell me what you, the best Soviet atomic physicist, were doing there?
GNF—(śmieje się) Takich komplementów mi nie mówcie, ja nie dziewczyna. Wielu lepszych ode mnie było. I u nas, choćby Igor Kurczatow, a i u Niemców jak się okazało.	Flerov—(laughs) Don't give me such compliments; I'm not a girl. There were many better than me. With us there was for example Igor Kurchatov, but also [some] with the Germans, as it turned out.

JR—Jak to u Niemców? Więc to prawda z tą niemiecką bombą atomową?	JR—What do you mean by Germans? So it is true about the German atomic bomb?
GNF—Prawda i nieprawda—to zawsze się ze sobą miesza (milczy dłuższą chwilę). Ile lat minęło, trzydzieści osiem chyba, no dobrze—opowiem Wam, pytajcie.	Flerov—Truth and untruth—they are always mixed with each other. (He is silent for a long time.) How many years have passed, 38, I think? Well, I will tell you, ask me.
JR—Powiem szczerze, nie wiem, o co mam pytać. Wiem za mało. Jak było w Rudolfswaldu, co tam były za ciekawe rzeczy, o których mówiliście?	JR—I will tell you honestly, I do not know what to ask you. I know too little. How was it in Rudolfswald, what were the interesting things there that you mentioned?
GNF—Rudolfswald to inna historia. Tam wojsko badało i o tym mówić nie mogę.	Flerov—Rudolfswald is a different story. The military was investigating there and I cannot talk about it.
JR—A w Wałbrzychu byliście?	JR—Were you in Wałbrzych?
GNF—W Waldenbergu byłem, ale tuż przed powrotem z Niemiec do Moskwy.	Flerov—I was in Waldenburg, but just before I came back from Germany to Moscow.
JR—Po co jechaliście do Niemiec, czy możecie opowiedzieć?	JR—Why did you go to Germany, can you tell me about it?
GNF—Mnie tam Stalin i Kurczatow wysłali. Meldunki były, że Niemcy badania atomowe prowadzą. Pojechałem tam jako przedstawiciel Ministerstwa Maszyn Lekkich. Okazało się na miejscu, że Niemcy byli bardziej zaawansowani w tych badaniach niż można było przypuszczać.	Flerov—Stalin and Kurchatov sent me there. There were reports that the Germans were conducting atomic tests. I went there as a representative of the Ministry of Light Machines. It turned out on the spot that the Germans were more advanced in the tests than one could have imagined.
JR—Przekazywali Wam informacje?	JR—Did they give you information?
GNF—Informacje i wyniki badań, różne miejsca pokazywali, i dlatego w Waldenbergu się znalazłem.	Flerov—Information and test results, various locations came up, and that is why I went to Waldenburg.
JR—Pokazywali coś w Wałbrzychu?	JR—Did they show anything in Wałbrzych?
GNF—Nie, w Waldenbergu nie, ale dowiedziałem się, że w Dreźnie wywiad trzymał niemieckiego naukowca, fizyka, który mi opowiadał o tajnych badaniach w Waldenburgu, to go wziąłem i pojechaliśmy, ale wiedział zbyt mało.	Flerov—No, not in Waldenburg, but I found out that in Dresden the “Service” [NKVD] had captured a German scientist, a physicist, who told me about secret experiments in Waldenburg, so I took him with me and we went there, but he knew too little.

JR—Jak to—za mało?	JR—What do you mean—too little?
GNF—Widzicie, Niemcy mieli dużo badawczych grup. Mój Niemiec pracował w instytucie drezdeńskim podległym Ministerstwu Poczty, tylko raz był w Waldenbergu instalować urządzenia, bo tamten ośrodek podlegał SS.	Flerov—You see, the Germans had a lot of research groups. My German worked in an institute in Dresden that belonged to the Postal Ministry. He was in Waldenburg only one time to install equipment, because that institute belonged to the SS.
JR—Zaraz, zaraz, pogubiłem się. SS mogło prowadzić badania, ale Ministerstwo Poczty? Co Poczta ma wspólnego z badaniami naukowymi?	JR—Wait a minute, wait a minute, I got lost. The SS could carry out research, but the Postal Ministry? What does the Post Office have to do with scientific research?
GNF—(śmieje się) Takie czasy były, przecież mówiłem. Nikt by się nie spodziewał atomu w Ministerstwie Poczty i (śmiech) w Ministerstwie Maszyn Lekkich jak u nas też.	Flerov—(laughs) Times were like that, I told you. No one would have expected atom [research] in the Postal Ministry and (laughs) also in the Ministry of Light Machines in our country.
JR—Ale Wasz Niemiec, ten fizyk pracował w Wałbrzychu.	JR—But your German, this physicist, worked in Wałbrzych.
GNF—Jego instytut przekazywał część urządzeń dla SS i on tylko pomagał w instalacji, ja to laboratorium chciałem koniecznie zobaczyć, ale nic z tego nie wyszło.	Flerov—His institute gave some equipment to the SS and he only helped with the installation. I wanted to see the laboratory, but was not able to.
JR—Niemcy wysadzili?	JR—Did the Germans blow it up?
GNF—Wysadzić chyba nie wysadzili, bo to pod samym miastem było, tylko on trafić nie mógł.	Flerov—I do not think they blew it up, because it was just outside the city, but he could not find it.
JR—?	JR—?
GNF—Był tam tylko raz. Samochód, który go wiózł z dworca kolejowego długo jeździł po mieście i Niemcowi droga się pogubiła. Później wjechali na teren kopalni i zwieźli go pod ziemię. Dwa dni tam siedział, pracował, jadł i spał pod ziemią. Jak skończył, to znów samochód powoził go po mieście, zanim dotarł na stację. I dlatego ze mną Niemiec niczego nie mógł znaleźć.	Flerov—He was there only once. The car that carried him from the railway station drove around the city for a long time until the German had forgotten the way. Then they drove into the mine and drove him underground. He sat there for two days, worked, ate, and slept underground. When he finished, the car drove him around the city again, before he reached the station. And that is why the German could not find anything with me.

JR—Ale przecież kopalni w Wałbrzychu nie jest tak dużo nie - mógł poznać otoczenia, budynków?	JR—But there are not so many mines in Wałbrzych—could he recognize the surroundings, buildings?
GNF—Jeździłem z nim długo, namawiałem, straszyłem, nic nie dało. On mówił, że wtedy, gdy był pierwszy raz też się bał. Mówił, że wszędzie pilnowali ludzie SS, określił ich jako "ostrych", mówił że mieli takie dziwne znaczki przy mundurach, jakich wcześniej nie widział.	Flerov—I drove around with him for a long time, I persuaded him, I threatened him, it did not work. He said that when he was there for the first time he was also afraid. He said that SS people were guarding everywhere; he described them as "sharp." He said they had strange emblems on their uniforms that he had never seen before.
JR—Mówił coś o tym co było w kopalni?	JR—Did he say anything about what was in the mine?
GNF—Tak, mówił, że z kolegami zawiózł tam cyklotron, ale okazało się, że to drugi, bo jeden już tam był. Oni zamontowali ten drugi. Opowiadał, że kopalnię specjalnie dostosowano. Były wózki, stoły, wszystkie konieczne urządzenia, a na wejściach śluzy i wartownicy. On wejść nie mógł, bo nie miał specjalnej przepustki.	Flerov—Yes, he said that with his colleagues he had installed a cyclotron there, but it turned out that it was the second one, because one was already there. They installed the second one. He told us that the mine had been specially adapted. There were trolleys, tables, all the necessary equipment, and at the entrances there were locks and guards. He could not enter because he did not have a special pass.
JR—Czy opowiadał o podziemnym laboratorium atomowym, uwierzyliście mu Grigoriju Nikołajewiczu?	JR—Did he talk about the underground atomic laboratory, did you believe him Georgy Nikolayevich?
GNF—Uwierzyłem. Mówił o drobiazgach, które znał nasz wywiad. Oni tam mieli w tej kopalni pod ziemią łączność telefoniczną z całymi Niemcami. Była podobno telewizja. Tak, ja mu uwierzyłem, on nie miał potrzeby kłamać, za to była wtedy kula.	Flerov—I believed him. He described little details that our intelligence knew. They had a telephone connection with all the Germans in the underground mine. Apparently, there was television. Yes, I believed him; he had no reason to lie, otherwise he would have been shot.
JF—Nie szukaliście dalej tej kopalni?	JR—Did you not search any further for this mine?
GNF—Jak to nie szukaliśmy? Jak można było nie szukać? Ja już nie, ale nasi długo szukali. Mieli niemieckie plany kopalni, chodzili z polskimi górnikami. Na nic było. Nie znaleźli, a kilku zginęło.	Flerov—What do you mean did we not search for it? How could one not search? I myself did not [search] further, but others were searching on our behalf for a long time. They had German plans for mines; they went out with Polish miners. It was for nothing. They did not find it, and a few died.

JR—Zawał był jakiś w kopalni?	JR—Was there a heart attack in the mine?
GNF—Nie zawał, tylko Niemcy pracujący z Polakami w kopalni potajemnie podkładali miny. To i przestali szukać.	Flerov—Not a heart attack, but Germans working with Poles in the mine had secretly laid explosive mines. So they stopped searching.
JR—I Niemcy mieli bombę atomową?	JR—And did the Germans have an atomic bomb?
GNF—Ja Wam na to pytanie nie odpowiem, ale historia może da odpowiedź. Oni mieli znacznie więcej niż mogliśmy się spodziewać.	Flerov—I will not answer that question for you, but maybe history will give you an answer. They had much more than we could have expected.

[Some especially noteworthy points from Flerov's interview include:

- Apparently a very advanced German scientific facility was located at Rudolfswald/Modrzewki (now called Sierpnica) and was removed by the Russians. It was so important and so secret that it was handled by special Russian scientists working with the Russian military, and Flerov could not discuss it even 38 years later. What work was conducted at that facility—was it nuclear or something else?

- Another advanced German scientific facility was located at Waldenburg/Wałbrzych and conducted important nuclear work during the war.

- According to conventional histories, the various underground facilities that were part of the Riese construction project in Silesia were never finished, let alone utilized. According to Flerov, though, at least two underground scientific facilities there (in Waldenburg/Wałbrzych and Rudolfswald/Modrzewki) were fully equipped and fully operational. How many other Riese facilities were equipped and operational during the war? See Figs. D.709–D.717 for examples of other Riese facilities.

- German security on the nuclear program was extremely tight. Even a German physicist working on the program was taken on a lengthy car detour between the train station and the underground nuclear facility on his way to and from the facility, so that he would not know where the facility was. He and the other workers there were not able to leave the underground facility, so they worked, ate, and slept there round the clock. Everything was tightly locked up and closely guarded. The SS guards were described as being especially "sharp," even by the standards of wartime SS members.

- At the end of the war, “the Germans destroyed a lot of documents and experimental materials” from their nuclear program. Germans kept the nuclear program very secret both during and after the war.

- Likewise, at the end of the war, the Germans sealed and booby-trapped their underground scientific facilities. That helps to explain why so little has been found, and it also poses challenges for modern researchers hoping to find and open those underground facilities.

- At the end of the war, “the Americans took a lot” of documents and materials from the German nuclear program. Flerov could not have been referring to the documents and materials that were taken by the Alsos Mission but then publicly disclosed (especially regarding the small group around Heisenberg), because he lamented that the documents and materials to which he referred were not available. What other—more important and more secret—documents and materials from the German nuclear program were taken by the United States, and where are those documents and materials now?

- Even the Russian scientific investigators like Flerov who scoured large parts of the former Third Reich and conscripted thousands of German scientists and engineers never got a complete understanding of the full extent and accomplishments of the German nuclear program, due to material that was destroyed by the Germans or removed by other Allied countries.

- The Reichspost (Post Office) and the SS were collaborating on a highly secret, high-priority nuclear program, and they had a number of advanced laboratories in remote locations, exactly as independently stated by Werner Grothmann.

- The Germans were operating multiple cyclotrons in remote locations for a highly secret, high-priority war program. That information strongly suggests that they were conducting electronuclear breeding of fission fuel for nuclear weapons.

- Even in such remote areas, German underground scientific facilities were able to communicate with other German facilities not just by telephone, but also by television for two-way video teleconferencing in a remarkably modern manner. This video teleconferencing technology was first publicly available in Germany in 1936 and was utilized for government business during the war (pp. 1013, 1014).

- Members of the specialized SS division that was conducting advanced nuclear work wore a strange emblem on their uniforms that even a German physicist has never seen before. Different parts of the SS had different emblems, but I am not aware of an example of what this one would have been. What was the emblem of the SS’s most advanced and most secret scientific division? It must have been quite distinctive to have stood out in the memory of the German physicist, and then to have been mentioned by Flerov too 38 years later.

- When asked if the Germans had an atomic bomb, rather than saying no, Flerov replied, “They had much more than we could have expected,” and predicted that history might later reveal it.

Can additional relevant documents written by Flerov, written to Flerov, or related to Flerov’s investigations of the German nuclear program be located and released from Russian archives?]

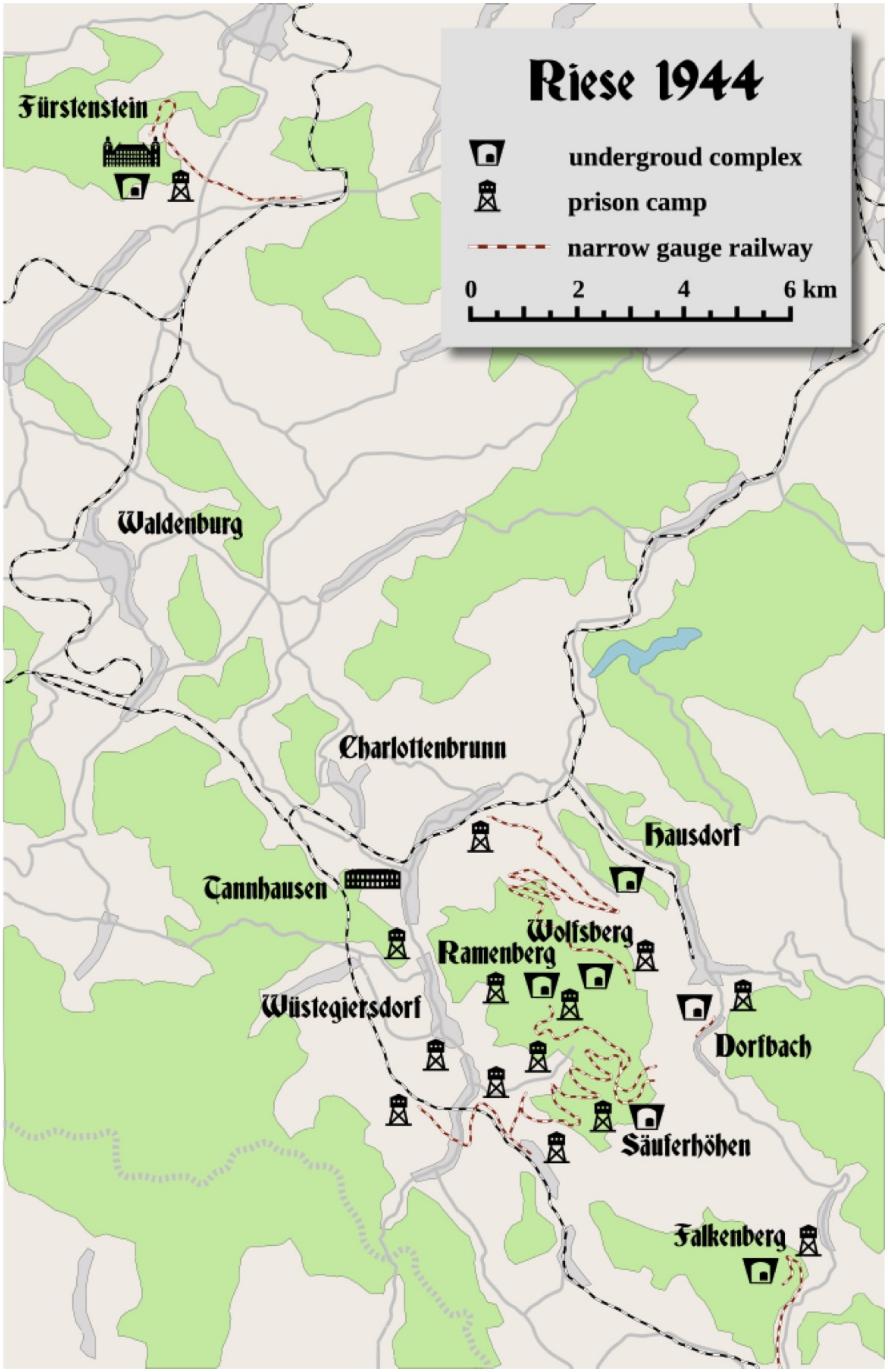

Riese 1944
underground complex
prison camp
narrow gauge railway
0
2
4
6 km
Fürstenstein
Waldenburg
Charlottenbrunn
Hausdorf
Tannhausen
Wolfsberg
Ramenberg
Wüstegiersdorf
Dorfbach
Säuferhöhen
Falkenberg

Figure D.709: Some of the known underground complexes that were part of the wartime Riese construction project in Silesia.

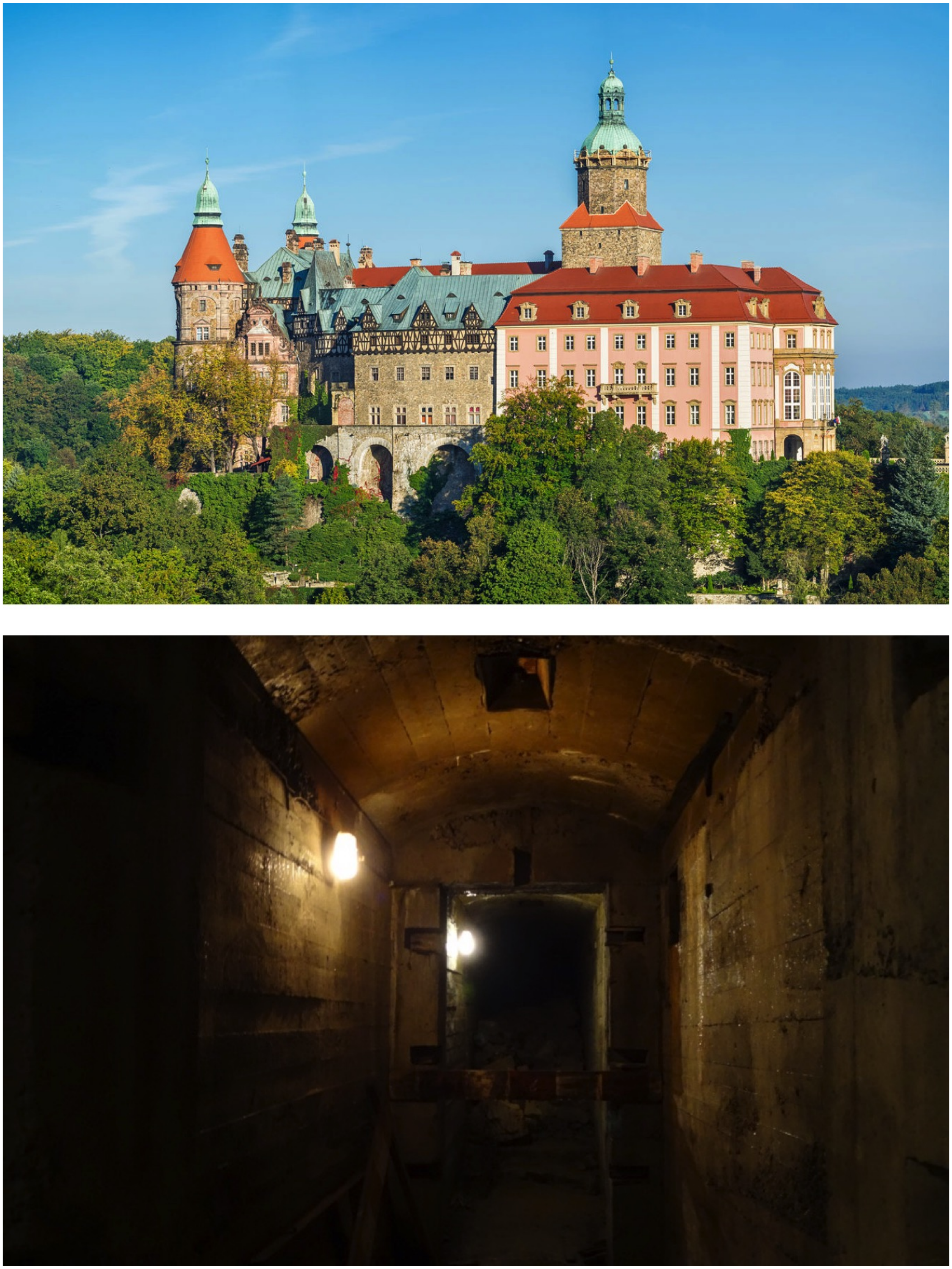


Figure D.710: The former Schloss Fürstenstein, Ksiaż castle in Silesia, and the tunnels under it.

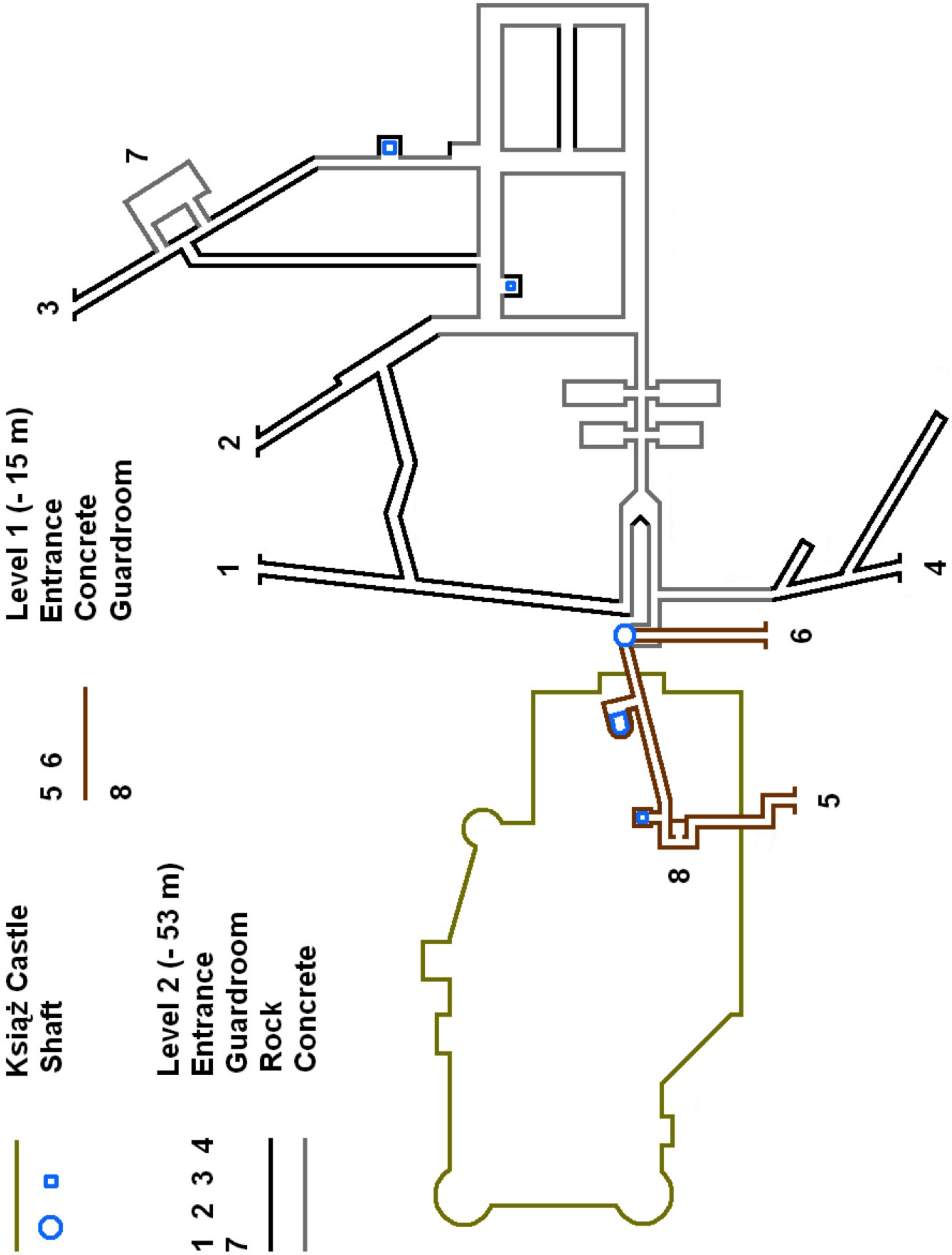

Książ Castle
Shaft
Level 1 (- 15 m)
Entrance
Concrete
Guardroom
Level 2 (- 53 m)
Entrance
Guardroom
Rock
Concrete
1 2 3 4
7
5 6
8
1
2
3
4
5
6
7
8

Figure D.711: The tunnels under the former Schloss Fürstenstein, Ksiaż castle in Silesia.

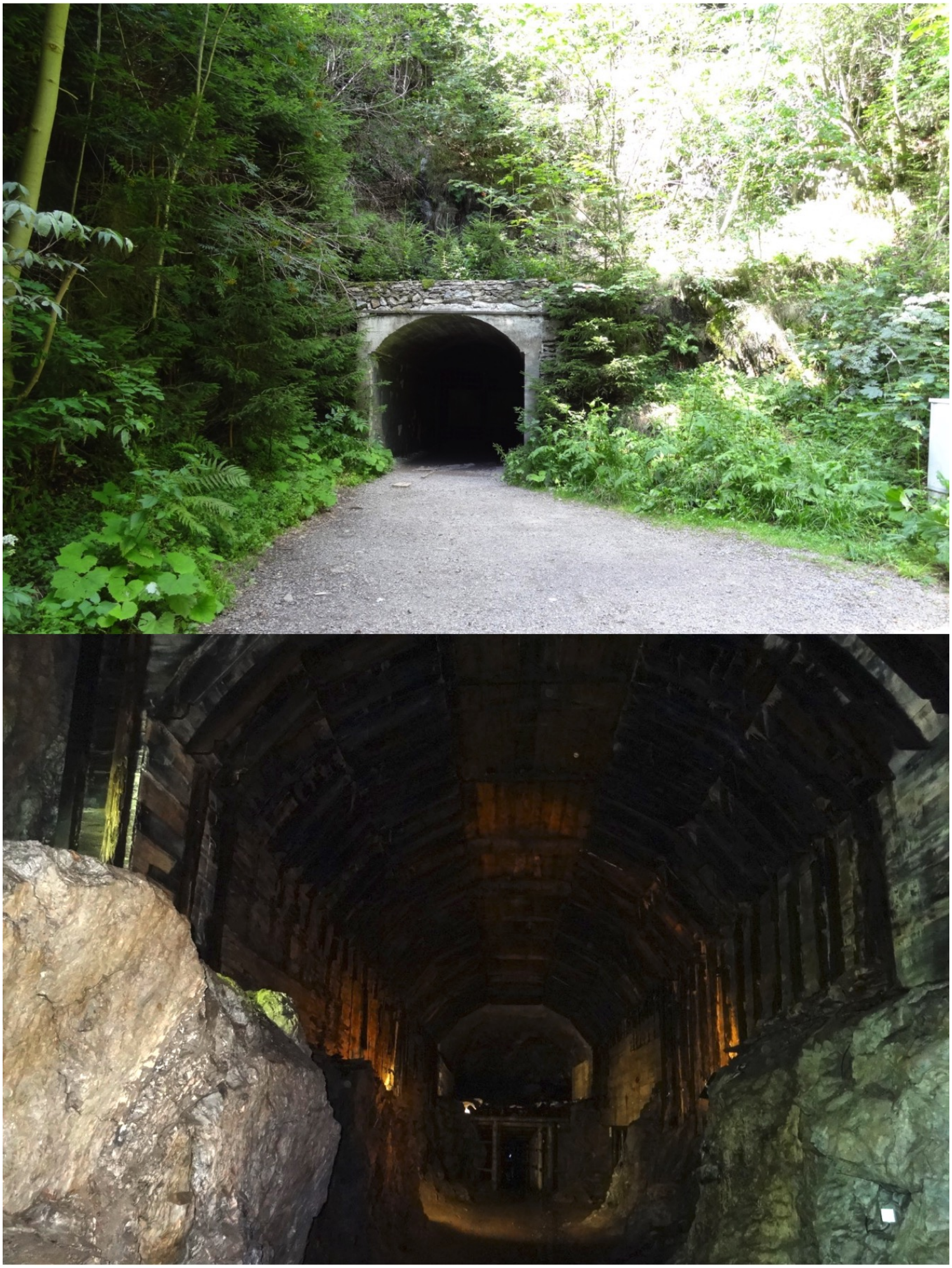


Figure D.712: The former Säuferhöhen tunnel complex, Osówka in Silesia.

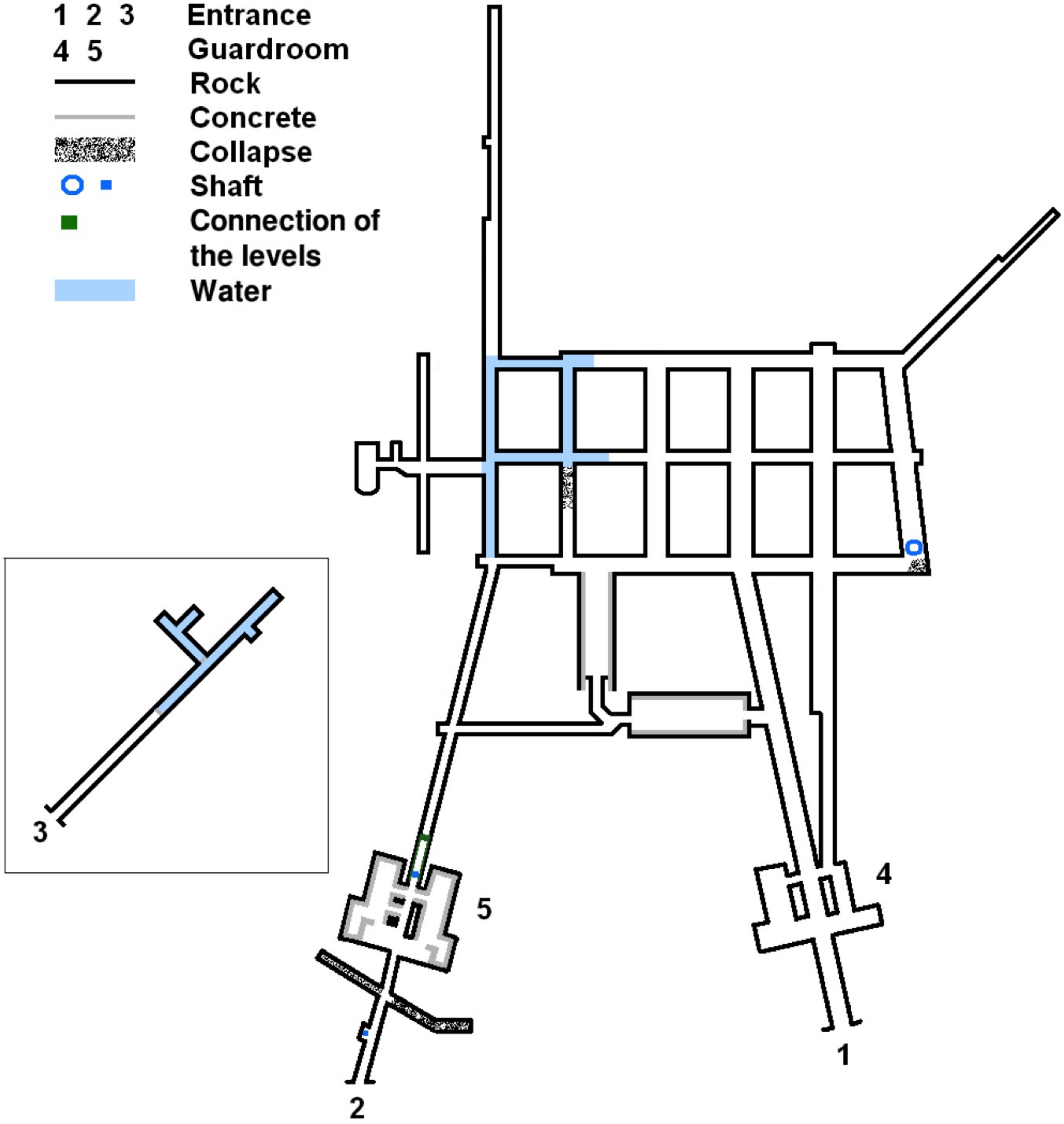

1 2 3 Entrance
4 5 Guardroom
Rock
Concrete
Collapse
Shaft
Connection of the levels
Water
1
2
3
4
5

Figure D.713: The former Säuferhöhen tunnel complex, Osówka in Silesia.

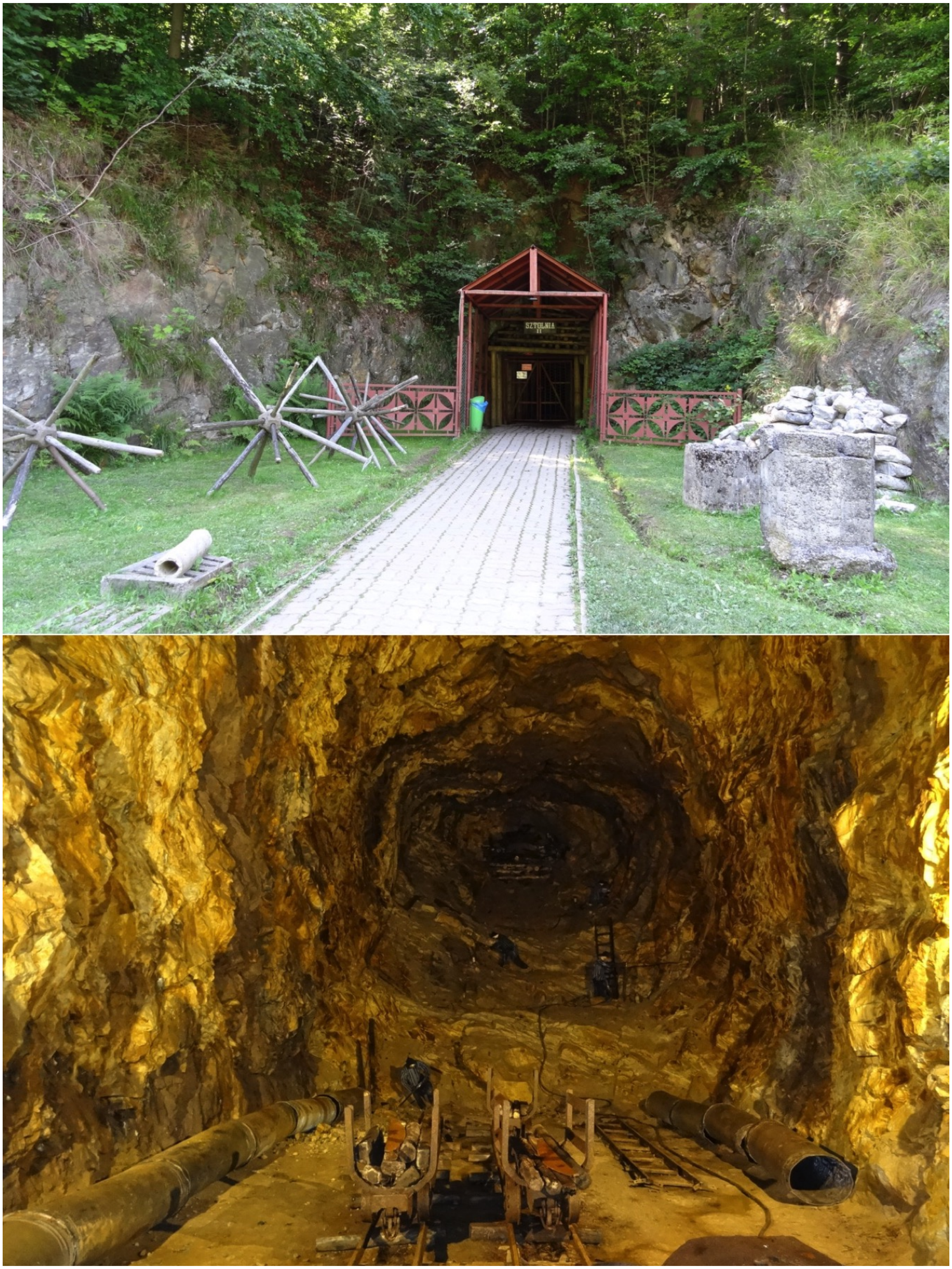


Figure D.714: The former Dorfberg tunnel complex, Rzeczka/Walim in Silesia.

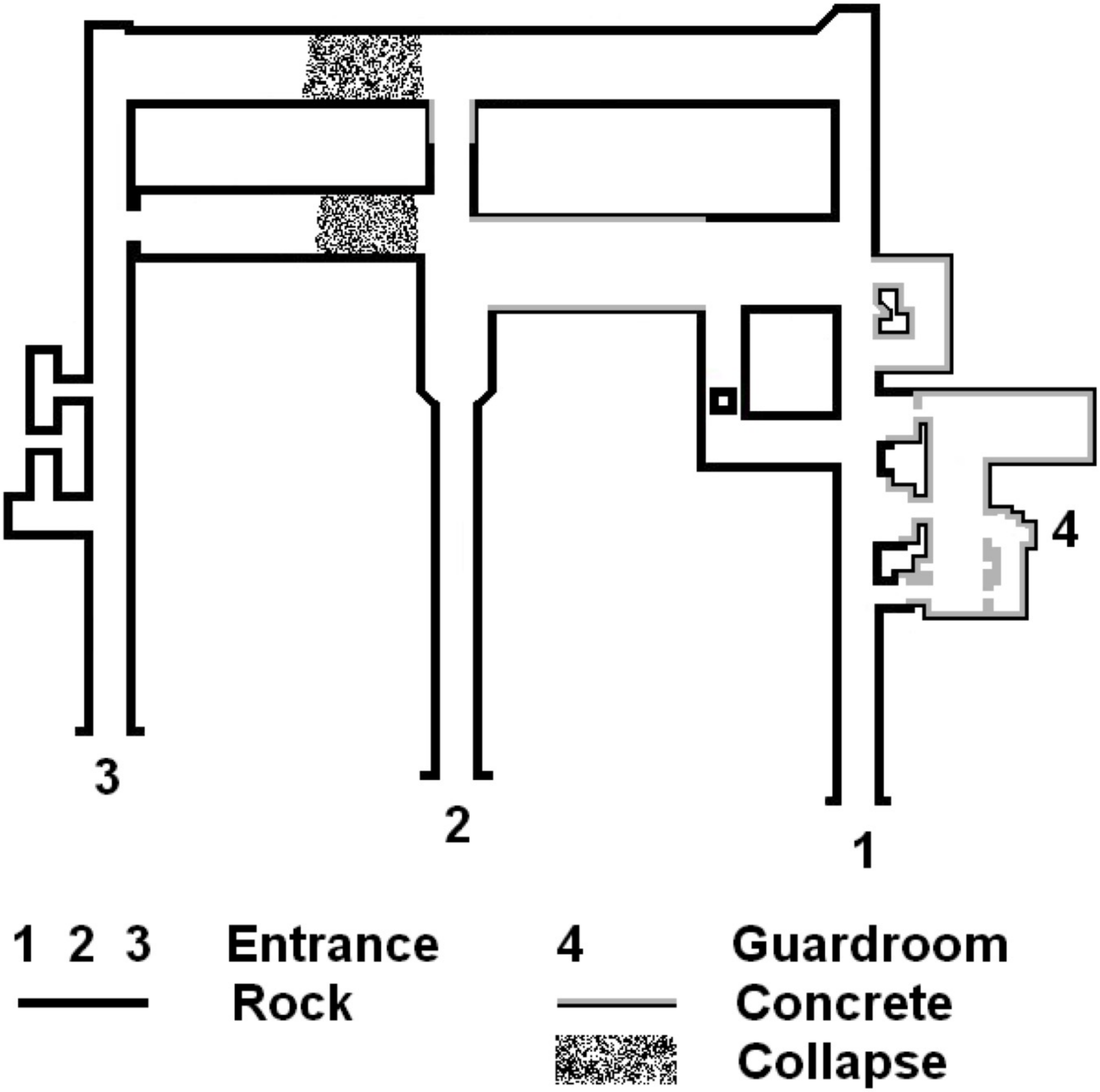

3
2
1
4
1 2 3 Entrance
Rock
4 Guardroom
Concrete
Collapse

Figure D.715: The former Dorfberg tunnel complex, Rzeczka/Walim in Silesia.

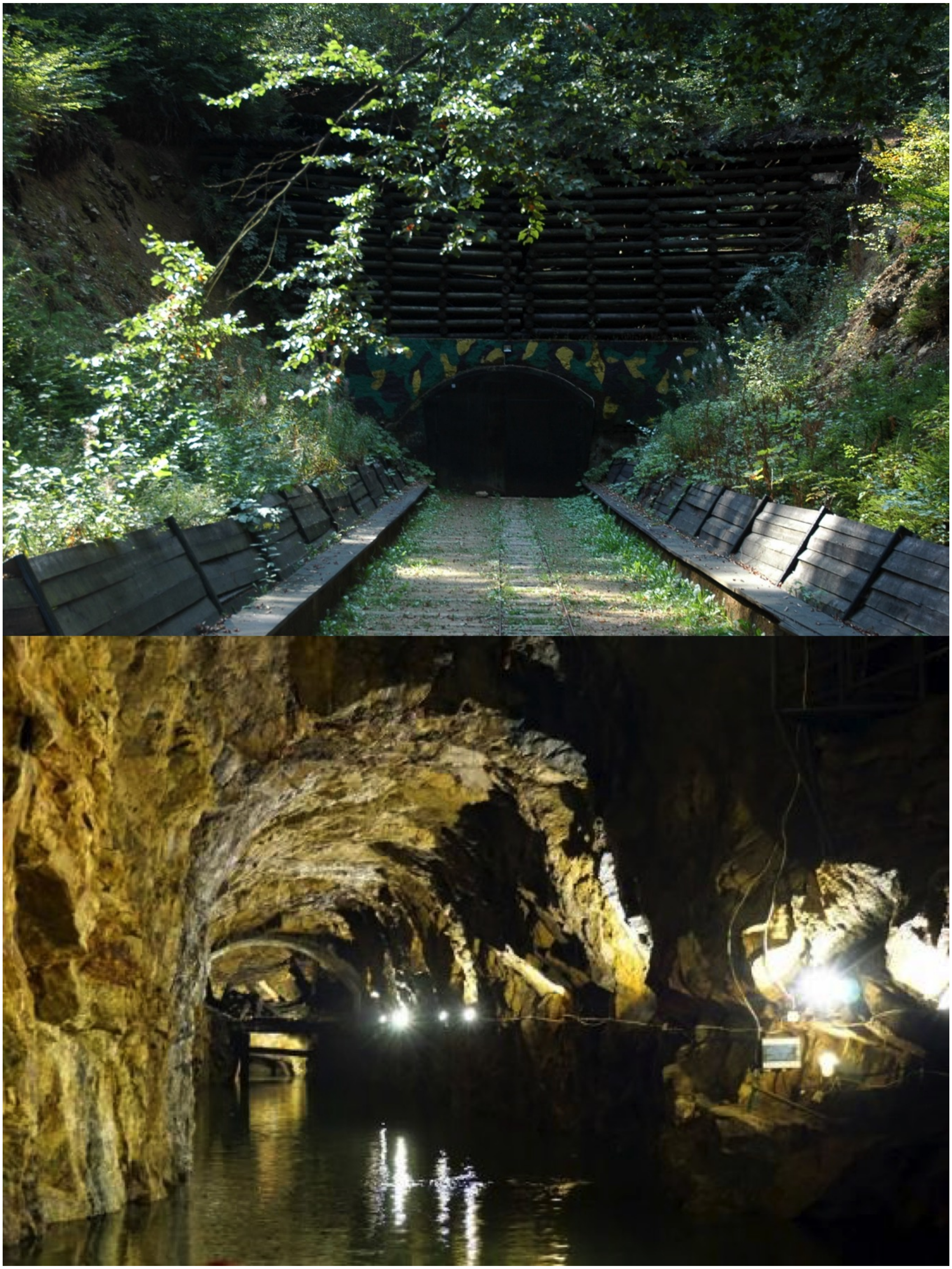


Figure D.716: The former Wolfsberg tunnel complex, Włodarz in Silesia.

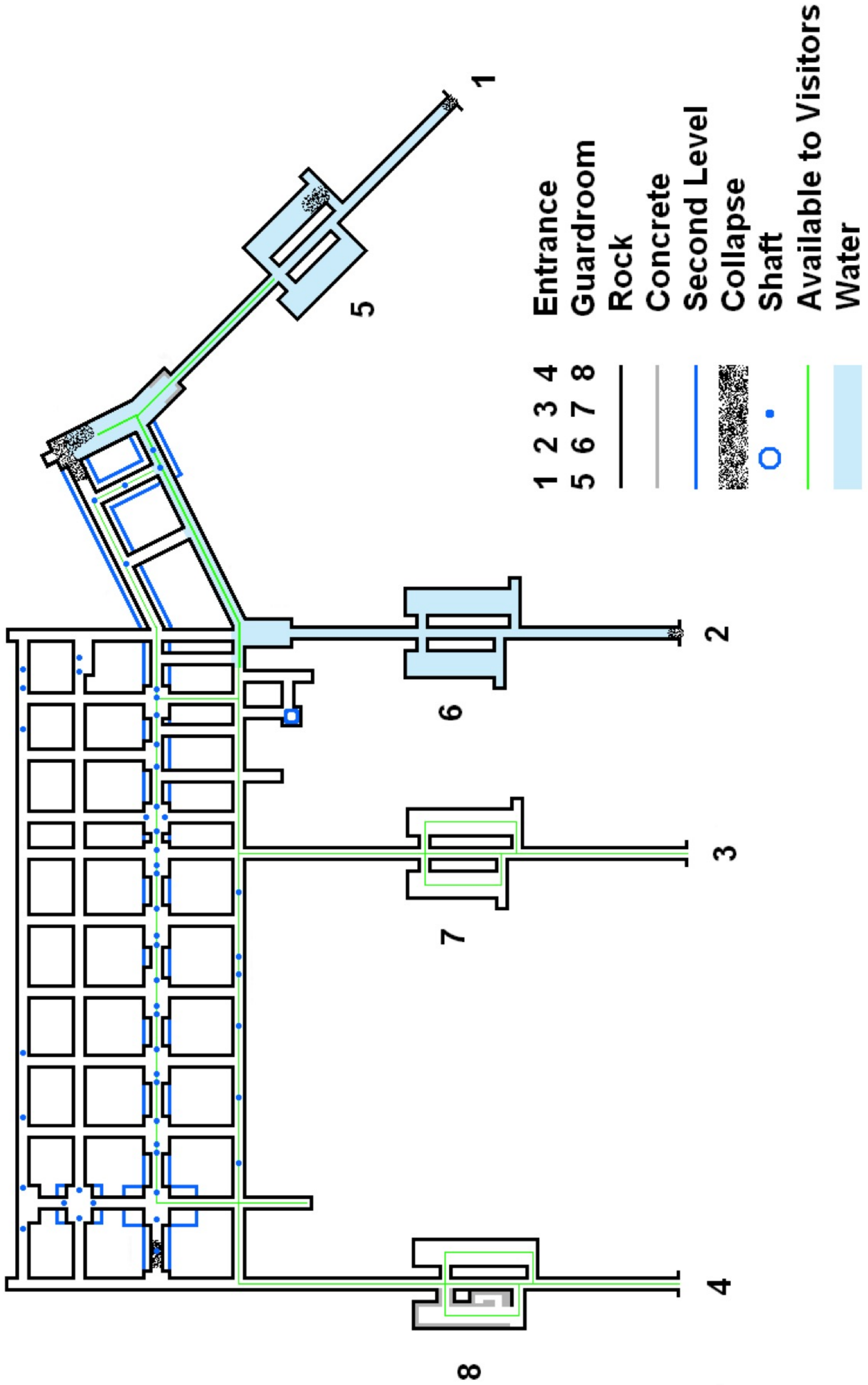

1
5
2
6
3
7
4
8
1 2 3 4 Entrance
5 6 7 8 Guardroom
Rock
Concrete
Second Level
Collapse
Shaft
Available to Visitors
Water

Figure D.717: The former Wolfsberg tunnel complex, Włodarz in Silesia.

Marshal Georgy Zhukov. 2 October 1945. Report to Joseph Stalin [Archive of the President of the Russian Federation, Fund 93, Division 77 (45), List 4–11, published in Riabev 2006c, pp. 60–64]. [See document on pp. 4525–4528.]

2 October 1945
Sov. Secret
Ex. No. 1

Moscow

Generalissimo of the Soviet Union
to Comrade Stalin I.V.

In August and September, a group of employees of the Soviet Military Administration organized an inspection in the Soviet occupation zone, which was done by German scientists in the field of creating an atomic bomb.

I present brief conclusions from what I have been able to establish:

1. After the discovery in 1939 by Professor Hahn and Dr. Strassmann in Germany of the uranium decay, a society was created to use atomic energy obtained from the fission of the atom.

The society included:

> Kaiser Wilhelm Institute of Physics. Berlin-Dahlem (American zone). In 1943, it was evacuated to Hechingen (American zone), led by Professor Heisenberg and staff.
>
> Kaiser Wilhelm Institute of Chemistry. Berlin-Dahlem (American zone). Evacuated to Tailfingen (American zone), led by Professor Hahn, Dr. Strassmann, and staff.
>
> Technische Hochschule. Berlin, Institute of Physics, Professor Geiger.
>
> Dr. Diebner's working group. Berlin, later Stadtilm (Thuringia)—Soviet zone. Dr. Diebner, Dr. Czulius, Dr. Hartwig, Dr. Berkei, Professor Gerlach.
>
> Kaiser Wilhelm Institute for Brain Research, Genetic Department. Dr. Zimmer, Professor Timoféeff. Berlin-Buch (Soviet zone).
>
> Physikalische-Techische Reichsanstalt, Radiological Department. Dr. Weiss.
>
> Research Institute of the Reichspost, Miersdorf, Berlin (Soviet zone). Dr. Otterbein, Professor Flügge.
>
> Kaiser Wilhelm Medical Research Institute, Physics Department. Heidelberg (American zone). Professor Bothe.
>
> Physics Institute of Leipzig University. Professor Hofmann, Professor Döpel, Professor Heisenberg, Professor Pose.
>
> Physicochemical Institute of the University of Leipzig. Leipzig (Soviet zone). Professor Bonhoeffer.

Physicochemical Institute, University of Hamburg. Hamburg (English zone). Professor Harteck, Professor Jensen, Professor Knauer.

Physics Institute, University of Strasbourg (France). Professors Fleischmann, von Weizsacker.

Second Physics Institute, University of Vienna. Professors Stetter, Ortmann.

Institute of Physics, University of Cologne (English zone). Professor Kirchner.

Physics Institute, University of Göttingen (English zone).

Institute of Chemistry, University of Kiel (English zone). Dr. Martin.

Kaiser Wilhelm Institute of Biochemistry. Frankfurt am Main (American zone). Professor Raevsky.

Institute of Chemistry, Danzig University (Poland). Professor Albers.

Physics Institute of the University of Bon (France). Professors Schmitz, Schmitz-Dumont.

French College (Paris). Professor Bothe.

Physics Institute. Munich (American zone). Professor Clusius.

In addition, the study of the atomic nucleus in Germany was carried out by the following leading German scientists:

Von Laue – US zone
Professor von Ardenne [USSR]
Professor Kallmann – Berlin, Westend (English zone)
Professor Flügge – US area
Professor Max Planck – Rodetz, USSR zone
Professor Pascual [Jordan] – Göttingen, University (US zone)
Professor Gustav Hertz [USSR]
Professor Smekal – whereabouts unknown
Professor Erich Regener – Friedrichshafen, Bodensee (American zone)
Professor Hans Bauer – Vienna
Professor Stark – Bavaria (American zone)
Professor Seliger – Greifswalde (Soviet zone)
Professor Bechter – Munich (American zone)
Dr. Ullman – Berlin (US area)
Professor Westphal – Berlin, Zehlendorf (American zone)

Most of the major scientists working in this field were evacuated to southern Germany by the Allies.

2. In 1941, the German [Army] Ordnance Office, the Navy Research Institute, and the Air Force Research Institute set the task for the companies Pinch [or Hinch, maybe Henschel?], Siemens, and Allgemeine Elektricitäts-Gesellschaft [AEG] to create atomic weapons.

For the practical implementation of this task, German scientists worked:

> a) on the production of pure uranium oxide (coded under the name "preparation No. 38") and then from it—uranium metal.
>
> The firms of the Auergesellschaft and Degussa (Frankfurt am Main, American zone) were used.
>
> The scientific advisors were Drs. Riehl, Zimmer, Schulenburg;
>
> b) on the production of the isotope uranium-235.
>
> Scientists have found that the active element (ie, capable of explosion) is uranium-235, which is only 0.7% of the total uranium mixture.
>
> The main specialists in the field of isotope separation in Germany were Professor Harteck, Dr. Groth, who, together with the chief designer of the Anschütz company (Kiel, English zone), Dr. Beyerle, invented an ultracentrifuge built by the above company, as well as by the Hellige company (Breslau, USSR zone).
>
> Another method for separating uranium isotopes and obtaining uranium-235 was proposed by Dr. Bagge (Kaiser Wilhelm Institute of Physics);
>
> c) over the organization of the production of heavy water.
>
> Heavy water in Germany was initially brought from Norway (Norsk Hydro plant). After the termination of supplies from Norway, the Germans tried to organize their own production of heavy water in the city of Merseburg (zone of the USSR), the Leunawerke plant at two installations—"small" and "large," and at the Bitterfeld plant.
>
> Currently at the Leunawerke plant the "small installation" has been fixed again on September 7. The "large installation," destroyed by bombing during its construction, is being restored.
>
> Scientific works were supervised by Professors Harteck, Jensen, Bonhoeffer, Clusius;
>
> d) on the creation of the "Uranium-machine" installation as a source of energy obtained as a result of uranium disintegration.

3. At the direction of Professor Bonhoeffer (Leipzig, Soviet zone), valuable information about the practical application of the Hahn-Strassmann process could be given by Professor Döpel, Professor Pose, and Professor Hund (Leipzig, USSR zone). The latter showed that he knew about the existence of the atomic bomb, but the details were unknown to him. Professor Hund considers the Hechingen and Tailfingen (American zone) institutes to be important institutes where work on the atomic bomb was carried out.

4. It was established that Professor Heisenberg (Hechingen, American zone) was engaged in the practical issues of making the atomic bomb.

Gerlach (Munich, American zone) was in charge of all secret materials.

5. The Germans created to disintegrate the atomic nucleus:

- the cyclotron, built by Siemens-Schuckert, is located in Heidelberg (American zone) in an almost finished condition;
- the cyclotron built by the Pinch [or Hinch, maybe Henschel?] company in Beaune (France) has been in operation for several months;
- an installation with a high voltage of 5 million volts (Hennigsdorf, Soviet zone);
- the large cyclotron of Allgemeine Elektricitäts-Gesellschaft [AEG] in the Reichspost Zeuthen Institute (Soviet zone). Construction is not finished yet.

At the Kaiser Wilhelm Institute, Berlin-Dahlem (American zone), there is a structure for a cyclotron, not completely finished.

From the Kaiser Wilhelm Institute we have removed part of the archive of the Main Directorate of the Kaiser Wilhelm Institute, as well as laboratory and chemical preparations of Professor Hahn.

At present, in the city of Stadtilm (Thuringia, Soviet zone), Dr. Hartwig and Berkei are from the working group of Dr. Diebner (Dr. Diebner was the initiator of the creation of the working society for the use of atomic energy obtained from the decay of the atom). There is also a laboratory for experiments with the "Uran-machine," various laboratory equipment, chemicals and a physicochemical library (2,000 volumes).

According to Dr. Berkei and Hartwig, at the departure of Dr. Diebner with the Americans to the south of Germany (American zone) the following equipment and raw materials were taken:

- radium — about 4 grams;
- metal-uranium — about 1 ton;
- heavy water — 400 kg;
- 2 sets of measuring equipment for measuring machine experiments;
- photographic laboratory;
- technical library;
- instruments required for laboratory equipment: transformers, capacitors, rheostats, amplifiers, meters, vacuum pumps, etc.

When the Americans left, they took away about 10 tons of uranium oxide, beryllium, all available documentation, including personnel cards.

According to Dr. Hartwig and Dr. Berkei, Dr. Osenberg (who booked scientists on important government issues) handed over the complete list of the latter to the Americans.

Based on the collected materials, it can be concluded that the German scientists in the field of theoretical and practical research and application of atomic energy have achieved good results up to the creation of the atomic bomb.

According to German scientists, the Americans partially took advantage of the results of the work of German scientists on this issue.

All materials on the above issue, as well as those removed from the Institute Kaiser Wilhelm's chemical preparations, a group of German scientists in the field of atomic energy and the equipment, materials and a library available in Stadtilm, containing about 2,000 volumes, we handed over to the representative of the NKVD of the USSR, who arrived in Berlin, Lieutenant Colonel Comrade Sidenko on 19 September 1945.

In the future, I would consider it necessary to use the remaining group of scientists and the laboratory of the Physical Chemistry Institute in Stadtilm (Soviet zone) to collect German scientists working on atomic energy, and after gathering these scientists, evacuate them to the Soviet Union.

Commander-in-Chief of the Group of Soviet Occupation Forces in Germany,
Marshal of the Soviet Union G. Zhukov

[The names of people and places got slightly distorted in being translated from German to Russian. The proper German names are used in this English translation of the Russian document.

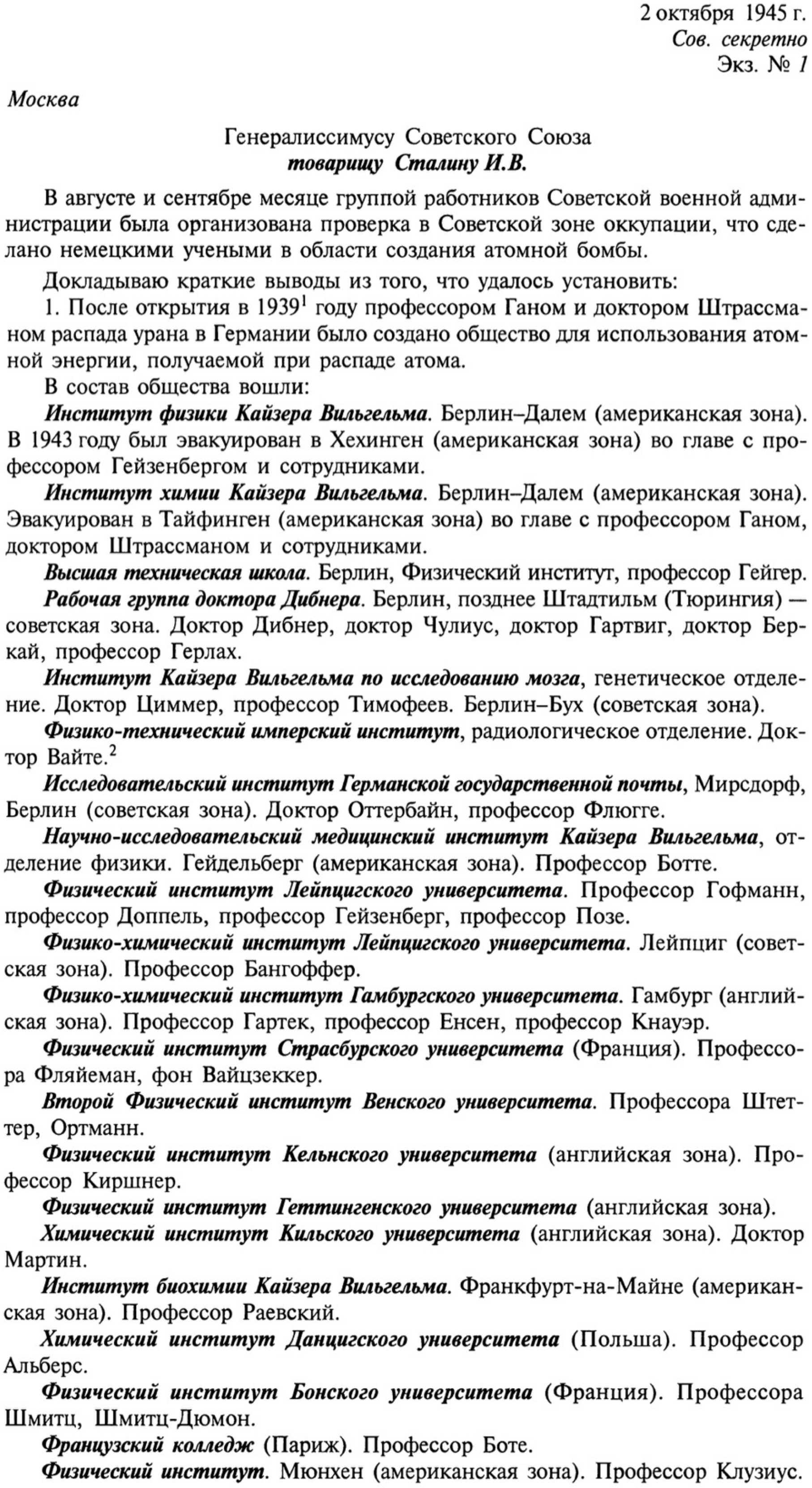
Georgy Zhukov (Russian, 1896–1974) became Marshal of the Soviet Union, the highest possible military rank, in January 1943. He led battles on the Soviet/German front, accepted the German surrender in Berlin on 8 May 1945, and commanded Soviet troops in (East) Germany after the war.

Zhukov listed numerous examples of the scientists, organizations, and locations involved in the German nuclear program. On the other hand, there are many German nuclear scientists who went to work for the Soviet Union (e.g., pp. 1633–1636) and many nuclear sites in areas occupied by the Soviet Union (e.g., pp. 2086–2099, 3405, 3407, 3671, 3841, 4030) after the war that Zhukov did not mention. Those omissions might be because Zhukov:

- Considered those details too numerous to include in this report.
- Considered those details too sensitive to include in this report.
- Did not personally inspect those sites or former projects.
- Was excluded from some of those sensitive details by other Soviet officials such as Antonov, Molotov, and Beria who were more closely associated with the fledgling Soviet nuclear program.

Nonetheless, Zhukov clearly stated that he had seen enough evidence to know for himself: "Based on the collected materials, it can be concluded that the German scientists in the field of theoretical and practical research and application of atomic energy have achieved good results up to the creation of the atomic bomb."

Zhukov stated that uranium gas centrifuges were produced by the Hellige company in Breslau (Wrocław), an important detail that does not seem to appear in any other publicly released documents. A heavy water production plant was also reported to be located just outside Breslau (pp. 4070–4071), so Breslau appears to have been an important area for nuclear work.]



2 октября 1945 г.
Сов. секретно
Экз. № *1*

Москва

Генералиссимусу Советского Союза
товарищу Сталину И.В.

В августе и сентябре месяце группой работников Советской военной администрации была организована проверка в Советской зоне оккупации, что сделано немецкими учеными в области создания атомной бомбы.

Докладываю краткие выводы из того, что удалось установить:

1. После открытия в 1939[1] году профессором Ганом и доктором Штрассманом распада урана в Германии было создано общество для использования атомной энергии, получаемой при распаде атома.

В состав общества вошли:

Институт физики Кайзера Вильгельма. Берлин–Далем (американская зона). В 1943 году был эвакуирован в Хехинген (американская зона) во главе с профессором Гейзенбергом и сотрудниками.

Институт химии Кайзера Вильгельма. Берлин–Далем (американская зона). Эвакуирован в Тайфинген (американская зона) во главе с профессором Ганом, доктором Штрассманом и сотрудниками.

Высшая техническая школа. Берлин, Физический институт, профессор Гейгер.

Рабочая группа доктора Дибнера. Берлин, позднее Штадтильм (Тюрингия) — советская зона. Доктор Дибнер, доктор Чулиус, доктор Гартвиг, доктор Беркай, профессор Герлах.

Институт Кайзера Вильгельма по исследованию мозга, генетическое отделение. Доктор Циммер, профессор Тимофеев. Берлин–Бух (советская зона).

Физико-технический имперский институт, радиологическое отделение. Доктор Вайте.[2]

Исследовательский институт Германской государственной почты, Мирсдорф, Берлин (советская зона). Доктор Оттербайн, профессор Флюгге.

Научно-исследовательский медицинский институт Кайзера Вильгельма, отделение физики. Гейдельберг (американская зона). Профессор Ботте.

Физический институт Лейпцигского университета. Профессор Гофманн, профессор Доппель, профессор Гейзенберг, профессор Позе.

Физико-химический институт Лейпцигского университета. Лейпциг (советская зона). Профессор Бангоффер.

Физико-химический институт Гамбургского университета. Гамбург (английская зона). Профессор Гартек, профессор Енсен, профессор Кнауэр.

Физический институт Страсбургского университета (Франция). Профессора Фляйеман, фон Вайцзеккер.

Второй Физический институт Венского университета. Профессора Штеттер, Ортманн.

Физический институт Кельнского университета (английская зона). Профессор Киршнер.

Физический институт Геттингенского университета (английская зона).

Химический институт Кильского университета (английская зона). Доктор Мартин.

Институт биохимии Кайзера Вильгельма. Франкфурт-на-Майне (американская зона). Профессор Раевский.

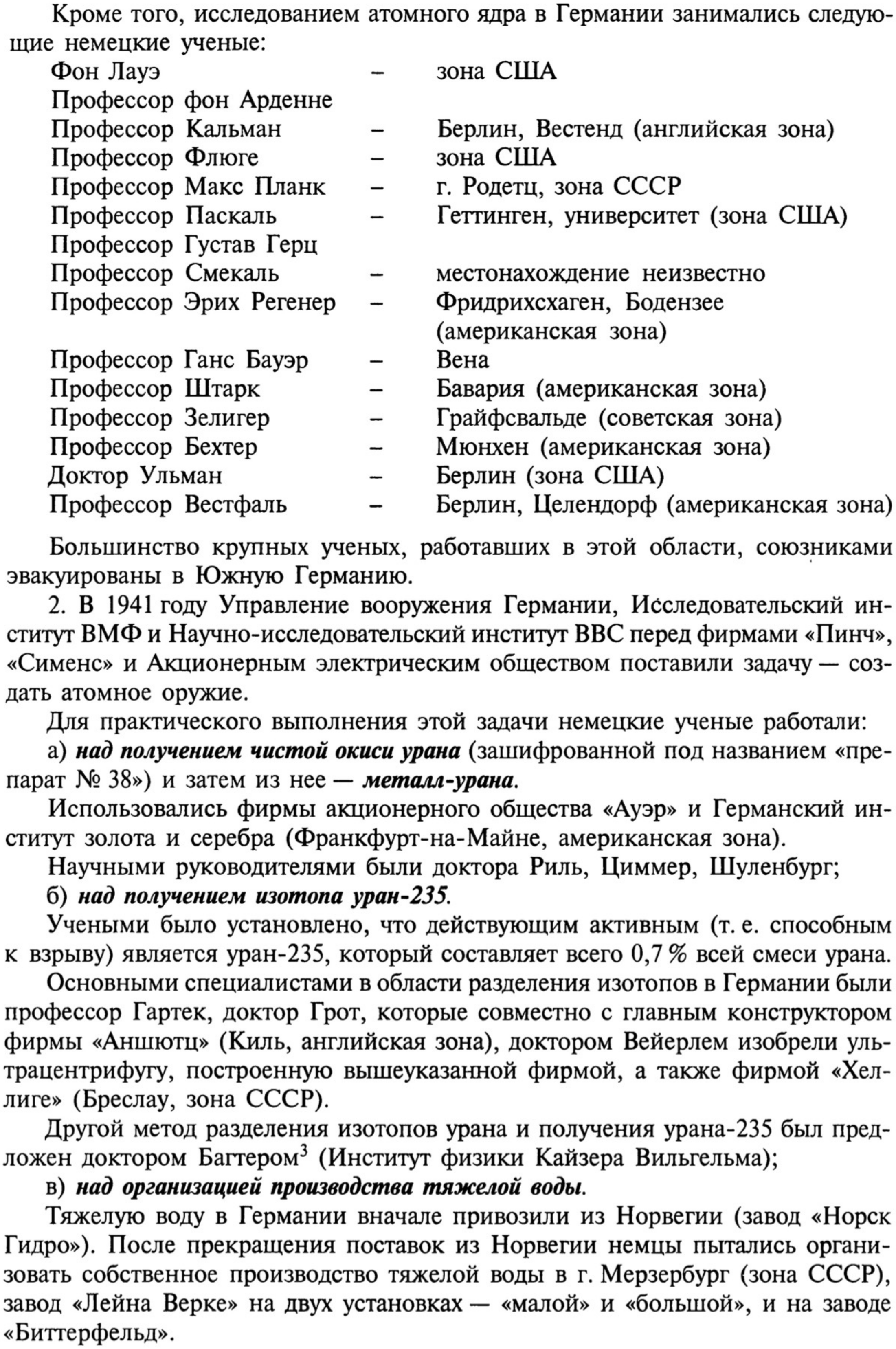
Химический институт Данцигского университета (Польша). Профессор Альберс.

Физический институт Бонского университета (Франция). Профессора Шмитц, Шмитц-Дюмон.

Французский колледж (Париж). Профессор Боте.

Физический институт. Мюнхен (американская зона). Профессор Клузиус.

Figure D.718: Marshal Georgy Zhukov. 2 October 1945. Report to Joseph Stalin [Archive of the President of the Russian Federation, Fund 93, Division 77 (45), List 4–11, published in Riabev 2006c, pp. 60–64].



Кроме того, исследованием атомного ядра в Германии занимались следующие немецкие ученые:

Фон Лауэ – зона США
Профессор фон Арденне
Профессор Кальман – Берлин, Вестенд (английская зона)
Профессор Флюге – зона США
Профессор Макс Планк – г. Родетц, зона СССР
Профессор Паскаль – Геттинген, университет (зона США)
Профессор Густав Герц
Профессор Смекаль – местонахождение неизвестно
Профессор Эрих Регенер – Фридрихсхаген, Бодензее (американская зона)
Профессор Ганс Бауэр – Вена
Профессор Штарк – Бавария (американская зона)
Профессор Зелигер – Грайфсвальде (советская зона)
Профессор Бехтер – Мюнхен (американская зона)
Доктор Ульман – Берлин (зона США)
Профессор Вестфаль – Берлин, Целендорф (американская зона)

Большинство крупных ученых, работавших в этой области, союзниками эвакуированы в Южную Германию.

2. В 1941 году Управление вооружения Германии, Исследовательский институт ВМФ и Научно-исследовательский институт ВВС перед фирмами «Пинч», «Сименс» и Акционерным электрическим обществом поставили задачу — создать атомное оружие.

Для практического выполнения этой задачи немецкие ученые работали:

а) ***над получением чистой окиси урана*** (зашифрованной под названием «препарат № 38») и затем из нее — ***металл-урана***.

Использовались фирмы акционерного общества «Ауэр» и Германский институт золота и серебра (Франкфурт-на-Майне, американская зона).

Научными руководителями были доктора Риль, Циммер, Шуленбург;

б) ***над получением изотопа уран-235***.

Учеными было установлено, что действующим активным (т. е. способным к взрыву) является уран-235, который составляет всего 0,7 % всей смеси урана.

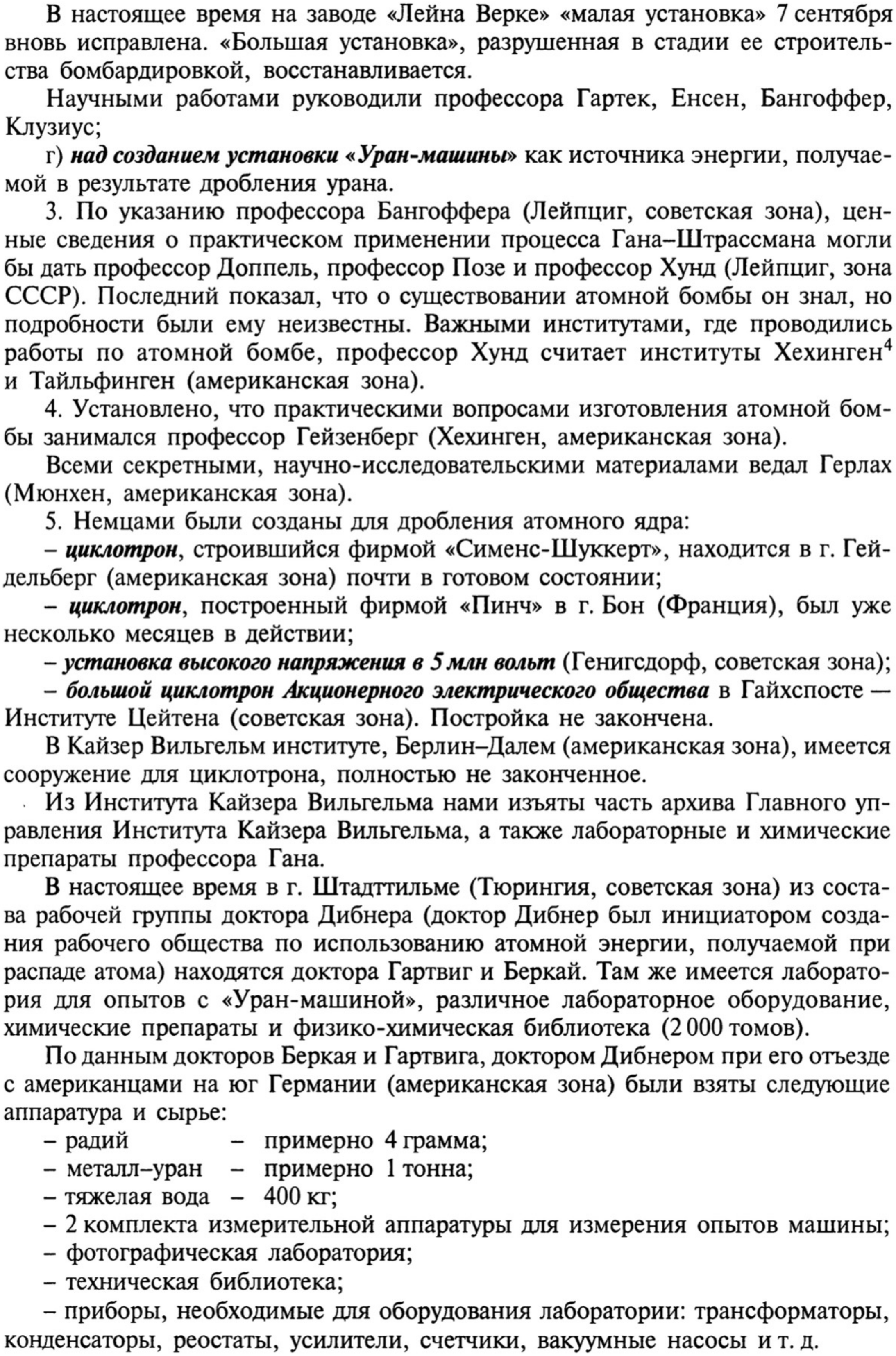
Основными специалистами в области разделения изотопов в Германии были профессор Гартек, доктор Грот, которые совместно с главным конструктором фирмы «Аншютц» (Киль, английская зона), доктором Вейерлем изобрели ультрацентрифугу, построенную вышеуказанной фирмой, а также фирмой «Хеллиге» (Бреслау, зона СССР).

Другой метод разделения изотопов урана и получения урана-235 был предложен доктором Багтером[3] (Институт физики Кайзера Вильгельма);

в) ***над организацией производства тяжелой воды***.

Тяжелую воду в Германии вначале привозили из Норвегии (завод «Норск Гидро»). После прекращения поставок из Норвегии немцы пытались организовать собственное производство тяжелой воды в г. Мерзербург (зона СССР), завод «Лейна Верке» на двух установках — «малой» и «большой», и на заводе «Биттерфельд».

Figure D.719: Marshal Georgy Zhukov. 2 October 1945. Report to Joseph Stalin [Archive of the President of the Russian Federation, Fund 93, Division 77 (45), List 4–11, published in Riabev 2006c, pp. 60–64].



В настоящее время на заводе «Лейна Верке» «малая установка» 7 сентября вновь исправлена. «Большая установка», разрушенная в стадии ее строительства бомбардировкой, восстанавливается.

Научными работами руководили профессора Гартек, Енсен, Бангоффер, Клузиус;

г) ***над созданием установки «Уран-машины»*** как источника энергии, получаемой в результате дробления урана.

3. По указанию профессора Бангоффера (Лейпциг, советская зона), ценные сведения о практическом применении процесса Гана–Штрассмана могли бы дать профессор Доппель, профессор Позе и профессор Хунд (Лейпциг, зона СССР). Последний показал, что о существовании атомной бомбы он знал, но подробности были ему неизвестны. Важными институтами, где проводились работы по атомной бомбе, профессор Хунд считает институты Хехинген[4] и Тайльфинген (американская зона).

4. Установлено, что практическими вопросами изготовления атомной бомбы занимался профессор Гейзенберг (Хехинген, американская зона).

Всеми секретными, научно-исследовательскими материалами ведал Герлах (Мюнхен, американская зона).

5. Немцами были созданы для дробления атомного ядра:

– ***циклотрон***, строившийся фирмой «Сименс-Шуккерт», находится в г. Гейдельберг (американская зона) почти в готовом состоянии;

– ***циклотрон***, построенный фирмой «Пинч» в г. Бон (Франция), был уже несколько месяцев в действии;

– ***установка высокого напряжения в 5 млн вольт*** (Генигсдорф, советская зона);

– ***большой циклотрон Акционерного электрического общества*** в Гайхспосте — Институте Цейтена (советская зона). Постройка не закончена.

В Кайзер Вильгельм институте, Берлин–Далем (американская зона), имеется сооружение для циклотрона, полностью не законченное.

Из Института Кайзера Вильгельма нами изъяты часть архива Главного управления Института Кайзера Вильгельма, а также лабораторные и химические препараты профессора Гана.

В настоящее время в г. Штадттильме (Тюрингия, советская зона) из состава рабочей группы доктора Дибнера (доктор Дибнер был инициатором создания рабочего общества по использованию атомной энергии, получаемой при распаде атома) находятся доктора Гартвиг и Беркай. Там же имеется лаборатория для опытов с «Уран-машиной», различное лабораторное оборудование, химические препараты и физико-химическая библиотека (2 000 томов).

По данным докторов Беркая и Гартвига, доктором Дибнером при его отъезде с американцами на юг Германии (американская зона) были взяты следующие аппаратура и сырье:

– радий	– примерно 4 грамма;
– металл–уран	– примерно 1 тонна;
– тяжелая вода	– 400 кг;

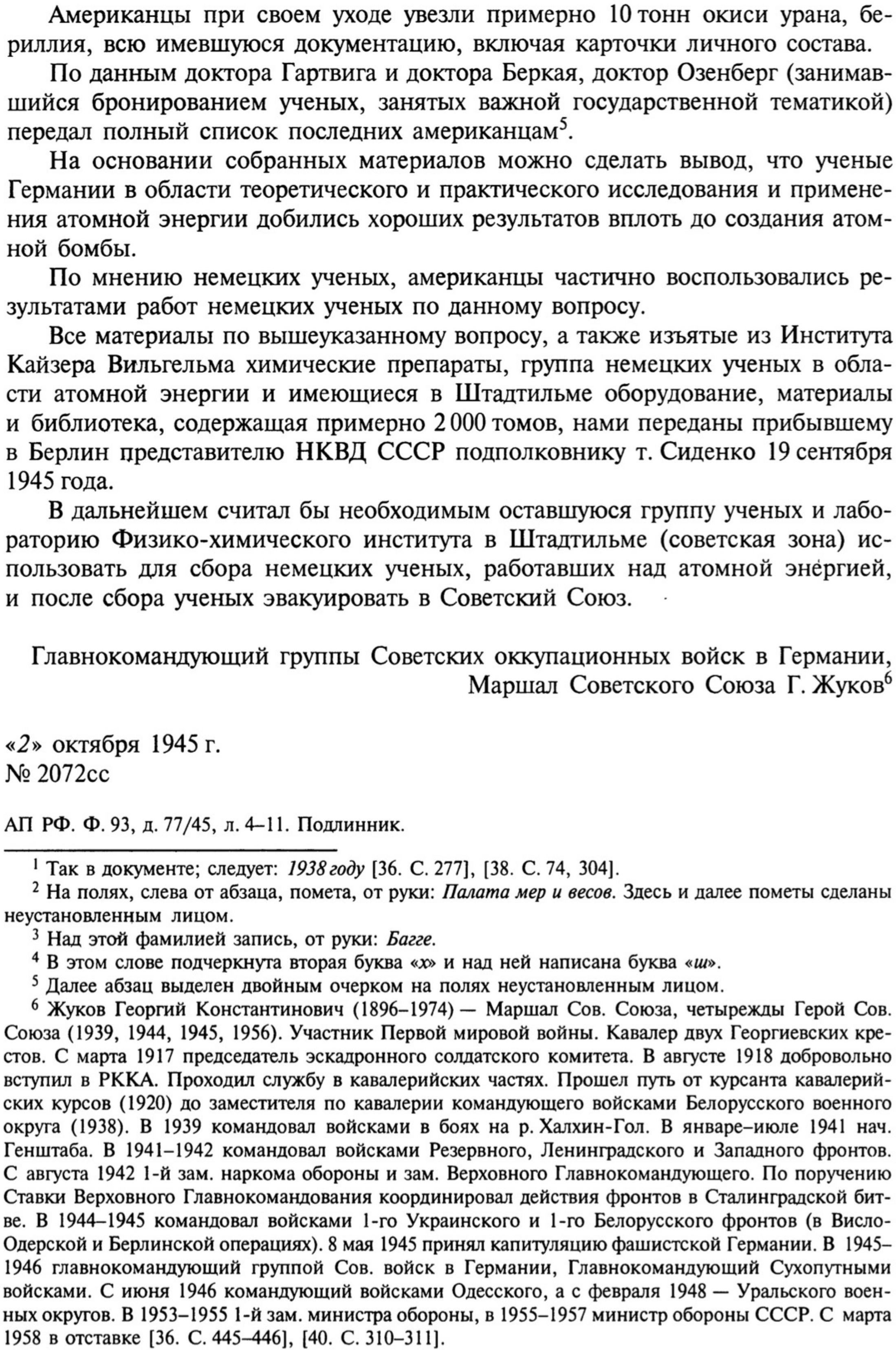
– 2 комплекта измерительной аппаратуры для измерения опытов машины;

– фотографическая лаборатория;

– техническая библиотека;

– приборы, необходимые для оборудования лаборатории: трансформаторы, конденсаторы, реостаты, усилители, счетчики, вакуумные насосы и т. д.

Figure D.720: Marshal Georgy Zhukov. 2 October 1945. Report to Joseph Stalin [Archive of the President of the Russian Federation, Fund 93, Division 77 (45), List 4–11, published in Riabev 2006c, pp. 60–64].



Американцы при своем уходе увезли примерно 10 тонн окиси урана, бериллия, всю имевшуюся документацию, включая карточки личного состава.

По данным доктора Гартвига и доктора Беркая, доктор Озенберг (занимавшийся бронированием ученых, занятых важной государственной тематикой) передал полный список последних американцам[5].

На основании собранных материалов можно сделать вывод, что ученые Германии в области теоретического и практического исследования и применения атомной энергии добились хороших результатов вплоть до создания атомной бомбы.

По мнению немецких ученых, американцы частично воспользовались результатами работ немецких ученых по данному вопросу.

Все материалы по вышеуказанному вопросу, а также изъятые из Института Кайзера Вильгельма химические препараты, группа немецких ученых в области атомной энергии и имеющиеся в Штадтильме оборудование, материалы и библиотека, содержащая примерно 2 000 томов, нами переданы прибывшему в Берлин представителю НКВД СССР подполковнику т. Сиденко 19 сентября 1945 года.

В дальнейшем считал бы необходимым оставшуюся группу ученых и лабораторию Физико-химического института в Штадтильме (советская зона) использовать для сбора немецких ученых, работавших над атомной энергией, и после сбора ученых эвакуировать в Советский Союз.

Главнокомандующий группы Советских оккупационных войск в Германии,
Маршал Советского Союза Г. Жуков[6]

«*2*» октября 1945 г.
№ 2072сс

АП РФ. Ф. 93, д. 77/45, л. 4–11. Подлинник.

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[1] Так в документе; следует: *1938 году* [36. С. 277], [38. С. 74, 304].

[2] На полях, слева от абзаца, помета, от руки: *Палата мер и весов*. Здесь и далее пометы сделаны неустановленным лицом.

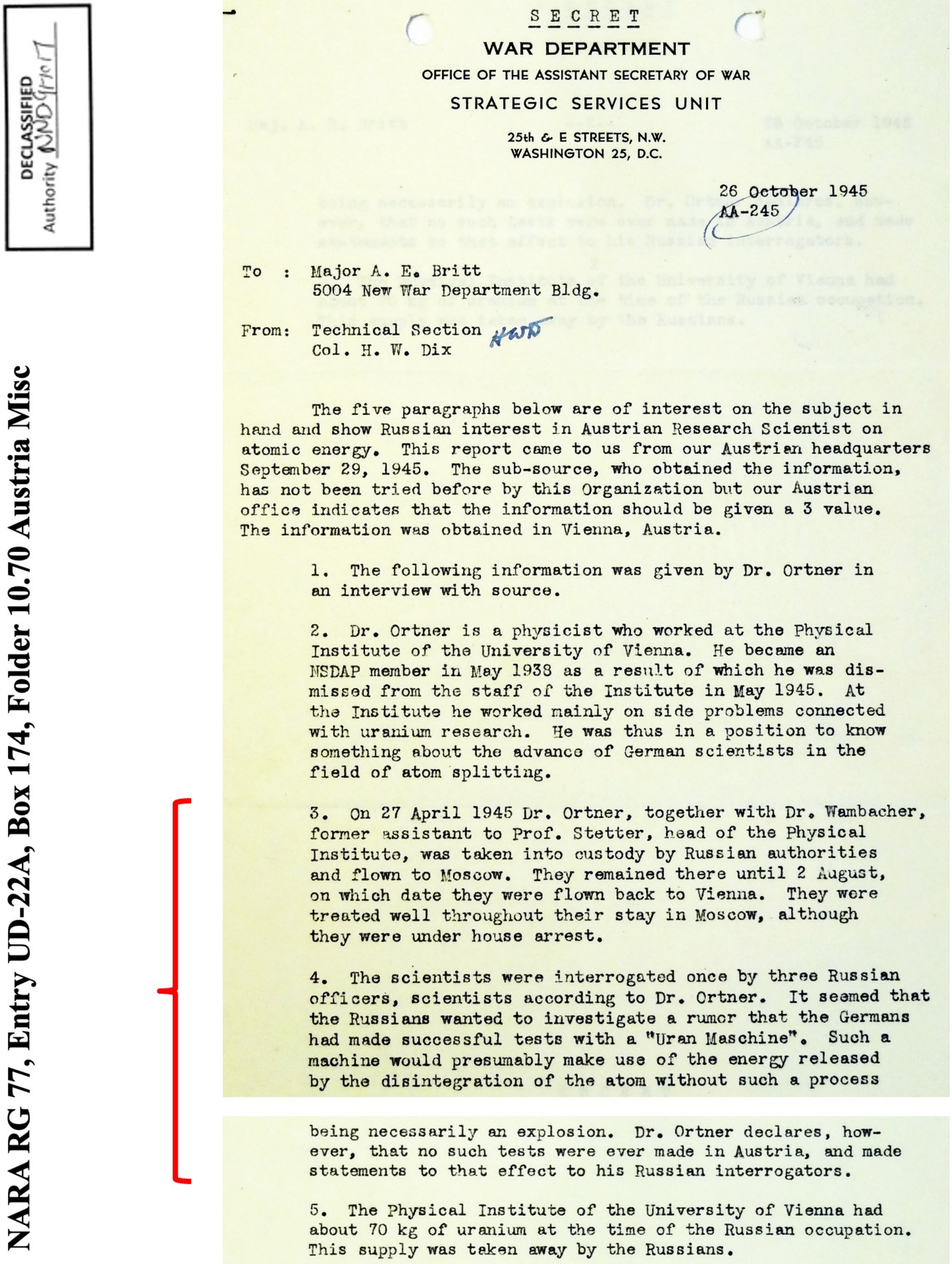
[3] Над этой фамилией запись, от руки: *Багге*.

[4] В этом слове подчеркнута вторая буква «*х*» и над ней написана буква «*ш*».

[5] Далее абзац выделен двойным очерком на полях неустановленным лицом.

[6] Жуков Георгий Константинович (1896–1974) — Маршал Сов. Союза, четырежды Герой Сов. Союза (1939, 1944, 1945, 1956). Участник Первой мировой войны. Кавалер двух Георгиевских крестов. С марта 1917 председатель эскадронного солдатского комитета. В августе 1918 добровольно вступил в РККА. Проходил службу в кавалерийских частях. Прошел путь от курсанта кавалерийских курсов (1920) до заместителя по кавалерии командующего войсками Белорусского военного округа (1938). В 1939 командовал войсками в боях на р. Халхин-Гол. В январе–июле 1941 нач. Генштаба. В 1941–1942 командовал войсками Резервного, Ленинградского и Западного фронтов. С августа 1942 1-й зам. наркома обороны и зам. Верховного Главнокомандующего. По поручению Ставки Верховного Главнокомандования координировал действия фронтов в Сталинградской битве. В 1944–1945 командовал войсками 1-го Украинского и 1-го Белорусского фронтов (в Висло-Одерской и Берлинской операциях). 8 мая 1945 принял капитуляцию фашистской Германии. В 1945–1946 главнокомандующий группой Сов. войск в Германии, Главнокомандующий Сухопутными войсками. С июня 1946 командующий войсками Одесского, а с февраля 1948 — Уральского военных округов. В 1953–1955 1-й зам. министра обороны, в 1955–1957 министр обороны СССР. С марта 1958 в отставке [36. С. 445–446], [40. С. 310–311].

Figure D.721: Marshal Georgy Zhukov. 2 October 1945. Report to Joseph Stalin [Archive of the President of the Russian Federation, Fund 93, Division 77 (45), List 4–11, published in Riabev 2006c, pp. 60–64].



DECLASSIFIED
Authority NND927017

NARA RG 77, Entry UD-22A, Box 174, Folder 10.70 Austria Misc

SECRET

WAR DEPARTMENT
OFFICE OF THE ASSISTANT SECRETARY OF WAR
STRATEGIC SERVICES UNIT
25th & E STREETS, N.W.
WASHINGTON 25, D.C.

26 October 1945
AA-245

To : Major A. E. Britt
5004 New War Department Bldg.

From: Technical Section HWD
Col. H. W. Dix

The five paragraphs below are of interest on the subject in hand and show Russian interest in Austrian Research Scientist on atomic energy. This report came to us from our Austrian headquarters September 29, 1945. The sub-source, who obtained the information, has not been tried before by this Organization but our Austrian office indicates that the information should be given a 3 value. The information was obtained in Vienna, Austria.

1. The following information was given by Dr. Ortner in an interview with source.

2. Dr. Ortner is a physicist who worked at the Physical Institute of the University of Vienna. He became an NSDAP member in May 1938 as a result of which he was dismissed from the staff of the Institute in May 1945. At the Institute he worked mainly on side problems connected with uranium research. He was thus in a position to know something about the advance of German scientists in the field of atom splitting.

3. On 27 April 1945 Dr. Ortner, together with Dr. Wambacher, former assistant to Prof. Stetter, head of the Physical Institute, was taken into custody by Russian authorities and flown to Moscow. They remained there until 2 August, on which date they were flown back to Vienna. They were treated well throughout their stay in Moscow, although they were under house arrest.

4. The scientists were interrogated once by three Russian officers, scientists according to Dr. Ortner. It seemed that the Russians wanted to investigate a rumor that the Germans had made successful tests with a "Uran Maschine". Such a machine would presumably make use of the energy released by the disintegration of the atom without such a process being necessarily an explosion. Dr. Ortner declares, however, that no such tests were ever made in Austria, and made statements to that effect to his Russian interrogators.

5. The Physical Institute of the University of Vienna had about 70 kg of uranium at the time of the Russian occupation. This supply was taken away by the Russians.

Figure D.722: H. W. Dix to A.E. Britt. 26 October 1945 [NARA RG 77, Entry UD-22A, Box 174, Folder 10.70 Austria Misc]. This memo from the Strategic Services Unit (formerly OSS) confirms that Russian officials were conducting a high-priority investigation of reports that German scientists had carried out successful tests of uranium devices (bombs, reactors, or both) during the war.

H. W. Dix to A.E. Britt. 26 October 1945 [NARA RG 77, Entry UD-22A, Box 174, Folder 10.70 Austria Misc].

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[See photo on p. 4529. This 26 October 1945 memo from the Strategic Services Unit (SSU, formerly OSS) confirms that Russian officials were conducting a high-priority investigation of reports that German scientists had carried out successful tests of uranium devices (bombs, reactors, or both) during the war. Note that Ortner only denied that such tests had occurred in Austria, not elsewhere.]

Russian summary of information obtained from Robert Döpel. 1946 [Archive of the President of the Russian Federation, courtesy of Rainer Karlsch]. [See photo p. 4531.]

Some information related to materials of Prof. Döpel about extremely powerful atomic bombs and an atomic heat source for energy-generating machines.

1. A method has been found to split atoms of uranium with the help of heavy water and rays of radium, which is accompanied by the discharge of a large amount of energy.

2. The names of institutes that worked on this problem are provided in the note.

3. It is noted that the problem of a uranium bomb has been developed to the point of testing on a [military] base.

4. The solution of the problem of a uranium heat source for use in energy-generating machines is outlined.

5. The Americans forcibly removed over 20 individuals, professors and scientists, working on this problem, and over 20 grams of radium was also removed after the transfer of the region by our troops.

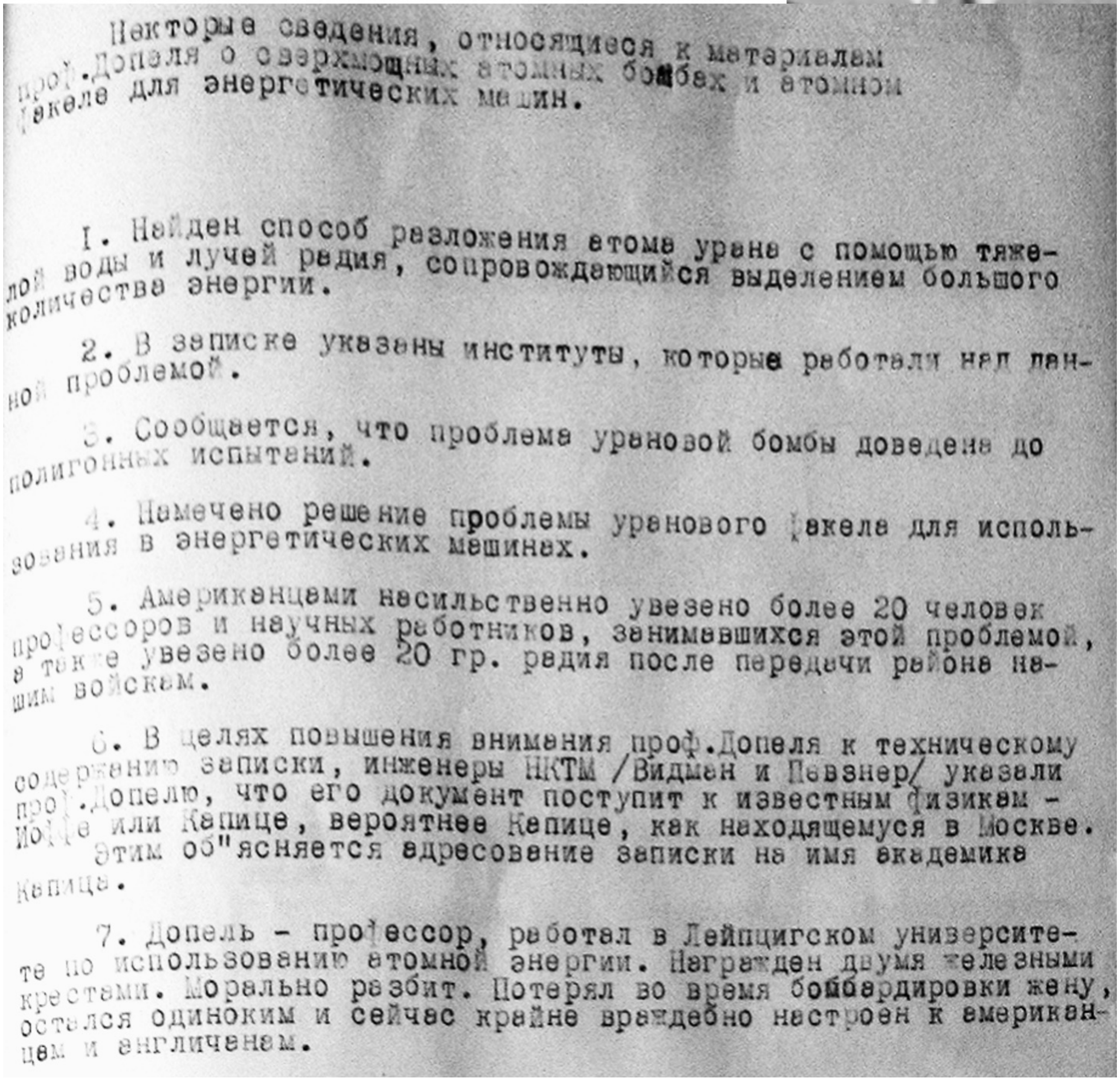
6. In order to heighten the attention of Prof. Döpel to the technical content of the note, the NKTM engineers (Vidman and Pevzner) indicated to Prof. Döpel that his document would be received by the famous physicists, Joffe or Kapitsa, more likely Kapitsa, who is located in Moscow.

This explains the fact that the note is addressed to Academic Kapitsa.

7. Döpel is a professor who worked at Leipzig University on the use of atomic energy. He has been awarded two iron crosses. He is emotionally broken. He lost his wife during the bombing and was left alone and is now extremely hostile toward the Americans and the English.

Robert Döpel
(1895–1982)

1946 Russian summary
of information obtained
from Robert Döpel



Некторые сведения, относящиеся к материалам проф.Допеля о сверхмощных атомных бомбах и атомном факеле для энергетических машин.

I. Найден способ разложения атома урана с помощью тяжелой воды и лучей радия, сопровождающийся выделением большого количества энергии.

2. В записке указаны институты, которые работали над данной проблемой.

3. Сообщается, что проблема урановой бомбы доведена до полигонных испытаний.

4. Намечено решение проблемы уранового факела для использования в энергетических машинах.

5. Американцами насильственно увезено более 20 человек профессоров и научных работников, занимавшихся этой проблемой, а также увезено более 20 гр. радия после передачи района нашим войскам.

6. В целях повышения внимания проф.Допеля к техническому содержанию записки, инженеры НКТМ /Видман и Певзнер/ указали проф.Допелю, что его документ поступит к известным физикам - Иоффе или Капице, вероятнее Капице, как находящемуся в Москве.

Этим об"ясняется адресование записки на имя академика Капица.

7. Допель - профессор, работал в Лейпцигском университете по использованию атомной энергии. Награжден двумя железными крестами. Морально разбит. Потерял во время бомбардировки жену, остался одиноким и сейчас крайне враждебно настроен к американцам и англичанам.

Figure D.723: 1946 Russian summary of information obtained from Robert Döpel, in which he mentioned a German atomic bomb test on a military base [Archive of the President of the Russian Federation, courtesy of Rainer Karlsch].

Report of the Head of the Special Camp Department of SMAD, Colonel Sviridov, No. 00400 of 11 June 1946 to the Deputy Minister of Interior of the USSR General Serov, GARF, Fund 9409, Catalog 1, File 14, Sheet 72 [discovered by Rainer Karlsch].

3. Kirfes, Horst—born 1916 in Erfurt (Thuringia), recently living in central Berlin; engineer for aircraft engine construction, took part in the production of the aircraft "jet fighter," a diesel fighter without propeller and with a speed of 1600 km/h. He was acquainted with the director of the department for the production of the V1, 2 and 4. That one told about how the V2 was made and that it was equipped with an atomic bomb. (The director died.) (At present [Kirfes] is in Special Camp 7.)

[During interrogation in the Soviet Union after the war, the engineer Horst Kirfes said he was involved in the wartime production of a supersonic jet aircraft. From his testimony, apparently that program was also somehow connected to nuclear weapons production (possibly to deliver a nuclear weapon, or to use nuclear power for the propulsion?). See p. 5761 for a very similar account of the wartime production of a nuclear-related supersonic jet aircraft by Josef Ernst, an engineer found by British investigators after the war.

Kirfes mentioned the "production" (not merely design) of the V-4. Since several different projects were vying for the title of "V-4," which one did he mean?

The department director who gave detailed information on rocket and nuclear programs to Kirfes but later died may have been Dr. Albin Sawatzki of Peenemünde.

According to the information from Kirfes, an atomic bomb was actually produced, and it was designed to be carried by a V-2 or similar rocket. That information agrees with the March 1945 report by Ivan Ilyichev (p. 4485).

Moreover, the information from Kirfes seems to indicate that the rocket was *already* "equipped with an atomic bomb," or in other words that the rocket, the atomic bomb, and the mated system of those two were either fully ready or very nearly ready before the end of the war. That information agrees with what the U.S. Army Air Forces publicly published in July 1946 (p. 5038).

For many more references to nuclear-armed rockets that were intended to attack Allied targets during the war, see the list of documents on p. 5821.]

Commentary on Horst Kirfes from Rainer Karlsch [Karlsch 2005, p. 224].

Dazu gehören die Schilderungen von Gerhard Rundnagel und Horst Kirfes. Letzterer berichtete in sowjetischer Gefangenschaft über die Verlegung von Atomforschern mitsamt fertiger Bomben aus Berlin Anfang 1945.

These include the descriptions of Gerhard Rundnagel and Horst Kirfes. The latter reported in Soviet captivity on the transfer of nuclear researchers together with finished bombs from Berlin in early 1945.

Rainer Karlsch. Stalin, der Bluff und die Bombe: Verwirrspiel um den ersten sowjetischen Atomtest. *Osteuropa* December 2007 pp. 117–175. English translation courtesy of Rainer Karlsch. [https://zeitschrift-osteuropa.de/hefte/2007/12/stalin-der-bluff-und-die-bombe/ and https://www.freitag.de/autoren/rainer-karlsch/der-grosse-bluff]

[...]In May 1949, the central committee of the Chinese Communist Party (CCP) decided to send a government delegation headed by the second highest party functionary of the CCP, Liu Shaochi, to Moscow. [...] Stalin met with Liu Shaochi for five rounds of discussions. The first reception took place at Stalin's dacha in Kuntsevo and the second that is of special interest to us, took place in the evening of July 11 in the Kremlin. [...]

However, Stalin denied the wish of Liu Shaochi. It was not in his calculation to provide nuclear technology to the Chinese. As compensation and a demonstration of his own strength, he invited his guests to a film showing instead. It showed the test explosion of an atomic bomb! The test, according to Stalin, had taken place in the upper north of the Soviet Union, in a deserted region near the polar circle. After the showing of the film Stalin bragged about the progress in science and technology achieved by the Soviet Union. His country was soon to be in the position to manufacture substantially effective weapons.[18] One thing about this story is extremely noteworthy: The showing of the film took place a few weeks before the first successful test of a Soviet atomic bomb in Semipalatinsk (on August 29, 1949). [...]

Kovalev, Stalin's China expert and the most important of Soviet functionaries in China, has reported the film showing in his unpublished memoir. He presented the background of the Soviet-Chinese relation in a series of articles in 1991/1992.[20]

Shi Zhe held a position comparable to Kovalev's function. [...] Shi Zhe also mentioned the film showing in his memoirs.[22] The Chinese historian Zhu Yuanshi also drew upon it in his account of the secret visit of Liu Shaochi in Moscow.[23]

[...] Possibly the said film was found after the war somewhere in Germany. That sounded at first like a wild conspiracy theory. Yet there are written records that support this theory. For example, a very interesting inventory of sources is in the Archive of Russian Contemporary History in Moscow. In it, hundreds of German files on the rocket development are listed. All these documents were looted in the German Reich, taken to Moscow and inventoried. Besides files, films were also listed. The content of one roll of film is written word for word as follows: "Film of the launch of a V2 and the explosion of an atomic bomb."[25] This film and still a few others, and the complete documentation on German rocket development were turned over in May 1946 by the Director of the Main Administration for Artillery of the Red Army, Marshall Nikolai Jakovlev, to the Deputy Chairman of the Special Committee for Rocket Technology, Ivan G. Zubovic.[26] [...]

For our connection, it is important to make a note of the fact that the films of interest to us were discovered sometime between May 1945 and April 1946 in Germany by workers of the Special Committee for "Reactive Technology." Likely, these films are mostly about the recordings of various rocket launches. But on one roll of film, not only a rocket launch was to be seen, but also the "Explosion of an Atomic Bomb," according to the archive inventory. This title designation seems to have been carried over word by word from the German film roll into Russian, particularly it was similarly experienced in cases of other film rolls. A translation error is to be ruled out. [...]

Unexpectedly, we came across the sequel of this saga at another station. It concerns more papers of the Special Committee for Rocket Technology (Committee No. 2) and Interior Ministry from 1948 to 1950 related to the "top-secret special films." On October 28, 1948, the already mentioned Ivan G. Zubovic turned over "top-secret' Special Film No. 185 in eight parts to the Secretary of the Interior Ministry Haritov.[30] [...]

The deputy Interior Minister Serov was responsible for the archiving. He will have inquired at the Technical Archive of the Committee No. 2 as to where the films were. Thereupon he was informed on September 23, 1949 by Zubovic that at the instigation of Nikolai Bulganin, one of Stalin's deputies, one copy of the special film had been loaned to the Ministry of Interior already on October 28, 1948.[37] A second copy, which the Committee No. 2 got from the Ministry of Armament, should be also handed over to Serov. It comes from the chief of Stalin's private chancellery, Alexander N. Poskrebyschew.[38] [...]

The last letter concerning the films was dated January 20, 1950.[39] In it, Haritonov informed his boss Serov that the archive of the MVD had turned over both top-secret special films no. 185 and no. 127 to the National Movies and Photo Archive for final safekeeping. The letter was enclosed with the film copy in turnover action. Accordingly the National Movies and Photo Archive took over the special film 185 in eight parts and also the suitcase with the second copy of the special film. All seals on the suitcase were undamaged. Furthermore the top-secret film no. 127 in two copies with four parts each were turned over to the National Movies and Photo Archive. At the end, one passage was yet included: "Inspection in the file on the movie films is prohibited without the expressed consent of the MVD."

Up until today the top secret "special films" still could not be located. They were removed in the mid-fifties from the inventory of the National Movies and Photo Archive at the instigation of the MVD (Serov's Department) and have since been missing. [...]

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[18] Cf. Sergei Goncharov, John Lewis, Xue Litai, *Uncertain Partners, Uncertain Partners, Mao and the Korean War.* Stanford 1993, p. 71.

[20] Cf. Ivan Kovalev, Stalin's Dialogue with Mao Zedong, Two parts, in: *Problems of the Far East*, No. 6, 1991 and No.1-3, 1992; unpublished memoirs.

[22] Cf. Shi Zhe, *Zai Lishi Juren Shenbian Shi Zhe Huiyilu* (*Beside Great Historical Figures: The Memoirs of Shi Zhe*), Beijing 1991, p. 410.

[23] Cf. Zhu Yuanshi, Liu Shaoqi's Secret Visit to the Soviet Union in 1949, in: *Dang de Wenxian* (*Party Documents*), no. 3, 1991, p. 76f.

[25] Archive list with material on the reactive technology for safekeeping by the Cadre Administration of ZK KPSU and for preparation of tasks of Special Committee of the Soviet Minister Council, May 1946, RGASPI Moscow, Fond 17, Cat. 127, file 1294, p. 7f.

[26] Cf. letter of May 1946 from Ivan Zubovic to Cadre Department of KPSU, Georgij Malenkov, and the Special Committee, Ibd., p. 16.

[30] Cf. top-secret file note of Haritonov (Committee No. 2) of October 29, 1948, GARF (National Archive of the Russian Federation), Fond 9401, Cat. 1, File 4153, p. 366.

[37] Vgl. Documentation of the handover of film number 185 from the Special committee Nr. 2 to the Deputy of the Minister of Inferior of October 29, 1948. GARF Moscow, Fond 9401, Cat. 1, file 4153, p. 366.

[38] Cf. top-secret letter of September 3, 1949 from the Director of the Liquidation Commission of the Committee No. 2, Ivan Zubovic, to Ivan Serov (MVD), ibid, p. 361.

[39] Cf. top-secret letter of January 20, 1950 from Haritonov (Committee No. 2) to Serov (MVD), ibid, p. 364f.

[Can any copies of this film (or other films of German technologies that have not been publicly acknowledged) be located in the archives of any nation and declassified?

The fact that the film highlights two projects back-to-back ("Film of the Launch of a V-2 and the Explosion of an Atomic Bomb") suggests that those two projects—long-range rockets and atomic bombs—were intended to go together. That agrees very well with evidence from many independent sources (p. 5821). Just how far did the integration of an atomic bomb with a rocket get by the end of the war?]

[There were persistent reports of one or more Soviet nuclear weapons tests in 1946, long before the first known Soviet-built bomb test in 1949 (RDS-1/Joe-1). Could those 1946 reports have been Soviet tests of captured German nuclear weapons?]

U.S. Military Attaché Moscow to War Department. 14 September 1946. [**NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret January 1946 thru December 1946**]

[See document photo on p. 4537.]

CG USAFIK Korea to War Department. 6 October 1946. [**NARA RG 77, Entry UD-22A, Box 160, Folder In & Out July 16, 1946–Jan. 1947**]

[See document photo on p. 4538.]

R. H. Free to U.S. Military Attaché London. 5 December 1946. [**NARA RG 77, Entry UD-22A, Box 160, Folder 205.3 Cables Outgoing, Secret and Under January 1946 thru December 1946**]

[See document photo on p. 4539.]

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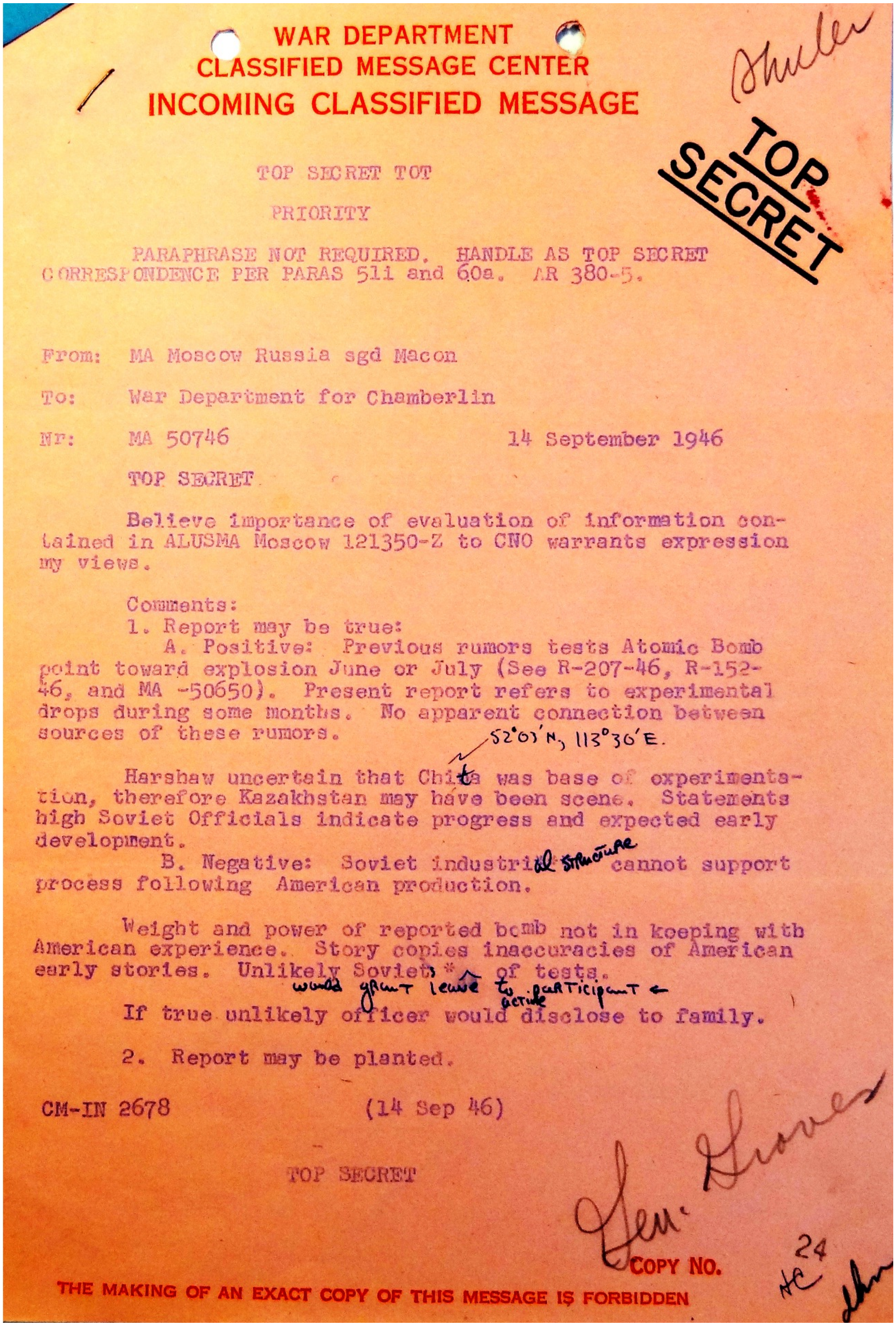
Authority NND 917017



WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
INCOMING CLASSIFIED MESSAGE

TOP SECRET

TOP SECRET TOT

PRIORITY

PARAPHRASE NOT REQUIRED. HANDLE AS TOP SECRET CORRESPONDENCE PER PARAS 511 and 60a. AR 380-5.

From: MA Moscow Russia sgd Macon

To: War Department for Chamberlin

Nr: MA 50746 14 September 1946

TOP SECRET

Believe importance of evaluation of information contained in ALUSMA Moscow 121350-Z to CNO warrants expression my views.

Comments:
1. Report may be true:
A. Positive: Previous rumors tests Atomic Bomb point toward explosion June or July (See R-207-46, R-152-46, and MA -50650). Present report refers to experimental drops during some months. No apparent connection between sources of these rumors.

52°03'N, 113°30'E.

Harshaw uncertain that Chita was base of experimentation, therefore Kazakhstan may have been scene. Statements high Soviet Officials indicate progress and expected early development.
B. Negative: Soviet industrial structure cannot support process following American production.

Weight and power of reported bomb not in keeping with American experience. Story copies inaccuracies of American early stories. Unlikely Soviets * of tests.
would grant leave to active participant ←

If true unlikely officer would disclose to family.

2. Report may be planted.

CM-IN 2678 (14 Sep 46)

TOP SECRET

Gen. Groves

COPY NO. 24

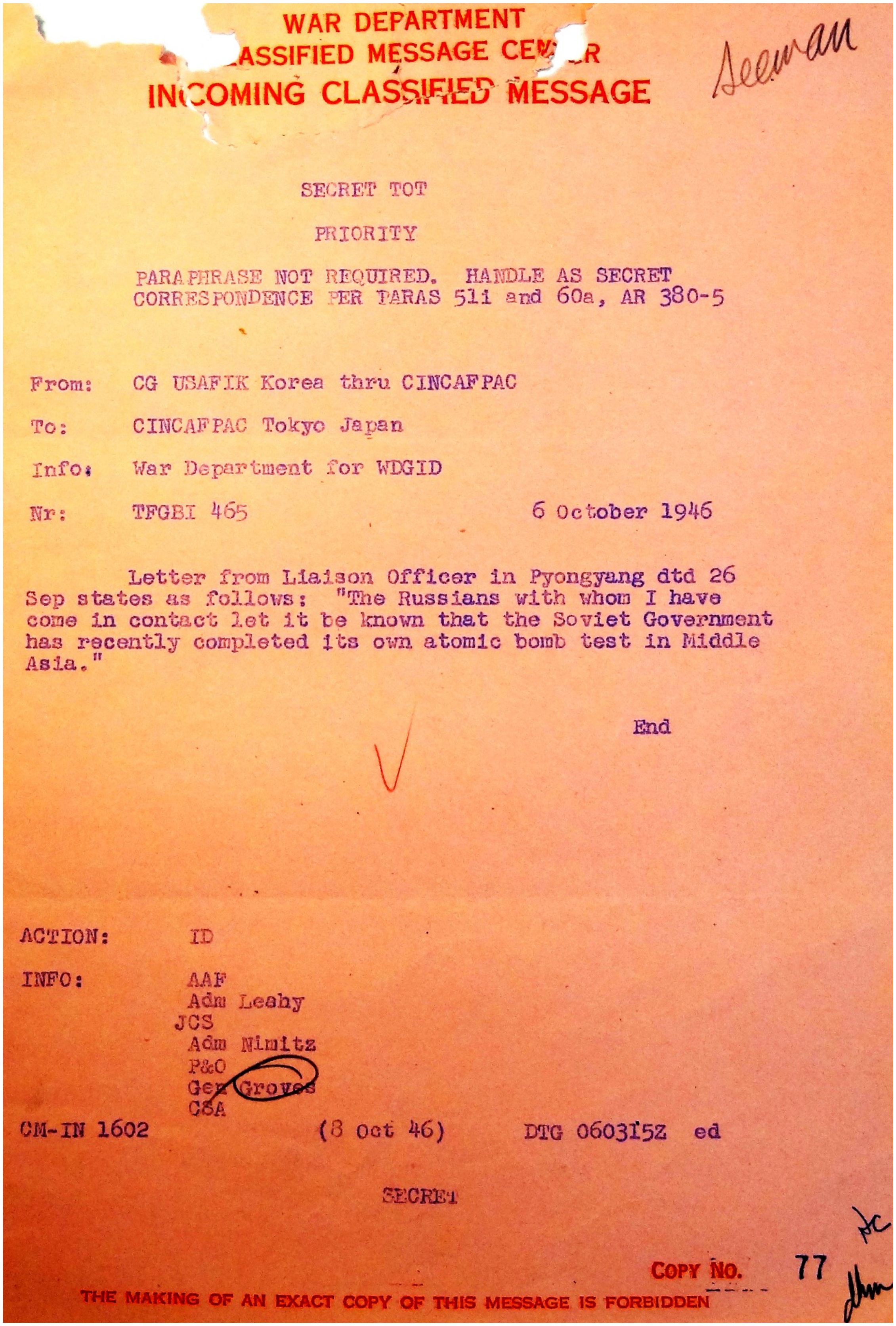
AC

THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN

NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret January 1946 thru December 1946

Figure D.724: There were persistent reports of one or more Soviet nuclear weapons tests in 1946, long before the first known Soviet-built bomb test in 1949 (RDS-1/Joe-1). Could those 1946 reports have been Soviet tests of captured German nuclear weapons? U.S. Military Attaché Moscow to War Department. 14 September 1946 [NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret January 1946 thru December 1946].

DECLASSIFIED
Authority NND 917017



WAR DEPARTMENT
ASSIFIED MESSAGE CE R
INCOMING CLASSIFIED MESSAGE

Seeman

SECRET TOT

PRIORITY

PARAPHRASE NOT REQUIRED. HANDLE AS SECRET CORRESPONDENCE PER PARAS 51i and 60a, AR 380-5

From: CG USAFIK Korea thru CINCAFPAC
To: CINCAFPAC Tokyo Japan
Info: War Department for WDGID
Nr: TFGBI 465 6 October 1946

Letter from Liaison Officer in Pyongyang dtd 26 Sep states as follows: "The Russians with whom I have come in contact let it be known that the Soviet Government has recently completed its own atomic bomb test in Middle Asia."

End

ACTION: ID

INFO:
AAF
Adm Leahy
JCS
Adm Nimitz
P&O
Gen Groves
CSA

CM-IN 1602 (8 Oct 46) DTG 060315Z ed

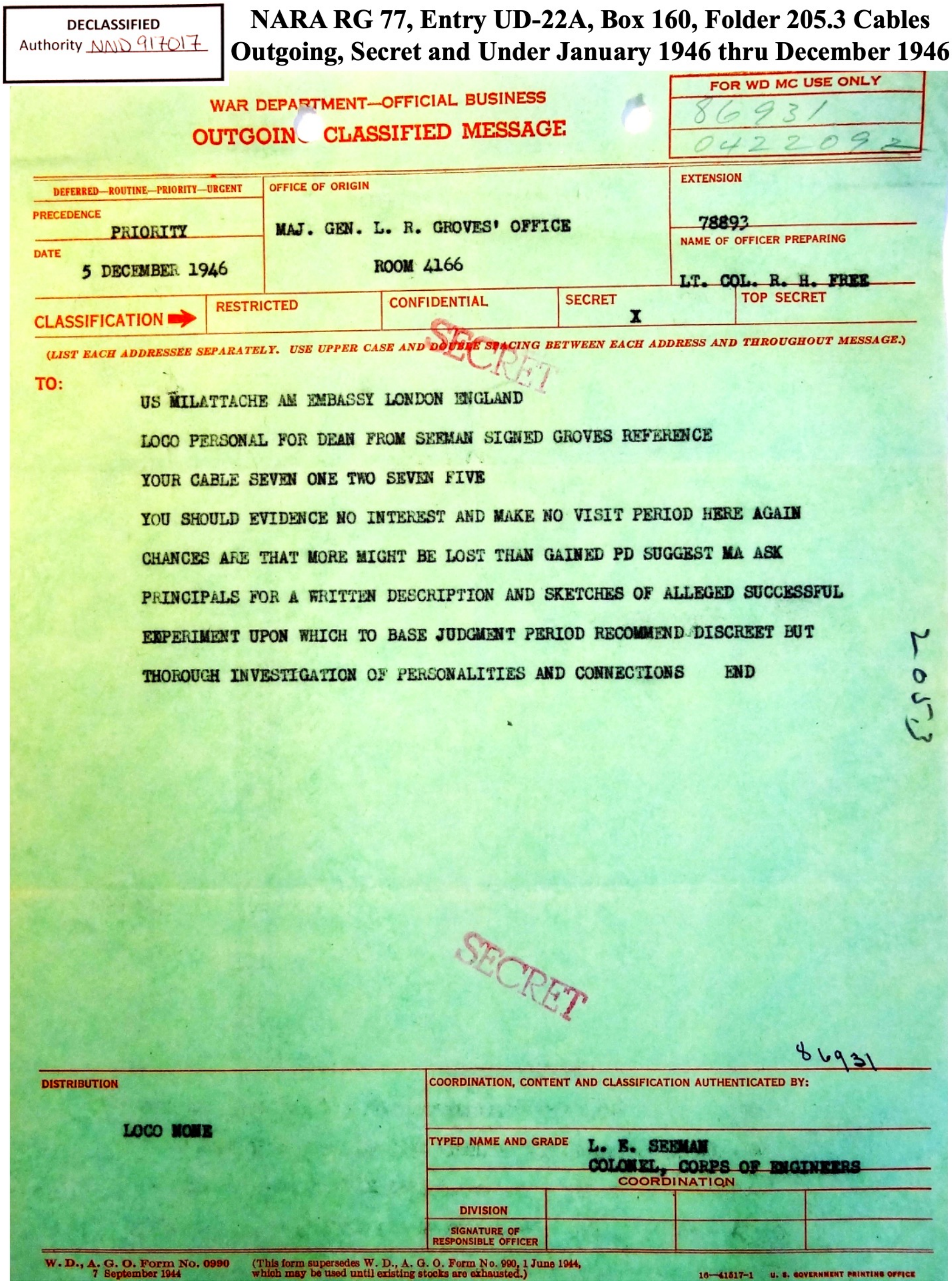
SECRET

COPY NO. 77

THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN

NARA RG 77, Entry UD-22A, Box 160,
Folder In & Out July 16, 1946–Jan. 1947

Figure D.725: There were persistent reports of one or more Soviet nuclear weapons tests in 1946, long before the first known Soviet-built bomb test in 1949 (RDS-1/Joe-1). Could those 1946 reports have been Soviet tests of captured German nuclear weapons? CG USAFIK Korea to War Department. 6 October 1946 [NARA RG 77, Entry UD-22A, Box 160, Folder In & Out July 16, 1946–Jan. 1947].



DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 160, Folder 205.3 Cables Outgoing, Secret and Under January 1946 thru December 1946

WAR DEPARTMENT—OFFICIAL BUSINESS
OUTGOING CLASSIFIED MESSAGE

FOR WD MC USE ONLY
86931
042209Z

DEFERRED—ROUTINE—PRIORITY—URGENT
PRECEDENCE: PRIORITY
DATE: 5 DECEMBER 1946
OFFICE OF ORIGIN: MAJ. GEN. L. R. GROVES' OFFICE ROOM 4166
EXTENSION: 78893
NAME OF OFFICER PREPARING: LT. COL. R. H. FREE

CLASSIFICATION ➡ RESTRICTED ☐ CONFIDENTIAL ☐ SECRET X TOP SECRET ☐

(LIST EACH ADDRESSEE SEPARATELY. USE UPPER CASE AND DOUBLE SPACING BETWEEN EACH ADDRESS AND THROUGHOUT MESSAGE.)

SECRET

TO:

US MILATTACHE AM EMBASSY LONDON ENGLAND

LOCO PERSONAL FOR DEAN FROM SEEMAN SIGNED GROVES REFERENCE YOUR CABLE SEVEN ONE TWO SEVEN FIVE YOU SHOULD EVIDENCE NO INTEREST AND MAKE NO VISIT PERIOD HERE AGAIN CHANCES ARE THAT MORE MIGHT BE LOST THAN GAINED PD SUGGEST MA ASK PRINCIPALS FOR A WRITTEN DESCRIPTION AND SKETCHES OF ALLEGED SUCCESSFUL EXPERIMENT UPON WHICH TO BASE JUDGMENT PERIOD RECOMMEND DISCREET BUT THOROUGH INVESTIGATION OF PERSONALITIES AND CONNECTIONS END

2053

SECRET

86931

DISTRIBUTION: LOCO NONE

COORDINATION, CONTENT AND CLASSIFICATION AUTHENTICATED BY:

TYPED NAME AND GRADE: L. E. SEEMAN COLONEL, CORPS OF ENGINEERS

COORDINATION

DIVISION

SIGNATURE OF RESPONSIBLE OFFICER

W. D., A. G. O. Form No. 0990 7 September 1944 (This form supersedes W. D., A. G. O. Form No. 990, 1 June 1944, which may be used until existing stocks are exhausted.) 16—41517-1 U. S. GOVERNMENT PRINTING OFFICE

Figure D.726: There were persistent reports of one or more Soviet nuclear weapons tests in 1946, long before the first known Soviet-built bomb test in 1949 (RDS-1/Joe-1). Could those 1946 reports have been Soviet tests of captured German nuclear weapons? R. H. Free to U.S. Military Attaché London. 5 December 1946 [NARA RG 77, Entry UD-22A, Box 160, Folder 205.3 Cables Outgoing, Secret and Under January 1946 thru December 1946].

Rainer Karlsch. 2013. Die Abteilung Atomphysik der PTR in Ronneburg und das deutsche Uranprojekt. *PTB-Mitteilungen* 123:1:73–81. [See also Karlsch 2005, p. 211.]

Am 28. Februar 1945 kamen Diebner und Gerlach von Berlin nach Ronneburg und forderten von Carl-Friedrich Weiss die Übergabe des gesamten Poloniumvorrates. Wofür das Polonium gebraucht wurde, erfuhren die Wissenschaftler der PTR nicht: "Bei den Besuchen hat er [Gerlach] mit mir [Weiss] nicht über die Uranfragen gesprochen, zumal wir nicht allein waren. Auf Verletzung der Geheimhaltung standen schwerste Strafen; keiner durfte mehr erfahren, als unbedingt nötig war." Was danach mit den Polonium-Präparaten geschah, ist unklar. Sie wurden nach Kriegsende nicht mehr gefunden. Die Polonium-Anlage sowie das gesamte noch in Kisten befindliche Bleinitrat mußte von Mitarbeitern der PTR am 25. Juni 1945 einer amerikanischen Militärkommission übergeben werden.

On 28 February 1945, Diebner and Gerlach came from Berlin to Ronneburg and demanded the transfer of the entire stock of polonium from Carl-Friedrich Weiss. The scientists of the PTR did not learn why the polonium was needed: "During the visits he [Gerlach] did not talk with me [Weiss] about the uranium questions, especially since we were not alone. Violations of secrecy were severely punished; no one was allowed to know more than was absolutely necessary." What happened afterwards with the polonium preparations is unclear. They were no longer found after the end of the war. The polonium plant as well as all of the lead nitrate still contained in boxes had to be handed over to an American military commission on 25 June 1945 by employees of the PTR.

[This information comes from these archival references:

Protokoll der Befragung von Dr. Carl-Friedrich Weiss am 28.10.1945, Archiv der Max Planck Gesellschaft, Abt. I, Rep. 34, KWI für Physik, Nr. 99a, Diebner-Gruppe, Nr. 19208.

Görken: Bericht über den Abtransport der Anlage zur Polonium-Gewinnung, 6.7.1945, BArch, Berlin-Lichterfelde, DF-5, Nr. 14.]

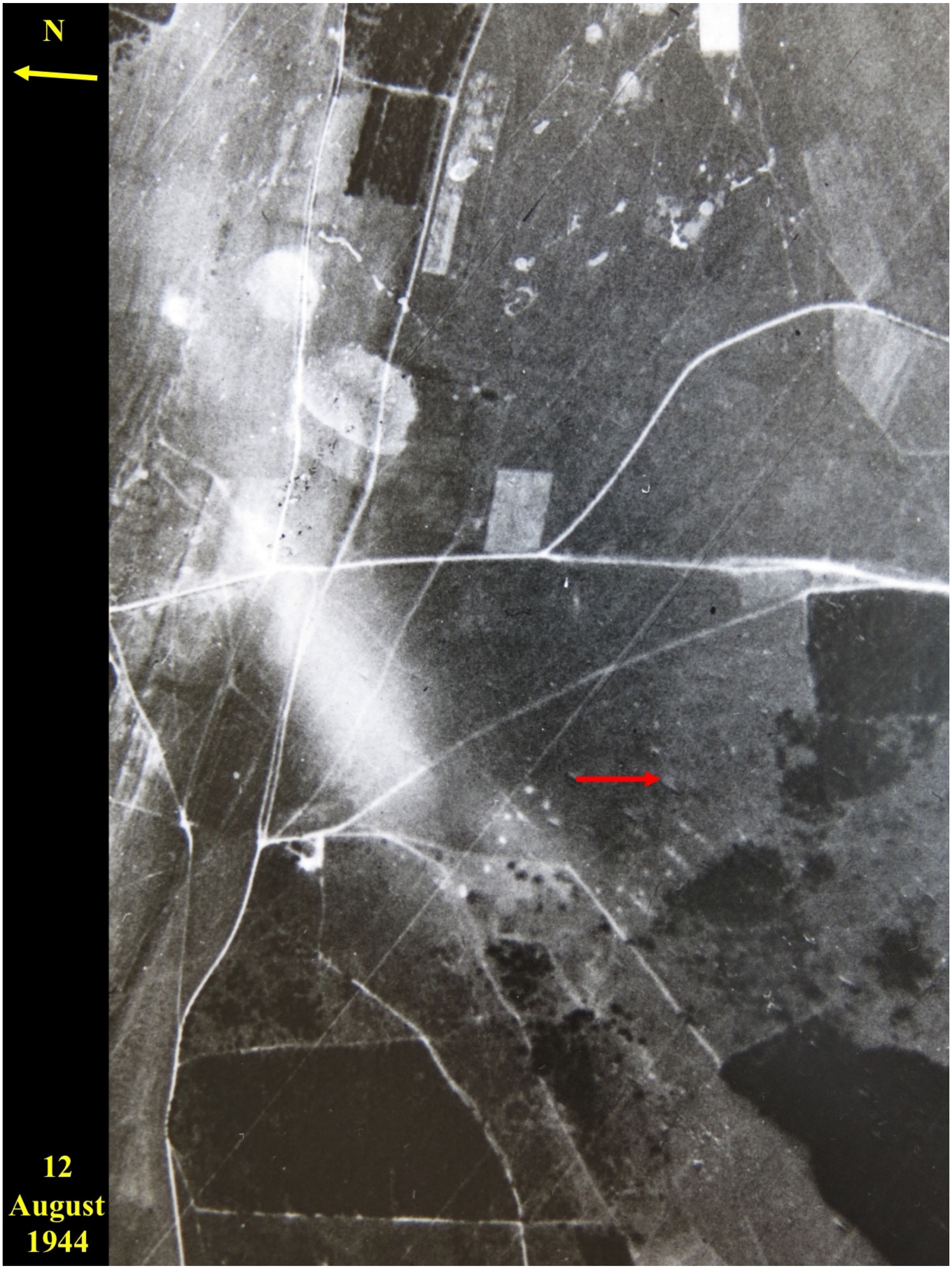


Figure D.727: 12 August 1944 U.S. aerial reconnaissance photo of Ohrdruf military training base, showing location (red arrow) before possible March 1945 test explosion. Note the absence of visible craters or blast damage, and the rectangular structures to the east that appear to be partially camouflaged buildings.

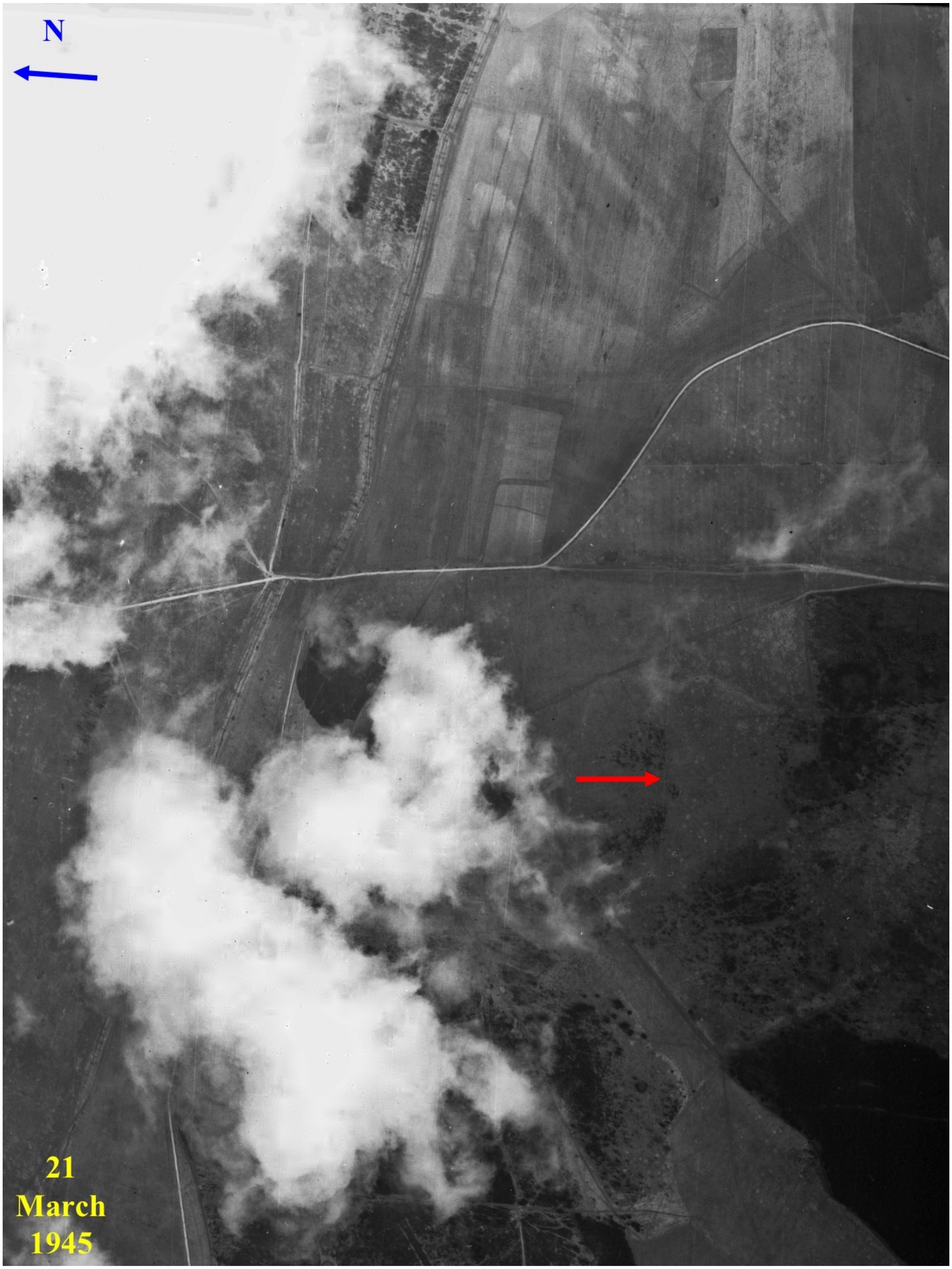


Figure D.728: 21 March 1945 U.S. aerial reconnaissance photo of Ohrdruf military training base, showing location after possible March 1945 test explosion. Note the apparent crater with many streaks of ejecta radiating outward from its center (denoted by the red arrow), and the removal or alteration of buildings.

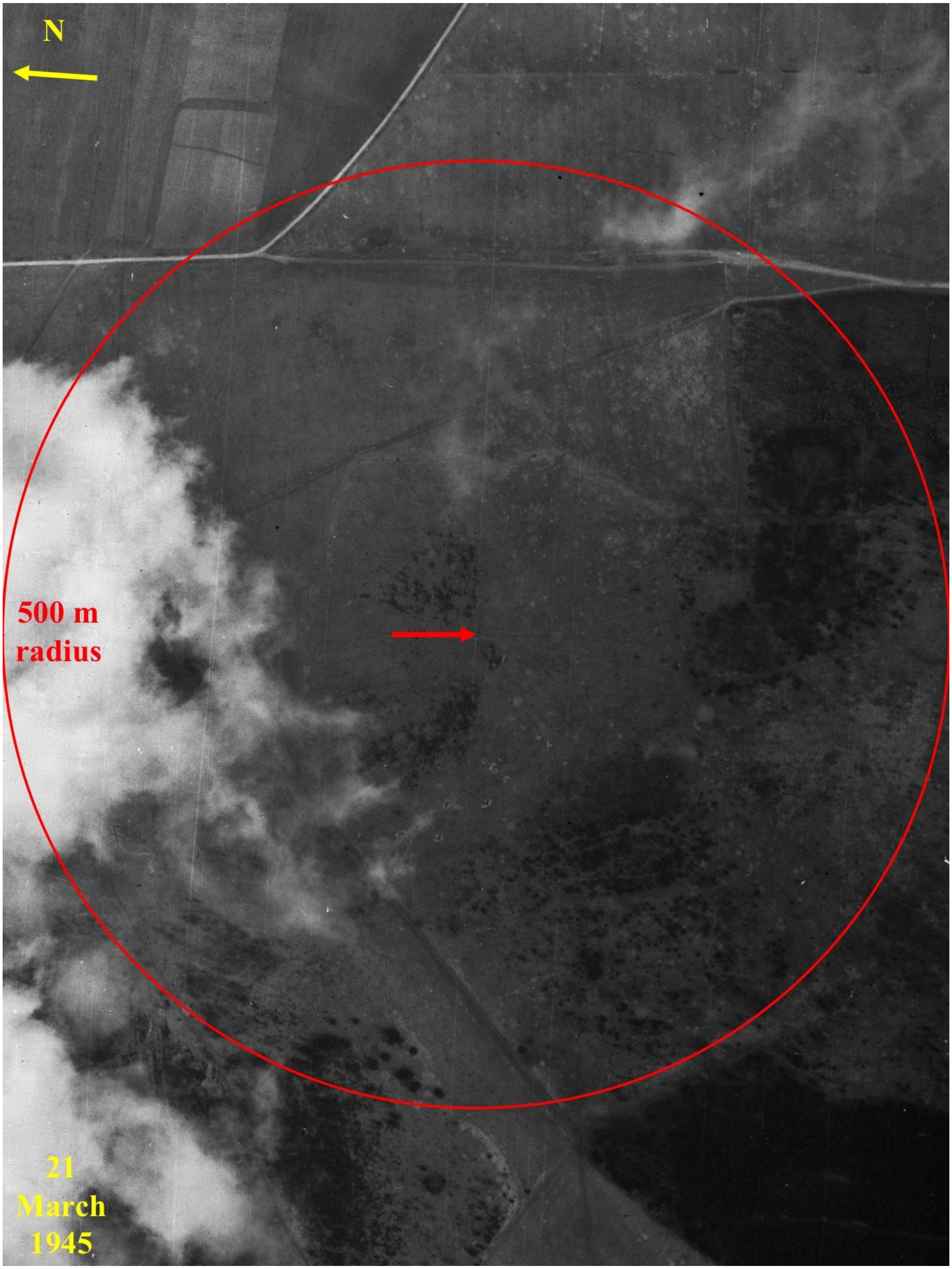

N
500 m radius
21 March 1945

Figure D.729: 21 March 1945 U.S. aerial reconnaissance photo of Ohrdruf, zoomed in on the apparent crater, with a circle to show the scale of a possible 500-meter blast radius.

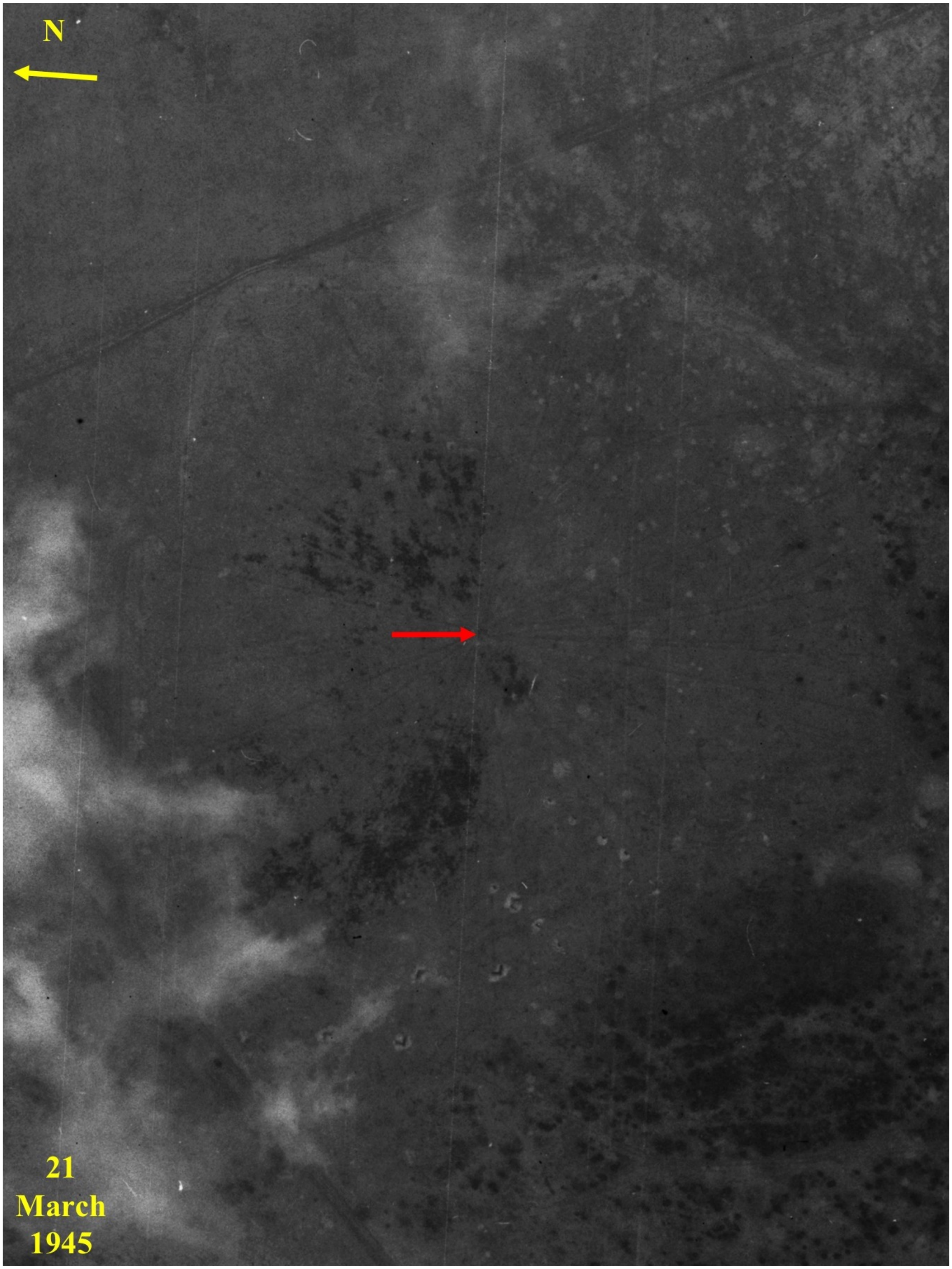


Figure D.730: 21 March 1945 U.S. aerial reconnaissance photo of Ohrdruf, zoomed in further to more clearly show the many streaks of ejecta radiating outward from the center (red arrow) of the apparent crater.

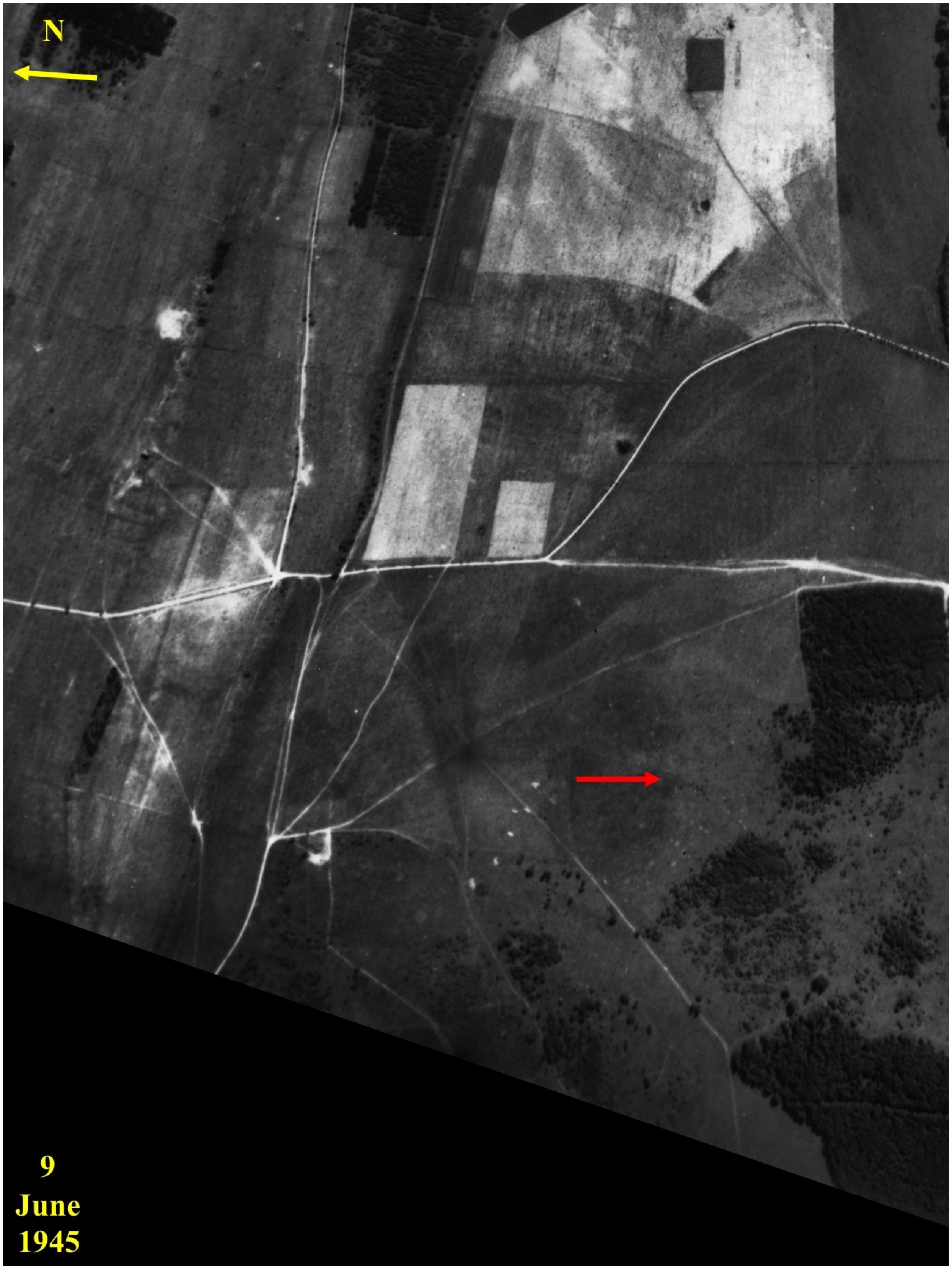


Figure D.731: 9 June 1945 U.S. aerial reconnaissance photo of Ohrdruf military training base, showing location after possible March 1945 test explosion. Note the circular shape with a center denoted by the red arrow and a radius approximately the same size as the red arrow. Again, note the apparent removal or alteration of buildings that had previously been on the field.

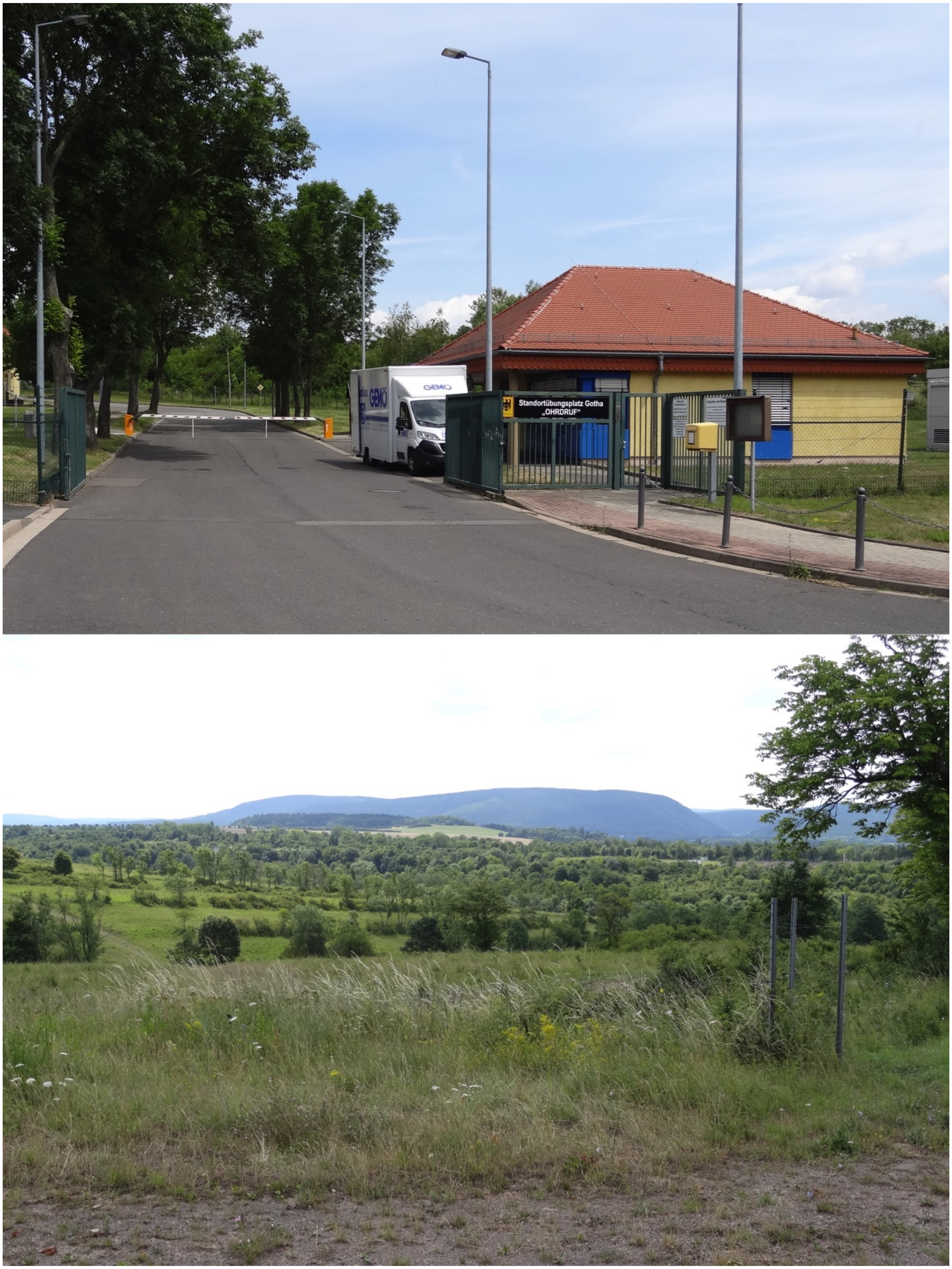

Standortübungsplatz Gotha
„OHRDRUF“
GEMO

Figure D.732: Entrance to the Ohrdruf Truppenübungsplatz now, and overview of the base and the surrounding area.

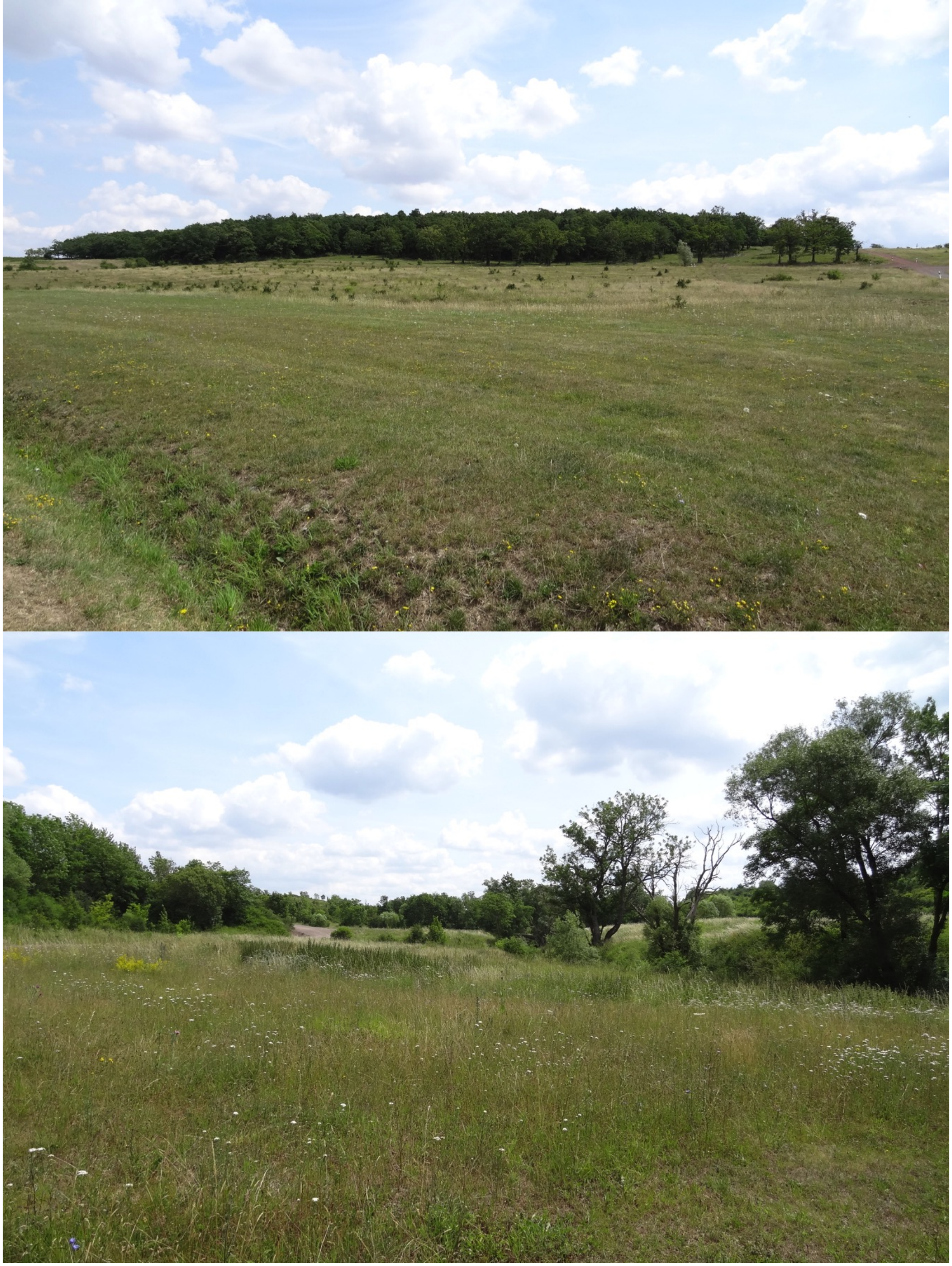


Figure D.733: Even now, the Ohrdruf Truppenübungsplatz is a mixture of fields and forested areas in close proximity.

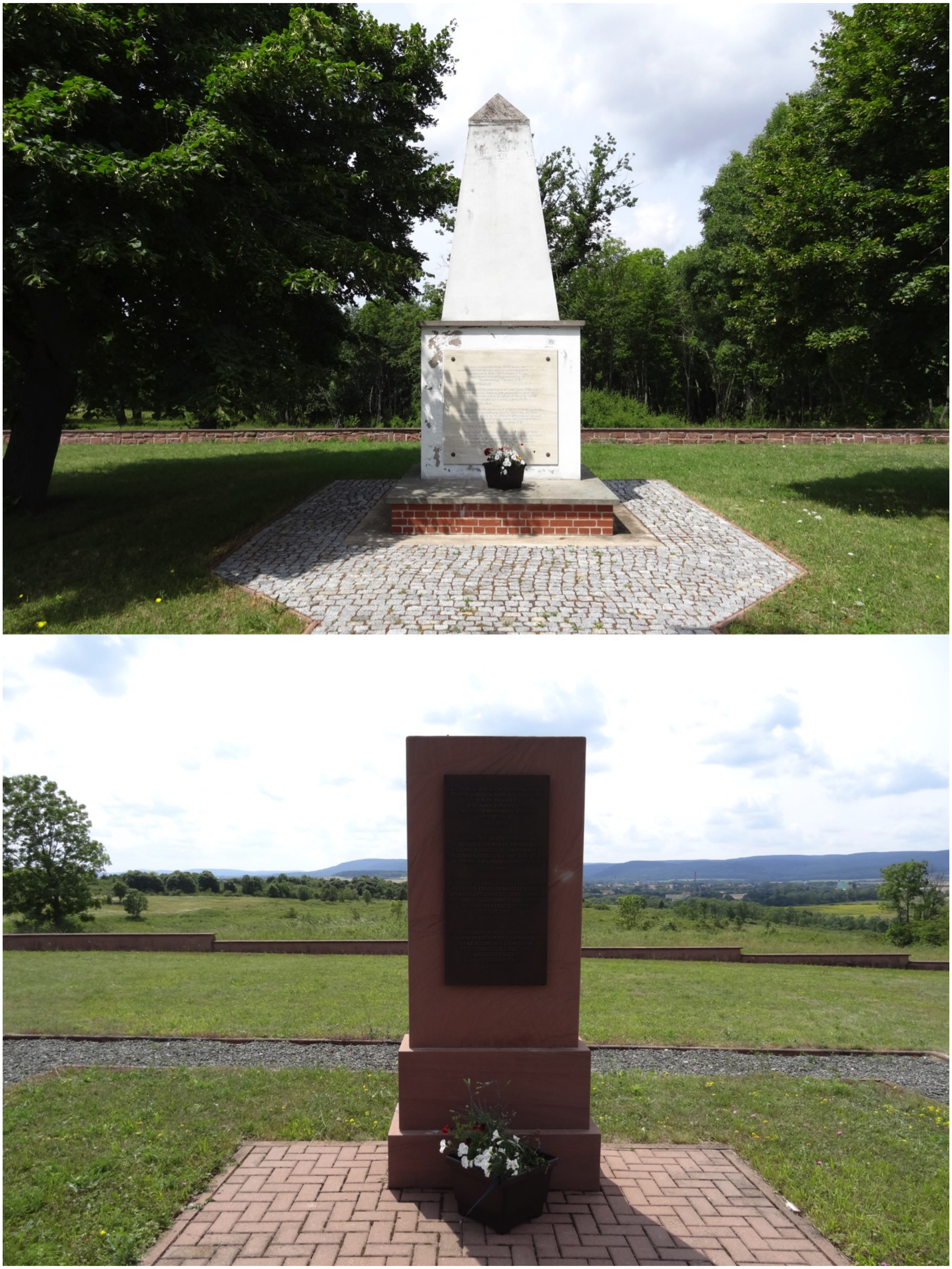


Figure D.734: Memorials to concentration camp victims at the Ohrdruf Truppenübungsplatz.

Franciszek Stryjewski. 1960. *We Cieniu Krematorium.* Katowice. [Translation from Polish to German by Stefan Wohanka in Jonastalverein archive, Arnstadt.]

Die Organisation dieses Lagers fiel dem Lager Buchenwald zuteil, welches als Mutterlager wenigstens 95000 Häftlinge in verschiedenen Kommandos beschäftigte. Grössere Ansammlungen der Häftlinge, die unter der direkten Leitung der SS untergebracht waren, wie z. B. "Dora" mit 32000 Häftlingen, haben sich von dem Mutterlager nicht so langer her, erst vor drei Monaten getrennt.

- Dieses verdammte Schlachthaus Ohrdruf—fuhr der Vorarbeiter fort—besteht schon erst seit ein paar Jahren. Wir wurden mal in Buchenwald auf den Appellplatz zusammengerufen, von allen Seiten umgeben, 1000 Männer wurden ausgewählt und noch an demselben Abend abgeschickt; aus uns wurde der Ansatz eines neuen Nebenlagers Ohrdruf S: III (S = Sonderlager) organisiert. Wir haben uns als Lager schon vergrössert, wenn trotz sehr zahlreicher Todesfälle über 3000 Häftlinge heute da sind, abgesehen von diesen dort im Nordlager. Transporte kamen doch zahlreich aus Sachsenhausen, Stutthof, Krakow-Plaszow, Dachau, Auschwitz und aus vielen anderen Lagern.

Am Heiligen Abend [1944] waren wir nur durch einen halben Tag in Arbeit. Die SS-Leute wollten auch freihaben.

Der Lagerführer, der ein Stockwerk eines der repräsentativen Blocks für sein Büro reserviert hatte, lud zum Heiligen Abend alle Blockführer, Oberkapos und Kapos zu sich ein, um ihnen eine schnelle Heimkehr zu wünschen, wenn die Deutschen den vom Führer versprochenen "Endsieg" davontrügen.

- Ihr könnt ganz ruhig in die Zukunft schauen—sagte er—weil der Führer angekündigt hat, dass er eine neue Waffe einsetzen wird, die den ganzen bisherigen Verlauf des Krieges radikal verändern und die ganze Welt zu Füssen des Grossen Deutschen Reichs legen soll. [...]

The organization of this camp fell to the Buchenwald camp, which, as the mother camp, employed at least 95,000 prisoners in various commandos. Larger concentrations of prisoners housed under the direct direction of the SS, such as "Dora" with 32,000 prisoners, separated from the mother camp not so long ago, only three months ago.

- This damned Ohrdruf slaughterhouse—the foreman continued—has only existed for a few years. We were once called together on the roll call square in Buchenwald, surrounded on all sides, 1000 men were selected and sent off that very evening; the beginnings of a new Ohrdruf S: III (S = special camp) subcamp were organized from among us. We have already expanded as a camp, even though there are more than 3000 prisoners there today despite numerous deaths, apart from those in the north camp. Transports came in large numbers from Sachsenhausen, Stutthof, Krakow-Plaszow, Dachau, Auschwitz and many other camps.

On Christmas Eve [1944] we were only at work for half a day. The SS people also wanted the day off.

The camp commander, who had reserved a floor of one of the representative blocks for his office, invited all the block leaders, head kapos and kapos to his house on Christmas Eve to wish them a speedy return home when the Germans delivered the "final victory" promised by the Führer.

- You can look quite calmly into the future—said he—because the Führer has announced that he will use a new weapon which will radically change the whole course of the war so far and lay the whole world at the feet of the Great German Reich. [...]

Das Eschebachkommando wurde Anfang Februar [1945] liquidiert. Ich musste zum Steinbruch übergehen. Wir verliessen als die ersten das Lagergelände, sofort nach dem Morgenappell. Unsere Kolonne zählte 2,3–3 Tausend Häftlinge. Wir wurden von über 200 SS-Leuten begleitet. Wir gingen auf Waldwegen, immer aufwärts, bis wir nach einer Stunde Marsch einen Gebirgspass zwischen zwei Ketten von ziemlich hohen Anhöhen erreicht haben. Das war eigentlich ein grosser Bergkessel, voll von Eisenbahngleisen, Weichen und einer grossen Menge von Baustoffen. Am Fuss des südlichen Abhangs eines ca. 200 Meter hohen Berges schienen schwarze Löcher von Tunnels, die tief in den Kalkberg liefen. Etwas weiter flossen Rutschen von gelben und weissen Steinen herunter.

- Hier ist—erklärte mir August Szary—der Ort unserer Qualen. Die Deutschen nennen ihn “Jonas Tal”. Siehst du diese zwei Tunnels dort? Sie sind schon seit langem fertig. Sie sind mit Händen unserer Vorgänger gebaut worden. An diesen Tunnels fahren täglich Waggons und Kraftwagen vor. Soldaten entladen und tragen Kästen, Maschinen und weiss der Teufel was für einen Mist noch herein. In diesen Tunnels sollen superneue Einrichtungen zur Produktion von noch unbekannten Bomben montiert werden. Jemand sprach sogar von Atombomben, die durch Hitler als die “neue Waffe” angekündigt wurden. Diese drei Tunnels sind noch im Bau. Einer von ihnen reicht bis ca. 40 Meter in die Tiefe, der zweite—27 Meter, und den dritten haben wir erst begonnen, auszuhauen. Willst du eine ziemlich leichte Arbeit haben, dann ergreife die Arbeit mit einer Lore. Man belädt sie dir schön mit dem Hauerausschlag, du fährst das dorthin auf den Sturzplatz aus und so immer wieder.

The Eschebachkommando was liquidated at the beginning of February [1945]. I had to go over to the quarry. We were the first to leave the camp grounds immediately after the morning roll call. Our column numbered 2300–3000 prisoners. We were accompanied by over 200 SS men. We walked along forest paths, always uphill, until after an hour's march we reached a mountain pass between two chains of fairly high hills. This was actually a large mountain basin, full of railroad tracks, switches and a large amount of building materials. At the foot of the southern slope of a mountain about 200 meters high, black holes appeared from tunnels running deep into the limestone mountain. A little further on, chutes of yellow and white stones flowed down.

- Here is—explained August Szary to me—the place of our torment. The Germans call it “Jonas Valley.” See those two tunnels there? They were finished a long time ago. They were built with the hands of our predecessors. Wagons and motor vehicles pull up to these tunnels every day. Soldiers unload and carry in boxes, machines and who knows what else. In these tunnels, super-new facilities for the production of as yet unknown bombs are to be assembled. Someone even spoke of atomic bombs, which were announced by Hitler as the “new weapon.” These three tunnels are still under construction. One of them reaches to a depth of about 40 meters, the second one 27 meters, and the third one we have just started to excavate. If you want to have a fairly easy job, then take on the work with a wagon. You load it up with a heap of material, drive it out to the fall site and so on.

Cläre Werner. 16 May 1962 SED transcript. Jonastalverein Archive, Arnstadt.

Auch dies habe ich schon alles gesagt. Ich kann mich noch gut an den Tag erinnern. Es war der 4. März 1945. Für den Tag hatten wir eine Geburtstagsfeier für den Abend, diese wurde abgesagt. Am Nachmittag war der BDM von Gotha auf der Burg. Hans war auch da und half uns noch, dann sagte er uns, daß heute auf dem Platz Weltgeschichte geschrieben wird. Es wird etwas gemacht, was es auf der Welt noch nicht gegeben hat. Wir sollen am Abend auf den Turm [der Wachsenburg] gehen und in Richtung Röhrensee schauen. Er wisse auch nicht, wie das neue Ding aussehen wird. So waren wir ab 20 Uhr auf dem Turm.

I have already said all of this. I still remember the day well. It was March 4, 1945. For the day, we had a birthday party for the evening that was canceled. In the afternoon the BDM [Federation of German Girls] of Gotha was at the castle. Hans was also there and was helping us, and then he told us that today world history would be written on the [military training] ground. Something would be made that had not previously existed in the world. We should go on top of the tower [of Wachsenburg castle] in the evening and look in the direction of Röhrensee. He also did not know what the new thing would look like. So we were on top of the tower by 20:00.

Nach 21 Uhr, gegen halb Zehn, war hinter Röhrensee mit einmal eine Helligkeit wie Hunderte von Blitzen, innen war es rot und außen war es gelb, man hätte die Zeitung lesen können. Es war alles sehr kurz, und wir konnten dann alle nichts sehen, wir merkten nur, daß es eine mächtige Sturmbö gab, aber dann alles ruhig war.

After 21:00, at 21:30, behind Röhrensee there was all at once a brightness like hundreds of lightning bolts, it was red on the inside and yellow on the outside, you could have read the newspaper. It was all very brief, and then we could not see anything, we only realized that there was a powerful squall, but then all was quiet.

Ich wie auch viele Einwohner von Röhrensee, Holzhausen, Mühlberg, Wechmar und Bittstädt hatten am anderen Tag oft Nasenbluten, Kopfschmerzen und auch einen Druck auf den Ohren. Am Nachmittag, gegen 14 Uhr, waren so zwischen 100 und 150 SS-Leute auf einmal auf der Burg, sie fragten wo die Leichen seien, wo sie hingebracht worden seien und wer schon da war. Wir wußten von nichts, und sie fragten uns, ob sie hier im “Objekt Burg” seien. Ich sagte ihnen, sie seien hier auf der Veste Wachsenburg, die im Volk immer nur als Burg bezeichnet wird. Ein Kradfahrer gab eine Meldung ab, daß die “Burg” über Ringhofen zu erreichen ist. Daraufhin fuhren die Autos von der Burg nach Mühlberg. Ich sah vom Turm, daß sie dann zum Übungsplatz fuhren.

Like many residents of Röhrensee, Holzhausen, Mühlberg, Wechmar, and Bittstädt, the next day I also had frequent nosebleeds, headaches, and also a pressure on the ears. In the afternoon, at 14:00, between 100 and 150 SS men at one time came to the castle, they asked where the bodies were, where they had been brought and who was already there. We knew nothing, and they asked us if this was “Installation Castle [Burg].” I told them that they are here in the Veste Wachsenburg which is popularly always referred to as a castle. A motorcyclist gave a message that the “Castle” is accessible via Ringhofen. Then the cars drove from the castle toward Mühlberg. I saw from the tower that they then drove to the training ground.

Bei der zweiten Explosion war Hans mit einigen Leuten auf dem Turm, wir waren nur im Turmzimmer. Es war am 12. März 1945 gegen 22.15 Uhr. Es war nicht eine so große Helligkeit wie das erste Mal. Auch hatten wir kein Nasenbluten usw.

Auch hatte er uns verboten, etwas über die Blitze zu sagen.

For the second explosion, Hans was with some people on top of the tower, we were only in the tower room. It was on March 12, 1945, at 22:15. It was not so great a brightness like the first time. We also had no nosebleeds, etc.

He had also forbidden us to say anything about the lightning.

Figure D.735: Cläre Werner.

[In the 1990s, after the reunification of East and West Germany, a document surfaced in southern Thuringia that appeared to be transcripts of 1962 interrogations of local residents by officials from the then-ruling East German communist party, the Sozialistische Einheitspartei Deutschlands (SED, Socialist Unity Party of Germany). In these transcripts, a number of people who had lived in southern Thuringia for many years were asked what they knew about secret German military research and development that occurred in that area during World War II. Some of the respondents described witnessing or hearing about tests of a powerful new explosive and separate tests of a new rocket.

The chain of custody of the transcripts from 1962 until the 1990s is unclear, and therefore their authenticity cannot be proven. It is possible that the transcripts are simply fictions that were created by a forger in the 1990s or earlier, or that they are real transcripts that contain fictional insertions supplied by a forger. Indeed, some researchers have raised serious questions about the transcripts [e.g., Frank Döbert, in *Geheimnis Jonastal* 2011, No. 11, p. 25].

It is also possible that the testimony in the 1962 SED transcripts is authentic. Due to the highly sensitive nature of the statements in these transcripts, East German officials would almost certainly not have stored them in a regular archive where they could be routinely and permanently accessed. In any event, the 1990 transition from communist rule to unified German government rule was chaotic, and many files were destroyed, stolen, or hidden to avoid embarrassing or implicating East German officials and citizens. According to former East German officials, the 1962 SED transcripts seem to be consistent in appearance with other East German interrogation transcripts from that place and time.

Cläre Werner (1913–2003), the most important witness quoted in the 1962 SED transcripts, was a wartime lookout living in Veste Wachsenburg, a castle on a hill with an excellent view of the Ohrdruf Truppenübungsplatz military base and the surrounding area (see Fig. D.736).

In several interviews conducted between 1998 and 2003, Werner confirmed that she had seen extraordinary explosions from the castle in March 1945, consistent with the more detailed account attributed to her in the 1962 SED transcripts [Petermann 2000; Karlsch 2005, pp. 215–216; Karlsch and Petermann 2007, pp. 34–36].

Werner's testimony in the 1962 transcripts is also consistent with those of other witnesses in the transcripts and consistent with details from the other sources quoted in this section that reported the 4 March 1945 test, as summarized in Table D.6.

According to Werner's testimony in the 1962 SED transcripts, the 4 March 1945 test explosion occurred at approximately 9:30 p.m. Archived seismographic recordings from the Institut für Geowissenschaften Jena (approximately 60 km from Ohrdruf) appear to show an otherwise unidentified seismic event on 4 March 1945 at 9:25 p.m. local German time [Ziegert 2011]. See Fig. D.737. Note the jittering on the indicated line just after the square clock pulse. Could that have been the nuclear explosion, or merely an unrelated event or noise? (A nuclear explosion may not have created strong seismic waves, especially if the explosion was small and/or the bomb was detonated on a tower and not on the ground.)

As shown in the scientific analysis beginning on p. 5138, the transcribed testimony of Werner and others is highly consistent with the physics of nuclear weapons, in ways that could not have been foreseen by Werner, her interrogators, or a document forger who was not a nuclear physicist.

Therefore, despite many unanswered questions about the 1962 SED transcripts, they are quoted and analyzed in Appendices D (for parts relevant to nuclear tests) and E (for parts relevant to rocket tests; see pp. 5344–5347). I certainly do not and cannot claim that this analysis "proves" the authenticity of the SED transcripts, yet the transcripts do seem to be in remarkably good agreement with all of the other evidence.

I strongly recommend that researchers search for information to either support or refute the authenticity of the 1962 SED transcripts. Please contact me if you find relevant information.]

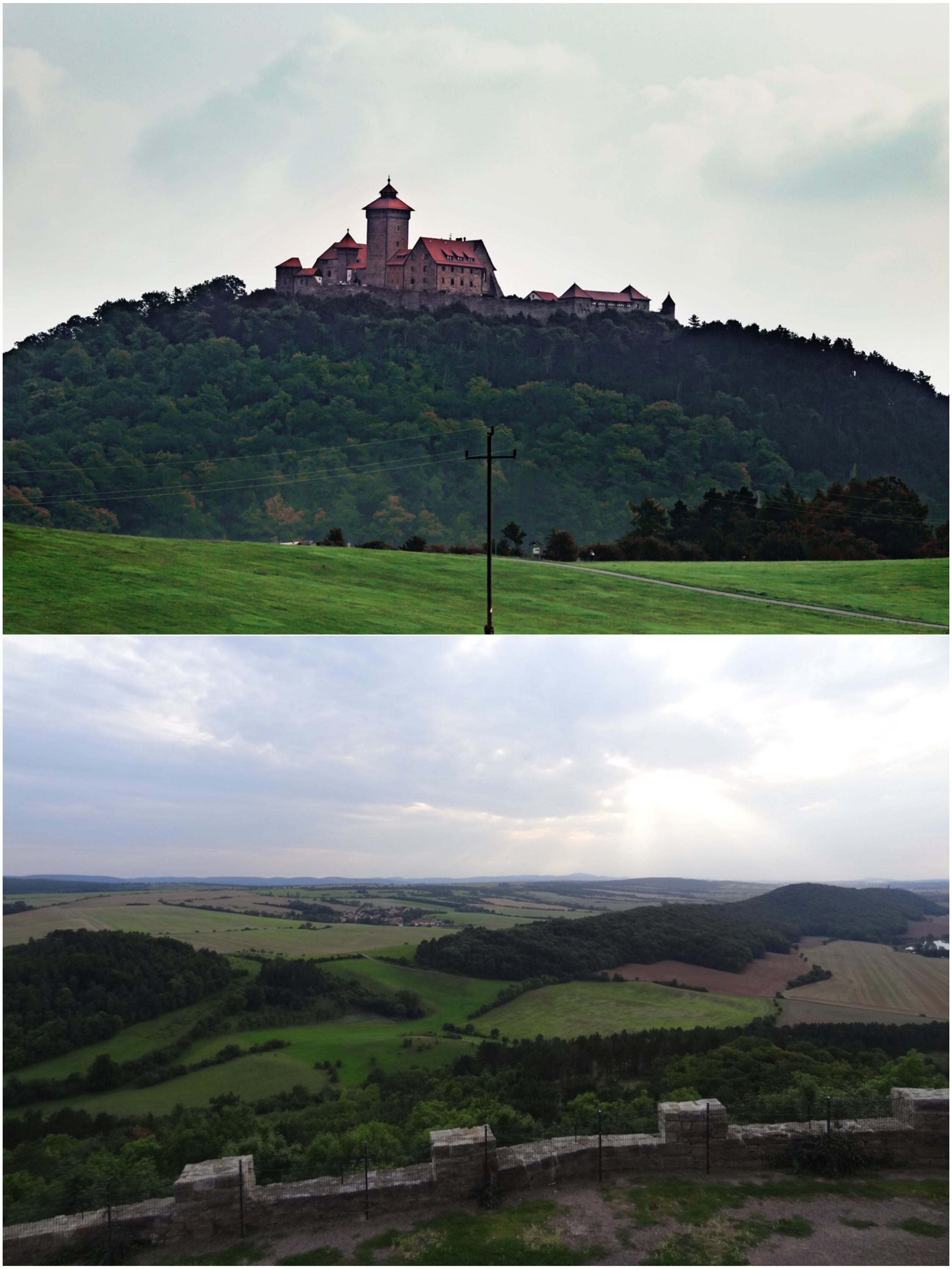


Figure D.736: Wachsenburg castle now, and the view from the castle of the village of Röhrensee and beyond.

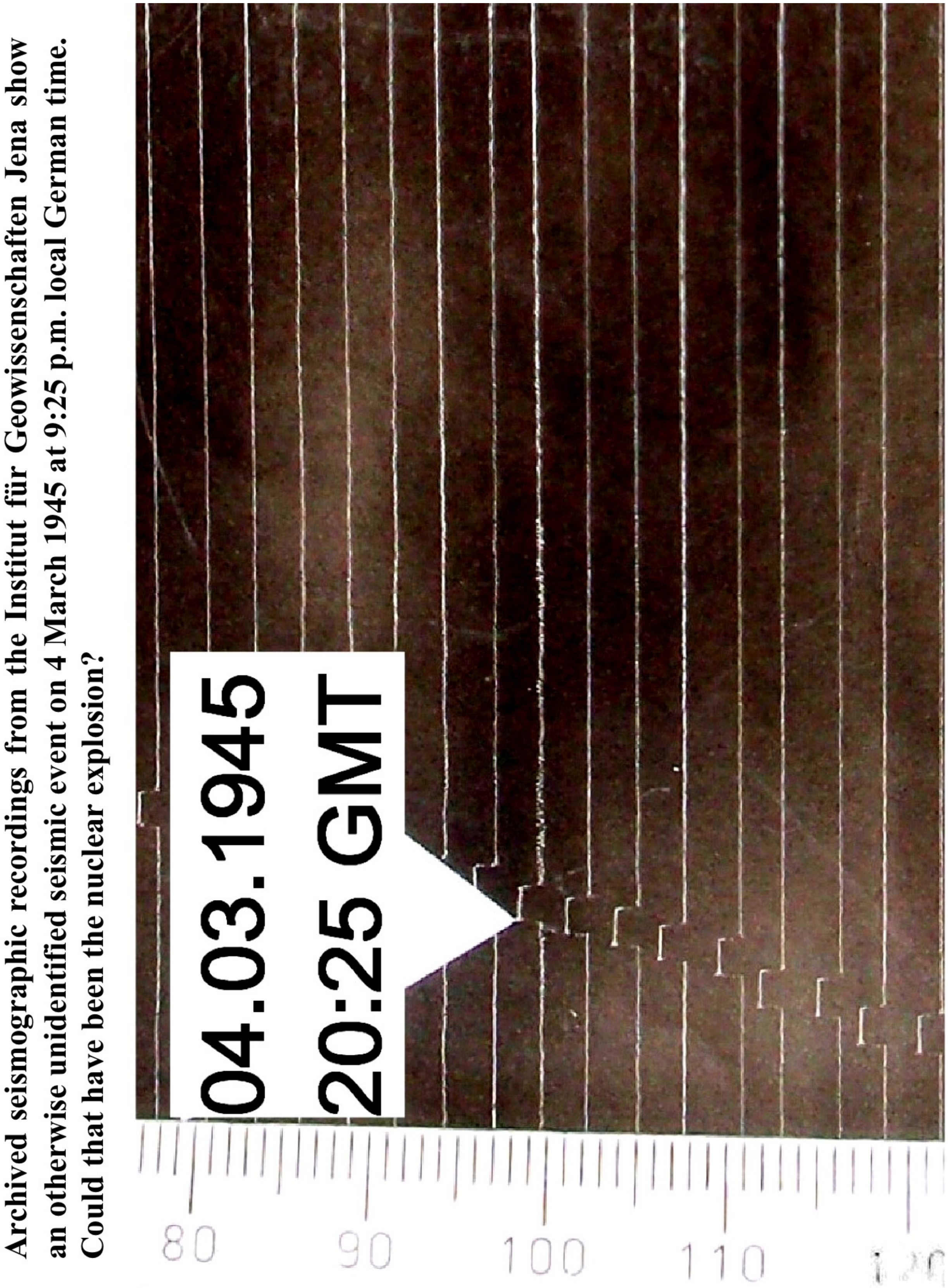


Figure D.737: Archived seismographic recordings from the Institut für Geowissenschaften Jena (approximately 60 km from Ohrdruf) appear to show an otherwise unidentified seismic event on 4 March 1945 at 9:25 p.m. local German time [Ziegert 2011]. Note the jittering on the indicated line just after the square clock pulse. Could that have been the nuclear explosion, or merely an unrelated event or noise?

Heinz Wachsmut. 16 May 1962 SED transcript. Jonastalverein Archive, Arnstadt.

[Heinz Wachsmut's testimony was also part of the 1962 SED transcripts. As discussed on p. 4551, the chain of custody for the 1962 SED transcripts is uncertain and hence their authenticity cannot be proven. However, the written testimony of Wachsmut is consistent with stories he told his family before he died [Karlsch and Petermann 2007, p. 37], consistent with Cläre Werner's testimony, and consistent in appearance with other East German interrogation transcripts from that place and time. It is also consistent with other reports of the 4 March 1945 test quoted in this section, as summarized on p. 4480. As shown in the scientific analysis beginning on p. 5138, Wachsmut's testimony is highly consistent with the physics of nuclear weapons, in ways that would not have been possible for Wachsmut, his interrogators, or a document forger to foresee. Nonetheless, I cannot claim that this analysis "proves" the authenticity of the SED transcripts. Much more research is needed to investigate their background and authenticity.]

Nach einer Straftat... wurde ich zwangsverpflichtet. Wir waren sechs Deutsche und hatten zur Hilfe 18 Häftlinge, darunter sieben Ungarn, fünf Polen und vier Russen; es waren alles Techniker, sie trugen keine Häftlingsanzüge, sondern Felddienst, und wurden auch mit uns verpflegt. Unsere Hauptaufgabe war, Tarnarbeiten durchzuführen. An gelandeten Flugzeugen, an Objekten, an Transportgut, das nicht immer sofort eingelagert werden konnte, und auch zu Hilfsarbeiten (wurden wir eingesetzt), wenn zu viele Häftlinge verstorben waren. Dazu mußten wir dann oft Holzhaufen errichten, wo die Leichen dann draufgelegt und angezündet wurden. Es gab keine Listen über die verstorbenen Häftlinge.

After a crime... I was conscripted. We were six Germans and had help from 18 prisoners, including seven Hungarians, five Poles, and four Russians; they were all engineers, they wore no prisoner suits, rather field service uniforms, and were also fed with us. Our main task was to conduct camouflage work at landed airplanes, bases, transported goods, which could not always be immediately removed, and also for auxiliary work (we were used) if too many prisoners had died. For that we often had to build wood piles, upon which the bodies were laid and set on fire. There were no lists of the prisoners who died.

Ein Tag, der immer in meinem Leben Bilder vor den Augen macht, war der Nachmittag des 5. März 1945. Wir mußten in der Polte Rudisleben Gerüste errichten für einen Versuch, der in wenigen Tagen stattfinden sollte. Am Nachmittag fuhr die SS mit LKWs vor, eigentlich hatte uns die SS nichts zu sagen, da wir ja immer mit Sonderbefehlen arbeiteten, die immer die Stempel der Reichspost bzw. des Forschungsrates trugen und nach dem Lesen sofort vernichtet werden mußten. Es war ein Befehl, der die Unterschrift von Kammler trug. Wir mußten alles Holz, das verfügbar war, aufladen. Die Fahrt ging nach Röhrensee, dort waren einige SS Ärzte tätig, da eine große Anzahl von Bewohnern Kopfschmerzen hatte und Blut spuckte. Wir waren dort falsch und wurden sofort nach Gut Ringhofen bei Mühlberg gebracht. Dort wurde uns gesagt, wir müssen Holzhaufen am Waldrand errichten, ca. 12x12 m und nur höchstens 1 m hoch, dazu mußten wir Vollschutz tragen, auch unsere Häftlinge. Am Waldrand sahen wir schon einige Haufen von Menschenleichen, die wohl ehemalige Häftlinge waren. Die Menschen hatten alle absolut keine Haare mehr, teils fehlten Kleidungsteile, sie hatten aber auch zum Teil Hautblasen, Feuerblasen, nacktes rohes Fleisch, teilweise waren einige Teile nicht mehr vorhanden. SS und Häftlinge brachten die Leichen an. Als wir die ersten sechs Haufen fertig hatten, wurden die Leichen darauf gelegt, je Haufen ca. 50 Stück, und Feuer gelegt. Wir wurden zurückgefahren. Im Gut mußten wir den Schutz und unsere gesamte Kleidung ausziehen. Diese wurde ebenfalls sofort von der SS angezündet, wir mußten uns waschen und erhielten neue Kleidung und neuen Schutz, dazu jeder eine Flasche Schnaps, auch unsere Häftlinge.

A day whose images I see before my eyes throughout my life, was the afternoon of 5 March 1945. In the Polte Rudisleben we had to erect scaffolding for a test that was supposed to take place in a few days. [16 March A-9/A-10 launch? See pp. 5344–5347.] In the afternoon the SS drove up with trucks, actually the SS did not have anything to say to us since we always worked with special orders that always bore the stamp of the Reich Post Office or the Research Council and had to be immediately destroyed after reading. It was an order that bore the signature of Kammler. We had to load up all the wood that was available. The trip went to Röhrensee, where some SS doctors were busy, since a large number of residents had headaches and were spitting up blood. We were there mistakenly and were immediately brought to the Ringhofen estate by Mühlberg. There we were told we must build woodpiles at the edge of the forest, approximately 12x12 m and only 1 m high at the highest, plus we had to wear full protection, as did our prisoners. At the edge of the forest we saw there were already a few piles of human corpses that were probably former prisoners. The people all had absolutely no more hair, some missing items of clothing, but they had also some skin blisters, fire blisters, exposed raw flesh, some were missing some [body] parts. SS and prisoners brought the bodies. When we had made the first six piles ready, the bodies were placed on them, approximately 50 per pile, and set on fire. We were driven back. At the estate we had to take off the protection and all our clothes. This was also immediately burned by the SS, we had to wash ourselves and received new clothes and new protection, to each a bottle of Schnaps, including our prisoners.

Ein hoher SS-Mann sagte mir, es habe da oben eine große Stichflamme gegeben gestern, man hat etwas neues gemacht, davon wird die ganze Welt sprechen, und wir Deutschen sind die ersten. Leider sei dabei einiges nicht so gelaufen wie geplant und einige Nichtsnutze habe man weniger.

A high-ranking SS man told me, there had been a big flash of flame up there yesterday, something new had been made, of which the whole world will speak, and we Germans are the first. Unfortunately some things did not go as planned and some unwanted people had been eliminated.

Beim zweiten Einsatz wurden nochmals drei Haufen errichtet. Dabei sahen wir, wie aus dem Wald einige völlig unmenschliche Lebewesen angekrochen kamen. Wahrscheinlich konnten einige nichts mehr sehen.—Pause—Ich kann es auch heute nicht beschreiben. Von zwei SS Leuten wurden diese ca. zwölf bis fünfzehn Menschen sofort erschossen. Ob sie wirklich schon erschossen waren, kann ich nicht sagen, da einige noch den Mund bewegten. Sie wurden bzw. mußten von anderen Häftlingen auf die in Flammen stehenden Haufen getragen werden. Wir wurden wieder zum Gut gebracht und es wiederholte sich alles. Gegen 23 Uhr fuhren wir zurück zur Polte. Am Waldrand waren 14 Feuerstellen zu sehen. Wir konnten an diesem und am nächsten Tag nichts essen, es gab für uns und die Häftlinge immer wieder Schnaps.

During our second operation three more piles were erected. There we saw, out of the forest some totally inhuman creatures came crawling. Probably some of them could no longer see. (Pause.) I cannot describe it even today. These approximately 12 to 15 people were immediately shot by two SS men. I cannot say whether they were really [all] shot, as some still moved their mouths. They were or had to be carried to the flaming pile by other prisoners. We were brought back to the estate and it [decontamination] was all repeated. At 23:00 we drove back to Polte. At the edge of the forest there were 14 fires to be seen. [14 fires × 50 bodies each = 700 bodies?] We could not eat anything on this and the next day, there was for us and the prisoners always more Schnaps.

Einer unserer russischen Häftlinge sagte uns, er habe einen der Erschossenen noch verstanden, "... großer Blitz—Feuer, viele sofort tot, von der Erde weg, einfach nicht mehr da, viele mit großen Feuerwunden, viele blind, Gruß an Mutter von Olek Barto nach Gurjew..."

One of our Russian prisoners told us that he had understood one of the injured: "... big flash—fire, many dead immediately, gone from the earth, simply not there any more, many with large burns, many blind, greetings to Mother in Guriev from Olek Barto..."

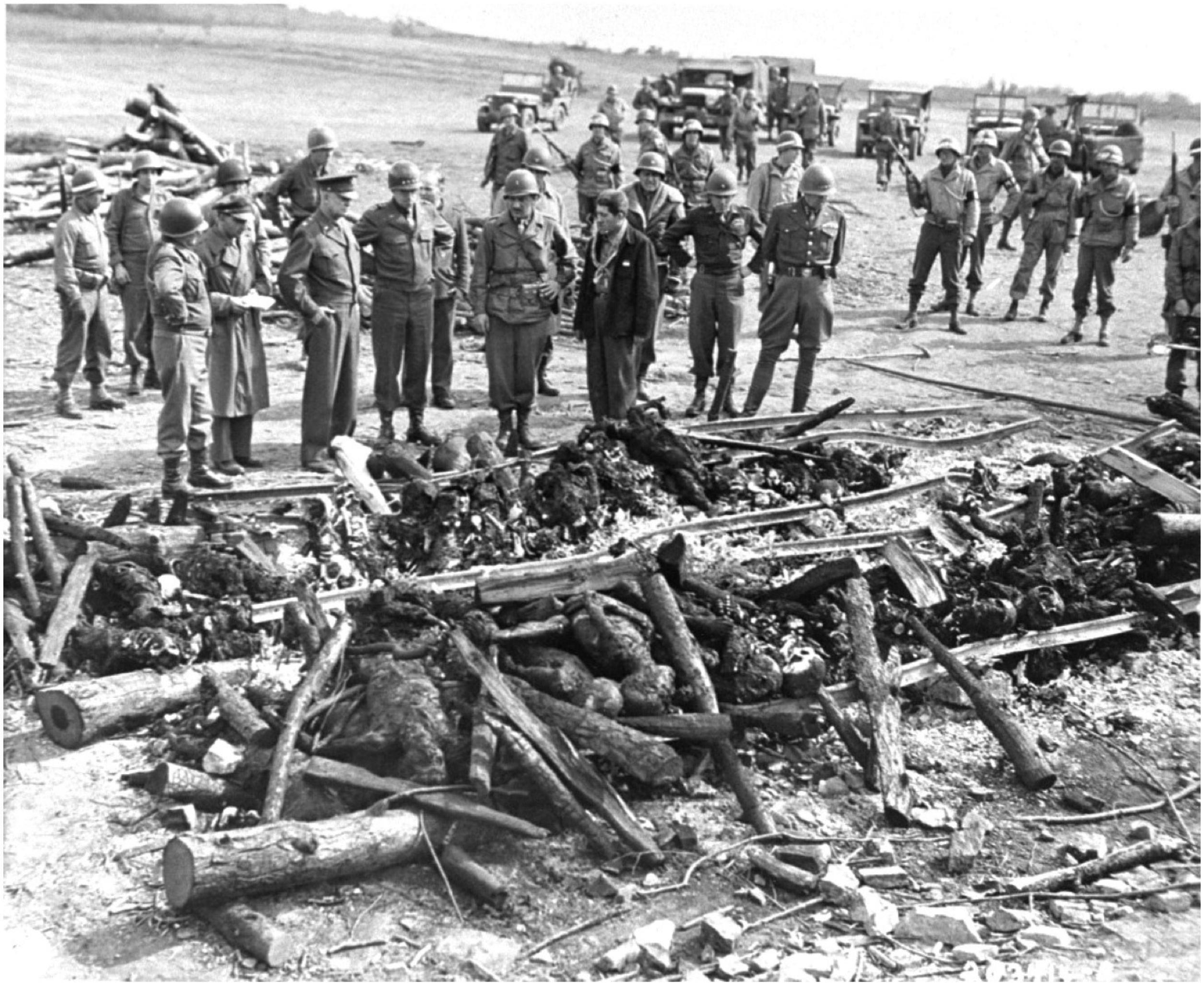


Figure D.738: U.S. Generals Dwight Eisenhower, Omar Bradley, and George Patton inspect burned human remains at Ohrdruf on 12 April 1945.

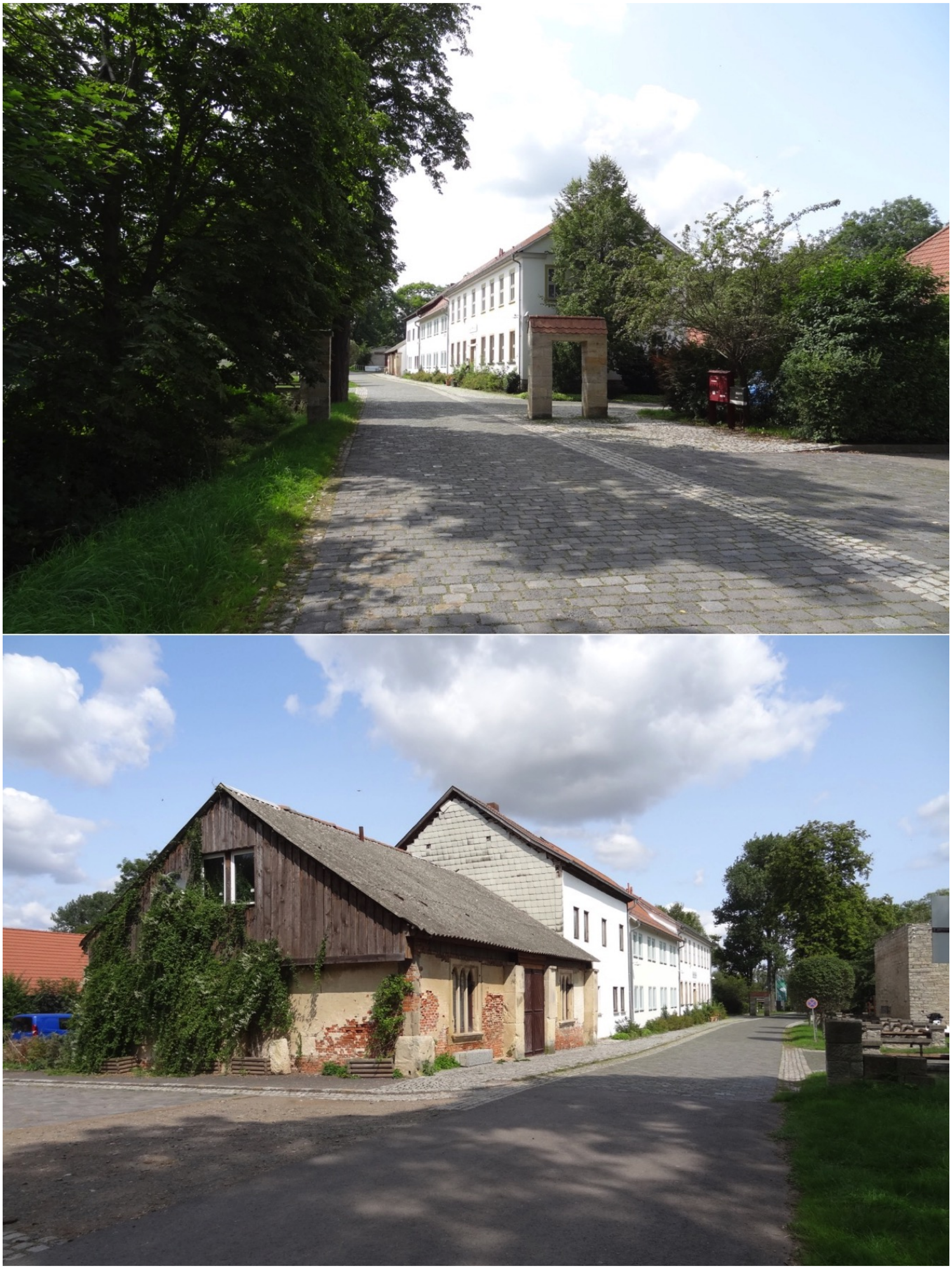


Figure D.739: The Ringhofen estate now.

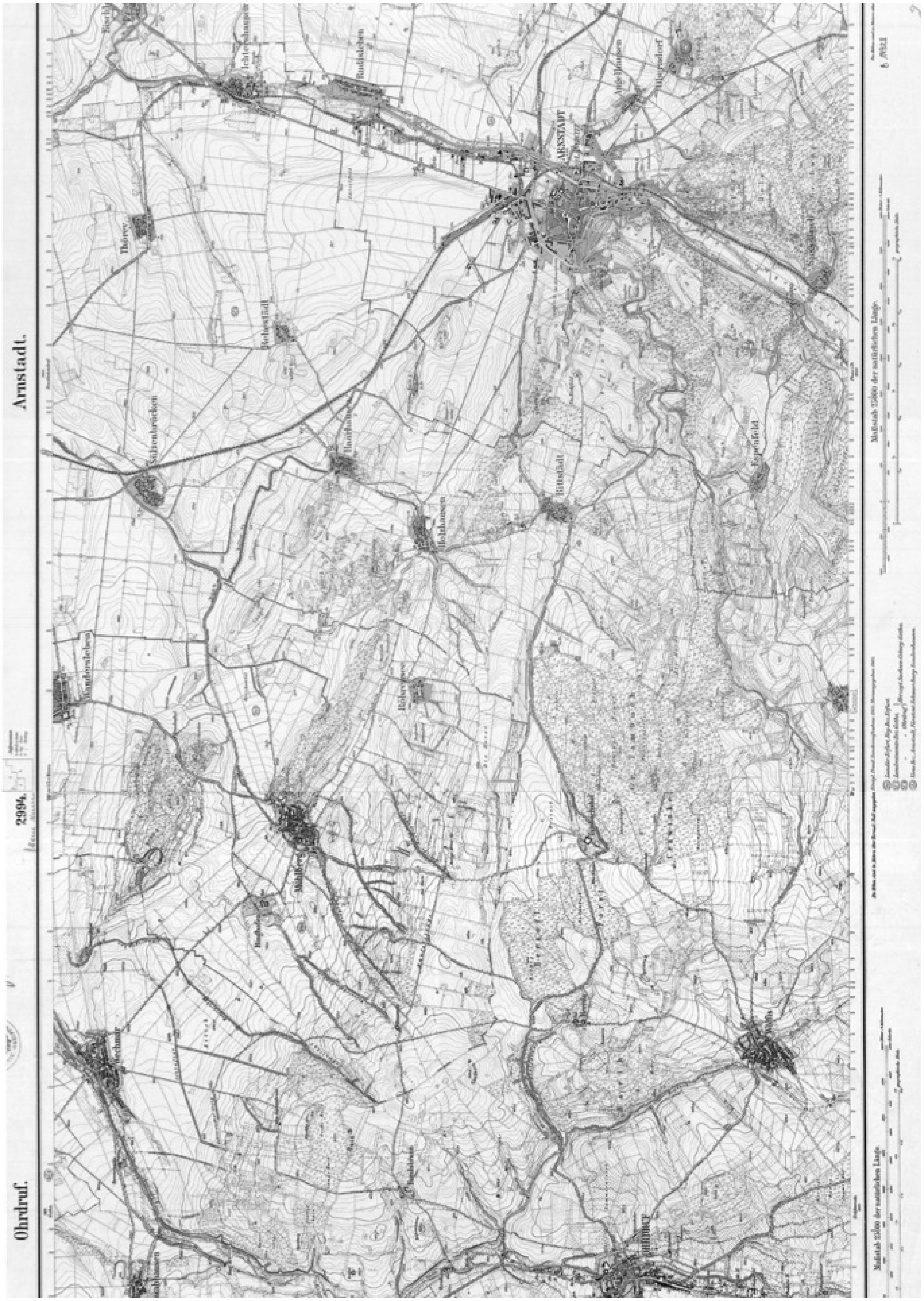

Arnstadt.
Ohrdruf.
2994.
ARNSTADT
Mühlberg

Figure D.740: 1907 map of test area described by Cläre Werner and Heinz Wachsmut.

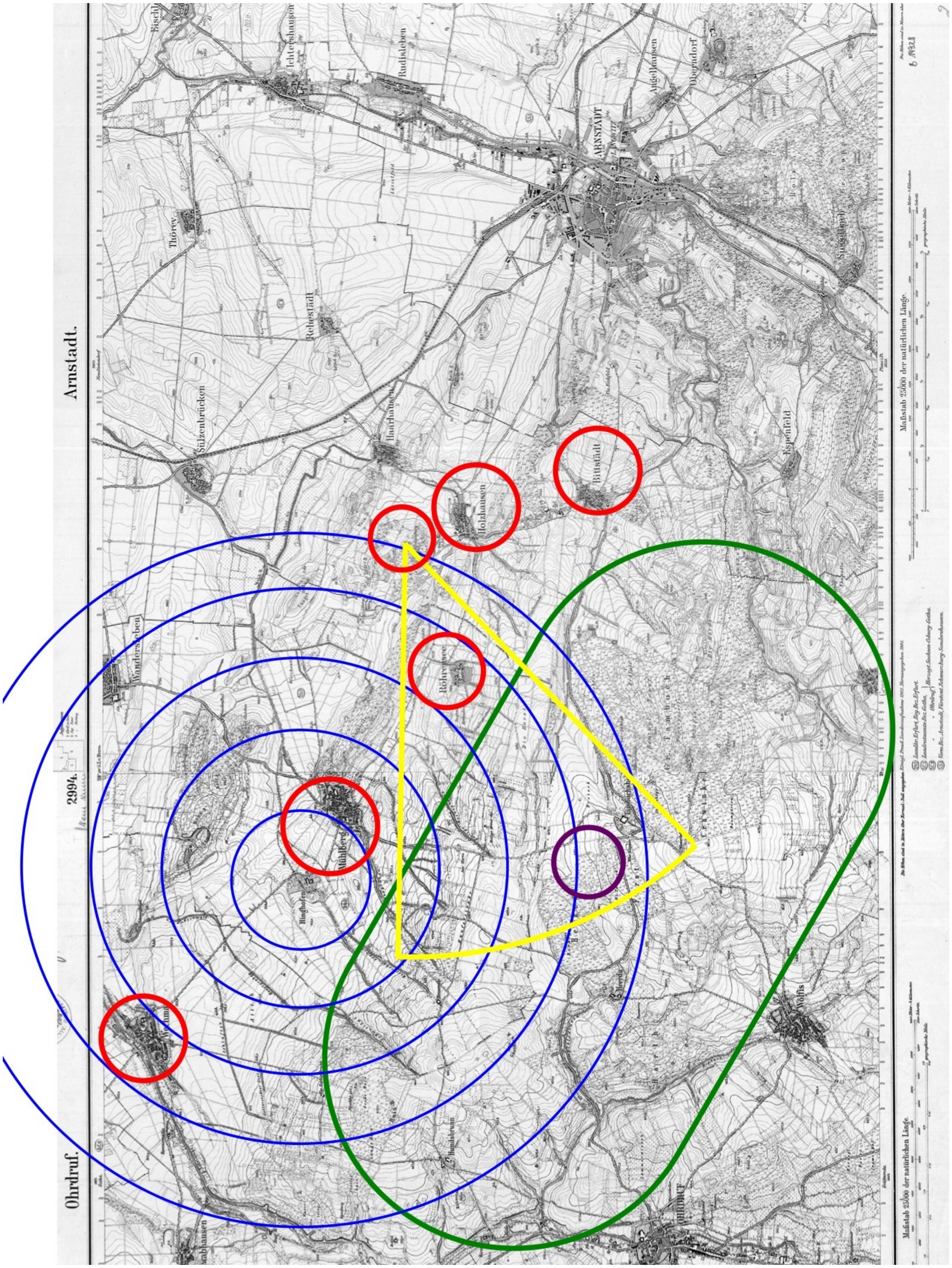

Arnstadt.
2994.
Ohrdruf.
Arnstadt
Ichtershausen
Rudisleben
Thörey
Rehestädt
Sülzenbrücken
Holzhausen
Bittstädt
Espenfeld
Wandersleben
Röhrensee
Mühlberg
Ringhofen
Wechmar
Ohrdruf
Angelhausen
Oberndorf
Siegelbach
Maßstab 25000 der natürlichen Länge

Figure D.741: Test area with clues described by Cläre Werner and Heinz Wachsmut. Green: approximate boundary of military training base. Red: population centers reporting sickness from radioactive fallout. Yellow: Direction in which Werner reported seeing explosion. Blue: driving range (1 km per circle) for Wachsmut from Ringhofen estate. Purple: 1-km-diameter explosion centered on the apparent crater from aerial photos (pp. 4541–4545).

Report on interview of Erich Rundnagel. 8 July 1966 SED Arnstadt transcript. MfS-Kreisdienststelle Arnstadt, BStU Außenstelle Erfurt. Rundnagel was a plumber who worked with Fritz Rehbein and Heinz Rackwitz, members of Kurt Diebner's research group. As shown on the next page, his nephew confirmed that he had spoken to the Stasi and did not dispute the details.

[...] Weiterhin will er Gesprächen mit Dr. Rehbein entnommen haben, daß sich in dem anderen Panzerschrank zwei Atombomben befunden haben sollen, die seiner Vermutung nach später auf Hiroshima und Nagasaki abgeworfen wurden. [...]

[...] Furthermore he [Rundnagel] wanted to infer from conversations with Dr. Rehbein that two atomic bombs were supposed to have been found in the other safe, which in his speculation were later dropped on Hiroshima and Nagasaki. [...]

Erich Rundnagel [Remdt and Wermusch 2006, pp. 125–126]

[...] Ich hatte vor allem mit Dr. Rehbein und Ingenieur Rackwitz zu tun, mit denen ich in eine Art Vertrauensverhältnis kam. Es war also am 7., nein am 9. Juli [1944], als mir Dr. Rehbein sagte: "Rundnagel, nun hören Sie mal ganz genau Nachrichten, innerhalb von ein paar Tagen werden Sie eine entscheidende Meldung hören, von der abhängt, wie der Krieg ausgeht." [...] Am 20. Juli war dann das Attentat auf Hitler. Als ich Rehbein fragte, ob er das gemeint habe, lachte er nur und sagte: "Jetzt kommt sie nicht mehr zum Einsatz, der Krieg ist verloren."

Ich unterhielt mich öfters mit ihm darüber, was hier eigentlich gemacht werde; denn nach Arbeit sah das alles wirklich nicht aus. Da erzählte er mir, dass hier etwas entwickelt werde, das eine größere Sprengkraft habe als all das, was ich mir als alter Pionier vorstellen könne. Mit einer einzigen Bombe könne man im Umkreis von zwanzig Kilometern alles Leben vernichten, und wenn es hunderttausend Menschen wären. Ich antwortete, das sei doch Quatsch, mir altem Soldaten könne er so was nicht vormachen, das gebe es nicht. Ein bisschen kenne ich mich wirklich mit Sprengstoffen aus. Rehbein lächelte nur und sagte, die ganze Bombe sei nur ein paar Dezimeter groß, wiege aber so um die acht Kilo. Als ich ihn fragte, ob ich das Ding mal sehen könnte, winkte er ab: "Das könnte uns beide den Kopf kosten." [...]

[...] I was mainly involved with Dr. Rehbein and engineer Rackwitz, with whom I came into a kind of relationship of trust. It was on the 7th, no on the 9th of July [1944], when Dr. Rehbein told me: "Rundnagel, now you listen closely to the news, within a few days you will hear a decisive report, on which will depend how the war ends." [...] On July 20th was then the assassination attempt on Hitler. When I asked Rehbein whether he meant that, he just laughed and said, "Now it will no longer come to deployment, the war is lost."

I often talked to him about what was really being done here, because after work, it really did not look like anything. Then he told me that something was being developed here that had a greater explosive power than anything I could imagine as an old pioneer. With a single bomb, you could destroy all life within a radius of twenty kilometers, and if there were a hundred thousand people. I replied, that was nonsense, that he could not make such a claim to me the old soldier, that was not the case. I know something about explosives. Rehbein just smiled and said the whole bomb was only a few decimeters in size but weighs about eight kilograms. When I asked him if I could see the thing, he waved it off: "That could cost us both our heads." [...]

Gerhard Rundnagel. Letter to *Der Spiegel*. 21 March 2005 p. 14.

Sie haben aus Rainer Karlschs Buch “Hitlers Bombe” die Behauptung übernommen, ich hätte gegenüber der Stasi Aussagen über deutsche Atomwaffentests in Ohrdruf gemacht. Das stimmt nicht. Es war mein Onkel Erich Rundnagel, der mit der Stasi gesprochen hat.

Based on Rainer Karlsch’s book “Hitler’s Bomb,” you made the assertion that I had made statements to the Stasi about German atomic weapons tests in Ohrdruf. That is not correct. It was my uncle Erich Rundnagel who spoke to the Stasi.

Rainer Karlsch. 2013. Die Abteilung Atomphysik der PTR in Ronneburg und das deutsche Uranprojekt. *PTB-Mitteilungen* 123:1:73–81.

Unterdessen hatte die 3. US-Armee unter General Patton ihren schnellen Vorstoß nach Thüringen begonnen. Georg Graue, der die Kriegswirtschaftsstelle des Reichsforschungsrates leitete und die Details der Uranversuche nicht kannte, reagierte auf die Meldung über den amerikanischen Vorstoß mit den Worten: “Ja, von Stadtilm muss sofort die Atombombe weg.”

In the meantime the 3rd US Army under General Patton had begun its rapid advance to Thuringia. Georg Graue, who headed the War Office of the Reich Research Council and did not know the details of the uranium tests, responded to the report of the American attack with the words: “Yes, the atomic bomb must be immediately removed from Stadtilm.”

[The original quote is from an interview with Georg Graue on 4 April 1966, Institut für Zeitgeschichte (IfZ) München, Irving collection.]

Oscar W. Koch with Robert G. Hays. 1999. *G-2: Intelligence for Patton.* Atglen, Pennsylvania: Schiffer. pp. 115–118. Note: Koch died in 1970, but he worked on this manuscript with Hays in the 1960s, and it was published after his death.

Time had run out on Hitler's grand plan; the final chapter of the war in Europe began when soldiers of the First United States Army crossed the Remagen Bridge on March 7. The Third Army attack jumped off that same day.

In the next week, 38,572 prisoners of war passed through Third Army cages. [...]

On March 15, with well over 185,000 prisoners taken since the preceding August 1, the actual count varied from our advance intelligence estimates by only 518.

Prisoners of war could prove valuable sources of intelligence information. German soldiers, experience had shown, were remarkably well-informed. Experience had also shown that some were willing to talk. Sometimes *too* willing.

The Third Army intelligence staff would never forget one particular prisoner captured sometime earlier who had told us a convincing story.

His unit had been working on a new and unusual weapon, the PW told interrogators. Then, he said, while he was temporarily away from his post, there had been a terrific explosion. Everything at the site was a shambles and trees in a wide area of the surrounding forest had been laid low. No aircraft had been near and the blast—the most forceful he ever had witnessed—could not possibly have resulted from a bomb.

To add even more intrigue, the soldier was unable to say just what kind of weapon he had been working on. It was so secret that the individuals in his unit never knew the complete story. He knew only enough to be able to carry on his own duties.

The prisoner knew precisely where he was at the time of the blast. He readily pinpointed the exact location on a map.

His story aroused great interest in the intelligence section. The Germans had already launched V-1 and V-2 rockets, and Hitler had promised a "secret weapon" which would one day make its appearance and bring the Allies to their knees. With no other information explaining the explosion, the prisoner's account might very well mark the Allied discovery of a significant new enemy weapon.

The prisoner's story was put through the usual process of challenge. Was the information hearsay? No, it came from an eyewitness. Was the witness reliable? There was no way to know. Was the information confirmed by other sources? No, it was not. Did the information make sense in light of other data at hand? Somewhat.

There was only one loophole in the story. Through calculations of time and space, we concluded that the witness himself should have been caught in the death-dealing blast. But perhaps he had misjudged his own position, an understandable error under the circumstances. In any event, his story was worthy of further investigation. If it turned out to be true, it would be of enormous intelligence significance.

Fortunately, the story could be checked through a relatively simple expedient. If the trees had been laid low over a wide area of the forest as the prisoner said, the effects of the explosion would be readily apparent in aerial photos. Such a mission was requested and flown. The results were awaited with great anticipation.

But the photos showed that all of the trees were still standing; the area was undisturbed. The prisoner's story had been pulled out of the blue.

One of the prisoners taken in the early days of the March offensive, on the other hand, was to prove an extremely valuable source of intelligence information. [...]

Spreading the map, the prisoner explained that his duties as a German officer had been concerned with construction. Symbols on his map, he said, marked locations selected by the German high command for construction of proposed military installations as the war progressed. These were to become communications centers housed in bombproof underground shelters. A color code indicated the status of work in progress at the various sites. The map, he added, was current; none of the work had been ordered stopped.

Command requires communications. A marked map showing locations of communications centers would reflect as well the proximity of major headquarters. And from the location of headquarters sites the future planning of the German high command could be deduced. [...]

In view of the possible significance of information gained from the German major, we wanted to check the credibility of his story as quickly as possible. Some of the installations shown on his map were located in the Third Army zone of advance and could be confirmed on the ground in the near future. Until such a time, however, the prisoner's disclosure would be known to only a few persons. Patton, of course, was briefed at once.

On April 6, early in the morning, word was received that advance elements of the 4th Armored Division were approaching Ohrdruf. The closest of the reported secret underground centers would be nearby. Colonel Allen, personally selected for the mission by General Patton, departed for the 4th Armored Division command post. Following a briefing there, he would head a small inspection party which, on the following day, would visit the reported site of the enemy installation to see if things there supported the prisoner's story.

[...] At the Ohrdruf site, however, they visited the location described by the prisoner. Construction of the underground, bombproof center was complete, although the equipment was not yet operative. Time had obviously been insufficient to allow completion of the installation of the expensive and highly technical equipment. The building had never been occupied. But the site confirmed, at least in part, that the story the German major had told [...] was true.

[The German prisoner of war was apparently captured by the Americans sometime around mid-March 1945, apparently placing the test in early March. Can records of the interrogation and aerial photos be located in U.S. archives?

The account of the test is consistent with the other reports in this section, but why was it not possible to confirm the test by aerial photos? Did the test not actually occur? Were the aerial photos not of the correct location? Did senior U.S. military officials suppress aerial photos confirming the test due to secrecy? Or did the Germans replant trees or otherwise camouflage the damage at the test site?

This account also confirms the existence of some German underground installations.]

Oscar Koch
(1897–1970)

Robert Allen
(1900–1981)

Figure D.742: Oscar Koch mentioned a massive test explosion in Thuringia, and Robert Allen was sent in to investigate the area.

Robert S. Allen. [Allen 1947, pp. 369, 371–372]

The mop-up of the hilly Meiningen-Gotha-Eisenach sector produced some startling war trophies.

At Ohrdruf, 4th Armored liberated the first of the grisly Nazi horror camps and uncovered a number of astounding subterranean installations. And in the little town of Merkers, 90th Division discovered the German gold reserve.

It was found in a chemical-salt mine of tremendous proportions. The main shaft descended over 2,000 feet and there were more than 200 miles of tunnels. Some were 30 feet in height and width. [...]

The grisly horror camp and a vast, indescribably nauseous open-pit crematorium were on the outskirts of Ohrdruf.

The main architectural feature of this little Thuringian city is an imposing stone *Schloss* built before the war by a local baron. Surrounded by handsome landscaped grounds, the massive edifice was lavishly furnished and equipped with modern facilities, including tiled bathrooms, flush toilets, and an elevator. The baron was a large "employer" of inmates of the horror camp who slaved in his chemical plant. The baron also was a leading dignitary of the local Nazi organization. [...]

The underground installations were amazing. They were literally subterranean towns.

There were four in and around Ohrdruf: one near the horror camp, one under the *Schloss*, and two west of the town. Others were reported in near-by villages. None were natural caves or mines. All were man-made military installations. The horror camp had provided the labor. An interesting feature of the construction was the absence of any spoil. It had been carefully scattered in hills miles away.

Over 50 feet underground, the installations consisted of two and three stories several miles in length and extending like the spokes of a wheel. The entire hull structure was of massive, reinforced concrete. Purpose of the installations was to house the High Command after it was bombed out of Berlin. The Ohrdruf installations were to have been used by the Signal Communications Section. One, near the horror camp, was a huge telephone exchange equipped with the latest and finest apparatus. Signal Corps experts estimated their cost at $10,000,000.

This place also had paneled and carpeted offices, scores of large work and store rooms, tiled bathrooms with both tubs and showers, flush toilets, electrically equipped kitchens, decorated dining rooms and mess halls, giant refrigerators, extensive sleeping quarters, recreation rooms, separate bars for officers and enlisted personnel, a moving-picture theater, and air-conditioning and sewage systems.

Begun in 1944, the installations had been completed but never occupied. Third Army's lightning advance through central Germany had blocked that.

[U.S. government censors limited what Robert Allen could write. However, he did mention that there were many massive and well-equipped underground installations in the greater Ohrdruf area, and that U.S. forces visited “a number of astounding subterranean installations.” Where are the detailed reports of what they found there?

Allen only mentioned (or was only allowed by censors to mention) a command center and a communications center, but it is likely that most of the underground installations were involved in research, development, and production for advanced weapons.

In fact, a brief report from U.S. Army’s 80th Infantry Division in April 1945 mentioned an underground plant close to Wölfis (near Ohrdruf) and described the whole region as a “very important production area” (p. 5363).]

G-2 Periodic Report No. 177. 7 April 1945. [NARA RG 407, Entry NM3-427, Box 12342, Folder 604-2.1 G-2 Periodic Reports 4th Armored Div 1 Jan–18 May 45]

Murdercamp, vic[inity] OHRDRUF: A PW, NCO, rpts that a Concentration Camp of political prisoners, existed in the vic of OHRDRUF. According to stories told him by members of the guards, several thousand persons were killed during this winter at the camp. The PW himself happened onto an open mass grave some weeks ago, and he states that he saw nude bodies laying in lakes of blood. The PW further rpts that many, or perhaps all, of the bodies were exhumed lately and burned in the woods, vic J 115565. On 28 Mar 45, PW believes, several hundred of the political prisoners were still alive. He further states that guards in part belonged to the SS Das REICH and in part to SS LEIB-STANDARTE Adolf Hitler.

The entire area btwn OHRDRUF – SCHWABHAUSEN – WOLFIS – WECHMAR (J 1156) was a tk troop drill and maneuver ground. PW was told by an ordnance man stationed at OHRDRUF that from here a new secret wpn will shortly rise (wird steigen). It is believed that the entire area should be very thoroughly examined for new material. If any of the above mentioned political prisoners can be found alive, interesting evidence should also be forthcoming. (Source: 89 Inf Div Per Rpt No. 27).

Office of Military Government for Germany (US). Field Information Agency, Technical. DI 254-82 (FIAT) EP. 24 June 1946. Personality List No 2. [NARA RG 238, Entry NM70-160, Box 30, Folder FIAT—Misc.—Reports—No. 1–10]

BÜHL Dr. Alfons

Dir. of Inst. of Physics, Technische Hochschule, KARLSRUHE (Laboratory equipment for atomic research evacuated and also ballistic measurement apparatus)

FROM: HILDBURGHAUSEN

TO: HEIDENHEIM

[This is one of several lists of German scientists and technicians who had been relocated from the Russian Zone of postwar Germany to U.S.-controlled territory. Why did Bühl have "laboratory equipment for atomic research" and "ballistic measurement apparatus" at Hildburghausen, south of Ohrdruf? Does that confirm wartime nuclear work in the general Ohrdruf area? What exactly did Bühl do during the war? What information, hardware, or assistance did Bühl give the Soviets during his time in the Soviet Zone? What information, hardware, or assistance did Bühl give the Americans after that? Where are other U.S. records about Bühl?

Note that after the war, Bühl worked at the Karlsruhe Nuclear Research Center, was an advisor to the West German government in the field of nuclear civil defense, and wrote a book on nuclear weapons [Bühl 1972].]

Heinrich Himmler's chief adjutant Werner Grothmann [Krotzky 2002]

[See p. 4436 for Werner Grothmann's testimony about the March 1945 test in Thuringia.]

D.13 Axis Belief in the Reality of German Nuclear Weapons

[Among Axis officials in positions of knowledge, there was a widespread belief in the reality of German nuclear weapons, both during and after the war:

- There are photographs of Hitler visiting the Reichswerke Hermann Göring at Linz, Austria on 4 April 1943, apparently surrounded by nuclear scientists, indicating that the German nuclear weapons program had the highest level of support (pp. 3877–3879).

- One of Heinrich Himmler's closest diplomatic contacts, Grand Mufti Amin al-Husaini of Jerusalem, said Himmler had informed him in July 1943 that Germany was developing an atomic bomb (p. 4578).

- Himmler's political rival, Albert Speer, confirmed that Himmler was keenly interested in developing an atomic bomb during the war (p. 4593).

- Hans Ulrich Rudel, the most decorated German pilot of the war, reported that in March 1944 Hitler told him that (1) atomic bombs were at a highly advanced stage of development and (2) the bombs were intended to be delivered via V-type rockets (p. 4591).

- On 5 August 1944, Hitler informed the Romanian Prime Minister Ion Antonescu that Germany had developed and would use a V-series weapon with "such a tremendous effect that all human life would be destroyed within a radius of three to four kilometers from the impact point" (p. 4594).

- On 16 December 1944, Benito Mussolini stated that "thousands of German scientists are working day and night" to develop new weapons that would change the war, apparently in reference to information he received via Luigi Romersa (p. 4603).

- In 16 November 1944 and 9 February 1945 letters from FBI Director J. Edgar Hoover to Franklin Roosevelt's top advisor Harry Hopkins, Hoover reported that intercepted messages from Germany to German spies in the U.S. asked the spies about "the probable reaction of the people of the United States if Germany used the explosive power obtained through the splitting of the uranium atom," high-priority targets in the United States that Germany could bomb, and methods that U.S. laboratories used to avoid criticality accidents with large quantities of enriched uranium, suggesting that Germany possessed large quantities of enriched uranium (pp. 4604–4625).

- Widespread German reports from late 1944 through 1945 claimed that Germany was on the verge of deploying atomic bombs and missiles for them (p. 4627).

- On 14 February 1945, Hitler told one of his doctors: "In no time at all, I'm going to start using my Victory weapon and then the war will come to a glorious end. Some time ago we solved the problem of nuclear fission, and we have developed it so far that we can exploit the energy for armaments purposes. They won't know what hit them! It's the weapon of the future. With it Germany's future is assured" (p. 4634).

- Heinrich Himmler's physical therapist, Felix Kersten, wrote that in early March 1945, Himmler was very optimistic about the imminent success of an atomic bomb (p. 4470).

- Heinrich Himmler's personal astrologer, Wilhelm Wulff, confirmed that in mid-March 1945, Himmler was very optimistic about the imminent success of an atomic bomb (p. 4471).

- Henry Picker, a close confidant of Hitler, wrote that before the war ended, prototype fission bombs were completed and ready, and facilities for mass-producing the bombs had been built (pp. 4635–4639).

- In 2000–2002 interviews, Werner Grothmann described how an extensive program run by Heinrich Himmler developed, tested, and debated the deployment of atomic bombs (p. 4668).

- In a 1 April 1945 telegram to Allied leaders, Allen Dulles reported that Luftwaffe General Albert Kesselring mentioned deliberations among Hitler's top staff about whether to use a final secret weapon, referred to as the "desperation weapon," that would cause a "terrible blood bath" (p. 4670).

- In a September 1945 interrogation, the father of an SS officer told Americans about deliberations among Hitler's top staff over an atomic bomb in April 1945 (p. 4670).

- In Otto Hahn's autobiography, he wrote that he had heard from reliable sources that there were at least three completed atomic bombs at the end of the war (p. 4182). Lending additional credibility to Hahn's story, the bombs were said to be at Lüneburger Heide, which wartime Allied intelligence reports had identified as the site of what sounded like large underground uranium enrichment facilities producing fuel for spherical implosion bombs (Section 8.8.4). There were also other reports of nuclear-related work at Lüneburger Heide (pp. 4176–4181, 4406).

- Former SS officer Erwin Bartmann reported very similar information from his insider knowledge of conversations among Hitler, Göring, and others—there were specific mentions of "three special bombs" and even up to nine completed bombs by the end of the war (p. 4667).

- Shortly after the war, German rocket engineers Wernher von Braun and Walter Dornberger, as well as American officials who examined the German rocket program, reported that Germany planned to use its rockets to carry a "much more powerful explosive," presumably atomic bombs (p. 4681).

In the end, German leaders appear to have concluded that they did not have a sufficient number of nuclear weapons (and/or sufficiently reliable delivery vehicles) to strike enough Allied targets to change the ultimate outcome of the war. Moreover, Franklin Roosevelt and Winston Churchill had made it clear that if Germany used anything other than conventional weapons in the war, the Allies would respond by killing tens of millions of German civilians with crude but effective WWI-style chemical weapons (mustard agent and phosgene) or other means; see pp. 2632–2651. Individual German political or military leaders may have also feared even greater postwar prosecutions if they used nuclear weapons, or considered it more personally beneficial to try to trade German nuclear and other technologies to the Allies than to employ them against the Allies.]

Adolf Hitler. 19 September 1939. Speech in Danzig.
https://learninglink.oup.com/access/content/von-sivers-3e-dashboard- resources/ document-adolf-hitler-speech-in-danzig-after-the-invasion-of-poland- september-1939

[...] If peoples go to pieces it will not be the German people, who are fighting for justice, who have no war aims and who were attacked.

Rather, those peoples will break when they gradually find out what their misleaders plan, and gradually grasp for what little reason they are fighting, and that the only reasons for war are the profits or political interests of a very small clique. [...]

These gentlemen should take note of the following: Today you have the Germany of Frederick the Great before you. These gentlemen can believe this. The German people will not split up in this fight but become more unified. If anything splits up it will be those States that are not so homogeneous, those empires built on the oppression of peoples. We are fighting only for our naked beings. We are not able ourselves to be misled by propaganda.

Just imagine! There are people who say there are those ruling in another land who do not please us, so now we have war with them. Naturally they do not carry on the war themselves, but look about for someone to conduct it for them. They provide cannon and grenades while others provide grenadiers and soldiers. Such an utter lack of conscience!

What would be said if one of us should say that the present regime in France or Britain does not suit us and consequently we are conducting a war? What immeasurable lack of conscience. For that, millions of persons are whipped into death. These gentlemen can say that calmly, for they themselves never have been on the battlefield for even an hour.

But we will see how long they keep nations at war. There can be no doubt of one thing. however. We will take up the gauntlet and we will fight as the enemy fights. England, with lies and hypocrisy, already has begun to fight against women and children. They found a weapon which they think is invincible: namely, sea power. And because they cannot be attacked with this weapon they think they are justified in making war with it against women and children—not only of enemies but also of neutrals if necessary.

Let them make no mistake here, however. The moment could come very suddenly in which we could use a weapon with which we cannot be attacked. I hope then they do not suddenly begin to think of humaneness and of the impossibility of waging war against women and children. We Germans do not like that. It is not in our nature. In this campaign I gave an order to spare human beings. When columns cross a market-place it can occur that someone else becomes the victim of attack.

In those places where insane or crazy people did not offer resistance not one windowpane was broken. In Cracow, except for the air field, railroads and the railroad station, which were military objectives, not one bomb fell. On the other hand, in Warsaw the war is carried on by civilian shootings in all streets and houses. There, of course, the war will take in the whole city. We followed these rules and would like to follow them in the future. It is entirely up to England to carry out her blockade in a form compatible with international law or incompatible with international law. We will adapt ourselves thereto.

But there should be no doubt about one thing:

England's goal is not 'a fight against the regime' but a fight against the German people, women and children. Our reaction will be compatible, and one thing will be certain: This Germany does not capitulate. We know too well what fate would be in store for Germany. [...]

We are determined to carry on and stand this war one way or another. We have only this one wish, that the Almighty, who now has blessed our arms, will now perhaps make other peoples understand and give them comprehension of how useless this war, this debacles of peoples, will be intrinsically, and that He may perhaps cause reflection on the blessings of peace which they are sacrificing because a handful of fanatic warmongers, persons who stand to gain by war, want to involve peoples in war.

Raymond J. Batvinis. 2014. *Hoover's Secret War Against Axis Spies: FBI Counterespionage During World War II.*

[p. 156:] This priceless German smorgasbord included three dots filled with questions[...]

The next instruction raised terrifying concerns for the small group of scientists who would soon offer their recommendations to President Roosevelt regarding a decision to move forward on the atomic bomb:

> Decay Uran. According to some information obtained there is reason to believe that the scientific works for the utilization of the atoxic [*sic*]—kernel energy are being driven forward into a certain direction in the U.S. partly by use of helium. Continuous information about tests made on this subject are required particularly 1. What process is practiced in the U.S. for sending of heavy uran? 2. When are being made [*sic*] tests with more important quantities of uran? (Universities, industrial laboratories, etc.) 3. Which other raw-materials are being used at these tests? It is recommended to entrust only best experts with this test, and if not available, to abstain from it. [13 April 1942]

[...] The contents of these eleven microdots provided military analysts with a goldmine of insights into German intelligence gaps concerning U.S. readiness, capabilities, and strategic planning so soon after the Pearl Harbor attack.

[p. 187:] [Hans] Blum then raised another consideration, atomic research, ordering [Jorge] Mosquera to search out any information concerning "experiments performed in the United States relative to shattering of atoms." The German military was anxious to develop high explosives from atom sources that they believed would weigh no more than a pound to a pound and a half. In what was almost a premonition of the future five years hence, Blum speculated that the nation which "will be victor in this war will be the one which has accomplished the task of shattering the atoms and applying the results thereof." With training behind him and instructions in hand, Mosquera left Hamburg by train on June 15, 1941[...]

[The preceding information demonstrates that remarkably early in the war (spring 1941 to spring 1942):

- The German military knew that nuclear technology could create extremely powerful bombs (not just reactors).
- The German military was committed to developing nuclear weapons.
- The German military believed that whichever country was the first to perfect nuclear weapons would win the war.
- Germany was aware that the United States had also begun work on nuclear weapons.
- Germany was actively seeking as much information about the U.S. program as possible.
- Germany's awareness of the U.S. nuclear weapons program, combined with its belief that the first country to create such weapons would win the war, was a strong incentive for Germany to proceed as rapidly as possible with its own program.
- No later than spring 1941, German scientists believed that the critical mass of fission fuel required for a bomb could be less than one kilogram.
- That value for the critical mass appears to indicate that German scientists had a very good understanding of the relevant nuclear physics.
- That value for the critical mass also appears to show that German scientists intended to use an implosion bomb design with compression to achieve that critical mass. (A gun-type design without compression would require a far larger critical mass.)

[See also a similar version of this story in Bryden 2014, pp. 223–226.]]

Ulrich von Hassell. 2011. *The Ulrich von Hassell Diaries, 1938–1944: The Story of the Forces Against Hitler Inside Germany.* London: Frontline. p. 198

9 June 1943. [...]

In their pessimism people are clinging to the idea of 'a miracle weapon', a rocket gun which can reduce whole sections of a city to ashes from extreme distances at one blow—a terrible vision! a frightful prospect in view of the fact that this will not shorten the war with a satisfactory conclusion, but most probably lengthen it with increasing bitterness.

Heinrich Himmler's diplomatic contact, Muhammad Amin Al-Husayni, the Grand Mufti of Jerusalem. Translated and paraphrased in: Wolfgang G. Schwanitz. Review of Karlsch, Rainer; Petermann, Heiko, Für und Wider "Hitlers Bombe": Studien zur Atomforschung in Deutschland. *H-Soz-u-Kult, H-Net Reviews.* February 2009. https://www.h-net.org/reviews/showrev.php?id=24129

Am selben Tage (nach Widmung auf ihrem gemeinsamen Foto der 4. Juli 1943) habe Himmler ihm, neben einem Bericht über Panzer, eine Geheiminformation gegeben, die, wie er ihm sagte, nicht mehr als zehn Eingeweihte im Deutschen Reich kennen: den Bau einer Atombombe, die den Sieg garantiere. Dies trug seine Siegesgewissheit. Die Deutschen kamen, erläuterte Himmler dem Großmufti, in der Atomforschung voran. Die Atomwaffe werde die stärkste Waffe sein, die den Sieg garantiere." Wir haben erfahren, dass Engländer und Amerikaner auch begonnen haben, eine Atomwaffe zu erlangen. Jedoch sind wir ihnen um drei Jahre voraus. Wir werden die Atomwaffe wenigstens drei Jahre vor ihnen haben." Abd al-Karim Umar, *Muzakkirat al-Hagg Muhammad Amin al-Husaini* [*The Memoires of al-Hagg Muhammad Amin al-Husaini*], Damascus 1999, S. 127, 162f. Al-Husaini beschrieb in (alliiert abgefangenen) Briefen an den Araber Shakib Arslan 1944 "V-Waffen".

Nach 1945 meinte der Großmufti, dass die Feindspionage durch "jüdische, englische und amerikanische Geheimdienste" Deutschland "größten Schaden" zufügte. Sie konnten die Orte der "Atomreaktoren" in Ostpreußen entdecken. Ein Teil der Spione sei unter den 17 Millionen Fremdarbeitern gewesen. Sie hätten auch die geheimen Plätze in Peenemünde an der Ostsee in Ostdeutschland verraten, die die Alliierten dann zerstörten. Auch wären eine Anzahl deutscher Atomforscher getötet worden. So hätten die Alliierten verhindert, dass Deutschland eine Atombombe baute. Deutsche seien gezwungen gewesen, Betriebe auf eine Insel vor Dänemark mit unterirdischen Werken der Atomforschung zu verlagern. Abd al-Karim Umar, *Guerilla-Fidaiyun-Kommandos*, S. 145.

On the same day (after the dedication in the joint photo of 4 July 1943), Himmler had given him, besides a report on tanks, secret information which, as he told him, was known to only ten people in the German Reich: the construction of an atomic bomb guaranteeing victory. This bore its certainty. The Germans, Himmler explained to the Grand Mufti, were advanced in atomic research. The atomic weapon would be the strongest of all weapons, guaranteeing victory. "We have learned that the British and Americans have also begun to develop an atomic weapon, but we are three years ahead of them, and we will have the atomic weapon at least three years before them." Abd al-Karim Umar, *Muzakkirat al-Hagg Muhammad Amin al-Husaini* [*The Memoirs of al-Hagg Muhammad Amin al-Husaini*], Damascus 1999, p. 127, 162f. In 1944 Al-Husaini described "V-weapons" in (Allied intercepted) letters to the Arab Shakib Arslan.

After 1945 the Grand Mufti said that the enemy espionage by "Jewish, English and American intelligence services" caused "the greatest damage." They were able to discover the locations of "atomic reactors" in East Prussia. Some of the spies were among the 17 million foreign workers. They also betrayed the secret places in Peenemünde on the Baltic Sea in eastern Germany, which were then destroyed by the Allies. A number of German atomic researchers were also killed. Thus the Allies prevented Germany from building an atomic bomb. Germans had been forced to relocate operations to an island off the coast of Denmark with underground installations for atomic research. Abd al-Karim Umar, *Guerilla-Fidaiyun-Kommandos*, p. 145.

[The Grand Mufti provided numerous details that are very useful (if they are accurate):

- German intelligence was aware of the U.S. Manhattan Project.
- The goal of the German nuclear program was to develop a bomb as rapidly as possible, before the United States could.
- As of mid-1943, Heinrich Himmler (and hence the SS) was in charge of the German nuclear program.
- Security for the German nuclear program was highly compartmentalized—"only ten people" knew the whole truth about it.
- As of mid-1943, Himmler thought the German nuclear program was "three years ahead" of the U.S. program, so the German program was at least three years old and could have begun no later than mid-1940. Since Himmler knew that the U.S. program was already underway in 1943, that would push the origin of the German program back even earlier, likely to 1939 when war was declared.
- There were one or more fission reactors under construction (or operational?) in East Prussia (now northeastern Poland and western Russia). See also pp. 3929 and 4998.
- Allied intelligence was aware of the German nuclear program.
- Allied bombing and sabotage caused significant delays in the German nuclear program.
- Some nuclear work was being conducted at Peenemünde (or elsewhere on the Baltic coast).
- Some nuclear work was being conducted on the island of Bornholm.
- To avoid Allied bombing, some nuclear work was being conducted in underground installations.

The Mufti's account was not translated from Arabic until after Werner Grothmann had already died, yet all of these details are remarkably consistent with Grothmann's account of the German nuclear program and lend credibility to Grothmann as an historical source. Whether the details are accurate could still be debated, but both the Mufti and Grothmann were close associates of Heinrich Himmler and heard the same information from him.]

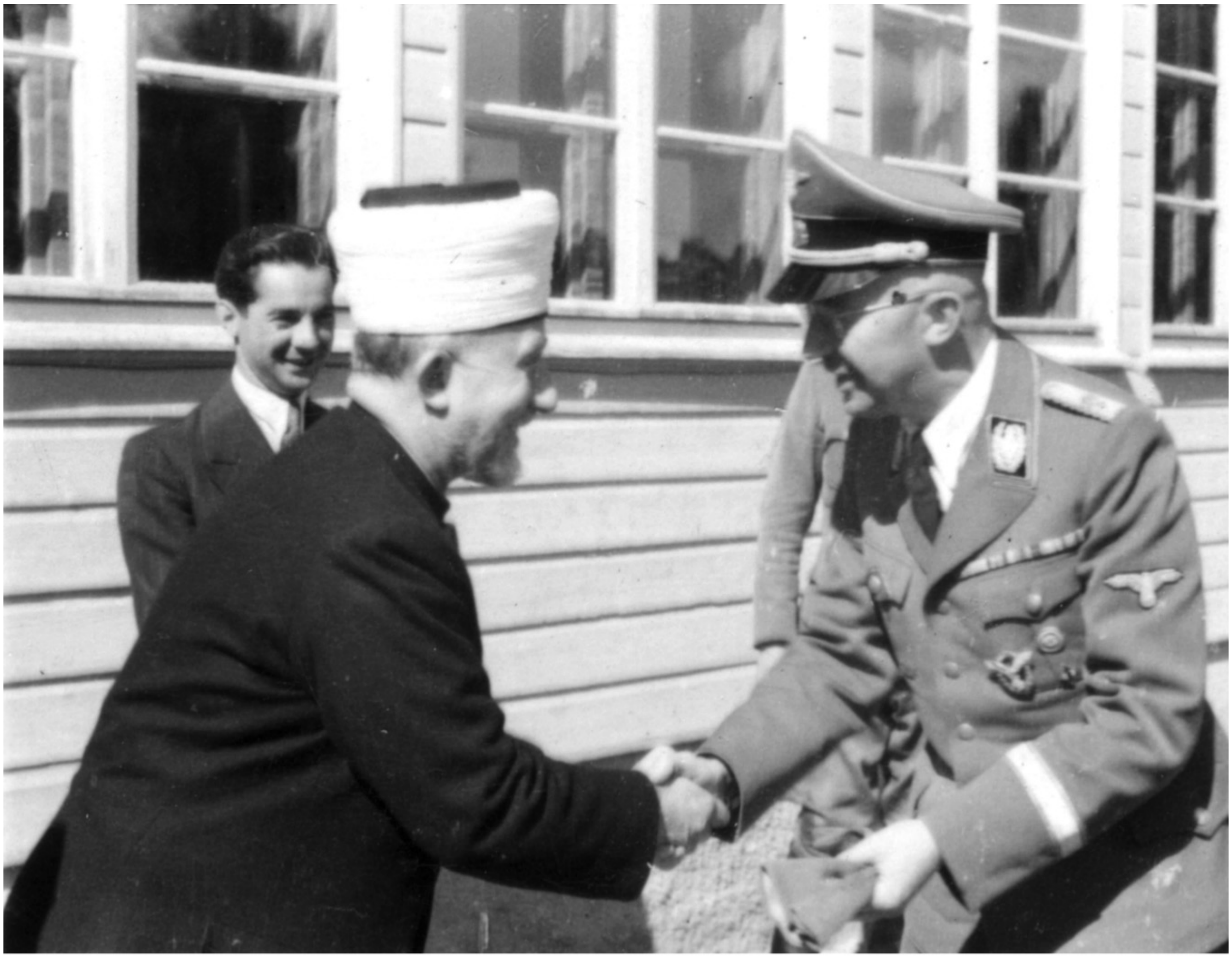
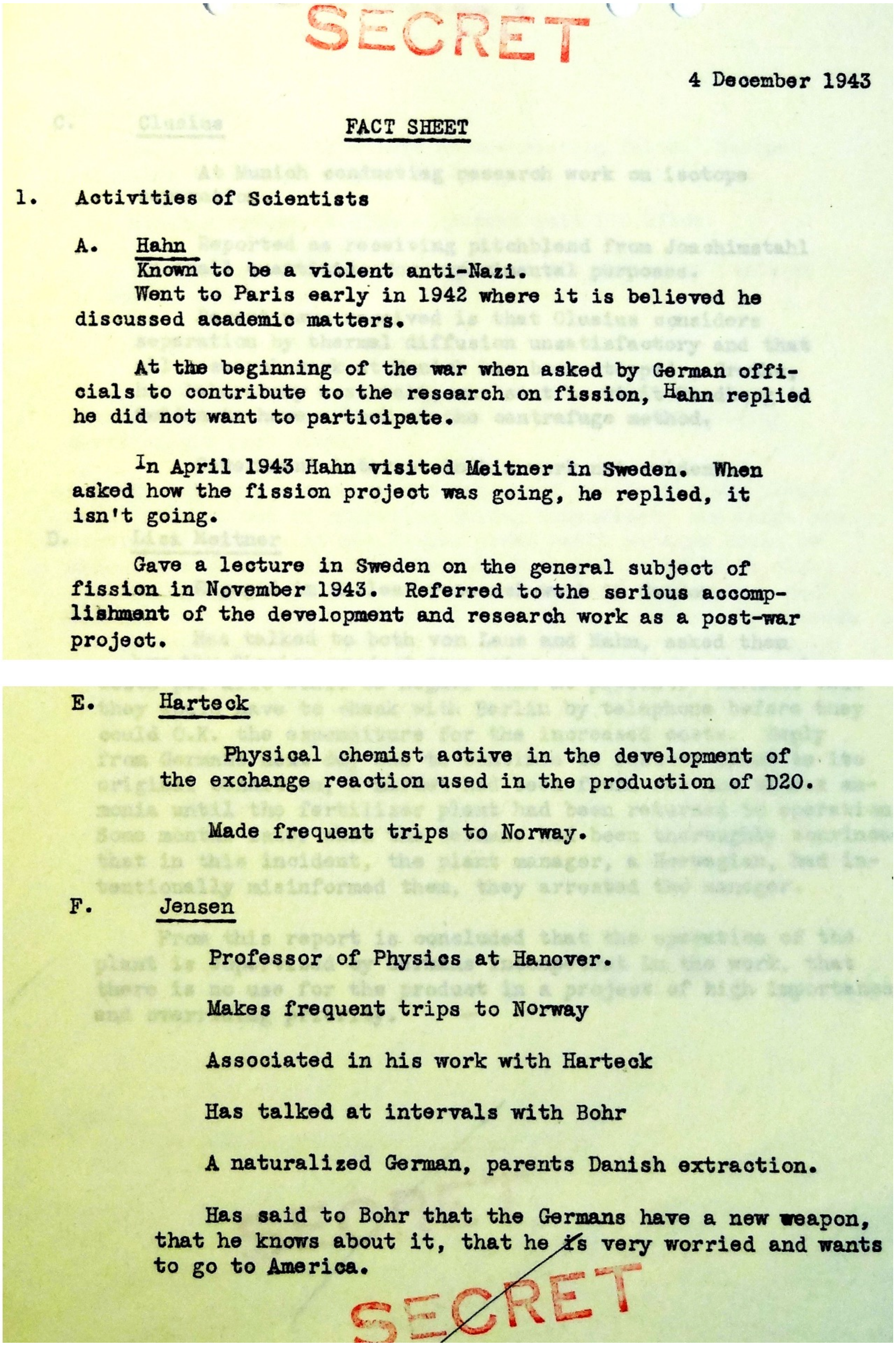


Figure D.743: Muhammad Amin Al-Husayni, the Grand Mufti of Jerusalem, meeting with Heinrich Himmler on 4 July 1943. See pp. 4578–4579.

NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)



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4 December 1943

FACT SHEET

1. Activities of Scientists

A. **Hahn**

Known to be a violent anti-Nazi.

Went to Paris early in 1942 where it is believed he discussed academic matters.

At the beginning of the war when asked by German officials to contribute to the research on fission, Hahn replied he did not want to participate.

In April 1943 Hahn visited Meitner in Sweden. When asked how the fission project was going, he replied, it isn't going.

Gave a lecture in Sweden on the general subject of fission in November 1943. Referred to the serious accomplishment of the development and research work as a post-war project.

E. **Harteck**

Physical chemist active in the development of the exchange reaction used in the production of D2O.

Made frequent trips to Norway.

F. **Jensen**

Professor of Physics at Hanover.

Makes frequent trips to Norway

Associated in his work with Harteck

Has talked at intervals with Bohr

A naturalized German, parents Danish extraction.

Has said to Bohr that the Germans have a new weapon, that he knows about it, that he is very worried and wants to go to America.

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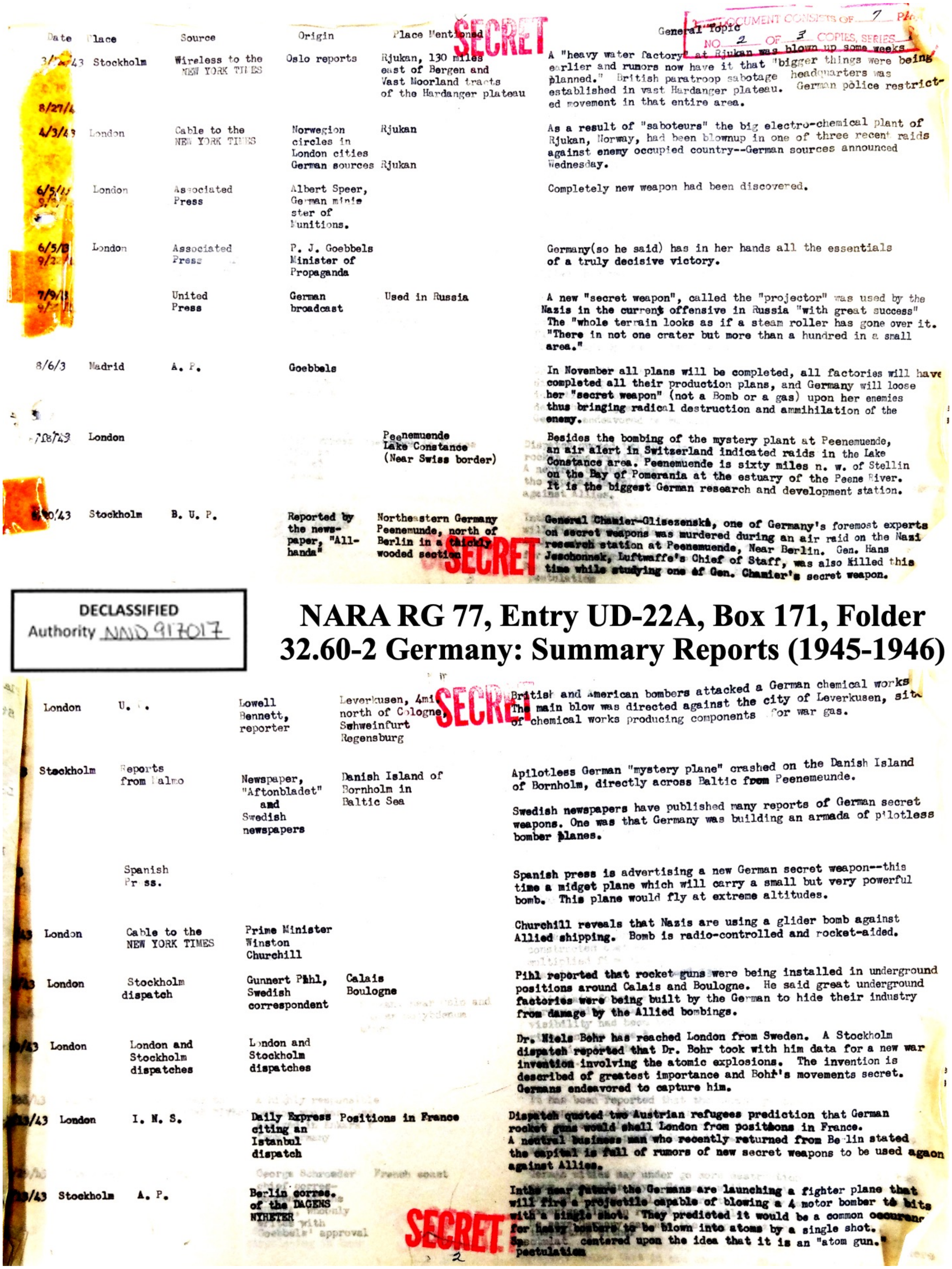
Figure D.744: In 1943, the German nuclear physicist Johannes Hans Jensen passed word via Niels Bohr to the United States “that the Germans have a new weapon, that he knows about it, that he is very worried and wants to go to America.” Fact Sheet. 4 December 1943 [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].



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Date	Place	Source	Origin	Place Mentioned	General Topic
3/[illegible]/43 8/27/4	Stockholm	Wireless to the NEW YORK TIMES	Oslo reports	Rjukan, 130 miles east of Bergen and Vast Moorland tracts of the Hardanger plateau	A "heavy water factory" at Rjukan was blown up some weeks earlier and rumors now have it that "bigger things were being planned." British paratroop sabotage headquarters was established in vast Hardanger plateau. German police restricted movement in that entire area.
4/3/43	London	Cable to the NEW YORK TIMES	Norwegion circles in London cities German sources	Rjukan Rjukan	As a result of "saboteurs" the big electro-chemical plant of Rjukan, Norway, had been blownup in one of three recent raids against enemy occupied country--German sources announced Wednesday.
6/5/4	London	Associated Press	Albert Speer, German minister of Munitions.		Completely new weapon had been discovered.
6/5/3 9/2	London	Associated Press	P. J. Goebbels Minister of Propaganda		Germany(so he said) has in her hands all the essentials of a truly decisive victory.
7/9/3		United Press	German broadcast	Used in Russia	A new "secret weapon", called the "projector" was used by the Nazis in the current offensive in Russia "with great success" The "whole terrain looks as if a steam roller has gone over it. "There in not one crater but more than a hundred in a small area."
8/6/3	Madrid	A. P.	Goebbels		In November all plans will be completed, all factories will have completed all their production plans, and Germany will loose her "secret weapon" (not a Bomb or a gas) upon her enemies thus bringing radical destruction and ammihilation of the enemy.
7/18/43	London			Peenemuende Lake Constance (Near Swiss border)	Besides the bombing of the mystery plant at Peenemuende, an air alert in Switzerland indicated raids in the Lake Constance area. Peenemuende is sixty miles n. w. of Stellin on the Bay of Pomerania at the estuary of the Peene River. It is the biggest German research and development station.
0/43	Stockholm	B. U. P.	Reported by the newspaper, "Allhanda"	Northeastern Germany Peenemunde, north of Berlin in a thickly wooded section	General Chamier-Glisezenski, one of Germany's foremost experts on secret weapons was murdered during an air raid on the Nazi research station at Peenemuende, Near Berlin. Gen. Hans Jeschonnek, Luftwaffe's Chief of Staff, was also killed this time while studying one of Gen. Chamier's secret weapon.

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NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945-1946)

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	London	U. [illegible].	Lowell Bennett, reporter	Leverkusen, 4mi. north of Cologne, Schweinfurt Regensburg	British and American bombers attacked a German chemical works The main blow was directed against the city of Leverkusen, site of chemical works producing components for war gas.
	Stockholm	Reports from Malmo	Newspaper, "Aftonbladet" amd Swedish newspapers	Danish Island of Bornholm in Baltic Sea	Apilotless German "mystery plane" crashed on the Danish Island of Bornholm, directly across Baltic from Peenemeunde. Swedish newspapers have published many reports of German secret weapons. One was that Germany was building an armada of pilotless bomber planes.
		Spanish Press.			Spanish press is advertising a new German secret weapon--this time a midget plane which will carry a small but very powerful bomb. This plane would fly at extreme altitudes.
43	London	Cable to the NEW YORK TIMES	Prime Minister Winston Churchill		Churchill reveals that Nazis are using a glider bomb against Allied shipping. Bomb is radio-controlled and rocket-aided.
/43	London	Stockholm dispatch	Gunnert Pihl, Swedish correspondent	Calais Boulogne	Pihl reported that rocket guns were being installed in underground positions around Calais and Boulogne. He said great underground factories were being built by the German to hide their industry from damage by the Allied bombings.
/43	London	London and Stockholm dispatches	London and Stockholm dispatches		Dr. Niels Bohr has reached London from Sweden. A Stockholm dispatch reported that Dr. Bohr took with him data for a new war invention involving the atomic explosions. The invention is described of greatest importance and Bohr's movements secret. Germans endeavored to capture him.
13/43	London	I. N. S.	Daily Express citing an Istanbul dispatch	Positions in France	Dispatch quoted two Austrian refugees prediction that German rocket guns would shell London from positions in France. A neutral business man who recently returned from Berlin stated the capital is full of rumors of new secret weapons to be used agaon against Allies.
3/43	Stockholm	A. P.	Berlin corres. of the DAGENS NYHETER		Inthe near future the Germans are launching a fighter plane that will fire a projectile capable of blowing a 4 motor bomber to bits with a single shot. They predicted it would be a common occurenc for heavy bombers to be blown into atoms by a single shot. Sp centered upon the idea that it is an "atom gun." pectulation

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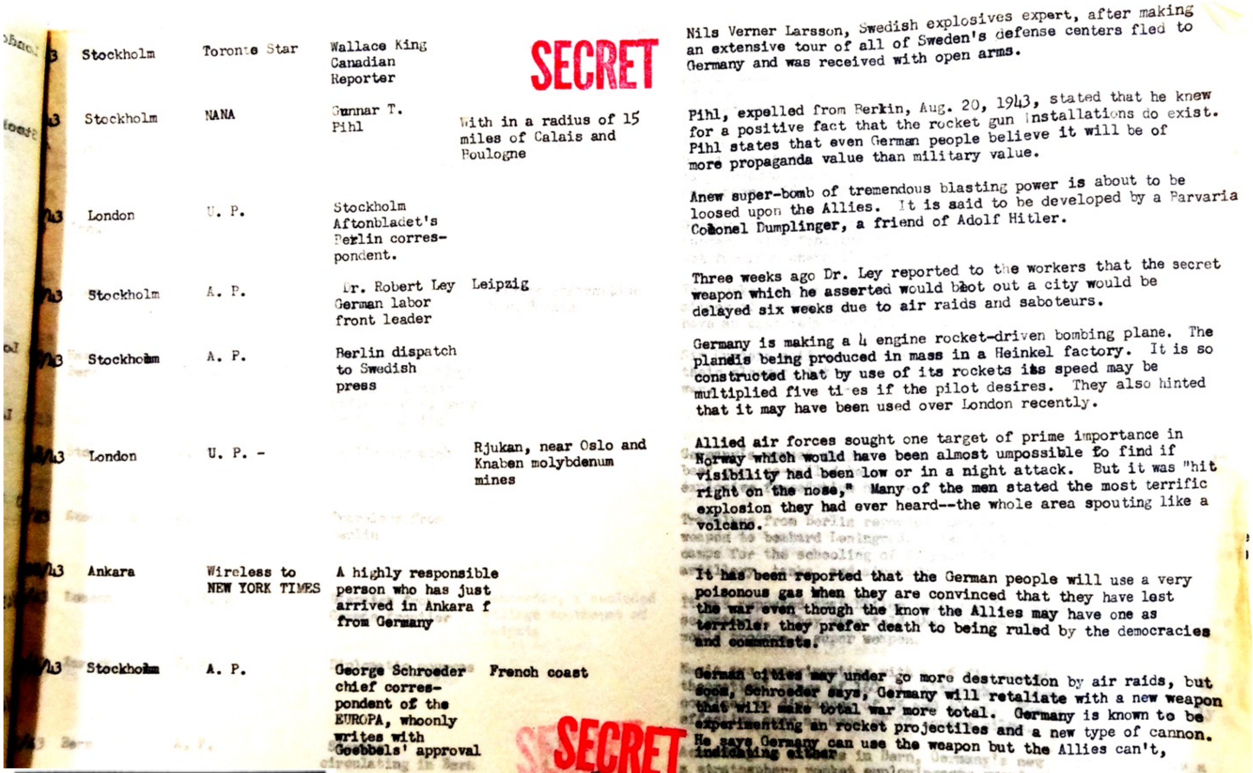
Figure D.745: During the war, especially in its later years, countless newspaper articles reported that Germany was developing an atomic bomb. The U.S. Manhattan Project's Foreign Intelligence Unit analyzed many of those articles [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



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3	Stockholm	Toronto Star	Wallace King Canadian Reporter		Nils Verner Larsson, Swedish explosives expert, after making an extensive tour of all of Sweden's defense centers fled to Germany and was received with open arms.
3	Stockholm	NANA	Gunnar T. Pihl	With in a radius of 15 miles of Calais and Boulogne	Pihl, expelled from Berkin, Aug. 20, 1943, stated that he knew for a positive fact that the rocket gun installations do exist. Pihl states that even German people believe it will be of more propaganda value than military value.
43	London	U. P.	Stockholm Aftonbladet's Berlin correspondent.		Anew super-bomb of tremendous blasting power is about to be loosed upon the Allies. It is said to be developed by a Parvaria Colonel Dumplinger, a friend of Adolf Hitler.
43	Stockholm	A. P.	Dr. Robert Ley German labor front leader	Leipzig	Three weeks ago Dr. Ley reported to the workers that the secret weapon which he asserted would blot out a city would be delayed six weeks due to air raids and saboteurs.
43	Stockholm	A. P.	Berlin dispatch to Swedish press		Germany is making a 4 engine rocket-driven bombing plane. The plandis being produced in mass in a Heinkel factory. It is so constructed that by use of its rockets its speed may be multiplied five times if the pilot desires. They also hinted that it may have been used over London recently.
/43	London	U. P. -		Rjukan, near Oslo and Knaben molybdenum mines	Allied air forces sought one target of prime importance in Norway which would have been almost umpossible fo find if visibility had been low or in a night attack. But it was "hit right on the nose," Many of the men stated the most terrific explosion they had ever heard--the whole area spouting like a volcano.
/43	Ankara	Wireless to NEW YORK TIMES	A highly responsible person who has just arrived in Ankara f from Germany		It has been reported that the German people will use a very poisonous gas when they are convinced that they have lest the war even though the know the Allies may have one as terrible: they prefer death to being ruled by the democracies and communists.
/43	Stockholm	A. P.	George Schroeder chief correspondent of the EUROPA, whoonly writes with Goebbels' approval	French coast	German cities may under go more destruction by air raids, but soon, Schroeder says, Germany will retaliate with a new weapon that will make total war more total. Germany is known to be experimenting an rocket projectiles and a new type of cannon. He says Germany can use the weapon but the Allies can't, indicating either

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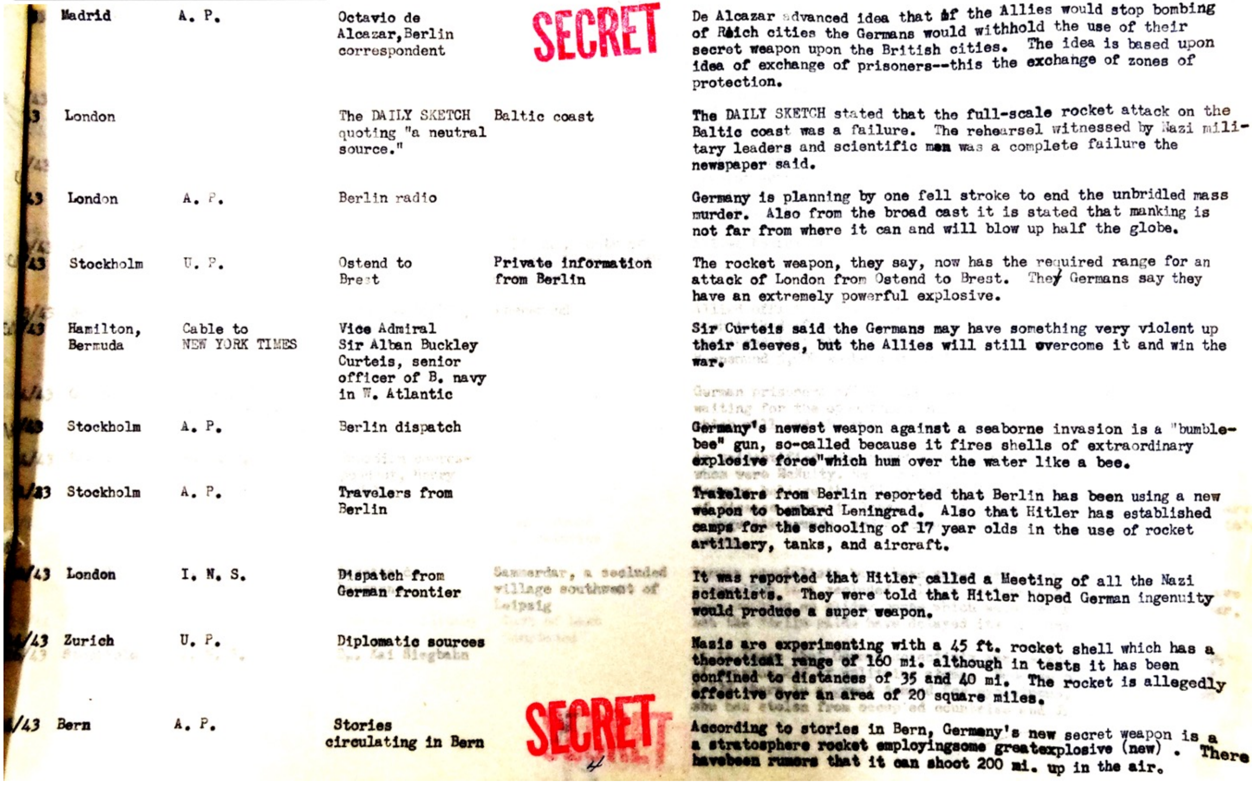
NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945-1946)



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	Madrid	A. P.	Octavio de Alcazar, Berlin correspondent		De Alcazar advanced idea that if the Allies would stop bombing of Reich cities the Germans would withhold the use of their secret weapon upon the British cities. The idea is based upon idea of exchange of prisoners--this the exchange of zones of protection.
3	London		The DAILY SKETCH quoting "a neutral source."	Baltic coast	The DAILY SKETCH stated that the full-scale rocket attack on the Baltic coast was a failure. The rehearsel witnessed by Nazi military leaders and scientific men was a complete failure the newspaper said.
43	London	A. P.	Berlin radio		Germany is planning by one fell stroke to end the unbridled mass murder. Also from the broad cast it is stated that manking is not far from where it can and will blow up half the globe.
/43	Stockholm	U. P.	Ostend to Brest	Private information from Berlin	The rocket weapon, they say, now has the required range for an attack of London from Ostend to Brest. The~~y~~ Germans say they have an extremely powerful explosive.
/43	Hamilton, Bermuda	Cable to NEW YORK TIMES	Vice Admiral Sir Alban Buckley Curteis, senior officer of B. navy in W. Atlantic		Sir Curteis said the Germans may have something very violent up their sleeves, but the Allies will still overcome it and win the war.
/43	Stockholm	A. P.	Berlin dispatch		Germany's newest weapon against a seaborne invasion is a "bumble-bee" gun, so-called because it fires shells of extraordinary explosive force"which hum over the water like a bee.
/43	Stockholm	A. P.	Travelers from Berlin		Travelers from Berlin reported that Berlin has been using a new weapon to bombard Leningrad. Also that Hitler has established camps for the schooling of 17 year olds in the use of rocket artillery, tanks, and aircraft.
/43	London	I. N. S.	Dispatch from German frontier		It was reported that Hitler called a Meeting of all the Nazi scientists. They were told that Hitler hoped German ingenuity would produce a super weapon.
/43	Zurich	U. P.	Diplomatic sources		Nazis are experimenting with a 45 ft. rocket shell which has a theoretical range of 160 mi. although in tests it has been confined to distances of 35 and 40 mi. The rocket is allegedly effective over an area of 20 square miles.
/43	Bern	A. P.	Stories circulating in Bern		According to stories in Bern, Germany's new secret weapon is a a stratosphere rocket employingsome greatexplosive (new) . There havebeen rumors that it can shoot 200 mi. up in the air.

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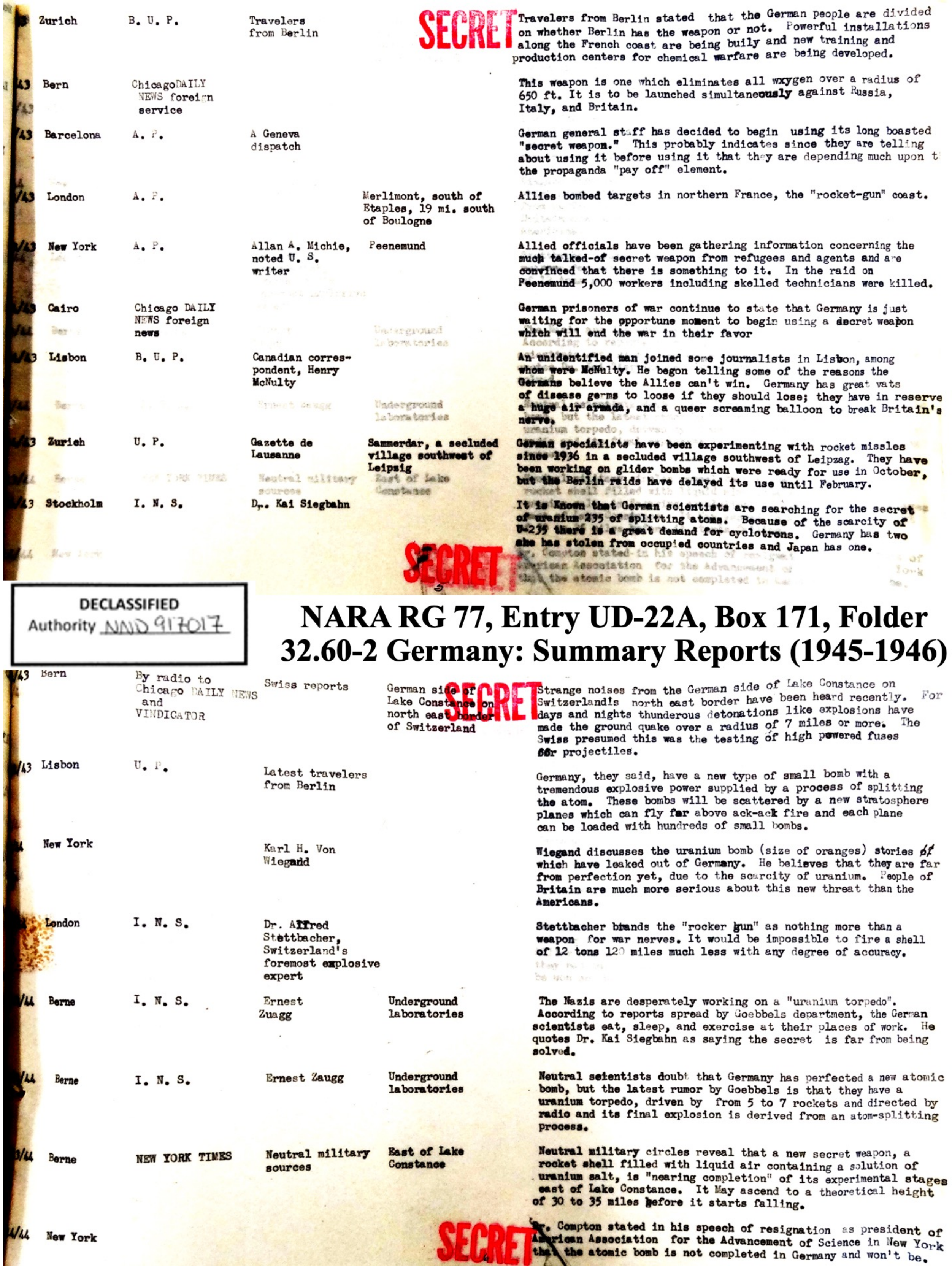
Figure D.746: During the war, especially in its later years, countless newspaper articles reported that Germany was developing an atomic bomb. The U.S. Manhattan Project's Foreign Intelligence Unit analyzed many of those articles [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



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	Zurich	B. U. P.	Travelers from Berlin		Travelers from Berlin stated that the German people are divided on whether Berlin has the weapon or not. Powerful installations along the French coast are being buily and new training and production centers for chemical warfare are being developed.
43	Bern	ChicagoDAILY NEWS foreign service			This weapon is one which eliminates all wxygen over a radius of 650 ft. It is to be launched simultaneously against Russia, Italy, and Britain.
/43	Barcelona	A. P.	A Geneva dispatch		German general staff has decided to begin using its long boasted "secret weapon." This probably indicates since they are telling about using it before using it that they are depending much upon t the propaganda "pay off" element.
/43	London	A. P.		Merlimont, south of Etaples, 19 mi. south of Boulogne	Allies bombed targets in northern France, the "rocket-gun" coast.
/43	New York	A. P.	Allan A. Michie, noted U. S. writer	Peenemund	Allied officials have been gathering information concerning the much talked-of secret weapon from refugees and agents and are convinced that there is something to it. In the raid on Peenemund 5,000 workers including skelled technicians were killed.
/43	Cairo	Chicago DAILY NEWS foreign news			German prisoners of war continue to state that Germany is just waiting for the opportune moment to begin using a secret weapon which will end the war in their favor
/43	Lisbon	B. U. P.	Canadian correspondent, Henry McNulty		An unidentified man joined some journalists in Lisbon, among whom were McNulty. He begon telling some of the reasons the Germans believe the Allies can't win. Germany has great vats of disease germs to loose if they should lose; they have in reserve a huge air armada, and a queer screaming balloon to break Britain's nerve.
/43	Zurich	U. P.	Gazette de Lausanne	Sammerdar, a secluded village southwest of Leipsig	German specialists have been experimenting with rocket missles since 1936 in a secluded village southwest of Leipzag. They have been working on glider bombs which were ready for use in October, but the Berlin raids have delayed its use until February.
3	Stockholm	I. N. S.	Dr. Kai Siegbahn		It is Known that German scientists are searching for the secret of uranium 235 of splitting atoms. Because of the scarcity of U-235 there is a great demand for cyclotrons. Germany has two she has stolen from occupied countries and Japan has one.

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NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945-1946)

/43	Bern	By radio to Chicago DAILY NEWS and VINDICATOR	Swiss reports	German side of Lake Constance on north east border of Switzerland	Strange noises from the German side of Lake Constance on Switzerland!s north east border have been heard recently. For days and nights thunderous detonations like explosions have made the ground quake over a radius of 7 miles or more. The Swiss presumed this was the testing of high powered fuses for projectiles.
/43	Lisbon	U. P.	Latest travelers from Berlin		Germany, they said, have a new type of small bomb with a tremendous explosive power supplied by a process of splitting the atom. These bombs will be scattered by a new stratosphere planes which can fly far above ack-ack fire and each plane can be loaded with hundreds of small bombs.
	New York		Karl H. Von Wiegand		Wiegand discusses the uranium bomb (size of oranges) stories of which have leaked out of Germany. He believes that they are far from perfection yet, due to the scarcity of uranium. People of Britain are much more serious about this new threat than the Americans.
	London	I. N. S.	Dr. Alfred Stettbacher, Switzerland's foremost explosive expert		Stettbacher brands the "rocker gun" as nothing more than a weapon for war nerves. It would be impossible to fire a shell of 12 tons 120 miles much less with any degree of accuracy.
/44	Berne	I. N. S.	Ernest Zuagg	Underground laboratories	The Nazis are desperately working on a "uranium torpedo". According to reports spread by Goebbels department, the German scientists eat, sleep, and exercise at their places of work. He quotes Dr. Kai Siegbahn as saying the secret is far from being solved.
/44	Berne	I. N. S.	Ernest Zaugg	Underground laboratories	Neutral seientists doubt that Germany has perfected a new atomic bomb, but the latest rumor by Goebbels is that they have a uranium torpedo, driven by from 5 to 7 rockets and directed by radio and its final explosion is derived from an atom-splitting process.
3/44	Berne	NEW YORK TIMES	Neutral military sources	East of Lake Constance	Neutral military circles reveal that a new secret weapon, a rocket shell filled with liquid air containing a solution of uranium salt, is "nearing completion" of its experimental stages east of Lake Constance. It May ascend to a theoretical height of 30 to 35 miles before it starts falling.
/44	New York				Dr. Compton stated in his speech of resignation as president of American Association for the Advancement of Science in New York that the atomic bomb is not completed in Germany and won't be.

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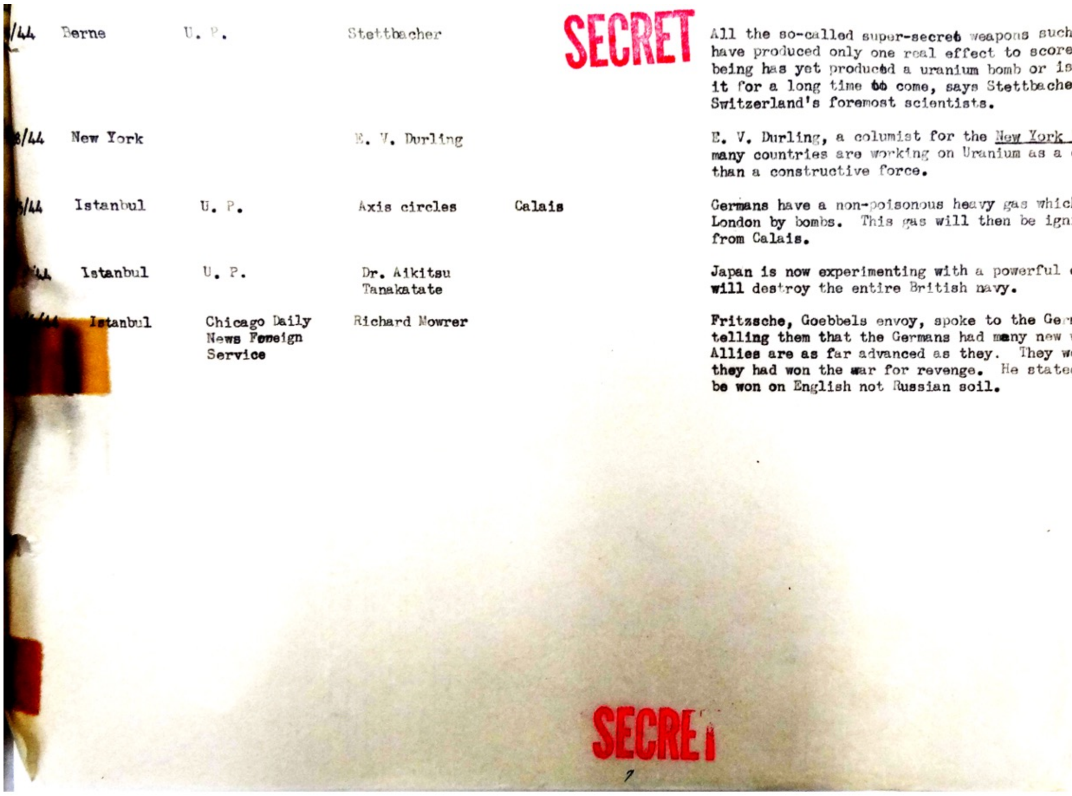
Figure D.747: During the war, especially in its later years, countless newspaper articles reported that Germany was developing an atomic bomb. The U.S. Manhattan Project's Foreign Intelligence Unit analyzed many of those articles [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



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/44	Berne	U. P.	Stetthacher		All the so-called super-secret weapons such as uranium bombs have produced only one real effect to score people . No human being has yet produced a uranium bomb or is capable of inventing it for a long time to come, says Stettbacher who is one of Switzerland's foremost scientists.
/44	New York		E. V. Durling		E. V. Durling, a columist for the New York Times, states that many countries are working on Uranium as a destructive rather than a constructive force.
/44	Istanbul	U. P.	Axis circles	Calais	Germans have a non-poisonous heavy gas which will be laid over London by bombs. This gas will then be ignited by shells fired from Calais.
/44	Istanbul	U. P.	Dr. Aikitsu Tanakatate		Japan is now experimenting with a powerful explosive which will destroy the entire British navy.
/44	Istanbul	Chicago Daily News Foreign Service	Richard Mowrer		Fritzsche, Goebbels envoy, spoke to the Germans in Istanbul telling them that the Germans had many new weapons, but that the Allies are as far advanced as they. They would have to wait until they had won the war for revenge. He stated that the war will be won on English not Russian soil.

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NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945-1946)

Figure D.748: During the war, especially in its later years, countless newspaper articles reported that Germany was developing an atomic bomb. The U.S. Manhattan Project's Foreign Intelligence Unit analyzed many of those articles [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Winston Churchill. 21 September 1943. Address to Parliament, *War Situation* Vol. 392 https://hansard.parliament.uk/Commons/1943-09-21/debates/1083c667-4ccd-40de-b6a1-e387f595fee8/WarSituation

We must not in any circumstances allow these favourable tendencies to weaken our efforts or lead us to suppose that our dangers are past or that the war is coming to an end. On the contrary, we must expect that the terrible foe we are smiting so heavily will make frenzied efforts to retaliate. The speeches of the German leaders, from Hitler downwards, contain mysterious allusions to new methods and new weapons which will presently be tried against us. It would, of course, be natural for the enemy to spread such rumours in order to encourage his own people, but there is probably more in it than that. For example we now have experience of a new type of aerial bomb which the enemy has begun to use in attacks on our shipping, when at close quarters with the coast. This bomb, which may be described as a sort of rocket-assisted glider, is released from a considerable height, and is then apparently guided towards its target by the parent aircraft. It may be that the Germans are developing other weapons on novel lines with which they may hope to do us damage and to compensate to some extent for the injury which they are daily receiving from us. I can only assure the House that unceasing vigilance and the most intense study of which we are capable are given to these possibilities. We have always hitherto found the answer to any of the problems which have been presented to us. At the same time I do not exclude, and no one must exclude from their minds, that novel forms of attack will be employed, and, should they be employed, I should be able to show to the House in detail the prolonged, careful examination beforehand which we have made into these possibilities, and I trust we shall be able to show the measures which will be brought into force against them.

Associated Press. Heavy 'Retaliation' Threatened by Nazis. [Alternate title in some editions of that day's newspaper: "Huge Reprisal Blow Threatened by Nazis."] *New York Times*, 4 December 1943, p. 1.

LONDON, Dec. 3—Again threatening retaliation for the air war upon Germany, the Berlin radio said today that the German High Command "intends by one fell, drastic stroke to end the unbridled mass murder," and added that "mankind is not far from the point where it can at will blow up half the globe."

The broadcast quoted the periodical Reich as saying that "the commencement of retaliation no longer depends on technical matters, but solely on the object which is to be attained by it."

"The retaliation," it continues, "will be so powerful and will be started at such a psychologically opportune moment as to influence the development of the war. It would be superfluous to retaliate for ruins with ruins. The sense of retaliation will find quite a different and surprising expression spiritually as well as politically."

[A clipping of this newspaper article is in the Franklin Delano Roosevelt Library in Hyde Park, New York [Small Collections, Box 1, Folder 3, ATOMIC BOMB FILE]. The fact that this article was singled out to be saved and placed in a presidential file labelled "ATOMIC BOMB FILE" demonstrates that President Roosevelt and other senior officials of the U.S. government clearly understood this article to be a reference to the German nuclear weapons program.

This same 3 December 1943 German announcement was analyzed in more detail in the following article from *Newsweek*.]

Can the Nazis 'Blow Up Half the Globe'? *Newsweek* Vol. 22, No. 24, 13 December 1943, p. 32.

The plane was flying so high that only a few people saw it. And when the bombs that it dropped struck it was doubtful if anyone in the city heard the explosion. For that explosion was so tremendous and all-inclusive that in a fraction of a second the entire community had been wiped from the face of the earth.

This is the sort of destruction that scientists and novelists have often envisioned as taking place in some future war. By and large, it has had little foundation in actuality. The possibilities of inventing new explosives out of known materials have been discounted as being so remote as almost to be out of the question. The only chance seemed to be in tapping some new and frightful source of energy—as in the favorite scientific fantasy in which the atom is broken up and a cupful of water made to generate enough power to drive a steamer across the Atlantic.

Now the Germans are claiming, although not in so many words, that they have developed some such phenomenal new instrument of destruction. It is, of course, part of the propaganda campaign promising retaliation for British and American air raids. For the moment, it is obviously intended to bolster the morale of a badly shaken people. And as such it has not been taken seriously by the Allied public. However, a number of peculiar circumstances coupled with this boast give it a deeply serious significance—so serious that perhaps the world should prepare for the last stage of the war to unleash a terror beyond present comprehension.

The first circumstance is that Allied leaders expect new forms of war to be developed and have said so. Churchill was most explicit. In the same speech in which he told of the Nazi rocket-glider-bomb (and effective but not decisive weapon), he warned: "It may be that the Germans are developing other weapons on novel lines with which they hope to do us damage." Then he underlined the importance of this otherwise rather uninformative statement by referring to the "prolonged, careful examination beforehand that we have given to these possibilities."

Another circumstance stems from the reported blowing up last spring of a German electrochemical plant at Rjukan in Norway. This plant was supposed to be manufacturing "heavy water," a substance extremely useful in atom cracking (NEWSWEEK, April 19). Still another was the RAF raid last August in which 1,730 tons of bombs were lavished on a German research laboratory in the woods at Peenemünde, north of Berlin.

The wording of the German propaganda lent weight to all this evidence. On Dec. 3, the Berlin radio quoted the German High Command as saying that "the retaliation will be so powerful and will be started at such a psychologically opportune moment as to influence the development of the war." The High Command also said that it "intends by one fell, drastic stroke to end the unbridled mass murder." A hint of the method was contained in the declaration that mankind is not far from the point where it can at will blow up half the globe."

These boasts did not sound like the ordinary propaganda line for two reasons. First, they came directly from the High Command, an unusual proceeding. Second, there was no qualification to these and similar earlier promises that the retaliation would surely come. The inference was strong that the weapon itself had been perfected—a Stockholm dispatch said flatly that it was a new high explosive—and that only the moment when the maximum effect could be secured was being awaited. Finally, Hitler himself in his beer-hall speech last November proclaimed that the next target would be Britain.

U.S. Military Attaché, U.S. Embassy in Istanbul. 8 December 1943. [AFHRA A1261 electronic version p. 31] [See document photo on p. 4589 top.]

Source: M/A Istanbul, Turkey, #8507, 8 December 1943.

Before Mr. Shimura left the office, informant asked him about the damage to Berlin. Mr. Shimura said damage was enormous and effect on morale serious but not to the point of a German collapse.

"However," remarked Mr. Shimura, "the raids will not continue much longer."

"How so?", asked informant.

"Because the Allies will soon receive ten times more than they have given. The Germans have a weapon in preparation which is more devastating than anything we have ever seen." Mr. Shimura laughed. "Yes", he said, "It is coming very, very soon."

U.S. Military Attaché, U.S. Embassy in Istanbul. 18 December 1943. [AFHRA A1261 electronic version p. 27] [See document photo on p. 4589 bottom.]

Source: M/A Istanbul, Turkey, #8609, 18 December 1943.

In the course of a violent argument with a Bulgarian officer, an engineer of the Todt organization revealed in Sofia that the Germans now possess a new type of incendiary far surpassing anything yet used in warfare. The engineer intimated that London would suffer a fate worse than that of Berlin or Hamburg in the near future.

The Japanese have been given technical details about some new German weapon, possibly this one.

[Organisation Todt, founded by Fritz Todt (German, 1891–1942), developed the autobahn and many other large government and military engineering projects before and during World War II. One would expect it to have played an important role in any German nuclear weapons program, just as the U.S. Army Corps of Engineers did in the Manhattan Project.

After Fritz Todt's death in early 1942 (officially an accidental plane crash, but quite likely an assassination by his political rivals or Allied agents), formal control of Organisation Todt was granted to Albert Speer. However, direct management of Organisation Todt was carried out by Todt's former deputy, Franz Xaver Dorsch (German, 1899–1986). It seems likely that the nuclear-related aspects of Organisation Todt were subsumed by the SS's nuclear program under Heinrich Himmler and Hans Kammler.

Since 1938, Germany had been operating and receiving shipments from a uranium mine at Buchovo (or Buhovo), a suburb of Sofia, Bulgaria [Hayes 2004, p. 235; https://ejatlas.org/conflict/life-after-the-uranium-mines-in-buhovo-bulgaria]. That would explain why an engineer from Organisation Todt with apparent knowledge of the German nuclear weapons program was in Sofia in 1943.

As of late 1943, the engineer seemed to believe that the German nuclear weapons program was very far along and would soon deliver a final product. That implies that the program had been running for several years, and it is consistent with conducting the first successful tests in 1944.

Although unsigned, the above two intelligence reports are likely from George Earle, a U.S. Naval Attaché who ran a very well connected spy ring in Turkey that gathered a great deal of valuable intelligence (p. 4701).]

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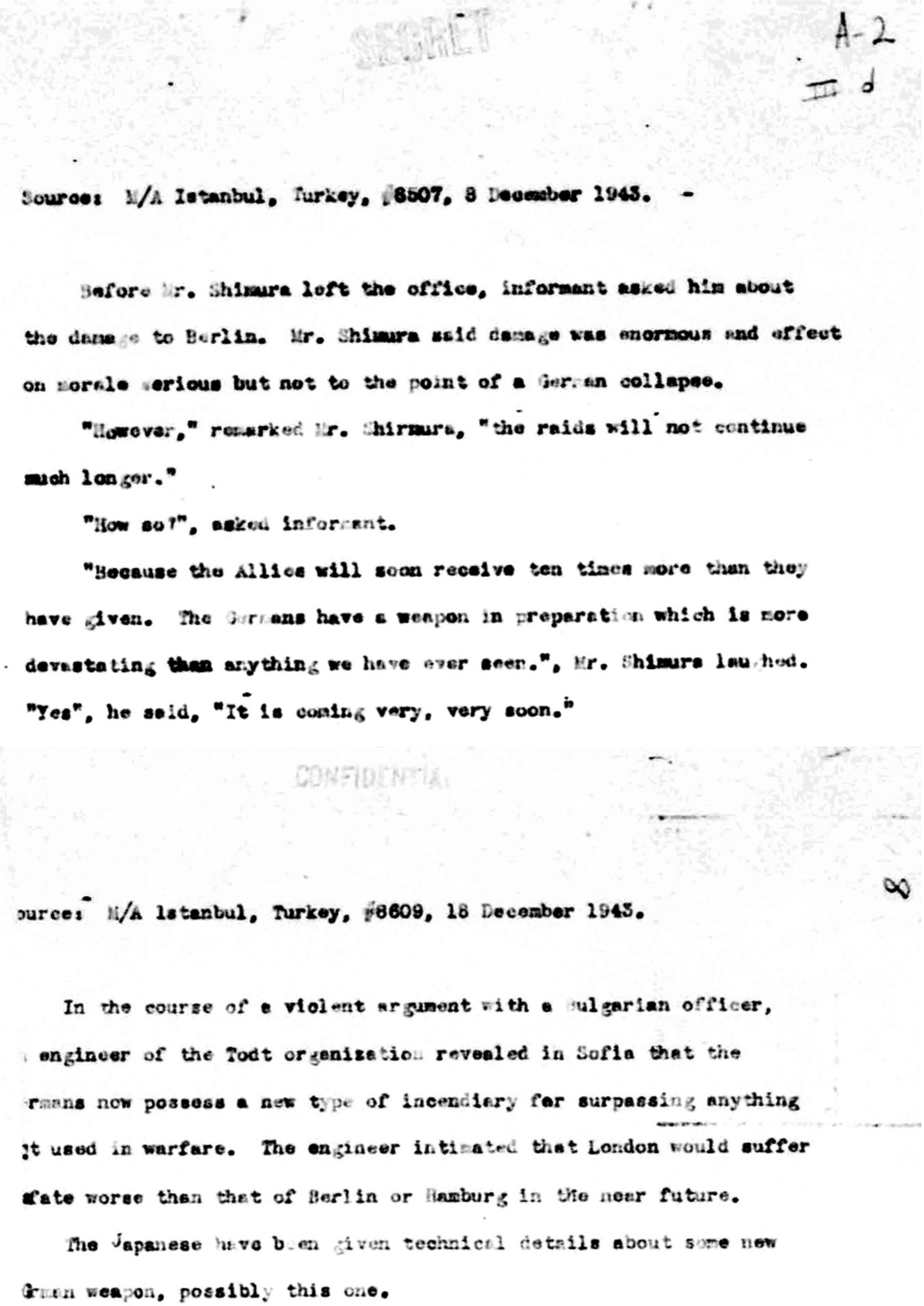
AFHRA A1260 electronic pp. 27, 31



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Source: M/A Istanbul, Turkey, #8507, 8 December 1943.

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Figure D.749: U.S. Military Attaché, U.S. Embassy in Istanbul. December 1943 [AFHRA A1261 electronic version pp. 31 (top) and 27 (bottom)].

Rocket Weapons. *New York Times*, 23 January 1944, p. 75.

Fantastic tales come out of neutral Switzerland and Sweden about Germany's secret rocket weapons. Jules Verne never gave us anything more hair-raising. The splitting of the uranium atom a few years ago, with the release of energy on a minute scale, evidently inspired the recent Swiss account of a German rocket shell which is loaded with liquid air and a solution of uranium salt. It sounds terrible after the vivid pictures that were drawn of uranium's possibilities in driving factory wheels and lighting cities. The truth is that almost any existing fuel will do for a rocket plane and any existing explosive for a rocket shell, bomb or torpedo.

Ordnance experts will probably raise a skeptical eyebrow at the devastation supposedly wrought by "uraniated" rocket shells. Buildings and vegetation are said to be destroyed with a radius of half a mile from the point of explosion. [...]

[Despite the newspaper's mixture of condescension and cluelessness, this article said that an unnamed Swiss source reported that Germany was developing a completely new type of bomb that used fission reactions, uranium, and liquid oxygen ("liquid air"), that had a blast radius of at least half a mile, and that could be delivered by a rocket. According to an intelligence report to Joseph Stalin, a German bomb exactly matching that description was successfully tested in March 1945 (p. 4485).]

Hans Ulrich Rudel. 1958. *Stuka Pilot.* New York: Ballantine Books. Ch. 13.

In March 1944 our southern front is on the defensive, fiercely contesting the efforts of strong Russian forces to effect a decisive southward breakthrough so as to liquidate the whole German front in the South. [...]

At noon the General summons me to Odessa by telephone. [...]

For two days I bask in the sun on the terrace of the Berchtesgadener Hotel, inhaling the glorious mountain air of home. Now gradually I relax. Two days later I stand in the presence of the Führer in the magnificent Berghof. [...]

Now at last I am glad and happily look forward to seeing the pleasure in the faces of my comrades when they hear that I am back.We have tea together and chat for an hour or two. New technical weapons, the strategic situation, and history are the staple of our conversation. He specially explains to me the V weapons which have recently been tried out. For the present, he says, it would be a mistake to overestimate their effectiveness because the accuracy of these weapons is still very small, adding that this is not so important, as he is now hopeful of producing flying rockets which will be absolutely infallible. Later on we should not rely as at present on the normal high explosives, but on something quite different which will be so powerful that once we begin to use them they should end the war decisively. He tells me that their development is already well advanced and that their final completion may be expected very soon. For me this is entirely virgin ground, and I cannot yet imagine it. Later I learn that the explosive effect of these new rockets is supposed to be based on atomic energy.

The impression left after every visit to the Führer is enduring.

[Rudel was the most decorated German pilot of World War II and was closely connected to Hitler and his inner circle. *Stuka Pilot* is an English translation of Rudel's memoir *Trotzdem*, which he wrote soon after the war. Thus he would have been an excellent source of information.

According to Rudel, in March 1944 Hitler said that (1) atomic bombs were at a highly advanced stage of development and (2) the bombs were intended to be delivered via V-type rockets. Both points are consistent with many other sources in this appendix.]

C.S.D.I.C. (U.K.) S. R. Report S.R.G.G. 932. 3 July 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)]

M 179—Generalleutnant (GOC 10th Pz. Division) Captured TUNISIA 12 May 43
CS/23(N)—Konteradmiral (Commandant, Sea Defence NORMANDY) Captured CHERBOURG 26 Jun 44

CS/23: [...] The things they told us: within a radius of 6 km—I told him 3 km would do—not a bird would remain alive, not a leaf would be left on the trees—one hit on an airfield and it would be destroyed. [...] Well, it is quite possible—they are always drivelling here about an atom bomb. With an atom bomb I can destroy the whole world.

Otto Hofmann. 22 June 1944 letter. [Bundesarchiv (Berlin Lichterfelde), Collection NS 19 (Persönlicher Stab Reichsführer SS), 317]

Reichsführer-SS [Himmler] hat bei seiner heutigen Anwesenheit wiederholt seiner Auffassung Ausdruck gegeben, daß überall, wo es nur einigermaßen angängig ist, empfindliche Rüstungsbetriebe oder zumindest die empfindlichsten Teile der Rüstungsbetriebe unterirdisch und bombensicher unterzubringen sind. Er hat kein Verständnis dafür, wenn ihm Betriebsführer erklären, daß es im Augenblick ja doch schon zu spät sei, mit entsprechenden Bauten zu beginnen. Die Dauer des Krieges sei noch nicht abzusehen, außerdem dürfte das nicht der letzte Krieg sein und zukünftige Kriege werden sicherlich nicht mehr durch lange Erklärungen eröffnet, auch nicht durch Anflüge von Luftflotten, die einigermaßen rechtzeitig erkannt werden können. Er ist der Meinung, daß durch die Fortschritte der Technik urplötzlich Sprengkörper auftauchen, deren Wirkungen und deren Schnelligkeit unsere neuesten Sprengmittel der Vergeltungswaffe in den Schatten stellen. [...]

In his presence today, the Reichsführer-SS [Himmler] has repeatedly expressed his view that, wherever there is only a moderate risk, sensitive armament plants, or at least the most sensitive parts of them, must be accommodated underground and bomb-proof. He has no sympathy for the fact that plant managers tell him that it is already too late at the moment to start building such facilities. The duration of the war could not yet be foreseen, it would also not be the last war and future wars would certainly not be opened by long explanations, not even by approaches of air fleets which could be recognized in time. He is of the opinion that with the progress of technology, explosives are suddenly emerging whose speed and effect overshadow the newest explosives of the retaliatory weapon. [...]

[As shown on the next page, Albert Speer later quoted part of the above 22 June 1944 announcement by Himmler and explained that Himmler was specifically referring to the development of an atomic bomb.]

Heinrich Himmler's political rival, Albert Speer. [Speer 1981, pp. 150–152]

A few months earlier, Himmler had been hot on the trail of new explosives. On June 22, 1944, he had announced "that with the progress of technology, explosives are suddenly emerging whose speed and effect overshadow the newest explosives of our retaliatory weapons." In my ministry, we had long since come to realize than an atomic bomb (that was the only thing he could have meant) could not be produced before the winter of 1945...

Himmler was reticent in the area of atomic research. Nevertheless, he rebuked me for neglecting it, precisely because of the consequences of nuclear fission. Himmler's letter is not extant. But my reply shows that I was forced to defend myself. On September 23, 1944, "in order to prevent misunderstandings," I informed Himmler of the following: "There can be no doubt that research must go on even in wartime, and indeed very intensively... Ultimately, however, the main issue in research is that projects advantageous to the war effort should be given preference..."

Ohlendorf [one of Himmler's deputies] interfered to a huge extent with atomic research in a letter of January 25, 1945. He accused me of neglecting a discipline that had been labeled "Jewish physics" for many years, and he rebuked me for not paying the necessary attention to atomic research...

As a precaution, I had already written to Professor Gerlach on December 19, 1944: "Because of urgent tasks, I am unable to come into personal contact with you and your work. However, I place extraordinary value on research in the field of nuclear physics and I am following your work with great expectations..."

All these orders and arrogance on the part of the SS and especially Himmler reduced our capacity for research and development and created uncertainty about the command channels and areas of responsibility.

[Speer confirmed that:

- Heinrich Himmler was strongly interested in developing nuclear weapons.
- Interest in the German nuclear program intensified further in 1944 (the Allies invaded Normandy on 6 June 1944, and there was an attempted assassination of Hitler on 20 July 1944).
- There was political rivalry for the control and direction of the German nuclear program.

This information is consistent with a number of other accounts of the German nuclear program in this appendix.]

Discussion between Adolf Hitler and Romanian Prime Minister Ion Antonescu on 5 August 1944. Reported in: Andreas Hillgruber, ed. 1970. *Staatsmänner und Diplomaten bei Hitler: Vertrauliche Aufzeichnungen über Unterredungen mit Vertretern des Auslandes 1942-1944.* Vol. 2. Frankfurt am Main: Bernard & Graefe. pp. 482–484.

In diesem Zusammenhang machte der Führer noch technische Ausführungen über weitere neue Sprengstoffe, deren Entwicklung bis zum Experimentierstadium durchgeführt sei. Er habe den Eindruck, daß der Sprung von den jetzt gebräuchlichen Explosivstoffen bis zu diesen neuartigen Sprengmaterialien größer sei, als der vom Schwarzpulver bis zu den bei Kriegsbeginn gebräuchlichen Sprengmaterialien gewesen wäre.

Als der Marschall darauf erwiderte, dass er hoffe, die Zeit der Anwendung dieser neuen Explosivstoffe, die vielleicht das Ende der Welt herbeiführen würden, nicht mehr zu erleben, erwähnte der Führer die von einem deutschen Schriftsteller vorausgesehenen weiteren Entwicklungsstufen auf diesem Gebiet, die bis zu einem Punkt führen würden, wo die Materie als solche sich auflöse und dann allerdings Katastrophen von ungeahnter Größe herbeiführen würde.

Bei dieser Forschungstätigkeit müsse man zwei Richtungen unterscheiden: einmal die militärische Auswertung bereits vervollkommneter und voll durchentwickelter Waffen und andererseits die wissenschaftlich vorbereitete, experimentell allmählich erprobte und langsam bis zur fabrikatorischen Massenherstellung durchgeführte Entwicklung neuartiger Stoffe.

Ganz allgemein gelte bei der Einführung neuer Waffen der Grundsatz, dass man sie nur dann unverzüglich zur Anwendung bringen könne, wenn man der felsenfesten Überzeugung sei, dass sie mit einem Schlage den Krieg beenden würden. In der Mehrzahl der Fälle bestehe jedoch die Gefahr, dass der Gegner sich nach Ablauf von zehn bis zwölf Monaten der gleichen Stoffe bedienen würde, so dass man solche Stoffe erst praktisch anwenden könne, wenn man selbst vorher ein Abwehrmittel entwickelt habe. [...]

In this context the Führer gave technical explanations about further new explosives, whose development had been brought to the experimental stage. He had the impression that the leap from the currently used explosives to these new explosive materials was greater than that from black powder to the explosive materials used at the beginning of the war.

When the Marshal replied that he hoped not to live to experience the time of the utilization of these new explosives, which would perhaps lead to the end of the world, the Führer mentioned the further development stages foreseen by a German writer in this field would lead to a point where matter as such would dissolve, and then disasters of unimagined size would be produced.

In these research activities, one had to distinguish two directions: on one hand the military utilization of already perfected and fully developed weapons, and on the other hand, the scientifically prepared, experimentally gradually tested and slowly developed creation of novel substances.

In general, the introduction of new weapons is based on the principle that they can only be applied without delay if one is firmly convinced that they will end the war in one stroke. In the majority of cases, however, there is a danger that the opponent would use the same substances after ten to twelve months, so that such substances can only be applied in practice if a defensive agent has already been developed. [...]

Dabei sei V1 nur eine von 4 Waffen, die Deutschland einsetzen würde. Eine andere dieser Waffen habe z.B. eine so gewaltige Wirkung, dass in einem Umkreis von 3–4 km von der Einschlagstelle alles menschliche Leben vernichtet würde.	V1 is only one of four weapons that Germany would use. Another of these weapons has for example such a tremendous effect that all human life would be destroyed within a radius of three to four kilometers from the impact point.

[During the war, uranium was being very actively mined in Romania for the German nuclear weapons program (pp. 3449–3455). Thus Hitler was telling Antonescu about some of the results of that work, and also trying to persuade him to continue the Romanian alliance with Germany. Antonescu was overthrown by pro-Soviet Romanians in late August 1944; subsequently, Romanian uranium was sent to what became the postwar Soviet nuclear weapons program.]

Figure D.750: Ion Antonescu and Adolf Hitler together in Munich on 10 June 1941.

Summary of information from OSS report. 5 August 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)]

5 August 1944

Summary of Information

The Germans have succeeded in isolating a small quantity of powder involving atomic separation from the element "iran" [Uran, uranium]. To do so the process has used heavy water. The product is considered of such explosive energy that the Germans have not yet dared to conduct experiments with it. Before using the secret weapon, V-2, which is not the atomic powder they want to be sure that the American experiments have not reached the point where the British and Americans could respond with a destructive weapon so powerful as they believe can be evolved from these experiments.

(OSS report)

Summary of information. August 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)]

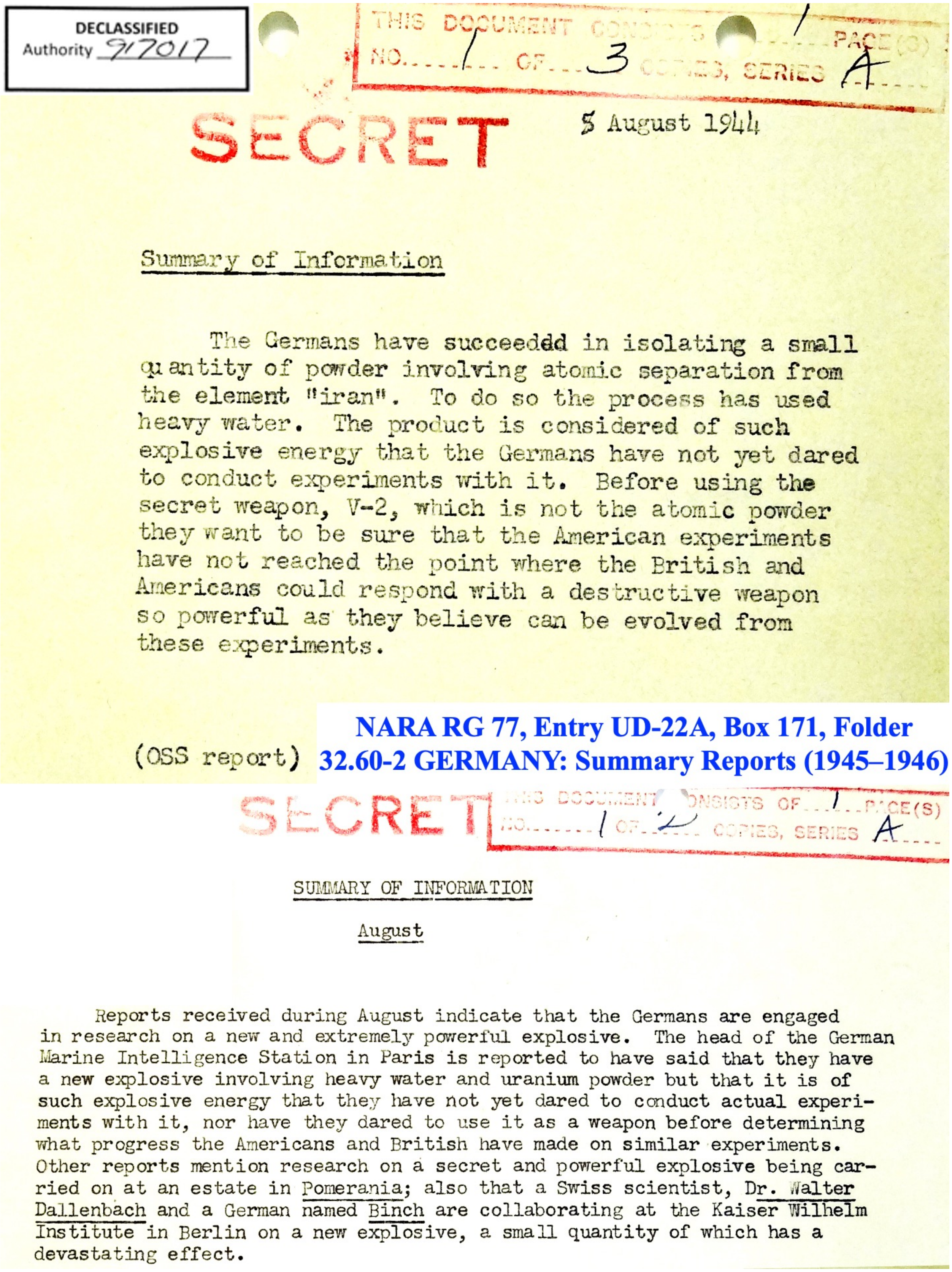
SUMMARY OF INFORMATION

August

Reports received during August indicate that the Germans are engaged in research on a new and extremely powerful explosive. The head of the German Marine Intelligence Station in Paris is reported to have said that they have a new explosive involving heavy water and uranium powder but that it is of such explosive energy that they have not yet dared to conduct actual experiments with it, nor have they dared to use it as a weapon before determining what progress the Americans and British have made on similar experiments. Other reports mention research on a secret and powerful explosive being carried on at an estate in Pomerania; also that a Swiss scientist, Dr. Walter Dallenbach and a German named Binch are collaborating at the Kaiser Wilhelm Institute in Berlin on a new explosive, a small quantity of which has a devastating effect. [...]

[See document photos on p. 4597. These two documents paraphrase an OSS report from July or very early August 1944. Where is that original OSS report?

The use of uranium and heavy water, as well as the mention of separation from uranium, all suggest that the "new and extremely powerful explosive" was plutonium-239. As of July/early August 1944, the Germans were very seriously contemplating testing a device using that new explosive but had not yet done so. Progress on that atomic bomb program was directly linked to progress on the rocket program, suggesting that rockets were intended to be the (or a) delivery vehicle for the atomic bomb. Germany was concerned that use of its atomic bomb could provoke an Allied response using similar (or other) weapons of mass destruction.]



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(OSS report)

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Figure D.751: Summary of information from OSS report. August 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)]

William L. Shirer. 27 August 1944 CBS radio broadcast [Shirer 1947, p. 4].

Berlin is trying to frighten us with tall talk about an atomic bomb. Scientists do say that the explosive force released by splitting the atom is more deadly than any hitherto discovered. But a scientist who knows a great deal about the atom—Theodore Svedberg, a Swede and Nobel prize-winner for his work with atoms—said last week: "Talk about the atom bomb is so much hooey."

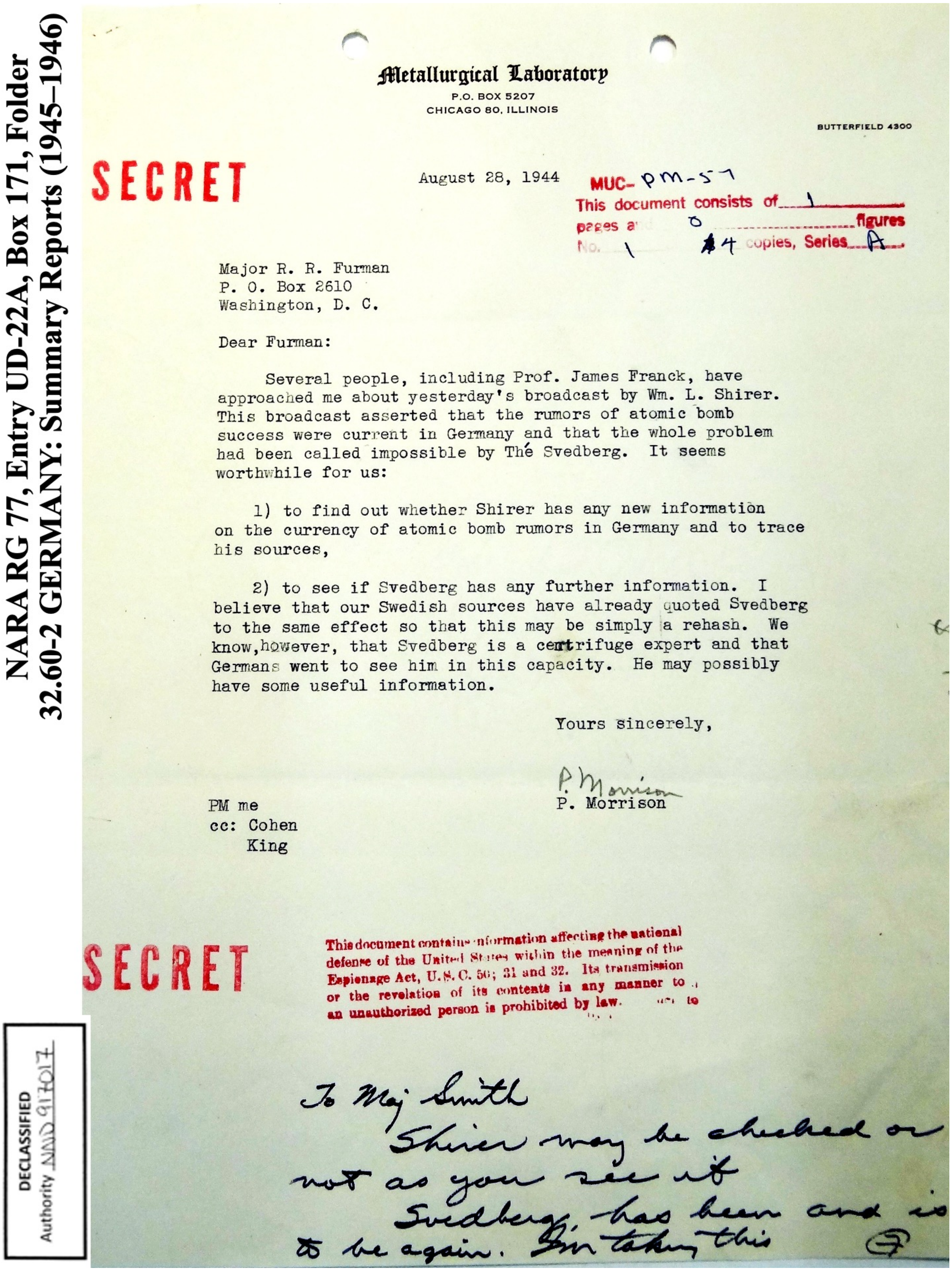
Philip Morrison to Robert R. Furman. 28 August 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)]

Several people, including Prof. James Franck, have approached me about yesterday's broadcast by Wm. L. Shirer. This broadcast asserted that the rumors of atomic bomb success were current in Germany and that the whole problem had been called impossible by Thé Svedberg. It seems worthwhile for us:

1) to find out whether Shirer has any new information on the currency of atomic bomb rumors in Germany and to trace his sources,

2) to see if Svedberg has any further information. I believe that our Swedish sources have already quote Svedberg to the same effect so that this may be simply a rehash. We know, however, that Svedberg is a centrifuge expert and that Germans went to see him in this capacity. He may possibly have some useful information.

[See document photo on p. 4599.]



NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)

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August 28, 1944

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Major R. R. Furman
P. O. Box 2610
Washington, D. C.

Dear Furman:

Several people, including Prof. James Franck, have approached me about yesterday's broadcast by Wm. L. Shirer. This broadcast asserted that the rumors of atomic bomb success were current in Germany and that the whole problem had been called impossible by The Svedberg. It seems worthwhile for us:

1) to find out whether Shirer has any new information on the currency of atomic bomb rumors in Germany and to trace his sources,

2) to see if Svedberg has any further information. I believe that our Swedish sources have already quoted Svedberg to the same effect so that this may be simply a rehash. We know, however, that Svedberg is a centrifuge expert and that Germans went to see him in this capacity. He may possibly have some useful information.

Yours sincerely,

P. Morrison
P. Morrison

PM me
cc: Cohen
King

SECRET

This document contains information affecting the national defense of the United States within the meaning of the Espionage Act, U.S.C. 50; 31 and 32. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

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To Maj Smith
Shirer may be checked or not as you see if Svedberg has been and is to be again. I'm taking this

Figure D.752: Philip Morrison to Robert R. Furman. 28 August 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)]

Bruno Spampanato. 1974. *Contromemoriale.* Rome: Centro Editoriale Nazionale. pp. 1115–1116.

Nel settembre del 1944 l'ambasciatore della R. S. a Berlino trasmetteva al sottosegretario agli Esteri, Mazzolini, un rapporto "segretissimo" circa le "armi nuove". L'ambasciatore aveva avuto le informazioni da un elemento sicuro: un italiano nato in Germania e da tempo investito di funzioni di responsabilità nel Consorzio Junker (costruzioni aeronautiche).

Questi furono i dati trasmessi dall'ambasciatore Anfuso:

a) "V-2".—Si tratta di un grosso proiettile avente un carico utile di dieci tonnellate. Questo proiettile viene lanciato verticalmente fino alla stratosfera nella quale può percorrere una distanza fino a settecento chilometri, andando poi a cadere sull'obbiettivo desiderato. L'esplosione di questo proiettile provoca la totale distruzione di fabbricati esistenti in un raggio di 1.500 metri.

b) "V-3".—Si tratta di un nuovo esplosivo molto potente, applicabile soprattutto per i proiettili della Contraerea; proiettili i quali, col solo spostamento d'aria, hanno il potere di distruggere gli aerei esistenti nel raggio di un chilometra.

c) "V-4".—Si tratta di un altro nuovo e speciale esplosivo il quale, venendo a contatto con l'aria, la dissocia nei suoi componenti, sottraendo poi l'ossigeno in essa contenuto.

"Trattandosi, come è evidente, di un mezzo di guerra chimica, i tedeschi dovrebbero prepararsi ad una reazione avversaria a mezzo di gas.

"Secondo le notizie pervenute, prima ad essere messa in azione, fra breve, sarebbe la "V-3", allo scopo di ridurre fortemente l'aviazione "alleata".

In September 1944 the R. S. ambassador in Berlin forwarded to the undersecretary for foreign affairs, Mazzolini, a "secret report" about the "new weapons." The ambassador had gotten the information from a sure element: an Italian born in Germany and long invested with responsible functions in the Junker Consortium (aircraft construction).

These were the data forwarded by Ambassador Anfuso:

a) "V-2".—This is a large projectile having a carrying capacity of ten tons. This projectile is launched vertically up to the stratosphere in which it can travel a distance of up to seven hundred kilometers, eventually falling on the desired target. The explosion of this projectile causes the total destruction of existing buildings within a radius of 1,500 meters.

b) "V-3".—This is a very powerful new explosive, applicable especially for antiaircraft projectiles; projectiles which, by the mere displacement of air, have the power to destroy existing aircraft within a one-kilometer radius.

c) "V-4".—This is another new and special explosive which, coming into contact with air, dissociates it into its components, then subtracting the oxygen it contains.

"Because it is, as is evident, a means of chemical warfare, the Germans should prepare for an adversary reaction by means of gas.

"According to the reports received, first to be put into action, shortly, would be the "V-3," for the purpose of greatly reducing the "allied air force."

“Subito dopo si darebbe inizio all’impiego della “V-4”, contro le truppe combattenti.

d)—Nei dintorni di Berlino sono stati osservati voli di apparecchi da caccia di nuovo tipo, a reazione, i quali salgono, a tempo di primato, a quote altissime e sono velocissimi”. [...]

In proposito, appena finita la il generale americano Lucius Clay, governatore militare “alleato” della Germania, dichiarò che era stato scoperto un laboratorio tra i monti della Baviera, presso Braunnenberg. Il generale rivelò che in quel laboratorio scienziati tedeschi avevano posto a punto i piani di costruzione di un proiettile razzo a reazione, noto come V-3, e che doveva essere impiegato contro Londra. La dichiarazione del generale Clay fu pubblicata anche in Italia nel giornale che il PWB pubblicava a Milano (“Giornale Lombardo”. 28-5-1945).

“Subsequently, the employment of the “V-4”, against the fighting troops, would begin soon afterwards.

“d)—Flights of fighter aircraft of a new type, jet-powered, have been observed in the vicinity of Berlin, which climb, in record time, to very high altitudes and are very fast.” [...]

In this regard, as soon as the American General Lucius Clay, the “allied” military governor of Germany, was finished, he declared that a laboratory had been discovered in the mountains of Bavaria, near Braunnenberg. The general revealed that in that laboratory German scientists had finalized plans for the construction of a jet rocket projectile, known as the V-3, and that it was to be employed against London. General Clay’s statement was also published in Italy in the newspaper that the PWB published in Milan (“Giornale Lombardo.” 28-5-1945). [...]

[Bruno Spampanato (1902–1960) was a journalist and politician who was a longtime supporter of Mussolini and very well connected with high-ranking Italian officials. After the war, he wrote a multivolume memoir that preserved information from a huge number of sources that otherwise might have been lost or forgotten.

Filippo Anfuso (1901–1963) served as a diplomat to various other countries for Mussolini’s government from the 1920s to 1945. He was the ambassador to Berlin 1943–1945 and would have been an excellent source of information.

The carrying capacity of the V-2 (A-4) was 10 tons total for propellant plus warhead. With wings (A-4b or A-9 configuration), it was expected to have a 700-km range. A blast radius of 1.5 km suggests that a nuclear warhead was planned, in agreement with numerous other sources (p. 5821).]

Division of Naval Intelligence. 15 June 1945. *German Technical Aid to Japan: A Survey.* ETO S(or N)-13960, 177647, p. 177. https://ww2aircraft.net/forum/threads/german-technical-aid-to-japan.20033/

ITEM: ATOM SMASHING

INTELLIGENCE: 1. In November 1944 PW heard from his Platoon Leader, a 1st Lt. Military Academy graduate, that some time during 1944 the Japs exchanged the blueprints of their V-12 diesel tank engine used in the Type 97 Med. Tanks (HAKE) for the formula of the German Atom Bomb. According to the officer, the bombs were match box size and had an effective radius of 1,000 meters. PW did not know if the bombs were being manufactured by the Japs, nor how they would be employed. They were not used in the Philippines.

2. The U-234 had uranium oxide aboard (destination Tokyo) at the time of its surrender. It is not known that this cargo was earmarked for research on the atom bomb, but its presence in quantity is of possible significance.

[The most scientifically consistent explanation is that "match box size" referred to the size of the fission pit or the quantity of fission fuel required for the bomb, and not the overall size of the complete bomb.]

PW Intelligence Bulletin No 1/49. 19 March 1945. [AFHRA A5185 frame 0841]

13. Radium and Liquid Air Torpedoes

PW was civilian technical expert on high tension electrical systems. He reported weekly at Base Construction Depot, 20 Goslerschestr, HILDESHEIM. He overheard a discussion, middle Jan, on the safest place to store radium and liquid air rocket propelled torpedoes. All the mine shafts in HILS GEBIRGE were required. The asphalt works at ESCHERHAUSEN was most often mentioned. It is known as GUSTAV ADOLPH STOLLEN (GSGS 4416/14/361710)

(Source: Martin BINDERNAGEL, arrested ÖRDINGEN? 5 March)

[See document photo on p. 552. The wording of this report is unclear yet intriguing. Were there two separate types of valuable items to be stored: a radium stockpile (e.g., for glow-in-the-dark paints on instrument dials) and liquid air torpedoes (weapons using liquid oxygen as oxidizer for part of the propellant or part of the explosive)? Or were these weapons that used both "radium" (likely not meaning actually radium, but rather a radioactive material more generally—perhaps enriched uranium) and liquid oxygen to help implode that radioactive material?]

Benito Mussolini. 16 December 1944 speech in Milan Opera House. Variously known as the "Discorso della Riscossa" ("Speech of Revenge" or "Counterattack Speech"), "Ultimo discorso di Mussolini" ("Last Speech of Mussolini"), or "Discorso di Milano al Teatro Lirico" ("Speech at the Milan Opera House").
http://www.mussolinibenito.net/lultimo-discorso-del-dvce-dal-teatro-lirico-di-milano/

Nel periodo di tale euforia venivano svalutate e dileggiate le nuove armi tedesche, impropriamente chiamate "segrete." Molti hanno creduto che grazie all'impiego di tali armi, a un certo punto, premendo un bottone, la guerra sarebbe finita di colpo. Questo miracolismo è ingenuo quando non sia doloso. Non si tratta di armi segrete, ma di "armi nuove," che, è lapalissiano il dirlo, sono segrete sino a quando non vengono impiegate in combattimento. Che tali armi esistano, lo sanno per amara constatazione gli inglesi; che le prime saranno seguite da altre, lo posso con cognizione di causa affermare che esse siano tali da ristabilire l'equilibrio e successivamente la ripresa della iniziativa in mani germaniche, è nel limite delle umane previsioni quasi sicuro e anche non lontano.

Niente di più comprensibile delle impazienze, dopo cinque anni di guerra, ma si tratta di ordigni nei quali scienza, tecnica, esperienza, addestramento di singoli e di reparti devono procedere di conserva. Certo è che la serie delle sorprese non è finita; e che migliaia di scienziati germanici lavorano giorno e notte per aumentare il potenziale bellico della Germania.

In the period of this euphoria, the new German weapons, incorrectly called "secret," were written down and ridiculed. Others believed that through the use of such weapons, at some point, by pressing a button, the war would end abruptly. This concept is naive or even shows bad faith. There are no secret weapons, but "new weapons," and it is obvious but has to be said, that they are secret until they have been used in combat for the first time. The bitter experiences of the English people have shown them that these weapons exist indeed, and I can affirm with full knowledge of the facts that the first types will be followed by others. That they will be able to reestablish the balance and then put the initiative back into German hands, is something as sure as it can be within the limits of human foresight, and is not far off in the future.

After five years of war it is easy to understand the impatience, but these are weapons in which science, technology, experience, training of individuals and departments must proceed in tandem. What is certain is that the succession of surprises is not over; and that thousands of German scientists are working day and night to increase the war potential of Germany.

Letter from J. Edgar Hoover to Harry Hopkins. 16 November 1944. Franklin Delano Roosevelt Library, Hyde Park, New York. Small Collections, Box 1, Folder 3, ATOMIC BOMB FILE.

A German espionage agent presently in the United States under the control of this Bureau advised that he was instructed to obtain, among other subjects, information concerning (1) the progress made by the United States since 1941 with respect to the development of atomic explosives, (2) whether "heavy water" is used instead of helium in their manufacture, (3) the type of container in which the atom of uranium is split, and (4) the probable reaction of the people of the United States if Germany used the explosive power obtained through the splitting of the uranium atom.

This information is being made available to you as possibly indicating the degree to which the Germans have progressed in the development of atomic explosives. There are two other recent developments of possible interest in this connection. The first of these is that the Germans have recently made numerous inquiries of other espionage agents controlled by this Bureau concerning the exact size, number of employees, and location of various armament plants in the United States. For example, the following inquiry was received from Germany by a double agent controlled by this Bureau:

> "OF GREAT INTEREST IS SIZE, FLOOR AREA, TOTAL EMPLOYEES OF BELL, BOEING, BREWSTER, BRIGGS, BUDD, CHRYSLER, CONSOLIDATED VULTEE, CURTISS WRIGHT AIRPLANE DIVISION, DOUGLAS, EASTERN, FISHER BODY, FORD, GOODYEAR, GRUMMAN, HIGGINS, HUDSON, KAISER FACTORIES. CONTINUATION FOLLOWS."

The continuation of the above message has not as yet been received.

The second recent development of interest is the receipt of an inquiry from the Germans through a controlled double agent channel indicating that the Germans are desirous of determining the extent of off-shore coastal protection on the Atlantic seaboard of the United States and particularly as to any areas where this protection may have been curtailed.

[The first four questions suggest that Germany had or expected to soon have an atomic bomb that it could use, and wanted to know how the United States would react and whether the United States could retaliate with an atomic bomb of its own.

The questions about armament plants suggest that Germany was compiling a large list of U.S. targets to bomb in the near future, which in turn implies that Germany had or expected to soon have methods of delivering an atomic bomb or a large amount of conventional bombs to those targets via long-range bombers, long-range rockets, or submarine-launched rockets.

The final questions seem to confirm German capability for submarine-launched rockets.]

Letter from J. Edgar Hoover to Harry Hopkins. 8 December 1944. [Franklin Delano Roosevelt Library, Hyde Park, New York. Official File 10b. Box 20. Folder OF 10-b, Justice Department, FBI Reports 1944–45. 2597–2618]

As of possible interest to the President and you, information has been received from a confidential source in South America, but not confirmed by investigation, to the effect that the German Government recently sent an emissary via Spain to Argentina. This emissary contacted the heads of various German firms in Argentina and advised them to "hold the line and make no changes," because Germany has not lost the war. This German emissary is alleged to have stated that the German Army will hold out until February, 1945, when a new secret weapon with a very long range will be used. This weapon fires a projectile which on explosion will destroy an area of forty square kilometers around the point of impact.

Information has also been received that a known German agent in Latin America has recently stated that he has information that Germany will soon utilize a new explosive which will kill everyone within an area of five miles. This German agent has advised other Germans that Germany will win the war due to the use of this new explosive.

[The very large expected areas of destruction described in Hoover's 8 December 1944 letter seem to indicate an explosive yield of at least several hundred kilotons, which would suggest that the weapon was some sort of fusion-boosted fission bomb or hydrogen bomb (Section D.9), instead of a much simpler and smaller fission bomb. It was described as being delivered by a rocket (projectile) with a very long range, even by the standards of the A-4 (V-2) rocket. That strongly suggests that the intended delivery vehicle was an intercontinental rocket such as the A-9/A-10, Silbervogel, V-101, or another large rocket (Appendix E).]

OSS Report No. B-624. 20 November 1944. Secret Weapons. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)] [See document photos on p. 4607.]

Report No. B-624

Report from Switzerland

OSS PARIS

Distribution		
WASH	Information Date:	As noted
LONDON	Report Date:	5 November 1944
	Dissemination Date:	20 November 1944
	Value:	C-3
	Source:	OSS

GERMANY: MILITARY/AIR

Secret Weapons

The source, a highly placed and sober-minded neutral industrialist, reports the following conversation with a prominent German in mid-October 1944.

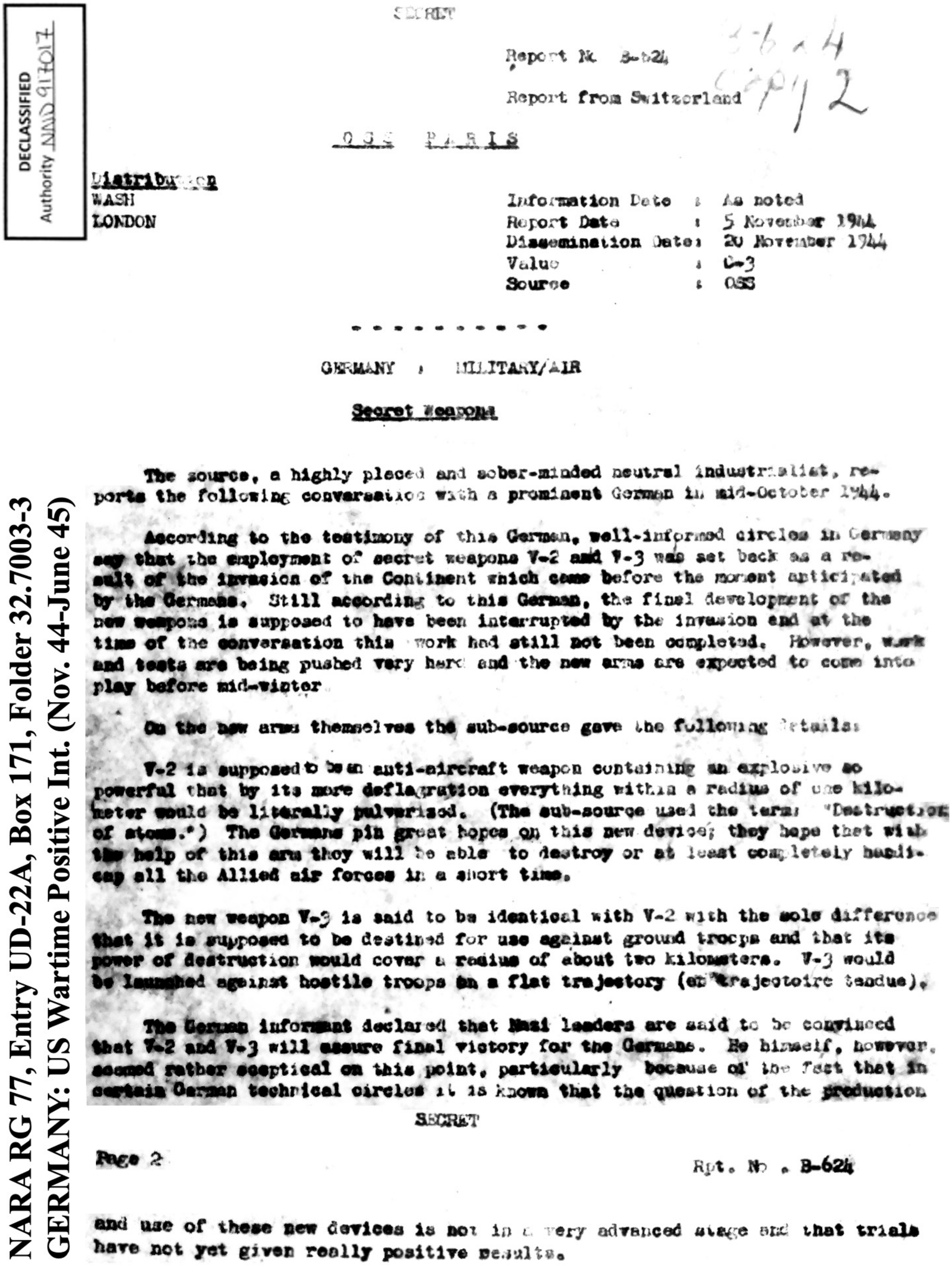
According to the testimony of this German, well-informed circles in Germany say that the employment of secret weapons V-2 and V-3 was set back as a result of the invasion of the Continent which came before the moment anticipated by the Germans. Still according to this German, the final development of the new weapons is supposed to have been interrupted by the invasion and at the time of the conversation this work had still not been completed. However, work and tests are being pushed very hard and the new arms are expected to come into play before mid-winter.

On the new arms themselves the sub-source gave the following details:

V-2 is supposed to be an anti-aircraft weapon containing an explosive so powerful that by its mere deflagration everything within a radius of one kilometer would be literally pulverized. (The sub-source used the term: “Destruction of atoms.”) The Germans pin great hopes on this new device; they hope that with the help of this arm they will be able to destroy or at least completely handicap all the Allied air forces in a short time.

The new weapon V-3 is said to be identical with V-2 with the sole difference that it is supposed to be destined for use against ground troops and that its power of destruction would cover a radius of about two kilometers. V-3 would be launched against hostile troops on a flat trajectory (en trajectoire tendus).

The German informant declared that Nazi leaders are said to be convinced that V-2 and V-3 will assure final victory for the Germans. He himself, however, seemed rather skeptical on this point, particularly because of the fact that in certain German technical circles it is known that the question of the production and use of these new devices is not in a very advanced stage and that trials have not yet given really positive results.



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Report No. B-624

Report from Switzerland

B-624
Copy 2

OSS PARIS

Distribution
WASH
LONDON

Information Date : As noted
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Page 2

Rpt. No. B-624

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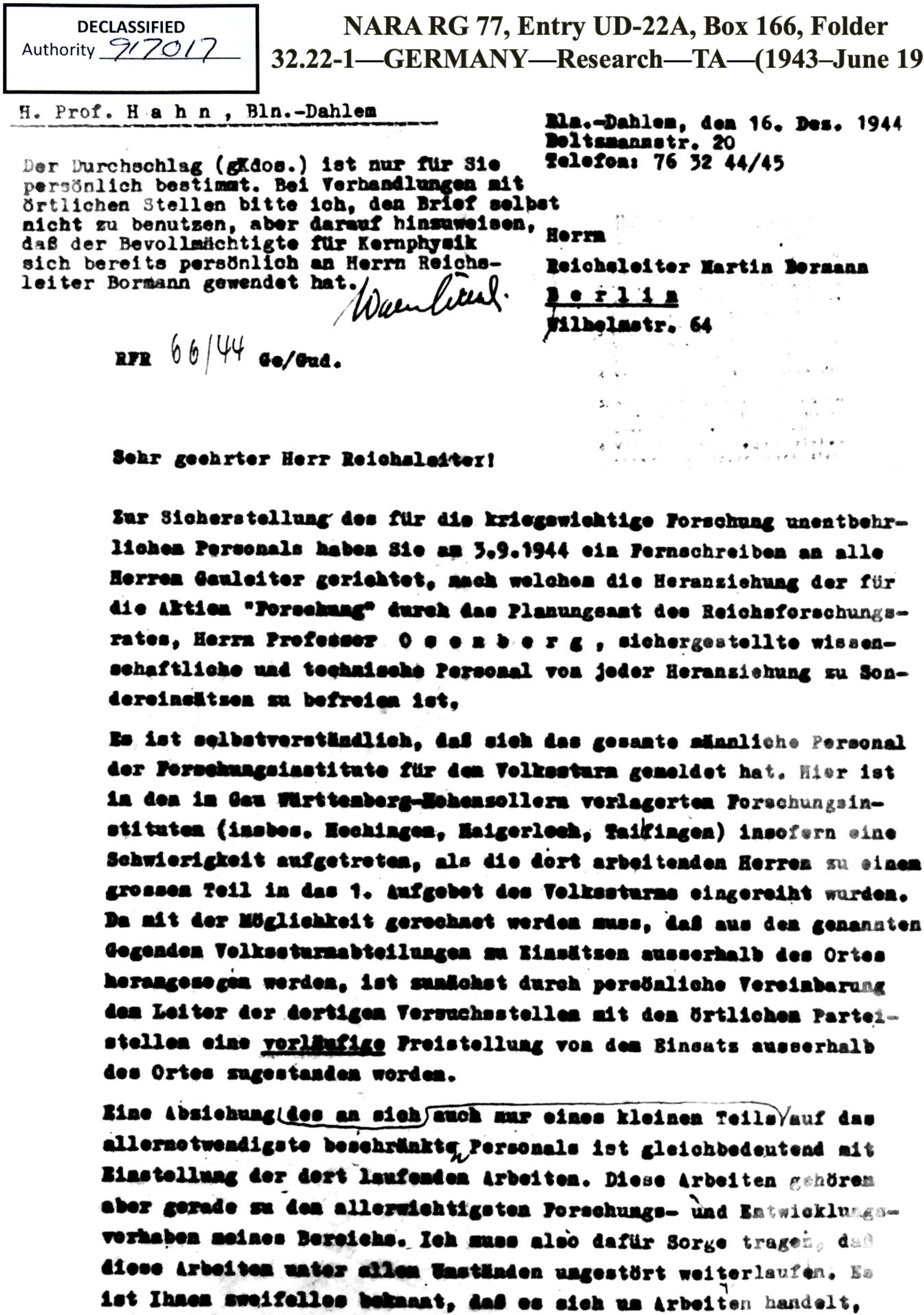
NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3
GERMANY: US Wartime Positive Int. (Nov. 44-June 45)

Figure D.753: OSS Report No. B-624. 20 November 1944. Secret Weapons [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].



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NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)

H. Prof. Hahn, Bln.-Dahlem

Der Durchschlag (gKdos.) ist nur für Sie persönlich bestimmt. Bei Verhandlungen mit örtlichen Stellen bitte ich, den Brief selbst nicht zu benutzen, aber darauf hinzuweisen, daß der Bevollmächtigte für Kernphysik sich bereits persönlich an Herrn Reichsleiter Bormann gewendet hat.

Bln.-Dahlem, den 16. Dez. 1944
Boltzmannstr. 20
Telefon: 76 32 44/45

Herrn
Reichsleiter Martin Bormann
Berlin
Wilhelmstr. 64

RFR 66/44 Ge/Gud.

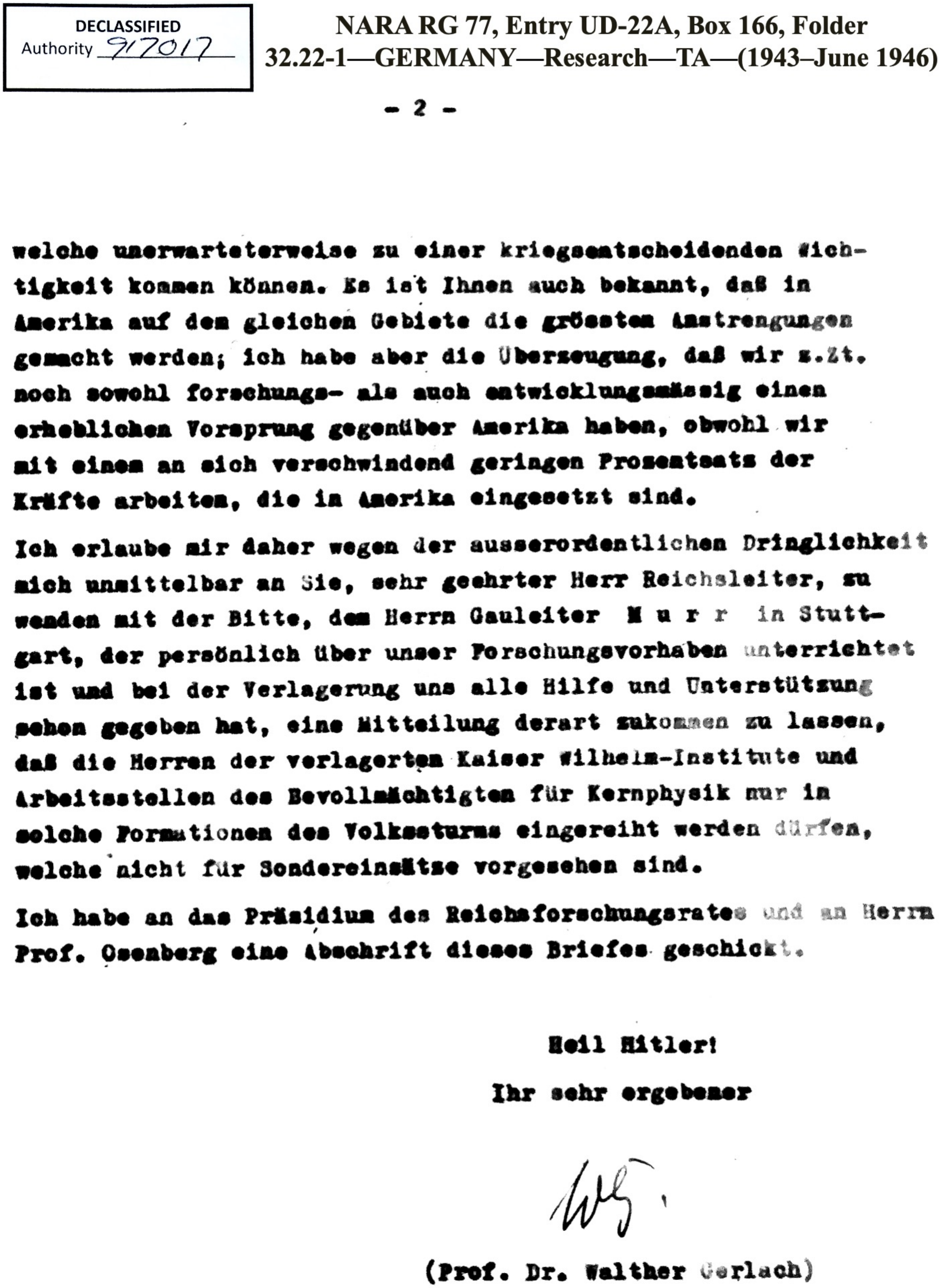
Sehr geehrter Herr Reichsleiter!

Zur Sicherstellung des für die kriegswichtige Forschung unentbehrlichen Personals haben Sie am 3.9.1944 ein Fernschreiben an alle Herren Gauleiter gerichtet, nach welchem die Heranziehung der für die Aktion "Forschung" durch das Planungsamt des Reichsforschungsrates, Herrn Professor Osenberg, sichergestellte wissenschaftliche und technische Personal von jeder Heranziehung zu Sondereinsätzen zu befreien ist.

Es ist selbstverständlich, daß sich das gesamte männliche Personal der Forschungsinstitute für den Volkssturm gemeldet hat. Hier ist in den im Gau Württemberg-Hohenzollern verlagerten Forschungsinstituten (insbes. Hechingen, Haigerloch, Tailfingen) insofern eine Schwierigkeit aufgetreten, als die dort arbeitenden Herren zu einem grossen Teil in das 1. Aufgebot des Volkssturms eingereiht wurden. Da mit der Möglichkeit gerechnet werden muss, daß aus den genannten Gegenden Volkssturmabteilungen zu Einsätzen ausserhalb des Ortes herangezogen werden, ist zunächst durch persönliche Vereinbarung der Leiter der dortigen Versuchsstellen mit den örtlichen Parteistellen eine vorläufige Freistellung von dem Einsatz ausserhalb des Ortes zugestanden worden.

Eine Abziehung des an sich auch nur eines kleinen Teils auf das allernotwendigste beschränkten Personals ist gleichbedeutend mit Einstellung der dort laufenden Arbeiten. Diese Arbeiten gehören aber gerade zu den allerwichtigsten Forschungs- und Entwicklungsvorhaben meines Bereichs. Ich muss also dafür Sorge tragen, daß diese Arbeiten unter allen Umständen ungestört weiterlaufen. Es ist Ihnen zweifellos bekannt, daß es sich um Arbeiten handelt,

Figure D.754: Walther Gerlach to Martin Bormann. 16 December 1944 [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)]



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Authority 917017

NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)

- 2 -

welche unerwarteterweise zu einer kriegsentscheidenden Wichtigkeit kommen können. Es ist Ihnen auch bekannt, daß in Amerika auf dem gleichen Gebiete die grössten Anstrengungen gemacht werden; ich habe aber die Überzeugung, daß wir z.Zt. noch sowohl forschungs- als auch entwicklungsmässig einen erheblichen Vorsprung gegenüber Amerika haben, obwohl wir mit einem an sich verschwindend geringen Prozentsatz der Kräfte arbeiten, die in Amerika eingesetzt sind.

Ich erlaube mir daher wegen der ausserordentlichen Dringlichkeit mich unmittelbar an Sie, sehr geehrter Herr Reichsleiter, zu wenden mit der Bitte, dem Herrn Gauleiter Murr in Stuttgart, der persönlich über unser Forschungsvorhaben unterrichtet ist und bei der Verlagerung uns alle Hilfe und Unterstützung schon gegeben hat, eine Mitteilung derart zukommen zu lassen, daß die Herren der verlagerten Kaiser Wilhelm-Institute und Arbeitsstellen des Bevollmächtigten für Kernphysik nur in solche Formationen des Volkssturms eingereiht werden dürfen, welche nicht für Sondereinsätze vorgesehen sind.

Ich habe an das Präsidium des Reichsforschungsrates und an Herrn Prof. Osenberg eine Abschrift dieses Briefes geschickt.

Heil Hitler!
Ihr sehr ergebener

(Prof. Dr. Walther Gerlach)

Figure D.755: Walther Gerlach to Martin Bormann. 16 December 1944 [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)]

Walther Gerlach to Martin Bormann. 16 December 1944 [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)] [See document photos on pp. 4608–4609.]

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Drafting even a small part of the [nuclear] staff, which is limited to the bare essentials, is tantamount to discontinuing the work being carried out there. However, this work is one of the most important research and development projects in my field. I must therefore ensure that this work continues undisturbed under all circumstances. You are undoubtedly aware that this is work which could unexpectedly turn out to be of decisive importance for the war effort. You are also aware that the greatest efforts are being made in America in the same field; but I am convinced that we still have a considerable lead over America in terms of both research and development, although we are working with a small percentage of the forces deployed in America.

H. K. Calvert to Robert Furman. 30 December 1944. Subject: C.S.D.I.C. (U.K.) G.R.G.G. 238. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

1. In the above report which was prepared on P/W information gathered between the dates 23–26 December 1944, the following statement is noticed:

> "In conversation with General EBERBACH, Generalleutnant HEIM said he thought the counter-attack was only justified if it was intended to win time for the further development of secret weapons and in particular the atom-bomb. There was otherwise no point in just winning time at this stage of the war."

2. This particular paragraph has been called to the attention of C.S.D.I.C. with the request that more information be obtained from Generalleutnant HEIM, if possible, concerning what he describes in his conversation as the "atom-bomb".

3. You will be advised of the result, if any, of our inquiry.

Günter Nagel. 2012a. *Wissenschaft für den Krieg: Die geheimen Arbeiten der Abteilung Forschung des Heereswaffenamtes.* Stuttgart: Franz Steiner. pp. 177, 445.

Bei den für die Uranversorgung zuständigen Stellen dachte man offenkundig über den Tag hinaus und ergriff Maßnahmen zur Erkundung neuer Uranerzvorkommen. Daran soll auch der Grazer Prof. Armin Dadieu mitgewirkt haben.[407]

407 [...] Zur angeblichen Beteiligung von Dadieu vgl. Jürgen Scheffran: *Die heimliche Raketenmacht*, in *Info-Dienst der Informationsstelle Wissenschaft und Frieden 9 (1991) Heft 1/2*, Dossier Nr. 8, 47–62, insb. 51, vgl. auch Anm. 1173.

1173 Hermann Ibler: *Nachruf auf Prof. Dr. Armin Dadieu*, in *Akademisches Leben, Juni 1978*, I–III[....]

The authorities responsible for uranium supply were obviously thinking beyond the day and took measures to explore new uranium ore deposits. Prof. Armin Dadieu from Graz is also said to have been involved in this.[407]

407 [...] On the alleged involvement of Dadieu, see Jürgen Scheffran: *Die heimliche Raketenmacht*, in *Info-Dienst der Informationsstelle Wissenschaft und Frieden 9 (1991) Heft 1/2*, Dossier No. 8, 47–62, esp. 51, see also note 1173.

1173 Hermann Ibler: *Nachruf auf Prof. Dr. Armin Dadieu*, in *Akademisches Leben, Juni 1978*, I–III[....]

Mark Wade. 2020. *Encyclopedia Astronautica.* http://www.astronautix.com/d/dadieu.html

Dadieu, Armin

German engineer, SS Officer, and wartime governor of Styria. Worked on German uranium processing in World War 2, and for Saenger post-war. By the 1970's on review committees for post-Apollo space programs in US and Europa III LV in Europe. Consultant to West German government on OTRAG.

Born: 1901-08-20. *Died*: 1978-04-06.

Dadieu was responsible in during World War II for uranium storage and handling research in Styria, Austria. After the war he became involved in rocketry and spaceflight, working with Eugen Saenger in the 1950's. By the 1970's he was on committees on Post-Apollo space programs in the United States and reviewing the potential Europa III launch vehicle. He later was a consultant to the West German government on the work of OTRAG.

Armin Dadieu was an Austrian chemist, a National Socialist politician, and high-ranking SS officer.

Armin Dadieu was born in 1901 in Brunn bei Maribor, the son of railway inspector Josef Dadieu and his wife Friederike Dadieu Pelkhofer. His primary and secondary schooling were in Maribor. The family was expelled from Slovenia in 1919 as part of the post-World War I drawing of borders and movement of people within what was the Austro-Hungarian Empire.

In the fall of 1919 he began chemistry at the Technical University in Graz. He was active in fraternities and the Alpine Association. He graduated in 1923 as an engineer and thereafter was a research assistant at the Technical University Graz. In 1926 he received his doctorate with a thesis on electromotive behavior of aluminum. From 1930 he moved to the University of Graz, where in March 1932 he became an associate professor of inorganic and physical chemistry. In 1935 he received the Lieben Prize (the "Austrian Nobel Prize") for his work in the field of Raman spectroscopy.

Dadieu was politically active, first from 1927 to 1930 in the Styrian Homeland Security. In 1932 he joined the NSDAP (Nazi Party). In 1936 he was "People Policy Advisor" for the Fatherland Front in Styria and worked secretly for the banned NSDAP. From 1937 he covertly made explosives for the party in his university laboratory, and carried out research and set up an intelligence service for Hermann Goering. After the German annexation of Austria in March 1938 Dadieu was named state governor and Gauhauptmanns for Styria. He had joined the SS in July 1936 and was appointed Standartenfuehrer. Until 1941 he was also the NSDAP Gau Economics Adviser in Gau Styria and Head of the Chamber of Commerce, Trade and Industry. From July 1940 to July 1941 Dadieu served as a Stuka pilot in World War II. In 1942 he was appointed Oberfuehrer, then from 1943-1945, Gaudozentenbundfuehrer in Styria.

In May 1945 Dadieu was arrested by soldiers of the Red Army, but was able to escape after a brief detention. On January 13, 1946, his name appeared on a list of war criminals in the Wiener Zeitung. In March 1948 he was arrested in Austria and again set free, after which he fled across the border into Italy and then to Argentina. He was adviser to the Peron government, especially on the subject of rocket propellants (Argentine Condor missile). Austria seized Dadieu's assets in 1950.

In 1958 Dadieu left Argentina and took up a position at the Institute of Jet Propulsion in Stuttgart. Since 1962 he headed the Institute of Rocket Propellants in Stuttgart, then from 1970 the Institute of Chemical rocket engines in Lampoldshausen. He was a member of the Committees on Post-Apollo Projects and the successor for the Europa III launcher. He worked for the OTRAG and as an expert for the German government. He retired to Graz.

[See also pp. 4613–4624, 5585–5587.

Just exactly what sort of nuclear-related work was done in or near Graz during the war?

Where are the records of wartime work and postwar interrogations and reports?]

Theodor Soucek. 2001. *Mein Richter, mein Henker.* Malmö, Sweden: Bright Rainbow.

[Soucek (1919–20??) was born in Graz, Austria and served throughout the war as an officer. After the war he returned to Austria and helped run one of the "ratlines" for people fleeing Austria and Germany; in that context he sheltered and became well acquainted with Armin Dadieu, a scientist and former senior official from Graz. Soucek's memoirs were written near the end of his life and mix what he had actually seen with what he had heard or believed, so one must be quite cautious in using them, but they contain several intriguing passages that align well with independent sources.]

[S. 55–59:] Irgendwann nahm neben mir ein vielleicht fünfunddreißig Jahre alter—sicher bis vor wenigen Wochen diensttuender—Offizier der Deutschen Wehrmacht Platz, seine Uniform war deutlich erkennbar, nur die Dienstrangabzeichen und Auszeichnungen fehlten. Schnell kamen wir ins Gespräch.

"Woher kommst du und wohin willst du?", fragte ich ihn, nachdem wir festgestellt hatten, beide aus Graz zu stammen.

"Ich muß nach Graz, wichtige Papiere holen!"

"Da kannst du nicht hin, die Russen sind da und du landest schnell irgendwo in Sibirien, in einem Gefangenenlager oder Bergwerk."

"Keine Sorge, ich reise als Berater von höchsten alliierten Oberkommandos mit US-Ausweisen nach Graz und werde von den Sowjet-Dienststellen sicheres, freies Geleit erhalten, weil ich Mitarbeiter eines Forschungsteams im Dienste der US-Regierung bin, mir passiert nichts beiden Russen, da gelten Gegenseitigkeitsabkommen."

"Das ist natürlich etwas anderes! Aber wie kommst du nach Graz?"

"Man stellt mir einen US-Dienstwagen und der fährt mich hin und zurück."

Er hatte schnell Vertrauen zu mir gewonnen, nachdem ich ihm von wichtigen Persönlichkeiten berichtete, die wir in Graz und Berlin kannten und ihm meine Vertrauensposition deutlich machte, die ich aus dem Stab des Generaloberst Ringel und im Aufbau der Alpenfestung innehatte.

[pp. 55–59:] At some point, a thirty-five year old—certainly a serving officer of the German Wehrmacht until a few weeks ago—took a seat next to me, his uniform was clearly recognizable, only the rank insignia and decorations were missing. We quickly struck up a conversation.

"Where are you from and where are you going?" I asked him, after we had established that we were both from Graz.

"I have to go to Graz to get important papers!"

"You can't go there, the Russians are there and you'll quickly end up somewhere in Siberia, in a prison camp or a mine."

"Don't worry, I'm traveling to Graz as an advisor to the highest Allied high command with U.S. ID and will be given safe, free passage by the Soviet authorities because I'm a member of a research team in the service of the U.S. government, nothing will happen to me with the Russians, reciprocity agreements apply."

"That's something else, of course! But how do you get to Graz?"

"They provide me with a U.S. service car and it drives me there and back."

He quickly gained his trust in me after I told him about important people we knew in Graz and Berlin and explained to him the position of trust I held on Colonel General Ringel's staff and in the construction of the Alpine fortress.

“Was war deine Funktion in den letzten Kriegsmonaten?”	“What was your function in the last months of the war?”
“Ich gehörte zu den Forschungsgruppen des Kaiser-Wilhelm-Instituts in Berlin und habe in den Alpen der Obersteiermark unterirdische Forschungsstellen betreut, in Gstatterboden. Dort waren im Berg Spezialbauten eingerichtet, die intensiv bis Kriegsende für die Raketentechnik unter Prof. Dadieu aus Graz arbeiteten.”	“I belonged to the research groups of the Kaiser Wilhelm Institute in Berlin and was in charge of underground research stations in the Alps of Upper Styria, in Gstatterboden. Special buildings were set up in the mountain there, which worked intensively on rocket technology under Prof. Dadieu from Graz until the end of the war.”
“Aber das werden die Russen doch alles besetzt und mitgenommen haben!”	“But the Russians will have occupied all that and taken it with them!”
“Ja und nein: ich habe Zugang zu Dokumenten und Einrichtungen, die sicher bis jetzt unentdeckt geblieben sind und hole Papiere und Berichte, von denen ich weiß, wo sie sind, um diese nach den USA zu bringen.”	“Yes and no: I have access to documents and facilities that have certainly remained undiscovered until now and I am retrieving papers and reports that I know where they are in order to bring them to the USA.”
Und dann erzählte er mir von einer erstaunlichen und geradezu sensationellen Mission, an der er vor wenigen Wochen teilgenommen hatte.	And then he told me about an amazing and almost sensational mission he had taken part in a few weeks ago.
In der Nähe von Magdeburg gab es ein deutsches Bergwerk in größerer Tiefe, in welchem sich geheime Forschungszentren der Reichsregierung befanden, speziell in Verbindung mit den Atomforschungsprojekten des 3. Reiches unter Leitung des Kaiser-Wilhelm-Institutes Berlin.	Near Magdeburg there was a German mine at a great depth in which secret research centers of the Reich government were located, especially in connection with the nuclear research projects of the Third Reich under the direction of the Kaiser Wilhelm Institute in Berlin.
In einem solchen unterirdischen Bau befand sich das einzige arbeitende Zyklotron der Welt, eine Beschleunigeranlage, die so leistungsfähig nirgends sonst entwickelt worden war. Als die amerikanischen Besatzungs-Sonderkommandos, die mit höchstem Auftrag und größter Dringlichkeit nach den Geheimwaffenentwicklungen des 3. Reiches suchten, von dieser Anlage erfuhren, wurde ein US-Sonderkommando aufgestellt, das den Berichten der deutschen Mitarbeiter folgend, die Aufgabe erhielt, dieses Zyklotron auszubauen und vor dem Zugriff der Sowjets zu retten bzw. es nach den USA zum Nutzen der dortigen Forschungsarbeiten zu verbringen.	The only working cyclotron [of its type] in the world, an accelerator facility that had not been developed anywhere else with such high performance, was located in such an underground building. When the American occupation special commandos, who were searching for the secret weapons developments of the Third Reich with the utmost mission and urgency, learned of this facility, a US special commando was set up, which, following the reports of the German employees, was given the task of exploiting this cyclotron and rescuing it from the Soviets or transferring it to the USA for the benefit of the research work there.

[Compare with similar reports on pp. 3761–3772, 4853, 4980–4981, 5050.]

“Wir wurden, zum Großteil deutsche Spezialisten und Sonderkommandotrupps, mit russischen Lastwagen, russischen Uniformen und russischen Ausweisen versehen, bei Nacht und Nebel in das Bergwerk geschickt mit dem Auftrag, dieses Zyklotron auszubauen zu verladen und in die Hände der US-beauftragten Spezialeinheiten zu bringen.”

“Und das gelang?”, fragte ich erstaunt.

“Perfekt, wir haben so gut wie unentdeckt, unerkannt und unbehindert diesen Überraschungsauftrag erfüllt, das Gerät ist schon in den USA.” [...]

Mein Gesprächspartner wurde aufgerufen und verabschiedete sich herzlich.

“Glückauf”, rief ich ihm zu, “mach ’s gut, vielleicht auf Wiedersehen später in Graz!”

Viel später, im Jahre 1966, kam mir ein Sonderbericht der “Presse”, Wien, in die Hände, daß große Bombengeschwader der USA in den letzten Kriegswochen nahe Magdeburg wichtigste Forschungszentren des 3. Reiches in mehrfachen Wellen bombardiert hatten, weil es sich um Atomforschungszentren Deutschlands handelte, die zerstört werden sollten, um diese nicht in die Hände der vorrückenden, vor den Amerikanern eintreffenden, Sowjettruppen fallen zu lassen.

So bestätigte sich der Bericht meines Gesprächspartners in Liezen und fand eine Teilerklärung, deren voller Umfang wohl bis heute in Geheimakten ruht bzw. bei Teilnehmern in verschlossenen Erinnerungen und Wissensvorgängen lebt, die wir nicht kennen.

[S. 71:] Die Gattin des weithin bekannten Rektors der Universität Graz, des führenden Wissenschaftlers Prof. Dr. Armin Dadieu, kommt sehr schnell zum Kernpunkt ihres Anliegens.

“We were sent, mostly German specialists and special commandos, equipped with Russian trucks, Russian uniforms and Russian ID cards, into the mine at night and in fog with the task of dismantling this cyclotron and loading it into the hands of the U.S. special forces.”

“And that was successful?” I asked in amazement.

“Perfect, we have fulfilled this surprise mission as good as undetected, unrecognized and unhindered, the device is already in the USA.” [...]

My interlocutor was called and said goodbye warmly.

“Good luck,” I called out to him, “take care, maybe we’ll see you again later in Graz!”

Much later, in 1966, I came across a special report in the Vienna “Press” that large U.S. bombing squadrons had bombed the most important research centers of the Third Reich in several waves near Magdeburg in the last weeks of the war, because these were nuclear research centers in Germany that were to be destroyed so that they would not fall into the hands of the advancing Soviet troops arriving before the Americans.

This confirmed the report of my interlocutor in Liezen and found a partial explanation, the full extent of which is probably still kept in secret files today or lives among participants in closed memories and knowledge processes that we do not know.

[p. 71:] The wife of the widely known rector of the University of Graz, the leading scientist Prof. Dr. Armin Dadieu, very quickly came to the heart of her request.

“Lieber Herr Soucek, bitte helfen Sie meinem Mann und retten Sie ihn! Es drohen ihm sowohl die Auslieferung an Tito als auch eine Anklage seitens der alliierten Besatzungsmächte, die ihn wegen seiner Funktion und seines Ranges als Gauhauptmann der Steiermark einkerkern wollen. Sie wissen ja auch sicher, daß er als Wissenschaftler seines Ranges den Sowjets eine begehrte Beute wäre. Mein Mann befand sich bei Kriegsende im Forschungszentrum Gstatterboden, wo er mit seinen Mitarbeitern die im Auftrag des Kaiser-Wilhelm-Institutes, Berlin, eingerichteten und vom Kriegsforschungsrat bzw. dem Verteidigungsministerium unter Minister Speer geführten unterirdischen und in die Berge verlagerten Einrichtungen kontrollierte. Seine Aufgabe war es, diese Forschungsarbeiten vordem Zugriff der Alliierten zu sichern und die Arbeitsgruppen vor einer Gefangenschaft durch die Sowjets zu bewahren.”

[S. 94–105:] Dadieu wurde zu einem Treffen nach Wien bzw. auf den Semmering eingeladen, um sich mit seinem früheren Chef des Kaiser-Wilhelm-Instituts, Prof. Peter Adolf Thiessen, zu treffen, einem der führenden Atomforscher des 3. Reiches, der in Berlin und ganz Deutschland die bedeutendsten Atomforschungsanlagen errichtet hatte, die verschiedensten Forschergruppen dirigierte, die an der deutschen Atombombe arbeiteten und unter anderem auch Dadieus geheime, unterirdische Forschungsstätten in Gstatterboden führte bzw. kontrollierte. [...]

Was wir in dieser Stunde noch nicht genau und im ganzen Umfang wußten, war, daß die Sowjets in den ersten Nachkriegsmonaten über 25.000 deutsche Spitzenkräfte der Geheimwaffenentwicklung zur Verteidigung mit glänzenden Vertragsbedingungen angelockt hatten, kontrollierten und dann in einer Nacht- und Nebelaktion als Gefangene nach Rußland gebracht hatten. So auch Männer wie Prof. Thiessen.

Dear Mr. Soucek, please help my husband and save him! He is threatened with extradition to Tito as well as prosecution by the Allied occupying powers, who want to imprison him because of his function and rank as Gauhauptmann of Styria. As I’m sure you know, as a scientist of his rank he would have been coveted prey for the Soviets. At the end of the war, my husband was at the Gstatterboden research center, where he and his staff controlled the underground facilities set up by the Kaiser Wilhelm Institute in Berlin and run by the War Research Council and the Ministry of Defense under Minister Speer and relocated to the mountains. His task was to secure this research work from the Allies and to protect the research groups from being captured by the Soviets.”

[pp. 94–105:] Dadieu was invited to a meeting in Vienna and on the Semmering to meet with his former head of the Kaiser Wilhelm Institute, Prof. Peter Adolf Thiessen, one of the leading atomic researchers of the Third Reich, who had built the most important atomic research facilities in Berlin and throughout Germany, directed the various research groups working on the German atomic bomb and also managed or controlled Dadieu’s secret, underground research facilities in Gstatterboden. [...]

What we did not know at that time was that in the first months after the war, the Soviets had lured more than 25,000 top German secret weapons developers for defense purposes with brilliant contract conditions, controlled them and then brought them to Russia as prisoners in a night and fog operation. This included men like Prof. Thiessen.

Während die Amerikaner die Spitzengruppen der Geheimwaffenentwicklungen unter Führung Wernher von Brauns, die Elite der Peenemünder Raketen- und Weltraumforscher, gefangen genommen und in die USA gebracht hatten, zusammen mit der modernsten und letzten Entwicklung an Raketenprojekten, Plänen, Modellen, Fabrikanlagen und Serienerzeugnissen von V-1 bis V-9, den serienreifen interkontinentalen Fernschußraketen, die auch Atomsprengköpfe nach den USA hätten fliegen können, also kriegsentscheidend waren, hatten sich die Russen neben den in ihren Zonen gefundenen Rüstungsprodukten, Einrichtungen und Spezialisten auch entscheidender Köpfe der Atomforschung bemächtigt, wie Prof. Thiessen, Manfred von Ardenne und Dr. Riehl, dem führendsten Mann der Welt zur Herstellung von reinem Uran, der Ausgangsbasis für den Bau von Atombomben.

While the Americans had captured the top groups of secret weapons developers under the leadership of Wernher von Braun, the elite of the Peenemünde rocket and space researchers, and brought them to the USA, together with the most modern and latest developments in rocket projects, plans, models, factory equipment and series products from V-1 to V-9, the production-ready intercontinental long-range missiles, which could also have flown nuclear warheads to the USA, i.e. were decisive for the war, the Russians had seized not only the armaments products, facilities and specialists found in their zones, but also key minds in nuclear research, such as Prof. Thiessen, Manfred von Ardenne and Dr. Riehl, the world's leading man in the production of pure uranium, the starting point for the construction of atomic bombs.

Dadieu gehörte selbst zu diesen Forschern und stand bis Kriegsende in laufendem Kontakt mit Prof. Thiessen, dem Kaiser-Wilhelm-Institut und dem Reichsforschungsrat Berlins unter Minister Speer bzw. Hermann Görings Führungsorganen.

Dadieu himself was one of these researchers and was in constant contact with Prof. Thiessen, the Kaiser Wilhelm Institute and the Reich Research Council in Berlin under Minister Speer and Hermann Göring's leadership until the end of the war.

Dadieu wollte wissen, wer der Überbringer war, und wie man sich diese Zusammenkunft in der Sowjetbesatzungszone gedacht hatte. Wir waren uns sofort darüber im Klaren, daß Dadieu von einem solchen Treffen in der Russenzone nie mehr frei zurückkehren würde, daß man ihn als wichtige Beute entführen und nach der Sowjetunion verbringen würde und er vermutlich schon bei diesem Treffen gar nicht mit Prof. Thiessen zu einem Gespräch käme, sondern dessen Name nur als Leimrute zum Einfangen des "Paradiesvogels Dadieu" diene. [...]

Dadieu wanted to know who the messenger was and how this meeting had been planned in the Soviet occupation zone. We were immediately aware that Dadieu would never return free from such a meeting in the Russian zone, that he would be kidnapped as important prey and taken to the Soviet Union and that he would probably not even have a conversation with Prof. Thiessen at this meeting, but that his name would only serve as bait to catch the "game bird Dadieu." [...]

“Hast du, Hans [Dadieu], in deinen Forschungs- und Geheimwaffenentwicklungen keine direkte Kenntnis davon gehabt, wieso die Ankündigungen von Dr. Goebbels in der Wochenzeitung “Das Reich” und in seinen Reden immer wieder darin gipfelten, daß der Sieg Deutschlands nahe und unaufhaltsam sei, daß die Entscheidung zu Gunsten des Deutschen Reiches im 2. Weltkrieg noch 1945 fallen würde?”

“Natürlich hatte ich als oftmaliger Besucher Berlins bei Thiessen und im Kaiser-Wilhelm-Institut laufende Kenntnis der allgemeinen Steigerung und Verbesserung unserer Waffentechnik, unserer neuen industriellen Ergebnisse, von der Panzerfaust bis V 2, von den Schnorchelbooten bis zu den Raketenjägern, aber die Geheimhaltung war so streng, für jeden Teilbereich so bedingungslos getrennt, daß ich selbst an der Spitze bestimmter Projektarbeiten keinen Entwicklungsstand in der Atombombenforschung oder im Fernraketenbau kannte. Jeder von uns war auf seine Zielsetzungen verschworen, aber nur Thiessen, Minister Speer und das Führerhauptquartier wußten in den letzten Kriegsmonaten Einzelheiten der Schwerpunktentwicklungen, verfügten über die Resultate und trafen die Entscheidungen.”

“Aber du hast doch wie ich die im Herbst 1944 erfolgten Hinweise aus der Feder und dem Munde von Dr. Goebbels gekannt:

“Dankdem Geist der deutschen Wissenschaftler sind wir nicht mehr weit von dem Zeitpunkt entfernt, daß wir einen Teil der Erde in die Luft sprengen könnten.”

Wie er wörtlich 1944 im “Reich” schrieb, deutlich auf die Atomkraft anspielend, die dank Hahn 1939 durch die Entdeckung der Atomspaltung Deutschland allein zugänglich war, derübrigen Welt weit voraus.”

Dadieu erwiderte:

“Did you, Hans [Dadieu], in your research and secret weapons developments, have no direct knowledge of why the announcements of Dr. Goebbels in the weekly newspaper “Das Reich” and in his speeches repeatedly culminated in the fact that the victory of Germany was near and unstoppable, that the decision in favor of the German Reich in the Second World War would still fall in 1945?”

“Of course, as a frequent visitor to Berlin for Thiessen and the Kaiser Wilhelm Institute, I had ongoing knowledge of the general increase and improvement of our weapons technology, our new industrial results, from the Panzerfaust to V 2, from the snorkel boats to the rocket fighters, but the secrecy was so strict, so unconditionally separated for each sub-area, that even at the top of certain project work I knew no development status in atomic bomb research or in long-range rocket construction. Each of us was conspiring to achieve our goals, but only Thiessen, Minister Speer, and the Führer’s headquarters knew the details of the main developments in the final months of the war, had the results at their disposal and made the decisions.”

“But you, like me, were aware of the information that came from the pen and mouth of Dr. Goebbels in the autumn of 1944:

“Thanks to the spirit of the German scientists, we are not far from the time when we could blow up part of the earth.”

As he literally wrote in 1944 in “Reich,” clearly alluding to atomic power, which, thanks to Hahn’s discovery of atomic fission in 1939, was available to Germany alone, far ahead of the rest of the world.”

Dadieu replied:

“Natürlich wußten wir, daß die verschiedensten Forschergruppen unter strengster Geheimhaltung, voneinander unabhängig, an zukunftsweisenden Systemen arbeiteten. Aber alle diese Arbeiten unterlagen dem strengen Führerbefehl, daß jeder Geheimnisträger nur soviel über seinen Aufgabenbereich wissen durfte, wie dieser zur unmittelbaren Aufgabenerfüllung im Rahmen seines Wirkungsbereiches an Kenntnissen benötigte.

Nachdem ich als Mitarbeiter des Reichsforschungsrates unter dem Präsidenten des Kaiser-Wilhelm-Institutes Berlin, Prof. Dr. Adolf Thiessen, für feste Raketentreibstoffe zuständig war, wußte ich, daß in Peenemünde Dr. Walter Thiel für die Raketenantriebssysteme führend arbeitete.”

Dr. Thiel studierte bereits die Möglichkeit, als Raketenantrieb Atomenergie zu nutzen. Aber als, infolge von Verrat, im August 1944 durch eine Welle von Fliegerangriffen in der Wohnsiedlung des Raketenforschungszentrums Peenemünde auf Usedom über siebenhundert Forscher mit ihren Familienangehörigen getötet wurden, starb auch Dr. Thiel mit Frau und Kindern. Mit ihm wurden alle seine Arbeitsergebnisse vernichtet und blieben auch für die alliierten Sieger verloren.

Welchen hohen, überlegenen Stand unsere Geheimwaffenforschung einschließlich der Arbeiten an deutschen Atomwaffen erreicht hat, wissen heute in letzten Einzelheiten nur die USA und die Sowjetunion, die sich der deutschen Spitzenleistungen als Siegesbeute bemächtigten. [...]

Der Anteil der deutschen Atomforschungsergebnisse an der Atombewaffnung Amerikas bleibt ebenso ein Geheimnis in den Archiven der USA, wie die Ergebnisse deutscher Vorleistungen in den Händen der Sowjetunion, die deutsche Spitzenforscher wie Prof. Thiessen und Manfred von Ardenne mit vielen anderen Spezialisten gefangen nahm und für sich arbeiten ließ.

Of course, we knew that the most diverse research groups were working on forward-looking systems in the strictest secrecy, independently of each other. But all this work was subject to the Führer’s strict order that every person working in secrecy was only allowed to know as much about his area of responsibility as he needed to know in order to directly fulfill his tasks within his area of responsibility.

Having been responsible for solid rocket propellants as an employee of the Reich Research Council under the President of the Kaiser Wilhelm Institute in Berlin, Prof. Dr. Adolf Thiessen, I knew that Dr. Walter Thiel was working in Peenemünde as a leader in rocket propulsion systems.”

Dr. Thiel was already studying the possibility of using atomic energy for rocket propulsion. But when, as a result of betrayal, over seven hundred researchers and their families were killed in a wave of air raids on the housing estate of the Peenemünde rocket research center on Usedom in August 1944, Dr. Thiel and his wife and children also died. All the results of his work were destroyed with him and remained lost to the Allied victors.

Today, only the USA and the Soviet Union know the final details of the high, superior level of our secret weapons research, including the work on German nuclear weapons, which seized Germany’s top achievements as spoils of victory. [...]

The share of German nuclear research results in America’s nuclear armament remains just as much a secret in the archives of the USA as the results of German preliminary work in the hands of the Soviet Union, which captured top German researchers such as Prof. Thiessen and Manfred von Ardenne along with many other specialists and made them work for itself.

In diesem Zusammenhang erzählte ich Dadieu von einer außerordentlichen Begegnung mit einem hochrangigen ungarischen General, als ich mich—noch verwundet—im gleichen Zugabteil auf der Bahnfahrt von Berlin nach Wien Mitte Januar 1945 befand.

Am Vortag meiner Rückreise aus Berlin, wo ich mich auf Grund eines Sonderauftrages zur Entgegennahme neuer Einsatzbefehle befand, besuchte ich den Leiter der Privatkanzlei Adolf Hitlers, Herrn von Blankenburg, mit dem ich seit 1938 befreundet war. Von Blankenburg nahm mich zu einer Lagebesprechung zu Reichsminister Dr. J. Goebbels mit, in der dieser den geladenen Sondergästen aus höchsten deutschen und europäischen Führungs- und Regierungspositionen unter faszinierenden Erklärungen in seiner bekannten mitreißenden rednerischen Kraft wörtlich erklärte:

“Die Aufgabe der deutschen Wehrmacht in Erfüllung der Verteidigung des Deutschen Reiches besteht darin, die Feinde Deutschlands noch sechs Monate vom Reichskern fernzuhalten, denn dann wird dank der Entwicklung unserer modernen, neuen Geheimwaffen dieser Weltkrieg in 24 Stunden also am selben Tag, mit dem Sieg Deutschlands und seiner Verbündeten beendet sein.”

Noch stärkstens beeindruckt von den am Vortag erlebten Erklärungen des Propagandaministers Dr. Goebbels betrat ich mein Zugabteil zur Rückreise nach Wien und weiter in mein Lazarett, wo ich mich zur endgültigen Ausheilung meiner Verwundungen befand.

Mir gegenüber hatte ein älterer, weißhaariger Herr Platz genommen, der sich mir im Laufe der Reise nach vertraulichem und angeregtestem Gespräch als hochrangiger ungarischer General vorstellte.

Nach mehr als einer Stunde Bahnfahrt wandte sich der General überraschend und vertraulich zu mir:

In this context, I told Dadieu about an extraordinary encounter with a high-ranking Hungarian general when I was—still wounded—in the same train compartment on the train ride from Berlin to Vienna in mid-January 1945.

On the day before my return from Berlin, where I was on a special assignment to receive new deployment orders, I visited the head of Adolf Hitler’s private chancellery, Mr. von Blankenburg, with whom I had been friends since 1938. Von Blankenburg took me to a briefing with Reich Minister Dr. J. Goebbels, in which he literally explained to the invited special guests from the highest German and European leadership and government positions with fascinating explanations and his well-known rousing oratory power:

“The task of the German Wehrmacht in fulfilling the defense of the German Reich is to keep Germany’s enemies away from the Reich core for another six months, because then, thanks to the development of our modern, new secret weapons, this world war will be over in 24 hours, i.e. on the same day, with the victory of Germany and its allies.”

Still highly impressed by the statements made the day before by the Minister of Propaganda, Dr. Goebbels, I entered my train compartment for the return journey to Vienna and on to my military hospital, where I was in the process of finally healing my wounds.

An elderly, white-haired gentleman had taken a seat opposite me, who introduced himself to me as a high-ranking Hungarian general during the course of the journey after a confidential and animated conversation.

After more than an hour’s train ride, the general turned to me surprisingly and confidentially:

[Cf. pp. 4549–4550, 4587, 4627–4665, 4679–4681, 4766, 5038, 5218, 5380, 5454–5466, 5658–5659.]

“Schauen Sie, lieber junger Freund, Sie sind für mich ein frontbewährter Offizier und offenbar bedingungslos Ihrer Nation und der Verteidigung Europas verschworen, dazu noch Schriftsteller von höchstem Verantwortungsbewußtsein zur Rettung vor dem Kommunismus. So kann ich Ihnen von meinem Besuch als Vertreter der ungarischen Regierung in Berlin erzählen, weil man uns mit anderen verbündeten Regierungsvertretern der Achsenmächte in den letzten Tagen die jüngsten Entwicklungen der deutschen Geheimwaffen vorführte.

Wir wurden an der Ostsee in ein Sperrgebiet der Wehrmacht geflogen und es geschah folgendes: Als Zielgebiet zeigte man uns eine vielleicht 20–25 km entfernte kleine Insel und beschoß diese mit einer neuartigen Bombe, aus einem Flugzeug abgeworfen. Diese Bombe wirkte so beispiellos, daß von der Insel nichts mehr zu sehen war, sie war im Wasser verschwunden![4]

Mit dieser neuen Waffe werden Sie den Krieg gewinnen, Deutschlands Sieg ist nicht mehr aufzuhalten. Ich gratuliere Ihnen!”

Das waren seine Worte. Der General betonte:

“Weitere Einzelheiten möchte ich Ihnen nicht berichten, weil wir zur Geheimhaltung aus ganz natürlichen Gründen von Seiten Ihrer Regierung veranlaßt wurden, aber diese Gewißheit wollte ich Ihnen mitgeben, weil Sie ein so überzeugender Repräsentant des jungen Deutschland für mich waren.”

4 [...] Der “Schwedische Beobachter” bericht vom Verschwinden einer Insel nach Beschuß durch eine deutsche Sonderwaffe.

“Look, dear young friend, you are for me a front-line officer and obviously unconditionally sworn to your nation and the defense of Europe, in addition to being a writer of the highest sense of responsibility to save us from communism. So I can tell you about my visit to Berlin as a representative of the Hungarian government, because in the last few days we were shown the latest developments in German secret weapons together with other allied government representatives of the Axis powers.

We were flown to a Wehrmacht restricted area on the Baltic Sea and the following happened: We were shown a small island perhaps 20–25 km away as a target area and bombarded it with a new type of bomb, dropped from an airplane. This bomb had such an unprecedented effect that nothing could be seen of the island, it had disappeared into the water![4]

With this new weapon you will win the war, Germany’s victory can no longer be stopped. I congratulate you!”

Those were his words. The general emphasized:

“I don’t want to tell you any more details because we were induced to secrecy for quite natural reasons on the part of your government, but I wanted to give you this certainty because you were such a convincing representative of young Germany for me.”

4 [...] The “Swedish Observer” reports on the disappearance of an island after bombing by a German special weapon.

[Compare with similar reports in Sections D.10–D.11.]

Theodor Soucek. 4 May 2001 filmed interview with Heiko Petermann [Karlsch 2005, p. 203]. [Joseph Goebbels speaking with German military officers on 6–7 January 1945:]

Meine Herren, es kommt darauf an, dass die deutsche Wehrmacht den Feind vom Reichskern sechs Monate fern hält, dann wird die neueste Waffe, über die wir verfügen, zum Einsatz kommen, und in 24 Stunden wird dieser Krieg mit dem Sieg Deutschlands entschieden sein.

Gentlemen, it is important that the German Wehrmacht keeps the enemy away from the central Reich for six months, then the newest weapon we have will be used, and in 24 hours this war will be decided with the victory of Germany.

Maximilian Brunner. 2017. *Armin Dadieu: Versuch der Biographie eines Nationalsozialisten.* Thesis, University of Graz.
https://unipub.uni-graz.at/obvugrhs/download/pdf/1703351

[From the sources cited in this thesis, during the war Armin Dadieu was a senior administrator for at least two secretive research institutes (at Hörgas and Gstatterboden); he may have been involved with other secret research facilities as well (see p. 4624). These sources indicate that Dadieu was not merely connected with nuclear research or uranium mining, but that he was part of the German atomic bomb program. In his unpublished manuscript, Dadieu appeared to claim that by the end of the war in Europe, he knew that a horrifically powerful bomb—the German atomic bomb—had been successfully developed but that officials wisely refrained from using it. The curious mention of research on military applications of "artificial thunderstorms" may have been some nonscientific person's attempt after the fact to describe real scientific work that had been conducted during the war on particle accelerators, perhaps for electronuclear breeding or for directed energy weapons.]

[S. 35:] In den letzten Zeilen seiner Memoiren berichtet Dadieu von einer von abziehenden Wehrmachtseinheiten blockierten Straße bei Frohnleiten, dass er deswegen eine Nacht in Hörgas, wo er ebenfalls ein Institut leitete, verbringen musste und dass er am nächsten Morgen, als "die Russen bereits da" waren, seine Flucht zu Fuß weiter setzte. Obwohl er sich schon in amerikanischen Gebiet wägte, wurde Dadieu von russischen Truppen aufgespürt und verhaftet.[140] Mit dieser Episode beendet er seine autobiographischen Aufzeichnungen:

Nach einer Füsilierungsszene, an der alles dran war, haben sie mich abtransportiert, um mich in Trieben zu der dort stationierten russischen Division mit Dolmetschern zu bringen. Zusammen mit zirka fünfzig Leuten habe ich in Strechau eine sehr unangenehme Nacht verbracht. Am Morgen auf dem Weg zwischen Strechau und Trieben, an einer Stelle, wo der Wald ganz nahe an die Bundesstraße herankommt, habe ich ein 'Halt' provoziert und bin in einem unbewachten Augenblick in den Wald gesprungen und damit den Russen nach 22stündiger Haft entkommen. Damit war diese Geschichte für mich vorbei.[141]

[140–141:] DADIEU, Aus meinen Aufzeichnungen. 1978, p. 341.

[p. 35:] In the last lines of his memoirs, Dadieu tells of a road near Frohnleiten that was blocked by retreating Wehrmacht units, that he had to spend a night in Hörgas, where he also ran an institute, and that the next morning, when "the Russians were already there," he continued his escape on foot. Although he was already in American territory, Dadieu was tracked down and arrested by Russian troops.[140] He ends his autobiographical notes with this episode:

After a fusilization scene where everything was up, they took me away to bring me to the Russian division stationed there in Trieben with interpreters. Together with about fifty people, I spent a very unpleasant night in Strechau. In the morning, on the road between Strechau and Trieben, at a point where the forest came very close to the main road, I provoked a 'halt' and jumped into the forest at an unguarded moment, thus escaping from the Russians after 22 hours of detention. That was the end of the story for me.[141]

[140–141:] DADIEU, From My Notes. 1978, p. 341.

[S. 111:] Einen eindeutigen thematischen Bruch liefert das zwölfte und letzte Kapitel des Manuskriptes: Hier geht Dadieu nicht mehr per se auf dessen persönliche Kriegserfahrungen und Fronterlebnisse ein, sondern berichtet über die Schrecken der ‘neuen Waffe’, “welche die innersten Kräfte der Materie entfesselt und so ein Ausmaß der Vernichtung erreichen läßt, das jeden Widerstand zerstört”. Diese eben erst entwickelte Bombe gleiche seinem Wortlaut nach “vielmehr den Mitteln, die man verwendet um schädliche Insekten samt ihrer Brut bis in die letzten Winkel zu vertilgen”. “Der rechte Mann jedoch wird immer eine Waffe wählen die viel von ihm verlangt und welche auch dem Gegner Chancen gibt”, führt Dadieu diesen Absatz weiter aus und kommt wieder auf seine Fliegertruppe sowie auf die speziellen Attribute, die man als Pilot beziehungsweise als Bordschütze mitbringen müsse, zu sprechen, ehe seine Aufzeichnungen ganz enden.[454]

[454] Private Kriegsaufzeichnungen Armin Dadieu, Kapitel 12, p. 31, Privatsammlung Renate Moszkowicz.

[S. 134:] Abseits dieser zitierten Textauszüge versucht sich der Journalist im Zuge der Aufarbeitung verschiedener Geschehnisse immer wieder an einer Charakterisierung Dadieus, beziehungsweise, an einer Erläuterung seiner Taten und seines Wirkens. So wird einerseits berichtet, Dadieu habe in Gstatterboden an der deutschen Atombombe sowie auch an der Entwicklung künstlicher Gewitter als Kriegswaffen geforscht, andererseits wiederum wird er als ‘gemäßigter’ Nationalsozialist bezeichnet, der durch seine Haltung vor dem ‘Anschluss’, aber auch danach, auf einer Femeliste des radikalen Flügels der Partei stand.[543] Es wird sogar erwähnt, Dadieu habe gemeinsam mit Seyss-Inquart noch in den letzten Stunden der ‘Volkserhebung’ versucht, den Einmarsch der Deutschen Wehrmacht zu verhindern, um Österreich eine gewisse Eigenständigkeit zu bewahren.

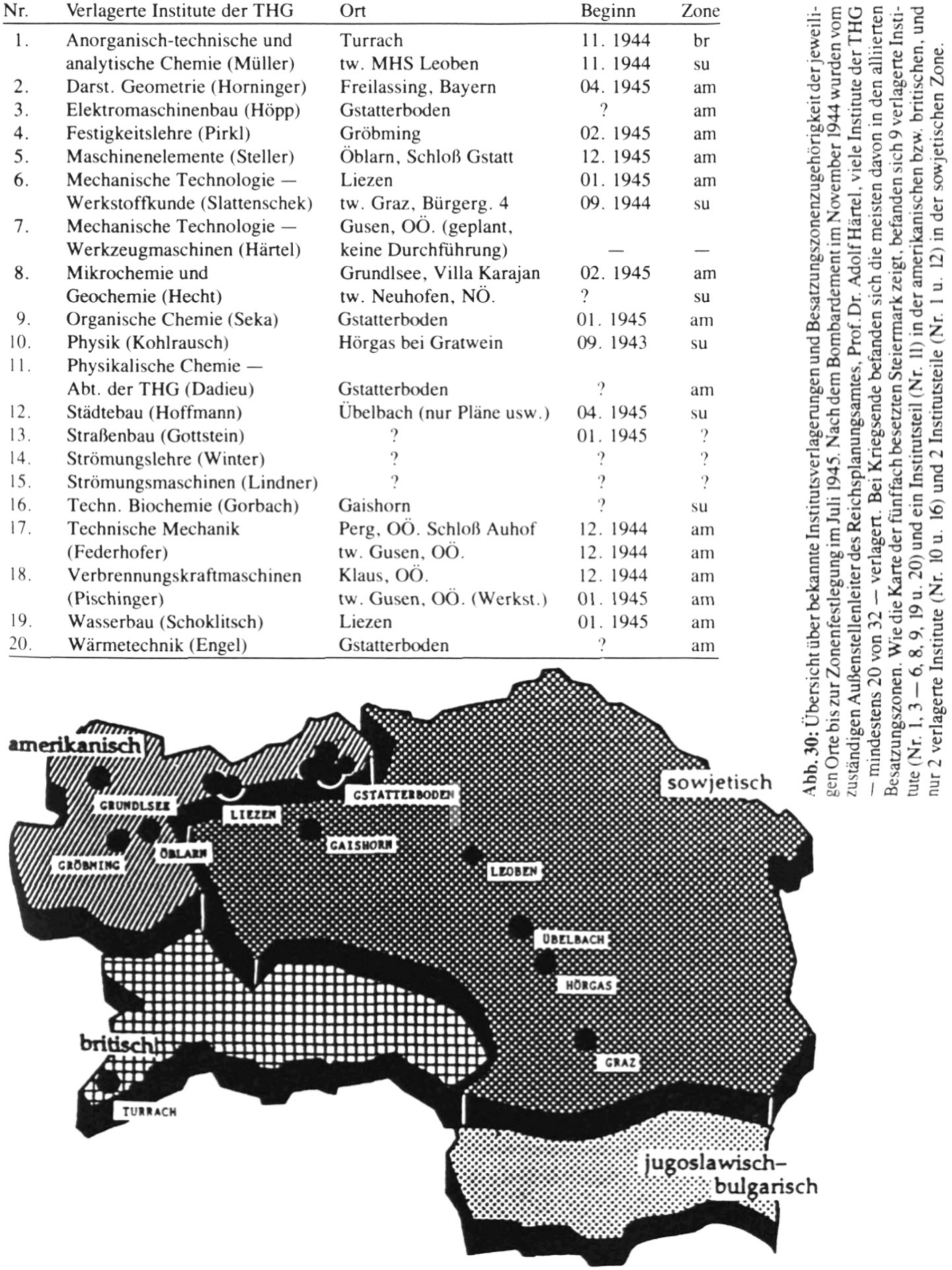
[543] Vgl.: DICHAND, GRAZ. 8.1.1988, p. 21 (Teil 3).

[p. 111:] The twelfth and final chapter of the manuscript provides a clear thematic break: Here Dadieu no longer deals per se with his personal war experiences and experiences on the front, but reports on the horrors of the ‘new weapon,’ “which unleashes the innermost forces of matter and thus allows an extent of destruction to be achieved that destroys all resistance.” According to his wording, this newly developed bomb is “much more like the means used to exterminate harmful insects and their brood down to the last corner.” “The upright man, however, will always choose a weapon that demands a lot from him and which also gives the enemy a chance,” Dadieu continues this paragraph and returns to his air force and the special attributes that one must have as a pilot or gunner before his notes come to an end.[454]

[454] Private war records of Armin Dadieu, Chapter 12, p. 31, Private Collection Renate Moszkowicz.

[p. 134:] Apart from these quoted text excerpts, the journalist repeatedly attempts to characterize Dadieu and explain his deeds and his work in the course of coming to terms with various events. On the one hand, Dadieu is reported to have researched the German atomic bomb in Gstatterboden as well as the development of artificial thunderstorms as weapons of war; on the other hand, he is described as a ’moderate’ National Socialist who, due to his attitude before and after the Anschluss, was on a femelist of the radical wing of the party.[543] It is even mentioned that Dadieu, together with Seyss-Inquart, tried to prevent the invasion of the German Wehrmacht in the final hours of the ’national uprising’ in order to preserve a certain degree of independence for Austria.

[543] Cf.: DICHAND, GRAZ. 8.1.1988, p. 21 (Part 3).



Nr.	Verlagerte Institute der THG	Ort	Beginn	Zone
1.	Anorganisch-technische und analytische Chemie (Müller)	Turrach tw. MHS Leoben	11. 1944 11. 1944	br su
2.	Darst. Geometrie (Horninger)	Freilassing, Bayern	04. 1945	am
3.	Elektromaschinenbau (Höpp)	Gstatterboden	?	am
4.	Festigkeitslehre (Pirkl)	Gröbming	02. 1945	am
5.	Maschinenelemente (Steller)	Öblarn, Schloß Gstatt	12. 1945	am
6.	Mechanische Technologie — Werkstoffkunde (Slattenschek)	Liezen tw. Graz, Bürgerg. 4	01. 1945 09. 1944	am su
7.	Mechanische Technologie — Werkzeugmaschinen (Härtel)	Gusen, OÖ. (geplant, keine Durchführung)	—	—
8.	Mikrochemie und Geochemie (Hecht)	Grundlsee, Villa Karajan tw. Neuhofen, NÖ.	02. 1945 ?	am su
9.	Organische Chemie (Seka)	Gstatterboden	01. 1945	am
10.	Physik (Kohlrausch)	Hörgas bei Gratwein	09. 1943	su
11.	Physikalische Chemie — Abt. der THG (Dadieu)	Gstatterboden	?	am
12.	Städtebau (Hoffmann)	Übelbach (nur Pläne usw.)	04. 1945	su
13.	Straßenbau (Gottstein)	?	01. 1945	?
14.	Strömungslehre (Winter)	?	?	?
15.	Strömungsmaschinen (Lindner)	?	?	?
16.	Techn. Biochemie (Gorbach)	Gaishorn	?	su
17.	Technische Mechanik (Federhofer)	Perg, OÖ. Schloß Auhof tw. Gusen, OÖ.	12. 1944 12. 1944	am am
18.	Verbrennungskraftmaschinen (Pischinger)	Klaus, OÖ. tw. Gusen, OÖ. (Werkst.)	12. 1944 01. 1945	am am
19.	Wasserbau (Schoklitsch)	Liezen	01. 1945	am
20.	Wärmetechnik (Engel)	Gstatterboden	?	am

Abb. 30: Übersicht über bekannte Institutsverlagerungen und Besatzungszonenzugehörigkeit der jeweiligen Orte bis zur Zonenfestlegung im Juli 1945. Nach dem Bombardement im November 1944 wurden vom zuständigen Außenstellenleiter des Reichsplanungsamtes, Prof. Dr. Adolf Härtel, viele Institute der THG — mindestens 20 von 32 — verlagert. Bei Kriegsende befanden sich die meisten davon in den alliierten Besatzungszonen. Wie die Karte der fünffach besetzten Steiermark zeigt, befanden sich 9 verlagerte Institute (Nr. 1, 3 — 6, 8, 9, 19 u. 20) und ein Institutsteil (Nr. 11) in der amerikanischen bzw. britischen, und nur 2 verlagerte Institute (Nr. 10 u. 16) und 2 Institutsteile (Nr. 1 u. 12) in der sowjetischen Zone.

Figure D.756: Some wartime research sites in southeastern Austria, including Hörgas and Gstatterboden [Weingand 1995, pp. 60–61; https://diglib.tugraz.at/die-technische-hochschule-graz-im-dritten-reich-1995].

Letter from J. Edgar Hoover to Harry Hopkins. 9 February 1945. Franklin Delano Roosevelt Library, Hyde Park, New York. Small Collections, Box 1, Folder 3, ATOMIC BOMB FILE. https://blog.nuclearsecrecy.com/wp-content/uploads/2013/09/1945-Hoover-to-Hopkins-German-spies.pdf

As you are well aware, the Army for the past two years has been vitally interested in a highly secret project for the development of an atomic explosive. This explosive, as you know, involves the release of energy through the shattering of atoms of heavy elements.

During the period that the Army has been engaged in the supervision of this experimentation, numerous efforts have been made by the Soviets to obtain the highly secret information concerning the experimentation and this Bureau has been actively following such Soviet efforts.

The German Government has also been interested in the same type of experimentation in Germany and has attempted to get information regarding the atomic experimentation in the United States.

Recently, in connection with the operation of a radio station by a German agent under control of the Federal Bureau of Investigation but which station the Germans believe to be a free station, an inquiry was received from Germany containing the following questions regarding the status of atomic explosive experimentation in the United States:

> First, where is heavy water being produced? In what quantities? What method? Who are users?
>
> Second, in what Laboratories is work being carried on with large quantities of uranium? Did accidents happen there? What does the protection against Neutronic Rays consist of in these Laboratories? What is the material and the strength of coating?
>
> Third, is anything known concerning the production of bodies or molecules out of metallic uranium rods, tubes, plates? Are these bodies provided with coverings for protection? Of what do these coverings consist?

We have already advised the appropriate authorities in the War Department concerning these German inquiries.

I thought the foregoing would be of considerable interest to the President.

[The Germans sounded very concerned about criticality accidents with large quantities of unshielded uranium housed in the same laboratory. That is generally only a problem with highly enriched uranium, and suggests that the Germans may have had large quantities of highly enriched uranium and may have already had a criticality accident. See p. 4626 for a report of what sounds like a criticality accident.]

PW Intelligence Bulletin 1/47, 13 March 1945 [NARA RG 165, Entry NM84-79, Box 1915]. See document photo with diagram on p. 2622.

17. Uranium Explosive

O/Lt GOTT, a chemist, OC coy in PW's bn (959 Gren Regt) had been granted indefinite leave to resume his former position as director of a chemical laboratory in S Germany. This laboratory was experimenting with uranium. It produced 1/10 milligram of an explosive which, when accidentally set off, destroyed the plant and killed the scientists engaged in the experiments. O/Lt GOTT maintained that if subsequent experiments and production have proceeded without accident, enough of the explosive should now (Feb 45) be available to "destroy England in one blow".

(Source: Lt Helmut SCHWOTZER 959 Gren Regt captured 25 Feb vic WELLDORF)

[This is a description of a laboratory somewhere in southern Germany that was enriching uranium—producing and accumulating enough uranium (235) for novel highly explosive weapons to attack the United Kingdom (and perhaps other Allied targets).

The laboratory had what sounds like a criticality accident. The interpretation of the PW's remarks that seems to make the most scientific sense is that the accident released an energy equivalent to 1/10 milligram of mass converted to energy. Using $E = mc^2$ and converting to the equivalent energy of tons of TNT, 1/10 milligram of mass would correspond to $(10^{-7}\text{ kg})(3 \cdot 10^8\text{ m/s})^2/(4.184 \cdot 10^9\text{ J/ton TNT}) = 2$ tons of TNT. That would certainly be enough explosive energy to destroy a laboratory, and that explosive energy plus the accompanying radiation would kill any personnel at the site.]

See p. 4625 for German concern about criticality accidents. Since the German nuclear weapons program was so highly compartmentalized and secretive, personnel who were producing and accumulating enriched uranium may not have been informed about the risk of criticality accidents and about safety precautions necessary to prevent them.

Wilhelm Haus, letter from the Wetzlar Court Prison to the Chairman of the 1st Criminal Chamber of the District Court in Limburg on 20 June 1947. Hessian Hauptstaatsarchiv Wiesbaden, section 463, number 920, pp. 109–112. [Porezag 1996, p. 46]

Etwa Anfang Februar 1945 erzählte mir der damalige Wehrkreisbeauftragte, Ingenieur Marsch aus Gießen, im Beisein meines damaligen ständigen Kreiswirtschaftsberaters, Dr. Hans Hensoldt, in meinem Dienstzimmer von neuen Waffen und dem 'Schweren Wasser', welche bald eingesetzt werden sollten und kriegsentscheidend wären.

Ebenfalls im Februar 1945 besuchte mich der Oberingenieur Coenders von den Röchling-Werken im Buro. Er erzählte mir von neuen Waffen, die aber nicht vor April eingesetzt werden könnten. Herr Coenders war öfters beim Führer gewesen und hatte den ersten Fritz-Todt-Preis erhalten, so daß ich des Glaubens sein konnte: Der Mann weiß sehr viel. Auch er sprach vom Sieg.

Am 26. März 1945 abends erschien auf meiner Dienststelle der damalige Gauamtsleiter von Koblenz, Andreas Bang. Er zeigte mir ein Flugblatt, welches über dem Westerwald und dem Siegerland abgeworfen wurde. Dieses Flugblatt vom Oberkommando der Deutschen Wehrmacht forderte die Bevölkerung auf, eine Zone von 50 km vom Rhein zu räumen, da mit dem 1. April neue, kriegsentscheidende Waffen eingesetzt würden, die den deutschen Sieg verbürgten. Ein gleiches Flugblatt wurde mir am 28.3.45 in Frankenberg/Eder gezeigt.

Hätte ich eine deutsche Niederlage vor Augen gehabt, hätte ich den Befehl zur Vollstreckung des Standgerichtsurteils wohl nicht befolgt, denn bei einer Niederlage hätte ich keine Folgen wegen Nichtbeachtung eines gegebenen Befehls zu fürchten brauchen.

Around the beginning of February 1945, in my office in the presence of my former ever-present economic council adviser, Dr. Hans Hensoldt, the then Military District Supervisor, Engineer Marsch from Giessen, told me about new weapons and 'heavy water' that were supposed to be used soon and would be decisive for the war.

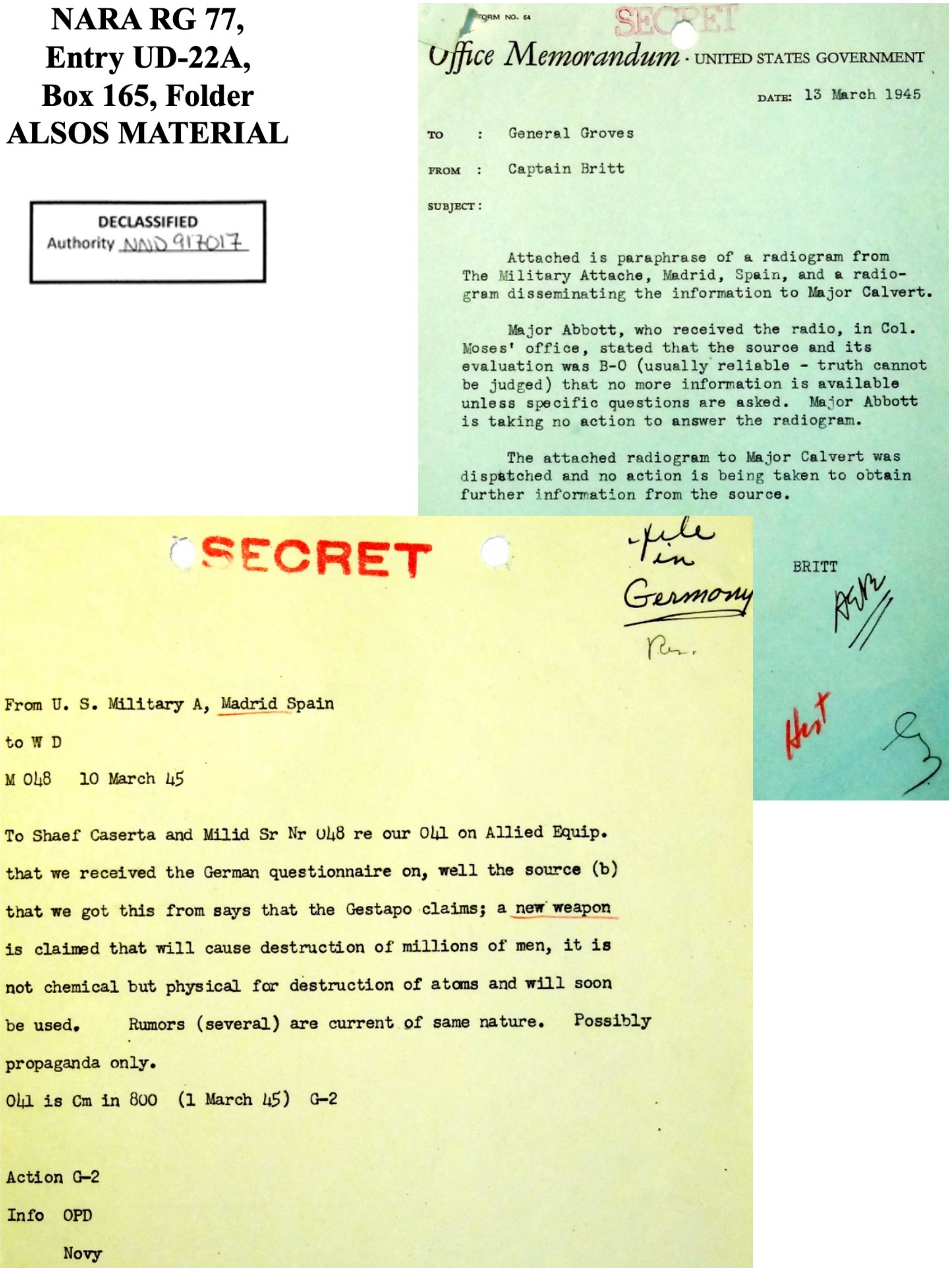
Also in February 1945, I was visited in my office by Chief Engineer Coenders from the Röchling factory. He told me about new weapons which however could not be used before April. Mr. Coenders had often been with the Führer and had received the first Fritz Todt Prize, so I could be sure: The man knows a lot. He also spoke of victory.

On the evening of 26 March 1945, the then Office Head of Koblenz, Andreas Bang, appeared in my office. He showed me a leaflet, which had been dropped over the Westerwald and Siegerland regions. This leaflet from the High Command of the German Armed Forces urged the population to clear a zone of 50 km from the Rhine, as on April 1, new war-decisive weapons would be used, which would guarantee German victory. A similar leaflet was shown to me on 28 March 1945 in Frankenberg/Eder.

If I had envisioned a German defeat, I would probably not have followed the order for enforcing the court-martial's judgment, because in a defeat I would have had no need to fear consequences for non-compliance of a given instruction.

**NARA RG 77,
Entry UD-22A,
Box 165, Folder
ALSOS MATERIAL**

DECLASSIFIED
Authority NND 917017



FORM NO. 64

SECRET

Office Memorandum · UNITED STATES GOVERNMENT

DATE: 13 March 1945

TO : General Groves

FROM : Captain Britt

SUBJECT :

Attached is paraphrase of a radiogram from The Military Attache, Madrid, Spain, and a radiogram disseminating the information to Major Calvert.

Major Abbott, who received the radio, in Col. Moses' office, stated that the source and its evaluation was B-0 (usually reliable - truth cannot be judged) that no more information is available unless specific questions are asked. Major Abbott is taking no action to answer the radiogram.

The attached radiogram to Major Calvert was dispatched and no action is being taken to obtain further information from the source.

BRITT

file in Germany
Res.

Hist

SECRET

From U. S. Military A, Madrid Spain

to W D

M 048 10 March 45

To Shaef Caserta and Milid Sr Nr 048 re our 041 on Allied Equip. that we received the German questionnaire on, well the source (b) that we got this from says that the Gestapo claims; a new weapon is claimed that will cause destruction of millions of men, it is not chemical but physical for destruction of atoms and will soon be used. Rumors (several) are current of same nature. Possibly propaganda only.

041 is Cm in 800 (1 March 45) G-2

Action G-2
Info OPD
Novy

Figure D.757: Left: U.S. Military Attaché, Madrid. 10 March 1945. “The Gestapo claims... a new weapon is claimed that will cause destruction of millions of men, it is not chemical but physical for destruction of atoms and will soon be used.” Right: A. E. Britt to Leslie Groves. 13 March 1945 [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

U.S. Military Attaché Madrid. 4 April 1945. Destruction of the Atom as German Secret Weapon. [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL] [See document photos on pp. 4630– 4631. See also p. 4628.]

A member of the Gestapo in Madrid early in March stated that the Germans would soon use a new secret weapon for smashing the atom by physical means which would cause the death of millions of people.

2. Upon further investigation of source of above information, it was ascertained that informant was under the influence of liquor when he made his statement and our contact expressed the belief that it might readily be propaganda.

3. Rumors concerning the use of atom destruction as a weapon have recurred frequently since October 1944. It is reliably reported that during recent weeks, the subject has been frequently discussed in the German Embassy in Madrid. [...]

5. In August, 1944, Dr. Schmidt Losberg, one of the directing heads of the Speer organization in Germany, informed contact that atom destruction was the third project under study for secret weapons and that experiments were being made by I. G. Farben Industry and the more important electric manufacturing companies such as AEG and Siemens-Halske. The first project was the use of V1 and V2 bombs with possible distance development to bomb the United States. The second project was the use of bacteria and gas. [...] Secret experiments were being conducted by the SS in forests located somewhere in Germany. [...]

COMMENT: It is reported (C-2) that on 27 March, a "pep talk" was given to the Staff at the Germany Embassy urging them not to be discouraged by present Allied successes. The tide would soon change, it was said and the German High Command was only waiting for the right moment to turn loose a secret weapon of such devastating effect against the Allied Armies that ultimate German victory was assured. This talk may have been for propaganda.

A similar report has come from Bilbao that German sympathizers there have been told that a new secret terrifying weapon would soon be used and that Germans has been warned to prepare to use gas masks if the Allies retaliate with gas.

According to a "B" source on 31 March, Lieut. General Kramer, German Air Attaché in Madrid told Lindenberg, head of the Lufthansa in Spain, that preparations had been completed for use of an atom destroying bomb. Lindenberg did not believe this possible.

[This document contains details that agree with many other sources quoted in this appendix:

- Several independent sources within this document reported the development of German nuclear weapons.
- Reports of a German atomic bomb greatly intensified beginning in October 1944, which coincided with the first successful test explosion of a prototype atomic bomb (Section D.10).
- Germany had been spending the months since then working to produce enough atomic bombs to use them in a strategic strike against Allied targets.
- The development of German atomic bombs was a huge industrial program involving companies such as I. G. Farben, AEG, and Siemens-Halske.
- The German government feared that if they did use their atomic bombs, the Allies would retaliate with a devastating chemical attack on the German populace.]

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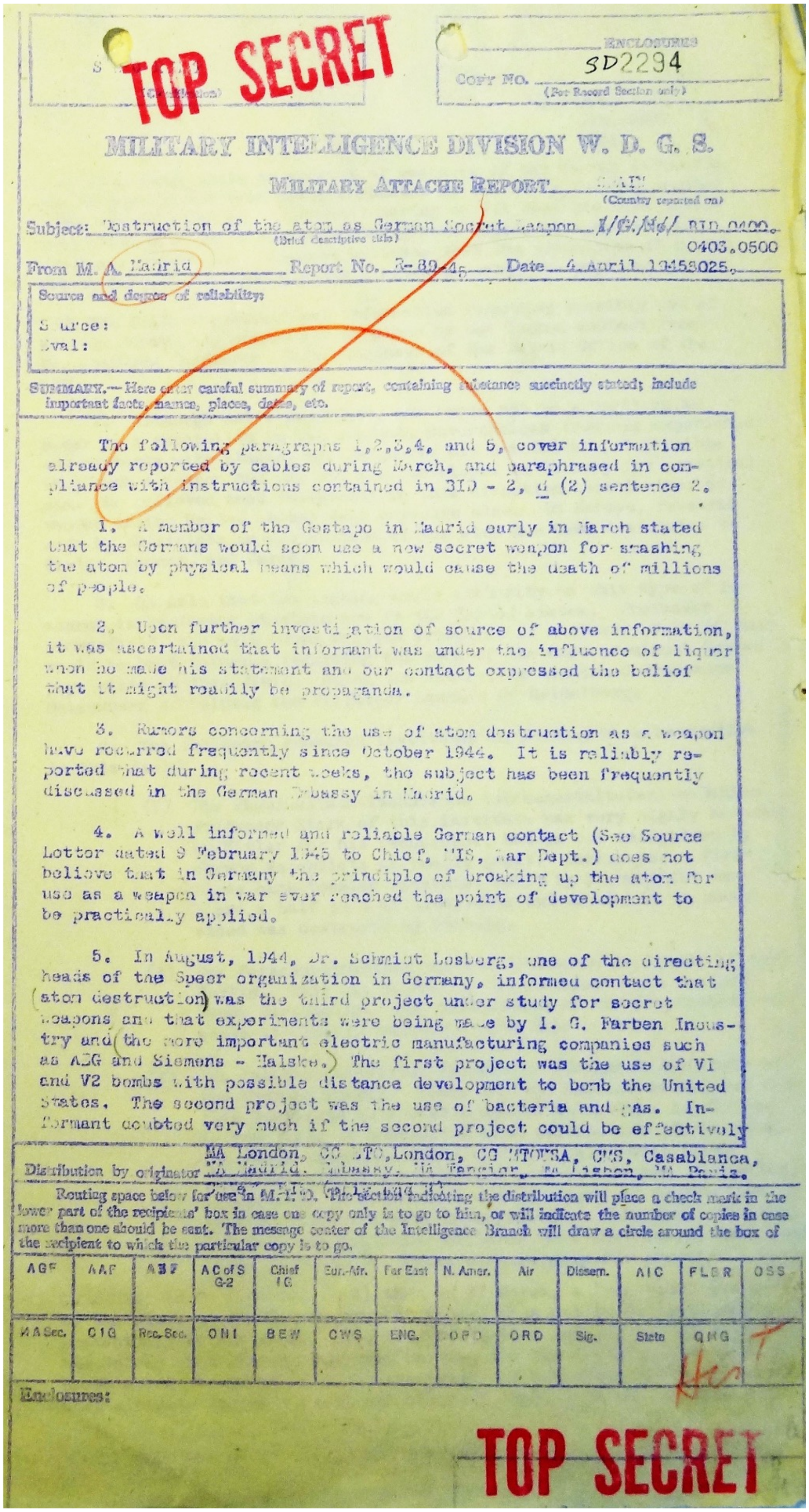
Authority NND917017

NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL



S
(Classification)

TOP SECRET

ENCLOSURES
COPY NO. SD2294
(For Record Section only)

MILITARY INTELLIGENCE DIVISION W. D. G. S.

MILITARY ATTACHE REPORT SPAIN
(Country reported on)

Subject: Destruction of the atom as German Secret Weapon 1/G/M/ BID 0400. 0403.0500
(Brief descriptive title)

From M. A. Madrid Report No. R-89-45 Date 4 April 1945 8025.

Source and degree of reliability:

Source:
Eval:

SUMMARY.—Here enter careful summary of report, containing substance succinctly stated; include important facts, names, places, dates, etc.

The following paragraphs 1,2,3,4, and 5, cover information already reported by cables during March, and paraphrased in compliance with instructions contained in BID - 2, d (2) sentence 2.

1. A member of the Gestapo in Madrid early in March stated that the Germans would soon use a new secret weapon for smashing the atom by physical means which would cause the death of millions of people.

2. Upon further investigation of source of above information, it was ascertained that informant was under the influence of liquor when he made his statement and our contact expressed the belief that it might readily be propaganda.

3. Rumors concerning the use of atom destruction as a weapon have recurred frequently since October 1944. It is reliably reported that during recent weeks, the subject has been frequently discussed in the German Embassy in Madrid.

4. A well informed and reliable German contact (See Source Letter dated 9 February 1945 to Chief, MIS, War Dept.) does not believe that in Germany the principle of breaking up the atom for use as a weapon in war ever reached the point of development to be practically applied.

5. In August, 1944, Dr. Schmidt Losberg, one of the directing heads of the Speer organization in Germany, informed contact that (atom destruction) was the third project under study for secret weapons and that experiments were being made by I. G. Farben Industry and (the more important electric manufacturing companies such as AEG and Siemens - Halske.) The first project was the use of VI and V2 bombs with possible distance development to bomb the United States. The second project was the use of bacteria and gas. Informant doubted very much if the second project could be effectively

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Figure D.758: U.S. Military Attaché Madrid. 4 April 1945. Destruction of the Atom as German Secret Weapon [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

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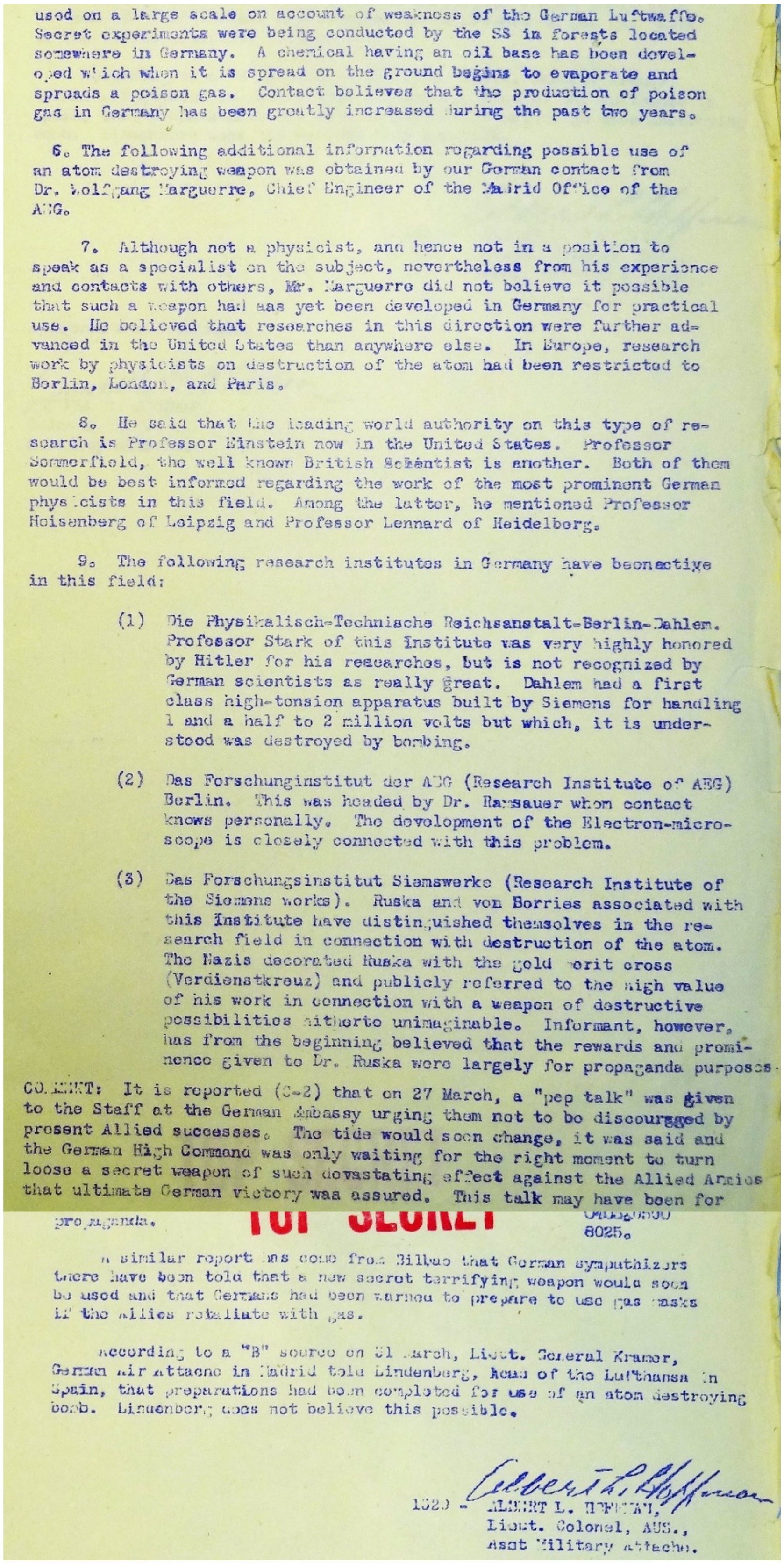


used on a large scale on account of weakness of the German Luftwaffe. Secret experiments were being conducted by the SS in forests located somewhere in Germany. A chemical having an oil base has been developed which when it is spread on the ground begins to evaporate and spreads a poison gas. Contact believes that the production of poison gas in Germany has been greatly increased during the past two years.

6. The following additional information regarding possible use of an atom destroying weapon was obtained by our German contact from Dr. Wolfgang Marguerre, Chief Engineer of the Madrid Office of the AEG.

7. Although not a physicist, and hence not in a position to speak as a specialist on the subject, nevertheless from his experience and contacts with others, Mr. Marguerre did not believe it possible that such a weapon had aas yet been developed in Germany for practical use. He believed that researches in this direction were further advanced in the United States than anywhere else. In Europe, research work by physicists on destruction of the atom had been restricted to Berlin, London, and Paris.

8. He said that the leading world authority on this type of research is Professor Einstein now in the United States. Professor Sommerfield, the well known British Scientist is another. Both of them would be best informed regarding the work of the most prominent German physicists in this field. Among the latter, he mentioned Professor Heisenberg of Leipzig and Professor Lennard of Heidelberg.

9. The following research institutes in Germany have beenactive in this field:

(1) Die Physikalisch-Technische Reichsanstalt-Berlin-Dahlem. Professor Stark of this Institute was very highly honored by Hitler for his researches, but is not recognized by German scientists as really great. Dahlem had a first class high-tension apparatus built by Siemens for handling 1 and a half to 2 million volts but which, it is understood was destroyed by bombing.

(2) Das Forschunginstitut der AEG (Research Institute of AEG) Berlin. This was headed by Dr. Ramsauer whom contact knows personally. The development of the Electron-microscope is closely connected with this problem.

(3) Das Forschungsinstitut Siemswerke (Research Institute of the Siemens works). Ruska and von Borries associated with this Institute have distinguished themselves in the research field in connection with destruction of the atom. The Nazis decorated Ruska with the gold Merit cross (Verdienstkreuz) and publicly referred to the high value of his work in connection with a weapon of destructive possibilities hitherto unimaginable. Informant, however, has from the beginning believed that the rewards and prominence given to Dr. Ruska were largely for propaganda purposes.

COMMENT: It is reported (C-2) that on 27 March, a "pep talk" was given to the Staff at the German Embassy urging them not to be discourgged by present Allied successes. The tide would soon change, it was said and the German High Command was only waiting for the right moment to turn loose a secret weapon of such devastating effect against the Allied Armies that ultimate German victory waa assured. This talk may have been for propaganda.

8025.

A similar report has come from Bilbao that German sympathizers there have been told that a new secret terrifying weapon would soon be used and that Germans had been warned to prepare to use gas masks if the Allies retaliate with gas.

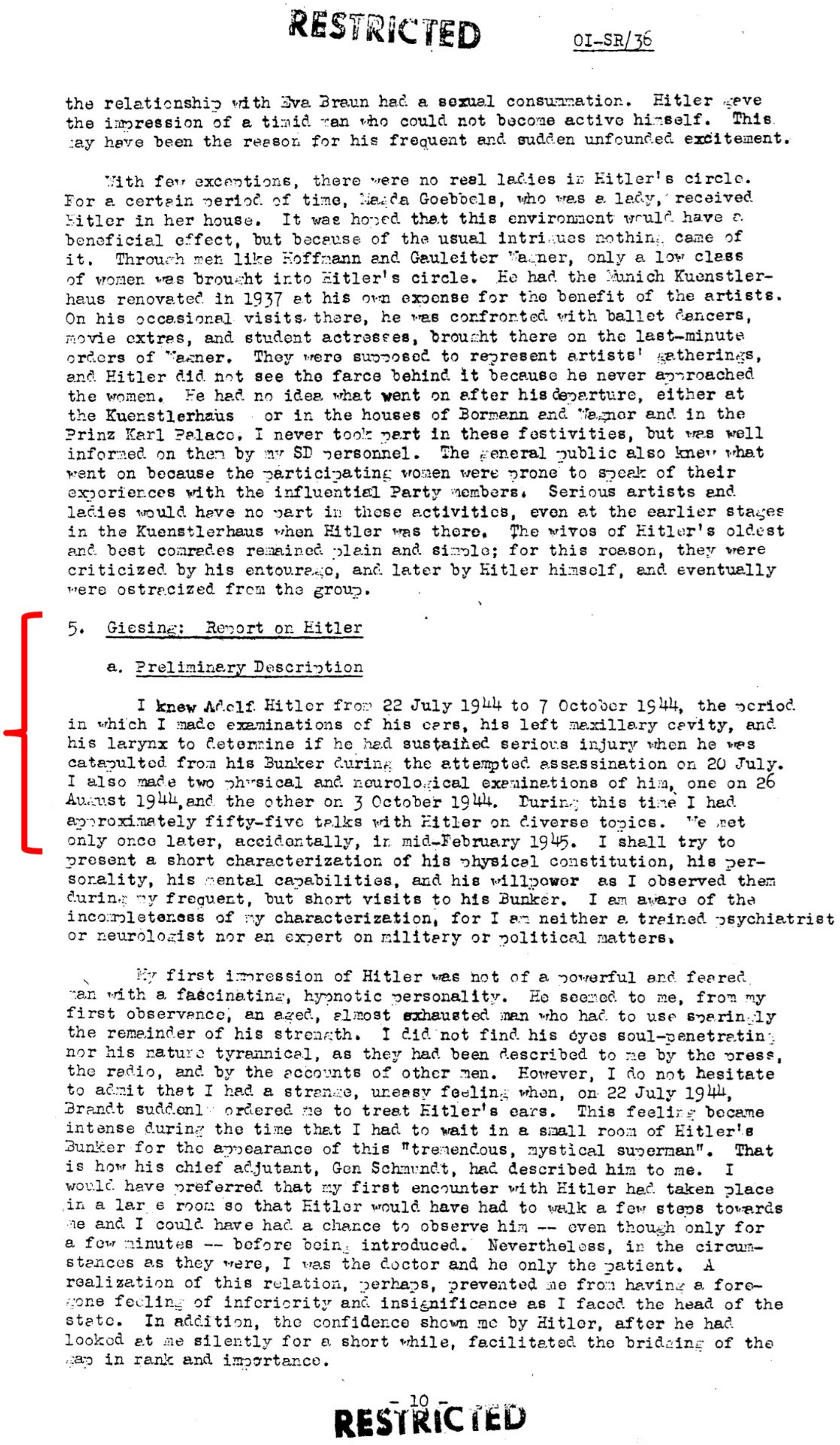
According to a "B" source on 31 March, Lieut. General Kramer, German Air Attache in Madrid told Lindenberg, head of the Lufthansa in Spain, that preparations had been completed for use of an atom destroying bomb. Lindenberg does not believe this possible.

Albert L. Hoffman

1520 - ALBERT L. HOFFMAN,
Lieut. Colonel, AUS.,
Asst Military Attache.

NARA RG 77, Entry UD-22A,
Box 165, Folder ALSOS MATERIAL

Figure D.759: U.S. Military Attaché Madrid. 4 April 1945. Destruction of the Atom as German Secret Weapon [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].



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the relationship with Eva Braun had a sexual consummation. Hitler gave the impression of a timid man who could not become active himself. This may have been the reason for his frequent and sudden unfounded excitement.

With few exceptions, there were no real ladies in Hitler's circle. For a certain period of time, Magda Goebbels, who was a lady, received Hitler in her house. It was hoped that this environment would have a beneficial effect, but because of the usual intrigues nothing came of it. Through men like Hoffmann and Gauleiter Wagner, only a low class of women was brought into Hitler's circle. He had the Munich Kuenstlerhaus renovated in 1937 at his own expense for the benefit of the artists. On his occasional visits there, he was confronted with ballet dancers, movie extras, and student actresses, brought there on the last-minute orders of Wagner. They were supposed to represent artists' gatherings, and Hitler did not see the farce behind it because he never approached the women. He had no idea what went on after his departure, either at the Kuenstlerhaus or in the houses of Bormann and Wagner and in the Prinz Karl Palace. I never took part in these festivities, but was well informed on them by my SD personnel. The general public also knew what went on because the participating women were prone to speak of their experiences with the influential Party members. Serious artists and ladies would have no part in these activities, even at the earlier stages in the Kuenstlerhaus when Hitler was there. The wives of Hitler's oldest and best comrades remained plain and simple; for this reason, they were criticized by his entourage, and later by Hitler himself, and eventually were ostracized from the group.

5. Giesing: Report on Hitler

a. Preliminary Description

I knew Adolf Hitler from 22 July 1944 to 7 October 1944, the period in which I made examinations of his ears, his left maxillary cavity, and his larynx to determine if he had sustained serious injury when he was catapulted from his Bunker during the attempted assassination on 20 July. I also made two physical and neurological examinations of him, one on 26 August 1944, and the other on 3 October 1944. During this time I had approximately fifty-five talks with Hitler on diverse topics. We met only once later, accidentally, in mid-February 1945. I shall try to present a short characterization of his physical constitution, his personality, his mental capabilities, and his willpower as I observed them during my frequent, but short visits to his Bunker. I am aware of the incompleteness of my characterization, for I am neither a trained psychiatrist or neurologist nor an expert on military or political matters.

My first impression of Hitler was not of a powerful and feared man with a fascinating, hypnotic personality. He seemed to me, from my first observance, an aged, almost exhausted man who had to use sparingly the remainder of his strength. I did not find his eyes soul-penetrating nor his nature tyrannical, as they had been described to me by the press, the radio, and by the accounts of other men. However, I do not hesitate to admit that I had a strange, uneasy feeling when, on 22 July 1944, Brandt suddenly ordered me to treat Hitler's ears. This feeling became intense during the time that I had to wait in a small room of Hitler's Bunker for the appearance of this "tremendous, mystical superman". That is how his chief adjutant, Gen Schmundt, had described him to me. I would have preferred that my first encounter with Hitler had taken place in a large room so that Hitler would have had to walk a few steps towards me and I could have had a chance to observe him -- even though only for a few minutes -- before being introduced. Nevertheless, in the circumstances as they were, I was the doctor and he only the patient. A realization of this relation, perhaps, prevented me from having a foregone feeling of inferiority and insignificance as I faced the head of the state. In addition, the confidence shown me by Hitler, after he had looked at me silently for a short while, facilitated the bridging of the gap in rank and importance.

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F. J. Trauttsmansdorff. March 1947. OI Special Report 36:
Adolf Hitler: A Composite Picture. Military Intelligence Service Center.
https://www.cia.gov/readingroom/docs/OSS%20-%20SSU%20-
%20CIG%20EARLY%20CIA%20DOCUMENTS%20%20%20VOL.%205_0008.pdf

Figure D.760: F. J. Trauttsmansdorff. March 1947. OI Special Report 36: Adolf Hitler: A Composite Picture. Military Intelligence Service Center.

F. J. Trauttsmansdorff. March 1947. OI Special Report 36:
Adolf Hitler: A Composite Picture. Military Intelligence Service Center.
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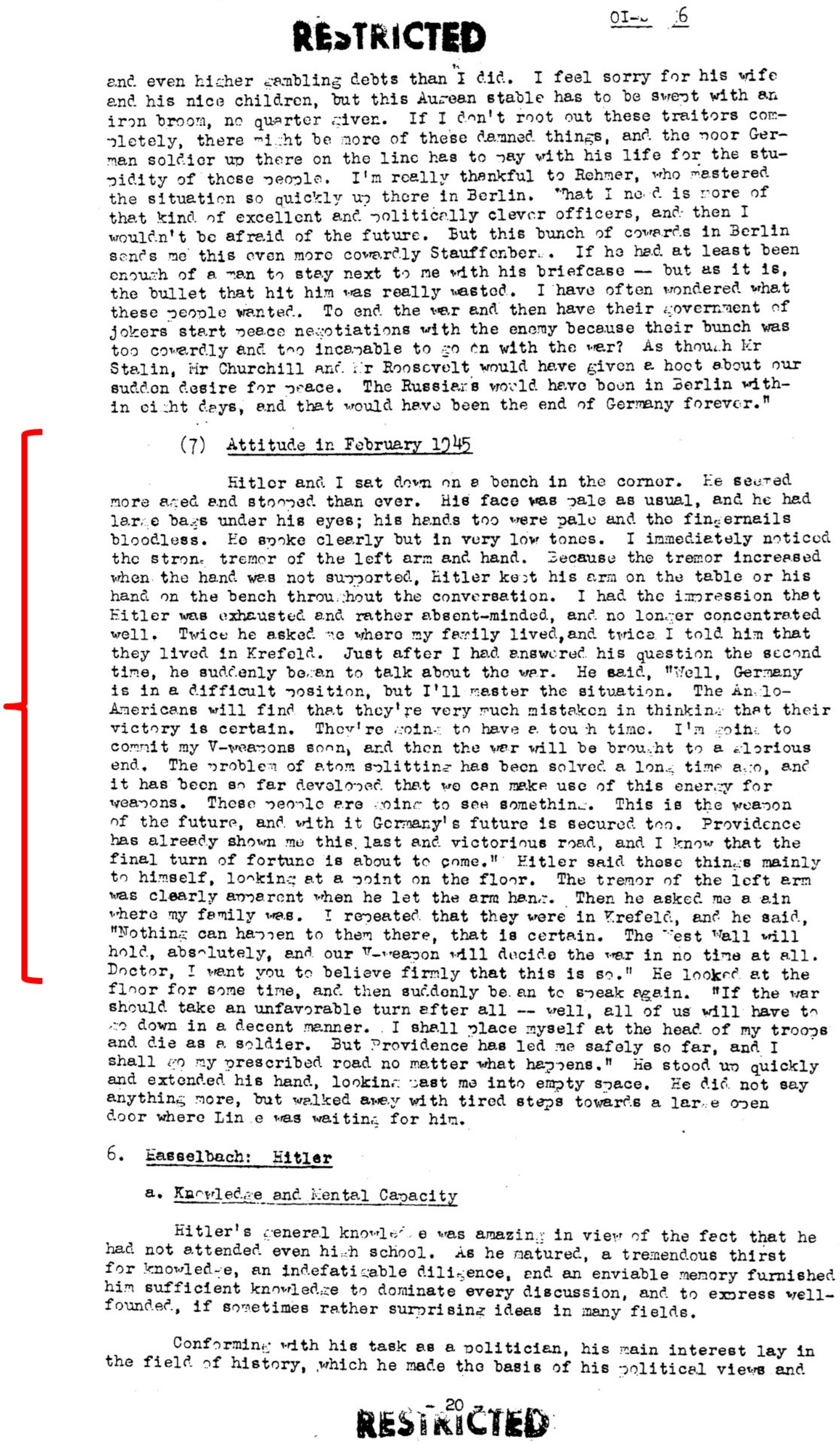

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and even higher gambling debts than I did. I feel sorry for his wife and his nice children, but this Augean stable has to be swept with an iron broom, no quarter given. If I don't root out these traitors completely, there might be more of these damned things, and the poor German soldier up there on the line has to pay with his life for the stupidity of those people. I'm really thankful to Rehmer, who mastered the situation so quickly up there in Berlin. What I need is more of that kind of excellent and politically clever officers, and then I wouldn't be afraid of the future. But this bunch of cowards in Berlin sends me this even more cowardly Stauffenberg. If he had at least been enough of a man to stay next to me with his briefcase — but as it is, the bullet that hit him was really wasted. I have often wondered what these people wanted. To end the war and then have their government of jokers start peace negotiations with the enemy because their bunch was too cowardly and too incapable to go on with the war? As though Mr Stalin, Mr Churchill and Mr Roosevelt would have given a hoot about our sudden desire for peace. The Russians would have been in Berlin within eight days, and that would have been the end of Germany forever."

(7) Attitude in February 1945

Hitler and I sat down on a bench in the corner. He seemed more aged and stooped than ever. His face was pale as usual, and he had large bags under his eyes; his hands too were pale and the fingernails bloodless. He spoke clearly but in very low tones. I immedietely noticed the strong tremor of the left arm and hand. Because the tremor increased when the hand was not supported, Hitler kept his arm on the table or his hand on the bench throughout the conversation. I had the impression that Hitler was exhausted and rather absent-minded, and no longer concentrated well. Twice he asked me where my family lived, and twice I told him that they lived in Krefeld. Just after I had answered his question the second time, he suddenly began to talk about the war. He said, "Well, Germany is in a difficult position, but I'll master the situation. The Anglo-Americans will find that they're very much mistaken in thinking that their victory is certain. They're going to have a tough time. I'm going to commit my V-weapons soon, and then the war will be brought to a glorious end. The problem of atom splitting has been solved a long time ago, and it has been so far developed that we can make use of this energy for weapons. These people are going to see something. This is the weapon of the future, and with it Germany's future is secured too. Providence has already shown me this last and victorious road, and I know that the final turn of fortune is about to come." Hitler said these things mainly to himself, looking at a point on the floor. The tremor of the left arm was clearly apparent when he let the arm hang. Then he asked me again where my family was. I repeated that they were in Krefeld, and he said, "Nothing can happen to them there, that is certain. The West Wall will hold, absolutely, and our V-weapon will decide the war in no time at all. Doctor, I want you to believe firmly that this is so." He looked at the floor for some time, and then suddenly began to speak again. "If the war should take an unfavorable turn after all -- well, all of us will have to go down in a decent manner. I shall place myself at the head of my troops and die as a soldier. But Providence has led me safely so far, and I shall go my prescribed road no matter what happens." He stood up quickly and extended his hand, looking past me into empty space. He did not say anything more, but walked away with tired steps towards a large open door where Linge was waiting for him.

6. Hasselbach: Hitler

a. Knowledge and Mental Capacity

Hitler's general knowledge was amazing in view of the fact that he had not attended even high school. As he matured, a tremendous thirst for knowledge, an indefatigable diligence, and an enviable memory furnished him sufficient knowledge to dominate every discussion, and to express well-founded, if sometimes rather surprising ideas in many fields.

Conforming with his task as a politician, his main interest lay in the field of history, which he made the basis of his political views and

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Figure D.761: F. J. Trauttsmansdorff. March 1947. OI Special Report 36: Adolf Hitler: A Composite Picture. Military Intelligence Service Center.

F. J. Trauttsmansdorff. March 1947. OI Special Report 36: Adolf Hitler: A Composite Picture. Military Intelligence Service Center. [See document photos on pp. 4632–4633.] https://www.cia.gov/readingroom/docs/OSS%20-%20SSU%20-%20CIG%20EARLY%20CIA%20DOCUMENTS%20%20%20VOL.%205_0008.pdf

Giesing, Erwin Oberstabsarzt in charge of EENT clinic in the military hospital at Loetzen, East Prussia. On 22 July 1944, he was called by Brandt to examine Hitler's injuries from the 20 July explosion. He treated Hitler's ears, nose, and throat from July to October 1944. [...]

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[The above passage was translated from Giesing's diary entry for 13–15 February 1945: Erwin Giesing. 1944–1945. Diary. Institut für Zeitgeschichte, Munich. p. 176. https://fpp.co.uk/Hitler/Giesing/]

Monthly Intelligence Summary. March 1945. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

a. In a broadcast by German Home Service the program took the form of two Germans discussing the reasons for the Germans continuing to fight. The following conversation was noted:

> "In the air war a first victory has likewise been won by the German mind over material. The...... retaliation weapon goes on its destructive uncanny way without needing men or a costly return flight...... Do not forget that all these things had to be created at five minutes to twelve out of nothing. We need time to exploit all possibilities, to make them reality. Our enemies know this and this is the point of this gruesome race for time."

It was also recalled that "Hitler once said: 'May God forgive me for the last ten minutes of the war!'"

Henry Picker. 2009. *Hitlers Tischgespräche im Führerhauptquartier.* 2nd ed. Berlin: Propyläen-Taschenbuch bei Ullstein.

[S. 42:] Und um wieviel mehr Tote, Kriegsbeschädigte, Flüchtlinge und Zerstörungen wären zu beklagen gewesen, wenn Hitlers Gegner nicht—wie Churchill sagte—“fünf Minuten vor 12 Uhr” gesiegt gehabt und im Frühjahr 1945 damit Hitlers neue Rundumverteidigung vereitelt hätten. Denn mit den in Peenemünde entwickelten, auch ihre Ziele in den USA erreichenden “Interglobalraketen” A 9 und mit den kleinkürbisgroßen, im Lichterfelder Forschungsamt der Reichspost nach Mitteilung Schaubs bis zur Prototyp-Reife durchkonstruierten “Uraniumbomben” (mit ihrer Vollzerstörungskraft im 3-km-Radius) hätte Hitler, wenn er diese Waffen de facto noch einsatzbereit bekommen hätte, das Leid, die Grausamkeit, die Härte, die Ausdehnung und die Dauer des II. Weltkriegs mit Sicherheit vervielfacht.

[S. 245:] Der durch Treibstoffmangel und Luftunterlegenheit bedingte endgültige Mißerfolg wirkte dann ab Februar 1945 doppelt niederschmetternd auf ihn. Während sein Geist zupackend, sein Namens- und Zahlengedächtnis präsent blieben, wurde er körperlich zum Greis. Nur unter Aufbietung aller Kräfte bewegte er sich—aschgrau im Gesicht, mit dicken Tränensäcken unter glanzlosen Augen—fast schleppend durch die Räume seines letzten FHQu, der Berliner Reichskanzlei. Auf seine neuen Waffen, insbesondere die Uraniumbombe hoffend, stimulierte aber immer noch der Glaube an seine “Mission” ein erstaunliches Durchhaltevermögen bei ihm. Noch am 11. März 1945 besuchte er die Oderfront und bemühte sich, sie mit Durchhalteparolen zum Standhalten zu bringen.

[p. 42:] And how much more death, war damage, refugees, and destruction would have been the result if Hitler’s opponents had not won—as Churchill said—“five minutes before midnight” and thus thwarted Hitler’s new end-run defense in the spring of 1945. For with the A-9 “interglobal rockets” developed in Peenemünde, which also reached their targets in the USA, and with the small-pumpkin-sized “uranium bombs” (with their full destructive energy in a 3-km radius), which according to Schaub’s information had been developed to ready prototypes at the Reichspost’s research office in Lichterfeld, if Hitler had been able to make these weapons actually deployed, the suffering, the cruelty, the harshness, the extension, and the duration of World War II would certainly have been multiplied.

[p. 245:] The final failure caused by lack of fuel and air inferiority had a doubly devastating effect on him from February 1945 onward. While his mind was sharp and his memory for names and numbers remained present, he physically became an old man. Only with the exertion of all his strength did he move—ash gray in the face, with thick bags under dull eyes—almost dragging himself through the rooms of his last Führer Headquarters, the Berlin Reich Chancellery. Hoping for his new weapons, especially the uranium bomb, the belief in his “mission” still stimulated an amazing staying power in him. As late as 11 March 1945, he visited the Oder front and tried to make it hold out with slogans of endurance.

[S. 493:] Hitlers letzter Frontbesuch erfolgte am 11. März 1945 an der mittleren Oderfront in Schloß, Freienwalde bei der 9. Armee. Hitler beschwor den Oberbefehlshaber, General Theodor Busse, und seine Offiziere, den russischen Ansturm auf Berlin wenigstens so lange aufzuhalten, bis seine neuen Waffen einsatzbereit seien. Er verwies auf das Beispiel des Generalfeldmarschalls Ferdinand Schörner, der mit seiner "Heeresgruppe Mitte" Schlesien und den böhmischen Raum mit unverminderter Kampfkraft verteidige. Und er erklärte abschließend: "Jeder Tag und jede Stunde sind kostbar, um die fürchterlichen Waffen fertigzustellen, welche die Wende bringen!"

Mit den "fürchterlichen Waffen" war nach Schaub vor allem die prototypreif durchkonstruierte "Uranium-Bombe" gemeint, die in der Größe eines kleinen Kürbis in einem unterirdischen SS-Werk im Süd-Harz (mit einer Produktionskapazität von 30 000 Arbeitskräften) hergestellt werden sollte. Das Werk wurde 1945 nach der bedingungslosen Kapitulation Deutschlands von der Roten Armee nach der UdSSR verlagert. Die gelegentliche Mitteilung des US-Präsidenten über die amerikanische Entwicklung einer Atombombe tat Stalin daher mit absolutem Desinteresse ab. Den deutschen Atom-Praktiker Manfred von Ardenne aber zeichnete er mit dem damaligen sowjetischen "Nobel"-Preis, dem "Stalinpreis", aus.

[S. 531:] 9. 6. 1942 mittags (Reichskanzlei)

Hitler freute sich über die Rüstigkeit der beiden alten Herren, die beim Essen links und rechts von ihm saßen und die er verstohlen immer wieder betrachtete: Reichsschatzmeister Schwarz und Reichspostminister Ohnesorge.

[p. 493:] Hitler's last visit to the front took place on 11 March 1945, on the middle Oder front in Freienwalde Castle with the 9th Army. Hitler implored the commander-in-chief, General Theodor Busse, and his officers to delay the Russian onslaught on Berlin at least until his new weapons were ready for use. He referred to the example of Field Marshal Ferdinand Schörner, who with his "Central Army Group" defended Silesia and the Bohemian region with undiminished fighting strength. And he concluded: "Every day and every hour is precious to complete the terrible weapons that will bring about the turnaround!"

According to Schaub, the "terrible weapons" meant above all the "uranium bomb" with the size of a small pumpkin which was to be produced in an underground SS plant in the southern Harz region (with a production capacity of 30,000 workers). The plant was relocated to the USSR by the Red Army in 1945 after Germany's unconditional surrender. The statement around that time by the U.S. President about the American development of an atomic bomb was therefore dismissed by Stalin with absolute disinterest. He did, however, award the German nuclear practitioner Manfred von Ardenne with what was then the Soviet "Nobel" Prize, the "Stalin Prize."

[p. 531:] 9 June 1942 noon (Reich Chancellery)

Hitler was pleased with the sprightliness of the two old gentlemen who sat to his left and right during dinner and whom he secretly looked at again and again: Reich Treasurer Schwarz and Reich Post Office Minister Ohnesorge.

Dr. Ohnesorges "Reichspost-Forschungsanstalt" in Berlin-Lichterfelde und Klein-Machnow, wo—parallel zu einem erfolglosen Professoren-Team [Heisenberg et al.]—tatsächlich ein Prototyp der deutschen "Uranium-Bombe" konstruktionsreif entwickelt wurde, stattete Hitler bei Berlin-Aufenthalten Besuche ab, bei denen Dr. Ohnesorge nicht einmal den Hitler begleitenden Militäradjutanten Engel die Forschungsanlagen mit besichtigen ließ. Der 1872 geborene Ohnesorge verstand sich auf Geheimhaltung. Er war im I. Weltkrieg Chef der Telegraphendirektion des Großen Hauptquartiers gewesen. Nach dem Kriege an diversen Oberpostdirektionen tätig, wurde er 1929 Präsident des Reichspostzentralamtes in Berlin-Tempelhof und 1933 Staatssekretär, 1937 Reichsminister im Reichspostministerium. Von Haus aus Mathematiker und Physiker, hatte er als Elektro- und Elektronikspezialist zahlreiche, von aller Welt übernommene Erfindungen gemacht (z. B. die der Fernkabel-Telephonie aufgrund der Vierdrahtschaltung).

At Dr. Ohnesorge's "Post Office Research Institute" in Berlin-Lichterfelde and Klein-Machnow—parallel to an unsuccessful team of professors [Heisenberg et al.]—a prototype of the German "uranium bomb" was actually developed ready for production. Hitler paid visits during which Dr. Ohnesorge did not even let the military adjutant Engel, who accompanied Hitler, visit the research facilities near Berlin. Ohnesorge, born in 1872, was a man who understood secrecy. During World War I, he had been head of the telegraph directorate of the supreme headquarters. After the war, he worked in various senior postal administrations, becoming president of the Post Office Central Department in Berlin-Tempelhof in 1929 and state secretary in 1933, then head of the Post Office Ministry in 1937. A mathematician and physicist by training, he had made numerous inventions as an electrical and electronics specialist that were adopted from all over the world (e.g. the invention of long-distance cable telephony based on the four-wire circuit).

Hitler, der ihn seit 1920 kannte, bewunderte an dem schweigsamen Mann, daß, er aus seinen und seiner Mitarbeiter Erfindungen stets praktisch anwendbare Resultate zu entwickeln verstand. Unter den Mitarbeitern Ohnesorges in der Reichsforschungsanstalt finden sich u. a. solche Kapazitäten wie der Atomphysiker Baron Manfred von Ardenne. Der Uranbrenner in Kummersdorf fiel 1945 in sowjetische Hände. 1 kg Uran 235 entwickelte die Explosionskraft von 20 000 t chemischen Sprengstoffs. Die Amerikaner zündeten den Prototyp ihrer ersten Atombombe am 16. Juli 1945 in New Mexico auf dem Versuchsgelände Alamogordo.

Hitler, who had known him since 1920, admired that the quiet man always knew how to develop practical results from his and his colleagues' inventions. Among Ohnesorge's collaborators at the Reich Research Institute are such experts as the nuclear physicist Baron Manfred von Ardenne. The uranium reactor in Kummersdorf fell into Soviet hands in 1945. 1 kg of uranium-235 developed the explosive energy of 20,000 tons of chemical explosives. The Americans detonated the prototype of their first atomic bomb on 16 July 1945 in New Mexico at the Alamogordo test site.

[S. 586:] Auch die Flüssigstoff-Fernrakete 'Rheinbote' und die USA-Fernrakete A9 waren erst 1945 einsatzbereit.

[p. 586:] Also the liquid-material long-range rocket 'Rheinbote' and the USA long-range rocket A-9 were not operational until 1945. [Rheinbote had solid propellant. Did Picker mean the intended payload was liquid material?]

[S. 683:] Am 7. Juli 1943 empfing Hitler die Erbauer der Weltraum-Rakete V2, den Oberst Walter Dornberger und den Diplomingenieur Wernher Freiherr von Braun, im FHQu, sah voller Begeisterung ihre V-2-Farbfilme und ernannte Dornberger zum Generalmajor und v. Braun zum Professor. Die Ernennungsurkunden unterschrieb er persönlich. Immer wieder betonte er seine Verehrung für den 1894 in Herrmannstadt (Siebenbürgen) geborenen Professor Hermann Oberth, der mit seinen wissenschaftlichen Erkenntnissen und Berechnungen die Flüssigstoffrakete V2 und die späteren Weltraumraketen erst möglich gemacht hatte.

Über 2000 Wissenschaftler und Ingenieure ließ, Hitler für die Entwicklung der Flugkörper-Feststoffrakete V1 und die der Flüssigstoffraketen V2 (= A4) und A9 vom Wehrdienst freistellen. Bis Anfang 1945 wollte er auch die—gegen die USA konstruierte—Fernrakete A-9 serienmäßig und zielsicher einsatzbereit haben. Er hoffte, mit dieser Interkontinental-Rakete die USA "friedensbereit" schießen zu können, zumal wenn er erst einmal den Raketenkopf mit mehreren kleinen Uranium-Bomben hätte bestücken können. Bereits 1943 ließ, er an der Nordspitze der ost-kanadischen Halbinsel Labrador durch U 537 eine Wetterstation hierfür errichten.

Ich habe aus militärischen Geheimhaltungsgründen Hitlers Raketen-Ausführungen seinerzeit nicht mitaufgezeichnet. Hitler äußerte sich z.B. am 5. Mai 1942 recht ärgerlich, daß, die Peenemünder über alle möglichen Erfindungen und Entwicklungen ihre eigentliche Aufgabe, Raketen-Waffen zu bauen, vernachlässigten.

[p. 683:] On July 7, 1943, Hitler received the builders of the V-2 space rocket, Colonel Walter Dornberger and the graduate engineer Wernher Freiherr von Braun, at the Führer Headquarters, watched their V-2 color films with enthusiasm and appointed Dornberger a major general and von Braun a professor. He personally signed the certificates of appointment. Again and again, he emphasized his admiration for Professor Hermann Oberth, born in Herrmannstadt (Transylvania) in 1894, whose scientific knowledge and calculations had made the V-2 liquid fuel rocket and the later space rockets possible in the first place.

Hitler had over 2000 scientists and engineers exempted from military service for the development of the V-1 missile/solid rocket [for launching it] and the liquid fuel rockets V-2 (= A-4) and A-9. Up to early 1945, he also wanted the A-9 long-range rocket, intended against the USA, to be ready for series production and completely operational. He hoped that this intercontinental rocket would make the USA "amenable to peace," especially if he could have equipped the rocket warhead with several small uranium bombs. As early as 1943, he had a weather station built for this purpose [trans-Atlantic guidance] at the northern tip of the eastern Canadian peninsula of Labrador by submarine U-537.

For reasons of military secrecy, I did not record Hitler's rocket plans at the time. Hitler, for example, on 5 May 1942, was quite annoyed that the Peenemünde people, pursuing all kinds of inventions and developments, neglected their actual task of building rocket weapons.

[Henry Picker (German, 1912–1988) was a lawyer whom Hitler invited to attend and take notes on many of his mealtime meetings and conversations. After the war, Picker published those notes, along with his own postwar commentary, as *Hitlers Tischgespräche*, or *Hitler's Table Talk*. Many former officials of the Third Reich vouched for the accuracy of Picker's recollections and comments.]

Picker openly stated that he did not take notes on the more secret meetings, and of course he would have been excluded from many secret meetings. However, through his conversations with Hitler and others within the inner circle, Picker learned the gist of some of the most important secret weapons programs. He mentioned a few details about them, and those details agree well with information from other sources in Appendices D and E:

- Werner Heisenberg's group never even got close to producing a nuclear weapon.
- However, a program that involved Reichspost scientists such as Manfred von Ardenne and was managed by Wilhelm Ohnesorge did produce a prototype uranium fission bomb.
- A 30,000-person underground facility in Thuringia was set up to mass-produce such fission bombs, but was interrupted by the end of the war. The facility had reached a sufficient point of readiness, though, that it was removed by Soviet forces and taken back to the Soviet Union to help start the nuclear weapons program there.
- The nuclear weapons program was so secretive that even one of Hitler's military adjutants, Gerhard Engel (German, 1906–1976) was not allowed to tour the nuclear production facilities. Whatever Engel learned directly or indirectly was likely one of Henry Picker's sources of information. Picker wrote repeatedly that another of his key sources of information on the secret weapons programs was another of Hitler's adjutants, Julius Schaub (German, 1898–1967).
- The uranium fission bomb was approximately the size of a pumpkin. For a spherical fission implosion bomb, the inner nuclear components and the outer conventional explosive components would have been produced separately. While the complete fission implosion bomb would have been much larger than a pumpkin, the inner nuclear core would have been pumpkin-sized. Plausible physics estimates (p. 5157) are that the uranium tamper and the key nuclear components within it would have had a radius of $\sim$11 cm, or a diameter of $\sim$22 cm. If the surrounding aluminum pusher were also included, the radius would have been $\sim$23 cm, or the diameter $\sim$46 cm.
- The fission bomb had a radius of destruction of approximately 3 km, or an explosive yield (p. 5142) of roughly $(3000 \text{ meters}/85.5 \text{ meters})^3$ tons, or $\sim$40 kilotons. That would have been approximately twice the yield of the first U.S. fission bombs.
- The fission bomb was designed to be delivered by a rocket such as the A-9.
- The A-9 rocket was intended to strike targets in the United States. To achieve that sort of range, the A-9 would have had to be launched on top of a larger A-10 first stage. Thus whenever Picker mentioned the A-9, he was apparently referring to the complete A-9/A-10 intercontinental rocket.
- Prototypes of the A-9/A-10 rocket were completed and ready for launch before the war ended.
- Mass-production of the A-9/A-10 was planned and facilities were built, but those operations were interrupted by the end of the war.
- Hitler considered it vital for the German military to hold geographical areas that were closely associated with the nuclear weapons and intercontinental rocket programs until those weapons could be used. Those areas included Silesia, Bohemia, Thuringia, and the Berlin area.]

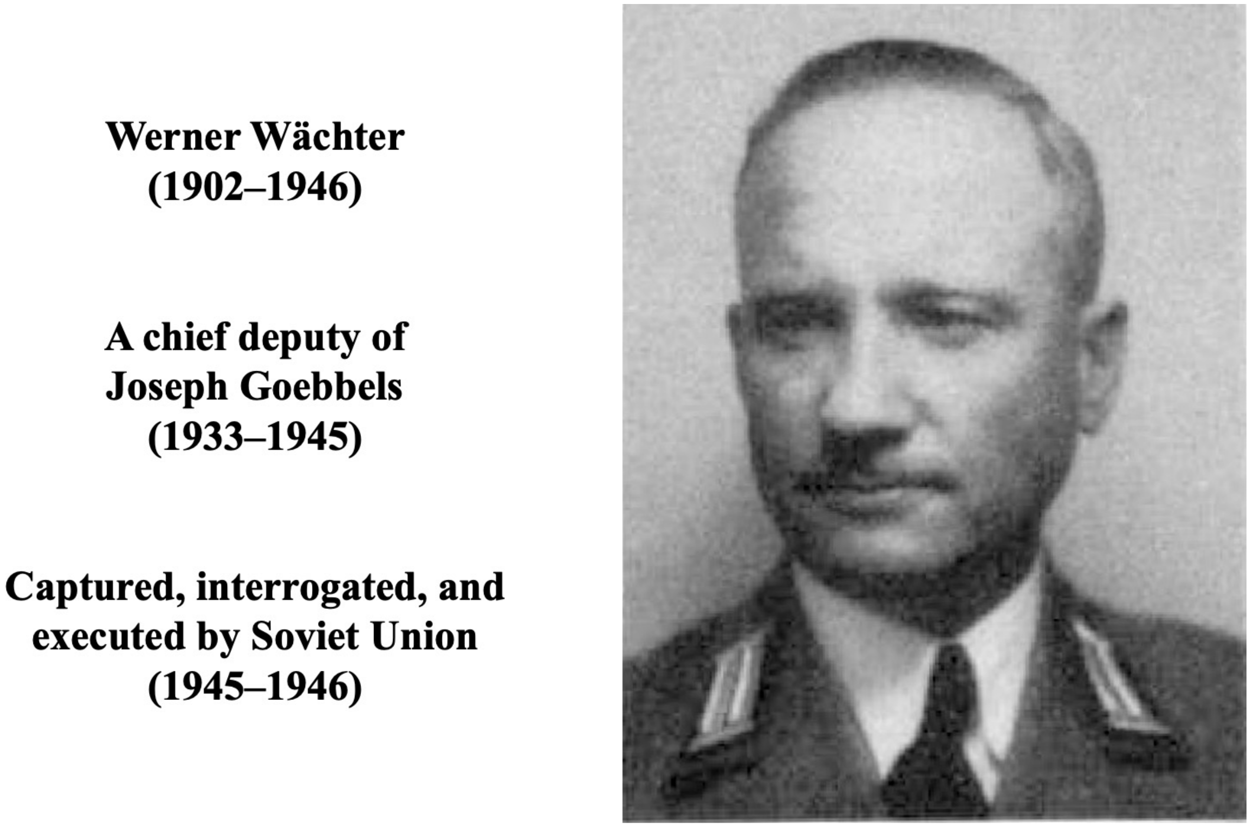

Figure D.762: Werner Wächter, one of the chief deputies of Joseph Goebbels.

[The following pages present original Russian reports (plus English translations) regarding postwar Soviet interrogations of Werner Wächter. Wächter (born in 1902) was one of the chief deputies of Joseph Goebbels from the 1930s until the end of the war. In September 1945, he was captured by Aleksei Sidnev, head of Soviet NKVD forces in Berlin. Wächter was interrogated in September by Sidnev and again in October 1945 by Sidnev's NKVD boss, Ivan Serov. Wächter was executed by the Soviet Union in 1946.

During World War II, Wächter had a high-ranking and well-connected position, and (according to these interrogations) he received information from multiple official and unofficial channels that:

- Germany had a large program throughout the war to develop nuclear weapons and by 1943 was already very close to attaining its first nuclear weapon.
- By the end of the war in Europe, Germany possessed a significant number of nuclear weapons, and it was on the verge of using them against several targets in the Soviet Union and the United States when the war ended.
- Long-range bombers capable of transporting atomic bombs to the United States and deep into the Soviet Union had been constructed.
- A number of these long-range bombers were actually stationed at an airfield near Celle (a documented German nuclear site) and also "were concentrated at other airfields."
- Rockets more advanced than the standard V-2 (A-4), capable of carrying an atomic bomb and traveling from Germany to the United States, were under development and almost ready by the end of the war.]

Aleksei Sidnev to Ivan Serov. Letter regarding NKVD interrogation of Werner Wächter. September 1945 (filed away 20 October 1945). [FSB Archive, Moscow]

In. No. 2343
20.10.45

TOP SECRET.-

TO THE DEPUTY PEOPLE'S COMMISSAR OF INTERNAL AFFAIRS OF THE USSR

Colonel-General

COMRADE SEROV

SPECIAL MESSAGE

In addition to the special messages of 6 and 10.9.45 regarding the detainee

WÄCHTER Werner, born 1902, former
Chief of Staff of the NSDAP Propaganda Directorate

we are transmitting additional materials received as a result of further investigation of the case.

As already reported, WÄCHTER, in addition to the post of Chief of Staff of the Propaganda Directorate, also held the post of Chief of the General Armament and Construction Reporting, which is part of the Propaganda Ministry.

The tasks of reporting included:

First, joint work with the Speer Ministry of Armaments to review and accept into production the latest inventions in the field of military technology. To carry out this task, WÄCHTER was subordinate to: Referent Etlich from the Speer Ministry; the head of the military-economic department of the General Staff, Reuter; the representative of the Aviation Ministry, Schroeter; and Doctor Wiebe from the Propaganda Ministry.

The invention projects were checked by special commissions and then passed on to the scientific consultant Professor Dietrich. In their finished form, the proposals of the reporting office were forwarded to the head of the production department of the Ministry of Armaments Saur.

During the interrogation, WÄCHTER gave a number of examples regarding those latest inventions that passed through his reporting office.

In 1943, the office examined and approved a 21 cm caliber jet aircraft weapon for firing at ground targets. Testing of this weapon yielded positive results.

The Messerschmitt factories developed and launched into production a project for a jet fighter, the fuel for which was special grades of oil, which was very important given the shortage of ordinary gasoline that the German economy had been experiencing recently.

At a meeting on this issue, Sauer and Speer stated that German industry was capable of producing up to 5,000 aircraft monthly in November 1944. Speer proposed to eliminate the fuel difficulties by building several hundred small hydrogenation plants capable of producing up to 3,000 tons of synthetic gasoline per month. According to WÄCHTER, these plants were built and began operating. As a result of these measures, the fuel situation improved significantly, since the scattered small plants had very little exposure to danger [from Allied bombing].

In the same year of 1944, projects were developed for very long-range bombers capable of bombing military manufacturing centers of the Soviet Union in the Urals and industrial facilities in North America. These bombers were supposed to be used to transport atomic bombs.

WÄCHTER reports that, according to the report of Air Force Colonel [Hajo] Hermann, at one of the meetings with Hitler, the latter very sharply singled out Goering for the failure of the Aviation Ministry to implement the program for the construction of these aircraft. Soon after this meeting, the aviation industry was transferred to the Speer Ministry, where General Field Marshal of the Air Force Milch also transferred to work.

The main manager of all work on the latest types of weapons was General [Walter] Dornberger, who was responsible for the production of the V-1 and V-2, as well as atomic bombs.

A direct inventor of the V-2 missiles was engineer Dr. Paul Heylandt.[16] While the V-1 missile was launched by a machine device [catapult] and had a very limited range, the V-2 could hit targets located in the middle of the Atlantic Ocean with its missiles. Heylandt informed WÄCHTER that work was being done as a result of which the V-2 missile would be able to rise to 120 km in altitude and hit industrial targets in North America. A standard V-2 missile could reach an altitude of 80 km.

WÄCHTER knows that the V-2 missile is fired from the HARZ region and near the city of Saalfeld (Thuringia).

Heylandt was also the organizer of the construction of large oxygen liquefaction plants. These plants were of great importance in the V-2 production program, since it was precisely with the help of liquid oxygen that the engines that launched the V-2 rockets operated. Liquid air factories were located in Erfurt, Frankfurt, and Munich (Linde company). The missile itself was manufactured at the Rax plant on the outskirts of Vienna, at a test plant near the town of Bodensee (Swiss, border), and at Peenemünde (near Stettin).

The head of the testing center in Peenemünde was Freiherr von Braun.

Already in 1943, WÄCHTER learned in a conversation with the chief engineer of the propaganda ministry, [Hans] Dominik, that a lot of work was being done to invent atomic bombs. Later, in conversations with Professor Dr. Erich Schumann [pp. 4186–4255] and Prof. [Rudolf] Mentzel, WÄCHTER learned that the work on atomic bombs was being carried out at the Kaiser Wilhelm Institute in Berlin. The head of the production department of the armament ministry, [Karl-Otto] Saur, and his deputy, Feldmann, were personally responsible for the production of atomic bombs.

The most knowledgeable people in this regard should be General Dornberger and Dr. Erich Schumann, who worked specifically on scientific research questions related to the production of the atomic bomb.

Schumann was simultaneously a professor of physics, biology, medicine, and music, and was known to the general public as a professor of music.

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[16] https://repository.si.edu/bitstream/handle/10088/30574/Winter%20Neufeld%20Heylandt.pdf

According to WÄCHTER's testimony, Schumann lived in Berlin until the end of April and should be in the city to this day. (Schumann is being sought [pp. 3294–3296]).

WÄCHTER himself does not know the factories where the atomic bomb was manufactured and designed, since he was not admitted to the secret meetings on this issue held at Speer's [office].

The second task of the general office headed by WÄCHTER was to conduct so-called economic propaganda. This included: propaganda for saving coal, water, electricity, propaganda for intensive work, the struggle (agitational) against "chatterboxes", spies, etc.

All the largest posters on this topic were published on the initiative of WÄCHTER.

The reporting office also published a special magazine titled "A Handbook for Propagandists," which gave advice and instructions to the propagandists of the regional offices.

Finally, the function of the armament reporting office included propaganda about new weapons. It was assumed that as a result of this propaganda it would be possible to convince the German people to hold out to the last degree, since a new victorious weapon would soon come into action.

WÄCHTER also testified that he headed a special council for repairing Berlin streets damaged by the bombing.

The investigation into WÄCHTER's case continues. Further results will be reported separately.

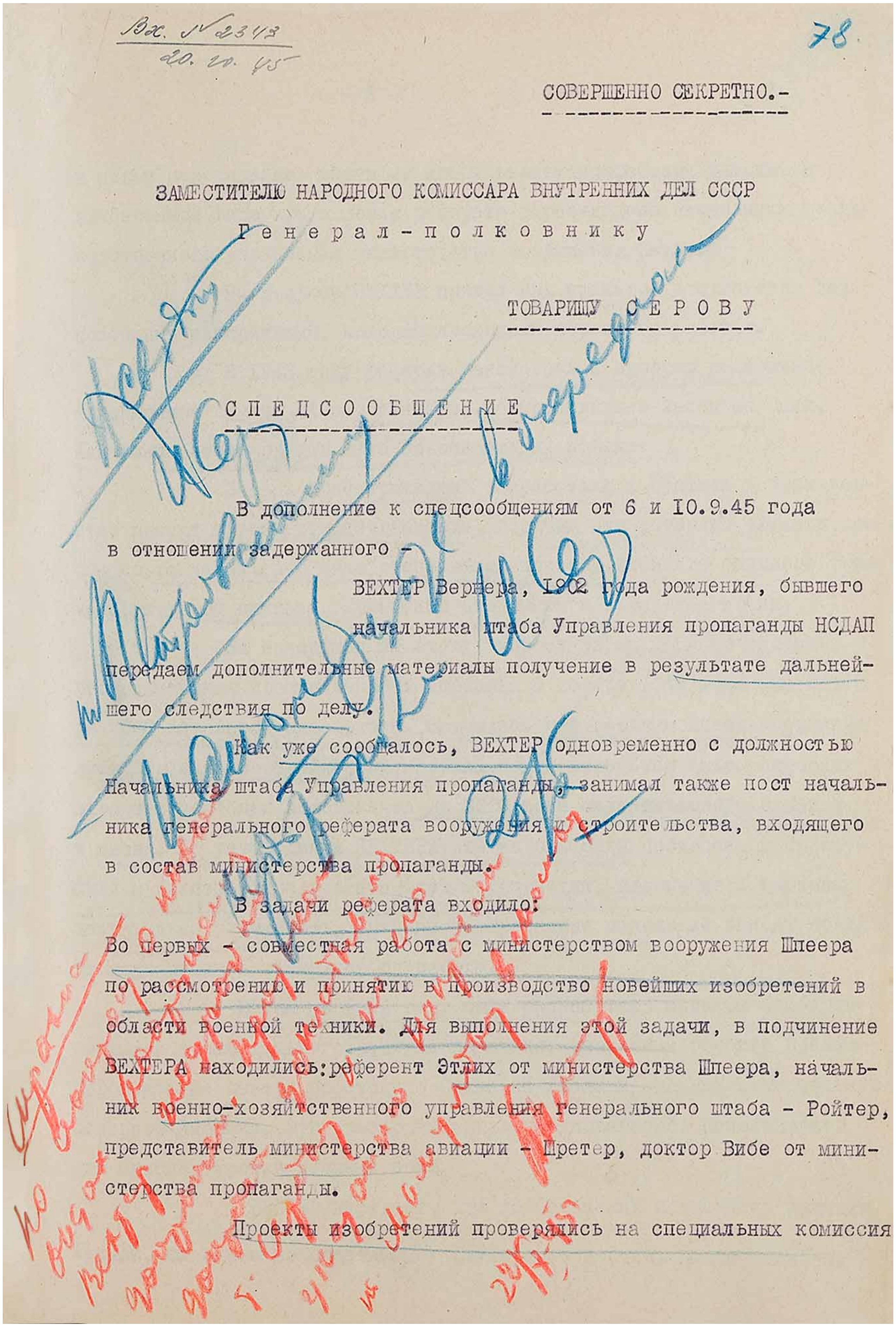
CHIEF OF THE OPERATIONAL SECTOR OF THE NKVD BERLIN

Major-General SIDNEV.-

" " September 1945.

No 2/ ......

[See document photos on pp. 4644–4648.]



Вх. № 2343
20.10.45

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СОВЕРШЕННО СЕКРЕТНО.-

ЗАМЕСТИТЕЛЮ НАРОДНОГО КОМИССАРА ВНУТРЕННИХ ДЕЛ СССР
Генерал-полковнику

ТОВАРИЩУ СЕРОВУ

СПЕЦСООБЩЕНИЕ

В дополнение к спецсообщениям от 6 и 10.9.45 года в отношении задержанного -

ВЕХТЕР Вернера, 1902 года рождения, бывшего начальника штаба Управления пропаганды НСДАП

передаем дополнительные материалы получение в результате дальнейшего следствия по делу.

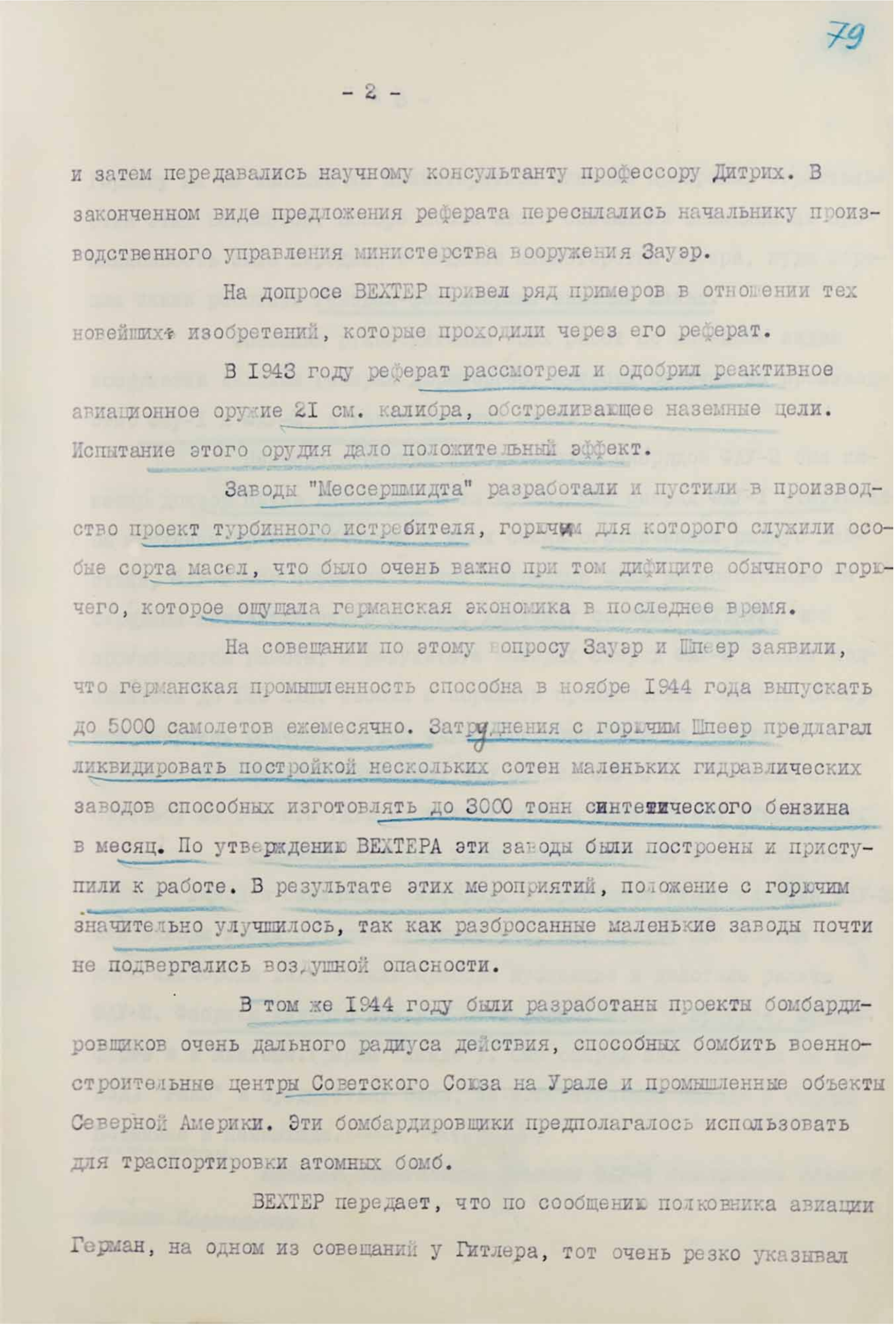
Как уже сообщалось, ВЕХТЕР одновременно с должностью Начальника штаба Управления пропаганды, занимал также пост начальника генерального реферата вооружения и строительства, входящего в состав министерства пропаганды.

В задачи реферата входило:

Во первых - совместная работа с министерством вооружения Шпеера по рассмотрению и принятию в производство новейших изобретений в области военной техники. Для выполнения этой задачи, в подчинение ВЕХТЕРА находились: референт Этлих от министерства Шпеера, начальник военно-хозяйственного управления генерального штаба - Ройтер, представитель министерства авиации - Претер, доктор Вибе от министерства пропаганды.

Проекты изобретений проверялись на специальных комиссия

Figure D.763: Aleksei Sidnev to Ivan Serov. Letter regarding NKVD interrogation of Werner Wächter. September 1945 [FSB Archive, Moscow, courtesy of Matthias Uhl].



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и затем передавались научному консультанту профессору Дитрих. В законченном виде предложения реферата пересылались начальнику производственного управления министерства вооружения Зауэр.

На допросе ВЕХТЕР привел ряд примеров в отношении тех новейших изобретений, которые проходили через его реферат.

В I943 году реферат рассмотрел и одобрил реактивное авиационное оружие 2I см. калибра, обстреливающее наземные цели. Испытание этого орудия дало положительный эффект.

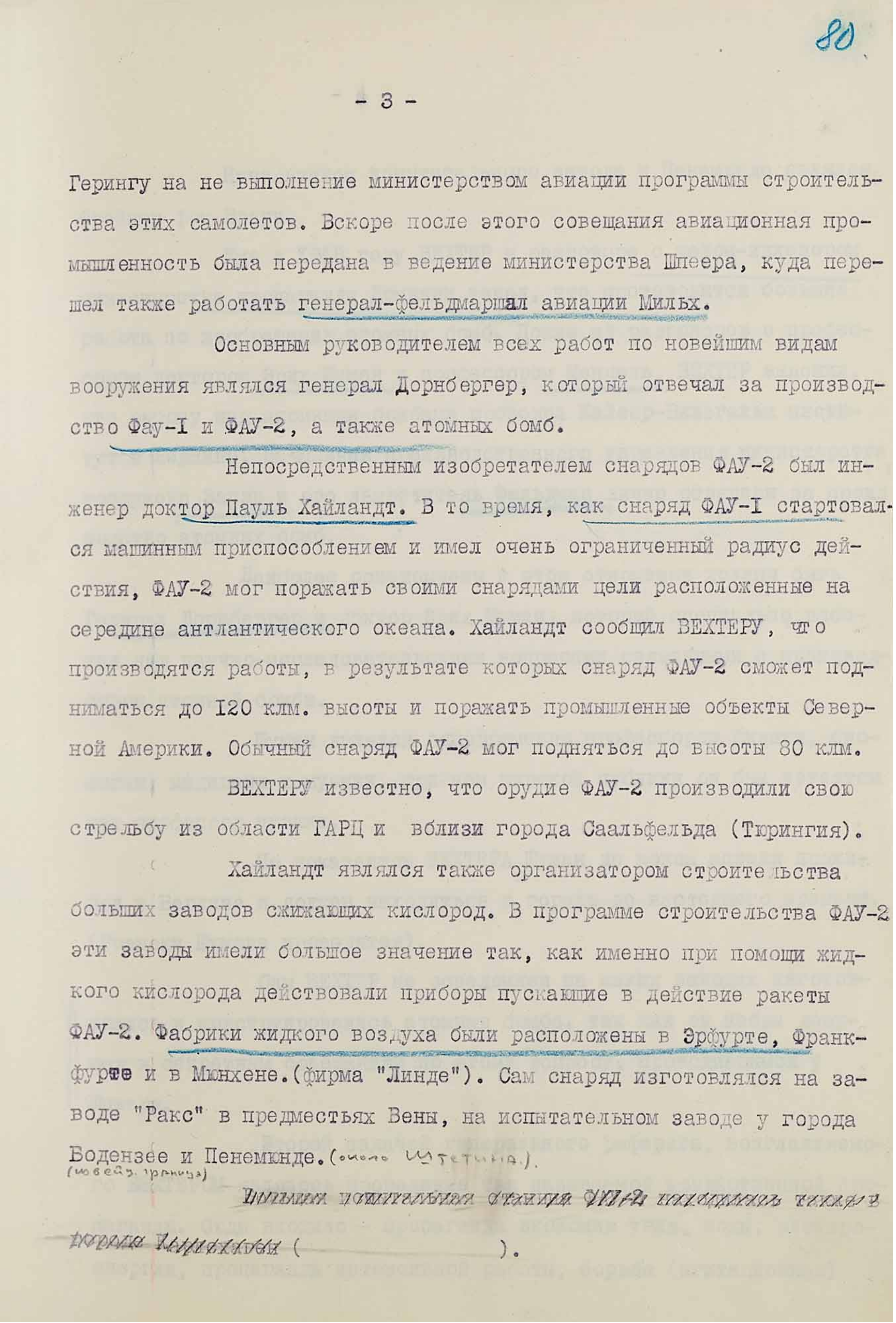
Заводы "Мессершмидта" разработали и пустили в производство проект турбинного истребителя, горючим для которого служили особые сорта масел, что было очень важно при том дифиците обычного горючего, которое ощущала германская экономика в последнее время.

На совещании по этому вопросу Зауэр и Шпеер заявили, что германская промышленность способна в ноябре I944 года выпускать до 5000 самолетов ежемесячно. Затруднения с горючим Шпеер предлагал ликвидировать постройкой нескольких сотен маленьких гидравлических заводов способных изготовлять до 3000 тонн синтетического бензина в месяц. По утверждению ВЕХТЕРА эти заводы были построены и приступили к работе. В результате этих мероприятий, положение с горючим значительно улучшилось, так как разбросанные маленькие заводы почти не подвергались воздушной опасности.

В том же I944 году были разработаны проекты бомбардировщиков очень дальнего радиуса действия, способных бомбить военностроительные центры Советского Союза на Урале и промышленные объекты Северной Америки. Эти бомбардировщики предполагалось использовать для траспортировки атомных бомб.

ВЕХТЕР передает, что по сообщению полковника авиации Герман, на одном из совещаний у Гитлера, тот очень резко указывал

Figure D.764: Aleksei Sidnev to Ivan Serov. Letter regarding NKVD interrogation of Werner Wächter. September 1945 [FSB Archive, Moscow, courtesy of Matthias Uhl].



Герингу на не выполнение министерством авиации программы строительства этих самолетов. Вскоре после этого совещания авиационная промышленность была передана в ведение министерства Шпеера, куда перешел также работать генерал-фельдмаршал авиации Мильх.

Основным руководителем всех работ по новейшим видам вооружения являлся генерал Дорнбергер, который отвечал за производство Фау-I и ФАУ-2, а также атомных бомб.

Непосредственным изобретателем снарядов ФАУ-2 был инженер доктор Пауль Хайландт. В то время, как снаряд ФАУ-I стартовался машинным приспособлением и имел очень ограниченный радиус действия, ФАУ-2 мог поражать своими снарядами цели расположенные на середине антлантического океана. Хайландт сообщил ВЕХТЕРУ, что производятся работы, в результате которых снаряд ФАУ-2 сможет подниматься до I20 клм. высоты и поражать промышленные объекты Северной Америки. Обычный снаряд ФАУ-2 мог подняться до высоты 80 клм.

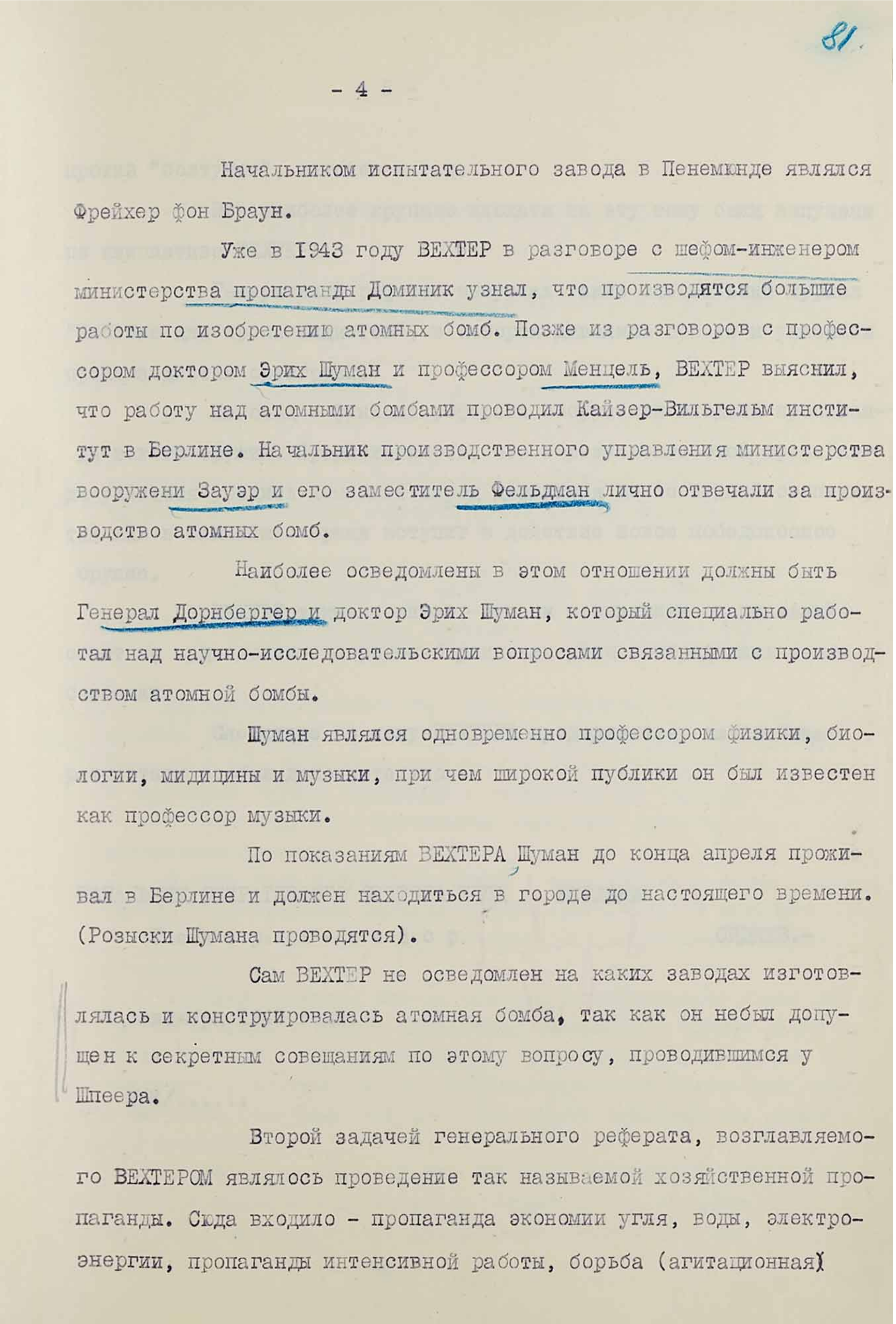
ВЕХТЕРУ известно, что орудие ФАУ-2 производили свою стрельбу из области ГАРЦ и вблизи города Саальфельда (Тюрингия).

Хайландт являлся также организатором строительства больших заводов сжижающих кислород. В программе строительства ФАУ-2 эти заводы имели большое значение так, как именно при помощи жидкого кислорода действовали приборы пускающие в действие ракеты ФАУ-2. Фабрики жидкого воздуха были расположены в Эрфурте, Франкфурте и в Мюнхене. (фирма "Линде"). Сам снаряд изготовлялся на заводе "Ракс" в предместьях Вены, на испытательном заводе у города Бодензее и Пенемюнде. (около Штетина.)
(швейц. граница)

~~[illegible] станция ФАУ-2 [illegible]~~

~~[illegible]~~ (   ).

Figure D.765: Aleksei Sidnev to Ivan Serov. Letter regarding NKVD interrogation of Werner Wächter. September 1945 [FSB Archive, Moscow, courtesy of Matthias Uhl].



Начальником испытательного завода в Пенемюнде являлся Фрейхер фон Браун.

Уже в 1943 году ВЕХТЕР в разговоре с шефом-инженером министерства пропаганды Доминик узнал, что производятся большие работы по изобретению атомных бомб. Позже из разговоров с профессором доктором Эрих Шуман и профессором Менцель, ВЕХТЕР выяснил, что работу над атомными бомбами проводил Кайзер-Вильгельм институт в Берлине. Начальник производственного управления министерства вооружени Зауэр и его заместитель Фельдман лично отвечали за производство атомных бомб.

Наиболее осведомлены в этом отношении должны быть Генерал Дорнбергер и доктор Эрих Шуман, который специально работал над научно-исследовательскими вопросами связанными с производством атомной бомбы.

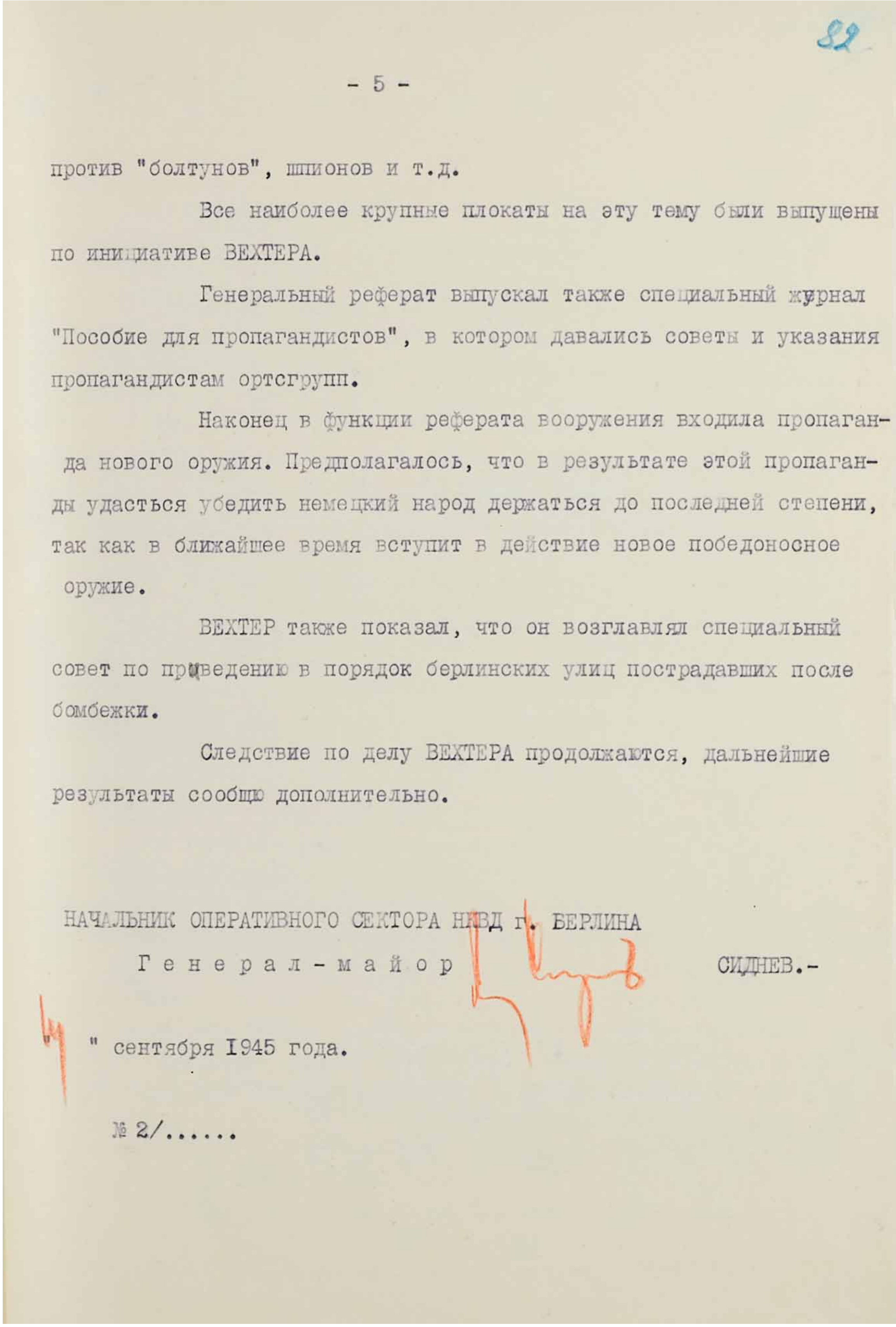
Шуман являлся одновременно профессором физики, биологии, мидицины и музыки, при чем широкой публики он был известен как профессор музыки.

По показаниям ВЕХТЕРА Шуман до конца апреля проживал в Берлине и должен находиться в городе до настоящего времени. (Розыски Шумана проводятся).

Сам ВЕХТЕР не осведомлен на каких заводах изготовлялась и конструировалась атомная бомба, так как он небыл допущен к секретным совещаниям по этому вопросу, проводившимся у Шпеера.

Второй задачей генерального реферата, возглавляемого ВЕХТЕРОМ являлось проведение так называемой хозяйственной пропаганды. Сюда входило - пропаганда экономии угля, воды, электроэнергии, пропаганды интенсивной работы, борьба (агитационная)

Figure D.766: Aleksei Sidnev to Ivan Serov. Letter regarding NKVD interrogation of Werner Wächter. September 1945 [FSB Archive, Moscow, courtesy of Matthias Uhl].



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против "болтунов", шпионов и т.д.

Все наиболее крупные плокаты на эту тему были выпущены по инициативе ВЕХТЕРА.

Генеральный реферат выпускал также специальный журнал "Пособие для пропагандистов", в котором давались советы и указания пропагандистам ортсгрупп.

Наконец в функции реферата вооружения входила пропаганда нового оружия. Предполагалось, что в результате этой пропаганды удастся убедить немецкий народ держаться до последней степени, так как в ближайшее время вступит в действие новое победоносное оружие.

ВЕХТЕР также показал, что он возглавлял специальный совет по приведению в порядок берлинских улиц пострадавших после бомбежки.

Следствие по делу ВЕХТЕРА продолжаются, дальнейшие результаты сообщу дополнительно.

НАЧАЛЬНИК ОПЕРАТИВНОГО СЕКТОРА НКВД г. БЕРЛИНА
Генерал-майор СИДНЕВ.-

"14" сентября 1945 года.

№ 2/......

Figure D.767: Aleksei Sidnev to Ivan Serov. Letter regarding NKVD interrogation of Werner Wächter. September 1945 [FSB Archive, Moscow, courtesy of Matthias Uhl].

Transcript of NKVD interrogation of Werner Wächter by Ivan Serov. 10 October 1945. [FSB Archive, Moscow]

Transcript.

INTERROGATION PROTOCOL

of the arrested WÄCHTER Werner.-

10 October 1945.

WÄCHTER W., born in 1902, native of Erfurt, Germany, former Chief of the Economic Administration of the German Ministry of Propaganda and staff officer of the Main Administration of NSDAP Propaganda with the rank of "SA Gruppenführer."

Interrogation began at 11:50.
Interrogation ended at 17:00.

Question — In previous interrogations you testified that you were aware of the preparations being carried out in Germany for the use of an atomic bomb.

From what sources did you know about this?

Answer — I first learned that the German Ministry of Armaments was preparing to use an atomic bomb from engineer [Hans] DOMINIK [pp. 1218, 1968, 1970].

Question — Who is DOMINIK?

Answer — Dominik (I don't remember his name) worked in the Ministry of Propaganda as a communications engineer and, by the nature of his work, maintained contact with senior engineers, specialists working in the field of secret weapons and, in particular, on the atomic bomb. I had known DOMINIK since 1940 from our joint work in the Propaganda Ministry.

Question — In connection with what and what exactly did DOMINIK tell you about the manufacture of the atomic bomb?

Answer — DOMINIK spoke to me about the atomic bomb in 1943 in one of his private conversations.

He told me that German scientists had succeeded in achieving the splitting of the atomic nucleus and that engineers and specialists were developing methods and ways of practical application of this energy as a means of waging war. To my question—is the enemy working on a solution to this problem—DOMINIK answered that similar work was being carried out by the British and Americans, but Germany, allegedly, was ahead of them in this field by a year and a half. He did not name the exact date of the beginning of this work.

Question — Obviously, corresponding practical work was also carried out in Germany to prepare for the use of the atomic bomb? Can you tell us about it?

Answer — I knew that the Ministry of Armaments was carrying out practical work to prepare for the use of the atomic bomb. I learned about this from my friend, the editor of the secret government bulletin, Hans HERTEL.

As HERTEL told me, in February 1945, on behalf of the Minister of Propaganda GOEBBELS, he went on a business trip to the city of Celle and met there with his acquaintance, the head of the military air force school for special purposes, Colonel Hajo HERMANN, who told him in a private conversation that the school was armed with aircraft of the latest design. These aircraft have a long range and will be armed with this bomb. As Colonel Hajo [HERMANN] stated to HERTEL—the new aircraft were intended for bombing industrial centers of the Soviet Union, located in the Urals and Central Asia, with atomic bombs.

From HERTEL, I know that at the airfield in the city of Celle there were both bombers of the latest design and fighters intended to protect them during flights. In addition, HERTEL reported that aircraft of this design were concentrated at other airfields.

Based on conversations with DOMINIK and HERTEL, I came to the conclusion that the German Ministry of Armaments was preparing to use atomic bombs in 1945. I could also judge this from other facts that were known to me as a leading official of the German Ministry of Propaganda.

Question — What other facts are you talking about?

Answer — I do not have precise information about the exact dates the atomic bombs would have been used against the Soviet Union during the war. However, I would like to tell the investigation about certain signs that give me reason to believe that an atomic bomb could have been used in the war against the Soviet Union in the summer of 1945.

In one of my conversations with him, the State Secretary of the Propaganda Ministry, Dr. [Werner] NAUMANN, speaking about the military and political situation in Germany at the last stage of the war, stated that everything should soon change for the better [p. 4429] and referred to the words of Hitler, who in a narrow circle of trusted people said: “Yes, God forgive me for the last 14 days of the war.”

In addition, at the beginning of 1945, I met with the head of the armament department, [Karl-Otto] SAUR, one of the leaders of German industry and, in fact, the deputy minister of armaments of [Albert] SPEER. SAUR secretly informed me that at present intensive work is being carried out on the production of the newest weapons, which will soon be used at the front.

In the spring of 1945, the inventor from the German Scientific Research Council, Professor [Erich] SCHUMANN, spoke to me about this, stating that he was carrying out a lot of work on a secret weapon that could change the entire course of the war in Germany’s favor [pp. 4186–4255].

Question — What secret weapon did SAUR and SCHUMANN talk to you about?

Answer — They did not tell me what new weapon had been invented, but knowing from DOMINIK and HERTEL that work was underway to make an atomic bomb, I believe that SCHUMANN and SAUR also meant an atomic bomb.

I must state that the conversations with SCHUMANN and SAUR were of a strictly confidential nature and they could not tell me in detail about the manufacture of the new weapon, since it was a special state secret.

Question — It must be assumed that you, as a leading official of the fascist party and the Propaganda Ministry, were also aware of other, more specific facts.

Answer — I told the investigation all the facts known to me and some signs indicating the plans of the German government to use secret weapons and, in particular, an atomic bomb in the war against the USSR in the summer of 1945. I can add that in March 1945, GOEBBELS, in my presence, gave instructions to an employee of the Propaganda Ministry, von BORKE, to put up a horoscope for the month of June, supposedly predicting HITLER's fate, since June was considered especially favorable for HITLER. The predictions of the horoscope, by order of GOEBBELS, were supposed to be distributed among the population of Germany in June 1945.

When compared with other data, I believe that behind this instruction was concealed the intensive preparations for the use of secret weapons, calculated for June 1945.

In addition, in April 1945, GOEBBELS, at a meeting of the employees of the Propaganda Ministry, in a report on the tasks of National Socialist propaganda, stated: "Despite the difficult challenges, we should not lose confidence, since soon a new weapon will be used that will change the entire course of the war."

Question — Can you name the specialists who directly worked on the manufacture of the atomic bomb in Germany?

Answer — I know that the following persons had a direct relationship with all types of secret weapons and, in particular, the atomic bomb: General [Walter] DORNBERGER, head of the office of new types of weapons of the SPEER Ministry, previously lived in Berlin-Charlottenburg, Riehlstrasse. I do not know where DORNBERGER is now.

SAUR, the head of the industry department of the Ministry of Armaments was one of the trusted people of the Minister of Armaments TODT, and then of his successor SPEER. SAUR was actually in charge of the production of all the new types of weapons in Germany. As far as I know, he personally reported every month to HITLER about the quantity of military products manufactured.

FELDMANN (I don't know his name) was SAUR's deputy in the Ministry of Armaments. I know that SAUR and FELDMANN fled to Kulmbach (northern Bavaria) in April 1945.

Professor [Max] PLANCK is one of the oldest leaders of the Kaiser Wilhelm Research Institute. He worked for a long time on the problem of splitting the atomic nucleus, which was known to the leading officials of Germany, including me.

Question — Where is PLANCK currently located?

Answer — I assume that PLANCK lives in Berlin in the Dahlem district. In addition to Planck, Professor [Wilhelm] ZEYSS [pp. 5674–5682], who was in charge of the construction of aircraft intended for dropping atomic bombs, had a direct relationship with secret weapons issues.

From the words of ZEYSS's nephew I know that he currently lives in the suburb of Berlin-Rahnsdorf.

Question — Regarding the production of new types of weapons, besides the V-bomb [V-1], what do you know?

Answer — I also knew about the production of the new secret weapon “V-2.” I knew about this from my close friend HEYLANDT.

Question — Who is HEYLANDT?

Answer — Dr. Paul HEYLANDT, an engineer and inventor. I have known him since 1925. Back in 1930, he told me that he had managed to invent a new type of rocket engine for a car. In 1935, the German Ministry of War confiscated the patent for this invention. However, HEYLANDT continued to work on this invention, but under the control of the Ministry of War, and he was the owner of a rocket engine factory in Berlin.

In 1943, while visiting HEYLANDT at his country house in the Königs Wusterhausen area, he told me that he was working on a new, in his words ”terrible and deadly weapon” rocket projectile, which Hitler named “V-2.”

According to HEYLANDT, the “V-2” is a rocket-propelled missile of enormous destructive power, loaded with one ton of explosive and with a high flight speed. According to HEYLANDT’s calculations, this speed is so high [during reentry] that the missile’s controls would become unusable and its practical use would be impossible. He solved this problem by enclosing the missile’s control mechanisms in a shell of liquid air [coolant].

HEYLANDT also said that he is working on solving the problem of increasing the flight altitude to 120 kilometers. The fact is that, according to his reckoning, the “V-2” can reach an altitude of 80 kilometers during flight, but this is not enough to fire at the USA from German territory. Having reached an altitude of 120 km, a rocket projectile fired from Germany could reach New York.

Question — Have you personally visited the HEYLANDT plant?

Answer — Yes, I have been to this plant many times, but I have never seen a “V-2.” I personally examined 7–8 meter high rocket towers in special halls. The towers were intended for launching “V-2,” which gave them a direction of flight.

Later, the HEYLANDT plant was moved to the town of Gassen [Guben or Gablenz?] near Sohmer not far from the city of Cottbus.

Question — What else do you know about the production of “V-2”?

Answer — HEYLANDT told me that in 1943–44 in Belgium, in the area of the city of Liège, underground structures were built for firing the rocket projectile “V-2.” Later, these underground structures were destroyed by Anglo-American aircraft, and the remaining equipment was taken to Thuringia in the area of the city of Saalfeld and in the area of Harz, where practical testing of the “V-2” was carried out.

Question — Where else were the test stations located?

Answer — I know from HEYLANDT that there were also testing stations in the Peenemünde area (northern Germany) and one testing site was located on the Swiss border in the Lake Constance area. For the sake of secrecy, the town of Peenemünde was recently renamed “Karlshagen.”

HEYLANDT said that he was present at the “V-2” test at the testing station in the Lake Constance area. According to his stories, the inhabitants of the Swiss border strip were very surprised by the bright light and loud noise produced by the test.

Question — Do you know where HEYLANDT is currently located?

Answer — I know from my brother's wife Charlotte WÄCHTER that HEYLANDT was sent to Moscow by representatives of the Soviet military authorities.

Question — Can you name the persons who were directly involved in the development of secret weapons or were aware of it?

Answer — A person knowledgeable about secret weapons was the former head of the culture department and head of propaganda of the Ministry of Armaments, HOFFMANN.

Question — What do you know about the whereabouts of HOFFMANN?

Answer — HOFFMANN lived in the eastern part of Berlin. My former personal secretary Edith RICHERT, who lives in Berlin-Weissensee, Generalstrasse, can tell about him.

In addition, the person in the know was the secretary for secret affairs of Minister SPEER, Annemarie KEMPF (maiden name WITTENBERG). KEMPF lives in Berlin-Steglitz with her mother WITTENBERG, not far from the Magistracy (Rathaus). I know that KEMPF was in charge of the special secret correspondence of Minister SPEER and personally printed his reports for Hitler on the state of the military industry.

The interrogation transcript from my words is written down correctly and the German language spoken to me is correct:

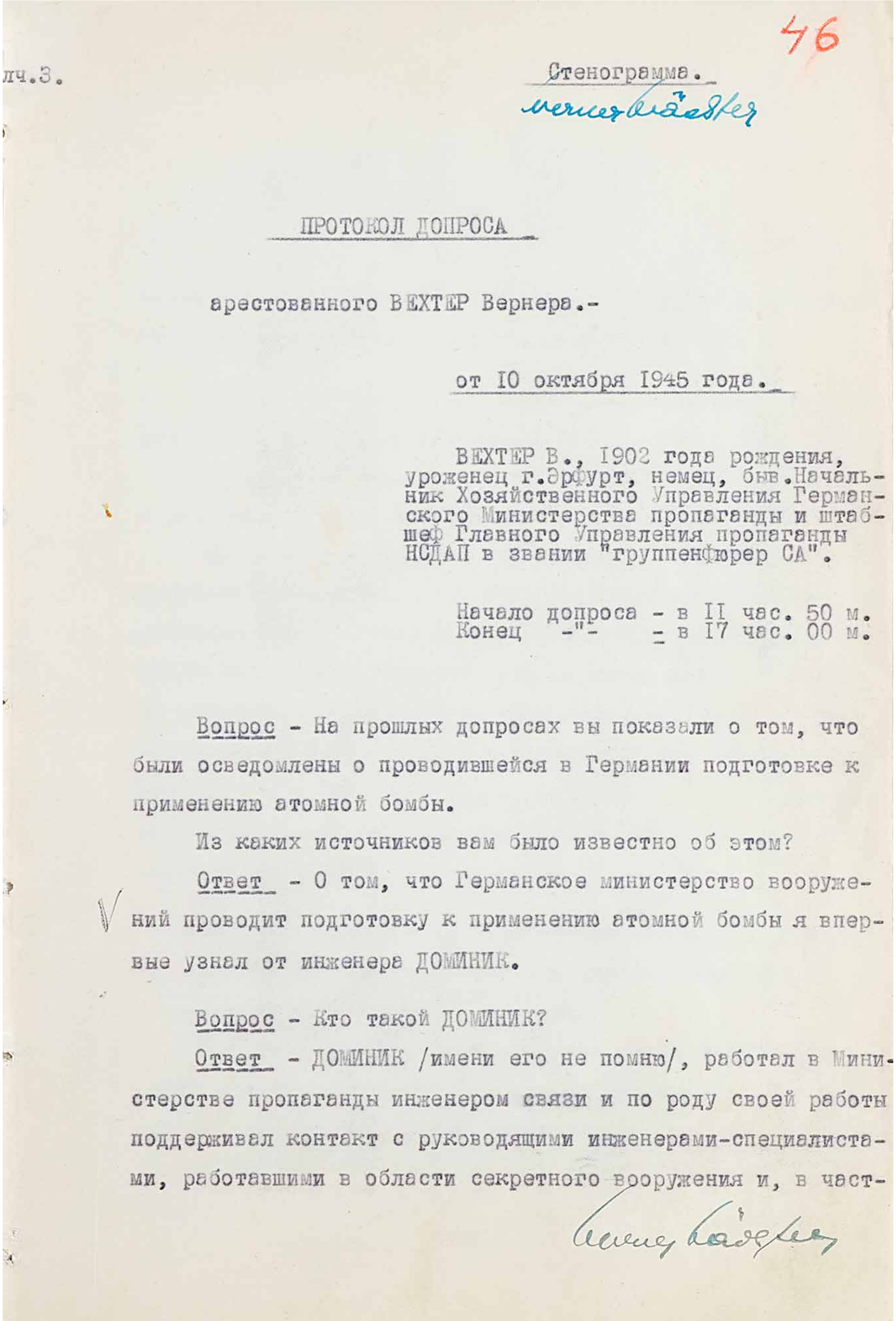
(WÄCHTER)

INTERROGATOR: COLONEL-GENERAL: (SEROV)

MAJOR: (KOZYREV)

TRANSLATOR: JUNIOR LIEUTENANT: (RUDIN)

[See document photos on pp. 4654–4664.]



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лч.3.

Стенограмма.

Werner Wächter

ПРОТОКОЛ ДОПРОСА

арестованного ВЕХТЕР Вернера.-

от 10 октября 1945 года.

ВЕХТЕР В., 1902 года рождения, уроженец г.Эрфурт, немец, быв.Начальник Хозяйственного Управления Германского Министерства пропаганды и штаб-шеф Главного Управления пропаганды НСДАП в звании "группенфюрер СА".

Начало допроса - в 11 час. 50 м.
Конец -"- - в 17 час. 00 м.

Вопрос - На прошлых допросах вы показали о том, что были осведомлены о проводившейся в Германии подготовке к применению атомной бомбы.

Из каких источников вам было известно об этом?

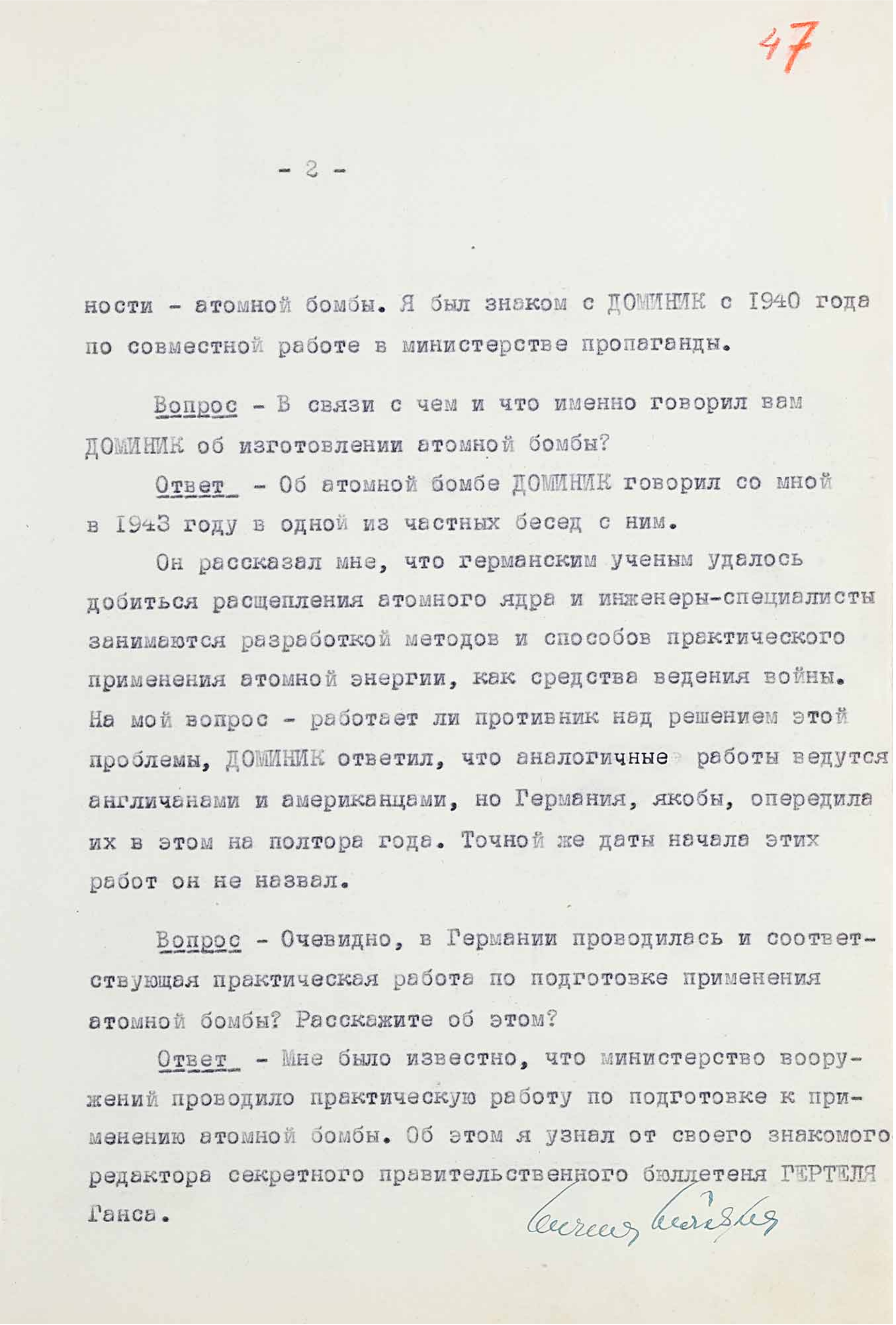
Ответ - О том, что Германское министерство вооружений проводит подготовку к применению атомной бомбы я впервые узнал от инженера ДОМИНИК.

Вопрос - Кто такой ДОМИНИК?

Ответ - ДОМИНИК /имени его не помню/, работал в Министерстве пропаганды инженером связи и по роду своей работы поддерживал контакт с руководящими инженерами-специалистами, работавшими в области секретного вооружения и, в част-

Werner Wächter

Figure D.768: Transcript of NKVD interrogation of Werner Wächter by Ivan Serov. 10 October 1945 [FSB Archive, Moscow, courtesy of Matthias Uhl].



ности - атомной бомбы. Я был знаком с ДОМИНИК с 1940 года по совместной работе в министерстве пропаганды.

Вопрос - В связи с чем и что именно говорил вам ДОМИНИК об изготовлении атомной бомбы?

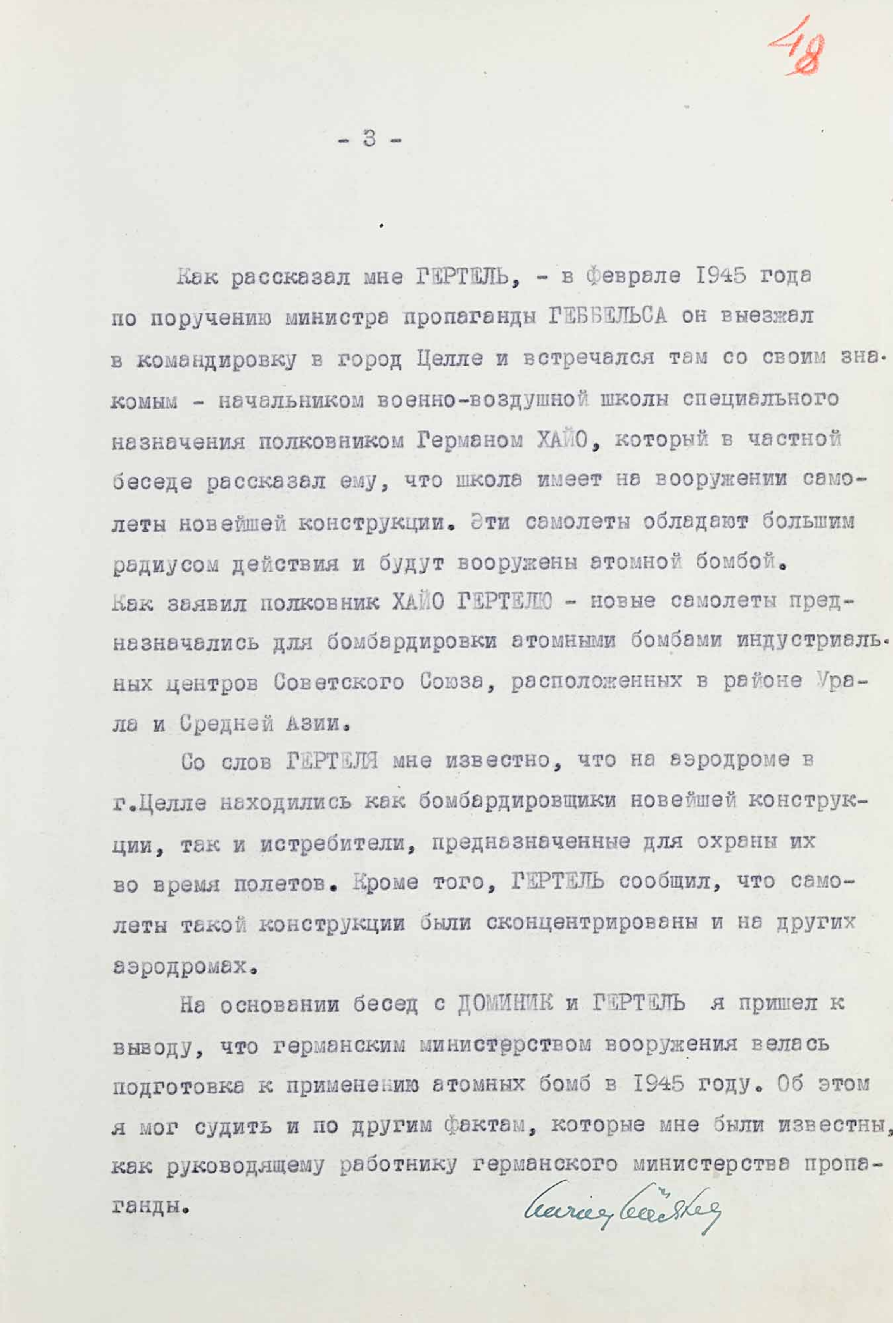
Ответ - Об атомной бомбе ДОМИНИК говорил со мной в 1943 году в одной из частных бесед с ним.

Он рассказал мне, что германским ученым удалось добиться расщепления атомного ядра и инженеры-специалисты занимаются разработкой методов и способов практического применения атомной энергии, как средства ведения войны. На мой вопрос - работает ли противник над решением этой проблемы, ДОМИНИК ответил, что аналогичные работы ведутся англичанами и американцами, но Германия, якобы, опередила их в этом на полтора года. Точной же даты начала этих работ он не назвал.

Вопрос - Очевидно, в Германии проводилась и соответствующая практическая работа по подготовке применения атомной бомбы? Расскажите об этом?

Ответ - Мне было известно, что министерство вооружений проводило практическую работу по подготовке к применению атомной бомбы. Об этом я узнал от своего знакомого редактора секретного правительственного бюллетеня ГЕРТЕЛЯ Ганса.

Figure D.769: Transcript of NKVD interrogation of Werner Wächter by Ivan Serov. 10 October 1945 [FSB Archive, Moscow, courtesy of Matthias Uhl].



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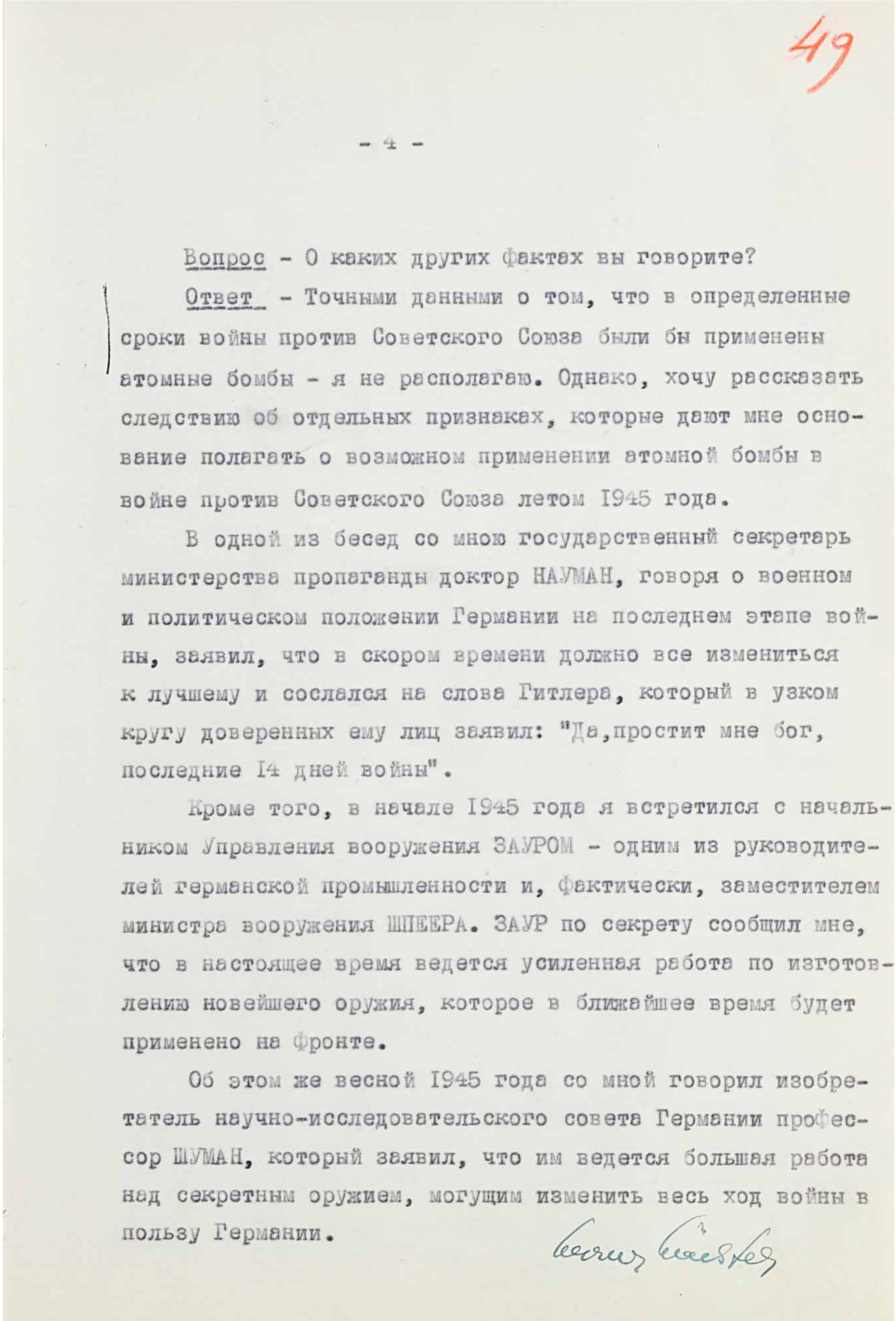
Как рассказал мне ГЕРТЕЛЬ, - в феврале 1945 года по поручению министра пропаганды ГЕББЕЛЬСА он выезжал в командировку в город Целле и встречался там со своим знакомым - начальником военно-воздушной школы специального назначения полковником Германом ХАЙО, который в частной беседе рассказал ему, что школа имеет на вооружении самолеты новейшей конструкции. Эти самолеты обладают большим радиусом действия и будут вооружены атомной бомбой.

Как заявил полковник ХАЙО ГЕРТЕЛЮ - новые самолеты предназначались для бомбардировки атомными бомбами индустриальных центров Советского Союза, расположенных в районе Урала и Средней Азии.

Со слов ГЕРТЕЛЯ мне известно, что на аэродроме в г.Целле находились как бомбардировщики новейшей конструкции, так и истребители, предназначенные для охраны их во время полетов. Кроме того, ГЕРТЕЛЬ сообщил, что самолеты такой конструкции были сконцентрированы и на других аэродромах.

На основании бесед с ДОМИНИК и ГЕРТЕЛЬ я пришел к выводу, что германским министерством вооружения велась подготовка к применению атомных бомб в 1945 году. Об этом я мог судить и по другим фактам, которые мне были известны, как руководящему работнику германского министерства пропаганды.

Figure D.770: Transcript of NKVD interrogation of Werner Wächter by Ivan Serov. 10 October 1945 [FSB Archive, Moscow, courtesy of Matthias Uhl].



Вопрос - О каких других фактах вы говорите?

Ответ - Точными данными о том, что в определенные сроки войны против Советского Союза были бы применены атомные бомбы - я не располагаю. Однако, хочу рассказать следствию об отдельных признаках, которые дают мне основание полагать о возможном применении атомной бомбы в войне против Советского Союза летом 1945 года.

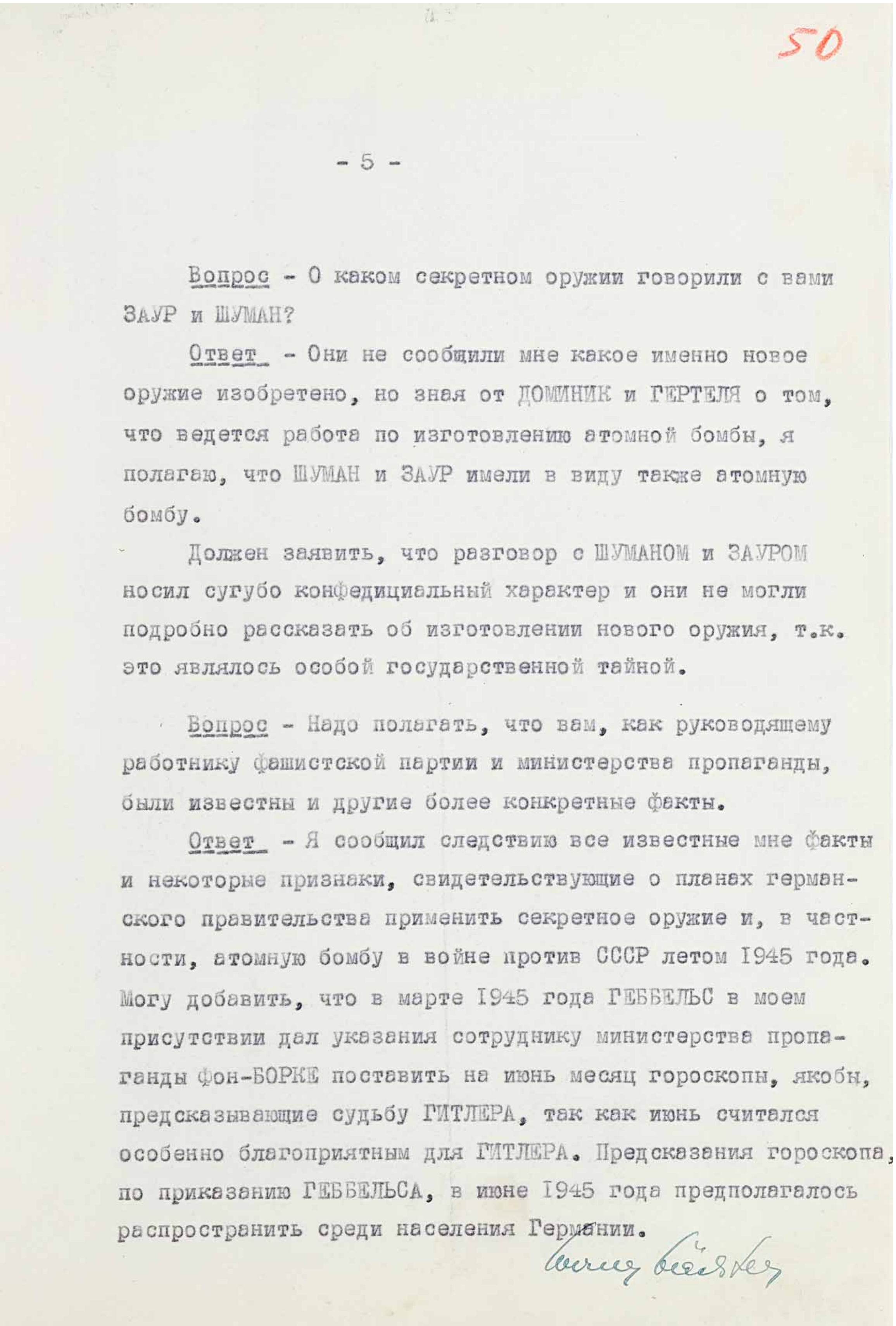
В одной из бесед со мною государственный секретарь министерства пропаганды доктор НАУМАН, говоря о военном и политическом положении Германии на последнем этапе войны, заявил, что в скором времени должно все измениться к лучшему и сослался на слова Гитлера, который в узком кругу доверенных ему лиц заявил: "Да,простит мне бог, последние 14 дней войны".

Кроме того, в начале 1945 года я встретился с начальником Управления вооружения ЗАУРОМ - одним из руководителей германской промышленности и, фактически, заместителем министра вооружения ШПЕЕРА. ЗАУР по секрету сообщил мне, что в настоящее время ведется усиленная работа по изготовлению новейшего оружия, которое в ближайшее время будет применено на фронте.

Об этом же весной 1945 года со мной говорил изобретатель научно-исследовательского совета Германии профессор ШУМАН, который заявил, что им ведется большая работа над секретным оружием, могущим изменить весь ход войны в пользу Германии.

Werner Wächter

Figure D.771: Transcript of NKVD interrogation of Werner Wächter by Ivan Serov. 10 October 1945 [FSB Archive, Moscow, courtesy of Matthias Uhl].



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Вопрос - О каком секретном оружии говорили с вами ЗАУР и ШУМАН?

Ответ - Они не сообщили мне какое именно новое оружие изобретено, но зная от ДОМИНИК и ГЕРТЕЛЯ о том, что ведется работа по изготовлению атомной бомбы, я полагаю, что ШУМАН и ЗАУР имели в виду также атомную бомбу.

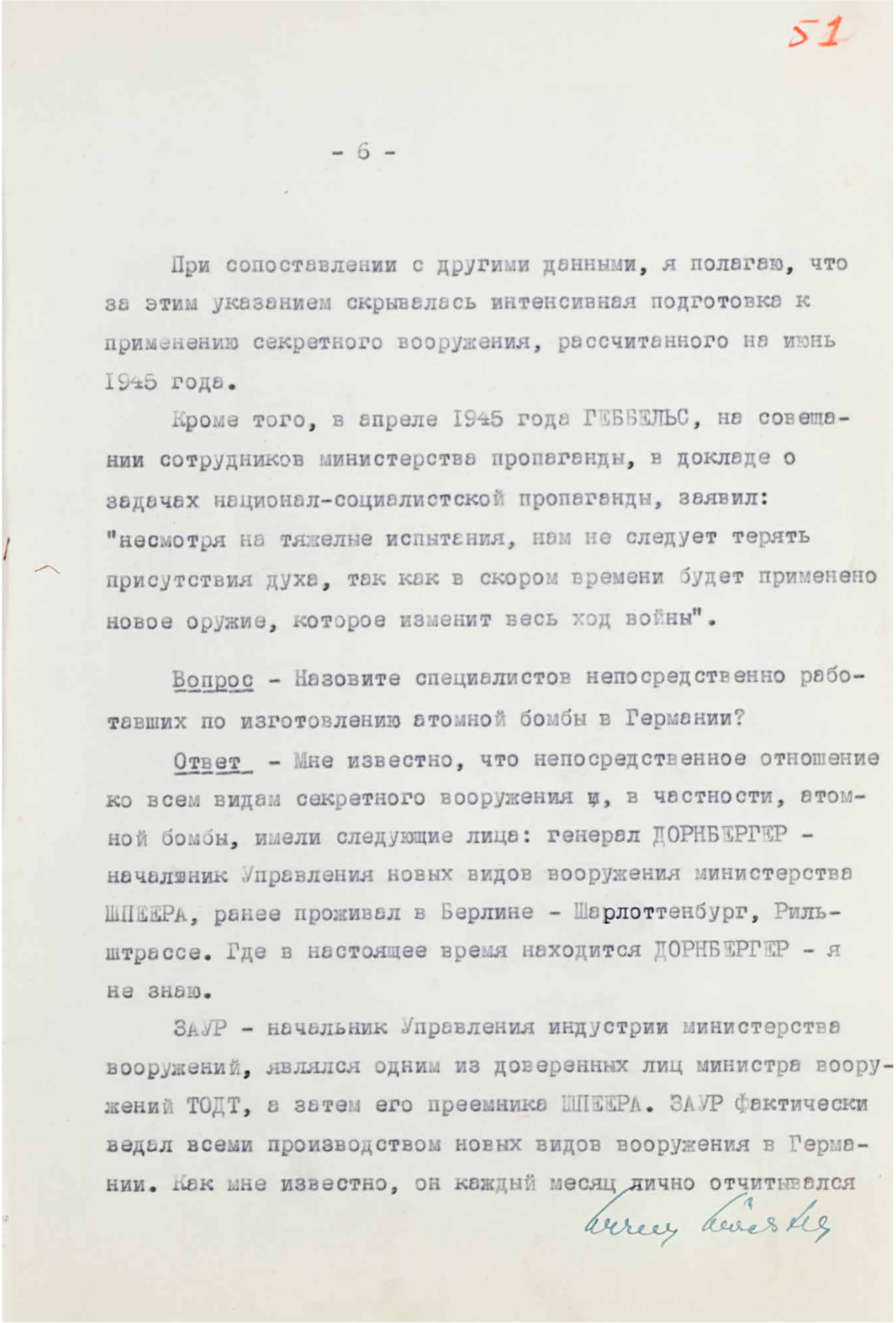
Должен заявить, что разговор с ШУМАНОМ и ЗАУРОМ носил сугубо конфедициальный характер и они не могли подробно рассказать об изготовлении нового оружия, т.к. это являлось особой государственной тайной.

Вопрос - Надо полагать, что вам, как руководящему работнику фашистской партии и министерства пропаганды, были известны и другие более конкретные факты.

Ответ - Я сообщил следствию все известные мне факты и некоторые признаки, свидетельствующие о планах германского правительства применить секретное оружие и, в частности, атомную бомбу в войне против СССР летом 1945 года. Могу добавить, что в марте 1945 года ГЕББЕЛЬС в моем присутствии дал указания сотруднику министерства пропаганды фон-БОРКЕ поставить на июнь месяц гороскопы, якобы, предсказывающие судьбу ГИТЛЕРА, так как июнь считался особенно благоприятным для ГИТЛЕРА. Предсказания гороскопа, по приказанию ГЕББЕЛЬСА, в июне 1945 года предполагалось распространить среди населения Германии.

Werner Wächter

Figure D.772: Transcript of NKVD interrogation of Werner Wächter by Ivan Serov. 10 October 1945 [FSB Archive, Moscow, courtesy of Matthias Uhl].



При сопоставлении с другими данными, я полагаю, что за этим указанием скрывалась интенсивная подготовка к применению секретного вооружения, рассчитанного на июнь 1945 года.

Кроме того, в апреле 1945 года ГЕББЕЛЬС, на совещании сотрудников министерства пропаганды, в докладе о задачах национал-социалистской пропаганды, заявил: "несмотря на тяжелые испытания, нам не следует терять присутствия духа, так как в скором времени будет применено новое оружие, которое изменит весь ход войны".

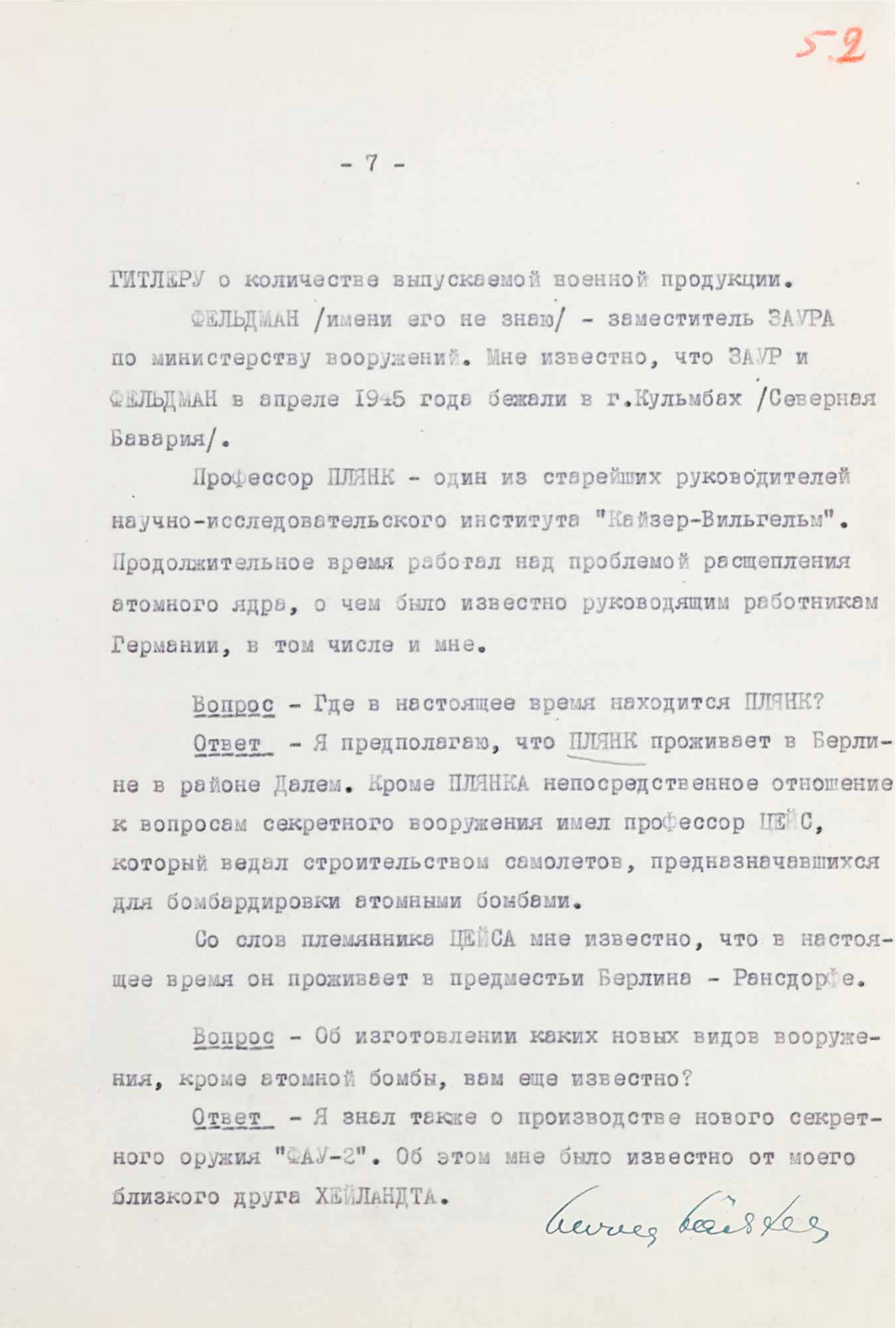
Вопрос - Назовите специалистов непосредственно работавших по изготовлению атомной бомбы в Германии?

Ответ - Мне известно, что непосредственное отношение ко всем видам секретного вооружения и, в частности, атомной бомбы, имели следующие лица: генерал ДОРНБЕРГЕР - начальник Управления новых видов вооружения министерства ШПЕЕРА, ранее проживал в Берлине - Шарлоттенбург, Рильштрассе. Где в настоящее время находится ДОРНБЕРГЕР - я не знаю.

ЗАУР - начальник Управления индустрии министерства вооружений, являлся одним из доверенных лиц министра вооружений ТОДТ, а затем его преемника ШПЕЕРА. ЗАУР фактически ведал всеми производством новых видов вооружения в Германии. Как мне известно, он каждый месяц лично отчитывался

Werner Wächter

Figure D.773: Transcript of NKVD interrogation of Werner Wächter by Ivan Serov. 10 October 1945 [FSB Archive, Moscow, courtesy of Matthias Uhl].



ГИТЛЕРУ о количестве выпускаемой военной продукции.

ФЕЛЬДМАН /имени его не знаю/ - заместитель ЗАУРА по министерству вооружений. Мне известно, что ЗАУР и ФЕЛЬДМАН в апреле 1945 года бежали в г.Кульмбах /Северная Бавария/.

Профессор ПЛЯНК - один из старейших руководителей научно-исследовательского института "Кайзер-Вильгельм". Продолжительное время работал над проблемой расщепления атомного ядра, о чем было известно руководящим работникам Германии, в том числе и мне.

Вопрос - Где в настоящее время находится ПЛЯНК?

Ответ - Я предполагаю, что ПЛЯНК проживает в Берлине в районе Далем. Кроме ПЛЯНКА непосредственное отношение к вопросам секретного вооружения имел профессор ЦЕЙС, который ведал строительством самолетов, предназначавшихся для бомбардировки атомными бомбами.

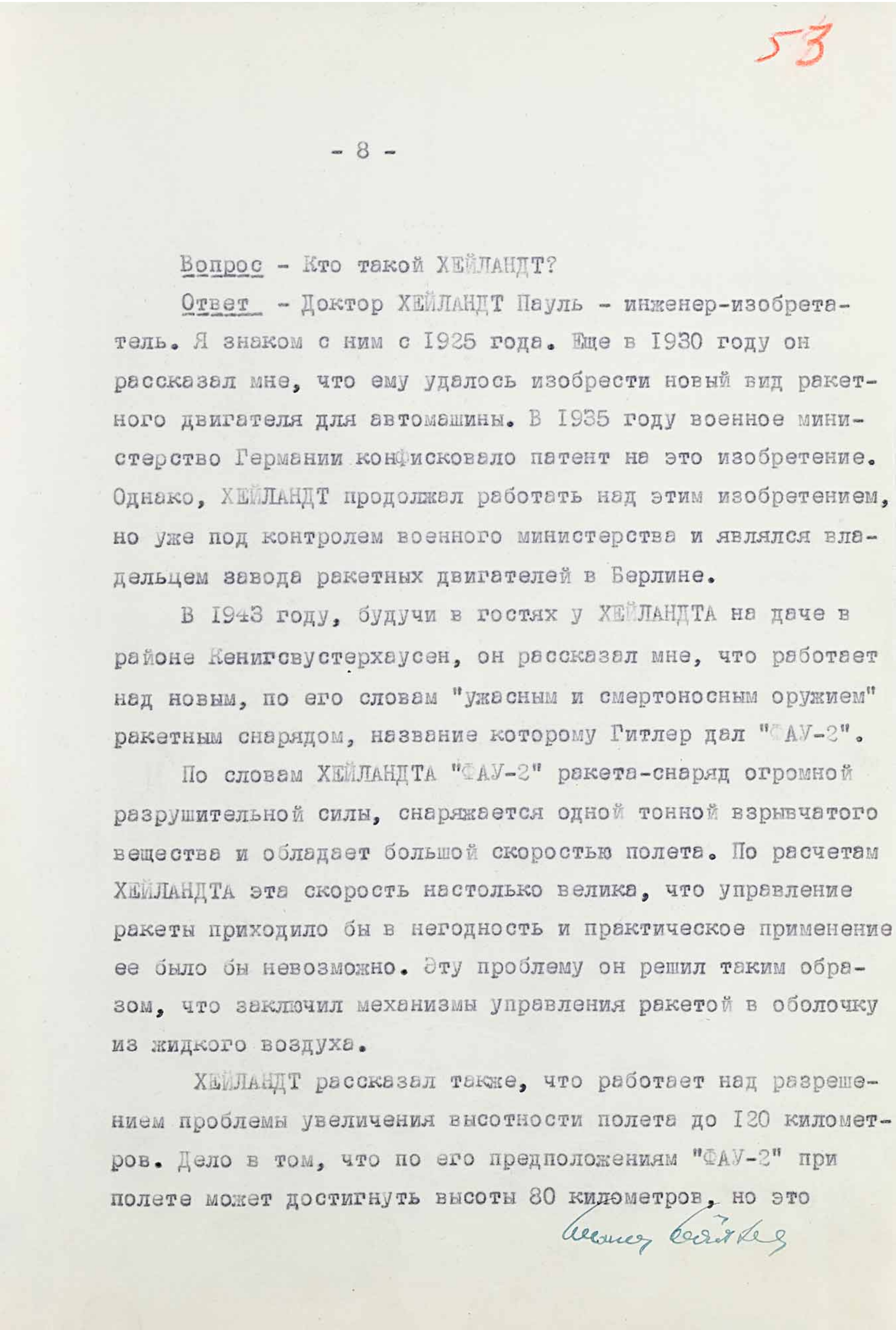
Со слов племянника ЦЕЙСА мне известно, что в настоящее время он проживает в предместьи Берлина - Рансдорфе.

Вопрос - Об изготовлении каких новых видов вооружения, кроме атомной бомбы, вам еще известно?

Ответ - Я знал также о производстве нового секретного оружия "ФАУ-2". Об этом мне было известно от моего близкого друга ХЕЙЛАНДТА.

Werner Wächter

Figure D.774: Transcript of NKVD interrogation of Werner Wächter by Ivan Serov. 10 October 1945 [FSB Archive, Moscow, courtesy of Matthias Uhl].



53

Вопрос - Кто такой ХЕЙЛАНДТ?

Ответ - Доктор ХЕЙЛАНДТ Пауль - инженер-изобретатель. Я знаком с ним с I925 года. Еще в I930 году он рассказал мне, что ему удалось изобрести новый вид ракетного двигателя для автомашины. В I935 году военное министерство Германии конфисковало патент на это изобретение. Однако, ХЕЙЛАНДТ продолжал работать над этим изобретением, но уже под контролем военного министерства и являлся владельцем завода ракетных двигателей в Берлине.

В I943 году, будучи в гостях у ХЕЙЛАНДТА на даче в районе Кенигсвустерхаусен, он рассказал мне, что работает над новым, по его словам "ужасным и смертоносным оружием" ракетным снарядом, название которому Гитлер дал "ФАУ-2".

По словам ХЕЙЛАНДТА "ФАУ-2" ракета-снаряд огромной разрушительной силы, снаряжается одной тонной взрывчатого вещества и обладает большой скоростью полета. По расчетам ХЕЙЛАНДТА эта скорость настолько велика, что управление ракеты приходило бы в негодность и практическое применение ее было бы невозможно. Эту проблему он решил таким образом, что заключил механизмы управления ракетой в оболочку из жидкого воздуха.

ХЕЙЛАНДТ рассказал также, что работает над разрешением проблемы увеличения высотности полета до I20 километров. Дело в том, что по его предположениям "ФАУ-2" при полете может достигнуть высоты 80 километров, но это

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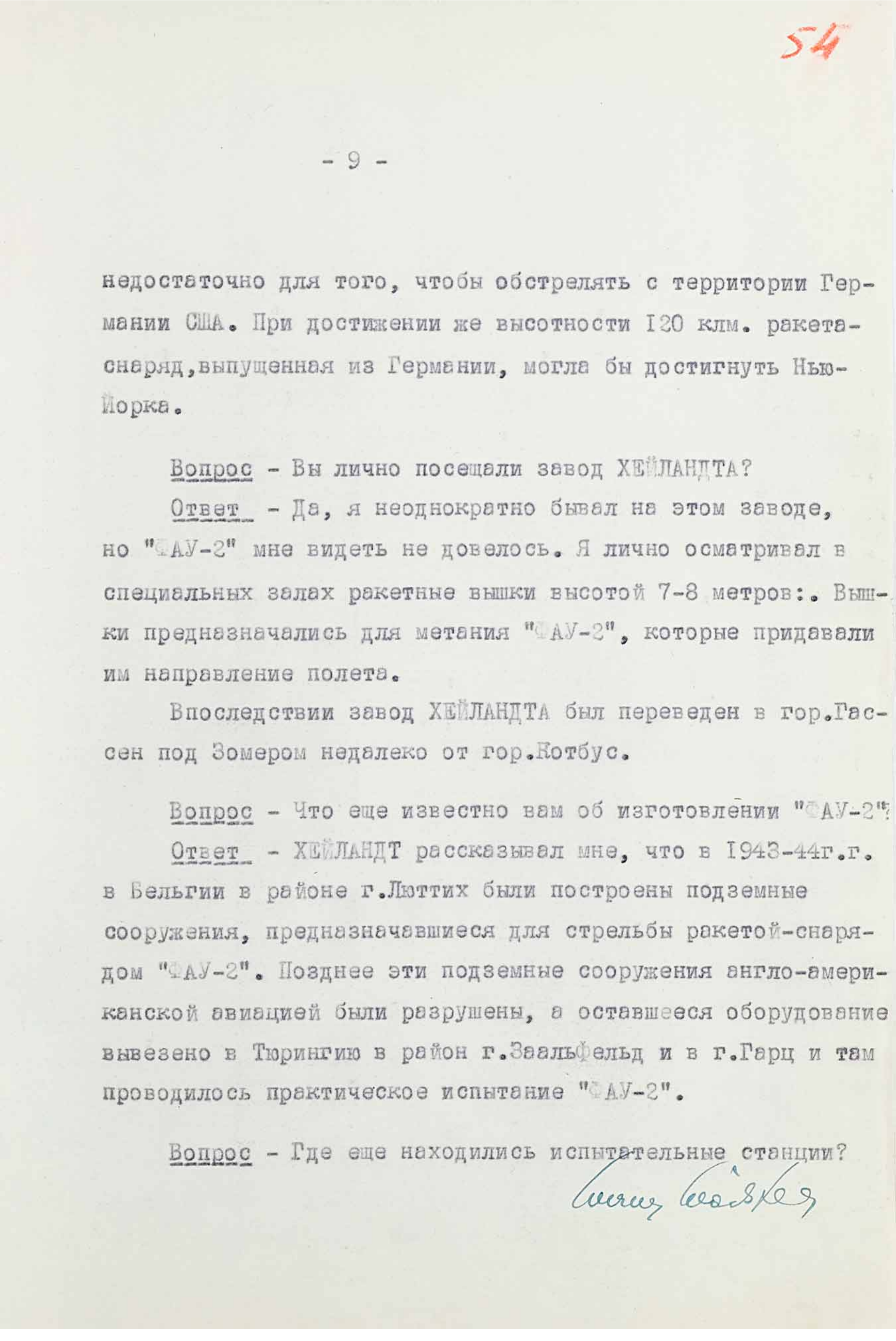

недостаточно для того, чтобы обстрелять с территории Германии США. При достижении же высотности I20 клм. ракета-снаряд,выпущенная из Германии, могла бы достигнуть Нью-Йорка.

Вопрос - Вы лично посещали завод ХЕЙЛАНДТА?

Ответ - Да, я неоднократно бывал на этом заводе, но "ФАУ-2" мне видеть не доводилось. Я лично осматривал в специальных залах ракетные вышки высотой 7-8 метров:. Вышки предназначались для метания "ФАУ-2", которые придавали им направление полета.

Впоследствии завод ХЕЙЛАНДТА был переведен в гор.Гассен под Зомером недалеко от гор.Котбус.

Вопрос - Что еще известно вам об изготовлении "ФАУ-2"?

Ответ - ХЕЙЛАНДТ рассказывал мне, что в I943-44г.г. в Бельгии в районе г.Люттих были построены подземные сооружения, предназначавшиеся для стрельбы ракетой-снарядом "ФАУ-2". Позднее эти подземные сооружения англо-американской авиацией были разрушены, а оставшееся оборудование вывезено в Тюрингию в район г.Заальфельд и в г.Гарц и там проводилось практическое испытание "ФАУ-2".

Вопрос - Где еще находились испытательные станции?

Werner Wächter

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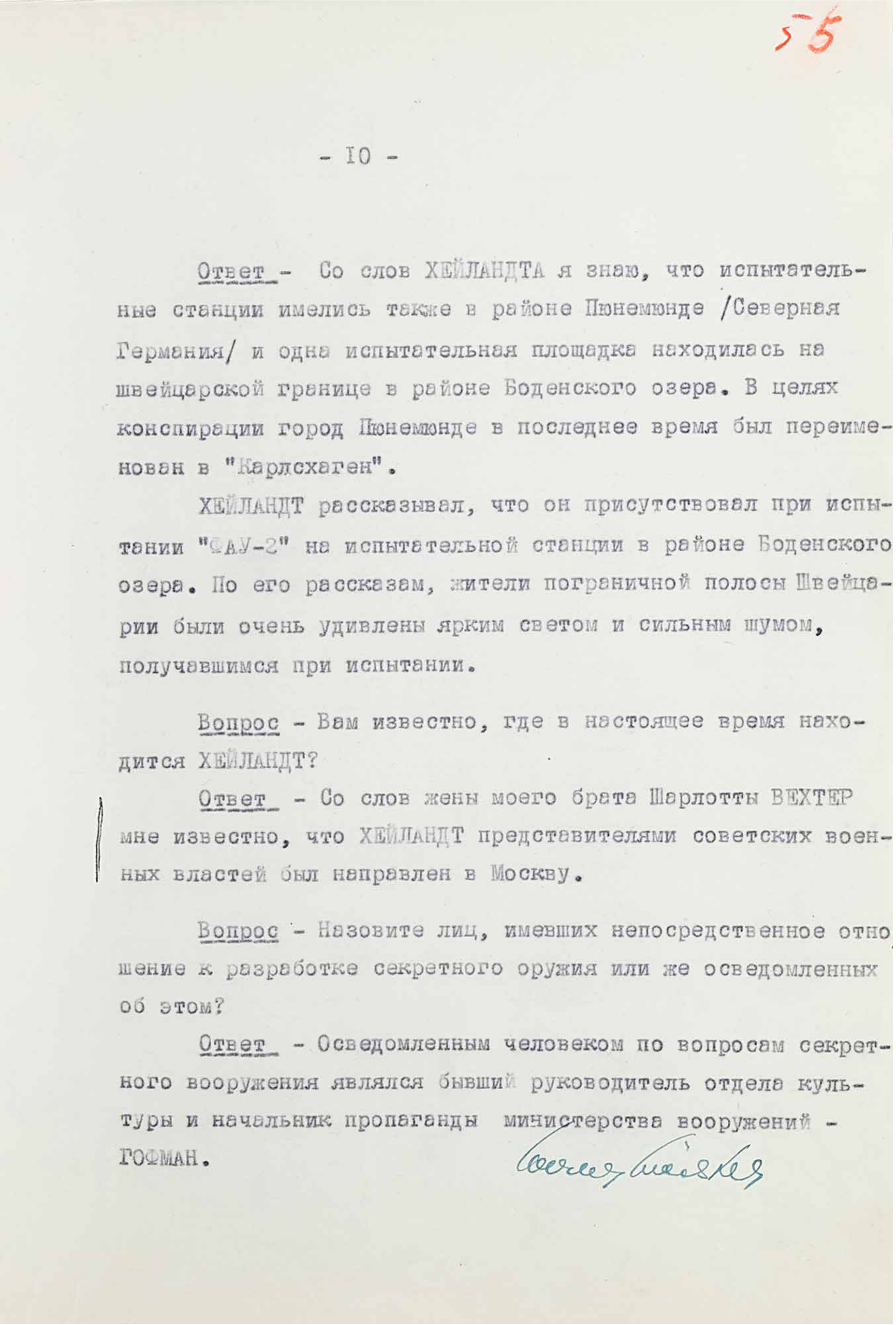

Ответ - Со слов ХЕЙЛАНДТА я знаю, что испытательные станции имелись также в районе Пюнемюнде /Северная Германия/ и одна испытательная площадка находилась на швейцарской границе в районе Боденского озера. В целях конспирации город Пюнемюнде в последнее время был переименован в "Карлсхаген".

ХЕЙЛАНДТ рассказывал, что он присутствовал при испытании "ФАУ-2" на испытательной станции в районе Боденского озера. По его рассказам, жители пограничной полосы Швейцарии были очень удивлены ярким светом и сильным шумом, получавшимся при испытании.

Вопрос - Вам известно, где в настоящее время находится ХЕЙЛАНДТ?

Ответ - Со слов жены моего брата Шарлотты ВЕХТЕР мне известно, что ХЕЙЛАНДТ представителями советских военных властей был направлен в Москву.

Вопрос - Назовите лиц, имевших непосредственное отношение к разработке секретного оружия или же осведомленных об этом?

Ответ - Осведомленным человеком по вопросам секретного вооружения являлся бывший руководитель отдела культуры и начальник пропаганды министерства вооружений - ГОФМАН.

Werner Wächter

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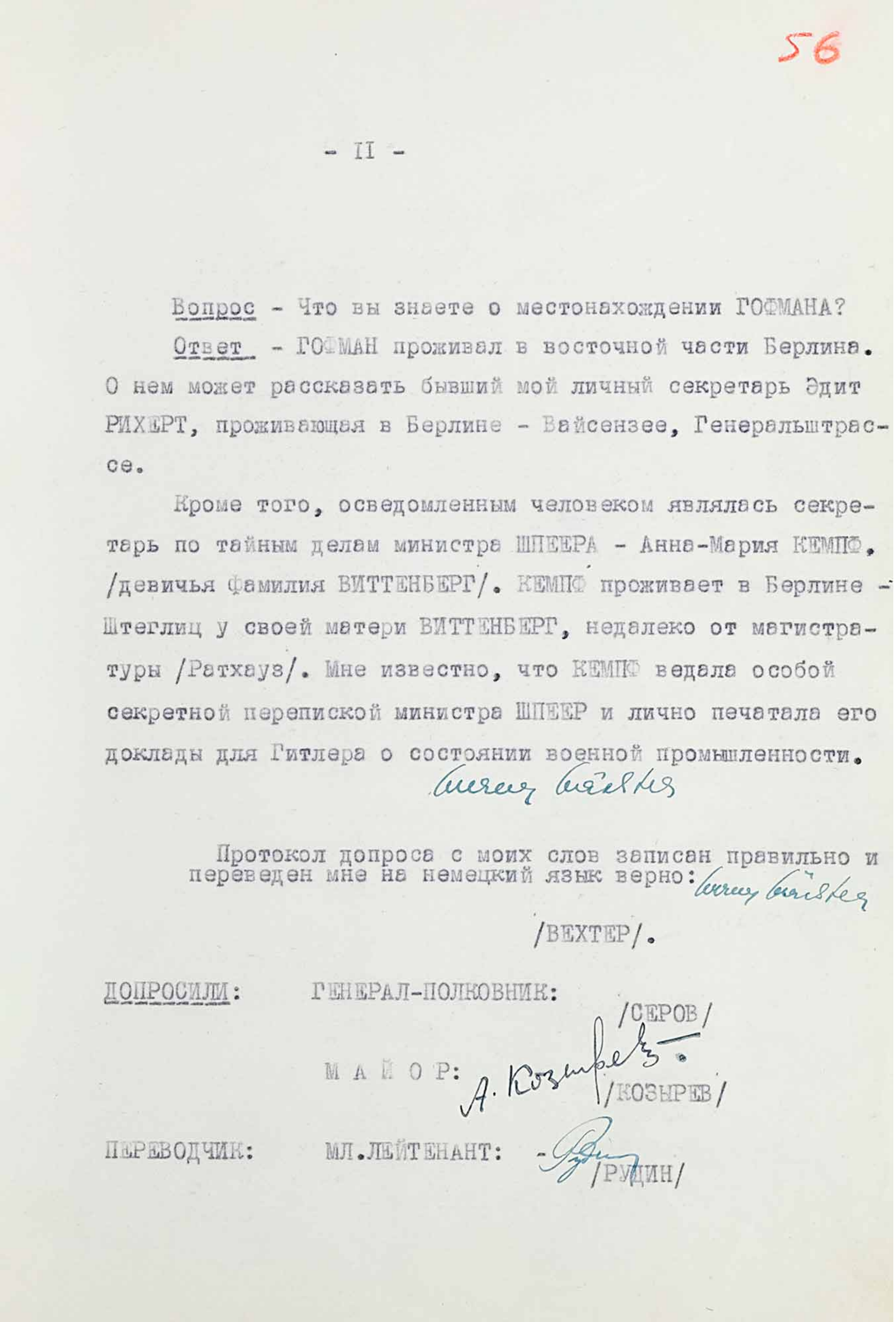

Вопрос - Что вы знаете о местонахождении ГОФМАНА?

Ответ - ГОФМАН проживал в восточной части Берлина. О нем может рассказать бывший мой личный секретарь Эдит РИХЕРТ, проживающая в Берлине - Вайсензее, Генеральштрассе.

Кроме того, осведомленным человеком являлась секретарь по тайным делам министра ШПЕЕРА - Анна-Мария КЕМПФ, /девичья фамилия ВИТТЕНБЕРГ/. КЕМПФ проживает в Берлине - Штеглиц у своей матери ВИТТЕНБЕРГ, недалеко от магистратуры /Ратхауз/. Мне известно, что КЕМПФ ведала особой секретной перепиской министра ШПЕЕР и лично печатала его доклады для Гитлера о состоянии военной промышленности.

Werner Wächter

Протокол допроса с моих слов записан правильно и переведен мне на немецкий язык верно: Werner Wächter

/ВЕХТЕР/.

ДОПРОСИЛИ: ГЕНЕРАЛ-ПОЛКОВНИК: /СЕРОВ/

МАЙОР: А. Козырев /КОЗЫРЕВ/

ПЕРЕВОДЧИК: МЛ.ЛЕЙТЕНАНТ: /РУДИН/

Figure D.778: Transcript of NKVD interrogation of Werner Wächter by Ivan Serov. 10 October 1945 [FSB Archive, Moscow, courtesy of Matthias Uhl].

Leroy Vogel. Interrogation Records Prepared for War Crimes Proceedings. Activities of Jürgen Stroop. 1945. https://www.fold3.com/image/232067115

14 Apr Held 20 minute talk with HIMMLER who convinced STROOP that Germany could still win the war. Received instructions to convey this opinion to all HSSPF's in Southern Germany. HIMMLER gave STROOP full freedom of action.

[Jürgen Stroop was an SS general who reported directly to Heinrich Himmler. The above interrogation record indicates that Himmler told him about a weapon so powerful that even in April 1945, it had the potential to help Germany win the war.

In 1949, Stroop spent over eight months in the same Polish jail cell as Kazimierz Moczarski, a dissident journalist who later wrote about his conversations with Stroop. In the conversation below, Stroop confirmed to Moczarski that the powerful new weapon was indeed an atomic bomb.

During the war, Stroop would have had direct knowledge of the development of the German atomic bomb, both from his conversations with Himmler and likely from other conversations within the SS, which was deeply involved in running the German nuclear program in the final years of the war. After the war, on the other hand, Stroop would have been left wondering why the German atomic bomb had not been employed by the end of the war, so his 1949 explanations for that below must be regarded as simply his own speculations.]

Kazimierz Moczarski. 1981. *Conversations with an Executioner: An Incredible 255-Day-Long Interview with the Man Who Destroyed the Warsaw Ghetto.* Englewood Cliffs, New Jersey: Prentice-Hall. p. 214

One day the talk turned to the wonder weapons which Germany had dreamed of producing in 1944–45.

"What were they going to be?" I asked. "Improved V rockets? A new kind of artillery along the lines of the Russian Katyusha? Jet aircraft?"

"None of those, *Herr* Moczarski," Stroop said firmly. "We hadn't started mass-producing jet planes yet, although we had prototypes in the air. I saw one once in my district. It flew amazingly fast. But new planes, rockets, and artillery weren't what Adolf Hitler was after." Stroop paused, then continued dramatically: "We were one step away from discovering a new explosive to be used in aerial warfare."

I tried not to smile.

"You mean you were about the invent the atomic bomb?"

"Exactly. All through the war, German and Anglo-Saxon scientists raced neck and neck to perfect such a weapon. . . ."

"And guess who crossed the finish line first? The Americans at Hiroshima," I said with satisfaction.

"Inevitable, *Herr* Moczarski. Inevitable. We lacked topflight physicists, and our research laboratories had been badly bombed."

Benito Mussolini. 20 April 1945 interview. In: Gian Gaetano Cabella. 1948. *Testamento politico di Mussolini.* Rome: Tosi. p. 45.
https://antonioportobello.wordpress.com/2011/04/24/il-testamento-politico-di-mussolini-lultima-intervista-dettata-corretta-siglata-dal-duce-il-22-aprile-1945-gian-gaetano-cabella/

"Le famose bombe distruttrici sono per essere approntate. Ho, ancora pochi giorni fa, avuto notizie precisissime. Forse Hitler non vuole vibrare il colpo che nella assoluta certezza che sia decisivo.

Pare che siano tre, queste bombe e di efficacia sbalorditiva. La costruzione di ognuna ètremendamente complicata e lunga."

"The famous destroyer bombs are going to be prepared. I have, still a few days ago, received very precise news. Perhaps Hitler does not want to strike the blow except in the absolute certainty that it is decisive.

It seems that there are three of them, these bombs, and of astounding effectiveness. The construction of each is tremendously complicated and time-consuming."

[According to Cabella, this 1948 booklet is a transcript of an interview he conducted with Mussolini on 20 April 1945 (eight days before his execution). Cabella was a journalist who had manufactured propaganda for Mussolini during the war and thus his writings must be treated cautiously.[17]

However, Edoardo Susmel and Duilio Susmel considered Cabella's account of his 20 April 1945 interview with Mussolini to be accurate and included it in their *Opera omnia di Benito Mussolini*, Vol. XXXII, pp. 191–201. Moreover, the details of Cabella's account agree with other sources that Cabella would not have known about at the time he wrote:

- Cabella wrote that he interviewed Mussolini on 20 April 1945 starting at 15:20 (3:20 p.m., pp. 14–16). The calendar of Mussolini's appointments has since been published, and it shows that Mussolini met with a long series of people that day [Guerrazzi 2020, p. 359]. While it does not name Cabella specifically, it shows that Mussolini had a gap in his schedule 15:20–16:00 during which he would have been available to meet with Cabella, exactly as Cabella claimed.
- After the war, Luigi Romersa repeatedly confirmed that he had provided Mussolini with information about German nuclear weapons (pp. 4427–4434).
- Mussolini had other sources of information about German nuclear weapons (e.g., pp. 4366, 4600).
- Mussolini spoke on other occasions about German nuclear weapons (e.g., pp. 4603, 4667).
- According to Cabella, Mussolini spoke of three bombs. If he meant three physical bombs ready for deployment, there were other sources that also spoke of three deployable bombs (e.g., pp. 4182, 4667). If he meant three different types of bombs, with unspecified numbers of each, there were other sources that mentioned three different types of nuclear weapons (e.g., p. 3401).
- According to Cabella, Mussolini thought Germany was reluctant to use the nuclear weapons if they would not have a decisive effect on the war. Other knowledgeable sources said the same thing (e.g., pp. 4668–4670).]

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[17] See for example:
Pietro Caporilli. 1962. *L'ombra di Giuda.* Rome: Edizioni Ardita, Roma. pp. 122–123.
Arrigo Petacco. 2002. *Ammazzate quel fascista! Vita intrepida di Ettore Muti.* Milan: Mondadori. p. 200.
Donato D'Urso. Sept.-Oct. 2012. Il Popolo di Alessandria e il Testamento politico di Mussolini. Gian Gaetano Cabella, protagonista del giornalismo della RSI. *Nuova Storia Contemporanea* 16:5:134.

Georg Zachariae. 1948. *Mussolini si confessa.* Milan: Garzanti. Reprinted in 2004 by Milan: BUR; see p. 183. [Zachariae was Mussolini's personal physician.]

Il duce fino all'ultimo momento non aveva perso la speranza che si potesse vincere la guerra; egli era convinto che le armi segrete tedesche avrebbero provocato un capovolgimento della situazione, che appariva ormai disperata. Egli aveva apertamente sostenuto questa sua convizione con tutti coloro che negli ultimi mesi avevano avuto contatti con lui. Anche intrattenendosi confidenzialmente con me era difficile che si lasciasse persuadere della fallacia delle sue opinioni. Verso la fine però egli ammise che la guerra era perduta militarmente, e nel riconoscere l'ineluttabilità della disfatta egli mi diceva che anche il suo destino era segnato.

Until the last moment the duce had not lost hope that the war could be won; he was convinced that the German secret weapons would cause a reversal of the situation, which by then appeared desperate. He had openly supported this belief of his with all those who had had contact with him in the last months. Even talking confidentially with me it was difficult for him to be persuaded of the fallacy of his opinions. Towards the end, however, he admitted that the war was militarily lost, and, in recognizing the inevitability of defeat, he told me that his fate was also sealed.

Erwin Bartmann. 2013. *Für Volk und Führer: The Memoir of a Veteran of the 1st SS Panzer Division Leibstandarte SS Adolf Hitler.* Solihull, UK: Helion.

[pp. 160–161:] 'What I am about to tell you is top secret—you must not repeat this—tell no one.'

Wide-eyed with expectation, Papa and I nodded.

Mama's brows furled. 'Then perhaps you shouldn't tell us, Horst.'

'I trust my own family Mama,' replied Horst, brushing across her concerns. He leaned forward in his seat and whispered, 'As you know, I am responsible for making the telephone connections when calls are made to and from the Air Ministry. Listen to this—the other day I made a connection between Göring and the *Führer.*'

Mama gasped. 'Oh Horst.'

'Göring asked the *Führer* for permission to use three special bombs but he refused. "If I use them in the east they will get us from the west," said the *Führer.*'

Papa pulled his chair closer to the table. 'What were these special bombs?'

'I don't know for sure but they must be powerful—although Göring clearly mentioned three I got the impression there might be more.'

'This is the *Wunderwaffe*,' exclaimed my father. 'Our scientists have done well with their rockets—who would put it past them to come up with something like this? It would really surprise the British if they put one of these special bombs in a rocket.' [...]

[p. 231:] After the war, I became friends with Rochus Misch, a fellow *Leibstandarte* veteran and communications officer in the *Führerbunker* until the final days of the *Reich.* The topic of the special bombs came up in conversation. 'Three bombs,' he said, 'where did you hear that? There were nine.'

There has been much speculation about the possession of atomic weapons by Germany. Whether the bombs that my brother mentioned were conventional or atomic remains a matter of conjecture.

Heinrich Himmler's chief adjutant Werner Grothmann on why nuclear weapons were not used in combat [Krotzky 2002]. For a discussion of the background and reliability of this source, see pp. 3396–3397. See also Grothmann's testimony on pp. 3401, 4271, and 4436.

[S. 13] Himmler hat sich jedenfalls Bericht erstatten lassen und es wurde beraten, was wir jetzt noch machen können. Das eine Problem war die geringe Menge und immer noch die Unsicherheit, wie es im Einsatz klappen würde. Das andere war die Frage nach der tatsächlichen politischen Wirkung.

[S. 13] Manche meinten, ein Volltreffer auf Moskau müßte das erste Ziel sein. Dem ist aber widersprochen worden mit dem Argument, das würde an der Ostfront nichts mehr ändern.

[S. 14] Wenn wir also jetzt auf Hitlers Befehl eine solche Waffe zum Beispiel über London einsetzen würden, ergäbe sich eine völlig neue Situation, aber nicht in unserem Sinne. Wenn die Waffenwirkung den Berechnungen entspricht, fallen zwar wichtige Teile der politischen und militärischen Führung aus, aber viele andere Ebenen, die außerhalb untergebracht waren, bleiben erhalten. Es gibt schwere Verluste unter der Zivilbevölkerung und wenn sich das Entsetzen gelegt hat stellt man fest, dass die Versorgung der englischen Truppen, die im Reich stehen, über ihre Häfen und die unter ihrer Kontrolle weiter möglich ist. Außerdem stehen die Engländer eben auf unserem Gebiet. Und das wichtigste Argument: bei uns glaubte niemand wirklich daran, dass die dann abziehen würden. Ganz im Gegenteil. Ihre Reaktionen gegenüber unserer Bevölkerung konnten wir uns ausmalen. Die andere Seite, die man auch betrachten muß, sind die Amerikaner.

[S. 15] Bei den Besprechungen, die ich erlebt hatte oder über die ich in Andeutungen erfuhr, war keiner so verrückt, eine Waffe einzusetzen, die uns nicht mehr helfen konnte, sondern nach Lage der Dinge alles nur noch viele schlimmer machen würde.

[p. 13] Himmler had in any case come up with a report, and a consultation took place regarding what we could make now. The one problem was the small quantity [of fuel] and always still the uncertainty of how it would work in action. The other was the question of the real political effect.

[p. 13] Some said that a direct hit on Moscow must be the first goal. But this has been countered by the argument that this would not change anything on the eastern front.

[p. 14] If we were now to use such a weapon on Hitler's order, for example to employ it on London, a completely new situation would arise, but not in our favor. If the weapon's impact corresponds to the calculations, important parts of the political and military leadership will fall, but many other levels that have been relocated outside will be preserved. There are heavy casualties among the civilian population, and when the horror has subsided, it is clear that the supply of potential British troops in the Reich is still possible via their ports and is still under their control. Besides, the British are also on our territory. And the most important argument: with us, no one really believed that they would then withdraw. Quite the contrary! We could picture their reactions to our population. The other side, which must also be considered, is the Americans.

[p. 15] At the meetings I attended, or about which I learned in hints, no one was so crazy to use a weapon which could no longer help us, but would only make things even much worse.

[S. 16] Also, der erste Punkt war, dass die Entscheidungsträger wissen mussten, was ihnen persönlich blüht, wenn eine völlig neue, furchtbare Massenvernichtungswaffe von unserer Seite eingesetzt würde, Wirkung erzielt, der Krieg aber trotzdem von uns verloren wird. Was die Sieger dann aus der Genfer Konvention herauslesen würden war klar.	[p. 16] So, the first point was that the decision-makers had to know how they personally fared, if a completely new, terrible mass-destruction weapon were deployed by our side and achieved its effect, but the war were nevertheless lost by us. What the victors would then read out of the Geneva Convention was clear.
Der zweite Punkt war der hier: Damals lag doch die Forderung nach bedingungsloser Kapitulation schon längst auf dem Tisch. Und die war das Ergebnis der normalen Kriegslage. Was hätte sich dann ergeben nach dem Einsatz unserer Atombombe? Ihnen sind bestimmt auch die Vorstellungen von Morgenthau bekannt. Es würde alles noch viel schlimmer kommen.	The second point was that: At that time, the demand for unconditional surrender had long been on the table. And that was the result of the normal war situation. What would have happened after the use of our atomic bomb? You are certainly familiar with the ideas of Morgenthau. Everything would be much worse.

[Grothmann made several points:

- By the end of the war, there was only enough fission fuel for a very small number of bombs.
- With the possibilities of rockets malfunctioning, aircraft getting shot down, or the bombs themselves malfunctioning, there was no guarantee that those bombs could be successfully delivered to Allied targets.
- Even if the bombs were successfully delivered and destroyed a very small number of Allied cities, they would not stop the large Allied military forces that were invading Germany, and in fact they would only inspire the Allied forces to defeat Germany more quickly before it could deliver more bombs.
- If Germany had used nuclear bombs against Allied targets, the Allies would have retaliated with even greater destruction (such as firebombing or mustard gas) against German targets than what the Allies were already doing.
- If Germany had used nuclear bombs against Allied targets, those individuals who were responsible would have been prosecuted for war crimes after the war.
- If Germany had used nuclear bombs against Allied targets, the Allies would have imposed much harsher terms on Germany after the war. Grothmann mentioned the Allied Morgenthau plan that was actually considered but not implemented, which would have eliminated all industry in postwar Germany.

Grothmann's arguments are the same reasons why Germany did not use its stockpile of very advanced nerve gas [Tucker 2006], which was far larger than its stockpile of nuclear weapons as estimated by Grothmann.]

Allen Dulles. 1 April 1945. Cable IN 9061 from Bern, Switzerland to Office of Strategic Services. [NARA RG 226, Entry UD-90, Box 6, Folder 64 SUNRISE] [See document photos on pp. 4671–4672.]

[...] 8. In his conversation with Emperor [Kesselring], latter said to Critic [Wolff] our situation is desperate, nobody dares tell truth to Fuehrer who surrounded by small group of advisers who still believe in a last specific secret weapon which they call "Verzweiflunge" weapon [die Verzweiflungswaffe or the "desperation weapon"]. Emperor believed this weapon can prolong war but not decide it, but might cause terrible blood bath on both sides. Emperor said if Fuehrer gave him order to use weapon he would surrender his command. [...]

Allen Dulles. 5 April 1945. Cable IN 9470 from Bern, Switzerland to Office of Strategic Services. [NARA RG 226, Entry UD-90, Box 7, Folder 86 BERN–IN OUT 1944–1945]

[...] Following information given by Wood mostly dated middle March when he left Berlin. [...]

4. Archivabteilung of Foreign Office is located in the Harz near Quedlinburg and archives distributed in old salt mines. Current files were still Berlin middle March.

5. Burning of archives proceeding on large scale and instructions to this effect have been given to every government office in case of danger of enemy occupation. Unfortunately material which Wood had put in his office safe was burned during his last absence from Berlin. [...]

Karlsch 2005, pp. 253–254, 388, citing: CIC Documentation "Adolf Hitler" 1944–1953, Interrogation of Hans Fegelein. 21 September 1945. Institut für Zeitgeschichte (IfZ), Munich, F 135/3, pp. 384ff.

Mit Vorsicht kann dies auch aus einer Befragung von Hans Fegelein, dem Vater Hermann Fegeleins, geschlossen werden. SS-Gruppenführer Hermann Fegelein, seit 1944 Himmlers Verbindungsoffizier im Führerhauptquartier und Schwager Eva Brauns, war noch am 28. April 1945 wegen Fahnenflucht standrechtlich erschossen worden. Sein Vater berichtete den Amerikanern im September 1945 über die dramatischen letzten Kriegstage. Hitler sei sehr erregt darüber gewesen, dass ihm Himmler die neue Atombombe vorenthalten hätte. Er wollte damit noch eine Kriegswende herbeiführen.Im Befragungsprotokoll heißt es: "Die Ingenieure, die zuletzt im Führerhauptquartier waren, und auch der Führer selbst erwarteten täglich den Gefechtseinsatz der Atombombe. Aber Saboteure verhinderten dies." Wer die Saboteure gewesen sein sollen, erwähnte Hans Fegelein nicht.

With caution this can also be inferred from a survey conducted by Hans Fegelein, the father of Hermann Fegelein. SS group leader Hermann Fegelein, since 1944 Himmler's liaison officer at the Führer's headquarters and brother-in-law of Eva Braun, had been legally shot dead on 28 April 1945 because of desertion. His father told the Americans in September 1945 about the dramatic last war days. Hitler was very angered that Himmler had deprived him of the new atomic bomb. He wanted to turn the war around. The survey report states: "The engineers who were last at the Führer Headquarters and also the Führer himself expected the atomic bomb to be deployed every day. But saboteurs prevented this." Hans Fegelein did not mention who the saboteurs were.

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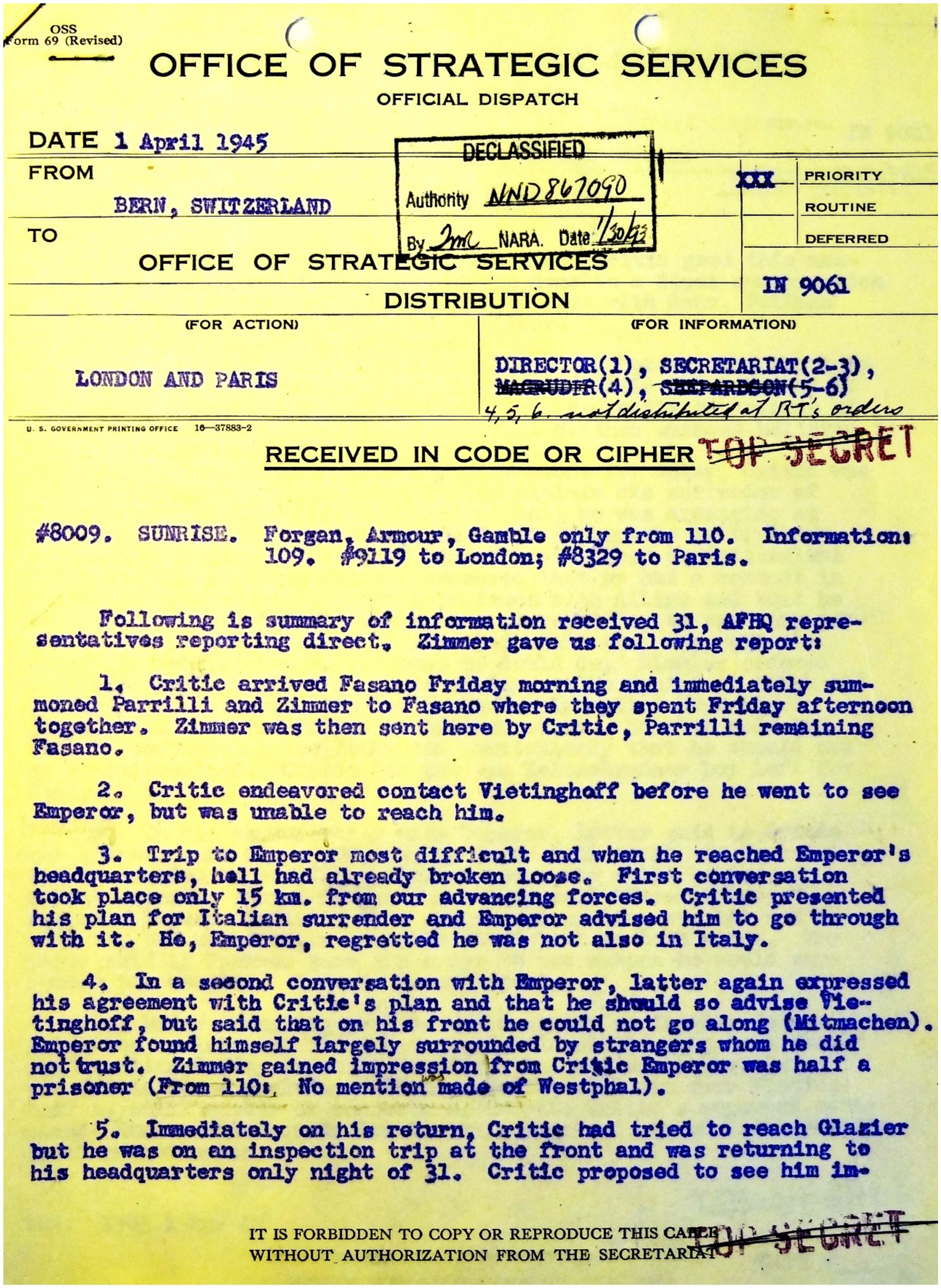
NARA RG 226, Entry UD-90, Box 6, Folder 64 SUNRISE



OSS
Form 69 (Revised)

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OFFICIAL DISPATCH

DATE 1 April 1945

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#8009. SUNRISE. Forgan, Armour, Gamble only from 110. Information: 109. #9119 to London; #8329 to Paris.

Following is summary of information received 31, AFHQ representatives reporting direct. Zimmer gave us following report:

1. Critic arrived Fasano Friday morning and immediately summoned Parrilli and Zimmer to Fasano where they spent Friday afternoon together. Zimmer was then sent here by Critic, Parrilli remaining Fasano.

2. Critic endeavored contact Vietinghoff before he went to see Emperor, but was unable to reach him.

3. Trip to Emperor most difficult and when he reached Emperor's headquarters, hell had already broken loose. First conversation took place only 15 km. from our advancing forces. Critic presented his plan for Italian surrender and Emperor advised him to go through with it. He, Emperor, regretted he was not also in Italy.

4. In a second conversation with Emperor, latter again expressed his agreement with Critic's plan and that he should so advise Vietinghoff, but said that on his front he could not go along (Mitmachen). Emperor found himself largely surrounded by strangers whom he did not trust. Zimmer gained impression from Critic Emperor was half a prisoner (From 110: No mention was made of Westphal).

5. Immediately on his return, Critic had tried to reach Glazier but he was on an inspection trip at the front and was returning to his headquarters only night of 31. Critic proposed to see him im-

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Figure D.779: Allen Dulles. 1 April 1945. Cable IN 9061 from Bern, Switzerland to Office of Strategic Services. [NARA RG 226, Entry UD-90, Box 6, Folder 64 SUNRISE]

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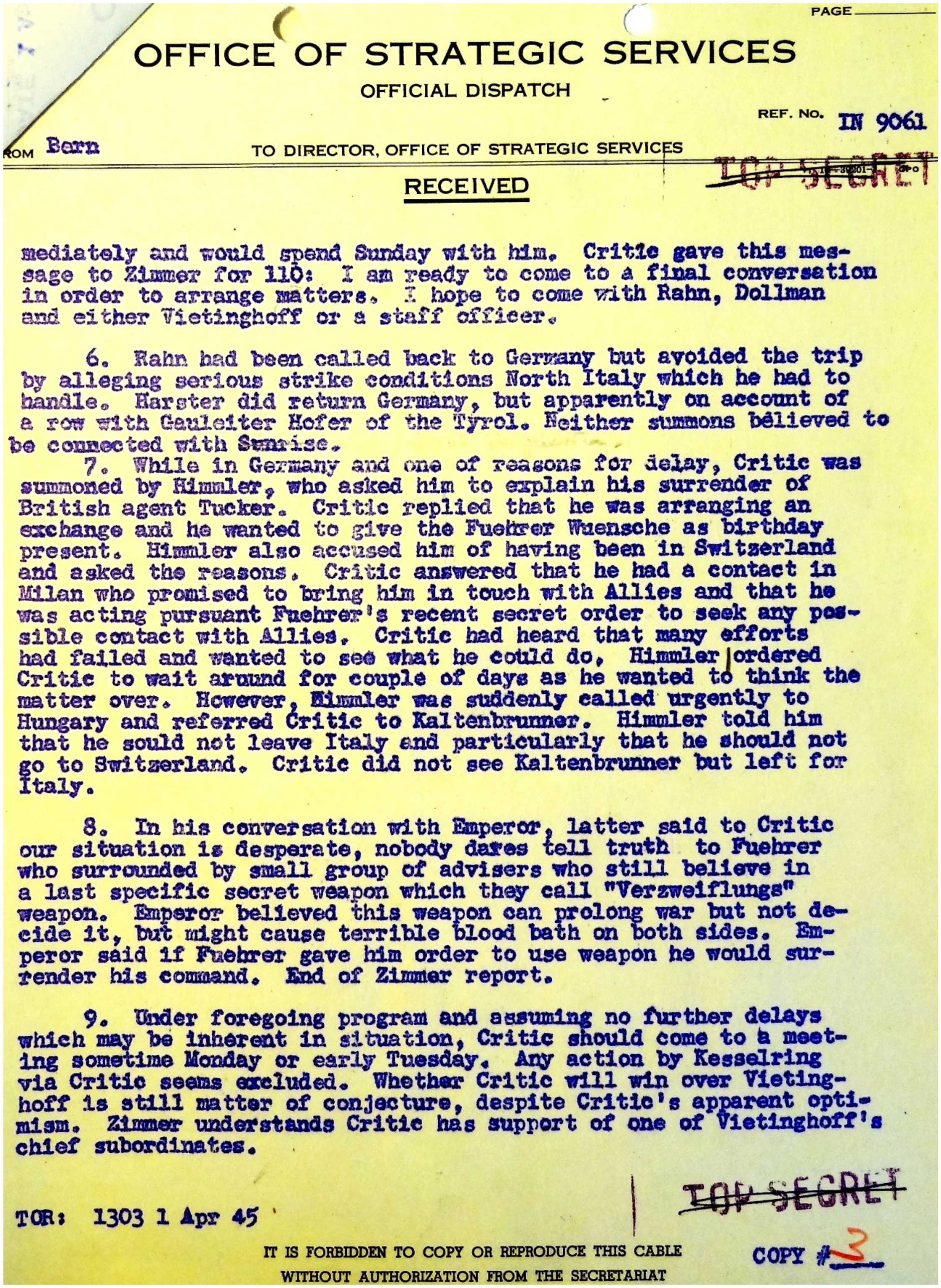

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mediately and would spend Sunday with him. Critic gave this message to Zimmer for 110: I am ready to come to a final conversation in order to arrange matters. I hope to come with Rahn, Dollman and either Vietinghoff or a staff officer.

6. Rahn had been called back to Germany but avoided the trip by alleging serious strike conditions North Italy which he had to handle. Harster did return Germany, but apparently on account of a row with Gauleiter Hofer of the Tyrol. Neither summons believed to be connected with Sunrise.

7. While in Germany and one of reasons for delay, Critic was summoned by Himmler, who asked him to explain his surrender of British agent Tucker. Critic replied that he was arranging an exchange and he wanted to give the Fuehrer Wuensche as birthday present. Himmler also accused him of having been in Switzerland and asked the reasons. Critic answered that he had a contact in Milan who promised to bring him in touch with Allies and that he was acting pursuant Fuehrer's recent secret order to seek any possible contact with Allies. Critic had heard that many efforts had failed and wanted to see what he could do. Himmler ordered Critic to wait around for couple of days as he wanted to think the matter over. However, Himmler was suddenly called urgently to Hungary and referred Critic to Kaltenbrunner. Himmler told him that he sould not leave Italy and particularly that he should not go to Switzerland. Critic did not see Kaltenbrunner but left for Italy.

8. In his conversation with Emperor, latter said to Critic our situation is desperate, nobody dares tell truth to Fuehrer who surrounded by small group of advisers who still believe in a last specific secret weapon which they call "Verzweiflungs" weapon. Emperor believed this weapon can prolong war but not decide it, but might cause terrible blood bath on both sides. Emperor said if Fuehrer gave him order to use weapon he would surrender his command. End of Zimmer report.

9. Under foregoing program and assuming no further delays which may be inherent in situation, Critic should come to a meeting sometime Monday or early Tuesday. Any action by Kesselring via Critic seems excluded. Whether Critic will win over Vietinghoff is still matter of conjecture, despite Critic's apparent optimism. Zimmer understands Critic has support of one of Vietinghoff's chief subordinates.

TOR: 1303 1 Apr 45

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NARA RG 226, Entry UD-90, Box 6, Folder 64 SUNRISE

Figure D.780: Allen Dulles. 1 April 1945. Cable IN 9061 from Bern, Switzerland to Office of Strategic Services. [NARA RG 226, Entry UD-90, Box 6, Folder 64 SUNRISE]

T. R. Hogness and F. A. C. Wardenburg. 4 April 1945. Subject: Report on Interrogation of Professor Walter Bothe. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA (1943–June 1946)]

Dr. Bothe said that about two weeks ago, under orders from the German government, all secret documents in connection with his work were burned and this included some correspondence with Heisenberg and all papers relating to the TA project.

Samuel A. Goudsmit and Robert R. Furman. 9 April 1945. TA Report—Detailed Report of Conversation with Gentner on 5 April 1945. [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)]

A military committee visited Heidelberg about a week before the German troops retreated and carried out orders to burn all secret documents. This included Bothe's work on uranium and anything else marked "Secret." The fact that these records were destroyed was confirmed by rigorous interrogation of the persons involved. The practice seems to be current and can be expected in other localities. All scientific work seems to be classified whether it is directly connected with war work or not because it is necessary to have a classification in order to get priority for materials.

T. R. Hogness to Francis J. Smith. 9 April 1945. Re: Position of German TA Work. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)]

All papers and data pertaining to nuclear physics were stamped "secret" and two weeks before the Americans arrived in Heidelberg a general order was issued to the effect that all "secret" papers were to be destroyed.

C.S.D.I.C. (U.K.) S.R.G.G. 1163(C). [Recorded conversation of two German prisoners of war held in the United Kingdom. AFHRA A5415 electronic pp. 84–85]

CS/1948—Generalleutnant BOINEBURG (Comd., BERGEN (HANNOVER)) Captd ALLSTADT 13 Apr 45

CS/1963—Generalmajor FRANZ (Comd., 256 V.G. Div.) Captured BIRNFELD 8 Apr 45

CS/1965—Generalmajor GOERBIG (Comd., SENNE, Captured BAD GRUND 10 Apr 45

Information received: 29 Apr 1945

TRANSLATION

(?) FRANZ: I hope HIMMLER doesn't fire V-6 or V-7.

(?) GOERBIG: Do you really think we still have something up our sleeves?

(?) FRANZ: Yes, I believe so most definitely. I mean to say it wasn't ready; they hadn't advanced far enough to be brought into use. But I'm certain that a lot of experiments were in progress; it is a fact that some of those projectiles could be fired as far as NEW YORK or elsewhere.

(?) GOERBIG: Did you get that from a reliable source?

(?) FRANZ: I know that for certain.

(?) GOERBIG: With what effect?

(?) FRANZ: With a colossal explosive effect, a strong detonation which really would wipe out everything within a radius of 2 or 3 km. However, the thing isn't ready for immediate use yet. They couldn't make any progress, but next time they will and next time a think like this starts it'll be ghastly. If HIMMLER and his faithful followers turn up one day with all the patents etc., with a sample, it will not be viewed with displeasure by STALIN. There is a risk of HIMMLER betraying the V-weapon preparations to the Russians: "Here are half-completed inventions which will give you great power. You can have them on such and such conditions."

[See document photos on pp. 4676–4677.

All three prisoners being held together were very high-ranking generals in the German army who had been captured in mid-April 1945, and thus would have known the very latest wartime information that they had had access to. The British personnel who were secretly recording and translating the prisoners' conversation were somewhat uncertain which prisoner was speaking, but believed that the main speaker was General Gerhard Franz (German, 1902–1975).

On the basis of whatever high-level classified information Franz had seen or heard before he was captured on 8 April 1945, he was certain that:

- In addition to the well-known V-1 and V-2, there were at least five or so other new secret weapons systems that were sufficiently revolutionary to be dubbed V-weapons.

- Those weapon systems had definitely reached the point at which "a lot of experiments were in progress," and some were sufficiently mature that Franz thought they might be "fired" in actual combat at any time.

- Some of the new V-weapons could reach New York. Franz believed "it is a fact" they already existed. He also seemed to believe that there were multiple V-weapons that could reach New York and other U.S. cities ("some of those projectiles").

- There was a weapon "with a colossal explosive effect, a strong detonation which really would wipe out everything within a radius of 2 or 3 km." That sounds exactly like a fission bomb, and Franz's certainty implied that it had already been tested.

- The long-range V-weapons were intended to deliver such fission bombs to New York or other Allied targets. While Franz seemed to imply that the long-range delivery methods were ready to be fired and that the fission bomb had been tested, he apparently felt that the integrated systems of the nuclear-armed intercontinental weapons were still being perfected.

- All of these advanced weapons were completely controlled by "Himmler and his faithful followers," not other branches of the government or even Hitler.]

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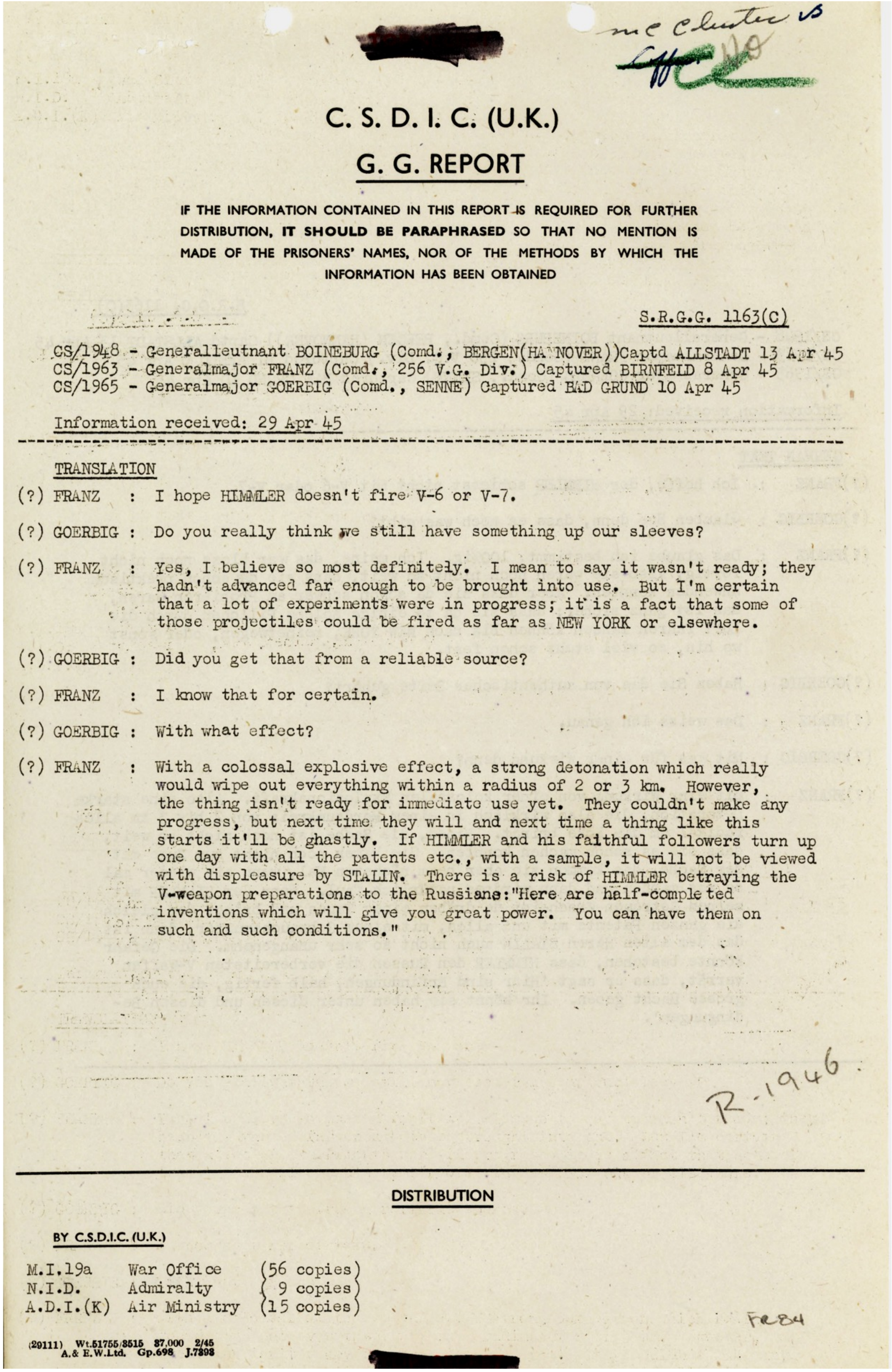
AFHRA folder 512.619C-6C 1944-1945



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C. S. D. I. C. (U.K.)

G. G. REPORT

IF THE INFORMATION CONTAINED IN THIS REPORT IS REQUIRED FOR FURTHER DISTRIBUTION, IT SHOULD BE PARAPHRASED SO THAT NO MENTION IS MADE OF THE PRISONERS' NAMES, NOR OF THE METHODS BY WHICH THE INFORMATION HAS BEEN OBTAINED

S.R.G.G. 1163(C)

CS/1948 - Generalleutnant BOINEBURG (Comd., BERGEN(HANNOVER))Captd ALLSTADT 13 Apr 45
CS/1963 - Generalmajor FRANZ (Comd., 256 V.G. Div.) Captured BIRNFELD 8 Apr 45
CS/1965 - Generalmajor GOERBIG (Comd., SENNE) Captured BAD GRUND 10 Apr 45

Information received: 29 Apr 45

TRANSLATION

(?) FRANZ	:	I hope HIMMLER doesn't fire V-6 or V-7.
(?) GOERBIG	:	Do you really think we still have something up our sleeves?
(?) FRANZ	:	Yes, I believe so most definitely. I mean to say it wasn't ready; they hadn't advanced far enough to be brought into use. But I'm certain that a lot of experiments were in progress; it is a fact that some of those projectiles could be fired as far as NEW YORK or elsewhere.
(?) GOERBIG	:	Did you get that from a reliable source?
(?) FRANZ	:	I know that for certain.
(?) GOERBIG	:	With what effect?
(?) FRANZ	:	With a colossal explosive effect, a strong detonation which really would wipe out everything within a radius of 2 or 3 km. However, the thing isn't ready for immediate use yet. They couldn't make any progress, but next time they will and next time a thing like this starts it'll be ghastly. If HIMMLER and his faithful followers turn up one day with all the patents etc., with a sample, it will not be viewed with displeasure by STALIN. There is a risk of HIMMLER betraying the V-weapon preparations to the Russians:"Here are half-completed inventions which will give you great power. You can have them on such and such conditions."

R-1946.

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Figure D.781: C.S.D.I.C. (U.K.) S.R.G.G. 1163(C). [Recorded conversation of two German prisoners of war held in the United Kingdom. AFHRA folder 512.619C-6C 1944–1945; AFHRA A5415 electronic pp. 84–85]

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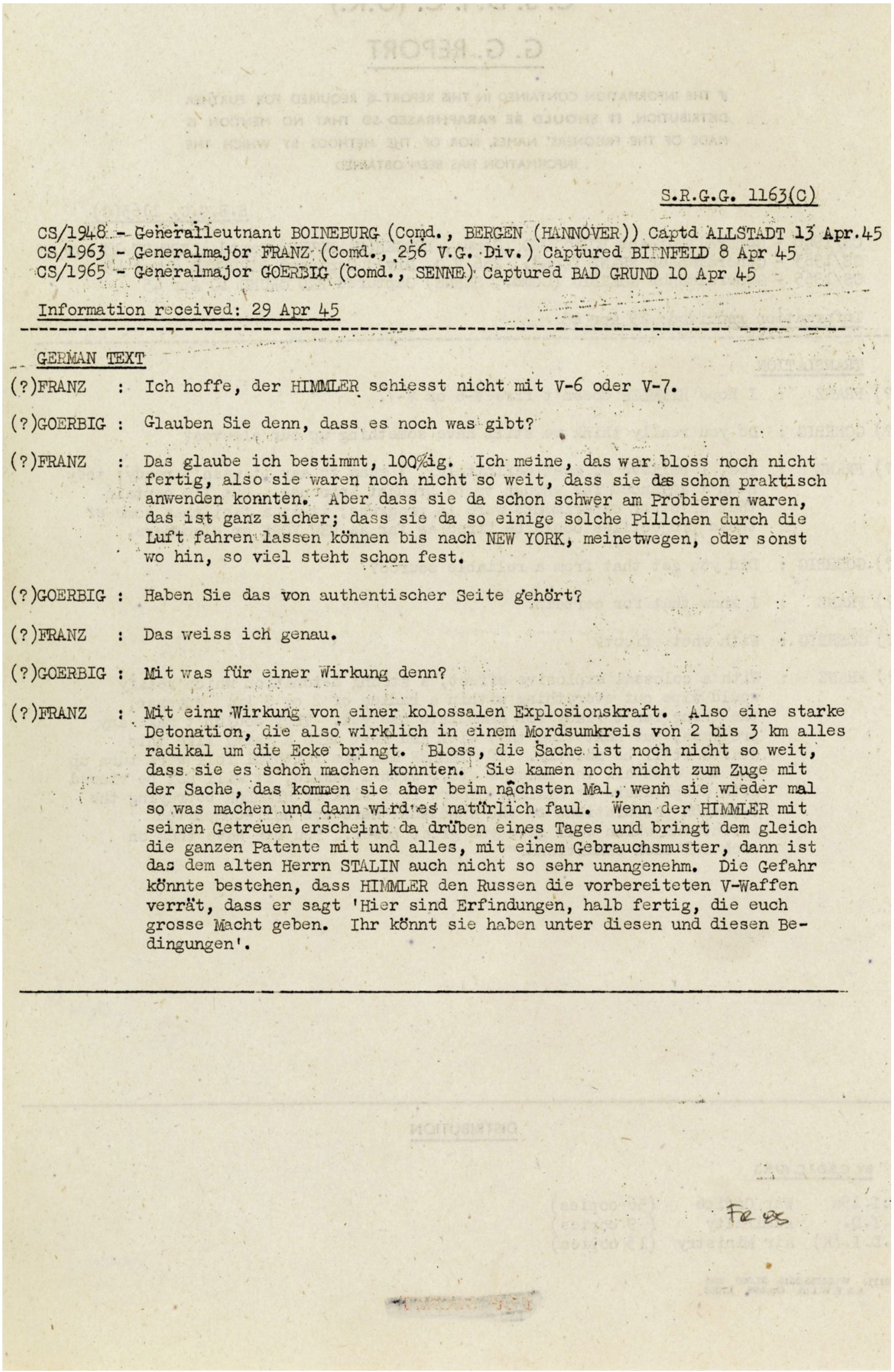
AFHRA folder 512.619C-6C 1944-1945



S.R.G.G. 1163(C)

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CS/1965 - Generalmajor GOERBIG (Comd., SENNE) Captured BAD GRUND 10 Apr 45

Information received: 29 Apr 45

GERMAN TEXT

(?)FRANZ : Ich hoffe, der HIMMLER schiesst nicht mit V-6 oder V-7.

(?)GOERBIG : Glauben Sie denn, dass es noch was gibt?

(?)FRANZ : Das glaube ich bestimmt, 100%ig. Ich meine, das war bloss noch nicht fertig, also sie waren noch nicht so weit, dass sie das schon praktisch anwenden konnten. Aber dass sie da schon schwer am Probieren waren, das ist ganz sicher; dass sie da so einige solche Pillchen durch die Luft fahren lassen können bis nach NEW YORK, meinetwegen, oder sonst wo hin, so viel steht schon fest.

(?)GOERBIG : Haben Sie das von authentischer Seite gehört?

(?)FRANZ : Das weiss ich genau.

(?)GOERBIG : Mit was für einer Wirkung denn?

(?)FRANZ : Mit einr Wirkung von einer kolossalen Explosionskraft. Also eine starke Detonation, die also wirklich in einem Mordsumkreis von 2 bis 3 km alles radikal um die Ecke bringt. Bloss, die Sache ist noch nicht so weit, dass sie es schon machen konnten. Sie kamen noch nicht zum Zuge mit der Sache, das kommen sie aber beim nächsten Mal, wenn sie wieder mal so was machen und dann wird es natürlich faul. Wenn der HIMMLER mit seinen Getreuen erscheint da drüben eines Tages und bringt dem gleich die ganzen Patente mit und alles, mit einem Gebrauchsmuster, dann ist das dem alten Herrn STALIN auch nicht so sehr unangenehm. Die Gefahr könnte bestehen, dass HIMMLER den Russen die vorbereiteten V-Waffen verrät, dass er sagt 'Hier sind Erfindungen, halb fertig, die euch grosse Macht geben. Ihr könnt sie haben unter diesen und diesen Bedingungen'.

Fr 85

Figure D.782: C.S.D.I.C. (U.K.) S.R.G.G. 1163(C). [Recorded conversation of two German prisoners of war held in the United Kingdom. AFHRA folder 512.619C-6C 1944–1945; AFHRA A5415 electronic pp. 84–85]

Gordon Young. Dr. V2 Braun Laughs—at London. *Daily Express* (U.K.), Monday, 18 June 1945, pp. 1, 4.

Garmisch-Partenkirchen, Sunday [17 June 1945].

Thirty-four-year-old Dr. Wernher von Braun today told exclusively for the Daily Express the whole story of how he had invented the V2 rockets which bombarded Britain. [...]

I found von Braun in the white-walled bed-sitting-room of General Dornberger, head of the rocket research section.

It is a room in a former museum in this little mountain town in Bavaria, to which rocket scientists from Peenemünde were moved during the Allied advance into Germany.

Here they carried on their V2 experiments right up to the time of the entry of the American Army.

From the start of our talk he made it clear that his one passion in life was the success of his rockets. [...]

“I always thought, and still believe, that rockets will be the future means of high-speed travel.”

Here General Dornberger interposed excitedly: “Yes, that’s right—why, you may soon be able to develop a rocket plane that will travel at well over 2,000 miles an hour and take you, say, from Europe to America in an hour or so.”

“Yes,” nodded von Braun. [...]

Von Braun said the maximum range of the rockets used on London was about 225 miles, while that of the best experimental types was about 340 miles. [...]

“And now,” said Dornberger, “what we hope is that the world will use our experiences of the last 15 years for rocket development in travel and other ways.”

[This story was partially reprinted in other newspapers, for example:

> V2 Rocket Inventor Tells Story of Bomb. *The Advertiser* (Adelaide, Australia), 19 June 1945, p. 4. https://trove.nla.gov.au/newspaper/article/43498163
>
> V2 Rocket Inventor Tells Story of Bomb. *Army News* (Darwin, Australia), 21 June 1945, p. 4. https://trove.nla.gov.au/newspaper/article/47719491

This is one of several independent sources that reported that during the war, Germany successfully produced improved rockets with a range of ∼350 miles (∼560 km) instead of the usual ∼200 miles (∼320 km) for the standard A-4 (V-2), and/or a length of 18 meters instead of the usual 14 meters (p. 5794).

During this 17 June 1945 interview, von Braun and Dornberger appear to have also told Gordon Young about nuclear warheads that were almost ready for the rockets—see the next page.]

Unconditional Bombs for More Jap War Bases Soon: How We Dropped It: By Atomic Raiders. *The Daily Express* (U.K.), 8 August 1945 p. 1, column 1.

[...] General Spaatz, who commanded the U.S. strategic air forces in Europe, said that one of his major worries then was the fear that the Germans had perfected some secret weapon comparable with the atomic bomb.

Date fixed last year

“They were experimenting in this direction in a huge factory at Oranienburg, on the northern edge of Berlin, but we wiped out the factory in a big raid in the spring of this year,” he added.

(Gordon Young, cabling from Paris last night, said that the Germans planned to have atomic V2s in use by this month.)

Replying to a question whether the atomic bomb would have speeded the end of the European war, General Spaatz said: “If we had had it, it might have shortened the war by six or eight months. We might not even have had a D Day.” [...]

Brigadier-General Thomas F. Farrell, aide to Major-General Leslie Groves, who was in charge of the bomb development programme, disclosed that the date for dropping the first atomic bomb—August 6, 1945—was set well over a year ago.

[George Gordon Young (English, 1908–1963) was a field reporter on staff at *The Daily Express*. He was stationed in continental Europe to find, write, and cable back to the U.K. stories for his newspaper (or others on the wire service) to print. He would not have sent a cable from Paris to his newspaper telling them to add one tangential sentence to an article they had not even finished writing yet—he would have sent a complete story of his own. Judging from the one sentence above, on the evening of 7 August 1945, Gordon Young sent *The Daily Express* an article stating that during the war, the Germans had developed an atomic bomb, had adapted a V-2 rocket to carry it, and had made definite plans to begin launching nuclear-armed V-2 rockets at Allied targets by early August 1945 if the war had continued. Gordon Young interviewed Wernher von Braun and Walter Dornberger in Germany on 17 June 1945 (p. 4678), so this information appears to have come directly from them. The following sequence of events seems likely:

- Gordon Young presumably wrote a story about German plans to launch nuclear-armed V-2s immediately after interviewing von Braun and Dornberger on 17 June 1945. Finding and immediately reporting sensational stories was what he was paid to do.

- A story about atomic bombs, and certainly German atomic bombs, would have been rejected by government censors in June 1945, when the United States was still racing to finish its own highly classified atomic bomb program. This general policy is confirmed by the document on p. 5018, and the censors’ specific rejection of Young’s June 1945 story is confirmed in the following documents.

- Young did publish a story about von Braun and Dornberger in June 1945, but it mostly covered the well-known conventional V-2 program, with two somewhat cryptic mentions of improved rockets (p. 4678).

- Once the United States dropped an atomic bomb on Japan and publicly announced its capabilities to the world, Gordon Young must have decided to submit an updated version of his original atomic V-2 story for publication, now that (he thought) atomic censorship had been lifted. He filed his story on the evening of 7 August and expected it to be published on 8 August 1945.

- Young's atomic V-2 story, announced in advance by the one sentence in the article above, never appeared in *The Daily Express* or any other European or American newspapers. The government censors must have still banned the story.

- However, as shown below, a version of Young's story went out on the wire to affiliated newspapers in Australia, and a few of them published it before the censors realized what happened.

- The story as it appeared in the Australian newspapers is curiously brief, as if parts were still cut out. Perhaps the Australian newspapers received a brief summary of Young's story, and not the actual story itself. Alternatively, maybe the cautious newspaper editors significantly censored the story themselves, or maybe a government censor in charge of Australia had at least approved part of the story.

- In any event, the Australian stories do reveal the basic details: there was a German atomic bomb, there were V-2 rockets designed to carry that it, and there were detailed plans to begin launching such nuclear-armed rockets by early August if the war had continued. The Australian stories also explicitly confirmed that government censors had prevented Young from publishing his story in June 1945.

- The story was never mentioned again by Gordon Young. The censors were almost entirely successful in erasing the history of what had really happened.

However, in 1947, Squadron Leader E. J. André Kenny (one of the most important British aerial photo interpreters for Operation Crossbow) confirmed that von Braun "had spoken of atomic energy at Garmisch, in 1945" (p. 5763).

See also the testimony given by former Nordhausen forced laborer Alex Baum (p. 5335). Baum remembered that von Braun eagerly expected the arrival of a new rocket warhead with tremendous destructive power.

For further evidence of rockets with nuclear warheads, see the summary of the interrogation of engineer Horst Kirfes (p. 4532), as well as the July 1946 *AAF Review* (p. 5038).

For additional references that escaped historical censorship and mentioned nuclear-armed rockets that were intended to attack Allied targets during the war, see the list of documents on p. 5821.]

Hitler's Physicists Hoped to Blast British Cities with Atomic Bombs. *The Mercury* (Hobart, Tasmania, Australia) 9 August 1945 p. 2.
https://trove.nla.gov.au/newspaper/article/26155313

Radio-steered rockets with atomic bombs in their warheads to blast British cities were "weapons to end war," which Hitler's scientists hoped to produce, says Gordon Young, "Daily Express" correspondent in Paris.

"When I met the rocket inventor, Prof von Braun, and Gen Dornberger, head of the Wehrmacht's rocket research branch, they referred to 'much more powerful explosive' with which they had planned to load V-2s," Young says.

"There seemed little doubt that they envisioned the atomic bomb, but nothing could be written then because of a censorship ban.

"The explosion which shattered Hiroshima will have blasted the hopes of von Braun, Dornberger, and 400 other German research workers under guard in Bavaria that the German general staff might be able to keep their atomic bomb for use in another war after just—but only just—failing to use it in this.

"A member of the American Embassy in London recently disclosed that the Germans hoped to have the atomic bomb ready this month."

Nazis Planned to Link Atomic Bomb with V-2's. *The Courier Mail* (Brisbane, Queensland, Australia, 9 August 1945 p. 2).
https://trove.nla.gov.au/newspaper/article/50272870

LONDON, August 8 (Special).—Hitler's scientists hoped to produce radio-steered rockets, with atomic bombs in the war heads.

The Daily Express correspondent in Paris, reporting this, says that the rocket inventor (Professor von Braun) and the head of the Wehrmacht Rocket Research (General Dornberger) had referred to "much more powerful explosives" with which they planned to load V-2's.

"There is little doubt that they envisioned the atomic bomb," he writes.

"The explosion which shattered Hiroshima will have blasted the hopes of von Braun, Dornberger, and 400 other German research workers under guard in Bavaria."

The German General Staff had no doubt planned to keep their atomic bomb for use in another war after just—but only just—failing to use it in this.

An American of the Embassy staff in London recently disclosed that the Germans hoped to have had their atomic bomb ready this month.

[The above version of the article from *The Courier Mail* was also reprinted verbatim (with only a few punctuation changes) as: Nazis Planned Atom Rocket. *Army News* (Darwin, Australia) 16 August 1945 p. 3. https://trove.nla.gov.au/newspaper/article/47723184

Note that these stories also reference Herbert Agar's June 1945 statement that Germany had planned to use atomic bombs by 6 August 1945; see pp. 5017–5018.]

August 1945. Germany, Anglo-American controlled. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)]

Political:
The first reaction was one of astonishment. Then came widespread comment. Everyone is glad that the US and not Russia has the bomb. [...]

Scientific:
A Reuters report states that most of the German scientists who had worked on the atomic bomb are living in the US zone. Other reports indicate that the Germans used heavy water from Norway. Keitel indicated that the Germans never got out of the theoretical stage. There is a widespread rumor in Germany that the bomb was a Hitler invention that had [been] on the verge of completion at the time of the collapse of Germany. Subsequently it was stolen by the allies and used against Japan. [...]

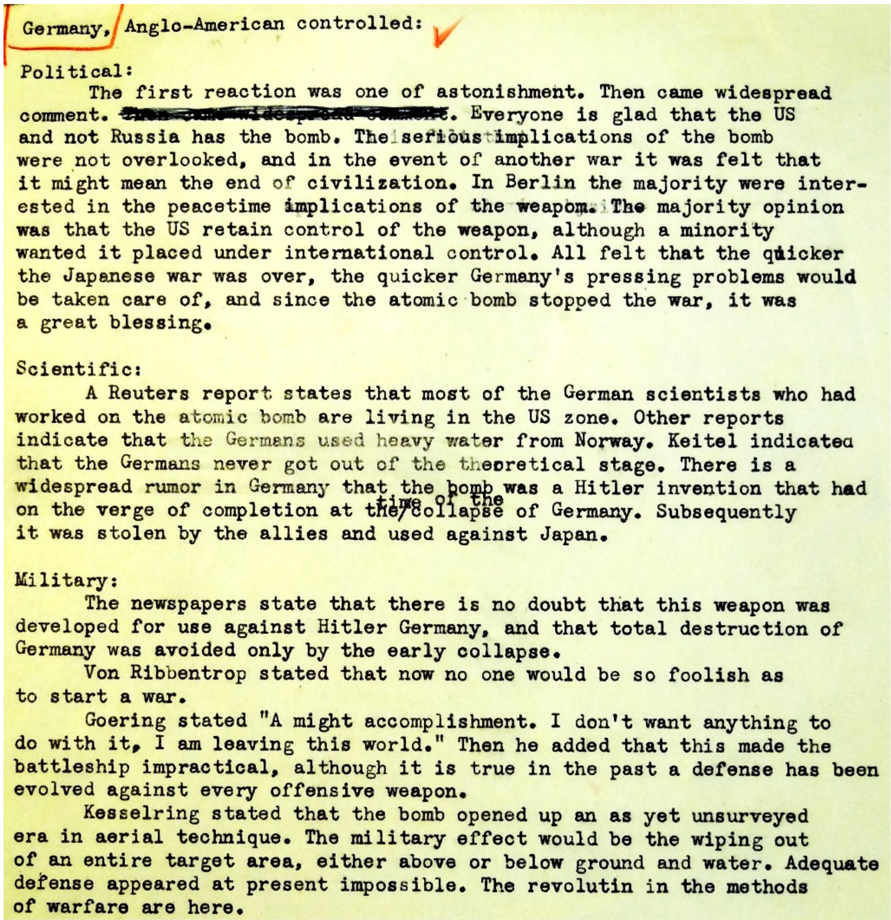
[See document photo on p. 4683 top.]

H. W. Dix to Francis J. Smith. 23 August 1945. [NARA RG 77, Entry UD-22A, Box 174, Folder 10.70 Austria Misc]

From Salzburg, Germany we have received comments dated August 21 about the bomb and the reaction thereto. The cable answer is as follows:

> REACTION TO ATOMIC BOMB IN WESTERN AUSTRIA LARGELY RELIEF AT FACT THAT AMERICA HAS PERFECTED WEAPON WHICH MAY BECOME CHECK ON FURTHER RUSSIAN MILITARY EXPANSION. WIDESPREAD BELIEF THAT BASIC MATERIALS FOR IT AVAILABLE IN QUANTITY ONLY IN AMERICA AND BRITAIN. RUMORS CIRCULATING IN SOME QUARTERS THAT ATOMIC BOMB REALLY GERMAN INVENTION.

[See document photo on p. 4683 bottom.]



Germany, Anglo-American controlled: ✓

Political:

The first reaction was one of astonishment. Then came widespread comment. ~~Then came widespread comment~~. Everyone is glad that the US and not Russia has the bomb. The serious implications of the bomb were not overlooked, and in the event of another war it was felt that it might mean the end of civilization. In Berlin the majority were interested in the peacetime implications of the weapom. The majority opinion was that the US retain control of the weapon, although a minority wanted it placed under international control. All felt that the quicker the Japanese war was over, the quicker Germany's pressing problems would be taken care of, and since the atomic bomb stopped the war, it was a great blessing.

Scientific:

A Reuters report states that most of the German scientists who had worked on the atomic bomb are living in the US zone. Other reports indicate that the Germans used heavy water from Norway. Keitel indicated that the Germans never got out of the theoretical stage. There is a widespread rumor in Germany that the bomb was a Hitler invention that had on the verge of completion at the time of the collapse of Germany. Subsequently it was stolen by the allies and used against Japan.

Military:

The newspapers state that there is no doubt that this weapon was developed for use against Hitler Germany, and that total destruction of Germany was avoided only by the early collapse.

Von Ribbentrop stated that now no one would be so foolish as to start a war.

Goering stated "A might accomplishment. I don't want anything to do with it, I am leaving this world." Then he added that this made the battleship impractical, although it is true in the past a defense has been evolved against every offensive weapon.

Kesselring stated that the bomb opened up an as yet unsurveyed era in aerial technique. The military effect would be the wiping out of an entire target area, either above or below ground and water. Adequate defense appeared at present impossible. The revolutin in the methods of warfare are here.

**NARA RG 77,
Entry UD-22A,
Box 171,
Folder 32.60-2
Germany:
Summary
Reports
(1945-1946)**

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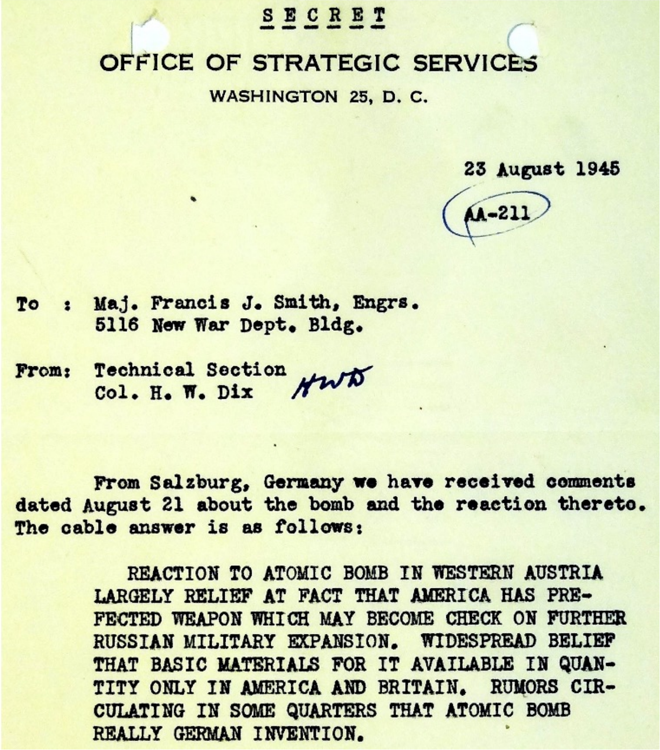
Authority NND911017



S E C R E T

OFFICE OF STRATEGIC SERVICES
WASHINGTON 25, D. C.

23 August 1945

AA-211

To : Maj. Francis J. Smith, Engrs.
5116 New War Dept. Bldg.

From: Technical Section
Col. H. W. Dix HWD

From Salzburg, Germany we have received comments dated August 21 about the bomb and the reaction thereto. The cable answer is as follows:

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**NARA RG 77,
Entry UD-22A, Box 174,
Folder 10.70 Austria Misc**

Figure D.783: Top: August 1945. Germany, Anglo-American controlled. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)]. Bottom: H. W. Dix to Francis J. Smith. 23 August 1945. [NARA RG 77, Entry UD-22A, Box 174, Folder 10.70 Austria Misc].

C.S.D.I.C. (U.K.) G.R.G.G. 341. [Recorded conversation of Walter Dornberger and several other high-ranking German prisoners held in the United Kingdom after the war. AFHRA folder 512.619C-5F 1945, IRIS 212009; AFHRA A5414 frames 760–775; TNA WO 208/4178]

Report on information obtained from Senior Officer PW on 28 Jul – 7 Aug 45 [...]

V THE ATOM BOMB

1. Generalleutnant DORNBERGER gave to SS-Obergruppenführer v. HERFF and Generalleutnant HEIM the following account of German attempts to split the atom:

DORNBERGER: Our people [at Peenemünde] tried to split the atom by means of high tension current. About 50 [or 5 or 15, if misheard by the translator or misremembered by Dornberger?] million volts are needed to get the pitchblende [uranium oxide], mixed with heavy water, to disintegrate. But the amount of energy released was only as much as that put in. We haven't yet got it to the stage where the process will continue independently. That was the result obtained in 1941. There is also another method, not with high tension [voltage] but with some kind of static tension [pressure]. It's not the destruction of the atom, but the disintegration of the atom. That can be harnessed, and considerably less energy is needed. It's done by chemicals which disintegrate [chemical explosives]. That is what this [Hiroshima] appears to be, because chemists were largely involved in those experiments, and not nearly so many physicists.

DORNBERGER (Cont'd): I wanted Professor [Wernher von] BRAUN to give us a lecture on the atom bomb, as the results of the research work could have materially influenced the development of the V-weapons.

DORNBERGER also spoke as below to HEIM and Generalmajor BASSENGE:

DORNBERGER: The IO [interrogation officer] also asked me if we intended to produce one, radio-activated—

HEIM: Was it something to do with your thing?

DORNBERGER: Yes, with tungsten(?) as the motive power. It would be a fine thing if they had it, but I don't believe they can direct the rays. That is the decisive thing we need. Because the speed is a hundred times great than that of our ...... which we have now. [This seems to have been a description of using nuclear energy to obtain much higher exhaust velocities for rocket propulsion.]

[...]

VI THE 'V 2'

1. Generalleutnant DORNBERGER stated as below to Generalleutnant HEIM that HITLER had publicly apologised for his failure to appreciate the full worth of the 'V 2' weapon:

DORNBERGER: The following incident was interesting: When I saw the Führer the last time, which was in May 1943, after I'd shown him a film about us, he was quite taken aback. Formerly the Führer had always turned the V-2 business down 100%. He said: "If only I'd believed in it!" "If it really comes to anything, Europe is too small for the war", and all kind of things like that. Then he said: "There are two people in my life whose pardon I must ask. One is Generalfeldmarschall v BRAUCHITSCH, who said at the end of each report he made to me: "My Führer, think of Peenemünde!", and the other is you, general, for not having believed in you."

HEIM: It's incredible that he admitted it.

DORNBERGER: he admitted it in front of Keitel and the others.

HEIM: I believe that really is the only thing he ever admitted in his life.

2. DORNBERGER claimed, on the other hand, that he had begged the Führer to stop the V-weapon propaganda, because nothing more could be expected from just one ton of explosive. To this Hitler had replied that DORNBERGER: might not expect more but he himself certainly did.

3. DORNBERGER alleged in the following passage with Generalmajor BASSENGE that the Russians had made offers to men concerned in "V 2" development and had undertaken to double any bids from the American side:

DORNBERGER: The Russians sent one of my engineers to me when I was with the Americans, who told me under the seal of secrecy that he had such and such an offer to make to us on behalf of the Russians. We were to go back to Peenemünde. Peenemünde would be rebuilt and a parallel factory in Russia, and they offered us double what the Americans were offering us, and we could move our families with us and all that sort of thing. We turned it down flat. They tried again to kidnap our leading lights from us—BRAUN at Witzenhausen(?). They appeared at night time in English uniform; they didn't realize it was the American zone. They came to us and wanted to come in. They had a proper pass. But the Americans were quick to realize it and wouldn't let them in. So they got into cars and drove off again. That's how the people work. Real kidnapping, they don't stick to the boundaries at all.

4. DORNBERGER spoke to Generalleutnant HEIM as below about his intention to sell his services to the best bidder:

DORNBERGER: If the English make me a better offer than the Americans within the next fortnight, I'm preparing to work for them at Vancouver. I have given instructions that nothing is to be signed yet., Actually I don't want to work for the English at all, I only want to play them off against the Americans.

5. Asked by Generalmajor v. PFUHLSTEIN whether he spoke English, DORNBERGER replied that with the Englishmen he did not do so on principle. He could understand them quite well but it gave him more time if he pretend otherwise. To PFUHLSTEIN's suggestion that he should not weaken his position by giving too much away, DORNBERGER replied that he intended to reveal no real technical secrets noting of decisive value. Asked by Generalleutnant HEIM whether he was going to America to work there, he replied that he was, or rather that he did not know whether, as a 'general' he would be allowed to go there.

6. DORNBERGER stated to General FINK that KAMMLER had been ordered by the Führer not

to let BRAUN, DORNBERGER and the 450 scientists and technicians at Peenemünde fall into Anglo-American hands but to liquidate them all beforehand.

7. DORNBERGER, in conversation with Generalmajor BASSENGE, made the following miscellaneous remarks dealing with the 'V 2'. He said that:

a. 720 persons were killed in the first raid on PEENEMÜNDE [17 August 1943] and all the work there suffered two months' delay.

b. In POLAND, at the HEIDELAGER, they had once fired a 'V 2' into a concentration camp. He consoled himself with the thought that that would be chalked up to the SS and not to themselves.

c. A German general in a Russian tank had one day appeared in front of one of DORNBERGER's 'Regimenter' which was near ARNSWALDE and had called upon its members by megaphone to come over to the Russians. He had promised them that the TCHOCHINSKI Works were waiting to receive them and would pay them the maximum wages to build 'V 2s' for STALIN.

d. BRAUN and DORNBERGER himself had realised at the end of December 1944 that things were going wrong and had consequently been in touch since that time with the General Electric Company through the German Embassy in Portugal, with a view to coming to some arrangement.

VII GERMAN ATROCITIES

[...]

DORNBERGER: Look, what a fuss they've made about all those concentration camps. In the first place, one can counter them simply, because all the [unsupportive?] ministers and officials have been in concentration camps, and if things had gone as badly as that with them, they wouldn't be alive. Of course, swinish things did happen. At Nordhausen Standartenführer BEHR (?) said: "We've got 6000 people who are ill and cannot be taken away; what shall we do with them?" KAMMLER said: "Get rid of them!" He said: "How am I supposed to get rid of 6,000 people?" "Oh, take them to that rock and then blow it up over them, and then the matter's settled." That's how he dealt with people. The Allies are very much after him. The fellow was ruthless. In Holland, he made Dutchmen build the sites for the V 2, then he had them herded together and killed by MG fire. He opened brothels for his soldiers with 20 Dutch girls. When they'd been there a fortnight they were shot and new ones were brought along, so that they couldn't divulge anything they might discover from the soldiers.

VIII THE 20TH JULY 'PUTSCH'

[...]

They shot FROMM, quite recently, perhaps a fortnight before the collapse. HIMMLER had a persecution mania. He had me arrested on 27 Apr, for not carrying out orders. I only got away thanks to KAMMLER, who was also to be arrested. We both drove off to Garmisch.

[See document photos on pp. 4688–4691.

Dornberger and the other high-ranking German prisoners may have suspected that their conversations were being monitored and thus withheld information or provided false information. Nonetheless, the details given in the preceding document at least sound credible.

This is only an English translation of the German conversations. If a German version was typed up, it was either destroyed or not included with the English copy in this file. Can a German version be located in other archival files? The English translation does not choose the optimum words for translating scientific German, since the translator was probably not overly familiar with scientific details. While it would be better to have the original German transcript, one can still make sense of the English version.

In Section V, Dornberger appeared to describe three different nuclear approaches:

1. An accelerator-driven subcritical fission reactor, with less than a critical mass of unenriched uranium dioxide fuel in heavy water, with a 50(?)-MeV particle beam (either an electron beam from a betatron or an ion beam from a cyclotron) focused on the uranium to initiate and maintain fission reactions. Dornberger said this experiment occurred in 1941, apparently at Peenemünde. It is unclear if larger or more sophisticated experiments were conducted later or at other locations. Even the 1941 experiment could be suitable for electronuclear breeding of plutonium if it were continued long enough and done at sufficient scale (pp. 5133–5134). There were numerous other reports of similar experiments (pp. 3020–3091, 3954–4022, 4504–4510).

2. An approach using chemical explosives to create high pressure, which would then cause the fission of a mass of uranium, resulting in the sudden release of a large amount of nuclear energy. This seems like a clear reference to a fission implosion bomb; there were numerous other reports of the same design (Section D.8). Dornberger was apparently prompted to make this remark by news of the U.S. bombing of Hiroshima. He said that during the war, he wanted Wernher von Braun to give the other Peenemünde staff a lecture on the (apparently quite real) German atomic bomb, since it was intended to be a payload for their rockets.

3. A method of using fission power to obtain much higher rocket exhaust velocities than were possible with chemical rocket propellants. Unfortunately only a snippet of this conversation was recorded and translated, so it is unclear which of several possible nuclear rocket propulsion approaches Dornberger was referring to.

If the SS was willing to launch a V-2 rocket into a Polish concentration camp as Dornberger mentioned here, one could envision the SS also testing a fission bomb on a Polish concentration camp as reported by a number of sources in Section D.11. Perhaps those were even the same test, if the fission bomb was delivered by a rocket instead of an aircraft or other means.

Dornberger said that he and von Braun had been in touch with U.S. representatives months before the end of the war. This information raises an enormous unanswered historical question: How much contact did the Allies have with key German officials, and how much did those contacts influence the course of the war, especially in the final months of the war?

Can U.S./U.K. transcripts and reports on postwar interrogations of Dornberger and von Braun be located and declassified?]

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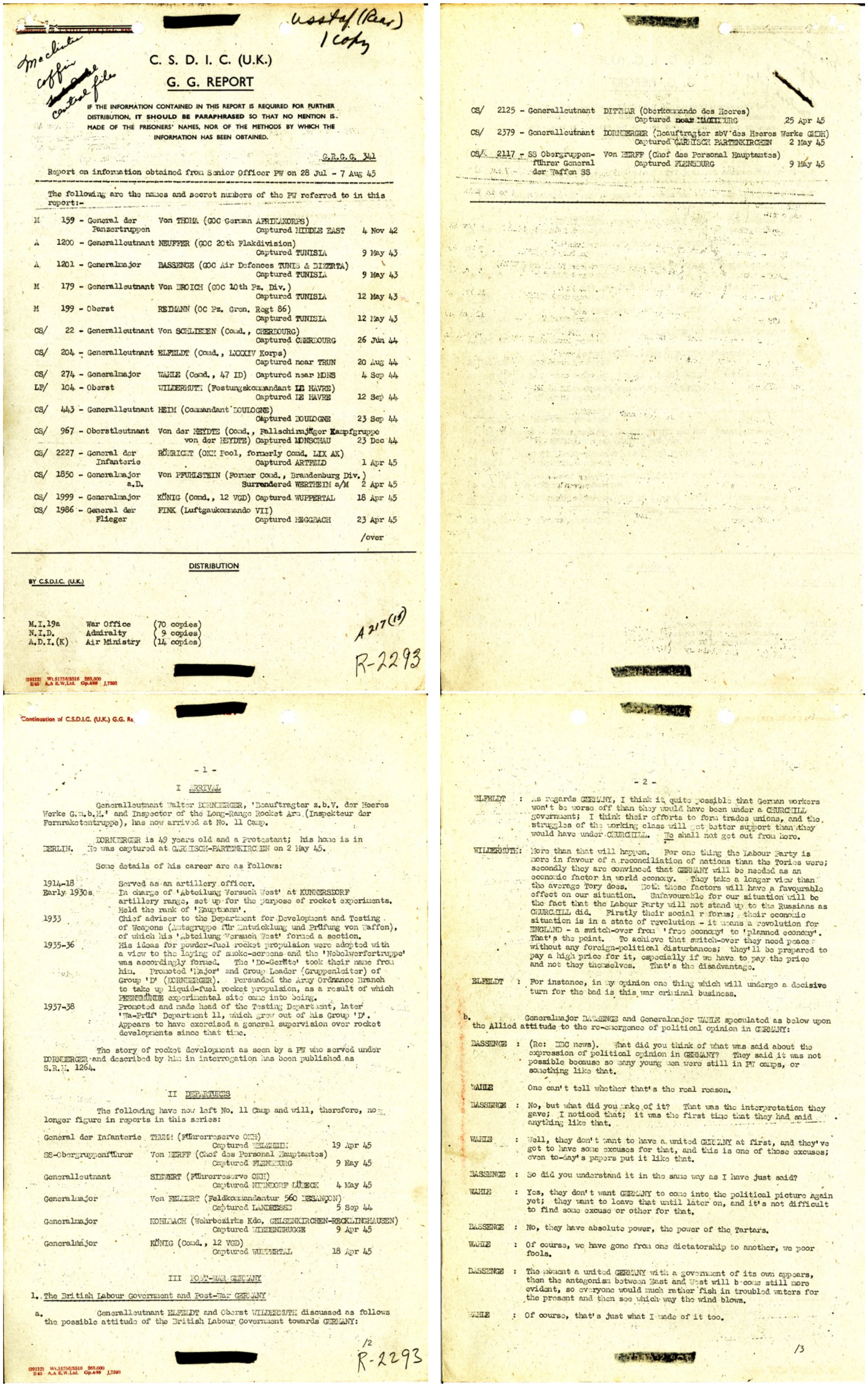
C.S.D.I.C. (U.K.) G.R.G.G. 341, AFHRA folder 512.619C-5F 1945, IRIS 212009



~~Continuation of C.S.D.I.C. (U.K.) G.G. Rep~~

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C. S. D. I. C. (U.K.)

G. G. REPORT

IF THE INFORMATION CONTAINED IN THIS REPORT IS REQUIRED FOR FURTHER DISTRIBUTION, IT SHOULD BE PARAPHRASED SO THAT NO MENTION IS MADE OF THE PRISONERS' NAMES, NOR OF THE METHODS BY WHICH THE INFORMATION HAS BEEN OBTAINED.

G.R.G.G. 341

Report on information obtained from Senior Officer PW on 28 Jul - 7 Aug 45

The following are the names and secret numbers of the PW referred to in this report:-

M	159 -	General der Panzertruppen	Von THOMA (GOC German AFRIKAKORPS)	Captured MIDDLE EAST	4 Nov 42
A	1200 -	Generalleutnant	NEUFFER (GOC 20th Flakdivision)	Captured TUNISIA	9 May 43
A	1201 -	Generalmajor	BASSENGE (GOC Air Defences TUNIS & BIZERTA)	Captured TUNISIA	9 May 43
M	179 -	Generalleutnant	Von BROICH (GOC 10th Pz. Div.)	Captured TUNISIA	12 May 43
M	199 -	Oberst	REIMANN (OC Pz. Gren. Regt 86)	Captured TUNISIA	12 May 43
CS/	22 -	Generalleutnant	Von SCHLIEBEN (Comd., CHERBOURG)	Captured CHERBOURG	26 Jun 44
CS/	204 -	Generalleutnant	ELFELDT (Comd., LXXXIV Korps)	Captured near TRUN	20 Aug 44
CS/	274 -	Generalmajor	WAHLE (Comd., 47 ID)	Captured near MONS	4 Sep 44
LF/	104 -	Oberst	WILDERMUTH (Festungskommandant LE HAVRE)	Captured LE HAVRE	12 Sep 44
CS/	443 -	Generalleutnant	HEIM (Commandant BOULOGNE)	Captured BOULOGNE	23 Sep 44
CS/	967 -	Oberstleutnant	Von der HEYDTE (Comd., Fallschirmjäger Kampfgruppe von der HEYDTE)	Captured MONSCHAU	23 Dec 44
CS/	2227 -	General der Infanterie	RÖHRICHT (OKH Pool, formerly Comd. LIX AK)	Captured ARTFELD	1 Apr 45
CS/	1850 -	Generalmajor a.D.	Von PFUHLSTEIN (Former Comd., Brandenburg Div.)	Surrendered WERTHEIM a/M	2 Apr 45
CS/	1999 -	Generalmajor	KÖNIG (Comd., 12 VGD)	Captured WUPPERTAL	18 Apr 45
CS/	1986 -	General der Flieger	FINK (Luftgaukommando VII)	Captured HEGGBACH	23 Apr 45

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CS/	2125 -	Generalleutnant	DITTMAR (Oberkommando des Heeres)	Captured near MAGDEBURG	25 Apr 45
CS/	2379 -	Generalleutnant	DORNBERGER (Beauftragter zbV des Heeres Werke GMBH)	Captured GARMISCH PARTENKIRCHEN	2 May 45
CS/	2117 -	SS Obergruppenführer General der Waffen SS	Von HERFF (Chef des Personal Hauptamtes)	Captured FLENSBURG	9 May 45

[redacted]

Continuation of C.S.D.I.C. (U.K.) G.G. Re

[redacted]

- 1 -

I ARRIVAL

Generalleutnant Walter DORNBERGER, 'Beauftragter z.b.V. der Heeres Werke G.m.b.H.' and Inspector of the Long-Range Rocket Arm (Inspekteur der Fernraketentruppe), has now arrived at No. 11 Camp.

DORNBERGER is 49 years old and a Protestant; his home is in BERLIN. He was captured at GARMISCH-PARTENKIRCHEN on 2 May 45.

Some details of his career are as follows:

1914-18	Served as an artillery officer.
Early 1930s.	In charge of 'Abteilung Versuch West' at KUMMERSDORF artillery range, set up for the purpose of rocket experiments. Held the rank of 'Hauptmann'.
1933	Chief adviser to the Department for Development and Testing of Weapons (Amtsgruppe für Entwicklung und Prüfung von Waffen), of which his 'Abteilung Versuch West' formed a section.
1935-36	His ideas for powder-fuel rocket propulsion were adopted with a view to the laying of smoke-screens and the 'Nebelwerfertruppe' was accordingly formed. The 'Do-Geräte' took their name from him. Promoted 'Major' and Group Leader (Gruppenleiter) of Group 'D' (DORNBERGER). Persuaded the Army Ordnance Branch to take up liquid-fuel rocket propulsion, as a result of which PEENEMÜNDE experimental site came into being.
1937-38	Promoted and made head of the Testing Department, later 'Wa-Prüf' Department 11, which grew out of his Group 'D'. Appears to have exercised a general supervision over rocket developments since that time.

The story of rocket development as seen by a PW who served under DORNBERGER and described by him in interrogation has been published as S.R.M. 1264.

II DEPARTURES

The following have now left No. 11 Camp and will, therefore, no longer figure in reports in this series:

General der Infanterie	THUMM (Führerreserve OKH)	Captured WELZHEIM	19 Apr 45
SS-Obergruppenführer	Von HERFF (Chef des Personal Hauptamtes)	Captured FLENSBURG	9 May 45
Generalleutnant	SIEWERT (Führerreserve OKH)	Captured NIENDORF LÜBECK	4 May 45
Generalmajor	Von FELLERT (Feldkommandantur 560 BESANÇON)	Captured LANDRESSE	5 Sep 44
Generalmajor	KOHLBACH (Wehrbezirks Kdo. GELSENKIRCHEN-RECKLINGHAUSEN)	Captured WIEDENBRUGGE	9 Apr 45
Generalmajor	KÖNIG (Comd., 12 VGD)	Captured WUPPERTAL	18 Apr 45

III POST-WAR GERMANY

1. The British Labour Government and Post-War GERMANY

a. Generalleutnant ELFELDT and Oberst WILDERMUTH discussed as follows the possible attitude of the British Labour Government towards GERMANY:

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- 2 -

ELFELDT : As regards GERMANY, I think it quite possible that German workers won't be worse off than they would have been under a CHURCHILL government; I think their efforts to form trades unions, and the struggles of the working class will get better support than they would have under CHURCHILL. We shall not get out from here.

WILDERMUTH: More than that will happen. For one thing the Labour Party is more in favour of a reconciliation of nations than the Tories were; secondly they are convinced that GERMANY will be needed as an economic factor in world economy. They take a longer view than the average Tory does. Both these factors will have a favourable effect on our situation. Unfavourable for our situation will be the fact that the Labour Party will not stand up to the Russians as CHURCHILL did. Firstly their social reforms; their economic situation is in a state of revolution - it means a revolution for ENGLAND - a switch-over from 'free economy' to 'planned economy'. That's the point. To achieve that switch-over they need peace without any foreign-political disturbances; they'll be prepared to pay a high price for it, especially if we have to pay the price and not they themselves. That's the disadvantage.

ELFELDT : For instance, in my opinion one thing which will undergo a decisive turn for the bad is this war criminal business.

b. Generalmajor BASSENGE and Generalmajor WAHLE speculated as below upon the Allied attitude to the re-emergence of political opinion in GERMANY:

BASSENGE : (Re: BBC news). What did you think of what was said about the expression of political opinion in GERMANY? They said it was not possible because so many young men were still in PW camps, or something like that.

WAHLE One can't tell whether that's the real reason.

BASSENGE : No, but what did you make of it? That was the interpretation they gave; I noticed that; it was the first time that they had said anything like that.

WAHLE : Well, they don't want to have a united GERMANY at first, and they've got to have some excuses for that, and this is one of those excuses; even to-day's papers put it like that.

BASSENGE : So did you understand it in the same way as I have just said?

WAHLE : Yes, they don't want GERMANY to come into the political picture again yet; they want to leave that until later on, and it's not difficult to find some excuse or other for that.

BASSENGE : No, they have absolute power, the power of the Tartars.

WAHLE : Of course, we have gone from one dictatorship to another, we poor fools.

BASSENGE : The moment a united GERMANY with a government of its own appears, then the antagonism between East and West will become still more evident, so everyone would much rather fish in troubled waters for the present and then see which way the wind blows.

WAHLE : Of course, that's just what I made of it too.

/3

[redacted]

Figure D.784: C.S.D.I.C. (U.K.) G.R.G.G. 341 [Recorded conversation of Walter Dornberger and several other high-ranking German prisoners held in the United Kingdom after the war. AFHRA folder 512.619C-5F 1945, IRIS 212009; AFHRA A5414 frames 760–775; TNA WO 208/4178].

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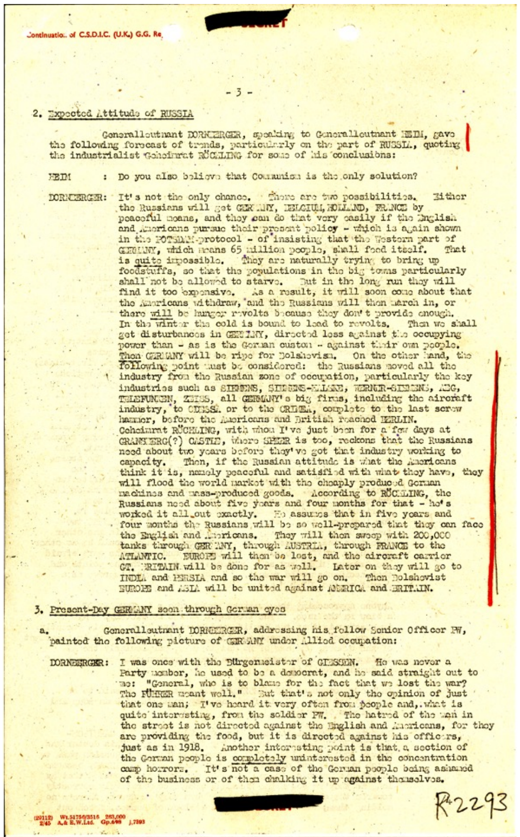

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Continuation of C.S.D.I.C. (U.K.) G.G. Re

- 3 -

2. Expected Attitude of RUSSIA

Generalleutnant DORNBERGER, speaking to Generalleutnant HEIM, gave the following forecast of trends, particularly on the part of RUSSIA, quoting the industrialist Geheimrat RÖCHLING for some of his conclusions:

HEIM : Do you also believe that Communism is the only solution?

DORNBERGER: It's not the only chance. There are two possibilities. Either the Russians will get GERMANY, BELGIUM, HOLLAND, FRANCE by peaceful means, and they can do that very easily if the English and Americans pursue their present policy - which is again shown in the POTSDAM-protocol - of insisting that the Western part of GERMANY, which means 65 million people, shall feed itself. That is quite impossible. They are naturally trying to bring up foodstuffs, so that the populations in the big towns particularly shall not be allowed to starve. But in the long run they will find it too expensive. As a result, it will soon come about that the Americans withdraw, and the Russians will then march in, or there will be hunger revolts because they don't provide enough. In the winter the cold is bound to lead to revolts. Then we shall get disturbances in GERMANY, directed less against the occupying power than - as is the German custom - against their own people. Then GERMANY will be ripe for Bolshevism. On the other hand, the following point must be considered: the Russians moved all the industry from the Russian zone of occupation, particularly the key industries such as SIEMENS, SIEMENS-HALSKE, WERNER-SIEMENS, AEG, TELEFUNKEN, ZEISS, all GERMANY's big firms, including the aircraft industry, to ODESSA or to the CRIMEA, complete to the last screw hammer, before the Americans and British reached BERLIN. Geheimrat RÖCHLING, with whom I've just been for a few days at GRANSBERG(?) CASTLE, where SPEER is too, reckons that the Russians need about two years before they've got that industry working to capacity. Then, if the Russian attitude is what the Americans think it is, namely peaceful and satisfied with what they have, they will flood the world market with the cheaply produced German machines and mass-produced goods. According to RÖCHLING, the Russians need about five years and four months for that - he's worked it all out exactly. He assumes that in five years and four months the Russians will be so well-prepared that they can face the English and Americans. They will then sweep with 200,000 tanks through GERMANY, through AUSTRIA, through FRANCE to the ATLANTIC. EUROPE will then be lost, and the aircraft carrier GT. BRITAIN will be done for as well. Later on they will go to INDIA and PERSIA and so the war will go on. Then Bolshevist EUROPE and ASIA will be united against AMERICA and BRITAIN.

3. Present-Day GERMANY seen through German eyes

a. Generalleutnant DORNBERGER, addressing his fellow Senior Officer PW, painted the following picture of GERMANY under Allied occupation:

DORNBERGER: I was once with the Bürgermeister of GIESSEN. He was never a Party member, he used to be a democrat, and he said straight out to me: "General, who is to blame for the fact that we lost the war? The FÜHRER meant well." But that's not only the opinion of just that one man; I've heard it very often from people and, what is quite interesting, from the soldier PW. The hatred of the man in the street is not directed against the English and Americans, for they are providing the food, but it is directed against his officers, just as in 1918. Another interesting point is that a section of the German people is completely uninterested in the concentration camp horrors. It's not a case of the German people being ashamed of the business or of them chalking it up against themselves.

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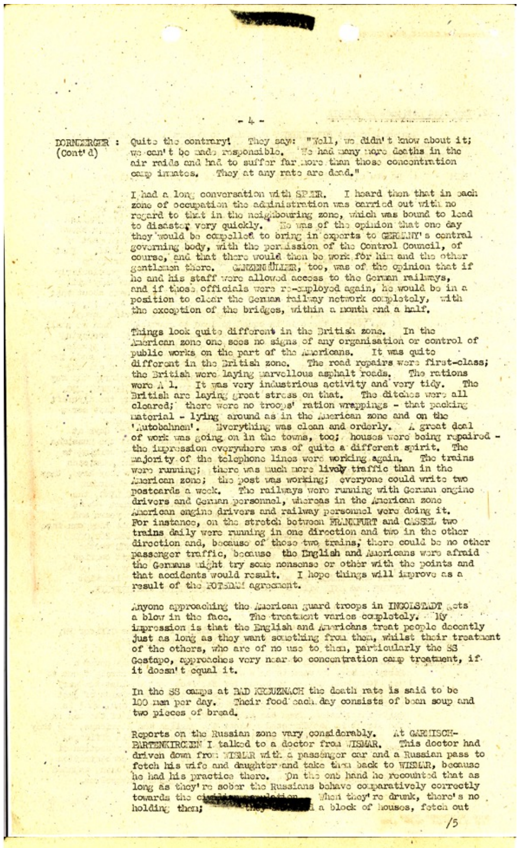

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DORNBERGER : (Cont'd) Quite the contrary! They say: "Well, we didn't know about it; we can't be made responsible. We had many more deaths in the air raids and had to suffer far more than those concentration camp inmates. They at any rate are dead."

I had a long conversation with SPEER. I heard then that in each zone of occupation the administration was carried out with no regard to that in the neighbouring zone, which was bound to lead to disaster very quickly. He was of the opinion that one day they would be compelled to bring in experts to GERMANY's central governing body, with the permission of the Control Council, of course, and that there would then be work for him and the other gentlemen there. GANZENMÜLLER, too, was of the opinion that if he and his staff were allowed access to the German railways, and if those officials were re-employed again, he would be in a position to clear the German railway network completely, with the exception of the bridges, within a month and a half.

Things look quite different in the British zone. In the American zone one sees no signs of any organisation or control of public works on the part of the Americans. It was quite different in the British zone. The road repairs were first-class; the British were laying marvellous asphalt roads. The rations were A 1. It was very industrious activity and very tidy. The British are laying great stress on that. The ditches were all cleared; there were no troops' ration wrappings - that packing material - lying around as in the American zone and on the 'Autobahnen'. Everything was clean and orderly. A great deal of work was going on in the towns, too; houses were being repaired - the impression everywhere was of quite a different spirit. The majority of the telephone lines were working again. The trains were running; there was much more lively traffic than in the American zone; the post was working; everyone could write two postcards a week. The railways were running with German engine drivers and German personnel, whereas in the American zone American engine drivers and railway personnel were doing it. For instance, on the stretch between FRANKFURT and CASSEL two trains daily were running in one direction and two in the other direction and, because of those two trains, there could be no other passenger traffic, because the English and Americans were afraid the Germans might try some nonsense or other with the points and that accidents would result. I hope things will improve as a result of the POTSDAM agreement.

Anyone approaching the American guard troops in INGOLSTADT gets a blow in the face. The treatment varies completely. My impression is that the English and Americans treat people decently just as long as they want something from them, whilst their treatment of the others, who are of no use to them, particularly the SS Gestapo, approaches very near to concentration camp treatment, if it doesn't equal it.

In the SS camps at BAD KREUZNACH the death rate is said to be 100 men per day. Their food each day consists of bean soup and two pieces of bread.

Reports on the Russian zone vary considerably. At GARMISCH-PARTENKIRCHEN I talked to a doctor from WISMAR. This doctor had driven down from WISMAR with a passenger car and a Russian pass to fetch his wife and daughter and take them back to WISMAR, because he had his practice there. On the one hand he recounted that as long as they're sober the Russians behave comparatively correctly towards the c[redacted] When they're drunk, there's no holding them; [redacted] a block of houses, fetch out

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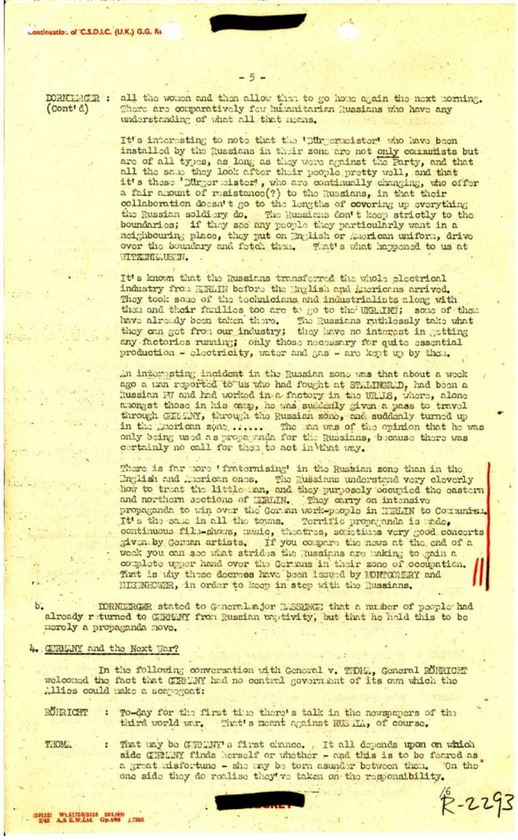

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DORNBERGER : (Cont'd) all the women and then allow them to go home again the next morning. There are comparatively few humanitarian Russians who have any understanding of what all that means.

It's interesting to note that the 'Bürgermeister' who have been installed by the Russians in their zone are not only communists but are of all types, as long as they were against the Party, and that all the same they look after their people pretty well, and that it's those 'Bürgermeister', who are continually changing, who offer a fair amount of resistance(?) to the Russians, in that their collaboration doesn't go to the lengths of covering up everything the Russian soldiery do. The Russians don't keep strictly to the boundaries; if they see any people they particularly want in a neighbouring place, they put on English or American uniform, drive over the boundary and fetch them. That's what happened to us at WITZENHAUSEN.

It's known that the Russians transferred the whole electrical industry from BERLIN before the English and Americans arrived. They took some of the technicians and industrialists along with them and their families too are to go to the UKRAINE; some of them have already been taken there. The Russians ruthlessly take what they can get from our industry; they have no interest in getting any factories running; only those necessary for quite essential production - electricity, water and gas - are kept up by them.

An interesting incident in the Russian zone was that about a week ago a man reported to us who had fought at STALINGRAD, had been a Russian PW and had worked in a factory in the URALS, where, alone amongst those in his camp, he was suddenly given a pass to travel through GERMANY, through the Russian zone, and suddenly turned up in the American zone...... The man was of the opinion that he was only being used as propaganda for the Russians, because there was certainly no call for them to act in that way.

There is far more 'fraternising' in the Russian zone than in the English and American ones. The Russians understand very cleverly how to treat the little man, and they purposely occupied the eastern and northern sections of BERLIN. They carry on intensive propaganda to win over the German work-people in BERLIN to Communism. It's the same in all the towns. Terrific propaganda is made, continuous film-shows, music, theatres, sometimes very good concerts given by German artists. If you compare the news at the end of a week you can see what strides the Russians are making to gain a complete upper hand over the Germans in their zone of occupation. That is why these decrees have been issued by MONTGOMERY and EISENHOWER, in order to keep in step with the Russians.

b. DORNBERGER stated to Generalmajor BASSENGE that a number of people had already returned to GERMANY from Russian captivity, but that he held this to be merely a propaganda move.

4. GERMANY and the Next War?

In the following conversation with General v. THOMA, General RÖHRICHT welcomed the fact that GERMANY had no central government of its own which the Allies could make a scapegoat:

RÖHRICHT : To-day for the first time there's talk in the newspapers of the third world war. That's meant against RUSSIA, of course.

THOMA : That may be GERMANY's first chance. It all depends upon on which side GERMANY finds herself or whether - and this is to be feared as a great misfortune - she may be torn asunder between them. On the one side they do realise they've taken on the responsibility.

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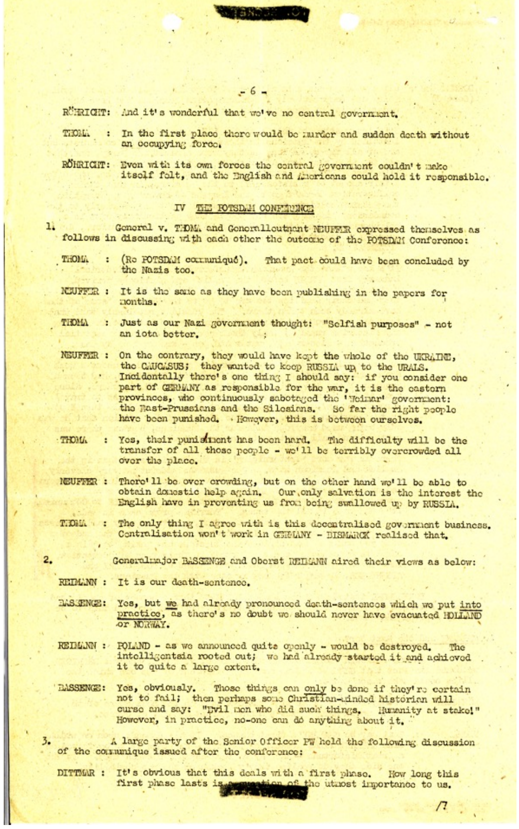

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RÖHRICHT: And it's wonderful that we've no central government.

THOMA : In the first place there would be murder and sudden death without an occupying force.

RÖHRICHT: Even with its own forces the central government couldn't make itself felt, and the English and Americans could hold it responsible.

IV THE POTSDAM CONFERENCE

1. General v. THOMA and Generalleutnant NEUFFER expressed themselves as follows in discussing with each other the outcome of the POTSDAM Conference:

THOMA : (Re POTSDAM communiqué). That pact could have been concluded by the Nazis too.

NEUFFER : It is the same as they have been publishing in the papers for months.

THOMA : Just as our Nazi government thought: "Selfish purposes" - not an iota better.

NEUFFER : On the contrary, they would have kept the whole of the UKRAINE, the CAUCASUS; they wanted to keep RUSSIA up to the URALS. Incidentally there's one thing I should say: if you consider one part of GERMANY as responsible for the war, it is the eastern provinces, who continuously sabotaged the 'Weimar' government: the East-Prussians and the Silesians. So far the right people have been punished. However, this is between ourselves.

THOMA : Yes, their punishment has been hard. The difficulty will be the transfer of all those people - we'll be terribly overcrowded all over the place.

NEUFFER : There'll be over crowding, but on the other hand we'll be able to obtain domestic help again. Our only salvation is the interest the English have in preventing us from being swallowed up by RUSSIA.

THOMA : The only thing I agree with is this decentralised government business. Centralisation won't work in GERMANY - BISMARCK realised that.

2. Generalmajor BASSENGE and Oberst REIMANN aired their views as below:

REIMANN : It is our death-sentence.

BASSENGE: Yes, but we had already pronounced death-sentences which we put into practice, as there's no doubt we should never have evacuated HOLLAND or NORWAY.

REIMANN : POLAND - as we announced quite openly - would be destroyed. The intelligentsia rooted out; we had already started it and achieved it to quite a large extent.

BASSENGE: Yes, obviously. Those things can only be done if they're certain not to fail; then perhaps some Christian-minded historian will curse and say: "Evil men who did such things. Humanity at stake!" However, in practice, no-one can do anything about it.

3. A large party of the Senior Officer PW held the following discussion of the communique issued after the conference:

DITTMAR : It's obvious that this deals with a first phase. How long this first phase lasts is [redacted] the utmost importance to us.

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C.S.D.I.C. (U.K.) G.R.G.G. 341, AFHRA folder 512.619C-5F 1945, IRIS 212009

Figure D.785: C.S.D.I.C. (U.K.) G.R.G.G. 341 [Recorded conversation of Walter Dornberger and several other high-ranking German prisoners held in the United Kingdom after the war. AFHRA folder 512.619C-5F 1945, IRIS 212009; AFHRA A5414 frames 760–775; TNA WO 208/4178].

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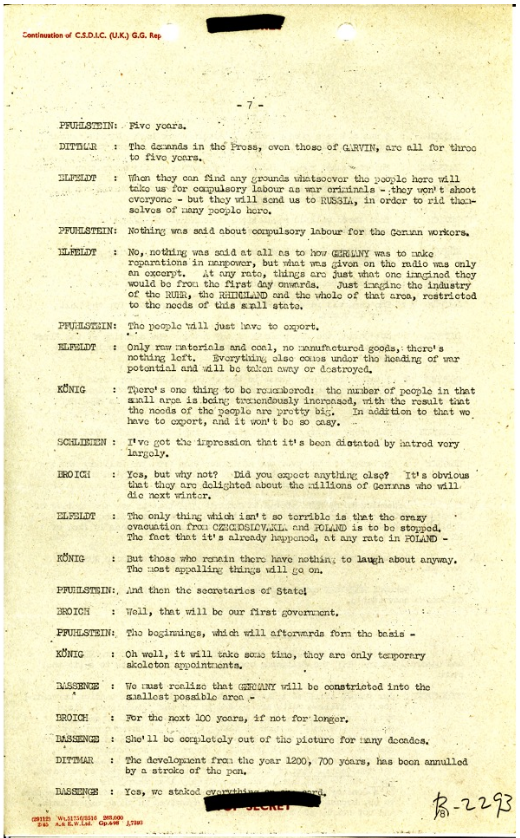
C.S.D.I.C. (U.K.) G.R.G.G. 341, AFHRA folder 512.619C-5F 1945, IRIS 212009



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PFUHLSTEIN: Five years.

DITTMAR : The demands in the Press, even those of GARVIN, are all for three to five years.

ELFELDT : When they can find any grounds whatsoever the people here will take us for compulsory labour as war criminals - they won't shoot everyone - but they will send us to RUSSIA, in order to rid themselves of many people here.

PFUHLSTEIN: Nothing was said about compulsory labour for the German workers.

ELFELDT : No, nothing was said at all as to how GERMANY was to make reparations in manpower, but what was given on the radio was only an excerpt. At any rate, things are just what one imagined they would be from the first day onwards. Just imagine the industry of the RUHR, the RHINELAND and the whole of that area, restricted to the needs of this small state.

PFUHLSTEIN: The people will just have to export.

ELFELDT : Only raw materials and coal, no manufactured goods, there's nothing left. Everything else comes under the heading of war potential and will be taken away or destroyed.

KÖNIG : There's one thing to be remembered: the number of people in that small area is being tremendously increased, with the result that the needs of the people are pretty big. In addition to that we have to export, and it won't be so easy.

SCHLIEBEN : I've got the impression that it's been dictated by hatred very largely.

BROICH : Yes, but why not? Did you expect anything else? It's obvious that they are delighted about the millions of Germans who will die next winter.

ELFELDT : The only thing which isn't so terrible is that the crazy evacuation from CZECHOSLOVAKIA and POLAND is to be stopped. The fact that it's already happened, at any rate in POLAND -

KÖNIG : But those who remain there have nothing to laugh about anyway. The most appalling things will go on.

PFUHLSTEIN: And then the secretaries of State!

BROICH : Well, that will be our first government.

PFUHLSTEIN: The beginnings, which will afterwards form the basis -

KÖNIG : Oh well, it will take some time, they are only temporary skeleton appointments.

BASSENGE : We must realize that GERMANY will be constricted into the smallest possible area -

BROICH : For the next 100 years, if not for longer.

BASSENGE : She'll be completely out of the picture for many decades.

DITTMAR : The development from the year 1200, 700 years, has been annulled by a stroke of the pen.

BASSENGE : Yes, we staked [redacted] card.

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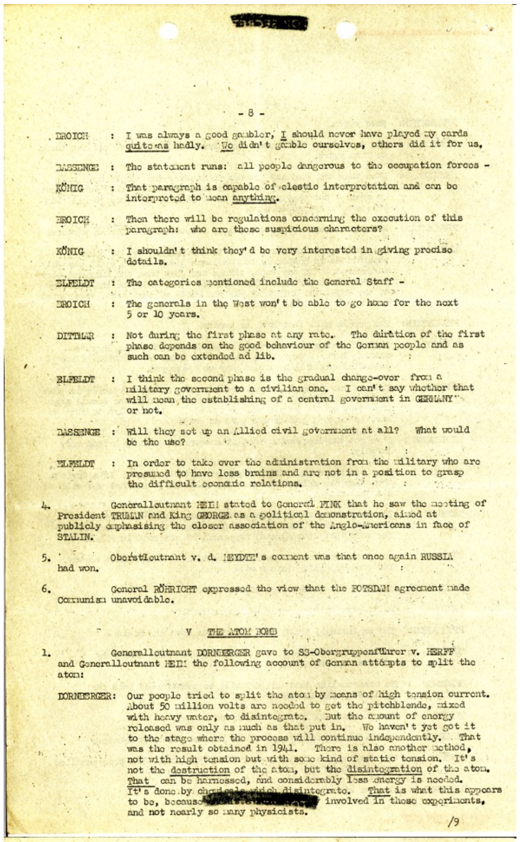

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BROICH : I was always a good gambler, I should never have played my cards quite as badly. We didn't gamble ourselves, others did it for us.

BASSENGE : The statement runs: all people dangerous to the occupation forces -

KÖNIG : That paragraph is capable of elastic interpretation and can be interpreted to mean anything.

BROICH : Then there will be regulations concerning the execution of this paragraph: who are these suspicious characters?

KÖNIG : I shouldn't think they'd be very interested in giving precise details.

ELFELDT : The categories mentioned include the General Staff -

BROICH : The generals in the West won't be able to go home for the next 5 or 10 years.

DITTMAR : Not during the first phase at any rate. The duration of the first phase depends on the good behaviour of the German people and as such can be extended ad lib.

ELFELDT : I think the second phase is the gradual change-over from a military government to a civilian one. I can't say whether that will mean the establishing of a central government in GERMANY or not.

BASSENGE : Will they set up an Allied civil government at all? What would be the use?

ELFELDT : In order to take over the administration from the military who are presumed to have less brains and are not in a position to grasp the difficult economic relations.

4. Generalleutnant HEIM stated to General FINK that he saw the meeting of President TRUMAN and King GEORGE as a political demonstration, aimed at publicly emphasising the closer association of the Anglo-Americans in face of STALIN.

5. Oberstleutnant v. d. HEYDTE's comment was that once again RUSSIA had won.

6. General RÖHRICHT expressed the view that the POTSDAM agreement made Communism unavoidable.

V THE ATOM BOMB

1. Generalleutnant DORNBERGER gave to SS-Obergruppenführer v. HERFF and Generalleutnant HEIM the following account of German attempts to split the atom:

DORNBERGER: Our people tried to split the atom by means of high tension current. About 50 million volts are needed to get the pitchblende, mixed with heavy water, to disintegrate. But the amount of energy released was only as much as that put in. We haven't yet got it to the stage where the process will continue independently. That was the result obtained in 1941. There is also another method, not with high tension but with some kind of static tension. It's not the destruction of the atom, but the disintegration of the atom. That can be harnessed, and considerably less energy is needed. It's done by ch[redacted] disintegrate. That is what this appears to be, because[redacted] involved in those experiments, and not nearly so many physicists.

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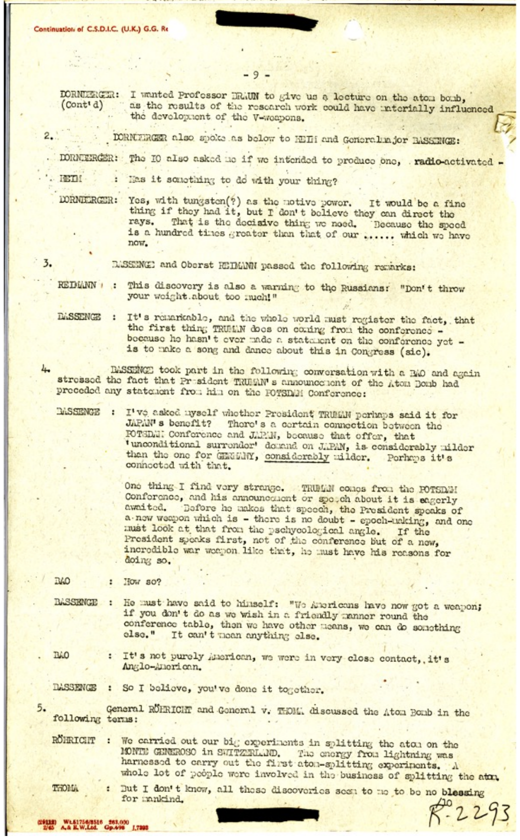

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DORNBERGER: (Cont'd) I wanted Professor BRAUN to give us a lecture on the atom bomb, as the results of the research work could have materially influenced the development of the V-weapons.

2. DORNBERGER also spoke as below to HEIM and Generalmajor BASSENGE:

DORNBERGER: The IO also asked me if we intended to produce one, radio-activated -

HEIM : Has it something to do with your thing?

DORNBERGER: Yes, with tungsten(?) as the motive power. It would be a fine thing if they had it, but I don't believe they can direct the rays. That is the decisive thing we need. Because the speed is a hundred times greater than that of our ...... which we have now.

3. BASSENGE and Oberst REIMANN passed the following remarks:

REIMANN : This discovery is also a warning to the Russians: "Don't throw your weight about too much!"

BASSENGE : It's remarkable, and the whole world must register the fact, that the first thing TRUMAN does on coming from the conference - because he hasn't ever made a statement on the conference yet - is to make a song and dance about this in Congress (sic).

4. BASSENGE took part in the following conversation with a BAO and again stressed the fact that President TRUMAN's announcement of the Atom Bomb had preceded any statement from him on the POTSDAM Conference:

BASSENGE : I've asked myself whether President TRUMAN perhaps said it for JAPAN's benefit? There's a certain connection between the POTSDAM Conference and JAPAN, because that offer, that 'unconditional surrender' demand on JAPAN, is considerably milder than the one for GERMANY, considerably milder. Perhaps it's connected with that.

One thing I find very strange. TRUMAN comes from the POTSDAM Conference, and his announcement or speech about it is eagerly awaited. Before he makes that speech, the President speaks of a new weapon which is - there is no doubt - epoch-making, and one must look at that from the pschycological angle. If the President speaks first, not of the conference but of a new, incredible war weapon like that, he must have his reasons for doing so.

BAO : How so?

BASSENGE : He must have said to himself: "We Americans have now got a weapon; if you don't do as we wish in a friendly manner round the conference table, then we have other means, we can do something else." It can't mean anything else.

BAO : It's not purely American, we were in very close contact, it's Anglo-American.

BASSENGE : So I believe, you've done it together.

5. General RÖHRICHT and General v. THOMA discussed the Atom Bomb in the following terms:

RÖHRICHT : We carried out our big experiments in splitting the atom on the MONTE GENEROSO in SWITZERLAND. The energy from lightning was harnessed to carry out the first atom-splitting experiments. A whole lot of people were involved in the business of splitting the atom.

THOMA : But I don't know, all these discoveries seem to me to be no blessing for mankind.

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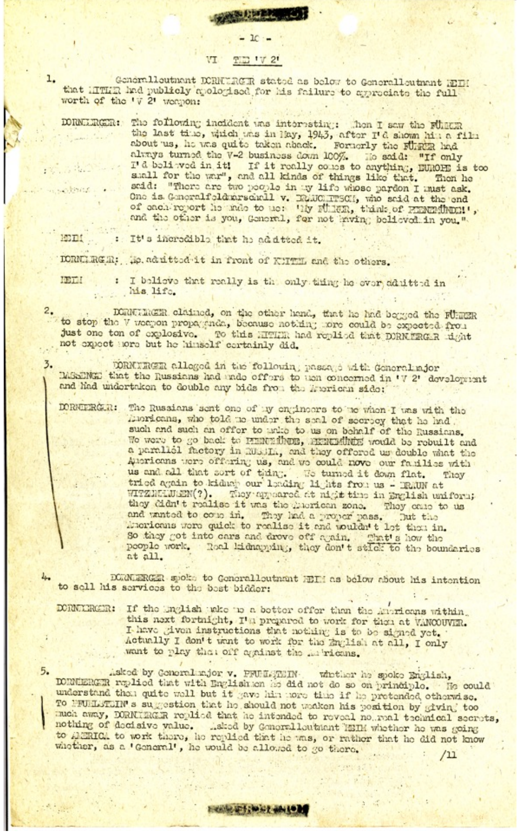

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VI THE 'V 2'

1. Generalleutnant DORNBERGER stated as below to Generalleutnant HEIM that HITLER had publicly apologised for his failure to appreciate the full worth of the 'V 2' weapon:

DORNBERGER: The following incident was interesting: When I saw the FÜHRER the last time, which was in May, 1943, after I'd shown him a film about us, he was quite taken aback. Formerly the FÜHRER had always turned the V-2 business down 100%. He said: "If only I'd believed in it! If it really comes to anything, EUROPE is too small for the war", and all kinds of things like that. Then he said: "There are two people in my life whose pardon I must ask. One is Generalfeldmarschall v. BRAUCHITSCH, who said at the end of each report he made to me: 'My FÜHRER, think of PEENEMÜNDE!', and the other is you, General, for not having believed in you."

HEIM : It's incredible that he admitted it.

DORNBERGER: He admitted it in front of KEITEL and the others.

HEIM : I believe that really is the only thing he ever admitted in his life.

2. DORNBERGER claimed, on the other hand, that he had begged the FÜHRER to stop the V weapon propaganda, because nothing more could be expected from just one ton of explosive. To this HITLER had replied that DORNBERGER might not expect more but he himself certainly did.

3. DORNBERGER alleged in the following passage with Generalmajor BASSENGE that the Russians had made offers to men concerned in 'V 2' development and had undertaken to double any bids from the American side:

DORNBERGER: The Russians sent one of my engineers to me when I was with the Americans, who told me under the seal of secrecy that he had such and such an offer to make to us on behalf of the Russians. We were to go back to PEENEMÜNDE, PEENEMÜNDE would be rebuilt and a parallel factory in RUSSIA, and they offered us double what the Americans were offering us, and we could move our families with us and all that sort of thing. We turned it down flat. They tried again to kidnap our leading lights from us - BRAUN at WITZENHAUSEN(?). They appeared at night time in English uniform; they didn't realise it was the American zone. They came to us and wanted to come in. They had a proper pass. But the Americans were quick to realise it and wouldn't let them in. So they got into cars and drove off again. That's how the people work. Real kidnapping, they don't stick to the boundaries at all.

4. DORNBERGER spoke to Generalleutnant HEIM as below about his intention to sell his services to the best bidder:

DORNBERGER: If the English make me a better offer than the Americans within this next fortnight, I'm prepared to work for them at VANCOUVER. I have given instructions that nothing is to be signed yet. Actually I don't want to work for the English at all, I only want to play that off against the Americans.

5. Asked by Generalmajor v. PFUHLSTEIN whether he spoke English, DORNBERGER replied that with Englishmen he did not do so on principle. He could understand them quite well but it gave him more time if he pretended otherwise. To PFUHLSTEIN's suggestion that he should not weaken his position by giving too much away, DORNBERGER replied that he intended to reveal no real technical secrets, nothing of decisive value. Asked by Generalleutnant HEIM whether he was going to AMERICA to work there, he replied that he was, or rather that he did not know whether, as a 'General', he would be allowed to go there.

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Figure D.786: C.S.D.I.C. (U.K.) G.R.G.G. 341 [Recorded conversation of Walter Dornberger and several other high-ranking German prisoners held in the United Kingdom after the war. AFHRA folder 512.619C-5F 1945, IRIS 212009; AFHRA A5414 frames 760–775; TNA WO 208/4178].

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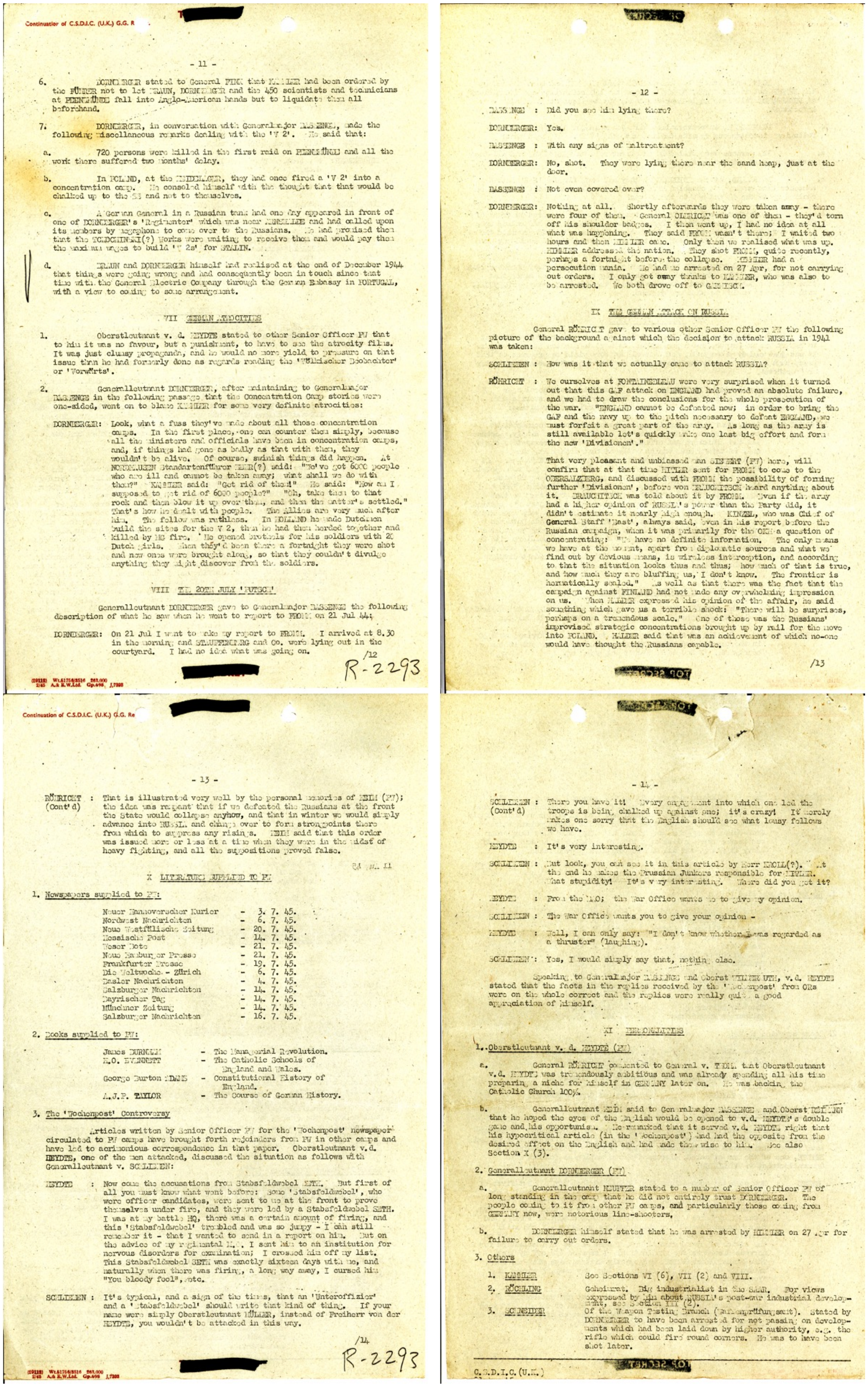

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6. DORNBERGER stated to General FINK that KAMMLER had been ordered by the FÜHRER not to let BRAUN, DORNBERGER and the 450 scientists and technicians at PEENEMÜNDE fall into Anglo-American hands but to liquidate them all beforehand.

7. DORNBERGER, in conversation with Generalmajor BASSENGE, made the following miscellaneous remarks dealing with the 'V 2'. He said that:

a. 720 persons were killed in the first raid on PEENEMÜNDE and all the work there suffered two months' delay.

b. In POLAND, at the HEIDELAGER, they had once fired a 'V 2' into a concentration camp. He consoled himself with the thought that that would be chalked up to the SS and not to themselves.

c. A German General in a Russian tank had one day appeared in front of one of DORNBERGER's 'Regimenter' which was near ARNSWALDE and had called upon its members by megaphone to come over to the Russians. He had promised them that the TCHOCHINSKI(?) Works were waiting to receive them and would pay them the maximum wages to build 'V 2s' for STALIN.

d. BRAUN and DORNBERGER himself had realised at the end of December 1944 that things were going wrong and had consequently been in touch since that time with the General Electric Company through the German Embassy in PORTUGAL, with a view to coming to some arrangement.

VII GERMAN ATROCITIES

1. Oberstleutnant v. d. HEYDTE stated to other Senior Officer PW that to him it was no favour, but a punishment, to have to see the atrocity films. It was just clumsy propaganda, and he would no more yield to pressure on that issue than he had formerly done as regards reading the 'Völkischer Beobachter' or 'Vorwärts'.

2. Generalleutnant DORNBERGER, after maintaining to Generalmajor BASSENGE in the following passage that the Concentration Camp stories were one-sided, went on to blame KAMMLER for some very definite atrocities:

DORNBERGER: Look, what a fuss they've made about all those concentration camps. In the first place, one can counter them simply, because all the ministers and officials have been in concentration camps, and, if things had gone as badly as that with them, they wouldn't be alive. Of course, swinish things did happen. At NORDHAUSEN Standartenführer BEER(?) said: "We've got 6000 people who are ill and cannot be taken away; what shall we do with them?" KAMMLER said: "Get rid of them!" He said: "How am I supposed to get rid of 6000 people?" "Oh, take them to that rock and then blow it up over them, and then the matter's settled." That's how he dealt with people. The Allies are very much after him. The fellow was ruthless. In HOLLAND he made Dutchmen build the sites for the V 2, then he had them herded together and killed by MG fire. He opened brothels for his soldiers with 20 Dutch girls. When they'd been there a fortnight they were shot and new ones were brought along, so that they couldn't divulge anything they might discover from the soldiers.

VIII THE 20TH JULY 'PUTSCH'

Generalleutnant DORNBERGER gave to Generalmajor BASSENGE the following description of what he saw when he went to report to FROMM on 21 Jul 44:

DORNBERGER: On 21 Jul I went to make my report to FROMM. I arrived at 8.30 in the morning and STAUFFENBERG and Co. were lying out in the courtyard. I had no idea what was going on.

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BASSENGE : Did you see him lying there?

DORNBERGER: Yes.

BASSENGE : With any signs of maltreatment?

DORNBERGER: No, shot. They were lying there near the sand heap, just at the door.

BASSENGE : Not even covered over?

DORNBERGER: Nothing at all. Shortly afterwards they were taken away - there were four of them. General OLBRICHT was one of them - they'd torn off his shoulder badges. I then went up, I had no idea at all what was happening. They said FROMM wasn't there; I waited two hours and then HIMMLER came. Only then we realised what was up. HIMMLER addressed the nation. They shot FROMM, quite recently, perhaps a fortnight before the collapse. HIMMLER had a persecution mania. He had me arrested on 27 Apr, for not carrying out orders. I only got away thanks to KAMMLER, who was also to be arrested. We both drove off to GARMISCH.

IX THE GERMAN ATTACK ON RUSSIA

General RÖHRICHT gave to various other Senior Officer PW the following picture of the background against which the decision to attack RUSSIA in 1941 was taken:

SCHLIEBEN : How was it that we actually came to attack RUSSIA?

RÖHRICHT : We ourselves at FONTAINEBLEAU were very surprised when it turned out that this GAF attack on ENGLAND had proved an absolute failure, and we had to draw the conclusions for the whole prosecution of the war. "ENGLAND cannot be defeated now; in order to bring the GAF and the navy up to the pitch necessary to defeat ENGLAND, we must forfeit a great part of the army. As long as the army is still available let's quickly make one last big effort and form the new 'Divisionen'."

That very pleasant and unbiassed man SIEWERT (PW) here, will confirm that at that time HITLER sent for FROMM to come to the OBERSALZBERG, and discussed with FROMM the possibility of forming further 'Divisionen', before von BRAUCHITSCH heard anything about it. BRAUCHITSCH was told about it by FROMM. Even if the army had a higher opinion of RUSSIA's power than the Party did, it didn't estimate it nearly high enough. KINZEL, who was Chief of General Staff 'East', always said, even in his report before the Russian campaign, when it was primarily for the OKH a question of concentrating: "We have no definite information. The only means we have at the moment, apart from diplomatic sources and what we find out by devious means, is wireless interception, and according to that the situation looks thus and thus; how much of that is true, and how much they are bluffing us, I don't know. The frontier is hermetically sealed." As well as that there was the fact that the campaign against FINLAND had not made any overwhelming impression on us. When HALDER expressed his opinion of the affair, he said something which gave us a terrible shock: "There will be surprises, perhaps on a tremendous scale." One of those was the Russians' improvised strategic concentrations brought up by rail for the move into POLAND. HALDER said that was an achievement of which no-one would have thought the Russians capable.

/13

TOP SECRET

Continuation of C.S.D.I.C. (U.K.) G.G. Re

[redacted]

- 13 -

RÖHRICHT (Cont'd) : That is illustrated very well by the personal memories of HEIM (PW); the idea was rampant that if we defeated the Russians at the front the State would collapse anyhow, and that in winter we would simply advance into RUSSIA and change over to form strongpoints there from which to suppress any risings. HEIM said that this order was issued more or less at a time when they were in the midst of heavy fighting, and all the suppositions proved false.

X LITERATURE SUPPLIED TO PW

1. Newspapers supplied to PW:

Neuer Hannoverscher Kurier	- 3. 7. 45.
Nordwest Nachrichten	- 6. 7. 45.
Neue Westfälische Zeitung	- 20. 7. 45.
Hessische Post	- 14. 7. 45.
Weser Bote	- 21. 7. 45.
Neue Hamburger Presse	- 21. 7. 45.
Frankfurter Presse	- 19. 7. 45.
Die Weltwoche - Zürich	- 6. 7. 45.
Basler Nachrichten	- 4. 7. 45.
Salzburger Nachrichten	- 14. 7. 45.
Bayrischer Tag	- 14. 7. 45.
Münchner Zeitung	- 14. 7. 45.
Salzburger Nachrichten	- 16. 7. 45.

2. Books supplied to PW:

James BURNHAM	- The Managerial Revolution.
H.O. EVENNETT	- The Catholic Schools of England and Wales.
George Burton ADAMS	- Constitutional History of England.
A.J.P. TAYLOR	- The Course of German History.

3. The 'Wochenpost' Controversy

Articles written by Senior Officer PW for the 'Wochenpost' newspaper circulated to PW camps have brought forth rejoinders from PW in other camps and have led to acrimonious correspondence in that paper. Oberstleutnant v.d. HEYDTE, one of the men attacked, discussed the situation as follows with Generalleutnant v. SCHLIEBEN:

HEYDTE : Now come the accusations from Stabsfeldwebel SETH. But first of all you must know what went before: Some 'Stabsfeldwebel', who were officer candidates, were sent to us at the front to prove themselves under fire, and they were led by a Stabsfeldwebel SETH. I was at my battle HQ, there was a certain amount of firing, and this 'Stabsfeldwebel' trembled and was so jumpy - I can still remember it - that I wanted to send in a report on him. But on the advice of my regimental M.O. I sent him to an institution for nervous disorders for examination; I crossed him off my list. This Stabsfeldwebel SETH was exactly sixteen days with me, and naturally when there was firing, a long way away, I cursed him "You bloody fool", etc.

SCHLIEBEN : It's typical, and a sign of the times, that an 'Unteroffizier' and a 'Stabsfeldwebel' should write that kind of thing. If your name were simply Oberstleutnant MÜLLER, instead of Freiherr von der HEYDTE, you wouldn't be attacked in this way.

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- 14 -

SCHLIEBEN (Cont'd) : There you have it! Every engagement into which one led the troops is being chalked up against one; it's crazy! It merely makes one sorry that the English should see what lousy fellows we have.

HEYDTE : It's very interesting.

SCHLIEBEN : But look, you can see it in this article by Herr KROLL(?). At the end he makes the Prussian Junkers responsible for HITLER. What stupidity! It's very interesting. Where did you get it?

HEYDTE : From the M.O.; the War Office wants me to give my opinion.

SCHLIEBEN : The War Office wants you to give your opinion -

HEYDTE : Well, I can only say: "I don't know whether I was regarded as a thruster" (laughing).

SCHLIEBEN : Yes, I would simply say that, nothing else.

Speaking to Generalmajor BASSENGE and Oberst WILDERMUTH, v.d. HEYDTE stated that the facts in the replies received by the 'Wochenpost' from ORs were on the whole correct and the replies were really quite a good appreciation of himself.

XI PERSONALITIES

1. Oberstleutnant v. d. HEYDTE (PW)

a. General RÖHRICHT commented to General v. THOMA that Oberstleutnant v.d. HEYDTE was tremendously ambitious and was already spending all his time preparing a niche for himself in GERMANY later on. He was backing the Catholic Church 100%.

b. Generalleutnant HEIM said to Generalmajor BASSENGE and Oberst REIMANN that he hoped the eyes of the English would be opened to v.d. HEYDTE's double game and his opportunism. He remarked that it served v.d. HEYDTE right that his hypocritical article (in the 'Wochenpost') had had the opposite from the desired effect on the English and had made them wise to him. See also Section X (3).

2. Generalleutnant DORNBERGER (PW)

a. Generalleutnant NEUFFER stated to a number of Senior Officer PW of long standing in the camp that he did not entirely trust DORNBERGER. The people coming to it from other PW camps, and particularly those coming from GERMANY now, were notorious line-shooters.

b. DORNBERGER himself stated that he was arrested by HIMMLER on 27 Apr for failure to carry out orders.

3. Others

1.	KAMMLER	See Sections VI (6), VII (2) and VIII.
2.	RÖCHLING	Geheimrat. Big industrialist in the SAAR. For views expressed by him about RUSSIA's post-war industrial development, see Section III (2).
3.	SCHNEIDER	Of the Weapon Testing Branch (Waffenprüfungsamt). Stated by DORNBERGER to have been arrested for not passing on developments which had been laid down by higher authority, e.g. the rifle which could fire round corners. He was to have been shot later.

TOP SECRET

C.S.D.I.C. (U.K.)

Figure D.787: C.S.D.I.C. (U.K.) G.R.G.G. 341 [Recorded conversation of Walter Dornberger and several other high-ranking German prisoners held in the United Kingdom after the war. AFHRA folder 512.619C-5F 1945, IRIS 212009; AFHRA A5414 frames 760–775; TNA WO 208/4178].

D.14 Allied Belief in the Reality of German Nuclear Weapons

[Both during and after the war, highly placed Allied officials expressed belief in the reality of advanced German nuclear weapons programs. In fact, it appears that after the war, the four major Allied countries found and benefited from materials and expertise from the German nuclear weapons program. All of the relevant wartime and postwar reports with the detailed evidence remain classified or missing entirely from archives. Nonetheless, enough sources are available to prove that those reports did indeed exist, and presumably still do exist.

For convenience, this section is divided into categories of intelligence sources:

D.14.1. U.S. presidential intelligence.

D.14.2. Alsos and other Manhattan Project intelligence.

D.14.3. Dutch intelligence.

D.14.4. French intelligence.

D.14.5. German and Japanese submarines.

D.14.6. High-level interrogations.

D.14.7. U.S. inspections of possible nuclear facilities.

D.14.8. German and Austrian scientists in the United States.

D.14.9. Other intelligence services.

D.14.10. Fritz Lang and the leak that almost revealed everything.

D.14.11. Allied intelligence officials who would/should have known.

Some examples of Allied wartime and postwar intelligence include:

- Vice President Henry Wallace, Vannevar Bush, George Strong, and other top U.S. officials were actively investigating the German nuclear program in 1942 and 1943, but their reports are still classified and unavailable to the public (pp. 4699–4700). Why?

- In two December 1943 cables to Washington, the U.S. Military Attaché in Istanbul warned that "an engineer of the Todt organization revealed in Sofia that the Germans now possess a new type of incendiary far surpassing anything yet used in warfare. The engineer intimated that London would suffer a fate worse than that of Berlin or Hamburg in the near future." The reports added: "The Germans have a weapon in preparation which is more devastating than anything we have ever seen" (pp. 4588–4588). Germany had been mining uranium in Sofia since 1938 (Section 8.8.3).

- In July 1944, Manhattan Project physicists Philip Morrison and Karl Cohen analyzed available intelligence on the German nuclear program and concluded (p. 4739): "Recent evidence essentially confirms our earlier general statements on enemy bomb production. The reports now at hand lead us to conclude: A German "Y" [enrichment] project has been underway since early 1943. A D_2O pile is in operation, but we do not believe that this is on production level. [...] In either case the first completed device could be in enemy hands now." Just exactly what evidence did the United States possess?

- The *Daily Telegraph and Morning Post* reported that in August 1944, the British government had intelligence that Germany was preparing "an atomic bomb" with "an explosive radius of more than two miles," or three kilometers (p. 5011). As noted in Section 8.8.5, the Royal Air Force went to extreme lengths to bomb what appears to have been a German fission reactor and fuel reprocessing complex near Königsberg during the period 26–30 August 1944.

- In September 1944, the *Los Angeles Times* reported that invading U.S. troops in France had found evidence that Germany was preparing a rocket-launched bomb "with an explosive radius of three kilometers" (p. 5012). What exactly was the evidence, and where are the official reports?

- Margaret Suckley, Franklin Roosevelt's secretary, wrote in her diary on 9 December 1944 that Roosevelt had received reliable reports that the Germans had successfully developed a bomb capable of killing everything within a mile and that the German program was "way ahead" of similar U.S. research (p. 4703).

- A tantalizing December 1944 summary report from the Manhattan Project's Foreign Intelligence Unit concluded (p. 4703): "Intelligence indicates that the enemy is working in the project field. It is likely that he has undertaken one or several of the various processes for the production of bombs on a small scale and to have organized an installation equivalent to our project on final utilization. (TAB A)." Unfortunately, instead of TAB A, the collected intelligence evidence for the German nuclear weapons program, the NARA file only includes a note stating: "In the review of this file this item was removed because access to it is restricted" (p. 4707).

- In a 9 December 1944 memo, U.S. Admiral William Leahy stated that on 8 December the Joint Chiefs of Staff discussed the possibility of a "V-3 stratospheric bomb attack" on the United States (p. 4702).

- In March 1945, Gerard Kuiper, a highly knowledgeable investigator in the Alsos Mission, wrote a letter that contradicted what the heads of Alsos were claiming at that time (p. 4766): "One is again surprised to see quotations from U.S. senators who think that the war will be over 'within a few days'. It would be wiser to worry about the chance we still have of losing it if certain high explosives are developed in time. This possibility may, incidentally, be one reason why the Germans are not giving in."

- Rather than heading toward the logical objective of Berlin to topple the German government and beat Soviet forces to the prize, U.S. troops under Generals Patton, Bradley, and Eisenhower rushed straight toward Thuringia. Justifications for this strategy have ranged from preventing Hitler from fleeing south to liberating concentration camps. However, at the very least it seems like an intriguing coincidence that Patton, Bradley, Eisenhower, and other top

Allied officials were personally inspecting the Ohrdruf Truppenübungsplatz military base all together on 12 April 1945 (U.S. forces captured the base on 4 April), only a month after the possible nuclear weapons tests at that site (Section 8.8.12) [Karlsch 2005, p. 218]. Other than photos of the generals and some of the concentration camp victims, none of what must have been numerous detailed written reports about what technologies or documents the U.S. forces found at that and nearby facilities have ever been declassified and released to the public.

- A 31 May 1945 cable from Eisenhower to Washington, D.C. reported: "A laboratory containing equipment and documents related to experimental work on atomic bombs and AA rockets was located near Lofer, E 7399 by Third US Army" (p. 4974). Eisenhower later told *The New York Times* how seriously he regarded the German nuclear program: "My main concern was that the Germans did not get the atomic bomb to use on us" (pp. 5033–5034).

- Indeed, at the end of the war, Allied investigators personally inspected many sites that conducted work related to the German nuclear weapons program, including sites in Germany (Lüneburger Heide, Hillersleben, I.G. Farben installations, numerous locations in Thuringia, etc.), Austria (St. Georgen an der Gusen, Ebensee, Redl-Zipf, Lofer, etc.), Czech territory (Pilsen, Podmokly, St. Joachimsthal/Jáchymov, etc.), and elsewhere (pp. 3670–3677, 4962–4985). Detailed reports on what they discovered and learned about the German nuclear program have never been publicly released.

- In May 1945, the German submarine U-234 surrendered to the United States. It contained 560 kg of uranium oxide (possibly enriched), bomb detonators, other materials, plans, and technical experts that would have shed light on the German nuclear program. Other submarines carried additional relevant materials, documents, and personnel (Section D.14.5). Where are the many tons of documents, prototypes, and other cargo from the U-234 and the other submarines, as well as all of the reports on the German nuclear and other technology programs that the United States compiled in the process of investigating the submarines' cargoes and interrogating their passengers?

- By the end of the war, SS General (and Dr. Ing.) Hans Kammler controlled and knew the details of virtually all German secret weapons research and development programs, including the nuclear weapons program. According to official histories, Kammler died in early May 1945. However, multiple documents in U.S. government archives prove that he surrendered to U.S. forces in May 1945 and was alive and being interrogated by the United States for many months (and perhaps even many years) after the war (pp. 4914–4961). The U.S. government must possess lengthy transcripts or even audio/video recordings of Kammler's interrogations. It would also possess any documents and materials that Kammler had with him when he was captured, or that he was able to direct the Americans to afterward. Kammler's interrogations and documents would almost certainly have provided the United States with considerable detail about the German nuclear program and other very advanced developments. (Albert Speer's capture and interrogation resulted in many shelves full of documents.) How can all of that Kammler material be located and declassified from U.S. government archives?

- When nuclear-related censorship was relaxed somewhat after the U.S. atomic bombings of Japan in August 1945, Allied officials made a stunning admission to *Newsweek* (p. 5022): "Since the surrender of the Nazi armies, Allied officers have revealed that Germany would have been able to strike with atomic bombs by January 1945, if the invasion had not come six months before. The highest Allied officials knew that such explosives could have won the war for the Axis."

- In a 25 August 1945 press release, the U.S. Office of War Information stated that "Germany's inner war secrets" included "experiments with the atomic bomb," that "Germans made significant progress in the development of an atomic bomb," and that not all "of the secrets. . . may be disclosed at this time" (p. 5023).

- A 31 August 1945 U.S. report mentioned "Gerald Klein (Dr.), Dipl.-Eng., Manager of LGW. . . Worked at Peenemünde and later became group director of atomic devices in RLM. At present being used by the British. Evacuated by 'T' Force" (p. 5010). Klein was listed as the manager of "LGW," which was the Luftgerätewerk Hakenfelde A.G., part of the huge Siemens electrical company. If wartime Germany never had atomic devices or even serious plans to make them, as maintained by official histories, why did the RLM or Reichsluftfahrtministerium (Ministry of Aviation) have an entire group dedicated to atomic devices, of which Dr. Klein was the director? Where are the U.K. and U.S. reports on Klein, the organizations named, and the nuclear work?

- A remarkable 14 September 1945 OSS cable revealed (p. 5045): "Our work on this subject is to correlate and cooperate with specially appointed general who has charge of the whole AZUSA [German nuclear] situation and has overall responsibility. . . . On present sub feature of AZUSA about assisting locating German scientists, special general asked to have the information sent only to Calvert, London Embassy, or to Washington. . . . This insures desired maximum security with fewest number persons involved. Copies of any reports to be sent OSS Washington without delay and showing action taken. This subject so tight at this time we are playing very close with special general." Does this OSS cable show that the U.S. started to really appreciate the full extent of the wartime German nuclear program by September 1945, and took steps to limit that knowledge to the "fewest number persons"? Is that why Zinsser's report of a German atomic bomb test was upgraded from Secret to Top Secret in early October 1945 (Section 8.8.10)? Who was the "special general" mentioned in this cable—Leslie Groves or someone else?

- The joint chairs of CIOS, U.S. General Thomas Jeffries Betts, Deputy G-2 of SHAEF, and U.K. Ministry of Supply chief advisor and F.R.S. Professor Reginald Patrick Linstead, wrote a 15 September 1945 final report based on specific discoveries by their CIOS investigators (p. 5030): "Certain items have been omitted because of security considerations. . . Of particular significance were the statements, made by German experts in the rocket and controlled missile field, that much of the priority accorded their work by the German High Command was in anticipation of the use of atomic explosives. These authorities stated that KWI had repeatedly assured Hitler that an atomic explosive would be available for use within a comparatively short time. During the last months of work by the Peenemünde staff, V-weapons were designed with much smaller war-heads. Quite possibly this trend was in anticipation of the successful development of a German atomic explosive." Thus the CIOS chairs directly contradicted the public statements of the Alsos Mission and confirmed that there was indeed a German program to develop an atomic bomb, and that it was far more than a paper design program—its hardware had passed through sufficient development, production, and testing by the end of the war that it was ready or nearly ready to be used in combat.

- In September and October 1945, General George C. Marshall made several noteworthy public statements: (1) “German technological advances such as in the development of atomic explosives made it imperative that we attack before these terrible weapons could be turned against us.” (2) “At the close of the German war in Europe they [U.S. factories] were just on the outer fringes of the range of fire from an enemy in Europe. Goering stated after his capture that it was a certainty the eastern American cities would have been under rocket bombardment had Germany remained undefeated for two more years. The first attacks would have started much sooner.” (3) “It is not hard to predict that supersonic atomic rockets will have a profound influence on any war that ever again has to be fought” (p. 5031).

- T. M. Odarenko, a longtime physicist from Bell Telephone, was one of the senior scientists involved in transferring advanced technologies from Germany and Austria to the United States after the war. He wrote of encountering a large group of refugee nuclear scientists in Austria (pp. 4788–4785): “Contrary to the statements, attributed by the U.S. newspapers to the various U.S. atomic experts, that it “would take the Germans some 100 years to solve the problem of atomic disintegration on an explosive basis” (for the manufacture of bombs), the opinion of the members of the Institute themselves was that, given a supply of radium and uranium, and permitting their return to Vienna, where certain of their materials and equipments are stored, they would be able to “complete their work” in some 3 to 6 months. . . . That these claims of the Institute are not to be disregarded too readily would follow from the fact that Prof. [Charles P.] Smyth spent considerable time with the Institute, revisited them several times, and thought it necessary to insist on the most stringent type of control over the scientific activities of the group, as well as on close individual observations.” Smyth reported to Leslie Groves, and Odarenko’s reports on the nuclear scientists were also forwarded to Groves. The Austrian nuclear scientists were closely monitored and controlled for years by U.S. intelligence and military agencies. For example, the leader of the Austrian group, Georg Stetter, was kept under virtual house arrest by U.S. agents in Austria from 1945 until the 1950s, nearly destroying his career (pp. 4798–4800).

- A large number of Alsos-related documents from Samuel Goudsmit’s files remain classified (pp. 4772–4779). Likewise, some very important German-related files from the Manhattan Project’s Foreign Intelligence Unit and the OSS remain classified and unavailable (pp. 4812–4827) [NARA RG 77, Entry UD-22A; NARA RG 226]. Even Lt. Col. George R. Eckman’s “Final Report on the ALSOS Mission,” written in December 1945, seems to be missing from modern archives (p. 3333). There may be countless other relevant files whose absence is not even noted in the archives.

- There is evidence that Dutch intelligence provided important information about the German nuclear weapons program to the United States during and after the war (pp. 4832–4853). Samuel Goudsmit’s entire folder of Dutch intelligence on the German nuclear program remains classified and unavailable.

- Likewise, there is evidence that French intelligence gave important information about the German nuclear weapons program to the United States (pp. 4854–4855).

- Werner Grothmann stated that the fission fuel and components of at least one German atomic bomb were found and removed from Germany by U.S. forces in 1945 (pp. 5040–5043). An archived card catalog of U.S. intelligence reports on Germany shows that there were postwar reports containing detailed information on the German atomic bomb, including a 2 January

1946 document labelled "Blueprints of Atomic Bomb," a 28 March 1946 report on "Atom Bomb Research in Germany & Influence on Developments in Soviet Russia," a 4 June 1947 report entitled "Atomic Bomb," a 25 July 1947 report on "Atomic Bomb Detonating Plans," and others. The reports themselves are still classified and unavailable to the public (pp. 5074–5075).

- In private, General Leslie Groves wrote a February 1946 secret memorandum revealing (p. 4806): "Government measures to encourage the long term exploitation of German scientists by the United States are desirable, particularly with reference to nuclear physicists and chemists who might be of some service to scientists in this country in the field of atomic energy. . . I suggest, therefore, a fifth category, defined as, those German scientists of outstanding ability in the field of nuclear physics and chemistry who, by their past reputation and present knowledge, would be of more value to the national interest of this country if they could be employed here rather than in any other country. . . However, it is extremely important that these persons be prevented from giving their services to a potential enemy of the United States." In public, though, Groves knowingly and repeatedly made false claims that Germany's nuclear scientists had been few in number and hopelessly backward [Groves 1962].

- At the "Ashcan" interrogation center after the war, Hermann Goering told his Allied interrogators that "Germany was within 90 days of producing its first atom bomb when the war ended" (p. 4894).

- In similar postwar interrogations, Wilhelm Voss, the former director of the Skoda works, told Allied interrogators about the organization and results of the German nuclear weapons program (p. 4914).

- A U.S. Department of Commerce press release praised wartime German scientific accomplishments that were more advanced than those of the United States and that were being transferred to the United States to improve its programs: "Spectacular accomplishments in uranium, nitrogen, oxygen recovery, plastics, nuclear physics and many other fields, have been uncovered in the investigation of the chemicals field alone" (p. 5066).

- In July 1946, the U.S. *Army Air Forces Review* published an article stating, "it is still a matter of scientific conjecture just how many weeks—or days—it might have taken Germany to be ready with her atomic devices for the V-2s" (p. 5038).

- In 1946, U.S. Army Air Forces Colonel George Woods wrote of "Germany's Plans for the 'A-9' with Atomic Bomb": "it is well known that the Germans originally had hoped to have their atomic bomb developments completed by the end of 1944." See p. 5073.

- Top Secret 1946 cables from the U.S. Joint Chiefs of Staff to General Joseph T. McNarney (the military governor of the U.S.-occupied zone of Germany and also the commander in chief of the U.S. Forces of Occupation in Europe) ordered him (pp. 5065–5066): "Except for most cogent reasons you will not permit representatives of nations other than British Commonwealth (excluding Eire) to have access in any U.S. zone of occupation under your jurisdiction to technical information on the following subjects or to related intelligence targets: [...] Applied and theoretical nuclear physics, including design and operation of devices for producing highly energetic particles, and isotope separation." These Top Secret Orders from the highest level were written over a year after the end of the war in Europe, after the U.S.

had had time to investigate wartime German programs in detail, and they specifically noted advanced nuclear-weapons-related work.

- In a 17 August 1946 interrogation, Edmund Sorg described a piloted version of the V-1 cruise missile armed with an atomic bomb (p. 4896).

- In discussing German rockets as weapons in an August 1947 interview, General William L. Richardson said "there is evidence to believe that the Germans intended to utilize an atomic warhead which would have made this weapon extremely deadly" (pp. 5035–5036). General Richardson would have been a highly knowledgeable and very sober source for this information. What "evidence" did he have?

- In a 19 August 1947 intelligence report that is still heavily censored, Edmund Tilley discussed wartime nuclear weapons work at Tucheler Heide in Poland, including the production of ^{235}U and ^{239}Pu and apparently even 1–5 kg fission pits for atomic bombs. According to Tilley, one of the German scientists most directly responsible for that work, "Dr. Niels" (Walter Nielsch?), had already been taken to the United States for interrogation and/or work (p. 4902).

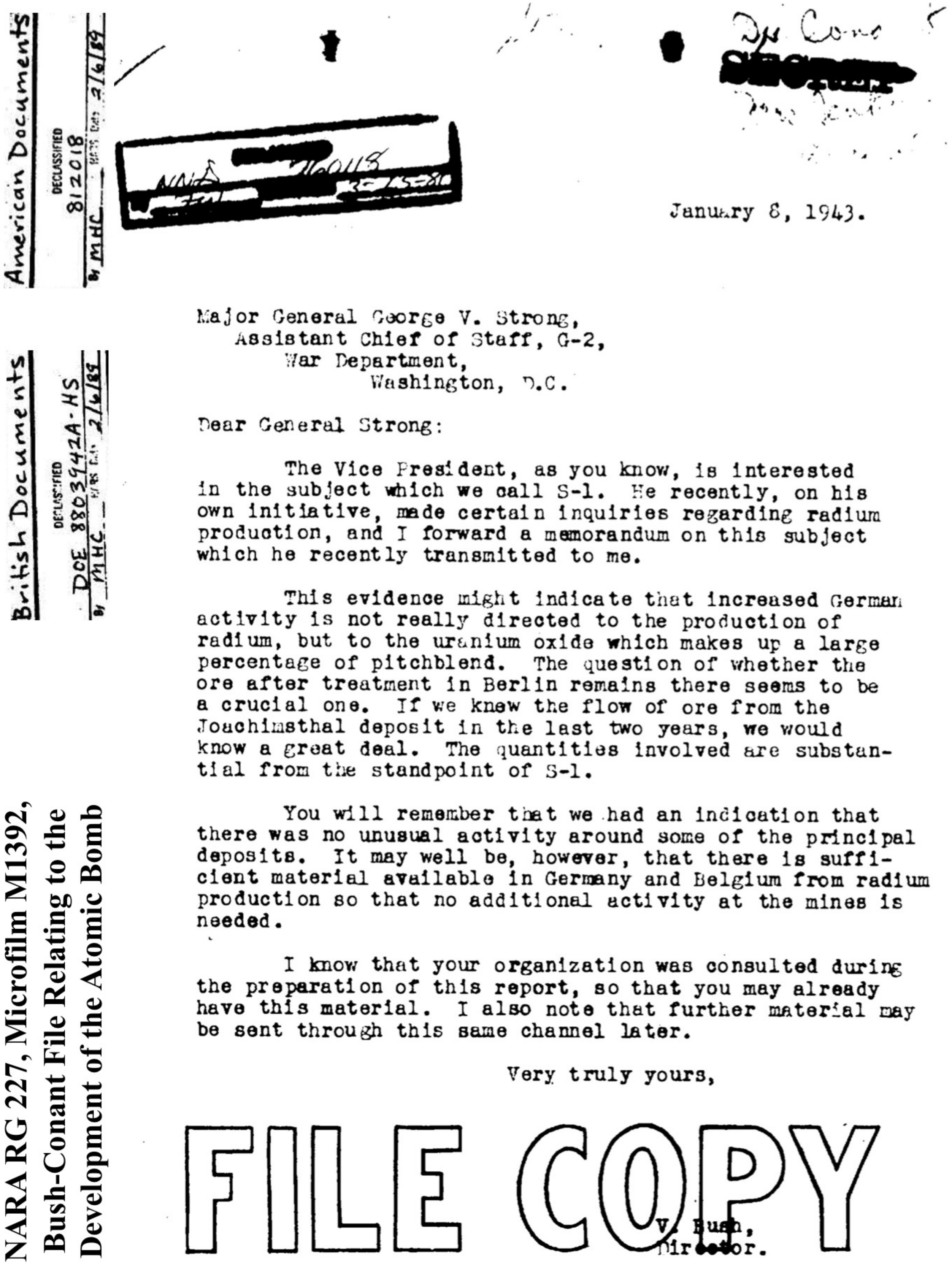
- Many German and Austrian scientists who appear to have been involved in the nuclear program visited or worked in the United States and/or United Kingdom after the war. They may have provided information about wartime German work and aided the U.S./U.K. nuclear programs. Even basic files for some scientists are still not available to the public. For example, virtually the entire "Foreign Scientist Case File" (Paperclip file) of nuclear physicist Otto Haxel has been redacted in response to recent Freedom of Information Act Requests, and Wernher von Braun's Paperclip file is missing entirely. Furthermore, a large number of additional scientists were interrogated in Europe. The complete interrogation reports and all other files on all of these scientists and engineers should be sought and released.

From examples such as those given throughout this appendix, it is clear that there is an enormous amount of information about the wartime German nuclear weapons program that remains classified and/or hidden by various governments. Why is that the case, if the German program was as small and as primitive as government officials and historians have maintained for 75+ years? What is the true history of the German program? What is the true history of Allied knowledge about the German program, both during and after the war? Where is all of the relevant archival and physical evidence stored now?]

D.14.1 U.S. Presidential Intelligence

[Some of the best Allied wartime intelligence on the German nuclear program was centered around Franklin Roosevelt and the top presidential advisors. Most of the actual intelligence is still not available to the public. From the information that is available, it appears that much of this intelligence came from channels other than the Alsos Mission, which was supposed to be the official intelligence investigation of the German program.

As shown on pp. 4699–4700, Vice President Henry Wallace, Vannevar Bush, George Strong, and other top U.S. officials were actively investigating the German nuclear program in 1942 and 1943, but their reports are still classified and unavailable to the public. Why?]



Dr Conant

[redacted]

American Documents
DECLASSIFIED
812018
By MHC NARS Date 2/6/89

British Documents
DECLASSIFIED
DOE 8803942A-HS
By MHC NARS Date 2/6/89

[redacted]

January 8, 1943.

Major General George V. Strong,
Assistant Chief of Staff, G-2,
War Department,
Washington, D.C.

Dear General Strong:

The Vice President, as you know, is interested in the subject which we call S-1. He recently, on his own initiative, made certain inquiries regarding radium production, and I forward a memorandum on this subject which he recently transmitted to me.

This evidence might indicate that increased German activity is not really directed to the production of radium, but to the uranium oxide which makes up a large percentage of pitchblend. The question of whether the ore after treatment in Berlin remains there seems to be a crucial one. If we knew the flow of ore from the Joachimsthal deposit in the last two years, we would know a great deal. The quantities involved are substantial from the standpoint of S-1.

You will remember that we had an indication that there was no unusual activity around some of the principal deposits. It may well be, however, that there is sufficient material available in Germany and Belgium from radium production so that no additional activity at the mines is needed.

I know that your organization was consulted during the preparation of this report, so that you may already have this material. I also note that further material may be sent through this same channel later.

Very truly yours,

FILE COPY

V. Bush,
Director.

NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb

Figure D.788: Vice President Henry Wallace, Vannevar Bush, George Strong, and other top U.S. officials were actively investigating the German nuclear program in 1942 and 1943, but their reports are still classified. Why??? [NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb, https://downloads.paperlessarchives.com, pp. 11,357–11,361.]

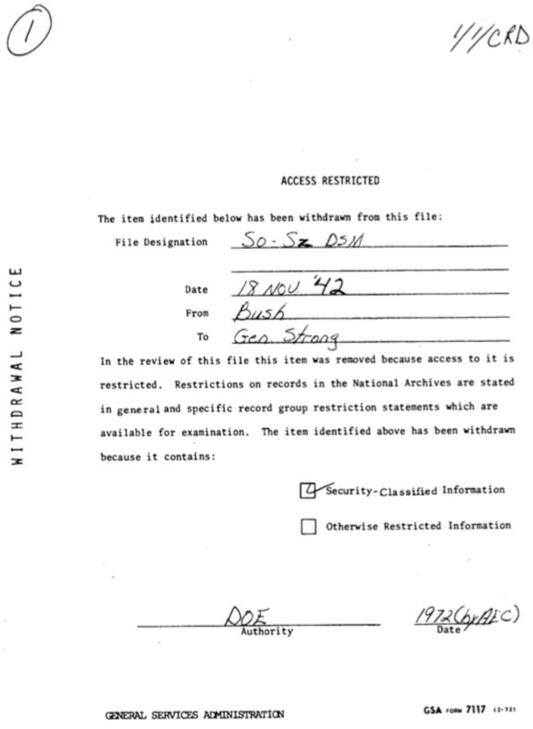
American Documents

DECLASSIFIED
812018
By MHC NARS Date 2/6/89

British Documents

DECLASSIFIED
DOE 8803942A-HS
By MHC NARS Date 2/6/89

NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb



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File Designation So-Sz DSM

Date 18 NOV. '42

From Bush

To Gen. Strong

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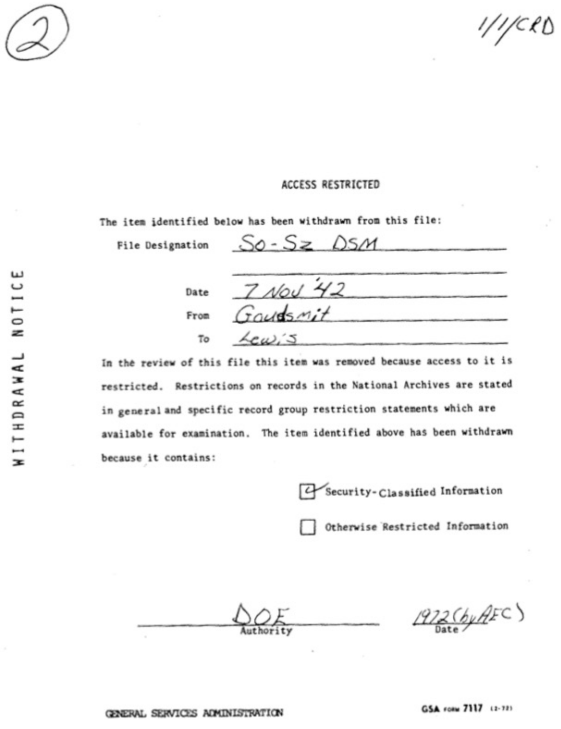

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File Designation So-Sz DSM

Date 7 NOV '42

From Goudsmit

To Lewis

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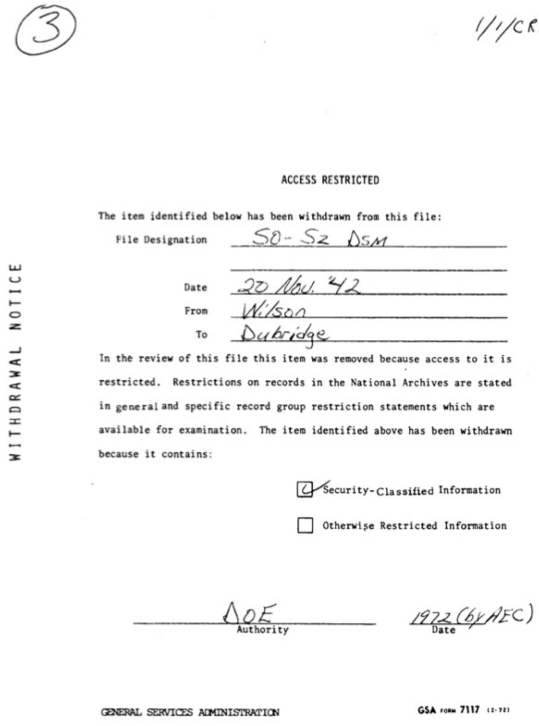

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File Designation So-Sz DSM

Date 20 Nov. '42

From Wilson

To Dubridge

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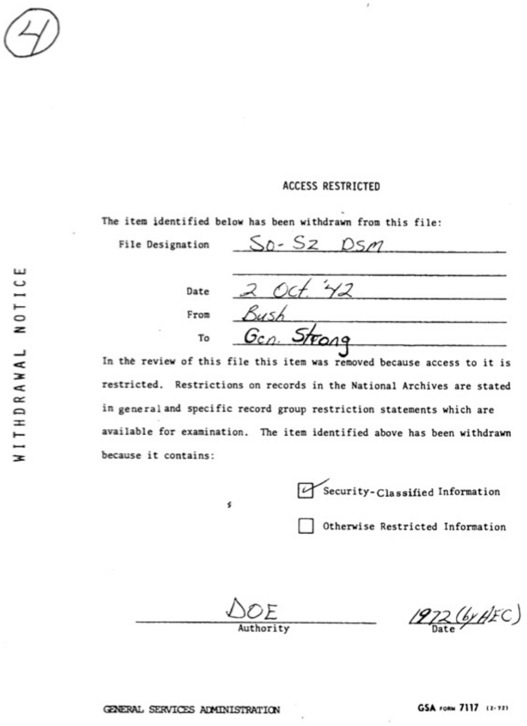

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File Designation So-Sz DSM

Date 2 Oct. '42

From Bush

To Gen. Strong

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Date

GENERAL SERVICES ADMINISTRATION GSA FORM 7117 (2-72)

Figure D.789: Vice President Henry Wallace, Vannevar Bush, George Strong, and other top U.S. officials were actively investigating the German nuclear program in 1942 and 1943, but their reports are still classified. Why??? [NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb, https://downloads.paperlessarchives.com, pp. 11,357–11,361.]

Joseph E. Persico. 2001. *Roosevelt's Secret War: FDR and World War II Espionage.* pp. 381–382

The President had sent the rambunctious George Earle, former Pennsylvania governor, former ambassador, and permanent playboy, to Istanbul in 1943 as his eyes and ears. Earle's reports from that den of intrigue had proved a mixed but respectable bag. He had provided FDR with solid, if unwelcome intelligence on what the Russians had done to the Poles in the Katyn forest. He had correctly predicted the German rockets falling on England. But he had overestimated the destruction and underestimated the time for the Germans to rebuild the bombed Ploeşti oil fields. [...]

He fired off a warning to the President on December 5 [1944] that the Germans, already using V-1 buzz bombs and V-2 rockets against England, were about to launch another secret weapon, the V-3, against the American East Coast.

[George Earle's 5 December 1944 report is mentioned in several archival documents, but that report itself does not seem to be available in archives. Can it be located?

Earle's earlier reports on secret activities were correct and highly valuable intelligence. If anything, they underestimated German capabilities, such as their ability to withstand and to repair damage to their oil facilities in Ploeşti, Romania. During his time in Turkey, Earle had close contacts with Wilhelm Canaris, Paul Leverkühn, Franz von Papen, and other highly placed German officials who had inside knowledge of very secret projects.]

Franklin Roosevelt to William Leahy. 7 December 1944. [Franklin Delano Roosevelt Library, Hyde Park, New York. Map Room Files, Box 20. Folder Trips to Warm Springs, Ga. 28 Nov.–8 Dec. 1944]

MR-IN-217 7 December 1944

MEMORANDUM FOR ADMIRAL LEAHY FROM THE PRESIDENT:

In view of message from Lt. Commander Earle 051444 NCR 4414, please tell Joint Staff I am inclined to think Office Civilian Defense and Air Corps and Eastern Frontier of Navy should reconstitute all alert preparations. The telegram is probably a rumor and there may be nothing in it but every precaution should be taken.

RECD 072006Z

Clayton Bissell and Hewlett Thebaud to the Joint Chiefs of Staff. 9 December 1944. Subject: Agreed Joint Evaluation of the Possible Existence of the V-3 Rocket and Probability of Attack against the U.S. [Franklin Delano Roosevelt Library, Hyde Park, New York. Map Room Files, Box 164, Folder Naval Aides. Files: A/16—General Correspondence]

1. The cable from Lieutenant Commander Earle, Naval Attaché, Turkey is probably propaganda and represents a plant by the Germans. There is no reliable information available of German development of a long range rocket other than the V-2.

2. The V-3 may possibly be a rocket of smaller dimensions than the V-2 with a shorter range. It would be possible to launch such a missile from specially designed or modified submarines. Attached is a sketch of a German submarine based in a southern Norwegian port showing a pair of rails extending from conning tower to the bow and terminating at a flat, rectangular surface. The purpose of this is unknown.

3. German attack from Europe of United States cities by long range rockets is deemed impossible now. Small rocket or flying bomb attacks from specially constructed submarines are considered possible. Any such action would be made with propaganda effect rather than material damage as the primary objective.

[The sketch mentioned in this document is on p. 5623.

In this and other documents, Allied intelligence analysts were seemingly puzzled why Germany would go to so much trouble to deliver such a small number of payloads to the United States. They reasoned that a few payloads of conventional explosives would not do much damage to U.S. cities and would only serve a propaganda purpose. The obvious answer, which some intelligence analysts realized but others did not, is that the intended payloads were not conventional explosives. They were probably nuclear weapons as explained in this appendix, or possibly chemical or biological weapons as covered in Appendix A.]

Admiral William D. Leahy. 9 December 1944. Memorandum for the President. [Franklin Delano Roosevelt Library, Hyde Park, New York. Map Room Files, Box 20. Folder Warm Springs, Dec. 9-18, 1944]

Reference MR-in 217

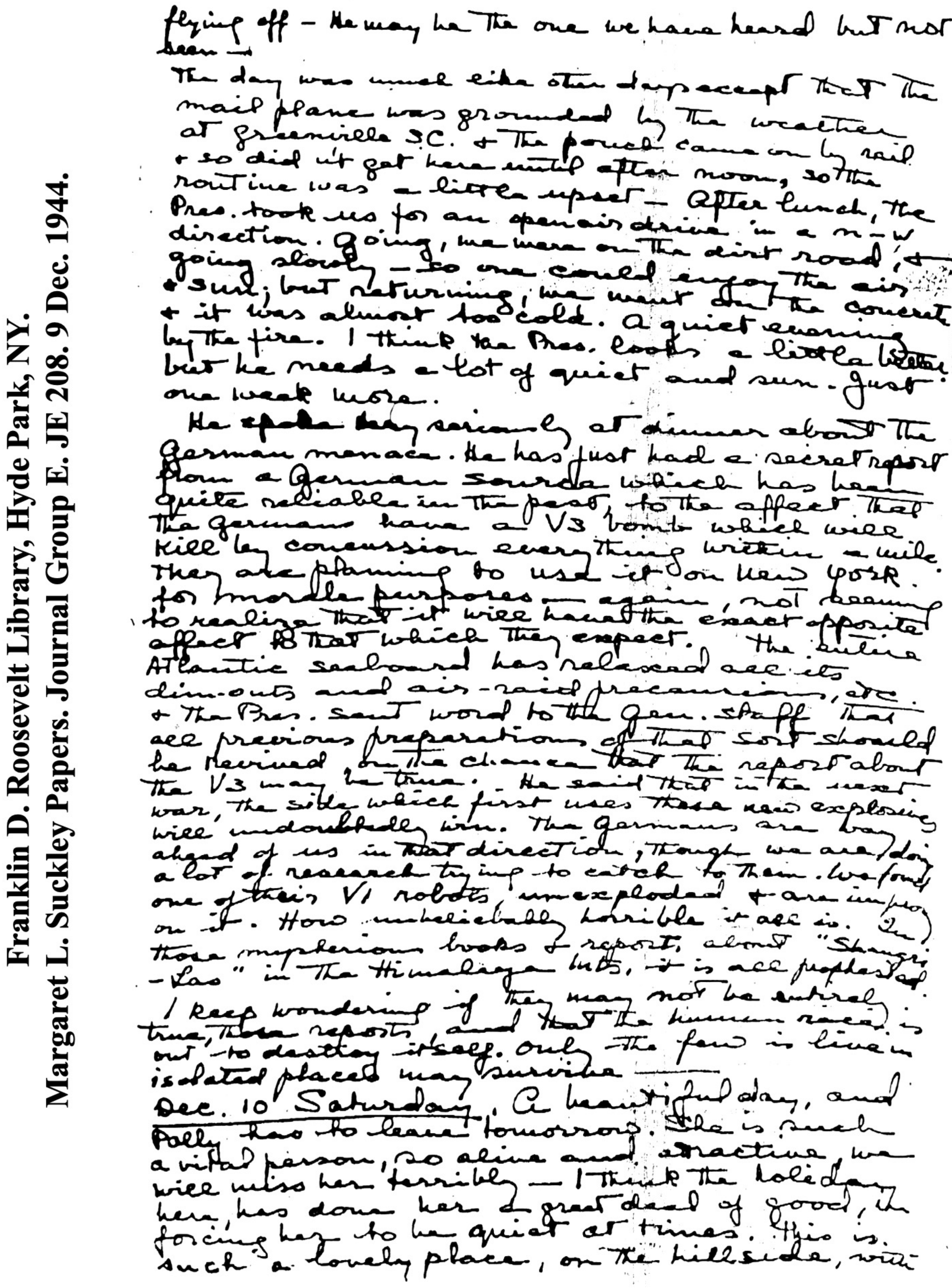
Possibility of V-3 stratospheric bomb attack on U. S. was discussed at a meeting of the Joint Chiefs of Staff yesterday. General Marshall and Admiral King have sent messages to defense commands, sea frontiers and the First Air Force at Mitchell Field ordering precautionary measures taken.

1944 diary of Margaret Suckley, personal secretary of Franklin Roosevelt [Ward 1995, pp. 357–358; Franklin Delano Roosevelt Library, Hyde Park, New York, Margaret Suckley Papers, Journal Group E, 06/30/1944-12/29/1944, Journal Entry 1-253, 9 December 1944].

Dec 9 Friday... A quiet evening by the fire. I think the Pres. looks a little better, but he needs a lot of quiet and sun. Just one week more.

He spoke very seriously at dinner about the German menace. He has just had a secret report from a German source which has been quite reliable in the past, to the effect that the Germans have a V3 bomb which will kill by concussion everything within a mile. They are planning to use it on New York for morale purposes—again, not seeming to realize that it will have the exact opposite effect to that which they expect. The entire Atlantic seaboard has relaxed all its dim-outs and air-raid precautions, etc. & the Pres. sent word to the Gen. staff that all previous preparations of that sort should be reviewed on the chance that the report about the V3 may be true. He said that in the next war, the side which first uses these new explosives will undoubtedly win. The Germans are way ahead of us in that direction, though we are doing a lot of research trying to catch up to them. We found one of their V1 robots, unexploded, & are improving on it.

[Franklin Roosevelt would of course have had access to the very best Allied intelligence on German secret weapons programs, from a wide variety of organizations and sources. His reaction as recorded here appears to have been due at least in part to George Earle's 5 December 1944 report and the flurry of U.S. officials' memos it inspired. However, his reaction also seems to suggest that he had received further information from other sources (the payload of the V-3 was a nuclear weapon, the German nuclear weapons program was way ahead of the U.S. program, etc.). What sources provided the most detailed and accurate information on the true state of the German programs to Roosevelt—Dutch intelligence, French intelligence, Eisenhower's Special Force Headquarters, etc.? Can any remaining classified files that are relevant be located, declassified, and released?]



Franklin D. Roosevelt Library, Hyde Park, NY.
Margaret L. Suckley Papers. Journal Group E. JE 208. 9 Dec. 1944.

flying off — He may be the one we have heard but not seen —

The day was much like other days except that the mail plane was grounded by the weather at Greenville S.C. & the pouch came on by rail & so didn't get here until after noon, so the routine was a little upset — After lunch, the Pres. took us for an open air drive in a n-w direction. Going, we were on the dirt road, & going slowly — so one could enjoy the air & sun; but returning, we went down the concrete & it was almost too cold. A quiet evening by the fire. I think the Pres. looks a little better but he needs a lot of quiet and sun. Just one week more.

He ~~spoke~~ ~~very~~ seriously at dinner about the German menace. He has just had a secret report from a German source which has been quite reliable in the past, to the effect that the Germans have a V3 bomb which will kill by concussion everything within a mile. They are planning to use it on New York for morale purposes — again, not seeming to realize that it will have the exact opposite effect to that which they expect. The entire Atlantic seaboard has relaxed all its dim-outs and air-raid precautions, etc. & the Pres. sent word to the Gen. Staff that all previous preparations of that sort should be revived on the chance that the report about the V3 may be true. He said that in the next war, the side which first uses these new explosives will undoubtedly win. The Germans are way ahead of us in that direction, though we are doing a lot of research trying to catch up to them. We found one of their V1 robots unexploded & are improving on it. How unbelievably horrible it all is. (In those mysterious books & reports about "Shangri-La" in the Himalaya Mts, it is all prophesied.) I keep wondering if they may not be entirely true, those reports, and that the human race is out to destroy itself. Only the few who live in isolated places may survive —

Dec. 10 Saturday. A beautiful day, and Polly has to leave tomorrow. She is such a vital person, so alive and attractive, we will miss her terribly — I think the holiday here, has done her a great deal of good, in forcing her to be quiet at times. This is such a lovely place, on the hillside, with

Figure D.790: 1944 diary of Margaret Suckley, personal secretary of Franklin Roosevelt [Franklin Delano Roosevelt Library, Hyde Park, New York, Margaret Suckley Papers, Journal Group E, 06/30/1944-12/29/1944, Journal Entry 1-253, 9 December 1944].

Enemy Production of Atomic Bombs—Summary, Third Draft. 11 December 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)]

1. Intelligence indicates that the enemy is working in the project field. It is likely that he has undertaken one or several of the various processes for the production of bombs on a small scale and to have organized an installation equivalent to our project on final utilization. (TAB A).

2. The various methods for the production of U-233, U-235 and Pu-239 have been considered in the light of scientific development, basic materials, and industrial effort required. (TAB B). The liquid thermal diffusion process for production of U-235 on a moderate scale and the pile process using heavy water for the production of Pu-239 on a small scale appear to be the most likely possibilities; the production of U-233 on a useful scale appears to be unlikely. Activities inferred from the intelligence and other reports indicate that these processes could have come into operation during 1943. (TAB C).

3. On the basis of the above analysis it is possible for the enemy to have at least one device in his hands now, but it is improbable for him to have more than three.

[Handwritten in lower right corner:] Cross referenced in Enemy Prod.[uction] of Devices—G[roves?]

[...] TAB A: In the review of this file this item was removed because access to it is restricted.

[What specific information was in Tab A? Can that part of the document be declassified?]

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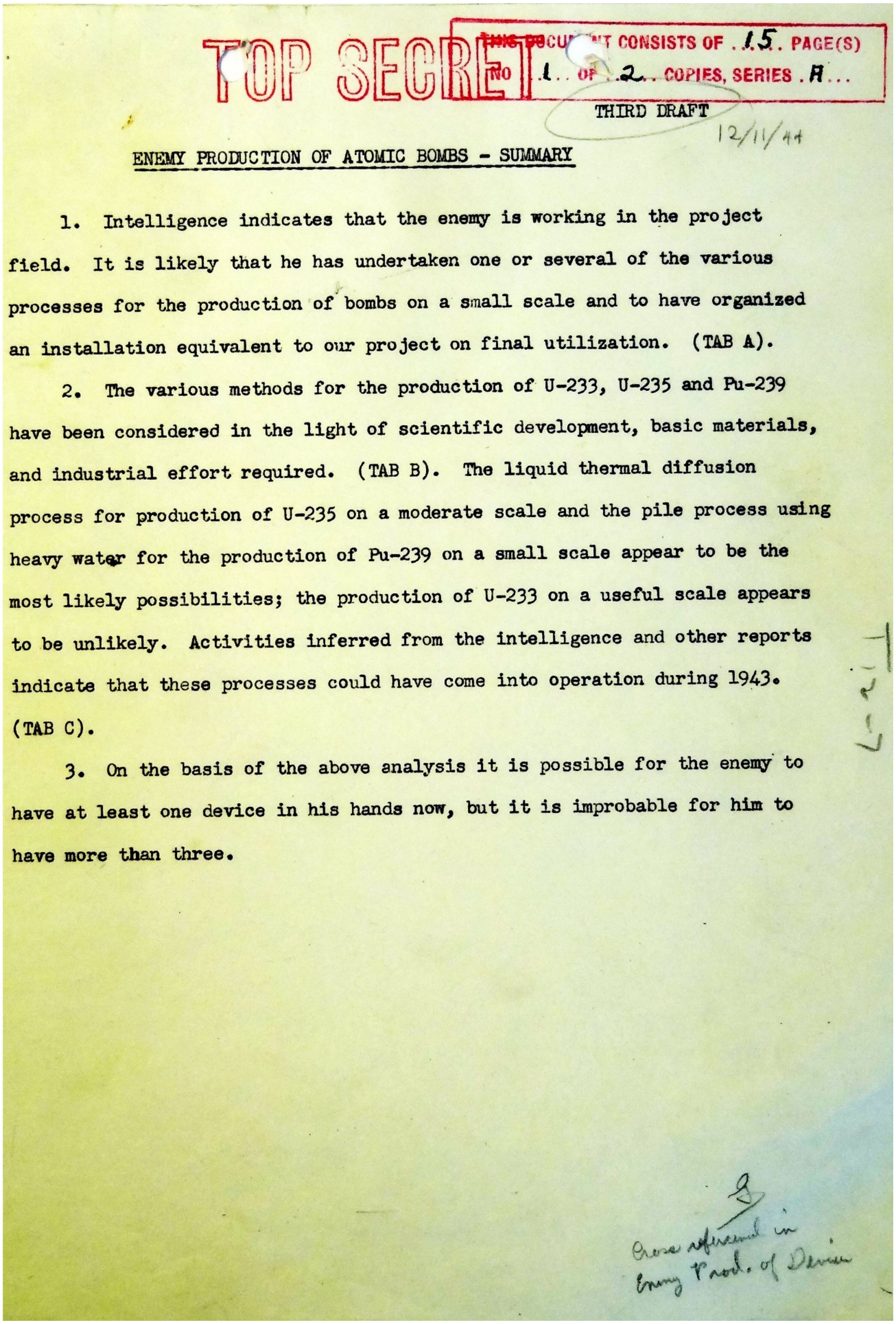

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THIS DOCUMENT CONSISTS OF 15 PAGE(S)
NO 1 OF 2 COPIES, SERIES A

THIRD DRAFT

12/11/44

ENEMY PRODUCTION OF ATOMIC BOMBS - SUMMARY

1. Intelligence indicates that the enemy is working in the project field. It is likely that he has undertaken one or several of the various processes for the production of bombs on a small scale and to have organized an installation equivalent to our project on final utilization. (TAB A).

2. The various methods for the production of U-233, U-235 and Pu-239 have been considered in the light of scientific development, basic materials, and industrial effort required. (TAB B). The liquid thermal diffusion process for production of U-235 on a moderate scale and the pile process using heavy water for the production of Pu-239 on a small scale appear to be the most likely possibilities; the production of U-233 on a useful scale appears to be unlikely. Activities inferred from the intelligence and other reports indicate that these processes could have come into operation during 1943. (TAB C).

3. On the basis of the above analysis it is possible for the enemy to have at least one device in his hands now, but it is improbable for him to have more than three.

Cross referenced in
Enemy Prod. of Device

NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945-1946)

Figure D.791: Enemy Production of Atomic Bombs—Summary, Third Draft. 11 December 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

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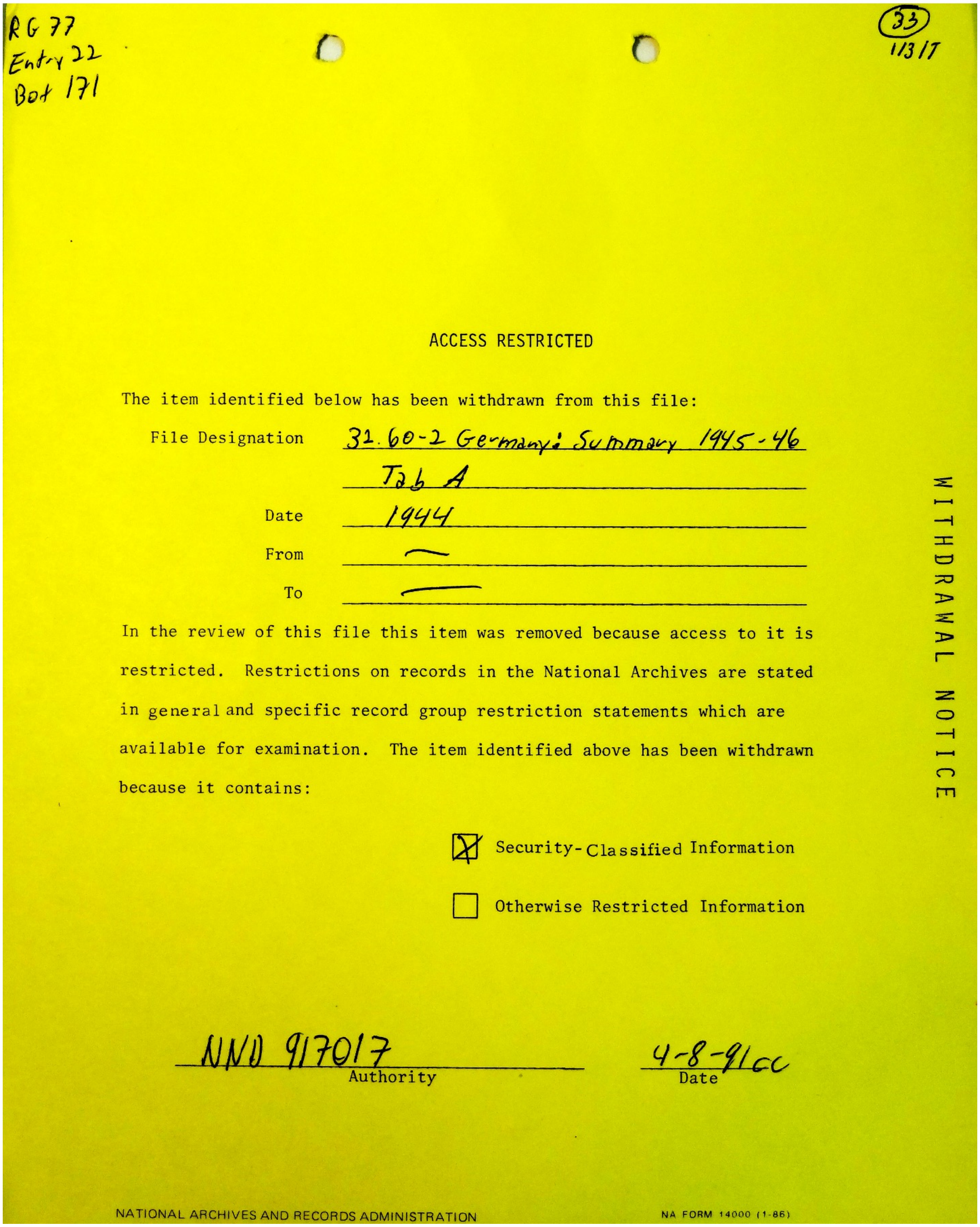
NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945-1946)



RG 77
Entry 22
Box 171

33
1/3/17

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File Designation 32.60-2 Germany: Summary 1945-46
Tab A

Date 1944

From —

To —

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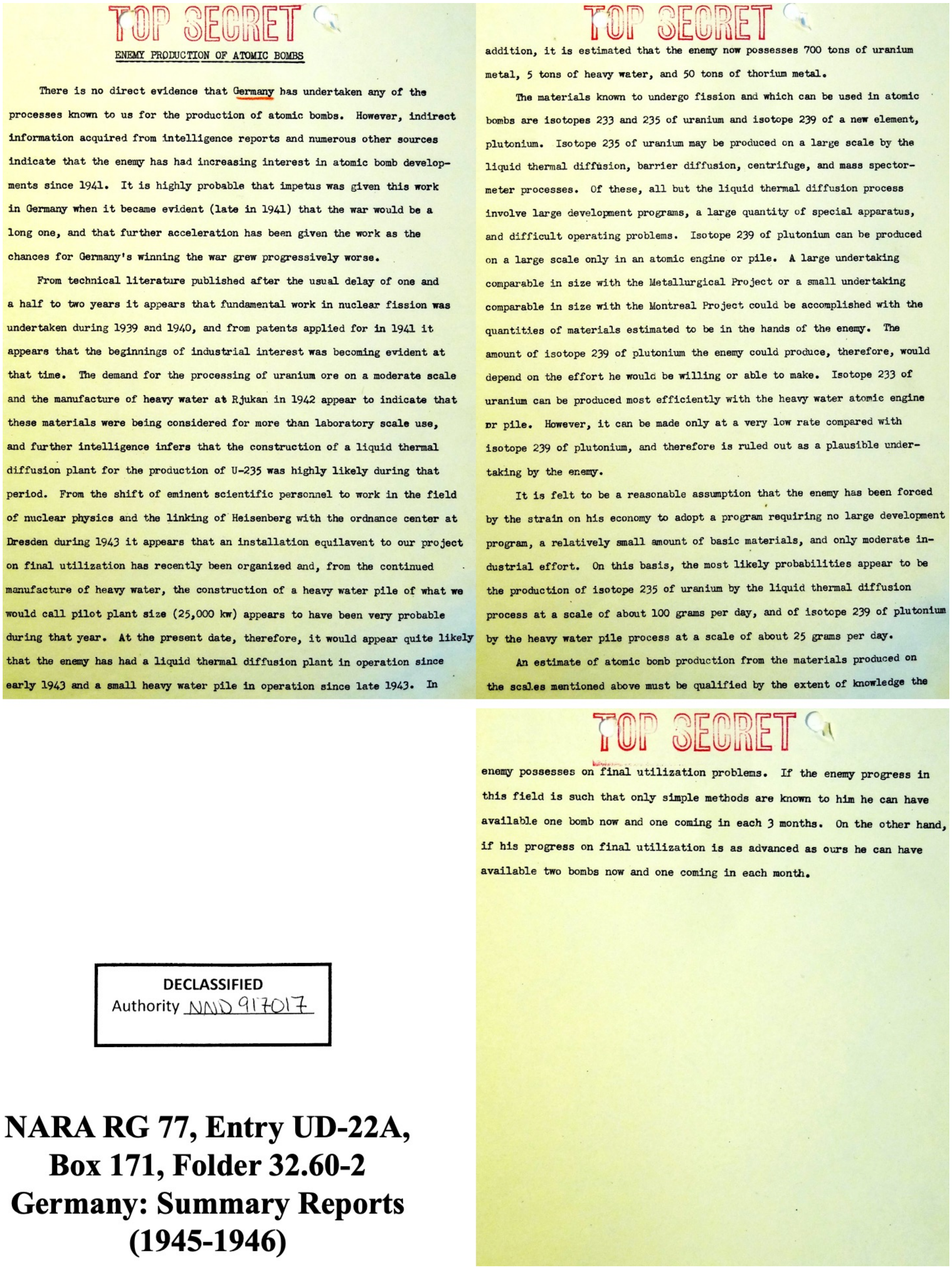
Date

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

Figure D.792: Enemy Production of Atomic Bombs. 11 December 1944. TAB A, which the report summary said contained intelligence showing that Germany was likely producing atomic bombs, remains classified and unavailable [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



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ENEMY PRODUCTION OF ATOMIC BOMBS

There is no direct evidence that Germany has undertaken any of the processes known to us for the production of atomic bombs. However, indirect information acquired from intelligence reports and numerous other sources indicate that the enemy has had increasing interest in atomic bomb developments since 1941. It is highly probable that impetus was given this work in Germany when it became evident (late in 1941) that the war would be a long one, and that further acceleration has been given the work as the chances for Germany's winning the war grew progressively worse.

From technical literature published after the usual delay of one and a half to two years it appears that fundamental work in nuclear fission was undertaken during 1939 and 1940, and from patents applied for in 1941 it appears that the beginnings of industrial interest was becoming evident at that time. The demand for the processing of uranium ore on a moderate scale and the manufacture of heavy water at Rjukan in 1942 appear to indicate that these materials were being considered for more than laboratory scale use, and further intelligence infers that the construction of a liquid thermal diffusion plant for the production of U-235 was highly likely during that period. From the shift of eminent scientific personnel to work in the field of nuclear physics and the linking of Heisenberg with the ordnance center at Dresden during 1943 it appears that an installation equilavent to our project on final utilization has recently been organized and, from the continued manufacture of heavy water, the construction of a heavy water pile of what we would call pilot plant size (25,000 kw) appears to have been very probable during that year. At the present date, therefore, it would appear quite likely that the enemy has had a liquid thermal diffusion plant in operation since early 1943 and a small heavy water pile in operation since late 1943. In

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addition, it is estimated that the enemy now possesses 700 tons of uranium metal, 5 tons of heavy water, and 50 tons of thorium metal.

The materials known to undergo fission and which can be used in atomic bombs are isotopes 233 and 235 of uranium and isotope 239 of a new element, plutonium. Isotope 235 of uranium may be produced on a large scale by the liquid thermal diffusion, barrier diffusion, centrifuge, and mass spectormeter processes. Of these, all but the liquid thermal diffusion process involve large development programs, a large quantity of special apparatus, and difficult operating problems. Isotope 239 of plutonium can be produced on a large scale only in an atomic engine or pile. A large undertaking comparable in size with the Metallurgical Project or a small undertaking comparable in size with the Montreal Project could be accomplished with the quantities of materials estimated to be in the hands of the enemy. The amount of isotope 239 of plutonium the enemy could produce, therefore, would depend on the effort he would be willing or able to make. Isotope 233 of uranium can be produced most efficiently with the heavy water atomic engine or pile. However, it can be made only at a very low rate compared with isotope 239 of plutonium, and therefore is ruled out as a plausible undertaking by the enemy.

It is felt to be a reasonable assumption that the enemy has been forced by the strain on his economy to adopt a program requiring no large development program, a relatively small amount of basic materials, and only moderate industrial effort. On this basis, the most likely probabilities appear to be the production of isotope 235 of uranium by the liquid thermal diffusion process at a scale of about 100 grams per day, and of isotope 239 of plutonium by the heavy water pile process at a scale of about 25 grams per day.

An estimate of atomic bomb production from the materials produced on the scales mentioned above must be qualified by the extent of knowledge the

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enemy possesses on final utilization problems. If the enemy progress in this field is such that only simple methods are known to him he can have available one bomb now and one coming in each 3 months. On the other hand, if his progress on final utilization is as advanced as ours he can have available two bombs now and one coming in each month.

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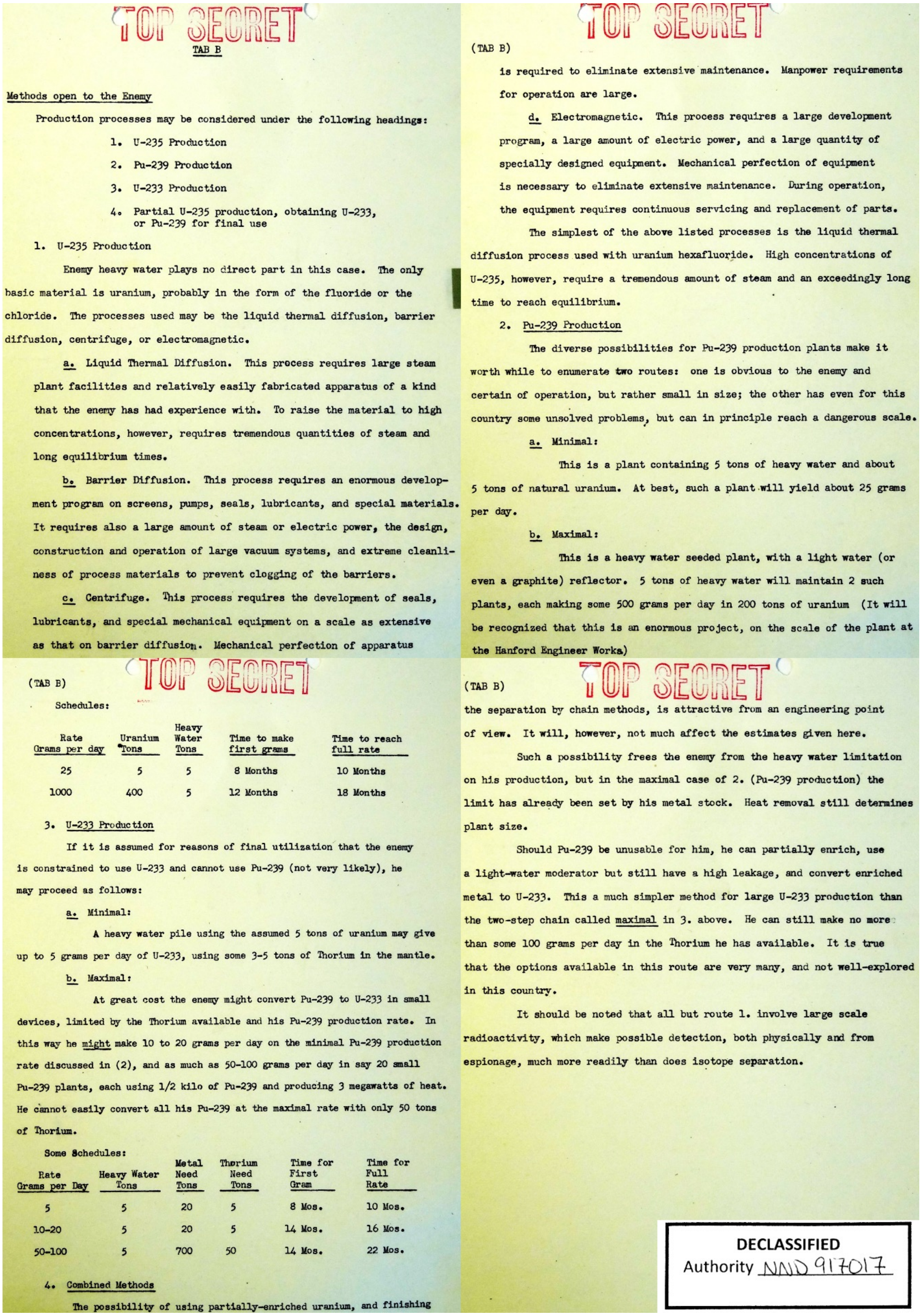
NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945-1946)

Figure D.793: Enemy Production of Atomic Bombs. 11 December 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945-1946)



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TAB B

Methods open to the Enemy

Production processes may be considered under the following headings:

1. U-235 Production
2. Pu-239 Production
3. U-233 Production
4. Partial U-235 production, obtaining U-233, or Pu-239 for final use

1. U-235 Production

Enemy heavy water plays no direct part in this case. The only basic material is uranium, probably in the form of the fluoride or the chloride. The processes used may be the liquid thermal diffusion, barrier diffusion, centrifuge, or electromagnetic.

a. Liquid Thermal Diffusion. This process requires large steam plant facilities and relatively easily fabricated apparatus of a kind that the enemy has had experience with. To raise the material to high concentrations, however, requires tremendous quantities of steam and long equilibrium times.

b. Barrier Diffusion. This process requires an enormous development program on screens, pumps, seals, lubricants, and special materials. It requires also a large amount of steam or electric power, the design, construction and operation of large vacuum systems, and extreme cleanliness of process materials to prevent clogging of the barriers.

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(TAB B)

c. Centrifuge. This process requires the development of seals, lubricants, and special mechanical equipment on a scale as extensive as that on barrier diffusion. Mechanical perfection of apparatus is required to eliminate extensive maintenance. Manpower requirements for operation are large.

d. Electromagnetic. This process requires a large development program, a large amount of electric power, and a large quantity of specially designed equipment. Mechanical perfection of equipment is necessary to eliminate extensive maintenance. During operation, the equipment requires continuous servicing and replacement of parts.

The simplest of the above listed processes is the liquid thermal diffusion process used with uranium hexafluoride. High concentrations of U-235, however, require a tremendous amount of steam and an exceedingly long time to reach equilibrium.

2. Pu-239 Production

The diverse possibilities for Pu-239 production plants make it worth while to enumerate two routes: one is obvious to the enemy and certain of operation, but rather small in size; the other has even for this country some unsolved problems, but can in principle reach a dangerous scale.

a. Minimal:

This is a plant containing 5 tons of heavy water and about 5 tons of natural uranium. At best, such a plant will yield about 25 grams per day.

b. Maximal:

This is a heavy water seeded plant, with a light water (or even a graphite) reflector. 5 tons of heavy water will maintain 2 such plants, each making some 500 grams per day in 200 tons of uranium (It will be recognized that this is an enormous project, on the scale of the plant at the Hanford Engineer Works)

TOP SECRET

(TAB B)

Schedules:

Rate Grams per day	Uranium Tons	Heavy Water Tons	Time to make first grams	Time to reach full rate
25	5	5	8 Months	10 Months
1000	400	5	12 Months	18 Months

3. U-233 Production

If it is assumed for reasons of final utilization that the enemy is constrained to use U-233 and cannot use Pu-239 (not very likely), he may proceed as follows:

a. Minimal:

A heavy water pile using the assumed 5 tons of uranium may give up to 5 grams per day of U-233, using some 3-5 tons of Thorium in the mantle.

b. Maximal:

At great cost the enemy might convert Pu-239 to U-233 in small devices, limited by the Thorium available and his Pu-239 production rate. In this way he might make 10 to 20 grams per day on the minimal Pu-239 production rate discussed in (2), and as much as 50-100 grams per day in say 20 small Pu-239 plants, each using 1/2 kilo of Pu-239 and producing 3 megawatts of heat. He cannot easily convert all his Pu-239 at the maximal rate with only 50 tons of Thorium.

Some Schedules:

Rate Grams per Day	Heavy Water Tons	Metal Need Tons	Thorium Need Tons	Time for First Gram	Time for Full Rate
5	5	20	5	8 Mos.	10 Mos.
10-20	5	20	5	14 Mos.	16 Mos.
50-100	5	700	50	14 Mos.	22 Mos.

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(TAB B)

4. Combined Methods

The possibility of using partially-enriched uranium, and finishing the separation by chain methods, is attractive from an engineering point of view. It will, however, not much affect the estimates given here.

Such a possibility frees the enemy from the heavy water limitation on his production, but in the maximal case of 2. (Pu-239 production) the limit has already been set by his metal stock. Heat removal still determines plant size.

Should Pu-239 be unusable for him, he can partially enrich, use a light-water moderator but still have a high leakage, and convert enriched metal to U-233. This a much simpler method for large U-233 production than the two-step chain called maximal in 3. above. He can still make no more than some 100 grams per day in the Thorium he has available. It is true that the options available in this route are very many, and not well-explored in this country.

It should be noted that all but route 1. involve large scale radioactivity, which make possible detection, both physically and from espionage, much more readily than does isotope separation.

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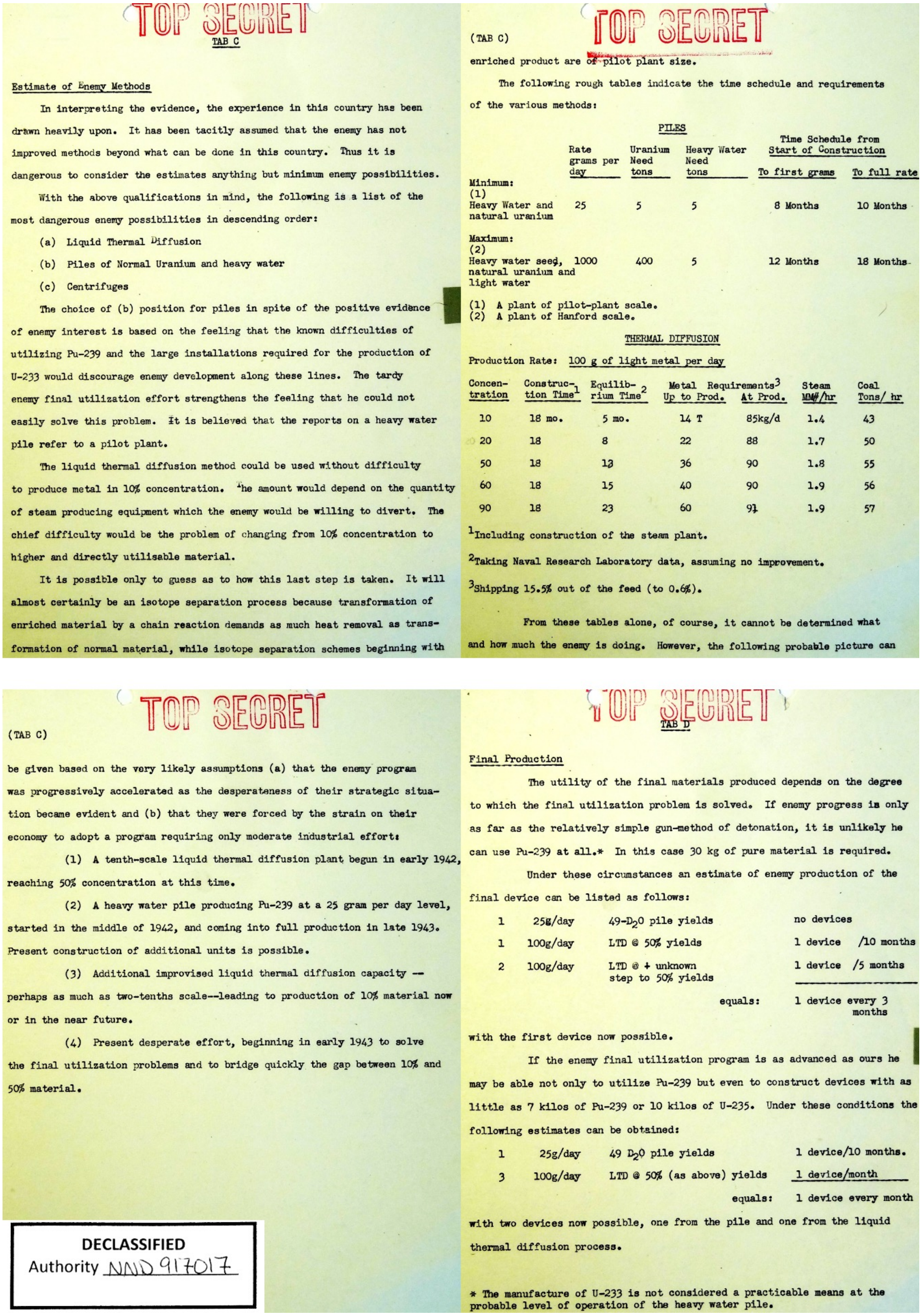
Figure D.794: Enemy Production of Atomic Bombs. 11 December 1944. TAB B [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945-1946)



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TAB C

Estimate of Enemy Methods

In interpreting the evidence, the experience in this country has been drawn heavily upon. It has been tacitly assumed that the enemy has not improved methods beyond what can be done in this country. Thus it is dangerous to consider the estimates anything but minimum enemy possibilities.

With the above qualifications in mind, the following is a list of the most dangerous enemy possibilities in descending order:

(a) Liquid Thermal Diffusion

(b) Piles of Normal Uranium and heavy water

(c) Centrifuges

The choice of (b) position for piles in spite of the positive evidence of enemy interest is based on the feeling that the known difficulties of utilizing Pu-239 and the large installations required for the production of U-233 would discourage enemy development along these lines. The tardy enemy final utilization effort strengthens the feeling that he could not easily solve this problem. It is believed that the reports on a heavy water pile refer to a pilot plant.

The liquid thermal diffusion method could be used without difficulty to produce metal in 10% concentration. The amount would depend on the quantity of steam producing equipment which the enemy would be willing to divert. The chief difficulty would be the problem of changing from 10% concentration to higher and directly utilisable material.

TOP SECRET

(TAB C)

It is possible only to guess as to how this last step is taken. It will almost certainly be an isotope separation process because transformation of enriched material by a chain reaction demands as much heat removal as transformation of normal material, while isotope separation schemes beginning with enriched product are of pilot plant size.

The following rough tables indicate the time schedule and requirements of the various methods:

PILES

	Rate grams per day	Uranium Need tons	Heavy Water Need tons	Time Schedule from Start of Construction	
				To first grams	To full rate
Minimum: (1) Heavy Water and natural uranium	25	5	5	8 Months	10 Months
Maximum: (2) Heavy water seed, natural uranium and light water	1000	400	5	12 Months	18 Months

(1) A plant of pilot-plant scale.
(2) A plant of Hanford scale.

THERMAL DIFFUSION

Production Rate: 100 g of light metal per day

Concentration	Construction Time[1]	Equilibrium Time[2]	Metal Requirements[3]		Steam MM#/hr	Coal Tons/ hr
			Up to Prod.	At Prod.		
10	18 mo.	5 mo.	14 T	85kg/d	1.4	43
20	18	8	22	88	1.7	50
50	18	13	36	90	1.8	55
60	18	15	40	90	1.9	56
90	18	23	60	91	1.9	57

[1] Including construction of the steam plant.

[2] Taking Naval Research Laboratory data, assuming no improvement.

[3] Shipping 15.5% out of the feed (to 0.6%).

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(TAB C)

From these tables alone, of course, it cannot be determined what and how much the enemy is doing. However, the following probable picture can be given based on the very likely assumptions (a) that the enemy program was progressively accelerated as the desperateness of their strategic situation became evident and (b) that they were forced by the strain on their economy to adopt a program requiring only moderate industrial effort:

(1) A tenth-scale liquid thermal diffusion plant begun in early 1942, reaching 50% concentration at this time.

(2) A heavy water pile producing Pu-239 at a 25 gram per day level, started in the middle of 1942, and coming into full production in late 1943. Present construction of additional units is possible.

(3) Additional improvised liquid thermal diffusion capacity -- perhaps as much as two-tenths scale--leading to production of 10% material now or in the near future.

(4) Present desperate effort, beginning in early 1943 to solve the final utilization problems and to bridge quickly the gap between 10% and 50% material.

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TAB D

Final Production

The utility of the final materials produced depends on the degree to which the final utilization problem is solved. If enemy progress is only as far as the relatively simple gun-method of detonation, it is unlikely he can use Pu-239 at all.* In this case 30 kg of pure material is required.

Under these circumstances an estimate of enemy production of the final device can be listed as follows:

1	25g/day	49-D_2O pile yields	no devices
1	100g/day	LTD @ 50% yields	1 device /10 months
2	100g/day	LTD @ + unknown step to 50% yields	1 device /5 months
		equals:	1 device every 3 months

with the first device now possible.

If the enemy final utilization program is as advanced as ours he may be able not only to utilize Pu-239 but even to construct devices with as little as 7 kilos of Pu-239 or 10 kilos of U-235. Under these conditions the following estimates can be obtained:

1	25g/day	49 D_2O pile yields	1 device/10 months.
3	100g/day	LTD @ 50% (as above) yields	1 device/month
		equals:	1 device every month

with two devices now possible, one from the pile and one from the liquid thermal diffusion process.

---

* The manufacture of U-233 is not considered a practicable means at the probable level of operation of the heavy water pile.

Figure D.795: Enemy Production of Atomic Bombs. 11 December 1944. TAB C and TAB D [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

AFHRA 142.0423-13, Folder Jet-Propelled Aircraft—Top Secret Excerpts [AFHRA electronic version pp. 1103–1120].

[The following series of memos was apparently initiated by two of the earlier intelligence reports, George Earle's 5 December 1944 report (p. 4701) and J. Edgar Hoover's 8 December 1944 letter (p. 4605), although neither of those reports is included on this microfilm reel.]

Headquarters of the Army Air Forces to Assistant Chief of Staff, G-2, WDGS. 12 December 1944. Subject: Evaluation of Reports of Very Long Range Secret German Weapons Capable of Devastating a Large Area.

1. Based on Allied scientific research and developments, the Germans may have the capability of developing and using a devastating explosive or force.

2. At the present time, rockets are not capable of 2,000 to 3,000 mile flight, and no such development ~~can~~ should be expected in the near future.

3. It is possible that larger rockets with longer range or heavier war-heads than those presently employed are in the course of development by the Germans, and that actual experiments have been conducted with larger rockets.

4. No specific information has been received by A-2 on the existence of any long range German rockets other than V-1 and V-2.

5. The Germans have the capability of launching from a submarine a V-1, a V-2 or a modified version of either.

1. Incl:
Memo for AC/AS, Intelligence fr G-2 dtd 9 November [sic: December] w/2 reports.

W.M.B. to Operational Deputy. 12 December 1944. Subject: Evaluation of German Guided Missiles Reports Requested by G-2.

1. General Hodges is not satisfied with the draft evaluation of reports as requested by G-2. You may wish to assign someone else to it. There follows a rough outline of the approach general Hodges believes desirable.

2. The evaluation should start off with a list of the more important evidence available to us on the existence of some weapon above and beyond the V-1 and V-2. Such things as, to date unexplained sites, such as Watten—prisoner of war reports which have mentioned the existence of vengeance weapons on a vaster scale—newspaper reports. Specific tonnages, speeds, accuracy, etc. including proposed targets of these rumored weapons, should be given. [...]

What is the least amount of presently known explosive which would "level" an area 40 square kilometers? [...]

3. The complete facilities of the Air Staff should be used in gathering evidence for this—Requirements Division, OC&R, General Gross—Dr. Bowles' office—electronics experts—ordnance, et al should be freely consulted. [...]

Memorandum for [blank.] 14 December 1944. Subject: Evaluation Report on New German Guided Missiles.

1. On 9 December 1944, AC of S, G-2 forwarded to AC/AS, Intelligence copies of reports recently received from U.S. Naval Attaché in Turkey and the Federal Bureau of Investigation with a request for evaluation. Subject reports dealt with range, destructiveness and expected date of employment of some new type (V-3, V-4 or V-5) German rocket bomb.

2. Copy of memorandum prepared in response to above request is attached.

3. Brief of memorandum prepared for your information is also attached.

2 Incl.
Incl. 1. Memo to AC of S, G-2
Incl. 2. Brief of Memo to AC of S, G-2

Memorandum for —. 14 December. Subject: Evaluation of Two Reports on New German Guided Missiles.

1. Reports forwarded by Colonel Moses contain information which has been received before from a scattering of OSS, Underground[,] PW interrogations and German propaganda sources. While they add somewhat to available knowledge, they are not to be interpreted as of immediate a significance. [...]

2. An analysis of the intelligence reports and propaganda now being received on V-3 as compared with those which preceded the appearance of V-1 and V-2 suggests very strongly that German efforts are undoubtedly now being devoted to the production of new rocket bombs which will exceed V-1 and V-2 in range or destructive power. However, it is not believed that sufficient progress has been made to make the V-3 or any other new rocket bomb an immediate threat. [...]

11. Capabilities Based on Scientific Information

a. A rocket or a bomb causing devastation to an area of 40 square kilometers would have to be some explosive force such as atomic energy since known explosives are not capable of such effects unless used in excessive quantities.

To devastate a typical British or German area of 40 square kilometers the following amounts of explosive would be required:

Single charge: TNT: 650,000,000 lbs. [...] [approximately 300 kilotons]

b. German capability of putting into use a long range rocket capable of 2,000 and 3,000 mile flight needs to be carefully analyzed by scientists such as Dr. von Kármán. [...]

14 December 1944. Brief of Memorandum Evaluating Two Reports on New German Guided Missiles.

1. Reports supplied by Naval Attaché in Turkey and FBI are not new and have no immediate significance.

2. Reports on V-3, when compared with the flow of intelligence and propaganda on V-1 and V-2, suggest that any improvements on these weapons are in an experimental stage only.

3. [...] It must be concluded that if the Germans were about to employ any such weapon they would now be flooding the Reich with definite claims. Their failure to do so is significant.

4. Based on the capabilities of known explosives a charge of prohibitive size (approximately a half billion pounds) would be required to devastate 40 square kilometers of built-up area. Some other explosive force such as atomic energy might be employed in considerably smaller quantities, if available. [...] At the present time rockets are not capable of such a 2,000 to 3,000 mile flight, but experimentation may ultimately produce such a rocket.

5. While no specific information has been received by A-2 on the existence of any new long range rocket, it is possible that the Germans are now conducting experiments with rockets having longer range and heavier warheads than V-1 or V-2.

[U.S. intelligence analysts estimated that an explosive yield of approximately 300 kilotons would be required to destroy an area of 40 square kilometers, as the German weapon was reported to be capable of doing. That suggests that the weapon was some sort of fusion-boosted fission bomb or hydrogen bomb (Section D.9), instead of a much simpler and smaller fission bomb.

In view of evidence such as that presented in Appendix E, the intelligence analysts appear to have been too hasty in assuming that intercontinental rockets could not have reached an advanced stage of development in Germany at that time.]

D.14.2 Alsos and Other Manhattan Project Intelligence

[A large number of Alsos-related documents from Samuel Goudsmit's files remain classified, as illustrated by some examples on pp. 4772–4779 [NARA RG GOUDS, Entry UD-7420].

Some very important Alsos-related files from the Manhattan Project's Foreign Intelligence Unit also remain classified and unavailable, as shown by the examples on pp. 4812–4827.

Where is George Eckman's missing December 1945 final report on the Alsos Mission (p. 3333)?

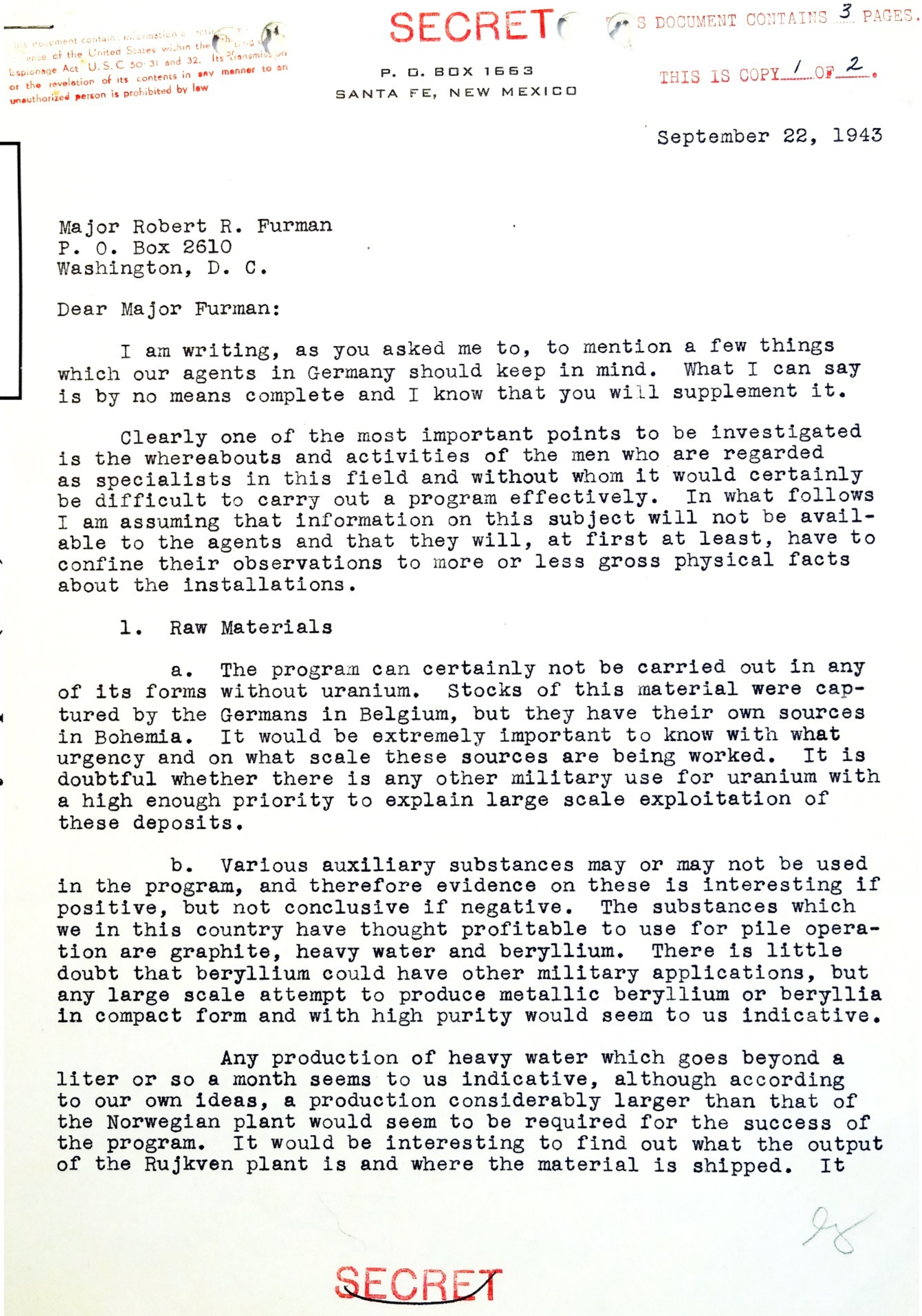
There are many proven or likely cases of Leslie Groves or his office censoring and reprimanding independent investigators who uncovered evidence that the German nuclear weapons program was more advanced than had been publicly admitted. See for example:

- Trying (and failing) to keep German nuclear documents out of the hands of other groups of Allied investigators (p. 3287).
- Dr. Richard P. Fischer (p. 3948).
- Caperton Horseley (p. 3970).
- Charles Chamberlain (pp. 4056–4061).
- "An alert and inquisitive reporter" for *Time* magazine (p. 4185).
- Colonel John A. Keck (p. 4187).
- Gordon Young (pp. 4679–4681).
- Commander Herbert Agar (pp. 5017–5018).
- Fritz Lang (pp. 5076–5081).
- Captain Heinz Stoelzel (pp. 5393–5396).

Can more information about these cases of censorship be uncovered? Can other cases of Allied censorship regarding the German program be identified?

Are there other files on the German nuclear program that remain classified, without even a yellow withdrawal notice card to mark where they should be in the NARA files?

Can all of these files be declassified?]



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THIS IS COPY 1 OF 2.

P. O. BOX 1663
SANTA FE, NEW MEXICO

DECLASSIFIED
Authority NND917017

September 22, 1943

Major Robert R. Furman
P. O. Box 2610
Washington, D. C.

Dear Major Furman:

I am writing, as you asked me to, to mention a few things which our agents in Germany should keep in mind. What I can say is by no means complete and I know that you will supplement it.

Clearly one of the most important points to be investigated is the whereabouts and activities of the men who are regarded as specialists in this field and without whom it would certainly be difficult to carry out a program effectively. In what follows I am assuming that information on this subject will not be available to the agents and that they will, at first at least, have to confine their observations to more or less gross physical facts about the installations.

1. Raw Materials

a. The program can certainly not be carried out in any of its forms without uranium. Stocks of this material were captured by the Germans in Belgium, but they have their own sources in Bohemia. It would be extremely important to know with what urgency and on what scale these sources are being worked. It is doubtful whether there is any other military use for uranium with a high enough priority to explain large scale exploitation of these deposits.

b. Various auxiliary substances may or may not be used in the program, and therefore evidence on these is interesting if positive, but not conclusive if negative. The substances which we in this country have thought profitable to use for pile operation are graphite, heavy water and beryllium. There is little doubt that beryllium could have other military applications, but any large scale attempt to produce metallic beryllium or beryllia in compact form and with high purity would seem to us indicative.

Any production of heavy water which goes beyond a liter or so a month seems to us indicative, although according to our own ideas, a production considerably larger than that of the Norwegian plant would seem to be required for the success of the program. It would be interesting to find out what the output of the Rujkven plant is and where the material is shipped. It

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NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)

Figure D.796: J. Robert Oppenheimer to Robert Furman. 22 September 1943 [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

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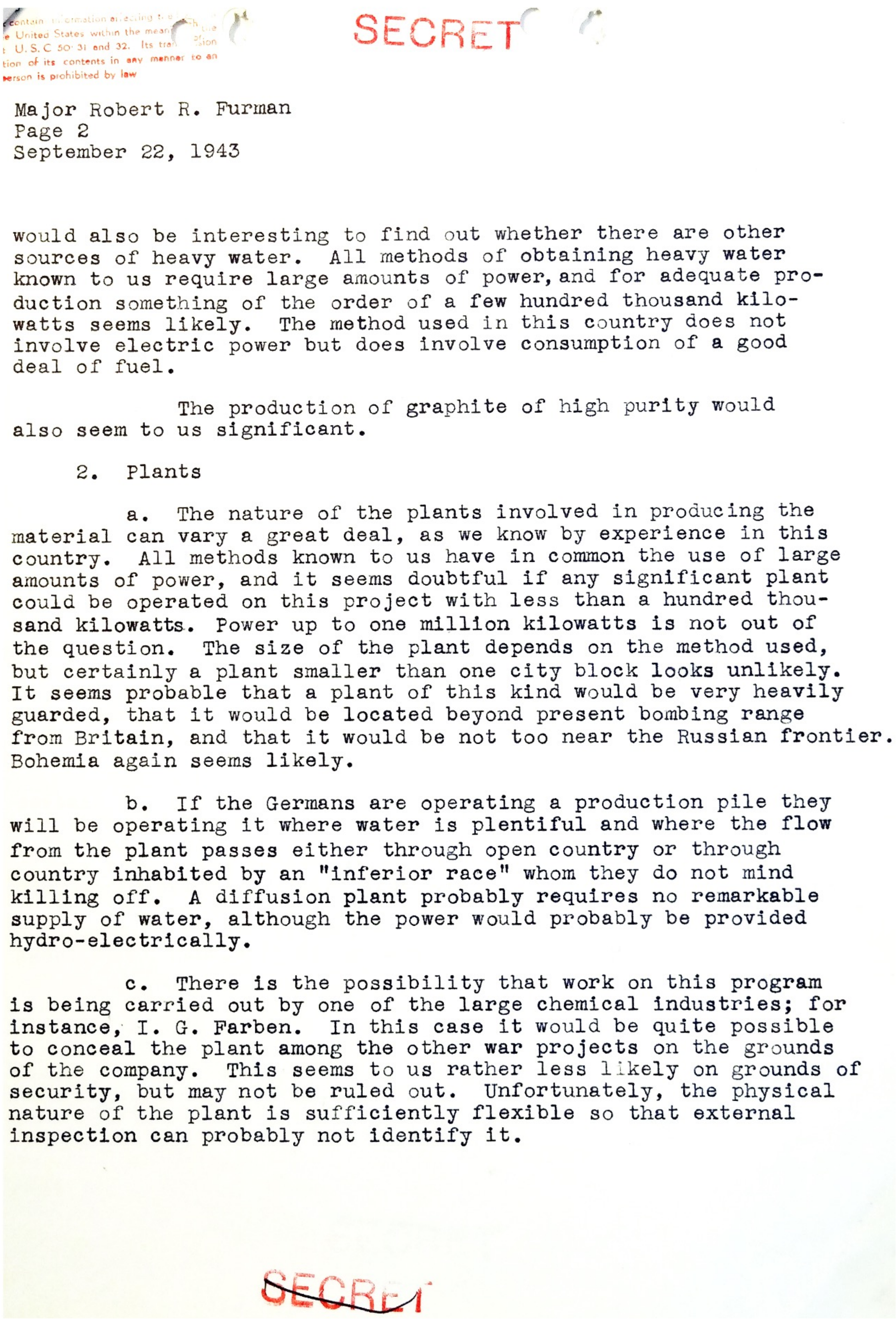

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Major Robert R. Furman
Page 2
September 22, 1943

would also be interesting to find out whether there are other sources of heavy water. All methods of obtaining heavy water known to us require large amounts of power, and for adequate production something of the order of a few hundred thousand kilowatts seems likely. The method used in this country does not involve electric power but does involve consumption of a good deal of fuel.

The production of graphite of high purity would also seem to us significant.

2. Plants

a. The nature of the plants involved in producing the material can vary a great deal, as we know by experience in this country. All methods known to us have in common the use of large amounts of power, and it seems doubtful if any significant plant could be operated on this project with less than a hundred thousand kilowatts. Power up to one million kilowatts is not out of the question. The size of the plant depends on the method used, but certainly a plant smaller than one city block looks unlikely. It seems probable that a plant of this kind would be very heavily guarded, that it would be located beyond present bombing range from Britain, and that it would be not too near the Russian frontier. Bohemia again seems likely.

b. If the Germans are operating a production pile they will be operating it where water is plentiful and where the flow from the plant passes either through open country or through country inhabited by an "inferior race" whom they do not mind killing off. A diffusion plant probably requires no remarkable supply of water, although the power would probably be provided hydro-electrically.

c. There is the possibility that work on this program is being carried out by one of the large chemical industries; for instance, I. G. Farben. In this case it would be quite possible to conceal the plant among the other war projects on the grounds of the company. This seems to us rather less likely on grounds of security, but may not be ruled out. Unfortunately, the physical nature of the plant is sufficiently flexible so that external inspection can probably not identify it.

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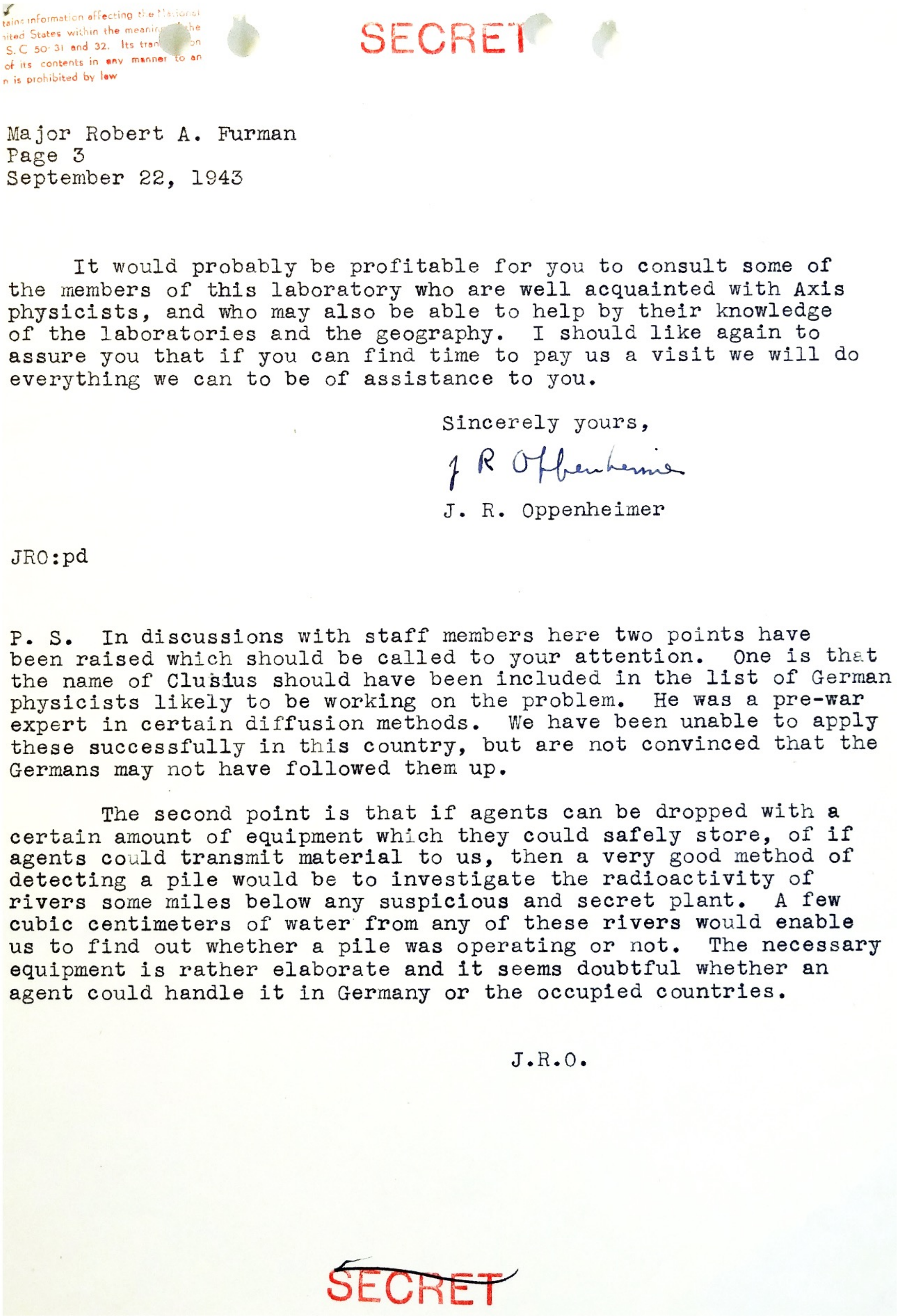
Figure D.797: J. Robert Oppenheimer to Robert Furman. 22 September 1943 [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].



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Major Robert A. Furman
Page 3
September 22, 1943

It would probably be profitable for you to consult some of the members of this laboratory who are well acquainted with Axis physicists, and who may also be able to help by their knowledge of the laboratories and the geography. I should like again to assure you that if you can find time to pay us a visit we will do everything we can to be of assistance to you.

Sincerely yours,

J R Oppenheimer

J. R. Oppenheimer

JRO:pd

P. S. In discussions with staff members here two points have been raised which should be called to your attention. One is that the name of Clusius should have been included in the list of German physicists likely to be working on the problem. He was a pre-war expert in certain diffusion methods. We have been unable to apply these successfully in this country, but are not convinced that the Germans may not have followed them up.

The second point is that if agents can be dropped with a certain amount of equipment which they could safely store, of if agents could transmit material to us, then a very good method of detecting a pile would be to investigate the radioactivity of rivers some miles below any suspicious and secret plant. A few cubic centimeters of water from any of these rivers would enable us to find out whether a pile was operating or not. The necessary equipment is rather elaborate and it seems doubtful whether an agent could handle it in Germany or the occupied countries.

J.R.O.

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NARA RG 77, Entry UD-22A, Box 170,
Folder 32.60-1 GERMANY: Summary Reports (1944)

Figure D.798: J. Robert Oppenheimer to Robert Furman. 22 September 1943 [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

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b. Various auxiliary substances may or may not be used in the program, and therefore evidence on these is interesting if positive, but not conclusive if negative. [See p. 4026.] The substances which we in this country have thought profitable to use for pile operation are graphite, heavy water and beryllium. There is little doubt that beryllium could have other military applications, but any large scale attempt to produce metallic beryllium or beryllia in compact form and with high purity would seem to us indicative. [See p. 4096.]

Any production of heavy water which goes beyond a liter or so a month seems to us indicative, although according to our own ideas, a production considerably larger than that of the Norwegian plant would seem to be required for the success of the program. It would be interesting to find out what the output of the Rujkven plant is and where the material is shipped. It would also be interesting to find out whether there are other sources of heavy water. [See p. 4027.] All methods of obtaining heavy water known to us require large amounts of power, and for adequate production something of the order of a few hundred thousand kilowatts seems likely. The method used in this country does not involve electric power but does involve consumption of a good deal of fuel.

The production of graphite of high purity would also seem to us significant. [See p. 4110.]

2. Plants

a. The nature of the plants involved in producing the material can vary a great deal, as we know by experience in this country. All methods known to us have in common the use of large amounts of power, and it seems doubtful if any significant plant could be operated on this project with less than a hundred thousand kilowatts. Power up to one million kilowatts is not out of the question. The size of the plant depends on the method used, but certainly a plant smaller than one city block looks unlikely. It seems probable that a plant of this kind would be very heavily guarded, that it would be located beyond present bombing range from Britain, and that it would be not too near the Russian frontier. Bohemia again seems likely. [See p. 2098.]

b. If the Germans are operating a production pile they will be operating it where water is plentiful and where the flow from the plant passes either through open country or through country inhabited by an “inferior race” whom they do not mind killing off. [See pp. 3874, 3928.] A diffusion plant probably requires no remarkable supply of water, although the power would probably be provided hydro-electrically. [See p. 3755.]

c. There is the possibility that work on this program is being carried out by one of the large chemical industries; for instance, I. G. Farben. In this case it would be quite possible to conceal the plant among the other war projects on the grounds of the company. [See pp. 2089, 3749, 3935, 4443.] This seems to us rather less likely on grounds of security, but may not be ruled out. Unfortunately, the physical nature of the plant is sufficiently flexible so that external inspection can probably not identify it.

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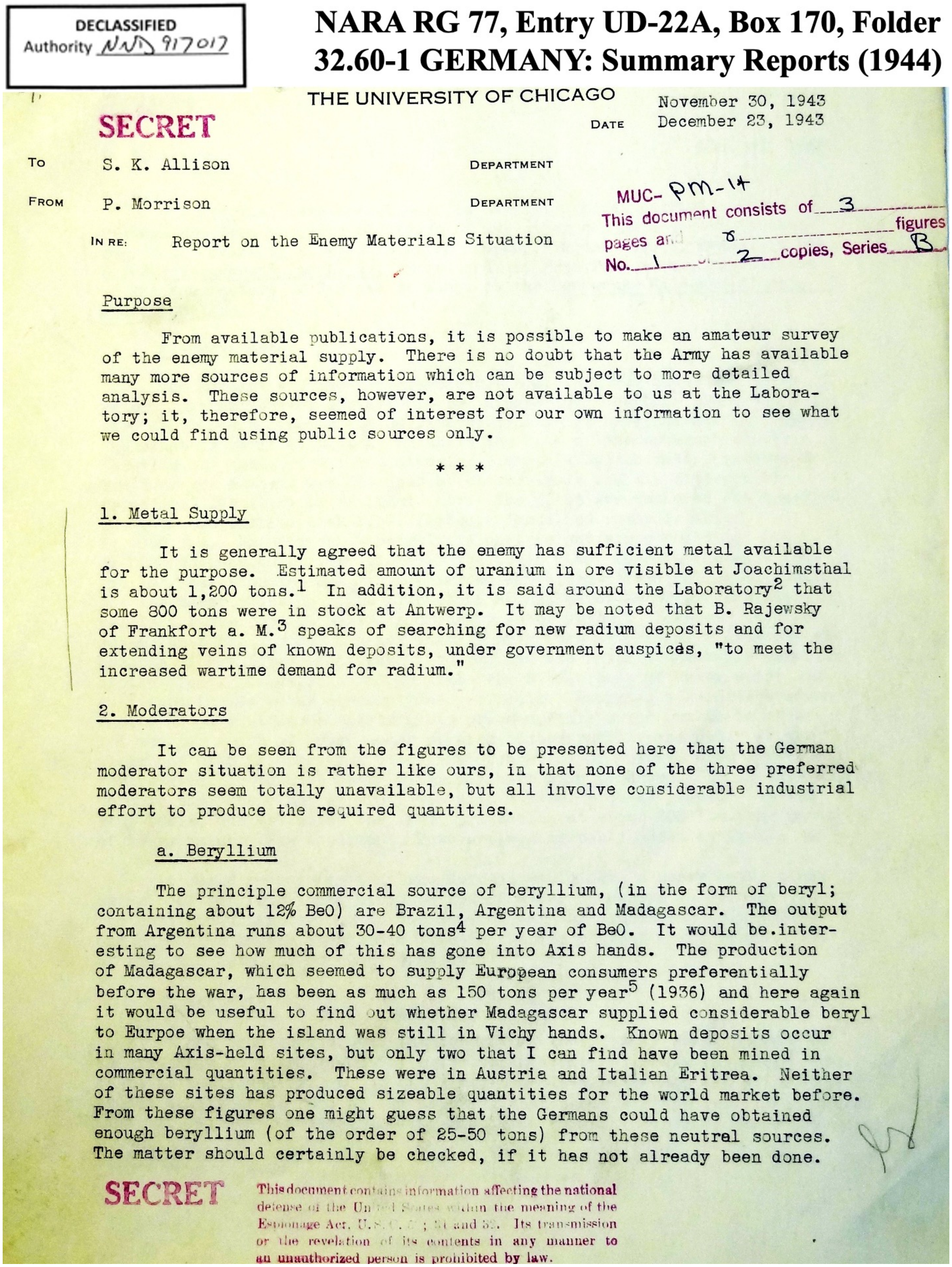
J.R.O.

[Where are all the wartime reports from the “agents in Germany”? Where are all the wartime and postwar Allied reports on any water, soil, air, or other samples that were collected and analyzed for signs of the German nuclear, chemical, or biological weapons programs? Can those be located and declassified?]



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NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)

THE UNIVERSITY OF CHICAGO

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DATE November 30, 1943
December 23, 1943

TO S. K. Allison DEPARTMENT

FROM P. Morrison DEPARTMENT

IN RE: Report on the Enemy Materials Situation

MUC- PM-14
This document consists of 3
pages and 0 figures
No. 1 of 2 copies, Series B

Purpose

From available publications, it is possible to make an amateur survey of the enemy material supply. There is no doubt that the Army has available many more sources of information which can be subject to more detailed analysis. These sources, however, are not available to us at the Laboratory; it, therefore, seemed of interest for our own information to see what we could find using public sources only.

* * *

1. Metal Supply

It is generally agreed that the enemy has sufficient metal available for the purpose. Estimated amount of uranium in ore visible at Joachimsthal is about 1,200 tons.[1] In addition, it is said around the Laboratory[2] that some 800 tons were in stock at Antwerp. It may be noted that B. Rajewsky of Frankfort a. M.[3] speaks of searching for new radium deposits and for extending veins of known deposits, under government auspices, "to meet the increased wartime demand for radium."

2. Moderators

It can be seen from the figures to be presented here that the German moderator situation is rather like ours, in that none of the three preferred moderators seem totally unavailable, but all involve considerable industrial effort to produce the required quantities.

a. Beryllium

The principle commercial source of beryllium, (in the form of beryl; containing about 12% BeO) are Brazil, Argentina and Madagascar. The output from Argentina runs about 30-40 tons[4] per year of BeO. It would be.interesting to see how much of this has gone into Axis hands. The production of Madagascar, which seemed to supply European consumers preferentially before the war, has been as much as 150 tons per year[5] (1936) and here again it would be useful to find out whether Madagascar supplied considerable beryl to Eurpoe when the island was still in Vichy hands. Known deposits occur in many Axis-held sites, but only two that I can find have been mined in commercial quantities. These were in Austria and Italian Eritrea. Neither of these sites has produced sizeable quantities for the world market before. From these figures one might guess that the Germans could have obtained enough beryllium (of the order of 25-50 tons) from these neutral sources. The matter should certainly be checked, if it has not already been done.

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This document contains information affecting the national defense of the United States within the meaning of the Espionage Act, U.S.C. 50; 31 and 32. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

Figure D.799: Philip Morrison to Samuel K. Allison. 30 November 1943. Report on Enemy Materials Situation. [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]
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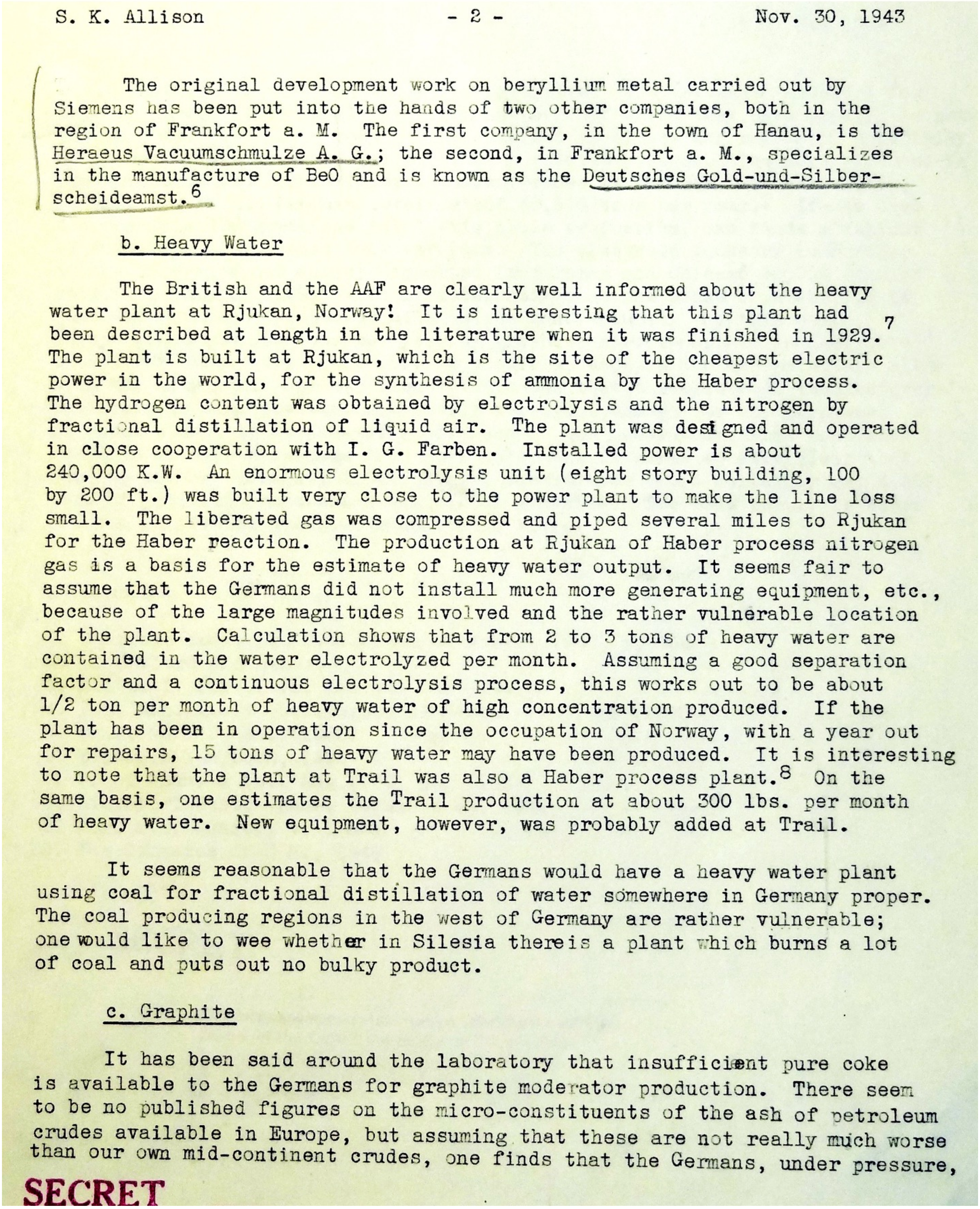

S. K. Allison - 2 - Nov. 30, 1943

The original development work on beryllium metal carried out by Siemens has been put into the hands of two other companies, both in the region of Frankfort a. M. The first company, in the town of Hanau, is the Heraeus Vacuumschmulze A. G.; the second, in Frankfort a. M., specializes in the manufacture of BeO and is known as the Deutsches Gold-und-Silber-scheideamst.[6]

b. Heavy Water

The British and the AAF are clearly well informed about the heavy water plant at Rjukan, Norway! It is interesting that this plant had been described at length in the literature when it was finished in 1929.[7] The plant is built at Rjukan, which is the site of the cheapest electric power in the world, for the synthesis of ammonia by the Haber process. The hydrogen content was obtained by electrolysis and the nitrogen by fractional distillation of liquid air. The plant was designed and operated in close cooperation with I. G. Farben. Installed power is about 240,000 K.W. An enormous electrolysis unit (eight story building, 100 by 200 ft.) was built very close to the power plant to make the line loss small. The liberated gas was compressed and piped several miles to Rjukan for the Haber reaction. The production at Rjukan of Haber process nitrogen gas is a basis for the estimate of heavy water output. It seems fair to assume that the Germans did not install much more generating equipment, etc., because of the large magnitudes involved and the rather vulnerable location of the plant. Calculation shows that from 2 to 3 tons of heavy water are contained in the water electrolyzed per month. Assuming a good separation factor and a continuous electrolysis process, this works out to be about 1/2 ton per month of heavy water of high concentration produced. If the plant has been in operation since the occupation of Norway, with a year out for repairs, 15 tons of heavy water may have been produced. It is interesting to note that the plant at Trail was also a Haber process plant.[8] On the same basis, one estimates the Trail production at about 300 lbs. per month of heavy water. New equipment, however, was probably added at Trail.

It seems reasonable that the Germans would have a heavy water plant using coal for fractional distillation of water somewhere in Germany proper. The coal producing regions in the west of Germany are rather vulnerable; one would like to wee whether in Silesia there is a plant which burns a lot of coal and puts out no bulky product.

c. Graphite

It has been said around the laboratory that insufficient pure coke is available to the Germans for graphite moderator production. There seem to be no published figures on the micro-constituents of the ash of petroleum crudes available in Europe, but assuming that these are not really much worse than our own mid-continent crudes, one finds that the Germans, under pressure,

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Figure D.800: Philip Morrison to Samuel K. Allison. 30 November 1943. Report on Enemy Materials Situation. [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]

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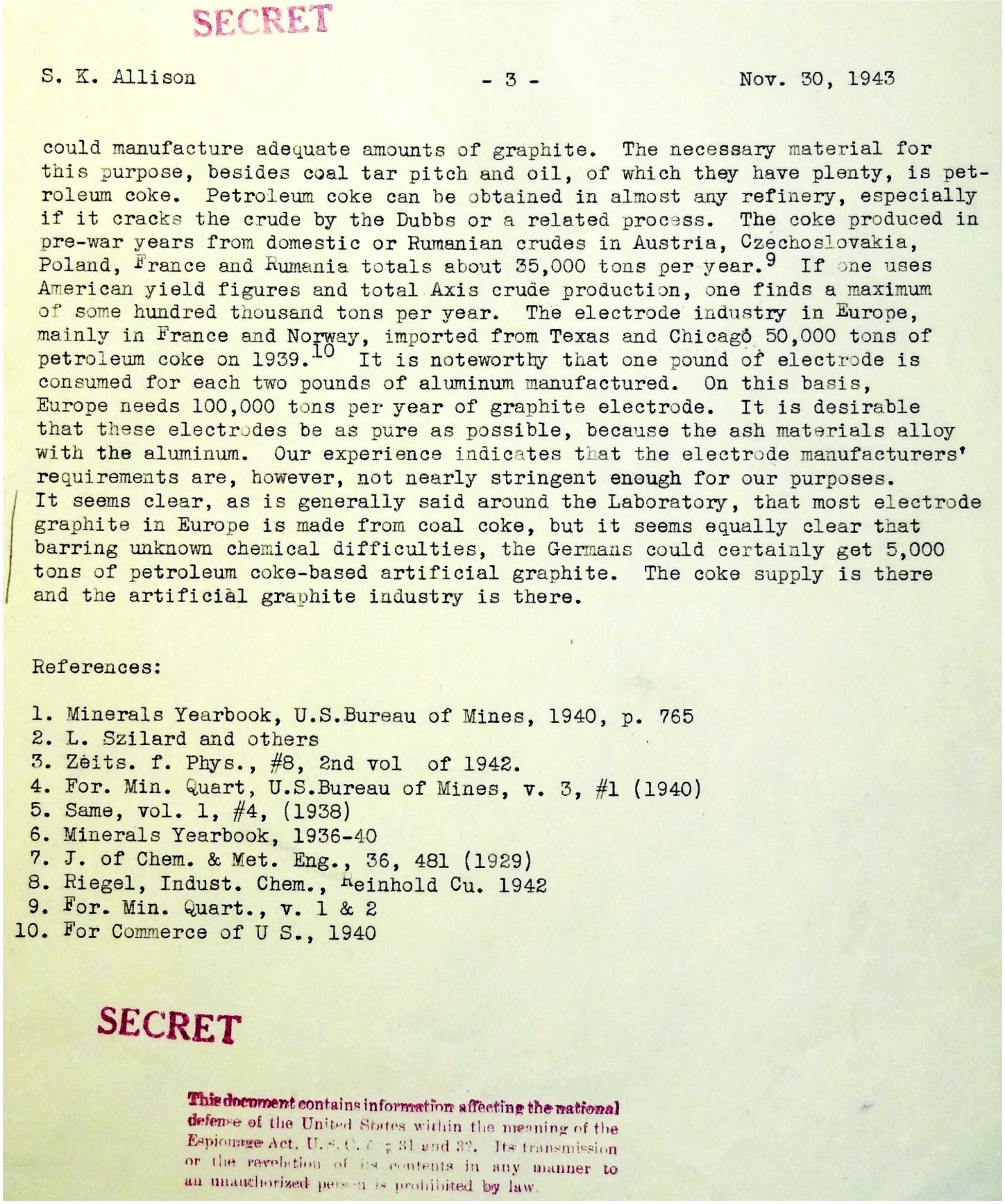

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S. K. Allison - 3 - Nov. 30, 1943

could manufacture adequate amounts of graphite. The necessary material for this purpose, besides coal tar pitch and oil, of which they have plenty, is petroleum coke. Petroleum coke can be obtained in almost any refinery, especially if it cracks the crude by the Dubbs or a related process. The coke produced in pre-war years from domestic or Rumanian crudes in Austria, Czechoslovakia, Poland, France and Rumania totals about 35,000 tons per year.[9] If one uses American yield figures and total Axis crude production, one finds a maximum of some hundred thousand tons per year. The electrode industry in Europe, mainly in France and Norway, imported from Texas and Chicago 50,000 tons of petroleum coke on 1939.[10] It is noteworthy that one pound of electrode is consumed for each two pounds of aluminum manufactured. On this basis, Europe needs 100,000 tons per year of graphite electrode. It is desirable that these electrodes be as pure as possible, because the ash materials alloy with the aluminum. Our experience indicates that the electrode manufacturers' requirements are, however, not nearly stringent enough for our purposes. It seems clear, as is generally said around the Laboratory, that most electrode graphite in Europe is made from coal coke, but it seems equally clear that barring unknown chemical difficulties, the Germans could certainly get 5,000 tons of petroleum coke-based artificial graphite. The coke supply is there and the artificial graphite industry is there.

References:

1. Minerals Yearbook, U.S.Bureau of Mines, 1940, p. 765
2. L. Szilard and others
3. Zeits. f. Phys., #8, 2nd vol of 1942.
4. For. Min. Quart, U.S.Bureau of Mines, v. 3, #1 (1940)
5. Same, vol. 1, #4, (1938)
6. Minerals Yearbook, 1936-40
7. J. of Chem. & Met. Eng., 36, 481 (1929)
8. Riegel, Indust. Chem., Reinhold Cu. 1942
9. For. Min. Quart., v. 1 & 2
10. For Commerce of U S., 1940

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Figure D.801: Philip Morrison to Samuel K. Allison. 30 November 1943. Report on Enemy Materials Situation. [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]

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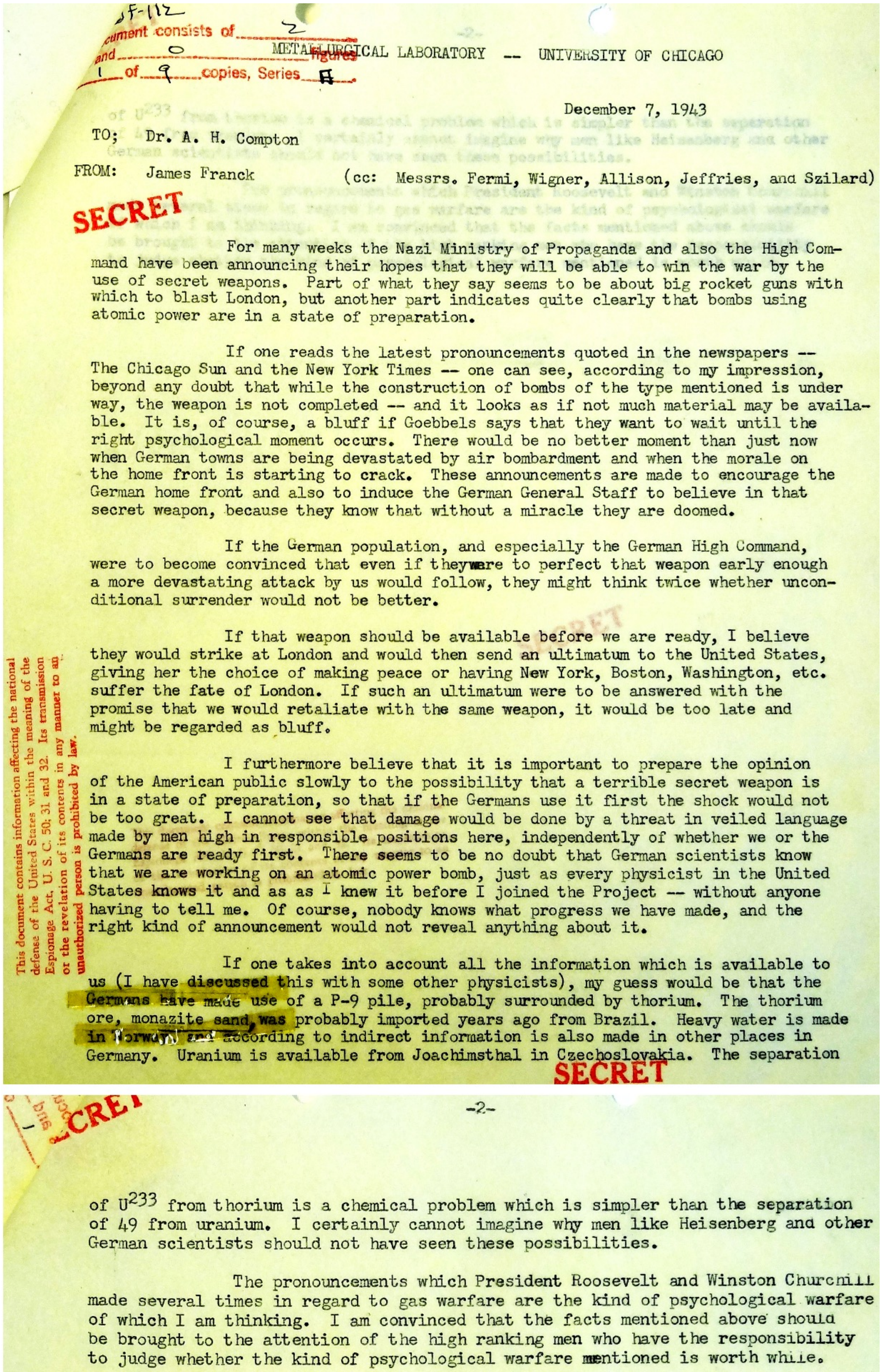
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 168, Folder 203.11---Tech. Countermeasures + RW---1943-1944



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METALLURGICAL LABORATORY -- UNIVERSITY OF CHICAGO

December 7, 1943

TO; Dr. A. H. Compton

FROM: James Franck (cc: Messrs. Fermi, Wigner, Allison, Jeffries, and Szilard)

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For many weeks the Nazi Ministry of Propaganda and also the High Command have been announcing their hopes that they will be able to win the war by the use of secret weapons. Part of what they say seems to be about big rocket guns with which to blast London, but another part indicates quite clearly that bombs using atomic power are in a state of preparation.

If one reads the latest pronouncements quoted in the newspapers -- The Chicago Sun and the New York Times -- one can see, according to my impression, beyond any doubt that while the construction of bombs of the type mentioned is under way, the weapon is not completed -- and it looks as if not much material may be available. It is, of course, a bluff if Goebbels says that they want to wait until the right psychological moment occurs. There would be no better moment than just now when German towns are being devastated by air bombardment and when the morale on the home front is starting to crack. These announcements are made to encourage the German home front and also to induce the German General Staff to believe in that secret weapon, because they know that without a miracle they are doomed.

If the German population, and especially the German High Command, were to become convinced that even if theywere to perfect that weapon early enough a more devastating attack by us would follow, they might think twice whether unconditional surrender would not be better.

If that weapon should be available before we are ready, I believe they would strike at London and would then send an ultimatum to the United States, giving her the choice of making peace or having New York, Boston, Washington, etc. suffer the fate of London. If such an ultimatum were to be answered with the promise that we would retaliate with the same weapon, it would be too late and might be regarded as bluff.

I furthermore believe that it is important to prepare the opinion of the American public slowly to the possibility that a terrible secret weapon is in a state of preparation, so that if the Germans use it first the shock would not be too great. I cannot see that damage would be done by a threat in veiled language made by men high in responsible positions here, independently of whether we or the Germans are ready first. There seems to be no doubt that German scientists know that we are working on an atomic power bomb, just as every physicist in the United States knows it and as as I knew it before I joined the Project -- without anyone having to tell me. Of course, nobody knows what progress we have made, and the right kind of announcement would not reveal anything about it.

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If one takes into account all the information which is available to us (I have discussed this with some other physicists), my guess would be that the Germans have made use of a P-9 pile, probably surrounded by thorium. The thorium ore, monazite sand, was probably imported years ago from Brazil. Heavy water is made in Norway, and according to indirect information is also made in other places in Germany. Uranium is available from Joachimsthal in Czechoslovakia. The separation

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of U^{233} from thorium is a chemical problem which is simpler than the separation of 49 from uranium. I certainly cannot imagine why men like Heisenberg and other German scientists should not have seen these possibilities.

The pronouncements which President Roosevelt and Winston Churchill made several times in regard to gas warfare are the kind of psychological warfare of which I am thinking. I am convinced that the facts mentioned above should be brought to the attention of the high ranking men who have the responsibility to judge whether the kind of psychological warfare mentioned is worth while.

Figure D.802: James Franck to Arthur Holly Compton. 7 December 1943 [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944]

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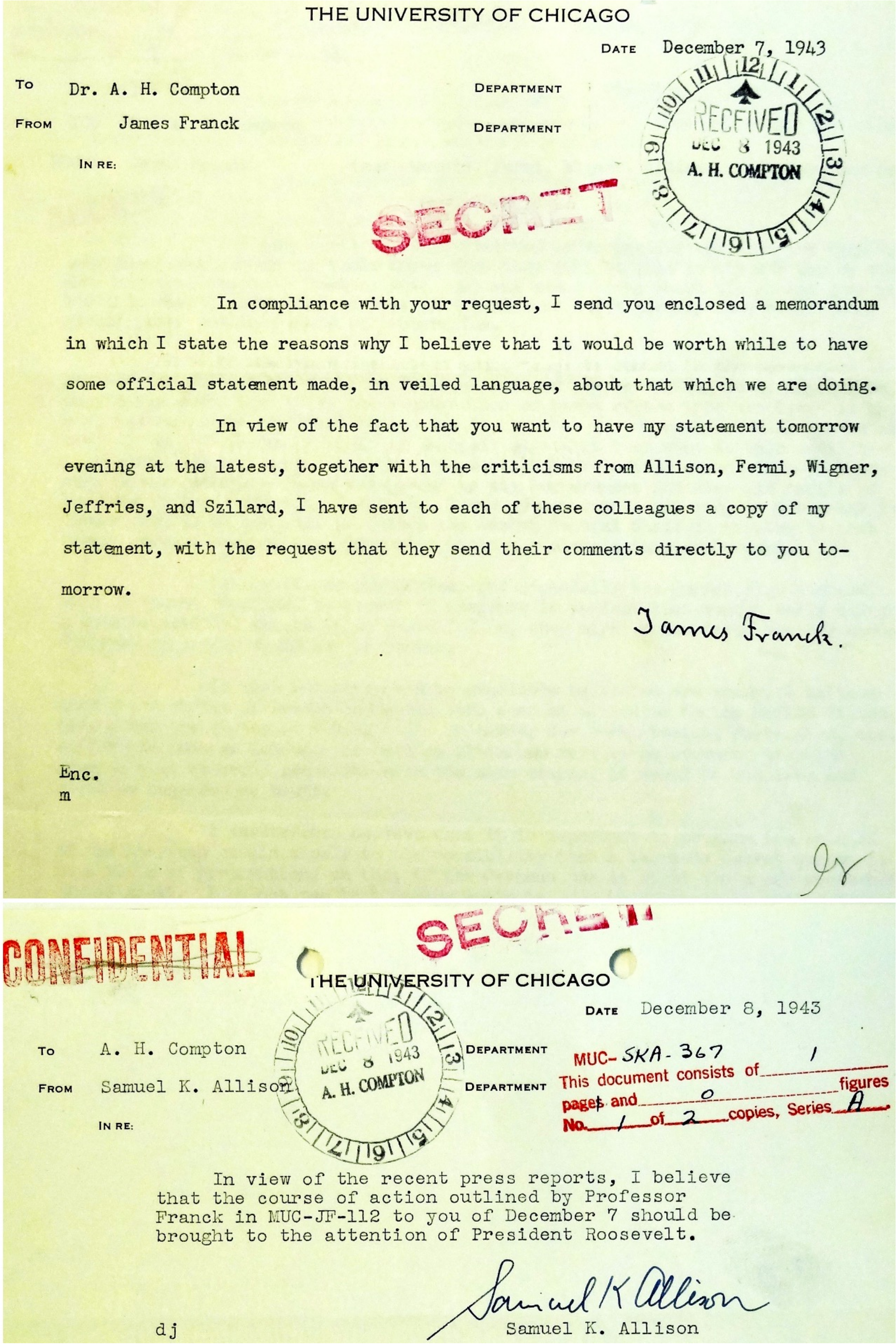

THE UNIVERSITY OF CHICAGO

DATE December 7, 1943

TO Dr. A. H. Compton DEPARTMENT

FROM James Franck DEPARTMENT

IN RE:

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DEC 8 1943
A. H. COMPTON

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In compliance with your request, I send you enclosed a memorandum in which I state the reasons why I believe that it would be worth while to have some official statement made, in veiled language, about that which we are doing.

In view of the fact that you want to have my statement tomorrow evening at the latest, together with the criticisms from Allison, Fermi, Wigner, Jeffries, and Szilard, I have sent to each of these colleagues a copy of my statement, with the request that they send their comments directly to you tomorrow.

James Franck.

Enc.
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THE UNIVERSITY OF CHICAGO

DATE December 8, 1943

TO A. H. Compton DEPARTMENT

FROM Samuel K. Allison DEPARTMENT

IN RE:

RECEIVED
DEC 8 1943
A. H. COMPTON

MUC-SKA-367
This document consists of 1
page~~s~~ and 0 figures
No. 1 of 2 copies, Series A.

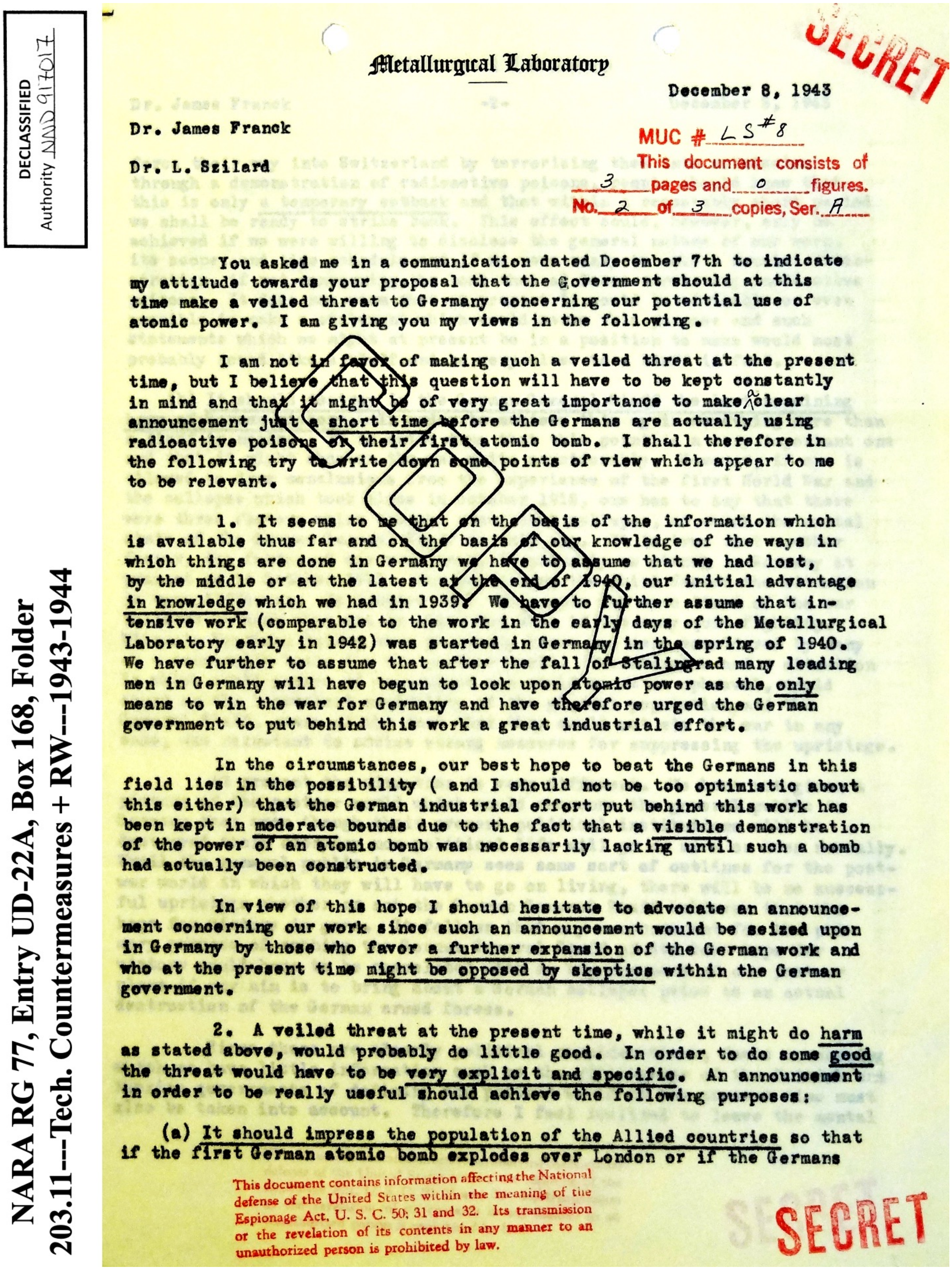
In view of the recent press reports, I believe that the course of action outlined by Professor Franck in MUC-JF-112 to you of December 7 should be brought to the attention of President Roosevelt.

Samuel K Allison
Samuel K. Allison

dj

NARA RG 77, Entry UD-22A, Box 168, Folder 203.11---Tech. Countermeasures + RW---1943-1944

Figure D.803: Top: James Franck to Arthur Holly Compton. 7 December 1943. Bottom: Samuel K. Allison to Arthur Holly Compton. 8 December 1943 [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944]



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NARA RG 77, Entry UD-22A, Box 168, Folder 203.11---Tech. Countermeasures + RW---1943-1944

SECRET

Metallurgical Laboratory

December 8, 1943

Dr. James Franck

Dr. L. Szilard

MUC # LS #8
This document consists of 3 pages and 0 figures.
No. 2 of 3 copies, Ser. A

COPY

You asked me in a communication dated December 7th to indicate my attitude towards your proposal that the Government should at this time make a veiled threat to Germany concerning our potential use of atomic power. I am giving you my views in the following.

I am not in favor of making such a veiled threat at the present time, but I believe that this question will have to be kept constantly in mind and that it might be of very great importance to make a clear announcement just a short time before the Germans are actually using radioactive poisons or their first atomic bomb. I shall therefore in the following try to write down some points of view which appear to me to be relevant.

1. It seems to me that on the basis of the information which is available thus far and on the basis of our knowledge of the ways in which things are done in Germany we have to assume that we had lost, by the middle or at the latest at the end of 1940, our initial advantage in knowledge which we had in 1939. We have to further assume that intensive work (comparable to the work in the early days of the Metallurgical Laboratory early in 1942) was started in Germany in the spring of 1940. We have further to assume that after the fall of Stalingrad many leading men in Germany will have begun to look upon atomic power as the only means to win the war for Germany and have therefore urged the German government to put behind this work a great industrial effort.

In the circumstances, our best hope to beat the Germans in this field lies in the possibility (and I should not be too optimistic about this either) that the German industrial effort put behind this work has been kept in moderate bounds due to the fact that a visible demonstration of the power of an atomic bomb was necessarily lacking until such a bomb had actually been constructed.

In view of this hope I should hesitate to advocate an announcement concerning our work since such an announcement would be seized upon in Germany by those who favor a further expansion of the German work and who at the present time might be opposed by skeptics within the German government.

2. A veiled threat at the present time, while it might do harm as stated above, would probably do little good. In order to do some good the threat would have to be very explicit and specific. An announcement in order to be really useful should achieve the following purposes:

(a) It should impress the population of the Allied countries so that if the first German atomic bomb explodes over London or if the Germans

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Figure D.804: Leo Szilard to James Franck and Arthur Holly Compton. 8 December 1943 [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944]

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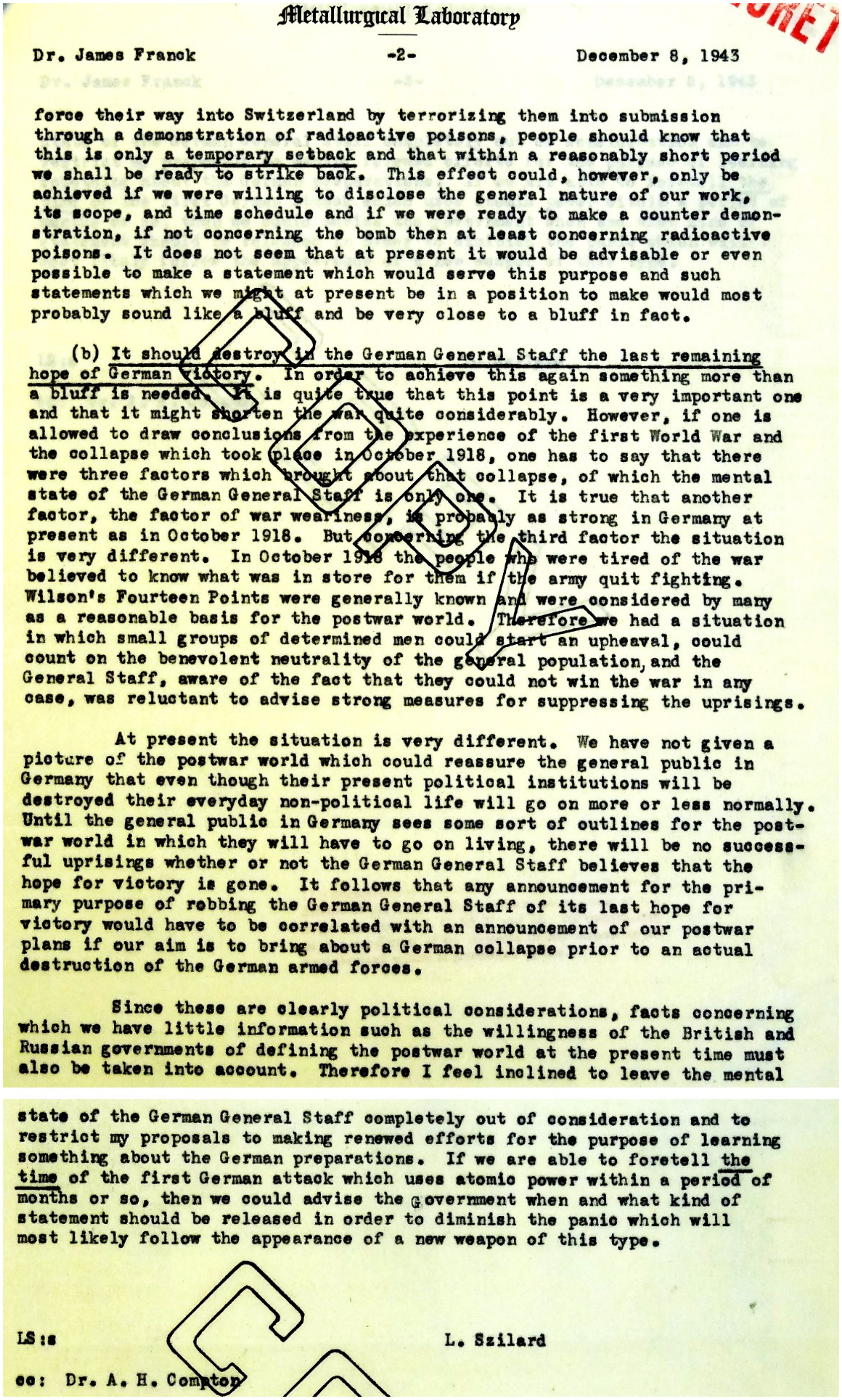


Metallurgical Laboratory

Dr. James Franck -2- December 8, 1943

force their way into Switzerland by terrorizing them into submission through a demonstration of radioactive poisons, people should know that this is only a temporary setback and that within a reasonably short period we shall be ready to strike back. This effect could, however, only be achieved if we were willing to disclose the general nature of our work, its scope, and time schedule and if we were ready to make a counter demonstration, if not concerning the bomb then at least concerning radioactive poisons. It does not seem that at present it would be advisable or even possible to make a statement which would serve this purpose and such statements which we might at present be in a position to make would most probably sound like a bluff and be very close to a bluff in fact.

(b) It should destroy in the German General Staff the last remaining hope of German victory. In order to achieve this again something more than a bluff is needed. It is quite true that this point is a very important one and that it might shorten the war quite considerably. However, if one is allowed to draw conclusions from the experience of the first World War and the collapse which took place in October 1918, one has to say that there were three factors which brought about that collapse, of which the mental state of the German General Staff is only one. It is true that another factor, the factor of war weariness, is probably as strong in Germany at present as in October 1918. But concerning the third factor the situation is very different. In October 1918 the people who were tired of the war believed to know what was in store for them if the army quit fighting. Wilson's Fourteen Points were generally known and were considered by many as a reasonable basis for the postwar world. Therefore we had a situation in which small groups of determined men could start an upheaval, could count on the benevolent neutrality of the general population, and the General Staff, aware of the fact that they could not win the war in any case, was reluctant to advise strong measures for suppressing the uprisings.

At present the situation is very different. We have not given a picture of the postwar world which could reassure the general public in Germany that even though their present political institutions will be destroyed their everyday non-political life will go on more or less normally. Until the general public in Germany sees some sort of outlines for the postwar world in which they will have to go on living, there will be no successful uprisings whether or not the German General Staff believes that the hope for victory is gone. It follows that any announcement for the primary purpose of robbing the German General Staff of its last hope for victory would have to be correlated with an announcement of our postwar plans if our aim is to bring about a German collapse prior to an actual destruction of the German armed forces.

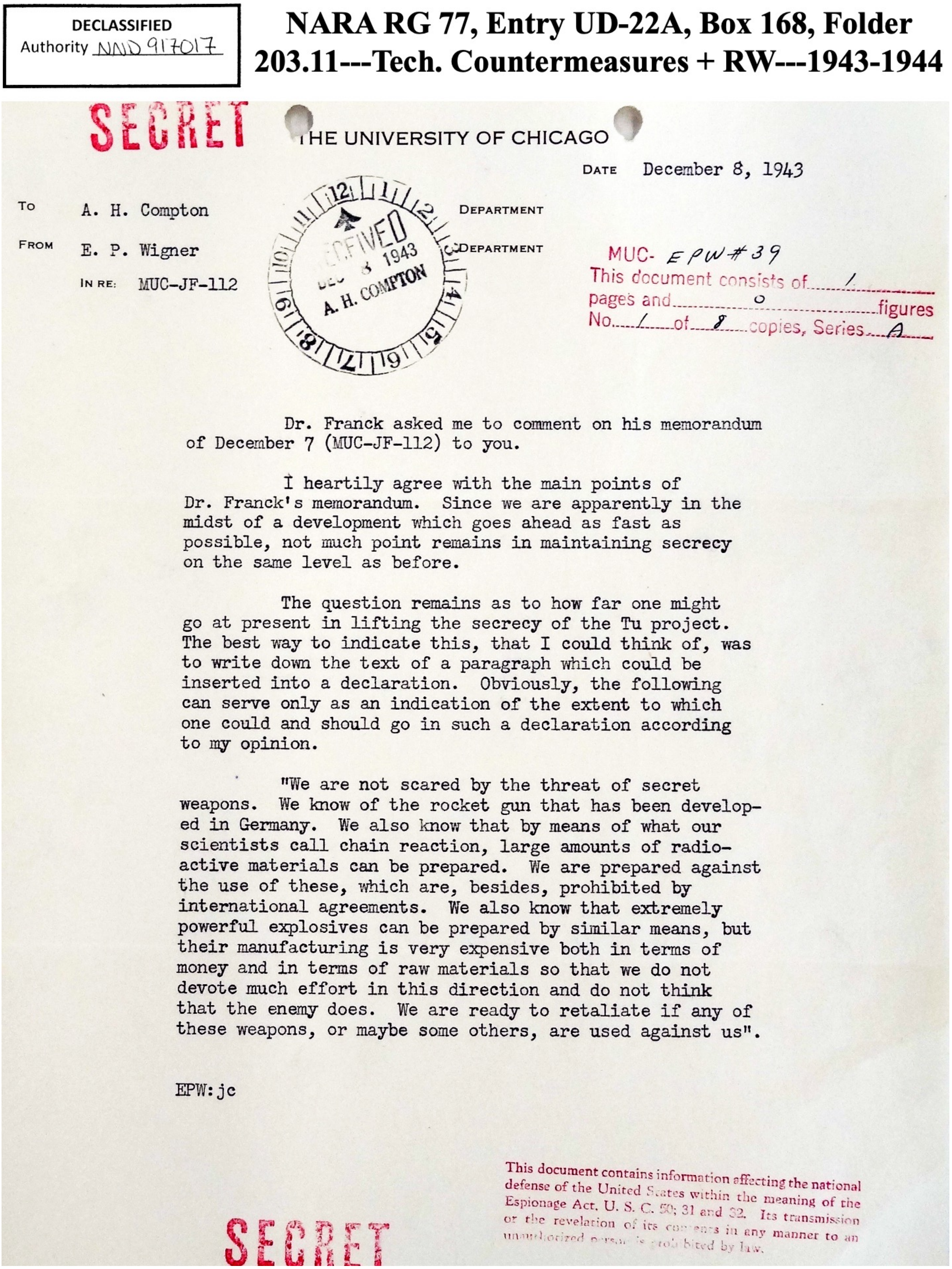
Since these are clearly political considerations, facts concerning which we have little information such as the willingness of the British and Russian governments of defining the postwar world at the present time must also be taken into account. Therefore I feel inclined to leave the mental state of the German General Staff completely out of consideration and to restrict my proposals to making renewed efforts for the purpose of learning something about the German preparations. If we are able to foretell the time of the first German attack which uses atomic power within a period of months or so, then we could advise the government when and what kind of statement should be released in order to diminish the panic which will most likely follow the appearance of a new weapon of this type.

LS:s L. Szilard

cc: Dr. A. H. Compton

NARA RG 77, Entry UD-22A, Box 168, Folder 203.11---Tech. Countermeasures + RW---1943-1944

Figure D.805: Leo Szilard to James Franck and Arthur Holly Compton. 8 December 1943 [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944]



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THE UNIVERSITY OF CHICAGO

DATE December 8, 1943

TO A. H. Compton DEPARTMENT

FROM E. P. Wigner DEPARTMENT

IN RE: MUC-JF-112

RECEIVED DEC 8 1943 A. H. COMPTON

MUC- EPW #39
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Dr. Franck asked me to comment on his memorandum of December 7 (MUC-JF-112) to you.

I heartily agree with the main points of Dr. Franck's memorandum. Since we are apparently in the midst of a development which goes ahead as fast as possible, not much point remains in maintaining secrecy on the same level as before.

The question remains as to how far one might go at present in lifting the secrecy of the Tu project. The best way to indicate this, that I could think of, was to write down the text of a paragraph which could be inserted into a declaration. Obviously, the following can serve only as an indication of the extent to which one could and should go in such a declaration according to my opinion.

"We are not scared by the threat of secret weapons. We know of the rocket gun that has been developed in Germany. We also know that by means of what our scientists call chain reaction, large amounts of radioactive materials can be prepared. We are prepared against the use of these, which are, besides, prohibited by international agreements. We also know that extremely powerful explosives can be prepared by similar means, but their manufacturing is very expensive both in terms of money and in terms of raw materials so that we do not devote much effort in this direction and do not think that the enemy does. We are ready to retaliate if any of these weapons, or maybe some others, are used against us".

EPW:jc

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Figure D.806: Eugene P. Wigner to Arthur Holly Compton. 8 December 1943 [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944]

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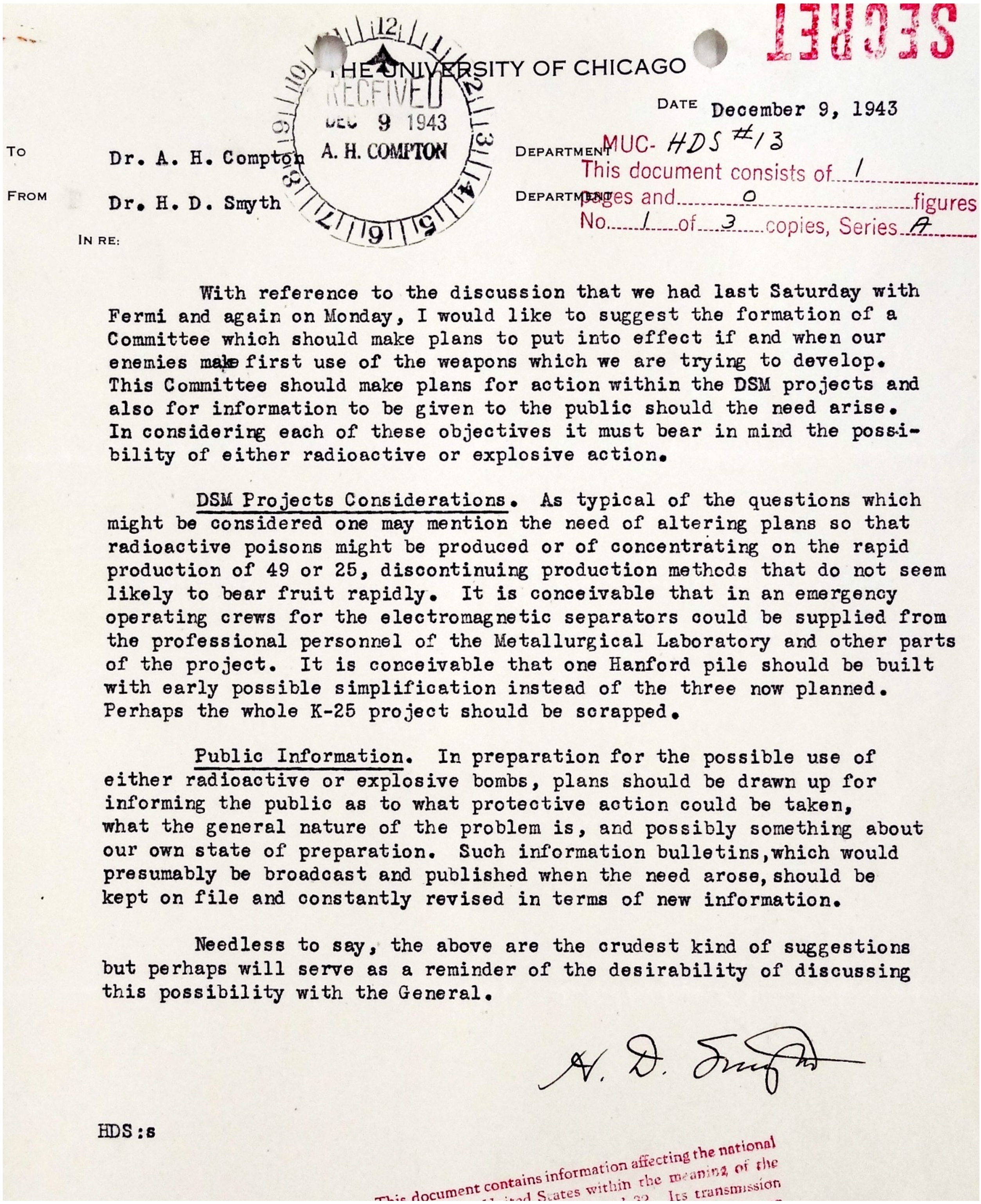
NARA RG 77, Entry UD-22A, Box 168, Folder 203.11---Tech. Countermeasures + RW---1943-1944



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THE UNIVERSITY OF CHICAGO

RECEIVED
DEC 9 1943
A. H. COMPTON

DATE December 9, 1943

TO Dr. A. H. Compton DEPARTMENT MUC- HDS #13

FROM Dr. H. D. Smyth DEPARTMENT

IN RE:

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With reference to the discussion that we had last Saturday with Fermi and again on Monday, I would like to suggest the formation of a Committee which should make plans to put into effect if and when our enemies make first use of the weapons which we are trying to develop. This Committee should make plans for action within the DSM projects and also for information to be given to the public should the need arise. In considering each of these objectives it must bear in mind the possibility of either radioactive or explosive action.

DSM Projects Considerations. As typical of the questions which might be considered one may mention the need of altering plans so that radioactive poisons might be produced or of concentrating on the rapid production of 49 or 25, discontinuing production methods that do not seem likely to bear fruit rapidly. It is conceivable that in an emergency operating crews for the electromagnetic separators could be supplied from the professional personnel of the Metallurgical Laboratory and other parts of the project. It is conceivable that one Hanford pile should be built with early possible simplification instead of the three now planned. Perhaps the whole K-25 project should be scrapped.

Public Information. In preparation for the possible use of either radioactive or explosive bombs, plans should be drawn up for informing the public as to what protective action could be taken, what the general nature of the problem is, and possibly something about our own state of preparation. Such information bulletins,which would presumably be broadcast and published when the need arose, should be kept on file and constantly revised in terms of new information.

Needless to say, the above are the crudest kind of suggestions but perhaps will serve as a reminder of the desirability of discussing this possibility with the General.

H. D. Smyth

HDS:s

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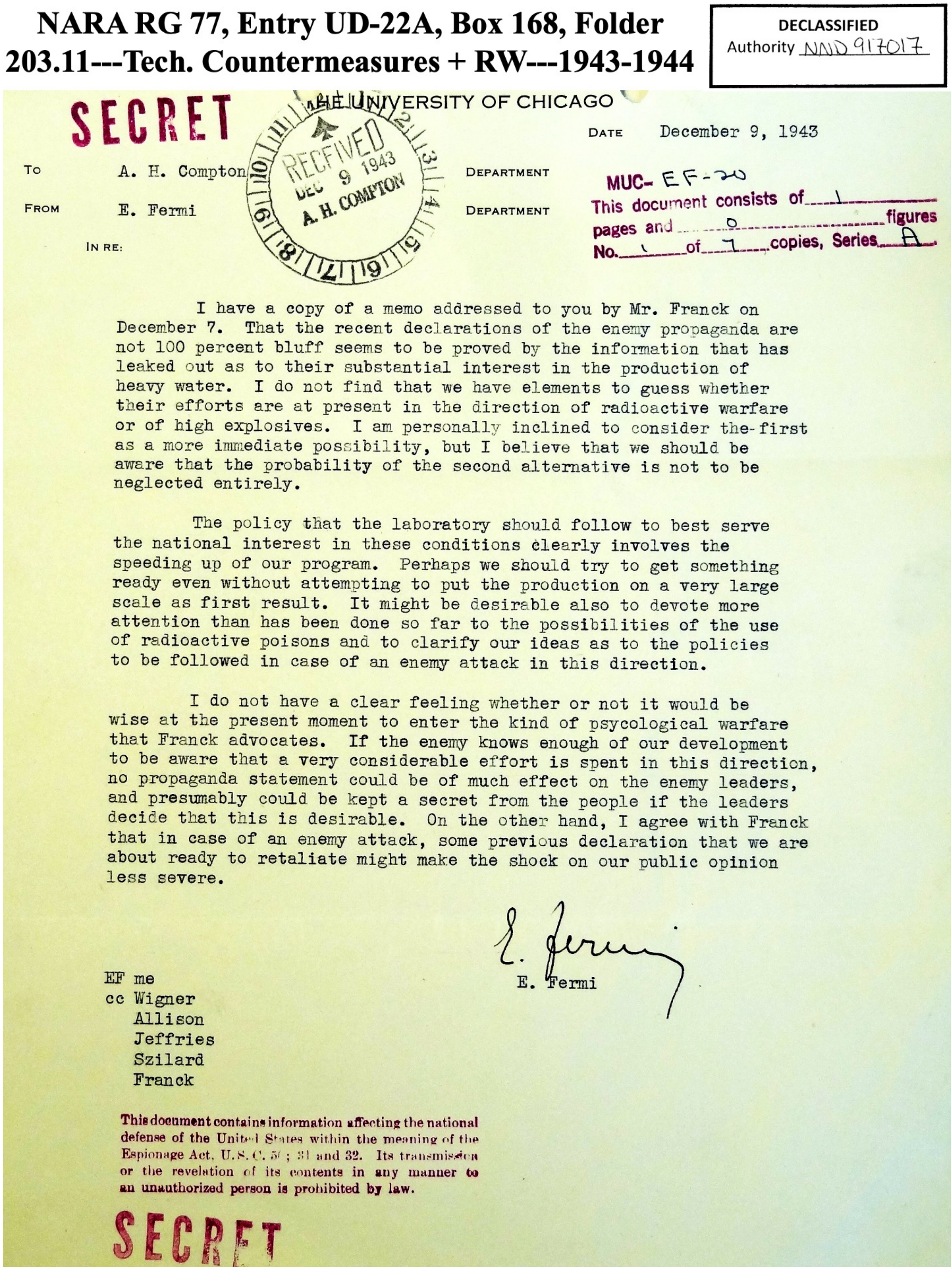
Figure D.807: Henry DeWolf Smyth to Arthur Holly Compton. 9 December 1943 [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].



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DATE December 9, 1943

TO A. H. Compton DEPARTMENT

FROM E. Fermi DEPARTMENT

IN RE:

MUC- EF-20
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I have a copy of a memo addressed to you by Mr. Franck on December 7. That the recent declarations of the enemy propaganda are not 100 percent bluff seems to be proved by the information that has leaked out as to their substantial interest in the production of heavy water. I do not find that we have elements to guess whether their efforts are at present in the direction of radioactive warfare or of high explosives. I am personally inclined to consider the first as a more immediate possibility, but I believe that we should be aware that the probability of the second alternative is not to be neglected entirely.

The policy that the laboratory should follow to best serve the national interest in these conditions clearly involves the speeding up of our program. Perhaps we should try to get something ready even without attempting to put the production on a very large scale as first result. It might be desirable also to devote more attention than has been done so far to the possibilities of the use of radioactive poisons and to clarify our ideas as to the policies to be followed in case of an enemy attack in this direction.

I do not have a clear feeling whether or not it would be wise at the present moment to enter the kind of psycological warfare that Franck advocates. If the enemy knows enough of our development to be aware that a very considerable effort is spent in this direction, no propaganda statement could be of much effect on the enemy leaders, and presumably could be kept a secret from the people if the leaders decide that this is desirable. On the other hand, I agree with Franck that in case of an enemy attack, some previous declaration that we are about ready to retaliate might make the shock on our public opinion less severe.

E. Fermi

E. Fermi

EF me
cc Wigner
Allison
Jeffries
Szilard
Franck

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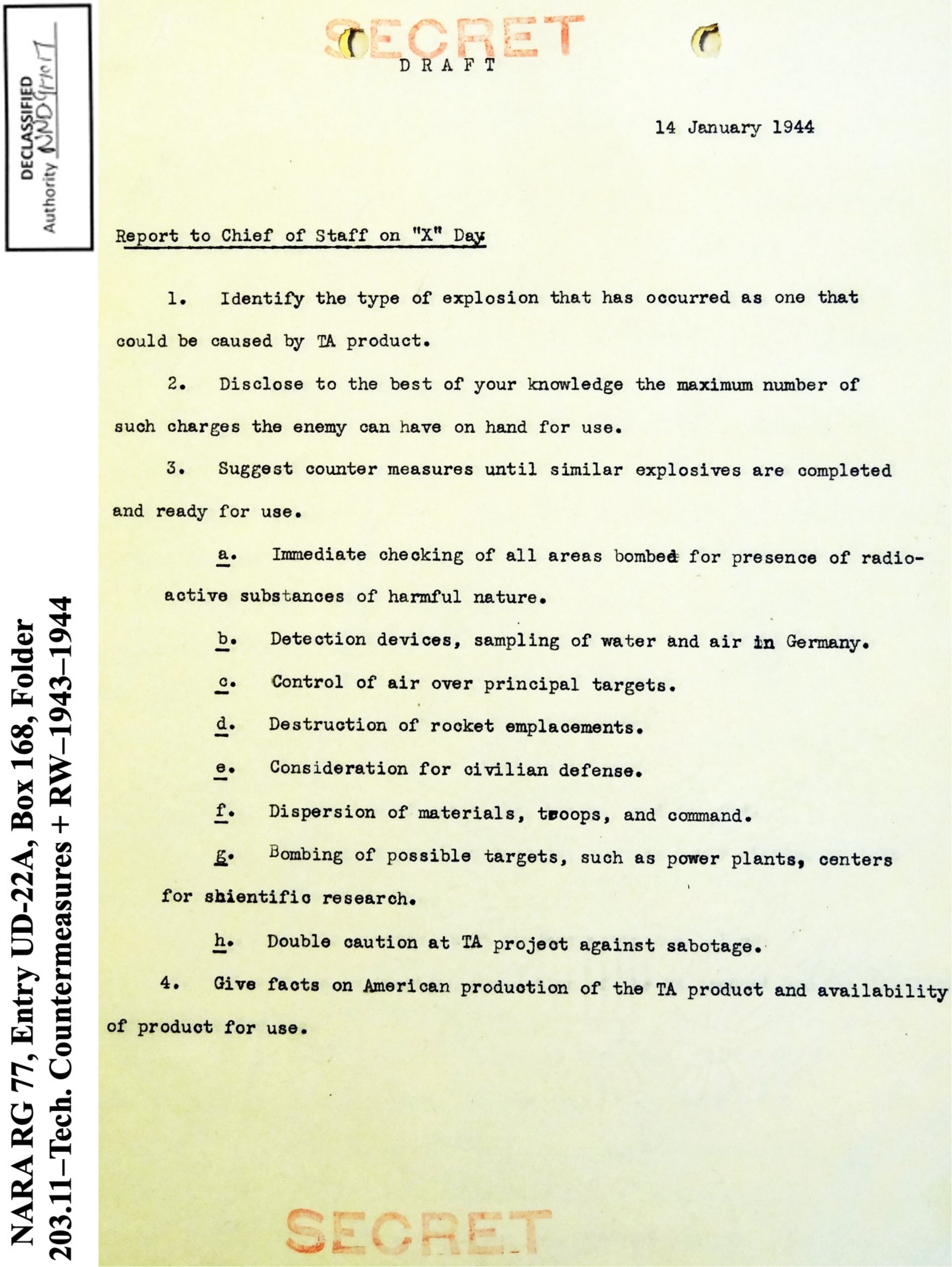
Figure D.808: Enrico Fermi to Arthur Holly Compton. 9 December 1943 [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].



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DRAFT

14 January 1944

Report to Chief of Staff on "X" Day

1. Identify the type of explosion that has occurred as one that could be caused by TA product.

2. Disclose to the best of your knowledge the maximum number of such charges the enemy can have on hand for use.

3. Suggest counter measures until similar explosives are completed and ready for use.

   a. Immediate checking of all areas bombed for presence of radioactive substances of harmful nature.

   b. Detection devices, sampling of water and air in Germany.

   c. Control of air over principal targets.

   d. Destruction of rocket emplacements.

   e. Consideration for civilian defense.

   f. Dispersion of materials, troops, and command.

   g. Bombing of possible targets, such as power plants, centers for shientific research.

   h. Double caution at TA project against sabotage.

4. Give facts on American production of the TA product and availability of product for use.

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NARA RG 77, Entry UD-22A, Box 168, Folder 203.11–Tech. Countermeasures + RW–1943–1944

Figure D.809: Report to Chief of Staff on "X" Day [if the explosion of a German atomic bomb is detected]. 14 January 1944 [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42-June 44)

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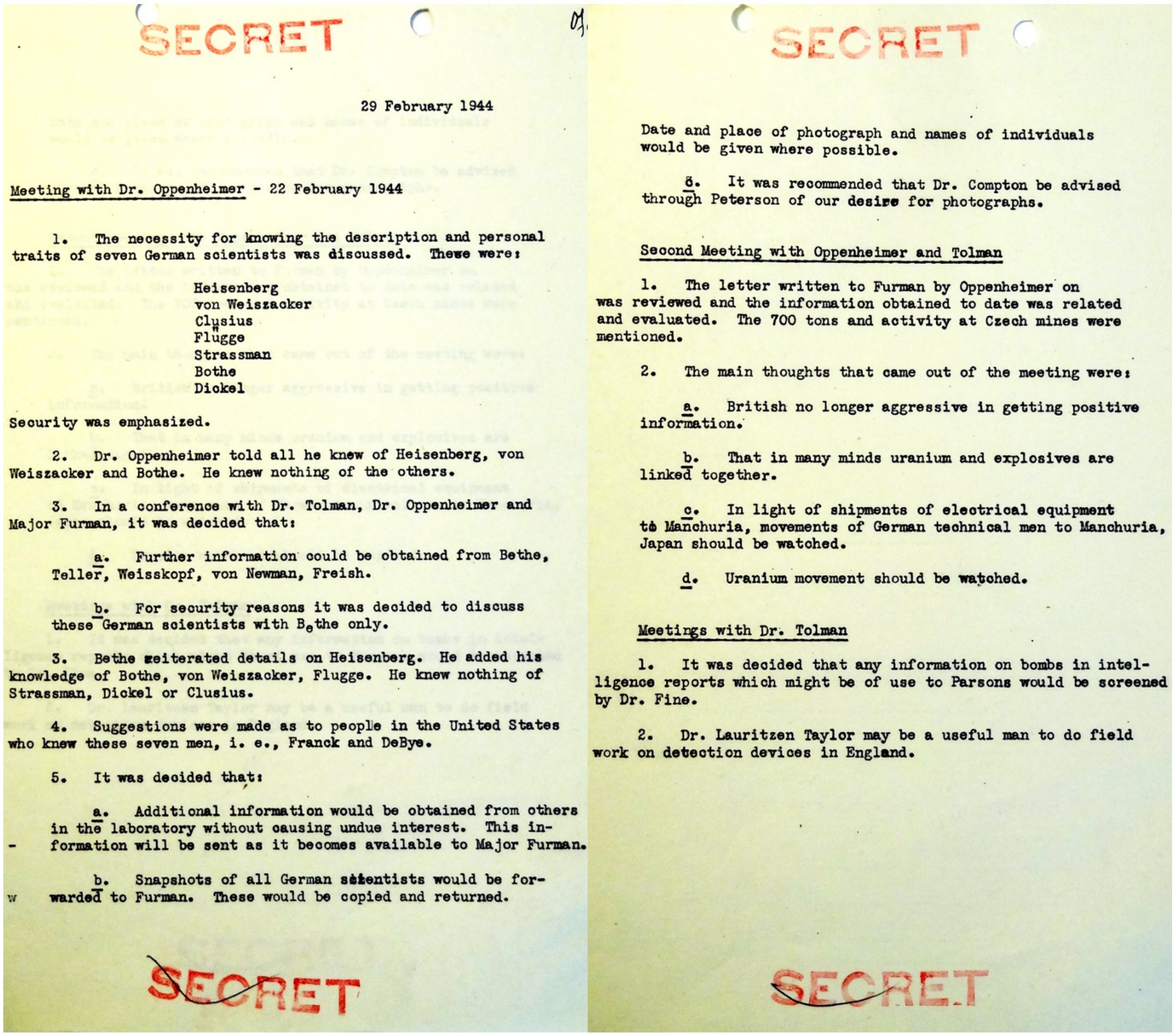

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Oj.

29 February 1944

Meeting with Dr. Oppenheimer - 22 February 1944

1. The necessity for knowing the description and personal traits of seven German scientists was discussed. These were:

Heisenberg
von Weiszacker
Clusius
Flugge
Strassman
Bothe
Dickel

Security was emphasized.

2. Dr. Oppenheimer told all he knew of Heisenberg, von Weiszacker and Bothe. He knew nothing of the others.

3. In a conference with Dr. Tolman, Dr. Oppenheimer and Major Furman, it was decided that:

a. Further information could be obtained from Bethe, Teller, Weisskopf, von Newman, Freish.

b. For security reasons it was decided to discuss these German scientists with Bethe only.

3. Bethe reiterated details on Heisenberg. He added his knowledge of Bothe, von Weiszacker, Flugge. He knew nothing of Strassman, Dickel or Clusius.

4. Suggestions were made as to people in the United States who knew these seven men, i. e., Franck and DeBye.

5. It was decided that:

a. Additional information would be obtained from others in the laboratory without causing undue interest. This information will be sent as it becomes available to Major Furman.

b. Snapshots of all German scientists would be forwarded to Furman. These would be copied and returned.

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Date and place of photograph and names of individuals would be given where possible.

6. It was recommended that Dr. Compton be advised through Peterson of our desire for photographs.

Second Meeting with Oppenheimer and Tolman

1. The letter written to Furman by Oppenheimer on was reviewed and the information obtained to date was related and evaluated. The 700 tons and activity at Czech mines were mentioned.

2. The main thoughts that came out of the meeting were:

a. British no longer aggressive in getting positive information.

b. That in many minds uranium and explosives are linked together.

c. In light of shipments of electrical equipment to Manchuria, movements of German technical men to Manchuria, Japan should be watched.

d. Uranium movement should be watched.

Meetings with Dr. Tolman

1. It was decided that any information on bombs in intelligence reports which might be of use to Parsons would be screened by Dr. Fine.

2. Dr. Lauritzen Taylor may be a useful man to do field work on detection devices in England.

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Figure D.810: Robert R. Furman. 29 February 1944. Memo on meetings with Oppenheimer, Bethe, and Tolman [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)].

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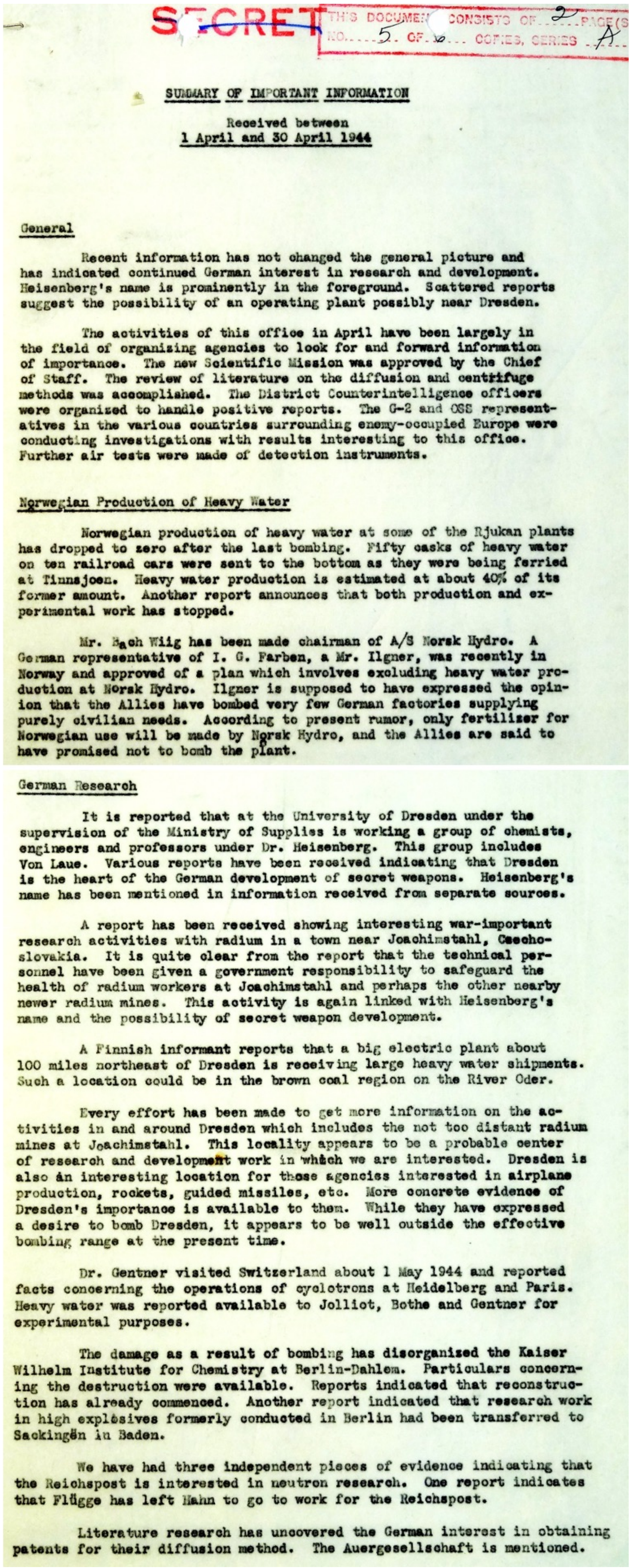
NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)



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NO. 5 OF 6 COPIES, SERIES A

SUMMARY OF IMPORTANT INFORMATION

Received between
1 April and 30 April 1944

General

Recent information has not changed the general picture and has indicated continued German interest in research and development. Heisenberg's name is prominently in the foreground. Scattered reports suggest the possibility of an operating plant possibly near Dresden.

The activities of this office in April have been largely in the field of organizing agencies to look for and forward information of importance. The new Scientific Mission was approved by the Chief of Staff. The review of literature on the diffusion and centrifuge methods was accomplished. The District Counterintelligence officers were organized to handle positive reports. The G-2 and OSS representatives in the various countries surrounding enemy-occupied Europe were conducting investigations with results interesting to this office. Further air tests were made of detection instruments.

Norwegian Production of Heavy Water

Norwegian production of heavy water at some of the Rjukan plants has dropped to zero after the last bombing. Fifty casks of heavy water on ten railroad cars were sent to the bottom as they were being ferried at Tinnsjoen. Heavy water production is estimated at about 40% of its former amount. Another report announces that both production and experimental work has stopped.

Mr. Bach Wiig has been made chairman of A/S Norsk Hydro. A German representative of I. G. Farben, a Mr. Ilgner, was recently in Norway and approved of a plan which involves excluding heavy water production at Norsk Hydro. Ilgner is supposed to have expressed the opinion that the Allies have bombed very few German factories supplying purely civilian needs. According to present rumor, only fertilizer for Norwegian use will be made by Norsk Hydro, and the Allies are said to have promised not to bomb the plant.

German Research

It is reported that at the University of Dresden under the supervision of the Ministry of Supplies is working a group of chemists, engineers and professors under Dr. Heisenberg. This group includes Von Laue. Various reports have been received indicating that Dresden is the heart of the German development of secret weapons. Heisenberg's name has been mentioned in information received from separate sources.

A report has been received showing interesting war-important research activities with radium in a town near Joachimstahl, Czechoslovakia. It is quite clear from the report that the technical personnel have been given a government responsibility to safeguard the health of radium workers at Joachimstahl and perhaps the other nearby newer radium mines. This activity is again linked with Heisenberg's name and the possibility of secret weapon development.

A Finnish informant reports that a big electric plant about 100 miles northeast of Dresden is receiving large heavy water shipments. Such a location could be in the brown coal region on the River Oder.

Every effort has been made to get more information on the activities in and around Dresden which includes the not too distant radium mines at Joachimstahl. This locality appears to be a probable center of research and development work in which we are interested. Dresden is also an interesting location for those agencies interested in airplane production, rockets, guided missiles, etc. More concrete evidence of Dresden's importance is available to them. While they have expressed a desire to bomb Dresden, it appears to be well outside the effective bombing range at the present time.

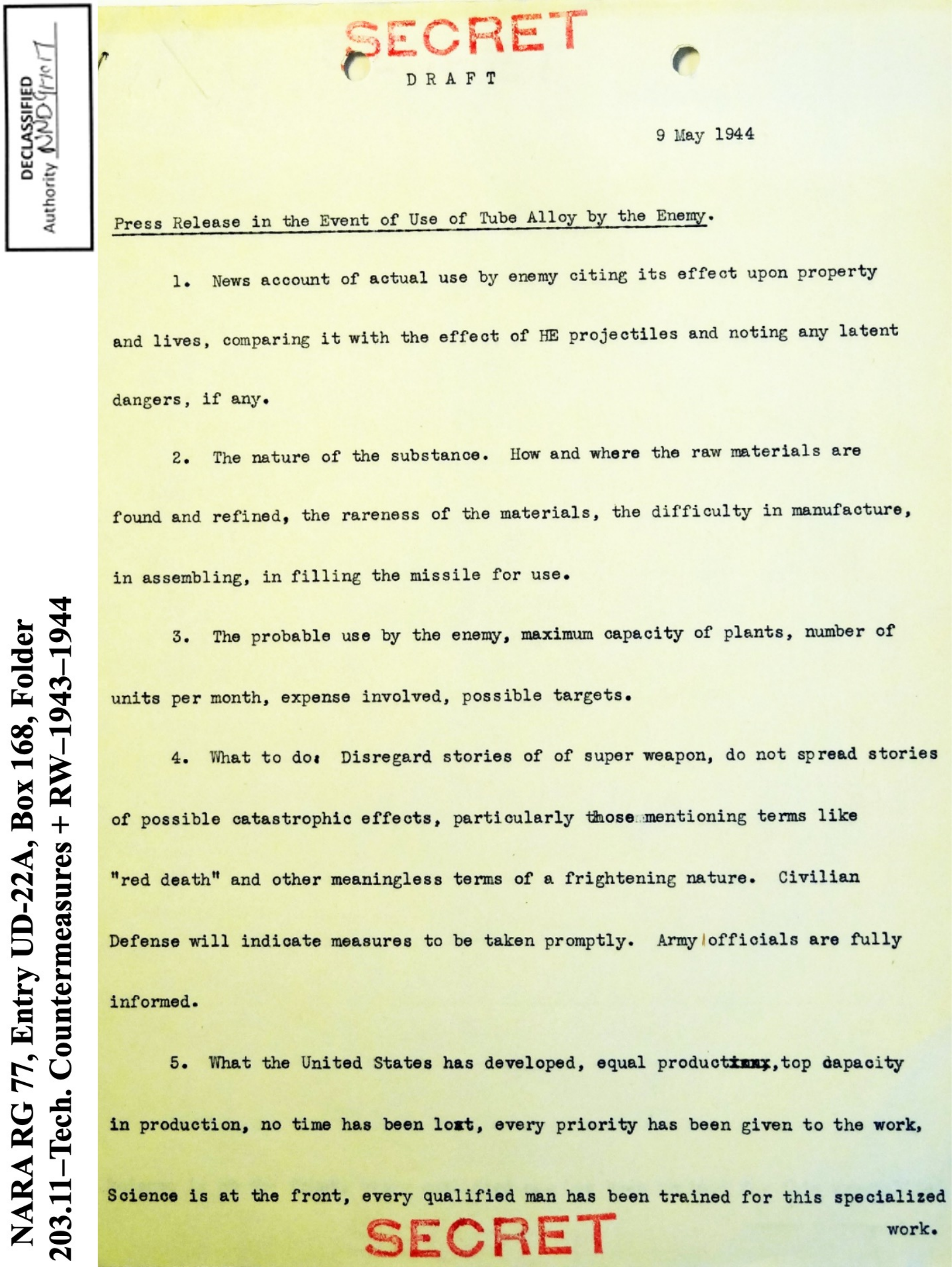
Dr. Gentner visited Switzerland about 1 May 1944 and reported facts concerning the operations of cyclotrons at Heidelberg and Paris. Heavy water was reported available to Jolliot, Bothe and Gentner for experimental purposes.

The damage as a result of bombing has disorganized the Kaiser Wilhelm Institute for Chemistry at Berlin-Dahlem. Particulars concerning the destruction were available. Reports indicated that reconstruction has already commenced. Another report indicated that research work in high explosives formerly conducted in Berlin had been transferred to Sackingen in Baden.

We have had three independent pieces of evidence indicating that the Reichspost is interested in neutron research. One report indicates that Flügge has left Hahn to go to work for the Reichspost.

Literature research has uncovered the German interest in obtaining patents for their diffusion method. The Auergesellschaft is mentioned.

Figure D.811: Summary of Important Information Received between 1 April and 30 April 1944 [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].



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NARA RG 77, Entry UD-22A, Box 168, Folder 203.11–Tech. Countermeasures + RW–1943–1944

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DRAFT

9 May 1944

Press Release in the Event of Use of Tube Alloy by the Enemy.

1. News account of actual use by enemy citing its effect upon property and lives, comparing it with the effect of HE projectiles and noting any latent dangers, if any.

2. The nature of the substance. How and where the raw materials are found and refined, the rareness of the materials, the difficulty in manufacture, in assembling, in filling the missile for use.

3. The probable use by the enemy, maximum capacity of plants, number of units per month, expense involved, possible targets.

4. What to do: Disregard stories of of super weapon, do not spread stories of possible catastrophic effects, particularly those mentioning terms like "red death" and other meaningless terms of a frightening nature. Civilian Defense will indicate measures to be taken promptly. Army officials are fully informed.

5. What the United States has developed, equal production,top capacity in production, no time has been lost, every priority has been given to the work, Science is at the front, every qualified man has been trained for this specialized work.

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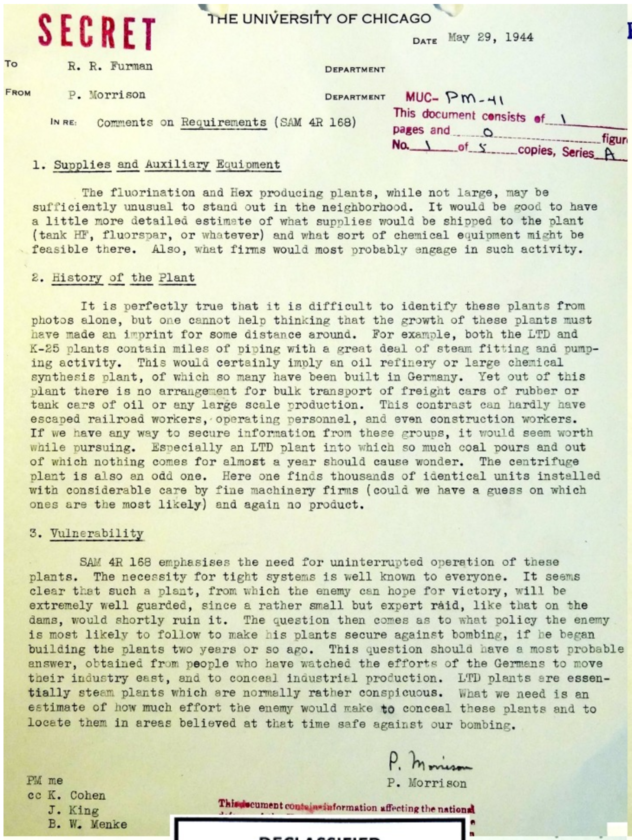
Figure D.812: Press Release in the Event of Use of Tube Alloy by the Enemy. 9 May 1944 [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].



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THE UNIVERSITY OF CHICAGO

DATE May 29, 1944

TO R. R. Furman DEPARTMENT

FROM P. Morrison DEPARTMENT

MUC- PM-41

This document consists of 1 pages and 0 figur

No. 1 of 5 copies, Series A

IN RE: Comments on Requirements (SAM 4R 168)

1. Supplies and Auxiliary Equipment

The fluorination and Hex producing plants, while not large, may be sufficiently unusual to stand out in the neighborhood. It would be good to have a little more detailed estimate of what supplies would be shipped to the plant (tank HF, fluorspar, or whatever) and what sort of chemical equipment might be feasible there. Also, what firms would most probably engage in such activity.

2. History of the Plant

It is perfectly true that it is difficult to identify these plants from photos alone, but one cannot help thinking that the growth of these plants must have made an imprint for some distance around. For example, both the LTD and K-25 plants contain miles of piping with a great deal of steam fitting and pumping activity. This would certainly imply an oil refinery or large chemical synthesis plant, of which so many have been built in Germany. Yet out of this plant there is no arrangement for bulk transport of freight cars of rubber or tank cars of oil or any large scale production. This contrast can hardly have escaped railroad workers, operating personnel, and even construction workers. If we have any way to secure information from these groups, it would seem worth while pursuing. Especially an LTD plant into which so much coal pours and out of which nothing comes for almost a year should cause wonder. The centrifuge plant is also an odd one. Here one finds thousands of identical units installed with considerable care by fine machinery firms (could we have a guess on which ones are the most likely) and again no product.

3. Vulnerability

SAM 4R 168 emphasises the need for uninterrupted operation of these plants. The necessity for tight systems is well known to everyone. It seems clear that such a plant, from which the enemy can hope for victory, will be extremely well guarded, since a rather small but expert raid, like that on the dams, would shortly ruin it. The question then comes as to what policy the enemy is most likely to follow to make his plants secure against bombing, if he began building the plants two years or so ago. This question should have a most probable answer, obtained from people who have watched the efforts of the Germans to move their industry east, and to conceal industrial production. LTD plants are essentially steam plants which are normally rather conspicuous. What we need is an estimate of how much effort the enemy would make to conceal these plants and to locate them in areas believed at that time safe against our bombing.

P. Morrison
P. Morrison

PM me
cc K. Cohen
J. King
B. W. Menke

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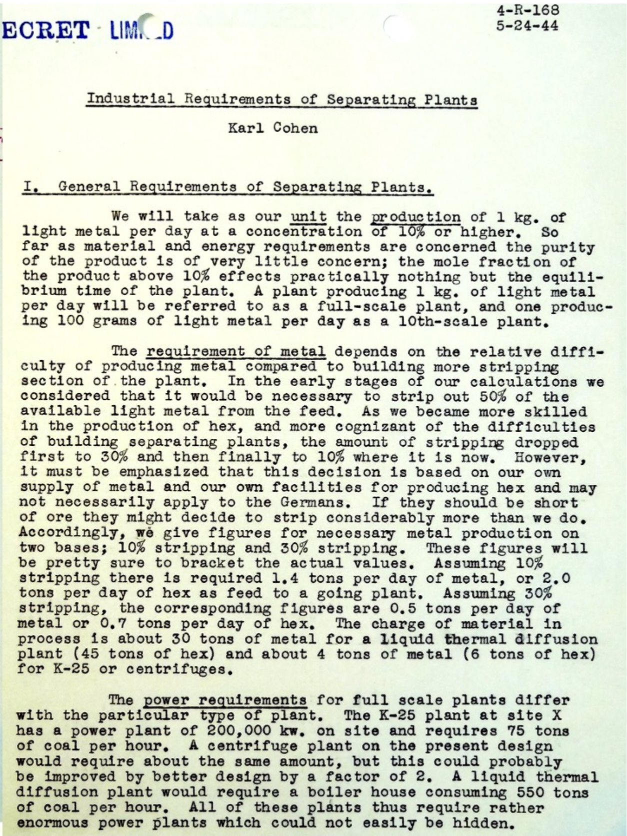

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4-R-168
5-24-44

Industrial Requirements of Separating Plants

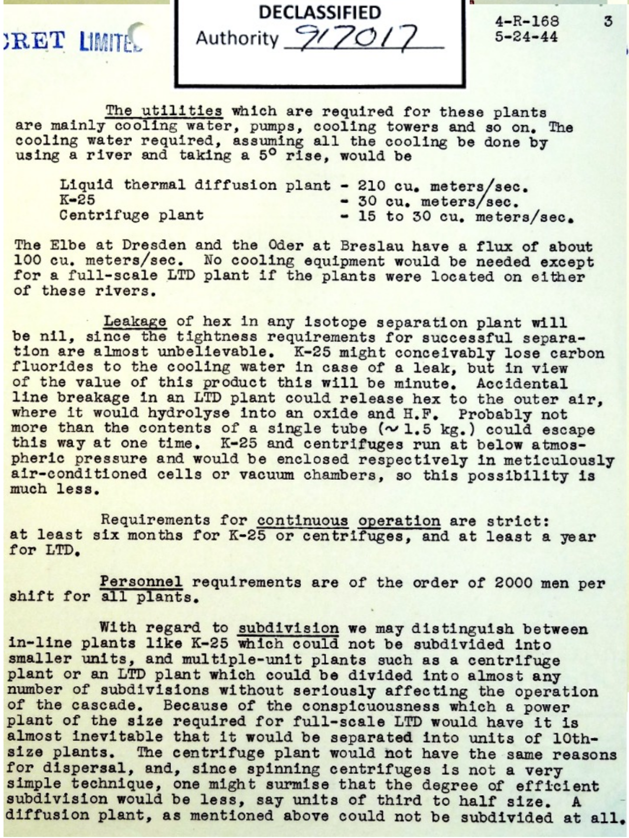
Karl Cohen

I. General Requirements of Separating Plants.

We will take as our unit the production of 1 kg. of light metal per day at a concentration of 10% or higher. So far as material and energy requirements are concerned the purity of the product is of very little concern; the mole fraction of the product above 10% effects practically nothing but the equilibrium time of the plant. A plant producing 1 kg. of light metal per day will be referred to as a full-scale plant, and one producing 100 grams of light metal per day as a 10th-scale plant.

The requirement of metal depends on the relative difficulty of producing metal compared to building more stripping section of the plant. In the early stages of our calculations we considered that it would be necessary to strip out 50% of the available light metal from the feed. As we became more skilled in the production of hex, and more cognizant of the difficulties of building separating plants, the amount of stripping dropped first to 30% and then finally to 10% where it is now. However, it must be emphasized that this decision is based on our own supply of metal and our own facilities for producing hex and may not necessarily apply to the Germans. If they should be short of ore they might decide to strip considerably more than we do. Accordingly, we give figures for necessary metal production on two bases; 10% stripping and 30% stripping. These figures will be pretty sure to bracket the actual values. Assuming 10% stripping there is required 1.4 tons per day of metal, or 2.0 tons per day of hex as feed to a going plant. Assuming 30% stripping, the corresponding figures are 0.5 tons per day of metal or 0.7 tons per day of hex. The charge of material in process is about 30 tons of metal for a liquid thermal diffusion plant (45 tons of hex) and about 4 tons of metal (6 tons of hex) for K-25 or centrifuges.

The power requirements for full scale plants differ with the particular type of plant. The K-25 plant at site X has a power plant of 200,000 kw. on site and requires 75 tons of coal per hour. A centrifuge plant on the present design would require about the same amount, but this could probably be improved by better design by a factor of 2. A liquid thermal diffusion plant would require a boiler house consuming 550 tons of coal per hour. All of these plants thus require rather enormous power plants which could not easily be hidden.



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The utilities which are required for these plants are mainly cooling water, pumps, cooling towers and so on. The cooling water required, assuming all the cooling be done by using a river and taking a 5° rise, would be

Liquid thermal diffusion plant	- 210 cu. meters/sec.
K-25	- 30 cu. meters/sec.
Centrifuge plant	- 15 to 30 cu. meters/sec.

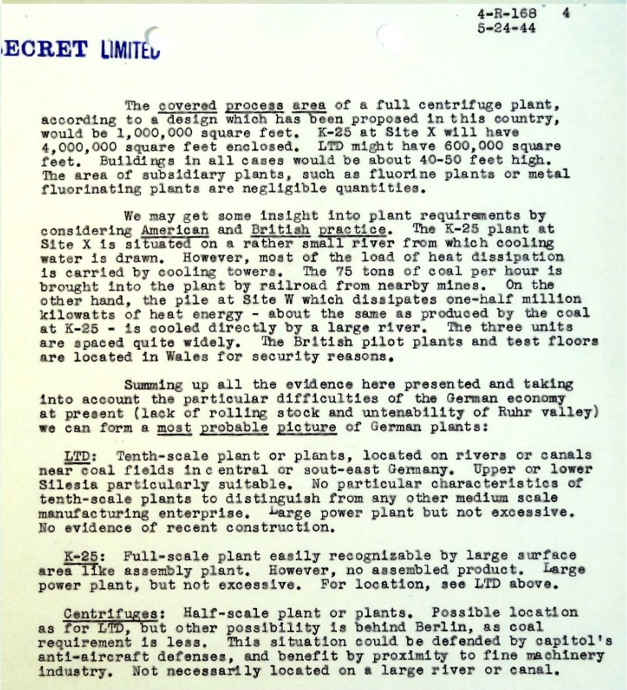
The Elbe at Dresden and the Oder at Breslau have a flux of about 100 cu. meters/sec. No cooling equipment would be needed except for a full-scale LTD plant if the plants were located on either of these rivers.

Leakage of hex in any isotope separation plant will be nil, since the tightness requirements for successful separation are almost unbelievable. K-25 might conceivably lose carbon fluorides to the cooling water in case of a leak, but in view of the value of this product this will be minute. Accidental line breakage in an LTD plant could release hex to the outer air, where it would hydrolyse into an oxide and H.F. Probably not more than the contents of a single tube (~1.5 kg.) could escape this way at one time. K-25 and centrifuges run at below atmospheric pressure and would be enclosed respectively in meticulously air-conditioned cells or vacuum chambers, so this possibility is much less.

Requirements for continuous operation are strict: at least six months for K-25 or centrifuges, and at least a year for LTD.

Personnel requirements are of the order of 2000 men per shift for all plants.

With regard to subdivision we may distinguish between in-line plants like K-25 which could not be subdivided into smaller units, and multiple-unit plants such as a centrifuge plant or an LTD plant which could be divided into almost any number of subdivisions without seriously affecting the operation of the cascade. Because of the conspicuousness which a power plant of the size required for full-scale LTD would have it is almost inevitable that it would be separated into units of 10th-size plants. The centrifuge plant would not have the same reasons for dispersal, and, since spinning centrifuges is not a very simple technique, one might surmise that the degree of efficient subdivision would be less, say units of third to half size. A diffusion plant, as mentioned above could not be subdivided at all.



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The covered process area of a full centrifuge plant, according to a design which has been proposed in this country, would be 1,000,000 square feet. K-25 at Site X will have 4,000,000 square feet enclosed. LTD might have 600,000 square feet. Buildings in all cases would be about 40-50 feet high. The area of subsidiary plants, such as fluorine plants or metal fluorinating plants are negligible quantities.

We may get some insight into plant requirements by considering American and British practice. The K-25 plant at Site X is situated on a rather small river from which cooling water is drawn. However, most of the load of heat dissipation is carried by cooling towers. The 75 tons of coal per hour is brought into the plant by railroad from nearby mines. On the other hand, the pile at Site W which dissipates one-half million kilowatts of heat energy - about the same as produced by the coal at K-25 - is cooled directly by a large river. The three units are spaced quite widely. The British pilot plants and test floors are located in Wales for security reasons.

Summing up all the evidence here presented and taking into account the particular difficulties of the German economy at present (lack of rolling stock and untenability of Ruhr valley) we can form a most probable picture of German plants:

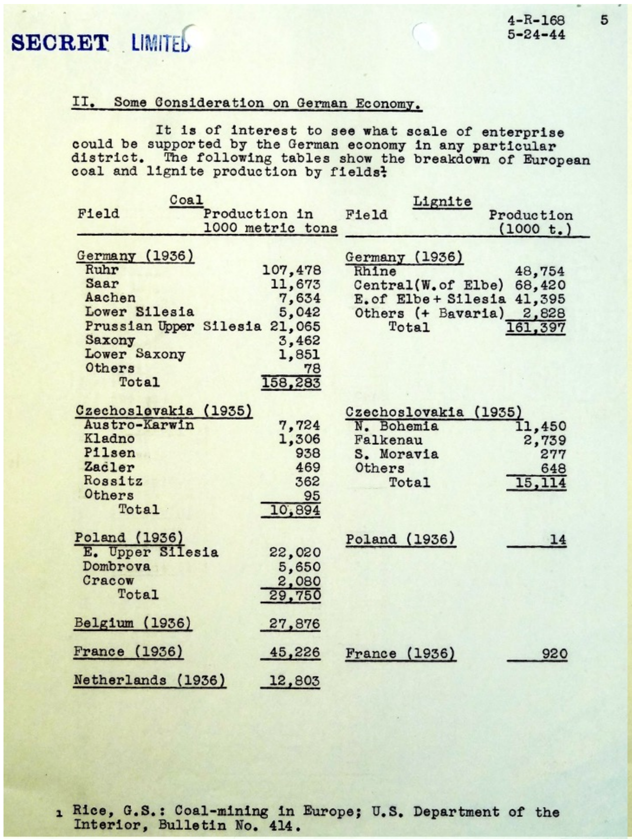
LTD: Tenth-scale plant or plants, located on rivers or canals near coal fields in central or sout-east Germany. Upper or lower Silesia particularly suitable. No particular characteristics of tenth-scale plants to distinguish from any other medium scale manufacturing enterprise. Large power plant but not excessive. No evidence of recent construction.

K-25: Full-scale plant easily recognizable by large surface area like assembly plant. However, no assembled product. Large power plant, but not excessive. For location, see LTD above.

Centrifuges: Half-scale plant or plants. Possible location as for LTD, but other possibility is behind Berlin, as coal requirement is less. This situation could be defended by capitol's anti-aircraft defenses, and benefit by proximity to fine machinery industry. Not necessarily located on a large river or canal.

NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)

Figure D.813: Karl Cohen. 24 May 1944. Requirements. [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]



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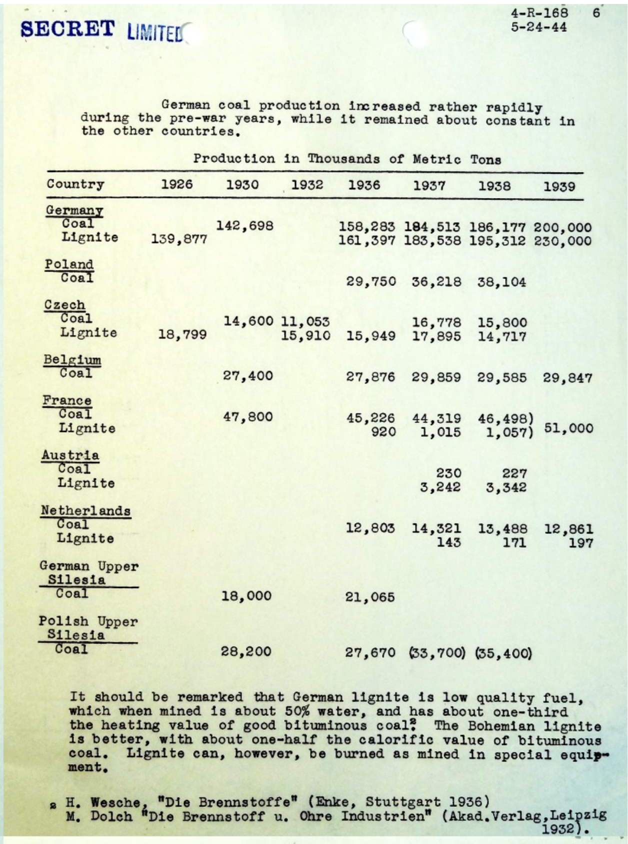
II. Some Consideration on German Economy.

It is of interest to see what scale of enterprise could be supported by the German economy in any particular district. The following tables show the breakdown of European coal and lignite production by fields[1]:

Coal Field	Production in 1000 metric tons	Lignite Field	Production (1000 t.)
Germany (1936)		Germany (1936)	
Ruhr	107,478	Rhine	48,754
Saar	11,673	Central(W.of Elbe)	68,420
Aachen	7,634	E.of Elbe + Silesia	41,395
Lower Silesia	5,042	Others (+ Bavaria)	2,828
Prussian Upper Silesia	21,065	Total	161,397
Saxony	3,462		
Lower Saxony	1,851		
Others	78		
Total	158,283		
Czechoslovakia (1935)		Czechoslovakia (1935)	
Austro-Karwin	7,724	N. Bohemia	11,450
Kladno	1,306	Falkenau	2,739
Pilsen	938	S. Moravia	277
Zacler	469	Others	648
Rossitz	362	Total	15,114
Others	95		
Total	10,894		
Poland (1936)		Poland (1936)	14
E. Upper Silesia	22,020		
Dombrova	5,650		
Cracow	2,080		
Total	29,750		
Belgium (1936)	27,876		
France (1936)	45,226	France (1936)	920
Netherlands (1936)	12,803		

[1] Rice, G.S.: Coal-mining in Europe; U.S. Department of the Interior, Bulletin No. 414.



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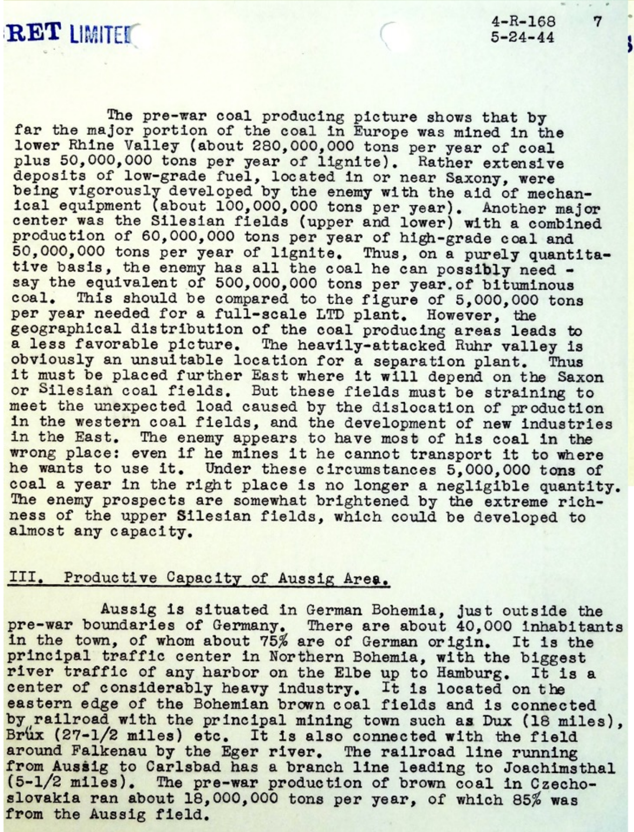
German coal production increased rather rapidly during the pre-war years, while it remained about constant in the other countries.

Production in Thousands of Metric Tons

Country	1926	1930	1932	1936	1937	1938	1939
Germany							
Coal		142,698		158,283	184,513	186,177	200,000
Lignite	139,877			161,397	183,538	195,312	230,000
Poland							
Coal				29,750	36,218	38,104	
Czech							
Coal		14,600	11,053		16,778	15,800	
Lignite	18,799		15,910	15,949	17,895	14,717	
Belgium							
Coal		27,400		27,876	29,859	29,585	29,847
France							
Coal		47,800		45,226	44,319	46,498)	51,000
Lignite				920	1,015	1,057)	
Austria							
Coal					230	227	
Lignite					3,242	3,342	
Netherlands							
Coal				12,803	14,321	13,488	12,861
Lignite					143	171	197
German Upper Silesia							
Coal		18,000		21,065			
Polish Upper Silesia							
Coal		28,200		27,670	(33,700)	(35,400)	

It should be remarked that German lignite is low quality fuel, which when mined is about 50% water, and has about one-third the heating value of good bituminous coal[2]. The Bohemian lignite is better, with about one-half the calorific value of bituminous coal. Lignite can, however, be burned as mined in special equipment.

[2] H. Wesche, "Die Brennstoffe" (Enke, Stuttgart 1936)
M. Dolch "Die Brennstoff u. Ohre Industrien" (Akad.Verlag,Leipzig 1932).



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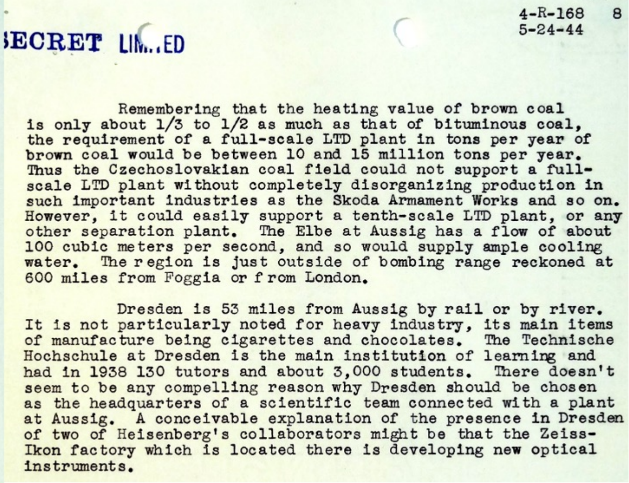
The pre-war coal producing picture shows that by far the major portion of the coal in Europe was mined in the lower Rhine Valley (about 280,000,000 tons per year of coal plus 50,000,000 tons per year of lignite). Rather extensive deposits of low-grade fuel, located in or near Saxony, were being vigorously developed by the enemy with the aid of mechanical equipment (about 100,000,000 tons per year). Another major center was the Silesian fields (upper and lower) with a combined production of 60,000,000 tons per year of high-grade coal and 50,000,000 tons per year of lignite. Thus, on a purely quantitative basis, the enemy has all the coal he can possibly need - say the equivalent of 500,000,000 tons per year.of bituminous coal. This should be compared to the figure of 5,000,000 tons per year needed for a full-scale LTD plant. However, the geographical distribution of the coal producing areas leads to a less favorable picture. The heavily-attacked Ruhr valley is obviously an unsuitable location for a separation plant. Thus it must be placed further East where it will depend on the Saxon or Silesian coal fields. But these fields must be straining to meet the unexpected load caused by the dislocation of production in the western coal fields, and the development of new industries in the East. The enemy appears to have most of his coal in the wrong place: even if he mines it he cannot transport it to where he wants to use it. Under these circumstances 5,000,000 tons of coal a year in the right place is no longer a negligible quantity. The enemy prospects are somewhat brightened by the extreme richness of the upper Silesian fields, which could be developed to almost any capacity.

III. Productive Capacity of Aussig Area.

Aussig is situated in German Bohemia, just outside the pre-war boundaries of Germany. There are about 40,000 inhabitants in the town, of whom about 75% are of German origin. It is the principal traffic center in Northern Bohemia, with the biggest river traffic of any harbor on the Elbe up to Hamburg. It is a center of considerably heavy industry. It is located on the eastern edge of the Bohemian brown coal fields and is connected by railroad with the principal mining town such as Dux (18 miles), Brüx (27-1/2 miles) etc. It is also connected with the field around Falkenau by the Eger river. The railroad line running from Aussig to Carlsbad has a branch line leading to Joachimsthal (5-1/2 miles). The pre-war production of brown coal in Czechoslovakia ran about 18,000,000 tons per year, of which 85% was from the Aussig field.



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Remembering that the heating value of brown coal is only about 1/3 to 1/2 as much as that of bituminous coal, the requirement of a full-scale LTD plant in tons per year of brown coal would be between 10 and 15 million tons per year. Thus the Czechoslovakian coal field could not support a full-scale LTD plant without completely disorganizing production in such important industries as the Skoda Armament Works and so on. However, it could easily support a tenth-scale LTD plant, or any other separation plant. The Elbe at Aussig has a flow of about 100 cubic meters per second, and so would supply ample cooling water. The region is just outside of bombing range reckoned at 600 miles from Foggia or from London.

Dresden is 53 miles from Aussig by rail or by river. It is not particularly noted for heavy industry, its main items of manufacture being cigarettes and chocolates. The Technische Hochschule at Dresden is the main institution of learning and had in 1938 130 tutors and about 3,000 students. There doesn't seem to be any compelling reason why Dresden should be chosen as the headquarters of a scientific team connected with a plant at Aussig. A conceivable explanation of the presence in Dresden of two of Heisenberg's collaborators might be that the Zeiss-Ikon factory which is located there is developing new optical instruments.

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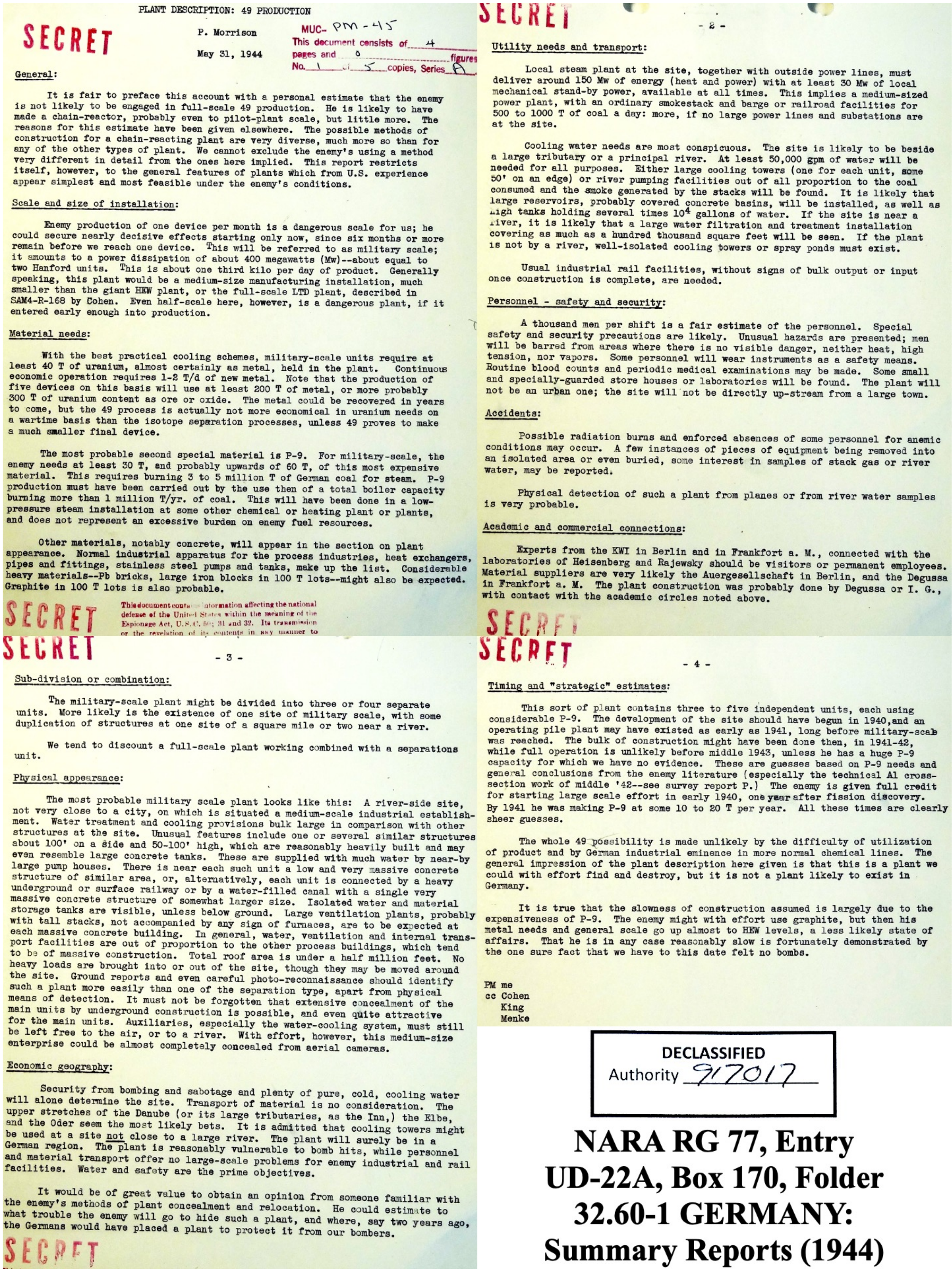
NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)

Figure D.814: Karl Cohen. 24 May 1944. Requirements. [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]



PLANT DESCRIPTION: 49 PRODUCTION

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P. Morrison

May 31, 1944

MUC- PM-45
This document consists of 4
pages and 0 figures
No. 1 of 5 copies, Series A

General:

It is fair to preface this account with a personal estimate that the enemy is not likely to be engaged in full-scale 49 production. He is likely to have made a chain-reactor, probably even to pilot-plant scale, but little more. The reasons for this estimate have been given elsewhere. The possible methods of construction for a chain-reacting plant are very diverse, much more so than for any of the other types of plant. We cannot exclude the enemy's using a method very different in detail from the ones here implied. This report restricts itself, however, to the general features of plants which from U.S. experience appear simplest and most feasible under the enemy's conditions.

Scale and size of installation:

Enemy production of one device per month is a dangerous scale for us; he could secure nearly decisive effects starting only now, since six months or more remain before we reach one device. This will be referred to as military scale; it amounts to a power dissipation of about 400 megawatts (Mw)--about equal to two Hanford units. This is about one third kilo per day of product. Generally speaking, this plant would be a medium-size manufacturing installation, much smaller than the giant HEW plant, or the full-scale LTD plant, described in SAM4-R-168 by Cohen. Even half-scale here, however, is a dangerous plant, if it entered early enough into production.

Material needs:

With the best practical cooling schemes, military-scale units require at least 40 T of uranium, almost certainly as metal, held in the plant. Continuous economic operation requires 1-2 T/d of new metal. Note that the production of five devices on this basis will use at least 200 T of metal, or more probably 300 T of uranium content as ore or oxide. The metal could be recovered in years to come, but the 49 process is actually not more economical in uranium needs on a wartime basis than the isotope separation processes, unless 49 proves to make a much smaller final device.

The most probable second special material is P-9. For military-scale, the enemy needs at least 30 T, and probably upwards of 60 T, of this most expensive material. This requires burning 3 to 5 million T of German coal for steam. P-9 production must have been carried out by the use then of a total boiler capacity burning more than 1 million T/yr. of coal. This will have been done in a low-pressure steam installation at some other chemical or heating plant or plants, and does not represent an excessive burden on enemy fuel resources.

Other materials, notably concrete, will appear in the section on plant appearance. Normal industrial apparatus for the process industries, heat exchangers, pipes and fittings, stainless steel pumps and tanks, make up the list. Considerable heavy materials--Pb bricks, large iron blocks in 100 T lots--might also be expected. Graphite in 100 T lots is also probable.

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Utility needs and transport:

Local steam plant at the site, together with outside power lines, must deliver around 150 Mw of energy (heat and power) with at least 30 Mw of local mechanical stand-by power, available at all times. This implies a medium-sized power plant, with an ordinary smokestack and barge or railroad facilities for 500 to 1000 T of coal a day: more, if no large power lines and substations are at the site.

Cooling water needs are most conspicuous. The site is likely to be beside a large tributary or a principal river. At least 50,000 gpm of water will be needed for all purposes. Either large cooling towers (one for each unit, some 50' on an edge) or river pumping facilities out of all proportion to the coal consumed and the smoke generated by the stacks will be found. It is likely that large reservoirs, probably covered concrete basins, will be installed, as well as high tanks holding several times 10^4 gallons of water. If the site is near a river, it is likely that a large water filtration and treatment installation covering as much as a hundred thousand square feet will be seen. If the plant is not by a river, well-isolated cooling towers or spray ponds must exist.

Usual industrial rail facilities, without signs of bulk output or input once construction is complete, are needed.

Personnel - safety and security:

A thousand men per shift is a fair estimate of the personnel. Special safety and security precautions are likely. Unusual hazards are presented; men will be barred from areas where there is no visible danger, neither heat, high tension, nor vapors. Some personnel will wear instruments as a safety means. Routine blood counts and periodic medical examinations may be made. Some small and specially-guarded store houses or laboratories will be found. The plant will not be an urban one; the site will not be directly up-stream from a large town.

Accidents:

Possible radiation burns and enforced absences of some personnel for anemic conditions may occur. A few instances of pieces of equipment being removed into an isolated area or even buried, some interest in samples of stack gas or river water, may be reported.

Physical detection of such a plant from planes or from river water samples is very probable.

Academic and commercial connections:

Experts from the KWI in Berlin and in Frankfort a. M., connected with the laboratories of Heisenberg and Rajewsky should be visitors or permanent employees. Material suppliers are very likely the Auergesellschaft in Berlin, and the Degussa in Frankfort a. M. The plant construction was probably done by Degussa or I. G., with contact with the academic circles noted above.

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Sub-division or combination:

The military-scale plant might be divided into three or four separate units. More likely is the existence of one site of military scale, with some duplication of structures at one site of a square mile or two near a river.

We tend to discount a full-scale plant working combined with a separations unit.

Physical appearance:

The most probable military scale plant looks like this: A river-side site, not very close to a city, on which is situated a medium-scale industrial establishment. Water treatment and cooling provisions bulk large in comparison with other structures at the site. Unusual features include one or several similar structures about 100' on a side and 50-100' high, which are reasonably heavily built and may even resemble large concrete tanks. These are supplied with much water by near-by large pump houses. There is near each such unit a low and very massive concrete structure of similar area, or, alternatively, each unit is connected by a heavy underground or surface railway or by a water-filled canal with a single very massive concrete structure of somewhat larger size. Isolated water and material storage tanks are visible, unless below ground. Large ventilation plants, probably with tall stacks, not accompanied by any sign of furnaces, are to be expected at each massive concrete building. In general, water, ventilation and internal transport facilities are out of proportion to the other process buildings, which tend to be of massive construction. Total roof area is under a half million feet. No heavy loads are brought into or out of the site, though they may be moved around the site. Ground reports and even careful photo-reconnaissance should identify such a plant more easily than one of the separation type, apart from physical means of detection. It must not be forgotten that extensive concealment of the main units by underground construction is possible, and even quite attractive for the main units. Auxiliaries, especially the water-cooling system, must still be left free to the air, or to a river. With effort, however, this medium-size enterprise could be almost completely concealed from aerial cameras.

Economic geography:

Security from bombing and sabotage and plenty of pure, cold, cooling water will alone determine the site. Transport of material is no consideration. The upper stretches of the Danube (or its large tributaries, as the Inn,) the Elbe, and the Oder seem the most likely bets. It is admitted that cooling towers might be used at a site not close to a large river. The plant will surely be in a German region. The plant is reasonably vulnerable to bomb hits, while personnel and material transport offer no large-scale problems for enemy industrial and rail facilities. Water and safety are the prime objectives.

It would be of great value to obtain an opinion from someone familiar with the enemy's methods of plant concealment and relocation. He could estimate to what trouble the enemy will go to hide such a plant, and where, say two years ago, the Germans would have placed a plant to protect it from our bombers.

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- 4 -

Timing and "strategic" estimates:

This sort of plant contains three to five independent units, each using considerable P-9. The development of the site should have begun in 1940, and an operating pile plant may have existed as early as 1941, long before military-scale was reached. The bulk of construction might have been done then, in 1941-42, while full operation is unlikely before middle 1943, unless he has a huge P-9 capacity for which we have no evidence. These are guesses based on P-9 needs and general conclusions from the enemy literature (especially the technical Al cross-section work of middle '42--see survey report P.) The enemy is given full credit for starting large scale effort in early 1940, one year after fission discovery. By 1941 he was making P-9 at some 10 to 20 T per year. All these times are clearly sheer guesses.

The whole 49 possibility is made unlikely by the difficulty of utilization of product and by German industrial eminence in more normal chemical lines. The general impression of the plant description here given is that this is a plant we could with effort find and destroy, but it is not a plant likely to exist in Germany.

It is true that the slowness of construction assumed is largely due to the expensiveness of P-9. The enemy might with effort use graphite, but then his metal needs and general scale go up almost to HEW levels, a less likely state of affairs. That he is in any case reasonably slow is fortunately demonstrated by the one sure fact that we have to this date felt no bombs.

PM me
cc Cohen
King
Menke

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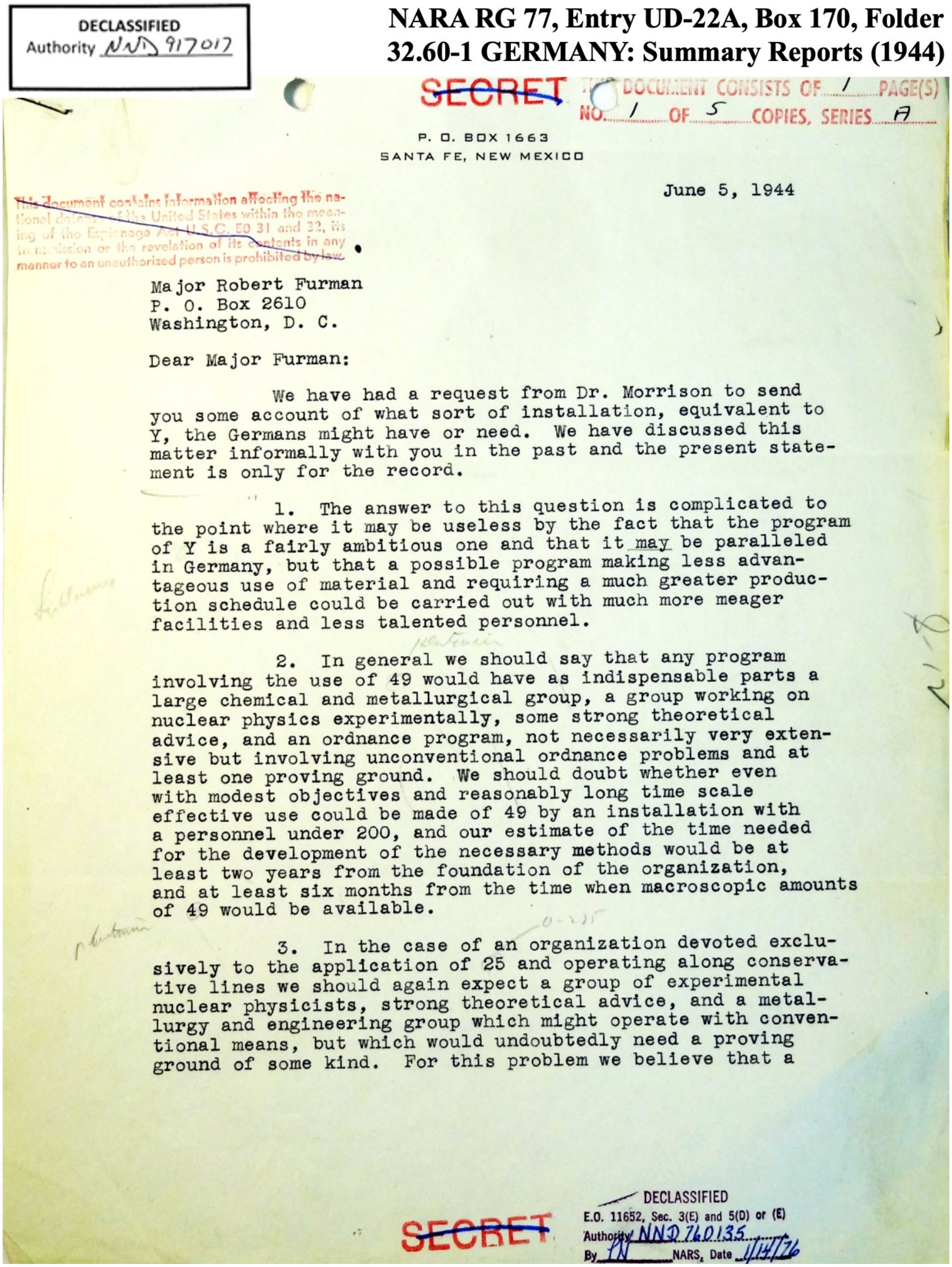
Authority 917017

NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)

Figure D.815: Philip Morrison. 31 May 1944. Plant Description: 49 Production. [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]



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NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)

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THIS DOCUMENT CONSISTS OF 1 PAGE(S)
NO. 1 OF 5 COPIES, SERIES A

P. O. BOX 1663
SANTA FE, NEW MEXICO

June 5, 1944

This document contains information affecting the national defense of the United States within the meaning of the Espionage Act U.S.C. 50 31 and 32, its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

Major Robert Furman
P. O. Box 2610
Washington, D. C.

Dear Major Furman:

We have had a request from Dr. Morrison to send you some account of what sort of installation, equivalent to Y, the Germans might have or need. We have discussed this matter informally with you in the past and the present statement is only for the record.

1. The answer to this question is complicated to the point where it may be useless by the fact that the program of Y is a fairly ambitious one and that it may be paralleled in Germany, but that a possible program making less advantageous use of material and requiring a much greater production schedule could be carried out with much more meager facilities and less talented personnel.

plutonium

2. In general we should say that any program involving the use of 49 would have as indispensable parts a large chemical and metallurgical group, a group working on nuclear physics experimentally, some strong theoretical advice, and an ordnance program, not necessarily very extensive but involving unconventional ordnance problems and at least one proving ground. We should doubt whether even with modest objectives and reasonably long time scale effective use could be made of 49 by an installation with a personnel under 200, and our estimate of the time needed for the development of the necessary methods would be at least two years from the foundation of the organization, and at least six months from the time when macroscopic amounts of 49 would be available.

plutonium

U-235

3. In the case of an organization devoted exclusively to the application of 25 and operating along conservative lines we should again expect a group of experimental nuclear physicists, strong theoretical advice, and a metallurgy and engineering group which might operate with conventional means, but which would undoubtedly need a proving ground of some kind. For this problem we believe that a

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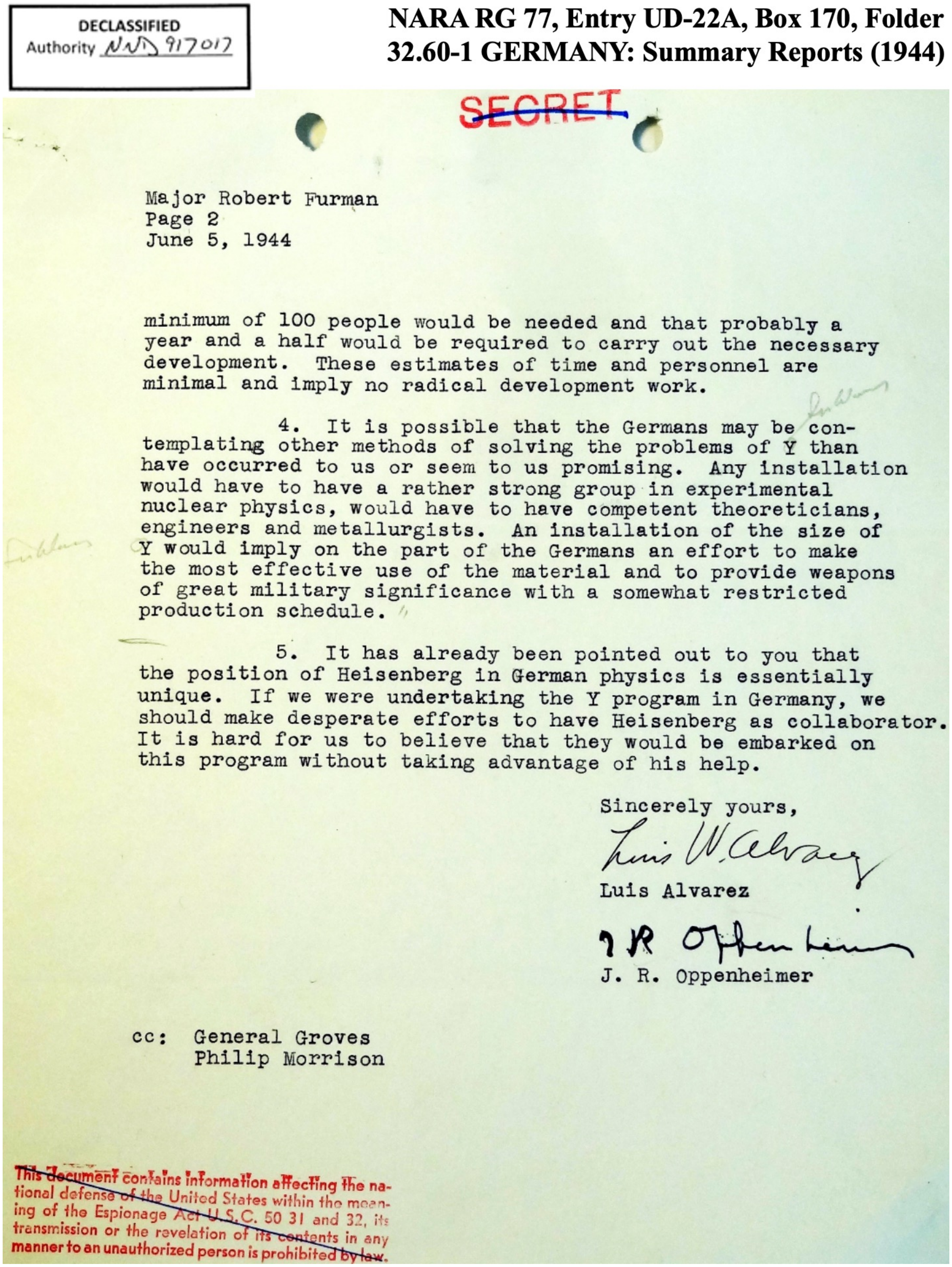
E.O. 11652, Sec. 3(E) and 5(D) or (E)
Authority NND 760135
By TN NARS, Date 1/14/76

Figure D.816: Luis Alvarez and J. Robert Oppenheimer to Robert Furman. 5 June 1944 [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].



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NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)

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Major Robert Furman
Page 2
June 5, 1944

minimum of 100 people would be needed and that probably a year and a half would be required to carry out the necessary development. These estimates of time and personnel are minimal and imply no radical development work.

4. It is possible that the Germans may be contemplating other methods of solving the problems of Y than have occurred to us or seem to us promising. Any installation would have to have a rather strong group in experimental nuclear physics, would have to have competent theoreticians, engineers and metallurgists. An installation of the size of Y would imply on the part of the Germans an effort to make the most effective use of the material and to provide weapons of great military significance with a somewhat restricted production schedule.

5. It has already been pointed out to you that the position of Heisenberg in German physics is essentially unique. If we were undertaking the Y program in Germany, we should make desperate efforts to have Heisenberg as collaborator. It is hard for us to believe that they would be embarked on this program without taking advantage of his help.

Sincerely yours,

Luis W. Alvarez
Luis Alvarez

J R Oppenheimer
J. R. Oppenheimer

cc: General Groves
Philip Morrison

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Figure D.817: Luis Alvarez and J. Robert Oppenheimer to Robert Furman. 5 June 1944 [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Luis Alvarez and J. Robert Oppenheimer to Robert Furman. 5 June 1944. [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)]

P. O. BOX 1663
SANTA FE, NEW MEXICO

June 5, 1944

Major Robert Furman
P. O. Box 2610
Washington, D.C.

Dear Major Furman:

We have had a request from Dr. Morrison to send you some account of what sort of installation, equivalent to Y [Project Y = Los Alamos, i.e., production of nuclear bombs], the Germans might have or need. We have discussed this matter informally with you in the past and the present statement is only for the record.

1. The answer to this question is complicated to the point where it may be useless by the fact that the program of Y is a fairly ambitious one and that it may be paralleled in Germany, but that a possible program making less advantageous use of material and requiring a much greater production schedule could be carried out with much more meager facilities and less talented personnel.

2. In general we should say that any program involving the use of 49 [plutonium-239] would have as indispensable parts a large chemical and metallurgical group, a group working on nuclear physics experimentally, some strong theoretical advice, and an ordnance program, not necessarily very extensive but involving unconventional ordnance problems and at least one proving ground. We should doubt whether even with modest objectives and reasonably long time scale effective use could be made of 49 by an installation with a personnel under 200, and our estimate of the time needed for the development of the necessary methods would be at least two years from the foundation of the organization, and at least six months from the time when macroscopic amounts of 49 would be available.

3. In the case of an organization devoted exclusively to the application of 25 [uranium-235] and operating along conservative lines we should again expect a group of experimental nuclear physicists, strong theoretical advice, and a metallurgy and engineering group which might operate with conventional means, but which would undoubtedly need a proving ground of some kind. For this problem we believe that a minimum of 100 people would be needed and that probably a year and half would be required to carry out the necessary development. These estimates of time and personnel are minimal and imply no radical development work.

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Sincerely yours,

Luis Alvarez

J. R. Oppenheimer

cc: General Groves
Philip Morrison

Robert R. Furman to Leslie R. Groves. 13 June 1944. Subject: Report of Meetings in London from 24 May to 3 June 1944. [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)]

[...] 5. Professor Jensen of Hamburg, who was reporting directly to Bohr on activities in Germany and Norway, has not come out of Germany again since Bohr's escape. It is suspected that he is either dead or came to Bohr with definite intentions to spy.

6. Dresden, often rumored to be active in the project field, was definitely tied to the crossbow project and to hydrogen peroxide, the propellant of the rocket. Little evidence is now at hand which can prove that Dresden is active in the field except in minor experimental research.

7. Bohr has new fears of German activity and after a meeting with me wrote a full report of his feelings in the matter which is attached. A plan was initiated to aid a German scientific publisher who has written neutrals of his intention to escape from Nazi Germany.

8. Several teams parachuted into Czechoslovakia on other business and have been requested to report on activities at Dresden and Joachimsthal. [...]

[This NARA document references attachments that are no longer with it. Where did they go?]

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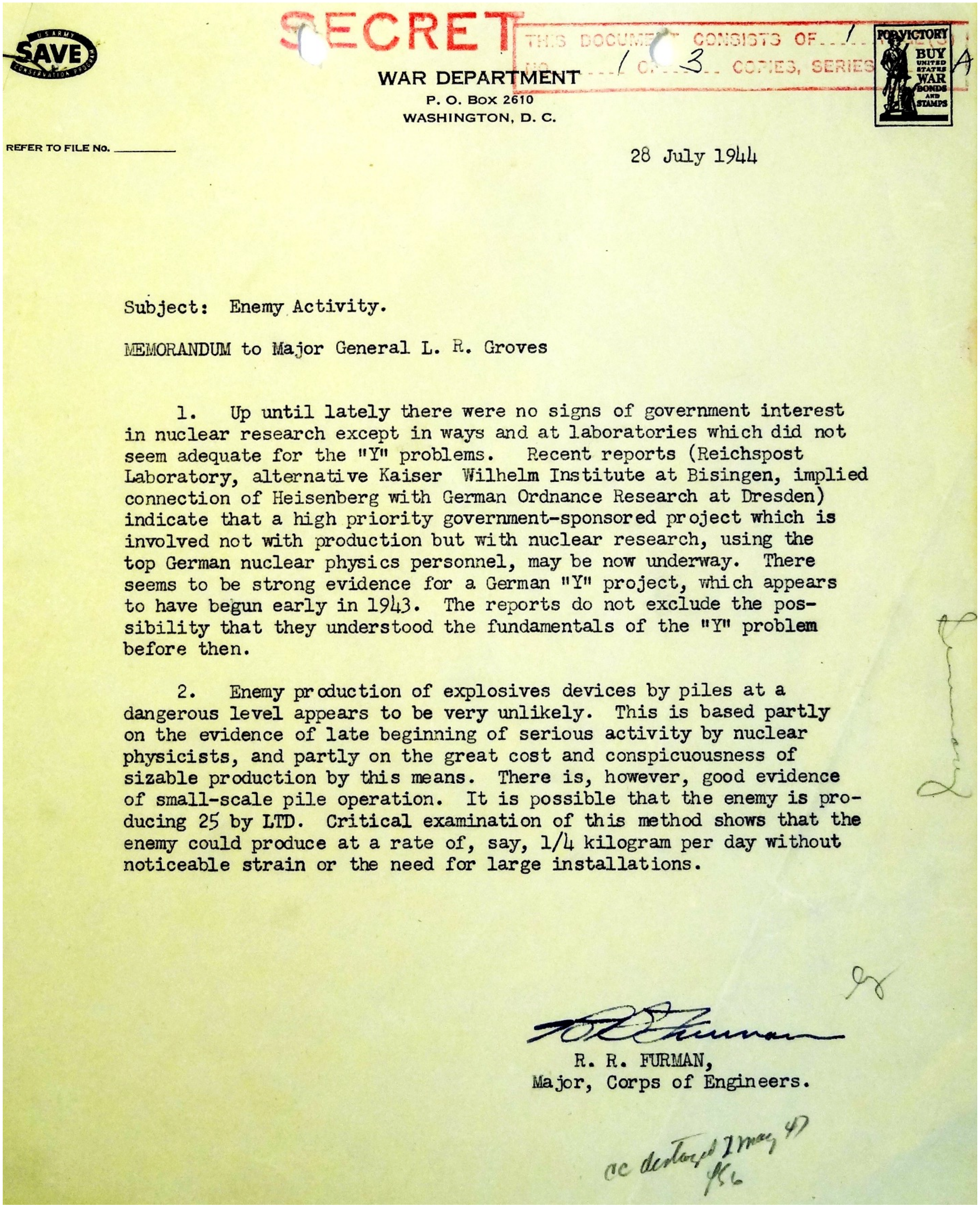
NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)



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NO. 1 OF 3 COPIES, SERIES A

WAR DEPARTMENT
P. O. Box 2610
WASHINGTON, D. C.

FOR VICTORY BUY UNITED STATES WAR BONDS AND STAMPS

REFER TO FILE NO. ________

28 July 1944

Subject: Enemy Activity.

MEMORANDUM to Major General L. R. Groves

1. Up until lately there were no signs of government interest in nuclear research except in ways and at laboratories which did not seem adequate for the "Y" problems. Recent reports (Reichspost Laboratory, alternative Kaiser Wilhelm Institute at Bisingen, implied connection of Heisenberg with German Ordnance Research at Dresden) indicate that a high priority government-sponsored project which is involved not with production but with nuclear research, using the top German nuclear physics personnel, may be now underway. There seems to be strong evidence for a German "Y" project, which appears to have begun early in 1943. The reports do not exclude the possibility that they understood the fundamentals of the "Y" problem before then.

2. Enemy production of explosives devices by piles at a dangerous level appears to be very unlikely. This is based partly on the evidence of late beginning of serious activity by nuclear physicists, and partly on the great cost and conspicuousness of sizable production by this means. There is, however, good evidence of small-scale pile operation. It is possible that the enemy is producing 25 by LTD. Critical examination of this method shows that the enemy could produce at a rate of, say, 1/4 kilogram per day without noticeable strain or the need for large installations.

Gr

R. R. Furman

R. R. FURMAN,
Major, Corps of Engineers.

cc destroyed 1 May 47
[illegible]

Figure D.818: Robert Furman to Leslie Groves. 28 July 1944. Subject: Enemy Activity [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Philip Morrison and Karl Cohen. 31 July 1944. Appraisal of Enemy Bomb Production. [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944]

APPRAISAL OF ENEMY BOMB PRODUCTION

Summary

Recent evidence essentially confirms our earlier general statements on enemy bomb production. The reports now at hand lead us to conclude:

1. A German "Y" project has been underway since early 1943. [Project Y = Los Alamos, i.e., production of nuclear bombs.]

2. A D_2O pile is in operation, but we do not believe that this is on production level.

3. It is implied that a separation method is operating at a production level, for it is surely improbable that the enemy will organize a utilization group without something to use.

We include a time schedule, and a technical discuss of the probable means employed.

Enemy production of devices can be as high as:

1. 1 device every 3 months—on the assumption that 30 kg of material are required per device.

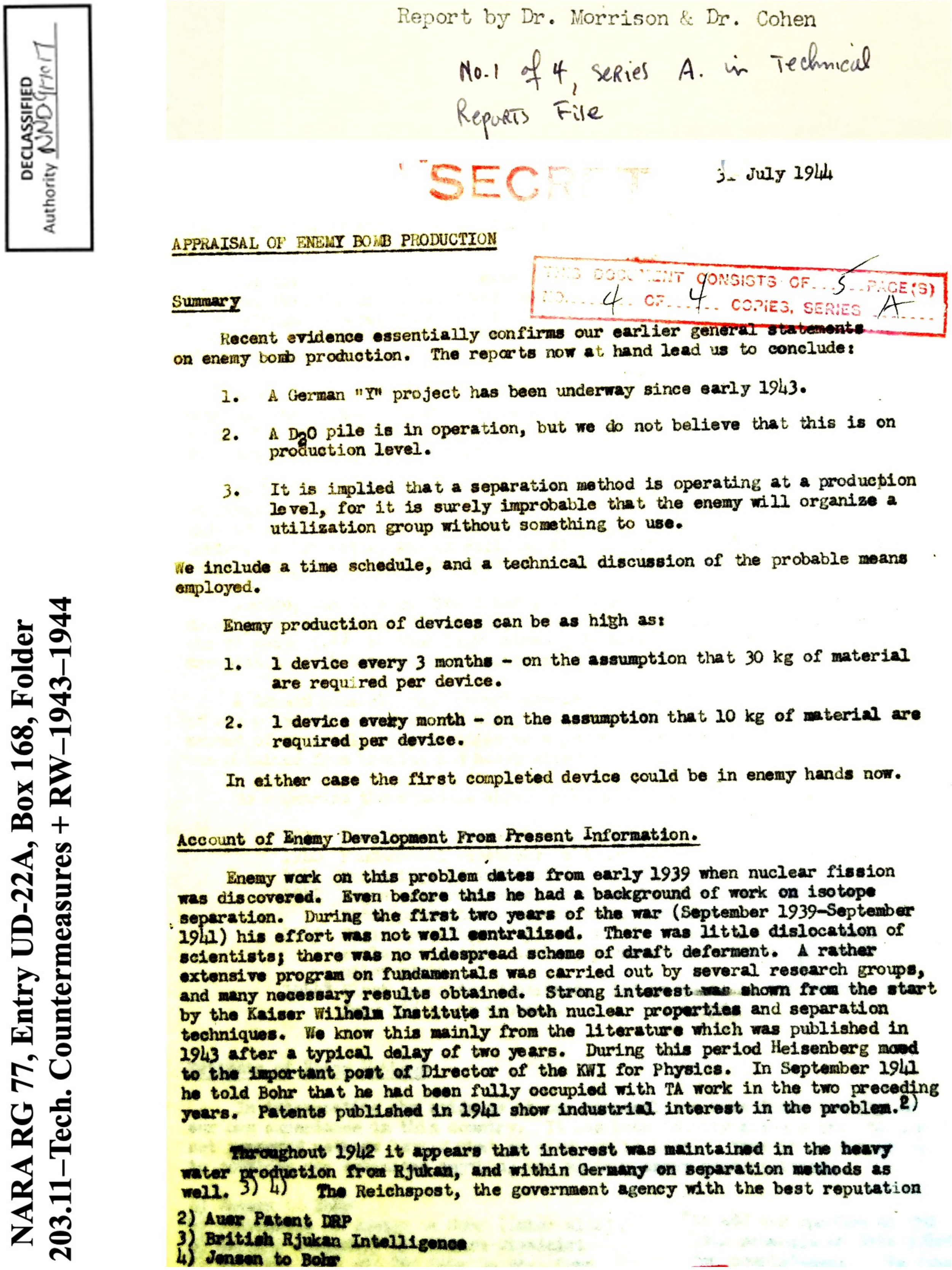
2. 1 device every month—on the assumption that 10 kg of material are required per device.

In either case the first completed device could be in enemy hands now.

[Morrison and Cohen then spent several pages of their 31 July 1944 memo explaining their assumptions and calculations that led to these estimates. See pp. 4743–4744 for photos of the complete memo.

U.S. Manhattan Project scientists wrote a number of memos that proposed various scenarios by which Germany could be pursuing a nuclear weapons program that would be consistent both with what little information Allied intelligence had from Germany and also with the scientific requirements of U-235/Pu-239/U-233 production that the Manhattan Project scientists had learned firsthand. The memos shown here are just a few examples.

The basic conclusion of all of these memos was that as far as Allied intelligence and the inherent requirements of nuclear physics could tell, it was entirely possible (although certainly not proven) that Germany could be producing enough U-235, Pu-239, and/or U-233 for nuclear weapons.]



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NARA RG 77, Entry UD-22A, Box 168, Folder 203.11–Tech. Countermeasures + RW–1943–1944

Report by Dr. Morrison & Dr. Cohen

No. 1 of 4, series A. in Technical Reports File

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31 July 1944

THIS DOCUMENT CONSISTS OF 5 PAGE(S)
NO. 4 OF 4 COPIES, SERIES A

APPRAISAL OF ENEMY BOMB PRODUCTION

Summary

Recent evidence essentially confirms our earlier general statements on enemy bomb production. The reports now at hand lead us to conclude:

1. A German "Y" project has been underway since early 1943.
2. A D_2O pile is in operation, but we do not believe that this is on production level.
3. It is implied that a separation method is operating at a production level, for it is surely improbable that the enemy will organize a utilization group without something to use.

We include a time schedule, and a technical discussion of the probable means employed.

Enemy production of devices can be as high as:

1. 1 device every 3 months - on the assumption that 30 kg of material are required per device.
2. 1 device every month - on the assumption that 10 kg of material are required per device.

In either case the first completed device could be in enemy hands now.

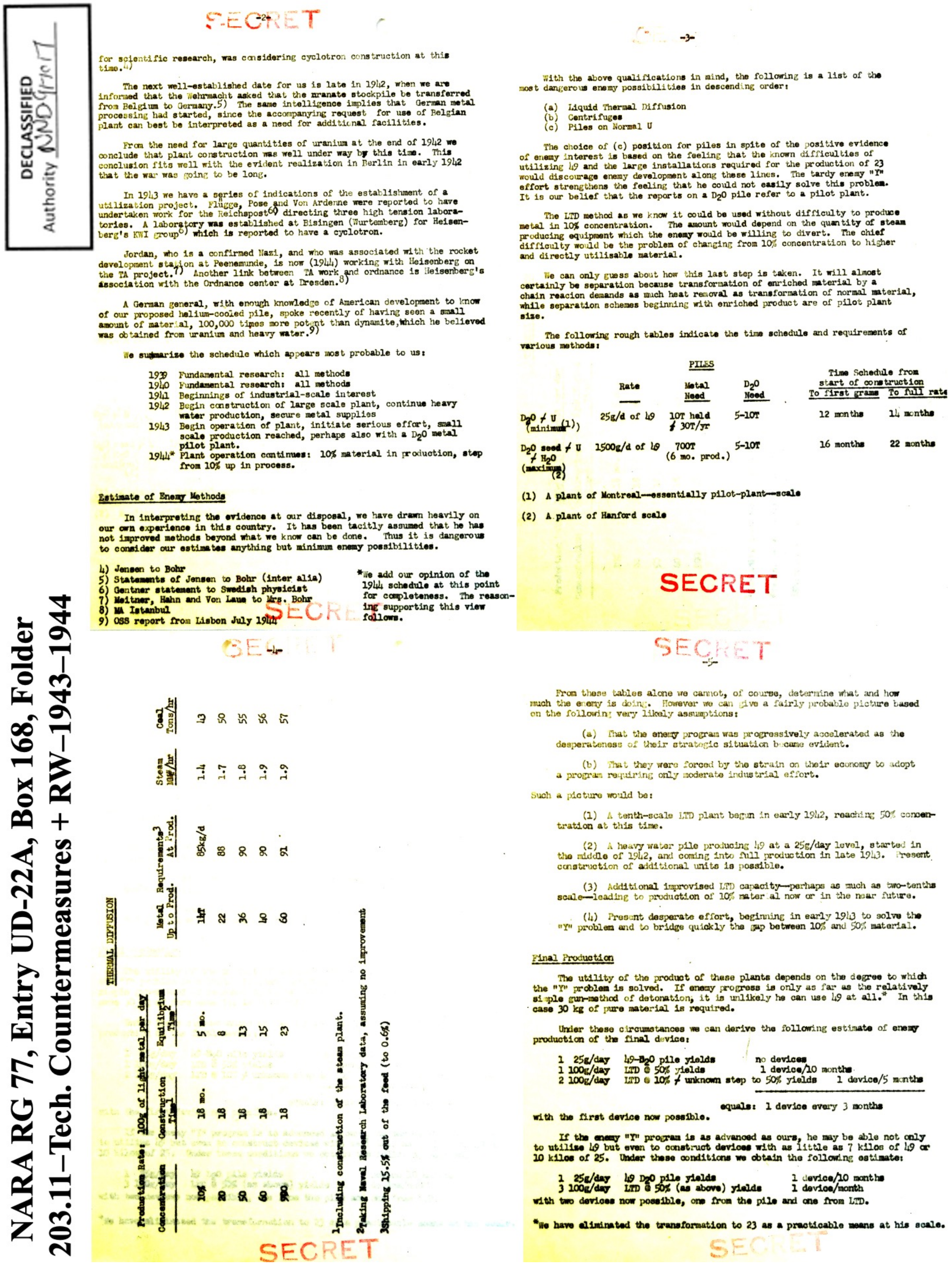
Account of Enemy Development From Present Information.

Enemy work on this problem dates from early 1939 when nuclear fission was discovered. Even before this he had a background of work on isotope separation. During the first two years of the war (September 1939–September 1941) his effort was not well centralized. There was little dislocation of scientists; there was no widespread scheme of draft deferment. A rather extensive program on fundamentals was carried out by several research groups, and many necessary results obtained. Strong interest was shown from the start by the Kaiser Wilhelm Institute in both nuclear properties and separation techniques. We know this mainly from the literature which was published in 1943 after a typical delay of two years. During this period Heisenberg moved to the important post of Director of the KWI for Physics. In September 1941 he told Bohr that he had been fully occupied with TA work in the two preceding years. Patents published in 1941 show industrial interest in the problem.2)

Throughout 1942 it appears that interest was maintained in the heavy water production from Rjukan, and within Germany on separation methods as well. 3) 4) The Reichspost, the government agency with the best reputation

2) Auer Patent DRP
3) British Rjukan Intelligence
4) Jensen to Bohr

Figure D.819: Philip Morrison and Karl Cohen. 31 July 1944. Appraisal of Enemy Bomb Production. [Y=nuclear bombs, 49=plutonium-239, 23=uranium-233, 25=uranium-235] [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944]



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NARA RG 77, Entry UD-22A, Box 168, Folder 203.11–Tech. Countermeasures + RW–1943–1944

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for scientific research, was considering cyclotron construction at this time.4)

The next well-established date for us is late in 1942, when we are informed that the Wehrmacht asked that the uranate stockpile be transferred from Belgium to Germany.5) The same intelligence implies that German metal processing had started, since the accompanying request for use of Belgian plant can best be interpreted as a need for additional facilities.

From the need for large quantities of uranium at the end of 1942 we conclude that plant construction was well under way by this time. This conclusion fits well with the evident realization in Berlin in early 1942 that the war was going to be long.

In 1943 we have a series of indications of the establishment of a utilization project. Flügge, Pose and Von Ardenne were reported to have undertaken work for the Reichspost6) directing three high tension laboratories. A laboratory was established at Bisingen (Wurtemberg) for Heisenberg's KWI group6) which is reported to have a cyclotron.

Jordan, who is a confirmed Nazi, and who was associated with the rocket development station at Peenemunde, is now (1944) working with Heisenberg on the TA project.7) Another link between TA work and ordnance is Heisenberg's association with the Ordnance center at Dresden.8)

A German general, with enough knowledge of American development to know of our proposed helium-cooled pile, spoke recently of having seen a small amount of material, 100,000 times more potent than dynamite, which he believed was obtained from uranium and heavy water.9)

We summarize the schedule which appears most probable to us:

1939	Fundamental research: all methods
1940	Fundamental research: all methods
1941	Beginnings of industrial-scale interest
1942	Begin construction of large scale plant, continue heavy water production, secure metal supplies
1943	Begin operation of plant, initiate serious effort, small scale production reached, perhaps also with a D_2O metal pilot plant.
1944*	Plant operation continues: 10% material in production, step from 10% up in process.

Estimate of Enemy Methods

In interpreting the evidence at our disposal, we have drawn heavily on our own experience in this country. It has been tacitly assumed that he has not improved methods beyond what we know can be done. Thus it is dangerous to consider our estimates anything but minimum enemy possibilities.

4) Jensen to Bohr
5) Statements of Jensen to Bohr (inter alia)
6) Gentner statement to Swedish physicist
7) Meitner, Hahn and Von Laue to Mrs. Bohr
8) MA Istanbul
9) OSS report from Lisbon July 1944

*We add our opinion of the 1944 schedule at this point for completeness. The reasoning supporting this view follows.

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-3-

With the above qualifications in mind, the following is a list of the most dangerous enemy possibilities in descending order:

(a) Liquid Thermal Diffusion
(b) Centrifuges
(c) Piles on Normal U

The choice of (c) position for piles in spite of the positive evidence of enemy interest is based on the feeling that the known difficulties of utilizing 49 and the large installations required for the production of 23 would discourage enemy development along these lines. The tardy enemy "Y" effort strengthens the feeling that he could not easily solve this problem. It is our belief that the reports on a D_2O pile refer to a pilot plant.

The LTD method as we know it could be used without difficulty to produce metal in 10% concentration. The amount would depend on the quantity of steam producing equipment which the enemy would be willing to divert. The chief difficulty would be the problem of changing from 10% concentration to higher and directly utilisable material.

We can only guess about how this last step is taken. It will almost certainly be separation because transformation of enriched material by a chain reacion demands as much heat removal as transformation of normal material, while separation schemes beginning with enriched product are of pilot plant size.

The following rough tables indicate the time schedule and requirements of various methods:

PILES

	Rate	Metal Need	D_2O Need	Time Schedule from start of construction To first grams	 To full rate
D_2O + U (minimum(1))	25g/d of 49	10T held + 30T/yr	5-10T	12 months	14 months
D_2O seed + U + H_2O (maximum(2))	1500g/d of 49	700T (6 mo. prod.)	5-10T	16 months	22 months

(1) A plant of Montreal—essentially pilot-plant—scale

(2) A plant of Hanford scale

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THERMAL DIFFUSION

Production Rate: 100g of light metal per day

Concentration	Construction Time[1]	Equilibrium Time[2]	Metal Requirements[3] Up to Prod.	 At Prod.	Steam MM#/hr	Coal Tons/hr
10%	18 mo.	5 mo.	14T	85kg/d	1.4	43
20	18	8	22	88	1.7	50
50	18	13	36	90	1.8	55
60	18	15	40	90	1.9	56
90	18	23	60	91	1.9	57

[1] Including construction of the steam plant.

[2] Taking Naval Research Laboratory data, assuming no improvement

[3] Shipping 15.5% out of the feed (to 0.6%)

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-5-

From these tables alone we cannot, of course, determine what and how much the enemy is doing. However we can give a fairly probable picture based on the following very likely assumptions:

(a) That the enemy program was progressively accelerated as the desperateness of their strategic situation became evident.

(b) That they were forced by the strain on their economy to adopt a program requiring only moderate industrial effort.

Such a picture would be:

(1) A tenth-scale LTD plant begun in early 1942, reaching 50% concentration at this time.

(2) A heavy water pile producing 49 at a 25g/day level, started in the middle of 1942, and coming into full production in late 1943. Present construction of additional units is possible.

(3) Additional improvised LTD capacity—perhaps as much as two-tenths scale—leading to production of 10% material now or in the near future.

(4) Present desperate effort, beginning in early 1943 to solve the "Y" problem and to bridge quickly the gap between 10% and 50% material.

Final Production

The utility of the product of these plants depends on the degree to which the "Y" problem is solved. If enemy progress is only as far as the relatively simple gun-method of detonation, it is unlikely he can use 49 at all.* In this case 30 kg of pure material is required.

Under these circumstances we can derive the following estimate of enemy production of the final device:

1	25g/day	49-D_2O pile yields	no devices
1	100g/day	LTD @ 50% yields	1 device/10 months
2	100g/day	LTD @ 10% + unknown step to 50% yields	1 device/5 months

equals: 1 device every 3 months

with the first device now possible.

If the enemy "Y" program is as advanced as ours, he may be able not only to utilise 49 but even to construct devices with as little as 7 kilos of 49 or 10 kilos of 25. Under these conditions we obtain the following estimate:

1	25g/day	49 D_2O pile yields	1 device/10 months
3	100g/day	LTD @ 50% (as above) yields	1 device/month

with two devices now possible, one from the pile and one from LTD.

*We have eliminated the transformation to 23 as a practicable means at his scale.

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Figure D.820: Philip Morrison and Karl Cohen. 31 July 1944. Appraisal of Enemy Bomb Production. [Y=nuclear bombs, 49=plutonium-239, 23=uranium-233, 25=uranium-235] [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944]

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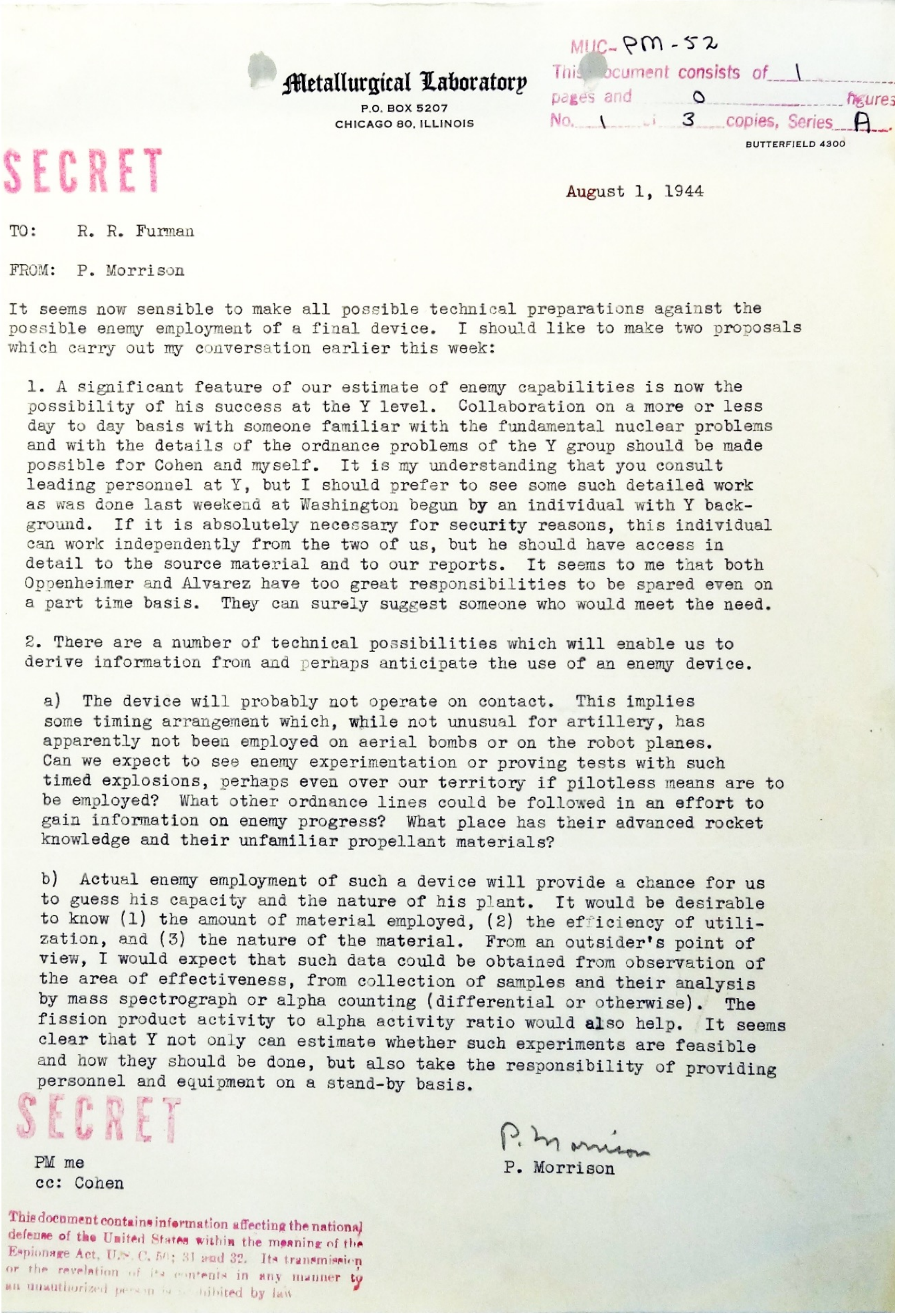

MUC-PM-52
This document consists of 1 pages and 0 figures
No. 1 of 3 copies, Series A

Metallurgical Laboratory
P.O. BOX 5207
CHICAGO 80, ILLINOIS
BUTTERFIELD 4300

SECRET

August 1, 1944

TO: R. R. Furman

FROM: P. Morrison

It seems now sensible to make all possible technical preparations against the possible enemy employment of a final device. I should like to make two proposals which carry out my conversation earlier this week:

1. A significant feature of our estimate of enemy capabilities is now the possibility of his success at the Y level. Collaboration on a more or less day to day basis with someone familiar with the fundamental nuclear problems and with the details of the ordnance problems of the Y group should be made possible for Cohen and myself. It is my understanding that you consult leading personnel at Y, but I should prefer to see some such detailed work as was done last weekend at Washington begun by an individual with Y background. If it is absolutely necessary for security reasons, this individual can work independently from the two of us, but he should have access in detail to the source material and to our reports. It seems to me that both Oppenheimer and Alvarez have too great responsibilities to be spared even on a part time basis. They can surely suggest someone who would meet the need.

2. There are a number of technical possibilities which will enable us to derive information from and perhaps anticipate the use of an enemy device.

a) The device will probably not operate on contact. This implies some timing arrangement which, while not unusual for artillery, has apparently not been employed on aerial bombs or on the robot planes. Can we expect to see enemy experimentation or proving tests with such timed explosions, perhaps even over our territory if pilotless means are to be employed? What other ordnance lines could be followed in an effort to gain information on enemy progress? What place has their advanced rocket knowledge and their unfamiliar propellant materials?

b) Actual enemy employment of such a device will provide a chance for us to guess his capacity and the nature of his plant. It would be desirable to know (1) the amount of material employed, (2) the efficiency of utilization, and (3) the nature of the material. From an outsider's point of view, I would expect that such data could be obtained from observation of the area of effectiveness, from collection of samples and their analysis by mass spectrograph or alpha counting (differential or otherwise). The fission product activity to alpha activity ratio would also help. It seems clear that Y not only can estimate whether such experiments are feasible and how they should be done, but also take the responsibility of providing personnel and equipment on a stand-by basis.

SECRET

P. Morrison
P. Morrison

PM me
cc: Cohen

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NARA RG 77, Entry UD-22A, Box 168, Folder 203.11–Tech. Countermeasures + RW–1943–1944

Figure D.821: Philip Morrison to Robert R. Furman. 1 August 1944 [Y=Los Alamos/nuclear bombs] [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

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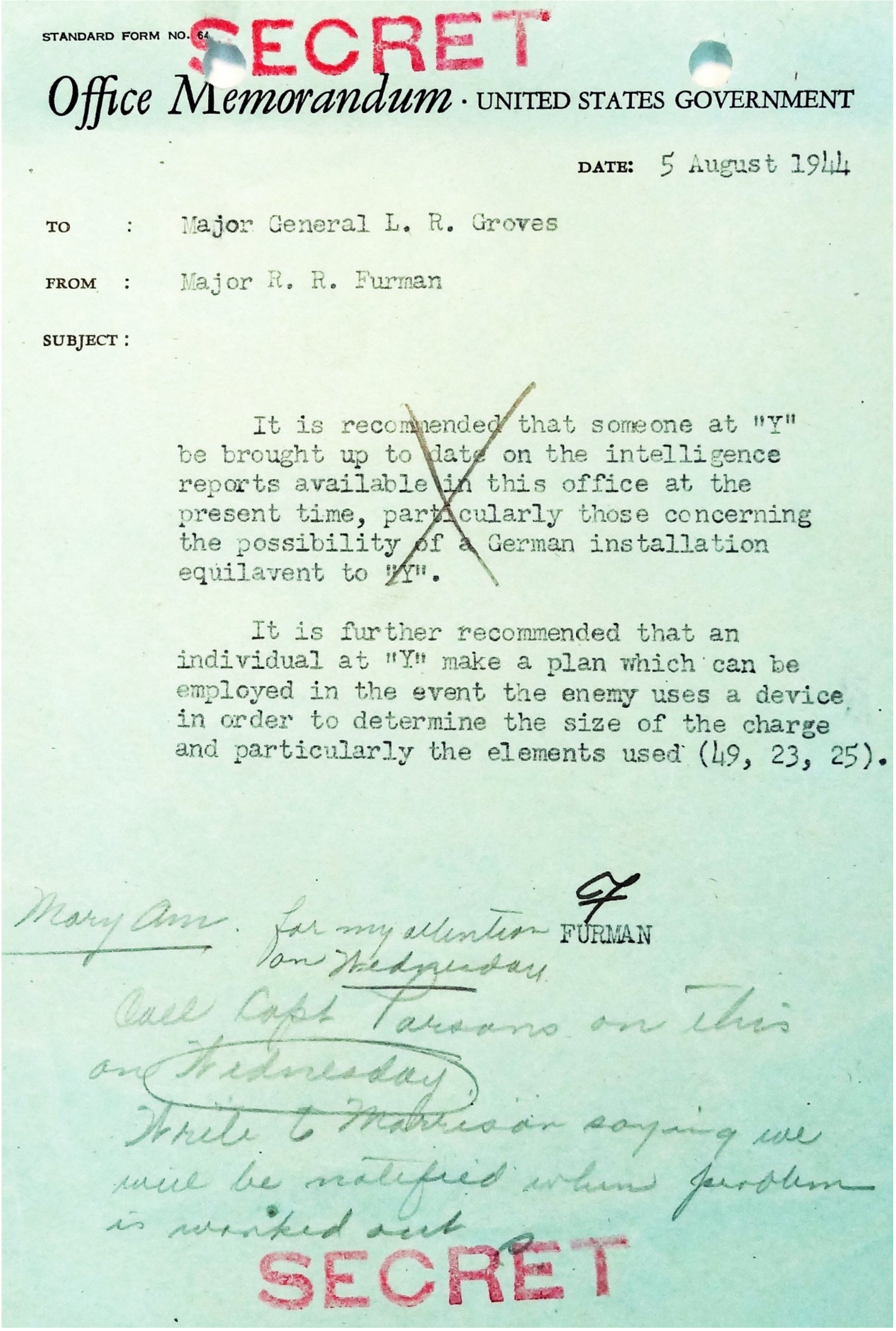

STANDARD FORM NO. 64

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Office Memorandum · UNITED STATES GOVERNMENT

DATE: 5 August 1944

TO : Major General L. R. Groves

FROM : Major R. R. Furman

SUBJECT :

~~It is recommended that someone at "Y" be brought up to date on the intelligence reports available in this office at the present time, particularly those concerning the possibility of a German installation equilavent to "Y".~~

It is further recommended that an individual at "Y" make a plan which can be employed in the event the enemy uses a device in order to determine the size of the charge and particularly the elements used (49, 23, 25).

FURMAN

Mary Ann. for my attention on Wednesday

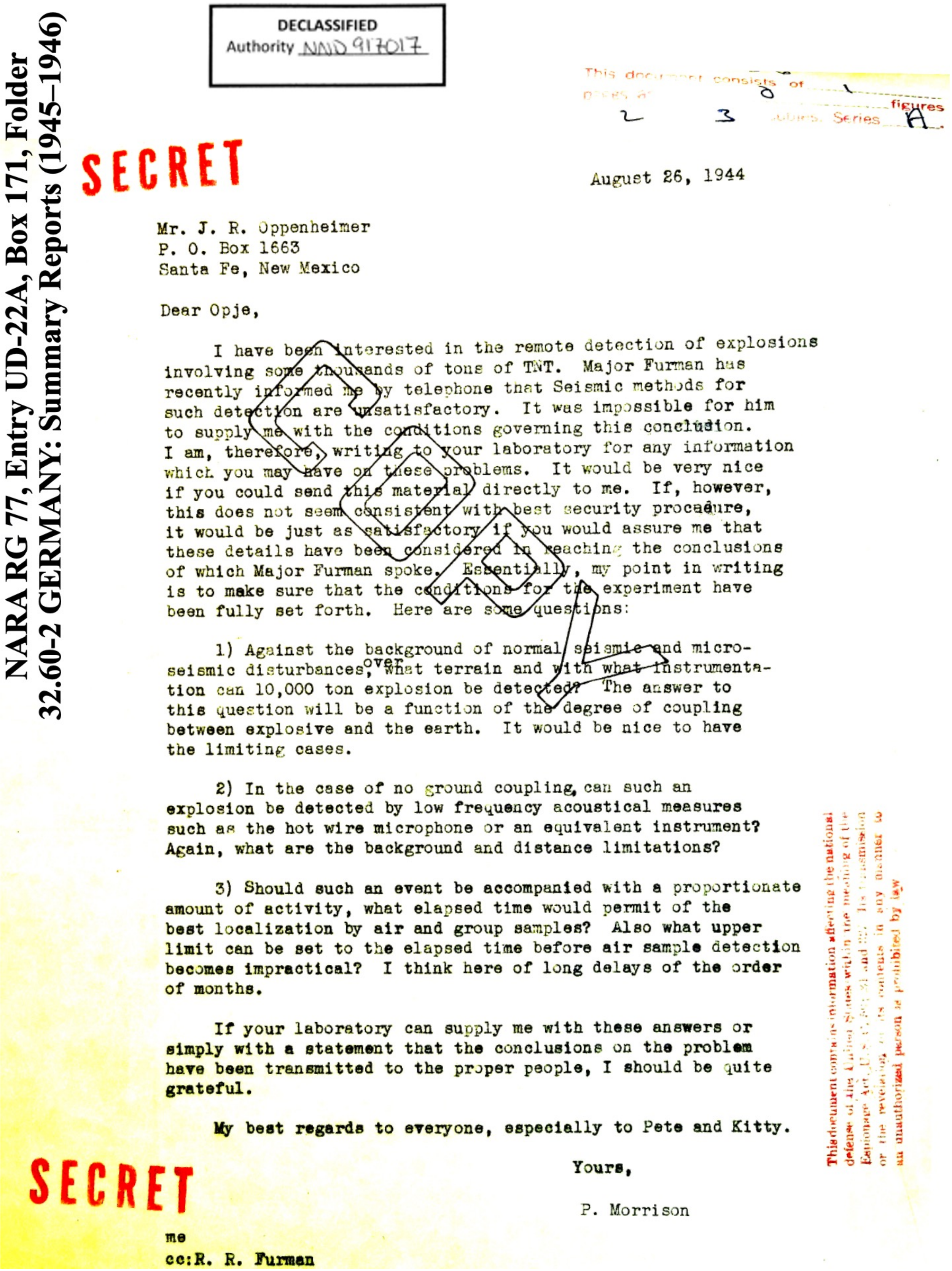
Call Capt Parsons on this on Wednesday

Write to Morrison saying we will be notified when problem is worked out

SECRET

NARA RG 77, Entry UD-22A, Box 168, Folder 203.11–Tech. Countermeasures + RW–1943–1944

Figure D.822: Robert R. Furman to Leslie Groves. 5 August 1944. [Y=Los Alamos/nuclear bombs, 49=plutonium-239, 23=uranium-233, 25=uranium-235] [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944]



NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)

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August 26, 1944

Mr. J. R. Oppenheimer
P. O. Box 1663
Santa Fe, New Mexico

Dear Opje,

I have been interested in the remote detection of explosions involving some thousands of tons of TNT. Major Furman has recently informed me by telephone that Seismic methods for such detection are unsatisfactory. It was impossible for him to supply me with the conditions governing this conclusion. I am, therefore, writing to your laboratory for any information which you may have on these problems. It would be very nice if you could send this material directly to me. If, however, this does not seem consistent with best security procedure, it would be just as satisfactory if you would assure me that these details have been considered in reaching the conclusions of which Major Furman spoke. Essentially, my point in writing is to make sure that the conditions for the experiment have been fully set forth. Here are some questions:

1) Against the background of normal seismic and micro-seismic disturbances, over what terrain and with what instrumentation can 10,000 ton explosion be detected? The answer to this question will be a function of the degree of coupling between explosive and the earth. It would be nice to have the limiting cases.

2) In the case of no ground coupling, can such an explosion be detected by low frequency acoustical measures such as the hot wire microphone or an equivalent instrument? Again, what are the background and distance limitations?

3) Should such an event be accompanied with a proportionate amount of activity, what elapsed time would permit of the best localization by air and group samples? Also what upper limit can be set to the elapsed time before air sample detection becomes impractical? I think here of long delays of the order of months.

If your laboratory can supply me with these answers or simply with a statement that the conclusions on the problem have been transmitted to the proper people, I should be quite grateful.

My best regards to everyone, especially to Pete and Kitty.

Yours,

P. Morrison

SECRET

me
cc:R. R. Furman

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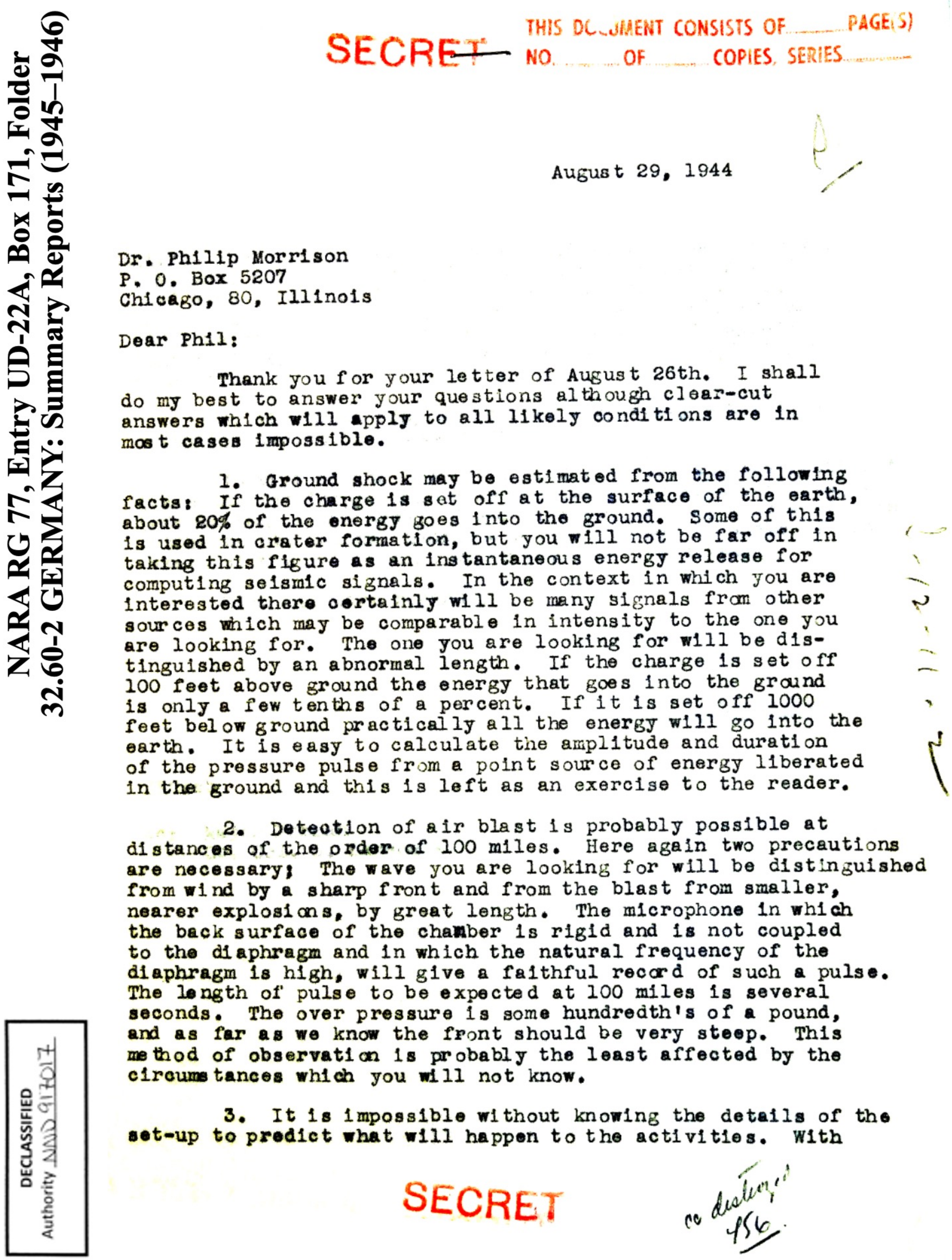
Figure D.823: Philip Morrison to J. Robert Oppenheimer. 26 August 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)

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NO. ...... OF ...... COPIES, SERIES ......

August 29, 1944

Dr. Philip Morrison
P. O. Box 5207
Chicago, 80, Illinois

Dear Phil:

Thank you for your letter of August 26th. I shall do my best to answer your questions although clear-cut answers which will apply to all likely conditions are in most cases impossible.

1. Ground shock may be estimated from the following facts: If the charge is set off at the surface of the earth, about 20% of the energy goes into the ground. Some of this is used in crater formation, but you will not be far off in taking this figure as an instantaneous energy release for computing seismic signals. In the context in which you are interested there certainly will be many signals from other sources which may be comparable in intensity to the one you are looking for. The one you are looking for will be distinguished by an abnormal length. If the charge is set off 100 feet above ground the energy that goes into the ground is only a few tenths of a percent. If it is set off 1000 feet below ground practically all the energy will go into the earth. It is easy to calculate the amplitude and duration of the pressure pulse from a point source of energy liberated in the ground and this is left as an exercise to the reader.

2. Detection of air blast is probably possible at distances of the order of 100 miles. Here again two precautions are necessary; The wave you are looking for will be distinguished from wind by a sharp front and from the blast from smaller, nearer explosions, by great length. The microphone in which the back surface of the chamber is rigid and is not coupled to the diaphragm and in which the natural frequency of the diaphragm is high, will give a faithful record of such a pulse. The length of pulse to be expected at 100 miles is several seconds. The over pressure is some hundredth's of a pound, and as far as we know the front should be very steep. This method of observation is probably the least affected by the circumstances which you will not know.

3. It is impossible without knowing the details of the set-up to predict what will happen to the activities. With

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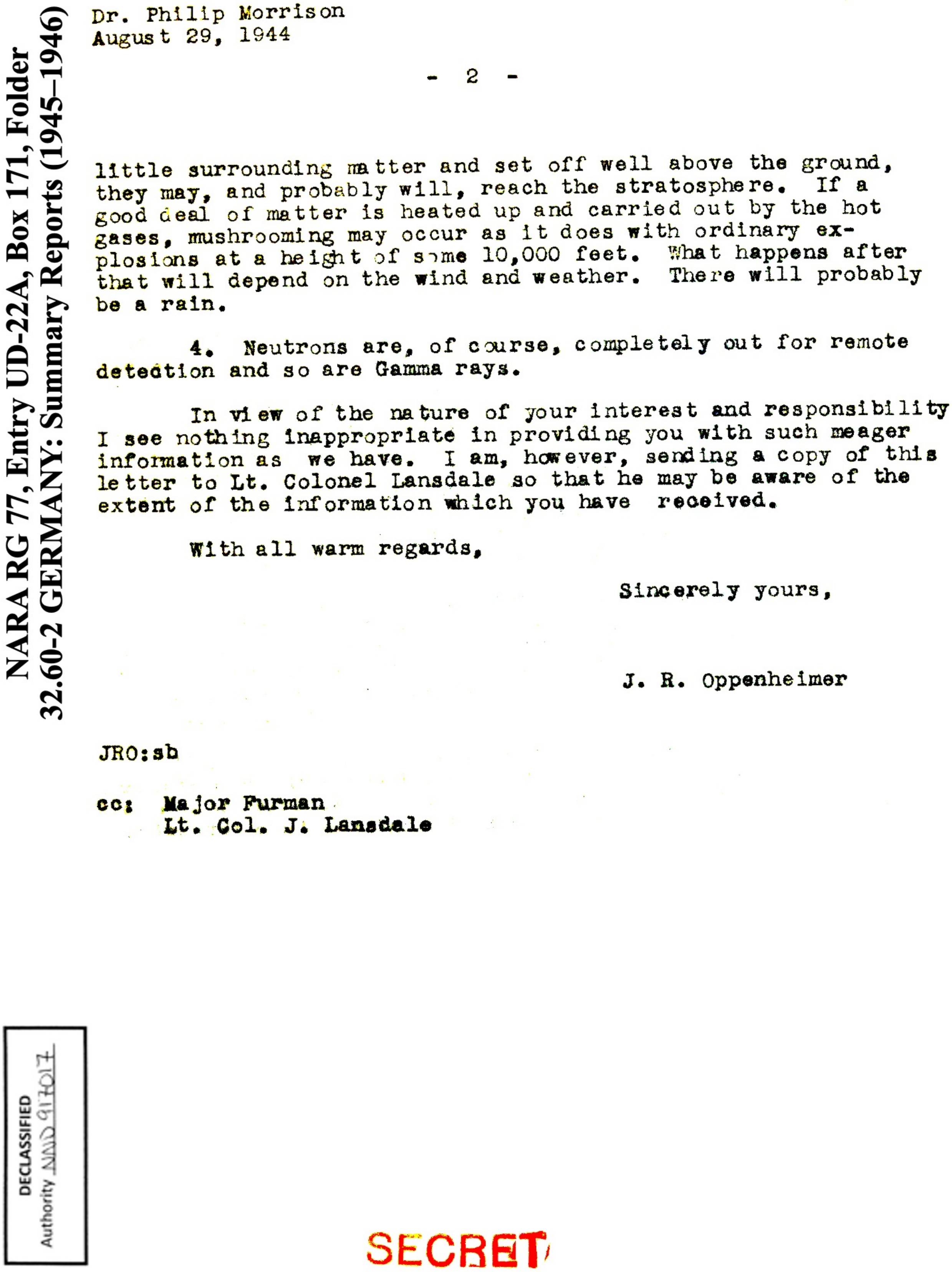
Figure D.824: J. Robert Oppenheimer to Philip Morrison. 29 August 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)

Dr. Philip Morrison
August 29, 1944

- 2 -

little surrounding matter and set off well above the ground, they may, and probably will, reach the stratosphere. If a good deal of matter is heated up and carried out by the hot gases, mushrooming may occur as it does with ordinary explosions at a height of some 10,000 feet. What happens after that will depend on the wind and weather. There will probably be a rain.

4. Neutrons are, of course, completely out for remote detection and so are Gamma rays.

In view of the nature of your interest and responsibility I see nothing inappropriate in providing you with such meager information as we have. I am, however, sending a copy of this letter to Lt. Colonel Lansdale so that he may be aware of the extent of the information which you have received.

With all warm regards,

Sincerely yours,

J. R. Oppenheimer

JRO:sb

cc: Major Furman
Lt. Col. J. Lansdale

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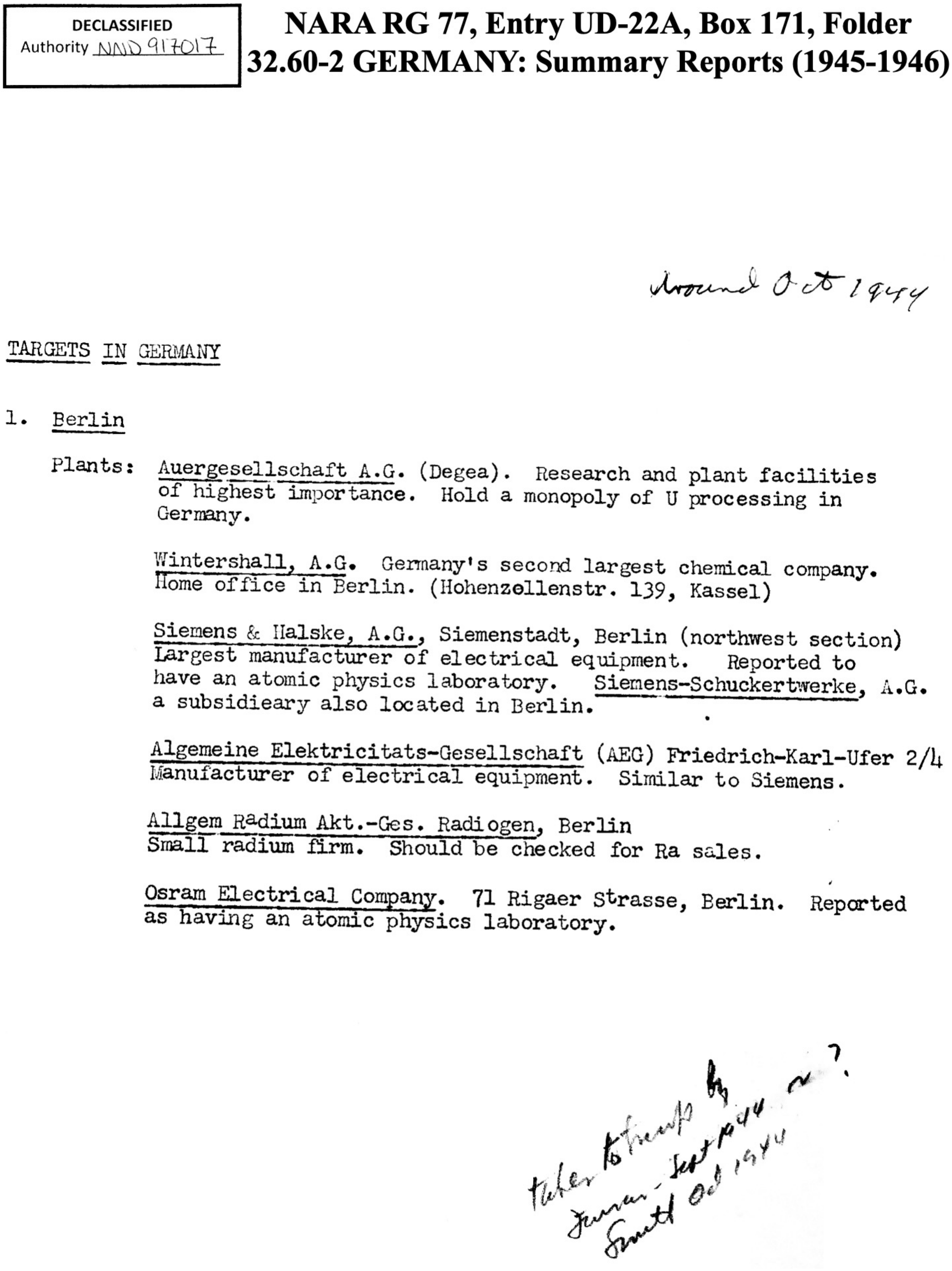
Figure D.825: J. Robert Oppenheimer to Philip Morrison. 29 August 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



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NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945-1946)

Around Oct 1944

TARGETS IN GERMANY

1. Berlin

Plants: Auergesellschaft A.G. (Degea). Research and plant facilities of highest importance. Hold a monopoly of U processing in Germany.

Wintershall, A.G. Germany's second largest chemical company. Home office in Berlin. (Hohenzollenstr. 139, Kassel)

Siemens & Halske, A.G., Siemenstadt, Berlin (northwest section) Largest manufacturer of electrical equipment. Reported to have an atomic physics laboratory. Siemens-Schuckertwerke, A.G. a subsidieary also located in Berlin.

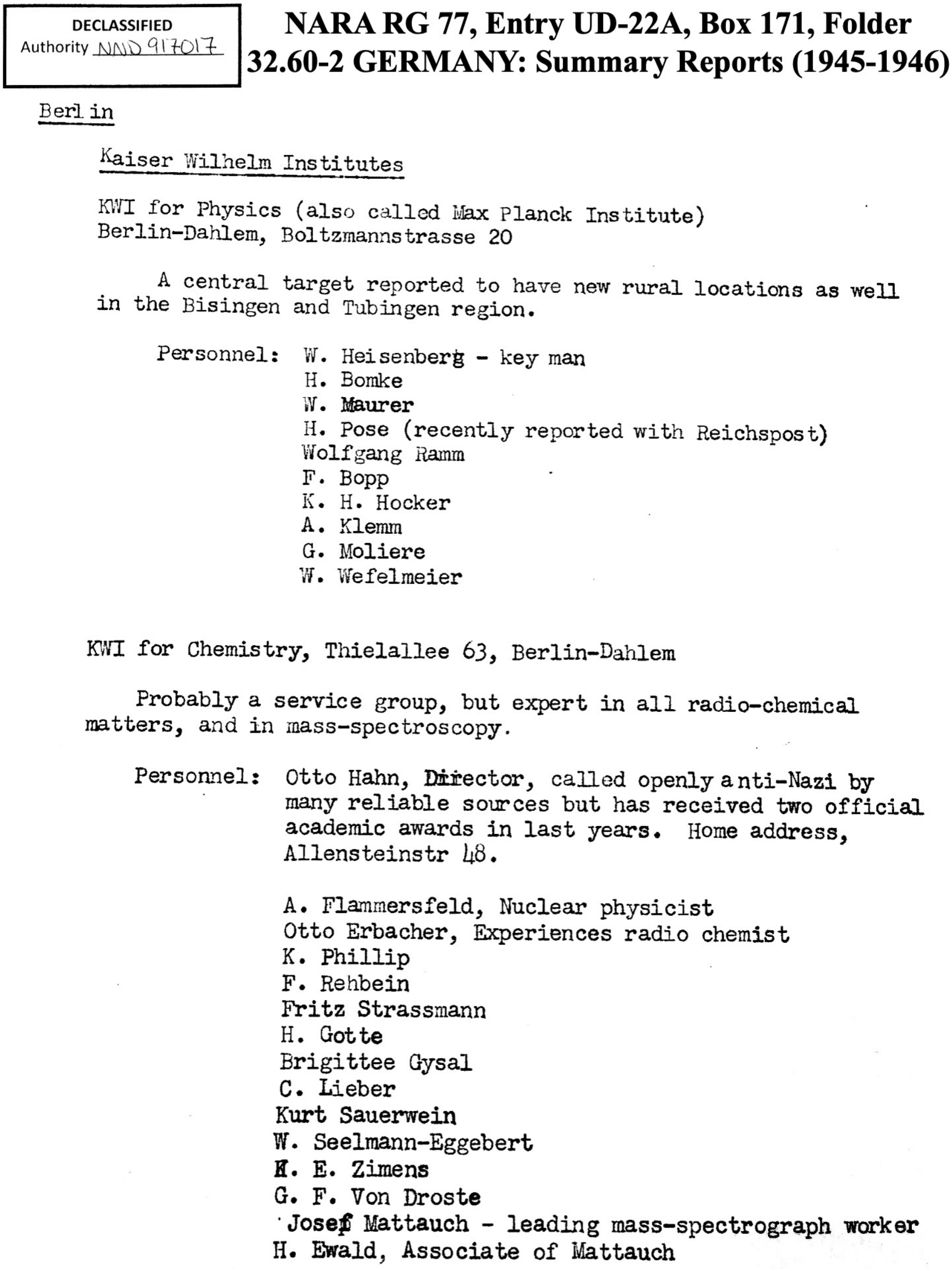
Algemeine Elektricitats-Gesellschaft (AEG) Friedrich-Karl-Ufer 2/4 Manufacturer of electrical equipment. Similar to Siemens.

Allgem Radium Akt.-Ges. Radiogen, Berlin
Small radium firm. Should be checked for Ra sales.

Osram Electrical Company. 71 Rigaer Strasse, Berlin. Reported as having an atomic physics laboratory.

taken to Groves by
Furman - Sept 1944 or ?
Smith Oct 1944

Figure D.826: Targets in Germany. October 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



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NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945-1946)

Berlin

Kaiser Wilhelm Institutes

KWI for Physics (also called Max Planck Institute)
Berlin-Dahlem, Boltzmannstrasse 20

A central target reported to have new rural locations as well in the Bisingen and Tubingen region.

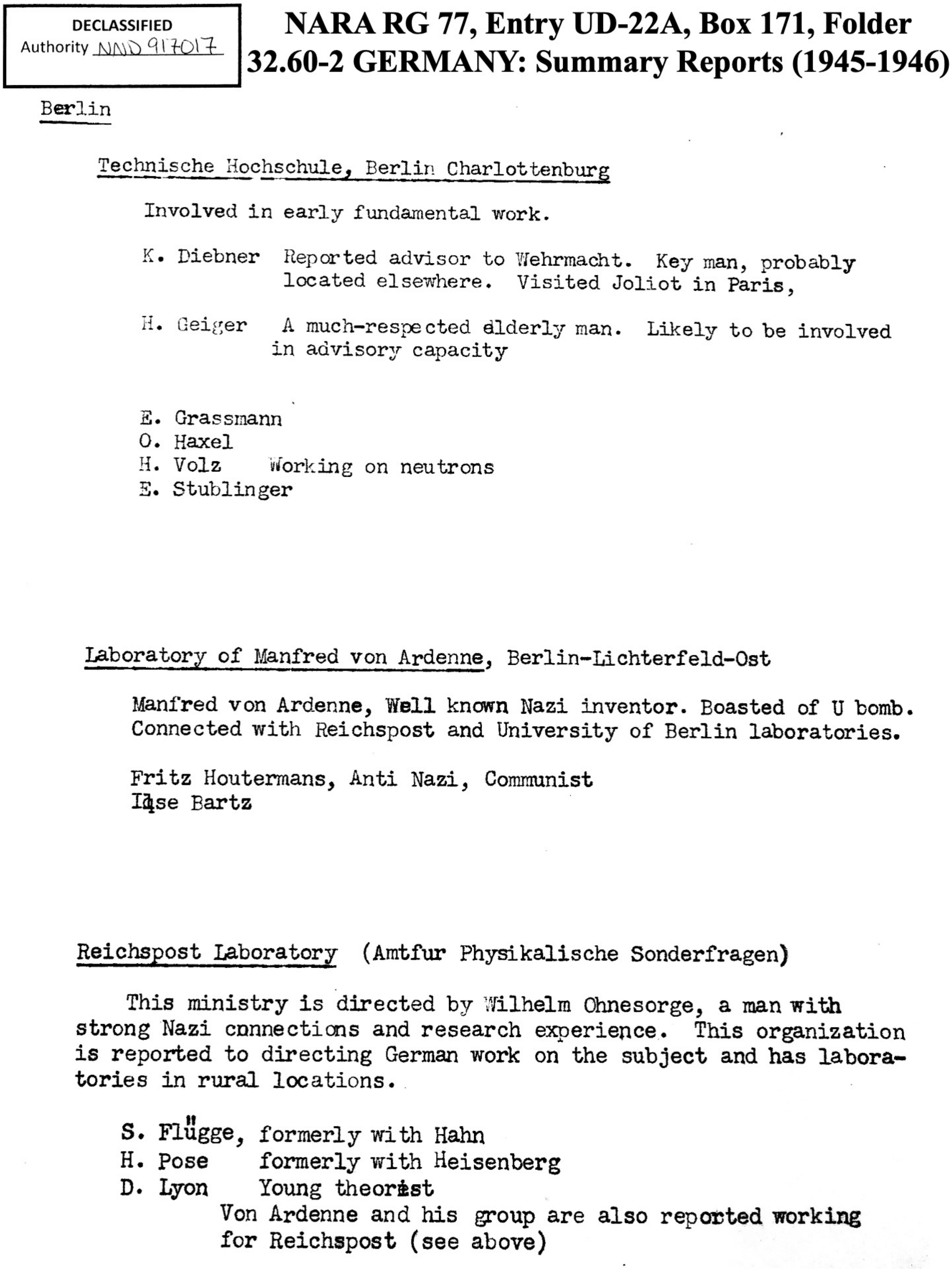
Personnel:	W. Heisenberg - key man
	H. Bomke
	W. Maurer
	H. Pose (recently reported with Reichspost)
	Wolfgang Ramm
	F. Bopp
	K. H. Hocker
	A. Klemm
	G. Moliere
	W. Wefelmeier

KWI for Chemistry, Thielallee 63, Berlin-Dahlem

Probably a service group, but expert in all radio-chemical matters, and in mass-spectroscopy.

Personnel:	Otto Hahn, Director, called openly anti-Nazi by many reliable sources but has received two official academic awards in last years. Home address, Allensteinstr 48.
	A. Flammersfeld, Nuclear physicist
	Otto Erbacher, Experiences radio chemist
	K. Phillip
	F. Rehbein
	Fritz Strassmann
	H. Gotte
	Brigittee Gysal
	C. Lieber
	Kurt Sauerwein
	W. Seelmann-Eggebert
	K. E. Zimens
	G. F. Von Droste
	Josef Mattauch - leading mass-spectrograph worker
	H. Ewald, Associate of Mattauch

Figure D.827: Targets in Germany. October 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



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Berlin

Technische Hochschule, Berlin Charlottenburg

Involved in early fundamental work.

K. Diebner	Reported advisor to Wehrmacht. Key man, probably located elsewhere. Visited Joliot in Paris,
H. Geiger	A much-respected elderly man. Likely to be involved in advisory capacity
E. Grassmann	
O. Haxel	
H. Volz	Working on neutrons
E. Stublinger	

Laboratory of Manfred von Ardenne, Berlin-Lichterfeld-Ost

Manfred von Ardenne, Well known Nazi inventor. Boasted of U bomb. Connected with Reichspost and University of Berlin laboratories.

Fritz Houtermans, Anti Nazi, Communist
Ilse Bartz

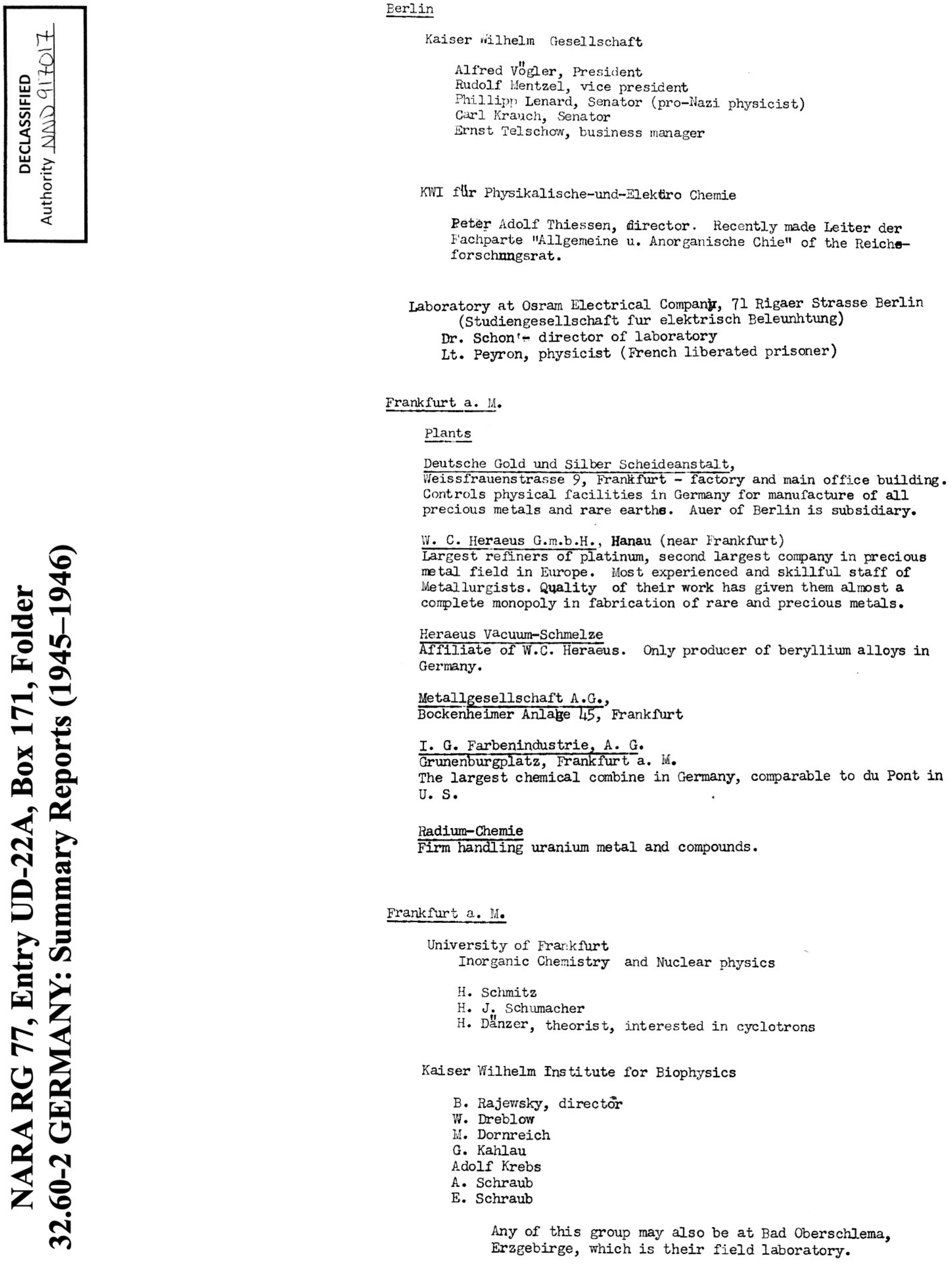
Reichspost Laboratory (Amtfur Physikalische Sonderfragen)

This ministry is directed by Wilhelm Ohnesorge, a man with strong Nazi connections and research experience. This organization is reported to directing German work on the subject and has laboratories in rural locations.

S. Flügge,	formerly with Hahn
H. Pose	formerly with Heisenberg
D. Lyon	Young theorist

Von Ardenne and his group are also reported working for Reichspost (see above)

Figure D.828: Targets in Germany. October 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



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Berlin

Kaiser Wilhelm Gesellschaft

Alfred Vögler, President
Rudolf Mentzel, vice president
Phillipp Lenard, Senator (pro-Nazi physicist)
Carl Krauch, Senator
Ernst Telschow, business manager

KWI für Physikalische-und-Elektro Chemie

Peter Adolf Thiessen, director. Recently made Leiter der Fachparte "Allgemeine u. Anorganische Chie" of the Reicheforschnngsrat.

Laboratory at Osram Electrical Company, 71 Rigaer Strasse Berlin
(Studiengesellschaft fur elektrisch Beleunhtung)
Dr. Schon'- director of laboratory
Lt. Peyron, physicist (French liberated prisoner)

Frankfurt a. M.

Plants

Deutsche Gold und Silber Scheideanstalt, Weissfrauenstrasse 9, Frankfurt - factory and main office building. Controls physical facilities in Germany for manufacture of all precious metals and rare earths. Auer of Berlin is subsidiary.

W. C. Heraeus G.m.b.H., Hanau (near Frankfurt)
Largest refiners of platinum, second largest company in precious metal field in Europe. Most experienced and skillful staff of Metallurgists. Quality of their work has given them almost a complete monopoly in fabrication of rare and precious metals.

Heraeus Vacuum-Schmelze
Affiliate of W.C. Heraeus. Only producer of beryllium alloys in Germany.

Metallgesellschaft A.G.,
Bockenheimer Anlage 45, Frankfurt

I. G. Farbenindustrie, A. G.
Grunenburgplatz, Frankfurt a. M.
The largest chemical combine in Germany, comparable to du Pont in U. S.

Radium-Chemie
Firm handling uranium metal and compounds.

Frankfurt a. M.

University of Frankfurt
Inorganic Chemistry and Nuclear physics

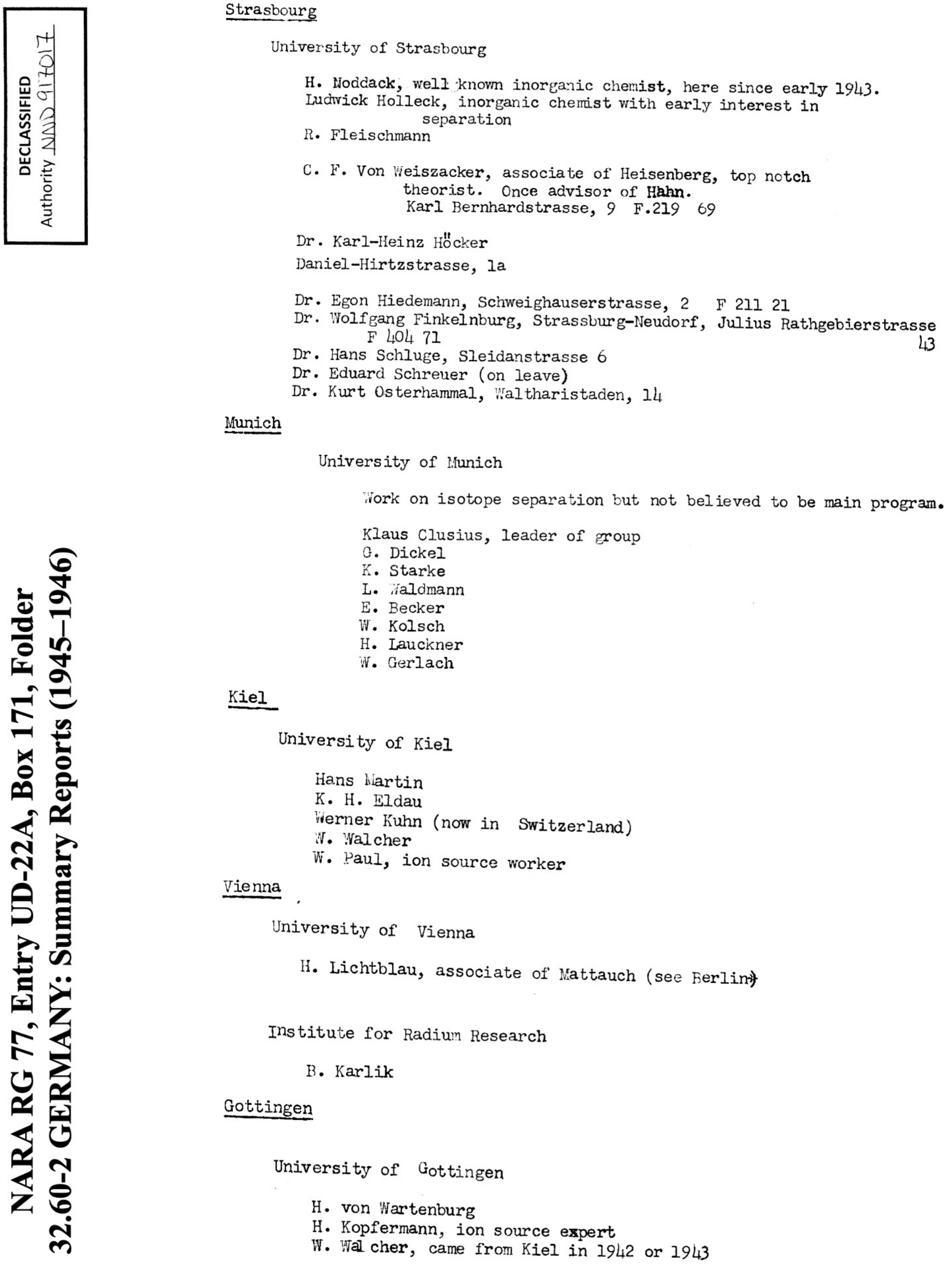
H. Schmitz
H. J. Schumacher
H. Dänzer, theorist, interested in cyclotrons

Kaiser Wilhelm Institute for Biophysics

B. Rajewsky, director
W. Dreblow
M. Dornreich
G. Kahlau
Adolf Krebs
A. Schraub
E. Schraub

Any of this group may also be at Bad Oberschlema, Erzgebirge, which is their field laboratory.

Figure D.829: Targets in Germany. October 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



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32.60-2 GERMANY: Summary Reports (1945–1946)

Strasbourg

University of Strasbourg

H. Noddack, well known inorganic chemist, here since early 1943.
Ludwick Holleck, inorganic chemist with early interest in separation
R. Fleischmann

C. F. Von Weiszacker, associate of Heisenberg, top notch theorist. Once advisor of Hahn.
Karl Bernhardstrasse, 9 F.219 69

Dr. Karl-Heinz Höcker
Daniel-Hirtzstrasse, 1a

Dr. Egon Hiedemann, Schweighauserstrasse, 2 F 211 21
Dr. Wolfgang Finkelnburg, Strassburg-Neudorf, Julius Rathgebierstrasse 43
F 404 71
Dr. Hans Schluge, Sleidanstrasse 6
Dr. Eduard Schreuer (on leave)
Dr. Kurt Osterhammal, Waltharistaden, 14

Munich

University of Munich

Work on isotope separation but not believed to be main program.

Klaus Clusius, leader of group
G. Dickel
K. Starke
L. Waldmann
E. Becker
W. Kolsch
H. Lauckner
W. Gerlach

Kiel

University of Kiel

Hans Martin
K. H. Eldau
Werner Kuhn (now in Switzerland)
W. Walcher
W. Paul, ion source worker

Vienna

University of Vienna

H. Lichtblau, associate of Mattauch (see Berlin)

Institute for Radium Research

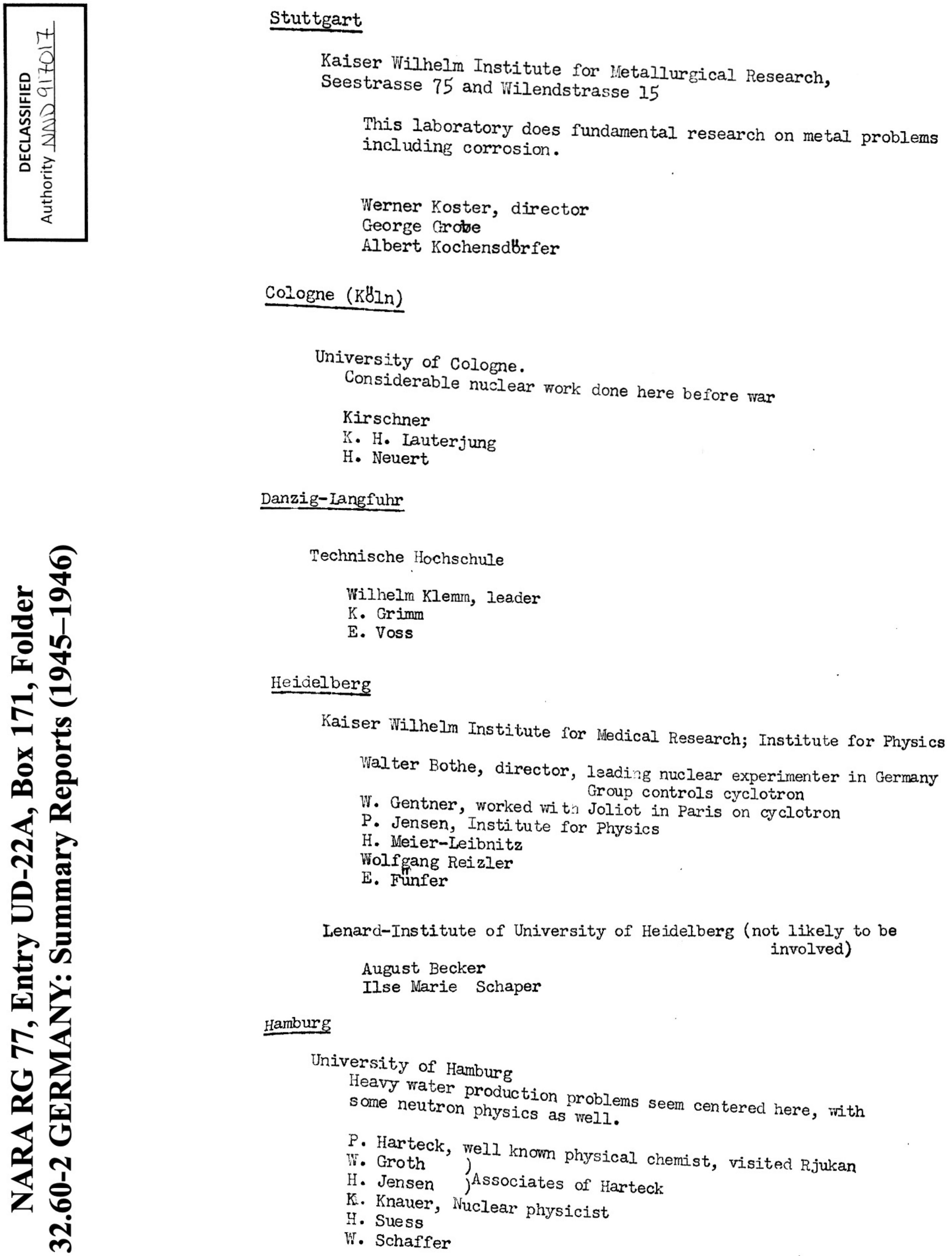
B. Karlik

Gottingen

University of Gottingen

H. von Wartenburg
H. Kopfermann, ion source expert
W. Walcher, came from Kiel in 1942 or 1943

Figure D.830: Targets in Germany. October 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



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NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)

Stuttgart

Kaiser Wilhelm Institute for Metallurgical Research,
Seestrasse 75 and Wilendstrasse 15

This laboratory does fundamental research on metal problems including corrosion.

Werner Koster, director
George Grobe
Albert Kochensdörfer

Cologne (Köln)

University of Cologne.
Considerable nuclear work done here before war

Kirschner
K. H. Lauterjung
H. Neuert

Danzig-Langfuhr

Technische Hochschule

Wilhelm Klemm, leader
K. Grimm
E. Voss

Heidelberg

Kaiser Wilhelm Institute for Medical Research; Institute for Physics

Walter Bothe, director, leading nuclear experimenter in Germany
Group controls cyclotron
W. Gentner, worked with Joliot in Paris on cyclotron
P. Jensen, Institute for Physics
H. Meier-Leibnitz
Wolfgang Reizler
E. Fünfer

Lenard-Institute of University of Heidelberg (not likely to be involved)

August Becker
Ilse Marie Schaper

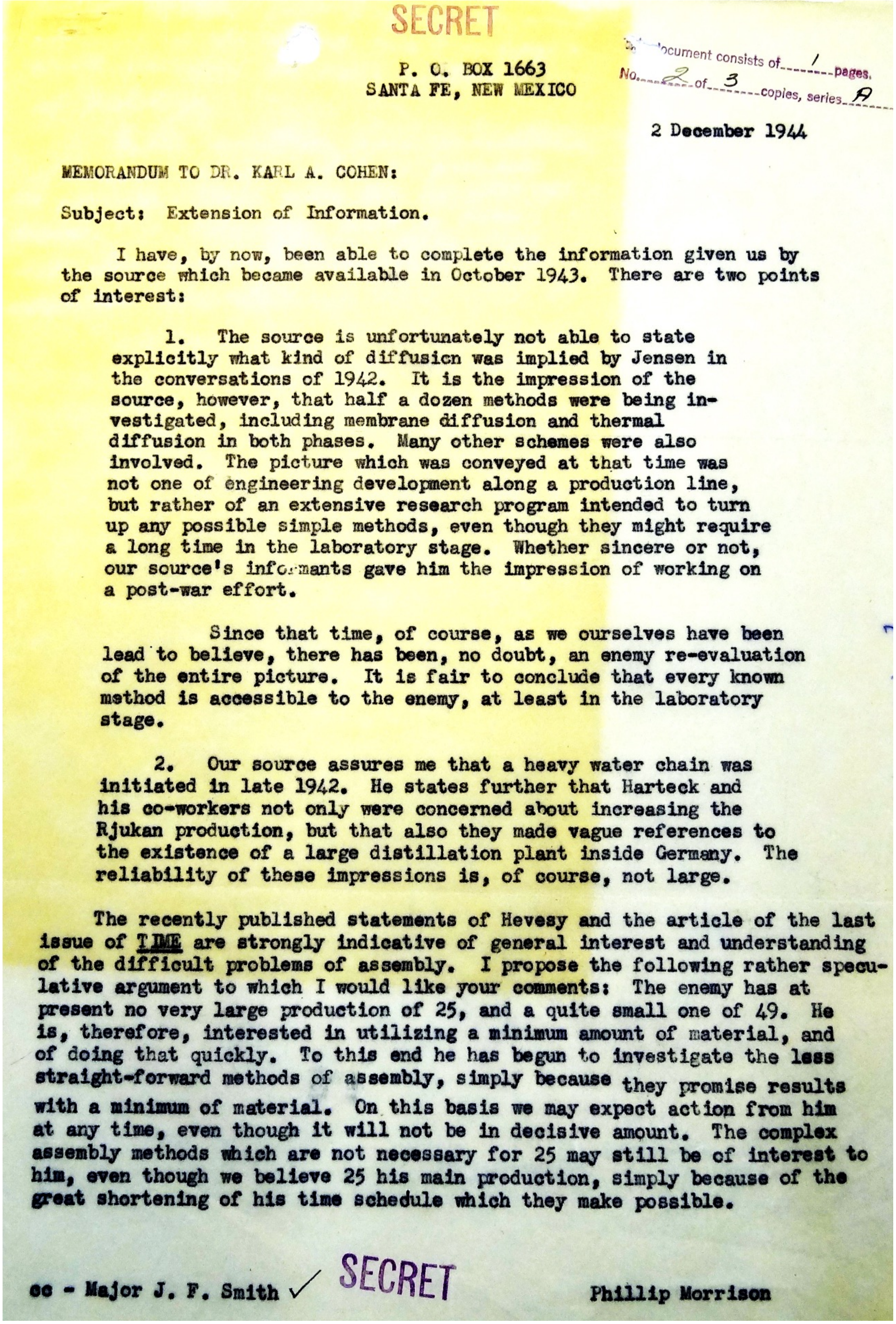
Hamburg

University of Hamburg
Heavy water production problems seem centered here, with some neutron physics as well.

P. Harteck, well known physical chemist, visited Rjukan
W. Groth)
H. Jensen)Associates of Harteck
K. Knauer, Nuclear physicist
H. Suess
W. Schaffer

Figure D.831: Targets in Germany. October 1944 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)



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P. O. BOX 1663
SANTA FE, NEW MEXICO

This document consists of 1 pages.
No. 2 of 3 copies, series A

2 December 1944

MEMORANDUM TO DR. KARL A. COHEN:

Subject: Extension of Information.

I have, by now, been able to complete the information given us by the source which became available in October 1943. There are two points of interest:

1. The source is unfortunately not able to state explicitly what kind of diffusion was implied by Jensen in the conversations of 1942. It is the impression of the source, however, that half a dozen methods were being investigated, including membrane diffusion and thermal diffusion in both phases. Many other schemes were also involved. The picture which was conveyed at that time was not one of engineering development along a production line, but rather of an extensive research program intended to turn up any possible simple methods, even though they might require a long time in the laboratory stage. Whether sincere or not, our source's informants gave him the impression of working on a post-war effort.

Since that time, of course, as we ourselves have been lead to believe, there has been, no doubt, an enemy re-evaluation of the entire picture. It is fair to conclude that every known method is accessible to the enemy, at least in the laboratory stage.

2. Our source assures me that a heavy water chain was initiated in late 1942. He states further that Harteck and his co-workers not only were concerned about increasing the Rjukan production, but that also they made vague references to the existence of a large distillation plant inside Germany. The reliability of these impressions is, of course, not large.

The recently published statements of Hevesy and the article of the last issue of TIME are strongly indicative of general interest and understanding of the difficult problems of assembly. I propose the following rather speculative argument to which I would like your comments: The enemy has at present no very large production of 25, and a quite small one of 49. He is, therefore, interested in utilizing a minimum amount of material, and of doing that quickly. To this end he has begun to investigate the less straight-forward methods of assembly, simply because they promise results with a minimum of material. On this basis we may expect action from him at any time, even though it will not be in decisive amount. The complex assembly methods which are not necessary for 25 may still be of interest to him, even though we believe 25 his main production, simply because of the great shortening of his time schedule which they make possible.

cc - Major J. F. Smith ✓

SECRET

Phillip Morrison

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Figure D.832: Philip Morrison to Karl Cohen. 2 December 1944. Subject: Extension of Information [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

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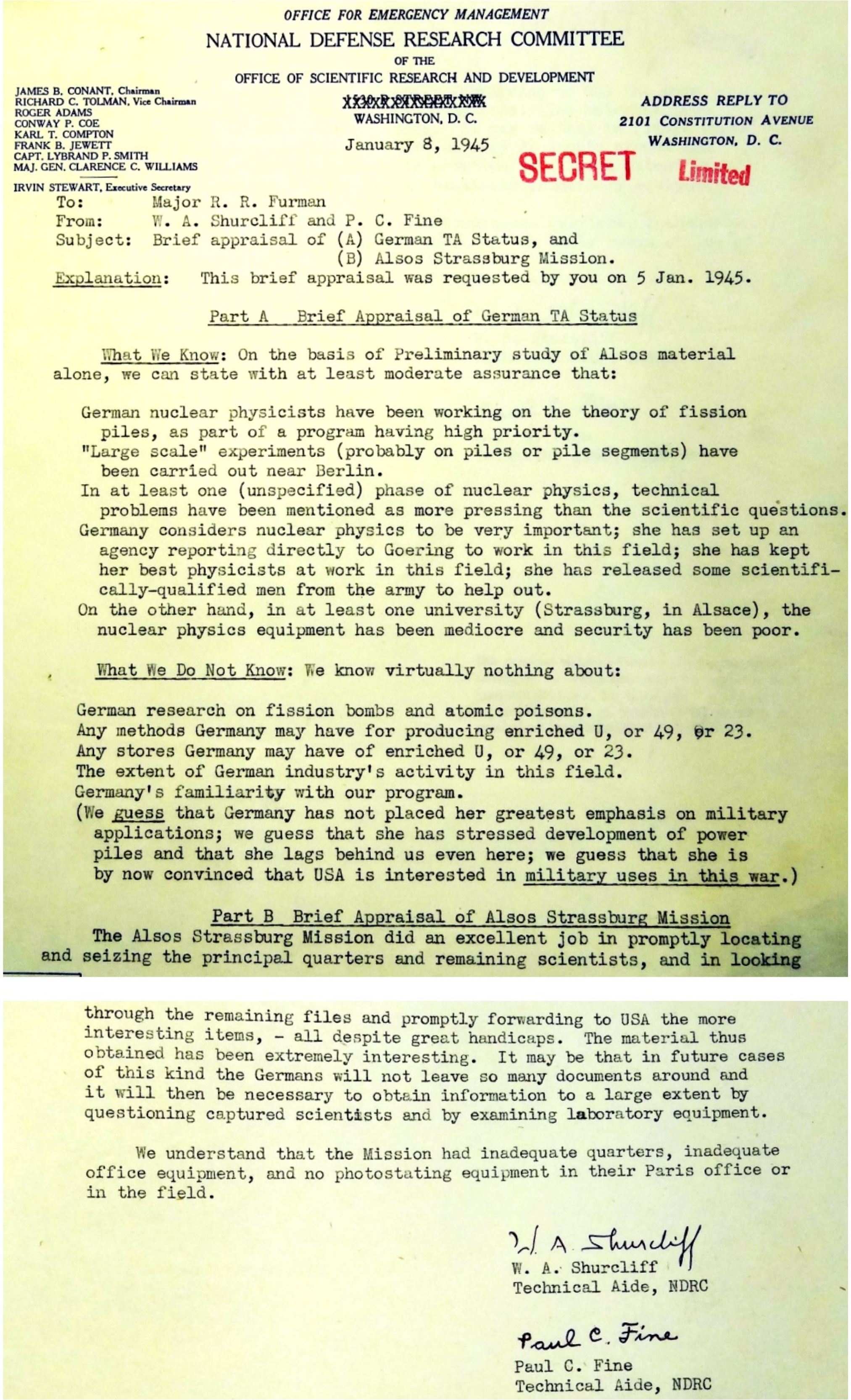

OFFICE FOR EMERGENCY MANAGEMENT
NATIONAL DEFENSE RESEARCH COMMITTEE
OF THE
OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT
~~1530 P STREET NW~~
WASHINGTON, D. C.

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IRVIN STEWART, Executive Secretary

ADDRESS REPLY TO
2101 CONSTITUTION AVENUE
WASHINGTON, D. C.

January 8, 1945

SECRET Limited

To: Major R. R. Furman
From: W. A. Shurcliff and P. C. Fine
Subject: Brief appraisal of (A) German TA Status, and
(B) Alsos Strassburg Mission.

Explanation: This brief appraisal was requested by you on 5 Jan. 1945.

Part A Brief Appraisal of German TA Status

What We Know: On the basis of Preliminary study of Alsos material alone, we can state with at least moderate assurance that:

German nuclear physicists have been working on the theory of fission piles, as part of a program having high priority.
"Large scale" experiments (probably on piles or pile segments) have been carried out near Berlin.
In at least one (unspecified) phase of nuclear physics, technical problems have been mentioned as more pressing than the scientific questions.
Germany considers nuclear physics to be very important; she has set up an agency reporting directly to Goering to work in this field; she has kept her best physicists at work in this field; she has released some scientifically-qualified men from the army to help out.
On the other hand, in at least one university (Strassburg, in Alsace), the nuclear physics equipment has been mediocre and security has been poor.

What We Do Not Know: We know virtually nothing about:

German research on fission bombs and atomic poisons.
Any methods Germany may have for producing enriched U, or 49, or 23.
Any stores Germany may have of enriched U, or 49, or 23.
The extent of German industry's activity in this field.
Germany's familiarity with our program.
(We guess that Germany has not placed her greatest emphasis on military applications; we guess that she has stressed development of power piles and that she lags behind us even here; we guess that she is by now convinced that USA is interested in military uses in this war.)

Part B Brief Appraisal of Alsos Strassburg Mission

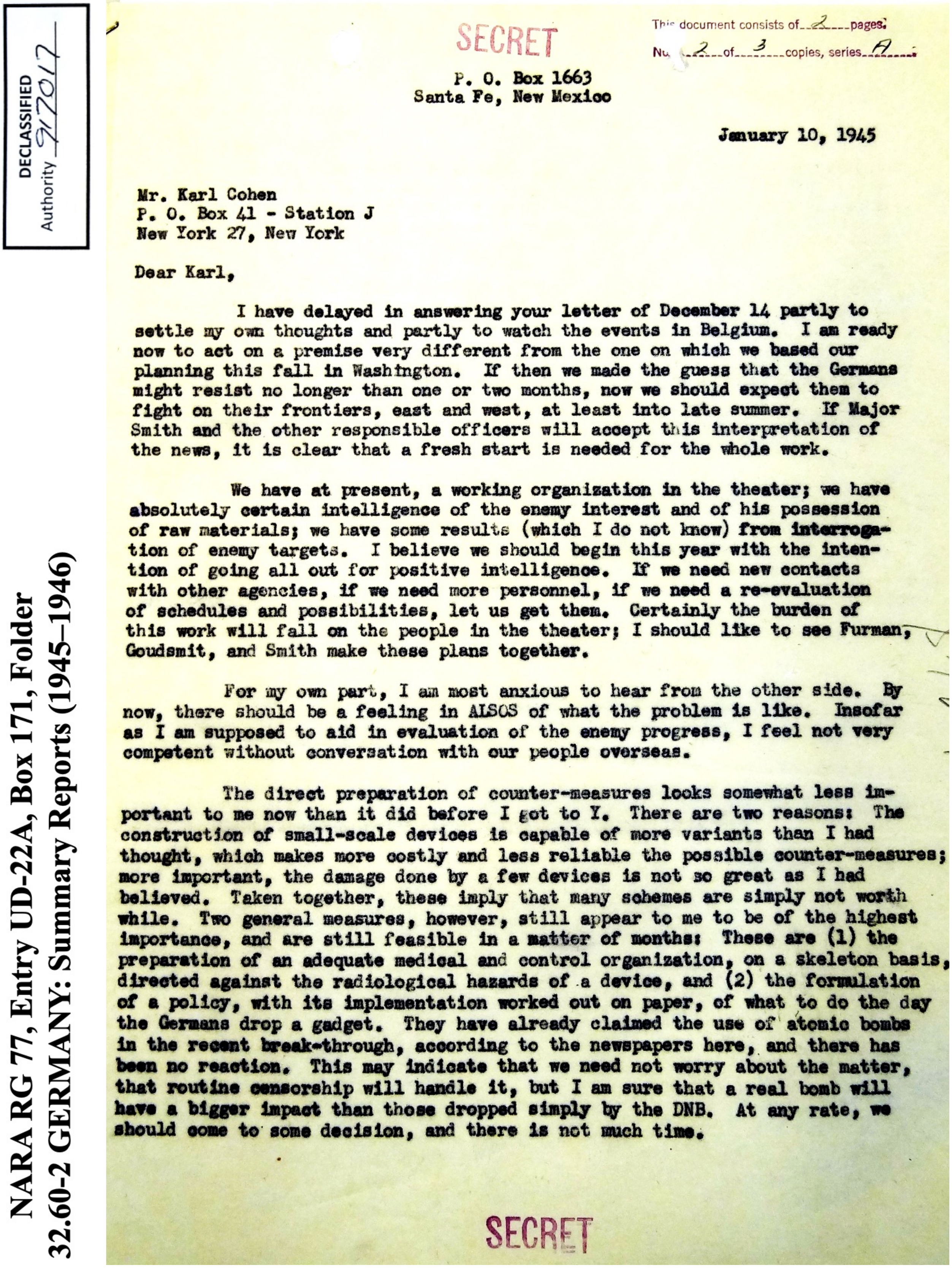
The Alsos Strassburg Mission did an excellent job in promptly locating and seizing the principal quarters and remaining scientists, and in looking through the remaining files and promptly forwarding to USA the more interesting items, - all despite great handicaps. The material thus obtained has been extremely interesting. It may be that in future cases of this kind the Germans will not leave so many documents around and it will then be necessary to obtain information to a large extent by questioning captured scientists and by examining laboratory equipment.

We understand that the Mission had inadequate quarters, inadequate office equipment, and no photostating equipment in their Paris office or in the field.

W. A. Shurcliff
W. A. Shurcliff
Technical Aide, NDRC

Paul C. Fine
Paul C. Fine
Technical Aide, NDRC

Figure D.833: W. A. Shurcliff and Paul C. Fine to Robert R. Furman. 8 January 1945. Subject: Brief appraisal of (A) German TA Status, and (B) Alsos Strassburg Mission [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



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No. 2 of 3 copies, series A.

P. O. Box 1663
Santa Fe, New Mexico

January 10, 1945

Mr. Karl Cohen
P. O. Box 41 - Station J
New York 27, New York

Dear Karl,

I have delayed in answering your letter of December 14 partly to settle my own thoughts and partly to watch the events in Belgium. I am ready now to act on a premise very different from the one on which we based our planning this fall in Washington. If then we made the guess that the Germans might resist no longer than one or two months, now we should expect them to fight on their frontiers, east and west, at least into late summer. If Major Smith and the other responsible officers will accept this interpretation of the news, it is clear that a fresh start is needed for the whole work.

We have at present, a working organization in the theater; we have absolutely certain intelligence of the enemy interest and of his possession of raw materials; we have some results (which I do not know) from interrogation of enemy targets. I believe we should begin this year with the intention of going all out for positive intelligence. If we need new contacts with other agencies, if we need more personnel, if we need a re-evaluation of schedules and possibilities, let us get them. Certainly the burden of this work will fall on the people in the theater; I should like to see Furman, Goudsmit, and Smith make these plans together.

For my own part, I am most anxious to hear from the other side. By now, there should be a feeling in ALSOS of what the problem is like. Insofar as I am supposed to aid in evaluation of the enemy progress, I feel not very competent without conversation with our people overseas.

The direct preparation of counter-measures looks somewhat less important to me now than it did before I got to Y. There are two reasons: The construction of small-scale devices is capable of more variants than I had thought, which makes more costly and less reliable the possible counter-measures; more important, the damage done by a few devices is not so great as I had believed. Taken together, these imply that many schemes are simply not worth while. Two general measures, however, still appear to me to be of the highest importance, and are still feasible in a matter of months: These are (1) the preparation of an adequate medical and control organization, on a skeleton basis, directed against the radiological hazards of a device, and (2) the formulation of a policy, with its implementation worked out on paper, of what to do the day the Germans drop a gadget. They have already claimed the use of atomic bombs in the recent break-through, according to the newspapers here, and there has been no reaction. This may indicate that we need not worry about the matter, that routine censorship will handle it, but I am sure that a real bomb will have a bigger impact than those dropped simply by the DNB. At any rate, we should come to some decision, and there is not much time.

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Figure D.834: Philip Morrison to Karl Cohen and Francis J. Smith. 10 January 1945 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

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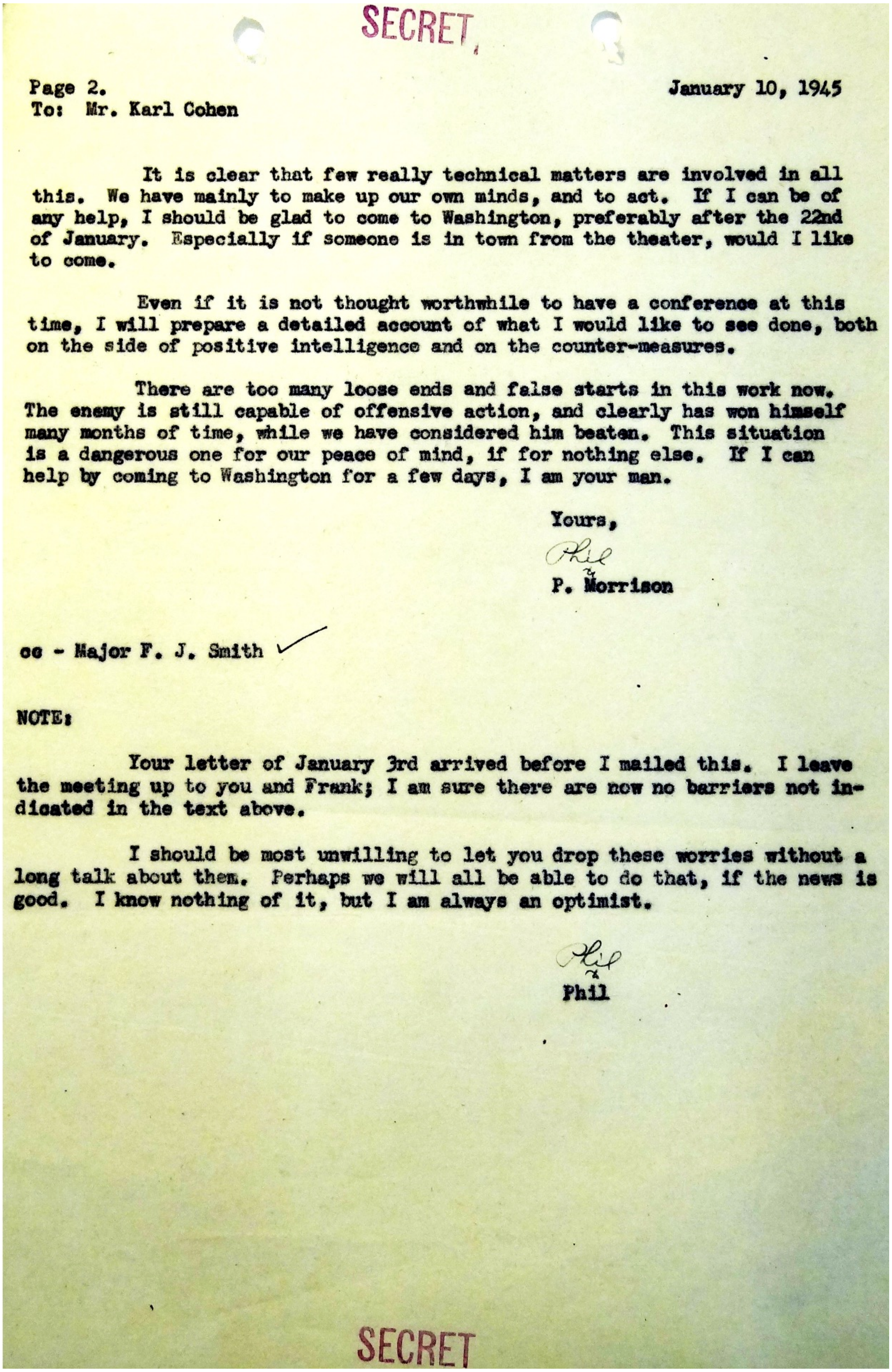
NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)



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Page 2.
To: Mr. Karl Cohen

January 10, 1945

It is clear that few really technical matters are involved in all this. We have mainly to make up our own minds, and to act. If I can be of any help, I should be glad to come to Washington, preferably after the 22nd of January. Especially if someone is in town from the theater, would I like to come.

Even if it is not thought worthwhile to have a conference at this time, I will prepare a detailed account of what I would like to see done, both on the side of positive intelligence and on the counter-measures.

There are too many loose ends and false starts in this work now. The enemy is still capable of offensive action, and clearly has won himself many months of time, while we have considered him beaten. This situation is a dangerous one for our peace of mind, if for nothing else. If I can help by coming to Washington for a few days, I am your man.

Yours,

Phil

P. Morrison

cc - Major F. J. Smith ✓

NOTE:

Your letter of January 3rd arrived before I mailed this. I leave the meeting up to you and Frank; I am sure there are now no barriers not indicated in the text above.

I should be most unwilling to let you drop these worries without a long talk about them. Perhaps we will all be able to do that, if the news is good. I know nothing of it, but I am always an optimist.

Phil

Phil

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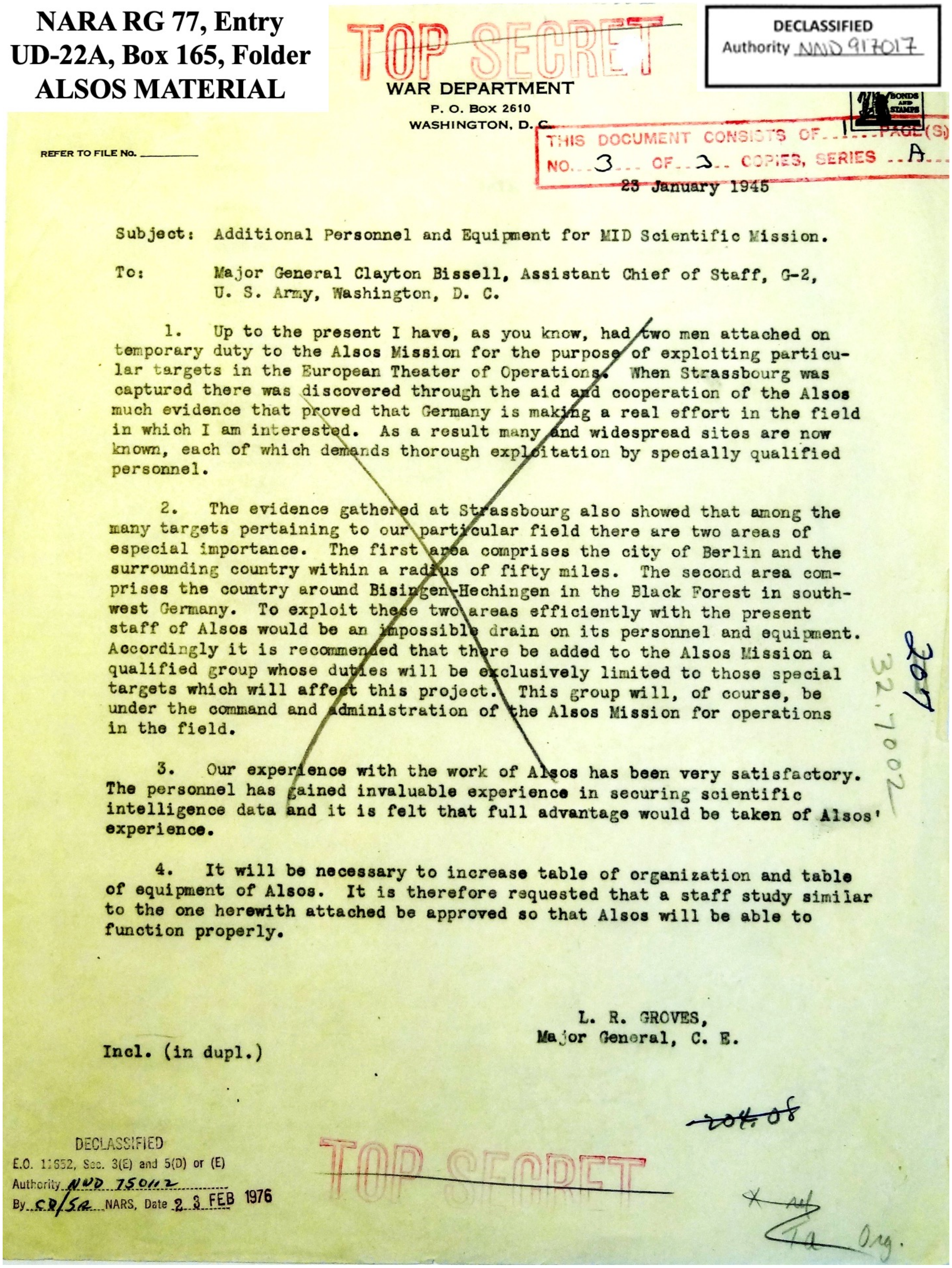
Figure D.835: Philip Morrison to Karl Cohen and Francis J. Smith. 10 January 1945 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL

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Authority NND 917017

WAR DEPARTMENT
P. O. Box 2610
WASHINGTON, D. C.

REFER TO FILE No. ________

THIS DOCUMENT CONSISTS OF 1 PAGE(S)
NO. 3 OF 2 COPIES, SERIES A

23 January 1945

Subject: Additional Personnel and Equipment for MID Scientific Mission.

To: Major General Clayton Bissell, Assistant Chief of Staff, G-2, U. S. Army, Washington, D. C.

1. Up to the present I have, as you know, had two men attached on temporary duty to the Alsos Mission for the purpose of exploiting particular targets in the European Theater of Operations. When Strassbourg was captured there was discovered through the aid and cooperation of the Alsos much evidence that proved that Germany is making a real effort in the field in which I am interested. As a result many and widespread sites are now known, each of which demands thorough exploitation by specially qualified personnel.

2. The evidence gathered at Strassbourg also showed that among the many targets pertaining to our particular field there are two areas of especial importance. The first area comprises the city of Berlin and the surrounding country within a radius of fifty miles. The second area comprises the country around Bisingen-Hechingen in the Black Forest in southwest Germany. To exploit these two areas efficiently with the present staff of Alsos would be an impossible drain on its personnel and equipment. Accordingly it is recommended that there be added to the Alsos Mission a qualified group whose duties will be exclusively limited to those special targets which will affect this project. This group will, of course, be under the command and administration of the Alsos Mission for operations in the field.

3. Our experience with the work of Alsos has been very satisfactory. The personnel has gained invaluable experience in securing scientific intelligence data and it is felt that full advantage would be taken of Alsos' experience.

4. It will be necessary to increase table of organization and table of equipment of Alsos. It is therefore requested that a staff study similar to the one herewith attached be approved so that Alsos will be able to function properly.

207

32.7002

L. R. GROVES,
Major General, C. E.

Incl. (in dupl.)

~~204.08~~

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By CD/SA NARS, Date 2 3 FEB 1976

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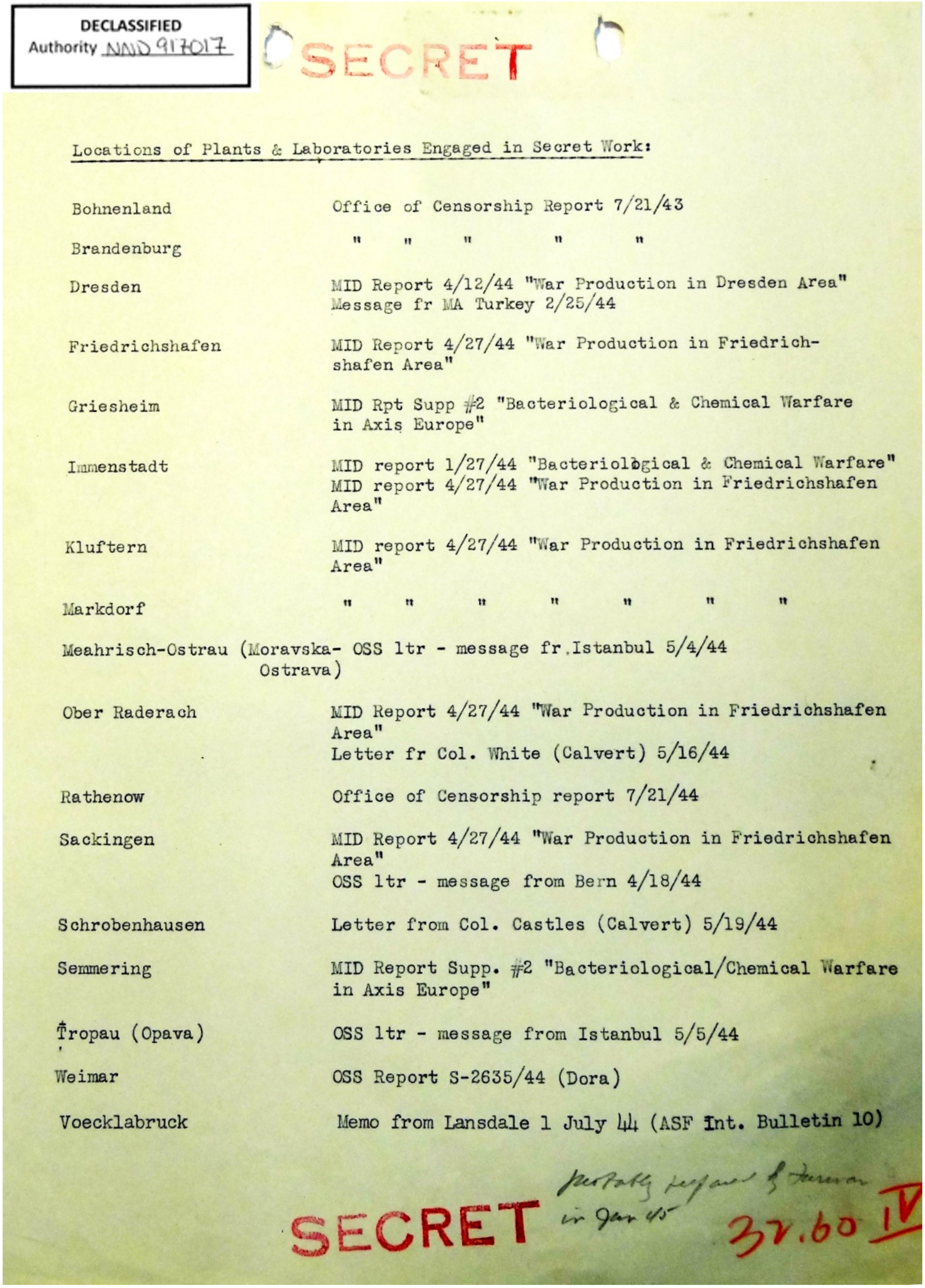
Figure D.836: Leslie Groves to Clayton Bissell. 23 January 1945. Subject: Additional Personnel and Equipment for MID Scientific Mission [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945-1946)



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Locations of Plants & Laboratories Engaged in Secret Work:

Bohnenland	Office of Censorship Report 7/21/43
Brandenburg	" " " " "
Dresden	MID Report 4/12/44 "War Production in Dresden Area" Message fr MA Turkey 2/25/44
Friedrichshafen	MID Report 4/27/44 "War Production in Friedrichshafen Area"
Griesheim	MID Rpt Supp #2 "Bacteriological & Chemical Warfare in Axis Europe"
Immenstadt	MID report 1/27/44 "Bacteriological & Chemical Warfare" MID report 4/27/44 "War Production in Friedrichshafen Area"
Kluftern	MID report 4/27/44 "War Production in Friedrichshafen Area"
Markdorf	" " " " " " "
Meahrisch-Ostrau (Moravska-Ostrava)	OSS ltr - message fr.Istanbul 5/4/44
Ober Raderach	MID Report 4/27/44 "War Production in Friedrichshafen Area" Letter fr Col. White (Calvert) 5/16/44
Rathenow	Office of Censorship report 7/21/44
Sackingen	MID Report 4/27/44 "War Production in Friedrichshafen Area" OSS ltr - message from Bern 4/18/44
Schrobenhausen	Letter from Col. Castles (Calvert) 5/19/44
Semmering	MID Report Supp. #2 "Bacteriological/Chemical Warfare in Axis Europe"
Tropau (Opava)	OSS ltr - message from Istanbul 5/5/44
Weimar	OSS Report S-2635/44 (Dora)
Voecklabruck	Memo from Lansdale 1 July 44 (ASF Int. Bulletin 10)

probably prepared for Furman in Jan 45

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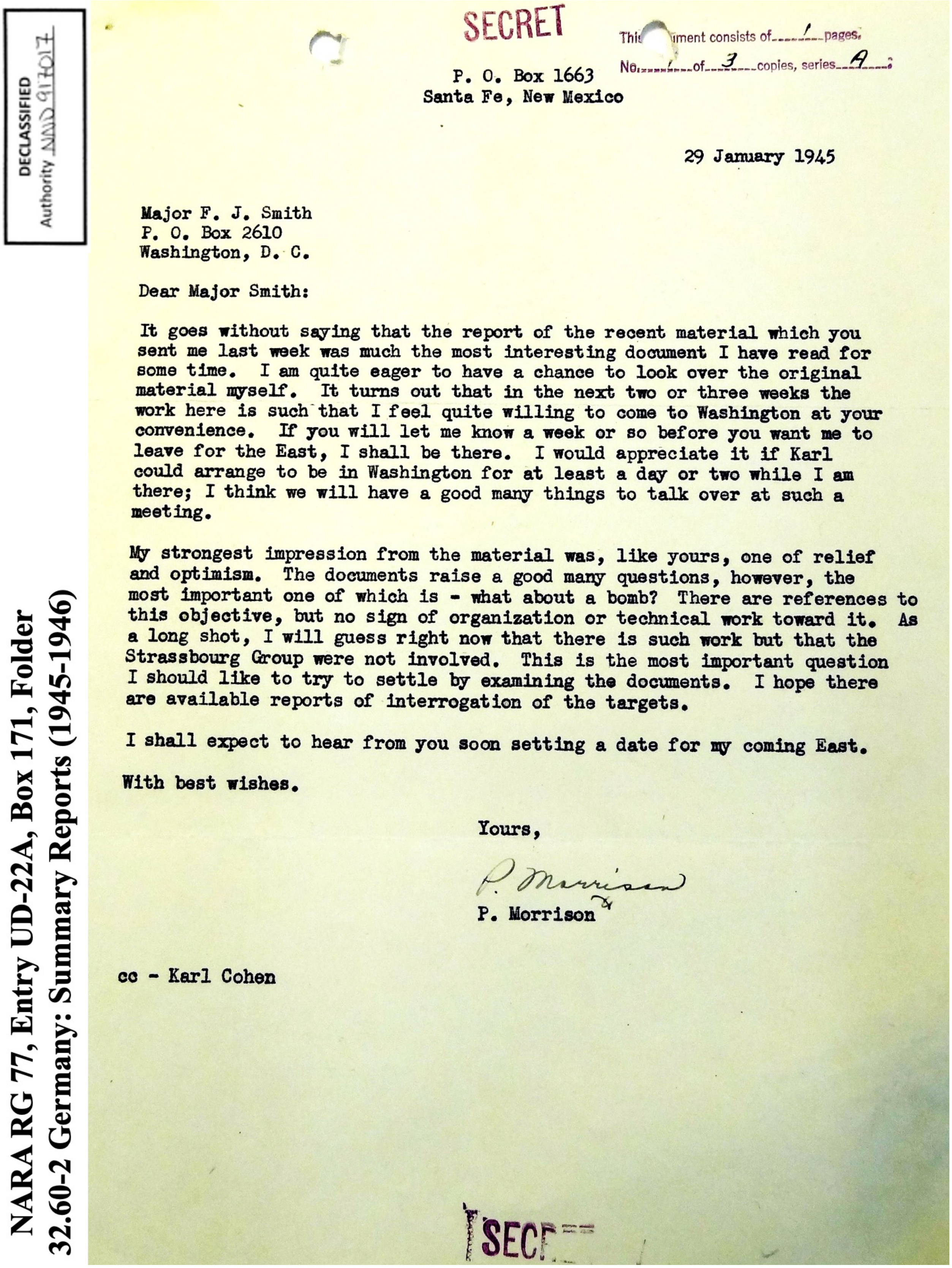
Figure D.837: Locations of Plants & Laboratories Engaged in Secret Work. January 1945 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].



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NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945-1946)

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Thi ument consists of 1 pages.
No. 1 of 3 copies, series A.

P. O. Box 1663
Santa Fe, New Mexico

29 January 1945

Major F. J. Smith
P. O. Box 2610
Washington, D. C.

Dear Major Smith:

It goes without saying that the report of the recent material which you sent me last week was much the most interesting document I have read for some time. I am quite eager to have a chance to look over the original material myself. It turns out that in the next two or three weeks the work here is such that I feel quite willing to come to Washington at your convenience. If you will let me know a week or so before you want me to leave for the East, I shall be there. I would appreciate it if Karl could arrange to be in Washington for at least a day or two while I am there; I think we will have a good many things to talk over at such a meeting.

My strongest impression from the material was, like yours, one of relief and optimism. The documents raise a good many questions, however, the most important one of which is - what about a bomb? There are references to this objective, but no sign of organization or technical work toward it. As a long shot, I will guess right now that there is such work but that the Strassbourg Group were not involved. This is the most important question I should like to try to settle by examining the documents. I hope there are available reports of interrogation of the targets.

I shall expect to hear from you soon setting a date for my coming East.

With best wishes.

Yours,

P. Morrison

P. Morrison

cc - Karl Cohen

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Figure D.838: Philip Morrison to Francis J. Smith. 29 January 1945 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

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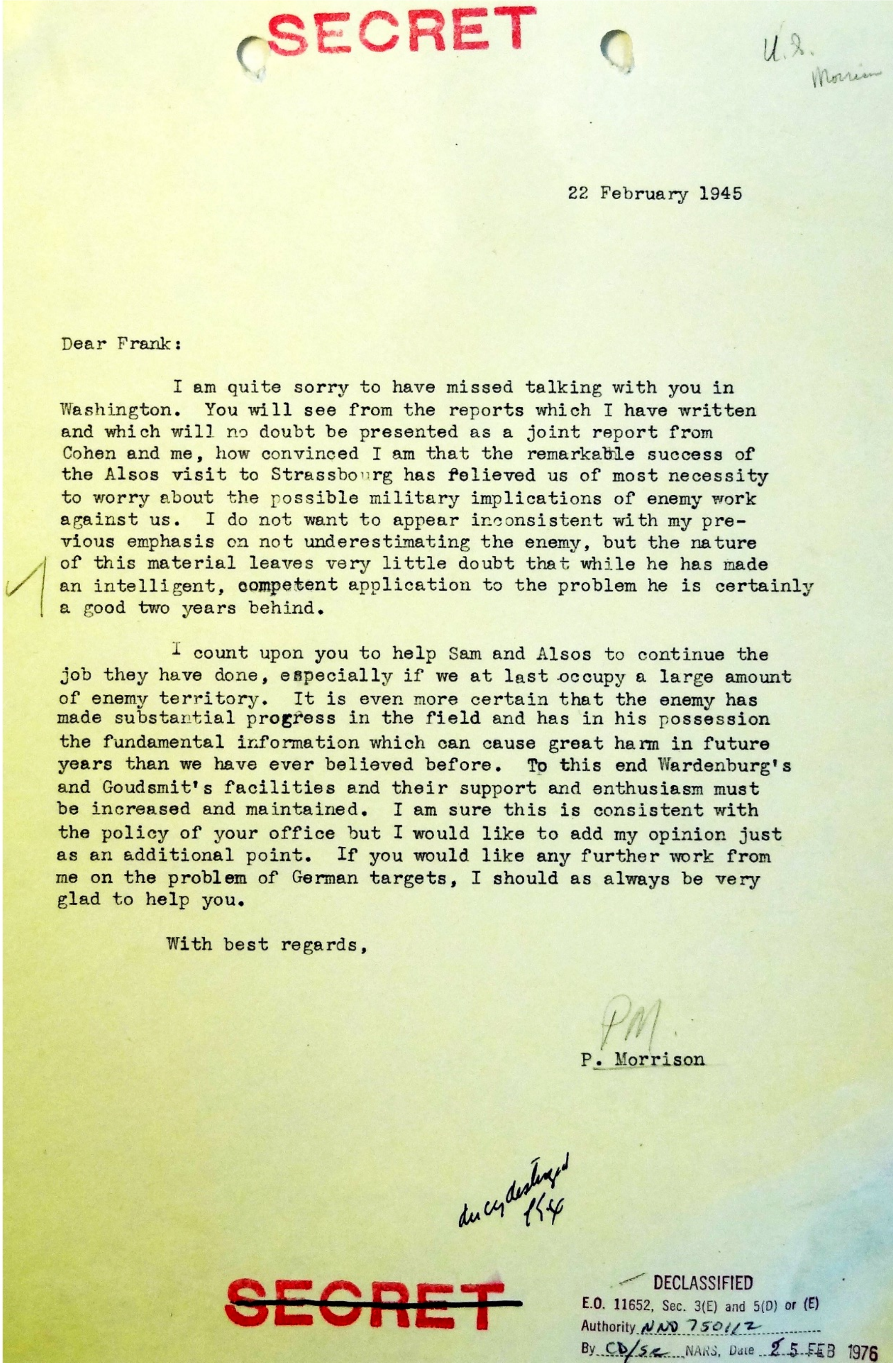
NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)



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U.S.
Morrison

22 February 1945

Dear Frank:

I am quite sorry to have missed talking with you in Washington. You will see from the reports which I have written and which will no doubt be presented as a joint report from Cohen and me, how convinced I am that the remarkable success of the Alsos visit to Strassbourg has felieved us of most necessity to worry about the possible military implications of enemy work against us. I do not want to appear inconsistent with my previous emphasis on not underestimating the enemy, but the nature of this material leaves very little doubt that while he has made an intelligent, competent application to the problem he is certainly a good two years behind.

I count upon you to help Sam and Alsos to continue the job they have done, especially if we at last occupy a large amount of enemy territory. It is even more certain that the enemy has made substantial progress in the field and has in his possession the fundamental information which can cause great harm in future years than we have ever believed before. To this end Wardenburg's and Goudsmit's facilities and their support and enthusiasm must be increased and maintained. I am sure this is consistent with the policy of your office but I would like to add my opinion just as an additional point. If you would like any further work from me on the problem of German targets, I should as always be very glad to help you.

With best regards,

PM

P. Morrison

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By CD/SC NARS, Date 25 FEB 1976

Figure D.839: Philip Morrison to Francis J. Smith. 22 February 1945 [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

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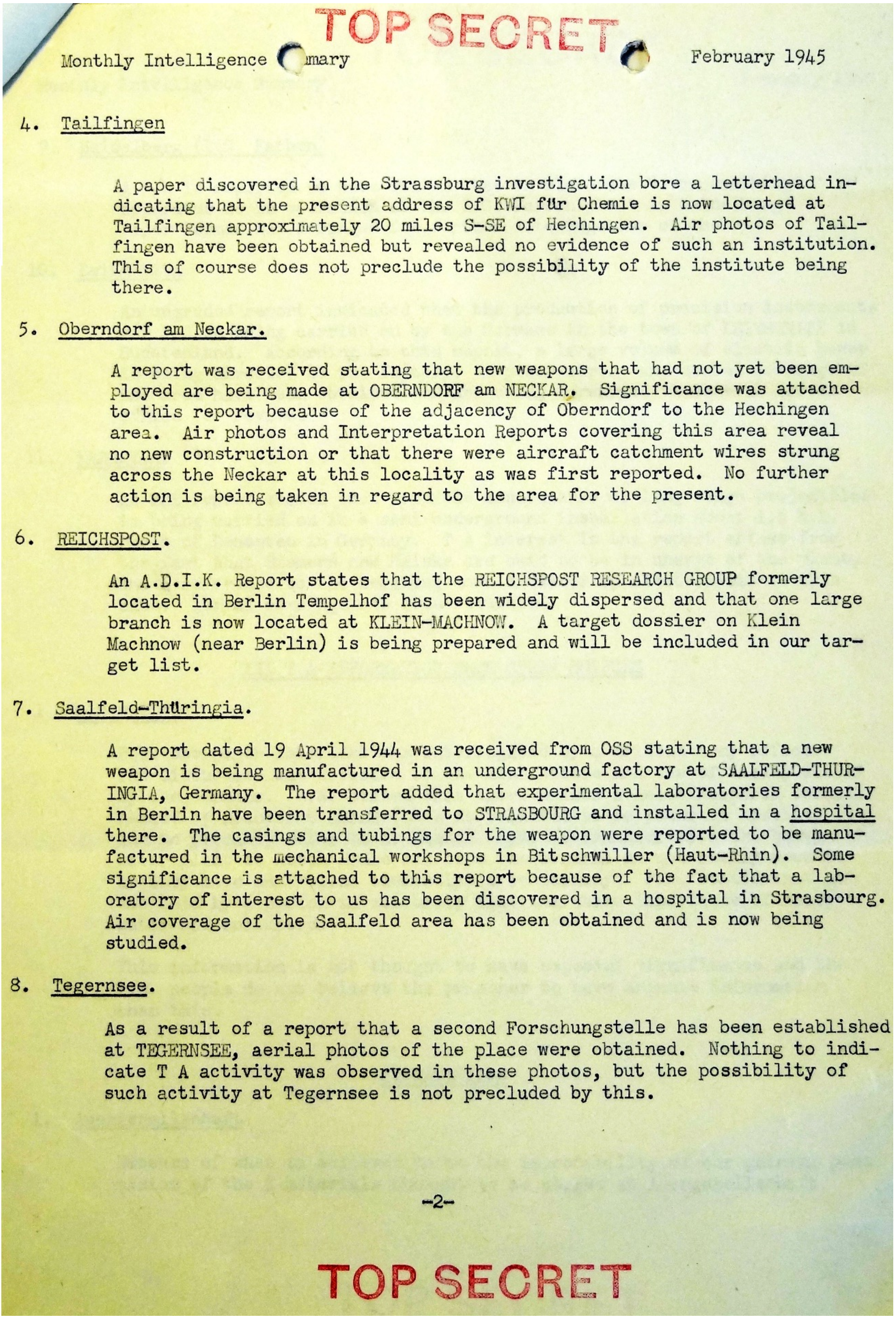

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Monthly Intelligence Summary February 1945

4. Tailfingen

A paper discovered in the Strassburg investigation bore a letterhead indicating that the present address of KWI für Chemie is now located at Tailfingen approximately 20 miles S-SE of Hechingen. Air photos of Tailfingen have been obtained but revealed no evidence of such an institution. This of course does not preclude the possibility of the institute being there.

5. Oberndorf am Neckar.

A report was received stating that new weapons that had not yet been employed are being made at OBERNDORF am NECKAR. Significance was attached to this report because of the adjacency of Oberndorf to the Hechingen area. Air photos and Interpretation Reports covering this area reveal no new construction or that there were aircraft catchment wires strung across the Neckar at this locality as was first reported. No further action is being taken in regard to the area for the present.

6. REICHSPOST.

An A.D.I.K. Report states that the REICHSPOST RESEARCH GROUP formerly located in Berlin Tempelhof has been widely dispersed and that one large branch is now located at KLEIN-MACHNOW. A target dossier on Klein Machnow (near Berlin) is being prepared and will be included in our target list.

7. Saalfeld-Thüringia.

A report dated 19 April 1944 was received from OSS stating that a new weapon is being manufactured in an underground factory at SAALFELD-THURINGIA, Germany. The report added that experimental laboratories formerly in Berlin have been transferred to STRASBOURG and installed in a hospital there. The casings and tubings for the weapon were reported to be manufactured in the mechanical workshops in Bitschwiller (Haut-Rhin). Some significance is attached to this report because of the fact that a laboratory of interest to us has been discovered in a hospital in Strasbourg. Air coverage of the Saalfeld area has been obtained and is now being studied.

8. Tegernsee.

As a result of a report that a second Forschungstelle has been established at TEGERNSEE, aerial photos of the place were obtained. Nothing to indicate T A activity was observed in these photos, but the possibility of such activity at Tegernsee is not precluded by this.

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NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.

Figure D.840: Monthly Intelligence Summary for February 1945 [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

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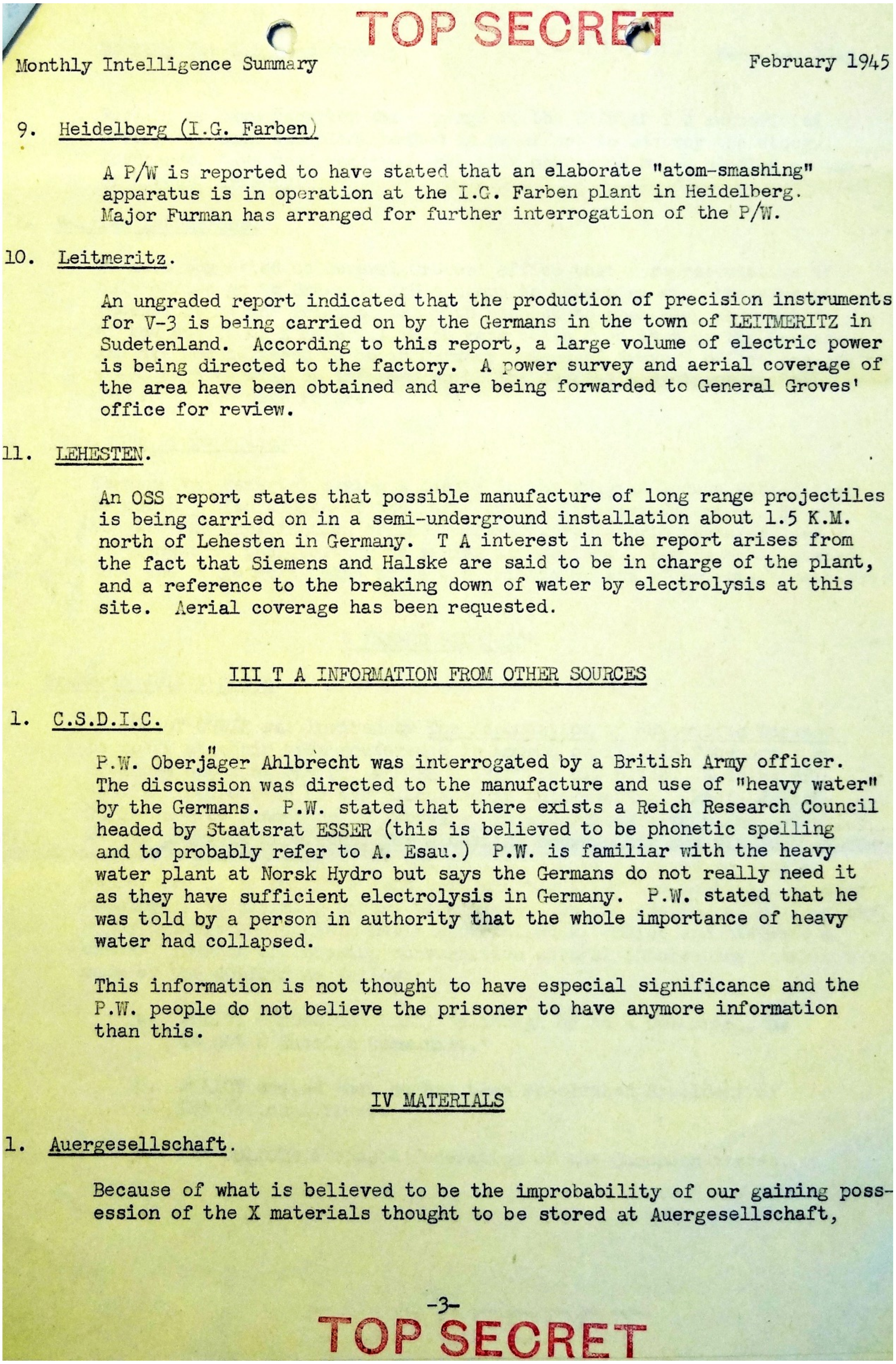

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Monthly Intelligence Summary February 1945

9. Heidelberg (I.G. Farben)

A P/W is reported to have stated that an elaborate "atom-smashing" apparatus is in operation at the I.G. Farben plant in Heidelberg. Major Furman has arranged for further interrogation of the P/W.

10. Leitmeritz.

An ungraded report indicated that the production of precision instruments for V-3 is being carried on by the Germans in the town of LEITMERITZ in Sudetenland. According to this report, a large volume of electric power is being directed to the factory. A power survey and aerial coverage of the area have been obtained and are being forwarded to General Groves' office for review.

11. LEHESTEN.

An OSS report states that possible manufacture of long range projectiles is being carried on in a semi-underground installation about 1.5 K.M. north of Lehesten in Germany. T A interest in the report arises from the fact that Siemens and Halske are said to be in charge of the plant, and a reference to the breaking down of water by electrolysis at this site. Aerial coverage has been requested.

III T A INFORMATION FROM OTHER SOURCES

1. C.S.D.I.C.

P.W. Oberjäger Ahlbrecht was interrogated by a British Army officer. The discussion was directed to the manufacture and use of "heavy water" by the Germans. P.W. stated that there exists a Reich Research Council headed by Staatsrat ESSER (this is believed to be phonetic spelling and to probably refer to A. Esau.) P.W. is familiar with the heavy water plant at Norsk Hydro but says the Germans do not really need it as they have sufficient electrolysis in Germany. P.W. stated that he was told by a person in authority that the whole importance of heavy water had collapsed.

This information is not thought to have especial significance and the P.W. people do not believe the prisoner to have anymore information than this.

IV MATERIALS

1. Auergesellschaft.

Because of what is believed to be the improbability of our gaining possession of the X materials thought to be stored at Auergesellschaft,

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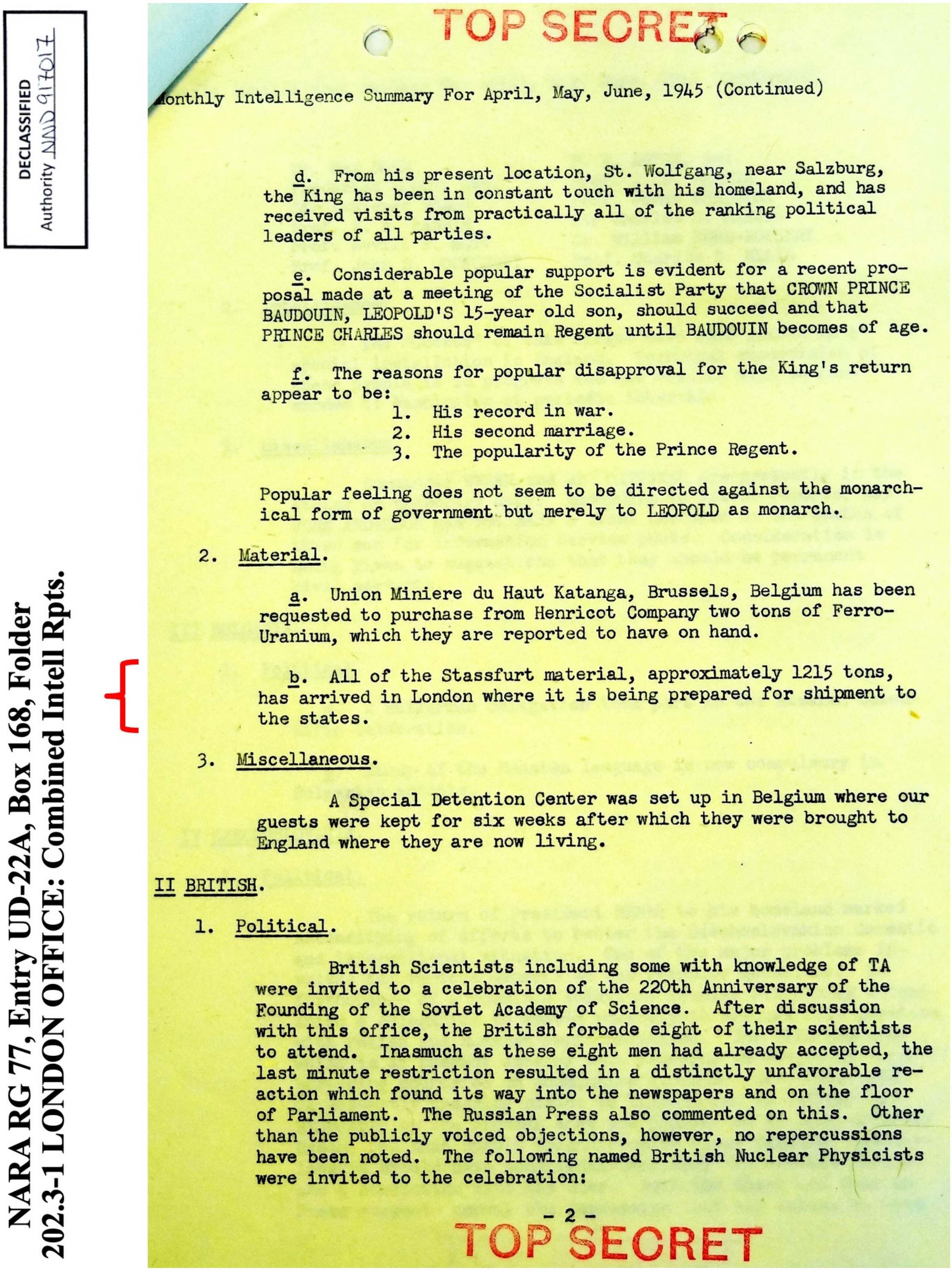
Figure D.841: Monthly Intelligence Summary for February 1945 [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

Gerard P. Kuiper to Frederick E. Terman. 13 March 1945. [University of Arizona Libraries, Special Collections, Gerard P. Kuiper Papers, Box 57, Folder 15, ALSOS Mission (1), 1945, p. 61. https://speccoll.library.arizona.edu/collections/gerard-p-kuiper-papers]

[...] One is again surprised to see quotations from U.S. senators who think that the war will be over "within a few days". It would be wiser to worry about the chance we still have of losing it if certain high explosives are developed in time. This possibility may, incidentally, be one reason why the Germans are not giving in. Few people here [in Alsos] expect an immediate collapse.

[By late 1944, Samuel Goudsmit seemed convinced that there was no German nuclear weapons program. This letter shows that even in mid-March 1945, shortly before the end of the war, Gerard Kuiper and other members of Alsos were still deeply concerned that there was indeed a German nuclear weapons program, and that it was on the verge of deploying a final product. What information had Kuiper or other members of Alsos discovered themselves or learned from others?]



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Monthly Intelligence Summary For April, May, June, 1945 (Continued)

d. From his present location, St. Wolfgang, near Salzburg, the King has been in constant touch with his homeland, and has received visits from practically all of the ranking political leaders of all parties.

e. Considerable popular support is evident for a recent proposal made at a meeting of the Socialist Party that CROWN PRINCE BAUDOUIN, LEOPOLD'S 15-year old son, should succeed and that PRINCE CHARLES should remain Regent until BAUDOUIN becomes of age.

f. The reasons for popular disapproval for the King's return appear to be:

1. His record in war.
2. His second marriage.
3. The popularity of the Prince Regent.

Popular feeling does not seem to be directed against the monarchical form of government but merely to LEOPOLD as monarch.

2. Material.

a. Union Miniere du Haut Katanga, Brussels, Belgium has been requested to purchase from Henricot Company two tons of Ferro-Uranium, which they are reported to have on hand.

b. All of the Stassfurt material, approximately 1215 tons, has arrived in London where it is being prepared for shipment to the states.

3. Miscellaneous.

A Special Detention Center was set up in Belgium where our guests were kept for six weeks after which they were brought to England where they are now living.

II BRITISH.

1. Political.

British Scientists including some with knowledge of TA were invited to a celebration of the 220th Anniversary of the Founding of the Soviet Academy of Science. After discussion with this office, the British forbade eight of their scientists to attend. Inasmuch as these eight men had already accepted, the last minute restriction resulted in a distinctly unfavorable reaction which found its way into the newspapers and on the floor of Parliament. The Russian Press also commented on this. Other than the publicly voiced objections, however, no repercussions have been noted. The following named British Nuclear Physicists were invited to the celebration:

- 2 -

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Figure D.842: Monthly Intelligence Summary for April, May, June 1945 [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

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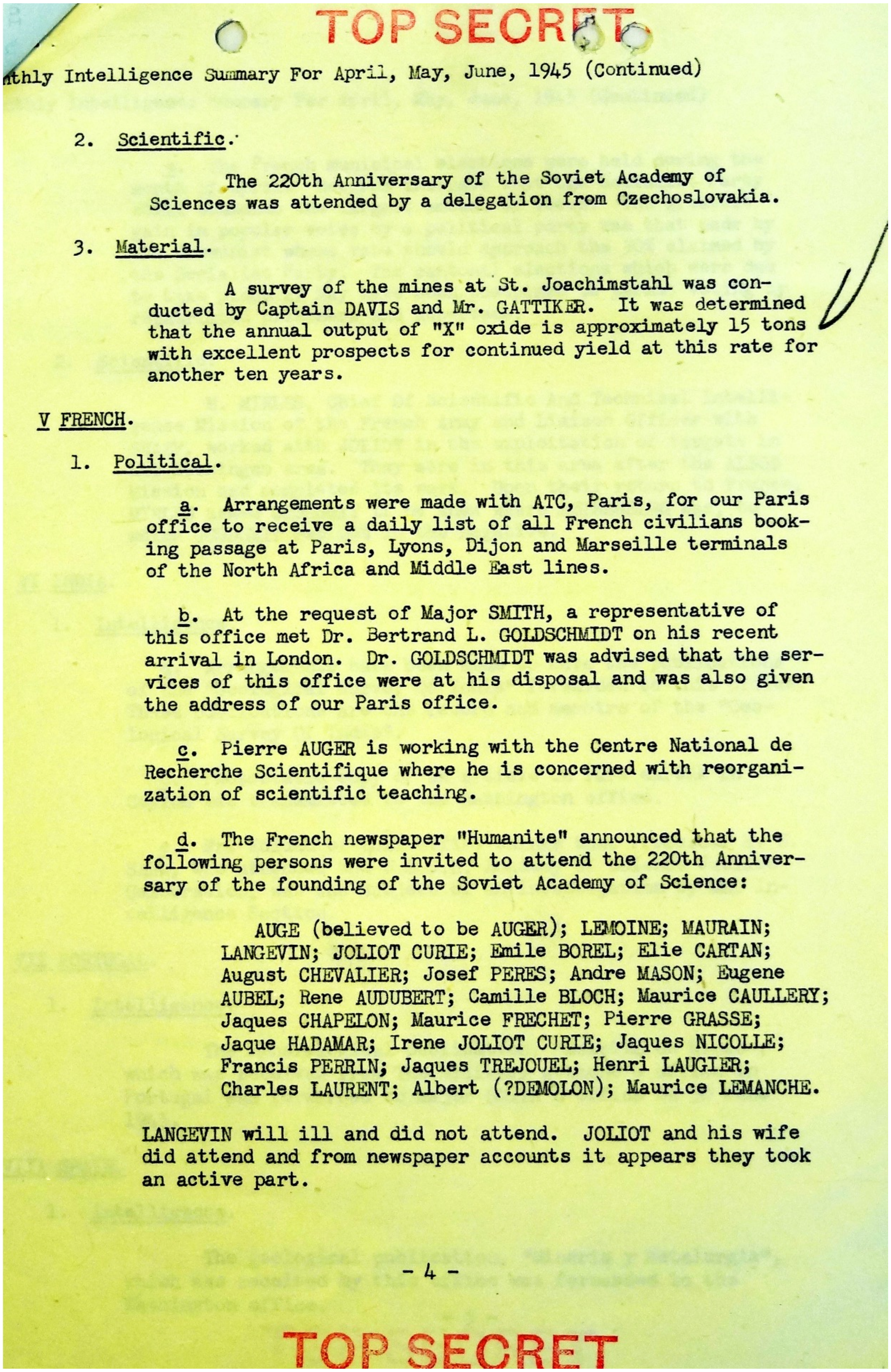

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nthly Intelligence Summary For April, May, June, 1945 (Continued)

2. Scientific.

The 220th Anniversary of the Soviet Academy of Sciences was attended by a delegation from Czechoslovakia.

3. Material.

A survey of the mines at St. Joachimstahl was conducted by Captain DAVIS and Mr. GATTIKER. It was determined that the annual output of "X" oxide is approximately 15 tons with excellent prospects for continued yield at this rate for another ten years.

V FRENCH.

1. Political.

a. Arrangements were made with ATC, Paris, for our Paris office to receive a daily list of all French civilians booking passage at Paris, Lyons, Dijon and Marseille terminals of the North Africa and Middle East lines.

b. At the request of Major SMITH, a representative of this office met Dr. Bertrand L. GOLDSCHMIDT on his recent arrival in London. Dr. GOLDSCHMIDT was advised that the services of this office were at his disposal and was also given the address of our Paris office.

c. Pierre AUGER is working with the Centre National de Recherche Scientifique where he is concerned with reorganization of scientific teaching.

d. The French newspaper "Humanite" announced that the following persons were invited to attend the 220th Anniversary of the founding of the Soviet Academy of Science:

AUGE (believed to be AUGER); LEMOINE; MAURAIN; LANGEVIN; JOLIOT CURIE; Emile BOREL; Elie CARTAN; August CHEVALIER; Josef PERES; Andre MASON; Eugene AUBEL; Rene AUDUBERT; Camille BLOCH; Maurice CAULLERY; Jaques CHAPELON; Maurice FRECHET; Pierre GRASSE; Jaque HADAMAR; Irene JOLIOT CURIE; Jaques NICOLLE; Francis PERRIN; Jaques TREJOUEL; Henri LAUGIER; Charles LAURENT; Albert (?DEMOLON); Maurice LEMANCHE.

LANGEVIN will ill and did not attend. JOLIOT and his wife did attend and from newspaper accounts it appears they took an active part.

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Figure D.843: Monthly Intelligence Summary for April, May, June 1945 [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

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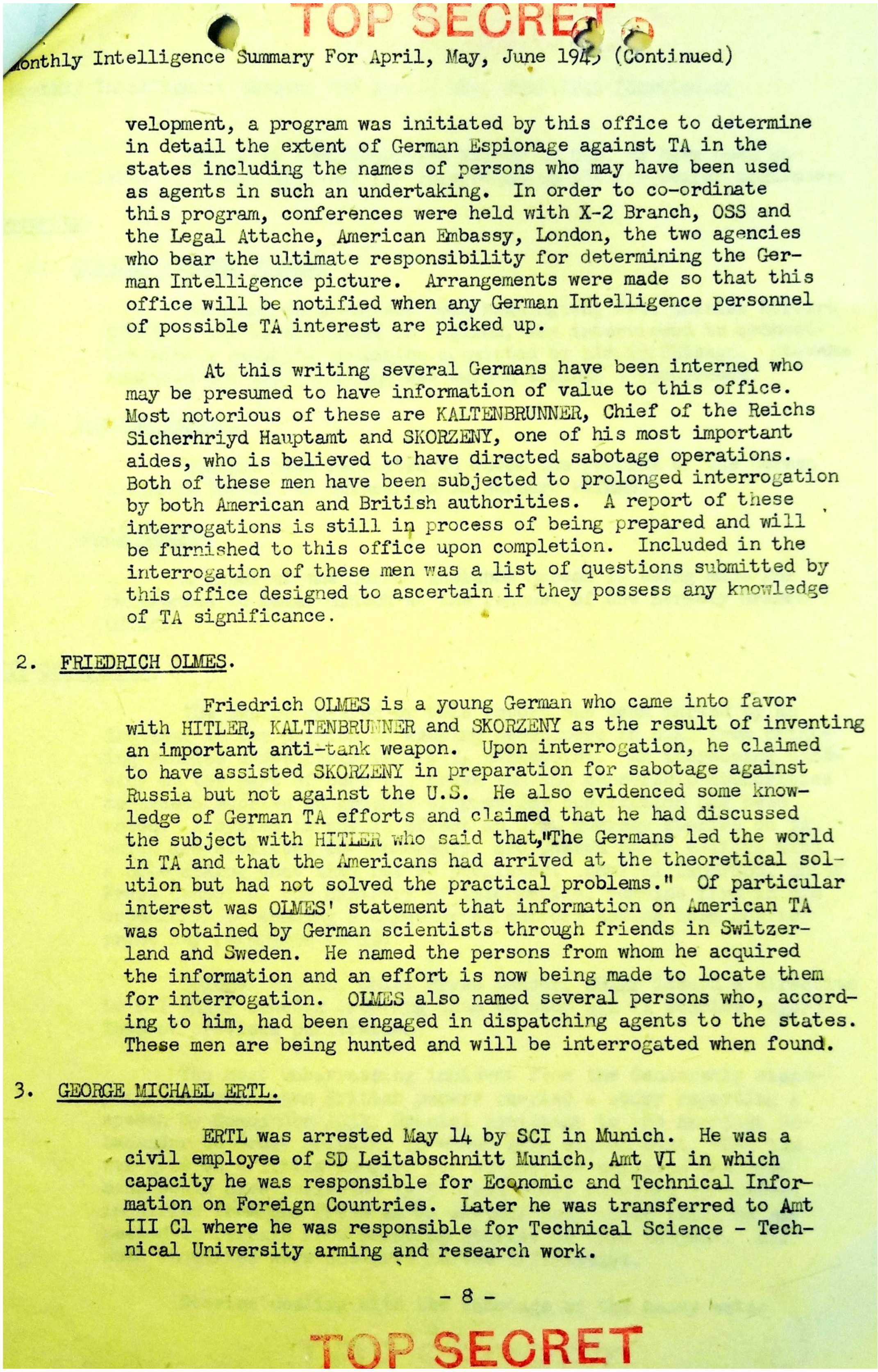

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Monthly Intelligence Summary For April, May, June 1945 (Continued)

velopment, a program was initiated by this office to determine in detail the extent of German Espionage against TA in the states including the names of persons who may have been used as agents in such an undertaking. In order to co-ordinate this program, conferences were held with X-2 Branch, OSS and the Legal Attache, American Embassy, London, the two agencies who bear the ultimate responsibility for determining the German Intelligence picture. Arrangements were made so that this office will be notified when any German Intelligence personnel of possible TA interest are picked up.

At this writing several Germans have been interned who may be presumed to have information of value to this office. Most notorious of these are KALTENBRUNNER, Chief of the Reichs Sicherhriyd Hauptamt and SKORZENY, one of his most important aides, who is believed to have directed sabotage operations. Both of these men have been subjected to prolonged interrogation by both American and British authorities. A report of these interrogations is still in process of being prepared and will be furnished to this office upon completion. Included in the interrogation of these men was a list of questions submitted by this office designed to ascertain if they possess any knowledge of TA significance.

2. FRIEDRICH OLMES.

Friedrich OLMES is a young German who came into favor with HITLER, KALTENBRUNNER and SKORZENY as the result of inventing an important anti-tank weapon. Upon interrogation, he claimed to have assisted SKORZENY in preparation for sabotage against Russia but not against the U.S. He also evidenced some knowledge of German TA efforts and claimed that he had discussed the subject with HITLER who said that,"The Germans led the world in TA and that the Americans had arrived at the theoretical solution but had not solved the practical problems." Of particular interest was OLMES' statement that information on American TA was obtained by German scientists through friends in Switzerland and Sweden. He named the persons from whom he acquired the information and an effort is now being made to locate them for interrogation. OLMES also named several persons who, according to him, had been engaged in dispatching agents to the states. These men are being hunted and will be interrogated when found.

3. GEORGE MICHAEL ERTL.

ERTL was arrested May 14 by SCI in Munich. He was a civil employee of SD Leitabschnitt Munich, Amt VI in which capacity he was responsible for Economic and Technical Information on Foreign Countries. Later he was transferred to Amt III Cl where he was responsible for Technical Science - Technical University arming and research work.

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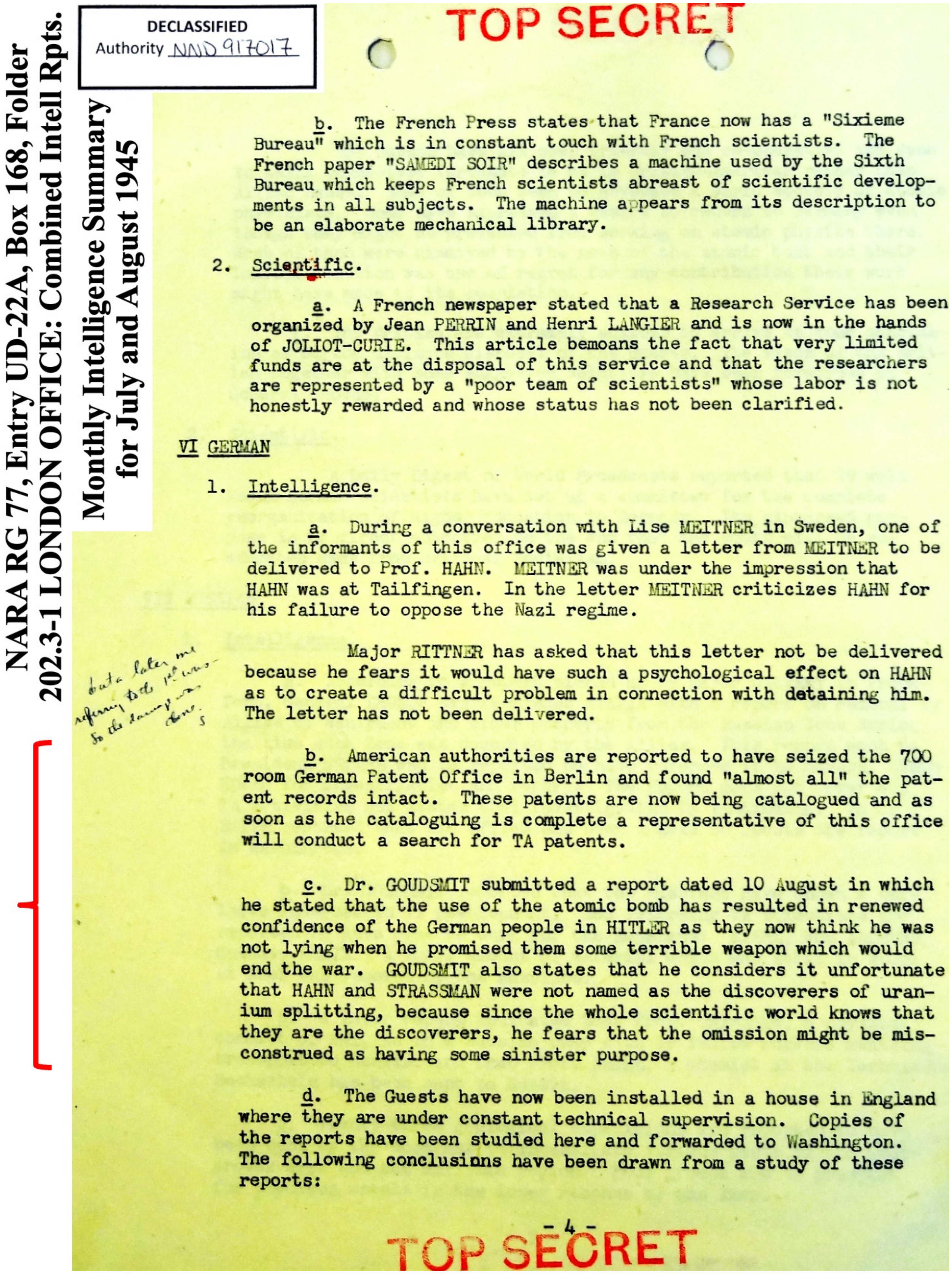
Figure D.844: Monthly Intelligence Summary for April, May, June 1945 [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].



NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.

Monthly Intelligence Summary for July and August 1945

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b. The French Press states that France now has a "Sixieme Bureau" which is in constant touch with French scientists. The French paper "SAMEDI SOIR" describes a machine used by the Sixth Bureau which keeps French scientists abreast of scientific developments in all subjects. The machine appears from its description to be an elaborate mechanical library.

2. Scientific.

a. A French newspaper stated that a Research Service has been organized by Jean PERRIN and Henri LANGIER and is now in the hands of JOLIOT-CURIE. This article bemoans the fact that very limited funds are at the disposal of this service and that the researchers are represented by a "poor team of scientists" whose labor is not honestly rewarded and whose status has not been clarified.

VI GERMAN

1. Intelligence.

a. During a conversation with Lise MEITNER in Sweden, one of the informants of this office was given a letter from MEITNER to be delivered to Prof. HAHN. MEITNER was under the impression that HAHN was at Tailfingen. In the letter MEITNER criticizes HAHN for his failure to oppose the Nazi regime.

Major RITTNER has asked that this letter not be delivered because he fears it would have such a psychological effect on HAHN as to create a difficult problem in connection with detaining him. The letter has not been delivered.

but a later one referring to the 1st was - So the damage was done. S

b. American authorities are reported to have seized the 700 room German Patent Office in Berlin and found "almost all" the patent records intact. These patents are now being catalogued and as soon as the cataloguing is complete a representative of this office will conduct a search for TA patents.

c. Dr. GOUDSMIT submitted a report dated 10 August in which he stated that the use of the atomic bomb has resulted in renewed confidence of the German people in HITLER as they now think he was not lying when he promised them some terrible weapon which would end the war. GOUDSMIT also states that he considers it unfortunate that HAHN and STRASSMAN were not named as the discoverers of uranium splitting, because since the whole scientific world knows that they are the discoverers, he fears that the omission might be misconstrued as having some sinister purpose.

d. The Guests have now been installed in a house in England where they are under constant technical supervision. Copies of the reports have been studied here and forwarded to Washington. The following conclusinns have been drawn from a study of these reports:

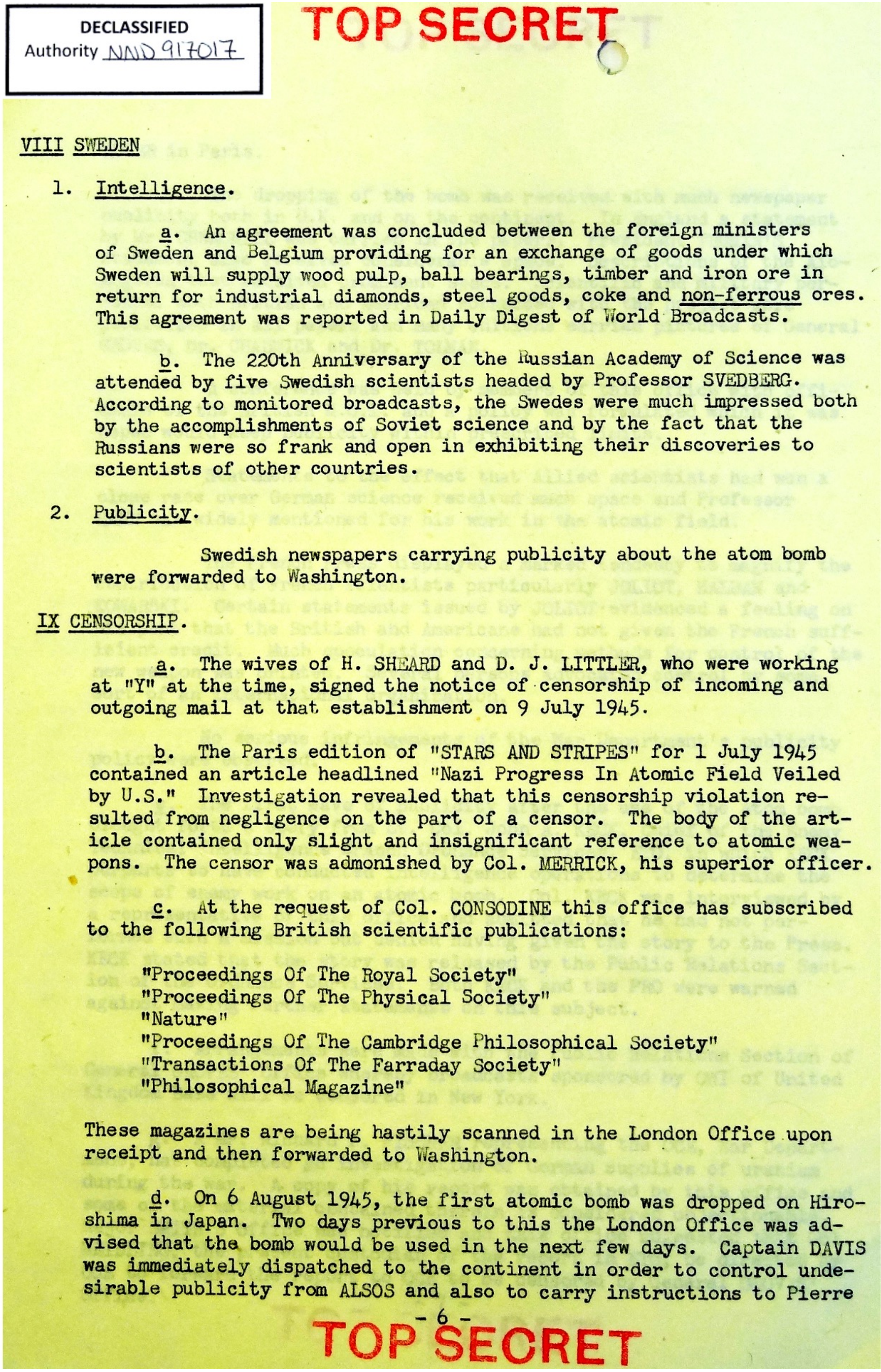
- 4 -

TOP SECRET

Figure D.845: Monthly Intelligence Summary for July and August 1945 [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

Monthly Intelligence Summary for July and August 1945

NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.



DECLASSIFIED
Authority NND 917017

TOP SECRET

VIII SWEDEN

1. Intelligence.

a. An agreement was concluded between the foreign ministers of Sweden and Belgium providing for an exchange of goods under which Sweden will supply wood pulp, ball bearings, timber and iron ore in return for industrial diamonds, steel goods, coke and non-ferrous ores. This agreement was reported in Daily Digest of World Broadcasts.

b. The 220th Anniversary of the Russian Academy of Science was attended by five Swedish scientists headed by Professor SVEDBERG. According to monitored broadcasts, the Swedes were much impressed both by the accomplishments of Soviet science and by the fact that the Russians were so frank and open in exhibiting their discoveries to scientists of other countries.

2. Publicity.

Swedish newspapers carrying publicity about the atom bomb were forwarded to Washington.

IX CENSORSHIP.

a. The wives of H. SHEARD and D. J. LITTLER, who were working at "Y" at the time, signed the notice of censorship of incoming and outgoing mail at that establishment on 9 July 1945.

b. The Paris edition of "STARS AND STRIPES" for 1 July 1945 contained an article headlined "Nazi Progress In Atomic Field Veiled by U.S." Investigation revealed that this censorship violation resulted from negligence on the part of a censor. The body of the article contained only slight and insignificant reference to atomic weapons. The censor was admonished by Col. MERRICK, his superior officer.

c. At the request of Col. CONSODINE this office has subscribed to the following British scientific publications:

"Proceedings Of The Royal Society"
"Proceedings Of The Physical Society"
"Nature"
"Proceedings Of The Cambridge Philosophical Society"
"Transactions Of The Farraday Society"
"Philosophical Magazine"

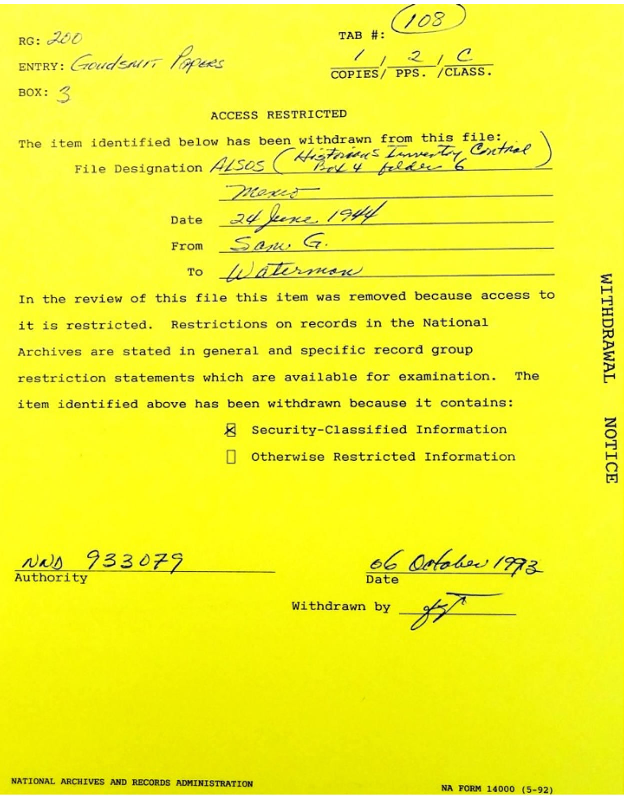
These magazines are being hastily scanned in the London Office upon receipt and then forwarded to Washington.

d. On 6 August 1945, the first atomic bomb was dropped on Hiroshima in Japan. Two days previous to this the London Office was advised that the bomb would be used in the next few days. Captain DAVIS was immediately dispatched to the continent in order to control undesirable publicity from ALSOS and also to carry instructions to Pierre

- 6 -

TOP SECRET

Figure D.846: Monthly Intelligence Summary for July and August 1945 [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].



RG: 200
ENTRY: Goudsmit Papers
BOX: 3

TAB #: (108)
1 / 2 / C
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:
File Designation ALSOS (Historian's Inventory Control Box 4 folder 6)
Memo
Date 24 June 1944
From Sam G.
To Waterman

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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06 October 1993
Date

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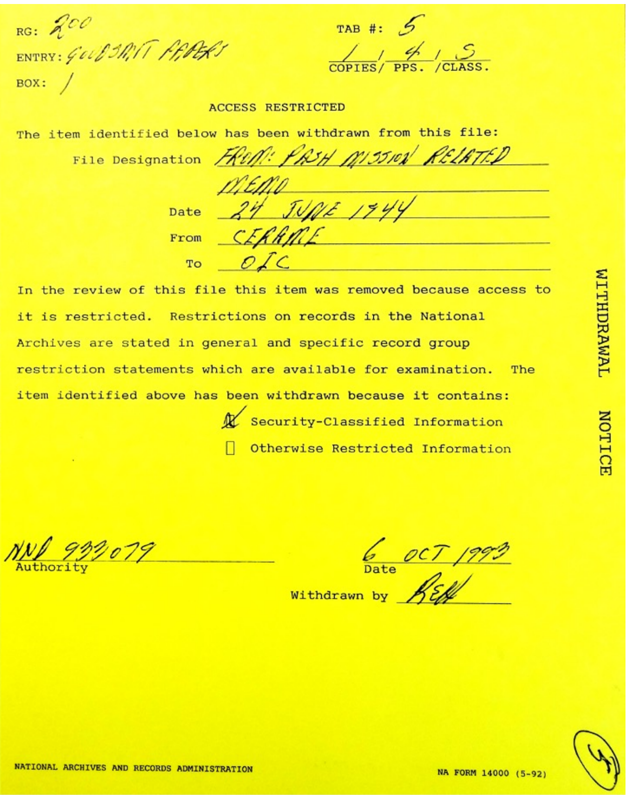

RG: 200
ENTRY: GOUDSMIT PAPERS
BOX: 1

TAB #: 5
1 / 4 / S
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:
File Designation FROM: PASH MISSION RELATED
MEMO
Date 24 JUNE 1944
From CERRME
To OIC

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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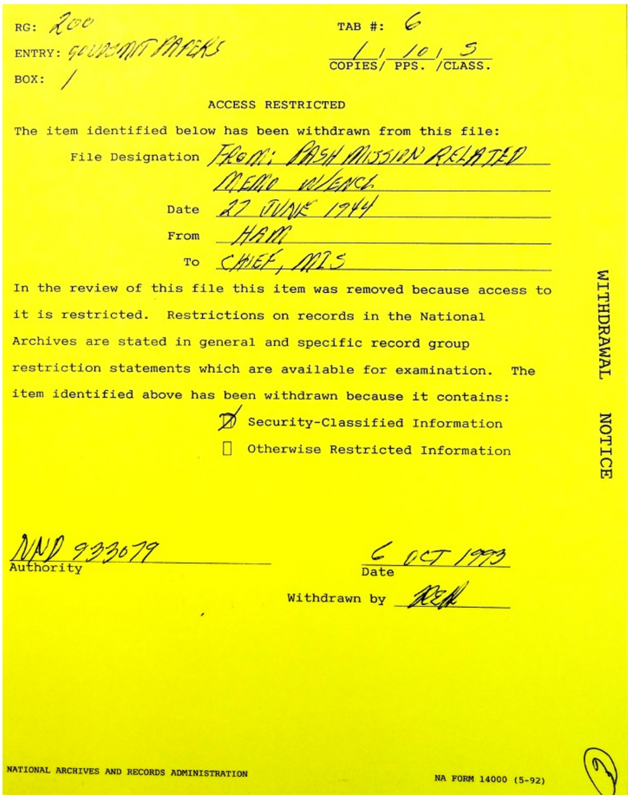
NARA RG GOUDS, Entry UD-7420, Boxes 1–9

DECLASSIFIED
Authority NND933079



RG: 200
ENTRY: GOUDSMIT PAPERS
BOX: 1

TAB #: 6
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:
File Designation FROM: PASH MISSION RELATED
MEMO W/ENCL
Date 27 JUNE 1944
From HAM
To CHIEF, MIS

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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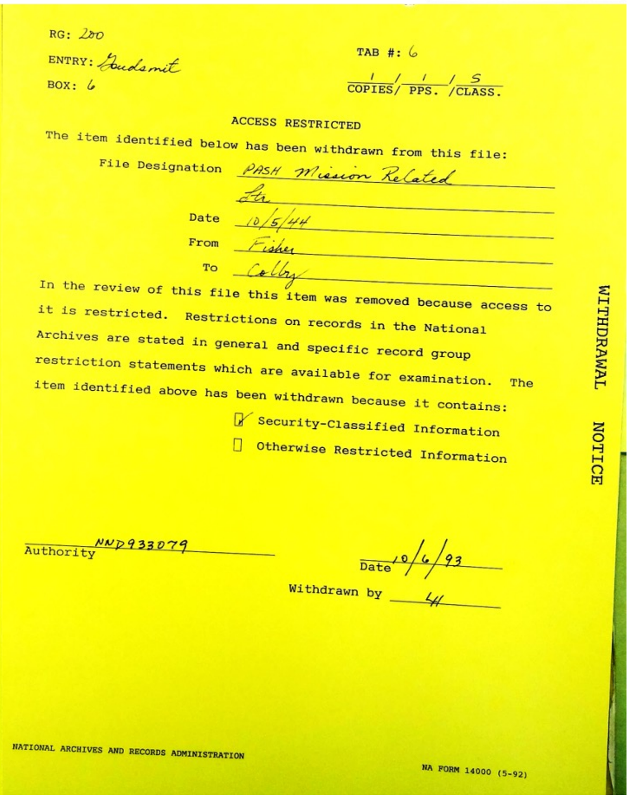

RG: 200
ENTRY: Goudsmit
BOX: 6

TAB #: 6
1 / 1 / S
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:
File Designation PASH Mission Related
Ltr
Date 10/5/44
From Fisher
To Colby

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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NND933079
Authority

10/6/93
Date

Withdrawn by

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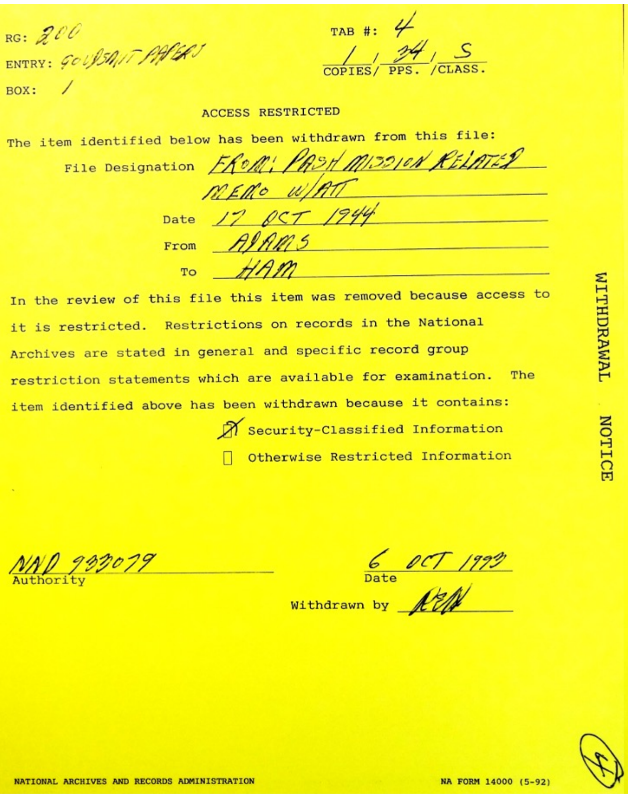
NA FORM 14000 (5-92)

Figure D.847: Many Alsos-related documents from Samuel Goudsmit's files remain classified [NARA RG GOUDS, Entry UD-7420].



RG: 200
ENTRY: GOUDSMIT PAPERS
BOX: 1

TAB #: 4
1 / 34 / S
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation FROM: PASH MISSION RELATED MEMO W/ATT
Date 17 OCT 1944
From ADAMS
To HAM

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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Authority

6 OCT 1993
Date

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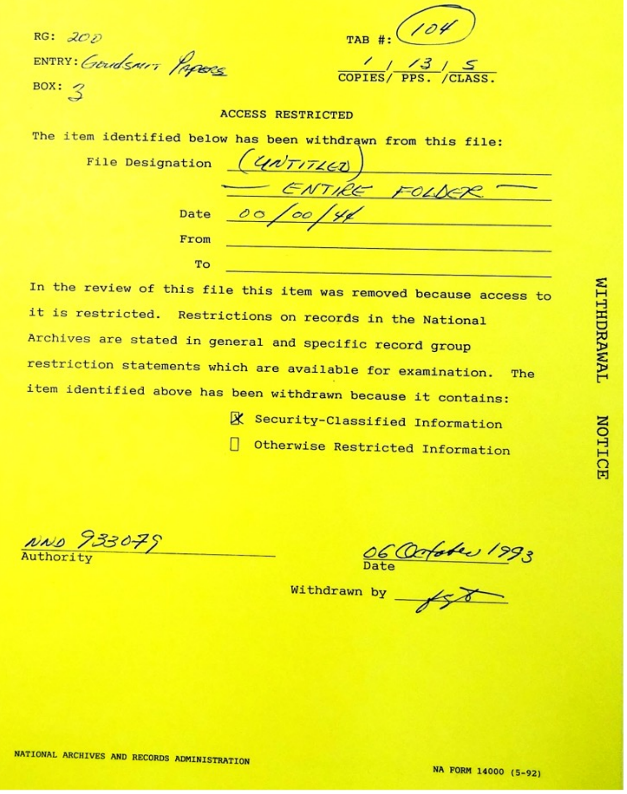

RG: 200
ENTRY: Goudsmit Papers
BOX: 3

TAB #: 104
1 / 13 / S
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation (UNTITLED) — ENTIRE FOLDER —
Date 00/00/44
From
To

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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NARA RG GOUDS, Entry UD-7420, Boxes 1–9

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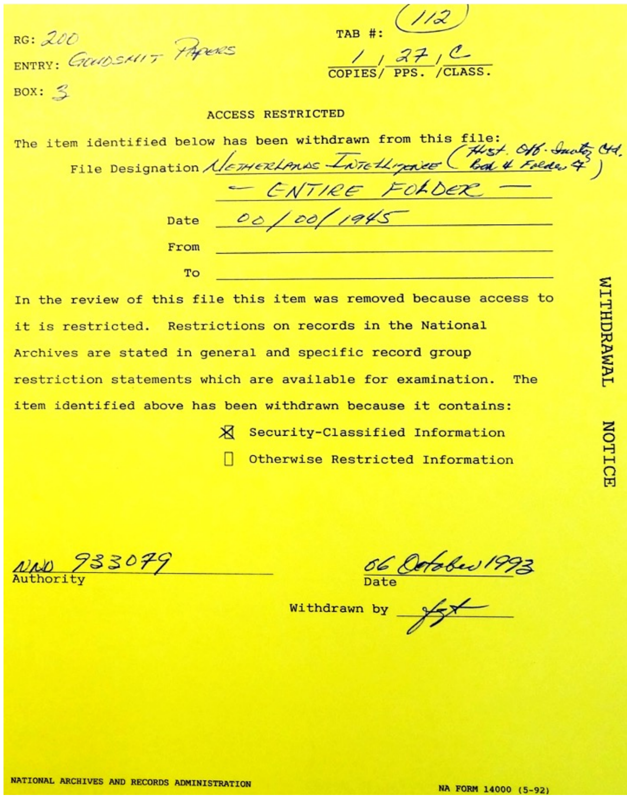
Authority NND933079



RG: 200
ENTRY: GOUDSMIT PAPERS
BOX: 3

TAB #: 112
1 / 27 / C
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation NETHERLANDS INTELLIGENCE (Hist. Off. [illegible] Box 4 Folder 4) — ENTIRE FOLDER —
Date 00/00/1945
From
To

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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Authority

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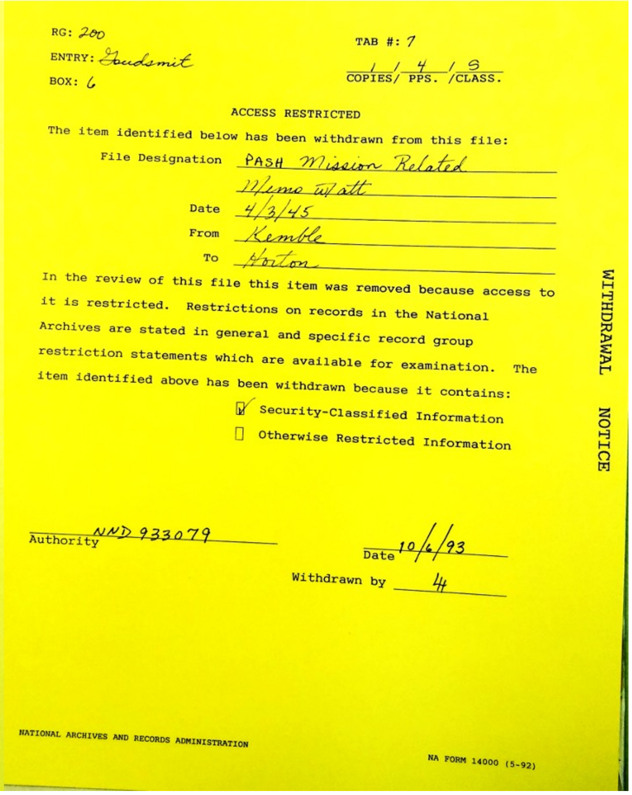
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (5-92)



RG: 200
ENTRY: Goudsmit
BOX: 6

TAB #: 7
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation PASH Mission Related Memo w/att
Date 4/3/45
From Kemble
To Horton

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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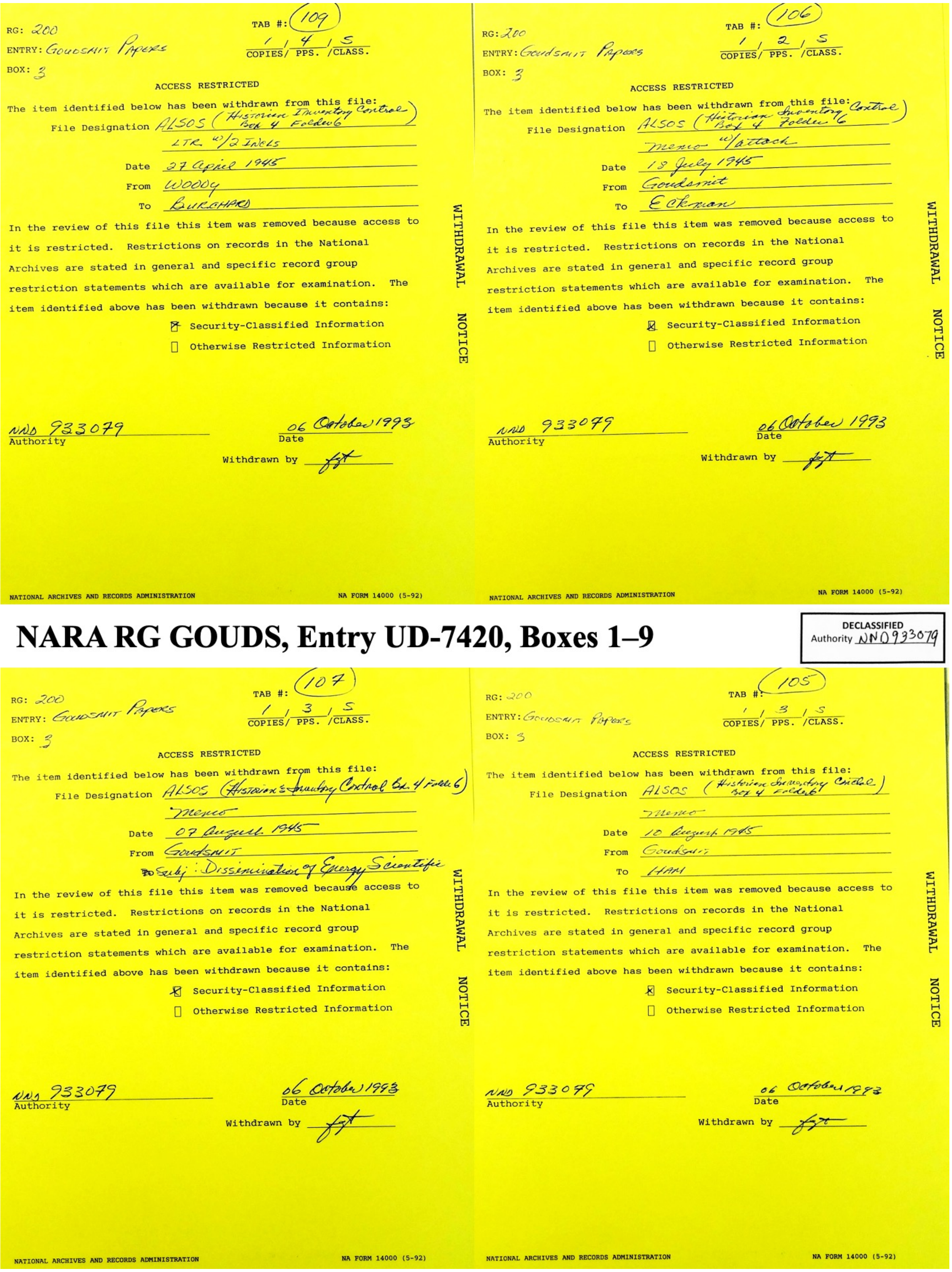
Authority NND 933079

Date 10/6/93

Withdrawn by 4

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (5-92)

Figure D.848: Many Alsos-related documents from Samuel Goudsmit's files remain classified [NARA RG GOUDS, Entry UD-7420].



RG: 200
ENTRY: GOUDSMIT PAPERS
BOX: 3

TAB #: 109
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation ALSOS (Historian Inventory Control Box 4 Folder 6)
LTR. w/2 INCLS
Date 27 April 1945
From WOODY
To BURCHARD

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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Authority

06 October 1993
Date

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RG: 200
ENTRY: Goudsmit Papers
BOX: 3

TAB #: 106
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation ALSOS (Historian Inventory Control Box 4 Folder 6)
memo w/attach
Date 18 July 1945
From Goudsmit
To Eckman

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information
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NND 933079
Authority

06 October 1993
Date

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NARA RG GOUDS, Entry UD-7420, Boxes 1–9

DECLASSIFIED
Authority NND933079

RG: 200
ENTRY: GOUDSMIT Papers
BOX: 3

TAB #: 107
1 / 3 / S
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation ALSOS (Historian's Inventory Control Bx. 4 Folder 6)
memo
Date 07 August 1945
From GOUDSMIT
~~To~~ Subj: Dissemination of Energy Scientific

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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RG: 200
ENTRY: GOUDSMIT Papers
BOX: 3

TAB #: 105
1 / 3 / S
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation ALSOS (Historian Inventory Control Box 4 Folder 6)
memo
Date 10 August 1945
From Goudsmit
To HAM

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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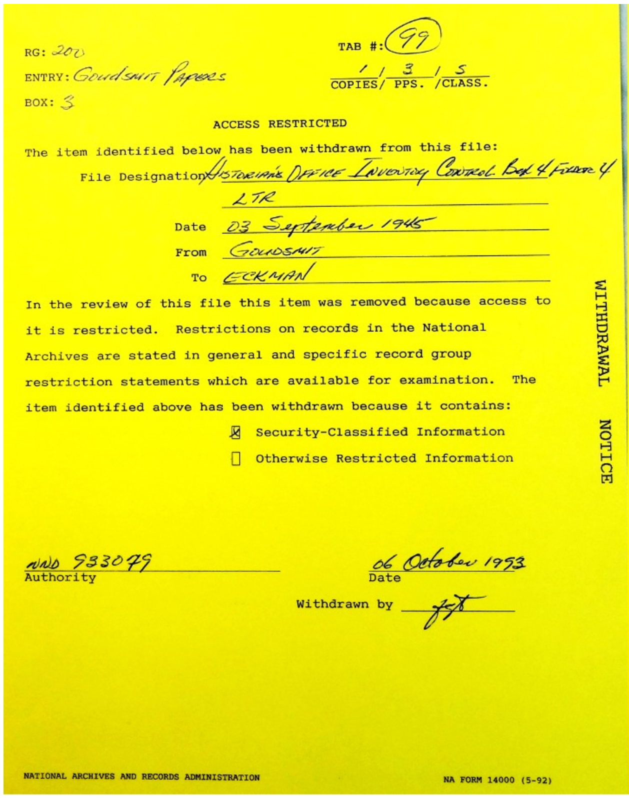
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (5-92)

Figure D.849: Many Alsos-related documents from Samuel Goudsmit's files remain classified [NARA RG GOUDS, Entry UD-7420].



RG: 200

ENTRY: Goudsmit Papers

BOX: 3

TAB #: 99

1 / 3 / S
COPIES/ PPS. /CLASS.

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Historian's Office Inventory Control Box 4 Folder 4
LTR

Date 03 September 1945

From Goudsmit

To Eckman

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

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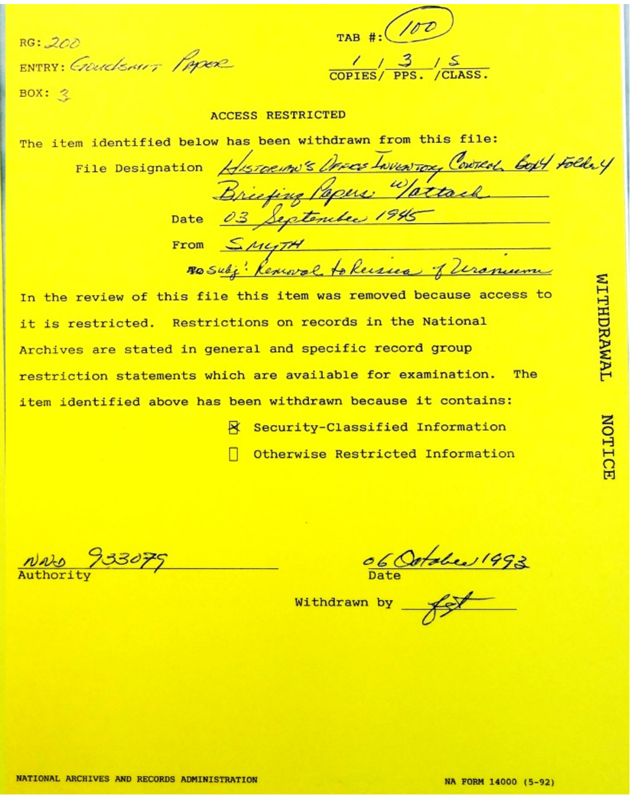
NND 933079
Authority

06 October 1993
Date

Withdrawn by fgt

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (5-92)



RG: 200

ENTRY: Goudsmit Paper

BOX: 3

TAB #: 100

1 / 3 / S
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Historian's Office Inventory Control Box 4 Folder 4
Briefing Papers w/attach

Date 03 September 1945

From Smyth

Subj: Removal to Russia of Uranium

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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NND 933079
Authority

06 October 1993
Date

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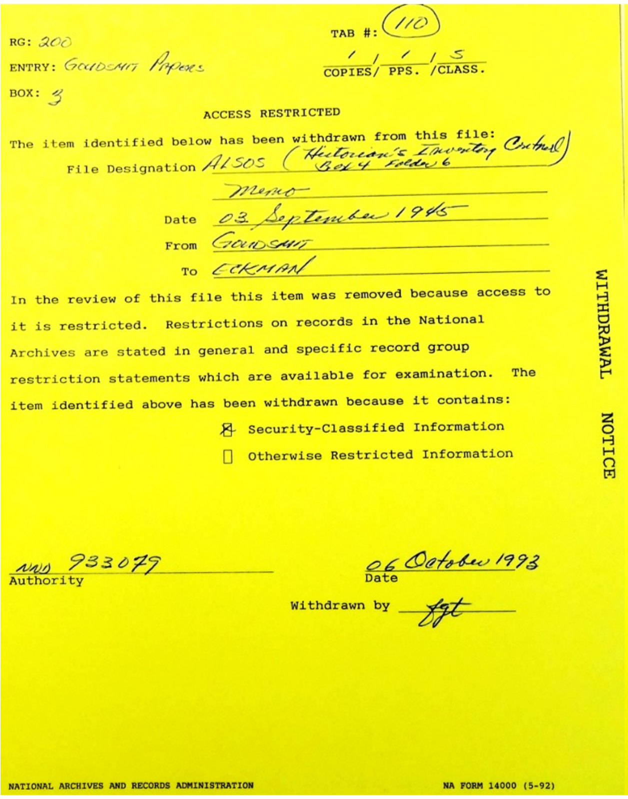
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (5-92)

NARA RG GOUDS, Entry UD-7420, Boxes 1–9

DECLASSIFIED
Authority NND933079



RG: 200

ENTRY: Goudsmit Papers

BOX: 3

TAB #: 110

1 / 1 / S
COPIES/ PPS. /CLASS.

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation ALSOS (Historian's Inventory Control Box 4 Folder 6)
Memo

Date 03 September 1945

From Goudsmit

To Eckman

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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NND 933079
Authority

06 October 1993
Date

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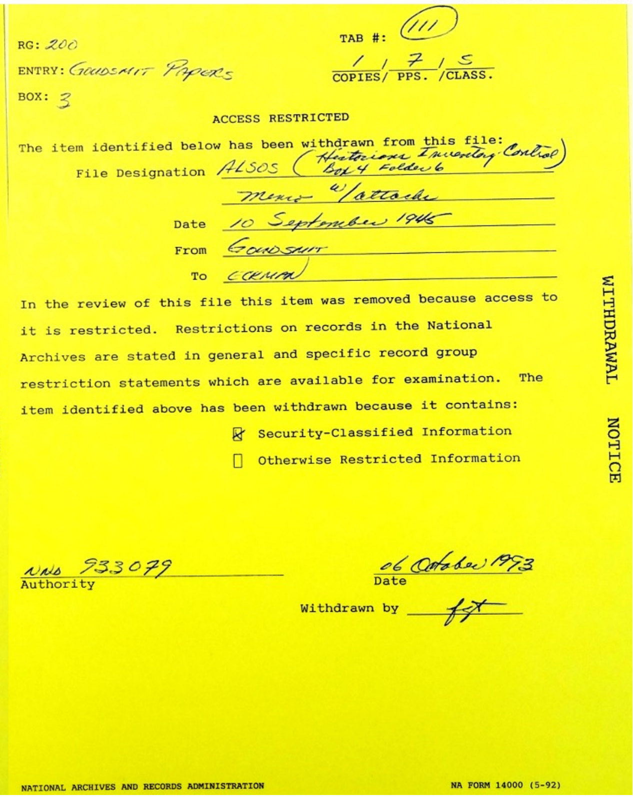

RG: 200

ENTRY: Goudsmit Papers

BOX: 3

TAB #: 111

1 / 7 / S
COPIES/ PPS. /CLASS.

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation ALSOS (Historians Inventory Control Box 4 Folder 6)
Memo w/attache

Date 10 September 1945

From Goudsmit

To Eckman

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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Authority

06 October 1993
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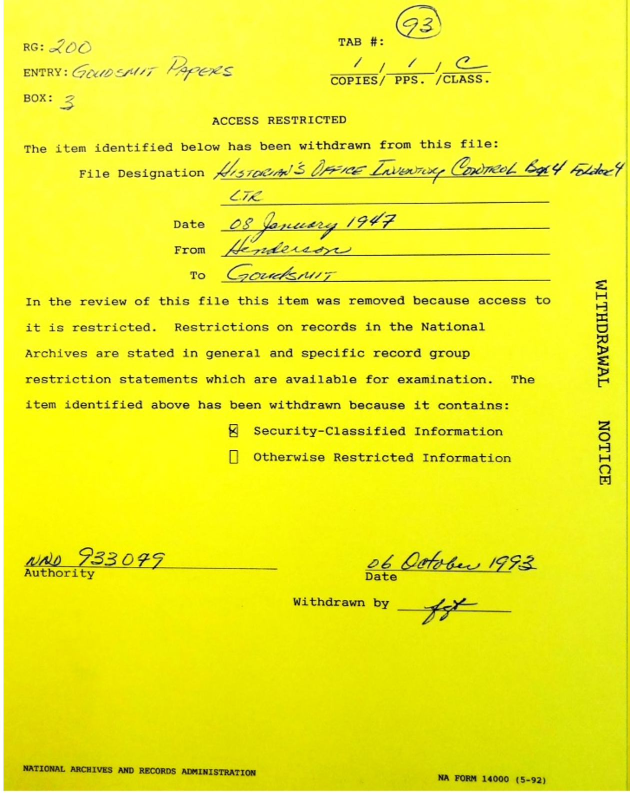
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (5-92)

Figure D.850: Many Alsos-related documents from Samuel Goudsmit's files remain classified [NARA RG GOUDS, Entry UD-7420].



RG: 200
ENTRY: GOUDSMIT PAPERS
BOX: 3

TAB #: 93
1 / 1 / C
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation HISTORIAN'S OFFICE INVENTORY CONTROL Box 4 Folder 4
LTR
Date 08 January 1947
From Henderson
To Goudsmit

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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NND 933079
Authority

06 October 1993
Date

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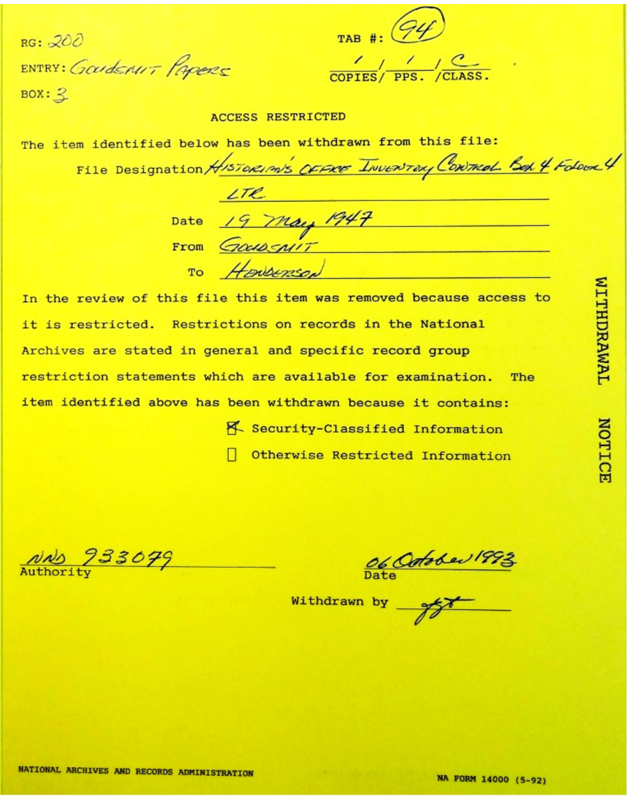
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION
NA FORM 14000 (5-92)



RG: 200
ENTRY: GOUDSMIT PAPERS
BOX: 3

TAB #: 94
1 / 1 / C
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation HISTORIAN'S OFFICE INVENTORY CONTROL Box 4 Folder 4
LTR
Date 19 May 1947
From GOUDSMIT
To HENDERSON

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information
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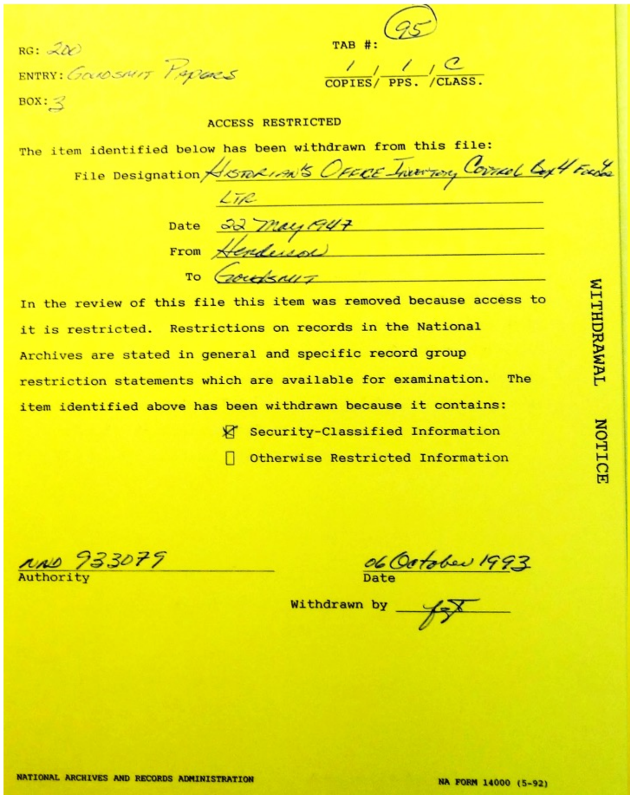
NARA RG GOUDS, Entry UD-7420, Boxes 1–9

DECLASSIFIED
Authority NND933079



RG: 200
ENTRY: GOUDSMIT PAPERS
BOX: 3

TAB #: 95
1 / 1 / C
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation HISTORIAN'S OFFICE INVENTORY CONTROL Box 4 Folder 4
LTR
Date 22 May 1947
From Henderson
To Goudsmit

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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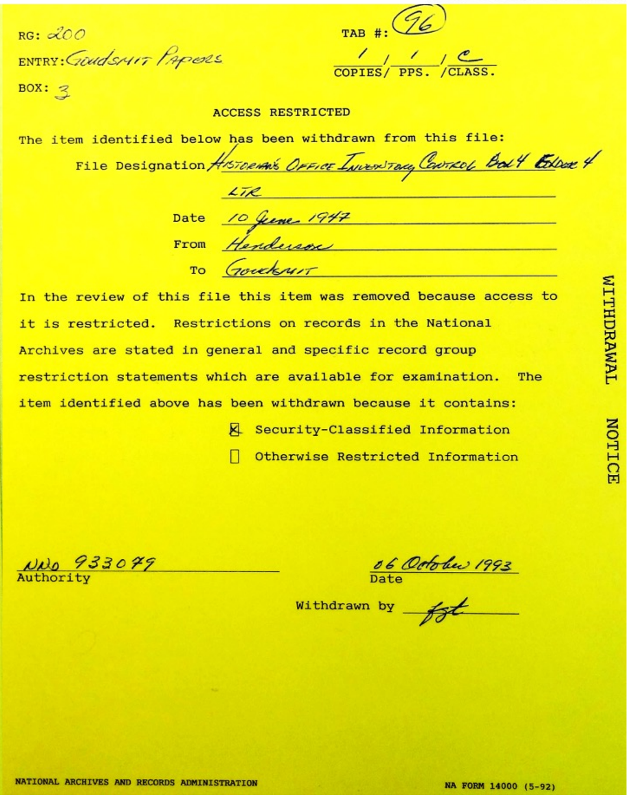

RG: 200
ENTRY: Goudsmit Papers
BOX: 3

TAB #: 96
1 / 1 / C
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation HISTORIAN'S OFFICE INVENTORY CONTROL Box 4 Folder 4
LTR
Date 10 June 1947
From Henderson
To Goudsmit

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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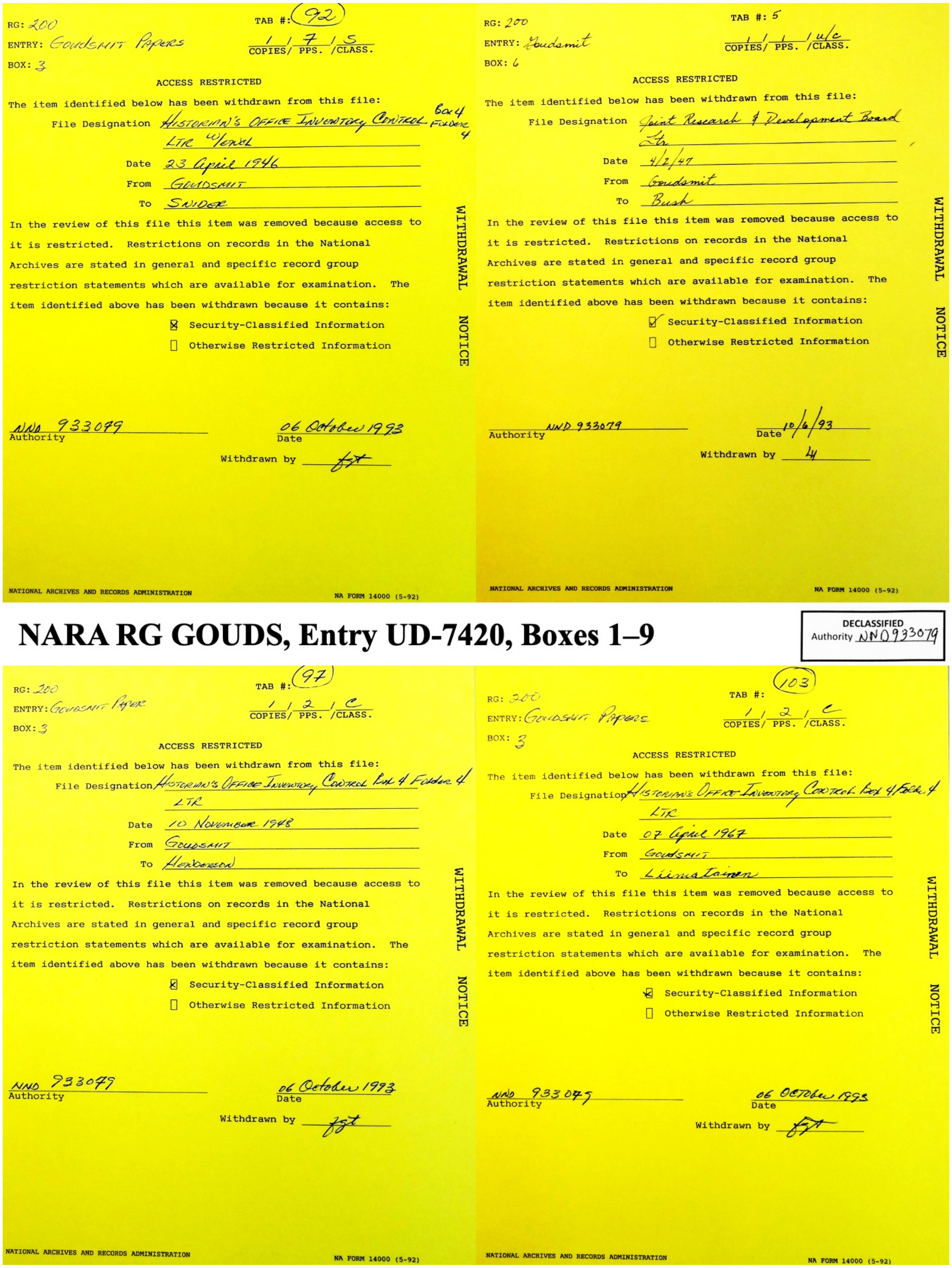
Figure D.851: Many Alsos-related documents from Samuel Goudsmit's files remain classified [NARA RG GOUDS, Entry UD-7420].



RG: 200
ENTRY: GOUDSMIT PAPERS
BOX: 3
TAB #: 92
1 / 7 / S
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation HISTORIAN'S OFFICE INVENTORY CONTROL Box 4 FOLDER 4
LTR W/ENCL
Date 23 April 1946
From GOUDSMIT
To SNIDER

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WITHDRAWAL NOTICE

NND 933079
Authority

06 October 1993
Date

Withdrawn by fgt

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NA FORM 14000 (5-92)

RG: 200
ENTRY: Goudsmit
BOX: 6
TAB #: 5
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The item identified below has been withdrawn from this file:

File Designation Joint Research & Development Board
Ltr
Date 4/2/47
From Goudsmit
To Bush

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NA FORM 14000 (5-92)

NARA RG GOUDS, Entry UD-7420, Boxes 1–9

DECLASSIFIED
Authority NND933079

RG: 200
ENTRY: GOUDSMIT PAPER
BOX: 3
TAB #: 97
1 / 2 / C
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation HISTORIAN'S OFFICE INVENTORY CONTROL Box 4 Folder 4
LTR
Date 10 NOVEMBER 1948
From GOUDSMIT
To HENDERSON

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NA FORM 14000 (5-92)

RG: 200
ENTRY: GOUDSMIT PAPERS
BOX: 3
TAB #: 103
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation HISTORIAN'S OFFICE INVENTORY CONTROL Box 4/Folder 4
LTR
Date 07 April 1967
From GOUDSMIT
To Liimatainen

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WITHDRAWAL NOTICE

NND 933079
Authority

06 OCTOBER 1993
Date

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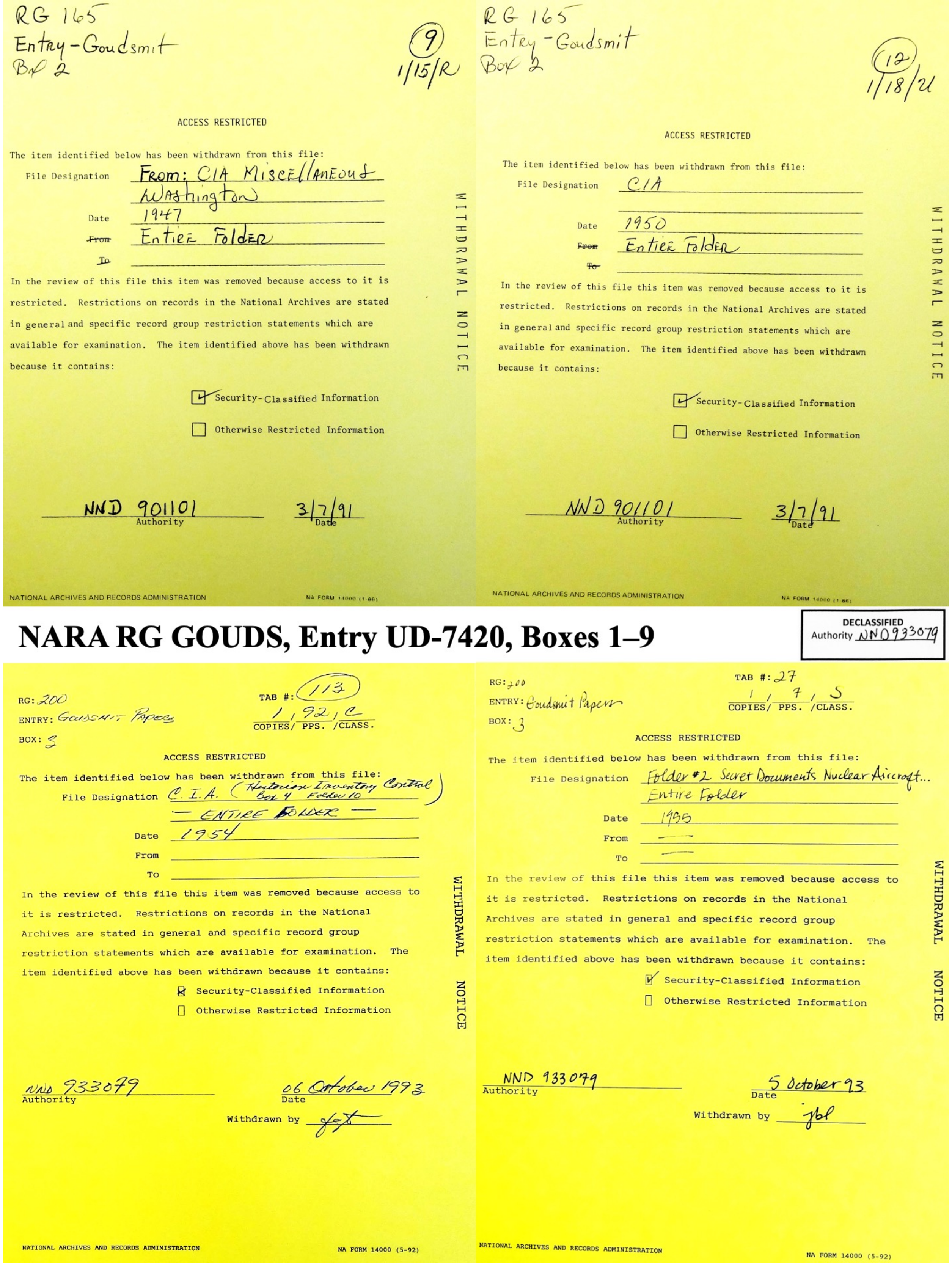
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION
NA FORM 14000 (5-92)

Figure D.852: Many Alsos-related documents from Samuel Goudsmit's files remain classified [NARA RG GOUDS, Entry UD-7420].



RG 165
Entry-Goudsmit
Box 2

(9)
1/15/R

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation From: CIA Miscellaneous Washington
Date 1947
~~From~~ Entire Folder
~~To~~

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☑ Security-Classified Information
☐ Otherwise Restricted Information

NND 901101 Authority
3/7/91 Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

RG 165
Entry-Goudsmit
Box 2

(12)
1/18/21

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation CIA
Date 1950
~~From~~ Entire Folder
~~To~~

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☑ Security-Classified Information
☐ Otherwise Restricted Information

NND 901101 Authority
3/7/91 Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

NARA RG GOUDS, Entry UD-7420, Boxes 1–9

DECLASSIFIED
Authority NND933079

RG: 200
ENTRY: GOUDSMIT PAPERS
BOX: 3

TAB #: (113)
1 / 92 / C
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation C. I. A. (Historian Inventory Control Box 4 Folder 10)
— ENTIRE FOLDER —
Date 1954
From
To

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☒ Security-Classified Information
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NND 933079 Authority
06 October 1993 Date

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WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (5-92)

RG: 200
ENTRY: Goudsmit Papers
BOX: 3

TAB #: 27
1 / 7 / S
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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Folder #2 Secret Documents Nuclear Aircraft...
Entire Folder
Date 1955
From —
To —

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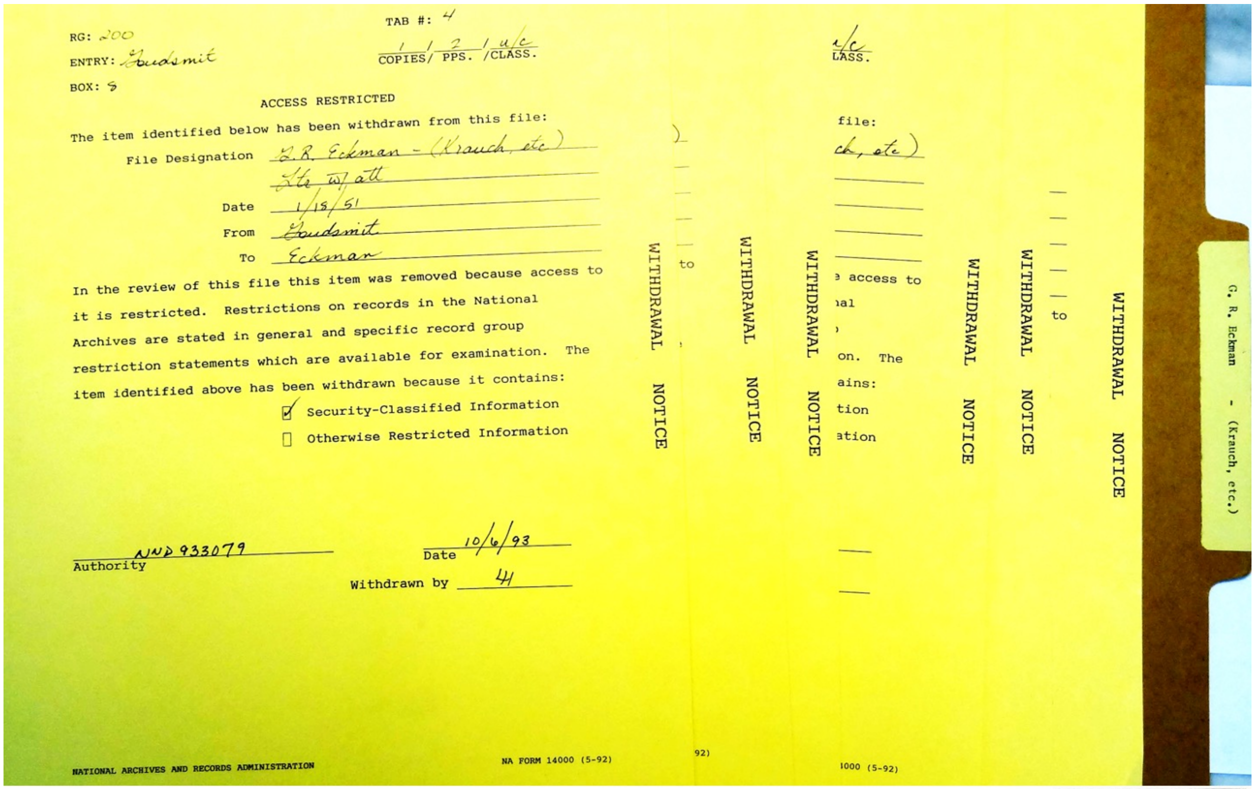
NND 933079 Authority
5 October 93 Date

Withdrawn by jbl

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (5-92)

Figure D.853: Many Alsos-related documents from Samuel Goudsmit's files remain classified [NARA RG GOUDS, Entry UD-7420].



RG: 200

ENTRY: Goudsmit

BOX: 5

TAB #: 4

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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation G.R. Eckman - (Krauch, etc)
Ltr w/ att
Date 1/18/51
From Goudsmit
To Eckman

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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Authority NND 933079

Date 10/6/93

Withdrawn by 41

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION

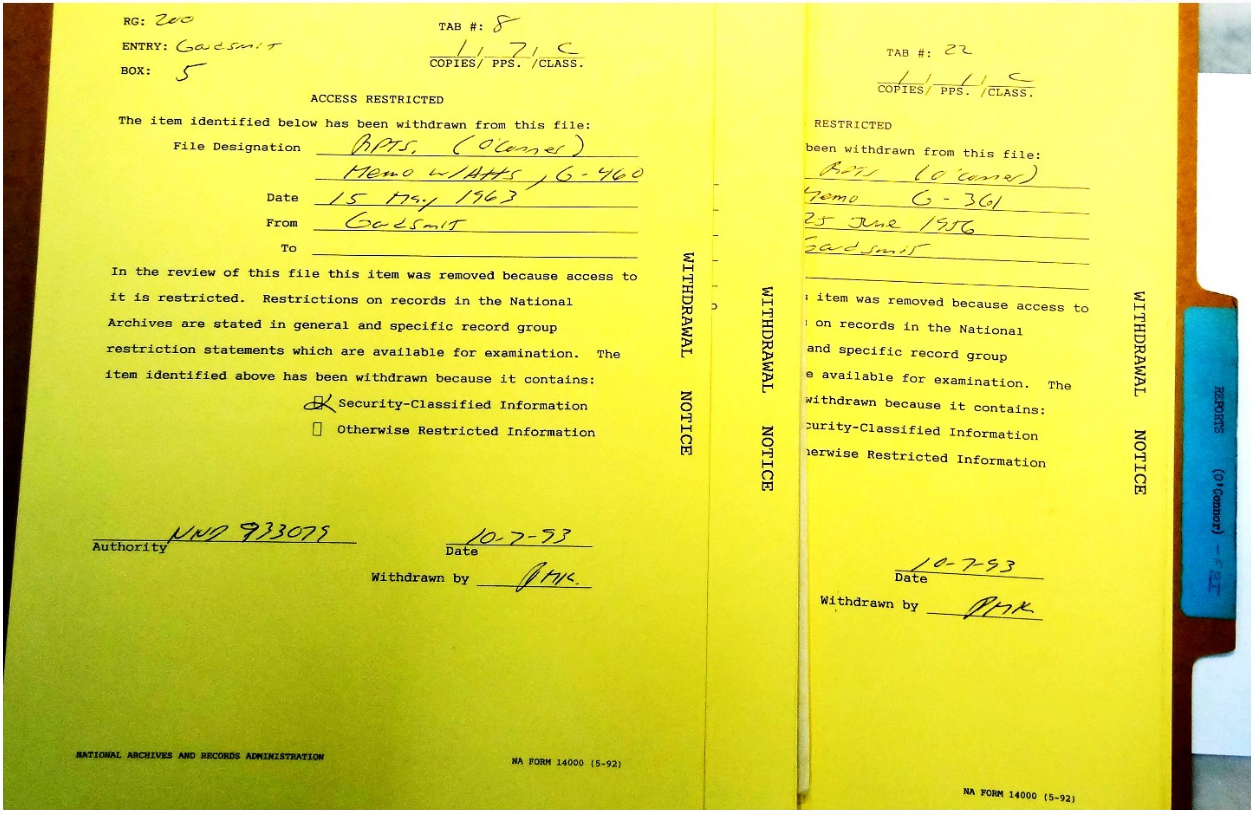
NA FORM 14000 (5-92)

WITHDRAWAL NOTICE

G. R. Eckman - (Krauch, etc.)

NARA RG GOUDS, Entry UD-7420, Boxes 1–9

DECLASSIFIED
Authority NND 933079



RG: 200

ENTRY: Goudsmit

BOX: 5

TAB #: 8

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ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation RPTS. (O'Connor)
Memo w/Atts, G-460
Date 15 May 1963
From Goudsmit
To

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☐ Otherwise Restricted Information

Authority NND 933079

Date 10-7-93

Withdrawn by PMK

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION

NA FORM 14000 (5-92)

WITHDRAWAL NOTICE

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been withdrawn from this file:

RPTS (O'Connor)
Memo G-361
25 June 1956
Goudsmit

Date 10-7-93

Withdrawn by PMK

NA FORM 14000 (5-92)

REPORTS (O'Connor)

Figure D.854: Many Alsos-related documents from Samuel Goudsmit's files remain classified [NARA RG GOUDS, Entry UD-7420].

OSS. TOP SECRET—CONTROL Number 67. Subject: Experts on Atomic Fission. Late 1945 (?). [NARA RG 226, Entry A1-215, Box 6, Folder WN26150–26164]

1. The following list includes the names, approximate locations, field of interest, and relative importance of the scientists now living in Germany who are outstanding for their theoretical knowledge of atomic fission.

NAME	ADDRESS	FIELD	RATING
BAGGE	Goettingen	Nuclear physics	B
BERKEI, Fritz	Berlin	Nuclear physics	B–C
*BONHOEFFER, K. F.	Leipzig	Phys-chemistry; heavy water	A
*BORN, Dr. H. J.	Berlin-Karlshorst	Bio-physics	B
BOTHE, Prof. Walter	Heidelberg	Nuclear physics	A
BRILL, Prof. Dr. R.	Darmstadt	Inorganic chemistry	A
BRUNA, Dr. Otto	Tailfingen	Nuclear physics	B–C
CLUSIUS, Klaus	Munich	Nuclear physics	A
CZULIUS, Werner	Berlin (?)	Nuclear physics	B–C
DAENZER, Dr. H.	Heidelberg (?)	Nuclear physics	A–B
DIEBNER, Dr. K.	Br. Zone	Nuclear physics	C
DIECKEL	Munich	Nuclear physics	B
DOPEL, R.	Leipzig (?)	Nuclear physics	B
DROSTE, Dr. G. von	Berlin-Dahlem	Nuclear physics	B
ERBACHER, Prof. Otto	Tailfingen (?) (May be in Berlin-Dahlem)	Nuclear physics	B
EWALD, Dr. Heinz	Tailfingen (?)	Mass spectroscopy	B
FLAMMERSFELD, Dr. Arnold	Berlin-Dahlem	Theoretical physics	B
FUCHTBAUER, Prof. Dr.	Beboldehausen (Formerly Bonn)	Spectroscopy	B
FLÜGGE, Siegfried	Goettingen (?)	Nuclear physics	A–B
GENTNER, Dr. Wolfgang	Heidelberg	Nuclear physics	B
GERLACH, W.	Bonn	Nuclear physics	B
GERTHSEN, Prof.	Berlin	Nuclear physics	A–B
GOTTE, Dr. Hans	Tailfingen (?)	Nuclear physics	B
GRASSMAN, E.	Berlin (?)	Nuclear physics	C
GROTH, Dr. Will	Hamburg	Physical chemistry	B
HAHN, Prof. Dr. Otto	Goettingen	Nuclear physics	A
HARTECK, P.	Hamburg	Nuclear physics	A
HAXEL, O.	Berlin (?)	Nuclear physics	B
HILSCH, Dr. R.	Erlangen	Experimental physics	B
HEISENBERG, Werner	Goettingen	Nuclear physics	A
*HILGERS, Dr.	Berlin-Oberschoeneweide	Nuclear physics	C

HINTERBERGER, Dr. Heinrich	(?—is Austrian)	Mass spectroscopy	B
HOCKER, Karl Heinz	Hechingen	Nuclear physics	C
HOFFMAN, Prof.	Leipzig	Physics	B
HOUTERMANS, Fritz G.	Goettingen	Physics	B
JENSEN, Dr. J.	Hannover	Theoretical physics	B
JORDAN, Pasqual	Berlin	Theoretical physics	A
JUILFS, Dr.	Berlin	Theoretical physics	B–C
KIRCHNER, Dr.	Garmisch	Nuclear physics	B
KLEMM, Dr. Alfred	Tailfingen (?)	Nuclear physics	B
KLUGE, Dr.	Berlin (?)	High frequency cables (AEG)	C
KOCHENDORFER, Dr. Albert	Stuttgart	Physics	B
KOPPERMANN, H.	Goettingen	Nuclear physics	A
KOSSEL, Prof. W.	?	Physics	A
LAUE, Max von	Goettingen	Nuclear physics	A
LINDNER, Dr. Roland	Tailfingen (?)	Nuclear physics	C
MATTAUCH, Dr. Joseph	Tailfingen	Nuclear physics	A
MECKE, Prof. Dr. F.	Freiburg	Theoretical physics (Spectroscopy)	B
MOLIERE, G.	Heckingen	Theoretical physics (Cosmic Rays)	B
PHILIPP, Kurt	?	Physics Geiger-Mueller counters	B
POHL, Dr. R. W.	Goettingen	Physics	A
POSE, H.	Leipzig (?) Heckingen (?)	Nuclear physics	B
RAMSAUER, Prof. Dr. K. W.	Berlin (?)	Physics	A–B
REGENER, E.	Weissenantal (Ravensburg)	Cosmic radiation; physics of ionosphere	A
REHBEIN, F.	Stadtilm, Thur.	Nuclear physics	B–C
RIEZLER, Prof. Dr. W.	Garmisch	Nuclear physics	B
RUCHARDT, E.	Munden	Nuclear physics	B–C
SAUERWEIN, Kurt	Tailfingen	Theoretical physics	B
SCHMIDT, Dr. Theo	Greifswald (N. of Berlin)	Theoretical physics	B
SEELMANN-EGGEBERT, Dr. Walter	Tailfingen	Nuclear chemistry	B
STRASSMANN, Dr. Fritz	Goettingen	Nuclear physics	A
*STEIMEL, Dr.	Berlin (?)	Electronic tubes	B
WALDMANN, Dr. Ludwig	Tailfingen	Theoretical physics	A
WEIZSAECKER, Carl Fred. von	Goettingen	Nuclear physics	B
WIRTZ, Karl	Goettingen	Nuclear physics	B
*ZIMMER, Dr.	Berlin-Karlshorst	Bio-physics	B

(Asterisks denote men who have been invited to work in Russia but have declined.)

2. Any of these men becomes an important intelligence target whenever it appears that his services have been sought by any other nation. Any attempts to recruit these scientists should be reported in detail; especially the name and German address of the man, exactly what he is being recruited for, where he would go, and all inducements offered. This information should be forwarded by the quickest means possible.

3. The following is a list of German scientists known to be working in the USSR at the invitation of the Russians.

ARDENNE, Baron Manfred von: Germany's foremost builder of cyclotrons. Taken to Russia June 1945; now reported in Taupse on Black Sea. Rating: A.

HERTZ, Prof. G.: Partially Jewish; non-Nazi. Went to Russia in June 1945 with 25 assistants. Rating: A.

MIE, Dr.: Nazi; physicist. Arrived Moscow July 1945. Rating: C.

RIEHL, Prof. N.: Non-Nazi; Director of Research for the Auergesellschaft AG Oranienburg, Berlin. Radio chemist. Went to Russia June 1945. Rating: A.

STEENBECK, Dr.: Nazi; atomic physicist and rheotron expert. Arrested by Russians and sent to Moscow in September 1945. Rating: A.

THIESSEN, Prof. P. A.: Former Director Kaiser Wilhelm Institute for physical chemistry. Taken to Russia in October 1945 with two assistants and VON ARDENNE. Rating: B.

VOLMER, Prof. M.: Non-Nazi; physical chemist. In Russia with HERTZ. Rating: A.

4. The activities of these men are of the greatest interest, as are those of any other men who may be added to the list. If any of these men returns to Germany information as to his whereabouts should be forwarded at once.

5. The names and activities of engineers and other technical experts possibly connected with atomic research also become of great intelligence interest when such men are known to be working for other nations or to have been successfully recruited or even approached by another nation. Full details are required.

[This is the final version of a list that was created and distributed by the Alsos Mission. There was a similar but separate list for Austrians such as those Georg Stetter's group—see the following pages. If the U.S. government truly believed that these scientists knew and accomplished so little during the war, why were they so concerned about what these scientists might tell or do for other countries that wanted to develop nuclear weapons?

In some respects this list shows a remarkably detailed knowledge of wartime German nuclear work, including many relatively obscure scientists. In other respects this list reveals areas of ignorance about the wartime German nuclear program. It underestimates the importance of some people. For example, it assigns the lowest value (C) to Diebner, who appears to have been instrumental in running the nuclear program, and gives a B to Jensen, who went on to win a Nobel Prize for his nuclear work. It also omits a number of important people.]

Todos M. Odarenko. FIAT 63. ***Activities of the Second Institute of Physics of the University of Vienna.*** **[The original German version of this report is G-345.]**

[See document photos on pp. 4786–4787.]

1.0 Introduction.

The material presented here on the activities of the Second Physics Institute of Vienna University was obtained from Prof. Stetter, as the result of my visit to Thumersbach and to Zell-am-See between October 10 and 13, 1945. The primary purpose of the visit was to establish the contribution of the Institute to the atomic work on the so-called "Uran-Motor" project, and to determine the work of the Institute on radiation absorption materials. Two days were used for interviews with Prof. Stetter and his associates, at the end of which a series of reports were obtained, the English translation of which is attached herewith, as Appendix I.

Although some of these reports, and additional documents, were removed from the Institute earlier by Prof. Smyth of the Alsos Mission, the reports obtained were translated and are released herewith as a matter of record. The original German reports were turned over to the Naval Intelligence Division, Navy Department, Washington, D.C.

2.0 General Observations on the Institute and its Work.

2.1 The Institute.

The Institute, with its present component parts, was the largest and the most important research organization in Austria. Before the war, it was involved primarily in the so-called pure research. During the war, it became engaged in certain special problems, of which the Uran-Motor project was one. In addition, the problems relating to the radar field, high frequency development work on testing equipment and the radiation absorption materials, received a certain amount of attention. A very brief review of these activities is undertaken below. A series of the reports prepared by the members of the Institute is attached for a more searching study.

2.2 Work in Nuclear Physics.

Not having been intimately connected with the work on atomic energy release, I am not in a position to fully evaluate the importance of the Institute's work in this field. The significance of the work of the Institute, from the point of view of the potential utilization of its research, was very sketchily discussed in my reports on "Atomic Bomb Research in the Russian Zone of Czechoslovakia", dated October 26, 1945, and on "Problems of Displaced Scientists Now Residing in the American Zone of Austria", dated October 26, 1945.

Contrary to the statements, attributed by the U.S. newspapers to the various U.S. atomic experts, that it "would take the Germans some 100 years to solve the problem of atomic disintegration on an explosive basis" (for the manufacture of bombs), the opinion of the members of the Institute themselves was that, given a supply of radium and uranium, and permitting their return to Vienna, where certain of their materials and equipments are stored, they would be able to "complete their work" in some 3 to 6 months. Some small scale experiments were claimed to be performed successfully by the Institute before the end of the war in Europe.

That these claims of the Institute are not to be disregarded too readily would follow from the fact that Prof. Smyth spent considerable time with the Institute, revisited them several times, and thought it necessary to insist on the most stringent type of control over the scientific activities of the group, as well as on close individual observations. Perhaps equally significant are the indications of the substantial interest of the Russians in several members of the Institute.

Incidentally, the following list of materials was obtained from Prof. Stetter, as held in Vienna by Prof. E. Haschek of the Vienna University: a mass-spectrograph, amplifiers, oscillographs, an X-ray equipment, various testing devices for work on nuclear physics, 200 kg. of Wolfram, some Beryllium, Heavy water, 500 kg. of Lead, a small quantity of Uranium, (most of the Uranium had been removed by the Russians from the laboratories of the University).

As a result of the forced idleness, the group has occupied itself with the problems of Uranium split-up on a considerably more concentrated basis than they were able to do in Vienna. They also managed to attract the attention to this problem of other members of the scientific body in the region around Zell-am-See. I am inclined to think that, given an opportunity, such as their return to Vienna, and some sort of inducement, the Institute would concentrate on this problem to the exclusion of other activities, with a good chance of success.

2.3 Radiation Absorption Material.

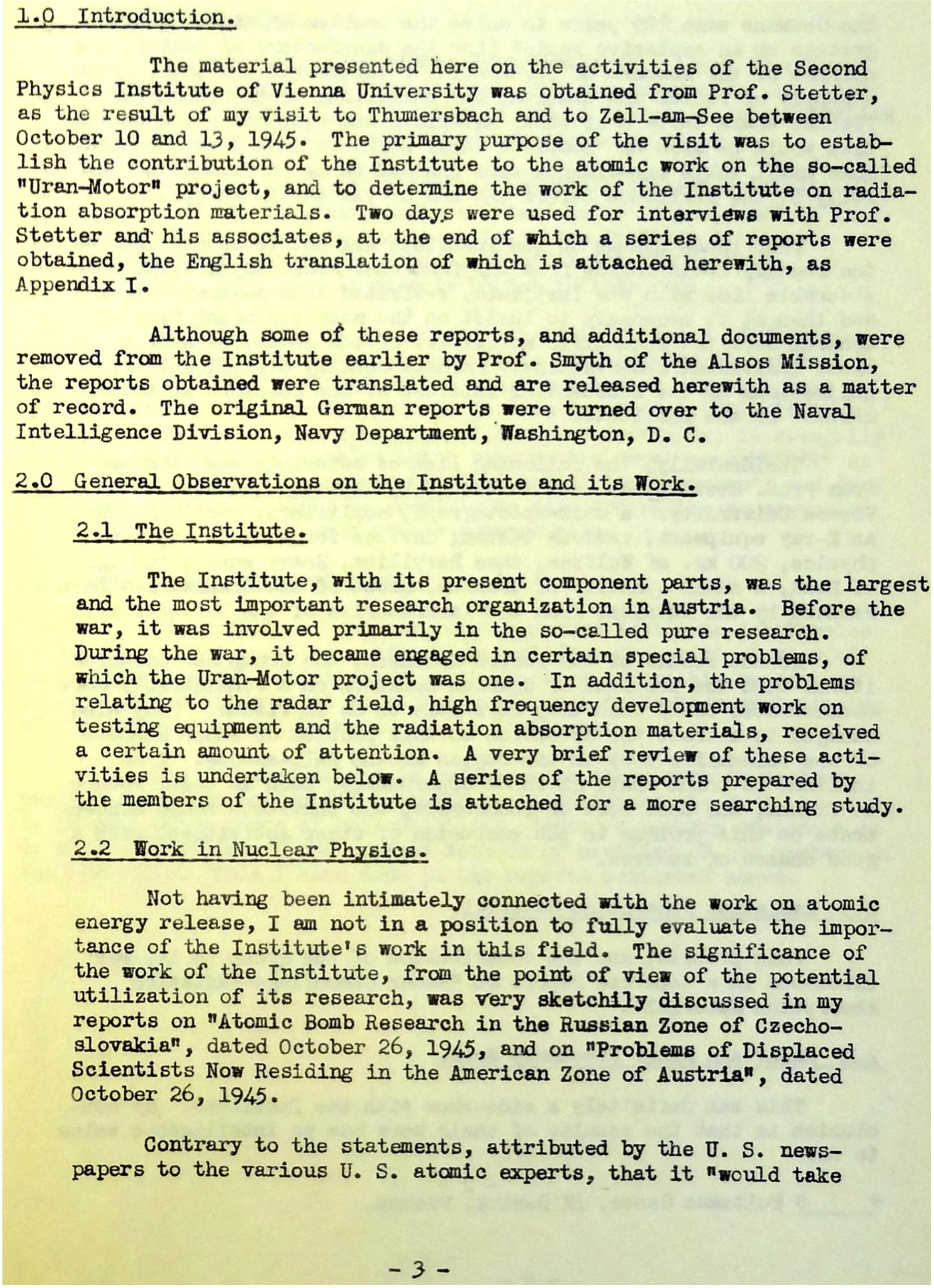
This problem, and the contribution of the group to it, was discussed in a separate report on "Radar Camouflage-Radiation Absorption Material".

[Georg Stetter and his fellow Austrian researchers were heavily involved in both the wartime fission and fusion programs (pp. 3372–3375, 4330–4345, 4784–4800, 4992).

The information from Odarenko was forwarded directly to Leslie Groves—see pp. 4794–4795.

"Prof. Smyth" was Charles P. Smyth, a Princeton chemistry professor and member of the Alsos Mission. He should not be confused with his brother Henry DeWolf Smyth, a Manhattan Project physicist who wrote the August 1945 "Smyth Report" that gave public information about the U.S. atomic bomb program.

As a result of the reports of Odarenko and Smyth, the Austrian nuclear scientists were closely monitored and controlled for years by U.S. intelligence and military agencies. For example, Georg Stetter was kept under virtual house arrest by U.S. agents in Austria from 1945 until the 1950s, nearly destroying his career (pp. 4796–4800).]



T. M. Odarenko. FIAT 63. ***Activities of the Second Institute of Physics of the University of Vienna.***

1.0 Introduction.

The material presented here on the activities of the Second Physics Institute of Vienna University was obtained from Prof. Stetter, as the result of my visit to Thumersbach and to Zell-am-See between October 10 and 13, 1945. The primary purpose of the visit was to establish the contribution of the Institute to the atomic work on the so-called "Uran-Motor" project, and to determine the work of the Institute on radiation absorption materials. Two days were used for interviews with Prof. Stetter and his associates, at the end of which a series of reports were obtained, the English translation of which is attached herewith, as Appendix I.

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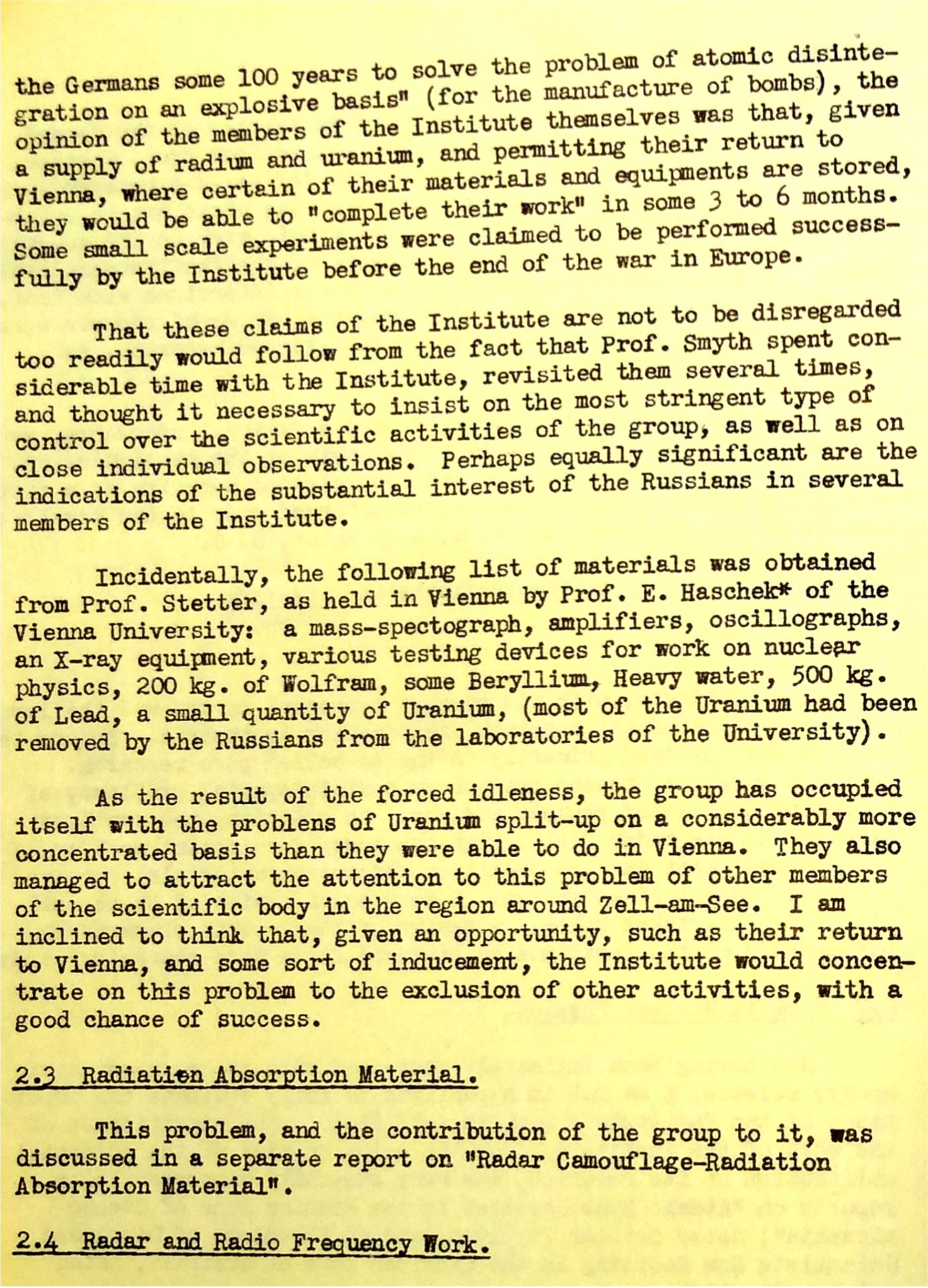
Contrary to the statements, attributed by the U. S. newspapers to the various U. S. atomic experts, that it "would take

- 3 -

Figure D.855: Longtime Bell Telephone physicist Todos M. Odarenko interviewed Georg Stetter and some of his group members soon after the war and wrote, “Contrary to the statements [by Goudsmit...] that it ‘would take the Germans some 100 years to solve the problem of atomic disintegration on an explosive basis’ [...] the opinion of the members of the Institute themselves was that [...] they would be able to ‘complete their work’ in some 3 to 6 months.” [FIAT 63]

T. M. Odarenko. FIAT 63. *Activities of the Second Institute of Physics of the University of Vienna.*



the Germans some 100 years to solve the problem of atomic disintegration on an explosive basis" (for the manufacture of bombs), the opinion of the members of the Institute themselves was that, given a supply of radium and uranium, and permitting their return to Vienna, where certain of their materials and equipments are stored, they would be able to "complete their work" in some 3 to 6 months. Some small scale experiments were claimed to be performed successfully by the Institute before the end of the war in Europe.

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As the result of the forced idleness, the group has occupied itself with the problens of Uranium split-up on a considerably more concentrated basis than they were able to do in Vienna. They also managed to attract the attention to this problem of other members of the scientific body in the region around Zell-am-See. I am inclined to think that, given an opportunity, such as their return to Vienna, and some sort of inducement, the Institute would concentrate on this problem to the exclusion of other activities, with a good chance of success.

2.3 Radiation Absorption Material.

This problem, and the contribution of the group to it, was discussed in a separate report on "Radar Camouflage-Radiation Absorption Material".

2.4 Radar and Radio Frequency Work.

Figure D.856: Longtime Bell Telephone physicist Todos M. Odarenko interviewed Georg Stetter and some of his group members soon after the war and wrote, “Contrary to the statements [by Goudsmit...] that it ‘would take the Germans some 100 years to solve the problem of atomic disintegration on an explosive basis’ [...] the opinion of the members of the Institute themselves was that [...] they would be able to ‘complete their work’ in some 3 to 6 months.” [FIAT 63]

Todos M. Odarenko. 26 October 1945. Problem of Displaced Scientists Now Residing in the American Zone of Austria. [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)]

1. This memorandum is prepared for Col. R. M. Osborne, Chief of FIAT, and Dr. H. P. Robertson, Chief of Scientific and Technological Branch of FIAT, upon their request to point out certain problems arising out of the presence of a very large group of displaced German and Austrian scientists, now residing in and around Zell-am-See, south of Salzburg, Austria. [...]

3. The total number of scientists is not known to the undersigned. It was variously estimated for him by the officers of G-2 and OSS in Salzburg as being between 150 to 250 individuals. They come from the high institutions of learning originally located in Berlin, Insbruck, Graz, Wien, Dresden, etc. A complete list of the evacuated organizations might be in the hands of OSS, Salzburg, or in the hands of Education, Religion, Muniment and Fine Art Office of the military government of Salzburg. [...]

6. Among these evacuees there is a very large group of capable scientists who worked in the field of nuclear physics and chemistry and who have been carrying this work with such facilities as they have been able to assemble. There are two (or possibly more) institutes which were directly involved before the end of the war in a secret German project called “Uranmotor” whose purpose was to split uran atoms in order to obtain a powerful source of intra-atomic energy. It is apparent that the end result of this work is a method of obtaining an explosive release of atomic energy, or atomic bomb. The two groups definitely identified with the Uranmotor project are Kaiser Wilhelm Institute and Institut für Neutronenforschung. Professor Stetter, Professor Mattauch, Professor Thirring, Dr. Schintlmeister, Dr. Jentschke, Dr. Ortner, Dr. Ing. F. Focke are some of the names reported to the undersigned to have been directly involved in the project and capable of completing it as soon as the opportunity will present itself.

7. The undersigned spent a day with one of these groups, namely Professor Stetter and his men. He was assured that the work on the project reached the state before the end of the war when small scale experiments were completed and were quite satisfactory. The present status is that if given an opportunity to return to Vienna, where certain equipment and raw materials were left (and are still intact in the hands of Professor E. Haschek, Poltzman Gasse S, Wien IX) and given a supply of uran, the project could be completed in three to six months with the available personnel and equipment.

8. Professor Smyth of the Alsos Mission visited the region and Professor Stetter’s group three times (last on August 14, 1945) and spent considerable time with them. It is reasonable to assume that he is fully cognizant of the significance of the experience and qualification of the group, since his recommendation to OSS in Salzburg was to keep the group under a “constant and strict survey”. [...]

10. It must be also kept in mind that because of the decision of the United States not to share the secrets of atomic explosion with other nations, there is an ever increasing desire on the part of certain nations to arrive at the solution of the atomic disintegration problem by an independent method. The undersigned has some information indicating that USSR has a large scale research organization with the best of German scientists working on the problem and expect the solution shortly. They are also reputed to be anxious to get certain of the men now in Austria to join their organization. Thus, it would appear that a careful consideration must be given promptly to the disposition and utilization of the scientific personnel in Austria. It has been repeatedly stated to the undersigned by the occupational officers in Austria that the final decision on the disposition of the displaced scientists in Austria must come from the highest quarters in USFET, and that if the decision does not come soon enough it might come too late. [...]

[See document photos on pp. 4790–4793.

Georg Stetter and his fellow Austrian researchers were heavily involved in both the wartime fission and fusion programs (pp. 3372–3375, 4330–4345, 4784–4800, 4992).

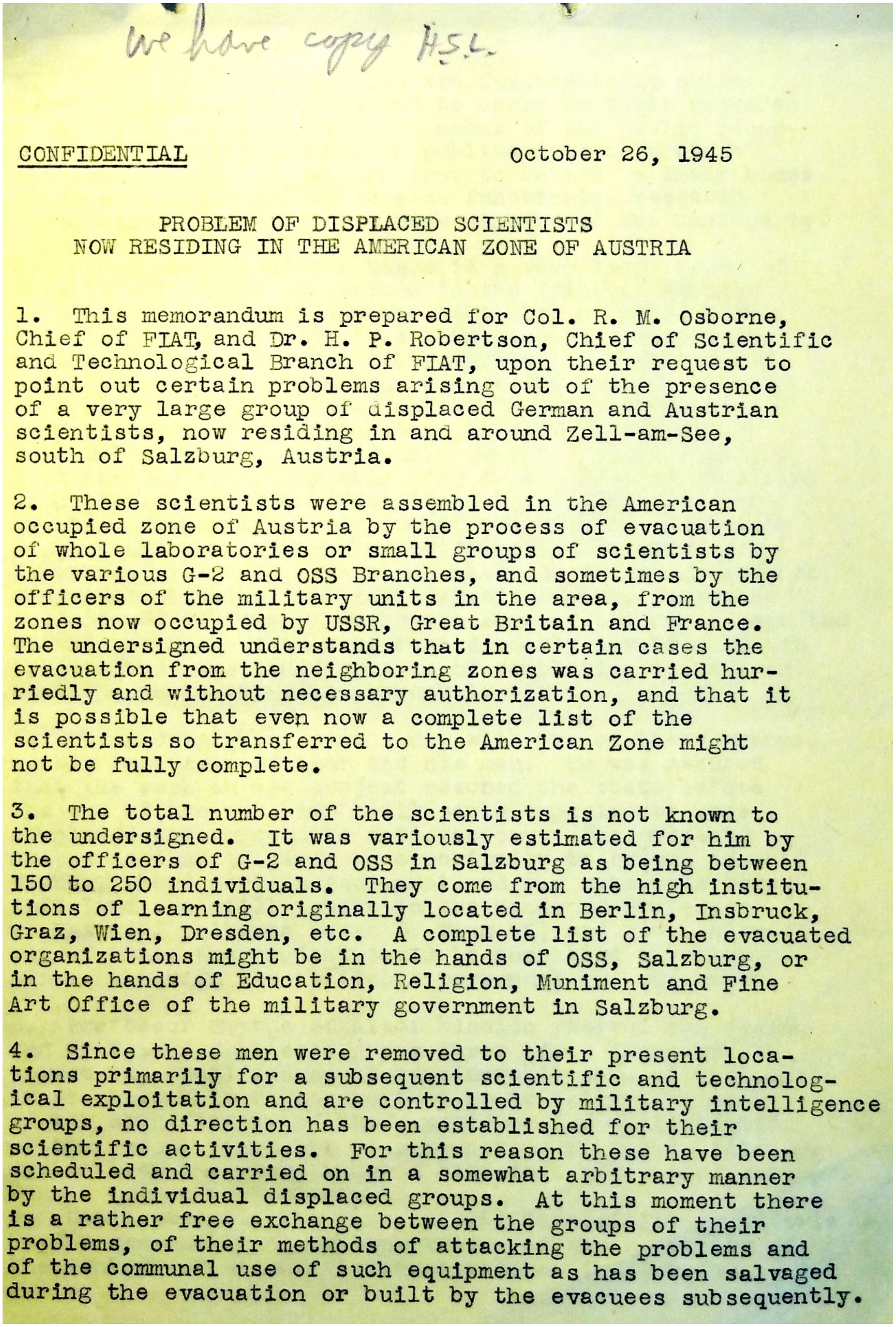
The information from Odarenko was forwarded directly to Leslie Groves—see pp. 4794–4795.

“Prof. Smyth” was Charles P. Smyth, a Princeton chemistry professor and member of the Alsos Mission. He should not be confused with his brother Henry DeWolf Smyth, a Manhattan Project physicist who wrote the August 1945 “Smyth Report” that gave public information about the U.S. atomic bomb program.

As a result of the reports of Odarenko and Smyth, the Austrian nuclear scientists were closely monitored and controlled for years by U.S. intelligence and military agencies. For example, Georg Stetter was kept under virtual house arrest by U.S. agents in Austria from 1945 until the 1950s, nearly destroying his career (pp. 4796–4800).]

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45-Dec 45)



We have copy H.S.L.

CONFIDENTIAL October 26, 1945

PROBLEM OF DISPLACED SCIENTISTS
NOW RESIDING IN THE AMERICAN ZONE OF AUSTRIA

1. This memorandum is prepared for Col. R. M. Osborne, Chief of FIAT, and Dr. H. P. Robertson, Chief of Scientific and Technological Branch of FIAT, upon their request to point out certain problems arising out of the presence of a very large group of displaced German and Austrian scientists, now residing in and around Zell-am-See, south of Salzburg, Austria.

2. These scientists were assembled in the American occupied zone of Austria by the process of evacuation of whole laboratories or small groups of scientists by the various G-2 and OSS Branches, and sometimes by the officers of the military units in the area, from the zones now occupied by USSR, Great Britain and France. The undersigned understands that in certain cases the evacuation from the neighboring zones was carried hurriedly and without necessary authorization, and that it is possible that even now a complete list of the scientists so transferred to the American Zone might not be fully complete.

3. The total number of the scientists is not known to the undersigned. It was variously estimated for him by the officers of G-2 and OSS in Salzburg as being between 150 to 250 individuals. They come from the high institutions of learning originally located in Berlin, Insbruck, Graz, Wien, Dresden, etc. A complete list of the evacuated organizations might be in the hands of OSS, Salzburg, or in the hands of Education, Religion, Muniment and Fine Art Office of the military government in Salzburg.

4. Since these men were removed to their present locations primarily for a subsequent scientific and technological exploitation and are controlled by military intelligence groups, no direction has been established for their scientific activities. For this reason these have been scheduled and carried on in a somewhat arbitrary manner by the individual displaced groups. At this moment there is a rather free exchange between the groups of their problems, of their methods of attacking the problems and of the communal use of such equipment as has been salvaged during the evacuation or built by the evacuees subsequently.

Figure D.857: Todos M. Odarenko. 26 October 1945. Problem of Displaced Scientists Now Residing in the American Zone of Austria. [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)]

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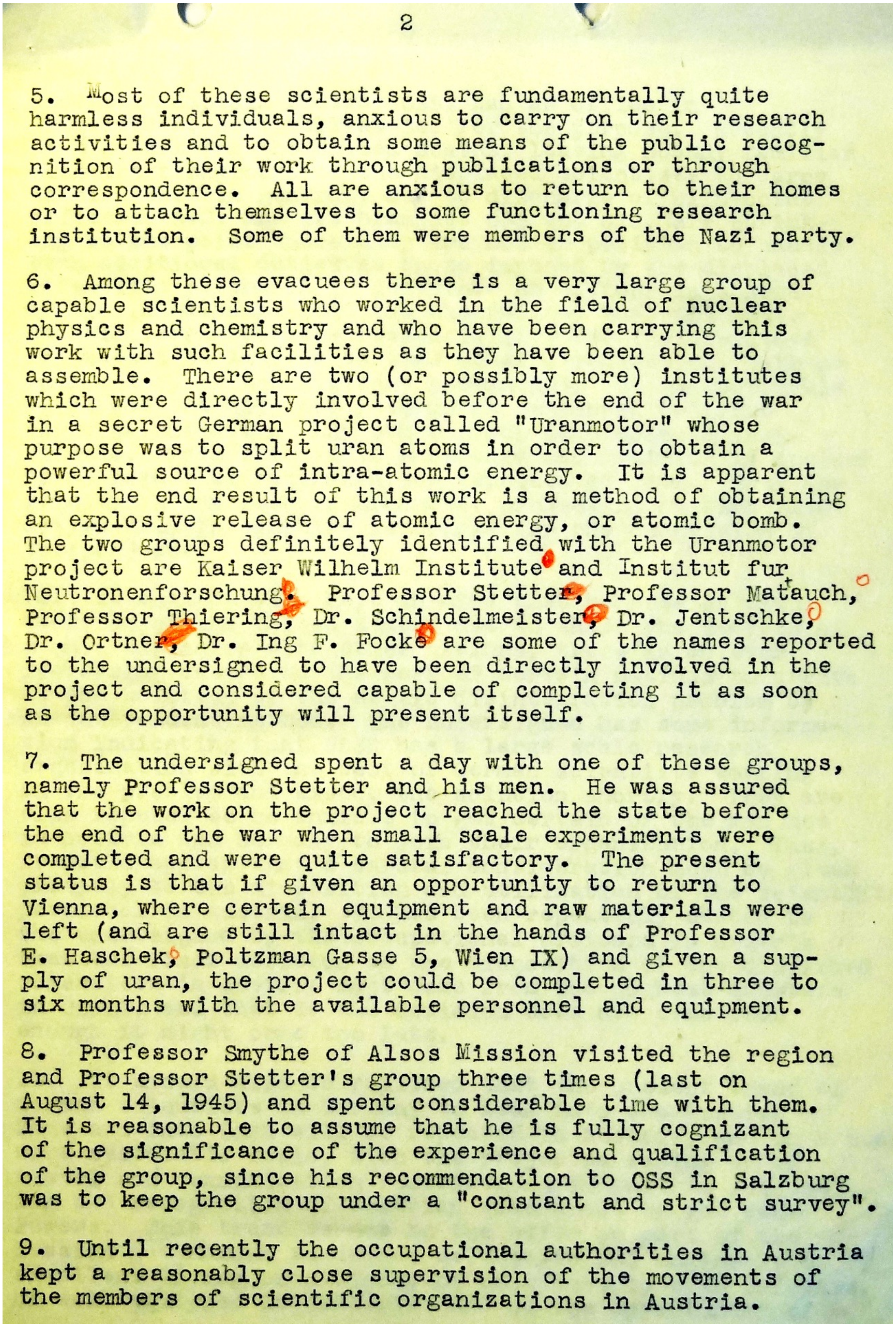
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45-Dec 45)



2

5. Most of these scientists are fundamentally quite harmless individuals, anxious to carry on their research activities and to obtain some means of the public recognition of their work through publications or through correspondence. All are anxious to return to their homes or to attach themselves to some functioning research institution. Some of them were members of the Nazi party.

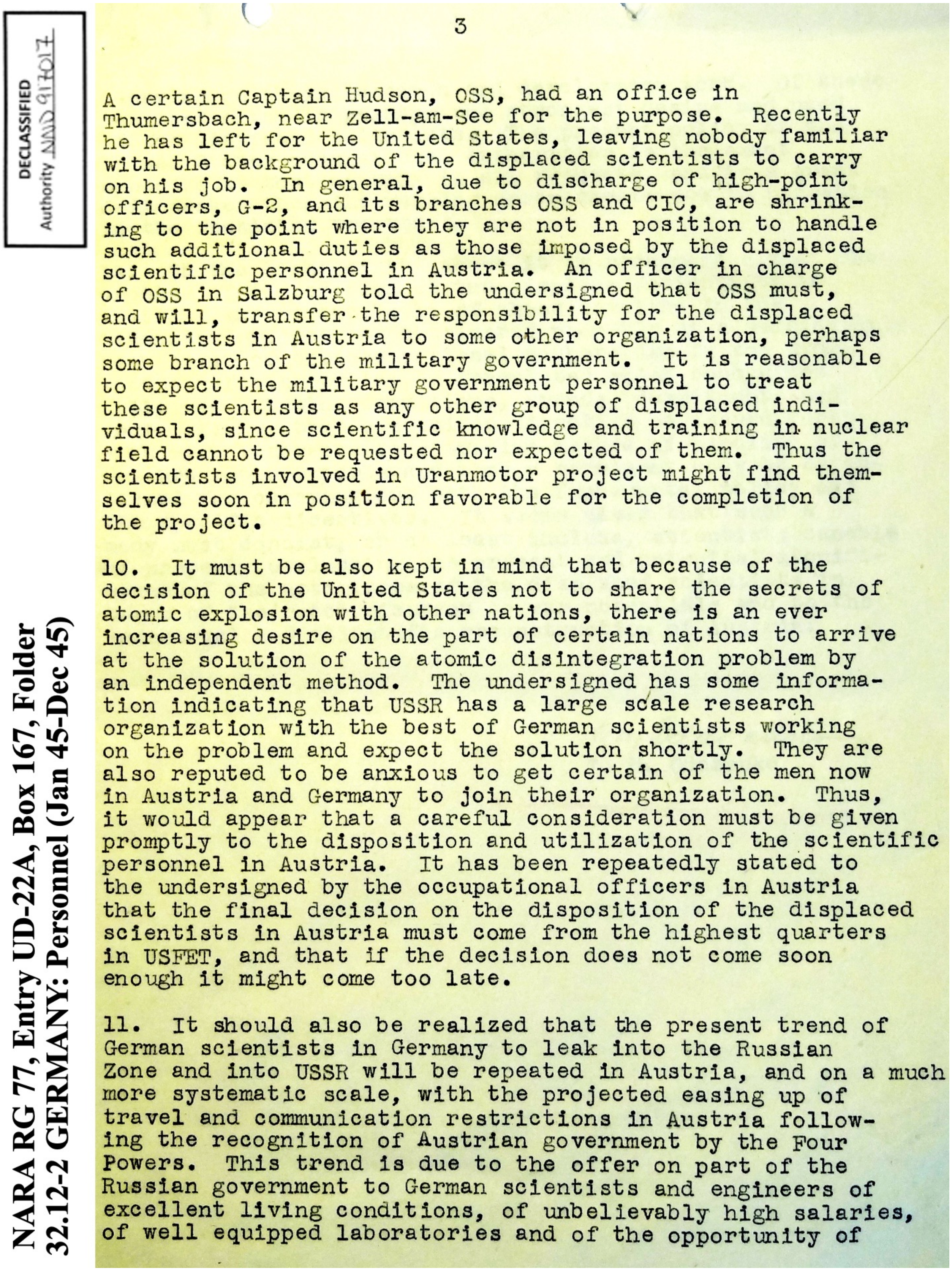
6. Among these evacuees there is a very large group of capable scientists who worked in the field of nuclear physics and chemistry and who have been carrying this work with such facilities as they have been able to assemble. There are two (or possibly more) institutes which were directly involved before the end of the war in a secret German project called "Uranmotor" whose purpose was to split uran atoms in order to obtain a powerful source of intra-atomic energy. It is apparent that the end result of this work is a method of obtaining an explosive release of atomic energy, or atomic bomb. The two groups definitely identified with the Uranmotor project are Kaiser Wilhelm Institute and Institut fur Neutronenforschung. Professor Stetter, Professor Mattauch, Professor Thiering, Dr. Schindelmeister, Dr. Jentschke, Dr. Ortner, Dr. Ing F. Focke are some of the names reported to the undersigned to have been directly involved in the project and considered capable of completing it as soon as the opportunity will present itself.

7. The undersigned spent a day with one of these groups, namely Professor Stetter and his men. He was assured that the work on the project reached the state before the end of the war when small scale experiments were completed and were quite satisfactory. The present status is that if given an opportunity to return to Vienna, where certain equipment and raw materials were left (and are still intact in the hands of Professor E. Haschek, Poltzman Gasse 5, Wien IX) and given a supply of uran, the project could be completed in three to six months with the available personnel and equipment.

8. Professor Smythe of Alsos Mission visited the region and Professor Stetter's group three times (last on August 14, 1945) and spent considerable time with them. It is reasonable to assume that he is fully cognizant of the significance of the experience and qualification of the group, since his recommendation to OSS in Salzburg was to keep the group under a "constant and strict survey".

9. Until recently the occupational authorities in Austria kept a reasonably close supervision of the movements of the members of scientific organizations in Austria.

Figure D.858: Todos M. Odarenko. 26 October 1945. Problem of Displaced Scientists Now Residing in the American Zone of Austria. [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)]



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Authority NND 917017

NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45-Dec 45)

3

A certain Captain Hudson, OSS, had an office in Thumersbach, near Zell-am-See for the purpose. Recently he has left for the United States, leaving nobody familiar with the background of the displaced scientists to carry on his job. In general, due to discharge of high-point officers, G-2, and its branches OSS and CIC, are shrinking to the point where they are not in position to handle such additional duties as those imposed by the displaced scientific personnel in Austria. An officer in charge of OSS in Salzburg told the undersigned that OSS must, and will, transfer the responsibility for the displaced scientists in Austria to some other organization, perhaps some branch of the military government. It is reasonable to expect the military government personnel to treat these scientists as any other group of displaced individuals, since scientific knowledge and training in nuclear field cannot be requested nor expected of them. Thus the scientists involved in Uranmotor project might find themselves soon in position favorable for the completion of the project.

10. It must be also kept in mind that because of the decision of the United States not to share the secrets of atomic explosion with other nations, there is an ever increasing desire on the part of certain nations to arrive at the solution of the atomic disintegration problem by an independent method. The undersigned has some information indicating that USSR has a large scale research organization with the best of German scientists working on the problem and expect the solution shortly. They are also reputed to be anxious to get certain of the men now in Austria and Germany to join their organization. Thus, it would appear that a careful consideration must be given promptly to the disposition and utilization of the scientific personnel in Austria. It has been repeatedly stated to the undersigned by the occupational officers in Austria that the final decision on the disposition of the displaced scientists in Austria must come from the highest quarters in USFET, and that if the decision does not come soon enough it might come too late.

11. It should also be realized that the present trend of German scientists in Germany to leak into the Russian Zone and into USSR will be repeated in Austria, and on a much more systematic scale, with the projected easing up of travel and communication restrictions in Austria following the recognition of Austrian government by the Four Powers. This trend is due to the offer on part of the Russian government to German scientists and engineers of excellent living conditions, of unbelievably high salaries, of well equipped laboratories and of the opportunity of

Figure D.859: Todos M. Odarenko. 26 October 1945. Problem of Displaced Scientists Now Residing in the American Zone of Austria. [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)]

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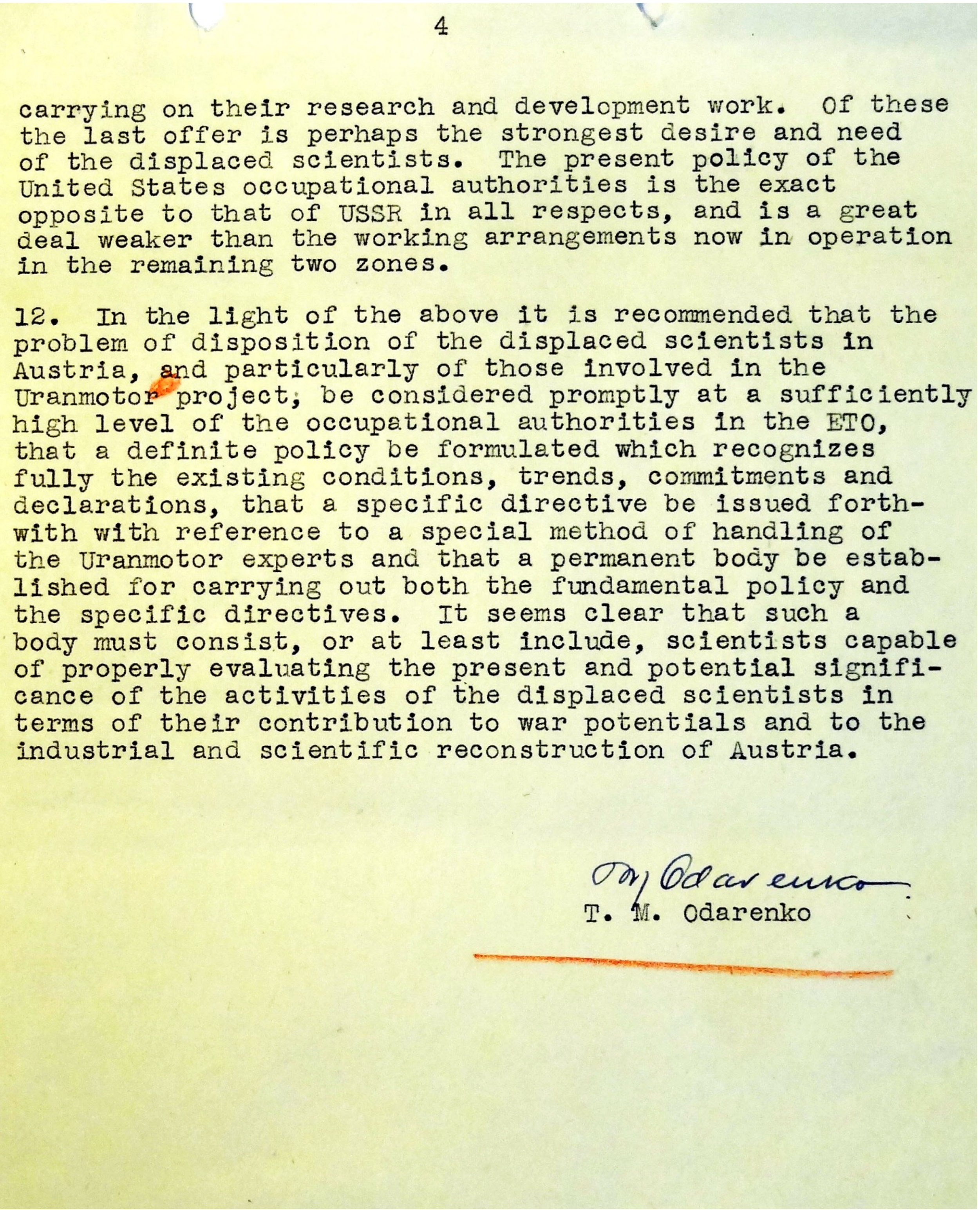
NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45-Dec 45)



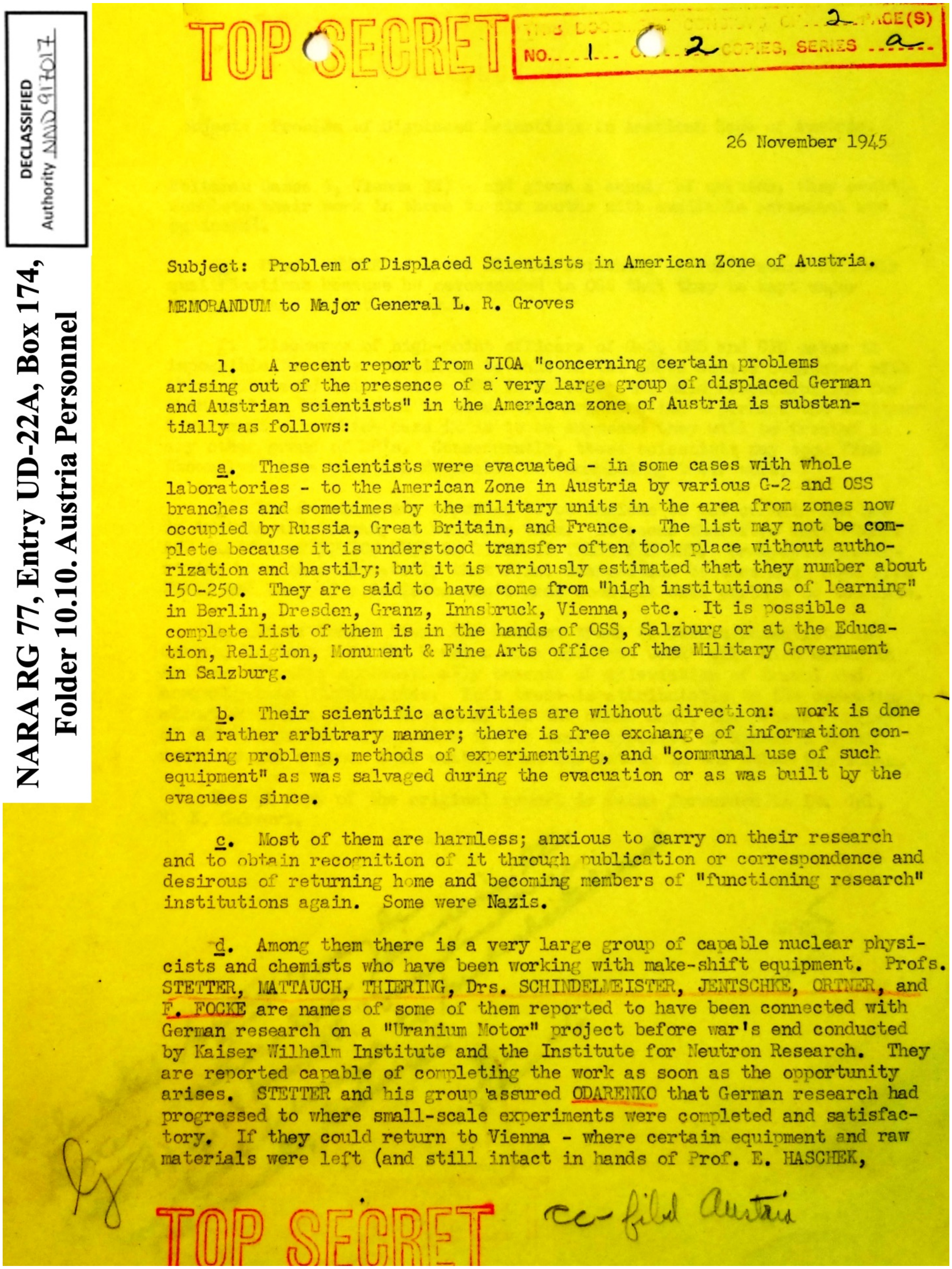
4

carrying on their research and development work. Of these the last offer is perhaps the strongest desire and need of the displaced scientists. The present policy of the United States occupational authorities is the exact opposite to that of USSR in all respects, and is a great deal weaker than the working arrangements now in operation in the remaining two zones.

12. In the light of the above it is recommended that the problem of disposition of the displaced scientists in Austria, and particularly of those involved in the Uranmotor project, be considered promptly at a sufficiently high level of the occupational authorities in the ETO, that a definite policy be formulated which recognizes fully the existing conditions, trends, commitments and declarations, that a specific directive be issued forthwith with reference to a special method of handling of the Uranmotor experts and that a permanent body be established for carrying out both the fundamental policy and the specific directives. It seems clear that such a body must consist, or at least include, scientists capable of properly evaluating the present and potential significance of the activities of the displaced scientists in terms of their contribution to war potentials and to the industrial and scientific reconstruction of Austria.

T. M. Odarenko

Figure D.860: Todos M. Odarenko. 26 October 1945. Problem of Displaced Scientists Now Residing in the American Zone of Austria. [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)]



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Authority NND 917017

NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel

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THIS DOCUMENT CONSISTS OF 2 PAGE(S)
NO. 1 OF 2 COPIES, SERIES a

26 November 1945

Subject: Problem of Displaced Scientists in American Zone of Austria.

MEMORANDUM to Major General L. R. Groves

1. A recent report from JIOA "concerning certain problems arising out of the presence of a very large group of displaced German and Austrian scientists" in the American zone of Austria is substantially as follows:

a. These scientists were evacuated - in some cases with whole laboratories - to the American Zone in Austria by various G-2 and OSS branches and sometimes by the military units in the area from zones now occupied by Russia, Great Britain, and France. The list may not be complete because it is understood transfer often took place without authorization and hastily; but it is variously estimated that they number about 150-250. They are said to have come from "high institutions of learning" in Berlin, Dresden, Granz, Innsbruck, Vienna, etc. It is possible a complete list of them is in the hands of OSS, Salzburg or at the Education, Religion, Monument & Fine Arts office of the Military Government in Salzburg.

b. Their scientific activities are without direction: work is done in a rather arbitrary manner; there is free exchange of information concerning problems, methods of experimenting, and "communal use of such equipment" as was salvaged during the evacuation or as was built by the evacuees since.

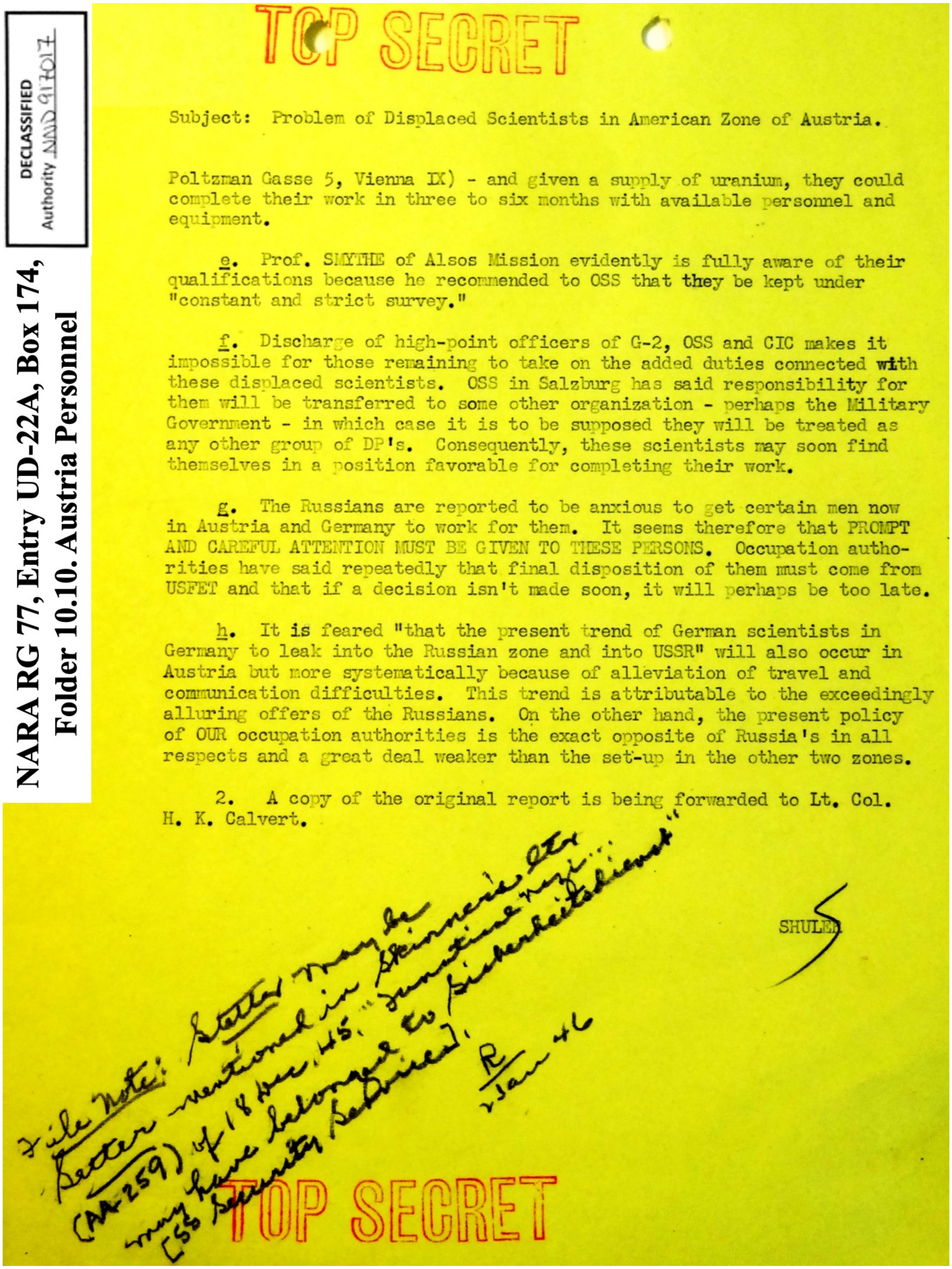
c. Most of them are harmless; anxious to carry on their research and to obtain recognition of it through publication or correspondence and desirous of returning home and becoming members of "functioning research" institutions again. Some were Nazis.

d. Among them there is a very large group of capable nuclear physicists and chemists who have been working with make-shift equipment. Profs. STETTER, MATTAUCH, THIERING, Drs. SCHINDELMEISTER, JENTSCHKE, ORTNER, and F. FOCKE are names of some of them reported to have been connected with German research on a "Uranium Motor" project before war's end conducted by Kaiser Wilhelm Institute and the Institute for Neutron Research. They are reported capable of completing the work as soon as the opportunity arises. STETTER and his group assured ODARENKO that German research had progressed to where small-scale experiments were completed and satisfactory. If they could return to Vienna - where certain equipment and raw materials were left (and still intact in hands of Prof. E. HASCHEK,

TOP SECRET

cc-filed Austria

Figure D.861: W. R. Shuler to Leslie R. Groves. 26 November 1945. Subject: Problem of Displaced Scientists in American Zone of Austria [NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel].



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Authority NND 917017

NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel

TOP SECRET

Subject: Problem of Displaced Scientists in American Zone of Austria.

Poltzman Gasse 5, Vienna IX) - and given a supply of uranium, they could complete their work in three to six months with available personnel and equipment.

e. Prof. SMYTHE of Alsos Mission evidently is fully aware of their qualifications because he recommended to OSS that they be kept under "constant and strict survey."

f. Discharge of high-point officers of G-2, OSS and CIC makes it impossible for those remaining to take on the added duties connected with these displaced scientists. OSS in Salzburg has said responsibility for them will be transferred to some other organization - perhaps the Military Government - in which case it is to be supposed they will be treated as any other group of DP's. Consequently, these scientists may soon find themselves in a position favorable for completing their work.

g. The Russians are reported to be anxious to get certain men now in Austria and Germany to work for them. It seems therefore that PROMPT AND CAREFUL ATTENTION MUST BE GIVEN TO THESE PERSONS. Occupation authorities have said repeatedly that final disposition of them must come from USFET and that if a decision isn't made soon, it will perhaps be too late.

h. It is feared "that the present trend of German scientists in Germany to leak into the Russian zone and into USSR" will also occur in Austria but more systematically because of alleviation of travel and communication difficulties. This trend is attributable to the exceedingly alluring offers of the Russians. On the other hand, the present policy of OUR occupation authorities is the exact opposite of Russia's in all respects and a great deal weaker than the set-up in the other two zones.

2. A copy of the original report is being forwarded to Lt. Col. H. K. Calvert.

SHULER

File Note: Stetter may be
Better mentioned in Steinmeie ltr
(AA-259) of 18 Dec 45. "Sometime nazi...
may have belonged to Sicherheitsdienst"
[SS Security Service].

R
2 Jan 46

TOP SECRET

Figure D.862: W. R. Shuler to Leslie R. Groves. 26 November 1945. Subject: Problem of Displaced Scientists in American Zone of Austria [NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel].

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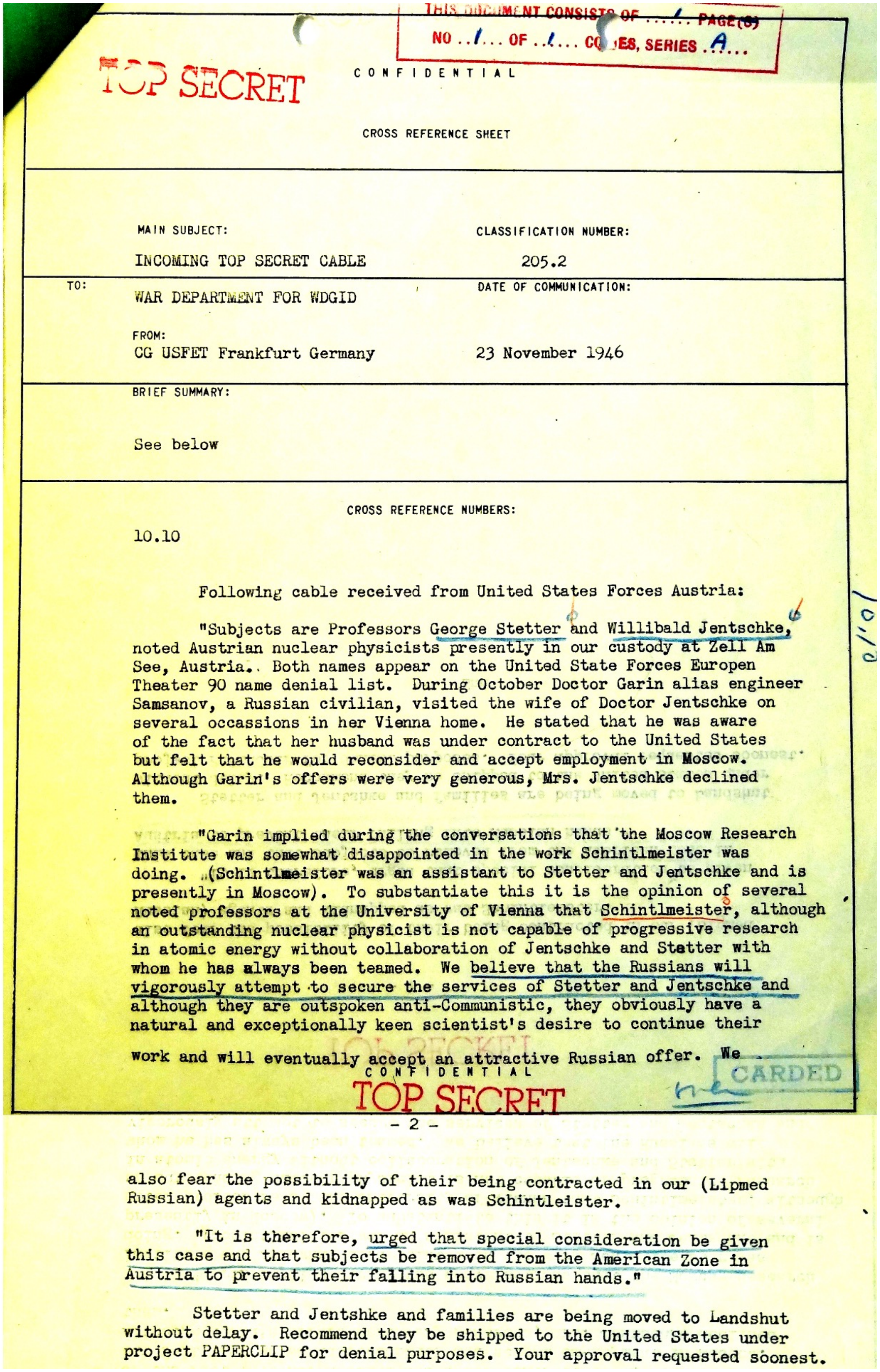
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 174,
Folder 10.10. Austria Personnel



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TOP SECRET

C O N F I D E N T I A L

CROSS REFERENCE SHEET

MAIN SUBJECT: INCOMING TOP SECRET CABLE

CLASSIFICATION NUMBER: 205.2

TO: WAR DEPARTMENT FOR WDGID

DATE OF COMMUNICATION: 23 November 1946

FROM: CG USFET Frankfurt Germany

BRIEF SUMMARY:

See below

CROSS REFERENCE NUMBERS:

10.10

10/10

Following cable received from United States Forces Austria:

"Subjects are Professors George Stetter and Willibald Jentschke, noted Austrian nuclear physicists presently in our custody at Zell Am See, Austria. Both names appear on the United State Forces Europen Theater 90 name denial list. During October Doctor Garin alias engineer Samsanov, a Russian civilian, visited the wife of Doctor Jentschke on several occassions in her Vienna home. He stated that he was aware of the fact that her husband was under contract to the United States but felt that he would reconsider and accept employment in Moscow. Although Garin's offers were very generous, Mrs. Jentschke declined them.

"Garin implied during the conversations that the Moscow Research Institute was somewhat disappointed in the work Schintlmeister was doing. (Schintlmeister was an assistant to Stetter and Jentschke and is presently in Moscow). To substantiate this it is the opinion of several noted professors at the University of Vienna that Schintlmeister, although an outstanding nuclear physicist is not capable of progressive research in atomic energy without collaboration of Jentschke and Stetter with whom he has always been teamed. We believe that the Russians will vigorously attempt to secure the services of Stetter and Jentschke and although they are outspoken anti-Communistic, they obviously have a natural and exceptionally keen scientist's desire to continue their work and will eventually accept an attractive Russian offer. We

C O N F I D E N T I A L

TOP SECRET

CARDED

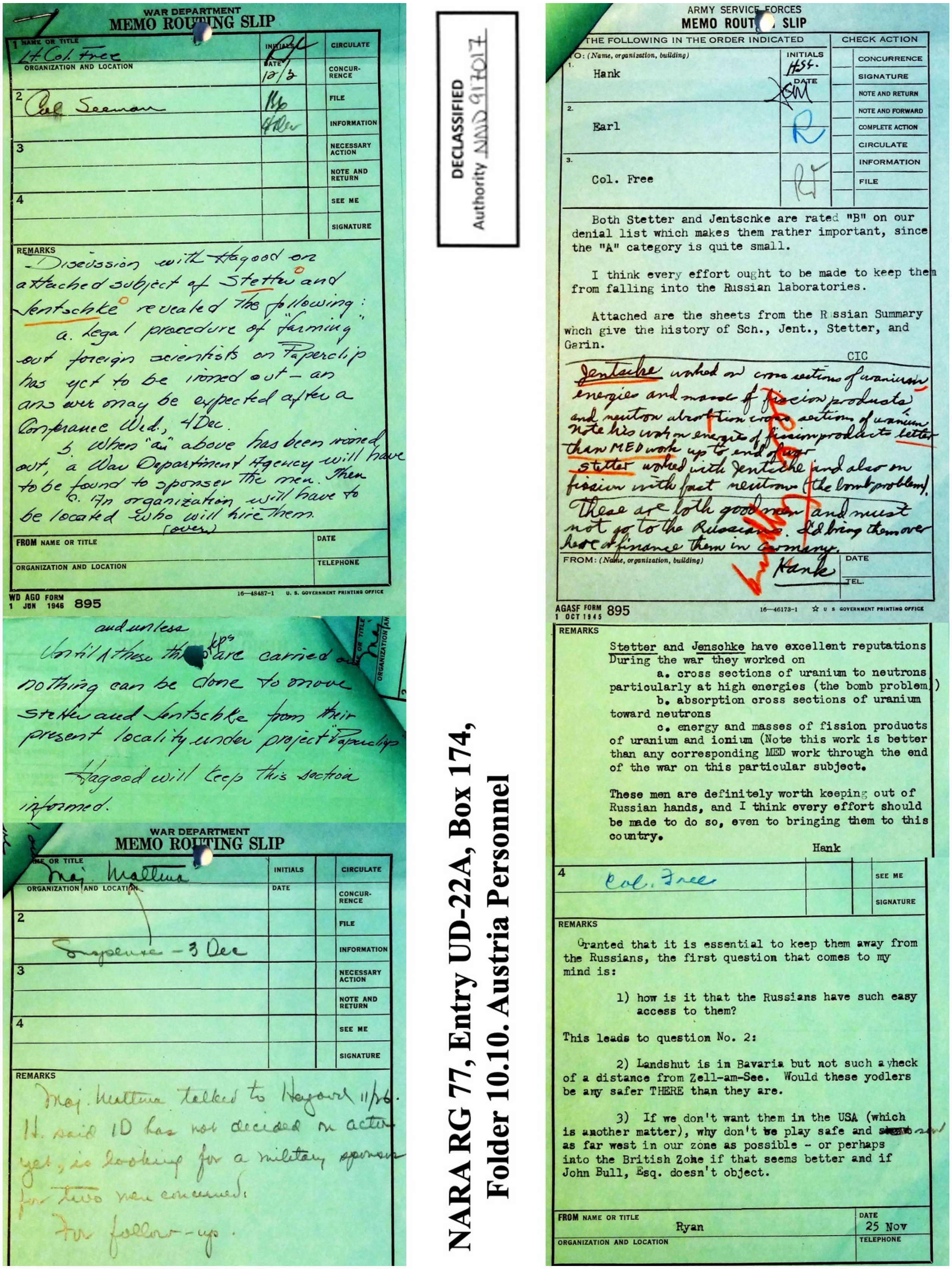
- 2 -

also fear the possibility of their being contracted in our (Lipmed Russian) agents and kidnapped as was Schintleister.

"It is therefore, urged that special consideration be given this case and that subjects be removed from the American Zone in Austria to prevent their falling into Russian hands."

Stetter and Jentshke and families are being moved to Landshut without delay. Recommend they be shipped to the United States under project PAPERCLIP for denial purposes. Your approval requested soonest.

Figure D.863: Georg Stetter was kept under virtual house arrest by U.S. agents from 1945 until the 1950s [NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel].



WAR DEPARTMENT
MEMO ROUTING SLIP

1 NAME OR TITLE Lt. Col. Free	INITIALS		CIRCULATE
ORGANIZATION AND LOCATION	DATE 12/3		CONCURRENCE
2 Col Seeman			FILE
			INFORMATION
3			NECESSARY ACTION
			NOTE AND RETURN
4			SEE ME
			SIGNATURE

REMARKS

Discussion with Hagood on attached subject of Stetter and Jentschke revealed the following:

a. Legal procedure of "farming" out foreign scientists on Paperclip has yet to be ironed out – an answer may be expected after a Conference Wed., 4 Dec.

b. When "a" above has been ironed out, a War Department Agency will have to be found to sponser the men. Then

c. An organization will have to be located who will hire them.

(over)

FROM NAME OR TITLE | DATE

ORGANIZATION AND LOCATION | TELEPHONE

WD AGO FORM 895
1 JUN 1946
16—48487-1 U. S. GOVERNMENT PRINTING OFFICE

and unless
Until these steps are carried out nothing can be done to move Stetter and Jentschke from their present locality under project "Paperclip".

Hagood will keep this section informed.

WAR DEPARTMENT
MEMO ROUTING SLIP

NAME OR TITLE Maj. Mattina	INITIALS		CIRCULATE
ORGANIZATION AND LOCATION	DATE		CONCURRENCE
2			FILE
Suspense – 3 Dec			INFORMATION
3			NECESSARY ACTION
			NOTE AND RETURN
4			SEE ME
			SIGNATURE

REMARKS

Maj. Mattina talked to Hagood 11/26. H. said ID has not decided on action yet, is looking for a military sponsor for two men concerned.

For follow-up.

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel

ARMY SERVICE FORCES
MEMO ROUTING SLIP

THE FOLLOWING IN THE ORDER INDICATED	INITIALS	CHECK ACTION	
TO: (Name, organization, building) 1. Hank	H.S.S.		CONCURRENCE
	DATE		SIGNATURE
			NOTE AND RETURN
2. Earl	R		NOTE AND FORWARD
			COMPLETE ACTION
			CIRCULATE
3. Col. Free	RF		INFORMATION
			FILE

Both Stetter and Jentschke are rated "B" on our denial list which makes them rather important, since the "A" category is quite small.

I think every effort ought to be made to keep them from falling into the Russian laboratories.

Attached are the sheets from the Russian Summary which give the history of Sch., Jent., Stetter, and Garin.

CIC

Jentschke worked on cross sections of uranium energies and masses of fission products and neutron absorption cross sections of uranium. Note his work on energies of fission products better than MED work up to end of war.

Stetter worked with Jentschke and also on fission with fast neutrons (the bomb problem).

These are both good men and must not go to the Russians. I'd bring them over here or finance them in Germany.

FROM: (Name, organization, building) Hank | DATE | TEL.

AGASF FORM 895
1 OCT 1945
16—46173-1 ☆ U S GOVERNMENT PRINTING OFFICE

REMARKS

Stetter and Jenschke have excellent reputations During the war they worked on

a. cross sections of uranium to neutrons particularly at high energies (the bomb problem)

b. absorption cross sections of uranium toward neutrons

c. energy and masses of fission products of uranium and ionium (Note this work is better than any corresponding MED work through the end of the war on this particular subject.

These men are definitely worth keeping out of Russian hands, and I think every effort should be made to do so, even to bringing them to this country.

Hank

4 Col. Free			SEE ME
			SIGNATURE

REMARKS

Granted that it is essential to keep them away from the Russians, the first question that comes to my mind is:

1) how is it that the Russians have such easy access to them?

This leads to question No. 2:

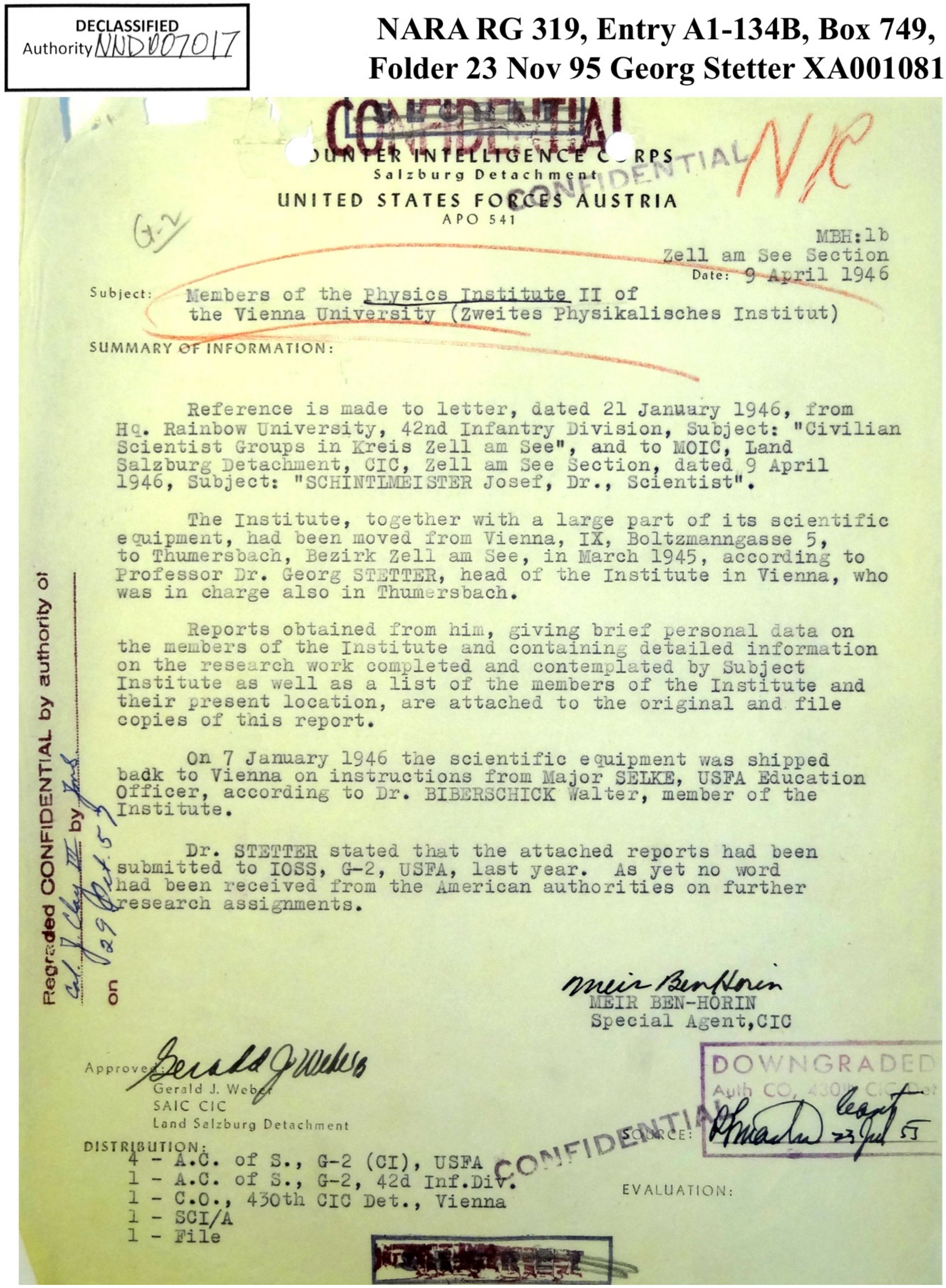
2) Landshut is in Bavaria but not such a heck of a distance from Zell-am-See. Would these yodlers be any safer THERE than they are.

3) If we don't want them in the USA (which is another matter), why don't ~~we~~ play safe and ~~shoot~~ send as far west in our zone as possible – or perhaps into the British Zone if that seems better and if John Bull, Esq. doesn't object.

FROM NAME OR TITLE Ryan | DATE 25 Nov

ORGANIZATION AND LOCATION | TELEPHONE

Figure D.864: "Stetter and Jenschke... During the war they worked on a. cross sections of uranium to neutrons particularly at high energies (the bomb problem)... c. energy and masses of fission products of uranium and ionium [thorium] (Note this work is better than any corresponding MED [Manhattan Engineering District] work through the end of the war on this particular subject." [NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel].



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NARA RG 319, Entry A1-134B, Box 749, Folder 23 Nov 95 Georg Stetter XA001081

CONFIDENTIAL

N/R

COUNTER INTELLIGENCE CORPS
Salzburg Detachment
UNITED STATES FORCES AUSTRIA
APO 541

CONFIDENTIAL

G-2

MBH:lb
Zell am See Section
Date: 9 April 1946

Subject: Members of the Physics Institute II of the Vienna University (Zweites Physikalisches Institut)

SUMMARY OF INFORMATION:

Reference is made to letter, dated 21 January 1946, from Hq. Rainbow University, 42nd Infantry Division, Subject: "Civilian Scientist Groups in Kreis Zell am See", and to MOIC, Land Salzburg Detachment, CIC, Zell am See Section, dated 9 April 1946, Subject: "SCHINTLMEISTER Josef, Dr., Scientist".

The Institute, together with a large part of its scientific equipment, had been moved from Vienna, IX, Boltzmanngasse 5, to Thumersbach, Bezirk Zell am See, in March 1945, according to Professor Dr. Georg STETTER, head of the Institute in Vienna, who was in charge also in Thumersbach.

Reports obtained from him, giving brief personal data on the members of the Institute and containing detailed information on the research work completed and contemplated by Subject Institute as well as a list of the members of the Institute and their present location, are attached to the original and file copies of this report.

On 7 January 1946 the scientific equipment was shipped badk to Vienna on instructions from Major SELKE, USFA Education Officer, according to Dr. BIBERSCHICK Walter, member of the Institute.

Dr. STETTER stated that the attached reports had been submitted to IOSS, G-2, USFA, last year. As yet no word had been received from the American authorities on further research assignments.

Regraded CONFIDENTIAL by authority of Col. J. Clay III by
on 29 Oct. 55

Meir Ben Horin
MEIR BEN-HORIN
Special Agent,CIC

Approved: Gerald J. Weber
Gerald J. Weber
SAIC CIC
Land Salzburg Detachment

DOWNGRADED
Auth CO, 430th CIC Det
Capt 23 Jul 55

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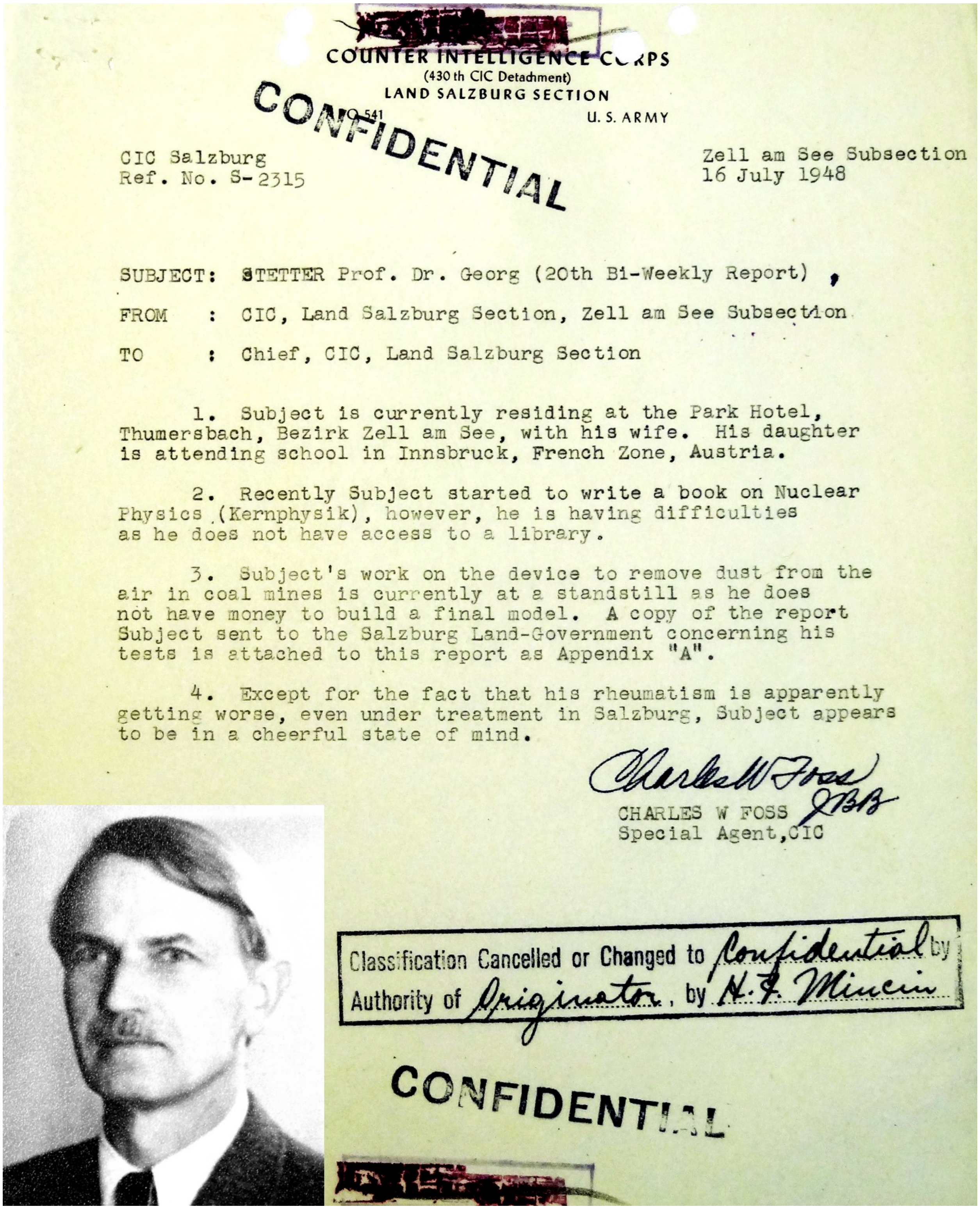
1 - SCI/A
1 - File

Figure D.865: Georg Stetter was kept under virtual house arrest by U.S. agents from 1945 until the 1950s [NARA RG 319, Entry A1-134B, Box 749, Folder 23 Nov 95 Georg Stetter XA001081].

DECLASSIFIED
Authority NND007017

NARA RG 319, Entry A1-134B, Box 749, Folder 23 Nov 95 Georg Stetter XA001081



[redacted]

COUNTER INTELLIGENCE CORPS
(430 th CIC Detachment)
LAND SALZBURG SECTION
APO 541
U. S. ARMY

CONFIDENTIAL

CIC Salzburg
Ref. No. S-2315

Zell am See Subsection
16 July 1948

SUBJECT: STETTER Prof. Dr. Georg (20th Bi-Weekly Report)

FROM : CIC, Land Salzburg Section, Zell am See Subsection

TO : Chief, CIC, Land Salzburg Section

1. Subject is currently residing at the Park Hotel, Thumersbach, Bezirk Zell am See, with his wife. His daughter is attending school in Innsbruck, French Zone, Austria.

2. Recently Subject started to write a book on Nuclear Physics (Kernphysik), however, he is having difficulties as he does not have access to a library.

3. Subject's work on the device to remove dust from the air in coal mines is currently at a standstill as he does not have money to build a final model. A copy of the report Subject sent to the Salzburg Land-Government concerning his tests is attached to this report as Appendix "A".

4. Except for the fact that his rheumatism is apparently getting worse, even under treatment in Salzburg, Subject appears to be in a cheerful state of mind.

Charles W Foss
JBB
CHARLES W FOSS
Special Agent,CIC

Classification Cancelled or Changed to Confidential by Authority of Originator, by H. F. Mincin

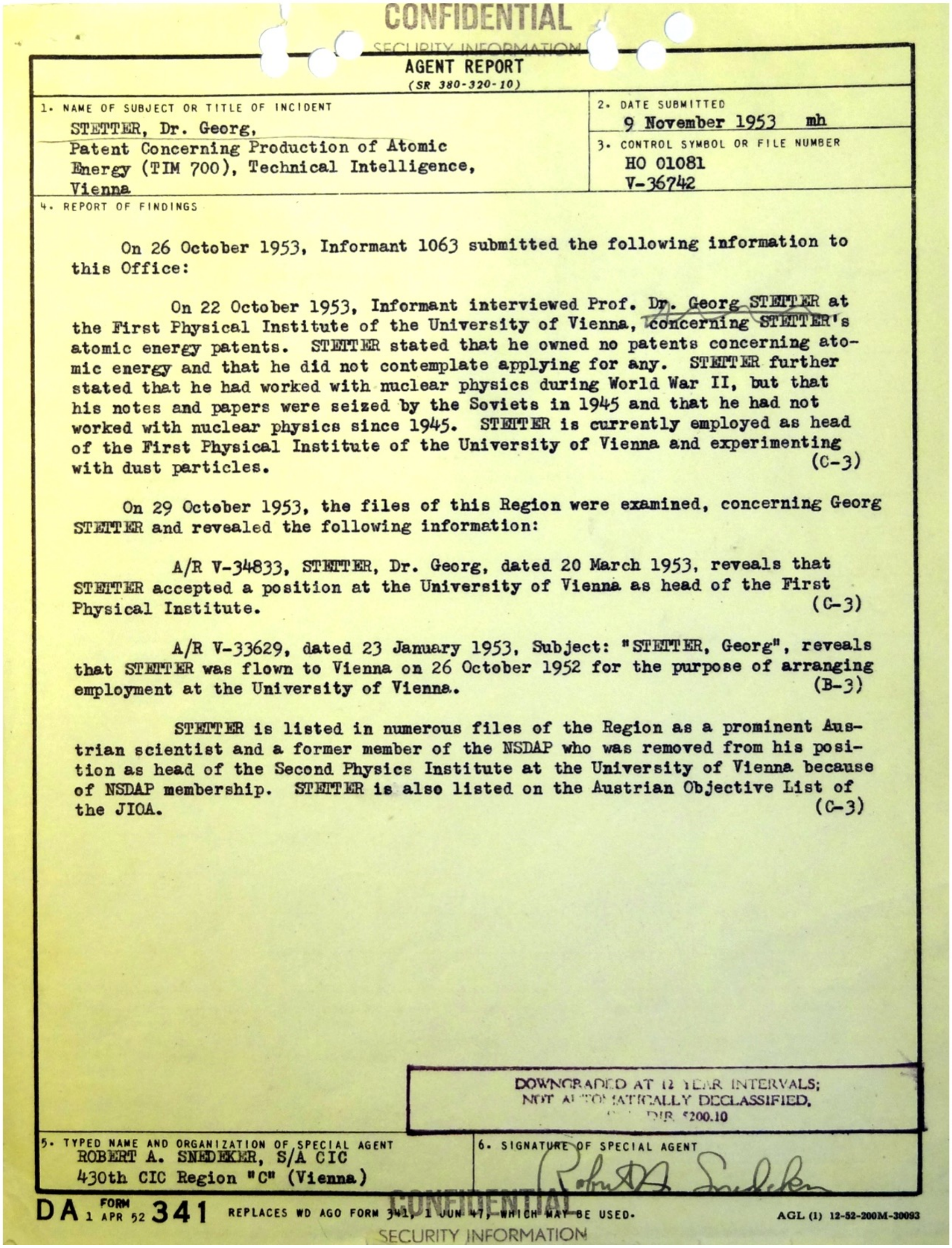
CONFIDENTIAL

[redacted]

Figure D.866: Georg Stetter was kept under virtual house arrest by U.S. agents from 1945 until the 1950s [NARA RG 319, Entry A1-134B, Box 749, Folder 23 Nov 95 Georg Stetter XA001081].

DECLASSIFIED
Authority NND007017

NARA RG 319, Entry A1-134B, Box 749, Folder 23 Nov 95 Georg Stetter XA001081



CONFIDENTIAL
SECURITY INFORMATION

AGENT REPORT
(SR 380-320-10)

1. NAME OF SUBJECT OR TITLE OF INCIDENT
STETTER, Dr. Georg,
Patent Concerning Production of Atomic Energy (TIM 700), Technical Intelligence, Vienna

2. DATE SUBMITTED
9 November 1953 mh

3. CONTROL SYMBOL OR FILE NUMBER
HO 01081
V-36742

4. REPORT OF FINDINGS

On 26 October 1953, Informant 1063 submitted the following information to this Office:

On 22 October 1953, Informant interviewed Prof. Dr. Georg STETTER at the First Physical Institute of the University of Vienna, concerning STETTER's atomic energy patents. STETTER stated that he owned no patents concerning atomic energy and that he did not contemplate applying for any. STETTER further stated that he had worked with nuclear physics during World War II, but that his notes and papers were seized by the Soviets in 1945 and that he had not worked with nuclear physics since 1945. STETTER is currently employed as head of the First Physical Institute of the University of Vienna and experimenting with dust particles. (C-3)

On 29 October 1953, the files of this Region were examined, concerning Georg STETTER and revealed the following information:

A/R V-34833, STETTER, Dr. Georg, dated 20 March 1953, reveals that STETTER accepted a position at the University of Vienna as head of the First Physical Institute. (C-3)

A/R V-33629, dated 23 January 1953, Subject: "STETTER, Georg", reveals that STETTER was flown to Vienna on 26 October 1952 for the purpose of arranging employment at the University of Vienna. (B-3)

STETTER is listed in numerous files of the Region as a prominent Austrian scientist and a former member of the NSDAP who was removed from his position as head of the Second Physics Institute at the University of Vienna because of NSDAP membership. STETTER is also listed on the Austrian Objective List of the JIOA. (C-3)

DOWNGRADED AT 12 YEAR INTERVALS;
NOT AUTOMATICALLY DECLASSIFIED.
DOD DIR 5200.10

5. TYPED NAME AND ORGANIZATION OF SPECIAL AGENT
ROBERT A. SNEDEKER, S/A CIC
430th CIC Region "C" (Vienna)

6. SIGNATURE OF SPECIAL AGENT
Robert A. Snedeker

DA FORM 1 APR 52 341 REPLACES WD AGO FORM 341, 1 JUN 47, WHICH MAY BE USED. AGL (1) 12-52-200M-30093

CONFIDENTIAL
SECURITY INFORMATION

Figure D.867: Georg Stetter was kept under virtual house arrest by U.S. agents from 1945 until the 1950s [NARA RG 319, Entry A1-134B, Box 749, Folder 23 Nov 95 Georg Stetter XA001081].

William A. Consodine and A. E. Britt. August 1945. Notes to Aid in the Discussion with Dr. Vannevar Bush Concerning the Captured German Scientists. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.]

[...]

III. REASON FOR DETENTION

A. Security

In view of our impending operations, security was the initial and remains the paramount reason for their detention. Any publicity on TA, either foreign or domestic, at this critical period would be detrimental to overall security. This action is in alignment with the treatment accorded to other important German scientists who are being held for interrogation.

B. Fear of their falling into French hands

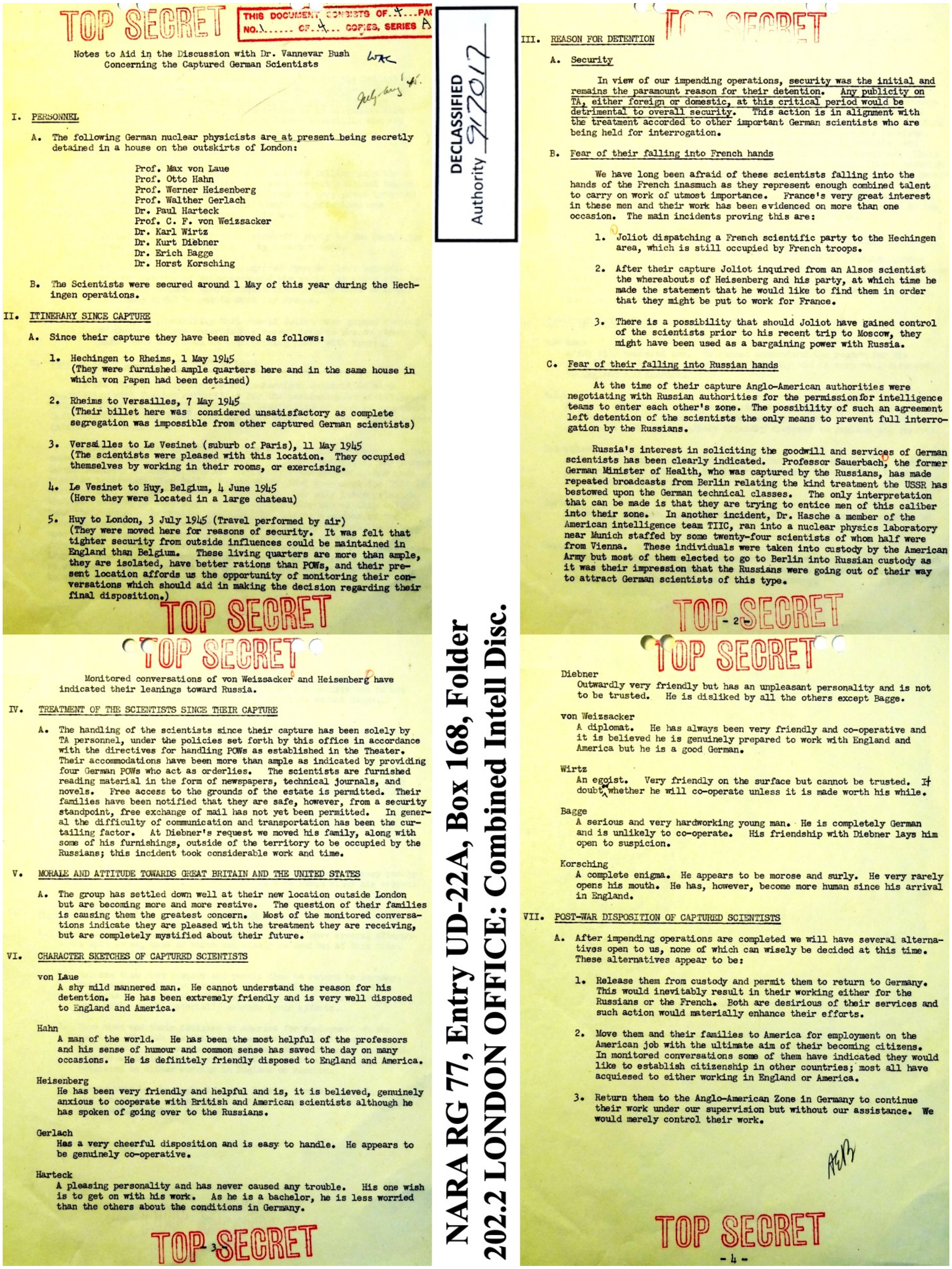
We have long been afraid of these scientists falling into the hands of the French inasmuch as they represent enough combined talent to carry on work of utmost importance. France's very great interest in these men and their work has been evidenced on more than one occasion. [...]

C. Fear of their falling into Russian hands

At the time of their capture Anglo-American authorities were negotiating with Russian authorities for the permission for intelligence teams to enter each other's zone. The possibility of such an agreement left detention of the scientists the only means to prevent full interrogation by the Russians.

Russia's interest in soliciting the goodwill and services of German scientists has been clearly indicated. [...]

[See document photos on p. 4802.]



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THIS DOCUMENT CONSISTS OF..4...PA
NO..1...... OF..4... COPIES, SERIES A

Notes to Aid in the Discussion with Dr. Vannevar Bush
Concerning the Captured German Scientists

WAC

July-Aug '45.

DECLASSIFIED
Authority 917017

I. PERSONNEL

A. The following German nuclear physicists are at present being secretly detained in a house on the outskirts of London:

Prof. Max von Laue
Prof. Otto Hahn
Prof. Werner Heisenberg
Prof. Walther Gerlach
Dr. Paul Harteck
Prof. C. F. von Weizsacker
Dr. Karl Wirtz
Dr. Kurt Diebner
Dr. Erich Bagge
Dr. Horst Korsching

B. The Scientists were secured around 1 May of this year during the Hechingen operations.

II. ITINERARY SINCE CAPTURE

A. Since their capture they have been moved as follows:

1. Hechingen to Rheims, 1 May 1945
(They were furnished ample quarters here and in the same house in which von Papen had been detained)

2. Rheims to Versailles, 7 May 1945
(Their billet here was considered unsatisfactory as complete segregation was impossible from other captured German scientists)

3. Versailles to Le Vesinet (suburb of Paris), 11 May 1945
(The scientists were pleased with this location. They occupied themselves by working in their rooms, or exercising.

4. Le Vesinet to Huy, Belgium, 4 June 1945
(Here they were located in a large chateau)

5. Huy to London, 3 July 1945 (Travel performed by air)
(They were moved here for reasons of security. It was felt that tighter security from outside influences could be maintained in England than Belgium. These living quarters are more than ample, they are isolated, have better rations than POWs, and their present location affords us the opportunity of monitoring their conversations which should aid in making the decision regarding their final disposition.)

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III. REASON FOR DETENTION

A. Security

In view of our impending operations, security was the initial and remains the paramount reason for their detention. Any publicity on TA, either foreign or domestic, at this critical period would be detrimental to overall security. This action is in alignment with the treatment accorded to other important German scientists who are being held for interrogation.

B. Fear of their falling into French hands

We have long been afraid of these scientists falling into the hands of the French inasmuch as they represent enough combined talent to carry on work of utmost importance. France's very great interest in these men and their work has been evidenced on more than one occasion. The main incidents proving this are:

1. Joliot dispatching a French scientific party to the Hechingen area, which is still occupied by French troops.

2. After their capture Joliot inquired from an Alsos scientist the whereabouts of Heisenberg and his party, at which time he made the statement that he would like to find them in order that they might be put to work for France.

3. There is a possibility that should Joliot have gained control of the scientists prior to his recent trip to Moscow, they might have been used as a bargaining power with Russia.

C. Fear of their falling into Russian hands

At the time of their capture Anglo-American authorities were negotiating with Russian authorities for the permission for intelligence teams to enter each other's zone. The possibility of such an agreement left detention of the scientists the only means to prevent full interrogation by the Russians.

Russia's interest in soliciting the goodwill and services of German scientists has been clearly indicated. Professor Sauerbach, the former German Minister of Health, who was captured by the Russians, has made repeated broadcasts from Berlin relating the kind treatment the USSR has bestowed upon the German technical classes. The only interpretation that can be made is that they are trying to entice men of this caliber into their zone. In another incident, Dr. Hasche a member of the American intelligence team TIIC, ran into a nuclear physics laboratory near Munich staffed by some twenty-four scientists of whom half were from Vienna. These individuals were taken into custody by the American Army but most of them elected to go to Berlin into Russian custody as it was their impression that the Russians were going out of their way to attract German scientists of this type.

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TOP SECRET

Monitored conversations of von Weizsacker and Heisenberg have indicated their leanings toward Russia.

IV. TREATMENT OF THE SCIENTISTS SINCE THEIR CAPTURE

A. The handling of the scientists since their capture has been solely by TA personnel, under the policies set forth by this office in accordance with the directives for handling POWs as established in the Theater. Their accommodations have been more than ample as indicated by providing four German POWs who act as orderlies. The scientists are furnished reading material in the form of newspapers, technical journals, and novels. Free access to the grounds of the estate is permitted. Their families have been notified that they are safe, however, from a security standpoint, free exchange of mail has not yet been permitted. In general the difficulty of communication and transportation has been the curtailing factor. At Diebner's request we moved his family, along with some of his furnishings, outside of the territory to be occupied by the Russians; this incident took considerable work and time.

V. MORALE AND ATTITUDE TOWARDS GREAT BRITAIN AND THE UNITED STATES

A. The group has settled down well at their new location outside London but are becoming more and more restive. The question of their families is causing them the greatest concern. Most of the monitored conversations indicate they are pleased with the treatment they are receiving, but are completely mystified about their future.

VI. CHARACTER SKETCHES OF CAPTURED SCIENTISTS

von Laue
A shy mild mannered man. He cannot understand the reason for his detention. He has been extremely friendly and is very well disposed to England and America.

Hahn
A man of the world. He has been the most helpful of the professors and his sense of humour and common sense has saved the day on many occasions. He is definitely friendly disposed to England and America.

Heisenberg
He has been very friendly and helpful and is, it is believed, genuinely anxious to cooperate with British and American scientists although he has spoken of going over to the Russians.

Gerlach
Has a very cheerful disposition and is easy to handle. He appears to be genuinely co-operative.

Harteck
A pleasing personality and has never caused any trouble. His one wish is to get on with his work. As he is a bachelor, he is less worried than the others about the conditions in Germany.

TOP SECRET

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TOP SECRET

Diebner
Outwardly very friendly but has an unpleasant personality and is not to be trusted. He is disliked by all the others except Bagge.

von Weizsacker
A diplomat. He has always been very friendly and co-operative and it is believed he is genuinely prepared to work with England and America but he is a good German.

Wirtz
An egoist. Very friendly on the surface but cannot be trusted. It doubt whether he will co-operate unless it is made worth his while.

Bagge
A serious and very hardworking young man. He is completely German and is unlikely to co-operate. His friendship with Diebner lays him open to suspicion.

Korsching
A complete enigma. He appears to be morose and surly. He very rarely opens his mouth. He has, however, become more human since his arrival in England.

VII. POST-WAR DISPOSITION OF CAPTURED SCIENTISTS

A. After impending operations are completed we will have several alternatives open to us, none of which can wisely be decided at this time. These alternatives appear to be:

1. Release them from custody and permit them to return to Germany. This would inevitably result in their working either for the Russians or the French. Both are desirious of their services and such action would materially enhance their efforts.

2. Move them and their families to America for employment on the American job with the ultimate aim of their becoming citizens. In monitored conversations some of them have indicated they would like to establish citizenship in other countries; most all have acquiesed to either working in England or America.

3. Return them to the Anglo-American Zone in Germany to continue their work under our supervision but without our assistance. We would merely control their work.

AEB

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- 4 -

NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.

Figure D.868: William A. Consodine and A. E. Britt. August 1945. Notes to Aid in the Discussion with Dr. Vannevar Bush Concerning the Captured German Scientists [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.].

Henry Maitland Wilson to John Anderson. 26 October 1945 [TNA FO 800/565].

ANCAM 453 26th October 1945

TOP SECRET AND PERSONAL.

Your CANAM 453.

Following for Sir John Anderson from Field Marshal Wilson.

I saw Groves yesterday morning and found him very difficult to move on this question. He seems completely convinced

(a) that all but one or two of the Group would certainly try to go to Russia

(b) that if they did they would be of the greatest value to the Soviet Government and

(c) that even if they did not go to Russia voluntarily some would almost certainly be kidnapped. (Groves alleged that there have been one or two cases of kidnapping of scientists already by the Russians in the American zone).

On the second point (b) he expressed the view that as a Group they were superior in all-round ability to the Group which had started the New Mexico laboratory.

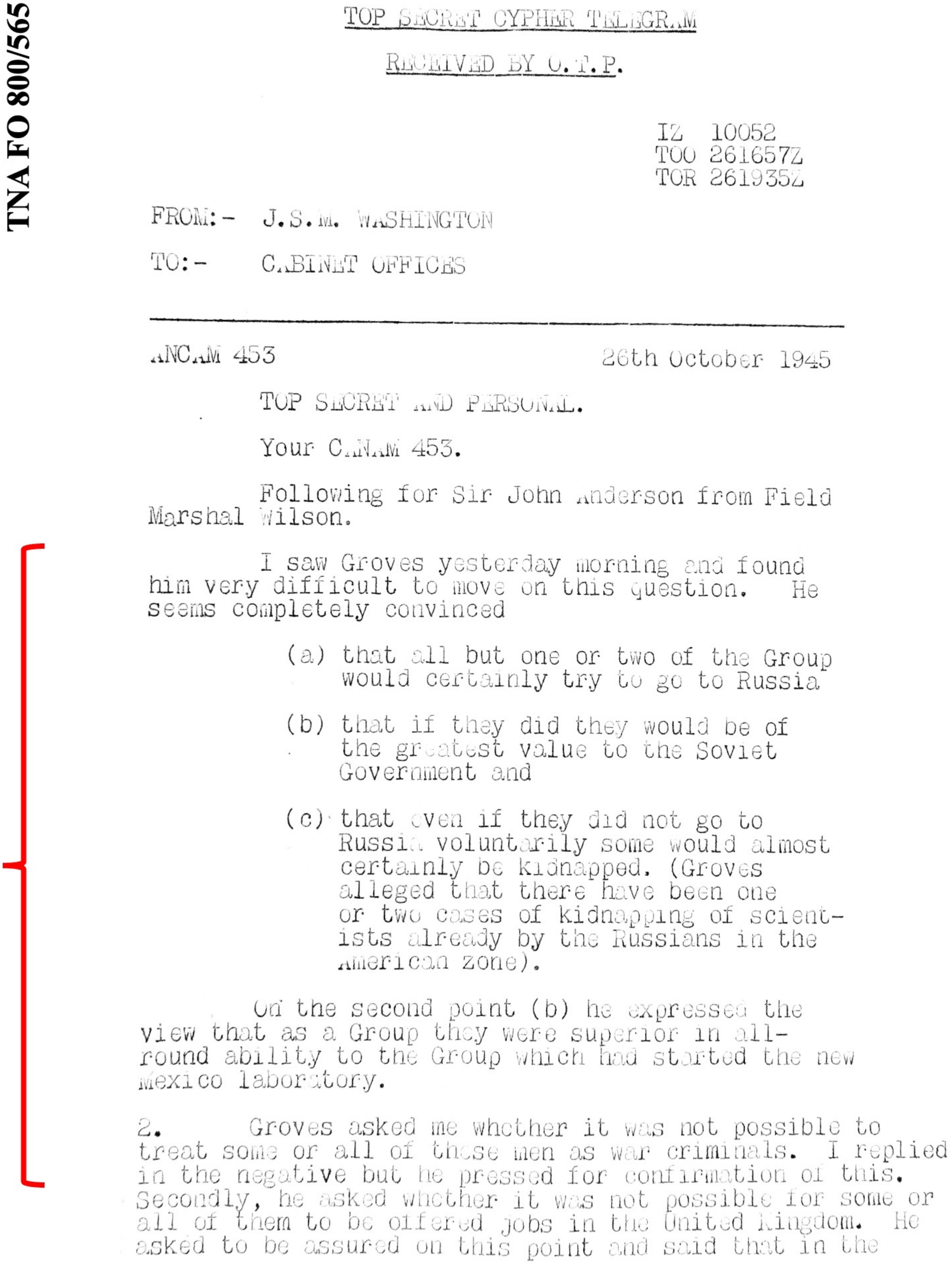
2. Groves asked me whether it was not possible to treat some or all of these men as war criminals. I replied in the negative but he pressed for confirmation of this. Secondly, he asked whether it was not possible for some or all of them to be offered jobs in the United Kingdom. He asked to be assured on this point and said that in the meantime he would explore the possibility of employing them in the United States, though he did not seem to be very optimistic.

3. Groves is being very unreasonable on this question, but I do not quite follow what is to be gained by taking the matter up with the State Department; who will merely consult the War Department. My inclination would be to give Groves a week to reply about the opportunities in the United States. If there is no result we should then tell him that there are no grounds on which we can legally justify their continued detention (if this is indeed the case) and that we have no alternative to sending them back to the zones in Germany from which they came, in order to join their families. But I do not think that it would be right that we should do this unless, at the same time, special instruction were given to our security forces to pay special attention to these men with the object of preventing them escaping either to the Russian occupied zone or to Berlin. I see no reason why such instructions should not be issued.

[See photos on pp. 4804–4805. Field Marshal Henry Maitland Wilson was chief of the British Joint Staff Mission to Washington, DC (JSM Washington) from 1945 to 1947. In this lofty official capacity, he met with Leslie Groves on 25 October 1945 and reported it in this Top Secret encrypted cable the next day. His cable was addressed to Sir John Anderson, who was the chair of the U.K. Advisory Committee on Atomic Energy, as well as to several other top advisors in the British government.

Leslie Groves said the German scientists held at Farm Hall "were superior in all-round ability to the Group which had started the New Mexico laboratory" and were "of the greatest value," and he wanted to either employ them or prosecute them as war criminals. See also the 20 February 1946 memorandum from Groves below. These private admissions by Groves demonstrate that his public statements denigrating the German nuclear scientists and their work were knowingly false. If German nuclear scientists had not done anything of consequence during the war, Groves would not have had any reason to believe they were superior to the Manhattan Project scientists. Likewise, if German nuclear scientists had not done anything of consequence during the war, Groves would not have had any possible grounds on which to consider prosecuting them as war criminals.]

TNA FO 800/565



TOP SECRET CYPHER TELEGRAM

RECEIVED BY O.T.P.

IZ 10052
TOO 261657Z
TOR 261935Z

FROM:- J.S.M. WASHINGTON

TO:- CABINET OFFICES

ANCAM 453 26th October 1945

TOP SECRET AND PERSONAL.

Your CANAM 453.

Following for Sir John Anderson from Field Marshal Wilson.

I saw Groves yesterday morning and found him very difficult to move on this question. He seems completely convinced

(a) that all but one or two of the Group would certainly try to go to Russia

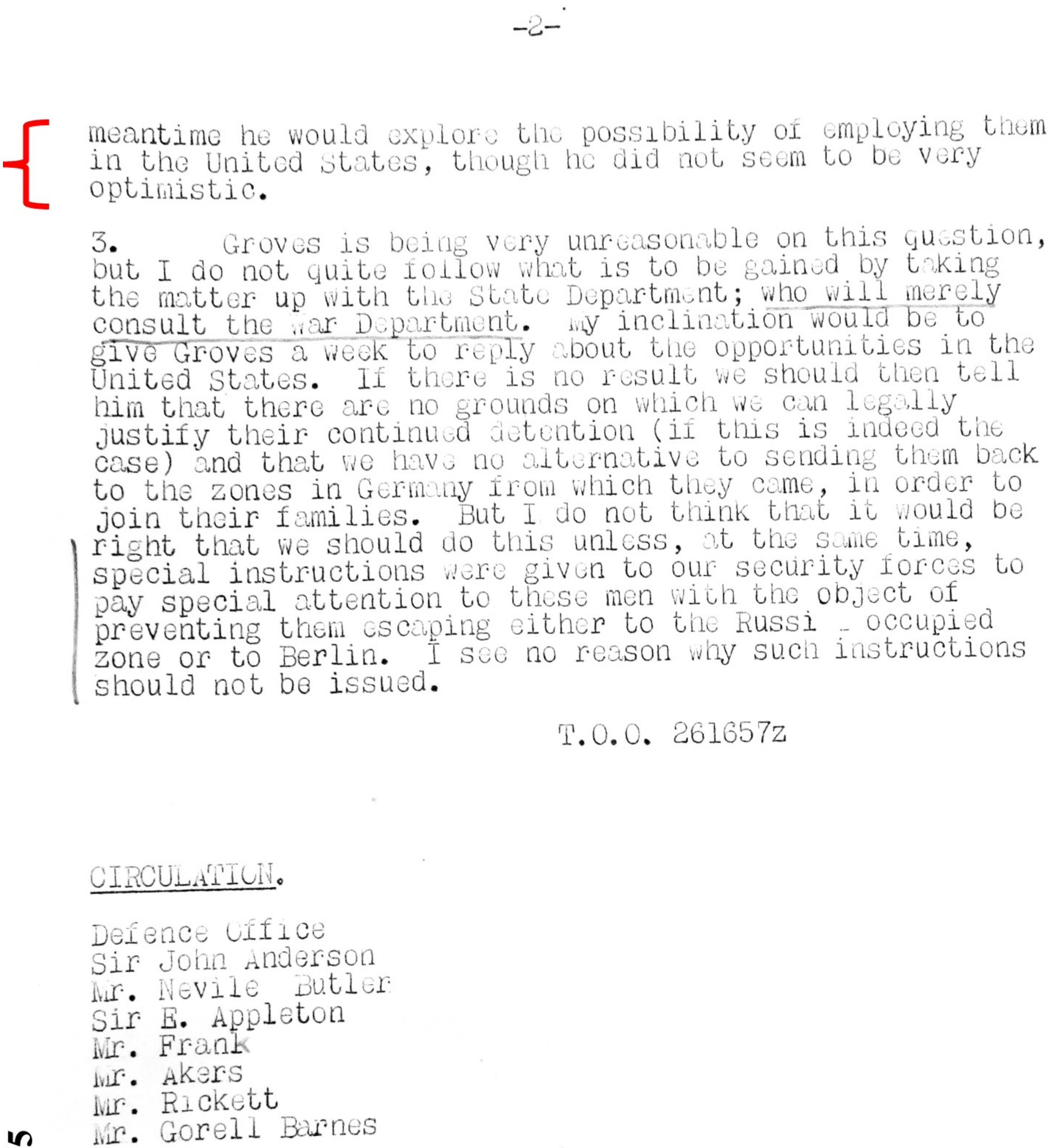
(b) that if they did they would be of the greatest value to the Soviet Government and

(c) that even if they did not go to Russia voluntarily some would almost certainly be kidnapped. (Groves alleged that there have been one or two cases of kidnapping of scientists already by the Russians in the American zone).

On the second point (b) he expressed the view that as a Group they were superior in all-round ability to the Group which had started the new Mexico laboratory.

2. Groves asked me whether it was not possible to treat some or all of these men as war criminals. I replied in the negative but he pressed for confirmation of this. Secondly, he asked whether it was not possible for some or all of them to be offered jobs in the United Kingdom. He asked to be assured on this point and said that in the

Figure D.869: Leslie Groves said the German scientists held at Farm Hall "were superior in all-round ability to the Group which had started the New Mexico laboratory" and were "of the greatest value," and he wanted to either employ them or prosecute them as war criminals [TNA FO 800/565, Henry Maitland Wilson to John Anderson, 26 October 1945].



-2-

meantime he would explore the possibility of employing them in the United States, though he did not seem to be very optimistic.

3. Groves is being very unreasonable on this question, but I do not quite follow what is to be gained by taking the matter up with the State Department; who will merely consult the War Department. My inclination would be to give Groves a week to reply about the opportunities in the United States. If there is no result we should then tell him that there are no grounds on which we can legally justify their continued detention (if this is indeed the case) and that we have no alternative to sending them back to the zones in Germany from which they came, in order to join their families. But I do not think that it would be right that we should do this unless, at the same time, special instructions were given to our security forces to pay special attention to these men with the object of preventing them escaping either to the Russi _ occupied zone or to Berlin. I see no reason why such instructions should not be issued.

T.O.O. 261657z

CIRCULATION.

Defence Office
Sir John Anderson
Mr. Nevile Butler
Sir E. Appleton
Mr. Frank
Mr. Akers
Mr. Rickett
Mr. Gorell Barnes

TNA FO 800/565

Figure D.870: Leslie Groves said the German scientists held at Farm Hall "were superior in all-round ability to the Group which had started the New Mexico laboratory" and were "of the greatest value," and he wanted to either employ them or prosecute them as war criminals [TNA FO 800/565, Henry Maitland Wilson to John Anderson, 26 October 1945].

John Weckerling. 6 February 1946 secret memorandum. [**NARA RG 319, Entry NM3-47B, Box 991, Folder Implementation, General Policy & History**]

MIL 920 6 February 1946

MEMORANDUM FOR THE COMMANDING GENERAL, ARMY SERVICE FORCES:

SUBJECT: Plans for Extended Exploitation of OVERCAST Personnel

1. In the event that governmental policies are promulgated that will permit long-term exploitation of German scientists with inducements such as legal status in the United States, possible transfer of families, patent protection, etc., it is desirable that the War Department be prepared to take immediate advantage of such a policy. It is requested that you submit lists of scientists, in the following categories, whose indefinite stay in this country appears to be in the national interest[...]

Leslie Groves. 20 February 1946 secret memorandum. [**NARA RG 319, Entry NM3-47B, Box 991, Folder Implementation, General Policy & History**]

20 February 1946

MEMORANDUM FOR THE COMMANDING GENERAL, ARMY SERVICE FORCES:
THRU: Chief, Personnel Division, Office Chief of Engineers.

SUBJECT: Plans for Extended Exploitation of OVERCAST Personnel.

1. Reference is made to memorandum for the Commanding General, ASF, subject as above, dated 6 February 1946, from Brigadier General John Weckerling, WDGS, MID G-2, reference MIL 920.

2. Government measures to encourage the long term exploitation of German scientists by the United States are desirable, particularly with reference to nuclear physicists and chemists who might be of some service to scientists in this country in the field of atomic energy.

3. There are a number of German scientists who might well be included for the policies and procedures set forth in reference memorandum. However, they do not fall within any of the categories listed in paragraph 1 of that memorandum. The atomic bomb was created without the direct exploitation of any German scientists. I suggest, therefore, a fifth category, defined as, those German scientists of outstanding ability in the field of nuclear physics and chemistry who, by their past reputation and present knowledge, would be of more value to the national interest of this country if they could be employed here rather than in any other country. A list of the men falling within such category is given below. In order for you to place them in the proper priority group, I have included a brief critical analysis of their relative merit. It should be borne in mind that strong opposition will be encountered in placing these men in American institutions best fitted to exploit their efforts. The Manhattan District does not want them because of obvious security reasons. However, it is extremely important that these persons be prevented from giving their services to a potential enemy of the United States.

PROFESSOR OTTO HAHN

He is one of the greatest living chemists in the field of radioactivity, and winner of the 1944 Nobel prize in Chemistry for the discovery of the fission of uranium. Hahn is not known to have been a Nazi and is apparently well disposed to both England and America.

PROFESSOR MAX VON LAUE

He never actively worked on the German nuclear physics project. However, he is or has been well disposed toward America. His son is presently in the United States Army and was formerly at Princeton. Von Laue is noted in the field of physical chemistry and X-ray diffraction as a top flight man. He is over seventy years of age.

PROFESSOR WALTHER GERLACH

Gerlach is an experimental atomic physicist of considerable ability but is a thorough Nazi and served as Goering's deputy in charge of the German atomic energy effort in its later stages. He is reported to feel like a defeated general because of the failure of the German nuclear project and has discussed suicide. He is not believed sympathetic to other countries but is essentially a German nationalist.

PROFESSOR W. HEISENBERG

He is a theoretical nuclear physicist, a Nobel prize winner and probably the present German leader in physics. He is particularly known for his work in quantum mechanics and nuclear theory. Although Heisenberg may not have been an active Nazi he is a patriotic German. It is conceivable that some persuasion might be necessary as he may desire to take his chances in Germany or England.

PROFESSOR P. HARTECK

He is a famous physical chemist who seems to have what has been characterized as an "American approach" to atomic energy problems, i.e.—he demonstrated a competence in the engineering phases of the work. He is not believed to have any profound political sympathies but has confined himself to his research work.

PROFESSOR C. P. VON WEIZSACKER

He is a first-class physicist and astro-physicist quite interested in philosophy and certain philosophical implications of his work. He is an opportunist and son of a diplomat. He is not believed to be a Nazi.

DR. K. WIRTZ

He is an experimental physicist, comparatively unknown prior to the German atomic energy project but the author, while on the project, of a number of worthwhile reports, particularly on pile theory. Wirtz is the sort who will go to another country if offered what he considers good terms.

DR. E. BAGGE

He is a fairly young, reasonably competent, experimental physicist who has done considerable work on isotope separation. Bagge is of humble origin, a serious, hard-working, completely German nationalist. He might work for another country.

H. KORSCHING

He is a rather obscure physicist who has done good work on isotope separation on the German energy project. He was probably a Nazi.

K. DIEBNER

He was Gerlach's administrative assistant on the German atomic energy project. He is not a particularly well known physicist although he has a pretty good grasp of the German project.

FREDERICK WEYGAND

He is a chemist and biologist and not a physicist. He is believed to be anti-Nazi and has been cooperative with American authorities. He has until recently been located in an American P/W camp. He has recently written the Rockefeller Foundation and requested a position with them.

DR. WERNER MAURER

He has been, until recently, in an American P/W camp but is presently on his way back to Germany. Maurer is a relatively young physicist who did considerable experimental work in Joliot's laboratory in Paris after the German occupation. He is unquestionably a reliable Nazi in addition to being an able young physicist.

DR. RUDOLPH FLEISCHMANN

He was, until recently, in an American P/W camp. He is a first-rate physicist formerly head of the Physical Research Division of the Medical Institute of the University of Strassburg and is generally considered to be an extreme Nazi. His particular field has centered around the application of induced radioactivity in the field of biological research.

PROFESSOR FRITZ G. HOUTERMANS

Houtermans is of Dutch extraction, grew up in Austria, lived in Germany until 1933 when he left because of the Nazi Party and worked at Cambridge University in England. He subsequently went to Kharkov, Russia, where he worked at the Kharkov Physico-Technical Institute. In 1937, as he was preparing to leave Russia, Houtermans, according to his own statement, was arrested by the NKVD on vague charges of counter-revolutionary activity for Germany. As a result of the intervention of Dr. R. A. Millikan of Cal. Tech., he was released in 1940 after preparing what he claims was a false confession of technical espionage which he framed in such a manner as to be obviously scientifically fallacious, but which satisfied the NKVD, who exiled him to Germany in spite of his requests not to be sent there. In Germany, Houtermans says he was immediately imprisoned by the Gestapo but was released after questioning as to why he had left Russia.

Houtermans' connection with the German nuclear physics project was not great, although he was in close contact with von Weizsacker and von Ardenne and worked with the latter on a cyclotron. Houtermans' official position was with the PTR (German Bureau of Standards) at Ronneburg, Thuringen, where he worked with counter-tubes. He was the first man in Germany to propose the fissionability of plutonium and wrote several memoranda on the subject, but little attention was paid to him in Germany.

L. R. GROVES,
Major General, U.S.A.

[Publicly, Leslie Groves agreed with Samuel Goudsmit's statements that the wartime German nuclear program was very small and very primitive, had never considered plutonium, and had never even tried to produce a fission bomb. Privately, Groves wrote this secret memorandum admitting that the German program had recognized the potential of plutonium very early on, had done "considerable work" on uranium isotope separation, and had a number of "nuclear physicists and chemists who might be of some service to scientists in this country in the field of atomic energy." Groves also warned that because of those scientists' "present knowledge," "it is extremely important that these persons be prevented from giving their services to a potential enemy of the United States."

This document also shows that in addition to the ten nuclear scientists who were held at Farm Hall, a significant number of German nuclear scientists were taken to the United States for extended interrogations in "American P/W camps." How many scientists were interrogated? Where are the reports on their interrogations? What did Groves learn from those interrogations or other intelligence sources that convinced him to write this secret memo, which contradicts what Groves and Goudsmit publicly asserted?]

Walter Trinks. Undated but probably summer 1945. [NARA RG 319, Entry A1-134B, Box ??, Folder XE098301 Trinks, Walter]

Dr. Walter Trinks
Int. No. 8-3448-M-AA
7th Coy.

TO THE AMERICAN COMMAND OF THE INTERNMENT CAMP? CIC-STAFF.

When I was imprisoned at Bad Aibling an American officer in an address asked German scientists and specialists to present themselves. Having presented myself I was told to give further written information on my altuition [education] and my career. Having been transferred to this camp I could not do so. I am a Physicist and have been employed with the OKH [Oberkommando des Heeres] until the end of the war in the research dept. of the office for arms [Heereswaffenamt] as referee for the physics of explosions and blasting. The tasks of that dept. included:

1st Research of physical phenomena at the explosion

2nd Augmentation of and defense against the effect of blasting materials through physical methods

3rd Research of difficulties and troubles.

4th The replacement of valuable raw materials.

During the war the principal labor was dedicated to the principle of hollow charges and its use in armour breaking amunition as F-I-7,5 cm grenade, HL(ABC), 10 cm G.Hl, rifle grenade, Panzerfaust and Panzerschreck, Panzerhandgrenade, Redcap, Magnetic H 3 and H 15.

At the end of the war I was occupied with experiments for producing extreme high pressures and temperatures, extreme velocities (up to 15 km/sec) and heavy swingings of the air [shock waves]. The practical use of these researches comprises:

1st for the war: the defense against V-weapons super- and atomic bombs by destroying them before they reach their target and the initiation of atomic bombs.

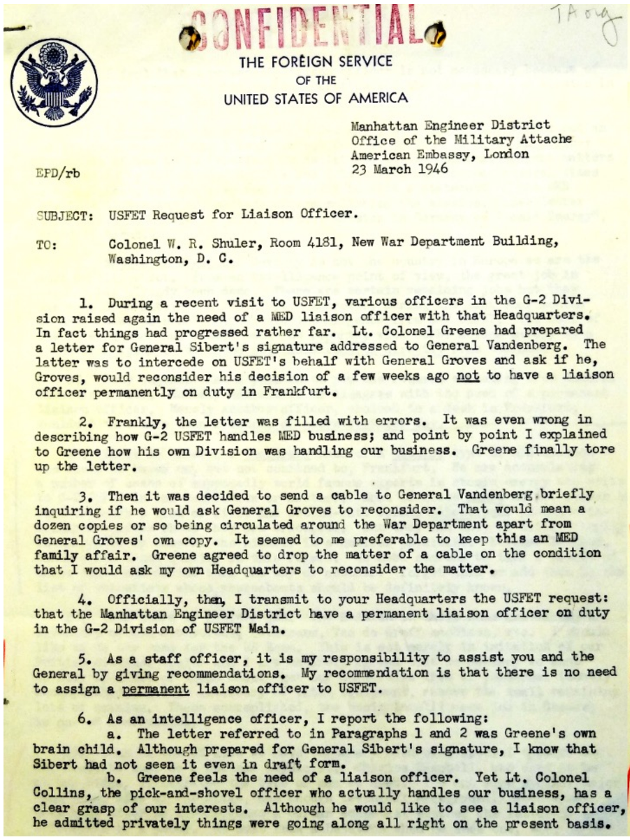
2nd for peacetime: the producing of artificial diamonds and the enriching of minerals and materials.

3rd for purely scientific research of special molecules and atoms under extreme pressures and temperatures.

I esteem these researches to be important and promising and therefore ask to be allowed to prosecute them at the service of the U.S.A.

[See document photos on pp. 4258–4259. Due to the number of English spelling and capitalization mistakes, this document appears to have been written in English by Trinks himself, not translated by a native English speaker. For ease of understanding, I have corrected most of the document's English mistakes in the above transcription.

Trinks was imprisoned by the U.S. Army from June 1945 to June 1946, and he informed them that "At the end of the war I was occupied with experiments for... the initiation of atomic bombs." Where are the detailed reports on his interrogations and everything he told U.S. officials about his wartime work? What exactly did he work on after the war, and for whom?]



CONFIDENTIAL

THE FOREIGN SERVICE
OF THE
UNITED STATES OF AMERICA

Manhattan Engineer District
Office of the Military Attache
American Embassy, London
23 March 1946

EPD/rb

SUBJECT: USFET Request for Liaison Officer.

TO: Colonel W. R. Shuler, Room 4181, New War Department Building, Washington, D. C.

1. During a recent visit to USFET, various officers in the G-2 Division raised again the need of a MED liaison officer with that Headquarters. In fact things had progressed rather far. Lt. Colonel Greene had prepared a letter for General Sibert's signature addressed to General Vandenberg. The latter was to intercede on USFET's behalf with General Groves and ask if he, Groves, would reconsider his decision of a few weeks ago not to have a liaison officer permanently on duty in Frankfurt.

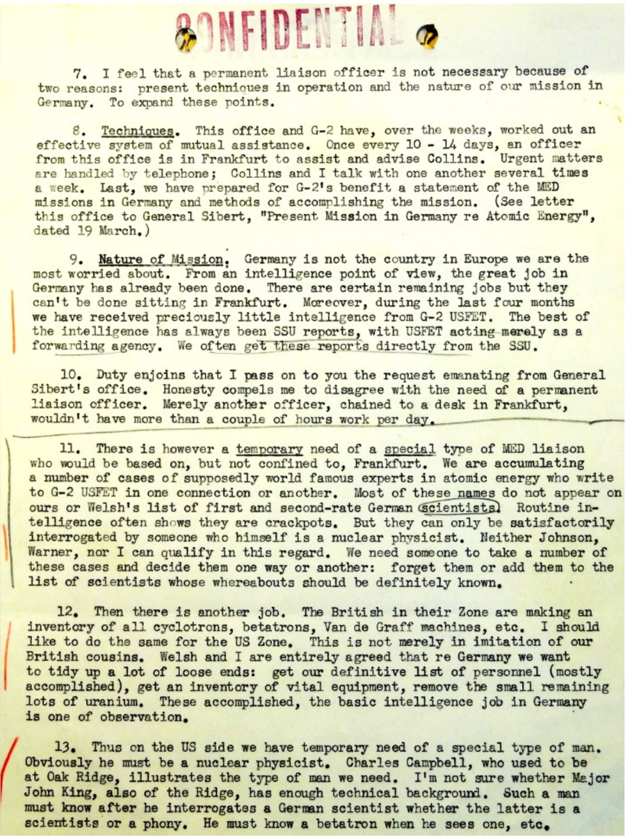
2. Frankly, the letter was filled with errors. It was even wrong in describing how G-2 USFET handles MED business; and point by point I explained to Greene how his own Division was handling our business. Greene finally tore up the letter.

3. Then it was decided to send a cable to General Vandenberg briefly inquiring if he would ask General Groves to reconsider. That would mean a dozen copies or so being circulated around the War Department apart from General Groves' own copy. It seemed to me preferable to keep this an MED family affair. Greene agreed to drop the matter of a cable on the condition that I would ask my own Headquarters to reconsider the matter.

4. Officially, then, I transmit to your Headquarters the USFET request: that the Manhattan Engineer District have a permanent liaison officer on duty in the G-2 Division of USFET Main.

5. As a staff officer, it is my responsibility to assist you and the General by giving recommendations. My recommendation is that there is no need to assign a permanent liaison officer to USFET.

6. As an intelligence officer, I report the following:
a. The letter referred to in Paragraphs 1 and 2 was Greene's own brain child. Although prepared for General Sibert's signature, I know that Sibert had not seen it even in draft form.
b. Greene feels the need of a liaison officer. Yet Lt. Colonel Collins, the pick-and-shovel officer who actually handles our business, has a clear grasp of our interests. Although he would like to see a liaison officer, he admitted privately things were going along all right on the present basis.



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7. I feel that a permanent liaison officer is not necessary because of two reasons: present techniques in operation and the nature of our mission in Germany. To expand these points.

8. Techniques. This office and G-2 have, over the weeks, worked out an effective system of mutual assistance. Once every 10 - 14 days, an officer from this office is in Frankfurt to assist and advise Collins. Urgent matters are handled by telephone; Collins and I talk with one another several times a week. Last, we have prepared for G-2's benefit a statement of the MED missions in Germany and methods of accomplishing the mission. (See letter this office to General Sibert, "Present Mission in Germany re Atomic Energy", dated 19 March.)

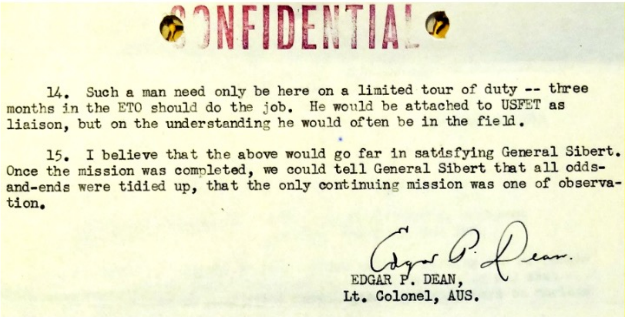
9. Nature of Mission. Germany is not the country in Europe we are the most worried about. From an intelligence point of view, the great job in Germany has already been done. There are certain remaining jobs but they can't be done sitting in Frankfurt. Moreover, during the last four months we have received preciously little intelligence from G-2 USFET. The best of the intelligence has always been SSU reports, with USFET acting merely as a forwarding agency. We often get these reports directly from the SSU.

10. Duty enjoins that I pass on to you the request emanating from General Sibert's office. Honesty compels me to disagree with the need of a permanent liaison officer. Merely another officer, chained to a desk in Frankfurt, wouldn't have more than a couple of hours work per day.

11. There is however a temporary need of a special type of MED liaison who would be based on, but not confined to, Frankfurt. We are accumulating a number of cases of supposedly world famous experts in atomic energy who write to G-2 USFET in one connection or another. Most of these names do not appear on ours or Welsh's list of first and second-rate German scientists. Routine intelligence often shows they are crackpots. But they can only be satisfactorily interrogated by someone who himself is a nuclear physicist. Neither Johnson, Warner, nor I can qualify in this regard. We need someone to take a number of these cases and decide them one way or another: forget them or add them to the list of scientists whose whereabouts should be definitely known.

12. Then there is another job. The British in their Zone are making an inventory of all cyclotrons, betatrons, Van de Graff machines, etc. I should like to do the same for the US Zone. This is not merely in imitation of our British cousins. Welsh and I are entirely agreed that re Germany we want to tidy up a lot of loose ends: get our definitive list of personnel (mostly accomplished), get an inventory of vital equipment, remove the small remaining lots of uranium. These accomplished, the basic intelligence job in Germany is one of observation.

13. Thus on the US side we have temporary need of a special type of man. Obviously he must be a nuclear physicist. Charles Campbell, who used to be at Oak Ridge, illustrates the type of man we need. I'm not sure whether Major John King, also of the Ridge, has enough technical background. Such a man must know after he interrogates a German scientist whether the latter is a scientists or a phony. He must know a betatron when he sees one, etc.



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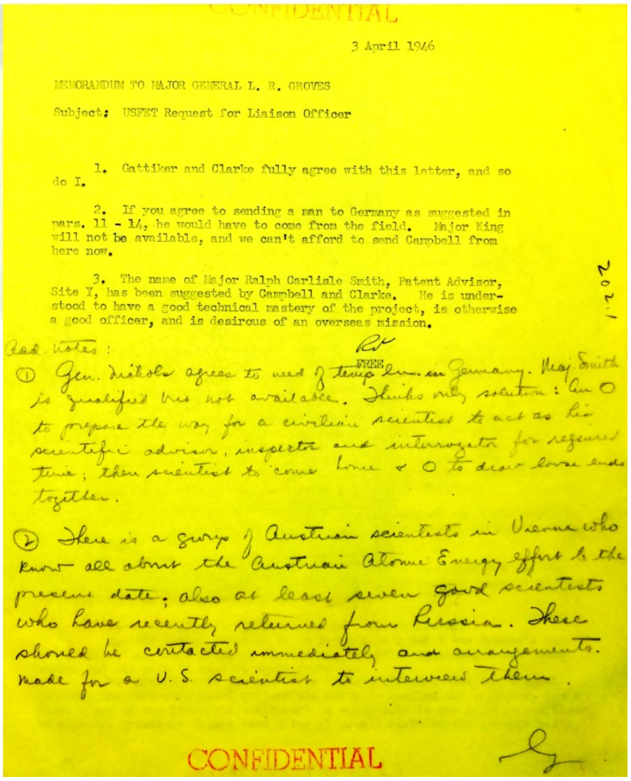
14. Such a man need only be here on a limited tour of duty -- three months in the ETO should do the job. He would be attached to USFET as liaison, but on the understanding he would often be in the field.

15. I believe that the above would go far in satisfying General Sibert. Once the mission was completed, we could tell General Sibert that all odds-and-ends were tidied up, that the only continuing mission was one of observation.

Edgar P. Dean
EDGAR P. DEAN,
Lt. Colonel, AUS.



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3 April 1946

MEMORANDUM TO MAJOR GENERAL L. R. GROVES

Subject: USFET Request for Liaison Officer

1. Gattiker and Clarke fully agree with this letter, and so do I.

2. If you agree to sending a man to Germany as suggested in pars. 11 - 14, he would have to come from the field. Major King will not be available, and we can't afford to send Campbell from here now.

3. The name of Major Ralph Carlisle Smith, Patent Advisor, Site Y, has been suggested by Campbell and Clarke. He is understood to have a good technical mastery of the project, is otherwise a good officer, and is desirous of an overseas mission.

202.1

RF
FREE

Add. Notes:

① Gen. Nichols agrees to need of temp. man in Germany. Maj. Smith is qualified but not available. Thinks only solution: An O to prepare the way for a civilian scientist to act as his scientific advisor, inspector and interrogator for required time; then scientist to come home & O to draw loose ends together.

② There is a group of Austrian scientists in Vienna who know all about the Austrian Atomic Energy effort to the present date; also at least seven good scientists who have recently returned from Russia. These should be contacted immediately and arrangements made for a U.S. scientist to interview them.

G

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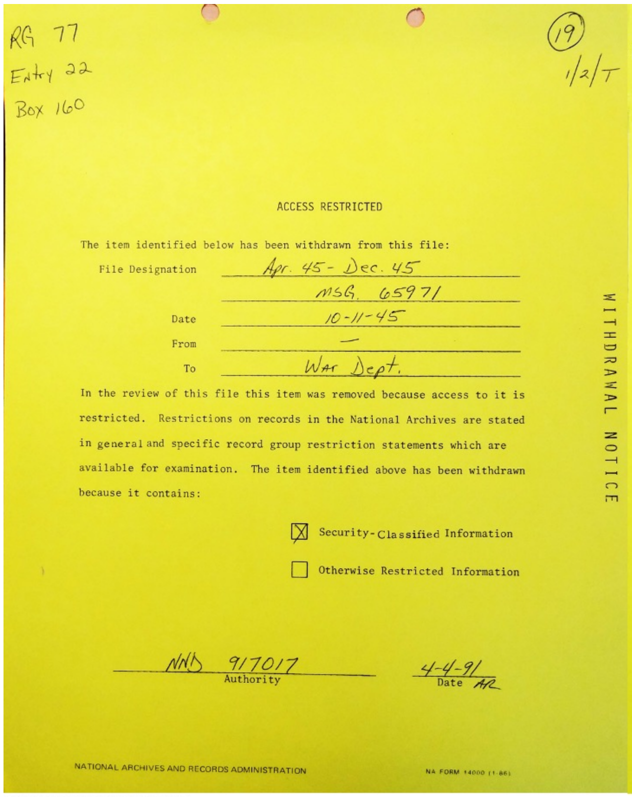
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.

Figure D.871: If the wartime German nuclear program was so small and primitive, why did the U.S. keep investigating and discovering more and more information about scientists, sites, and equipment from that program a year after the war? Edgar P. Dean to W. R. Shuler, 23 March 1946. R. H. Free to Leslie Groves, 3 April 1946. Subject: USFET Request for Liaison Officer. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.]



RG 77
Entry 22
Box 160

(19)
1/2/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Apr. 45- Dec. 45
MSG. 65971
Date 10-11-45
From —
To War Dept.

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4-4-91
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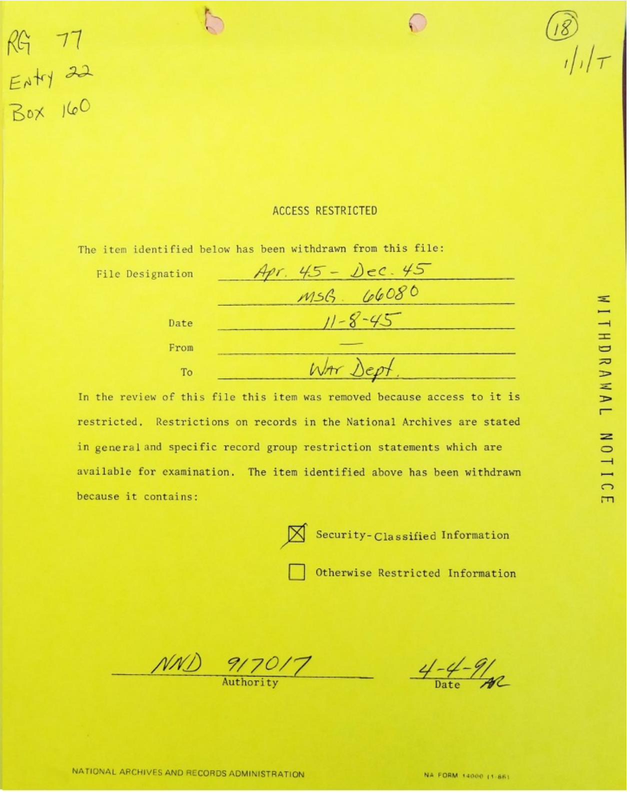

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(18)
1/1/T

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File Designation Apr. 45 - Dec. 45
MSG. 66080
Date 11-8-45
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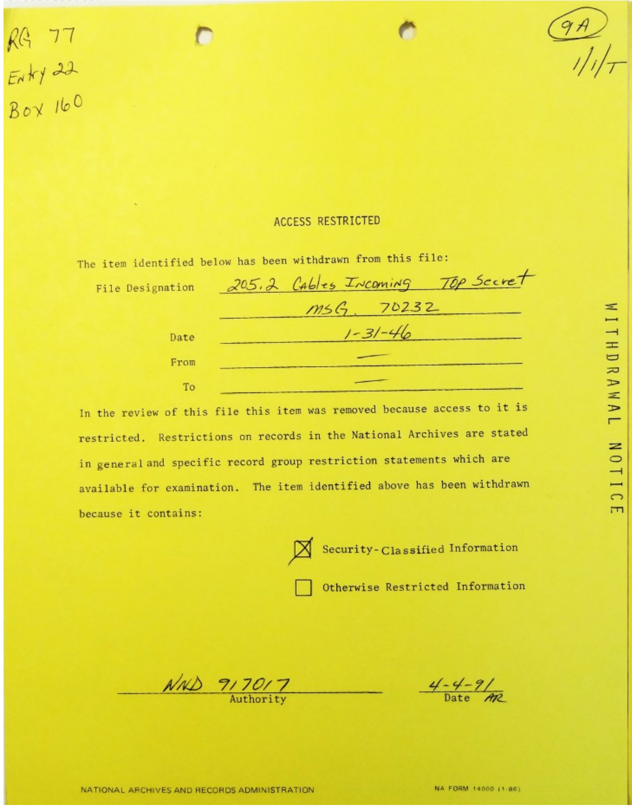

RG 77
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(9A)
1/1/T

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File Designation 205.2 Cables Incoming Top Secret
MSG. 70232
Date 1-31-46
From —
To —

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4-4-91
Date AR

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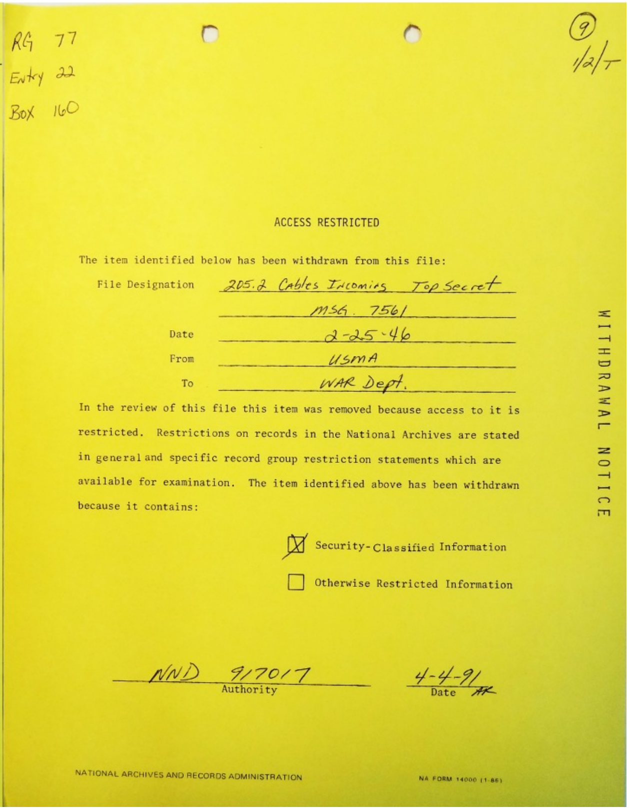

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(9)
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File Designation 205.2 Cables Incoming Top Secret
MSG. 7561
Date 2-25-46
From USMA
To WAR Dept.

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4-4-91
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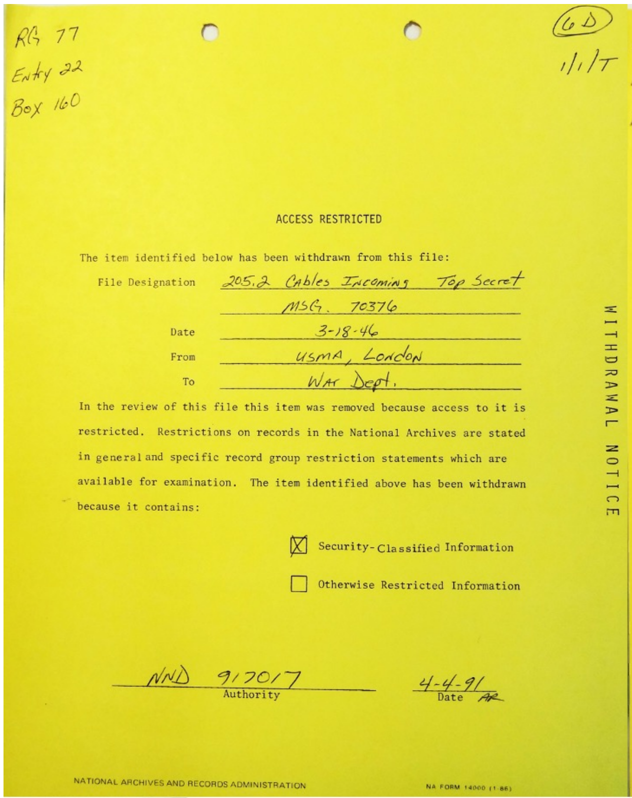
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

Figure D.872: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]



RG 77
Entry 22
Box 160

6D

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File Designation 205.2 Cables Incoming Top Secret
MSG. 70376
Date 3-18-46
From USMA, London
To War Dept.

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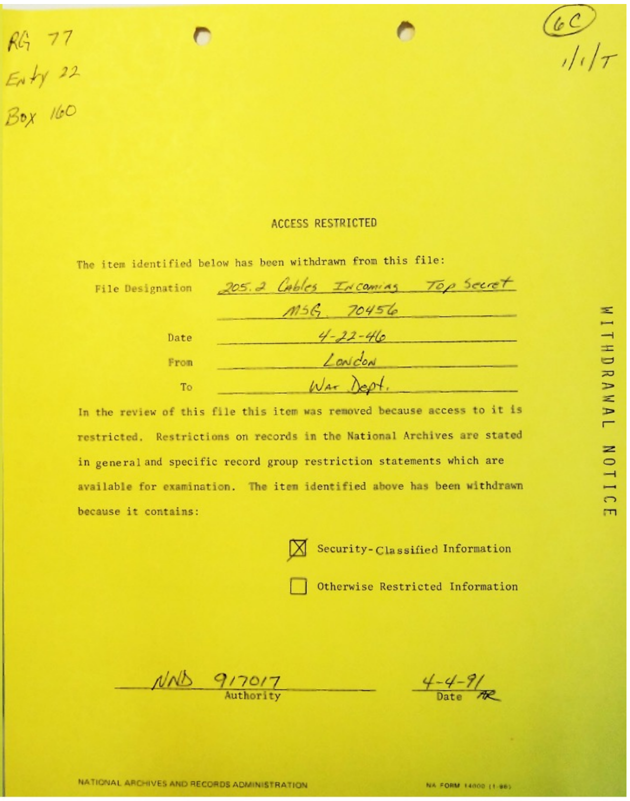

RG 77
Entry 22
Box 160

6C

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File Designation 205.2 Cables Incoming Top Secret
MSG. 70456
Date 4-22-46
From London
To War Dept.

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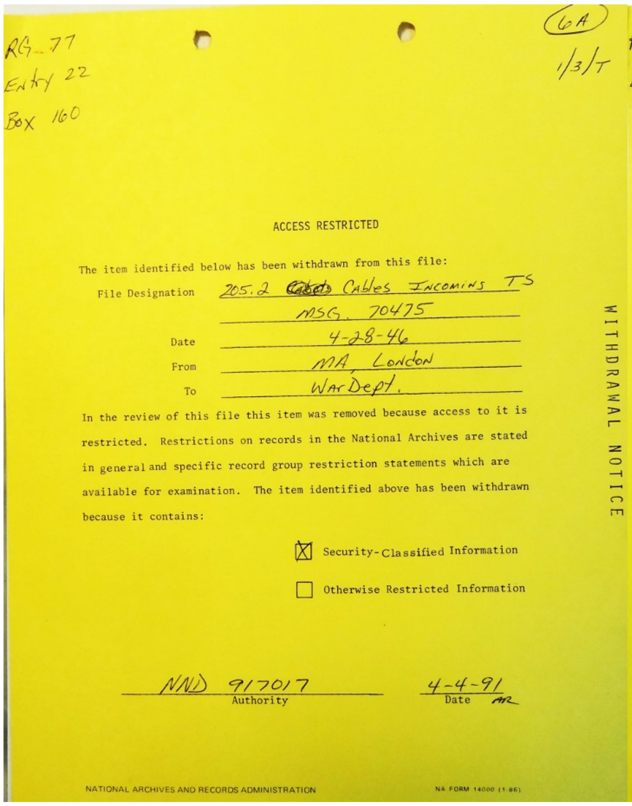
NARA RG 77, Entry UD-22A, Box 160



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Entry 22
Box 160

6A

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File Designation 205.2 ~~Cables~~ Cables Incomins TS
MSG. 70475
Date 4-28-46
From MA, London
To War Dept.

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Authority

4-4-91
Date AR

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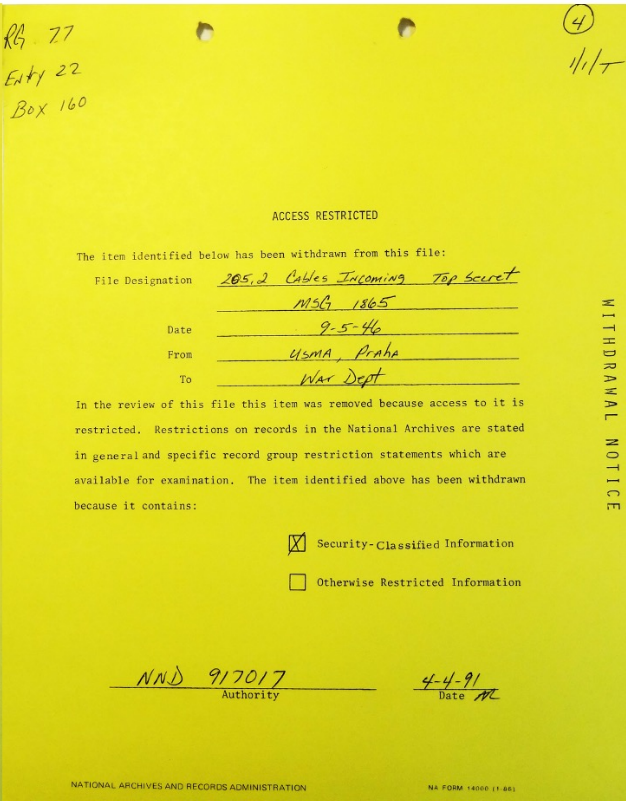

RG 77
Entry 22
Box 160

4

1/1/T

ACCESS RESTRICTED

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File Designation 205.2 Cables Incoming Top Secret
MSG 1865
Date 9-5-46
From USMA, Praha
To War Dept

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Authority

4-4-91
Date AR

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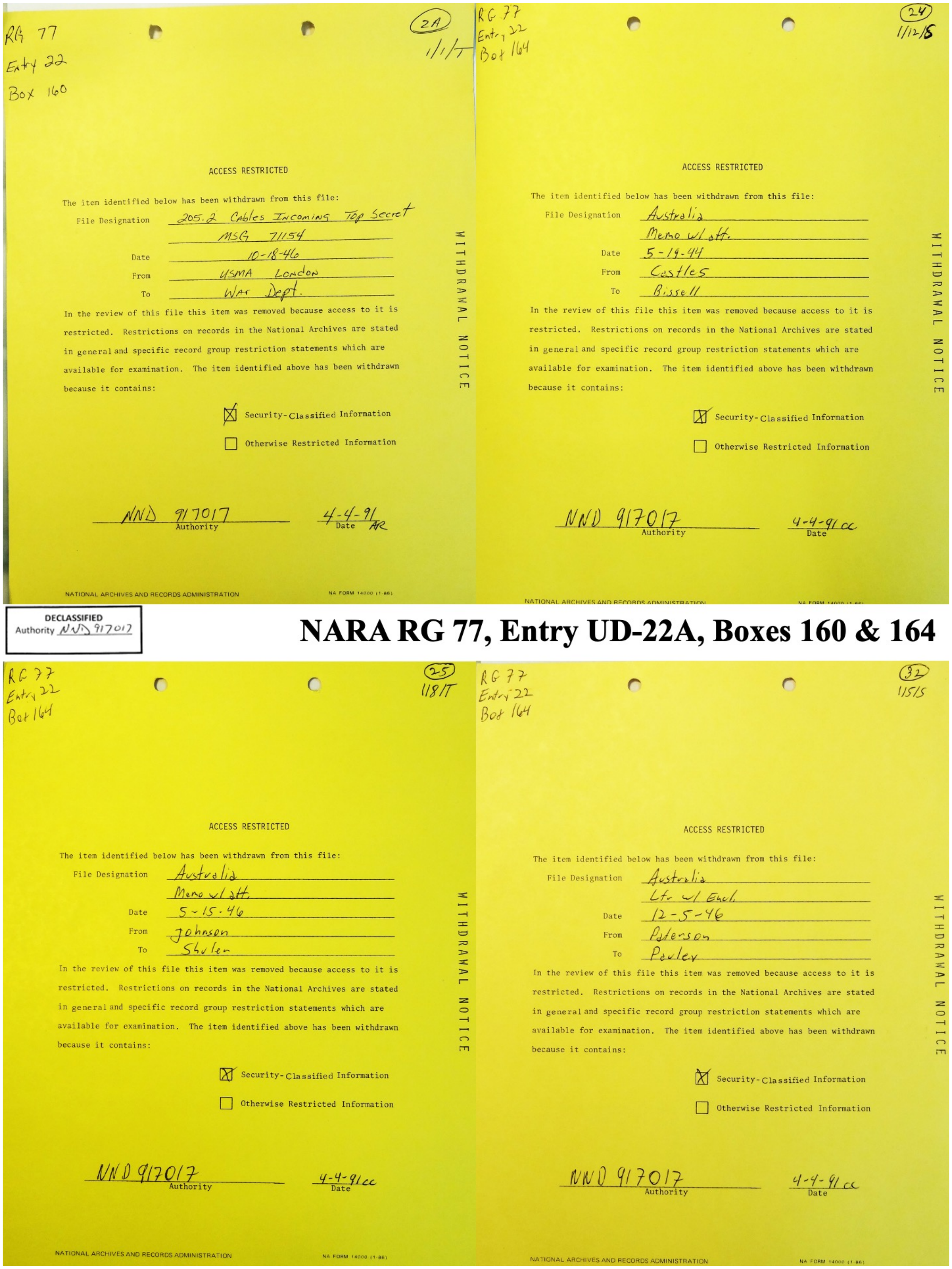
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

Figure D.873: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]



RG 77
Entry 22
Box 160

2A
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File Designation 205.2 Cables Incoming Top Secret
MSG 71154
Date 10-18-46
From USMA London
To War Dept.

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4-4-91 AR Date

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RG 77
Entry 22
Box 164

24
1/12/S

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File Designation Australia
Memo w/ att.
Date 5-19-44
From Castles
To Bissell

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Authority NND 917017

NARA RG 77, Entry UD-22A, Boxes 160 & 164

RG 77
Entry 22
Box 164

25
1/18/T

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File Designation Australia
Memo w/ att.
Date 5-15-46
From Johnson
To Shuler

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NND 917017 Authority
4-4-91 cc Date

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RG 77
Entry 22
Box 164

32
1/5/S

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Australia
Ltr. w/ Encl.
Date 12-5-46
From Peterson
To Pauley

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NND 917017 Authority
4-4-91 cc Date

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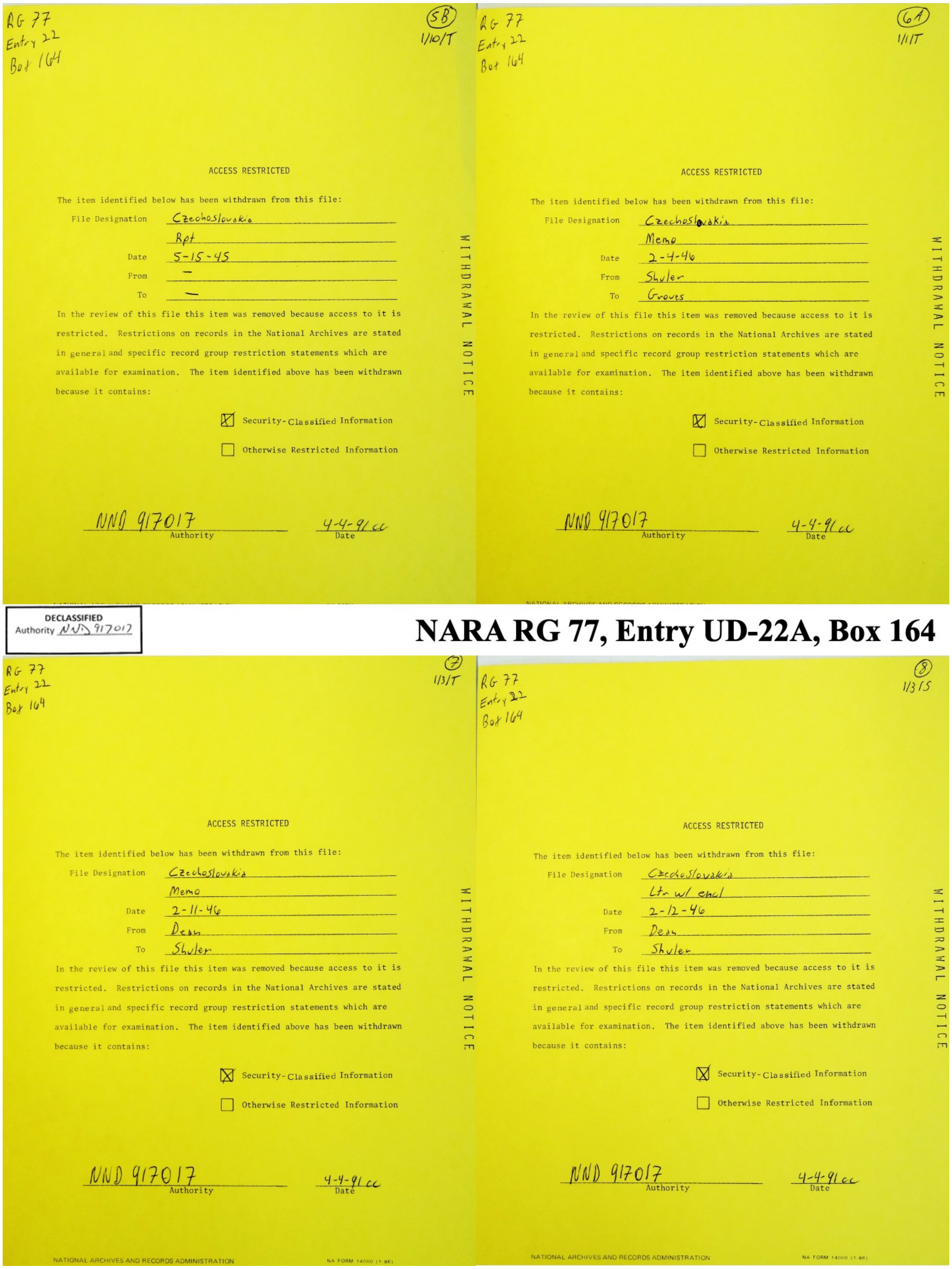
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

Figure D.874: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? (Despite its name, the "Australia" folder is filled with German nuclear files. Either "Australia" was simply a code name or an otherwise empty folder was used to stored excess German files. [NARA RG 77, Entry UD-22A]



RG 77
Entry 22
Box 164

5B
1/10/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Czechoslovakia
Rpt
Date 5-15-45
From —
To —

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4-4-91 cc Date

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RG 77
Entry 22
Box 164

6A
1/11/T

ACCESS RESTRICTED

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File Designation Czechoslovakia
Memo
Date 2-4-46
From Shuler
To Groves

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4-4-91 cc Date

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Authority NND 917017

NARA RG 77, Entry UD-22A, Box 164

RG 77
Entry 22
Box 164

⑦
1/13/T

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The item identified below has been withdrawn from this file:

File Designation Czechoslovakia
Memo
Date 2-11-46
From Dean
To Shuler

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NND 917017 Authority
4-4-91 cc Date

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NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

RG 77
Entry 22
Box 164

⑧
1/13/S

ACCESS RESTRICTED

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File Designation Czechoslovakia
Ltr w/ encl
Date 2-12-46
From Dean
To Shuler

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NND 917017 Authority
4-4-91 cc Date

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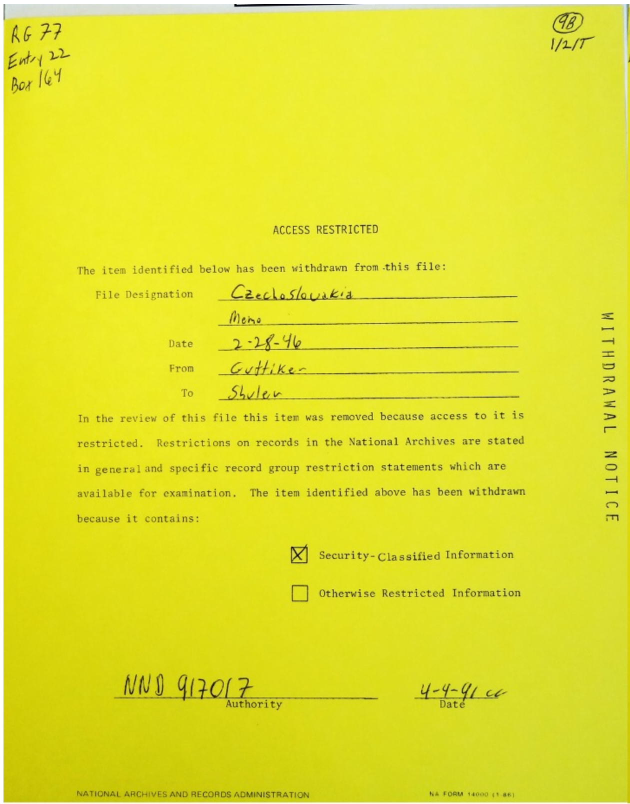
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

Figure D.875: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]



RG 77
Entry 22
Box 164

⑨B
1/2/T

ACCESS RESTRICTED

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File Designation Czechoslovakia
Memo
Date 2-28-46
From Guttiker
To Shuler

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4-4-91 cc Date

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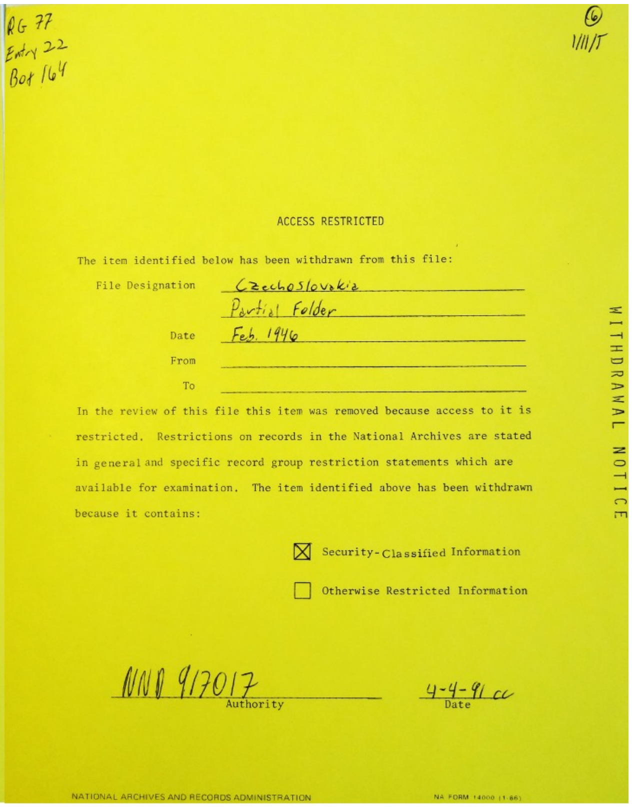
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)



RG 77
Entry 22
Box 164

⑥
1/11/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Czechoslovakia
Partial Folder
Date Feb. 1946
From
To

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

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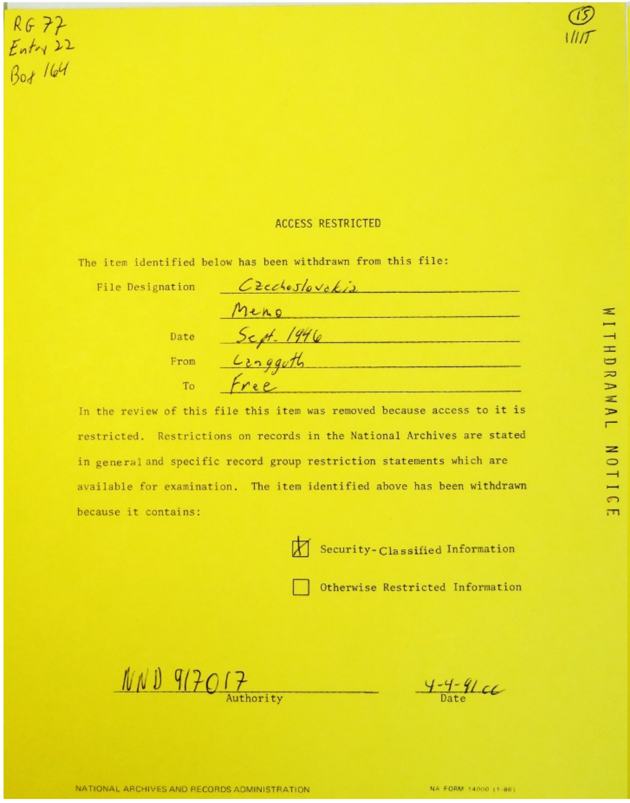
NND 917017 Authority
4-4-91 cc Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 164



RG 77
Entry 22
Box 164

⑮
1/11/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Czechoslovakia
Memo
Date Sept. 1946
From Langguth
To Free

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

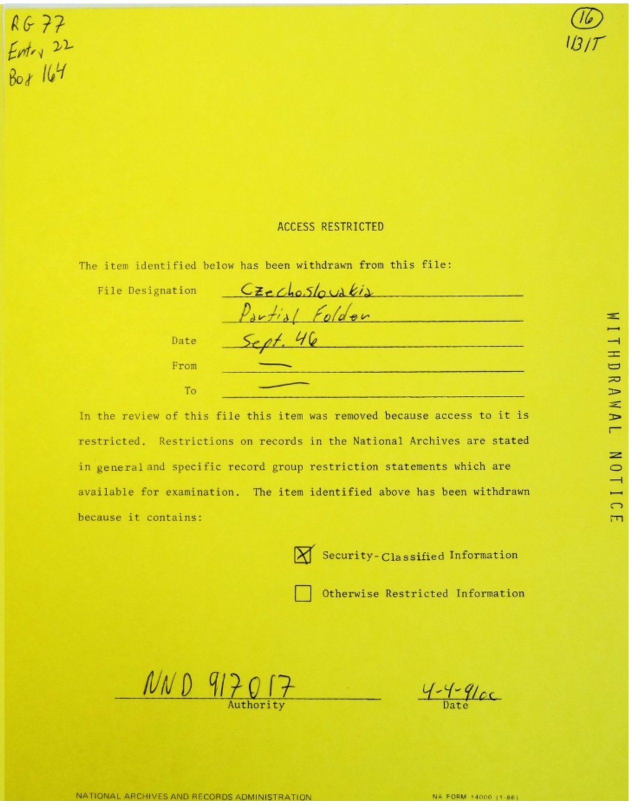
☒ Security-Classified Information

☐ Otherwise Restricted Information

NND 917017 Authority
4-4-91 cc Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)



RG 77
Entry 22
Box 164

⑯
1/13/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Czechoslovakia
Partial Folder
Date Sept. 46
From —
To —

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

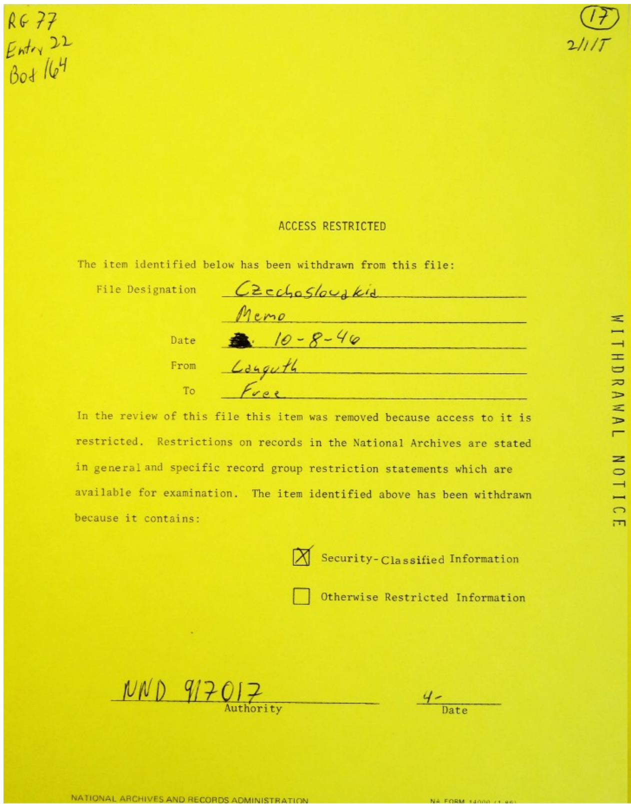
☐ Otherwise Restricted Information

NND 917017 Authority
4-4-91 cc Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

Figure D.876: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]



RG 77
Entry 22
Box 164

⑰
2/1/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Czechoslovakia
Memo
Date 10-8-46
From Languth
To Free

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

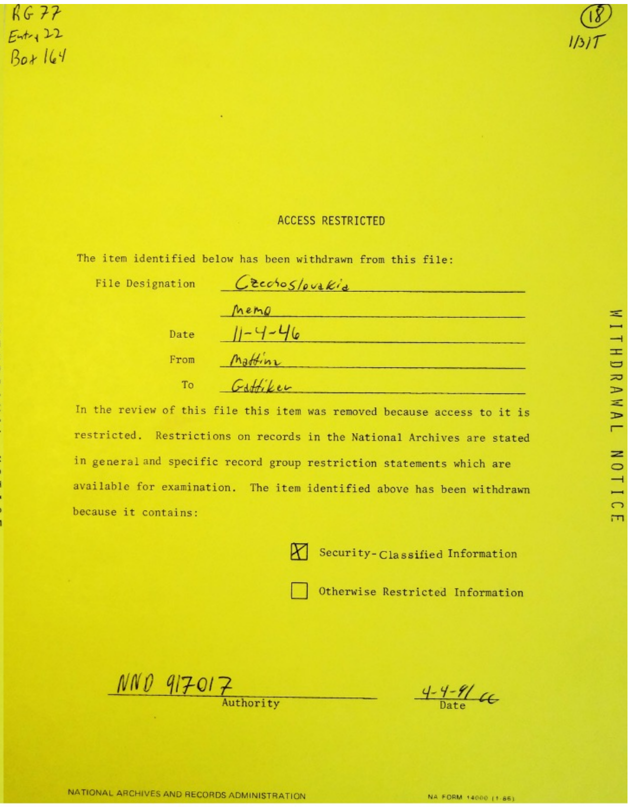
☐ Otherwise Restricted Information

NND 917017
Authority

4-
Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-85)



RG 77
Entry 22
Box 164

⑱
1/3/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Czechoslovakia
Memo
Date 11-4-46
From Mattina
To Gattiker

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

NND 917017
Authority

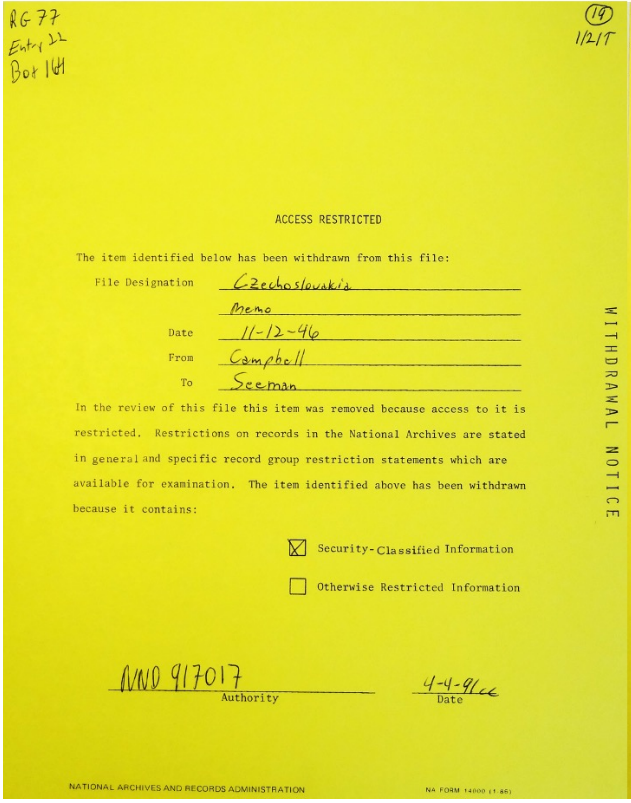
4-4-91 cc
Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-85)

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 164



RG 77
Entry 22
Box 164

⑲
1/2/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Czechoslovakia
Memo
Date 11-12-46
From Campbell
To Seeman

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

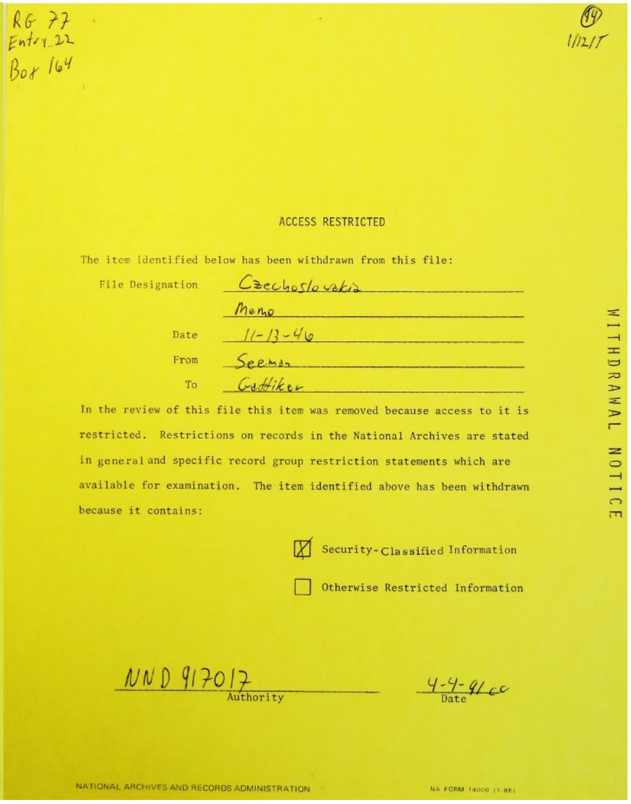
☐ Otherwise Restricted Information

NND 917017
Authority

4-4-91 cc
Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-85)



RG 77
Entry 22
Box 164

(94)
1/12/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Czechoslovakia
Memo
Date 11-13-46
From Seeman
To Gattiker

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

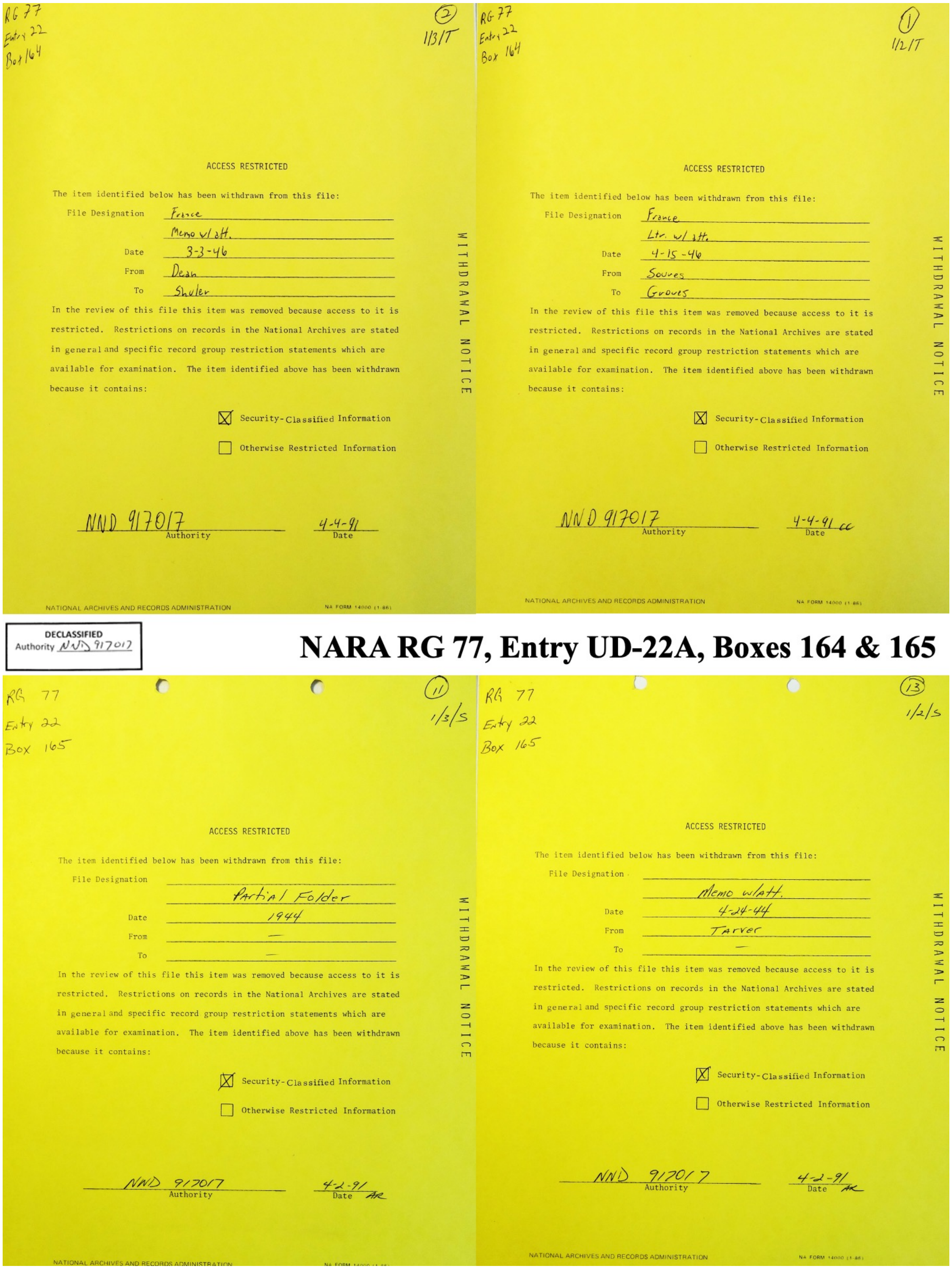
NND 917017
Authority

4-4-91 cc
Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-85)

Figure D.877: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]



RG 77
Entry 22
Box 164

②
1/3/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation France
Memo w/ att.
Date 3-3-46
From Dean
To Shuler

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

NND 917017 Authority
4-4-91 Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION
NA FORM 14000 (1-86)

RG 77
Entry 22
Box 164

①
1/2/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation France
Ltr. w/ att.
Date 4-15-46
From Souves
To Groves

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

NND 917017 Authority
4-4-91 cc Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION
NA FORM 14000 (1-86)

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Boxes 164 & 165

RG 77
Entry 22
Box 165

⑪
1/3/S

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation
Partial Folder
Date 1944
From —
To —

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

NND 917017 Authority
4-2-91 Date AR

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION
NA FORM 14000 (1-86)

RG 77
Entry 22
Box 165

⑬
1/2/S

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation
Memo w/att.
Date 4-24-44
From Tarver
To —

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

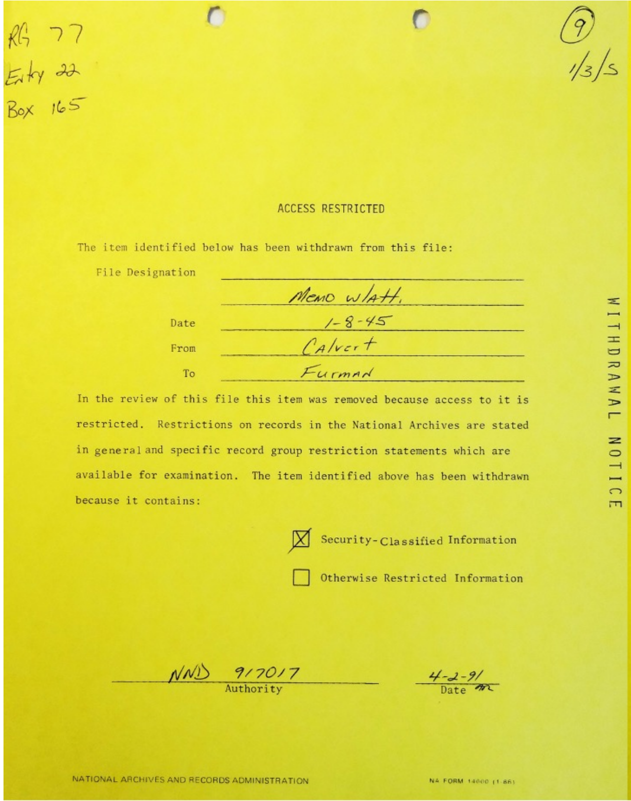
☐ Otherwise Restricted Information

NND 917017 Authority
4-2-91 Date AR

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION
NA FORM 14000 (1-86)

Figure D.878: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]


RG 77
Entry 22
Box 165

⑨
1/3/S

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation
Memo w/att.
Date 1-8-45
From Calvert
To Furman

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

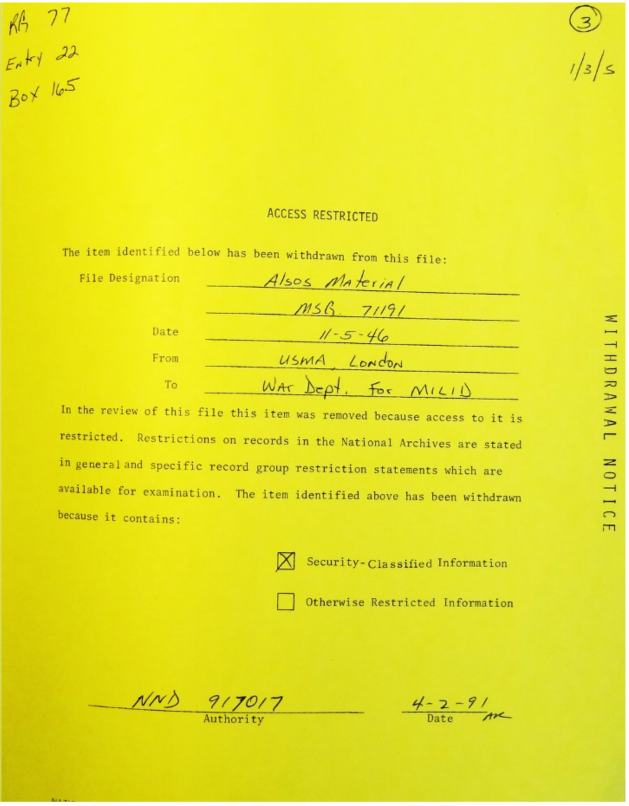
☐ Otherwise Restricted Information

NND 917017
Authority

4-2-91
Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)


RG 77
Entry 22
Box 165

③
1/3/S

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Alsos Material
MSG. 71191
Date 11-5-46
From USMA, London
To War Dept. for MILID

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

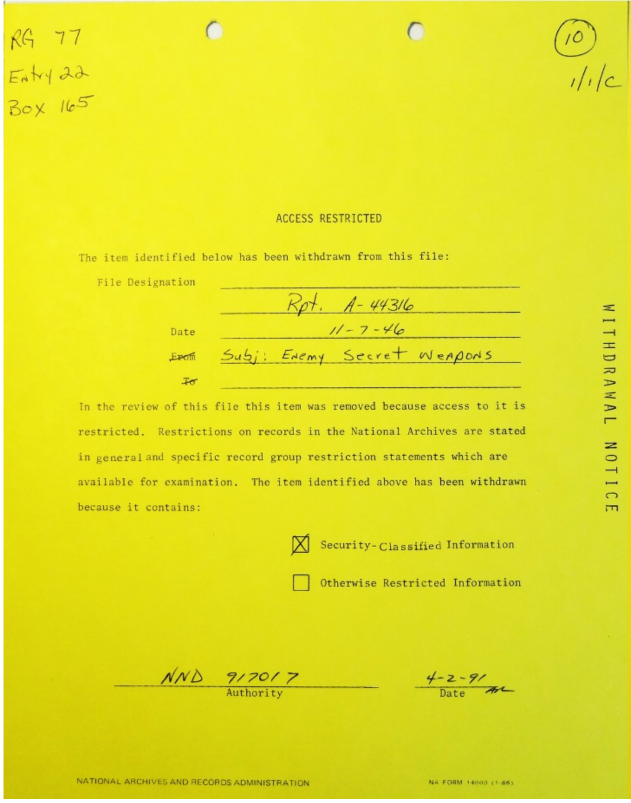
NND 917017
Authority

4-2-91
Date

WITHDRAWAL NOTICE

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 165


RG 77
Entry 22
Box 165

⑩
1/1/C

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation
Rpt. A-44316
Date 11-7-46
~~From~~ Subj: Enemy Secret Weapons
~~To~~

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

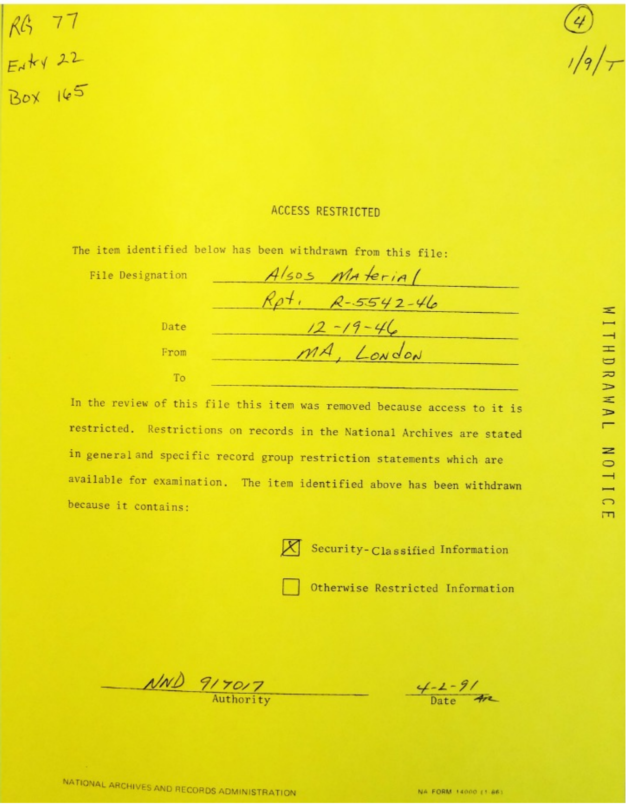
☐ Otherwise Restricted Information

NND 917017
Authority

4-2-91
Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)


RG 77
Entry 22
Box 165

④
1/9/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation Alsos Material
Rpt. R-5542-46
Date 12-19-46
From MA, London
To

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

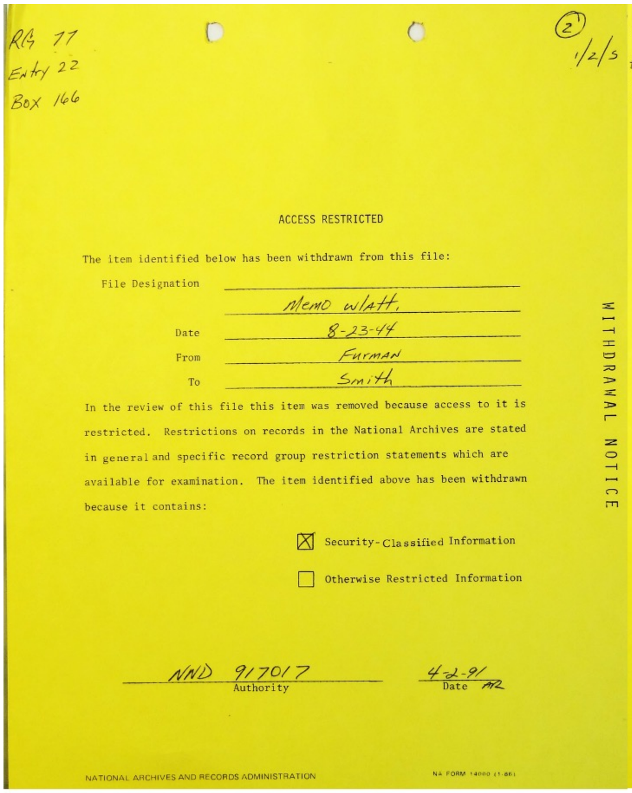
NND 917017
Authority

4-2-91
Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

Figure D.879: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]



RG 77
Entry 22
Box 166

②
1/2/S

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation ____
Memo w/att.
Date 8-23-44
From Furman
To Smith

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

NND 917017
Authority

4-2-91
Date AR

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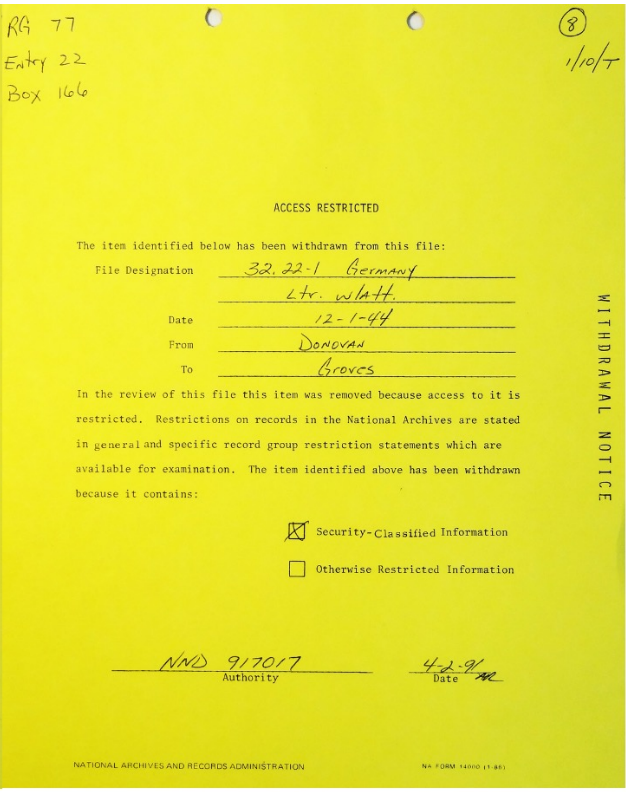
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)



RG 77
Entry 22
Box 166

⑧
1/10/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 32.22-1 Germany
Ltr. w/att.
Date 12-1-44
From Donovan
To Groves

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

NND 917017
Authority

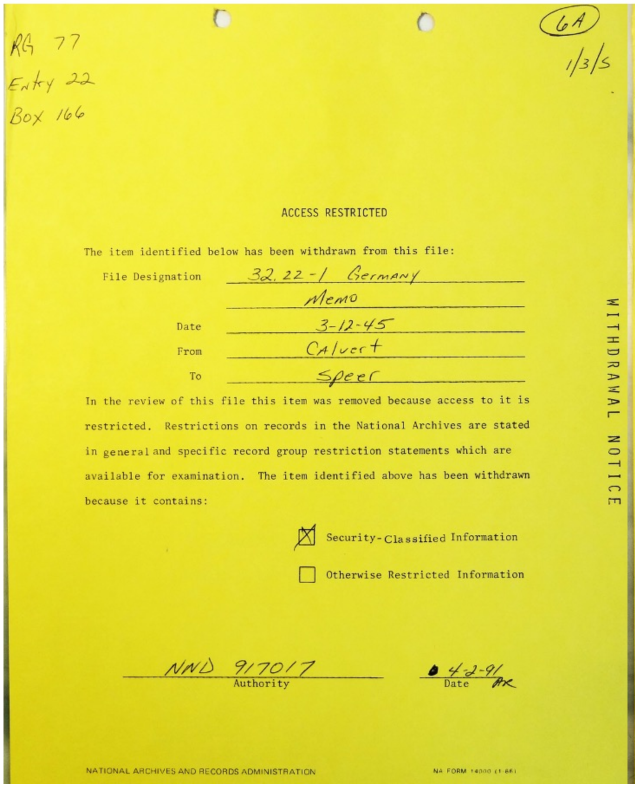
4-2-91
Date AR

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 166



RG 77
Entry 22
Box 166

6A
1/3/S

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 32.22-1 Germany
Memo
Date 3-12-45
From Calvert
To Speer

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

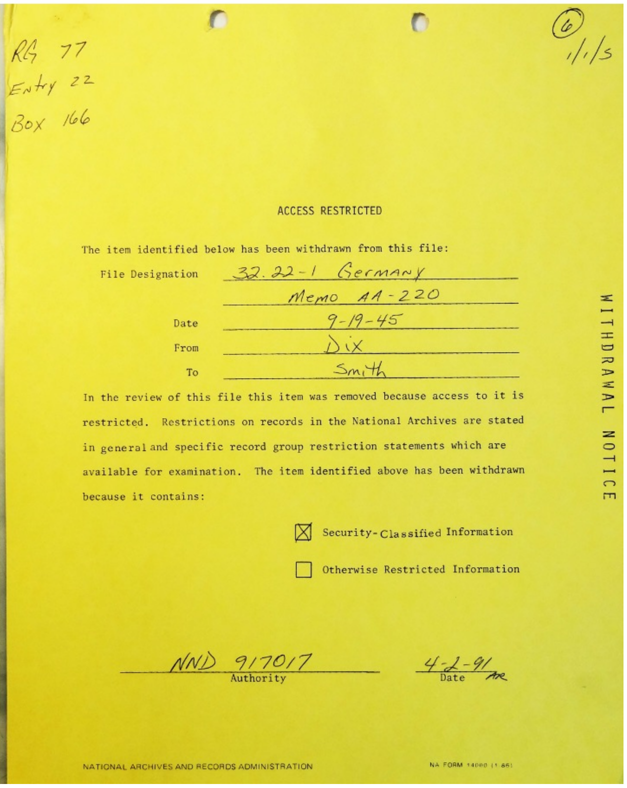
☐ Otherwise Restricted Information

NND 917017
Authority

4-2-91
Date AR

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)



RG 77
Entry 22
Box 166

⑥
1/1/S

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 32.22-1 Germany
Memo AA-220
Date 9-19-45
From Dix
To Smith

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

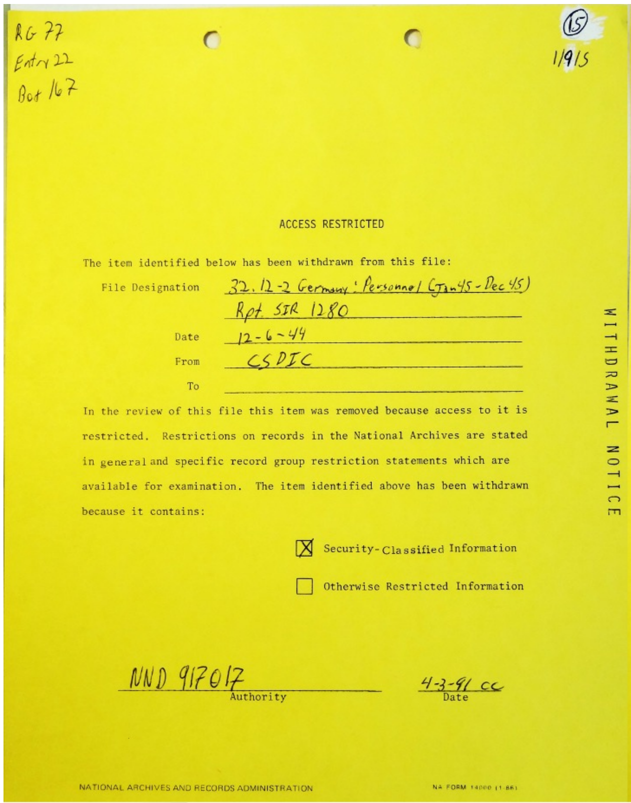
NND 917017
Authority

4-2-91
Date AR

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

Figure D.880: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]



RG 77
Entry 22
Box 167

⑮
1/9/5

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 32.12-2 Germany: Personnel (Jan 45 - Dec 45)
Rpt. SIR 1280
Date 12-6-44
From CSDIC
To

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

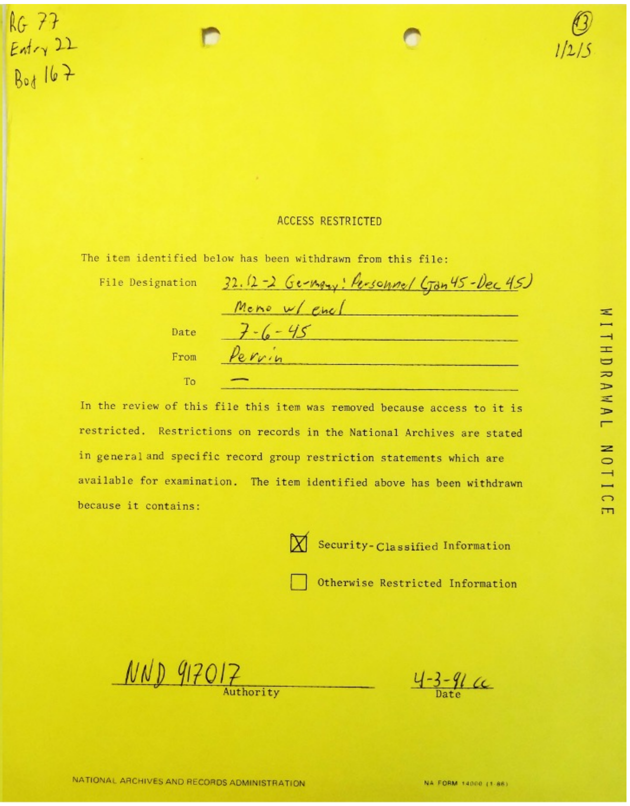
☐ Otherwise Restricted Information

NND 917017
Authority

4-3-91 cc
Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)



RG 77
Entry 22
Box 167

⑬
1/2/5

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 32.12-2 Germany: Personnel (Jan 45 - Dec 45)
Memo w/ encl
Date 7-6-45
From Perrin
To —

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

NND 917017
Authority

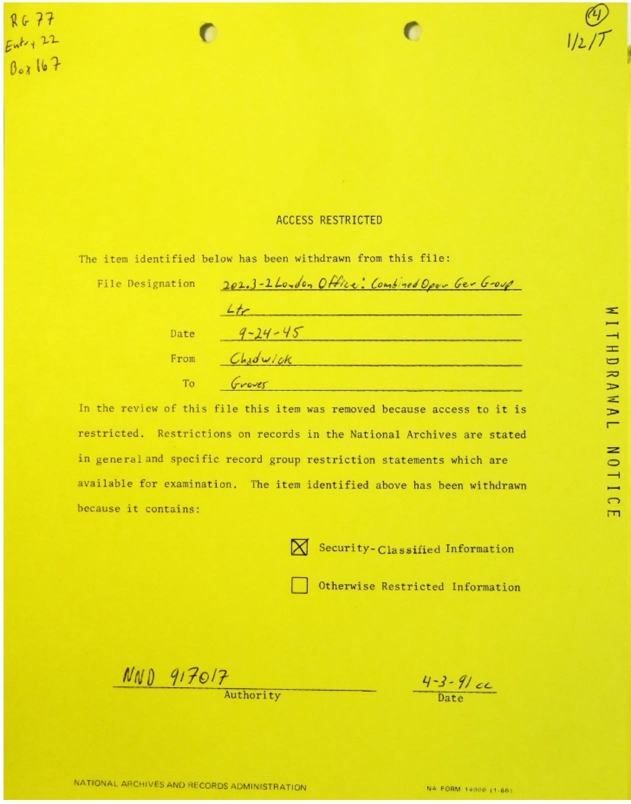
4-3-91 cc
Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 167



RG 77
Entry 22
Box 167

④
1/2/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 202.3-2 London Office: Combined Oper Ger Group
Ltr
Date 9-24-45
From Chadwick
To Groves

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

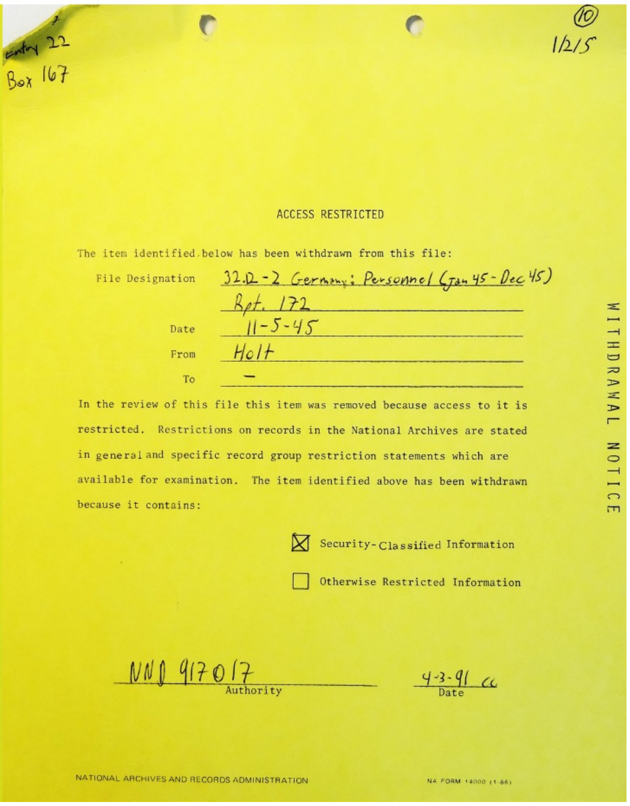
☐ Otherwise Restricted Information

NND 917017
Authority

4-3-91 cc
Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)



Entry 22
Box 167

⑩
1/2/5

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 32.12-2 Germany: Personnel (Jan 45 - Dec 45)
Rpt. 172
Date 11-5-45
From Holt
To —

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

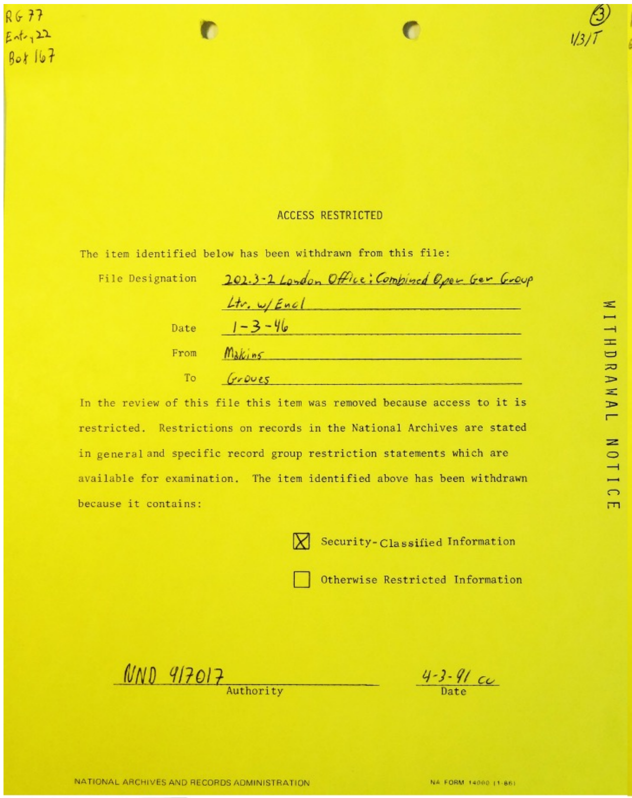
NND 917017
Authority

4-3-91 cc
Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

Figure D.881: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]



RG 77
Entry 22
Box 167

③
1/3/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 202.3-2 London Office: Combined Oper Ger Group
Ltr. w/ Encl
Date 1-3-46
From Makins
To Groves

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

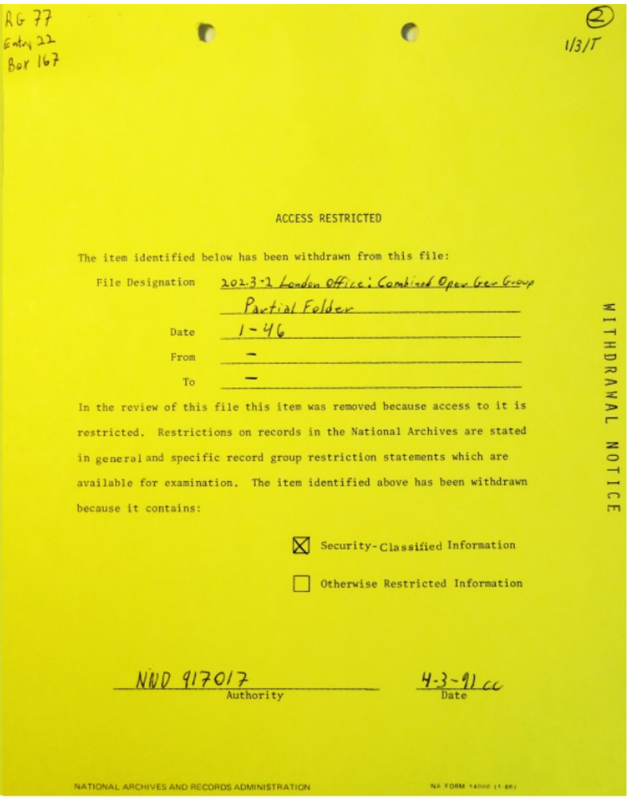
☐ Otherwise Restricted Information

NND 917017 — Authority

4-3-91 cc — Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)



RG 77
Entry 22
Box 167

②
1/3/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 202.3-2 London Office: Combined Oper Ger Group
Partial Folder
Date 1-46
From –
To –

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

NND 917017 — Authority

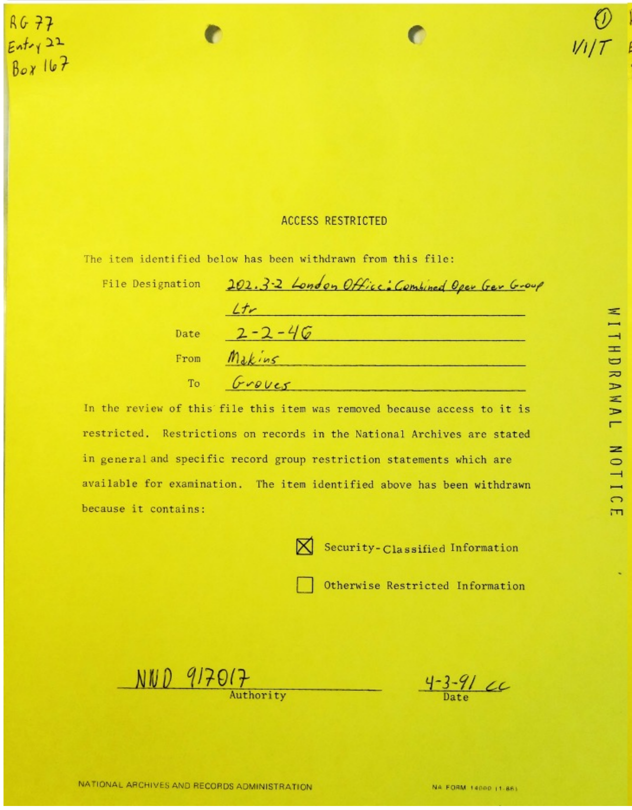
4-3-91 cc — Date

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 167



RG 77
Entry 22
Box 167

①
1/1/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 202.3-2 London Office: Combined Oper Ger Group
Ltr
Date 2-2-46
From Makins
To Groves

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NND 917017 — Authority

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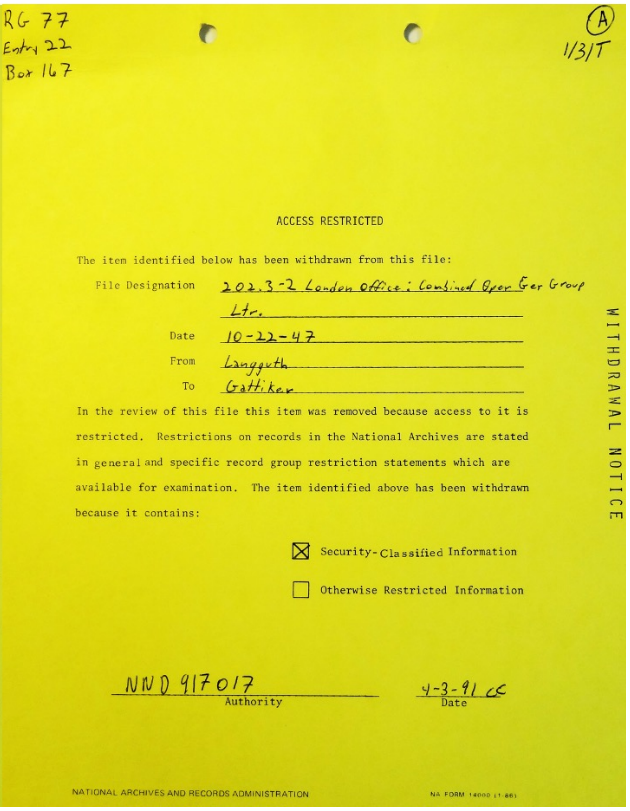

RG 77
Entry 22
Box 167

Ⓐ
1/3/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 202.3-2 London Office: Combined Oper Ger Group
Ltr.
Date 10-22-47
From Langguth
To Gattiker

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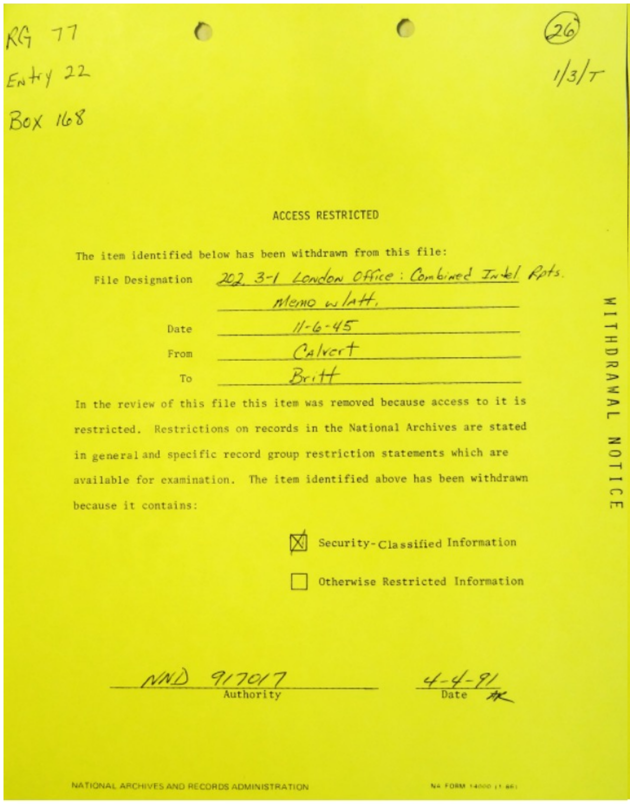
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

Figure D.882: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]


RG 77
Entry 22
Box 168

(26)
1/3/T

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File Designation 202.3-1 London Office : Combined Intel Rpts.
Memo w/att.
Date 11-6-45
From Calvert
To Britt

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Authority

4-4-91 AR
Date

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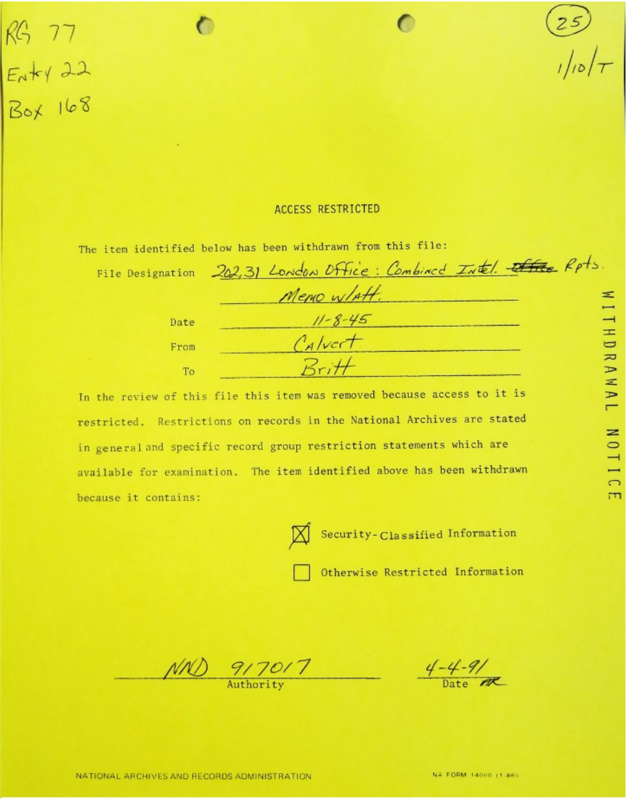
RG 77
Entry 22
Box 168

(25)
1/10/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 202.31 London Office : Combined Intel. ~~Office~~ Rpts.
Memo w/att.
Date 11-8-45
From Calvert
To Britt

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Authority

4-4-91 AR
Date

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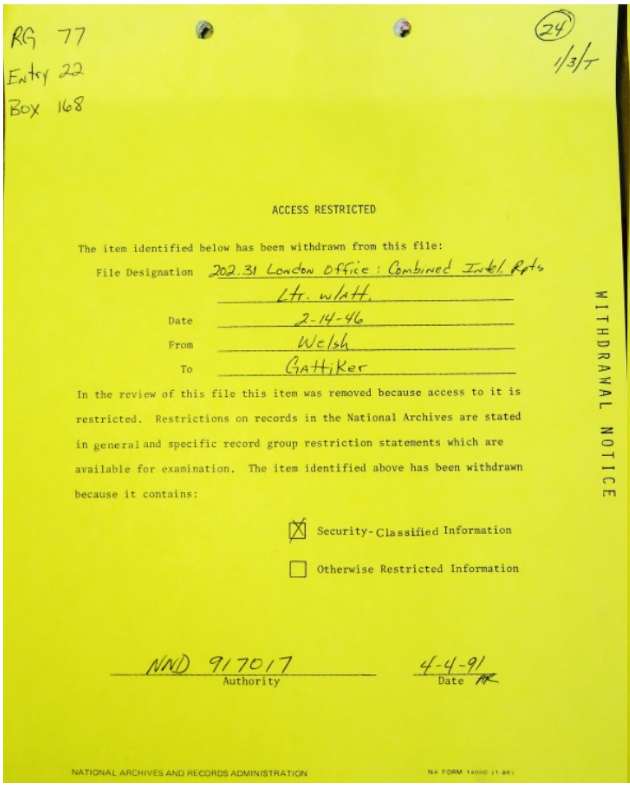
DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 168


RG 77
Entry 22
Box 168

(24)
1/3/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 202.31 London Office : Combined Intel Rpts
Ltr. w/att.
Date 2-14-46
From Welsh
To Gattiker

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Authority

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Date

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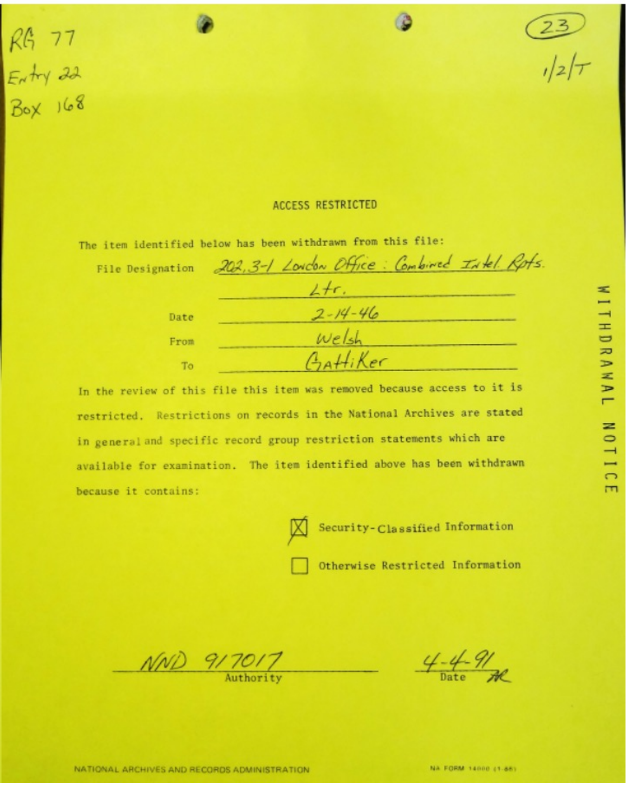
RG 77
Entry 22
Box 168

(23)
1/2/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 202.3-1 London Office : Combined Intel Rpts.
Ltr.
Date 2-14-46
From Welsh
To Gattiker

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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Authority

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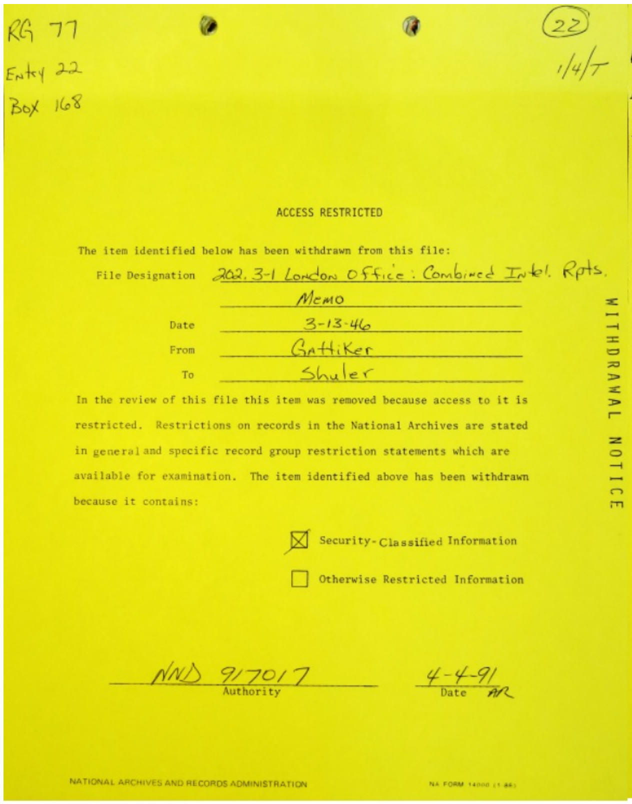
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

Figure D.883: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]



RG 77
Entry 22
Box 168

(22)
1/4/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 202.3-1 London Office: Combined Intel. Rpts.
Memo
Date 3-13-46
From Gattiker
To Shuler

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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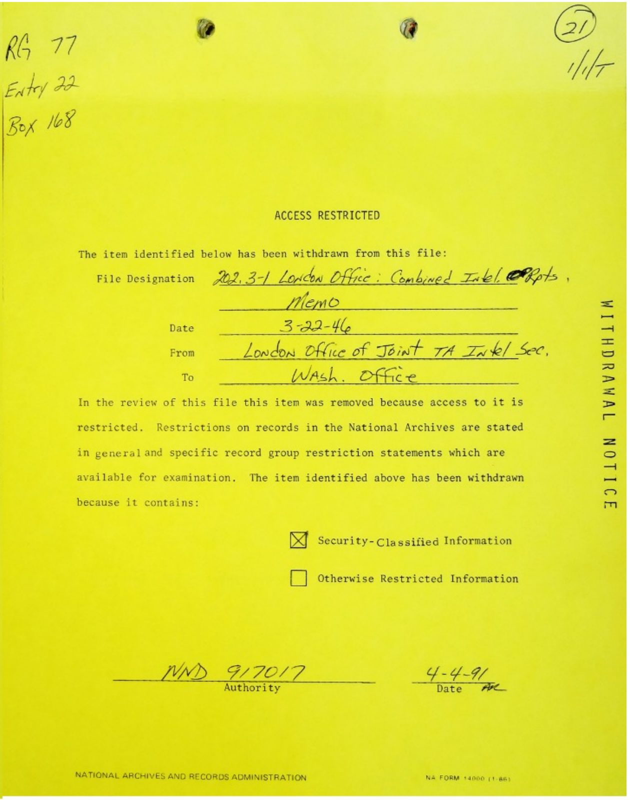

RG 77
Entry 22
Box 168

(21)
1/1/T

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The item identified below has been withdrawn from this file:

File Designation 202.3-1 London Office: Combined Intel. Rpts.
Memo
Date 3-22-46
From London Office of Joint TA Intel Sec.
To Wash. Office

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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NND 917017 Authority
4-4-91 Date AR

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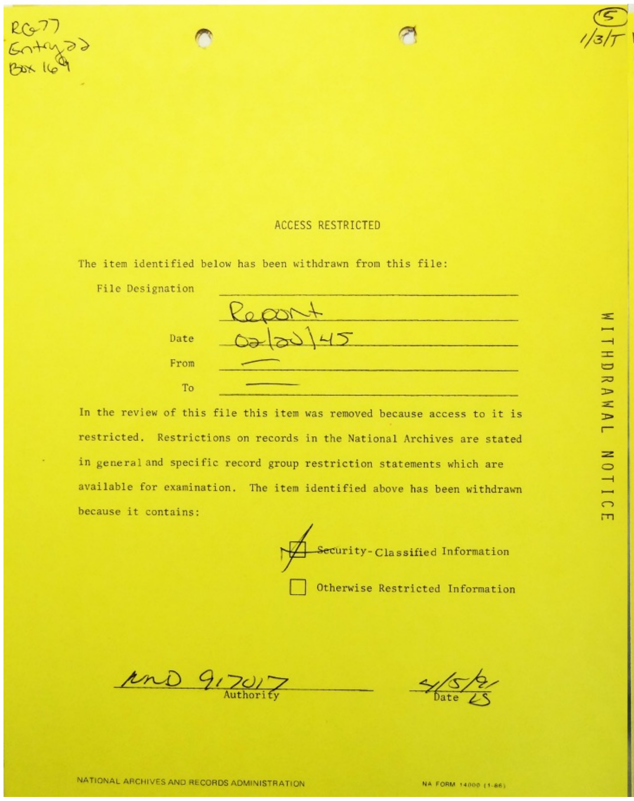
DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Boxes 168 & 169



RG77
Entry 22
Box 169

(5)
1/3/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation
Report
Date 02/20/45
From —
To —

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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☐ Otherwise Restricted Information

NND 917017 Authority
4/5/91 Date LS

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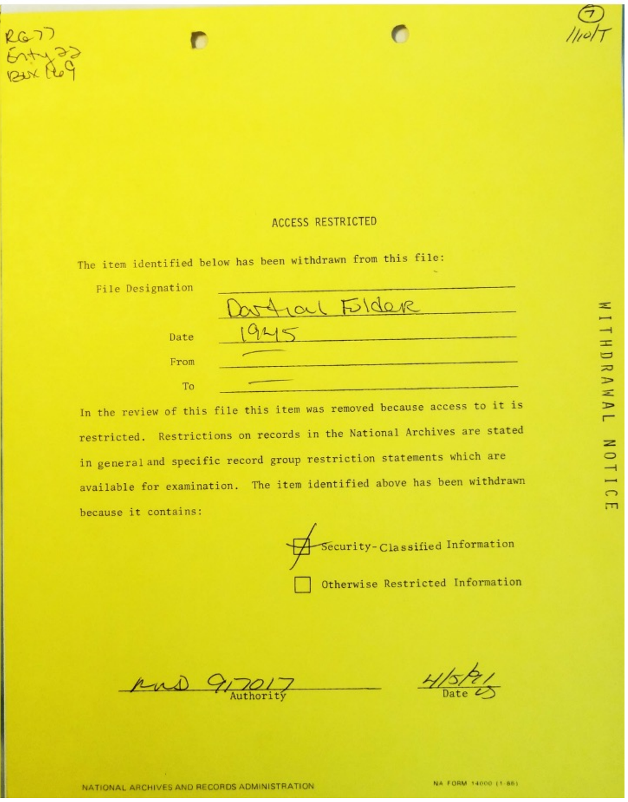
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)



RG77
Entry 22
Box 169

(7)
1/10/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation
Partial Folder
Date 1945
From —
To —

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

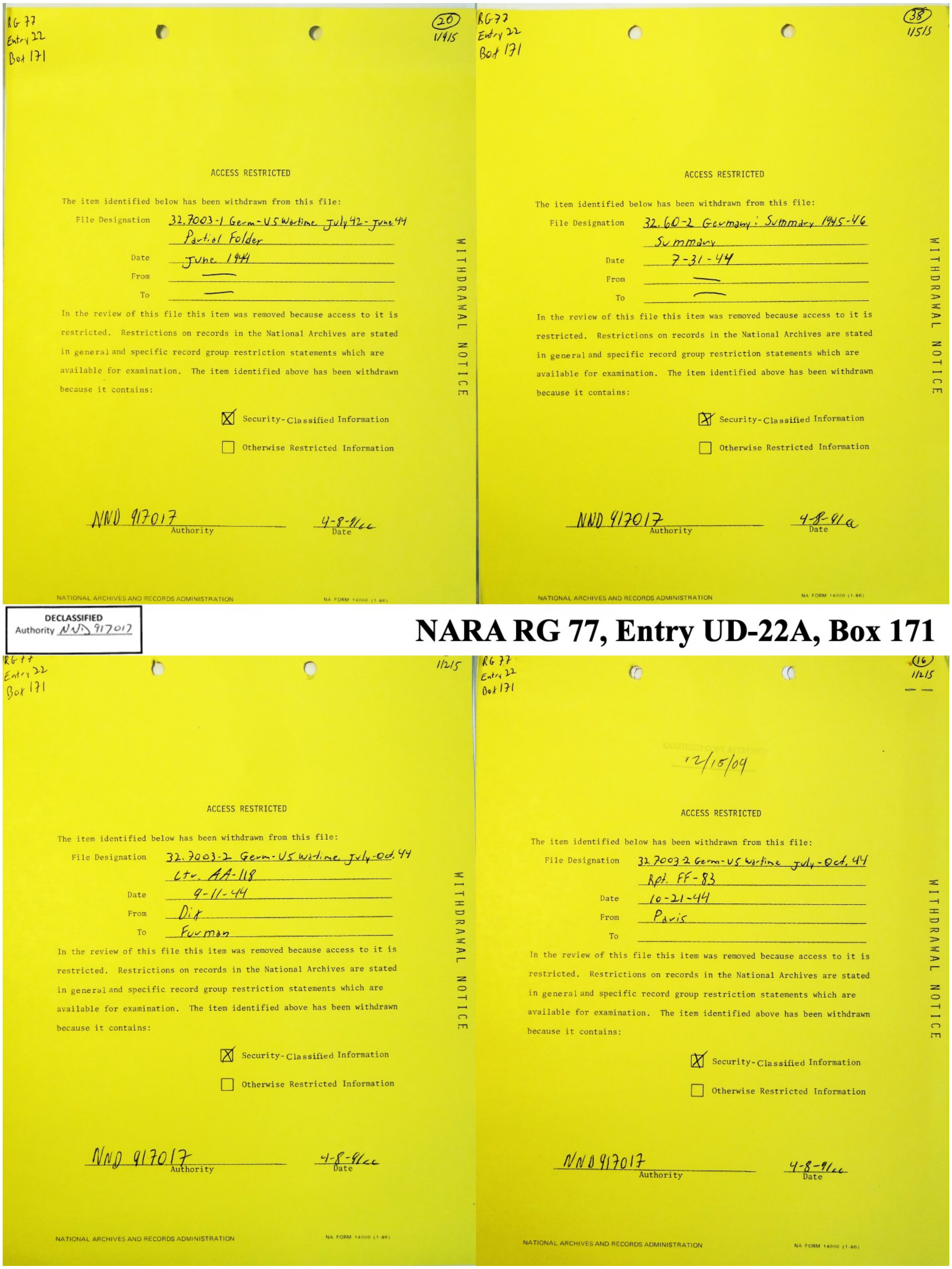
☐ Otherwise Restricted Information

NND 917017 Authority
4/5/91 Date LS

WITHDRAWAL NOTICE

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

Figure D.884: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]



RG 77
Entry 22
Box 171

(20)
1/4/15

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 32.7003-1 Germ-US Wartime July 42 - June 44
Partial Folder
Date June 1944
From —
To —

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Authority

4-8-91
Date

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RG 77
Entry 22
Box 171

(38)
1/5/15

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 32.60-2 Germany: Summary 1945-46
Summary
Date 7-31-44
From —
To —

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Authority

4-8-91
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Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171

RG 77
Entry 22
Box 171

1/2/15

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 32.7003-2 Germ-US Wartime July-Oct. 44
Ltr. AA-118
Date 9-11-44
From Dix
To Furman

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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☐ Otherwise Restricted Information

NND 917017
Authority

4-8-91
Date

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RG 77
Entry 22
Box 171

(16)
1/2/15

SANITIZED COPY ATTACHED
12/15/09

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 32.7003-2 Germ-US Wartime July-Oct. 44
Rpt. FF-83
Date 10-21-44
From Paris
To

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NND 917017
Authority

4-8-91
Date

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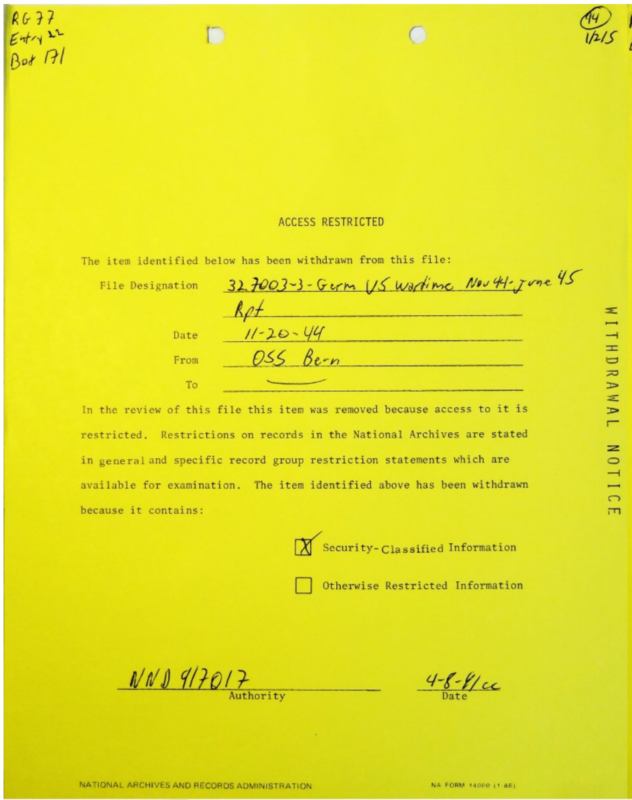
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

Figure D.885: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]



RG 77
Entry 22
Box 171

(44)
1/2/5

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 32.7003-3-Germ US wartime Nov 41-June 45 Rpt
Date 11-20-44
From OSS Bern
To —

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4-8-91cc Date

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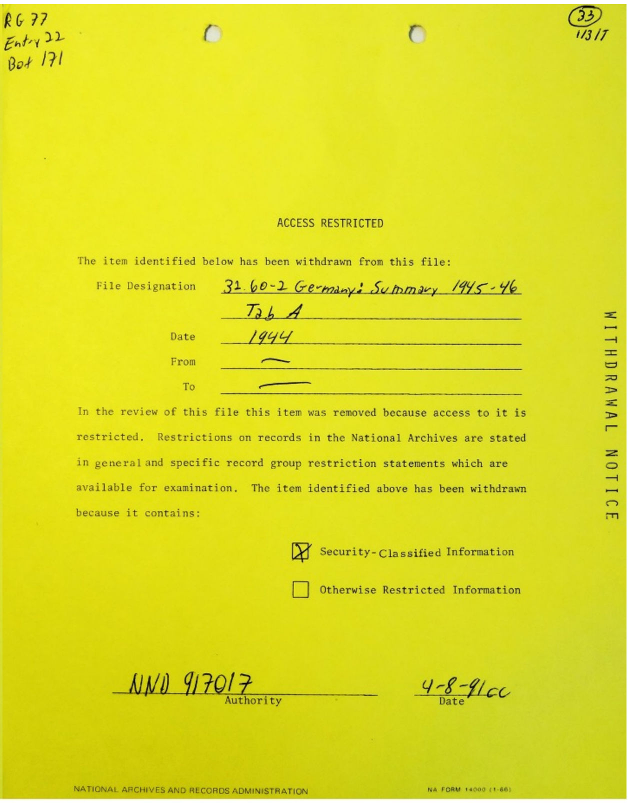

RG 77
Entry 22
Box 171

(33)
1/3/7

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 32.60-2 Germany: Summary 1945-46 Tab A
Date 1944
From —
To —

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☐ Otherwise Restricted Information

NND 917017 Authority
4-8-91cc Date

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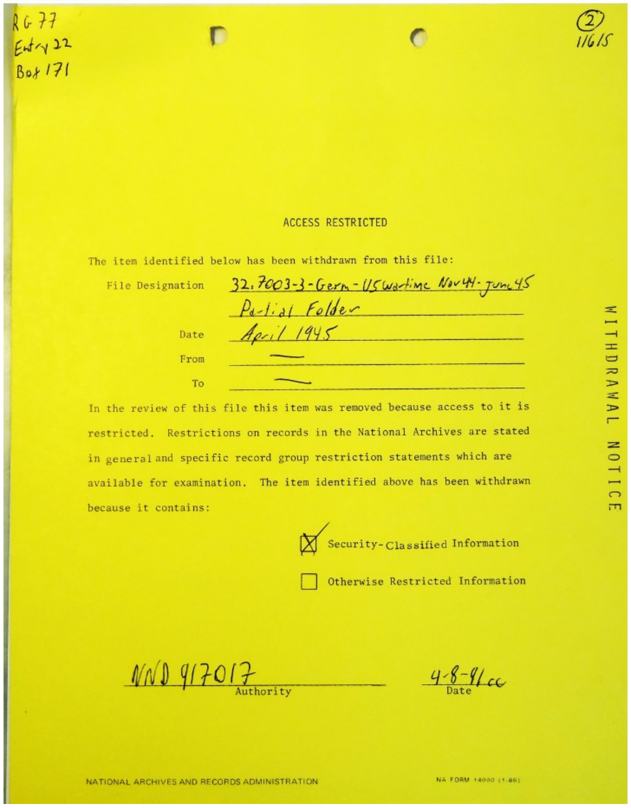
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171



RG 77
Entry 22
Box 171

(2)
1/6/5

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 32.7003-3-Germ-US wartime Nov 41-June 45 Partial Folder
Date April 1945
From —
To —

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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NND 917017 Authority
4-8-91cc Date

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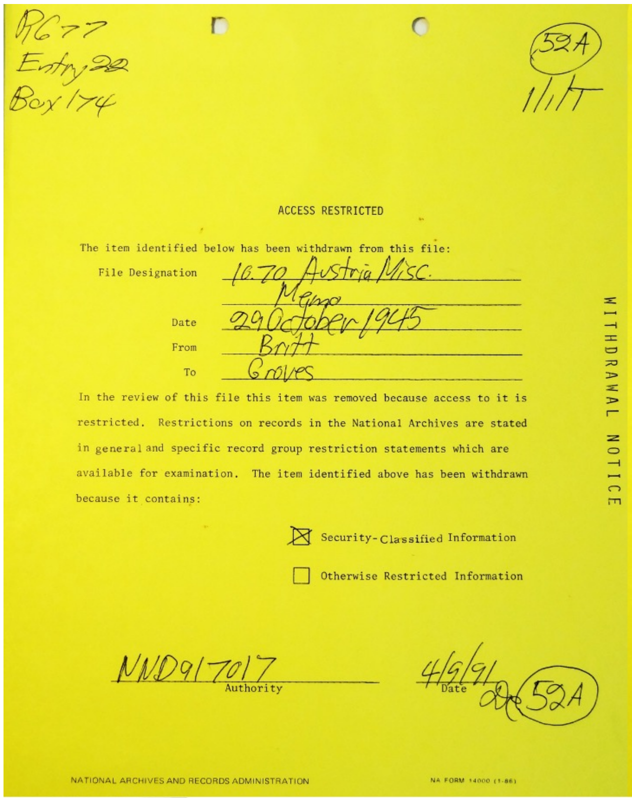
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)

Figure D.886: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]


RG77
Entry 22
Box 174

52A
1/1/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 10.70 Austria Misc.
Memo
Date 29 October 1945
From Britt
To Groves

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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Authority

4/9/91 dc
Date

52A

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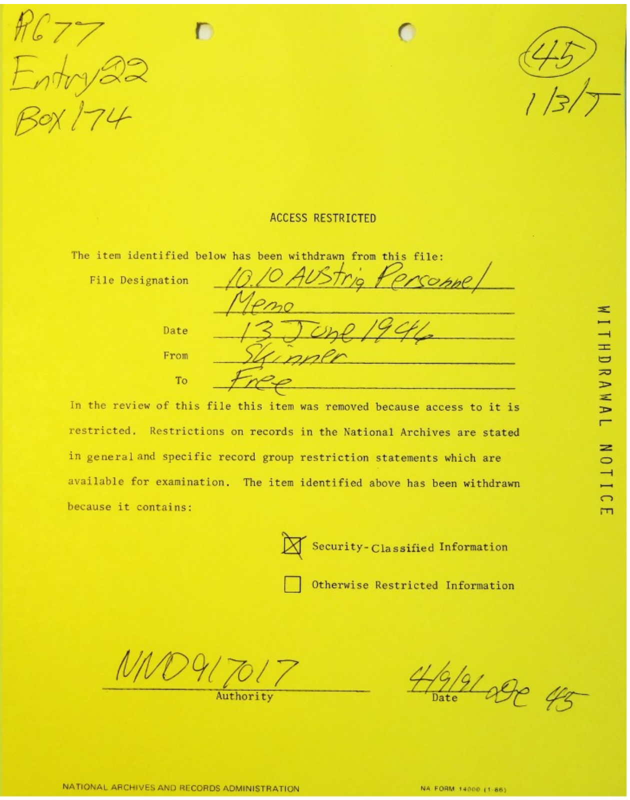
RG77
Entry 22
Box 174

45
1/3/T

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 10.10 Austria Personnel
Memo
Date 13 June 1946
From Skinner
To Free

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Authority

4/9/91 dc 45
Date

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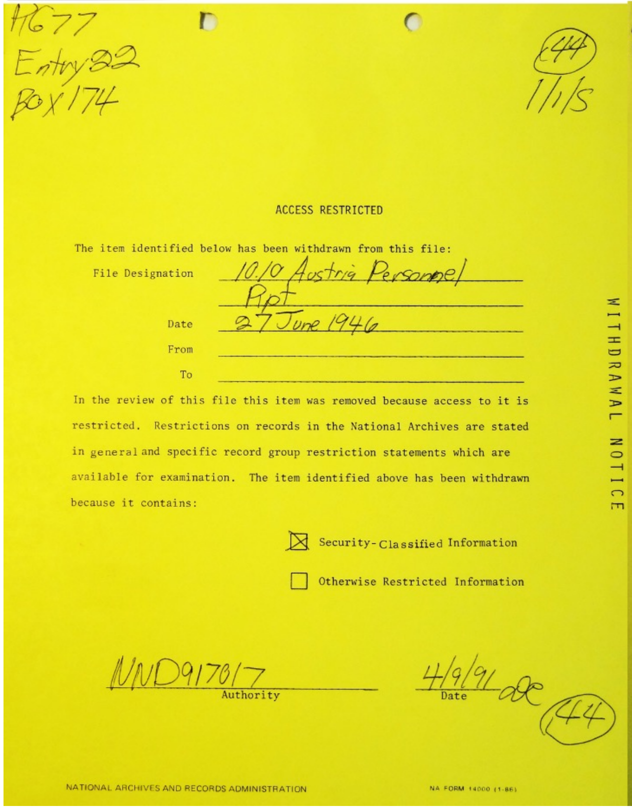
Authority NND 917017

NARA RG 77, Entry UD-22A, Boxes 174 & 175


RG77
Entry 22
Box 174

44
1/1/S

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation 10.10 Austria Personnel
Rpt.
Date 27 June 1946
From
To

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

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☐ Otherwise Restricted Information

NND917017
Authority

4/9/91 dc
Date

44

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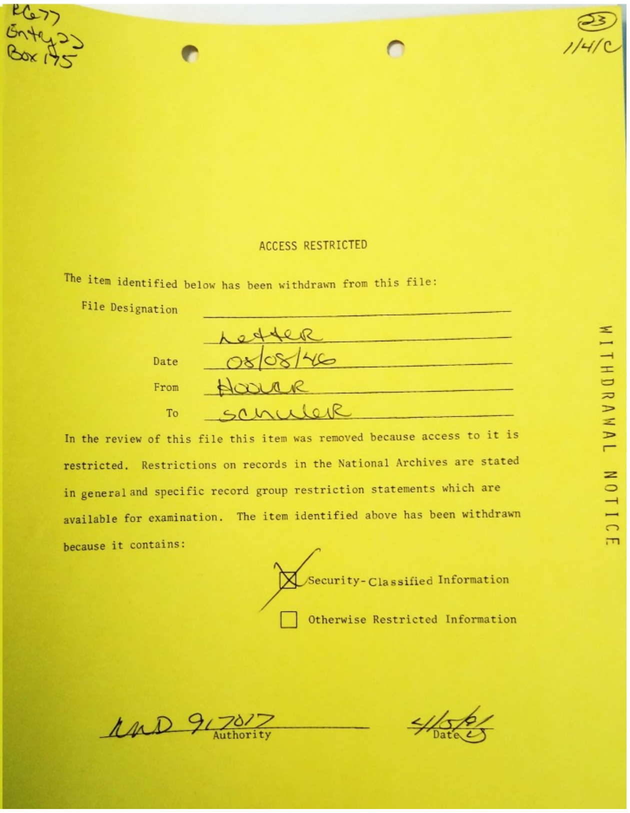
NATIONAL ARCHIVES AND RECORDS ADMINISTRATION NA FORM 14000 (1-86)


RG77
Entry 22
Box 175

23
1/4/C

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation
Letter
Date 08/08/46
From Hoover
To Schuler

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

NND 917017
Authority

4/5/91
Date

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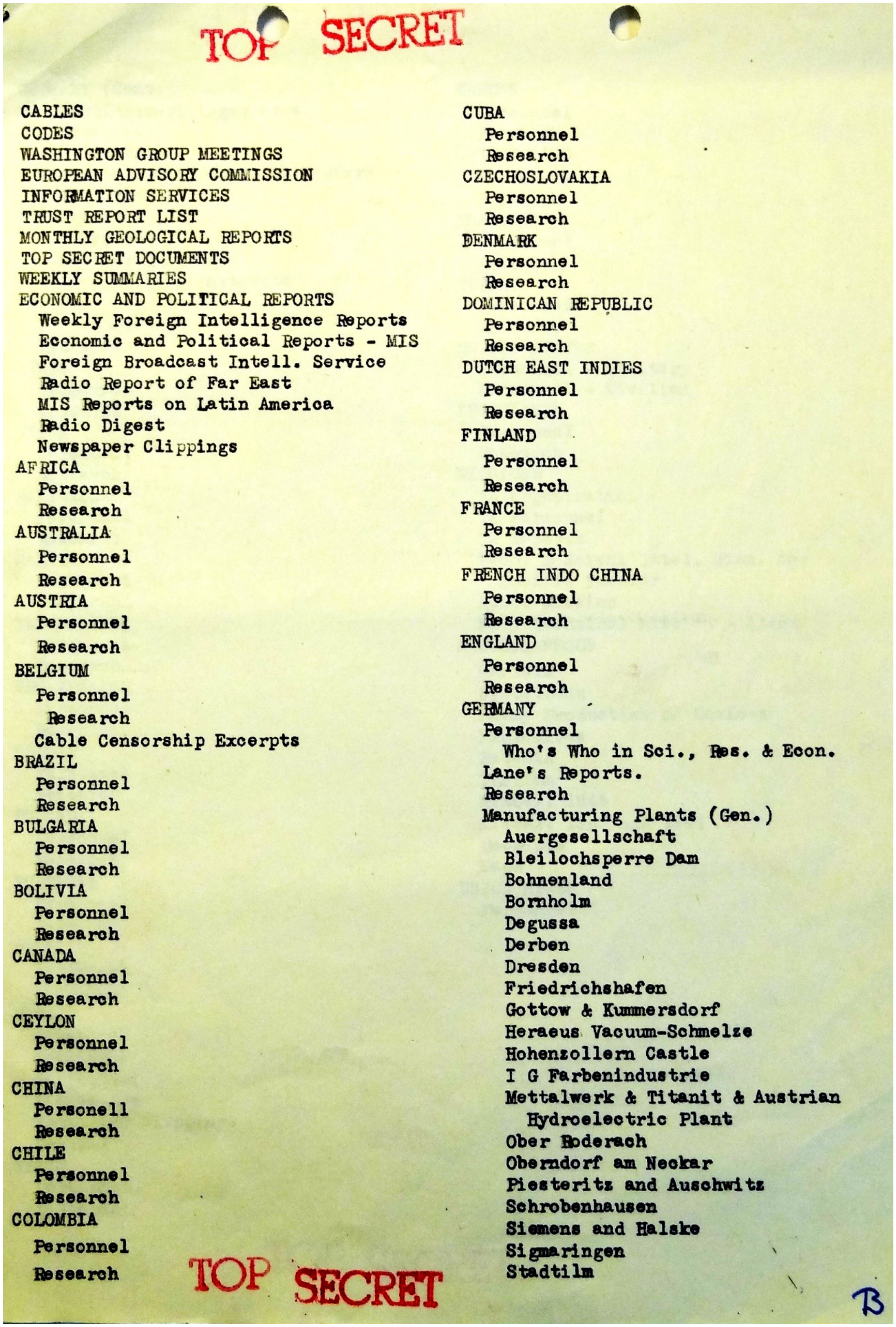
Figure D.887: Why do so many documents from the files of Leslie Groves related to the wartime German nuclear program remain classified and unavailable to the public, even after 75+ years? [NARA RG 77, Entry UD-22A]



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- WEEKLY SUMMARIES
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  - Weekly Foreign Intelligence Reports
  - Economic and Political Reports - MIS
  - Foreign Broadcast Intell. Service
  - Radio Report of Far East
  - MIS Reports on Latin America
  - Radio Digest
  - Newspaper Clippings
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  - Personnel
  - Research
- BULGARIA
  - Personnel
  - Research
- BOLIVIA
  - Personnel
  - Research
- CANADA
  - Personnel
  - Research
- CEYLON
  - Personnel
  - Research
- CHINA
  - Personell
  - Research
- CHILE
  - Personnel
  - Research
- COLOMBIA
  - Personnel
  - Research
- CUBA
  - Personnel
  - Research
- CZECHOSLOVAKIA
  - Personnel
  - Research
- DENMARK
  - Personnel
  - Research
- DOMINICAN REPUBLIC
  - Personnel
  - Research
- DUTCH EAST INDIES
  - Personnel
  - Research
- FINLAND
  - Personnel
  - Research
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  - Personnel
  - Research
- ENGLAND
  - Personnel
  - Research
- GERMANY
  - Personnel
    - Who's Who in Sci., Res. & Econ.
  - Lane's Reports.
  - Research
  - Manufacturing Plants (Gen.)
    - Auergesellschaft
    - Bleilochsperre Dam
    - Bohnenland
    - Bornholm
    - Degussa
    - Derben
    - Dresden
    - Friedrichshafen
    - Gottow & Kummersdorf
    - Heraeus Vacuum-Schmelze
    - Hohenzollern Castle
    - I G Farbenindustrie
    - Mettalwerk & Titanit & Austrian Hydroelectric Plant
    - Ober Roderach
    - Oberndorf am Neckar
    - Piesteritz and Auschwitz
    - Schrobenhausen
    - Siemens and Halske
    - Sigmaringen
    - Stadtilm

TOP SECRET

B

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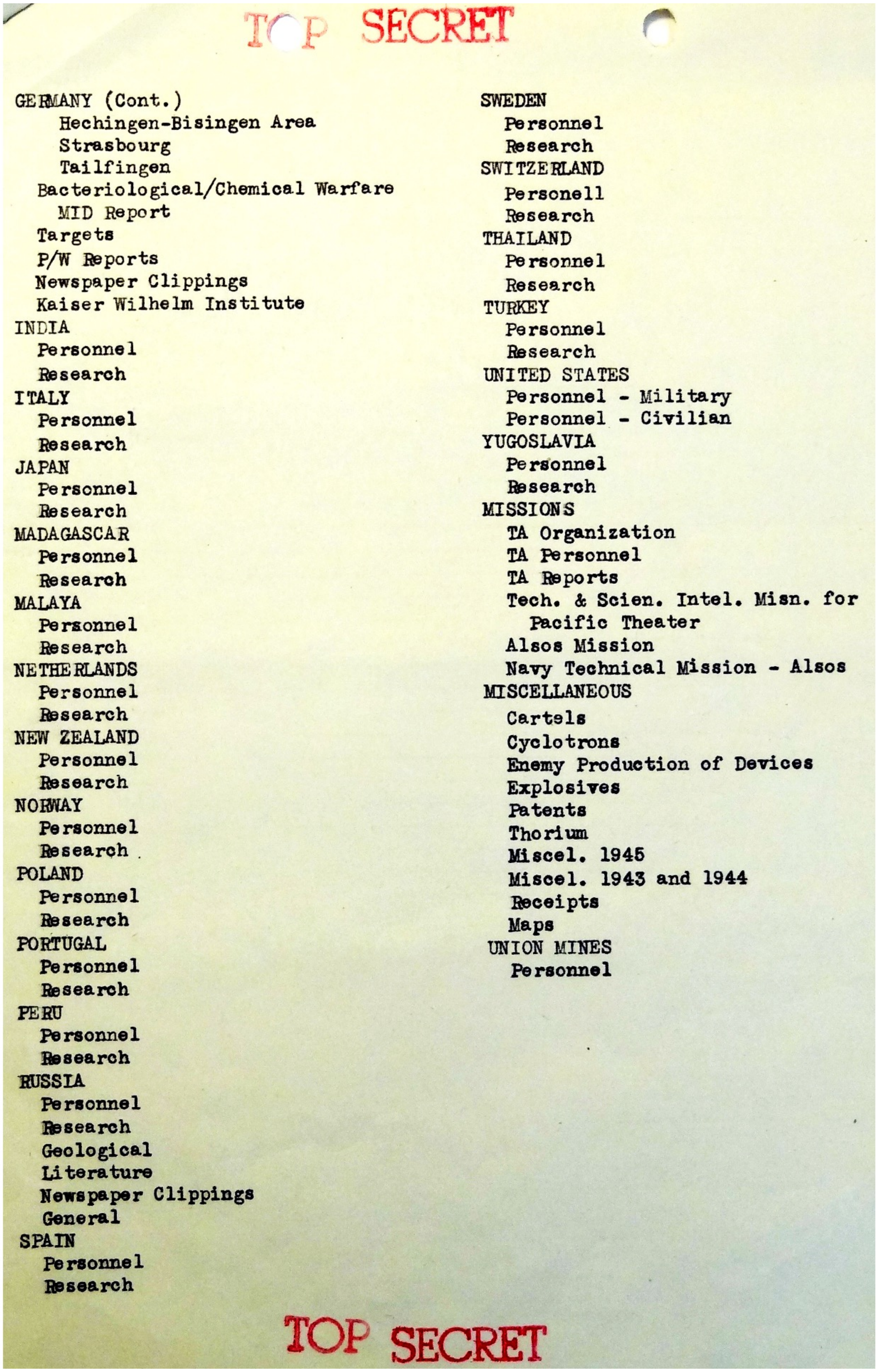
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.

Figure D.888: Where are the rest of the documents that were in the folders with these titles? [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]



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- P/W Reports
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- Kaiser Wilhelm Institute

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- Research

ITALY
- Personnel
- Research

JAPAN
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- Research

MADAGASCAR
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- Research

MALAYA
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- Research

NETHERLANDS
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- Research

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- Research

NORWAY
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- Research

POLAND
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- Research

PORTUGAL
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- Research

PERU
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- Research

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- Research

SWITZERLAND
- Personell
- Research

THAILAND
- Personnel
- Research

TURKEY
- Personnel
- Research

UNITED STATES
- Personnel - Military
- Personnel - Civilian

YUGOSLAVIA
- Personnel
- Research

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- Alsos Mission
- Navy Technical Mission - Alsos

MISCELLANEOUS
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- Cyclotrons
- Enemy Production of Devices
- Explosives
- Patents
- Thorium
- Miscel. 1945
- Miscel. 1943 and 1944
- Receipts
- Maps

UNION MINES
- Personnel

TOP SECRET

NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.

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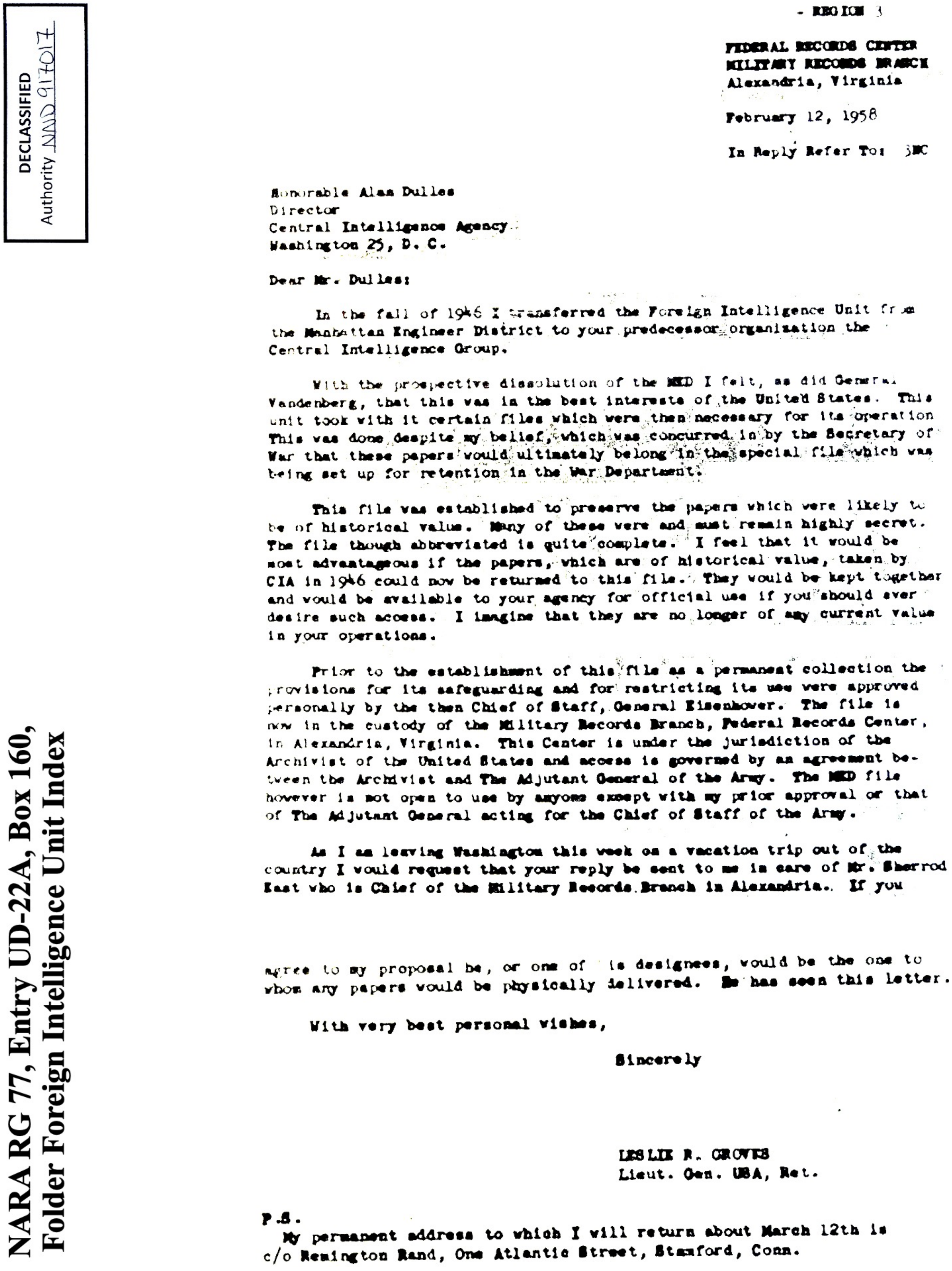
Figure D.889: Where are the rest of the documents that were in the folders with these titles? [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]



DECLASSIFIED
Authority NND 917017

- REGION 3

FEDERAL RECORDS CENTER
MILITARY RECORDS BRANCH
Alexandria, Virginia

February 12, 1958

In Reply Refer To: 3MC

Honorable Alan Dulles
Director
Central Intelligence Agency
Washington 25, D. C.

Dear Mr. Dulles:

In the fall of 1946 I transferred the Foreign Intelligence Unit from the Manhattan Engineer District to your predecessor organization the Central Intelligence Group.

With the prospective dissolution of the MED I felt, as did General Vandenberg, that this was in the best interests of the United States. This unit took with it certain files which were then necessary for its operation This was done despite my belief, which was concurred in by the Secretary of War that these papers would ultimately belong in the special file which was being set up for retention in the War Department.

This file was established to preserve the papers which were likely to be of historical value. Many of these were and must remain highly secret. The file though abbreviated is quite complete. I feel that it would be most advantageous if the papers, which are of historical value, taken by CIA in 1946 could now be returned to this file. They would be kept together and would be available to your agency for official use if you should ever desire such access. I imagine that they are no longer of any current value in your operations.

Prior to the establishment of this file as a permanent collection the provisions for its safeguarding and for restricting its use were approved personally by the then Chief of Staff, General Eisenhower. The file is now in the custody of the Military Records Branch, Federal Records Center, in Alexandria, Virginia. This Center is under the jurisdiction of the Archivist of the United States and access is governed by an agreement between the Archivist and The Adjutant General of the Army. The MED file however is not open to use by anyone except with my prior approval or that of The Adjutant General acting for the Chief of Staff of the Army.

As I am leaving Washington this week on a vacation trip out of the country I would request that your reply be sent to me in care of Mr. Sherrod East who is Chief of the Military Records Branch in Alexandria. If you agree to my proposal he, or one of his designees, would be the one to whom any papers would be physically delivered. He has seen this letter.

With very best personal wishes,

Sincerely

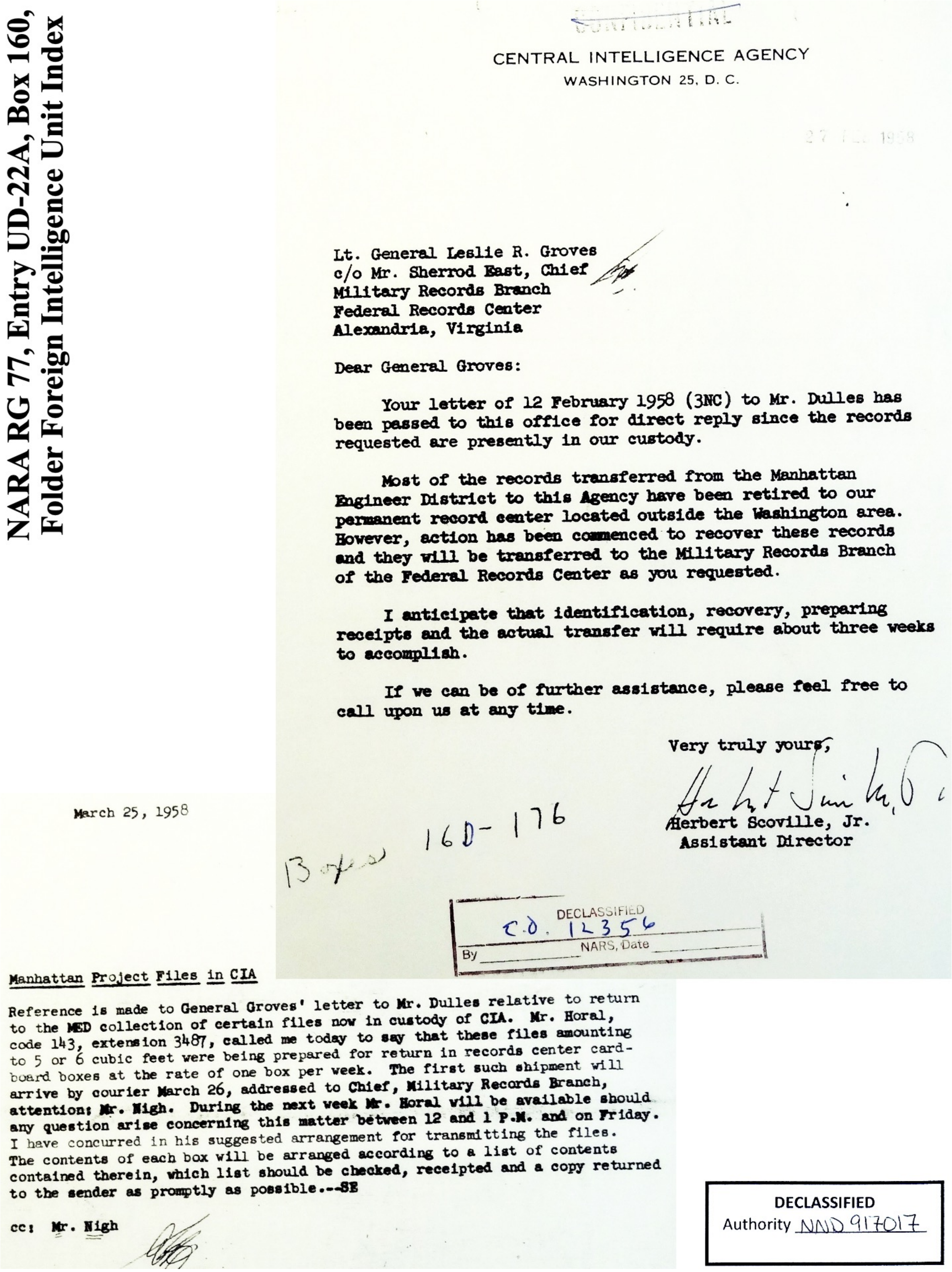
LESLIE R. GROVES
Lieut. Gen. USA, Ret.

P.S.
My permanent address to which I will return about March 12th is c/o Remington Rand, One Atlantic Street, Stamford, Conn.

NARA RG 77, Entry UD-22A, Box 160,
Folder Foreign Intelligence Unit Index

Figure D.890: To what degree were the wartime and early postwar files of the Foreign Intelligence Unit sanitized before they were ultimately transferred to NARA? [NARA RG 77, Entry UD-22A, Box 160, Folder Foreign Intelligence Unit Index]

NARA RG 77, Entry UD-22A, Box 160, Folder Foreign Intelligence Unit Index



~~CONFIDENTIAL~~

CENTRAL INTELLIGENCE AGENCY
WASHINGTON 25, D. C.

27 FEB 1958

Lt. General Leslie R. Groves
c/o Mr. Sherrod East, Chief
Military Records Branch
Federal Records Center
Alexandria, Virginia

Dear General Groves:

Your letter of 12 February 1958 (3NC) to Mr. Dulles has been passed to this office for direct reply since the records requested are presently in our custody.

Most of the records transferred from the Manhattan Engineer District to this Agency have been retired to our permanent record center located outside the Washington area. However, action has been commenced to recover these records and they will be transferred to the Military Records Branch of the Federal Records Center as you requested.

I anticipate that identification, recovery, preparing receipts and the actual transfer will require about three weeks to accomplish.

If we can be of further assistance, please feel free to call upon us at any time.

Very truly yours,

Herbert Scoville, Jr.
Assistant Director

13 boxes 160-176

DECLASSIFIED
E.O. 12356
By ______ NARS, Date ______

March 25, 1958

Manhattan Project Files in CIA

Reference is made to General Groves' letter to Mr. Dulles relative to return to the MED collection of certain files now in custody of CIA. Mr. Horal, code 143, extension 3487, called me today to say that these files amounting to 5 or 6 cubic feet were being prepared for return in records center card-board boxes at the rate of one box per week. The first such shipment will arrive by courier March 26, addressed to Chief, Military Records Branch, attention: Mr. Nigh. During the next week Mr. Horal will be available should any question arise concerning this matter between 12 and 1 P.M. and on Friday. I have concurred in his suggested arrangement for transmitting the files. The contents of each box will be arranged according to a list of contents contained therein, which list should be checked, receipted and a copy returned to the sender as promptly as possible.--SE

cc: Mr. Nigh

DECLASSIFIED
Authority NND 917017

Figure D.891: To what degree were the wartime and early postwar files of the Foreign Intelligence Unit sanitized before they were ultimately transferred to NARA? [NARA RG 77, Entry UD-22A, Box 160, Folder Foreign Intelligence Unit Index]

D.14.3 Dutch Intelligence

[Dutch intelligence appears to have provided information about the German nuclear weapons program to the United States both during and after the war.

During the war, Dutch citizens interacted with German programs in several ways:

- Many scientists and institutions in the Netherlands worked directly on German programs; Philips Laboratory in Eindhoven was a good example [CIOS III-1; CIOS VI-26, 27; CIOS X-13; CIOS XI-10; CIOS XII-22]. For more information see pp. 4314–4318.
- Many Dutch citizens worked in Germany or in other German-controlled territories as anything from paid research staff to slave laborers (pp. 4846, 4853).
- Some Dutch scientists were recruited by Germany to spy on its behalf; the Cellastic spy ring was one example [[Goudsmit 1947, pp. 37–46; Klinkenberg 1971; Van Calmthout 2018, pp. 129–148].

In all of those Dutch-German interactions, there would have been the opportunity for Dutch citizens who were secretly opposed to Germany's war effort to gather information on German secret weapons programs and to forward that information through a network of like-minded individuals to Dutch resistance leaders in the Netherlands or in exile.

Among other connections between the United States and the Netherlands, Alsos members Samuel Goudsmit and Gerard Kuiper were Dutch and had excellent contacts in the Dutch scientific community.]

Nazis' Secret Weapon Declared One of Horror; Wipe Out Civilization. *Indiana Evening Gazette* (Indiana, Pennsylvania). 30 March 1945 p. 1. https://newspaperarchive.com/indiana-evening-gazette-mar-30-1945-p-1/

PORTLAND, Ore., March 30—(AP)—A member of the Dutch underground declared today the Nazis do have a secret—and deadly effective—weapon.

Jacob van Berkel, here under auspices of the Netherlands Information Bureau, told an interviewer the European front is now a race between victory for the Allies and Germany's resort to the ultimate weapon—"so powerfully destructive it is almost inconceivable."

"The new weapon, a tiny gadget which could be placed in a rocket bomb, may be launched with complete effectiveness against the continental United States," Van Berkel said.

He declared the Germans are saving it for a last stand, probably in the Bavarian Alps. "They are confident that their secret weapon will wipe out civilization and save them at the very end."

Van Berkel—fictitious name to hide his identity from the enemy—gave no details, except to say that the weapon does not involve poison gas. He said that while Allied officials know of the weapon, they do not know in what form it might be launched.

The 27-year-old economist, who has made 60 secret trips through Germany in the last four years, said the weapon was discovered by espionage agents.

[This story was also reported in many other newspapers such as:

The Evening Independent (St. Petersburg, Florida) 30 March 1945 p. 8. https://news.google.com/newspapers?id=cwNQAAAAIBAJ&sjid=DlUDAAAAIBAJ&pg=2700,2575615

Pittsburgh Post-Gazette 30 March 1945 p. 2. https://news.google.com/newspapers?id=ULhRAAAAIBAJ&sjid=wWkDAAAAIBAJ&pg=4865,6710842

The Palm Beach Post (West Palm Beach, Florida) 30 March 1945 p. 1. https://palmbeachpost.newspapers.com/image/134142783/

The Deseret News 29 March 1945 p. 27. https://news.google.com/newspapers?id=0r0KAAAAIBAJ&sjid=nE0DAAAAIBAJ&pg=4566,2984860

Daytona Beach Morning Journal (Florida) 30 March 1945 p. 3. https://news.google.com/newspapers?nid=1873&dat=19450330&id=vvonAAAAIBAJ&sjid=6sYEAAAAIBAJ&pg=3599,5349888

Daily Journal-World (Lawrence, Kansas) 30 March 1945 p. 9. https://news.google.com/newspapers?nid=2199&dat=19450330&id=YBhGAAAAIBAJ&sjid=uugMAAAAIBAJ&pg=5384,4064567

Daily Mirror (Sydney, Australia) 31 March 1945 p. 10. https://trove.nla.gov.au/newspaper/article/272476029

The Sun (Sydney, Australia) 1 April 1945 p. 5. https://trove.nla.gov.au/newspaper/article/231704491

“Jacob van Berkel” was a pseudonym used by Anthony van der Steenhoven (unless that was a pseudonym too). According to files in the Dutch National Archive (pp. 4834–4849), van der Steenhoven was born in 1917 and worked for the Philips Laboratory in Eindhoven 1937–1944 as a secretary for the management.

During the war, van der Steenhoven also began secretly working for the Dutch resistance. He used his official position to travel to laboratories and industrial sites throughout the Netherlands, Belgium, Germany, Austria, Czechoslovakia, and Poland, gathering information on German activities, including work on nuclear weapons and delivery vehicles for them. His intelligence collection was aided by the facts that the Philips Laboratory was producing nuclear technology and collaborating with other organizations throughout German-controlled Europe, and that huge numbers of conscripted Dutch laborers worked at industrial sites throughout German-controlled Europe. Van der Steenhoven then reported what he had learned to his contacts in the Dutch resistance, the Dutch government in exile in London, British intelligence, OSS, and France.

In late 1944, the Dutch government in exile sent van der Steenhoven to the United States on a lecture tour to raise awareness and support. Although van der Steenhoven was supposed to talk about generalities of living in German-controlled Europe, and he largely did so, in some of his public presentations he briefly alluded to the German work on nuclear weapons and their delivery vehicles. After such a lecture in Boston, van der Steenhoven ended up having a lengthy private discussion with Gerard Kuiper, a member of Alsos. Van der Steenhoven’s allusions to German nuclear weapons attracted the attention of a number of journalists, and through the resulting newspaper articles the disapproving attention of the U.S. government (probably censors from Leslie Groves’s office). During his months in the United States, van der Steenhoven even wrote a book giving more details about the German nuclear weapons program, but due to pressure from Philips Laboratory (likely concerned about their public image) and perhaps also from Leslie Groves’s office, the book was never published, and van der Steenhoven was sent back to Europe in summer 1945.

This warning from a highly knowledgeable member of the Dutch resistance that Germany was on the verge of launching an intercontinental nuclear attack that would be strong enough to win the war was highly consistent with information from a number of independent sources. See for example pp. 4638, 5022, 5031, and 5073.]

Anthony van der Steenhoven. 2 April 1945. Report regarding secret weapon [Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945–1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010.]

[See document photo on p. 4836.]

RAPPORT BETREFFENDE GEHEIM WAPEN

In Duitschland kreeg ik in 1943 bericjten van Duitsche bronnen betreffende het in vergevorderd stadium zijnde onderzoek naar het gebruik van de zoogenaamde atoom splitsing van Uraan in een wapen.

Verschillende Duitschers, z.g. ingewijden, gaven hier hoog over op. Het kwam ongeveer hier op neer dat als dit wapen eenmaal in een bruikbaren vorm gebracht kon worden Duitschland in enkele klappen al haar vijanden zou kunnen vernietigen. Ik begon hier aan te werken en kreeg inderdaad de bevestiging dat verschillende Duitsche laboratoria hiermede druk bezig waren. Einde 1943 vloog een geheel laboratorium in de buurt van Berlijn in de lucht en later hoorde ik van een secretaresse uit de Privatkanzlei des Führers dat dit iets met het geheime wapen te maken had. Een officier die bereid was mij meerdere inlichtingen te verschaffen sneuvelde helaas ontijdig. Het een en ander meldde ik later aan O.S.S. maar over de eigenaardige houding van 0SS hoef ik nu niet meer te spreken, ik kreeg sterk de indruk dat men of, hierover reeds voldoende wist, of mij niet serieus nam. In de Ambassade sprak ik hierover zoowel met Dr. van Houten als met den Schout-bij-nacht. Gezien echter de houding van OSS, was ik wat huiverig geworden om dingen als belangrijk voor te stellen dus zal ik het waarschijnlijk wel terloops genoemd hebben.

REPORT REGARDING SECRET WEAPON

In Germany in 1943 I received messages from German sources regarding the advanced stage of research into the use of the so-called atomic fission of uranium in a weapon.

Several Germans, so-called insiders, spoke highly of this. It basically came down to the following: if this weapon could once be brought into a usable form, Germany could destroy all her enemies in a few blows. I started working on this and indeed received confirmation that several German laboratories were busy working on this. At the end of 1943, an entire laboratory flew into the air near Berlin and later I heard from a secretary at the "Privatkanzlei des Führers" that it had something to do with the secret weapon. Unfortunately, an officer who was prepared to provide me with more information was suddenly killed. I later reported some things to the OSS, but I no longer need to talk about OSS's peculiar attitude; I got the strong impression that they either already knew enough about this or did not take me seriously. In the Embassy I spoke about it with Dr. van Houten and also with the Rear Admiral. However, given OSS's attitude, I had become a little hesitant to present things as important, so I probably mentioned it in passing.

In Boston ontmoette ik Prof. Kuiper, die mij hiernaar vroeg en nadat hij zich als G 2 geidentificeerd had vertelde ik hem wat ik wist, hetgeen hij zeer belangrijk vond aangezien het zijn gegevens volkomen bevestigde. Helaas was ik niet in staat hem te vertellen of het reeds in bruikbaren vorm bestond hetgeen hen verontrustte aangezien volgens hem G. 2 dit ook niet wist. Hij was van meening dat het zeer wel mogelijk was dat als zij het konden gebruiken het zeer zeker ook tegen de United States aangewend zou kunnen worden. Sinds Boston heb ik er toen af en toe melding van gemaakt in den vorm zooals getelegrafeerd. Niemand had hier blijkbaar bezwaar tegen, en het merkwaardige is dat verschillende malen interviewers mij man en paard reeds noemden waardoor ik den indruk kreeg dat het een publiek geheim was. Verdere inlichtingen gaf ik nooit. Nu en dan gebruikte ik het als gedeelte van een interview om den indruk van mijn andere indrukken te versterken namelijk: denk er aan, niet te optimistisch, de oorlog is morgen nog niet over!

Hierbij de “clipping” van het geheele bewuste interview hetgeen dus op de gebruikelijke wijze door den interviewer geinterpreteerd en aangedikt, en een andere “clipping” van het “secret-weapon” gedeelte wat aldus afgedrukt natuurlijk een verkeerde indruk geeft.

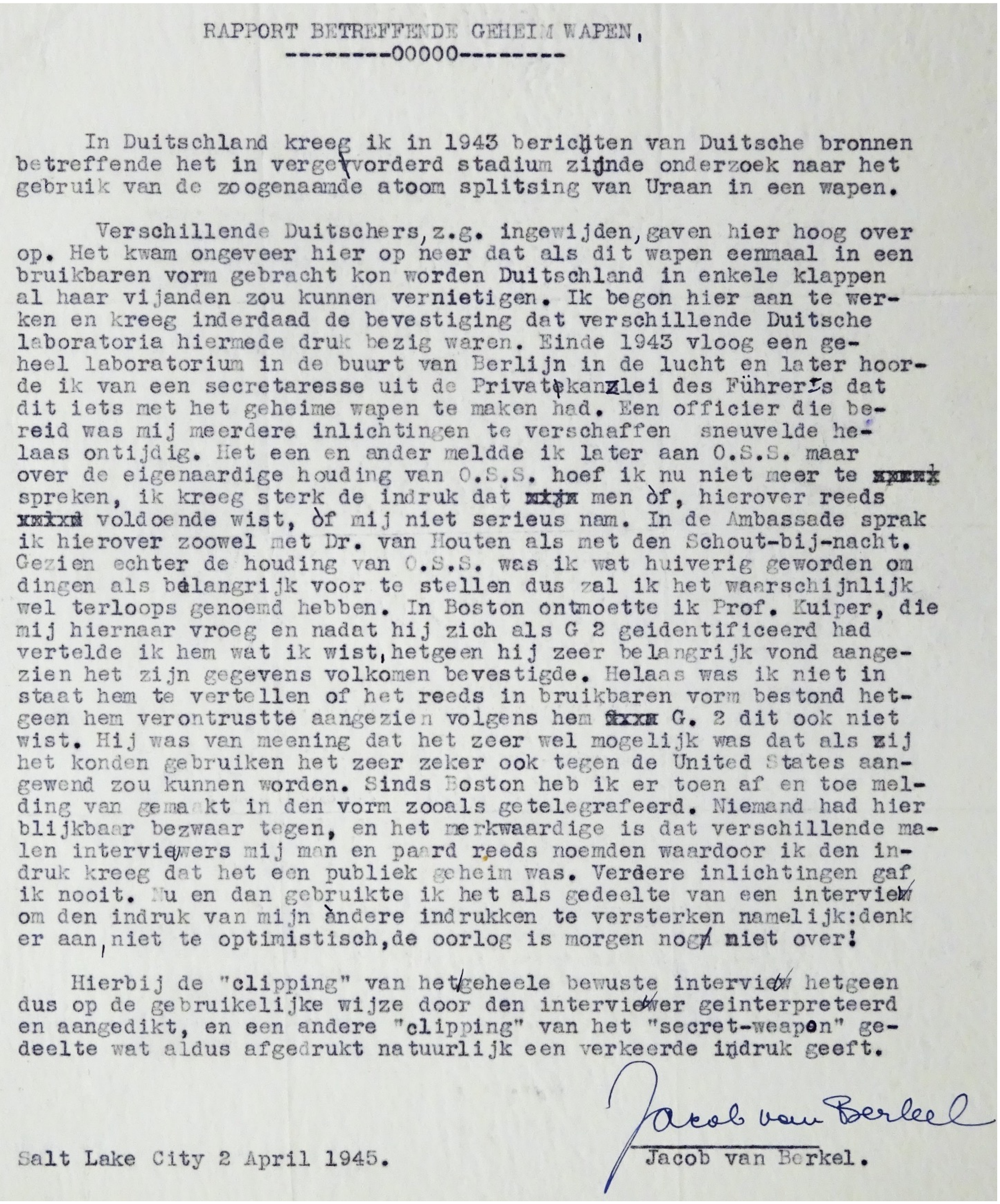
Salt Lake City 2 April 1945

In Boston I met Prof. Kuiper, who asked me about this matter and after he identified himself as G-2, I told him what I knew, which he considered very important given that it completely confirmed his own information. Unfortunately I was unable to tell him whether it already existed in a usable form, which worried them given that G-2 (according to him) did not know this either. He believed that it was entirely possible that if they could use it, it could certainly be used against the United States. Since Boston, I have occasionally reported about the subject in the form as telegraphed. Apparently no one objected to this, and the strange thing is that several times interviewers already called me man and horse, which gave me the impression that it was an open secret. I never provided any further information. Occasionally I used it as part of an interview to reinforce my other impressions, namely: remember, don’t be too optimistic, the war won’t be over tomorrow!

Here is the “clipping” of the entire interview in question, which is interpreted and enhanced by the interviewer in the usual way, and another “clipping” about the “secret-weapon” part, which of course gives a wrong impression when printed in this way.

Salt Lake City 2 April 1945

Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945-1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010



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Jacob van Berkel

Salt Lake City 2 April 1945.

Jacob van Berkel.

Figure D.892: Anthony van der Steenhoven. 2 April 1945. Report regarding secret weapon [Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945–1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010].

H. van den Berg. 16 January 1945. Hearing of: van der STEENHOVEN Anthony [Nationaal Archief (Den Haag), Ministerie van Justitie Bureaus Kabinet en Juridische Zaken van de Afdeling Politie (1932-) 1945–1952 (-1968), Blok J36, Toegang 2.09.107, Inv. nr. 931].

[See document photos on pp. 4842–4844.]

Politie-Buitendienst

Departement van Justitie

Verhoor van: van der STEENHOVEN Anthony, geboren 28 October 1917 te DORDRECHT, van beroep secretaris directie N. V. Gloeilampenfabrieken PHILIPS te Eindhoven, laatstelijk gewoond hebbende Hertogstraat 30 te EINDHOVEN, die Nederland heeft verlaten op 24 September 1944, in Engeland ia aangekomen op 29 September 1944, die op 17 October 1944 uit de R.V.P.S. werd ontslagen en zich alhier meldde op 31 October 1944. [...]

Op 16 Februari 1944 te Hilligersberg gehuwd met Cornelia BERGER, geboren 23 November 1922 te Hilligersberg, wonende Hertogstraat 30 EINDHOVEN. [...]

Ik genoot Lager Onderwijs te Dordrecht. Juni 1935 behaalde ik einddiploma A. op de H.B.S. te Dordrecht. Vervolgens heb ik nog tot 1937 Mei gestudeerd op de Economische Hoogeschool te Rotterdam.

Door tusschenkomst van mijn vader, die een kennis was van den directeur van de Holland Amerika Lijn, heb ik 4 maanden gevaren als stuurmansleerling op de MAASDAM. Vervolgens heb ik thuis gestudeerd en ben tevens werkzaam geweest in de zaak van mijn vader. In November 1937 kreeg ik een betrekking bij de N. V. PHILIPS te Eindhoven als assistent-correspondent met een tweejarige opleiding voor het buitenland. Toen in 1940 deze cursus was afgeloopen werd ik eind 1940 aangezocht om naar Duitschland te gaan om in Berlijn de versterkersafdeeling te organiseeren.

Police External Service

Department of Justice

Hearing of: van der STEENHOVEN Anthony, born 28 October 1917 in DORDRECHT, by profession secretary management N. V. Gloeilampenfabrieken PHILIPS in Eindhoven, last living Hertogstraat 30 in EINDHOVEN, who left the Netherlands on 24 September 1944, arrived in England on 29 September 1944, was discharged from the R.V.P.S. on 17 October 1944 and reported here on 31 October 1944. [...]

On 16 February 1944 in Hilligersberg married Cornelia BERGER, born 23 November 1922 in Hilligersberg, living Hertogstraat 30 EINDHOVEN. [...]

I received my primary education in Dordrecht. In June 1935 I obtained my final diploma A at the H.B.S. in Dordrecht. Then I studied at the Economic School in Rotterdam until May 1937.

Through the intervention of my father, who was an acquaintance of the director of the Holland America Line, I sailed for 4 months as an apprentice mate on the MAASDAM. After that I studied at home and also worked in my father's business. In November 1937 I got a job at the N. V. PHILIPS in Eindhoven as an assistant correspondent with a two-year course abroad. When this course was finished in 1940, I was asked to go to Germany to organize the amplifier division in Berlin.

Ik kreeg deze opdracht van den heer KETEL, personeelschef en ook van den heer KAMSTRA, die destijds personeelschef was. In werkelijkheid was echter mijn opdracht om oogen en ooren open te zetten. Ik vertrok dus naar Berlijn, alwaar ik op 23 Januari 1941 arriveerde. Ik werd geplaatst op de Philipsfabrieken als chef van de afdeeling versterkers. Ik begon met het organiseeren van de civiele verkoopafdeeling, doch na 2 maanden werd de verkoop verboden en mocht alleen onder zeer speciale omstandigheden daarvan worden afgeweken. Intusschen was ik lid geworden van de plaatselijke Amerikaansche kerk en -club. Ik werd bevriend met den Amerikaanschen dominee Stewart HERMAN, doordat wij gemeenschappellijk kennissen hadden in de Vereenigde Staten van Amerika. Bovendien werd ik lid van den inmiddels door de Gestapo opgeheven Nederlandsche club “Nederland en Oranje”, alwaar iederen Donderdagavond bijeenkomsten plaatsvonden. Op die bijeenkomsten ontmoette ik den Heer MILLENAAR van het Zweedsche Gezantschap, die daar zat ter behartiging van de Nederlandsche belangen in Duitschland. Hij was vroeger werkzaam op het Nederlandsche Gezantschap, doch was bij het uitbreken van den oorlog door den Gezant aangewezen om in Berlijn te blijven. MILLENAAR en ik werden spoedig bevriend en er ontstond samenwerking op groote schaal, hetgeen beteekende het onderhouden van zijn contacten in Nederland, (Dit had hoofdzakelijk plaats met den heer MEES van de N. V. Philips, wonende te Rotterdam) en het verstrekken van alle mogelijke hulp in Duitschland zelf, zooals het bezoeken van studenten en arbeiders in ziekenhuizen en werkkampen enz, hetgeen ik op mij nam en deed. Hierbij was veel handigheid vereischt. Ik bleef ca. 3 jaar in Berlijn en had veel moeilijkheden. Ik reisde geregeld op en neer naar Nederland. Ik ben 2 keer aan de grens en 2 keer in Duitschaldn aangehouden, doch telkens vrijgelaten, zonder resultaat voor de Duitschers. Intusschen werkte ik ook voor de K.L.M. als tusschenpersoon tusschen Berlijn en PLESMAN en hied mij bezig met brievensmokkelarij enz. Op 24 December 1943 keerde ik definitief naar Nederland terug. Nadien heb ik in Januari en Februari 1944 nog eenige reizen heen en terug naar Berlijn. Ik was den laatsten tijd nog wel bij N. V. Philips in dienst, doch deed niets.

I received this assignment from Mr. KETEL, chief of staff, and also from Mr. KAMSTRA, who was chief of staff at the time. In reality, however, my assignment was to open eyes and ears. So I left for Berlin, where I arrived on 23 January 1941. I was placed at the Philips factories as head of the amplifier division. I began to organize the civil sales department, but after two months sales were prohibited and could only be deviated from under very special circumstances. Meanwhile, I had joined the local American church and club. I became friends with the American pastor Stewart HERMAN, because we had mutual acquaintances in the United States of America. In addition, I became a member of the Dutch club “Netherlands and Orange,” which had been disbanded by the Gestapo, where meetings were held every Thursday evening. At these meetings I met Mr. MILLENAAR of the Swedish Legation, who was there to represent Dutch interests in Germany. He used to work at the Dutch legation, but at the outbreak of war had been assigned by the envoy to stay in Berlin. MILLENAAR and I soon became friends and there was cooperation on a large scale, which meant maintaining his contacts in the Netherlands, (This mainly took place with Mr. MEES of N. V. Philips, living in Rotterdam) and providing all possible help in Germany itself, such as visiting students and workers in hospitals and work camps etc., which I took on and did. This required a lot of skill. I stayed in Berlin for about 3 years and had many difficulties. I regularly traveled back and forth to Holland. I was stopped twice at the border and twice in Germany, but each time I was released without any result for the Germans. In the meantime I also worked for the K.L.M. as an intermediary between Berlin and PLESMAN and was engaged in letter smuggling etc. On 24 December 1943 I returned to Holland for good. In January and February 1944 I made several trips to Berlin and back. I was employed by N. V. Philips lately, but did nothing.

Op 21 September 1944 kwam ik te EINDHOVEN in contact met Majoor WATERSCHOOT VAN DER GRACHT van de Amerikaansche dienst O.S.S. Hoe die mij kende weet ik niet. Hij vroeg mij of ik hem over Duitschland in wilde lichten, hetgeen ik voor zoover dit in mijn vermogen lag deed. Hij stelde mij voor terug te gaan naar Duitschland, zoogenaamd als een soort gevluchte N.S.B.er, hetgeen echter niet door kon gaan, omdat ik op de zwarte lijst van de N.S.B. stond. Dat ik in Duitschland geen moeilijkheden heb ondervonden was min of meer het gevolg van het feit, dat ik het hoofd van de Gestapo van het Philipsconcern, genaamd Majoor LIESE, goed kende. LIESE had een vreeselijken hekel aan de N.S.B. LIESE was volgens mij goed en is na de laatste beruchte aanslag op HITLER (Goerdelaffaire) door de Duitschers doodgeschoten. LIESE wist niet wat ik deed, doch was de meening toegedaan, dat ik een harde werker van N. V. Philips was.	On 21 September 1944 in EINDHOVEN I came into contact with Major WATERSCHOOT VAN DER GRACHT of the American service O.S.S. How he knew me I do not know. He asked me to inform him about Germany, which I did as far as I could. He suggested that I return to Germany, supposedly as a kind of N.S.B. [Dutch National Socialists] refugee, but this could not be done, because I was on the black list of the N.S.B. I could not go. That I encountered no difficulties in Germany was more or less due to the fact that I knew the head of the Gestapo of the Philips concern, named Major LIESE, well. LIESE had a dreadful dislike for the N.S.B. LIESE was good, in my opinion, and was shot dead by the Germans after the last infamous attack on HITLER (Goerdel affair). LIESE did not know what I did, but was of the opinion that I was a hard worker for N. V. Philips.
WATERSCHOOT stelde mij toen voor mij per parachute in Berlijn neer te laten hetgeen ik als zelfmoord beschouwde, aangezien ik te goed in Berlijn bekend ben en daarvan de moeilijkheden kende.	WATERSCHOOT then proposed to me to drop me by parachute in Berlin, which I considered suicide, since I am too well known in Berlin and knew its difficulties.
In December 1943 had ik te BERLIJN van den Gestapoagent, Inspecteur LANGE, die goed was en in contact stond met MILLENAAR, de tip gekregen Duitschland te verlaten, aangezien mijn activiteiten te verdacht werden.	In December 1943 I had been tipped off in BERLIN by the Gestapo agent, Inspector LANGE, who was well and in contact with MILLENAAR, to leave Germany, since my activities were becoming too suspicious.

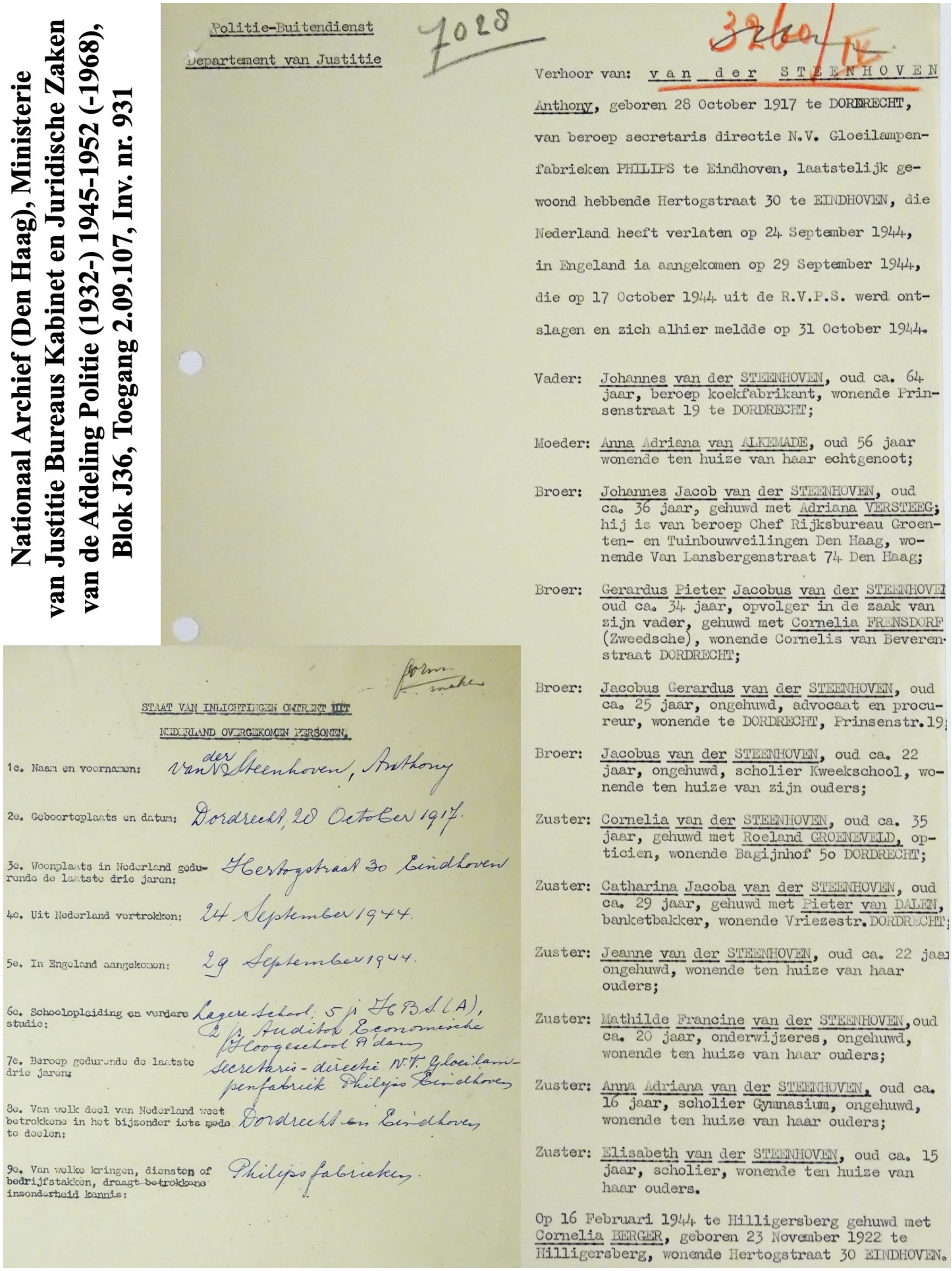
WATERSCHOOT stelde mij vervolgens voor naar STOCKHOLM te gaan om door tusschenkomst van mijn contacten weer contact op te nemen met MILLENAAR, hetgeen ook weer niet door kon gaan vanwege het gevaar voor MILLENAAR. Tenslotte werd mij voorgesteld, dat ik met de bezettende Amerikaansche troepen BERLIN zal binnenrukken om door mijn contacten de zaak zoo vlug mogelijk voor elkaar te brengen. Intusschen zou ik dan in LONDEN moeten afwachten tot het zoover zou zijn en inmiddels rapport uitbrengen over mijn bevindingen van het laatste jaar. Dit laatste voorstel is door mij aangenomen. Ik ben thans echter door het Nederlandsche Ministerie van Buitenlandsche Zaken aangezocht om onder de naam van Jacob van BERKEL een propagandatour door de Vereenigde Staten van Amerika te maken.

Op 24 September 1944 vertrok ik per jeep naar BRUSSEL. Op 26 September 1944 met een Amerikaansch vliegtuig van BRUSSEL naar PARIJS en vandaar op 29 September 1944 met een Amerikaansch vliegtuig naar LONDEN, op laatstgenoemde reizen vergezled van WATERSCHOOT. Na mijn aankomst in LONDEN bezocht ik gedurende die week op 30 September den Minister BURGER (een overbuurman van mij in Nederland), die onmiddellijk den heer F. van 't SANT opbelde. Die week heb ik zonder medeweten van de Engelsche autoriteiten in LONDEN rondgezworven. Op 2 October 1944 had ik weer een onderhoud met den Minister BURGER en op 3 October 1944 met den Minister President GERBRANDY. Van 5 tot 17 October 1944 ben ik verhoord geworden in de R.V.P.S. Op laatstgenoemden datum werd ik afgehaald door een Amerikaansch officier. Op 18 October 1944 had ik een onderhoud met den heer HAARSMA DE WIT, secretaris van den Minister-President GERBRANDY, de laatste Gezant in BERLIJN, die mij mededeelde, dat ik mij bij Minister KLEFFENS moest vervoegen en dien ik op 23 October 1944 bezocht. Ik werd toen aangenomen voor de propagandatour in Amerika. Op 28 October 1944 ben ik ontvangen bij Prinses JULIANA en op 31 October 1944 bij H. M. de KONINGIN.

WATERSCHOOT then proposed to me to go to STOCKHOLM to get back in touch with MILLENAAR through my contacts, which again could not take place because of the danger to MILLENAAR. In the end it was suggested to me that I go into BERLIN with the occupying American troops in order to get things done as quickly as possible through my contacts. In the meantime I would have to wait in LONDON until the time would come and in the meantime report on my findings of the last year. This last proposal was accepted by me. However, I have now been asked by the Dutch Ministry of Foreign Affairs to make a propaganda tour through the United States of America under the name of Jacob van BERKEL.

On 24 September 1944, I left by jeep for BRUSSELS. On 26 September 1944 with an American airplane from BRUSSELS to PARIS and from there on 29 September 1944 with an American airplane to LONDON, accompanied by WATERSCHOOT on the latter trips. After my arrival in LONDON on 30 September, I visited Minister BURGER (a neighbor of mine in Holland), who immediately called Mr. F. van 't SANT. That week I wandered around LONDEN without the knowledge of the English authorities. On 2 October 1944 I had another meeting with Minister BURGER and on 3 October 1944 with Minister President GERBRANDY. From 5 to 17 October 1944 I was interrogated in the R.V.P.S. [Royal Victoria Patriotic School] On the latter date I was picked up by an American officer. On 18 October 1944 I had a meeting with Mr. HAARSMA DE WIT, Secretary to Prime Minister GERBRANDY, the last Envoy to BERLIN, who informed me that I had to report to Minister KLEFFENS, whom I visited on 23 October 1944. I was then accepted for the propaganda tour in America. On 28 October 1944 I was received by Princess JULIANA and on 31 October 1944 by Her Majesty the Queen.

Daar ik verwachtte in moeilijkheden te zullen komen in verband met het feit, dat ik niet door een officieele instantie van Nederlandsche zijde was gehoord geworden, heb ik U op aanraden van Hugo KLEIN van den Voorlichtingsdienst, dien ik in Netherlands House ontmoette, opgebeld en om een onderhoud verzocht. Mijns inziens was het ook veel beter geweest, dat de Amerikaansche autoriteiten mijn geval niet geheimzinnig behandeld hadden en mij den officieelen weg hadden laten volgen.	Since I expected to get into trouble because I had not been heard by an official Dutch authority, I called you on the advice of Hugo KLEIN of the Information Service, whom I met in Netherlands House, and asked for an interview. In my opinion it would have been better if the American authorities had not treated my case secretively and had let me follow the official route.
Ik ben officieel door Minister KLEFFEN aangenomen met ingang van 3 November 1944.	I was officially hired by Minister KLEFFEN effective 3 November 1944.
De N.S.B.ers die ik kende in EINDHOVEN zijn inmiddels opgeruimd.	The N.S.B.ers [Dutch national socialists] I knew in EINDHOVEN have in the meantime been cleared out.
Verdere bijzonderheden kan ik U niet mededeelen.	I cannot give you any further details.
CONCLUSIE: v. d. STEENHOVEN maakt een gunstigen indruk, doch doet erg gewichtig. Mijns inziens is na dit verhoor moeilijk na te gaan of deze man politiek betrouwbaar is. Daarvour zouden nadere informaties moeten worden ingewonnen.	CONCLUSION: v. d. STEENHOVEN makes a favorable impression, but acts very pompous. I think that after this interrogation it is difficult to ascertain whether this man is politically reliable. Further information should be obtained.
Londen, 16 Januari 1945.	London, 16 January 1945.
De wachtmeester tit. der Kon. Marechaussee,	The appointed sentry of the Royal Military Police,
(H. van den BERG).	(H. van den BERG).
OPMERKING: Weer een van de gevallen de Nederlandsche instanties volkomen onkundig waren van de aankomst van een Nederlander. Na opname in de R.V.P.S. werd van andere Engelandvaarders vernomen, dat v.d.S. zich daar bevond en later was hij weer op mysterieuze wijze verdwenen.	NOTE: Another of the cases the Dutch authorities were completely unaware of the arrival of a Dutchman. After being admitted to the R.V.P.S., it was learned from others knowledgeable about England that v.d.S. was there and later he had mysteriously disappeared again.
H. van den BERG.	H. van den BERG.



Nationaal Archief (Den Haag), Ministerie van Justitie Bureaus Kabinet en Juridische Zaken van de Afdeling Politie (1932-) 1945-1952 (-1968), Blok J36, Toegang 2.09.107, Inv. nr. 931

Politie-Buitendienst
Departement van Justitie

7028

3260/IV

Verhoor van: van der STEENHOVEN Anthony, geboren 28 October 1917 te DORDRECHT, van beroep secretaris directie N.V. Gloeilampenfabrieken PHILIPS te Eindhoven, laatstelijk gewoond hebbende Hertogstraat 30 te EINDHOVEN, die Nederland heeft verlaten op 24 September 1944, in Engeland ia aangekomen op 29 September 1944, die op 17 October 1944 uit de R.V.P.S. werd ontslagen en zich alhier meldde op 31 October 1944.

Vader: Johannes van der STEENHOVEN, oud ca. 64 jaar, beroep koekfabrikant, wonende Prinsenstraat 19 te DORDRECHT;

Moeder: Anna Adriana van ALKEMADE, oud 56 jaar wonende ten huize van haar echtgenoot;

Broer: Johannes Jacob van der STEENHOVEN, oud ca. 36 jaar, gehuwd met Adriana VERSTEEG; hij is van beroep Chef Rijksbureau Groenten- en Tuinbouwveilingen Den Haag, wonende Van Lansbergenstraat 74 Den Haag;

Broer: Gerardus Pieter Jacobus van der STEENHOVE oud ca. 34 jaar, opvolger in de zaak van zijn vader, gehuwd met Cornelia FRENSDORF (Zweedsche), wonende Cornelis van Beverenstraat DORDRECHT;

Broer: Jacobus Gerardus van der STEENHOVEN, oud ca. 25 jaar, ongehuwd, advocaat en procureur, wonende te DORDRECHT, Prinsenstr.19;

Broer: Jacobus van der STEENHOVEN, oud ca. 22 jaar, ongehuwd, scholier Kweekschool, wonende ten huize van zijn ouders;

Zuster: Cornelia van der STEENHOVEN, oud ca. 35 jaar, gehuwd met Roeland GROENEVELD, opticien, wonende Bagijnhof 50 DORDRECHT;

Zuster: Catharina Jacoba van der STEENHOVEN, oud ca. 29 jaar, gehuwd met Pieter van DALEN, banketbakker, wonende Vriezestr. DORDRECHT;

Zuster: Jeanne van der STEENHOVEN, oud ca. 22 jaa ongehuwd, wonende ten huize van haar ouders;

Zuster: Mathilde Francine van der STEENHOVEN, oud ca. 20 jaar, onderwijzeres, ongehuwd, wonende ten huize van haar ouders;

Zuster: Anna Adriana van der STEENHOVEN, oud ca. 16 jaar, scholier Gymnasium, ongehuwd, wonende ten huize van haar ouders;

Zuster: Elisabeth van der STEENHOVEN, oud ca. 15 jaar, scholier, wonende ten huize van haar ouders.

Op 16 Februari 1944 te Hilligersberg gehuwd met Cornelia BERGER, geboren 23 November 1922 te Hilligersberg, wonende Hertogstraat 30 EINDHOVEN.

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form maken

STAAT VAN INLICHTINGEN OMTRENT UIT NEDERLAND OVERGEKOMEN PERSONEN.

1e. Naam en voornamen: van der Steenhoven, Anthony

2e. Geboorteplaats en datum: Dordrecht, 28 October 1917.

3e. Woonplaats in Nederland gedurende de laatste drie jaren: Hertogstraat 30 Eindhoven

4e. Uit Nederland vertrokken: 24 September 1944.

5e. In Engeland aangekomen: 29 September 1944.

6e. Schoolopleiding en verdere studie: Lagere School, 5 j. H.B.S. (A), 2 j. Auditor Economische Hoogeschool A'dam

7e. Beroep gedurende de laatste drie jaren: secretaris-directie N.V. Gloeilampenfabriek Philips Eindhoven

8e. Van welk deel van Nederland weet betrokkene in het bijzonder iets mede te deelen: Dordrecht en Eindhoven

9e. Van welke kringen, diensten of bedrijfstakken, draagt ~~betrokkene~~ inzonderheid kennis: Philips fabrieken.

Figure D.893: H. van den Berg. 16 January 1945. Hearing of: van der STEENHOVEN Anthony [Nationaal Archief (Den Haag), Ministerie van Justitie Bureaus Kabinet en Juridische Zaken van de Afdeling Politie (1932-) 1945–1952 (-1968), Blok J36, Toegang 2.09.107, Inv. nr. 931].

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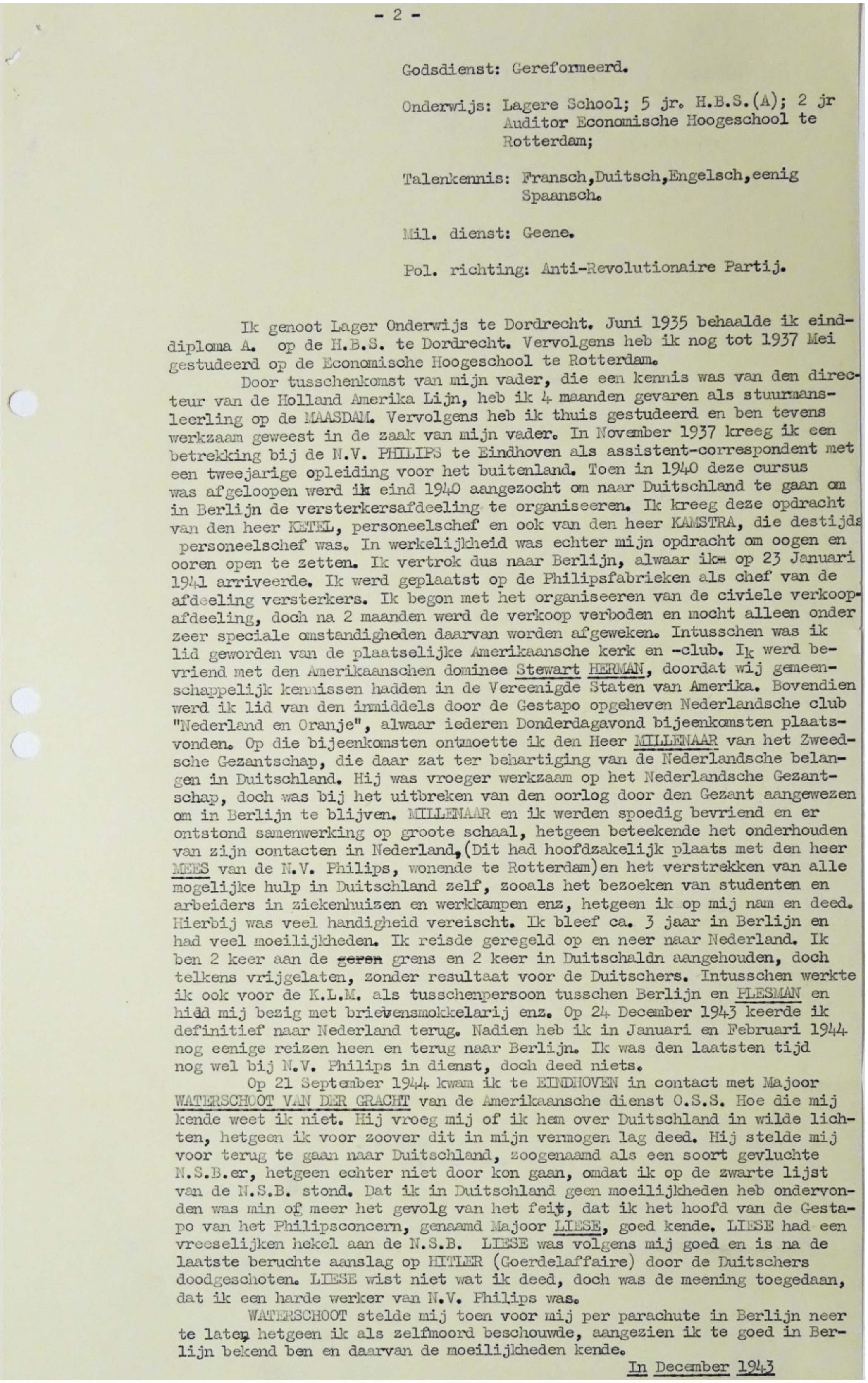

- 2 -

Godsdienst: Gereformeerd.

Onderwijs: Lagere School; 5 jr. H.B.S.(A); 2 jr Auditor Economische Hoogeschool te Rotterdam;

Talenkennis: Fransch,Duitsch,Engelsch,eenig Spaansch.

Mil. dienst: Geene.

Pol. richting: Anti-Revolutionaire Partij.

Ik genoot Lager Onderwijs te Dordrecht. Juni 1935 behaalde ik einddiploma A. op de H.B.S. te Dordrecht. Vervolgens heb ik nog tot 1937 Mei gestudeerd op de Economische Hoogeschool te Rotterdam.

Door tusschenkomst van mijn vader, die een kennis was van den directeur van de Holland Amerika Lijn, heb ik 4 maanden gevaren als stuurmansleerling op de MAASDAM. Vervolgens heb ik thuis gestudeerd en ben tevens werkzaam geweest in de zaak van mijn vader. In November 1937 kreeg ik een betrekking bij de N.V. PHILIPS te Eindhoven als assistent-correspondent met een tweejarige opleiding voor het buitenland. Toen in 1940 deze cursus was afgeloopen werd ik eind 1940 aangezocht om naar Duitschland te gaan om in Berlijn de versterkersafdeeling te organiseeren. Ik kreeg deze opdracht van den heer KETEL, personeelschef en ook van den heer KAMSTRA, die destijds personeelschef was. In werkelijkheid was echter mijn opdracht om oogen en ooren open te zetten. Ik vertrok dus naar Berlijn, alwaar ik op 23 Januari 1941 arriveerde. Ik werd geplaatst op de Philipsfabrieken als chef van de afdeeling versterkers. Ik begon met het organiseeren van de civiele verkoopafdeeling, doch na 2 maanden werd de verkoop verboden en mocht alleen onder zeer speciale omstandigheden daarvan worden afgeweken. Intusschen was ik lid geworden van de plaatselijke Amerikaansche kerk en -club. Ik werd bevriend met den Amerikaanschen dominee Stewart HERMAN, doordat wij gemeenschappelijk kennissen hadden in de Vereenigde Staten van Amerika. Bovendien werd ik lid van den inmiddels door de Gestapo opgeheven Nederlandsche club "Nederland en Oranje", alwaar iederen Donderdagavond bijeenkomsten plaatsvonden. Op die bijeenkomsten ontmoette ik den Heer MILLENAAR van het Zweedsche Gezantschap, die daar zat ter behartiging van de Nederlandsche belangen in Duitschland. Hij was vroeger werkzaam op het Nederlandsche Gezantschap, doch was bij het uitbreken van den oorlog door den Gezant aangewezen om in Berlijn te blijven. MILLENAAR en ik werden spoedig bevriend en er ontstond samenwerking op groote schaal, hetgeen beteekende het onderhouden van zijn contacten in Nederland,(Dit had hoofdzakelijk plaats met den heer MEES van de N.V. Philips, wonende te Rotterdam)en het verstrekken van alle mogelijke hulp in Duitschland zelf, zooals het bezoeken van studenten en arbeiders in ziekenhuizen en werkkampen enz, hetgeen ik op mij nam en deed. Hierbij was veel handigheid vereischt. Ik bleef ca. 3 jaar in Berlijn en had veel moeilijkheden. Ik reisde geregeld op en neer naar Nederland. Ik ben 2 keer aan de ~~geren~~ grens en 2 keer in Duitschaldn aangehouden, doch telkens vrijgelaten, zonder resultaat voor de Duitschers. Intusschen werkte ik ook voor de K.L.M. als tusschenpersoon tusschen Berlijn en PLESMAN en hield mij bezig met brievensmokkelarij enz. Op 24 December 1943 keerde ik definitief naar Nederland terug. Nadien heb ik in Januari en Februari 1944 nog eenige reizen heen en terug naar Berlijn. Ik was den laatsten tijd nog wel bij N.V. Philips in dienst, doch deed niets.

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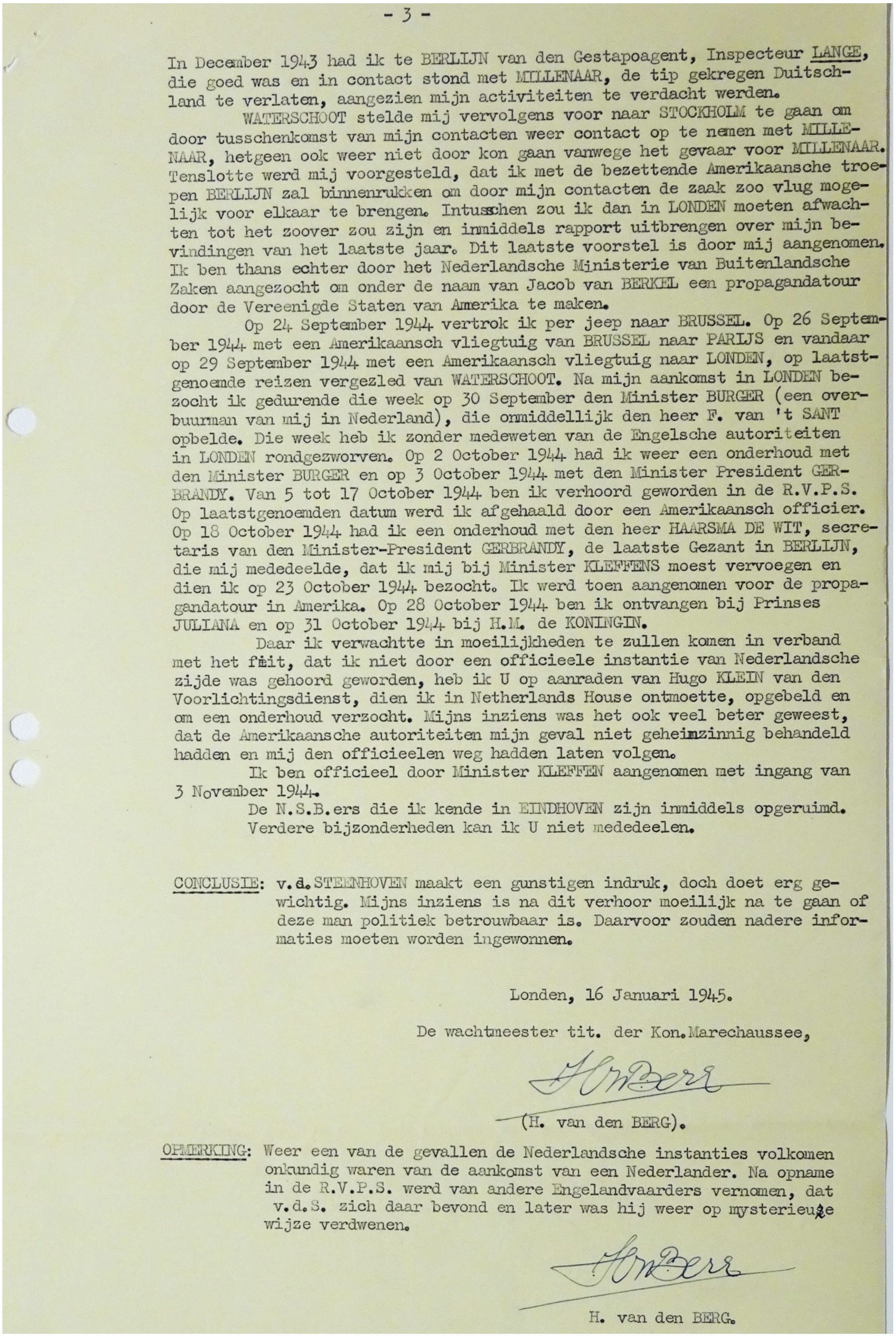
WATERSCHOOT stelde mij toen voor mij per parachute in Berlijn neer te laten, hetgeen ik als zelfmoord beschouwde, aangezien ik te goed in Berlijn bekend ben en daarvan de moeilijkheden kende.

In December 1943

Figure D.894: H. van den Berg. 16 January 1945. Hearing of: van der STEENHOVEN Anthony [Nationaal Archief (Den Haag), Ministerie van Justitie Bureaus Kabinet en Juridische Zaken van de Afdeling Politie (1932-) 1945–1952 (-1968), Blok J36, Toegang 2.09.107, Inv. nr. 931].



- 3 -

In December 1943 had ik te BERLIJN van den Gestapoagent, Inspecteur LANGE, die goed was en in contact stond met MILLENAAR, de tip gekregen Duitschland te verlaten, aangezien mijn activiteiten te verdacht werden.

WATERSCHOOT stelde mij vervolgens voor naar STOCKHOLM te gaan om door tusschenkomst van mijn contacten weer contact op te nemen met MILLENAAR, hetgeen ook weer niet door kon gaan vanwege het gevaar voor MILLENAAR. Tenslotte werd mij voorgesteld, dat ik met de bezettende Amerikaansche troepen BERLIJN zal binnenrukken om door mijn contacten de zaak zoo vlug mogelijk voor elkaar te brengen. Intusschen zou ik dan in LONDEN moeten afwachten tot het zoover zou zijn en inmiddels rapport uitbrengen over mijn bevindingen van het laatste jaar. Dit laatste voorstel is door mij aangenomen. Ik ben thans echter door het Nederlandsche Ministerie van Buitenlandsche Zaken aangezocht om onder de naam van Jacob van BERKEL een propagandatour door de Vereenigde Staten van Amerika te maken.

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Daar ik verwachtte in moeilijkheden te zullen komen in verband met het feit, dat ik niet door een officieele instantie van Nederlandsche zijde was gehoord geworden, heb ik U op aanraden van Hugo KLEIN van den Voorlichtingsdienst, dien ik in Netherlands House ontmoette, opgebeld en om een onderhoud verzocht. Mijns inziens was het ook veel beter geweest, dat de Amerikaansche autoriteiten mijn geval niet geheimzinnig behandeld hadden en mij den officieelen weg hadden laten volgen.

Ik ben officieel door Minister KLEFFEN aangenomen met ingang van 3 November 1944.

De N.S.B.ers die ik kende in EINDHOVEN zijn inmiddels opgeruimd.

Verdere bijzonderheden kan ik U niet mededeelen.

CONCLUSIE: v.d.STEENHOVEN maakt een gunstigen indruk, doch doet erg gewichtig. Mijns inziens is na dit verhoor moeilijk na te gaan of deze man politiek betrouwbaar is. Daarvoor zouden nadere informaties moeten worden ingewonnen.

Londen, 16 Januari 1945.

De wachtmeester tit. der Kon.Marechaussee,

H v Berg

(H. van den BERG).

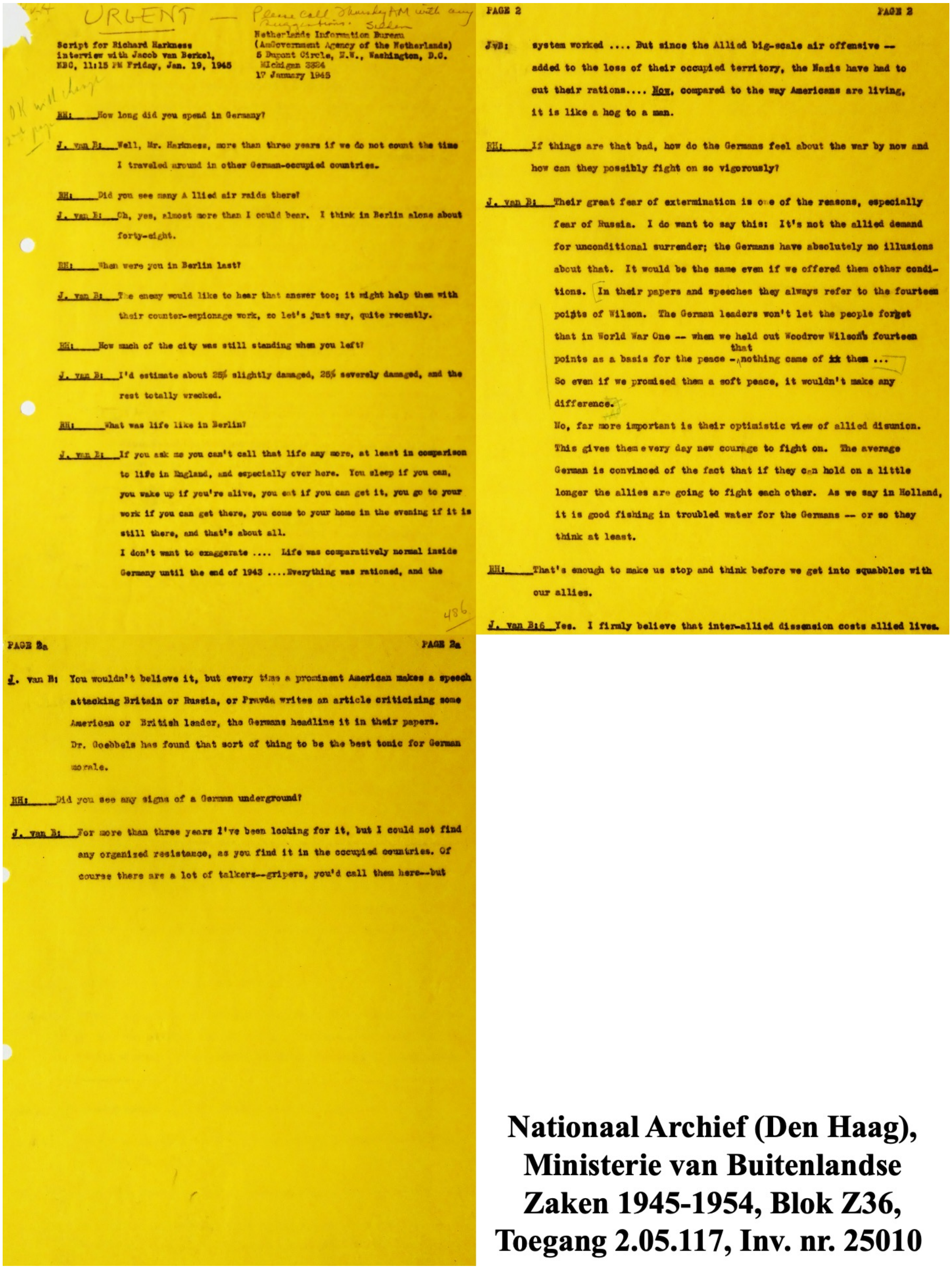
OPMERKING: Weer een van de gevallen de Nederlandsche instanties volkomen onkundig waren van de aankomst van een Nederlander. Na opname in de R.V.P.S. werd van andere Engelandvaarders vernomen, dat v.d.S. zich daar bevond en later was hij weer op mysterieuze wijze verdwenen.

H v Berg

H. van den BERG.

Nationaal Archief (Den Haag), Ministerie van Justitie Bureaus Kabinet en Juridische Zaken van de Afdeling Politie (1932-) 1945-1952 (-1968), Blok J36, Toegang 2.09.107, Inv. nr. 931

Figure D.895: H. van den Berg. 16 January 1945. Hearing of: van der STEENHOVEN Anthony [Nationaal Archief (Den Haag), Ministerie van Justitie Bureaus Kabinet en Juridische Zaken van de Afdeling Politie (1932-) 1945–1952 (-1968), Blok J36, Toegang 2.09.107, Inv. nr. 931].



v-4

URGENT — Please call Thursday AM with any suggestions.

Script for Richard Harkness
interview with Jacob van Berkel,
NBC, 11:15 PM Friday, Jan. 19, 1945

Netherlands Information Bureau
(A Government Agency of the Netherlands)
5 Dupont Circle, N.W., Washington, D.C.
Michigan 3324
17 January 1945

OK will change 2nd page

RH: How long did you spend in Germany?

J. van B: Well, Mr. Harkness, more than three years if we do not count the time I traveled around in other German-occupied countries.

RH: Did you see many Allied air raids there?

J. van B: Oh, yes, almost more than I could bear. I think in Berlin alone about forty-eight.

RH: When were you in Berlin last?

J. van B: The enemy would like to hear that answer too; it might help them with their counter-espionage work, so let's just say, quite recently.

RH: How much of the city was still standing when you left?

J. van B: I'd estimate about 25% slightly damaged, 25% severely damaged, and the rest totally wrecked.

RH: What was life like in Berlin?

J. van B: If you ask me you can't call that life any more, at least in comparison to life in England, and especially over here. You sleep if you can, you wake up if you're alive, you eat if you can get it, you go to your work if you can get there, you come to your home in the evening if it is still there, and that's about all.

I don't want to exaggerate .... Life was comparatively normal inside Germany until the end of 1943 ....Everything was rationed, and the

486

PAGE 2 PAGE 2

JvB: system worked .... But since the Allied big-scale air offensive -- added to the loss of their occupied territory, the Nazis have had to cut their rations.... Now, compared to the way Americans are living, it is like a hog to a man.

RH: If things are that bad, how do the Germans feel about the war by now and how can they possibly fight on so vigorously?

J. van B: Their great fear of extermination is one of the reasons, especially fear of Russia. I do want to say this: It's not the allied demand for unconditional surrender; the Germans have absolutely no illusions about that. It would be the same even if we offered them other conditions. In their papers and speeches they always refer to the fourteen points of Wilson. The German leaders won't let the people forget that in World War One -- when we held out Woodrow Wilson's fourteen points as a basis for the peace -- that nothing came of ~~it~~ them ... So even if we promised them a soft peace, it wouldn't make any difference.

No, far more important is their optimistic view of allied disunion. This gives them every day new courage to fight on. The average German is convinced of the fact that if they can hold on a little longer the allies are going to fight each other. As we say in Holland, it is good fishing in troubled water for the Germans -- or so they think at least.

RH: That's enough to make us stop and think before we get into squabbles with our allies.

J. van B: Yes. I firmly believe that inter-allied dissension costs allied lives.

PAGE 2a PAGE 2a

J. van B: You wouldn't believe it, but every time a prominent American makes a speech attacking Britain or Russia, or Pravda writes an article criticizing some American or British leader, the Germans headline it in their papers. Dr. Goebbels has found that sort of thing to be the best tonic for German morale.

RH: Did you see any signs of a German underground?

J. van B: For more than three years I've been looking for it, but I could not find any organized resistance, as you find it in the occupied countries. Of course there are a lot of talkers--gripers, you'd call them here--but

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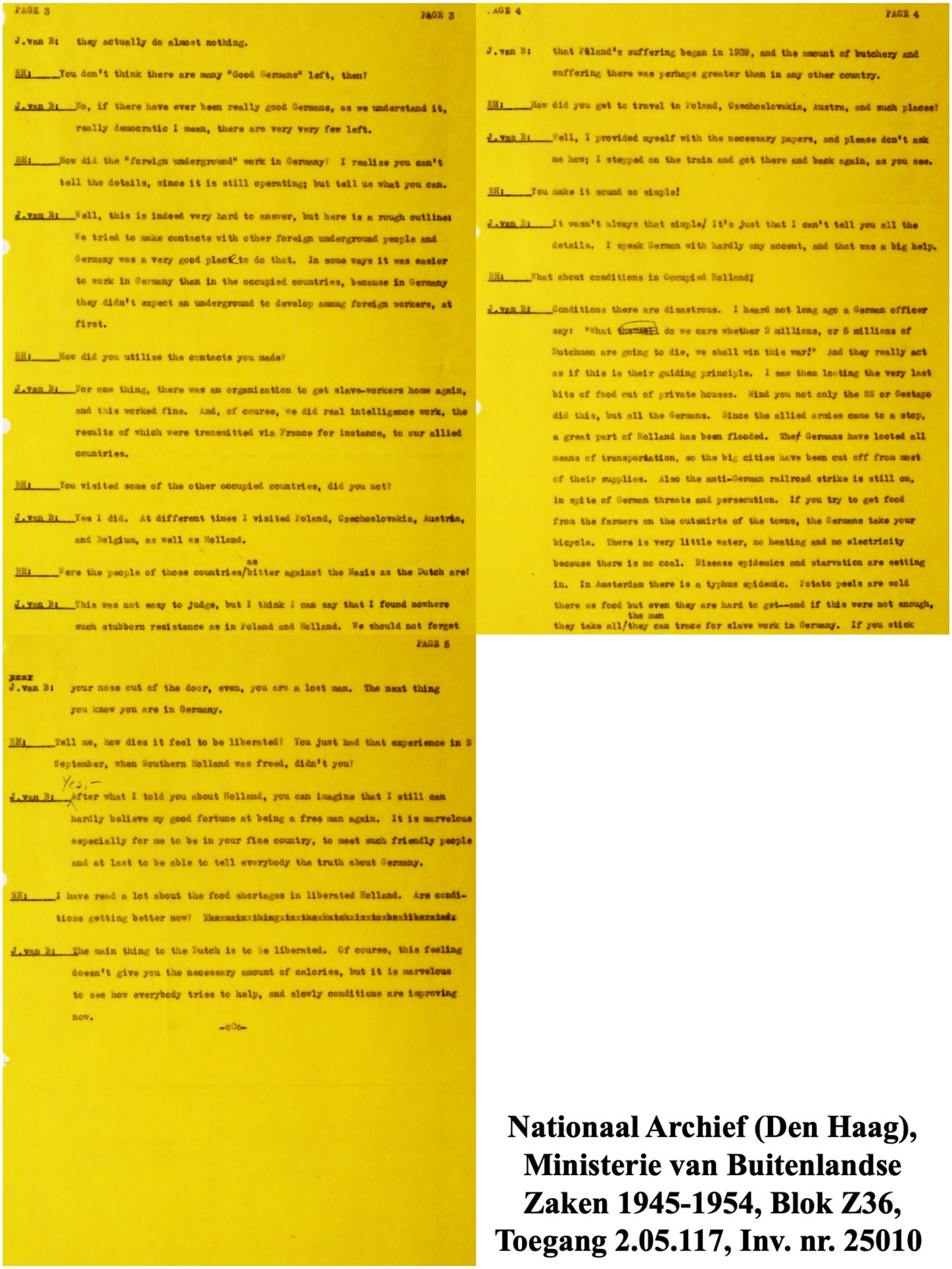
Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945-1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010

Figure D.896: Script for Richard Harkness interview with Jacob van Berkel, NBC, 19 January 1945 [Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945–1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010].



PAGE 3 PAGE 3

J.van B: they actually do almost nothing.

RH: You don't think there are many "Good Germans" left, then?

J.van B: No, if there have ever been really good Germans, as we understand it, really democratic I mean, there are very very few left.

RH: How did the "foreign underground" work in Germany? I realise you can't tell the details, since it is still operating; but tell us what you can.

J.van B: Well, this is indeed very hard to answer, but here is a rough outline: We tried to make contacts with other foreign underground people and Germany was a very good placeto do that. In some ways it was easier to work in Germany then in the occupied countries, because in Germany they didn't expect an underground to develop among foreign workers, at first.

RH: How did you utilize the contacts you made?

J.van B: For one thing, there was an organization to get slave-workers home again, and this worked fine. And, of course, we did real intelligence work, the results of which were transmitted via France for instance, to our allied countries.

RH: You visited some of the other occupied countries, did you not?

J.van B: Yes I did. At different times I visited Poland, Czechoslovakia, Austria, and Belgium, as well as Holland.

as
RH: Were the people of those countries/bitter against the Nazis as the Dutch are?

J.van B: This was not easy to judge, but I think I can say that I found nowhere such stubborn resistance as in Poland and Holland. We should not forget

PAGE 4 PAGE 4

J.van B: that Pöland's suffering began in 1939, and the amount of butchery and suffering there was perhaps greater than in any other country.

RH: How did you get to travel to Poland, Czechoslovakia, Austra, and such places?

J.van B: Well, I provided myself with the necessary papers, and please don't ask me how; I stepped on the train and got there and back again, as you see.

RH: You make it sound so simple!

J.van B: It wasn't always that simple/ It's just that I can't tell you all the details. I speak German with hardly any accent, and that was a big help.

RH: What about conditions in Occupied Holland?

J.van B: Conditions there are disastrous. I heard not long ago a German officer say: "What [illegible] do we care whether 2 millions, or 5 millions of Dutchmen are going to die, we shall win this war!" And they really act as if this is their guiding principle. I saw them looting the very last bits of food out of private houses. Mind you not only the SS or Gestapo did this, but all the Germans. Since the allied armies came to a stop, a great part of Holland has been flooded. The/ Germans have looted all means of transportation, so the big cities have been cut off from most of their supplies. Also the anti-German railroad strike is still on, in spite of German threats and persecution. If you try to get food from the farmers on the outskirts of the towns, the Germans take your bicycle. There is very little water, no heating and no electricity because there is no coal. Disease epidemics and starvation are setting in. In Amsterdam there is a typhus epidemic. Potato peels are sold there as food but even they are hard to get—and if this were not enough,
the men
they take all/they can trace for slave work in Germany. If you stick

PAGE 5

~~xaxx~~
J.van B: your nose out of the door, even, you are a lost man. The next thing you know you are in Germany.

RH: Tell me, how dies it feel to be liberated? You just had that experience in S September, when Southern Holland was freed, didn't you?

Yes, —
J.van B: After what I told you about Holland, you can imagine that I still can hardly believe my good fortune at being a free man again. It is marvelous especially for me to be in your fine country, to meet such friendly people and at last to be able to tell everybody the truth about Germany.

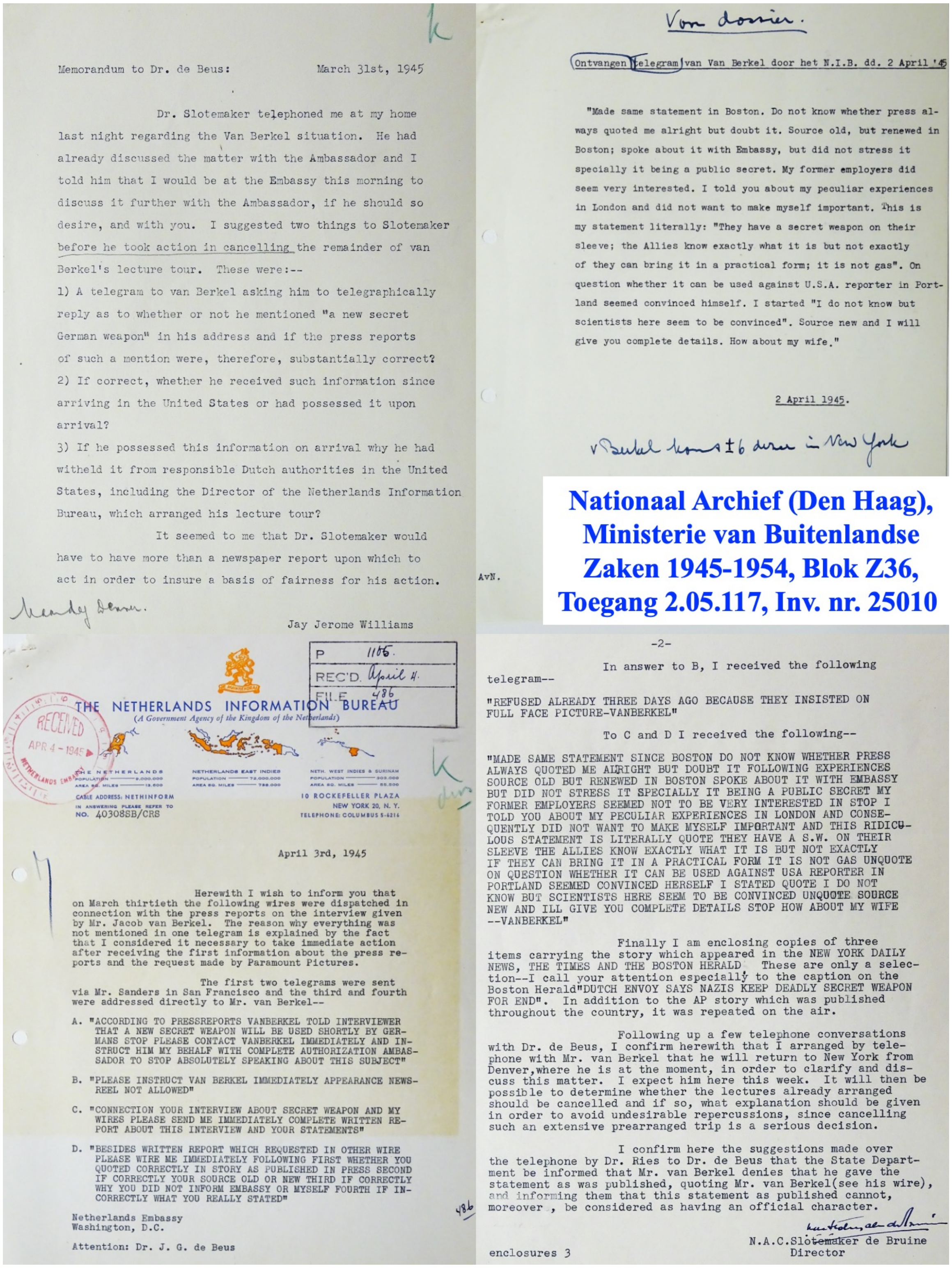
RH: I have read a lot about the food shortages in liberated Holland. Are conditions getting better now? ~~Thexmainxthingxtoxthexdutchxisxtoxbexliberated.~~

J.van B: The main thing to the Dutch is to be liberated. Of course, this feeling doesn't give you the necessary amount of calories, but it is marvelous to see how everybody tries to help, and slowly conditions are improving now.

-oOo-

Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945-1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010

Figure D.897: Script for Richard Harkness interview with Jacob van Berkel, NBC, 19 January 1945 [Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945–1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010].



k

Memorandum to Dr. de Beus: March 31st, 1945

Dr. Slotemaker telephoned me at my home last night regarding the Van Berkel situation. He had already discussed the matter with the Ambassador and I told him that I would be at the Embassy this morning to discuss it further with the Ambassador, if he should so desire, and with you. I suggested two things to Slotemaker before he took action in cancelling the remainder of van Berkel's lecture tour. These were:--

1) A telegram to van Berkel asking him to telegraphically reply as to whether or not he mentioned "a new secret German weapon" in his address and if the press reports of such a mention were, therefore, substantially correct?

2) If correct, whether he received such information since arriving in the United States or had possessed it upon arrival?

3) If he possessed this information on arrival why he had witheld it from responsible Dutch authorities in the United States, including the Director of the Netherlands Information Bureau, which arranged his lecture tour?

It seemed to me that Dr. Slotemaker would have to have more than a newspaper report upon which to act in order to insure a basis of fairness for his action.

Monday Denver.

Jay Jerome Williams

Voor dossier.

Ontvangen telegram van Van Berkel door het N.I.B. dd. 2 April '45

"Made same statement in Boston. Do not know whether press always quoted me alright but doubt it. Source old, but renewed in Boston; spoke about it with Embassy, but did not stress it specially it being a public secret. My former employers did seem very interested. I told you about my peculiar experiences in London and did not want to make myself important. This is my statement literally: "They have a secret weapon on their sleeve; the Allies know exactly what it is but not exactly of they can bring it in a practical form; it is not gas". On question whether it can be used against U.S.A. reporter in Portland seemed convinced himself. I started "I do not know but scientists here seem to be convinced". Source new and I will give you complete details. How about my wife."

2 April 1945.

v Berkel komt ±6 dezer in New York

AvN.

Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945-1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010

P 1165.
REC'D. April 4.
FILE 486

RECEIVED
APR 4 - 1945
NETHERLANDS EMBASSY

THE NETHERLANDS INFORMATION BUREAU
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THE NETHERLANDS
POPULATION 9,000,000
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NETHERLANDS EAST INDIES
POPULATION 72,000,000
AREA SQ. MILES 735,000

NETH. WEST INDIES & SURINAM
POPULATION 303,000
AREA SQ. MILES 55,500

CABLE ADDRESS: NETHINFORM
IN ANSWERING PLEASE REFER TO
NO. 40308SB/CRS

10 ROCKEFELLER PLAZA
NEW YORK 20, N. Y.
TELEPHONE: COLUMBUS 5-6216

k

April 3rd, 1945

Herewith I wish to inform you that on March thirtieth the following wires were dispatched in connection with the press reports on the interview given by Mr. Jacob van Berkel. The reason why everything was not mentioned in one telegram is explained by the fact that I considered it necessary to take immediate action after receiving the first information about the press reports and the request made by Paramount Pictures.

The first two telegrams were sent via Mr. Sanders in San Francisco and the third and fourth were addressed directly to Mr. van Berkel--

A. "ACCORDING TO PRESSREPORTS VANBERKEL TOLD INTERVIEWER THAT A NEW SECRET WEAPON WILL BE USED SHORTLY BY GERMANS STOP PLEASE CONTACT VANBERKEL IMMEDIATELY AND INSTRUCT HIM MY BEHALF WITH COMPLETE AUTHORIZATION AMBASSADOR TO STOP ABSOLUTELY SPEAKING ABOUT THIS SUBJECT"

B. "PLEASE INSTRUCT VAN BERKEL IMMEDIATELY APPEARANCE NEWSREEL NOT ALLOWED"

C. "CONNECTION YOUR INTERVIEW ABOUT SECRET WEAPON AND MY WIRES PLEASE SEND ME IMMEDIATELY COMPLETE WRITTEN REPORT ABOUT THIS INTERVIEW AND YOUR STATEMENTS"

D. "BESIDES WRITTEN REPORT WHICH REQUESTED IN OTHER WIRE PLEASE WIRE ME IMMEDIATELY FOLLOWING FIRST WHETHER YOU QUOTED CORRECTLY IN STORY AS PUBLISHED IN PRESS SECOND IF CORRECTLY YOUR SOURCE OLD OR NEW THIRD IF CORRECTLY WHY YOU DID NOT INFORM EMBASSY OR MYSELF FOURTH IF INCORRECTLY WHAT YOU REALLY STATED"

Netherlands Embassy
Washington, D.C.

Attention: Dr. J. G. de Beus

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-2-

In answer to B, I received the following telegram--

"REFUSED ALREADY THREE DAYS AGO BECAUSE THEY INSISTED ON FULL FACE PICTURE-VANBERKEL"

To C and D I received the following--

"MADE SAME STATEMENT SINCE BOSTON DO NOT KNOW WHETHER PRESS ALWAYS QUOTED ME ALRIGHT BUT DOUBT IT FOLLOWING EXPERIENCES SOURCE OLD BUT RENEWED IN BOSTON SPOKE ABOUT IT WITH EMBASSY BUT DID NOT STRESS IT SPECIALLY IT BEING A PUBLIC SECRET MY FORMER EMPLOYERS SEEMED NOT TO BE VERY INTERESTED IN STOP I TOLD YOU ABOUT MY PECULIAR EXPERIENCES IN LONDON AND CONSEQUENTLY DID NOT WANT TO MAKE MYSELF IMPORTANT AND THIS RIDICULOUS STATEMENT IS LITERALLY QUOTE THEY HAVE A S.W. ON THEIR SLEEVE THE ALLIES KNOW EXACTLY WHAT IT IS BUT NOT EXACTLY IF THEY CAN BRING IT IN A PRACTICAL FORM IT IS NOT GAS UNQUOTE ON QUESTION WHETHER IT CAN BE USED AGAINST USA REPORTER IN PORTLAND SEEMED CONVINCED HERSELF I STATED QUOTE I DO NOT KNOW BUT SCIENTISTS HERE SEEM TO BE CONVINCED UNQUOTE SOURCE NEW AND ILL GIVE YOU COMPLETE DETAILS STOP HOW ABOUT MY WIFE --VANBERKEL"

Finally I am enclosing copies of three items carrying the story which appeared in the NEW YORK DAILY NEWS, THE TIMES AND THE BOSTON HERALD. These are only a selection--I call your attention especially to the caption on the Boston Herald"DUTCH ENVOY SAYS NAZIS KEEP DEADLY SECRET WEAPON FOR END". In addition to the AP story which was published throughout the country, it was repeated on the air.

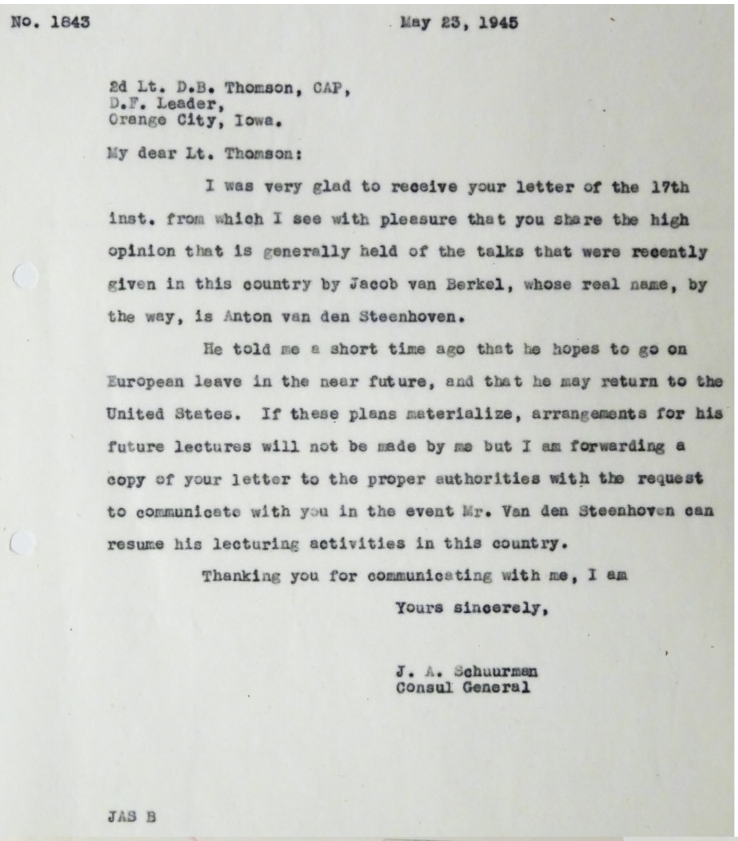
Following up a few telephone conversations with Dr. de Beus, I confirm herewith that I arranged by telephone with Mr. van Berkel that he will return to New York from Denver,where he is at the moment, in order to clarify and discuss this matter. I expect him here this week. It will then be possible to determine whether the lectures already arranged should be cancelled and if so, what explanation should be given in order to avoid undesirable repercussions, since cancelling such an extensive prearranged trip is a serious decision.

I confirm here the suggestions made over the telephone by Dr. Ries to Dr. de Beus that the State Department be informed that Mr. van Berkel denies that he gave the statement as was published, quoting Mr. van Berkel(see his wire), and informing them that this statement as published cannot, moreover , be considered as having an official character.

N.A.C.Slotemaker de Bruine
Director

enclosures 3

Figure D.898: Anthony van der Steenhoven, 2 April 1945: "Made same statement in Boston. Do not know whether press always quoted me alright but doubt it. Source old, but renewed in Boston; spoke about it with Embassy, but did not stress it specially it being a public secret. My former employers did seem very interested. I told you about my peculiar experiences in London and did not want to make myself important. This is my statement literally: 'They have a secret weapon on their sleeve; the Allies know exactly what it is but not exactly if they can bring it in a practical form; it is not gas'. On question whether it can be used against U.S.A. reporter in Portland seemed convinced himself. I started 'I do not know but scientists here seem to be convinced'. Source new and I will give you complete details." [Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945–1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010].



No. 1843 May 23, 1945

2d Lt. D.B. Thomson, CAP,
D.F. Leader,
Orange City, Iowa.

My dear Lt. Thomson:

I was very glad to receive your letter of the 17th inst. from which I see with pleasure that you share the high opinion that is generally held of the talks that were recently given in this country by Jacob van Berkel, whose real name, by the way, is Anton van den Steenhoven.

He told me a short time ago that he hopes to go on European leave in the near future, and that he may return to the United States. If these plans materialize, arrangements for his future lectures will not be made by me but I am forwarding a copy of your letter to the proper authorities with the request to communicate with you in the event Mr. Van den Steenhoven can resume his lecturing activities in this country.

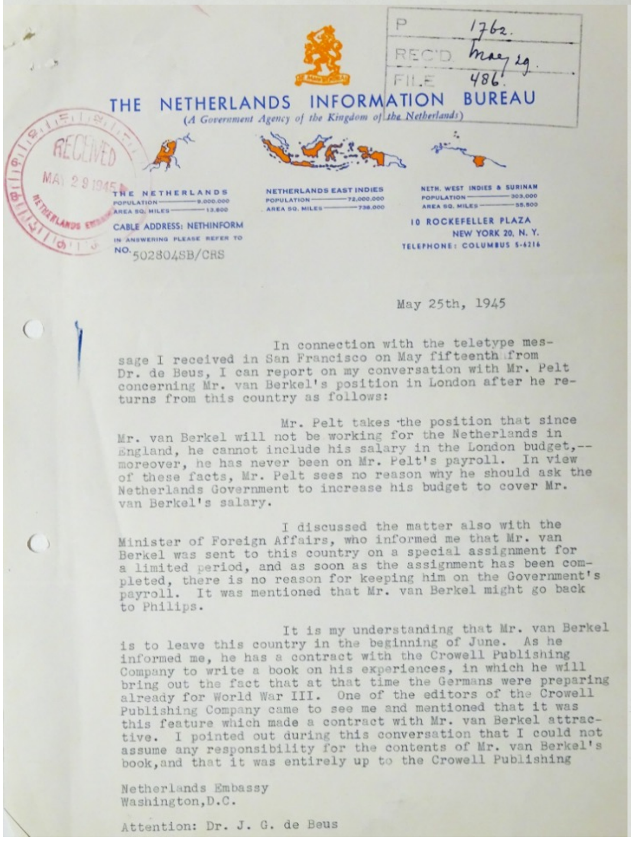
Thanking you for communicating with me, I am

Yours sincerely,

J. A. Schuurman
Consul General

JAS B

Nationaal Archief (Den Haag),
Ministerie van Buitenlandse
Zaken 1945-1954, Blok Z36,
Toegang 2.05.117, Inv. nr. 25010



P 1762.
REC'D May 29.
FILE 486.

THE NETHERLANDS INFORMATION BUREAU
(A Government Agency of the Kingdom of the Netherlands)

THE NETHERLANDS
POPULATION 9,000,000
AREA SQ. MILES 13,500

NETHERLANDS EAST INDIES
POPULATION 72,000,000
AREA SQ. MILES 736,000

NETH. WEST INDIES & SURINAM
POPULATION 303,000
AREA SQ. MILES 55,500

CABLE ADDRESS: NETHINFORM

10 ROCKEFELLER PLAZA
NEW YORK 20, N. Y.
TELEPHONE: COLUMBUS 5-6216

RECEIVED
MAY 29 1945
NETHERLANDS EMBASSY

IN ANSWERING PLEASE REFER TO
NO. 502804SB/CRS

May 25th, 1945

In connection with the teletype message I received in San Francisco on May fifteenth from Dr. de Beus, I can report on my conversation with Mr. Pelt concerning Mr. van Berkel's position in London after he returns from this country as follows:

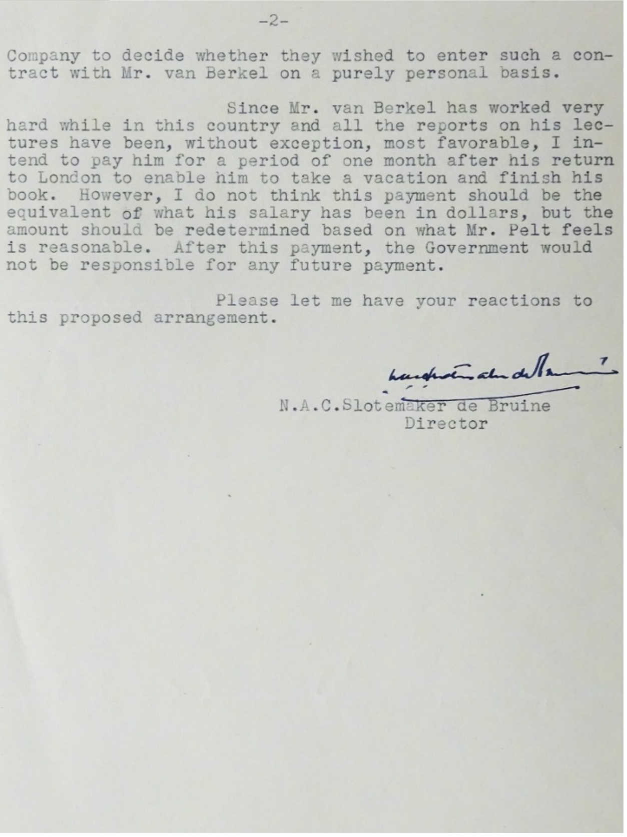
Mr. Pelt takes the position that since Mr. van Berkel will not be working for the Netherlands in England, he cannot include his salary in the London budget,--moreover, he has never been on Mr. Pelt's payroll. In view of these facts, Mr. Pelt sees no reason why he should ask the Netherlands Government to increase his budget to cover Mr. van Berkel's salary.

I discussed the matter also with the Minister of Foreign Affairs, who informed me that Mr. van Berkel was sent to this country on a special assignment for a limited period, and as soon as the assignment has been completed, there is no reason for keeping him on the Government's payroll. It was mentioned that Mr. van Berkel might go back to Philips.

It is my understanding that Mr. van Berkel is to leave this country in the beginning of June. As he informed me, he has a contract with the Crowell Publishing Company to write a book on his experiences, in which he will bring out the fact that at that time the Germans were preparing already for World War III. One of the editors of the Crowell Publishing Company came to see me and mentioned that it was this feature which made a contract with Mr. van Berkel attractive. I pointed out during this conversation that I could not assume any responsibility for the contents of Mr. van Berkel's book,and that it was entirely up to the Crowell Publishing

Netherlands Embassy
Washington,D.C.

Attention: Dr. J. G. de Beus



-2-

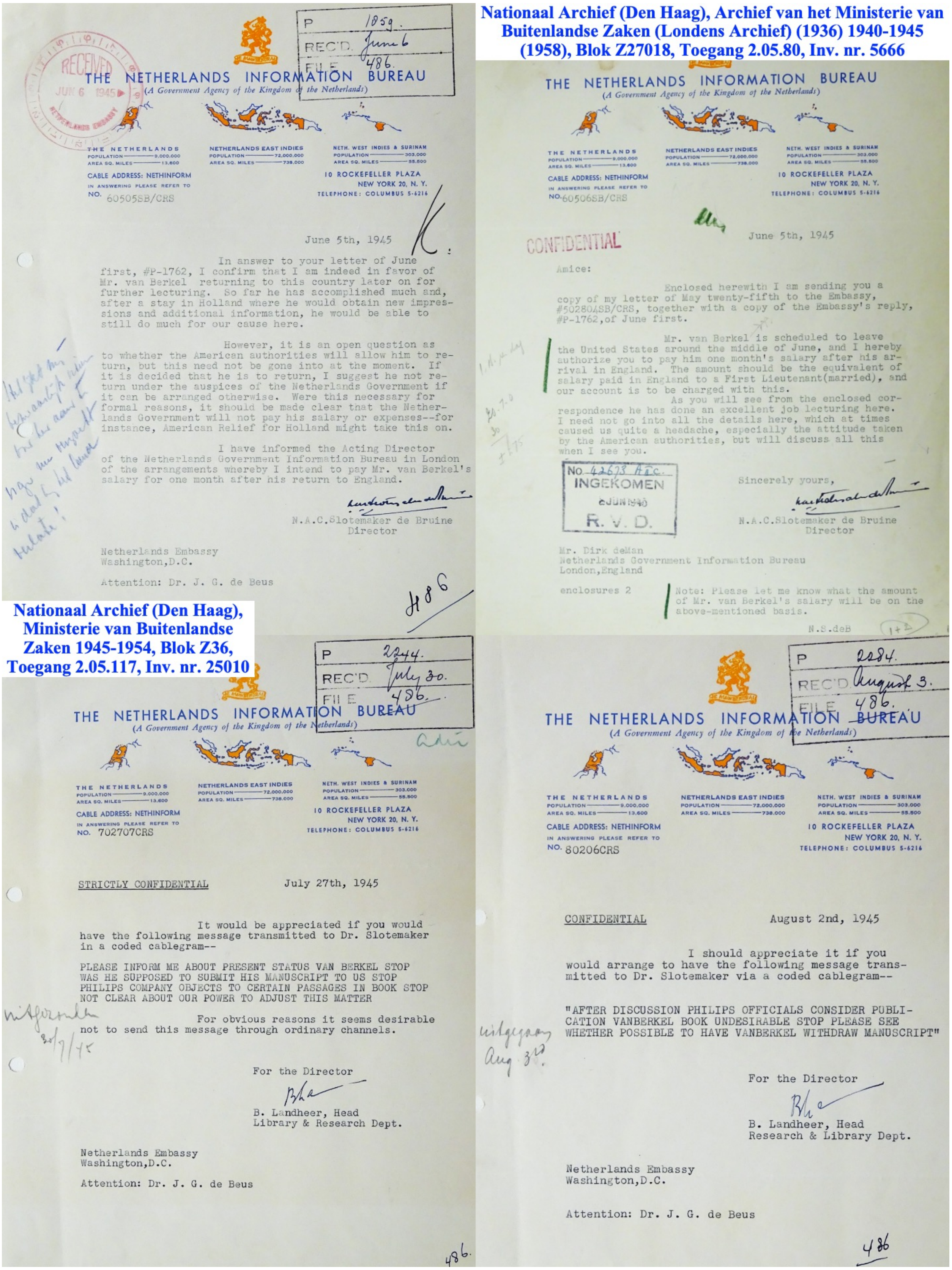
Company to decide whether they wished to enter such a contract with Mr. van Berkel on a purely personal basis.

Since Mr. van Berkel has worked very hard while in this country and all the reports on his lectures have been, without exception, most favorable, I intend to pay him for a period of one month after his return to London to enable him to take a vacation and finish his book. However, I do not think this payment should be the equivalent of what his salary has been in dollars, but the amount should be redetermined based on what Mr. Pelt feels is reasonable. After this payment, the Government would not be responsible for any future payment.

Please let me have your reactions to this proposed arrangement.

N.A.C.Slotemaker de Bruine
Director

Figure D.899: N. A. C. Slotemaker de Bruine, 25 May 1945: "Mr. van Berkel... has a contract with the Crowell Publishing Company to write a book on his experiences, in which he will bring out the fact that at that time the Germans were preparing already for World War III." [Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945–1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010].



Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945-1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010

RECEIVED
JUN 6 1945
NETHERLANDS EMBASSY

P 1859.
REC'D. June 6
FILE 486.

THE NETHERLANDS INFORMATION BUREAU
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NETH. WEST INDIES & SURINAM
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CABLE ADDRESS: NETHINFORM
IN ANSWERING PLEASE REFER TO
NO. 60505SB/CRS

10 ROCKEFELLER PLAZA
NEW YORK 20, N. Y.
TELEPHONE: COLUMBUS 5-6216

June 5th, 1945

In answer to your letter of June first, #P-1762, I confirm that I am indeed in favor of Mr. van Berkel returning to this country later on for further lecturing. So far he has accomplished much and, after a stay in Holland where he would obtain new impressions and additional information, he would be able to still do much for our cause here.

However, it is an open question as to whether the American authorities will allow him to return, but this need not be gone into at the moment. If it is decided that he is to return, I suggest he not return under the auspices of the Netherlands Government if it can be arranged otherwise. Were this necessary for formal reasons, it should be made clear that the Netherlands Government will not pay his salary or expenses--for instance, American Relief for Holland might take this on.

I have informed the Acting Director of the Netherlands Government Information Bureau in London of the arrangements whereby I intend to pay Mr. van Berkel's salary for one month after his return to England.

[illegible]

N.A.C.Slotemaker de Bruine
Director

Netherlands Embassy
Washington,D.C.

Attention: Dr. J. G. de Beus

486

Nationaal Archief (Den Haag), Archief van het Ministerie van Buitenlandse Zaken (Londens Archief) (1936) 1940-1945 (1958), Blok Z27018, Toegang 2.05.80, Inv. nr. 5666

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CABLE ADDRESS: NETHINFORM
IN ANSWERING PLEASE REFER TO
NO. 60506SB/CRS

10 ROCKEFELLER PLAZA
NEW YORK 20, N. Y.
TELEPHONE: COLUMBUS 5-6216

CONFIDENTIAL

June 5th, 1945

Amice:

Enclosed herewith I am sending you a copy of my letter of May twenty-fifth to the Embassy, #502804SB/CRS, together with a copy of the Embassy's reply, #P-1762,of June first.

Mr. van Berkel is scheduled to leave the United States around the middle of June, and I hereby authorize you to pay him one month's salary after his arrival in England. The amount should be the equivalent of salary paid in England to a First Lieutenant(married), and our account is to be charged with this.

As you will see from the enclosed correspondence he has done an excellent job lecturing here. I need not go into all the details here, which at times caused us quite a headache, especially the attitude taken by the American authorities, but will discuss all this when I see you.

No. 42673 A.C.
INGEKOMEN
6 JUN 1945
R. V. D.

Sincerely yours,

N.A.C.Slotemaker de Bruine
Director

Mr. Dirk deMan
Netherlands Government Information Bureau
London,England

enclosures 2

Note: Please let me know what the amount of Mr. van Berkel's salary will be on the above-mentioned basis.

N.S.deB

1+2

P 2244.
REC'D. July 30.
FILE 486.

THE NETHERLANDS INFORMATION BUREAU
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NETH. WEST INDIES & SURINAM
POPULATION 303,000
AREA SQ. MILES 55,500

CABLE ADDRESS: NETHINFORM
IN ANSWERING PLEASE REFER TO
NO. 702707CRS

10 ROCKEFELLER PLAZA
NEW YORK 20, N. Y.
TELEPHONE: COLUMBUS 5-6216

STRICTLY CONFIDENTIAL July 27th, 1945

It would be appreciated if you would have the following message transmitted to Dr. Slotemaker in a coded cablegram--

PLEASE INFORM ME ABOUT PRESENT STATUS VAN BERKEL STOP
WAS HE SUPPOSED TO SUBMIT HIS MANUSCRIPT TO US STOP
PHILIPS COMPANY OBJECTS TO CERTAIN PASSAGES IN BOOK STOP
NOT CLEAR ABOUT OUR POWER TO ADJUST THIS MATTER

uitgezonden 30/7/45

For obvious reasons it seems desirable not to send this message through ordinary channels.

For the Director

B. Landheer, Head
Library & Research Dept.

Netherlands Embassy
Washington,D.C.

Attention: Dr. J. G. de Beus

486.

P 2284.
REC'D. August 3.
FILE 486.

THE NETHERLANDS INFORMATION BUREAU
(A Government Agency of the Kingdom of the Netherlands)

THE NETHERLANDS
POPULATION 9,000,000
AREA SQ. MILES 13,600

NETHERLANDS EAST INDIES
POPULATION 72,000,000
AREA SQ. MILES 738,000

NETH. WEST INDIES & SURINAM
POPULATION 303,000
AREA SQ. MILES 55,500

CABLE ADDRESS: NETHINFORM
IN ANSWERING PLEASE REFER TO
NO. 80206CRS

10 ROCKEFELLER PLAZA
NEW YORK 20, N. Y.
TELEPHONE: COLUMBUS 5-6216

CONFIDENTIAL August 2nd, 1945

I should appreciate it if you would arrange to have the following message transmitted to Dr. Slotemaker via a coded cablegram--

"AFTER DISCUSSION PHILIPS OFFICIALS CONSIDER PUBLICATION VANBERKEL BOOK UNDESIRABLE STOP PLEASE SEE WHETHER POSSIBLE TO HAVE VANBERKEL WITHDRAW MANUSCRIPT"

uitgegaan Aug 3rd.

For the Director

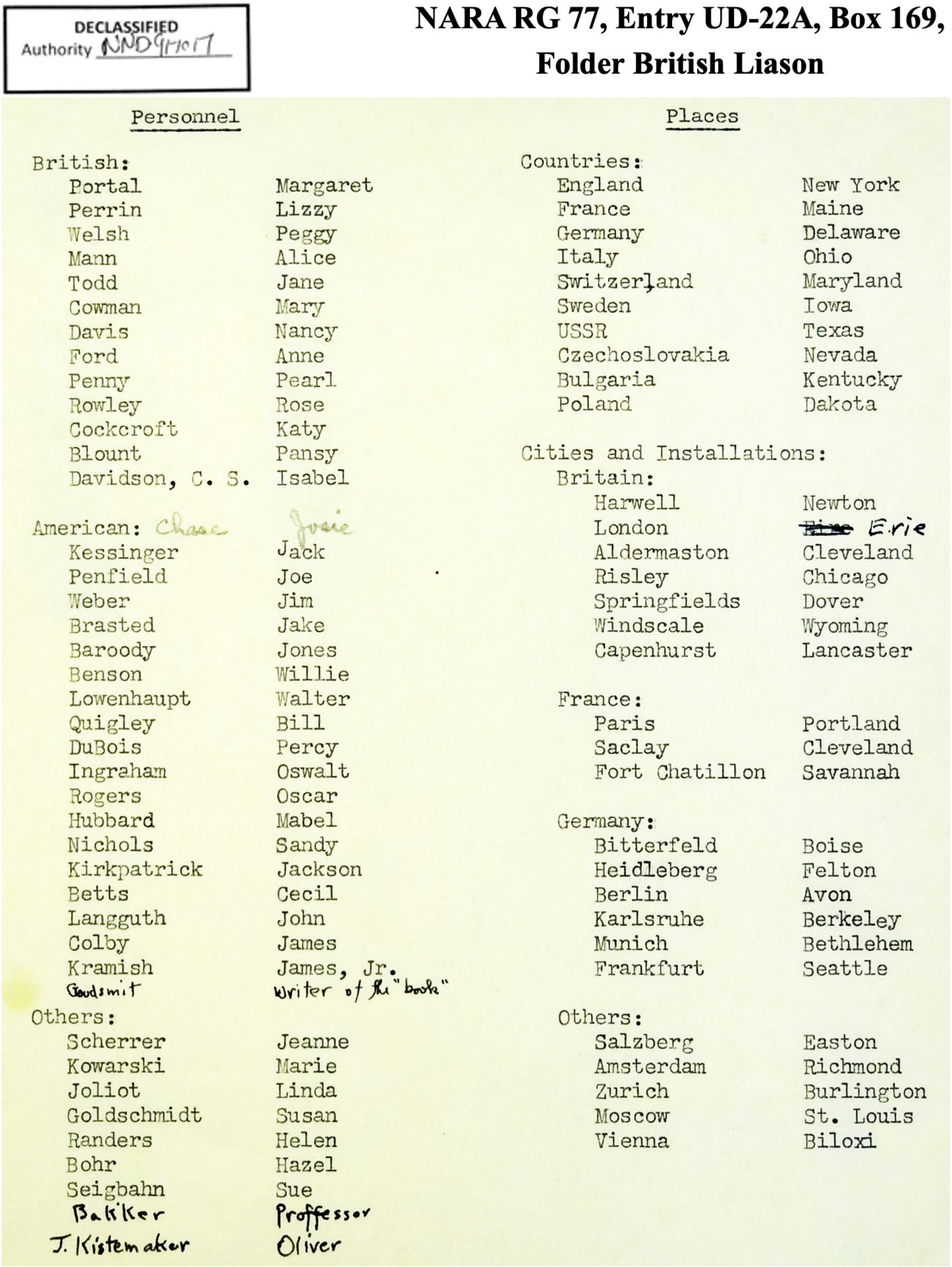
B. Landheer, Head
Research & Library Dept.

Netherlands Embassy
Washington,D.C.

Attention: Dr. J. G. de Beus

486

Figure D.900: Both Philips Eindhoven and unnamed U.S. government officials (likely censors from Leslie Groves's office) blocked van der Steenhoven from publicly revealing what he knew about the German nuclear program [Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945–1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010; Archief van het Ministerie van Buitenlandse Zaken (Londens Archief) (1936) 1940–1945 (1958), Blok Z27018, Toegang 2.05.80, Inv. nr. 5666].



DECLASSIFIED
Authority NND917017

NARA RG 77, Entry UD-22A, Box 169,
Folder British Liason

Personnel

British:	
Portal	Margaret
Perrin	Lizzy
Welsh	Peggy
Mann	Alice
Todd	Jane
Cowman	Mary
Davis	Nancy
Ford	Anne
Penny	Pearl
Rowley	Rose
Cockcroft	Katy
Blount	Pansy
Davidson, C. S.	Isabel
American: Chase	Josie
Kessinger	Jack
Penfield	Joe
Weber	Jim
Brasted	Jake
Baroody	Jones
Benson	Willie
Lowenhaupt	Walter
Quigley	Bill
DuBois	Percy
Ingraham	Oswalt
Rogers	Oscar
Hubbard	Mabel
Nichols	Sandy
Kirkpatrick	Jackson
Betts	Cecil
Langguth	John
Colby	James
Kramish	James, Jr.
Goudsmit	writer of the "book"
Others:	
Scherrer	Jeanne
Kowarski	Marie
Joliot	Linda
Goldschmidt	Susan
Randers	Helen
Bohr	Hazel
Seigbahn	Sue
Bakker	Proffessor
J. Kistemaker	Oliver

Places

Countries:	
England	New York
France	Maine
Germany	Delaware
Italy	Ohio
Switzerland	Maryland
Sweden	Iowa
USSR	Texas
Czechoslovakia	Nevada
Bulgaria	Kentucky
Poland	Dakota
Cities and Installations:	
Britain:	
Harwell	Newton
London	[illegible] Erie
Aldermaston	Cleveland
Risley	Chicago
Springfields	Dover
Windscale	Wyoming
Capenhurst	Lancaster
France:	
Paris	Portland
Saclay	Cleveland
Fort Chatillon	Savannah
Germany:	
Bitterfeld	Boise
Heidleberg	Felton
Berlin	Avon
Karlsruhe	Berkeley
Munich	Bethlehem
Frankfurt	Seattle
Others:	
Salzberg	Easton
Amsterdam	Richmond
Zurich	Burlington
Moscow	St. Louis
Vienna	Biloxi

Figure D.901: Jacob Kistemaker was one of the developers of uranium gas centrifuges; his code name "Oliver" (bottom left) appeared on a postwar list of other U.S./U.K. intelligence sources [NARA RG 77, Entry UD-22A, Box 169, Folder British Liason]. Kistemaker's wartime work and allegiances are rather murky [Goudsmit 1947, pp. 37–46; Klinkenberg 1971; Van Calmthout 2018, pp. 129–148]. How much did he know and reveal about the wartime German nuclear program?

Samuel Goudsmit to Jan Hendrik de Boer. 1 March 1946. [American Institute of Physics Niels Bohr Library & Archives. Samuel A. Goudsmit papers. Series 04: Alsos Mission. Subseries A. Alsos Mission material. Box 25, Folder 08, Dutch intelligence, 1944–1948. https://repository.aip.org/islandora/object/nbla:252943#page/1/mode/2up]

March 1, 1946

Col. J. H. De Boer
Netherlands Government
Arlington House
London W 1, England

Dear De Boer:

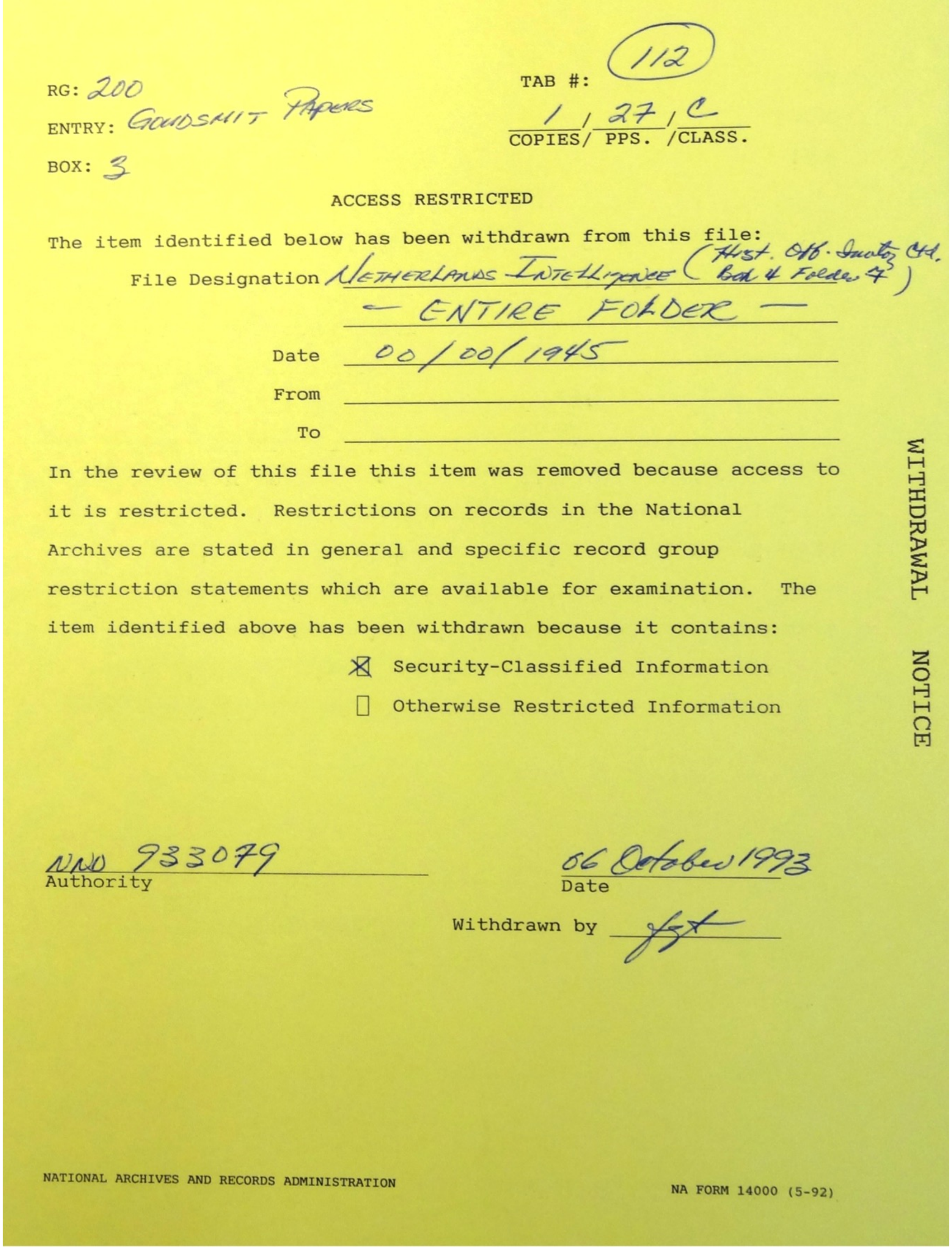
I have had some dealings with the Netherlands Attaché in Paris and recently received a cable from them asking some important information. I now received a letter from Rosbaud in which he mentions that the colonel in question has been dismissed. I would appreciate getting some more information about this and would like to know who is taking his place.

I hear that you are staying [in] England. I had a very interesting trip on the continent. I returned straight from there to the States in October [1945] and had to give up my plan to spend a couple of weeks in England. [...]

[Jan Hendrik de Boer (Dutch, 1899–1971) was a physical chemist who was closely connected with the Dutch and German scientific communities. He was apparently one of the leaders of a Dutch spy network that obtained information on the wartime German nuclear program. The Manhattan Project contacted him in 1944 via Samuel Goudsmit (p. 4398).

Paul Rosbaud (Austrian, 1896–1963) worked as a metallurgist in Germany but secretly provided information on the German nuclear program to U.K. and U.S. intelligence.

Samuel Goudsmit's entire folder of Dutch intelligence on the German nuclear program [NARA RG GOUDS, Entry UD-7420, Box 3] remains classified and unavailable 75+ years after the war ended (Fig. D.902). Why is that the case, if the German nuclear program said to be so small and ineffective?]



RG: 200
ENTRY: GOUDSMIT PAPERS
BOX: 3

TAB #: 112

1 / 27 / C
COPIES/ PPS. /CLASS.

ACCESS RESTRICTED

The item identified below has been withdrawn from this file:

File Designation NETHERLANDS INTELLIGENCE (Hist. Off. Inactive Ctl. Box 4 Folder 7)
— ENTIRE FOLDER —

Date 00/00/1945

From

To

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

WITHDRAWAL NOTICE

NND 933079
Authority

06 October 1993
Date

Withdrawn by

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION

NA FORM 14000 (5-92)

Figure D.902: Samuel Goudsmit's entire folder of Dutch intelligence on the German nuclear program remains classified and unavailable [NARA RG GOUDS, Entry UD-7420, Box 3].

Dutch Aide Seized as Spy in Prague. *New York Times* 29 August 1948.

Police Say He Confessed and Named Foreign Superiors—Czech Group Also Accused

[...] The police disclosed that Leonardus Bartolomeous van Dam, described as investigation officer at the Netherlands Embassy, had been taken into custody together with a group of Czechoslovaks.

Mr. van Dam confessed to police, according to an official announcement, and gave the names of Netherlands officials who instructed him to carry on military and political espionage in Czechoslovakia. The same official announcement said several important documents were found on him and that these seriously implicated other subjects of Netherlands in espionage in Czechoslovakia. The documents, according to the statement, reveal the methods of the foreign intelligence service in question and the tasks laid down of its agents to execute.

Dutch officials told the United Press that Mr. van Dam was attached to the Netherlands Ministry of Social Affairs and did not have diplomatic immunity. He had been collecting death certificates and other data on Dutch slave laborers under the German occupation in Czechoslovakia. [...]

[Leonardus Bartholomeus van Dam (1917–1983; https://www.tracesofwar.com/persons/65909/Dam-van-Leonardus-Bartholomeus.htm) was a very important Dutch spy working for the resistance and reporting to the Allies during the war, and from this report he apparently continued to spy on German technologies and sites after the war.

Even for at least three years after the war ended, Dutch intelligence continued to collect information on wartime German secret weapons programs that had been conducted in Czech territory (and elsewhere), and on how the advanced technology left over from those programs was being exploited by Russian and Czech military forces. That seems to be another indicator of how advanced and how strategically important the wartime German programs were.

Can files detailing the wartime German secret weapons programs, as well as their postwar investigation and exploitation, be located in Dutch archives and released to the public now?]

D.14.4 French Intelligence

[In a fashion highly analogous with Dutch intelligence, there is evidence that French intelligence may have provided information about the German nuclear weapons program to the United States during and after the war.]

Rodney P. Carlisle, ed. 2005. *Encyclopedia of Intelligence and Counterintelligence.* New York: M.E. Sharpe. p. xxi.

c. 1940
Jacques Bergier of the Red Orchestra network helps establish French MARCO POLO group which gains information about German atomic program under Werner Heisenberg and the development of the V-1 and V-2 rockets.

Présidence du Gouvernement Provisoire de la République Française. 30 April 1945. No. 205/2. English translation. [Document courtesy of Andreas Sulzer]

Source: Commandant CHIGOT

Origins: Interrogation of repatriates of the Reprisal Camp of MAUTHAUSEN, particularly the following:

MARCO POLO whose correct name is not known, but is probably known to the D.G.E.R.

RABATE, member of the Communist Party, whose wife is Communist Municipal Councilor in Paris.

Information received indicates that the Germans started on 22 April the massacre of the 80,000 men and women interned in this camp.

These massacres would be completed before the arrival of Russian troops.

Mr. BURCKARDT sent a message, by a convoy leaving for MAUTHAUSEN, to the German commander of the camp, warning him that he would be held responsible if these massacres continued.

It would seem necessary to intervene by force, or if that is impossible to parachute arms and ammunition in order to at least permit these men to defend themselves before being killed.

The Germans have removed from MAUTHAUSEN the Spanish Communists and the Austrian anti-Nazis, dressed them in SS uniforms, and placed them on the bridge of LINZ to be massacred by the Russian troops.

In Block VI of the camp at MAUTHAUSEN is M. Jacques BERGIER, a great specialist on the splitting of the atom.

The Germans have given him a false identification as a Polish Jew; it is requested that everything humanly possible be done to find M. J. BERGIER and to save him regardless of cost.

Jacques Bergier. 1977. *Je Ne Suis Pas Une Legend.* Paris: Retz. pp. 131–132.

Le convoi qui m'emmenait de Sarrebruck arriva à Mauthausen dans la soirée du 2 avril 1944. [...]

Personnellement, je n'ai quitté le camp que le 19 mai 1945, car avant d'être rapatrié par avion, il me fallait régler un certain nombre de problèmes d'importance vitale pour l'avenir. J'avais en effet reçu des confidences, *in articulo mortis*, donnant la solution d'importantes affaires de trahison et il convenait d'en avertir immédiatement le gouvernement français afin qu'il procède à l'arrestation des coupables, ce qui fut fait. Je possédais aussi des renseignements sur de nouvelles armes allemandes et sur les endroits où l'on pouvait soit les trouver à l'état de prototype, soit se procurer la documentation les concernant. Près de huit cents kilomètres de microfilms sur les armes secrètes ont été ainsi découverts.

The convoy that took me from Saarbrücken arrived in Mauthausen on the evening of 2 April 1944. [...]

Personally, I did not leave the camp until 19 May 1945, because before being repatriated by plane, I had to solve a number of problems of vital importance for the future. I had indeed received confidences, at the moment of death, giving the solution of important treason cases and it was necessary to immediately inform the French government so that it could arrest the guilty parties, which was done. I also had information on new German weapons and where they could be found in prototype form or where to obtain documentation about them. Thus nearly eight hundred kilometers of microfilm on secret weapons have been discovered.

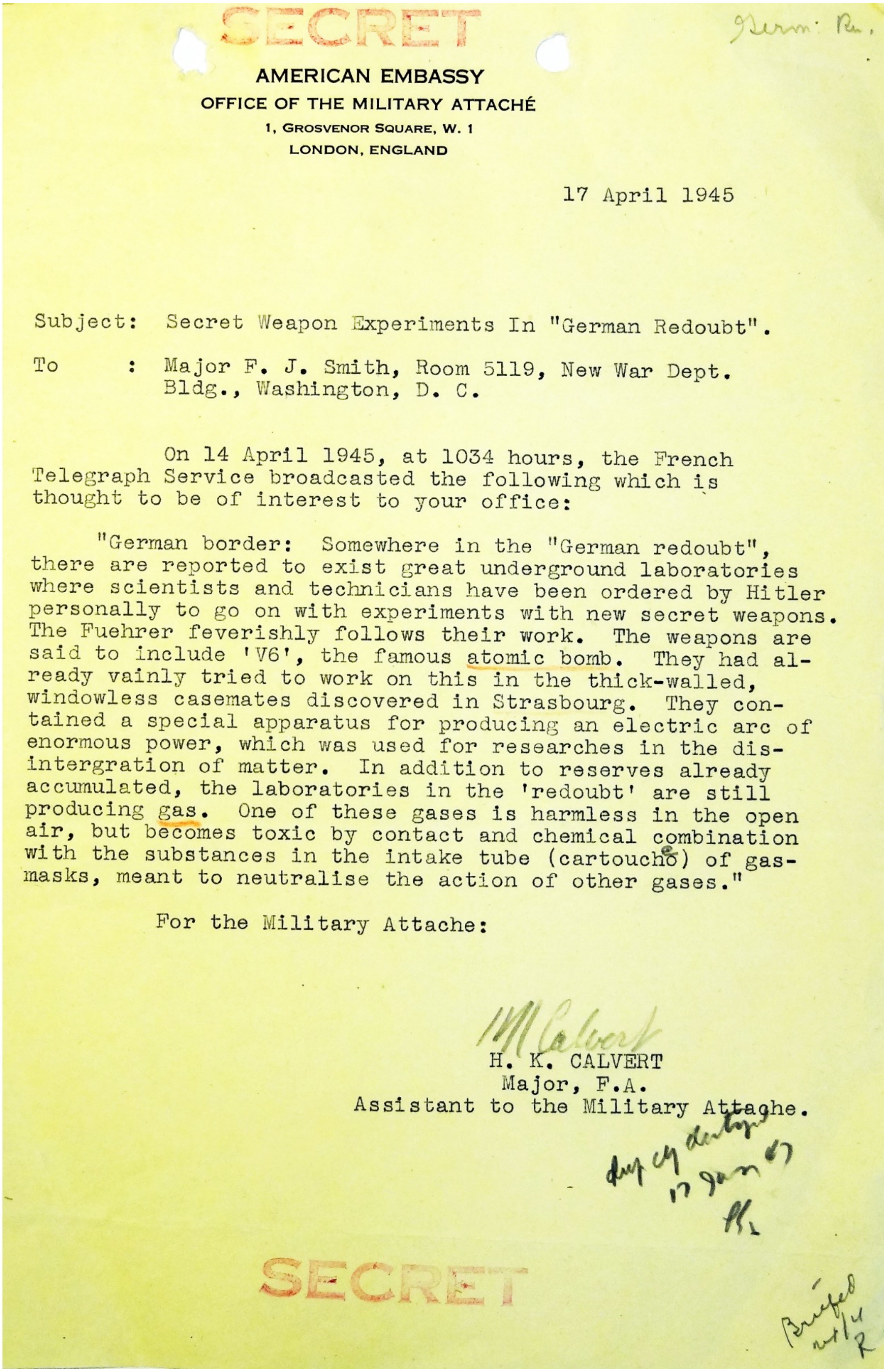
[Jacques Bergier had a scientific background, like many others who were sent to the underground Gusen facilities that were part of the St. Georgen-Gusen-Mauthausen camp system [https://www.jewishgen.org/databases/Holocaust/0117_Mauthausen-Gusen-Death-Book.html]. From the available documentation and Bergier's own writings, it is very unclear what work he did at Gusen, but it may have been related to his knowledge of nuclear physics. The fact that even the scientific prisoners at Gusen were issued false identification papers suggests an extreme level of security about the work that was conducted there.

From the available documentation, Bergier and his associates appear to have provided valuable information about German technologies to Allied intelligence, both during and after the war. That suggests that at least parts of those technologies were being developed at Gusen. However, it is quite unclear just what the technologies or the information were.

Can additional relevant documents be located and released from French, U.S., or other archives? Where is the "nearly eight hundred kilometers of microfilm on secret weapons"?]

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL



SECRET

Germ: Re.

AMERICAN EMBASSY
OFFICE OF THE MILITARY ATTACHÉ
1, GROSVENOR SQUARE, W. 1
LONDON, ENGLAND

17 April 1945

Subject: Secret Weapon Experiments In "German Redoubt".

To : Major F. J. Smith, Room 5119, New War Dept. Bldg., Washington, D. C.

On 14 April 1945, at 1034 hours, the French Telegraph Service broadcasted the following which is thought to be of interest to your office:

"German border: Somewhere in the "German redoubt", there are reported to exist great underground laboratories where scientists and technicians have been ordered by Hitler personally to go on with experiments with new secret weapons. The Fuehrer feverishly follows their work. The weapons are said to include 'V6', the famous atomic bomb. They had already vainly tried to work on this in the thick-walled, windowless casemates discovered in Strasbourg. They contained a special apparatus for producing an electric arc of enormous power, which was used for researches in the disintergration of matter. In addition to reserves already accumulated, the laboratories in the 'redoubt' are still producing gas. One of these gases is harmless in the open air, but becomes toxic by contact and chemical combination with the substances in the intake tube (cartouche) of gasmasks, meant to neutralise the action of other gases."

For the Military Attache:

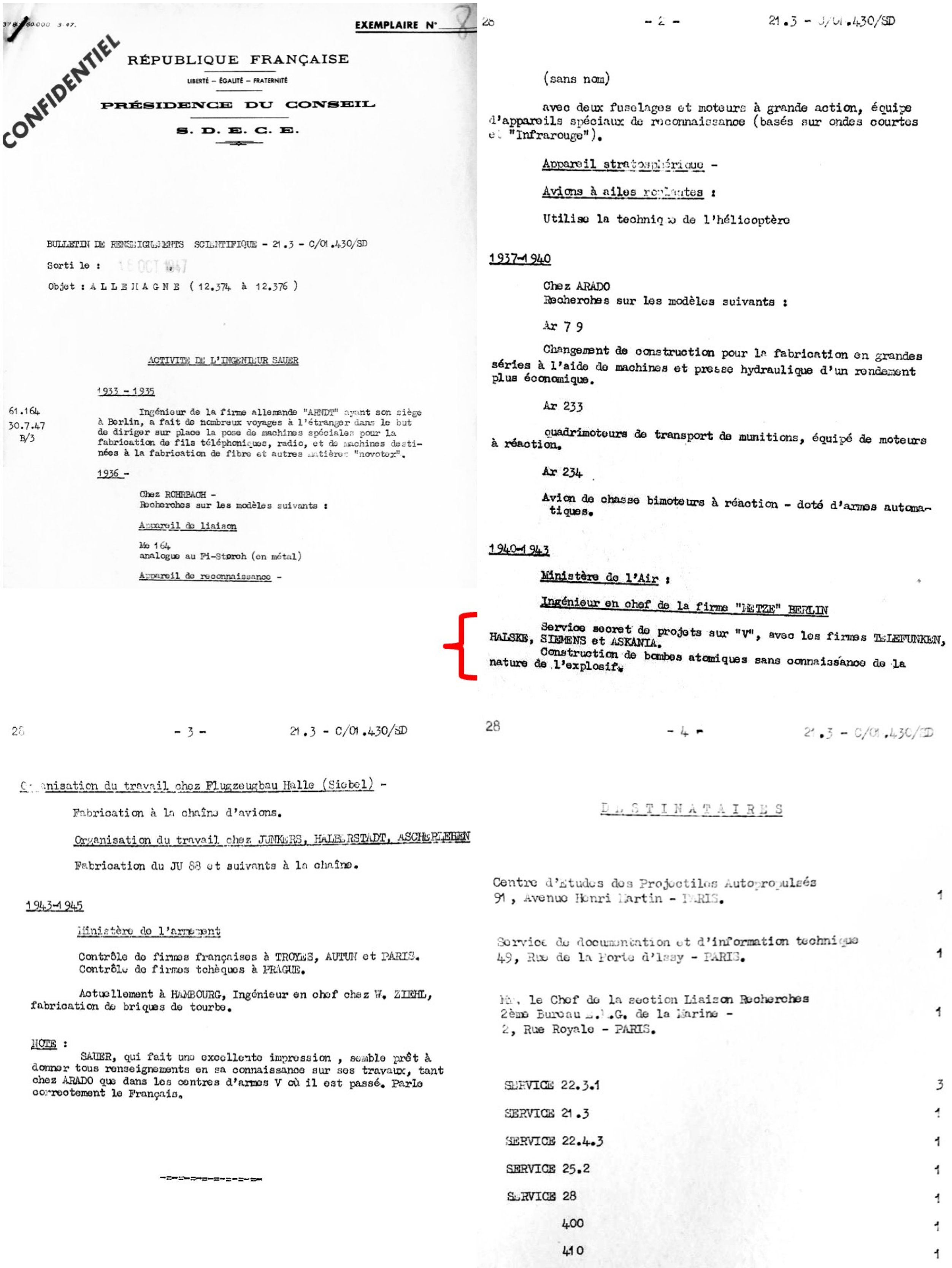
H K Calvert
H. K. CALVERT
Major, F.A.
Assistant to the Military Attache.

dup cy destroyed
17 Jan 47

Briefed

SECRET

Figure D.903: Example of a wartime French report on high-priority work toward a German atomic bomb involving high-voltage machines for what sounds like electromagnetic isotope separation or electronuclear breeding. Horace K. Calvert to Francis J. Smith. 17 April 1945. Subject: Secret Weapon Experiments in "German Redoubt". [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL]



378 60.000 3-47.

EXEMPLAIRE N° 8

CONFIDENTIEL

RÉPUBLIQUE FRANÇAISE

LIBERTÉ – ÉGALITÉ – FRATERNITÉ

PRÉSIDENCE DU CONSEIL

S. D. E. C. E.

BULLETIN DE RENSEIGNEMENTS SCIENTIFIQUE - 21.3 - C/01.430/SD

Sorti le : 16 OCT 1947

Objet : ALLEMAGNE (12.374 à 12.376)

ACTIVITE DE L'INGENIEUR SAUER

1933 - 1935

61.164
30.7.47
B/3

Ingénieur de la firme allemande "ARNDT" ayant son siège à Berlin, a fait de nombreux voyages à l'étranger dans le but de diriger sur place la pose de machines spéciales pour la fabrication de fils téléphoniques, radio, et de machines destinées à la fabrication de fibre et autres matières "novotex".

1936 -

Chez ROHRBACH -
Recherches sur les modèles suivants :

Appareil de liaison

Me 164
analogue au Fi-Storch (en métal)

Appareil de reconnaissance -

28 - 2 - 21.3 - C/01.430/SD

(sans nom)

avec deux fuselages et moteurs à grande action, équipe d'appareils spéciaux de reconnaissance (basés sur ondes courtes et "Infrarouge").

Appareil stratosphérique -

Avions à ailes roulantes :

Utilise la technique de l'hélicoptère

1937-1940

Chez ARADO
Recherches sur les modèles suivants :

Ar 79

Changement de construction pour la fabrication en grandes séries à l'aide de machines et presse hydraulique d'un rendement plus économique.

Ar 233

quadrimoteurs de transport de munitions, équipé de moteurs à réaction.

Ar 234

Avion de chasse bimoteurs à réaction - doté d'armes automatiques.

1940-1943

Ministère de l'Air :

Ingénieur en chef de la firme "METZE" BERLIN

Service secret de projets sur "V", avec les firmes TELEFUNKEN, HALSKE, SIEMENS et ASKANIA.
Construction de bombes atomiques sans connaissance de la nature de l'explosif.

28 - 3 - 21.3 - C/01.430/SD

Organisation du travail chez Flugzeugbau Halle (Siebel) -

Fabrication à la chaîne d'avions.

Organisation du travail chez JUNKERS, HALBERSTADT, ASCHERSLEBEN

Fabrication du JU 88 et suivants à la chaîne.

1943-1945

Ministère de l'armement

Contrôle de firmes françaises à TROYES, AUTUN et PARIS.
Contrôle de firmes tchèques à PRAGUE.

Actuellement à HAMBOURG, Ingénieur en chef chez W. ZIEHL, fabrication de briques de tourbe.

NOTE :
SAUER, qui fait une excellente impression, semble prêt à donner tous renseignements en sa connaissance sur ses travaux, tant chez ARADO que dans les centres d'armes V où il est passé. Parle correctement le Français.

-=-=-=-=-=-=-=-=-

28 - 4 - 21.3 - C/01.430/SD

DESTINATAIRES

Centre d'Etudes des Projectiles Autopropulsés 91, Avenue Henri Martin - PARIS.	1
Service de documentation et d'information technique 49, Rue de la Porte d'Issy - PARIS.	1
Mr. le Chef de la section Liaison Recherches 2ème Bureau E.M.G. de la Marine - 2, Rue Royale - PARIS.	1
SERVICE 22.3.1	3
SERVICE 21.3	1
SERVICE 22.4.3	1
SERVICE 25.2	1
SERVICE 28	1
400	1
410	1

Figure D.904: After the war, France hired many Germans who had worked on the nuclear weapons program (e.g., pp. 2069, 4921, 5698), such as engineer Saur, who had expertise in mechanical and electrical engineering and had constructed non-nuclear components of "atomic bombs" for "V projects" (missiles) from 1940 to 1943 [Archives of the French Army Ministry of Defense, courtesy of Norberto Lahuerta].

D.14.5 German and Japanese Submarines

[In May 1945, the German submarine U-234 surrendered to the United States and was found to be carrying a large and diverse cargo of high-tech materials (including uranium), prototypes, plans, and scientific experts originally intended for Japan. Details of that cargo and how it was ultimately used by the United States remain very mysterious, despite the efforts of a number of investigators [e.g., Brooks 1992, 2002; Grunden 2005; Gutzeit 2001; Hirschfeld 1991; Hirschfeld and Brooks 1996; Hydrick 1998, 2016; Naujoks and Nelson 2002; Scalia 2000; Sellwood 1956; Robert K. Sutton. 2021; Trevethan 1999; Wilcox 2019; *Boston Globe* 1993-07-27; NYT 1995-12-31].

Note that a number of other German and Japanese submarines evacuating materials, documents, and personnel from Germany were also captured or sunk by Allies, or made it through to countries such as Japan and Argentina; details of what those submarines carried are even less clear than for U-234.]

Wolfgang Hirschfeld, Chief Radio Operator of U-234. Wolfgang Hirschfeld and Geoffrey Brooks. 1996. *Hirschfeld: The Story of a U-Boat NCO 1940-1946.* Annapolis, Maryland: Naval Institute Press. pp. 198–200, 216–217. [Hirschfeld's spelling, Falk, has been corrected to Falck in the passage below.]

The most important and secret item of cargo, the uranium oxide, which I believe was highly radioactive, was loaded into one of the vertical steel tubes one morning in February, 1945. Two Japanese officers were to travel aboard *U-234* on the voyage to Tokyo: Air Force Colonel Genzo Shosi, an aeronautical engineer, and Navy Captain Hideo Tomonaga, a submarine architect who, it will be recalled, had arrived in France aboard *U-180* about eighteen months previously with a fortune in gold for the Japanese Embassy in Berlin. I saw these two officers seated on a crate on the forecasing engaged in painting a description in black characters on the brown paper wrapping gummed around each of a number of containers of uniform size. At the time I didn't see how many containers there were, but the Loading Manifest showed ten. Each case was a cube, possibly steel and lead, nine inches along each side and enormously heavy.

Once the inscription *U235* had been painted on the wrapping of a package, it would then be carried over to the knot of crewmen under the supervision of Sub-Lt Pfaff and the Boatswain, Peter Schölch, and stowed in one of the six vertical mineshafts.

I asked Tomonaga what the lead cubes contained, and he said, 'It is the cargo from *U-235*. That boat is no longer going to Japan.' When I enquired at the 5th Flotilla Office, they told me that *U-235* was a small Type VII training U-boat which had never been earmarked for operations outside the Baltic. So I knew that Tomonaga had lied to me. I mentioned all this to Lt Cdr Fehler that evening, but he told me not to bring up the subject again with the Japanese. Recently I was informed by the naval historian Professor Jürgen Rohwer that the nuclear material had been requested, probably in the military attaché code, at the end of December, 1944, or very early in 1945. The Japanese Military Attaché in Berlin, Kigoishi, organized the transport of the material with the German authorities and from the quayside at Kiel had watched the loading of the ten cases of uranium oxide into *U-234*. This seemed to me to confirm that the uranium oxide was of a nature which rendered it of especial value to the Japanese.

When the loading of *U-234* was finished it was estimated that the total weight of the cargo was 260 tons.

[...] The eleven passengers boarding in Germany were the two Japanese, Lt Cdr Richard Bulla, a specialist in air-sea cooperation, who was also the First Lieutenant, and the following eight;

> Colonel Fritz Sandrath (Luftwaffe); former head of Bremen AA defences.
>
> Colonel Erich Menzel (Luftwaffe): technical aide to the Air Attaché, communications
>
> Lt Cdr Heinrich Hellendorn (Navy); specialist in naval AA gunnery.
>
> Captain (Eng.) (S) Heinz Schlicke (Navy, honorary rank); radar, infra-red and direction finding scientist.
>
> Lt Colonel Kai Nieschling (Luftwaffe): Nazi military judge.
>
> Captain Gerhard Falck (Navy): specialist in shipbuilding and design.
>
> August Bringewald: Senior Messerschmitt engineer, Me 262, Me 163 and rocketry.
>
> Franz Ruf: procurement specialist for Messerschmitt.

[Did U-234 carry additional technical experts not listed here? See p. 4891.]

The final passenger was to board in Norway. Nieschling, the judge, was going to investigate allegations against Embassy staff implicated in the Sorge spy scandal and to keep an eye on other passengers during the voyage. The two Japanese, Nieschling and Falck slept in the deck below the NCO's quarters while all remaining passengers slept where they could.

The US National Archive has now declassified a document under reference *373/3679/Box 22/FOLDER OP-16-Z Day File 1/1/45.* This is a memorandum concerning the interrogation of Judge Nieschling. No Memorandum regarding the interrogation of Captain Gerhard Falck has ever been released.

Personally I saw very little of Falck who never socialized except with the Judge.

In the Memorandum [...] Nieschling said that 'the meaning behind the ore' was known to Gerhard Falck, who had taken some secret courses before he boarded *U-234* and was to be chief technician on all naval matters in Tokyo under Admiral Wenneker.

On the afternoon of 25 March, 1945, squatting low in the water from all the fuel, ammunition, provisions, and cargo she had aboard, *U-234* dieseled out of the U-boat basin into the Förde.

[... After surrendering to the USS *Sutton*:] The *Sutton* dropped anchor outside the harbour of Portsmouth, New Hampshire, on the glorious morning of 19 May, 1945. [...]

The ten specialists were driven off to a secret destination. We located them all after the war with the exception of Captain Gerhard Falck. Possibly, like Peter Schölch, our Boatswain, and Lt Pfaff, who loaded and unloaded the uranium cases, he accepted US citizenship in exchange for his silence. But as Judge Nieschling said, Falck knew everything about the uranium oxide, and he probably knew too much for his own good. His eventual fate after he disappeared into the abyss on 19 May, 1945, remains a mystery.

[Gerhard Falck was apparently the resident expert on the uranium and how to use it. Note that he was closely guarded during the voyage and mysteriously vanished after it. In the publicly available transcripts of his May–July 1945 interrogations by U.S. authorities, the uranium is never mentioned [NARA RG 38, Entry UD-38, Box 13]. Can transcripts of his interrogations about the uranium be located, declassified, and released? Could his prior history and connections in Germany be traced?

Heinz Schlicke may have been in charge of detonators for fission implosion bombs, as shown in the documents on p. 4882.

Captain Johann Fehler recounted the general details of U-234's voyage to the British naval journalist Arthur V. Sellwood. Fehler said the submarine carried over 260 tons of important cargo, but otherwise he was remarkably close-lipped about the details of that cargo, even over a decade after the war [Sellwood 1956, p. 137].

The U.S. National Archives appears to have only seven small boxes of information from or about the U-234's cargo [NARA RG 38, Entry UD-16, Boxes 3–8 and RG 38, Entry UD-38, Box 13]. Where are the over 260 tons of documents, prototypes, and other cargo from the U-234, as well as all of the information the United States compiled in the process of analyzing them?

Where is all the cargo and documentation for at least five other German submarines filled with high-tech cargo that were captured at the end of the war (p. 4892)?]

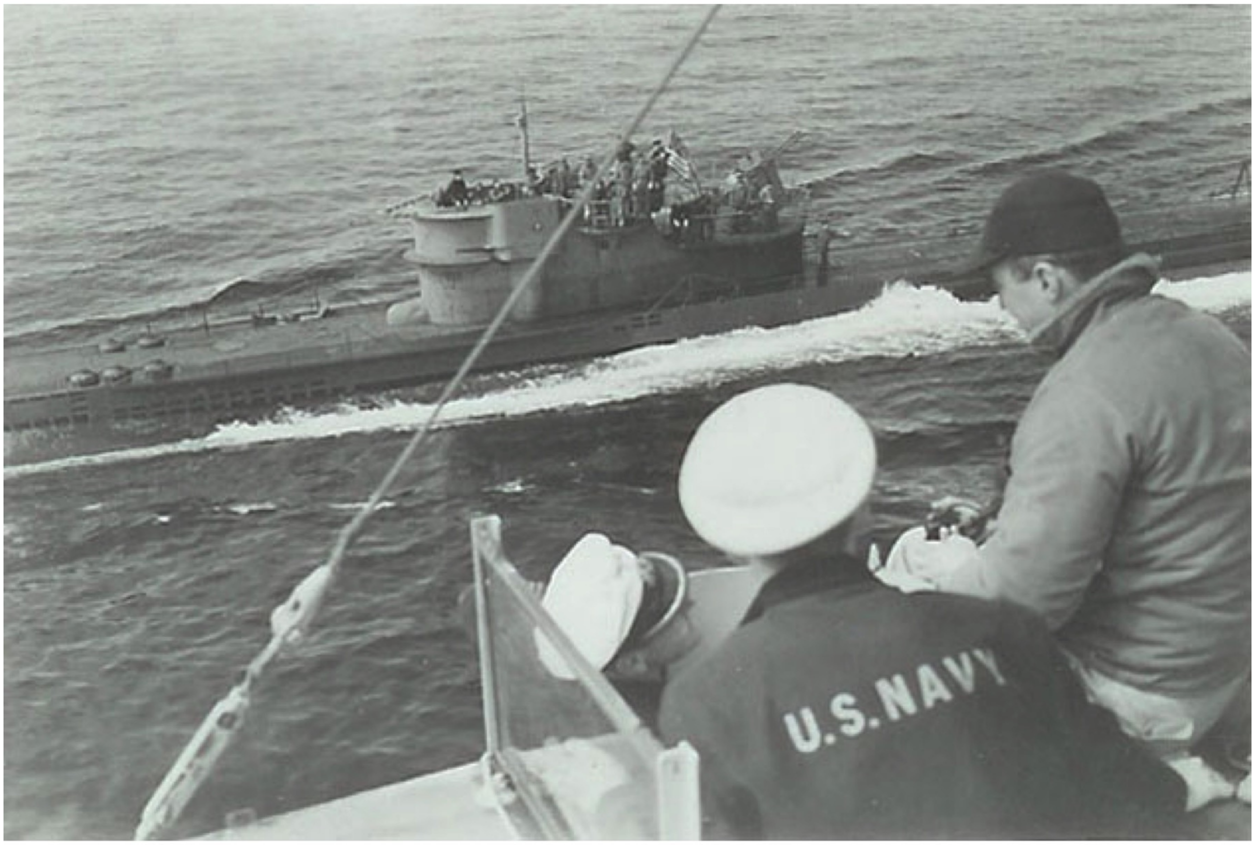
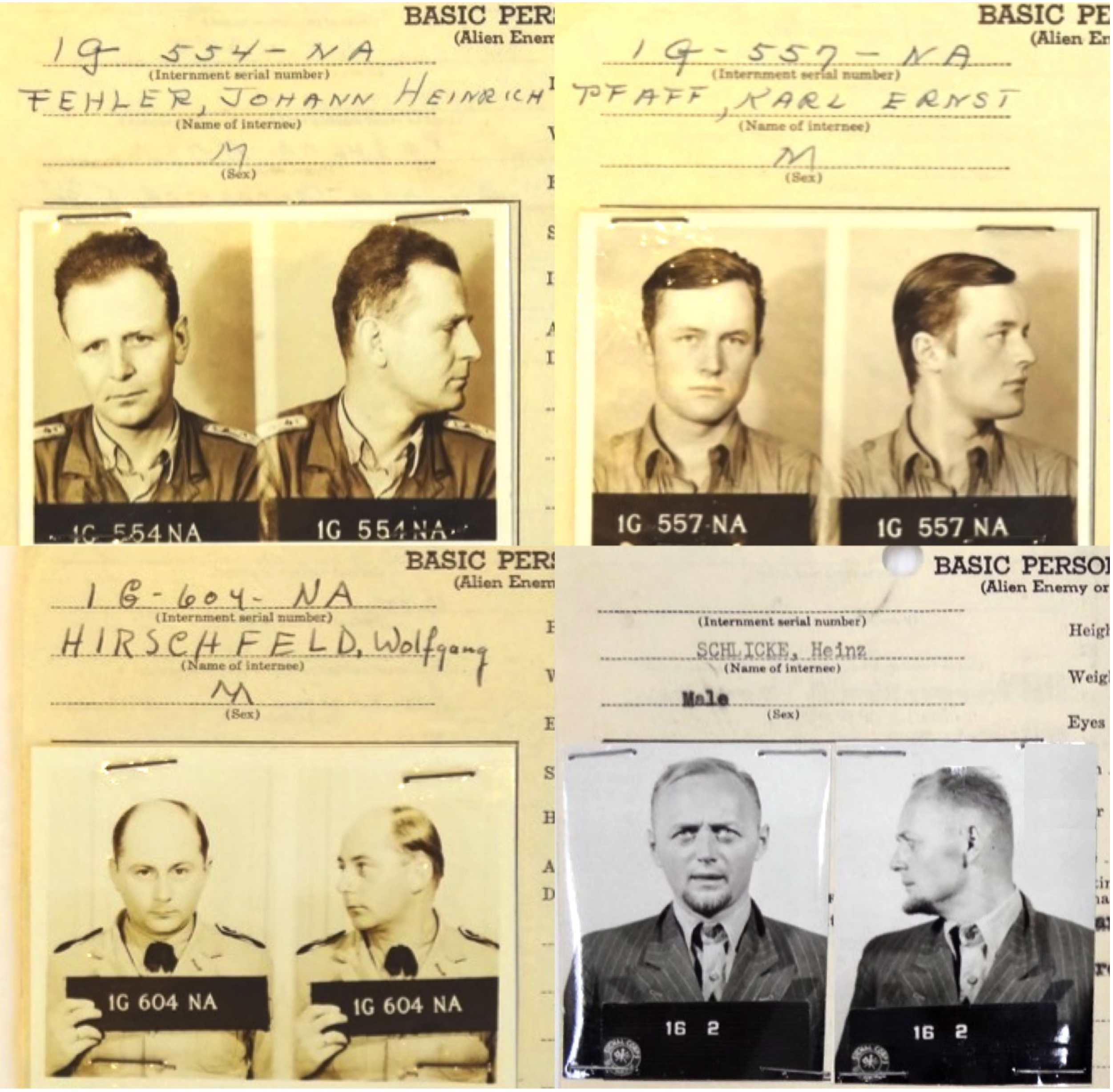


Figure D.905: German submarine U-234 surrendering to the USS Sutton on 14 May 1945.



BASIC PER
(Alien Enem
1G 554-NA
(Internment serial number)
FEHLER, JOHANN HEINRICH
(Name of internee)
M
(Sex)

BASIC PE
(Alien En
1G-557-NA
(Internment serial number)
PFAFF, KARL ERNST
(Name of internee)
M
(Sex)

BASIC PER
(Alien Enem
1G-604-NA
(Internment serial number)
HIRSCHFELD, Wolfgang
(Name of internee)
M
(Sex)

BASIC PERSO
(Alien Enemy or
(Internment serial number)
SCHLICKE, Heinz
(Name of internee)
Male
(Sex)
Heigh
Weig
Eyes

Figure D.906: U-234 Captain Johann Fehler, Lt. Karl Pfaff, radio operator Wolfgang Hirschfeld, and Dr. Heinz Schlicke [NARA RG 38, Entry UD-38, Box 13, Folder U-234 and RG 330, Entry A1-1B, Box 145, Folder Schlicke, Heinz].

U.S. Navy Confidential Dispatch 131509. Subject: Interviewing of Prisoners. 13 May 1945. [NARA Boston RG 181]

CONFIDENTIAL 13 May 1945
131509

FROM: CESF
TO: CTG 02.1
CTG 02.4
INFO: CTG 02.3
02.5
02.6
SUBJECT: Interviewing of Prisoners

1. Press representatives may be permitted to interview officers and men of German submarines that surrender. This message applies only to submarines that surrender. It does not apply to other prisoners of war. It does not apply to prisoners of the U-234. Prisoners of the U-234 must not be interviewed by press representatives.

[See document photo on p. 4863 top.]

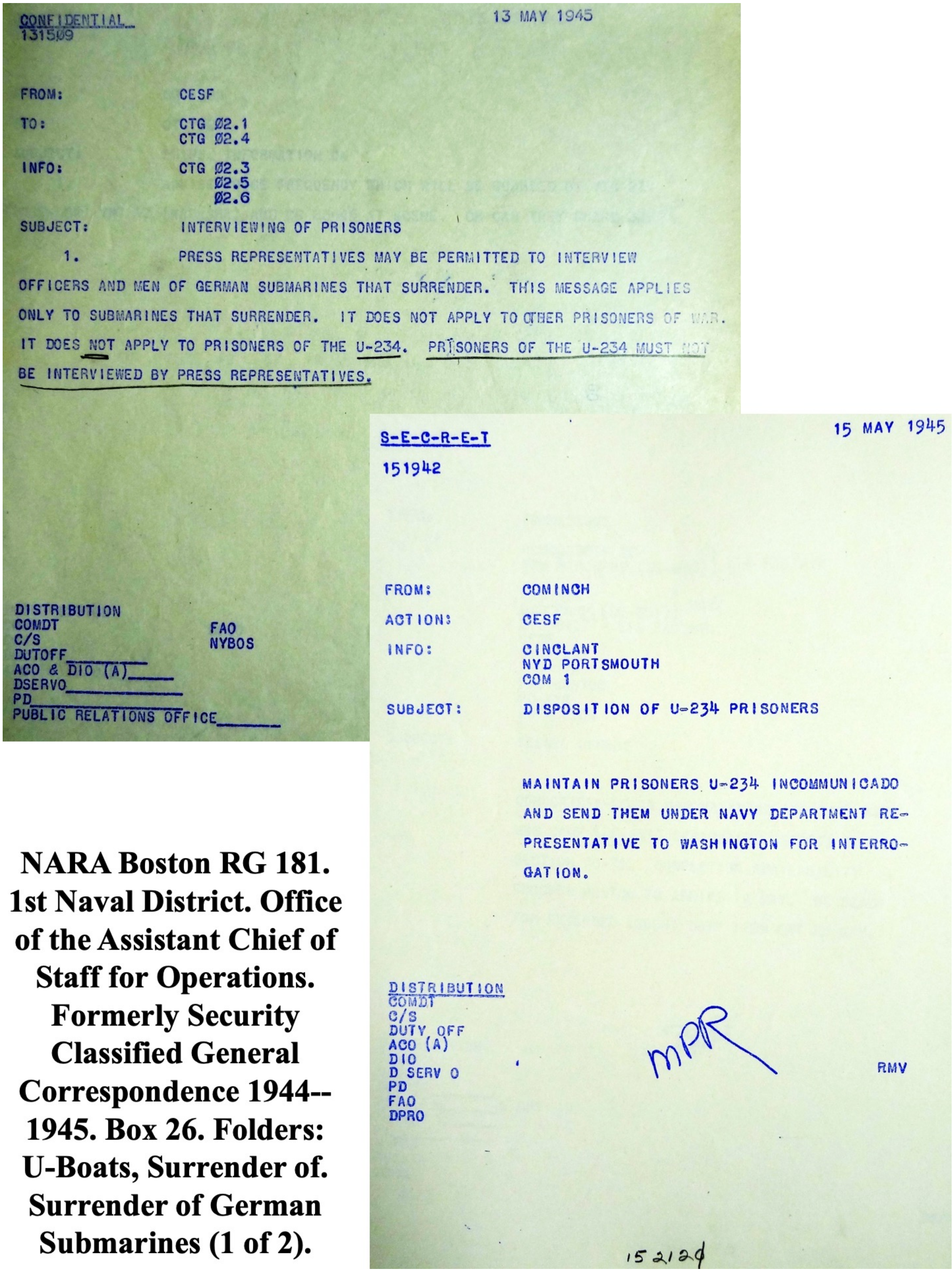
U.S. Navy Secret Dispatch 151942. Subject: Disposition of U-234 Prisoners. 15 May 1945. [NARA Boston RG 181]

SECRET 15 May 1945
151942

FROM: COMINCH
ACTION: CESF
INFO: CINCLANT
NYD Portsmouth
COM 1
SUBJECT: Disposition of U-234 Prisoners

Maintain prisoners U-234 incommunicado and send them under Navy department representative to Washington for interrogation.

[See document photo on p. 4863 bottom.]



CONFIDENTIAL
131509

13 MAY 1945

FROM: CESF

TO: CTG 02.1
CTG 02.4

INFO: CTG 02.3
02.5
02.6

SUBJECT: INTERVIEWING OF PRISONERS

1. PRESS REPRESENTATIVES MAY BE PERMITTED TO INTERVIEW OFFICERS AND MEN OF GERMAN SUBMARINES THAT SURRENDER. THIS MESSAGE APPLIES ONLY TO SUBMARINES THAT SURRENDER. IT DOES NOT APPLY TO OTHER PRISONERS OF WAR. IT DOES NOT APPLY TO PRISONERS OF THE U-234. PRISONERS OF THE U-234 MUST NOT BE INTERVIEWED BY PRESS REPRESENTATIVES.

DISTRIBUTION
COMDT
C/S
DUTOFF
ACO & DIO (A)
DSERVO
PD
PUBLIC RELATIONS OFFICE

FAO
NYBOS

S-E-C-R-E-T

151942

15 MAY 1945

FROM: COMINCH

ACTION: CESF

INFO: CINCLANT
NYD PORTSMOUTH
COM 1

SUBJECT: DISPOSITION OF U-234 PRISONERS

MAINTAIN PRISONERS U-234 INCOMMUNICADO AND SEND THEM UNDER NAVY DEPARTMENT REPRESENTATIVE TO WASHINGTON FOR INTERROGATION.

DISTRIBUTION
COMDT
C/S
DUTY OFF
ACO (A)
DIO
D SERV O
PD
FAO
DPRO

MPR

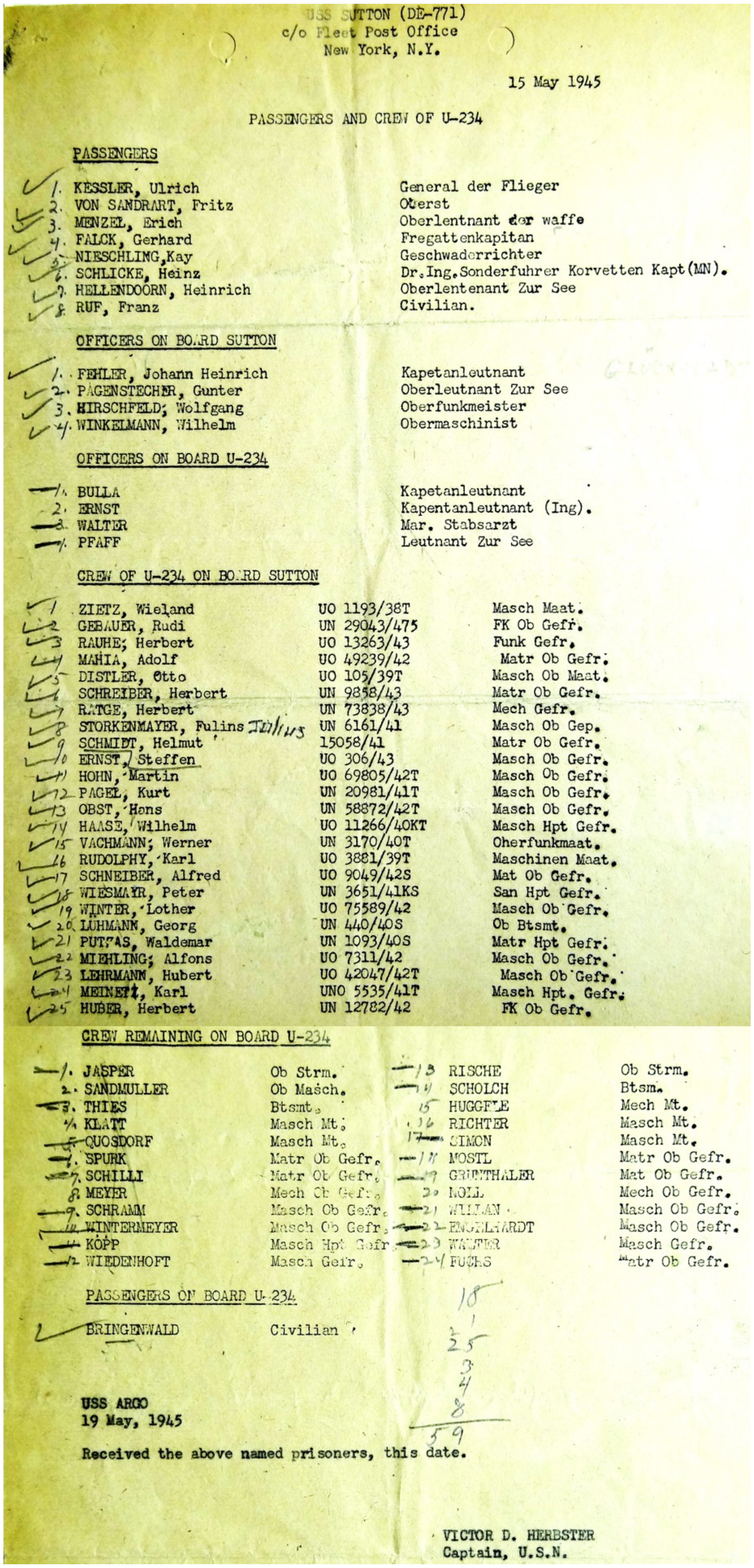
RMV

152120

NARA Boston RG 181. 1st Naval District. Office of the Assistant Chief of Staff for Operations. Formerly Security Classified General Correspondence 1944--1945. Box 26. Folders: U-Boats, Surrender of. Surrender of German Submarines (1 of 2).

Figure D.907: U.S. Navy Secret Dispatches [NARA Boston RG 181]

NARA Boston RG 181. 1st Naval District. Office of the Assistant Chief of Staff for Operations. Formerly Security Classified General Correspondence 1944--1945. Box 26. Folder Surrender of German Submarines (1 of 2).



USS SUTTON (DE-771)
c/o Fleet Post Office
New York, N.Y.

15 May 1945

PASSENGERS AND CREW OF U-234

PASSENGERS

1.	KESSLER, Ulrich	General der Flieger
2.	VON SANDRART, Fritz	Oberst
3.	MENZEL, Erich	Oberlentnant der waffe
4.	FALCK, Gerhard	Fregattenkapitan
5.	NIESCHLING, Kay	Geschwaderrichter
6.	SCHLICKE, Heinz	Dr.Ing.Sonderfuhrer Korvetten Kapt(MN).
7.	HELLENDOORN, Heinrich	Oberlentenant Zur See
8.	RUF, Franz	Civilian.

OFFICERS ON BOARD SUTTON

1.	FEHLER, Johann Heinrich	Kapetanleutnant
2.	PAGENSTECHER, Gunter	Oberleutnant Zur See
3.	HIRSCHFELD, Wolfgang	Oberfunkmeister
4.	WINKELMANN, Wilhelm	Obermaschinist

OFFICERS ON BOARD U-234

1.	BULLA	Kapetanleutnant
2.	ERNST	Kapentanleutnant (Ing).
3.	WALTER	Mar. Stabsarzt
4.	PFAFF	Leutnant Zur See

CREW OF U-234 ON BOARD SUTTON

1	ZIETZ, Wieland	UO 1193/38T	Masch Maat.
2	GEBAUER, Rudi	UN 29043/475	FK Ob Gefr.
3	RAUHE, Herbert	UO 13263/43	Funk Gefr.
4	MAHIA, Adolf	UO 49239/42	Matr Ob Gefr.
5	DISTLER, Otto	UO 105/39T	Masch Ob Maat.
6	SCHREIBER, Herbert	UN 9858/43	Matr Ob Gefr.
7	RATGE, Herbert	UN 73838/43	Mech Gefr.
8	STORKENMAYER, Fulins Julius	UN 6161/41	Masch Ob Gep.
9	SCHMIDT, Helmut	15058/41	Matr Ob Gefr.
10	ERNST, Steffen	UO 306/43	Masch Ob Gefr.
11	HOHN, Martin	UO 69805/42T	Masch Ob Gefr.
12	PAGEL, Kurt	UN 20981/41T	Masch Ob Gefr.
13	OBST, Hans	UN 58872/42T	Masch Ob Gefr.
14	HAASE, Wilhelm	UO 11266/40KT	Masch Hpt Gefr.
15	VACHMANN, Werner	UN 3170/40T	Oherfunkmaat.
16	RUDOLPHY, Karl	UO 3881/39T	Maschinen Maat.
17	SCHNEIBER, Alfred	UO 9049/42S	Mat Ob Gefr.
18	WIESMAYR, Peter	UN 3651/41KS	San Hpt Gefr.
19	WINTER, Lother	UO 75589/42	Masch Ob Gefr.
20	LUHMANN, Georg	UN 440/40S	Ob Btsmt.
21	PUTZAS, Waldemar	UN 1093/40S	Matr Hpt Gefr.
22	MIEHLING, Alfons	UO 7311/42	Masch Ob Gefr.
23	LEHRMANN, Hubert	UO 42047/42T	Masch Ob Gefr.
24	MEINERT, Karl	UNO 5535/41T	Masch Hpt. Gefr.
25	HUBER, Herbert	UN 12782/42	FK Ob Gefr.

CREW REMAINING ON BOARD U-234

1.	JASPER	Ob Strm.	13	RISCHE	Ob Strm.
2.	SANDMULLER	Ob Masch.	14	SCHOLCH	Btsm.
3.	THIES	Btsmt.	15	HUGGFLE	Mech Mt.
4.	KLATT	Masch Mt.	16	RICHTER	Masch Mt.
5.	QUOSDORF	Masch Mt.	17	SIMON	Masch Mt.
6.	SPURK	Matr Ob Gefr.	18	MOSTL	Matr Ob Gefr.
7.	SCHILLI	Matr Ob Gefr.	19	GRUNTHALER	Mat Ob Gefr.
8.	MEYER	Mech Ob Gefr.	20	NOLL	Mech Ob Gefr.
9.	SCHRAMM	Masch Ob Gefr.	21	WILLIAN	Masch Ob Gefr.
10.	WINTERMEYER	Masch Ob Gefr.	22	ENGELHARDT	Masch Ob Gefr.
11.	KÖPP	Masch Hpt Gefr.	23	WALTER	Masch Gefr.
12.	WIEDENHOFT	Masch Gefr.	24	FUCHS	Matr Ob Gefr.

PASSENGERS ON BOARD U-234

BRINGENWALD	Civilian

18
1
25
3
4
8
59

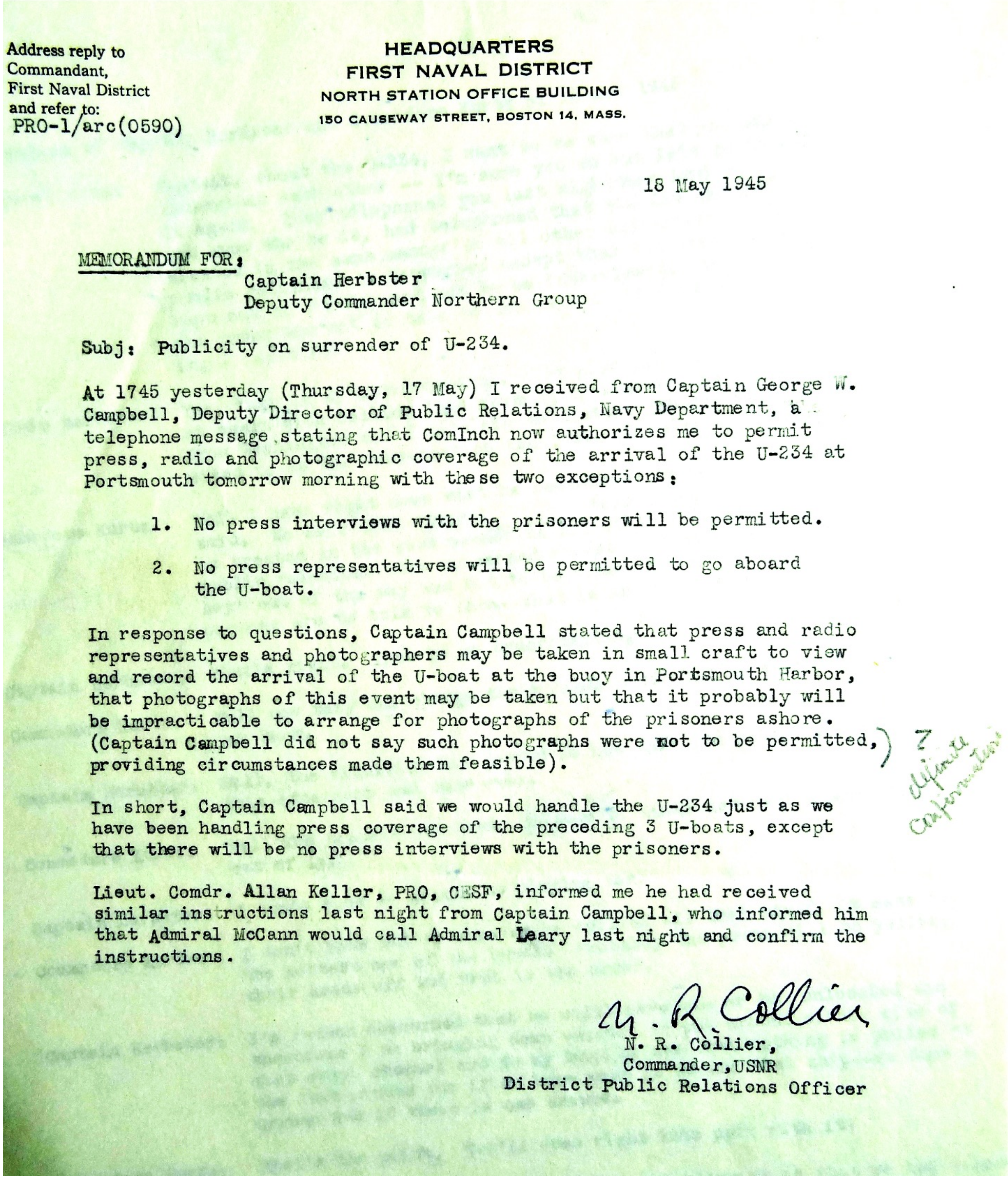
USS ARGO
19 May, 1945

Received the above named prisoners, this date.

VICTOR D. HERBSTER
Captain, U.S.N.

Figure D.908: U.S. Navy Secret Dispatches [NARA Boston RG 181]

NARA Boston RG 181. 1st Naval District. Office of the Assistant Chief of Staff for Operations. Formerly Security Classified General Correspondence 1944--1945. Box 26. Folder Surrender of German Submarines (1 of 2).



Address reply to
Commandant,
First Naval District
and refer to:
PRO-1/arc(0590)

HEADQUARTERS
FIRST NAVAL DISTRICT
NORTH STATION OFFICE BUILDING
150 CAUSEWAY STREET, BOSTON 14, MASS.

18 May 1945

MEMORANDUM FOR:
Captain Herbster
Deputy Commander Northern Group

Subj: Publicity on surrender of U-234.

At 1745 yesterday (Thursday, 17 May) I received from Captain George W. Campbell, Deputy Director of Public Relations, Navy Department, a telephone message stating that ComInch now authorizes me to permit press, radio and photographic coverage of the arrival of the U-234 at Portsmouth tomorrow morning with these two exceptions:

1. No press interviews with the prisoners will be permitted.

2. No press representatives will be permitted to go aboard the U-boat.

In response to questions, Captain Campbell stated that press and radio representatives and photographers may be taken in small craft to view and record the arrival of the U-boat at the buoy in Portsmouth Harbor, that photographs of this event may be taken but that it probably will be impracticable to arrange for photographs of the prisoners ashore. (Captain Campbell did not say such photographs were not to be permitted, providing circumstances made them feasible).

? definite confirmation

In short, Captain Campbell said we would handle the U-234 just as we have been handling press coverage of the preceding 3 U-boats, except that there will be no press interviews with the prisoners.

Lieut. Comdr. Allan Keller, PRO, CESF, informed me he had received similar instructions last night from Captain Campbell, who informed him that Admiral McCann would call Admiral Leary last night and confirm the instructions.

N. R. Collier
N. R. Collier,
Commander, USNR
District Public Relations Officer

Figure D.909: Commander N. R. Collier to Captain Herbster. Subj: Publicity on surrender of U-234. 18 May 1945. [NARA Boston RG 181]

U.S. Navy Secret Dispatch 151716. 15 May 1945. [NARA Boston RG 181]

Documents and personnel of U-234 are most important and any and all doubtful personnel should be sent here.

[See document photo on p. 4867.]

Jack H. Alberti to John L. Riheldaffer. 22 May 1945. Subject: U-234. [NARA RG 38, Entry UD-38, Box 13, unlabelled folder]

1. The cargo of this U-boat consisting of some eight tons of documents, one ton of diplomatic mail and approximately 210 tons of miscellaneous cargo including numerous explosives, fuses, prototypes of radar, etc., is stowed in steel tubes fitted into the mine shafts of the boat. It is believed that the documents are not stowed in separate shafts but together with other cargo. The Portsmouth Navy Yard intends to unload these tubes and forward them "as is" to their destination. It is believed possible that some of these tubes contain hydrostatic scuttling charges designed to blow up the tubes in case of jettisoning. The tubes are sealed shut and will have to be opened with an oxyacetylene torch. Instructions are requested as to whether or not these tubes are to be opened at Portsmouth for segregation of their contents or if they are to be shipped to Washington unopened.

U-234, U-805, U-873. Undated but apparently late May 1945. [NARA RG 38, Entry UD-38, Box 13, unlabelled folder]

U-234

U-234, a type XB boat under Fehler, left Kristiansand on 14 April 1945[...] She carried 240 tons of cargo for Japan including one ton of diplomatic mail. While in transit she made or received no attacks. The ship's ciphers and papers were jettisoned, Fehler saying this was done by orders of Bdu. [...]

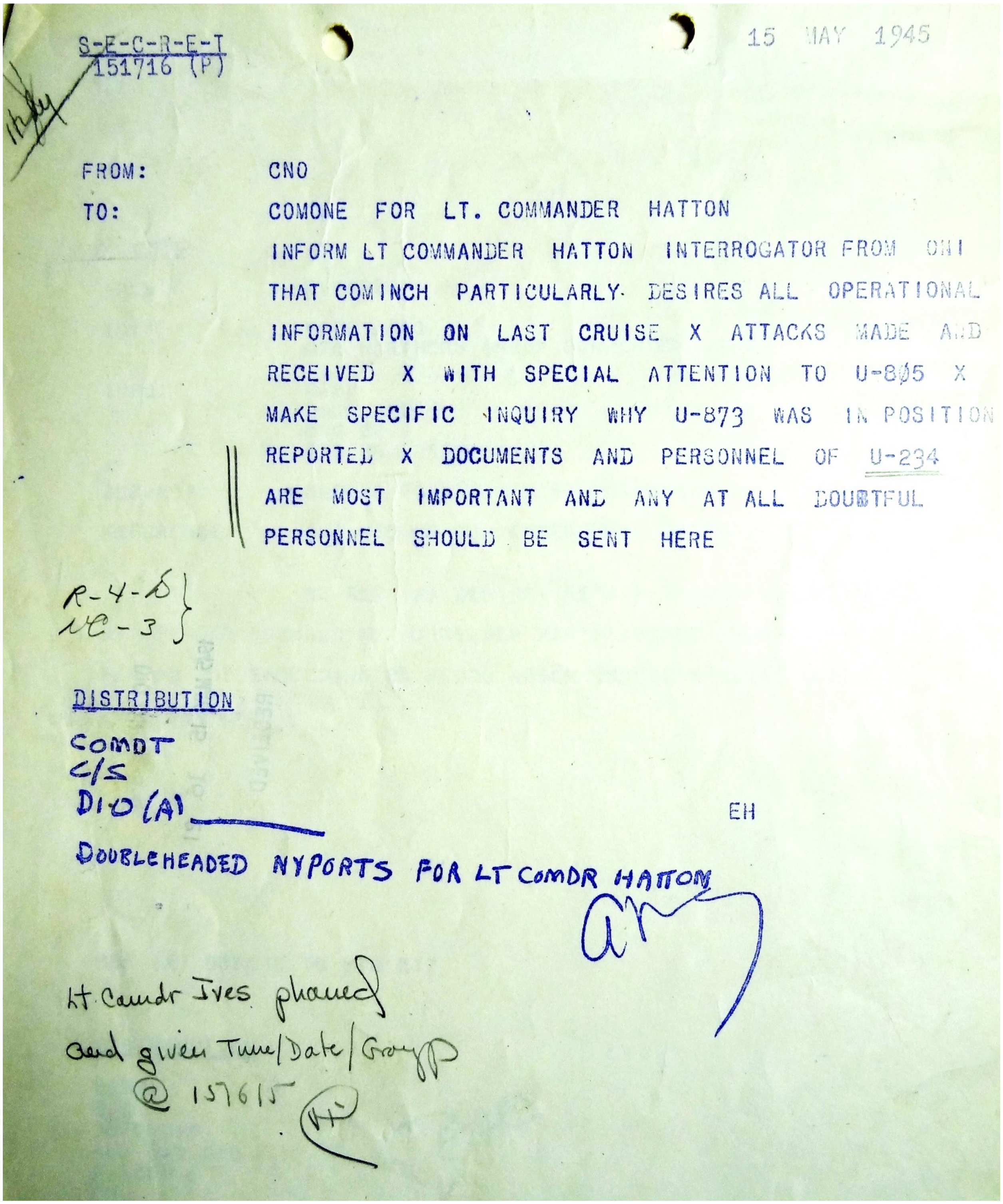
U-805

Interrogation of crew of U-805 reveals she left Kiel 10 February and Trondheim on 17 March. [...] After receipt of surrender orders, the commanding officer destroyed the envelope containing the special CO code, Kartenschluessel and Kurzsignal heft. Commanding Officer and second watch officer will be sent Washington for further investigation. [...]

U-873

U-873, commanded by Steinhoff, left Kristiansand about 1 April[...] All ship's papers and code machines were destroyed. In her ballast tanks was stowed a cargo of mercury and optical glass, and she was originally scheduled for Japan voyage instead of U-234. [...]

NARA Boston RG 181. 1st Naval District. Office of the Assistant Chief of Staff for Operations. Formerly Security Classified General Correspondence 1944--1945. Box 26. Folder U-Boats, Surrender of.



S-E-C-R-E-T
151716 (P)

15 MAY 1945

FROM: CNO

TO: COMONE FOR LT. COMMANDER HATTON

INFORM LT COMMANDER HATTON INTERROGATOR FROM ONI THAT COMINCH PARTICULARLY DESIRES ALL OPERATIONAL INFORMATION ON LAST CRUISE X ATTACKS MADE AND RECEIVED X WITH SPECIAL ATTENTION TO U-805 X MAKE SPECIFIC INQUIRY WHY U-873 WAS IN POSITION REPORTED X DOCUMENTS AND PERSONNEL OF U-234 ARE MOST IMPORTANT AND ANY AT ALL DOUBTFUL PERSONNEL SHOULD BE SENT HERE

R-4-D
NC-3

DISTRIBUTION

COMDT
C/S
DIO (A)

EH

DOUBLEHEADED NYPORTS FOR LT COMDR HATTON

Lt. Comdr Ives phoned
and given Time/Date/Group
@ 157615

Figure D.910: U.S. Navy Secret Dispatch 151716. 15 May 1945 [NARA Boston RG 181]

Captain Johann Fehler [Sellwood 1956]

[p. 137] The fitting-out of our U-boat proved interesting enough, and more complicated than we had thought. The packing side of it was extremely tricky, for some of the cargo was extremely sensitive to condensation, and every drum had to be thoroughly sealed before being cased in a protective skin of chemicals. Command now wanted us to carry an increased quota: this time we used reserve torpedo cylinders as containers . . . cutting deep into our diving tanks in order to stow them.

Finally our submarine was almost bursting at the seams. We had managed to take on board over two hundred and sixty tons of cargo!

[p. 195] The Yanks had left a strong guard on the *U-234* to supervise Bulla and his men. Now the buzz went round the *Sutton* that one of the Americans had been shot in the stomach. The Captain sent for me and I arrived at his cabin a very worried man, wondering what the hell had gone wrong, and which of my boys had fired the blasted bullet. It turned out, however, that there had been no quarrel. The guard had been accidentally shot by his own pal. They had been fooling around with a pistol in the W/T locker. He was badly wounded, but our [German] doctor was looking after him until a U.S. warship, equipped with an operating theatre, arrived. [...]

At first I bewildered. Then I got annoyed. I had handed over a U-boat not a kindergarten.

Jack H. Alberti to John L. Riheldaffer. 22 May 1945. Subject: Report on Events at Portsmouth Navy Yard in Connection with the Surrender of German Submarines U-234, U-805, U-873 and U-1228. [NARA RG 38, Entry UD-38, Box 13, unlabelled folder]

I. LOOTING

The usual extensive looting by boarding parties from the DE's had taken place. In the case of the USS SUTTON, which captured the U-234, interrogators were able to board the destroyer and examine the "souvenirs". Items of possible intelligence interest were removed, but the great majority of souvenirs were left in the hands of the ships' crews. There was no looting of prisoners about the USCG ARGO or aboard the tugs ENSEMORE and YAKIMA.

Because of the need of the presence of one of the interrogators, Lt. Cdr. Hatton, aboard U-234 until her docking, the passengers aboard this U-boat were accompanied to the Portsmouth Naval Prison on arrival by interrogators Lt. Maxwell and Mr. J. H. Alberti. These passengers were personally searched by these two interrogators.

The crew of the U-boat and their baggage were searched in the cell block by Marine guards in the presence of five or six Marine officers and at least two U.S.N. Medical Officers attached to the prison. Practically all items of value, such as watches, rings, decorations, wallets, even those containing personal photographs, etc. were looted from the prisoners. In some instances where enlisted men had taken watches from prisoners, these watches were taken from the enlisted men by Marine officers who retained them as souvenirs. This action has had a most detrimental effect on interrogation of the crew and jeopardizes the willingness to cooperate on the part of those members of the crew retained aboard the U-boats.

After the departure for Washington of the passengers, accompanied by Lt. Maxwell, the presence of Mr. Alberti was required aboard the U-boat. [...]

Looting aboard the U-boats at the dock has been carried on in a very large scale, both by members of the naval working party aboard and the Marine guard establishment. [...]

II. SAFETY OF THE CAPTURED GERMAN U-BOATS

All four U-boats carried large quantities of liquor. [...]

On the morning of 20 May, Lt. Ewald of Op-20-G boarded U-234 and found U.S. Naval ratings drunk aboard. At various times on 20 and 21 May, U.S. Naval ratings were found asleep in the bunks while on duty in U-234. [...]

The captain of the U-234, while complaining to interrogating officers about the looting of the personal effects of his crew and himself, mentioned that he was all the more indignant at this treatment considering that all he had to do was to pull a lever and everyone of his mine shafts would have been emptied of their contents. [...]

[Jack Alberti, though an American himself, gave extremely unflattering descriptions of the behavior of the Americans who received this submarine, which had made such a remarkable journey to deliver over 260 tons of the world's most advanced technologies.

Johann Fehler also described in detail widespread conduct among the receiving American forces that was highly unprofessional, unethical, and uneducated [Sellwood 1956].

The "extensive looting" that was "carried on in a very large scale" (in Alberti's words) makes it even more difficult to reconstruct exactly what information and items were carried by the submarine and its personnel.]

U.S. Navy Secret Dispatch 222115. U-234, Disposition of. 23 May 1945. [NARA Boston RG 181]

Desire following accomplished cargo U-234... All material after rendering safe by mine disposal personnel placed safe stowage and inventory list sent CNO who will give shipping instructions and will control access to and disposition of all cargo due to vital importance to Pacific War.

[See document photo on p. 4871.]

Lt. Best. 24 May 1945. Report of Interrogation: PW: NIESCHLING, Kay. [NARA RG 38, Entry UD-38, Box 13, Folder U-234]

Veracity:

The following is believed reliable.

Report: Regarding "URANIUM OXIDE" and other CARGO aboard U-234:

P/W does not know anything in particular about this ore, but only heard that it was valuable and that it was to be exchanged for some other valuable ore that the Germans needed.

Lt. PFAFF was the man responsible for loading the U-Boat.

The meaning behind the ore would, according to P/W be known by the technician Fregattenkapitan FALCK (Commander). The latter also knows magnetic problems, Naval mine problems, Naval building problems. He also took some secret courses before he boarded the U-Boat. Was to be chief technician on all naval matters under Admiral WENNECKER.

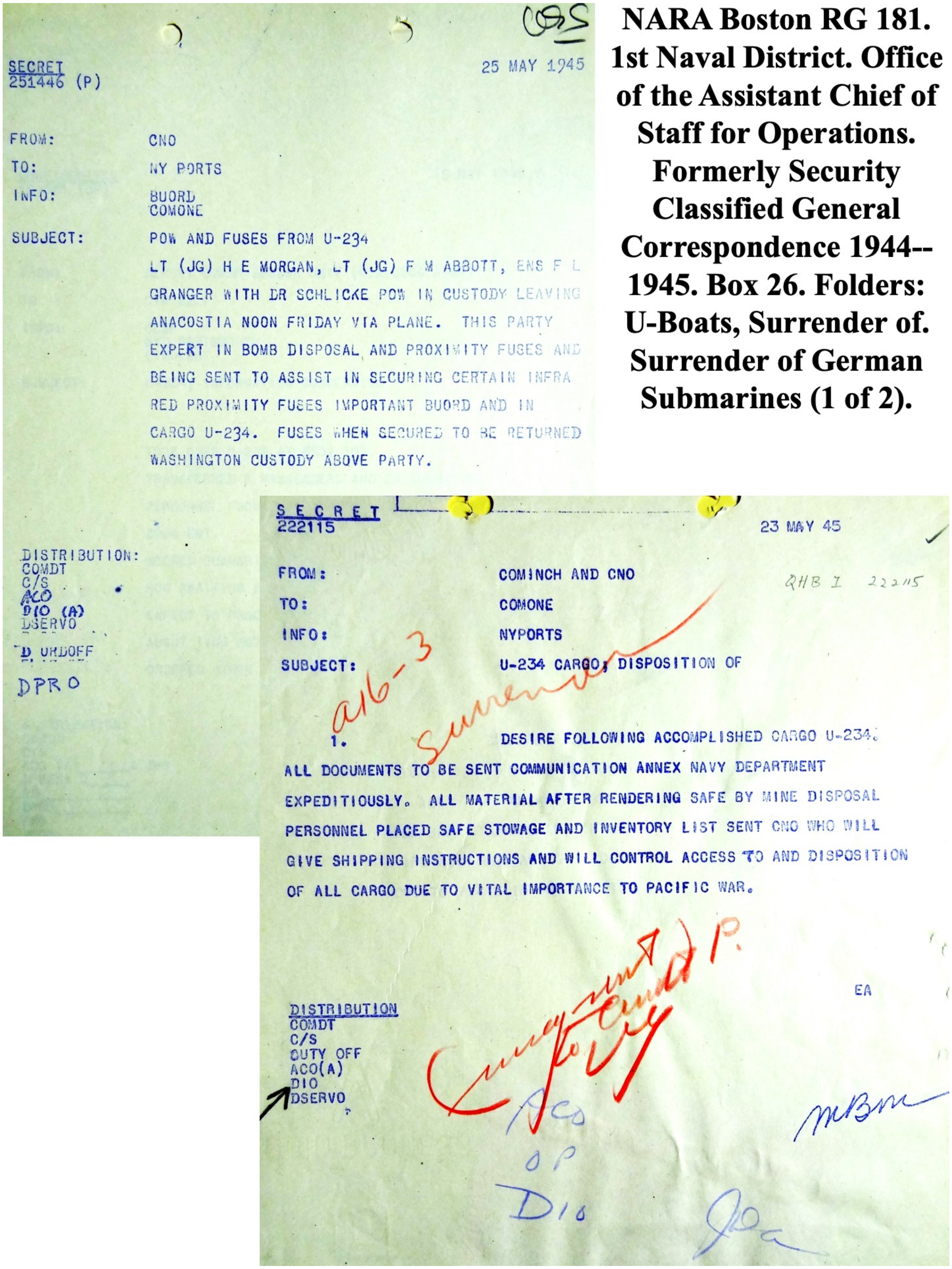
Captain FEHLER as commander of the U-Boat should also know something about the ore.

It may be important to contact a man named Korvettenkapitan BECKER (Lt. Commander), living in KIEL-WIG, who was a member of the Marine Sonderstabzweigstelleheimat. (Special Naval Home Sub-station Branch).

This man traveled to the various factories in NUERNBERG and others in South Germany. He was responsible for contacting the various agencies regarding what and how much was to be included in the cargo.

The Marine Attache Abt. in Berlin Oberkommando, Referat Japan under Captain zur see "SOUCHON" decided together with the Japanese just what the most important things were that should be included in the cargo. The latter's assistant a Korvettenkapitan von KROSIGK (Lt. Commander) also should know the details.

NARA Boston RG 181. 1st Naval District. Office of the Assistant Chief of Staff for Operations. Formerly Security Classified General Correspondence 1944--1945. Box 26. Folders: U-Boats, Surrender of. Surrender of German Submarines (1 of 2).



SECRET
251446 (P)

25 MAY 1945

FROM: CNO
TO: NY PORTS
INFO: BUORD
COMONE
SUBJECT: POW AND FUSES FROM U-234

LT (JG) H E MORGAN, LT (JG) F M ABBOTT, ENS F L GRANGER WITH DR SCHLICKE POW IN CUSTODY LEAVING ANACOSTIA NOON FRIDAY VIA PLANE. THIS PARTY EXPERT IN BOMB DISPOSAL AND PROXIMITY FUSES AND BEING SENT TO ASSIST IN SECURING CERTAIN INFRA RED PROXIMITY FUSES IMPORTANT BUORD AND IN CARGO U-234. FUSES WHEN SECURED TO BE RETURNED WASHINGTON CUSTODY ABOVE PARTY.

DISTRIBUTION:
COMDT
C/S
ACO
DIO (A)
DSERVO
D URDOFF
DPRO

SECRET
222115

23 MAY 45

QHB I 222115

FROM: COMINCH AND CNO
TO: COMONE
INFO: NYPORTS
SUBJECT: U-234 CARGO; DISPOSITION OF

a16-3
Surrender

1. DESIRE FOLLOWING ACCOMPLISHED CARGO U-234. ALL DOCUMENTS TO BE SENT COMMUNICATION ANNEX NAVY DEPARTMENT EXPEDITIOUSLY. ALL MATERIAL AFTER RENDERING SAFE BY MINE DISPOSAL PERSONNEL PLACED SAFE STOWAGE AND INVENTORY LIST SENT CNO WHO WILL GIVE SHIPPING INSTRUCTIONS AND WILL CONTROL ACCESS TO AND DISPOSITION OF ALL CARGO DUE TO VITAL IMPORTANCE TO PACIFIC WAR.

EA

DISTRIBUTION
COMDT
C/S
DUTY OFF
ACO(A)
DIO
DSERVO

Consignment to Comdt P. Wy

ACO
OP
DIO

MBM

Figure D.911: U.S. Navy Secret Dispatches [NARA Boston RG 181]

U.S. Navy Secret Dispatch 262151. Subject: Mine Tubes, Unloading of. 27 May 1945. [NARA Boston RG 181]

Interrogation Lt Pfaff second watch officer U-234 discloses he was in charge of cargo and personally supervised loading all mine tubes.

Pfaff prepared manifest list and knows kind documents and cargo in each tube.

Pfaff states long containers should be unpacked in horizontal position and short containers in vertical position.

Uranium oxide loaded in gold lined cylinders and as long as cylinders not opened can be handled like crude TNT.

These containers should not be opened as substance will become sensitive and dangerous.

Pfaff is available and willing to aid unloading if RNEDT desires.

Advise.

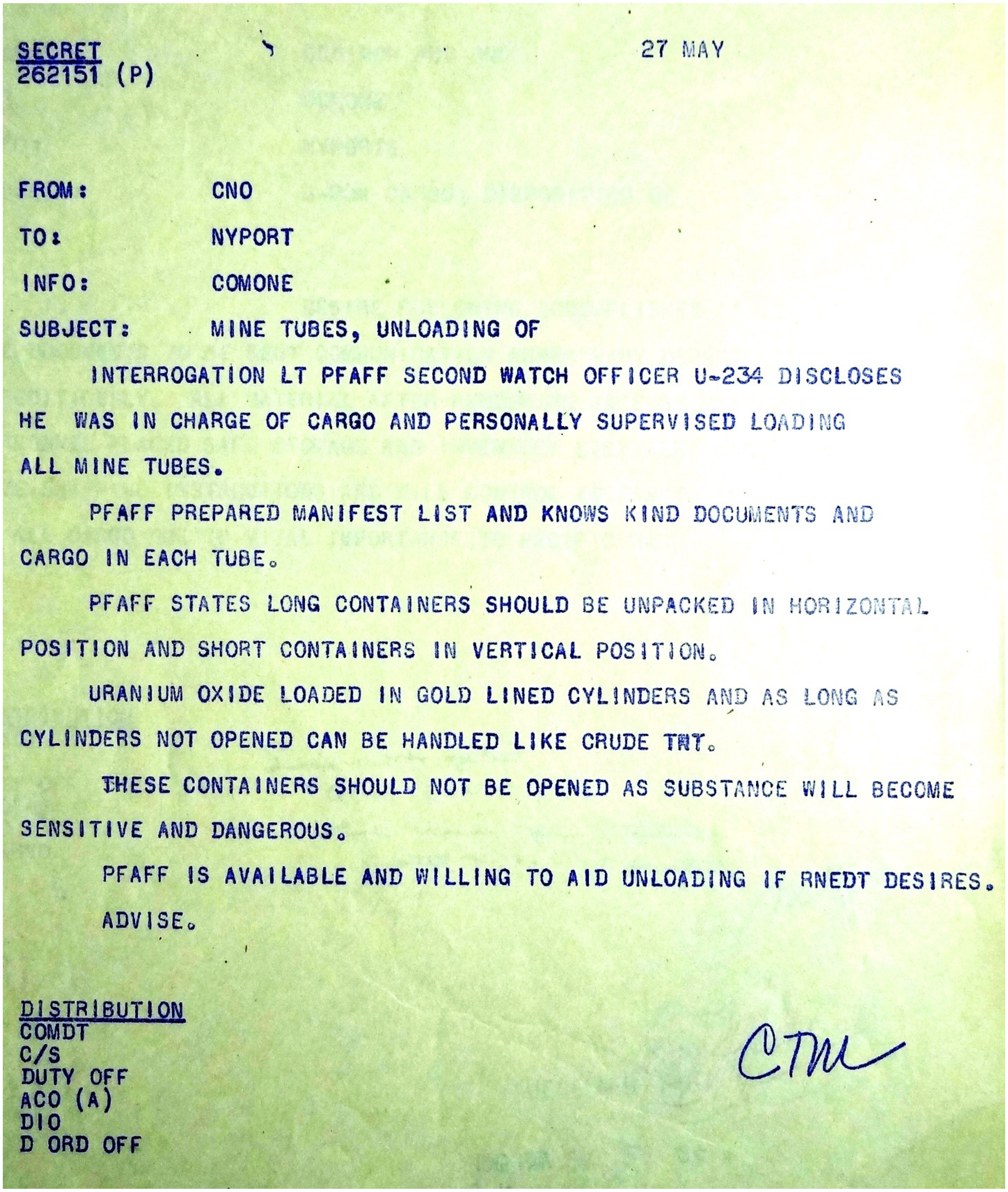
[See photo on p. 4873. Lt. Pfaff, the German naval officer in charge of loading the U-234's cargo, specifically informed the U.S. Navy that the uranium oxide was stored in many separate, sealed, gold-lined cylinders. Moreover, he told the U.S. Navy that the uranium oxide could be dangerous if the cylinders were opened and it were mishandled, just as TNT would. Pfaff's warning suggests that the uranium might have been capable of starting a neutron chain reaction if the cylinders were opened and gold shielding no longer separated the individual pieces of uranium from each other.

Gold is very resistant to chemical corrosion, and it is extremely dense, which makes it good at shielding neutrons or other radiation. Unenriched uranium oxide is not dangerously radioactive and would require no special shielding or packaging. Furthermore, unenriched uranium oxide could not form a critical mass and initiate a neutron chain reaction no matter how much was brought together and how it was mishandled, so there would be no need to package it into many separate, sealed, gold-lined cylinders and issue warnings about it being dangerous and explosive if mishandled.

On the other hand, storing small quantities of uranium in many separate, sealed, gold-lined cylinders would be exactly the right approach for handling weapons-grade, highly enriched uranium. When the United States produced and shipped weapons-grade, highly enriched uranium from Oak Ridge to Los Alamos, it did in fact divide the uranium into many separate, sealed, gold-lined containers, as documented on pp. 4874–4875.

Of course, there are many possibilities. Maybe all of the uranium oxide cargo of U-234 had been highly enriched, in which case 560 kg would provide enough for a shockingly large arsenal of $\sim$10–100 fission bombs, depending on their size and design. Perhaps the uranium oxide had been somewhat enriched, but not yet to weapons-grade levels. Maybe different batches of the uranium oxide had been enriched by different amounts. Perhaps the uranium oxide was unenriched or only somewhat enriched but had been neutron-irradiated inside a functioning fission reactor somewhere in the Third Reich, which would have made it highly radioactive and also a good source for extracting plutonium-239 that had been produced in the process. One might imagine other possibilities as well. Thus it is very important for future archival researchers to find historical documents that will answer these questions.]

NARA Boston RG 181. 1st Naval District. Office of the Assistant Chief of Staff for Operations. Formerly Security Classified General Correspondence 1944--1945. Box 26. Folder U-Boats, Surrender of.



SECRET
262151 (P)

27 MAY

FROM: CNO

TO: NYPORT

INFO: COMONE

SUBJECT: MINE TUBES, UNLOADING OF

INTERROGATION LT PFAFF SECOND WATCH OFFICER U-234 DISCLOSES HE WAS IN CHARGE OF CARGO AND PERSONALLY SUPERVISED LOADING ALL MINE TUBES.

PFAFF PREPARED MANIFEST LIST AND KNOWS KIND DOCUMENTS AND CARGO IN EACH TUBE.

PFAFF STATES LONG CONTAINERS SHOULD BE UNPACKED IN HORIZONTAL POSITION AND SHORT CONTAINERS IN VERTICAL POSITION.

URANIUM OXIDE LOADED IN GOLD LINED CYLINDERS AND AS LONG AS CYLINDERS NOT OPENED CAN BE HANDLED LIKE CRUDE TNT.

THESE CONTAINERS SHOULD NOT BE OPENED AS SUBSTANCE WILL BECOME SENSITIVE AND DANGEROUS.

PFAFF IS AVAILABLE AND WILLING TO AID UNLOADING IF RNEDT DESIRES.

ADVISE.

DISTRIBUTION
COMDT
C/S
DUTY OFF
ACO (A)
DIO
D ORD OFF

CTM

Figure D.912: U.S. Navy Secret Dispatch 262151. Subject: Mine Tubes, Unloading of. 27 May 1945. [NARA Boston RG 181]

Oak Ridge National Laboratory. Operations start and shipments begin.
[http://www.y12.doe.gov/sites/default/files/assets/document/07-12-06.pdf]

[The uranium transported on the U-234 was stored in many separate, gold-lined cylinders. As described below, highly enriched uranium was transported from Oak Ridge to Los Alamos in many separate, gold-lined cylinders. There was no need to transport unenriched uranium in such an elaborate fashion.]

The first successful shipment from Y-12 served also to demonstrate that the concept of a production factory was basically in place. The process included the full sequence of events required to take uranium ore and process the material to the final special end product of uranium 235 suitable for shipment by courier.

A most unusual method was used to transport this extremely valuable material. It was carefully packaged in a small room in the center of Building 9733-1. Then the material was placed in gold-lined nickel containers about the size of coffee cups. Two of these containers were placed in a briefcase size container and the container strapped to an Army Lieutenant's arm. He was dressed in a suit to look like a salesman and along with a couple of other Army personnel also dressed as salesmen, was driven to Knoxville where he boarded a passenger train to Chicago.

At Chicago, the courier transferred his case to yet another Army Lieutenant also dressed as a salesman who took the material on to Los Alamos. A new set of escorts were assigned to this new courier and the original group returned to Oak Ridge by way of Knoxville.

In *The New World*, by Richard G. Hewlett and Oscar E. Anderson Jr., the following description is provided regarding the transportation of uranium-235 from Y-12 to Los Alamos.

> "Transporting the precious material to Los Alamos involved all the melodrama of an undercover operation.
>
> "Since air travel seemed too risky, the Army shipped the product by rail. The containers of uranium tetrafluoride were placed in special luggage. At 10:30 a.m. on specified days, armed couriers wearing civilian clothes took the shipments to Knoxville in an unmarked Chevrolet sedan with Tennessee license plates. At 12:50 p.m., the couriers left for Chicago in a private compartment aboard the 'Southland.'
>
> "Arriving in Chicago the next morning, the Oak Ridge couriers were met by Chicago couriers who boarded the Santa Fe 'Chief' for the long ride west. The next day at 2:10 p.m., a car from Los Alamos met the train at Lamy, a way station in the New Mexico desert. There was some danger that conductors, porters, and station attendants might come to recognize the couriers no matter how hard they tried to make themselves inconspicuous, but train transportation was cheap and relatively safe."

That "special luggage" mentioned in the book was a briefcase-type container with two coffee-cup-sized gold-lined nickel containers. The "briefcase" was strapped to the arm of an Army lieutenant who was dressed to look like a salesman.

This method of shipment kept folks in Knoxville asking, "What's going on over there at Y-12?" They saw trainload after trainload of building materials going to Oak Ridge, but they never saw anything being shipped out because they did not expect the product to be shipped in something as small as a briefcase.

Here's another story that shows the value placed on the uranium 235. The entire Y-12 production of U-235 prior to the dropping of the bomb Little Boy passed through room 22 of Building 9733-1. At one time, there were bars on the windows and a guard was posted outside the door to protect the output of Y-12's calutrons. The material was processed in one kilogram batches.

Twenty-four karat gold trays weighing about four pounds were used to process the material. The first batches were ground by hand using a mortar and pestle made of nickel. After the grinding operations, the workers had to check under their fingernails to be sure the material had not accumulated there.

The coffee-cup-size nickel cylinders used to transport the U-235 were made by a group in the Y-12 shops headed by Jack Case, Y-12 plant manager from 1967 to 1982 and namesake of the Jack Case Center. They were gold plated in Slack's Plating Shop in Knoxville. Johnsson was driven to Knoxville to deliver and pick up the cylinders by one of Y-12's Motor Pool drivers (a Mrs. Justice).

The filled cylinders were delivered to Captain Lloyd Zumwalt, who was located in an office two blocks from Building 9733-1. When the captain found out they were walking with cylinders containing U-235, he instructed those delivering it to, "Call for a car. If you got run over it would be a mess to dig up the ground to recover the uranium but in a car it would be all in one place."

U.S. Navy Secret Dispatch 292045. Subject: U-234, Cargo Information. 30 May 1945. [NARA Boston RG 181]

Lieut Comdr Karl B Reese USNR, Lieut (JG) Edward P McDermott USNR and Major John E Vance CE USA [Corps of Engineers, United States Army] will report to commandant May 30th Wednesday in connection with cargo U-234.

It is contemplated that shipment will be made by ship to ordnance investigation laboratory NAVPOWFAC Indian Head Maryland if this is feasible.

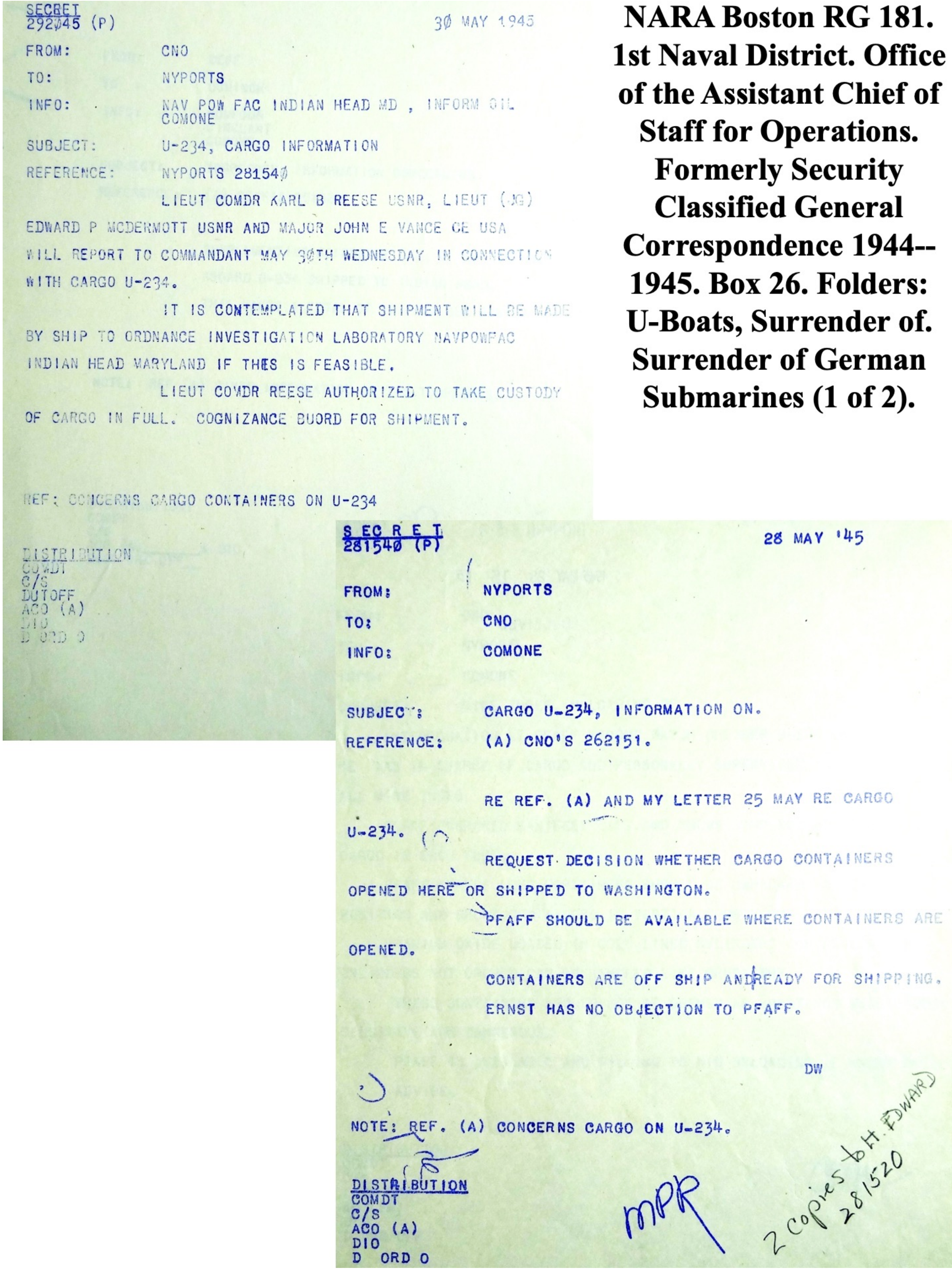
[See document photo on p. 4877.

John Vance worked for the Manhattan Project and would have been an ideal person to facilitate the transport of the uranium from the U-234 to the Manhattan Project. The uranium was temporarily stored at Indian Head, Maryland, along the way.]

Joseph Mark Scalia. 2000. *Germany's Last Mission to Japan: The Failed Voyage of U-234.* Annapolis, Maryland: Naval Institute Press. p. 233.

35. Interview, Pfaff with Wilcox, 24 February 1995. Pfaff recalled that once the welders opened the cylinders, he noticed "a tall civilian... with a large hat" examining the boxes. Because the stranger was rather conspicuous, Pfaff inquired as to his identity and was told that he was "Oppenheimer". Only later, as a prisoner of war in Louisiana, did he realize that the man with the large hat might have been J. Robert Oppenheimer, director of the Manhattan Project. While it cannot be confirmed that the man Pfaff saw was Oppenheimer, the physicist was in the vicinity during late May and early June 1945. He was in Washington to attend a meeting with Henry Stimson, James F. Byrnes, and Gen. Leslie Groves and the Interim Committee; that he would travel to southern Maryland to examine a captured German stock of uranium oxide is not out of the realm of possibility.

[Karl Pfaff also described the same incident with Oppenheimer when interviewed in: Andreas Gutzeit. 2001. *U-234: Hitler's Last U-Boat.* Film. Washington, D.C.: Story House Productions.]



SECRET
292045 (P) 30 MAY 1945

FROM: CNO
TO: NYPORTS
INFO: NAV POW FAC INDIAN HEAD MD , INFORM OIL
COMONE
SUBJECT: U-234, CARGO INFORMATION
REFERENCE: NYPORTS 281540

LIEUT COMDR KARL B REESE USNR, LIEUT (JG) EDWARD P MCDERMOTT USNR AND MAJOR JOHN E VANCE CE USA WILL REPORT TO COMMANDANT MAY 30TH WEDNESDAY IN CONNECTION WITH CARGO U-234.

IT IS CONTEMPLATED THAT SHIPMENT WILL BE MADE BY SHIP TO ORDNANCE INVESTIGATION LABORATORY NAVPOWFAC INDIAN HEAD MARYLAND IF THES IS FEASIBLE.

LIEUT COMDR REESE AUTHORIZED TO TAKE CUSTODY OF CARGO IN FULL. COGNIZANCE BUORD FOR SHIPMENT.

REF: CONCERNS CARGO CONTAINERS ON U-234

DISTRIBUTION
COMDT
C/S
DUTOFF
ACO (A)
DIO
D ORD O

SECRET
281540 (P) 28 MAY '45

FROM: NYPORTS
TO: CNO
INFO: COMONE

SUBJECT: CARGO U-234, INFORMATION ON.
REFERENCE: (A) CNO'S 262151.

RE REF. (A) AND MY LETTER 25 MAY RE CARGO U-234.

REQUEST DECISION WHETHER CARGO CONTAINERS OPENED HERE OR SHIPPED TO WASHINGTON.

PFAFF SHOULD BE AVAILABLE WHERE CONTAINERS ARE OPENED.

CONTAINERS ARE OFF SHIP AND READY FOR SHIPPING.

ERNST HAS NO OBJECTION TO PFAFF.

DW

NOTE: REF. (A) CONCERNS CARGO ON U-234.

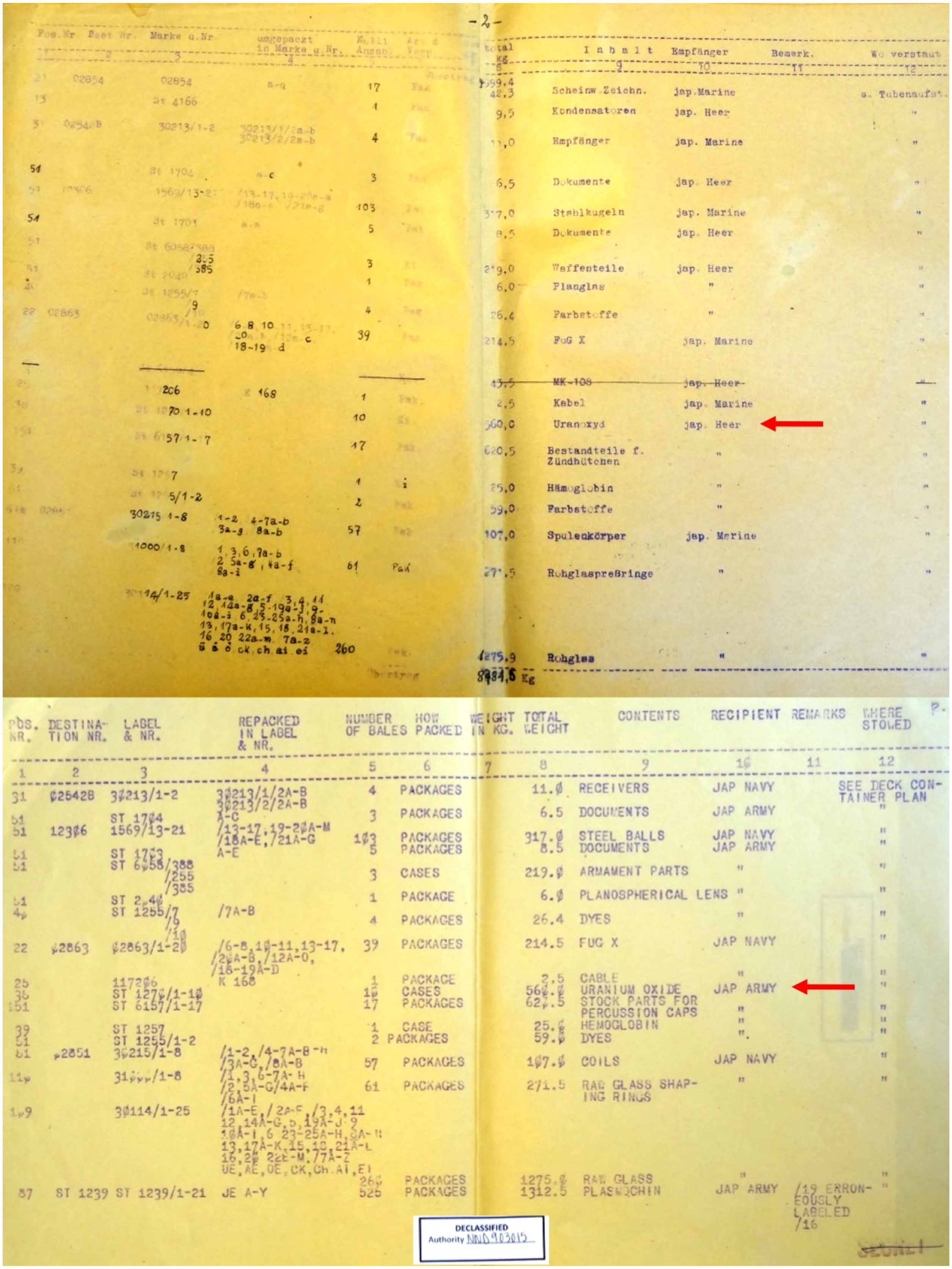
DISTRIBUTION
COMDT
C/S
ACO (A)
DIO
D ORD O

MPR

2 copies to H. EDWARD
281520

NARA Boston RG 181. 1st Naval District. Office of the Assistant Chief of Staff for Operations. Formerly Security Classified General Correspondence 1944--1945. Box 26. Folders: U-Boats, Surrender of. Surrender of German Submarines (1 of 2).

Figure D.913: U.S. Navy Secret Dispatches [NARA Boston RG 181]



-2-

Pos.Nr	Best Nr.	Marke u.Nr	umgepackt in Marke u.Nr.	Kolli Anzahl	Art d. Verp.	total kg	Inhalt	Empfänger	Bemerk.	Wo verstaut
1	2	3	4	5	6	8	9	10	11	12
21	02854	02854	a-q	17	Pak	Übertrag 1599,4				
13		St 4166		1	Pak	42,3	Scheinw.Zeichn.	jap.Marine		s. Tubenaufst.
31	02542B	30213/1-2	30213/1/2a-b 30213/2/2a-b	4	Pak	11,0	Empfänger	jap. Marine		"
51		St 1704	a-c	3	Pak	6,5	Dokumente	jap. Heer		"
51	12306	1569/13-21	/13-17,19-20a-m /18a-e /21a-g	103	Pak	317,0	Stahlkugeln	jap. Marine		"
54		St 1703	a-e	5	Pak	8,5	Dokumente	jap. Heer		"
51		St 6058/388 /255 /385		3	Ki	219,0	Waffenteile	jap. Heer		"
51		St 2040		1	Pak	6,0	Planglas	"		"
40		St 1255/7 /9 /10	/7a-b	4	Pak	26,4	Farbstoffe	"		"
22	02863	02863/1-20	6-8, 10-11, 13-17, 20a-b, /12a-c, 18-19a-d	39	Pak	214,5	FuG X	jap. Marine		"
						~~43,5~~	~~MK-108~~	~~jap. Heer~~		~~"~~
25		117206	K 168	1	Pak	2,5	Kabel	jap. Marine		"
38		St 1270/1-10		10	Ki	560,0	Uranoxyd	jap. Heer		"
151		St 6157/1-17		17	Pak	620,5	Bestandteile f. Zündhütchen	"		"
39		St 1257		1	Ki	25,0	Hämoglobin	"		"
51		St 1255/1-2		2	Pak	59,0	Farbstoffe	"		"
51a	02851	30215/1-8	1-2 4-7a-b 3a-g 8a-b	57	Pak	107,0	Spulenkörper	jap. Marine		"
110		31000/1-8	1,3,6,7a-b 2,5a-g, 4a-f 8a-i	61	Pak	271,5	Rohglaspreßringe	"		"
109		30114/1-25	1a-e 2a-f 3,4,11 12,14a-g,5-19a-j,9- 10a-i 6,23-25a-h,8a-n 13,17a-k,15,18,21a-l. 16 20 22a-m 7a-z ü ä ö ck ch ai ei	260	Pak.	1275,9	Rohglas	"		"
					Übertrag	8484,5 Kg				

P.

POS. NR.	DESTINATION NR.	LABEL & NR.	REPACKED IN LABEL & NR.	NUMBER OF BALES	HOW PACKED	WEIGHT IN KG.	TOTAL WEIGHT	CONTENTS	RECIPIENT	REMARKS	WHERE STOWED
1	2	3	4	5	6	7	8	9	10	11	12
31	02542B	30213/1-2	30213/1/2A-B 30213/2/2A-B	4	PACKAGES		11.0	RECEIVERS	JAP NAVY		SEE DECK CONTAINER PLAN
51		ST 1704	A-C	3	PACKAGES		6.5	DOCUMENTS	JAP ARMY		"
51	12306	1569/13-21	/13-17,19-20A-M /18A-E,/21A-G	103	PACKAGES		317.0	STEEL BALLS	JAP NAVY		"
51		ST 1703	A-E	5	PACKAGES		8.5	DOCUMENTS	JAP ARMY		"
51		ST 6058/388 /255 /385		3	CASES		219.0	ARMAMENT PARTS	"		"
51		ST 2040		1	PACKAGE		6.0	PLANOSPHERICAL LENS	"		"
40		ST 1255/7 /9 /10	/7A-B	4	PACKAGES		26.4	DYES	"		"
22	02863	02863/1-20	/6-8,10-11,13-17, /20A-B,/12A-0, /18-19A-D	39	PACKAGES		214.5	FUG X	JAP NAVY		"
25		117206	K 168	1	PACKAGE		2.5	CABLE	"		"
38		ST 1270/1-10		10	CASES		560.0	URANIUM OXIDE	JAP ARMY		"
151		ST 6157/1-17		17	PACKAGES		620.5	STOCK PARTS FOR PERCUSSION CAPS	"		"
39		ST 1257		1	CASE		25.0	HEMOGLOBIN	"		"
51		ST 1255/1-2		2	PACKAGES		59.0	DYES	".		"
61	02851	30215/1-8	/1-2,/4-7A-B-H /3A-G,/8A-B	57	PACKAGES		107.0	COILS	JAP NAVY		"
110		31000/1-8	/1,3,6-7A-H /2,5A-G/4A-F /6A-I	61	PACKAGES		271.5	RAW GLASS SHAPING RINGS	"		"
109		30114/1-25	/1A-E,/2A-F,/3,4,11 12,14A-G,5,19A-J 9 10A-I,6 23-25A-H,8A-N 13,17A-K,15,18,21A-L 16,20 22E-M,77A-Z UE,AE,OE,CK,CH.AI,EI	260	PACKAGES		1275.0	RAW GLASS	"		"
87	ST 1239	ST 1239/1-21	JE A-Y	525	PACKAGES		1312.5	PLASMOCHIN	JAP ARMY	/19 ERRONEOUSLY LABELED /16	"

DECLASSIFIED
Authority NND 903015

~~SECRET~~

Figure D.914: U-234 German cargo manifest and English translation, both listing 10 cases totaling 560 kg of uranium oxide [NARA RG 38, Entry UD-16, Box 4, Folder Manifest of U-234].

William J. Broad, Captured Cargo, Captivating Mystery. *New York Times* 1995-12-31 p. A22.

Historians have quietly puzzled over that uranium shipment for years, wondering, among other things, what the American military did with it. Little headway was made because of Federal secrecy. Now, however, a former official of the Manhattan Project, John Lansdale Jr., says that the uranium went into the mix of raw materials used for making the world's first atom bombs. At the time he was an Army lieutenant colonel for intelligence and security for the atom bomb project. One of his main jobs was tracking uranium.

Mr. Lansdale's assertion in an interview raises the possibility that the American weapons that leveled the Japanese cities of Hiroshima and Nagasaki contained at least some nuclear material originally destined for Japan's own atomic program and, perhaps, for attacks on the United States.

[...] But Mr. Lansdale, the former official of the Manhattan Project, displayed no doubts in the interview about the fate of the U-234's shipment. "It went to the Manhattan District," he said without hesitation. "It certainly went into the Manhattan District supply of uranium."

[John Lansdale wrote or received many of the memos on the German nuclear program in the Manhattan Project's files [NARA RG 77, Entry UD-22A]. He stated unequivocally to the *New York Times* that the U-234's uranium cargo went to Oak Ridge ("the Manhattan District supply of uranium"), and he presumably would have been in a good position to know that. It makes perfect sense that the U-234's uranium would go to Oak Ridge, regardless of its state of enrichment. Its precise composition could be tested much more thoroughly and easily at the Oak Ridge laboratory than in the field at the Portsmouth Navy Yard. If the U-234's uranium was unenriched, it would have gone into the general stockpile of uranium awaiting enrichment by Oak Ridge's K-25 gaseous diffusion plant and Y-12 calutrons. If the uranium was somewhat enriched, it would have been sent to the calutrons for further enrichment. Even if it were highly enriched, it would been inspected and repackaged, and likely would have had its chemical form altered (at that time, the United States preferred to ship highly enriched uranium as uranium tetrafluoride, not uranium oxide) before it was sent on to Los Alamos.

I spent several days searching Oak Ridge's 1945 files at the NARA Atlanta archive, including detailed files of uranium shipments received at Oak Ridge, weekly enrichment reports from the gaseous diffusion plant and the calutrons, and records of enriched uranium shipped out of Oak Ridge. As Carter Hydrick first pointed out [Hydrick 1998, 2016], there was a significant increase in the output of highly enriched uranium from the calutrons beginning in mid-June 1945, but that appears to have been due to the first moderately enriched uranium from the gaseous diffusion plant being forwarded to the calutrons at that time, not the arrival of the U-234's uranium. In fact, I could find no records whatsoever of the U-234's uranium entering Oak Ridge or being processed there. Perhaps I overlooked those records among the vast collection of files, or maybe they are stored elsewhere, or perhaps they are still classified. Alternatively, maybe the U-234's uranium was officially entered into the record books as something else, for example by falsely labelling it as a shipment of uranium oxide from the Belgian Congo, a batch of uranium that had already been partially enriched by Oak Ridge's gaseous diffusion plant, or some other such subterfuge.

Again, hopefully future archival researchers can dig even more deeply into these mysteries and finally find some answers.]

[In addition to the uranium, the following documents suggest that detonators from the U-234 submarine, as well as passenger Heinz Schlicke's knowledge of those detonators, may have been useful for the U.S. plutonium implosion bombs.]

Dr. Delmar Bergen, former director of the nuclear weapons program at Los Alamos National Laboratory [Hydrick 2016, pp. ix–xi].

I began my career at Los Alamos in the summer of 1957, directly involved in nuclear weapons work, which remained the case until my retirement. I started as a staff member working on nuclear weapon design, and eventually was promoted to Director of the LANL (Los Alamos National Laboratory) Nuclear Weapons Program. Other assignments included serving as a consultant to the Assistant Secretary of Defense for Atomic Energy, and as a consultant to the US delegation developing the protocols for the Short and Intermediate Range Missile Treaty between the U.S. and the U.S.S.R.

[...] I would like to stress two points that I believe materially change the important history of the birth of the Nuclear Age as we know it:

First, it is my view as a physicist, based on documentation provided here in *Critical Mass* that the effort the Germans put into preparing and shipping the 560 kilograms of uranium oxide surrendered on board the German submarine U-234, was enriched in the isotope U235. In other words, it was enriched to create a nuclear weapon. [. . .]

The second material information you should take note of, I believe, is that the contributions to the Manhattan Project of the surrendered U-234 did not stop there. I believe the surrender of U-234 had impact on the development of the implosion device—the plutonium bomb dropped on Nagasaki—as well.

I was well acquainted with the development of the implosion device and the difficulties our scientists experienced in developing a detonation system that would give a proper spherical implosion. This concern kept the entire group on edge until the famous Trinity Test in New Mexico proved it to be successful... Surprisingly, as the date of the test approached, last-minute improvements in the firing system reduced their concern enough about the reliability of the detonation system...

I was never told how the details of the improvements came about, but it was during this period that the passengers on board U-234 were debriefed and it was learned that one in particular, the scientist Heinz Schlicke, had knowledge of fast operating energy transfer systems. The rapid and consistent release of electrical energy was a key part of the problem the LANL scientists were experiencing triggering the detonators with the simultaneity necessary to achieve a clean spherical implosion. There apparently is no written unclassified record available to provide us with what may have come from the debriefing of Heinz Schlicke but this we do know, over the summer months after his capture and the surrender of U-234 the confidence in the detonation system greatly improved, and the production of uranium for the gun weapon increased significantly.

Jack H. Alberti to John L. Riheldaffer. 24 May 1945. Subject: U-234. [NARA RG 38, Entry UD-16, Box 4, Folder Manifest of U-234]

The following information has been obtained from P/W Leutnant Menzel of the Luftwaffe, passenger on U-234.

1. The two after mine shafts of the forward line of six mine shafts amidships contain the personal baggage, documents and other property belonging to General Kessler, Col. von Sandart and Leutnant Menzel, in addition to some other cargo.

2. The Captain of U-234, Kapitänleutnant Fehler, and the II.W.O., Leutnant Pfaff (believed at Fort Meade), and the engineer of the boat (retained aboard U-234), between them, know most about cargo stowage and can be of great assistance in identifying it, as well as in proper and safe unloading.

3. In the U-Raum of U-234 there are two steel chests, marked Erich Menzel. These contain 15 rolls of secret films and all documents concerned with Menzel's mission.

4. U-843, C.O. Kapitänleutnant Herwartz, arrived in Norway from Japan about 10 April. She was sunk on her way to Kiel and two survivors were rescued by the Germans.

5. U-864, C.O. Kapitänleutnant Wolfram, was to go to Japan. She was sunk off Bergen with two Messerschmidt experts on board. Lt. Col. Stepp of the Luftwaffe and Baurat Wahlfeldt, the high-frequency expert, who were to sail on this boat were not aboard and remained in Horten.

6. The packages for Dr. Schlicke, one of the passengers, and contained in one of the tubes are marked "TONI". Dr. Schlicke knows about the infra-red proximity fuses which are in some of these packages. He warns that they must be handled with the utmost care as they may either explode or be irreparably damaged if handled improperly. Dr. Schlicke knows how to handle them and is willing to do so.

7. Fregattenkapitän Falck states that in addition to the mine shafts there are containers with cargo and documents inside the fuel tanks.

8. General Kessler, who was going to Japan to relieve General von Gronau, had originally planned to go to Japan via Northern Norway in a Junkers 290. Although this plan was abandoned in his case, it is possible that others went to Japan in this manner.

9. An empty envelope, found in the passport of Col. von Sandrat, is inscribed on the outside to the effect that it originally contained 1500 Swiss Francs. Since General Kessler only claims to own 1500 Swiss Francs, and since only 1800 francs have been recovered, 1200 francs must still be scattered among the souvenir hunters at Portsmouth, and this is on the assumption that none of the other passengers had any Swiss Francs.

[From information that is currently available, U-234's cargo apparently included a wide variety of advanced detonator technologies, and Heinz Schlicke was an expert on those and many other technologies. Although only infrared detonators were mentioned as an example in the above document and the next document, the other technologies may have included exploding bridgewire detonators such as would be especially useful for implosion bombs. Erich Schumann appears to have referred to exploding bridgewire detonators in his description of German implosion bombs (p. 4241).]

Secret dispatch from Commander of Naval Operations to Portsmouth Naval Yard. Subject: POW and fuses from U-234. 25 May 1945. [NARA Boston RG 181]

Lt (JG) H E Morgan, Lt (JG) F M Abbott, Ens F L Granger with Dr Schlicke POW in custody leaving Anacostia noon Friday via plane. This party expert in bomb disposal and proximity fuses and being sent to assist in securing certain infra red proximity fuses important BUORD [Navy Bureau of Ordnance] and in cargo U-234. Fuses when secured to be returned Washington custody above party.

[See document photo on p. 4871.]

First lecture given by Dr. Schlicke at the Navy Department. 19 July 1945. [NARA RG 38, Entry UD-38, Box 13, Folder U-234]

After Dr Schlicke completes his lecture he will be available for questions that people ask. But we will kindly ask you not to ask any questions during the lecture and after the lecture Mr Alvarez will sit at the table and the person who wishes to ask a question is asked to come forward so that we can get in the microphone and keep a record of all the questions and answers. Thank you.

[For more information on some of Schlicke's U.S. lectures, see AFHRA B1975, frames 1325–1495.]

Luis W. Alvarez. 1987. *Alvarez: Adventures of a Physicist.* New York: Basic Books. p. 137.

The gamma-ray records proved less definitive than we had hoped but helped the implosion design. I cleaned up some loose ends in detonator design. By April 1945 that work had moved on to engineering, and I was again unemployed.

[...] Normally a new weapon is proof fired at a proving ground before it's used in combat. We had only one U-235 weapon, however, every atom of which had been run twice at enormous expense through the Oak Ridge calutrons, and as of July 1945, there would be about one plutonium bomb a month, the first of which would have to be used up in a static test to make sure the Fat Man implosion system worked as we predicted it would.

[Note from this passage that Alvarez had been directly involved in the design of the detonators for the U.S. implosion bomb, was available for additional assignments by April 1945, and recognized there was still uncertainty about whether the implosion bomb detonation system would work as intended. From the document on p. 4739, Alvarez was also directly involved in U.S. intelligence efforts to analyze the progress of the German nuclear weapons program. Thus if U-234, Heinz Schicke, or Allied discoveries of German nuclear weapons components in Europe (p. 4241) did in fact provide improved detonators for an implosion bomb, Alvarez would have been an ideally qualified person to assign to apply them to the U.S. bomb.]

Pam Fessler. 18 August 2008. Former GIs Spill Secrets Of WWII POW Camp. National Public Radio. https://www.npr.org/templates/story/story.php?storyId=93649575 [See also: https://www.npr.org/templates/story/story.php?storyId=93640350 and https://www.npr.org/2008/08/18/93635950/breaking-the-silence-of-a-secret-pow-camp]

Amid the shade trees, swings and picnic grounds at Fort Hunt Park just outside Washington, D.C., there are few traces of the site's top-secret military past. But for the GIs who were stationed there during World War II, the park is alive with memories of what it had been: an interrogation camp for nearly 4,000 mostly German prisoners of war.

The park, then code-named P.O. Box 1142, was where the military elicited crucial information from top enemy officers and scientists. It also was where the United States had a clandestine program to help American POWs escape.

Until recently, much of what occurred at P.O. Box 1142 was unknown. Many who participated went to their graves without revealing—even to their families—what they'd done. The buildings were razed after the war. And many documents about the camp were destroyed in an effort to conceal its existence.

The National Park Service, which now runs Fort Hunt Park, is trying desperately to capture some of this history before it disappears. It has conducted more than 40 oral interviews with vets who had been stationed there.

One GI who worked at P.O. Box 1142 was John Gunther Dean, a young American soldier singled out while in basic training because he seemed well-suited for the intelligence operation. Dean, now 82, recalls how he was summoned to the Pentagon, where an Army officer asked him if he knew how to speak German.

"And I said, 'Yeah, I speak German like a native,'" says Dean.

His family, which was Jewish, had fled Germany in the late 1930s. When everyone else at Fort Belvoir—a U.S. Army base in Virginia—was sent overseas, Dean was handed a nickel and a phone number and then mysteriously dropped off in the middle of Alexandria, Va.

"There was a drug store. I went in, called the number and they said, 'Dean, you stay outside and we'll pick you up in a staff car.' And they drove me up towards Mount Vernon and that's how I ended up at Fort Hunt. It must have been end of November, early December 1944," he says.

George Mandel, now an 84-year-old professor at George Washington University, also ended up at P.O. Box 1142 during the war.

Mandel says when he was there, things looked quite different than they do today. There were prison barracks and buildings where American soldiers would interrogate Nazi and other enemy prisoners. About 4,000 high-ranking prisoners passed through the camp.

"My job was to interrogate scientifically trained and experienced Germans who had been sent to this country by the military," says Mandel. He knew German and had a chemistry degree.

But he admits that at age 20, he was naïve in the face of some of the Third Reich's top scientists.

"One of them was a person who worked on enriching uranium, and I didn't know why anybody would want to enrich uranium. I mean, what does this have to do with anything?" he says. "And so my job was to find out what he was doing and how it was being carried out, and then I reported this to the Pentagon."

It was part of a U.S. effort to learn what the Germans were up to. The prisoners were asked about troop movements, scientific advances and anything else that could help the Allied cause.

For years, Mandel, Dean and others kept quiet about P.O. Box 1142 because they had been sworn to secrecy. The operation has since been declassified, but many records were lost, which is why the veterans' stories are so important to the park service.

For Chief Ranger Vincent Santucci, it's like trying to glue together a broken vase—with some important pieces missing.

"Many of the archives were destroyed directly after the war. And so if we didn't have the opportunity to speak with these men and capture their stories, much of it may have been lost forever," Santucci says. [...]

One of those Dean befriended was German engineer Heinz Schlicke, who developed infrared fuses that could be used to trigger an atomic bomb. Schlicke was brought to P.O. Box 1142 after the U-boat on which he and other scientists were fleeing Germany for Japan was surrendered in 1945.

Schlicke's time at Fort Hunt was part of Operation Paperclip, a secret effort to bring hundreds of top German scientists—and their expertise—to the U.S. before the Russians got their hands on them. Dean says he and Schlicke played tennis and rode horses.

"It took quite some time before he was willing to cooperate. The war had ended in Europe and at that point, he said, he's willing to help us, but his wife was at that point in what was in the Russian zone," says Dean.

Dean was eventually sent to Europe to find Schlicke's wife and two small children and to reunite the family. Schlicke ended up working in the U.S. for the remainder of his life.

[See also p. 2045.

At least some of the surviving records from Fort Hunt are at NARA RG 165, Entry 179. Those and any other relevant records should be searched thoroughly.

Are there detailed reports of the interrogations of German-speaking prisoners who described uranium enrichment, atomic bomb fuses, or other nuclear-related work?

What are the names of the 4,000 German-speaking prisoners who were interrogated at Fort Hunt?

What all did the United States learn from them?]

Robert K. Sutton. 2021. *Nazis on the Potomac: The Top-Secret Intelligence Operation That Helped Win World War II.* Philadelphia: Casemate. pp. 74–75.

[George] Mandel's special expertise was chemistry, but, in time, he became comfortable asking questions about more technical issues, such as German jets and jet engines. In short order he became one of the experts on jets at Fort Hunt. Once he learned about the technical capabilities, flight characteristics, speed, and everything else about German jets, he came to the chilling conclusion that had the Nazis developed these machines at the peak of their manufacturing capabilities, the war could well have ended very differently. These airplanes were far superior to anything the Allies had in the air. [...]

One German scientist described his responsibility of enriching uranium. Mandel would later say that he could not understand why anyone would bother to enrich uranium, but as he probed deeper, he learned that the Germans had been working on developing a nuclear bomb. This was critical information that needed to be passed along to the Pentagon—immediately! [...]

While interrogating another scientist, Mandel learned about proximity fuses. The Allies had developed proximity fuses—which could detonate an explosive shell when it was close to or in the proximity of a target for maximum effect—but the Pentagon wanted to better understand the German uses of the devices. Mandel discovered that the German development of these devices was further advanced than those in the United States.

[Johann Gunther Dienstfertig (1926–2019) was born in Breslau, moved to the United States in 1939, and became much better known as John Gunther Dean. As a native German speaker who was drafted into the U.S. Army, he was assigned to obtain information from German prisoners of war at Fort Hunt and was also sent on a mission to Europe after the war. In multiple interviews, he stated that POWs from the U-234 as well as other German personnel captured earlier provided information about the German nuclear program, and that the German nuclear program was highly advanced. He spent most of his career as a high-ranking diplomat working around the world on behalf of the U.S. government.]

Ambassador John Gunther Dean. Interviewed by Charles Stuart Kennedy. 6 September 2000. p. 19. https://www.jimmycarterlibrary.gov/sites/default/files/pdf_documents/assets/documents/oral_histories/project/Initial_Interview_Part_One.pdf

DEAN: [...] For the next two years, I served at Post Office Box 1142, Alexandria, Virginia. I was sent to Europe at one point, but I always remained part of "Post Office Box 1142."

Q: Was this OSS?

DEAN: It was military intelligence. The OSS colleagues with whom I worked lived in a mansion on the road to Mount Vernon. I went to Fort Hunt, also a stop on the Mount Vernon Highway, about 5 minutes from our OSS friends. Today, at Fort Hunt, you can see nothing that existed during the war. I took my wife there, 30 years later. There is nothing there except some areas designated "Off Limits". During my military career, I could wear most anything I wanted—civilian clothes, military clothes (but I was a little young guy at 18 to pose as an officer). In 1944, I heard for the first time the word "atomzertrummerung" meaning splitting of the atom. Few people had ever heard about it until one year later.

Fort Hunt Oral History. P.O. Box 1142. Interview with John Dean by Brandon Bies. 2 October 2007. https://www.nps.gov/museum/exhibits/fohu_oral_history/transcripts/Fort%20Hunt_NPS_PO%20Box%201142_JDean.pdf
[There are also many other enlightening interviews of former Fort Hunt interrogators at this website https://www.nps.gov/museum/exhibits/fohu_oral_history/index.html]

[p. 22:] BB: So, these room conversations, the listening in that you would do—does any particular room conversation stand out, do you remember any time—

JD: One of them was, and I heard it for the first time, the word [speaks German], the splitting of the atom. Now, whether this is recorded; I don't—did I push the button? But I knew, was my uncle Otto Stern [...] had worked in Germany with Hahn and people like that, and he was fleeing and he went to the States. He got the Nobel Prize in 1948 in physics, so I knew the word [speaks German]. I know nothing of how you get to that, and I'm not at all a scientist, but I knew that's the time you press the button, because that was of major interest to the United States. [...]

[pp. 23-24:] JD: I just turned the damn stuff in; I don't remember. We all turned the stuff in, and we were told not to talk much about the thing. But then they used us younger guys—I was used because Heinz Schlicke, when he came, he was young, sports-oriented, and he wanted—we wanted to be nice to him. So somebody had to go and do things with him; so I did. He was a nice guy—he was Nazi—yes, he was a good Nazi, and he was at Peenemünde; so what? My job was to see what he could do for the United States. And I was told to do this. [...]

[p. 30:] JD: [...] At 1142, there was no pressure. There was psychological power being used. We put a stoolpigeon in because this guy was knowledgeable on atomic energy. [...]

[pp. 42–44:] JD: What happened with the—in January of 1945, the war was going badly for the Germans. Hitler sent U-boat number 234 to help the Japanese allies. You have the documentary. Now, how we got involved is we got it after these people came to 235, and it was the following—that we—that a—this submarine was on its way to Japan, and it had, we were told, mercury for $300 million, which was a number so extraordinary in 1945, but it wasn't. It was actually uranium oxide on there, and the captain was Captain Fehler. It had a German four-star general on it, and if I reached back, I'd give you the name somewhat.

BB: Was it Kessler?

JD: It—

BB: Ulrich Kessler?

JD: It was an air force general.

BB: And Luftwaffe. Yeah, that's Ulrich Kessler.

JD: And it was—and it was two colonels—Japanese colonels who committed hari-kari because—and then there was our friend Heinz Schlicke on there. Now, that U-boat was on its way and got as far—as I remember it—as far as Uruguay and was then supposed to go—you have to remember at that point, in May of 1945, Japan was very much still in the war. The atomic weapons—we had—we weren't using it and may not have had it, and the Germans had been very far advanced on atomic energy. Hahn—Professor—was it Hahn or whatever—was the head of it, and that's where my uncle came in—Otto Stern was—he had been down—but these guys—the Jewish people left and fled, you know, okay. So, when this boat surrendered, 234, the two Japanese committed hari-kari because Fehler said, "I will only surrender to the Americans." All I know that—at that point, these guys came—some of these guys came to P.O. Box 1142, and it took quite some time, to be very frank, for Heinz Schlicke to come around to working with us and the willingness to work with us, and it was only later that I was sent with prisoners who were being sent back to Europe, and I was put on a ship, and I went back, and I delivered these guys, and everything was so well planned, I was in luck. In Normandy, it was pretty normal, and at that point I was asked to go to Kiel, British zone, and there I was told that—that since I'd known Schlicke that I should go and get his wife and two kids. Everything was worked out. [... I]t was in South Hampton, I believe, somewhere on Long Island that they first put him, and he worked with us, and he gave us the secrets of infrared we didn't have, and he then stayed with his wife and children in the United States, and he died last year—

BB: Right.

JD: —and Schlicke was a good Nazi. He had worked in Peenemünde[....]

[pp. 54–57:] BB: Okay. Do you—again, realizing completely that your views were that of an 18 and a half year old, do you have a feeling or any sense that anything at all that went on at 1142 somehow assisted the American nuclear program, the atomic program?

JD: It definitely did. Definitely we had people who knew something about it. Now, I am not at that level, but they probably told them who the names were, and what level they were at and something like that. You see, that is what they could find out. But they didn't have the bomb yet. But they were close, because they sent that stuff over to the Japanese. [...]

BB: Okay. Were you aware of any operations going on outside of 1142 up in Boston? Now we're at a place called Fort Strong in Long Island in Boston.

JD: No, sir. [...]

BB: Getting a little bit—well actually, while we're on that subject of other locations, how about a place called Pine Grove Furnace up in Pennsylvania? [...] This would've been a location where it was kind of used as a holding facility for prisoners prior to them coming to 1142.

JD: No, sir. [...]

BB: Are you familiar with another camp similar to 1142 on the West Coast? [...] It was called Camp Tracy. It was in Byron Hot Springs, California. It also had a P.O. Box number. It was P.O. Box 751.

[Fort Hunt was just one of several interrogation facilities. Are the complete lists of POWs and the interrogation transcripts from all of these facilities at NARA RG 165, Entry 179 or elsewhere?

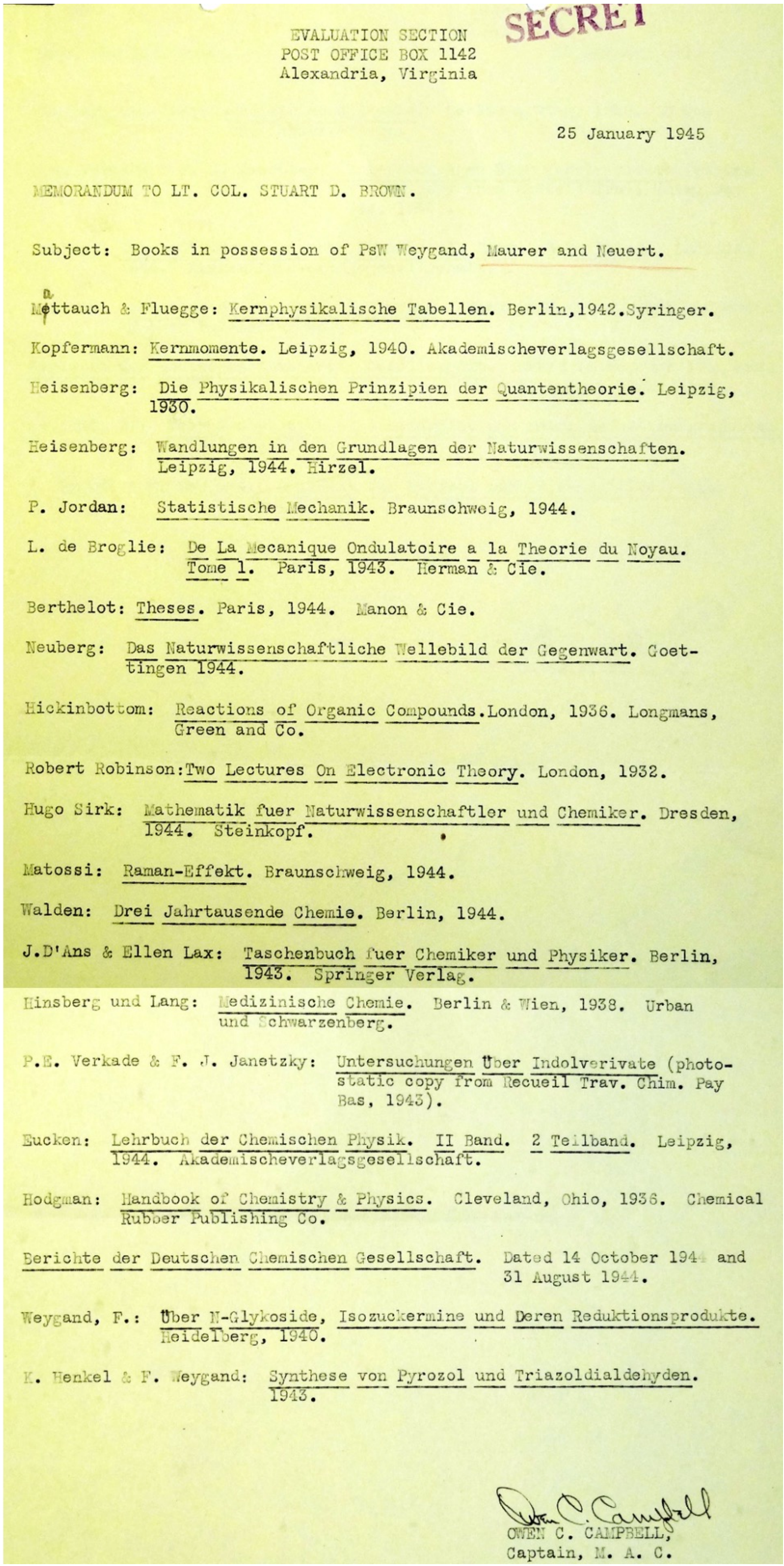
What details of the German nuclear program were learned from the occupants of the U-234 submarine?

What details of the German nuclear program were learned from other POWs who mentioned "the splitting of the atom"?

How did all of that information aid the U.S. nuclear program?]

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3
GERMANY: US Wartime Positive Int. (Nov. 44-June 45)



EVALUATION SECTION
POST OFFICE BOX 1142
Alexandria, Virginia

SECRET

25 January 1945

MEMORANDUM TO LT. COL. STUART D. BROWN.

Subject: Books in possession of PsW Weygand, Maurer and Neuert.

M~~e~~attauch & Fluegge: Kernphysikalische Tabellen. Berlin, 1942. Syringer.

Kopfermann: Kernmomente. Leipzig, 1940. Akademischeverlagsgesellschaft.

Heisenberg: Die Physikalischen Prinzipien der Quantentheorie. Leipzig, 1930.

Heisenberg: Wandlungen in den Grundlagen der Naturwissenschaften. Leipzig, 1944. Hirzel.

P. Jordan: Statistische Mechanik. Braunschweig, 1944.

L. de Broglie: De La Mecanique Ondulatoire a la Theorie du Noyau. Tome 1. Paris, 1943. Herman & Cie.

Berthelot: Theses. Paris, 1944. Manon & Cie.

Neuberg: Das Naturwissenschaftliche Wellebild der Gegenwart. Goettingen 1944.

Hickinbottom: Reactions of Organic Compounds. London, 1936. Longmans, Green and Co.

Robert Robinson: Two Lectures On Electronic Theory. London, 1932.

Hugo Sirk: Mathematik fuer Naturwissenschaftler und Chemiker. Dresden, 1944. Steinkopf.

Matossi: Raman-Effekt. Braunschweig, 1944.

Walden: Drei Jahrtausende Chemie. Berlin, 1944.

J.D'Ans & Ellen Lax: Taschenbuch fuer Chemiker und Physiker. Berlin, 1943. Springer Verlag.

Hinsberg und Lang: Medizinische Chemie. Berlin & Wien, 1938. Urban und Schwarzenberg.

P.E. Verkade & F. J. Janetzky: Untersuchungen Über Indolverivate (photostatic copy from Recueil Trav. Chim. Pay Bas, 1943).

Eucken: Lehrbuch der Chemischen Physik. II Band. 2 Teilband. Leipzig, 1944. Akademischeverlagsgesellschaft.

Hodgman: Handbook of Chemistry & Physics. Cleveland, Ohio, 1936. Chemical Rubber Publishing Co.

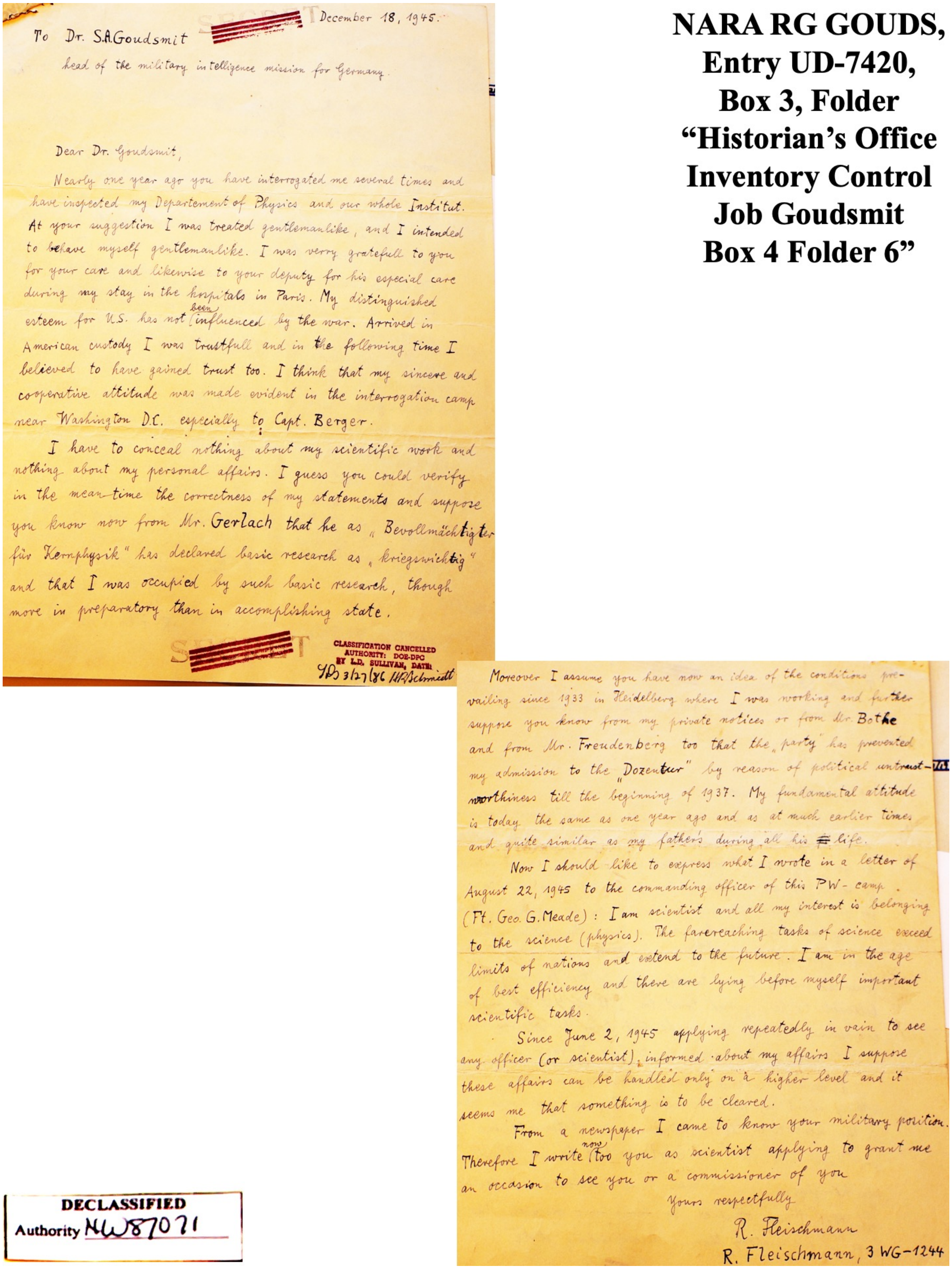
Berichte der Deutschen Chemischen Gesellschaft. Dated 14 October 1944 and 31 August 1944.

Weygand, F.: Über N-Glykoside, Isozuckermine und Deren Reduktionsprodukte. Heidelberg, 1940.

K. Henkel & F. Weygand: Synthese von Pyrozol und Triazoldialdehyden. 1943.

Owen C. Campbell
OWEN C. CAMPBELL,
Captain, M. A. C.

Figure D.915: Owen C. Campbell to Stuart D. Brown. 25 January 1945. Subject: Books in possession of PsW Weygand, Maurer and Neuert [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].



NARA RG GOUDS, Entry UD-7420, Box 3, Folder "Historian's Office Inventory Control Job Goudsmit Box 4 Folder 6"

~~SECRET~~ December 18, 1945.

To Dr. S.A.Goudsmit

head of the military intelligence mission for Germany.

Dear Dr. Goudsmit,

Nearly one year ago you have interrogated me several times and have inspected my Departement of Physics and our whole Institut. At your suggestion I was treated gentlemanlike, and I intended to behave myself gentlemanlike. I was verry gratefull to you for your care and likewise to your deputy for his especial care during my stay in the hospitals in Paris. My distinguished esteem for U.S. has not been influenced by the war. Arrived in American custody I was trustfull and in the following time I believed to have gained trust too. I think that my sincere and cooperative attitude was made evident in the interrogation camp near Washington D.C. especially to Capt. Berger.

I have to conceal nothing about my scientific work and nothing about my personal affairs. I guess you could verify in the mean-time the correctness of my statements and suppose you know now from Mr. Gerlach that he as „Bevollmächtigter für Kernphysik" has declared basic research as „kriegswichtig" and that I was occupied by such basic research, though more in preparatory than in accomplishing state.

~~SECRET~~

CLASSIFICATION CANCELLED
AUTHORITY: DOE-DPC
BY L.D. SULLIVAN, DATE:
3/27/86 H.R.Schmidt

Moreover I assume you have now an idea of the conditions prevailing since 1933 in Heidelberg where I was working and further suppose you know from my private notices or from Mr. Bothe and from Mr. Freudenberg too that the „party" has prevented my admission to the „Dozentur" by reason of political untrustworthiness till the beginning of 1937. My fundamental attitude is today the same as one year ago and as at much earlier times and quite similar as my father's during all his ~~f~~ life.

Now I should like to express what I wrote in a letter of August 22, 1945 to the commanding officer of this PW-camp. (Ft. Geo. G. Meade): I am scientist and all my interest is belonging to the science (physics). The farereaching tasks of science exceed limits of nations and extend to the future. I am in the age of best efficiency and there are lying before myself important scientific tasks.

Since June 2, 1945 applying repeatedly in vain to see any officer (or scientist), informed about my affairs I suppose these affairs can be handled only on a higher level and it seems me that something is to be cleared.

From a newspaper I came to know your military position. Therefore I write now too you as scientist applying to grant me an occasion to see you or a commissioner of you

Yours respectfully

R. Fleischmann

R. Fleischmann, 3 WG-1244

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Authority NW87071

Figure D.916: Rudolf Fleischmann to Samuel Goudsmit. 18 December 1945 [NARA RG GOUDS, Entry UD-7420, Box 3, Folder "Historian's Office Inventory Control Job Goudsmit Box 4 Folder 6"]. "I think that my sincere and cooperative attitude was made evident in the interrogation camp near Washington D.C. especially to Capt. Berger.... this PW-camp (Ft. Geo. G. Meade)."

Robert A. Carr. October 1949. How German Experts Aid Our Research. *Army Information Digest* 4:10:15–19.

[...] By 1 September 1949—ten years after Hitler's attack on Poland—many changes had been wrought in the life of Dr. [Wolfgang] Finkelnburg. Now 44, he lives with his wife and two-year-old son at Fort Belvoir, where he is employed by the United States Government as a research expert in light and radiation sources. He also is a research consultant on atomic physics; and his textbook on the subject is currently on the press of the leading American publisher.

Dr. Finkelnburg's activities in the field of pure science are not confined to the seclusion of the laboratories at Fort Belvoir. During the past two years he has lectured at Ohio State, New York and Northwestern Universities; Massachusetts Institute of Technology, Bell Telephone and Brookhaven National Laboratories; and before the Society of Motion Picture Engineers. For many months, he has carried a heavy schedule of classes, teaching atomic physics in extension classes conducted by Catholic University at Fort Belvoir.

Dr. Finkelnburg is only one of about 500 [the actual total was far larger] outstanding German scientists and technical experts whose talents are being utilized by the United States, to help maintain our position of world leadership in scientific research and development. Under this far-reaching program, known as Project Paperclip, German experts are brought to the United States. Here they are provided with facilities for research in electronics, supersonics, guided missiles and jet propulsion. They pioneer in the vast realms of chemistry, physics, metallurgy, engineering, synthetic fuels, environmental protection, and the like. Some are doing advanced work in medicine, including the design of artificial limbs and prosthetic appliances. Nearly all of the technical services of the Armed Forces are now employing these scientists; and a few have been made available to civilian industry.

Among Dr. Finkelnburg's associates at the Engineer Research and Development Laboratories are Dr. Alexander Smakula, a specialist on optics, formerly with the Zeiss Company [p. 1282]; Dr. Werner K. Weihe, electronics researcher who was formerly chief of the Zeiss electrotechnical laboratories [p. 1152]; and Dr. George Hass, formerly on the faculty of the Technical University of Danzig, who is now doing research in optics and in other aspects of physics [p. 2757].

Although the idea of capitalizing on the knowledge and skills of German scientists had been conceived early in World War II, it was not until the summer of 1945 that a firm plan could be put into operation. However, immediately after VE day, we acquired our first German experts by chance, as part of a drama that had the earmarks of a movie thriller.

In obedience to Allied orders, Nazi submarines in every sector of the world were to surface, report their positions, and display a black flag in token of surrender. Among the submarines docking at the Portsmouth (New Hampshire) Navy Yard was the U-234, one of Germany's largest U-boats, a minelayer of the latest type. Here was a haul! This sub was not on an ordinary errand. She carried Hitler's last, most valuable gift to his Japanese ally. Her compartments were filled with treasure—platinum and mercury, blueprints by the thousands, samples of the newest electronic tubes and other inventions, uranium oxide of a high degree of purity, and a rich human cargo—ten of Germany's leading scientific and technical experts. [Does this mean that U-234 had additional technical experts not listed on p. 4859?]

It was intended that these men should carry on in Japan the newest research projects which the increasing fury of the war had prevented Germany from realizing. The group included Lieutenant General Ulric Kessler, the former head of the *Luftwaffe Flieger Korps*; Dr. Gerhardt Falck, one of the top designers in the German Bureau of Ships; and August Bringewald, the star production engineer of the Messerschmitt Works, carrying with him blueprints which would enable him to set up a complete plant for construction of the latest Messerschmitt jet aircraft in Japan.

Some of these men were placed on special military projects, and later were returned to Germany. Several are still employed at Army, Navy, and Air Force research centers, where they continue their work under Government supervision. Today, Bringewald is employed at Wright-Patterson Air Force Base, and Dr. Falck has returned to Germany.

Among the cream of German scientists now working for the Armed Forces are the former director of Germany's air-to-ground and ground-to-air missiles projects; eminent V-2 and remote control specialists; the former research directors for Junkers and Zeiss; and some of Germany's leading parachute experts and aeronautical engineers.

From the beginning, the process of screening German scientists for admission to this country has been thorough. Even before the European phase of World War II ended, technical teams of the military services were surveying major plants and research organizations in Germany. They catalogued the names of thousands of Germans engaged in research; and they forwarded many thousands of scientific documents and reports to Washington for study by our technical experts. Commercial teams followed the military, analyzing the progress of German commercial research, locating the leading experts. Finally, a panel of top-notch German specialists was assembled and was directed by the Theater Commander to compile a list of all German scientists and technical specialists. This roster contained the names of 24,000 Germans, ranging from world-acknowledged experts to lesser technical specialists.

From all these sources, the military services, in cooperation with other interested Government agencies, made the final selection. The dominant factor in each case was the ability of the scientist to make an "otherwise unobtainable" contribution to American military research and development. Every using agency was required to certify that the skills and experience offered by the German could not be obtained from an available American scientist. [...]

Hundreds of millions of dollars and from two to ten years of research time, it is estimated, have been saved by the program. Out of the experience of the German scientists has come a knowledge of the many blind alleys to be avoided, thus narrowing the fields to be explored.

MAJOR ROBERT A. CARR, Inf., is on the staff of the Security Review Branch, Office of Public Information, Department of Defense. He was formerly Public Information Officer for the Department of the Army on Project Paperclip.

[One of the U-234 passengers that the above article named, Gerhard[t] Falck, had some sort of nuclear expertise, which this article did not mention [p. 4870]. This article also carefully avoided mentioning another U-234 passenger, Heinz Schlicke, who may have had knowledge related to nuclear components [pp. 4881–4880]. Even the main scientist featured in this article, Wolfgang Finkelnburg (who was not a passenger on U-234), focused on fission reactors for much of his postwar career, so he likely had some nuclear-related wartime experience that was never explicitly named.

More broadly, the above article—written directly by the U.S. Army—openly admitted that German scientists were up to a decade ahead of the U.S. during the war and that in postwar U.S. programs, the German scientists were making enormous contributions in a wide variety of fields that were beyond the capabilities of U.S. scientists.

Where in current archival files is this list of 24,000 German names? That would be even more extensive than the Osenberg list of 15,000 names.]

Operation LUSTY. January 1946. [AFHRA C5098 electronic version p. 586.]
http://www.indianamilitary.org/FreemanAAF/OperationLusty/OperationLusty-s.pdf

A casual remark made by a technical engineer, who stated that he had recently been offered a position in Japan, led to his being thoroughly interrogated for significant technical information. As an aside, and what he probably considered a relatively unimportant incident, he stated that less than a month ago, about the middle of April, ten submarines heavily loaded with the latest German equipment relative to aerial warfare, were dispatched from Kiel to Japan. When Lt Col. O'Brien was thus informed he immediately advised the Directorate of Intelligence, USAFE, who in turn notified the Japanese Intelligence Section of SHAFE. A cable was then dispatched to all commands.

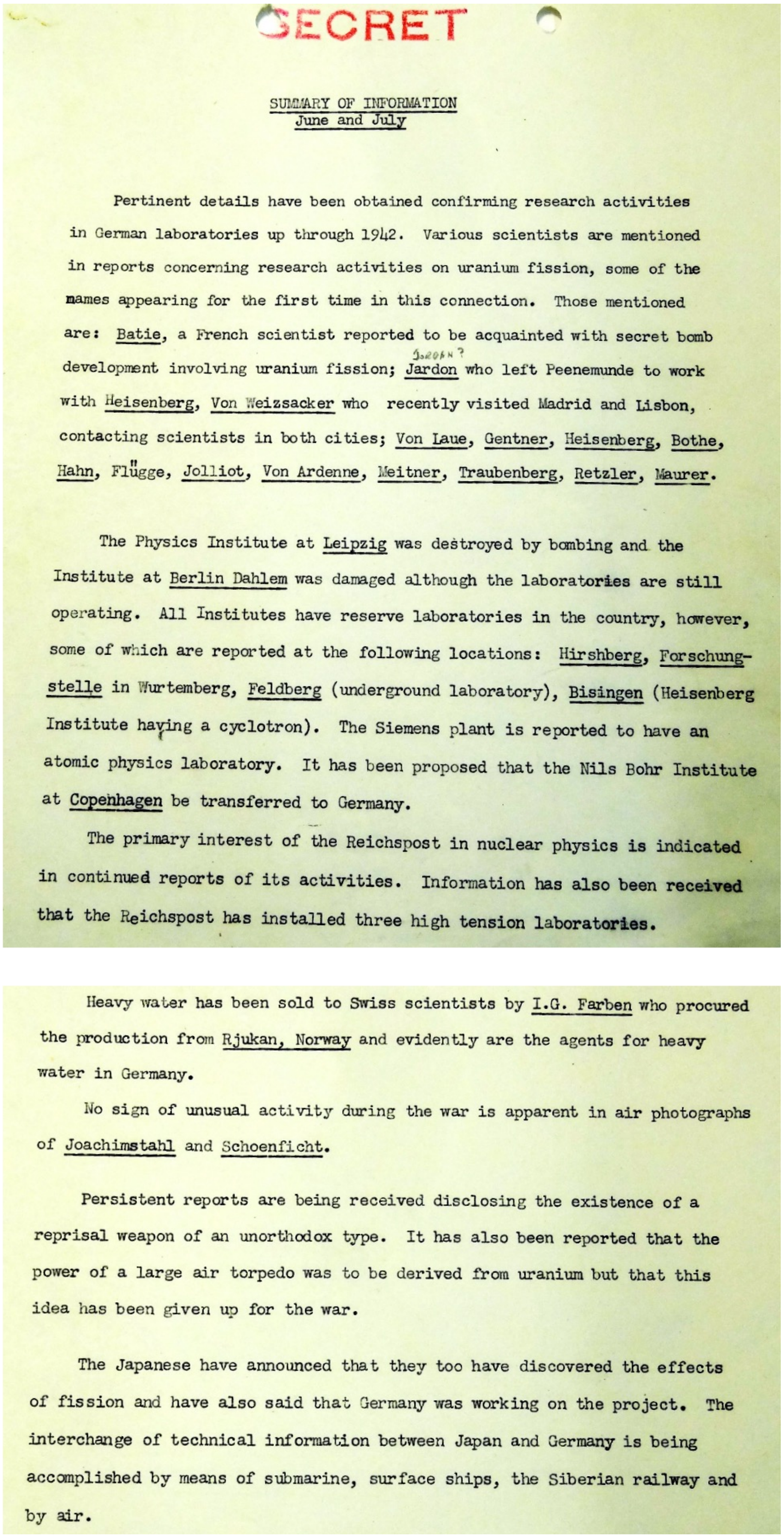
In every theater of war, all vessels in ports and at sea were notified, and one of the biggest searches ever undertaken during the war for submarines was initiated. What route they had taken, whether they had gone alone or together, no one knew. But so extensive was the search and so carefully was it executed by warships of all Allied nations, that by the end of June, six of these ten submarines had been captured intact, some a relatively short distance away from their bases, others perilously close to Japan.

[What technologies were on the U-234 submarine, in terms of its cargo, documents, and the knowledge of its passengers and crew?

What technologies were on other submarines (both German and Japanese) that evacuated materials and personnel from Germany?

What technologies were evacuated from Germany by other means—aircraft, smuggling across borders, etc.?]

DECLASSIFIED
Authority 917017



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SUMMARY OF INFORMATION
June and July

Pertinent details have been obtained confirming research activities in German laboratories up through 1942. Various scientists are mentioned in reports concerning research activities on uranium fission, some of the names appearing for the first time in this connection. Those mentioned are: Batie, a French scientist reported to be acquainted with secret bomb development involving uranium fission; Jardon (JORDAN ?) who left Peenemunde to work with Heisenberg, Von Weizsacker who recently visited Madrid and Lisbon, contacting scientists in both cities; Von Laue, Gentner, Heisenberg, Bothe, Hahn, Flügge, Jolliot, Von Ardenne, Meitner, Traubenberg, Retzler, Maurer.

The Physics Institute at Leipzig was destroyed by bombing and the Institute at Berlin Dahlem was damaged although the laboratories are still operating. All Institutes have reserve laboratories in the country, however, some of which are reported at the following locations: Hirshberg, Forschungstelle in Wurtemberg, Feldberg (underground laboratory), Bisingen (Heisenberg Institute having a cyclotron). The Siemens plant is reported to have an atomic physics laboratory. It has been proposed that the Nils Bohr Institute at Copenhagen be transferred to Germany.

The primary interest of the Reichspost in nuclear physics is indicated in continued reports of its activities. Information has also been received that the Reichspost has installed three high tension laboratories.

Heavy water has been sold to Swiss scientists by I.G. Farben who procured the production from Rjukan, Norway and evidently are the agents for heavy water in Germany.

No sign of unusual activity during the war is apparent in air photographs of Joachimstahl and Schoenficht.

Persistent reports are being received disclosing the existence of a reprisal weapon of an unorthodox type. It has also been reported that the power of a large air torpedo was to be derived from uranium but that this idea has been given up for the war.

The Japanese have announced that they too have discovered the effects of fission and have also said that Germany was working on the project. The interchange of technical information between Japan and Germany is being accomplished by means of submarine, surface ships, the Siberian railway and by air.

NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946), Summary of Information June and July [1944]

Figure D.917: "The Japanese have announced that they too have discovered the effects of fission and have also said that Germany was working on the project. The interchange of technical information between Japan and Germany is being accomplished by means of submarine, surface ships, the Siberian railway and by air." [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946), Summary of Information June and July [1944]]

D.14.6 High-Level Interrogations

[Many high-level German military and political officials who would have known a great amount about the German nuclear program were captured and interrogated at length by the United States and/or United Kingdom. Available documents show that those officials did indeed discuss the German nuclear program, although currently available declassified documents do not reveal most of the details that those German officials provided.]

Nazis' A-Bomb 90 Days Late, Says Goering. *Chicago Daily Tribune.* 26 January 1946 p. 10.

Germany was within 90 days of producing its first atom bomb when the war ended, Hermann Goering, former Luftwaffe chief, told his jailers at an American army prison in Mondorf, Luxemburg.

Authority for this statement is former Tech. Sgt. Robert Bock, 1203 S. 57th St., Milwaukee, who was warden of "Ashcan" prison, where Goering and other top flight Nazis were questioned for 100 days prior to the trails at Nuernberg, Germany.

"Goering told me Germany had made extensive progress in the use of the element uranium as a source of destructive atomic power, and that he had plans for an atomic anti-aircraft grenade which would have crumpled the wings of every plane within one kilometer (5/8 of a mile) of its bursting point," Bock asserted.

But Goering believed America would have defeated Germany even if the Nazis had developed the atom bomb, Sgt. Bock said.

[Nuclear weapons could have been employed in a variety of ways during the war. One possible tactical application would have been as an anti-aircraft weapon, such that one nuclear weapon exploded in the air might conceivably destroy an entire formation of Allied bombers. Since Hermann Goering was the head of the Luftwaffe, that application would have been most significant to him.

As the single most talented, most utilized, and most secretive native German-speaking interrogator in the investigation of German scientific programs by the United Kingdom (and by collaboration, the United States), Edmund Tilley (1892–1966) gained a deep knowledge of German programs to develop nerve agents (below), fission bombs (pp. 4902–4903), manned V-1 cruise missiles armed with fission bombs (pp. 4896–4897), a 6-ton H-bomb (pp. 4350–4359), advanced rockets (pp. 5762–5763) and goodness knows what else. Can all of the files related to Tilley's interrogations, reports, and knowledge be located and declassified?]

Dan Kaszeta. 2020. *Toxic: A History of Nerve Agents, from Nazi Germany to Putin's Russia.* London: C. Hurst. pp. 66–68, 74, 318.

Edmund Tilley played a pivotal role in the history of nerve agents because of his skills as a German-speaking interrogator. He spoke German with native fluency, having been born in Marburg in 1892 where his father was an English lecturer and ran a series of language schools.[5]

Edmund Tilley was in the US by the time of World War I, but his father and brothers were interned by the Kaiser's government. After studying at Union College in Schenectady, New York, Edmund spent time as a language and dramatics teacher, at both Union College and in Istanbul at Robert College, which was and is an elite private high school. A generation of the political and economic elite of Turkey may have been taught English by Tilley. By 1937, his mother's obituary lists him residing in England,[6] yet even then he was something of an enigma as he is missing from all records other than an immigration form completed when he visited relatives in the USA, listing a modest house in North London as his current address.

Due to his fluency in German, Edmund became involved in intelligence work with the British Army. The beginnings of his war service are also a bit of a mystery. The Army records show him being made a second lieutenant in the Intelligence Corps in the autumn of 1940, shortly after it was formally re-established. At forty-eight, he made for an old lieutenant. From 1940 through 1943 he either did little of note or it was very secret. One suspects the latter. Tilley could mimic most regional German accents and it is highly likely that these talents were not squandered. A book on wartime espionage in Persia makes a single tangential reference to Edmund Tilley being in Egypt in November 1943. He was part of the intelligence services and assigned to the Combined Services Detailed Interrogation Centre, in Maadi, Egypt. Special Intelligence Middle East's director, Brigadier Maunsell, described Tilley in his memoirs:

> By far the best interrogator we had in SIME: a gentle person, paranoically [sic] devoted to duty and a crashing bore! Major Tilley succeeded in breaking down our most difficult suspect, where all others had failed.[7]

He is described as one of the intelligence service's "most expert interrogators" who, after a full month of interrogation, broke a hardened German spy named Hans Merz and cracked another in thirty minutes.[8] Details of his remaining service in the Middle East and Mediterranean theatres is largely still a secret, but whatever Tilley did, it was worthy enough for him to appear in a picture shaking hands with King George VI in Italy in 1944.[9] Tilley was mentioned in dispatches for his work in Egypt and toward the end of the war was assigned to FIAT.

After the D-Day invasions, the liberation of Europe was no longer a planning effort but an operational one. Tarr, Tilley, and their team headed to the field, arriving in Paris shortly after it fell to Allied forces. They followed the Allied advance all the way to Germany, often only a few days behind British, American, and Free French forces. [...]

The archives are replete with both summary and detailed interrogation reports by Edmund Tilley. It is abundantly clear that he could persuade Germans of any rank or position to talk. No doubt some of this was through his native fluency. He knew every regional accent and famously once rumbled a German spy by telling him, quite correctly, that his accent was from Altona, outside of Hamburg. By the time Tilley was chasing scientists, he had years of interrogation experience with prisoners in the Middle Eastern and Mediterranean theatres. He had interrogated hundreds, if not thousands, of Germans before he even set foot in Germany towards the end of the war. [...]

5. Philip Thomson, 'William Henry (1860–1935)', Australian Dictionary of Biography, National Centre of Biography, Australian National University, https://adb.anu.edu.au/biography/tilly-william-henry-8815/text15339, published first in hardcopy 1990, accessed online 22 March 2019.

6. Bronxville Press, 7 January 1937.

7. Private papers of Raymond Maunsell, 4829, IWM, pp. 51–52.

8. O'Sullivan, Adrian. *Nazi Secret Warfare in Occupied Persia (Iran)*, Palgrave Macmillan, 2014, p. 201.

9. https://www.iwm.org.uk/collections/item/object/205259615—Note that this photo wrongly describes Tilley as a Lt Col when he was, in fact, a Major at the time.

Edmund Sorg. 17 August 1946. Betrachtungen über die bemannte V 1 im Zusammenhang mit Atomenergie. [TNA FO 1031/57]

Betrachtungen über die bemannte V 1 im Zusammenhang mit Atomenergie.

Bei der Durcharbeitung der Interrogation vom 16.8.46 habe ich folgende Gedankengänge über die Verwendung der bemannten V 1 in Zusammenhang mit Atomenergie erwogen:

Die Betrachtung der in viele Millionen Menschen gehenden Verluste und ungeheuren Materialzerstörungen, die ein moderner Angreifer im Laufe mehrerer Jahre verursacht, zwingt zu der Überlegung, welche Möglichkeiten gegeben sind, einen Angriffskrieg und damit diese Verluste und Schäden zu verhindern.

Jedes sich mit Angriffsabsichten tragende Land ist durch Vernichtung einer verhältnismässig kleinen Zahl von Punkten, die für den Angreifer lebenswichtig sind, schlagartig zu lähmen. Es sind dies, wie allgemein bekannt, z.B. Werke der Energiewirtschaft (Kohle, Elektrizität), der Öl Förderung, Aufbereitung und Lagerung, Kunstbauten des Verkehrs, Schlüsselindustrien der Rüstungswirtschaft, Schlachtschiffe u.s.w. Die Zahl dieser verwundbaren Stellen ist zwar bei den einzelnen Staaten verschieden, liegt aber zahlenmässig bei allen im Bereich der praktischen Einwirkungsmöglichkeit. Es liegt ebenfalls im Bereich der Möglichkeit, die kleine Zahl Menschen zu finden, die als internationale Polizeitruppe—als Flugzeugführer einer bemannten V 1—jederzeit bereit sind, eine Bedrohung des Weltfriedens durch sofortige Vernichtung der oben erwähnten lebenswichtigen Punkte des angreifenden Staates zu verhindern.

Reflections on the manned V 1 in the context of atomic energy.

In working through the interrogation of 16.8.46, I thought about the use of manned V 1 in connection with atomic energy:

The consideration of the losses in many millions of people and immeasurable material destruction caused by a modern attacker in the course of several years compels us to consider the possible ways of preventing an attack and thus to prevent these losses and damage.

Every country with hostile intentions could be immediately paralyzed by the destruction of a relatively small number of places that are vital for this aggressor. As is well known such places are for instance the factories for the production of energy (coal, electricity); the oil production, processing, and storage industries; engineering infrastructures for transport; key sectors of the armament industry; battleships; etc. The number of these vulnerable places may differ in each nation, but is numerically in a range that makes a practical intervention possible. It is also within the realm of possibility, to find the small number of people necessary to establish an international police force—pilots of manned V1—ready at any time to stop a menace to world peace by the immediate destruction of the vital places of an aggressive nation of the kind mentioned above.

Eine verbesserte bemannte V 1 mit Atomenergie als Ladung, kurz eine bemannte steuerbare Atombombe, die mit Sicherheit von modernen schnellen Grossflugzeugen in der Nähe ihres Zieles abgesetzt wird, gewährleistet bei Lenkung von Menschenhand und bei Selbstaufopferung des Piloten eine sichere Vernichtung ihres Zieles. Die Lenkung einer solchen Bombe durch Fernsteuerung, gleich welcher Art, gewährt nicht die absolute Sicherheit, das Ziel richtig zu treffen. Denn die technische Beeinflussungsmöglichkeit der Fernsteuerung sowie des die Fernsteurung bedienenden Menschen durch den Feind liegt zur Zeit im Bereich des möglichen. Daraus ergeben sich Fehlerquellen, die die Erfolgsaussichten einer solchen Bombe sehr in Frage stellen. Dagegen bietet eine durch Menschenhand gesteuerte Bombe die nach menschlichem Ermessen grössten Erfolgsaussichten.

An improved manned V1 with atomic energy as a charge, in short a manned controllable atomic bomb, which can certainly be released by modern, fast, large airplanes close to its target, ensures a safe destruction of this target given that it is steered by the hands of a pilot ready to sacrifice himself. Guiding such a bomb by a remote control of any kind does not ensure the absolute certainty of hitting the target correctly. This happens because at this time it is technically possible for the enemy to interfere with the remote control and also influence the people controlling the remote guidance. This results in sources of error that seriously jeopardize the success of such a bomb. On the other hand, a human-controlled bomb offers the greatest possible prospects of success.

Edmund Tilley. October 1946. Report on the interrogation of Edmund Sorg. [TNA FO 1031/57]

“Specially adapted models of V-1 manned by pilots prepared to sacrifice their lives were to receive a powerful charge with which to destroy key targets, such as vital war plants and large battleships... It is more likely that the charge for the warhead which had been envisaged was not available in sufficient quantities. Significantly SORG mentioned an atomic charge for these suicide V-1s as the ideal explosive in a future ‘defensive’ war.”

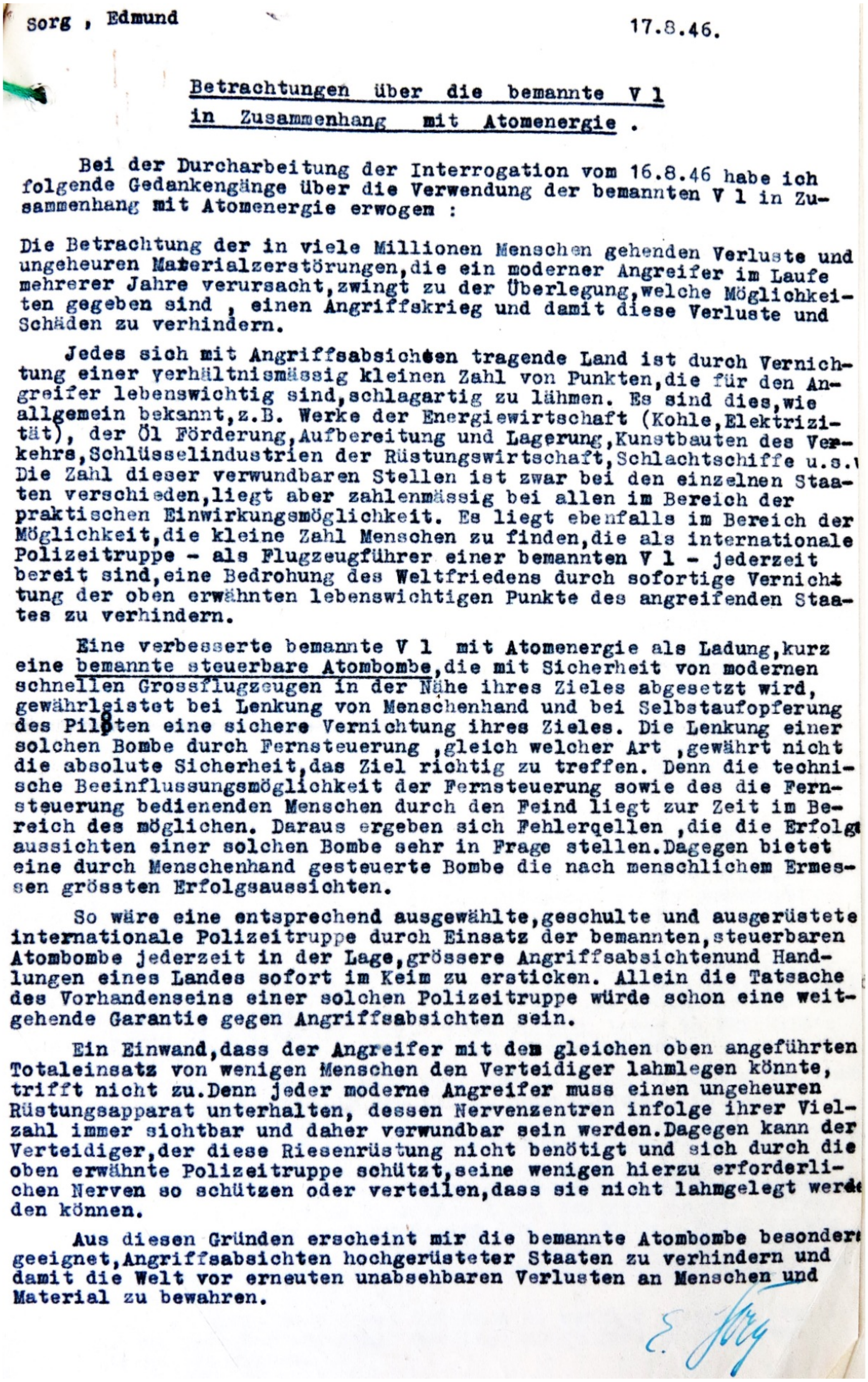
[See document photos pp. 4898–4899.

For another document on the interrogation of Edmund Sorg by Edmund Tilley, see p. 4354.

It seems likely that there are many other detailed documents summarizing information that was learned from interrogating Sorg. Can those documents be located and declassified?

For photos of actual piloted and air-launched V-1s similar to what Sorg described, see p. 1841. For a news description that may be related, see p. 5012. For submarine-launched V-1s that may have been intended to carry weapons of mass destruction, see pp. 5618–5627. See also Henshall 2000, pp. 129–130, redrawn from original document 824B-Sk 895/a, 19 September 1944, in the U.S. Air and Space Museum archive. For photos of a similar air-to-ground nuclear missile system that was created (or recreated?) in the United States by Walter Dornberger beginning in 1946, see p. 1854.]

TNA (Kew) FO 1031/112 Sorg V2



Sorg , Edmund 17.8.46.

Betrachtungen über die bemannte V 1 in Zusammenhang mit Atomenergie .

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Die Betrachtung der in viele Millionen Menschen gehenden Verluste und ungeheuren Materialzerstörungen, die ein moderner Angreifer im Laufe mehrerer Jahre verursacht, zwingt zu der Überlegung, welche Möglichkeiten gegeben sind , einen Angriffskrieg und damit diese Verluste und Schäden zu verhindern.

Jedes sich mit Angriffsabsichten tragende Land ist durch Vernichtung einer verhältnismässig kleinen Zahl von Punkten, die für den Angreifer lebenswichtig sind, schlagartig zu lähmen. Es sind dies, wie allgemein bekannt, z.B. Werke der Energiewirtschaft (Kohle, Elektrizität), der Öl Förderung, Aufbereitung und Lagerung, Kunstbauten des Verkehrs, Schlüsselindustrien der Rüstungswirtschaft, Schlachtschiffe u.s.w. Die Zahl dieser verwundbaren Stellen ist zwar bei den einzelnen Staaten verschieden, liegt aber zahlenmässig bei allen im Bereich der praktischen Einwirkungsmöglichkeit. Es liegt ebenfalls im Bereich der Möglichkeit, die kleine Zahl Menschen zu finden, die als internationale Polizeitruppe - als Flugzeugführer einer bemannten V 1 - jederzeit bereit sind, eine Bedrohung des Weltfriedens durch sofortige Vernichtung der oben erwähnten lebenswichtigen Punkte des angreifenden Staates zu verhindern.

Eine verbesserte bemannte V 1 mit Atomenergie als Ladung, kurz eine bemannte steuerbare Atombombe, die mit Sicherheit von modernen schnellen Grossflugzeugen in der Nähe ihres Zieles abgesetzt wird, gewährleistet bei Lenkung von Menschenhand und bei Selbstaufopferung des Piloten eine sichere Vernichtung ihres Zieles. Die Lenkung einer solchen Bombe durch Fernsteuerung ,gleich welcher Art ,gewährt nicht die absolute Sicherheit, das Ziel richtig zu treffen. Denn die technische Beeinflussungsmöglichkeit der Fernsteuerung sowie des die Fernsteuerung bedienenden Menschen durch den Feind liegt zur Zeit im Bereich des möglichen. Daraus ergeben sich Fehlerqellen ,die die Erfolgsaussichten einer solchen Bombe sehr in Frage stellen. Dagegen bietet eine durch Menschenhand gesteuerte Bombe die nach menschlichem Ermessen grössten Erfolgsaussichten.

So wäre eine entsprechend ausgewählte, geschulte und ausgerüstete internationale Polizeitruppe durch Einsatz der bemannten, steuerbaren Atombombe jederzeit in der Lage, grössere Angriffsabsichtenund Handlungen eines Landes sofort im Keim zu ersticken. Allein die Tatsache des Vorhandenseins einer solchen Polizeitruppe würde schon eine weitgehende Garantie gegen Angriffsabsichten sein.

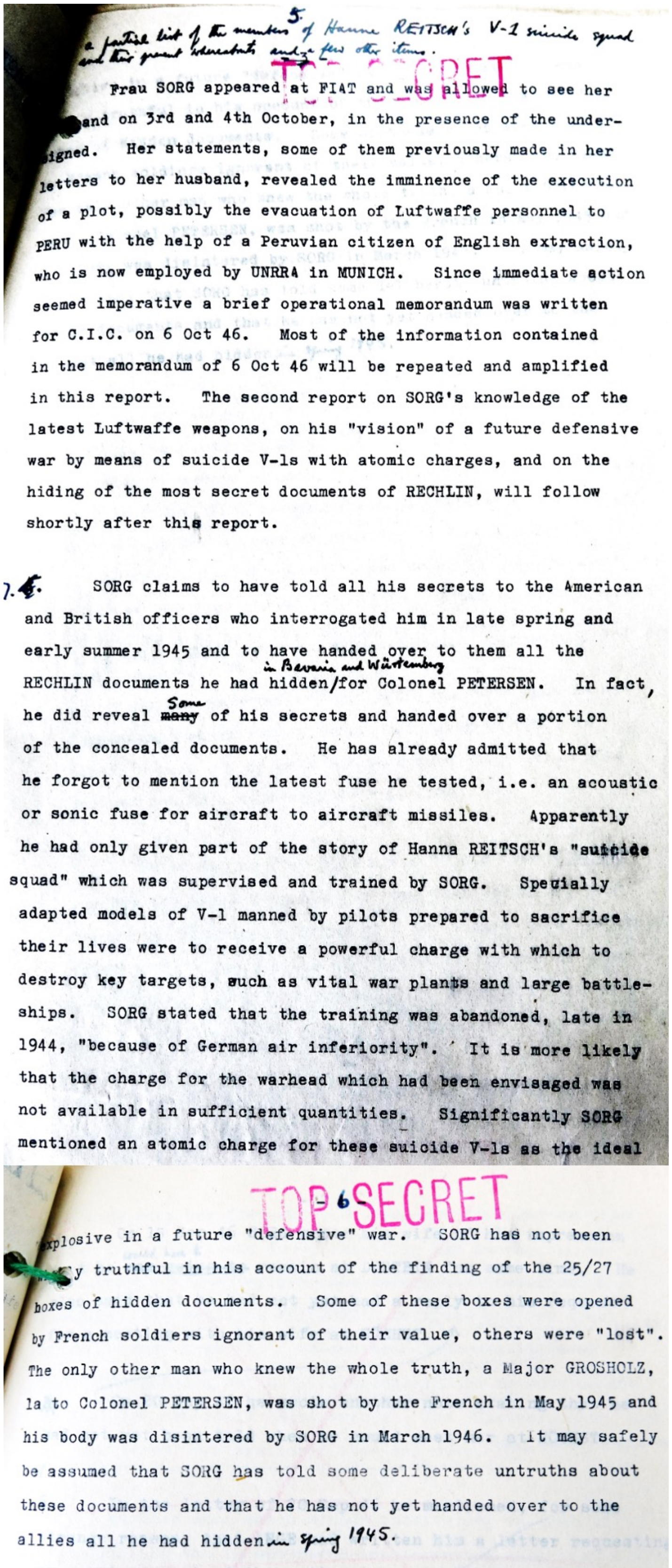
Ein Einwand, dass der Angreifer mit dem gleichen oben angeführten Totaleinsatz von wenigen Menschen den Verteidiger lahmlegen könnte, trifft nicht zu. Denn jeder moderne Angreifer muss einen ungeheuren Rüstungsapparat unterhalten, dessen Nervenzentren infolge ihrer Vielzahl immer sichtbar und daher verwundbar sein werden. Dagegen kann der Verteidiger, der diese Riesenrüstung nicht benötigt und sich durch die oben erwähnte Polizeitruppe schützt, seine wenigen hierzu erforderlichen Nerven so schützen oder verteilen, dass sie nicht lahmgelegt werden können.

Aus diesen Gründen erscheint mir die bemannte Atombombe besonders geeignet, Angriffsabsichten hochgerüsteter Staaten zu verhindern und damit die Welt vor erneuten unabsehbaren Verlusten an Menschen und Material zu bewahren.

E. Sorg

Figure D.918: Edmund Sorg. 17 August 1946. Betrachtungen über die bemannte V 1 im Zusammenhang mit Atomenergie. [TNA FO 1031/57]

TNA (Kew) FO 1031/112 Sorg V2



5.

a partial list of the members of Hanna REITSCH's V-1 suicide squad and their present whereabouts and a few other items.

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Frau SORG appeared at FIAT and was allowed to see her and on 3rd and 4th October, in the presence of the undersigned. Her statements, some of them previously made in her letters to her husband, revealed the imminence of the execution of a plot, possibly the evacuation of Luftwaffe personnel to PERU with the help of a Peruvian citizen of English extraction, who is now employed by UNRRA in MUNICH. Since immediate action seemed imperative a brief operational memorandum was written for C.I.C. on 6 Oct 46. Most of the information contained in the memorandum of 6 Oct 46 will be repeated and amplified in this report. The second report on SORG's knowledge of the latest Luftwaffe weapons, on his "vision" of a future defensive war by means of suicide V-1s with atomic charges, and on the hiding of the most secret documents of RECHLIN, will follow shortly after this report.

7. SORG claims to have told all his secrets to the American and British officers who interrogated him in late spring and early summer 1945 and to have handed over to them all the RECHLIN documents he had hidden/in Bavaria and Würtemburg for Colonel PETERSEN. In fact, he did reveal ~~many~~ some of his secrets and handed over a portion of the concealed documents. He has already admitted that he forgot to mention the latest fuse he tested, i.e. an acoustic or sonic fuse for aircraft to aircraft missiles. Apparently he had only given part of the story of Hanna REITSCH's "suicide squad" which was supervised and trained by SORG. Specially adapted models of V-1 manned by pilots prepared to sacrifice their lives were to receive a powerful charge with which to destroy key targets, such as vital war plants and large battleships. SORG stated that the training was abandoned, late in 1944, "because of German air inferiority". It is more likely that the charge for the warhead which had been envisaged was not available in sufficient quantities. Significantly SORG mentioned an atomic charge for these suicide V-1s as the ideal

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xplosive in a future "defensive" war. SORG has not been y truthful in his account of the finding of the 25/27 boxes of hidden documents. Some of these boxes were opened by French soldiers ignorant of their value, others were "lost". The only other man who knew the whole truth, a Major GROSHOLZ, Ia to Colonel PETERSEN, was shot by the French in May 1945 and his body was disintered by SORG in March 1946. It may safely be assumed that SORG has told some deliberate untruths about these documents and that he has not yet handed over to the allies all he had hidden in spring 1945.

Figure D.919: Edmund Tilley. October 1946. Report on the interrogation of Edmund Sorg. [TNA FO 1031/57] “Specially adapted models of V-1 manned by pilots prepared to sacrifice their lives were to receive a powerful charge with which to destroy key targets, such as vital war plants and large battleships... It is more likely that the charge for the warhead which had been envisaged was not available in sufficient quantities. Significantly SORG mentioned an atomic charge for these suicide V-1s as the ideal explosive in a future ‘defensive’ war.”

Hans Kammler. 23 April 1945 telegram. [BA (Bundesarchiv). Bestand NS 3/514, pp. 31–32. Microfilmed as: NARA RG 242, Records of the Reich Leader of the Schutzstaffel (SS) and Chief of the German Police, Microfilm 183, NAID 273992206 (https://catalog.archives.gov/id/273992206)].

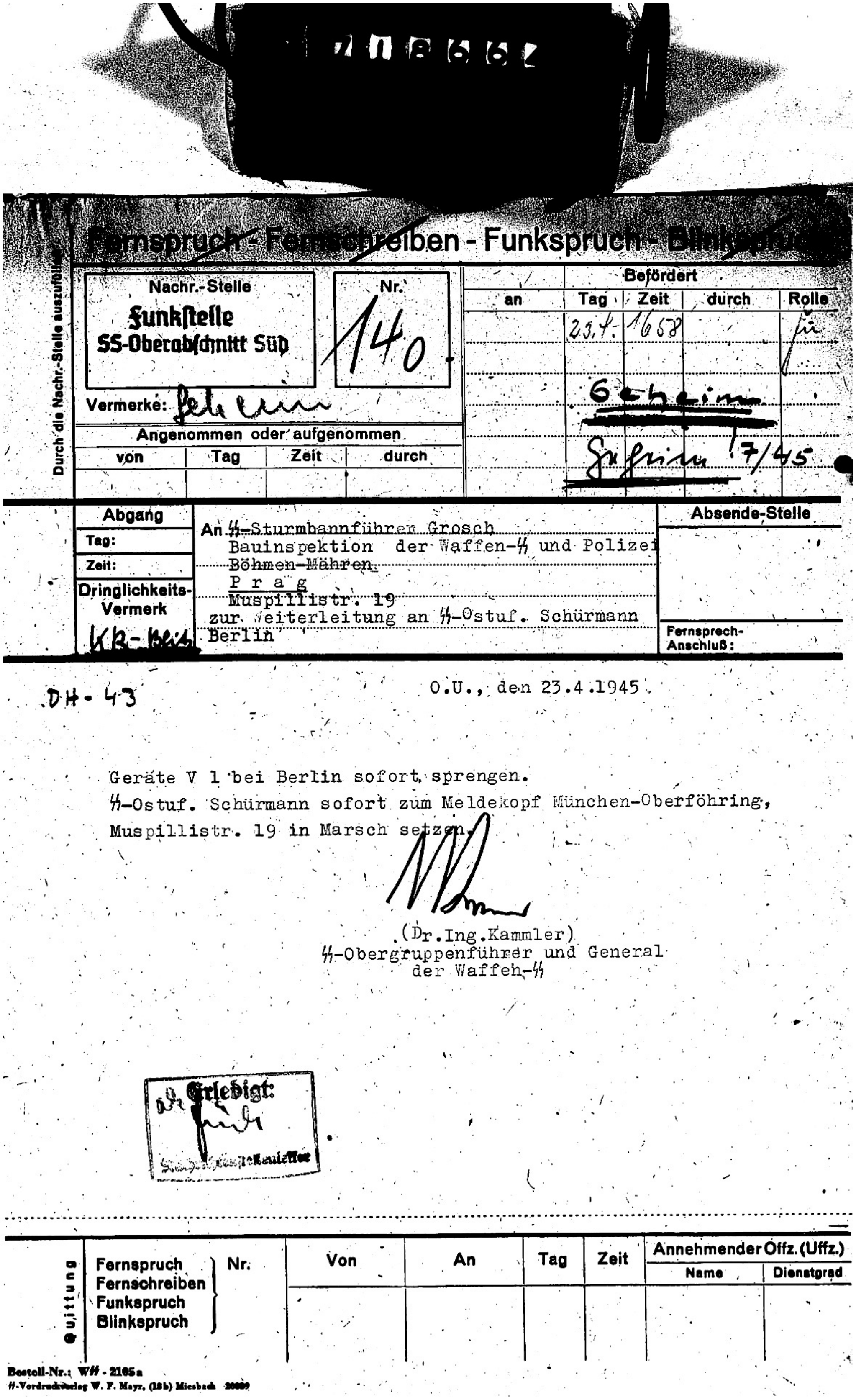
Geräte V 1 bei Berlin sofort sprengen.	Immediately blow up V 1 devices near Berlin.

[See document photo on p. 4901.

This was one of the last known communications Hans Kammler sent before he (secretly) surrendered to U.S. forces (pp. 4931–4959). "V 1" probably meant V-1 cruise missiles, although it is possible that it referred to some other type of device. V-1 cruise missiles had been mass-produced and were widely available, so there must have been something especially noteworthy about these particular V-1s. "Blow up" (sprengen) seems to have meant to destroy them before they could be captured, not to detonate them by firing them at targets, since no targets were mentioned.

The most likely explanation is that these were V-1s that had been modified to carry nuclear, chemical, or biological weapons, and that Kammler wanted those advanced weapons/evidence destroyed before Russian forces captured Berlin. Note that there were more than one of them (Geräte is plural). This document complements the evidence cited above that specially modified V-1s were constructed during the war and intended for strategic Allied targets before the end of the war.]

NARA RG 242, Records of the Reich Leader of the Schutzstaffel (SS) and Chief of the German Police, Microfilm 183, NAID 273992206 (https://catalog.archives.gov/id/273992206)



~~Fernspruch~~ - ~~Fernschreiben~~ - Funkspruch - ~~Blinkspruch~~

Durch die Nachr.-Stelle auszufüllen

Nachr.-Stelle: **Funkstelle SS-Oberabschnitt Süd**

Nr.: 140

Vermerke: geheim

Angenommen oder aufgenommen

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Geheim 7/45

Abgang

Tag:

Zeit:

Dringlichkeits-Vermerk: KR-Blitz

An ~~ᛋᛋ-Sturmbannführer Grosch~~
Bauinspektion der Waffen-ᛋᛋ und Polizei
~~Böhmen-Mähren~~
Prag
~~Muspillistr. 19~~
zur Weiterleitung an ᛋᛋ-Ostuf. Schürmann
Berlin

Absende-Stelle

Fernsprech-Anschluß:

DH-43

O.U., den 23.4.1945

Geräte V 1 bei Berlin sofort sprengen.
ᛋᛋ-Ostuf. Schürmann sofort zum Meldekopf München-Oberföhring,
Muspillistr. 19 in Marsch setzen.

(Dr.Ing.Kammler)
ᛋᛋ-Obergruppenführer und General
der Waffen-ᛋᛋ

Erledigt:

Quittung

Fernspruch Fernschreiben Funkspruch Blinkspruch	Nr.	Von	An	Tag	Zeit	Annehmender Offz. (Uffz.) Name	Annehmender Offz. (Uffz.) Dienstgrad

Bestell-Nr.: ᛋᛋ - 2165a
ᛋᛋ-Vordruckverlag W. F. Mayr, (13b) Miesbach 20000

Figure D.920: Hans Kammler. 23 April 1945 telegram: “Immediately blow up V 1 devices near Berlin.” [NARA RG 242, Records of the Reich Leader of the Schutzstaffel (SS) and Chief of the German Police, Microfilm 183, NAID 273992206 (https://catalog.archives.gov/id/273992206)]

Edmund Tilley. Brief Operational Report on [censored] and Other Germans and Italians Connected with Project Abstract. 19 August 1947. [NARA RG 319, Entry A1-134A, Box 29, Folder Operation Oberjoch]

1. On 11 August 1947 [censored] on the Italian phase of PROJECT ABSTRACT, which, in a few previous reports, was called Operation Arrival or Arrivederci, [censored] Headquarters, USAFE, by Captain R.R. SNEIDER of the CIC Detachment, BAD KISSINGEN. Major A J. LEOCHA [censored]

2. [Censored]

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[...] New Facts and Re-affirmation of Statements on PROJECT ABSTRACT.

4. Thorough cross-examination has not been effective in shaking [censored] on matters directly concerned with or related to PROJECT ABSTRACT.

a. Atomic research and development at TUCHELER HEIDE was coupled with research on guided missiles, in 1943 and 1944. (Note: In March 1947 Professor W. von BRAUN admitted that in the summer of 1943 he had been interested in atomic energy for use in V-2. Von BRAUN claimed to have dropped the project for lack of available raw materials. It may be mere coincidence that [censored] also places the beginning of combined research and development in 1943.—In March and April 1945 the undersigned heard rumors in Germany of such a combination. The most persistent rumors in I.G. FARBEN circles had it that this combination would be linked with Chemical Warfare, especially with the new nerve gases, i.e., the TABUN series. These rumors were repeated by responsible members of I.G. FARBEN, who added that this vague plan or hope had been abandoned. At the time no progress was made in the investigation of the atomic side of the problem because all effort was concentrated on a solution of the new Chemical Warfare problem. [Censored] now reveals that the ampullae (phials) he saw in four boxes in Italy had originated with I.G. FARBEN. (See b below).

b. Four boxes, probably originating in the Luftwaffe Ministry in Berlin, were sent in March 1945 by SD, POTSDAM, to ITALY in the care of a FELDWEBEL (Sergeant) HEINZ (surname forgotten!), [censored] and a Private (name forgotten!). The boxes contained (i) reports and research data on V-weapons and atomic research; (ii) 40–50 small ampullae (phials) "full of a whitish liquid", labeled U-234, U-235 and PLU, stamped "IG" (= IG Farbenindustrie); (iii) a new and not completely developed optical instrument probably intended for measuring speed and trajectory of guided missiles at the firing point; (iv) various small and delicate parts of guided missiles, fastened to cardboard by fine wires, with full description of each item attached to the cardboard.

c. The boxes were buried near VERONA by the FELDWEBEL, [censored] and a third soldier. (The site has been explored. Parts of wooden boxes or of a wooden box, fragments of paper and an ampullae (phial) marked U234 or U235 were seen by Captain SNEIDER and [censored]. The rest had vanished). [...]

BREE may be the same "person with a French name" (BOREU?) who worked spasmodically on "electric fuses for guided missiles" at TUCHELER HEIDE in 1943 and 1944. Thus he would know valuable details on the combined "guided missiles–atomic energy" research and development and would perhaps know where the missing documents were sent, whether they went first from TUCHELER HEIDE to BERLIN, as [censored] vaguely stated, and thence to SD, POTSDAM, and to Italy.

24. Ingenieur KRUEGER should be traced and brought at once to ECIC. He may give us valuable information on the combined "guided missiles–atomic energy" program at TUCHELER HEIDE in 1943 and 1944 and may know exactly where documents and instruments have been sent. [Censored] obtained most of his information on activities at TUCHELER HEIDE from KRUEGER, in 1944.

25. Prof. Dr. NIELS [Walter Nielsch?], now said to be in the United States, was, according to [censored,] concerned with chemical and atomic problems at TUCHELER HEIDE and produced a number of atomic bombs, weighing from 1 to 5 kilograms. NIELS should be traced and questioned in detail.

26. Prof. Dr. HUETTEN. Present whereabouts unknown to [censored.] He should be located and brought to ALASKA for questioning. According to [censored] he was the originator of the combined project of research and development of atomic energy and guided missiles at TUCHELER HEIDE. This project was named "Aktion HUETTEN" after him. He was transferred elsewhere, probably in 1943 (see paragraph 7).

27. Prof. Dr. HOFMANN, successor of HUETTEN as chief of the combined program at TUCHELER HEIDE, is now at "ALEXANDROWKA Kononien" near BAKU where he is continuing his former work. [...]

28. Prof W. Von BRAUN should be re-interrogated on the following: [...]

[For information on Edmund Tilley, see pp. 4894–4895. For more information on Project Abstract, see Mills and Johanson 2019.

The German military took over Tucheler Heide in September 1939 and used it as a proving ground (Truppenübungsplatz Westpreußen or Heidekraut) for rockets, nuclear work, and other experiments until January 1945. See p. 4462.

Walter Dornberger briefly mentioned rocket testing at Tucheler Heide [Dornberger 1958, pp. 227–229].

Dr. Walter Nielsch (German, 1915–20??) was an expert on chemical metallurgy [e.g., https://www.semanticscholar.org/author/W.-Nielsch/16969230] and a plausible candidate to have been involved in the purification of uranium-235, uranium-233, and/or plutonium-239. What exactly did Dr. Nielsch and/or Dr. Niels do during the war and also after the war?

Were the "number of atomic bombs, weighing from 1 to 5 kilograms" fission fuel pits for bombs?

Was this work on a nuclear-armed projectile at Tucheler Heide in Poland related to the alleged test of a nuclear-armed projectile in Poland (Section D.11)? See p. 2096 for a map of other known research sites in Poland.

The March 1947 interrogation of Wernher von Braun, mentioned in this document, is described in more detail in the document on p. 5762.]

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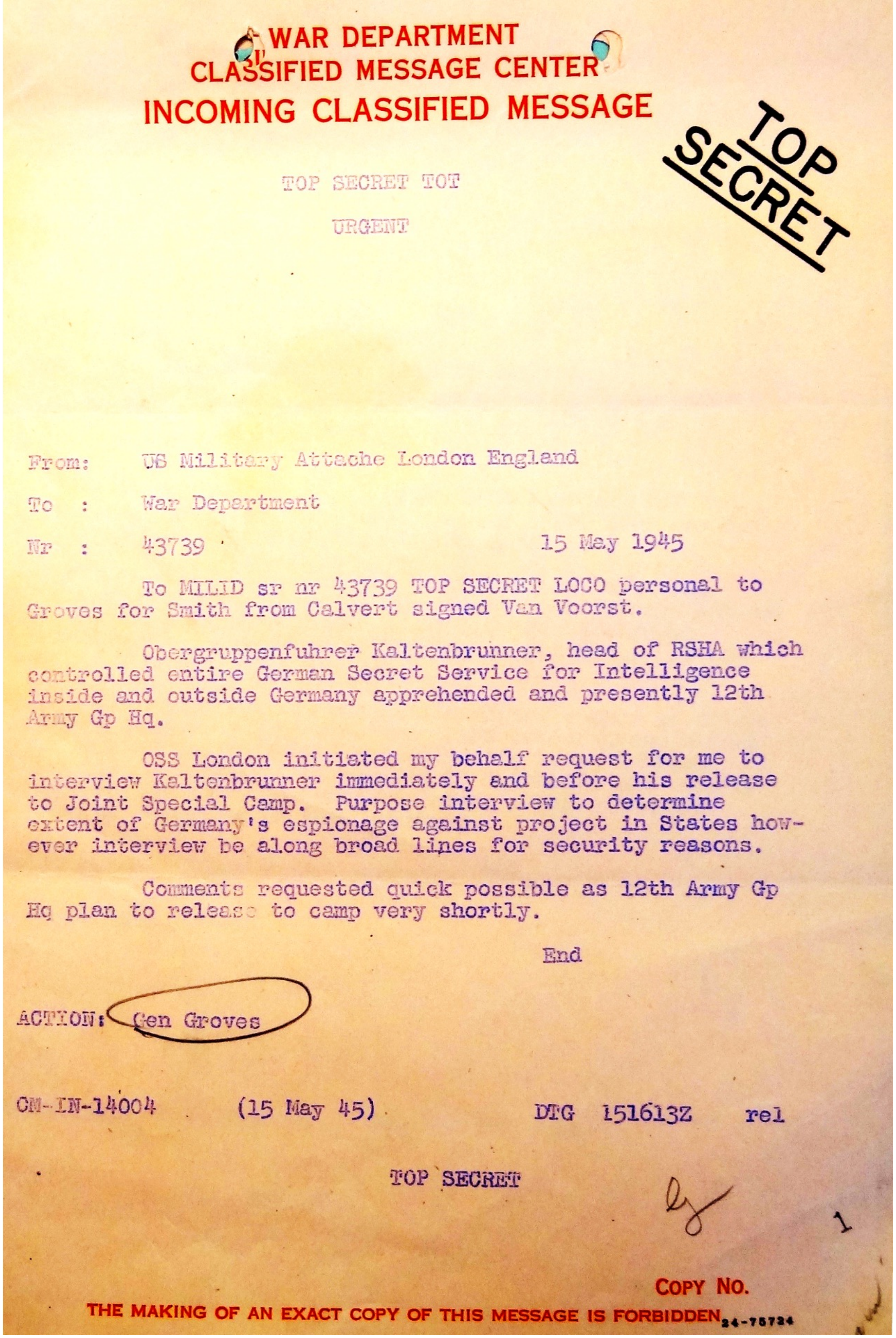
Authority NND 917017



WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
INCOMING CLASSIFIED MESSAGE

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URGENT

From: US Military Attache London England

To : War Department

Nr : 43739 15 May 1945

To MILID sr nr 43739 TOP SECRET LOCO personal to Groves for Smith from Calvert signed Van Voorst.

Obergruppenfuhrer Kaltenbrunner, head of RSHA which controlled entire German Secret Service for Intelligence inside and outside Germany apprehended and presently 12th Army Gp Hq.

OSS London initiated my behalf request for me to interview Kaltenbrunner immediately and before his release to Joint Special Camp. Purpose interview to determine extent of Germany's espionage against project in States however interview be along broad lines for security reasons.

Comments requested quick possible as 12th Army Gp Hq plan to release to camp very shortly.

End

ACTION: Gen Groves

CM-IN-14004 (15 May 45) DTG 151613Z rel

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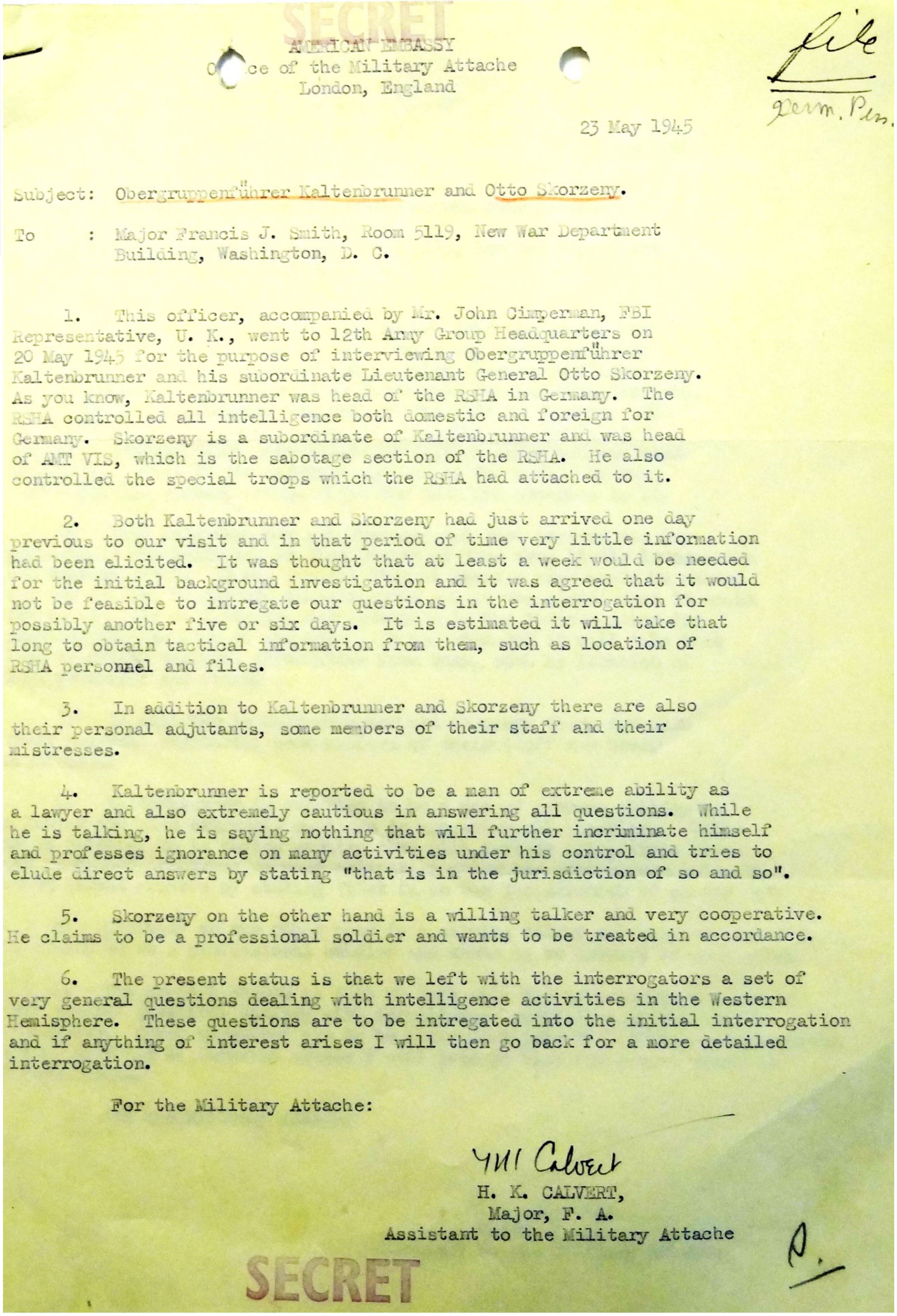
THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN 24-75734

NARA RG 77, Entry UD-22A, Box 160, Folder Apr 45—Dec. '45

Figure D.921: Horace K. Calvert to Leslie Groves and Francis J. Smith. 15 May 1945 [NARA RG 77, Entry UD-22A, Box 160, Folder Apr 45—Dec. '45]. After the war, Ernst Kaltenbrunner was interrogated regarding wartime nuclear research; he had been in a position to know a great deal about both the German and the U.S. programs. Where are the resulting reports?

DECLASSIFIED
Authority NND 917017



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AMERICAN EMBASSY
Office of the Military Attache
London, England

file
Germ. Pers.

23 May 1945

Subject: Obergruppenführer Kaltenbrunner and Otto Skorzeny.

To : Major Francis J. Smith, Room 5119, New War Department Building, Washington, D. C.

1. This officer, accompanied by Mr. John Cimperman, FBI Representative, U. K., went to 12th Army Group Headquarters on 20 May 1945 for the purpose of interviewing Obergruppenführer Kaltenbrunner and his subordinate Lieutenant General Otto Skorzeny. As you know, Kaltenbrunner was head of the RSHA in Germany. The RSHA controlled all intelligence both domestic and foreign for Germany. Skorzeny is a subordinate of Kaltenbrunner and was head of AMT VIS, which is the sabotage section of the RSHA. He also controlled the special troops which the RSHA had attached to it.

2. Both Kaltenbrunner and Skorzeny had just arrived one day previous to our visit and in that period of time very little information had been elicited. It was thought that at least a week would be needed for the initial background investigation and it was agreed that it would not be feasible to intregate our questions in the interrogation for possibly another five or six days. It is estimated it will take that long to obtain tactical information from them, such as location of RSHA personnel and files.

3. In addition to Kaltenbrunner and Skorzeny there are also their personal adjutants, some members of their staff and their mistresses.

4. Kaltenbrunner is reported to be a man of extreme ability as a lawyer and also extremely cautious in answering all questions. While he is talking, he is saying nothing that will further incriminate himself and professes ignorance on many activities under his control and tries to elude direct answers by stating "that is in the jurisdiction of so and so".

5. Skorzeny on the other hand is a willing talker and very cooperative. He claims to be a professional soldier and wants to be treated in accordance.

6. The present status is that we left with the interrogators a set of very general questions dealing with intelligence activities in the Western Hemisphere. These questions are to be intregated into the initial interrogation and if anything of interest arises I will then go back for a more detailed interrogation.

For the Military Attache:

HK Calvert
H. K. CALVERT,
Major, F. A.
Assistant to the Military Attache

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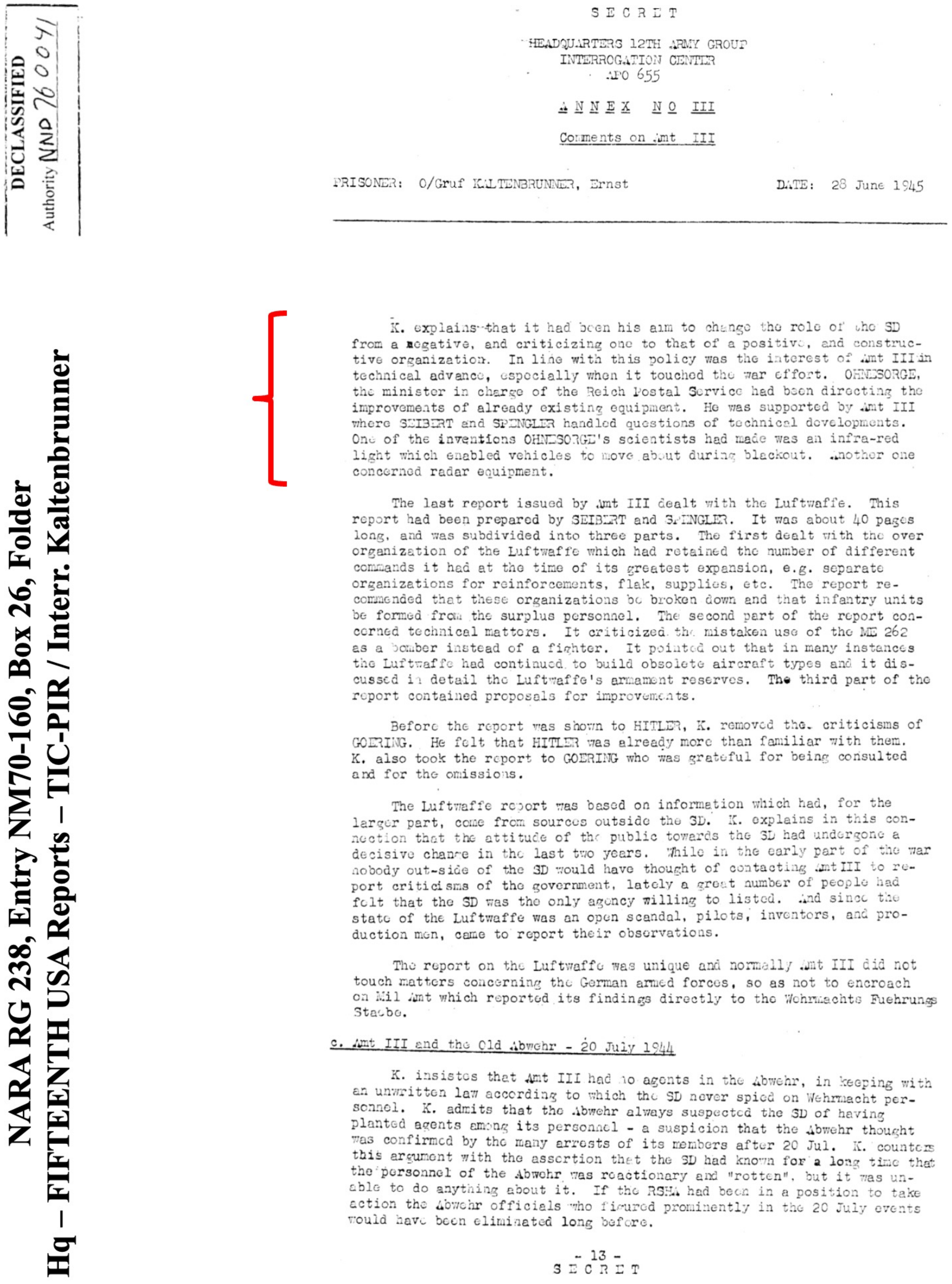
NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45--Dec 45)

Figure D.922: Horace K. Calvert to Francis J. Smith. 23 May 1945. Subject: Obergruppenführer Kaltenbrunner and Otto Skorzeny. [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)]. After the war, Ernst Kaltenbrunner was interrogated regarding wartime nuclear research; he had been in a position to know a great deal about both the German and the U.S. programs. Where are the resulting reports?



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NARA RG 238, Entry NM70-160, Box 26, Folder
Hq – FIFTEENTH USA Reports – TIC-PIR / Interr. Kaltenbrunner

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HEADQUARTERS 12TH ARMY GROUP
INTERROGATION CENTER
APO 655

ANNEX NO III

Comments on Amt III

PRISONER: O/Gruf KALTENBRUNNER, Ernst DATE: 28 June 1945

K. explains that it had been his aim to change the role of the SD from a negative, and criticizing one to that of a positive, and constructive organization. In line with this policy was the interest of Amt III in technical advance, especially when it touched the war effort. OHNESORGE, the minister in charge of the Reich Postal Service had been directing the improvements of already existing equipment. He was supported by Amt III where SEIBERT and SPENGLER handled questions of technical developments. One of the inventions OHNESORGE's scientists had made was an infra-red light which enabled vehicles to move about during blackout. Another one concerned radar equipment.

The last report issued by Amt III dealt with the Luftwaffe. This report had been prepared by SEIBERT and SPENGLER. It was about 40 pages long, and was subdivided into three parts. The first dealt with the over organization of the Luftwaffe which had retained the number of different commands it had at the time of its greatest expansion, e.g. separate organizations for reinforcements, flak, supplies, etc. The report recommended that these organizations be broken down and that infantry units be formed from the surplus personnel. The second part of the report concerned technical matters. It criticized the mistaken use of the ME 262 as a bomber instead of a fighter. It pointed out that in many instances the Luftwaffe had continued to build obsolete aircraft types and it discussed in detail the Luftwaffe's armament reserves. The third part of the report contained proposals for improvements.

Before the report was shown to HITLER, K. removed the criticisms of GOERING. He felt that HITLER was already more than familiar with them. K. also took the report to GOERING who was grateful for being consulted and for the omissions.

The Luftwaffe report was based on information which had, for the larger part, come from sources outside the SD. K. explains in this connection that the attitude of the public towards the SD had undergone a decisive change in the last two years. While in the early part of the war nobody out-side of the SD would have thought of contacting Amt III to report criticisms of the government, lately a great number of people had felt that the SD was the only agency willing to listed. And since the state of the Luftwaffe was an open scandal, pilots, inventors, and production men, came to report their observations.

The report on the Luftwaffe was unique and normally Amt III did not touch matters concerning the German armed forces, so as not to encroach on Mil Amt which reported its findings directly to the Wehrmachts Fuehrungs Stabe.

c. Amt III and the Old Abwehr - 20 July 1944

K. insistes that Amt III had no agents in the Abwehr, in keeping with an unwritten law according to which the SD never spied on Wehrmacht personnel. K. admits that the Abwehr always suspected the SD of having planted agents among its personnel - a suspicion that the Abwehr thought was confirmed by the many arrests of its members after 20 Jul. K. counters this argument with the assertion that the SD had known for a long time that the personnel of the Abwehr was reactionary and "rotten", but it was unable to do anything about it. If the RSHA had been in a position to take action the Abwehr officials who figured prominently in the 20 July events would have been eliminated long before.

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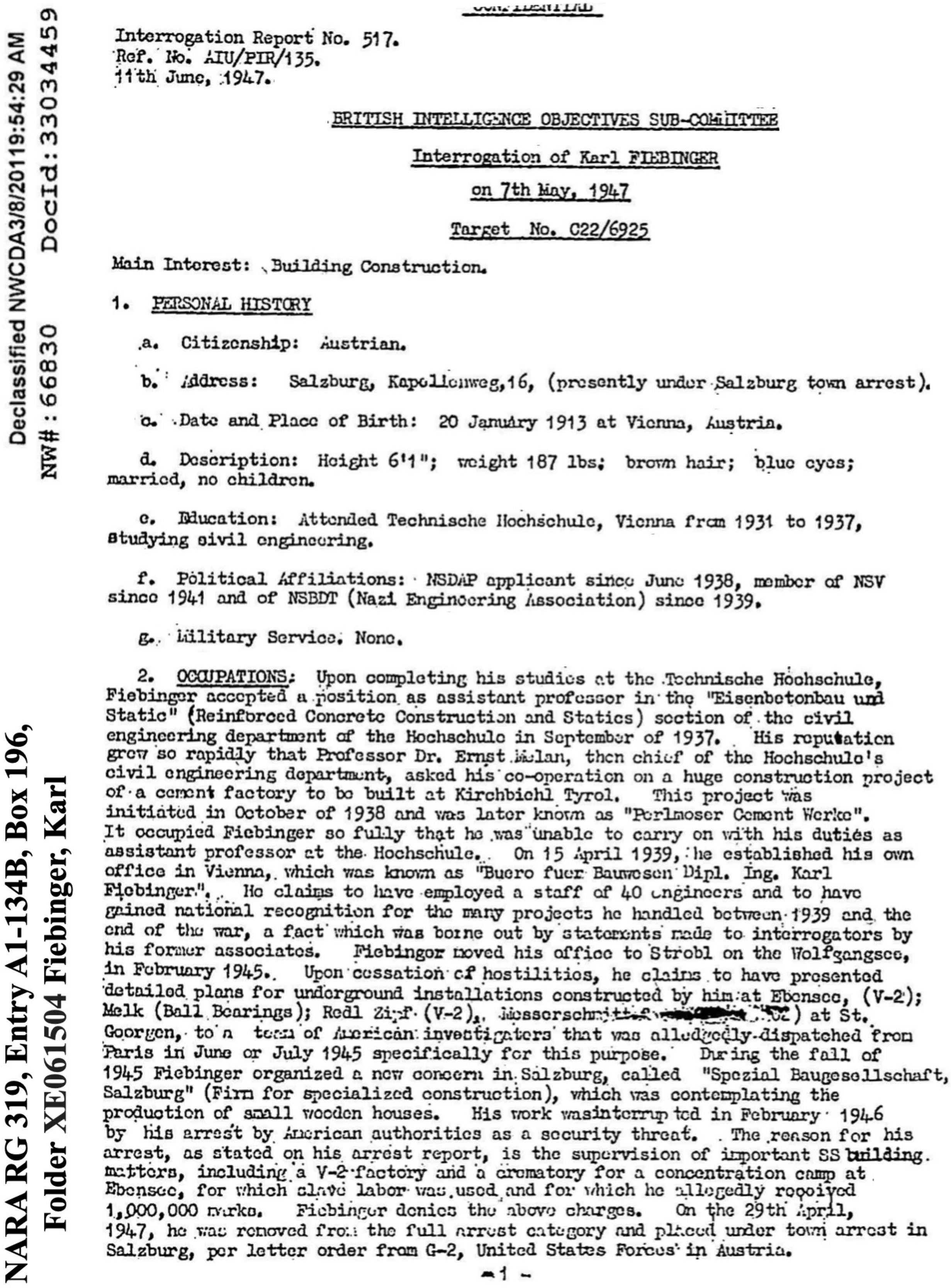
Figure D.923: Headquarters 12th Army Group Interrogation Center. 28 June 1945. PRISONER: O/Gruf KALTENBRUNNER, Ernst [NARA RG 238, Entry NM70-160, Box 26, Folder: Hq—FIFTEENTH USA Reports—TIC-PIR / Interr. Kaltenbrunner]. Ernst Kaltenbrunner had been deeply involved in technological collaborations between the SS and the Reichspost, which had been important for the German nuclear program. Where are the detailed reports on what he knew?



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Interrogation Report No. 517.
Ref. No. AIU/PIR/135.
11th June, 1947.

BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE

Interrogation of Karl FIEBINGER
on 7th May, 1947

Target No. C22/6925

Main Interest: Building Construction.

1. PERSONAL HISTORY

a. Citizenship: Austrian.

b. Address: Salzburg, Kapellenweg,16, (presently under Salzburg town arrest).

c. Date and Place of Birth: 20 January 1913 at Vienna, Austria.

d. Description: Height 6'1"; weight 187 lbs; brown hair; blue eyes; married, no children.

e. Education: Attended Technische Hochschule, Vienna from 1931 to 1937, studying civil engineering.

f. Political Affiliations: NSDAP applicant since June 1938, member of NSV since 1941 and of NSBDT (Nazi Engineering Association) since 1939.

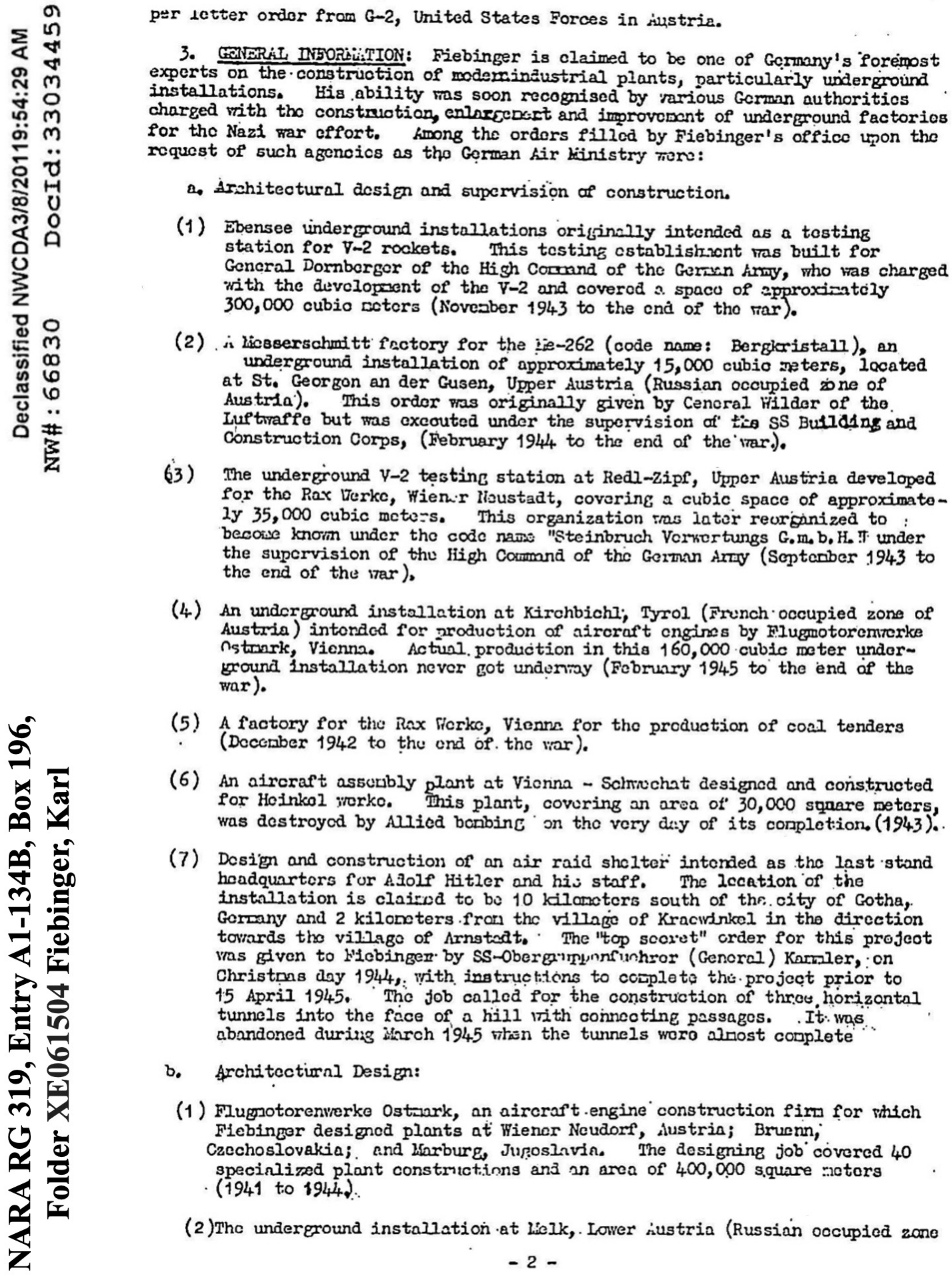
g. Military Service. None.

2. OCCUPATIONS: Upon completing his studies at the Technische Hochschule, Fiebinger accepted a position as assistant professor in the "Eisenbetonbau und Static" (Reinforced Concrete Construction and Statics) section of the civil engineering department of the Hochschule in September of 1937. His reputation grew so rapidly that Professor Dr. Ernst Melan, then chief of the Hochschule's civil engineering department, asked his co-operation on a huge construction project of a cement factory to be built at Kirchbichl Tyrol. This project was initiated in October of 1938 and was later known as "Perlmoser Cement Werke". It occupied Fiebinger so fully that he was unable to carry on with his duties as assistant professor at the Hochschule. On 15 April 1939, he established his own office in Vienna, which was known as "Buero fuer Bauwesen Dipl. Ing. Karl Fiebinger". He claims to have employed a staff of 40 engineers and to have gained national recognition for the many projects he handled between 1939 and the end of the war, a fact which was borne out by statements made to interrogators by his former associates. Fiebinger moved his office to Strobl on the Wolfgangsee, in February 1945. Upon cessation of hostilities, he claims to have presented detailed plans for underground installations constructed by him at Ebensee, (V-2); Melk (Ball Bearings); Redl Zipf (V-2), Messerschmitt [redacted]) at St. Georgen, to a team of American investigators that was alledgedly dispatched from Paris in June or July 1945 specifically for this purpose. During the fall of 1945 Fiebinger organized a new concern in Salzburg, called "Spezial Baugesellschaft, Salzburg" (Firm for specialized construction), which was contemplating the production of small wooden houses. His work wasinterrupted in February 1946 by his arrest by American authorities as a security threat. The reason for his arrest, as stated on his arrest report, is the supervision of important SS building matters, including a V-2 factory and a crematory for a concentration camp at Ebensee, for which slave labor was used and for which he allegedly received 1,000,000 marks. Fiebinger denies the above charges. On the 29th April, 1947, he was removed from the full arrest category and placed under town arrest in Salzburg, per letter order from G-2, United States Forces in Austria.

-1 -

NARA RG 319, Entry A1-134B, Box 196, Folder XE061504 Fiebinger, Karl

Figure D.924: Karl Fiebinger was the chief engineer of many massive underground facilities for advanced weapons production in the Third Reich. After the war he was interrogated by the U.K. and U.S. and worked for the United States. [NARA RG 319, Entry A1-134B, Box 196, Folder XE061504 Fiebinger, Karl]



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NARA RG 319, Entry A1-134B, Box 196, Folder XE061504 Fiebinger, Karl

per letter order from G-2, United States Forces in Austria.

3. GENERAL INFORMATION: Fiebinger is claimed to be one of Germany's foremost experts on the construction of modern industrial plants, particularly underground installations. His ability was soon recognised by various German authorities charged with the construction, enlargement and improvement of underground factories for the Nazi war effort. Among the orders filled by Fiebinger's office upon the request of such agencies as the German Air Ministry were:

a. Architectural design and supervision of construction.

(1) Ebensee underground installations originally intended as a testing station for V-2 rockets. This testing establishment was built for General Dornberger of the High Command of the German Army, who was charged with the development of the V-2 and covered a space of approximately 300,000 cubic meters (November 1943 to the end of the war).

(2) A Messerschmitt factory for the Me-262 (code name: Bergkristall), an underground installation of approximately 15,000 cubic meters, located at St. Georgen an der Gusen, Upper Austria (Russian occupied zone of Austria). This order was originally given by General Wilder of the Luftwaffe but was executed under the supervision of the SS Building and Construction Corps, (February 1944 to the end of the war).

(3) The underground V-2 testing station at Redl-Zipf, Upper Austria developed for the Rax Werke, Wiener Neustadt, covering a cubic space of approximately 35,000 cubic meters. This organization was later reorganized to become known under the code name "Steinbruch Verwertungs G.m.b.H." under the supervision of the High Command of the German Army (September 1943 to the end of the war).

(4) An underground installation at Kirchbichl, Tyrol (French occupied zone of Austria) intended for production of aircraft engines by Flugmotorenwerke Ostmark, Vienna. Actual production in this 160,000 cubic meter underground installation never got underway (February 1945 to the end of the war).

(5) A factory for the Rax Werke, Vienna for the production of coal tenders (December 1942 to the end of the war).

(6) An aircraft assembly plant at Vienna - Schwechat designed and constructed for Heinkel werke. This plant, covering an area of 30,000 square meters, was destroyed by Allied bombing on the very day of its completion. (1943).

(7) Design and construction of an air raid shelter intended as the last stand headquarters for Adolf Hitler and his staff. The location of the installation is claimed to be 10 kilometers south of the city of Gotha, Germany and 2 kilometers from the village of Kraewinkel in the direction towards the village of Arnstadt. The "top secret" order for this project was given to Fiebinger by SS-Obergruppenfuehrer (General) Kammler, on Christmas day 1944, with instructions to complete the project prior to 15 April 1945. The job called for the construction of three horizontal tunnels into the face of a hill with connecting passages. It was abandoned during March 1945 when the tunnels were almost complete

b. Architectural Design:

(1) Flugmotorenwerke Ostmark, an aircraft engine construction firm for which Fiebinger designed plants at Wiener Neudorf, Austria; Bruenn, Czechoslovakia; and Marburg, Jugoslavia. The designing job covered 40 specialized plant constructions and an area of 400,000 square meters (1941 to 1944).

(2) The underground installation at Melk, Lower Austria (Russian occupied zone

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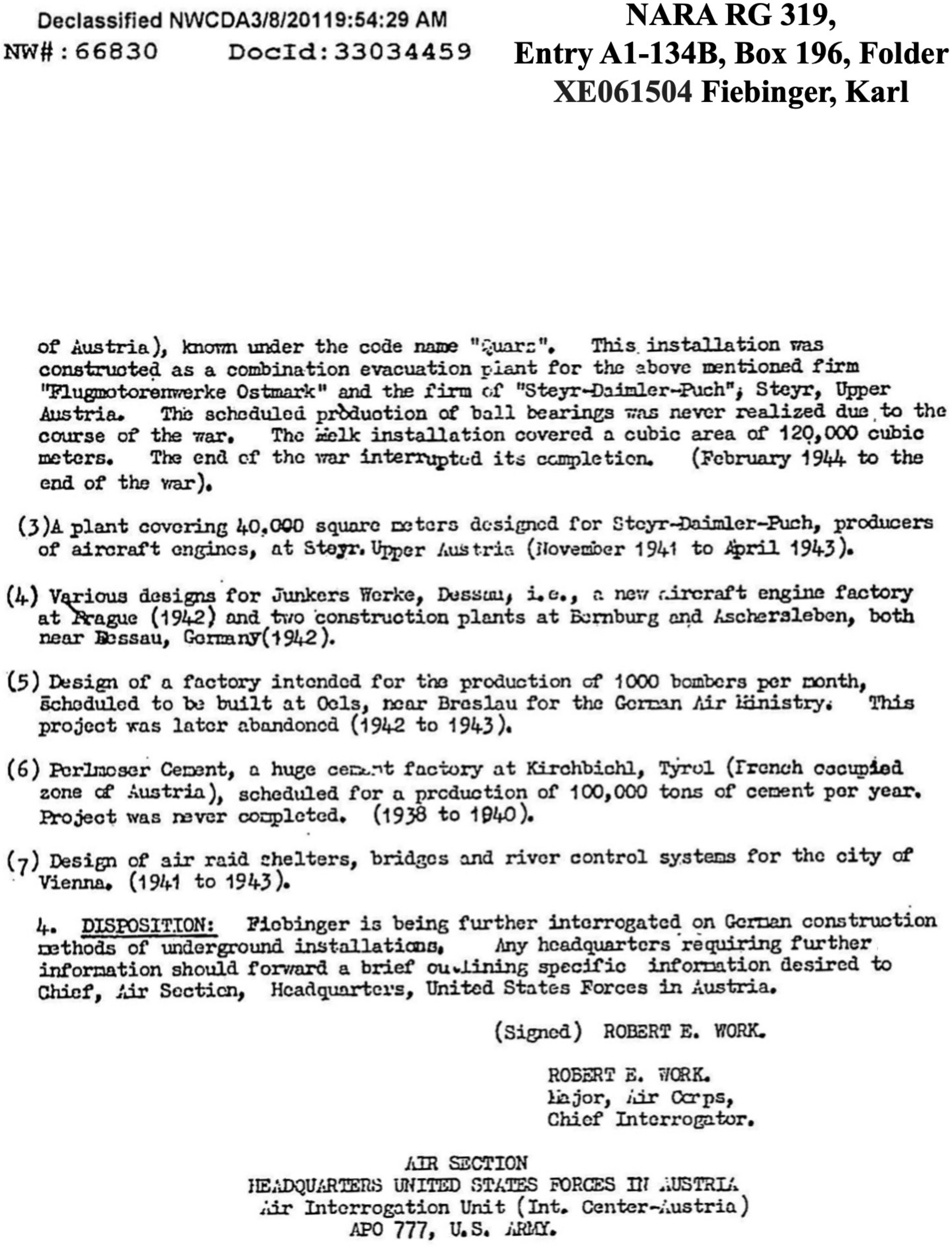
Figure D.925: Karl Fiebinger was the chief engineer of many massive underground facilities for advanced weapons production in the Third Reich. After the war he was interrogated by the U.K. and U.S. and worked for the United States. [NARA RG 319, Entry A1-134B, Box 196, Folder XE061504 Fiebinger, Karl]



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NARA RG 319, Entry A1-134B, Box 196, Folder XE061504 Fiebinger, Karl

of Austria), known under the code name "Quarz". This installation was constructed as a combination evacuation plant for the above mentioned firm "Flugmotorenwerke Ostmark" and the firm of "Steyr-Daimler-Puch", Steyr, Upper Austria. The scheduled production of ball bearings was never realized due to the course of the war. The Melk installation covered a cubic area of 120,000 cubic meters. The end of the war interrupted its completion. (February 1944 to the end of the war).

(3) A plant covering 40,000 square meters designed for Steyr-Daimler-Puch, producers of aircraft engines, at Steyr. Upper Austria (November 1941 to April 1943).

(4) Various designs for Junkers Werke, Dessau, i.e., a new aircraft engine factory at Prague (1942) and two construction plants at Bernburg and Aschersleben, both near Dessau, Germany (1942).

(5) Design of a factory intended for the production of 1000 bombers per month, scheduled to be built at Oels, near Breslau for the German Air Ministry. This project was later abandoned (1942 to 1943).

(6) Perlmoser Cement, a huge cement factory at Kirchbichl, Tyrol (French occupied zone of Austria), scheduled for a production of 100,000 tons of cement per year. Project was never completed. (1938 to 1940).

(7) Design of air raid shelters, bridges and river control systems for the city of Vienna. (1941 to 1943).

4. DISPOSITION: Fiebinger is being further interrogated on German construction methods of underground installations. Any headquarters requiring further information should forward a brief outlining specific information desired to Chief, Air Section, Headquarters, United States Forces in Austria.

(Signed) ROBERT E. WORK.

ROBERT E. WORK.
Major, Air Corps,
Chief Interrogator.

AIR SECTION
HEADQUARTERS UNITED STATES FORCES IN AUSTRIA
Air Interrogation Unit (Int. Center-Austria)
APO 777, U.S. ARMY.

Figure D.926: Karl Fiebinger was the chief engineer of many massive underground facilities for advanced weapons production in the Third Reich. After the war he was interrogated by the U.K. and U.S. and worked for the United States. [NARA RG 319, Entry A1-134B, Box 196, Folder XE061504 Fiebinger, Karl]

Günter Nagel. 2012a. *Wissenschaft für den Krieg: Die geheimen Arbeiten der Abteilung Forschung des Heereswaffenamtes.* Stuttgart: Franz Steiner. pp. 489–490. [Where are the postwar British reports on information that Erich Schumann gave to the U.K. or work that he did for the U.K.? Schumann must have provided something of great value for the U.K. not to turn him over to the ongoing war crimes trials or to the United States. See pp. 3294–3296.]

In der Erklärung Schumanns von Januar 1957 heißt es weiter:

"Ich hielt mich zwischen Mai 1945 und Mai 1947 bei Bekannten auf, meist in Berlin. So entging ich zunächst einer Fest- bzw. Gefangennahme. Erst in Frühjahr 1947 habe ich mit Herrn Geh. Rat. Prof. Dr. Planck (damals in Göttingen) wegen meiner Einfädelung im Westen Verbindung aufgenommen. Dieser empfahl mir, nachdem er bei englischen Dienststellen hatte anfragen lassen, eine persönliche Meldung bei den Engländern in Göttingen. Daraufhin meldete ich mich im Juli 1947 bei der englischen Besatzungsbehörde in Göttingen (unter Übergabe eines Abmeldescheines damaligen Datums aus Dolgelin, wo ich mich nicht persönlich abmeldete, aber abmelden ließ. Ein guter Bekannter überbrachte mir den Abmeldeschein.)

Die englische Besatzungsbehörde veranlaßte dann

a) Befragung (aber noch auf freiem Fuß),

b) Gefangennahme,

c) Registrierung meines Einganges in die britische Zone (festgesetzt auf den 14. 08. 1947—aber bereits in Lübeck—s. anliegende Abschrift des englischen Registrierscheines Nr. 001013 vom 1. 09. 1947, Intelligence Team Friedland Camp),

d) Entlassung aus der Gefangenschaft und

e) Zuzugsgenehmigung durch den Regierungspräsidenten Hildesheim (Bezirksflüchtlingsamt) von 9. 9. 1947 (s. Anlage zu 25 c)."

Als Wohnorte gab Schumann an: Göttingen 1947, Hamburg 1948, Düsseldorf 1953 und Detmold 1956.[1313]

Schumann's statement from January 1957 goes on to say:

"I stayed with friends between May 1945 and May 1947, mostly in Berlin. That's how I initially escaped capture or imprisonment. It was only in the spring of 1947 that I spoke to Mr. Geh. Rat. Prof. Dr. Planck (in Göttingen at the time) about my placement in the West. After making inquiries with the British authorities, he recommended that I report personally to the British in Göttingen. As a result, I registered with the British occupation authorities in Göttingen in July 1947 (handing over a deregistration form of that date from Dolgelin, where I did not personally deregister, but had myself deregistered. A good acquaintance gave me the deregistration certificate).

The British occupation authorities then arranged for

a) Interrogation (but still at large),

b) capture,

c) registration of my arrival in the British zone (for 14 August 1947—but already in Lübeck—see attached copy of British registration certificate No. 001013 dated 1 September 1947, Intelligence Team Friedland Camp),

d) release from captivity and

e) Relocation permit from the Hildesheim District President (District Refugee Office) dated 9 Sept. 1947 (see attachment to 25 c)."

Schumann gave his places of residence as: Göttingen 1947, Hamburg 1948, Düsseldorf 1953, and Detmold 1956.[1313]

Für die von Planck empfohlene Verbindungsaufnahme mit englischen Stellen in Göttingen nutzte Schumann seine frühere Bekanntschaft mit Telschow, der sich in Göttingen aufhielt—damals Sitz der aus Berlin ausgewichenen KWG. Am 4. August 1947 stellte Telschow den Kontakt Schumanns mit den Engländern her. Zwei Monate später übergab Schumann in Göttingen an "Herrn Porhase (AVA)" einen kurzen Bericht über das Reichweitengeschoss, der für einen Mister Groves bestimmt war. Dieser Vorgang belegt ein weiteres Mal die bekannte "Situations-Geschicklichkeit" (Cobarg) Schumanns. Vergleicht man nämlich den dürftigen Bericht (eine Schreibmaschinenseite!) mit den tatsächlichen Forschungsergebnissen zum Trommsdorff-Geschoss (vgl. Kapitel 12), dann weiß man sofort: Schumann hielt den Engländern einen kleinen Happen hin, den eigentlichen Braten behielt er für sich.[1314]

Was Schumann damals alles seinen "neuen englischen Freunden" von den Geheimnissen der deutschen Rüstungsforschung preisgab, lässt sich nur erahnen. Aber es muss—wie noch an anderer Stelle belegt wird—so ergiebig und wertvoll gewesen sein, dass die Engländer hin und wieder ihre schützende Hand über den Professor hielten. Solche Art Fürsorge hatte Schumann in den ersten Jahren nach dem Krieg mitunter auch bitter nötig, vor allem wegen einiger Prozesse, in denen seine Person eine Rolle spielte.

Schumann used his previous acquaintance with Telschow, who was in Göttingen–at that time the headquarters of the KWG, which had been evacuated from Berlin–to establish contact with the British authorities in Göttingen, as recommended by Planck. On August 4, 1947, Telschow established Schumann's contact with the British. Two months later, Schumann handed over a short report on the long-range projectile to "Mr. Porhase (AVA)" in Göttingen, which was intended for Mr. Groves. This process once again demonstrates Schumann's well-known "situational dexterity" (Cobarg). If one compares the meagre report (one typewritten page!) with the actual research results on the Trommsdorff projectile (cf. Chapter 12), then one knows immediately: Schumann held out a small morsel to the English, he kept the actual roast for himself.[1314]

We can only guess what Schumann revealed to his "new English friends" about the secrets of German armaments research. But it must have been—as is documented elsewhere—so productive and valuable that the English occasionally held their protective hand over the professor. Schumann was in dire need of this kind of care in the early years after the war, especially because of a number of [war-related] trials in which he played a role.

[1313] Schriftliche Erklärung Schumanns vom 5. January 1957 "Anlage zu 24c und 25a", NL Schumann. Die Grunde, die zu dieser Erklärung führten, sind nicht bekannt.

[1314] Briefwechsel Schumann/Telschow 1947/48, AMPG, III. Abt., Rep. 83, Nr. 286. Interessant ist, dass in dem kurzem Vermerk auf den Bericht "Reichweitengeschoss" hingewiesen wird, dieses Dokument jedoch im Nachlass Telschow nicht vorhanden ist. Eine Kopie befand sich im Nachlass Schumann, mit handschriftlichem Vermerk zum Termin der der Abgabe an "Porhase", bestimmt für den Empfänger Groves.

[1313] Written declaration by Schumann dated January 5, 1957 "Annex to 24c and 25a," Schumann estate. The reasons that led to this declaration are not known.

[1314] Correspondence between Schumann and Telschow 1947/48, AMPG, III. Abt., Rep. 83, No. 286. It is interesting that the short note refers to the report "Reichweitengeschoss," but this document does not exist in the Telschow estate. A copy was found in the Schumann estate, with a handwritten note on the date of delivery to "Porhase," intended for the recipient Groves.

[How much information from Schumann was forwarded to Leslie Groves and the United States?]

Heinrich Klein. 1977. *Vom Geschoß zum Feuerpfeil: Der große Umbruch der Waffentechnik in Deutschland 1900–1970: Eine Dokumentation.* Stuttgart: Motorbuch. pp. 96–97.

[Heinrich Klein (German, 19??–19??) led the Rheinmetall-Borsig team that created the Rheintochter two-stage, radio-guided, surface-to-air missile, which was first demonstrated in 1943 (p. 1912). Klein's team also created the larger Rheinbote four-stage missile, first launched in 1943 (p. 1913) [Klein 1977; Margry 2001; Mills 2020, 2022]. In fact, according to a 1947 French military document, during the war Klein was even personally involved in "the construction of flying rockets... capable of crossing the Atlantic in 40 minutes" (p. 5452).]

Mitte Mai 1945, nach der Kapitulation Deutschlands, wurde der Verfasser durch eine gemischte amerik.-engl.-austral. technische Kommission auf dem Schießplatz Unterlüss über die neuen Waffenentwicklungen in Deutschland befragt. Zuvor hatte die Kommission die gesamten Einrichtungen des Meßhauses, die Laborieranstalt und der Füllanlage Neulüss besichtigt und natürlich Meßgeräte und Munition durch ein englisches Truppenkommando sicherstellen lassen. Bei der Besichtigung der Laborieranstalt war die Kommission auch auf einige Brennkammern der Flugstufe des "Rheinboten" gestoßen, die mit dem letzten Troß von Leba nach Unterlüss gebracht worden waren. Im Zuge der Befragungen wandte sich der Leiter der Kommission an den Verfasser und fragte nach dem Sinn und Zweck der gesichteten Brennkammern. Die Kommission habe ähnliche Kammern auf der Strecke über Holland in Richtung Antwerpen gefunden.

In mid-May 1945, after the capitulation of Germany, the author was questioned by a mixed American-English-Australian technical commission at the Unterlüss firing range about the new weapons developments in Germany. The commission had previously inspected the entire facilities of the measuring station, the laboratory, and the Neulüss filling plant, and of course had measuring instruments and ammunition that had been secured by an English troop detachment. During the inspection of the laboratory, the commission also came across some combustion chambers from a stage of the "Rheinbote," which had been brought to Unterlüss with the last convoy from Leba. In the course of the questioning, the head of the commission approached the author and asked about the purpose of the combustion chambers he had seen. The commission had found similar chambers along the trajectory towards Antwerp in Holland.

Irgendwelche Einzelheiten waren dem Verfasser über den Einsatz des “Rheinboten” im Westen nicht bekannt geworden, aber es lag nahe, daß es sich um Stufenteile jener Geräte handeln mußte, die für den Einsatz vorbereitet worden waren. Aus der Fragestellung der Kommission war eindeutig zu entnehmen, daß ihnen das Gerät vollkommen unbekannt war. Sie wollten es zunächst auch nicht glauben, daß das Stufenprinzip für Raketen in Deutschland bereits gelöst wäre, ließen sich dann aber später an Hand einigen Erklärungen davon überzeugen. Mehrere Male während dieser Befragung sprach die Kommission davon, ob der “Rheinbote” die Rakete gewesen wäre, die mit einem atomaren Sprengkopf versehen werden sollte. Auf diese Frage konnte der Verfasser keine Antwort geben, da ihm nicht bekannt war, daß man den Nutzlastkopf dieser Rakete für einen besonderen Zweck verwenden wollte. Wie aus einem später mit dem Leiter der Einsatzabteilung, Oberstleutnant Tröller, geführten Gespräch erkennbar wurde, hat tatsächlich die Überlegung bestanden, den “Rheinboten” mit einer atomaren Nutzlast auszustatten. Wieweit dies nach dem Stand der atomaren Technik in Deutschland möglich gewesen wäre, vermag der Verfasser nicht zu beurteilen. Die Mitteilung von Tröller beruhte darauf, daß ihm SS-Obergruppenführer Dr. Kammler ganz real von einer solchen Einsatzmöglichkeit gesprochen hatte.

The author did not know any details about the use of the “Rheinbote” on the western front, but it was obvious that its stages must have been prepared for [combat] use. It was clear from the commission’s questions that the device was completely unknown to them. At first they did not want to believe that the stage principle for rockets had already been solved in Germany, but they were later convinced by some explanations. Several times during this questioning, the commission asked whether the “Rheinbote” would have been the missile to be fitted with a nuclear warhead. The author could not give an answer to this question, as he was not aware that the payload compartment of this missile was to be used for a special purpose. As became clear from a later conversation with the head of the Operations Department, Lieutenant Colonel Tröller, the idea of equipping the “Rheinbote” with a nuclear payload had indeed been considered. The author is not in a position to judge to what extent this would have been possible given the state of nuclear technology in Germany. Tröller’s report was based on the fact that SS-Obergruppenführer Dr. Kammler had actually spoken to him about such a possible use.

[Based on evidence they had seen, this postwar Allied commission was convinced that Germany possessed or would have soon possessed operational nuclear weapons. What exactly was this commission? Where are their reports? What was their evidence?

German officials who would have been in a position to know, including Hans Kammler and Oberstleutnant Tröller, were convinced that Germany possessed or would have soon possessed operational nuclear weapons. Where are the wartime and postwar documents regarding what they knew?

The Rheinbote version deployed during the war only carried 40 kg of payload. Were the Allied and German officials referring to using Rheinbote missiles with each carrying 40 kg of radioisotopes as a radiological weapon? If so, that would imply that Allied and German officials had knowledge of at least one operational German fission reactor, since a fission reactor would be required to produce sufficiently large quantities of sufficiently radioactive isotopes to support such a weapon system.

The known Rheinbote was rushed to deployment and was likely just a technological stepping stone toward a larger solid propellant Rheinbote-series rocket with a larger payload capacity [Georg 2009, pp. 502–504; https://archive.org/stream/WaffenArsenal189/Waffen%20Revue%2084_djvu.txt]. A larger Rheinbote version might have been able to carry the ~300 kg of the small nonspherical fission implosion bomb that was described by other sources (p. 5170).]

HQ CIC, USFET, Region Munich IV, Munich Sub-Regional Office, 25 April 1946. Subject: Wilhelm Voss. Declassified 2006 [NARA RG 263, Entry ZZ-18, Box 133, File Voss, Friedrich Wilhelm].

1. Dr. Wilhelm VOSS reported to this office 24 April 1946. Subject was the director of the Skoda Works and Bruenner Waffenwerke in Prague, Czechoslovakia from 1939–1945. Subject claims that he has valuable information on atom bomb research in Germany. He also states that he has information on a new type torpedo which is radar controlled and leave no trace in water.

2. Dr. Wilhelm VOSS was born 1 July 1896 in Rostock, Mecklenburg. [...] He was one of the founders of Reichswerke Hermann Goering and in 1938 became its commercial director. In 1939 VOSS was appointed director of Skoda and Bruenner Waffenwerke by Goering.

3. Subject states that the two men that were responsible for research on the most secret weapons at Skoda were SS Gruppenfuehrer Prof. KAMMLER and his deputy SS Oberfuehrer PURUCKER. On the 10 May 1945 VOSS and PURUCKER were in Schimelitz, fleeing in the direction of the American troops. PURUCKER was driving a large civilian car which contained many of the plans on the atom bomb. This car plus material fell into the hands of the Russians, and VOSS was separated from PURUCKER. VOSS at present does not know where PURUCKER is located.

4. Subject was held prisoner by the Czechs in the concentration camp Modran. He was released two weeks ago and at present resides in Odelzhausen near Munich. Subject is moving on 25 April 46 to Egern/a, Tegernsee, Seestrasse 68, c/o REINHOLD. CIC in Tegernsee was notified by phone on the 24 April 1946, and VOSS was told to report to CIC Tegernsee immediately on arrival there.

5. VOSS states that the following men know more detailed plans on the atom bomb and other secret weapons.

> a. Director Alfred BAUBIN of the staff of KAMMLER. Middle of March BAUBIN was supposed to have still been in Internment Camp Schtehowitz near Prague. He was slated to be returned to his native Austria.
>
> b. Director ENGEL, manager of research laboratory in Pibrams and closely connected with KAMMLER. VOSS believes that ENGEL escaped from Czechoslovakia and might subsequently have become PW in American hands.
>
> c. Members of the Research Group could be found in the secret "Mitteilungsblatt des Ruestungsministeriums."

[See pp. 4915– 4919 for excerpts from the original German-language interrogation transcript of Voss that is referenced in this document.]

Wilhelm Voss. April 1946 statement [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm]. [See photos on pp. 4916– 4919.]

Die zentrale Leitung der Entwicklung und Fertigung der geheimsten Waffen und Geräte lag in den letzten Jahren in Händen des SS-Gruppenführers Prof. Kammler und seiner Arbeitsgruppe. Dabei handelt es sich um die geheimsten Waffen, Geräte und Verfahren, die z.T. tatsächlich eingesetzt wurden, z.T. aber auch nicht mehr zur Anwendung kamen, und zwar auf dem Gebeit der Atomzertrümmerung, der Umwandlung der Elemente, der Atombombe und der Atomenergie, weiter der Raketenwaffen, neuester Antriebkräfte für Flugzeuge, der Fernsteuerung usw. Während auf manchen Gebieten noch bis in die letzte Zeit des Krieges die verschiedenen Wehrmachtsteile unabhängig voneinander arbeiteten, gelang es Kammler, auf seinem Gebiet vor allem die Entwicklungsarbeiten zentral bei sich zu vereinigen. Er war der Vertreter zugleich des Rüstungsministeriums, des Heereswaffenamtes, des Luftfahrtministeriums und der SS. [...]

In the last years [of the war], the central management of the development and production of the most secret weapons and devices was in the hands of SS General Professor Kammler and his working group. These were the most secret weapons, devices, and processes, some of which were actually used, but some of which were not used [in the war], namely in the field of atom smashing, the [nuclear] transformation of elements, the atomic bomb and atomic energy, and also rocket weapons, the latest propulsion systems for aircraft, remote control, etc. While in some areas the various parts of the Wehrmacht worked independently of each other until the last days of the war, Kammler succeeded in centralizing the development work in his field. He was the representative of the Ministry of Armaments, the Army Ordnance Office, the Air Force, and the SS at the same time. [...]

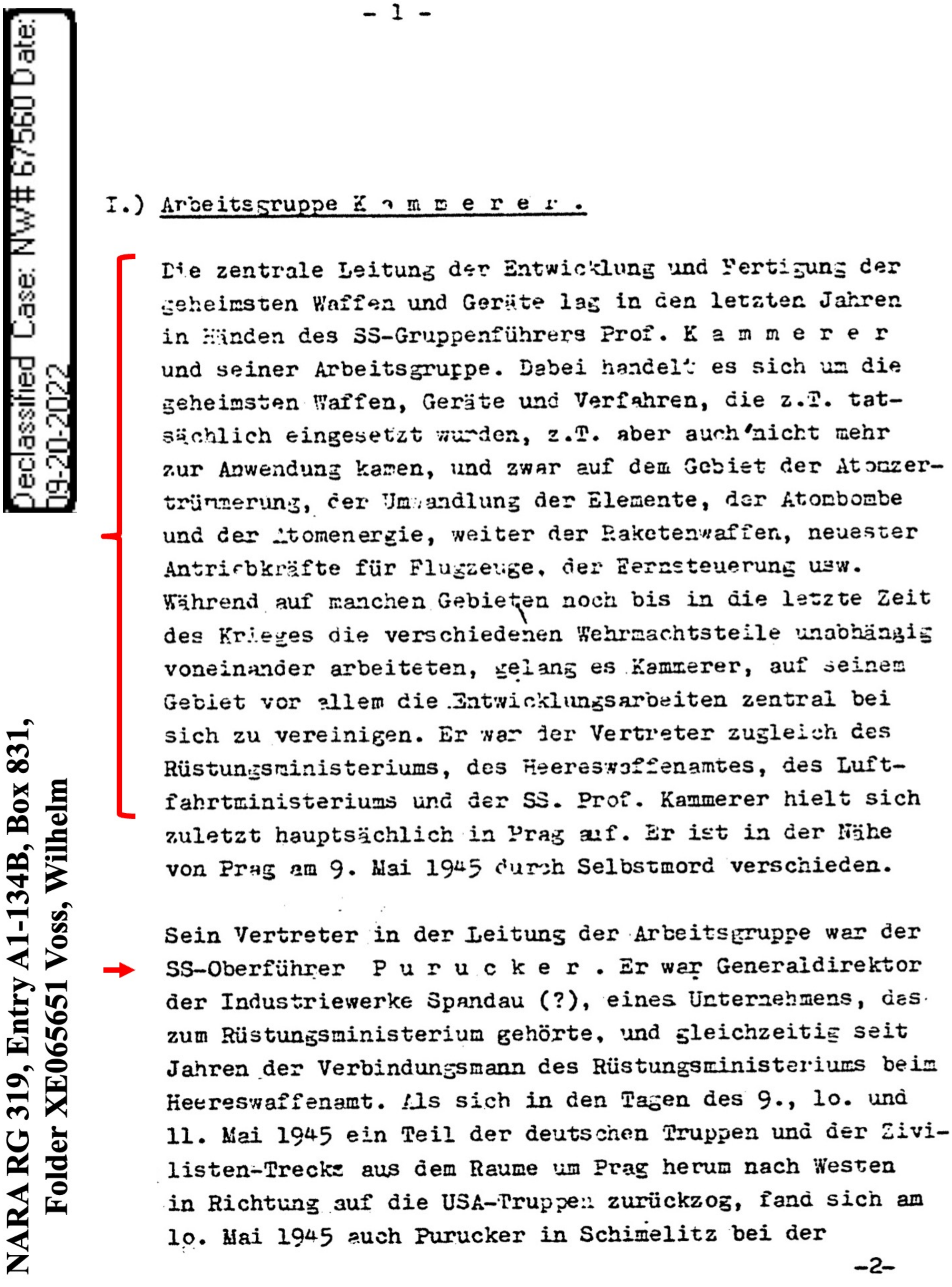
Mir unterstanden ausser den Konzernen der Skoda-Werke und der Brünner Waffen-Werke u.a. auch die Avia-Flugzeug- und Motorenwerke, die elektrotechnischen Werke Krizik, die optischen Werke in Prerau, die Sprengstoffwerke der Explosia in Semtin, die Radio-Slavia in Prag usw. Ich hatte also Spezial-Sachverständige und Spezialwerkstätten aller in Betracht kommenden Gebiete zur Verfügung. Ausserdem habe ich für längerfristige Forschungen und Entwicklungen die Spezialisten in unseren zentralen Forschungs- und Entwicklungswerkstätten in Pibrans konzentriert.

In addition to the Skoda-Werke and Brünner Waffen-Werke groups, I was also in charge of the Avia Aircraft and Engine Works, the Krizik electrotechnical works, the optical works in Prerau, the Explosia explosives works in Semtin, Radio-Slavia in Prague, and so on. I therefore had access to specialized experts and workshops in all relevant fields. I also concentrated specialists in our central research and development workshops in Pibrans for longer-term research and development.

[In this document, Kammler's name is misspelled as "Kammerer." Voss certainly would have known how to spell Kammler's name, so the document appears to have been transcribed by an Allied interrogator from Voss's oral explanation. Kammler's name is spelled correctly in the other documents related to Voss's interrogations, and I have corrected the spelling here to avoid any confusion.

The first paragraph is a very clear statement of the projects under Kammler's control. Voss, who made that statement, was an extremely senior and experienced official in a position to know, as shown by the other paragraph from later in the same document. Note that many of the sites named by Voss were involved in nuclear work, as reported by documents elsewhere in this appendix.

Surely Allied interrogators would ask Voss for much more information about these very hot topics. Where are those more detailed interrogation reports?]



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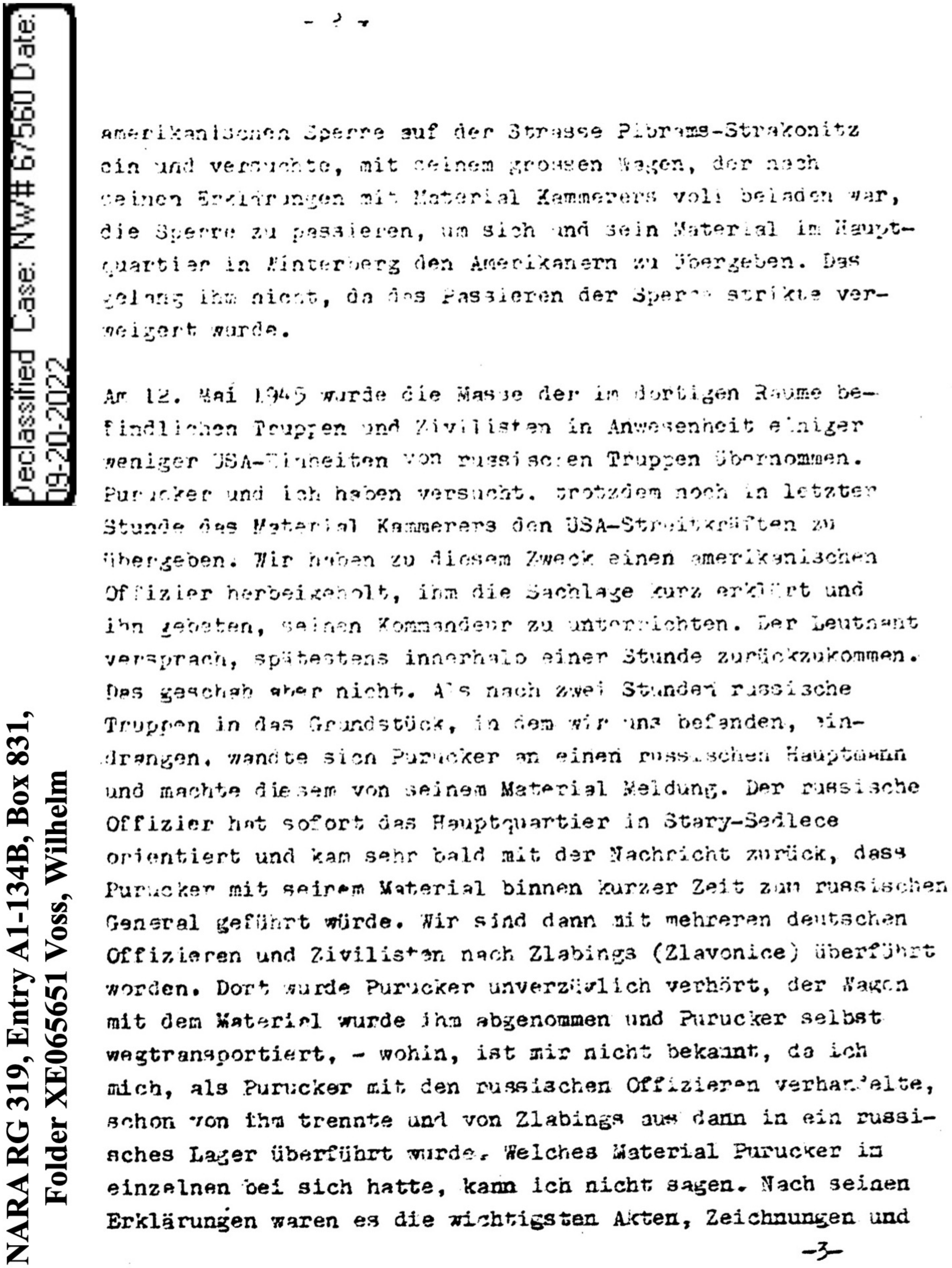
I.) Arbeitsgruppe Kammerer.

Die zentrale Leitung der Entwicklung und Fertigung der geheimsten Waffen und Geräte lag in den letzten Jahren in Händen des SS-Gruppenführers Prof. Kammerer und seiner Arbeitsgruppe. Dabei handelt es sich um die geheimsten Waffen, Geräte und Verfahren, die z.T. tatsächlich eingesetzt wurden, z.T. aber auch nicht mehr zur Anwendung kamen, und zwar auf dem Gebiet der Atomzertrümmerung, der Umwandlung der Elemente, der Atombombe und der Atomenergie, weiter der Raketenwaffen, neuester Antriebkräfte für Flugzeuge, der Fernsteuerung usw. Während auf manchen Gebieten noch bis in die letzte Zeit des Krieges die verschiedenen Wehrmachtsteile unabhängig voneinander arbeiteten, gelang es Kammerer, auf seinem Gebiet vor allem die Entwicklungsarbeiten zentral bei sich zu vereinigen. Er war der Vertreter zugleich des Rüstungsministeriums, des Heereswaffenamtes, des Luftfahrtministeriums und der SS. Prof. Kammerer hielt sich zuletzt hauptsächlich in Prag auf. Er ist in der Nähe von Prag am 9. Mai 1945 durch Selbstmord verschieden.

Sein Vertreter in der Leitung der Arbeitsgruppe war der SS-Oberführer Purucker. Er war Generaldirektor der Industriewerke Spandau (?), eines Unternehmens, das zum Rüstungsministerium gehörte, und gleichzeitig seit Jahren der Verbindungsmann des Rüstungsministeriums beim Heereswaffenamt. Als sich in den Tagen des 9., lo. und 11. Mai 1945 ein Teil der deutschen Truppen und der Zivilisten-Trecks aus dem Raume um Prag herum nach Westen in Richtung auf die USA-Truppen zurückzog, fand sich am lo. Mai 1945 auch Purucker in Schimelitz bei der

-2-

Figure D.927: Wilhelm Voss. Excerpts from April 1946 statement [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].



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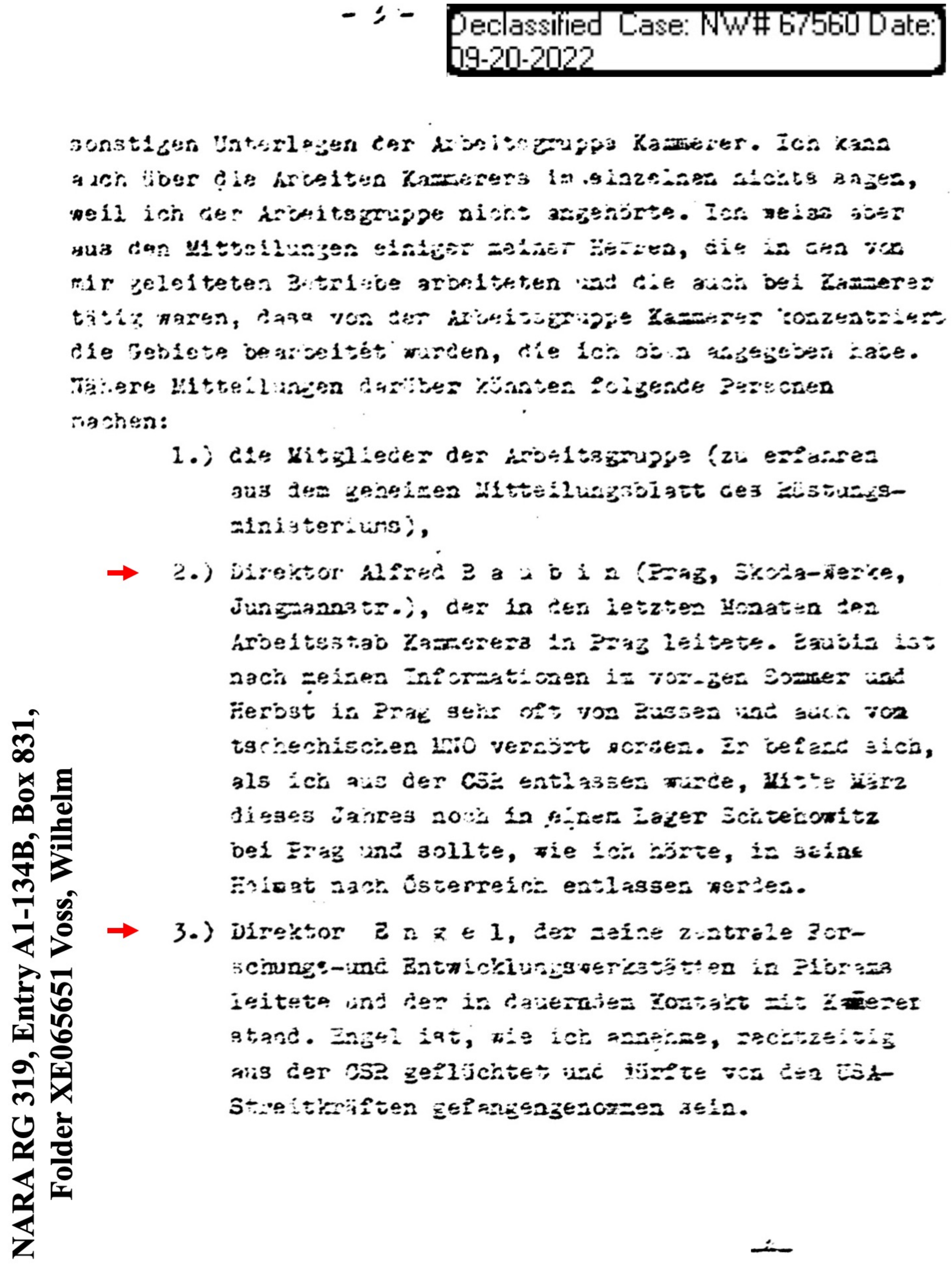
amerikanischen Sperre auf der Strasse Pibrams-Strakonitz ein und versuchte, mit seinem grossen Wagen, der nach seinen Erklärungen mit Material Kammerers voll beladen war, die Sperre zu passieren, um sich und sein Material im Hauptquartier in Winterberg den Amerikanern zu übergeben. Das gelang ihm nicht, da das Passieren der Sperre strikte verweigert wurde.

Am 12. Mai 1945 wurde die Masse der im dortigen Raume befindlichen Truppen und Zivilisten in Anwesenheit einiger weniger USA-Einheiten von russischen Truppen übernommen. Purucker und ich haben versucht, trotzdem noch in letzter Stunde das Material Kammerers den USA-Streitkräften zu übergeben. Wir haben zu diesem Zweck einen amerikanischen Offizier herbeigeholt, ihm die Sachlage kurz erklärt und ihn gebeten, seinen Kommandeur zu unterrichten. Der Leutnant versprach, spätestens innerhalb einer Stunde zurückzukommen. Das geschah aber nicht. Als nach zwei Stunden russische Truppen in das Grundstück, in dem wir uns befanden, eindrangen, wandte sich Purucker an einen russischen Hauptmann und machte diesem von seinem Material Meldung. Der russische Offizier hat sofort das Hauptquartier in Stary-Sedlece orientiert und kam sehr bald mit der Nachricht zurück, dass Purucker mit seinem Material binnen kurzer Zeit zum russischen General geführt würde. Wir sind dann mit mehreren deutschen Offizieren und Zivilisten nach Zlabings (Zlavonice) überführt worden. Dort wurde Purucker unverzüglich verhört, der Wagen mit dem Material wurde ihm abgenommen und Purucker selbst wegtransportiert, - wohin, ist mir nicht bekannt, da ich mich, als Purucker mit den russischen Offizieren verhandelte, schon von ihm trennte und von Zlabings aus dann in ein russisches Lager überführt wurde. Welches Material Purucker im einzelnen bei sich hatte, kann ich nicht sagen. Nach seinen Erklärungen waren es die wichtigsten Akten, Zeichnungen und

-3-

Figure D.928: Wilhelm Voss. Excerpts from April 1946 statement [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].



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sonstigen Unterlagen der Arbeitsgruppe Kammerer. Ich kann auch über die Arbeiten Kammerers im einzelnen nichts sagen, weil ich der Arbeitsgruppe nicht angehörte. Ich weiss aber aus den Mitteilungen einiger meiner Herren, die in den von mir geleiteten Betriebe arbeiteten und die auch bei Kammerer tätig waren, dass von der Arbeitsgruppe Kammerer konzentriert die Gebiete bearbeitet wurden, die ich oben angegeben habe. Nähere Mitteilungen darüber könnten folgende Personen machen:

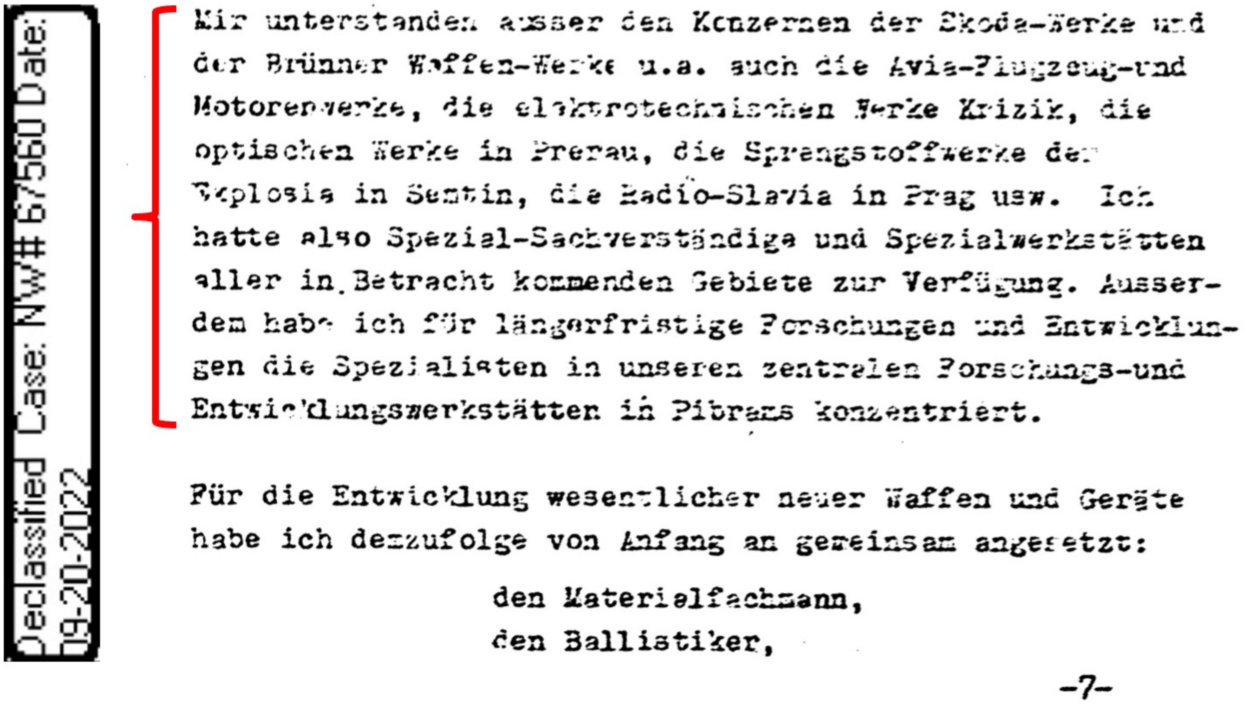
1.) die Mitglieder der Arbeitsgruppe (zu erfahren aus dem geheimen Mitteilungsblatt des Rüstungsministeriums),

2.) Direktor Alfred Baubin (Prag, Skoda-Werke, Jungmannstr.), der in den letzten Monaten den Arbeitsstab Kammerers in Prag leitete. Baubin ist nach meinen Informationen im vorigen Sommer und Herbst in Prag sehr oft von Russen und auch vom tschechischen MNO verhört worden. Er befand sich, als ich aus der CSR entlassen wurde, Mitte März dieses Jahres noch in einem Lager Schtehowitz bei Prag und sollte, wie ich hörte, in seine Heimat nach Österreich entlassen werden.

3.) Direktor Engel, der meine zentrale Forschungs-und Entwicklungswerkstätten in Pibrams leitete und der in dauerndem Kontakt mit Kammerer stand. Engel ist, wie ich annehme, rechtzeitig aus der CSR geflüchtet und dürfte von den USA-Streitkräften gefangengenommen sein.

NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm

Figure D.929: Wilhelm Voss. Excerpts from April 1946 statement [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].



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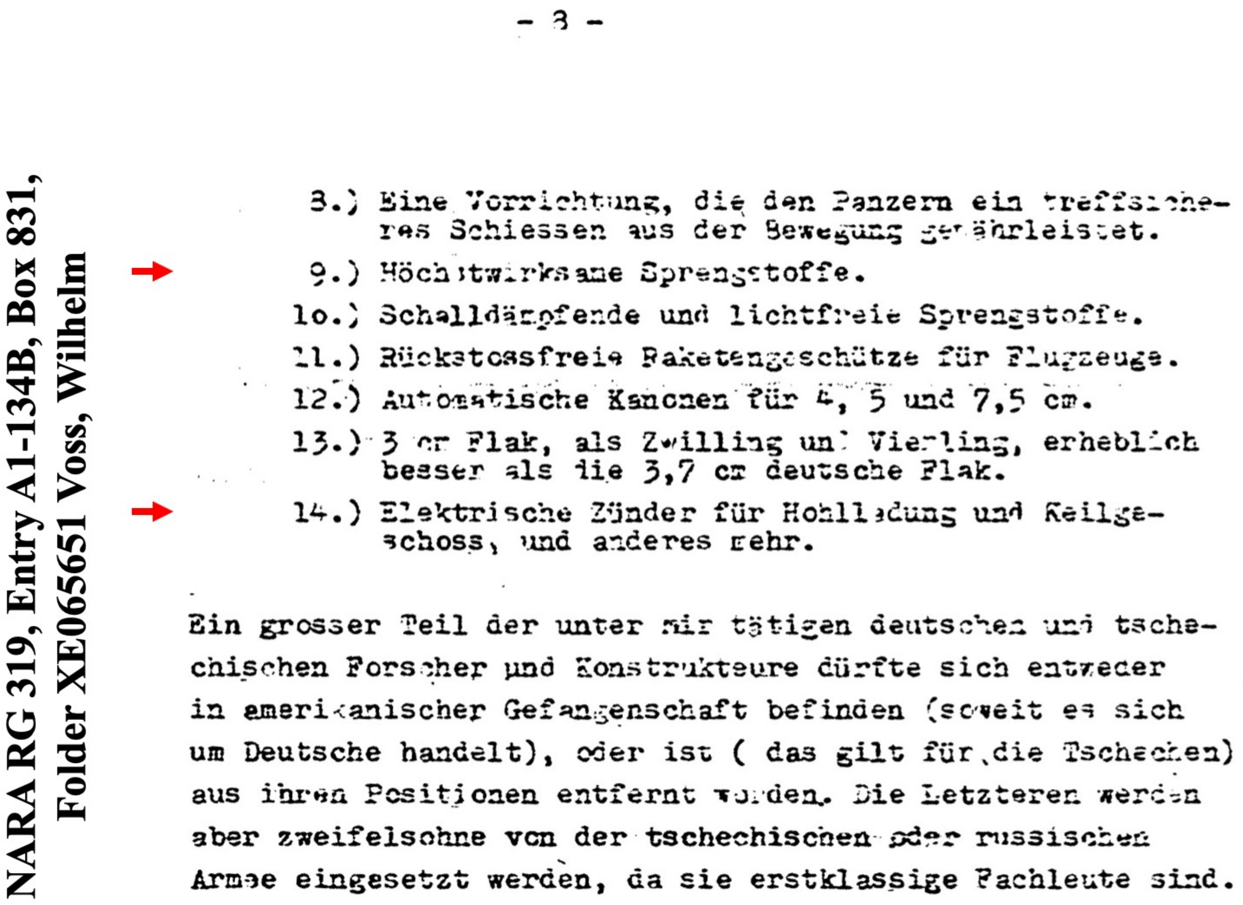
Mir unterstanden ausser den Konzernen der Skoda-Werke und der Brünner Waffen-Werke u.a. auch die Avia-Flugzeug-und Motorenwerke, die elektrotechnischen Werke Krizik, die optischen Werke in Prerau, die Sprengstoffwerke der Explosia in Semtin, die Radio-Slavia in Prag usw. Ich hatte also Spezial-Sachverständige und Spezialwerkstätten aller in Betracht kommenden Gebiete zur Verfügung. Ausserdem habe ich für längerfristige Forschungen und Entwicklungen die Spezialisten in unseren zentralen Forschungs-und Entwicklungswerkstätten in Pibrams konzentriert.

Für die Entwicklung wesentlicher neuer Waffen und Geräte habe ich demzufolge von Anfang an gemeinsam angesetzt:

den Materialfachmann,
den Ballistiker,

-7-



NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm

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8.) Eine Vorrichtung, die den Panzern ein treffsicheres Schiessen aus der Bewegung gewährleistet.
9.) Höchstwirksame Sprengstoffe.
10.) Schalldämpfende und lichtfreie Sprengstoffe.
11.) Rückstossfreie Raketengeschütze für Flugzeuge.
12.) Automatische Kanonen für 4, 5 und 7,5 cm.
13.) 3 cm Flak, als Zwilling und Vierling, erheblich besser als die 3,7 cm deutsche Flak.
14.) Elektrische Zünder für Hohlladung und Keilgeschoss, und anderes mehr.

Ein grosser Teil der unter mir tätigen deutschen und tschechischen Forscher und Konstrukteure dürfte sich entweder in amerikanischer Gefangenschaft befinden (soweit es sich um Deutsche handelt), oder ist (das gilt für die Tschechen) aus ihren Positionen entfernt worden. Die Letzteren werden aber zweifelsohne von der tschechischen oder russischen Armee eingesetzt werden, da sie erstklassige Fachleute sind.

Figure D.930: Wilhelm Voss. Excerpts from April 1946 statement [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm]. Note the manufactured items 9 ("highest energy explosives") and 14 ("electric detonators for shaped charge and wedge projectiles").

Wilhelm Voss. Statement. 18 September 1946. The first two pages are present in the U.K. copy of this document [TNA FO 1031/64] but appear to have been redacted in the U.S. copy [NARA RG 263, Entry ZZ-18, Box 133, File Voss, Friedrich Wilhelm].

1. Professor Kammler (G).

He was the Head of a staff of specialists who developed highly secret weapons and war-equipment. Whereas up to a recent date each Branch of the Wehrmacht and its competent authorities had their developments carried out separately, Kammler succeeded in creating in his field a centralized command for all Branches of the Wehrmacht. His field consisted mainly of V-weapons, rocket apparatus, remote control, atomic energy, jet-propulsion and other similar subjects.

According to my information, Kammler, who shifted his office to Prague during the last month of the war—committed suicide on May 9th near Prague. His first assistant and second in command was

2. Generaldirektor (General Manager) [Erich] Purucker (G).

He was General Manager of the Vereinigte Industriewerke, Spandau, and of the Berliner Spreewerk (production of guns and ammunition). He was in the first place the liaison between SS, Heereswaffenamt (Army Ordnance Branch) and Ruestungsministerium (Ministry of Armaments and War Production) and in the end he became the assistant of Kammler. On May 10th I met him at the American demarcation line outside Schimmelitz on the road Pibrams–Strakonitz, where a large convoy of civilian lorries and military formations stopped, in order to be taken over and directed into the Reich by American troops. We stayed there until May 12th. On that day an order was given all of a sudden to the effect that not the Americans, but approaching Russian Formations would take us over. Therefore Purucker and I tried to hand over to the Americans the very bulky material of the staff of scientists under Kammler, which Purucker had packed and carried with him in a large lorry and in order to hand the material over to the Americans, Purucker called an American officer. This officer promised to inform his Commanding Officer according to our wish and to fetch us and the material within an hour latest. Apparently, however, he did not realize the importance of this matter, because he did not come back. Therefore Purucker handed all his material over to Russian officers. I was still with him on May 15th in the Russian camp in Zlavonice at the southern border of Bohemia. Purucker was interrogated there several times by night by the Russians and one day he was moved together with his material. Where—I don't know—but recently I heard by chance that he is working in Moscow and that his family has joined him there.

3. Ing. Karel Staller (C)

This man is the most versatile and intelligent designer and scientist I ever met. Towards the end he became second General Manager of the Bruenner Waffen-Werke under me—worked, however, as before, mainly in the field of research and development. He himself was the designer of the famous British machine-gun (Bren ZB 26 and 37) and he carried out more or less himself all developments within the Bruenner Waffen-Konzern in the fields of optics, machine-construction, construction of arms, fuzes, ammunition, rocket-projectors, etc. [...]

4. Fritz (?) [actually Rolf] Engel (G)

This man was, if I am not mistaken—until 1942/43 Head of the experimental workshops at Helamuende, which he founded himself. Then I took him over (with the experimental workshops) and made him Chief of our research institute at Pibrams. Engel was a specialist for many years in the field of rockets and he was a member of the Central Commission for rocket-research, Berlin. For a long time he worked together with Kammler, and he knew almost everything of the secret research and development work, especially because he was the President of a special Commission which had to carry out the entire calculations in the chemical and physical fields with regard to ballistics of special weapons and apparatus. Engel and his wife lived in Pibrams. I suppose that he escaped in time across the American demarcation line into Germany and that he lives probably somewhere in the American Zone.

5. Ing Odstracil (C)

After Staller he is, according to my opinion, the best scientist and designer of the Bruenner-Waffen-Konzern, of which he was the official Chief designer. He worked mainly in the fields of rocket projectors, automatic weapons, fuzes and ammunition. [...]

6. Ing. Adolf Vambersky (C).

This man was General Manager of the Skoda Konzern (Combine) and in that capacity he was more or less the Chief of research and development in all fields with regard to the combine. [...]

7. Ing. Alesch (C).

Until May 1945 he was Chief of Explosia AG and Synthesia AG He is a former Austrian Officer of the Engineers in Blumen. Alesch is an excellent expert in the field of high explosives, therefore he directed our latest developments in high explosives. [...]

8. Dr. Kappel (G).

He, as a chemist was in charge of the laboratories of our plants for high-explosives in Semtin. He himself was a scientist and the inventor of the latest patents. [...]

11. Ing. Novy (C)

He was the Chief of our foundries, including the attached plants and the casting houses. He was a specialist in the field of light metal. He is an excellent expert as well as technician. [...]

12. Professor Dr. Maurer (G).

Before he worked with Krupp's, then he was advisor with the Skoda Konzern in all questions of metallurgy and foundries. He was in the first place a University professor (ordentlicher Professor) at the Academy for Mining in Freiberg/Saxony [see pp. 3433–3437, 3456–3416, 3708]. As far as I know he had to resign at the instigation of the Russians. He is an excellent scientific capacity on iron and steel including the working-up process and he is also very practical-minded. [...]

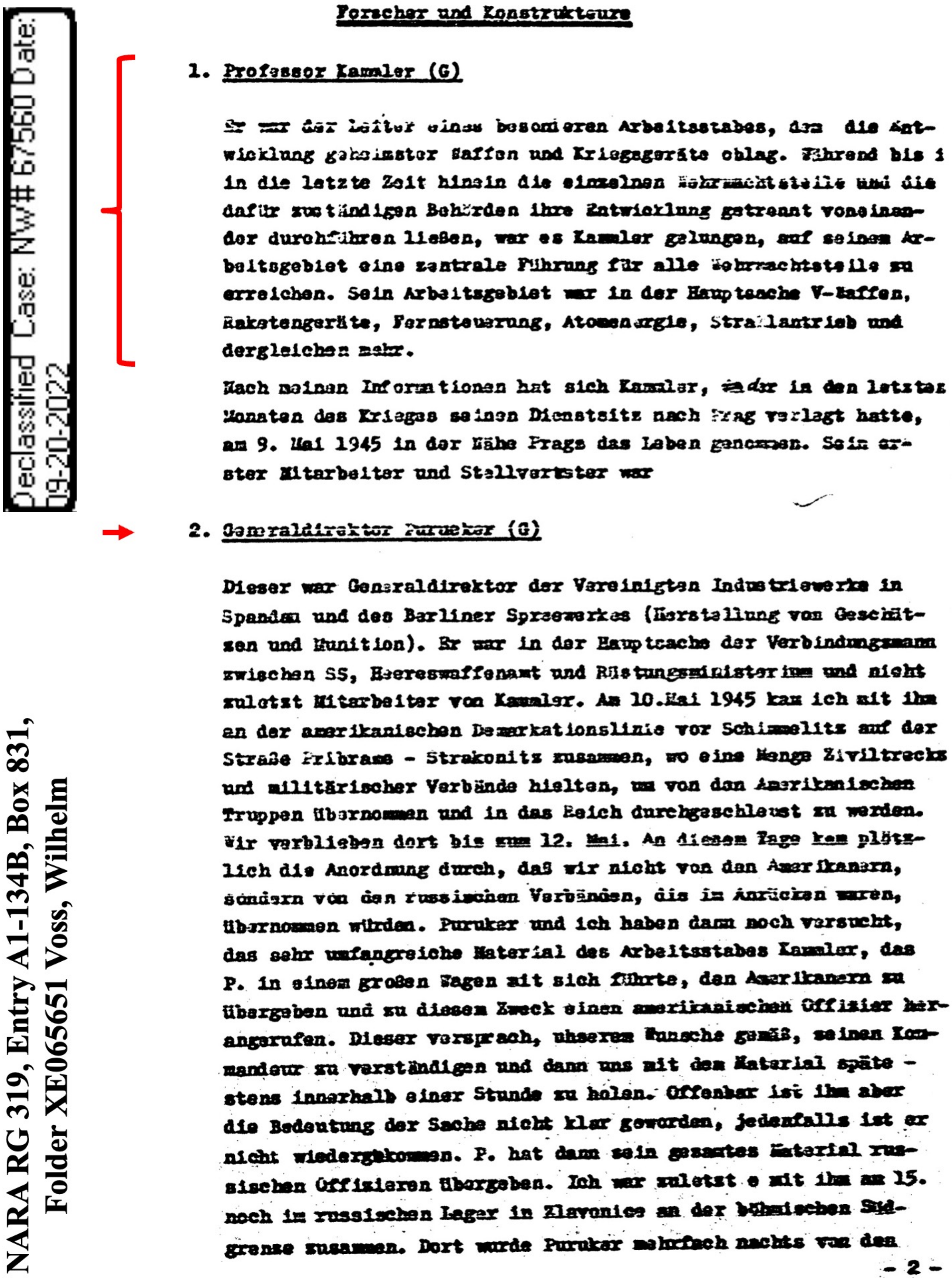
14. Dr. Pavlicek (G).

He was the Chief of the Optiko-Techna.—the optical plants of the Bruenner Waffen Konzern in Prerov. His field was mainly research and development. He was also informed with regard to many particulars concerning his field, inside Germany, as he had to function at general conferences and discussions in these questions, created by various firms under the leadership of Zeiss. [...]

[For the German-language original of this document, see pp. 4923–4929.

This document supports the story of Purucker fleeing with (atomic bomb) plans in his car and being forced to surrender to Russians instead of Americans.

It also provides more information on Rolf Engel and other experts working in wartime Czechoslovakia, and demonstrates that their expertise covered many of the areas necessary to build an atomic bomb. See also pp. 3751–3754.]



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Forscher und Konstrukteure

1. Professor Kammler (G)

Er war der Leiter eines besonderen Arbeitsstabes, dem die Entwicklung geheimster Waffen und Kriegsgeräte oblag. Während bis i in die letzte Zeit hinein die einzelnen Wehrmachtsteile und die dafür zuständigen Behörden ihre Entwicklung getrennt voneinander durchführen ließen, war es Kammler gelungen, auf seinem Arbeitsgebiet eine zentrale Führung für alle Wehrmachtsteile zu erreichen. Sein Arbeitsgebiet war in der Hauptsache V-Waffen, Raketengeräte, Fernsteuerung, Atomenergie, Strahlantrieb und dergleichen mehr.

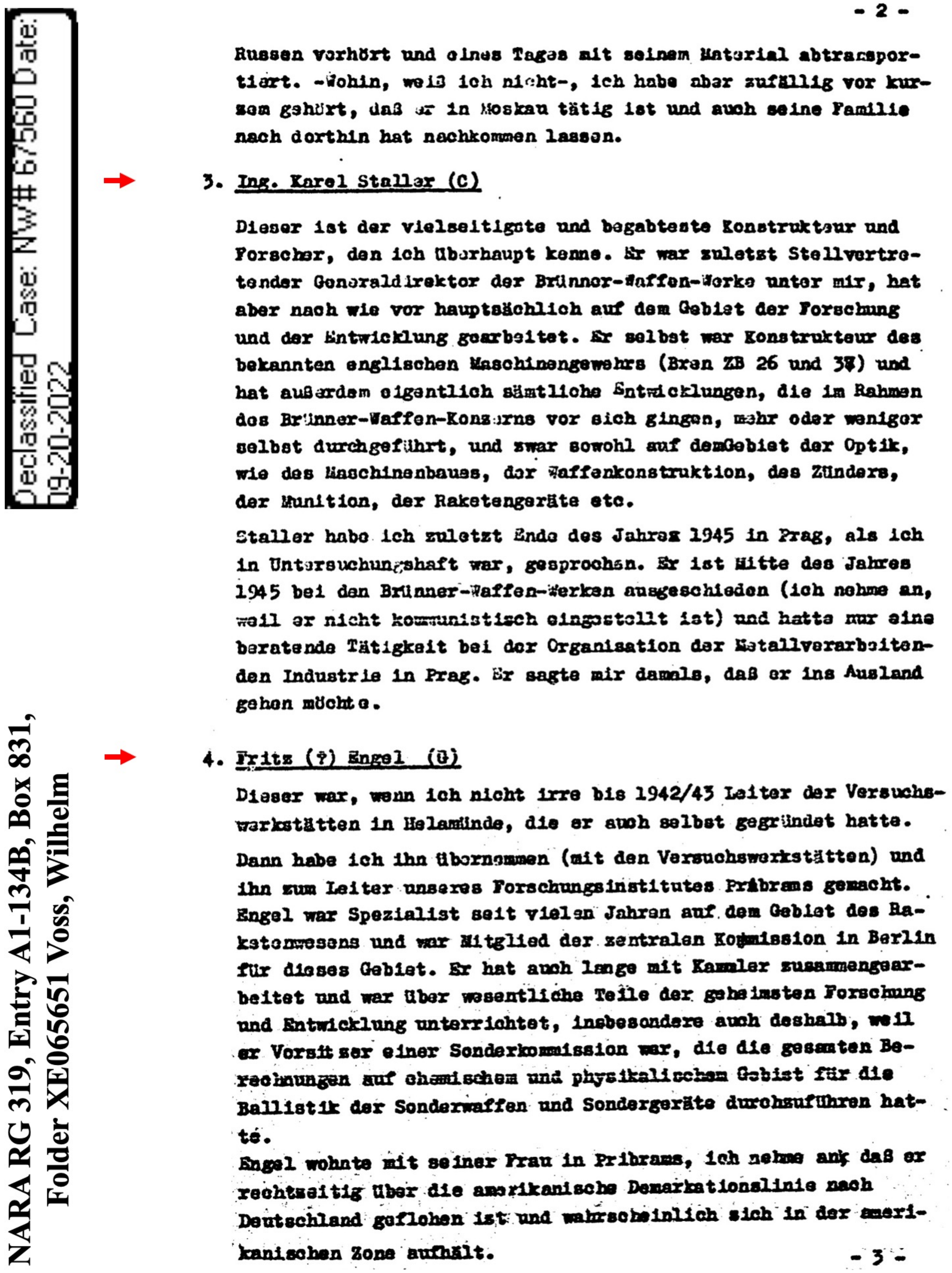
Nach meinen Informationen hat sich Kammler, der in den letzten Monaten des Krieges seinen Dienstsitz nach Prag verlegt hatte, am 9. Mai 1945 in der Nähe Prags das Leben genommen. Sein erster Mitarbeiter und Stellvertreter war

2. Generaldirektor Puruker (G)

Dieser war Generaldirektor der Vereinigten Industriewerke in Spandau und des Berliner Spreewerkes (Herstellung von Geschützen und Munition). Er war in der Hauptsache der Verbindungsmann zwischen SS, Heereswaffenamt und Rüstungsministerium und nicht zuletzt Mitarbeiter von Kammler. Am 10.Mai 1945 kam ich mit ihm an der amerikanischen Demarkationslinie vor Schimmelitz auf der Straße Pribrams - Strakonitz zusammen, wo eine Menge Ziviltrecks und militärischer Verbände hielten, um von den Amerikanischen Truppen übernommen und in das Reich durchgeschleust zu werden. Wir verblieben dort bis zum 12. Mai. An diesem Tage kam plötzlich die Anordnung durch, daß wir nicht von den Amerikanern, sondern von den russischen Verbänden, die im Anrücken waren, übernommen würden. Puruker und ich haben dann noch versucht, das sehr umfangreiche Material des Arbeitsstabes Kammler, das P. in einem großen Wagen mit sich führte, den Amerikanern zu übergeben und zu diesem Zweck einen amerikanischen Offizier herangerufen. Dieser versprach, unserem Wunsche gemäß, seinen Kommandeur zu verständigen und dann uns mit dem Material spätestens innerhalb einer Stunde zu holen. Offenbar ist ihm aber die Bedeutung der Sache nicht klar geworden, jedenfalls ist er nicht wiedergekommen. P. hat dann sein gesamtes Material russischen Offizieren übergeben. Ich war zuletzt e mit ihm am 15. noch im russischen Lager in Zlavonice an der böhmischen Südgrenze zusammen. Dort wurde Puruker mehrfach nachts von den

- 2 -

Figure D.931: Wilhelm Voss. Excerpts from September 1946 statement [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].



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Russen verhört und eines Tages mit seinem Material abtransportiert. -Wohin, weiß ich nicht-, ich habe aber zufällig vor kurzem gehört, daß er in Moskau tätig ist und auch seine Familie nach dorthin hat nachkommen lassen.

3. Ing. Karel Staller (C)

Dieser ist der vielseitigste und begabteste Konstrukteur und Forscher, den ich überhaupt kenne. Er war zuletzt Stellvertretender Generaldirektor der Brünner-Waffen-Werke unter mir, hat aber nach wie vor hauptsächlich auf dem Gebiet der Forschung und der Entwicklung gearbeitet. Er selbst war Konstrukteur des bekannten englischen Maschinengewehrs (Bren ZB 26 und 37) und hat außerdem eigentlich sämtliche Entwicklungen, die im Rahmen des Brünner-Waffen-Konzerns vor sich gingen, mehr oder weniger selbst durchgeführt, und zwar sowohl auf demGebiet der Optik, wie des Maschinenbaues, der Waffenkonstruktion, des Zünders, der Munition, der Raketengeräte etc.

Staller habe ich zuletzt Ende des Jahres 1945 in Prag, als ich in Untersuchungshaft war, gesprochen. Er ist Mitte des Jahres 1945 bei den Brünner-Waffen-Werken ausgeschieden (ich nehme an, weil er nicht kommunistisch eingestellt ist) und hatte nur eine beratende Tätigkeit bei der Organisation der Metallverarbeitenden Industrie in Prag. Er sagte mir damals, daß er ins Ausland gehen möchte.

4. Fritz (?) Engel (G)

Dieser war, wenn ich nicht irre bis 1942/43 Leiter der Versuchswerkstätten in Helamünde, die er auch selbst gegründet hatte.

Dann habe ich ihn übernommen (mit den Versuchswerkstätten) und ihn zum Leiter unseres Forschungsinstitutes Pribrams gemacht. Engel war Spezialist seit vielen Jahren auf dem Gebiet des Raketenwesens und war Mitglied der zentralen Kommission in Berlin für dieses Gebiet. Er hat auch lange mit Kammler zusammengearbeitet und war über wesentliche Teile der geheimsten Forschung und Entwicklung unterrichtet, insbesondere auch deshalb, weil er Vorsitzer einer Sonderkommission war, die die gesamten Berechnungen auf chemischem und physikalischem Gebiet für die Ballistik der Sonderwaffen und Sondergeräte durchzuführen hatte.

Engel wohnte mit seiner Frau in Pribrams, ich nehme an, daß er rechtzeitig über die amerikanische Demarkationslinie nach Deutschland geflohen ist und wahrscheinlich sich in der amerikanischen Zone aufhält.

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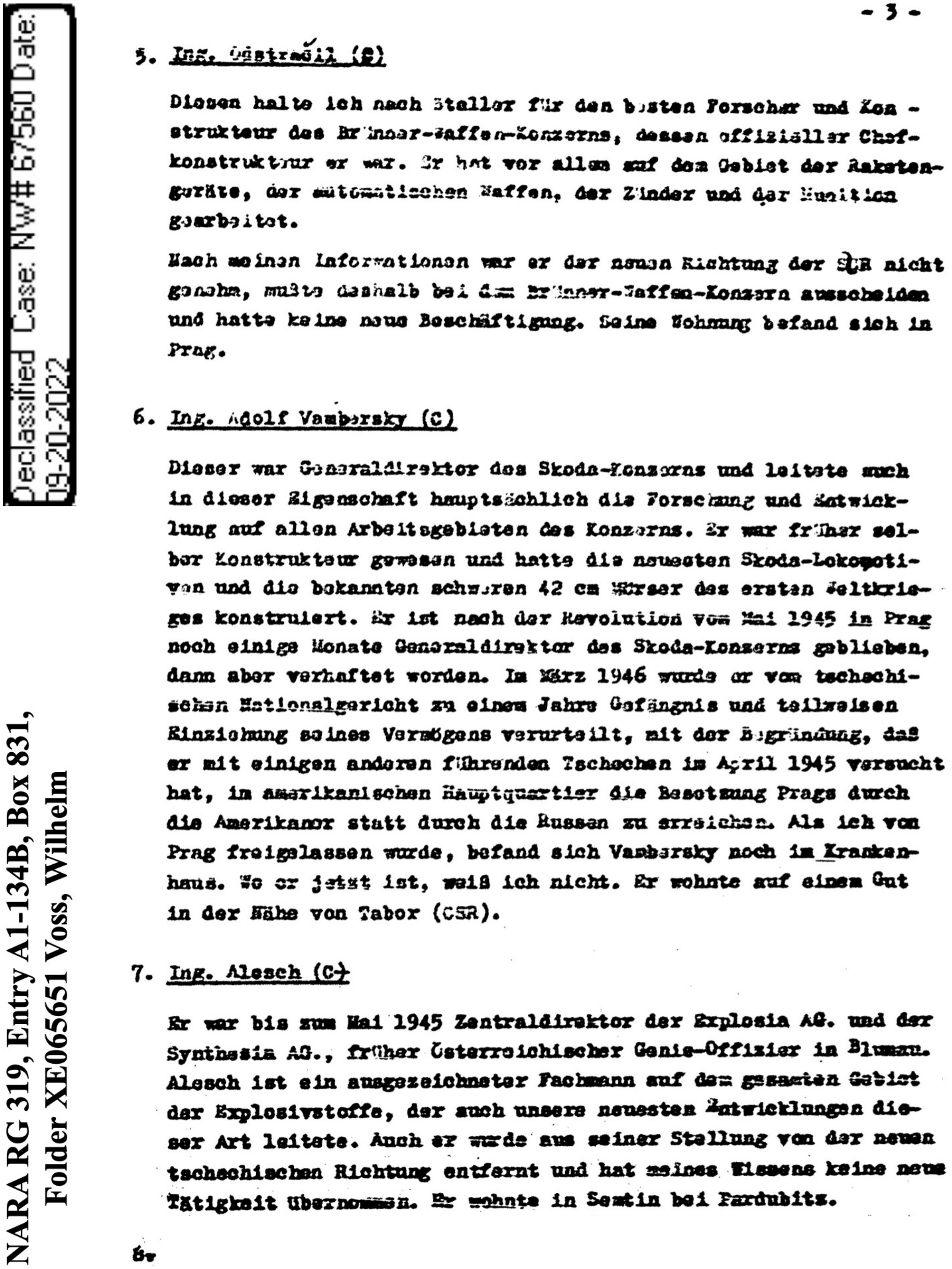
Figure D.932: Wilhelm Voss. Excerpts from September 1946 statement [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].



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5. Ing. Ostračil (C)

Diesen halte ich nach Staller für den besten Forscher und Konstrukteur des Brünner-Waffen-Konzerns, dessen offizieller Chefkonstrukteur er war. Er hat vor allem auf dem Gebiet der Raketengeräte, der automatischen Waffen, der Zünder und der Munition gearbeitet.

Nach meinen Informationen war er der neuen Richtung der ČSR nicht genehm, mußte deshalb bei dem Brünner-Waffen-Konzern ausscheiden und hatte keine neue Beschäftigung. Seine Wohnung befand sich in Prag.

6. Ing. Adolf Vambersky (C)

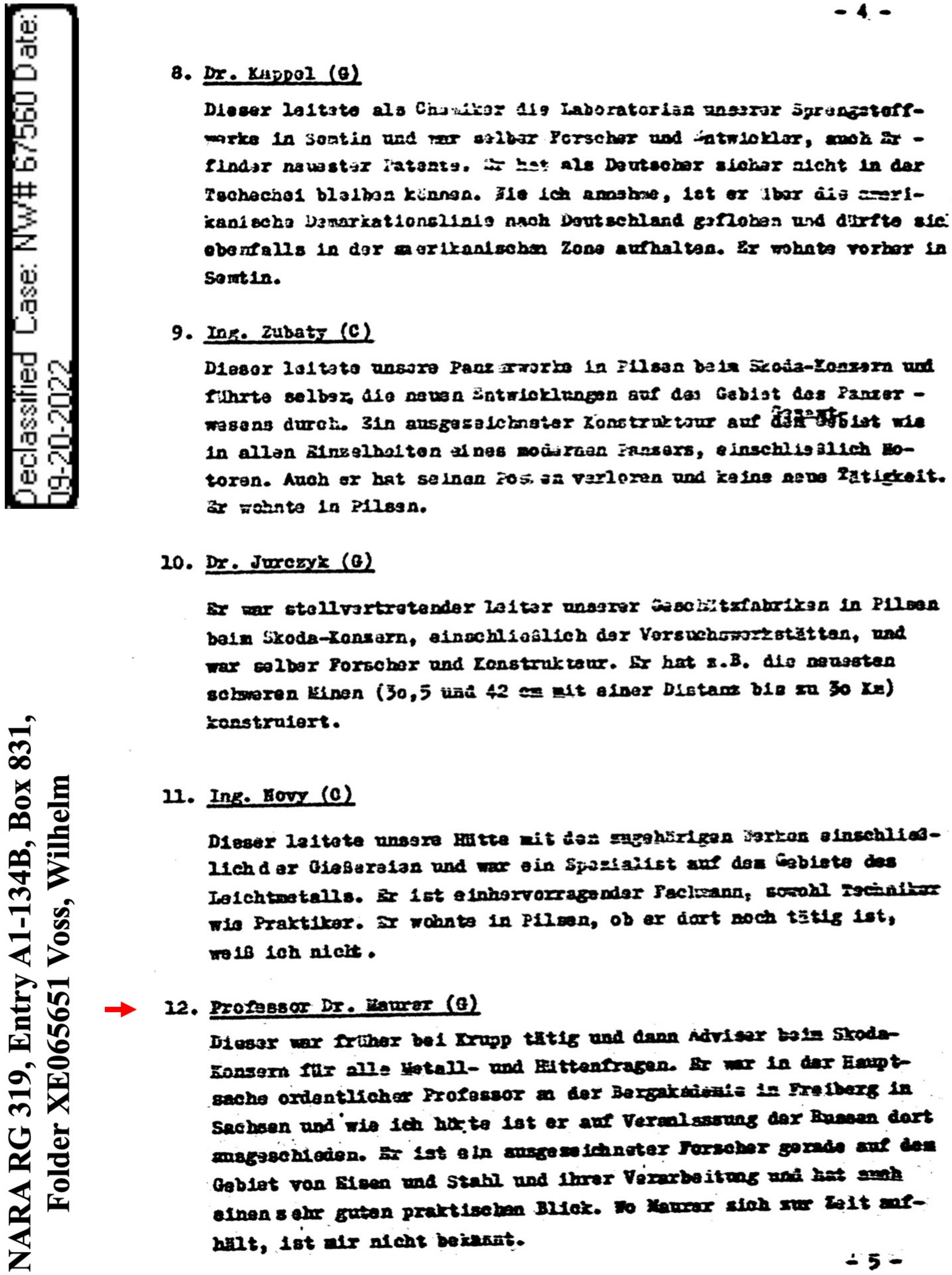
Dieser war Generaldirektor des Skoda-Konzerns und leitete auch in dieser Eigenschaft hauptsächlich die Forschung und Entwicklung auf allen Arbeitsgebieten des Konzerns. Er war früher selber Konstrukteur gewesen und hatte die neuesten Skoda-Lokomotiven und die bekannten schweren 42 cm Mörser des ersten Weltkrieges konstruiert. Er ist nach der Revolution vom Mai 1945 in Prag noch einige Monate Generaldirektor des Skoda-Konzerns geblieben, dann aber verhaftet worden. Im März 1946 wurde er vom tschechischen Nationalgericht zu einem Jahre Gefängnis und teilweisen Einziehung seines Vermögens verurteilt, mit der Begründung, daß er mit einigen anderen führenden Tschechen im April 1945 versucht hat, im amerikanischen Hauptquartier die Besetzung Prags durch die Amerikaner statt durch die Russen zu erreichen. Als ich von Prag freigelassen wurde, befand sich Vambersky noch im Krankenhaus. Wo er jetzt ist, weiß ich nicht. Er wohnte auf einem Gut in der Nähe von Tabor (CSR).

7. Ing. Alesch (C)

Er war bis zum Mai 1945 Zentraldirektor der Explosia AG. und der Synthesia AG., früher Österreichischer Genie-Offizier in Blumau. Alesch ist ein ausgezeichneter Fachmann auf dem gesamten Gebiet der Explosivstoffe, der auch unsere neuesten Entwicklungen dieser Art leitete. Auch er wurde aus seiner Stellung von der neuen tschechischen Richtung entfernt und hat meines Wissens keine neue Tätigkeit übernommen. Er wohnte in Semtin bei Pardubitz.

6.

Figure D.933: Wilhelm Voss. Excerpts from September 1946 statement [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].



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8. Dr. Kappol (G)

Dieser leitete als Chemiker die Laboratorien unserer Sprengstoffwerke in Semtin und war selber Forscher und Entwickler, auch Erfinder neuester Patente. Er hat als Deutscher sicher nicht in der Tschechei bleiben können. Wie ich annehme, ist er über die amerikanische Demarkationslinie nach Deutschland geflohen und dürfte sich ebenfalls in der amerikanischen Zone aufhalten. Er wohnte vorher in Semtin.

9. Ing. Zubaty (C)

Dieser leitete unsere Panzerwerke in Pilsen beim Skoda-Konzern und führte selber die neuen Entwicklungen auf dem Gebiet des Panzerwesens durch. Ein ausgezeichneter Konstrukteur auf dem ~~Gebiet~~ Ganzen wie in allen Einzelheiten eines modernen Panzers, einschließlich Motoren. Auch er hat seinen Posten verloren und keine neue Tätigkeit. Er wohnte in Pilsen.

10. Dr. Jurczyk (G)

Er war stellvertretender Leiter unserer Geschützfabriken in Pilsen beim Skoda-Konzern, einschließlich der Versuchswerkstätten, und war selber Forscher und Konstrukteur. Er hat z.B. die neusten schweren Minen (3o,5 und 42 cm mit einer Distanz bis zu 3o Km) konstruiert.

11. Ing. Novy (C)

Dieser leitete unsere Hütte mit den zugehörigen Werken einschließlich der Gießereien und war ein Spezialist auf dem Gebiete des Leichtmetalls. Er ist einhervorragender Fachmann, sowohl Techniker wie Praktiker. Er wohnte in Pilsen, ob er dort noch tätig ist, weiß ich nicht.

12. Professor Dr. Maurer (G)

Dieser war früher bei Krupp tätig und dann Adviser beim Skoda-Konzern für alle Metall- und Hüttenfragen. Er war in der Hauptsache ordentlicher Professor an der Bergakademie in Freiberg in Sachsen und wie ich hörte ist er auf Veranlassung der Russen dort ausgeschieden. Er ist ein ausgezeichneter Forscher gerade auf dem Gebiet von Eisen und Stahl und ihrer Verarbeitung und hat auch einen sehr guten praktischen Blick. Wo Maurer sich zur Zeit aufhält, ist mir nicht bekannt.

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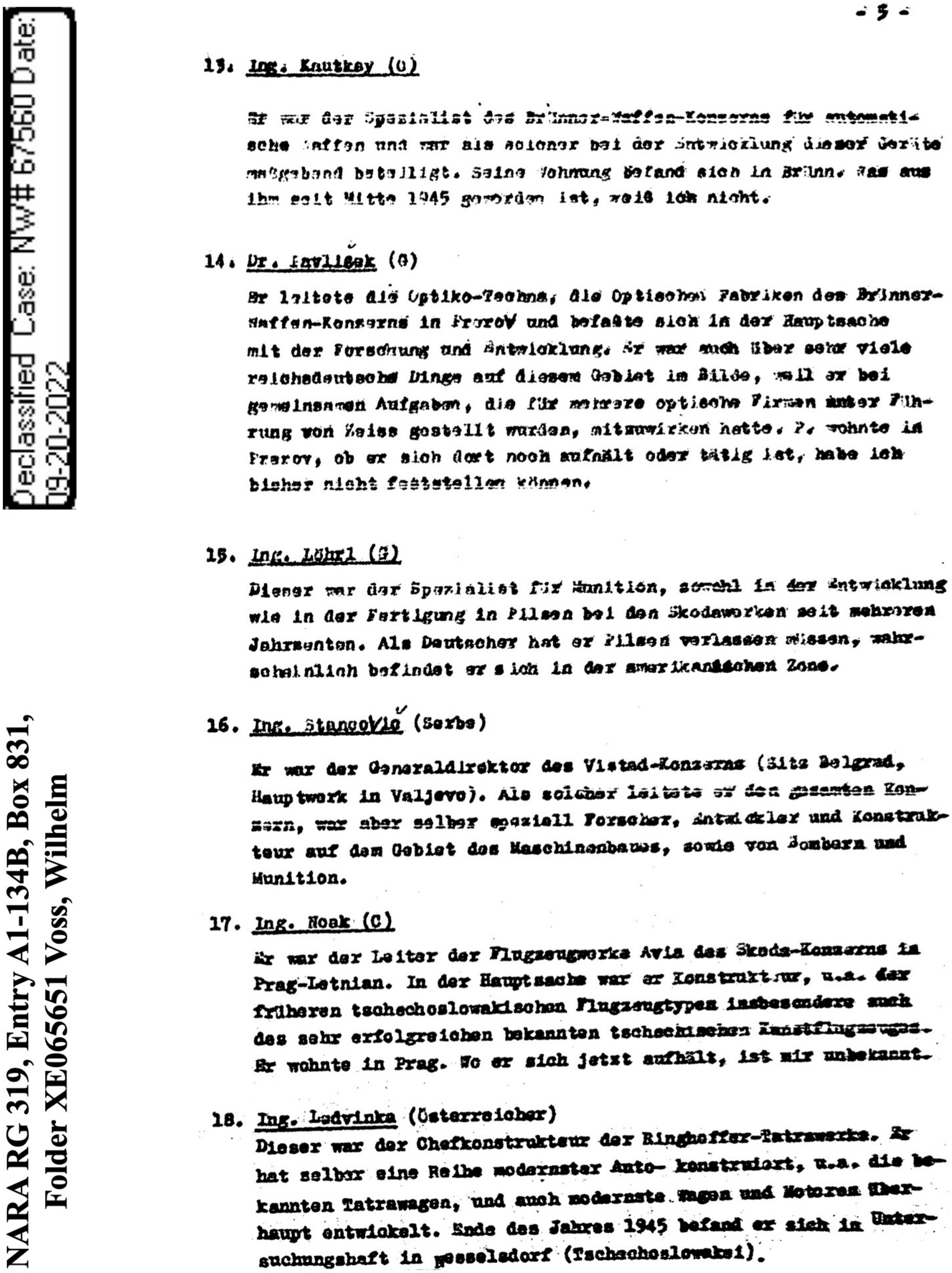
Figure D.934: Wilhelm Voss. Excerpts from September 1946 statement [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].



- 5 -

13. **Ing. Kautkay (Ö)**

Er war der Spezialist des Brünner-Waffen-Konzerns für automatische Waffen und war als solcher bei der Entwicklung dieser Geräte maßgebend beteiligt. Seine Wohnung befand sich in Brünn. Was aus ihm seit Mitte 1945 geworden ist, weiß ich nicht.

14. **Dr. Pavliček** (G)

Er leitete die Optiko-Techna, die Optischen Fabriken des Brünner-Waffen-Konzerns in Prerov und befaßte sich in der Hauptsache mit der Forschung und Entwicklung. Er war auch über sehr viele reichsdeutsche Dinge auf diesem Gebiet im Bilde, weil er bei gemeinsamen Aufgaben, die für mehrere optische Firmen unter Führung von Zeiss gestellt wurden, mitzuwirken hatte. P. wohnte in Prerov, ob er sich dort noch aufhält oder tätig ist, habe ich bisher nicht feststellen können.

15. **Ing. Löhrl (G)**

Dieser war der Spezialist für Munition, sowohl in der Entwicklung wie in der Fertigung in Pilsen bei den Skodawerken seit mehreren Jahrzenten. Als Deutscher hat er Pilsen verlassen müssen, wahrscheinlich befindet er sich in der amerikanischen Zone.

16. **Ing. Stancovič** (Serbe)

Er war der Generaldirektor des Vistad-Konzerns (Sitz Belgrad, Hauptwerk in Valjevo). Als solcher leitete er den gesamten Konzern, war aber selber speziell Forscher, Entwickler und Konstrukteur auf dem Gebiet des Maschinenbaues, sowie von Bomben und Munition.

17. **Ing. Noak (C)**

Er war der Leiter der Flugzeugwerke Avia des Skoda-Konzerns in Prag-Letnian. In der Hauptsache war er Konstrukteur, u.a. der früheren tschechoslowakischen Flugzeugtypen insbesondere auch des sehr erfolgreichen bekannten tschechischen Kunstflugzeuges. Er wohnte in Prag. Wo er sich jetzt aufhält, ist mir unbekannt.

18. **Ing. Ledvinka** (Österreicher)

Dieser war der Chefkonstrukteur der Ringhoffer-Tatrawerke. Er hat selber eine Reihe modernster Auto- konstruiert, u.a. die bekannten Tatrawagen, und auch modernste Wagen und Motoren überhaupt entwickelt. Ende des Jahres 1945 befand er sich in Untersuchungshaft in Wesseldorf (Tschechoslowakei).

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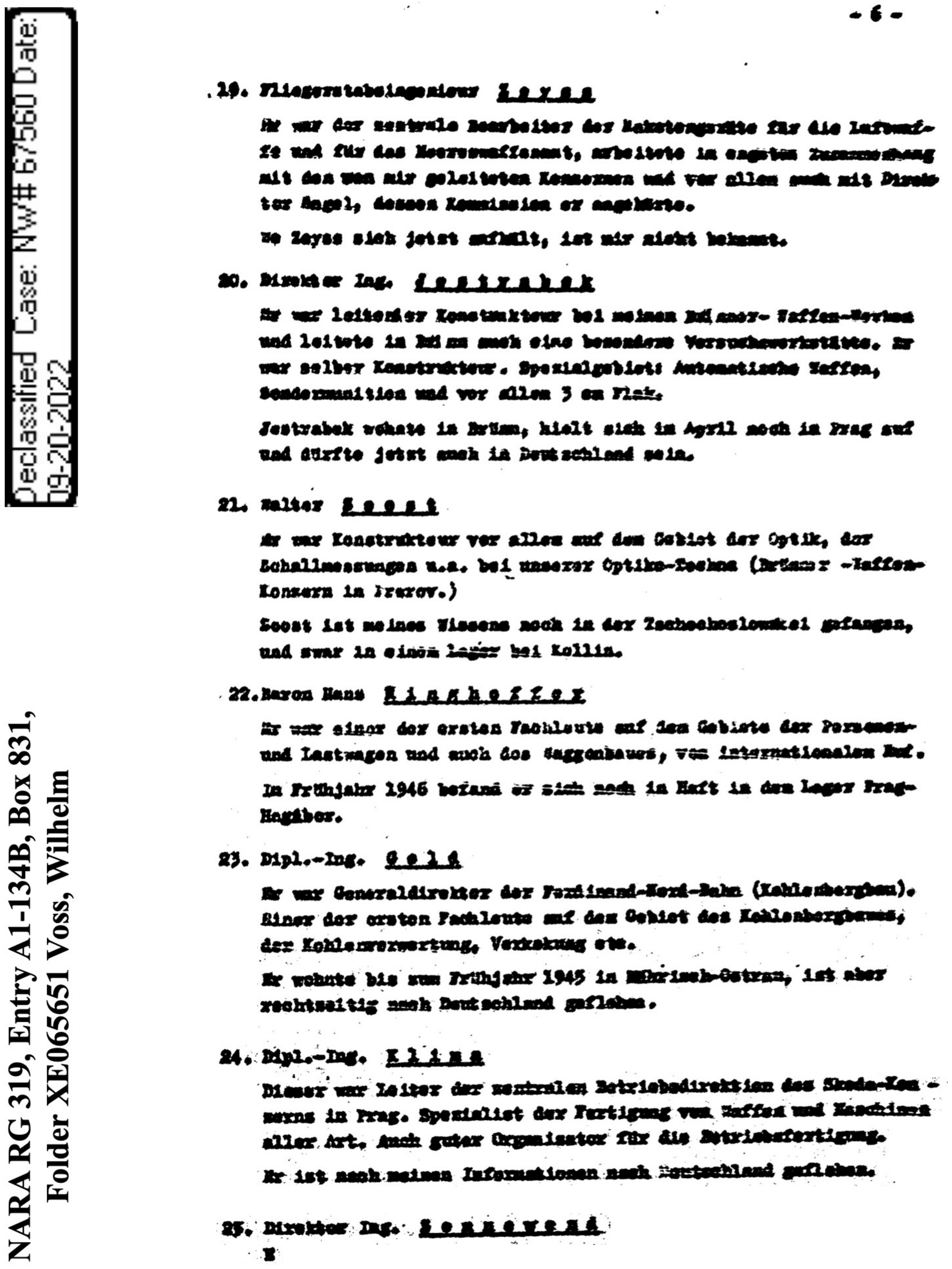
Figure D.935: Wilhelm Voss. Excerpts from September 1946 statement [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].



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19. Fliegerstabsingenieur **Zeyss**

Er war der zentrale Bearbeiter der Raketengeräte für die Luftwaffe und für das Heereswaffenamt, arbeitete im engsten Zusammenhang mit den von mir geleiteten Konzernen und vor allem auch mit Direktor Engel, dessen Kommission er angehörte.

Wo Zeyss sich jetzt aufhält, ist mir nicht bekannt.

20. Direktor Ing. **Jestrabek**

Er war leitender Konstrukteur bei meinen Brünner-Waffen-Werken und leitete in Brünn auch eine besondere Versuchswerkstätte. Er war selber Konstrukteur. Spezialgebiet: Automatische Waffen, Sondermunition und vor allem 3 cm Flak.

Jestrabek wohnte in Brünn, hielt sich im April noch in Prag auf und dürfte jetzt auch in Deutschland sein.

21. Walter **Soost**

Er war Konstrukteur vor allem auf dem Gebiet der Optik, der Schallmessungen u.a. bei unserer Optiko-Techna (Brünner-Waffen-Konzern in Prerov.)

Soost ist meines Wissens noch in der Tschechoslowakei gefangen, und zwar in einem Lager bei Kollin.

22. Baron Hans **Ringhoffer**

Er war einer der ersten Fachleute auf dem Gebiete der Personen- und Lastwagen und auch des Waggonbaues, von internationalem Ruf.

Im Frühjahr 1946 befand er sich noch in Haft in dem Lager Prag-Hagibor.

23. Dipl.-Ing. **Gold**

Er war Generaldirektor der Ferdinand-Nord-Bahn (Kohlenbergbau). Einer der ersten Fachleute auf dem Gebiet des Kohlenbergbaues, der Kohlenverwertung, Verkokung etc.

Er wohnte bis zum Frühjahr 1945 in Mährisch-Ostrau, ist aber rechtzeitig nach Deutschland geflohen.

24. Dipl.-Ing. **Klima**

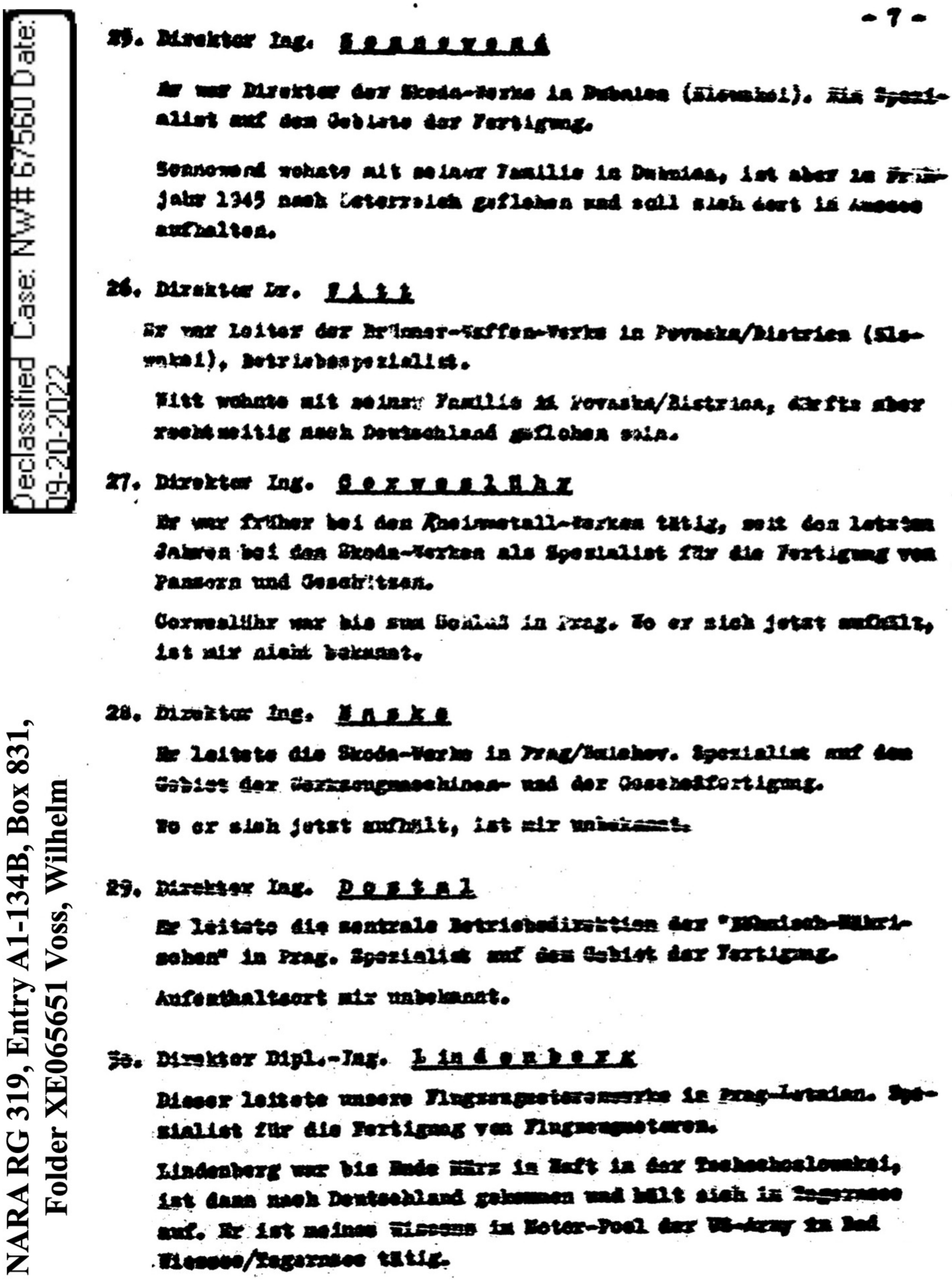
Dieser war Leiter der zentralen Betriebsdirektion des Skoda-Konzerns in Prag. Spezialist der Fertigung von Waffen und Maschinen aller Art. Auch guter Organisator für die Betriebsfertigung.

Er ist nach meinen Informationen nach Deutschland geflohen.

25. Direktor Ing. **Sonnevend**

E

Figure D.936: Wilhelm Voss. Excerpts from September 1946 statement [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].



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25. Direktor Ing. **Sonnewend**

Er war Direktor der Skoda-Werke in Dubnica (Slowakei). Ein Spezialist auf dem Gebiete der Fertigung.

Sonnewend wohnte mit seiner Familie in Dubnica, ist aber im Frühjahr 1945 nach Österreich geflohen und soll sich dort im Aussee aufhalten.

26. Direktor Dr. **Witt**

Er war Leiter der Brünner-Waffen-Werke in Povaska/Bistrica (Slowakei), Betriebsspezialist.

Witt wohnte mit seiner Familie in Povaska/Bistrica, dürfte aber rechtzeitig nach Deutschland geflohen sein.

27. Direktor Ing. **Gerwealühr**

Er war früher bei den Rheinmetall-Werken tätig, seit den letzten Jahren bei den Skoda-Werken als Spezialist für die Fertigung von Panzern und Geschützen.

Gerwealühr war bis zum Schluß in Prag. Wo er sich jetzt aufhält, ist mir nicht bekannt.

28. Direktor Ing. **Haske**

Er leitete die Skoda-Werke in Prag/Smichov. Spezialist auf dem Gebiet der Werkzeugmaschinen- und der Geschoßfertigung.

Wo er sich jetzt aufhält, ist mir unbekannt.

29. Direktor Ing. **Dostal**

Er leitete die zentrale Betriebsdirektion der "Böhmisch-Mährischen" in Prag. Spezialist auf dem Gebiet der Fertigung.

Aufenthaltsort mir unbekannt.

30. Direktor Dipl.-Ing. **Lindenberg**

Dieser leitete unsere Flugzeugmotorenwerke in Prag-Letnian. Spezialist für die Fertigung von Flugzeugmotoren.

Lindenberg war bis Ende März in Haft in der Tschechoslowakei, ist dann nach Deutschland gekommen und hält sich im Tegernsee auf. Er ist meines Wissens im Motor-Pool der US-Army in Bad Wiessee/Tegernsee tätig.

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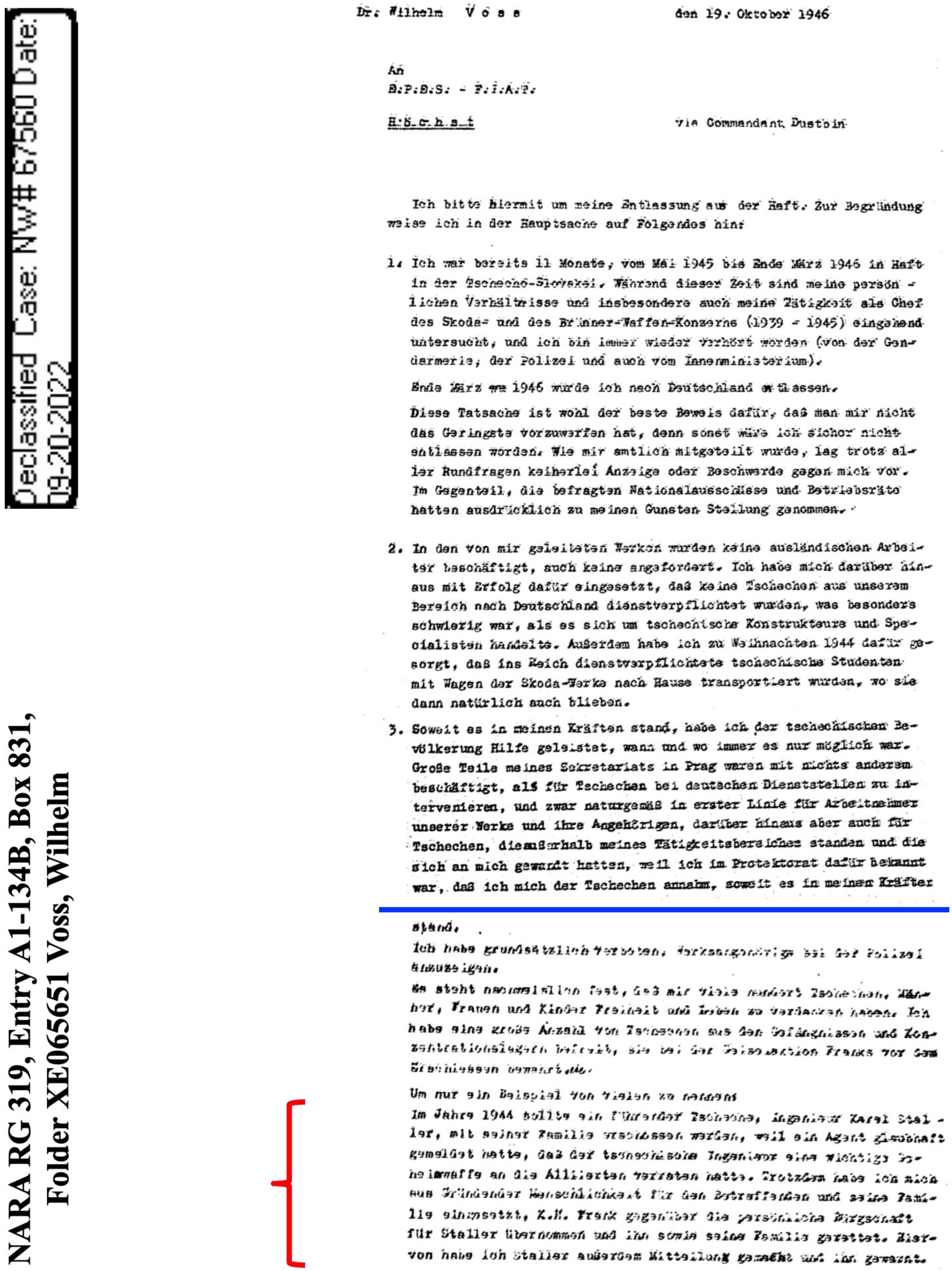
Figure D.937: Wilhelm Voss. Excerpts from September 1946 statement [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].



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Dr. Wilhelm Voss den 19. Oktober 1946

An
D.P.D.S. - F.I.A.T.

Höchst via Commandant Dustbin

Ich bitte hiermit um meine Entlassung aus der Haft. Zur Begründung weise ich in der Hauptsache auf Folgendes hin:

1. Ich war bereits 11 Monate, vom Mai 1945 bis Ende März 1946 in Haft in der Tschecho-Slowakei. Während dieser Zeit sind meine persönlichen Verhältnisse und insbesondere auch meine Tätigkeit als Chef des Skoda- und des Brünner-Waffen-Konzerns (1939 - 1945) eingehend untersucht, und ich bin immer wieder verhört worden (von der Gendarmerie, der Polizei und auch vom Innenministerium).

   Ende März 1946 wurde ich nach Deutschland entlassen.

   Diese Tatsache ist wohl der beste Beweis dafür, daß man mir nicht das Geringste vorzuwerfen hat, denn sonst wäre ich sicher nicht entlassen worden. Wie mir amtlich mitgeteilt wurde, lag trotz aller Rundfragen keinerlei Anzeige oder Beschwerde gegen mich vor. Im Gegenteil, die befragten Nationalausschüsse und Betriebsräte hatten ausdrücklich zu meinen Gunsten Stellung genommen.

2. In den von mir geleiteten Werken wurden keine ausländischen Arbeiter beschäftigt, auch keine angefordert. Ich habe mich darüber hinaus mit Erfolg dafür eingesetzt, daß keine Tschechen aus unserem Bereich nach Deutschland dienstverpflichtet wurden, was besonders schwierig war, als es sich um tschechische Konstrukteure und Specialisten handelte. Außerdem habe ich zu Weihnachten 1944 dafür gesorgt, daß ins Reich dienstverpflichtete tschechische Studenten mit Wagen der Skoda-Werke nach Hause transportiert wurden, wo sie dann natürlich auch blieben.

3. Soweit es in meinen Kräften stand, habe ich der tschechischen Bevölkerung Hilfe geleistet, wann und wo immer es nur möglich war. Große Teile meines Sekretariats in Prag waren mit nichts anderem beschäftigt, als für Tschechen bei deutschen Dienststellen zu intervenieren, und zwar naturgemäß in erster Linie für Arbeitnehmer unserer Werke und ihre Angehörigen, darüber hinaus aber auch für Tschechen, die außerhalb meines Tätigkeitsbereiches standen und die sich an mich gewandt hatten, weil ich im Protektorat dafür bekannt war, daß ich mich der Tschechen annahm, soweit es in meinen Kräften stand.

   Ich habe grundsätzlich verboten, Werksangehörige bei der Polizei anzuzeigen.

   Es steht nachweislich fest, daß mir viele hundert Tschechen, Männer, Frauen und Kinder Freiheit und Leben zu verdanken haben. Ich habe eine große Anzahl von Tschechen aus den Gefängnissen und Konzentrationslagern befreit, sie bei der Geiselaktion Franks vor dem Erschiessen bewahrt, usw.

   Um nur ein Beispiel von vielen zu nennen:
   Im Jahre 1944 sollte ein führender Tscheche, Ingenieur Karel Staller, mit seiner Familie erschossen werden, weil ein Agent glaubhaft gemeldet hatte, daß der tschechische Ingenieur eine wichtige Geheimwaffe an die Alliierten verraten hatte. Trotzdem habe ich mich aus gründender Menschlichkeit für den Betreffenden und seine Familie eingesetzt, K.H. Frank gegenüber die persönliche Bürgschaft für Staller übernommen und ihn sowie seine Familie gerettet. Hiervon habe ich Staller außerdem Mitteilung gemacht und ihn gewarnt.

Figure D.938: Wilhelm Voss. Excerpts from October 1946 statement [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].

[According to official histories, Hans Kammler died in early May 1945. However, documents in U.S. government archives prove that he surrendered to U.S. forces in May 1945 and was alive and being interrogated by the United States long after the war.]

Albert Speer. 1981. *Infiltration: How Heinrich Himmler Schemed to Build an SS Industrial Empire.* p. 243

[...] Kammler [...] came to me in early April in order to say goodbye. For the first time in our four-year association, Kammler did not display his usual dash. On the contrary, he seemed insecure and slippery with his vague, obscure hints about why I should transfer to Munich with him. He said efforts were being made in the SS to get rid of the Führer. He himself, however, was planning to contact the Americans. In exchange for their guaranty of his freedom, he would offer them the entire technology of our jet planes, as well as the A-4 rocket and other important developments, including the transcontinental rocket. For this purpose, he was assembling all development experts in Upper Bavaria in order to hand them over to the Americans.

Hans Kammler's Adjutant Heinz Schürmann. 6 November 2003 filmed interview with Heiko Petermann [courtesy of Heiko Petermann].

[Kammler's last words to Schürmann before leaving him on 4 May 1945:]

Wenn es heisst, Hänschen ist tot, ist Hans noch lange nicht tot.	If it is said that little Hans is dead, Hans is far from dead.

7 May 1945 memorandum discovered by or provided to Gerald Fleming (Surrey University). What is the original archival source for this document? [It was published in **Reuter et al. 2019, p. 168**].

[Redaction 1]

TOP SECRET

[Redaction 2]

7 May 1945

BY DIPLOMATIC POUCH

SUBJECT: Interrogation Report **[Redaction 3]** HANS KAMMLER

General der S.S. KAMMLER (chief of all V-weapons production) office at 7, Taunusstrasse, Berlin - Grunewald.

Age: 43 and party member since 1932. Dr. Ing. KAMMLER is a trained architect by profession and was head of all secret weapons projects including the V-1 and V-2. He further claims to have been head of **[Redaction 4]** project based at the **[Redaction 5]**. CIC Officer is in possession of documents from KAMMLER which may prove to be of considerable value.

Dr. KAMMLER surrendered 6 May with other named persons attached. Dressed in Heer uniform he later identified himself to an officer of **[Redaction 6]**. By way of special order KAMMLER is to be transferred immediately to KOHNSTEIN, Germany for purposes of detailed interrogation and evaluation of underground weapons research and production facilities.

DETAILED REPORT: At the suggestion of the investigating officers KAMMLER is preparing a detailed report (in German). This is to include the following:

Secret weapons development

[Redaction 7]

Underground research and production facilities

Security measures concerning the above

[Redaction 8]

[See document photo on p. 4934 (courtesy of Rainer Karlsch).

This document was typed in a monospace font, with an equal amount of space for every character. It used a single space after each period. The number of characters in each redacted phrase gives some clue as to what that phrase could have been.

Redaction 1 seems to have been added sometime after the document was typed and was probably an identification number for the document within an archive. That information was apparently removed to prevent investigators from locating the source of the document, verifying its authenticity, and finding other related documents.

Redaction 2 was the name of the organization that created this memorandum. Again, it was probably removed to prevent investigators from locating the source of the document, verifying its authenticity, and finding other related documents. Based on the style of the document, it was created by the U.S. military. From information later in the document, the creating organization was either the U.S. Army Counter-Intelligence Corps (CIC) itself or some other organization that collaborated with or oversaw CIC.

Redaction 3 contained 6 characters between "Report" and "HANS", including any spaces (which I will show as "_") before, after, and in between. Presumably it named the organization that interrogated Kammler and was redacted for that reason. The most likely answer was "s_CIC_" or ":_CIC_". CIC is named later in the document as being involved in possessing information from Kammler. It appears very sloppy or hasty that one mention of CIC was redacted while the other was not.

Redaction 4 contained 16 characters between "of" and "project", including any spaces before, after, and in between. It named some secret weapons project that was much more sensitive than the V-1 and V-2, and that still required redaction even many decades later. Based on the sorts of projects that Germany appears to have been conducting, and the sorts of projects that would provoke such secrecy from U.S. officers and censors, it seems almost certain that Redaction 4 concerned the German nuclear weapons program. There are several plausible wordings that match the 16-character space, including "_the_Tube_Alloy_", "_the_German_T_A_", "_an_atomic_bomb_", "_SS_atomic_bomb_", or "_atomic_weapons_".

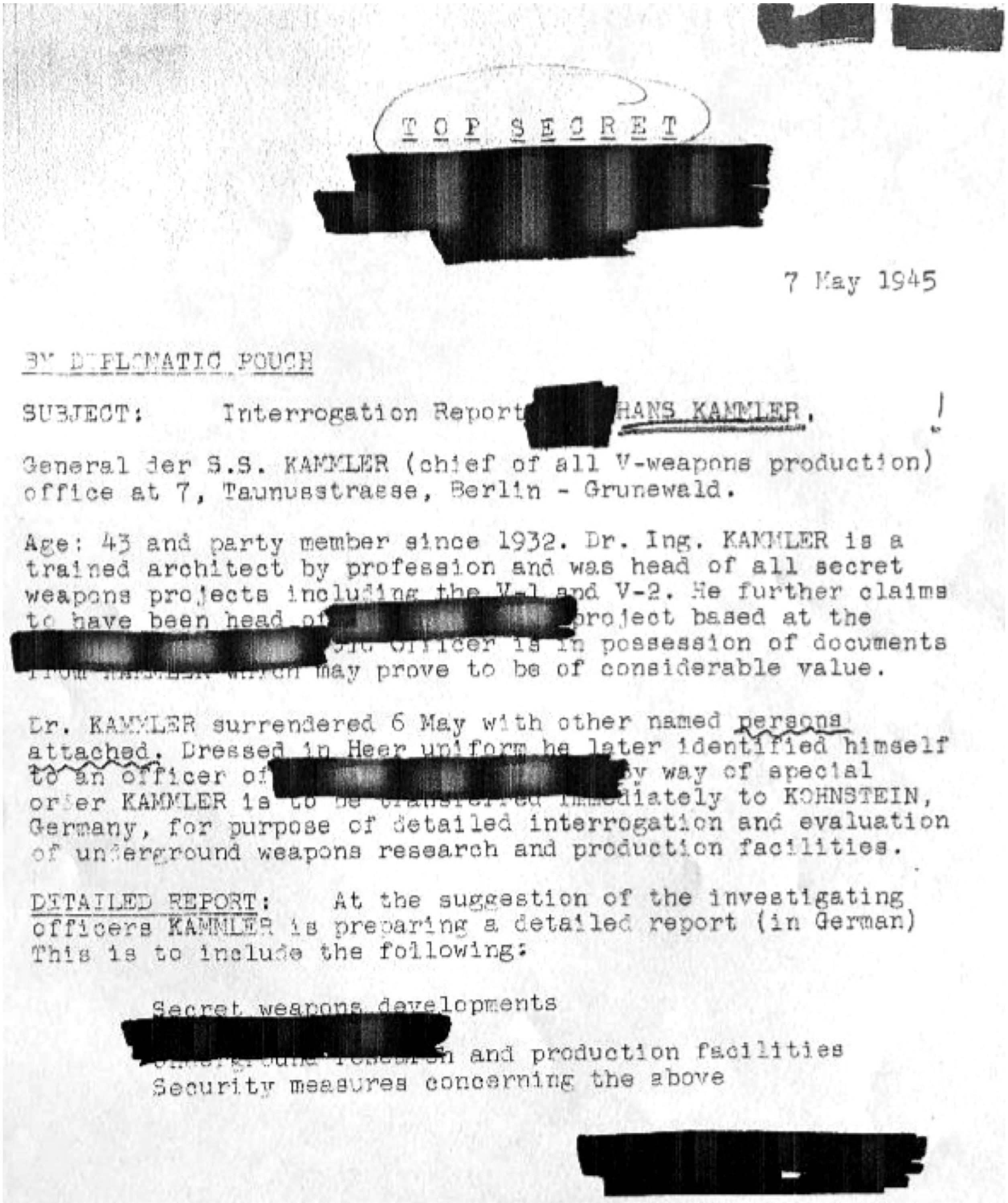
Redaction 5 contained 18 characters between the beginning of the line and the apparent location of the period, including any spaces. It seems to have named the headquarters and/or the most important production location for the German nuclear weapons program. As such, this information would be of great interest to modern investigators. The 18-character location name is preceded by "the", which also helps to narrow down the possible answers. "BERGKRISTALL_plant" (St. Georgen/Gusen) and "Truppenübungsplatz" (Ohrdruf) are plausible answers. Other possible locations might have included Linz, Pilsen, Prague, Tuchola Forest/Tucheler Heide, etc., although it is challenging to think of names that the U.S. military would have used for those locations and that would have been preceded by "the" and had 18 characters.

Redaction 6 contained 21 characters between "of" and the apparent location of the period, including any spaces. It named the military unit to which Kammler surrendered, and it was probably redacted to prevent investigators from verifying this document and finding related documents. Based on U.S. troop movements and locations in early May 1945, a plausible answer is "_4th_Armored_Division".

Redaction 7 contained 17–19 characters, and most likely 18 characters based on how far the other black marks protrude beyond the edge of a redacted word. Redaction 7 was the second in a list of four items. The first and third items were almost exactly as named earlier in the memorandum, so the redacted phrase was probably the same or nearly the same as named in Redaction 4. Some possibilities include "Tube_Alloy_project" (18 characters), "German_T_A_project" (18 characters), "German_TA_project" (17 characters), "Atomic_development" (18 characters), "SS_atomic_research" (18 characters), "SS_atomic_weapons" (17 characters), "Atomic_bomb_project" (19 characters), etc.

Redaction 8 was the person who wrote this memorandum. Once again, it was apparently redacted to prevent investigators from locating the source of the document, verifying its authenticity, and finding other related documents.

Can the archival source of this document be identified, and can unredacted versions of this document, the documents it mentions, and other related documents be released?]



[redacted] [redacted]

TOP SECRET

[redacted]

7 May 1945

BY DIPLOMATIC POUCH

SUBJECT: Interrogation Report [redacted] HANS KAMMLER.

General der S.S. KAMMLER (chief of all V-weapons production) office at 7, Taunusstrasse, Berlin - Grunewald.

Age: 43 and party member since 1932. Dr. Ing. KAMMLER is a trained architect by profession and was head of all secret weapons projects inclu[redacted]nd V-2. He further claims to have been head o[redacted]project based at the [redacted] possession of documents [redacted] may prove to be of considerable value.

Dr. KAMMLER surrendered 6 May with other named persons attached. Dressed in Heer uniform he later identified himself to an officer of [redacted] by way of special order KAMMLER is [redacted]iately to KOHNSTEIN, Germany, for purpose of detailed interrogation and evaluation of underground weapons research and production facilities.

DETAILED REPORT: At the suggestion of the investigating officers KAMMLER is preparing a detailed report (in German) This is to include the following:

Secret weapons developments
[redacted] and production facilities
Security measures concerning the above

[redacted]

Figure D.939: 7 May 1945 memorandum, proving that Hans Kammler was alive and being interrogated by the United States as of 7 May 1945 [courtesy of Rainer Karlsch; published in Reuter et al. 2019, p. 168].

Frederick I. Ordway III and Mitchell Sharpe. 1979. *The Rocket Team.* pp. 282–283.

On the same day that the first ship left [22 May 1945], Staver learned the exact location of the documents hidden by Huzel and Tessmann on April 3. He did so by a clever ruse. A couple of days earlier, talking with Fleischer in Bleicherode, he casually pulled a notebook from his pocket and read an imaginary entry:

> Von Braun, Steinhoff, and all the others who fled south have been interned at Garmisch. Our intelligence officers have talked to von Ploetz [Kammler's intelligence officer], General Dornberger, General Rossmann, and General Kammler. They told us that many of your important drawings and documents were buried underground in a mine somewhere around here, and that you, Fleischer, could help us find them.

As he finished, he watched the German closely. Fleischer was upset by what he had heard and reacted visibly. Staver, not wanting to appear overly eager to find the cache of documents, merely told him to think things over and that he would see him the next day. [...]

Fleischer and Rees finally located the mine[...] Then they returned to Nordhausen to inform Staver, arriving there at 1:30 AM on May 22.

[Wernher von Braun and other key German rocket experts provided direct input for this book, which covered the work by those experts in Germany during the war and in the United States after the war. The book was published in 1979, a couple of years after von Braun's death.

According to this book, U.S. Army Major Robert B. Staver told a false story to a German, Karl Otto Fleischer, in order to persuade him to reveal where some rocket documents had been buried. The allegedly false story was that under interrogation by U.S. intelligence officers, Hans Kammler had said that Fleischer knew where the documents were. Even if it was false that Fleischer had been implicated during the interrogation of Kammler, it was in fact true that Kammler was in the custody of U.S. intelligence officers and was being interrogated at that time.

According to official accounts, which presumably would have been widely reported both in these German circles and in U.S. military circles since Kammler was such a high-ranking figure, Kammler had been killed or committed suicide in early May. Staver's bluff suggests that both Staver and Fleischer knew that Kammler was in fact alive and in U.S. custody; otherwise the bluff would not have been credible.

Perhaps it was not even a bluff at all. Maybe Kammler really did discuss the buried documents during his interrogation, and Staver was simply using an actual fact as leverage to persuade Fleischer to reveal where the documents were hidden. In order to maintain the official story that Kammler died in early May 1945, Staver's claim to Fleischer may have later been explained away as fictional.]

James McGovern. 1964. *Crossbow and Overcast.* pp. 167–169.

On the afternoon of May 18, a plane arrived from Brunswick with Drs. [Victor H.] Fraenckel and [Howard P.] Robertson, two civilian technical investigators attached to General Eisenhower's headquarters. [...]

Dr. Robertson agreed with Staver's view, then glanced through his pocket notebook and read a notation: "Von Ploetz said that General Dornberger told General Rossmann that documents of V-weapon production were hidden in *Kaliwerke* (salt mine) at Bleicherode, walled into one of the mine shafts. Von Ploetz was G-2 [intelligence] to Kammler." Dr. Robertson suggested that Rees or Fleischer might be able to direct Major Staver to the salt mine in question, but other than that Dr. Robertson had no further information to offer.

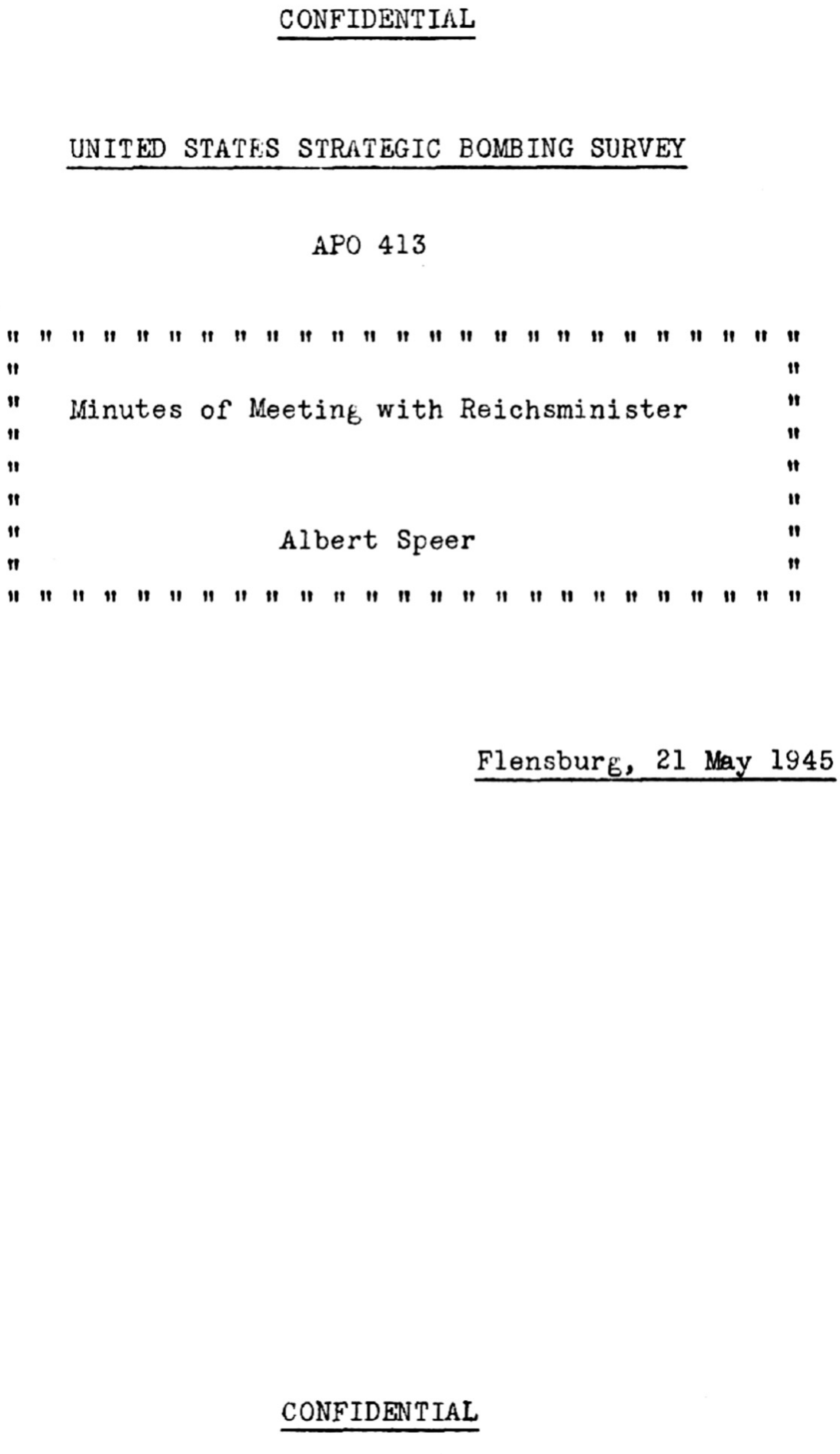
Major Staver spent the rest of the afternoon interrogating Walther Riedel with the thought constantly in the back of his mind of how to turn Dr. Robertson's sketchy lead to the best advantage. The V-2 documents, of course, were not in the salt mine at Bleicherode, which contained only some minor material relating to production. At 6 P.M., Staver left the U.S. Military Government building with Riedel and found that Fleischer had been waiting for them in his two-seater roadster. As casually as he could, after a few words of greeting with Fleischer, Staver took out his own pocket notebook and read from it: "Von Braun, Steinhoff, and all of the others who fled to the south have been interned at Garmisch. Our intelligence officers have talked to von Ploetz, General Dornberger, General Rossmann, and General Kammler. They told us that many of your drawings and important documents were buried underground in a mine somewhere around here, and that Riedel, or *you*, Fleischer, could help us find them."

This was, of course, a fabrication designed to make Fleischer and Riedel think they had been put on the spot by their superiors. Staver reasoned that if they did have any knowledge of a cache of documents they would believe either that they had to tell him where it was or risk being imprisoned for withholding information their superiors wanted the Americans to have.

[James McGovern gave an independent account of the same incident and added a few details. In particular, he mentioned the involvement of Dr. Howard P. Robertson and Dr. Victor H. Fraenckel. Robertson was the head and Fraenckel was a member of the Scientific Intelligence Advisory Section (SIAS) at the Supreme Headquarters Allied Expeditionary Force (SHAEF). Thus they were scientific advisors of the highest level for Dwight Eisenhower. Their direct personal involvement out in the field suggests that this was a matter of the greatest impossible importance. Robertson and Frankel seem to have been involved in interrogating Hans Kammler's intelligence chief, von Ploetz. Could they also have been involved in interrogating Kammler?

What information and archival documents can be located regarding the wartime work and postwar interrogations of von Ploetz? As Kammler's intelligence chief, he would have known a great deal about the most secret German weapons programs.

See also: Jacobsen 2014, p. 97; Neufeld 2007, pp. 206–207, 505; Reuter et al. 2019, pp. 154–155, 273, 367–370.]



CONFIDENTIAL

UNITED STATES STRATEGIC BOMBING SURVEY

APO 413

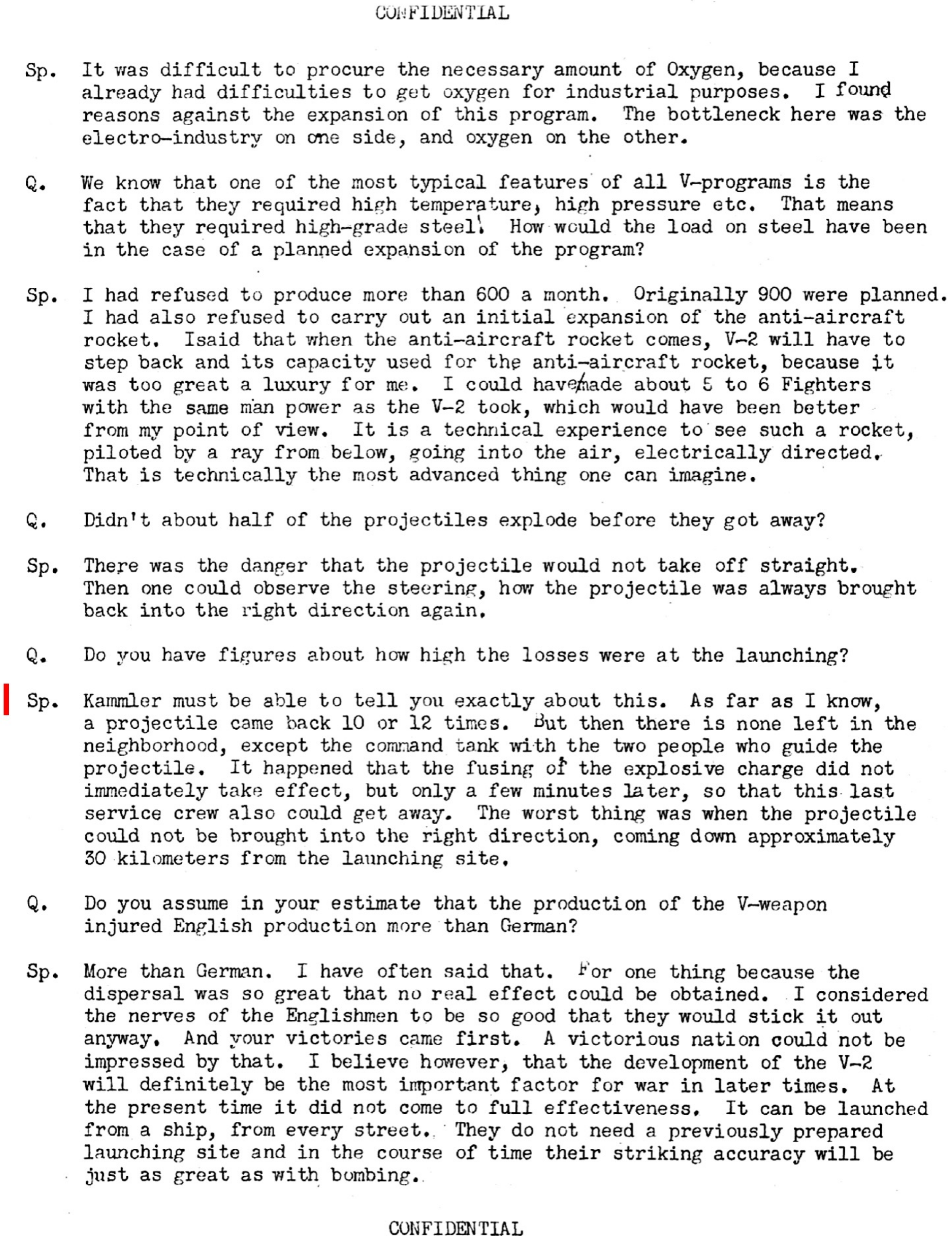
Minutes of Meeting with Reichsminister

Albert Speer

Flensburg, 21 May 1945

CONFIDENTIAL

Figure D.940: In this 21 May 1945 interrogation, Albert Speer knew or at least had correctly concluded that Hans Kammler was also alive, in U.S. custody, and cooperating with interrogations. [https://digital.library.cornell.edu/catalog/nur01453]



CONFIDENTIAL

Sp. It was difficult to procure the necessary amount of Oxygen, because I already had difficulties to get oxygen for industrial purposes. I found reasons against the expansion of this program. The bottleneck here was the electro-industry on one side, and oxygen on the other.

Q. We know that one of the most typical features of all V-programs is the fact that they required high temperature, high pressure etc. That means that they required high-grade steel. How would the load on steel have been in the case of a planned expansion of the program?

Sp. I had refused to produce more than 600 a month. Originally 900 were planned. I had also refused to carry out an initial expansion of the anti-aircraft rocket. Isaid that when the anti-aircraft rocket comes, V-2 will have to step back and its capacity used for the anti-aircraft rocket, because it was too great a luxury for me. I could have made about 5 to 6 Fighters with the same man power as the V-2 took, which would have been better from my point of view. It is a technical experience to see such a rocket, piloted by a ray from below, going into the air, electrically directed. That is technically the most advanced thing one can imagine.

Q. Didn't about half of the projectiles explode before they got away?

Sp. There was the danger that the projectile would not take off straight. Then one could observe the steering, how the projectile was always brought back into the right direction again.

Q. Do you have figures about how high the losses were at the launching?

Sp. Kammler must be able to tell you exactly about this. As far as I know, a projectile came back 10 or 12 times. But then there is none left in the neighborhood, except the command tank with the two people who guide the projectile. It happened that the fusing of the explosive charge did not immediately take effect, but only a few minutes later, so that this last service crew also could get away. The worst thing was when the projectile could not be brought into the right direction, coming down approximately 30 kilometers from the launching site.

Q. Do you assume in your estimate that the production of the V-weapon injured English production more than German?

Sp. More than German. I have often said that. For one thing because the dispersal was so great that no real effect could be obtained. I considered the nerves of the Englishmen to be so good that they would stick it out anyway. And your victories came first. A victorious nation could not be impressed by that. I believe however, that the development of the V-2 will definitely be the most important factor for war in later times. At the present time it did not come to full effectiveness. It can be launched from a ship, from every street. They do not need a previously prepared launching site and in the course of time their striking accuracy will be just as great as with bombing.

CONFIDENTIAL

Figure D.941: In this 21 May 1945 interrogation, Albert Speer knew or at least had correctly concluded that Hans Kammler was also alive, in U.S. custody, and cooperating with interrogations: "Kammler must be able to tell you exactly about this." [https://digital.library.cornell.edu/catalog/nur01453]

Colonel Loyd K. Pepple. 30 May 1945 Memorandum to Colonel Sheldon. [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data. Microfilmed as AFHRA C5089, electronic version pp. 792–806]

HEADQUARTERS
UNITED STATES STRATEGIC AIR FORCES IN EUROPE
Office of Asst. Chief of Staff A-2
Exploitation Division, Operations Section

30 May, 1945

MEMORANDUM: Summary of Activities, Operations Section, Exploitation Division.

TO: Colonel Sheldon

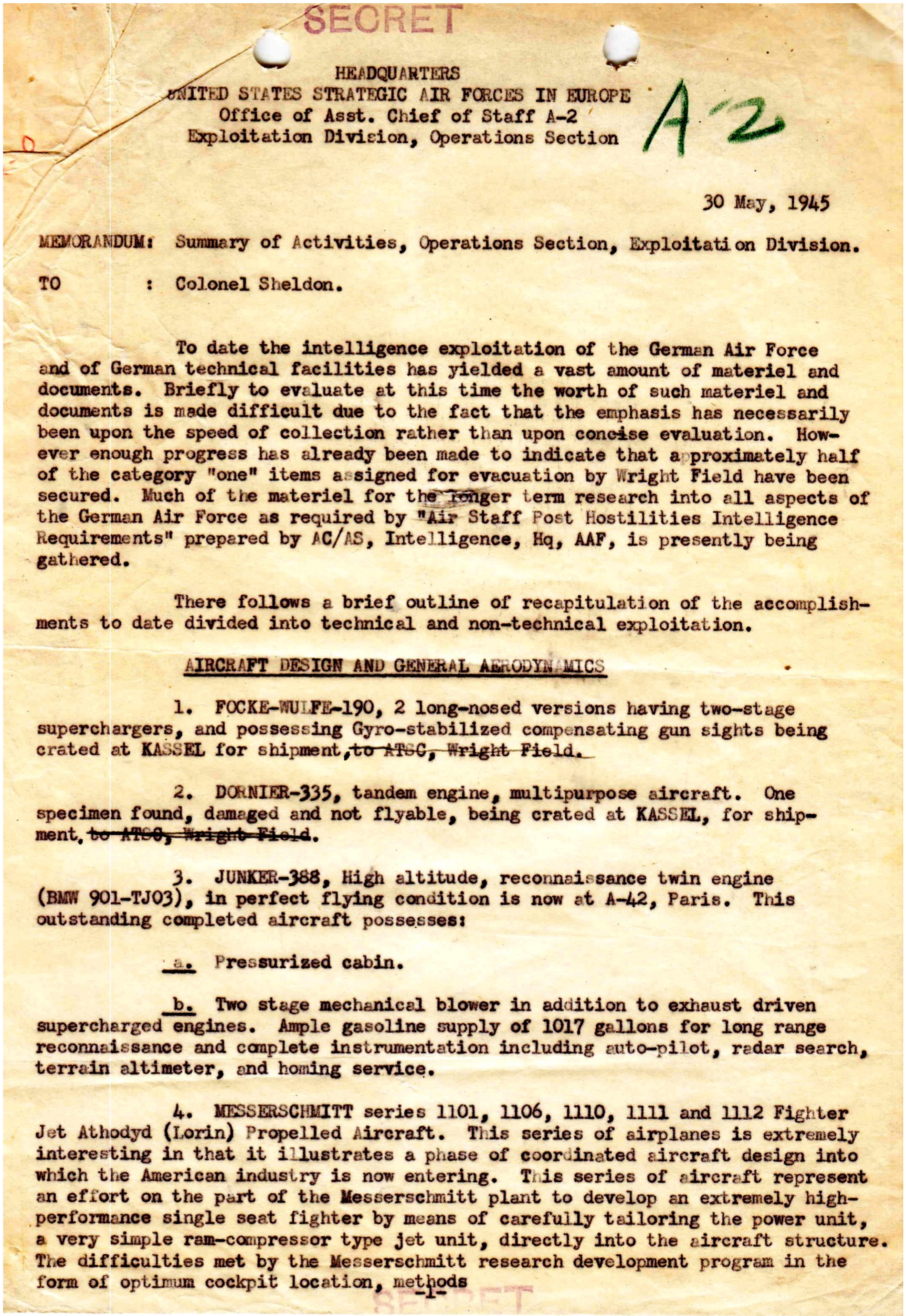
[...]

47. The following is a list of key German Air Force non-technical personnel presently being held for interrogation.

Reichsmarschall Hermann Goering	Commander in Chief of Luftwaffe.
Generalfeldmarschall Ehrhard Milch	Secretary of State for Air and Inspector General of the GAF—Director General of Equipment.
General der Flieger Koller	Chief of General Staff of Luftwaffe.
Dr. Albert Speer	Minister for Armament and War Production.
[...]	
SS-Obergruppenführer Kammler	Inspector of all units of the Luftwaffe working with rocket-propelled arms.
[...]	

[See document photos on pp. 4940–4953.]

AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data



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HEADQUARTERS
UNITED STATES STRATEGIC AIR FORCES IN EUROPE
Office of Asst. Chief of Staff A-2
Exploitation Division, Operations Section

A 2

30 May, 1945

MEMORANDUM: Summary of Activities, Operations Section, Exploitation Division.

TO : Colonel Sheldon.

To date the intelligence exploitation of the German Air Force and of German technical facilities has yielded a vast amount of materiel and documents. Briefly to evaluate at this time the worth of such materiel and documents is made difficult due to the fact that the emphasis has necessarily been upon the speed of collection rather than upon concise evaluation. However enough progress has already been made to indicate that approximately half of the category "one" items assigned for evacuation by Wright Field have been secured. Much of the materiel for the longer term research into all aspects of the German Air Force as required by "Air Staff Post Hostilities Intelligence Requirements" prepared by AC/AS, Intelligence, Hq, AAF, is presently being gathered.

There follows a brief outline of recapitulation of the accomplishments to date divided into technical and non-technical exploitation.

AIRCRAFT DESIGN AND GENERAL AERODYNAMICS

1. FOCKE-WULFE-190, 2 long-nosed versions having two-stage superchargers, and possessing Gyro-stabilized compensating gun sights being crated at KASSEL for shipment~~, to ATSC, Wright Field.~~

2. DORNIER-335, tandem engine, multipurpose aircraft. One specimen found, damaged and not flyable, being crated at KASSEL, for shipment, ~~to ATSC, Wright Field~~.

3. JUNKER-388, High altitude, reconnaissance twin engine (BMW 901-TJ03), in perfect flying condition is now at A-42, Paris. This outstanding completed aircraft possesses:

a. Pressurized cabin.

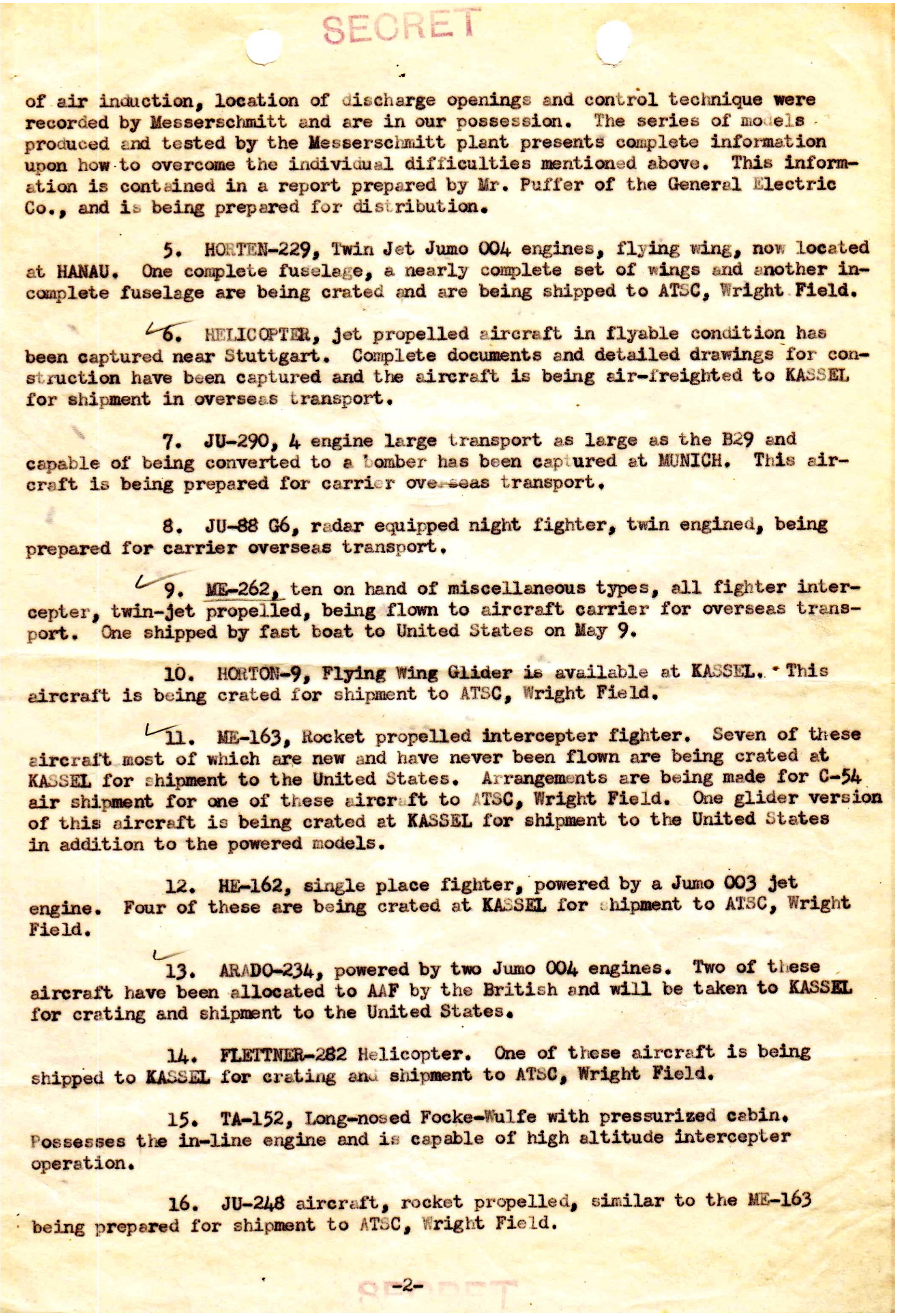
b. Two stage mechanical blower in addition to exhaust driven supercharged engines. Ample gasoline supply of 1017 gallons for long range reconnaissance and complete instrumentation including auto-pilot, radar search, terrain altimeter, and homing service.

4. MESSERSCHMITT series 1101, 1106, 1110, 1111 and 1112 Fighter Jet Athodyd (Lorin) Propelled Aircraft. This series of airplanes is extremely interesting in that it illustrates a phase of coordinated aircraft design into which the American industry is now entering. This series of aircraft represent an effort on the part of the Messerschmitt plant to develop an extremely high-performance single seat fighter by means of carefully tailoring the power unit, a very simple ram-compressor type jet unit, directly into the aircraft structure. The difficulties met by the Messerschmitt research development program in the form of optimum cockpit location, methods

-1-

SECRET

Figure D.942: 30 May 1945 memorandum from Colonel Loyd K. Pepple to Colonel Sheldon, proving that Hans Kammler was alive and being interrogated by the United States as of 30 May 1945 [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].



SECRET

of air induction, location of discharge openings and control technique were recorded by Messerschmitt and are in our possession. The series of models produced and tested by the Messerschmitt plant presents complete information upon how to overcome the individual difficulties mentioned above. This information is contained in a report prepared by Mr. Puffer of the General Electric Co., and is being prepared for distribution.

5. HORTEN-229, Twin Jet Jumo 004 engines, flying wing, now located at HANAU. One complete fuselage, a nearly complete set of wings and another incomplete fuselage are being crated and are being shipped to ATSC, Wright Field.

6. HELICOPTER, jet propelled aircraft in flyable condition has been captured near Stuttgart. Complete documents and detailed drawings for construction have been captured and the aircraft is being air-freighted to KASSEL for shipment in overseas transport.

7. JU-290, 4 engine large transport as large as the B29 and capable of being converted to a bomber has been captured at MUNICH. This aircraft is being prepared for carrier overseas transport.

8. JU-88 G6, radar equipped night fighter, twin engined, being prepared for carrier overseas transport.

9. ME-262, ten on hand of miscellaneous types, all fighter intercepter, twin-jet propelled, being flown to aircraft carrier for overseas transport. One shipped by fast boat to United States on May 9.

10. HORTON-9, Flying Wing Glider is available at KASSEL. This aircraft is being crated for shipment to ATSC, Wright Field.

11. ME-163, Rocket propelled intercepter fighter. Seven of these aircraft most of which are new and have never been flown are being crated at KASSEL for shipment to the United States. Arrangements are being made for C-54 air shipment for one of these aircraft to ATSC, Wright Field. One glider version of this aircraft is being crated at KASSEL for shipment to the United States in addition to the powered models.

12. HE-162, single place fighter, powered by a Jumo 003 jet engine. Four of these are being crated at KASSEL for shipment to ATSC, Wright Field.

13. ARADO-234, powered by two Jumo 004 engines. Two of these aircraft have been allocated to AAF by the British and will be taken to KASSEL for crating and shipment to the United States.

14. FLETTNER-282 Helicopter. One of these aircraft is being shipped to KASSEL for crating and shipment to ATSC, Wright Field.

15. TA-152, Long-nosed Focke-Wulfe with pressurized cabin. Possesses the in-line engine and is capable of high altitude intercepter operation.

16. JU-248 aircraft, rocket propelled, similar to the ME-163 being prepared for shipment to ATSC, Wright Field.

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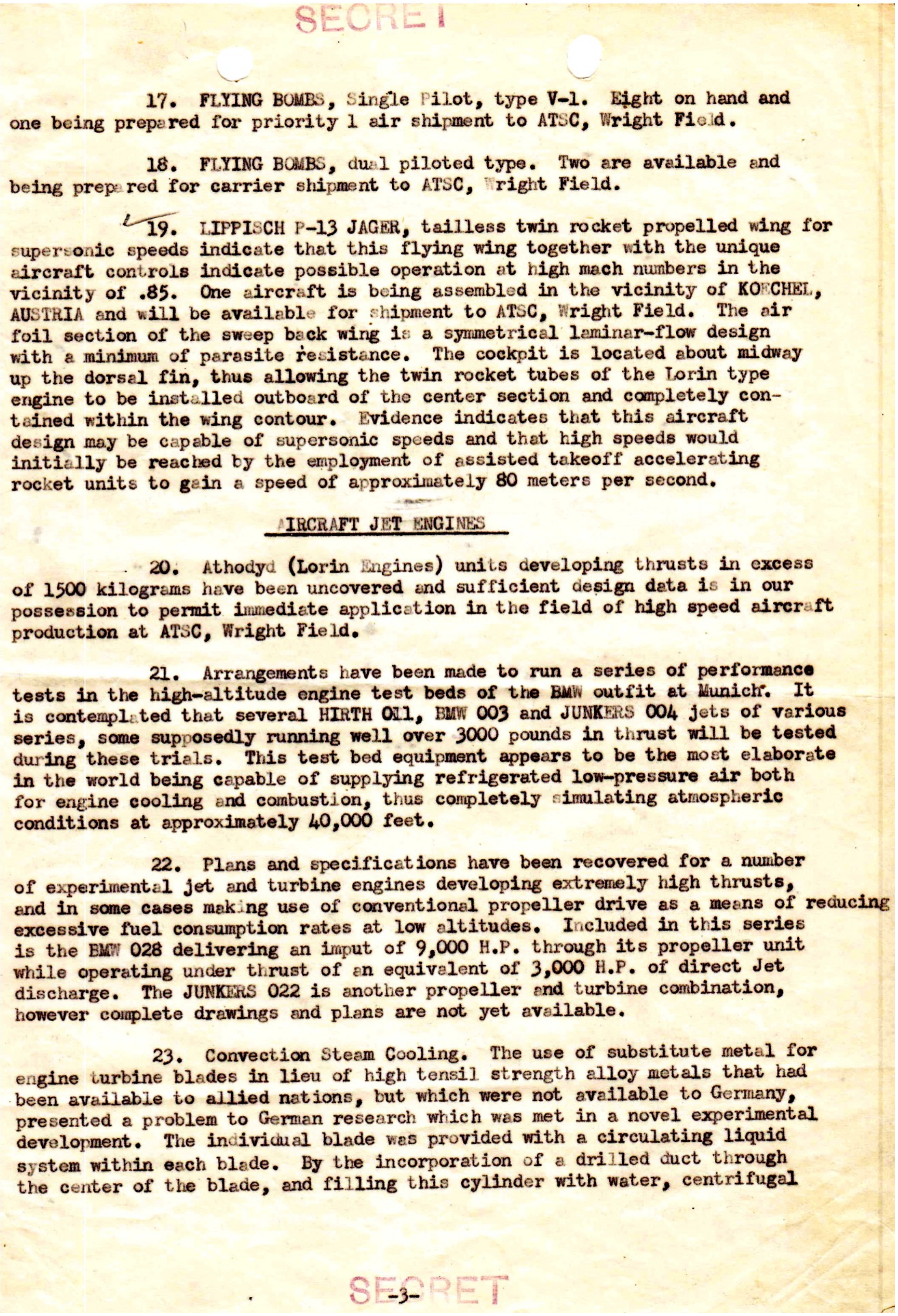
SECRET

AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data

Figure D.943: 30 May 1945 memorandum from Colonel Loyd K. Pepple to Colonel Sheldon, proving that Hans Kammler was alive and being interrogated by the United States as of 30 May 1945 [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data



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17. FLYING BOMBS, Single Pilot, type V-1. Eight on hand and one being prepared for priority 1 air shipment to ATSC, Wright Field.

18. FLYING BOMBS, dual piloted type. Two are available and being prepared for carrier shipment to ATSC, Wright Field.

19. LIPPISCH P-13 JAGER, tailless twin rocket propelled wing for supersonic speeds indicate that this flying wing together with the unique aircraft controls indicate possible operation at high mach numbers in the vicinity of .85. One aircraft is being assembled in the vicinity of KOECHEL, AUSTRIA and will be available for shipment to ATSC, Wright Field. The air foil section of the sweep back wing is a symmetrical laminar-flow design with a minimum of parasite resistance. The cockpit is located about midway up the dorsal fin, thus allowing the twin rocket tubes of the Lorin type engine to be installed outboard of the center section and completely contained within the wing contour. Evidence indicates that this aircraft design may be capable of supersonic speeds and that high speeds would initially be reached by the employment of assisted takeoff accelerating rocket units to gain a speed of approximately 80 meters per second.

AIRCRAFT JET ENGINES

20. Athodyd (Lorin Engines) units developing thrusts in excess of 1500 kilograms have been uncovered and sufficient design data is in our possession to permit immediate application in the field of high speed aircraft production at ATSC, Wright Field.

21. Arrangements have been made to run a series of performance tests in the high-altitude engine test beds of the BMW outfit at Munich. It is contemplated that several HIRTH 011, BMW 003 and JUNKERS 004 jets of various series, some supposedly running well over 3000 pounds in thrust will be tested during these trials. This test bed equipment appears to be the most elaborate in the world being capable of supplying refrigerated low-pressure air both for engine cooling and combustion, thus completely simulating atmospheric conditions at approximately 40,000 feet.

22. Plans and specifications have been recovered for a number of experimental jet and turbine engines developing extremely high thrusts, and in some cases making use of conventional propeller drive as a means of reducing excessive fuel consumption rates at low altitudes. Included in this series is the BMW 028 delivering an imput of 9,000 H.P. through its propeller unit while operating under thrust of an equivalent of 3,000 H.P. of direct Jet discharge. The JUNKERS 022 is another propeller and turbine combination, however complete drawings and plans are not yet available.

23. Convection Steam Cooling. The use of substitute metal for engine turbine blades in lieu of high tensil strength alloy metals that had been available to allied nations, but which were not available to Germany, presented a problem to German research which was met in a novel experimental development. The individual blade was provided with a circulating liquid system within each blade. By the incorporation of a drilled duct through the center of the blade, and filling this cylinder with water, centrifugal

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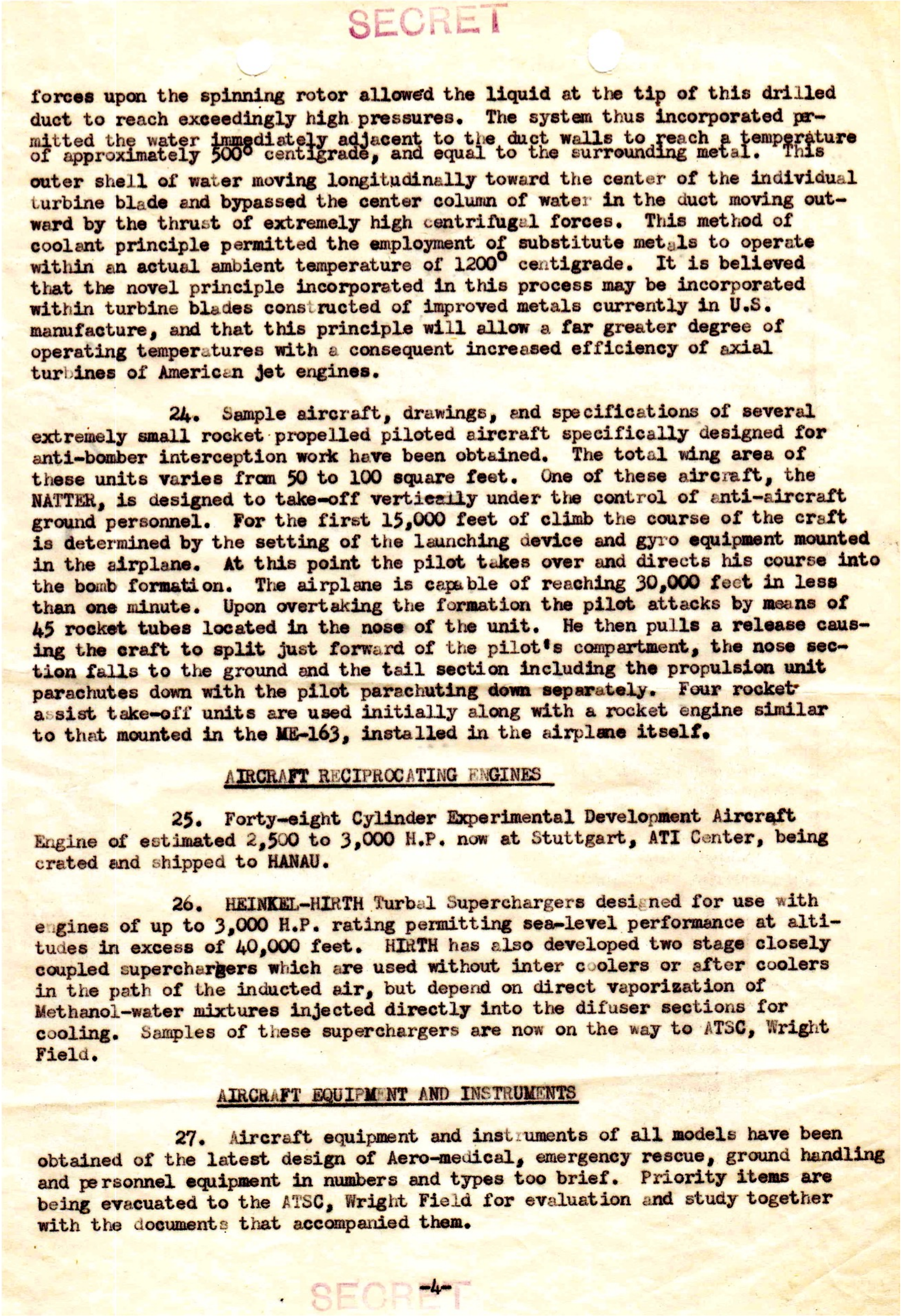
SECRET

Figure D.944: 30 May 1945 memorandum from Colonel Loyd K. Pepple to Colonel Sheldon, proving that Hans Kammler was alive and being interrogated by the United States as of 30 May 1945 [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data



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forces upon the spinning rotor allowed the liquid at the tip of this drilled duct to reach exceedingly high pressures. The system thus incorporated prmitted the water immediately adjacent to the duct walls to reach a temperature of approximately 500° centigrade, and equal to the surrounding metal. This outer shell of water moving longitudinally toward the center of the individual turbine blade and bypassed the center column of water in the duct moving outward by the thrust of extremely high centrifugal forces. This method of coolant principle permitted the employment of substitute metals to operate within an actual ambient temperature of 1200° centigrade. It is believed that the novel principle incorporated in this process may be incorporated within turbine blades constructed of improved metals currently in U.S. manufacture, and that this principle will allow a far greater degree of operating temperatures with a consequent increased efficiency of axial turbines of American jet engines.

24. Sample aircraft, drawings, and specifications of several extremely small rocket propelled piloted aircraft specifically designed for anti-bomber interception work have been obtained. The total wing area of these units varies from 50 to 100 square feet. One of these aircraft, the NATTER, is designed to take-off vertically under the control of anti-aircraft ground personnel. For the first 15,000 feet of climb the course of the craft is determined by the setting of the launching device and gyro equipment mounted in the airplane. At this point the pilot takes over and directs his course into the bomb formation. The airplane is capable of reaching 30,000 feet in less than one minute. Upon overtaking the formation the pilot attacks by means of 45 rocket tubes located in the nose of the unit. He then pulls a release causing the craft to split just forward of the pilot's compartment, the nose section falls to the ground and the tail section including the propulsion unit parachutes down with the pilot parachuting down separately. Four rocket assist take-off units are used initially along with a rocket engine similar to that mounted in the ME-163, installed in the airplane itself.

AIRCRAFT RECIPROCATING ENGINES

25. Forty-eight Cylinder Experimental Development Aircraft Engine of estimated 2,500 to 3,000 H.P. now at Stuttgart, ATI Center, being crated and shipped to HANAU.

26. HEINKEL-HIRTH Turbal Superchargers designed for use with engines of up to 3,000 H.P. rating permitting sea-level performance at altitudes in excess of 40,000 feet. HIRTH has also developed two stage closely coupled superchargers which are used without inter coolers or after coolers in the path of the inducted air, but depend on direct vaporization of Methanol-water mixtures injected directly into the difuser sections for cooling. Samples of these superchargers are now on the way to ATSC, Wright Field.

AIRCRAFT EQUIPMENT AND INSTRUMENTS

27. Aircraft equipment and instruments of all models have been obtained of the latest design of Aero-medical, emergency rescue, ground handling and personnel equipment in numbers and types too brief. Priority items are being evacuated to the ATSC, Wright Field for evaluation and study together with the documents that accompanied them.

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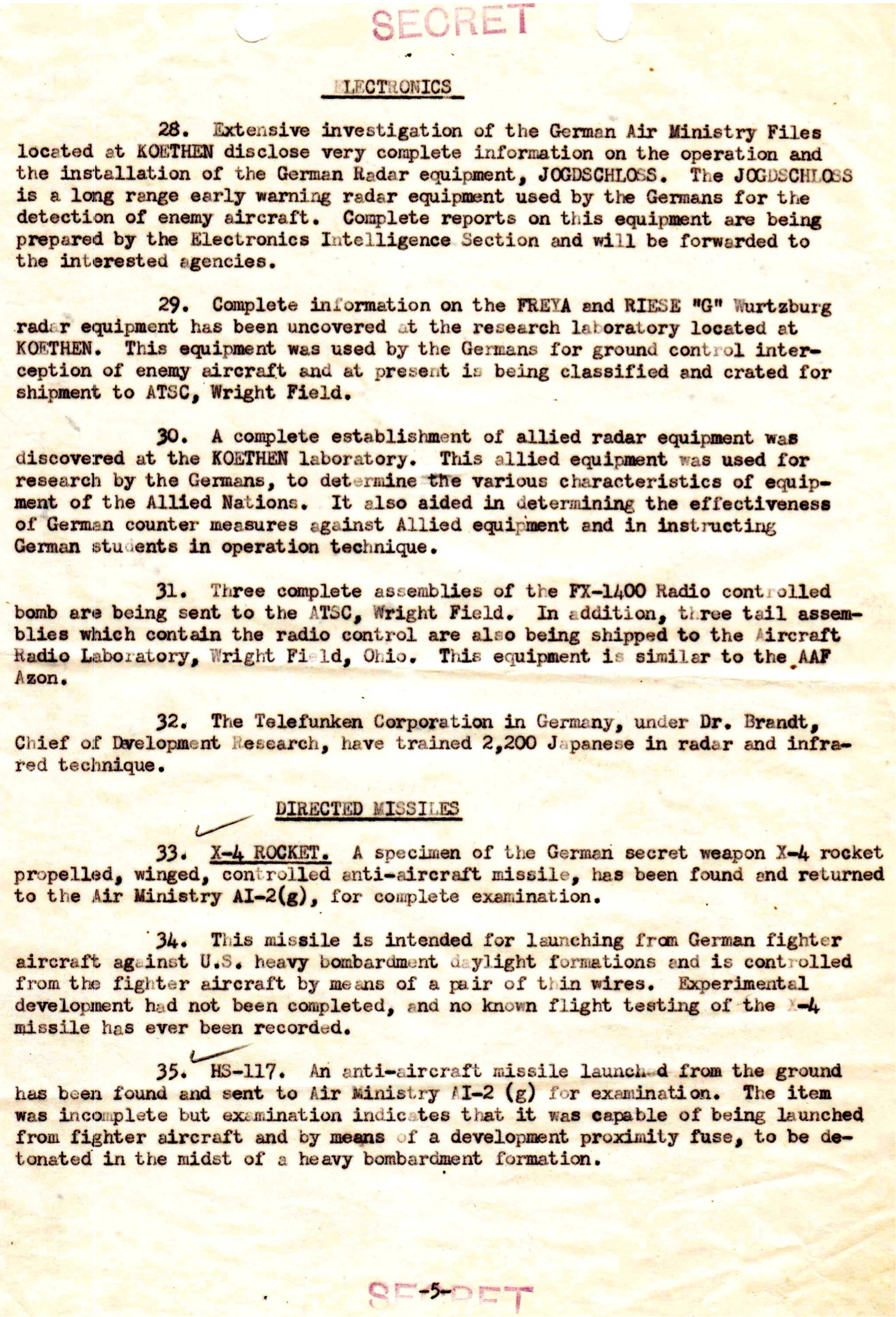
SECRET

Figure D.945: 30 May 1945 memorandum from Colonel Loyd K. Pepple to Colonel Sheldon, proving that Hans Kammler was alive and being interrogated by the United States as of 30 May 1945 [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data



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ELECTRONICS

28. Extensive investigation of the German Air Ministry Files located at KOETHEN disclose very complete information on the operation and the installation of the German Radar equipment, JOGDSCHLOSS. The JOGDSCHLOSS is a long range early warning radar equipment used by the Germans for the detection of enemy aircraft. Complete reports on this equipment are being prepared by the Electronics Intelligence Section and will be forwarded to the interested agencies.

29. Complete information on the FREYA and RIESE "G" Wurtzburg radar equipment has been uncovered at the research laboratory located at KOETHEN. This equipment was used by the Germans for ground control interception of enemy aircraft and at present is being classified and crated for shipment to ATSC, Wright Field.

30. A complete establishment of allied radar equipment was discovered at the KOETHEN laboratory. This allied equipment was used for research by the Germans, to determine the various characteristics of equipment of the Allied Nations. It also aided in determining the effectiveness of German counter measures against Allied equipment and in instructing German students in operation technique.

31. Three complete assemblies of the FX-1400 Radio controlled bomb are being sent to the ATSC, Wright Field. In addition, three tail assemblies which contain the radio control are also being shipped to the Aircraft Radio Laboratory, Wright Field, Ohio. This equipment is similar to the AAF Azon.

32. The Telefunken Corporation in Germany, under Dr. Brandt, Chief of Development Research, have trained 2,200 Japanese in radar and infrared technique.

DIRECTED MISSILES

33. X-4 ROCKET. A specimen of the German secret weapon X-4 rocket propelled, winged, controlled anti-aircraft missile, has been found and returned to the Air Ministry AI-2(g), for complete examination.

34. This missile is intended for launching from German fighter aircraft against U.S. heavy bombardment daylight formations and is controlled from the fighter aircraft by means of a pair of thin wires. Experimental development had not been completed, and no known flight testing of the X-4 missile has ever been recorded.

35. HS-117. An anti-aircraft missile launched from the ground has been found and sent to Air Ministry AI-2 (g) for examination. The item was incomplete but examination indicates that it was capable of being launched from fighter aircraft and by means of a development proximity fuse, to be detonated in the midst of a heavy bombardment formation.

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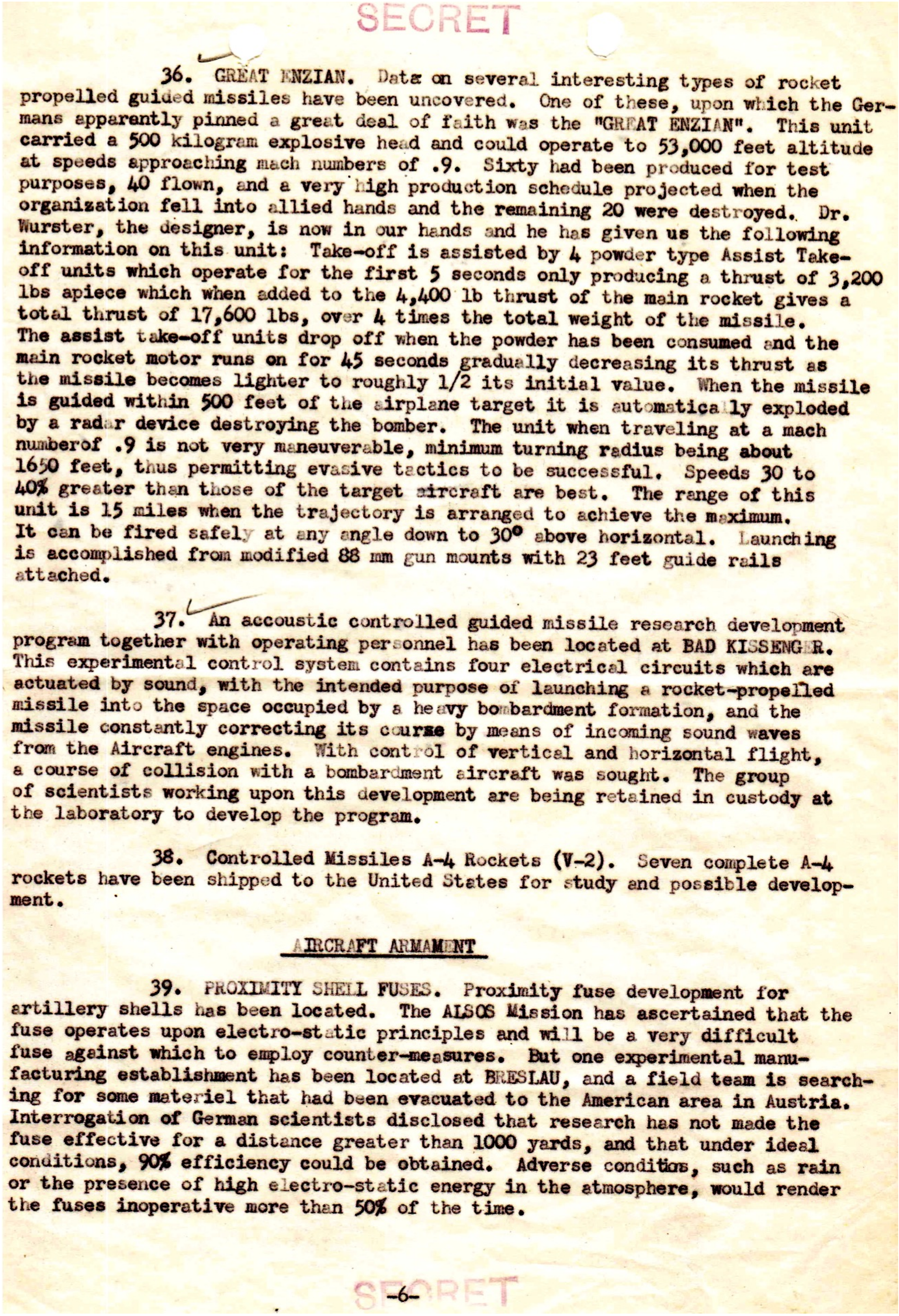
SECRET

Figure D.946: 30 May 1945 memorandum from Colonel Loyd K. Pepple to Colonel Sheldon, proving that Hans Kammler was alive and being interrogated by the United States as of 30 May 1945 [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data



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36. GREAT ENZIAN. Data on several interesting types of rocket propelled guided missiles have been uncovered. One of these, upon which the Germans apparently pinned a great deal of faith was the "GREAT ENZIAN". This unit carried a 500 kilogram explosive head and could operate to 53,000 feet altitude at speeds approaching mach numbers of .9. Sixty had been produced for test purposes, 40 flown, and a very high production schedule projected when the organization fell into allied hands and the remaining 20 were destroyed. Dr. Wurster, the designer, is now in our hands and he has given us the following information on this unit: Take-off is assisted by 4 powder type Assist Take-off units which operate for the first 5 seconds only producing a thrust of 3,200 lbs apiece which when added to the 4,400 lb thrust of the main rocket gives a total thrust of 17,600 lbs, over 4 times the total weight of the missile. The assist take-off units drop off when the powder has been consumed and the main rocket motor runs on for 45 seconds gradually decreasing its thrust as the missile becomes lighter to roughly 1/2 its initial value. When the missile is guided within 500 feet of the airplane target it is automatically exploded by a radar device destroying the bomber. The unit when traveling at a mach numberof .9 is not very maneuverable, minimum turning radius being about 1650 feet, thus permitting evasive tactics to be successful. Speeds 30 to 40% greater than those of the target aircraft are best. The range of this unit is 15 miles when the trajectory is arranged to achieve the maximum. It can be fired safely at any angle down to 30° above horizontal. Launching is accomplished from modified 88 mm gun mounts with 23 feet guide rails attached.

37. An accoustic controlled guided missile research development program together with operating personnel has been located at BAD KISSENGER. This experimental control system contains four electrical circuits which are actuated by sound, with the intended purpose of launching a rocket-propelled missile into the space occupied by a heavy bombardment formation, and the missile constantly correcting its course by means of incoming sound waves from the Aircraft engines. With control of vertical and horizontal flight, a course of collision with a bombardment aircraft was sought. The group of scientists working upon this development are being retained in custody at the laboratory to develop the program.

38. Controlled Missiles A-4 Rockets (V-2). Seven complete A-4 rockets have been shipped to the United States for study and possible development.

AIRCRAFT ARMAMENT

39. PROXIMITY SHELL FUSES. Proximity fuse development for artillery shells has been located. The ALSOS Mission has ascertained that the fuse operates upon electro-static principles and will be a very difficult fuse against which to employ counter-measures. But one experimental manufacturing establishment has been located at BRESLAU, and a field team is searching for some materiel that had been evacuated to the American area in Austria. Interrogation of German scientists disclosed that research has not made the fuse effective for a distance greater than 1000 yards, and that under ideal conditions, 90% efficiency could be obtained. Adverse conditions, such as rain or the presence of high electro-static energy in the atmosphere, would render the fuses inoperative more than 50% of the time.

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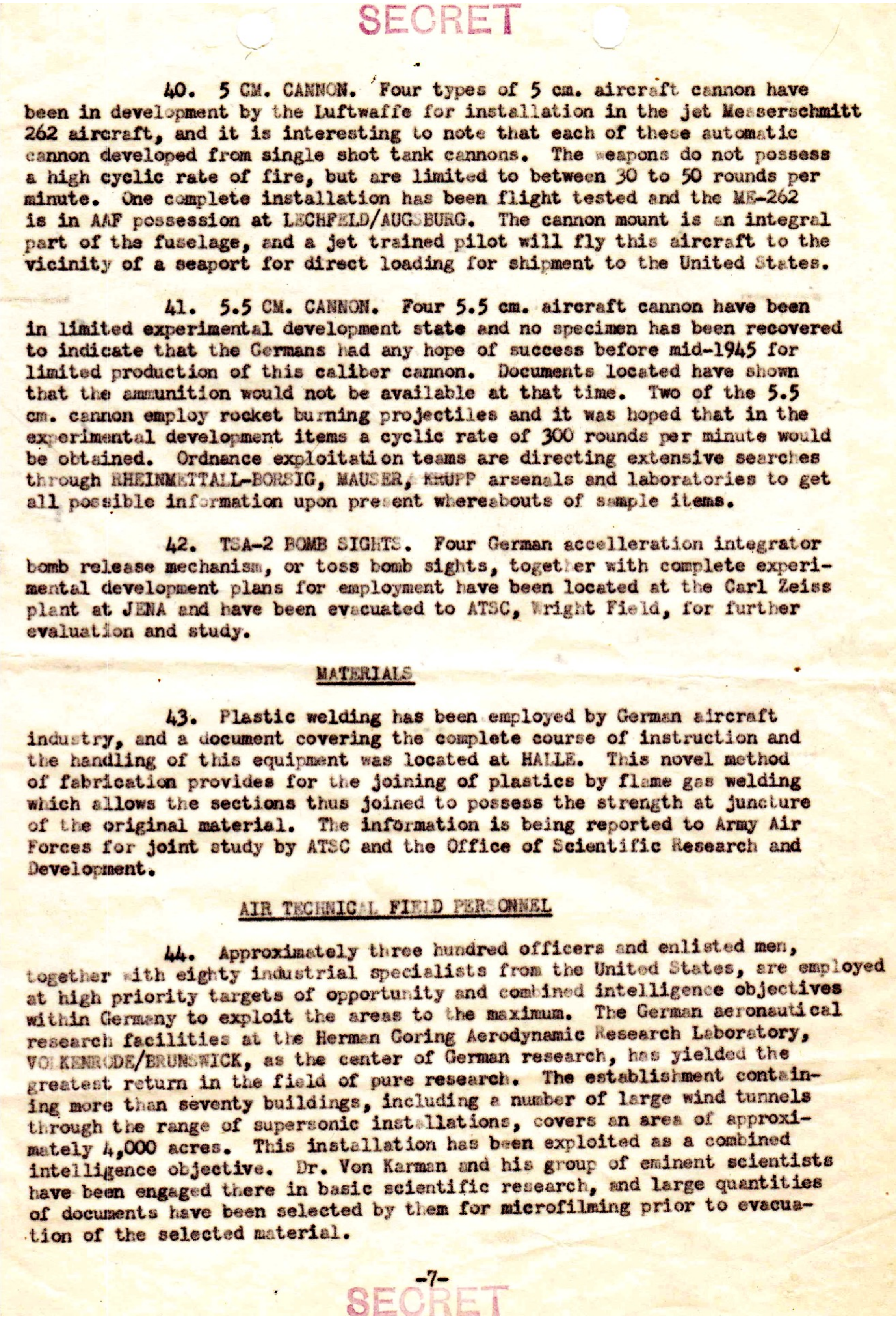
Figure D.947: 30 May 1945 memorandum from Colonel Loyd K. Pepple to Colonel Sheldon, proving that Hans Kammler was alive and being interrogated by the United States as of 30 May 1945 [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data



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40. 5 CM. CANNON. Four types of 5 cm. aircraft cannon have been in development by the Luftwaffe for installation in the jet Messerschmitt 262 aircraft, and it is interesting to note that each of these automatic cannon developed from single shot tank cannons. The weapons do not possess a high cyclic rate of fire, but are limited to between 30 to 50 rounds per minute. One complete installation has been flight tested and the ME-262 is in AAF possession at LECHFELD/AUGSBURG. The cannon mount is an integral part of the fuselage, and a jet trained pilot will fly this aircraft to the vicinity of a seaport for direct loading for shipment to the United States.

41. 5.5 CM. CANNON. Four 5.5 cm. aircraft cannon have been in limited experimental development state and no specimen has been recovered to indicate that the Germans had any hope of success before mid-1945 for limited production of this caliber cannon. Documents located have shown that the ammunition would not be available at that time. Two of the 5.5 cm. cannon employ rocket burning projectiles and it was hoped that in the experimental development items a cyclic rate of 300 rounds per minute would be obtained. Ordnance exploitation teams are directing extensive searches through RHEINMETTALL-BORSIG, MAUSER, KRUPF arsenals and laboratories to get all possible information upon present whereabouts of sample items.

42. TSA-2 BOMB SIGHTS. Four German accelleration integrator bomb release mechanism, or toss bomb sights, together with complete experimental development plans for employment have been located at the Carl Zeiss plant at JENA and have been evacuated to ATSC, Wright Field, for further evaluation and study.

MATERIALS

43. Plastic welding has been employed by German aircraft industry, and a document covering the complete course of instruction and the handling of this equipment was located at HALLE. This novel method of fabrication provides for the joining of plastics by flame gas welding which allows the sections thus joined to possess the strength at juncture of the original material. The information is being reported to Army Air Forces for joint study by ATSC and the Office of Scientific Research and Development.

AIR TECHNICAL FIELD PERSONNEL

44. Approximately three hundred officers and enlisted men, together with eighty industrial specialists from the United States, are employed at high priority targets of opportunity and combined intelligence objectives within Germany to exploit the areas to the maximum. The German aeronautical research facilities at the Herman Goring Aerodynamic Research Laboratory, VOLKENRODE/BRUNSWICK, as the center of German research, has yielded the greatest return in the field of pure research. The establishment containing more than seventy buildings, including a number of large wind tunnels through the range of supersonic installations, covers an area of approximately 4,000 acres. This installation has been exploited as a combined intelligence objective. Dr. Von Karman and his group of eminent scientists have been engaged there in basic scientific research, and large quantities of documents have been selected by them for microfilming prior to evacuation of the selected material.

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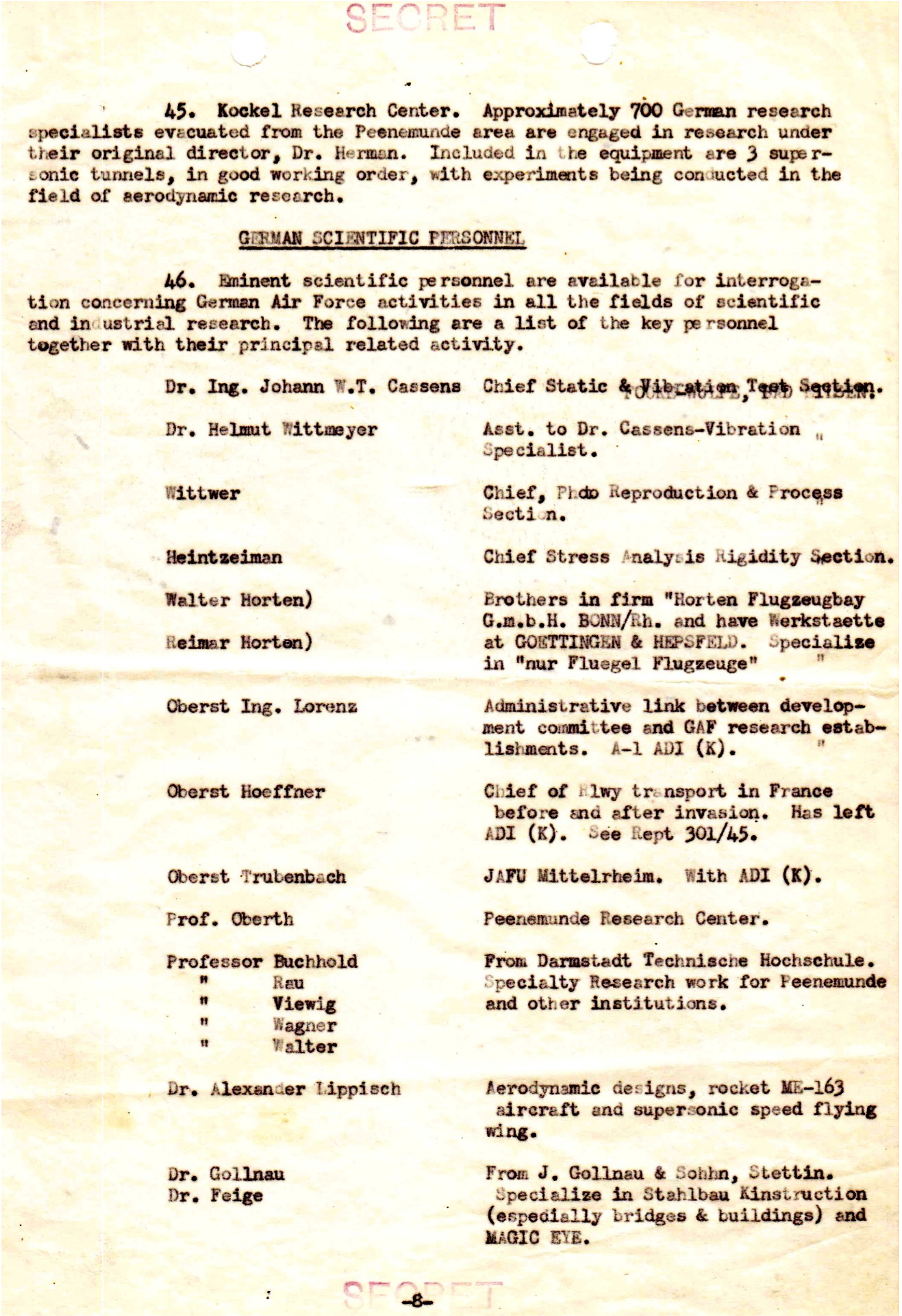
Figure D.948: 30 May 1945 memorandum from Colonel Loyd K. Pepple to Colonel Sheldon, proving that Hans Kammler was alive and being interrogated by the United States as of 30 May 1945 [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data



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45. Kockel Research Center. Approximately 700 German research specialists evacuated from the Peenemunde area are engaged in research under their original director, Dr. Herman. Included in the equipment are 3 supersonic tunnels, in good working order, with experiments being conducted in the field of aerodynamic research.

GERMAN SCIENTIFIC PERSONNEL

46. Eminent scientific personnel are available for interrogation concerning German Air Force activities in all the fields of scientific and industrial research. The following are a list of the key personnel together with their principal related activity.

Dr. Ing. Johann W.T. Cassens	Chief Static & Vibration Test Section.
Dr. Helmut Wittmeyer	Asst. to Dr. Cassens-Vibration Specialist.
Wittwer	Chief, Photo Reproduction & Process Section.
Heintzeiman	Chief Stress Analysis Rigidity Section.
Walter Horten) Reimar Horten)	Brothers in firm "Horten Flugzeugbay G.m.b.H. BONN/Rh. and have Werkstaette at GOETTINGEN & HEPSFELD. Specialize in "nur Fluegel Flugzeuge"
Oberst Ing. Lorenz	Administrative link between development committee and GAF research establishments. A-1 ADI (K).
Oberst Hoeffner	Chief of Rlwy transport in France before and after invasion. Has left ADI (K). See Rept 301/45.
Oberst Trubenbach	JAFU Mittelrheim. With ADI (K).
Prof. Oberth	Peenemunde Research Center.
Professor Buchhold " Rau " Viewig " Wagner " Walter	From Darmstadt Technische Hochschule. Specialty Research work for Peenemunde and other institutions.
Dr. Alexander Lippisch	Aerodynamic designs, rocket ME-163 aircraft and supersonic speed flying wing.
Dr. Gollnau Dr. Feige	From J. Gollnau & Sohhn, Stettin. Specialize in Stahlbau Kinstruction (especially bridges & buildings) and MAGIC EYE.

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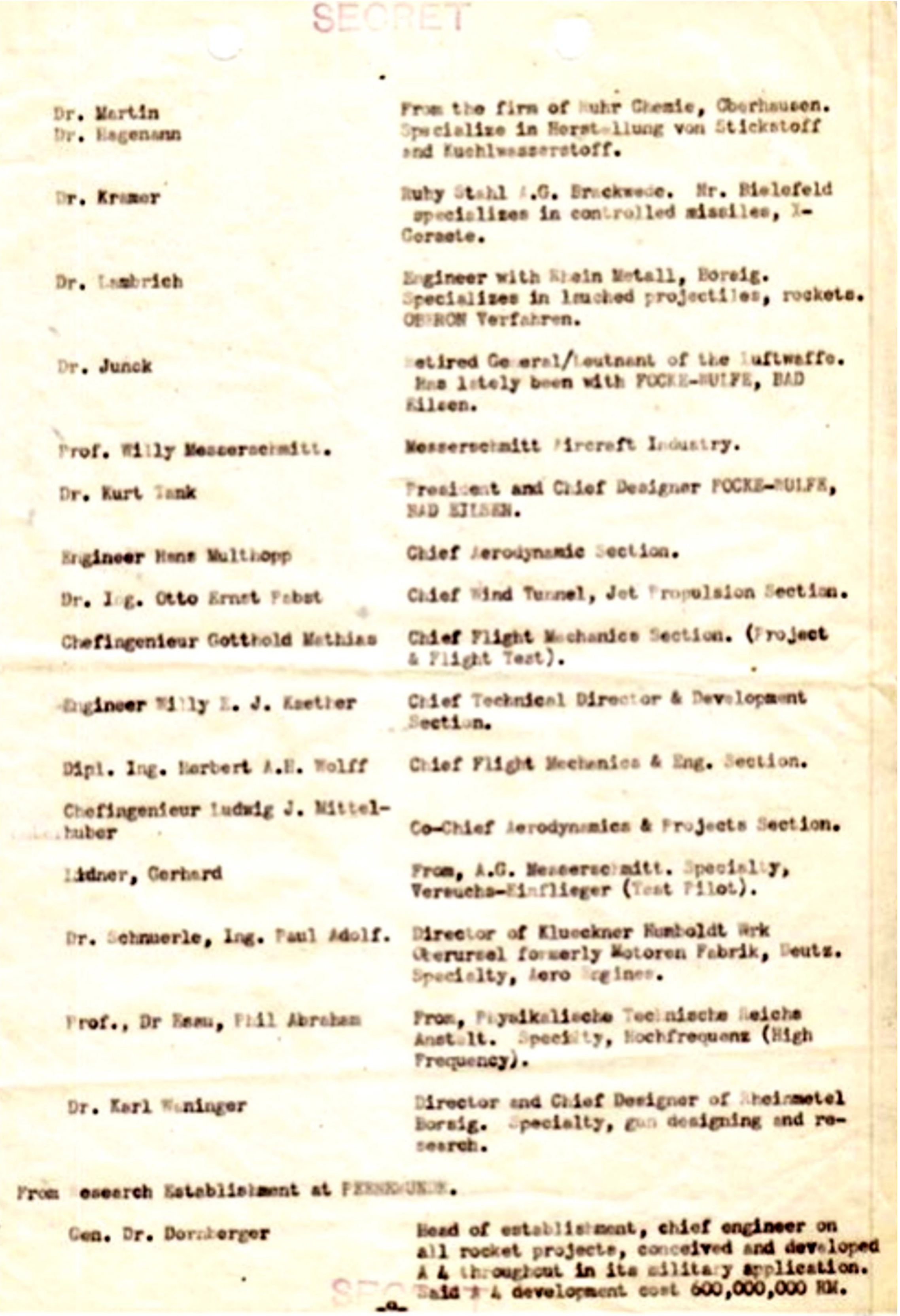
Figure D.949: 30 May 1945 memorandum from Colonel Loyd K. Pepple to Colonel Sheldon, proving that Hans Kammler was alive and being interrogated by the United States as of 30 May 1945 [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data



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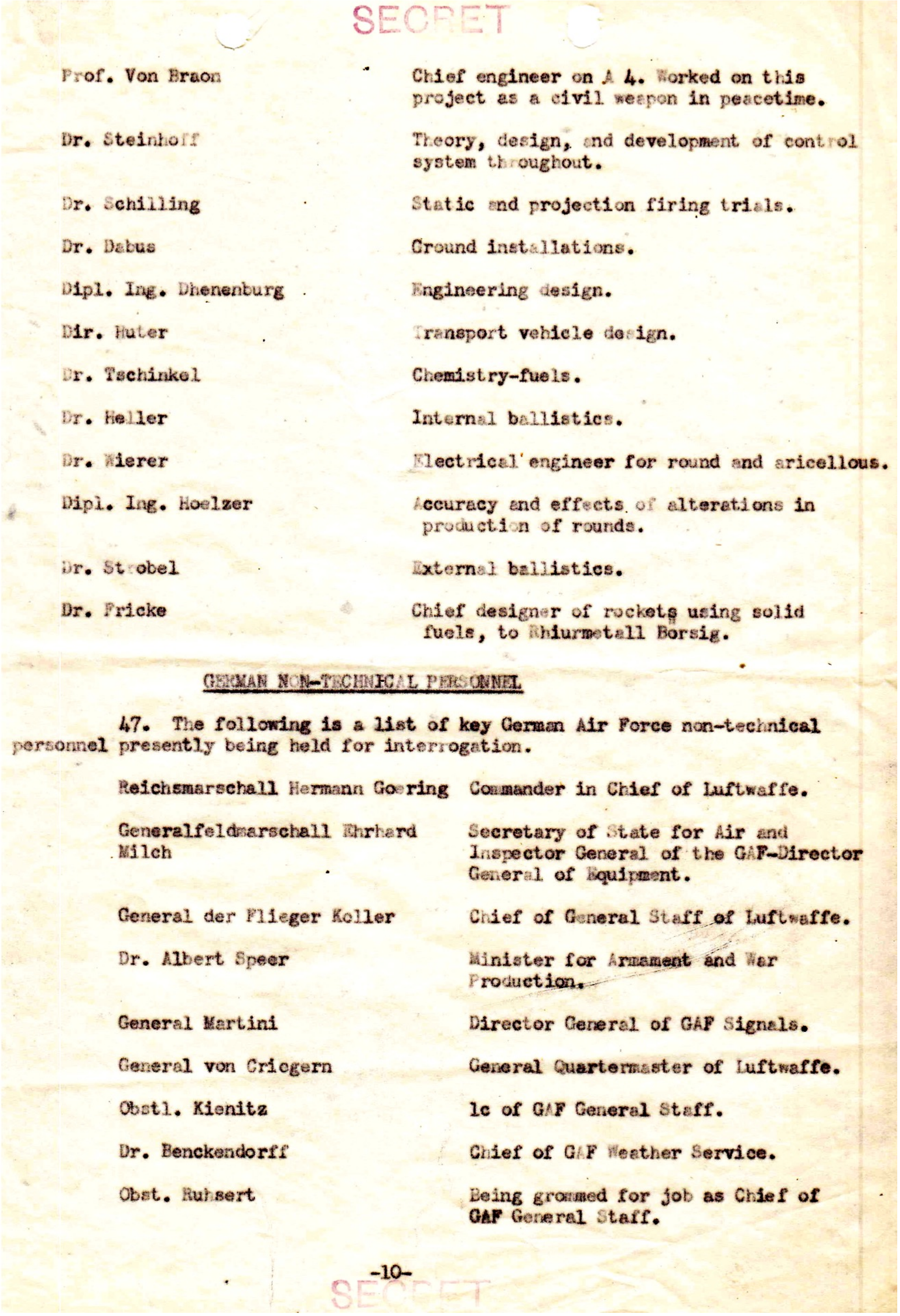
Dr. Martin Dr. Hagenann	From the firm of Ruhr Chemie, Oberhausen. Specialize in Herstellung von Stickstoff and Kuchlwasserstoff.
Dr. Kramer	Ruhr Stahl A.G. Brackwede. Nr. Bielefeld specializes in controlled missiles, X-Geraete.
Dr. Lambrich	Engineer with Rhein Metall, Borsig. Specializes in lauched projectiles, rockets. OBERON Verfahren.
Dr. Junck	Retired General/Leutnant of the Luftwaffe. Has lately been with FOCKE-WULFE, BAD Eilsen.
Prof. Willy Messerschmitt.	Messerschmitt Aircraft Industry.
Dr. Kurt Tank	President and Chief Designer FOCKE-WULFE, BAD EILSEN.
Engineer Hans Multhopp	Chief Aerodynamic Section.
Dr. Ing. Otto Ernst Pabst	Chief Wind Tunnel, Jet Propulsion Section.
Chefingenieur Gotthold Mathias	Chief Flight Mechanics Section. (Project & Flight Test).
Engineer Willy E. J. Kaether	Chief Technical Director & Development Section.
Dipl. Ing. Herbert A.H. Wolff	Chief Flight Mechanics & Eng. Section.
Chefingenieur Ludwig J. Mittelhuber	Co-Chief Aerodynamics & Projects Section.
Lidner, Gerhard	From, A.G. Messerschmitt. Specialty, Versuchs-Einflieger (Test Pilot).
Dr. Schmuerle, Ing. Paul Adolf.	Director of Klueckner Humboldt Werk Oberursel formerly Motoren Fabrik, Deutz. Specialty, Aero Engines.
Prof., Dr Esau, Phil Abraham	From, Physikalische Technische Reichs Anstalt. Specialty, Hochfrequenz (High Frequency).
Dr. Karl Waninger	Director and Chief Designer of Rheinmetal Borsig. Specialty, gun designing and research.

From Research Establishment at PEENEMUNDE.

Gen. Dr. Dornberger	Head of establishment, chief engineer on all rocket projects, conceived and developed A 4 throughout in its military application. Said A 4 development cost 600,000,000 RM.

SEC

Figure D.950: 30 May 1945 memorandum from Colonel Loyd K. Pepple to Colonel Sheldon, proving that Hans Kammler was alive and being interrogated by the United States as of 30 May 1945 [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].



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Prof. Von Braon	Chief engineer on A 4. Worked on this project as a civil weapon in peacetime.
Dr. Steinhoff	Theory, design, and development of control system throughout.
Dr. Schilling	Static and projection firing trials.
Dr. Dabus	Ground installations.
Dipl. Ing. Dhenenburg	Engineering design.
Dir. Huter	Transport vehicle design.
Dr. Tschinkel	Chemistry-fuels.
Dr. Heller	Internal ballistics.
Dr. Wierer	Electrical engineer for round and aricellous.
Dipl. Ing. Hoelzer	Accuracy and effects of alterations in production of rounds.
Dr. Strobel	External ballistics.
Dr. Fricke	Chief designer of rockets using solid fuels, to Rhiurmetall Borsig.

GERMAN NON-TECHNICAL PERSONNEL

47. The following is a list of key German Air Force non-technical personnel presently being held for interrogation.

Reichsmarschall Hermann Goering	Commander in Chief of Luftwaffe.
Generalfeldmarschall Ehrhard Milch	Secretary of State for Air and Inspector General of the GAF-Director General of Equipment.
General der Flieger Koller	Chief of General Staff of Luftwaffe.
Dr. Albert Speer	Minister for Armament and War Production.
General Martini	Director General of GAF Signals.
General von Criegern	General Quartermaster of Luftwaffe.
Obstl. Kienitz	lc of GAF General Staff.
Dr. Benckendorff	Chief of GAF Weather Service.
Obst. Ruhsert	Being grommed for job as Chief of GAF General Staff.

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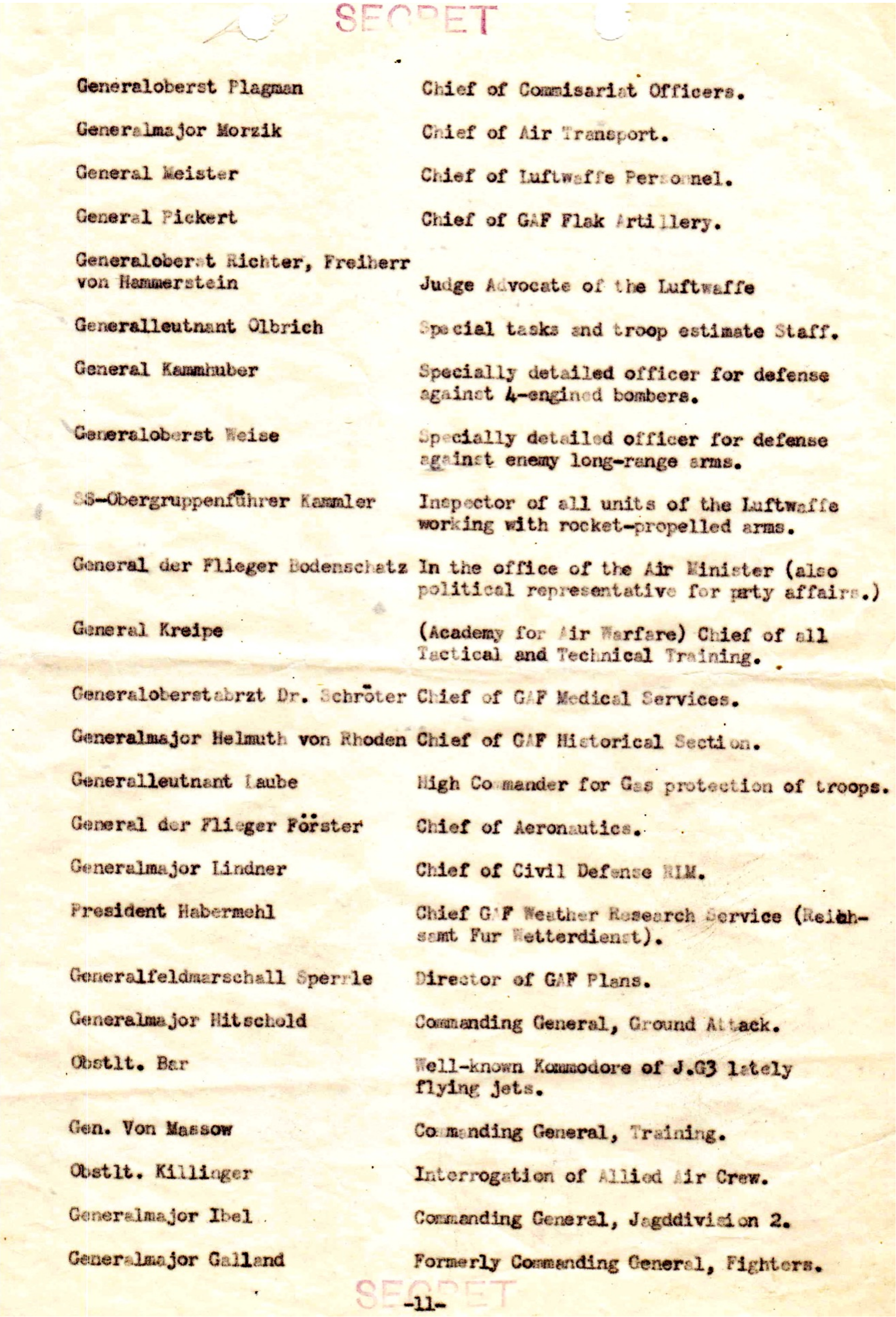
AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data

Figure D.951: 30 May 1945 memorandum from Colonel Loyd K. Pepple to Colonel Sheldon, proving that Hans Kammler was alive and being interrogated by the United States as of 30 May 1945 [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data



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Generaloberst Plagman	Chief of Commisariat Officers.
Generalmajor Morzik	Chief of Air Transport.
General Meister	Chief of Luftwaffe Personnel.
General Pickert	Chief of GAF Flak Artillery.
Generaloberst Richter, Freiherr von Hammerstein	Judge Advocate of the Luftwaffe
Generalleutnant Olbrich	Special tasks and troop estimate Staff.
General Kammhuber	Specially detailed officer for defense against 4-engined bombers.
Generaloberst Weise	Specially detailed officer for defense against enemy long-range arms.
SS-Obergruppenführer Kammler	Inspector of all units of the Luftwaffe working with rocket-propelled arms.
General der Flieger Bodenschatz	In the office of the Air Minister (also political representative for party affairs.)
General Kreipe	(Academy for Air Warfare) Chief of all Tactical and Technical Training.
Generaloberstabrzt Dr. Schröter	Chief of GAF Medical Services.
Generalmajor Helmuth von Rhoden	Chief of GAF Historical Section.
Generalleutnant Laube	High Commander for Gas protection of troops.
General der Flieger Förster	Chief of Aeronautics.
Generalmajor Lindner	Chief of Civil Defense RLM.
President Habermehl	Chief GAF Weather Research Service (Reichsamt Fur Wetterdienst).
Generalfeldmarschall Sperrle	Director of GAF Plans.
Generalmajor Hitschold	Commanding General, Ground Attack.
Obstlt. Bar	Well-known Kommodore of J.G3 lately flying jets.
Gen. Von Massow	Commanding General, Training.
Obstlt. Killinger	Interrogation of Allied Air Crew.
Generalmajor Ibel	Commanding General, Jagddivision 2.
Generalmajor Galland	Formerly Commanding General, Fighters.

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Figure D.952: 30 May 1945 memorandum from Colonel Loyd K. Pepple to Colonel Sheldon, proving that Hans Kammler was alive and being interrogated by the United States as of 30 May 1945 [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

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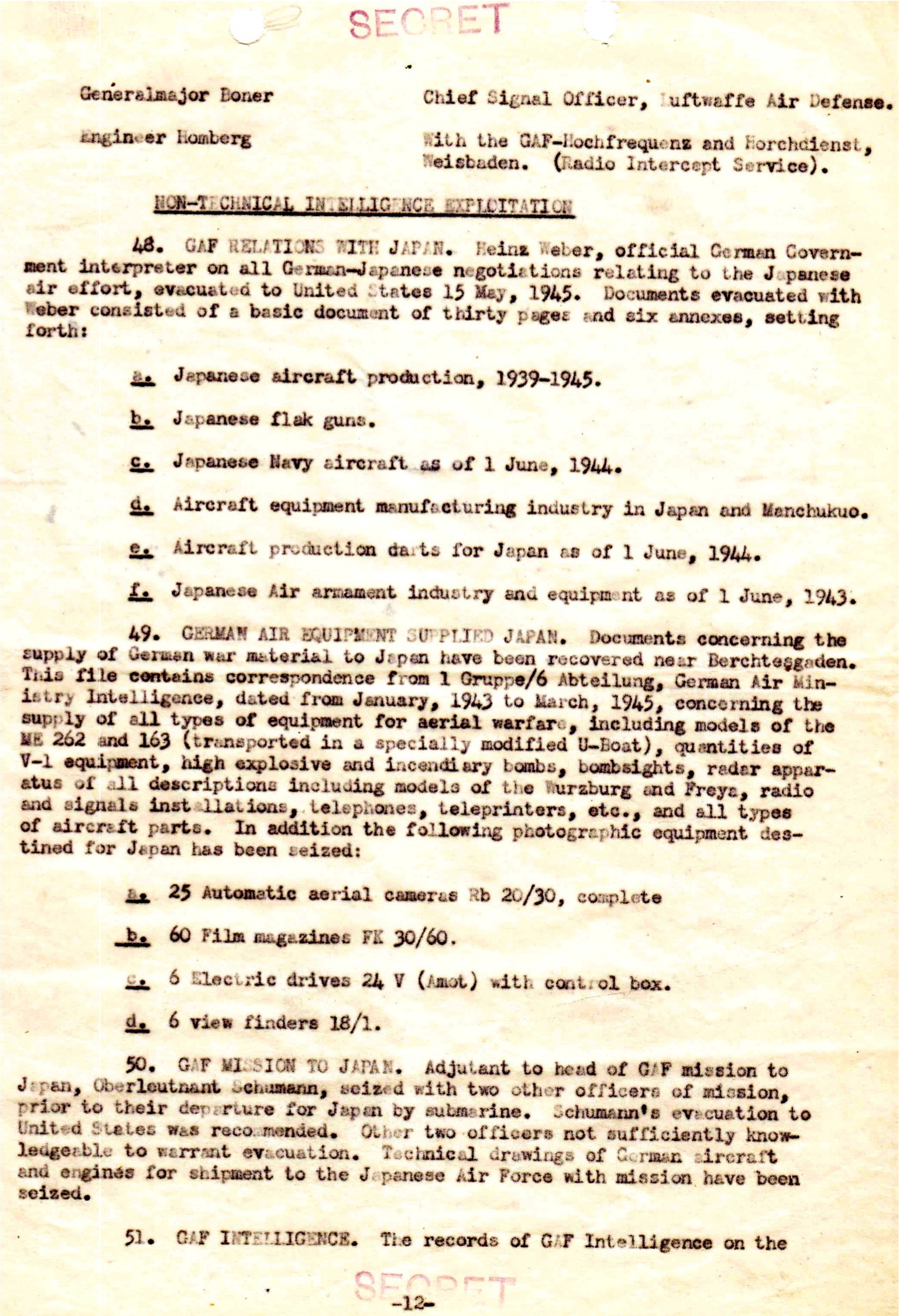

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Generalmajor Boner	Chief Signal Officer, Luftwaffe Air Defense.
Engineer Homberg	With the GAF-Hochfrequenz and Horchdienst, Weisbaden. (Radio Intercept Service).

NON-TECHNICAL INTELLIGENCE EXPLOITATION

48. GAF RELATIONS WITH JAPAN. Heinz Weber, official German Government interpreter on all German-Japanese negotiations relating to the Japanese air effort, evacuated to United States 15 May, 1945. Documents evacuated with Weber consisted of a basic document of thirty pages and six annexes, setting forth:

a. Japanese aircraft production, 1939-1945.

b. Japanese flak guns.

c. Japanese Navy aircraft as of 1 June, 1944.

d. Aircraft equipment manufacturing industry in Japan and Manchukuo.

e. Aircraft production darts for Japan as of 1 June, 1944.

f. Japanese Air armament industry and equipment as of 1 June, 1943.

49. GERMAN AIR EQUIPMENT SUPPLIED JAPAN. Documents concerning the supply of German war material to Japan have been recovered near Berchtesgaden. This file contains correspondence from 1 Gruppe/6 Abteilung, German Air Ministry Intelligence, dated from January, 1943 to March, 1945, concerning the supply of all types of equipment for aerial warfare, including models of the ME 262 and 163 (transported in a specially modified U-Boat), quantities of V-1 equipment, high explosive and incendiary bombs, bombsights, radar apparatus of all descriptions including models of the Wurzburg and Freya, radio and signals installations, telephones, teleprinters, etc., and all types of aircraft parts. In addition the following photographic equipment destined for Japan has been seized:

a. 25 Automatic aerial cameras Rb 20/30, complete

b. 60 Film magazines FK 30/60.

c. 6 Electric drives 24 V (Amot) with control box.

d. 6 view finders 18/1.

50. GAF MISSION TO JAPAN. Adjutant to head of GAF mission to Japan, Oberleutnant Schumann, seized with two other officers of mission, prior to their departure for Japan by submarine. Schumann's evacuation to United States was recommended. Other two officers not sufficiently knowledgeable to warrant evacuation. Technical drawings of German aircraft and engines for shipment to the Japanese Air Force with mission have been seized.

51. GAF INTELLIGENCE. The records of GAF Intelligence on the

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Figure D.953: 30 May 1945 memorandum from Colonel Loyd K. Pepple to Colonel Sheldon, proving that Hans Kammler was alive and being interrogated by the United States as of 30 May 1945 [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

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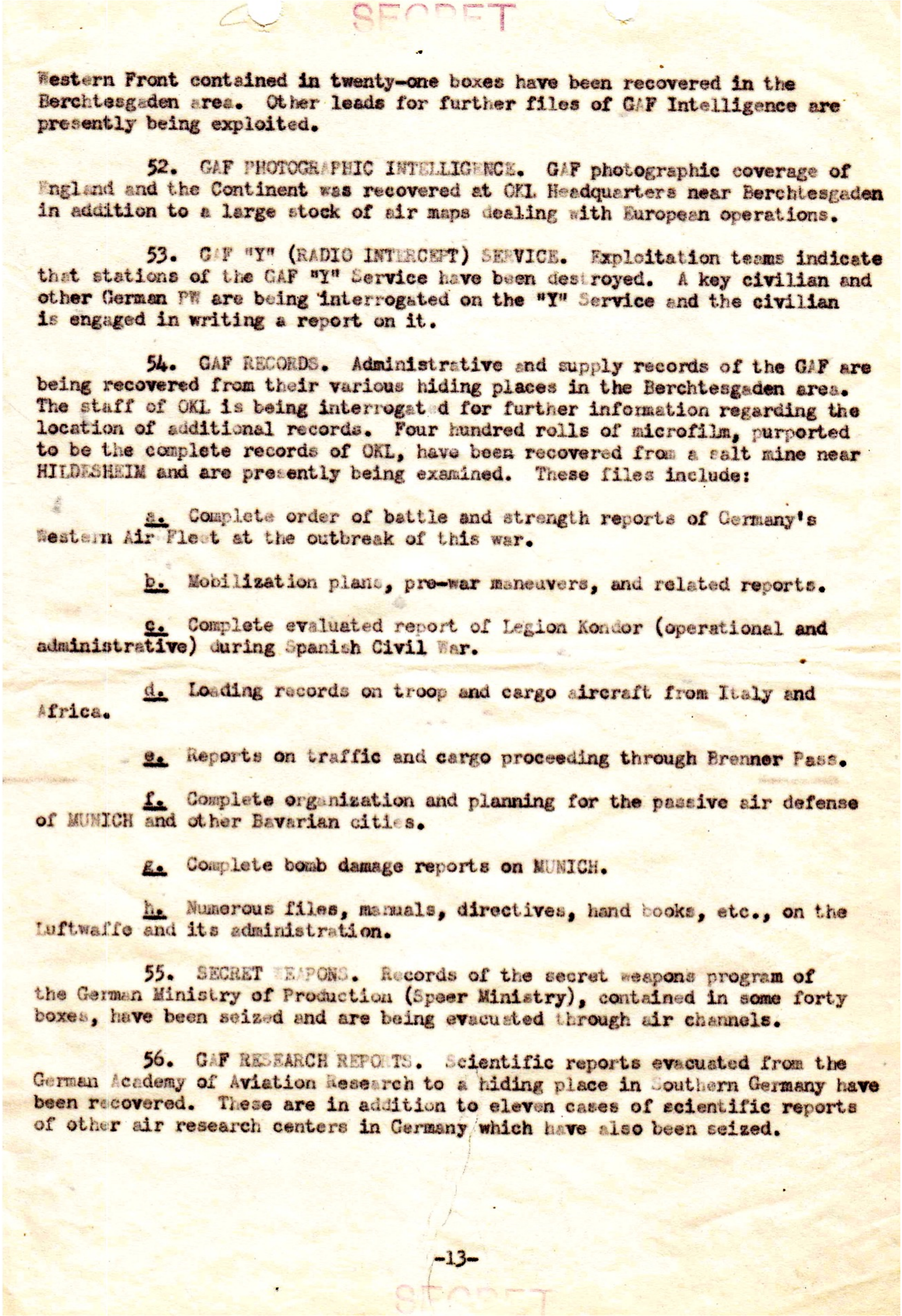

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Western Front contained in twenty-one boxes have been recovered in the Berchtesgaden area. Other leads for further files of GAF Intelligence are presently being exploited.

52. GAF PHOTOGRAPHIC INTELLIGENCE. GAF photographic coverage of England and the Continent was recovered at OKL Headquarters near Berchtesgaden in addition to a large stock of air maps dealing with European operations.

53. GAF "Y" (RADIO INTERCEPT) SERVICE. Exploitation teams indicate that stations of the GAF "Y" Service have been destroyed. A key civilian and other German PW are being interrogated on the "Y" Service and the civilian is engaged in writing a report on it.

54. GAF RECORDS. Administrative and supply records of the GAF are being recovered from their various hiding places in the Berchtesgaden area. The staff of OKL is being interrogated for further information regarding the location of additional records. Four hundred rolls of microfilm, purported to be the complete records of OKL, have been recovered from a salt mine near HILDESHEIM and are presently being examined. These files include:

a. Complete order of battle and strength reports of Germany's Western Air Fleet at the outbreak of this war.

b. Mobilization plans, pre-war maneuvers, and related reports.

c. Complete evaluated report of Legion Kondor (operational and administrative) during Spanish Civil War.

d. Loading records on troop and cargo aircraft from Italy and Africa.

e. Reports on traffic and cargo proceeding through Brenner Pass.

f. Complete organization and planning for the passive air defense of MUNICH and other Bavarian cities.

g. Complete bomb damage reports on MUNICH.

h. Numerous files, manuals, directives, hand books, etc., on the Luftwaffe and its administration.

55. SECRET WEAPONS. Records of the secret weapons program of the German Ministry of Production (Speer Ministry), contained in some forty boxes, have been seized and are being evacuated through air channels.

56. GAF RESEARCH REPORTS. Scientific reports evacuated from the German Academy of Aviation Research to a hiding place in Southern Germany have been recovered. These are in addition to eleven cases of scientific reports of other air research centers in Germany which have also been seized.

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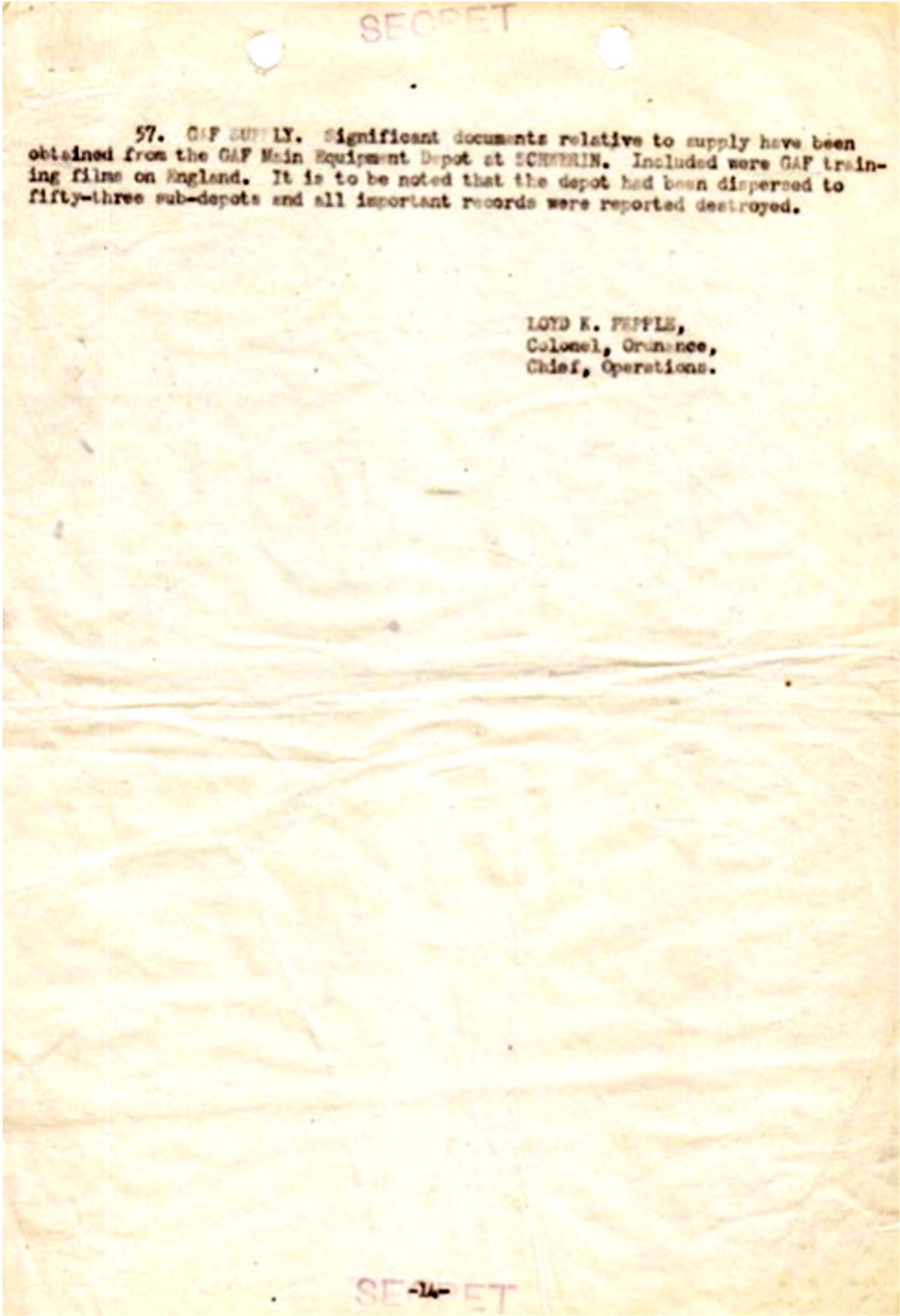
Figure D.954: 30 May 1945 memorandum from Colonel Loyd K. Pepple to Colonel Sheldon, proving that Hans Kammler was alive and being interrogated by the United States as of 30 May 1945 [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data



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57. GAF SUPPLY. Significant documents relative to supply have been obtained from the GAF Main Equipment Depot at SCHWERIN. Included were GAF training films on England. It is to be noted that the depot had been dispersed to fifty-three sub-depots and all important records were reported destroyed.

LOYD K. PEPPLE,
Colonel, Ordnance,
Chief, Operations.

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SECRET

Figure D.955: 30 May 1945 memorandum from Colonel Loyd K. Pepple to Colonel Sheldon, proving that Hans Kammler was alive and being interrogated by the United States as of 30 May 1945 [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

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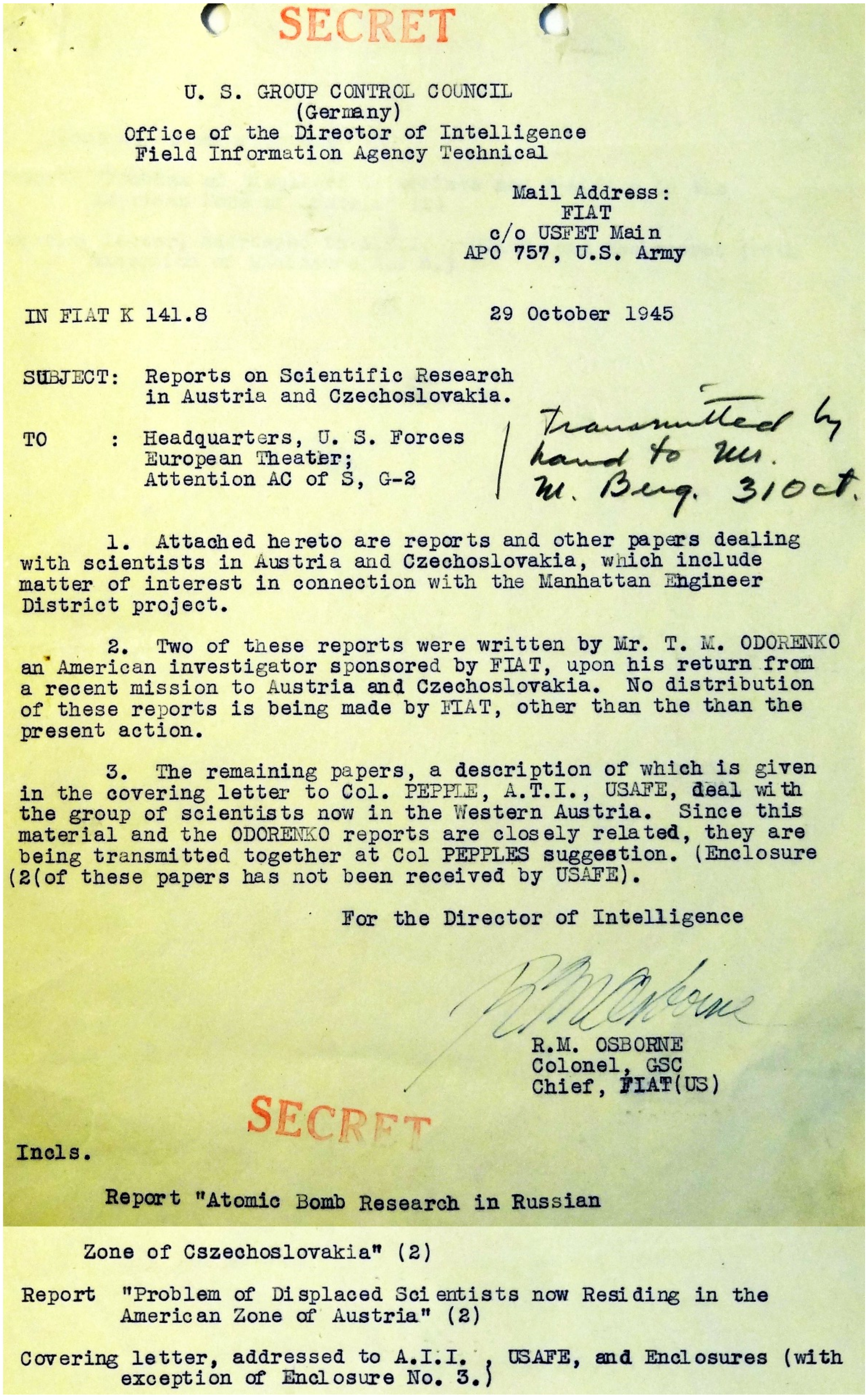

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U. S. GROUP CONTROL COUNCIL
(Germany)
Office of the Director of Intelligence
Field Information Agency Technical

Mail Address:
FIAT
c/o USFET Main
APO 757, U.S. Army

IN FIAT K 141.8

29 October 1945

SUBJECT: Reports on Scientific Research in Austria and Czechoslovakia.

TO : Headquarters, U. S. Forces European Theater; Attention AC of S, G-2

Transmitted by hand to Mr. M. Berg. 31 Oct.

1. Attached hereto are reports and other papers dealing with scientists in Austria and Czechoslovakia, which include matter of interest in connection with the Manhattan Engineer District project.

2. Two of these reports were written by Mr. T. M. ODORENKO an American investigator sponsored by FIAT, upon his return from a recent mission to Austria and Czechoslovakia. No distribution of these reports is being made by FIAT, other than the than the present action.

3. The remaining papers, a description of which is given in the covering letter to Col. PEPPLE, A.T.I., USAFE, deal with the group of scientists now in the Western Austria. Since this material and the ODORENKO reports are closely related, they are being transmitted together at Col PEPPLES suggestion. (Enclosure (2(of these papers has not been received by USAFE).

For the Director of Intelligence

R.M. Osborne

R.M. OSBORNE
Colonel, GSC
Chief, FIAT(US)

SECRET

Incls.

Report "Atomic Bomb Research in Russian Zone of Cszechoslovakia" (2)

Report "Problem of Displaced Scientists now Residing in the American Zone of Austria" (2)

Covering letter, addressed to A.I.I. , USAFE, and Enclosures (with exception of Enclosure No. 3.)

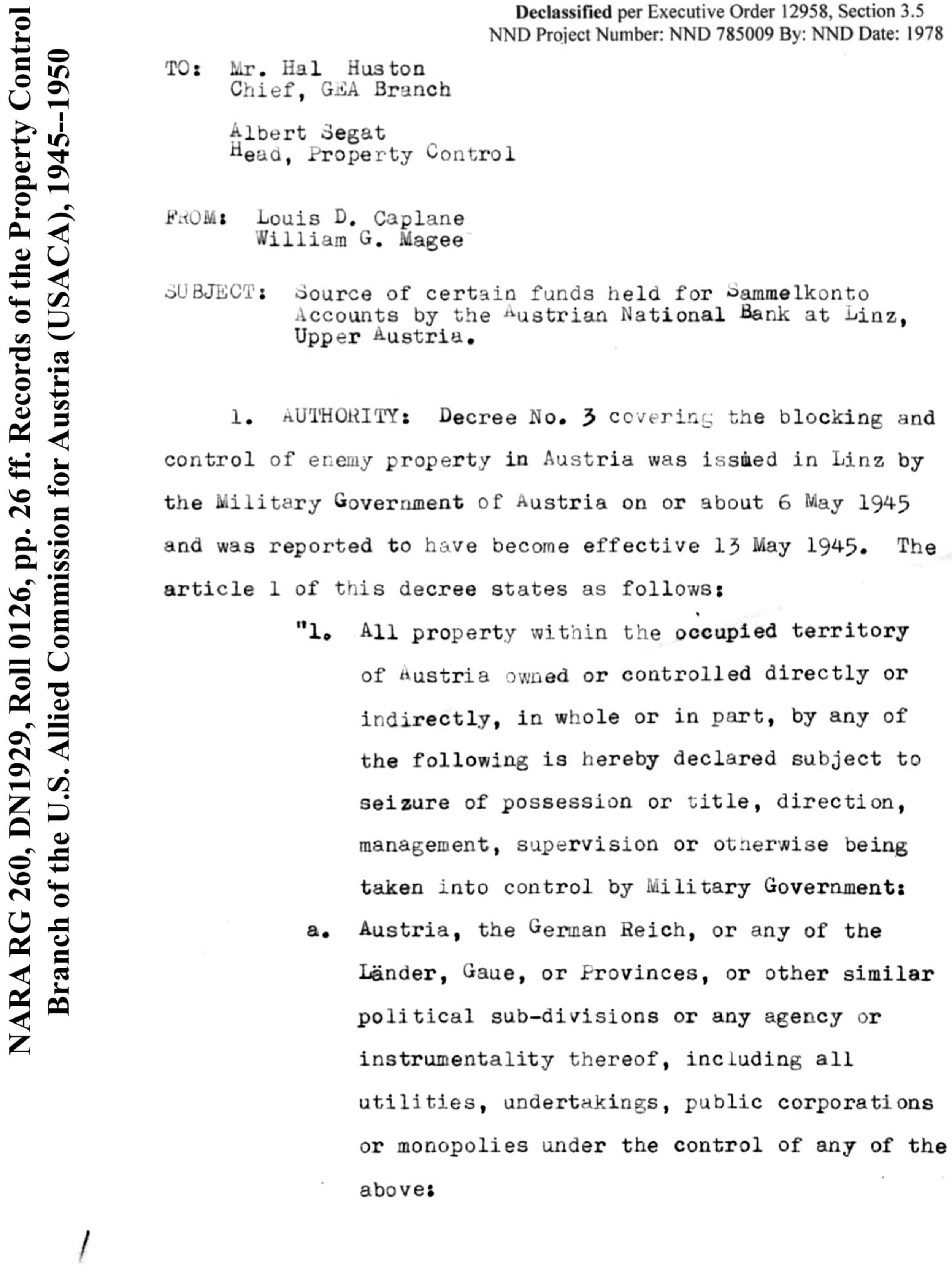
NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel

Figure D.956: R. M. Osborne. 29 October 1945. Subject: Reports on Scientific Research in Austria and Czechoslovakia. This memo demonstrates the intersection of Loyd K. Pepple, Todos M. Odarenko, Moe Berg, and others involved in deep investigations of the German nuclear program after the war [NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel].

Louis D. Caplane and William G. Magee. Undated but apparently ca. August 1949. Source of certain funds held for Sammelkonto Accounts by the Austrian National Bank at Linz, Upper Austria. Records of the Property Control Branch of the U.S. Allied Commission for Austria (USACA), 1945–1950. [NARA RG 260, DN1929, Roll 0126, pp. 26 ff.]

[...] Shortly after the occupation, Hans Kammler appeared before the CIC in Gmünden and made a detailed statement on the operations and activities on the Baustelle Ebensee, as well as on the account, and his own authority and authority of Karl Engelhardt. None of the present American officers at the CIC, Gmünden, is familiar with his statement but it should be in the files there. Mr. Morrison of the CIC, Gmünden was requested by the team to send a copy of this statement to Mr. Loehr. [...]

[See document photos on pp. 4956–4957.]



NARA RG 260, DN1929, Roll 0126, pp. 26 ff. Records of the Property Control Branch of the U.S. Allied Commission for Austria (USACA), 1945--1950

Declassified per Executive Order 12958, Section 3.5
NND Project Number: NND 785009 By: NND Date: 1978

TO: Mr. Hal Huston
Chief, GEA Branch

Albert Segat
Head, Property Control

FROM: Louis D. Caplane
William G. Magee

SUBJECT: Source of certain funds held for Sammelkonto Accounts by the Austrian National Bank at Linz, Upper Austria.

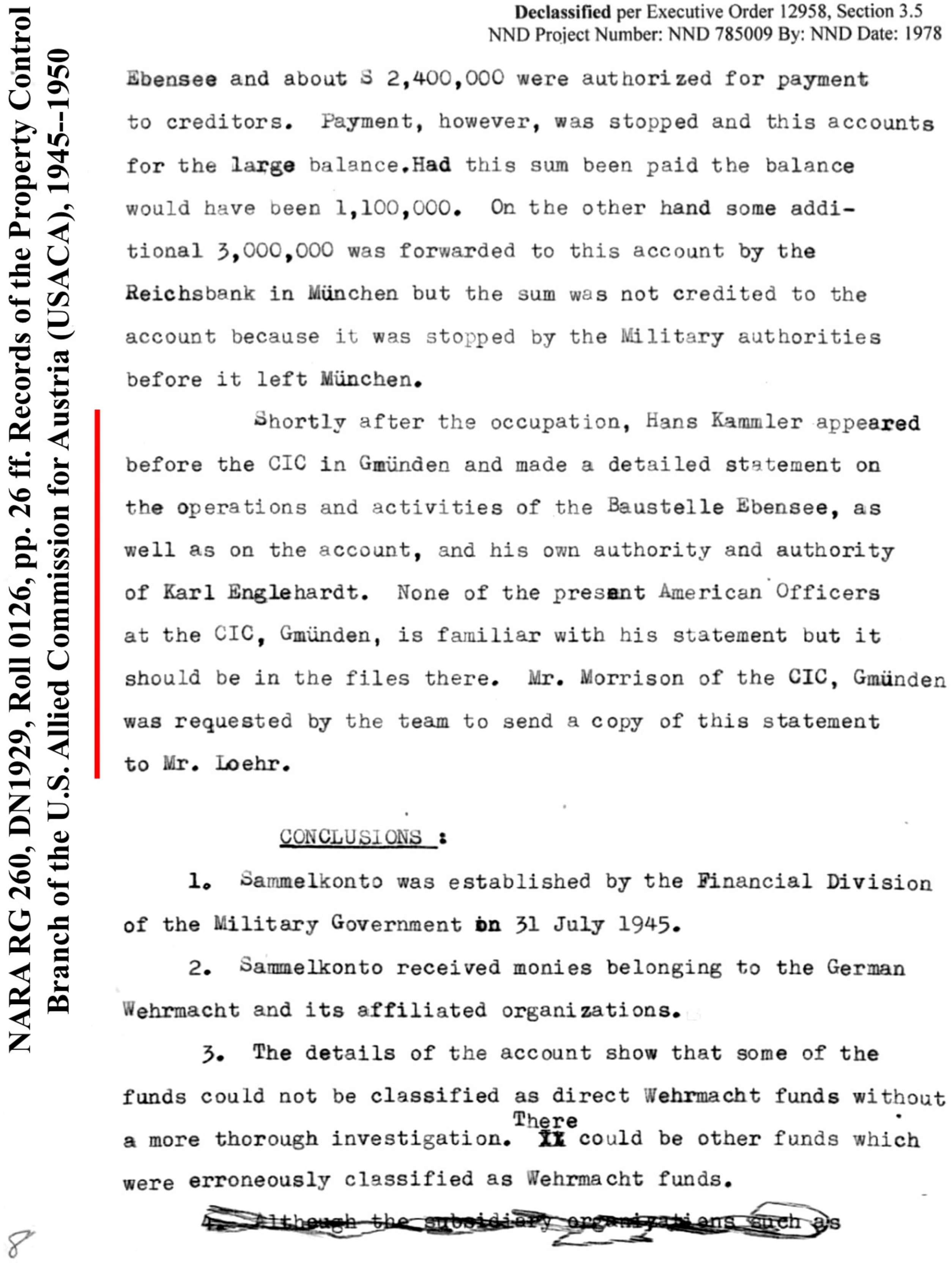
1. AUTHORITY: Decree No. 3 covering the blocking and control of enemy property in Austria was issued in Linz by the Military Government of Austria on or about 6 May 1945 and was reported to have become effective 13 May 1945. The article 1 of this decree states as follows:

"1. All property within the occupied territory of Austria owned or controlled directly or indirectly, in whole or in part, by any of the following is hereby declared subject to seizure of possession or title, direction, management, supervision or otherwise being taken into control by Military Government:

a. Austria, the German Reich, or any of the Länder, Gaue, or Provinces, or other similar political sub-divisions or any agency or instrumentality thereof, including all utilities, undertakings, public corporations or monopolies under the control of any of the above:

/

Figure D.957: 1949 memorandum from Louis D. Caplane and William G. Magee, proving that Hans Kammler was alive and being interrogated by the United States as of mid-1945 [NARA RG 260, DN1929, Roll 0126, pp. 26 ff].



NARA RG 260, DN1929, Roll 0126, pp. 26 ff. Records of the Property Control Branch of the U.S. Allied Commission for Austria (USACA), 1945--1950

Declassified per Executive Order 12958, Section 3.5
NND Project Number: NND 785009 By: NND Date: 1978

Ebensee and about S 2,400,000 were authorized for payment to creditors. Payment, however, was stopped and this accounts for the large balance. Had this sum been paid the balance would have been 1,100,000. On the other hand some additional 3,000,000 was forwarded to this account by the Reichsbank in München but the sum was not credited to the account because it was stopped by the Military authorities before it left München.

Shortly after the occupation, Hans Kammler appeared before the CIC in Gmünden and made a detailed statement on the operations and activities of the Baustelle Ebensee, as well as on the account, and his own authority and authority of Karl Englehardt. None of the presant American Officers at the CIC, Gmünden, is familiar with his statement but it should be in the files there. Mr. Morrison of the CIC, Gmünden was requested by the team to send a copy of this statement to Mr. Loehr.

CONCLUSIONS :

1. Sammelkonto was established by the Financial Division of the Military Government on 31 July 1945.

2. Sammelkonto received monies belonging to the German Wehrmacht and its affiliated organizations.

3. The details of the account show that some of the funds could not be classified as direct Wehrmacht funds without a more thorough investigation. ~~XX~~ There could be other funds which were erroneously classified as Wehrmacht funds.

~~4. Although the subsidiary organizations such as~~

8

Figure D.958: 1949 memorandum from Louis D. Caplane and William G. Magee, proving that Hans Kammler was alive and being interrogated by the United States as of mid-1945 [NARA RG 260, DN1929, Roll 0126, pp. 26 ff].

George C. McDonald to Ernst Englander. 2 November 1945. Subject: German Underground Installations. [AFHRA folder 570.6501A 1945–46, Special Projects—Current. Microfilmed as AFHRA C5098 frame 0886.]

HEADQUARTERS
UNITED STATES AIR FORCES IN EUROPE
Office of Asst. Chief of Staff A-2
APO 633

AAF Station 179
2 November 1945

SUBJECT: German Underground Installations.

TO: Major ERNST ENGLANDER, A.C., Headquarters USAFE, APO 633.

1. I have been instructed by the AC of S A-2, Headquarters Army Air Forces, Washington, D.C. to furnish detailed information from many aspects on enemy underground installations, techniques, etc.

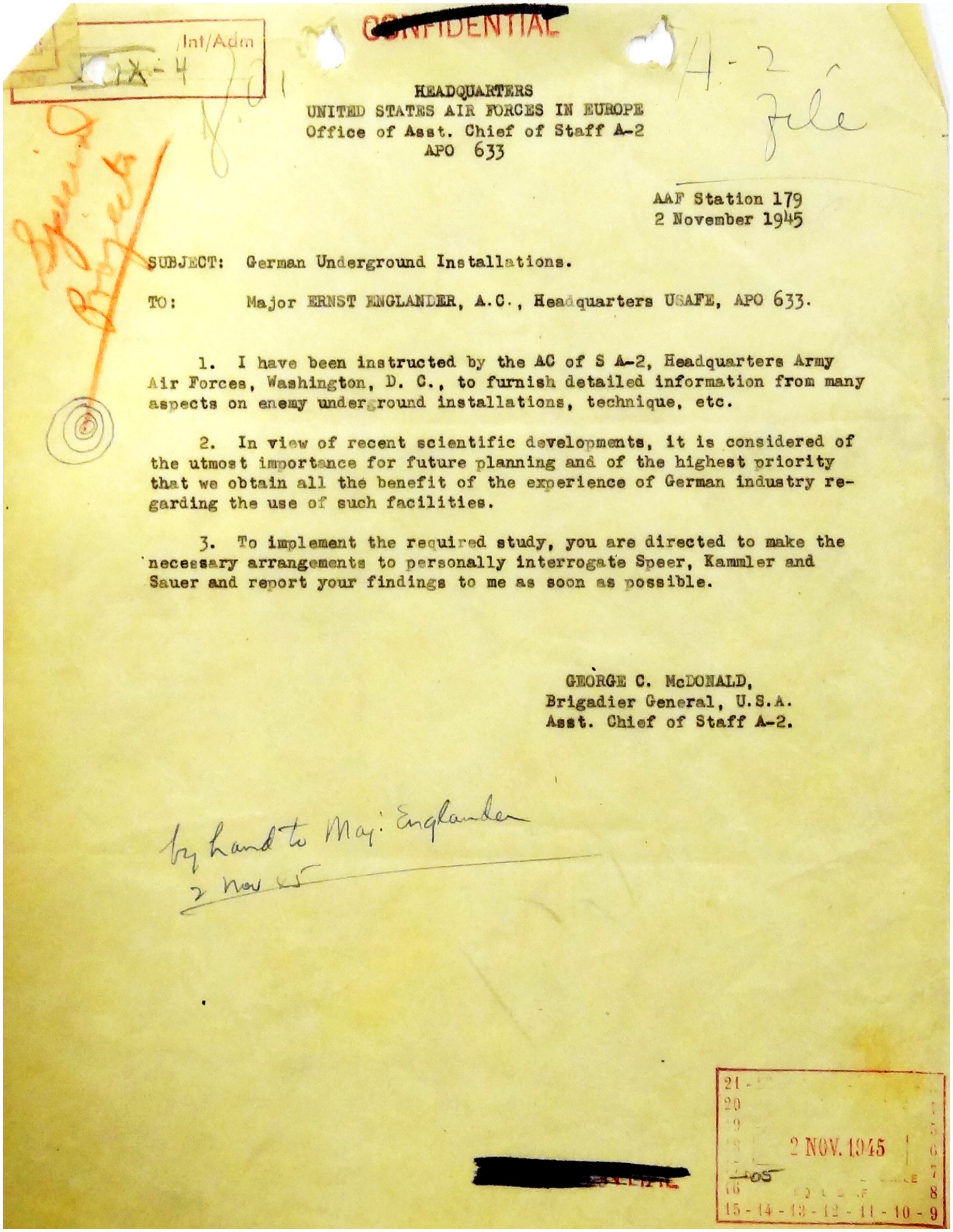
2. In view of recent scientific developments, it is considered of the utmost importance for future planning and of the highest priority that we obtain all the benefit of the experience of German industry regarding the use of such facilities.

3. To implement the required study, you are directed to make the necessary arrangements to personally interrogate Speer, Kammler and Sauer and report your findings to me as soon as possible.

GEORGE C. McDONALD
Brigadier General, U.S.A.
Asst. Chief of Staff A-2.

[See document photo on p. 4959.]

AFHRA folder 570.6501A 1945–46, Special Projects—Current



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Int/Adm

IX-4

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Special Projects

HEADQUARTERS
UNITED STATES AIR FORCES IN EUROPE
Office of Asst. Chief of Staff A-2
APO 633

AAF Station 179
2 November 1945

SUBJECT: German Underground Installations.

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GEORGE C. McDONALD,
Brigadier General, U.S.A.
Asst. Chief of Staff A-2.

by hand to Maj: Englander
2 Nov 45

[redacted]

2 NOV. 1945

-05

Figure D.959: 2 November 1945 letter from General George C. McDonald to Major Ernst Englander, proving that Hans Kammler was alive and being interrogated by the United States as of November 1945 [AFHRA folder 570.6501A 1945–46, Special Projects—Current].

[By the end of the war, SS General (and Dr. Ing.) Hans Kammler controlled and knew the details of virtually all secret German weapons research and development. There are a number of reasons to believe that Kammler's authority and knowledge also included the nuclear program by the end of the war:

- In postwar interrogations, Skoda chief Wilhelm Voss stated that Kammler and his staff were in charge of the "most secret" weapons, including the atomic bomb (p. 4914).
- Heinrich Himmler's adjutant, Werner Grothmann, repeatedly said that Kammler was in charge of executing the nuclear program for Himmler and the SS, in direct association with Wilhelm Ohnesorge from the Reichspost [see for example pp. 3402 and 3865, and many other examples in Krotzky 2002].
- Surviving documents demonstrate that Kammler was indeed closely involved in technical discussions between Himmler at the SS and Ohnesorge at the Reichspost, and apparently directly responsible for implementing their programs (pp. 3385–3387).
- According to the 1962 interrogation of Heinz Wachsmut, written orders related to the March 1945 Thuringia nuclear test were signed by Hans Kammler, along with other SS and Reichspost offices (p. 4558).
- Kammler was in charge of all underground factories, including those where nuclear work apparently occurred, as well as the concentration camps that supplied the labor for those factories.
- Kammler was listed as a recipient for train shipments of supplies at the Gusen underground facility, alongside scientists such as the nuclear physicist Siegfried Flügge and the implosion bomb expert Hubert Schardin (p. 3882).
- Refugees from a nuclear facility in Lüneburger Heide seemed to indicate that Kammler was in charge of that and other similar facilities (p. 4180–4181).
- By the end of the war, Kammler controlled the potential delivery methods for nuclear weapons, including long-range rockets and jet aircraft.
- Kammler steadily amassed power over all types and aspects of advanced weapons development over the course of the war, apparently due to a combination of great political skill, extreme ambition, and ruthless efficiency. It would seem inevitable for the nuclear program to have eventually fallen under his control—he would not have let anything stop him.
- The documents on pp. 4931–4959 demonstrate that the United States concealed the fact that Kammler was alive after the war, shielded him from prosecution, and relied on his knowledge and assistance. Moreover, the United States has tried to keep that secret for 75+ years. Kammler must have offered the United States information that was especially useful—and especially damning—to have justified such extraordinary measures. Details of the German nuclear program would qualify as sufficiently important information.

The documents on pp. 4931–4959 prove that Kammler did not die in early May 1945, as was reported in various conflicting accounts, but rather that Kammler was alive, in U.S. custody, and available for interrogation at least as of November 1945. Apparently he surrendered to U.S. forces in early May, so he would have been in U.S. custody for approximately six months by the time of McDonald's memo, and perhaps for many more years afterward.

The U.S. government must possess lengthy transcripts or even audio/video recordings of Kammler's interrogations. It would also possess any documents and materials that Kammler had with him when he was captured, or that he was able to direct the Americans to afterward. Kammler's interrogations and documents would have provided the United States with considerable detail about the German nuclear program and other very advanced developments, such as the transcontinental rocket mentioned by Speer. (Albert Speer's own capture and interrogation, also referenced in McDonald's memo, resulted in many shelves full of documents.)

How can all of that Kammler material be located and declassified from U.S. government archives? For starters, where are:

- Kammler's detailed statement to the U.S. Counter-Intelligence Corps (likely in May 1945)?
- Ernst Englander's "as soon as possible" report to George McDonald about what he learned from interrogating Kammler (likely in November 1945)?

[For background information and more details, see Agoston 1985; Döbert 2015; Döbert and Karlsch 2019; Karlsch 2014; Michalski et al. 2019; Reuter et al. 2019; Sulzer and Brauburger 2014, 2019a.]]

D.14.7 U.S. Inspections of Possible Nuclear Facilities

[At the end of the war, investigators from the United States personally inspected many of the facilities where German nuclear work may have occurred. Reports on what they found have never been publicly released.]

German Underground Structures [AFHRA C5098 frames 0886–0890]

HEADQUARTERS
UNITED STATES AIR FORCES IN EUROPE
Office of Asst. Chief of Staff A-2

AAF Station 379
APO 633, U S Army
29 August 1945

SUBJECT: German Underground Structures.

TO: Commanding General, U. S. Air Forces in Europe, APO 633, U S Army.

1. In compliance with your instructions, the following report on German underground structures is rendered.

2. This is based on the writer's personal observations during the period 14 May to 1 August 1945. It is of necessity in the nature of a preliminary report for an insufficient number of undergrounds were visited to make a complete report on so large a subject. Again, these installations were inspected primarily for their equipment installations of urgent ATI interests, rather than for the details of their construction. However, the main structural features were examined and noted.

3. A list of the undergrounds visited is attached hereto as Appendix 1. These varied in size from approximately five (5) to twenty-six (26) kilometers, lineal measure, of underground galleries. Dimensions of the galleries varied from four (4) to twenty (20) meters in width and five (5) to fifteen (15) meters in height, the floor space from twenty five thousand (25,000) to one hundred thirty thousand (130000) square meters.

4. All of the undergrounds examined are level entries driven into solid limestone, requiring drilling and blasting for excavation, to a soft, fine-grained sandstone which could be dug by pick alone. These last are all well supported by heavy masonry or concrete linings. Some of the solid limestone galleries are also lined. In all cases the workmanship (though chiefly done by slave labor) is excellent and the construction is of permanent nature for long endurance, rather than to meet temporary war construction.

5. All entries are in steep hillsides having slopes of thirty (30) degrees or more. In nearly every case an open cut was excavated in the hillside so that even the portals are under one hundred (100) feet, or more, of overburden. From the portals the rising slope of the surface increased the solid overburden rapidly to two hundred (200) to five hundred (500) feet.

CONCLUSIONS

6. Even though well drained, lighted and ventilated, these underground structures are, of necessity, inferior to surface buildings for housing industrial plants. Their only advantage is protection from bombing and they, therefore, have no place in a peacetime industry. Their continued existence is a military asset.

7. Well supported excavations under the protection of a deep solid rock overburden are extremely stable and are impervious to damage by attack from the air by any existing bomb. The future developments of the atomic bomb cannot now be predicted. However, to destroy the workings from the air, the entire overlying hill would have to be blown off, a matter of shattering solid rock, from above, to a depth of 200 feet or more. This is now considered impractical.

8. Neutralization of level entry undergrounds must include nearly complete destruction to be effective. Sealing the entrances only would be merely a short delaying action. However, where entry is by vertical, or inclined shaft, the destruction of the shaft may render reopening impractical under certain conditions. It would in any case cause a long delay.

9. So long as these undergrounds remain intact they are available for bombproof housings of important industries in any future war. It is recommended that careful consideration be given to their neutralization even though its accomplishment will be a difficult and costly work.

10. To approach this problem, it is recommended that all existing undergrounds be examined by personnel qualified to judge not only the strength of the supporting structures, but the character of the overlying rock, its structure, joints, bedding planes and other lines of weakness. Maps showing the underground galleries should also have the surface contours superimposed to show depth of overburden at all points. The above information is needed before any detailed plan of neutralization can be made.

11. It is believed that the most effective method will follow the general plan of blasting out the strategic supporting column of rock with explosive blasts strong enough to shatter the overlying rock along lines of natural weakness sufficiently to render its support impractical.

RECOMMENDATIONS

12. The overall problem can best be evaluated under the direction of a geologist with practical experience in underground development. He can correlated the primary factors:

a. the overlying rock structure and strength, with

b. its support.

With him should be associated men of extended practical experience in underground construction and an explosive expert.

13. It is recommended that this paper be forwarded to Headquarters, Army Air Forces, with the idea of selecting targets of above mentioned types for secret experiment of rocket propelled atomic bomb.

GEORGE C. McDONALD
Brigadier General, U.S.A.
Asst. Chief of Staff A-2.

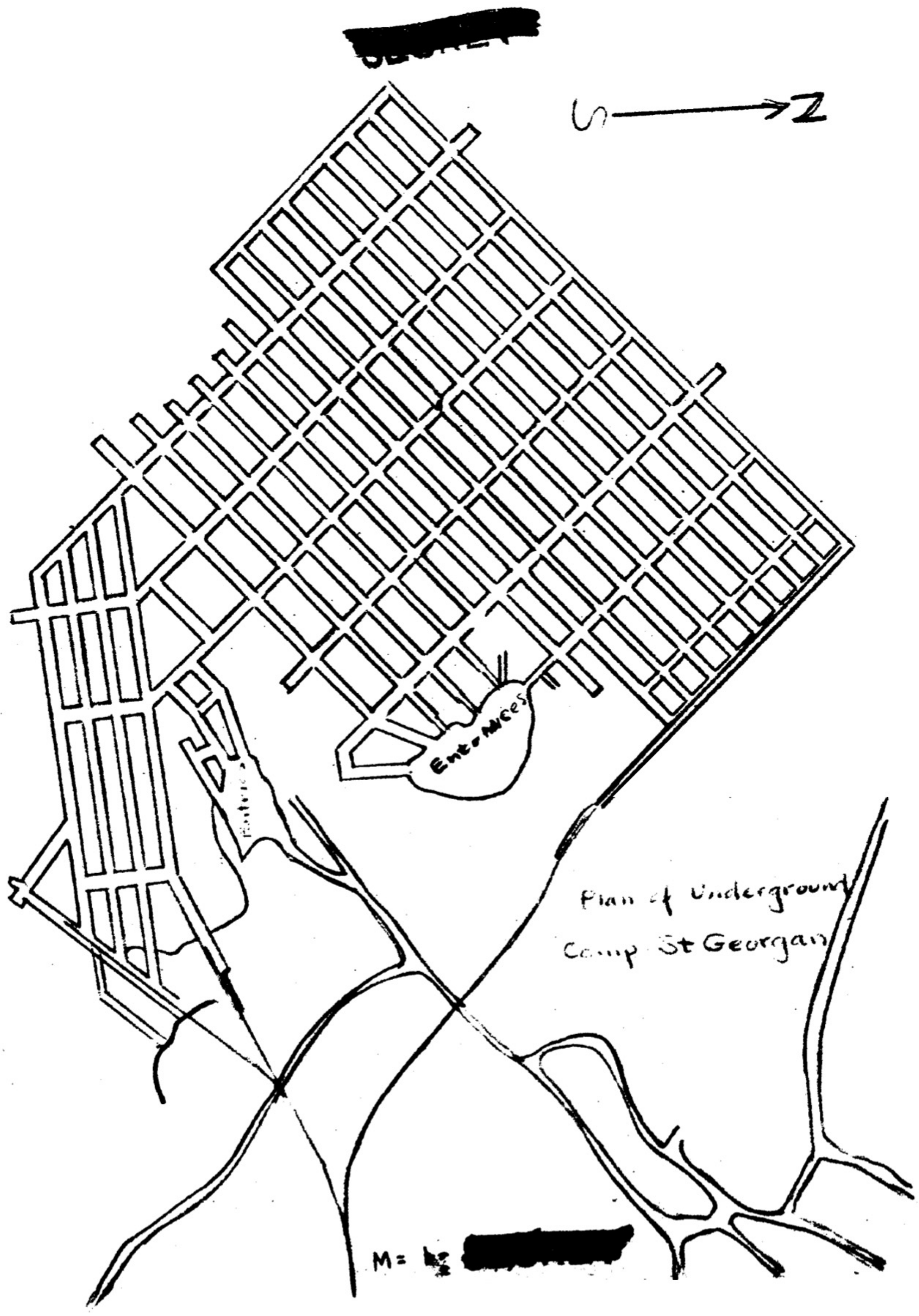

[redacted]
S → N
Entrances
Entrance
Plan of Underground
Camp St Georgan
M= 1: [redacted]

Figure D.960: Map of Camp St. Georgen from General McDonald's report.

2 Incls: List of undergrounds.
Map of Camp St. Georgen.

APPENDICES

1. List of undergrounds examined.

Camp Gusen	Aircraft component factory
Camp St. Georgen	" " "
Camp Ebensee	" " "
Kahla	" " "
Between Kahla and Jena	Optical lens grinding plant.
Redl-Zipf	Oxygen making plant.

2. Attached is the map of the underground workings at Camp St. Georgen. This illustrates the general type of structure though it is more regularly laid out than the others.

[This document demonstrates several important facts:

- There were a very large number of German underground installations (the six that McDonald visited were only an "insufficient number," Point 2 and Appendix 1).

- The German underground installations were massive (Point 3—up to 26 km of galleries each, with the galleries up to 15 m high and up to 20 m wide), built with "workmanship" that was "excellent... for long endurance" (Point 4) and "well drained, lighted and ventilated" (Point 6).

- The German underground installations that he described sounded fully functional during the war, not still under construction and unoccupied at the end of the war.

- Allied personnel conducted detailed inspections of the underground installations, yet (with only a few exceptions) the results of those inspections, or even the facts that they occurred at all, have not been made public.

- The Allies removed urgent war-critical materials from the underground installations (Point 2). What materials could have been so urgently needed by the United States in its continuing war with Japan—perhaps materials related to nuclear weapons development?

- After the war, the Allies expended great effort to destroy and prevent access to the many underground installations (Points 8–12).

- Underground installations that were so numerous, so large, and so advanced could have provided suitable locations not only for the aircraft, lens, and oxygen production that McDonald mentioned, but also potentially for producing large rockets, nuclear materials or weapons, or other advanced weapons systems or components.

- McDonald could only describe what he observed. It is possible that some German underground installations were evacuated and/or destroyed by German troops before Allied military forces even arrived.

- Point 13: Presumably McDonald was not suggesting nuclear test strikes on these facilities in postwar Austria and Germany, which would cause radioactive contamination of the area, not be a "secret experiment" at all, and likely provoke negative reactions from local countries and from the Soviet Union. Rather, he was apparently suggesting that the United States should build test structures similar to those he described (likely in the southwestern United States or on a Pacific island) and then detonate an atomic bomb on that test structure to see how much damage the bomb could do.

- Point 13: During the war, Heinrich Himmler apparently wanted German underground facilities to be so well built that they could even survive an Allied strike by an atomic bomb (see p. 4592). McDonald may have been aware of that intention, and may have wanted to put it to the test (but somewhere else where the test could be conducted safely and secretly, as already discussed).

- Point 13: In August 1945, the U.S. was apparently preparing "secret experiment of rocket propelled atomic bomb." However, the only atomic bombs that the United States officially possessed were more Fat Man bombs weighing 3000-4000 kg (depending on the casing), and the largest rockets that the United States officially possessed were captured German V-2 rockets, which could not carry a payload that heavy. Officially the United States did not develop its first rocket-propelled atomic bombs until the early 1950s [Chuck Hansen 1988, pp. 189–191]. In August 1945, how could the U.S. military have, or expect to soon have, a rocket-propelled atomic bomb for a "secret experiment"? Does that suggest that the United States acquired German rockets larger than the V-2 that could carry a larger payload like the U.S. Fat Man? Does it suggest that the United States acquired a German atomic bomb (or plans thereof) that was smaller than the U.S. Fat Man? Or does it suggest that the United States acquired an advanced German rocket and atomic bomb that were already an integrated system? (There is also an earlier draft of this report with the comment about a rocket propelled atomic bomb added in handwriting [AFHRA C5098 frames 0990–0991].)

- McDonald was involved in preparing the U.S. Army Air Force's January 1945 "Evaluation of German Capabilities" that discussed existing German rockets larger than the V-2, as well as sites of possible German atomic bomb tests (see pp. 5336–5337). After the end of the war in Europe, he spent months visited highly secret German weapons production plants (Point 2 and Appendix 1). He knew that Hans Kammler survived the war, was in U.S. custody, and was being interrogated (see pp. 4931–4959). Thus McDonald was probably one of the best informed Americans in terms of his knowledge of the German secrets weapons programs.]

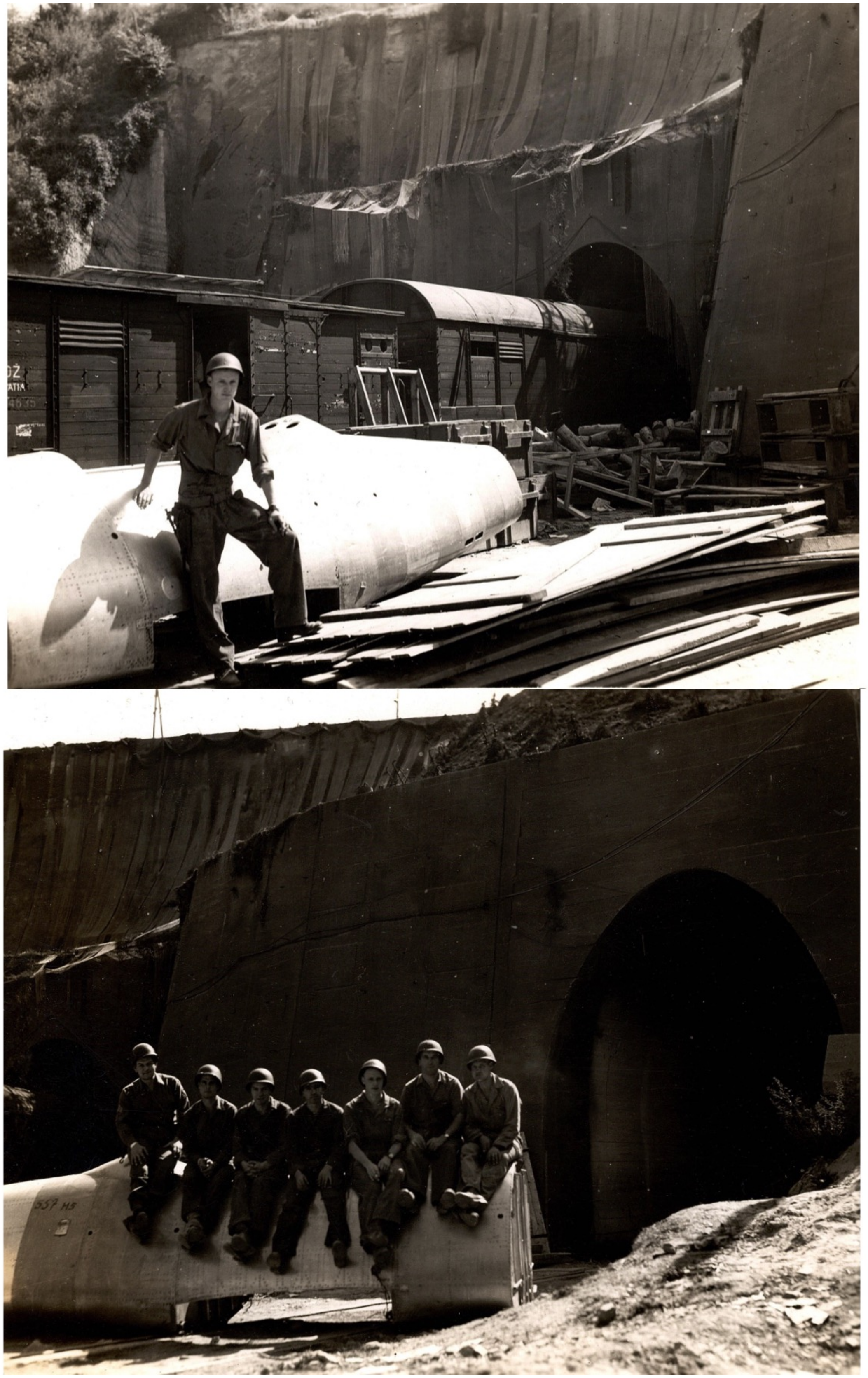


Figure D.961: Photos taken by U.S. soldiers at the “Bergkristall” tunnel complex at St. Georgen an der Gusen near Linz, Austria, in May 1945 [AFHRA 00043922 SQ-BOMB-34-HI 1–31 July 1945]. Where are the Allied reports on what was discovered by inspections and interrogations?

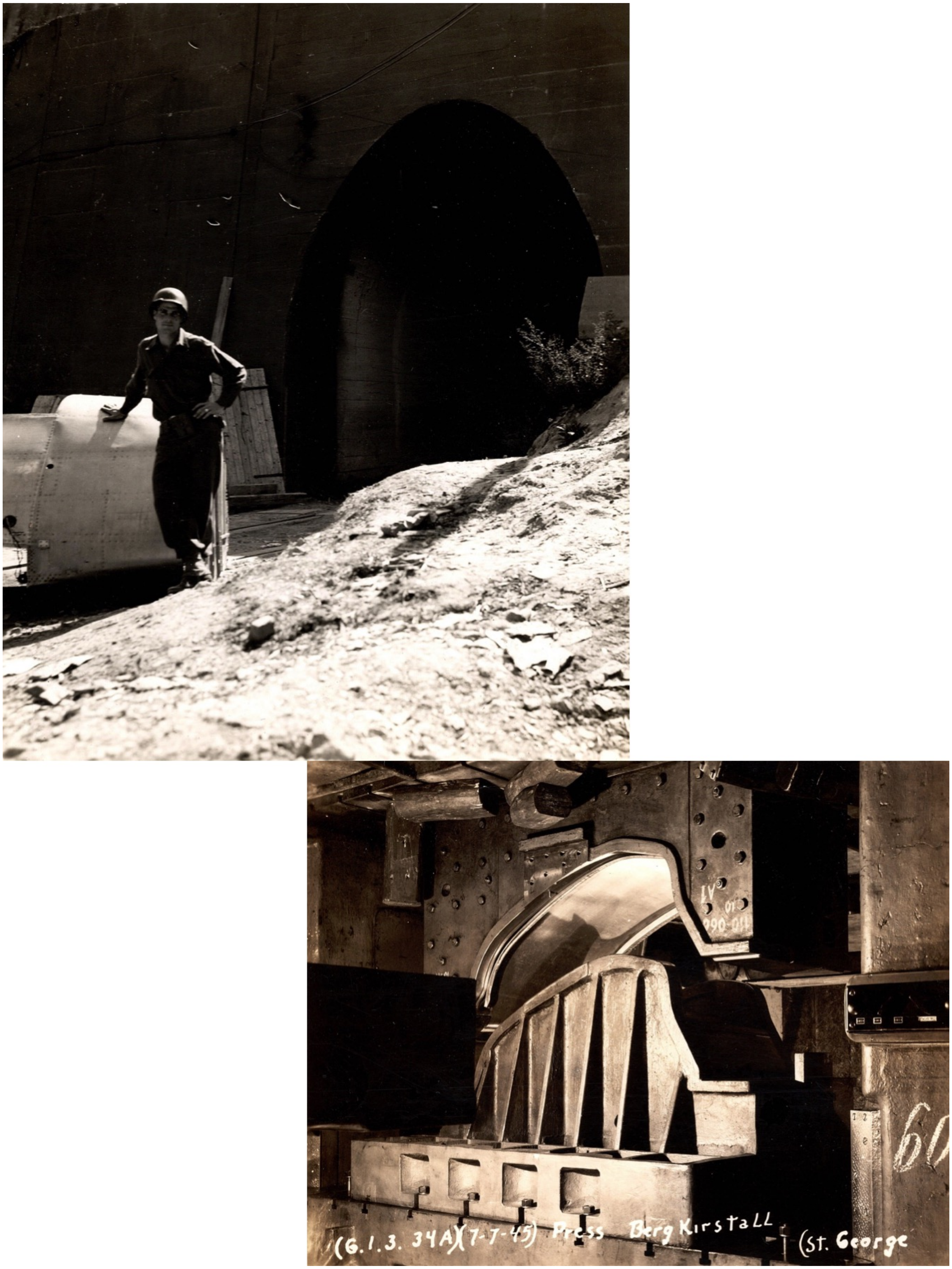
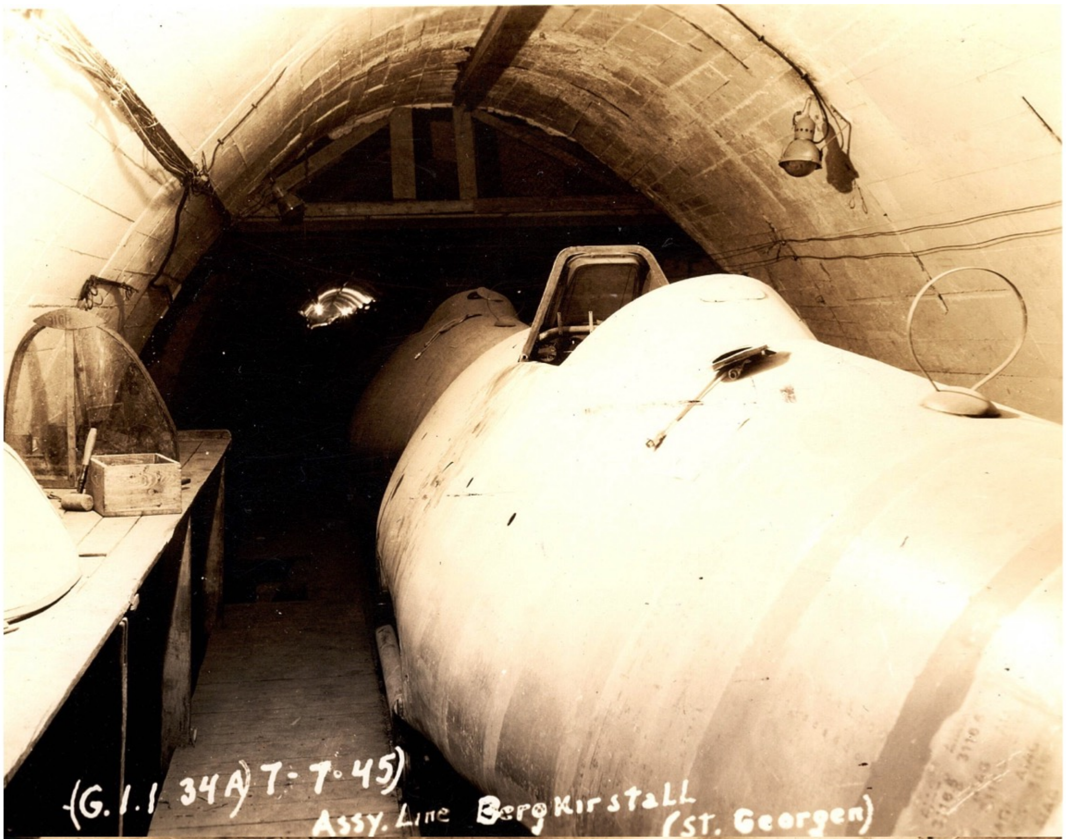

IV
(6.1.3. 34A)(7-7-45) Press Berg Kirstall (St. George
60

Figure D.962: More photos taken by U.S. soldiers at the Bergkristall tunnel complex at St. Georgen an der Gusen in May 1945 [AFHRA 00043922 SQ-BOMB-34-HI 1–31 July 1945].


(G.1.1 34A) 7-7-45)
Assy. Line BergKirstall
(St. Georgen)

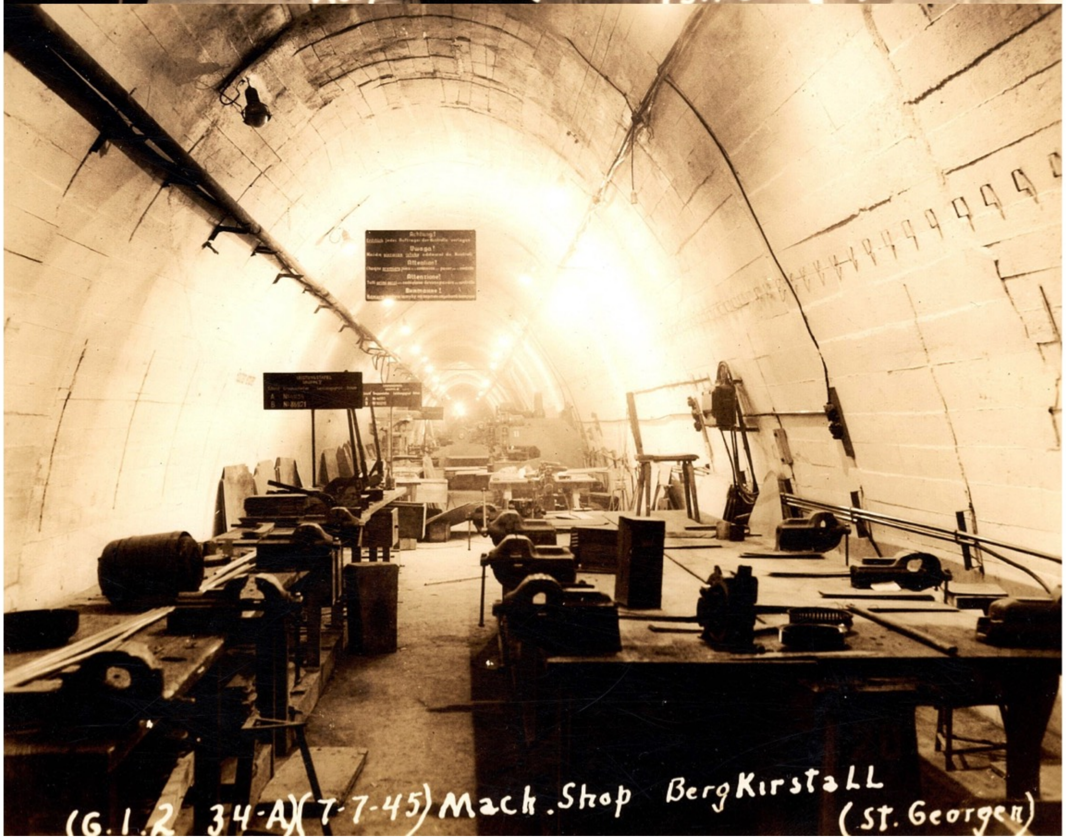
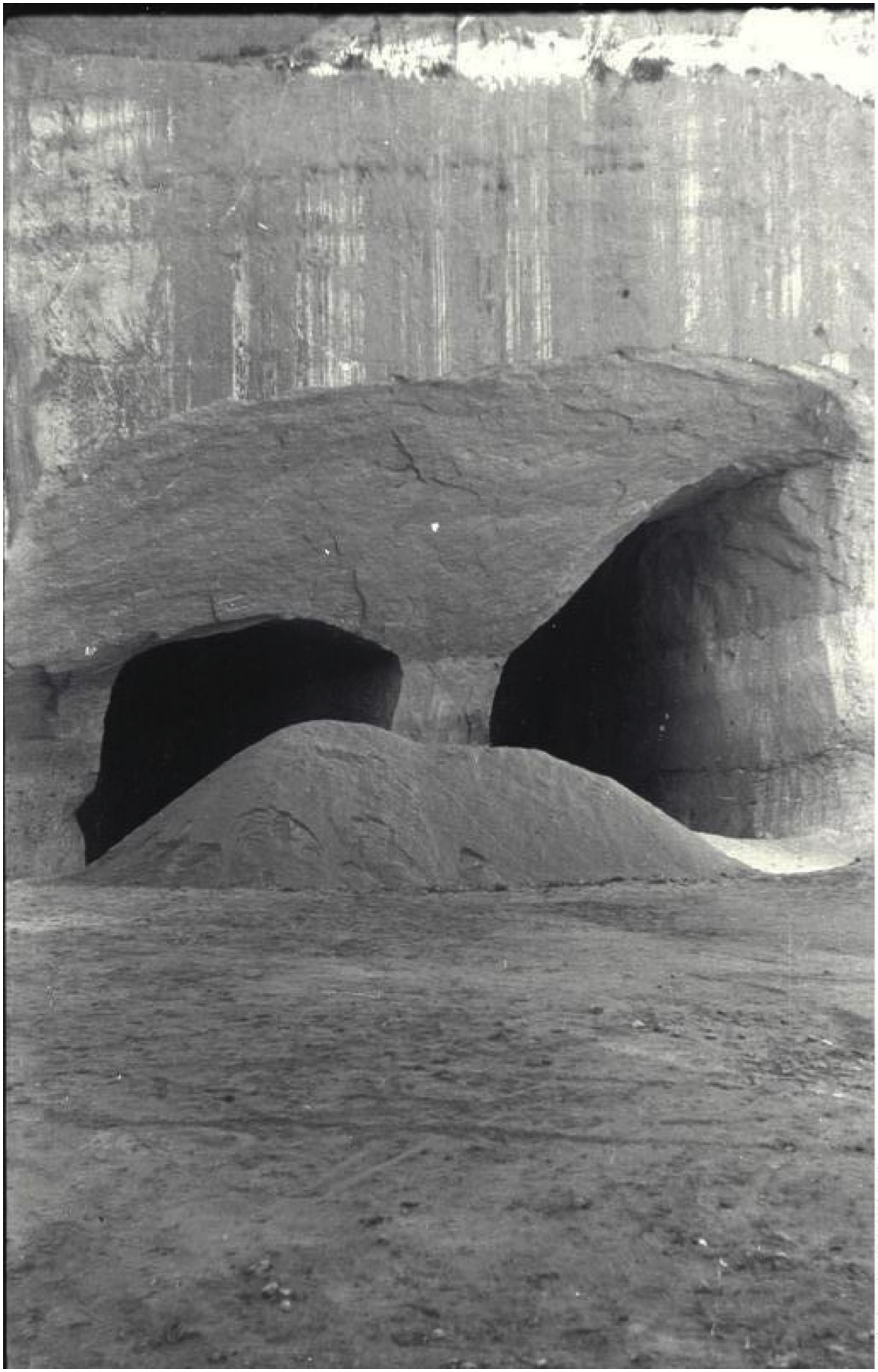

(G.1.2 34-A)(7-7-45) Mach. Shop BergKirstaLL
(St. Georgen)

Figure D.963: More photos taken by U.S. soldiers at the Bergkristall tunnel complex at St. Georgen an der Gusen in May 1945 [AFHRA 00043922 SQ-BOMB-34-HI 1–31 July 1945].



Bundesarchiv, Bild 192-275
Foto: o.Ang. | o.Dat.

Figure D.964: Another photo of entrances to the Bergkristall tunnel complex at St. Georgen an der Gusen in 1945.

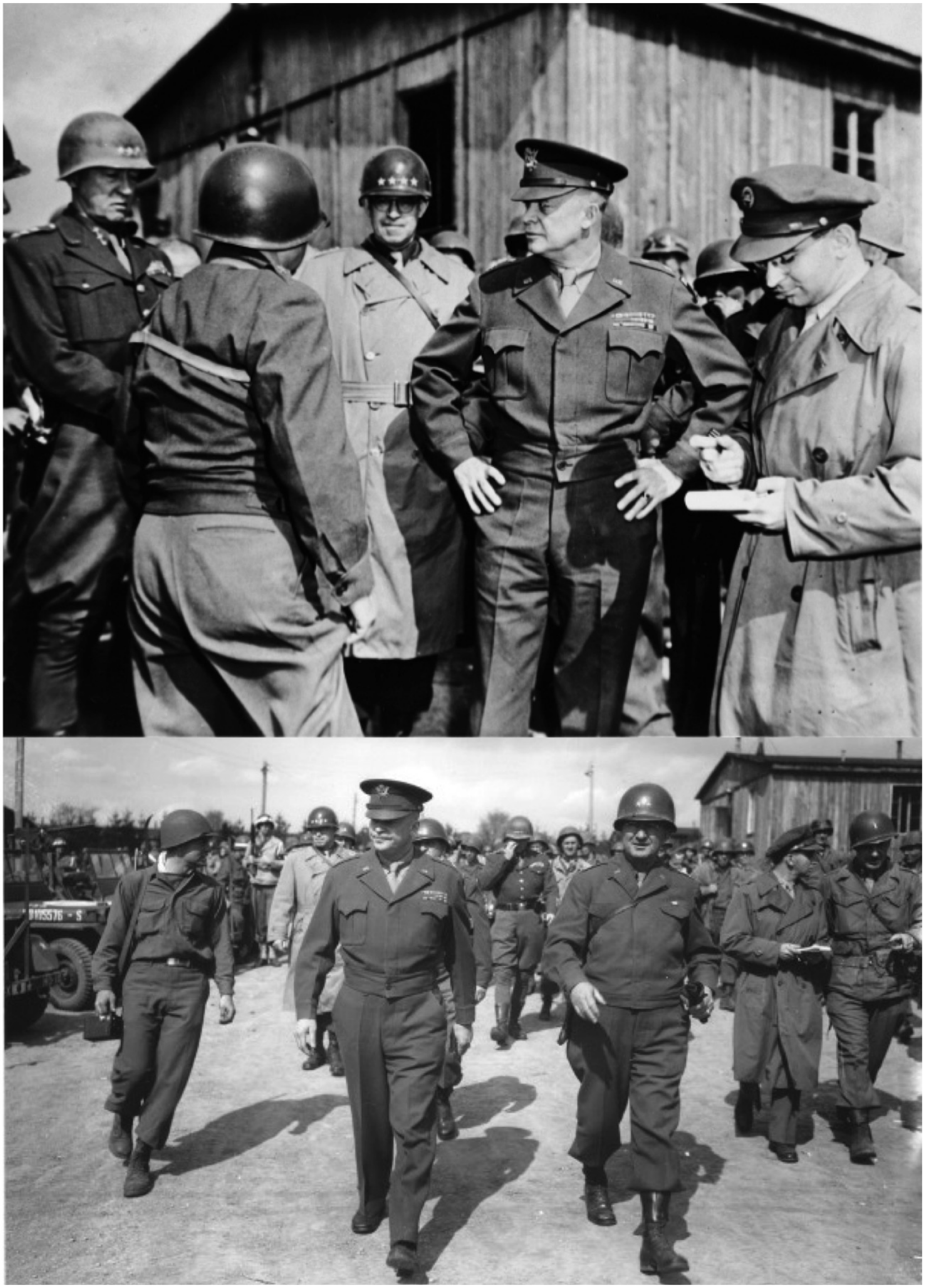
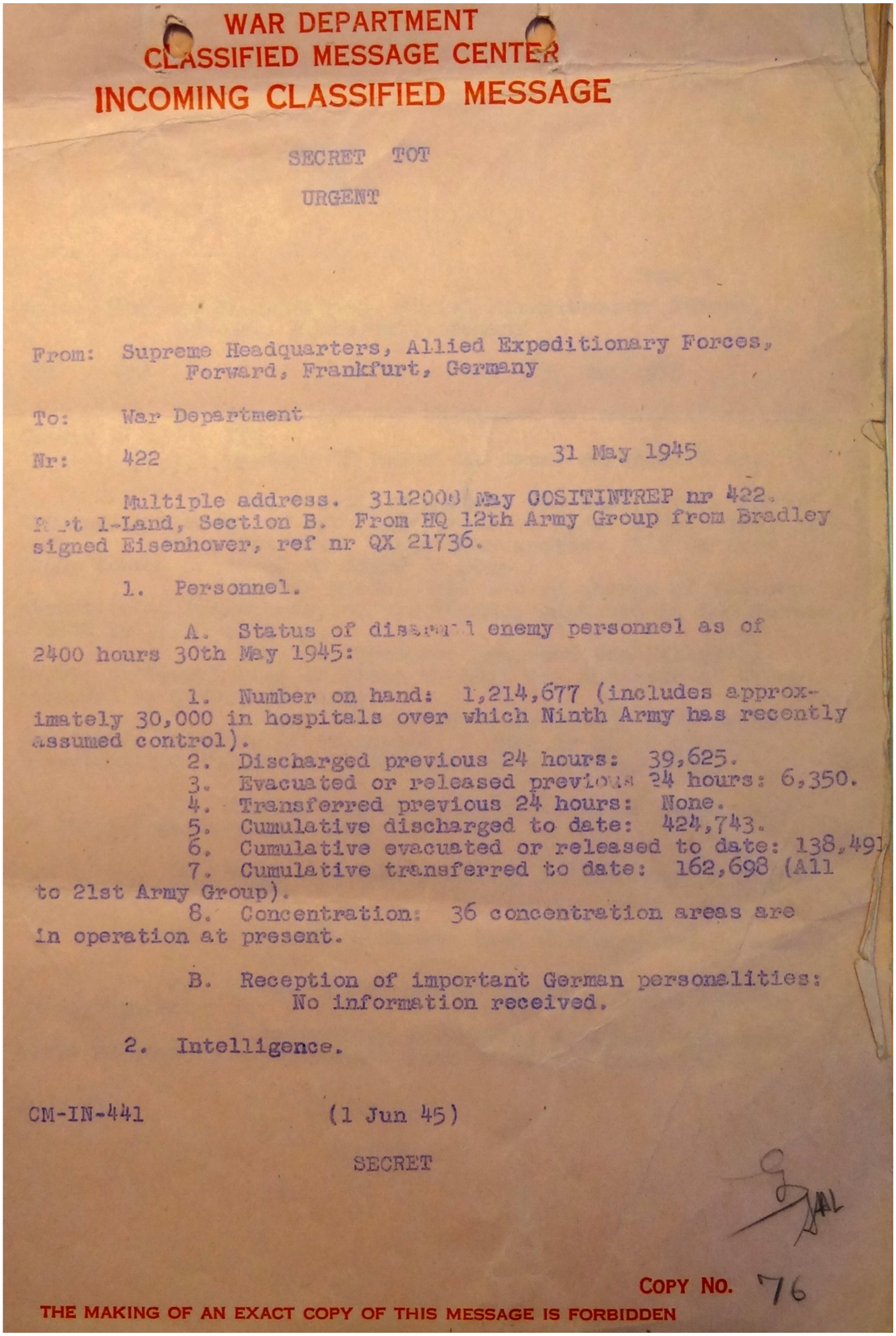


Figure D.965: U.S. Generals Dwight Eisenhower, Omar Bradley, George Patton, and Troy Middleton inspecting Ohrdruf on 12 April 1945. Where are the Allied reports on detailed inspections of the above-ground and underground facilities, equipment, technologies, and documents from that area, as well as interrogation reports?

DECLASSIFIED
Authority NND917017



WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
INCOMING CLASSIFIED MESSAGE

SECRET TOT

URGENT

From: Supreme Headquarters, Allied Expeditionary Forces, Forward, Frankfurt, Germany

To: War Department

Nr: 422 31 May 1945

Multiple address. 311200B May COSITINTREP nr 422. Part 1-Land, Section B. From HQ 12th Army Group from Bradley signed Eisenhower, ref nr QX 21736.

1. Personnel.

A. Status of disarmed enemy personnel as of 2400 hours 30th May 1945:

1. Number on hand: 1,214,677 (includes approximately 30,000 in hospitals over which Ninth Army has recently assumed control).
2. Discharged previous 24 hours: 39,625.
3. Evacuated or released previous 24 hours: 6,350.
4. Transferred previous 24 hours: None.
5. Cumulative discharged to date: 424,743.
6. Cumulative evacuated or released to date: 138,491
7. Cumulative transferred to date: 162,698 (All to 21st Army Group).
8. Concentration: 36 concentration areas are in operation at present.

B. Reception of important German personalities: No information received.

2. Intelligence.

CM-IN-441 (1 Jun 45)

SECRET

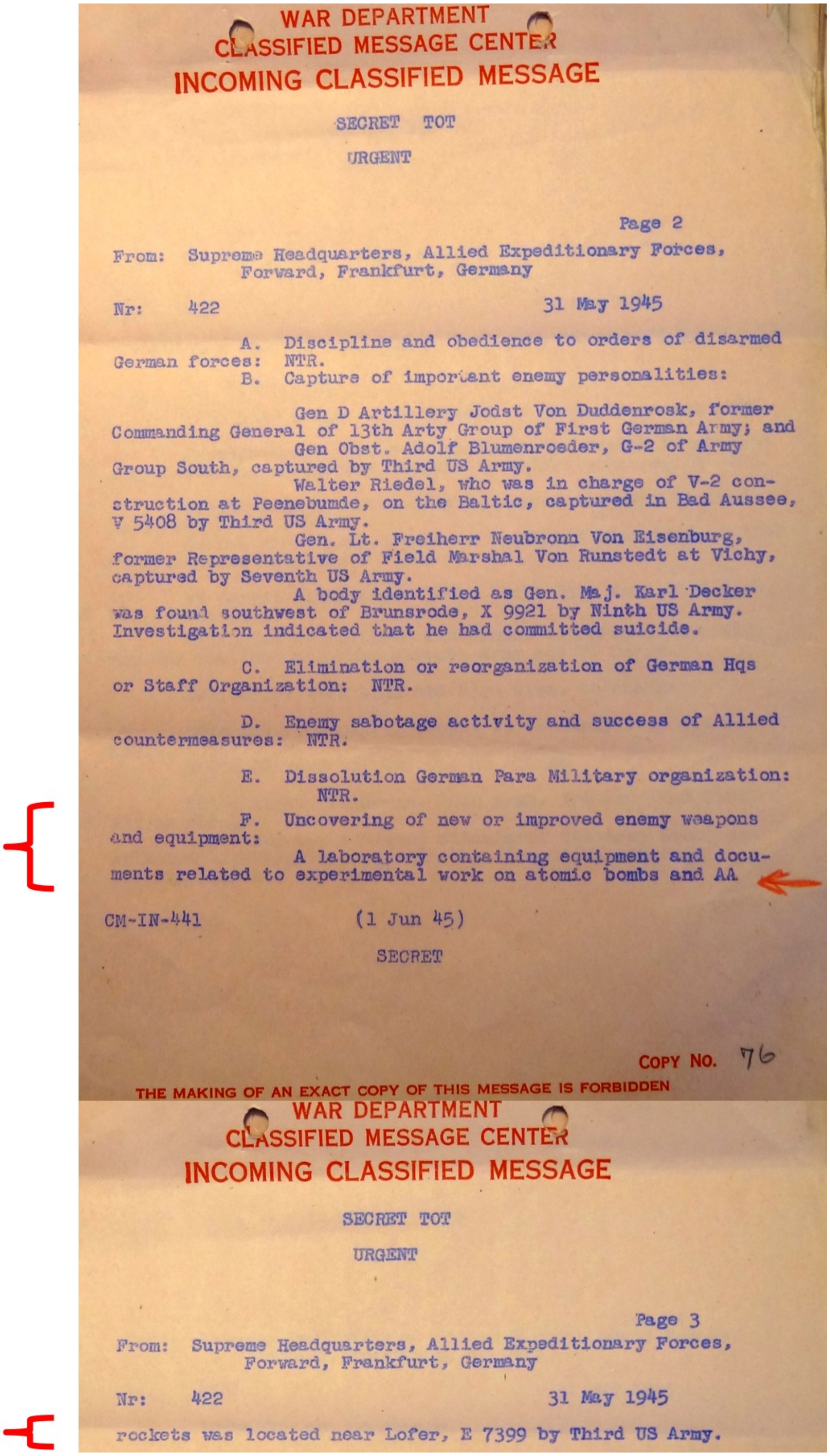
COPY NO. 76

THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN

NARA RG 77, Entry UD-22A, Box 160, Folder APR 45--Dec. '45

Figure D.966: Secret 31 May 1945 cable from Generals Bradley and Eisenhower to Washington reporting the discovery of “a laboratory containing equipment and documents related to experimental work on atomic bombs” in Austria [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. ’45].

DECLASSIFIED
Authority NND917017



WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
INCOMING CLASSIFIED MESSAGE

SECRET TOT

URGENT

Page 2

From: Supreme Headquarters, Allied Expeditionary Forces,
Forward, Frankfurt, Germany

Nr: 422 31 May 1945

A. Discipline and obedience to orders of disarmed German forces: NTR.

B. Capture of important enemy personalities:

Gen D Artillery Jodst Von Duddenrosk, former Commanding General of 13th Arty Group of First German Army; and

Gen Obst. Adolf Blumenroeder, G-2 of Army Group South, captured by Third US Army.

Walter Riedel, who was in charge of V-2 construction at Peenebumde, on the Baltic, captured in Bad Aussee, V 5408 by Third US Army.

Gen. Lt. Freiherr Neubronn Von Eisenburg, former Representative of Field Marshal Von Runstedt at Vichy, captured by Seventh US Army.

A body identified as Gen. Maj. Karl Decker was found southwest of Brunsrode, X 9921 by Ninth US Army. Investigation indicated that he had committed suicide.

C. Elimination or reorganization of German Hqs or Staff Organization: NTR.

D. Enemy sabotage activity and success of Allied countermeasures: NTR.

E. Dissolution German Para Military organization: NTR.

F. Uncovering of new or improved enemy weapons and equipment:

A laboratory containing equipment and documents related to experimental work on atomic bombs and AA

CM-IN-441 (1 Jun 45)

SECRET

COPY NO. 76

THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN

WAR DEPARTMENT
CLASSIFIED MESSAGE CENTER
INCOMING CLASSIFIED MESSAGE

SECRET TOT

URGENT

Page 3

From: Supreme Headquarters, Allied Expeditionary Forces,
Forward, Frankfurt, Germany

Nr: 422 31 May 1945

rockets was located near Lofer, E 7399 by Third US Army.

NARA RG 77, Entry UD-22A,
Box 160, Folder APR 45--Dec. '45

Figure D.967: Secret 31 May 1945 cable from Generals Bradley and Eisenhower to Washington reporting the discovery of "a laboratory containing equipment and documents related to experimental work on atomic bombs" in Austria [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45].

SHAEF to War Department. Cable 422. 31 May 1945 [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45] [See document photos on pp. 4972–4973.]

From: Supreme Headquarters, Allied Expeditionary Forces, Forward, Frankfurt, Germany

To: War Department

Nr: 422 31 May 1945

Multiple address. 3112000 May COSITINTREP nr 422, Part 1—Land, Section B. From HQ 12th Army Group from Bradley signed Eisenhower, ref nr QX 21736.

2. Intelligence. [...]

F. Uncovering of new or improved enemy weapons and equipment:

A laboratory containing equipment and documents related to experimental work on atomic bombs and AA rockets was located near Lofer, E 7399 by Third US Army. [...]

Royal Army Ordnance Corps. October 1946. *R.A.O.C. Gazette* 28:5:150. [U.K. Imperial War Museum LBY E. 14449. https://www.rlcarchive.org]

Many interesting discoveries were made by Ordnance representatives *en route.* D.D.O.S. of 8 Corps found a factory engaged in production work for the German atomic bomb. The ammunition for Germany's largest gun was also located. Two of these massive guns had been captured by the Russians, but this was the first time their ammunition had been seen. At Belsen [concentration camp], the Ordnance service found itself faced with an unprecedented task.

PARAGRAPHS 8, 9, 10 of MFIU/HQ/CSDIC/12. Undated but apparently late 1944. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)] [See document photo on p. 3693.]

PARAGRAPHS 8, 9, 10 of MFIU/HQ/CSDIC/12

I. "SECRET WEAPONS"

8. Factory nr: Pilsen. (No date). A P/W, who lives near Pilsen, supplies the following information which he had only at second-hand from friends working in Pilsen.

9. A large underground factory is being constructed in the woods within 8–9 km of Pilsen and was said to be finished shortly. Workers of many nationalities were employed in this construction work and were confined to the site of the plant at all times.

10. Rumour has it that one of the secret weapons is to be produced there.

[Where are the Allied reports on detailed inspections of the facilities, equipment, technologies, and documents from these areas, as well as interrogation reports?]

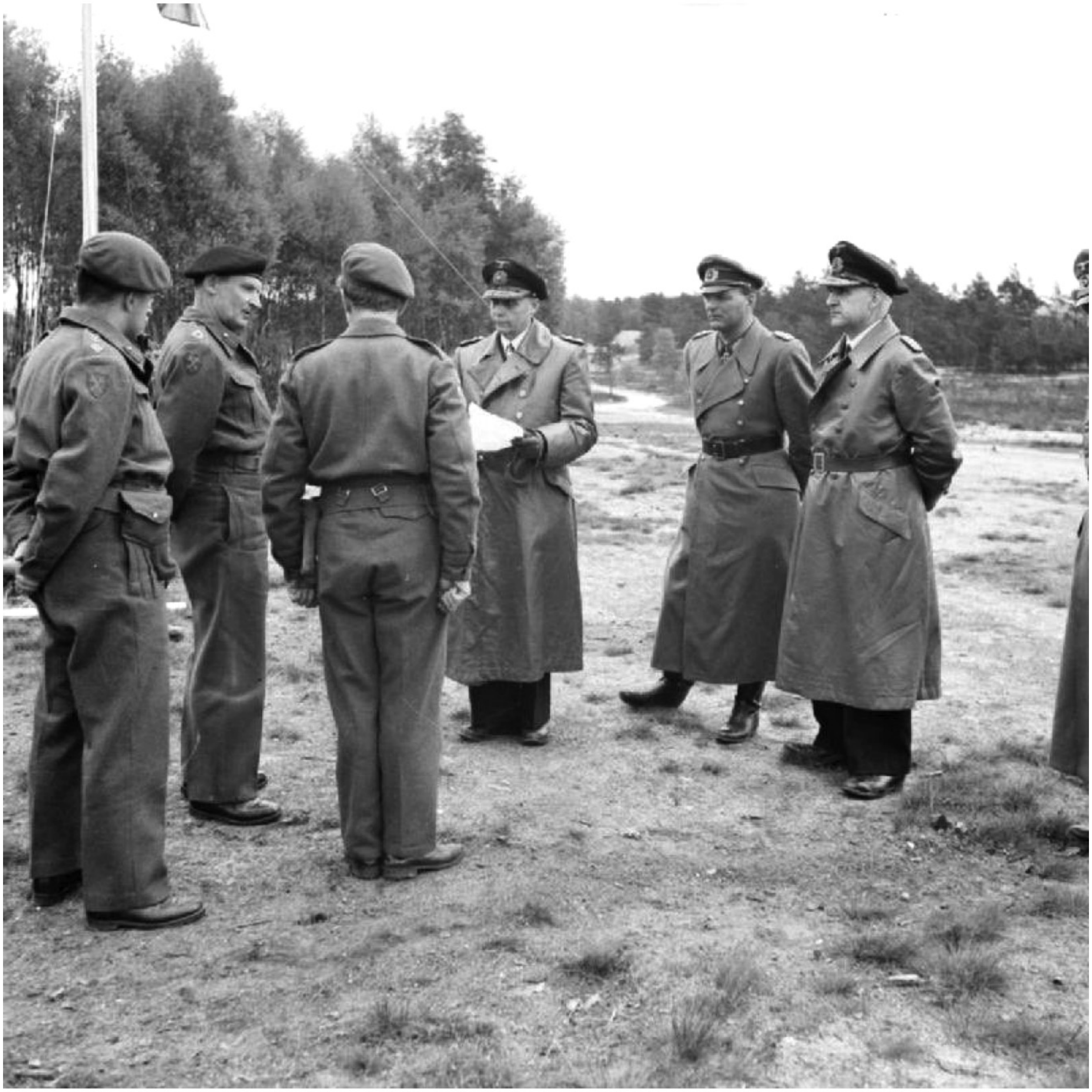


Figure D.968: U.K. Field Marshal Bernard Montgomery accepting the German surrender at Lüneburger Heide on 4 May 1945. Where are the Allied reports on detailed inspections of the above-ground and underground facilities, equipment, technologies, and documents from that area, as well as interrogation reports? See pp. 4176–4182, 4406, 4987–4988.

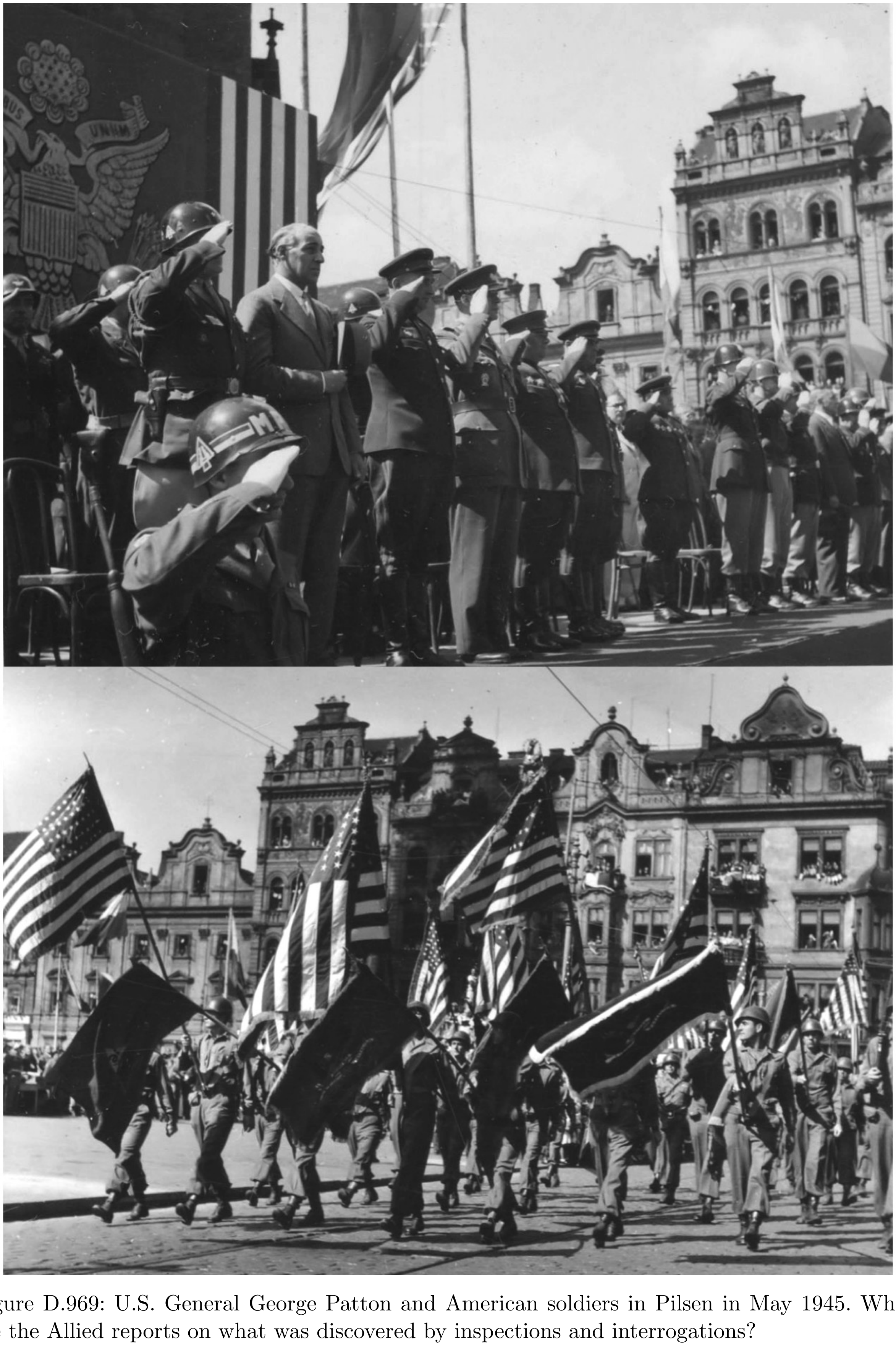


Figure D.969: U.S. General George Patton and American soldiers in Pilsen in May 1945. Where are the Allied reports on what was discovered by inspections and interrogations?

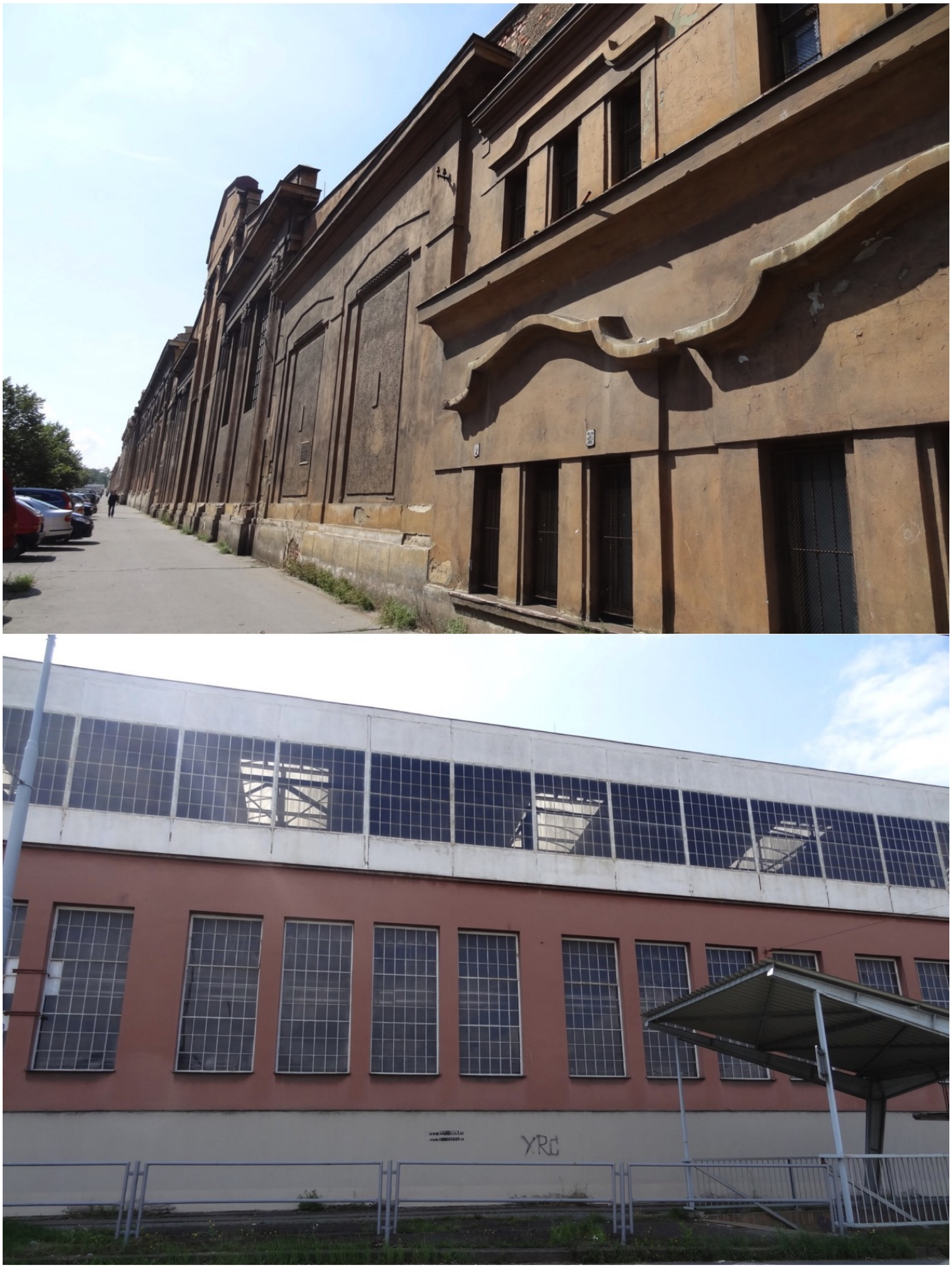
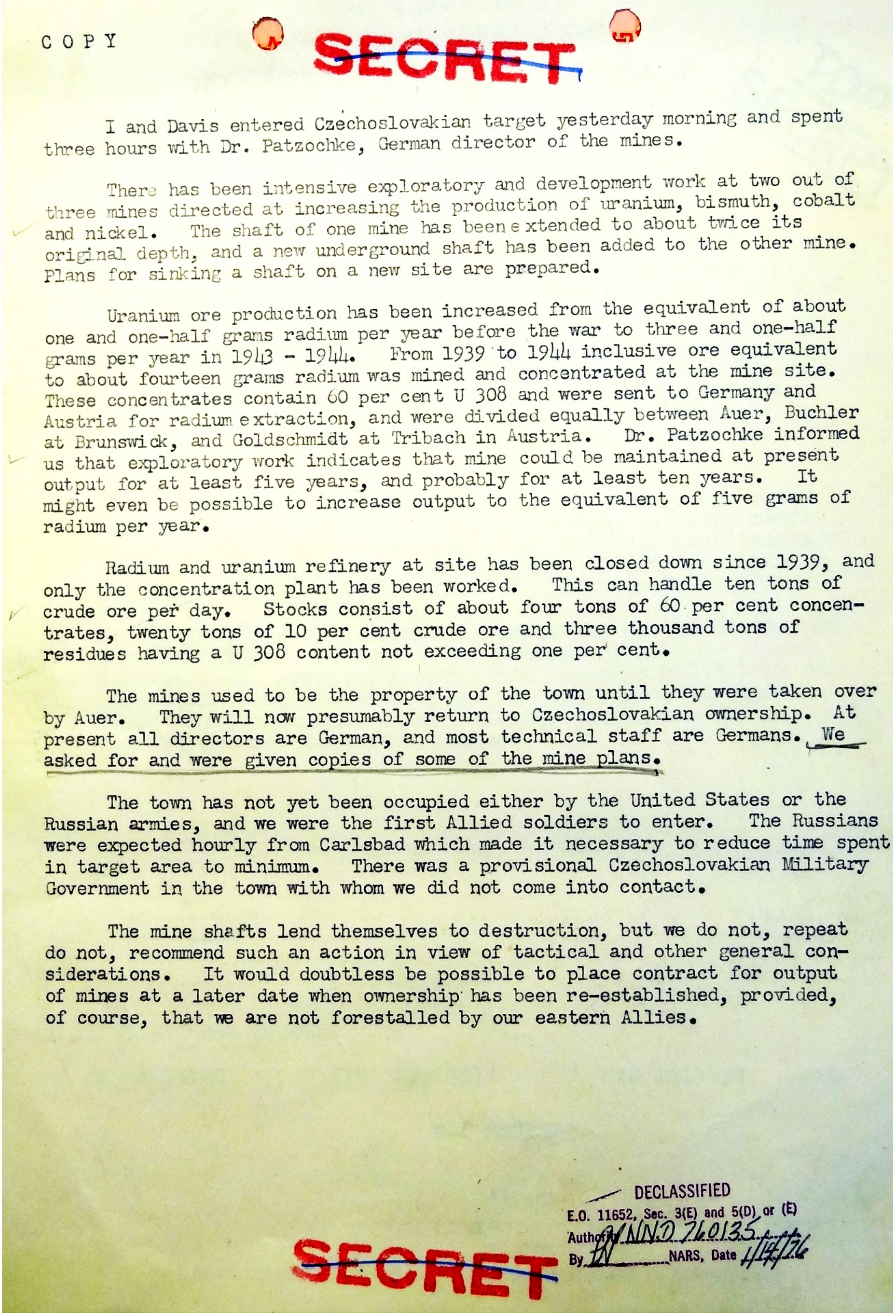


Figure D.970: Location of the former Skoda R&D complex in Pilsen.

DECLASSIFIED
Authority NND 917017



C O P Y

~~SECRET~~

I and Davis entered Czechoslovakian target yesterday morning and spent three hours with Dr. Patzochke, German director of the mines.

There has been intensive exploratory and development work at two out of three mines directed at increasing the production of uranium, bismuth, cobalt and nickel. The shaft of one mine has been extended to about twice its original depth, and a new underground shaft has been added to the other mine. Plans for sinking a shaft on a new site are prepared.

Uranium ore production has been increased from the equivalent of about one and one-half grams radium per year before the war to three and one-half grams per year in 1943 - 1944. From 1939 to 1944 inclusive ore equivalent to about fourteen grams radium was mined and concentrated at the mine site. These concentrates contain 60 per cent U 308 and were sent to Germany and Austria for radium extraction, and were divided equally between Auer, Buchler at Brunswick, and Goldschmidt at Tribach in Austria. Dr. Patzochke informed us that exploratory work indicates that mine could be maintained at present output for at least five years, and probably for at least ten years. It might even be possible to increase output to the equivalent of five grams of radium per year.

Radium and uranium refinery at site has been closed down since 1939, and only the concentration plant has been worked. This can handle ten tons of crude ore per day. Stocks consist of about four tons of 60 per cent concentrates, twenty tons of 10 per cent crude ore and three thousand tons of residues having a U 308 content not exceeding one per cent.

The mines used to be the property of the town until they were taken over by Auer. They will now presumably return to Czechoslovakian ownership. At present all directors are German, and most technical staff are Germans. We asked for and were given copies of some of the mine plans.

The town has not yet been occupied either by the United States or the Russian armies, and we were the first Allied soldiers to enter. The Russians were expected hourly from Carlsbad which made it necessary to reduce time spent in target area to minimum. There was a provisional Czechoslovakian Military Government in the town with whom we did not come into contact.

The mine shafts lend themselves to destruction, but we do not, repeat do not, recommend such an action in view of tactical and other general considerations. It would doubtless be possible to place contract for output of mines at a later date when ownership has been re-established, provided, of course, that we are not forestalled by our eastern Allies.

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NARA RG 77, Entry UD-22A,
Box 160, Folder APR 45-Dec. '45

Figure D.971: David Gattiker and George C. Davis. 16 May 1945. Report on visit to Joachimsthal/Jáchymov [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45].

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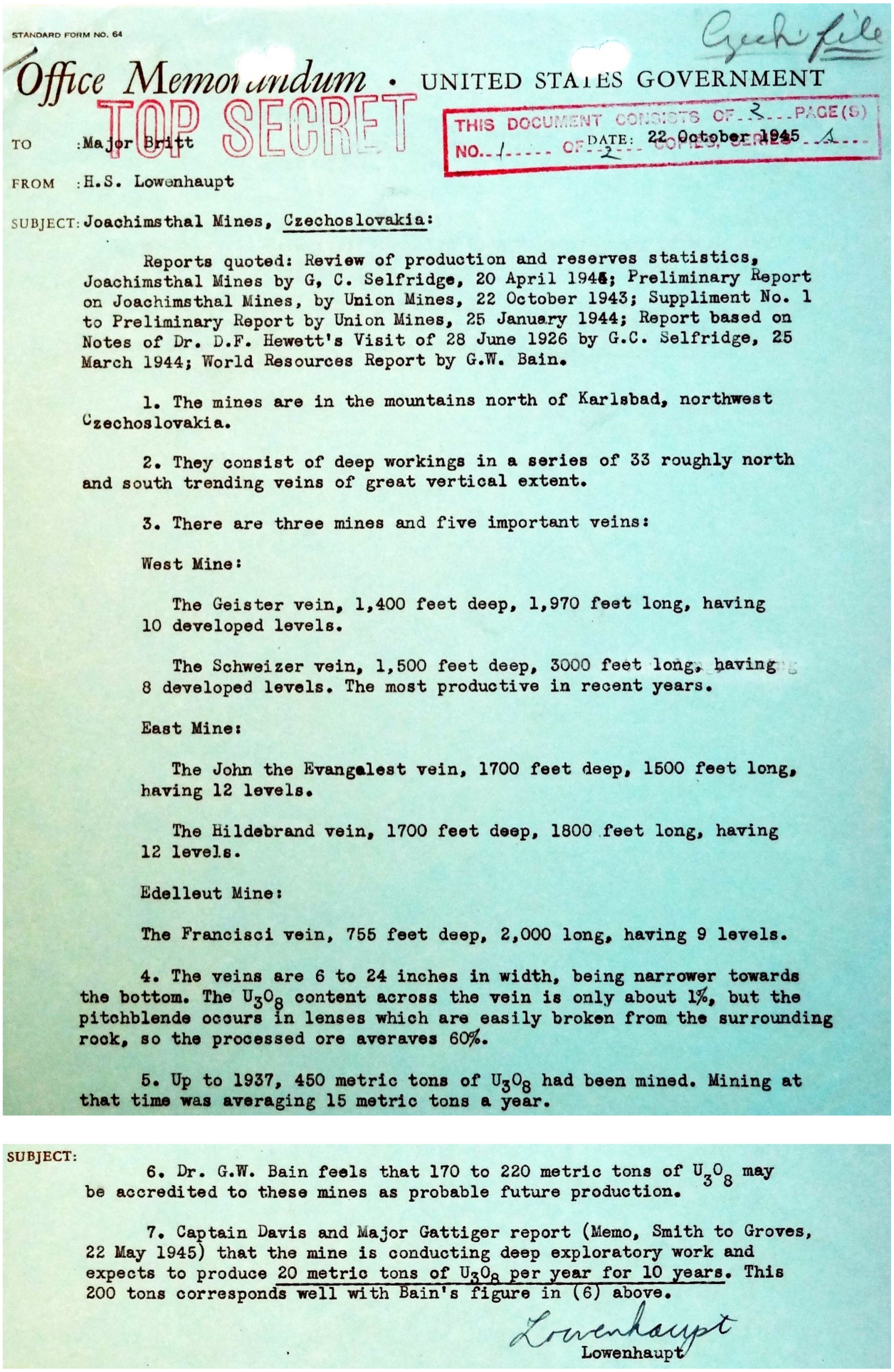

STANDARD FORM NO. 64

Czech file

Office Memorandum • UNITED STATES GOVERNMENT

TOP SECRET

THIS DOCUMENT CONSISTS OF 3 PAGE(S)
NO. 1 OF 2 COPIES, SERIES A

TO :Major Britt

DATE: 22 October 1945

FROM :H.S. Lowenhaupt

SUBJECT: Joachimsthal Mines, Czechoslovakia:

Reports quoted: Review of production and reserves statistics, Joachimsthal Mines by G, C. Selfridge, 20 April 1944; Preliminary Report on Joachimsthal Mines, by Union Mines, 22 October 1943; Suppliment No. 1 to Preliminary Report by Union Mines, 25 January 1944; Report based on Notes of Dr. D.F. Hewett's Visit of 28 June 1926 by G.C. Selfridge, 25 March 1944; World Resources Report by G.W. Bain.

1. The mines are in the mountains north of Karlsbad, northwest Czechoslovakia.

2. They consist of deep workings in a series of 33 roughly north and south trending veins of great vertical extent.

3. There are three mines and five important veins:

West Mine:

The Geister vein, 1,400 feet deep, 1,970 feet long, having 10 developed levels.

The Schweizer vein, 1,500 feet deep, 3000 feet long, having 8 developed levels. The most productive in recent years.

East Mine:

The John the Evangalest vein, 1700 feet deep, 1500 feet long, having 12 levels.

The Hildebrand vein, 1700 feet deep, 1800 feet long, having 12 levels.

Edelleut Mine:

The Francisci vein, 755 feet deep, 2,000 long, having 9 levels.

4. The veins are 6 to 24 inches in width, being narrower towards the bottom. The U_3O_8 content across the vein is only about 1%, but the pitchblende occurs in lenses which are easily broken from the surrounding rock, so the processed ore averaves 60%.

5. Up to 1937, 450 metric tons of U_3O_8 had been mined. Mining at that time was averaging 15 metric tons a year.

SUBJECT:

6. Dr. G.W. Bain feels that 170 to 220 metric tons of U_3O_8 may be accredited to these mines as probable future production.

7. Captain Davis and Major Gattiger report (Memo, Smith to Groves, 22 May 1945) that the mine is conducting deep exploratory work and expects to produce 20 metric tons of U_3O_8 per year for 10 years. This 200 tons corresponds well with Bain's figure in (6) above.

Lowenhaupt
Lowenhaupt

NARA RG 77, Entry UD-22A,
Box 163, Folder Czechoslovakia

Figure D.972: H. S. Lowenhaupt to A. E. Britt. 22 October 1945. Joachimsthal Mines, Czechoslovakia [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

David Gattiker and George C. Davis. 16 May 1945. Report on visit to Joachimsthal/Jáchymov. [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45] [See document photos on pp. 4978–4979.]

I and Davis entered Czechoslovakian target yesterday morning and spent three hours with Dr. Patzochke, German director of the mines.

There has been intensive exploratory and development work at two out of three mines directed at increasing the production of uranium, bismuth, cobalt and nickel. The shaft of one mine has been extended to about twice its original depth, and a new underground shaft has been added to the other mine. Plans for sinking a shaft on a new site are prepared.

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A WWII smuggler helped Cambridge get its new ice rink. *Cambridge News.* 7 November 2017. [https://www.cambridge-news.co.uk/news/wwii-smuggler-helped-cambridge-new-13863896]

[...] David Gattiker, who studied chemistry from 1929 to 1931, bequeathed £1 million to the university to build a permanent ice hockey facility in the city. [...]

During the Second World War, Gattiker was involved in smuggling uranium ore out of Germany, as recounted in his book 'The Uranium Trail', which he wrote under a pseudonym.

He moved to Canada after the war and became an agricultural chemist. [...]

Cordell Richardson [David Gattiker]. 1977. *Uranium Trail East* pp. 8, 104.

Some names have been altered where otherwise embarrassment might occur. [...]

Dr. Fischer [Patzochke] was surprised to see that his visitors were British and American officers. “Gentlemen, I am delighted to see you. I was expecting the Russians. They are reported to be already at Carlsbad, only ten miles south. Does your presence mean that the Sudetenland and my mine will come under British and American control?” His eyes were bright at the thought. [...]

“During the war the mine has produced to capacity,” he explained with pride, “nearly fifteen grams of radium, a record. It was all sent to Germany. And it is interesting to note that the Germans suddenly wanted the uranium waste product as well! For the first time! Nearly 500 tons but I don’t know what for...”

Vladimir L. Rychly. Czechoslovakia—Jachymov Uranium Mines—General Information. 5 December 1946. [NARA RG 38, Entry 98C, Box 12, Folder TSC # 3301–3400]

Czechoslovak miners, formerly employed in the Pribram area, and now resettled with their families at Jachymov, Czechoslovakia, furnished the following general information on the pitchblende deposits in Jachymov: [...]

There are three individual uranium mines at Jachymov. [...]

(a) “Werner” Mine is located about 2 km northeast of Jachymov. The “Werner” mine contains two vertical shafts which at present are in full operation. During the German occupation of Czechoslovakia, the Germans continued operations in this mine to the very last moment.

(b) “Stalin” Mine (formerly “Rovnost” Mine) is located in the southwest outskirts of Jachymov. This mine, now in operation, has only one entrance for both miners and bogietrucks.

(c) “Svornost” Mine is located in the northern section of the city of Jachymov. During the German occupation of Czechoslovakia, the Germans abandoned this mine and claimed it was unproductive. However, the Svornost mine kept on supplying most of Jachymov’s Health Institutions with radioactive water at a depth of 530 meters—radioactivity of 500 Mache units with temperature of 28^{o}C. It might be for this reason that the Soviet geologists are so keenly interested in starting operation in this mine. The difficulties encountered by the Soviets are greater than expected as most tunnels are flooded. [...]

[See document photos on pp. 4982–4984.]

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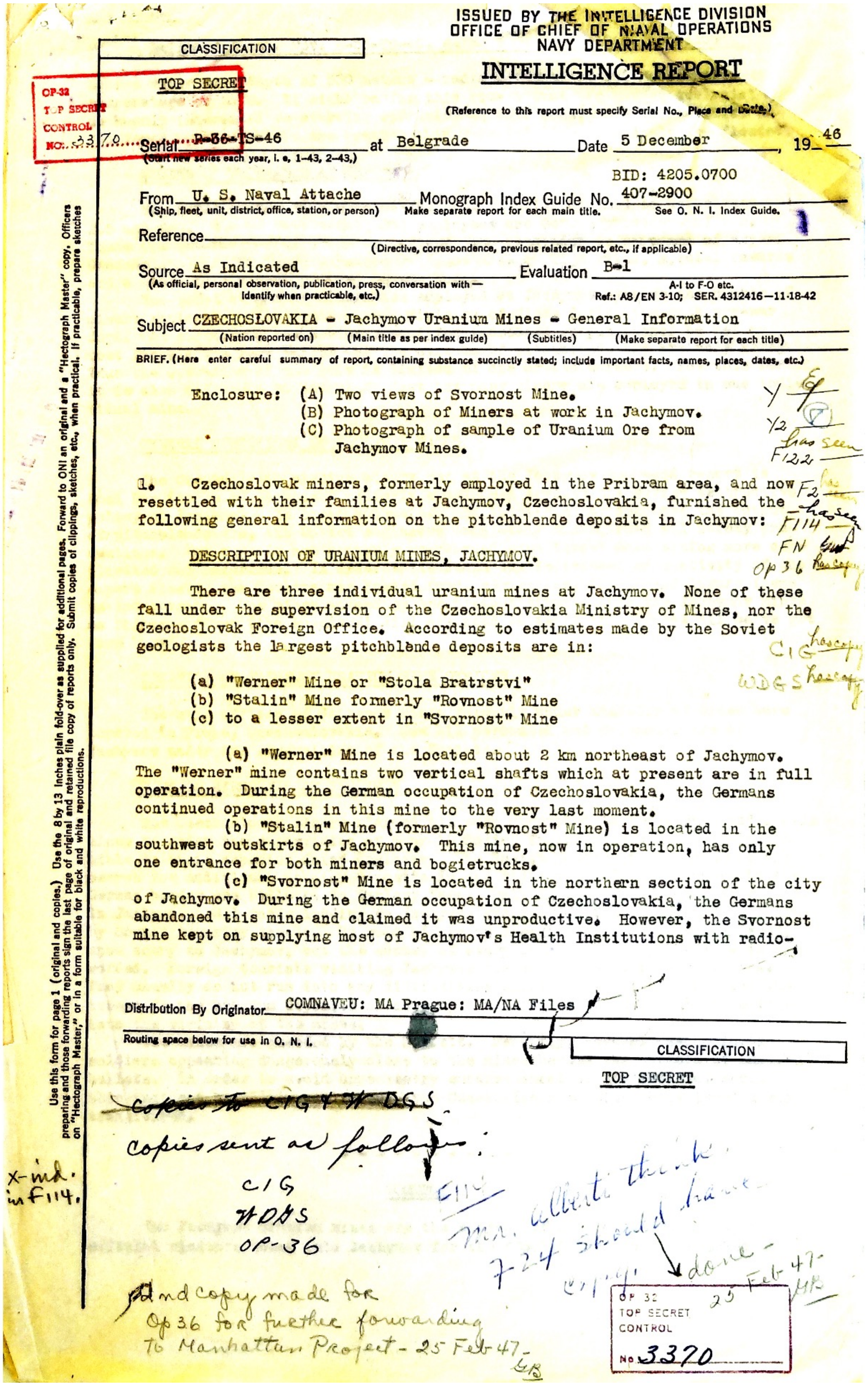

ISSUED BY THE INTELLIGENCE DIVISION
OFFICE OF CHIEF OF NAVAL OPERATIONS
NAVY DEPARTMENT

INTELLIGENCE REPORT

CLASSIFICATION
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OP-32
TOP SECRET
CONTROL
NO. 3370

(Reference to this report must specify Serial No., Place and Date.)

Serial R-36-TS-46 at Belgrade Date 5 December, 1946
(Start new series each year, i. e, 1-43, 2-43,)

BID: 4205.0700

From U. S. Naval Attache Monograph Index Guide No. 407-2900
(Ship, fleet, unit, district, office, station, or person) Make separate report for each main title. See O. N. I. Index Guide.

Reference
(Directive, correspondence, previous related report, etc., if applicable)

Source As Indicated Evaluation B-1
(As official, personal observation, publication, press, conversation with—identify when practicable, etc.) A-I to F-O etc. Ref.: A8/EN 3-10; SER. 4312416—11-18-42

Subject CZECHOSLOVAKIA - Jachymov Uranium Mines - General Information
(Nation reported on) (Main title as per index guide) (Subtitles) (Make separate report for each title)

BRIEF. (Here enter careful summary of report, containing substance succinctly stated; include important facts, names, places, dates, etc.)

Enclosure: (A) Two views of Svornost Mine.
(B) Photograph of Miners at work in Jachymov.
(C) Photograph of sample of Uranium Ore from Jachymov Mines.

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F2 has seen
F114 has seen
FN
Op 36 has copy
CIG has copy
WDGS has copy

1. Czechoslovak miners, formerly employed in the Pribram area, and now resettled with their families at Jachymov, Czechoslovakia, furnished the following general information on the pitchblende deposits in Jachymov:

DESCRIPTION OF URANIUM MINES, JACHYMOV.

There are three individual uranium mines at Jachymov. None of these fall under the supervision of the Czechoslovakia Ministry of Mines, nor the Czechoslovak Foreign Office. According to estimates made by the Soviet geologists the largest pitchblende deposits are in:

(a) "Werner" Mine or "Stola Bratrstvi"
(b) "Stalin" Mine formerly "Rovnost" Mine
(c) to a lesser extent in "Svornost" Mine

(a) "Werner" Mine is located about 2 km northeast of Jachymov. The "Werner" mine contains two vertical shafts which at present are in full operation. During the German occupation of Czechoslovakia, the Germans continued operations in this mine to the very last moment.

(b) "Stalin" Mine (formerly "Rovnost" Mine) is located in the southwest outskirts of Jachymov. This mine, now in operation, has only one entrance for both miners and bogietrucks.

(c) "Svornost" Mine is located in the northern section of the city of Jachymov. During the German occupation of Czechoslovakia, the Germans abandoned this mine and claimed it was unproductive. However, the Svornost mine kept on supplying most of Jachymov's Health Institutions with radio-

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OP 32
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No. 3370

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NARA RG 38, Entry 98C, Box 12, Folder TSC # 3301-3400

Figure D.973: Vladimir L. Rychly. Czechoslovakia—Jachymov Uranium Mines—General Information. 5 December 1946. [NARA RG 38, Entry 98C, Box 12, Folder TSC # 3301–3400]

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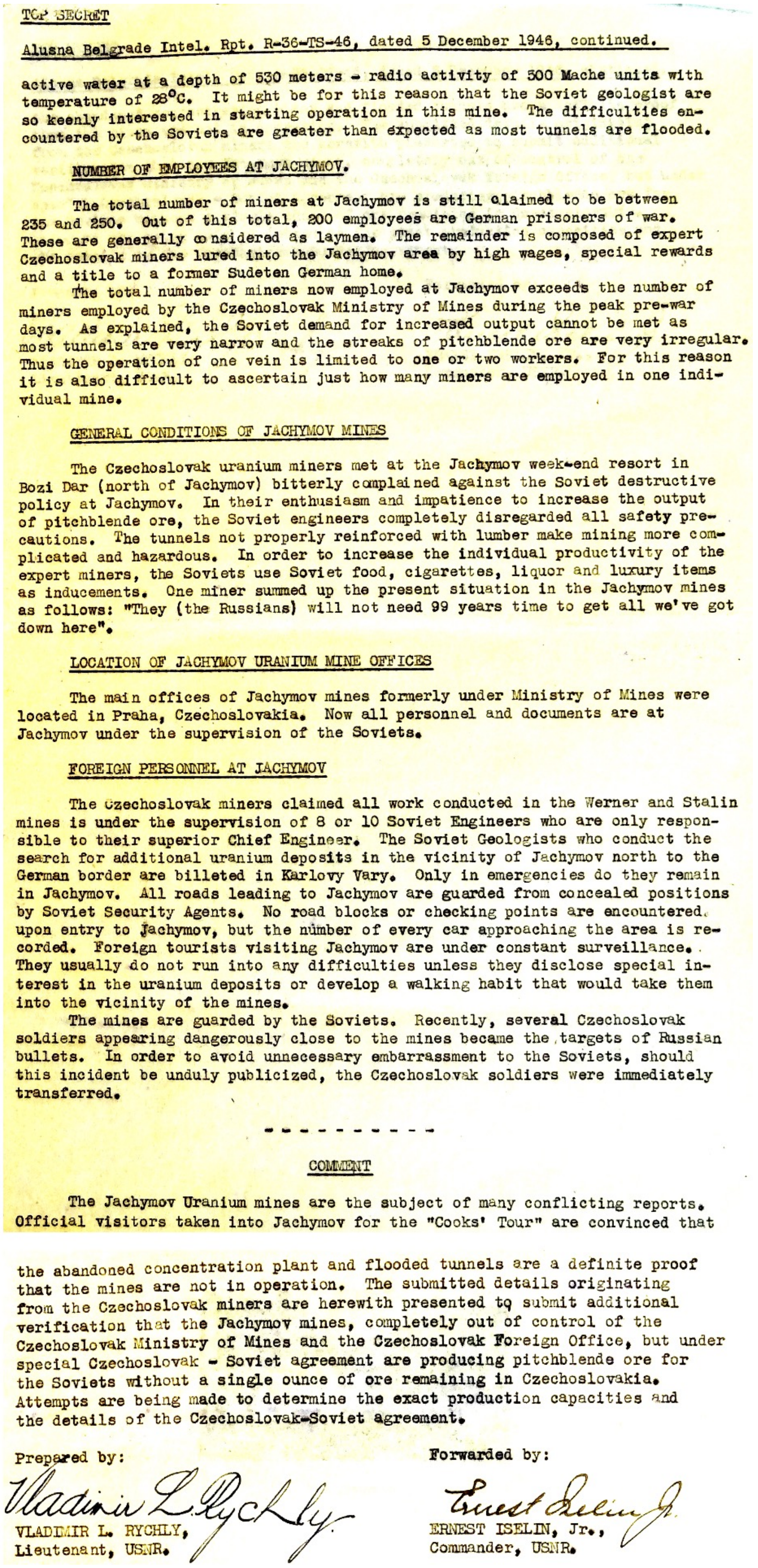

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Alusna Belgrade Intel. Rpt. R-36-TS-46, dated 5 December 1946, continued.

active water at a depth of 530 meters - radio activity of 500 Mache units with temperature of 28°C. It might be for this reason that the Soviet geologist are so keenly interested in starting operation in this mine. The difficulties encountered by the Soviets are greater than expected as most tunnels are flooded.

NUMBER OF EMPLOYEES AT JACHYMOV.

The total number of miners at Jachymov is still claimed to be between 235 and 250. Out of this total, 200 employees are German prisoners of war. These are generally considered as laymen. The remainder is composed of expert Czechoslovak miners lured into the Jachymov area by high wages, special rewards and a title to a former Sudeten German home.

The total number of miners now employed at Jachymov exceeds the number of miners employed by the Czechoslovak Ministry of Mines during the peak pre-war days. As explained, the Soviet demand for increased output cannot be met as most tunnels are very narrow and the streaks of pitchblende ore are very irregular. Thus the operation of one vein is limited to one or two workers. For this reason it is also difficult to ascertain just how many miners are employed in one individual mine.

GENERAL CONDITIONS OF JACHYMOV MINES

The Czechoslovak uranium miners met at the Jachymov week-end resort in Bozi Dar (north of Jachymov) bitterly complained against the Soviet destructive policy at Jachymov. In their enthusiasm and impatience to increase the output of pitchblende ore, the Soviet engineers completely disregarded all safety precautions. The tunnels not properly reinforced with lumber make mining more complicated and hazardous. In order to increase the individual productivity of the expert miners, the Soviets use Soviet food, cigarettes, liquor and luxury items as inducements. One miner summed up the present situation in the Jachymov mines as follows: "They (the Russians) will not need 99 years time to get all we've got down here".

LOCATION OF JACHYMOV URANIUM MINE OFFICES

The main offices of Jachymov mines formerly under Ministry of Mines were located in Praha, Czechoslovakia. Now all personnel and documents are at Jachymov under the supervision of the Soviets.

FOREIGN PERSONNEL AT JACHYMOV

The Czechoslovak miners claimed all work conducted in the Werner and Stalin mines is under the supervision of 8 or 10 Soviet Engineers who are only responsible to their superior Chief Engineer. The Soviet Geologists who conduct the search for additional uranium deposits in the vicinity of Jachymov north to the German border are billeted in Karlovy Vary. Only in emergencies do they remain in Jachymov. All roads leading to Jachymov are guarded from concealed positions by Soviet Security Agents. No road blocks or checking points are encountered upon entry to Jachymov, but the number of every car approaching the area is recorded. Foreign tourists visiting Jachymov are under constant surveillance. They usually do not run into any difficulties unless they disclose special interest in the uranium deposits or develop a walking habit that would take them into the vicinity of the mines.

The mines are guarded by the Soviets. Recently, several Czechoslovak soldiers appearing dangerously close to the mines became the targets of Russian bullets. In order to avoid unnecessary embarrassment to the Soviets, should this incident be unduly publicized, the Czechoslovak soldiers were immediately transferred.

- - - - - - - - - -

COMMENT

The Jachymov Uranium mines are the subject of many conflicting reports. Official visitors taken into Jachymov for the "Cooks' Tour" are convinced that the abandoned concentration plant and flooded tunnels are a definite proof that the mines are not in operation. The submitted details originating from the Czechoslovak miners are herewith presented to submit additional verification that the Jachymov mines, completely out of control of the Czechoslovak Ministry of Mines and the Czechoslovak Foreign Office, but under special Czechoslovak - Soviet agreement are producing pitchblende ore for the Soviets without a single ounce of ore remaining in Czechoslovakia. Attempts are being made to determine the exact production capacities and the details of the Czechoslovak-Soviet agreement.

Prepared by:
Vladimir L. Rychly
VLADIMIR L. RYCHLY,
Lieutenant, USNR.

Forwarded by:
Ernest Iselin Jr.
ERNEST ISELIN, Jr.,
Commander, USNR.

NARA RG 38, Entry 98C,
Box 12, Folder TSC # 3301-3400

Figure D.974: Vladimir L. Rychly. Czechoslovakia—Jachymov Uranium Mines—General Information. 5 December 1946. [NARA RG 38, Entry 98C, Box 12, Folder TSC # 3301–3400]

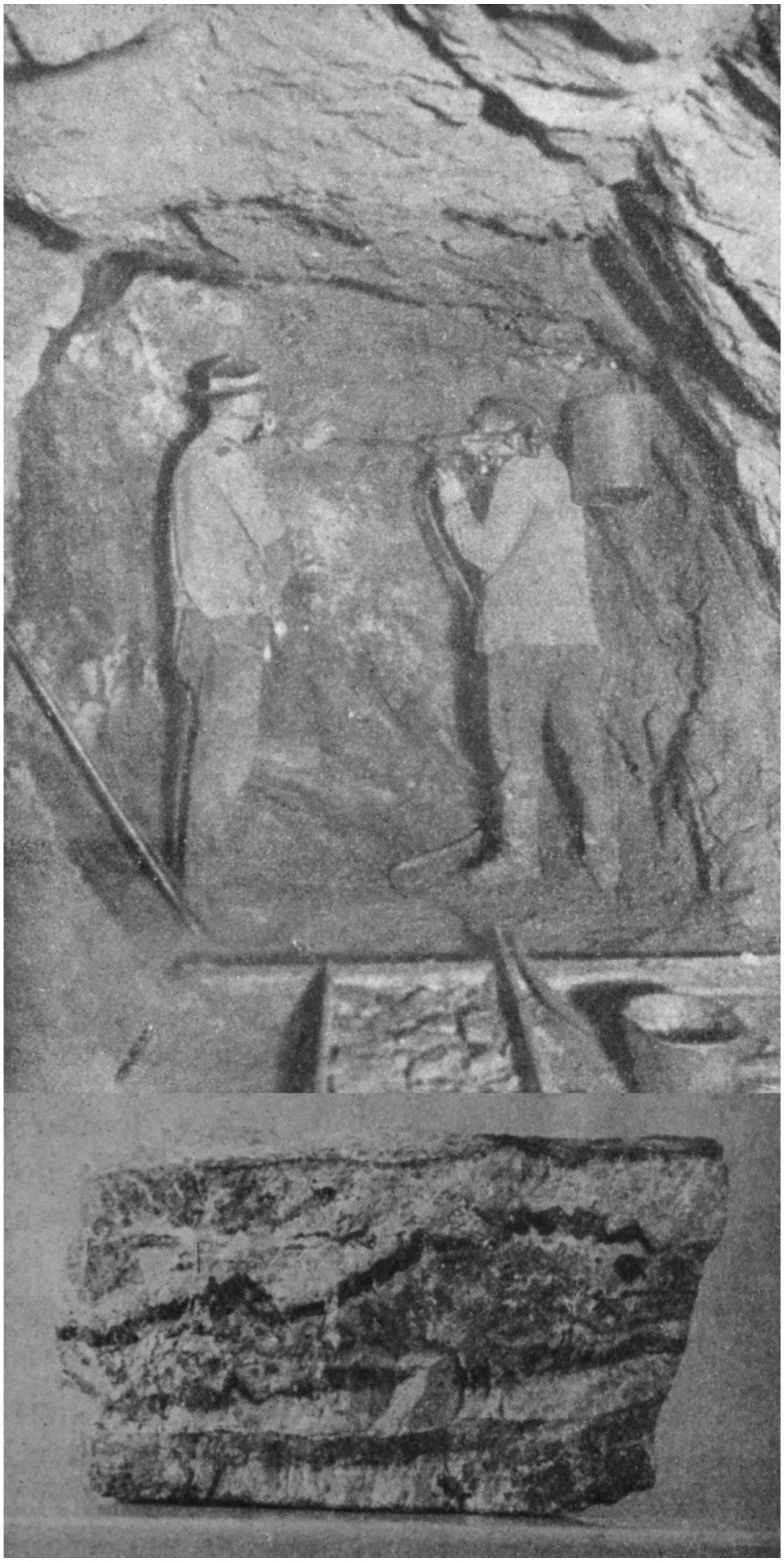
Joachimsthal or Jáchymov uranium mine
Uranium ore from Jáchymov mine
NARA RG 38, Entry 98C, Box 12, Folder TSC # 3301–3400, Vladimir L. Rychly, 5 December 1946

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Figure D.975: Joachimsthal or Jáchymov uranium mine and uranium ore circa 1945. [NARA RG 38, Entry 98C, Box 12, Folder TSC # 3301–3400. Vladimir L. Rychly, 5 December 1946]

Underground Factories in Europe [AFHRA C5098 frames 0931–0932]

Underground Factories in Europe

Commanding General, Air Material Command, Wright Field, Dayton, Ohio. Attn: TSDIN

1. In compliance with Restricted letter, Subj: Request for Information on German Underground Plants, dated 19 Oct 1945 (Incl. 1), a report has been prepared entitled "Preliminary Report on Underground Factories and Facilities in Germany and Austria" (Incl. 2).

2. The completed survey disclosed a considerably larger number of German underground factories than had hitherto been suspected. In addition to Germany and Austria, the Germans built underground factories in France, Italy, Hungary and Czechoslovakia. Although the Germans did not go underground on a large scale until March, 1944, they managed to get approximately one-hundred and forty three (143) underground factories into production by the last few months of the war. Statistics are as follows:

a. Number of factories in production by the end of the war......................	143	
b. Number of factories being built, being excavated, and planned............	107	
c. Number of factories reported, and potential sites (mines and caves).....	600	
Grand Total......	860	[850?]

3. In summarizing the results of the survey three facts are outstanding:

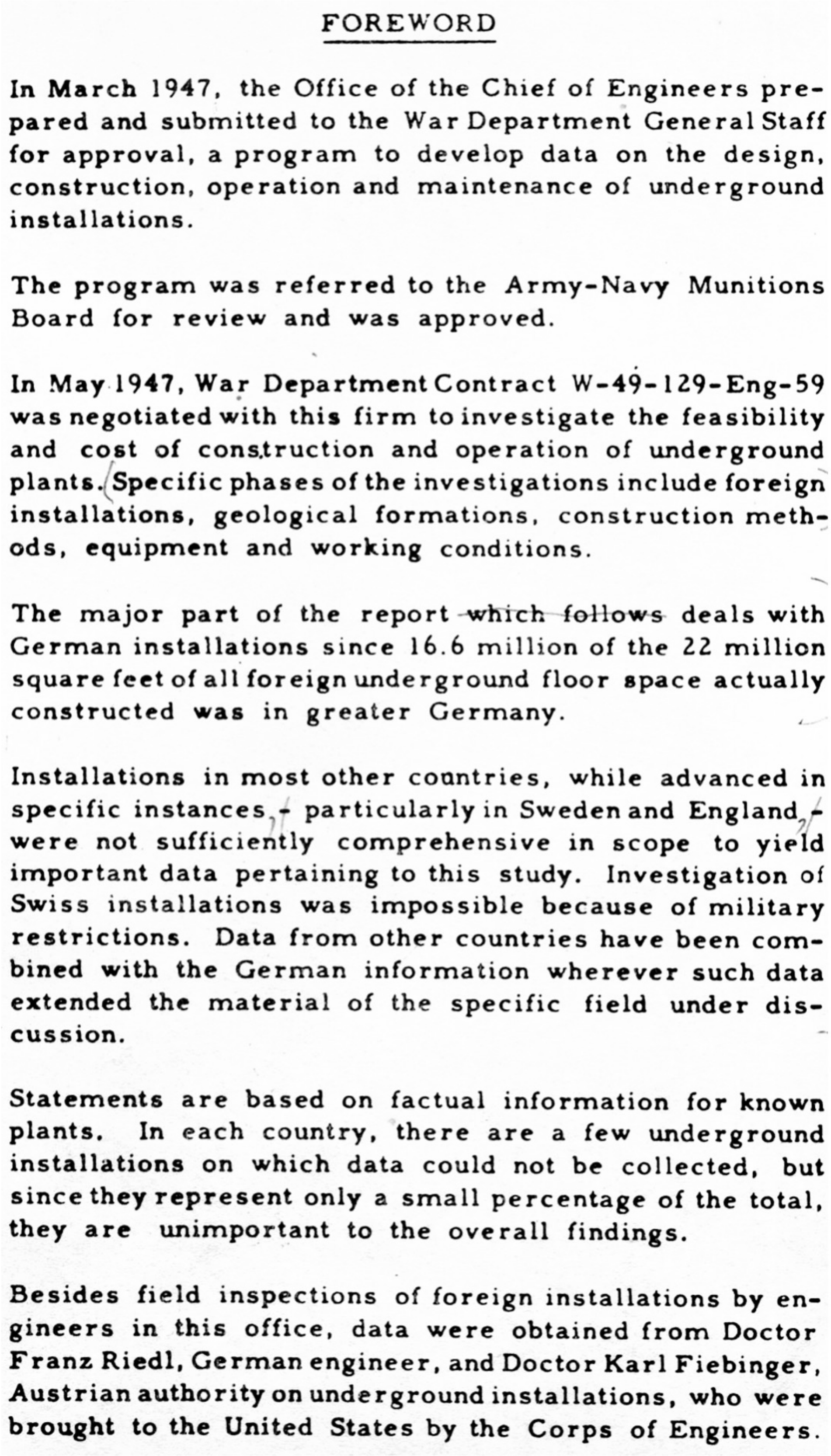
a. The tremendous advantages of placing factories under ground are concealment and protection. Of these two concealment is at least of equal importance as protection, since more underground factories remained undetected during the war than were discovered prior to the termination of hostilities. This is especially true of those located in old mines and natural caves where the presence of the mine or cave was not known to the Allies.

b. Self-contained underground factories are practical for any industry with the possible exception of those classified as heavy industries. All technical problems, mainly ventilation and air conditioning, appear to have been solved by the Germans by the end of the war.

c. The Germans initiated the movement of industry under ground so late that the program did not have an opportunity to seriously affect the outcome of the war. It is a matter of conjecture as to what would have occurred if the Germans had gone under ground before the beginning of the war.

[Where are detailed reports on what was in all of these facilities?

How much work in these facilities was buried, overlooked, and forgotten?]



FOREWORD

In March 1947, the Office of the Chief of Engineers prepared and submitted to the War Department General Staff for approval, a program to develop data on the design, construction, operation and maintenance of underground installations.

The program was referred to the Army-Navy Munitions Board for review and was approved.

In May 1947, War Department Contract W-49-129-Eng-59 was negotiated with this firm to investigate the feasibility and cost of construction and operation of underground plants. Specific phases of the investigations include foreign installations, geological formations, construction methods, equipment and working conditions.

The major part of the report ~~which follows~~ deals with German installations since 16.6 million of the 22 million square feet of all foreign underground floor space actually constructed was in greater Germany.

Installations in most other countries, while advanced in specific instances,- particularly in Sweden and England,- were not sufficiently comprehensive in scope to yield important data pertaining to this study. Investigation of Swiss installations was impossible because of military restrictions. Data from other countries have been combined with the German information wherever such data extended the material of the specific field under discussion.

Statements are based on factual information for known plants. In each country, there are a few underground installations on which data could not be collected, but since they represent only a small percentage of the total, they are unimportant to the overall findings.

Besides field inspections of foreign installations by engineers in this office, data were obtained from Doctor Franz Riedl, German engineer, and Doctor Karl Fiebinger, Austrian authority on underground installations, who were brought to the United States by the Corps of Engineers.

Figure D.976: Excerpts from a postwar report written with the assistance of Karl Fiebinger (p. 4993) and Franz Riedl. PB 123064. *Underground Installations: Foreign Installations.* 31 October 1948. U.S. Department of Commerce [Library of Congress].

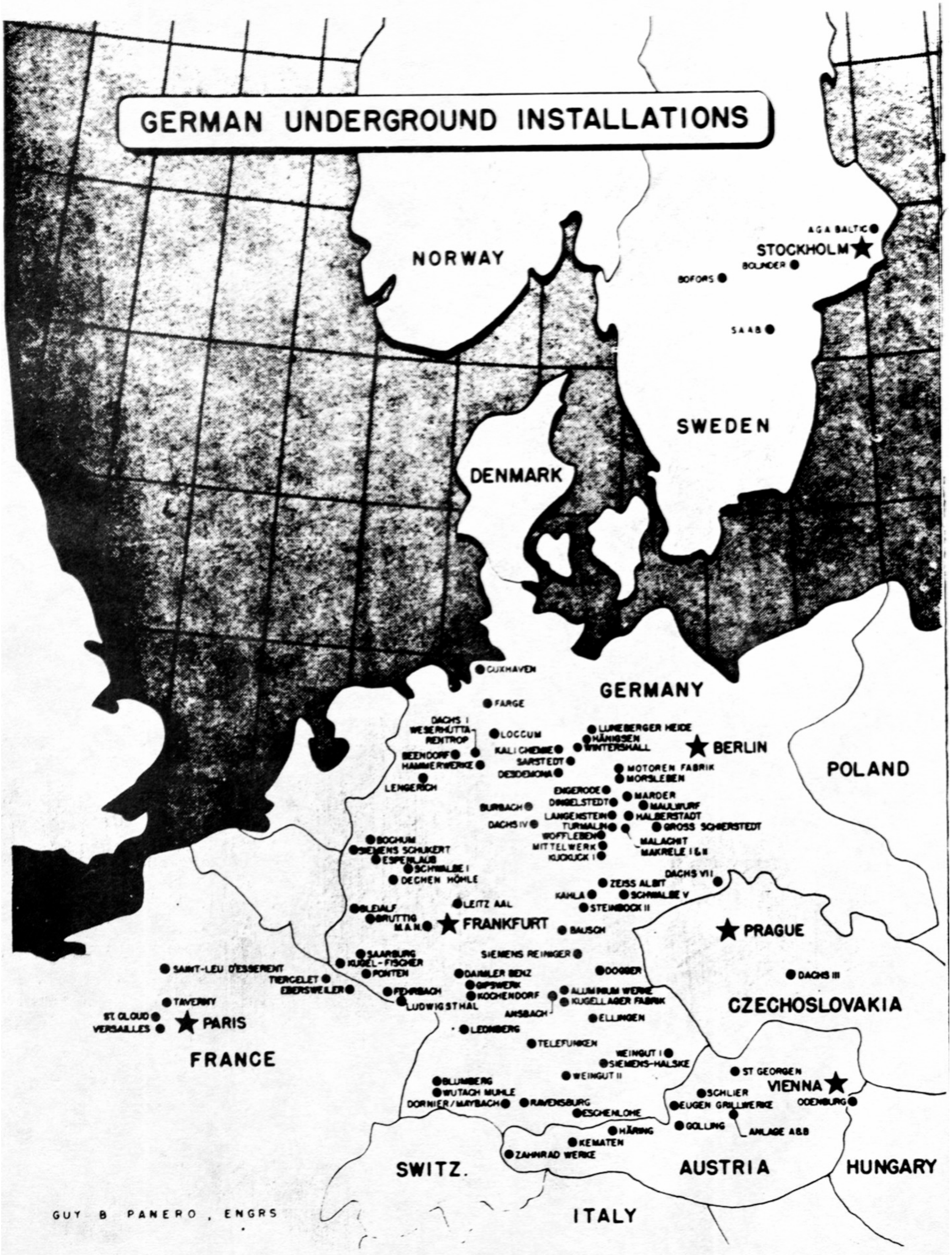
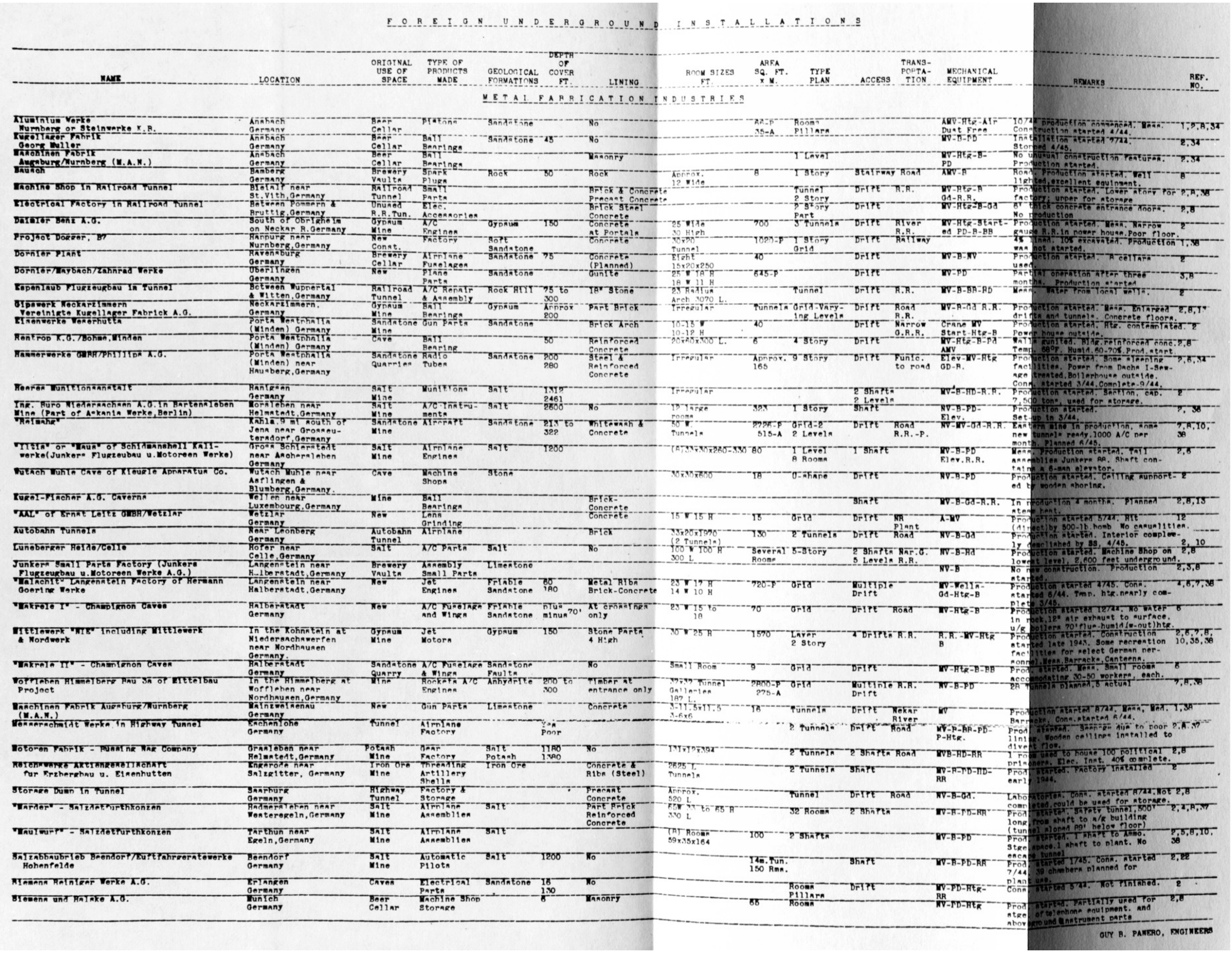

GERMAN UNDERGROUND INSTALLATIONS
NORWAY
SWEDEN
AGA BALTIC
STOCKHOLM
BOLINDER
BOFORS
SAAB
DENMARK
GERMANY
POLAND
CUXHAVEN
FARGE
DACHS I
WESERHÜTTA
RENTROP
LOCCUM
BEENDORF
HAMMERWERKE
LENGERICH
KALI CHEMIE
SARSTEDT
DESDEMONA
LUNEBERGER HEIDE
HÄNIGSEN
WINTERSHALL
BERLIN
MOTOREN FABRIK
MORSLEBEN
EINGERODE
DINGELSTEDT
LANGENSTEIN
TURMALIN
WOFFLEBEN
MITTELWERK
KUCKUCK I
MARDER
MAULWURF
HALBERSTADT
GROSS SCHIERSTEDT
MALACHIT
MAKRELE I & II
BURBACH
DACHS IV
BOCHUM
SIEMENS SCHUKERT
ESPENLAUB
SCHWALBE I
DECHEN HÖHLE
DACHS VII
ZEISS ALBIT
KAHLA
SCHWALBE V
STEINBOCK II
BLEIALF
BRUTTIG
M.A.N.
LEITZ AAL
FRANKFURT
BAUSCH
PRAGUE
SIEMENS REINIGER
SAARBURG
KUGEL-FISCHER
PONTEN
SAINT-LEU D'ESSERENT
TIERCELET
EBERSWEILER
TAVERNY
ST. CLOUD
VERSAILLES
PARIS
FRANCE
FEHRBACH
LUDWIGSTHAL
DAIMLER BENZ
GIPSWERK
KOCHENDORF
ANSBACH
DOGGER
ALUMINIUM WERKE
KUGELLAGER FABRIK
ELLINGEN
DACHS III
CZECHOSLOVAKIA
LEONBERG
TELEFUNKEN
WEINGUT I
SIEMENS-HALSKE
WEINGUT II
BLUMBERG
WUTACH MUHLE
DORNIER/MAYBACH
RAVENSBURG
ESCHENLOHE
HÄRING
KEMATEN
ZAHNRAD WERKE
ST GEORGEN
VIENNA
SCHLIER
EUGEN GRILLWERKE
GOLLING
ANLAGE A&B
ODENBURG
SWITZ.
AUSTRIA
HUNGARY
ITALY
GUY B PANERO, ENGRS

Figure D.977: This map and the following tables provide a small amount of information about a fraction of the underground installations that were in German-controlled territory, yet they are still quite enlightening. PB 123064. *Underground Installations: Foreign Installations.* 31 October 1948. U.S. Department of Commerce [Library of Congress].



F O R E I G N U N D E R G R O U N D I N S T A L L A T I O N S

NAME	LOCATION	ORIGINAL USE OF SPACE	TYPE OF PRODUCTS MADE	GEOLOGICAL FORMATIONS	DEPTH OF COVER FT.	LINING	ROOM SIZES FT.	AREA SQ. FT. x M.	TYPE PLAN	ACCESS	TRANS-PORTA-TION	MECHANICAL EQUIPMENT	REMARKS	REF. NO.
M E T A L F A B R I C A T I O N I N D U S T R I E S														
Aluminium Werke Nurnberg or Steinwerke K.B.	Ansbach Germany	Beer Cellar	Pistons	Sandstone		No		66-P 35-A	Rooms Pillars			AMV-Htg-Air Dust Free	10/44 production commenced. Mess. Construction started 4/44.	1,2,8,34
Kugellager Fabrik Georg Muller	Ansbach Germany	Beer Cellar	Ball Bearings	Sandstone	45	No						MV-B-PD	Installation started 7/44. Stopped 4/45.	2,34
Maschinen Fabrik Augsburg/Nurnberg (M.A.N.)	Ansbach Germany	Beer Cellar	Ball Bearings			Masonry			1 Level			MV-Htg-B-PD	No unusual construction features. Production started.	2,34
Bausch	Bamberg Germany	Brewery Vaults	Spark Plugs	Rock	50	Rock	Approx. 12 Wide	8	1 Story	Stairway	Road	AMV-B	Road. Production started. Well lighted, excellent equipment.	8
Machine Shop in Railroad Tunnel	Bleialf near St. Vith, Germany	Railroad Tunnel	Small Parts			Brick & Concrete Precast Concrete			Tunnel 2 Story	Drift	R.R.	MV-Htg-B Gd-R.R.	Production started. Lower story for factory; upper for storage	2,8,38
Electrical Factory in Railroad Tunnel	Between Pommern & Bruttig, Germany	Unused R.R.Tun.	Elec. Accessories			Brick Steel Concrete			2 Story Part	Drift		MV-Htg-B-Gd	8' thick concrete entrance doors. No production	2,8
Daimler Benz A.G.	South of Obrigheim on Neckar R. Germany	Gypsum Mine	A/C Engines	Gypsum	150	Concrete at Portals	25 Wide 30 High	700	3 Tunnels	Drift	River R.R.	MV-Htg-Started PD-B-BB	Production started. Mess. Narrow gauge R.R. in power house. Poor floor.	2
Project Dogger, B7	Happurg near Nurnberg, Germany	New Const.	Factory	Soft Sandstone		Concrete	30x20 Tunnel	1020-P	1 Story Grid	Drift	Railway		4% lined. 10% excavated. Production was not started.	1,38
Dornier Plant	Ravensburg Germany	Brewery Cellar	Airplane Fuselages	Sandstone	75	Concrete (Planned)	Eight 15x20x250	40		Drift		MV-B-NV	Production started. 8 cellars used.	2
Dornier/Maybach/Zahnrad Werke	Uberlingen Germany	New	Plane Parts	Sandstone		Gunite	25 W 18 H 18 W 11 H	645-P		Drift		MV-PD	Partial operation after three months. Production started	3,8
Espenlaub Flugzeugbau in Tunnel	Between Wuppertal & Witten, Germany	Railroad Tunnel	A/C Repair & Assembly	Rock Hill	75 to 300	18" Stone	23 Radius Arch 3070 L.		Tunnel	Drift	R.R.	MV-B-BB-RD	Mess. Water from local wells.	2
Gipswerk Neckarzimmern Vereinigte Kugellager Fabrick A.G.	Neckarzimmern, Germany	Gypsum Mine	Ball Bearings	Gypsum	Approx 200	Part Brick	Irregular	Tunnels	Grid-Varying Levels	Drift	Road R.R.	MV-B-Gd R.R.	Production started. Mess. Enlarged drifts and tunnels. Concrete floors.	2,8,17
Eisenwerke Weserhutte	Porta Westphalia (Minden) Germany	Sandstone Mine	Gun Parts	Sandstone		Brick Arch	10-15 W 10-12 H	40		Drift	Narrow G.R.R.	Crane MV Start-Htg-B	Production started. Htg. contemplated. Power house outside.	2
Rentrop K.G./Bohme, Minden	Porta Westphalia (Minden) Germany	Cave	Ball Bearing		50	Reinforced Concrete	20x60x300 L.	6	4 Story	Drift		MV-Htg-B-Pd AMV	Walls gunited. Bldg. reinforced conc. Temp. 68°F. Humid. 60-70%. Prod. start.	2,8
Hammerwerke GMBH/Phillips A.G.	Porta Westphalia (Minden) near Hausberg, Germany	Sandstone Quarries	Radio Tubes	Sandstone	200 280	Steel & Reinforced Concrete	Irregular	Approx. 165	9 Story	Drift	Funic. to road	Elev-MV-Htg GD-R.	Production started. Some sleeping facilities. Power from Dachs I-Sewage treated. Boilerhouse outside. Cons. started 3/44. Complete-9/44.	2,8,34
Heeres Munitionsanstalt	Hanigsen Germany	Salt Mine	Munitions	Salt	1312 2461		Irregular			2 Shafts 2 Levels		MV-B-HD-R.R.	Production started. Section, cap. 7,500 tons, used for storage.	2
Ing. Buro Niedersachsen A.G. in Bartensleben Mine (Part of Askania Werke, Berlin)	Morsleben near Helmstedt, Germany	Salt Mine	A/C Instruments	Salt	2600	No	12 large rooms	323	1 Story	Shaft		NV-B-PD-Elev.	Production started. Set-up in 3/44.	7, 38
"Reimahg"	Kahla, 9 mi south of Jena near Grosseutersdorf, Germany	Sandstone Mine	Aircraft	Sandstone	213 to 322	Whitewash & Concrete	50 W. Tunnels	2726-P 515-A	Grid-2 2 Levels	Drift	Road R.R.-P.	NV-MV-Gd-R.R.	Eastern mine in production, some new tunnels ready. 1000 A/C per month. Planned 6/45.	7,8,10, 38
"Iltis" or "Maus" of Schidmanshell Kaliwerke (Junkers Flugzeubau u. Motoreen Werke)	Gross Schierstedt near Aschersleben Germany	Salt Mine	Airplane Engines	Salt	1200		(8)33x30x260-330	80	1 Level 8 Rooms	1 Shaft		MV-B-PD Elev.R.R.	Mess. Production started. Tail assemblies Junkers 88. Shaft contains a 6-man elevator.	2,6
Wutach Muhle Cave of Kleugle Apparatus Co.	Wutach Muhle near Aaflingen & Blumberg, Germany.	Cave	Machine Shops	Stone			30x30x600	18	U-shape	Drift		NV-B-PD	Production started. Ceiling supported by wooden shoring.	2
Kugel-Fischer A.G. Caverns	Wellen near Luxembourg, Germany	Mine	Ball Bearings			Brick-Concrete				Shaft		MV-B-Gd-R.R.	In production 4 months. Planned steam heat.	2,8,13
"AAL" of Ernst Leitz GMBH/Wetzlar	Wetzlar Germany	New	Lens Grinding			Concrete	15 W 15 H	15	Grid	Drift	NR Plant	A-MV	Production started 5/44. Hit (direct) by 500-lb. bomb No casualities.	12
Autobahn Tunnels	Near Leonberg Germany	Autobahn Tunnel	Airplane			Brick	33x20x1970 (2 Tunnels)	130	2 Tunnels	Drift	Road	NV-B-Gd	Production started. Interior completely demolished by SS, 4/45.	2, 10
Luneberger Heide/Celle	Hofer near Celle, Germany	Salt	A/C Parts	Salt		No	100 W 100 H 300 L	Several Rooms	5-Story	2 Shafts 5 Levels	Nar.G. R.R.	NV-B-Hd	Production started. Machine Shop on lowest level, 2,600 feet underground.	2,8
Junkers Small Parts Factory (Junkers Flugzeugbau u. Motoreen Werke A.G.)	Langenstein near Halberstadt, Germany	Brewery Vaults	Assembly Small Parts	Limestone								NV-B	No new construction. Production started.	2,3,8
"Malachit" Langenstein Factory of Hermann Goering Werke	Langenstein near Halberstadt, Germany	New	Jet Engines	Friable Sandstone	60 180	Metal Ribs Brick-Concrete	23 W 17 H 14 W 10 H	720-P	Grid	Multiple Drift		MV-Wells-Gd-Htg-B	Production started 4/45. Cons. started 6/44. Temp. htg. nearly complete 3/45.	4,6,7,38
"Makrele I" - Champignon Caves	Halberstadt Germany	New	A/C Fuselage and Wings	Friable Sandstone	plus minus 70'	At crossings only	23 W 15 to 18	70	Grid	Drift	Road	MV-Htg-B	Production started 12/44. No water in rock, 12" air exhaust to surface. u/g boilers 70' flue-humid (w-out) htg.	6
Mittlewerk "NIE" including Mittlewerk & Nordwerk	In the Kohnstein at Niedersachswerfen near Nordhausen Germany.	Gypsum Mine	Jet Motors	Gypsum	150	Stone Parts 4 High	30 W 25 H	1570	Layer 2 Story	4 Drifts	R.R.	R.R.-MV-Htg B	Production started. Construction started late 1943. Some recreation facilities for select German personnel. Mess, Barracks, Canteens.	2,6,7,8, 10,35,38
"Makrele II" - Champignon Caves	Halberstadt Germany	Sandstone Quarry	A/C Fuselage & Wings	Sandstone Faults		No	Small Room	9	Grid	Drift		MV-Htg-B-BB	Prod. started. Mess. Small rooms accommodating 30-50 workers, each.	6
Woffleben Himmelberg Bau 3a of Mittelbau Project	In the Himmelberg at Woffleben near Nordhausen, Germany	Mine	Rockets A/C Engines	Anhydrite	200 to 300	Timber at entrance only	32x32 Tunnel Galleries 187 L.	2800-P 275-A	Grid	Multiple Drift	R.R.	NV-B-PD	28 Tunnels planned, 5 actual	7,8,38
Maschinen Fabrik Augsburg/Nurnberg (M.A.N.)	Mainzweisenau Germany	New	Gun Parts	Limestone		Concrete	3-11.5x11.5 3-6x6	18	Tunnels	Drift	Nekar River	MV	Production started 8/44. Mess, Med. Barracks. Cons. started 6/44.	1,38
Messerschmidt Werke in Highway Tunnel	Eschenlohe Germany	Tunnel	Airplane Factory		Yes Poor				2 Tunnels	Drift	Road	MV-P-BR-PD-P-Htg.	Prod. started. Seepage due to poor lining. Wooden ceilings installed to divert flow.	2,8,37
Motoren Fabrik - Bussing Nag Company	Grasleben near Helmstedt, Germany	Potash Mine	Gear Factory	Salt Potash	1180 1380	No	131x12x394		2 Tunnels	2 Shafts	Road	MVB-HD-RR	1 room used to house 100 political prisoners. Elec. Inst. 40% complete.	2,8
Reichswerke Aktiengesellschaft fur Erzbergbau u. Eisenhutten	Engerode near Salzgitter, Germany	Iron Ore Mine	Threading Artillery Shells	Iron Ore		Concrete & Ribs (Steel)	2625 L Tunnels		2 Tunnels	Shaft		MV-B-PD-HD-RR	Prod. started. Factory installed early 1944.	2
Storage Dump in Tunnel	Saarburg Germany	Highway Tunnel	Factory & Storage			Precast Concrete	Approx. 520 L		Tunnel	Drift	Road	NV-B-Gd.	Laboratories. Cons. started 8/44. Not completed, could be used for storage.	2,8
"Marder" - Salzdetfurthkonzen	Hadmersleben near Westeregeln, Germany	Salt Mine	Airplane Assemblies	Salt		Part Brick Reinforced Concrete	65W 33 to 65 H 330 L		32 Rooms	2 Shafts		MV-B-PD-RR	Prod. started. Safety tunnel, 500' long, from shaft to a/g building (tunnel sloped 89' below floor)	2,4,8,37
"Maulwurf" - Salzdetfurthkonzen	Tarthun near Egeln, Germany	Salt Mine	Airplane Assemblies	Salt			(8) Rooms 59x35x164	100	2 Shafts			MV-B-PD	Prod. started. 1 shaft to Ammo. Stge. space. 1 shaft to plant. No escape tunnel	2,5,8,10, 38
Salzabbaubrieb Beendorf/Luftfahrgeratewerke Hohenfelde	Beendorf Germany	Salt Mine	Automatic Pilots	Salt	1200	No		14m. Tun. 150 Rms.		Shaft		MV-B-PD-RR	Prod. started 1/45. Cons. started 7/44. 39 chambers planned for plant use.	2,22
Siemens Reiniger Werke A.G.	Erlangen Germany	Caves	Electrical Parts	Sandstone	16 130	No			Rooms Pillars	Drift		MV-PD-Htg-RR	Cons. started 5/44. Not finished.	2
Siemens und Halske A.G.	Munich Germany	Beer Cellar	Machine Shop Storage		8	Masonry		65	Rooms			NV-PD-Htg	Prod. started. Partially used for stge. of telephone equipment. and aboveground instrument parts	2,8

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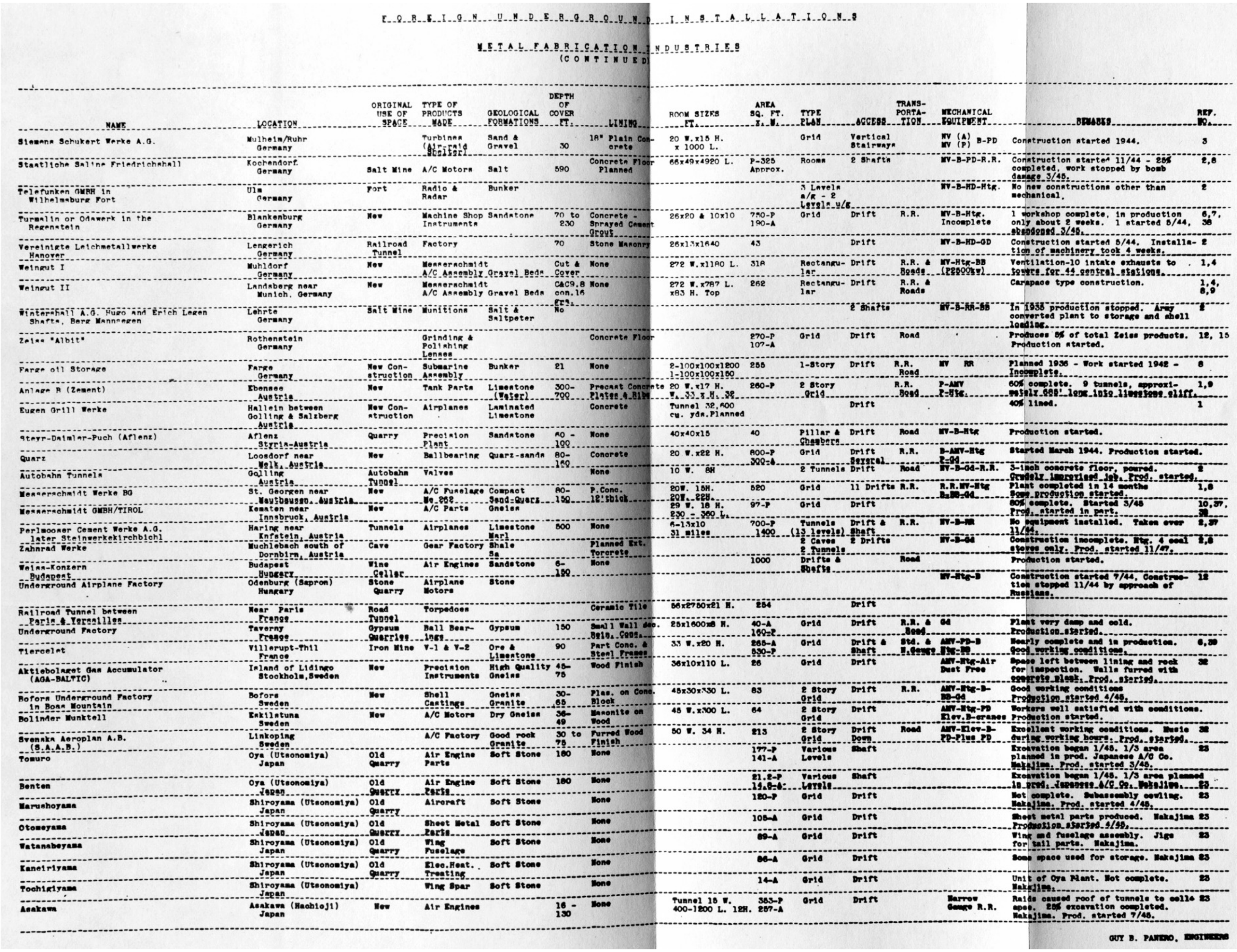
Figure D.978: PB 123064. *Underground Installations: Foreign Installations.* 31 October 1948. U.S. Department of Commerce [Library of Congress]. For Lüneburger Heide, see pp. 4176–4182, 4406, 4975.



FOREIGN UNDERGROUND INSTALLATIONS

METAL FABRICATION INDUSTRIES
(CONTINUED)

NAME	LOCATION	ORIGINAL USE OF SPACE	TYPE OF PRODUCTS MADE	GEOLOGICAL FORMATIONS	DEPTH OF COVER FT.	LINING	ROOM SIZES FT.	AREA SQ. FT. X. M.	TYPE PLAN	ACCESS	TRANS-PORTA-TION	MECHANICAL EQUIPMENT	REMARKS	REF. NO.
Siemens Schukert Werke A.G.	Mulheim/Ruhr Germany		Turbines (Air-raid Shelter)	Sand & Gravel	30	18" Plain Concrete	20 W.x15 H. x 1000 L.		Grid	Vertical Stairways		MV (A) MV (P) B-PD	Construction started 1944.	3
Staatliche Saline Friedrichshall	Kochendorf Germany	Salt Mine	A/C Motors	Salt	590	Concrete Floor Planned	66x49x4920 L.	P-325 Approx.	Rooms	2 Shafts		MV-B-PD-R.R.	Construction started 11/44 - 25% completed, work stopped by bomb damage 3/45.	2,8
Telefunken GMBH in Wilhelmsburg Fort	Ulm Germany	Fort	Radio & Radar	Bunker					3 Levels a/g - 2 Levels u/g			MV-B-HD-Htg.	No new constructions other than mechanical.	2
Turmalin or Odawerk in the Regenstein	Blankenburg Germany	New	Machine Shop Instruments	Sandstone	70 to 230	Concrete - Sprayed Cement Grout	26x20 & 10x10	750-P 190-A	Grid	Drift	R.R.	MV-B-Htg. Incomplete	1 workshop complete, in production only about 2 weeks. 1 started 5/44, abandoned 3/45.	6,7, 38
Vereinigte Leichmetallwerke Hanover	Lengerich Germany	Railroad Tunnel	Factory		70	Stone Masonry	26x13x1640	43		Drift		MV-B-HD-GD	Construction started 5/44. Installation of machinery took 4 weeks.	2
Weingut I	Muhldorf Germany	New	Messerschmidt A/C Assembly	Gravel Beds	Cut & Cover	None	272 W.x1180 L.	318	Rectangular	Drift	R.R. & Roads	MV-Htg-BB (P2500kw)	Ventilation-10 intake exhausts to towers for 44 central stations.	1,4
Weingut II	Landsberg near Munich, Germany	New	Messerschmidt A/C Assembly	Gravel Beds	C&C9.8 con.16 grs.	None	272 W.x787 L. x83 H. Top	262	Rectangular	Drift	R.R. & Roads		Carapace type construction.	1,4, 8,9
Wintershall A.G. Hugo and Erich Legen Shafts, Berg Mannsegen	Lehrte Germany	Salt Mine	Munitions	Salt & Saltpeter	No					2 Shafts		MV-B-RR-BB	In 1935 production stopped. Army converted plant to storage and shell loading.	2
Zeiss "Albit"	Rothenstein Germany		Grinding & Polishing Lenses			Concrete Floor		270-P 107-A	Grid	Drift	Road		Produces 5% of total Zeiss products. Production started.	12, 15
Farge oil Storage	Farge Germany	New Construction	Submarine Assembly	Bunker	21	None	2-100x100x1200 1-100x100x150	255	1-Story	Drift	R.R. Road	MV RR	Planned 1936 - Work started 1942 - Incomplete.	8
Anlage B (Zement)	Ebensee Austria	New	Tank Parts	Limestone (Water)	300-700	Precast Concrete Plates & Ribs	20 W.x17 H. W. 33 x H. 32	260-P	2 Story Grid		R.R. Road	P-AMV P-Htg.	60% complete. 9 tunnels, approximately 685' long into limestone cliff.	1,9
Eugen Grill Werke	Hallein between Golling & Salzberg Austria	New Construction	Airplanes	Laminated Limestone		Concrete	Tunnel 32,600 cu. yds. Planned			Drift			40% lined.	1
Steyr-Daimler-Puch (Aflenz)	Aflenz Styria-Austria	Quarry	Precision Plant	Sandstone	60 - 100	None	40x40x15	40	Pillar & Chambers	Drift	Road	MV-B-Htg	Production started.	
Quarz	Loosdorf near Melk, Austria	New	Ballbearing	Quarz-sands	80-150	Concrete	20 W.x22 H.	800-P 300-A	Grid	Drift Several	R.R.	B-AMV-Htg P-Gd	Started March 1944. Production started.	
Autobahn Tunnels	Golling Austria	Autobahn Tunnel	Valves			None	10 W. 8H		2 Tunnels	Drift	Road	MV-B-Gd-R.R.	3-inch concrete floor, poured. Crudely improvised job. Prod. started.	2
Messerschmidt Werke BG	St. Georgen near Mauthausen, Austria	New	A/C Fuselage Me 262	Compact Sand-Quarz	80-150	P.Conc. 12' thick	20W. 15H. 20W. 22H.	520	Grid	11 Drifts	R.R.	R.R.MV-Htg B-BB-Gd	Plant completed in 14 months Some production started.	1,8
Messerschmidt GMBH/TIROL	Kematen near Innsbruck, Austria	New	A/C Parts	Gneiss			29 W. 18 H. 230 - 360 L.	97-P	Grid	Drift			80% complete. Started 3/45 Prod. started in part.	10,37, 38
Perlmooser Cement Werke A.G. later Steinwerkekirchbichl	Haring near Kufstein, Austria	Tunnels	Airplanes	Limestone Marl	500	None	6-13x10 31 miles	700-P 1400	Tunnels (13 levels)	Drift & Shaft	R.R.	MV-B-RR	No equipment installed. Taken over 11/44.	2,37
Zahnrad Werke	Muchlebach south of Dornbirn, Austria	Cave	Gear Factory	Shale Sa		Planned Ext. Torcrete			2 Caves 2 Tunnels	2 Drifts		MV-B-Gd	Construction incomplete. Htg. 4 coal stoves only. Prod. started 11/47.	2,8
Weiss-Konzern Budapest	Budapest Hungary	Wine Cellar	Air Engines	Sandstone	6-150	None		1000	Drifts & Shafts		Road		Production started.	
Underground Airplane Factory	Odenburg (Sapron) Hungary	Stone Quarry	Airplane Motors	Stone								MV-Htg-B	Construction started 7/44, Construction stopped 11/44 by approach of Russians.	12
Railroad Tunnel between Paris & Versailles	Near Paris France	Road Tunnel	Torpedoes			Ceramic Tile	56x2750x21 H.	254		Drift				
Underground Factory	Taverny France	Gypsum Quarries	Ball Bearings	Gypsum	150	Small Wall dec. Rein. Conc.	25x1600x8 H.	40-A 160-P	Grid	Drift	R.R. & Road	Gd	Plant very damp and cold. Production started.	
Tiercelet	Villerupt-Thil France	Iron Mine	V-1 & V-2	Ore & Limestone	90	Part Conc. & Steel Frames	33 W.x20 H.	265-A 530-P	Grid	Drift & Shaft	Std. & N.Gauge	AMV-PD-B Htg-BB	Nearly complete and in production. Good working conditions.	6,38
Aktiebolaget Gas Accumulator (AGA-BALTIC)	Island of Lidingo Stockholm,Sweden	New	Precision Instruments	High Quality Gneiss	45-75	Wood Finish	36x10x110 L.	26	Grid	Drift		AMV-Htg-Air Dust Free	Space left between lining and rock for inspection. Walls furred with concrete plank. Prod. started.	32
Bofors Underground Factory in Boas Mountain	Bofors Sweden	New	Shell Castings	Gneiss Granite	30-65	Plas. on Conc. Block	45x30x330 L.	83	2 Story Grid	Drift	R.R.	AMV-Htg-B-BB-Gd	Good working conditions Production started 4/45.	
Bolinder Munktell	Eskilstuna Sweden	New	A/C Motors	Dry Gneiss	36-49	Masonite on Wood	45 W.x300 L.	64	2 Story Grid	Drift		AMV-Htg-PD Elev.B-cranes	Workers well satisfied with conditions. Production started.	
Svenska Aeroplan A.B. (S.A.A.B.)	Linkoping Sweden		A/C Factory	Good rock Granite	30 to 75	Furred Wood Finish	50 W. 34 H.	213	2 Story Grid	Drift Down	Road	AMV-Elev-B-PD-Plus PD	Excellent working conditions. Music during working hours. Prod. started.	32
Tomuro	Oya (Utsonomiya) Japan	Old Quarry	Air Engine Parts	Soft Stone	180	None		177-P 141-A	Various Levels	Shaft			Excavation began 1/45. 1/3 area planned in prod. Japanese A/C Co. Nakajima. Prod. started 3/45.	23
Benten	Oya (Utsonomiya) Japan	Old Quarry	Air Engine Parts	Soft Stone	180	None		21.2-P 14.8-A	Various Levels	Shaft			Excavation began 1/45. 1/3 area planned in prod. Japanese A/C Co. Nakajima.	23
Marushoyama	Shiroyama (Utsonomiya) Japan	Old Quarry	Aircraft	Soft Stone		None		120-P	Grid	Drift			Not complete. Subassembly cowling. Nakajima. Prod. started 4/45.	23
Otomeyama	Shiroyama (Utsonomiya) Japan	Old Quarry	Sheet Metal Parts	Soft Stone		None		105-A	Grid	Drift			Sheet metal parts produced. Nakajima Production started 4/45.	23
Watanabeyama	Shiroyama (Utsonomiya) Japan	Old Quarry	Wing Fuselage	Soft Stone		None		89-A	Grid	Drift			Wing and fuselage assembly. Jigs for tail parts. Nakajima.	23
Kaneiriyama	Shiroyama (Utsonomiya) Japan	Old Quarry	Elec.Heat. Treating	Soft Stone		None		86-A	Grid	Drift			Some space used for storage. Nakajima	23
Tochigiyama	Shiroyama (Utsonomiya) Japan		Wing Spar	Soft Stone		None		14-A	Grid	Drift			Unit of Oya Plant. Not complete. Nakajima.	23
Asakawa	Asakawa (Hachioji) Japan	New	Air Engines		16 - 130	None	Tunnel 15 W. 400-1200 L. 12H.	353-P 257-A	Grid	Drift		Narrow Gauge R.R.	Raids caused roof of tunnels to collapse. 25% excavation completed. Nakajima. Prod. started 7/45.	23

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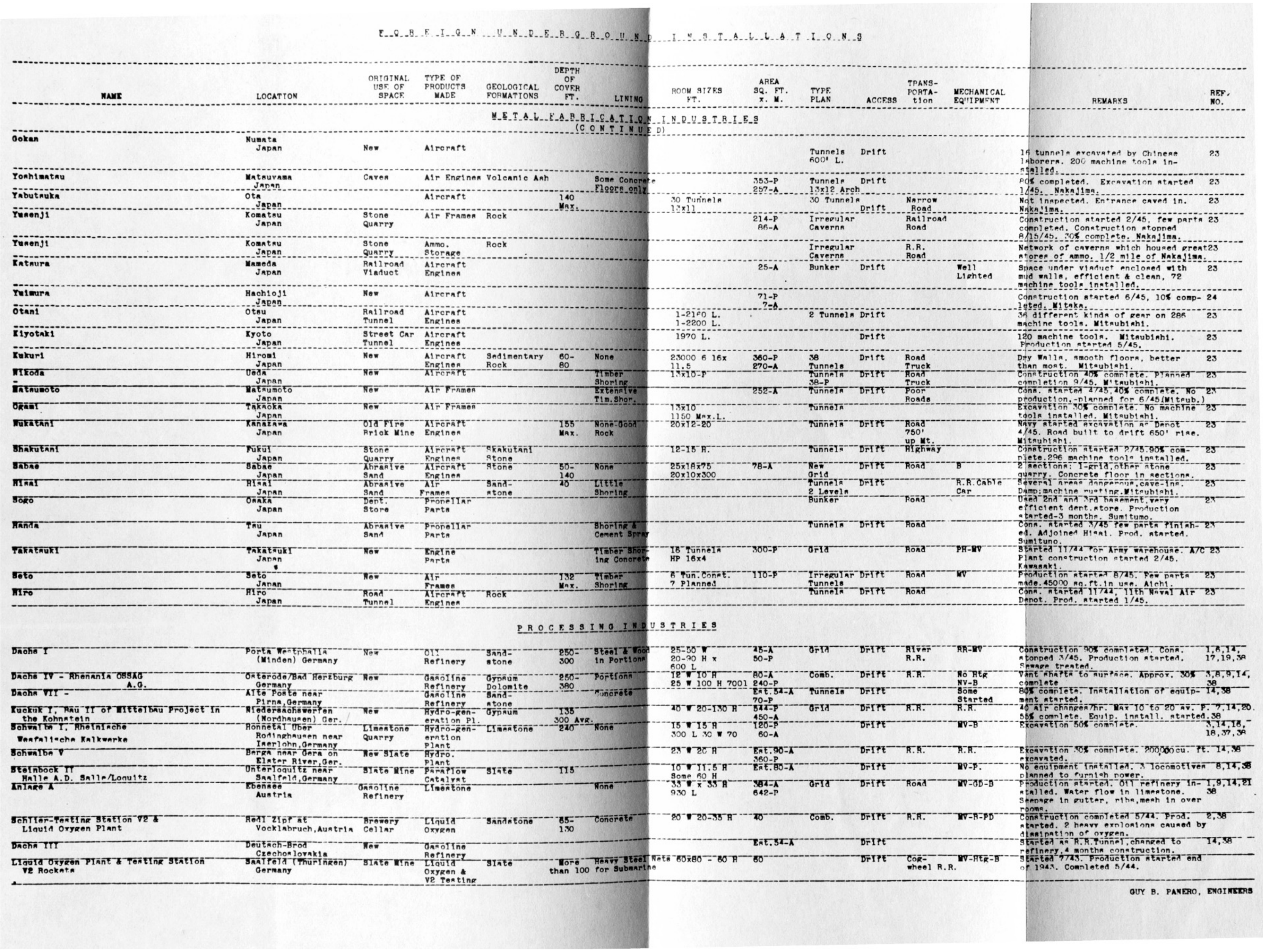
Figure D.979: PB 123064. *Underground Installations: Foreign Installations.* 31 October 1948. U.S. Department of Commerce [Library of Congress]. For Ödenburg/Sopron, Hungary, see p. 3747.

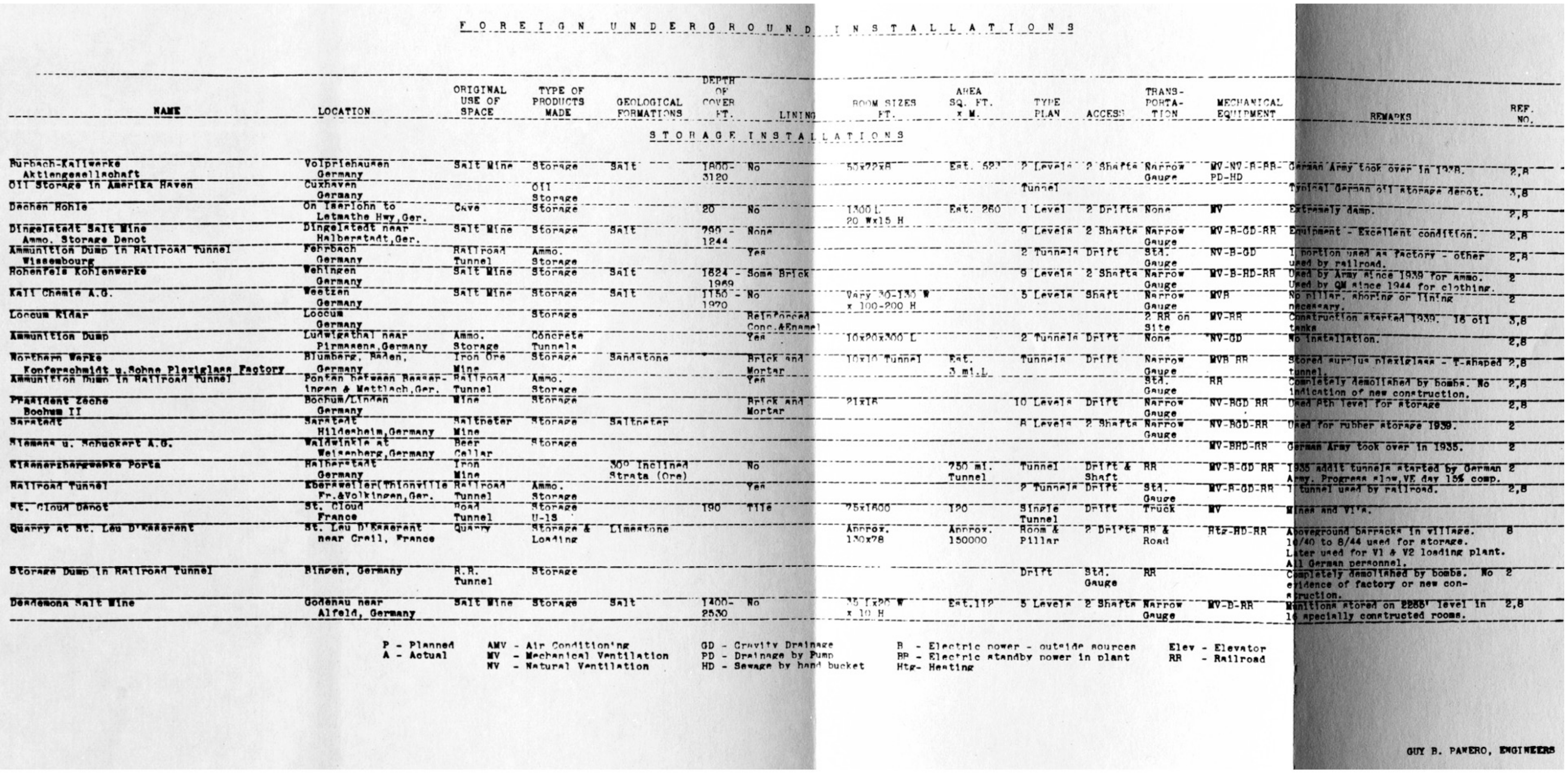


FOREIGN UNDERGROUND INSTALLATIONS

NAME	LOCATION	ORIGINAL USE OF SPACE	TYPE OF PRODUCTS MADE	GEOLOGICAL FORMATIONS	DEPTH OF COVER FT.	LINING	ROOM SIZES FT.	AREA SQ. FT. x. M.	TYPE PLAN	ACCESS	TRANS-PORTA-tion	MECHANICAL EQUIPMENT	REMARKS	REF. NO.
METAL FABRICATION INDUSTRIES (CONTINUED)														
Gokan	Numata Japan	New	Aircraft						Tunnels 600' L.	Drift			16 tunnels excavated by Chinese laborers. 200 machine tools installed.	23
Yoshimatsu	Matsuyama Japan	Caves	Air Engines	Volcanic Ash		Some Concrete Floors only		353-P 257-A	Tunnels 13x12 Arch	Drift			80% completed. Excavation started 1/45. Nakajima.	23
Yabutsuka	Ota Japan		Aircraft		140 Max.		30 Tunnels 13x11		30 Tunnels	Drift	Narrow Road		Not inspected. Entrance caved in. Nakajima.	23
Yusenji	Komatsu Japan	Stone Quarry	Air Frames	Rock				214-P 86-A	Irregular Caverns		Railroad Road		Construction started 2/45, few parts completed. Construction stopped 8/15/45. 30% complete. Nakajima.	23
Yusenji	Komatsu Japan	Stone Quarry	Ammo. Storage	Rock					Irregular Caverns		R.R. Road		Network of caverns which housed great stores of ammo. 1/2 mile of Nakajima.	23
Katsura	Mameda Japan	Railroad Viaduct	Aircraft Engines					25-A	Bunker	Drift		Well Lighted	Space under viaduct enclosed with mud walls, efficient & clean, 72 machine tools installed.	23
Yuimura	Hachioji Japan	New	Aircraft					71-P 7-A					Construction started 6/45, 10% completed. Mitaka.	24
Otani	Otsu Japan	Railroad Tunnel	Aircraft Engines				1-2160 L. 1-2200 L.		2 Tunnels	Drift			36 different kinds of gear on 286 machine tools. Mitsubishi.	23
Kiyotaki	Kyoto Japan	Street Car Tunnel	Aircraft Engines				1970 L.			Drift			120 machine tools. Mitsubishi. Production started 5/45.	23
Kukuri	Hiromi Japan	New	Aircraft Engines	Sedimentary Rock	60-80	None	23000 6 16x 11.5	360-P 270-A	38 Tunnels	Drift	Road Truck		Dry Walls, smooth floors, better than most. Mitsubishi.	23
Nikoda -	Ueda Japan	New	Aircraft			Timber Shoring	13x10-P		Tunnels 38-P	Drift	Road Truck		Construction 40% complete. Planned completion 9/45. Mitsubishi.	23
Matsumoto	Matsumoto Japan	New	Air Frames			Extensive Tim.Shor.		252-A	Tunnels	Drift	Poor Roads		Cons. started 4/45, 40% complete. No production,-planned for 6/45(Mitsub.)	23
Ogami	Takaoka Japan	New	Air Frames				13x10 1150 Max.L.		Tunnels				Excavation 30% complete. No machine tools installed. Mitsubishi.	23
Nukatani	Kanazawa Japan	Old Fire Brick Mine	Aircraft Engines		155 Max.	None-Good Rock	20x12-20		Tunnels	Drift	Road 750' up Mt.		Navy started excavation as Depot 4/45. Road built to drift 650' rise. Mitsubishi.	23
Shakutani	Fukui Japan	Stone Quarry	Aircraft Engines	Skakutani Stone			12-15 H.		Tunnels	Drift	Highway		Construction started 2/45.90% complete.296 machine tools installed.	23
Sabae	Sabae Japan	Abrasive Sand	Aircraft Engines	Stone	50-140	None	25x18x75 20x10x300	78-A	New Grid	Drift	Road	B	2 sections: 1-grid,other stone quarry. Concrete floor in sections.	23
Hisai	Hisai Japan	Abrasive Sand	Air Frames	Sand-stone	40	Little Shoring			Tunnels 2 Levels	Drift		R.R.Cable Car	Several areas dangerous,cave-ins. Damp:machine rusting.Mitsubishi.	23
Sogo	Osaka Japan	Dept. Store	Propellar Parts						Bunker		Road		Used 2nd and 3rd basement,very efficient dept.store. Production started-3 months. Sumitumo.	23
Handa	Tsu Japan	Abrasive Sand	Propellar Parts			Shoring & Cement Spray			Tunnels	Drift	Road		Cons. started 3/45 few parts finished. Adjoined Hisai. Prod. started. Sumituno.	23
Takatsuki	Takatsuki Japan	New	Engine Parts			Timber Shoring Concrete	16 Tunnels HP 16x4	300-P	Grid		Road	PH-MV	Started 11/44 for Army warehouse. A/C Plant construction started 2/45. Kawasaki.	23
Seto	Seto Japan	New	Air Frames		132 Max.	Timber Shoring	6 Tun.Const. 7 Planned	110-P	Irregular Tunnels	Drift	Road	MV	Production started 8/45. Few parts made.45000 sq.ft.in use. Aichi.	23
Hiro	Hiro Japan	Road Tunnel	Aircraft Engines	Rock					Tunnels	Drift	Road		Cons. started 11/44, 11th Naval Air Depot. Prod. started 1/45.	23
PROCESSING INDUSTRIES														
Dachs I	Porta Westphalia (Minden) Germany	New	Oil Refinery	Sand-stone	250-300	Steel & Wood in Portions	25-50 W 20-90 H x 600 L	45-A 50-P	Grid	Drift	River R.R.	RR-MV	Construction 90% completed. Cons. stopped 3/45. Production started. Sewage treated.	1,6,14, 17,19,38
Dachs IV - Rhenania OSSAG A.G.	Osterode/Bad Herzburg Germany	New	Gasoline Refinery	Gypsum Dolomite	250-380	Portions	12 W 10 H 25 W 100 H 7001	80-A 240-P	Comb.	Drift	R.R.	No Htg NV-B	Vent shafts to surface. Approx. 30% complete	3,8,9,14, 38
Dachs VII -	Alte Poste near Pirna,Germany		Gasoline Refinery	Sand-stone		Concrete		Est.54-A 70-P	Tunnels	Drift		Some Started	80% complete. Installation of equipment started.	14,38
Kuckuk I, Bau II of Mittelbau Project in the Kohnstein	Niedersachswerfen (Nordhausen) Ger.	New	Hydro-generation Pl.	Gypsum	135 300 Avg.		40 W 20-130 H	544-P 450-A	Grid	Drift	R.R.	R.R.	40 air changes/hr. Max 10 to 20 av. P. 55% complete. Equip. install. started.	7,14,20. 38
Schwalbe I, Rheinische Wesfalische Kalkwerke	Honnetal Uber Rodinghausen near Iserlohn,Germany	Limestone Quarry	Hydro-generation Plant	Limestone	240	None	15 W 15 H 300 L 30 W 70	120-P 60-A		Drift		MV-B	Excavation 50% complete.	3,14,16, 18,37,38
Schwalbe V	Berga near Gera on Elster River,Ger.	New Slate	Hydro. Plant				23 W 20 H	Est.90-A 360-P		Drift	R.R.	R.R.	Excavation 30% complete. 200,000 cu. ft. excavated.	14,38
Steinbock II Halle A.D. Salle/Loquitz	Unterloquitz near Saalfeld,Germany	Slate Mine	Paraflow Catalyst	Slate	115		10 W 11.5 H Some 60 H	Est.80-A		Drift		MV-P.	No equipment installed. 3 locomotives planned to furnish power.	8,14,38
Anlage A	Ebensee Austria	Gasoline Refinery	Limestone			None	33 W x 33 H 930 L	384-A 642-P	Grid	Drift	Road	MV-GD-B	Production started. Oil refinery installed. Water flow in limestone. Seepage in gutter, ribs,mesh in over rooms.	1,9,14,21 38
Schlier-Testing Station V2 & Liquid Oxygen Plant	Redl Zipf at Vocklabruch,Austria	Brewery Cellar	Liquid Oxygen	Sandstone	65-130	Concrete	80 W 20-35 H	40	Comb.	Drift	R.R.	MV-B-PD	Construction completed 5/44. Prod. started. 2 heavy explosions caused by dissipation of oxygen.	2,38
Dachs III	Deutsch-Brod Czechoslovakia	New	Gasoline Refinery					Est.54-A		Drift			Started as R.R.Tunnel,changed to refinery,4 months construction.	14,38
Liquid Oxygen Plant & Testing Station V2 Rockets	Saalfeld (Thuringen) Germany	Slate Mine	Liquid Oxygen & V2 Testing	Slate	More than 100	Heavy Steel Nets for Submarine	60x80 - 60 H	60		Drift	Cog-wheel R.R.	MV-Htg-B	Started 7/43. Production started end of 1943. Completed 5/44.	

GUY B. PANERO, ENGINEERS

Figure D.980: PB 123064. *Underground Installations: Foreign Installations.* 31 October 1948. U.S. Department of Commerce [Library of Congress].



FOREIGN UNDERGROUND INSTALLATIONS

STORAGE INSTALLATIONS

NAME	LOCATION	ORIGINAL USE OF SPACE	TYPE OF PRODUCTS MADE	GEOLOGICAL FORMATIONS	DEPTH OF COVER FT.	LINING	ROOM SIZES FT.	AREA SQ. FT. x M.	TYPE PLAN	ACCESS	TRANS-PORTA-TION	MECHANICAL EQUIPMENT	REMARKS	REF. NO.
Burbach-Kaliwerke Aktiengesellschaft	Volpriehausen Germany	Salt Mine	Storage	Salt	1800-3120	No	53x72x8	Est. 52[illegible]	2 Levels	2 Shafts	Narrow Gauge	MV-NV-B-RR-PD-HD	German Army took over in 1938.	2,8
Oil Storage in Amerika Haven	Cuxhaven Germany		Oil Storage						Tunnel				Typical German oil storage depot.	3,8
Dechen Hohle	On Iserlohn to Letmathe Hwy, Ger.	Cave	Storage		20	No	1300 L 20 Wx15 H	Est. 260	1 Level	2 Drifts	None	MV	Extremely damp.	2,8
Dingelstedt Salt Mine Ammo. Storage Depot	Dingelstedt near Halberstadt, Ger.	Salt Mine	Storage	Salt	790 - 1244	None			9 Levels	2 Shafts	Narrow Gauge	MV-B-GD-RR	Equipment - Excellent condition.	2,8
Ammunition Dump in Railroad Tunnel Wissembourg	Fehrbach Germany	Railroad Tunnel	Ammo. Storage			Yes			2 Tunnels	Drift	Std. Gauge	NV-B-GD	1 portion used as factory - other used by railroad.	2,8
Hohenfels Kohlenwerke	Wehingen Germany	Salt Mine	Storage	Salt	1824 - 1969	Some Brick			9 Levels	2 Shafts	Narrow Gauge	MV-B-HD-RR	Used by Army since 1939 for ammo. Used by QM since 1944 for clothing.	2
Kali Chemie A.G.	Weetzen Germany	Salt Mine	Storage	Salt	1150 - 1970	No	Vary 30-130 W x 100-200 H		5 Levels	Shaft	Narrow Gauge	MVB	No pillar, shoring or lining necessary.	2
Loccum Kidar	Loccum Germany		Storage			Reinforced Conc.&Enamel					2 RR on Site	MV-RR	Construction started 1939. 16 oil tanks	3,8
Ammunition Dump	Ludwigsthal near Pirmasens, Germany	Ammo. Storage	Concrete Tunnels			Yes	10x20x300 L		2 Tunnels	Drift	None	NV-GD	No installation.	2,8
Northern Werke Kopferschmidt u.Sohne Plexiglass Factory	Blumberg, Baden, Germany	Iron Ore Mine	Storage	Sandstone		Brick and Mortar	10x10 Tunnel	Est. 3 mi.L	Tunnels	Drift	Narrow Gauge	MVB RR	Stored surplus plexiglass - T-shaped tunnel.	2,8
Ammunition Dump in Railroad Tunnel	Ponten between Besseringen & Mettlach, Ger.	Railroad Tunnel	Ammo. Storage			Yes					Std. Gauge	RR	Completely demolished by bombs. No indication of new construction.	2,8
President Zeche Bochum II	Bochum/Linden Germany	Mine	Storage			Brick and Mortar	21x16		10 Levels	Drift	Narrow Gauge	NV-BGD RR	Used 8th level for storage	2,8
Sarstedt	Sarstedt Hildesheim, Germany	Saltpeter Mine	Storage	Saltpeter					8 Levels	2 Shafts	Narrow Gauge	NV-BGD-RR	Used for rubber storage 1939.	2
Siemens u. Schuckert A.G.	Waldwinkle at Weisenberg, Germany	Beer Cellar	Storage									MV-BHD-RR	German Army took over in 1935.	2
Eisenerzbergwerke Porta	Halberstadt Germany	Iron Mine		30° Inclined Strata (Ore)		No		750 mi. Tunnel	Tunnel	Drift & Shaft	RR	MV-B-GD RR	1935 addit tunnels started by German Army. Progress slow, VE day 15% comp.	2
Railroad Tunnel	Eberweiler(Thionville Fr.&Volkingen, Ger.	Railroad Tunnel	Ammo. Storage			Yes			2 Tunnels	Drift	Std. Gauge	MV-B-GD-RR	1 tunnel used by railroad.	2,8
St. Cloud Depot	St. Cloud France	Road Tunnel	Storage U-18		190	Tile	75x1600	120	Single Tunnel	Drift	Truck	MV	Mines and V1's.	
Quarry at St. Leu D'Esserent	St. Leu D'Esserent near Creil, France	Quarry	Storage & Loading	Limestone			Approx. 130x78	Approx. 150000	Room & Pillar	2 Drifts	RR & Road	Htg-HD-RR	Aboveground barracks in village. 10/40 to 8/44 used for storage. Later used for V1 & V2 loading plant. All German personnel.	8
Storage Dump in Railroad Tunnel	Bingen, Germany	R.R. Tunnel	Storage						Drift	Std. Gauge	RR		Completely demolished by bombs. No evidence of factory or new construction.	2
Desdemona Salt Mine	Godenau near Alfeld, Germany	Salt Mine	Storage	Salt	1400-2530	No	35 Lx20 W x 10 H	Est.112	5 Levels	2 Shafts	Narrow Gauge	MV-B-RR	Munitions stored on 2288' level in 16 specially constructed rooms.	2,8

P - Planned
A - Actual

AMV - Air Conditioning
MV - Mechanical Ventilation
NV - Natural Ventilation

GD - Gravity Drainage
PD - Drainage by Pump
HD - Sewage by hand bucket

B - Electric power - outside sources
BP - Electric standby power in plant
Htg- Heating

Elev - Elevator
RR - Railroad

GUY B. PANERO, ENGINEERS

Figure D.981: PB 123064. *Underground Installations: Foreign Installations.* 31 October 1948. U.S. Department of Commerce [Library of Congress].

D.14.8 German and Austrian Scientists in the United States

[Many German and Austrian scientists who appear to have been involved in the nuclear program visited the United States and/or United Kingdom after the war, and may have provided information about wartime German work. See p. 4993 for a few examples. Files for some scientists are still not available to the public. For example, almost the complete file of nuclear physicist Otto Haxel has been redacted (p. 4994), and Wernher von Braun's file is missing entirely [NARA RG 330, Entry A1-1B].

How much influence did information, scientists, and materials from the German nuclear weapons program have on the U.S./U.K. nuclear programs, both during and after the war? Detailed information, scientists, and materials from the German program began arriving in the United States and United Kingdom no later than late 1944, and continued for several years after the war.

The late-wartime and postwar influx of scientists and engineers who were from or at least had knowledge of the German nuclear program included:

Karl-Friedrich Bonhoeffer
Wernher von Braun
Rudolf Brill
Adolf Busemann
Walter Dornberger
Rudolf Edse
Krafft Ehricke
Wilhelm Eitel
Gerhard Falck
Karl Fiebinger
Wolfgang Finkelnburg
Rudolf Fleischmann
Siegfried Flügge
Walter Glaser
Wilhelm Groth
Gottfried Guderley
Paul Harteck
Otto Haxel
Richard Herzog
Johannes Hans Jensen
Willibald Jentschke
Ulrich Jetter
Georg Joos
Hartmut Kallmann
Hans Kammler
Gerald Klein
Stanley Kronenberg
Heinz Maier-Leibnitz
Werner Maurer
Hugo Neuert
"Dr. Niels" (Walter Nielsch?)
Edgar Petersen
Heinz Schlicke
Erich Schumann
Otto Schwede
Edmund Sorg
Kurt Starke
Ernst Stuhlinger
Hans Suess
Herbert Wagner
Wilhelm Westphal
Friedwardt Winterberg
Karl Wirtz
Gernot Zippe
Etc.

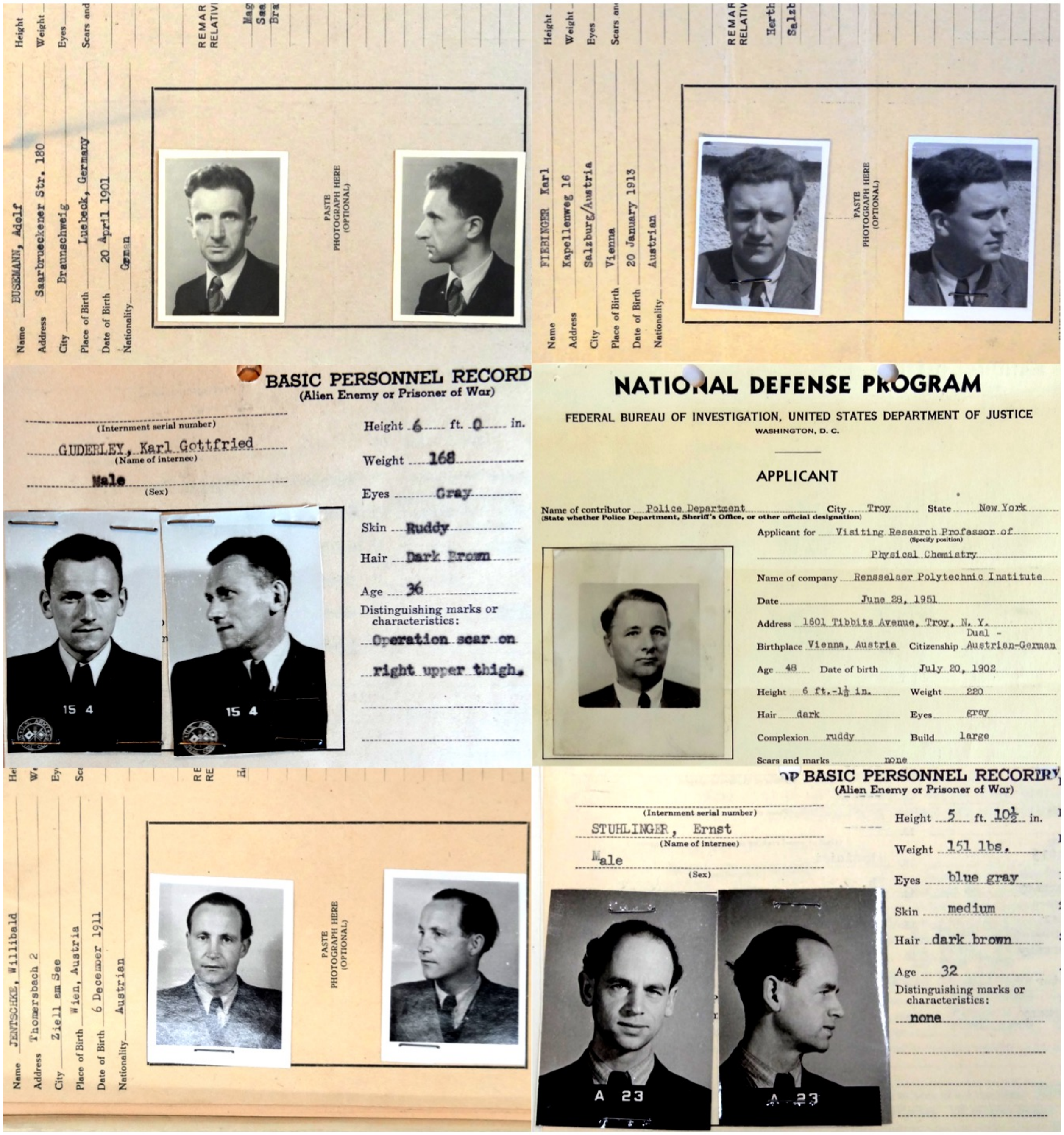
This list is by no means exhaustive. Furthermore, countless other scientists were interrogated in Europe. See also Section D.14.9 for examples of additional people. The complete files on all of these scientists and engineers should be sought and released.

A number of the above scientists appear to have been closely tied to German work on H-bombs, and may have especially aided the U.S. H-bomb development program between 1945 and 1954. Some of the scientists may have also been able to contribute to improvements in U.S./U.K. fission bombs (e.g., smaller sizes and higher efficiencies) and fission fuel production (such as the uranium centrifuges of Groth, Harteck, and Zippe).

There is a great need for archival researchers and historians to investigate this area in much more detail in the future.]

DECLASSIFIED
Authority NND 013039

NARA RG 330, Entry A1-1B, Boxes 1–186.
JIOA Foreign Scientist Case Files [Paperclip].



Name BUSEMANN, Adolf
Address Saarbrueckener Str. 180
City Braunschweig
Place of Birth Luebeck, Germany
Date of Birth 20 April 1901
Nationality German

Height
Weight
Eyes
Scars and

PASTE PHOTOGRAPH HERE (OPTIONAL)

REMAR
RELATIV

Name FIEBINGER Karl
Address Kapellenweg 16
City Salzburg/Austria
Place of Birth Vienna
Date of Birth 20 January 1913
Nationality Austrian

PASTE PHOTOGRAPH HERE (OPTIONAL)

BASIC PERSONNEL RECORD
(Alien Enemy or Prisoner of War)

(Internment serial number)
GUDERLEY, Karl Gottfried
(Name of internee)
Male
(Sex)

Height 6 ft. 0 in.
Weight 168
Eyes Gray
Skin Ruddy
Hair Dark Brown
Age 36
Distinguishing marks or characteristics:
Operation scar on right upper thigh.

NATIONAL DEFENSE PROGRAM

FEDERAL BUREAU OF INVESTIGATION, UNITED STATES DEPARTMENT OF JUSTICE
WASHINGTON, D. C.

APPLICANT

Name of contributor Police Department City Troy State New York
(State whether Police Department, Sheriff's Office, or other official designation)
Applicant for Visiting Research Professor of Physical Chemistry
(Specify position)
Name of company Rensselaer Polytechnic Institute
Date June 28, 1951
Address 1601 Tibbits Avenue, Troy, N. Y.
Birthplace Vienna, Austria Citizenship Dual - Austrian-German
Age 48 Date of birth July 20, 1902
Height 6 ft.-1½ in. Weight 220
Hair dark Eyes gray
Complexion ruddy Build large
Scars and marks none

Name JENTSCHKE, Willibald
Address Thomersbach 2
City Ziell em See
Place of Birth Wien, Austria
Date of Birth 6 December 1911
Nationality Austrian

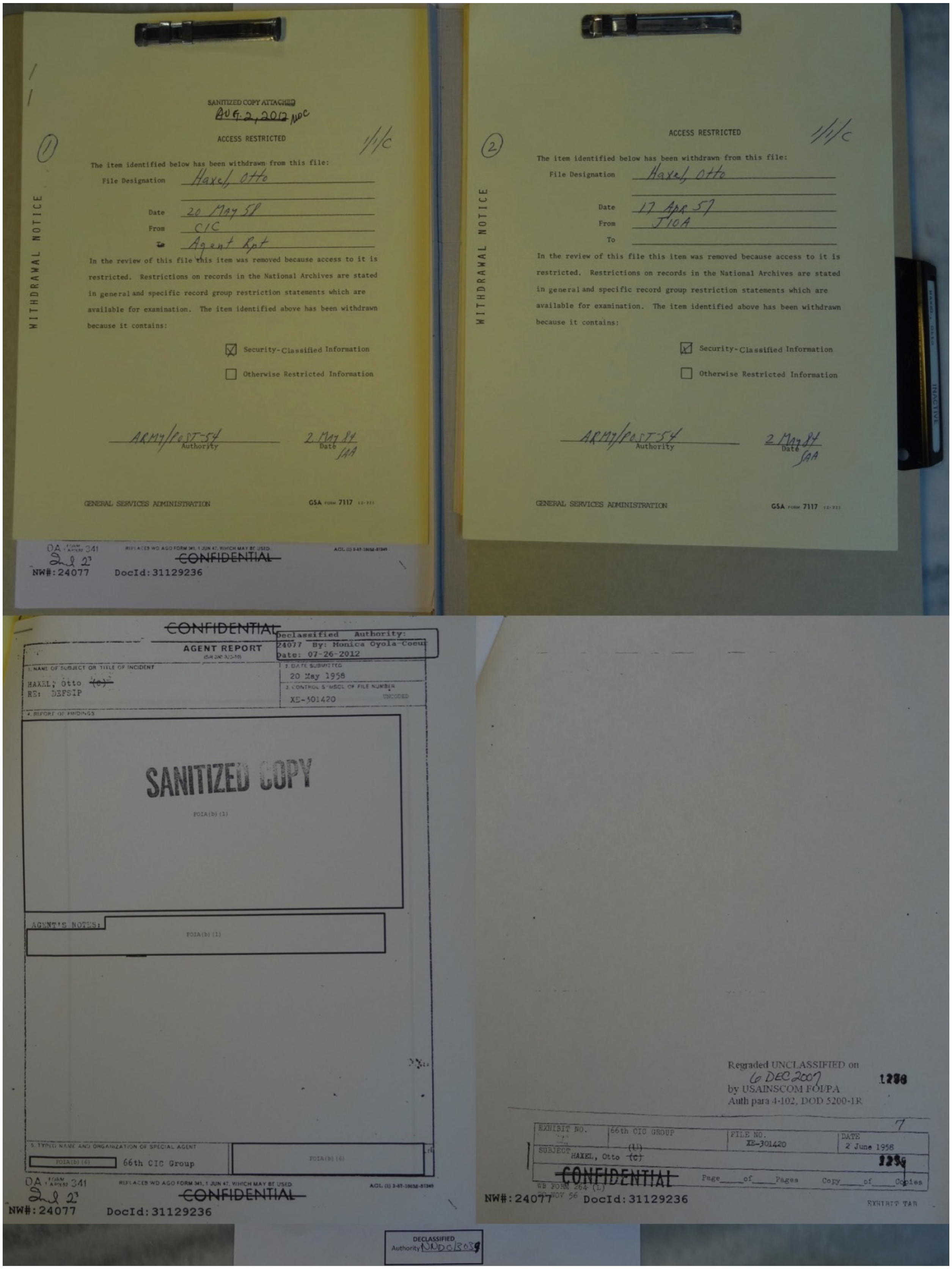
PASTE PHOTOGRAPH HERE (OPTIONAL)

BASIC PERSONNEL RECORD
(Alien Enemy or Prisoner of War)

(Internment serial number)
STUHLINGER, Ernst
(Name of internee)
Male
(Sex)

Height 5 ft. 10½ in.
Weight 151 lbs.
Eyes blue gray
Skin medium
Hair dark brown
Age 32
Distinguishing marks or characteristics:
none

Figure D.982: Examples of scientists who were apparently involved in the German nuclear program and were brought to the United States to work after the war [NARA RG 330, Entry A1-1B].



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AUG. 2, 2012 NDC

ACCESS RESTRICTED

① 1/1/C

WITHDRAWAL NOTICE

The item identified below has been withdrawn from this file:

File Designation Haxel, Otto

Date 20 May 58

From CIC

Agent Rpt

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

ARMY/POST-54
Authority

2 May 84
Date
SAA

GENERAL SERVICES ADMINISTRATION GSA FORM 7117

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② 1/1/C

ACCESS RESTRICTED

WITHDRAWAL NOTICE

The item identified below has been withdrawn from this file:

File Designation Haxel, Otto

Date 17 Apr 57

From J10A

To

In the review of this file this item was removed because access to it is restricted. Restrictions on records in the National Archives are stated in general and specific record group restriction statements which are available for examination. The item identified above has been withdrawn because it contains:

☒ Security-Classified Information

☐ Otherwise Restricted Information

ARMY/POST-54
Authority

2 May 84
Date
SAA

GENERAL SERVICES ADMINISTRATION GSA FORM 7117

~~CONFIDENTIAL~~

AGENT REPORT

Declassified Authority: 24077 By: Monica Oyola-Cocu Date: 07-26-2012

1. NAME OF SUBJECT OR TITLE OF INCIDENT
HAXEL, Otto ~~(c)~~
RE: DEFSIP

2. DATE SUBMITTED
20 May 1958

3. CONTROL SYMBOL OR FILE NUMBER
XE-301420 UNCODED

4. REPORT OF FINDINGS

SANITIZED COPY

FOIA(b)(1)

AGENT'S NOTES:
FOIA(b)(1)

5. TYPED NAME AND ORGANIZATION OF SPECIAL AGENT
FOIA(b)(6) 66th CIC Group

FOIA(b)(6)

DA FORM 341 REPLACES WD AGO FORM 341, 1 JUN 47, WHICH MAY BE USED.
~~CONFIDENTIAL~~
Incl 2

NW#:24077 DocId:31129236

DECLASSIFIED
Authority NND 013059

Regraded UNCLASSIFIED on
6 DEC 2007
by USAINSCOM FOI/PA
Auth para 4-102, DOD 5200-1R

1288

7

EXHIBIT NO.	66th CIC GROUP	FILE NO. XE-301420	DATE 2 June 1958
SUBJECT HAXEL, Otto ~~(C)~~ (U)			

1256

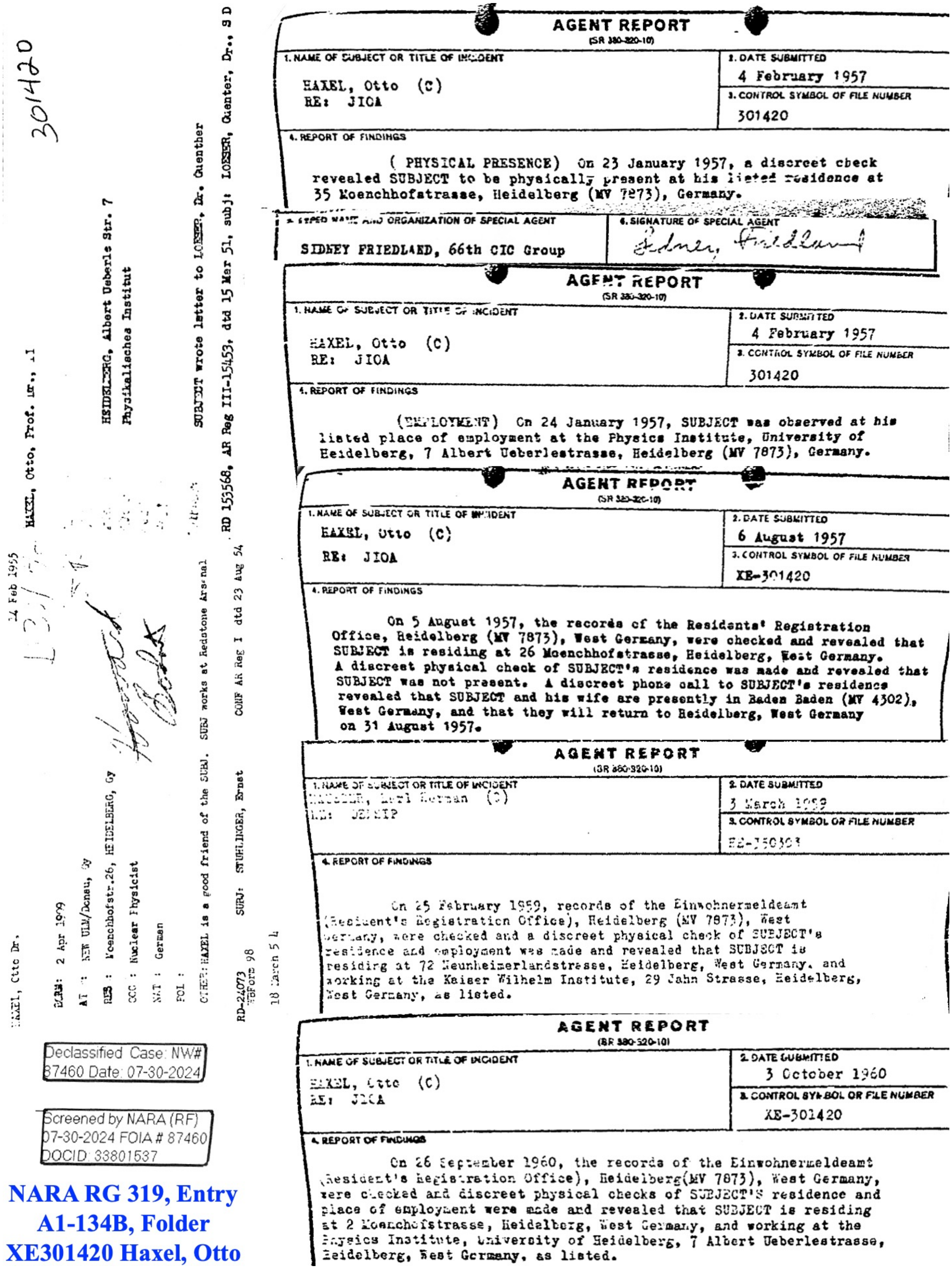
~~CONFIDENTIAL~~ Page____of____Pages Copy____of____Copies

WB FORM 264 (L)
20 NOV 56

NW#:24077 DocId:31129236

EXHIBIT TAB

Figure D.983: Virtually the entire "foreign scientist case file" on Otto Haxel remains classified, with the documents removed or completely blanked out [NARA RG 330, Entry A1-1B, Box 66].



HAXEL, Otto Dr.

BORN: 2 Apr 1909

AT : NEW ULM/Donau, Gy

RES : Moenchhofstr.26, HEIDELBERG, Gy

OCC : Nuclear Physicist

NAT : German

POL :

OTHER: HAXEL is a good friend of the SUBJ. SUBJ works at Redstone Arsenal

RD-24073 SUBJ: STUHLINGER, Ernst CONF AR Reg I dtd 23 Aug 54
WBForm 98

18 March 54

14 Feb 1955

HAXEL, Otto, Prof. Dr., ..I

301420

HEIDELBERG, Albert Ueberle Str. 7
Physikalisches Institut

SUBJECT wrote letter to LOESER, Dr. Guenther

. RD 153568, AR Reg III-15453, dtd 15 Mar 51, subj: LOESER, Guenter, Dr., S D

Declassified Case: NW# 87460 Date: 07-30-2024

Screened by NARA (RF) 07-30-2024 FOIA # 87460 DOCID: 33801537

NARA RG 319, Entry A1-134B, Folder XE301420 Haxel, Otto

AGENT REPORT
(SR 380-320-10)

1. NAME OF SUBJECT OR TITLE OF INCIDENT: HAXEL, Otto (C)
RE: JIOA

2. DATE SUBMITTED: 4 February 1957

3. CONTROL SYMBOL OR FILE NUMBER: 301420

4. REPORT OF FINDINGS

(PHYSICAL PRESENCE) On 23 January 1957, a discreet check revealed SUBJECT to be physically present at his listed residence at 35 Moenchhofstrasse, Heidelberg (MV 7873), Germany.

5. TYPED NAME AND ORGANIZATION OF SPECIAL AGENT: SIDNEY FRIEDLAND, 66th CIC Group

6. SIGNATURE OF SPECIAL AGENT: Sidney Friedland

AGENT REPORT
(SR 380-320-10)

1. NAME OF SUBJECT OR TITLE OF INCIDENT: HAXEL, Otto (C)
RE: JIOA

2. DATE SUBMITTED: 4 February 1957

3. CONTROL SYMBOL OF FILE NUMBER: 301420

4. REPORT OF FINDINGS

(EMPLOYMENT) On 24 January 1957, SUBJECT was observed at his listed place of employment at the Physics Institute, University of Heidelberg, 7 Albert Ueberlestrasse, Heidelberg (MV 7873), Germany.

AGENT REPORT
(SR 380-320-10)

1. NAME OF SUBJECT OR TITLE OF INCIDENT: HAXEL, Otto (C)
RE: JIOA

2. DATE SUBMITTED: 6 August 1957

3. CONTROL SYMBOL OF FILE NUMBER: XE-301420

4. REPORT OF FINDINGS

On 5 August 1957, the records of the Residents' Registration Office, Heidelberg (MV 7873), West Germany, were checked and revealed that SUBJECT is residing at 26 Moenchhofstrasse, Heidelberg, West Germany. A discreet physical check of SUBJECT's residence was made and revealed that SUBJECT was not present. A discreet phone call to SUBJECT's residence revealed that SUBJECT and his wife are presently in Baden Baden (MV 4302), West Germany, and that they will return to Heidelberg, West Germany on 31 August 1957.

AGENT REPORT
(SR 380-320-10)

1. NAME OF SUBJECT OR TITLE OF INCIDENT: [illegible], Karl Herman (C)
RE: [illegible]

2. DATE SUBMITTED: 3 March 1959

3. CONTROL SYMBOL OR FILE NUMBER: [illegible]

4. REPORT OF FINDINGS

On 25 February 1959, records of the Einwohnermeldeamt (Resident's Registration Office), Heidelberg (MV 7873), West Germany, were checked and a discreet physical check of SUBJECT's residence and employment was made and revealed that SUBJECT is residing at 72 Neunheimerlandstrasse, Heidelberg, West Germany, and working at the Kaiser Wilhelm Institute, 29 Jahn Strasse, Heidelberg, West Germany, as listed.

AGENT REPORT
(SR 380-320-10)

1. NAME OF SUBJECT OR TITLE OF INCIDENT: HAXEL, Otto (C)
RE: JIOA

2. DATE SUBMITTED: 3 October 1960

3. CONTROL SYMBOL OR FILE NUMBER: XE-301420

4. REPORT OF FINDINGS

On 26 September 1960, the records of the Einwohnermeldeamt (Resident's Registration Office), Heidelberg (MV 7873), West Germany, were checked and discreet physical checks of SUBJECT'S residence and place of employment were made and revealed that SUBJECT is residing at 2 Moenchofstrasse, Heidelberg, West Germany, and working at the Physics Institute, University of Heidelberg, 7 Albert Ueberlestrasse, Heidelberg, West Germany, as listed.

Figure D.984: Otto Haxel was closely monitored by the U.S. Army Counter Intelligence Corps until at least 1960 [NARA RG 319, Entry A1-134B, Box ??, Folder XE301420 Haxel, Otto].

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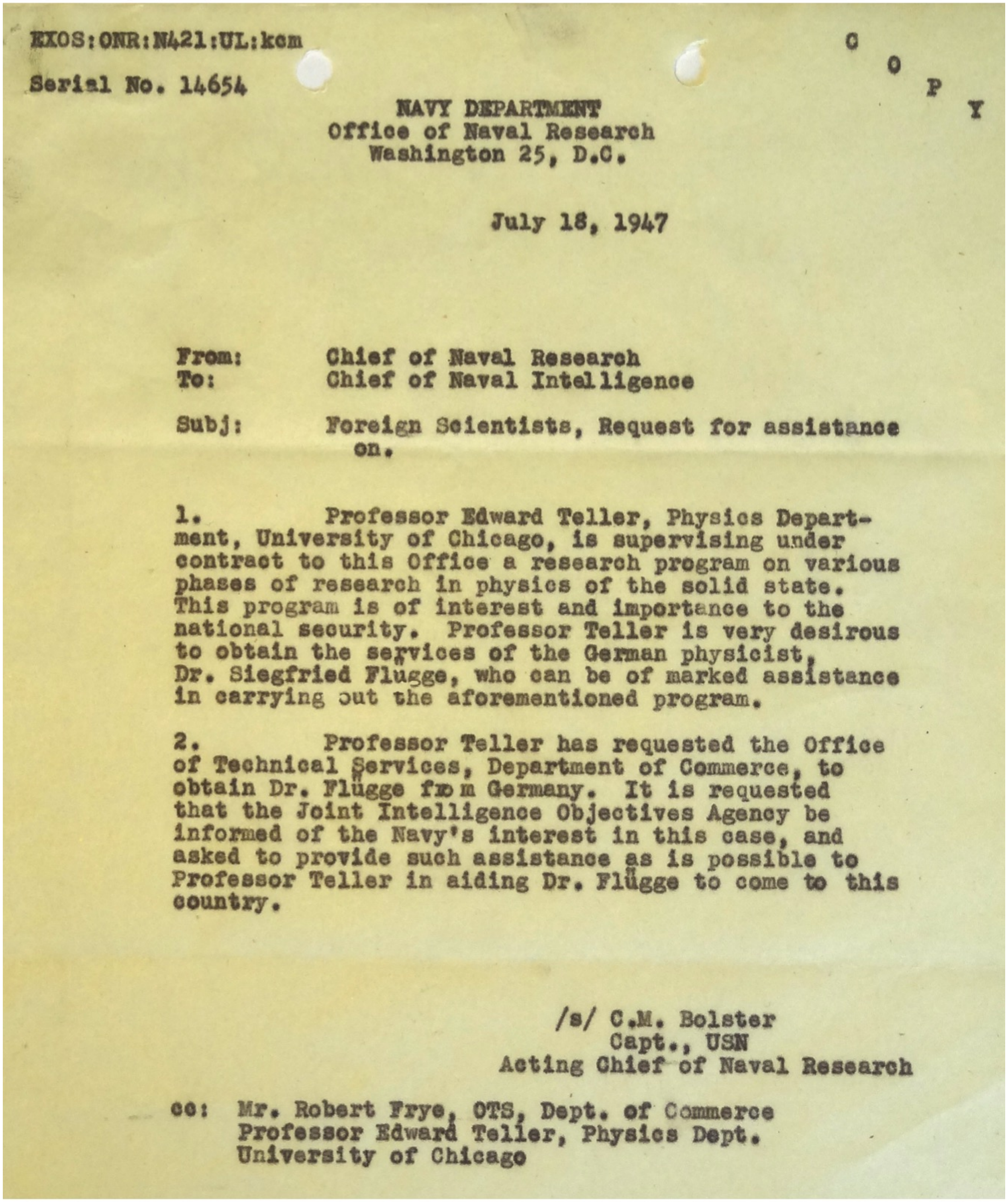
Authority NND 013039

NARA RG 330, Entry A1-1B,
Box 43, Folder Flügge, Siegfried



EXOS:ONR:N421:UL:kcm

Serial No. 14654

C O P Y

NAVY DEPARTMENT
Office of Naval Research
Washington 25, D.C.

July 18, 1947

From: Chief of Naval Research
To: Chief of Naval Intelligence

Subj: Foreign Scientists, Request for assistance on.

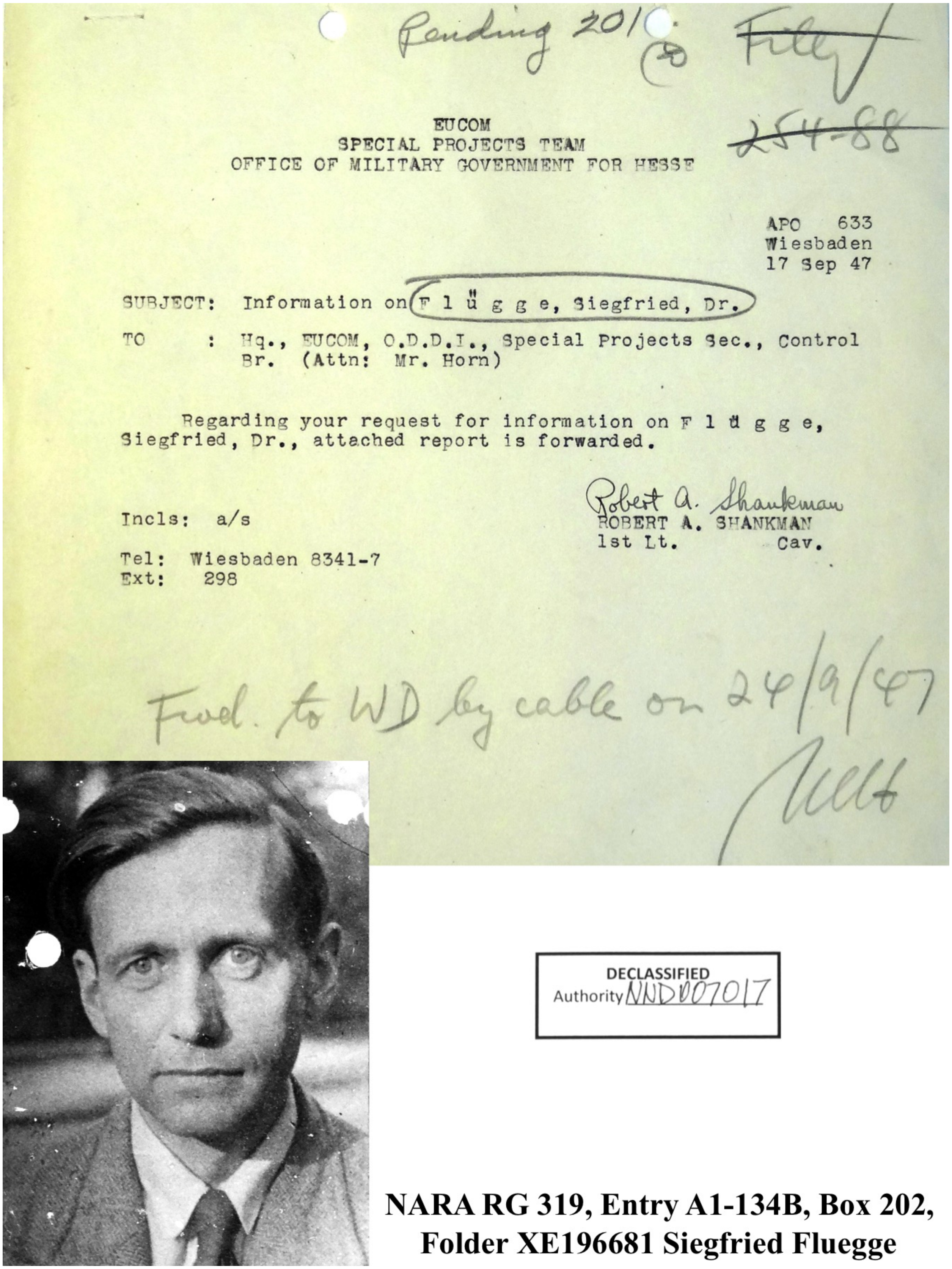
1. Professor Edward Teller, Physics Department, University of Chicago, is supervising under contract to this Office a research program on various phases of research in physics of the solid state. This program is of interest and importance to the national security. Professor Teller is very desirous to obtain the services of the German physicist, Dr. Siegfried Flugge, who can be of marked assistance in carrying out the aforementioned program.

2. Professor Teller has requested the Office of Technical Services, Department of Commerce, to obtain Dr. Flügge from Germany. It is requested that the Joint Intelligence Objectives Agency be informed of the Navy's interest in this case, and asked to provide such assistance as is possible to Professor Teller in aiding Dr. Flügge to come to this country.

/s/ C.M. Bolster
Capt., USN
Acting Chief of Naval Research

cc: Mr. Robert Frye, OTS, Dept. of Commerce
Professor Edward Teller, Physics Dept.
University of Chicago

Figure D.985: After the war, Edward Teller made a highly unusual, specific, and urgent request for Siegfried Flügge to help him with a "physics... program... of interest and importance to the national security," stating that Flügge would "be of marked assistance in carrying out the aforementioned program" [NARA RG 330, Entry A1-1B, Box 43, Folder Flügge, Siegfried]. Flügge was brought to the United States to work during 1949–1950 and 1953, which were critical periods for the development of the first H-bomb and the first dry (lithium deuteride) H-bomb.



Pending 201 (C) ~~Filed~~

~~254-88~~

EUCOM
SPECIAL PROJECTS TEAM
OFFICE OF MILITARY GOVERNMENT FOR HESSE

APO 633
Wiesbaden
17 Sep 47

SUBJECT: Information on Flügge, Siegfried, Dr.

TO : Hq., EUCOM, O.D.D.I., Special Projects Sec., Control Br. (Attn: Mr. Horn)

Regarding your request for information on Flügge, Siegfried, Dr., attached report is forwarded.

Robert A. Shankman
ROBERT A. SHANKMAN
1st Lt. Cav.

Incls: a/s

Tel: Wiesbaden 8341-7
Ext: 298

Fwd. to WD by cable on 24/9/47

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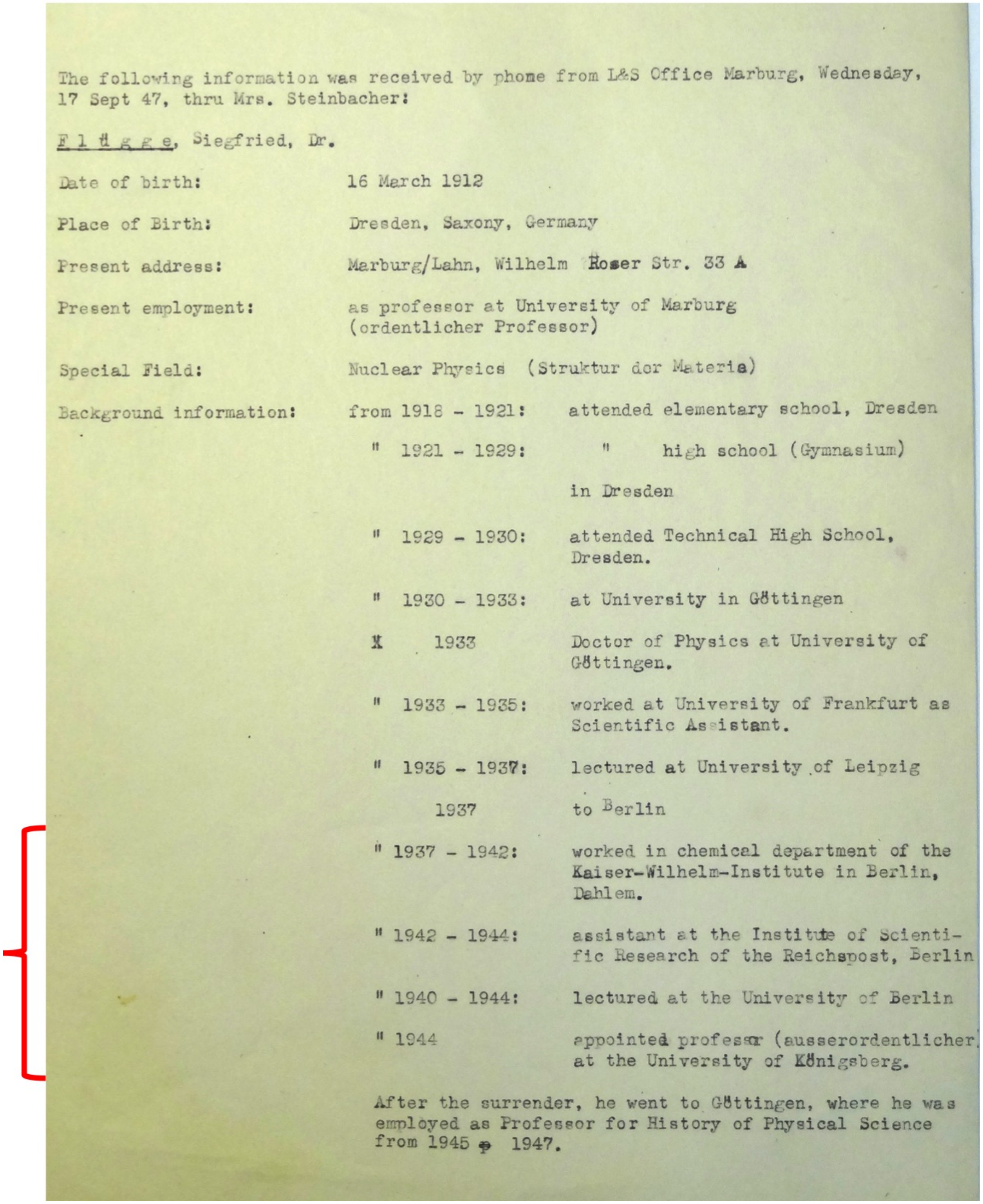
Authority NND007017

NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge

Figure D.986: At the specific request of Edward Teller, Siegfried Flügge was brought to the United States to work during 1949–1950 and 1953. Those were critical periods for the development of the first H-bomb and the first dry (lithium deuteride) H-bomb. [NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge]

DECLASSIFIED
Authority NND007017

**NARA RG 319, Entry A1-134B, Box 202,
Folder XE196681 Siegfried Fluegge**



The following information was received by phone from L&S Office Marburg, Wednesday, 17 Sept 47, thru Mrs. Steinbacher:

Flügge, Siegfried, Dr.

Date of birth: 16 March 1912

Place of Birth: Dresden, Saxony, Germany

Present address: Marburg/Lahn, Wilhelm Roser Str. 33 A

Present employment: as professor at University of Marburg (ordentlicher Professor)

Special Field: Nuclear Physics (Struktur dor Materie)

Background information:

from 1918 - 1921: attended elementary school, Dresden

" 1921 - 1929: " high school (Gymnasium) in Dresden

" 1929 - 1930: attended Technical High School, Dresden.

" 1930 - 1933: at University in Göttingen

" 1933 Doctor of Physics at University of Göttingen.

" 1933 - 1935: worked at University of Frankfurt as Scientific Assistant.

" 1935 - 1937: lectured at University of Leipzig

1937 to Berlin

" 1937 - 1942: worked in chemical department of the Kaiser-Wilhelm-Institute in Berlin, Dahlem.

" 1942 - 1944: assistant at the Institute of Scientific Research of the Reichspost, Berlin

" 1940 - 1944: lectured at the University of Berlin

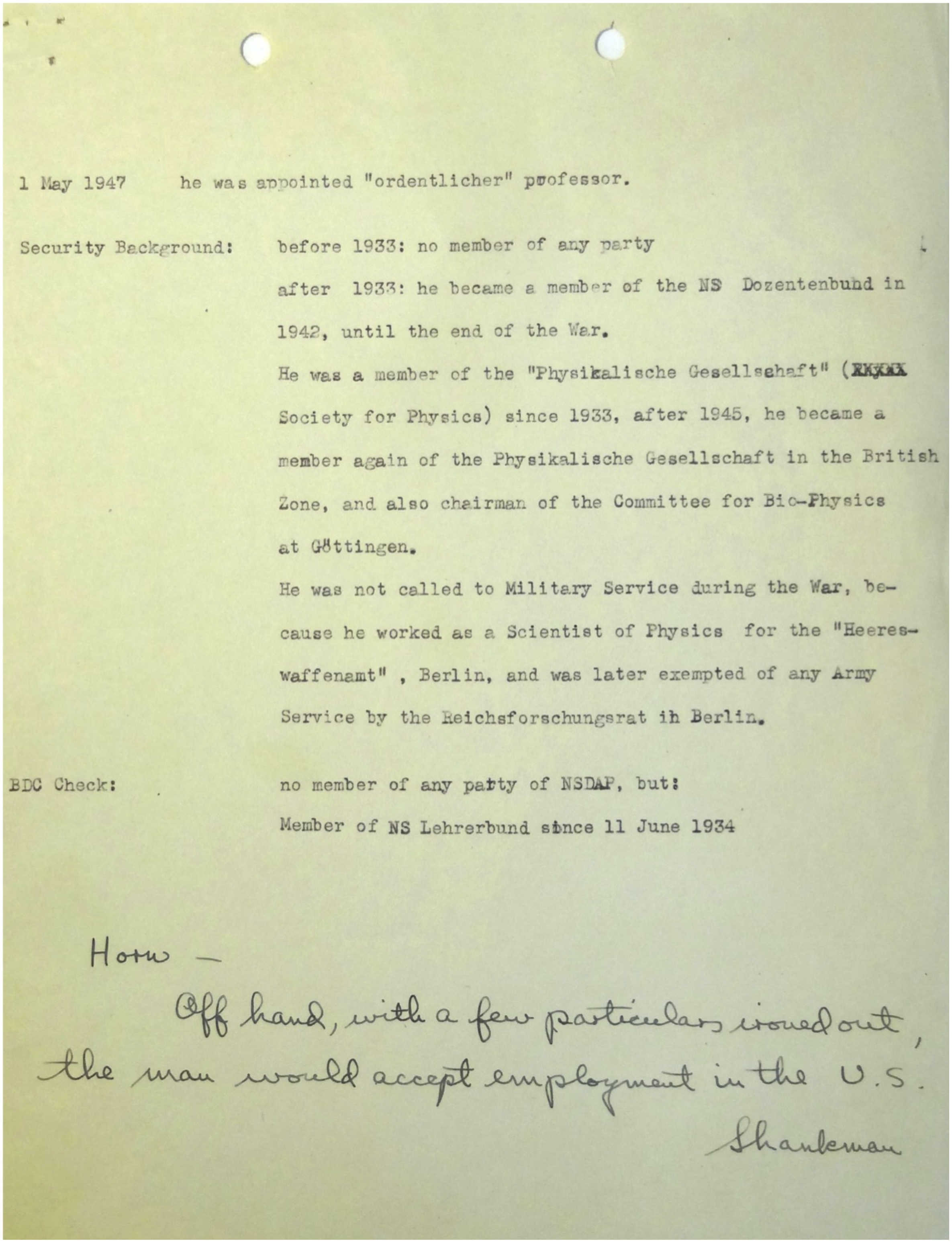
" 1944 appointed professor (ausserordentlicher) at the University of Königsberg.

After the surrender, he went to Göttingen, where he was employed as Professor for History of Physical Science from 1945 - 1947.

Figure D.987: During the war, Flügge worked for the Reichspost, Heereswaffenamt (also listed as University of Berlin since Erich Schumann was at both), Kaiser Wilhelm Institutes, Reichsforschungsrat, and University of Königsberg in East Prussia (said to have fission reactors, pp. 3928, 4578) [NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge]. He also apparently worked at St. Georgen an der Gusen (p. 3882), another suspected nuclear facility.

DECLASSIFIED
Authority NND007017

NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge



1 May 1947 he was appointed "ordentlicher" professor.

Security Background: before 1933: no member of any party

after 1933: he became a member of the NS Dozentenbund in 1942, until the end of the War.

He was a member of the "Physikalische Gesellschaft" (Society for Physics) since 1933, after 1945, he became a member again of the Physikalische Gesellschaft in the British Zone, and also chairman of the Committee for Bio-Physics at Göttingen.

He was not called to Military Service during the War, because he worked as a Scientist of Physics for the "Heereswaffenamt", Berlin, and was later exempted of any Army Service by the Reichsforschungsrat in Berlin.

BDC Check: no member of any party of NSDAP, but:

Member of NS Lehrerbund since 11 June 1934

Horn —

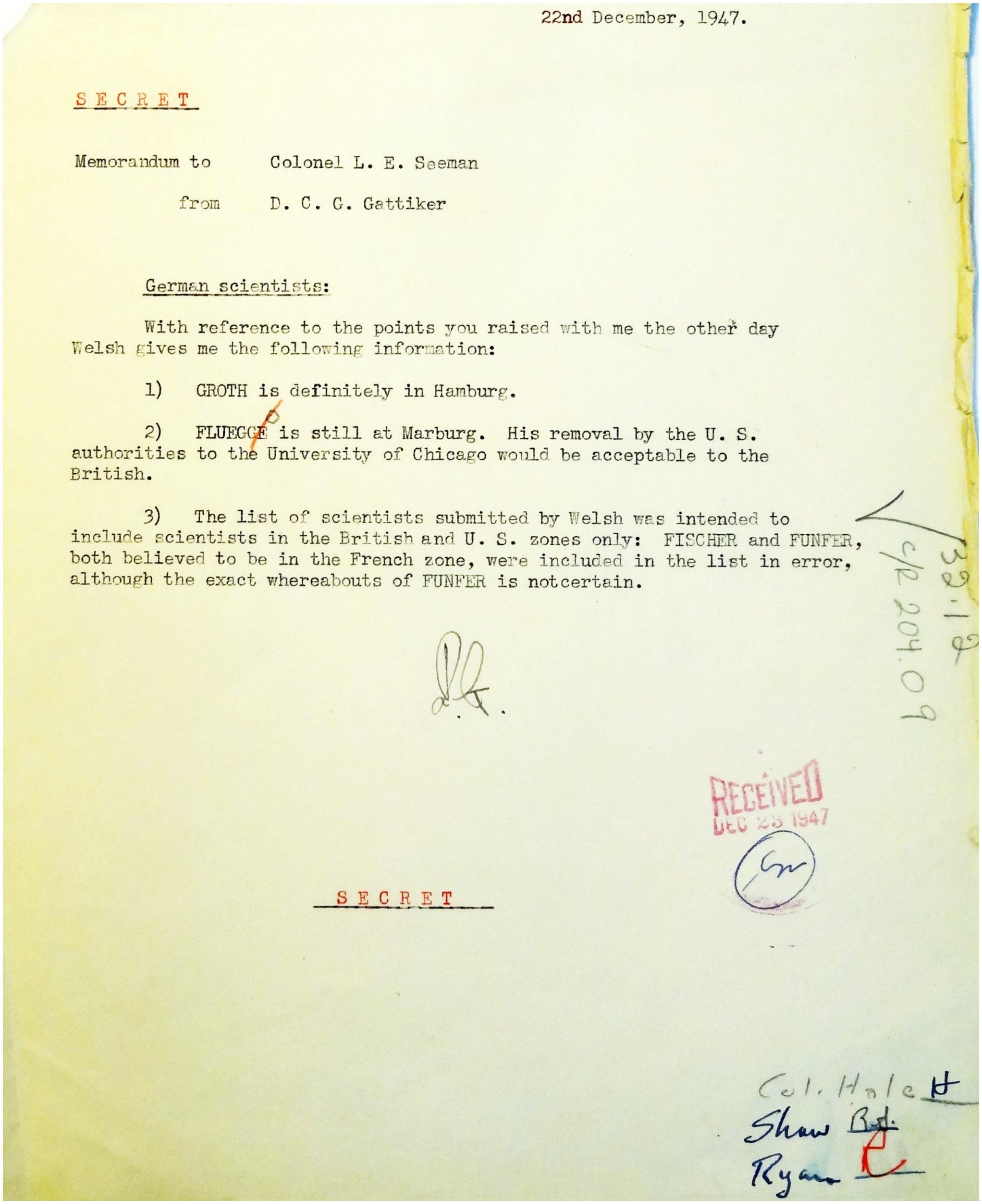
Off hand, with a few particulars ironed out, the man would accept employment in the U.S.

Shankman

Figure D.988: During the war, Flügge worked for the Reichspost, Heereswaffenamt (also listed as University of Berlin since Erich Schumann was at both), Kaiser Wilhelm Institutes, Reichsforschungsrat, and University of Königsberg in East Prussia (said to have fission reactors, pp. 3928, 4578) [NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge]. He also apparently worked at St. Georgen an der Gusen (p. 3882), another suspected nuclear facility.

DECLASSIFIED
Authority NND971017

NARA RG 77, Entry UD-22A, Box 167, Folder 202.3-2 LONDON OFFICE: Combined Oper Ger Group



22nd December, 1947.

SECRET

Memorandum to Colonel L. E. Seeman

from D. C. G. Gattiker

German scientists:

With reference to the points you raised with me the other day Welsh gives me the following information:

1) GROTH is definitely in Hamburg.

2) FLUEGGE is still at Marburg. His removal by the U. S. authorities to the University of Chicago would be acceptable to the British.

3) The list of scientists submitted by Welsh was intended to include scientists in the British and U. S. zones only: FISCHER and FUNFER, both believed to be in the French zone, were included in the list in error, although the exact whereabouts of FUNFER is notcertain.

D.G.

32.12
c/R 204.09

RECEIVED
DEC 23 1947

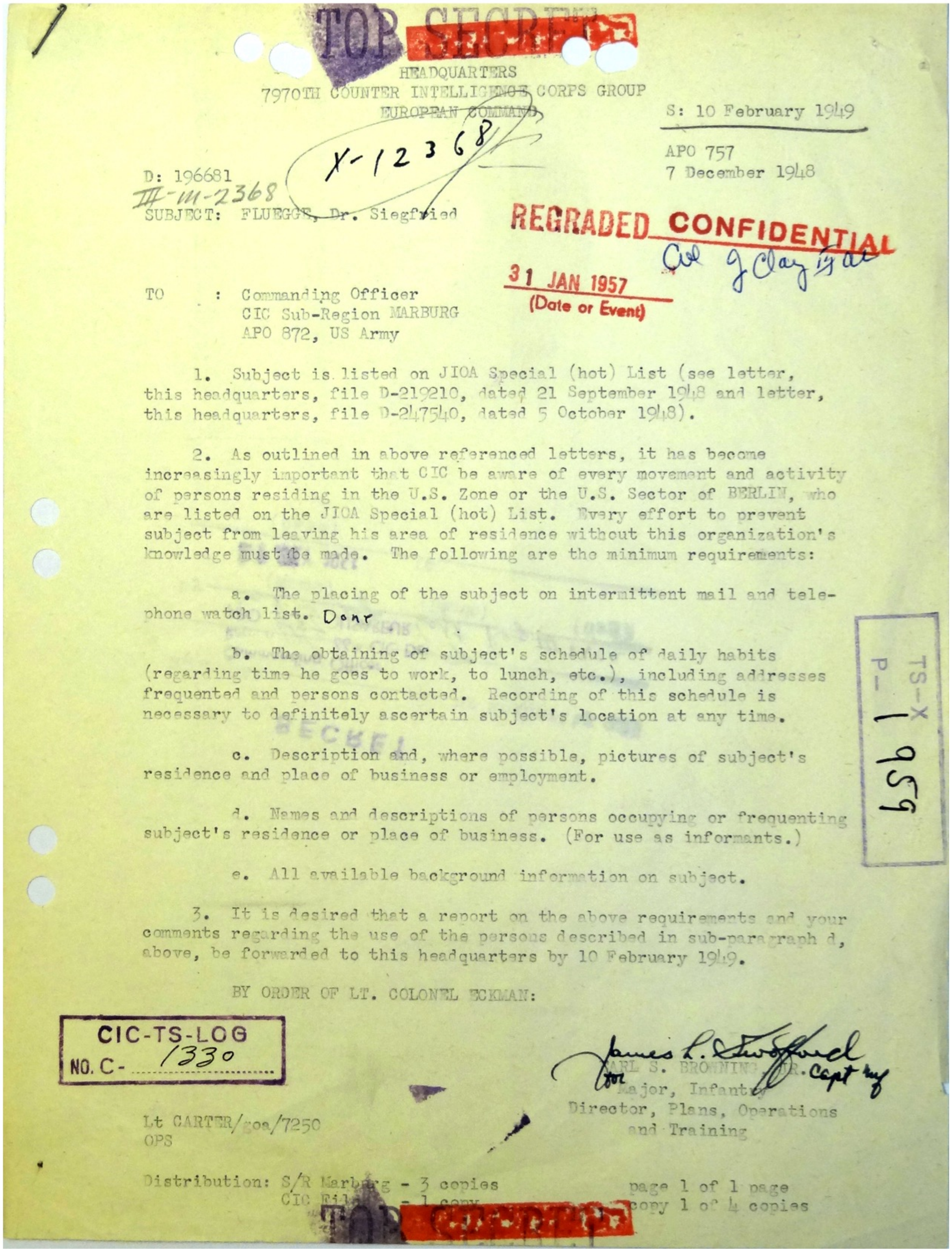
SECRET

Col. Hale H
Shaw Bd.
Ryan

Figure D.989: At the specific request of Edward Teller, Siegfried Flügge was brought to the United States. Another potential recruit named in this memo was Wilhelm Groth, who was also involved in the German H-bomb program (e.g., p. 4367). Flügge and Groth were being requested and discussed by Allied officials specifically in charge of nuclear work: Teller, Gattiker, Seeman, Welsh, etc. [NARA RG 77, Entry UD-22A, Box 167, Folder 202.3-2 LONDON OFFICE: Combined Oper Ger Group].

DECLASSIFIED
Authority NND007017

NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge



TOP SECRET

HEADQUARTERS
7970TH COUNTER INTELLIGENCE CORPS GROUP
EUROPEAN COMMAND

S: 10 February 1949

X-12368

APO 757
7 December 1948

D: 196681
III-M-2368
SUBJECT: FLUEGGE, Dr. Siegfried

REGRADED CONFIDENTIAL
Col J Clay Ig dv
31 JAN 1957
(Date or Event)

TO : Commanding Officer
CIC Sub-Region MARBURG
APO 872, US Army

1. Subject is listed on JIOA Special (hot) List (see letter, this headquarters, file D-219210, dated 21 September 1948 and letter, this headquarters, file D-247540, dated 5 October 1948).

2. As outlined in above referenced letters, it has become increasingly important that CIC be aware of every movement and activity of persons residing in the U.S. Zone or the U.S. Sector of BERLIN, who are listed on the JIOA Special (hot) List. Every effort to prevent subject from leaving his area of residence without this organization's knowledge must be made. The following are the minimum requirements:

a. The placing of the subject on intermittent mail and telephone watch list. Done

b. The obtaining of subject's schedule of daily habits (regarding time he goes to work, to lunch, etc.), including addresses frequented and persons contacted. Recording of this schedule is necessary to definitely ascertain subject's location at any time.

c. Description and, where possible, pictures of subject's residence and place of business or employment.

d. Names and descriptions of persons occupying or frequenting subject's residence or place of business. (For use as informants.)

e. All available background information on subject.

3. It is desired that a report on the above requirements and your comments regarding the use of the persons described in sub-paragraph d, above, be forwarded to this headquarters by 10 February 1949.

TS-X
P-1959

BY ORDER OF LT. COLONEL ECKMAN:

CIC-TS-LOG
NO. C- 1330

James L. Swofford
for CARL S. BROWNING, JR. Capt Inf
Major, Infantry
Director, Plans, Operations
and Training

Lt CARTER/goa/7250
OPS

Distribution: S/R Marburg - 3 copies
CIC File - 1 copy

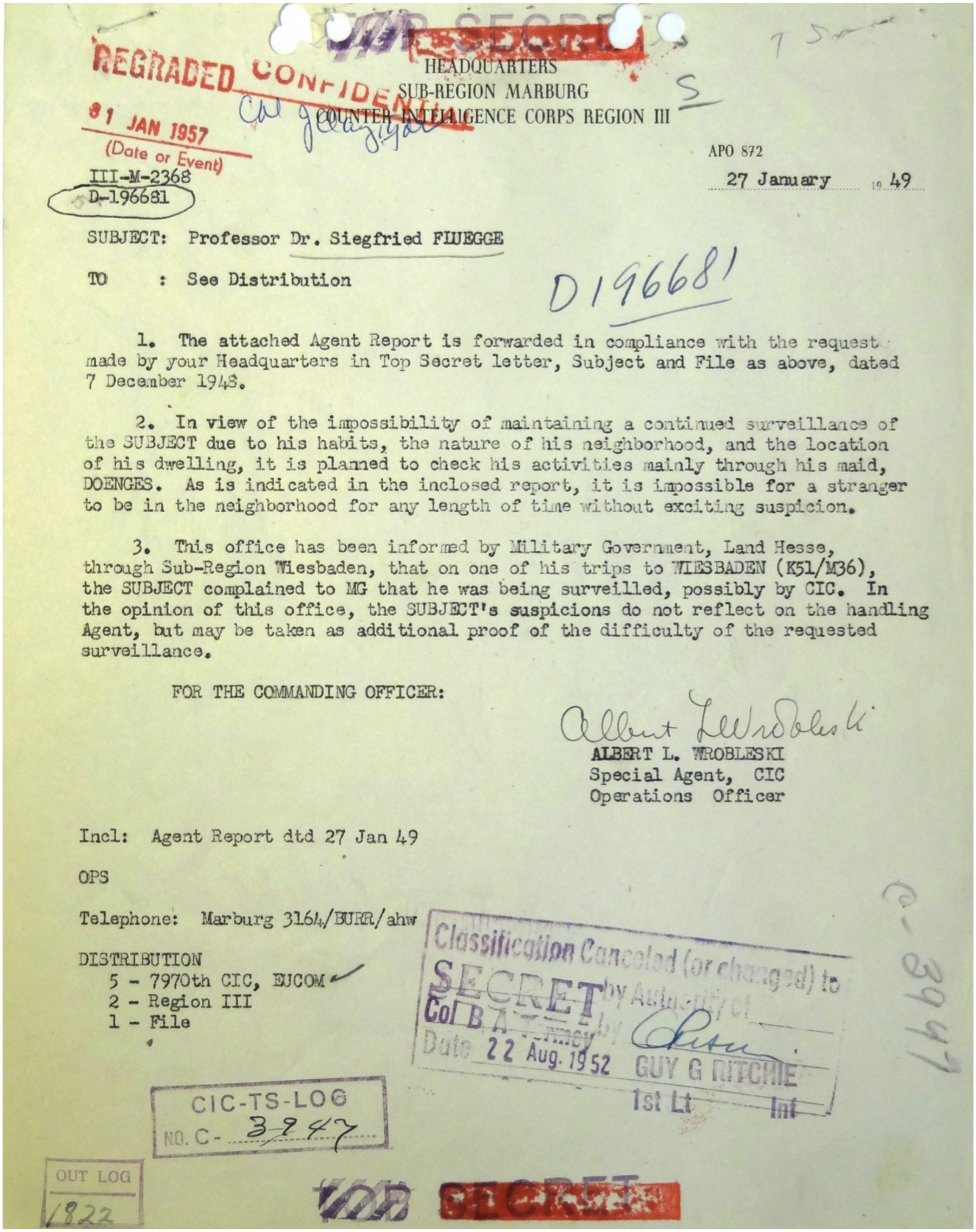
page 1 of 1 page
copy 1 of 4 copies

TOP SECRET

Figure D.990: When not in the United States, Flügge was placed on the Top Secret JIOA K "hot list" and constantly monitored for at least a decade after the war, on the direct orders of Lt. Col. George R. Eckman, formerly of the Alsos Mission [NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge].

DECLASSIFIED
Authority NND007017

NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge



TOP SECRET

REGRADED CONFIDENTIAL
31 JAN 1957
(Date or Event)

Col Gleazigal

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HEADQUARTERS
SUB-REGION MARBURG
COUNTER INTELLIGENCE CORPS REGION III

APO 872

27 January 1949

III-M-2368
D-196681

SUBJECT: Professor Dr. Siegfried FLUEGGE

TO : See Distribution

D196681

1. The attached Agent Report is forwarded in compliance with the request made by your Headquarters in Top Secret letter, Subject and File as above, dated 7 December 1948.

2. In view of the impossibility of maintaining a continued surveillance of the SUBJECT due to his habits, the nature of his neighborhood, and the location of his dwelling, it is planned to check his activities mainly through his maid, DOENGES. As is indicated in the inclosed report, it is impossible for a stranger to be in the neighborhood for any length of time without exciting suspicion.

3. This office has been informed by Military Government, Land Hesse, through Sub-Region Wiesbaden, that on one of his trips to WIESBADEN (K51/M36), the SUBJECT complained to MG that he was being surveilled, possibly by CIC. In the opinion of this office, the SUBJECT's suspicions do not reflect on the handling Agent, but may be taken as additional proof of the difficulty of the requested surveillance.

FOR THE COMMANDING OFFICER:

Albert L Wrobleski
ALBERT L. WROBLESKI
Special Agent, CIC
Operations Officer

Incl: Agent Report dtd 27 Jan 49

OPS

Telephone: Marburg 3164/BURR/ahw

DISTRIBUTION
5 - 7970th CIC, EUCOM
2 - Region III
1 - File

Classification Canceled (or changed) to
SECRET by Authority of
Col B A [illegible] by
Date 22 Aug. 1952 GUY G RITCHIE
1st Lt Inf

CIC-TS-LOG
NO. C- 3947

C-3947

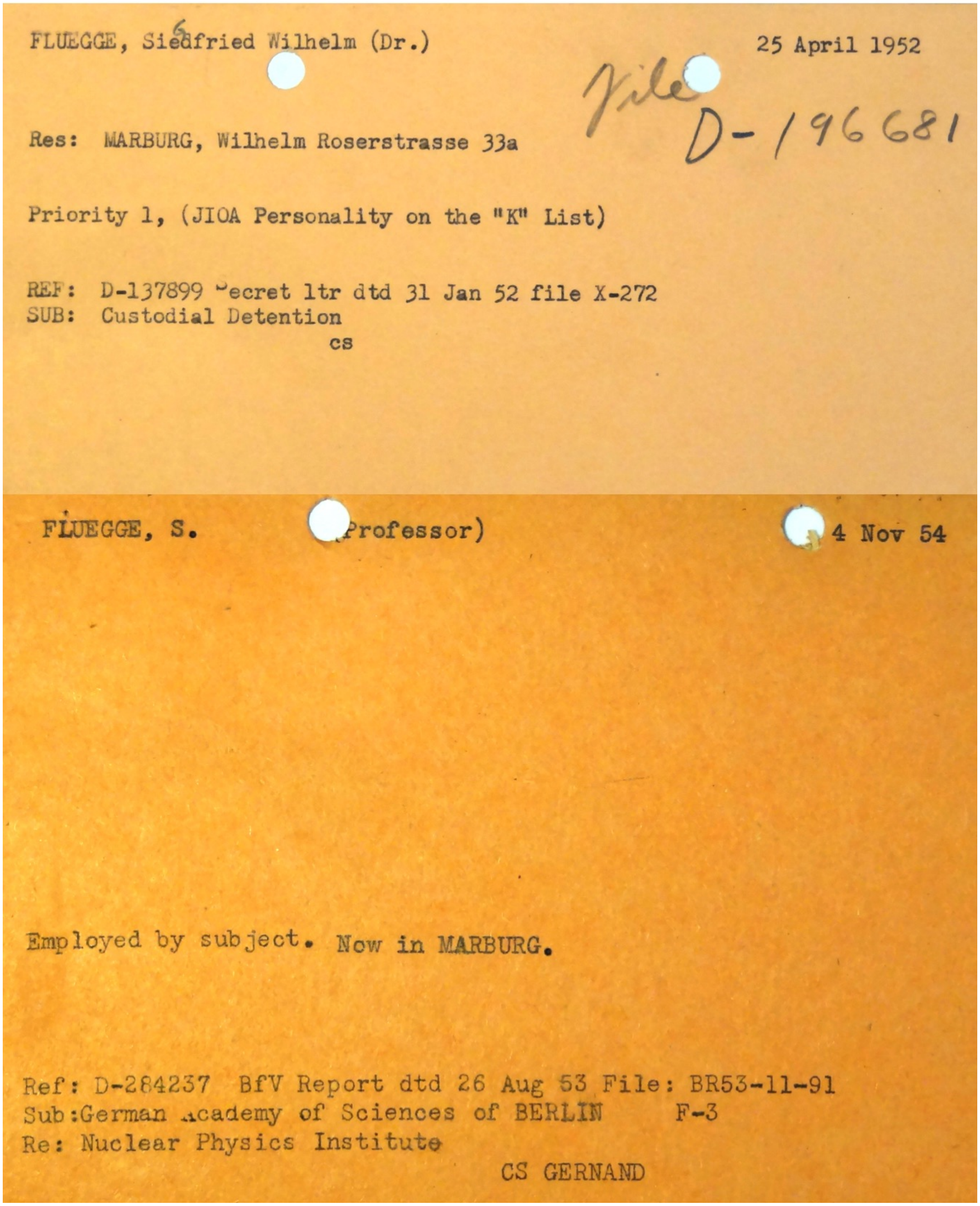
OUT LOG
1822

TOP SECRET

Figure D.991: When not in the United States, Flügge was placed on the Top Secret JIOA K "hot list" and constantly monitored for at least a decade after the war, on the direct orders of Lt. Col. George R. Eckman, formerly of the Alsos Mission [NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge].

DECLASSIFIED
Authority NND007017

NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge



g
FLUEGGE, Siedfried Wilhelm (Dr.) 25 April 1952

File
D-196681

Res: MARBURG, Wilhelm Roserstrasse 33a

Priority 1, (JIOA Personality on the "K" List)

REF: D-137899 Secret ltr dtd 31 Jan 52 file X-272
SUB: Custodial Detention
cs

FLUEGGE, S. (Professor) 4 Nov 54

Employed by subject. Now in MARBURG.

Ref: D-284237 BfV Report dtd 26 Aug 53 File: BR53-11-91
Sub: German Academy of Sciences of BERLIN F-3
Re: Nuclear Physics Institute
CS GERNAND

Figure D.992: When not in the United States, Flügge was placed on the Top Secret JIOA K "hot list" and constantly monitored for at least a decade after the war, on the direct orders of Lt. Col. George R. Eckman, formerly of the Alsos Mission [NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge].

Edward Teller's request for Siegfried Flügge's assistance. [NARA RG 330, Entry A1-1B, Box 43, Folder Flügge, Siegfried]

EXOS:ONR:N421:UL:kcm
Serial No. 14654

NAVY DEPARTMENT
Office of Naval Research
Washington 25, D.C.

July 18, 1947

From: Chief of Naval Research

To: Chief of Naval Intelligence

Subj: Foreign Scientists, Request for assistance on.

1. Professor Edward Teller, Physics Department, University of Chicago, is supervising under contract to this Office a research program on various phases of research in physics of the solid state. This program is of interest and importance to the national security. Professor Teller is very desirous to obtain the services of the German physicist, Dr. Siegfried Flügge, who can be of marked assistance in carrying out the aforementioned program.

2. Professor Teller has requested the Office of Technical Services, Department of Commerce, to obtain Dr. Flügge from Germany. It is requested that the Joint Intelligence Objectives Agency be informed of the Navy's interest in this case, and asked to provide such assistance as is possible to Professor Teller in aiding Dr. Flügge to come to this country.

C. M. Bolster
Capt., USN
Acting Chief of Naval Research

cc: Mr. Robert Frye, OTS, Dept. of Commerce
Professor Edward Teller, Physics Dept.
University of Chicago

[See document photo on p. 4996.

In 1947, Edward Teller was arguably the leading theoretical physicist of the U.S. nuclear weapons program, since most of the other prominent physicists from the Manhattan Project returned to civilian projects after the war. Throughout the 1940s, Teller was obsessed with creating a working fusion (hydrogen or H) bomb that would be much more powerful than the Manhattan Project's fission bombs. In 1946, a panel of other U.S. physicists concluded that Teller's proposed "classical Super" design for an H bomb was unlikely to work and that they did not know how to improve upon it, so in 1947 Teller would have been especially desperate for advanced nuclear weapons design solutions.

Siegfried Flügge was arguably the leading theoretical physicist of the wartime German nuclear weapons program, although apart from two very early and introductory publications (p. 3366), that was far from public knowledge at that time (or even today).

Some German-speaking scientists who had already settled in the United States, such as Hermann Mark and Theodore von Kármán, actively worked to bring many other German-speaking scientists to the United States after the war. However, I am not aware of other examples of Edward Teller actively recruiting German-speaking scientists from Europe after the war.

Thus this letter shows an extraordinary degree of interest and a singular focus. The leading physicist of the U.S. nuclear weapons program was "very desirous to obtain the services" of the leading physicist of the wartime German nuclear weapons program, who could "be of marked assistance in carrying out" an unspecified physics program "of interest and importance to the national security."

If the United States had discovered, sometime after the war, that Germany had actually had an advanced nuclear weapons program, it would have needed a particular type of person to help interrogate people who were most closely associated with that program and who could provide the most detailed technical information about it. Specifically, the United States would have needed someone (the fewer people the better, for security reasons) who:

- Was a physicist with an intimate knowledge of nuclear weapons designs from the Manhattan Project. (Many potential candidates, such as Theodore von Kármán and Samuel Goudsmit, did not have that knowledge, so this criterion rules them out.)
- Was fluent in German, including very technical German.
- Was extremely close to the U.S. military, and could be trusted to strongly advocate for its interests and to religiously keep its secrets.

There would have been a number of possible candidates for that position (see p. 1549), but those best matching the above three qualifications probably would have been Edward Teller, Hans Bethe, J. Robert Oppenheimer, and John von Neumann. Of those four, after the war only Teller was still truly focused on nuclear weapons designs. Teller would have been the ideal physicist to help interrogate top scientists from the German nuclear program such as Flügge, or top administrators from the program such as Hans Kammler (if he was indeed in U.S. custody), in order to learn as many technical details as possible about the German program's weapons designs, production methods, and results.

Flügge did eventually visit the United States in 1949–1950 and 1953. It is probably no coincidence that those were critical periods for the development of the country's first (cryogenic) H-bomb and its first dry (lithium deuteride) H-bomb, respectively. It seems virtually certain that even before those visits, while he was in Europe, Flügge was also interrogated in detail by U.S. scientists (perhaps Teller himself) and intelligence officials; otherwise Teller would not have known to make this specific request.

Can the details of Flügge's U.S. visits, work, and interrogations be located in archives and released?

As shown on pp. 4997–5003 and in a number of other declassified documents in that same file [NARA RG 330, Entry A1-1B, Box 43, Folder Flügge, Siegfried], when not in the United States, Flügge was placed on the Top Secret JIOA K "hot list," and very closely and constantly monitored for at least a decade after the war. The U.S. official who issued those orders was none other than Lt. Col. George R. Eckman, who had been the Executive Officer of the Alsos Mission [p. 3333 and https://www.ikn.army.mil/apps/MIHOF/biographies/Eckman,%20George.pdf]!

Importantly, these files on Flügge (pp. 4998–4999) also prove that this leading physicist of the German nuclear weapons program worked with the:

- Reichspost (Post Office).
- Heereswaffenamt (Army Ordnance Office).
- Kaiser Wilhelm Institutes.
- Reichsforschungsrat (Reich Research Council).
- University of Königsberg in East Prussia (said to have fission reactors, pp. 3928–3929, 4578–4579).
- He also apparently worked in Austria at St. Georgen an der Gusen (p. 3882), another suspected nuclear facility.

This appears to demonstrate high-level scientific coordination of the nuclear activities among many different organizations throughout the Reich.

How much did the United States know about the German nuclear weapons program's structure (e.g., that Flügge was its leading physicist) and accomplishments (e.g., that it had successfully developed fission bombs and had conducted advanced work on H-bomb designs, lithium deuteride, fusion boosting, etc.) prior to Teller's request? How much did it ultimately learn?

Teller's highly specific and urgent request, presumably based on his own or other classified post-war U.S. intelligence on the wartime German nuclear program, strongly suggests that Flügge was involved not only in the design of German fission bombs (see p. 3366 and Section D.8), but also in the design of German H-bombs (Section D.9).

Although the Soviet Union detonated its first known fission bomb in August 1949, Flügge was kept on the JIOA K "hot list" and closely monitored by the United States until at least the end of 1954. Even the documents mentioning the U.S. surveillance of Flügge (with no military or scientific details) were classified Top Secret, which seems extraordinary. Moreover, those files were finally downgraded to Confidential in January 1957. All of that is further evidence that Flügge had detailed knowledge of not just fission bombs but also H-bombs, which the Soviet Union did not fully perfect until November 1955 (RDS-37). The United States kept Flügge on a very tight leash, and even classified any mention of that leash as Top Secret, until the Soviet H-bomb program had reached a level of technological maturity at which it no longer would have needed Flügge's knowledge about H-bomb design.

Georg Stetter and his fellow Austrian nuclear scientists were also deeply involved in the wartime German H-bomb program (pp. 4330–4345). Just as they did with Flügge, the United States kept Stetter under very close supervision until the 1950s, presumably until he too would no longer have been helpful for the Soviet H-bomb program (pp. 4788–4800). And like Flügge, some members of Stetter's team were brought to the United States after the war to work temporarily or permanently.]

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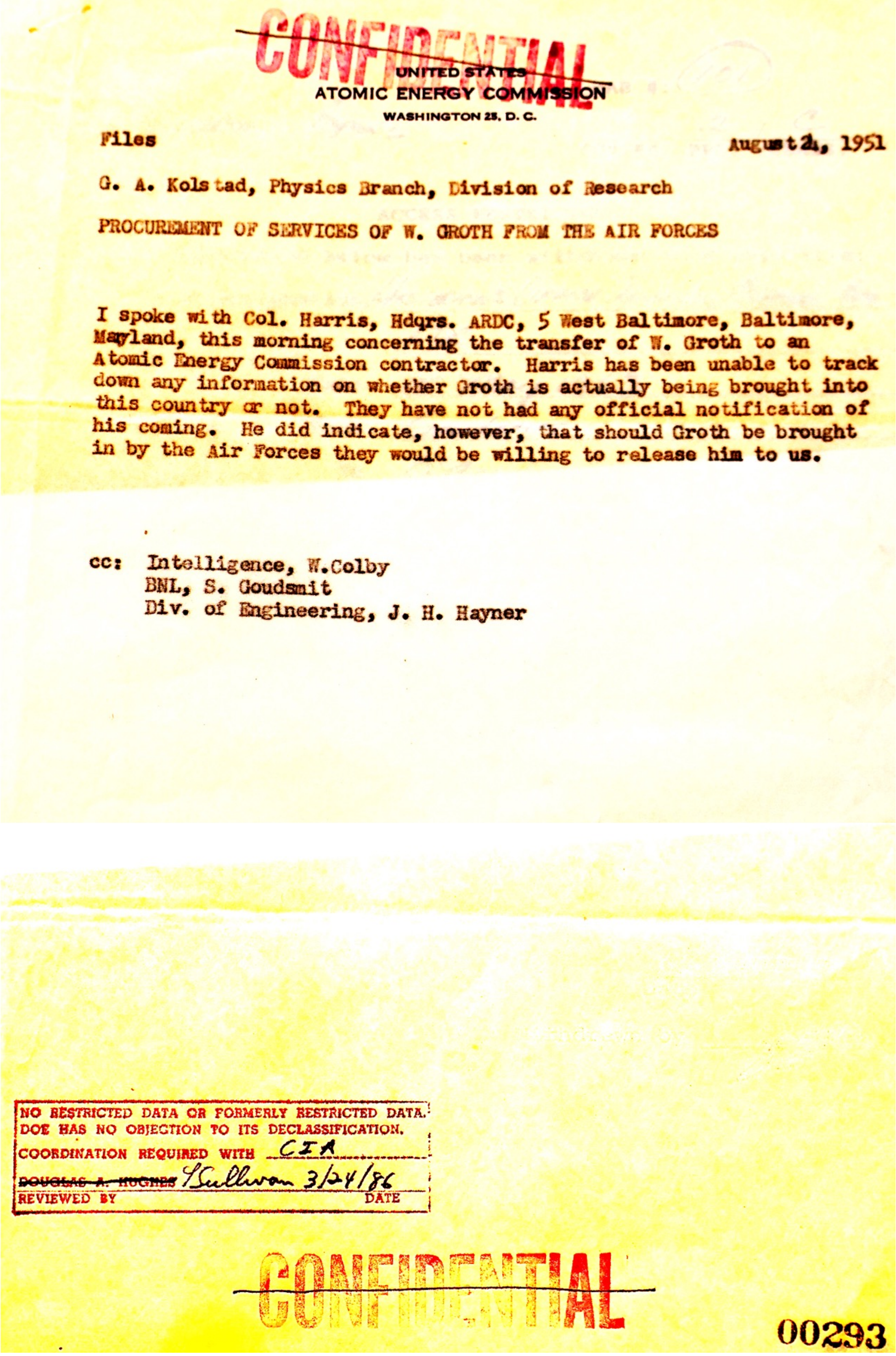
Authority NW87071

NARA RG GOUDS, Entry UD-7420, Box 3, Folder
"Historian's Office Inventory Control Job Goudsmit Box 4 Folder 4"



~~CONFIDENTIAL~~

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON 25, D. C.

Files August 24, 1951

G. A. Kolstad, Physics Branch, Division of Research

PROCUREMENT OF SERVICES OF W. GROTH FROM THE AIR FORCES

I spoke with Col. Harris, Hdqrs. ARDC, 5 West Baltimore, Baltimore, Mayland, this morning concerning the transfer of W. Groth to an Atomic Energy Commission contractor. Harris has been unable to track down any information on whether Groth is actually being brought into this country or not. They have not had any official notification of his coming. He did indicate, however, that should Groth be brought in by the Air Forces they would be willing to release him to us.

cc: Intelligence, W.Colby
BNL, S. Goudsmit
Div. of Engineering, J. H. Hayner

NO RESTRICTED DATA OR FORMERLY RESTRICTED DATA.
DOE HAS NO OBJECTION TO ITS DECLASSIFICATION.
COORDINATION REQUIRED WITH CIA
~~DOUGLAS A. HUGHES~~ J Sullivan 3/24/86
REVIEWED BY DATE

~~CONFIDENTIAL~~

00293

Figure D.993: G. A. Kolstad to Samuel Goudsmit et al. 24 August 1951. Procurement of Services of W. Groth from the Air Forces [NARA RG GOUDS, Entry UD-7420, Box 3, Folder "Historian's Office Inventory Control Job Goudsmit Box 4 Folder 4"]. "...concerning the transfer of W. Groth to an Atomic Energy Commission contractor. Harris has been unable to track down any information on whether Groth is actually being brought into this country or not... [S]hould Groth be brought in by the Air Forces they would be willing to release him to us."

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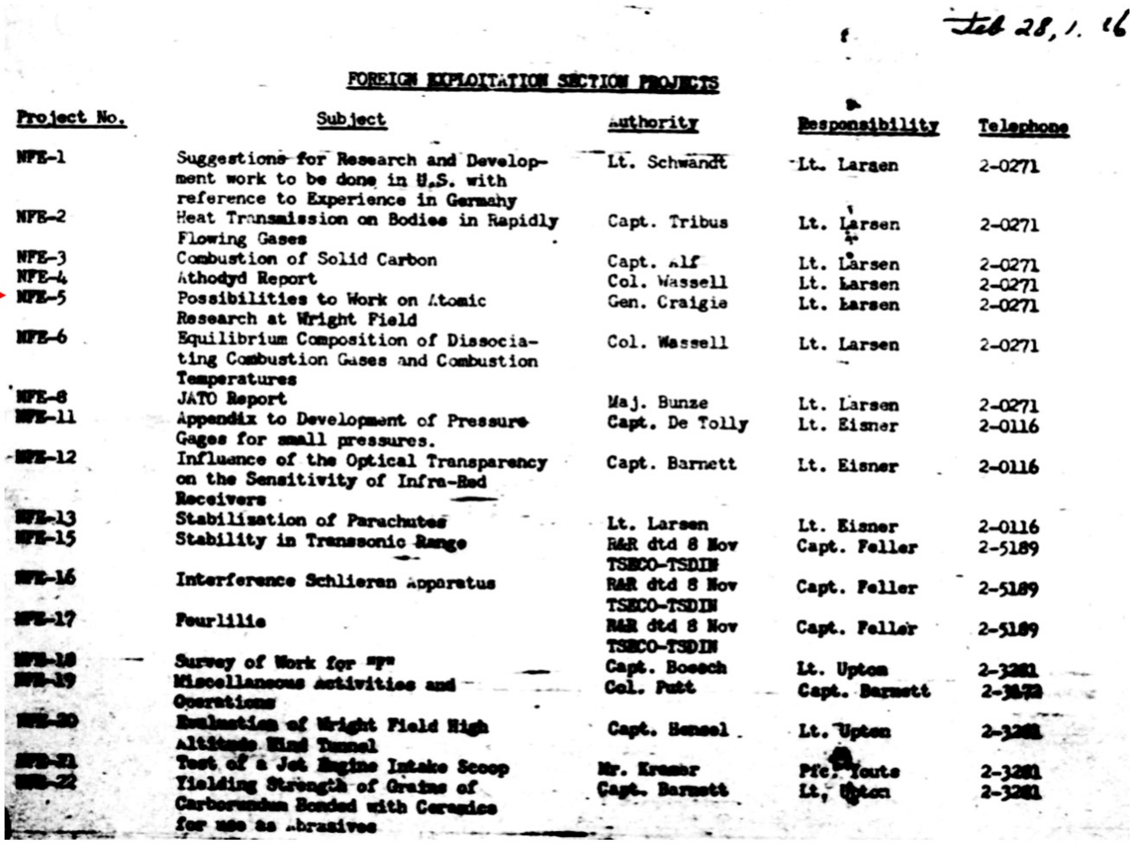
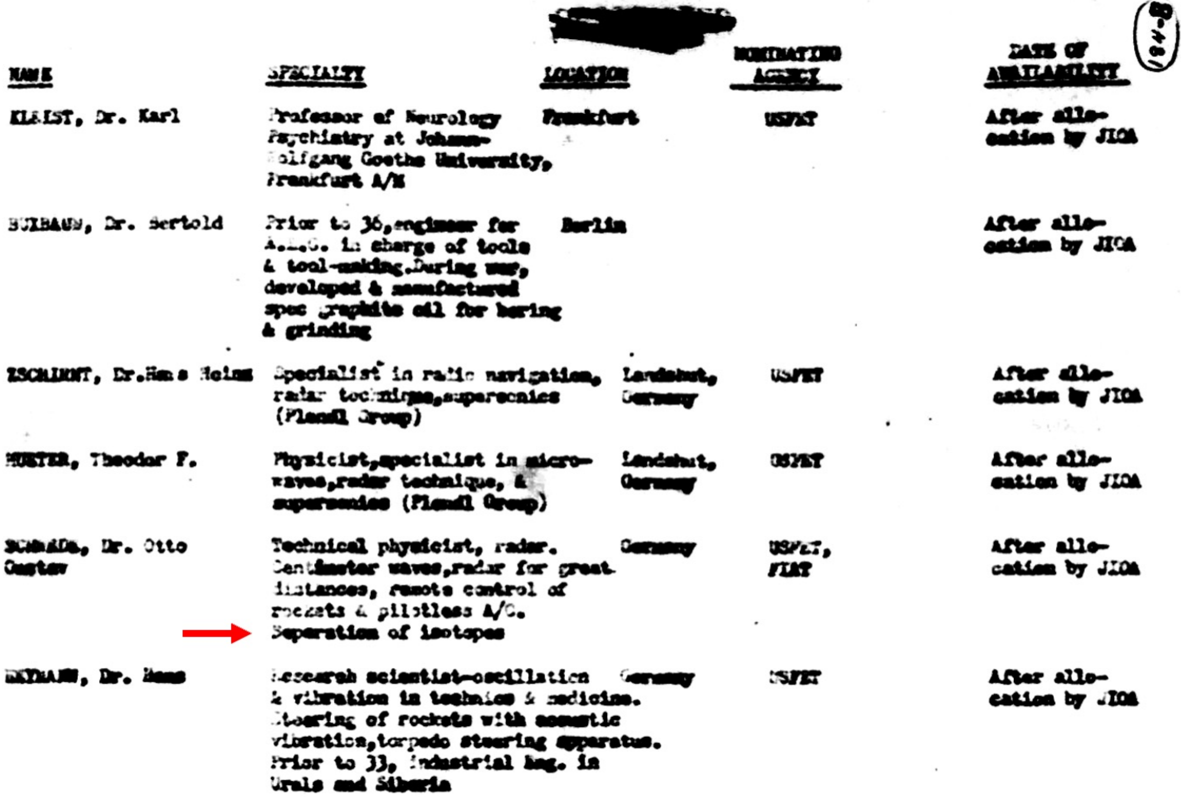


Feb 28, 1946

FOREIGN EXPLOITATION SECTION PROJECTS

Project No.	Subject	Authority	Responsibility	Telephone
NFE-1	Suggestions for Research and Development work to be done in U.S. with reference to Experience in Germany	Lt. Schwandt	Lt. Larsen	2-0271
NFE-2	Heat Transmission on Bodies in Rapidly Flowing Gases	Capt. Tribus	Lt. Larsen	2-0271
NFE-3	Combustion of Solid Carbon	Capt. Alf	Lt. Larsen	2-0271
NFE-4	Athodyd Report	Col. Wassell	Lt. Larsen	2-0271
NFE-5	Possibilities to Work on Atomic Research at Wright Field	Gen. Craigie	Lt. Larsen	2-0271
NFE-6	Equilibrium Composition of Dissociating Combustion Gases and Combustion Temperatures	Col. Wassell	Lt. Larsen	2-0271
NFE-8	JATO Report	Maj. Bunze	Lt. Larsen	2-0271
NFE-11	Appendix to Development of Pressure Gages for small pressures.	Capt. De Tolly	Lt. Eisner	2-0116
NFE-12	Influence of the Optical Transparency on the Sensitivity of Infra-Red Receivers	Capt. Barnett	Lt. Eisner	2-0116
NFE-13	Stabilization of Parachutes	Lt. Larsen	Lt. Eisner	2-0116
NFE-15	Stability in Transsonic Range	R&R dtd 8 Nov TSECO-TSDIN	Capt. Feller	2-5189
NFE-16	Interference Schlieren Apparatus	R&R dtd 8 Nov TSECO-TSDIN	Capt. Feller	2-5189
NFE-17	Feurlilie	R&R dtd 8 Nov TSECO-TSDIN	Capt. Feller	2-5189
NFE-18	Survey of Work for "P"	Capt. Boesch	Lt. Upton	2-3281
NFE-19	Miscellaneous Activities and Operations	Col. Putt	Capt. Barnett	2-3872
NFE-20	Evaluation of Wright Field High Altitude Wind Tunnel	Capt. Hensel	Lt. Upton	2-3281
NFE-21	Test of a Jet Engine Intake Scoop	Mr. Kramer	Pfc. Youte	2-3281
NFE-22	Yielding Strength of Grains of Carborundum Bonded with Ceramics for use as Abrasives	Capt. Barnett	Lt, Upton	2-3281

AFHRA A2055 Frames 1173, 1362



[redacted]

NAME	SPECIALTY	LOCATION	NOMINATING AGENCY	DATE OF AVAILABILITY
KLEIST, Dr. Karl	Professor of Neurology Psychiatry at Johann-Wolfgang Goethe University, Frankfurt A/M	Frankfurt	USFET	After allocation by JIOA
BUXBAUM, Dr. Bertold	Prior to 36, engineer for A.E.G. in charge of tools & tool-making. During war, developed & manufactured spec graphite oil for boring & grinding	Berlin		After allocation by JIOA
ZSCHAUNT, Dr. Hans Heinz	Specialist in radio navigation, radar technique, supersonics (Plendl Group)	Landshut, Germany	USFET	After allocation by JIOA
MUSTER, Theodor F.	Physicist, specialist in micro-waves, radar technique, & supersonics (Plendl Group)	Landshut, Germany	USFET	After allocation by JIOA
SCHMIDT, Dr. Otto Gustav	Technical physicist, radar. Centimeter waves, radar for great distances, remote control of rockets & pilotless A/C. Separation of isotopes	Germany	USFET, FIAT	After allocation by JIOA
HEYMANN, Dr. Hans	Research scientist-oscillation & vibration in technics & medicine. Steering of rockets with acoustic vibration, torpedo steering apparatus. Prior to 33, Industrial Eng. in Urals and Siberia	Germany	USFET	After allocation by JIOA

Figure D.994: German scientists who worked for the U.S. military were capable of leading research projects to advance the state of U.S. nuclear programs, including isotope separation. Top: Foreign Exploitation Section Projects. 28 February 1946 [AFHRA A2055 Frame 1173]. Bottom: R. F. Ennis. 27 January 1947. [AFHRA A2055 Frame 1362].

G. H. Morrison. How Adolf Hitler Lost the Atomic Bomb. *The Argus* (Melbourne). 6 October 1945, p. 2. https://trove.nla.gov.au/newspaper/article/12145557/631795

When Hitler learned that two German scientists had at last discovered a method by which it would ultimately be feasible to split uranium atoms when and as required, he imagined that Germany would soon hold a weapon whose mere possession would force her enemies to capitulate unconditionally. Hence his mysterious reference in the first days of the war to "a secret weapon" which, he said, he hesitated to use because of its deadliness. [...]

Again and again, Goebbels proclaimed the coming of the secret weapon that was to give Nazi Germany immediate and decisive victory. Over and over again Goebbels urged that "time was on the side of Germany." Just how far German atomic research had gone we were unable to discover. But it was quite certain the Germans were on the right track. [...]

On the laboratory scale U 235 was isolated for the first time in Germany in 1940. Even that, however, was far from being the end of the job of unravelling the skein of theoretical enigmas. Each problem solved raised some new problem. But German scientists stuck frantically to the task; and, as Professor Westphal, principal of the Berlin Technical High School, has since revealed, the Germans had solved the last laboratory problem in atom-splitting by 1944. That was about the time Goebbels began to assure his compatriots that the secret weapon would soon be in use.

[George H. Morrison (U.S., 1921–2004), an analytical chemist, worked on uranium purification and enrichment for the Manhattan Project: https://paw.princeton.edu/memorial/george-h-morrison-48

What exactly did Wilhelm Westphal do in Germany during the war and in the U.S. after the war?]

Dieter Hoffmann and Mark Walker, eds. 2007. *Physiker zwischen Autonomie und Anpassung.* Weinheim: Wiley. p. 340.

Ein Brief von Rudolf Ladenburg an Max von Laue, unmittelbar nach Erhalt dieses Artikels verfasst, führt uns zu einer weiteren Pointe:

"Otto Hahn's Artikel in der Göttinger Universitätszeitung bringt die Entlassung deutscher Professoren mit dem amerikanischen Angebot Professoren nach USA einzuladen in Zusammenhang. Wissen Sie von Kollegen, die erst entlassen + nun nach USA abgereist sind? Ich weiss nur, daß Westphal in USA ist + dass Joos hierher Anfang Juni abgereist ist [. . .] Westphal war, soweit ich weiss, nie abgesetzt + Joos ist nach kurzer Zeit wieder eingesetzt worden. In seinem Fall war die Absetzung, wie ich gehört habe, durch eine (unentschuldbare) Namensverwechslung verursacht."93)

A letter from Rudolf Ladenburg to Max von Laue, written immediately after receipt of this article, leads us to another point:

"Otto Hahn's article in the Göttingen University newspaper connects the dismissal of German professors with American offers to invite professors to the USA. Do you know of any colleagues who were first dismissed + have now left for USA? I only know that Westphal is in USA + that Joos left here at the beginning of June [...] Westphal, as far as I know, was never dismissed + Joos was reinstated after a short time. In his case, the removal, as I have heard, was caused by an (inexcusable) confusion of names."93)

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93) Ladenburg an Laue, 30.7.1947, MPGA, II. Abt., Rep. 50, Nr. 1158, zit. nach: Klaus Schlüpmann, Vergangenheit, S. 426 f.

93) Ladenburg to Laue, 30 July 1947, MPGA, II Dept, Rep. 50, No. 1158, quoted in: Klaus Schlüpmann, Vergangenheit, p. 426 f.

D.14.9 Other Intelligence Services

[There is evidence that other U.S. investigators, as well as intelligence services from other countries, found information about the German nuclear program.

For U.S. involvement in a postwar shipment of five tons of zirconium that apparently came from the wartime German nuclear program, and that indicates a deeper U.S. understanding of the German nuclear program, see p. 4146.]

Ernest K. Lindley, Chief of Washington Bureau of *Newsweek*. Men and Secret Weapon for 1944 Invasion. *The World's News* (Sydney). 5 February 1944, p. 3.
https://trove.nla.gov.au/newspaper/page/14771447

Rumors concerning Germany's "secret weapon" continue to trickle through neutral capitals.

Recently a United Press despatch from Lisbon attributed to travellers arriving from the Reich the statement that the weapon is an explosive based on the release of atomic energy.

According to this report, small atomic bombs of tremendous explosive force would be dropped by "super-stratosphere" planes.

In both London and Washington, there are several degrees of reaction to the "secret weapon" talk.

- That it is partly propaganda, chiefly for German internal consumption, partly "nerve warfare" against the Allies.
- That the Germans may have something of nuisance value, but probably not in sufficient quantity to do much damage.
- That the weapon, even if dangerous, can be knocked out of enemy hands by such preventive measures as the bombing of the so-called Rocket Coast of Northern France.
- That the threat is serious enough to require every precaution possible and preparation for severe counter-action, such as air-borne gas attacks.

Bombing the "Rocket Coast" would not, for example, interfere with the use of an atomic bomb dropped from high-flying planes.

If the Germans have been able not only to perfect a super explosive but to produce it in quantity, it would be logical to expect them to use it on Britain when they think the invasion armies are about ready to jump off, hoping to disorganise the assault on Europe and stave off defeat in 1944.

Churchill, as his published comments indicate, regards reports of the "secret weapon" with respect, but not with alarm.

Other informed sources are braced for a vengeful, hurtful attack on Britain.

[By the end of the war, Ernest Lindley or his colleagues at *Newsweek* seem to have found high-ranking Allied officials who corroborated this early report. See p. 5022.]

Nazis' Atom Bomb Plans: Britain Ready a Year Ago. ***Daily Telegraph and Morning Post.*** **11 August 1945.**

Britain prepared for the possibility of an atomic bomb attack on this country by Germany in August, 1944.

It can now be disclosed that details of the expected effect of such a bomb were revealed in a highly secret memorandum which was sent that summer to the chiefs of Scotland Yard, chief constables of provincial forces and senior officials of the defence services.

An elaborate scheme was drawn up by the Ministry of Home Security for prompt and adequate measures to cope with the widespread devastation and heavy casualties expected if the Germans succeeded in launching atomic bombs on this country.

Reports received from our agents on the Continent early last year indicated that German scientists were experimenting with an atomic bomb in Norway. According to these reports the bomb was launched by catapult, and had an explosive radius of more than two miles.

In view of our own progress in devising an atomic bomb, the Government gave the reports serious consideration. Thousands of men and women of the police and defence services were held in readiness for several months until reliable agents in Germany reported that the bomb had been tested and proved a failure.

[Allied intelligence reports confirmed that Germany was developing an atomic bomb. A blast radius of over 2 miles or over 3200 meters corresponds to an explosive energy of approximately $(3200/85.5)^3 \approx 50{,}000$ tons of TNT, definitely nuclear and over twice the explosive energy of the first U.S. fission bombs.

Allied intelligence also confirmed that there was at least one attempted test of the German atomic bomb. It was reported to have been a failure and to have been associated with Norway (as the development and/or test location?). Was that the same failed atomic bomb test that Werner Grothmann mentioned in the North Sea in late 1943 (p. 4436)? The German nuclear program was producing heavy water at several sites in Norway (pp. 4027–4041), so were there other important aspects of the program in Norway? Dwight Eisenhower mentioned some sort of mysterious nuclear work at Trondheim that is otherwise unknown in publicly available documents (p. 5034). See also p. 4404.

The catapult launch suggests that the bomb may have been designed to be carried on a V-1 cruise missile, which was launched by catapult, or by some other aircraft or rocket that had been designed or modified to be launched by catapult. The Sänger-Bredt Silbervogel space plane would have been launched by catapult, and some versions of the A-9 rocket were designed to be launched by catapult. V-1 launch catapults were installed on German submarines in 1944 in order to attack Allied targets from offshore (pp. 5618–5627). There were major German submarine bases at Trondheim and other locations in Norway. And there were plans to arm the V-1 with a nuclear warhead (e.g, pp. 4896–4897). Could that have been the connection among these several mysterious pieces of intelligence?

Allied fears that the German bomb was nearly ready for deployment heightened in summer and autumn 1944. The Royal Air Force went to extreme lengths to bomb what appears to have been a German fission reactor and fuel reprocessing complex near Königsberg during the period 26–30 August 1944 (pp. 3928–3929). The first successful German nuclear test may have occurred in October 1944 (p. 4390).]

Big Projectile Reported New Hitler Weapon. ***Los Angeles Times.*** **30 September 1944. p. 3.**

SOMEWHERE IN FRANCE, Sept. 23 (Delayed.) (AP)—American 3rd Army troops have obtained information indicating that a 14-ton projectile with an explosive radius of three kilometers—almost two miles—is scheduled as the third in Hitler's series of vengeance weapons.

V-1 is the robot bomb launched from a platform.

V-2 is the long-range rocket fired from a carrier plane, for which the Germans are reported using the Heinkel 111.

V-3, so far as is known here, has not yet been used against either England or the attacking Allied armies.

Information disclosed the projectile is just short of 60 feet in length, is five feet five inches in diameter and weighs 14 tons at the take-off. Propelled by a mixture of liquid air and alcohol, it is shot into the air vertically, then is controlled by radio.

[Germany had many secret weapons in development, and the "V" number would simply indicate the order in which they happened to be publicly announced. The V-1 cruise missile or "robot bomb" had been fired at London since June 1944 and was well known by the time of this article. However, the existence of the V-2 or A-4 rocket was not publicly known when this article was released. V-2 or A-4 rocket attacks on Allied countries began on 8 September 1944 but were not publicly admitted by Germany until 8 November 1944, and by the United Kingdom until 10 November 1944. The aircraft-fired rocket referred to as "V-2" in this article was not the large A-4 rocket that ultimately gained the V-2 name, but rather a different weapon. It was likely the air-launched version of the V-1, which was indeed fired from Heinkel He 111 carrier planes (p. 1841). Alternatively, it might have been some other large, long-range air-to-ground missile, perhaps similar to the RASCAL liquid-propellant rocket that Walter Dornberger began creating (or recreating?) in the United States in 1946.

The V-3 rocket specifications given in the article closely match those of the A-4 rocket that became the real V-2. The diameter was indeed five feet five inches (1.65 meters), the launch weight was indeed 14 tons, the propellant was indeed liquid oxygen ("liquid air") and alcohol, and the rocket was indeed controlled by radio. The one specification that does not match is the stated length of "just short of 60 feet," or approximately 18 meters. The actual A-4 rocket length was approximately 14 meters. This could simply be a mistake in the Allied intelligence or reporting, or it could indicate that 18-meter-long extended versions of the A-4 rocket were being developed or built. The 14-meter A-4 rocket could carry a 1-ton payload of conventional explosives to a maximum range of approximately 350 km. An 18-meter extended version of the A-4 rocket (very similar to the postwar

Soviet SS-2 or R-2 missile that was produced using captured German technology) would have been able to accommodate more propellant, and therefore would have been able to carry a significantly heavier payload, such as a nuclear bomb.

A blast radius of 3000 meters corresponds to an explosive energy of approximately $(3000/85.5)^3 \approx$ 40,000 tons of TNT, definitely nuclear and approximately twice the explosive energy of the first U.S. fission bombs. This suggests that Germany had been developing and was close to deploying a nuclear bomb, and that its large rockets had been intended from the beginning to be delivery systems for that bomb, not merely for conventional explosives.

What exactly did the Third Army discover that formed the basis of this article? Where was "somewhere in France"?

Note that the AP report was delayed for a full week by Allied censors. What details did the censors not allow to be included?

Similar versions of this AP news report were also published in:

> Americans Get Hint of New German Bomb. *New York Times.* 30 September 1944 p. 3.
>
> Hitler's V-3 Said to Blast 2-Mile Area. *Washington Post.* 30 September 1944 p. 5.
>
> Radio Controlled, 14 Ton Projectile New Nazi Weapon. *Blood and Fire* (Journal of U.S. Army 63rd Infantry Division). 30 September 1944 p. 1.]

U.K. House of Lords. 29–30 May 1945.
https://hansard.parliament.uk/lords/1945-05-29/debates/ba5ca4d2-43bd-4623-aa9c-33247efe9a93/LordsChamber
https://hansard.parliament.uk/Lords/1945-05-30/debates/12e7a0c3-87ba-413f-bee6-56c963d90dec/FutureOfDirectedMissiles

29 May 1945 [...]

LORD VANSITTART

had the following Notice on the Paper: To ask His Majesty's Government whether they will take the initiative in proposing to the Allied Governments the inclusion in the terms imposed upon Germany of an Article providing that a permanent Inter-Allied Committee of Scientists should be established to examine and control, and if necessary to prohibit the use by Germany of, any scientific discovery or invention considered dangerous to the safety of mankind; and to move for Papers.

The noble Lord said: My Lords, I venture to think that this Motion speaks for itself. I would suggest that the Prime Minister's last war review speaks for it even more loudly. In the last war the ingenious barbarians sprang gas upon us. That was a prelude. There was an insufficient answer to that. In this war we have had the V1 and the V2. There was only a still more insufficient answer to the V1, and the V2 found no answer at all, or rather it would be fairer to say that the answer was the same as for V3, the multiple long-range artillery described by the Prime Minister which was destined to endow us with five shells per minute. The remedy found was the old-fashioned one of conquering the sites—that is to say, the answer of infantry and not of science. Even that remedy will not always be available, because ranges increase and sites recede. Indeed, the ranges, in a very short while, may be almost unlimited. Even with short ranges we were very nearly too late. If the V1 and the V2 had been brought into action one year sooner they would probably have made an end of this island, and if they had been brought in some years sooner, that is at the beginning of the war, they might well have meant the end of civilization. Therefore, in dealing with a nation that is periodically homicidal, I think no precaution is excessive.

All precautions are indispensable, because without them I think the end might well be the end of an American fairy story which we read when we were very young. No doubt that story was written with an inkling of Reno because they lived happy ever after for quite a little while. I say that because destructive science has got out of hand. German science, like German religion, German economics, German pedagogy, has been very largely militarized and unless we keep a firm hand on it we shall very likely have the V10 in less than ten years. It is not my purpose to paint lurid pictures of cities dissolved by pressing a button, though I suppose that is now within the bounds of possibility. We have had one lesson and it will be our own fault if we have another. [...]

What exactly does all this involve? It involves a good deal, and I submit that a good deal is a good deal better than another raw deal. It involves control of all German laboratories, both industrial and university. That in turn involves the use of an extensive and intensive intelligence service which must be drawn from all the Allies. [...]

30 May 1945 [...]

LORD BRABAZON OF TARA

[...] The V2 was a very different machine altogether, and I want to draw attention to some of the possibilities of the V2 before we forget it altogether. Your Lordships must remember that this propelling power is entirely in its infancy. This projectile goes up forty or fifty miles in its flight. There is no limit at all to the range it can go to because the resistance is so small at those heights. I want your Lordships to remember that although the charge was only about a ton in the case of the V2, in the future the effect of the power of explosives is going to be very much bigger than that which we have to-day. The noble Lord who is to reply is a physicist and I should like him to tell us, if he can, what are the possibilities of explosives of an atomic type, because there are absolutely frightening possibilities. Consequently this weapon is one which is bound to be developed. It is the physicist's dream or nightmare that he can produce these terrible explosives. [...]

I can well imagine some people, with mischief in their hearts, planning what they can do. And what can they do: They can rope off a few miles of their own hilly country, they can sink shafts, nominally mining shafts, they can make the parts of this instrument all over their country, assemble them in the mine, and be all ready for a really efficient V2 attack upon their selected enemy. I want you Lordships to remember this, that you will see no apparent Army, you will see no apparent Air Force, you will see no apparent Navy, but they will have the power latent to launch an attack on the great cities of their enemies and the power to devastate them the moment they declare war. Before Armies can possibly assembled, let alone march, the great cities of the enemy will be destroyed. I hope you will not think for a moment that I am wrong when I say that these weapons, with the new power of the explosives which are possible and with the new accuracy of direction, are not only things which can be directed against this county. They can be directed against America and if the resources in manufacturing power of a great country like America are destroyed, as they could be in twenty years' time, we must look upon the fact that we are tied up to America and if she goes we go. Consequently this power of attack, which might be developed quietly in any part of the world, is a danger we must face. [...]

THE EARL OF DARNLEY

[...] This method of warfare may possibly in the future not only destroy humanity but also destroy the globe on which humanity resides. That sounds fantastic but from the information I have been able to get I believe it is not as fantastic as it sounds. The atomic bomb, so the Press tells us, was in a state of three-quarters preparation at the end of the war and may possibly in a generation accomplish even this.

But before discussing what must be the final fatuity of mankind, it is necessary to look a little, as the noble Lord has done, into the future of the flying bomb and the rocket. As he told us so ably and humorously, it only needs a little imagination to see what might happen from the enlargement and perfection of these two missiles. He has told us that the war of the future may last only a few minutes, and as it is now the fashion to make war without any warning the whole thing would be over before anybody is even aware that it has taken place. The first man to touch the trigger will achieve possibly the complete paralysis of his adversary by methods against which there can be no possible defence. Navies and Armies and Air Forces will be completely useless and even the other defences of Press and propaganda will be similarly completely useless. The fighters of the future will be a band of troglodytic alchemists living in catacombs in hidden valleys who will deal out inhuman death to millions and destruction to a world whose beauties and whose interests they have long since given up the art of appreciating. The machinations of these people will remove the last vestige of the so-called romance and chivalry from the original war which the noble Lord so amusingly described.

And then as to the atomic bomb. I am not speaking as an expert, I am merely passing on what I have seen described in the Press, as others of your Lordships have seen it, and perhaps the noble Lord who is going to answer will be able to give me some further information upon it. It was stated in the Press that a bomb as big as a man's hand was ready, or almost ready, for use at the end of the war, and that it could have destroyed the whole of a city as large as London. When this atomic bomb is added to these brainless horrors of metal and explosives, which we have heard about to-day, I believe—and again I ask for information from the noble Lord who is going to reply—that it may possibly be a fact that the release of the cohesive particles of the atom, which at present can only be released through intensive bombardment by great electric force, may cause such a violent reaction that the force engendered may be sufficient to release the coherence in the atoms contiguous to the explosion. If this is the case, every atom in the world might disintegrate and the whole globe disappear. Is this, then, the frightful possibility envisaged by the marriage of force and science and their use as a method of settling human disputes?

[Although the theoretical possibility of atomic bombs had been publicly known for many years, in May 1945 the Manhattan Project had not yet produced an operational atomic bomb. The fact that the United States (with British assistance) was trying to produce an atomic bomb was highly classified and probably unknown to the members of the House of Lords, and they certainly would not have publicly discussed that program if they had known of it.

The repeated references by the members appear to be to German atomic bombs. They even stated that "a bomb [with a fission pit] as big as a man's hand was ready, or almost ready, for use at the end of the war, and that it could have destroyed the whole of a city as large as London," and they repeatedly pointed out the viability of German rockets as a delivery system for such a bomb. They spoke of devastating attacks against numerous British and American cities.

Although the members attributed that information to "the Press," media mentions of atomic bombs were heavily censored until August 1945, and there do not appear to have been any newspaper articles that provided this detailed information by May 1945.

The most straightforward explanation is that these members of the House of Lords had received information from wartime and early postwar Allied investigations of German programs to develop atomic bombs and advanced rockets to carry them. Can any relevant information be located among the archived papers of these members?]

Germany Calls on Allies to Turn the Other Cheek. *Toronto Daily Star*. 30 June 1945 p. 6. https://news.google.com/newspapers?id=O7E7AAAAIBAJ&sjid=KisMAAAAIBAJ&pg=719,18615434

London, June 30—(BUP)—The Germans came within six months of splitting the atom and possibly destroying the world in the process, Herbert Agar, special assistant to the U.S. ambassador, said in a speech last night.

"If the war had gone on another six months, it was quite possible that this planet would have ceased to exist, because it was probable that someone would have learned to break the atom without controlling it," Agar said.

"There was a danger that the Germans would learn how to split it first, and our scientists gave the date as Aug. 6 of this year. I sincerely believe that in a very few years human beings will know how to destroy the human race."

[In June 1945, Agar appeared to suggest that Germany planned its first nuclear attack for 6 August 1945. If that information was correct, the planned date may have been determined both by the production schedule of the weapon and its delivery system and also by the historical significance of that date for Germans. On 6 August 1870 Germany (still in the process of uniting under Prussia) won decisive battles against France, and on 6 August 1914 Germany launched its first U-boats to fight World War I. Later, 6 August 1945 turned out to be the actual date that the United States launched its first nuclear attack, on Hiroshima. Was that simply an extraordinary coincidence, or was the Hiroshima date chosen in part to send a political message to anyone who knew about the earlier German plans? See also:

- Atomic Bomb Discovery of Germans Told. *Los Angeles Times*. 20 July 1945 p. 5.
- Description of New Bomb Called 'Leak.' *Syracuse Herald-Journal*. 21 July 1945 p. 7.
- Germans Aimed to Split the Atom. *The Scotsman*. 30 June 1945 p. 5.
- Splitting of Atom within Grasp. *The Mercury* (Hobart, Tasmania). 2 July 1945 p. 2.
- World Saved by 6 Months. *The Courier-Mail* (Brisbane, Queensland). 2 July 1945 p. 1.]

G. Verner Edlund to Leslie Groves. 2 July 1945. Cable 44165. [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45]

From: US Military Attaché, London, England
To: War Department
Nr: 44165 2 July 1945

To MILID from Edlund for Davis to Groves for Smith serial number 44165. TOP SECRET.

London papers 30 June mention speech here by Commander Herbert Agar, Special Assistant to American Ambassador to the effect that someone would have learned TA [tubealloy—nuclear technology] without controlling it if war had continued another six months, danger that Germans would have learned first and our scientists gave the date as 6 August. Will interview subject and transmit clippings and report forthwith.

End

ACTION: Gen Groves

Monthly Intelligence Summary. April–June 1945. [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.]

XII CENSORSHIP.

The period covered by this report has been marked by an increase in the problem of keeping newspapers in the U.K. from printing stories undesirable from a TA standpoint. An increasing tendency on the part of both the press and the censorship authorities to excuse stories on grounds of previous publication has been noted. A system is now in effect in U.S. whereby stories on TA, which are submitted to Censorship, are passed on to editors with a note asking that they not be published. Admiral THOMPSON, Chief Press Censor of the Ministry of Information, remains firm in his opposition to sending a circular to editors asking them not to print any reference to TA.

Colonel WARDEN, Chief Press Censor, SHAEF issued a directive to all SHAEF Censors ordering them to stop all TA stories regardless of previous publications.

The most embarrassing incident from the Censorship standpoint occurred when British papers carried a story reporting a speech by Commander AGAR, Special Assistant to the American Ambassador to Great Britain, in which AGAR stated that, “Had the war gone on a little longer, our scientists believed the Germans would have perfected TA.” This story resulted in several inquiries from the Press as to whether they would still be expected to refrain from printing stories on this subject. All such inquiries were answered in the affirmative.

Stories dealing with the sabotage of the heavy water plant at Norsk Hydro (Norway) also appeared in print during the period.

A party of SHAEF correspondents was taken to Norsk Hydro on a facility visit as a result of which fifteen stories were submitted to censorship authorities. These stories were all stopped.

Patrick S. Washburn. 1988. The Office of Censorship’s Attempt to Control Press Coverage of the Atomic Bomb during World War II.
https://files.eric.ed.gov/fulltext/ED295201.pdf

Yet, several days later, another “very bad bust,” as it was labeled by the Office of Censorship, originated in London. Cmdr. Herbert Agar, assistant to the U.S. ambassador to Great Britain, gave an address at an English college on June 29 that made no mention of atom splitting. However, three London newspapers obtained copies of his speech which contained some remarks that were deleted. These included the fact that American scientists estimated the Germans might have been able to split the atom by August 6, and thus if the war had lasted another six months, the Germans may have dominated the world.

The London newspapers rushed Agar’s written comments about atom splitting into print without checking with the government to see if they should be used, and then every American wire service filed stories. Since these were based solely on the newspaper stories, the English censor could not stop them because of prior publication. Agar was severely reprimanded by both the Navy and the American ambassador for being careless, but the Office of Censorship refused to try to get the wire services to suppress copy that had been approved by a foreign censor. However, it did discourage attempts by the United Press and others to further develop Agar’s remarks.

Charles A. Crowley to W. F. Heimlich. 31 August 1945. Headquarters United States Air Forces in Europe (Main). Berlin Intelligence Party. German V-1 and V-2 Personnel. [AFHRA C5094 frames 0957–0958]

1. In view of the fact that the wants of USAFE on V-1 and V-2 personnel have been satisfied, I am inclosing information on those men whose evacuation we have recommended. My memory of the conversation which we had a few weeks ago is to the effect that USFET was still anxious to either exploit or to know the exact location of these individuals. The list follows:

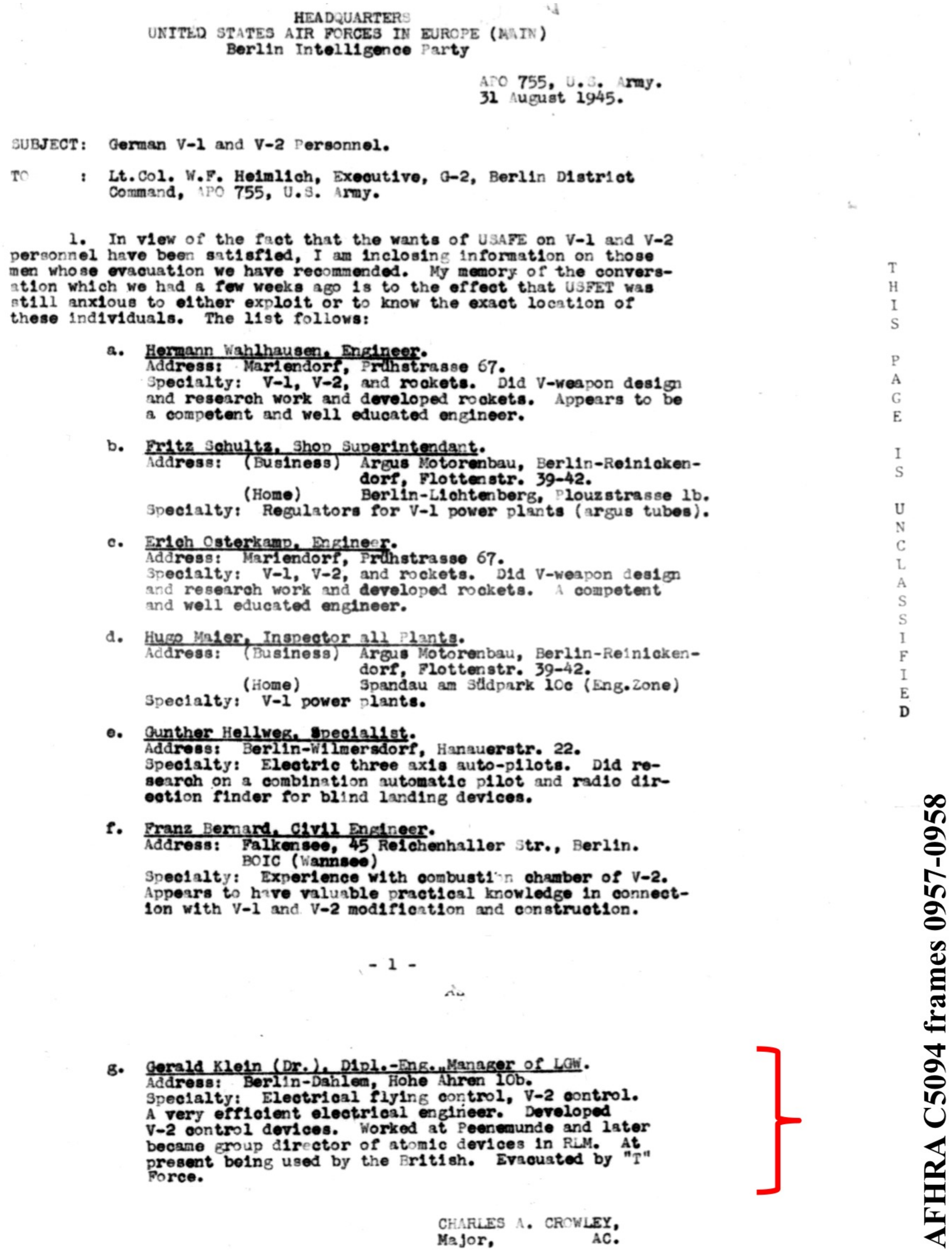
[...] g. Gerald Klein (Dr.), Dipl.-Eng., Manager of LGW.
Address: Berlin-Dahlem, Hohe Ähren 10b.
Specialty: Electrical flying control, V-2 control. A very efficient electrical engineer. Developed V-2 control devices. Worked at Peenemünde and later became group director of atomic devices in RLM. At present being used by the British. Evacuated by "T" Force.

[See document photo on p. 5020.

Dr. Gerald Klein was listed as the manager of "LGW," which was the Luftgerätewerk Hakenfelde A.G., part of the huge Siemens electrical company. If wartime Germany never had atomic devices or even serious plans to make them, as maintained by official histories, why did the RLM or Reichsluftfahrtministerium (Ministry of Aviation) have an entire group dedicated to atomic devices, of which Dr. Klein was the director? Note that Dr. Klein was evacuated by T-Force and "used by the British" after the war. Where are the reports on his interrogations? Where are the reports on his postwar work for the United Kingdom, or perhaps for other countries after that?

The Halstead Exploitation Centre is an example of a case where there seems to have been an especially large overlap between the interrogation of German-speaking scientists and collection of German-language reports on one hand, and the postwar development of British nuclear weapons on the other hand. See pp. 2127–2129 and 4166–4169. Just exactly what role did German-speaking scientists and information play in the British nuclear program?

The U.S. Army Air Forces officers writing and reading this memo seemed to casually understand what it meant that the Reichsluftfahrtministerium had an entire group on atomic devices, with no further explanation required in this memo. They also appeared to know about Dr. Klein from American interrogations of him. Where are the U.S. reports on American interrogations of Dr. Klein? Where are the U.S. reports explaining exactly what the atomic device group of the Reichsluftfahrtministerium was, what it accomplished during the war, and how it related to other nuclear-related work during the Third Reich?]



HEADQUARTERS
UNITED STATES AIR FORCES IN EUROPE (MAIN)
Berlin Intelligence Party

APO 755, U.S. Army.
31 August 1945.

SUBJECT: German V-1 and V-2 Personnel.

TO : Lt.Col. W.F. Heimlich, Executive, G-2, Berlin District Command, APO 755, U.S. Army.

1. In view of the fact that the wants of USAFE on V-1 and V-2 personnel have been satisfied, I am inclosing information on those men whose evacuation we have recommended. My memory of the conversation which we had a few weeks ago is to the effect that USFET was still anxious to either exploit or to know the exact location of these individuals. The list follows:

a. Hermann Wahlhausen, Engineer.
Address: Mariendorf, Prühstrasse 67.
Specialty: V-1, V-2, and rockets. Did V-weapon design and research work and developed rockets. Appears to be a competent and well educated engineer.

b. Fritz Schultz, Shop Superintendant.
Address: (Business) Argus Motorenbau, Berlin-Reinickendorf, Flottenstr. 39-42.
(Home) Berlin-Lichtenberg, Plouzstrasse 1b.
Specialty: Regulators for V-1 power plants (argus tubes).

c. Erich Osterkamp, Engineer.
Address: Mariendorf, Prühstrasse 67.
Specialty: V-1, V-2, and rockets. Did V-weapon design and research work and developed rockets. A competent and well educated engineer.

d. Hugo Maier, Inspector all Plants.
Address: (Business) Argus Motorenbau, Berlin-Reinickendorf, Flottenstr. 39-42.
(Home) Spandau am Südpark 10c (Eng.Zone)
Specialty: V-1 power plants.

e. Gunther Hellweg, Specialist.
Address: Berlin-Wilmersdorf, Hanauerstr. 22.
Specialty: Electric three axis auto-pilots. Did research on a combination automatic pilot and radio direction finder for blind landing devices.

f. Franz Bernard, Civil Engineer.
Address: Falkensee, 45 Reichenhaller Str., Berlin.
BOIC (Wannsee)
Specialty: Experience with combustion chamber of V-2. Appears to have valuable practical knowledge in connection with V-1 and V-2 modification and construction.

- 1 -

g. Gerald Klein (Dr.), Dipl.-Eng., Manager of LGW.
Address: Berlin-Dahlem, Hohe Ahren 10b.
Specialty: Electrical flying control, V-2 control. A very efficient electrical engineer. Developed V-2 control devices. Worked at Peenemunde and later became group director of atomic devices in RLM. At present being used by the British. Evacuated by "T" Force.

CHARLES A. CROWLEY,
Major, AC.

THIS PAGE IS UNCLASSIFIED

AFHRA C5094 frames 0957-0958

Figure D.995: Why did the RLM (Reichsluftfahrtministerium, Ministry of Aviation) have an entire group dedicated to atomic devices, of which Dr. Gerald Klein was the director? Where are the U.S. and U.K. reports on Klein's interrogations, wartime work, and postwar work? [AFHRA C5094 frames 0957–0958]

Nazis Really Had Atom Bomb Almost Ready. *Baltimore Sun.* 8 August 1945, p. 4.

London, Aug. 7 (AP)—Allied sabotage and bombing of experimental stations and plants along the Baltic coast and in southern Norway upset a German timetable to use atomic bombs against Britain last spring, an authoritative informant said today.

"But Nazi scientists had been carrying out experiments along this line for many years and if the war had not ended when it did they likely would have been able to launch attacks," said the informant, who throughout the war maintained contact with underground sources inside Germany.

He said the German super weapon was labeled the V-3 and was planned to follow the softening up work done by the V-1 and V-2.

[This AP story was also carried by other newspapers, for example:
Nazis Planned to Use Atomic Bombs. *Daily Colonist* (Victoria, Canada). 8 August 1945, p. 8.
https://ia800207.us.archive.org/0/items/dailycolonist0845uvic_5/dailycolonist0845uvic_5.pdf]

Future of the Atomic Bomb: Power for Peace or Chaos. *U.S. News.* 17 August 1945, pp. 20-23. www.usnews.com/cmsmedia/94/76/07545cb1465e8d8f022bea2bfc5d/19450817-future-of-the-atomic-bomb-power-for-peace-or-chaos.pdf

The Germans had planned to use the atomic bomb in the warhead of a V-type winged torpedo such as they fired upon England across the Channel. With such a bomb, they might have devastated England. [...]

At the moment, the only defense that military men can think of is to destroy the source of production for atomic bombs. High officials recognize that, if such a weapon were put into the hands of a madman like Hitler, civilization could be destroyed or held in pawn at will.

Awesome Force of Atom Bomb Loosed to Hasten Jap Surrender. *Newsweek.* 13 August 1945, p. 30.

On Sunday morning, August 5 (Washington time), an American airplane flew over Hiroshima, a Japanese army base on the Inland Sea. It dropped a single, small bomb. [...]

Thus the Allied nations had won what the President called "The Battle of the Laboratories" against the Axis. [...]

Metal of the Millennium: German scientists nearly succeeded in solving it. Since the surrender of the Nazi armies, Allied officers have revealed that Germany would have been able to strike with atomic bombs by January 1945, if the invasion had not come six months before. The highest Allied officials knew that such explosives could have won the war for the Axis.

The United States had begun research on them in late 1939. [...]

[This is an astounding public admission that the German nuclear weapons program existed, was actually ahead of the U.S. nuclear program, and drove the timetable for the Allied invasion of Europe during the war. See p. 5010. See also p. 5031 for a very similar admission from General George Marshall, the Chief of Staff of the U.S. Army, in his final public report on the war. That same fact was confirmed by a formerly Top Secret U.S. CIC document on p. 4411, paragraph 15. See also the written statement of Col. George Woods on p. 5073.

What is the true history of the German programs for developing nuclear weapons as well as methods to deliver them to Allied targets? What is the true history of Allied knowledge about those programs, both during and after the war? Where is all of the corresponding evidence stored now?]

Press release, Office of War Information, Franklin-2994, NB-3297, Technical Industrial Intelligence Committee. 25 August 1945. [NARA RG 40, Entry 75, Box 62 (Old 158); NARA RG 208, Entry 198, Box 1042]

Germany's inner war secrets ranged from experiments with the atomic bomb, anti-radar devices, and piloted rocket missiles that they expected to cross the Atlantic in 17 minutes, to butter made from coal, the Office of War Information reported today. [...]

CIOS teams combed Germany for Germany's hidden secrets on weapons, oil production, raw materials, synthetics, new engineering and chemical processes, inventions, patents, finance, economics, and German machinations in the political field.

Already more than 2,000 visits to German "intelligence targets" have been made by CIOS and 3,000 preliminary assessment reports have filtered through military channels to Washington, where they are made available to appropriate agencies. The agencies are authorized to translate the findings into projects useful to the allied cause and for post-war purposes.

Many of the German secrets, at the time CIOS uncovered them were considered of great potential value in the war against Japan and many of them were being adopted for use in the Pacific when the war ended. However, they are also of real value in the long-range control of Germany and also will facilitate technological advances in many industrial fields in peacetime, OWI reported on the basis of information provided by military authorities.

The secrets, it is conservatively estimated, would have saved the Allies many millions of dollars for research and scientific development, if the war had continued to the end of 1945 or longer. They indicate that German invention was far ahead of her capacity to translate theory into industry. The rapid advances of the Allied armies prevented her from putting into practice many of the technological advances evolved in the laboratories of her scientists. These same secrets, in some cases may shortly make some American technical processes obsolete and outmoded.

While German Government files yielded many of the secrets, the intelligence teams, which began to go into action on the heels of General Eisenhower's troops, soon after D-Day, often found vital clues through casual conversation with individuals, through close observation of physical facilities of war plants, in interviews with technical personnel and through meticulous and thorough search for hidden documents. [...]

Some of the more startling of the secrets that may be disclosed at this time, show that not only had Germans made significant progress in the development of an atomic bomb and in the production of "heavy water" but they:

1. Had contemplated a piloted missile with a possible range of 3,000 miles. The designer envisaged commercial applications for trans-Atlantic passenger crossing in 17 minutes.

2. Were working on a formula for new war gases that they hoped would prove more deadly than any chemical agent yet developed.

3. Had specifications and construction details for naval vessels of advanced design, including submarines with high underwater speeds and apparatus for sustained underwater operations.

4. Had developed a system of radar camouflage consisting of anti-radar coverings and coatings to be employed on submarines and other weapons.

5. Had highly advanced jet engine, rocket assisted take-off and aero-dynamics designs.

6. Had found new uses for many staples, as for example, coal. From coal the Germans were making a synthetic butter as well as alcohol of both beverage and industrial types, aviation lubricants, soap, and gasoline.

7. Had designs for various secret types of guns and gun sights, novel gear and transmission construction and air-cooled diesel engines.

Other German war secrets ranged from records on the location of German capital in neutral countries, and the status and composition of German cartels, to specifications of long-range rocket developments that scientists describe as “sensational.” In addition to the missile that they expected to have a range of 3,000 miles, the Germans had plans for V-type weapons much more advanced than those which they directed against the British Isles last year. [...]

The numerous German medical and pharmaceutical developments included the production of a “froth” clothing compound. This was designed to insulate and protect aviators lost in arctic waters.

Although many of the synthetics devised by the Germans are pronounced inferior to American products, a number of others are highly advanced. Processes used in their synthetic rubber industry, for example, are being made available to United States war manufacturers.

Similarly, synthetic gasoline and lubricants provide important keys for United States industry; some of the German methods already have been made available to United States produces, and will result in improved products for peacetime use.

Gasoline from coal, eventually to cost little more than the standard petroleum product of today, is also a possibility based on a German war formula. Technological improvements that may result from adaptation of the techniques in United States plants, scientists say, may make this and many other products envisioned by the Germans highly practical from a commercial standpoint.

Designs of long-range German smooth-bore guns that fire rocket-assisted finned projectiles, a “squeeze” gun that obtained higher velocities and longer range through use of a tapered bore, a device for reducing the wear on gun barrels, and data on the substitution of steel cartridge cases for both small and large calibre weapons (thus reducing requirements for copper and other critical materials), are now Allied possessions. Still other German developments range from improved acoustic, magnetic and non-magnetic anti-tank and anti-personnel mines to the use of salt water in electric torpedo propulsion. [...]

CIOS investigations were carried out in the field in two ways. First, Combined Advanced Field Teams, groups of technically qualified men who followed the combat forces, gave a rapid preliminary assessment of the technical value of the targets. More than 200 expert United States and British assessors were continuously in the field during the period of rapid military advance.

Second, following up plans already made and the reports coming back from the assessors, teams of expert scientists and technologists carried out detailed investigations. The number of such visits by July 1945 had exceeded 2,000.

Both the assessments and the investigations were carried out by teams, combining U.S. and British representatives. Government leaders, scientists, industrialists, economists and historians were represented in the groups. The small teams, each made up of experts in a particular field, were attached to the intelligence staff of all the major army commands on the Western Front.

Some of the industrial fields covered were: aeronautics, automotive production, building materials, chemicals, communications, food, forest products, general industrial equipment, liquid fuels and lubricants, machinery, medical wares, metals and materials, railroad equipment, rubber, safety and technical equipment, shipbuilding, solid fuels, textiles and utilities. [...]

The German processes, it was realized, not only would reduce research work in British and United States laboratories, releasing them for other scientific ventures, but would save millions of man-hours in war production and on the fighting fronts and, additionally, might alleviate shortages of some types of war materials. [...]

[See document photos on p. 5026.

The U.S. Office of War Information publicly stated that Germany had conducted "experiments with the atomic bomb," which is an extraordinary statement that cannot (or at least should not) be ignored.

This Office of War Information press release, as well as any related discussions of reporters with officials, prompted numerous newspaper articles such as the following examples, which stated, "The Germans... had reached the experimental stage with the devastating atomic bomb," "an atomic bomb, on which... the Germans had made considerable progress," and "Not all the secrets have been disclosed."]

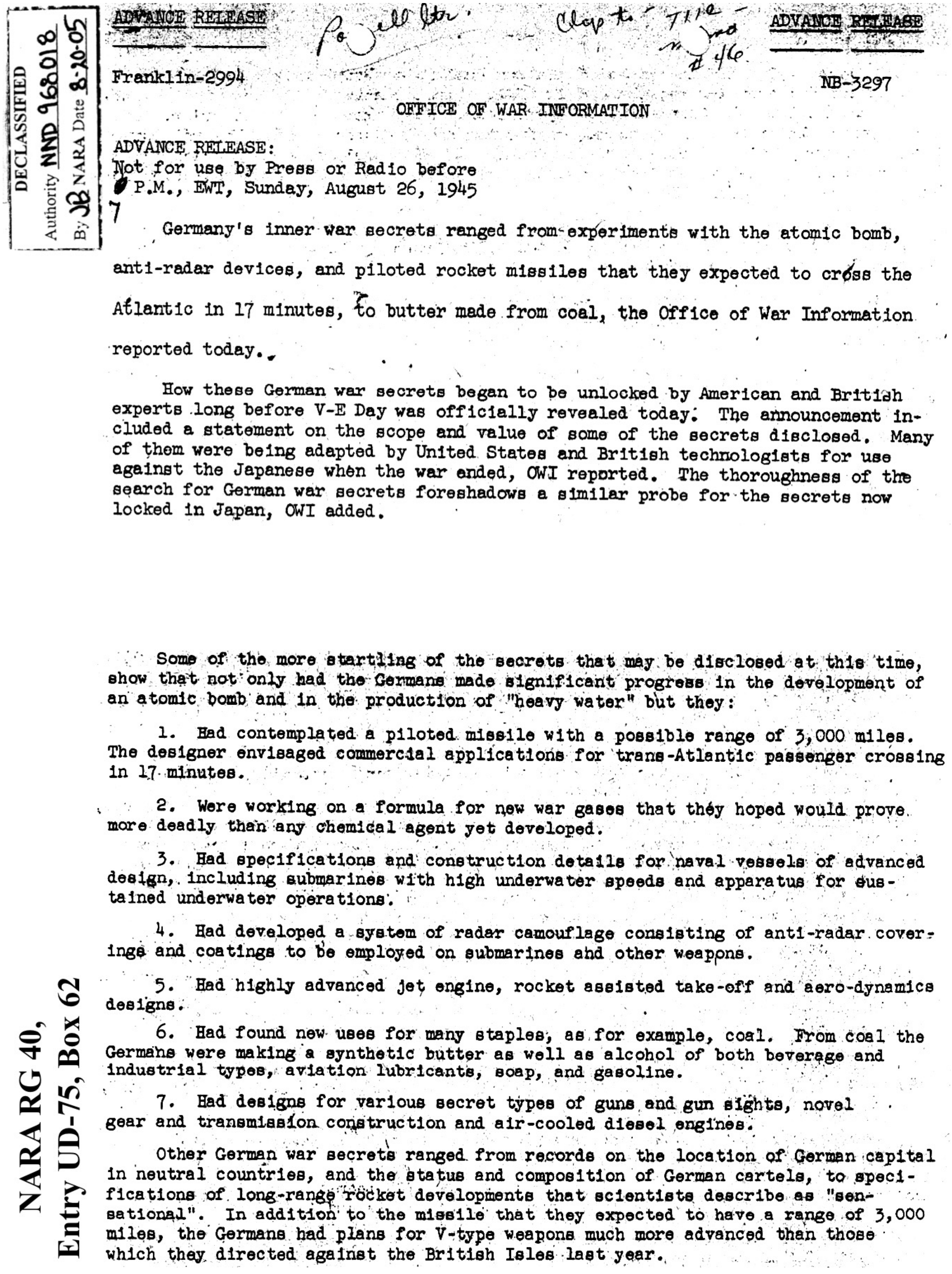
James E. Chinn, Nazis Almost Had Rocket for Atlantic Hop. *Washington Post.* 27 August 1945.

God blessed America.

Just before the European war ended the Nazis were experimenting with a piloted rocket missile designed to span the Atlantic in 17 minutes, the Office of War Information revealed yesterday as it unveiled a variety of Germany's inner war secrets.

The Germans also, according to OWI, had reached the experimental stage with the devastating atomic bomb, devices to destroy the sight of the all seeing eyes of radar, and new war gases they hoped would prove more deadly than any chemical agent yet developed. And that's not all.

Many More "Up Sleeve" [...]



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OFFICE OF WAR INFORMATION

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7 P.M., EWT, Sunday, August 26, 1945

Germany's inner war secrets ranged from experiments with the atomic bomb, anti-radar devices, and piloted rocket missiles that they expected to cross the Atlantic in 17 minutes, to butter made from coal, the Office of War Information reported today.

How these German war secrets began to be unlocked by American and British experts long before V-E Day was officially revealed today. The announcement included a statement on the scope and value of some of the secrets disclosed. Many of them were being adapted by United States and British technologists for use against the Japanese when the war ended, OWI reported. The thoroughness of the search for German war secrets foreshadows a similar probe for the secrets now locked in Japan, OWI added.

Some of the more startling of the secrets that may be disclosed at this time, show that not only had the Germans made significant progress in the development of an atomic bomb and in the production of "heavy water" but they:

1. Had contemplated a piloted missile with a possible range of 3,000 miles. The designer envisaged commercial applications for trans-Atlantic passenger crossing in 17 minutes.

2. Were working on a formula for new war gases that they hoped would prove more deadly than any chemical agent yet developed.

3. Had specifications and construction details for naval vessels of advanced design, including submarines with high underwater speeds and apparatus for sustained underwater operations.

4. Had developed a system of radar camouflage consisting of anti-radar coverings and coatings to be employed on submarines and other weapons.

5. Had highly advanced jet engine, rocket assisted take-off and aero-dynamics designs.

6. Had found new uses for many staples, as for example, coal. From coal the Germans were making a synthetic butter as well as alcohol of both beverage and industrial types, aviation lubricants, soap, and gasoline.

7. Had designs for various secret types of guns and gun sights, novel gear and transmission construction and air-cooled diesel engines.

Other German war secrets ranged from records on the location of German capital in neutral countries, and the status and composition of German cartels, to specifications of long-range rocket developments that scientists describe as "sensational". In addition to the missile that they expected to have a range of 3,000 miles, the Germans had plans for V-type weapons much more advanced than those which they directed against the British Isles last year.

NARA RG 40,
Entry UD-75, Box 62

Figure D.996: Excerpts from press release, Office of War Information, Franklin-2994, NB-3297, Technical Industrial Intelligence Committee. 25 August 1945 [NARA RG 40, Entry 75, Box 62].

17-Minute Oversea Rocket Plane Among Germany's War Secrets. *New York Times.* 27 August 1945 p. 10.

American and British technicians, closely and quickly following the Allies' military advances across France and Germany, have taken possession of a wealth of information about German "secret weapons" on which the enemy counted so much but that he did not have time enough to develop.

Besides an atomic bomb, on which, as has been made known, the Germans had made considerable progress, German scientists and engineers had developed a defense against radar and experimented on piloted rocket missiles that it was thought would be capable of crossing the Atlantic in seventeen minutes. These and many other German war secrets were disclosed today by the Office of War Information in reporting on the operations of a combined American and British intelligence organization that made daring forays on targets containing vital war information. [...]

They concentrated on the "targets" believed to be richest in vital information on weapons, oil production, raw materials, synthetics, new engineering and chemical processes, inventions, patents and machinations in finance, economics and politics.

More than 2,000 missions to such "targets" have already been made, and the information obtained was estimated by the receiving authorities as being worth "millions of dollars" in research and scientific development. The findings indicated, the OWI reported, that "German invention was far ahead of her capacity to translate theory into industry.

The rapid advances of the Allied armies prevented her from putting into practice many of the technological advances evolved in the laboratories of her scientists," the OWI said. It added that some of the unlocked secrets might soon make some American technical processes "obsolete and outmoded."

Some Secrets Unrevealed

Not all the secrets have been disclosed, but the most startling ones were said to pertain to the development of the atomic bomb and the production of "heavy water," used in one method of making the bomb. The defense against radar was a system of radar camouflage consisting of anti-radar coverings and coatings. It would be employed, presumably, on submarines and other weapons.

The Germans contemplated a piloted missile with a possible range of 3,000 miles. The designer envisioned for it a commercial application for flying passengers across the Atlantic in a little more than a quarter hour.

[Also reported in:

The Times (London). 27 August 1945.

Nazis Had 10,000 mph Atom Plane—In Theory. *Eighth Army News.* 28 August 1945.]

***Interview with Brig. Gen. Thomas J. Betts by Dr. Maclyn Burg, Oral Historian.* 18 October 1973. Dwight D. Eisenhower Library. pp. 277–289, 294–295, 297–298. https://www.eisenhowerlibrary.gov/sites/default/files/research/oral-histories/oral-history-transcripts/betts-thomas.pdf**

BETTS: Well, we got to this office of Stalin's, which was a long, narrow room with a rather small desk at one end. And between the desk and the door was a long, green beige-covered table. And there was Stalin. He came to see us, very pleasantly, and his first remark was, "Well, I'm happy to tell you that I responded to your pleas and have started an offensive to take the pressure off you in the Bulge." [...A]t the onset of the Bulge, Churchill had sent a personal message to Stalin saying, in effect, "We're in dire peril and will you please exert all possible pressure on the eastern front until we solve this Bulge problem." [...I]t took us from the 1st of January to the 14th to get to the Kremlin. [...]

BURG: So he was not alone in the room when you entered.

BETTS: No, he had an interpreter and he had a General [A.I.] Antonov, A-n-t-o-n-o-v[....] Who was the deputy chief of staff. The chief of staff, I think, at that time was—I think it was Malenkov, but I'm not sure. But the story in Russia, in Moscow, at the time was that the way Stalin really ran the war was that he sent the chief of staff out to inspect the armies and the army groups and shoot whatever generals were necessary, and Antonov was the office man who kept the papers going and worked out the policy. Stalin himself, apparently, did not inspect troops. He did not go out to the front. [...]

BURG: [...] Now was Air Marshal Tedder, in effect, presenting the allied case?

BETTS: [...] Tedder then just made the pitch that I described at the beginning here: mainly, that we were hoping that—we were expecting to close the Rhine, of course, in March—and we were hoping that even if the Russians could not put on an offensive at that time, that they would create enough of a disturbance so that the Germans would not reinforce the front. And Stalin shook his head and agreed. He said that they, that he understood, that, in effect, they had already started their offensive, which they had. They had started on the, I think the 13th or 14th, and at that time their armies were well into Poland. They had not reached German soil yet anywhere.

[Stalin and General Antonov were the recipients of the very best Soviet intelligence on the German nuclear weapons program (4481–4493). In particular, by the time of this January 1945 meeting they had already received the November 1944 intelligence report on p. 4481.]

General Thomas J. Betts appears to have played an important role in many world events from the 1920s through at least the 1950s, and he deserves far more study from historians than he has received. For the barest overviews, see:

> https://www.washingtonpost.com/archive/local/1977/05/26/retired-army-officer-served-in-intelligence/aac29316-adc0-469d-b194-c015297f360e/
>
> https://generals.dk/general/Betts/Thomas_Jeffries/USA.html

Since August 1944, General Betts had been the chair of the Combined Intelligence Objectives Subcommittee (CIOS) in charge of investigating and transferring Germany's most advanced technologies. He was also the Assistant Chief of Staff for Intelligence (G-2) at Supreme Headquarters Allied Expeditionary Forces (SHAEF) under Eisenhower. He appears to have been closely connected to the OSS and continued to work for the CIA until at least 1958. Thus he was in ideal positions to receive the best western Allied intelligence on the German nuclear weapons program. Indeed, he wrote some astonishing details about the German program to develop nuclear weapons and delivery vehicles for them (p. 5030) while admitting that some information could not be publicly disclosed, and he concluded that the U.S. Alsos Mission had failed to properly investigate that program (p. 3287).

The fact that someone with the position and knowledge of General Betts was sent all the way to Moscow to meet with Stalin and Antonov in January 1945 is truly extraordinary, and virtually unknown apart from his remarks in this obscure interview. From Betts's description of his mission, the U.S./U.K. and the Soviet Union were desperate to overrun German territory as soon as possible. At the very least, the U.S./U.K. intelligence and the Soviet intelligence on the German nuclear program would have been an unstated yet fundamental motivation for that strategy and for the meeting. Is there any archival evidence that something actually was stated, that the U.S./U.K. and the Soviet Union shared any intelligence on the German program during this January 1945 meeting or in other ways and times?

What more did General Betts learn about wartime German work when he served as the U.S. military attaché in Poland after the war, and in his other postwar positions?]

R. P. Linstead and T. J. Betts. 15 September 1945. ***The Intelligence Exploitation of Germany. Report of Combined Intelligence Objectives Subcommittee.*** **G-2 Division, SHAEF. Ch. 4, pp. 37, 47–51. [AFHRA A5186 electronic version pp. 904–1026]**

Certain items have been omitted because of security considerations. [...]

United States and British specialists have obtained complete information covering all German directed missiles from the pioneer model "A sub-o", which employed oxygen and alcohol fuel in attaining a range of 18 miles, to the latest model of the A-9 which was capable of a 3400 mile per hour speed and a range of 2400 miles. The A-9 was an improved development of the V-2 or A-4, and was equipped with wings thereby enabling it to level off at a height of 70,000 feet. One model of this missile was equipped with a Lorin tube which provided propulsion at the peak of the trajectory, the missile was expected to result in a maximum range of 2400 miles. Other variations of this model were capable of attaining altitudes 60 miles above the earth's surface and speeds in excess of 7300 feet per second. Improved radio controls were developed to supercede the "integrating accelerometer" used in early V-weapons. Some measure of the accuracy which could be achieved with these controls is evidenced by the fact that the radio controlled models were capable of an accuracy of plus-or-minus 150 feet in contrast to a plus-or-minus 50 mile error inherent in the V-2.

German scientists engaged in directed missiles envisaged important commercial applications of the long range missile. Experiments had already been conducted on piloted models. Missiles capable of trans-Atlantic crossings in approximately 40 minutes were found on design boards and scale models were undergoing wind tunnel tests. Amazing performances were considered practical because of the lessened atmospheric resistance and gravitational pull in stratospheric regions. [...]

Of particular significance were the statements, made by German experts in the rocket and controlled missile field, that much of the priority accorded their work by the German High Command was in anticipation of the use of atomic explosives. These authorities stated that KWI had repeatedly assured Hitler that an atomic explosive would be available for use within a comparatively short time. During the last months of work by the Peenemünde staff, V-weapons were designed with much smaller war-heads. Quite possibly this trend was in anticipation of the successful development of a German atomic explosive.

[See pp. 5446–5447 for photos.

This report was written by the CIOS chairs, U.S. General Thomas Jeffries Betts, Deputy G-2 of SHAEF (pp. 3287, 5028–5029), and U.K. Ministry of Supply chief advisor and F.R.S. Professor Reginald Patrick Linstead. Based on specific discoveries by their CIOS investigators, these high-ranking officials reported that "the latest model of the A-9 ... was capable of a 3400 mile per hour speed and a range of 2400 miles," and that "experiments had already been conducted on piloted models." That statement sounds like a description of completed hardware, not a mere drawing board design. What specific hardware and information were discovered that are not discussed in the presently unclassified reports? Can any reports that are still classified be located and released?

The CIOS chairs also reported that Hitler, the German High Command, and the leading experts in the rocket programs had been "repeatedly assured ... that an atomic explosive would be available for use within a comparatively short time." Thus the CIOS chairs contradicted the public statements of the Alsos Mission and confirmed that there was indeed a German program to develop an atomic bomb, and that it was far more than a paper design program—its hardware had passed through sufficient development, production, and testing by the end of the war that it was ready or nearly ready to be used in combat.]

General George C. Marshall. 1 September 1945 (publicly released 10 October 1945). Third and Final Biennial Report to the Secretary of War. In George C. Marshall. 1996. *Biennial Reports of the Chief of Staff of the United States Army to the Secretary of War: 1 July 1939–30 June 1945.* Washington, D.C.: U.S. Government Printing Office. pp. 132, 210. https://history.army.mil/html/books/070/70-57/CMH_Pub_70-57.pdf

Victory in this global war depended on the successful execution of OVERLORD. That must not fail. Yet the Japanese could not be permitted meanwhile to entrench in their stolen empire, and China must not be allowed to fall victim to further Japanese assaults. Allied resources were searched through again and again, and strategy reconsidered in the light of the deficiencies. These conclusions seemed inescapable: France must be invaded in 1944, to shorten the war by facilitating the advance westward of the Soviet forces. At the same time German technological advances such as in the development of atomic explosives made it imperative that we attack before these terrible weapons could be turned against us. In addition, the pressure on the Japanese in the Pacific must not be relaxed. Communications with China must be reopened. Resources were allocated accordingly. The balance was extremely delicate but we had to go ahead. [...]

Between Germany and America in 1914 and again in 1939 stood Great Britain and the USSR, France, Poland, and the other countries of Europe. Because the technique of destruction had not progressed to its present peak, these nations had to be eliminated and the Atlantic Ocean crossed by ships before our factories could be brought within the range of the enemy guns. At the close of the German war in Europe they were just on the outer fringes of the range of fire from an enemy in Europe. Goering stated after his capture that it was a certainty the eastern American cities would have been under rocket bombardment had Germany remained undefeated for two more years. The first attacks would have started much sooner. The technique of war has brought the United States, its homes and factories into the front line of world conflict. They escaped destructive bombardment in the second World War. They would not in a third.

[See also p. 5022 for a very similar public admission.

The same facts were confirmed by a formerly Top Secret U.S. CIC document on p. 4411, paragraph 15.

See also the written statement of Col. George Woods on p. 5073.

George Marshall was the Chief of Staff of the U.S. Army during World War II, responsible for the overall conduct of the war in both Europe and the Pacific. From that lofty position, he received reliable intelligence that:

1. "German technological advances such as in the development of atomic explosives made it imperative that we attack before these terrible weapons could be turned against us," thus necessitating his decision to launch Operation Overlord in early June 1944. The statement and decision suggest a potential timeline:
    (a) The United States received intelligence reports of an advanced German nuclear weapons program no later than late 1943.
    (b) Those intelligence reports indicated that Germany could have a functional nuclear weapon as soon as summer or autumn 1944.

2. “At the close of the German war in Europe,” American cities “were just on the outer fringes of the range of fire from an enemy in Europe.” That statement suggests that:
    (a) No later than April 1945, Germany had developed one or more methods of delivering a payload to the United States: intercontinental jet bombers, intercontinental ballistic missiles, and/or submarine-launched missiles.
    (b) No later than April 1945, Germany had developed a payload so destructive that it justified the enormous expense of delivering it to the United States: presumably a nuclear weapon.

Where did Marshall’s wartime intelligence come from? Where are those reports now?

What did the United States discover after the war that apparently confirmed that intelligence? Where are those reports and any collected materials now?

Marshall’s statements suggest that there were profound reasons behind the ways that Germany and the Allies prosecuted the war that have been omitted from history books ever since.

Marshall’s statements also appear to contradict the public conclusions of the Alsos Mission.]

George C. Marshall. Text of Marshall’s Address Warning of Peril in Loss of Concept of World Responsibility. *New York Times* 30 October 1945 p. 6.

In the current emotionalism of the hour we turn for relief from positive action to new theories, new discoveries—the supersonic rocket, of atomic power or explosion. If these remarkable products of our science are merely to turn us from action to inaction on one plea, one theory or another, they may well have a more tragic influence on the destiny of the United States than the most pessimistic fear they will have on civilization. I have been considering the military ramifications of atomic explosion for more than two years, since my job placed me in the middle of the grim race toward this scientific power. I think I have—if only because of my head-start—spent much more time than most Americans thinking about such bombs and what they will mean to military operations as well as to civilization at large.

I cannot escape the conclusion that the possibilities of atomic explosion make it more imperative than ever before that the United States keep itself militarily strong—and use this strength to promote cooperative world order.

No one can foresee unerringly into the future but it is not hard to predict that supersonic atomic rockets will have a profound influence on any war that ever again has to be fought. But, rather than decrease the necessity for our preparation, both in manpower and materiel, this terrible new weapon will tremendously increase it.

The present public apathy regarding our military obligations for the future comes as no surprise to me. [...]

Eisenhower to See Bomb: He Tells California Group He Will Watch Tests in Pacific. *New York Times.* 23 February 1946 p. 14.

Gen. Dwight D. Eisenhower, Army Chief of Staff, will witness the atomic bomb tests in the Pacific in May[...]

There was no thought of using the atomic bomb on Germany, General Eisenhower said.

"My main concern was that the Germans did not get the atomic bomb to use on us," he asserted.

Dwight D. Eisenhower. 1948. *Crusade in Europe.* Ch. 13–14, pp. 229, 258–260.

Alarming Intelligence reports concerning the progress of the Germans in developing new long-range weapons of great destructive capacity also indicated the advisability of attacking [launching D-Day] early.

From time to time during the spring [1944] months staff officers from Washington arrived at my headquarters to give me the latest calculations concerning German progress in the development of new weapons, including as possibilities bacteriological and atomic weapons. These reports were highly secret and were invariably delivered to me by word of mouth. I was told that American scientists were making progress in these two important types and that as a result of their own experience they were able to make shrewd guesses concerning some of the details of similar German activity. All of this information was supplemented by the periodic reports of Intelligence agencies in London. In addition, aerial photographs were scrutinized with the greatest care in order to discover new installations that would apparently be useful only in some new kind of warfare.

The finest scientific brains in both Britain and America were called upon to help us in evaluation and in making estimates of probabilities. Our only effective counteraction, during the preparatory months of 1944, was by bombing. We sent intermittent raids against every spot in Europe where the scientists believed that the Germans were attempting either to manufacture new types of weapons or where they were building launching facilities along the coast.

During this long period the calculations of the Intelligence agencies were necessarily based upon very meager information and as a consequence they shifted from time to time in their estimates of German progress. Nevertheless, before we launched the invasion, Intelligence experts were able to give us remarkably accurate estimates of the existence, characteristics, and capabilities of the new German weapons.

[...]

On June 12, 1944, the first flying bomb, known as V-1, reached London. The V-1 [...] contained a large amount of explosive which detonated upon contact, and the blast effect was terrific. The first V-2 was not used until early August. [...]

The V-2 bomb was particularly destructive when it fell directly into a structure of some kind. Owing to its speed, it penetrated deeply into the ground and its great explosive effect was exerted directly upward. As a consequence, when it fell into open spaces it was relatively ineffective, but so great was its explosive charge when it hit a building that destruction was almost complete.

The development and employment of these weapons were undoubtedly greatly delayed by our spring bombing campaign against the places were we suspected they were under manufacture. Peenemünde, in Germany, was known to be one of the largest of the German experimental plants and periodically we sent large formations of bombers to attack that area. There were other places indicated to us as suspicious. One was Trondheim, in Norway, where we thought that the Germans were engaged in atomic development. We also bombed the suspected launching sites along the coast of northwestern Europe, where our reconnaissance photography showed numerous facilities and installations that could not be interpreted in terms of any known weapon. These areas were continuously hammered.

The effect of the new German weapons was very noticeable upon morale. [...]

It seemed likely that, if the German had succeeded in perfecting and using these new weapons six months earlier than he did, our invasion of Europe would have proved exceedingly difficult, perhaps impossible. I feel sure that if he had succeeded in using these weapons over a six-month period, and particularly if he had made the Portsmouth-Southampton area one of his principal targets, Overlord might have been written off.

[Eisenhower's statements seem to agree with Marshall's statements about the very real and very urgent nuclear danger from Germany.

According to Eisenhower, U.S. intelligence information about the German nuclear program was so secret that it was only given to him in oral presentations, not in writing. That can help explain the absence of surviving documents in U.S. archives. Just how much did top U.S. intelligence officials know about the German nuclear program, and how did they know it? The time period that Eisenhower described was in early-mid 1944, long before the Alsos Mission, which in any event reported negative findings.

What German nuclear weapons development was being conducted at Trondheim? According to official histories, the only significant nuclear-related work in Norway was heavy water production in the Vemork area (pp. 4027–4041), but that was hundreds of kilometers to the south of Trondheim, so it seems unlikely that Eisenhower confused the two locations. For another report of German nuclear weapons development in Norway, see p. 5011. For two other sources that may be related, see pp. 4436 and 4404.]

Army To Use V-2 Bombs To Test Radar As Atom-Rocket Defense. *New York Times.* 1 March 1946 p. 1.

WASHINGTON, Feb. 28—The Army Air Forces disclosed today that it was seeking a means of protecting the United States against possible future atomic bombardment by experimenting with techniques for radar detection of captured German V-2 rockets.

Brig. Gen. William L. Richardson, chief of the Air Staff's Guided Missiles Division, explained that the idea was to devise a means of detecting and "tracing" by radar the enemy rockets as they came whizzing through the stratosphere at 3,000 miles an hour. [...]

General Richardson said that it was important that a means be found "as quickly as possible" to defend the United States against "a sudden enemy rocket attack."

He stated that the Air Forces had been working on rocket defense since 1943, and also stressed that, through the recently activated First Experimental Guided Missiles Group, it was conducting "extensive research" in offensive uses of rockets.

[General Richardson's desperation to find a means "as quickly as possible" to defend against "a sudden enemy rocket attack" by nuclear-armed German rockets suggests that some other nation already had that capability. Did he know that Germany had already developed that capability, prompting him to worry that German engineers would confer that capability on the Soviet Union?

The next article strongly suggests that General Richardson did indeed know that wartime Germany had developed, or at least nearly finished developing, both nuclear weapons and intercontinental rockets capable of carrying them.]

Reveal Nazis Planned Rocket to Blast N.Y. at 6000 MPH. *Indianapolis Times.* 2 August 1947, p. 4. https://newspapers.library.in.gov/?a=d&d=IPT19470802.1.4

A-9 Was Designed to Employ Booster Weighing 190,000 Pounds for Acceleration

By Science Service

WASHINGTON, Aug. 2—The Germans planned a bomb to cross the Atlantic and blast New York. It was a rocket to be started on its long journey by another rocket which detached itself when its job was done.

This was revealed today by Brig. Gen. William L. Richardson of the U.S. Army Air Forces.

Gen. Richardson, chief of the A.A.F. Guided Missiles and Air Defense Division, spoke as a guest of Watson Davis, director of Science Service, on "Adventures in Science," heard over the Columbia network.

The Germans, he said, developed several rockets known as the "A" series. The V-2, used against London, was one of these. Although it was the only one of this series to be used operationally in the last war, it is not hard to visualize what might have been in store for the Allies had the Germans been given sufficient time to complete developments.

Acid Used in Fuel

Each of the “A” series was developed primarily for research, with the exception of the A-4, later known as the V-2. The A-10 was the end result toward which this whole program was directed. This is the weapon which the Germans expected to use in bombing New York.

The A-10 was described by him as a booster rocket placed behind the A-9, giving it two-step co-operation to secure ranges of 3000 miles. The A-9 was much like the A-4, more familiarly called the V-2, with wings added to give increased range and using acid as an oxidizer in its fuel.

The A-10 was never actually constructed. However, all design studies and computations had been completed. It appears that it could have been built and used if the Germans had been given another year of development and production.

Speed Put at 6000 M. P. H.

The total weight of the A-10 was to have been 190,000 pounds. The weapon was nearly 12 feet in diameter and 25 feet long. The 29,000-pound A-9 was to have been accelerated to a speed of 2500 miles per hour by the use of the A-10 as a launching rocket, which detached itself and would drop free after serving its purpose.

It was the A-9 that would reach the target. Its rocket motor would be turned on when the A-10 dropped. This would increase its speed to about 6000 miles an hour. It would have carried a warhead of about 2000 pounds. This is a payload of only 1 per cent of the starting weight of the weapon, but there is evidence to believe, he stated, that the Germans intended to utilize an atomic warhead which would have made this weapon extremely deadly.

[The same article was also published as:

> Nazis Planned Bomb to Blast New York. *Brooklyn Daily Eagle.* 2 August 1947, p. 3. https://bklyn.newspapers.com/image/52866650/

General William L. Richardson would have been a highly knowledgeable and very sober source for this information. For more information on him, see:

> https://www.af.mil/About-Us/Biographies/Display/Article/105809/major-general-william-l-richardson/

> https://media.defense.gov/2020/Apr/29/2002290975/-1/-1/0/200429-F-XX123-2007.JPG

As General Richardson would have known very well, it would take many years of large-scale work to go from the paper design of an intercontinental rocket to an operational and mass-produced system. Likewise it would have taken many years of work to go from the paper design of a nuclear weapon to a deployable nuclear warhead suitable for launching on the rocket. He told Science Service that Germany would have soon possessed both intercontinental rockets and nuclear warheads for them if the war had not ended when it did. Therefore he must have had considerable evidence that production and testing of intercontinental rockets and nuclear warheads were in the final stages when the war ended.

What evidence did General Richardson have, and where is that evidence stored now?]

Charlotte Knight. 1946. German Rocketeers: German Rockets and Guided Missiles Almost Won the War for the Nazis. *AAF Review* (July) 29:6:24–26, 48.

That the Allies won the war in Europe by a terrifyingly narrow margin is a fact now accepted by almost all military leaders who have seen at first hand Germany's progress in the guided missiles field. Just how narrow that margin really was will probably be a matter of considerable debate for a long time to come, but many guided missile experts who should know whereof they speak say that it was relatively small.

It was too close for comfort, and simply serves to underline even more emphatically the substantial edge the Nazis had in this field. Most Allied rocket experts will now concede that edge to have been at least a 10-year lead in the research and development of guided missiles. [...]

At war's end, in spite of her defeat, Germany's scientists and technicians had nevertheless left behind them at Peenemunde, Brunswick, Wiener Nieustadt and elsewhere the signposts of future air wars. From the captured results—some in production lines, some in stages of near-completion, and others on paper—we have since learned much that is enlightening, much that is disquieting. [...]

With the hindsight we now have as a result of our discoveries, several things become clear. One is that the Nazis' oft-repeated threats concerning the "secret weapons" they would shortly direct against the Allies were far from being purely "propaganda." Hitler had boasted that England and the whole world would soon feel their effect. Examination of Germany's missiles at war's end left very little doubt that Der Fuehrer had come uncomfortably close to making good his boast.

Also understandable now on the basis of our present knowledge is Germany's almost suicidal last-ditch stand after Allied forces had crossed the Rhine in overwhelming numbers. Assuming that the Nazis were completely whipped, the Allied populace could not understand why they would not give up and put an end to senseless, wholesale slaughter. But German commanders, it now appears, were aware that if they could hold out for just a short time longer they could very well effect at least a stalemate, if not a short-cut victory, on the European battlefront.

It is now also fairly generally known that the atomic bomb race was close—again, closer than we care to think about. And paralleling the Nazis' research on atomic explosives was their accelerated development of the V-2 program. Linking these two projects together makes credible another theory which is current among Allied guided missile groups: namely, that it was the intention of Nazi technicians to put some sort of atomic device in the warhead of the V-2.

This, they point out, would then have made the V-2s economical beyond question. One of the facts which has puzzled observers is that the V-2, with its small-sized warhead permitting only one ton of conventional explosives, did not justify the tremendous cost of each missile. The damage achieved—actually less than that of the V-1 which was many times cheaper and took only 800 man-hours to make—did not begin to compensate for the 12,950 man-hours required for the manufacture of every V-2. But if, as they now believe it had been originally planned, even a few of these supersonic V-2s could have carried atomic warheads, there is little doubt that they could have wiped our invasion ports off the map and reduced England to the shambles that are Nagasaki and Hiroshima.

It is thought that the only reason the Germans did resort to their uneconomical use of the V-2s with ordinary explosives is the obvious one that the atomic warhead devices simply were not yet ready, and Nazi military leaders, with their backs against the wall, were forced to throw at the Allies any weapon they had available, regardless of cost. Actually, however, the terrorizing effect of these 3,500 mph missiles—against which there was absolutely no defense—on London and Antwerp that winter of 1944–45 must certainly have made the Nazis feel that the V-2s had a psychological value alone far in excess of their actual dollars and cents cost for amount of damage inflicted.

Allied bombings of the Nazi heavy-water plants in Norway quite obviously retarded her atomic development, as did also the consistent sabotage on the part of many Norwegian scientists. But it is still a matter of scientific conjecture just how many weeks—or days—it might have taken Germany to be ready with her atomic devices for the V-2s.

And continue this same subject of Hitlerian threats, the Nazi claim that Germany had rockets which could bombard the US was not too far removed from actual achievement. Long-range missiles were in the design stage when Allied troops moved into Germany. Larger than the V-2s, these winged rockets, carrying smaller rockets which would take off on their own at a specific point, attain speeds up to 5,800 mph, and finish their trajectories in a long glide, were predicted to be capable of ranges up to 3,000 miles.

[...] Even now, more than a year after V-E Day it is still frightening to imagine what *might have* happened had we not halted Germany when we did. We now know that it was later than we thought. It is not enough to concede that the call was close unless, in that closeness, we have learned one of the war's most valuable lessons.

[This article was based on Donald Putt's March 1946 presentation (see p. 5472), as well as other information from him and from other Allied inspectors. Published in the official U.S. *Army Air Forces Review*, it stated that:

- German scientists had "at least a 10-year lead" over Allied countries in the field of guided missiles.
- Hitler's promised new secret weapons were not simply propaganda or paper designs, but missiles that were subjected to "examination... at war's end."
- At the war's end, the German military was fiercely defending territory that held those secret weapons in the expectation that they would be used.
- It was "fairly generally known that the atomic bomb race was... closer than we care to think about," and it was just a matter of scientific conjecture whether it was weeks or days that separated Germany from deploying rocket-launched nuclear weapons at the end of the war.
- These statements officially published by the U.S. Army Air Forces completely contradicted the claims of Samuel Goudsmit and the Alsos Mission that Germany was not even close to having nuclear weapons.

- In fact, this Army Air Forces publication seemingly admitted details that demonstrate the German nuclear program was many years ahead of the U.S. program. At the beginning of May 1945, the United States was still trying to complete its first fission bomb, and that weapon was so cumbersome that it would need to be delivered by a large plane. According to the Army Air Forces, by that time Germany apparently had multiple nuclear weapons ("rockets with nuclear warheads"), they were small enough to deliver via rockets, and Germany had developed suitable rockets with which they were integrated and on the brink of deployment. The United States would not reach that level of technology for over a decade—in the late 1950s—and even then only with large amounts of assistance from German-speaking scientists.

- "Almost all military leaders" accepted "that the Allies won the war in Europe by a terrifyingly narrow margin." This conclusion by contemporary observers best positioned to know all the facts is quite different than the conventional historical view that has been propagated for 75+ years.

- For many more references to nuclear-armed rockets that were intended to attack Allied targets during the war, see the list of documents on p. 5821.

Charlotte Knight, the author of this article, was a staff journalist who had been working full-time for the U.S. Army Air Forces for several years. She had flown around the world covering events during World War II, and she was the only woman to witness the Operation Crossroads fission bomb tests at Bikini Atoll from the air in 1946. Thus she would have written this article in a very sober fashion, without any embellishment, and exactly as Donald Putt and the Army Air Forces wanted it. For more information on Knight, see:

> Utah Woman Tells of Work with Air Force. *Deseret News* (Salt Lake City, Utah) 17 June 1947, p. 20. https://news.google.com/newspapers?nid=336&dat=19470617&id=F9s0AAAAIBAJ&sjid=kXcDAAAAIBAJ&pg=5662,5995342

Other journalists repeated much of this information in various publications from summer 1946 through 1947. See for example:

> Nazis Worked on Plane to Bomb U.S. *Hartford Courant* 15 July 1946, p. 1.
>
> Hitler Planned Supersonic Bomber to Hit New York. *Los Angeles Times* 15 July 1946, p. 2.
>
> List of Terror Weapons of Nazis Revealed by AAF. *Plattsburgh Press-Republican* (Plattsburgh, New York) 15 July 1946, p. 1.
>
> Nazi Scientists Worked on 136 Secret Weapons. *Times Record* (Troy, New York) 15 July 1946, p. 3.
>
> Transatlantic Roller Coaster Designed to Bomb U.S.A. *Popular Science* October 1947. https://neverwasmag.com/2018/09/wonder-weapons-of-the-third-reich/transatlantic-roller-coaster-designed-to-bomb-usa/

For more information on German and Allied threats and counter-threats to use nuclear, chemical, and biological weapons of mass destruction during the final years of the war, see pp. 2632–2651.]

Heinrich Himmler's chief adjutant Werner Grothmann on nuclear technology transfer to the United States [Krotzky 2002]. For a discussion of the background and reliability of this source, see pp. 3396–3397.

[S. 32] Die zweite Schwierigkeit bestand darin, dass die Zünder für die Waffe nicht so funktionierten, wie man sich das ursprünglich dachte. Die haben mit allem möglichen experimentiert. Es war, glaube ich, erst im Herbst 1944, dass jemand bei Diebner eine praktikable Lösung fand, die aber immer noch sehr aufwendig war. Und ungefähr zur selben Zeit hat dann bei uns jemand in Zusammenarbeit mit..., glaube ich, und noch ein Unternehmen war beteiligt, oder dort ein Experte, mit Infrarot-Zündern einigen Erfolg. Wir nannten, die Dinger damals Ultrarot-Zünder.

[p. 32] The second problem was that the fuse for the weapon was not working as originally intended. They experimented with all kinds of things. I believe it was first in the autumn of 1944 that someone with Diebner found a viable solution, which was still very elaborate. And about the same time, someone with us [SS] who worked in collaboration with ..., I believe, and another company was involved, or there was an expert, with infrared detonators some success. We called the things then infrared igniters.

[S. 45] Die Zünderentwicklung muß für alle Beteiligten eine richtige Nervensache gewesen sein. Ich bin ja kein Technik-Sachverständiger gewesen, aber im Laufe der Zeit bekam man doch etwas mit. Deshalb kann ich wenigstens sagen, dass Himmler wiederholt Fehlschläge gemeldet worden sind. Dabei hatte man ja wirklich die erste Garnitur von Experten damit beauftragt und außerdem ist an verschiedenen speziellen Zündern für die Atombombe gearbeitet worden. Wenn ich jetzt überlege, was mir dazu noch einfällt, ist es die Ultra-Rot-Sache. An Zündern die auf dieser Basis funktionieren sollten, ist nach meiner Erinnerung von ganz wenigen Leuten bei einer Optik-Firma in Zusammenarbeit mit einem Elektro-Unternehmen gearbeitet worden. Den Auftrag haben wir aber nicht vergeben, so weit ich weiß, der ist wahrscheinlich von Ohnesorge weitergegeben worden. Dieser Zünder soll noch kurz vor Kriegsende als Laborgerät für die ersten Funktionsprüfungen vorbereitet worden sein, mehr weiß ich dazu nicht. [...]

[p. 45] The ignition development must have been a real problem for everyone involved. I was not a technical expert, but in the course of time one learned something about it. That is why I can at least say that Himmler had repeatedly received reports of failed tests. Therefore the first set of experts had been commissioned, and out of that a number of special detonators for the atomic bomb had been worked on. If I think what else I can remember now, then it is the infrared thing. According to my memory, a very small number of people at an optics company, cooperating with an electrical company, worked on detonators that were supposed to function on this basis. We did not give the assignment, however, as far as I know, it was probably passed on by Ohnesorge. This detonator is said to have been prepared shortly before the end of the war as a laboratory device for the first functional tests, more I do not know. [...]

Dann gab es Vorschläge, das Atom-Sprengmaterial mit einem ganz unkonventionellen Zünder auszulösen. Der Vorschlag ist bei dem Treffen bei Innsbruck schon bekannt gewesen. Man muß sich das so vorstellen: es war die Rede davon, dass man für die Zündung sehr viel Energie benötigt, um das Material zu zünden. Da hatte ein Ingenieur von einer Technischen Hochschule in anderem Zusammenhang vorgeschlagen, so eine Art Radarstrahlen einzusetzen, weil man die wohl auf ganz kurze Entfernung sehr gut bündeln konnte und weil die Energie enthalten würden oder selbst Energie sind. Das weiß ich nicht genauer.[18] Jetzt gab es ja das Problem, dass wir im Frühjahre von den Physikern ganz klar hörten, die Entwicklung der Bombe ist auf gutem Weg, also das heißt erst mal, das Sprengmaterial wird man für die notwendigen Versuche erzeugen können und dann muß man sehen, wie viel davon für die richtige Bombe, erzeugt werden kann. Ohnesorge machte da mächtig Druck mit dem Argument, wenn wir die Bombe mit so viel Aufwand hinbekommen und dann fehlt der Zünder, ist der Krieg trotzdem verloren. Das war auch Himmlers Ansicht. Wir konnten den Krieg nicht mehr anders gewinnen als mit einer durchschlagenden Waffe. Deshalb sind ja solche Forschungsaufträge auch sofort weitergegeben worden und man hat auch mit einzelnen Firmen darüber gesprochen, dass die ihre besten Leute an diese Sache setzen sollten. Rausgekommen ist nach meiner Kenntnis auch bei dem Zünder nichts.

Then there were proposals to trigger the nuclear explosive material with a completely unconventional detonator. The proposal was already known at the meeting near Innsbruck. You have to imagine it like this: there was talk about the fact that you need a lot of energy to ignite the material. In another context, an engineer from a technical university had suggested to use some kind of radar beams, because they could be focused very well at a very short distance and because they would contain energy or are energy themselves. I do not know that more exactly.[18] Now there was the problem that in the early years we heard quite clearly from the physicists that the development of the bomb is well on the way, so that means first of all that the explosive material will be able to be produced for the necessary tests and then we must see how much of it can be produced for the real bomb. Ohnesorge put on a lot of pressure, arguing that if we could make the bomb with so much effort and then the fuse was missing, the war would still be lost. That was also Himmler's view. We could no longer win the war any other way than with a breakthrough weapon. That is why such research contracts were passed on immediately, and they also talked to individual companies about putting their best people to work on this. As far as I know, nothing came of that [particular] detonator.

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[18] [Grothmann was not a scientist; his nonscientific description here seems to be referring to the use of a compact betatron as a neutron initiator. Grothmann would not be expected to understand the physics details of betatrons, but they use an electron beam and a magnetic field, as does a cavity magnetron for radar, with which Grothmann was probably much more familiar. Thus Grothmann was describing "a completely unconventional" device that used an electron beam and magnetic field to "focus" a "beam" over a "very short distance" "to trigger the nuclear explosive material." A betatron mounted on the outside of a fission implosion bomb could fire a high-energy electron beam toward the center of the bomb at the moment of implosion. The energy of the electrons would be converted to gamma rays via the bremsstrahlung process. Gamma rays absorbed by some ^{235}U or ^{239}Pu nuclei could release neutrons, which could initiate a fission chain reaction in the rest of the ^{235}U or ^{239}Pu fuel. The United States successfully demonstrated a betatron neutron initiator in a fission bomb on 1 June 1952 in the George test of Operation Tumbler-Snapper [https://nuclearweaponarchive.org/Usa/Tests/Tumblers.html].

In March 1945, Ivan Ilyichev reported that this method was one of the neutron initiators used in German atomic bombs (p. 4487: "Bomb ignition": "Ahead of this, before the explosion, the uranium sphere is irradiated with gamma-rays, the energy of which does not exceed 6 million electron volts, which many times increases its explosive qualities."). Compact, light-weight 6- and 7-MeV betatrons ideally suited for this particular application were manufactured during the war by Siemens-Reiniger Werke in Erlangen (pp. 3088–3089, 3957–3970).]

Dann gab es einen Vorschlag, der kam aus Österreich und war sehr gut begründet. Der schien ganz pfiffig. Mir war er nur als Netzzünder bekannt geworden. Im Versuch funktionierte er aber nur wie ich hörte, wenn die Position bestimmter Zünderteile ganz genau, also wirklich millimetergenau eingehalten werden konnte. Gab es eine winzige Lageveränderung war alles umsonst. Den konnte man natürlich so nicht einsetzen. Diebner hat übrigens selbst Zünder-Experimente angeregt, aber erst im Herbst 44 bekam man ein einigermaßen funktionierendes Ding hin.

[S. 34] Für das hier verbürge ich mich aber: Aus unseren Forschungs- und Entwicklungslabors in Thüringen sind Teile des Materials verbracht worden, aber nicht alles. Warum das so geschah, weiß ich nicht. Zumindest das wenige radioaktive Material für die erste Bombe und einen Teil des Zündmechanismus sollen dann die Amerikaner mitgenommen haben. Die von den Amerikanern erbeuteten Prototyp-Teile für unsere erste richtige Atombombe sind sofort von ihnen zum “Adlerhorst” gebracht worden. Ab da weiß ich nichts mehr dazu. Es gibt noch vielleicht, noch jemanden, der das bestätigen kann.

[S. 40] Die Sieger haben die Beute mitgenommen und spater der Öffentlichkeit ihre glänzende Rüstung vorgeführt. Bei Flugzeugen war das so, bei der U-Boot-Technik, in der Chemie und auch so manchen unserer tüchtigen Atomphysiker haben sie dann für sich arbeiten lassen, genauso wie die Raketenleute.

Then there was a proposal from Austria, which was justified very well. It seemed quite clever. I only knew it was called network ignition. In the experiment, however, it only worked as I heard, if the position of certain detonators was very exact, that is, precise to the millimeter. If there was a tiny change of location, all was in vain. Of course you could not use it that way. By the way, Diebner himself suggested detonator experiments, but it was not until autumn 44 that a well-functioning thing was discovered.

[p. 34] For this, however, I can vouch myself: Parts of the material had been removed from our research and development laboratories in Thuringia, but not everything. Why this happened, I do not know. The Americans are supposed to have taken at least the small amount of radioactive material for the first bomb and a part of the ignition mechanism. The prototype parts for our first real atomic bomb that were captured by the Americans were immediately taken to the “Eagle’s Nest.” I do not know any more about it, there may be someone who can confirm it.

[p. 40] The winners took the booty and later presented their shining armaments to the public. That was true for airplanes, with submarine technology, in chemistry, and with many of our capable nuclear physicists, who worked for them [Allied countries], just like the rocket people.

[In the first four quoted paragraphs, Grothmann told how German and Austrian engineers invented and tested several different detonation timing systems to allow the spherical implosion bomb (which he described elsewhere) to create a detonation with "millimeter-exact" accuracy across all of the ignition points around the bomb. As examples, he recounted a sophisticated optical method using infrared signaling to the detonators, and another system called "network ignition," likely an electrical network of exploding bridgewire detonators. Erich Schumann appears to have referred to exploding bridgewire detonators in his description of German implosion bombs (p. 4241).

Adlerhorst or Eagle's Nest was located near Bad Nauheim, and should not be confused with the better known Eagle's Nest or Kehlsteinhaus near Berchtesgaden. Adlerhorst was captured by the U.S. Army on 30 March 1945, and subsequently was used by the Allies as "Operation Dustbin" to imprison and interrogate high-value German intelligence targets, including Albert Speer, Wernher von Braun, and many others.

If the United States captured German atomic bomb components and immediately took them to Adlerhorst, those components could have been captured no earlier than April 1945. Since the United States could have taken the components to many other sites that were equally or more secure, Grothmann's statement that they were taken to Adlerhorst suggests that those components were shown to high-value German detainees so that they could not deny the existence of the German nuclear program. Furthermore, that would suggest that the United States had not captured a satisfactory amount of information about the nuclear program, and was desperate to learn more from the detainees. Is it possible to locate and declassify any U.S. records on what German atomic bomb components were found, or what the United States learned from German detainees?

If precisely timed implosion detonators or other sophisticated nuclear weapons components were captured in Europe in April–May 1945 or on the U-234 or other surrendered German submarines, those components may have been used to make final improvements to the U.S. fission bombs before they were detonated in New Mexico and Japan (p. 4880).

See p. 4992 for a very incomplete list of some German and Austrian nuclear-related scientists and engineers who temporarily visited or permanently moved to the United States or United Kingdom after the war, just as Grothmann said.]

From Office of Strategic Services Shepardson to Amzon. 10 September 1945. [NARA RG 226, Entry A1-134, Box 219, Folder 1371: OUT AZUSA Nov. '43 Sept. '45]

#3567. AZUSA. Wisner and Rositzke from 154 and Dix. Reur #2417 (IN 23590).

Any information gained concerning German scientists on AZUSA send only to Lt. Col. Horace K. Calvert care U. S. Embassy, London, and do not pass to G-2 USFET. This also applies other fields. Send copies Washington.

H. W. Dix to Francis J. Smith. 13 September 1945. Office of Strategic Services memo AA-217. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

Cable from our German office reads in accordance with the two following paragraphs:

> 1. Referring further our recent exchange cables RE handling Azusa material, General Sibert who has just returned here from Washington has informed us (A) that when in Washington he was given full information concerning this subject and all matters pertaining to it including U.S. policy (B) that he was designated as coordinator all such information in this theater and (C) that we are to disseminate all our information this subject to him and no one else in theater.
>
> 2. As OSS Germany is under direction command USFET, we consider General Sibert's instructions this subject as an order which we cannot ignore. If you disapprove we suggest as only solution that you approach War Department Washington with request that Sibert's instructions be altered.

This is different than our instructions to our office in Germany. The instructions we forwarded were from your office.

Please advise which way you desire our office in Germany to handle

> (a) the information about the search for German scientists
>
> (b) all information on this topic.

From Office of Strategic Services Shepardson to Berlin via Amzon. 14 September 1945. [NARA RG 226, Entry A1-134, Box 219, Folder 1371: OUT AZUSA Nov. '43 Sept. '45]

WASH 6437. AZUSA. To 110 Berlin from 154 and Dix. Information: Wisner Amzon.

RE BERL 1059 (IN 23766), please see WASH 3567 to Wisner. Our work on this subject is to correlate and cooperate with specially appointed general who has charge of the whole AZUSA situation and has overall responsibility.

In order that he may make decisions we pass our information to him, and thereby proceed as he may direct.

On present sub feature of AZUSA about assisting locating German scientists, special general asked to have the information sent only to Calvert, London Embassy, or to Washington.

RE your AMZO 4437 (IN 240370); our WASH 1167 and WASH 3567 were special general's instructions until he could talk with Sibert here. This now done and all AZUSA information obtained by OSS in ETO and applicable in ETO situations now to be coordinated only between you or Wisner Sibert and Calvert and advising OSS Washington of resulting decisions or information. This insures desired maximum security with fewest number persons involved. Copies of any reports to be sent OSS Washington without delay and showing action taken.

This subject so tight at this time we are playing very close with special general.

Phrase "other fields" from your BERL #2417 interpreted here as within scope AZUSA matters only and not applicable to all technical matters. WASH 3567 repeated the words "other fields" thereby trying to eliminate misunderstanding. This answers AMZO 3917.

[See document photo on p. 5048. Do these OSS cables show that the U.S. started to really appreciate the extent of the wartime German nuclear program by September 1945, and took steps to limit that knowledge to the "fewest number persons"? Is that why Zinsser's report of a German atomic bomb test was upgraded from Secret to Top Secret in early October 1945 (p. 4422)? Who was the "special general"—Leslie Groves or someone else?]

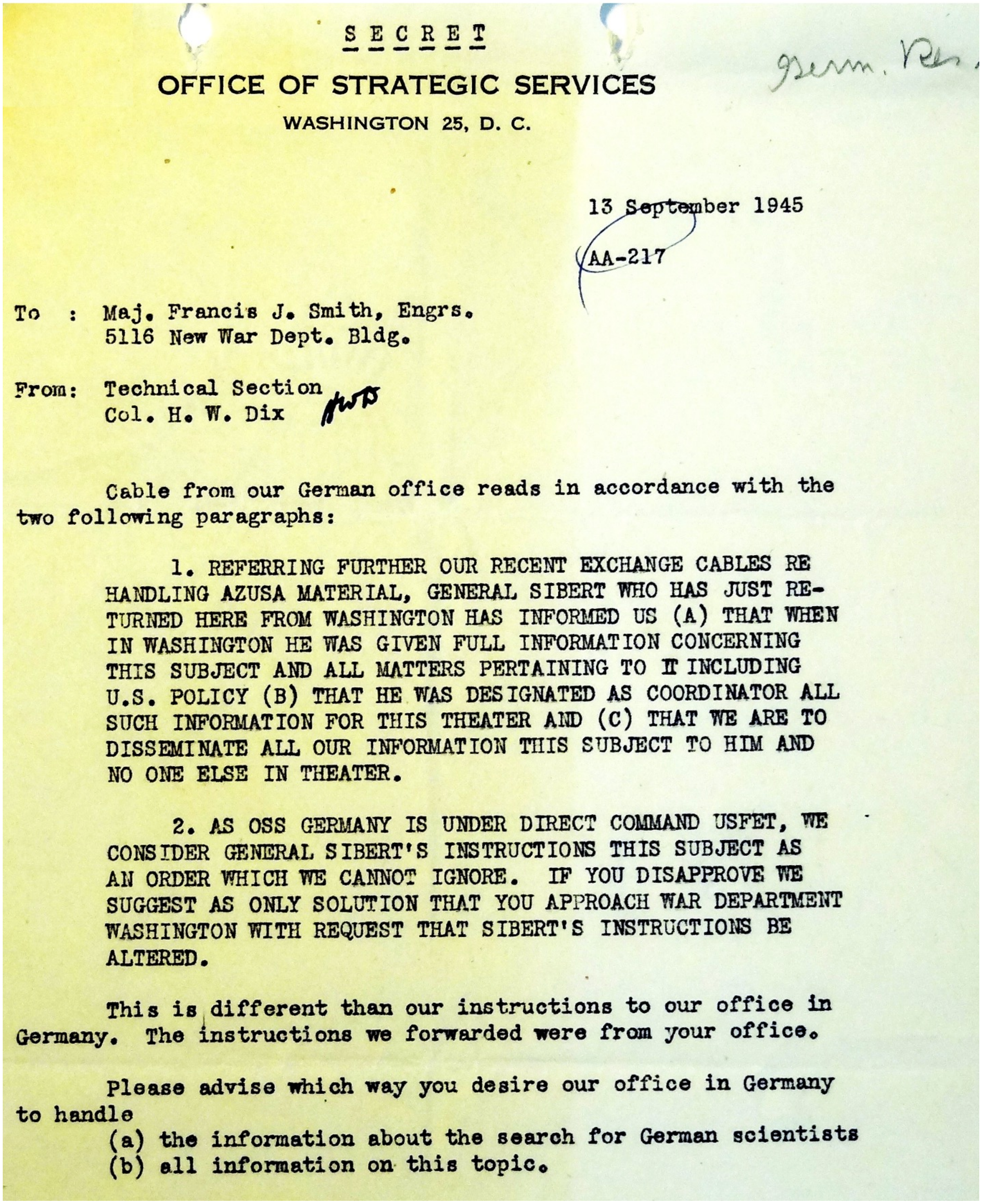
Captain Hugh T. Cunningham, Strategic Services Unit, to Brigadier General Edwin L. Sibert, U.S. Army, 6 May 1946. Subject: German Atomic Research [NARA RG 226, Entry A1-215, Box 6, Folder WN26150–26164]

1. One of our reliable sources is in contact with a certain Chef-Chemiker Sallie, at present employed in a chemical industry in Constance, who claims to be able to give detailed information on German atomic research as of February 1945. Sallie was in Berlin when the Russians blew up the Treasury Building in which the documents on German atomic research were stored, and claims to know exactly what documents thereby fell into the hands of the Russians.

2. If this man is of interest for further exploitation we can instruct our source accordingly.

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3
GERMANY: US Wartime Positive Int. (Nov. 44-June 45)



S E C R E T

Germ. Res.

OFFICE OF STRATEGIC SERVICES
WASHINGTON 25, D. C.

13 September 1945

AA-217

To : Maj. Francis J. Smith, Engrs.
5116 New War Dept. Bldg.

From: Technical Section
Col. H. W. Dix HWD

Cable from our German office reads in accordance with the two following paragraphs:

1. REFERRING FURTHER OUR RECENT EXCHANGE CABLES RE HANDLING AZUSA MATERIAL, GENERAL SIBERT WHO HAS JUST RETURNED HERE FROM WASHINGTON HAS INFORMED US (A) THAT WHEN IN WASHINGTON HE WAS GIVEN FULL INFORMATION CONCERNING THIS SUBJECT AND ALL MATTERS PERTAINING TO IT INCLUDING U.S. POLICY (B) THAT HE WAS DESIGNATED AS COORDINATOR ALL SUCH INFORMATION FOR THIS THEATER AND (C) THAT WE ARE TO DISSEMINATE ALL OUR INFORMATION THIS SUBJECT TO HIM AND NO ONE ELSE IN THEATER.

2. AS OSS GERMANY IS UNDER DIRECT COMMAND USFET, WE CONSIDER GENERAL SIBERT'S INSTRUCTIONS THIS SUBJECT AS AN ORDER WHICH WE CANNOT IGNORE. IF YOU DISAPPROVE WE SUGGEST AS ONLY SOLUTION THAT YOU APPROACH WAR DEPARTMENT WASHINGTON WITH REQUEST THAT SIBERT'S INSTRUCTIONS BE ALTERED.

This is different than our instructions to our office in Germany. The instructions we forwarded were from your office.

Please advise which way you desire our office in Germany to handle
(a) the information about the search for German scientists
(b) all information on this topic.

Figure D.997: H. W. Dix to Francis J. Smith. 13 September 1945. Office of Strategic Services memo AA-217. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

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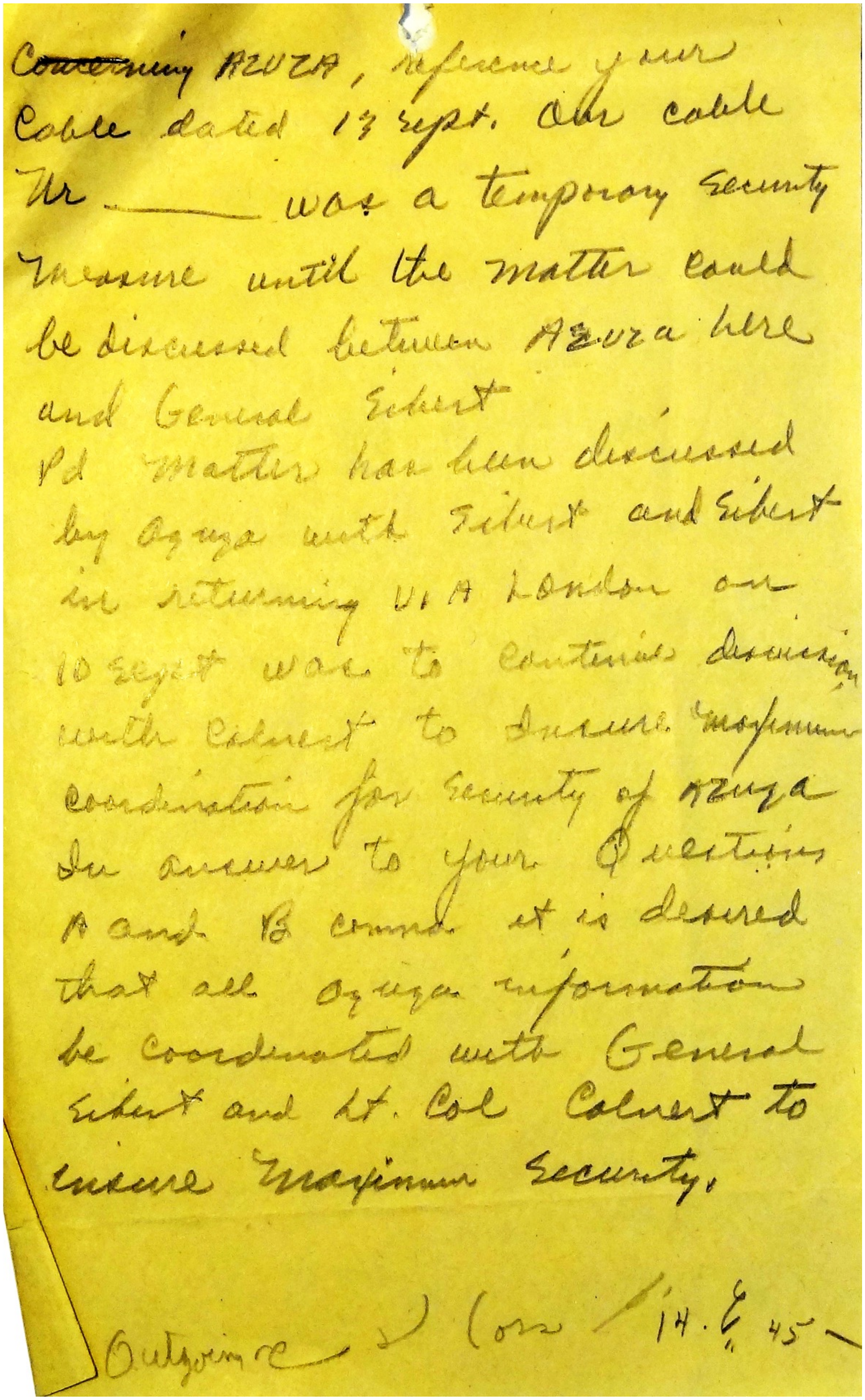
NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3
GERMANY: US Wartime Positive Int. (Nov. 44–June 45)



~~Concerning~~ AZUZA, reference your
Cable dated 13 Sept. Our cable
Nr ____ was a temporary security
measure until the matter could
be discussed between Azuza here
and General Sibert
Pd matter has been discussed
by Azuza with Sibert and Sibert
is returning via London on
10 Sept was to continue discussion
with Calvert to insure maximum
coordination for security of Azuza
In answer to your Questions
A and B comma it is desired
that all Azuza information
be coordinated with General
Sibert and Lt. Col Calvert to
insure maximum security.

Outgoing J Corr 14.9.45

Figure D.998: 14 September 1945. [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)]

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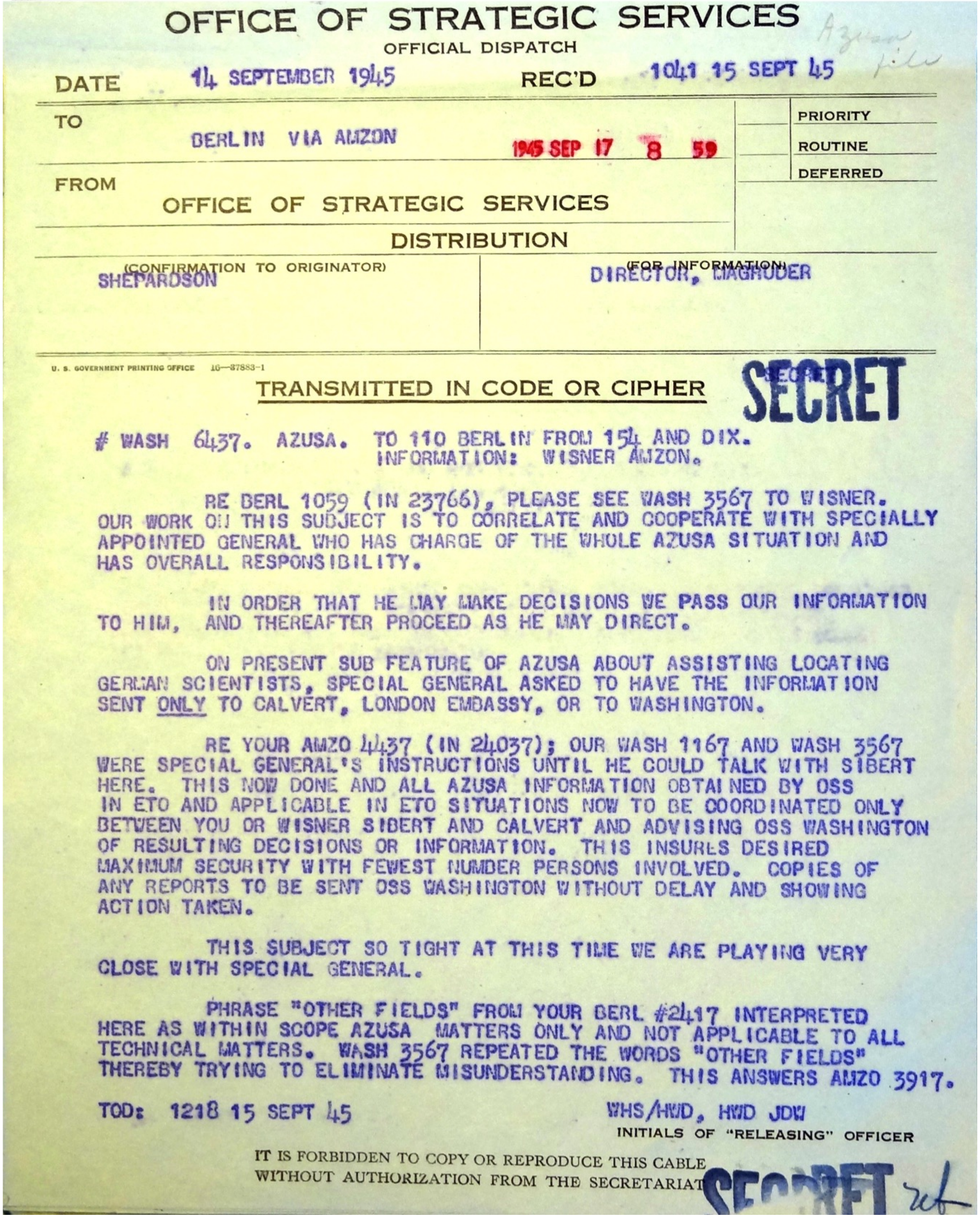
Authority NND 857134

NARA RG 226, Entry A1-134, Box 219,
Folder 1371: OUT AZUSA Nov. '43 Sept. '45



OFFICE OF STRATEGIC SERVICES
OFFICIAL DISPATCH

Azusa file

DATE 14 SEPTEMBER 1945 REC'D 1041 15 SEPT 45

TO BERLIN VIA AMZON 1945 SEP 17 8 59

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SECRET

WASH 6437. AZUSA. TO 110 BERLIN FROM 154 AND DIX.
INFORMATION: WISNER AMZON.

RE BERL 1059 (IN 23766), PLEASE SEE WASH 3567 TO WISNER. OUR WORK ON THIS SUBJECT IS TO CORRELATE AND COOPERATE WITH SPECIALLY APPOINTED GENERAL WHO HAS CHARGE OF THE WHOLE AZUSA SITUATION AND HAS OVERALL RESPONSIBILITY.

IN ORDER THAT HE MAY MAKE DECISIONS WE PASS OUR INFORMATION TO HIM, AND THEREAFTER PROCEED AS HE MAY DIRECT.

ON PRESENT SUB FEATURE OF AZUSA ABOUT ASSISTING LOCATING GERMAN SCIENTISTS, SPECIAL GENERAL ASKED TO HAVE THE INFORMATION SENT ONLY TO CALVERT, LONDON EMBASSY, OR TO WASHINGTON.

RE YOUR AMZO 4437 (IN 24037); OUR WASH 1167 AND WASH 3567 WERE SPECIAL GENERAL'S INSTRUCTIONS UNTIL HE COULD TALK WITH SIBERT HERE. THIS NOW DONE AND ALL AZUSA INFORMATION OBTAINED BY OSS IN ETO AND APPLICABLE IN ETO SITUATIONS NOW TO BE COORDINATED ONLY BETWEEN YOU OR WISNER SIBERT AND CALVERT AND ADVISING OSS WASHINGTON OF RESULTING DECISIONS OR INFORMATION. THIS INSURES DESIRED MAXIMUM SECURITY WITH FEWEST NUMBER PERSONS INVOLVED. COPIES OF ANY REPORTS TO BE SENT OSS WASHINGTON WITHOUT DELAY AND SHOWING ACTION TAKEN.

THIS SUBJECT SO TIGHT AT THIS TIME WE ARE PLAYING VERY CLOSE WITH SPECIAL GENERAL.

PHRASE "OTHER FIELDS" FROM YOUR BERL #2417 INTERPRETED HERE AS WITHIN SCOPE AZUSA MATTERS ONLY AND NOT APPLICABLE TO ALL TECHNICAL MATTERS. WASH 3567 REPEATED THE WORDS "OTHER FIELDS" THEREBY TRYING TO ELIMINATE MISUNDERSTANDING. THIS ANSWERS AMZO 3917.

TOD: 1218 15 SEPT 45

WHS/HWD, HWD JDW
INITIALS OF "RELEASING" OFFICER

IT IS FORBIDDEN TO COPY OR REPRODUCE THIS CABLE WITHOUT AUTHORIZATION FROM THE SECRETARIAT

SECRET

Figure D.999: Does this OSS cable show that the U.S. started to really appreciate the extent of the wartime German nuclear program by September 1945, and took steps to limit that knowledge to the "fewest number persons"? Who was the "special general"—Leslie Groves or someone else? [NARA RG 226, Entry A1-134, Box 219, Folder 1371: OUT AZUSA Nov. '43 Sept. '45].

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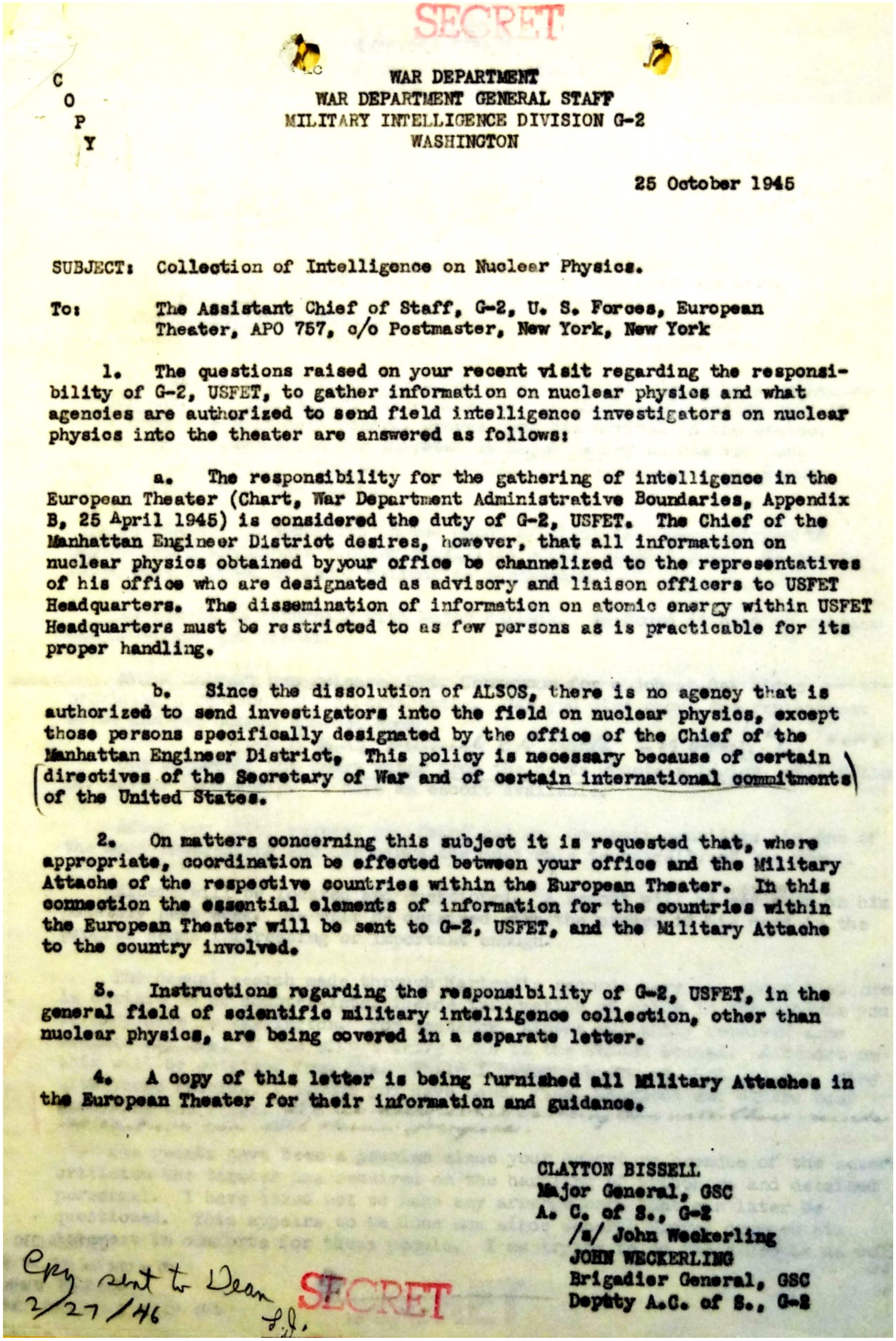

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WAR DEPARTMENT
WAR DEPARTMENT GENERAL STAFF
MILITARY INTELLIGENCE DIVISION G-2
WASHINGTON

25 October 1945

SUBJECT: Collection of Intelligence on Nuclear Physics.

To: The Assistant Chief of Staff, G-2, U. S. Forces, European Theater, APO 757, c/o Postmaster, New York, New York

1. The questions raised on your recent visit regarding the responsibility of G-2, USFET, to gather information on nuclear physics and what agencies are authorized to send field intelligence investigators on nuclear physics into the theater are answered as follows:

a. The responsibility for the gathering of intelligence in the European Theater (Chart, War Department Administrative Boundaries, Appendix B, 25 April 1945) is considered the duty of G-2, USFET. The Chief of the Manhattan Engineer District desires, however, that all information on nuclear physics obtained byyour office be channelized to the representatives of his office who are designated as advisory and liaison officers to USFET Headquarters. The dissemination of information on atomic energy within USFET Headquarters must be restricted to as few persons as is practicable for its proper handling.

b. Since the dissolution of ALSOS, there is no agency that is authorized to send investigators into the field on nuclear physics, except those persons specifically designated by the office of the Chief of the Manhattan Engineer District. This policy is necessary because of certain directives of the Secretary of War and of certain international commitments of the United States.

2. On matters concerning this subject it is requested that, where appropriate, coordination be effected between your office and the Military Attache of the respective countries within the European Theater. In this connection the essential elements of information for the countries within the European Theater will be sent to G-2, USFET, and the Military Attache to the country involved.

3. Instructions regarding the responsibility of G-2, USFET, in the general field of scientific military intelligence collection, other than nuclear physics, are being covered in a separate letter.

4. A copy of this letter is being furnished all Military Attaches in the European Theater for their information and guidance.

CLAYTON BISSELL
Major General, GSC
A. C. of S., G-2
/s/ John Weckerling
JOHN WECKERLING
Brigadier General, GSC
Deputy A.C. of S., G-2

Copy sent to Dean
2/27/46
L.J.

SECRET

NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.

Figure D.1000: Clayton Bissell and John Weckerling. 25 October 1945. Subject: Collection of Intelligence on Nuclear Physics [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.].

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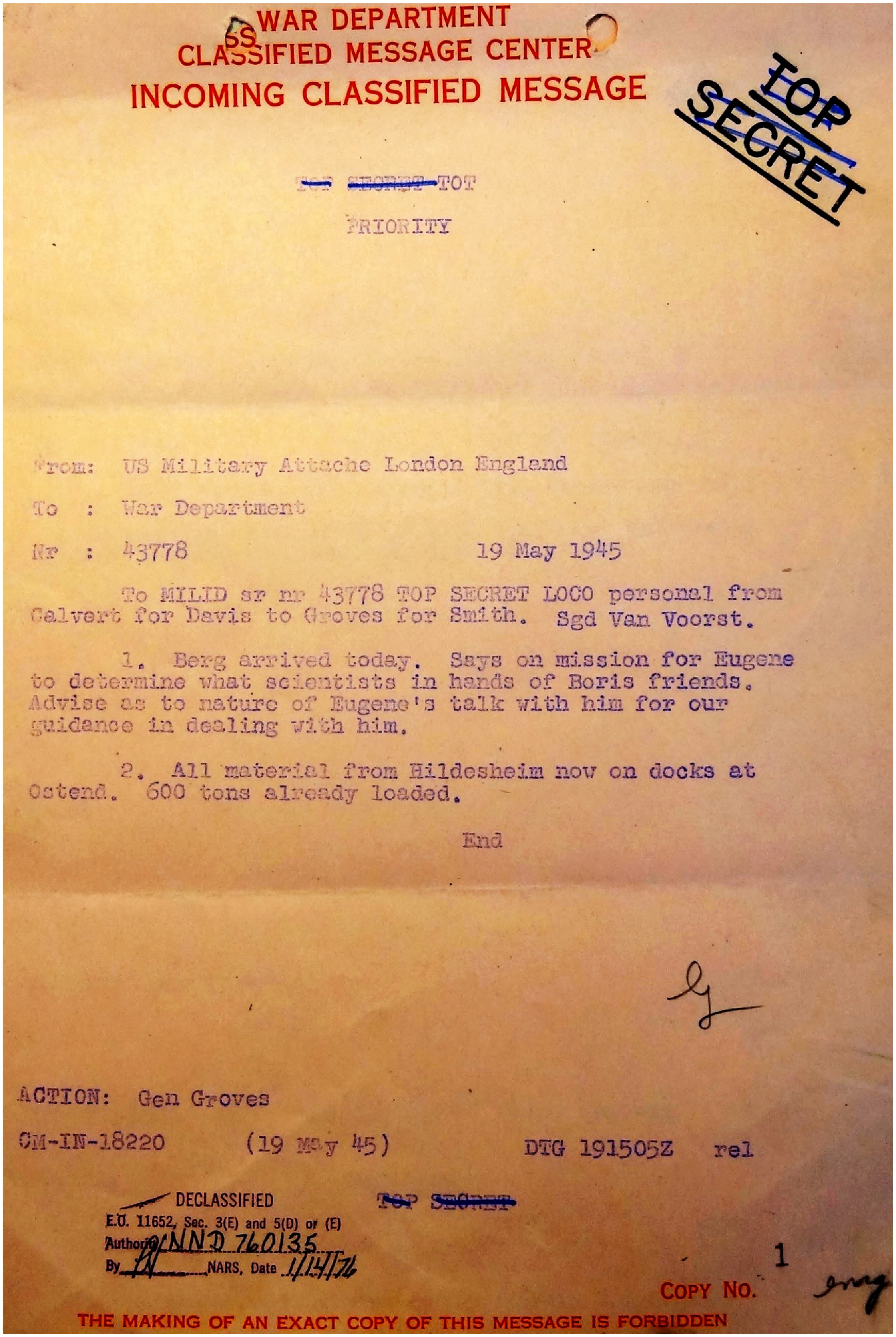

WAR DEPARTMENT
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INCOMING CLASSIFIED MESSAGE

~~TOP SECRET~~

~~TOP SECRET~~ TOT

PRIORITY

From: US Military Attache London England

To : War Department

Nr : 43778 19 May 1945

To MILID sr nr 43778 TOP SECRET LOCO personal from Calvert for Davis to Groves for Smith. Sgd Van Voorst.

1. Berg arrived today. Says on mission for Eugene to determine what scientists in hands of Boris friends. Advise as to nature of Eugene's talk with him for our guidance in dealing with him.

2. All material from Hildesheim now on docks at Ostend. 600 tons already loaded.

End

ACTION: Gen Groves

CM-IN-18220 (19 May 45) DTG 191505Z rel

DECLASSIFIED
E.O. 11652, Sec. 3(E) and 5(D) or (E)
Authority NND 760135
By ______ NARS, Date 1/14/76

~~TOP SECRET~~

COPY NO. 1

THE MAKING OF AN EXACT COPY OF THIS MESSAGE IS FORBIDDEN

NARA RG 77, Entry UD-22A, Box 160, Folder Apr 45—Dec. '45

Figure D.1001: After the war, OSS agent Moe Berg was sent on a mission by "Eugene" (probably a code name for a high-ranking person in the OSS or Manhattan Engineer District, or possibly Eugene Wigner?) to determine which German-speaking nuclear scientists had been recruited or captured by the Soviet Union ("Boris"). The "material from Hildesheim" included German uranium from Stassfurt [NARA RG 77, Entry UD-22A, Box 160, Folder Apr 45–Dec. '45].

Moe Berg. 1952. Handwritten notes. [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency.]

[See excerpts on pp. 5052–5063.

Moe Berg's 1952 notes reveal how extensively the postwar Soviet nuclear weapons program depended on scientists, companies, and resources from the wartime German nuclear weapons program.

Berg's notes appear to draw heavily upon a 1951 version of a CIA document, National Intelligence Survey (NIS) 26 (U.S.S.R.), Chapter VII, Section 73 (Atomic Energy). I have not been able to find that version, but a later 1955 version is available at:

https://www.cia.gov/readingroom/document/0000198124

https://www.cia.gov/readingroom/docs/DOC_0000198124.pdf

However, that 1955 version omits most of the information in pp. 5052–5063, probably because it was "old news" by then.

See pp. 3468–3471 for excerpts from the 1955 version that discuss postwar Soviet use of uranium sources from the wartime German nuclear weapons program.

If Moe Berg and his CIA colleagues knew this much about the highly secretive Soviet nuclear weapons program during the early Cold War, how much did Berg and his OSS colleagues know about the highly secretive German nuclear weapons program during World War II?

Among many other relevant details in Berg's notes, notice that:

Leftover wartime factories in Neustadt an der Orla, East Germany, were perfectly set up to make high-quality nickel membrane filters for gaseous diffusion uranium enrichment plants (pp. 5052, 5055–5057). Manufacturing the filters was so difficult that even years after the war, Soviet plants could not make comparable items. What exactly did these German factories do during the war? Did wartime Germany build gaseous diffusion uranium enrichment plants (Section D.4.4)?

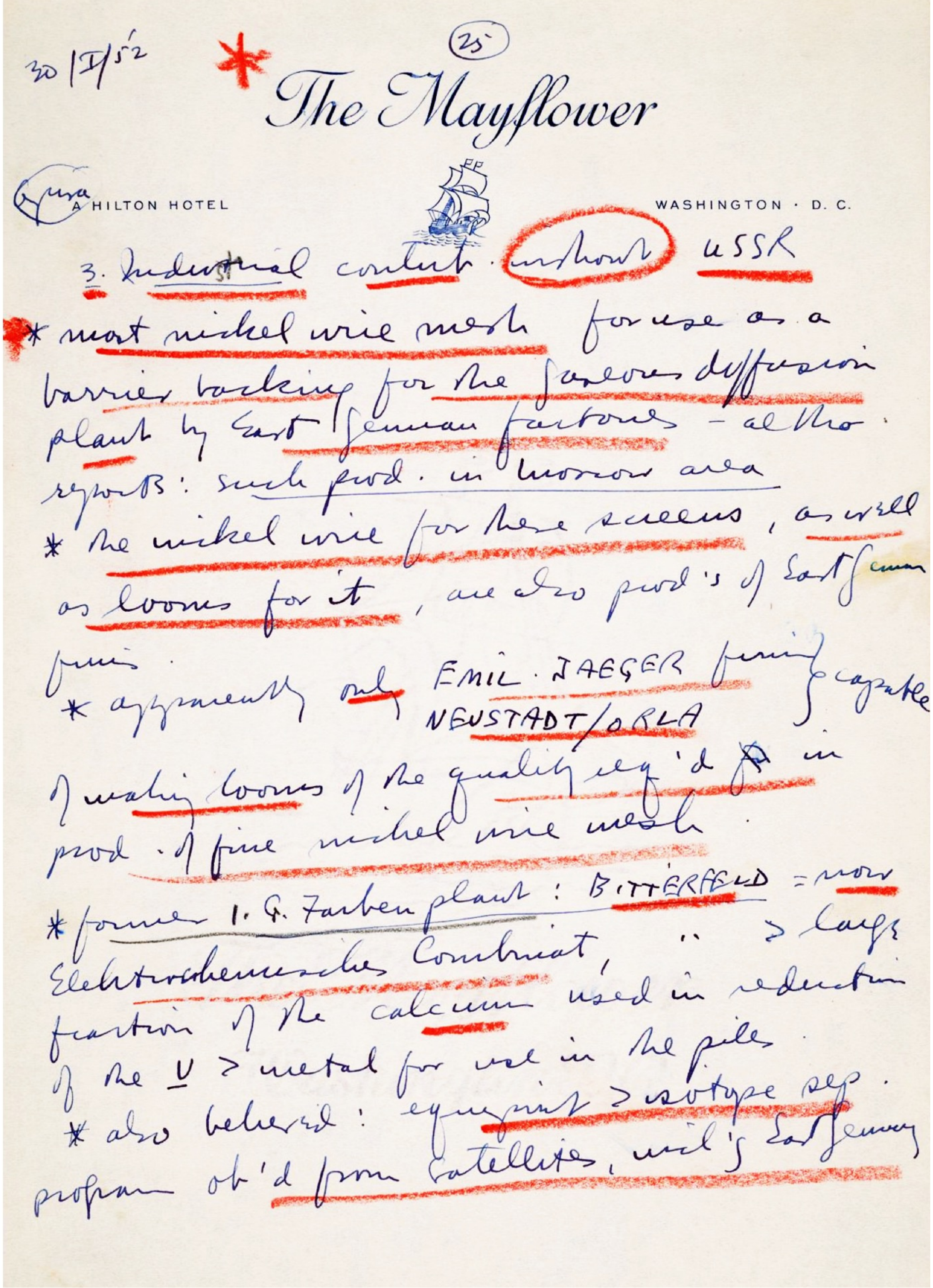
Ludwig Bewilogua (p. 5059) was extremely important for the postwar Soviet fission reactor program. What exactly did he do during the war? Note that another postwar U.S. intelligence report stated that Bewilogua was a "wartime expert on uranium piles" (p. 3991).

Wartime plants at I.G. Farben's Bitterfeld site were able to produce enough calcium for most of the huge postwar Soviet nuclear weapons program (pp. 5052, 5054). Calcium is used for key steps in purifying uranium metal (pp. 4132–4136). How much nuclear-weapons-related work did those plants do during the war? During the war, the Bitterfeld facility also produced heavy water (p. 4050), graphite (p. 4110), aluminum (p. 4128), and perhaps other potentially nuclear-related materials.

Czech manufacturers such as Skoda and Brünner were making significant contributions to the postwar Soviet nuclear weapons program (p. 5053), just as they apparently had for the wartime German nuclear weapons program (e.g., p. 4914).

Several Swiss factories were manufacturing and selling nuclear-related components to the postwar Soviet nuclear weapons program (p. 5053). Did they do the same for the wartime German program?]

Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3–Loose Notes: Central Intelligence Agency



30/II/52 (25)

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3. Industrial contrib. without USSR

* most nickel wire mesh for use as a barrier backing for the Soviet diffusion plant by East German factories – altho. reports: such prod. in Moscow area

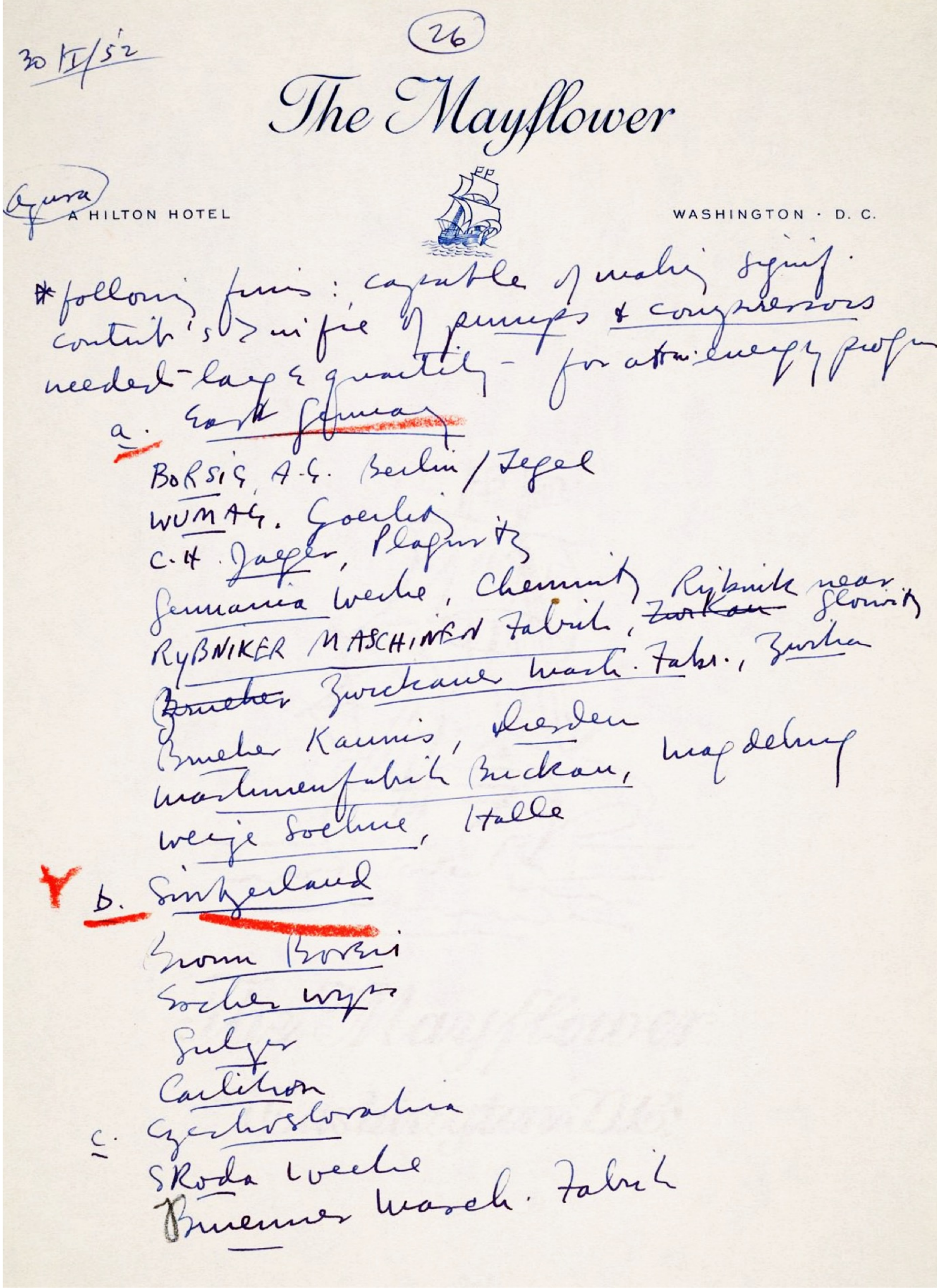
* the nickel wire for these screens, as well as looms for it, are also prod's of East German firms.

* apparently only EMIL JAEGER firm NEUSTADT/ORLA capable of making looms of the quality req'd in prod. of fine nickel wire mesh.

* former I. G. Farben plant: BITTERFELD = now Elektrochemisches Combinat, .. > large fraction of the calcium used in reduction of the U > metal for use in the piles.

* also believed: equipment > isotope sep. program ob'd from satellites, incl's East Germany

Figure D.1002: Moe Berg's 1952 notes reveal how extensively the postwar Soviet nuclear weapons program depended on scientists, companies, and resources from the wartime German nuclear weapons program [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].



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*following firms: capable of making signif. contrib's to mfr. of pumps & compressors needed—large quantity—for atom. energy prog.

a. East Germany

BORSIG A.G. Berlin/Tegel

WUMAG. Goerlitz

C.H. Jaeger, Plagwitz

Germania Werke, Chemnitz

RYBNIKER MASCHINEN Fabrik, ~~Zwickau~~ Rybnik near Glowitz

~~Bucher~~ Zwickauer Masch. Fabr., Zwickau

Brucher Kaumis, Dresden

Maschinenfabrik Buckau, Magdeburg

Weise Soehne, Halle

b. Switzerland

Brown Boveri

Escher Wyss

Sulzer

Carlithon

c. Czechoslovakia

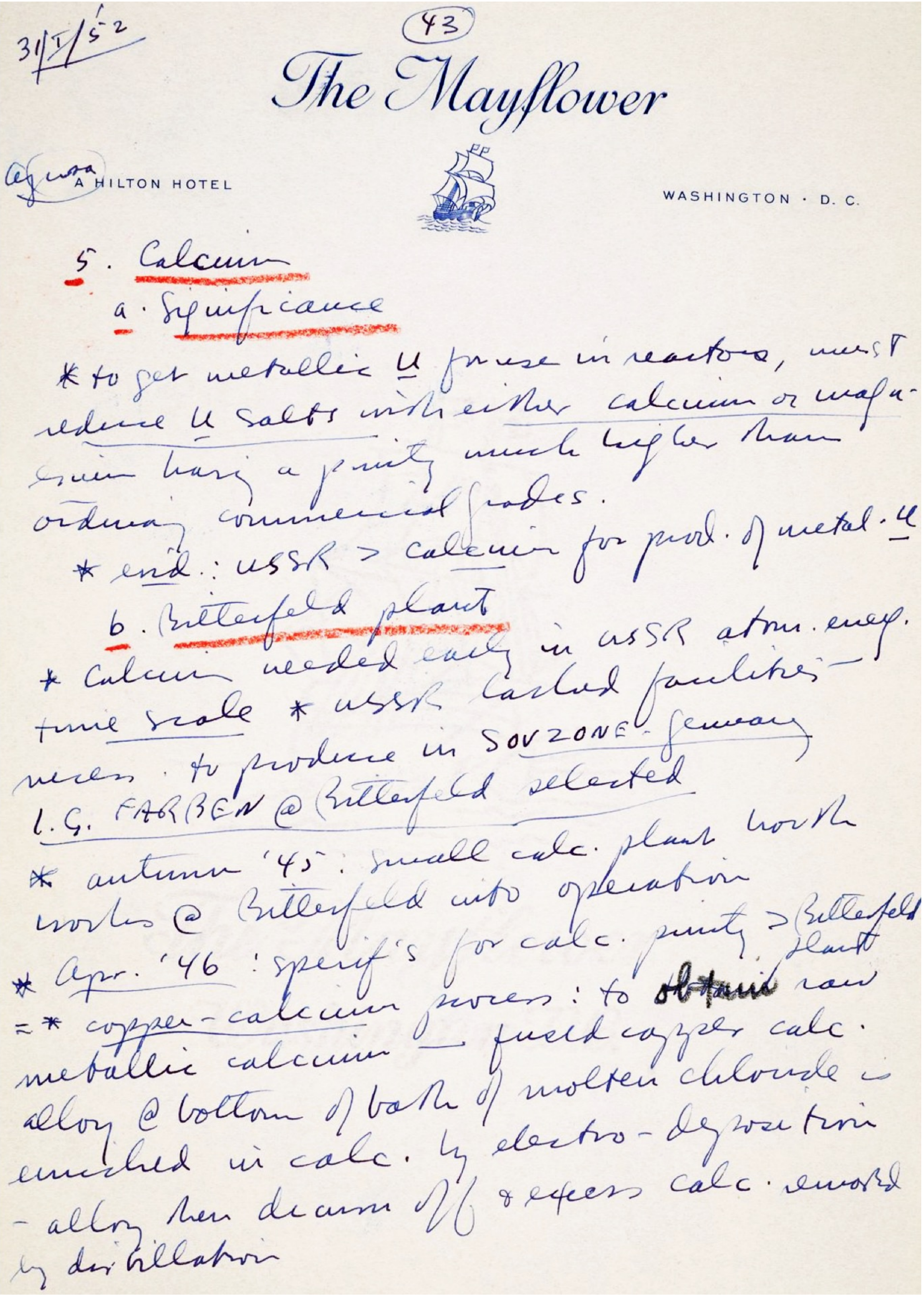
Skoda Werke

Bruenner Masch. Fabrik

Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3–Loose Notes: Central Intelligence Agency

Figure D.1003: Moe Berg's 1952 notes reveal how extensively the postwar Soviet nuclear weapons program depended on scientists, companies, and resources from the wartime German nuclear weapons program [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3–Loose Notes: Central Intelligence Agency



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5. Calcium

a. Significance

* to get metallic U for use in reactors, must reduce U salts with either calcium or magnesium having a purity much higher than ordinary commercial grades.

* end: USSR > calcium for prod. of metal. U

b. Bitterfeld plant

* Calcium needed early in USSR atom. energ. time scale * USSR lacked facilities — necess. to produce in SOVZONE-Germany

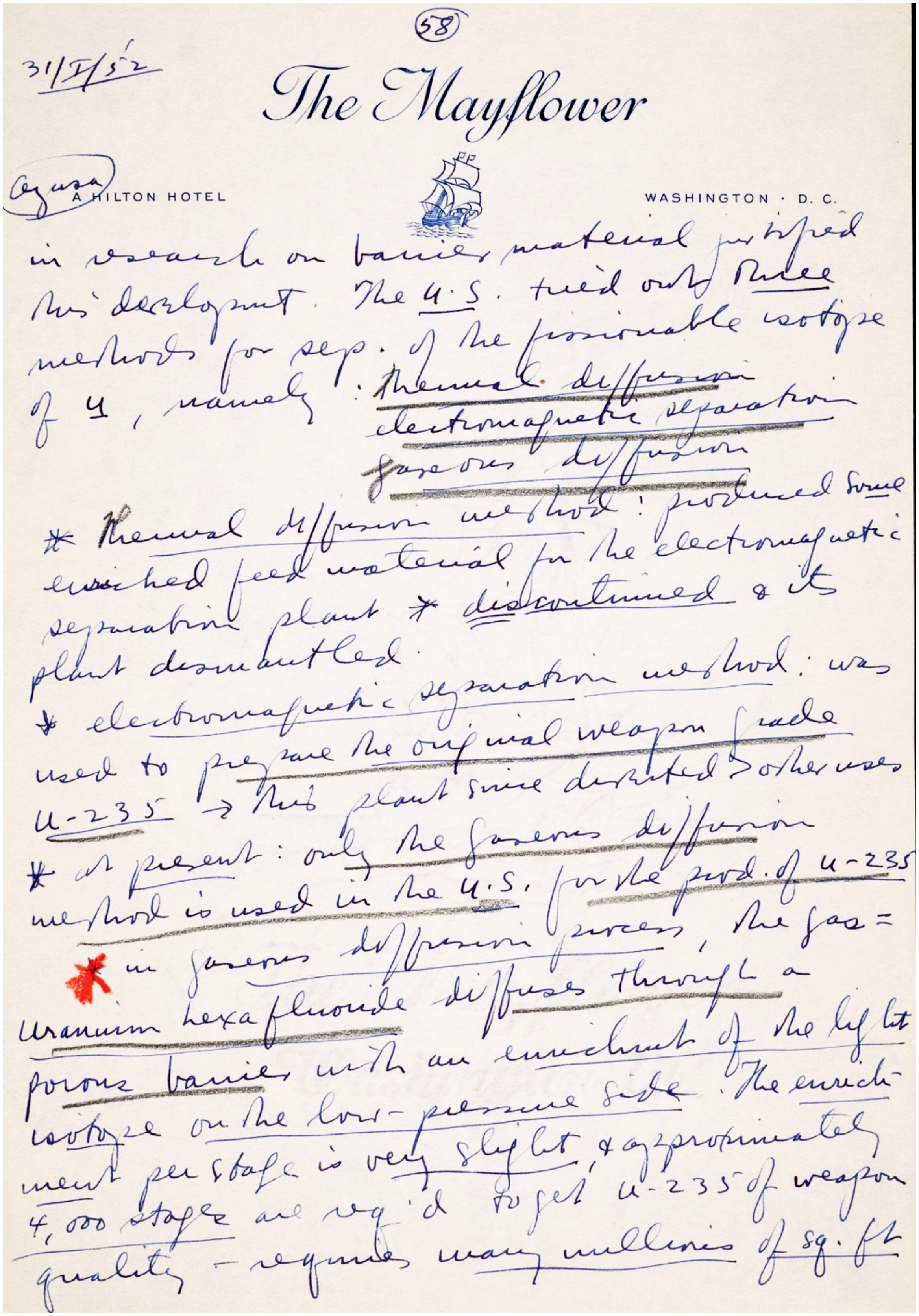
I.G. FARBEN @ Bitterfeld selected

* autumn '45: small calc. plant North works @ Bitterfeld into operation

* Apr. '46: specif's for calc. purity > Bitterfeld plant

=* copper-calcium process: to ~~obtain~~ raw metallic calcium — fused copper calc. alloy @ bottom of bath of molten chloride is enriched in calc. by electro-deposition - alloy then drawn off & excess calc. removed by distillation

Figure D.1004: Moe Berg's 1952 notes reveal how extensively the postwar Soviet nuclear weapons program depended on scientists, companies, and resources from the wartime German nuclear weapons program [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].



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in research on barrier material justified
this development. The U.S. tried out three
methods for sep. of the fissionable isotope
of U, namely: thermal diffusion
electromagnetic separation
gaseous diffusion

* thermal diffusion method: produced some
enriched feed material for the electromagnetic
separation plant * discontinued & its
plant dismantled.

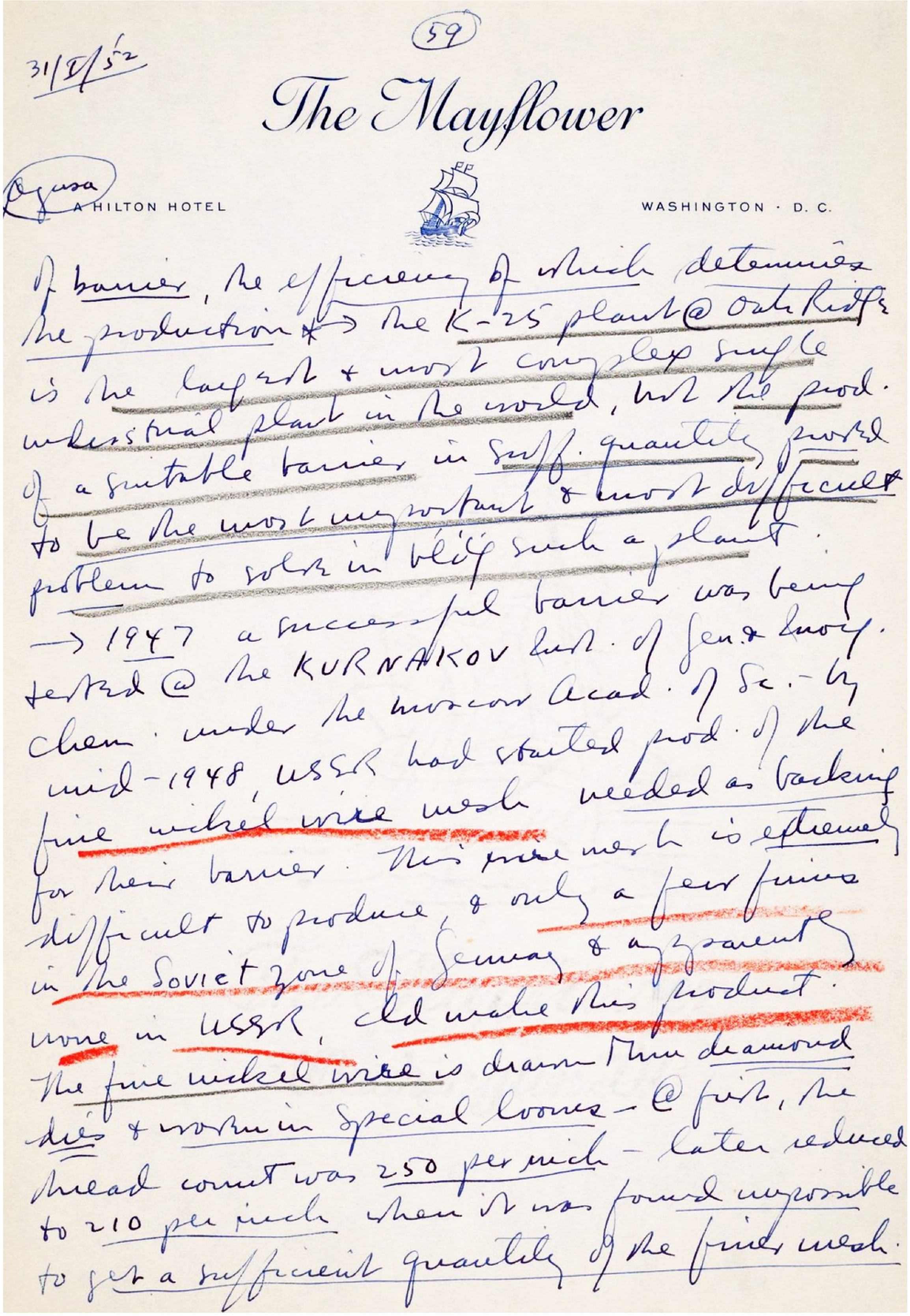
* electromagnetic separation method: was
used to prepare the original weapon grade
U-235 → this plant since diverted to other uses

* at present: only the gaseous diffusion
method is used in the U.S. for the prod. of U-235

* in gaseous diffusion process, the gas =
uranium hexafluoride diffuses through a
porous barrier with an enrichment of the light
isotope on the low-pressure side. The enrichment
per stage is very slight, & approximately
4,000 stages are req'd to get U-235 of weapon
quality — requires many millions of sq. ft

Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3–Loose Notes: Central Intelligence Agency

Figure D.1005: Moe Berg's 1952 notes reveal how extensively the postwar Soviet nuclear weapons program depended on scientists, companies, and resources from the wartime German nuclear weapons program [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].



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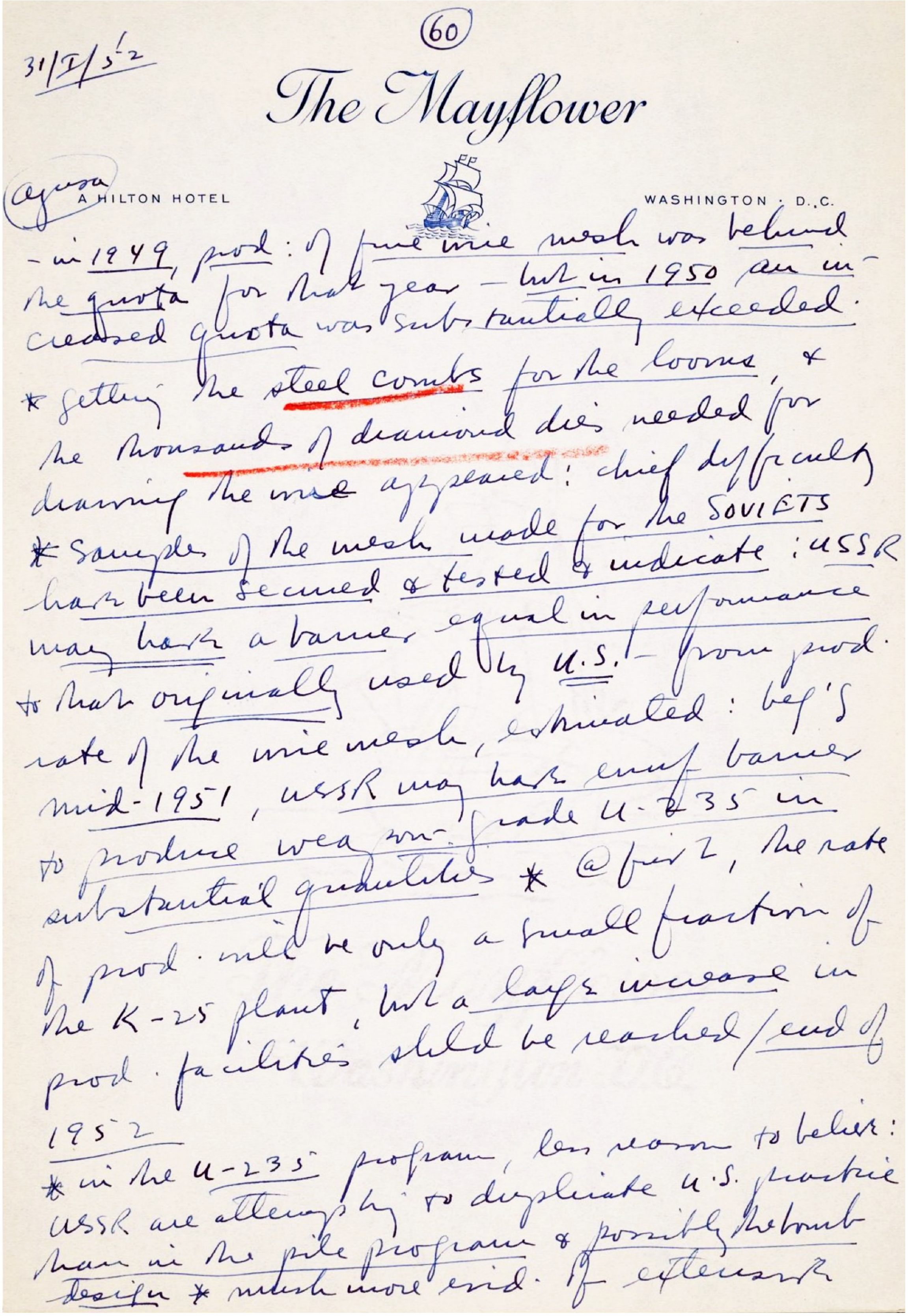
of barrier, the efficiency of which determines
the production* → the K-25 plant @ Oak Ridge
is the largest + most complex single
industrial plant in the world, but the prod.
of a suitable barrier in suff. quantity proved
to be the most important & most difficult*
problem to solve in bldg such a plant.
→ 1947 a successful barrier was being
tested @ the KURNAKOV Inst. of Gen. & Inorg.
Chem. under the Moscow Acad. of Sc. – by
mid-1948, USSR had started prod. of the
fine nickel wire mesh needed as backing
for their barrier. This wire mesh is extremely
difficult to produce, & only a few firms
in the Soviet zone of Germany & apparently
none in USSR, could make this product.
The fine nickel wire is drawn thru diamond
dies & woven in special looms – @ first, the
thread count was 250 per inch – later reduced
to 210 per inch when it was found impossible
to get a sufficient quantity of the fine mesh.

Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3–Loose Notes: Central Intelligence Agency

Figure D.1006: Moe Berg's 1952 notes reveal how extensively the postwar Soviet nuclear weapons program depended on scientists, companies, and resources from the wartime German nuclear weapons program [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].



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- in 1949, prod: of fine wire mesh was behind
the quota for that year — but in 1950 an in-
creased quota was substantially exceeded:
* getting the steel combs for the looms, &
the thousands of diamond dies needed for
drawing the wire appeared: chief difficulty
* Samples of the mesh made for the SOVIETS
have been secured & tested & indicate: USSR
may have a barrier equal in performance
to that originally used by U.S. — from prod.
rate of the wire mesh, estimated: beg's
mid-1951, USSR may have enuf barrier
to produce weapon-grade U-235 in
substantial quantities * @ first, the rate
of prod. will be only a small fraction of
the K-25 plant, but a large increase in
prod. facilities shld be reached / end of
1952
* in the U-235 program, less reason to believe:
USSR are attempting to duplicate U.S. practice
than in the pile program & possibly the bomb
design * much more evid. of extensive

Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3–Loose Notes: Central Intelligence Agency

Figure D.1007: Moe Berg's 1952 notes reveal how extensively the postwar Soviet nuclear weapons program depended on scientists, companies, and resources from the wartime German nuclear weapons program [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

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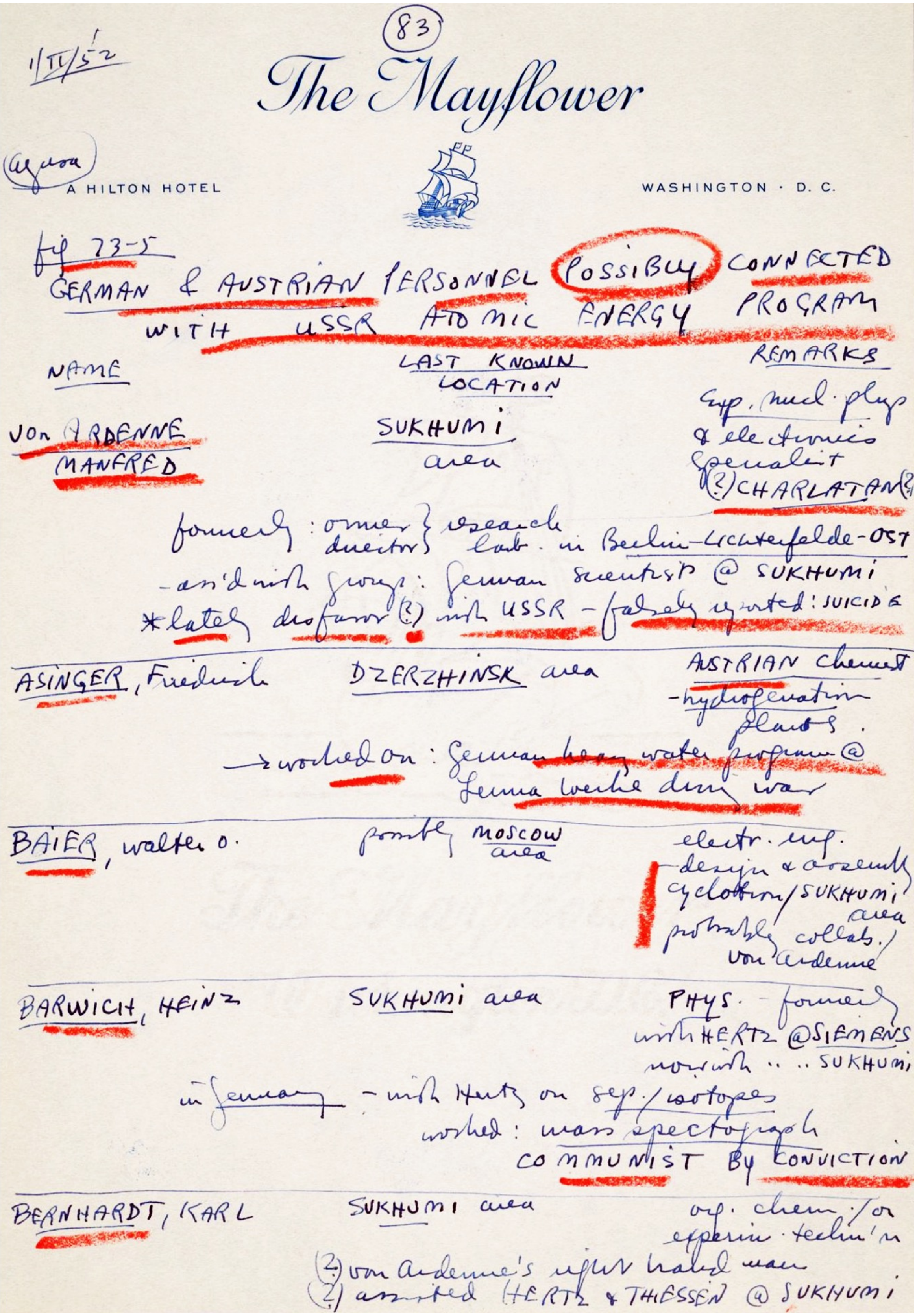

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(83)

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[illegible]

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fig 73-5

GERMAN & AUSTRIAN PERSONNEL POSSIBLY CONNECTED WITH USSR ATOMIC ENERGY PROGRAM

NAME	LAST KNOWN LOCATION	REMARKS
von ARDENNE MANFRED	SUKHUMI area	exp. nucl. phys & electronics specialist (?)CHARLATAN(?) formerly: owner } research lab. in Berlin-Lichterfelde-OST director } -ass'd with group: German scientists @ SUKHUMI *lately disfavor (?) with USSR – falsely reported: SUICIDE
ASINGER, Friedrich	DZERZHINSK area	AUSTRIAN chemist -hydrogenation plants. → worked on: German heavy water program @ Leuna Werke during war
BAIER, walter o.	possibly MOSCOW area	electr. eng. design & assembly cyclotron/SUKHUMI area probably collab./ von Ardenne
BARWICH, HEINZ	SUKHUMI area	PHYS. – formerly with HERTZ @SIEMENS now with .. .. SUKHUMI in Germany – with Hertz on sep./isotopes worked: mass spectograph COMMUNIST BY CONVICTION
BERNHARDT, KARL	SUKHUMI area	org. chem./or experim. techn'n (?) von Ardenne's right hand man (?) assisted HERTZ & THIESSEN @ SUKHUMI

Figure D.1008: Moe Berg's 1952 notes reveal how extensively the postwar Soviet nuclear weapons program depended on scientists, companies, and resources from the wartime German nuclear weapons program [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

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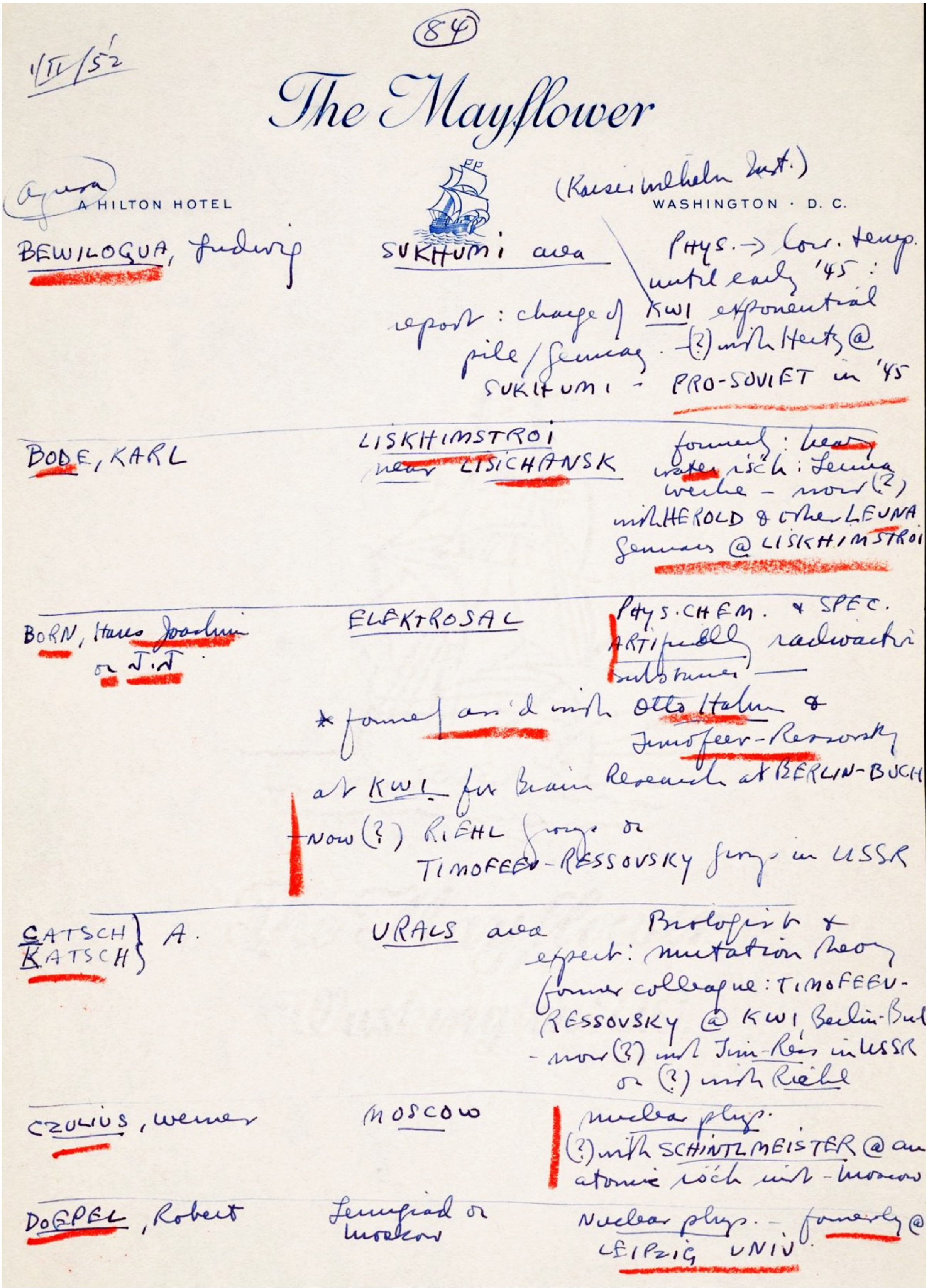

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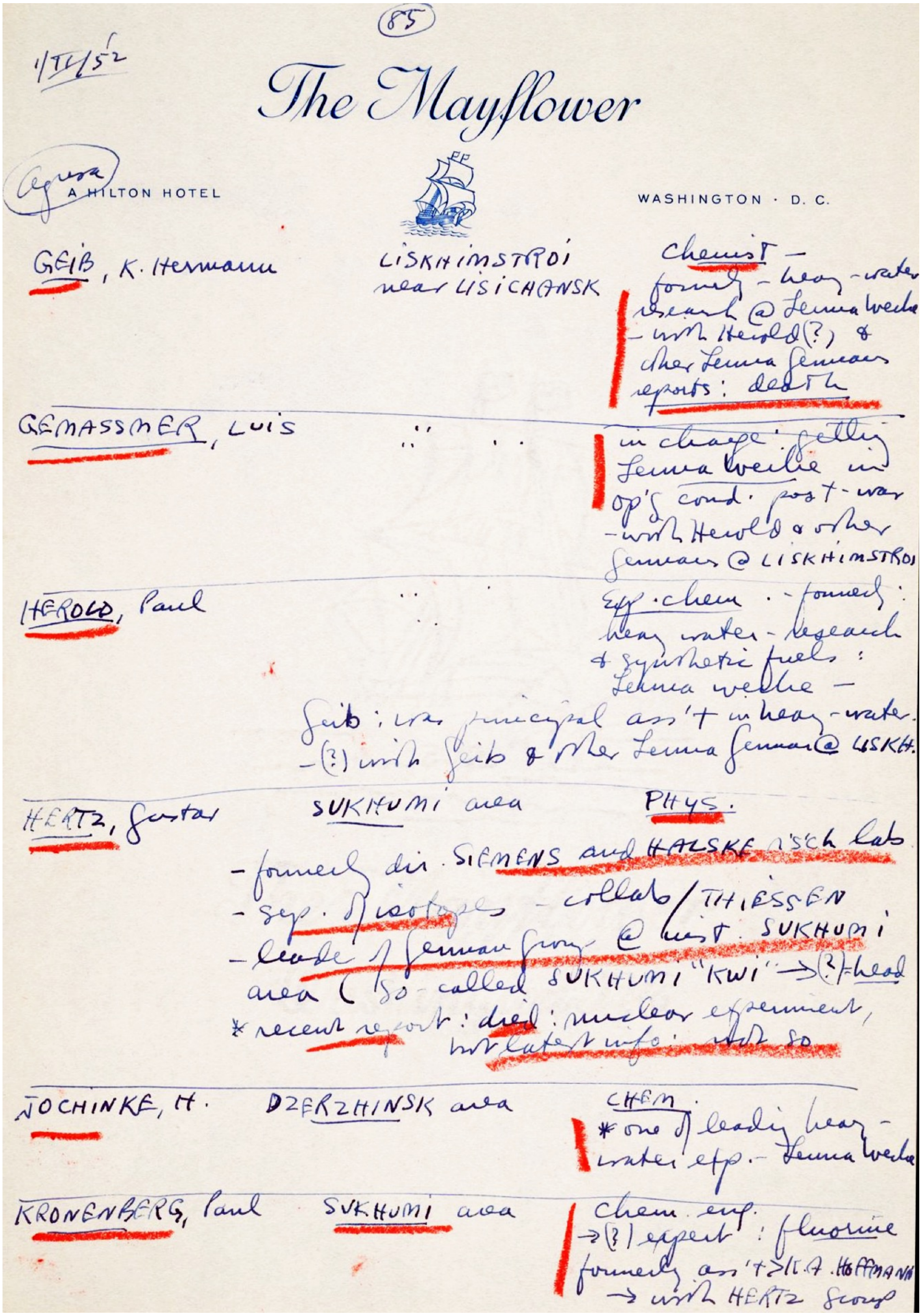
BEWILOGUA, Ludwig	SUKHUMI area	(Kaiser Wilhelm Inst.) PHYS. → low. temp. until early '45: report: charge of KWI exponential pile/Germany. (?) with Hertz @ SUKHUMI – PRO-SOVIET in '45
BODE, KARL	LISKHIMSTROI near LISICHANSK	formerly: heavy water rsch: Leuna werke – now (?) with HEROLD & other LEUNA Germans @ LISKHIMSTROI
BORN, Hans Joachim or J.J.	ELEKTROSAL	PHYS.CHEM. & SPEC. ARTIFICIALLY radioactive substances – * formerly ass'd with Otto Hahn & Timofeev-Ressovsky at KWI for Brain Research at BERLIN-BUCH now (?) RIEHL group or TIMOFEEV-RESSOVSKY group in USSR
CATSCH KATSCH } A.	URALS area	Biologist & expert: mutation theory former colleague: TIMOFEEV-RESSOVSKY @ KWI, Berlin-Buch – now (?) with Tim-Res in USSR or (?) with Riehl
CZULIUS, Werner	MOSCOW	nuclear phys. (?) with SCHINTLMEISTER @ an atomic rsch inst – Moscow
DOEPEL, Robert	Leningrad or Moscow	Nuclear phys. – formerly @ LEIPZIG UNIV.

Figure D.1009: Moe Berg's 1952 notes reveal how extensively the postwar Soviet nuclear weapons program depended on scientists, companies, and resources from the wartime German nuclear weapons program [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3–Loose Notes: Central Intelligence Agency



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GEIB, K. Hermann — LISKHIMSTROI near LISICHANSK — Chemist — formerly — heavy-water research @ Leuna Werke — with Herold(?) & other Leuna Germans reports: death

GEMASSMER, Luis — " " — in charge: getting Leuna Werke in op'g cond. post-war — with Herold & other Germans @ LISKHIMSTROI

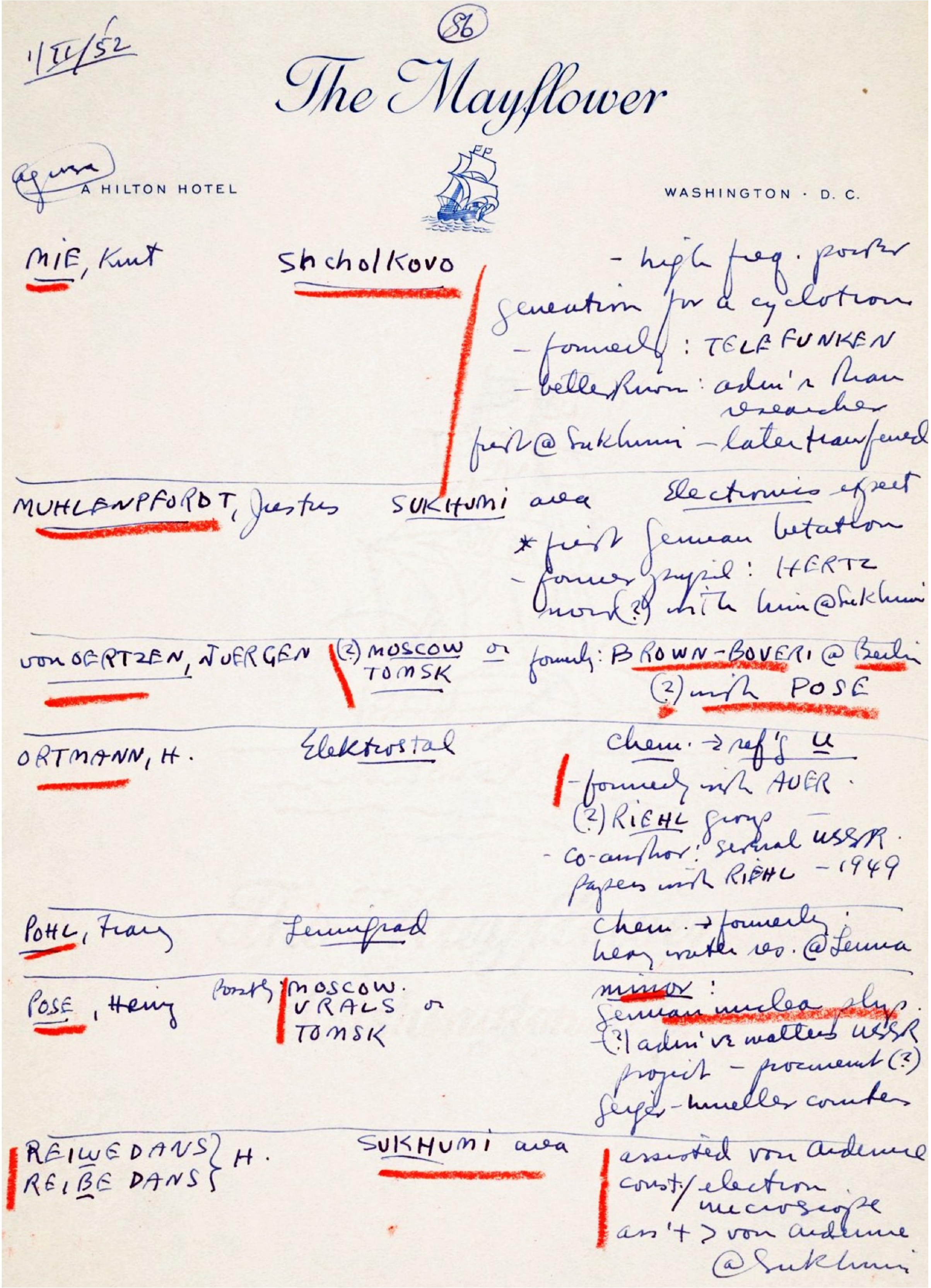
HEROLD, Paul — " " — Exp. chem. — formerly: heavy water-research & synthetic fuels: Leuna Werke —
Geib: was principal ass't in heavy-water.
— (?) with Geib & other Leuna Germans @ LISKH.

HERTZ, Gustav — SUKHUMI area — PHYS.
- formerly dir. SIEMENS and HALSKE Res'ch lab
- sep. of isotopes — collab/THIESSEN
- leader of German group @ Inst. SUKHUMI area (so-called SUKHUMI "KWI" → (?) head
* recent report: died: nuclear experiment, but latest info: not so

JOCHINKE, H. — DZERZHINSK area — CHEM. * one of leading heavy-water exp. — Leuna Werke

KRONENBERG, Paul — SUKHUMI area — Chem. eng. →(?) expert: fluorine formerly ass't to K.A. HOFFMANN → with HERTZ group

Figure D.1010: Moe Berg's 1952 notes reveal how extensively the postwar Soviet nuclear weapons program depended on scientists, companies, and resources from the wartime German nuclear weapons program [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].



1/II/52

(86)

The Mayflower

agenda

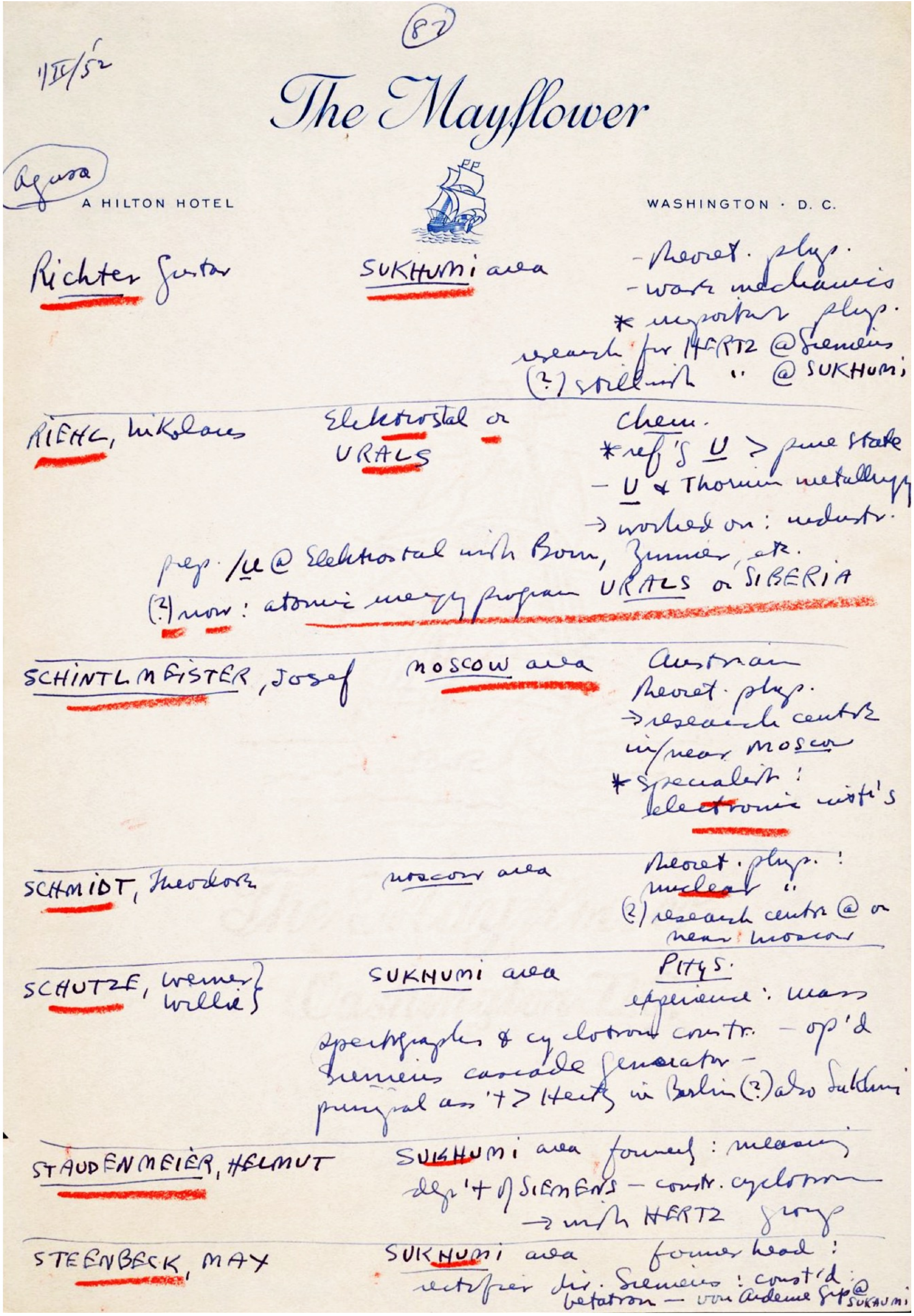
A HILTON HOTEL

WASHINGTON · D. C.

MIE, Kurt	Shcholkovo	- high freq. power generation for a cyclotron - formerly: TELEFUNKEN - better known: admin'r than researcher first @ Sukhumi - later transferred
MUHLENPFORDT, Justus	SUKHUMI area	Electronics expert * first German betatron - former pupil: HERTZ work(?) with him @Sukhumi
von OERTZEN, JUERGEN	(?) MOSCOW or TOMSK	formerly: BROWN-BOVERI @ Berlin (?) with POSE
ORTMANN, H.	Elektrostal	chem. → ref'g U - formerly with AUER. (?) RIEHL group - co-author: several USSR papers with RIEHL - 1949
POHL, Franz	Leningrad	chem. → formerly: heavy water res. @ Leuna
POSE, Heinz	Possibly MOSCOW. URALS or TOMSK	minor: German nuclear phys. (?) admin'r matters USSR project - procurement (?) geiger-mueller counters
REIWEDANS REIBEDANS } H.	SUKHUMI area	assisted von Ardenne const./electron microscope ass't → von Ardenne @Sukhumi

Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3–Loose Notes: Central Intelligence Agency

Figure D.1011: Moe Berg's 1952 notes reveal how extensively the postwar Soviet nuclear weapons program depended on scientists, companies, and resources from the wartime German nuclear weapons program [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].



(87)

1/II/52

The Mayflower

Agusa

A HILTON HOTEL

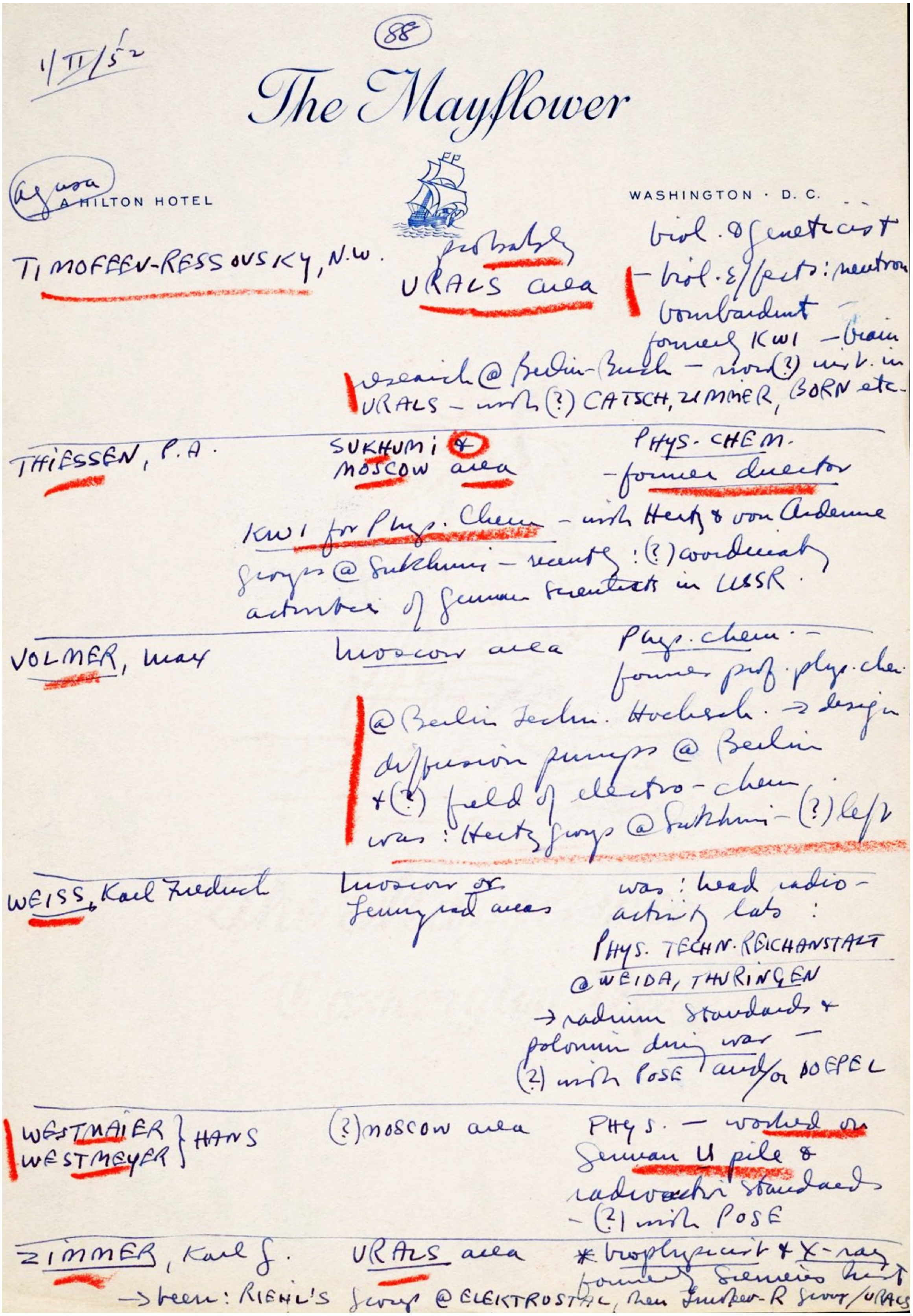
WASHINGTON · D. C.

Richter Gustav	SUKHUMI area	- theoret. phys. - wave mechanics * important phys. research for HERTZ @ Siemens (?) still with " @ SUKHUMI
RIEHL, Nikolaus	Elektrostal or URALS	chem. * ref's U > pure state - U & Thorium metallurgy → worked on: industr. prep. of U @ Elektrostal with Born, Zimmer, etc. (?) now: atomic energy program URALS or SIBERIA
SCHINTLMEISTER, Josef	MOSCOW area	Austrian theoret. phys. → research centre in/near MOSCOW * specialist: electronic instr's
SCHMIDT, Theodor	moscow area	theoret. phys.: nuclear " (?) research centre @ or near moscow
SCHUTZE, Werner } Willie }	SUKHUMI area	PHYS. experience: mass spectrographs & cyclotron constr. — op'd Siemens cascade generator — principal ass't > Hertz in Berlin (?) also Sukhumi
STAUDENMEIER, HELMUT	SUKHUMI area	formerly: measuring dep't of SIEMENS — constr. cyclotron → with HERTZ group
STEENBECK, MAX	SUKHUMI area	former head: rectifier div. Siemens: const'd betatron — von Ardenne grp @ SUKHUMI

Figure D.1012: Moe Berg's 1952 notes reveal how extensively the postwar Soviet nuclear weapons program depended on scientists, companies, and resources from the wartime German nuclear weapons program [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3–Loose Notes: Central Intelligence Agency

Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3–Loose Notes: Central Intelligence Agency



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1/II/52

The Mayflower

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A HILTON HOTEL

WASHINGTON · D. C.

TIMOFFEEV-RESSOVSKY, N.W. — probably URALS area — biol. & geneticist — biol. effects: neutron bombardment — formerly KWI — brain research @ Berlin-Buch — moved (?) unit in URALS — with (?) CATSCH, ZIMMER, BORN etc.

THIESSEN, P.A. — SUKHUMI & MOSCOW area — PHYS. CHEM. — former director KWI for Phys. Chem — with Hertz & von Ardenne groups @ Sukhumi — recently: (?) coordinating activities of German scientists in USSR.

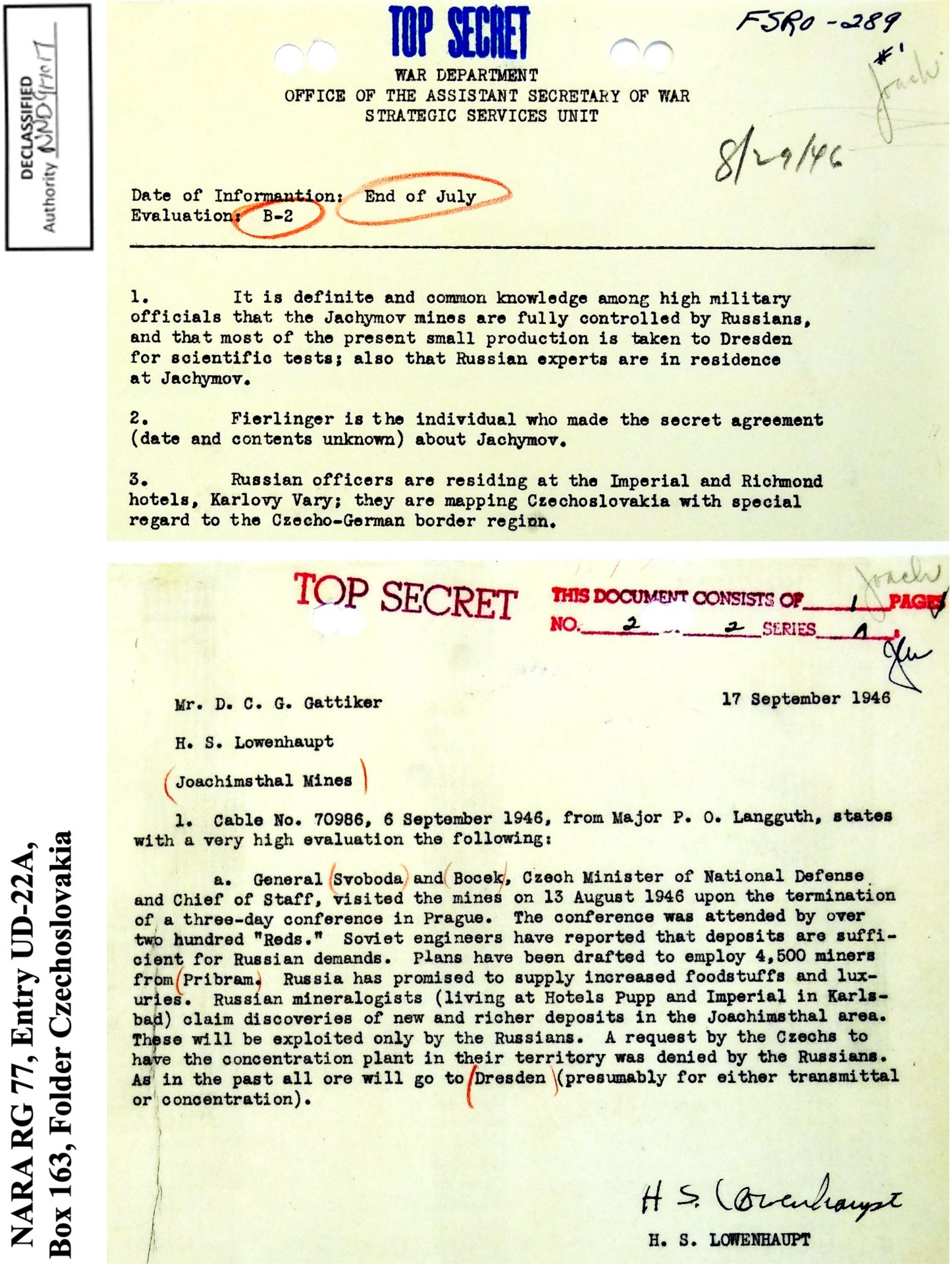
VOLMER, Max — Moscow area — Phys. chem. — former prof. phys. chem. @ Berlin Techn. Hochsch. → design diffusion pumps @ Berlin + (?) field of electro-chem. — was: Hertz group @ Sukhumi — (?) left

WEISS, Karl Friedrich — Moscow or Leningrad areas — was: head radio-activity lab: PHYS. TECHN. REICHANSTALT @ WEIDA, THURINGEN → radium standards & polonium during war — (?) with POSE and/or DOEPEL

WESTMAIER / WESTMEYER } HANS — (?) Moscow area — PHYS. — worked on German U pile & radioactive standards — (?) with POSE

ZIMMER, Karl G. — URALS area — * biophysicist & X-ray formerly Siemens firm → then: RIEHL'S group @ ELEKTROSTAHL, then Timofeev-R group/URALS

Figure D.1013: Moe Berg's 1952 notes reveal how extensively the postwar Soviet nuclear weapons program depended on scientists, companies, and resources from the wartime German nuclear weapons program [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].



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Authority NND 912017

TOP SECRET

FSRO -289

#1

Joach

WAR DEPARTMENT
OFFICE OF THE ASSISTANT SECRETARY OF WAR
STRATEGIC SERVICES UNIT

8/29/46

Date of Information: End of July
Evaluation: B-2

---

1. It is definite and common knowledge among high military officials that the Jachymov mines are fully controlled by Russians, and that most of the present small production is taken to Dresden for scientific tests; also that Russian experts are in residence at Jachymov.

2. Fierlinger is the individual who made the secret agreement (date and contents unknown) about Jachymov.

3. Russian officers are residing at the Imperial and Richmond hotels, Karlovy Vary; they are mapping Czechoslovakia with special regard to the Czecho-German border region.

TOP SECRET

THIS DOCUMENT CONSISTS OF 1 PAGES
NO. 2 . 2 SERIES A

Joach

Mr. D. C. G. Gattiker

17 September 1946

H. S. Lowenhaupt

(Joachimsthal Mines)

1. Cable No. 70986, 6 September 1946, from Major P. O. Langguth, states with a very high evaluation the following:

a. General Svoboda and Bocek, Czech Minister of National Defense and Chief of Staff, visited the mines on 13 August 1946 upon the termination of a three-day conference in Prague. The conference was attended by over two hundred "Reds." Soviet engineers have reported that deposits are sufficient for Russian demands. Plans have been drafted to employ 4,500 miners from Pribram. Russia has promised to supply increased foodstuffs and luxuries. Russian mineralogists (living at Hotels Pupp and Imperial in Karlsbad) claim discoveries of new and richer deposits in the Joachimsthal area. These will be exploited only by the Russians. A request by the Czechs to have the concentration plant in their territory was denied by the Russians. As in the past all ore will go to Dresden (presumably for either transmittal or concentration).

H S Lowenhaupt
H. S. LOWENHAUPT

NARA RG 77, Entry UD-22A,
Box 163, Folder Czechoslovakia

Figure D.1014: Some evidence of postwar Soviet use of wartime German nuclear facilities in and around Dresden [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

Outgoing cable WAR 92817. 27 June 1946. [NARA RG 77, Entry UD-22A, Box 160, Folder 205.4 CABLES OUTGOING, TOP SECRET]

TOPSEC to McNarney from the Joint Chiefs of Staff.

1. Except for most cogent reasons you will not permit representatives of nations other than British Commonwealth (excluding Eire) to have access in any U.S. zone of occupation under your jurisdiction to technical information on the following subjects or to related intelligence targets:

> applied nuclear physics;
>
> radar and Asdic [sonar] countermeasures;
>
> pressurized aerials for 3- and 10-cm GSR [radar] in U-Boats;
>
> control of guided missiles and homing devices;
>
> information concerning codes, cyphers, methods of communication, w/t deception or intelligence gained;
>
> Kurier Gerät;
>
> depth-keeping gear for submarines;
>
> very high voltage investigation;
>
> position-finding instruments (Prof. Pidery);
>
> method of causing temporary blindness by ultraviolet rays;
>
> biological warfare;
>
> infrared equipment;
>
> underwater propulsion employing hydrogen peroxide;
>
> URSEL (underwater rocket gun);
>
> LERCHE (wire-controlled homing torpedo);
>
> PASAN (acoustic pattern torpedo);
>
> NIBELUNG (Asdic device);
>
> manufacturing routine of new German war gas SARIN;
>
> results of trials with SARIN;
>
> German physiological trials with CW gases;
>
> laboratory developments in connection with SOMAN;
>
> supersonic aircraft, missiles, and engines.

[...]

Outgoing cable WAR 99857. 9 September 1946. [NARA RG 77, Entry UD-22A, Box 160, Folder 205.4 CABLES OUTGOING, TOP SECRET]

To McNarney from Joint Intelligence Committee

Under authority in WAR 92817 the Joint Intelligence Commitee hereby modifies list therein to include the following:

> Applied and theoretical nuclear physics, including design and operation of devices for producing highly energetic particles, and isotope separation.
>
> Control of guided missiles and homing devices (air and water).
>
> All asdic (sonar) devices.
>
> All proximity fuzes.
>
> Extremely potent chemicals producing physiological effects.
>
> Cold weather operations including guided missile launching.

[These lists come from people who would definitely have known what they were talking about. They were classified Top Secret and sent directly from the U.S. Joint Chiefs of Staff to General Joseph T. McNarney, who at the time was both the military governor of the U.S.-occupied zone of Germany and also the commander in chief of the U.S. Forces of Occupation in Europe. Others who received the lists (and probably helped to create them) included General Leslie Groves, who was still in charge of all U.S. nuclear work and intelligence on foreign nuclear work. These lists were written over a year after the end of the war in Europe, after the U.S. had had time to investigate wartime German R&D in detail. Coming from that authoritative position, these lists appear to show that:

- All of these German programs (including nuclear and biological warfare) actually existed; otherwise the Joint Chiefs would not have included them in such a carefully chosen high-priority list, putting them on the same level as well documented programs such as sarin and soman.
- German work in these areas was so advanced that the United States was determined both to obtain that German work for itself and also to try to prevent other countries (other than the United Kingdom) from obtaining it.

What was the “method of causing temporary blindness by ultraviolet rays”?]

U.S. Department of Commerce. The Chemical Problem in Germany. Undated press release, probably from 1946, p. 8 [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases]. [See document photos on p. 5067.]

Spectacular accomplishments in uranium, nitrogen, oxygen recovery, plastics, nuclear physics and many other fields, have been uncovered in the investigation of the chemicals field alone.

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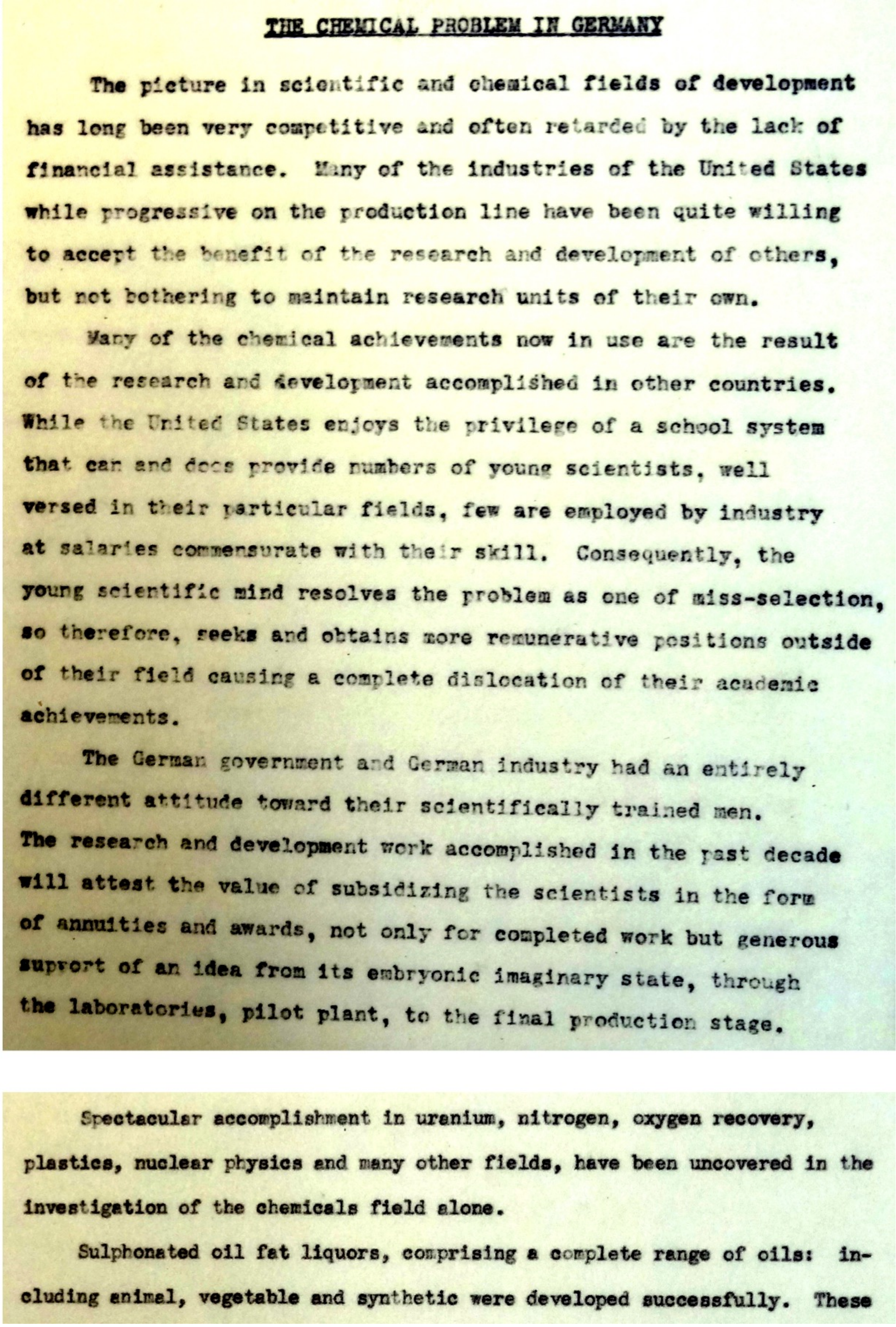
Authority NND 968018

NARA RG 40, Entry UD-75, Box 3, Folder
Press Releases, The Chemical Problem in Germany



THE CHEMICAL PROBLEM IN GERMANY

The picture in scientific and chemical fields of development has long been very competitive and often retarded by the lack of financial assistance. Many of the industries of the United States while progressive on the production line have been quite willing to accept the benefit of the research and development of others, but not bothering to maintain research units of their own.

Many of the chemical achievements now in use are the result of the research and development accomplished in other countries. While the United States enjoys the privilege of a school system that can and does provide numbers of young scientists, well versed in their particular fields, few are employed by industry at salaries commensurate with their skill. Consequently, the young scientific mind resolves the problem as one of miss-selection, so therefore, seeks and obtains more remunerative positions outside of their field causing a complete dislocation of their academic achievements.

The German government and German industry had an entirely different attitude toward their scientifically trained men. The research and development work accomplished in the past decade will attest the value of subsidizing the scientists in the form of annuities and awards, not only for completed work but generous support of an idea from its embryonic imaginary state, through the laboratories, pilot plant, to the final production stage.

Spectacular accomplishment in uranium, nitrogen, oxygen recovery, plastics, nuclear physics and many other fields, have been uncovered in the investigation of the chemicals field alone.

Sulphonated oil fat liquors, comprising a complete range of oils: including animal, vegetable and synthetic were developed successfully. These

Figure D.1015: U.S. Department of Commerce. The Chemical Problem in Germany. Undated press release, probably from 1946, excerpts [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases].

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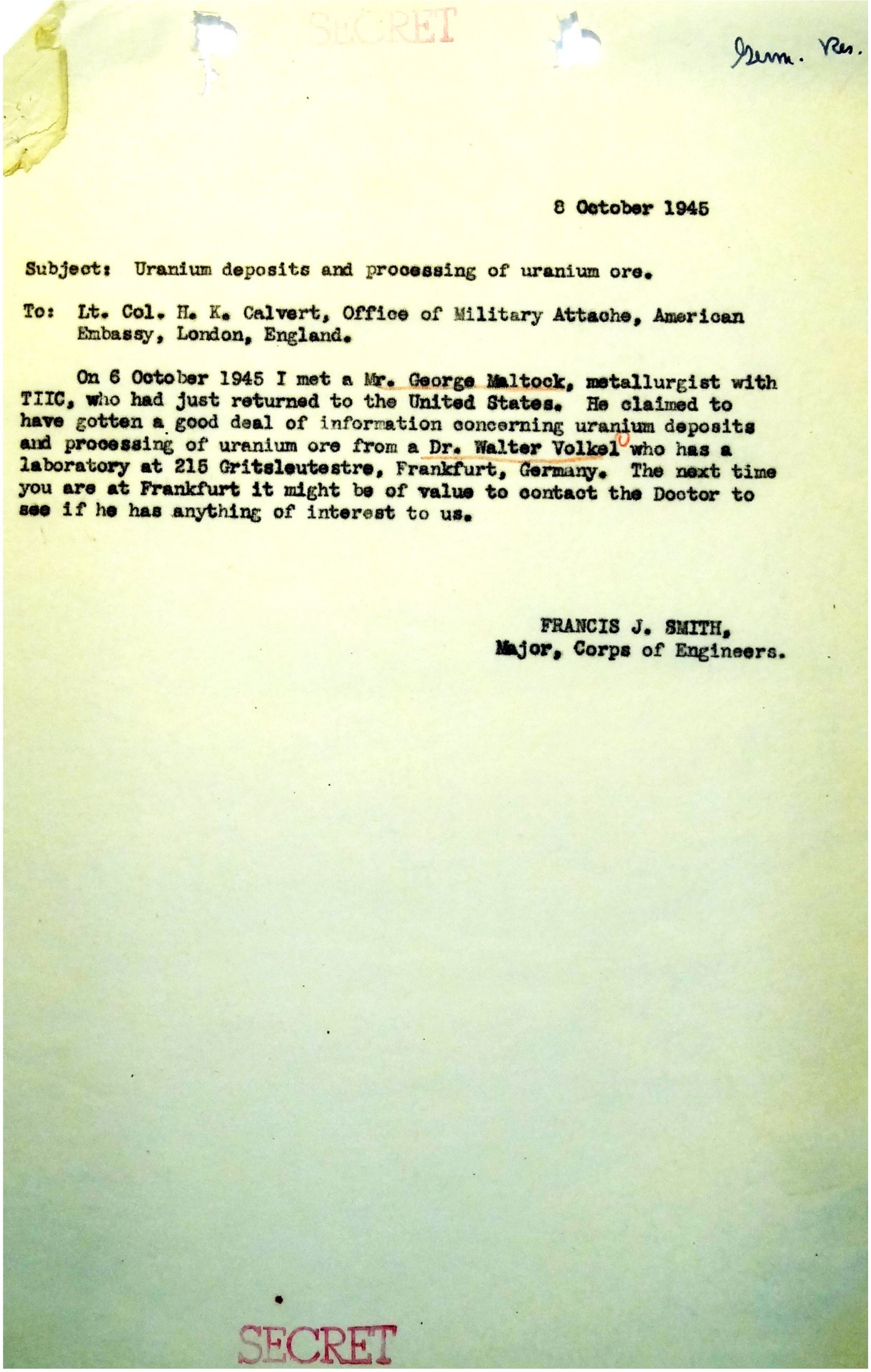
NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45-Dec 45)



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Germ. Res.

8 October 1945

Subject: Uranium deposits and processing of uranium ore.

To: Lt. Col. H. K. Calvert, Office of Military Attache, American Embassy, London, England.

On 6 October 1945 I met a Mr. George Maltock, metallurgist with TIIC, who had just returned to the United States. He claimed to have gotten a good deal of information concerning uranium deposits and processing of uranium ore from a Dr. Walter Volkel who has a laboratory at 215 Gritsleutestre, Frankfurt, Germany. The next time you are at Frankfurt it might be of value to contact the Doctor to see if he has anything of interest to us.

FRANCIS J. SMITH,
Major, Corps of Engineers.

SECRET

Figure D.1016: Francis J. Smith to Horace K. Calvert. 8 October 1945. Subject: Uranium deposits and processing of uranium ore [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

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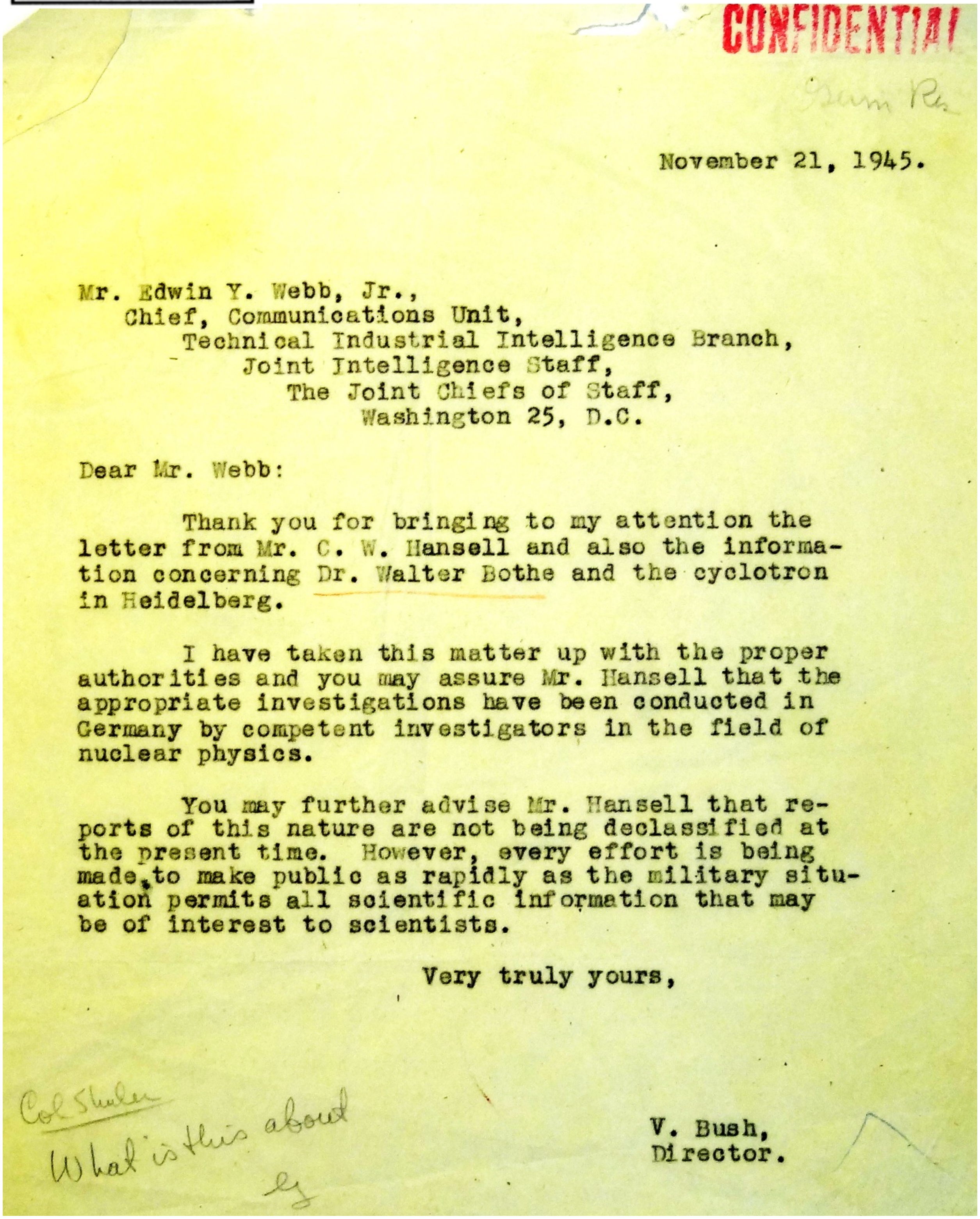
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45-Dec 45)



CONFIDENTIAL

Germ Res

November 21, 1945.

Mr. Edwin Y. Webb, Jr.,
Chief, Communications Unit,
Technical Industrial Intelligence Branch,
Joint Intelligence Staff,
The Joint Chiefs of Staff,
Washington 25, D.C.

Dear Mr. Webb:

Thank you for bringing to my attention the letter from Mr. C. W. Hansell and also the information concerning Dr. Walter Bothe and the cyclotron in Heidelberg.

I have taken this matter up with the proper authorities and you may assure Mr. Hansell that the appropriate investigations have been conducted in Germany by competent investigators in the field of nuclear physics.

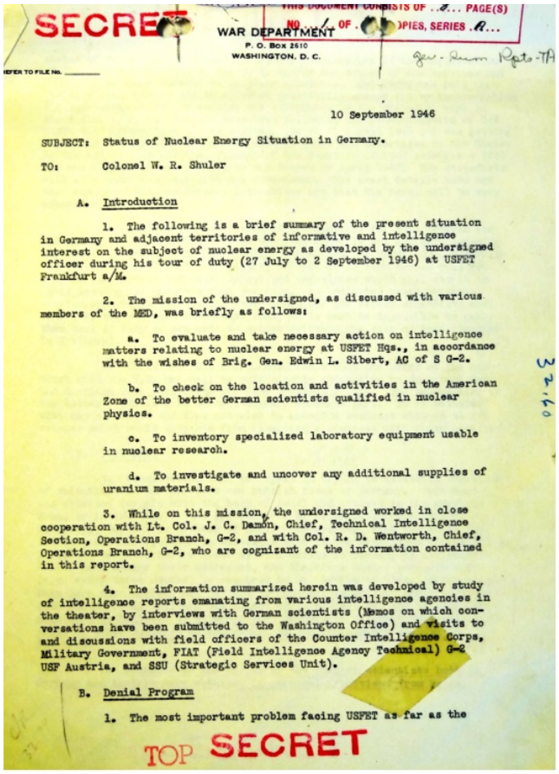
You may further advise Mr. Hansell that reports of this nature are not being declassified at the present time. However, every effort is being made to make public as rapidly as the military situation permits all scientific information that may be of interest to scientists.

Very truly yours,

V. Bush,
Director.

Col Shuler
What is this about
G

Figure D.1017: Vannevar Bush to Edwin Y. Webb Jr. 21 November 1945. [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)]



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NO. ..1.. OF . COPIES, SERIES .A...

WAR DEPARTMENT
P. O. Box 2610
WASHINGTON, D. C.

REFER TO FILE No. ______

Gen.-Sum Rpts-TA

10 September 1946

SUBJECT: Status of Nuclear Energy Situation in Germany.

TO: Colonel W. R. Shuler

A. Introduction

1. The following is a brief summary of the present situation in Germany and adjacent territories of informative and intelligence interest on the subject of nuclear energy as developed by the undersigned officer during his tour of duty (27 July to 2 September 1946) at USFET Frankfurt a/M.

2. The mission of the undersigned, as discussed with various members of the MED, was briefly as follows:

a. To evaluate and take necessary action on intelligence matters relating to nuclear energy at USFET Hqs., in accordance with the wishes of Brig. Gen. Edwin L. Sibert, AC of S G-2.

b. To check on the location and activities in the American Zone of the better German scientists qualified in nuclear physics.

c. To inventory specialized laboratory equipment usable in nuclear research.

d. To investigate and uncover any additional supplies of uranium materials.

32.60

3. While on this mission, the undersigned worked in close cooperation with Lt. Col. J. C. Damon, Chief, Technical Intelligence Section, Operations Branch, G-2, and with Col. R. D. Wentworth, Chief, Operations Branch, G-2, who are cognizant of the information contained in this report.

4. The information summarized herein was developed by study of intelligence reports emanating from various intelligence agencies in the theater, by interviews with German scientists (Memos on which conversations have been submitted to the Washington Office) and visits to and discussions with field officers of the Counter Intelligence Corps, Military Government, FIAT (Field Intelligence Agency Technical) G-2 USF Austria, and SSU (Strategic Services Unit).

B. Denial Program

1. The most important problem facing USFET as far as the

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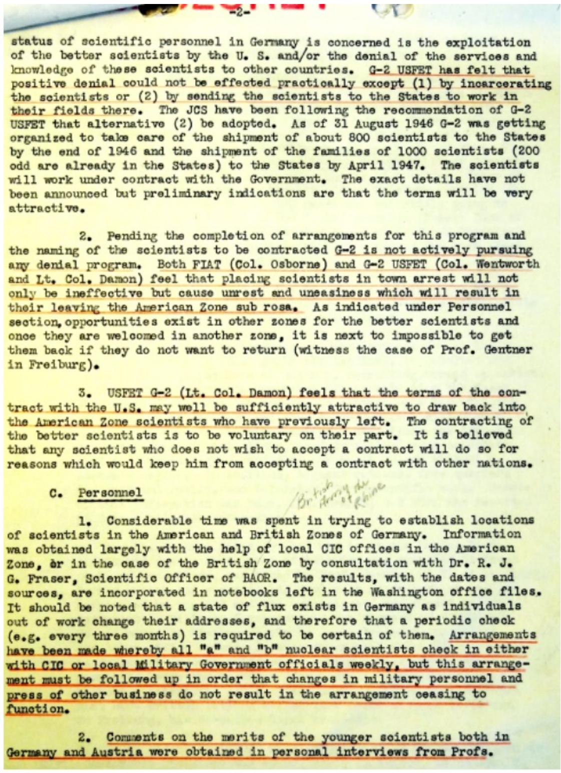

-2-

status of scientific personnel in Germany is concerned is the exploitation of the better scientists by the U. S. and/or the denial of the services and knowledge of these scientists to other countries. G-2 USFET has felt that positive denial could not be effected practically except (1) by incarcerating the scientists or (2) by sending the scientists to the States to work in their fields there. The JCS have been following the recommendation of G-2 USFET that alternative (2) be adopted. As of 31 August 1946 G-2 was getting organized to take care of the shipment of about 800 scientists to the States by the end of 1946 and the shipment of the families of 1000 scientists (200 odd are already in the States) to the States by April 1947. The scientists will work under contract with the Government. The exact details have not been announced but preliminary indications are that the terms will be very attractive.

2. Pending the completion of arrangements for this program and the naming of the scientists to be contracted G-2 is not actively pursuing any denial program. Both FIAT (Col. Osborne) and G-2 USFET (Col. Wentworth and Lt. Col. Damon) feel that placing scientists in town arrest will not only be ineffective but cause unrest and uneasiness which will result in their leaving the American Zone sub rosa. As indicated under Personnel section, opportunities exist in other zones for the better scientists and once they are welcomed in another zone, it is next to impossible to get them back if they do not want to return (witness the case of Prof. Gentner in Freiburg).

3. USFET G-2 (Lt. Col. Damon) feels that the terms of the contract with the U.S. may well be sufficiently attractive to draw back into the American Zone scientists who have previously left. The contracting of the better scientists is to be voluntary on their part. It is believed that any scientist who does not wish to accept a contract will do so for reasons which would keep him from accepting a contract with other nations.

C. Personnel

British Army of the Rhine

1. Considerable time was spent in trying to establish locations of scientists in the American and British Zones of Germany. Information was obtained largely with the help of local CIC offices in the American Zone, or in the case of the British Zone by consultation with Dr. R. J. G. Fraser, Scientific Officer of BAOR. The results, with the dates and sources, are incorporated in notebooks left in the Washington office files. It should be noted that a state of flux exists in Germany as individuals out of work change their addresses, and therefore that a periodic check (e.g. every three months) is required to be certain of them. Arrangements have been made whereby all "a" and "b" nuclear scientists check in either with CIC or local Military Government officials weekly, but this arrangement must be followed up in order that changes in military personnel and press of other business do not result in the arrangement ceasing to function.

2. Comments on the merits of the younger scientists both in Germany and Austria were obtained in personal interviews from Profs.

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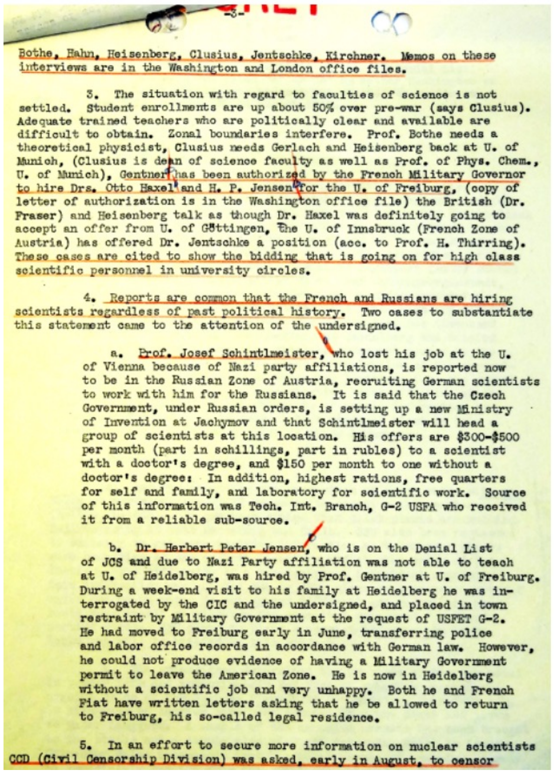
NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)



-3-

Bothe, Hahn, Heisenberg, Clusius, Jentschke, Kirchner. Memos on these interviews are in the Washington and London office files.

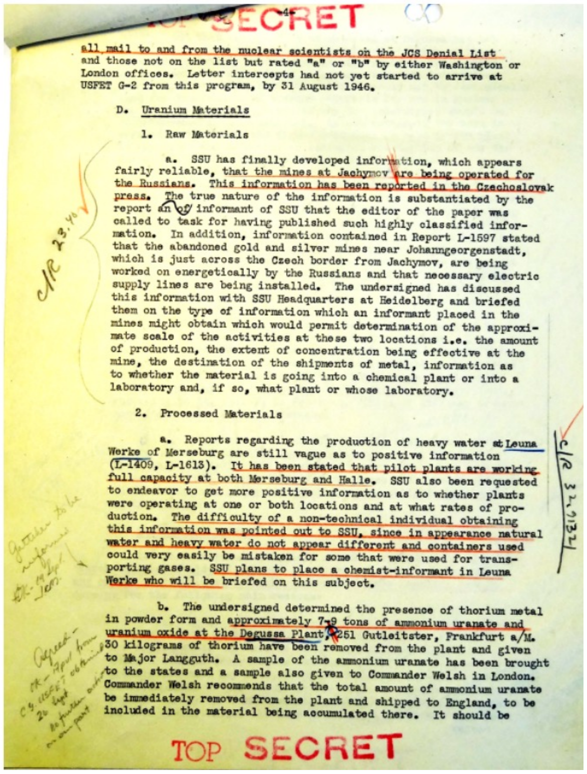
3. The situation with regard to faculties of science is not settled. Student enrollments are up about 50% over pre-war (says Clusius). Adequate trained teachers who are politically clear and available are difficult to obtain. Zonal boundaries interfere. Prof. Bothe needs a theoretical physicist, Clusius needs Gerlach and Heisenberg back at U. of Munich, (Clusius is dean of science faculty as well as Prof. of Phys. Chem., U. of Munich), Gentner has been authorized by the French Military Governor to hire Drs. Otto Haxel and H. P. Jensen for the U. of Freiburg, (copy of letter of authorization is in the Washington office file) the British (Dr. Fraser) and Heisenberg talk as though Dr. Haxel was definitely going to accept an offer from U. of Göttingen, the U. of Innsbruck (French Zone of Austria) has offered Dr. Jentschke a position (acc. to Prof. H. Thirring). These cases are cited to show the bidding that is going on for high class scientific personnel in university circles.

4. Reports are common that the French and Russians are hiring scientists regardless of past political history. Two cases to substantiate this statement came to the attention of the undersigned.

a. Prof. Josef Schintlmeister, who lost his job at the U. of Vienna because of Nazi party affiliations, is reported now to be in the Russian Zone of Austria, recruiting German scientists to work with him for the Russians. It is said that the Czech Government, under Russian orders, is setting up a new Ministry of Invention at Jachymov and that Schintlmeister will head a group of scientists at this location. His offers are \$300-\$500 per month (part in schillings, part in rubles) to a scientist with a doctor's degree, and \$150 per month to one without a doctor's degree: In addition, highest rations, free quarters for self and family, and laboratory for scientific work. Source of this information was Tech. Int. Branch, G-2 USFA who received it from a reliable sub-source.

b. Dr. Herbert Peter Jensen, who is on the Denial List of JCS and due to Nazi Party affiliation was not able to teach at U. of Heidelberg, was hired by Prof. Gentner at U. of Freiburg. During a week-end visit to his family at Heidelberg he was interrogated by the CIC and the undersigned, and placed in town restraint by Military Government at the request of USFET G-2. He had moved to Freiburg early in June, transferring police and labor office records in accordance with German law. However, he could not produce evidence of having a Military Government permit to leave the American Zone. He is now in Heidelberg without a scientific job and very unhappy. Both he and French Fiat have written letters asking that he be allowed to return to Freiburg, his so-called legal residence.

5. In an effort to secure more information on nuclear scientists CCD (Civil Censorship Division) was asked, early in August, to censor



-4-

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all mail to and from the nuclear scientists on the JCS Denial List and those not on the list but rated "a" or "b" by either Washington or London offices. Letter intercepts had not yet started to arrive at USFET G-2 from this program, by 31 August 1946.

D. Uranium Materials

1. Raw Materials

CIR 23.40

a. SSU has finally developed information, which appears fairly reliable, that the mines at Jachymov are being operated for the Russians. This information has been reported in the Czechoslovak press. The true nature of the information is substantiated by the report of an informant of SSU that the editor of the paper was called to task for having published such highly classified information. In addition, information contained in Report L-1597 stated that the abandoned gold and silver mines near Johanngeorgenstadt, which is just across the Czech border from Jachymov, are being worked on energetically by the Russians and that necessary electric supply lines are being installed. The undersigned has discussed this information with SSU Headquarters at Heidelberg and briefed them on the type of information which an informant placed in the mines might obtain which would permit determination of the approximate scale of the activities at these two locations i.e. the amount of production, the extent of concentration being effective at the mine, the destination of the shipments of metal, information as to whether the material is going into a chemical plant or into a laboratory and, if so, what plant or whose laboratory.

2. Processed Materials

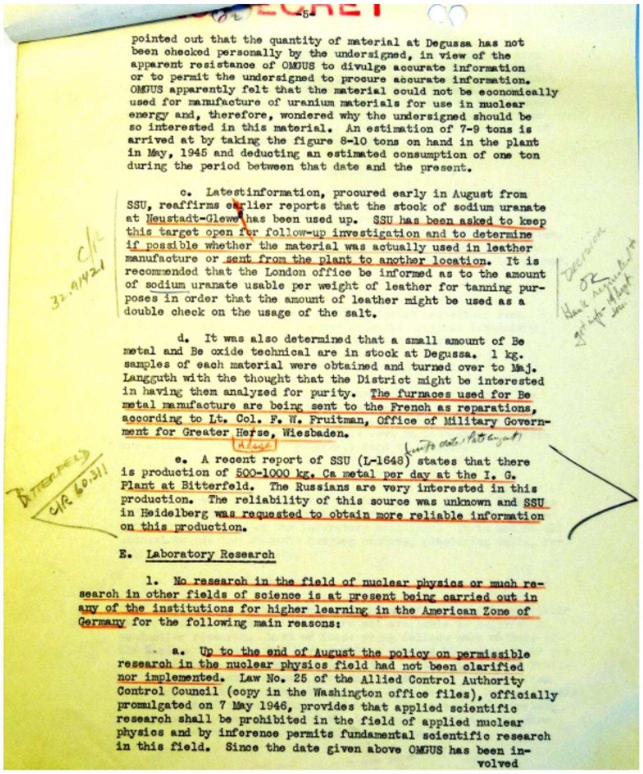
a. Reports regarding the production of heavy water at Leuna Werke of Merseburg are still vague as to positive information (L-1409, L-1613). It has been stated that pilot plants are working full capacity at both Merseburg and Halle. SSU also been requested to endeavor to get more positive information as to whether plants were operating at one or both locations and at what rates of production. The difficulty of a non-technical individual obtaining this information was pointed out to SSU, since in appearance natural water and heavy water do not appear different and containers used could very easily be mistaken for some that were used for transporting gases. SSU plans to place a chemist-informant in Leuna Werke who will be briefed on this subject.

C/R 32.9132

b. The undersigned determined the presence of thorium metal in powder form and approximately 7-9 tons of ammonium uranate and uranium oxide at the Degussa Plant, 251 Gutleitster, Frankfurt a/M. 30 kilograms of thorium have been removed from the plant and given to Major Langguth. A sample of the ammonium uranate has been brought to the states and a sample also given to Commander Welsh in London. Commander Welsh recommends that the total amount of ammonium uranate be immediately removed from the plant and shipped to England, to be included in the material being accumulated there. It should be

TOP SECRET

Figure D.1018: Canfield Hadlock to W. R. Shuler. 10 September 1946. Subject: Status of Nuclear Energy Situation in Germany [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].



-5-

pointed out that the quantity of material at Degussa has not been checked personally by the undersigned, in view of the apparent resistance of OMGUS to divulge accurate information or to permit the undersigned to procure accurate information. OMGUS apparently felt that the material could not be economically used for manufacture of uranium materials for use in nuclear energy and, therefore, wondered why the undersigned should be so interested in this material. An estimation of 7-9 tons is arrived at by taking the figure 8-10 tons on hand in the plant in May, 1945 and deducting an estimated consumption of one ton during the period between that date and the present.

c. Latestinformation, procured early in August from SSU, reaffirms earlier reports that the stock of sodium uranate at Neustadt-Glewe has been used up. SSU has been asked to keep this target open for follow-up investigation and to determine if possible whether the material was actually used in leather manufacture or sent from the plant to another location. It is recommended that the London office be informed as to the amount of sodium uranate usable per weight of leather for tanning purposes in order that the amount of leather might be used as a double check on the usage of the salt.

C/R 32.91421

Decision OK Hank requested to get info – 14 Sept

d. It was also determined that a small amount of Be metal and Be oxide technical are in stock at Degussa. 1 kg. samples of each material were obtained and turned over to Maj. Langguth with the thought that the District might be interested in having them analyzed for purity. The furnaces used for Be metal manufacture are being sent to the French as reparations, according to Lt. Col. F. W. Fruitman, Office of Military Government for Greater Herse, Wiesbaden.

Hesse

Info to date / Part August

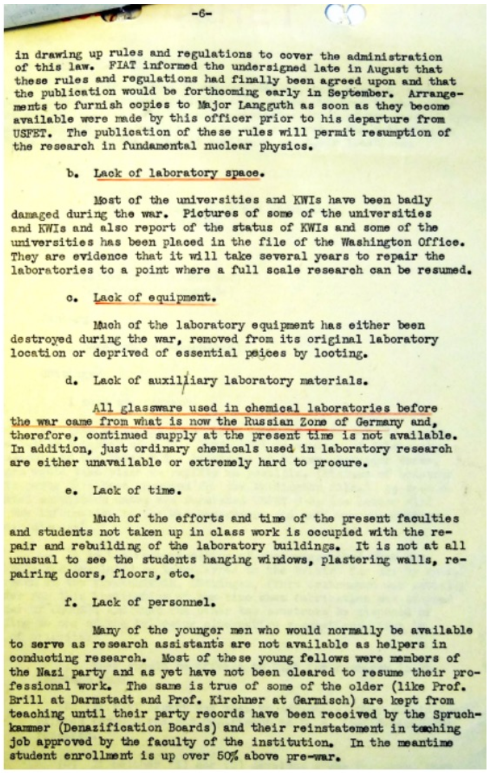
e. A recent report of SSU (L-1648) states that there is production of 500-1000 kg. Ca metal per day at the I. G. Plant at Bitterfeld. The Russians are very interested in this production. The reliability of this source was unknown and SSU in Heidelberg was requested to obtain more reliable information on this production.

Bitterfeld C/R 60.311

E. Laboratory Research

1. No research in the field of nuclear physics or much research in other fields of science is at present being carried out in any of the institutions for higher learning in the American Zone of Germany for the following main reasons:

a. Up to the end of August the policy on permissible research in the nuclear physics field had not been clarified nor implemented. Law No. 25 of the Allied Control Authority Control Council (copy in the Washington office files), officially promulgated on 7 May 1946, provides that applied scientific research shall be prohibited in the field of applied nuclear physics and by inference permits fundamental scientific research in this field. Since the date given above OMGUS has been involved



-6-

in drawing up rules and regulations to cover the administration of this law. FIAT informed the undersigned late in August that these rules and regulations had finally been agreed upon and that the publication would be forthcoming early in September. Arrangements to furnish copies to Major Langguth as soon as they become available were made by this officer prior to his departure from USFET. The publication of these rules will permit resumption of the research in fundamental nuclear physics.

b. Lack of laboratory space.

Most of the universities and KWIs have been badly damaged during the war. Pictures of some of the universities and KWIs and also report of the status of KWIs and some of the universities has been placed in the file of the Washington Office. They are evidence that it will take several years to repair the laboratories to a point where a full scale research can be resumed.

c. Lack of equipment.

Much of the laboratory equipment has either been destroyed during the war, removed from its original laboratory location or deprived of essential peices by looting.

d. Lack of auxilliary laboratory materials.

All glassware used in chemical laboratories before the war came from what is now the Russian Zone of Germany and, therefore, continued supply at the present time is not available. In addition, just ordinary chemicals used in laboratory research are either unavailable or extremely hard to procure.

e. Lack of time.

Much of the efforts and time of the present faculties and students not taken up in class work is occupied with the repair and rebuilding of the laboratory buildings. It is not at all unusual to see the students hanging windows, plastering walls, repairing doors, floors, etc.

f. Lack of personnel.

Many of the younger men who would normally be available to serve as research assistants are not available as helpers in conducting research. Most of these young fellows were members of the Nazi party and as yet have not been cleared to resume their professional work. The same is true of some of the older (like Prof. Brill at Darmstadt and Prof. Kirchner at Garmisch) are kept from teaching until their party records have been received by the Spruchkammer (Denazification Boards) and their reinstatement in teching job approved by the faculty of the institution. In the meantime student enrollment is up over 50% above pre-war.

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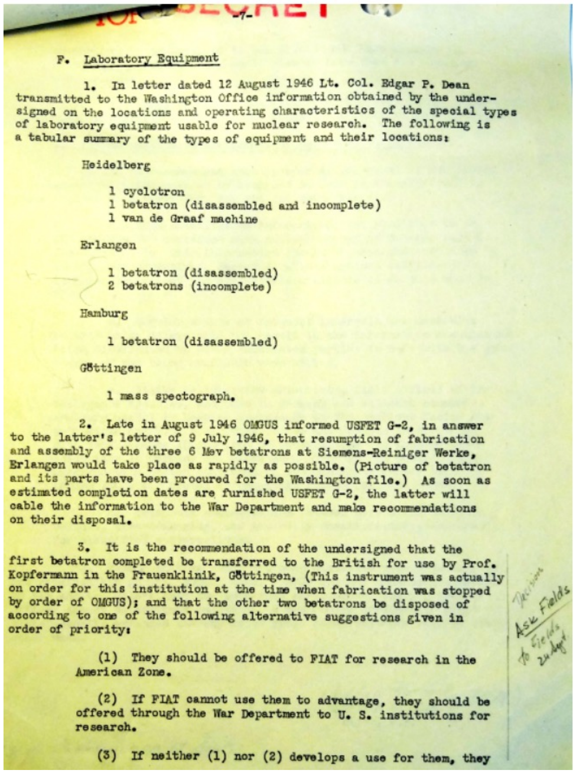
NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)



-7-

F. Laboratory Equipment

1. In letter dated 12 August 1946 Lt. Col. Edgar P. Dean transmitted to the Washington Office information obtained by the undersigned on the locations and operating characteristics of the special types of laboratory equipment usable for nuclear research. The following is a tabular summary of the types of equipment and their locations:

Heidelberg

- 1 cyclotron
- 1 betatron (disassembled and incomplete)
- 1 van de Graaf machine

Erlangen

- 1 betatron (disassembled)
- 2 betatrons (incomplete)

Hamburg

- 1 betatron (disassembled)

Göttingen

- 1 mass spectograph.

2. Late in August 1946 OMGUS informed USFET G-2, in answer to the latter's letter of 9 July 1946, that resumption of fabrication and assembly of the three 6 Mev betatrons at Siemens-Reiniger Werke, Erlangen would take place as rapidly as possible. (Picture of betatron and its parts have been procured for the Washington file.) As soon as estimated completion dates are furnished USFET G-2, the latter will cable the information to the War Department and make recommendations on their disposal.

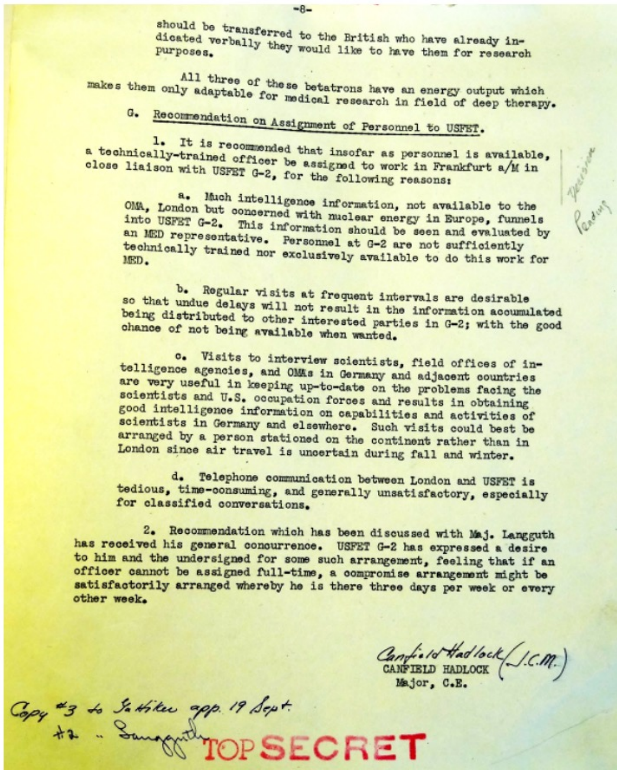
3. It is the recommendation of the undersigned that the first betatron completed be transferred to the British for use by Prof. Kopfermann in the Frauenklinik, Göttingen, (This instrument was actually on order for this institution at the time when fabrication was stopped by order of OMGUS); and that the other two betatrons be disposed of according to one of the following alternative suggestions given in order of priority:

(1) They should be offered to FIAT for research in the American Zone.

(2) If FIAT cannot use them to advantage, they should be offered through the War Department to U. S. institutions for research.

(3) If neither (1) nor (2) develops a use for them, they

Decision Ask Fields
to Fields 24 Aug



-8-

should be transferred to the British who have already indicated verbally they would like to have them for research purposes.

All three of these betatrons have an energy output which makes them only adaptable for medical research in field of deep therapy.

G. Recommendation on Assignment of Personnel to USFET.

1. It is recommended that insofar as personnel is available, a technically-trained officer be assigned to work in Frankfurt a/M in close liaison with USFET G-2, for the following reasons:

Decision Pending

a. Much intelligence information, not available to the OMA, London but concerned with nuclear energy in Europe, funnels into USFET G-2. This information should be seen and evaluated by an MED representative. Personnel at G-2 are not sufficiently technically trained nor exclusively available to do this work for MED.

b. Regular visits at frequent intervals are desirable so that undue delays will not result in the information accumulated being distributed to other interested parties in G-2; with the good chance of not being available when wanted.

c. Visits to interview scientists, field offices of intelligence agencies, and OMAs in Germany and adjacent countries are very useful in keeping up-to-date on the problems facing the scientists and U.S. occupation forces and results in obtaining good intelligence information on capabilities and activities of scientists in Germany and elsewhere. Such visits could best be arranged by a person stationed on the continent rather than in London since air travel is uncertain during fall and winter.

d. Telephone communication between London and USFET is tedious, time-consuming, and generally unsatisfactory, especially for classified conversations.

2. Recommendation which has been discussed with Maj. Langguth has received his general concurrence. USFET G-2 has expressed a desire to him and the undersigned for some such arrangement, feeling that if an officer cannot be assigned full-time, a compromise arrangement might be satisfactorily arranged whereby he is there three days per week or every other week.

Canfield Hadlock (J.C.M.)
CANFIELD HADLOCK
Major, C.E.

Copy #3 to Ga Hiker app. 19 Sept.
#2 " Langguth

TOP SECRET

Figure D.1019: Canfield Hadlock to W. R. Shuler. 10 September 1946. Subject: Status of Nuclear Energy Situation in Germany [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Colonel George Bryant Woods. 1946. *The Aircraft Manufacturing Industry: Present and Future Prospects.* New York: White, Weld & Co. Frontispiece and p. 32.

GERMAN SUPERSONIC SPEED ROCKET. This large anti-aircraft rocket called "Rheintochter" was under final development at the end of the war—a forerunner of future "push-button warfare." It was remotely controlled by radio and carried a 330-lb. explosive charge activated by a proximity fuse. [...]

Germany's Plans for the "A-9" with Atomic Bomb

The range of the V-2 was only something over 200 miles but this was sufficient to reach all intended targets at that time. The German scientists, however, had not stopped with the V-2. During 1945 they had already built at Peenemünde (in the hands of the Russians since that time) several "A-9's". This was a winged V-2, either manned or unmanned, and intended for a range of around 3,000 miles with the aid of a large auxiliary launching rocket. Together the launching rocket and the A-9 weighed 110 tons, as compared with 13½ tons for the V-2. After the auxiliary launching rocket had accomplished its purpose and dropped off, the A-9 was designed to continue under its own power wholly outside the earth's atmosphere at an altitude of approximately 150 miles, and at an estimated speed of 5,800 miles per hour. This obviously would mean an Atlantic crossing in well under an hour's time, and a launching ramp had already been constructed in Normandy prior to the Allied invasion.

In captured scientific German documents there are diagrams of the city of New York showing anticipated areas of destruction to be expected after perfection of such a weapon to carry an atomic war head, and it is well known that the Germans originally had hoped to have their atomic bomb developments completed by the end of 1944. The Germans had many other advanced developments in guided missiles, but the V-2 was an actual accomplishment and its further development for long range was just a matter of time. Meanwhile all the allied nations have recourse to the captured German documents describing their future plans for these weapons and many of the former German scientists responsible for these developments are known to be continuing their work in each of the allied countries. Adequate defense against such weapons as the V-2 and the A-9 will require highly ingenious and supersonic defensive weapons, and no country can afford to forego the necessary expense for basic and applied research to that end.

[See document photos on p. 5073. Woods was not merely speculating in the above text; he was writing from a position of very well-informed authority. He was a colonel in the Air Technical Services Command (ATSC)/Air Materiel Command (AMC), serving as an intelligence officer in Europe during World War II and helping to collect and analyze captured German research after the war (probably working for Donald Putt). After writing this book, he went on to become Assistant to the Undersecretary of the Air Force 1947–1950.

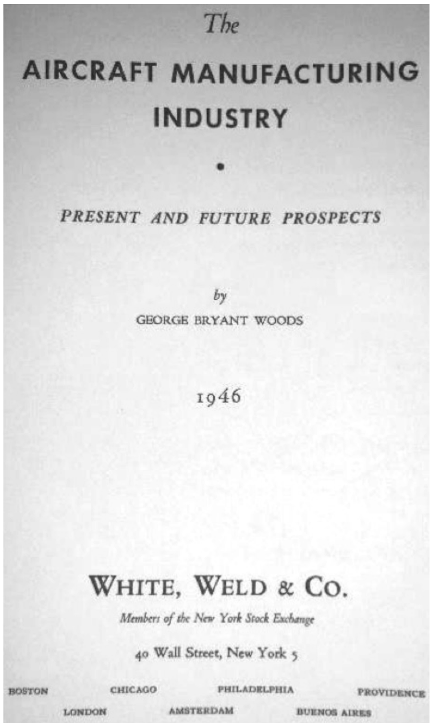
See for example: George B. Woods, Former Assistant to Air Undersecretary. *Evening Star* (Washington, D.C.), 5 March 1954, p. A-12. https://chroniclingamerica.loc.gov/lccn/sn83045462/1954-03-05/ed-1/seq-12/

For similar statements from other sources, see pp. 4411 (paragraph 15), 4638, 5022, 5031, 4832, and 5821.]

Colonel George Bryant Woods

Intelligence, Air Technical Services Command during WWII

Assistant to the Undersecretary of the Air Force 1947–1950

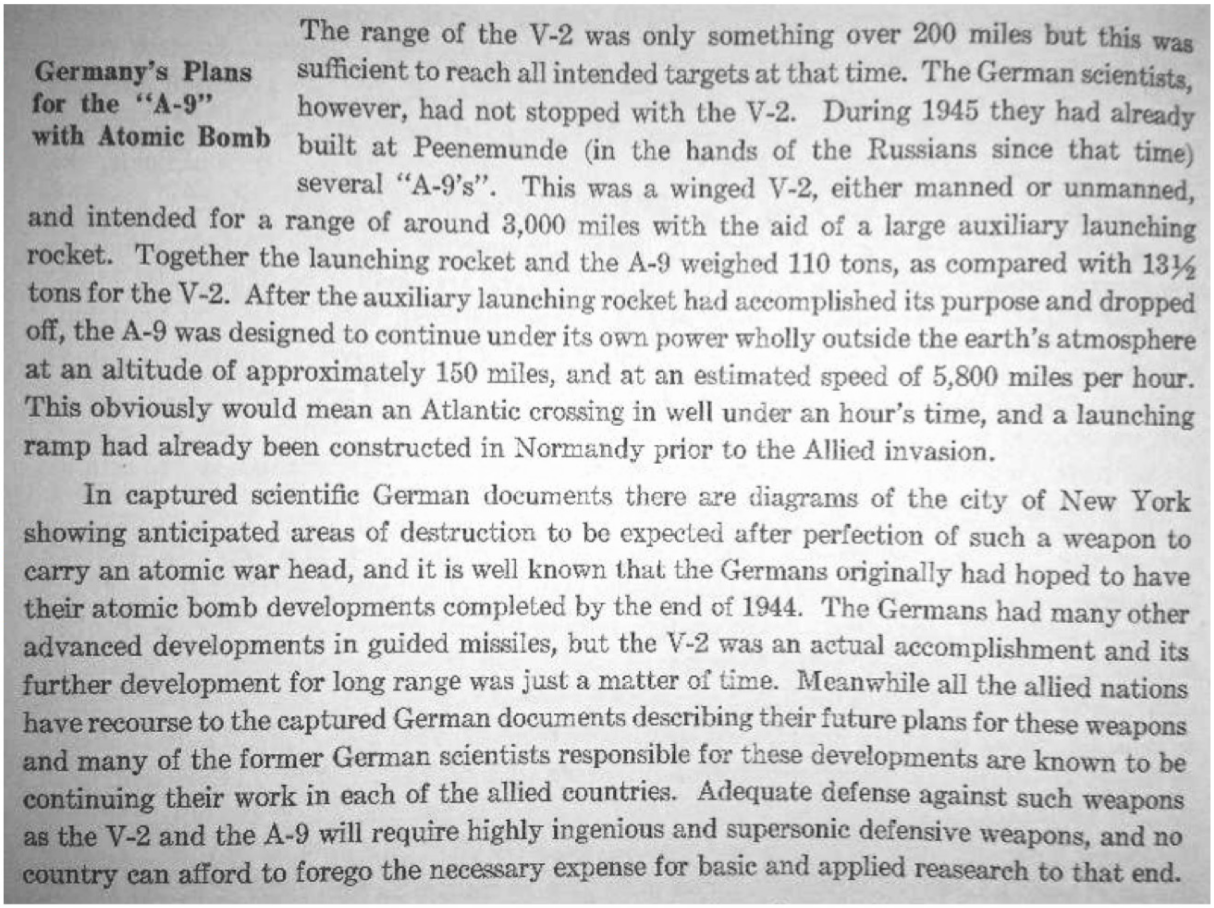


The
AIRCRAFT MANUFACTURING
INDUSTRY
•
PRESENT AND FUTURE PROSPECTS

by
GEORGE BRYANT WOODS

1946

WHITE, WELD & CO.
Members of the New York Stock Exchange
40 Wall Street, New York 5
BOSTON CHICAGO PHILADELPHIA PROVIDENCE
LONDON AMSTERDAM BUENOS AIRES



Germany's Plans for the "A-9" with Atomic Bomb

The range of the V-2 was only something over 200 miles but this was sufficient to reach all intended targets at that time. The German scientists, however, had not stopped with the V-2. During 1945 they had already built at Peenemunde (in the hands of the Russians since that time) several "A-9's". This was a winged V-2, either manned or unmanned, and intended for a range of around 3,000 miles with the aid of a large auxiliary launching rocket. Together the launching rocket and the A-9 weighed 110 tons, as compared with 13½ tons for the V-2. After the auxiliary launching rocket had accomplished its purpose and dropped off, the A-9 was designed to continue under its own power wholly outside the earth's atmosphere at an altitude of approximately 150 miles, and at an estimated speed of 5,800 miles per hour. This obviously would mean an Atlantic crossing in well under an hour's time, and a launching ramp had already been constructed in Normandy prior to the Allied invasion.

In captured scientific German documents there are diagrams of the city of New York showing anticipated areas of destruction to be expected after perfection of such a weapon to carry an atomic war head, and it is well known that the Germans originally had hoped to have their atomic bomb developments completed by the end of 1944. The Germans had many other advanced developments in guided missiles, but the V-2 was an actual accomplishment and its further development for long range was just a matter of time. Meanwhile all the allied nations have recourse to the captured German documents describing their future plans for these weapons and many of the former German scientists responsible for these developments are known to be continuing their work in each of the allied countries. Adequate defense against such weapons as the V-2 and the A-9 will require highly ingenious and supersonic defensive weapons, and no country can afford to forego the necessary expense for basic and applied reasearch to that end.

Figure D.1020: Colonel George Woods wrote of "Germany's Plans for the 'A-9' with Atomic Bomb": "it is well known that the Germans originally had hoped to have their atomic bomb developments completed by the end of 1944" [Woods 1946]. See also pp. 4411, 4638, 5022, 5031, 4832, and 5821.

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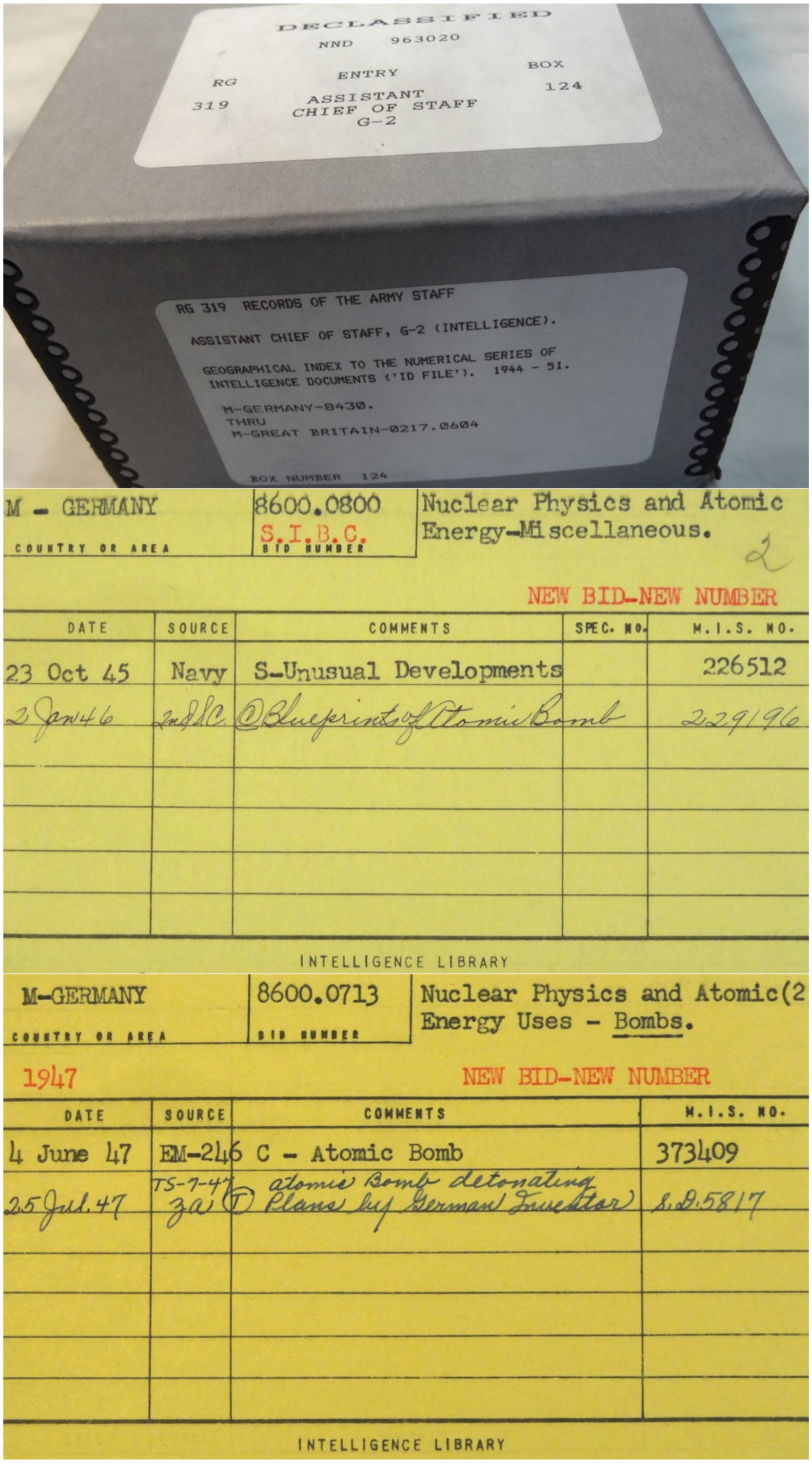

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NND 963020

RG	ENTRY	BOX
319	ASSISTANT CHIEF OF STAFF G-2	124

RG 319 RECORDS OF THE ARMY STAFF
ASSISTANT CHIEF OF STAFF, G-2 (INTELLIGENCE).
GEOGRAPHICAL INDEX TO THE NUMERICAL SERIES OF INTELLIGENCE DOCUMENTS ('ID FILE'). 1944 - 51.
M-GERMANY-8430.
THRU
M-GREAT BRITAIN-0217.0604
BOX NUMBER 124

COUNTRY OR AREA	BID NUMBER	
M - GERMANY	8600.0800 S.I.B.C.	Nuclear Physics and Atomic Energy-Miscellaneous. 2

NEW BID-NEW NUMBER

DATE	SOURCE	COMMENTS	SPEC. NO.	M.I.S. NO.
23 Oct 45	Navy	S-Unusual Developments		226512
2 Jan 46	2nd S.C.	Ⓒ Blueprints of Atomic Bomb		229196

INTELLIGENCE LIBRARY

COUNTRY OR AREA	BID NUMBER	
M-GERMANY	8600.0713	Nuclear Physics and Atomic(2 Energy Uses - Bombs.

1947

NEW BID-NEW NUMBER

DATE	SOURCE	COMMENTS	M.I.S. NO.
4 June 47	EM-246	C - Atomic Bomb	373409
25 Jul. 47	TS-7-47 3a	Ⓣ atomic Bomb detonating Plans by German Inventor	S.D.5817

INTELLIGENCE LIBRARY

NARA RG 319, Entry A1-84E, Box 124

Figure D.1021: A U.S. intelligence card catalog shows that there were postwar reports detailing German atomic bomb plans, but those reports are still classified and unavailable to the public [NARA RG 319, Entry A1-84E, Box 124].

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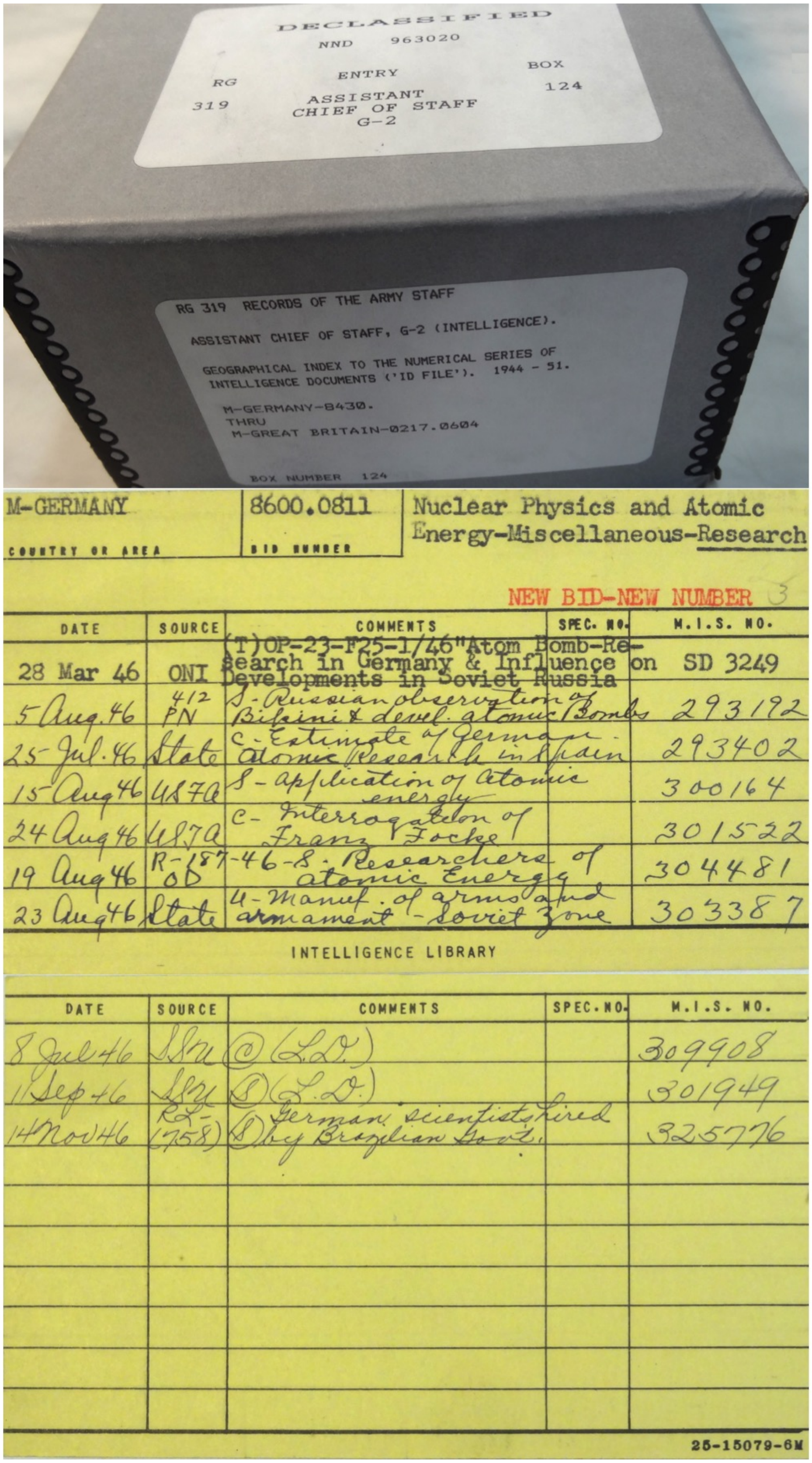

DECLASSIFIED
NND 963020
RG 319
ENTRY
ASSISTANT CHIEF OF STAFF G-2
BOX 124

RG 319 RECORDS OF THE ARMY STAFF
ASSISTANT CHIEF OF STAFF, G-2 (INTELLIGENCE).
GEOGRAPHICAL INDEX TO THE NUMERICAL SERIES OF INTELLIGENCE DOCUMENTS ('ID FILE'). 1944 - 51.
M-GERMANY-8430.
THRU
M-GREAT BRITAIN-0217.0604
BOX NUMBER 124

COUNTRY OR AREA	BID NUMBER	
M-GERMANY	8600.0811	Nuclear Physics and Atomic Energy-Miscellaneous-Research

NEW BID-NEW NUMBER 3

DATE	SOURCE	COMMENTS	SPEC. NO.	M.I.S. NO.
28 Mar 46	ONI	(T)OP-23-F25-1/46"Atom Bomb-Research in Germany & Influence on Developments in Soviet Russia		SD 3249
5 Aug. 46	412 PN	S-Russian observation of Bikini & devel. atomic Bombs		293192
25-Jul. 46	State	C-Estimate of German atomic Research in Spain		293402
15-Aug 46	USFA	S-application of atomic energy		300164
24 Aug 46	USFA	C-Interrogation of Franz Focke		301522
19 Aug 46	R-187-46 OD	S-Researchers of atomic Energy		304481
23 Aug 46	State	4-Manuf. of arms and armament-Soviet Zone		303387

INTELLIGENCE LIBRARY

DATE	SOURCE	COMMENTS	SPEC. NO.	M.I.S. NO.
8 Jul 46	SSU	Ⓒ (L.D.)		309908
11 Sep 46	SSU	Ⓢ (L.D.)		301949
14 Nov 46	RL-(758)	Ⓢ German scientists hired by Brazilian Govt.		325776

25-15079-6M

NARA RG 319,
Entry A1-84E, Box 124

Figure D.1022: A U.S. intelligence card catalog shows that there were postwar reports detailing German atomic bomb plans, but those reports are still classified and unavailable to the public [NARA RG 319, Entry A1-84E, Box 124].

D.14.10 Fritz Lang and the Leak That Almost Revealed Everything

[The famous German film director Fritz Lang (1890–1976, p. 1971) moved to the United States in 1933 and continued making movies there.[19] In 1946, Lang directed the film *Cloak and Dagger* for the Warner Bros. studio. *Cloak and Dagger* presented a fictionalized story of how during World War II, OSS and European resistance members investigated and combatted the German nuclear weapons program. As scripted and filmed, the movie ended with a visually impressive and highly expensive sequence in which U.S. forces bomb several German nuclear weapons factories and visit another one in person. However, before the film was released, that entire sequence was censored and apparently destroyed, leaving a short final film that focuses on personal melodrama and avoids any mention or depiction of German nuclear weapons factories.

Although *Cloak and Dagger* was fiction, Lang's story descriptions and the script versions included an extraordinary number of details that agree stunningly well with real information about the German nuclear weapons program (as presented elsewhere in this appendix) which was not publicly known in late 1945/early 1946 when the film was being written and shot, including for example:

- The German program completed construction of fission bombs (e.g., pp. 4182, 4436, 4635, 4666–4667, 4903).
- Germany successfully tested the bombs (e.g., Sections D.10, D.11, D.12).
- Germany was developing vehicles to deliver those bombs to Allied targets (e.g., Appendix E).
- Even in the final weeks of the war, Germany could have dramatically changed the war by using those weapons (e.g., pp. 4572–4681, 4703–4712, 4766, 5022–5039, 5072–5073).
- The German nuclear weapons program was divided among a number of sites in German-controlled territory (e.g., pp. 3671–3677, 4400–4403).
- Many of those sites were underground facilities (e.g., pp. 3874–3920, 4176–4182, 4400–4403, 4504–4519, 4568–4570, 4636, 4962–4970, 4985–4991).
- The German nuclear program used many thousands of slave laborers (e.g., pp. 3874–3920, 4176–4182, 4400–4403, 4440–4477, 4636, 4974).
- Many of the slave laborers actually lived underground full-time, instead of in nearby camps on the surface (e.g., pp. 3874–3922, 4400–4403, 4504–4510, 4974).
- Most of the slave laborers were killed by the end of the war (e.g., pp. 3874–3920, 4440–4570).
- At least one of the major sites was near Grünbach (in the 12 June 1946 final script by Ring Lardner Jr. and Albert Maltz), which is next to Johanngeorgenstadt in the uranium-rich Erzgebirge mountains of Saxony (e.g., pp. 3416, 3424, 3426–3428, 3433–3437, 3456, 3468–3469, 3708, 4922).[20]
- At least one of the major sites was in the vicinity of Linz, Austria (Bad Hall in the final script) (pp. 3874–3920, 4962–4970).

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[19] Bogdanovich 1967; Eisenschitz and Bertetto 1994; Eisner 1977; Jenkins 1981; McGilligan 1997.

[20] Some versions of the *Cloak and Dagger* script mistakenly indicated that Grünbach was in Bavaria. It is near the Bavaria-Saxony border but on the Saxony side.

- At least one of the major sites was in the Netherlands (Kaptein in the final script) (e.g., pp. 4314–4316, 4832–4852).
- At least one of the major sites was in southern Bavaria (Bad Tölz in the final script) (e.g., pp. 3473, 3871–3873).
- At least one of the major sites was in Czech territory (e.g., pp. 3749, 3689–3782, 3979–4022, 4914–4922, 4974–4984, 5503–5566, 5696), specifically near Bodenbach (pp. 3987–3998) in the 24 November 1945 screenplay outline by John Larkin and Boris Ingster.
- At least one of the major sites was on the Baltic coast in the outline (e.g., Section D.10).
- At least one of the major sites was a few tens of kilometers south of the Baltic coast of Germany in the outline (e.g., pp. 3694, 4176–4182, 4679).
- OSS had a major program to investigate the progress of German nuclear weapons development (Azusa, e.g., pp. 3747–3749, 4400–4403, 4670, 5044–5048).
- U.S. intelligence and European resistance members informed senior U.S. government officials about the advanced state of the German nuclear program (e.g., pp. 4703–4707, 4832–4852, 5012, 5022, 5031, 5072–5073).
- U.S. intelligence and European resistance members informed the U.S. government about some of the major sites of the German nuclear program, and those were targeted by Allied bombing raids (e.g., pp. 3334, 3617, 3928, 3979, 4068, 4411, 4679, 5199).
- Allied forces rushed to some of the remaining German nuclear sites at the end of the war and found that those sites had already been abandoned (e.g., Section D.14.7).
- German nuclear scientists and their technologies were establishing nuclear weapons programs in other countries after the war (e.g, Section 8.9).

It is theoretically possible it was just a sheer coincidence that the *Cloak and Dagger* scripts bore so many similarities to the real German nuclear weapons program. Yet because of the number, the level of detail, and the then-classified nature of those similarities, a pure coincidence seems highly unlikely. It is far more probable that Fritz Lang received information about the real German nuclear weapons program from one or more sources:

- Advisors who were in or had close ties to western Allied intelligence, such as Michael Burke (OSS), Andries Deinum (OSS/Dutch resistance), Corey Ford (OSS), Alastair MacBain (OSS), Milton Sperling (WWII intelligence and Jack Warner's nephew-in-law), an unnamed Los Alamos scientist who was an advisor for the film, etc.
- Friends who were members of or had close ties to members of wartime German rocket-related programs (including their intended nuclear payloads), such as Willy Ley, Hermann Oberth, any members of a whole generation of German-speaking rocket engineers that grew up inspired by Lang's *Frau im Mond* (1929), or other German-speaking scientists.[21]
- Writers, advisors, or friends who may potentially have had ties to Soviet, French, Spanish, or other European intelligence sources, such as Alvah Bessie, Ben Maddow, John Gates, John Larkin, Boris Ingster, Ring Lardner Jr., Albert Maltz, etc.

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[21] Herbert Wagner arrived in the United States in May 1945, Wernher von Braun and others arrived in September 1945, and many more members of the wartime German programs came after that.

The decision to censor the final part of *Cloak and Dagger* was delivered to Fritz Lang by Milton Sperling, Jack Warner's nephew-in-law. Although biographies of Lang (see the following pages) speculate that decision originated within the Warner Bros. studio and was made for one reason or another, that seems unlikely. If the studio had had any serious reservations about the scripted ending, they would not have kept essentially that same ending throughout numerous script versions from 1945 and 1946, and they certainly would not have invested the lavish amounts of money, resources, and time that they did to film that ending. And after having already invested so much and receiving what by all accounts was a visually and dramatically spectacular final third of the film, the studio would naturally want to benefit from that. *Cloak and Dagger* released complete with its final third would impress audiences much more and make far more money than *Cloak and Dagger* released with only its more mundane first two-thirds that lead nowhere.

Thus it seems likely that the decision to censor the film originated outside the Warner Bros. studio. Conceivably that decision could have come from almost anywhere within the U.S. government. In practice, major censorship decisions regarding nuclear weapons in general, and knowledge of the wartime German nuclear weapons program in particular, were typically handled by the office of Leslie Groves. There are a number of examples of Groves or his office censoring and reprimanding independent investigators who uncovered evidence that the German nuclear weapons program was more advanced than had been publicly admitted (e.g., pp. 3948, 3970, 4056–4061, 4185, 4187, 4679–4681, 5017–5018, 5393–5396).

The original documents for *Cloak and Dagger* are divided between two archives:

Warner Bros. Archive
University of Southern California
900 West 34th Street, Los Angeles, CA 90089-2211
https://cinema.usc.edu/about/warnerbrosarchives.cfm
wbarchives@cinema.usc.edu

Bibliothèque du film
La Cinémathèque française
51 Rue de Bercy, 75012 Paris
https://www.cinematheque.fr
http://www.cineressources.net

If Leslie Groves was involved in the decision to censor the film, documentation of that fact may (or may not) be included in his papers at NARA College Park:

NARA RG 77, Entry UD-22A (General Records), Boxes 160–177. Manhattan Engineer District Foreign Intelligence Section.

NARA RG LRG. Leslie R. Groves Papers, 1941–1970.

Can future researchers identify what sources (if any) provided real information about the German nuclear program for the film?

Can future researchers identify where the orders to censor the ending originated?]

Peter Bogdanovich. 1967. *Fritz Lang in America.* New York: Praeger. pp. 15, 69–71.

[*The following is an edited version of an interview with Mr Lang tape-recorded at his home in Beverly Hills, California, over a period of six days in August–September, 1965.*] [...]

CLOAK and DAGGER (1946)

Did you have much interference on this picture?

Yes and no. [...]

But the most significant thing in *Cloak and Dagger* was the ending. It now ends with the Italian scientist being saved by the Underground: the British airplane lands and the American O.S.S. man (who was built around the characteristics of Oppenheimer) has completed his mission; the plane flies away, the girl waves, he waves, and you know they will see each other again after the war. In the original ending, the Italian scientist dies of a heart attack on the plane and all they have left to go on is an amateur photo of the scientist and his daughter with a very peculiar mountain formation in the background. The U.S. and British secret services get together and they decide, 'That can only be in Bavaria.' So they go there (I *shot* all these things, you know, parachutists, everything) and they find a camouflaged highway and then a big electrified barbed-wire fence. They're very careful but the power has been cut off. They find pill boxes and everything—all deserted—and finally they come to a big cave that is empty. All the machines are gone. (You see, we already knew the Germans had experimented with heavy water to get Atomic power—and we knew there was a plant in Norway—but, remember, Los Alamos was still hush-hush.) Then there was a conversation and they decide, 'Probably the plant is in Argentina now—or somewhere.' A sergeant comes to report that 60,000 slave workers have been found dead underneath the cave. Gary Cooper walks outside and at the entrance of the cave is a parachutist—an American boy chewing on a blade of grass. The sun is shining, birds singing. And Cooper says *something* like: 'This is the Year One of the Atomic Age and God help us if we think we can keep this secret from the world, and keep it for ourselves.' And *this* was why I wanted to make the picture. The whole reel was cut out. I don't think it exists any more.

Do you know why it was cut?

You must ask Warners, I don't know. Maybe because it was after Hiroshima and Nagasaki.

[...] I had the help of two O.S.S. people on the film—Mike Burke and a man named Deinum.

Lotte H. Eisner. 1977. *Fritz Lang.* Oxford: Oxford University Press. pp. 272, 274.

[...] The film as it now exists ends here on this equivocally happy ending. In the original version as filmed, Polda dies in the plane just as he is about to reveal to Jasper the locations of the four main plants where the Nazi atomic bomb is being tested. Unable to finish, he takes a photograph from his pocket just as he dies. It shows him and his daughter in a lake landscape with wooded hill and unusual mountain formation in the background. From this the OSS are able to identify the fourth plant, the only one Polda had not named, as Grünbach in Bavaria.

An operation is mounted. Mysteriously, RAF reconnaissance planes sent in advance encounter no resistance. When Jasper and the task force arrive, they find the secret factory is deserted. Where is the work on the bomb being continued? In Spain? The Argentine?

It was at this point that Jasper made the speech which was for Lang the *raison d'être* of the film:

> God have mercy on us if we ever thought we could really keep science a secret—or even wanted to. God have mercy on us if we think we can wage other wars without destroying ourselves . . . And God have mercy on us if we haven't the sense to keep the world in peace.

Emerging from the cave that leads to the underground factory, Jasper takes a deep breath, then sees a paratrooper tossing pebbles and gazing at the sky. [...]

As usual Lang surrounded himself with experts for the preparation of this film. Two former OSS men gave him advice based on their own cloak-and-dagger experiences during the war—Milton Sperling, the producer, and Mike Burke who had actually had the task of smuggling out of Italy an Italian admiral who had invented an electronic torpedo device which the Allies wanted to prevent the Fascists from having.

Patrick McGilligan. 1997. *Fritz Lang: The Nature of the Beast.* London: Faber and Faber. pp. 333-334, 339–340.

Cloak and Dagger was based on a book by Corey Ford and Alastair MacBain, "the inside story of General Bill Donovan's famous O.S.S,"[....]

Two sets of writers—first Ben Maddow and John Gates, followed by Boris Ingster and John Larkin—had labored on the OSS scenario for several months before Lang was hired in November [1945]. [...]

Lang had just been put in charge when [Ring] Lardner [Jr.] came aboard. Lardner's mission was to accomplish, at improbable speed, a marriage of earlier, unsatisfactory drafts. The screenwriter recalled a series of agreeable meetings with Lang, mostly at the director's house, in which the two hashed over the revisions. [...]

[Albert] Maltz also met with Lang on a regular basis throughout January, but wrote his scenes separately from Lardner, concentrating on punching up the last third of the film. [...]

None of these writers was a reporter, so an expert had to be brought on to authenticate the spy-trappings. Michael Burke was the real thing. A former University of Pennsylvania all-American football player who had been with the OSS, Burke, in one famous exploit, had helped smuggle an anti-Nazi admiral out of Italy. Hired as technical adviser, Burke ventured a few sensible suggestions, and found himself gratefully "adopted" by Lang.

Andries Deinum also added a bit of expertise to the project. A native Dutchman and a friend of Milton Sperling's, Deinum also had OSS experience. At first employed as Sperling's assistant, an intermediary for the producer with Lang, Deinum also found a kinship with the director and was "adopted" by him. In part that was because Deinum was a young man just starting out in the business, in part because he was versed in German language and culture. [...]

Burke and Deinum became frequent dinner guests at Lang's house[....]

The *Cloak and Dagger* script had to be hastily finalized as the first week of photography approached in March 1946. [...]

The final scene in the released version of *Cloak and Dagger* is not the ending Lang preferred—and not the one he filmed. This, too, became a sort point in his memory.

In the last scene as the film stands, Professor Jasper manages to elude death on the ground in Italy. He escapes by boarding a plane with an elderly scientist defector. But this was yet another "happy ending" foisted on Lang. It had been augmented in the original script by an epilogue in which the scientist dies on the plane from a heart attack brought on by the stress of events. A snapshot in his pocket then provides the only clue to the whereabouts of a fascist atom-bomb factory in the Bavarian Alps.

The last scene was intended to be one of Fritz Lang's superclimaxes: the American going back on one final secret errand, determined to destroy the German atomic-bomb factory. [...]

Milton Sperling, Michael Burke, Andries Deinum, Willy Ley, and another adviser on the picture—a scientist from Los Alamos—all tried to talk Lang out of the scene on the principle that nothing of that sort had transpired during the war. Everyone knew the Nazis had fallen short of atomic capacity. Lang, only interested in authenticity when it served his purposes, was adamant. He wanted to make a statement against war and weapons of mass destruction. The producer, still bargaining for long-term goodwill, decided the wise thing to do would be to let the director have his way.

Lang took Gary Cooper and everybody out to Bronson Canyon, where Warner Brothers had built an imitation bomb factory and where for several days they filmed the superclimax—adding thousands upon thousands of dollars in budget costs. Planes flew overhead, paratroopers dropped from the skies, the bomb factory blew up for the cameras.

According to a plot synopsis prepared by the studio publicity department, this is how Lang's version would have ended: "They have come too late. The factory has been thoroughly stripped by the Germans, its equipment probably moved to Spain or Argentina, where the Nazis had a foothold. The picture ends with the lines of the American scientist [Professor Jasper]: 'God have mercy on us if we think we can keep science a secret! God have mercy on us if we think we can wage other wars without destroying ourselves.'"

After showing a rough cut to Warner Brothers executives in late August [1946], however, Sperling decided to drop the expensive and historically dubious sequence.

D.14.11 Allied Intelligence Officials Who Would/Should Have Known

[There are a number of Allied intelligence officials who would/should have known about the German nuclear weapons program, and whose files may reveal useful information if any relevant documents in them could be located, declassified, and released:

> Commander Herbert Agar (1897–1980), assistant to the U.S. ambassador to Great Britain (pp. 5017–5018).
>
> Civilian investigator Jack H. Alberti (??–??), U.S. Navy intelligence.
>
> Colonel Robert S. Allen (1900–1981), U.S. Army.
>
> Dr. Luis Walter Alvarez (1911–1988), Manhattan Engineer District.
>
> General Henry H. Arnold (1886–1950), U.S. Army Air Forces.
>
> Colonel Peter Beasley (1884–1957), U.S. Army Air Forces, Strategic Bombing Survey.
>
> Dr. Hans Bethe (1906–2005), Manhattan Engineer District (p. 5005).
>
> General Thomas J. Betts (1894–1977), Supreme Headquarters Allied Expeditionary Force, Assistant Chief of Staff for intelligence.
>
> General Clayton L. Bissell (1896–1972), U.S. Army Air Forces intelligence.
>
> Dr. Edward L. Bowles (1897–1990), MIT and advisor for General Henry Arnold.
>
> A. E. Britt (??–??), affiliation?
>
> Dr. Vannevar Bush (1890–1974), Director of Office of Scientific Research and Development (OSRD)/National Defense Research Committee (NDRC)
>
> Major Horace K. Calvert (1915–2006), U.S. Army/Manhattan Engineer District intelligence.
>
> Dr. Karl P. Cohen (1913–2012), Manhattan Engineer District.
>
> Dr. James B. Conant (1893–1978), Assistant Director of Office of Scientific Research and Development (OSRD)/National Defense Research Committee (NDRC)
>
> General George Bryan Conrad (1898–1976), Supreme Headquarters Allied Expeditionary Force, Assistant Chief of Staff for intelligence.
>
> Captain George C. Davis (??–??), U.S. Army/Manhattan Engineer District intelligence.
>
> Colonel Howard W. Dix (??–??), Office of Strategic Services.
>
> General William Donovan (1883–1959), Office of Strategic Services Director.

Allen Dulles (1893–1969), Office of Strategic Services senior agent and later Central Intelligence Agency Director.

Colonel George R. Eckman (??–1971), U.S. Army Counter Intelligence Corps and Alsos Mission Executive Office.

G. Verner Edlund (1906–2004), U.S. Army Counter Intelligence Corps.

Major Ernst Englander (??–??), U.S. Army Air Forces.

Dr. Richard Fischer (1910–1991), U.S. Geological Survey (p. 3948).

Dr. Victor H. Fraenckel (1908–1998), Scientific Intelligence Advisory Section (SIAS) for Supreme Headquarters Allied Expeditionary Force (SHAEF); one of Dwight Eisenhower's highest-level science advisors.

Major Robert R. Furman (1915–2008), U.S. Army/Manhattan Engineer District intelligence.

Colonel Dale M. Garvey (1914–2002), U.S. Army Counter Intelligence Corps.

David Gattiker (??–1993), U.K. Atomic Energy Office.

Dr. Samuel Goudsmit (1902–1978), Alsos Mission scientific head. [Did he really not know about the much larger and much more advanced parts of the German nuclear program, or did he just publicly pretend not to know? Many of his files are still classified and not available to scholars. Why?]

General Leslie Groves (1896–1970), U.S. Army/Manhattan Engineer District commanding officer.

Caperton Horsley (1903–1988) , civilian CIOS investigator (pp. 3957–3970).

General John Edwin Hull (1895–1975), U.S. Army.

Justice Robert H. Jackson (1892–1954), U.S. Prosecutor, Nuremberg trials.

Dr. Theodore von Kármán (1881–1963), chief scientific advisor for Henry Arnold and U.S. Army Air Forces.

Colonel John A. Keck (??–??), U.S. Army Ordnance.

Colonel Oscar Koch (1897–1970), U.S. Army intelligence.

General Egmont F. Koenig (1892–1974), U.S. military attaché in Czechoslovakia from January 1946 to May 1947.

Dr. Gerard P. Kuiper (1905–1973, p. 803), Alsos Mission.

Colonel John Lansdale, Jr. (1912–2003), U.S. Army/Manhattan Engineer District intelligence.

General John Magruder (1887–1958), Office of Strategic Services Deputy Director.

General George C. McDonald (1892–1969), U.S. Army Air Forces intelligence.

General Joseph T. McNarney (1893–1972), U.S. Army Air Forces.

Dr. Philip Morrison (1915–2005), Manhattan Engineer District.

Dr. John von Neumann (1903–1957), Manhattan Engineer District (p. 5005).

Dr. Todos M. Odarenko (1900–1975), AT&T Bell Laboratories.

Lt. Colonel John A. O'Mara (19??–19??), U.S. Strategic Air Forces in Europe, Office of the Director of Intelligence.

Dr. J. Robert Oppenheimer (1904–1967), Manhattan Engineer District (p. 5005).

Dr. Richard W. Porter (1913–1996), General Electric rocket programs.

General Donald Putt (1905–1988), U.S. (Army) Air Force.

General William L. Richardson (1901–1973), U.S. (Army) Air Force.

Dr. Howard P. Robertson (1903–1961), Chief of the Scientific Intelligence Advisory Section (SIAS) for Supreme Headquarters Allied Expeditionary Force (SHAEF); Dwight Eisenhower's highest-level science advisor.

Lt. Vladimir L. Rychly (1909–1992), U.S. Navy intelligence and U.S. military attaché in Czechoslovakia

A. J. Saxon (??–??), Manhattan Engineer District.

Whitney Shepardson (1890–1966), Office of Strategic Services.

Colonel W. R. Shuler (??–??), U.S. Army/Manhattan Engineer District intelligence.

General Edwin L. Sibert (1897–1977), U.S. Army intelligence and Central Intelligence Group.

Colonel Leslie E. Simon (1900–1983), U.S. Army.

Major Francis J. Smith, (??–??), U.S. Army/Manhattan Engineer District intelligence.

Dr. Charles P. Smyth (1895–1990), Princeton and Alsos Mission (p. 4788).

General George V. Strong (1880-1946), U.S. Army, commander of the Military Intelligence Corps.

Dr. Edward Teller (1908–2003), Manhattan Engineer District (p. 5005).

Major Edmund Tilley (1892–1966), U.K. military intelligence (pp. 4894–4895).

Dr. Richard C. Tolman (1881–1948), Manhattan Engineer District.

Major H. S. Traynor (??–??), Manhattan Engineer District.

Dr. Major John E. Vance (1905–1975), U.S. Army/Manhattan Engineer District.

Joseph Volpe, Jr. (1914–2002), U.S. Army/Manhattan Engineer District.

Frederic A. C. Wardenburg III (1905–1997), Alsos Mission.

Colonel Lowell P. Weicker (1903–1978), U.S. Strategic Air Forces in Europe, Office of the Director of Intelligence.

Major P. M. Wilson (??–??), Dustbin interrogation center.

Colonel George Bryant Woods (1896–1954), U.S. Air Technical Services Command (ATSC)/Air Materiel Command (AMC) intelligence, and later Assistant to the Undersecretary of the Air Force.

Are there other people who should be included here???

Intelligence sources or agencies for the United States, United Kingdom, France, Soviet Union, and Netherlands have already been mentioned. Was useful information on the German nuclear weapons program handled by intelligence agencies or spy networks in other countries—Norway, Sweden, Denmark, Belgium, Luxembourg, Switzerland, Poland, Czechoslovakia, Hungary, etc.?]

D.15 Analysis of Current Evidence; Recommended Further Work

Based on information from the sources regarding wartime German nuclear work that were quoted in the earlier sections of this appendix, this section analyzes:

D.15.1. Overarching programmatic considerations.

D.15.2. Uranium-235 enrichment methods.

D.15.3. Plutonium-239 or uranium-233 breeding methods.

D.15.4. Test explosions.

D.15.5. Design parameters of the tested devices.

D.15.6. Evidence for other device designs.

D.15.7. Conclusions and recommendations for further historical research in this area.

D.15.1 Overarching Considerations Regarding the German Nuclear Program

This section summarizes the known and extrapolated characteristics, secrecy, timeline, and organization of the wartime German nuclear weapons program. As instructive references, that program is compared to other wartime German programs on revolutionary new weapons technologies, as well as to the wartime U.S. nuclear weapons program.

A. Characteristics of the German Nuclear Program

The conventional historical narrative is that the wartime German nuclear program was very small, poorly funded, and badly misguided both scientifically and politically, and that as a result it never accomplished much.[22] On the other hand, the conventional historical view does recognize that other revolutionary German military programs such as those for rockets, jets, and chemical warfare agents were large and accomplished a great deal.[23] While currently available information on the German nuclear program is very incomplete, the data from the key sources quoted earlier in this appendix does not match the picture of a small and inconsequential program, but rather a large and advanced nuclear program quite comparable to the most successful German programs such as those on rockets, jets, and chemical warfare agents:

1. A large nuclear program would have begun with early theoretical research and proof-of-concept experiments. For example, in order to test their earlier designs and calculations, Wernher von Braun's team began experimenting with rockets in 1932 at Kummersdorf. Hans von Ohain began experimenting with jet engines in 1935 at Göttingen and then at Heinkel. Gerhard Schrader produced the first organophosphate nerve agents in 1936.
    (a) Fritz Houtermans was doing work on nuclear fusion at least as early as 1928 [Atkinson and Houtermans 1929a].
    (b) Rausch von Traubenberg, Arno Brasch and Fritz Lange, and others were conducting laboratory experiments with nuclear fusion reactions from 1933 onward [pp. 4281–4282].
    (c) Ida Noddack correctly predicted nuclear fission of uranium in 1934 [Noddack 1934].
    (d) Otto Hahn and Fritz Strassmann demonstrated and explained nuclear fission of uranium in late 1938 [Hahn and Strassmann 1939].

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[22] See for example: Bernstein 2001; Goudsmit 1947; Hentschel and Hentschel 1996; Hoffmann 2023; Pash 1969; Rose 1998; Schaaf 2001; von Schirach 2015; Walker 1989, 1995, 2020, 2024a, 2024b.

[23] See for example: Amtmann 1988; Bohr 2013; Butler 1994, 2007; Christensen 2002; Christopher 2013; Cole 2015; Conner 2001; Constant 1980; Cooke and Ingells 1945; Daso 2002; Dornberger 1958, 1994; Dorr 2013; Duffy 2012; Erfurth 2006; Forsyth and Creek 2007; Franz 1985; Friedrich et al. 2017; Gellermann 1986; Gleichmann 2013; Gleichmann and Bock 2009; Griehl 1990, 2004, 2005, 2015; Gröhler 1989; Hager 2008; Harris and Paxman 2002; Heinkel 1956; Hellmold 1999; Herwig and Rode 2000; Hirschel et al. 2004; Hein Hofmann 2008; Hölsken 1994; Huzel 1962; Hyland and Gill 1998; Irving 1965; Jakobs et al. 2009; Jacobsen 2011, 2014; Johnsen 2014; Kaszeta 2020; Kay 2002; King and Kutta 1998; Klee and Merk 1963; Kober 1990; Leyes and Fleming 1999; Lommel 2005; Longden 2009; Masters 1982; Hans-Ulrich Meier 2010; Jürgen Michels 1997; Miranda 2015; Miranda and Mercado 1996; Myhra 1998a, 1998b, 2000a, 2000b, 2001, 2002, 2003; Neufeld 1995; Nowarra 1988; Ordway and Sharpe 1979; Pavelec 2007; Pfingsten 2003; Samuel 2004, 2010; Shepelev and Ottens 2015; Simons 2016; Smith and Creek 1992, 2001; Smith and Kay 2002; Stuhlinger and Ordway 1994a, 1994b; Stüwe 1999, 2014, 2015; Thomas 1946; Trischler 1992a, 1992b; Tucker 2006; Vajda and Dancey 1998.

2. A nuclear program would have first become a major government program shortly before or at the beginning of the war. For example, the Peenemünde rocket center was set up in 1937, Luftwaffe-funded jet programs began in 1939, and organophosphate nerve agents became a major Army-funded program in 1937.
    (a) High-level, coordinated, and secret government meetings regarding nuclear research and development began in April 1939 [Irving 1967, p. 33].
    (b) Government programs for nuclear research and development were formalized in September 1939 [Irving 1967, pp. 38–43].
3. A large nuclear program would have been given the highest priority, just as the rocket, jet, and chemical warfare programs were given high priorities by the government.
    (a) Even Samuel Goudsmit admitted that the nuclear program "had the highest priority among all scientific research projects in Germany" [Goudsmit 1945] (see pp. 3297–3298).
    (b) The nuclear program was personally directed and supported by Heinrich Himmler [Krotzky 2002].
4. A large nuclear program would have been conducted in great secrecy, just as the rocket, jet, and chemical warfare programs were.
    (a) Heinrich Himmler's chief adjutant Werner Grothmann described the entire nuclear weapons program as being kept very secret (see pp. 3396–3397).
    (b) According to Ivan Ilyichev's 23 March 1945 intelligence report: "The regime of secrecy at the test site was at maximum level. Entrance and exit from the territory are by special pass only. SS soldiers have surrounded the area of tests and interrogated any person approaching the area." (See p. 4485).
5. A large nuclear program would have vigorously pursued all possible types of nuclear weapons in parallel, just as the rocket program pursued dozens of different types of missiles, the jet program pursued all possible types of engines and aircraft, and the chemical warfare program pursued hundreds of possible nerve agents and other compounds.
    (a) According to Werner Grothmann, the German nuclear program developed bombs using uranium, bombs using plutonium, bombs that apparently incorporated fusion fuel, at least two types of large bombs for cities, at least two types of small bombs for tactical targets, air-dropped bombs, and bombs that could be delivered via rockets (see pp. 3396–3397).
    (b) As will be discussed on p. 5169, there is other evidence that a wide variety of bomb types were pursued by the German nuclear program.
6. A large nuclear program would have been conducted by a large number of groups distributed throughout German-held territory yet coordinated with each other, just as the rocket, jet, and chemical warfare programs were conducted by numerous distributed but coordinated groups throughout Germany and German-occupied territory. Like the rocket, jet, and chemical warfare programs, a large nuclear program would have had at least half of its operations

outside of Germany, and much of its German operations in areas with high concentrations of military research and development, especially on the Baltic coast, near Berlin, and in Thuringia.

   (a) Within Germany proper, nuclear work was reported at Peenemünde, Rügen, and elsewhere on or near the Baltic coast (including the occupied Danish island of Bornholm just off the Baltic coast); at the Kaiser Wilhelm Institute for Physics, Manfred von Ardenne's laboratory, Auergesellschaft/Oranienburg, Kummersdorf/Gottow, and elsewhere in the greater Berlin area; and at Stadtilm, Ohrdruf, and elsewhere in Thuringia.

   (b) A great deal of work apparently occurred outside the traditional borders of Germany, in Norway, Austria, Czechoslovakia, and Poland.

   (c) Those various activities were not independent, parallel, small-scale efforts, but rather were all funded and coordinated from the highest levels by people such as Abraham Esau and Walther Gerlach, with joint backing from the Army, SS, Reichspost, and other agencies.

7. A large nuclear program would have experienced delays caused by Allied attacks, just as the rocket, jet, and chemical warfare programs did.

   (a) The Allied sabotage and then destruction of the Vemork heavy water plant in Norway is widely regarded as a major setback for the German nuclear program [Bascomb 2016; Dahl 1999; Rhodes 1986, pp. 455–517].

   (b) Other major Allied attacks included the August 1943 bombing of Peenemünde, the 1943–1944 bombings of the Frankfurt Degussa plant, bombings of targets around Berlin, and other attacks.

   (c) The Allied attacks were credited with delaying the German programs [see for example: Arnold 1949, p. 491; Casey 1988, p. 54; Knight 1946; Putt 1946b; Thomas 1946; *Chicago Daily Tribune* 1946-01-26 p. 10; *Daily Express* 1945-08-09; *Daily Mail* 1945-06-14 p. 1; *Daily Mail* 1945-08-09; *Daily Telegraph* 1945-08-09; *NYT* 1945-08-09].

8. A large nuclear program would have conducted the first phase of its experiments in more academic settings, just as the rocket, jet, and chemical warfare programs did. In fact, nuclear work was conducted by:

   (a) Werner Heisenberg and others at the Kaiser Wilhelm Institute for Physics in Berlin.

   (b) Otto Hahn, Fritz Strassmann, and others at the Kaiser Wilhelm Institute for Chemistry in Berlin.

   (c) Josef Mattauch, Alfred Klemm, and others at the Kaiser Wilhelm Institute for Chemistry in Tailfingen.

   (d) Manfred von Ardenne, Fritz Houtermans, and others at von Ardenne's laboratory in Berlin.

   (e) Paul Harteck, Wilhelm Groth, Johannes Jensen, and others at the University of Hamburg.

   (f) Walther Gerlach, Klaus Clusius, and others at the University of Munich.
   (g) Georg Stetter, Josef Schintlmeister, Willibald Jentschke, and others at the University of Vienna.

9. A large nuclear program would then have transferred mass-production based on those results to other locations featuring heavy industry, just as the rocket, jet, and chemical warfare programs did. For the nuclear program, those locations are known or suspected to have included:
   (a) Several Degussa locations.
   (b) Several I.G. Farben locations.
   (c) AEG locations.
   (d) Siemens locations.
   (e) Other industrial locations.

10. A large nuclear program would have shifted to locations that were more remote, more dispersed, and/or underground in order to be more resistant to Allied attacks, as the rocket, jet, and chemical warfare programs did. For the nuclear program, such locations included:
   (a) Underground installations in or near the Lüneburger Heide (pp. 4176–4182 and 4406).
   (b) Numerous underground installations reported around Thuringia [Baranowski 2013; Brunzel 2013; Fäth 1999, 2000; Gleichmann and Dörfer 2011; Mayer and Mehner 2001, 2002, 2004a, 2004b; Mehner 2004; Schambach 2011; Schilling 2010; Seidler and Zeigert 2006; Wichert 1999; Zeigert 2003; CIOS XXXIII-38].
   (c) Underground installations such as Gusen, Bergkristall, and Quarz in Austria [Bouchal and Sachslehner 2013; Joseph Fisher 2017; Haunschmied et al. 2007; Köberl 1993; Perz 2014; Schmitzberger 2004; Sulzer and Brauburger 2014, 2015, 2019a, 2019b].
   (d) The large underground Weser works near Podmokly, as well as other locations in Czechoslovakia, far from Allied bombing (pp. 3979–4022).
   (e) Underground installations in Silesia (pp. 4504–4510).

11. Like the rocket, jet, and chemical warfare programs, a large nuclear program would have used large-scale slave labor, with very poor working conditions and systematic extermination of any surviving slave laborers in order to maintain security. In fact, there was mass slave labor and mass extermination at:
   (a) Underground installations in Thuringia [Baranowski 2013; Brunzel 2013; Fäth 1999, 2000; Gleichmann and Dörfer 2011; Mayer and Mehner 2001, 2002, 2004a, 2004b; Mehner 2004; Schambach 2011; Schilling 2010; Seidler and Zeigert 2006; Wichert 1999; Zeigert 2003; CIOS XXXIII-38].
   (b) Underground installations in Austria [Bouchal and Sachslehner 2013; Joseph Fisher 2017; Haunschmied et al. 2007; Köberl 1993; Perz 2014; Schmitzberger 2004; Sulzer and Brauburger 2014, 2015, 2019a, 2019b].

   (c) Underground installations in Silesia (pp. 4504–4510).

12. A large nuclear program would have been partially under SS control for most of the war (especially in occupied areas outside of Germany), and would have come under complete SS control in the final stages of the war, as the rocket, jet, and chemical warfare programs did.

    (a) Rudolf Mentzel, an SS Oberführer with a Ph.D. in chemistry, was a central figure in the government nuclear program meetings from 1939 onward. He also played a key role in facilitating the scientific leadership transition from Abraham Esau to Walther Gerlach [Irving 1967].

    (b) Werner Grothmann, Heinrich Himmler's aide, said the nuclear program was run by the SS. Other people who were close to Himmler, such as Felix Kersten, Wilhelm Wulff, and Muhammad Amin Al-Husayni, all reported that Himmler had detailed knowledge of the nuclear program.

    (c) Ivan Ilyichev's 23 March 1945 intelligence report described the nuclear weapons tests as being under very tight SS control.

13. Between extreme pressure from the SS and intense bombing from the Allies in the final stages of the war, a large nuclear program would have been racing to perfect its weapons, would have been running late, and would have achieved or been on the verge of achieving its most significant results only at the very end of the war, just as the rocket, jet, and chemical warfare programs did.

    (a) Reportedly the first successful nuclear weapons tests did not occur until the final stage of the war, between October 1944 and March 1945; see Sections D.10–D.12.

    (b) A number of sources reported that military deployment of a nuclear weapon would not have been possible until the very end of the war, or a few months beyond that if the war had continued [see for example: Knight 1946; Putt 1946b; Thomas 1946; *Chicago Daily Tribune* 1946-01-26 p. 10; *Daily Mail* 1945-06-14 p. 1].

14. In the final stages of the war, a large nuclear program would have conducted major tests of prototypes in areas with relatively low populations of Germans but with very high concentrations of high-technology military research, development, and testing, such as on the Baltic coast, in German-occupied central Europe, and in Thuringia, just as the rocket and jet programs did.

    (a) There is some evidence for a nuclear weapons test on the Baltic coast; see Section D.10.

    (b) There is also some evidence for a nuclear weapons test in German-occupied Poland; see Section D.11.

    (c) There is significant evidence for nuclear weapons tests near Ohrdruf in Thuringia; see Section D.12.

15. A large nuclear program would have been prevented by high-level bureaucratic decision making from effectively using its weapons during the final stages of the war, just as the rocket, jet, and chemical warfare programs were.

  (a) As reported by Allen Dulles on 1 April 1945: “In his conversation with Kesselring, latter said to Wolff our situation is desperate, nobody dares tell truth to Fuehrer who surrounded by small group of advisers who still believe in a last specific secret weapon which they call “Verzweiflunge” weapon [die Verzweiflungswaffe or the desperation weapon]. Kesselring believed this weapon can prolong war but not decide it, but might cause terrible blood bath on both sides. Kesselring said if Fuehrer gave him order to use weapon he would surrender his command.” See p. 4670.
  (b) Werner Grothmann said that military use of the German nuclear weapons was debated and ultimately rejected (see p. 4668).

16. At the very end of the war, a large nuclear program would have been seen by German government officials directly in charge of it more as a bargaining chip to be offered to the Allies than a weapon to be used against the Allies, just as the rocket, jet, and chemical warfare programs were.
    (a) Documents in U.S. government archives prove that Hans Kammler, who was most directly in command of the nuclear and other high-technology military programs at the end of the war, made a deal with U.S. officials, avoided war crimes trials, and was taken to the United States for extended interrogations after the war (pp. 4931–4959).
    (b) There is also evidence that Martin Bormann or other German government officials may have tried to offer German nuclear materials to the United States [Hydrick 2016].

17. A large German nuclear program that had occurred in what ultimately became Soviet-occupied areas inside and outside of Germany would have been rapidly taken over, fully exploited, and completed removed by the Soviets at the end of the war and after the war, without much opportunity for western Allied observers to learn about the wartime German program, and would have been largely concealed by Russia ever since, just as happened with the rocket, jet, and chemical warfare programs.
    (a) Soviet forces controlled and could have easily removed any nuclear-program-related personnel, materials, and information from the Baltic coast, greater Berlin area, Thuringia (after the relatively brief U.S. presence there), Poland, Czechoslovakia, Hungary, Bulgarian uranium mine, parts of Austria, northern Norway, and Bornholm island.
    (b) Other than a few highly staged and closely escorted trips, U.S. and U.K. officials were never allowed to inspect those areas, interview German scientists there, or view all of the documents and materials that the Soviets removed from those areas.
    (c) Access to virtually all of this material in Russian archives is still restricted.

18. A large nuclear program would have had a direct impact on subsequent Soviet programs, just as the rocket, jet, and chemical warfare programs did.
    (a) Many dozens of German nuclear scientists played critical roles in all major branches of the postwar Soviet nuclear weapons program, and many of them were even officially recognized with Stalin prizes for their vital contributions. Uranium captured from Germany fueled at least the first two Soviet nuclear reactors, including their plutonium production program.

   (b) The contributions of German scientists, materials, and information appear to have saved the Soviet program many years of work [Albrecht et al. 1992; von Ardenne 1990, 1997; Barkleit 2008; Barwich and Barwich 1970; Boch and Karlsch 2011; Fengler 2014; Fengler and Sachse 2012; Goncharov 1996a, 1996b; Goncharov and Riabev 2001; Graham 1993; Heinemann-Gruder 1992; Holloway 1994; Karlsch 2011; Karlsch and Laufer 2002; Karlsch and Zeman 2016; Kozyrev 2005; Kruglov 2002; Maddrell 2006; Mick 2000; Nagel 2016; Naimark 1995; Oleynikov 2000; Pondrom 2018; Riabev 1998, 2002a, 2002b, 2002c, 2002d; 2006a; 2006b; 2006c; Riehl and Seitz 1993; Siddiqi 2009; Sokolov 1955; Wellerstein and Geist 2017; West 2004; Yudin; Zeman and Karlsch 2008; *News Chronicle* 1945-10-15 p. 1; NYT 1945-10-15 p. 4, 1945-10-31 p. 6, 1946-01-29 p. 1, 1946-11-28 p. 16, 1946-12-06 p. 17, 1947-02-24 p. 1, 1948-05-26 p. 3, 1948-12-28 p. 10b; *Spokane Daily Chronicle* 1948-03-16 p. 6; *Sydney Morning Herald* 1946-04-20 p. 2; *Times* 1945-05-15, 1945-05-18].

   (c) Can the designs of Soviet advanced fission bombs (Joe-2 and beyond) and H-bombs be traced to wartime German work?

19. Any U.S. or U.K. information on a large wartime German nuclear program would have been classified and concealed (even more so than the rocket, jet, and chemical warfare programs were) in order to (i) try to hide that information or western knowledge of that information from the Soviet Union; (ii) make imported German scientists more palatable to the U.S. public and politicians (avoiding questions along the lines of "Why are we hiring scientists this month who were on the verge of nuking us last month?"); (iii) downplay wartime German technological accomplishments; and (iv) play up U.S. wartime and postwar accomplishments to both domestic and foreign audiences.

   (a) Samuel Goudsmit's job as scientific head of the Alsos Mission was to investigate the German nuclear program in great detail and report his findings, yet there is well-documented evidence that completely contradicts his public portrayal of the German program. Goudsmit appears either to have been incredibly incompetent at his assigned job or else to have been deliberately making false public statements about the German program. Here are just a few examples:

      i. Goudsmit testified to the U.S. Senate that the German nuclear scientists "were still a hundred years away from" producing a bomb at the end of the war. Just a fraction of those scientists, completely starting over in the technologically backward Soviet Union, built an atomic bomb in four years.

      ii. Goudsmit stated that "approximately 100 scientists were active on this project," and that many of those "worked only part time on this important research and the rest of the time did routine teaching or administrative work." The list of known German nuclear scientists is much larger, the total number working on the program may well have been far larger still, and the urgency and time commitment that these scientists accorded to their wartime nuclear work is documented in many of their postwar accounts.

      iii. Goudsmit claimed that Erich Schumann was "a second-rate physicist" whose "main interest was the physics of piano strings." It is well documented that Erich Schumann was the Ph.D. thesis advisor of Wernher von Braun, spent years during the war developing, demonstrating, and optimizing highly sophisticated implosion bomb designs, and was directly involved in a number of other groundbreaking military research and development programs [Nagel 2012a].

        iv. Goudsmit characterized Manfred von Ardenne as merely "a clever technician and businessman" who tried to divert government funding away from "the really competent scientists." After the war, von Ardenne was the German nuclear scientist most highly courted by the Soviet Union (presumably based on Soviet intelligence about his wartime nuclear accomplishments in Germany), and he was ultimately awarded a first class Stalin prize for helping the Soviets build their first atomic bombs [Oleynikov 2000].

    (b) A large number of Alsos-related documents from Samuel Goudsmit's files remain classified (see for example pp. 4772–4779).

    (c) Some very important Alsos-related files from the Manhattan Project's Foreign Intelligence Unit also remain classified and unavailable, as shown by the examples on pp. 4812–4827.

    (d) Numerous other files related to the German nuclear program and its scientists have been removed from the U.S. National Archives as evidenced by yellow withdrawal cards (see for example pp. 4994), or never were there yet are referenced in documents that are present.

20. A large German nuclear program would have had a direct impact on subsequent U.S. programs, just as the rocket, jet, and chemical warfare programs did.

    (a) As discussed in Section D.14.5, there is evidence that captured German enriched uranium and implosion bomb detonators may have significantly aided and accelerated the final phase of the wartime U.S. nuclear program. The United States also captured large amounts of unenriched uranium, beryllium, zirconium, and other materials that would have aided the postwar U.S. nuclear program. German-developed rockets, missile silos, jet bombers, cruise missiles, and submarines proved to be the ideal delivery methods for U.S. nuclear weapons after the war, just as they were likely intended to be delivery methods for any nuclear weapons that Germany had been developing during the war.

    (b) More archival research is needed to determine whether postwar nuclear weapons work in the United States was influenced by German nuclear scientists, materials, or information that had been found at the end of the war, especially for lighter and smaller implosion systems, high-voltage fusion neutron initiators, lithium deuteride fusion fuel, the layer cake H-bomb design, two- and three-stage H-bomb designs, and improved U-235 enrichment methods. Evidence such as the U.S. capture and interrogation of Hans Kammler (pp. 4931–4959), Edward Teller's invitation to Siegfried Flügge (p. 4996), files on German fusion research (Section D.9), and redacted or missing files from German scientists (e.g., p. 4994) raise very serious questions that deserve to be thoroughly investigated.

B. Secrecy of the German Nuclear Program

It seems reasonable to expect that any German nuclear weapons program would have had secrecy equal to or greater than that of the German chemical weapons program. The chemical weapons program developed revolutionary nerve agents, operated highly specialized research and manufacturing facilities all over German territory, created and tested dozens of different nerve agents, produced and stockpiled over 12,000 tons of nerve agents, and developed and stockpiled a wide variety of rockets, bombs, and other delivery methods that were specifically designed for those agents.

Despite the enormous size and strategic implications of this German chemical weapons program, Allied intelligence, military forces, and leaders were essentially unaware of the existence of the program and the nerve agents until the war was over [Tucker 2006, pp. 49, 55, 85–86]:

> Because of the elaborate counterintelligence measures designed to protect the secrecy of Tabun and Sarin, the Allies remained unaware of these dramatic developments. A U.S. intelligence report in July 1942 titled "New German Poison Gas" reads as follows: "Disclosures relative to so-called 'Blau Gas' have occurred numerous times in the past and... are no longer seriously regarded. Intelligence reports lend considerable weight that new German agents are not of the nature of so-called nerve gases." In hindsight, this assessment could not have been more wrong. [...]
>
> On May 11, 1943, the British captured a German Army officer in Tunisia. Under interrogation, he revealed that he was a chemist who had done chemical weapons research at Spandau Citadel in Berlin. He described the development of a new warfare agent that was colorless, had little odor, and possessed "astounding properties." Minute doses made the pupils shrink to pinheads and constricted the bronchial tubes, causing an asthmalike shortness of breath, and higher doses were lethal within fifteen minutes. [...]
>
> The British interrogators judged the prisoner's information to be reliable and wrote a ten-page secret report that was sent on July 3, 1943, to Military Intelligence in London and the Chemical Warfare Experimental Establishment at Porton Down. [...] Because of a lack of corroborating evidence, however, British officials had doubts about the veracity of the intelligence report and decided to take no action. [...]
>
> On April 23 [1945], a CIOS chemical weapons team consisting of ten British and nine American and Canadian specialists, led by Commander A. K. Mills of the British Ministry of Aircraft Production, examined the unidentified German munitions. With the cooperation of German chemists from Raubkammer who had been taken into custody, British experts from the Chemical Defence Experimental Establishment at Porton Down analyzed the contents of one of the German 250-kilogram bombs. [...]
>
> According to the scientists' laconic report, "The shells were found to contain a markedly potent and hitherto unknown organophosphorus nerve agent." [...]
>
> The realization that the Germans had secretly developed and produced a new chemical warfare agent of unprecedented power came as a terrible shock to the Allies. Although a few intelligence reports from 1943 and 1944 could be interpreted in retrospect as having referred to a German nerve agent, they had contained no firm evidence or tangible clues about its composition.

Even though in April 1945 the U.S. Alsos Mission captured and interrogated Richard Kuhn, one of the top brains of the nerve agent program, they learned nothing about the program or his role in it, and they let him go. Moreover, even when they found Kuhn again in September 1945 and pressed him for more information, all they learned was that he had been involved in the production of plastics and other basic materials. (See p. 3316.)

One of the main reasons that security in the chemical weapons program was so effective was that knowledge was highly compartmentalized. Despite the huge numbers of scientists and workers involved in the program, each of them knew only enough to do their own job, and no more. In fact, the program was so compartmentalized that Richard Kuhn, who invented many of the nerve agents such as Soman, and Gerhard Schrader, who invented many other of the nerve agents such as Tabun and Sarin, were completely unaware of each other's work [Tucker 2006, pp. 48–49, 62–63]:

> All aspects of life at Dyhernfurth were overshadowed by elaborate security measures. Access to the site was strictly controlled and required passing through a series of heavily guarded perimeters and checkpoints. In addition, the technical details of the Tabun manufacturing process were classified and the "need to know" principle was strictly enforced: factory personnel were informed only about those operations in which they were directly involved. Although IG Farben chemists and engineers were naturally curious about other aspects of the production process, they did not ask their colleagues too many questions for fear of being informed on or suspected of espionage, which could result in interrogation and torture by agents of the Geheime Staatspolizei (abbreviated Gestapo), or secret state police. [...]
>
> German counterintelligence officials also developed elaborate methods to conceal the nerve agent program from foreign intelligence services. Tabun was given a variety of cover names [...], while Sarin was referred to as "Gelan III" or "Trilon 46." Chemical ingredients used in the manufacture of Tabun were also designated with code names to make it harder for enemy spies to track shipments. [...] Whenever an ingredient for Tabun arrived at Dyhernfurth, it was assigned another local code name, making correct identification nearly impossible if the plant and its records were to fall into enemy hands. The code-name system also had the effect of keeping most of the technical staff in the dark about the precise chemical reactions involved in the manufacture of Tabun. [...]
>
> [D]uring the spring of 1944, Richard Kuhn, working at the Kaiser Wilhelm Institute in Heidelberg, made a striking discovery. He was continuing his research for the German Army by screening a wide variety of organophosphorus compounds—some of which he had synthesized himself—for the ability to inhibit cholinesterase. Because of the Nazi obsession with secrecy, his research was "compartmented": he was not put into contact with other scientists in the nerve agent field and was completely unaware of Schrader's work.
>
> When Kuhn replaced the isopropyl alcohol used to make Sarin with a more complex alcohol known as pinacolyl, the resulting substance (which he called Compound 25075) had a camphorlike odor and was roughly twice as potent as Sarin in inhibiting cholinesterase. The War Office code-named this new compound "Soman" [...]

For more information on how such highly compartmented security was the usual practice for secret German weapons programs, and for the example of how Richard Kuhn was unaware of Gerhard Schrader's work, see p. 2584.

An 18 June 1945 Allied report described some of the security measures that were employed in the secret weapons programs [CIOS ER 112]:

> [...] Security Precautions Surrounding Secret Weapons: Plans, designs and other important papers concerning top secret weapons were distributed in four parts by relay teams. Each part was wholly unintelligible without the other three parts. To keep location of plants secret the relay system was used. One courier would take 1/4 of a plan about 100 km. and turn it over to another courier, whose destination was unknown to the first, just as point of origin of the first courier was unknown to the second. This procedure was repeated frequently so that the final courier alone knew the destination of plan.

Another important reason that security in the chemical weapons program was so effective was that most of the labor involved in production was performed by concentration camp inmates, and those inmates either died in the course of their work or were systematically tracked down and killed afterward [Tucker 2006, pp. 70–71]:

> On January 24 [1945], shortly before the first vanguard of Soviet troops reached the Oder River, the Dyhernfurth director, Dr. Albert Palm, gave the order to evacuate all staff members and the 3,000 inmates of the two satellite labor camps. [...]
>
> By the time the forced laborers reached the Gross-Rosen concentration camp, two thirds of the original 3,000 had died or been killed. On February 11, the SS transferred the survivors from Gross-Rosen to Mauthausen concentration camp. [...] Because the Nazis wanted to eliminate all outside witnesses of nerve gas production at Dyhernfurth, the Gestapo tracked down the survivors at Mauthausen and murdered them. [...]

The same German organizations (Army Ordnance Office, SS, I.G. Farben, etc.) that were involved with the chemical weapons program were involved with the nuclear program. If those organizations could conduct a very large, very advanced, and very successful chemical weapons program from the 1930s until the very end of the war without Allied intelligence and the Alsos Mission discovering that, they could have done the same for a nuclear weapons program.

In fact, existing sources of information on the German nuclear weapons program, such as Ivan Ilyichev (see pp. 4481–4485) and Werner Grothmann (see p. 3400), depicted the severe secrecy and security measures of that program. More specifically, they described the nuclear program as having employed both the same extreme compartmentalization of knowledge and the same systematic use and killing of large numbers of concentration camp inmates as are known to have been employed in the chemical weapons program.

In the years after the war, any scientists, military personnel, or political leaders who did have real insight into the nuclear weapons program would have been strongly motivated to permanently conceal their involvement for fear of being tried for war crimes by the Allies or secretly killed by surviving members of the SS. If any of those personnel went to work for Allied governments and revealed any of the information to them, they would have been equally sworn to secrecy by their new employers.

C. Timeline of the German Nuclear Program

The timeline of the wartime German nuclear program may be analyzed by comparing it to the timelines for the early U.S. and Soviet nuclear weapons development programs.

Figure D.1023 shows the timeline of the early U.S. nuclear weapons program, whose history is well documented.[24] The U.S. program was prompted by the famous 2 August 1939 letter from Albert Einstein and Leo Szilard to Franklin Roosevelt, but up until the end of 1941, the program accomplished remarkably little other than some relatively inexpensive academic experiments and some paper feasibility reports written by a succession of different study commissions. The 7 December 1941 Japanese attack on Pearl Harbor was the critical catalyzing event that brought the United States into the war and persuaded it to pursue a large and urgent nuclear weapons program from approximately the beginning of 1942 onward. The features most closely associated with the memory of the Manhattan Project generally happened very late in the war. The Los Alamos laboratory began operating in April 1943, just two years before the end of the war in Europe, and did not begin truly serious work on the implosion bomb design until July 1944, only 10 months before the end of the war in Europe. Sizeable quantities of uranium-235 and plutonium-239 were not available until the summer of 1945, when they were largely consumed by the 16 July Gadget plutonium implosion bomb test in New Mexico, the Little Boy gun-type uranium bomb dropped on Hiroshima on 6 August, and the Fat Man plutonium implosion bomb dropped on Nagasaki on 9 August.

Similarly, Fig. D.1024 shows the timeline of the early Soviet nuclear weapons program, whose history was shrouded in mystery for many decades but is now relatively well documented.[25] Although the Soviet government and its scientists had been interested in the possibility of nuclear weapons for several years, they were not in any position to pursue a serious program until 1945, when the war ended and they swept up as many scientists, materials, and information as possible from the former German nuclear program. Klaus Fuchs, Ted Hall, and other spies in the U.S. program also gave the Soviet government extremely detailed designs for the U.S. nuclear bombs, uranium enrichment plants, and plutonium production plants. According to the published histories, however, it was the 6 and 9 August 1945 U.S. nuclear attacks on Japan that served as the critical catalyzing event that persuaded Joseph Stalin to give his own nuclear program the greatest possible priority, funding, and urgency. The first Soviet fission bomb (RDS-1 or Joe-1), a direct copy of the U.S. Gadget/Fat Man plutonium implosion bomb, was successfully tested on 29 August 1949, and two more refined bombs (RDS-2 and RDS-3, or Joe-2 and Joe-3) were tested on 24 September and 18 October 1951. As with the U.S. program, significant quantities of uranium-235 and plutonium-239 were not available until very late in the Soviet program.

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[24] Bird and Sherwin 2005; Jennet Conant 2005; Coster-Mullen 2012; Davis 1968; Groves 1962; Chuck Hansen 1988, 2007; Hawkins et al. 1983; Hoddeson et al. 1993; Jungk 1958; Kelly 2007; Nichols 1987; Norris 2002; Oppenheimer 1984; Bruce Cameron Reed 2015a, 2019; Rhodes 1986, 1995; Serber 1992; Smyth 1945; Sublette 2019.

[25] Albrecht et al. 1992; von Ardenne 1990, 1997; Barkleit 2008; Barwich and Barwich 1970; Boch and Karlsch 2011; Fengler 2014; Fengler and Sachse 2012; Goncharov 1996a, 1996b; Goncharov and Riabev 2001; Graham 1993; Heinemann-Gruder 1992; Holloway 1994; Karlsch 2011; Karlsch and Laufer 2002; Karlsch and Zeman 2016; Kozyrev 2005; Kruglov 2002; Maddrell 2006; Mick 2000; Nagel 2016; Naimark 1995; Oleynikov 2000; Pondrom 2018; Riabev 1998, 2002a, 2002b, 2002c, 2002d; 2006a; 2006b; 2006c; Riehl and Seitz 1993; Siddiqi 2009; Sokolov 1955; Wellerstein and Geist 2017; West 2004; Yudin; Zeman and Karlsch 2008; *News Chronicle* 1945-10-15 p. 1; NYT 1945-10-15 p. 4, 1945-10-31 p. 6, 1946-01-29 p. 1, 1946-11-28 p. 16, 1946-12-06 p. 17, 1947-02-24 p. 1, 1948-05-26 p. 3, 1948-12-28 p. 10b; *Spokane Daily Chronicle* 1948-03-16 p. 6; *Sydney Morning Herald* 1946-04-20 p. 2; *Times* 1945-05-15, 1945-05-18.

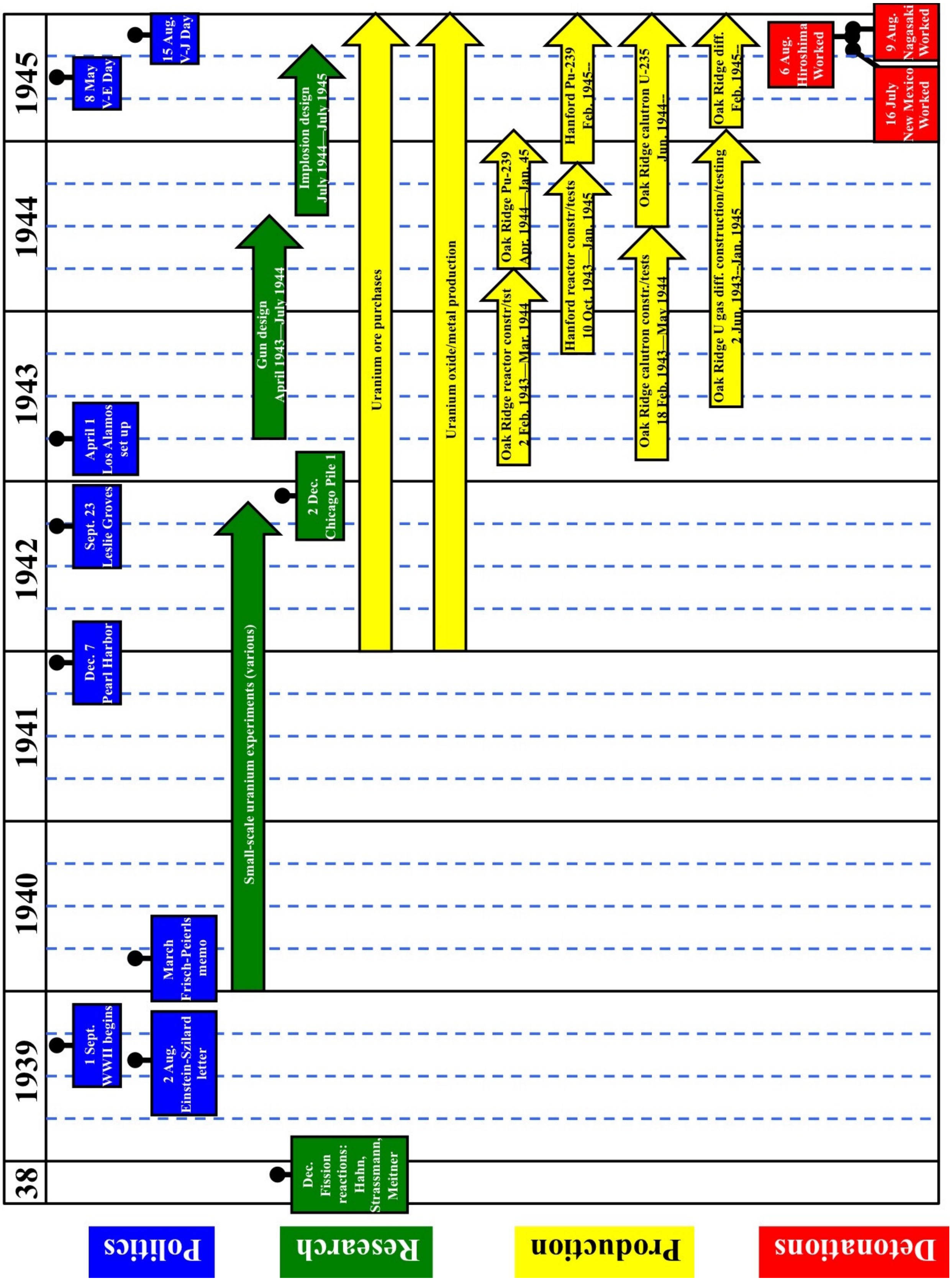

Figure D.1023: Timeline of the early U.S. nuclear weapons program.

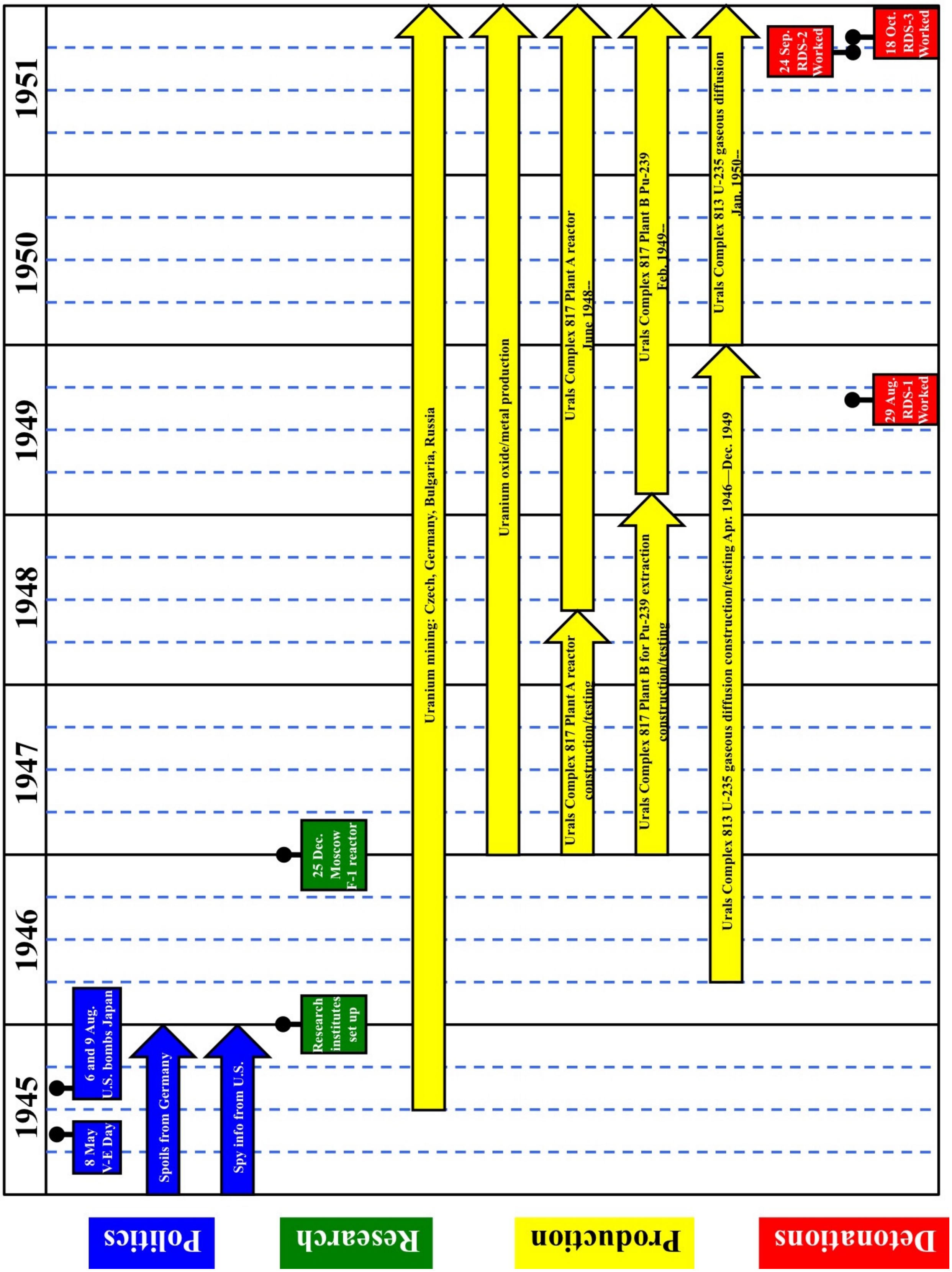
1945
1946
1947
1948
1949
1950
1951
8 May V-E Day
6 and 9 Aug. U.S. bombs Japan
Spoils from Germany
Spy info from U.S.
Research institutes set up
25 Dec. Moscow F-1 reactor
Uranium mining: Czech, Germany, Bulgaria, Russia
Uranium oxide/metal production
Urals Complex 817 Plant A reactor construction/testing
Urals Complex 817 Plant A reactor June 1948--
Urals Complex 817 Plant B for Pu-239 extraction construction/testing
Urals Complex 817 Plant B Pu-239 Feb. 1949--
Urals Complex 813 U-235 gaseous diffusion construction/testing Apr. 1946—Dec. 1949
Urals Complex 813 U-235 gaseous diffusion Jan. 1950--
29 Aug. RDS-1 Worked
24 Sep. RDS-2 Worked
18 Oct. RDS-3 Worked
Politics
Research
Production
Detonations

Figure D.1024: Timeline of the early Soviet nuclear weapons program.

The timelines of the U.S. and Soviet programs are remarkably similar, given that they happened at different times, in very different countries, and with different resources:

- The time from the critical catalyzing event to the first atomic bomb detonation was approximately 43.3 months for the U.S. program (7 December 1941 to 16 July 1945), and approximately 48.7 months for the Soviet program (6 and 9 August 1945 to 29 August 1949). If the United States benefitted significantly from information, materials, or personnel from the German program as some of the evidence in Section D.14 suggests, an unaided U.S. program would have required several more months and thus would have been even closer to the duration of the Soviet program.

- A fission reactor is a necessary step for a Pu-239 bomb program (unless a country resorts to accelerator-driven electronuclear breeding on a large scale); a fission reactor is optional (though potentially helpful) for a U-235 bomb program. The United States demonstrated its first fission reactor (Chicago Pile 1, or CP-1) on 2 December 1942, approximately 12 months after its critical catalyzing event. The Soviet Union demonstrated its first fission reactor (F-1) on 25 December 1946, approximately 16.5 months after its critical catalyzing event, or approximately 12 months after it was able to begin setting up its spoils from Germany (including at least 300 tons of German-produced uranium oxide, which fueled both F-1 and the larger second Soviet fission reactor).

- For both the U.S. and Soviet programs, significant quantities of Pu-239 were not available until just weeks prior to the first atomic bomb detonation, with a period of several years being required to build and test the infrastructure and equipment necessary to breed and purify Pu-239, and several months required to actually produce it. (An electronuclear breeding program would also require several years to build and operate enough particle accelerators to produce a sufficient quantity of Pu-239 or U-233 for a bomb.)

- For both the U.S. and Soviet programs, significant quantities of highly enriched U-235 were not available until just weeks or months prior to the first uranium bomb detonation, with a period of several years being required to build and test the infrastructure and equipment necessary to do high-level enrichment, and several months required to actually do the enrichment.

By comparison to the U.S. and Soviet programs, the timeline of the wartime German nuclear program is much less clear and much more controversial. Figure D.1025 shows the “minimalist” scenario for the German timeline, based on the widely held conventional historical view that relatively little of significance was accomplished during the program [Bernstein 2001; Cassidy 1992, 2009; Frank 1993; Goudsmit 1945, Goudsmit 1947; Groves 1962; Hentschel and Hentschel 1996; Hoffmann 2023; Irving 1967; Pash 1969; Powers 1993; Rose 1998; Schaaf 2001; von Schirach 2015; Walker 1989, 1995, 2020, 2024a, 2024b]. The minimalist scenario may or may not be the correct view of the actual historical events, but the basic details claimed for the program and its timeline have remained relatively fixed across a wide range of minimalist authors for 75+ years; thus at least in that sense, one may regard the minimalist scenario as fairly well documented and relatively well understood.

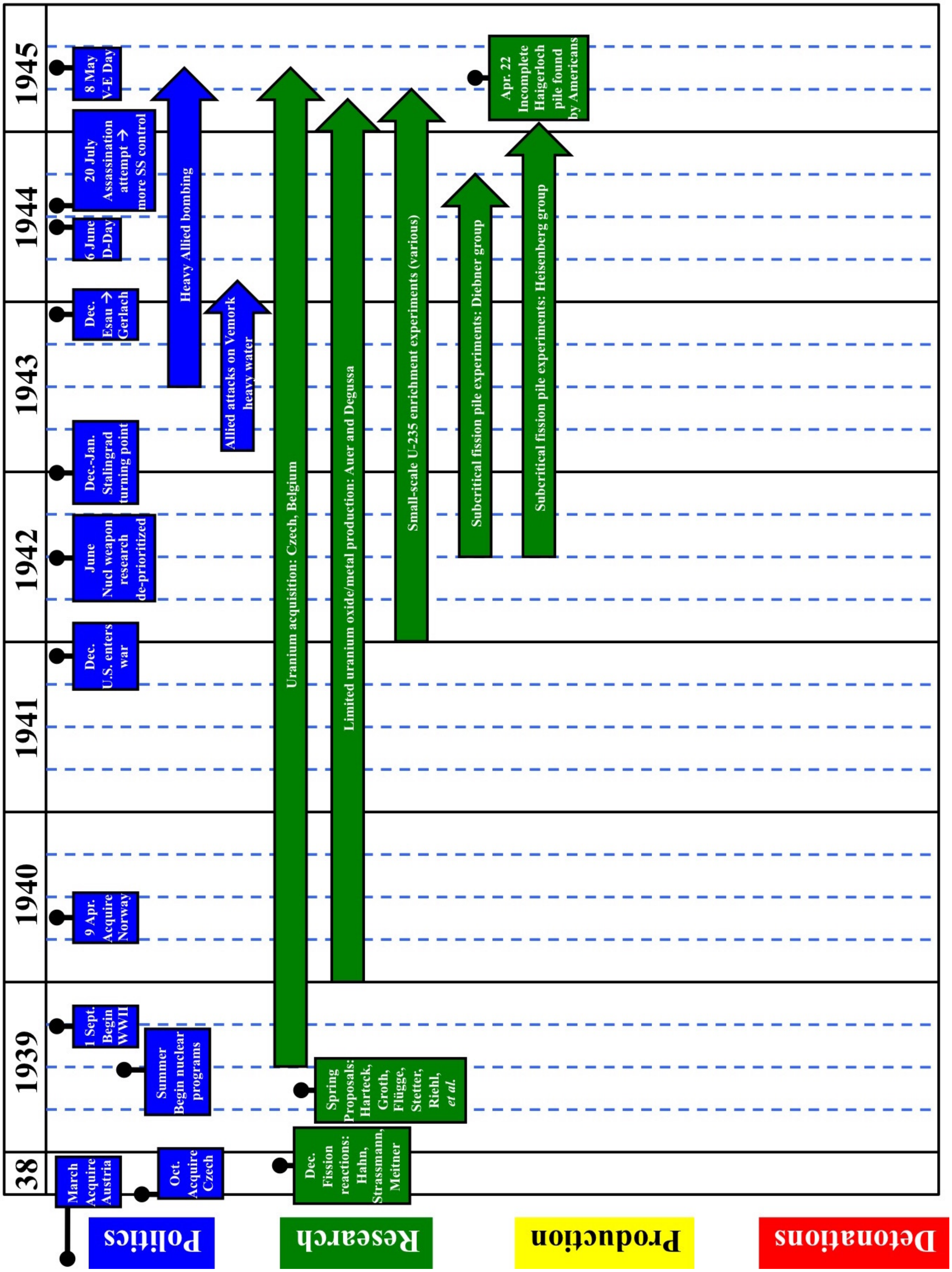
38
1939
1940
1941
1942
1943
1944
1945
March Acquire Austria
Oct. Acquire Czech
Summer Begin nuclear programs
1 Sept. Begin WWII
9 Apr. Acquire Norway
Dec. U.S. enters war
June Nucl weapon research de-prioritized
Dec.-Jan. Stalingrad turning point
Dec. Esau → Gerlach
6 June D-Day
20 July Assassination attempt → more SS control
8 May V-E Day
Heavy Allied bombing
Allied attacks on Vemork heavy water
Dec. Fission reactions: Hahn, Strassmann, Meitner
Spring Proposals: Harteck, Groth, Flügge, Stetter, Riehl, et al.
Uranium acquisition: Czech, Belgium
Limited uranium oxide/metal production: Auer and Degussa
Small-scale U-235 enrichment experiments (various)
Subcritical fission pile experiments: Diebner group
Subcritical fission pile experiments: Heisenberg group
Apr. 22 Incomplete Haigerloch pile found by Americans
Politics
Research
Production
Detonations

Figure D.1025: Timeline of the German nuclear weapons program, based on the minimalist scenario.

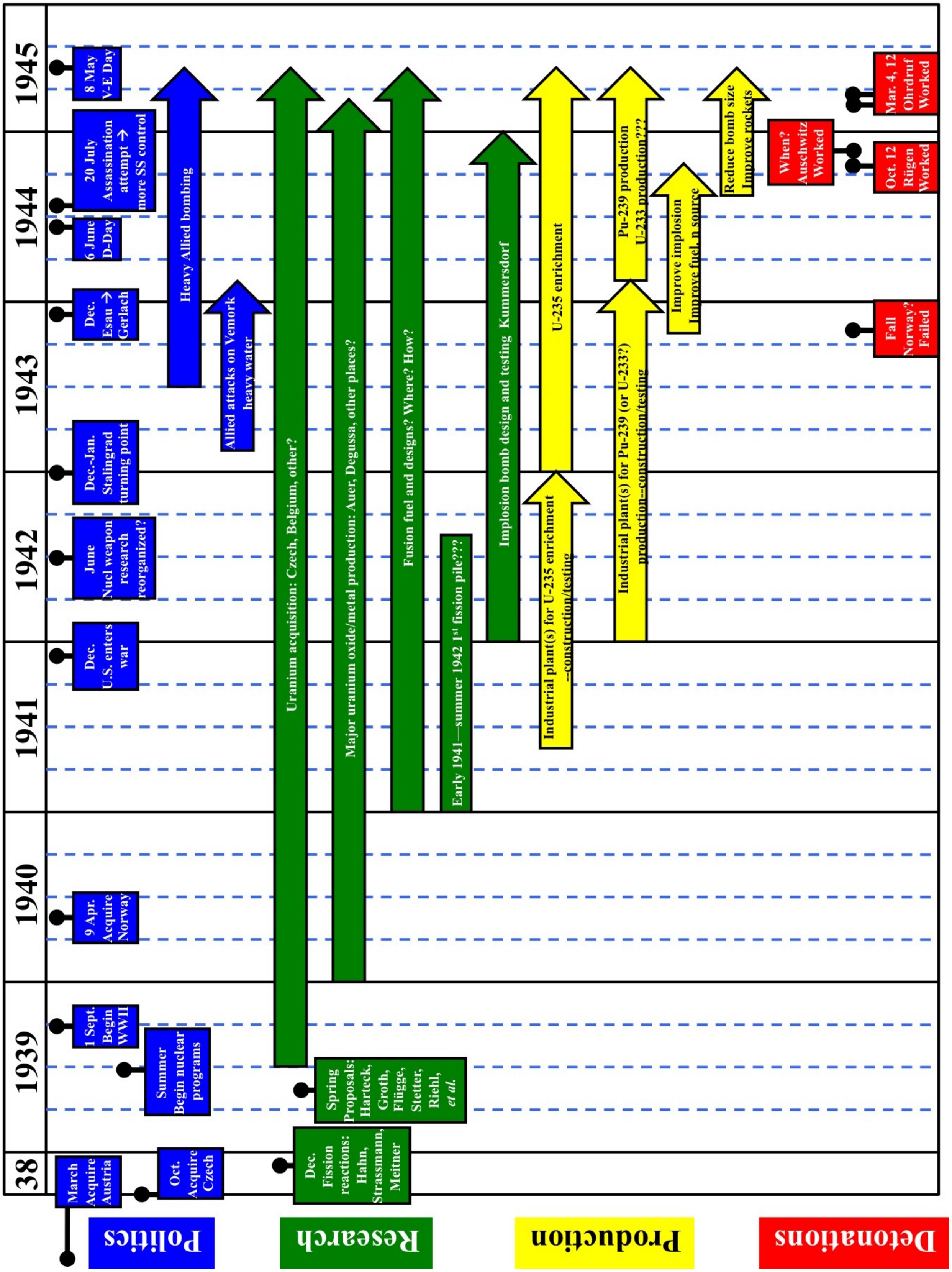

Figure D.1026: Timeline of the German nuclear weapons program, based on the maximalist scenario.

In stark contrast to the minimalist scenario, Fig. D.1026 shows the "maximalist" scenario for the German timeline, based largely on 2000–2002 interviews with Heinrich Himmler's chief adjutant Werner Grothmann, the source that both (a) made specific claims for the greatest amount of progress in the German nuclear program and (b) still had a plausible case for being historically well-informed. From p. 4436, the most profound claims made by Grothmann are that there was a failed nuclear weapons test in autumn 1943 in the North Sea, two successful tests in autumn 1944 (which could agree with the tests on the Baltic coast and in Poland that were reported by several other sources), and a test in March 1945 in Thuringia (or two tests, as reported by Ivan Ilyichev and Cläre Werner), and that Germany developed uranium bombs, plutonium bombs, and bombs apparently incorporating significant fusion reactions. As shown by the other documents quoted in this appendix, there is evidence from other sources that appears to support each of Grothmann's major claims. As was stated for the minimalist scenario, this maximalist scenario may or may not be the correct view of the actual historical events, but it is worthy of serious consideration and scrutiny.

The defining characteristics of the maximalist scenario are its end points—the development of uranium, plutonium, and fusion bombs, and the staging of at least five nuclear weapons tests before the end of the war. Unfortunately the key sources for the maximalist scenario give relatively little information about the program, intermediate steps, and timeline that led to those end points. Nonetheless, by using known historical events and parallels to the early U.S. and Soviet nuclear programs, one may "fill in the gaps" in the maximalist scenario and make plausible conjectures about the steps that would have been necessary for the German nuclear program to arrive at those end points:

1. For the very large and very urgent U.S. and Soviet nuclear programs, the time from the critical catalyzing event to the first atomic bomb detonation was roughly four years. Postwar Allied military accounts stated that the intense Allied bombing of Germany during the last two years of the war delayed Germany's development of new rockets, jets, and other strategic military technologies by at least six months. Coupled with materials shortages due to the Allied bombing and blockades, the total delay may have been more like 12 months. Thus one might expect that the German nuclear program would require roughly five years from its critical catalyzing event to its first successful bomb test. If the alleged 12 October 1944 atomic bomb test on the Baltic coast was indeed real and was indeed Germany's first successful test, one would look for a critical catalyzing event approximately five years before that, and the September 1939 declarations of war appear to be the most obvious choice. Corollaries to this line of reasoning are that:

    (a) If the German nuclear program began around September 1939 and truly did conduct a successful nuclear bomb test within five years (including the delays for Allied bombing and blockades), then during that five-year period, the German nuclear program would probably have had a size and urgency comparable to the U.S. and Soviet programs.

    (b) If the German nuclear program had been significantly smaller or less urgent than the wartime U.S. and postwar Soviet nuclear programs, it seems unlikely that it could have succeeded before the end of the war.

2. If Germany developed Pu-239 (or U-233) bombs, it would have needed to construct and operate one or more fission reactors (or a large electronuclear breeding program, which would have required a comparable amount of time). For the U.S. and Soviet programs, processed uranium oxide was already available prior to the critical catalyzing event (from earlier work for the U.S. program, and from German work for the Soviet program), and the first fission reactor became operational 12–16 months after the catalyzing event. A second, alternative criterion is that for both the U.S. and Soviet programs, the first fission reactor became operational approximately 32 months before a functional plutonium implosion bomb, due to the time required to transition from a small laboratory reactor to a large industrial reactor, create and optimize the plutonium extraction process, and actually produce enough plutonium for a bomb. Using the first criterion, if Germany had a critical catalyzing event in September 1939 and began processing uranium ore into uranium oxide at the beginning of 1940, one would expect the first fission reactor to become operational no earlier than the beginning of 1941. Using the second criterion, if Germany had a functional plutonium bomb ready no later than April 1945, one would expect the first fission reactor to have become operational no later than August 1942. How much evidence is there that Germany had one or more functional fission reactors? Is there any evidence that Germany's first fission reactor became operational sometime between early 1941 and summer 1942? If that actually happened, Germany would have demonstrated the world's first fission reactor sometime before the U.S. CP-1 became operational. Corollaries to this line of reasoning include:

    (a) If Germany did not have a functional fission reactor (or a very large electronuclear breeding program), it could not have had a serious plutonium bomb program.

    (b) If Germany had a functional fission reactor but it first became operational much later than August 1942 (or if the electronuclear breeding program became operational too late in the war), any plutonium bomb design would probably have still been waiting to receive a sufficient mass of Pu-239 when the war ended.

    (c) If Germany had a plutonium bomb program and operational fission reactors or electronuclear breeders, an industrial plant for extracting Pu-239 from spent uranium fuel (or U-233 from thorium) would have likely been adjacent to one or more of the fission reactors or electronuclear breeders.

3. It took the U.S. and Soviet programs at least 2.5 years to construct and test infrastructure and equipment to enrich U-235 to weapons-grade levels and to produce enough U-235 for their first uranium bombs; even before building that infrastructure, significant time was spent to research and develop the underlying scientific techniques. If Germany had enough enriched uranium to attempt a U-235 bomb test in late 1943, it most likely would have to have begun building industrial enrichment plants no later than early 1941, and to have been researching and developing enrichment techniques in laboratories before that. If Germany did not have enough enriched uranium for a bomb until March 1945, construction of industrial enrichment plants could have begun as late as around September 1942.

    (a) What evidence is there for large-scale, early, and/or high-level uranium enrichment work in Germany?

    (b) What possible industrial uranium enrichment plants began construction in 1941–1942?

4. If Germany conducted a failed bomb test in autumn 1943 but successful tests in autumn 1944, much of the work during the intervening period would have been focused on solving the problem(s) that led to the failure. (The failed autumn 1943 test may also account for the replacement of Abraham Esau by Walther Gerlach as "Plenipotentiary of Nuclear Physics" in late 1943.) The most obvious improvements would be:
    (a) Improving the implosion system to better synchronize and improve the symmetry of the implosion, and/or to increase the degree of compression of the fission fuel during the implosion.
    (b) Increasing the mass and/or purity of the fission fuel.
    (c) Improving the neutron output and/or reliability of the neutron source used to initiate a chain reaction when the fission fuel is maximally compressed.
5. If Germany conducted one or more successful bomb tests in autumn 1944 but still felt the need to conduct more bomb tests in March 1945, the simplest explanation is that the autumn 1944 bomb was so large and heavy (like the U.S. bombs) that it was much better suited to being dropped from an aircraft than carried by a rocket. Most German aircraft had become vulnerable to Allied attacks, whereas rockets could not be intercepted. Thus much of the work between autumn 1944 and March 1945 would have been focused on:
    (a) Reducing the mass and diameter of the bomb.
    (b) Increasing the payload capacity, range, and accuracy of rockets to carry the bomb.

It is important to reiterate that both the minimalist and maximalist scenarios considered here are hypothetical constructs that may be useful in thinking about this murky area of history. Each of these scenarios may or may not actually be true history; certainly both scenarios cannot be simultaneously correct. What were the actual historical events of the real German wartime nuclear program (Fig. D.1027)? Were they some suitably refined version of the minimalist scenario, some refined version of the maximalist scenario, or something intermediate between those two scenarios?

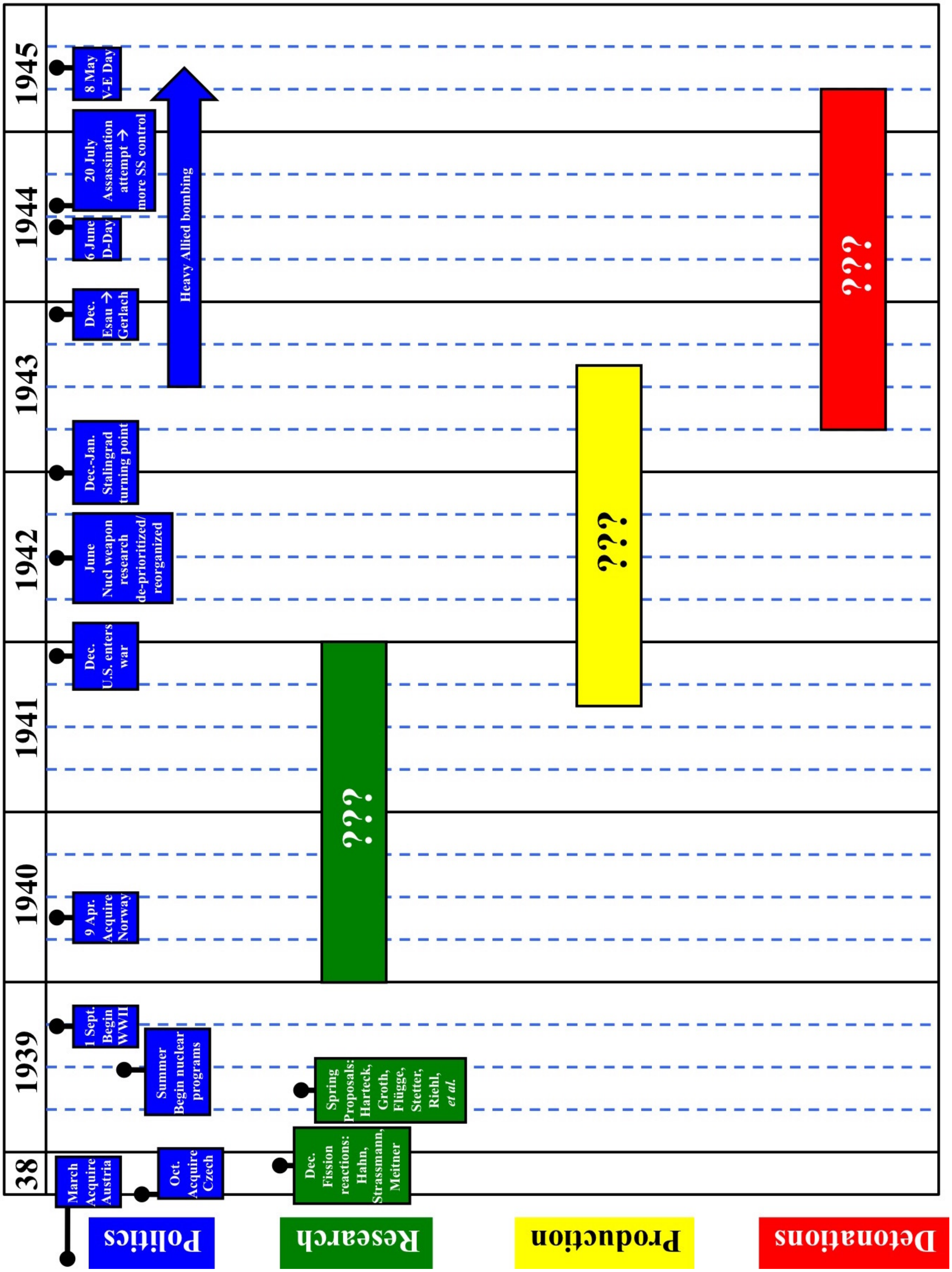

Figure D.1027: Timeline of the German nuclear weapons program, based on actual historical events.

D. Organization of the German Nuclear Program

The German nuclear program was very large and highly compartmentalized. Because so much of the relevant information was destroyed by the Germans at the end of the war or captured and classified by different Allied countries after the war, it is quite difficult for modern historians to accurately reconstruct the organizational details of the program.

Page 5109 presents a tentative organizational chart of the German nuclear program, based on information such as that from pp. 1565–1629 and 3402–3403.

In a nutshell, the overall management of the program was handled by the Army in the earlier years of the war and by the SS in the later years of the war, both with some input from the Reich Research Council.

Those managing agencies oversaw work that was spread over at least a couple dozen different organizations (military groups, other government-run laboratories, companies, and universities), many of which had multiple physical locations.

There was considerable redundancy among those organizations in their work, which may seem inefficient to the modern observer but appears to have served well to make the German nuclear program much less vulnerable to Allied intelligence and bombing.

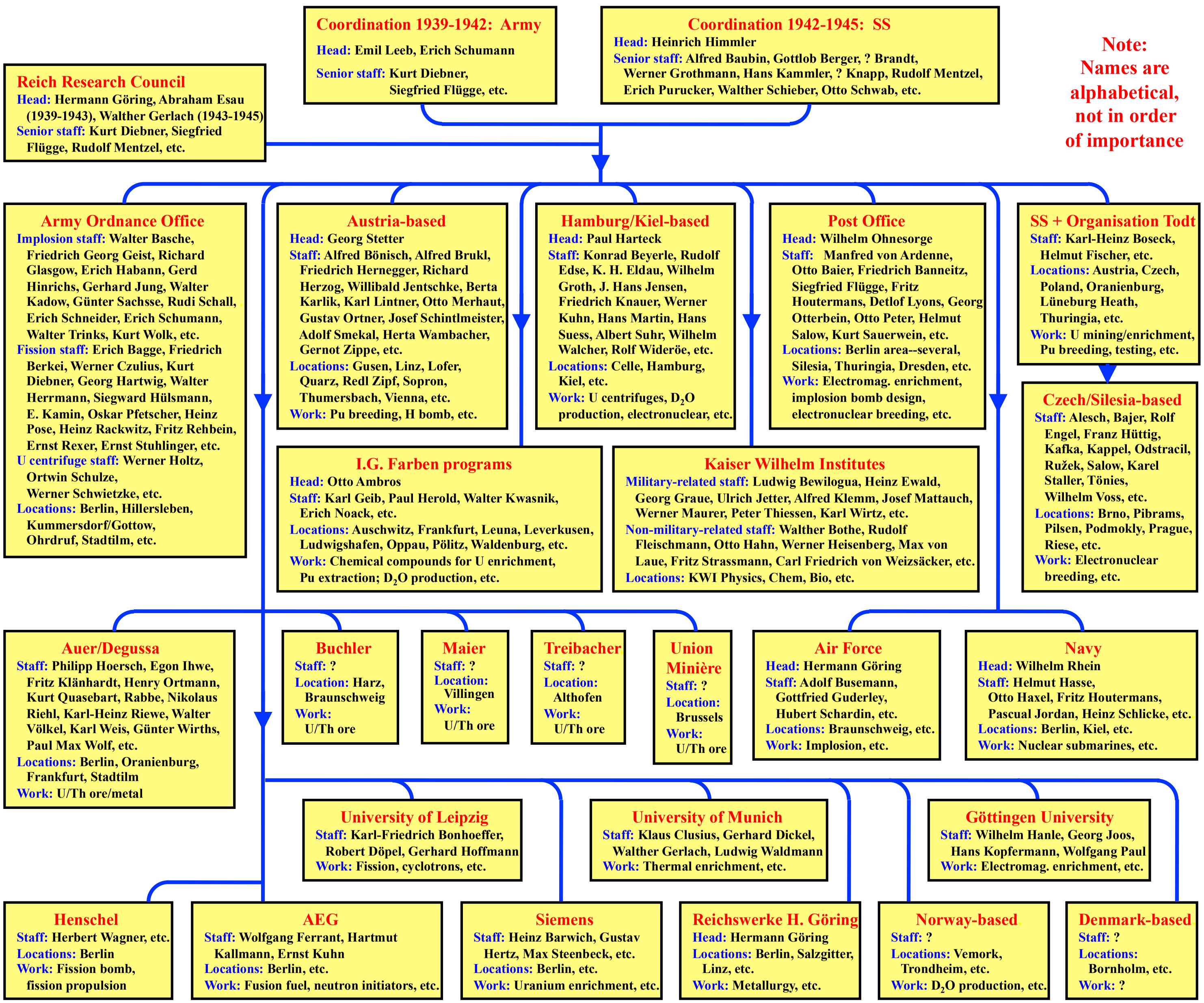
Note: Names are alphabetical, not in order of importance
Reich Research Council
Head: Hermann Göring, Abraham Esau (1939-1943), Walther Gerlach (1943-1945)
Senior staff: Kurt Diebner, Siegfried Flügge, Rudolf Mentzel, etc.
Coordination 1939-1942: Army
Head: Emil Leeb, Erich Schumann
Senior staff: Kurt Diebner, Siegfried Flügge, etc.
Coordination 1942-1945: SS
Head: Heinrich Himmler
Senior staff: Alfred Baubin, Gottlob Berger, ? Brandt, Werner Grothmann, Hans Kammler, ? Knapp, Rudolf Mentzel, Erich Purucker, Walther Schieber, Otto Schwab, etc.
Army Ordnance Office
Implosion staff: Walter Basche, Friedrich Georg Geist, Richard Glasgow, Erich Habann, Gerd Hinrichs, Gerhard Jung, Walter Kadow, Günter Sachsse, Rudi Schall, Erich Schneider, Erich Schumann, Walter Trinks, Kurt Wolk, etc.
Fission staff: Erich Bagge, Friedrich Berkei, Werner Czulius, Kurt Diebner, Georg Hartwig, Walter Herrmann, Siegward Hülsmann, E. Kamin, Oskar Pfetscher, Heinz Pose, Heinz Rackwitz, Fritz Rehbein, Ernst Rexer, Ernst Stuhlinger, etc.
U centrifuge staff: Werner Holtz, Ortwin Schulze, Werner Schwietzke, etc.
Locations: Berlin, Hillersleben, Kummersdorf/Gottow, Ohrdruf, Stadtilm, etc.
Austria-based
Head: Georg Stetter
Staff: Alfred Bönisch, Alfred Brukl, Friedrich Hernegger, Richard Herzog, Willibald Jentschke, Berta Karlik, Karl Lintner, Otto Merhaut, Gustav Ortner, Josef Schintlmeister, Adolf Smekal, Herta Wambacher, Gernot Zippe, etc.
Locations: Gusen, Linz, Lofer, Quarz, Redl Zipf, Sopron, Thumersbach, Vienna, etc.
Work: Pu breeding, H bomb, etc.
Hamburg/Kiel-based
Head: Paul Harteck
Staff: Konrad Beyerle, Rudolf Edse, K. H. Eldau, Wilhelm Groth, J. Hans Jensen, Friedrich Knauer, Werner Kuhn, Hans Martin, Hans Suess, Albert Suhr, Wilhelm Walcher, Rolf Wideröe, etc.
Locations: Celle, Hamburg, Kiel, etc.
Work: U centrifuges, D_2O production, electronuclear, etc.
Post Office
Head: Wilhelm Ohnesorge
Staff: Manfred von Ardenne, Otto Baier, Friedrich Banneitz, Siegfried Flügge, Fritz Houtermans, Detlof Lyons, Georg Otterbein, Otto Peter, Helmut Salow, Kurt Sauerwein, etc.
Locations: Berlin area--several, Silesia, Thuringia, Dresden, etc.
Work: Electromag. enrichment, implosion bomb design, electronuclear breeding, etc.
SS + Organisation Todt
Staff: Karl-Heinz Boseck, Helmut Fischer, etc.
Locations: Austria, Czech, Poland, Oranienburg, Lüneburg Heath, Thuringia, etc.
Work: U mining/enrichment, Pu breeding, testing, etc.
Czech/Silesia-based
Staff: Alesch, Bajer, Rolf Engel, Franz Hüttig, Kafka, Kappel, Odstracil, Ružek, Salow, Karel Staller, Tönies, Wilhelm Voss, etc.
Locations: Brno, Pibrams, Pilsen, Podmokly, Prague, Riese, etc.
Work: Electronuclear breeding, etc.
I.G. Farben programs
Head: Otto Ambros
Staff: Karl Geib, Paul Herold, Walter Kwasnik, Erich Noack, etc.
Locations: Auschwitz, Frankfurt, Leuna, Leverkusen, Ludwigshafen, Oppau, Pölitz, Waldenburg, etc.
Work: Chemical compounds for U enrichment, Pu extraction; D_2O production, etc.
Kaiser Wilhelm Institutes
Military-related staff: Ludwig Bewilogua, Heinz Ewald, Georg Graue, Ulrich Jetter, Alfred Klemm, Josef Mattauch, Werner Maurer, Peter Thiessen, Karl Wirtz, etc.
Non-military-related staff: Walther Bothe, Rudolf Fleischmann, Otto Hahn, Werner Heisenberg, Max von Laue, Fritz Strassmann, Carl Friedrich von Weizsäcker, etc.
Locations: KWI Physics, Chem, Bio, etc.
Auer/Degussa
Staff: Philipp Hoersch, Egon Ihwe, Fritz Klänhardt, Henry Ortmann, Kurt Quasebart, Rabbe, Nikolaus Riehl, Karl-Heinz Riewe, Walter Völkel, Karl Weis, Günter Wirths, Paul Max Wolf, etc.
Locations: Berlin, Oranienburg, Frankfurt, Stadtilm
Work: U/Th ore/metal
Buchler
Staff: ?
Location: Harz, Braunschweig
Work: U/Th ore
Maier
Staff: ?
Location: Villingen
Work: U/Th ore
Treibacher
Staff: ?
Location: Althofen
Work: U/Th ore
Union Minière
Staff: ?
Location: Brussels
Work: U/Th ore
Air Force
Head: Hermann Göring
Staff: Adolf Busemann, Gottfried Guderley, Hubert Schardin, etc.
Locations: Braunschweig, etc.
Work: Implosion, etc.
Navy
Head: Wilhelm Rhein
Staff: Helmut Hasse, Otto Haxel, Fritz Houtermans, Pascual Jordan, Heinz Schlicke, etc.
Locations: Berlin, Kiel, etc.
Work: Nuclear submarines, etc.
University of Leipzig
Staff: Karl-Friedrich Bonhoeffer, Robert Döpel, Gerhard Hoffmann
Work: Fission, cyclotrons, etc.
University of Munich
Staff: Klaus Clusius, Gerhard Dickel, Walther Gerlach, Ludwig Waldmann
Work: Thermal enrichment, etc.
Göttingen University
Staff: Wilhelm Hanle, Georg Joos, Hans Kopfermann, Wolfgang Paul
Work: Electromag. enrichment, etc.
Henschel
Staff: Herbert Wagner, etc.
Locations: Berlin
Work: Fission bomb, fission propulsion
AEG
Staff: Wolfgang Ferrant, Hartmut Kallmann, Ernst Kuhn
Locations: Berlin, etc.
Work: Fusion fuel, neutron initiators, etc.
Siemens
Staff: Heinz Barwich, Gustav Hertz, Max Steenbeck, etc.
Locations: Berlin, etc.
Work: Uranium enrichment, etc.
Reichswerke H. Göring
Head: Hermann Göring
Locations: Berlin, Salzgitter, Linz, etc.
Work: Metallurgy, etc.
Norway-based
Staff: ?
Locations: Vemork, Trondheim, etc.
Work: D_2O production, etc.
Denmark-based
Staff: ?
Locations: Bornholm, etc.
Work: ?

Figure D.1028: Very tentative organizational chart of the German nuclear program.

In order to understand the science of the German nuclear program, it is helpful to look at the program from a different viewpoint other than organizational approach of Fig. D.1028. In the film *All the President's Men*, the advice to "follow the money" was the key to investigating Watergate. Similarly, the key to investigating the wartime German nuclear program should be to "follow the actinides." Actinides are fissionable heavy elements, chiefly thorium, uranium, and plutonium.

Unfortunately, many vital details about the flow of actinides in the Third Reich are presently unknown.

As a guide in understanding the currently available information and in seeking more extensive information, p. 5111 presents a tentative and simplified overview of the actinide pathways and possibilities.

Much more research is needed to investigate and to clarify whether and how these pathways were actually implemented during the war.

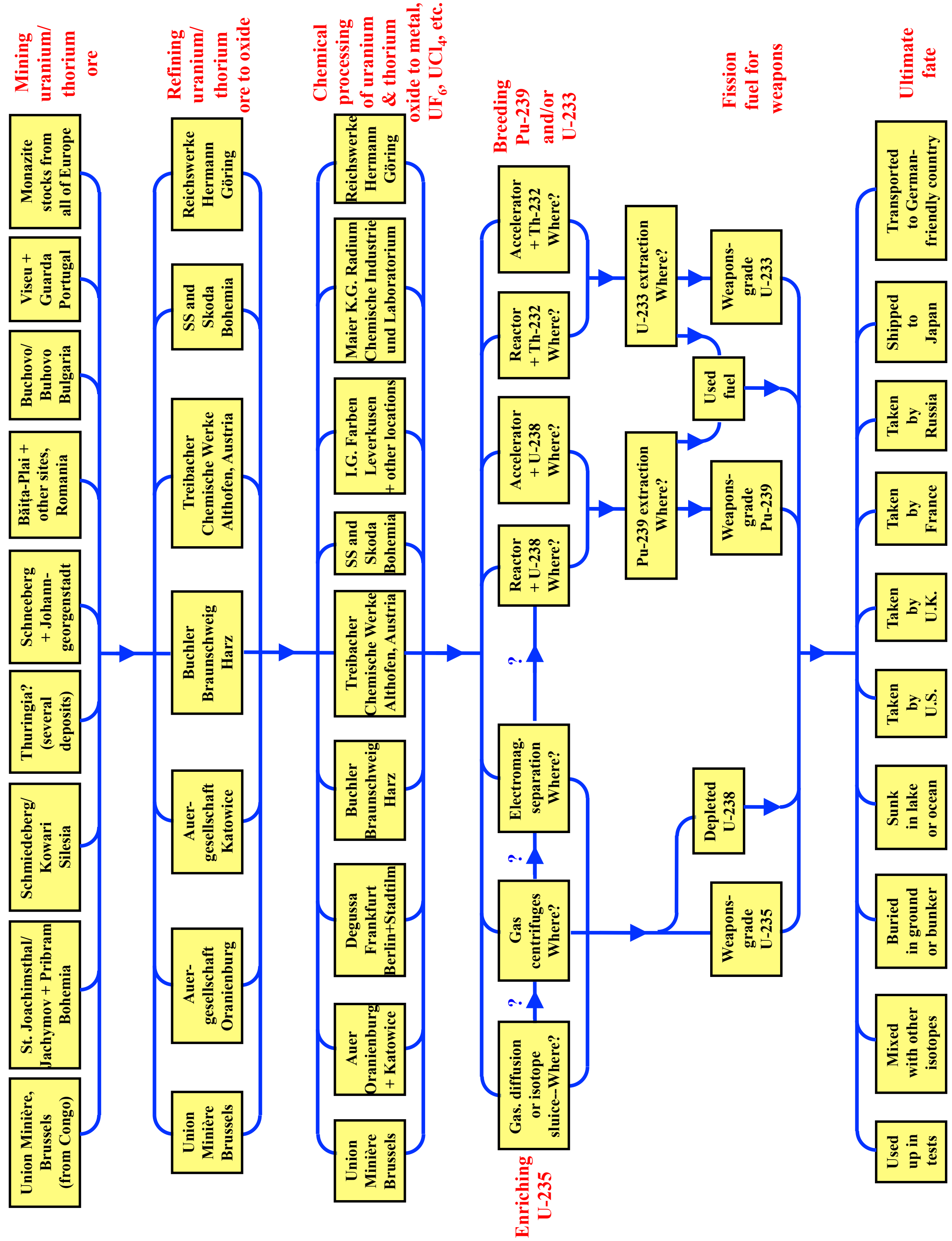
Mining uranium/ thorium ore
Union Minière, Brussels (from Congo)
St. Joachimsthal/ Jachymov + Pribram Bohemia
Schmiedeberg/ Kowari Silesia
Thuringia? (several deposits)
Schneeberg + Johann- georgenstadt
Băița-Plai + other sites, Romania
Buchovo/ Buhovo Bulgaria
Viseu + Guarda Portugal
Monazite stocks from all of Europe
Refining uranium/ thorium ore to oxide
Union Minière Brussels
Auer- gesellschaft Oranienburg
Auer- gesellschaft Katowice
Buchler Braunschweig Harz
Treibacher Chemische Werke Althofen, Austria
SS and Skoda Bohemia
Reichswerke Hermann Göring
Chemical processing of uranium & thorium oxide to metal, UF$_6$, UCl$_4$, etc.
Union Minière Brussels
Auer Oranienburg + Katowice
Degussa Frankfurt Berlin+Stadtilm
Buchler Braunschweig Harz
Treibacher Chemische Werke Althofen, Austria
SS and Skoda Bohemia
I.G. Farben Leverkusen + other locations
Maier K.G. Radium Chemische Industrie und Laboratorium
Reichswerke Hermann Göring
Enriching U-235
Gas. diffusion or isotope sluice--Where?
?
Gas centrifuges Where?
?
Electromag. separation Where?
?
Breeding Pu-239 and/or U-233
Reactor + U-238 Where?
Accelerator + U-238 Where?
Reactor + Th-232 Where?
Accelerator + Th-232 Where?
Depleted U-238
Pu-239 extraction Where?
Used fuel
U-233 extraction Where?
Fission fuel for weapons
Weapons- grade U-235
Weapons- grade Pu-239
Weapons- grade U-233
Ultimate fate
Used up in tests
Mixed with other isotopes
Buried in ground or bunker
Sunk in lake or ocean
Taken by U.S.
Taken by U.K.
Taken by France
Taken by Russia
Shipped to Japan
Transported to German- friendly country

Figure D.1029: Known and extrapolated actinide (thorium, uranium, and plutonium) use in the German nuclear program.

During the war, Germany had access to large amounts of natural uranium and thorium ore by (see map on p. 3405):

- Acquiring at least 1200 tons, and according to some well-informed sources 3500 tons, of uranium compounds (originally mined in the Belgian Congo) from Union Minière in Brussels [e.g., pp. 3335, 3408–3414].
- Expanding uranium mining at St. Joachimsthal (Jachymov), Bohemia [e.g., pp. 3418–3429, 3445, 3469–3470, 4978–4984; Hayes 2004, pp. 132–133, 235, 243].
- Mining uranium at Příbram/Przibram/Pibrans, Bohemia [e.g, pp. 3424, 3470, 3751–3754].
- Mining uranium at Schmiedeberg, Silesia [e.g., pp. 3328, 3424, 3429, 3445, 3471].
- Possibly using any of several uranium deposits in Thuringia [e.g., pp. 3468–3469; Zeman and Karlsch 2008].
- Mining uranium at Schneeberg, Saxony [e.g., pp. 3416, 3424, 3426–3428, 3433–3437, 3445, 3456, 3468–3469, 3708, 4922; Zeman and Karlsch 2008].
- Mining uranium at Johanngeorgenstadt, Saxony [e.g., pp. 3416, 3424, 3426–3428, 3433–3437, 3456, 3468–3469, 3708, 4922; Zeman and Karlsch 2008].
- Mining uranium at Freiberg, Saxony [e.g., pp. 3424, 3426–3429, 3445, 3468–3469].
- Mining uranium at Durrnaul near Marienbad [e.g., p. 3424].
- Mining or planning to mine uranium at Mladkov/Wichstadt, Bohemia [e.g., p. 3425].
- Operating and receiving shipments from Bulgarian uranium mines such as a mine at Buchovo (or Buhovo, a suburb of Sofia), since 1938 [e.g., Hayes 2004, p. 235; https://ejatlas.org/conflict/life-after-the-uranium-mines-in-buhovo-bulgaria]. See also pp. 3446, 3470, 4588.
- Mining uranium at Băiţa-Plai and other sites in Romania [e.g., pp. 3449–3455, 3471].
- Acquiring uranium from mines at Viseu and Guarda, Portugal [e.g., p. 3445; Hayes 2004, p. 235].
- Procuring all available monazite thorium ore in occupied Europe [e.g., Irving 1967].
- Exploiting other possible sources—Spain, Scandinavia, etc.?

One 1946 U.S. intelligence report on Czech uranium mines noted, “The Germans put mining on a high priority and only mining was done throughout the 6 years occupation. The ore was delivered by special planes to Germany and Austria” (p. 3998). Another 1946 U.S. intelligence report added: “The Germans continued operations in this mine to the very last moment” (p. 4981).

Thus Germany began actively mining uranium in 1938 and continued until the end of the war. During that time, Germany had access to (1) the same quality and a comparable quantity of Congolese uranium that served the Manhattan Project well, (2) Central/Eastern European uranium mines that later served the Soviet nuclear program well, and (3) additional uranium mines too.

Germany processed uranium and thorium ore to uranium oxide and thorium oxide, and thence to uranium or thorium metal or to a variety of useful chemical compounds—uranium hexafluoride, uranium tetrachloride, uranium nitrate, etc.—at numerous locations including (see map on p. 3407):

- Union Minière in Brussels [e.g., pp. 3335, 3408–3414; Irving 1967, p. 65].
- Auer in Oranienburg, Katowice/Kattowitz, and other locations [e.g., pp. 3446, 3458, 3461–3463, 3465, 4980; Nagel 2016].
- Buchler in Braunschweig [e.g., pp. 3420, 3430–3431, 3458, 3460–3463, 3465, 4980].
- Treibacher Chemische Werke in Althofen, Austria [e.g., pp. 3420, 3432–3437, 3458, 3460, 4980; Gollmann 1994].
- Degussa in Frankfurt, Berlin, Stadtilm, and possibly other locations [e.g., pp. 3458, 3461–3465; Hayes 2004; Nagel 2016].
- Chemische Fabrik Grünau in Berlin [e.g., pp. 3438–3439, 3461–3463].
- I.G. Farben in Leverkusen and other locations [e.g., pp. 3488–3489, 3492–3493, 3678–3680, 3748–3750, 4440–4477; Mader 1965, pp. 193–202, 229-233].
- Krupp in Essen [e.g., pp. 3458, 3461–3463, 3465–3467].
- W. de Boer in Hamburg and Wittingen [e.g., pp. 3458, 3461–3463, 3465].
- Radium-Chemie AG in Frankfurt [e.g., pp. 3440–3441, 3458, 3465].
- W. Maier KG Radiumchemische Industrie und Laboratorium in Villingen-Schwenningen am Neckar and other locations [e.g., Oleynikov 2000].
- Příbram/Przibram/Pibrans, Bohemia [e.g., pp. 3423, 3751–3754].
- Facilities in Dresden [e.g., pp. 3423, 3426].
- Reichswerke Hermann Göring in Linz and other locations [e.g., pp. 3877–3880].
- Possibly other facilities.

At the end of the war, Allied countries removed over 2800 tons of uranium and thorium compounds from former German-controlled territory (p. 3456). In addition, in 1974, Alwin Urff, deputy technical plant manager of the Asse nuclear disposal site in Germany, stated: “When we began storage in 1967, our company first sank radioactive waste from the last war, that uranium waste which arose in the preparation of the German atomic bomb” (p. 3472).

German scientists developed and demonstrated methods of enriching uranium-235 from natural uranium:

- Konrad Beyerle, Wilhelm Groth, Werner Holtz, Werner Schwietzke, and many others worked in teams that developed gas centrifuges to enrich uranium-235. Centrifugation proved so superior to the U.S. Manhattan Project's enrichment methods that the German gas centrifuge designs are now the worldwide standard for uranium enrichment (p. 3494).

- Manfred von Ardenne, Heinz Ewald, Wolfgang Paul, Wilhelm Walcher, and many others worked in teams that developed electromagnetic separators to enrich uranium-235. These electromagnetic separators were comparable to the Manhattan Project's calutrons (p. 3554).

- Erich Bagge invented and successfully demonstrated a unique uranium enrichment device called an isotope sluice, which combined some features of centrifuges, electromagnetic separators, and gaseous diffusion (p. 3651).

- Erika Cremer, Rudolf Fleischmann, Gustav Hertz, and others developed gaseous diffusion methods suitable for enriching uranium-235 that were comparable to the Manhattan Project's gaseous diffusion technology (p. 3618).

These enrichment methods are analyzed in Section D.15.2.

If Germany scaled up any of these proven uranium enrichment methods in order to produce nuclear weapons, it would presumably have distributed that production capability among a number of small underground locations for protection against Allied bombing. Archival documents mention dozens of highly suspicious sites that might have been used for that purpose and that still have not been properly investigated (p. 3670).

Two or more enrichment methods might have been used together, with one method enriching natural uranium to a level moderately enriched in uranium-235, then forwarding that material to another method to be enriched to a higher level.

Among the few currently available sources, there is some evidence that German scientists were working on breeding plutonium-239 or uranium-233:

- Ludwig Bewilogua, Kurt Diebner, Paul Harteck, Otto Haxel, and many others worked in teams trying to develop fission reactors suitable for breeding plutonium-239 from natural uranium-238 or uranium-233 from natural thorium-232. Two reactors were on the brink of criticality by the end of the war, and there is some evidence that other reactors may have actually become operational during the war (p. 3794).

- Walther Bothe, Walter Dällenbach, Max Steenbeck, Rolf Wideröe, and many others worked on particle-accelerator-driven electronuclear systems suitable for breeding plutonium-239 from natural uranium-238 or uranium-233 from natural thorium-232. There is some evidence that such systems may have been operational during the war (p. 3954).

These breeding methods are analyzed in Section D.15.3.

One or more enrichment methods might have also been used in conjunction with one or more breeding methods, providing uranium somewhat enriched in uranium-235 to a fission reactor or electronuclear breeder to make it easier to produce neutrons and thus easier to breed plutonium-239 from the remaining uranium-238.

Various subsets of the above processes could have produced any or all of these fission fuels for nuclear weapons:

- Uranium-235.
- Plutonium-239.
- Uranium-233.

If the Third Reich ever truly had significant quantities of any bomb-grade fission fuel, as well as the actinide waste products from enriching and/or breeding that fuel, they must have been disposed of in one or more of the following ways:

- Used up in test explosions.
- Smelted together with large enough quantities of natural uranium or other materials to render them effectively unusable.
- Buried in the ground or a bunker, sunk in a lake or ocean, or otherwise hidden so well that they were never found, or were found only after the Soviet nuclear program was already very far along.
- Captured by the United States.
- Captured by the United Kingdom.
- Captured by France.
- Captured by Russia (only small quantities and/or discovered years later[26]).
- Shipped to Japan.
- Sent to other sympathetic countries, such as Switzerland, Spain, Argentina, etc.

---

[26] While the postwar Soviet program benefited enormously from all of the German scientists, materials, equipment, and information it acquired, it still required four full years after the war to produce enough plutonium for one plutonium bomb test, RDS-1/Joe-1, and even longer to produce enough highly enriched uranium for its first uranium-235-based bomb test, RDS-2/Joe-2. Stalin was desperate to test a nuclear weapon as soon as he possibly could, in order to show the world that the United States was not the only nuclear superpower (p. 4533). Therefore, the timeline of the Soviet nuclear program appears to prove that as many spoils as the Soviets found in Germany and former German-occupied territories, useful quantities of plutonium-239, uranium-233, or highly enriched uranium-235 were not among them, or perhaps were only discovered after the Soviets had produced enough of their own fission fuel.

D.15.2 Enrichment Methods to Produce U-235

Uranium ore in most deposits typically consists of 0.1–2% uranium mixed with other elements. As the first step in processing, the uranium ore is milled or refined to at least 80% U_3O_8; this refined product is called yellowcake due to its color.

By mass, natural uranium contains approximately 0.72% ^{235}U, 99.275% ^{238}U, and just a trace amount (0.005%) of ^{234}U. Natural uranium can be used in fission reactors employing either heavy water or very pure graphite (not contaminated by neutron-absorbing boron) as a moderator to slow down the neutrons and facilitate the chain reaction. For use in reactors using light (ordinary) water as a moderator, the ^{235}U content of the fuel must be increased to 2–4%. For use in fast reactors or fission bombs, the ^{235}U content must be increased to $\sim$50–90% (the higher the better). The excess ^{238}U that is removed is called depleted uranium or tails; it used for other applications such as military ammunition and nuclear bomb casings, due to its very high density and other properties.

Preferentially accumulating one isotope versus another of the same element is called enrichment. As shown in Fig. D.1030, there are several different methods of enrichment:

A. Electromagnetic separation.

B. Gaseous diffusion.

C. Centrifugation.

D. Laser isotope separation.

The first two enrichment methods were used by the United States during World War II. Centrifugation is the main method used worldwide now. Laser isotope separation has been investigated for potential future use.

There is evidence that the wartime German nuclear program conducted research on all four of these enrichment methods. It is possible that any or all of the first three methods were used to produce enriched uranium for nuclear weapons, although most of the relevant information was either destroyed or may remain buried in classified archives. Much more work is needed to investigate the locations and methods of uranium enrichment that were used in the German nuclear program, as well as the amount and purity of the material that was produced.

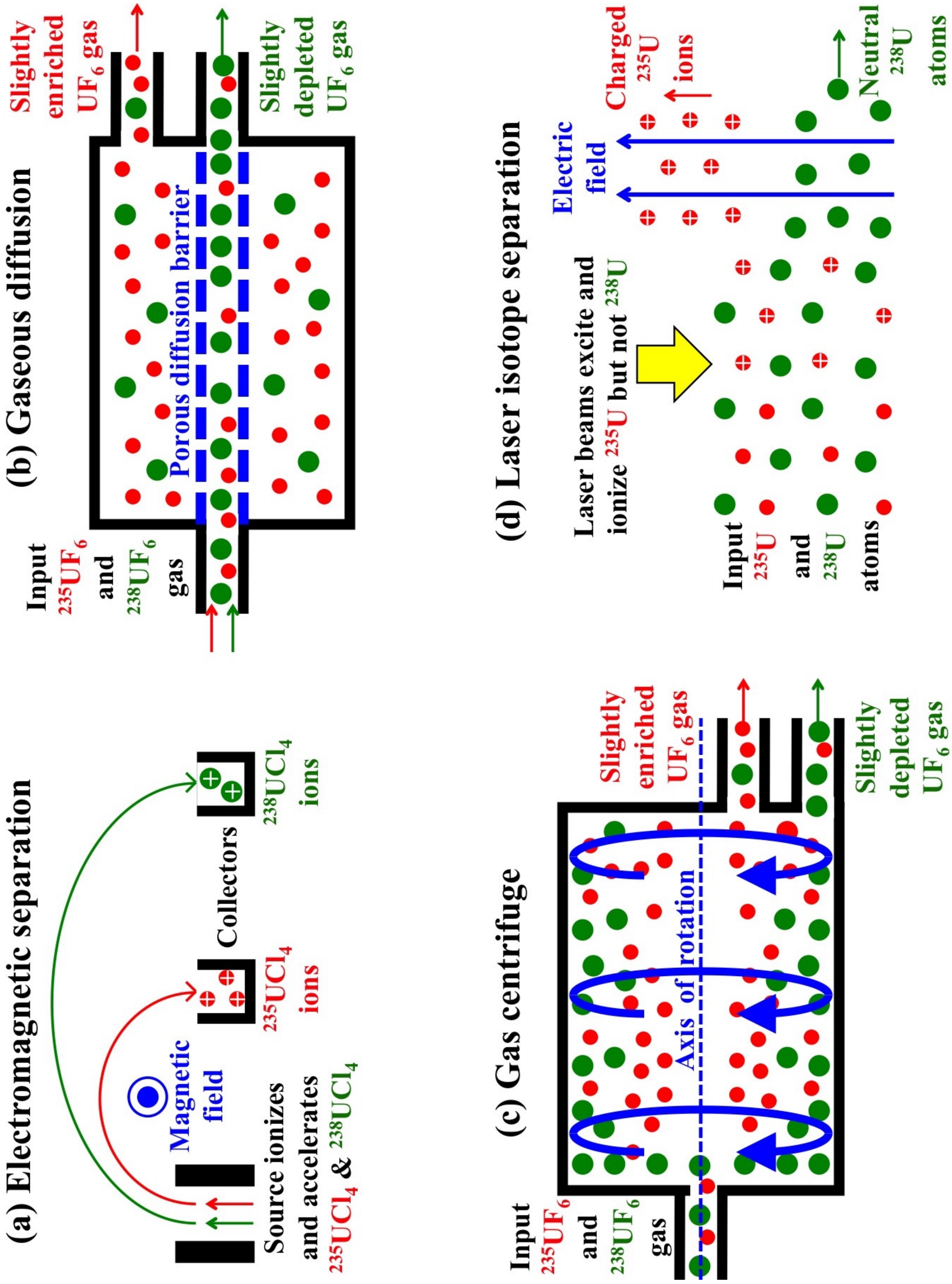
(a) Electromagnetic separation
Magnetic field
Collectors
^{235}UCl$_4$ ions
^{238}UCl$_4$ ions
Source ionizes and accelerates ^{235}UCl$_4$ & ^{238}UCl$_4$
(b) Gaseous diffusion
Input ^{235}UF$_6$ and ^{238}UF$_6$ gas
Porous diffusion barrier
Slightly enriched UF$_6$ gas
Slightly depleted UF$_6$ gas
(c) Gas centrifuge
Input ^{235}UF$_6$ and ^{238}UF$_6$ gas
Axis of rotation
Slightly enriched UF$_6$ gas
Slightly depleted UF$_6$ gas
(d) Laser isotope separation
Laser beams excite and ionize ^{235}U but not ^{238}U
Input ^{235}U and ^{238}U atoms
Electric field
Charged ^{235}U ions
Neutral ^{238}U atoms

Figure D.1030: Uranium enrichment methods include (a) electromagnetic separation, (b) gaseous diffusion, (c) centrifugation, and (d) laser isotope separation.

A. Electromagnetic Separation

Mass spectrometers or circular particle accelerators can separate particles with different masses, as illustrated in Fig. D.1030(a). If uranium atoms are ionized and accelerated to a certain energy, an applied magnetic field can bend the paths of the uranium ions, with the trajectories of lower-mass ^{235}U ions having more curvature than those of higher-mass ^{238}U ions. This effect creates spatial separation between the two isotopes and thus can enrich the isotopes to very high purities. However, because of the very low particle densities and sophisticated equipment required, this enrichment approach tends to be very expensive for fission fuel. Nonetheless, all highly enriched ^{235}U produced in the United States during and soon after World War II was purified using electromagnetic separators called calutrons. Since the calutrons could produce highly enriched uranium but were limited by how much uranium they could process, they were most effective when they were fed with low-enriched uranium (from a separate gaseous diffusion plant) instead of natural uranium [Bruce Cameron Reed 2015a, 2019].

Manfred von Ardenne, Heinz Ewald, Wolfgang Paul, Wilhelm Walcher, and other German scientists developed methods for enriching uranium-235 via electromagnetic separation that were comparable to the U.S. calutrons (p. 3554). If Germany was secretly able to mass-produce and operate separators copied from those prototypes, it could have enriched enough uranium for one or more implosion bombs, especially test bombs with relatively small explosive yields such as those described by Werner Grothmann (p. 4436) and other witnesses. Indeed, according to Grothmann, the Reichspost built and operated a large uranium enrichment facility somewhere outside Berlin apparently based on von Ardenne's technology (p. 3494).

The physical size of an electromagnetic separator, and the distance by which it can separate uranium isotopes into two different streams, can be estimated from basic physics. The Lorentz force on an ion of mass m, velocity vector $\mathbf{v}$ (magnitude v), and singly ionized charge e in a magnetic field vector $\mathbf{B}$ (magnitude B) is

$$m\,\frac{d\mathbf{v}}{dt} \;=\; e\,\mathbf{v}\times\mathbf{B} \tag{D.17}$$

If the centripetal acceleration of the ion from Eq. (D.17) is the centripetal acceleration v^2/r_c required to go in a circular cyclotron orbit of radius r_c,

$$\left|\frac{dv}{dt}\right| \;=\; \frac{e\,v\,B}{m} \;=\; \frac{v^2}{r_c}\,, \tag{D.18}$$

then one can use the ion's kinetic energy $E = mv^2/2$ and mass A in atomic mass units to calculate the cyclotron radius:

$$r_c \;=\; \frac{\sqrt{2\,E\,m}}{eB} \;=\; 0.456\,\frac{\sqrt{E_{keV}}}{B_T}\,\sqrt{A}\;\text{ cm} \tag{D.19}$$

The diameter d_c of such a circular orbit is twice its radius:

$$d_c \;=\; 2\frac{\sqrt{2\,E\,m}}{eB} \;=\; 0.912\,\frac{\sqrt{E_{keV}}}{B_T}\,\sqrt{A}\;\text{ cm} \tag{D.20}$$

Two types of ions of masses A_1 and A_2 that begin at the same point with the same energy will be maximally separated by a distance Δd after half an orbit by the difference of their orbital diameters:

$$\Delta d_c \;=\; 2(r_{c1} - r_{c2}) \;=\; 0.912\,\frac{\sqrt{E_{keV}}}{B_T}\left(\sqrt{A_1} - \sqrt{A_2}\right) \;\;\text{cm} \tag{D.21}$$

The U.S. calutrons used 35 keV beams of singly ionized UCl_4 molecules, which had masses of $A_1 = 378$ for $^{238}UCl_4$ and $A_2 = 375$ for $^{235}UCl_4$. There were two types of calutrons: alpha calultrons with a magnetic field of 0.34 Tesla, and beta calutrons with a magnetic field of 0.68 Tesla. Using these numbers, the separation distance between beams of U-238 and U-235 was:

$$\Delta d_c \;\approx\; 1.2 \text{ cm} \qquad \text{for alpha calutrons with B} = 0.34 \text{ T} \tag{D.22}$$

$$\approx\; 0.6 \text{ cm} \qquad \text{for beta calutrons with B} = 0.68 \text{ T} \tag{D.23}$$

The calutrons had to be sufficiently large to contain the orbits of the uranium beams:

$$d_c \;\approx\; 3.1 \text{ m} \qquad \text{for alpha calutrons with B} = 0.34 \text{ T} \tag{D.24}$$

$$\approx\; 1.5 \text{ m} \qquad \text{for beta calutrons with B} = 0.68 \text{ T} \tag{D.25}$$

German electromagnetic separators would almost certainly have had roughly comparable sizes and separation distances.

Fundamental physics can also give a ballpark estimate for the number of electromagnetic separators that would be required to achieve a given U-235 production rate. If N is the number of independent uranium ion beams, I is the current per beam in Amps, and $e \approx 1.602 \times 10^{-19}$ Coulombs is the electric charge of singly charged ions in the beam, the total number of ions per second is simply NI/e. Since there are $365 \times 24 \times 60 \times 60 = 3.1536 \times 10^7$ seconds per year, the annual ion production rate is

$$\frac{\text{Separated ions}}{\text{year}} \;=\; 3.1536 \times 10^7\,\frac{N\,I}{e}\;\frac{\text{ions}}{\text{year}} \tag{D.26}$$

Using Avogadro's number $N_A \approx 6.022 \times 10^{23}$ and the mass A of the ions in atomic mass units, there are N_A/A ions per gram of mass in the beam, or $1000 N_A/A$ ions/kg. Combining this information with Eq. (D.26), the annual production rate of mass is

$$\frac{\text{Separated mass}}{\text{year}} \;=\; 3.1536 \times 10^4\,\frac{N\,I\,A}{e\,N_A}\;\frac{\text{kg}}{\text{year}} \tag{D.27}$$

Space charge effects and other phenomena limit practical values of the current in the separated U-235 beam to around half a milliamp, or $I \sim 5 \times 10^{-4}$ A. (The current of the initial beam will be much larger, since most of the beam will be composed of U-238 ions.) Realistically the ion beams might operate at a somewhat lower current and would be taken offline periodically for maintenance and cleaning. Lowering the current to an average value of $I \sim 3 \times 10^{-4}$ A to account for those limitations, and using $A = 235$ for U-235, Eq. (D.27) becomes

$$\frac{\text{Separated U-235}}{\text{year}} \;\sim\; 0.023\,N\;\frac{\text{kg}}{\text{year}} \tag{D.28}$$

In early 1945, the U.S. Y-12 plant at Oak Ridge was producing approximately 0.2 kg U-235 per day, or approximately 73 kg/year. Equation (D.28) predicts a ballpark number on the order of 3200 calutron ion beams would be required for that production rate. In fact, the Y-12 plant used a two-stage process, with 2688 alpha calutron beams $(4 \times 2 \times 96 \ + \ 5 \times 4 \times 96)$ enriching to $\sim$ 20% U-235 in the first stage, and then 432 beta calutron beams $(6 \times 2 \times 36)$ further enriching that material to $\sim$ 80% U-235 [Bruce Cameron Reed 2015a, 2019]. Lumping the alpha and beta calutrons together, that makes 3120 ion beams, very close to the crude estimate from Eq. (D.28).

The maximum planned electrical power consumption of the entire Y-12 calutron plant was 200 MW (Fig. D.1031 and Table D.8). In practice, Y-12's electrical usage was generally less than that. As shown in Fig. D.1032, the total electrical consumption for Oak Ridge (Y-12 calutrons + K-25 gaseous diffusion + all other nuclear facilities + the town itself) peaked for the month ending 1 September 1945 at 200 GW hr for the month, or 0.269 GW = 269 MW time-averaged. For the 12 months ending 1 September 1945, the total electrical consumption for Oak Ridge was 1659 GW hr for the year, or 0.189 GW = 189 MW time-averaged.[27]

The total production of electrical energy in the United States increased from 161,308 GW hr for the year of 1939, or a time-average of 18.4 GW electric power production, to 271,255 GW hr for 1945, or a time-average of 31.0 GW electric power production.[28]

Thus Oak Ridge's electrical consumption during the peak final war month of August 1945 was 0.868% of the total U.S. electrical power at that time (0.269 GW/31.0 GW = 0.00868). Oak Ridge's electrical consumption averaged over that final year of the war was 0.610% of the total U.S. electrical power at that time (0.189 GW/31.0 GW = 0.00610). These figures disprove the oft-repeated myth that Oak Ridge required a large fraction of the nation's electricity. [See also Bruce Cameron Reed 2015b.]

According to the U.S. Strategic Bombing Survey (USSBS), at the end of 1944 the Greater German Reich (including modern Germany, Austria, Poland, and the Czech Republic) had a total known electrical production capacity of 22 GW, with at least 16 GW of that currently then in use despite territorial losses, extensive bombing, and ongoing repair work.[29] See pp. 2102–2104. BIOS 342 estimated a total of 23 GW for 1944 (pp. 2105–2106). Including secretive or specialized power plants for classified or dedicated projects within the Greater German Reich that were not known to the USSBS (especially in areas occupied by the Soviet Union after the war) plus the electrical production capacities of other countries that were occupied by Germany, allied with Germany, or nominally neutral but exporting aid to Germany, a reasonable estimate of the total electrical production capacity supporting the German war effort is roughly double the 22 GW figure, or $\sim$44 GW.

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[27] Manhattan District History. Book I, Volume 12, Part 1. Clinton Engineer Works: Central Facilities. p. 12.5. https://ia803409.us.archive.org/14/items/ManhattanDistrictHistory/MDH-B1V12P01-General-CEW_Central_Facilities.pdf
Manhattan District History. Book I, Volume 12, Part 2. Clinton Engineer Works. Appendix C-7. https://ia803409.us.archive.org/14/items/ManhattanDistrictHistory/MDH-B1V12P02-General-CEW_Central_Facilities_Appendices_A-C.pdf

[28] United States Census Bureau. 1949. *Statistical Abstract of the United States.* p. 512.
https://www.census.gov/library/publications/1949/compendia/statab/70ed.html
https://www2.census.gov/library/publications/1949/compendia/statab/70ed/1949-08.pdf

[29] United States Strategic Bombing Survey. 1947. *German Electric Utilities Industry Report.* pp. 1, 4, Exhibit C, Exhibit D. https://books.google.com/books?id=U9Q9TS-FtSgC

Using the average total electrical consumption of Oak Ridge during the final year of the war, Germany could have powered a fully equal facility by using:

- 1.18% of the electrical capacity known to remain in use in the Greater German Reich at the end of 1944 (0.189 GW/16 GW = 0.0118), or
- 0.859% of the known wartime electrical capacity in the Greater German Reich (0.189 GW/22 GW = 0.00859), or
- ∼0.43% of the estimated total electrical production capacity that was available to aid Germany during the war (0.189 GW/44 GW = 0.00430).

The U.S. electromagnetic separation plant was designed to produce so much U-235 because the United States planned to use that uranium in Little Boy, a gun-type fission bomb that needed over 60 kg of fuel because it did not compress the fuel and had a very low efficiency. The U.S. plant provided enough uranium for approximately one bomb of that design per year.

The sources that describe the German fission bomb design all indicate that it was an implosion bomb, which compresses the fuel, is much more efficient than a gun-type bomb, and therefore requires roughly 1/10 as much fuel as a gun-type bomb. If a German enrichment facility were designed to produce enough U-235 for one full-sized bomb per year (or several test bombs with smaller amounts of fuel and smaller explosive yields, as described by the sources), that German enrichment plant could have been roughly 1/10 the size of the U.S. Y-12 plant, as extrapolated in Table D.8. If that same production capacity were distributed among several production plants to minimize the risk of Allied bombing (p. 4400), each plant would have been even smaller.

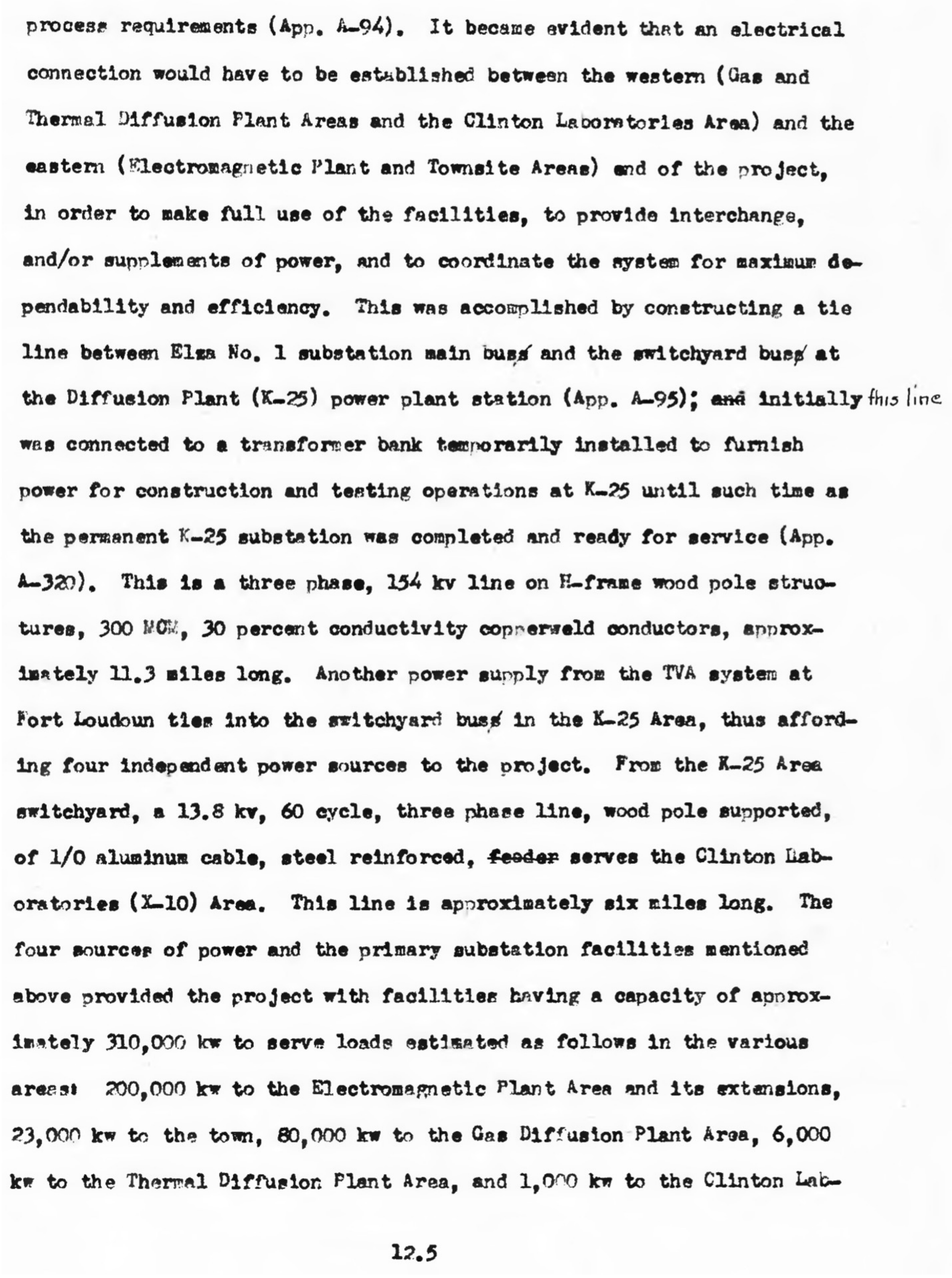
German enrichment facilities 1/10 the total size of Oak Ridge would have used:

- 0.118% of the electrical capacity known to remain in use in the Greater German Reich at the end of 1944, or
- 0.0859% of the known wartime electrical capacity in the Greater German Reich, or
- ∼0.043% of the estimated total electrical production capacity that was available to aid Germany during the war.

Due to the huge power consumption of the electromagnets, electromagnetic separators like the Y-12 calutrons are the least energy-efficient uranium enrichment method that has been employed on an industrial scale. As analyzed next, Germany developed more energy-efficient enrichment methods (gaseous diffusion and especially uranium gas centrifuges), so plants using those methods would have consumed even less of the total German electrical capacity than has been calculated above.

Characteristic	**U.S. Y-12 Plant**	**Hypothetical German Plant**
^{235}U production rate	73 kg/year	∼ 7 kg/year
Number of ion beams	3120	∼ 310
Number of workers	22,482	∼ 2,200
Facility floor space	∼ 400,000 m^2	∼ 40,000 m^2
Electric power consumption	200 MW	∼ 20 MW
Cost (1940s U.S. dollars)	$477,631,000	∼ $48,000,000

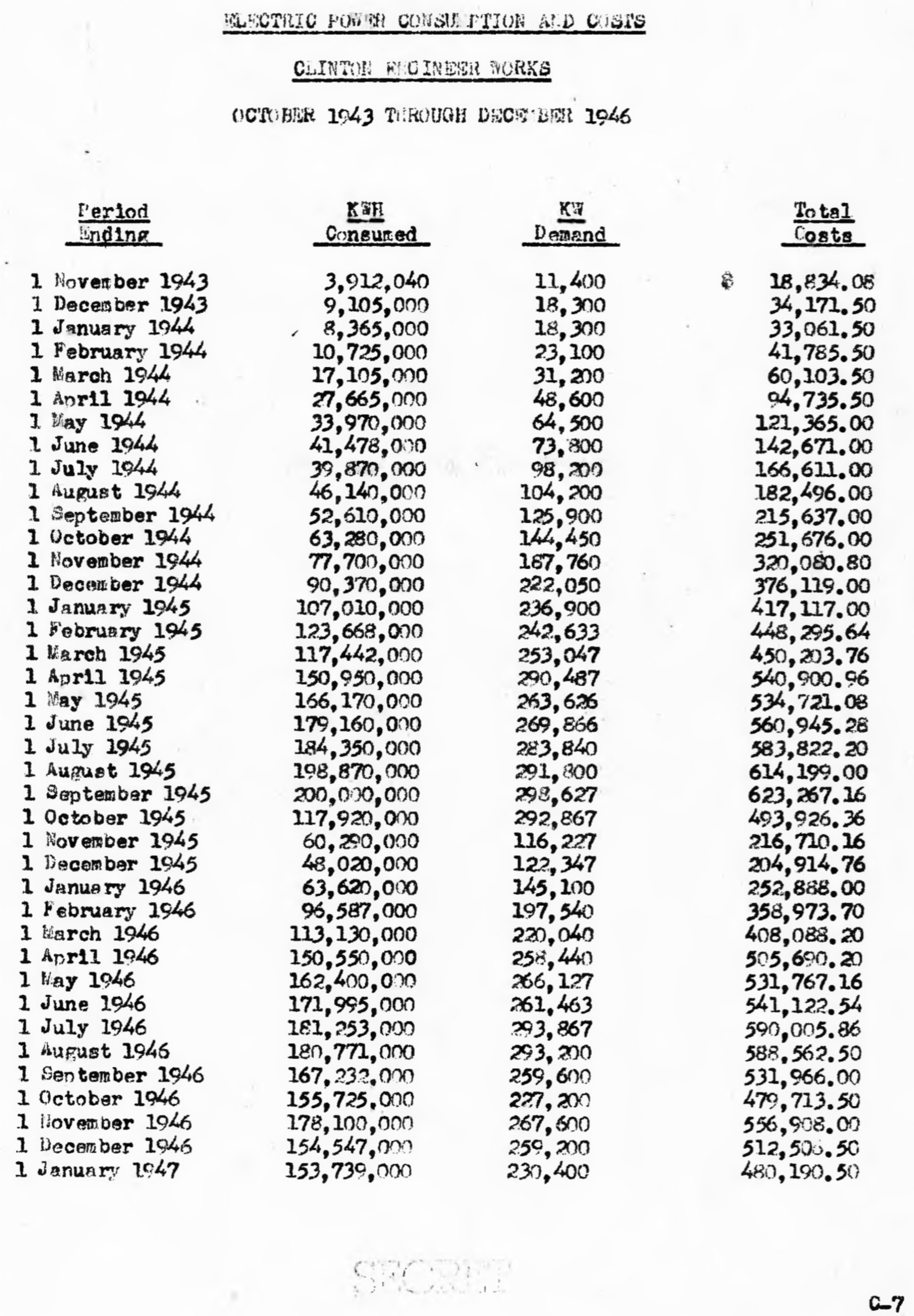
Table D.8: Known characteristics of the U.S. electromagnetic separation plant and extrapolated characteristics of a hypothetical German electromagnetic separation plant.



process requirements (App. A-94). It became evident that an electrical connection would have to be established between the western (Gas and Thermal Diffusion Plant Areas and the Clinton Laboratories Area) and the eastern (Electromagnetic Plant and Townsite Areas) end of the project, in order to make full use of the facilities, to provide interchange, and/or supplements of power, and to coordinate the system for maximum dependability and efficiency. This was accomplished by constructing a tie line between Elza No. 1 substation main bus~~s~~ and the switchyard bus~~s~~ at the Diffusion Plant (K-25) power plant station (App. A-95); ~~and~~ initially this line was connected to a transformer bank temporarily installed to furnish power for construction and testing operations at K-25 until such time as the permanent K-25 substation was completed and ready for service (App. A-320). This is a three phase, 154 kv line on H-frame wood pole structures, 300 MCM, 30 percent conductivity copperweld conductors, approximately 11.3 miles long. Another power supply from the TVA system at Fort Loudoun ties into the switchyard bus~~s~~ in the K-25 Area, thus affording four independent power sources to the project. From the K-25 Area switchyard, a 13.8 kv, 60 cycle, three phase line, wood pole supported, of 1/0 aluminum cable, steel reinforced, ~~feeder~~ serves the Clinton Laboratories (X-10) Area. This line is approximately six miles long. The four sources of power and the primary substation facilities mentioned above provided the project with facilities having a capacity of approximately 310,000 kw to serve loads estimated as follows in the various areas: 200,000 kw to the Electromagnetic Plant Area and its extensions, 23,000 kw to the town, 80,000 kw to the Gas Diffusion Plant Area, 6,000 kw to the Thermal Diffusion Plant Area, and 1,000 kw to the Clinton Lab-

12.5

Figure D.1031: Electrical power consumption for U.S. Oak Ridge during World War II. Manhattan District History. Book I, Volume 12, Part 1. Clinton Engineer Works: Central Facilities. p. 12.5. https://ia803409.us.archive.org/14/items/ManhattanDistrictHistory/MDH-B1V12P01-General-CEW_Central_Facilities.pdf



ELECTRIC POWER CONSUMPTION AND COSTS

CLINTON ENGINEER WORKS

OCTOBER 1943 THROUGH DECEMBER 1946

Period Ending	KWH Consumed	KW Demand	Total Costs
1 November 1943	3,912,040	11,400	$ 18,834.06
1 December 1943	9,105,000	18,300	34,171.50
1 January 1944	8,365,000	18,300	33,061.50
1 February 1944	10,725,000	23,100	41,785.50
1 March 1944	17,105,000	31,200	60,103.50
1 April 1944	27,665,000	48,600	94,735.50
1 May 1944	33,970,000	64,500	121,365.00
1 June 1944	41,478,000	73,800	142,671.00
1 July 1944	39,870,000	98,200	166,611.00
1 August 1944	46,140,000	104,200	182,496.00
1 September 1944	52,610,000	125,900	215,637.00
1 October 1944	63,280,000	144,450	251,676.00
1 November 1944	77,700,000	187,760	320,080.80
1 December 1944	90,370,000	222,050	376,119.00
1 January 1945	107,010,000	236,900	417,117.00
1 February 1945	123,668,000	242,633	448,295.64
1 March 1945	117,442,000	253,047	450,203.76
1 April 1945	150,950,000	290,487	540,900.96
1 May 1945	166,170,000	263,626	534,721.08
1 June 1945	179,160,000	269,866	560,945.28
1 July 1945	184,350,000	283,840	583,822.20
1 August 1945	198,870,000	291,800	614,199.00
1 September 1945	200,000,000	298,627	623,267.16
1 October 1945	117,920,000	292,867	493,926.36
1 November 1945	60,290,000	116,227	216,710.16
1 December 1945	48,020,000	122,347	204,914.76
1 January 1946	63,620,000	145,100	252,888.00
1 February 1946	96,587,000	197,540	358,973.70
1 March 1946	113,130,000	220,040	408,088.20
1 April 1946	150,550,000	258,440	505,690.20
1 May 1946	162,400,000	266,127	531,767.16
1 June 1946	171,995,000	261,463	541,122.54
1 July 1946	181,253,000	293,867	590,005.86
1 August 1946	180,771,000	293,200	588,562.50
1 September 1946	167,232,000	259,600	531,966.00
1 October 1946	155,725,000	227,200	479,713.50
1 November 1946	178,100,000	267,600	556,908.00
1 December 1946	154,547,000	259,200	512,506.50
1 January 1947	153,739,000	230,400	480,190.50

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C-7

Figure D.1032: Electrical power consumption for U.S. Oak Ridge during World War II. Manhattan District History. Book I, Volume 12, Part 2. Clinton Engineer Works. Appendix C-7. Electric Power Consumption and Costs, CEW. https://ia803409.us.archive.org/14/items/ManhattanDistrictHistory/MDH-B1V12P02-General-CEW_Central_Facilities_Appendices_A-C.pdf

B. Gaseous Diffusion and the Isotope Sluice

If a gas contains two isotopes with different masses m_{heavy} and m_{light} but the same temperature T, the thermal velocity of the lighter isotope will be $\sqrt{m_{\text{heavy}}/m_{\text{light}}}$ times faster than that of the heavier isotope ($v \sim \sqrt{k_B T/m}$). If pressurized gas is forced to diffuse through a barrier containing small pores, the lighter isotope will thus diffuse $\sqrt{m_{\text{heavy}}/m_{\text{light}}}$ times faster than the heavier isotope, permitting a small amount of enrichment per barrier stage, as shown in Fig. D.1030(b). By connecting many such diffusion barriers in series, significant amounts of enrichment can be obtained.

The only compound of uranium suitable for enrichment by gaseous diffusion is uranium hexafluoride (UF_6), which is solid below 56^oC but gaseous above that temperature. UF_6 is very chemically reactive with water and highly corrosive to organic materials (except Teflon) and most metals except nickel and aluminum, so the diffusion barriers are generally formed from porous nickel or possibly porous aluminum. The fluorine mass per molecule ($6 \times 19.0 = 114$) is small enough not to completely obscure the small mass difference between ^{235}U and ^{238}U. Including the fluorine, the ratio of the diffusion velocities v_{light} of $^{235}UF_6$ and v_{heavy} of $^{238}UF_6$ is

$$\frac{v_{\text{light}}}{v_{\text{heavy}}} = \sqrt{\frac{m_{\text{heavy}}}{m_{\text{light}}}} = \sqrt{\frac{238+114}{235+114}} \approx 1.0043 \tag{D.29}$$

In practice, at least 1000 pressurized barrier stages in series are required to obtain reactor-level (2–4%) enrichment, and many more to obtain bomb-level (> 50%) enrichment. The United States employed this method during and for quite some time after World War II, but it is very cumbersome and energy-intensive, due to the large number of stages and the energy required to pressurize each stage. Thus almost all enrichment nowadays uses centrifugation, which is much more energy-efficient [Benedict et al. 1981; Bruce Cameron Reed 2015a, 2019].

Gustav Hertz pioneered gaseous diffusion enrichment, starting before 1923, continuing to work in Germany throughout the Third Reich (even though he was partially Jewish), and playing a critical role in uranium enrichment in the Soviet Union after the war (p. 3618). Historians should investigate whether there may have been any secret programs in wartime Germany to mass-produce and operate copies of Hertz's technology, either by Hertz or anyone else.

Whereas Erich Bagge's isotope sluice had its own unique method of operation (p. 3651), ultimately its isotope separation was due to the same velocity ratio between light and heavy isotopes as Eq. (D.29) for gaseous diffusion. Thus Bagge's isotope sluice would have required a number of stages or repeated steps comparable to gaseous diffusion in order to achieve large-scale enrichment. Again, historians should dig more deeply to determine if such devices may have been mass-produced and operated anywhere within the Third Reich.

C. Gas Centrifuges

Centrifuges are routinely used to separate liquids of different densities, but specially designed centrifuges can also separate gas molecules of different masses. As with gaseous diffusion, the uranium is in the form of hot corrosive UF_6, so centrifuge components must be made from resistant materials such as aluminum, nickel, and Teflon [Benedict et al. 1981; Glaser 2008; Kemp 2009, 2012, 2017].

Konrad Beyerle, Wilhelm Groth, Paul Harteck, Werner Holtz, Werner Schwietzke, and other scientists and engineers in the German nuclear program developed a succession of improved gas centrifuges during the war (p. 3494). According to official histories, these centrifuges were one-of-a-kind prototypes that were simply used for research purposes. Yet there is evidence that these centrifuge designs were secretly mass-produced and used at other locations in the Third Reich (pp. 3544, 3670). If that was indeed the case, they could have been a highly effective method of producing enriched uranium for both fission bombs and fission reactors.

After the war, German gas centrifuge technology (along with the German experts on that technology) was ultimately adopted by the Soviet Union, western Europe, the United States, and the rest of the world, displacing the much less efficient and much more expensive enrichment technologies that the United States had developed during the war.

Figure D.1030(c) shows a highly simplified illustration of a gas centrifuge. The centrifuge is essentially a long rotating drum, and UF_6 is brought in along the axis of rotation. Heavier $^{238}\mathrm{UF}_6$ molecules tend to move toward the outer walls of the centrifuge, while lighter $^{235}\mathrm{UF}_6$ is more buoyant and tends to remain closer to the axis. Of course, the two isotopes still intermingle, but gas somewhat depleted of $^{235}\mathrm{U}$ can be removed near the outer wall of the cylinder, and gas somewhat enriched for $^{235}\mathrm{U}$ can be drawn off closer to the axis. The centrifuge operates in a continuous fashion with fresh gas entering the chamber and old gas leaving it.

The enrichment that can be achieved by one such centrifuge can be estimated by a simple model. During operation, most of the gas is in a thin layer adjacent to the outer wall. If the wall is at radius R and rotates at velocity v, gas molecules with mass m immediately adjacent to it will move at the same velocity and have kinetic energy $mv^2/2$. If molecules move to a radial position r closer to the axis, in equilibrium they must assume a rotation velocity $(r/R)v$, or a kinetic energy $(r/R)^2 mv^2/2$. The difference in kinetic energies between molecules at radii r and R is

$$E \;=\; \left(1 - \frac{r^2}{R^2}\right)\frac{mv^2}{2} \tag{D.30}$$

From statistical physics, in a thermal distribution the density of particles n with different energies E varies like $n(E) = n(0)\exp(-E/k_B T)$. In the rotating frame of reference at the outer wall, molecules adjacent to the wall have zero energy and molecules that climb "higher" (closer to the axis) have energy E from Eq. (D.30) relative to that. Therefore the ratio of the densities at radii r and R is

$$\frac{n_r}{n_R} \;=\; \exp\left[-\frac{mv^2}{2k_B T}\left(1 - \frac{r^2}{R^2}\right)\right] \tag{D.31}$$

By applying Eq. (D.31) first to the densities of light molecules ($^{235}\mathrm{UF}_6$) and second to the densities of heavy molecules ($^{238}\mathrm{UF}_6$), and then by taking the ratio of those densities, one finds:

$$\frac{(n_{\text{light}}/n_{\text{heavy}})_r}{(n_{\text{light}}/n_{\text{heavy}})_R} \quad = \quad \exp\left[\frac{(m_{\text{heavy}} - m_{\text{light}})v^2}{2k_B T}\left(1 - \frac{r^2}{R^2}\right)\right] \tag{D.32}$$

Note that the amount of separation that can be produced by centrifugation in Eq. (D.32) only depends on the difference of the isotope masses, not their ratio as was the case for gaseous diffusion in Eq. (D.29). The difference in masses between uranium isotopes is several mass units, yet their ratio is only a minute fraction over unity, so centrifugation is inherently superior to gaseous diffusion for uranium enrichment.

To better see the efficacy of centrifugation, one can use Eq. (D.32) with a mass difference of 3 atomic mass units (the difference between uranium-238 and uranium-235) and a temperature of 340^oK (just comfortably above the sublimation point of UF_6):

$$\frac{(n_{\text{light}}/n_{\text{heavy}})_r}{(n_{\text{light}}/n_{\text{heavy}})_R} \quad \approx \quad \exp\left[\left(\frac{v}{1370\ \text{m/sec}}\right)^2\left(1 - \frac{r^2}{R^2}\right)\right] \tag{D.33}$$

Using rough estimates of $v = 500$ m/sec (4800 revolutions per minute and $R = 0.1$ m) and $r/R = 0.8$, Eq. (D.33) yields

$$\frac{(n_{\text{light}}/n_{\text{heavy}})_r}{(n_{\text{light}}/n_{\text{heavy}})_R} \quad \approx \quad 1.049 \tag{D.34}$$

As shown by Eq. (D.34) vs. Eq. (D.29), the enrichment that can be obtained by one stage of gas centrifugation is $\sim$ 10x greater than that obtained from one stage of gaseous diffusion. Therefore, enrichment of natural uranium to reactor-grade material can be accomplished by $\sim$ 100 gas centrifuge stages vs. $\sim$ 1000 gaseous diffusion stages.

Each gas centrifuge also uses at least $\sim$ 2x less energy than each gaseous diffusion stage (due to the large pressure loss across each diffusion barrier), so enrichment via centrifuges consumes at least $\sim$ 20x less energy than enrichment via gaseous diffusion.

Because of these advantages, centrifuges are now the worldwide standard for enrichment (pp. 3549–3553).

Actual gas centrifuges are considerably more complicated than indicated by the schematic illustration in Fig. D.1030(c) or the simplified calculations above. Among other complexities, they include mechanisms to induce gas circulation within the chamber to optimize isotope separation while allowing for continuous throughput [Benedict et al. 1981; Glaser 2008; Kemp 2009, 2012, 2017].

Using information from these references and comparing to Table D.8 for electromagnetic separators, Table D.9 shows the extrapolated characteristics of a hypothetical German centrifuge separation plant. For this table, it has been assumed that the plant requires less than 1 worker per shift (3 shifts/day) per centrifuge, and less than 9 m^2 of floor space per centrifuge. For the same uranium enrichment rate, a centrifuge plant should have less than the cost of an electromagnetic separation plant (which has expensive electromagnets and ion beams), and less than 1/20 the electrical consumption of a gaseous diffusion plant (which in turn has less electrical consumption than an electromagnetic separation plant).

A German centrifuge separation plant as outlined in Table D.9 would have consumed less than 1 MW of electrical power, which corresponds to:

- Less than 0.00625% of the 16 GW electrical capacity known to remain in use in the Greater German Reich at the end of 1944, or
- Less than 0.00455% of the 22 GW known wartime electrical capacity in the Greater German Reich, or
- Less than ∼0.00227% of the ∼44 GW estimated total electrical production capacity that was available to aid Germany during the war.

If that same production capacity were distributed among several production plants to minimize the risk of Allied bombing (as confirmed in 1944 by the leading German industrialist Adolf Schneider, p. 4400), each plant would have been even smaller than indicated in Table D.9.

Historians need to clarify exactly how far gas centrifuge technology progressed in Germany during the war, how many gas centrifuges were used and where they were located, and how much uranium of what enrichment percentage was produced in the Third Reich. The critical role of German scientists and engineers in spreading this technology to other countries after the war also deserves to be much better known than it currently is.

Characteristic	**Hypothetical German Plant**
^{235}U production rate	$\sim$ 7 kg/year
Number of centrifuges	$\sim$ 467
Number of workers	< 1,400
Facility floor space	< 4,200 m^2
Electric power consumption	< 1 MW
Cost (1940s U.S. dollars)	< $48,000,000

Table D.9: Extrapolated characteristics of a hypothetical German centrifuge separation plant.

D. Laser Isotope Separation

By 1930 or earlier, groups of scientists within the German-speaking world began developing two (apparently) separate technologies: (1) photochemical methods of separating isotopes using inefficient plasma lamps (p. 3664) and (2) lasers as an efficient monochromatic light source (Section C.3). During and after the Third Reich, both technologies were transferred to other countries, where decades later they were combined to create laser isotope separation.

The mass of the nucleus has a very small but measurable effect on the energy levels of orbiting electrons, termed the hyperfine interaction in quantum physics, so different isotopes of the same element have slightly different energy levels and thus can be excited by photons at slightly different wavelengths. As shown in Fig. D.1030(d), this principle can be used to separate different isotopes when they are in the form of either individual atoms or molecules:

- In Atomic Vapor Laser Isotope Separation (AVLIS), pure uranium metal is heated to 2300^oC to vaporize it. Due to hyperfine interactions, the wavelength to elevate one electron to an excited state is 502.74 nm for ^{235}U but 502.73 nm for ^{238}U. Therefore a dye laser precisely tuned to 502.74 nm can excite ^{235}U atoms in the vapor without affecting ^{238}U. Photons with a wavelength of 262.5 nm from a second laser have enough energy to ionize (completely free the one excited electron) the excited ^{235}U but not the unexcited ^{238}U atoms. Electric and/or magnetic fields can remove the singly charged ^{235}U while leaving the neutral ^{238}U, as illustrated in Fig. D.1030(d). In practice, charge exchange between the two isotopes leads to some neutral ^{235}U and some charged ^{238}U, limiting the enrichment that can be achieved by one pass through an AVLIS system. Even so, natural uranium can be enriched to reactor-grade levels in one or at most a few passes, versus $\sim$ 100 for centrifugation and $\sim$ 1000 for gaseous diffusion. Moreover, AVLIS is precise enough that it can even harvest the small amount of ^{235}U that remains in the depleted uranium tails left by diffusion or centrifugation enrichment plants. For a given quantity of uranium and degree of enrichment, the input energy cost of AVLIS is roughly comparable to that of gas centrifuges, while the equipment cost is potentially lower, since the cheaper cost of a centrifuge vs. the laser setup is outweighed by the far larger number of centrifuges required for comparable enrichment.

- In Molecular Laser Isotope Separation (MLIS), UF_6 gas is used, just as it is for enrichment by diffusion and centrifugation. This is a great advantage over AVLIS, since UF_6 must only be heated to 56^oC to become a gas (vs. 2300^oC for pure uranium). However, UF_6 molecules must then be cooled to 30–77^oK to put them into their vibrational ground state, which largely conflicts with the goal of keeping them in the gaseous phase instead of solid phase [Benedict et al. 1981]. If this can be accomplished, photons from a carbon dioxide laser with a wavelength of 16 μm can be used to boost $^{235}UF_6$ (but not $^{238}UF_6$) molecules to the first excited vibrational state. Photons with a wavelength of 308 nm (or in some implementations, an infrared wavelength) from an excimer laser can then dissociate the excited $^{235}UF_6$ molecules (but not the unexcited$^{238}UF_6$ molecules) into UF_5 plus atomic fluorine. Under these conditions, UF_5 is a solid, so ^{235}U precipitates out in the solid pentafluoride phase, whereas ^{238}U remains in the gaseous hexafluoride phase. An improved version of this process, Separation of Isotopes by Laser Excitation (SILEX) apparently overcomes the previously conflicting requirements of MLIS by using the difference in electrical charge between the two laser-irradiated isotopes to separate them, but details of SILEX are still classified.

Much more archival research is needed to explore how far wartime German programs on photochemical isotope enrichment progressed, how far wartime German programs on lasers progressed, whether there were any connections between those two wartime programs, and exactly how those wartime German programs influenced postwar work in other countries.

D.15.3 Breeding Methods to Produce Pu-239 or U-233

As discussed in the previous section, enrichment of uranium is difficult due to the fact that highly fissionable uranium-235 and relatively inert uranium-238 are chemically identical and very close in mass. In contrast, one can use a fission reactor or a particle accelerator to breed highly fissionable plutonium-239 from natural uranium-238, or highly fissionable uranium-233 from natural thorium-232, then exploit the differences in chemical properties between the bred fission fuel and the natural starting material in order to rapidly purify the fuel for a bomb.[30] This section discusses (a) the fundamental nuclear physics of creating plutonium-239 and uranium-233, (b) how a fission reactor could be used to breed either fuel, (c) how a particle accelerator could be used to breed either fuel, and (d) what chemical processes could be used to separate the bred fuel from the natural starting material.

A. Fundamental Nuclear Physics of Creating Plutonium-239 and Uranium-233

By mass, approximately 99.275% of natural uranium is uranium-238 ($^{238}_{92}$U), which will not fission unless it is hit with high-energy (at least a few MeV) neutrons. However, if uranium-238 is irradiated with low energy neutrons, such as in a fission reactor, it can absorb a neutron (n) and release the excess energy as a gamma (γ) ray, then undergo two successive beta (β) decays to become plutonium-239 ($^{239}_{94}$Pu), which is an excellent fission fuel:

$$^{238}_{92}\mathrm{U} + \mathrm{n} \xrightarrow{(\mathrm{n},\gamma)} {}^{239}_{92}\mathrm{U} \;\; \beta \xrightarrow{23.5\ \mathrm{min}} {}^{239}_{93}\mathrm{Np} \;\; \beta \xrightarrow{2.36\ \mathrm{days}} {}^{239}_{94}\mathrm{Pu} \qquad \text{(D.35)}$$

The two beta decays to plutonium-239 happen within a few days, which means that they tend to happen before the fuel is removed from the breeding reactor, or within a few days of being removed from the breeding reactor. Many highly radioactive isotopes with short half-lives are created by fission of uranium-235 in the fuel, so it is customary to let the fuel "cool off" for a month or so after being removed from the breeder reactor before it is processed by people. Since the German nuclear program would have had a great sense of urgency and likely did not value the lives of its low-level workers, it might have processed irradiated fuel with a much shorter cooling off period.

If uranium-238 were irradiated with low-energy neutrons for a long enough period of time, most of it would convert to plutonium-239. Unfortunately, two problems greatly limit how long the uranium-238 can be exposed to neutrons, and therefore how much of it can be converted to plutonium-239. If significant amounts of plutonium-239 build up in the sample, slow neutrons will make them undergo fission reactions and burn up before they can be removed and purified for use in a bomb. Yet even before that effect becomes a problem, a second constraint is even more limiting: plutonium-239 that absorbs a neutron but does not fission becomes plutonium-240:

$$^{239}_{94}\mathrm{Pu} + \mathrm{n} \longrightarrow {}^{240}_{94}\mathrm{Pu} + \gamma \qquad \text{(D.36)}$$

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[30] Neptunium-237 fission fuel [Sanchez et al. 2008] could also have been bred with a reactor or accelerator (e.g., by knocking a neutron out of U-238), although it probably would have been more difficult to produce in quantity than Pu-239 or U-233 [Benedict et al. 1981].

Plutonium-240 is chemically identical to plutonium-239 and only one atomic mass unit different in mass, making these plutonium isotopes even harder to separate from each other than uranium-235 and uranium-238 (with three mass units of difference). Thus most bred plutonium-239 will contain some amount of contaminating plutonium-240.

Whereas plutonium-239 essentially only fissions when hit with a neutron, and therefore will wait to release its energy in a chain reaction in a bomb, plutonium-240 sometimes fissions spontaneously. The neutrons that are constantly emitted by this spontaneous fission of plutonium-240 could initiate a fission chain reaction too soon as the critical mass of a bomb is being brought together, greatly decreasing the net energy release of the bomb. A gun-type (Little Boy) bomb design assembles the critical mass too slowly to overcome this problem; only an implosion (Fat Man) bomb design can assemble the critical mass rapidly enough before the spontaneous fission events hinder the process.

Even with an implosion bomb design, it is important to minimize the amount of plutonium-240 contamination and the spontaneous fission rate, so for weapons production, typically uranium-238 is irradiated with neutrons only until $<0.01\%$ of the uranium-238 has become plutonium-239. That means that an enormous amount of (highly radioactive) irradiated uranium must be chemically processed to recover a small amount of plutonium.

In addition to uranium, another actinide that can be mined in useful quantities is thorium, virtually all of which is thorium-232 ($^{232}_{90}\mathrm{Th}$). While thorium-232 itself is not a good fission fuel, if it is irradiated with low energy neutrons, such as in a fission reactor, it can absorb a neutron and release the excess energy as a gamma ray, then undergo two successive beta decays to become uranium-233 ($^{233}_{92}\mathrm{U}$), which is an excellent fission fuel:

$$^{232}_{90}\mathrm{Th} + \mathrm{n} \xrightarrow{(\mathrm{n},\gamma)} {}^{233}_{90}\mathrm{Th} \;\; \overset{\beta\ \ 21.8\ \mathrm{min}}{\longrightarrow} \;\; {}^{233}_{91}\mathrm{Pa} \;\; \overset{\beta\ \ 27.0\ \mathrm{days}}{\longrightarrow} \;\; {}^{233}_{92}\mathrm{U} \tag{D.37}$$

The processes for breeding uranium-233 in Eq. (D.37) and for breeding plutonium-239 in Eq. (D.35) are clearly highly similar, though beta decay to uranium-233 takes over ten times longer, mandating that the fuel sit for at least a month or so after being removed from the breeder reactor.

Just as the buildup of an undesirable contaminant limits how much plutonium-239 can be bred from uranium-238, the buildup of another undesirable contaminant limits how much uranium-233 can be bred from thorium-232. Neutron bombardment can actually remove a neutron from the highly desirable uranium-233, converting it to the highly undesirable uranium-232:

$$^{233}_{92}\mathrm{U} + \mathrm{n} \longrightarrow {}^{232}_{92}\mathrm{U} + 2\mathrm{n} \tag{D.38}$$

Uranium-232 undergoes a series of alpha (α) decays with a net half-life of roughly 70 years, producing thallium-208 which emits intense gamma rays. Although that process does not interfere with fission reactions, steady decay of contaminating uranium-232 into gamma-emitting thallium-208 means that bred uranium-233 is intensely radioactive and harmful to people working with it, and remains that way for many years after its creation. Again, if the German nuclear program did not value the lives of its low-level workers, this concern may not have limited their use of this method of fission fuel production.

B. Breeding in a Fission Reactor to Produce Pu-239 or U-233

German scientists knew how to breed plutonium-239 or uranium-233 in a fission reactor, had two reactors on the brink of criticality by the end of the war (the Heisenberg group's Berlin/Haigerloch pile and the Diebner group's Gottow/Stadtilm pile), and may have had other reactors that actually became operational during the war (p. 3794). Such reactors could have used heavy water (D_2O) and/or pure graphite (without neutron-absorbing boron impurities) as a moderator to slow down the neutrons emitted by the fission reactions, so that the neutrons would be much more likely to create a chain reaction and also to breed plutonium-239 (or uranium-233).

In the wartime U.S. nuclear program, the main reactors breeding plutonium were three reactors in Hanford, Washington, dubbed reactors B, D, and F. When fully operational, each of those reactors produced approximately 250 MW of thermal power from approximately 250 tons of natural uranium, or about 1 MW/ton [Bruce Cameron Reed 2015a, 2019]. None of that energy was converted to electricity as in a modern power reactor; water was used to cool the reactor and carry the heat away, so the reactors needed direct access to large quantities of fresh water.

At that power, each reactor bred approximately 0.19 kg of plutonium-239 per day, or approximately 69 kg per year. To limit the production of plutonium-240, the 250 tons of reactor fuel was removed after approximately 100 days, and then the reactor was restarted with fresh natural uranium fuel [Bruce Cameron Reed 2015a, 2019]. Comparing the plutonium-239 production rate of 0.19 kg/day to the rate of using natural uranium, 250 tons/100 days = 2.5 tons/day, the amount of plutonium-239 bred per ton of natural uranium was

$$\frac{\text{Bred Pu-239}}{\text{Natural uranium}} \approx \frac{0.19 \text{ kg/day}}{2.5 \text{ tons/day}} \approx 0.076 \ \frac{\text{kg}}{\text{ton}} \tag{D.39}$$

Note that the amount of fissionable plutonium-239 produced from a ton of natural uranium is roughly 100 times smaller than the maximum amount of fissionable uranium-235 (7.2 kg) that could be extracted from that same ton of natural uranium via the enrichment methods of the previous section. Again, this low level of production is due to the need to avoid creating much plutonium-240 in the fuel. As a result, a fission fuel breeding program would use ∼100 times more uranium than a fission fuel enrichment program (unless the irradiated uranium were reused in the breeder reactor after the plutonium had been removed, but that would be even more time consuming, and a wartime program would presumably be under extreme time pressure).

Counterbalancing that disadvantage is the advantage that a breeder reactor and the accompanying chemical purification processes handle fission fuel in a very dense solid or liquid state, whereas enrichment methods handle fission fuel in a far less dense gaseous or plasma state. Therefore the equipment for breeding would be much more compact, and could potentially be built and operated by fewer people, than the equipment for enrichment.

Characteristic	**Approximate value (scales linearly)**
Thermal power	25 MW
Reactor core volume	100 m^3
Moderator	150 tons of graphite, or 80 tons of heavy water, or some of both
Natural uranium in reactor	25 tons
Replace uranium every	100 days
Uranium consumption rate	91 tons/year
Plutonium production rate	6.9 kg/year
Cost (1940s U.S. dollars)	$6,000,000

Table D.10: Approximate characteristics of a breeder reactor for producing plutonium-239.

As long as the reactor is large enough to have a self-sustaining fission chain reaction, these characteristics can be scaled up or down in a linear fashion, using the approximate numbers in Table D.10 as a basis for reference [Kemp 2005; OTA 1977]. For example, if each Hanford reactor held 250 tons of natural uranium and produced approximately 69 kg of plutonium-239 per year, a hypothetical German reactor holding approximately 22 tons of natural uranium could produce approximately 6 kg of plutonium-239 per year, enough for one full-sized ∼20 kiloton implosion bomb (like the U.S. Gadget and Fat Man bombs) per year. From Eq. D.39, producing 6 kg of plutonium would require processing approximately 79 tons of uranium.

Thorium-232 is useful for breeding uranium-233 but cannot sustain a fission chain reaction on its own. The reactor would need to contain natural uranium or uranium enriched in uranium-235. On the order of ∼90% of the neutrons from the uranium would be needed to sustain the chain reaction, so only ∼10% of the neutrons could be spared to breed uranium-233 from thorium-232, and hence only ∼10% of the total fuel in the reactor could be thorium. Thus a fission reactor for breeding uranium-233 might be ∼10 times larger in volume or mass than a reactor for breeding plutonium-239. (Of course, plutonium would also be bred within the ∼90% of the reactor fuel that was uranium, and that plutonium could be extracted as well.) For this reason, it seems likely that the German nuclear program would have generally preferred producing plutonium-239 instead of uranium-233, although scientists may have certainly tried uranium-233 (especially because of the large amount of thorium that was available to the German nuclear program).

C. Breeding with an Accelerator to Produce Pu-239 or U-233

Even without a fission reactor, it is possible to produce significant amounts of Pu-239 or U-233 via a process called electronuclear breeding. In this process, a particle accelerator fires a beam of high-energy charged particles (typically protons, deuterons, or electrons with a kinetic energy of many millions of electron-volts or MeV) at a target containing U-238 or Th-232. When those energetic charged particles strike the nuclei of the target material, they knock some neutrons free, and those neutrons are absorbed by U-238 atoms to become Pu-239 atoms, or by Th-232 atoms to become U-233 atoms. In more sophisticated and efficient systems, the target may also contain an initial layer of lithium or beryllium, which are especially good at releasing neutrons when struck by high-energy charged particles. If furthermore the target is immersed in a neutron moderator (such as heavy water or pure graphite) and surrounded by a neutron reflector (such as beryllium), each neutron that is originally generated can lead to a cascade of several more neutrons by subcritical fission reactions, yielding several atoms of bred fuel per charged particle in the beam.

If the target is lithium without uranium or thorium, electronuclear breeding can be used to produce tritium, which would be very useful for fusion boosting of fission bombs or for creating a hydrogen bomb.

Electronuclear breeding was seriously pursued by the United States and other countries after World War II, and even now is of concern as a proliferation risk for how new countries could produce nuclear weapons.[31] German scientists knew how to breed plutonium-239 (or uranium-233) in a particle-accelerator-driven electronuclear system, and built and operated suitable accelerator systems (pp. 3954–4022 and 4504–4510) that appear to have been a high priority part of the wartime German nuclear program.

Simple physics can give a ballpark estimate for the amount of Pu-239 or U-233 that could be produced by electronuclear breeding. If N is the number of particle accelerators, I is the beam current per particle accelerator, and $e \approx 1.602 \times 10^{-19}$ Coulombs is the electric charge of particles (protons, deuterons, or electrons) in the beam, the total number of charged particles per second is simply NI/e. Since there are $365 \times 24 \times 60 \times 60 = 3.1536 \times 10^7$ seconds per year, the annual charged particle production rate is

$$\frac{\text{Charged particles}}{\text{year}} = 3.1536 \times 10^7 \, \frac{N\,I}{e} \, \frac{\text{particles}}{\text{year}} \tag{D.40}$$

Let η be the number of bred Pu-239 or U-233 atoms per accelerated charged particle, or in other words the efficiency of converting accelerated charged particles to neutrons and then letting those neutrons be captured to breed the desired atoms. Thus the atom breeding rate is

$$\frac{\text{Bred atoms}}{\text{year}} = 3.1536 \times 10^7 \, \frac{N\,I\,\eta}{e} \, \frac{\text{atoms}}{\text{year}} \tag{D.41}$$

Using Avogadro's number $N_A \approx 6.022 \times 10^{23}$ and the mass A of the bred atoms in atomic mass units, there are N_A/A atoms per gram of mass, or $1000N_A/A$ atoms/kg. Combining this information with Eq. (D.41), the annual production rate of mass is

$$\frac{\text{Bred mass}}{\text{year}} = 3.1536 \times 10^4 \, \frac{N\,I\,\eta\,A}{e\,N_A} \, \frac{\text{kg}}{\text{year}} \tag{D.42}$$

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[31] Barashenkov et al. 1987; Barber and George 1959; Chichester 2009; Kemp 2005; Livdahl 1981; Magill and Peerani 1999; Riendeau et al. 1999; Van Atta 1977.

Space charge effects and other phenomena generally limit practical values of the beam current to around a milliamp, or $I \approx 10^{-3}$ amp [Kemp 2005]. For 10 accelerators operating in parallel to breed Pu-239 ($A = 239$) with an efficiency $\eta \sim 1$, Eq. (D.42) becomes

$$\frac{\text{Bred Pu-239}}{\text{year}} \sim 0.78 \ \frac{\text{kg}}{\text{year}} \tag{D.43}$$

Similarly, for 10 accelerators with $I \approx 10^{-3}$ amp breeding U-233 ($A = 233$) with an efficiency $\eta \sim 1$, Eq. (D.42) gives

$$\frac{\text{Bred U-233}}{\text{year}} \sim 0.76 \ \frac{\text{kg}}{\text{year}} \tag{D.44}$$

Likewise, for 10 accelerators with $I \approx 10^{-3}$ amp breeding tritium ($A = 3$) with an efficiency $\eta \sim 1$, Eq. (D.42) becomes

$$\frac{\text{Bred tritium}}{\text{year}} \sim 9.8 \ \frac{\text{g}}{\text{year}} \tag{D.45}$$

From these crude estimates, a year-long electronuclear breeding program could produce ~ 0.8 kg of plutonium-239 or uranium-233, or ~ 10 g of tritium. The equations reveal several ways to improve this output:

- The German program could have built and operated more than 10 particle accelerators in parallel. That is not unreasonable, considering that the United States built and operated 3120 calutron ion beams at Oak Ridge for U-235 enrichment.
- The beam current might have been increased. 1 mA per beam is a representative value but not a hard limit. Increasing the beam current by a factor of two or three would correspondingly increase the amount of bred fission fuel by a factor of two or three.
- The German program might have operated particle accelerators for longer than a year. If the accelerators began operation two years before the end of the war, twice as much fuel could have been produced.
- Most importantly, the efficiency η could have been optimized. Depending on the conditions, the efficiency could be as low as $\eta \sim 0.001$ or as high as $\eta \sim 100$ [Kemp 2005]. Using the highest possible beam energy, choosing the best type of charged particle for the beam (in some cases, deuterons work better than protons or electrons), and using a neutron-multiplying target could give efficiencies toward the upper end of that range. A neutron-multiplying target would essentially be a small, subcritical fission reactor, for example chunks of unenriched uranium metal immersed in heavy water and surrounded by a beryllium reflector. Whereas the reactor would not be large enough to create its own self-sustaining chain reaction of fission events, each neutron generated by the accelerator would trigger a small cascade of additional neutrons in the subcritical reactor, yielding several bred atoms per initial neutron.

Based on this simple analysis, it is evident that electronuclear breeding of kilograms of plutonium-239 or uranium-233 for a fission bomb, or of grams of tritium for fusion boosting a bomb, would be technically challenging but nevertheless quite feasible for the wartime German program. It is important for historians to search for more evidence of such an electronuclear breeding program, both in archival documents and at locations that may have been involved in this work.

D. Chemical Reprocessing to Purify Bred Pu-239 or U-233

In nuclear power programs, chemical reprocessing of "spent" fuel that has been in a fission reactor is used to recover plutonium-239 that has been bred during the time in the reactor, as well as any leftover uranium-235 that was not burned up inside the reactor. Those fissionable fuel components can be repackaged and used again for reactor fuel; uranium-238 can also be recycled. Many other actinides in the fuel can be recycled without adversely affecting the repackaged reactor fuel. For nuclear weapons programs, the same techniques may be used to extract and concentrate the plutonium-239 from a uranium reactor (or from an electronuclear breeding particle accelerator) to make high-grade fuel for fission bombs.

Documents show that German scientists knew how to produce plutonium-239 from uranium-238 (p. 3794) and how to produce uranium-233 from thorium-232 (p. 3832), and knew that both of those fission fuels would be suitable for bombs. If one or more fission reactors were operational before the end of the war (p. 3794), or if accelerators were able to produce a significant amount of fission fuel (p. 3954), it seems likely that Germany would have developed and utilized chemical reprocessing methods to extract and purify the bred plutonium-239 or uranium-233. In fact, in the highly fragmentary documentation that is now available to scholars shows that there was in fact work to develop such reprocessing methods (p. 3826).

Although it is current unknown just how far that work may have progressed during the war, or in what geographic locations, the scientific details of reprocessing constrain where and how it could have been done, and may guide historians in locating relevant documents and geographic sites:

- Due to the relatively sophisticated chemistry involved in reprocessing and the fact that it would be tied to secret weapons development, it seems probable that any such reprocessing would have been run by I.G. Farben, or at the very least would have intimately involved I.G. Farben.

- Because of the large amount of spent uranium that would need to be processed for a much smaller amount of plutonium, and because of the great personal danger involved in exposure to the associated high levels of radiation and toxic chemicals, it moreover seems likely that any such work in wartime Germany would have involved slave labor (at least if it advanced beyond small-scale proof-of-concept laboratory experiments).

- Because of the large amount of material to be processed and the extreme danger in handling it, chemical reprocessing would probably have been conducted at or near the fission reactor(s) or electronuclear breeding site(s) where the plutonium was bred.

- For cooling of the fission reactor and for both cooling and chemical steps during reprocessing, a breeding/reprocessing facility would likely be located next to an abundant source of fresh water.

The most widely used chemical method for reprocessing spent fission fuel is called the PUREX (Plutonium Uranium Reduction EXtraction) process. Although it is quite complex [Benedict et al. 1981], a very simplified overview is illustrated schematically in Fig. D.1033. This description covers modern reprocessing for nuclear power programs, but a wartime weapons program would use very similar (or perhaps streamlined) steps:

1. Spent fuel rods are soaked in hot nitric acid, which dissolves uranium, plutonium, and fission products, but not zirconium alloy claddings and other hardware. Thus non-fuel reactor materials can be separated out for waste disposal. Gaseous fission products are also removed at this time.

2. Then the polar aqueous nitric acid solution containing uranium nitrates, plutonium nitrates, and fission-product nitrates is mixed with a nonpolar organic solvent, which is a kerosene-like mixture containing *n*-tributyl phosphate (TBP). At this point, uranium is in a hexavalent state (VI) and plutonium is in a tetravalent state (IV), both of which prefer to pass into the nonpolar TBP layer of the immiscible polar-nonpolar fluid combination. In contrast, the fission products are generally in a pentavalent state (V) and prefer to remain in the polar nitric acid layer, so they can be separated out, concentrated, and vitrified for disposal as high-level radioactive waste.

3. The TBP organic solution containing uranium and plutonium is treated with a limited reductant (such as ferrous ions, Fe^{+2}), which reduces plutonium (IV) to plutonium (III) but leaves the uranium (VI) unaffected. The nonpolar organic solvent is again mixed with polar aqueous nitric acid. The uranium (VI) still prefers the nonpolar solvent, but unlike plutonium (IV), plutonium (III) actually prefers the polar solvent. Thus plutonium and uranium can be separated for individual processing.

4. Uranium nitrate is purified from the nonpolar solvent and converted to uranium hexafluoride for enrichment if desired.

5. Plutonium nitrate is purified from the polar solvent and converted to plutonium dioxide for reactor fuel or plutonium metal for bombs.

In practice, up to three rounds of polar-nonpolar solvent purification are used to achieve high purity of the fission product, uranium, and plutonium fractions.

A similar reprocessing method used for separating thorium, uranium, and fission products from spent fuel in thorium-232/uranium-233 fuel cycles is called the Thorex process [Benedict et al. 1981]. By means of this process, one could supply a fission reactor or electronuclear breeding accelerator with natural thorium-232 and produce high-grade uranium-233 for fission bombs.

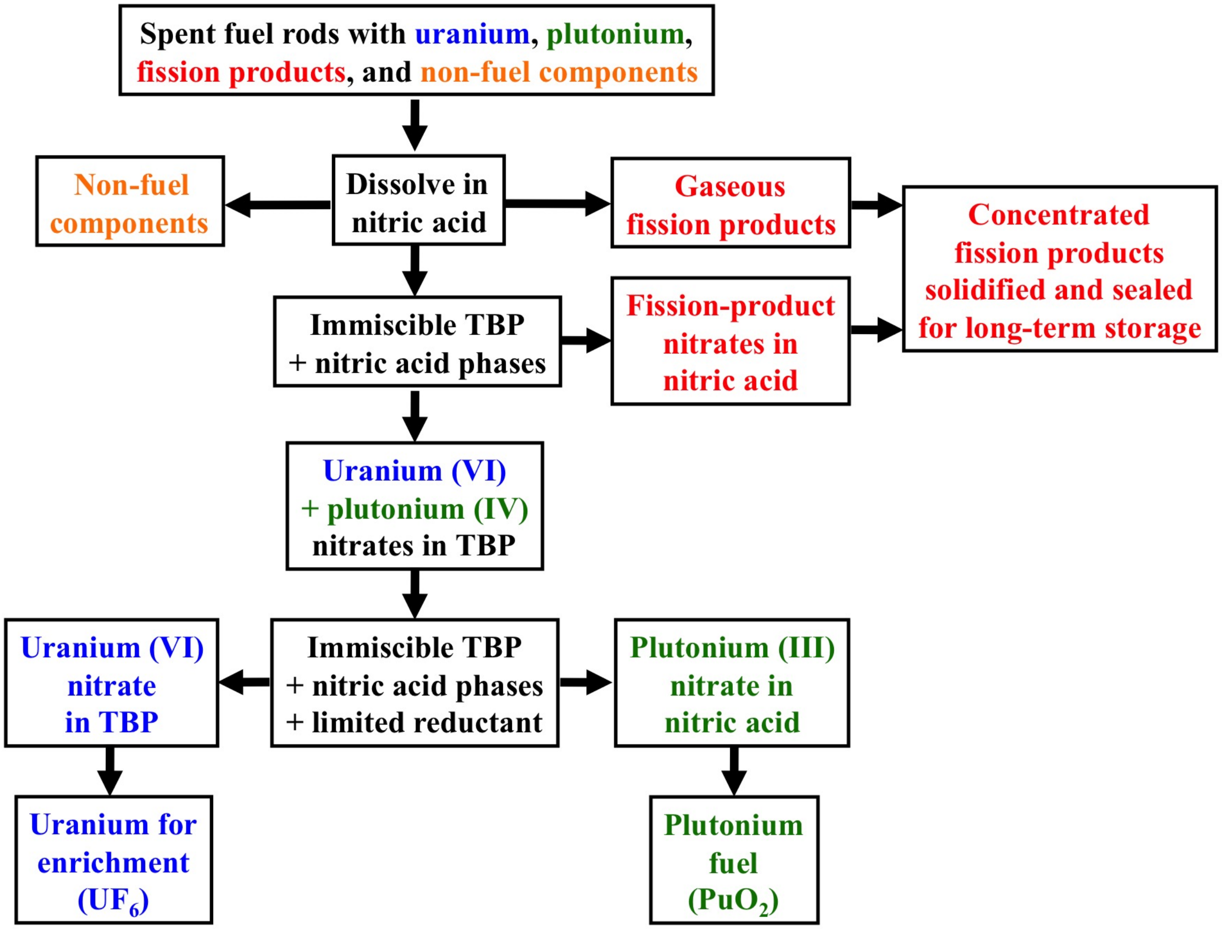
Spent fuel rods with uranium, plutonium, fission products, and non-fuel components
Non-fuel components
Dissolve in nitric acid
Gaseous fission products
Concentrated fission products solidified and sealed for long-term storage
Immiscible TBP + nitric acid phases
Fission-product nitrates in nitric acid
Uranium (VI) + plutonium (IV) nitrates in TBP
Uranium (VI) nitrate in TBP
Immiscible TBP + nitric acid phases + limited reductant
Plutonium (III) nitrate in nitric acid
Uranium for enrichment (UF_6)
Plutonium fuel (PuO_2)

Figure D.1033: Chemical reprocessing of spent fission fuel, often called the PUREX (Plutonium Uranium Reduction EXtraction) process.

D.15.4 Analysis of Test Explosions from Primary Sources

While there are many potential metrics for the progress of the German nuclear program, the definitive litmus test would be a successful wartime nuclear weapons test. Of the alleged Baltic, Polish, and Thuringian test explosions described by the primary sources quoted earlier in this appendix, there is the largest amount of evidence for the Thuringian test, including numerous details that may be subjected to scientific analysis. Without discounting the other possible tests, the remainder of this discussion will focus on analyzing all of the currently available details about that March 1945 Thuringian test.

A. Primary Sources Used for the Analysis

Several of the primary sources provided general background information for the March 1945 Thuringian test. Wartime and postwar documents showed that within the top echelons of the SS, there was a prolonged and intense interest in developing a nuclear weapon, and an expectation around March 1945 that battlefield use of such a weapon was imminent. Likewise, wartime and postwar documents from Diebner, Schumann, Trinks, Guderley, and others confirmed that there were very active research programs on fission reactions, fission fuel production, fusion reactions, fusion fuel production, and spherical implosion bomb designs. How far those programs got, and whether or how they were combined together, is very unclear from the primary sources themselves, but perhaps answerable at least in part by modern theoretical and/or experimental analysis of the available data.

As summarized on p. 4480, at least ten primary sources specifically addressed the Thuringian test:

1-2. Ilyichev's November 1944 and March 1945 Soviet intelligence reports described the preparations for the Thuringian tests, the immediate consequences of the tests, and the detailed design of the nuclear device that was supposedly tested. The authenticity of the documents appears beyond doubt, since they are part of an extended paper trail that includes published responses by Kurchatov and Flerov, and that went all the way to Joseph Stalin. Furthermore, since the documents cast doubt on the Soviet Union's claim to be the second nuclear nation or to have achieved that status by its own scientific strength, there appears to be no incentive for Russians of any time period to have forged or embellished them. Likewise, these reports do not appear to have been a German attempt to bluff the Russians into believing that the Germans possessed a weapon that they did not actually have; a bluff would surely have claimed that the test explosion was much larger, and would not have handed the Russians a highly detailed and very effective design for a fission bomb. Of course, despite the authenticity of these documents, how accurate or inaccurate they may be depends on the competence of the unknown Soviet spy who transmitted the details from Germany.

3-4. Kurchatov's March 1945 letter and Flerov's two brief reports from May 1945 repeated many of the details from Ilyichev's second report, supporting the authenticity of that document. Most of their information was directly derived from Ilyichev's second report (which did not give a specific location for the nuclear test). However, the fact that by May 1945 Kurchatov and Flerov apparently knew of a specific location where they wanted to measure residual artificial radioactivity seems to indicate that they had received additional information not in Ilyichev's November 1944 and March 1945 reports.

5. Robert Döpel's testimony under interrogation by the Russians in 1946 confirms that there was an atomic bomb test on a German military base (such as those in Thuringia) before the end of the war. Unfortunately the only Russian interrogation summary that has been found thus far does not give any further details.

6-7. The testimonies of Werner and Wachsmut described the Thuringian test and its immediate aftermath. Although the 1962 East German transcript's chain of custody is uncertain and hence its authenticity is difficult to prove, the written testimonies by Werner and Wachsmut are consistent with oral testimonies that they each gave later in life, consistent with each other, consistent with details from the other sources that reported the Thuringian test, and consistent in appearance with other East German interrogation transcripts from that place and time. As will be shown, they are also highly consistent with the physics of nuclear weapons, in ways that would not have been possible for Werner and Wachsmut, their interrogators, or a document forger to foresee. Therefore, the testimonies of Werner and Wachsmut will be included in the discussion here with appropriate caution. These two testimonies are the only sources that named a specific location for the Thuringian test, but otherwise the basic facts of the Thuringian test do not depend upon their testimonies.

8. The 1966 East German reports on the interrogation of Erich Rundnagel appear to be authentic and were confirmed by Rundnagel's nephew. Although Rundnagel did not address the actual test, he gave details that seem relevant to the bomb design and preparations.

9. Oscar Koch's 1960s description of a high-level 1945 U.S. intelligence report appears as credible as the Soviet intelligence report. Although it gave fewer details than Ilyichev's reports, those that it did contain are highly consistent with those given by Ilyichev. The most puzzling aspect is that Koch stated that U.S. aerial surveillance photos did not show the blast damage that had been reported in the test area. Some plausible explanations are (a) that the Germans quickly replanted, restored, cleaned, or camouflaged the affected area, (b) that the aerial surveillance photos were not of the correct location, and/or (c) that the Americans were looking for much larger-scale blast damage than the Thuringian test actually produced.

10. The interviews with Grothmann described many details about the Thuringian test, its background, and its aftermath. Major caveats are that the interviews were conducted in private, that they were held 55–57 years after the events in question, and that tapes of the interviews were erased. Nonetheless, historians have been able to independently confirm a large number of obscure details covered in the interviews [Karlsch and Petermann 2007, p. 29; Karlsch 2006; Nagel 2011, p. 64], and scientific details from the interviews are very consistent with known physics and engineering principles, even though Grothmann was not a scientist or engineer. Grothmann provided information that is in excellent agreement with Ilyichev's reports, which were discovered in a Moscow archive only after Grothmann had already died, and Grothmann's statements agree with other sources about the secret wartime programs that have only emerged in recent years. For a more extensive discussion of the reliability of this source, see pp. 3396–3397.

As shown on p. 4480, there is remarkably good agreement among these ten primary sources about the details of the test date, location, organizations or people who were involved, blast, radioactivity, resulting casualties, and device design. Those details will next be used as the basis for preliminary theoretical estimates of the explosive yield, radioactive release, and device design parameters.

Figure D.740 is a map of the Ohrdruf and Arnstadt area that was possibly involved in the March 1945 test. In Fig. D.741, colored lines illustrate clues to the location of the test as described by Werner and Wachsmut. These clues include the approximate boundary of the military base (green), population centers with possible sickness from radioactive fallout (red), the direction in which Werner reported seeing the explosion (yellow), driving distances for Wachsmut from the Ringhofen estate (blue), and the location of an apparent crater on aerial photos from pp. 4541–4545 (purple). Note that those clues place the test roughly in the center of the Ohrdruf military base, which would also make sense from a security perspective.

If information from Werner and Wachsmut is excluded from the analysis, the key facts and data regarding the nuclear test remain the same, except the exact location in Thuringia is then unknown. Based solely on the other sources, the test might have occurred on the Ohrdruf military base, or it might have occurred in some other remote wooded location in Thuringia that could be tightly secured by the SS (likely a military base).

B. Estimating Explosive Yield from Primary Sources

Simple estimates of the relationship between the energy released in an explosion and the radius of damage caused by that explosion can easily be made from first principles. The explosion will be assumed to release an energy E at a point source at radial position $r = 0$ at or very near the surface of the earth, surrounded by atmosphere of initial pressure p_{atm}, as shown in Fig. D.1034. For reference, one ton of TNT high explosive is defined to produce an energy of 4.184×10^9 Joules (J) (although the actual yield from real TNT can vary somewhat around this value). The energy of the explosion will be distributed throughout a hemispherical volume of ever-expanding radius R, where the surface at $r = R$ is a shock wave propagating outward into the atmosphere. Using the volume $(2/3)\pi R^3$ of the hemisphere and defining the average energy density deposited within the hemispherical volume as U_{avg}, the explosive energy yield may be written as

$$E = \frac{2}{3}\pi R^3 U_{\text{avg}} \tag{D.46}$$

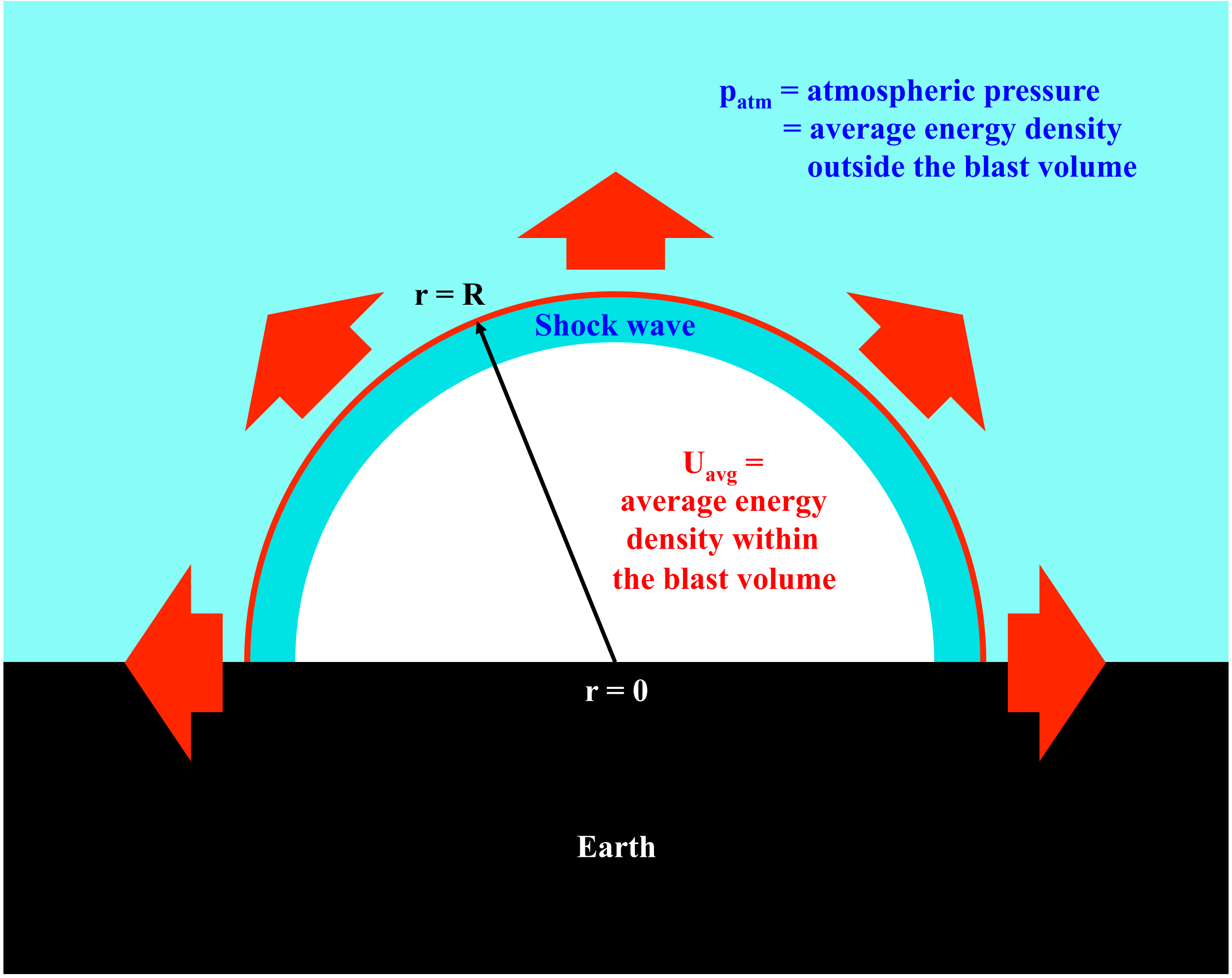
p_{atm} = atmospheric pressure
= average energy density
outside the blast volume
r = R
Shock wave
U_{avg} =
average energy
density within
the blast volume
r = 0
Earth

Figure D.1034: Hemispherical shock wave expanding from an initial point on the earth's surface.

Since the total energy E is constant (neglecting any losses), the average energy density U_{avg} of the explosion will decrease as the explosion radius R increases with time. The explosion will be the dominant force in the local environment until its average energy density drops below the pressure-derived potential energy density of normal atmospheric pressure, $p_{\text{atm}} \approx 1.01 \times 10^5$ Pascals (Pa=J/m^3) (using the sea-level average pressure). Of course, the shock wave at the expanding surface contains more energy density than the volume-averaged value, and the explosive energy density can do serious damage to buildings, trees, and people even when it is only a fraction of normal atmospheric pressure.

If one assumes that the explosion will do major damage until the average energy density drops to $U_{\text{avg}} \approx p_{\text{atm}}/10$ at some blast radius $R = R_{\text{blast}}$, the energy from Eq. (D.46) may be written as:

$$\begin{aligned} E_{\max} &\approx \frac{2}{3}\pi R_{\text{blast}}^3 \frac{p_{\text{atm}}}{10} = \left(\frac{2\pi \cdot 1.01 \times 10^5 \text{ J/m}^3}{3 \cdot 10 \cdot 4.184 \times 10^9 \text{ J/ton}} \right) R_{\text{blast}}^3 \\ &\approx \left(\frac{R_{\text{blast}}}{58.3 \text{ meters}} \right)^3 \text{ tons}\,, \end{aligned} \tag{D.47}$$

in which Eq. (D.47) expresses the explosive energy yield in equivalent tons of TNT.

On the other hand, if one assumes that the explosion will do significant damage until the average energy density drops much further to $U_{\text{avg}} \approx p_{\text{atm}}/100$ at some blast radius $R = R_{\text{blast}}$, the explosive yield from Eq. (D.46) may be written as:

$$\begin{aligned} E_{\min} &\approx \frac{2}{3}\pi R_{\text{blast}}^3 \frac{p_{\text{atm}}}{100} = \left(\frac{2\pi \cdot 1.01 \times 10^5 \text{ J/m}^3}{3 \cdot 100 \cdot 4.184 \times 10^9 \text{ J/ton}} \right) R_{\text{blast}}^3 \\ &\approx \left(\frac{R_{\text{blast}}}{126 \text{ meters}} \right)^3 \text{ tons} \end{aligned} \tag{D.48}$$

For a given measured blast radius, the released explosive energy could vary somewhere between the minimum value given by Eq. (D.48) and the maximum value given by Eq. (D.47), depending on how resistant to blast damage the surround area is, deviations of the actual terrain from the assumed perfectly flat surface, and other factors. Note that Eq. (D.47) gives a maximum energy 10 times larger than the minimum energy of Eq. (D.48), since its assumed energy density is 10 times larger ($p_{\text{atm}}/10$ vs. $p_{\text{atm}}/100$). Within that range, a good single value for a ballpark approximation would be the geometric mean, found by using Eq. (D.46) with $U_{\text{avg}} \approx p_{\text{atm}}/(10\sqrt{10})$:

$$\begin{aligned} E_{\text{geo mean}} &\approx \frac{2}{3}\pi R_{\text{blast}}^3 \frac{p_{\text{atm}}}{10\sqrt{10}} = \left(\frac{2\pi \cdot 1.01 \times 10^5 \text{ J/m}^3}{3 \cdot 10\sqrt{10} \cdot 4.184 \times 10^9 \text{ J/ton}} \right) R_{\text{blast}}^3 \\ &\approx \left(\frac{R_{\text{blast}}}{85.5 \text{ meters}} \right)^3 \text{ tons} \end{aligned} \tag{D.49}$$

Cold-War-era U.S. books tended to specify blast waves in terms of the pounds per square inch (psi) of peak overpressure in the shock wave. Converted into those terms, Eq. (D.49) for the geometric mean of the explosive energy would give the blast radius for 5.1 psi (35 kPa) of peak overpressure, which is generally considered enough to demolish trees or wood-frame buildings. Likewise, Eq. (D.47) for the maximum case would correspond to a peak overpressure of 9.1 psi (63 kPa, enough to damage or destroy even reinforced buildings), and Eq. (D.48) for the minimum case would correspond to a peak overpressure of 2.9 psi (20 kPa, enough to damage but perhaps not demolish trees or wood-frame buildings). Thus the equations derived here are highly consistent with the standard empirical equations from Cold War atmospheric nuclear tests, and Eq. (D.49) in particular should be a good guide for the level of destruction mentioned by Ilyichev.

Ilyichev described the blast radius as $R_{\text{blast}} = 500\text{–}600$ meters. Using Eqs. (D.47)–(D.49), a blast radius of $R_{\text{blast}} = 500$ meters corresponds to an explosive energy somewhere in the range $E = 63\text{–}630$ tons, with a geometric mean of 200 tons. Likewise, the larger blast radius $R_{\text{blast}} = 600$ meters corresponds to an explosive energy somewhere in the range $E = 110\text{–}1100$ tons, with a geometric mean of 350 tons. These values are consistent with previous estimates based on the same data [Eilers 2007, 2015; Mineev and Funtikov 2007].

Ilyichev also described the bomb as having a total weight of approximately 2 tons and being filled largely with TNT. If such a bomb had exploded in a conventional, non-nuclear manner, its explosive energy would therefore be only ~ 2 tons. The absolute minimum explosive energy consistent with the reported blast radius is 30 times larger than that value, and the actual energy may well have been several hundred times greater than the non-nuclear yield of TNT alone. Thus some sort of nuclear explosion appears to be the only satisfactory explanation for the reported blast size.

An independent method of estimating the explosive energy would be to use the dimensions of the crater it created in the ground. Unfortunately, if the bomb had an explosive energy less than 1000 tons and was mounted on a tower for the test (to facilitate diagnostics, as in the first U.S. fission bomb test in New Mexico on 16 July 1945, and as described by Schumann and Grothmann), it would likely not leave a significant crater [Glasstone and Dolan 1977, p. 255]. If the aerial reconnaissance photos on pp. 4541–4545 do indeed show the correct location of the test, the suggestive ejecta pattern that is visible in the 21 March 1945 and 9 June 1945 aerial reconnaissance photos may have been the only physical trace of the blast, apart from radioisotopes.

C. Estimating Radioactive Release from Primary Sources

In addition to the reported blast radius, the reports of radioactive effects or radiation sickness by Ilyichev, Grothmann, Werner, and Wachsmut seem to suggest some sort of nuclear explosion. In theory, a nuclear explosion could be due to fission reactions alone, fusion reactions alone, or some combination of fission and fusion reactions. In the 75+ years since 1945, scientists have been unable to create a net-energy-producing pure fusion reaction without the assistance of fission reactions [Gsponer and Hurni 2009, pp. 139–141; Winterberg 2010, pp. 297–298, 302], so the possibility that the described 1945 test was a pure fusion weapon seems too remote to consider. Both pure fission and fission-fusion hybrid designs are quite possible however. Even for plausible fission-fusion hybrid weapon designs, the fraction of released energy that comes from fusion reactions is negligible. Therefore the explosive energy yield (calculated from the reported blast radius) may be used to find the amount of fission fuel consumed and hence the amount of radioactive fallout.

Fission fuel consumed

By definition, one mole (6.022×10^{23}) of uranium-235 atoms has a total mass of 235 grams. Upon fission, each atom releases approximately 180 million electron-volts (eV) of energy (not counting energy lost as neutrinos, or energy released in delayed radioactivity), which can be converted into Joules or equivalent tons of TNT energy by the conversion factors 1.602×10^{-19} J/eV and 4.184×10^{9} J/ton. Putting all of this information together, the number of grams of U-235 that must be completely fissioned to produce one ton TNT equivalent of explosive energy is:

$$\frac{(235\text{ g})\ (4.184 \times 10^{9}\text{ J/ton})}{(6.022 \times 10^{23})\ (180 \times 10^{6}\text{ eV})\ (1.602 \times 10^{-19}\text{ J/eV})} \quad \approx \quad 0.0566\ \frac{\text{grams}}{\text{ton}} \tag{D.50}$$

Ilyichev specifically said the device used U-235 as fission fuel. In principle, other fission fuels could have been used: uranium-233 (U-233, created by bombarding natural thorium-232 with neutrons), neptunium-237 (Np-237, e.g., created by knocking a neutron out of natural uranium-238), or plutonium-239 (Pu-239, creating by bombarding natural uranium-238 with neutrons). Energy values for those other fission fuels are approximately the same as that for U-235, so Eq. (D.50) can safely be used as the basis for any fission calculations.

For explosive yields in the range of 63–1100 tons with a geometric mean of 200–350 tons, as calculated in Section D.15.4, the mass of fuel completely fissioned is:

$$M_{\text{fissioned}} \quad = \quad 3.6\text{–}62\text{ grams, with a geometric mean of }11.3\text{–}19.8\text{ grams.} \tag{D.51}$$

Thus the best ballpark guess is that the reported explosion would have completely fissioned $\sim$ 10–20 grams of uranium. This is a very small quantity considering that nuclear weapons would normally have many kilograms of fission fuel, but Grothmann reported that only a very small amount of fuel was used in this test device, and that larger amounts of fuel were ready to be used in subsequent devices. For a small test, the total amount of fissionable fuel might have been as little $\sim$100 grams, which is very consistent with the result in Eq. (D.51), since only some fraction of the fuel would have time to fission during the very brief time that the core of the bomb was maximally compressed.

Initial radiation from the explosion

People who were very close to the test site would have been exposed to the initial radiation (gamma, neutrons, and beta) released during the actual explosion. For a fission explosion of 200–350 tons, the lethality (10 Grays or 1000 rads) radius for this prompt radiation is $\sim$ 500 meters, very comparable to the blast radius [Glasstone and Dolan 1977, p. 333]. Thus anyone present on the field where the device was tested would have been either killed immediately or left injured and dying from the blast, radiation, and heat. This is highly consistent with the reports of Ilyichev, Grothmann, Werner, and Wachsmut.

If the blast radius was 500–600 meters as reported by Ilyichev, Wachsmut's estimate of 700 bodies was correct, and those victims had been uniformly spread out within an area $\pi R^2 \ \sim$ 785,000–1,130,000 m^2 around the device when it was tested, the spacing would have been

$$\sim 1100\text{–}1600\ \mathrm{m}^2 \text{ per person on average} \tag{D.52}$$

or

$$\sim 33\text{–}40\ \mathrm{m} \text{ between people if uniformly spread out} \tag{D.53}$$

Thus 700 people could have easily fit within the blast radius, even if they were spread out. It seems highly unlikely that the detonation would have been accidentally triggered at an unexpected time before people had had time to take cover. A far more plausible explanation is that the SS scattered POWs around the test area to serve as human guinea pigs to measure the effects at varying distances from the explosion.

Indeed, Ilyichev's report appears to suggest that the SS made detailed correlations of prisoners' positions before the explosion and their conditions after the explosion (p. 4485): "Prisoners of war who were near the epicenter of the explosion died, often without leaving a trace. Prisoners of war who were in the area beyond the center of the explosion have burns on their face and body, the strength of which depends on their position in relation to the epicenter of the explosion."

It is well documented that POWs were used as human test subjects for new nerve agents [Tucker 2006, p. 51] and for new biological weapons.[32] Thus the allegations made separately by Ilyichev and Wachsmut are highly consistent with what is known to have taken place in other Third Reich programs to develop weapons of mass destruction.

In fact, if the statements of Grothmann and Wachsmut are correct, the large size of the explosion and the large number of casualties for the very small amount of fission fuel used apparently surprised even the SS.

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[32] Barenblatt 2004; Blome 1941; Michael Carroll 2004; Deichmann 1996; Geißler 1998a, 1998b; Gold 1997; Haagen 1941; Friedrich Hansen 1993; Sheldon Harris 2002; Kater 1989; Keremidis 2013; Klee 2001; Leitenberg and Zilinskas 2012; Posner and Ware 2000; Regis 1999; Reinhardt 2013; Vivien Spitz 2005; Tokyo War Crimes Trial 1950; U.S. Army 1956.

Radioactive fallout from the explosion

From the explosive yield and amount of fuel fissioned, one can also calculate the amount of radioactive fallout. The radioactive fallout decays rapidly, emitting 80% of its total radiation within the first 24 hours, and gradually emitting the remaining 20% over the following days, months, and years [Glasstone and Dolan 1977, p. 397]. Radioactive fallout from a 1 kiloton fission explosion, spread uniformly over a flat area of 1 square mile, would cause a radiation exposure 3 feet above the ground (the approximate center of an adult human) of 2900 rads per hour 1 hour after the explosion, or 21,750 rads total within the first 24 hours after the explosion [Glasstone and Dolan 1977, pp. 390, 395—24 hour cumulative dose is dose rate at 1 hour multiplied by 7.5 hours due to decay]. Converting that information from kilotons to tons, from square miles to km^2, and from rads to Grays (Gy, where 1 Gy=100 rads), one finds:

$$1\ \frac{\text{ton}}{\text{km}^2} \implies 0.0751\ \frac{\text{Gy}}{\text{hr}}\ \text{at 1 hour averaged over area} \tag{D.54}$$

$$\implies 0.563\ \text{Gy within 24 hours averaged over area} \tag{D.55}$$

As calculated in Section D.15.4, the explosive yield had a geometric mean of 200–350 tons. The area over which the corresponding amount of fallout would be distributed could vary significantly depending on local winds and topography, but a plausible ballpark estimate for the affected region might be a $\sim$ 10 km $\times \sim$ 10 km area, or $\sim$ 100 km^2. Taken together, those estimates give an average of 2–3.5 tons/km^2, and Eqs. (D.54)–(D.55) can be scaled accordingly:

$$2\text{–}3.5\ \frac{\text{tons}}{\text{km}^2} \implies 0.150\text{–}0.263\ \frac{\text{Gy}}{\text{hr}}\ \text{at 1 hour averaged over area} \tag{D.56}$$

$$\implies 1.13\text{–}1.97\ \text{Gy within 24 hours averaged over area} \tag{D.57}$$

Gamma and beta radiation emitted by fission products in the fallout would begin to produce noticeable symptoms of radiation sickness after a cumulative exposure of $\sim$ 1 Gy, very serious illness at $\sim$ 2 Gy, and fairly consistent lethality (within hours or days after exposure) at $\sim$ 10 Gy [Glasstone and Dolan 1977, pp. 575–587, using 1 rad $\approx$ 1 rem or 1 Gray $\approx$ 1 Sievert for gamma, beta, and neutrons]. Thus the expected average dose from Eq. (D.57) falls perfectly within that 1–2 Gy window for noticeable but readily survivable radiation sickness.

Ilyichev reported that most the civilian population in the surrounding area had been evacuated. Someone who remained in the surrounding area (within the $\sim$ 100 km^2 general area but not at the test site), and who was exposed to the fallout with the first day or so after the test by being outside or consuming water or food that had been outside, might have experienced mild symptoms of radiation sickness that would have resolved themselves within a matter of days. People who remained in the surrounding area but did not have much exposure to the fallout may not have had any noticeable symptoms.

In the area immediately around the test site, the radioactive fallout and dosage would be significantly higher than in the larger surrounding region. Just how much higher would again depend on the local winds and topography, and also on the relative sizes of the areas in question. Data from a number of U.S. nuclear tests suggests that the fallout dosage immediately around a test site is $\sim$ 10–100 times higher than that in the much larger surrounding area that receives significant fallout, with a geometric mean value of $\sim$ 30 times higher [Glasstone and Dolan 1977, pp. 419–439]. Using that mean value to multiply Eqs. (D.56)–(D.57), ballpark values for the radiation dose at the Thuringia test site would be:

$$4.50\text{–}7.89\ \frac{\text{Gy}}{\text{hr}} \qquad \text{at 1 hour at test site} \tag{D.58}$$

$$33.9\text{–}59.1\ \text{Gy} \qquad \text{within 24 hours at test site} \tag{D.59}$$

As mentioned, those estimates use the estimated geometric mean from the fallout patterns, and the actual values might have been between $\sim$ 3 times smaller and $\sim$ 3 times larger than the results in Eqs. (D.58)–(D.59). Since a cumulative dose of $\sim$ 10 Gy will cause fairly consistent lethality within hours or days after exposure, even a person who was fully protected from the initial radiation, heat, and blast of the explosion but then visited the test site in the hours after the explosion could rapidly acquire a lethal dose. This factor may help account in part for the lack of later witnesses.

Based on the above analysis (which was derived only from the known physics of fission explosions and Ilyichev's statement that the blast radius was 500–600 meters), the explosion's prompt radiation at the test site, the radioactive fallout at the test site within the first 24 hours, and the radioactive fallout in nearby towns within 24 hours would easily fit Ilyichev's description that a "massive radioactive effect was observed."

Comparison of theoretical results with numerical estimates based on the statements of Werner and Wachsmut

Although the chain of custody and historical authenticity of the written testimonies by Werner and Wachsmut cannot be verified, those testimonies made several specific claims that can actually be tested numerically against the preceding physics calculations.

Werner and Wachsmut (and also Grothmann) reported symptoms of what sounded like radiation sickness among the populations of towns near the test site. Werner specifically listed the towns in which she said people had reported those symptoms, and they are indicated by red circles on p. 4563. The purple circle in that figure is the suspected location of the explosion. Note that the affected towns generally range from north to east of the explosion, which is plausible if the local winds were blowing from the southwest at the time of the test. Based on the distribution of affected towns around the test site, a reasonable estimate for the affected region is a $\sim 100\ \mathrm{km}^2$ area. (For reference, the outermost blue circle in Fig. D.741 has a diameter of 10 km.)

Noticeable but readily survivable radiation sickness in that area within a day after the test, as reported by Werner and Wachsmut (and also Grothmann), suggests an average dose of

$$1\text{–}2\ \ \mathrm{Gy}\ \ \text{within 24 hours averaged over area of} \sim 100\ \mathrm{km}^2 \tag{D.60}$$

Thus the area-averaged dose in Eq. (D.60), which was derived from the testimonies of Werner and Wachsmut, agrees extremely well with the prediction from Eq. (D.57), which was derived from Ilyichev's report and the physics of fission explosions.

A completely independent estimate of the radioactivity at the test site may also be derived from the testimony of Werner and Wachsmut. Werner stated that the test occurred at 9:30 p.m. on 4 March and that a large SS group came by at 2:00 p.m. on 5 March on their way to dispose of the bodies. Wachsmut testified that he worked to burn bodies at the test site from sometime in the afternoon until sometime before 11:00 p.m. on 5 March, with a break of unstated length in the middle for decontamination at the Ringhofen estate some distance away. Wachsmut also stated that he and his fellow workers were unable to eat for at least a couple of days afterward, which suggests moderate radiation sickness in the $\sim$ 1–2 Gy cumulative dose range. (An alternative interpretation is that the inability to eat for days was simply a psychological reaction to what they witnessed. That explanation is possible, but seems insufficient to account for the symptoms as Wachsmut stated he and his fellow workers were already very experienced at disposing of badly tortured prisoners' bodies, and that the inability to eat affected all of his work crew.)

To take nice round numbers as a very simple approximation, one could assume that Wachsmut was exposed to the fallout at the test site from $\sim$ 3:30 p.m. until $\sim$ 9:30 p.m. on 5 March, or in other words from 18 to 24 hours after the test. The cumulative dose from fallout between 18 and 24 hours after an explosion is equal to the dose rate 1 hour after the explosion multiplied by approximately 0.25 hours [Glasstone and Dolan 1977, p. 395, 7.5 hours - 7.25 hours = 0.25 hours for the multiplier]. Thus if Wachsmut received 1–2 Gy between 18 and 24 hours at the test site, the dose rate at the test site 1 hour after the explosion would have been

$$\frac{1\text{–}2\ \text{Gy}}{0.25\ \text{hr}} = 4\text{–}8\ \frac{\text{Gy}}{\text{hr}} \qquad \text{at 1 hour at test site} \qquad \text{or} \tag{D.61}$$

$$30\text{–}60\ \text{Gy} \qquad \text{within 24 hours at test site} \tag{D.62}$$

Therefore Eq. (D.61)'s completely independent estimate of the dose rate at the test site immediately after the test, derived from the testimonies of Werner and Wachsmut, agrees extremely well with the prediction from Eq. (D.58), which came from Ilyichev's report and the physics of fission explosions. The corresponding cumulative dose rate at the test site for the first 24 hours is given by Eq. (D.62), which may be compared with Eq. (D.59).

Furthermore, one should note that Werner and Wachsmut's statements suggest that the fallout dose at the test site, given by Eq. (D.62), was ~ 30 times larger than the average fallout dose received by the larger community, given by Eq. (D.60). That is in excellent agreement with typical fallout patterns for nuclear weapons [Glasstone and Dolan 1977, pp. 419–439], and is quite remarkable considering that this ratio was derived purely from unrelated details given in Werner and Wachsmut's statements.

In making these numerical assessments of details from the written statements of Werner and Wachsmut, one should bear in mind several very important caveats:

- These equations are simply **ballpark estimates** for the average exposure, based in turn on both a ballpark estimate for the explosive yield and also a ballpark estimate for the size of the affected region, so the actual average exposure could have been significantly higher or lower.

- The relative distribution of fallout at the test site and in the larger surrounding area would depend greatly on the local winds and geography, so again these are simply ballpark estimates.

- Since the numerical results derived from Ilyichev's report are ballpark estimates, and those derived from the statements of Werner and Wachsmut are ballpark estimates, at best one can say that the agreement between those two independently derived sets of numerical results is simply in the right ballpark. The fact that the numbers happened to be so similar is not of any physical significance, beyond confirming that the independent ballparks overlap well.

- This physics analysis cannot address whether the written statements of Werner and Wachsmut are authentic, or whether they might have been forged or altered. This analysis can only conclude that the statements of Werner and Wachsmut are highly consistent with the known physics of nuclear weapons, and with physics estimates derived from Ilyichev's report, which was not released until after the written statements of Werner and Wachsmut had already been published.

Expected radioisotopes after 75+ years

After 75+ years, the radioactivity of the fallout would have dropped to $\sim 2\times10^{-9}$ of its radioactivity 1 hour after the explosion [Glasstone and Dolan 1977, p. 393]. Using Eqs. (D.56) and (D.58) with this information, the residual radioactivity would be

$$\text{Averaged over area:} \quad 3.0\text{–}5.3 \times 10^{-10} \ \frac{\text{Gy}}{\text{hr}} \ \text{at 75 years} \tag{D.63}$$

$$2.6\text{–}4.6 \times 10^{-6} \ \frac{\text{Gy}}{\text{yr}} \ \text{at 75 years} \tag{D.64}$$

$$\text{At test site:} \quad 8\text{–}16 \times 10^{-9} \ \frac{\text{Gy}}{\text{hr}} \ \text{at 75 years} \tag{D.65}$$

$$7\text{–}14 \times 10^{-5} \ \frac{\text{Gy}}{\text{yr}} \ \text{at 75 years} \tag{D.66}$$

Since typical radioactive background from terrestrial, solar, and cosmic sources is at least $1\text{–}2\times10^{-3}$ Gy/yr, the residual radioactivity at the test site would be at least ~ 10–30 times smaller than the natural background and hence extremely difficult to detect.

Put differently, the estimated initial values that went into calculating this final value of the residual radioactivity would have to be off by a factor of ~ 10–30 times, and in the right direction, in order for the residual radioactivity to be detectable above the natural background level. For that to have been the case, the explosive yield would have to have been ~ 10–30 times larger than was estimated here, or ~ 2–10 kilotons, which seems highly unlikely given the descriptions of the test, and also the German military's logical desire to minimize the fission fuel consumed and the radioactivity produced on German soil by the test. Alternatively, for the residual radioactivity to be detectable with the explosive yield estimated here, the fallout would have to have been confined to an area ~ 10–30 times smaller than has been assumed here, which also seems highly unlikely. In fact, after 75+ years of water, wind, and human activity, the fallout could easily have become scattered over a significantly larger area than the initial area assumed here, and/or become buried to varying depths in the ground, making it even harder to detect than has been calculated here. As discussed above, the radioactivity in the larger surrounding area would be even lower than that at the test site, by a factor of ~ 10–100.

From fundamental physics, one must therefore conclude that measurements of residual radioactivity cannot be used to try to prove or disprove whether the March 1945 Thuringian nuclear test occurred. This same conclusion, for the same reasons, also applies to the Baltic, Polish, or any other possible wartime German nuclear tests.

Nonetheless, it is possible that methods other than radiation sensors might be used to detect residual products left by the test. For that approach to have some chance of success, the residual products should be (a) unique to the nuclear test, and (b) present in the largest quantities possible. The first criterion rules out common explosives such as TNT and RDX, as well as common metals such as aluminum and iron, that presumably would have made up large fractions of the nuclear device, but that could also have been left by conventional weapons that have been stored, tested, or used at that location for more than a century.

In addition to the radioactive fallout from fission products, any unfissioned uranium would be scattered by the explosion. If only ∼ 100 g U-235 was used (and only a faction of that was fissioned) and was surrounded by only non-uranium materials (gold, tungsten, rhenium, etc.) in the device, as little as ∼ 100 g of unfissioned uranium may have been scattered. On the other hand, if the device used a ∼ 100 kg natural uranium tamper as was reportedly used in the 1945 U.S. Gadget and Fat Man implosion bombs, as much as ∼ 100 kg of unfissioned uranium may have been scattered. Again assuming that the explosion and winds initially scattered the fallout over a ∼ 100 km^2 area, the expected amount of unfissioned uranium could be anywhere in the range:

$$\sim 1\text{ g} - 1\text{ kg of unfissioned uranium per km}^2\text{, or} \tag{D.67}$$

$$\sim 10^{-6} - 10^{-3}\text{ g of unfissioned uranium per m}^2 \tag{D.68}$$

As with the other explosion products, that is only the expected initial amount in 1945. After 75+ years, any unfissioned uranium could have become spread over a much larger area and/or seeped down into the ground, so the current amount could be far lower than this initial estimate.

Thus the residual radioactivity from a 1945 nuclear test of the magnitude described would now be far smaller than the average natural background radiation and therefore undetectable. Nonetheless, it might be possible to detect fission products or unfissioned fuel from the test by analyzing soil samples via mass spectrometry, particle-induced X-ray emission, neutron activation analysis, or other highly sensitive methods. Unfortunately, even these methods might have difficulty distinguishing the small amount of remaining telltale products from a background that would include not only naturally occurring isotopes but also fallout from the 1986 Chernobyl fission reactor accident and contamination from decades of Cold War military exercises (including both nuclear materials and depleted-uranium conventional projectiles).

Uranium-235 tends to fission into a light fragment with mass number $A_1 \sim 95$ and a heavy fragment with $A_2 \sim 140$. The sizes of the resulting light and heavy fragments vary somewhat, creating a double-peaked mass distribution [Fig. D.1035(a)]. Fig. D.1035(b) shows that for different masses of the fissioning nucleus, the heavy fragment mass peak remains essentially fixed, while the light peak is left to shift with the changes in total mass. If there is very little energy initially put into the fission reaction, the trough between the light and heavy mass peaks is quite deep. Yet as the input energy increases, the trough becomes less and less deep [Fig D.1035(c)]; the fissioning nucleus becomes able to fall into almost any final state, not just the energetically lowest ones.

In general, fission products are inherently β emitters due to their excess of neutrons inherited from the massive original nucleus, with some γ emission as well. Most fission products have half-lives less than a couple of years or so and thus will largely decay to more stable isotopes within a few years. Of the vast array of fission products, only a handful do not decay within a few years; these are listed in Table D.11 [using data drawn from Benedict et al. 1981]. (Note that actinides are not included.)

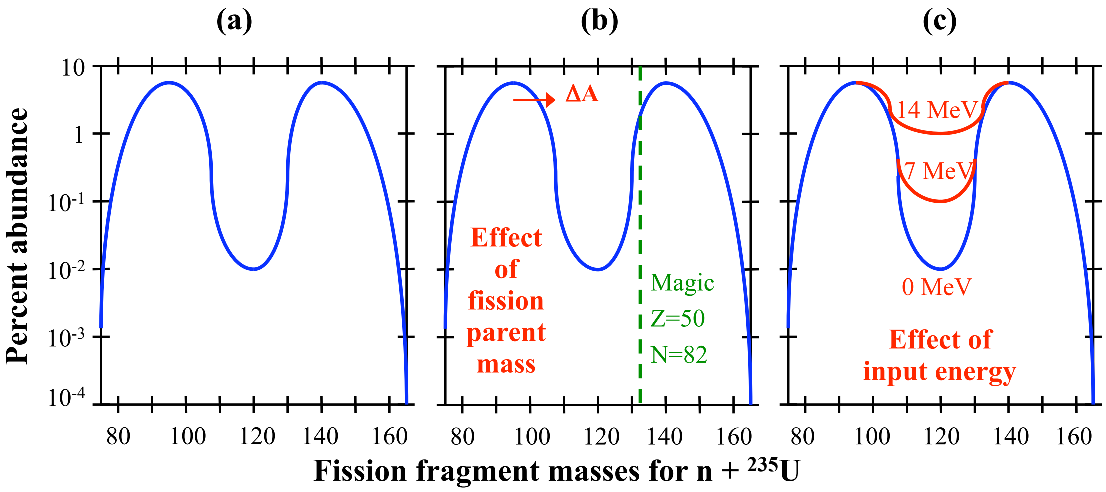


Figure D.1035: Mass distributions of nuclear fragments resulting from fission. (a) Low-energy neutron-induced fission of ^{235}U. (b) Effect of increasing the initial mass of the nucleus undergoing fission by ΔA. (c) Effect of input energy on neutron-induced ^{235}U fission.

Nuclide	**Half-life (years)**
Europium-154	16
Strontium-90	29
Cesium-137	30
Samarium-151	87
Technetium-99	2.1×10^5
Selenium-79	1.1×10^6
Zirconium-93	1.5×10^6
Cesium-135	2.3×10^6
Iodine-129	1.6×10^7

Table D.11: Major long-lived radioactive fission products.

Despite background contamination and the passage of time, the use of three approaches in combination might be able to provide good evidence of a wartime German nuclear weapons test:

1. Ion mass spectrometry, particle-induced X-ray emission, neutron activation analysis, or other highly sensitive methods could detect very low levels of fission products, even non-radioactive fission products or other bomb components, and identify not just elements but specific isotopes and their relative concentrations.

2. Analyzing numerous samples from suspected test sites as well as surrounding regions could determine what background levels of which isotopes are present (from Chernobyl, Cold War military programs, or natural sources), and how much variation there is in those background levels. If multiple samples from a suspected test site contain fission products that generally agree with each other but are well outside the range expected of background contamination, that finding would be of great interest.

3. From Fig. D.1035, the relative quantities of different fission products depend on whether they came from highly enriched U-235, low-enriched reactor-grade U-235, Pu-239, or U-233. The relative quantities also depend on the neutron energies used in the fission reactions—fast neutrons for weapons and slow neutrons for reactors (although could there have been significant fast fission during the Chernobyl event?). Thus the relative quantities of various isotopes in the sample could indicate the specific type of fission fuel and fission reactions from which they originated. However, there may not be enough fission products to detect (for a 200-ton explosion, $\sim$ 10 grams of fission products scattered over the area). In that case, the most promising component to detect would be the tamper (likely $\sim$ 100 kg of mostly U-238 scattered over the area), if that could be distinguished from U-238 background contamination.

D.15.5 Estimating Device Design Parameters from Primary Sources

Very tentative design parameters for the device that may have been tested in Thuringia in March 1945 may be estimated from the primary sources, simple physics, and unclassified documents about the United States' first implosion bombs (Gadget, shown in Fig. D.1036, that was detonated in New Mexico on 16 July 1945, and its fully packaged version, Fat Man, shown in Fig. D.1037, that was dropped on Nagasaki on 9 August 1945) and other nuclear weapon designs [Coster-Mullen 2012; Goncharov 1996a, 1996b; Goncharov and Riabev 2001; Gsponer and Hurni 2009; Chuck Hansen 1988, 2007; Bruce Cameron Reed 2015a, 2019; Rhodes 1986, 1995; Serber 1992; Smyth 1945; Sublette 2019; Wellerstein and Geist 2017; Winterberg 2010].

Of the primary sources, by far the most detailed and most authoritative is Ilyichev's March 1945 intelligence report, so it will be relied upon heavily here. Details from that report are supported by more general comments from Ilyichev's November 1944 intelligence report and the documents of Schumann, Trinks, Diebner, and Guderley. The most relevant design details from these sources are summarized on p. 4157.

The results of the following analysis are consistent with those of previous analyses [Eilers 2007, 2015; Mineev and Funtikov 2007].

(Can any information on wartime German work be extrapolated from the postwar Soviet program, especially RDS-2/Joe-2 (or later tests)? Soviet rockets were highly derivative of German rockets. The Soviet nuclear program and designs were likely highly derivative of German work as well, although RDS-1/Joe-1 was directly copied from the U.S. Fat Man design.)

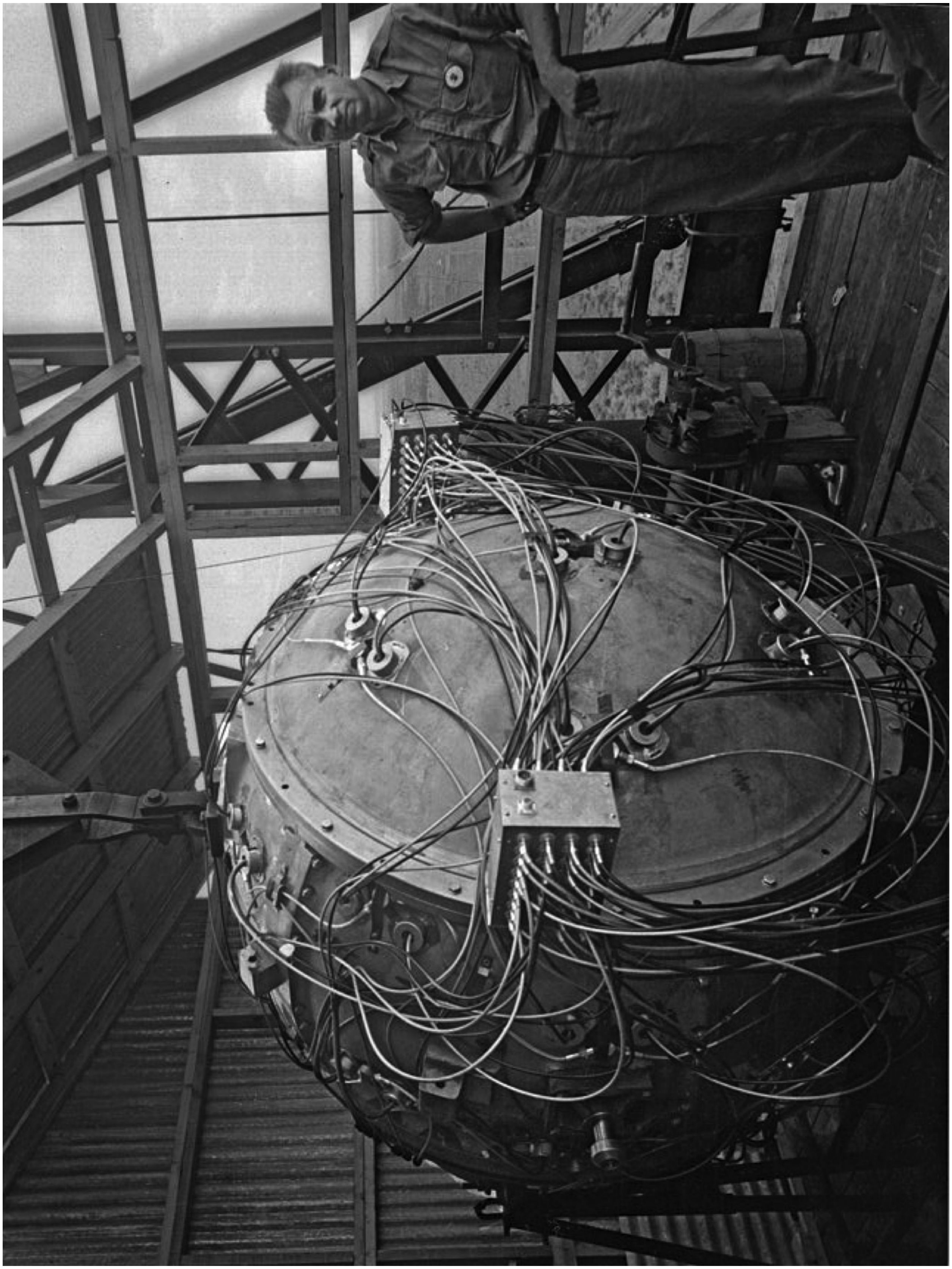
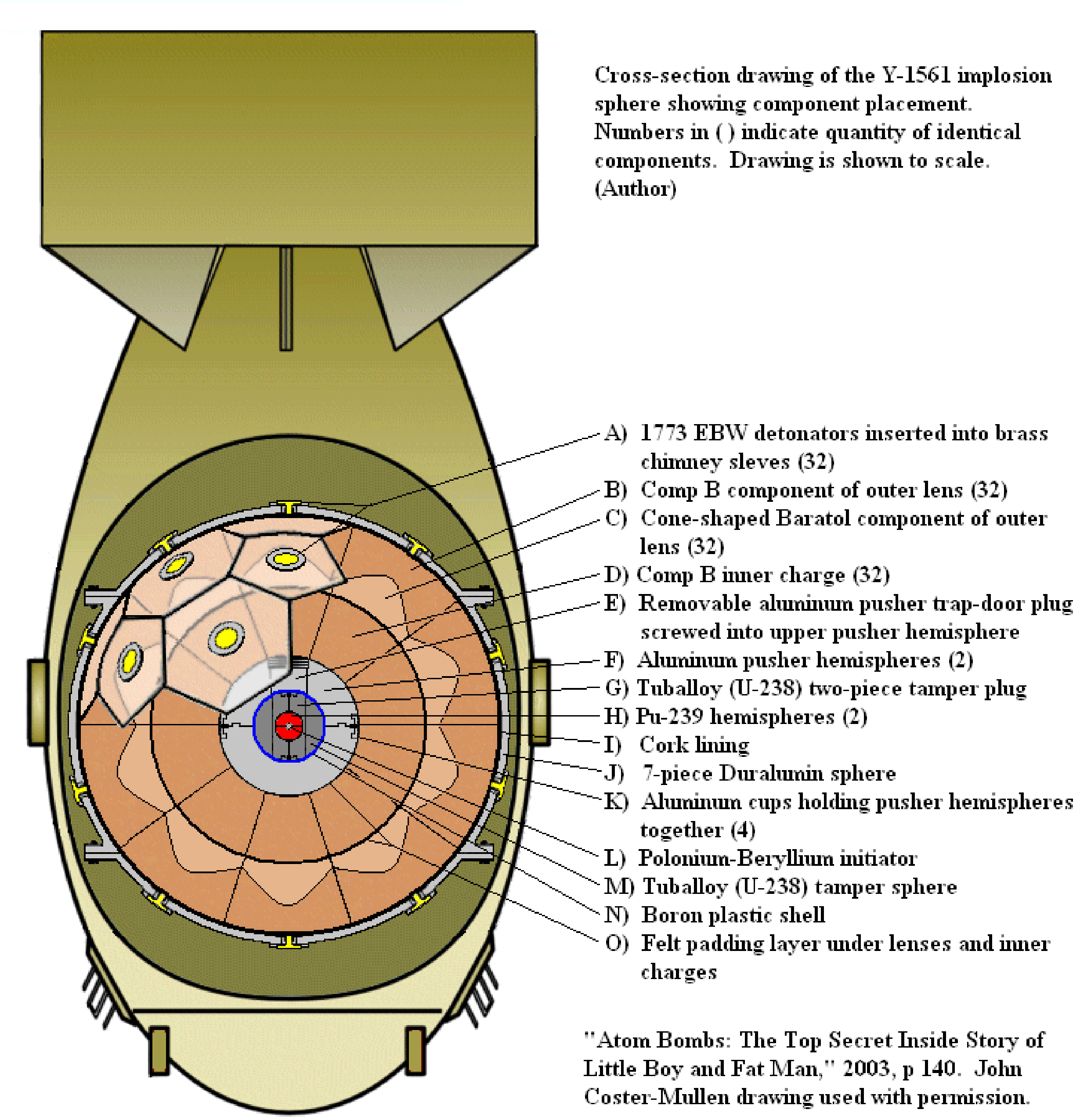


Figure D.1036: Gadget device being prepared by Norris Bradbury for 16 July 1945 test in New Mexico.



Cross-section drawing of the Y-1561 implosion sphere showing component placement. Numbers in ( ) indicate quantity of identical components. Drawing is shown to scale. (Author)

A) 1773 EBW detonators inserted into brass chimney sleves (32)
B) Comp B component of outer lens (32)
C) Cone-shaped Baratol component of outer lens (32)
D) Comp B inner charge (32)
E) Removable aluminum pusher trap-door plug screwed into upper pusher hemisphere
F) Aluminum pusher hemispheres (2)
G) Tuballoy (U-238) two-piece tamper plug
H) Pu-239 hemispheres (2)
I) Cork lining
J) 7-piece Duralumin sphere
K) Aluminum cups holding pusher hemispheres together (4)
L) Polonium-Beryllium initiator
M) Tuballoy (U-238) tamper sphere
N) Boron plastic shell
O) Felt padding layer under lenses and inner charges

"Atom Bombs: The Top Secret Inside Story of Little Boy and Fat Man," 2003, p 140. John Coster-Mullen drawing used with permission.

Figure D.1037: Scale drawing of Fat Man design according to unclassified sources [https://commons.wikimedia.org/wiki/File:Fat_Man_Internal_Components.png].

Table D.12 compares the Gadget/Fat Man design details from unclassified sources with extrapolated parameters for what the March 1945 Thuringian device design may have been. Each major component will then be discussed briefly.

Component	Gadget/Fat Man	Thuringian Device
Neutron initiator	$\sim$ 7 g beryllium/polonium-210 "urchin" 1.25 cm radius	Deuterium + lithium with high voltage $\sim$ 1.25 cm radius and/or external 6 MeV betatron
Pit	6.2 kg ^{239}Pu 4.6 cm radius	**For test:** <1 kg inner layer of ^{235}U with $\sim$ 5–10 kg natural or low-enriched U outer layer **For deployment:** $\sim$ 5–10 kg ^{235}U $\sim$ 5 cm radius
Tamper/ reflector	108 kg natural U 11.1 cm radius	$\sim$ 100 kg natural U $\sim$ 11 cm radius
Neutron absorber	Boron-10 plastic 3.2 mm thick	$\sim$ 1.3 kg cadmium $\sim$ 1 mm thick
Pusher	130 kg aluminum 23.5 cm radius	$\sim$ 130 kg aluminum $\sim$ 23 cm radius
Explosive	Composition B and baratol 2500 kg, segmented $\sim$ 70 cm radius	TNT, RDX, and liquid oxygen $\sim$ 1400 kg, segmented $\sim$ 63 cm radius
Explosive case	$\sim$ 180 kg aluminum 72.5 cm radius	$\sim$ 140 kg aluminum $\sim$ 64 cm radius
Ballistic case	Steel 4.5 mm thick 75 cm radius	$\sim$ 190 kg steel $\sim$ 4.5 mm thick 65 cm radius
Overall radius	75 cm	$\sim$ 65 cm
Total mass	3000 kg (bomb only) 4670 kg (with shell and fins)	$\sim$ 2000 kg
Delivery system	Boeing B-29 heavy bomber	A-4, A-9, or A-9/A-10 ballistic missile
Explosive yield	20 kilotons	**For test:** < 1 kiloton **For deployment:** $\sim$ 5–100 kilotons

Table D.12: Comparison of the U.S. Gadget/Fat Man implosion design (from unclassified sources) with extrapolated design parameters of the March 1945 Thuringian device.

A. Neutron Initiator

According to the unclassified references, fission bombs are generally equipped with a neutron source or initiator, which provides neutrons to initiate a fission chain reaction just as the fission fuel is being compressed toward its maximum density by implosion with conventional explosives. These references also indicate that the Gadget/Fat Man design used an internal polonium-210/beryllium initiator nicknamed the "urchin" that produced neutrons when crushed at the center of the bomb, and that modern bombs use an external (not inside the imploding part of the bomb) tube filled with deuterium and tritium gas that produces high-energy "fast" fusion neutrons when high voltage (several thousand volts) is applied.

There are at least five possible neutron initiators that could have been used in the Thuringian device, and there is some evidence for each one. Perhaps combinations of these were used to provide redundancy (in case one failed) or to increase the number of initial neutrons, or perhaps they were intended to be used in different versions of the bomb:

1. **Fusion fuel with high voltage at the center of the bomb.** Ilyichev's March 1945 report gave three similar descriptions (p. 4485):

    (a) "1. High-voltage discharge tube, which is charged by special generators."

    (b) "Initiator or bomb fuse: Consists of a special tube, which creates fast neutrons. It is charged by special generators, which create high voltage inside the tube. As a result, fast neutrons attack active material."

    (c) "The bomb ignition is carried out with the help of a high-voltage discharge tube. It forms a flow of neutrons, which attack the active material. When the flow of neutrons impacts upon uranium, element 93 fissions, which speeds up the creation of a chain reaction."

    These three descriptions seem to refer to a high-voltage tube that is filled with fusion fuel (deuterium, tritium, and/or lithium) and produces fast neutrons when a high voltage is applied to the tube. Those neutrons initiate fission reactions in the uranium, releasing more neutrons and starting the fission chain reaction. (The term "Element 93" was widely and scientifically loosely used in the German nuclear program to mean uranium that had absorbed a neutron, sometimes meaning neptunium and sometimes plutonium. Here it simply seems to mean the excited uranium compound nucleus, just after it has absorbed a high-energy fusion neutron and just before it fissions.)

    Ilyichev made it clear that the neutron initiator was at the center of the bomb; he described the core of the bomb as a

    > uranium 235 [...] sphere with an opening into which an initiator is inserted. Once this is done, the opening is sealed by a cork made of uranium 235.

    Due to the constraints of the small volume available at the center of the fission fuel pit, the requirement to avoid including any materials that could hinder the nuclear reactions, and the need for the electrical connections to the central neutron initiator to be functional during the implosion process, the internal high voltage fusion neutron source would need to have a very ingenious design. In fact, after the war Kurt Diebner obtained a patent on just such a high voltage fusion neutron source at the center of an implosion bomb (p. 4261).

2. **External fusion fuel with high voltage.** Since this neutron initiator would be external to the imploding part of the bomb and not be at the center of the bomb, there would be far fewer constraints on its design, which is why the unclassified references report that most modern bombs have used this method. High-voltage tubes that used fusion fuel to produce neutrons were well known and used in the wartime German nuclear program (pp. 3958–3970, 4281–4327).

3. **Internal fusion fuel (without high voltage).** Even without high voltage, fusion fuel placed at the center of the bomb might experience sufficient compression and heating during the implosion process that it would undergo some fusion reactions. While these fusion reactions would not create a measurable amount of released energy (as confirmed by the efforts of Schumann, Trinks, and others to implode pure fusion fuel), they might produce enough neutrons to initiate a fission chain reaction in the surrounding, imploding fission fuel. After the war, Schumann and Trinks and also Diebner published diagrams showing fusion fuel (without high voltage) at the center of an imploding uranium sphere (pp. 4229–4267).

4. **An internal polonium-210/beryllium urchin-like neutron initiator.** Although such an initiator was used in the early U.S. fission bombs, it is not mentioned in existing documents about German bomb designs. However, general use of an alpha emitter (such as radium, polonium, etc.) plus beryllium to produce neutrons was well known and widely practiced in the German nuclear program (see for example pp. 3374 and 4327). Many tons of beryllium were produced (p. 4096). A special installation also produced polonium-210. In fact, on 28 February 1945, just four days before the 4 March test in Thuringia, Kurt Diebner and Walther Gerlach appropriated Germany's entire stock of prepared polonium for a purpose that was too secret to specify (p. 4540).

5. **An external compact betatron directing electrons with energies of at least 6 MeV toward the center.** The >6 MeV electrons would produce <6 MeV gamma-ray photons in the uranium via bremsstrahlung and other absorptive processes, the photons would induce photofission reactions in the uranium, and neutrons would be released. Ilyichev's March 1945 report seems to indicate that the fission bombs tested in Thuringia used this process (p. 4487):

   > Ahead of this, before the explosion, the uranium sphere is irradiated with gamma-rays, the energy of which does not exceed 6 million electron volts [MeV], which many times increases its explosive qualities.

   The more initial neutrons are provided via the betatron or other methods, the larger the resulting fission chain reaction that can occur during the brief time before the bomb core blows apart—thus the betatron-induced radiation "many times increases its explosive qualities" as stated by Ilyichev. The betatron would also need "special generators, which create high voltage," so that part of Ilyichev's description could apply to betatron and/or high-voltage fusion neutron initiators.

   Werner Grothmann also appeared to refer to this type of neutron initiator (p. 5041).

   The basic physics of this process has been described in detail [Wagemans 1991, pp. 103–197]. Remarkably, documentation demonstrates that German scientists were aware of this process mediated by 5–6 MeV gamma rays no later than 1941 (p. 3814). In one of the most detailed yet unclassified modern references on nuclear weapons, Carey Sublette described the use of this process as a neutron initiator for fission bombs [Sublette 2019, Section 4.1.8.2]:

> An additional type of ENI [External Neutron Initiator], not based on fusion reactions, has been successfully tested but apparently never deployed. This is the use of a compact betatron, a type of electron accelerator, to produce energetic photons (several MeV). These photons cause photon induced fission, and photon → neutron reactions directly in the core.

Intriguingly, when Diebner fled Stadtilm ahead of U.S. forces, among the papers he left behind was a whole folder worth of papers on betatrons (p. 3862). A number of betatrons were available for the wartime German nuclear program (Appendix C). In particular, a betatron model produced by Siemens-Reiniger Werke in Erlangen was specifically described as having an energy of 6 MeV (pp. 3088–3089, 3957–3970). That betatron weighed a relatively modest 272 kg, and lighter versions may have been constructed too.

The United States did not begin any serious work on betatrons as neutron initiators until 1946. Could that postwar work have been based on what U.S. investigators learned about the wartime German nuclear program? The *Manhattan District History* reported [Supplement to Manhattan District History Book VIII, Los Alamos Project (Y) Volume 2, Technical, pp. IV-13–IV-14. https://ia803409.us.archive.org/14/items/ManhattanDistrictHistory/]:

> THE BETATRON GROUP [...] 4.55 Experiments were conducted throughout 1946 on photo fission thresholds in normal uranium, U^{235}, U^{238} and plutonium. The most dependable results have come from the use of a shielded paraffin geometry about five feet from the betatron. These findings indicate that all fissionable materials (such as plutonium, normal uranium, and U^{238} have thresholds at about 5.2 Mev. However, this work is not conclusive as it has been observed that the threshold for the production of neutrons from the betatron is also 5.2 Mev. Therefore, there is a doubt as to whether the fission observed is neutron produced fission or gamma fission.

According to further information from Carey Sublette, the United States actually successfully demonstrated a betatron neutron initiator in a fission bomb on 1 June 1952 in the George test of Operation Tumbler-Snapper [https://nuclearweaponarchive.org/Usa/Tests/Tumblers.html]:

> This device (code named XR2) used a Mk 5 bomb assembly. The test was intended to gather additional data on the initiation time vs yield curve. A novel feature of this test was the use of an external initiator—in this case employing a device called a betatron (which is a circular electron accelerator). In this test the high energy electrons were used to generate high energy X-rays that induced photo-fission in the core to initiate the chain reaction. The betatron allowed very accurate control of initiation time. The test device had a diameter of 40 inches and weighed 2700 lb, the predicted yield was 30 kt.

Whatever other neutron initiators may have been present or considered, if Ilyichev's description is correct, at least a small amount of fusion fuel was at the center to serve as a neutron source when triggered with high voltage. If that fusion fuel was deuterium + tritium or deuterium + lithium (but not pure deuterium, which is harder to fuse), it may have produced further high-energy neutrons once the surrounding fission fuel reached high enough temperatures and pressures. If so, those additional fusion neutrons could have significantly increased the number of fission reactions that could occur in the fission fuel before that fuel was scattered by the explosion.

In previous experiments, Schumann and Trinks had tried unsuccessfully to initiate reactions in pure fusion fuel by imploding it with conventional explosives [Irving 1967, pp. 193–197; Karlsch 2005, pp. 144–155; Nagel 2016, pp. 220–242]. If the designers of the Thuringian device did not expect further reactions from the central fusion fuel after the momentary high voltage, yet fusion reactions in the center and fission reactions in the surrounding U-235 mutually aided each other, the yield of the device could have been boosted to be significantly larger than the designers had expected, especially if only a small amount of fission fuel was used. This could explain comments from Wachsmut and Grothmann that the energy yield and casualties were much larger than expected. Potentially this might also explain why there may have been a second and apparently less dramatic test on 12 March 1945 (according to Werner), if the scientists wanted to run the experiment again but without the boosting effect, in order to make sure they fully understood how much difference the boosting effect had made and/or how well their design imploded under more controlled conditions.

On the other hand, perhaps the designers intended for fusion reactions to continue in the center and for fusion neutrons to boost the number of fission reactions in the surrounding fission fuel. In that case, the experiments imploding pure fusion fuel might be viewed merely as preliminary tests before imploding the full fission-fusion design. If one makes some allowances for Ilyichev's specific wording, the center might have been filled with a significant amount of fusion fuel, potentially up to several grams:

- Deuterium-tritium gas would be the most effective [Gsponer and Hurni 2009, p. 10]. Gram quantities of deuterium could easily have been spared from the heavy water production programs. Alfred Klemm mentioned that there was apparently some sort of secret wartime production and use for tritium (p. 4346). Tritium could have been produced by bombarding either deuterium (or heavy water) or lithium with neutrons, in either a fission reactor or a particle accelerator.

- Solid lithium-6 deuteride might also be effective [Gsponer and Hurni 2009, p. 10]. Alfred Klemm produced gram quantities of lithium-6 in his laboratory (pp. 4344–4347), and his process could have been replicated elsewhere. A number of documents show that there was wartime work using lithium and deuterium together as fusion fuel (pp. 4305–4341). Because lithium deuteride is solid and not a gas or cryogenic liquid, it makes a very convenient material for bombs.

- Pure deuterium might conceivably have worked in the high-voltage neutron initiator, but probably would not have been useful for producing further fusion neutrons during the implosion [Gsponer and Hurni 2009, p. 10].

B. Pit

According to the unclassified sources, “pit” is the customary name for the fission fuel in a bomb. Ilyichev’s March 1945 report described the pit of the Thuringian device: “Active bomb material is uranium 235. It represents a sphere with an opening into which an initiator is inserted. Once this is done, the opening is sealed by a cork made of uranium 235. ...A shock from the explosion of the external layer of TNT mixed with liquid oxygen takes place, which is directed toward the center. This allows the uranium to reach a critical mass.”

Although Ilyichev described the fission fuel as uranium-235, uranium-233, neptunium-237, or plutonium-239 might conceivably have been used instead, so we will consider all four possible fission fuels. Table D.13 gives the critical masses for spheres of uranium-233, uranium-235, neptunium-237, or plutonium-239 under various ideal conditions. Critical masses assuming no compression from implosion, no surrounding neutron reflector/tamper, and no fusion neutrons are taken from unclassified information [Bruce Cameron Reed 2015a, 2019; Sanchez et al. 2008]. At most, a single ideal shock wave could compress the fission fuel density by a factor of 4, or reduce the critical mass by a factor of $4^2 = 16$ [Sublette 2019, Section 2.1.4]. Similarly, at most an ideal neutron reflector could reduce the critical mass by a factor of $2^3 = 8$ [Serber 1992, p. 31]. Neutrons from fusion reactions at the center could also significantly reduce the critical mass; the exact factor of improvement depends on a number of details, but some theoretical predictions of the fusion-assisted critical mass are as low as 10 grams [Winterberg 2010, pp. 36, 206–208]. Of course, these are theoretical minimum values for the critical mass under absolutely ideal conditions. Real systems would have various inefficiencies and design tradeoffs and hence larger critical masses. Nonetheless, the critical masses in Table D.13 give some idea of the range of design possibilities that may have been involved in the Thuringian device.

The fission pit in the Thuringian device could have used one of these possible fuels, or it could have combined two or more of the possible fuels. If Germany only possessed a very limited supply of any individual fission fuel, it may have seemed especially attractive to combine them to produce a functional device (or as many functional devices as possible).

Conditions	**Uranium-233**	**Uranium-235**	**Neptunium-237**	**Plutonium-239**
No compression **No reflector** **No fusion**	14.2 kg	45.9 kg	57.0 kg	16.7 kg
Max compression **No reflector** **No fusion**	0.888 kg	2.87 kg	3.56 kg	1.04 kg
Max compression **Max reflector** **No fusion**	0.111 kg	0.359 kg	0.445 kg	0.130 kg
Max compression **Max reflector** **Fusion neutrons**	< 0.111 kg	< 0.359 kg	< 0.445 kg	< 0.130 kg

Table D.13: Critical masses for spheres of uranium-233, uranium-235, neptunium-237, or plutonium-239 under various ideal conditions.

While Table D.13 assumed that the U-235 was 100% enriched, that would not be required. In fact, the Little Boy bomb that the United States dropped on Hiroshima used 64 kg of 80% enriched U-235, which obviously worked. 70% enriched U-235 would also work but would require approximately twice the critical mass of 100% enriched U-235 under the same conditions (compression, reflector, fusion boost, etc.). Similarly, 45% enriched U-235 would require approximately four times the critical mass of 100% enriched U-235 under the same conditions [Sublette 2019]. Bomb performance would become much worse or impossible with enrichment levels significantly lower than those levels.

Grothmann reported that the device was tested with a very small amount of fission fuel but ready to be deployed with a much larger amount. Possible numbers might be < 1 kg for the tested version and ∼5–10 kg for the version to be deployed. Rundnagel specifically mentioned 8 kg for what was apparently the fission pit stored in a safe. Based on information about implosion device designs from the unclassified sources, it seems likely that the pit would have had a deployed mass in the range

$$M_{\mathrm{pit}} \quad \approx \quad 5 - 10 \text{ kg} \tag{D.69}$$

For the implosion of the test version to function as intended in the deployable version, any amount of fission fuel (U-235, or possibly U-233, Np-237, Pu-239, or some combination thereof) that was omitted from the test version would have been replaced with a less precious but similarly dense material for the outer pit, with the remaining true fission fuel at the inner surface of the pit. By far the best and most logical replacement would be low-enriched uranium, which may have been available, or natural uranium, which certainly was available. Considering that the density of uranium is 19.1 g/cm^3 and that of plutonium is 19.8 g/cm^3, other possible replacement materials include gold (19.3 g/cm^3), tungsten (19.3 g/cm^3), and rhenium (21.0 g/cm^3). Any of those materials would have also made a good neutron reflector to keep as many neutrons as possible within the small amount of fission fuel. Natural or low-enriched uranium would have acted as a good neutron reflector and also to some degree as additional fission fuel.[33]

Since U-235 makes up only 0.0072 of natural uranium, 13.9 kg of natural uranium would need to be completely processed to obtain 100 g of pure U-235, or 694–1390 kg of natural uranium would need to be processed to obtain 5–10 kg of pure U-235. (Of course, the U-235 may not have been enriched to 100% purity.) Any strategically useful nuclear weapons program would require multiple bombs and hence at least a few tons of completely processed natural uranium. Exactly how far did uranium enrichment programs progress during the war (p. 5116)?

Alternatively, could enough U-233 fission fuel have been produced from thorium-232, or enough Pu-239 or Np-237 fission fuel have been produced from uranium-238, using an operational fission reactor somewhere and/or particle accelerators (p. 5129)?

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[33] Large amounts of gold were available in the German-speaking world during the war, as shown by the large stashes of gold that were found at the end of the war.

Large quantities of tungsten were also available, as indicated for example by BIOS 684, *Production of Molybdenum & Tungsten for Radio Valves & Electric Lamps, Metallwerke Plansee, Reutte, Tyrol,* p. 16: “During the war the finished Tungsten production [from this factory] was stated to be 1½ tons per month for which they required 3 tons of Oxide. For carbide manufacture they used about 4 tons per month of metal powder made from oxide.” For another example of tungsten production, see BIOS 1356, *Grinding and Treatment of Minerals.*

Rhenium was available but much more scarce and therefore unlikely to have been used for this purpose [FIAT 697, 750].

C. Reflector/Tamper

According to the unclassified sources, the reflector serves both to reflect neutrons back into the pit and also (if it has much more mass than the pit) as a tamper to slow the explosion of the pit long enough to allow more fission reactions to occur. The most logical reflector/tamper material would be natural or low-enriched uranium. Although Ilyichev's March 1945 report did not specifically mention a reflector or tamper, it may have simply lumped the uranium pit and uranium reflector/tamper together in describing the inner part of the bomb as being "filled with uranium." Intriguingly though, Ilyichev did initially list a "delay mechanism" between the "sphere made of metal uranium 235" and the aluminum "protective casing," then go on to give more detailed descriptions of the uranium-235 and the protective casing but not the delay mechanism between them. Considering the imperfections inherent in translating from specialized scientific language to common language and also from German to Russian in a spy's brief report, "delay mechanism" would actually be a fairly accurate succinct description of the tamper's function.

According to the unclassified sources, the Gadget/Fat Man reflector/tamper was 108 kg of natural uranium. It seems reasonable to assume that the Thuringian device also had a tamper with a mass in the neighborhood of:

$$M_{\text{tamper}} \approx 100\text{ kg} \tag{D.70}$$

If for some reason it was decided not to use uranium for the reflector/tamper, the same alternative materials that might have formed the outer pit for the test version would also make good alternative materials for the reflector/tamper: gold, tungsten, and rhenium. Thorium (11.7 g/cm^3) and lead (11.3 g/cm^3) are lower density but might also be possibilities. Beryllium (1.85 g/cm^3) has a very low density and would not make a good tamper (unless combined with a heavier element), but it is an excellent neutron multiplier/reflector.

All of those candidate tamper materials would have been readily available in sufficient quantities in wartime Germany, with the possible exception of rhenium.

D. Neutron Absorber

According to Ilyichev's March 1945 report: "The uranium sphere is encased in a protective aluminum casing, which is covered by a layer of cadmium. This significantly impedes thermal neutrons emanating from uranium 235, which can cause premature detonation." According to the unclassified sources, in the Gadget/Fat Man design, the inner surface of the aluminum pusher was lined with a 3.2-mm-thick layer of plastic that was rich in boron-10. The boron-10 was intended to absorb any fast neutrons escaping from premature spontaneous individual fission events in the pit, so that they would not enter the hydrogen-rich conventional explosives, slow down to "thermal" speeds that are much more effective at inducing fission reactions, and find their way back into the pit to cause even more premature fission events.

Cadmium is also an excellent neutron absorber and would have served the same purpose in the Thuringian device. It seems likely that it was on the inner surface of the pusher, as the boron-10 was in Gadget/Fat Man, although that is somewhat unclear from Ilyichev's report.

Erich Schumann also mentioned a layer of cadmium in implosion bomb designs (p. 4254). After the war, a "capable young engineer" in Poland told the U.S. embassy there that "one of the best if not the only material for atomic bomb containers is cadmium" (p. 4255), which may have reflected knowledge that he gained from the construction and/or testing of a German fission bomb in Poland.

Cadmium was produced in large quantities in wartime Germany and widely used as a neutron absorber in the German nuclear program (p. 4148). Because cadmium is so dense (8.65 g/cm^3) compared to the density of boron or plastic (< 2 g/cm^3), only a very thin layer of cadmium would have been needed, probably less than 1 mm. German cadmium is known to have been produced in foils of thickness 1 mm or less, which could have been suitable for covering the aluminum pusher. For even better uniformity of coverage, especially to avoid any asymmetries during the implosion process, the cadmium could have been electroplated onto the aluminum. Technologies for electrodepositing cadmium, and electroplating layers onto aluminum, are documented to have existed in wartime Germany (p. 4148).

Assuming that the cadmium layer was on the inner surface of the aluminum pusher and had a radius of 11 cm (comparable to the inner pusher radius in Gadget/Fat Man), thickness of 1 mm, and density of 8.65 g/cm^3, its mass would have been:

$$M_{\text{cadmium}} \approx 4\pi\,(11\text{ cm})^2\,(0.1\text{ cm})\,\frac{8.65\text{ g/cm}^3}{1000\text{ g/kg}} \approx 1.3\text{ kg} \tag{D.71}$$

E. Pusher

Ilyichev's March 1945 report stated: "The uranium sphere is encased in a protective aluminum casing." From the unclassified sources, the Gadget/Fat Man design used a 130 kg aluminum "pusher" between the conventional explosive and the uranium reflector/tamper, so it seems reasonable to assume a comparable mass for the Thuringian device's aluminum pusher:

$$M_{\text{pusher}} \approx 130\text{ kg} \tag{D.72}$$

Because the aluminum pusher's density (2.70 g/cm^3) is higher than that of the explosive (~ 1.6 g/cm^3) but lower than that of the uranium (19.1 g/cm^3), the pusher helps to efficiently transfer the imploding shock wave from the explosive to the uranium.

There is some evidence that the aluminum pusher and aluminum explosive case spherical shells for fission implosion bombs were produced on Usedom peninsula (p. 4270), but if not, suitably sophisticated aluminum production and machining was widespread in wartime Germany (p. 4126).

F. Explosive

Ilyichev's March 1945 report stated: "After the layer of cadmium, it is placed inside explosives that consist of porous TNT saturated with liquid oxygen; TNT is made up of bars of a specially chosen shape. The inner surface of the bars has a spherical curvature, which is the same as that of the external surface of the cadmium layer. Each of the bars is supplied with one detonator or two electrical fuses. ...Liquid oxygen is pumped through the opening inside a protective casing, which covers the TNT. ...The detonating mechanism detonates the explosive matter, after which a shock from the explosion of the external layer of TNT mixed with liquid oxygen takes place, which is directed toward the center."

Most of the interior of the Gadget and Fat Man bombs was filled with TNT-based explosives (composition B and baratol) with shapes and a segmented design intended to optimize the creation of a spherical implosive shock wave. Thus one would expect something very similar in the Thuringian device, especially given the participants' extensive experience designing and testing implosion devices powered by conventional explosives [Irving 1967, pp. 193–197; Karlsch 2005, pp. 144–155; Nagel 2016, pp. 220–242]. Erich Schumann and Walter Trinks demonstrated a sophisticated knowledge of TNT, hexogen/RDX, other explosives, and explosive lenses using combinations of those explosives (pp. 4187–4255). There were also many other experts on implosion techniques, such as Rolf Engel, Rudi Schall, and Hubert Schardin.

Ilyichev said the Thuringian device used TNT, although that might possibly mean any of several TNT-related explosives as in the Gadget/Fat Man design. The average density of solid TNT is 1.654 g/cm^3. If the TNT-based explosive were porous to allow for liquid oxygen penetration, its density would be somewhat lower, say perhaps $\rho \approx 1.4$ g/cm^3.

Assuming that the Thuringian device's explosive layer had an outer radius of approximately $R_o = 63$ cm (slightly less than Ilyichev's stated 65 cm outside radius for the case), an inner radius of approximately $R_i = 23$ cm (if the pusher had an outer radius similar to that in Gadget/Fat Man), and an average density of $\rho = 1.4$ g/cm^3, the explosive layer's mass would be:

$$M_{\text{explosive layer}} \;=\; \frac{4}{3}\pi\left(R_o^3 - R_i^3\right)\rho \;\approx\; 1400\text{ kg} \tag{D.73}$$

TNT molecules ($C_7H_5N_3O_6$) contain relatively few oxygen atoms and normally release their explosive energy by decomposing into a number of smaller oxygen-deficient molecules. Without providing added oxygen, detonation releases 4.184 GJ of energy per ton of TNT.

If enough liquid oxygen were provided, all of those TNT decomposition products could be fully oxidized, and significantly more explosive energy would be released. With complete oxidation, detonation releases 14.5 GJ per ton of TNT, 3.47 times as much energy as without added oxygen.

Thus the provision of liquid oxygen might make the ~1400 kg of explosives in the Thuringian device comparable to up to ~4850 kg of explosives without added oxygen. Depending on the detailed chemical composition of the explosives (the relative amounts of TNT, hexogen, etc.) and the efficiency with which the liquid oxygen was utilized, the ~1400 kg of explosives in the Thuringian device could easily have been quite comparable to or even significantly more powerful than the 2500 kg of explosives in the Gadget/Fat Man design.

G. Explosive Case

According to Ilyichev's March 1945 report: "TNT is covered by a protective layer made of a light aluminum alloy. A blasting mechanism is attached on top of this casing." From the unclassified sources, the Gadget/Fat Man design used a cork-lined aluminum case to enclose the explosives. The aluminum case of the Thuringian device may have been unlined, or the Soviet spy may have simply not known about or considered it worth mentioning the lining. If the aluminum explosive case had an outside radius of $R = 64$ cm (just smaller than Ilyichev's quoted radius for the outer steel case), a thickness of 1 cm, and a density of 2.70 g/cm^3, its mass would have been

$$M_{\text{aluminum case}} \;\approx\; 4\pi\,(63.5\text{ cm})^2\,(1\text{ cm})\,\frac{2.70\text{ g/cm}^3}{1000\text{ g/kg}} \;\approx\; 140\text{ kg} \tag{D.74}$$

As already mentioned, the aluminum pusher and aluminum explosive case spherical shells for fission implosion bombs may have been produced on Usedom peninsula (p. 4270), but in any event, suitable aluminum production and machining was widespread in wartime Germany (p. 4126).

H. Ballistic Case

Ilyichev's March 1945 report stated: "An exterior casing of armored steel is installed above the blasting mechanism." It is not clear if the steel case was actually installed on the Thuringian device as tested, or if it only would have been installed on deployed versions. The tested Gadget bomb did not include a steel case, but the deployed Fat Man bomb had an outer 4.5-mm-thick steel case.

Steel alloys have densities in the range of 7.75–8.05 g/cm^3, so one may use an average density of 7.9 g/cm^3. If the Thuringian device had a steel ballistic case with an outside radius of $R = 65$ cm and the same thickness as Fat Man's case (0.45 cm), the mass of the case would have been:

$$M_{\text{ballistic case}} \approx 4\pi\,(64.8\text{ cm})^2\,(0.45\text{ cm})\,\frac{7.9\text{ g/cm}^3}{1000\text{ g/kg}} \approx 190\text{ kg} \qquad \text{(D.75)}$$

I. Overall Radius

Ilyichev's March 1945 report stated that the bomb diameter was 1.3 m (65 cm radius). On the other hand, his November 1944 report gave the bomb diameter as 1.5 m. That difference in numbers might mean that the Soviet spy's November details were more approximate (consistent with the much shorter and much less detailed November report). Alternatively, it might mean that the Germans had been able to reduce the bomb diameter from 1.5 m to 1.3 meters between November 1944 and March 1945, for example by adding the liquid oxygen to reduce the amount of TNT required.

J. Total Mass

Ilyichev's March 1945 report gave the bomb's weight as "approximately two tons." The weight was not stated more precisely, and it is not entirely clear if the weight given includes the outer steel ballistic case or not.

Adding up all of the extrapolated Thuringian device component masses from Table D.12 (including the ballistic case) yields a total mass of:

$$M_{\text{total}} \approx 2000\text{ kg} \qquad \text{(D.76)}$$

Thus the total mass is in excellent agreement with Ilyichev's reported estimate.

K. Delivery System

According to Ilyichev's March 1945 report: "A fairing made of a light alloy can be installed on top of the armored casing for future installation on a rocket of the V-type." This fits very well with all known data. V-2/A-4 rockets had become fairly reliable methods of delivering a payload to a target up to several hundred km away and could not be shot down by air defenses (unlike bomber aircraft or V-1 cruise missiles). Rockets with much longer ranges (A-4b, A-9, A-9/A-10) were apparently under development. The maximum payload fairing diameter for all of these rockets was approximately 1.37 meters, so a bomb with a diameter of 1.3 m would have been the largest implosion device that could fit within that space. (Alternatively, the bomb might have been placed in the middle of the rocket at the center of gravity, but space between the propellant tanks there would also be quite constrained.) These rockets used liquid oxygen as oxidizer for propulsion, and hence liquid oxygen would have been readily available to supplement the TNT in the bomb. The standard payload for the V-2/A-4 was one ton. If the Thuringian device was two tons, that would explain why it was never deployed militarily in the well tested standard V-2/A-4 rocket. It would have required either a modified V-2/A-4 with a larger payload capacity or one of the more advanced rocket designs, and such improved rockets were apparently still in the experimental phase (see Appendix E).

L. Explosive Yield

As discussed in Section D.15.4, the blast radius of 500–600 m stated in Ilyichev's March 1945 report suggests that the explosive yield of the Thuringian device as tested was around 200–350 tons. However, the device diameter, mass, and design details given by Ilyichev seem like those of a full-fledged fission bomb comparable to the 20-kiloton Gadget/Fat Man design, as shown in Table D.12. If the Thuringian device had been furnished with a full-sized ($\sim$ 5–10 kg) pit of high-quality fission fuel (U-235, U-233, or Pu-239) comparable to that in Gadget/Fat Man, it seems likely that it would have had a comparable explosive yield in the $\sim$ 20-kiloton range. If the pit was smaller and/or the fission efficiency was lower than in the U.S. design, the explosive yield may have been only a few kilotons. If the pit was $\sim$ 5–10 kg of high-quality fission fuel and significant fusion neutron boosting occurred from the deuterium-tritium (or deuterium-lithium) neutron initiator at the center, or if the center was deliberately filled with deuterium-tritium (or deuterium-lithium) fusion fuel, the device could have fissioned far more of its fission fuel and hence achieved far larger yields—potentially $\sim$ 100 kilotons or more for a $\sim$ 10 kg pit with $>$ 50% efficiency.

These estimates from physical considerations are supported by a number of historical sources that stated the expected blast radius of the deployed fission bomb. The estimates from these sources were in the range of 1–4 km, depending on how much fission and fusion fuel were used and what the fission efficiency was. Using Eq. (D.49), those blast ranges correspond to an expected explosive yield of ~1.6–100 kilotons, as summarized in Table D.14.

Note that these estimates are for the ~1.3-meter-diameter spherical implosion bomb that was described by many sources and analyzed in this section. Other sources mentioned a nonspherical fission bomb that was much smaller and had a yield of less than 1 kiloton (p. 5170). There were also many sources that mentioned an H-bomb weighing 6 tons that would have been far more powerful, with a 10-kilometer blast radius and ~1.6 megaton explosive yield (p. 5171–5172).

Historical sources	Expected blast radius	Corresponding yield
pp. 4590, 4600, 4602, 4605, 4894	~1 km	~1.6 kiloton
pp. 4600, 4703	~1.5 km	~5 kilotons
pp. 4605, 4674	~2 km	~13 kilotons
pp. 4400, 4595, 4674, 5011, 5012	~3 km	~40 kilotons
pp. 4176, 4595, 5011	~4 km	~100 kilotons

Table D.14: Expected blast radii and corresponding explosive yields for the German fission bomb as stated by various historical sources. The different expected blast radii originated from different assumptions about the amount of fission and fusion fuel used in the bomb and the expected efficiency of fission fuel consumption during the explosion.

D.15.6 Possible Evidence for Other Device Designs

The wartime German rocket program developed and demonstrated dozens of different types of missiles with a wide variety of designs, sizes, and applications. The German jet program produced designs, prototypes, and in some cases production-line models for jet aircraft with a similarly wide range of designs, sizes, and applications. Likewise, wartime German programs on submarines, electronics, chemical warfare, biological warfare, directed energy technologies, and other areas all pursued a wide variety of developments in each of those areas. If a wartime German nuclear program had been run with determination and methods at least comparable to all of those other wartime scientific programs, one would expect it to have developed or at least investigated a whole range of designs, sizes, and applications for nuclear weapons. Indeed, Werner Grothmann stated that there were at least five different nuclear weapon types under development (pp. 4271–4273).

While Ilyichev reported that a 1.3-meter-diameter spherical implosion bomb was tested at Thuringia (p. 4485), and that report seems plausible from the preceding physics analysis, there is considerable evidence to support Grothmann's assertion that the German nuclear program was also working on other nuclear weapons designs.

A. Larger Spherical Implosion Bombs

A spherical implosion bomb is mostly filled with TNT-based explosives, which have an average density of approximately 1.654 g/cm^3. The average density due to the smaller amount of other materials in the bomb does not deviate much from that density; for example uranium tends to be present in much smaller amounts, and its higher density is typically offset by hollow spaces. Thus one may take 1.654 g/cm^3 as an approximate average density for a spherical implosion bomb. For the 65-cm radius of the Thuringian device, that density predicts a total bomb mass of 1900 kg, very close to the 2000 kg estimate reported by Ilyichev in March 1945.

Larger implosion bombs could compress the fission pit to a higher degree, decreasing the probability of failure and increasing the fission efficiency and explosive yield. Larger bombs could also use more fission fuel for a larger explosive yield. The Thuringian device appears to have been limited to a 1.3-meter diameter simply to allow an A-4 or similar rocket to accommodate its size and mass.

1.5-meter-diameter bomb. Ilyichev's November 1944 report gave a bomb diameter of 1.5 meters, or a radius of 75 cm (p. 4481). That may have just been a less accurately reported estimate of the actual 1.3 meter bomb diameter. However, it seems at least as likely that the 1.5 meter value was indeed the correct diameter of the German implosion design as it existed in November 1944, prior to the final push to reduce its size by supplementing the TNT with liquid oxygen. The U.S. Gadget/Fat Man implosion bomb design had a radius of 75 cm (not counting the bomb shell and fins), so the number reported by Ilyichev in November 1944 seems extremely reasonable. At an average density of 1.654 g/cm^3, a 75-cm-radius implosion bomb would have a total mass of 2900 kg, very close to the 3000 kg approximate mass of the U.S. Gadget. Thus one version of the German implosion bomb may have had a diameter of 1.5 meters and a mass of approximately 3000 kg. That would make it more challenging to deliver via rocket, but still quite reasonable for an air-dropped weapon to be delivered by aircraft. Any nuclear weapons design program would have begun earlier in the war, when rockets were still an unproven technology and Luftwaffe aircraft were making routine bombing runs over Allied territory, and would probably have expected the first nuclear weapons to be delivered by aircraft.

1.8-meter-diameter bomb. Reports of earlier German programs producing and testing spherical aluminum shells for secret purposes indicated a diameter of approximately 1.8 meters (p. 4270). If those reports are accurate (and not a misremembering of 1.3-meter- or 1.5-meter-diameter spheres), they would suggest a spherical implosion bomb design with even more conventional explosives, a larger fission pit, and/or a larger hollow space in the center of the pit. At an average density of 1.654 g/cm^3, a 90-cm-radius implosion bomb would have a total mass of approximately 5 tons. If the radius were slightly larger or if the average density (due to larger amounts of uranium and other dense materials) were slightly higher, the bomb mass could be closer to 6 tons. Intriguingly, there were multiple reports of a new type of German bomb that weighed 6 tons, was radioactive, and would be delivered to the United States by a giant rocket (see pp. 4338, 4350–4363, and 5343). The 1.8-meter-diameter spherical aluminum shells were reportedly being produced and tested in Anklam and Friedland, not far from Peenemünde. As already covered, a spherical implosion bomb design could be used with U-235, U-233, or Pu-239 fission fuel, and with or without a small amount of fusion fuel at the center to add neutrons and boost the overall efficiency of the fission explosion. Therefore, even for spherical implosion bombs, there could be a number of variations with different sizes, fuels, and explosive yields.

B. Nonspherical Implosion Bombs

Spherical implosion gives the greatest efficiency and highest explosive yield for a given amount of conventional explosives and fission fuel, since the fission fuel is uniformly compressed from all sides. Likewise the larger an implosion bomb is, the more efficient it tends to be, as discussed above. However, very large spherical shapes are not particularly well suited for air-dropped bombs or for ballistic projectiles. Thus there would be a strong motivation to consider smaller and/or non-spherical implosion bombs, even if their explosive yield would be considerably less than that of a large spherical implosion bomb. Whereas a large fission implosion bomb can have an explosive yield of tens of kilotons and destroy an entire city (like Nagasaki), a smaller non-spherical fission implosion bomb might have a yield on the order of one kiloton or less, but that could still make it useful for destroying certain tactical military targets, especially considering the radioactive as well as the blast effects. As a further motivation, smaller bombs would require less fission fuel than larger bombs; fission fuel would be in short supply in the early phases of any nuclear weapons program, as Werner Grothmann specifically stated that it was for the German program.

In fact, several sources discussed the wartime development of a smaller fission bomb. It was described as a tactical, nonspherical, two-point-ignition, fission implosion bomb that was externally similar to a standard German 250 kg bomb, had a full yield likely less than one kiloton, and was potentially ready for deployment before the end of the war (pp. 4246–4248, 4271–4277, 5030).

C. Gun-Type Fission Bomb

German scientists also appear to have been aware of the gun-type fission bomb design [Karlsch and Walker 2005; Thirring 1946]. However, any development seems to have been focused on the implosion design, since it requires much less fission fuel and has a much higher efficiency than the gun design. The U.S. gun-type fission bomb, Little Boy, had a mass of 4400 kg, diameter of 71 cm, and length of 300 cm. That is far larger than the SC-250-like bomb described by Grothmann, and descriptions of other bombs alleged by Grothmann, Ilyichev, and other sources to have been constructed have geometries very different than Little Boy. Thus from the available evidence, the gun design appears to have been understood but not developed, probably due to its inherent disadvantages relative to implosion designs.

D. Radiological Dirty Bombs

As discussed in Section D.5, several sources stated that Germany possessed one or more operational fission reactors before the end of the war. If that were true, it would have been technologically very straightforward to remove highly radioactive spent fission fuel from a reactor, pack it around a modest amount of conventional explosives in a bomb, and detonate such a device over a target to scatter highly radioactive isotopes over the target area. Such a bomb would have no required critical mass and could be made as large or small as desired, so it could easily be carried by an A-4 or other rocket, missile, or aircraft. Because that approach would be so straightforward once a reactor was operational, and because there was such strong political and military pressure for Germany to develop powerful new weapons, it seems highly likely that this approach would have been pursued. During the war, high-level officials in the United States and United Kingdom wrote classified memos about the possibility of the Germans using such a radiological dirty bomb, although it is not clear if that was purely speculation or based on actual intelligence from Germany [TNA AB 1/608].

E. Layer Cake H Bomb

As summarized in Sections 8.8.9 and D.9 (see especially p. 4280), a large number of declassified and publicly available sources appear to describe a six-ton H-bomb with a planned yield around 1.6 megatons that used a fission implosion device to initiate fusion reactions in lithium deuteride fuel and was expected to be tested in 1945 or 1946 if the war had continued.

Many documents show that there was prewar and wartime work using lithium and deuterium together as fusion fuel (pp. 4281–4349). Because lithium deuteride is solid and not a gas or cryogenic liquid, it makes an ideal fuel for hydrogen (H) bombs. There were multiple reports that the Germans were developing a weapon with a 6-mile blast radius (pp. 4365–4367). From Eq. (D.49), a 6-mile or 10-km blast radius corresponds to an explosive energy of at least $(10,000/85.5)^3 \approx$ 1,600,000 tons of TNT equivalent, or at least 1.6 megatons. This is well beyond the kiloton ranges of fission bombs, as the German scientists knew from basic calculations of fission energies, and suggests that they were developing much more powerful H bombs. Knowledgeable German sources expected to complete a deliverable version of such a weapon later in 1945 or in 1946 (pp. 3401, 4272, 4367, 4334, 4359). If true, that was a feat that the United States and Soviet Union did not actually accomplish until 1953–1955 (Soviet Joe-4/RDS-6s, U.S. Castle Bravo, and Soviet RDS-37).

According to unclassified references, there are two major types of functional H-bomb designs [Goncharov 1996a, 1996b; Chuck Hansen 1988, 2007; Rhodes 1995; Sublette 2019; Wellerstein and Geist 2017]. The simpler one to build is what the Soviets later called a “layer cake” (*sloika*), a spherical implosion bomb with layers of fusion fuel interspersed with layers of fission fuel. The fusion reactions contribute only a modest amount of energy, but a huge number of neutrons that enable the consumption of far more fission fuel than would otherwise be possible.

Since the German program was producing fusion fuel such as deuterium and lithium, building spherical bombs with a diameter of at least 1.8 meters (significantly larger than even the U.S. Gadget/Fat Man fission implosion bomb), and expecting a blast radius corresponding to a megaton-level explosive yield, it is possible that a layer cake H bomb design was under development. (See also p. 4372.) This view might also be supported by the multiple reports of a new type of German bomb that weighed 6 tons, was radioactive, and would be delivered to the United States by a giant rocket (see pp. 4338, 4350–4363, and 5343). Furthermore, the postwar Soviet nuclear program was heavily dependent upon German scientists, materials, and ideas, and the first Soviet H bomb (Joe-4 or RDS-6, tested on 12 August 1953; see p. 1638) employed the layer cake design.

Joe-4 is reported to have weighed 4.5 tons, had a diameter of 1.5 meters, and produced an explosive yield of 400 kilotons; it is also reported that the bomb's yield could have been higher if its surrounding layer of conventional explosives had been better able to compress the layers of fission and fusion fuel [Wellerstein and Geist 2017]. (Joe-4's size was apparently constrained by the Soviet desire to make it no larger than the Joe-1 fission bomb, in order to facilitate delivery by aircraft). If there was a wartime German design that was very similar but had 1.5 tons more of surrounding conventional explosives (total weight of 6 tons), its diameter would have been around 1.8 meters, and its explosive yield could easily have been in the 1.5-megaton range.

F. Two-Stage H Bomb

According to unclassified references [Goncharov 1996a, 1996b; Chuck Hansen 1988, 2007; Rhodes 1995; Sublette 2019; Wellerstein and Geist 2017], the second major type of H bomb is a "two-stage" design, in which the dense outer bomb casing surrounds both a fission implosion bomb (the first stage) and a neighboring mass of fusion fuel (the second stage). When the fission bomb detonates, its heat and pressure ignite fusion reactions in the adjacent fusion fuel. If the outer bomb casing is made of fission fuel (even natural uranium), high-energy neutrons from the fusion reactions can trigger extensive fission reactions in the outer bomb casing, making it effectively a third stage of the explosion.

Friedwardt Winterberg, who worked very closely with Kurt Diebner after the war and never worked in the U.S. nuclear program, produced a book of designs for two- or three-stage fusion explosive devices that look rather different than publicly available U.S. H bomb designs but that are deeply steeped in earlier German hydrodynamics and physics research [Winterberg 1981]; see p. 4373. Whereas the outer casing of a U.S. H bomb design is generally depicted as cylindrical in the unclassified references, the outer casing of the Winterberg or Diebner H bomb design has a pronounced Prandtl-Meyer ellipsoidal shape. A surviving 1944 sketch from Walther Gerlach shows an ellipsoid in conjunction with nuclear reactions involving deuterium, which seems to support the wartime origin of Winterberg's ellipsoidal H bomb design (p. 4377). In addition to the more straightforward fission bomb designs, Werner Grothmann mentioned that an H bomb was being developed during the war, and that it was of an entirely different design that "looked like a swollen bomb" (p. 4272). The ellipsoidal H bomb design would seem to fit Grothmann's description perfectly. The multiple reports of a 6-ton bomb (pp. 4338, 4350–4363, and 5343) and a bomb with a 6-mile blast radius (pp. 4365–4367) could also describe this type of bomb.

In 1947, when Edward Teller was trying unsuccessfully to invent a workable design for the U.S. hydrogen bomb, he sent a highly unusual, specific, and urgent request for Siegfried Flügge to help him with a "physics... program... of interest and importance to the national security," stating that Flügge would "be of marked assistance in carrying out the aforementioned program" (p. 4996). Flügge was indeed brought to the United States, and it has never been publicly revealed what he worked on. In fact, late in the war and after the war, there was a large influx of scientists and engineers who came to the United States and/or United Kingdom and who were from or had knowledge of the German nuclear program (p. 1608). Many of those scientists appear to have been closely tied to the wartime German work on H-bombs, and may have especially aided the U.S. H-bomb development program between 1945 and 1954.

If enough archival material can be found, declassified, and released, it would be extremely interesting to find out how far German work on H-bombs may have progressed during the war, and how much that work (and the associated scientists, materials, and plans) influenced postwar work on H bombs in the United States, Soviet Union, or other countries.

D.15.7 Conclusions and Recommended Further Research

This appendix concludes by considering the plausibility of the primary source evidence, nuclear vs. non-nuclear explanations of that evidence, different possible nuclear devices, the reasons for not using any nuclear weapons in the war, the technological state of the German nuclear program relative to that of the United States, and recommendations for further research.

A. Plausibility of the Primary Source Evidence

The fundamental question underlying this appendix is the accuracy of the conventional historical view that Germany made little progress toward nuclear reactors and weapons during the war. While there are many types of potential documentation that Germany may have made significantly more progress than has been commonly acknowledged, the most dramatic proof would be the successful test explosion of a nuclear device. There is at least some evidence of several test explosions: one on or near the Baltic coast in October 1944, one in Poland during or around November 1944, and one or two in Thuringia in March 1945. Of those possible tests, currently there is the greatest amount of evidence for the early-March 1945 Thuringian test.

Wartime and postwar documents show that within the top echelons of the SS, there was a prolonged and intense interest in developing a nuclear weapon, and an expectation around March 1945 that battlefield use of such a weapon was imminent. Likewise, wartime and postwar documents from Diebner, Schumann, Trinks, Guderley, Harteck, Stetter, and others confirm that there were very active research programs on spherical implosion bomb designs, fission reactions, fission fuel production, fusion reactions, and fusion fuel production. The surviving documents do not indicate whether or how those research programs were combined or ultimately tested.

At least ten primary sources specifically address the March 1945 Thuringia test:

1. Ivan Ilyichev's November 1944 intelligence report to Stalin.
2. Ilyichev's 23 March 1945 report to Stalin.
3. Igor Kurchatov's 30 March 1945 response to Ilyichev.
4. Georgy Flerov's two brief May 1945 reports to Kurchatov and 1983 interview.
5. Robert Döpel's 1946 interrogation by the Russians.
6. Cläre Werner's testimony in 1962 and later in life.
7. Heinz Wachsmut's testimony in 1962 and later in life.
8. Erich Rundnagel's 1966 testimony.
9. Oscar Koch's 1960s testimony about a 1945 U.S. intelligence report.
10. Werner Grothmann's 2000–2002 testimony.

The details described in these ten primary sources are remarkably consistent with each other, as shown on p. 4480. The details are also consistent with other wartime and postwar primary sources that reported German work on a fission implosion bomb (see for example p. 4157). As shown in Section D.15.4 above, the details from all of these primary sources agree to a striking degree with the now well-established physics of nuclear weapons.

This may seem like an unacceptably small amount of evidence for such a dramatic historical claim as a German nuclear weapons test. However, even if the claim is true, it is not surprising that there is not more evidence. It is well known that Germans destroyed or buried documentation of military technologies at the end of the war.[34] Motivations for those actions included denying that technology to Allied nations, using that information as a bargaining chip, and/or avoiding imprisonment or execution for war crimes associated with the development, testing, use, or intended use of that technology. It is also well known that Allied nations vacuumed up as much documentation as they could find, and then kept it secret from the other Allies, or claimed it as their own technology, or simply lost the information within their large bureaucracies and the vast amount of material removed from Germany.[35]

Likewise it is not surprising that there is not more witness testimony. According to the ten primary sources, the test occurred in a sparsely populated area, most of the residents who did live there were evacuated ahead of time, and most of the residents who remained were sent to air raid shelters by warnings shortly before the test. Virtually all of the prisoners involved in the test or the preparations were worked to death, died in the test, or were killed afterward by the SS. Anyone else who spent much time at the test site in the hours immediately after the explosion would likely have received enough exposure to die of radiation sickness that would have been unrecognized in the chaos and hardship shortly before and after the end of the war. Scientists and military personnel who were involved would be strongly motivated to permanently conceal the test for fear of being executed for war crimes. Any others involved were threatened by the SS and sworn to secrecy or killed, and would have remained fearful of reprisals from former SS members for the rest of their lives if they revealed what they knew.

The Soviet intelligence reports from Ilyichev, Kurchatov, Flerov, Zhukov, and Döpel seem to prove that there was definitely some sort of test event, even if one might argue about the details of that event. The intelligence reports began at least as early as 15 November 1944, continued into 1946, went all the way to Stalin, and led to the commitment of major Soviet scientists, forces, and resources to investigate. These are certainly not forgeries, and it does not seem plausible that they are merely faulty intelligence about a completely nonexistent event.

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[34] See for example: Huzel 1962, pp. 138, 151–162; Petersen 2008, p. 491; Simon 1971, pp. 4–8; p. 4670 in this appendix.

[35] See for example Albrecht et al. 1992; Bar-Zohar 1967; Bower 1987; Buyer and Jensen 1948; Byrd 1948; Crim 2018; DOW 1945b, 1946; Gimbel 1986, 1990a, 1990b, 1990c; Goudsmit 1947; Glatt 1994; Hall 2019a; Linda Hunt 1985; Morton Hunt 1949; Jacobsen 2014; Jensen 1948; Jösten 1947; Matthias Judt and Ciesla 1996; Kurowski 1982; Lasby 1971; Mick 2000; Nagan 1947; Nagel 2016; O'Reagan 2014, 2019; Simpson 1988.

B. Nuclear vs. Non-nuclear Explanations of the Primary Source Evidence

All possibilities for what that test event might have been can be considered. Most of those possibilities can be rejected unless the primary sources are greatly in error:

- A conventional bomb would not have the blast radius reported by Ilyichev and Koch, the radioactive effects reported by Ilyichev, Werner, Wachsmut, and Grothmann, the design reported by Ilyichev, Döpel, and Grothmann, or the intense security reported by Ilyichev, Rundnagel, Grothmann, Werner, and Wachsmut.

- A fuel-air explosive device might have caused blast damage to an area as large as reported, but it would not have had the radioactive effects reported by Ilyichev, Grothmann, Werner, and Wachsmut, or the design reported by Ilyichev, Döpel, and Grothmann.

- A chemical agent test might have killed, burned, or sickened as many people as reported, but it would not have the blast radius reported by Ilyichev and Koch, or the design reported by Ilyichev, Döpel, and Grothmann.

- A fuel-air explosive device that dispersed a chemical agent might theoretically account for both the blast damage and the symptoms of the casualties, but would not be consistent with the design reported by Ilyichev, Döpel, and Grothmann, and a fuel-air explosion would be far more likely to incinerate a chemical agent than to efficiently disperse it.

- A radiological "dirty bomb," with radioactive elements packed around and dispersed by a conventional explosive, might explain the radioactive effects, but would not have the blast radius reported by Ilyichev and Koch, or the design reported by Ilyichev, Döpel, and Grothmann.

- A "hydrodynamic" test of a nuclear bomb without any of its nuclear fuel, purely to scientifically validate the design details, would have the outward appearance of a conventional bomb explosion; it would not have the blast radius reported by Ilyichev and Koch, or the radioactive effects reported by Ilyichev, Grothmann, Werner, and Wachsmut.

- A pure fusion device, with fusion fuel at the center of an implosion design powered by conventional explosives, would not produce a significant amount of nuclear reactions, radiation, or energy. Even with over 70 years of effort and steadily improving technology, scientists have not been able to trigger significant fusion reactions with conventional explosives [Gsponer and Hurni 2009, pp. 139–141; Winterberg 2010, pp. 297–298, 302]. Thus such a device would not have the blast radius reported by Ilyichev and Koch, or the radioactive effects reported by Ilyichev, Grothmann, Werner, and Wachsmut. It would also not contain uranium as reported by Ilyichev, Döpel, and Grothmann.

- A pure fission device would be highly consistent with the blast radius reported by Ilyichev and Koch, the radioactive effects reported by Ilyichev, Grothmann, Werner, and Wachsmut, and the design reported by Ilyichev, Döpel, and Grothmann.

- A hybrid fission-fusion device could also be highly consistent with the blast radius reported by Ilyichev and Koch, the radioactive effects reported by Ilyichev, Grothmann, Werner, and Wachsmut, and the design reported by Ilyichev, Döpel, and Grothmann.

C. Type of Nuclear Device

Therefore the only possibilities that seem consistent with the evidence from the primary sources appear to be either a pure fission device or a hybrid fission-fusion device. If it was a fission-fusion device, the fusion reactions would not have made a significant direct contribution to the energy output, but their neutrons could have greatly reduced the critical mass of fission fuel required.

If the device tested had an explosive energy yield of a few hundred tons or so (as found in Section D.15.4), that would make its energy ~ 100 times larger than that of a conventional bomb of the same size, yet ~ 100 times smaller than that of well-known fission bombs such as the Gadget and Fat Man bombs that the United States detonated in July and August 1945. Even in March 1945, Igor Kurchatov was puzzled by the reported energy yield (p. 4496). If the explosive energy of the test was indeed in the few-hundred-ton range, there are three possible explanations:

- The most likely explanation is that the device was a full-sized bomb capable of an energy yield in the range of tens of kilotons if used with a pit containing several kilograms of U-235, but was tested with a pit containing very little U-235, perhaps as little as ~ 100 grams. Any U-235 that Germany had produced would be a highly precious commodity that would be saved for battlefield deployment of such devices, not used up in a test. The Germans would also be reluctant to create a very large blast and very large amount of radioactivity deep in the heart of Germany, especially just for a test. (For the same reasons, several of India's 1998 Shakti nuclear detonations tested devices that produced explosions of less than 1 kiloton each yet successfully demonstrated their designs would have much higher yields if deployed.) This explanation fits well with Grothmann's statements that the test deliberately used only a very small amount of fuel. It is also very consistent with all of the other primary sources.

- A less likely but still possible explanation is that the device was a full-sized bomb, tested with the full amount of U-235, but misfired (for example if the neutron initiator failed or if the implosion was not spherically symmetric), causing the energy yield to be much smaller than expected. Evidence against this explanation includes the statements of Grothmann and Wachsmut that the energy yield was actually larger than expected, the comments of Grothmann that only a small amount of fuel was used, and the military undesirability of using up too much scarce U-235 or making too large of a mess purely for a test.

- Another unlikely but possible explanation is that the device was a small-sized "mini nuke" design, never intended to have a large yield even if deployed on the battlefield. Evidence against this explanation includes the large bomb diameters given in both of Ilyichev's reports, the large bomb mass given in Ilyichev's second report, the statement of Rundnagel that the bomb was designed to use at least 8 kg of fuel, the statements by Grothmann that these late-war efforts were focused on developing a large strategic nuclear weapon that could be delivered by rocket, and the military futility of testing or deploying a low-yield tactical weapon at that late stage of the war.

D. Reasons for Not Using a Nuclear Weapon in the War

One might try to argue that if Germany had really developed a nuclear bomb, it would have immediately used it during the war, so the fact that such a weapon was never used proves that it never existed. However, there are several reasons why Germany may not have used a nuclear weapon even if it had one in its possession. Conceivably any or all of these reasons might be true:

- The weapon may have been developed too late to be deployed. This seems quite plausible if the weapon was still being tested in March 1945 and the area was overrun by Allied forces on 4 April.

- A suitable delivery system for the weapon may have been developed too late or not at all. This also seems quite plausible if—as described by Ilyichev, Schumann, Grothmann, and others—the weapon was intended for delivery by rocket but weighed two tons. Existing A-4 or V-2 rockets were designed to carry a one-ton payload, and any rocket with a larger payload capacity would have still been in the experimental stage.

- There may have been only enough fission fuel for one or a very small number of weapons, and German leaders may have realized that even if those were used, they could not halt the advance of Allied forces into Germany from all sides. This seems very plausible, especially in light of Grothmann's comments about the uncertain political effect of any battlefield use of the weapon, and Grothmann's and Rundnagel's comments about the small amount of fuel.

- German leaders probably realized that if they used a nuclear weapon, Allied forces would respond by killing tens of millions of German civilians with crude but effective WWI-style chemical weapons (mustard agent and phosgene) or other means (pp. 2632–2651). This explanation is highly plausible, since that same reasoning seems to have prevented German leaders from employing the large amounts of advanced nerve gas that the country had in its arsenal (pp. 2632–2651).

- To extend the previous two points, German strategic plans may never have involved the use of just one or two nuclear weapons:

  - In the final years of the war, Allied forces were approaching Germany from all sides; it would have been obvious throughout those final years that destroying one or two Allied cities with nuclear bombs would never halt all of those Allied forces, let alone an Allied counterattack dropping mustard agent, firebombs, etc. on millions of German civilians.

  - Accordingly, the strategic thinking behind the German nuclear program may have been to mass-produce and stockpile nuclear weapons and the means to deliver them. Those weapons would have only been used once their numbers surpassed a capability threshold that would have enabled many simultaneous nuclear attacks [quite possibly in parallel with simultaneous attacks using German nerve agents and other chemical weapons (p. 2651), biological weapons, and/or fuel-air explosives] on Allied targets and the credible threat of further attacks if the Allies launched any counterattacks or if German demands were not met.

  - That approach appears to be supported by Grothmann and other sources that described mass-production or attempts at mass-production for nuclear weapons as well as their delivery methods.
  - Indeed, German officials spoke of plans to end the war within a matter of hours by such an overwhelming attack with their stockpiled weapons of mass destruction. Moreover, after studying German technologies after the war, Allied officials described exactly the same scenario of a massive German nuclear attack. See for example pp. 4549–4550, 4587, 4621, 4627–4665, 4679–4681, 4766, 5038, 5218, 5380, 5454–5466, 5658–5659.
  - If that was indeed the German strategy in the final years of the war, it suggests that the scale and level of advancement of the nuclear weapons/delivery programs may have been quite extraordinary, and that the world may have narrowly escaped a level of devastation that was unthinkable, at least until much later in the Cold War.

- Individual political or military leaders in charge of the deployment of a nuclear weapon may have realized that Germany would lose the war very soon regardless, and feared that they would be executed as war criminals if they actually used the weapon. That same reasoning may have prevented them from employing their nerve gas. For example, according to a 1 April 1945 Allied intelligence document, Luftwaffe General Albert Kesselring mentioned deliberations among Hitler's top staff about whether to use a final secret weapon, referred to as the "desperation weapon," that would cause a "terrible blood bath"; "Kesselring said if Fuehrer gave him order to use weapon he would surrender his command" (p. 4670). Grothmann confirmed this line of reasoning in the high command.

- Individual political or military leaders in charge of the deployment of a nuclear weapon may have realized that Germany would lose the war very soon, and come to individual decisions that they had more to gain personally by secretly offering the nuclear weapons technology and other advanced technologies to Allied countries than by employing the weapon against Allied forces. This is quite plausible since SS General Hans Kammler seems to have been directly in command of all advanced weapons (including any nuclear weapons) in the final stages of the war, and he secretly disappeared to America after faking his death—see pp. 4931–4959 [Agoston 1985; Döbert 2015; Döbert and Karlsch 2019; Karlsch 2014; Michalski et al. 2019; Reuter et al. 2019; Sulzer and Brauburger 2014, 2019a].

E. Technological State of the German Nuclear Program vs. the U.S. Program

Much more work is needed to gather and analyze relevant data from primary sources and physical evidence in order to verify that the Germans indeed tested a nuclear device, and to work out the design details of that device. With that large caveat, the extrapolated design details above and further details in the works of Schumann, Trinks, Diebner, Guderley, and others suggest that the wartime German nuclear program was actually ahead of the wartime and postwar U.S. nuclear programs:

- The implosion design reported by Ilyichev seems very detailed, physically feasible, and deeply grounded in experimental and engineering details. While similar to the U.S. Gadget design, it does not appear to be a carbon copy of that design, suggesting that it was arrived at independently and not by any German espionage of the U.S. program. It seems to be much more than an abstract concept never reduced to practice, or a hasty idea thrown together at the end of the war. It appears to be the end product of a well-funded, long-running, highly scientifically skilled nuclear weapons development program.

- As stated by Werner Grothmann (pp. 4271–4273) and supported by other evidence as discussed in Section D.15.6, the German program appears to have developed not just one nuclear weapon design, but rather a whole range of specialized designs for a variety of strategic and tactical applications. The United States did not have comparable diversity in its own nuclear arsenal until many years after World War II.

- German nuclear scientists appear to have been aware of the gun design, but seem to have focused their work on the implosion design from early on, since that would use much less fission fuel and offer much higher efficiency, which is why the implosion principle is still used in modern bomb designs. In contrast, the U.S. Manhattan Project spent most of its time and resources developing the gun-type design (called Thin Man in the early versions and Little Boy in the final version), and only began a serious program to develop an implosion design (Gadget/Fat Man) in July 1944.

- Germany appears to have conducted a test explosion of a nuclear device on 4 March 1945, four and a half months before the first U.S. test, and the German test appears to have been of a device that, if deployed, would have had a yield comparable to or even greater than the first U.S. fission bombs. If the reported October 1944 Baltic test explosion was real and was a successful nuclear test, that would have been over 9 months before the first U.S. test.

- The United States had produced no functioning nuclear weapons whatsoever by V-E Day, and only three by V-J Day (those detonated at Trinity, Hiroshima, and Nagasaki). In contrast, there is evidence that before V-E Day, Germany may have produced at least three nuclear weapons that were used in successful tests (Sections D.10, D.11, and D.12), and apparently several more that were held in a stockpile for possible military use (e.g., pp. 4182, 4436, 4667, and 4670). If that information is correct, then by the end of the war, Germany held an enormous lead over the United States in the world's first nuclear arms race.

- If allegations are true that the United States removed nuclear weapons technologies from Germany, used enriched uranium and bomb detonators obtained from the German submarine U-234, and relied at least in part upon those captured nuclear weapons technologies, captured enriched uranium, and captured experts for the first U.S. fission bombs (Section D.14.5), the German program was even further ahead of the U.S. program.

- The German nuclear program accomplished as much as it did despite the tremendous handicaps and setbacks of years of heavy Allied bombing, sabotage, and blockades, which the U.S. program did not have to endure.

- If the Thuringian device used a high-voltage fusion neutron source as an initiator, that was a more advanced solution than the U.S. polonium-210/beryllium initiator, and was ultimately adopted much later after the war by the United States.

- If the Thuringian device used a compact betatron as an initiator, that was also a more advanced solution than the U.S. polonium-210/beryllium initiator. The U.S. did not demonstrate a betatron neutron initiator for a fission bomb until the 1 June 1952 George test of Operation Tumbler-Snapper [https://nuclearweaponarchive.org/Usa/Tests/Tumblers.html].

- If the Thuringian device and other proposed German designs used neutrons from fusion fuel in the center to greatly "boost" the yield of the fission fuel, that was a major advance that could increase the energies of fission bombs by a factor of ~ 10 (from tens of kilotons to hundreds of kilotons). Officially, fusion boosting was first considered in the U.S. by Edward Teller in 1945 and in the Soviet Union by Andrei Sakharov in 1948, was first tested by the U.S. in 1951 and by the Soviet Union in 1953, and is commonly used in modern bombs [Goncharov 1996a, 1996b; Chuck Hansen 1988, 2007; Rhodes 1995; Sublette 2019; Wellerstein and Geist 2017].

- The Thuringian device appears to have been designed to be launched on a rocket (perhaps even the intercontinental A-9/A-10), which the United States was not prepared to do until 1958 (after help from hundreds of German-speaking scientists and engineers it had acquired). See p. 5821.

- The Thuringian device appears to have packed a full-fledged implosion design (and presumably an explosive yield to match) into a bomb with a total deployed mass less than half that of the first U.S. fission bombs (2000 kg for the Thuringian device vs. 4670 kg for Fat Man). Grothmann reported that Germany possessed tactical nuclear bombs that were even smaller. It took the United States several years to reduce the size and mass of fission bombs.

- Whereas the U.S. program relied heavily on a very inefficient and expensive gaseous diffusion process to help enrich uranium, the German program developed and employed (among other techniques) gas centrifuges, which were much more efficient and therefore subsequently became the preferred modern method. There is also evidence that the German program studied "photochemical" methods of uranium isotope enrichment, many decades before laser isotope separation was perfected in the United States.

- There is evidence that the German program developed electronuclear breeding of fission fuel (p. 3954), a technology that the United States did not seriously pursue until years after the war, and that is still of concern for nuclear weapons proliferation in the modern world.

- The German nuclear program appears to have produced and perhaps even used lithium-6 deuteride as readily storable solid fuel for producing fusion reactions in nuclear bombs (Section D.9), as an alternative to the much more troublesome cryogenic deuterium and tritium. Officially, lithium-6 deuteride was first considered in the United States by Edward Teller in 1947 and in the Soviet Union by Vitaly Ginzberg in 1949, was first tested by the United States in 1954, and is commonly used in modern H bombs [Goncharov 1996a, 1996b; Chuck Hansen 1988, 2007; Rhodes 1995; Sublette 2019; Wellerstein and Geist 2017].

- A 1948 U.S. intelligence document stated that Austrian and German scientists such as Josef Schintlmeister had produced and identified transuranic elements through element 104; if true, that is a feat that was not accomplished until 1969 in the United States (p. 4335).

- In addition to possibly using fusion fuel to improve a fission bomb design, there is significant evidence that the German program was working on full-fledged H-bomb versions with megaton-level yields (pp. 3401 and 4271–4273 and Sections D.9 and D.15.6). German sources stated that they expected to complete a deliverable version of such a weapon later in 1945 (see p. 4367) or in early 1946 (see p. 3401). If true, that was a feat that the United States and Soviet Union did not actually accomplish until 1953–1955 (Soviet Joe-4/RDS-6s, U.S. Castle Bravo, and Soviet RDS-37).

F. Final Perspective and Recommendations

As summarized in this appendix, the very incomplete information that is currently available about the wartime German nuclear weapons program appears to best match the pattern of a large and advanced program, not the small and primitive program that has generally been depicted for the last 75+ years. Some readers may object to this claim, but historians should actively search for additional information that could help to confirm or refute this picture:

1. Any relevant records in U.S., U.K., French, Russian, or other national archives should be located, declassified, and released to the public. Even from the currently available evidence, it is abundantly clear than highly relevant documents (wartime intelligence on German nuclear tests and progress; postwar interrogations of Hans Kammler, German and Austrian nuclear scientists, and other key players; reports on postwar investigations of nuclear-related sites and submarines; etc.) remain classified and unavailable to the public. The war ended 75+ years ago, and government censorship of all those historical documents must finally end.

2. Any relevant information in personal collections (war diaries, preserved documents, photographs, etc.) should be located, authenticated, and analyzed with the other available data.

3. Thorough scientific analyses of suspected test sites should be conducted (especially using mass spectrometry, particle-induced X-ray emission, neutron activation analysis, or other highly sensitive methods; looking for ^{238}U from the tamper; and comparing data at and away from the test sites to eliminate background signals), although after 75+ years of radioactive decay and weathering, even the most diligent testing might be inconclusive.

4. Extensive and meticulous industrial archaeological digs should be conducted at sites suspected to have been involved in developing or storing nuclear materials or nuclear weapons. Even

> if much of the material at those sites had been removed by German or Allied forces, any remaining evidence could provide conclusive proof about the nature and extent of the wartime nuclear program.

Until those searches have been thoroughly conducted, historians and scientists should cease making authoritative-sounding declarations that the nuclear program was small and unsuccessful, since there is already a great deal of evidence to the contrary.

An analogous historical mystery may be the 1960s Soviet program to land a cosmonaut on the moon. Prior to the U.S. manned landing on the moon, it was widely believed that the Soviet Union was very close to achieving the same goal. Yet once the United States had achieved victory, the Soviet Union denied that it had ever even attempted a manned lunar program. Soviet denials continued for two decades, and concrete proof of a Soviet manned lunar program could not be found. Most historians ignored the Soviet program, and only a handful of authors sifted through the small amount of available evidence and speculated about the program [Oberg 1981; Phelan 2013]. In 1990, Soviet officials finally revealed the entire former program and put five of the LK manned lunar landers that had been built for it on display in various museums [Siddiqi 2000].

Similarly, for most of World War II, it was widely believed that Germany was developing a nuclear bomb and might well beat the United States to that goal. Yet once Germany was defeated, there were denials that it had ever even attempted to develop a nuclear bomb. Those denials have continued for decades and concrete proof has not been found. Most historians have ignored the German nuclear weapons program, and only a handful of authors have sifted through the small amount of available evidence and speculated about the program. Whether those authors are correct, and whether concrete proof of the program will ever be released, remains to be determined.

If the German nuclear weapons program was indeed successful, one can understand why the major countries involved would have wanted to conceal that fact at the end of World War II and the beginning of the Cold War. Germans would not want to appear guilty of additional acts for which they might be punished after the war; key German players could find much greater personal reward in offering the fruits of the nuclear program to Allied nations and remaining silent. For purposes of internal morale and external public image, Allied countries might prefer to claim that such technological accomplishments were really their own, and in any event would be highly motivated to try to protect any new weapons technologies from rival Allied nations in the incipient Cold War.

Likewise, if the German nuclear weapons program was successful, one can also understand why the major countries involved might want to preserve that secret even 75+ years later. Germans and Austrians might not want yet another Third Reich offense from their past for which they would need to apologize. Former Allied countries might not want to admit that their wartime and postwar technological prowess was not as great as they had boasted for so many years, or that that of their vanquished enemy was greater than they had claimed for so long. In any event, routine security classification rules would prevent the release of archival documents with useful details about nuclear weapons designs and production methods, no matter what their age, history, and country of origin might have been.

Yet if the German nuclear program was truly successful, on the whole it would seem far more beneficial for all countries to finally acknowledge that fact than to continue to deny it:

1. As with “truth and reconciliation commissions” in other countries, Germany and Austria could finally acknowledge and address the full extent of the Third Reich’s actions, their current citizens (who were too young to have been involved in any of those events) could have a detailed understanding of those actions and history, and these countries could move forward with that chapter fully closed, rather than still having to hide or fear further revelations in the indefinite future.

2. Carefully inspecting and cleaning up any sites involved in producing or storing nuclear materials would prevent contamination of local drinking water and farms with radioactive isotopes, heavy metals, or other toxic chemicals.

3. Elucidating all the concentration camp prisoners who died in the preparation, production, and testing of nuclear weapons would finally bring justice to what may be many thousands of currently forgotten victims of the war.

4. The media-consuming public in former Allied countries seems fascinated with and proud of their countries’ roles in World War II, so they should be extremely interested in new details about that war, and should in fact find it exciting that their victory was even more hard-won and more consequential than previously known (somewhat similar to how sports fans are more excited by especially close or high-stakes wins).

5. Everyone would gain a much better understanding of the strategic decisions made by all countries during and after the war, making more sense of events and actions which have previously not been as well explained in the history books.

6. All nations would benefit tremendously by learning exactly how such revolutionary technologies were created then, so that they could employ similar methods of innovation to create and enjoy the benefits of new revolutionary technologies in the future.

Appendix E

Advanced Creations in Aerospace Engineering

Für den Ring nimm nun auch mein Roß!	For the Ring take now my horse!
Ging sein Lauf mit mir	Though he once carried me
einst kühn durch die Lüfte,	boldly through the air—
mit mir	with me
verlor es die mächt'ge Art;	he lost all his magic powers;
über Wolken hin	above the clouds
auf blitzenden Wettern	through lightning and thunder
nicht mehr	no more
schwingt es sich mutig des Wegs.	will he brave the way.

Richard Wagner. 1874. *Götterdämmerung* [*Twilight of the Gods*]. Prologue. Brünnhilde.

As discussed in Chapter 9, a tremendous number of aerospace technologies were invented by German-speaking creators, especially shortly before and during World War II: helicopters, guided missiles, smart bombs, jet engines and jet aircraft, ejection seats, ramjets, the V-1 cruise missile, the A-4 or V-2 single-stage rocket, supersonic wind tunnels, radar stealth technology, etc. There is also thorough documentation (though regrettably too little modern public recognition) that German-speaking creators personally carried those aerospace technologies to their limits during the postwar era, with funding and support from the United States, United Kingdom, France, Soviet Union, and other countries.

However, archival documents strongly suggest that there are several areas in which aerospace technologies may have advanced significantly further in wartime Germany than has been officially acknowledged in the conventional historical narrative.

This appendix presents:

E.1. Evidence for intercontinental jet bombers.

E.2. Evidence for liquid propellant rockets larger than the A-4 or V-2.

E.3. Evidence for space planes or space shuttles.

E.4. Evidence for large solid propellant rockets and submarine-launched rockets.

E.5. Evidence for longer-term technologies for space exploration.

E.6. A physics analysis of some of the evidence for advanced jet developments.

E.7. A physics analysis of some of the evidence for advanced rocket developments.

E.8. Conclusions.

This evidence that is currently publicly available should spur much more extensive searches in archives worldwide. Further searches could uncover documentation clarifying just how far development work proceeded during the war, how those technologies were transferred to other countries after the war, and which scientists were most responsible for the wartime and postwar work.

E.1 Intercontinental Jet Bombers

[English-language histories tend to regard intercontinental jet aircraft as an invention that originated primarily during the postwar period and primarily in Allied countries. For example, Oxford's *Biographical Dictionary of Scientists* says of Frank Whittle: "British engineer and inventor of the jet engine. The developments from his original designs were used first in the Gloster Meteor at the end of World War II. Direct descendents of these engines are now the sources of power for all kinds of military and civil aircraft" [Porter 1994, pp. 721–722]. This biographical dictionary does not mention Hans von Ohain or other German-speaking inventors of jet engines and jet aircraft, apart from briefly mentioning that "the Germans had produced the Messerschmitt Me 262 slightly earlier" than the British. While the existing literature does document the German production of small, shorter-range jet aircraft such as the Me 262, it generally describes more advanced jet aircraft as projects that never progressed much beyond the design stage [e.g., Griehl 2004; Masters 1982; Myhra 1998a].

In fact, there is evidence that even very advanced jet aircraft projects such as large intercontinental jet bombers may have progressed much further in wartime Germany than has been acknowledged in the conventional historical narrative, and that in turn those projects and their creators led directly to the postwar jet aircraft programs in Allied countries:

- March–June 1944 articles in the British magazine *Flight* reported that the Luftwaffe was rapidly constructing several large airfields near Oslo, including workshops for Heinkel, which was known for designing and building new jet aircraft, and BMW, which was known for building engines for jet aircraft (p. 5190).

- On 5 January 1945, Colonel Lowell Weicker at the Headquarters of the U.S. Strategic Air Forces in Europe wrote: "Germany... is leading the world in tested jet propelled airplanes... A large part of her manufacturing facilities have gone underground and she is bending every sinew for the last stand on the Vaterland frontiers. Our Ground Armies, despite superiority in manpower and quantity of equipment, are presently engaged more in defensive than offensive fighting and, unless this state of affairs is quickly changed or the Russians actually drive through to Berlin and victory, we must face the grim expectation of fighting Germany and her new capabilities through greater 1945... The first cycle and period of the war has ended without the capitulation of Germany and with Germany leading in the development of principal new weapons and methods, which will be included in her capabilities during 1945" (p. 5336).

- Based on a 10 May 1945 U.S. interrogation of former Luftwaffe head Hermann Goering, the *New York Times* reported on 8 June 1945 that the Germans had built a prototype Messerschmitt 264 "New York" bomber with four jet engines, found at an undisclosed place in France, and were "within a few months of working out the kinks" when the war ended (pp. 5200–5202).

- On 29–30 June 1945, numerous major newspapers reported that at the end of the war, "40 giant Heinkels of a new type, with a range of 7,000 miles" had been found near Oslo at "the largest Luftwaffe field I have ever seen" according to senior British military officers. The articles reported that "German ground crews said the planes were held in readiness for missions to New York," and that the planes had been captured by the British (pp. 5197–5198).

- On 26 June 1945, Henry Fowler, Director of the Enemy Branch of the U.S. Foreign Economic Administration testified to a U.S. Senate committee: "According to recent reports from Germany, it appears that if the Germans could have held out only 6 months longer they would have been able to smash New York City with improved V-2 bombs. Only a little longer period would have been needed to bring into production the jet-propelled planes that could have reached Washington. It is not necessary here to elaborate upon the terrifying scientific discoveries which our economic and industrial intelligence is gradually uncovering as we work beneath the lid in Germany. With the memories of her new V-weapons fresh in our minds, little needs to be added except to point out that they just didn't appear out of thin air. They were the fruit of carefully organized and adequately financed research institutions in which large numbers of highly trained and specialized scientists went about their business of inventing and developing the weapons that would establish German world supremacy... Germany could rapidly set up plants for such new products because of its enormous capacity to produce machines and machine tools, and the huge supplies of machine tools that were built up in advance of need" (p. 5206).

- On 27 August 1945, Consolidated Vultee Aircraft Corporation (Convair) stated in *Life* magazine: "In a converted salt mine, our ordnance officers examined nearly complete jet-propelled heavy bombers... bombers claimed by the Germans to be capable of crashing high explosives into the industrial cities of the eastern United States and flying back again across the Atlantic. Goering himself said that the planes had been successfully test-flown and would have been in operation if Germany could have held out 3 months longer" (p. 5208).

- In his 1956 autobiography, Ernst Heinkel did not mention the 40 giant Heinkel intercontinental bombers found in Norway, perhaps due to Cold-War censorship or to avoid self-incrimination. However, he did mention that he had long been a strong proponent of jet bombers that he believed could be built quickly, that his company participated in a late-war push to build new jet aircraft that nearly came to fruition, that those aircraft were found by the Allies, that his top designer Siegried Günter had been engrossed with flying wing bomber designs, and that Günter had submitted his information on the flying wings to U.S. Army Air Forces Major Robert L. Cardenas by the end of September 1945 (p. 5220).

- According to a report apparently written by Siegried Günter and filed by Major Cardenas on 1 October 1945, Heinkel engineers had been working on four-jet-engine long-range bombers with a flying wing design before the end of the war. Günter described 26-ton and 60-ton versions of the design with intercontinental ranges (p. 5223).

- If the British captured novel German intercontinental jet bombers with oversized wings at the end of the war, the first British intercontinental jet bombers with oversized wings such as Vulcan (1957) may be based on those German aircraft (p. 5226).

- Several different turbofan and turboprop engines with high fuel efficiencies, suitable for intercontinental bombing round trips, were under active development throughout the war, and at least some of them were built and successfully demonstrated (pp. 1746–1748, 5233–5241, 5779).

- Large numbers of German-speaking creators, designs, documentation, and prototypes for a wide range of jet engines and jet aircraft were taken to the United States and other Allied countries, directly shaping the course of postwar jet programs in those countries (pp. 1707, 5250).[1]

- German-speaking creators also developed a number of anti-radar stealth materials, coatings, configurations, and other techniques during that war that were captured and used by Allied countries after the war (p. 1234).

Today these directly German-derived technologies are represented by one third of the military "nuclear triad" (intercontinental jet bombers), as well as jet fighters, stealth aircraft, jet passenger aircraft, and gas turbines used in everything from helicopters to electric power plants.]

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[1] Amtmann 1988; Bohr 2013; Brix 2022; Butler 1994, 2007; Christensen 2002; Christopher 2013; Cole 2015; Conner 2001; Constant 1980; Cooke and Ingells 1945; Daso 2002; Diedrich 1999; Dorr 2013; Duffy 2012; Erfurth 2006; Forsyth and Creek 2007; Franz 1985; General Electric 1979; von Gersdorff et al. 2004; Gleichmann 2013; Gleichmann and Bock 2009; Griehl 1990, 2004, 2005; Griehl 2015; Gunston 2006a, 2006b; Herwig and Rode 2000, 2003; Hill and Peterson 1991; Hirschel et al. 2004; Hyland and Gill 1998; Jacobsen 2011, 2014; Jakobs et al. 2009; Johnsen 2014; Kay 2002; Kerrebrock 1992; Kober 1990; Leist and Wiening 1963; Leyes and Fleming 1999; Lichtfuss and Schubert 2014; Longden 2009; Masters 1982; Hans-Ulrich Meier 2010; Miranda 2015; Myhra 1998a, 1998b, 2000a; Nowarra 1988; Pavelec 2007; Samuel 2004, 2010; Schick and Meyer 1997; Shepelev and Ottens 2015; Simons 2016; Smith and Creek 1992, 2001; Smith and Kay 2002; Thomas 1946; Vajda and Dancey 1998; CIOS XXV-9, XXVI-27, XXVI-28, XXVI-29, XXVI-30, XXXII-41; *Air World* 1946; *Chicago Daily Tribune* 1945-06-29 p. 4; *Daily Telegraph* 1, 2, 5, 9 Oct. 1945, p. 4 each issue; *L.A. Times* 1945-06-29; NYT 1945-06-08, 1945-07-26 p. 6, 1948-04-15 p. 17, 1948-12-04 p. 3; *Washington Post* 1945-06-29.

Behind the Lines. *Flight.* 2 March 1944 p. 230.

For Defence

From neutral sources it is reported that the Germans have started work on two new big airfields in Norway. One of these is at Eggemo[en], between Ådalen and Randsfjorden, and the other at Haslemo[en], only some 18 miles from the Swedish border.

Behind the Lines. *Flight.* 11 May 1944 p. 503.

Preparing

Only time will show the real purpose of the new chain of airfields now being established by the *Luftwaffe* in Norway. But whether for defence or offence, reports indicate a feverish activity in the expansion of existing landing facilities and the construction of new ones.

Over 300 acres of forest have been cleared to make room for the big airfield which the Germans are building at Halsemoen, Flisa, about twenty miles from the Swedish border and about fifty miles from the big air base at Gardemoen which has recently been substantially enlarged.

The work on the Haslemoen airfield started in January and large areas have been evacuated, schools and churches requisitioned, and farms devastated. The whole district has been practically destroyed. One thousand Russian prisoners and 800 Norwegian slave labourers are engaged on the work.

Only twelve miles from this airfield another temporary one is being rapidly built, and the construction of a third situated close to the Swedish border, was started at the end of last month.

Both the Fornebu airfield, near Oslo, and the Bardufors, in the county of Troms, are being expanded.

The method used for the construction of these temporary airfields on frozen ground or lakes is first to remove the snow from the ice, then cover it with a layer of sawdust which acts as an insulator, and then a layer of gravel.

Ice treated in this way—it is said—can last until midsummer, provided the weather in the spring does not become unusually warm.

In Denmark, too, the *Luftwaffe* is preparing; the Kastrup airfield is being transformed from a training to an operational base; many bombers are reported to have arrived and stocks of bombs are placed around the periphery.

On the Avedore airfield the B.M.W. have installed repair workshops for their engines, while the Heinkel concern has taken over the engine shops of the naval dockyards.

[BMW was noted for its jet engines, and Heinkel was noted for its advanced jet aircraft models. Eggemoen airfield, though not specifically named in the May 1944 article, was named in the March article and was also very important.]

Behind the Lines. *Flight.* 29 June 1944 p. 693.

Preparing

From Norway it is reported that over 300 acres of forest have been felled to make room for the big airfield which the Germans are building at Haslemoen, Flisa, about 20 miles from the Swedish frontier. The work was started in January, and large areas have been evacuated and the forests cut down. Schools and churches have been requisitioned and farms devastated. The whole district has been practically destroyed.

Norwegians in the labour service have been conscripted for this work, in the teeth of the Hague Convention, which prohibits the employment of the people of an occupied country for the military purposes of an Occupying Power.

The airfield is situated only about 50 miles from the big German airfield at Gardermoen which the Germans have substantially enlarged.

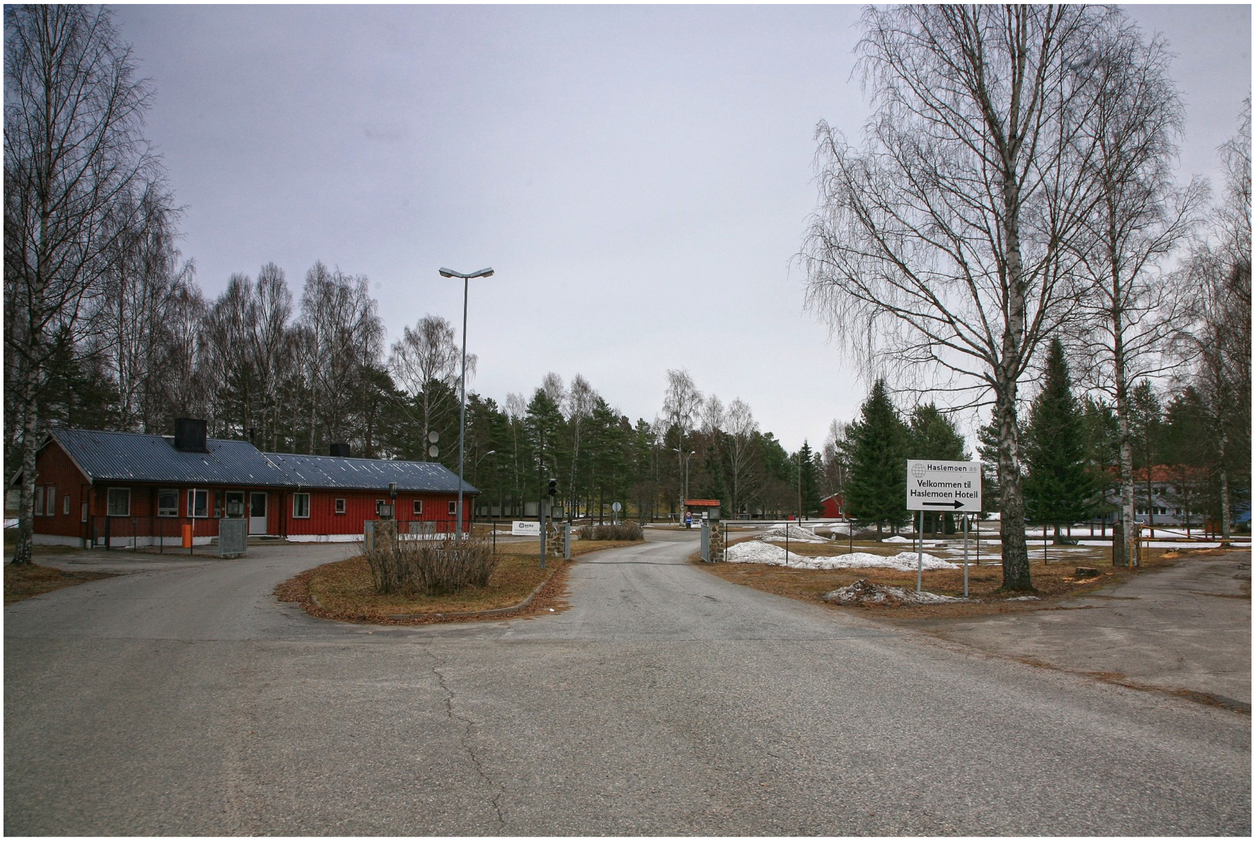


Figure E.1: Entrance to Haslemoen airfield, near the Swedish border, in 2011.

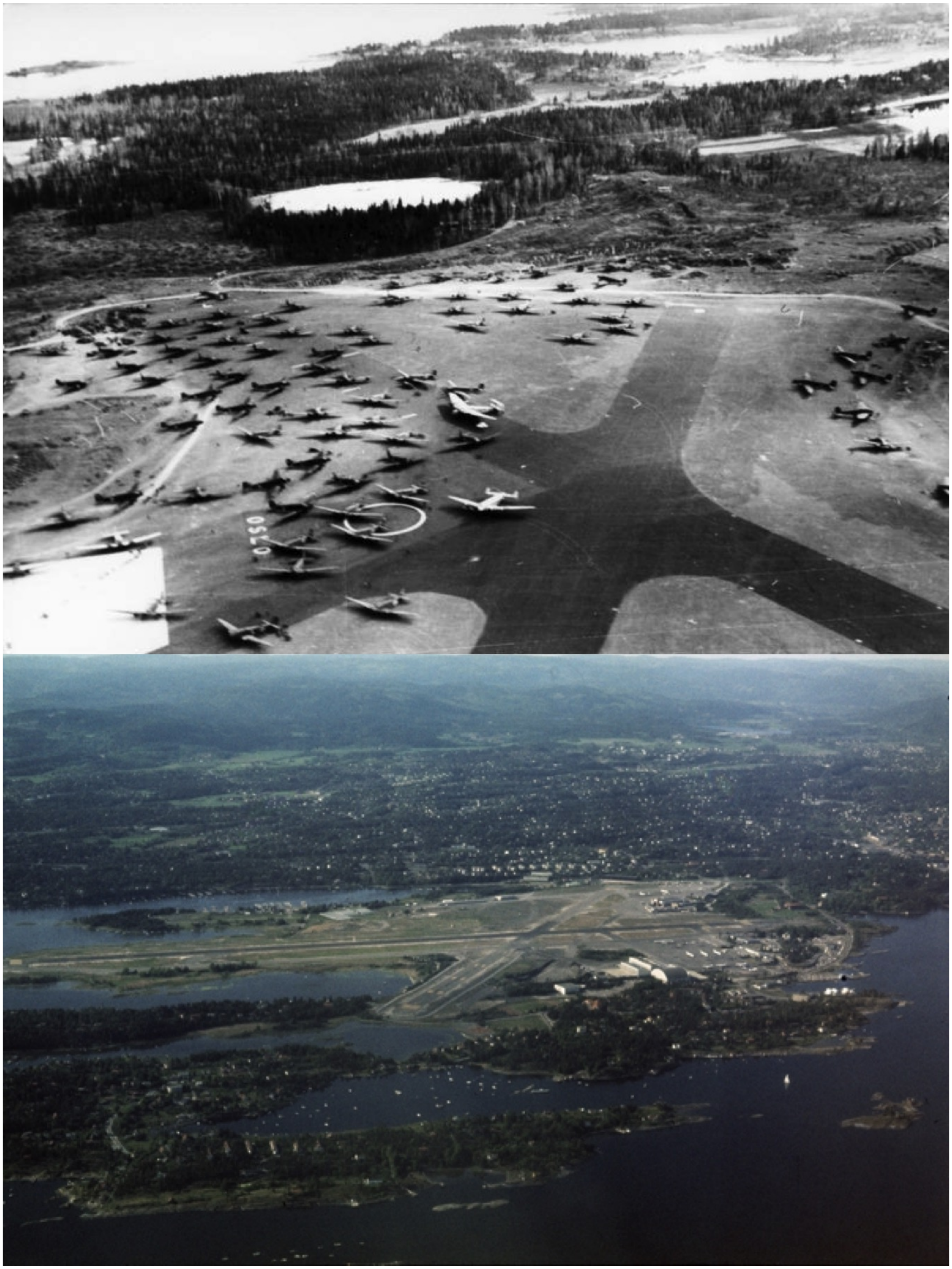


Figure E.2: Fornebu airfield, approximately 5 miles west of Oslo, in 1940 (upper) and in the late 1970s (lower).

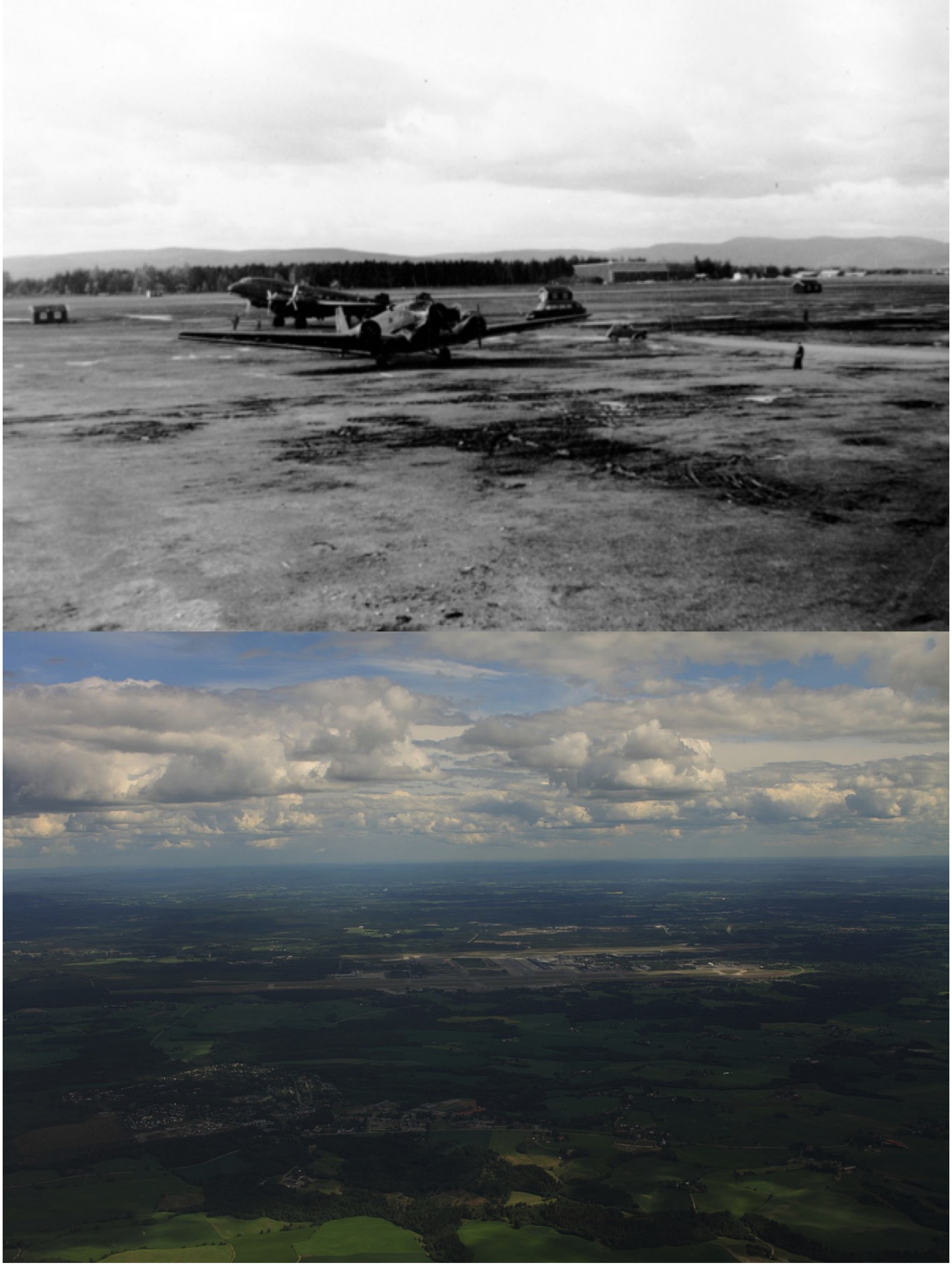


Figure E.3: Gardermoen airfield, approximately 23 miles northeast of Oslo, in 1942 (upper) and in 2010 (lower).

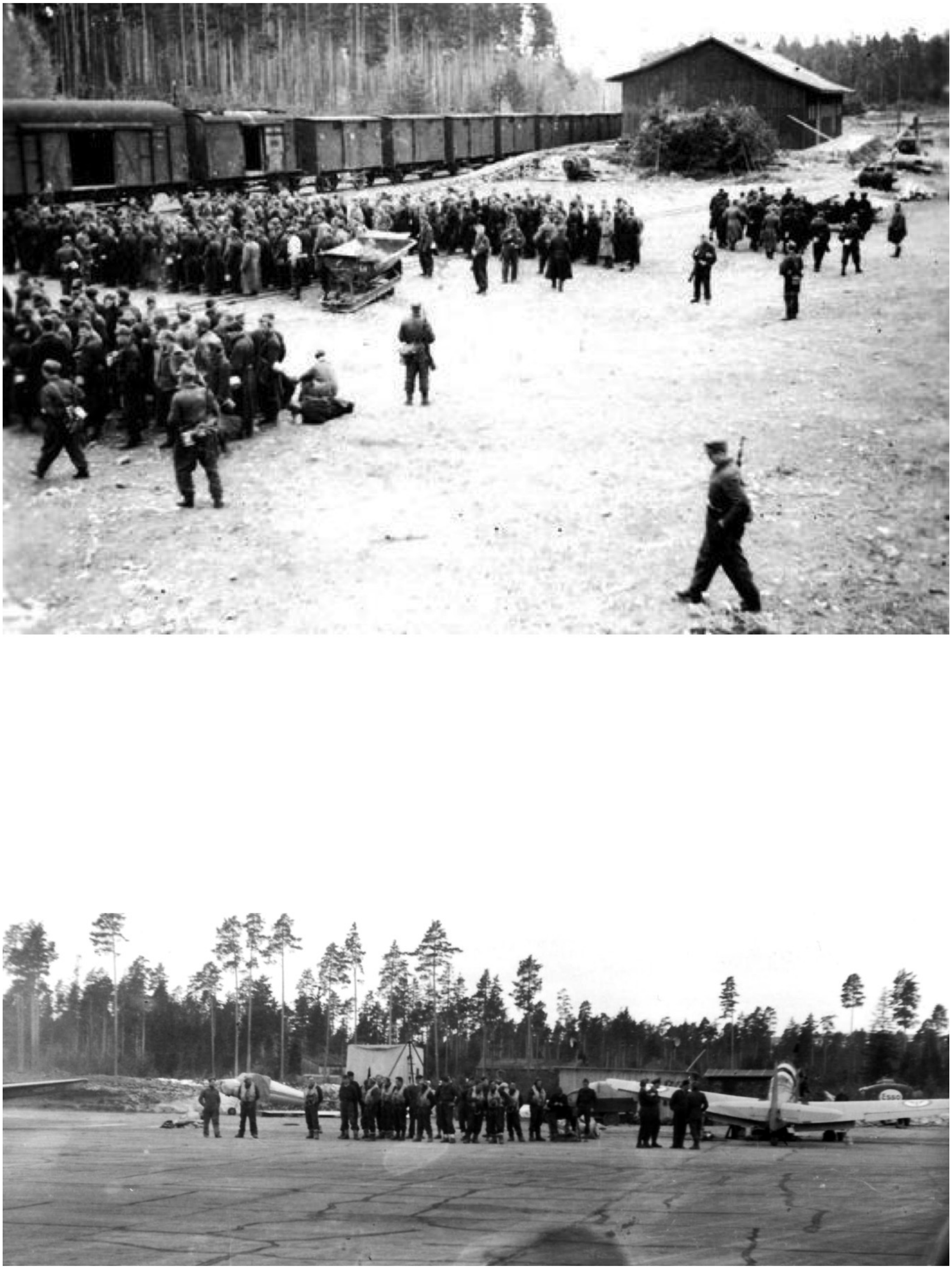


Figure E.4: Eggemoen airfield, approximately 23 miles northwest of Oslo, under construction in 1943 (upper) and operational in 1944 (lower).

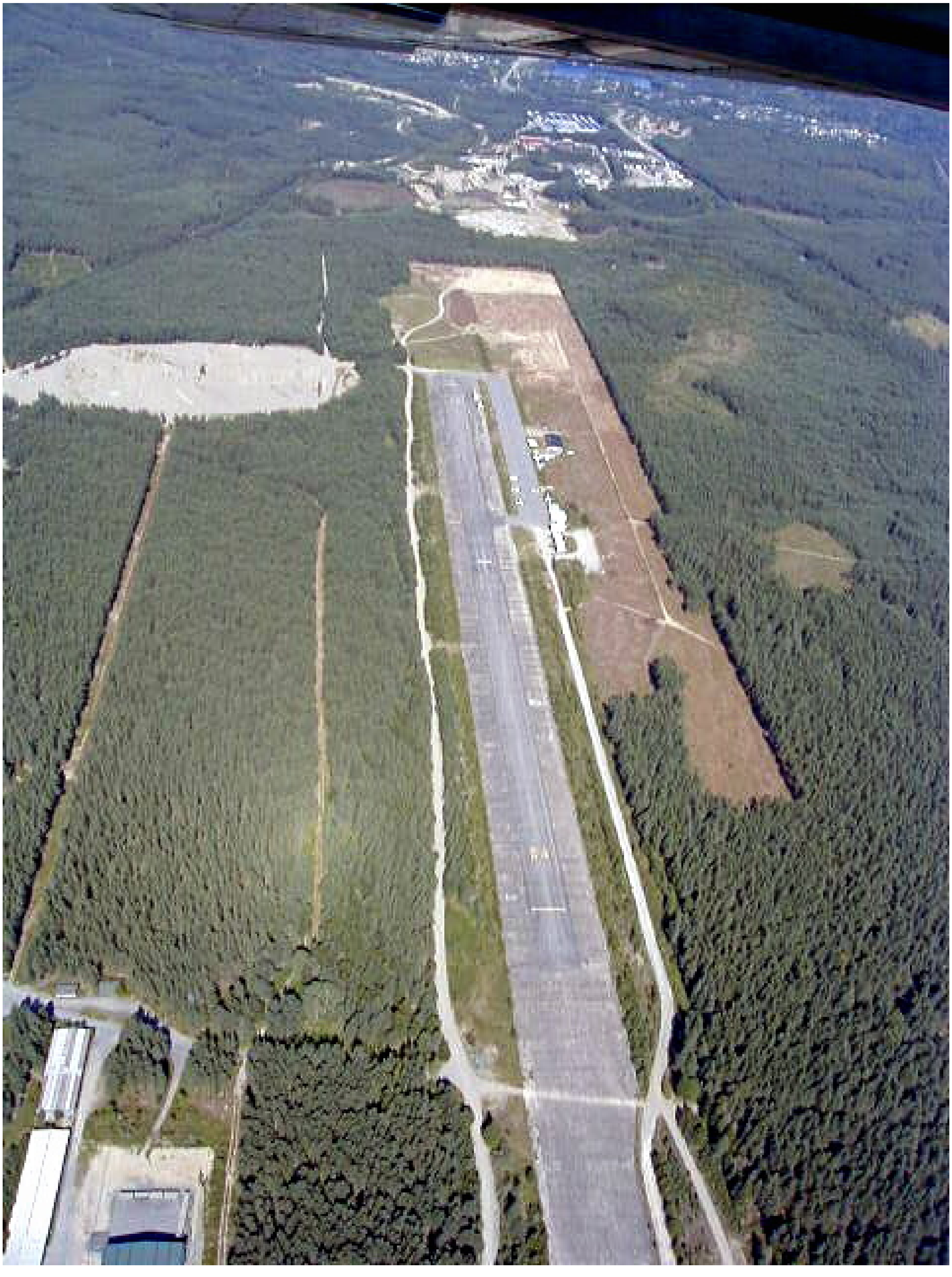


Figure E.5: Eggemoen airfield, approximately 23 miles northwest of Oslo, in 2007.

[These facts are firmly established:

- During the war, Germany built several separate airfields in southern Norway.
- Each of those airfields was massive.
- Each airfield had a remarkably large runway with the same dimensions: 1800 meters long and 60 meters wide.
- The German military placed a very high priority on finishing those airfields in 1944.
- The German military stubbornly held those airfields until V-E Day, making them an even higher priority than defending the German homeland.

The above facts are not explained in conventional histories of the war.

The above facts strongly suggest that:

- Germany expected by late 1944 or early 1945 to have huge aircraft that would need such large runways.
- Germany expected to have large numbers of those aircraft.
- Germany expected those aircraft to make war-critical missions to Allied targets—not just the United Kingdom, but also the east coast of the United States.
- Germany expected that those aircraft would be fast enough to make the trip before Allied defenses could be fully mobilized, and that at least some fraction of the aircraft could evade Allied propeller airplanes—apparently the large German aircraft were jet-propelled.
- Germany expected those aircraft to have payloads destructive enough to justify such expensive infrastructure and equipment—likely nuclear weapons, or at the very least chemical or biological weapons.

The following news articles demonstrate that such aircraft were indeed built and stationed at the Norwegian airfields.]

Planes to Bomb N. Y. Uncovered. *The Stars and Stripes* (Paris). 30 June 1945 p. 8.

Planes to Bomb N. Y. Uncovered

21st ARMY GROUP. June 29 (AP).—The Germans had “almost completed” preparations to bomb New York from a “colossal airfield” near Oslo when the war ended, RAF officers disclosed today.

“Forty giant bombers, with a 7000-mile range, were found on this base—the largest Luftwaffe field I have ever seen,” a senior officer said. “They were the new type bombers developed by Heinkel. They are now being dismantled for study. German ground crews said the planes were held in readiness for missions to New York.”

Hundreds of different type planes were taken intact on the field, cut through a pine forest about five miles from Oslo. Some of the latest model fighters, including the JU88 night fighters, equipped with intricate Radar devices to guide pilots to their target, were found.

RAF officers said they were indications that the Germans had planned a “last-ditch stand” in the area and were hoarding their newest bombers and fighters.

Bombing New York. *The West Australian* (Perth, WA). 30 June 1945 p. 7.

Bombing New York.

New Giant Heinkel.

Nazi Plan Disclosed.

London, June 29.—RAF officers have disclosed that the Germans had nearly completed preparations to bomb New York from a colossal airfield carved out of a forest 23 miles from Oslo, says a correspondent of the American Associated Press at Field Marshal Montgomery’s HQ.

A senior officer said that 40 giant Heinkels of a new type, with a range of 7,000 miles, had been found there.

German ground staff members admitted that they were being held in readiness for raids against New York.

Were Ready to Bomb N.Y. *Washington Post.* 29 June 1945.

Twenty-first Army Group Headquarters, June 28 (AP)—RAF officers said today that the Germans had nearly completed preparations for bombing New York from a “colossal airfield” near Oslo when the war ended.

“Forty giant bombers with a 7000-mile range were found on this base—the largest Luftwaffe field I have ever see,” one senior officer said.

“They were a new type bomber developed by Heinkel. They now are being dismantled for study. German ground crews said the planes were held in readiness for a mission to New York.”

[Discovery of the 40 giant Heinkel intercontinental bombers was also reported in many other newspapers worldwide, such as:

Planned N.Y. Bombing. *Chicago Daily Tribune.* 29 June 1945 p. 4.

Plan to Bomb New York Told. *Los Angeles Times.* 29 June 1945.

To Rocket Mail over Atlantic in 40 Minutes. *Toronto Daily Star.* 29 June 1945 p. 1.

Bombing New York: Germans' Plan Disclosed. *Kalgoorlie Miner* (Australia). 30 June 1945 p. 5.
[https://www.myheritage.com/research/record-10450-31024931/kalgoorlie-miner-wa]

Planes Ready to Bomb New York. *Examiner* (Launceston, Tasmania). 30 June 1945 p. 1.
[https://www.myheritage.com/research/record-10450-33164384/examiner-launceston-tas]

Bomb New York. *The Daily News* (Perth, WA, Australia). 29 June 1945 p. 3.

Nazis Almost Ready to Blast New York. *The Calgary Herald.* June 29, 1945 p. 7.

German Preparations to Bomb New York. *Cairns Post* (Queensland). 30 June 1945 p. 2.]

Long-Range Weapons. *The Evening Post* (Wellington, New Zealand). 29 June 1945 p. 5.
[https://paperspast.natlib.govt.nz/newspapers/evening-post/1945/06/29]

Nazis Nearly Bomb NY City. *Schenectady Gazette* (New York). 29 June 1945 p. 1.
[https://fultonhistory.com/newspaper%208/Schenectady%20NY%20Gazette/Schenectady%20NY%20Gazette%201945%20Grayscale/Schenectady%20NY%20Gazette%201945%20Grayscale%20-%203174.pdf]

The articles disagreed on whether the airfield was 5 miles from Oslo (the approximate distance of Fornebu) or 23 miles from Oslo (the approximate distances of both Gardermoen and Eggemoen). See Figs. E.2–E.5. The Luftwaffe used all of those airfields during the war, as well as Haslemoen (Fig. E.1). The Heinkel long-range bombers and other advanced German aircraft may have been found at all four airfields when the war ended. A combination of those or similar airfields likely would have been necessary to launch a coordinated, simultaneous, intercontinental mission by 40 large bombers and to receive the returning planes, which would have been running low on fuel after the round trip. The Luftwaffe equipped those airfields with some of the most advanced radars, approach lights, radio-guided blind landing systems, and other technology available at the time.]

Bombs Slow Down Nazi Atomic Use. *Wilmington Morning Star.* 28 September 1945, p. 8. [https://chroniclingamerica.loc.gov/lccn/sn78002169/1945-09-28/ed-1/seq-8/]

Washington, Sept. 27.—(AP)—A report by Maj. Alexander De Seversky that Allied strategic bombing of Germany may have prevented the Nazis from being the first to use atomic bombs was released today by the War Department.

De Seversky, aircraft designer and aviation writer, returned recently from Europe where he had gone as a special consultant to the Secretary of War to appraise the use of air power.

His report said that the Germans were far advanced in the aerodynamics of high speed flying, jet propulsion, the study of ballistics, rocket projectiles and synthetic fuels. He added that the German jet design was more efficient than ours.

"Moreover, there are indications that German science had made great advances in atomic power research," Seversky said. "If our strategic bombardment had not nipped enemy atomic research in the bud, the Germans might have succeeded in winning the race for the atomic bomb."

(While the De Seversky report did not detail where the air attacks on the German atomic bomb efforts occurred, the Allied air forces paid attention to German installations in Norway and islands in the Baltic sea.)

De Seversky was critical of some of the equipment used by the American Air Forces in the European war. He declared that the United States fought the war "largely with a bomber more than 10 years old in basic design."

Discussing bombsights, Seversky asserted that "I am constrained to say that there has been some gross exaggeration about the allegedly miraculous powers of our sighting devices."

Nazis Nearly Beat Allies to Atom Bomb Secret. Examiner (Launceston, Tasmania). 29 September 1945, p. 1. [https://trove.nla.gov.au/newspaper/article/91945338]

WASHINGTON (A.A.P.)—Major de Seversky, world famous aviation figure and special consultant to the Secretary for War, has reported after a five months' inspection of Europe, that German scientists might have beaten the Allies to a solution of the atomic power riddle if unrelenting Allied airpower had not interfered with their research.

De Seversky, who is at present in the Pacific, declared that the Germans were achieving sensational developments when the Reich fell. The U.S. should bring German scientists to America and make them complete their experiments for America's benefit.

The American air force must be prepared to jettison all its present equipment because, due to the advent of jet propulsion and the faster-than-sound era in aircraft design, it would be totally obsolete within 10 years.

De Seversky interrogated German military leaders, scientists and officials, including Goering. and also key figures in Britain, France, Sweden and Switzerland. He said the Germans excelled in high-speed flying research, jet propulsion, ballistics, and synthetic fuels. Their jet design was more efficient than America's.

[Can Alexander de Seversky's actual September 1945 report be located? See also:
Atomic Energy Control Board Voted in Senate. Chicago Daily Tribune. 28 Sept. 1945, p. 12.
Would Unify Air Forces. Army, Navy, Air Force Journal & Register. 29 Sept. 1945, p. 154.
German Progress in Atomic Research. *The Advertiser* (Adelaide, Australia). 29 Sept. 1945, p. 8. [https://trove.nla.gov.au/newspaper/article/48669930]
Germany Fell Just in Time. *Barrier Daily Truth* (Broken Hill, Australia). 1 Oct. 1945, p. 2. [https://trove.nla.gov.au/newspaper/article/141566398]]

Interrogation of Reich Marshall Hermann Goering. 10 May 1945. [Cornell University Donovan Archive]

(Because General Patch is personally responsible for the safe custody of the prisoner, it was necessary for General Spaatz' party to go from Headquarters Ninth Air Force to Headquarters Seventh U.S. Army). [...]

Interpreter provided by the Seventh Army.

Those present were:

Reich Marshal Hermann Goering.
General Spaatz, CG, USSTAF.
Lt. Gen. Patch (part of the time), CG, 7th Army.
Lt. Gen. Vandenberg, CG, Ninth Air Force.
Brig. Gen. E. P. Curtis, C/S, USSTAF.
Brig. Gen. Paul Barcus.
Major Alexander de Seversky, Special Consultant to Secretary of War.
Dr. Bruce Hopper, Historian, USSTAF.

SPAATZ: Would you tell us something of the organization of the Luftwaffe and the plans, especially the factors which went into the non-fulfillment of those plans?

GOERING: In the early years when I had supreme command of the Luftwaffe, I had definite plans, but in 1940 Hitler began to interfere, taking air fleets away from our planned operations. That was the beginning of the breakdown of the Luftwaffe efficiency. [...]

SPAATZ: Did the jet airplane really have a chance to win against us?

GOERING: Yes, I am still convinced, if we had only four to five months more time. Our underground installations were practically all ready. The factory at Kahla had a capacity of 1000 to 1200 jet airplanes a month. Now with 5000 to 6000 jets the outcome would have been different.

VANDENBERG: But could you train sufficient jet pilots, considering your shortage of oil?

GOERING: Yes, we would have had underground factories for oil, producing a sufficient quantity for the jets. The transition to jets was very easy in training. The jet pilot output was always ahead of the jet aircraft production.

SPAATZ: Could Germany have been defeated by air power alone, using England as a base, without invasion?

GOERING: No, because German industry was going underground, and our counter measures could have kept pace with your bombing. [...]

GOERING: We had too few long-range airplanes and then, later, when you got to Algiers the airfields in Italy were inadequate. You have no idea what a bad time we had in Italy. If they had only been our enemies instead of our Allies we might have won the war. [...]

SPAATZ: Have you any knowledge of a proximity fuze?

GOERING: Yes, in three or four months there would have been production. [...]

SPAATZ: If you had to design the Luftwaffe again, what would be the first airplane you would develop?

GOERING: The jet fighter and then the jet bomber. The problem of speed has been solved. It is now a question of fuel. The jet fighter takes too much. The jet bomber, ME 264, designed to go to America and back, awaited only the final solution of the fuel consumption problem. I might add that according to my view the future airplane is one without fuselage (flying wing) equipped with turbine in combination with the jet and propeller.

SEVERSKY: In view of your diminishing manufacturing resources, who made the decision to divert a large portion of your national effort to manufacture of V-1 and V-2 weapons instead of building up the Luftwaffe?

GOERING: Well, there was great confusion of thought in Germany. Prior to the invasion the V-1 would have been effective. After the invasion our effort should have been concentrated on the ME 262 (jet). The decision on the V-2 project was made at higher headquarters. [...]

SPAATZ: Did you have a three-inch gun for the jet?

GOERING: The 5.5 centimeter machine gun, only now going into production, would have made a great difference in the jet. While waiting for that we used the 5.5 centimeter rocket. You might find around Germany some jet airplanes equipped with anti-tank guns. Don't blame me for such monstrosities. This was done on the explicit orders of the Fuehrer. Hitler knew nothing about the air. He may have known something about the Army or Navy, but absolutely nothing about the air. He even considered the ME 262 to be a bomber; and he insisted it should be called a bomber.

SEVERSKY: I know that four-engine Focke-Wulf planes were in production in 1939. When you found after the Battle of Britain that your planes did not have sufficient fire power and bombing power, why didn't you concentrate on these four-engine planes as a heavy bomber?

GOERING: Instead of that, we were developing the HE 177 and tried to develop the ME 264 which was designed to go to America and return. We did use the Focke-Wulf against shipping from Norway. Because our production capacity was not so great as that of America we could not produce quickly everything we needed. Moreover, our plants were subject to constant bombing so that it was difficult to carry out our plans for heavy bomber production.

SEVERSKY: The reason why I asked the previous question was because I wanted to establish whether you failed to build the big bombers because you did not believe in strategic air power or because your productive capacity was restricted to the production of tactical aircraft for the Russian campaign.

GOERING: No, I always believed in strategic use of air power. I built the Luftwaffe as the finest bomber fleet, only to see it wasted on Stalingrad. My beautiful bomber fleet was used up in transporting munitions and supplies to the army of 200,000 at Stalingrad. I always was against the Russian campaign.

New York Bomber Built in Germany. *New York Times.* 8 June 1945.

New York Bomber Built in Germany.

De Seversky Says Principal Bar to Use Was Its High Rate of Fuel Consumption

The Germans planned to bomb New York and other eastern American ports and, according to Hermann Goering, were within a few months of working out the kinks in a jet-propelled plane that would do it, Maj. Alexander P. de Seversky, airplane designer and airpower advocate, said today.

Major de Seversky, World War I commander of the Russian Navy's Baltic fighter plane force, has been touring Germany as a special air consultant to Secretary of War Henry L. Stimson. He interviewed Goering with Gen. Carl A. Spaatz right after Goering was captured at Augsburg.

[...] The Germans' "New York" bomber, a prototype of which was found at an undisclosed place in France, was a Messerschmitt 264. It had four engines with jet propulsion for high altitudes, Major de Seversky said. The Germans started working on it before the war, designing it to cross the Atlantic and return nonstop with two or three tons of bombs. The only obstacle to its introduction was its big fuel consumption, but this, Goering asserted, the Germans had expected to solve in a few months.

[The intercontinental jet bomber described in the Goering interrogation and the article above was built by Messerschmitt and found in France. It was probably similar to, but should not be confused with, the intercontinental bombers described in the previous articles, which were built by Heinkel and found in Norway.]

Chicago Daily Tribune 1945-04-13 p. 9. German 'Flying Wing' Factory Found by Yanks. 718 M.P.H. Claimed; Plane Tailless.

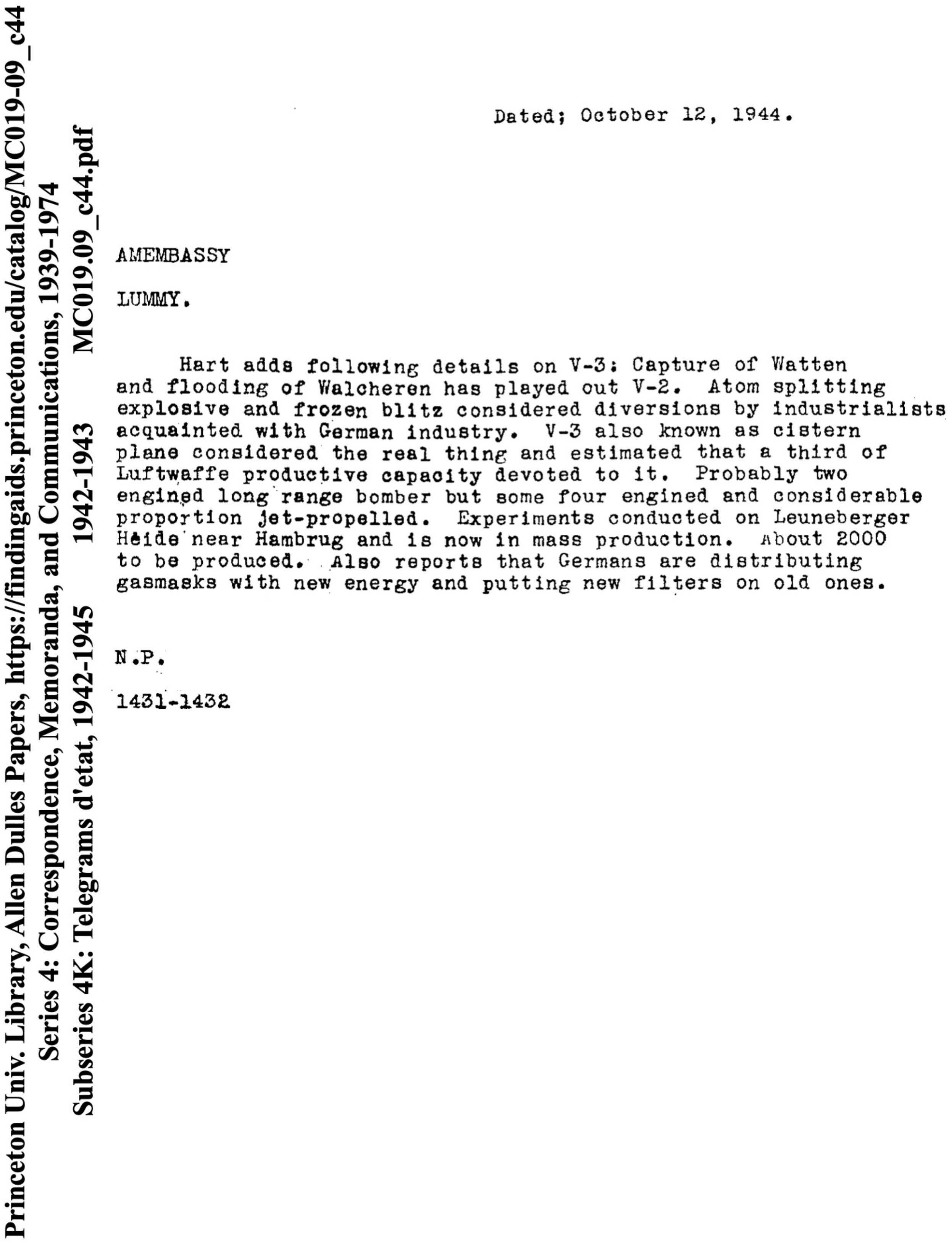
GOETTINGEN, Germany, April 9 [Delayed]—A factory in which the Germans had been experimenting with a "flying wing," a super-powerful plane without fuselage or tail, has been overrun by American infantry. Both bomber and fighter types had been produced, with one to six engines. Later models were jet propelled.

Eight German technicians who had been left behind said they had flown the flying wings and found them much more maneuverable and of greater stability than conventional type planes.

One model was said to have a speed of 625 miles an hour at an altitude of 3,280 feet and 718 miles an hour at 4,600 feet. The plane's ceiling is about 52,500 feet, with a climbing rate of 65.6 feet a second. Its flying radius was reported at 937 miles.

This plane was designed to carry two bombs under the wings. [...]

[For another report of a similar six-jet-engine flying-wing bomber, see pp. 5227–5231. Note that the demonstrated airspeed reported above is in the high subsonic range. For jet engines that were optimized to operate at such airspeeds and were successfully tested in 1943, see pp. 5233–5241.]



Princeton Univ. Library, Allen Dulles Papers, https://findingaids.princeton.edu/catalog/MC019-09_c44
Series 4: Correspondence, Memoranda, and Communications, 1939-1974
Subseries 4K: Telegrams d'etat, 1942-1945 1942-1943 MC019.09_c44.pdf

Dated; October 12, 1944.

AMEMBASSY

LUMMY.

Hart adds following details on V-3: Capture of Watten and flooding of Walcheren has played out V-2. Atom splitting explosive and frozen blitz considered diversions by industrialists acquainted with German industry. V-3 also known as cistern plane considered the real thing and estimated that a third of Luftwaffe productive capacity devoted to it. Probably two engined long range bomber but some four engined and considerable proportion jet-propelled. Experiments conducted on Leuneberger Heide near Hambrug and is now in mass production. About 2000 to be produced. Also reports that Germans are distributing gasmasks with new energy and putting new filters on old ones.

N.P.

1431-1432

Figure E.6: Allen Dulles. 12 October 1944. [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44].

PW Intelligence Bulletin No 1/34, 5 February 1945. [AFHRA folder 506.61951 Nos. 1/19–1/35 26 Dec 1944–7 Feb 1945, IRIS 207524; AFHRA A5185 frame 481; also NARA RG 165, Entry NM84-79, Box 1915]

11. Experimental Aircraft

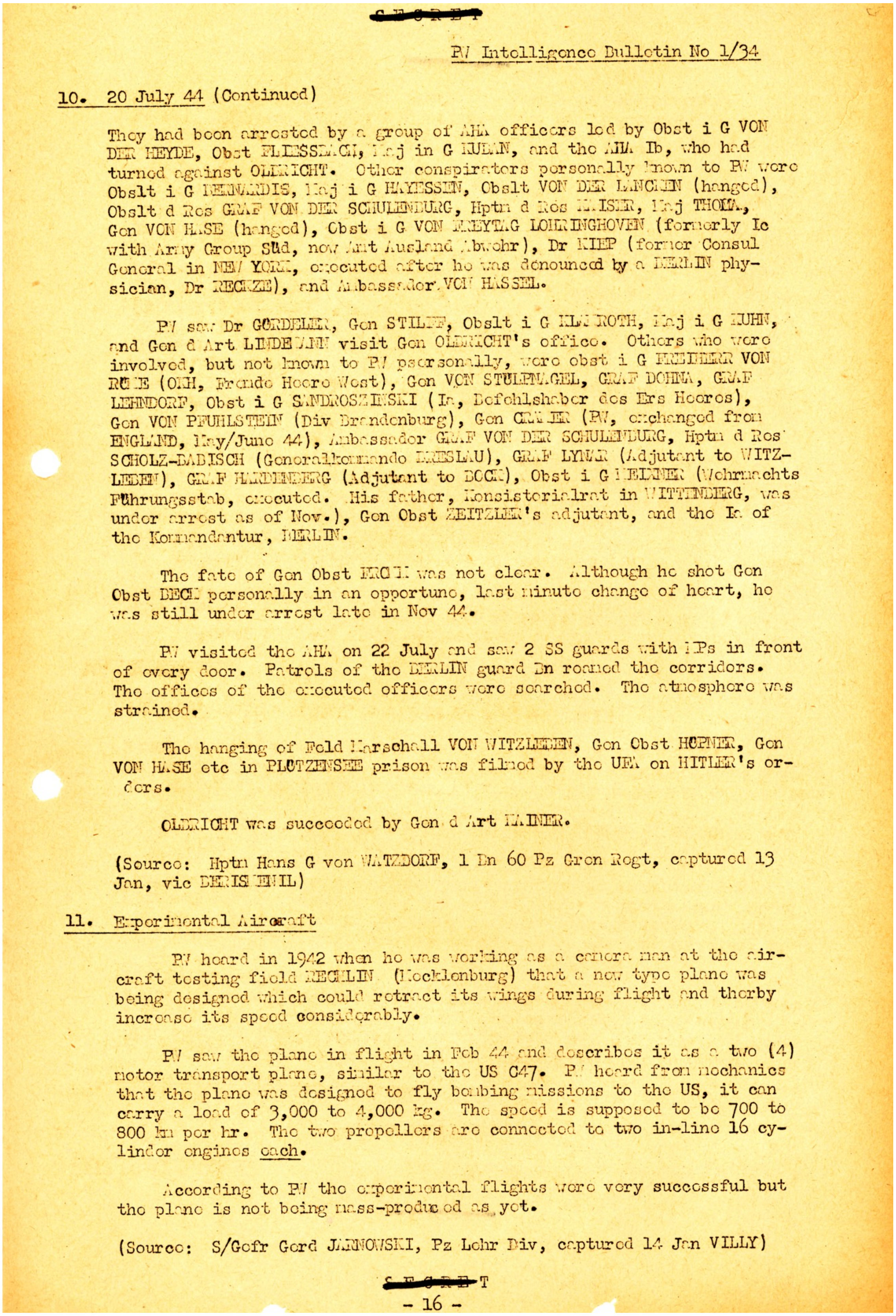
PW heard in 1942 when he was working as a camera man at the aircraft testing field RECHLIN (Mecklenburg) that a new type of plane was being designed which could retract its wings during flight and thereby increase its speed considerably.

PW saw the plane in flight in Feb 44 and describes it as a two (4) motor transport plane, similar to the US C47. PW heard from mechanics that the plane was designed to fly bombing missions to the US, it can carry a load of 3,000 to 4,000 kg. The speed is supposed to be 700 to 800 km per hr. The two propellers are connected to two in-line 16 cylinder engines each.

According to PW the experimental flights were very successful but the plane is not being mass-produced as yet.

(Source: S/Gefr Gerd JARNOWSKI, Pz Lohr Div, captured 14 Jan VILLY)

[See document photo on p. 5205.]



PW Intelligence Bulletin No 1/34, AFHRA folder THIS PAGE IS DECLASSIFIED IAW EO 13526
506.61951 Nos. 1/19–1/35 26 Dec 1944–7 Feb 1945, IRIS 207524

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PW Intelligence Bulletin No 1/34

10. 20 July 44 (Continued)

They had been arrested by a group of AHA officers led by Obst i G VON DER HEYDE, Obst FLIESSBACH, Maj in G KUBAN, and the AHA Ib, who had turned against OLBRICHT. Other conspirators personally known to PW were Obslt i G BERNARDIS, Maj i G HAYESSEN, Obslt VON DER LANCKEN (hanged), Obslt d Res GRAF VON DER SCHULENBURG, Hptm d Res KAISER, Maj THOMA, Gen VON HASE (hanged), Obst i G VON FREYTAG LOHRINGHOVEN (formerly Ic with Army Group Süd, now Amt Ausland Abwehr), Dr KIEP (former Consul General in NEW YORK, executed after he was denounced by a BERLIN physician, Dr RECKZE), and Ambassador VON HASSEL.

PW saw Dr GÖRDELER, Gen STIEFF, Obslt i G KLAMROTH, Maj i G KUHN, and Gen d Art LINDEMANN visit Gen OLBRICHT's office. Others who were involved, but not known to PW psersonally, were obst i G FREIHERR VON RÖNNE (OKH, Fremde Heere West), Gen VON STÜLPNAGEL, GRAF DOHNA, GRAF LEHNDORF, Obst i G SANDROSZINSKI (Ia, Befehlshaber des Ers Heeres), Gen VON PFUHLSTEIN (Div Brandenburg), Gen CRAMER (PW, exchanged from ENGLAND, May/June 44), Ambassador GRAF VON DER SCHULENBURG, Hptm d Res SCHOLZ-BABISCH (Generalkommando BRESLAU), GRAF LYNAR (Adjutant to WITZLEBEN), GRAF HARDENBERG (Adjutant to BOCK), Obst i G MEICHNER (Wehrmachts Führungsstab, executed. His father, Konsistorialrat in WITTENBERG, was under arrest as of Nov.), Gen Obst ZEITZLER's adjutant, and the Ia of the Kommandantur, BERLIN.

The fate of Gen Obst FROMM was not clear. Although he shot Gen Obst BECK personally in an opportune, last minute change of heart, he was still under arrest late in Nov 44.

PW visited the AHA on 22 July and saw 2 SS guards with MPs in front of every door. Patrols of the BERLIN guard Bn roamed the corridors. The offices of the executed officers were searched. The atmosphere was strained.

The hanging of Feld Marschall VON WITZLEBEN, Gen Obst HÖPNER, Gen VON HASE etc in PLÖTZENSEE prison was filmed by the UFA on HITLER's orders.

OLBRICHT was succeeded by Gen d Art MAINER.

(Source: Hptm Hans G von WATZDORF, 1 Bn 60 Pz Gren Regt, captured 13 Jan, vic BERISMENIL)

11. Experimental Aircraft

PW heard in 1942 when he was working as a camera man at the aircraft testing field RECHLIN (Mecklenburg) that a new type plane was being designed which could retract its wings during flight and therby increase its speed considerably.

PW saw the plane in flight in Feb 44 and describes it as a two (4) motor transport plane, similar to the US C47. PW heard from mechanics that the plane was designed to fly bombing missions to the US, it can carry a load of 3,000 to 4,000 kg. The speed is supposed to be 700 to 800 km per hr. The two propellers are connected to two in-line 16 cylinder engines each.

According to PW the experimental flights were very successful but the plane is not being mass-produced as yet.

(Source: S/Gefr Gerd JARNOWSKI, Pz Lehr Div, captured 14 Jan VILLY)

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Figure E.7: PW Intelligence Bulletin No 1/34, 5 February 1945 [AFHRA folder 506.61951 Nos. 1/19–1/35 26 Dec 1944–7 Feb 1945, IRIS 207524; AFHRA A5185 frame 481; also NARA RG 165, Entry NM84-79, Box 1915].

Testimony of Henry H. Fowler, Director, Enemy Branch, Foreign Economic Administration. *Elimination of German Resources for War. Hearings Before a Subcommittee of the Committee on Military Affairs, United States Senate, Seventy-Ninth Congress, First Session, Pursuant to S. Res. 107 (78th Congress) and S. Res. 46 (79th Congress) Authorizing a Study of War Mobilization Problems. Part 3: Testimony of Foreign Economic Administration and Materials on German Penetration of European Industry.* Washington, DC: U.S. Government Printing Office. 26 June 1945.) p. 162. [**https://www.economicsvoodoo.com/wp-content/uploads/Elimination-of-German-Resources-for-War-Hearing-1945-Part-3-German-Infiltration-of-European-Industry-mas-0015.pdf**]

In assessing these bare bones of Germany's industrial war potential certain other less tangible, but none the less important, aspects of her economic base for aggression should be appraised. These include her amazing technical ability to produce new weapons as a result of technological invention, her vast pool of skilled workmen and highly trained scientists, the existence abroad of extensive economic assets and activities, and finally, a highly integrated organization and control of her economy. Each of these aspects of Germany's base for aggression deserves a brief reappraisal as of today.

Ability to produce new weapons and products.—According to recent reports from Germany, it appears that if the Germans could have held out only 6 months longer they would have been able to smash New York City with improved V-2 bombs.

Only a little longer period would have been needed to bring into production the jet-propelled planes that could have reached Washington.

It is not necessary here to elaborate upon the terrifying scientific discoveries which our economic and industrial intelligence is gradually uncovering as we work beneath the lid in Germany. With the memories of her new V-weapons fresh in our minds, little needs to be added except to point out that they just didn't appear out of thin air. They were the fruit of carefully organized and adequately financed research institutions in which large numbers of highly trained and specialized scientists went about their business of inventing and developing the weapons that would establish German world supremacy. The results they achieved and would still achieve if opportunities are provided, spring from the existence of a laboratory here and pilot plant there and a research institution in another place. These institutions and these scientists are still on hand ready to do business for a new Germany when the break comes. Nor will their ideas and inventions be fruitless because of a lack of German capacity to translate them into mass production.

Germany could rapidly set up plants for such new products because of its enormous capacity to produce machines and machine tools, and the huge supplies of machine tools that were built up in advance of need. The plants the victors so innocently permitted to operate after the last war to turn out agricultural, construction, and textile machinery for the devastated regions of Europe were expanded and re-equipped to supply German factories to meet the needs of the war of 1939—already being planned when the armistice of 1918 was signed.

German economic assets and activities outside Germany.—One of the most important bases for German aggression consists of the properties owned or controlled by Germans, which are located outside the physical borders of the country. Coupled with these properties and based upon them, there are a wide variety of economic activities which act as transmission lines for the achievement of German economic and political objectives.

Consolidated Vultee Aircraft Corporation (Convair). 1945. ...By the Skin of Our Teeth. *Life* (27 August) 19:9:2–3.
https://books.google.com/books?id=e0gEAAAAMBAJ&pg=PA2

...by the Skin of our Teeth

Several times during the European phase of this war, victory was almost within Germany's grasp... on land, on the sea, or in the air.

Above all, knowing the vital importance of air supremacy, the Nazis tried time and again to wrest it back from the Allies.

And they almost succeeded.

Time ran out

Especially in the last months of the war, our margin of safety was slimmer than most of us suspected.

Just how slim it was is known best to certain American military experts who have since inspected some of Germany's underground research laboratories and war plants.

Here they saw secret weapons in various stages of development... weapons which might conceivably have turned the trick for the Nazis if they could have used them boldly in a last desperate gamble.

Some of these things can now be revealed. Others cannot—yet.

In one plant, the U.S. Army officers found partially assembled jet fighter planes of radical new design. There were planes potentially better than anything the Allies had in combat at that time.

If time hadn't run out on the Germans, quantities of these jet planes might have changed the balance of air power in their favor.

In a V rocket plant, burrowed 800 feet deep in limestone rock, our technicians found blueprints for a fearful V bomb with an estimated range of 3000 miles.

"We planned to destroy New York and other American cities starting in November," said a German rocket engineer.

Target: U.S.A.

In a converted salt mine, our ordnance officers examined nearly complete jet-propelled heavy bombers... bombers claimed by the Germans to be capable of crashing high explosives into the industrial cities of the eastern United States and flying back again across the Atlantic.

Goering himself said that the planes had been successfully test-flown and would have been in operation if Germany could have held out 3 months longer.

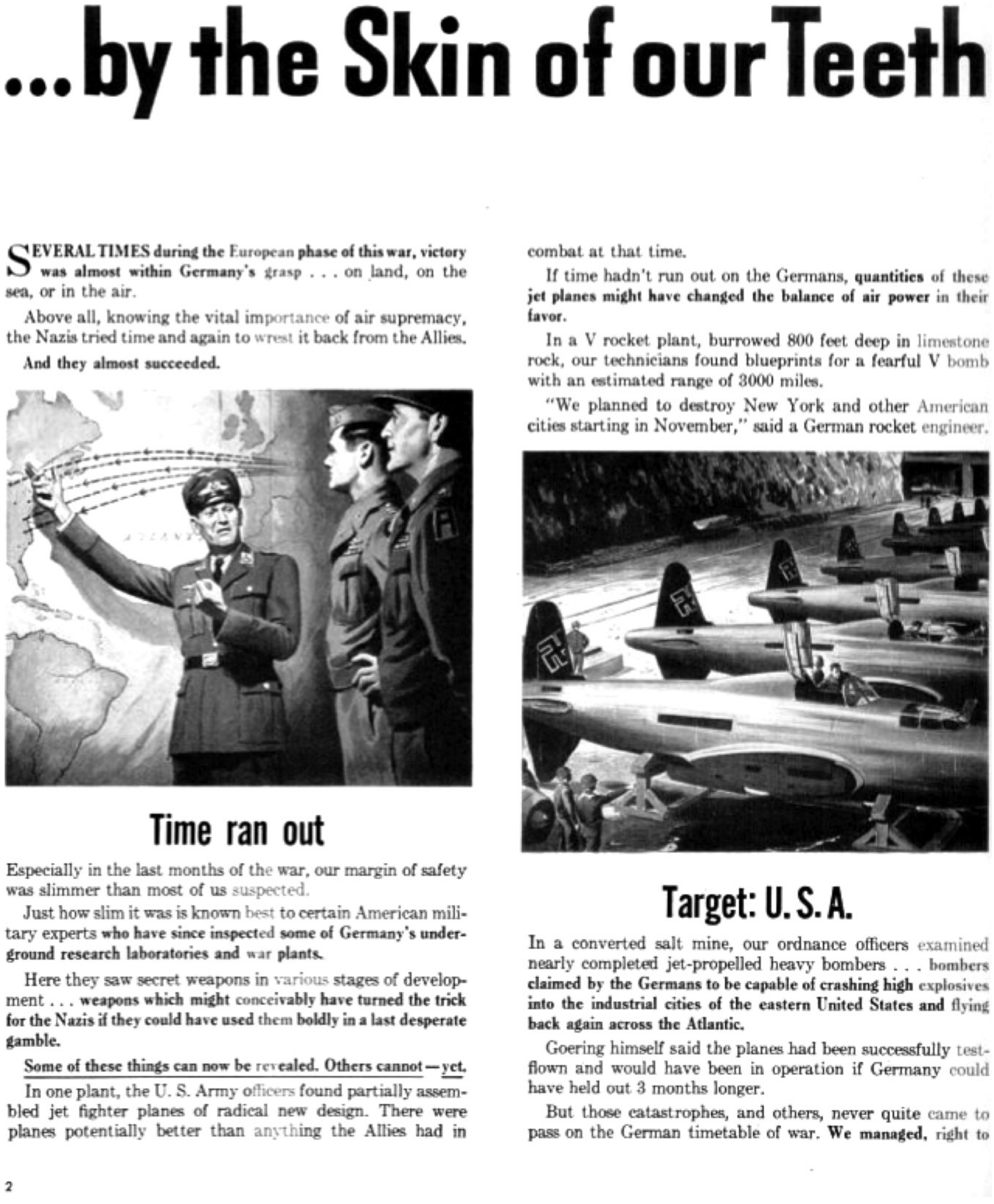
But those catastrophes, and others, never quite came to pass on the German timetable of war. We managed, right to the end, to maintain the air supremacy we had achieved... sometimes *just by the skin of our teeth.* [...]

[This two-page spread from *Life* is reproduced in full on pp. 5210–5211.

Although it was published on 27 August 1945, it was written before the 6 August 1945 bombing of Hiroshima, since it said the war with Japan was still a very serious concern. It references the end of the war in Europe and makes extensive use of postwar Allied discoveries in Europe, several of which are mentioned here but were never publicly disclosed in any other documents. Therefore the spread appears to have been written and finalized between May and July 1945.

The "nearly complete jet-propelled heavy bombers" for intercontinental missions found in the salt mine have never been publicly revealed, and appear to be distinct from the 40 intercontinental jet bombers discovered in Norway. Can documentation on this discovery be found and released? According to information given here, these long-range jet bombers had been successfully test-flown and mass produced, and would have been deployed to bomb American cities no later than the beginning of August 1945. For all of the time and money that Germany must have spent to develop such bombers, and for the long distance they would have had to travel, would their cargo really have been only conventional "high explosives," or would it have actually been atomic bombs? Note that U.S. government censorship would not have allowed any publications to write about atomic bombs prior to the public announcement of the Hiroshima bombing (and this spread was written before that time).

A German rocket engineer was specifically quoted as saying, "We planned to destroy New York and other American cities starting in November." He was not only talking about New York, but many American cities, which would have required a number of intercontinental rockets. Furthermore, he said that those cities would be "destroyed," which would have required atomic bombs and not merely one-ton conventional explosive warheads such as the V-2 rockets delivered to London. Thus this engineer who was apparently deeply involved with and knowledgeable about the German programs indicated that mass-production of both numerous intercontinental rockets and numerous atomic bombs apparently would have been completed before November 1945. That would have required mass production of both to begin well before that time, and prototype intercontinental rockets and atomic bombs to have been completed and tested even before that. From that timeline, the intercontinental rocket and atomic bomb programs must have been extremely advanced by the end of the war—they would have been far beyond the stage of just "blueprints for a fearful V bomb."]



...by the Skin of our Teeth

SEVERAL TIMES **during the European phase of this war, victory was almost within Germany's grasp** . . . on land, on the sea, or in the air.

Above all, knowing the vital importance of air supremacy, the Nazis tried time and again to wrest it back from the Allies.

And they almost succeeded.

Time ran out

Especially in the last months of the war, our margin of safety was slimmer than most of us suspected.

Just how slim it was is known best to certain American military experts **who have since inspected some of Germany's underground research laboratories and war plants.**

Here they saw secret weapons in various stages of development . . . **weapons which might conceivably have turned the trick for the Nazis if they could have used them boldly in a last desperate gamble.**

Some of these things can now be revealed. Others cannot—yet.

In one plant, the U. S. Army officers found partially assembled jet fighter planes of radical new design. There were planes potentially better than anything the Allies had in combat at that time.

If time hadn't run out on the Germans, **quantities of these jet planes might have changed the balance of air power in their favor.**

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Target: U. S. A.

In a converted salt mine, our ordnance officers examined nearly completed jet-propelled heavy bombers . . . **bombers claimed by the Germans to be capable of crashing high explosives into the industrial cities of the eastern United States and flying back again across the Atlantic.**

Goering himself said the planes had been successfully test-flown and would have been in operation if Germany could have held out 3 months longer.

But those catastrophes, and others, never quite came to pass on the German timetable of war. **We managed,** right to

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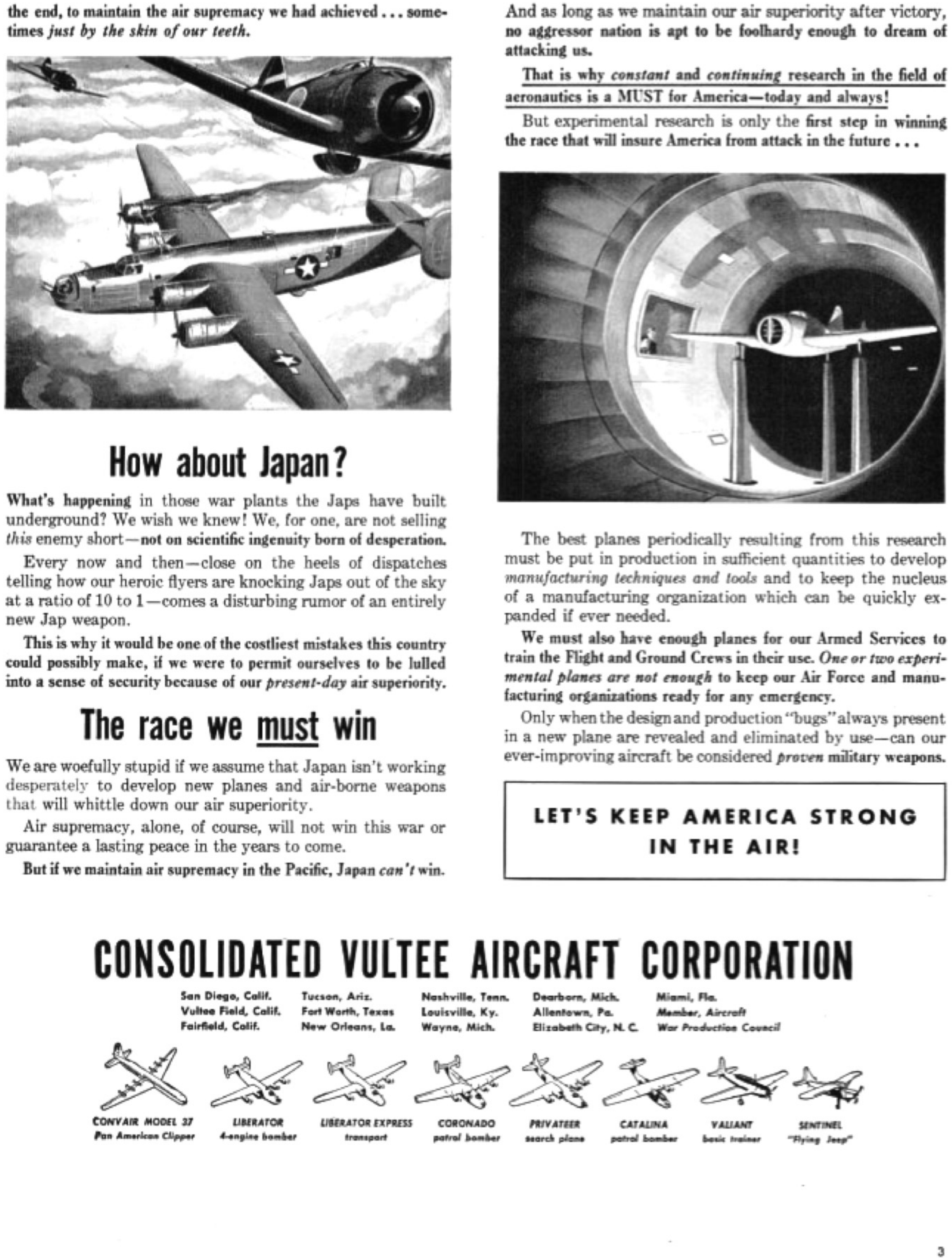
Figure E.8: Two-page spread from *Life*, 27 August 1945.



the end, to maintain the air supremacy we had achieved . . . sometimes *just by the skin of our teeth.*

How about Japan?

What's happening in those war plants the Japs have built underground? We wish we knew! We, for one, are not selling *this* enemy short—**not on scientific ingenuity born of desperation.**

Every now and then—close on the heels of dispatches telling how our heroic flyers are knocking Japs out of the sky at a ratio of 10 to 1—comes a disturbing rumor of an entirely new Jap weapon.

This is why it would be one of the costliest mistakes this country could possibly make, if we were to permit ourselves to be lulled into a sense of security because of our *present-day* air superiority.

The race we must win

We are woefully stupid if we assume that Japan isn't working desperately to develop new planes and air-borne weapons that will whittle down our air superiority.

Air supremacy, alone, of course, will not win this war or guarantee a lasting peace in the years to come.

But if we maintain air supremacy in the Pacific, Japan *can't* win.

And as long as we maintain our air superiority after victory, **no aggressor nation is apt to be foolhardy enough to dream of attacking us.**

That is why *constant* and *continuing* research in the field of aeronautics is a MUST for America—today and always!

But experimental research is only the **first step in winning the race that will insure America from attack in the future . . .**

The best planes periodically resulting from this research must be put in production in sufficient quantities to develop *manufacturing techniques and tools* and to keep the nucleus of a manufacturing organization which can be quickly expanded if ever needed.

We must also have enough planes for our Armed Services to train the Flight and Ground Crews in their use. *One or two experimental planes are not enough* to keep our Air Force and manufacturing organizations ready for any emergency.

Only when the design and production "bugs" always present in a new plane are revealed and eliminated by use—can our ever-improving aircraft be considered ***proven* military weapons.**

LET'S KEEP AMERICA STRONG IN THE AIR!

CONSOLIDATED VULTEE AIRCRAFT CORPORATION

San Diego, Calif.
Vultee Field, Calif.
Fairfield, Calif.
Tucson, Ariz.
Fort Worth, Texas
New Orleans, La.
Nashville, Tenn.
Louisville, Ky.
Wayne, Mich.
Dearborn, Mich.
Allentown, Pa.
Elizabeth City, N. C.
Miami, Fla.
Member, Aircraft War Production Council

CONVAIR MODEL 37
Pan American Clipper

LIBERATOR
4-engine bomber

LIBERATOR EXPRESS
transport

CORONADO
patrol bomber

PRIVATEER
search plane

CATALINA
patrol bomber

VALIANT
basic trainer

SENTINEL
"Flying Jeep"

3

Figure E.9: Two-page spread from *Life*, 27 August 1945.

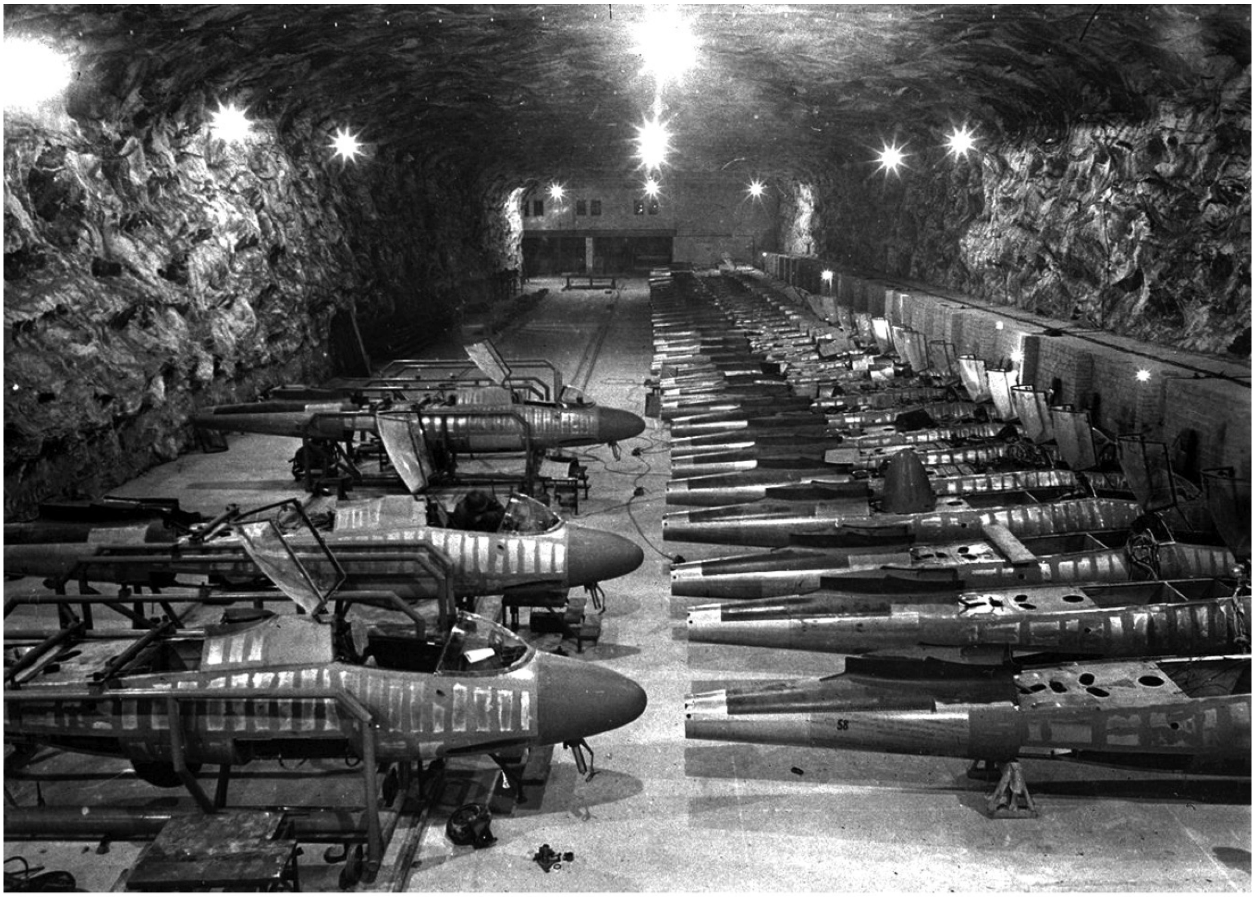


Figure E.10: Example of an underground factory for Heinkel jets (in this case, He 162 fighters at the Salzberwerk in Tarthun) discovered and photographed by the U.S. Army on 15 April 1945.

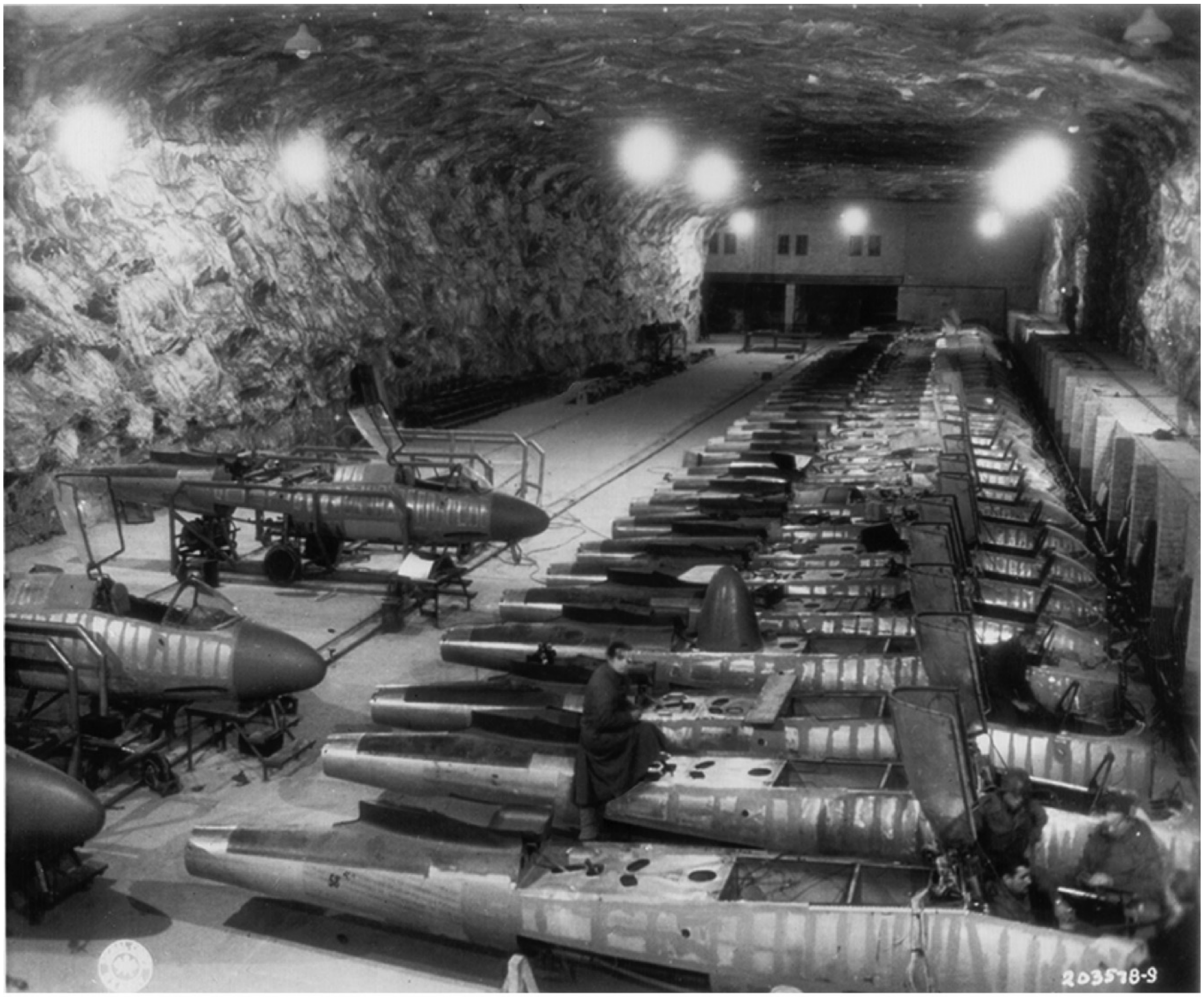


Figure E.11: Another photo of the underground factory for Heinkel jets (He 162 fighters at the Salzberwerk in Tarthun) discovered and photographed by the U.S. Army on 15 April 1945.

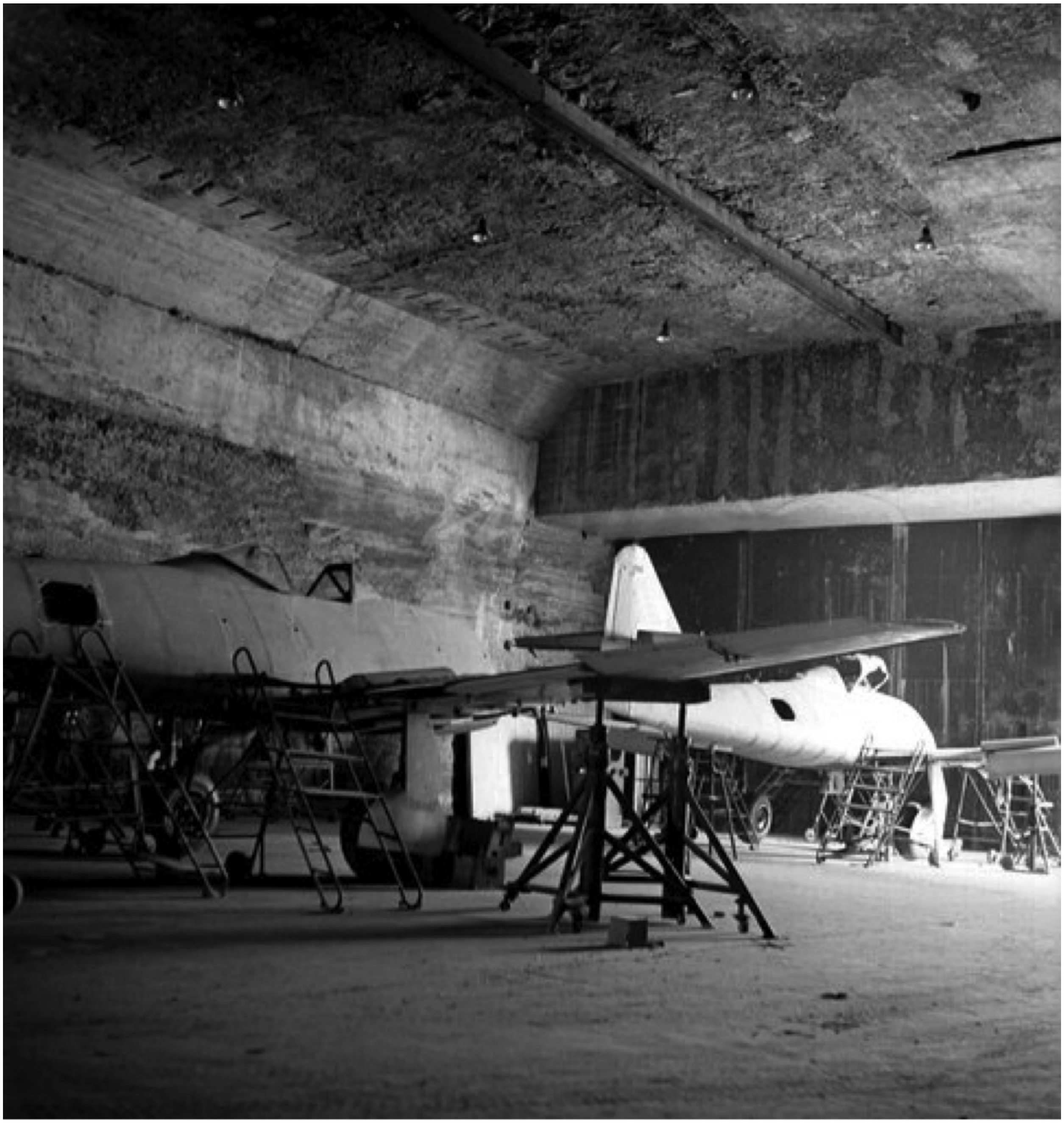


Figure E.12: 1945 photo of the huge underground factory for Me 262 jet fighters at Kahla. This factory was approximately 15 km from the reported location of an underground factory that was said to have been producing “V-4 two-man rockets” near the end of the war (pp. 5365–5373). There were also other large underground factories for Me 262 fighters throughout Reich territory, such as St. Georgen/Gusen in Austria (pp. 4967–4969).

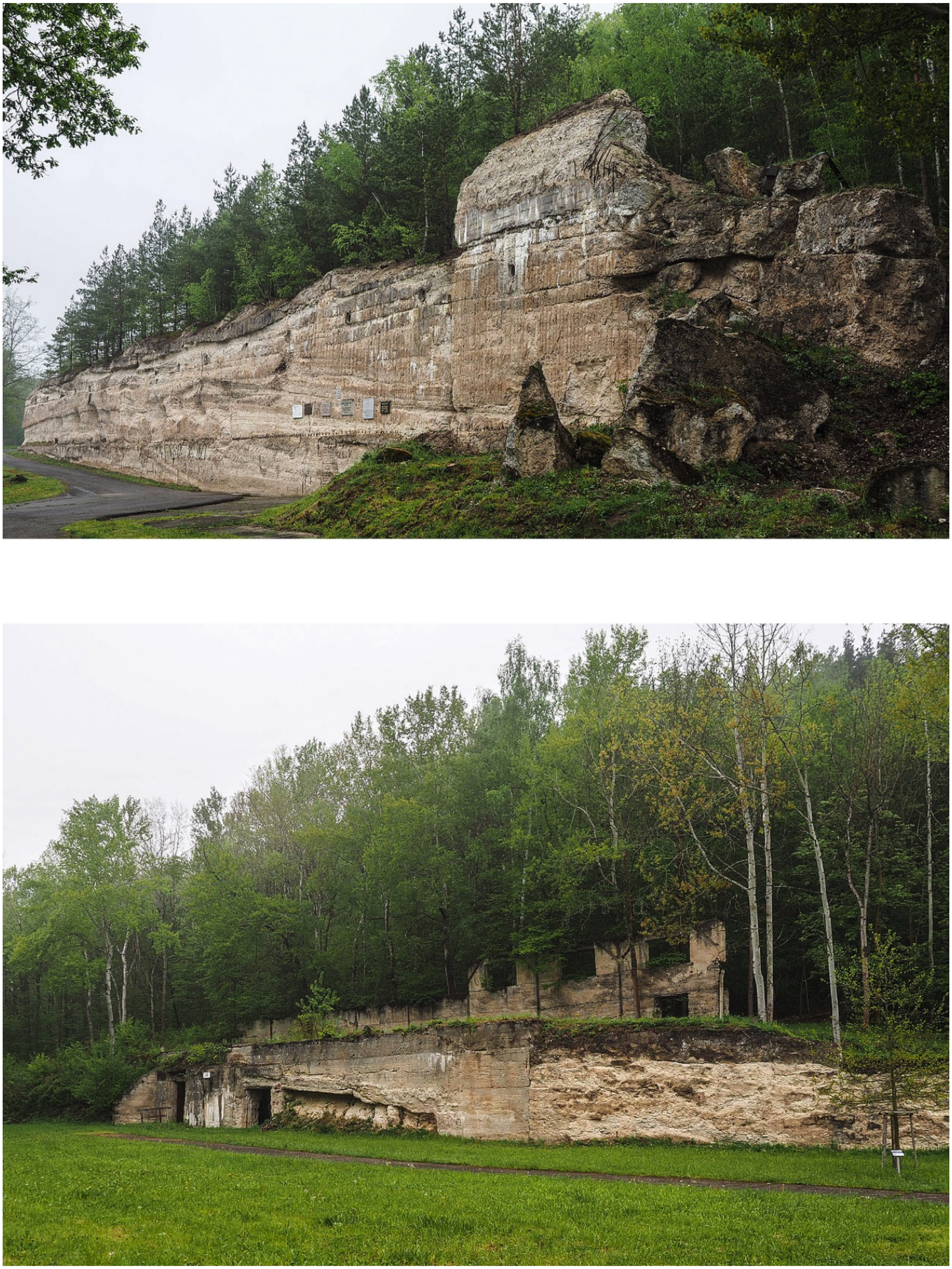


Figure E.13: Remains of the huge underground factory for Me 262 jet fighters at Kahla.

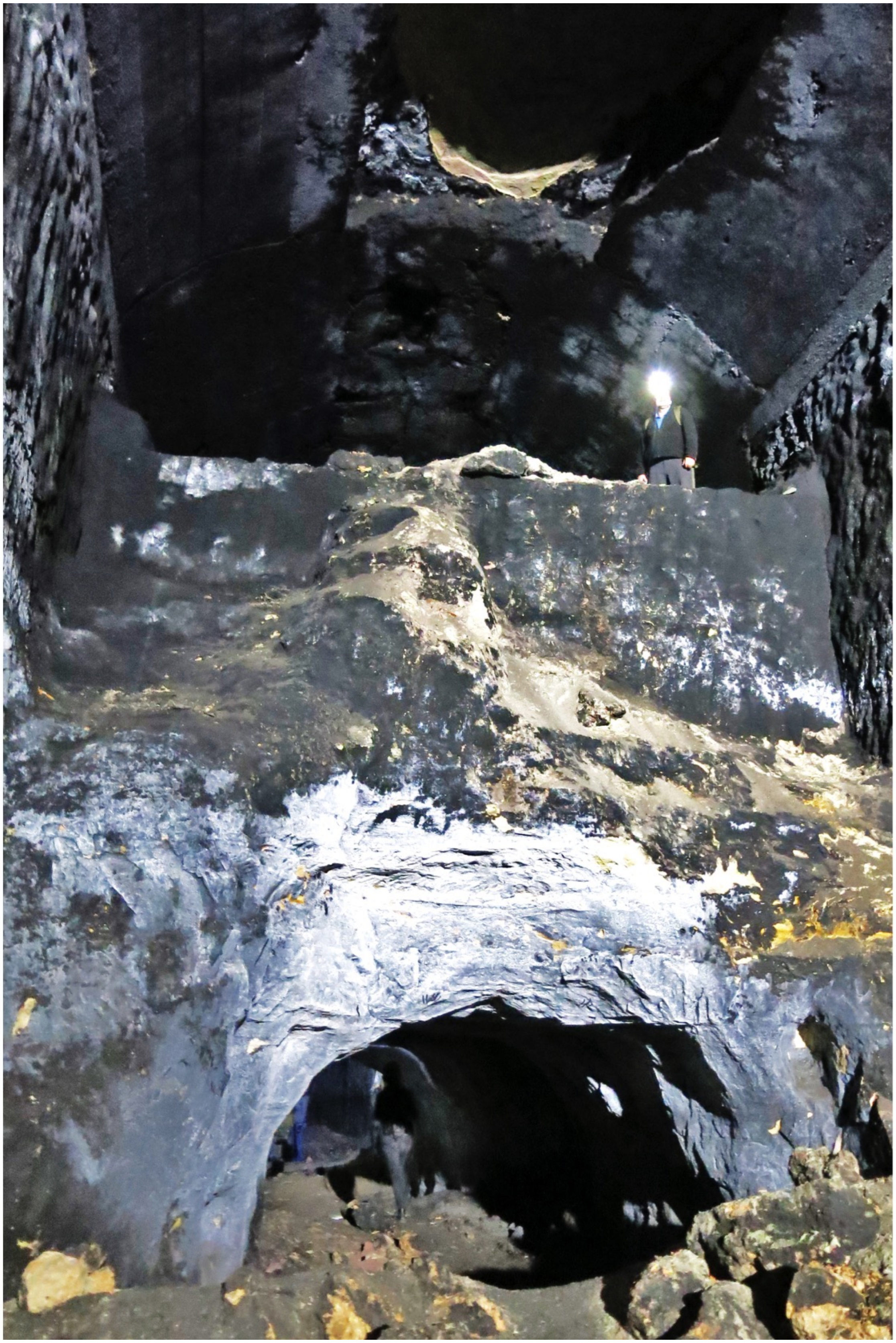


Figure E.14: Remains of the huge underground factory for Me 262 jet fighters at Kahla [photo courtesy of Frank Döbert].

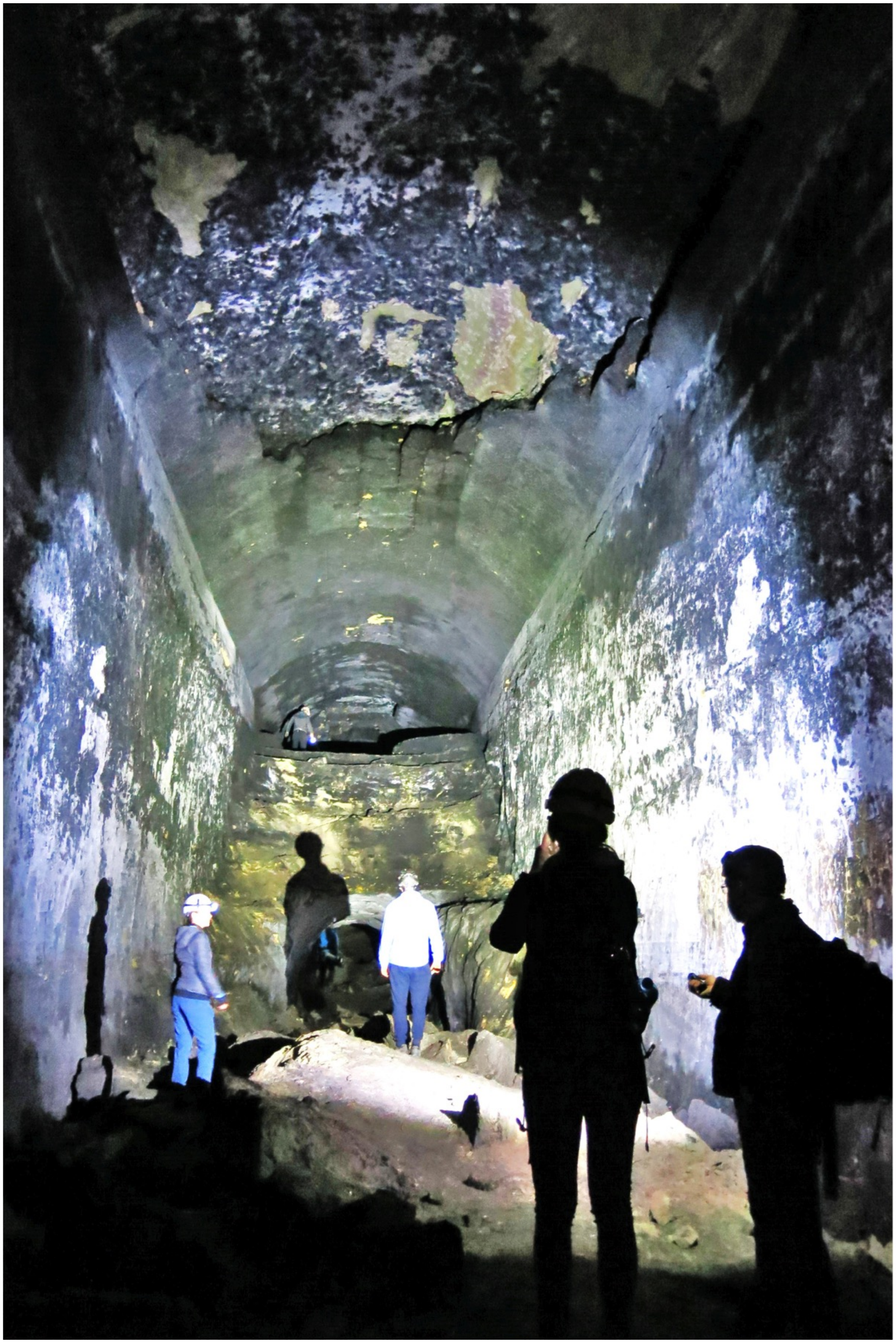


Figure E.15: Remains of the huge underground factory for Me 262 jet fighters at Kahla [photo courtesy of Frank Döbert].

Albert Ducrocq. 1947. *Les Armes Secrètes Allemandes.* Paris: Berger-Levrault. pp. 163–164.

Les bombardiers lourds intercontinentaux Heinkel

C'est vraisemblablement à partir du mois de juin 1945 que l'Allemagne pensait attaquer le territoire américain. Notons-le: alors que la mise en action d'autres armes secrètes, comme les bombes volantes et les nouveaux avions-fusées, était littéralement imminente, cette menace contre les États-Unis doit être située à six semaines ou deux mois après la date qui marqua l'effondrement du Reich. On nous permettra de la trouver pratiquement tout aussi dangereuse, d'autant plus que les V-2 amphibies, elles aussi, auraient très bien pu transporter des bombes atomiques.

Mais les Allemands préparaient, en plus, des raids de bombardement sur l'Amérique à partir de leurs bases européennes. Ils avaient, en effet, mis en construction sur une assez vaste échelle des bombardiers géants de type Heinkel, capables de couvrir sans escale de 11.000 à 12.000 kilomètres, c'est-à-dire largement un aller et retour Europe-Amérique!

La Norvège avait été choisie comme point de concentration de ces bombardiers intercontinentaux. Les Allemands avaient aménagé près d'Oslo le plus grand aérodrome de toute la Luftwaffe. Et il n'est pas sans intérêt de noter que, le 27 avril 1945—trois jours avant la fin de la bataille de Berlin et la disparition d'Hitler—400 [sic: 40] de ces bombardiers étaient bel et bien rassemblés sur l'aérodrome en question, prêts à prendre leur envol vers l'Amérique. C'est le 21e Groupe d'armées américain [sic: U.K.] qui devait les découvrir deux semaines plus tard...

Heinkel intercontinental heavy bombers

Germany was probably thinking of attacking American territory beginning in June 1945. It should be noted that while the use of other secret weapons, such as flying bombs and new rocket planes, was literally imminent, this threat to the United States must be located six weeks or two months after the date of the collapse of the Reich. We are allowed to consider it almost as dangerous, especially since the amphibious V-2s, too, could very well have carried atomic bombs.

But the Germans were also planning bombing raids on America from their European bases. They had, in fact, built giant Heinkel-type bombers on a fairly large scale, capable of covering non-stop 11,000 to 12,000 kilometers, i.e. a round trip from Europe to America!

Norway had been chosen as a concentration point for these intercontinental bombers. The Germans had set up near Oslo the largest airfield of the Luftwaffe. And it is not without interest to note that, on April 27, 1945—three days before the end of the battle of Berlin and the demise of Hitler—400 [sic: 40] of these bombers were indeed gathered on the airfield in question, ready to take off for America. It was the 21st American [sic: actually British] Army Group that was to discover them two weeks later...

[Albert Ducrocq (1921–2001) was a French scientist and science writer who was involved in the French investigations of German science and German scientists near the end of the war and after the war. He would have had considerable first-hand knowledge about German scientific plans and capabilities, although some of his knowledge would have been second- or third-hand. His story of the Heinkel intercontinental bombers agreed with the 29/30 June 1945 articles in English-speaking newspapers, but he also included several details that were not in those stories. It is not clear where Ducrocq got those details.

Note that Ducrocq suggested that Germany possessed atomic bombs and planned to deliver them via the Heinkel bombers or other means. Note too that he mentioned “amphibious V-2s,” submarine-launched missiles that also would have been nuclear armed; see Section E.4.

For more information from Ducrocq, see pp. 5380, 5658–5659, 5666.

For independent confirmation of German plans for a nearly simultaneous nuclear attack on multiple Allied targets, see pp. 4549–4550, 4587, 4621, 4627–4665, 4679–4681, 4766, 5038, 5454–5466.]

Rudolf Lusar. 1956. *Die deutschen Waffen und Geheimwaffen des 2. Weltkrieges und ihre Weiterentwicklung.* 1st ed., Munich: J. F. Lehmanns. p. 49

Kurz vor dem Kriegsende kam Professor Heinkel noch mit einem schweren Vierstrahltriebwerk-Bomber heraus, anscheinend He-343 (?), der eine Reichweite von 11000 bis 12000 km haben sollte. Dieses Bombenflugzeug war bestimmt Amerika anzugreifen. Nach amerikanischen Berichten waren am 27. April 1945 mehrere dieser Maschinen auf einem Flugplatz bei Oslo, Norwegen, versammelt, wo sie der amerikanischen 21. Armee in die Hände gefallen sein sollen. Sie sollten im Mai den ersten Einsatz gegen New York fliegen.	Just before the end of the war, Professor Heinkel came out with a heavy four-jet engine bomber, apparently He-343 (?), which was supposed to have a range of 11,000 to 12,000 km. This bomber was destined to attack America. According to American reports, on April 27, 1945, a number of these machines were massed at an airfield near Oslo, Norway, where they were to fall into the hands of the American [sic: actually British] 21st Army. They were supposed to be flying to New York in May.

[The details provided by Lusar were very similar to those provided by Ducrocq. Did Lusar obtain his information from Ducrocq, or did Lusar and Ducrocq have other sources that provided the same information? Lusar was apparently speculating about the exact identity of the Heinkel intercontinental bomber.]

Ernst Heinkel [Heinkel 1956, pp. 236–241, 246–247; see also Myhra 1998a, pp. 156–160]

On this occasion [early 1942] I was so upset that I declared, “At the present stage of jet units I am convinced we can produce jet bombers as well as very fast fighters in an extremely short time. I cannot see why we should delay for a moment. The Ministry must form a commission to eliminate all difficulties. It’s a matter of indifference whether Junkers or BMW units [jet engines] or any other units are used. The plane can, in any case, be built by the middle of next year.”

The conference ended without result. Neither Milch nor his colleagues would decide upon the building of jets. [...]

No one will take exception to my having had my doubts about the technical soundness of the reasons for scrapping my He 280...

After the rejection of the He 280 I remained excluded until the summer of 1944 from the development of jet airplanes, which Sauer now carried on with great vigor. This development, however, remained limited chiefly to the Me 262 and the outstanding Arado reconnaissance plane Ar 234. Much time had been lost and the general situation was now so precarious that up to October, 1944, only from one to three Me 262’s appeared each month. Then for the first time Sauer’s ruthlessness and powers of organization and improvisation made themselves felt, and by the end of the war about 1,600 Me 262’s were built, under the indescribable conditions that prevailed during those last six months.

They were produced in countless factories and small workshops, both above and below ground. Because of the disorganized railroad system, road convoys had to bring the individual parts to the assembly sheds. Smaller parts were brought by courier in haversacks. It is understandable that only a few hundred of these planes actually reached the last front-line units which still remained in South Germany and were largely destroyed from the air simply because it was no longer possible to supply them with some last piece of equipment, such as a cabin canopy. German industry could not bring the two-engined Me 262 into mass production, in spite of all improvisations and efforts. Destruction by enemy bombing, shifting of plants, the flight from occupied territory and constant communications breakdowns made it impossible. [...]

When I, too, received orders at Vienna to build a light single-engined jet fighter, I realized that this was a last attempt to struggle against the inevitable. Yet the fact that I had been shut out from the revolutionary development of jet aircraft, even though I had been the first to take it up, had left such scars in me that I was eager to prove my supremacy in the field once more.

[...] Now we started to work on the last jet fighter of the German Luftwaffe in World War II. It was the He 162, misnamed “people’s fighter.”

Construction began on September 24, 1944, in Vienna. [...]

All arrangements had been made when the heavy Allied attacks on German communications started in the spring of 1945. A few weeks later, despite our efforts, there was no further possibility of achieving a regular output. On April 1, 1945, we had to close all our factories in Vienna in the face of the advancing Russian armies.

Thus ended the last great effort in the field of jet-plane building, without a single plane ever getting to the front. Most of the completed planes were destroyed in the factories or in Oranienburg, where the Lufthansa had tried to open a test-flight center, or they fell into the hands of the British, American or Russian engineers advancing with their victorious armies through Germany. [...]

After returning home on August 5, 1945, I wanted to see the situation in Jenbach with my own eyes. [...]

Stopping at Landsberg, I searched for Siegfried Günter, who had escaped there in the middle of April, 1945, and had managed to carry on a primitive office with thirty-five other employees from my design office. I found him—the most important expert on airplane structures and aerodynamics that Europe had at that time—living with his wife in a small room. He was working with ten of my people in a technical office that an American, Major Cardenas, had established on the airfield. They had tried in vain to call the attention of the American military authorities to the importance of Günter.

Günter was too modest and shy to blow his own horn. Now he was happy that Cardenas had enabled him to carry on his scientific work. This work embraced everything we had planned for the future in the way of fresh developments in jet propulsion. He was particularly engrossed with new "flying wing" types. I hoped on this visit that Günter would find a permanent outlet for his activities, either in Landsberg or in America.

I knew him. His only happiness was in scientific work and I told this to Cardenas. A few weeks later, however, at the end of September, Cardenas closed his office and flew to England. He informed Günter that a larger office was planned in Wiesbaden and that he would send for him, but he never did.

Günter remained in Landsberg until the spring of 1946, when his money ran out. During the last weeks he constantly repeated that he had no skill for anything else—he had to build airplanes. If the West didn't want him, he might have to work for the East. At that moment, I was empty-handed and could do nothing for the man who for so many years had been my closest collaborator and whose unique abilities no one could appreciate better than myself.

In the spring of 1946 he used the last of his money to go to Berlin to see his father-in-law, who kept a garage. He still hoped the Americans would send for him, and left his address in case some message should arrive, but no message came.

Instead, the Soviet special experimental unit OKB IV, in Berlin, took him on. Günter continued to work on our latest designs and was then taken to Russia, where, I am convinced, he worked on constructions that today have become a problem for the Western world.

[Ernst Heinkel did not mention the 40 giant bombers in Norway, but due to Cold War censorship and Heinkel's motivation to avoid self-incrimination, one would not expect him to. However, he did mention that he had long been a strong proponent of jet bombers that he believed could be built quickly, that his company participated in a late-war push to build new jet aircraft that nearly came to fruition, that those aircraft were found by the Allies, that his top designer Siegried Günter had been engrossed with flying wing bomber designs, and that Günter had submitted his information on the flying wings to Major Robert L. Cardenas [see Johnsen 2014, pp. 119–120] by the end of September 1945.]

Bundesarchiv, Bild 183-1982-1022-509
Foto: o.Ang. | Juli 1941

Figure E.16: Siegfried Günter and Ernst Heinkel (1941).

Dieter Herwig and Heinz Rode. 2000. *Luftwaffe Secret Projects: Strategic Bombers 1935-1945.* 2nd ed. Hinckley, UK: Midland. p. 68:

Heinkel Projects for a Four-Jet Long-Range Bomber

According to a report which Dipl-Ing Siegfried Günter—who had been head of Heinkel's Project and Design Department in Vienna—was required to write for the US Technical Service on 1st October 1945, Heinkel engineers had been engaged on designs for four-jet long-range bombers right up until May 1945. These designs included not only aircraft of standard 'fuselage and tail' configuration, but also of flying-wing layout.

Work was concentrated particularly on one flying-wing bomber which was powered by four HeS 109-011 jet engines, each developing 1,300 kg (2,865 lb) static thrust, and which weighed 26 tons.

Another flying-wing bomber was to have been fitted with either four BMW 109-018s, each of 3,000 kg (6,612 lb) static thrust, or six Junkers Jumo 004 jet engines, each of 1,300 kg (2,865 lb) static thrust. This machine which possessed a very high wing loading, would have weighed 60 tons.

[...] Again according to Günter's report, the 60-ton flying-wing project was to have combined a 3,000 kg (6,612 lb) bomb load with a range of 28,000 km (17,388 miles).

[Can this 1 October 1945 report by Siegfried Günter be located? It appears to have been filed by Major Robert Cardenas when he left Germany.

Is this information directly related to the 40 Heinkel intercontinental bombers that were reported to have been found in Norway?

Oslo to New York is approximately 5930 km (3680 miles), or approximately 11,860 km (7360 miles) roundtrip. Oslo to Los Angeles is approximately 8570 km (5320 mi), or approximately 17,140 km (10,640 mi) roundtrip.

Are there UK or US aerial surveillance photos of the Oslo-area Luftwaffe airfields from 1944 or 1945?

Are some postwar Allied long-range jet bomber designs such as the British Valiant, Victor, and Vulcan series directly descended from these planned or completed German bombers?

Other German intercontinental jet bombers had been designed and may have been in various stages of development, testing, or production by the end of the war. [Herwig and Rode 2000; Miranda 2015; Masters 1982, especially pp. 79–80; Myhra 1998a, especially pp. 156–160; Griehl 2005, Vol. 2].]

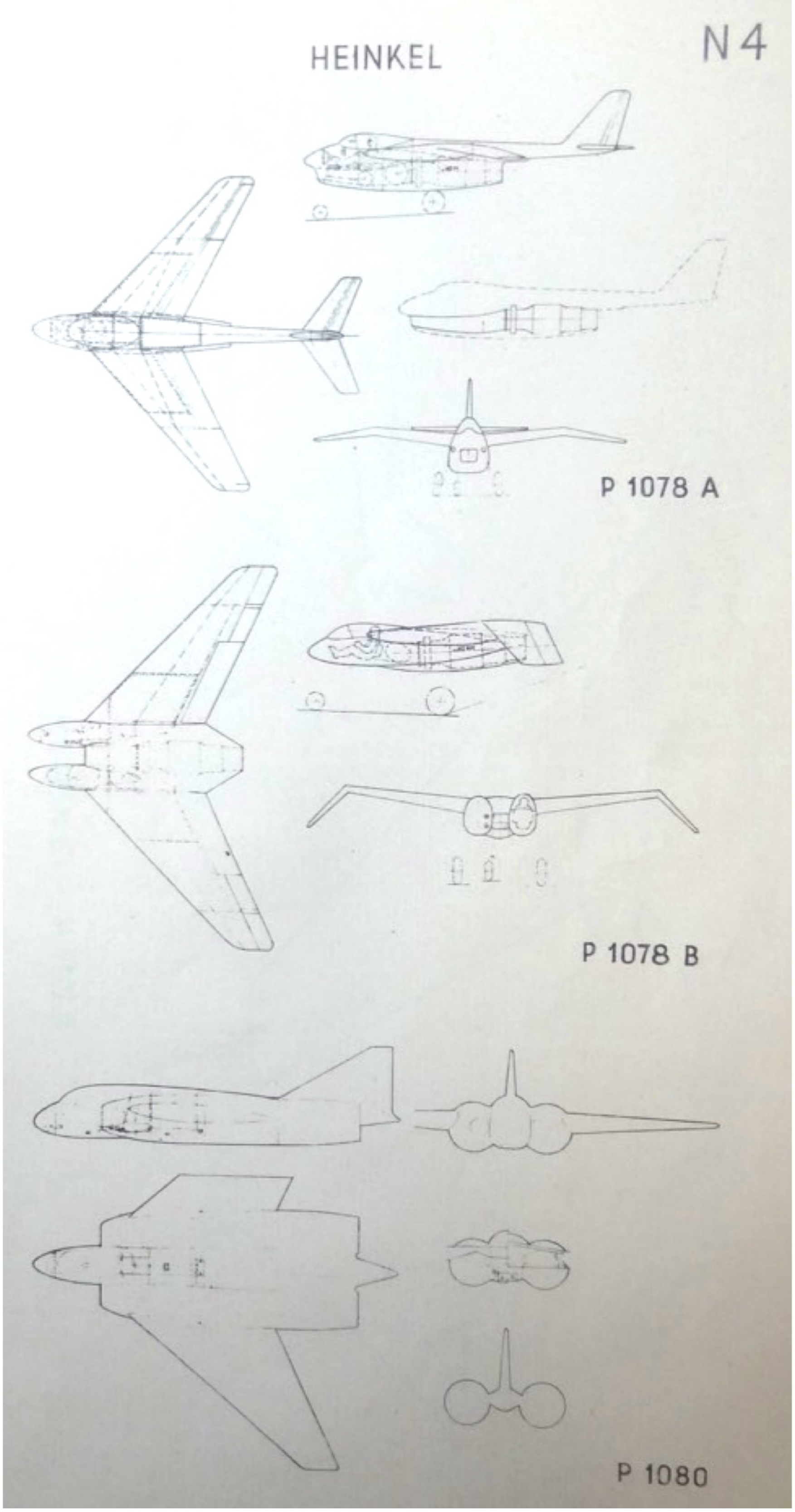
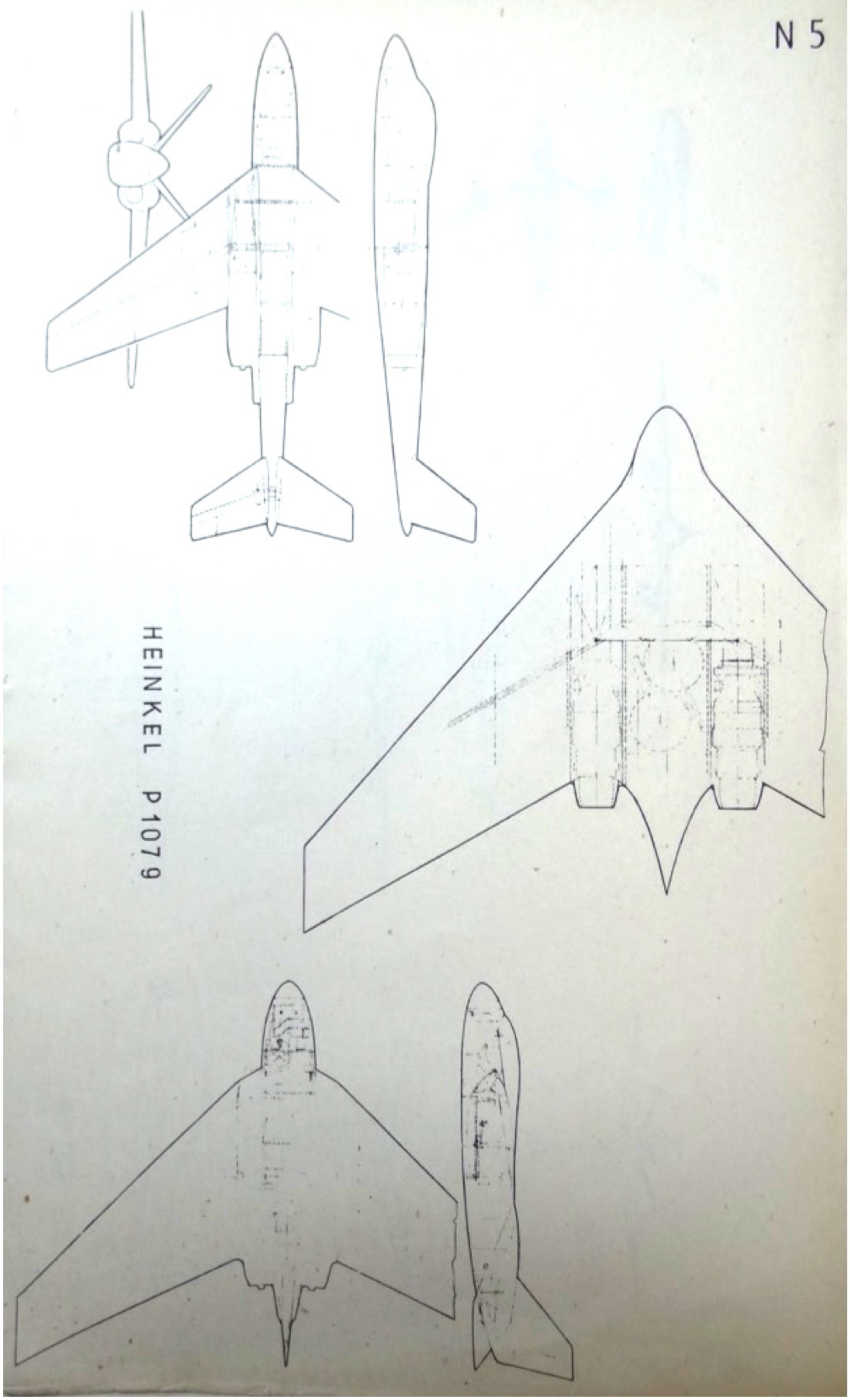

HEINKEL
N4
P 1078 A
P 1078 B
P 1080

Figure E.17: Wartime Heinkel jet bomber designs now in the U.K. Imperial War Museum, Duxford [Newton 1946].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HEINKEL P 1079

Figure E.18: Wartime Heinkel jet bomber designs now in the U.K. Imperial War Museum, Duxford [Newton 1946].

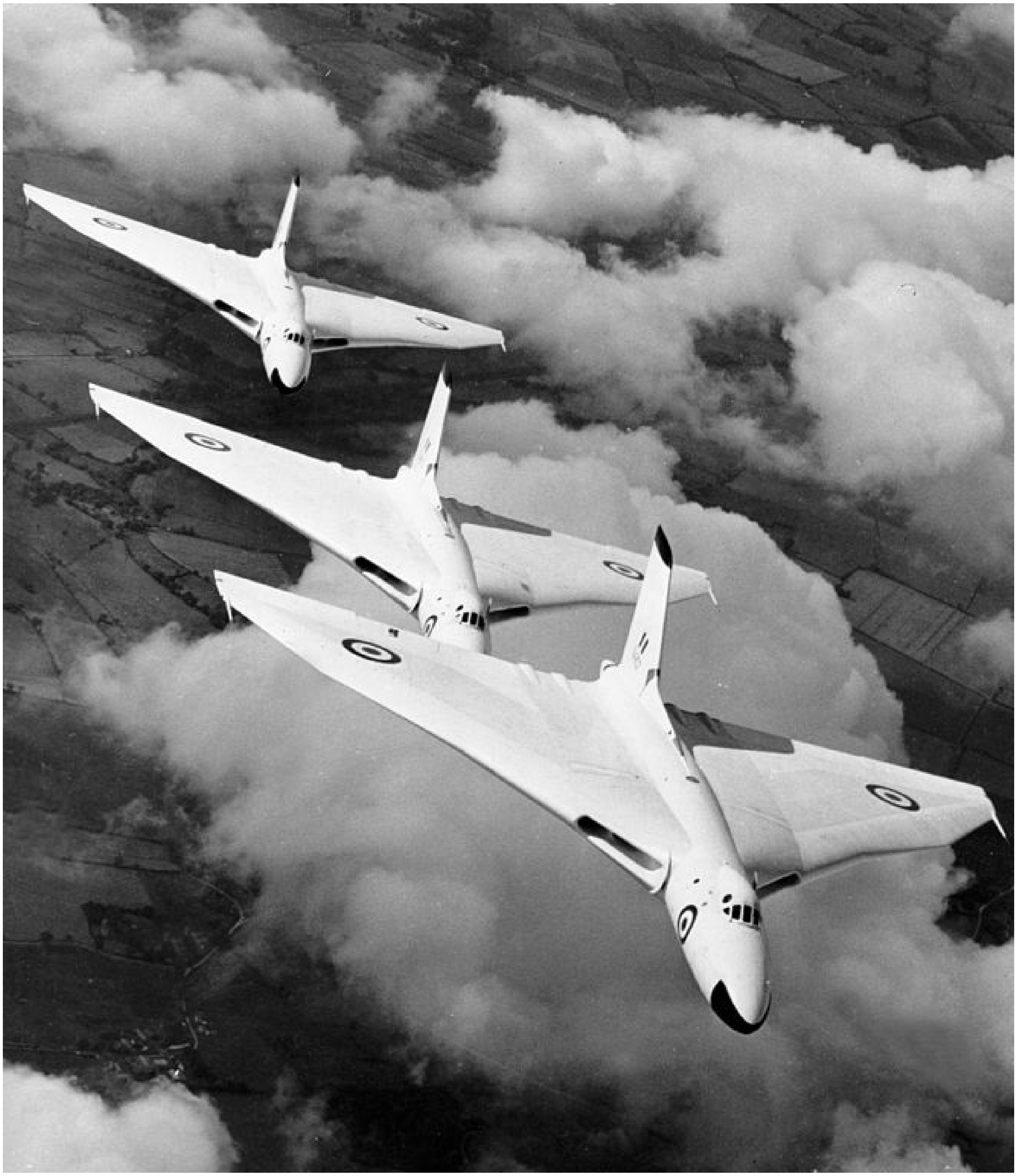


Figure E.19: British Vulcan bombers (1957).

FOIA: Operation Harass and the Horton [sic: Horten] Brothers. Control Number: FP-10-027542. Activity Number: FA-10-4911. Initial Reception Date: 7/13/2010. Requested by: Jacobsen, Annie. pp. 202–205 and 318–325.
http://documents.theblackvault.com/documents/ufos/ArmyUFOs.pdf
http://documents.theblackvault.com/documents/foia/4402F-12Greenewald_Redacted.pdf

[See pp. 5228–5231 for this document. It was released along with many other unrelated documents as part of a Freedom Of Information Act (FOIA) request.

This document was a proposal sent to the U.S. Army after World War II by a group of German aerospace engineers and pilots, including Albert Kalkert (German, 1902–1977, p. 1679) and Herbert Hintze (German, 1921–??). They offered to immediately begin building for the United States a Horten-style flying wing intercontinental bomber with 6 jet engines, various armaments, a 48-meter wingspan, an operating radius of 7,000 km (14,000 km total range round trip), and a speed of 900 km/hour ("900 Km/St." on the drawing, or 250 m/sec).

Since their offer was so specific and so immediate, was it based on an identical aircraft (or multiple aircraft) that they had already built during the war? For reports that such aircraft were actually constructed and even flown during the war, see for example p. 5202.

Note that the combined range and speed strongly suggest that the German engineers had a detailed and ready knowledge of (or access to) turbofan engines, not just the more common wartime German turbojet engines (p. 5779). In fact, a suitable turbofan engine that was specifically designed for a cruise velocity of 250 m/sec was first demonstrated in 1943–see pp. 5233–5241.]

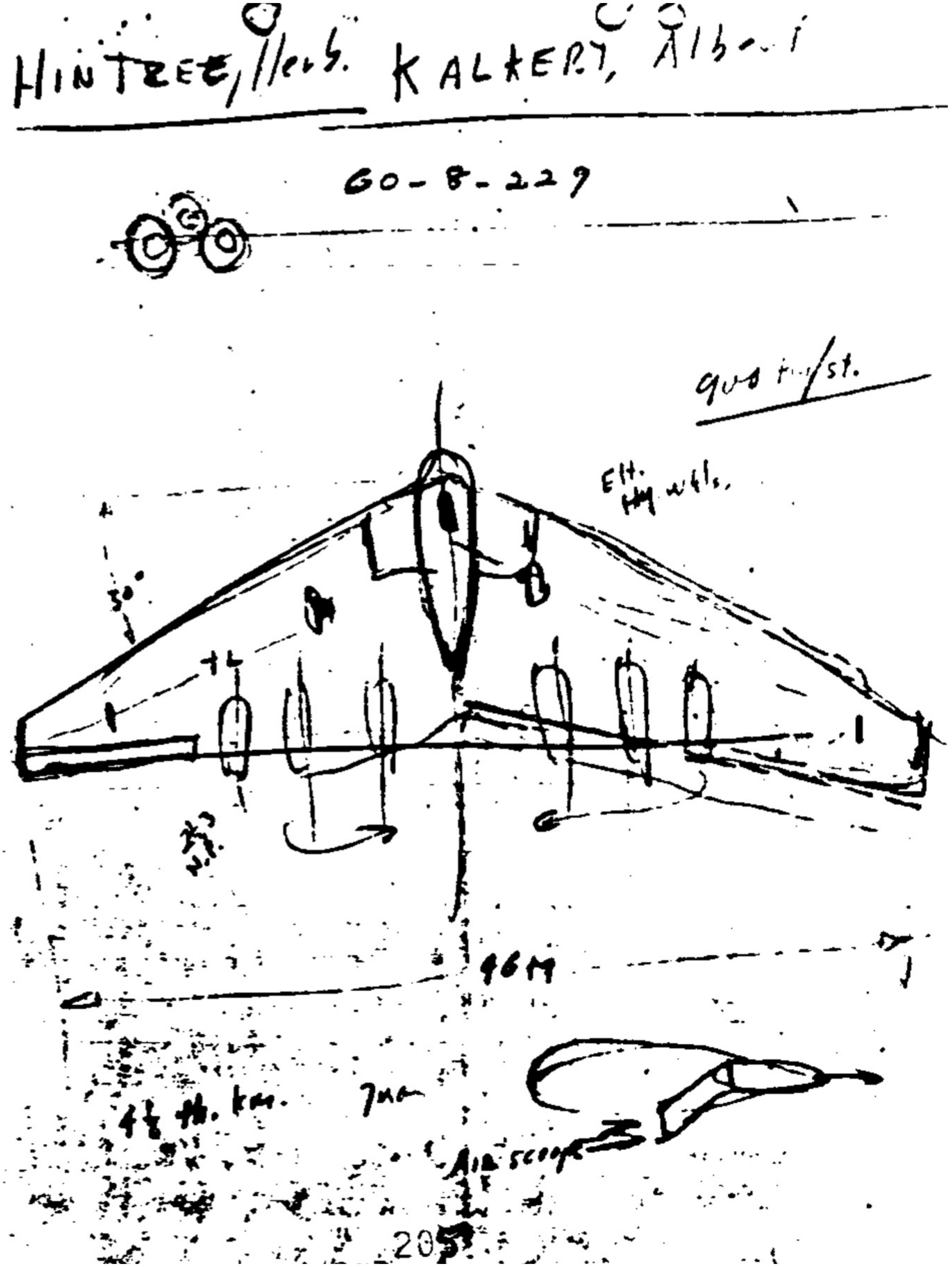
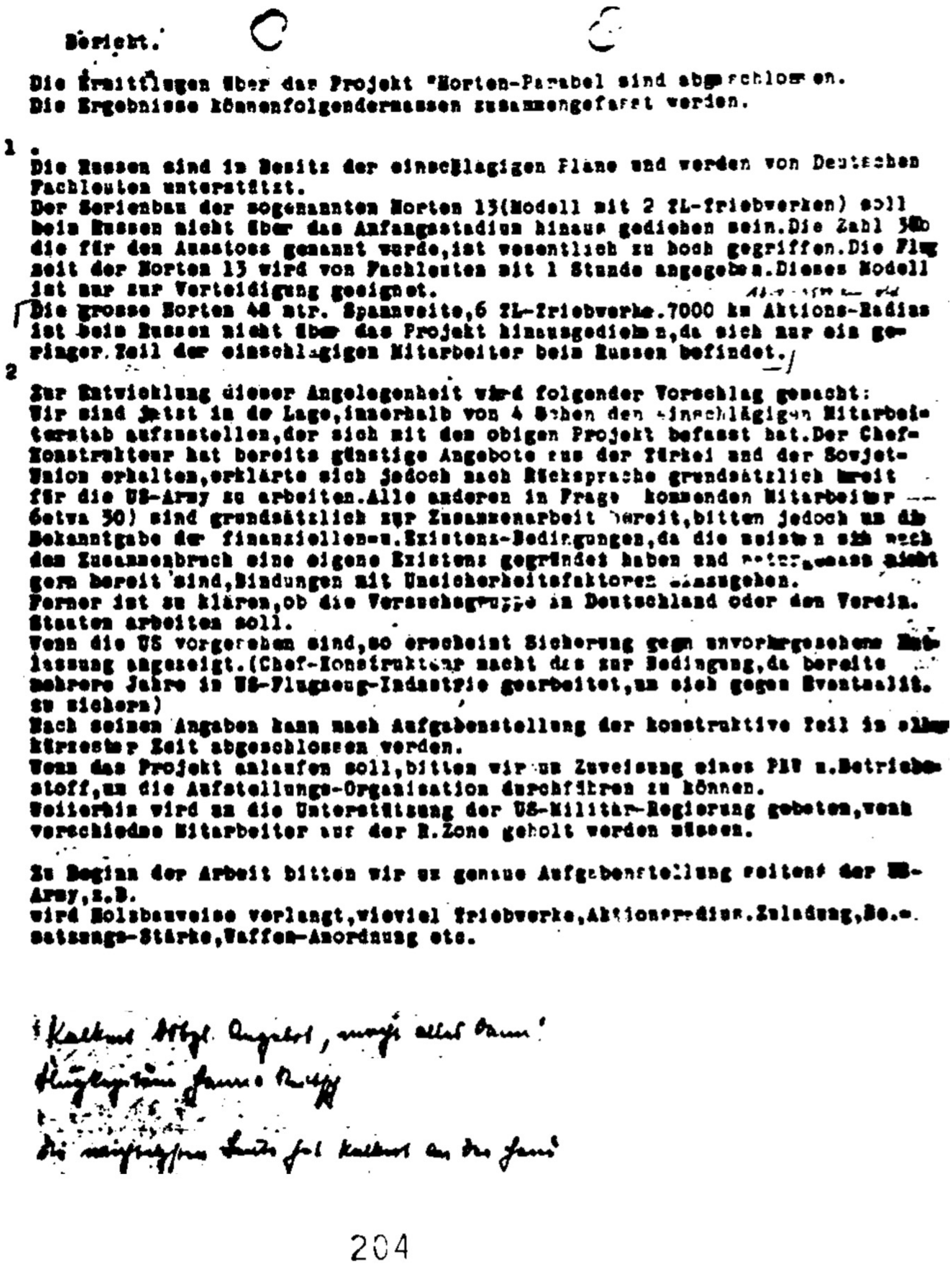

HINTREE, Herb. KALKERT, Alb
60-8-229
900 km/st.
Elt. Hy whls.
30°
46 M
14 th. km.
7m
AIR SCOOP
205

Figure E.20: After the war, a group of German aerospace engineers offered to immediately begin building for the U.S. military a 7,000-km-range (14,000-km round trip), 6-jet-engine flying wing bomber. Was their offer based on an aircraft they had already built during the war?



Bericht.

Die Ermittlungen über das Projekt "Horten-Parabel sind abgeschlossen.
Die Ergebnisse können folgendermassen zusammengefasst werden.

1.

Die Russen sind im Besitz der einschlägigen Pläne und werden von Deutschen Fachleuten unterstützt.
Der Serienbau der sogenannten Horten 13 (Modell mit 2 TL-Triebwerken) soll beim Russen nicht über das Anfangsstadium hinaus gediehen sein. Die Zahl 300 die für den Ausstoss genannt wurde, ist wesentlich zu hoch gegriffen. Die Flugzeit der Horten 13 wird von Fachleuten mit 1 Stunde angegeben. Dieses Modell ist nur zur Verteidigung geeignet.
Die grosse Horten 48 mtr. Spannweite, 6 TL-Triebwerke. 7000 km Aktions-Radius ist beim Russen nicht über das Projekt hinausgediehen, da sich nur ein geringer Teil der einschlägigen Mitarbeiter beim Russen befindet.

2

Zur Entwicklung dieser Angelegenheit wird folgender Vorschlag gemacht:
Wir sind jetzt in der Lage, innerhalb von 4 Wochen den einschlägigen Mitarbeiterstab aufzustellen, der sich mit dem obigen Projekt befasst hat. Der Chef-Konstrukteur hat bereits günstige Angebote aus der Türkei und der Sowjet-Union erhalten, erklärte sich jedoch nach Rücksprache grundsätzlich bereit für die US-Army zu arbeiten. Alle anderen in Frage kommenden Mitarbeiter (etwa 30) sind grundsätzlich zur Zusammenarbeit bereit, bitten jedoch um die Bekanntgabe der finanziellen- u. Existenz-Bedingungen, da die meisten sich nach dem Zusammenbruch eine eigene Existenz gegründet haben und naturgemäss nicht gern bereit sind, Bindungen mit Unsicherheitsfaktoren einzugehen.
Ferner ist zu klären, ob die Versuchsgruppe in Deutschland oder den Verein. Staaten arbeiten soll.
Wenn die US vorgesehen sind, so erscheint Sicherung gegen unvorhergesehene Entlassung angezeigt. (Chef-Konstrukteur macht dies zur Bedingung, da bereits mehrere Jahre in US-Flugzeug-Industrie gearbeitet, um sich gegen Eventualit. zu sichern)
Nach seinen Angaben kann nach Aufgabenstellung der konstruktive Teil in allerkürzester Zeit abgeschlossen werden.
Wenn das Projekt anlaufen soll, bitten wir um Zuweisung eines PKW u. Betriebsstoff, um die Aufstellungs-Organisation durchführen zu können.
Weiterhin wird um die Unterstützung der US-Militär-Regierung gebeten, wenn verschiedne Mitarbeiter aus der R.Zone geholt werden müssen.

Zu Beginn der Arbeit bitten wir um genaue Aufgabenstellung seitens der US-Army, z.B.
wird Holzbauweise verlangt, wieviel Triebwerke, Aktionsradius. Zuladung, Besatzungs-Stärke, Waffen-Anordnung etc.

Kalkert Abgl. Angebot, mögl. alles bauen!
Flugkapitän Hanna Reitsch
Die einschlägigen Leute hat Kalkert an der Hand

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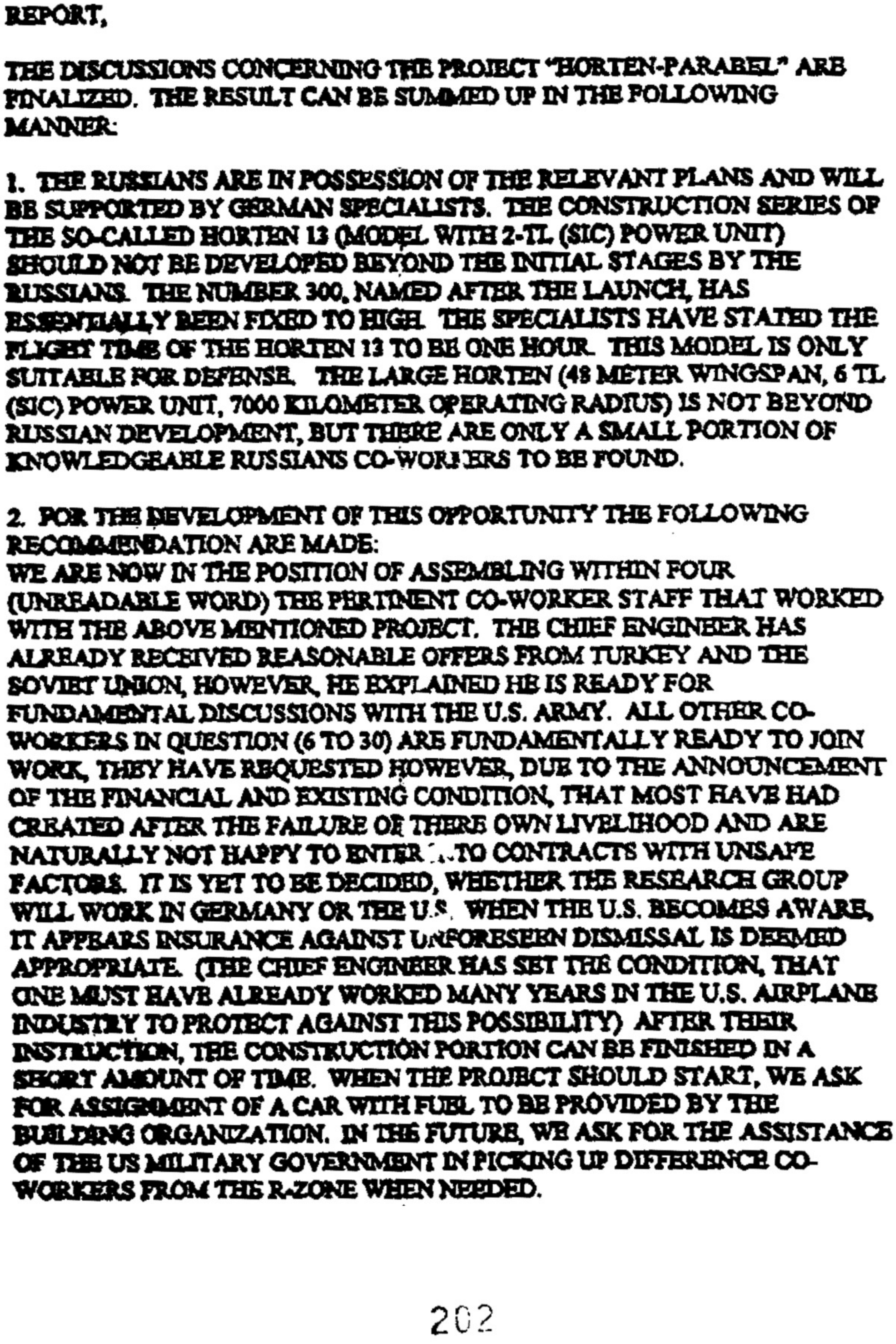
Figure E.21: After the war, a group of German aerospace engineers offered to immediately begin building for the U.S. military a 7,000-km-range (14,000-km round trip), 6-jet-engine flying wing bomber. Was their offer based on an aircraft they had already built during the war?



REPORT,

THE DISCUSSIONS CONCERNING THE PROJECT "HORTEN-PARABEL" ARE FINALIZED. THE RESULT CAN BE SUMMED UP IN THE FOLLOWING MANNER:

1. THE RUSSIANS ARE IN POSSESSION OF THE RELEVANT PLANS AND WILL BE SUPPORTED BY GERMAN SPECIALISTS. THE CONSTRUCTION SERIES OF THE SO-CALLED HORTEN 13 (MODEL WITH 2-TL (SIC) POWER UNIT) SHOULD NOT BE DEVELOPED BEYOND THE INITIAL STAGES BY THE RUSSIANS. THE NUMBER 300, NAMED AFTER THE LAUNCH, HAS ESSENTIALLY BEEN FIXED TO HIGH. THE SPECIALISTS HAVE STATED THE FLIGHT TIME OF THE HORTEN 13 TO BE ONE HOUR. THIS MODEL IS ONLY SUITABLE FOR DEFENSE. THE LARGE HORTEN (48 METER WINGSPAN, 6 TL (SIC) POWER UNIT, 7000 KILOMETER OPERATING RADIUS) IS NOT BEYOND RUSSIAN DEVELOPMENT, BUT THERE ARE ONLY A SMALL PORTION OF KNOWLEDGEABLE RUSSIANS CO-WORKERS TO BE FOUND.

2. FOR THE DEVELOPMENT OF THIS OPPORTUNITY THE FOLLOWING RECOMMENDATION ARE MADE:
WE ARE NOW IN THE POSITION OF ASSEMBLING WITHIN FOUR (UNREADABLE WORD) THE PERTINENT CO-WORKER STAFF THAT WORKED WITH THE ABOVE MENTIONED PROJECT. THE CHIEF ENGINEER HAS ALREADY RECEIVED REASONABLE OFFERS FROM TURKEY AND THE SOVIET UNION, HOWEVER, HE EXPLAINED HE IS READY FOR FUNDAMENTAL DISCUSSIONS WITH THE U.S. ARMY. ALL OTHER CO-WORKERS IN QUESTION (6 TO 30) ARE FUNDAMENTALLY READY TO JOIN WORK, THEY HAVE REQUESTED HOWEVER, DUE TO THE ANNOUNCEMENT OF THE FINANCIAL AND EXISTING CONDITION, THAT MOST HAVE HAD CREATED AFTER THE FAILURE OF THERE OWN LIVELIHOOD AND ARE NATURALLY NOT HAPPY TO ENTER INTO CONTRACTS WITH UNSAFE FACTORS. IT IS YET TO BE DECIDED, WHETHER THE RESEARCH GROUP WILL WORK IN GERMANY OR THE U.S. WHEN THE U.S. BECOMES AWARE, IT APPEARS INSURANCE AGAINST UNFORESEEN DISMISSAL IS DEEMED APPROPRIATE. (THE CHIEF ENGINEER HAS SET THE CONDITION, THAT ONE MUST HAVE ALREADY WORKED MANY YEARS IN THE U.S. AIRPLANE INDUSTRY TO PROTECT AGAINST THIS POSSIBILITY) AFTER THEIR INSTRUCTION, THE CONSTRUCTION PORTION CAN BE FINISHED IN A SHORT AMOUNT OF TIME. WHEN THE PROJECT SHOULD START, WE ASK FOR ASSIGNMENT OF A CAR WITH FUEL TO BE PROVIDED BY THE BUILDING ORGANIZATION. IN THE FUTURE, WE ASK FOR THE ASSISTANCE OF THE US MILITARY GOVERNMENT IN PICKING UP DIFFERENCE CO-WORKERS FROM THE R-ZONE WHEN NEEDED.

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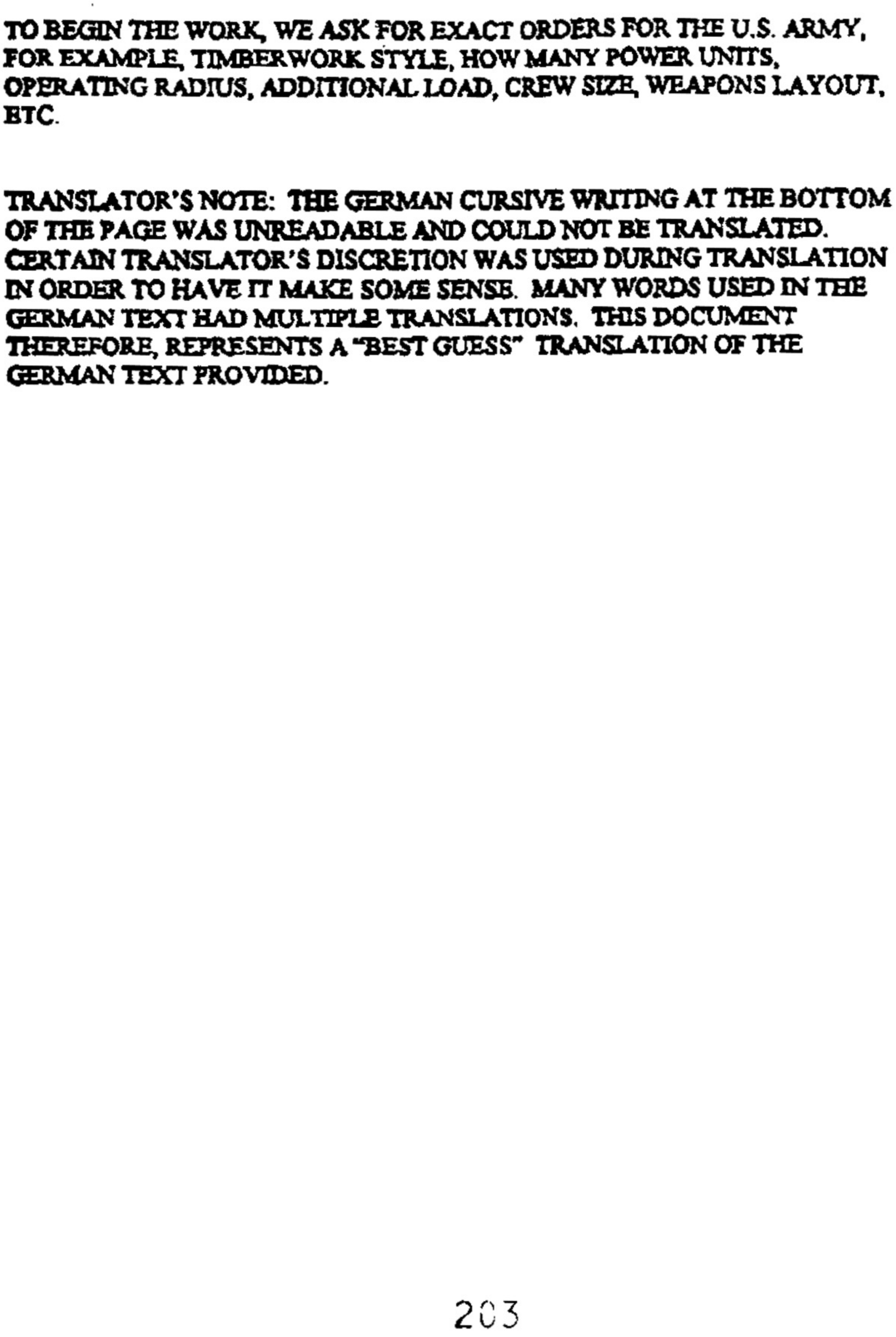
Figure E.22: After the war, a group of German aerospace engineers offered to immediately begin building for the U.S. military a 7,000-km-range (14,000-km round trip), 6-jet-engine flying wing bomber. Was their offer based on an aircraft they had already built during the war?



TO BEGIN THE WORK, WE ASK FOR EXACT ORDERS FOR THE U.S. ARMY, FOR EXAMPLE, TIMBERWORK STYLE, HOW MANY POWER UNITS, OPERATING RADIUS, ADDITIONAL LOAD, CREW SIZE, WEAPONS LAYOUT, ETC.

TRANSLATOR'S NOTE: THE GERMAN CURSIVE WRITING AT THE BOTTOM OF THE PAGE WAS UNREADABLE AND COULD NOT BE TRANSLATED. CERTAIN TRANSLATOR'S DISCRETION WAS USED DURING TRANSLATION IN ORDER TO HAVE IT MAKE SOME SENSE. MANY WORDS USED IN THE GERMAN TEXT HAD MULTIPLE TRANSLATIONS. THIS DOCUMENT THEREFORE, REPRESENTS A "BEST GUESS" TRANSLATION OF THE GERMAN TEXT PROVIDED.

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Figure E.23: After the war, a group of German aerospace engineers offered to immediately begin building for the U.S. military a 7,000-km-range (14,000-km round trip), 6-jet-engine flying wing bomber. Was their offer based on an aircraft they had already built during the war?

NARA Still Pictures, RG 111 SCA---Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941-1954. Captured German Equipment, German, Box 3353, Book 15, SC 314829.

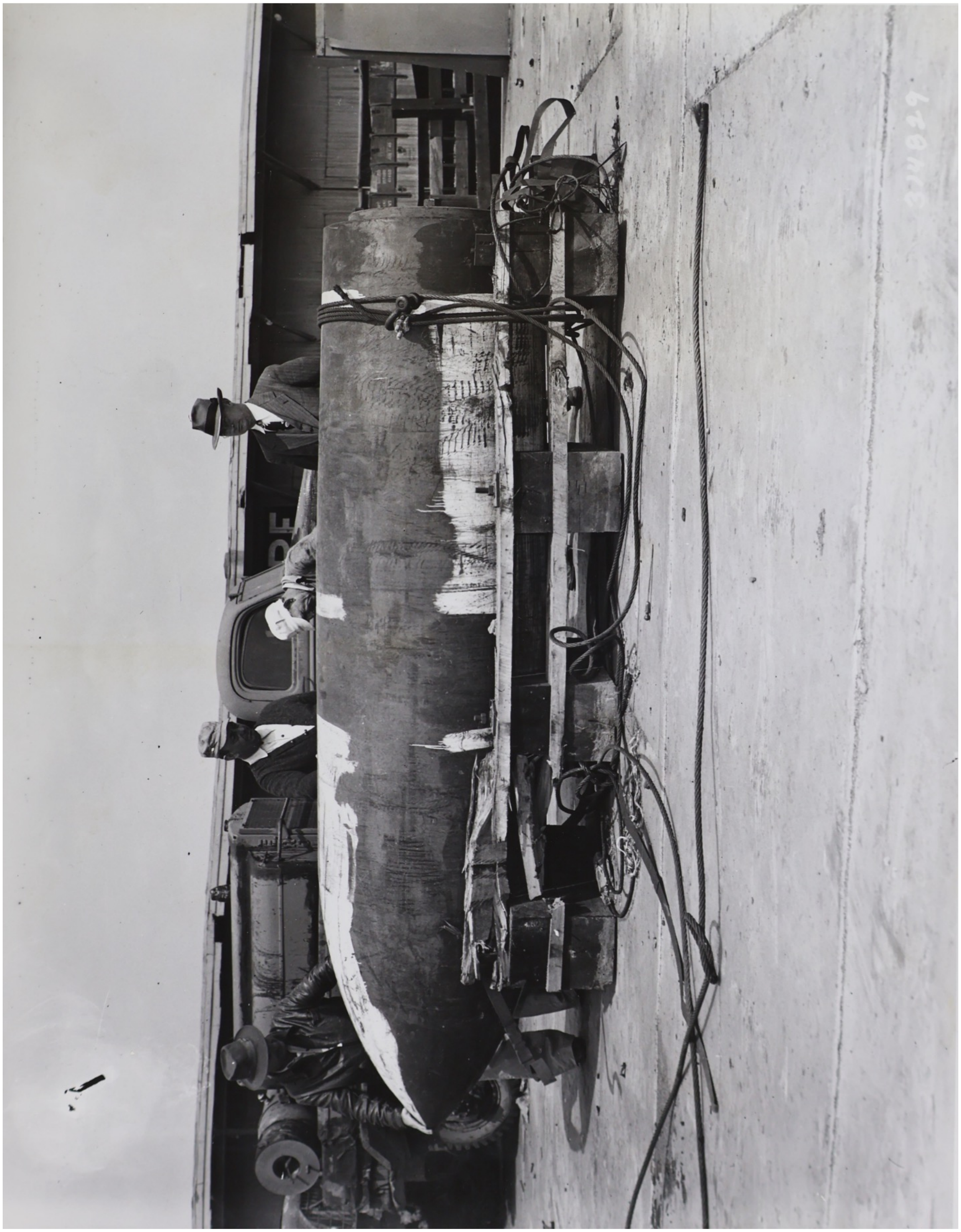

Figure E.24: Original photo caption: “Ordnance experts examine a 35,000 pound German giant aerial bomb upon its arrival at the New Orleans Port of Embarkation, La., from Germany. 11 March 1948.” What wartime German aircraft were intended to carry a 35,000 lb [15.9 metric ton] bomb? [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3353, Book 15, SC 314829.]

Karl Leist, and Hans Georg Wiening. 1963. *Enzyklopädische Abhandlung über ausgeführte Strahltriebwerke.* pp. 356–360: Daimler-Benz-Triebwerk 109-007.

Die Firma Daimler-Benz begann Mitte 1939 als letzte der deutschen Firmen mit der Entwicklung von Strahltriebwerken. Dies war in ester Linie die Folge davon, daß die Kapazität des Werkes weitgehend durch die Entwicklung und Fabrikation der Daimler-Benz-Kolbenflugmotoren ausgelastet war. Auch während des Krieges, wo erklärlicherweise die in sehr viele Flugzeugbaumuster eingebauten DB-601-, DB-605- und DB-603-Motoren mit ihren verschiedenen Abarten einen außerordentlichen Einsatz des gesamten Werkes erforderten, konnte sowohl in der Konstruktion wie in der Werkstatt nur sehr allmählich die auf die Gasturbinenentwicklung angesetzte Mannschaft verstärkt werden.

Der späte Beginn der TL-Entwicklung hatte zur Folge, daß die Firma vom Reichsluftfahrtministerium, da schon genügend Firmen auf einfache Strahltriebwerke angesetzt zu sein schienen, mit einer Weiterentwicklungsaufgabe, nämlich Schaffung eines Triebwerkes mit besonders geringem Kraftstoffverbrauch für längere Einsatzzeiten, betraut wurde, welches als Zweikreistriebwerk entwickelt werden sollte. Da bei dieser komplizierten Einheit gleichzeitig ein größerer Schub als bei den anderen gefordert wurde und außer dem späteren Entwicklungsbeginn die Erfahrungen, die an einem einfachen TL-Gerät hätten gesammelt werden können, übersprungen werden mußten, ergab sich hiermit eine Aufgabe, die besonders hohe Anforderungen an die Entwicklung stellte. Außerdem führte diese zu einer großen Reihe von zusätzlichen Problemen, da die spezielle Zielsetzung des Projektes, nämlich die Erreichung höchster Wirtschaftlichkeit durch den Ballastluftkreislauf und seine speziellen Forderungen, ein besonders starkes Heranrücken an die Grenzen der ausführbaren Werte in bezug auf Druckverhältnisse, Gastemperaturen usw. forderte. Hierdurch war bei dem damaligen frühen Entwicklungsstand der Strahltriebwerke und dem gänzlichen Fehlen von Erfahrungen, auf die man sich hätte stützen können, eine schnelle und einfache Lösung sehr erschwert.

Daimler-Benz was the last of the German companies to begin developing jet engines in mid-1939. This was primarily the result of the fact that the plant's capacity was largely utilized by the development and production of Daimler-Benz piston aircraft engines. Even during the war, when the DB-601, DB-605, and DB-603 engines with their various versions, which were installed in a large number of aircraft models, required an extraordinary commitment from the entire plant, it was only possible very gradually to strengthen the team dedicated to gas turbine development, both in the design department and in the workshop.

The late start of TL [turbojet] development meant that the company was entrusted by the Reich Aviation Ministry, since enough companies already seemed to be focused on simple jet engines, with a further development task, namely the creation of an engine with particularly low fuel consumption for longer operating times, which was to be developed as a dual-flow [turbofan] engine. Since this complicated unit also required greater thrust than the others and, apart from the later start of development, the experience that could have been gained on a simple TL unit had to be skipped, this resulted in a task that placed particularly high demands on development. Moreover, it led to a large number of additional problems, since the special objective of the project, i.e. to achieve maximum efficiency through the cold air flow and its special requirements, demanded a particularly strong approach to the limits of feasible values in terms of pressure ratios, gas temperatures, etc. This meant that the development of the TL unit at that time was not possible. Given the early stage of development of jet engines at that time and the complete lack of experience on which to draw, this made it very difficult to find a quick and simple solution.

Da der geforderte Kraftstoffverbrauch außerordentlich niedrig war, mußte zu einer für damalige Verhältnisse sehr hohen Verdichtung übergegangen werden (ca. 1: 8), die, da sonst durch zu viele Kompressorstufen die Länge außerordentlich groß ausgefallen wäre und auch die kritische Drehzahl kaum hätte beherrscht werden können, zu einem gegenläufigen Verdichter führte, der in einer Lösung von der Aerodynamischen Versuchsanstalt Göttingen, in einer späteren Parallelausführung von der Firma Voith konstruiert wurde. Die Entspannungsanfangstemperatur wurde—ebenfalls mit dem Ziel bester Wirtschaftlichkeit—auf 1100^o C festgelegt. Um diese hohen Temperaturen für die Laufschaufeln erträglich zu machen, wurden diese gekühlt, und zwar vermittels einer Teilbeaufschlagung durch Luft, die nicht auf den Brennkammerdruck, sondern nur auf den Druck hinter der Turbine verdichtet war. Für diese Kühlmethode, die als einzige im praktischen Betrieb eine Temperatur von 1100^o C bereits erlaubt hatte, lagen die Verhältnisse gerade beim Zweikreistriebwerk deswegen besonders günstig, weil der Verdichter, die Turbine und die Brennkammern von dem zweiten Kreis (Ballastluft) umströmt wurden, dem die Kühlluft zwanglos entnommen werden konnte. Auch ließ sich der durch die Teilbeaufschlagung etwas größere Turbinenraddurchmesser ohne weiteres in dem Hauptspantquerschnitt unterbringen, der durch den Verdichterdurchmesser zuzüglich des zweiten Kreises sowieso nötig war. Die für die Gastemperatur von 1100^o C ausreichende Kühlwirkung der auch in der ausländischen Literatur günstig beurteilten* kühlenden Beaufschlagung mit unverdichteter Luft war vorher aus einer ganzen Reihe von Versuchen an Abgasturbinenrädern mit geeignet geformten Schaufeln festgestellt worden, bei denen Dauerläufe über 200 Stunden mit höchsten Drehzahlen bei dieser Temperatur anstandlos durchgeführt worden waren.

Since the required fuel consumption was extraordinarily low, a very high compression ratio (approximately 1:8) had to be used, which, since the length would otherwise have been extraordinarily large due to too many compressor stages and the critical speed could hardly have been controlled, led to a counter-rotating compressor, which was designed in one solution by the Aerodynamische Versuchsanstalt Göttingen and in a later parallel design by the Voith company. The initial expansion temperature was set at 1100^o C—also with the aim of achieving the best efficiency. In order to make these high temperatures bearable for the rotor blades, they were cooled by means of a partial admission of air, which was not compressed to the combustion chamber pressure, but only to the pressure behind the turbine. The conditions for this cooling method, which was the only one to permit a temperature of 1100^o C in practical operation, were particularly favorable for the dual-flow engine because the compressor, the turbine and the combustion chambers were surrounded by the duct carrying the second flow (cold air), from which the cooling air could be taken without constraint. Also, the somewhat larger turbine wheel diameter due to the partial pressurization could be easily accommodated in the main bulkhead cross-section, which was necessary anyway due to the compressor diameter plus the second flow. The cooling effect of the non-compressed air, which is also favorably assessed in foreign literature*, was sufficient for the gas temperature of 1100^o C. This had previously been established from a whole series of tests on exhaust gas turbine wheels with suitably shaped blades, in which endurance runs over 200 hours at maximum speeds had been carried out at this temperature without any problems.

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* Vgl. z. B. JUDGE, Modern Gas Turbines.

* Cf., e.g., JUDGE, Modern Gas Turbines.

Als besonderes Kennzeichen der Konstruktion dieses Zweikreistriebwerks soll noch genannt werden, daß die Schaufeln zur Verdichtung der Ballastluft, also des zweiten Kreises, auf dem Außenläufer des gegenläufigen Verdichters angebracht waren, wodurch die Baulänge noch weiter verringert wurde.

Das DB-Triebwerk 109-007, wie die beschriebene Zweikreisentwicklung genannt wurde, sollte bei 250 m/sec Fluggeschwindigkeit in 6 km Höhe einen Schub von 600 kp erzeugen, das entsprach einer Vortriebsleistung von 2000 PS. Die Gastemperatur wurde aus den besprochenen Gründen auf 1100^o C, der Gasbeaufschlagungsgrad auf 67% festgelegt. Die Förderhöhe des Verbrennungsluftverdichters betrug 20 000 mkg/kg, die des Ballastluftverdichters 3000 m bei einer Drehzahl der Turbine von 12 600 U/min. Der Außenläufer des Verdichters der gleichzeitig die Beschaufelung des Ballastluftverdichters trug, lief mit 6200 U/min um und wurde durch ein Planetengetriebe von der Turbinenwelle aus angetrieben. Der Gegendruck der Turbine ergab sich zu 1,9 ata am Boden, so daß also weitgehend Schallgeschwindigkeit in der Enddüse herrschte. Der Luftdurchsatz betrug im ersten Kreis in Bodennähe 14,8, in 6 km Höhe 8,2 kg/sec; im zweiten Kreis 35,8 bzw. 19,9 kg/sec. Das Ballastluftvielfache betrug danach ca. 2,42.

Die Turbine war einstufig, obgleich das Expansionsdruckverhältnis bis 1 : 6 stieg, der Verdichter besaß 17 Stufen, d. h. gegenläufige Kränze. Dadurch war die Gesamtbaulänge trotz des hohen Druckverhältnisses relativ kurz.

Der feste Mittelträger unmittelbar hinter dem Verdichteraustritt hat die Rolle einer senkrechten Grundplatte, an der sich nach vorn ein die vorderen Lager tragender zylindrischer Teil als Verdichtergehäuse anschließt, und nach hinten der das Getriebe umhüllende konische Träger des Lagers der fliegend angeordneten Turbinenscheibe.

A special feature of the design of this dual-flow engine is that the blades for compressing the cold air, i.e. the second flow, were mounted on the outer rotor of the counter-rotating compressor, which further reduced the overall length.

The 109-007 DB engine, as this dual-flow project was called, was intended to produce 600 kp of thrust at 250 m/sec airspeed at 6 km altitude, equivalent to 2000 hp of propulsive power. The gas temperature was set at 1100^o C for the reasons discussed, and the gas impingement rate at 67%. The head of the combustion air compressor was 20,000 mkg/kg, that of the ballast air compressor 3000 m at a turbine speed of 12,600 rpm. The external rotor of the compressor, which also carried the blading of the cold air compressor, rotated at 6200 rpm and was driven by a planetary gear from the turbine shaft. The back pressure of the turbine was 1.9 ata at ground level, so that the speed of sound largely prevailed in the final nozzle. The air flow rate in the first flow near the ground was 14.8, at 6 km altitude 8.2 kg/sec; in the second flow 35.8 and 19.9 kg/sec, respectively. The air bypass ratio was thus approximately 2.42.

The turbine was single stage, although the expansion pressure ratio increased to 1:6; the compressor had 17 stages, i.e. counter-rotating rings. As a result, the overall length was relatively short despite the high pressure ratio.

The fixed center support immediately behind the compressor outlet had the role of a vertical base plate, to which a cylindrical part supporting the front bearings as the compressor housing was connected to the front, and to the rear the conical support of the bearing of the overhung turbine disk enclosing the gearbox.

Von den beiden Verdichterläufern ist der innere in einer Ausführung aus trommelartigen Ringen, in der anderen aus Rädern zusammengesetzt. Durch die Anbringung der zwei Stufen des Ballastluftgebläses auf dem Außenläufer des gegenläufigen Verbrennungsluftkompressors wird die Gesamtbaulänge des Kompressorteils trotz des hohen Verdichtungsverhältnisses und trotz der zwei notwendigen Verdichter sehr kurz, was der kritischen Drehzahl zugute kommt. Die erste Scheibe sowie die Schaufelringe sind sowohl beim Innen- wie beim Außenläufer aus einer besonderen Leichtmetallegierung gefertigt, die durch Nickelzusatz eine erhöhte Warmfestigkeit aufweist. Die letzten Stufen waren aus Stahl. Die Schaufeln der Erstlingsausführung waren aus dem Material der Ringe herausgeschnitten, für später war zwecks Verbilligung ein schräg einzuschiebender Schwalbenschwanzfuß für die Verdichterschaufeln vorgesehen. Die Lagerung wurde—mindestens bei der ersten Ausführung—als Gleitlagerung (teilweise mit schwimmenden Buchsen) ausgeführt mit einem Blockdrucklager zur Aufnahme des beträchtlichen Achsschubes, der durch einen Druckausgleichkolben am Außenläufer gesenkt wurde.

Die Düsen der einstufigen Turbine waren mit Rücksicht auf das sehr hohe Entspannungsverhältnis erweitert ausgeführt. Die Umfangsgeschwindigkeit des Turbinenrades betrug 375 m/sec. Das Rad ist mit Hirthverzahnung an der Welle befestigt und trägt einen radialen Schaufelkranz zur Förderung von Kühlluft zur Kühlung des Rades und insbesondere der Düsen. Ergänzend wurden Untersuchungen über eine zweistufige Ausführung der Turbine durchgeführt, die jedoch baulich ungünstigere Verhältnisse lieferte. Die Schaufelprofile warn vorn stark abgestumpft und im Verhältnis 1 : 2,7 verjüngt ausgeführt. Der Außenrand des Rades trug auf beiden Seiten eine konzentrische Umfangsrippe, die durch die radiale weiter nach innen reichende Kühlluftzuführung bespült wurde und somit dem besonders gefährdeten Radkranz die Wärme entzog.

Of the two compressor rotors, the inner one was composed of drum-like rings in one design and wheels in the other. By placing the two stages of the ballast air blower on the outer rotor of the counter-rotating combustion air compressor, the overall length of the compressor section becomes very short, despite the high compression ratio and despite the two compressors required, which benefits the critical speed. The first disk as well as the blade rings, both for the internal and external rotors, were made of a special light alloy that has increased high-temperature strength due to the addition of nickel. The last stages were made of steel. The blades of the first version were cut out of the material of the rings; for later versions, an oblique dovetail base was provided for the compressor blades in order to make them cheaper. The bearing arrangement was—at least in the first design—as a plain bearing (partly with floating bushings) with a block thrust bearing to absorb the considerable axle thrust, which was lowered by a pressure compensating piston on the outer rotor.

The nozzles of the single-stage turbine were of expanded design in consideration of the very high expansion ratio. The peripheral speed of the turbine wheel was 375 m/sec. The wheel was attached to the shaft with Hirth teeth and carried a radial vane ring for conveying cooling air to cool the wheel and, in particular, the nozzles. Supplementary investigations were carried out on a two-stage design of the turbine, which, however, provided structurally less favorable conditions. The blade profiles were heavily truncated at the front and tapered in a ratio of 1:2.7. The outer rim of the wheel had a concentric circumferential rib on both sides, which was flushed by the radial cooling air supply extending further inward and thus extracting heat from the particularly vulnerable wheel rim.

Die Zahl der Brennkammern betrug vier, wobei die Möglichkeit der Anbringung einer fünften Kammer offengelassen war, was während der Versuche bereits durchgeführt wurde. Der Luftüberschuß betrug mit Rücksicht auf die hohe Entspannungsanfangstemperatur 2,7–3. Die Düsen hatten neben ihrer hohen thermischen Beanspruchung durch die hohe Druckdifferenz der Entspannung auch hohe mechanische Beanspruchungen auszuhalten. Ihre Stege wurden daher hohl ausgeführt und von Kühlluft durchströmt.

Um den Gewinn durch den Ballastluftkreislauf vollständig zu machen, war eine möglichst weitgehende Mischung des Turbinenabgases mit der Luft des zweiten Kreises hinter der Turbine notwendig. Die Mischung geht dabei um so verlustärmer vor sich, je geringer die Strömungsgeschwindigkeit während derselben ist. Es wurden zwei Mischstrecken mit verschiedener Länge und mit verschieden aufwendigen Einbauten hergestellt, die diesem Gesichtspunkt bei verschiedenem Baugewicht und Werkstattaufwand Rechnung tragen sollten. Bei geringeren Geschwindigkeiten im Mischraum ergab sich gleichzeitig die Möglichkeit einer intensiveren Nachverbrennung ohne Erreichung der Schallgeschwindigkeit vor der Enddüse, d. h. also einer besseren Ausnutzung eines der wesentlichen Vorteile der Zweikreisers.

Der Einlaufverkleidung wurde zwecks Erzielung einer günstigen Einströmung sowohl im Stand wie bei voller Geschwindigkeit besondere Aufmerksamkeit durch Vorversuche gewidmet. Die Hilfsapparate waren mit dem Triebwerk unmittelbar verbunden. Sie bestanden aus je einer Pumpe für den Kraftstoff der Brennkammer und für die Zusatzverbrennung zuzüglich Vorpumpen, für den Schmierstoff wurden drei Druck- und drei Saugpumpen zunächst im Nabenkopf, später an einem gesonderten Apparateträger über dem Triebwerk untergebracht, an dem außerdem Einspritzregler, Drehzahlgeber, Anlasser und Zündgerät sowie Atemluftverdichter, drei Generatoren und eine Hydraulikpumpe für die Zelle usw. angeordnet waren.

The number of combustion chambers was four, leaving open the possibility of adding a fifth chamber, which was already carried out during the tests. The air ratio was 2.7–3. The nozzles had to withstand not only high thermal stress due to the high pressure difference during expansion, but also high mechanical stress. Their walls were therefore hollow and had cooling air flowing through them.

To make the gain from the cold air flow complete, it was necessary to mix the turbine exhaust gas as much as possible with the air from the second flow behind the turbine. The lower the flow velocity during mixing, the lower the losses. Two mixing sections of different lengths and with different complex internals were produced to take account of this aspect with different construction weights and workshop requirements. At lower velocities in the mixing chamber, there was at the same time the possibility of more intensive afterburning without the flow reaching the speed of sound upstream of the final nozzle, i.e., better utilization of one of the essential advantages of the two-flow mixer.

The inlet cowling was given special attention in preliminary tests for the purpose of obtaining a favorable inflow both at standstill and at full speed. The auxiliary equipment was directly connected to the engine. This consisted of one pump each for the fuel for the combustion chamber and for the auxiliary combustion plus backing pumps; for the lubricant, three pressure and three suction pumps were initially accommodated in the hub head, later on a separate apparatus support above the engine, on which were also arranged the injection governor, speed sensor, starter, and ignition unit as well as breathing air compressor, three generators, and a hydraulic pump for the airframe, etc.

Die für das Triebwerk benutzten Werkstoffe entsprachen bei den hohen Belastungen naturgemäß den besten damals verfügbaren Legierungen.

Wen auch in Anbetracht des durch den Krieg diktierten außergewöhnlich beschleunigten Entwicklungstempos viele Vorversuche, die wünschenswert gewesen wären, nicht durchgeführt werden konnten, wurde doch eine Reihe wichtiger Elemente, bezüglich derer besonders wenig Erfahrungen vorlagen, mindestens teilweise vorerprobt. Hierzu gehört insbesondere die Brennkammer und getrennt davon die Einspritzdüsen, der gegenläufige Verdichter, die Achsschublager, das Getriebe, welches bei leichtester Bauart 4000 PS übertragen mußte, die Einlaufverkleidung usw.; weiter gingen Schleuderversuche mit Überdrehzahlen, Schwingungsmessungen und umfangreiche Schaufelkühlungsversuche, Hilfsaggregatuntersuchungen usw. der Erprobung des Gesamttriebwerkes voraus. Zum Ausschleudern der Turbinenräder wurde en gesonderter Schleuderstand mit aufheizbarer Umgebungsluft und unter Absaugung auf Vakuum erstellt.

Die Gesamterprobung, die nach verschiedenen anfänglichen Schwierigkeiten mit allen Drehzahlen von der Abhebedrehzahl* 4000 U/min bis zur Auslegungsdrehzahl 12 600 U/min des Innenläufers (teilweise ohne Ballastluftverdichter) durchgeführt wurde, ergab für das erste Volltriebwerk eine Gesamtversuchszeit von 152 Stunden. Es wurde dabei auf eine Anzahl von Einzelfragen, die nicht in Vorversuchen geklärt werden konnten, miteingegangen. Teilweise wurde mit Wassereinspritzung in die Brennkammer gefahren.

The materials used for the engine naturally corresponded to the best alloys available at the time for the high loads.

Although, in view of the exceptionally accelerated pace of development dictated by the war, many preliminary tests that would have been desirable could not be carried out, a number of important elements with respect to which particularly little experience was available were at least partially pre-tested. These include in particular the combustion chamber and, separately, the injection nozzles, the counter-rotating compressor, the axle thrust bearings, the gearbox, which had to transmit 4000 hp in the lightest design, the inlet cowling, etc.; furthermore, spinning tests with overspeeds, vibration measurements, and extensive blade cooling tests, auxiliary unit tests, etc. preceded the testing of the overall engine. For spinning out the turbine wheels, a separate spinning stand was set up with heatable ambient air and under vacuum extraction.

The complete engine testing, which after various initial difficulties was carried out at all speeds from the lift-off speed* 4,000 rpm to the design speed 12,600 rpm of the internal rotor (partly without cold air compressor), resulted in a total test time of 152 hours for the first full engine. A number of individual issues that could not be resolved in preliminary tests were addressed. In some cases, the engine was run with water injection into the combustion chamber.

* Mindestdrehzahl, bei der das Triebwerk in der Lage ist, sich ohne Anlaßmotor selbst zu beschleunigen.

* Minimum speed at which the engine is capable of self-acceleration without a starter motor.

Die Brennkammerbelastung lag bei voller Drehzahl bei $94 \cdot 10^6$ kcal/Std. Die Freilaufdrehzahl rückt bei Zweikreisern, da die Ballastluft Leistung aufnimmt, ohne daß sie zur Leistungserzeugung herangezogen wird, höher als beim einfachen TL-Triebwerk. Sowohl die Einzelversuche wie insbesondere auch die Versuche am Volltriebwerk ergaben eine große Zahl von Erkenntnissen und aussichtsreichen Verbesserungsvorschlägen. Da andererseits die Aussicht gering erschien, daß dieses durch seine komplizierte Aufgabenstellung ziemlich problemreiche Triebwerk bei dem damaligen noch recht geringen Stand der allgemeinen Erfahrungen auf dem Strahltriebwerksgebiet noch innerhalb der im Rahmen des Kriegsfortgangs verfügbaren Zeit zur Betriebsreife würde entwickelt werden können, wurde die Weiterarbeit hieran von seiten des Luftfahrtministeriums zwecks Konzentration der Industriekapazität abgebrochen. Aus diesem Grunde mußten auch die im Gange befindlichen Schubmeßversuche des Gesamttriebwerks vor der Feststellung einigermaßen stichhaltiger Ergebnisse beendet werden. Auch Brennstoffverbrauchsmeßversuche, die einen Aufschluß über die Erreichung des Ziels der Zweikreisbauart mit einigermaßen zielsicher aufeinander abgestimmten Einzelmaschinen hätten geben können, konnten nicht mehr durchgeführt werden. Andererseits deuteten die zahlreichen Vorschläge für Konstruktionsvarianten und Auslegungsverbesserungen, die sich aus den Versuchen ergaben, darauf hin, daß trotz der schwierigen Aufgabenstellung bei ausreichender Zeit die Weitererprobung der mit Rücksicht auf unbekannte Havariequellen möglichst sicher und daher auch verhältnismäßig schwer konstruierten Erstausführung mindestens in der bei derartigen neuen Entwicklungen üblichen Zweit- und Drittkonstruktion eine erfolgreiche Entwicklung versprochen hätte.

The combustion chamber load at full speed was $94 \cdot 10^6$ kcal/hr. The freewheeling speed goes higher in turbofan engines than in the simple turbojet engine because the cold air absorbs power without being used to produce power. Both the individual tests and, in particular, the tests on the full engine yielded a large number of findings and promising suggestions for improvement. Since, on the other hand, there seemed little prospect of this engine, which was rather problematic because of its complicated task, being developed to operational maturity within the time available during the war, given the still rather limited state of general experience in the field of jet engines at that time, further work on it was discontinued by the Ministry of Aviation in order to concentrate industrial capacity. For this reason, the thrust measurement tests of the complete engine, which were currently in progress, had to be terminated before reasonably valid results could be obtained. Fuel consumption measurement tests, which could have provided information on the achievement of the goal of a dual-flow design with reasonably well-matched individual engines, could also no longer be carried out. On the other hand, the numerous suggestions for design variants and design improvements that resulted from the tests indicated that, despite the difficult task, given sufficient time, further testing of the first design, which was constructed to be as safe as possible with regard to unknown sources of damage and therefore also relatively heavy, would have promised successful development at least in the second and third design iterations that are customary for such new developments.

[For more information on the DB 007 and other early turbofan and turboprop engines, see pp. 1746, 1748 and Brix 2022; von Gersdorff et al. 2004; Jakobs et al. 2009; Kay 2002; Leyes and Fleming 1999.]

Ernst Heinrich Hirschel, Horst Prem, and Gero Madelung. 2004. *Aeronautical Research in Germany: From Lilienthal until Today.* Berlin: Springer.

[p. 227:] The development of the axial flow compressors for the BMW 003 and Junkers 004 engines was started already according to the requirements of the RLM. In this context a statement of *Helmut Schelp* is of significance, saying: *"Because in 1939 the development difficulties could not be foreseen, it was decided to assign as task a parallel development. Junkers was to work on a more conventional basis and BMW on a more advanced one with better technology [18]"*. For BMW this meant a compressor with seven stages, for Junkers one with eight stages for the same pressure rise. Both these compressors will be addressed later on.

Since the RLM had initiated promising development projects for turbo-jets and with a thrust of 8–9 kN (1,800-2,025 lbf), Daimler-Benz was given the task to develop an engine with higher thrust and a lower fuel consumption. The engine proposed under the direction of *Karl Leist* and tested 1943 on a test bed was one of the first bypass engines of the world [18]. For the required pressure ratio of eight, based on proposals made by *Walter Encke*, a compressor was designed consisting of two counter-rotating drums. A parallel development of the compressor was also undertaken and the compressor constructed by the company Voith in Heidenheim.

The development of the engine He S 30 under the direction of *Max Adolf Mülller* was the first engine of the company Heinkel with purely axial flow components: compressor, combustion chamber and turbine. The compressor, based on proposals by *Rudolph Friedrich* [18], reached a circumferential velocity of 313 m/s (1,027 ft/s) and a notable high efficiency of 87 per cent. The design of the compressor was based on the same considerations as for the *Wagner* engine, namely pressure transformation in the rotors and stators (degree of reaction 50 per cent). The He S 30 engine was thus superior at that time to all other designs regarding the important parameters for an aircraft like frontal area, weight and specific fuel consumption. By order of the RLM this engine development was however stopped at a time when a Me 262 with Jumo 004 engines took off on its first flight. Similar decisions of the RLM did also affect other developments.

The engines with axial flow compressors addressed here were followed by further ones with higher thrust. Apart from turbo-jet engines (TLs), developments were under way of turbo-propeller engines (PTLs) with axial flow compressors (BMW 028, Jumo 022). [...]

[p. 242:] **Combustion Chamber Development for a Bypass Engine at Daimler-Benz**

Daimler-Benz started after initial hesitation somewhat later with the jet engine development because of the large programme variety for piston aeroengines. From *Helmut Mauch* of the RLM the company obtained the difficult task to develop an engine with larger thrust and considerably lower fuel consumption. Under the leadership of *Karl Leist*, who had joined Daimler-Benz from the "Deutsche Versuchsanstalt für Luftfahrt, DVL", in September 1939 studies were commenced for the very advanced and very complex bypass engine DB 109-007 (later RLM designation) proposed by him, one of the first bypass engines of the world. After the start of the actual development work in the year 1941 the first of three test engines built was put on April 1, 1943 on a test bed in Stuttgart-Untertürkheim and reached in autumn of that year the full load rotational speed of 12,600 rpm. The combustion chamber module consisted initially of four single combustion chambers, later of five. In ground static operation a total of 50.6 kg/s (111.6 lb/s) of air flowed through the engine, of which 14.8 kg/s (32.6 lb/s) went through the gas generator with the combustion chambers. The design target for the combustion chamber outlet temperature had a very high value of 1,100 ^{o}C (1,373 K), requiring for the turbine an especially sophisticated cooling. At the end of 1943 the development was discontinued on order by the RLM [38]. [...]

[pp. 248–249:] **Turbine Cooling for the Daimler-Benz DB 109-007**

The development of turbo-jet engines at Daimler-Benz in Stuttgart-Untertürkheim began on request by the RLM in 1940/41. Preliminary work concerning the blade cooling was carried out under the leadership of *Karl Leist*, who came from the DVL in 1939, on exhaust-driven turbo-superchargers for the Daimler-Benz altitude engines. Because the bypass engine DB 109-007 possessed a turbine entry temperature of 1,100 ^{o}C (1,373 K), the single-stage axial turbine had to be cooled. A partial bleed of cooling air from the bypass flow duct was chosen, which was supplied via slots from the secondary air duct. Preliminary tests for these methods were performed at Daimler-Benz on exhaust gas turbine wheels also already at high gas temperatures. For supplying the cooling air a radial blade ring on the turbine rotor was responsible, a kind of radial fan. [...]

[pp. 257–258:]

18 Different Authors, DGLR-Symposium “50 Jahre Turbostrahlflug”, Munich, 26/27 October, 1989, Vol. I DGLR-Report 89-05 (1989) and Vol. II DGLR-Report 92-05 (1992) [...]

38 Erinnerungen: 1934–1984 Flugtriebwerkbau in München. Herausgegeben von der MTU Motoren- und Turbinen-Union München GmbH, Munich, May 1984 [...]

[p. 407:] A further aspect of the development of the jet engine was the introduction of the so-called bypass engine as powerplant for civil transport aircraft at the beginning of the sixties and the subsequent increase of the bypass ratio. This led to various research and development tasks of the past two decades and will be dealt with in the following in more detail. Bypass engines were, however, already the subject of investigations at the beginning of the jet engine development and were realized at the company Heinkel as engine He S 10 and particularly in 1943 tested in the successful test-bed runs of the Daimler-Benz bypass engine DB 109-007 with a thrust of 11.3 kN (2,543 lbf) and a bypass ratio of 2.42 [1]. The He S 10 was perhaps the most practical bypass engine that has been designed (1940) in the early days of the jet engine [2].

[p. 469:]

1 K. von Gersdorff, K. Grasmann, H. Schubert, Flugmotoren und Strahltriebwerke. Reihe “Die deutsche Luftfahrt”, Vol. 2, 3. Ed., Bernard & Graefe, Bonn, 1995

2 50 Jahre Turbostrahlflug—DGLR-Symposium 1989 Munich, DGLR-Report 89-05 and 92-05

[How far did work on turbofan engines such as the DB 007 actually progress during the war? How much did German wartime work on turbofan engines influence postwar work on turbofan engines such as the General Electric CJ805-23 (also by German-speaking creators)?]

National Air and Space Museum. General Electric CJ805-23 Turbofan Engine, Cutaway. https://airandspace.si.edu/collection-objects/general-electric-cj805-23-turbofan-engine-cutaway/nasm_A19760792000

In 1956, based on the commercialized CJ805-3 version of the military J79 turbojet then powering the Convair 880, GE began development of an aft fan engine, the J79-X220, later designated CJ-805-23. This uncomplicated and low cost development increased take-off thrust by 40 percent, lowered specific fuel consumption by 15 percent, and reduced takeoff and landing noise. The engine became the first U.S. turbofan and, on the Convair 990 in the 1960s, the first in the world to enter airline service.

George E. Smith and David A. Mindell. 2000. The Emergence of the Turbofan Engine. In: Peter Galison and Alex Roland, eds. 2000. *Atmospheric Flight in the Twentieth Century.* Alphen aan den Rijn: Kluwer. pp. 107–155.
https://vdoc.pub/documents/atmospheric-flight-in-the-twentieth-century-7o4lo0covue0

[p. 127:] Peter Kappus, the principal advocate of the turbofan engine within GE, then began pushing the concept of an aft fan. The idea was to install an independently rotating fan rotor behind the gas generator. The exhaust from the gas generator would drive turbine blades mounted on this rotor, and fan blades would extend from the tips of the turbine blades. This idea dates at least as far back as a Whittle patent [50] and the Metro-Vick counter-rotating fan discussed above. One of the leading academic experts on turbomachinery, G. F. Wislicenus of Penn State University, had promoted its advantages in a talk entitled “Principles and Applications of Bypass Engines” presented at the Society of Automotive Engineers Golden Anniversary Aeronautical Meeting in April 1955. The most obvious advantage of an aft fan from GE’s point of view was that a new core engine would not have to be developed. GE could use the J-79, or what amounted to almost the same thing, its commercial counterpart, the CJ805. [...]

[p. 142] Why then was P&W not the first to come up with a superior turbofan engine? Perhaps P&W had no influential in-house proponent of turbofan engines, comparable to Peter Kappus at GE. But this can at most be part of the answer, for the potential of bypass engines to realize high propulsion efficiency in the high subsonic flight speed range had been known for years, and Wislicenus had called attention to it prominently once again in 1955. So, the answer must also include aspects of P&W's engineering style and orientation. [...]

[pp. 144–145] As a first step toward unraveling this complexity, we can identify the several local factors that lay behind General Electric's developing their first turbofan, the CJ805-23, when they did: (1) persistent advocates of fan engines within GE, especially Peter Kappus; (2) an established gas generator with sufficient specific-power to drive the fan; (3) the aft fan concept, which allowed the turbofan engine to be developed at remarkably little cost; (4) the realization, which emerged in the last years of the NACA supersonic compressor research program, that comparatively high Mach number transonic stages could be designed without first having to learn how to control shocks; (5) the shift of key figures in this research program from NACA to GE, especially Lin Wright; (6) the advent of the computer, allowing the introduction of streamline-curvature methods for analyzing radial equilibrium effects in compressors; (7) the idea of adapting streamline-curvature methods to provide a through-blade analysis that could define a blade contour precisely tailored for the significant radial redistribution of the flow that occurs within a high pressure-ratio transonic blade row. Three other factors may have been important in GE's decision to commit money to developing the CJ805-23: (1) Rolls-Royce's Conway engine, perceived perhaps by some as heralding the advent of bypass engines; (2) Pratt & Whitney's overwhelmingly dominant position in high-subsonic flight, achieved initially through their J-57 on the B-52 and then in the process of being repeated by the commercial version of the J-57, the JT3C, on the Boeing 707 and Douglas DC-8; and (3) Wislicenus's talk at the SAE Golden Anniversary Aeronautical Meeting, promoting the concept of an aft fan engine.

[For more information on the postwar work of Peter Kappus, Bruno Bruckmann, and other German-speaking creators who produced jet engines at General Electric, see pp. 1750–1763.

Anselm Franz's team produced the first high-bypass turbofan engine (PLF1) at Lycoming after the war; see pp. 1732, 1739–1743.]

R. P. Linstead and T. J. Betts. 15 September 1945. *The Intelligence Exploitation of Germany. Report of Combined Intelligence Objectives Subcommittee.* G-2 Division, SHAEF. Ch. 4, pp. 37, 62–67. [AFHRA A5186 electronic version pp. 904–1026]

Certain items have been omitted because of security considerations. [...]

German progress in aerodynamics, particularly aircraft capable of super-sonic speeds, was the subject of intensive investigation by British and U.S. specialists. A wind tunnel, which is considered as probably the most advanced in the world was discovered near Kochel in the Bavarian Alps. This tunnel, with a test section 40 inches square, was capable of developing wind speeds of 3,360 miles per hour by utilizing only 880 kilowatts of electrical power. The maximum wind speed which could be obtained by this tunnel approached a Mach No. of 7.6 or 5,800 miles per hour. The power plant of this wind tunnel had a rated capacity of 57,000 horsepower.

The exceptional testing facilities provided by the German super-sonic wind tunnels made possible aerodynamic research by German experts which, at this writing, appears to be more advanced than any similar development in the United Kingdom or United States.

Perhaps the most important aerodynamic intelligence obtained related to the “swept-back” wing. Many authorities believe the development of the swept-back wing had never received the attention it deserved in British and United States aero-research establishments. Investigation of new German models and prototypes incorporating these wing features has disclosed apparent advantages. The sharply swept-back wing results in a substantial increase in the critical Mach number in speeds approaching supersonic velocities, therefore the development of shock waves and excess drag at extremely high speeds is minimized.

A second enemy aerodynamics development of perhaps equal significance is the trapezoidal wing. When tested at supersonic speeds, this type of wing has resulted in improved ease of control due to the slight shift of “center of pressure” in relation to center of gravity occurring when this wing design is used.

It was discovered that German designers had placed considerable emphasis on air duct designs for high-speed aircraft. An important design feature for which full data has been obtained is that of a center rod placed in the air duct. This device minimized pressure build-up and eliminated shock waves.

A research airplane known as the DFS-346 had been designed for the purpose of testing all flying qualities at extremely high speeds in the free air. This prototype was designed to test stability, controllability, maneuverability, the values and distributions of the forces of directional controls on the wing and on the tailplanes, and other essential conditions of flight. This plane was to be capable of a 1,250 miles per hour speed and a 66,000 foot ceiling. Investigation of German aerodynamic research records and interrogation of leading design personnel has disclosed that tests of aerodynamic speeds in wind tunnels did not always agree with actual tests of prototypes in the free air. The DFS-346 was designed for further research into the unknown conditions of supersonic speeds, notably the pronounced shifts of the center of pressure.

Of probably equal importance was German research activity in jet and rocket propulsion. Enemy developments in these latter fields were in general more advanced than our own. Interesting discoveries were encountered in the design of combustion chambers for greatly increased thermal efficiency and minimum pressure loss. Enemy technicians had devoted energy and skill to the design of jet turbine blades capable of withstanding extreme stresses and high temperatures. A particularly interesting development is that of the ceramic metal turbine blade which was molded with a composition of 100% metal at the rotor end of the blade with a gradual decrease in metal content until the composition became 100% ceramic at the blade tip. This type of construction had the advantage of providing the strength of metal at the base of the blade, where the greater stresses occur, and the heat resistant qualities of ceramics at the outside tip where temperatures are most extreme. Other innovations of blade design provided ingenious air vents or water-circulation-blade cooling. Hollow steel blades were discovered which possessed considerable advantage over blade types previously known. Another discovery was a construction and assembly technique in the production of turbine blades and rotors which used a novel method of welding pressed-steel materials. This method eliminates the cost of extensive machining and slashes man-hours required from approximately six hundred to ten.

German design of automatic controls for jet motors are believed to hold much promise when applied to similar work in the United States and the United Kingdom. These controls automatically regulate fuel ratios for optimum performance under given conditions. It was discovered that German jet motors normally incorporated bullet shaped devices which could be moved back and forth in the jet outlet varying the area of the nozzle, thereby keeping the engine working at maximum efficiency and economy.

A vast amount of enemy development on jet fuels was discovered. Test and development data covering 1,100 different fuel combinations have been obtained as a result of CIOS investigations. Of special importance are the German “multi-fuels” which provide specific chemical-dynamic characteristics for given combustion chamber designs. Fuel and water injection for turbojets permitted development of sudden bursts of speed when required. Test results indicate that a 14% increase in jet thrust can be sustained for five minutes.

[...] A new enemy method of attaching fins to air cooled engines is expected to provide a substantial saving in labor and expense.

United States and British experts were impressed with the extremely compact and simple arrangement of engine accessories in integral power units. The methods used have resulted in improved engine serviceability.

Investigation of German accomplishments in the aircraft instrument field revealed a new process which permits winding of potentiometers with very fine wire (approximately 1000th of an inch in diameter). This process permits extremely refined control by automatic pilot operation.

Roy Fedden. German Plans to Revolutionise Air Warfare. *Daily Telegraph & Morning Post* 1 October 1945, p. 4.

[...] In the course of two recent visits to Germany, as leader of a technical mission for the Minister of Aircraft Production, I have seen enough of their designs and production plans to realise that if they had managed to prolong the war some months longer, we might have been confronted with a set of entirely new and deadly developments in air warfare.

Atomic Explosives

There is some reason to believe that Hitler had been promised atomic explosives by October of this year, and if Germany had been first to use them the idea of changing the whole course of the war from a small base in the South German Mountains is by no means so far-fetched.

A new range of very high-speed fighters and jet bombers was already flying, or within a few weeks of flying, when the war ended. Immense developments were under way with robot rocket weapons, some of which had already started in production. They were simple and cheap to make, and with atomic explosives even a few such devices could have placed air warfare on a new nightmare plane of impersonal long-distance annihilation such as we have not so far contemplated. [...]

Superb Test Equipment

To an engineer who has seen the wonderful efforts made by the British aircraft industry with the restricted facilities at its disposal during the recent war, and the very small number of available scientists and trained investigators, it is staggering to see the lavish research plant and vast accumulation of most modern test equipment available in Germany.

Their scientific laboratories, supersonic wind tunnels, and high-altitude engine test beds are in some ways ahead of anything existing anywhere else in the world to-day. We witnessed tests of a jet propulsion engine on a high-altitude test plant which was capable of producing wind speeds above 560 m.p.h. and altitude conditions of over 36,000 ft. The plant was superbly equipped, and remotely controlled from a sound-proof room.

The power required to deliver refrigerated air in huge quantities at high speeds, and to run all the auxiliary services, was over 10,000 kw.

The cost of this engine test plant alone was 6,000,000 marks. Extensions in hand would have raised it to 9,000,000 marks, and four other similar establishments were in course of construction elsewhere. [...]

As soon as we depart from the orthodox aircraft with piston engine and airscrew and enter the field of thermal jet propulsion, a multiplicity of possible solutions presents itself, of which the turbine jet propulsion unit, as we now know it, is only one. The Germans tackled every line likely and unlikely, and they had already obtained some wonderful research results from their bold approach and lavish expenditure, but they came just too late to avert defeat. [...]

This thoroughness is typical of the German approach to any new problem, and it was only possible to pursue this course at such a critical period of their history by reason of the large number of highly trained and experienced technicians available.

The first fruit of their labours was, of course, the flying bomb V1. [...I]t was a historic weapon which marks the beginning of the new German conception of air warfare. [...]

When the V2 rockets, travelling faster than sound, began to blast the London suburbs, the pattern of the future became clearer. [...] Right up to the time when our armies overran the launching sites, no defence had been possible against them other than bomber attacks on the factories and assembly points.

Big V2 Output

The ordeal which might have faced the British people if the land forces had not liberated France, Belgium and Holland in time may be gauged from the fact that, at one underground factory I visited, slave workers had been producing V2 rockets at the rate of 1,000 a month, despite our bombing.

It is reported that the V2 attacks were to be supplemented by long-range incendiary rockets, fired from bomb-proof emplacements, and underground rocket guns with barrels of unprecedented length were being constructed on the invasion coast for the bombardment of London.

Another new weapon which was already in production, and had been used experimentally against our bombers over Germany, was an inter-aircraft rocket, fired from an aircraft shadowing the bomber formations at a safe distance, and controlled by a wire paid out from a spool. It had a speed of 620 m.p.h. and carried a warhead of 110 lb. It could be made in ten hours and cost only 250 marks.

Guiding V3 to Target

Even more interesting was the Schmetterling or Butterly, to be known as V3. This was a rocket missile to be fired from the ground, to defend very important targets against our bombers. It was beautifully shaped, with sharply swept back wings of about 7 ft. span, and had a speed of from 560 to 620 m.p.h.

It was controlled initially by radio, but was being developed with an acoustic "ear" and photo-electric "eye," which would enable it to follow and strike down the bombers automatically, once ground control had guided it into the vicinity of the attacking formations.

The rocket motor weighed a mere 350 lb, took less than 60 hours to make, and cost about 500 marks, but for a short period it gave a thrust greater than the most powerful aero engine or jet propulsion unit in production to-day, and it was said to be effective up to 30,000 feet. It was reported to be in production at the rate of 1,000 a month at one factory alone.

At the opposite extreme, some of the German designers had found time to scheme out proposals for passenger-carrying rockets which would cross the Atlantic in under an hour, but this was the only case of any interest in peaceful aviation which I heard of during my two visits.

Huge Power at Low Cost

[...] The new German rocket motors were in effect compact and very neat editions of the big V2 rocket unit, using a mixture of nitric acid and a hydrocarbon as fuel. Their fuel consumption is enormous, and their duration correspondingly short, but they give tremendous power at negligible cost, and every possible application for them was being explored. [...]

The Me. 262, first jet-propelled fighter to go into action in the war, was a practical machine capable of well over 500 m.p.h., but with two small rocket thrust augmenters, each giving about 2,700 lb thrust in addition to the 1,700 lb thrust given by each of its main engines, it was capable of phenomenal performances for short periods and was credited with climbing to 39,000 feet in three minutes. The thrust augmenters are permanent attachments which can be used as required by the pilot as long as the fuel lasts.

All possible drive was going into the development and production of both rocket and jet propulsion units. The jet propulsion turbine units, the Jumo 004 and the B.M.W. 003, were already in series production when the war ended, and experimental work was well advanced on a new range giving much higher powers.

The most modern production plant had been assembled in new bomb-proof underground factories, and by the spring of this year jet unit production was up to between 2,000 and 3,000 a month. By the middle of 1946 production was scheduled to reach a rate of 1000,000 jet units a year.

The German jets are in several ways not as efficient as our own, but they have certain features, such as air-cooled turbine blades, and small overall diameter, which merit careful study, and they are designed for rapid production at minimum cost.

German aircraft designers were working against time to produce an entirely new range of very high-speed fighters and bombers, using turbine and rocket jets.

Rocket-Driven Fighter

The little Me. 163, the only rocket-propelled fighter of the war, although actually a failure, was a remarkable experiment and indicates the shape planned for German high-speed aircraft if the war had continued.

It has a rocket motor weighing perhaps one-tenth as much as the engine and airscrew of a conventional fighter, and costing a fraction of the price. It has no tail and its wings are sharply swept back, so that it looks rather like a boy's paper dart. Its duration is short, but it is extremely fast and represents a conception capable of great development.

Two new Messerschmitt turbine jet fighters designed to do over 600 m.p.h. were being built on similar lines, with sharply swept back wings and very small fuselages carrying equally swept back tail surfaces. I saw one of these, which was within a few weeks of flying when the war ended.

The German technicians admitted that recent research work evolved in their superb wind tunnels at Goettingen and Volkenrode, near Brunswick, had completely revolutionised their ideas on the shape of high-speed aircraft, and they were putting the new conceptions into practice with all possible speed.

A new Horten tailless fighter with two jet engines was said to be nearly ready for flight testing, and Junkers were working on a tailless bomber with four jet engines.

Meanwhile production work was being rushed ahead on new bombers of more conventional shape.

Flight at Speed of Sound

Everywhere one found the utmost enthusiasm for jet propulsion for military aircraft. Aircraft designers said it simplified their airframe design problems, and in one case it was claimed that a new jet fighter had flown within seven months of the inception of the project.

Their many high-speed wind tunnels and elaborate laboratory equipment had already yielded a fund of data with which the Germans were confidently tackling the problems of flight at sonic speeds. [...]

[For more information on the postwar British "Fedden Mission" to investigate and appropriate German technologies, see:

Roy Fedden. 1945. *The Fedden Mission to Germany: Final Report.* U.K. Ministry of Aircraft Production.

John Christopher. 2013. *The Race for Hitler's X-Planes: Britain's 1945 Mission to Capture Secret Luftwaffe Technology.* The Mill, Gloucestershire: History Press.]

U.S. Air Forces in Europe. 1946. [AFHRA C5098 electronic version pp. 586–602; http://www.indianamilitary.org/FreemanAAF/OperationLusty/OperationLusty-s.pdf]

At a medieval inn near Thumersbach near Berchtesgaden, early in May 1945, the German General Air Staff patiently awaited the outcome of surrender negotiations taking place in the North. They had arrived by car and plane during the past weeks, when the fall of Berlin was imminent, and had kept in contact by radio with Admiral Doenitz at Flensburg. Through the interception of one of these messages, their location, which had previously been unknown, was discovered. Within twenty-four hours Lt Col. O'Brien and his small party, representing the Exploitation Division of the Directorate of Intelligence, USAFE, had arrived, located the party and conducted the first of a series of discussions with General Koller, who was then in command. All documents and records that had been brought by the High Command were immediately turned over, and the first unearthing of buried records and documents, in and around Berchtesgaden, as well as the initial interrogation of the staff officers present, took place.

A casual remark made by a technical engineer, who stated that he had recently been offered a position in Japan, led to his being thoroughly interrogated for significant technical information. As an aside, and what he probably considered a relatively unimportant incident, he stated that less than a month ago, about the middle of April, ten submarines heavily loaded with the latest German equipment relative to aerial warfare, were dispatched from Kiel to Japan. When Lt Col. O'Brien was thus informed he immediately advised the Directorate of Intelligence, USAFE, who in turn notified the Japanese Intelligence Section of SHAFE. A cable was then dispatched to all commands.

In every theater of war, all vessels in ports and at sea were notified, and one of the biggest searches ever undertaken during the war for submarines was initiated. What route they had taken, whether they had gone alone or together, no one knew. But so extensive was the search and so carefully was it executed by warships of all Allied nations, that by the end of June, six of these ten submarines had been captured intact, some a relatively short distance away from their bases, others perilously close to Japan.

In a mountain side near the camp of the German Staff officers, an air raid shelter had been blocked up and then carefully covered and concealed with dirt. Its presence was eventually revealed by the officer who had directed this concealment, but only after he had noticed that a hole, large enough for a man to crawl through, appeared in one or the sides. Thinking that the cache had been discovered, he explained to the USAFE party the location of the shelter, informed them that he had been in charge of the burying of some extremely important records of the High Command, and would be glad to supervise their excavation. When the contents were eventually removed, one important document after another was laid out and carefully examined. One file contained correspondence from 1 Gruppe/6 Abteilung, German Air Ministry Intelligence, dated January 1943 to March 1945, concerning the supply to Japan of all types of equipment for aerial warfare, including models of Me 262 and Me 163, quantities of V1 equipment, high explosives, incendiary bombs, bomb sights, radar apparatus of all description, including models of the Wurzburg and Freya radio and signals installations, telephone, teleprinters, and so forth, and all types of aircraft parts. Another contained the precise location of every plant in Japan presently engaged in the manufacture of the latest aerial plane designs, every research institution connected with the Japanese Air Force, and, many vital targets hitherto unknown and unsuspected by Army Air Forces Intelligence officers. These volumes were flown at once to Washington, D.C., and shortly thereafter bombers of the 20th Air Force were doing precision bombing of the secret targets whose existence had been disclosed in the documents captured at Berchtesgaden.

A report reached Lt Col O'Brien's party that a "strange aircraft" had been seen in a mountainous retreat near Salzburg. Investigation quickly determined that this "strange aircraft" was a jet-propelled helicopter, the only one of its kind in the world. The inventor and his entire staff, who had laboriously worked ten years to perfect it, were present, guarding his invention as one would a precious jewel. The helicopter was examined, and a preliminary superficial interrogation of the staff was sufficient to reveal its tremendous importance. It was carefully loaded in a large truck and taken to Munich. From there it was sent across Europe to France, placed on a boat and shipped to Wright Field, together with the confiscated notes, drawings, and meticulous records of experiments conducted by the scientist and his assistants. After lengthy and detailed interrogations of these persons by technical experts assigned to USAFE, the men were sent to P/W cages. After ten years of labor they were left with only their memories of a remarkable technical achievement. The only jet-propelled helicopter in the world had been found and disposed of in such a way that it would prove advantageous to American scientists and the government.

The presence of the USAFE party at Berchtesgaden before surrender negotiations had been concluded, the interrogation of a technical engineer and the subsequent seizure of six submarines, the unearthing of a detailed list of important and unknown Japanese laboratories, plants, and factories, the finding of a jet-propelled helicopter, and invaluable documents and records of the German General Staff, was neither accidental nor the result of fortuitous circumstances, but rather the outcome of a well-defined and executed policy known as "OPERATION LUSTY", which was the code designation for a project with a priority equal to those of military operations that had been put into immediate effect in April 1945. This project was a combined effort of the Exploitation Division of the Directorate of Intelligence, USAF, and the Disarmament Division of the IX Air Force Service Command. Its mission was the complete and minute exploitation of air intelligence and technical air objectives in liberated and hostile countries, which at that time were divided up into zones either already occupied or to be presently occupied by the 6th, 12th, and 21st Army Groups.

There was a substantial foundation for the belief that the Germans had made many, if not all, of their recent scientific developments available to the Japanese. The knowledge of these developments, consequently, was vitally needed to devise effective technical and tactical countermeasures, and to insure the technical superiority of our own equipment in the war in the Pacific. In February 1945, officers at Wright Field had prepared a list of enemy equipment, which subsequently became known as the CATEGORY "A" LIST, that they desired for technical intelligence and research purposes necessary for the execution of the above needs. This list, which was later supplemented and revised in the light of discoveries made, became the guide and working manual for teams later sent into the field by the Exploitation Division to discover, guard, and dispatch material for the expressed intelligence purposes. Headquarters, Army Air Forces, also prepared a large detailed pamphlet entitled "Air Staff Post Hostilities Requirements", which was an outline of proposed studies to be written on the German Air Force from evidence subsequently to be unearthed, discovered, and captured by members of the Exploitation Division. Thus, the exploitation logically fell into two categories: Technical and Non-Technical.

The Technical Intelligence Objectives were classified in two categories: (a) equipment or documents of immediate interest and value to technical research centers in the United States for evaluation and immediate application in the war against Japan, and (b) equipment or documents of interest to technical research centers in the United States for extended period of study and development. The Non-Technical Intelligence Objectives included the obtaining of equipment and information that would fulfill, in part, the requirements as outlined in the "Air Staff Post Hostilities Requirements". In general, these included the finding of such material as would enable officers to prepare scholarly reports on every aspect of the German Air Force: Organization & Personnel, Records & Reports Systems, Tactical Employment, Training, Installations, Air Defense, Maintenance & Supply, Aviation Medicine, Intelligence Organization and Procedures, Flying Safety, and Weather.

To handle, expeditiously, captured German aeronautical and industrial equipment the Directorate of Intelligence set up three collecting points in the forward area on 1 May 1945: Merseberg, Nuremberg, and Stuttgart airfields. Additional sub-collecting points were also established to feed the main centers. Later, when Merseberg fell under British jurisdiction, after Germany had been divided into zones, it was closed, and Munich, which eventually became the chief collecting center, was opened. Each of the points was maintained by technical personnel thoroughly acquainted with the type of intelligence material desired and the necessary equipment to explore all technical intelligence targets in the areas. An ATI (Air Technical Intelligence) team control section was established at each collecting point to supervise the several hundred mobile ATI teams, which usually consisted of two to four technicians and a driver fluent in German, exploiting both technical and non-technical targets in the forward areas. Captured technical equipment was taken to one of the collecting points where it was flown either directly to Washington or Wright Field, depending upon its importance, or across Europe to shipping ports in France. Technical documents and reports were likewise sent to collecting points and from there to the Air Documents Research Center in London, which was specifically set up to receive the thousands of sheaves of documents being sent from the various collecting points in Europe.

These ATI teams, upon whom fell the often laborious task of ferreting valuable information from German civilian scientists and enemy personnel who were frequently reluctant to talk or to tell the truth, were composed of perhaps the most heterogeneous group of men ever collected in the army to execute a valuable and important job. There were Army officers and enlisted men fluent in German, Austrian, Russian and the Slavonic languages, skilled lawyers, scientists, research scholars, historians, and technical representatives from such corporations as Bell Aircraft, Jack & Huntz, Western Electric, General Electric, Standard Oil, Sperry, Packard, Boeing, Bendix, Detroit Broach, Remington Rand, and Victor Adding Machine. In six weeks of operation they had exploited more than five hundred important targets and interrogated hundreds of eminent German scientists, research professors, technicians, and workers.

The difficulties encountered by ATI teams sent into the field to investigate a target were numerous and complex, offering, in some cases, no reward, or little at all, after days of laborious travelling, often in foul weather, over deteriorated roads, and after gruelling hours of interrogation in unfavorable circumstances. The information given a team about a target, moreover, was often too vague for quick and successful exploitation, and the quest frequently turned into a sleuthing job with information so scanty that a well-trained detective would have despaired. Excerpts from several reports from such teams present a graphic picture of the discouragement and difficulties so often encountered:

"Of the 11 cases of ZWB (Central Publishing Agency for German Scientific reports) in a chapel", writes an Air Force officer in charge of a team sent to investigate German Research Installations at Schloss Pullach/Aibling in Bavaria, "5 were empty......Herr Becker explained that Herr Strohmeier, the Secretary of the Lilienthal Gesellschaft, had disposed of them....... when the latter showed up, we were able to interrogate him in Becker's presence. The result was a considerable flop on the part of both gentlemen, since Strohmeier told an entirely different story. After hours of heated interrogation, Strohmeier gave way and led us to a spot in the garden where we ultimately recovered about a ton of buried documents. There was also a smaller hoard which he yielded up."

In search of additional documents, the President of the Lilienthal Gesellschaft was interrogated at Schloss Pullach, a few kilometers away.

"He had no documents and told substantially the same story as Strohmeier that the documents had been conveyed by rail from the Schloss to a "Tischlerei" in the Mittel Zelle Church. When the French Army approached, Baeumker and Strohmeier first tried to throw the cases of documents in the lake in the hope that they would sink, but that failed. Then they got a number of people together and burned the lot on the beach. This took them two days, and they were barely able to get back to Schlagenhofen and Bibling respectively before occupation."

From Pullach the team went to Ainring in an attempt to locate the Forschungs-Fuehrung. After two days of investigation they found........

"that the greater part of the important documents was gone, and that the place had, in general, been cleared of interesting documents by occupying troops as well as looters, although a substantial quantity of peculiar airplanes and mechanisms remained on the field ....we found our main problem the necessity of locating the "Forschungs-Fuehrung, over which Georgii had presided.

After much travelling in quest of the members of the "Forschungs-Fuehrung", the team located some of them on a cart road near a swamp.

"These people were briefly interrogated and proved to have very few documents or anything else left all parties told the same story of the fate of the major portion or their records, namely, that they were destroyed by fire and bombs in a raid. The Germans in the area were thoroughly spoiled and had lost most of their rear of us."

In locating desired target intelligence, teams all too frequently found German personnel reluctant to reveal the location of missing material, which, they claimed, was usually either already burned, destroyed, or forever lost. They manifested a reluctance to speak, deliberately lied to mislead, the intelligence workers, or feigned complete ignorance of the subject under question. One team captain in a report of a trip that took his party to survey the Luftfahrtforschungsanstalt found that....

"there was always some kind of a Restkommande" Jerry waiting to give a conducted tour of whatever we were investigating; generally someone surprisingly well informed The appearance of these various individuals so ready to collaborate with us is part of a pre-arranged plot controlled by unknown parties with the following objectives:

(1) To keep a close check on our activities and to learn our purpose from our questions.

(2) To establish themselves, especially in the factories and other concerns, as a kind of quisling government, operating under our nominal and their actual control.

(3) To guide us away from really important information.

(4) To make themselves indispensable and so keep alive the framework of the IVth Reich.

(5) To sow dissension among the various allied governments. (This might easily take the form of claiming that certain vital records have fallen into the hands of another government.)”

But, on the other hand, there were many scientists willing and anxious to collaborate and work for the United States. Various team captains stated over and again in their reports that the better grade scientists were not ill-disposed toward the Allies.

“They seem to regard”, one wrote, “the initial stages of the occupation as a temporary and regrettable interruption of their work, and are interested only in continuing their activities under any auspices. They do not understand why the Allies do not put them to work at once for our purposes. At Gottingen, some asked if they could not get grants of money from American institutions, such as the Carnegie Institute, for resuming their work..... There is no evidence”. he concludes, ’ ”that the war has changed moral values; but rather evidence to the effect that the loss of the war is regarded merely as an unpleasant and passing material incident. The hazard of continuing any scientific war work in Germany, even under the closest supervision, is all too obvious.

Team members often found, after initiating the exploitation of targets, that there were clues at each target which lead to others unknown: these usually were investigated at once. Quite frequently it was discovered that the Germans had almost always abstracted the documents they considered most valuable, generally hiding rather than burning them. Under pressure, however, their presence was revealed, quite frequently in lakes, swimming pools, mines, barns, buried in closed over shelters, tucked away in attic corners or in cellars of houses scattered over the country, in jails, insane asylums, or even grocery stores.

This detailed search throughout Germany, specially made to capture technical equipment to further our war against Japan and to provide research and materials for extended periods of study and development, was responsible far the successful and quick completion of scientific developments upon which the Government had already been directly or indirectly engaged. As ATI ordnance flak, armament, electronics, and other exploitation teams, fanned out in their extensive and exhaustive searches through arsenals, laboratories, factories, supply dumps, and airdromes in Germany, one important high priority target or opportunity and one combined intelligence objective target after another were investigated and exploited to the maximum.

The targets briefly discussed below may serve as illustrative examples of the tremendous scope and nature of exploitation that took place under the name of “OPERATION LUSTY”. One may reasonably be assured, moreover, that in this exhaustive intelligence search nothing of importance escaped detection, examination, and subsequent application. Practically everything of importance that was obtained and accomplished was done so during the first six operative weeks of the project, when it was so imperative that every technical effort be made to bring to a quick and successful conclusion the War in the Pacific.

(1) The Hermann Goering Aeronautical Research Establishment, located near Brunswick, yielded the greatest return in the field of research. Members of the Exploitation Division arrived on the 22nd April to organize and conduct the scientific exploitation of this establishment. Dr. von Kármán, General Arnold’s personal aeronautical advisor, and his Group, remained at this place, on several occasions for periods varying from several days to a week. According to Dr. von Kármán, seventy-five to ninety per cent of the technical aeronautical information in Germany was available at this establishment, and that information on research and development which had not previously been investigated in the United States would require approximately two years to accomplish with the

facilities available there. Information obtained on jet engine developments available at the Goering establishment, it was stated, would expedite the United States development by approximately six to nine months. In less than two months, one hundred and nineteen reports were written on the facilities, the research conducted there, and on the interrogation of many of the German scientists previously employed in the various institutes. The permanent members of the organizing party recovered from localities, as far as 50 kilometers from Brunswick, large quantities of buried and hidden documents and equipment which had been removed by the Germans to prevent their falling into the hands of Allied forces.

(2) During the exploitation of the aviation fuel objective—of which the I. G. Farben Ind. at Ludwigshaven and Leuna, was the largest and most important—concealed documents were uncovered and interrogation of key personnel made with respect to the fuel for the conventional Otto-cycle aircraft engines, fuel for jet aircraft power plants, and fuel for rocket aircraft. All the basic information on these, as they existed in Germany, is now in possession of the Army Air Forces. The exploitation conducted at these objectives indicated that the Germans were more advanced in rocket fuel and chemical supercharging than the AAF, but the material now in our possession is more than sufficient to supply the necessary intelligence on these subjects. A substantial portion of the information on production of aviation fuel and lubricants has already been made available and is in the possession of U.S. agencies and corporations interested in this field.

(3) A document covering a complete source of instruction in the handling of plastic welding, a process which had been employed by the German aircraft industry, was located at Halle. This novel method of fabrication provided for the joining of plastics by flame gas welding and enabled the sections joined together to possess the same strength at juncture as the original material. This information was reported to the AAF for joint study with the Office of Scientific and Research Development.

(4) An acoustic-controlled guided missile research development program, together with operating personnel; was located at Bad Kissingen. The experimental control system developed there contained four electrical circuits that are activated by sound with the intended purpose of launching a rocket-propelled missile into the space occupied by a heavy bombardment formation, and constantly correcting the missile's course by means of incoming sound waves from the aircraft engines. The group of scientists who were engaged upon this development were detained in American custody at the laboratory to develop the program for Allied use.

(5) Athodyd (Lorin Engine) units that developed thrust in excess of 1500 kilograms were uncovered, and sufficient data was in our possession in May 1945 to permit immediate application in the field of high-speed aircraft. production.

(6) High-altitude engine test beds, the most elaborate in the world, which were capable of supplying refrigerated low-pressure air both for engine cooling and combustion, thus simulating atmospheric conditions at approximately 40,000 feet, were found at the BMW plant the largest German plant engaged In manufacturing aircraft engines. The application of these test beds for experiments, intended to assist 'our own manufacturers and thus improve the of efficiency of our aircraft, was initiated at once.

(7) Complete information on the Freya and Reise "G" Wurtzburg and of the Jagdschloss radar equipment was uncovered at the research laboratory located at Koethen.

(8) After the Aerodynamic-Ballistics Research Station at Kochelsee was discovered about 15 May

1945, the Directorate of Intelligence, USAFE, assigned personnel to exploit fully this important target. Over one hundred and ninety German civilian research specialists under their original director, Dr. Herman, continued their work, the results of which, however, were turned over to us More than one hundred detailed reports concerning the station were prepared. The "Kochel Wind Tunnel" located there, had the largest testing sections and the greatest air flow of any known supersonic wind tunnel. It was considered by Army Air Forces of such exceptional importance for research in connection with jet fighter and fighter bomber priority projects that the War Department directed that it be dismantled at once and shipped to the United States. Approximately twenty key German scientists, including Dr. Herman, the director, were removed to America to assist in the reassembling of the tunnel.

(9) Documents of all descriptions and nature were eventually discovered. The records of the German Patent Office, for instance, were found buried 1500 feet underground in a potash mine near Bacha. There were approximately 225,000 volumes, which included secret files. An attempt had been made to destroy them but the resulting explosions brought down a mass of debris which had served to smother the fire. Eventually, the files were evacuated and studied.

(10) Five hundred and eleven microfilm rolls of copies of records of the Oberkommando der Luftwaffe, which was the supreme air force command, were recovered from a mine near Hildescheim where they were hidden. They comprised, for the most part, records of the GAF personnel office, together with statistics on climate at GAF airdromes.

(11) The records of a department of the Speer Ministry, the German Ministry of Production, which dealt with the secret weapons program, particularly V-weapons, rockets and jets, was seized and evacuated through air channels, together with Dr. Rickhei, who was charged with the primary responsibility for the program.

(12) The GAF main equipment depots at Schwein and Kolleda were exploited. The former depot was found dispersed to 53 sub-depots, and although a large proportion of the records was destroyed, sufficient documents were obtained to initiate studies into the GAF system. The Administrative and Quartermaster records of the GAF were recovered from hiding places near Berchtesgaden. The Flying Personnel records, included about 50,000 pilots' qualification cards, together with weather staff records, which were discovered in a swimming pool at Stradtroda. The pilots' cards are of particular value, from an intelligence viewpoint, for future control measures of German air force flying personnel.

(13) Practically the latest type of every German aircraft, some of which never saw combat, eventually were located intact, or a sufficient quantity-of available parts discovered for German mechanics to assemble a certain-type. Usually these were sent across Europe to France, where they were shipped to Wright Field. Occasionally some were flown back. At least one, in some cases as many as ten, of the following, which represent only a fraction of the types, were located, some only after extensive searching throughout Germany, and forwarded to the United States for extended study and development.

> The Messerschmitt aircraft series 1101, 1106, 1110, 1111 and 1112, a series particularly interesting in that it illustrates a phase of coordinated aircraft design into which American aircraft is only now entering; seven rocket-propelled piloted aircraft specifically designed for anti-bomber interception work; a jet-propelled helicopter;
>
> Flettner 282 helicopter;

Horton 9, a flying winged glider;

Ju 88, a radar equipped twin-engine night fighter;

Ju 290, four-engine long range transport;

seven Me 163s, rocket-propelled interceptor fighters;

ten Me 262s, twin jet-propelled fighter-interceptors;

HE-162, single place fighter powered by jet engines;

flying bombs, type V1 single and dual piloted;

Lippisch P-13 Jager, a tailless twin rocket-propelled wing for supersonic speeds;

designs and models of small rocket-propelled piloted aircraft created-for bomber interception work;

three sets of FX-1400, a radio controlled bomb,

and seven complete A-4 rockets (V2s).

Numerous types of aerial equipment and instruments of all models of latest designs were obtained and likewise quickly dispatched for evaluation and study. A specimen of the German secret weapon, the X-4 rocket-propelled, winged, flight-controlled anti-aircraft missile, intended for launching from fighter aircraft against United States heavy bombardment daylight formations, and the new anti-aircraft missile Hs-117, which was launched from the ground, were found and sent to the British Air Ministry for examination.

However great in quantity and extensive in scope the captured equipment, documents, and records of industrial concerns and technical research laboratories were, greater still was the extensive scope of information and salient facts gathered from eminent German scientists, technicians and factory managers through personal interrogations. During the early phase of “OPERATION LUSTY”, ATI teams and skilled American aeronautical engineers and scientists investigating intelligence targets carried out such detailed and extensive interrogations that a wealth of technical information of extreme importance was extricated from brilliant minds once directed to our own destruction. A typical team report submitted after a field trip, vividly illustrates the nature of such interrogations that took place. One team, composed of C. W. Chilson, representing Curtis Wright Company, and E. G. Haven and S. R. Puffer, from General Electric, prepared the following reports after an inspection of the BMW Company and interrogation of their key German personnel:

(a) Outline of Jet Propulsion Development Program Being Actively Followed in Germany.

(b) Outline of Entire Program of Non-Reciprocating Power. Plants Under Development in Germany.

(c) Metallurgical Data Used by BMW on Gas Turbines.

(d) Information on Gas Turbines for Propeller and Jets.

(e) Description of BMW 003 Jet Jumo, Together with the Rocket Assist for the Same Unit.

(f) Description of BMW 801 High Altitude Engine, with Turbo Supercharger and Automatic Control, Together with a Performance Report.

Interrogation reports flowed into the Directorate of Intelligence, USAFE, on such topics as Hollow Steel Jet Turbine Blades, Wind Tunnel Blades, Mica Substitutes, Ceramics, Lacquers, Cements, Buna Rubber, Rocket, Propellants (Fluid and Solid), German Aircraft Engine Types, Safety Fuels, Interferometer Measurements of Pressure Distribution of Wind Tunnel Models, Safety Fuels, Navy Torpedo Models, Temperature Controls on Me Planes, Electrical Controls on Me Planes, Production Design and Manufacturing, Technique Covering Hard Rubber Used in Aircraft Magnetos, Oxygen and Pressurized Cabin Control Equipment. Such reports were immediately prepared and forwarded to Washington for dissemination to various industrial concerns and laboratories for further study and development. Quite frequently it became necessary to keep in custody for extended periods groups of German scientists whose extensive information of the particular subjects precluded the possibility of obtaining for intelligence purposes in one or two interrogations the essence of their knowledge. For this reason, Albert Speer, Director of the German Ministry of Production, together with key members of his staff: Dr. Wurster, designer of the Great Enzian, a rocket-propelled guided missile capable of operating at 53,000 feet with speeds approximating the speed of sound; Professor Willi Messerschmitt; five technical research professors from Darmstad Technische Hochschule; Dr. Alexander Lippisch, who had accomplished important work on aerodynamic designs and supersonic speed flying wings; Dr. Kurt Tank, President and Chief designer of Focke-Wulf; fifteen brilliant scientists and technicians of the Peenemunde Research Institute; and scores of others equally as proficient in their Individual scientific accomplishments, were indefinitely retained for interrogation purposes. When the nature of the work being carried out in German research laboratories was of such vital importance that its completion would materially assist the U. S. Government, moreover, either in the prosecution of the war or in protecting her interests against future aggression, it was found expedient and wise to allow the research professors and technicians to execute their work under American supervision. This was accomplished both in Germany itself and in America, where many scientists were quickly sent during the early summer of 1945. Certain technical objectives, such as The Hermann Goering Aeronautical Research Establishment, the Aerodynamic-Ballistics Research Station, the Aerodynamic Institute & Kaiser Wilhelm Institute, and the Bayerische Motoren Werke, were of such outstanding importance that investigation by specially chosen teams, over extended periods, will be required if everything about them is to be completely exploited.

To catalogue and file the thousands of tons of German documents that were rapidly being discovered throughout the country and then forwarded to one of the three collecting points, the Assistant Chief of Staff (A-2) USAFE, together with the Chief of Technical Intelligence Division, set up in London in June 1945, an Air Documents Research Center, which became the temporary repository for all German air documents. This Center was housed in a six-story building containing approximately 28,000 square feet of usable space. All air documents from the British and American occupation zones in Germany and Austria flowed to this Center. In three months time, alone, over 111,000 tons of such documents were flown from Germany to the Center for processing before being sent elsewhere to one or more agencies interested in the subject.

As the documents poured in, enlisted personnel with a good knowledge of the German language, separated them into technical and non-technical categories. All non-technical documents were then distributed to their proper agencies, while the technical documents received a detailed processing. Each was subsequently catalogued, examined, their worth assessed, and then filed or distributed according to their importance. To assist in the proper screening, it was necessary to prepare a technical German-English dictionary, and a cataloguer's handbook to bring up-to-date the U. S.

Aeronautical Index. Two British agencies of the Air Ministry, A. D. I (K) and A.I.2(g), which were partially housed in the Center, not only met the responsibilities assigned to them by the Air Ministry, but materially assisted in the processing and cataloguing of documents. The U.S. Navy Bureau of Aeronautics also assisted in processing by supplying personnel, microfilm equipment and operators, and film-processing facilities, while twenty-five prominent American scientists and aeronautical engineers, such as Jean Piccard and Dr. John Akerman, University of Minnesota, Dr. Ernest Robischon, California Institute of Technology, Dr. Paul E. Hemke, Rensselaer Polytechnic Institute, and Dr. Richard Hartenberg, Northwestern University, acted in a consulting and advisory capacity. Individual unit libraries within the Center were set up to handle documentary material belonging to giant German concerns. Such libraries existed for the Messerschmitt Company, the ZBW, an organization which existed in Germany for the cooperation and dissemination of all formal technical aeronautical reports, the BMW, the Daimler-Benz, and others. Libraries, as well as sections, were set up to file documents of similar technical nature, such as Aircraft, Armament, Engines, Turbines and Propellers, Electronics, Rockets, Jets, and Guided Missiles. Once the documents were indexed and given a permanent library number, the laborious job of microfilming everything of importance, needed both in England and America, took place. The positive copies of the original microfilms were then sent to U. S. Army Air Forces, U.S. Navy, and British Agencies for further distribution. That which did not lend itself to reproduction by-this method was either photographed, photostated, or blueprinted. Eventually, a German Technical Air Documents Card Index will be prepared and copies distributed throughout Gt. Britain and the United States to Using Agencies, which include the aeronautical industry, government agencies, research establishments and educational institutions. At present, there are two hundred of these using agencies in the United States alone that have already made extensive use of captured German technical information gathered originally by ATI teams-from industrial firms, research institutions, and universities in Germany.

Non-technical documents after leaving the Documents Center were delivered to a combined research agency of USAFE, and Air Ministry known as "A.I.12/USAFE". This section was created in the fall of 1944 to meet the requirements of Post Hostilities planning staffs, and in anticipation of Air Intelligence requirements for the disarmament and demobilization of the German Air Force, as well as a comprehensive long range study of all phases of the GAF. The library on the German Air Force that had slowly been built up by British specialists and American officers under the Directorate of Intelligence, USAFE, prior to "OPERATION LUSTY", became suddenly augmented to such an extent by quantities of documents located by ATI teams that the staff of officers and enlisted men had to be substantially increased. In spite of the tremendous work involved—cataloguing, microfilming, photo-stating, translating, and preparing detailed library lists and reports for dissemination to interested agencies—the staff handled the work in a thorough and expeditious manner. By the time the first Air Force officers arrived from the United States in June to prepare staff studies on aspects of the German Air Force, practically all of the necessary material had been collected and catagorized so that work could immediately. commence.

Eventually, over two hundred officers, chosen, for the most part, by Hq Army Air Forces, from various air force commands in the United States, were engaged in scholarly research to fulfill their assigned requirements. Working from offices located in London and under the direction and guidance of the Assistant Chief of Staff A-2, USAFE, the officers exploited every available pertinent document located in repositories in London, A.I.12/USAFE, Air Documents Research Center, British and American Navy and Army libraries, and the British Museum. It was soon discovered, however, that in spite of the tremendous quantity and excellent quality of captured material available, too many questions remained unanswered and too many enigmas concerning various aspects of the enemy's air force unsolved. It became imperative, consequently, for field trips to be made into Germany in an attempt to fulfill the exact and comprehensive requirement's laid down, not only by Hq Army Air Forces, but by the staff officers themselves, who, through a desire to accomplish a superior research job and obtain for future-reference every iota of information relative to their enemy's strength, weakness, and ambitions of the past and future, refused to satisfy themselves with incomplete answers and results.

Officers preparing a study of German Air Defenses visited the Flak defenses at Bremen, Hamburg, Munster, Nuremberg, and Augsburg, interrogated General von Axthelm, Chief of German Air Force flak units, and his staff, as well as members of various flak organizations, such as the 8th Flak Division, and 8th Flak Brigade. A detailed study was made of the Air Force at Grove, Denmark, where a complete fighter defense installation was captured intact with plotting center and all-key personnel necessary for its operation. Similarly, officers preparing other staff studies made trips that took them as far south as Austria and as far north as Norway in their quest for the desired facts and figures, inspecting supply dumps, aerodromes, and other installations and interrogated appropriate German P/W officers located both in British and American zones.

Most of the detailed interrogations conducted by staff study offices were of members of the German Air Ministry Staff (OKL), which had been captured and held at Berchtesgaden as a combined USAFE/Air Ministry intelligence exploitation target, and of high ranking German army officers detained in P/W cages. When it became evident that many such interrogations would be necessary to fulfill the requirements, the OKL party was removed in toto to a camp close to London. Similarly, important German Ground Officers were likewise sent to England to further the project. Hundreds of detailed interrogations were conducted. To enumerate such German Officers interrogated would be comparable to listing a roster of the German Air Force. The following, most of whom were high ranking officers, is illustrative of the scope covered:

Reichsmarshall Goering.

Oberst von Brauchitsch, Goering's Aide.

General der Flieger Koller, Chief of General Staff.

Major Hermann, Administrative Officer.

Oberst Wolter, General Koller's advisor.

General Maj. von Rohden, Historian of the GAF.

Min. Dir Dr. Benkendorf, Chief Meteorological Service.

General Martini, Signals.

General Lt. von Criegern, General Quartermaster.

Oberst Fritz Nebel, ZRadar Inspector.

General Maj. Hitschold, Chief Ground Attack Operations.

Generalleutnant Galland, Chief Fighter Operations.

Generalleutnant von Massow, Gen. der Fliegerausbilding.

Gen. Oberstabsarzt Dr. Schroeder, Medical Services.

General Maj. Morzik, Luftransport Chef der Wehrmacht.

General Lt. Dahlmann, Flying Safety.

General Galland, a 33-year old flyer, who received his first battle experience in Spain and who has obtained a reputation among Allied officers as perhaps the most brilliant general in the German Air Force, prepared an historical narrative of fighter tactics employed for all campaigns, beginning with the Spanish and ending with the last concerted attacks against Allied fighters and bombers in 1945. This included, in part, a rather comprehensive history of the GAF. General von Rohden and his assistants, under the direction of the historical section, USAFE, prepared a lengthy dissertation on the history of the German theories of the application of air power. General Marzik and his assistants wrote up every airborne ' campaign the Germans had executed, or planned, such as the air invasions of Malta and England. Similarly, to satisfy the Post Hostilities requirements, German officers prepared detailed treatises on every topic intelligence officers wished discussed: medicine, training devices and procedures, weather, flak defenses, fighter defenses and attacks,. photo intelligence, provost marshal system, methods used to evade the Treaty of Versailles, methods used to indoctrinate Nazi principles in the Luftwaffe, and many others.

The first staff study prepared in compliance with the Air Force Post Hostilities Requirements was finished on. the 12 August 1945, the last on January 3, 1946. The list of scholarly studies below, comprising forty-five thick volumes, includes, it is reasonable to state, far more information concerning the German Air Force than the Germans themselves had ever collected during the war:

Communications.

Aviation Medicine.

Flying Safety.

Inspection.

Provost Marshall.

Personnel Administration.

Supply.

Maintenance.

Patent Activities.

Air Defense.

Propaganda in the Luftwaffe.

Records & Reports System, Statistical Controls & Planning Methods.

Tactical Employment: Liaison Operations.

Troop Carrier Operations.

Tables of Organization and Equipment.

> Coordination between the GAF Air and Ground Forces. Controlled Missile Program.
>
> Night Fighter Operations.
>
> Emergency Sea Rescue.
>
> Fighter Tactics employed against Allied fighters, fighter bombers, and heavy bombardment formations.
>
> Photo Intelligence.

Copies of these reports were given to the British Air Ministry and disseminated in America to every interested military command. They will eventually be studied in Staff and Command Schools and the War. College, and may serve as a nucleus for future historians interested in the aerial aspects of the second World War, or, in particular, of an air force once reputed to be the greatest and most efficient ever assembled. The military mistakes made by German Air Force generals, the clash of strong personalities that was so detrimental to their cause and purpose, the magnificent military plans created but never executed, tactics employed, principles of air power devised and used, adopted method of communications, supply, and training, are all lucidly and scholarly presented. In these documents lies the essence, so to speak, of a once sinister and destructive force now so hopelessly crushed that its rebirth appears highly improbable.

“OPERATION LUSTY” is now dead. No longer do ATI teams scour the German countryside exploiting intelligence targets. This work has been completed. The requirements, both technical and non-technical, have been fulfilled: equipment and documents of immediate interest and value to technical research centers in the United States for evaluation and immediate execution towards the war against Japan was expeditiously collected in the early weeks of the project’s existence; Air Staff Post Hostilities Intelligence Requirements were fulfilled; equipment and documents were sent to technical research centers for extended periods of study and development to increase the efficiency of United States aircraft, equipment, and research establishments. There still exists however, strict supervision of eminent German scientists and their assistants, and corporation directors and managers, technical workers, and university professors, who were once employed in scientific research. Many of such personnel are still actively engaged both in the United States and Germany in the furthering of inventions, technical discoveries and formulation of new scientific processes that they were doing directly or indirectly for the German government when hostilities ceased. Certain important corporations such as those previously mentioned, moreover, are still working though the war had never ended; the results of their labors, however, now benefit the United States rather than Germany. If necessary and advantageous, this aspect of exploitation will continue indefinitely. The results that have already been obtained and those that are certain to appear in the immediate future, compensate over and again for the time, effort, and money expended in extricating from the brains of brilliant German scientists every particle of information and knowledge they possess that in any way further the interests of our government.

Nazi Technical Papers Form Research File: Captured Documents Provide Complete History of Air Program. *The Lima News* (Lima, Ohio) 21 November 1947 p. 12.

DAYTON, Nov. 21—(AP)—Any student who ever tried to wade thru just a single page of German translation will appreciate this one:

What were once 1,500 tons of German documents—a complete history of the Nazi air research program from 1933 to 1945—have been evaluated, classified, catalogued, indexed and published in microfilm by air intelligence experts at nearby Wright field.

As a result, American aircraft industries have at their call products of the most intensified aeronautical development program the world ever has known.

Engineers estimated the actual research contained in the captured documents would cost between two and three billion dollars if reproduced today in this country.

The air documents division of the AAF air materiel command's intelligence department discarded 1,450 tons of lesser papers at the beginning of project index. But it handled 55,000 Nazi documents, all written in technical German and using at least 110,000 new German aeronautical terms familiar only to German scientists.

Included were tons of top secret details on the world's first production jet-engine fighter, the Messerschmitt-262; design, production and test information needed to duplicate the deadly V-1 and V-2 missiles, plus hundreds of other ideas ranging from swept-back wings for supersonic flight to formulas for making heat-resistant dyes and synthetic rubber for airplane tires.

Moving spirit behind the job has been a young AAF officer, Col. H. M. McCoy, West Point graduate and holder of two graduate degrees from the California Institute of Technology.

It was McCoy who evolved what seemed a fantastic idea in 1945 when the project actually got down to the work of abstracting and filing.

Colonel McCoy wanted to catalog German documents so they would form a nucleus of a huge file embracing the entire science of aeronautics, a ready-reference catalog which would save millions of dollars and hundreds of thousands of man-hours by avoiding duplications, costly literature searches and wasted efforts.

Suppose an American firm wanted to begin research on a particular type of guided missiles without having previous experience. Suppose that company went thru months of study and costly experimentation, only to find near the final test stage their missile already had been tried elsewhere and found impractical.

With an air catalog such as McCoy envisioned, the firm could have turned to a central government agency before experimentation began and learned the idea was impractical before they wasted time and money.

Colonel McCoy's index dream is in process of being realized. The Institute of the Aeronautical Sciences, under joint Air Force-Navy contract, is compiling the standard aeronautical index, considered the most radical innovation in classification history.

Wright field is serving in a similar manner with its German information. By August, 1947, the air documents division had furnished more than 10,000,000 index cards from its master file to 35 qualified government, scientific and industrial organizations thruout the nation, plus hundreds of thousands of documents in microfilm to 2,500 governmental agencies and contractors.

All captured Nazi documents are microfilmed. From its index, a qualified organization need only ask for a copy of a needed document.

Within 48 hours the requested document is on its way. In an emergency, that time can be cut to a few minutes.

[See the related photograph on p. 2118.

See related descriptions from other sources on p. 2140.

The above article was also published as:

Nazi Files Reveal Research Secrets: Data in Captured Documents Indexed for Air Industry. *The Malakoff News* (Malakoff, Texas) 23 January 1948, p. 4.

Nazi Files Reveal Research Secrets. *Pueblo Indicator* (Pueblo, Colorado) 24 January 1948, p. 4.]

E.2 Advanced Liquid Propellant Rockets

[Official histories acknowledge that Germans designed a two-stage liquid propellant intercontinental ballistic missile, A-9/A-10, during the war, but state that the project never progressed further. For example, Michael Neufeld, Senior Curator at the Smithsonian National Air and Space Museum, wrote: “The A-9/A-10 was never more than a drawing-board concept and was shelved in 1942” [Neufeld 1995, p. 283]. Neufeld also wrote that it was not possible to upgrade single-stage rockets during the war: “Emergency improvisations had less of an impact on the A-4, because its relative technical maturity puts limits on how much further improvement could be extracted in a short period of time” [Neufeld 1995, p. 251].

This section presents evidence that the A-9/A-10 rocket was much more than a paper design, as well as evidence for other wartime work on advanced liquid propellant rockets:

- There were several reports of upgraded wartime A-4 rockets that apparently had been lengthened (and therefore carried more propellant and presumably had higher-thrust engines to compensate) from the standard 14 meters long to 18 or 21 meters, and German teams in the United States, Soviet Union, and France readily built such upgraded versions after the war (pp. 5794–5799).

- David Irving wrote of the giant underground rocket launch complex that Germany built at Wizernes, France during 1943–1944: “The remaining site, at Wizernes, caused some anxiety, as it was not obviously aligned on any city in Europe. One interpreter caused a high degree of alarm early in the year when he discovered that one facet of the workings was within half a degree of the accurate Great Circle bearing on New York. [...I]t is a remarkable fact that the enormous bombproof doors and handling gear were all capable of handling a rocket about twice the height of the A 4[...]” (p. 5311).

- A 26 October 1944 U.S. report derived from a German prisoner of war indicated that there were advanced rocket installations near Erfurt, that two-stage rockets had already been tested up to a maximum altitude of 360 km, that an upper-stage rocket engine had successfully used liquid hydrogen and liquid oxygen, and that research was being conducted on ion rocket engines (p. 5311).

- In July 1944, U.S. Army Air Forces General Henry Arnold stated that the Germans were currently developing “large 75 ton rockets,” over five times the weight of an A-4 (V-2) rocket (p. 5316.

- A 14 December 1944 U.S. report derived from another German prisoner of war stated: “Two types of V-2 have been built: Type A 1, which is about 23 m long and 4.5 m in diameter, and Type A 4, which is about 18 m long and 2.5-3 m in diameter. Only the latter is in mass production... PW heard that German technicians intended to launch them to an altitude of 120 km, which would have permitted them to reach NEW YORK.” The description of the first type does not match the very small and decade-old A-1, but does match the A-10 if a “0” was dropped somewhere along the way (p. 5334).

- On 5 January 1945, Colonel Lowell Weicker at the Headquarters of the U.S. Strategic Air Forces in Europe wrote: "Germany... is leading the world... in long range missiles... A large part of her manufacturing facilities have gone underground and she is bending every sinew for the last stand on the Vaterland frontiers" (p. 5336). A 19 January 1945 report from the Headquarters of the U.S. Strategic Air Forces in Europe further stated: "The V-2, or rocket projectile, with a warhead of approximately one ton, and a current range of 225 miles, is being fired at London at the rate of 180/250 per month, and against Continental ports at the rate of approximately 300 per month... Larger rockets (68 feet in length as against 45 feet) are known to exist, and may appear in small quantities during the year. They would have a considerably larger warhead." The larger rockets "known to exist" sound like an enlarged V-2/A-4 or an A-10, despite the conventional historical narrative's denials of both possibilities (p. 5337).

- According to numerous press accounts on 26 January 1945, the German "head of an experimental station for V-bombs in Jutland" had just defected to Sweden and revealed that the V-3 was "an improved version of V-2," and the V-4 rocket, which could reach New York and other eastern U.S. cities from Europe, was "now in production" (p. 5341).

- In a transcript of her testimony before an East German government inquiry on 16 May 1962, Cläre Werner, a wartime lookout at the Veste Wachsenburg castle near Ohrdruf, reported watching the launch of a large new type of rocket on 16 March 1945 near Rudisleben, as well as being informed of the historic nature of the launch by visiting military and SS officials (p. 5344). In transcripts from the same 1962 East German inquiry, three witnesses (Werner Kasper, Albin Kummer, and Alfred Gründler) who worked at the Rudisleben complex reported seeing the 16 March 1945 rocket prior to its launch and described it as a two-stage rocket over 30 meters tall and over 4 meters in diameter at the base (pp. 5344–5347). Several U.S. intelligence documents mentioned the existence of very large military complexes at Rudisleben and Ichterhausen (pp. 5348–5351).

- In his 1995 autobiography, Otto Skorzeny, who had been a very prominent SS officer during the war, wrote: "Included in the V-weapons program was the construction of a rocket capable of bombarding New York or Moscow. This rocket was practically finished at the end of March 1945 and could have gone into series production beginning in July" (p. 5352). In his 2000 autobiography, U.S. "Mercury Seven" astronaut Gordon Cooper said that Wernher von Braun and his fellow team member Joachim "Jack" Kuettner had privately told Cooper that shortly before the end of the war, Germany had fully prepared a manned rocket capable of reaching New York (p. 5353). In 2000–2002 interviews, Heinrich Himmler's chief adjutant, Werner Grothmann, stated that prototypes of the two-stage "America rocket" were completed during the war, and that a prototype of some sort of large rocket was successfully test-launched on 16 March 1945 in Thuringia (pp. 5355–5359).

- Henry Picker, a close confidant of Hitler, wrote that before the war ended, prototype fission bombs and prototype A-9/A-10 intercontinental rockets were completed and ready, and that facilities for mass-producing the bombs and rockets had been built (pp. 4635–4639).

- A 7 April 1945 U.S. Army report stated that a German prisoner of war "was told by an ordnance man stationed at OHRDRUF that from here a new secret wpn will shortly rise (wird steigen)" (p. 5363). A 9 April 1945 U.S. Army report stated that near Ohrdruf was a large "underground plant. French workers... were escorted by armed guards, not allowed to look right or left... considered to be very important production area" (p. 5363).

- Several 8 April 1945 U.S. Army intelligence documents reported: "...underground factory ... employs some twenty to thirty thousand Russians, Poles, French, etc. They are making the V-4, which is a two man rocket of some sort... weapon then is sent to Weimar..." Another report from the same date clarified that the "gadget holds 2 men" (pp. 5365–5373). 18 April 1945 articles in French and British newspapers gave the accounts of French workers who had just been released from a 24-square-kilometer underground factory, where they had been building V-4 rockets. They also mention that the V-3 was a known, improved, and enlarged version of the V-2 (p. 5376–5377).

- Captain Heinz Stoelzel, a close associate of Wernher von Braun and Walter Dornberger at Peenemünde, was apparently relocated to near Erfurt, Thuringia no later than 3 November 1943, and fled to Switzerland at the end of the war to avoid Allied capture. Shortly after the war, he hand-copied detailed drawings showing the planned A-9/A-10 trajectory to New York and the design of an A-9 with a two-man crew to pilot it to its target. Most of his papers were destroyed after his death, including any information on the A-10 he may have had (pp. 5384–5388).

- A Russian description of German technology captured in 1945 showed a diagram of a complete A-9 upper stage on an A-10 lower stage (p. 5389). At least two A-9 or A-4b rockets were test fired without the A-10 booster in December 1944 and January 1945, and more A-9 rockets were known to have been built (p. 5390). According to a 1947 U.S. Army Air Forces report, one of the German scientists employed in the United States after the war had been developing "a guidance system for the transoceanic A-10 surface-to-surface missile when the war ended" (p. 5398).

- In a 13 May 1945 speech, Winston Churchill said: "When the Americans captured vast stores of rockets of all kinds near Leipzig, ...and when all the preparations being made on the coasts of France and Holland could be examined in detail ... only just in time did the Allied armies blast the viper in his nest. Otherwise the autumn of 1944, to say nothing of 1945, might well have seen London as shattered as Berlin" (p. 5398). Newspaper articles from 14 June 1945 reported that according to Allied investigators and German scientists, 3000-mile-range rockets would have been mass-produced by fall 1945, or even sooner if Allied bombing had not delayed the program (pp. 5402–5403).

- On 26 June 1945, Henry Fowler, Director of the Enemy Branch of the U.S. Foreign Economic Administration, testified to a U.S. Senate committee: "According to recent reports from Germany, it appears that if the Germans could have held out only 6 months longer they would have been able to smash New York City with improved V-2 bombs... It is not necessary here to elaborate upon the terrifying scientific discoveries which our economic and industrial intelligence is gradually uncovering as we work beneath the lid in Germany. With the memories of her new V-weapons fresh in our minds, little needs to be added except to point out that they just didn't appear out of thin air." It would be impossible to go from paper plans to deployed intercontinental ballistic missiles within six months, so the rockets must have been far beyond the paper design phase in May 1945 (p. 5206).

- On 27 August 1945, Consolidated Vultee Aircraft Corporation (Convair) stated in *Life* magazine: "Especially in the last months of the war, our margin of safety was slimmer than most of us suspected. Just how slim it was is known best to certain American military experts who have since inspected some of Germany's underground research laboratories and war plants. Here they saw secret weapons in various stages of development... weapons which might conceivably have turned the trick for the Nazis if they could have used them boldly in a last desperate gamble. Some of these things can now be revealed. Others cannot—yet... In a V rocket plant, burrowed 800 feet deep in limestone rock, our technicians found blueprints for a fearful V bomb with an estimated range of 3000 miles. 'We planned to destroy New York and other American cities starting in November,' said a German rocket engineer" (p. 5208).

- On 29 August 1945, Secretary of the Navy James Forrestal announced that Germany had been actively developing "at least two or three rockets which represented advances over what we call V-2" (p. 5441–5443). A 15 September 1945 U.S. intelligence report stated that "experiments had already been conducted on piloted models" of long range missiles, and that the missiles were intended to carry atomic explosives (p. 5444–5445).

- In October 1945, U.S. Army Air Forces General Henry H. Arnold testified to Congress that "German V-2 bombs alone, perfected with wings, radar and electronic devices, can now travel over 3000 miles and at 2000 miles hit a target on the button" (p. 5454. In December 1945, U.S. Army Air Forces General Carl Spaatz wrote regarding rockets: "The Germans were readying a transatlantic model when the war ended" (p. 5465). In General Arnold's 1949 autobiography, he wrote: "The V-10 (A-10), a very large rocket intended especially for New York, was being built" (p. 5466).

- In November 1945, numerous newspapers reported that a Swedish spy who had been working undercover in the German rocket programs provided detailed evidence that Germany had been developing the "V-10, which... was to cross the Atlantic in thirty-five minutes and devastate American industries and cities," and also "it should be possible to cruise around in space under human control" (p. 5458–5459).

- In a 7 March 1946 presentation to the Society of Automotive Engineers, U.S. Army Air Forces Colonel Donald L. Putt, who was in charge of the aerospace engineers, documents, and prototypes brought back from Germany, stated: "The Germans were preparing rocket surprises for the whole world in general and England in particular, which would have, it is believed, changed the course of the war if the invasion had been postponed for so short a time as six months... The most highly publicized missile of the Germans was the V-2, or as the Germans themselves knew it, the A-4. There were 10 variations of this weapon... Three were prototypes. Four were improved models. One was a launching device intended to increase the already great range to 5000 km. Interestingly enough, one of the improved models was to be equipped with wings, wheels, a pressurized cabin, and to carry a pilot" (p. 5472).

- A U.S. Army card catalog of intelligence documents shows that the U.S. government once possessed a complete history of the A-9/A-10 trans-Atlantic rocket, written two years after the war's end, but that this history was either destroyed or not transferred to NARA with the other files; no copies of this report have ever been located. If the A-9/A-10 never entered active development during the war, why would the U.S. government have commissioned a detailed history of its development in 1947, and why would the government have later ordered that history to be suppressed? Does the fact that the Army Assistant Chief of Staff for Intelligence specifically filed this report under "Nuclear Physics (Atomic Energy)—Uses" indicate that the A-9/A-10 had a nuclear warhead (p. 5485)?

- In December 1946, many newspapers reported that Wernher von Braun said that before the war ended, he and his team had been developing a rocket with a launch mass of 100 tons (approximately seven times larger than an A-4 or V-2 rocket) that was specifically designed to carry a mysterious explosive payload of six tons from Germany to the United States (pp. 5496–5497). A six-ton payload would have been beyond the capability of even an A-9/A-10, so was this an even more powerful rocket? Why was it so important to carry a six-ton payload? Even a fission bomb would be smaller. Was the intended payload a hydrogen bomb?

- A number of 1945–1947 U.S. intelligence reports indicated that Soviet forces had restarted production in German rocket factories including wartime rocket factories in the Erfurt area, plants producing hydrogen as well as oxygen, and factories producing manned A-9 rockets apparently manned. The reports also mentioned rockets called the V-3 and V-4 that were larger than the V-2, had longer ranges than the V-2, and were successfully produced in Germany and/or Bohemia during the war. From the described dimensions, these V-3/V-4 rockets were apparently not the A-9/A-10, but rather some roughly comparable long-range rockets that had been designed and produced in parallel with the A-9/A-10 (pp. 5503–5572).

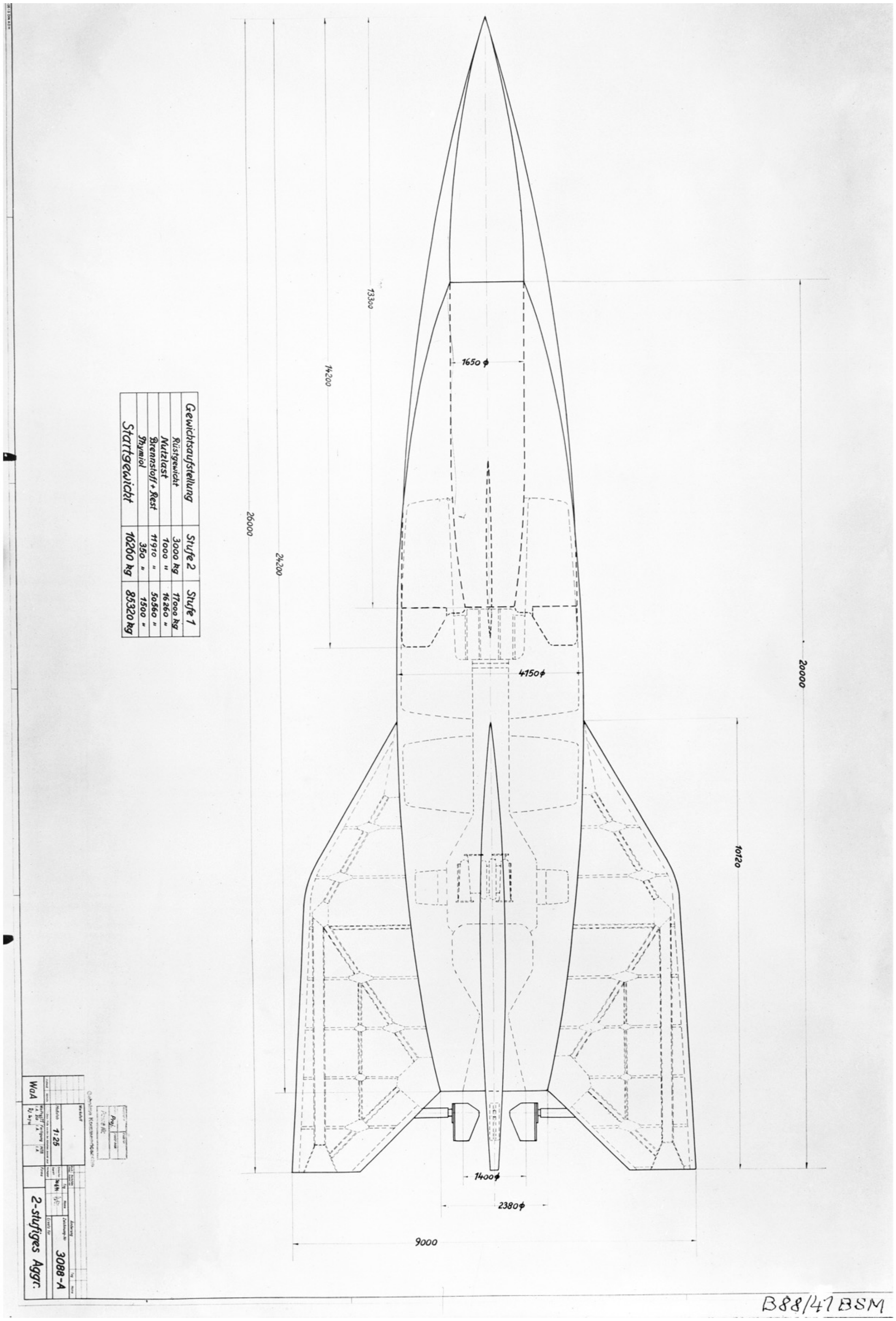
- A 1957 U.S. Air Force report stated: "A program known to the Germans as the A9/A10 development was designed to use a winged V-2 rocket as the second stage of a two-stage system. This vehicle was under development and test by the Germans when the war ended" (p. 5603).

These large wartime liquid propellant rockets and their creators led directly to the postwar development of large liquid propellant rockets in Allied countries, including modern intercontinental ballistic missiles (the second component of the nuclear triad) and launch vehicles for satellites and spacecraft.]

Ernst Klee and Otto Merk. 1963. *Damals in Peenemünde—Ein Dokumentarbericht.* Oldenburg: Gerhard Stalling. p. 99

Die Interkontinentalrakete, heute eine Selbstverständlichkeit, schwebte den Peenemünder Wissenschaftlern und Ingenieuren bereits 1940 vor—lange, ehe das Aggregat 4 überhaupt flog. Aus ersten Überschlagsberechnungen entstand das Projekt A 9/10, dessen hier wiedergegebene Zeichnung vom 10. Juni 1941 stammt. Das gesamte zweistufige Aggregat hatte ein Höhe von 26 Meter, war also größer als die heutigen amerikanischen ICBM. Das Startgewicht sollte 85.3 Tonnen betragen, wovon auf die zweite Stufe—eine ungeflügelte oder eine geflügelte A 4—16.2 Tonnen entfielen. Flugbahnberechnungen, die man damals anstellte, deuten darauf hin, daß man mit einer weiterentwickelten zweistufigen Kombination von West-Frankreich oder Portugal aus über den Atlantik hinweg Nordamerika zu erreichen hoffte. Da man jedoch nur einen Sprengkopf von 925 Kilogramm hätte befördern können, wäre dies militärisch ein ziemlich sinnloses, weil zu aufwendiges Unterfangen gewesen—höchstens geeignet, einen moralischen Effekt zu erzielen. Aber wie bei allen Projekten kam es den Peenemündern auch hier nicht unbedingt nur auf die Waffe an. Daß sie die ersten waren, die den Gedanken einer von Kontinent zu Kontinent fliegenden Rakete faßten, bleibt ihr Verdienst.

The intercontinental rocket, today a matter of course, was already in the minds of Peenemünde scientists and engineers in 1940—long before the Aggregate-4 even flew. The first estimated calculations resulted in the project A-9/A-10, the drawing of which shown here [p. 5271] dates from 10 June 1941. The entire two-stage aggregate had a height of 26 meters, which was larger than today's American ICBM. The take-off weight was to be 85.3 tons, of which the second stage–an A-4 without or with wings—comprised 16.2 tons. Flight trajectory calculations made at the time indicate that a developed two-stage combination could hopefully travel from Western France or Portugal to North America across the Atlantic. However, since only a 925 kilogram warhead could have been carried, this would have been a rather pointless military endeavor, as it would have been too costly—to achieve an effect on morale at most. But as with all projects, the Peenemünde people did not necessarily only care about the weapon. That they were the first to grasp the idea of a rocket flying from continent to continent remains their credit.



Gewichtsaufstellung	Stufe 2	Stufe 1
Rüstgewicht	3000 kg	17000 kg
Nutzlast	1000 "	16260 "
Brennstoff + Rest	11910 "	50560 "
Thymiol	350 "	1500 "
Startgewicht	16260 kg	85320 kg

13300
14200
26000
24200
1650 ⌀
4150 ⌀
20000
10120
1400 ⌀
2380 ⌀
9000
WaA
1:25
2-stufiges Aggr.
3088-A
B88/41 BSM

Figure E.25: 1941 design for A-9/A-10 two-stage intercontinental rocket [Deutsches Museum Archive, photo 9664].

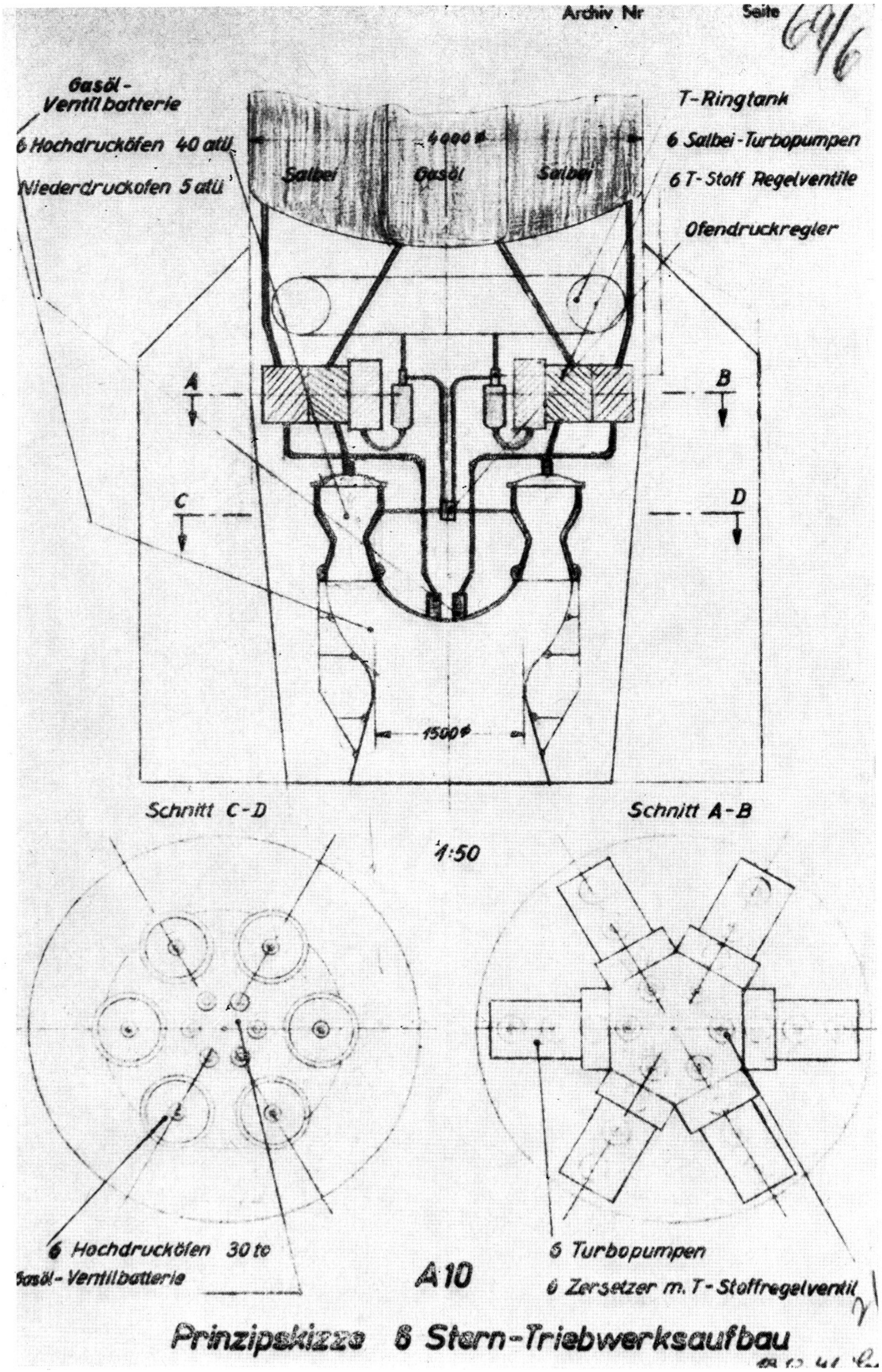

Archiv Nr
Seite
69/6
Gasöl-Ventilbatterie
6 Hochdrucköfen 40 atü
Niederdruckofen 5 atü
T-Ringtank
6 Salbei-Turbopumpen
6 T-Stoff Regelventile
Ofendruckregler
4000 ⌀
Salbei
Gasöl
Salbei
A
B
C
D
1500 ⌀
Schnitt C-D
Schnitt A-B
1:50
6 Hochdrucköfen 30 to
Gasöl-Ventilbatterie
6 Turbopumpen
6 Zersetzer m. T-Stoffregelventil
A10
Prinzipskizze 6 Stern-Triebwerksaufbau

Figure E.26: A-10 rocket engine design using six A-4 engines connected to one large shared exhaust nozzle [Deutsches Museum Archive, photo 32307; Klee and Merk 1963, p. 100].

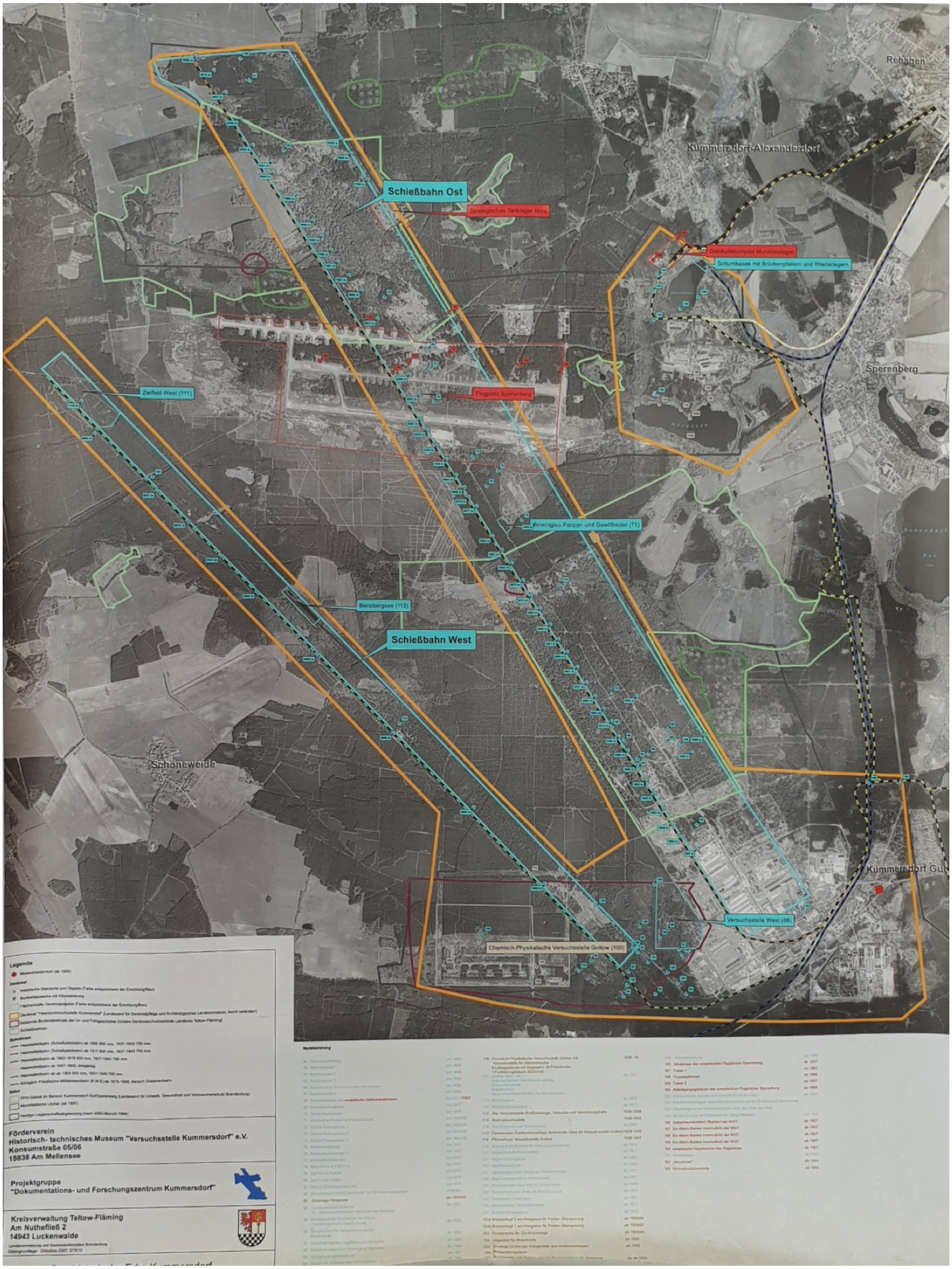

Rehagen
Kummersdorf-Alexanderdorf
Schießbahn Ost
Strategisches Tanklager Nord
Gebäudekomplex Munitionslager
Schumkasse mit Brückenpfeilern und Widerlagern
Sperenberg
Zielfeld West (111)
Flugplatz Sperenberg
Vereinigtes Panzer- und Gewölbeziel (71)
Benzbergsee (112)
Schießbahn West
Schöneweide
Kummersdorf Gut
Versuchsstelle West (58)
Chemisch-Physikalische Versuchsstelle Gottow (100)
Legende
Förderverein Historisch- technisches Museum "Versuchsstelle Kummersdorf" e.V.
Konsumstraße 05/06
15838 Am Mellensee
Projektgruppe "Dokumentations- und Forschungszentrum Kummersdorf"
Kreisverwaltung Teltow-Fläming
Am Nuthefließ 2
14943 Luckenwalde

Figure E.27: Map at the Historisch-Technisches Museum Versuchsstelle Kummersdorf.

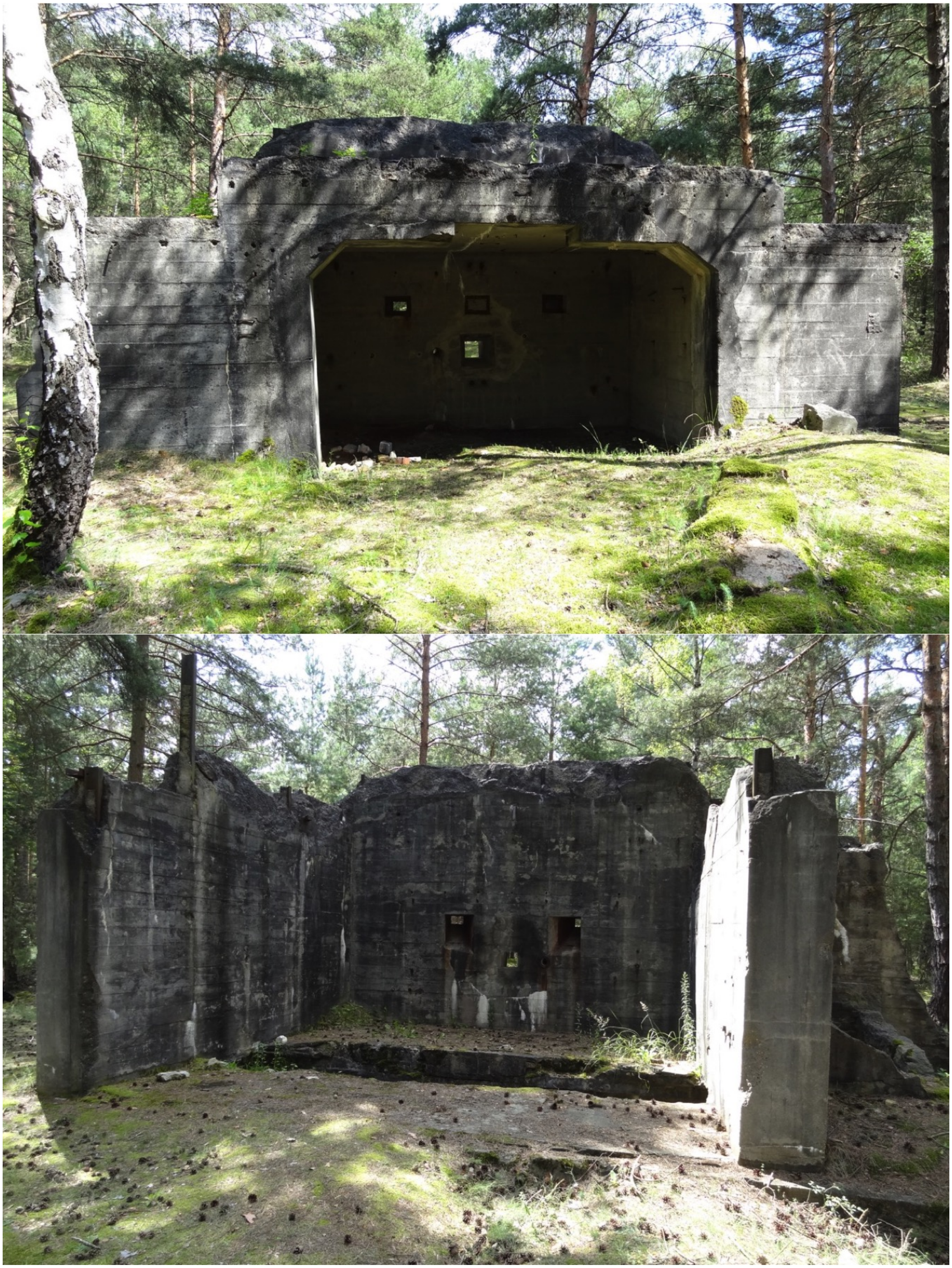


Figure E.28: Historisch-Technisches Museum Versuchsstelle Kummersdorf: A-3 rocket test stand and control bunker.

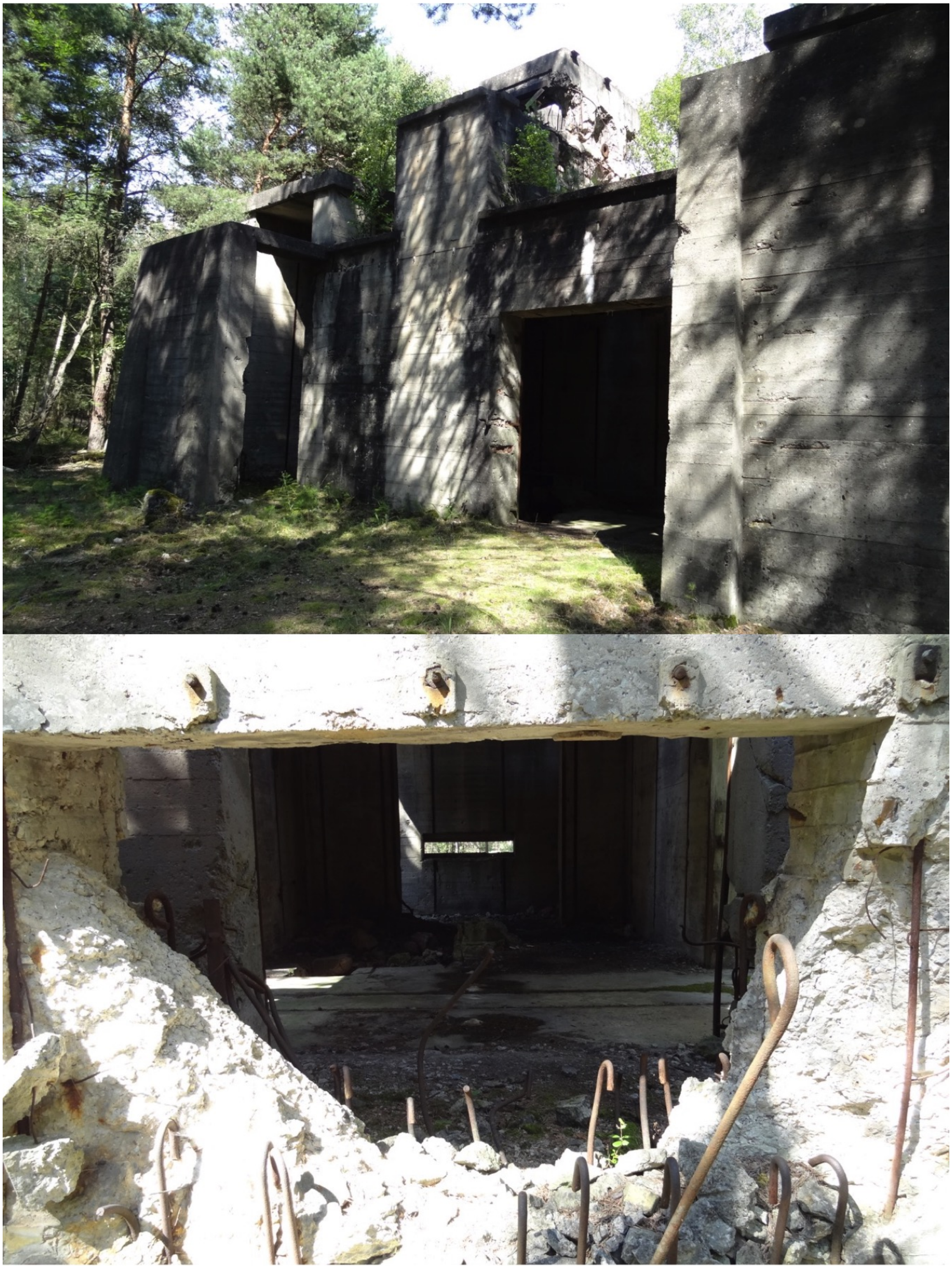


Figure E.29: Historisch-Technisches Museum Versuchsstelle Kummersdorf: Rocket engine test building large enough to accommodate test firings of A-4 engines (upside down with the exhaust vented through the roof).

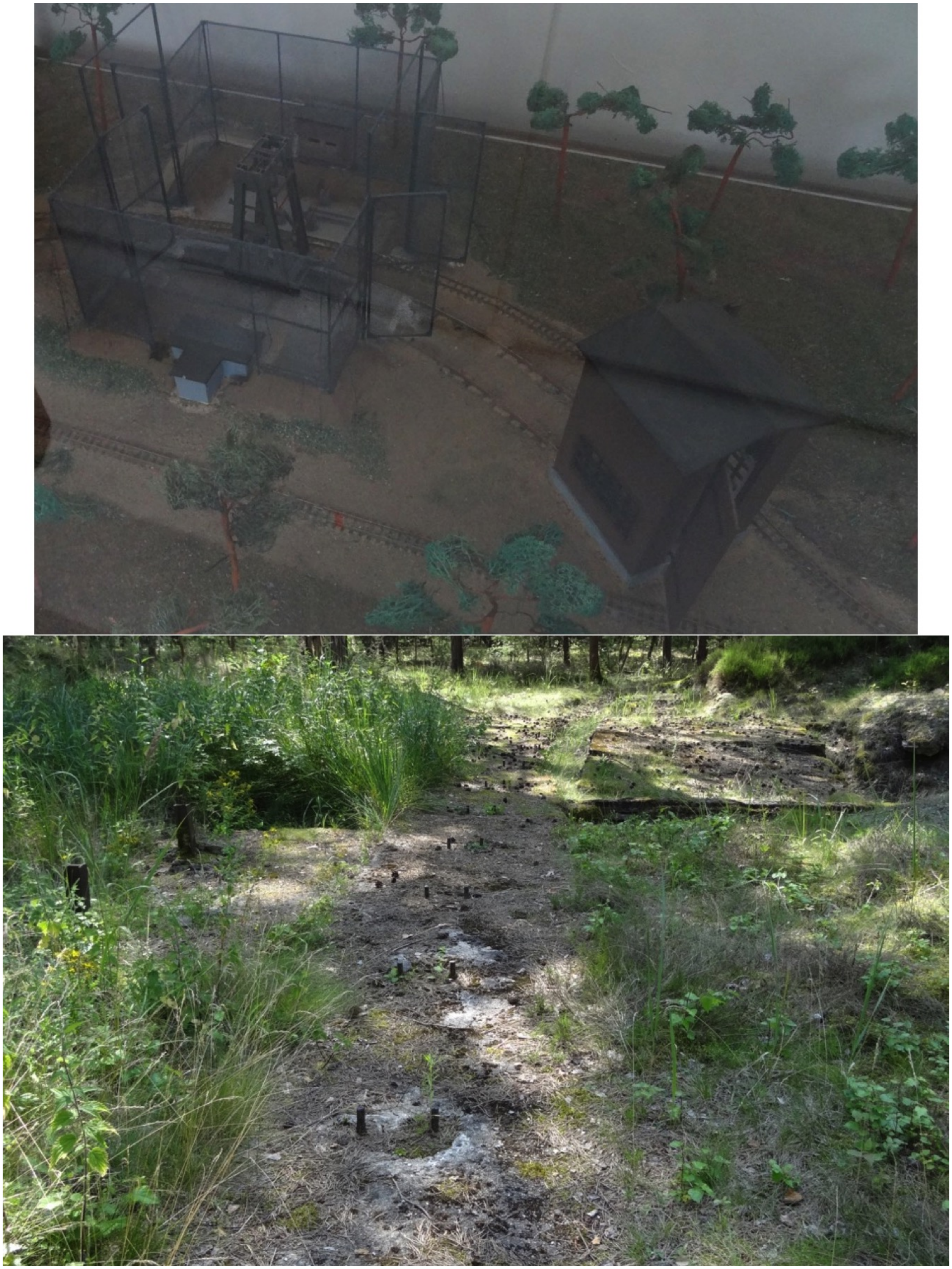


Figure E.30: Historisch-Technisches Museum Versuchsstelle Kummersdorf: Model showing vehicle assembling building, railroad track for crawler, and launch pad (above); railroad spikes from the crawler track at the launch site (below).

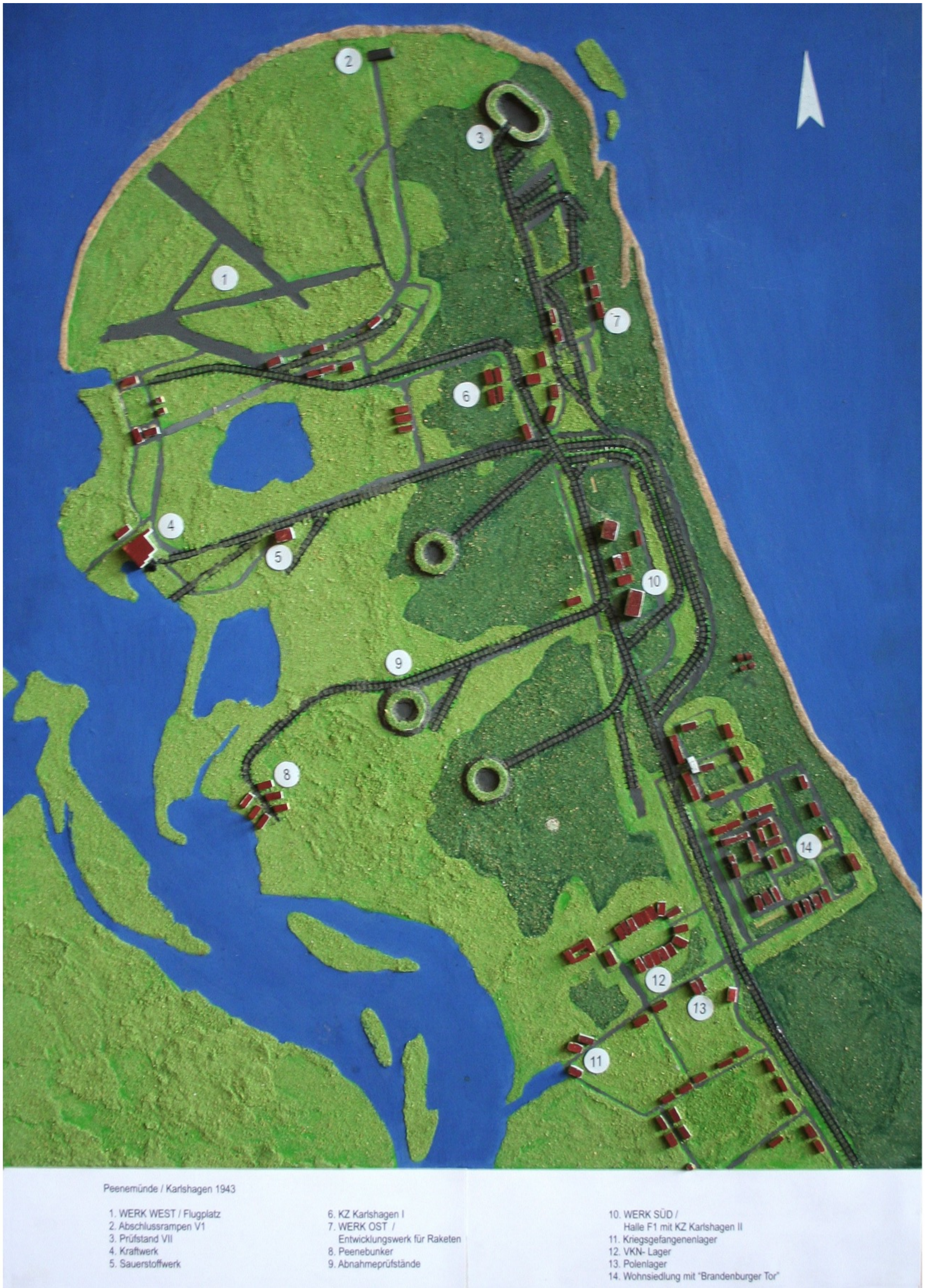

Peenemünde / Karlshagen 1943
1. WERK WEST / Flugplatz
2. Abschlussrampen V1
3. Prüfstand VII
4. Kraftwerk
5. Sauerstoffwerk
6. KZ Karlshagen I
7. WERK OST / Entwicklungswerk für Raketen
8. Peenebunker
9. Abnahmeprüfstände
10. WERK SÜD / Halle F1 mit KZ Karlshagen II
11. Kriegsgefangenenlager
12. VKN- Lager
13. Polenlager
14. Wohnsiedlung mit "Brandenburger Tor"

Figure E.31: Map at the Historisch-Technisches Museum Peenemünde.

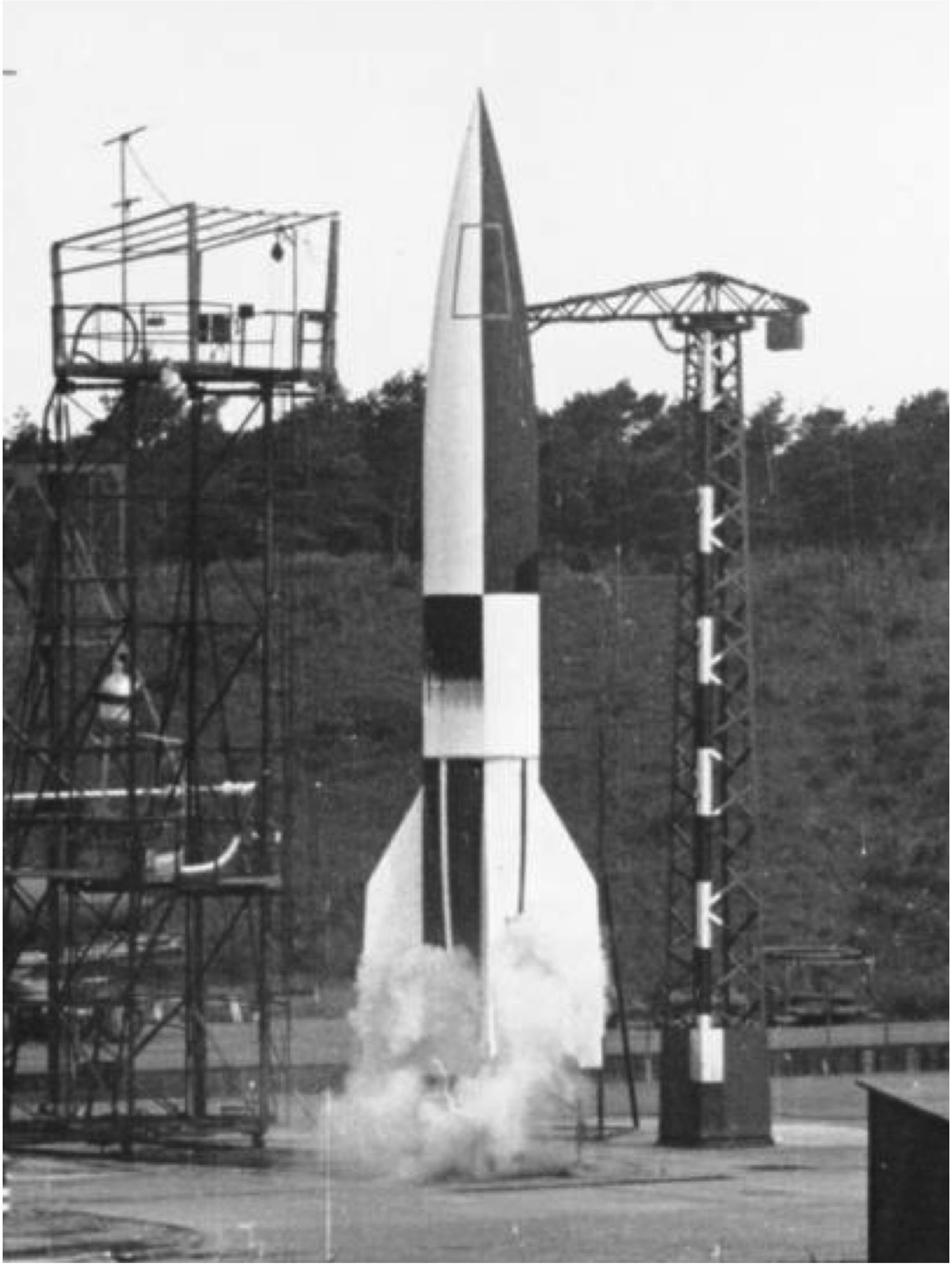


Figure E.32: A-4 (V-2) rocket launch at Peenemünde in 1943.

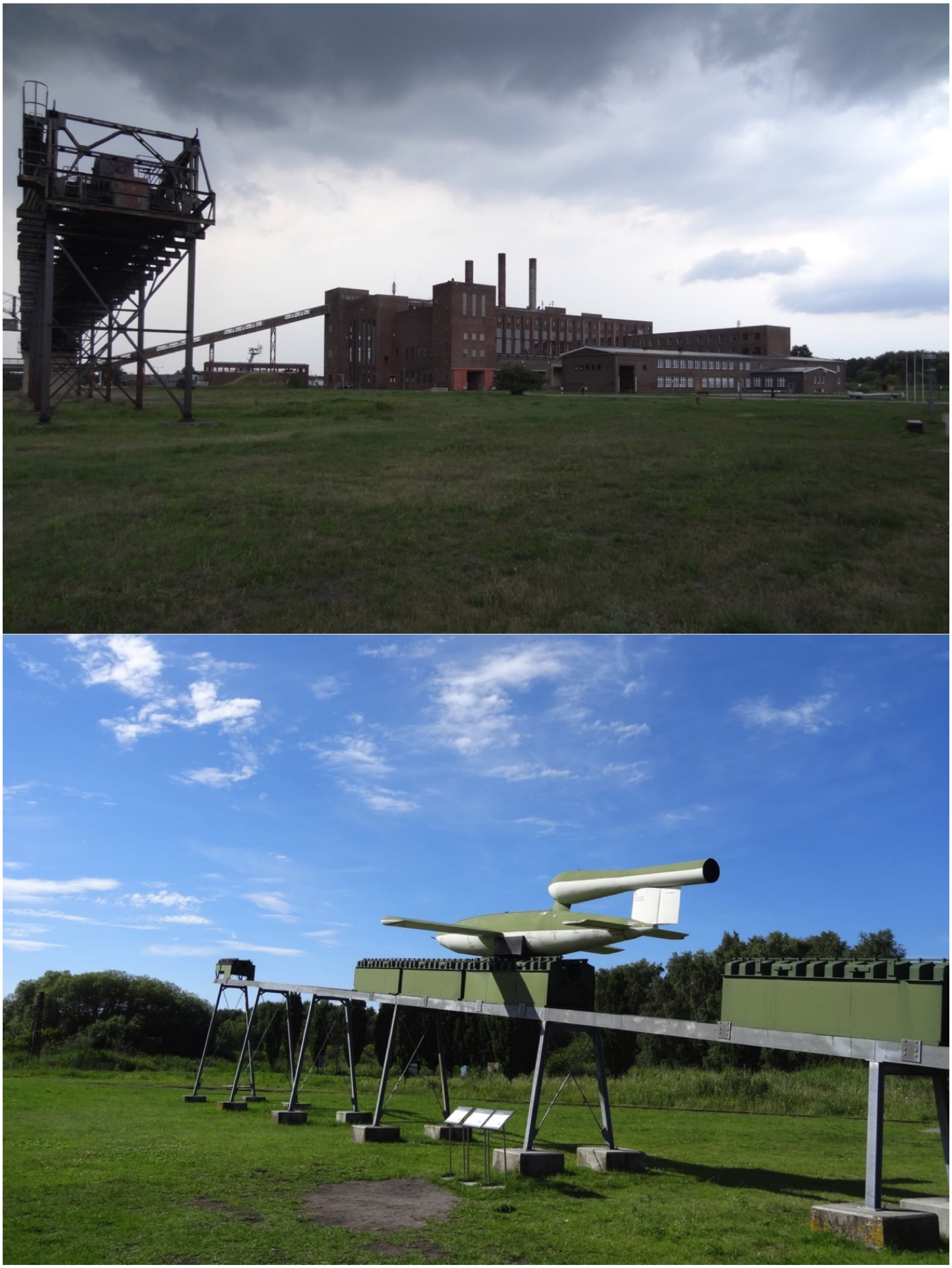


Figure E.33: Historisch-Technisches Museum Peenemünde: the former power plant and a reconstructed V-1 launch ramp.

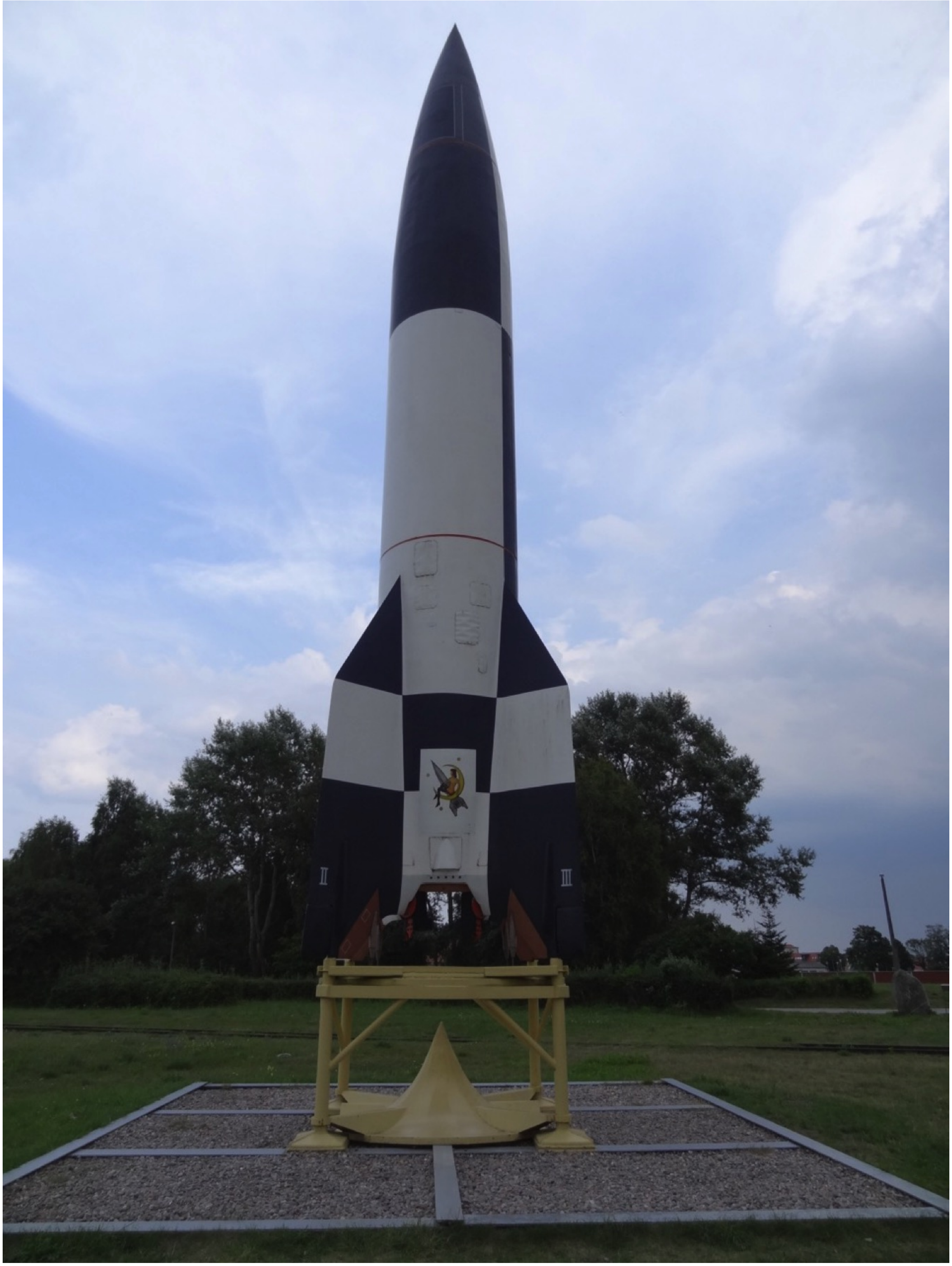


Figure E.34: A-4 (V-2) rocket at Historisch-Technisches Museum Peenemünde.

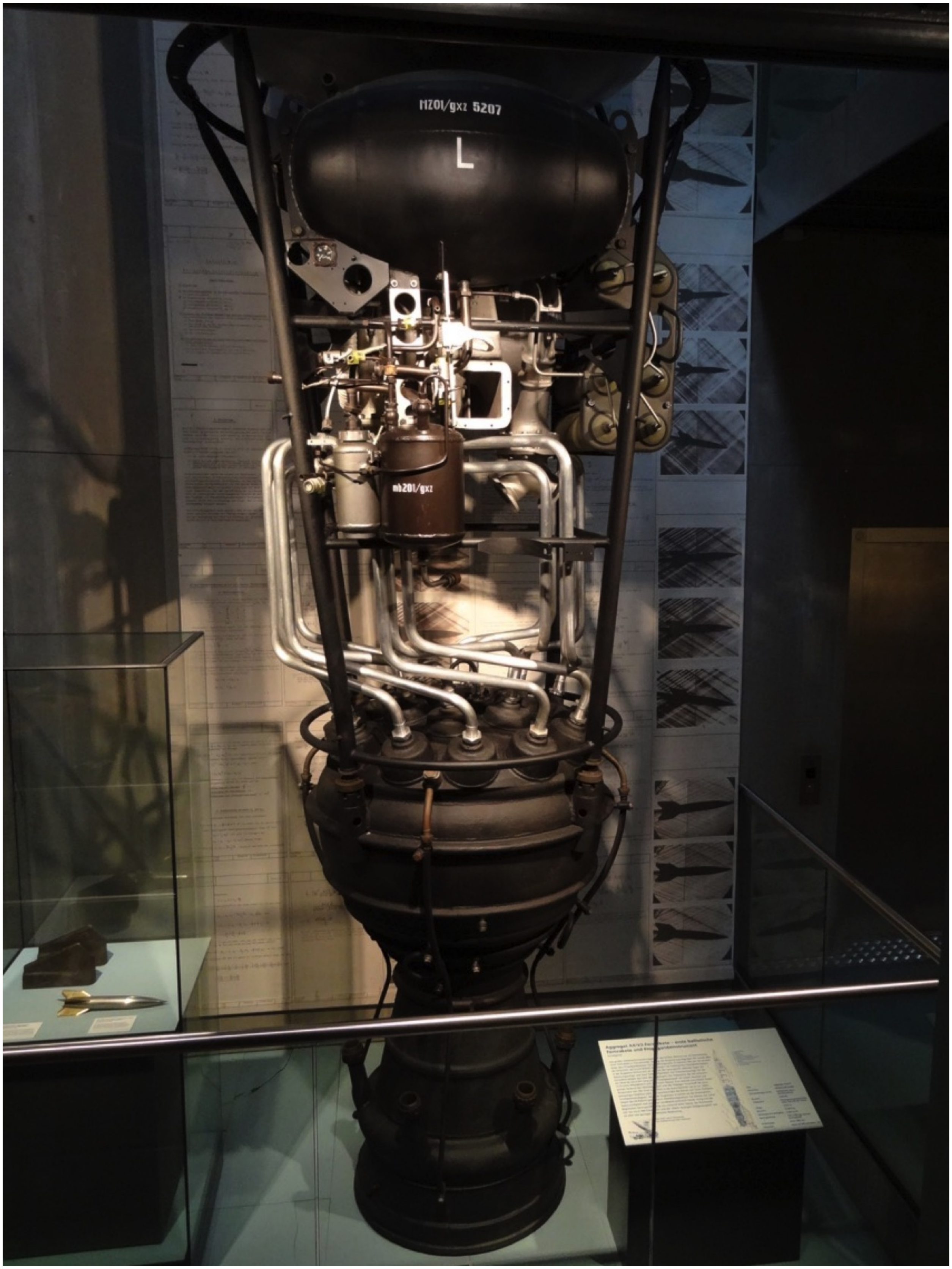

MZ01/gxz 5207
L
mb201/gxz

Figure E.35: A-4 rocket engine in Deutsches Technikmuseum Berlin.

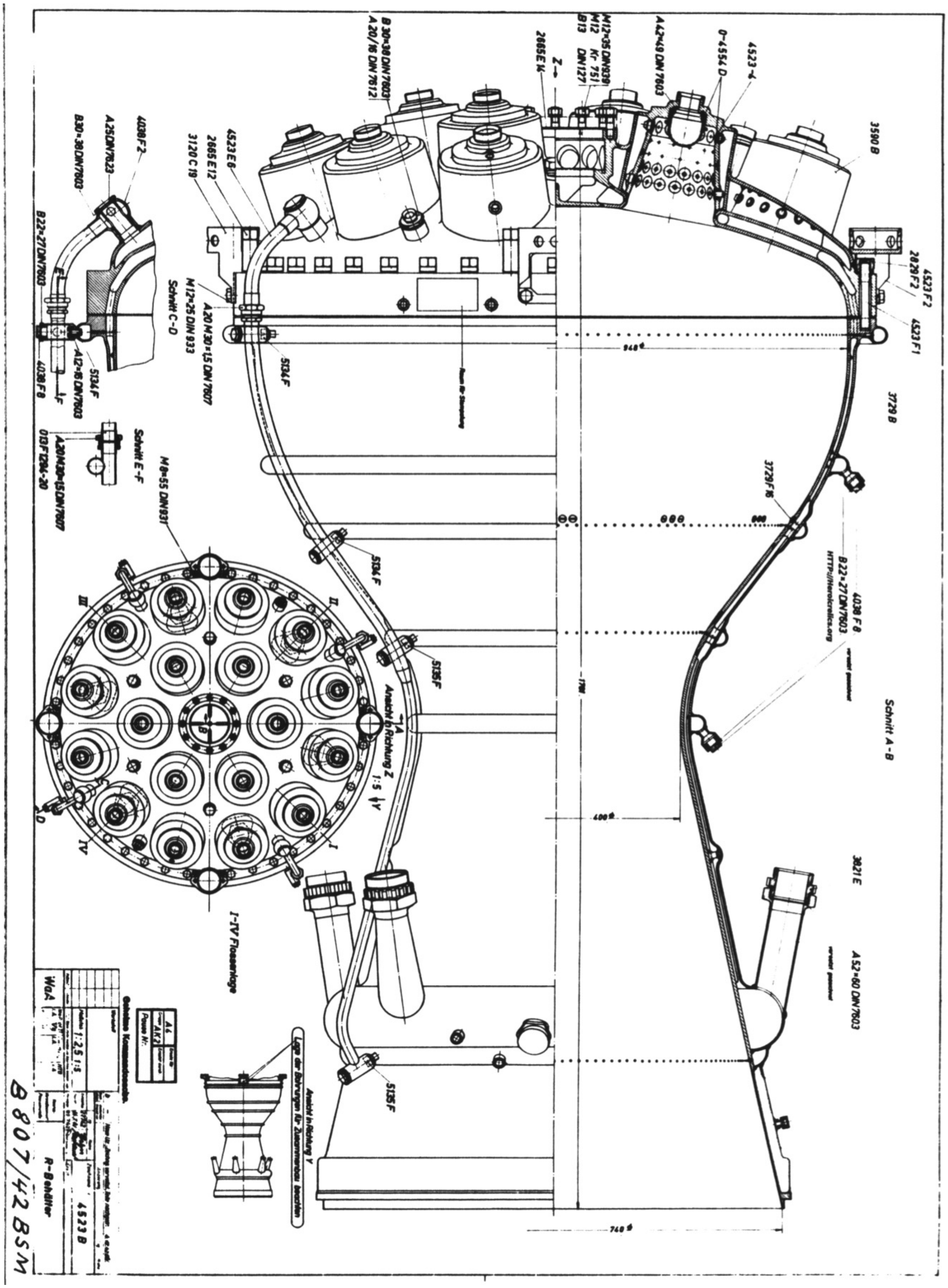

3590 B
4523-4
0-4554 D
A 42×49 DIN 7603
M12×35 DIN 939
M12 Kr. 751
B13 DIN 127
Z
2685 E 14
B 30×38 DIN 7603
A 20/16 DIN 7612
4523 E 6
2685 E 12
3120 C 19
4038 F 2
A 25 DIN 7623
B30×38 DIN 7603
B22×27 DIN 7603
Schnitt C-D
M12×25 DIN 933
A 20 M 30×1,5 DIN 7607
5134 F
A12×18 DIN 7603
4038 F 8
Schnitt E-F
A 20 M 30×1,5 DIN 7607
013 F 1084-20
M8×55 DIN 931
4523 F 2
2829 F 2
4523 F 1
948
3729 B
3729 F 16
B22×27 DIN 7603
HTTP://Heroicrelics.org
4038 F 8
Schnitt A-B
5134 F
5135 F
Ansicht in Richtung Z 1:5
I
II
III
IV
A
B
D
400
1781
3621 E
A 52×60 DIN 7603
I-IV Flossenlage
Ansicht in Richtung Y
Lage der Bohrungen für Zusammenbau beachten
5135 F
740
A 4
1:2,5 1:5
4523 B
R-Behälter
WaA
B 807/42 BSM

Figure E.36: Standard A-4 rocket engine design with propellant injection cups on top.

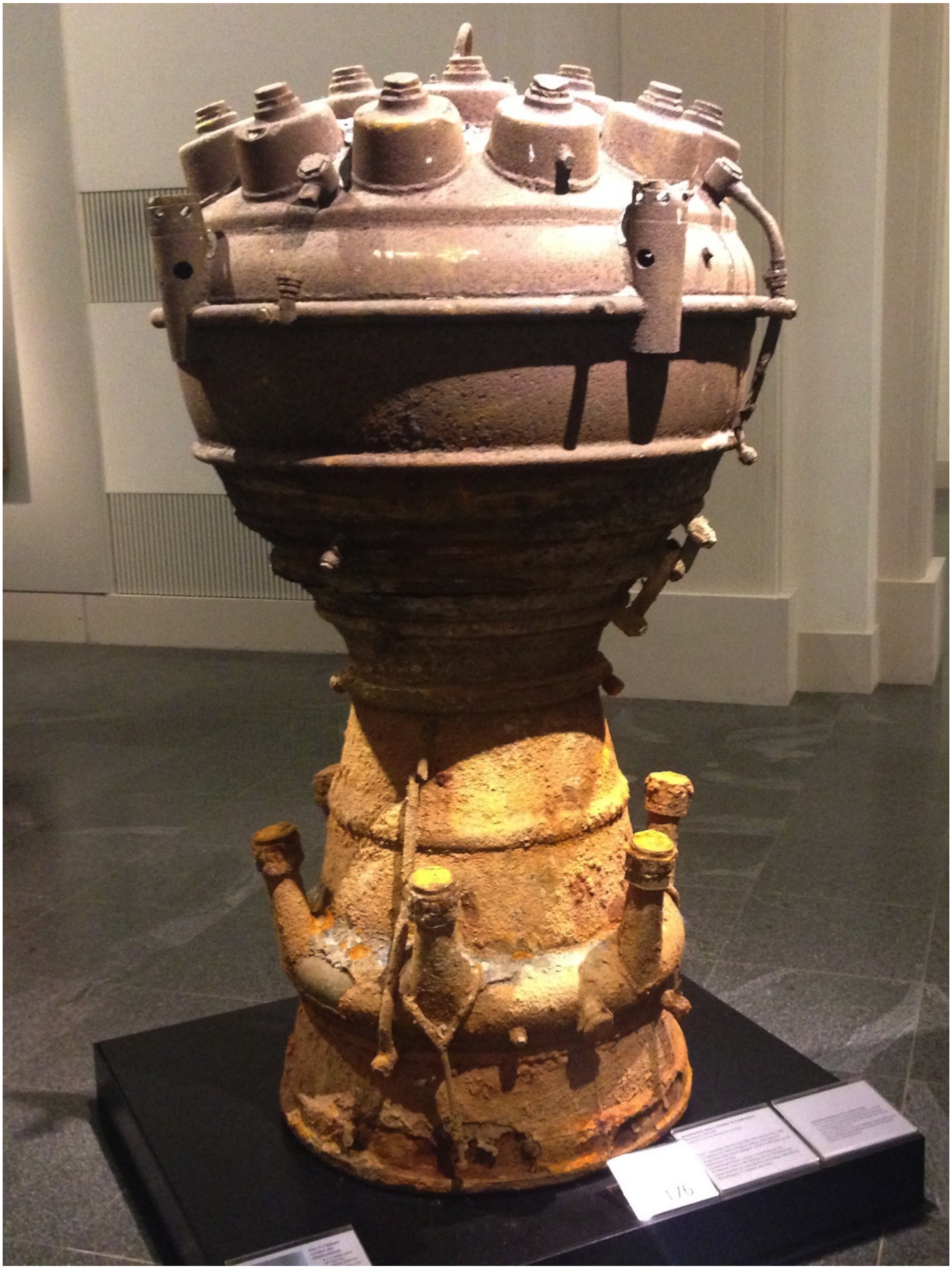


Figure E.37: Standard A-4 rocket engine with propellant injection cups on top.

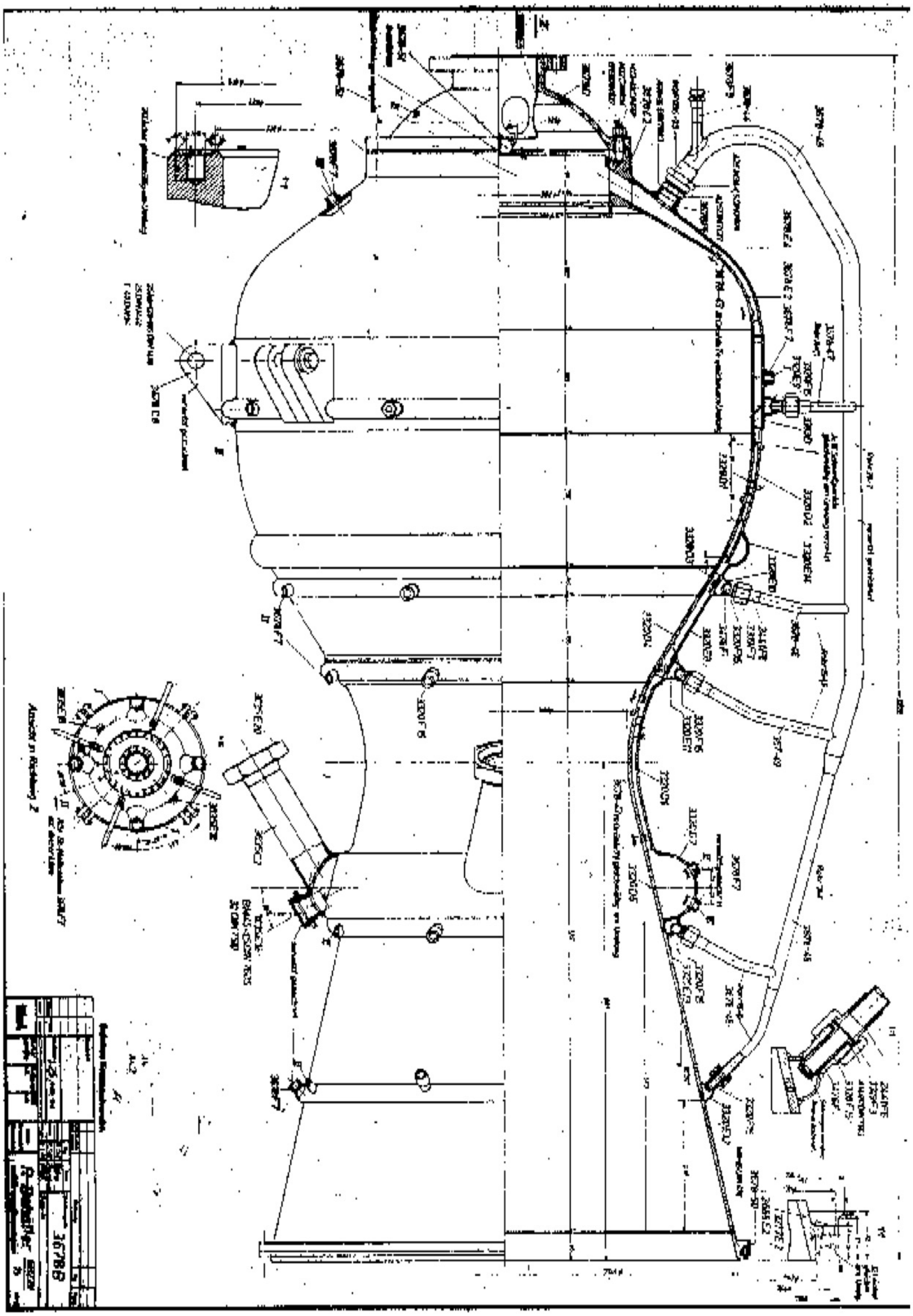
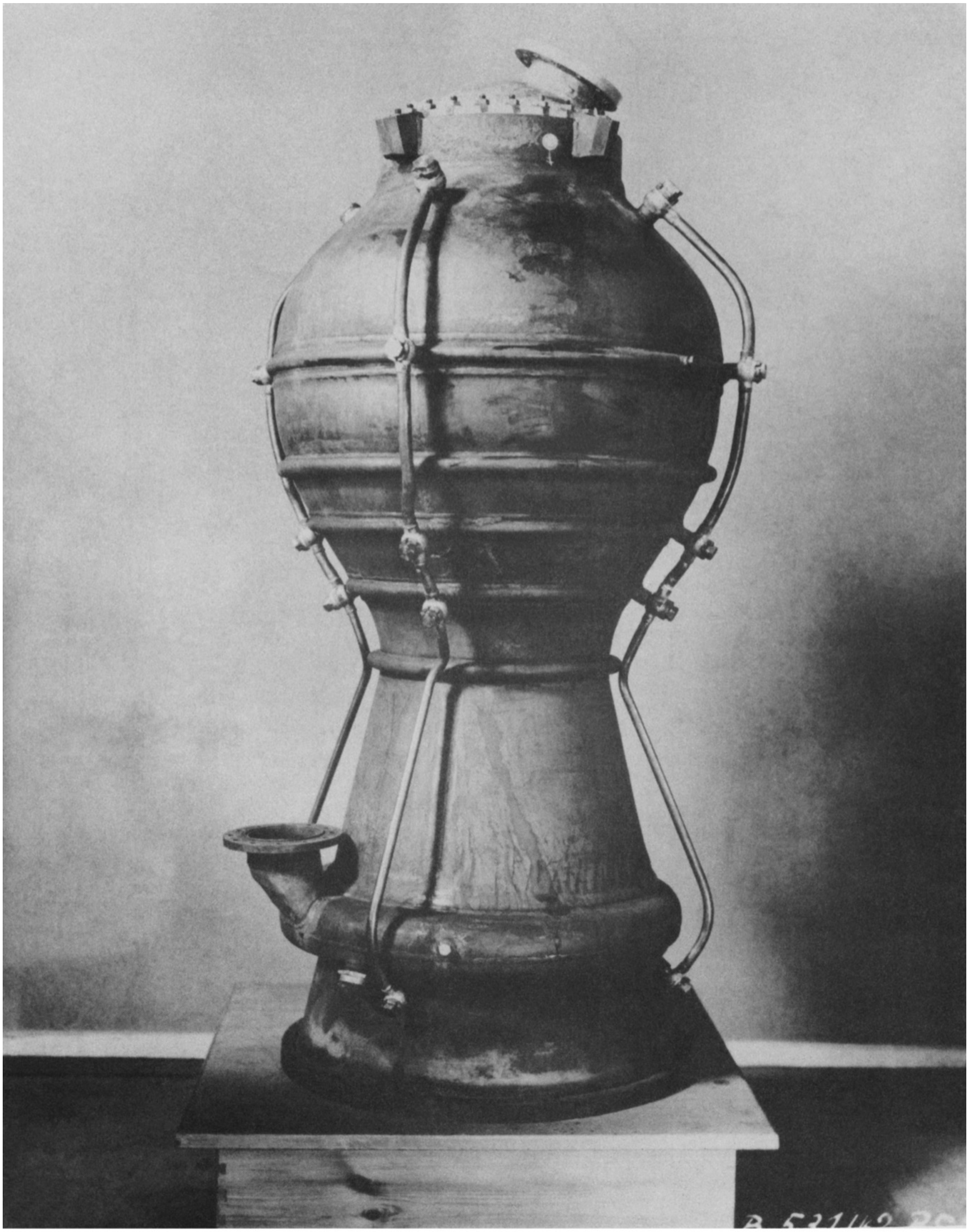
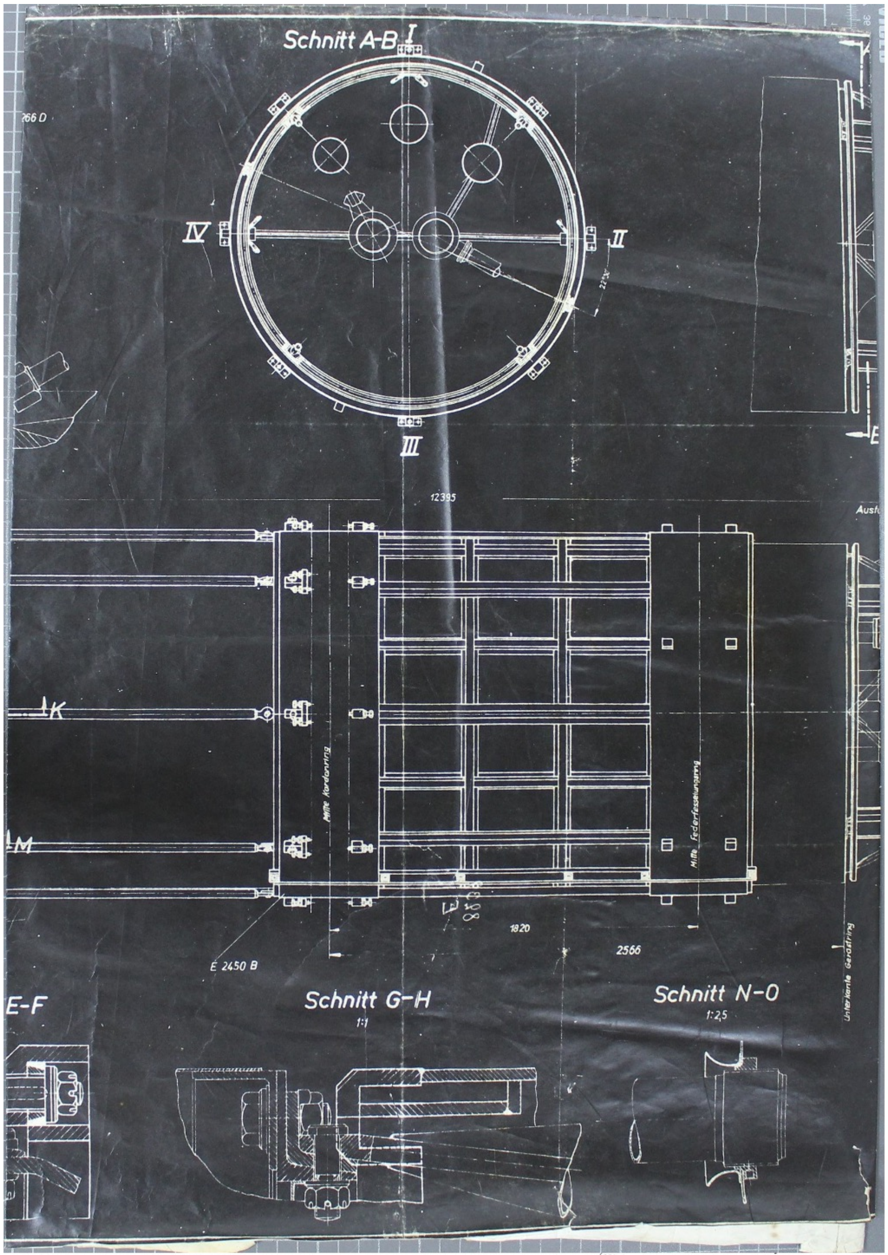


Figure E.38: Advanced A-4 rocket engine design with propellant injection plate on top.



GERMAN A-4 ROCKET COMBUSTION CHAMBER (PRODUCTION)

Figure E.39: Advanced A-4 rocket engine with propellant injection plate on top. According to the caption in the U.S. report, apparently this advanced engine was actually mass-produced during the war. [http://heroicrelics.org/info/v-2/a-4-combustion-chamber.html; Klee and Merk 1963, p. 31]


Schnitt A-B
I
II
III
IV
12395
Schnitt G-H
1:1
Schnitt N-O
1:2,5
E-F
K
M
E 2450 B
1820
2566
Mitte Federfesselungsring

Central payload compartment (?) for a modified A-4 rocket

TNA (Kew) AVIA 40/717. March 1943.

See also: Philip Henshall. 2000. *The Nuclear Axis: Germany, Japan and the Atom Bomb Race 1939-1945.* Phoenix Mill, UK: Sutton. p. 123.

Standard A-4

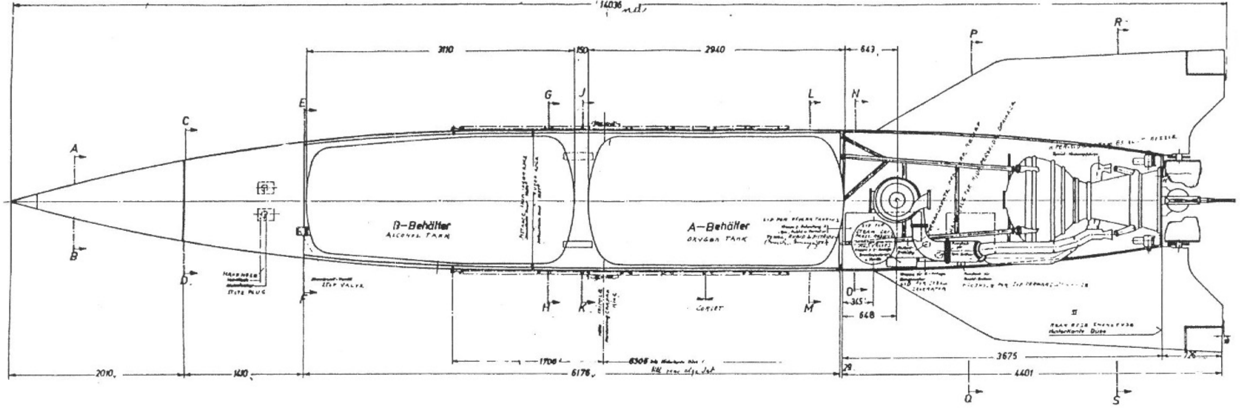

14036
3110
150
2940
643
A
B
C
D
E
F
G
H
J
K
L
M
N
O
P
Q
R
S
B-Behälter
ALCOHOL TANK
A-Behälter
OXYGEN TANK
2010
1410
1706
6178
6508
3675
4401
365
668

Figure E.40: March 1943 blueprint showing what appears to be a central payload compartment for a modified A-4 rocket [TNA AVIA 40/717, courtesy of Michael Haupt]. It may have been advantageous to carry a heavier-than-initially-planned payload (perhaps the 2-ton Thuringian device [p. 5157]?) closer to the rocket's center of mass instead of in the nosecone. [See Henshall 2000, p. 123.]

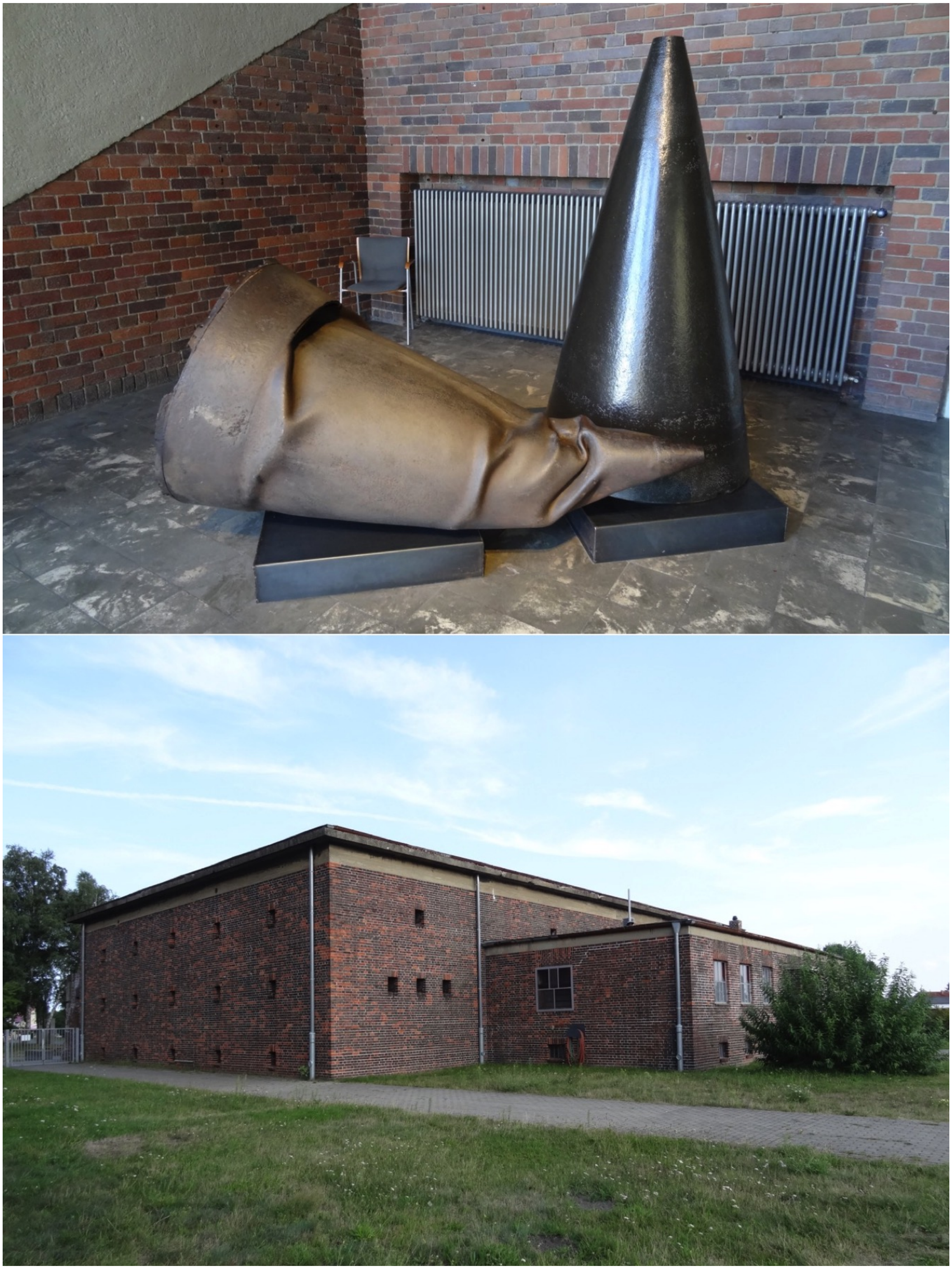


Figure E.41: Historisch-Technisches Museum Peenemünde. Above: A-4 rocket nosecones. Below: the current entrance building to the museum, formerly a bunker and control center for the power plant.

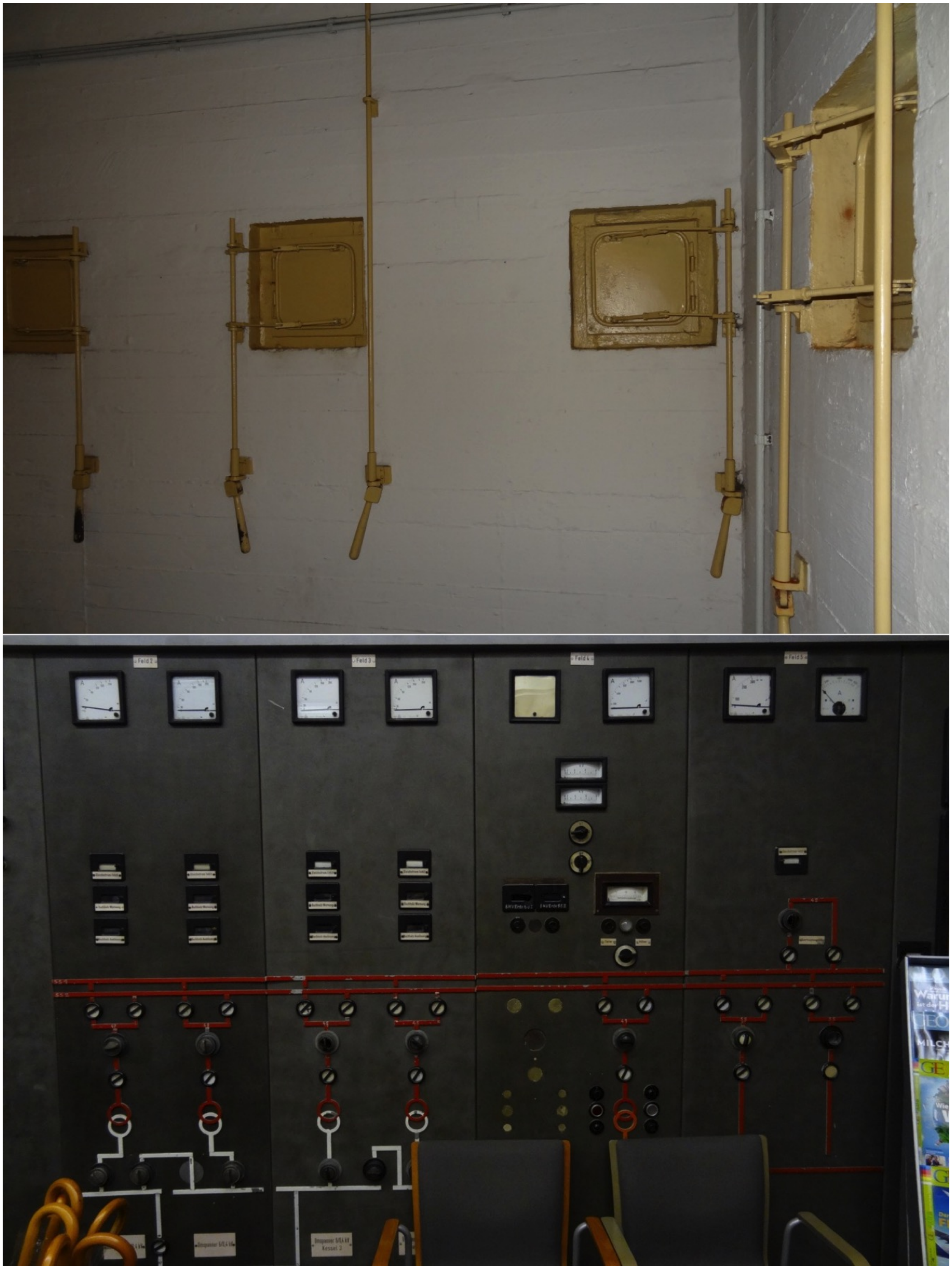


Figure E.42: Historisch-Technisches Museum Peenemünde. Above: window flaps in the entrance bunker. Below: instrumentation in a control room of the power plant.

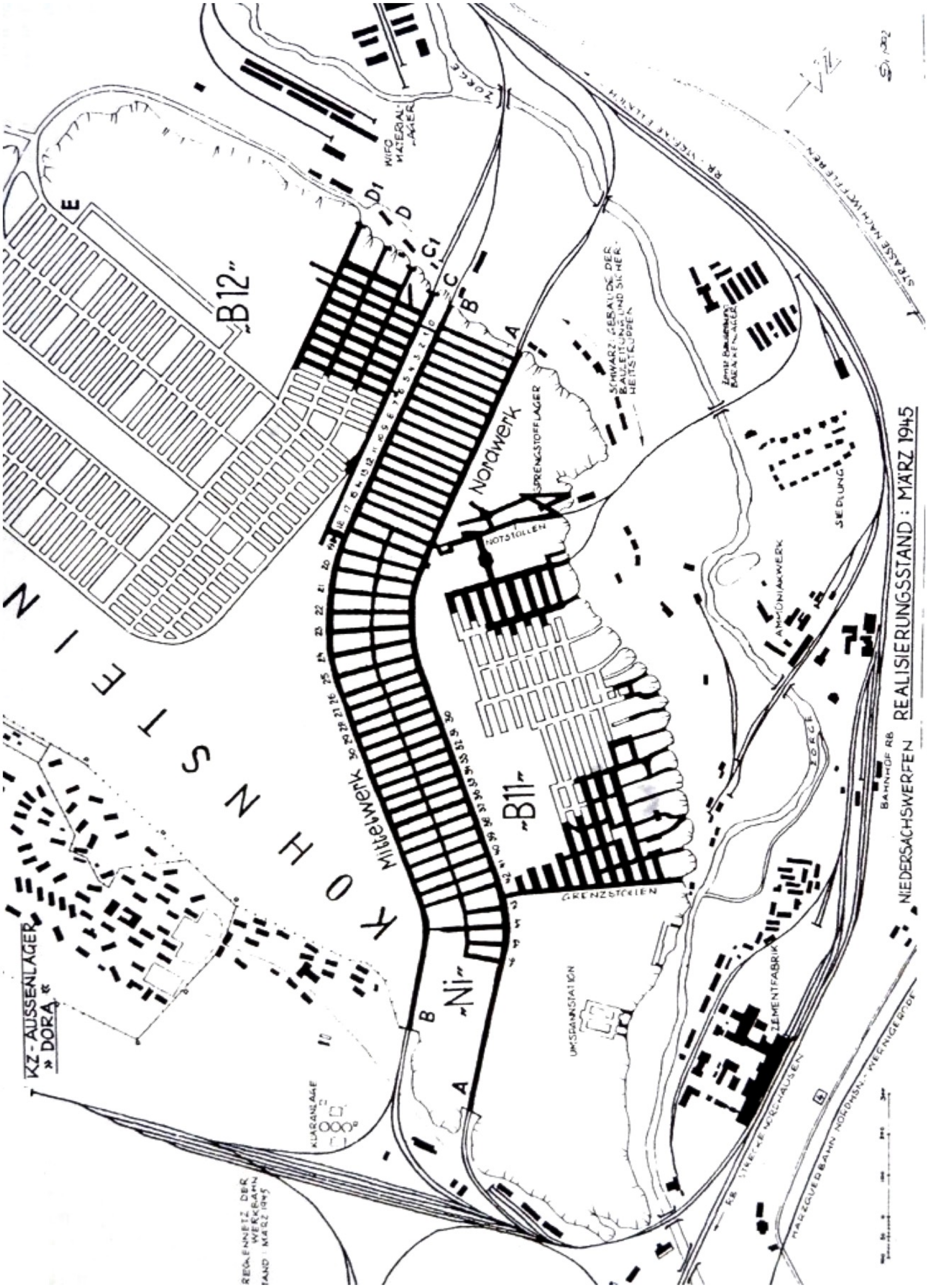

„B12"
E
D1
D
C1
C
B
A
KOHNSTEIN
Nordwerk
Mittelwerk
„B11"
„Ni"
NOTSTOLLEN
GRENZSTOLLEN
SPRENGSTOFFLAGER
WIFO MATERIAL-LAGER
ZORGE
SIEDLUNG
AMMONIAKWERK
ZEMENTFABRIK
UMSPANNSTATION
KLÄRANLAGE
BAHNHOF RB
KZ-AUSSENLAGER »DORA«
REALISIERUNGSSTAND: MÄRZ 1945
NIEDERSACHSWERFEN
RB.-STRECKE NORDHAUSEN
HARZQUERBAHN NORDHSN.-WERNIGERODE

Figure E.43: Map of the Mittelbau tunnel complex in Nordhausen.

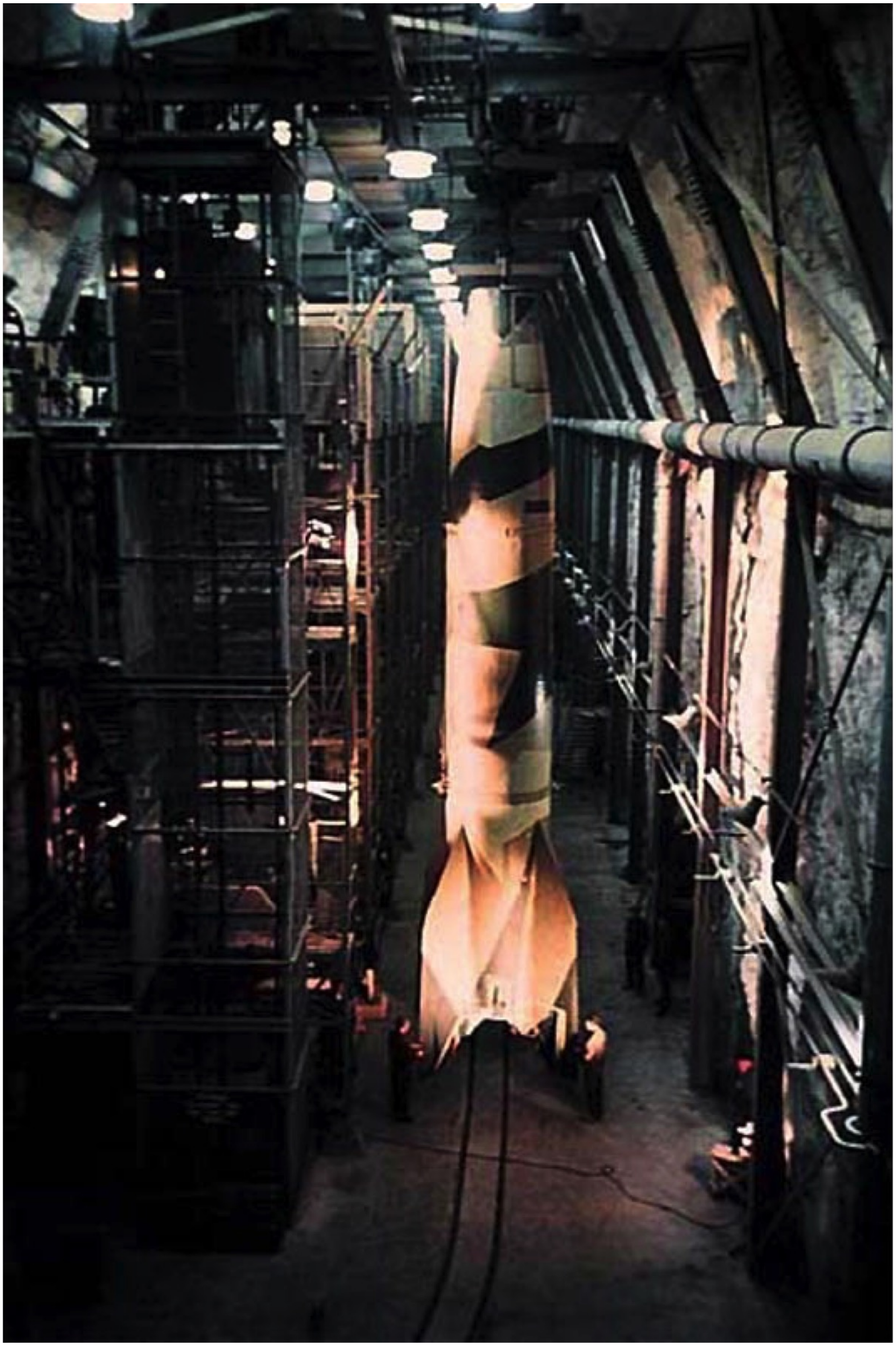


Figure E.44: The Mittelbau tunnel complex in Nordhausen when operational, circa 1944.

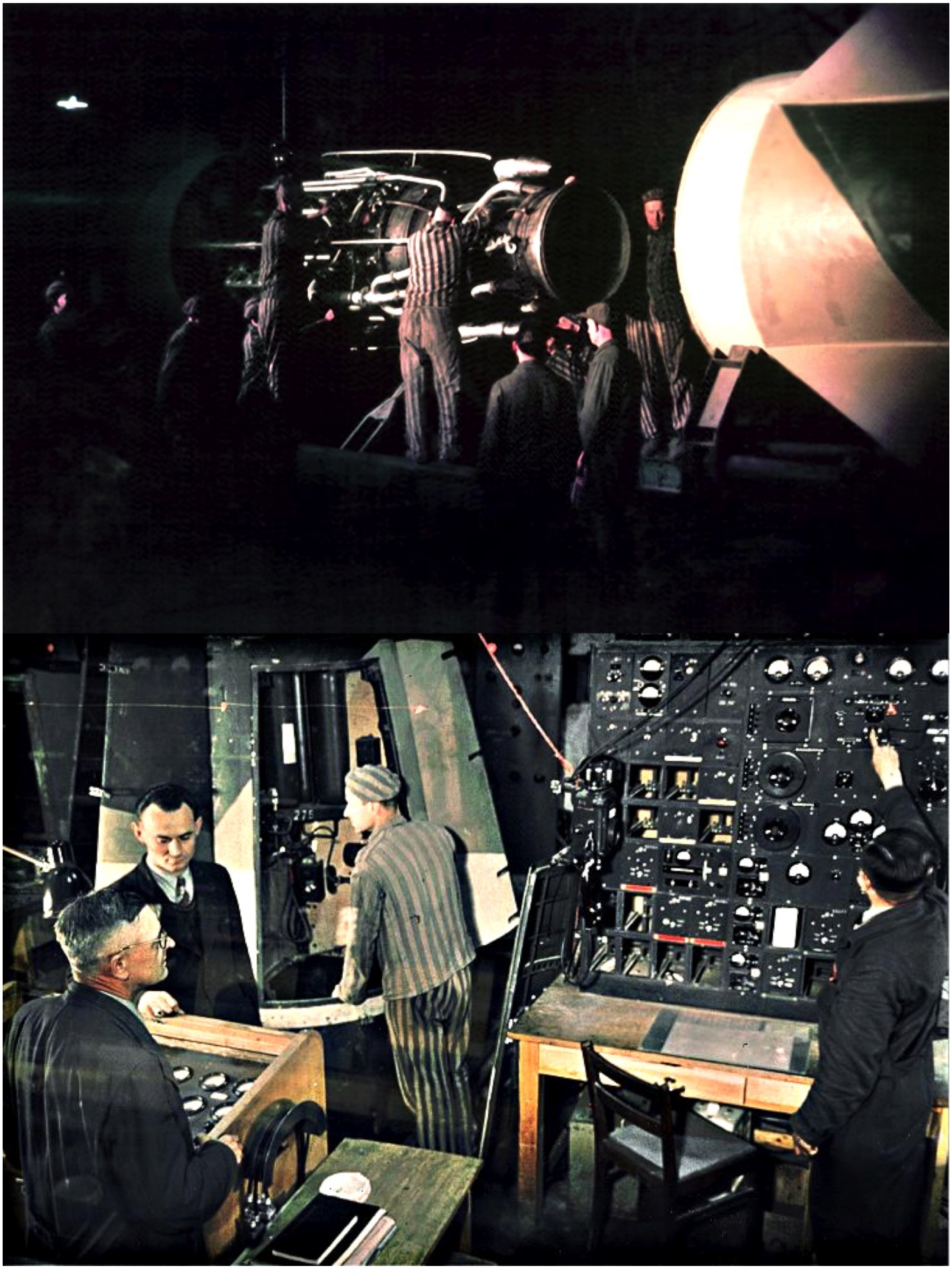


Figure E.45: The Mittelbau tunnel complex in Nordhausen when operational, circa 1944.

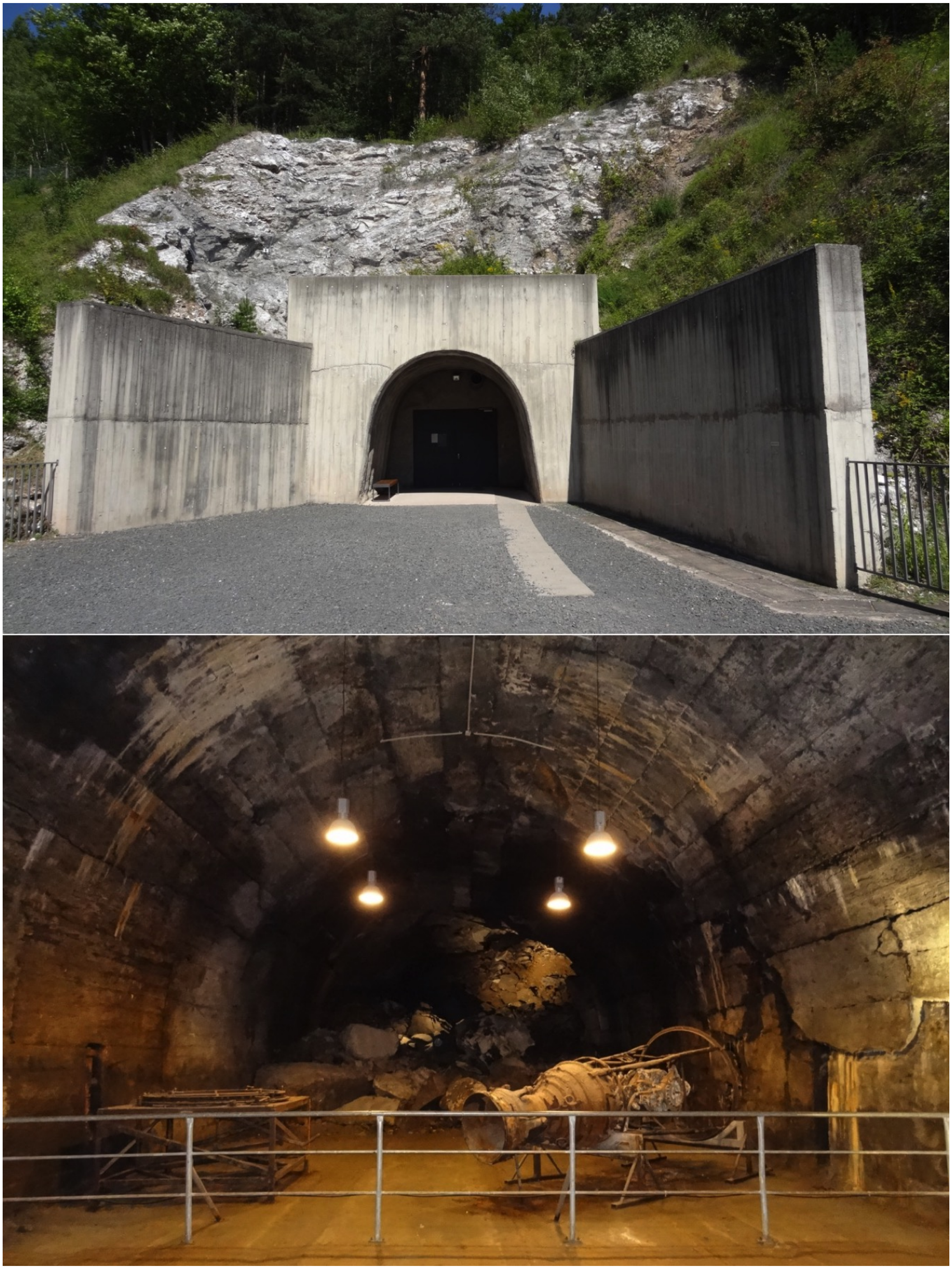


Figure E.46: The Mittelbau tunnel complex in Nordhausen now. In the foreground below is a V-2 (A-4) rocket engine.

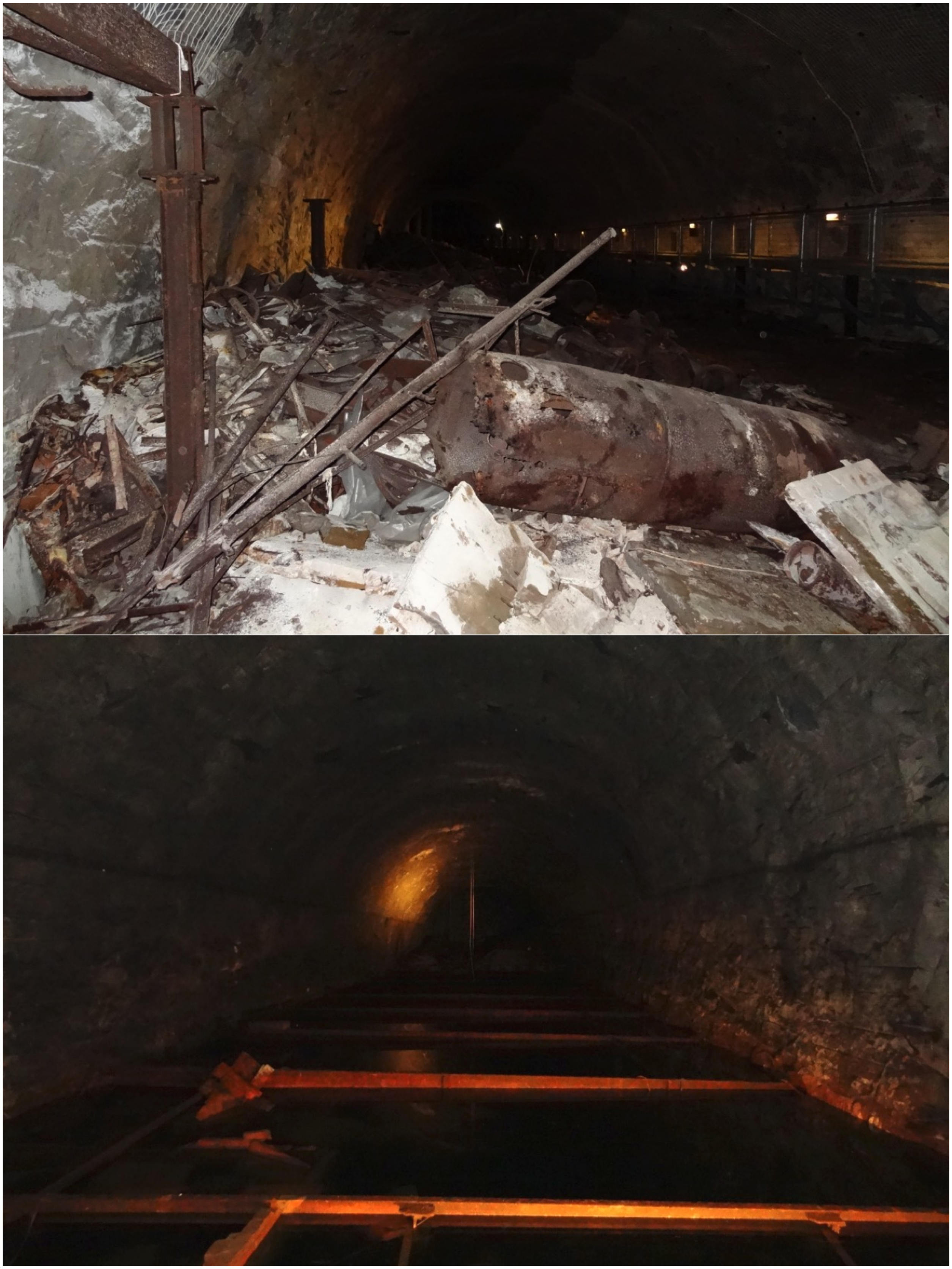


Figure E.47: The Mittelbau tunnel complex in Nordhausen now.

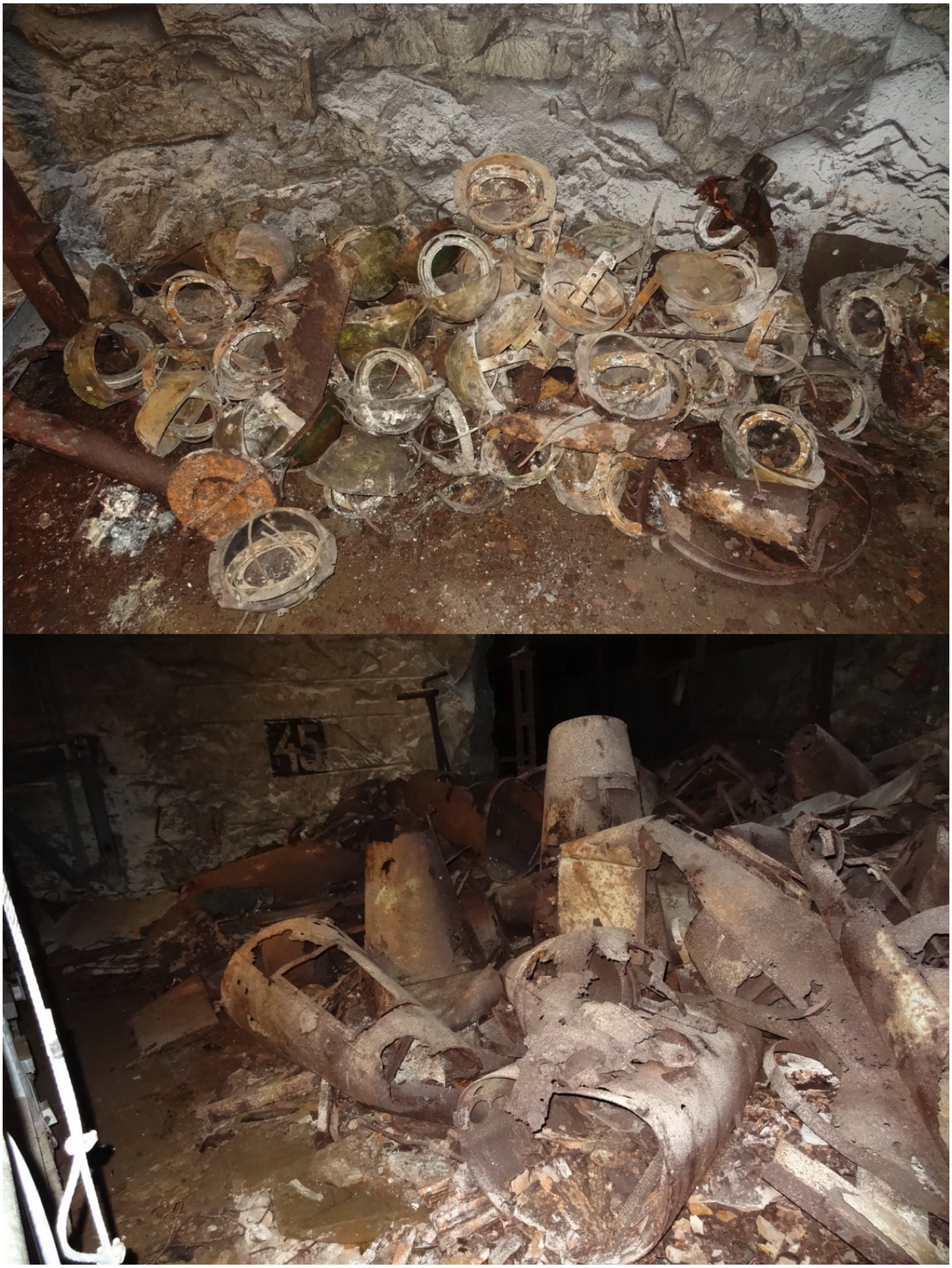


Figure E.48: The Mittelbau tunnel complex in Nordhausen now. In addition to the V-2 (A-4) rocket, the V-1 cruise missile was mass-produced here. Above are housings for V-1 magnetic compasses and below are V-1 tails.

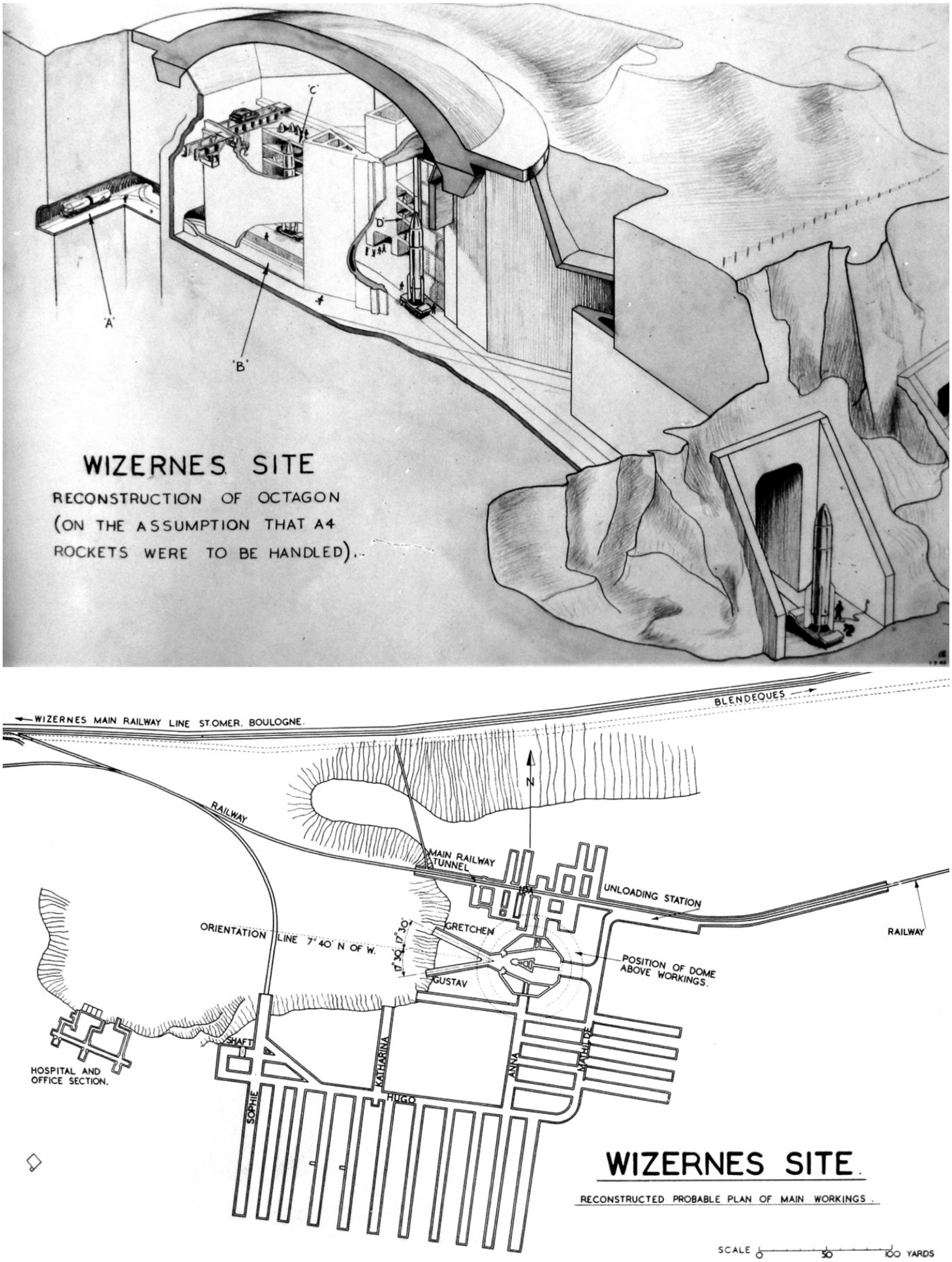

'C'
'D'
'A'
'B'
WIZERNES SITE
RECONSTRUCTION OF OCTAGON
(ON THE ASSUMPTION THAT A4
ROCKETS WERE TO BE HANDLED)..
WIZERNES MAIN RAILWAY LINE ST.OMER. BOULOGNE.
BLENDEQUES
N
RAILWAY
MAIN RAILWAY TUNNEL
UNLOADING STATION
RAILWAY
ORIENTATION LINE 7° 40' N OF W.
17° 30'
17° 30'
GRETCHEN
GUSTAV
POSITION OF DOME ABOVE WORKINGS.
SHAFT
HOSPITAL AND OFFICE SECTION.
SOPHIE
KATHARINA
HUGO
ANNA
MATHILDE
WIZERNES SITE.
RECONSTRUCTED PROBABLE PLAN OF MAIN WORKINGS.
SCALE 0 50 100 YARDS

Figure E.49: Layout of the Wizernes underground missile silo/bunker complex on the coast of northern France (built 1943–1944).

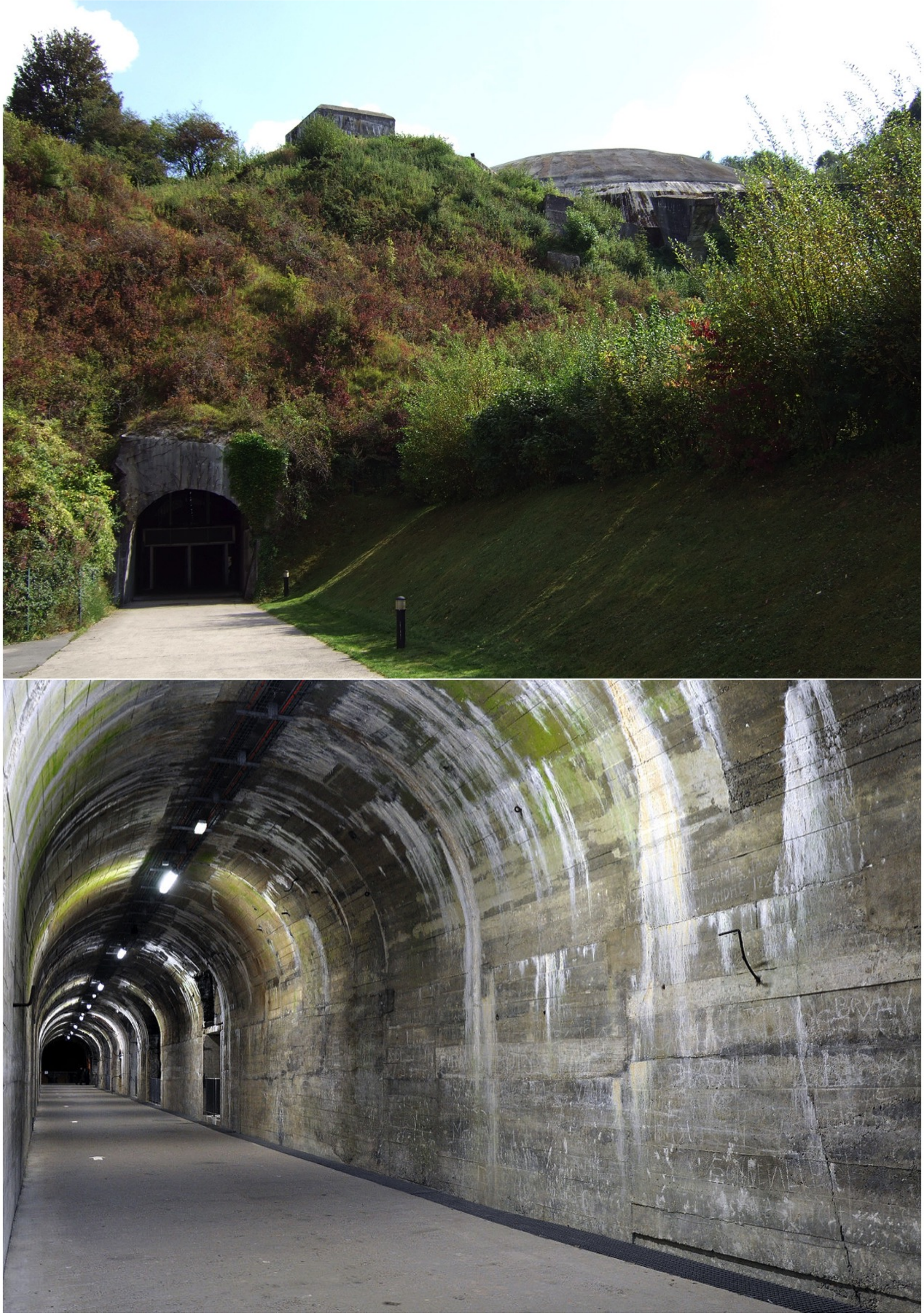


Figure E.50: The remains of the Wizernes underground missile silo/bunker complex on the coast of northern France are now a museum.

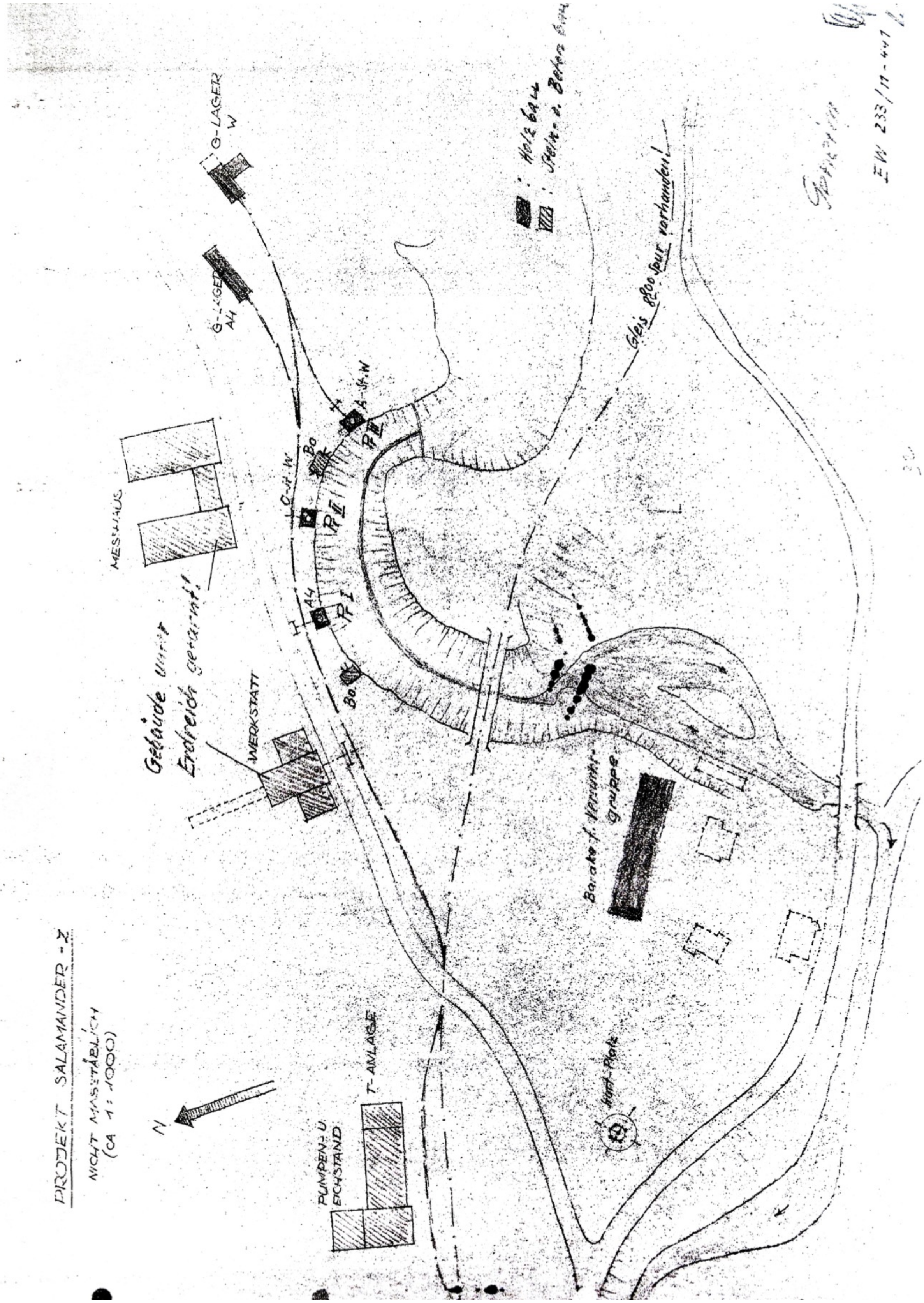
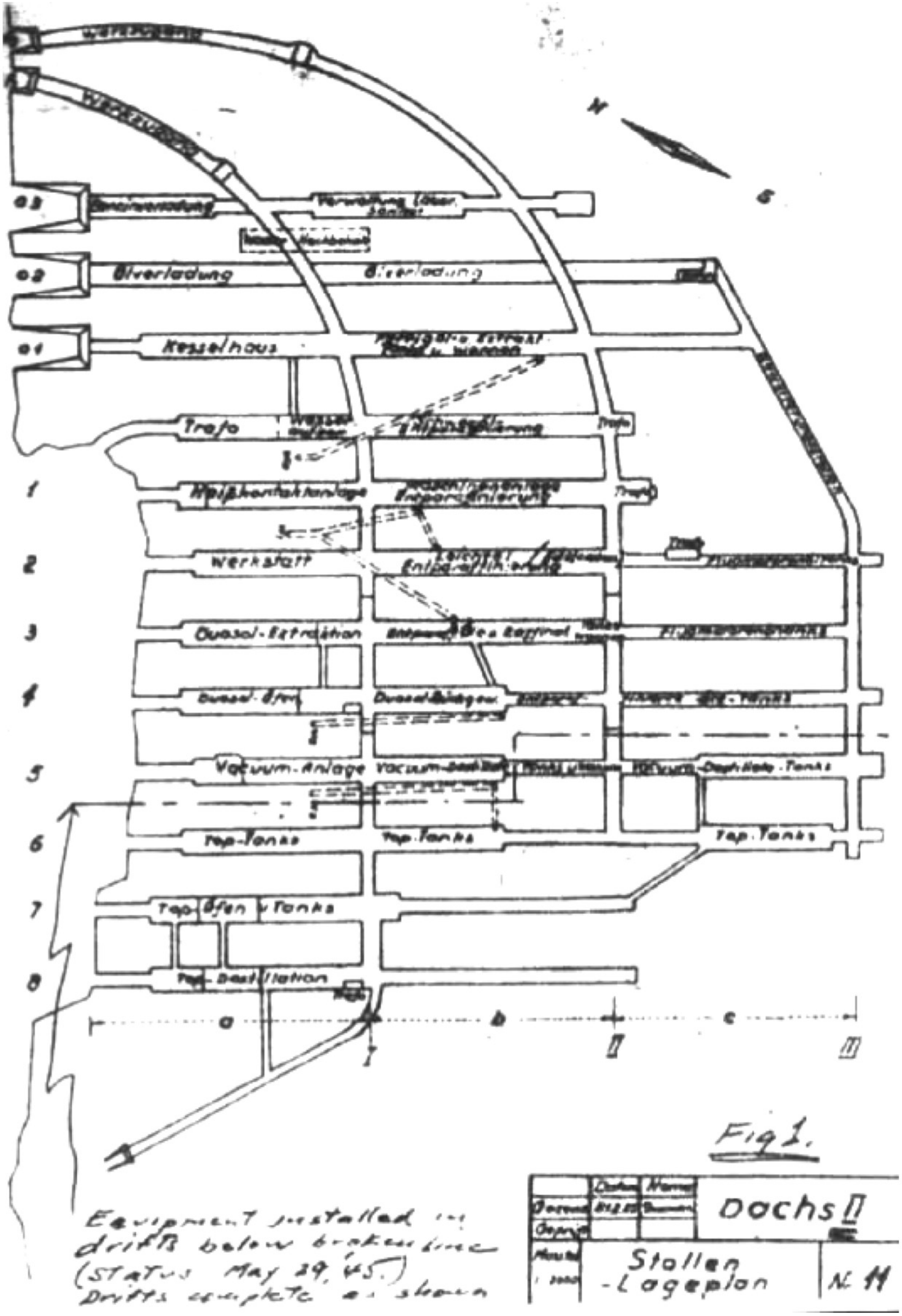

PROJEKT SALAMANDER - Z
NICHT MASSTÄBLICH (CA 1:1000)
N
PUMPEN- U. EICHSTAND
T-ANLAGE
WERKSTATT
Gebäude unter Erdreich geschützt!
MESSHAUS
Bo.
A4
P I
P II
P III
G-H-W
Bo
A-St.W
G-LAGER A4
G-LAGER W
Holzbau
Stein- u. Beton-Bau
Gleis 600 Spur vorhanden!
Baracke f. Versuchsgruppe
Start-Platz
EW 233/11-44

Figure E.51: Wartime sketch of the Salamander Z test site, one of several locations around Ebensee, Austria where it was planned to produce, test, and launch A-9/A-10 rockets.


N
S
03
02
01
1
2
3
4
5
6
7
8
Ölverladung
Ölverladung
Kesselhaus
Trafo
Trafo
Trafo
Werkstatt
Duasol-Extraktion
Duasol-Öfen
Vacuum-Anlage
Tap-Tanks
Tap-Tanks
Tap-Tanks
Tap-Öfen u Tanks
Tap-Destillation
a
b
c
I
II
III
Fig 1.
Dachs II
Stollen
-Lageplan
N. 11

Equipment installed in drifts below broken line (Status May 29, 45.) Drifts complete as shown

Figure E.52: Map of the Dachs II or Zement tunnel complex, one of several locations around Ebensee, Austria where it was planned to produce, test, and launch A-9/A-10 rockets.

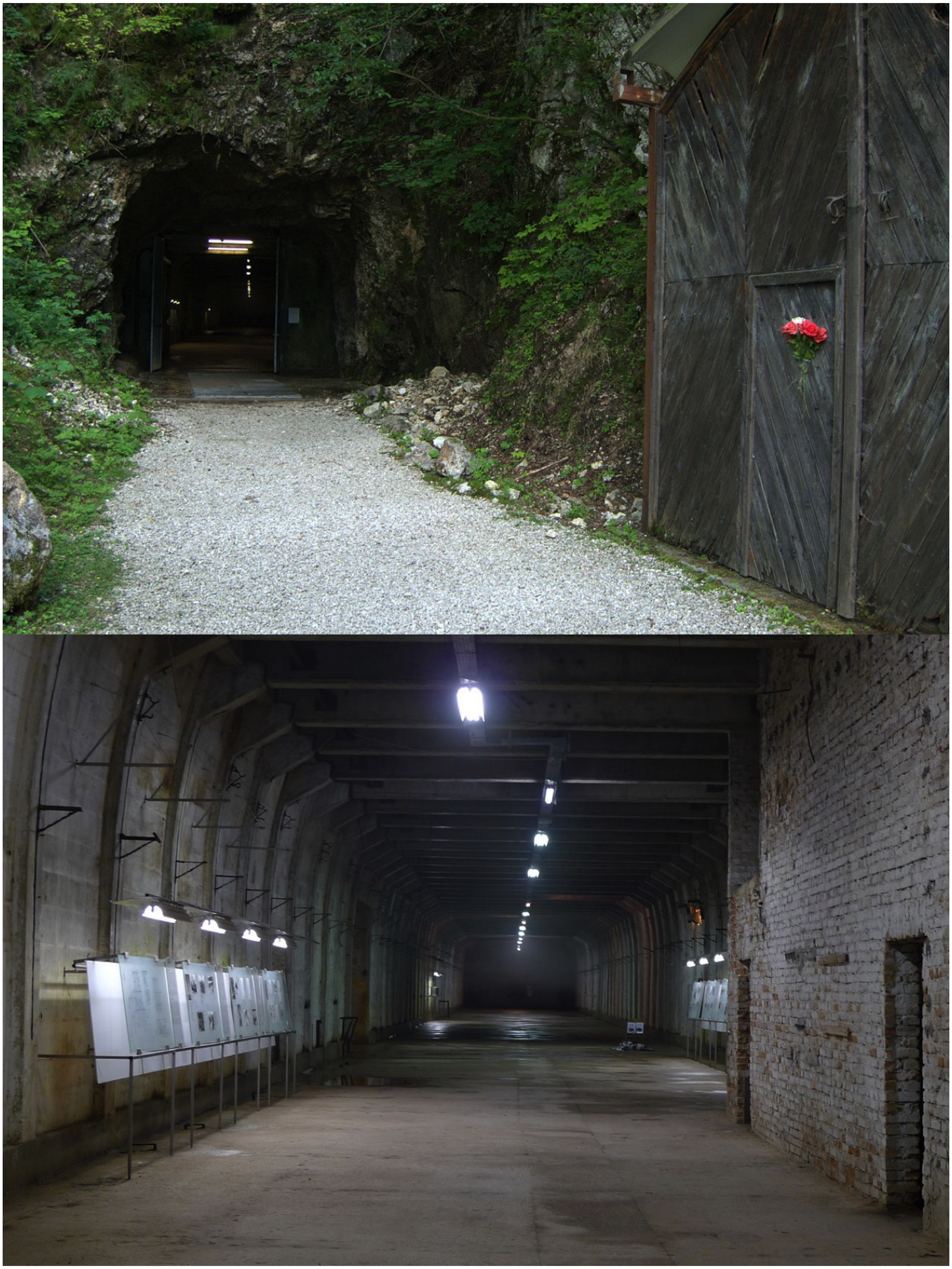


Figure E.53: The remains of some of the Ebensee tunnels as they look now.

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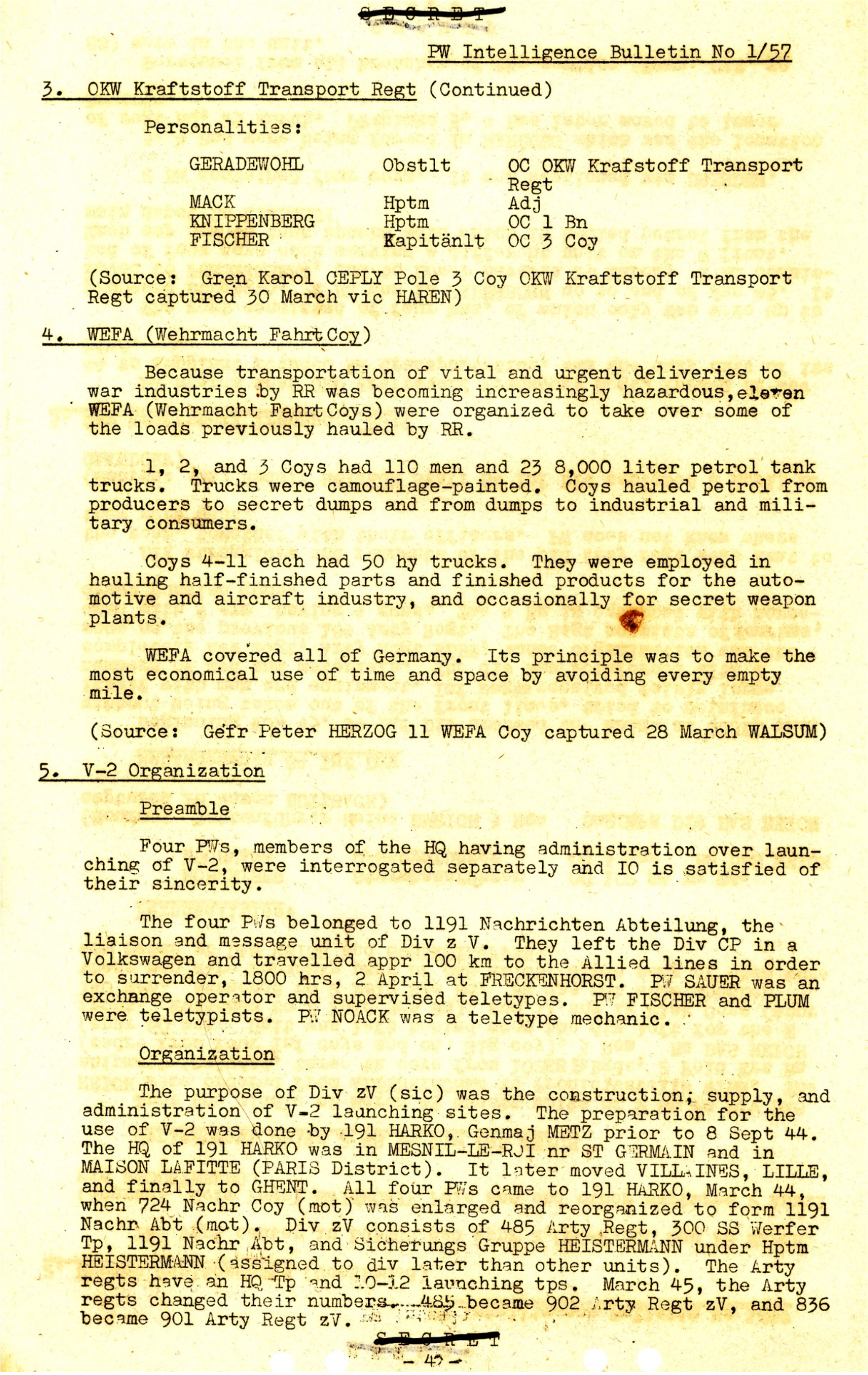
PW Intelligence Bulletin No 1/57, AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527



~~SECRET~~

PW Intelligence Bulletin No 1/57

3. OKW Kraftstoff Transport Regt (Continued)

Personalities:

GERADEWOHL	Obstlt	OC OKW Krafstoff Transport Regt
MACK	Hptm	Adj
KNIPPENBERG	Hptm	OC 1 Bn
FISCHER	Kapitänlt	OC 3 Coy

(Source: Gren Karol CEPLY Pole 3 Coy OKW Kraftstoff Transport Regt captured 30 March vic HAREN)

4. WEFA (Wehrmacht FahrtCoy)

Because transportation of vital and urgent deliveries to war industries by RR was becoming increasingly hazardous, eleven WEFA (Wehrmacht FahrtCoys) were organized to take over some of the loads previously hauled by RR.

1, 2, and 3 Coys had 110 men and 23 8,000 liter petrol tank trucks. Trucks were camouflage-painted. Coys hauled petrol from producers to secret dumps and from dumps to industrial and military consumers.

Coys 4-11 each had 50 hy trucks. They were employed in hauling half-finished parts and finished products for the automotive and aircraft industry, and occasionally for secret weapon plants.

WEFA covered all of Germany. Its principle was to make the most economical use of time and space by avoiding every empty mile.

(Source: Gefr Peter HERZOG 11 WEFA Coy captured 28 March WALSUM)

5. V-2 Organization

Preamble

Four PWs, members of the HQ having administration over launching of V-2, were interrogated separately and IO is satisfied of their sincerity.

The four PWs belonged to 1191 Nachrichten Abteilung, the liaison and message unit of Div z V. They left the Div CP in a Volkswagen and travelled appr 100 km to the Allied lines in order to surrender, 1800 hrs, 2 April at FRECKENHORST. PW SAUER was an exchange operator and supervised teletypes. PW FISCHER and PLUM were teletypists. PW NOACK was a teletype mechanic.

Organization

The purpose of Div zV (sic) was the construction, supply, and administration of V-2 launching sites. The preparation for the use of V-2 was done by 191 HARKO, Genmaj METZ prior to 8 Sept 44. The HQ of 191 HARKO was in MESNIL-LE-ROI nr ST GERMAIN and in MAISON LAFITTE (PARIS District). It later moved VILLAINES, LILLE, and finally to GHENT. All four PWs came to 191 HARKO, March 44, when 724 Nachr Coy (mot) was enlarged and reorganized to form 1191 Nachr Abt (mot). Div zV consists of 485 Arty Regt, 300 SS Werfer Tp, 1191 Nachr Abt, and Sicherungs Gruppe HEISTERMANN under Hptm HEISTERMANN (assigned to div later than other units). The Arty regts have an HQ Tp and 10-12 launching tps. March 45, the Arty regts changed their numbers... 485 became 902 Arty Regt zV, and 836 became 901 Arty Regt zV.

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Figure E.54: Several German prisoners of war captured by the Allies mentioned Hans Kammler and the rockets and underground facilities that were under his control. PW Intelligence Bulletin No 1/57. 12 April 1945 [AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527; AFHRA A5185 frames 1029–1047].

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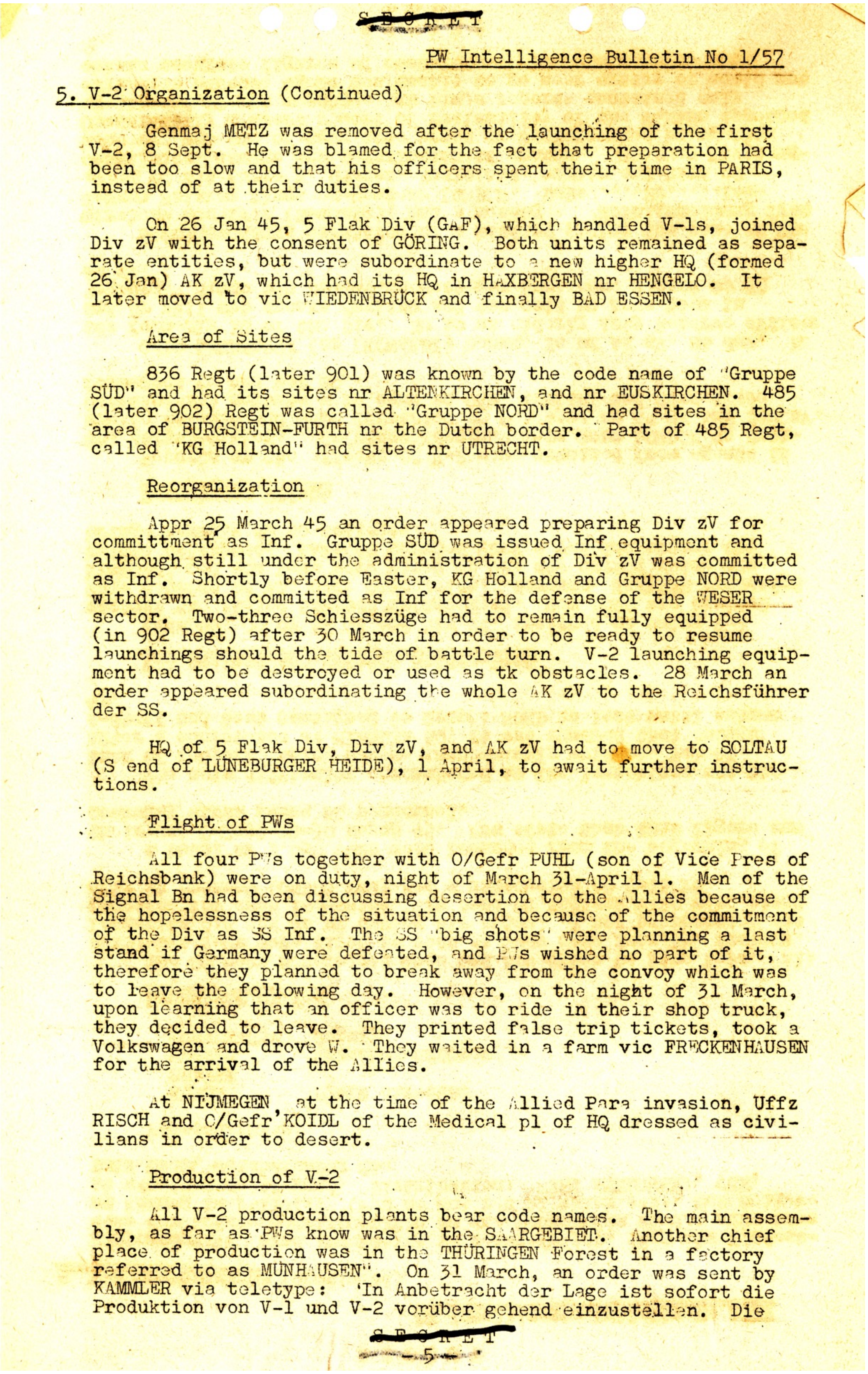

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5. V-2 Organization (Continued)

Genmaj METZ was removed after the launching of the first V-2, 8 Sept. He was blamed for the fact that preparation had been too slow and that his officers spent their time in PARIS, instead of at their duties.

On 26 Jan 45, 5 Flak Div (GAF), which handled V-1s, joined Div zV with the consent of GÖRING. Both units remained as separate entities, but were subordinate to a new higher HQ (formed 26 Jan) AK zV, which had its HQ in HAXBERGEN nr HENGELO. It later moved to vic WIEDENBRÜCK and finally BAD ESSEN.

Area of Sites

836 Regt (later 901) was known by the code name of "Gruppe SÜD" and had its sites nr ALTENKIRCHEN, and nr EUSKIRCHEN. 485 (later 902) Regt was called "Gruppe NORD" and had sites in the area of BURGSTEIN-FURTH nr the Dutch border. Part of 485 Regt, called "KG Holland" had sites nr UTRECHT.

Reorganization

Appr 25 March 45 an order appeared preparing Div zV for committment as Inf. Gruppe SÜD was issued Inf equipment and although still under the administration of Div zV was committed as Inf. Shortly before Easter, KG Holland and Gruppe NORD were withdrawn and committed as Inf for the defense of the WESER sector. Two-three Schiesszüge had to remain fully equipped (in 902 Regt) after 30 March in order to be ready to resume launchings should the tide of battle turn. V-2 launching equipment had to be destroyed or used as tk obstacles. 28 March an order appeared subordinating the whole AK zV to the Reichsführer der SS.

HQ of 5 Flak Div, Div zV, and AK zV had to move to SOLTAU (S end of LÜNEBURGER HEIDE), 1 April, to await further instructions.

Flight of PWs

All four PWs together with O/Gefr PUHL (son of Vice Pres of Reichsbank) were on duty, night of March 31-April 1. Men of the Signal Bn had been discussing desertion to the Allies because of the hopelessness of the situation and because of the commitment of the Div as SS Inf. The SS "big shots" were planning a last stand if Germany were defeated, and PWs wished no part of it, therefore they planned to break away from the convoy which was to leave the following day. However, on the night of 31 March, upon learning that an officer was to ride in their shop truck, they decided to leave. They printed false trip tickets, took a Volkswagen and drove W. They waited in a farm vic FRECKENHAUSEN for the arrival of the Allies.

At NIJMEGEN, at the time of the Allied Para invasion, Uffz RISCH and O/Gefr KOIDL of the Medical pl of HQ dressed as civilians in order to desert.

Production of V-2

All V-2 production plants bear code names. The main assembly, as far as PWs know was in the SAARGEBIET. Another chief place of production was in the THÜRINGEN Forest in a factory referred to as MUNHAUSEN". On 31 March, an order was sent by KAMMLER via teletype: 'In Anbetracht der Lage ist sofort die Produktion von V-1 und V-2 vorüber gehend einzustellen. Die

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Figure E.55: Several German prisoners of war captured by the Allies mentioned Hans Kammler and the rockets and underground facilities that were under his control. PW Intelligence Bulletin No 1/57. 12 April 1945 [AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527; AFHRA A5185 frames 1029–1047].

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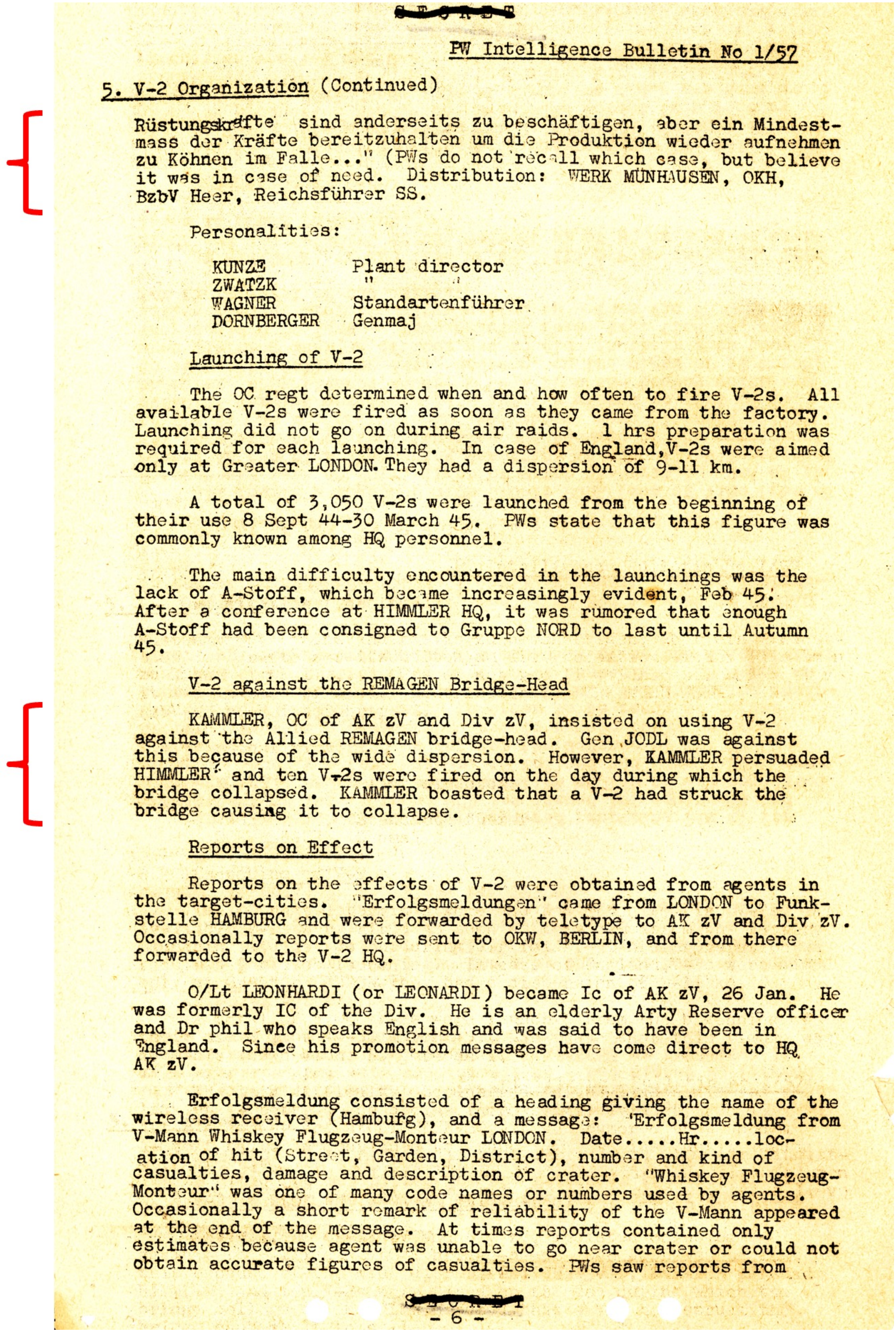

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PW Intelligence Bulletin No 1/57

5. V-2 Organization (Continued)

Rüstungskräfte sind anderseits zu beschäftigen, aber ein Mindestmass der Kräfte bereitzuhalten um die Produktion wieder aufnehmen zu Köhnen im Falle..." (PWs do not recall which case, but believe it was in case of need. Distribution: WERK MÜNHAUSEN, OKH, BzbV Heer, Reichsführer SS.

Personalities:

KUNZE	Plant director
ZWATZK	"
WAGNER	Standartenführer
DORNBERGER	Genmaj

Launching of V-2

The OC regt determined when and how often to fire V-2s. All available V-2s were fired as soon as they came from the factory. Launching did not go on during air raids. 1 hrs preparation was required for each launching. In case of England, V-2s were aimed only at Greater LONDON. They had a dispersion of 9-11 km.

A total of 3,050 V-2s were launched from the beginning of their use 8 Sept 44-30 March 45. PWs state that this figure was commonly known among HQ personnel.

The main difficulty encountered in the launchings was the lack of A-Stoff, which became increasingly evident, Feb 45. After a conference at HIMMLER HQ, it was rumored that enough A-Stoff had been consigned to Gruppe NORD to last until Autumn 45.

V-2 against the REMAGEN Bridge-Head

KAMMLER, OC of AK zV and Div zV, insisted on using V-2 against the Allied REMAGEN bridge-head. Gen JODL was against this because of the wide dispersion. However, KAMMLER persuaded HIMMLER and ten V-2s were fired on the day during which the bridge collapsed. KAMMLER boasted that a V-2 had struck the bridge causing it to collapse.

Reports on Effect

Reports on the effects of V-2 were obtained from agents in the target-cities. "Erfolgsmeldungen" came from LONDON to Funkstelle HAMBURG and were forwarded by teletype to AK zV and Div zV. Occasionally reports were sent to OKW, BERLIN, and from there forwarded to the V-2 HQ.

O/Lt LEONHARDI (or LEONARDI) became Ic of AK zV, 26 Jan. He was formerly IC of the Div. He is an elderly Arty Reserve officer and Dr phil who speaks English and was said to have been in England. Since his promotion messages have come direct to HQ AK zV.

Erfolgsmeldung consisted of a heading giving the name of the wireless receiver (Hambufg), and a message: "Erfolgsmeldung from V-Mann Whiskey Flugzeug-Monteur LONDON. Date.....Hr.....location of hit (Street, Garden, District), number and kind of casualties, damage and description of crater. "Whiskey Flugzeug-Monteur" was one of many code names or numbers used by agents. Occasionally a short remark of reliability of the V-Mann appeared at the end of the message. At times reports contained only estimates because agent was unable to go near crater or could not obtain accurate figures of casualties. PWs saw reports from

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Figure E.56: Several German prisoners of war captured by the Allies mentioned Hans Kammler and the rockets and underground facilities that were under his control. PW Intelligence Bulletin No 1/57. 12 April 1945 [AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527; AFHRA A5185 frames 1029–1047].

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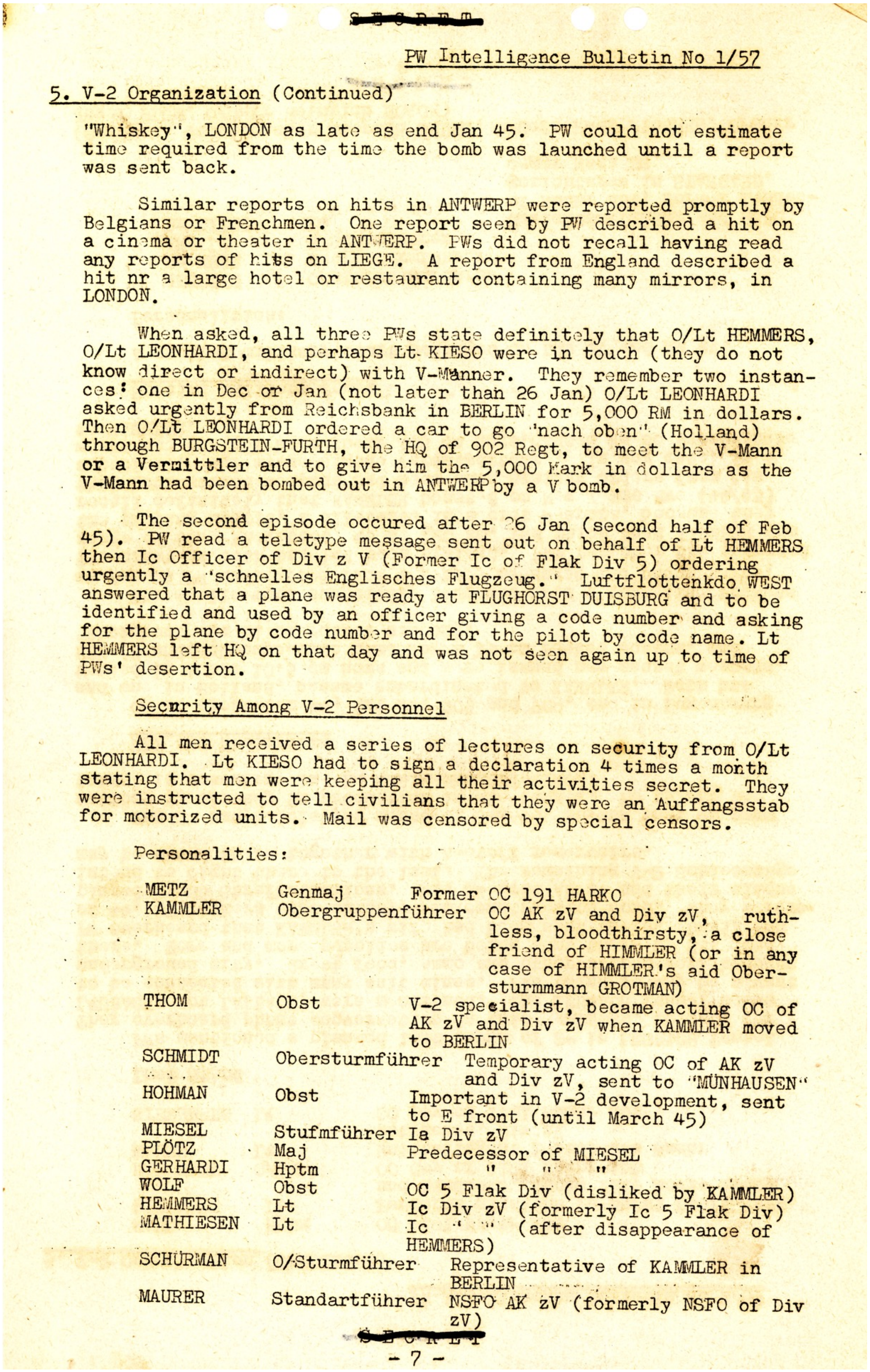

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PW Intelligence Bulletin No 1/57

5. V-2 Organization (Continued)

"Whiskey", LONDON as late as end Jan 45. PW could not estimate time required from the time the bomb was launched until a report was sent back.

Similar reports on hits in ANTWERP were reported promptly by Belgians or Frenchmen. One report seen by PW described a hit on a cinema or theater in ANTWERP. PWs did not recall having read any reports of hits on LIEGE. A report from England described a hit nr a large hotel or restaurant containing many mirrors, in LONDON.

When asked, all three PWs state definitely that O/Lt HEMMERS, O/Lt LEONHARDI, and perhaps Lt KIESO were in touch (they do not know direct or indirect) with V-Männer. They remember two instances: one in Dec or Jan (not later than 26 Jan) O/Lt LEONHARDI asked urgently from Reichsbank in BERLIN for 5,000 RM in dollars. Then O/Lt LEONHARDI ordered a car to go "nach oben" (Holland) through BURGSTEIN-FURTH, the HQ of 902 Regt, to meet the V-Mann or a Vermittler and to give him the 5,000 Mark in dollars as the V-Mann had been bombed out in ANTWERP by a V bomb.

The second episode occured after 26 Jan (second half of Feb 45). PW read a teletype message sent out on behalf of Lt HEMMERS then Ic Officer of Div z V (Former Ic of Flak Div 5) ordering urgently a "schnelles Englisches Flugzeug." Luftflottenkdo WEST answered that a plane was ready at FLUGHORST DUISBURG and to be identified and used by an officer giving a code number and asking for the plane by code number and for the pilot by code name. Lt HEMMERS left HQ on that day and was not seen again up to time of PWs' desertion.

Security Among V-2 Personnel

All men received a series of lectures on security from O/Lt LEONHARDI. Lt KIESO had to sign a declaration 4 times a month stating that men were keeping all their activities secret. They were instructed to tell civilians that they were an Auffangsstab for motorized units. Mail was censored by special censors.

Personalities:

METZ	Genmaj	Former OC 191 HARKO
KAMMLER	Obergruppenführer	OC AK zV and Div zV, ruthless, bloodthirsty, a close friend of HIMMLER (or in any case of HIMMLER's aid Obersturmmann GROTMAN)
THOM	Obst	V-2 specialist, became acting OC of AK zV and Div zV when KAMMLER moved to BERLIN
SCHMIDT	Obersturmführer	Temporary acting OC of AK zV and Div zV, sent to "MÜNHAUSEN"
HOHMAN	Obst	Important in V-2 development, sent to E front (until March 45)
MIESEL	Stufmführer	Ia Div zV
PLÖTZ	Maj	Predecessor of MIESEL
GERHARDI	Hptm	" " "
WOLF	Obst	OC 5 Flak Div (disliked by KAMMLER)
HEMMERS	Lt	Ic Div zV (formerly Ic 5 Flak Div)
MATHIESEN	Lt	Ic " " (after disappearance of HEMMERS)
SCHÜRMAN	O/Sturmführer	Representative of KAMMLER in BERLIN
MAURER	Standartführer	NSFO AK zV (formerly NSFO of Div zV)

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Figure E.57: Several German prisoners of war captured by the Allies mentioned Hans Kammler and the rockets and underground facilities that were under his control. PW Intelligence Bulletin No 1/57. 12 April 1945 [AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527; AFHRA A5185 frames 1029–1047].

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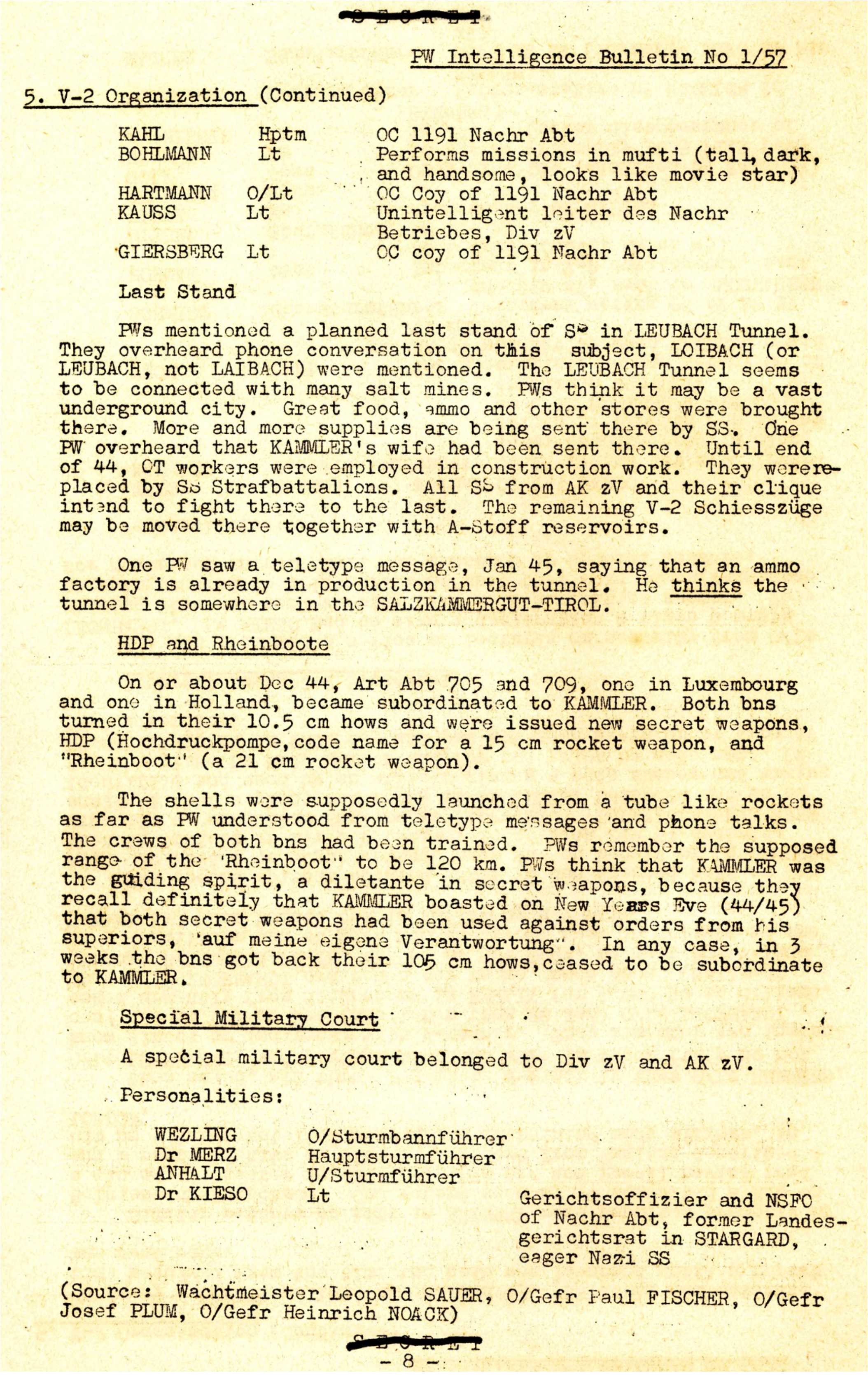

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5. V-2 Organization (Continued)

KAHL	Hptm	OC 1191 Nachr Abt
BOHLMANN	Lt	Performs missions in mufti (tall, dark, and handsome, looks like movie star)
HARTMANN	O/Lt	OC Coy of 1191 Nachr Abt
KAUSS	Lt	Unintelligent leiter des Nachr Betriebes, Div zV
GIERSBERG	Lt	OC coy of 1191 Nachr Abt

Last Stand

PWs mentioned a planned last stand of SS in LEUBACH Tunnel. They overheard phone conversation on this subject, LOIBACH (or LEUBACH, not LAIBACH) were mentioned. The LEUBACH Tunnel seems to be connected with many salt mines. PWs think it may be a vast underground city. Great food, ammo and other stores were brought there. More and more supplies are being sent there by SS. One PW overheard that KAMMLER's wife had been sent there. Until end of 44, CT workers were employed in construction work. They were replaced by SS Strafbattalions. All SS from AK zV and their clique intend to fight there to the last. The remaining V-2 Schiesszüge may be moved there together with A-Stoff reservoirs.

One PW saw a teletype message, Jan 45, saying that an ammo factory is already in production in the tunnel. He thinks the tunnel is somewhere in the SALZKAMMERGUT-TIROL.

HDP and Rheinboote

On or about Dec 44, Art Abt 705 and 709, one in Luxembourg and one in Holland, became subordinated to KAMMLER. Both bns turned in their 10.5 cm hows and were issued new secret weapons, HDP (Hochdruckpompe, code name for a 15 cm rocket weapon, and "Rheinboot" (a 21 cm rocket weapon).

The shells were supposedly launched from a tube like rockets as far as PW understood from teletype messages and phone talks. The crews of both bns had been trained. PWs remember the supposed range of the 'Rheinboot" to be 120 km. PWs think that KAMMLER was the guiding spirit, a diletante in secret weapons, because they recall definitely that KAMMLER boasted on New Years Eve (44/45) that both secret weapons had been used against orders from his superiors, 'auf meine eigene Verantwortung". In any case, in 3 weeks the bns got back their 105 cm hows, ceased to be subordinate to KAMMLER.

Special Military Court

A special military court belonged to Div zV and AK zV.

Personalities:

WEZLING	O/Sturmbannführer	
Dr MERZ	Hauptsturmführer	
ANHALT	U/Sturmführer	
Dr KIESO	Lt	Gerichtsoffizier and NSFO of Nachr Abt, former Landesgerichtsrat in STARGARD, eager Nazi SS

(Source: Wachtmeister Leopold SAUER, O/Gefr Paul FISCHER, O/Gefr Josef PLUM, O/Gefr Heinrich NOACK)

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Figure E.58: Several German prisoners of war captured by the Allies mentioned Hans Kammler and the rockets and underground facilities that were under his control. PW Intelligence Bulletin No 1/57. 12 April 1945 [AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527; AFHRA A5185 frames 1029–1047].

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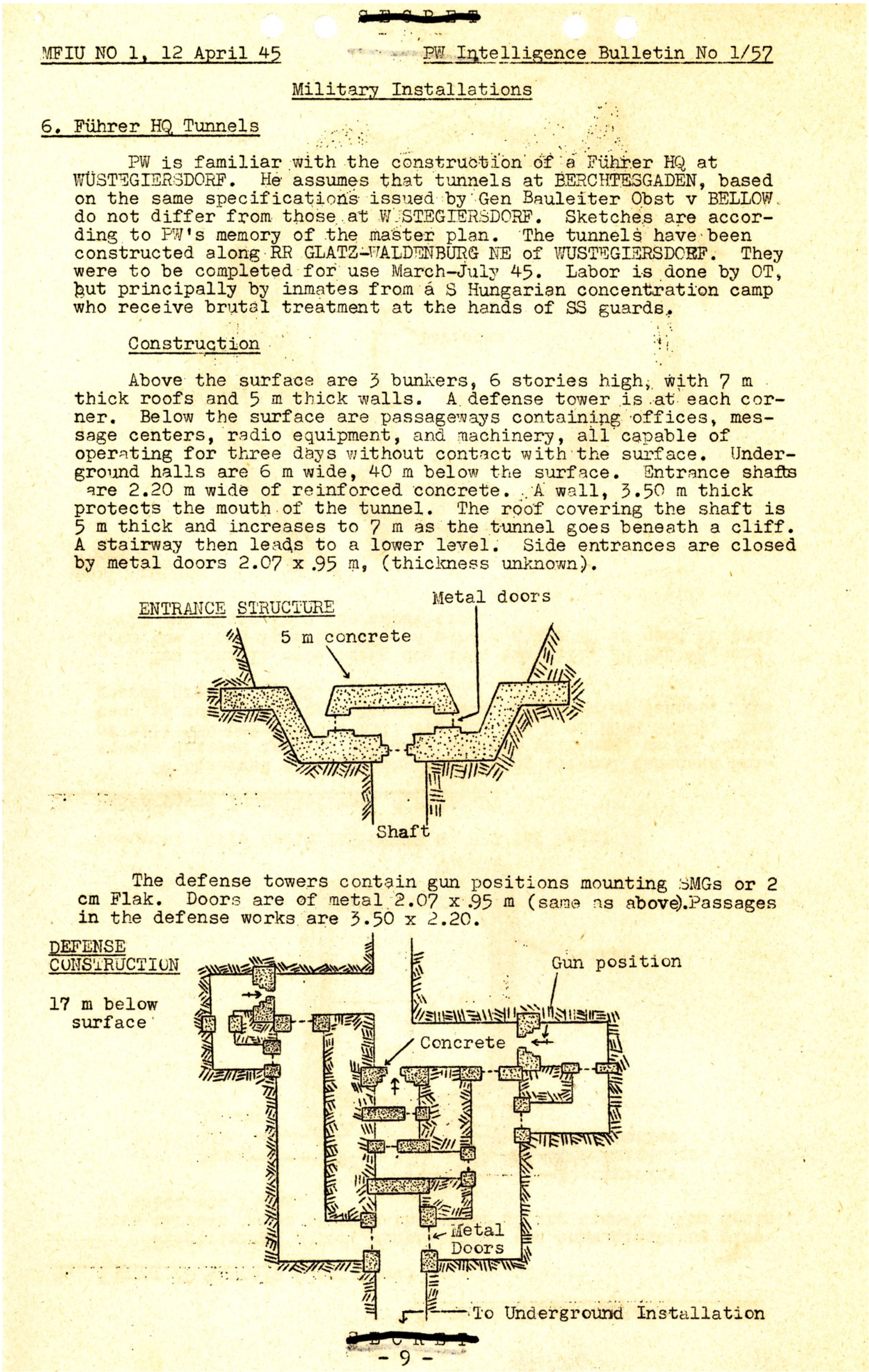

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MFIU NO 1, 12 April 45 PW Intelligence Bulletin No 1/57

Military Installations

6. Führer HQ Tunnels

PW is familiar with the construction of a Führer HQ at WÜSTEGIERSDORF. He assumes that tunnels at BERCHTESGADEN, based on the same specifications issued by Gen Bauleiter Obst v BELLOW do not differ from those at WÜSTEGIERSDORF. Sketches are according to PW's memory of the master plan. The tunnels have been constructed along RR GLATZ-WALDENBURG NE of WUSTEGIERSDORF. They were to be completed for use March-July 45. Labor is done by OT, but principally by inmates from a S Hungarian concentration camp who receive brutal treatment at the hands of SS guards.

Construction

Above the surface are 3 bunkers, 6 stories high, with 7 m thick roofs and 5 m thick walls. A defense tower is at each corner. Below the surface are passageways containing offices, message centers, radio equipment, and machinery, all capable of operating for three days without contact with the surface. Underground halls are 6 m wide, 40 m below the surface. Entrance shafts are 2.20 m wide of reinforced concrete. A wall, 3.50 m thick protects the mouth of the tunnel. The roof covering the shaft is 5 m thick and increases to 7 m as the tunnel goes beneath a cliff. A stairway then leads to a lower level. Side entrances are closed by metal doors 2.07 x .95 m, (thickness unknown).

ENTRANCE STRUCTURE

The defense towers contain gun positions mounting SMGs or 2 cm Flak. Doors are of metal 2.07 x .95 m (same as above). Passages in the defense works are 3.50 x 2.20.

DEFENSE CONSTRUCTION

17 m below surface

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Figure E.59: Several German prisoners of war captured by the Allies mentioned Hans Kammler and the rockets and underground facilities that were under his control. PW Intelligence Bulletin No 1/57. 12 April 1945 [AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527; AFHRA A5185 frames 1029–1047].

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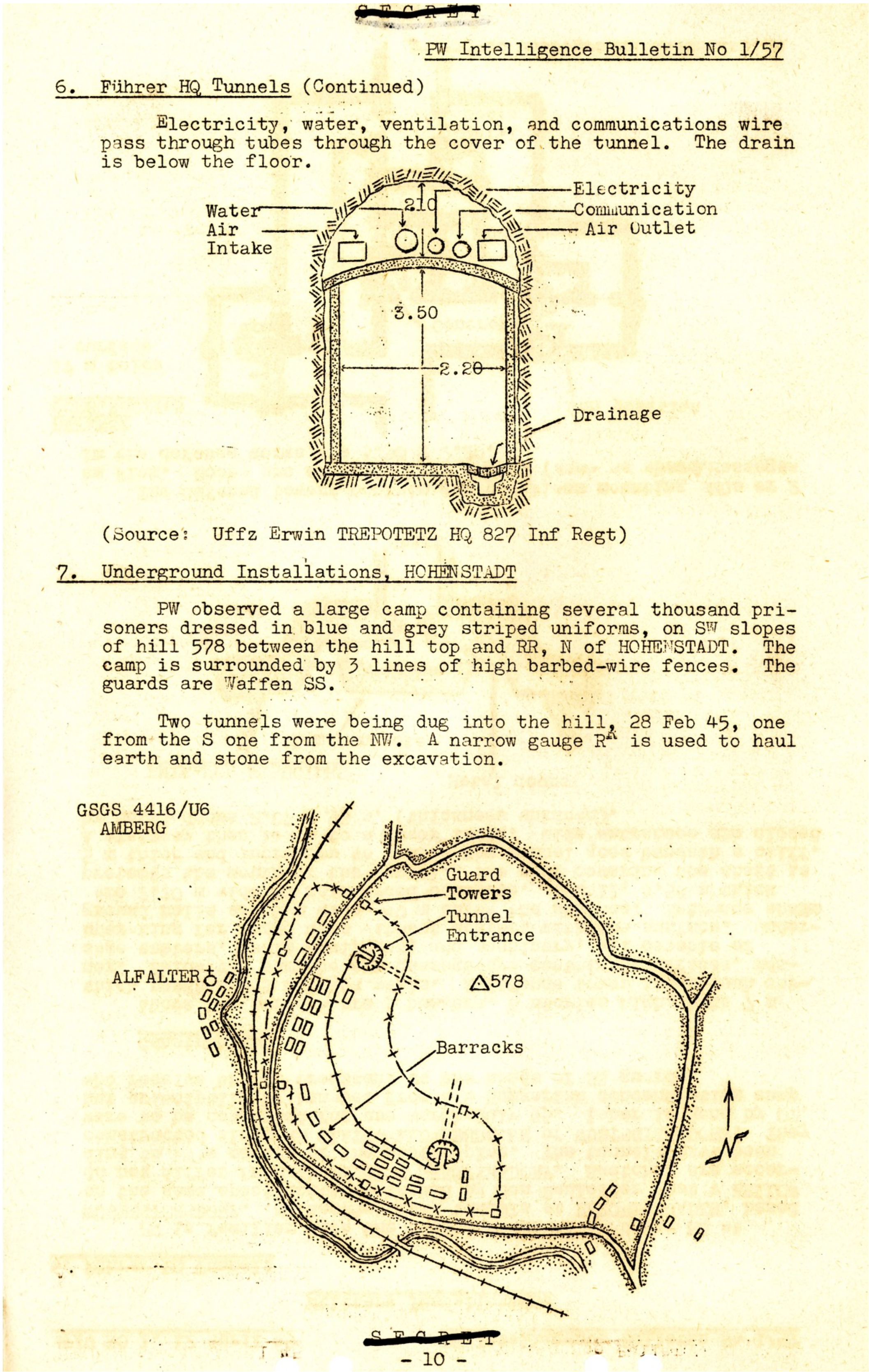

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6. Führer HQ Tunnels (Continued)

Electricity, water, ventilation, and communications wire pass through tubes through the cover of the tunnel. The drain is below the floor.

Water
Air Intake
2.10
Electricity
Communication
Air Outlet
3.50
2.20
Drainage

(Source: Uffz Erwin TREPOTETZ HQ 827 Inf Regt)

7. Underground Installations, HOHENSTADT

PW observed a large camp containing several thousand prisoners dressed in blue and grey striped uniforms, on SW slopes of hill 578 between the hill top and RR, N of HOHENSTADT. The camp is surrounded by 3 lines of high barbed-wire fences. The guards are Waffen SS.

Two tunnels were being dug into the hill, 28 Feb 45, one from the S one from the NW. A narrow gauge R^{R} is used to haul earth and stone from the excavation.

GSGS 4416/U6
AMBERG
Guard Towers
Tunnel Entrance
ALFALTER
△578
Barracks
N

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Figure E.60: Several German prisoners of war captured by the Allies mentioned Hans Kammler and the rockets and underground facilities that were under his control. PW Intelligence Bulletin No 1/57. 12 April 1945 [AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527; AFHRA A5185 frames 1029–1047].

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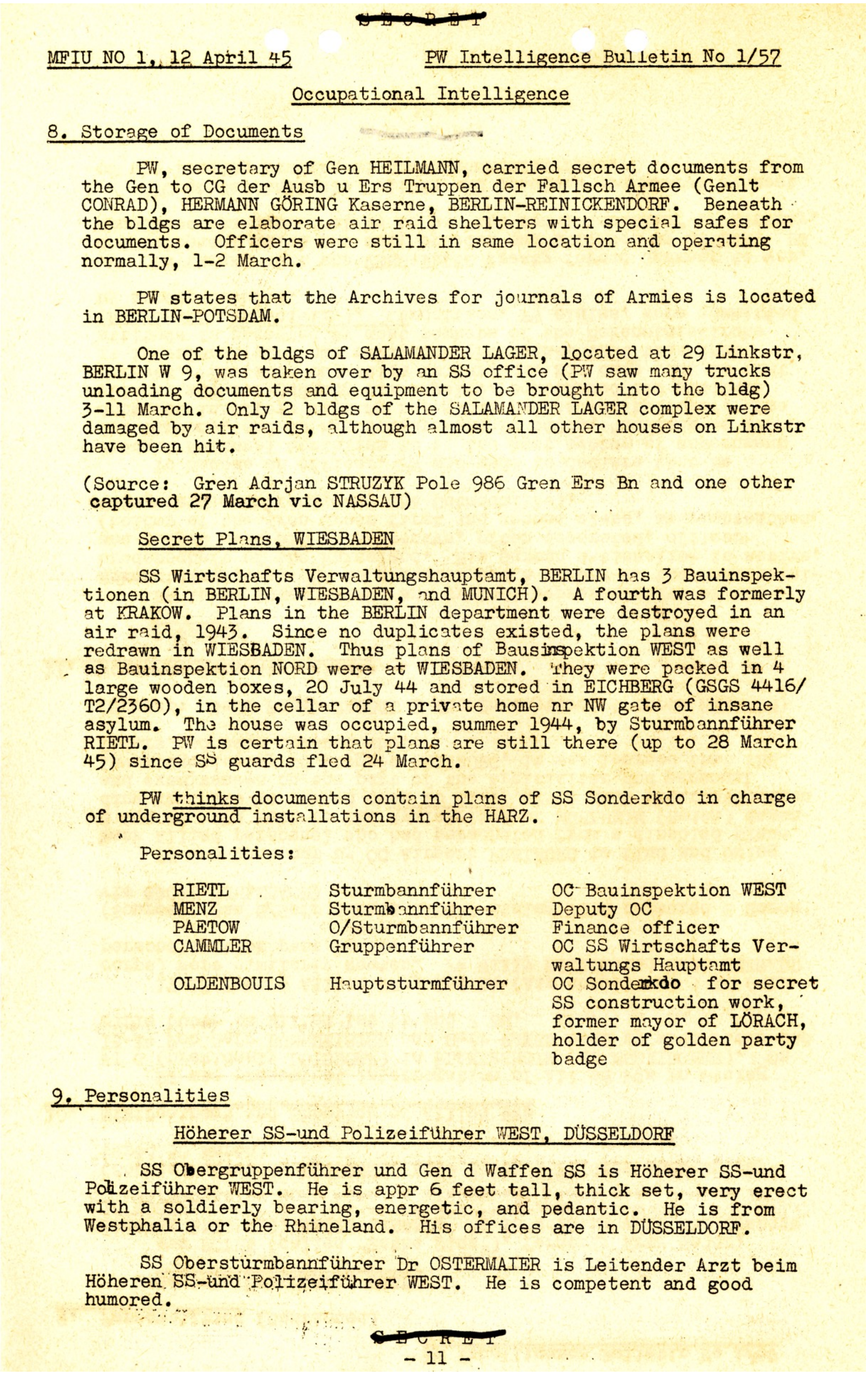

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Occupational Intelligence

8. Storage of Documents

PW, secretary of Gen HEILMANN, carried secret documents from the Gen to CG der Ausb u Ers Truppen der Fallsch Armee (Genlt CONRAD), HERMANN GÖRING Kaserne, BERLIN-REINICKENDORF. Beneath the bldgs are elaborate air raid shelters with special safes for documents. Officers were still in same location and operating normally, 1-2 March.

PW states that the Archives for journals of Armies is located in BERLIN-POTSDAM.

One of the bldgs of SALAMANDER LAGER, located at 29 Linkstr, BERLIN W 9, was taken over by an SS office (PW saw many trucks unloading documents and equipment to be brought into the bldg) 3-11 March. Only 2 bldgs of the SALAMANDER LAGER complex were damaged by air raids, although almost all other houses on Linkstr have been hit.

(Source: Gren Adrjan STRUZYK Pole 986 Gren Ers Bn and one other captured 27 March vic NASSAU)

Secret Plans, WIESBADEN

SS Wirtschafts Verwaltungshauptamt, BERLIN has 3 Bauinspektionen (in BERLIN, WIESBADEN, and MUNICH). A fourth was formerly at KRAKOW. Plans in the BERLIN department were destroyed in an air raid, 1943. Since no duplicates existed, the plans were redrawn in WIESBADEN. Thus plans of Bauinspektion WEST as well as Bauinspektion NORD were at WIESBADEN. They were packed in 4 large wooden boxes, 20 July 44 and stored in EICHBERG (GSGS 4416/T2/2360), in the cellar of a private home nr NW gate of insane asylum. The house was occupied, summer 1944, by Sturmbannführer RIETL. PW is certain that plans are still there (up to 28 March 45) since SS guards fled 24 March.

PW thinks documents contain plans of SS Sonderkdo in charge of underground installations in the HARZ.

Personalities:

RIETL	Sturmbannführer	OC Bauinspektion WEST
MENZ	Sturmbannführer	Deputy OC
PAETOW	O/Sturmbannführer	Finance officer
CAMMLER	Gruppenführer	OC SS Wirtschafts Verwaltungs Hauptamt
OLDENBOUIS	Hauptsturmführer	OC Sonderkdo for secret SS construction work, former mayor of LÖRACH, holder of golden party badge

9. Personalities

Höherer SS-und Polizeiführer WEST, DÜSSELDORF

SS Obergruppenführer und Gen d Waffen SS is Höherer SS-und Polizeiführer WEST. He is appr 6 feet tall, thick set, very erect with a soldierly bearing, energetic, and pedantic. He is from Westphalia or the Rhineland. His offices are in DÜSSELDORF.

SS Obersturmbannführer Dr OSTERMAIER is Leitender Arzt beim Höheren SS-und Polizeiführer WEST. He is competent and good humored.

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Figure E.61: Several German prisoners of war captured by the Allies mentioned Hans Kammler and the rockets and underground facilities that were under his control. PW Intelligence Bulletin No 1/57. 12 April 1945 [AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527; AFHRA A5185 frames 1029–1047].

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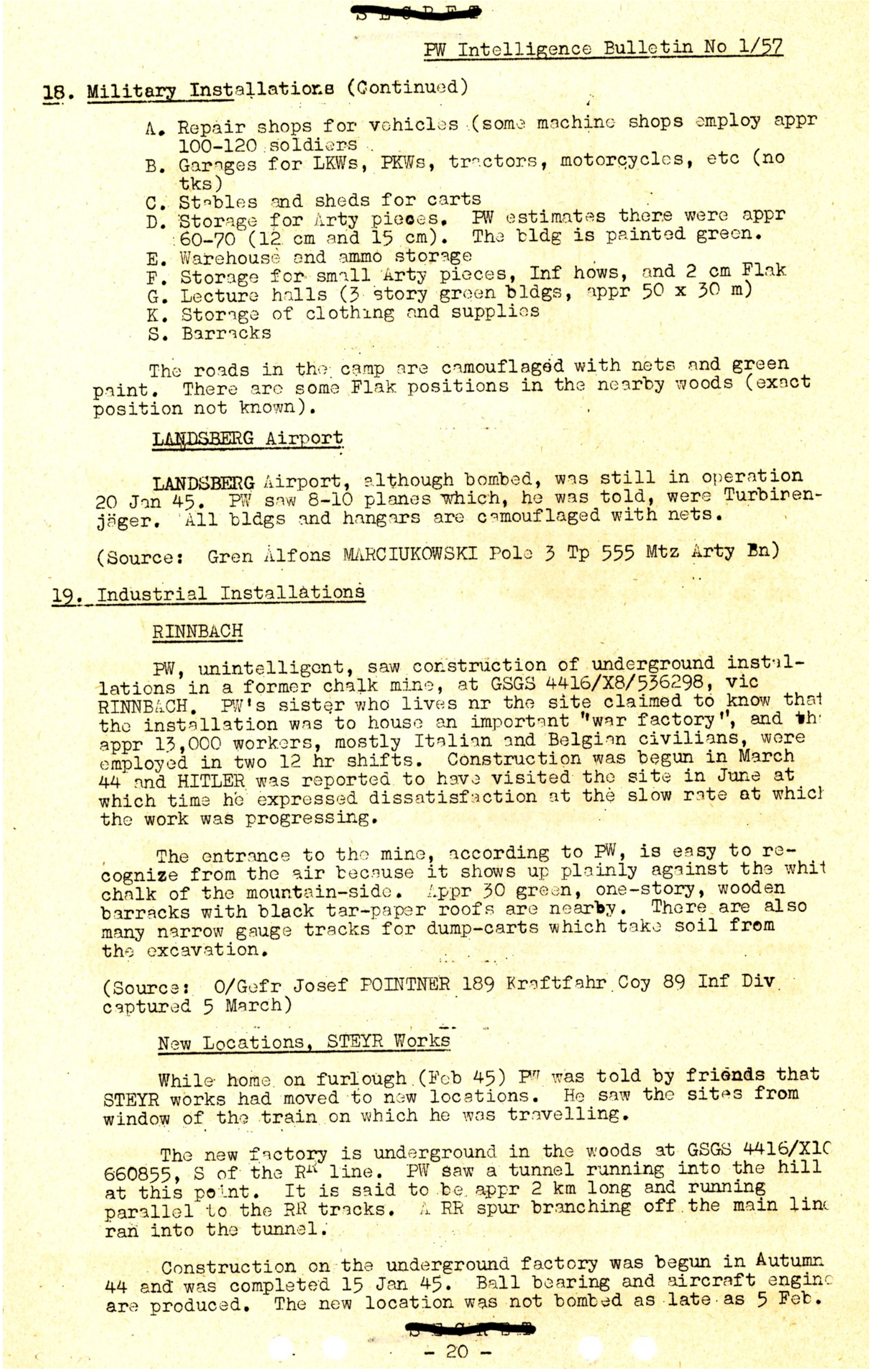

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18. Military Installations (Continued)

A. Repair shops for vehicles (some machine shops employ appr 100-120 soldiers
B. Garages for LKWs, PKWs, tractors, motorcycles, etc (no tks)
C. Stables and sheds for carts
D. Storage for Arty pieces. PW estimates there were appr 60-70 (12 cm and 15 cm). The bldg is painted green.
E. Warehouse and ammo storage
F. Storage for small Arty pieces, Inf hows, and 2 cm Flak
G. Lecture halls (3 story green bldgs, appr 50 x 30 m)
K. Storage of clothing and supplies
S. Barracks

The roads in the camp are camouflaged with nets and green paint. There are some Flak positions in the nearby woods (exact position not known).

LANDSBERG Airport

LANDSBERG Airport, although bombed, was still in operation 20 Jan 45. PW saw 8-10 planes which, he was told, were Turbinenjäger. All bldgs and hangars are camouflaged with nets.

(Source: Gren Alfons MARCIUKOWSKI Pole 3 Tp 555 Mtz Arty Bn)

19. Industrial Installations

RINNBACH

PW, unintelligent, saw construction of underground installations in a former chalk mine, at GSGS 4416/X8/536298, vic RINNBACH. PW's sister who lives nr the site claimed to know that the installation was to house an important "war factory", and th appr 13,000 workers, mostly Italian and Belgian civilians, were employed in two 12 hr shifts. Construction was begun in March 44 and HITLER was reported to have visited the site in June at which time he expressed dissatisfaction at the slow rate at which the work was progressing.

The entrance to the mine, according to PW, is easy to recognize from the air because it shows up plainly against the whit chalk of the mountain-side. Appr 30 green, one-story, wooden barracks with black tar-paper roofs are nearby. There are also many narrow gauge tracks for dump-carts which take soil from the excavation.

(Source: O/Gefr Josef POINTNER 189 Kraftfahr Coy 89 Inf Div captured 5 March)

New Locations, STEYR Works

While home on furlough (Feb 45) PW was told by friends that STEYR works had moved to new locations. He saw the sites from window of the train on which he was travelling.

The new factory is underground in the woods at GSGS 4416/X10 660855, S of the RR line. PW saw a tunnel running into the hill at this point. It is said to be appr 2 km long and running parallel to the RR tracks. A RR spur branching off the main line ran into the tunnel.

Construction on the underground factory was begun in Autumn 44 and was completed 15 Jan 45. Ball bearing and aircraft engine are produced. The new location was not bombed as late as 5 Feb.

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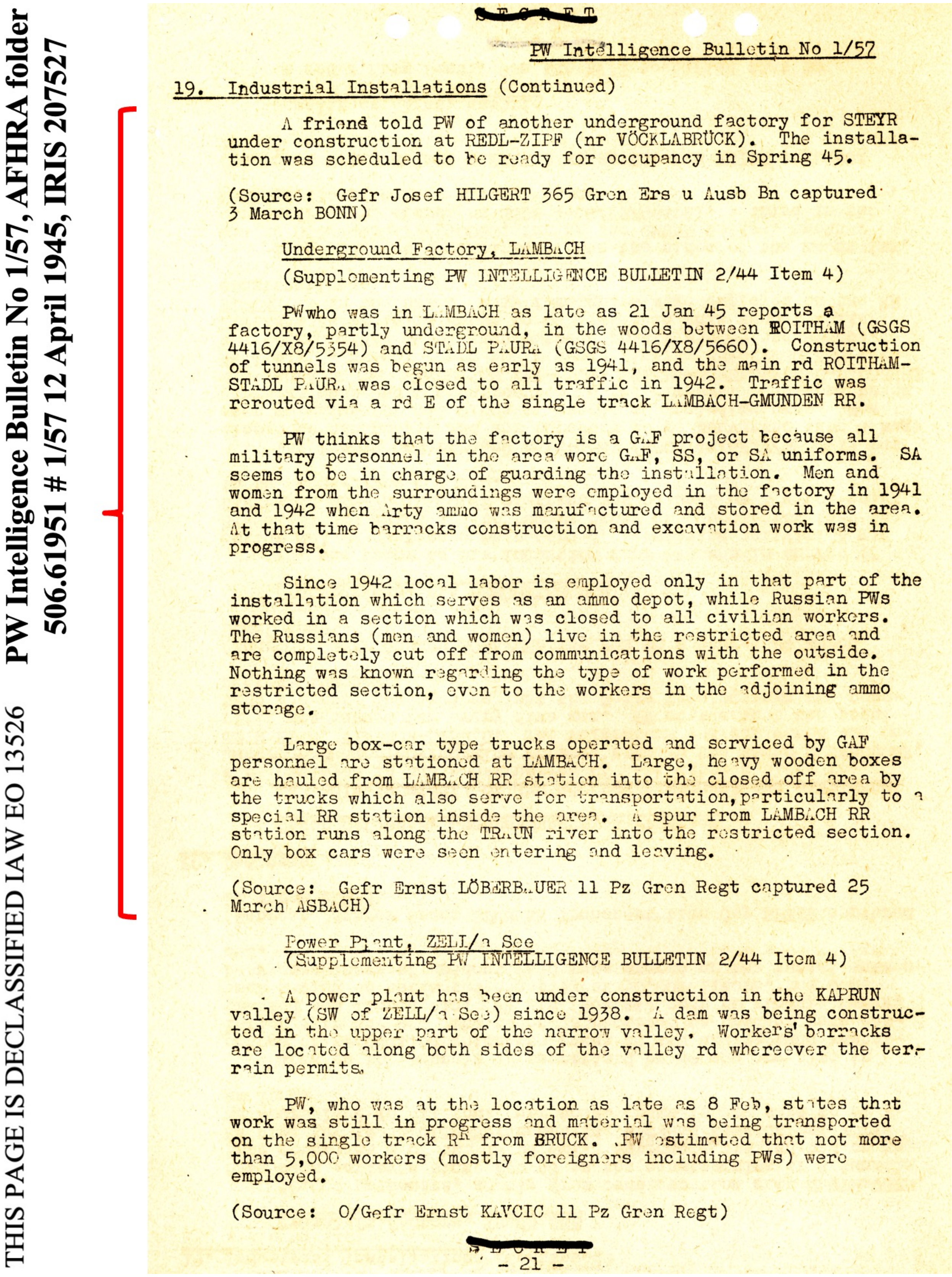
Figure E.62: Several German prisoners of war captured by the Allies mentioned Hans Kammler and the rockets and underground facilities that were under his control. PW Intelligence Bulletin No 1/57. 12 April 1945 [AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527; AFHRA A5185 frames 1029–1047].



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19. Industrial Installations (Continued)

A friend told PW of another underground factory for STEYR under construction at REDL-ZIPF (nr VÖCKLABRÜCK). The installation was scheduled to be ready for occupancy in Spring 45.

(Source: Gefr Josef HILGERT 365 Gren Ers u Ausb Bn captured 3 March BONN)

Underground Factory, LAMBACH

(Supplementing PW INTELLIGENCE BULLETIN 2/44 Item 4)

PW who was in LAMBACH as late as 21 Jan 45 reports a factory, partly underground, in the woods between ROITHAM (GSGS 4416/X8/5354) and STADL PAURA (GSGS 4416/X8/5660). Construction of tunnels was begun as early as 1941, and the main rd ROITHAM-STADL PAURA was closed to all traffic in 1942. Traffic was rerouted via a rd E of the single track LAMBACH-GMUNDEN RR.

PW thinks that the factory is a GAF project because all military personnel in the area wore GAF, SS, or SA uniforms. SA seems to be in charge of guarding the installation. Men and women from the surroundings were employed in the factory in 1941 and 1942 when Arty ammo was manufactured and stored in the area. At that time barracks construction and excavation work was in progress.

Since 1942 local labor is employed only in that part of the installation which serves as an ammo depot, while Russian PWs worked in a section which was closed to all civilian workers. The Russians (men and women) live in the restricted area and are completely cut off from communications with the outside. Nothing was known regarding the type of work performed in the restricted section, even to the workers in the adjoining ammo storage.

Large box-car type trucks operated and serviced by GAF personnel are stationed at LAMBACH. Large, heavy wooden boxes are hauled from LAMBACH RR station into the closed off area by the trucks which also serve for transportation, particularly to a special RR station inside the area. A spur from LAMBACH RR station runs along the TRAUN river into the restricted section. Only box cars were seen entering and leaving.

(Source: Gefr Ernst LÖBERBAUER 11 Pz Gren Regt captured 25 March ASBACH)

Power Plant, ZELL/a See
(Supplementing PW INTELLIGENCE BULLETIN 2/44 Item 4)

A power plant has been under construction in the KAPRUN valley (SW of ZELL/a See) since 1938. A dam was being constructed in the upper part of the narrow valley. Workers' barracks are located along both sides of the valley rd wherever the terrain permits.

PW, who was at the location as late as 8 Feb, states that work was still in progress and material was being transported on the single track R^R from BRUCK. PW estimated that not more than 5,000 workers (mostly foreigners including PWs) were employed.

(Source: O/Gefr Ernst KAVCIC 11 Pz Gren Regt)

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- 21 -

Figure E.63: Several German prisoners of war captured by the Allies mentioned Hans Kammler and the rockets and underground facilities that were under his control. PW Intelligence Bulletin No 1/57. 12 April 1945 [AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527; AFHRA A5185 frames 1029–1047].

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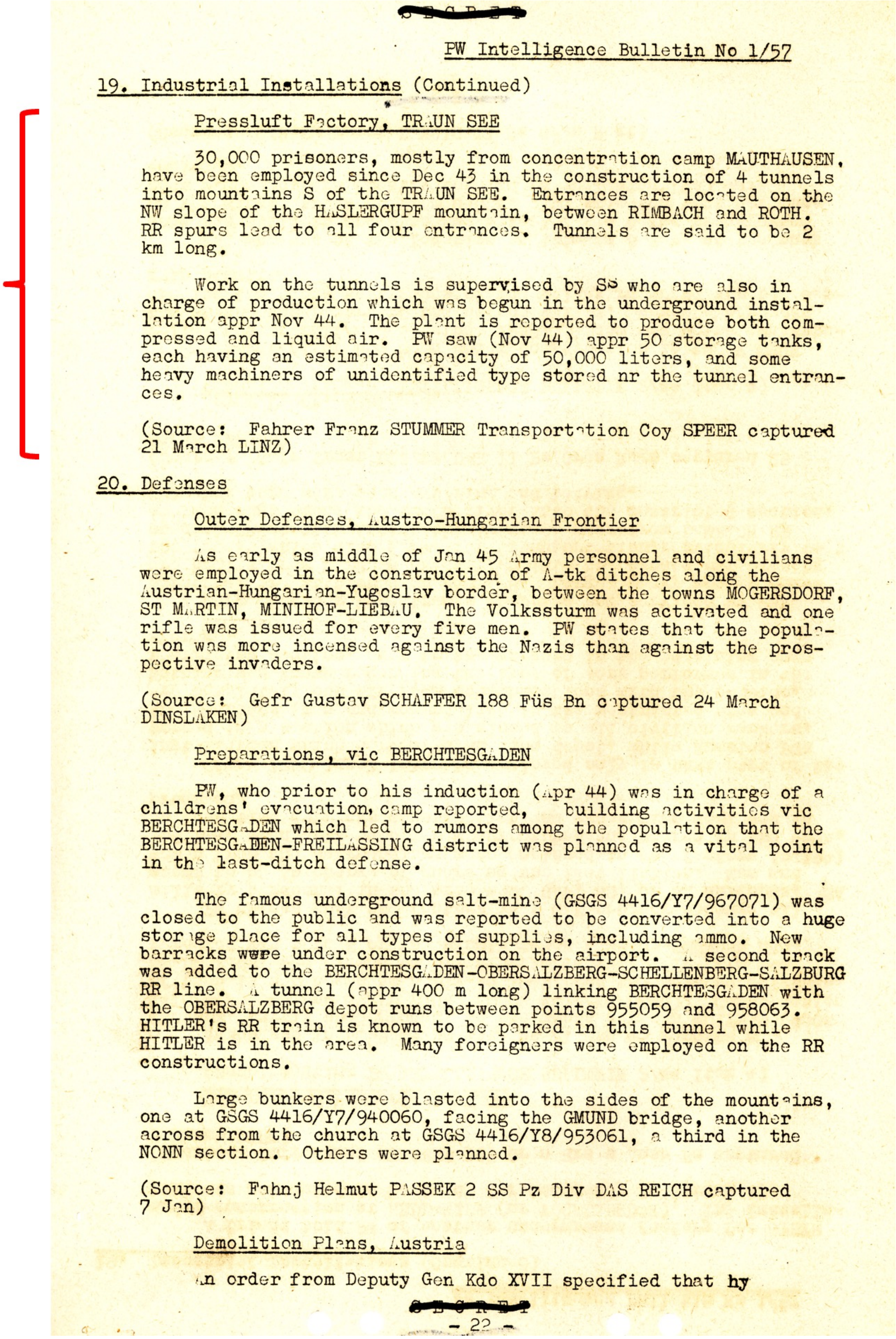
PW Intelligence Bulletin No 1/57, AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527



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PW Intelligence Bulletin No 1/57

19. Industrial Installations (Continued)

Pressluft Factory, TRAUN SEE

30,000 prisoners, mostly from concentration camp MAUTHAUSEN, have been employed since Dec 43 in the construction of 4 tunnels into mountains S of the TRAUN SEE. Entrances are located on the NW slope of the HASLERGUPF mountain, between RIMBACH and ROTH. RR spurs lead to all four entrances. Tunnels are said to be 2 km long.

Work on the tunnels is supervised by SS who are also in charge of production which was begun in the underground installation appr Nov 44. The plant is reported to produce both compressed and liquid air. PW saw (Nov 44) appr 50 storage tanks, each having an estimated capacity of 50,000 liters, and some heavy machiners of unidentified type stored nr the tunnel entrances.

(Source: Fahrer Franz STUMMER Transportation Coy SPEER captured 21 March LINZ)

20. Defenses

Outer Defenses, Austro-Hungarian Frontier

As early as middle of Jan 45 Army personnel and civilians were employed in the construction of A-tk ditches along the Austrian-Hungarian-Yugoslav border, between the towns MOGERSDORF, ST MARTIN, MINIHOF-LIEBAU. The Volkssturm was activated and one rifle was issued for every five men. PW states that the population was more incensed against the Nazis than against the prospective invaders.

(Source: Gefr Gustav SCHAFFER 188 Füs Bn captured 24 March DINSLAKEN)

Preparations, vic BERCHTESGADEN

PW, who prior to his induction (Apr 44) was in charge of a childrens' evacuation camp reported, building activities vic BERCHTESGADEN which led to rumors among the population that the BERCHTESGADEN-FREILASSING district was planned as a vital point in the last-ditch defense.

The famous underground salt-mine (GSGS 4416/Y7/967071) was closed to the public and was reported to be converted into a huge storage place for all types of supplies, including ammo. New barracks were under construction on the airport. A second track was added to the BERCHTESGADEN-OBERSALZBERG-SCHELLENBERG-SALZBURG RR line. A tunnel (appr 400 m long) linking BERCHTESGADEN with the OBERSALZBERG depot runs between points 955059 and 958063. HITLER's RR train is known to be parked in this tunnel while HITLER is in the area. Many foreigners were employed on the RR constructions.

Large bunkers were blasted into the sides of the mountains, one at GSGS 4416/Y7/940060, facing the GMUND bridge, another across from the church at GSGS 4416/Y8/953061, a third in the NONN section. Others were planned.

(Source: Fahnj Helmut PASSEK 2 SS Pz Div DAS REICH captured 7 Jan)

Demolition Plans, Austria

An order from Deputy Gen Kdo XVII specified that by

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- 22 -

Figure E.64: Several German prisoners of war captured by the Allies mentioned Hans Kammler and the rockets and underground facilities that were under his control. PW Intelligence Bulletin No 1/57. 12 April 1945 [AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527; AFHRA A5185 frames 1029–1047].

David Irving. 1965. *The Mare's Nest.* Boston: Little, Brown. pp. 219–220

The remaining site, at Wizernes, caused some anxiety, as it was not obviously aligned on any city in Europe. One interpreter caused a high degree of alarm early in the year when he discovered that one facet of the workings was within half a degree of the accurate Great Circle bearing on New York. Whether the Germans planned this out of sheer mischief is not known; certainly Albert Speer denied after the war that there was ever any intention of firing their New York rockets from Wizernes; but it is a remarkable fact that the enormous bombproof doors and handling gear were all capable of handling a rocket about twice the height of the A 4, if necessary.

W. L. Heiberg. 26 October 1944. Franz Peter (Austrian), Germany–Inventions–Rockets. [NARA RG 38, Entry 98C, Box 3, Folder TSC #1001–1100]

1. Source states he is an Austrian refugee, 22 years of age, and that he arrived in Sweden in August, 1944, where he has been in an internment camp. He claims to have been a rocket specialist for the past eight(!) years, and to have worked at the Rheinmetall-Borsig plant in Sömmerda (NNE of Erfurt, Germany) from December, 1943, to May, 1944, after which he fled to Sweden. He worked in section WKbt of the Sömmerda plant, which, he states, is concerned with the manufacture of Germany's rocket weapons.

2. Source expresses a desire to go to Great Britain or U.S.A. to work on rockets for the United Nations, and has shown a 114-page (page 43 missing) manuscript in substantiation of his claim to intimate knowledge of Germany's "V" weapons. The manuscript has been photographed, and the negative is forwarded as enclosure (A). Enclosure (B) is a table of contents compiled in this office after summary study. [...]

5. Chapter thirteen discusses the principle of the multiple or tandem rocket. The rear or "booster" rocket (Schubrakete) has ten times the mass of the forward or "main" rocket (Hauptrakete). The booster carries the rocket part-way to the target, until the fuel is exhausted; then after launching the main rocket, it falls away. Source claims altitudes of 360 kilometers (223.7 miles) had been reached by such rockets before he fled from Germany in the summer of 1944, and that at this altitude the main rocket could be expected to have a range of 500 to 700 kilometers (310 to 434 miles). (Source did not divulge how altitude was determined.) Such rockets are not launched by catapult, but from a launching track and under their own power. The booster uses gasoline and liquid oxygen as fuel, while the main rocket uses liquid hydrogen and liquid oxygen. (Rockets of this type with a series of boosters were mentioned by Source in course of conversation. He claims an Atlantic rocket, to bomb New York, was calculated to require fifty-six minutes in flight.)

6. Chapter fourteen describes a revolutionary method of electric propulsion which Source claims as his own invention. He stated it was demonstrated at the Kaiser Wilhelm Institute at Potsdam in late spring or early summer, 1944, with good results. This method does away with large fuel tanks, affording more space for useful load, and is much more powerful than present fuels. Electric energy at ten million volts is generated within the rocket by the ionization of a salt solution according to what Source calls the "Kesselring" process, which is described with accompanying diagrams. (Source states this process was discovered by a German scientist in 1937.) This high voltage is discharged in the rocket's exhaust tube, causing a vapor or gas (unidentified) to explode violently,

giving a propulsive exhaust impulse of 1,000 kilograms per second per square centimeter, of 78,590 kilograms (ca. 78 tons) per second, with a ten centimeter (2 1/2") exhaust tube. (Source stated orally that discharges occurred twenty times per second.) Source claims this process could also be used in propelling units for all types of transportation.

[Franz Peter's claim to have been working on rockets since age 14 is not unreasonable. Wernher von Braun began experimenting with rockets at age 12, and many other German-speaking students became interested in rockets at young ages in the 1920s and 1930s. Moreover, with most fighting-age men sent to the front lines, it was not unusual to employ younger individuals in war-related work at home, including rocket development (p. 5313).

Rheinmetall-Borsig is known to have made major advances in developing and demonstrating multi-stage, relatively large solid propellant rockets. See p. 5663. They may well have been involved in other rocket-related work.

Numerous other reports also stated that there were large rocket development and testing programs in the greater Erfurt area.

Franz Peter appeared to be very knowledgeable about rockets, and he appeared to have been involved with actual German rocket development programs for a considerable period of time. He claimed that prior to his leaving in May 1944, the German program had:

- Launched a rocket to an altitude of 360 km. The A-4 (V-2) rocket had a maximum altitude of approximately 200 km if launched vertically. Thus if Peter's claim is true, it describes a more advanced rocket.

- Launched two-stage liquid propellant rockets. If that claim was true, the simplest explanation may be that an A-4 (V-2) or similar rocket had been used as the first stage, and a much smaller rocket had been mounted on top of that as a second stage. Several such rockets, dubbed the Bumper series, were tested in the United States after the war (p. 5314). Those may have been based on successful wartime German experiments, if Franz Peter's information was accurate.

- Launched a rocket that used liquid hydrogen as fuel, a major advance over known German rockets that used ethanol or other hydrocarbons as fuel. As a very new and experimental technology, that would be consistent with the possibility of first testing just a very small hydrogen-powered rocket, for example mounted on top of a much larger A-4 rocket.

- Experimented with ion rocket engines. While Peter's claims for the performance of ion rocket engines and his own contributions to them may have been overstated, German scientists such as Ernst Stuhlinger did invent ion rocket engines, conduct at least some experiments during the war, and ultimately fully develop them in the United States after the war.

The above document mentioned a film negative containing Franz Peter's 114-page manuscript. That film roll was still stored in a canister alongside this document in the NARA file box. Unfortunately, due to the passage of time, the film is fused together and crumbling, and appears to be unreadable, as shown on p. 5315.]

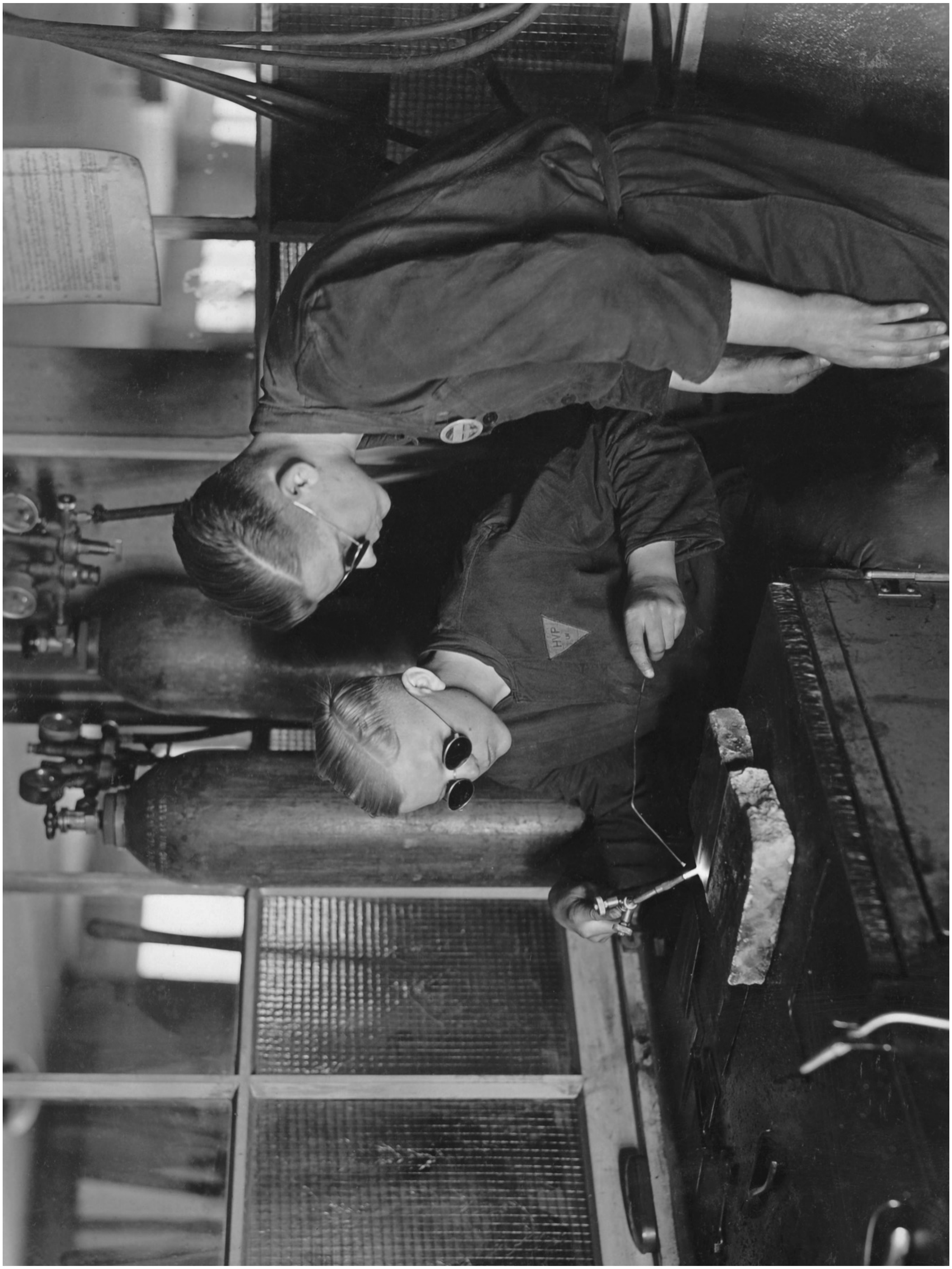


Figure E.65: Two boys working at Peenemünde in early 1942 [Deutsches Museum Archive, photo CD61663].

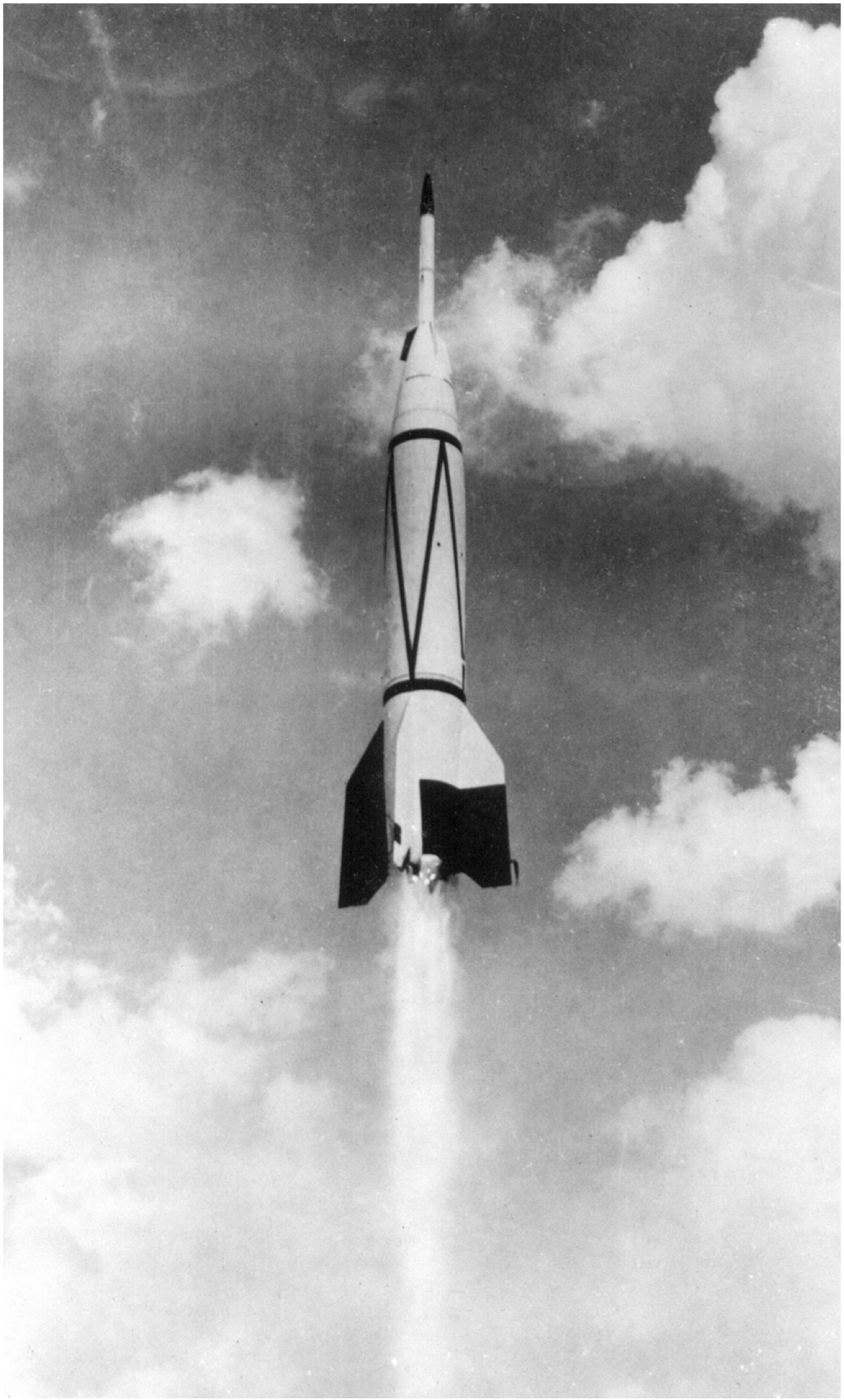
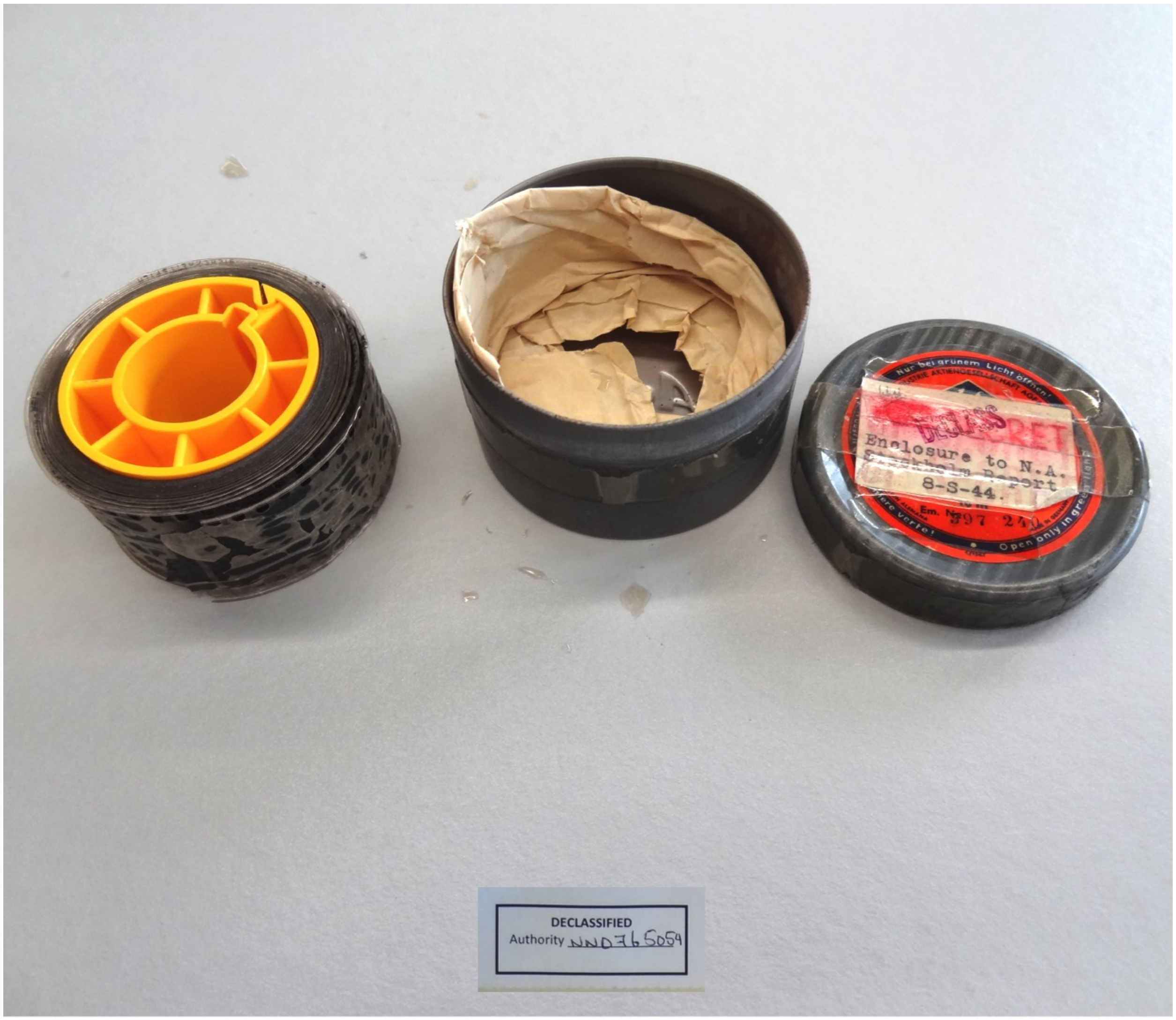


Figure E.66: Bumper 5, an A-4 (V-2) first stage with a small WAC Corporal second stage, was launched in the United States on 24 February 1949 and attained a maximum altitude of 393 km. It may have been based on successful similar wartime German experiments.


Nur bei grünem Licht öffnen!
DECLASS
SECRET
Enclosure to N.A.
~~Stockholm Report~~
8-S-44.
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Open only in green light
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Figure E.67: Unfortunately the film containing Franz Peter's 114-page manuscript on advanced rockets is fused together and crumbling, and appears to be unreadable due to the passage of time [NARA RG 38, Entry 98C, Box 3, Folder TSC #1001–1100].

Cable CM-IN-2077 from Naval Research Lab to NRL Field Group. 9 October 1946. [NARA RG 77, Entry UD-22A, Box 160, Folder In & Out July 16, 1946–Jan. 1947].

From: Naval Research Lab (Electrical Div)
To: NRL Field Group (for Dr Ernest H Krause) White Sands
Proving Ground Las Cruces New Mexico (War pls pass)
DTG: 092040Z NCR 9735 9 October 1946

Request you interview most prominent German rocket scientists to establish professional reputation and personal reliability of German rocket scientist Franz Peder, presumed to have worked on "Electrical Rocket" (Kesselring Process) at Erhfurt Experimental Weapon Station; also establish what work done and what success achieved by Peder or others on this electrical rocket.

End

Note: This message has been relayed to Las Cruces, N Mex.
ACTION: R&D
INFO: AAF, ID, P&O, Gen Groves

John A. O'Mara to Lowell P. Weicker. 14 June 1944. Headquarters, U.S. Strategic Air Forces in Europe, Office of the Director of Intelligence [AFHRA A5734 frames 1369–1370]. [See document photos on pp. 5317–5318.]

[...] Investigation quickly disclosed that there was a group of party technicians in the Wehrmacht experimenting with a very large conventional type of rocket with a total weight in the neighborhood of 68 tons. Another group of scientists in the GAF technical development section were working on a jet-propelled pilotless aircraft and both organizations were testing some of these weapons at Peenemünde, on the shores of the Baltic.

On the 17th of August 1943 construction on a number of strange sites located on the Cherbourg Peninsula and in the Calais area were discovered. Work on these sites progressed at a snail's pace. It took some little time before it was definitely established that these were the so-called secret weapon sites and were linked to the long range weapon experiments at Peenemünde. Ninety-six of them were constructed for the launching of pilotless aircraft and seven were for the launching of giant sized rockets. [...]

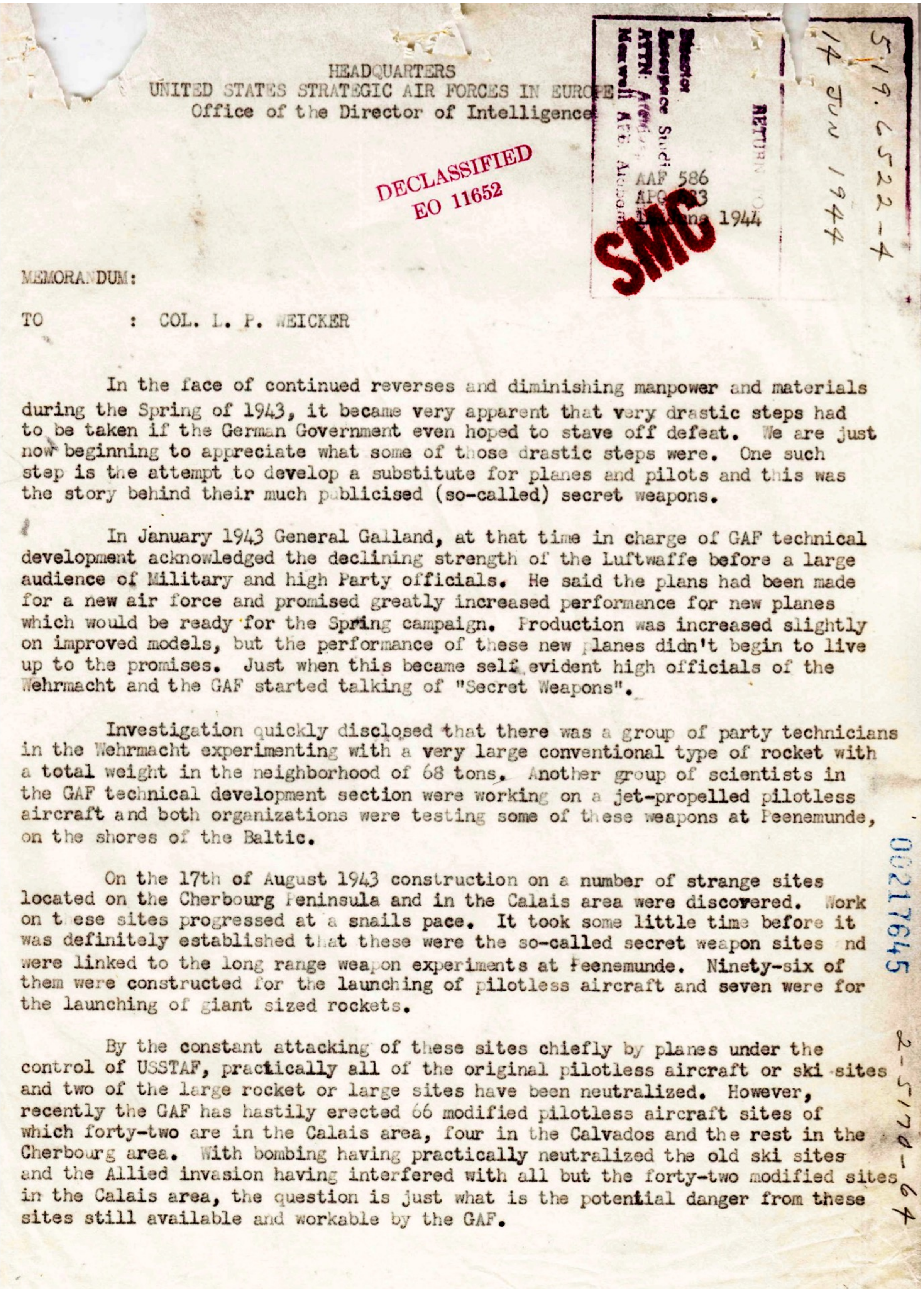
The reported explosions at Maidstone of giant conventional rockets turned out to be nothing but long range, eight inch, naval shells, so that as yet there is nothing upon which to assess the actual value of the projected 68 ton conventional rocket. [Not yet deployed in combat.]

Arnold Deeply Concerned with the German Developments of Robots, Rocket Torpedoes, and Jets—July 1944 [AFHRA 43811 electronic version pp. 962–963].

[...] Arnold was most concerned. "If this rocket procedure is allowed to be developed uninterrupted, there may come a time when these large 75 ton rockets land in England, in occupied France, or possibly if they are radio-controlled, in the United States. We must use everything in our power to prevent any such occurrences."

[The A-4 or V-2 rocket weighed 14 tons. Yet the highest levels of U.S. intelligence reported with great confidence that rockets weighing 68–75 tons were also under active development and experimentation through 1943 and 1944. What evidence did U.S. intelligence have? Note that an A-10 rocket by itself, with no A-4 upper stage or payload, would have weighed around 69 tons (p. 5800).]

AFHRA folder 519.6522-4



HEADQUARTERS
UNITED STATES STRATEGIC AIR FORCES IN EUROPE
Office of the Director of Intelligence

RETURN TO
Director
Aerospace Studies
ATTN: Archives
Maxwell AFB, Alabama

AAF 586
APO 633
14 June 1944

519.6522-4
14 Jun 1944

DECLASSIFIED
EO 11652

SMC

MEMORANDUM:

TO : COL. L. P. WEICKER

In the face of continued reverses and diminishing manpower and materials during the Spring of 1943, it became very apparent that very drastic steps had to be taken if the German Government even hoped to stave off defeat. We are just now beginning to appreciate what some of those drastic steps were. One such step is the attempt to develop a substitute for planes and pilots and this was the story behind their much publicised (so-called) secret weapons.

In January 1943 General Galland, at that time in charge of GAF technical development acknowledged the declining strength of the Luftwaffe before a large audience of Military and high Party officials. He said the plans had been made for a new air force and promised greatly increased performance for new planes which would be ready for the Spring campaign. Production was increased slightly on improved models, but the performance of these new planes didn't begin to live up to the promises. Just when this became self evident high officials of the Wehrmacht and the GAF started talking of "Secret Weapons".

Investigation quickly disclosed that there was a group of party technicians in the Wehrmacht experimenting with a very large conventional type of rocket with a total weight in the neighborhood of 68 tons. Another group of scientists in the GAF technical development section were working on a jet-propelled pilotless aircraft and both organizations were testing some of these weapons at Peenemunde, on the shores of the Baltic.

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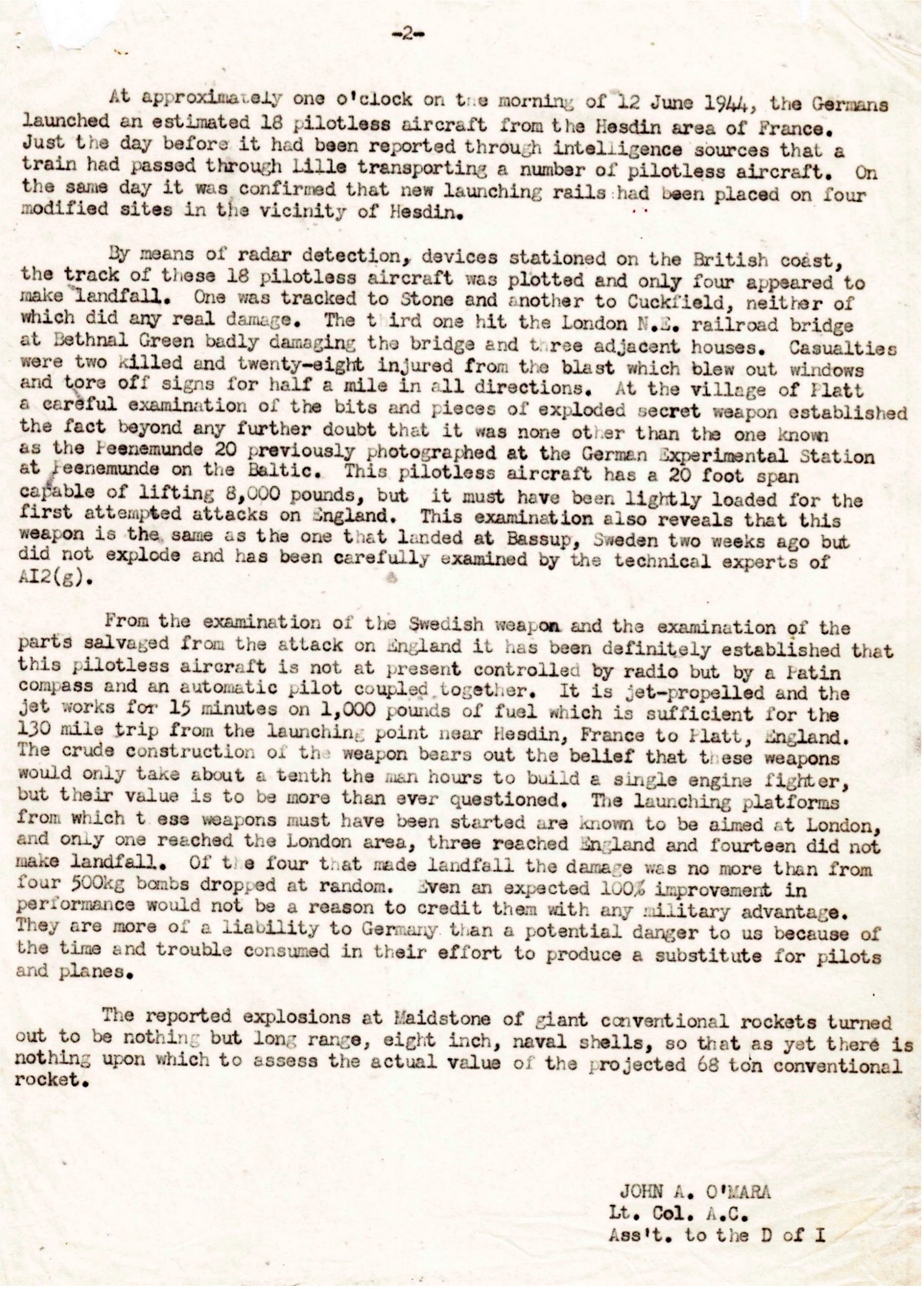
On the 17th of August 1943 construction on a number of strange sites located on the Cherbourg Peninsula and in the Calais area were discovered. Work on these sites progressed at a snails pace. It took some little time before it was definitely established that these were the so-called secret weapon sites and were linked to the long range weapon experiments at Peenemunde. Ninety-six of them were constructed for the launching of pilotless aircraft and seven were for the launching of giant sized rockets.

By the constant attacking of these sites chiefly by planes under the control of USSTAF, practically all of the original pilotless aircraft or ski sites and two of the large rocket or large sites have been neutralized. However, recently the GAF has hastily erected 66 modified pilotless aircraft sites of which forty-two are in the Calais area, four in the Calvados and the rest in the Cherbourg area. With bombing having practically neutralized the old ski sites and the Allied invasion having interfered with all but the forty-two modified sites in the Calais area, the question is just what is the potential danger from these sites still available and workable by the GAF.

2-5170-64

Figure E.68: John A. O'Mara to Lowell P. Weicker. 14 June 1944. Headquarters, U.S. Strategic Air Forces in Europe, Office of the Director of Intelligence [AFHRA folder 519.6522-4; AFHRA A5734 frame 1369].

AFHRA folder 519.6522-4



-2-

At approximately one o'clock on the morning of 12 June 1944, the Germans launched an estimated 18 pilotless aircraft from the Hesdin area of France. Just the day before it had been reported through intelligence sources that a train had passed through Lille transporting a number of pilotless aircraft. On the same day it was confirmed that new launching rails had been placed on four modified sites in the vicinity of Hesdin.

By means of radar detection, devices stationed on the British coast, the track of these 18 pilotless aircraft was plotted and only four appeared to make landfall. One was tracked to Stone and another to Cuckfield, neither of which did any real damage. The third one hit the London N.E. railroad bridge at Bethnal Green badly damaging the bridge and three adjacent houses. Casualties were two killed and twenty-eight injured from the blast which blew out windows and tore off signs for half a mile in all directions. At the village of Platt a careful examination of the bits and pieces of exploded secret weapon established the fact beyond any further doubt that it was none other than the one known as the Peenemunde 20 previously photographed at the German Experimental Station at Peenemunde on the Baltic. This pilotless aircraft has a 20 foot span capable of lifting 8,000 pounds, but it must have been lightly loaded for the first attempted attacks on England. This examination also reveals that this weapon is the same as the one that landed at Bassup, Sweden two weeks ago but did not explode and has been carefully examined by the technical experts of AI2(g).

From the examination of the Swedish weapon and the examination of the parts salvaged from the attack on England it has been definitely established that this pilotless aircraft is not at present controlled by radio but by a Patin compass and an automatic pilot coupled together. It is jet-propelled and the jet works for 15 minutes on 1,000 pounds of fuel which is sufficient for the 130 mile trip from the launching point near Hesdin, France to Platt, England. The crude construction of the weapon bears out the belief that these weapons would only take about a tenth the man hours to build a single engine fighter, but their value is to be more than ever questioned. The launching platforms from which these weapons must have been started are known to be aimed at London, and only one reached the London area, three reached England and fourteen did not make landfall. Of the four that made landfall the damage was no more than from four 500kg bombs dropped at random. Even an expected 100% improvement in performance would not be a reason to credit them with any military advantage. They are more of a liability to Germany than a potential danger to us because of the time and trouble consumed in their effort to produce a substitute for pilots and planes.

The reported explosions at Maidstone of giant conventional rockets turned out to be nothing but long range, eight inch, naval shells, so that as yet there is nothing upon which to assess the actual value of the projected 68 ton conventional rocket.

JOHN A. O'MARA
Lt. Col. A.C.
Ass't. to the D of I

Figure E.69: John A. O'Mara to Lowell P. Weicker. 14 June 1944. Headquarters, U.S. Strategic Air Forces in Europe, Office of the Director of Intelligence [AFHRA folder 519.6522-4; AFHRA A5734 frame 1370].

Henry Arnold to Carl Spaatz. 22 July 1944. Outgoing Classified Message WAR 69061. [Franklin Delano Roosevelt Library, Hyde Park, New York. Map Room Files, Box 49. Folder Rocket Bombs 1944]

I agree with you that everything possible must be done in order to determine ways and means of preventing the large German rockets from ever reaching their destination or causing damage to US. This in reply to your 65292. Doctor Bowles and his assistants are working on this problem and have been working on it for some time, particularly from the radio countermeasures viewpoint. Doctor Fraenckel has brought back from England information of great value in our countermeasure work and has already met with McClelland and others to formulate a specific program including proper search facilities and jamming equipment. We will keep you posted on techniques and on schedules of equipment which we propose to supply. As soon as suitable jamming materials are developed they will be sent to you posthaste. Doctor Fraenckel will return to England within a very short time and be prepared to give you such aid and advice as he can. He should be able to leave here not later than July 30th. If you have any other ideas as to how we can help you let us know.

War Cabinet. "Crossbow" Committee. "Big Ben" Sub-Committee. 17 August 1944 [AFHRA A1263 frame 1404]

Despite the reported lack of supporting evidence it was generally felt that the Swedish rocket [Peenemünde A-4 rocket that crashed in Sweden] had been designed to take more than one weight of warhead. It was pointed out that, within the suggested specification, an α of .62 would carry a charge of about 2 tons to a range of approximately 120 miles.

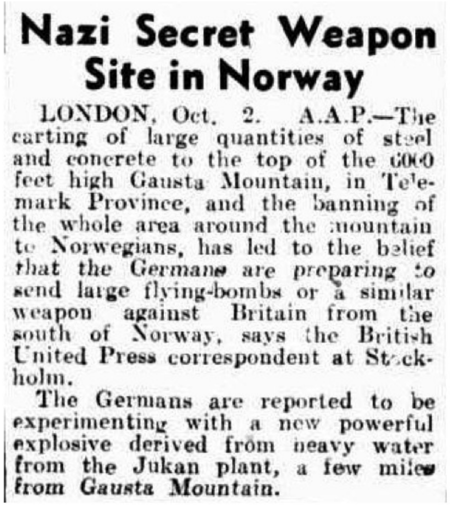
H. L. Morrow. 10 November 1944. Intelligence Information from Stockholm. [AFHRA C5095 frames 1496–1498]

The following observations constitute a resume of information received via the Italian "I" Office from the Air Attaché with the Italian Legation, Stockholm, together with a summary of his conversation with a Swedish Engineer, JOHANSON, representative of the Swedish Air Force in Italy, who returned to Sweden from MILAN at the end of September last. [...]

"V-1" is to be perfected in order to increase its range and size. When that is accomplished it will be known as "V-2", the chief difference being that "V-2" is to have a destructive power equal to 50 tons of explosive. In this connection important experiments are being made on the heights of Mount Gausta (1,900 m) near RJUKAN, Norway, where there is a probable launching site. Experiment on "V-2" has not so far evolved final adjustment of direction control and damage power (eg: its strike causes such excessive penetration that the explosive effect is less than "V-1"). Therefore the major German effort is now directed towards the development of "V-3"—a large chemical incendiary bomb (deflagrazione). This latter is constructed in two parts—actually two bombs—each loaded with different chemical compounds which ignite with devastating effect upon contact with air. [...]

[This was apparently a delayed report of intelligence from summer 1944, after the V-1 cruise missile had been publicly named and utilized but before the V-2 (A-4) rocket had been officially named and used in combat. That timing explains the confusion over whether the V-2 and V-3 were upgraded versions of the V-1 cruise missile or entirely different weapons. The upgraded warheads sound like Zippermayr-type fuel-air explosives or something else similar. The report of secretive German work on Mount Gausta in Norway may be the most interesting part of this report. The report also provided intelligence details about new jets, submarines, and tanks that appear relatively accurate in hindsight, so this V-2/V-3/Gausta report should also be taken quite seriously.]

Newcastle Morning Herald and Miners' Advocate
3 October 1944 p. 1

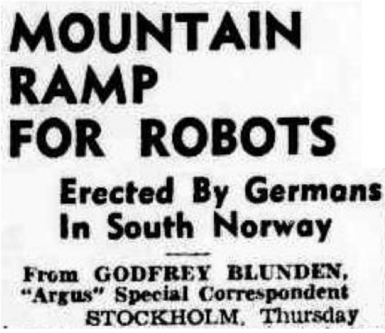


Nazi Secret Weapon Site in Norway

LONDON, Oct. 2. A.A.P.—The carting of large quantities of steel and concrete to the top of the 6000 feet high Gausta Mountain, in Telemark Province, and the banning of the whole area around the mountain to Norwegians, has led to the belief that the Germans are preparing to send large flying-bombs or a similar weapon against Britain from the south of Norway, says the British United Press correspondent at Stockholm.

The Germans are reported to be experimenting with a new powerful explosive derived from heavy water from the Jukan plant, a few miles from Gausta Mountain.

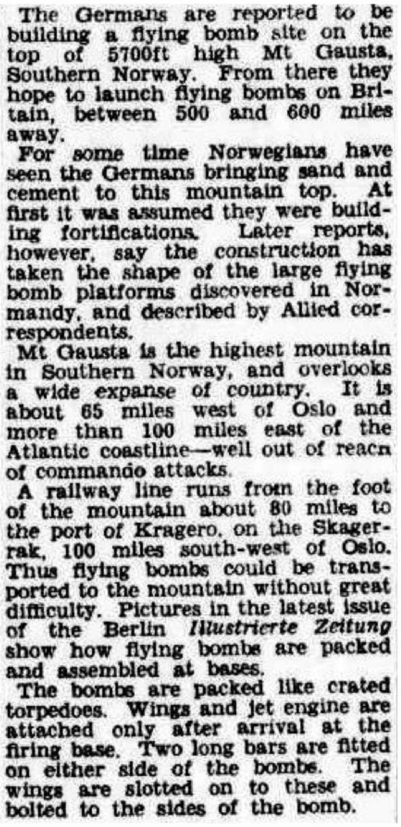
Argus
18 August 1944
p. 16



MOUNTAIN RAMP FOR ROBOTS

Erected By Germans In South Norway

From GODFREY BLUNDEN, "Argus" Special Correspondent
STOCKHOLM, Thursday



The Germans are reported to be building a flying bomb site on the top of 5700ft high Mt Gausta, Southern Norway. From there they hope to launch flying bombs on Britain, between 500 and 600 miles away.

For some time Norwegians have seen the Germans bringing sand and cement to this mountain top. At first it was assumed they were building fortifications. Later reports, however, say the construction has taken the shape of the large flying bomb platforms discovered in Normandy, and described by Allied correspondents.

Mt Gausta is the highest mountain in Southern Norway, and overlooks a wide expanse of country. It is about 65 miles west of Oslo and more than 100 miles east of the Atlantic coastline—well out of reach of commando attacks.

A railway line runs from the foot of the mountain about 80 miles to the port of Kragero, on the Skagerrak, 100 miles south-west of Oslo. Thus flying bombs could be transported to the mountain without great difficulty. Pictures in the latest issue of the Berlin *Illustrierte Zeitung* show how flying bombs are packed and assembled at bases.

The bombs are packed like crated torpedoes. Wings and jet engine are attached only after arrival at the firing base. Two long bars are fitted on either side of the bombs. The wings are slotted on to these and bolted to the sides of the bomb.

Gausta mountain near Vemork in Norway

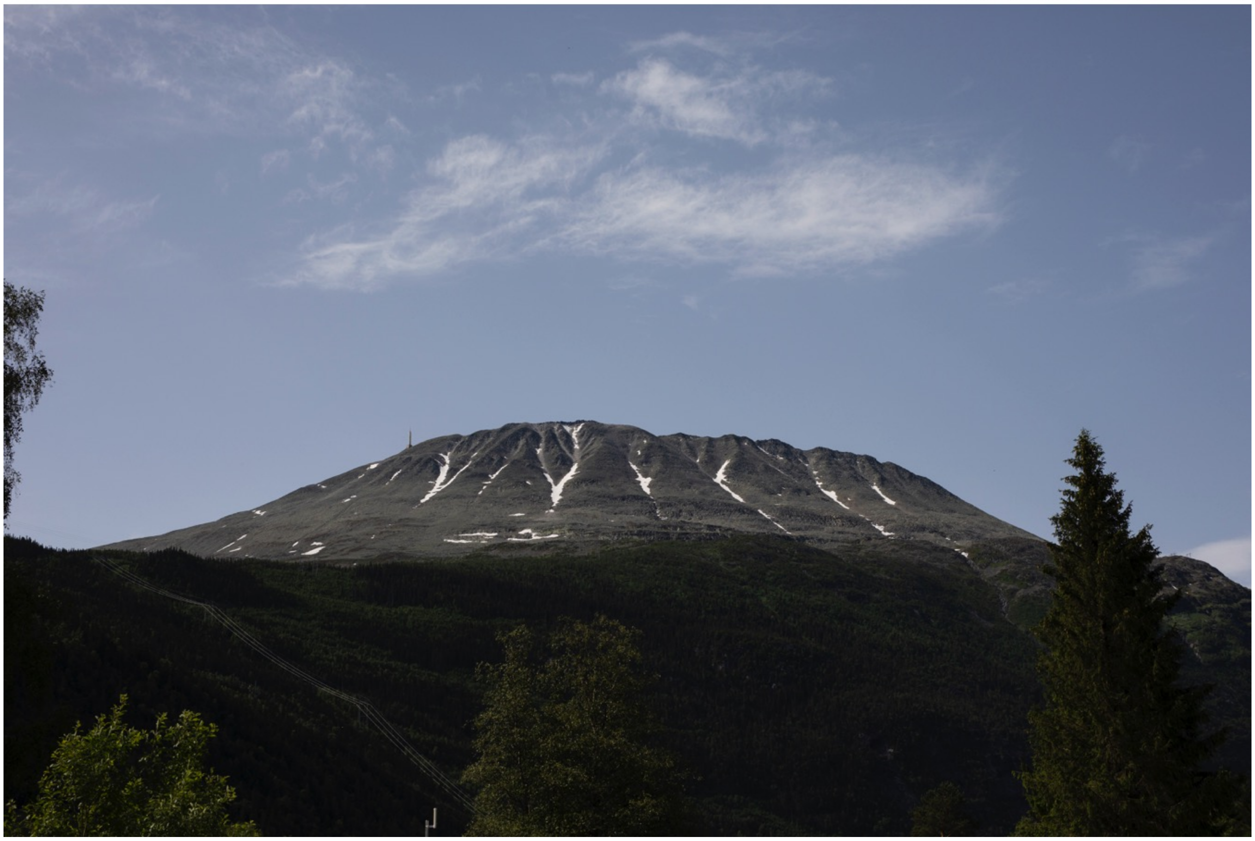


Figure E.70: Gausta mountain in Norway was the site of a very secretive German installation that may have been designed to launch and/or control long-range rockets.

Harry Vosser. Germans Are Still Striving to Perfect New V Weapons. *New York Times*. 22 October 1944, p. E5.

[...] If Hitler can get the necessary breathing space by holding the invading Allied armies on the borders of the Reich for from three to six months more, he may enable the scientists to complete their work.

V-2—a rocket projectile—was reported by the Germans to be ready some time ago. This was confirmed by neutral sources which said that rockets had landed in Sweden and Poland from the firing point at Peenemünde. [...]

Hitler is said to have stopped the production of that type of rocket and to have ordered scientists to concentrate on the production of bigger and more powerful ones. At least four of these latest experimental rockets are reported to have landed in Sweden and many more have crashed into the Baltic sea off Sweden's southeast coast. [...]

V-3 is reported to be the atom bomb. Dr. Goebbels has until now kept quiet regarding this one, but it is said that German scientists credit the weapon with having enormous possibilities.

Neutral sources describe the atom bomb as resembling an airplane in shape, with complicated machinery for steering and propelling the bomb to its target. The rest of the space is filled with explosives and fuel, the amount of explosives being governed by the amount of fuel necessary to carry to the bomb to its selected target.

An electric shock from a small instrument set to operate at a given time detonates explosive and atom simultaneously. The expansion caused by a normal explosive substance, such as dynamite when it becomes a gas, is increased by the force of the disintegrating atoms.

[...I]t is significant that two or three sources have reported the existence of the weapon. It is interesting too to note that a report from the Berlin correspondent of a Swedish newspaper describes V-3 as "the America Bomber and the biggest and best of all Hitler's secret weapons." The correspondent said that successful experiments had been completed in Austria and that the weapon would carry two members of Himmler's recently founded SS air force. He finished his article with the words "America will soon known what war is."

[...] There is no possible doubt that the Germans are straining every nerve to complete it and put it to use before the forthcoming onslaught by the Allied armies.

[This remarkably early article, based on several independent sources, publicly reported important details that were later confirmed by a number of additional sources:

- Germany was building a rocket that was "bigger and more powerful" than the V-2, "resembling an airplane in shape" (with wings), that "would carry two members of Himmler's recently founded SS air force" from its launch point in Europe to America (see all the other documents in Sections E.2 and E.3, but especially pp. 5365–5388 and 5600–5603).
- The rocket would deliver an atomic bomb that simultaneously used high-voltage electricity (a high-voltage fusion neutron initiator) and the detonation of surrounding conventional explosives (implosion) to release large amounts of energy from fission fuel ("the force of the disintegrating atoms"). See pp. 4485–4501 and Sections D.8 and D.15.5.

Where are the official reports on large rockets that were recovered outside Germany during the war, as well as any that were discovered after the war? Where are the reports on the "successful experiments" that "had been completed in Austria"? Can those be located and declassified?]

Aftontidningen **(Stockholm), 2 December 1944, p. 7.**

Raketbomben för New York färdig i år?	Rocket bomb for New York finished this year?
Minister Speer meddelade vid ett sammanträde med rustningsrådet för den tyska industrin att Wehrmachts överkommando ansåg de resultat som åstadkommits med V-2 tillfredsställande. Ytterligare förbättringar håller på att vidtagas. V-3, som är avsedd för beskjutning av New York, är så pass färdig att man har beräknat de första provskjutningarna till slutet av denna månad.	Minister Speer announced at a meeting of the German Industry Armaments Council that the Wehrmacht High Command considered the results achieved with V-2 satisfactory. Further improvements are being made. The V-3, which is intended for bombing of New York, is so complete that the first test launches are estimated by the end of this month.

V-3 Ready to Hit New York This Month, German Says. *New York Times*, 3 December 1944.

A Stockholm dispatch quoted the German labor chief, Albert Speer, yesterday as saying that Germany's V-3 weapon would be ready for firing against New York by the end of December. No intimation of its nature was given.

Deputy Chief Police Inspector Arthur W. Wallander, chief of staff of the city protective forces, said here yesterday: "Our services are ready." Mayor La Guardia warned on Nov. 12 that, "although there is no reason for alarm, we must be ready."

[In the Nuremberg trials, Albert Speer essentially denied the existence of any secret weapons, yet in this news report he publicly announced that they were being prepared for use. Many different weapon systems were competing for the title of V-3, the next German secret weapon to be publicly announced and demonstrated. Other than being able to hit New York, it is not clear if this particular "V-3" was a submarine-launched V-1 cruise missile, a submarine-launched V-2 or A-4 rocket, a European-launched A-9/A-10 intercontinental rocket, or something else.

Note that the *New York Times* misquoted the Stockholm newspaper. According to the Stockholm paper, Speer said that by the end of December 1944, the V-3 missile would be ready for test flights, not ready for an attack against New York then.]

Preparing the American Public for a V-3 Attack—Dec. 1944 [AFHRA 43811 electronic version p. 972]

At a CCS meeting in Washington, Dec 8, 1944, the CCS discussed "without much interest" a Presidential directive which would take action to meet a V-3 threat—intercontinental missile attack against the United States. Kuter reported to Arnold and Giles that the JCS was directing commanders to take preliminary actions and to prepare plans. "From their tone I feel they will accept or surely give serious consideration to a study pointing toward a Presidential announcement of the possibility of attack, the victory the enemy would achieve if we (don't?) take preparatory action and our decision to rely on the ability of the American public to take it." Kuter said he discussed the matter with Hull (Army Deputy Chief of Staff) and he directed Loutzenheiser, with McKee's assistance, to prepare a necessary study.

[See also related documents on pp. 4702–4703 and 5618–5660.]

Jürgen Michels. 1997. *Peenemünde und seine Erben in Ost und West: Entwicklung und Weg deutscher Geheimwaffen.* Bonn: Bernard & Graefe, p. 71.

Unter der Bezeichnung Aggregat 8 liefen eine ganze Reihe zum Teil stark voneinander abweichende Entwürfe. Die erste Studie entsprach in der Größe dem Aggregat 5, sollte aber durch Salbei und Visol (auch als Gasöl bezeichnet) angetrieben werden. Ende 1941 entstand eine sog. Hochdruck-Rakete, die in der Größe dem Aggregat 4 entsprechen sollte. Mit 8330 kg Salpetersäure und 1670 kg Gasöl sollten ca. 50,000 kp Schub erreicht werden. Diese Rakete sollte einen Sprengkopf von 2000 kg über 300 km tragen. Noch größer war ein weiterer Entwurf, der 14.295 kg Salpetersäure und 2860 kg Gasöl vorsah. Obwohl ein niedrigerer Schub von 35.000 kp geplant war, erhoffte man aufgrund einer langen Brenndauer von ca. 100 Sekunden eine Höchstgeschwindigkeit von 7380 km/hr zu erreichen und eine Nutzlast von 2500 kg etwa 450 km weit zu verschießen. Das Startgewicht war auf 22.370 kg ausgelegt.

Keine dieser Studien kam letztendlich über Windkanalversuche hinaus.

A whole series of designs, some of which differed greatly from one another, ran under the name Aggregat 8. The first study corresponded in size to Aggregat 5, but was to be powered by Salbei and Visol (also known as gas oil). At the end of 1941, a so-called high-pressure rocket was developed, which was to correspond in size to Aggregat 4. With 8330 kg of nitric acid and 1670 kg of gas oil, a thrust of approximately 50 tons was to be achieved. This rocket was to carry a warhead of 2000 kg over 300 km. Even larger was another design, which envisaged 14,295 kg of nitric acid and 2860 kg of gas oil. Although a lower thrust of 35 tons was planned, it was hoped that a maximum speed of 7380 km/hr could be achieved due to a long burn time of approximately 100 seconds and a payload of 2500 kg could be fired over a distance of around 450 km. The launch weight was intended to be 22,370 kg.

None of these studies ultimately got beyond wind tunnel tests.

[Among the several different proposed A-8 designs were some that were extended versions of the A-4 with higher thrust, for longer ranges and/or higher payload capacities. According to official postwar history books, such extended A-4 rockets were never actually built. However, as shown by documents throughout this section, there is significant evidence that at least some extended rockets were indeed built and possibly tested. These wartime prototypes also served as the basis of many postwar U.S., Soviet, and French rockets (Section E.7.2).]

Gerhard Reisig. 1997. *Raketenforschung in Deutschland: Wie die Menschen das all eroberten.* Münster: Edition Lenser. pp. 707–708.

In seinem Memorandum "Entwicklungsgrundsätze" vom November 1941 hatte W. Dornberger postuliert, daß die "A4"-Rakete nur eine temporäre Zwischenlösung sein sollte. Die tatsächliche militärische Forderung bestehe auf einer Fernrakete von 450 km Reichweite (Dornberger, 1941). Die entsprechende Raketentype erhielt die Bezeichnung "A8". [...]

In his memorandum "Development Principles" of November 1941, W. Dornberger postulated that the "A-4" rocket should only be a temporary interim solution. The actual military requirement was for a long-range missile with a range of 450 km (Dornberger, 1941). The corresponding rocket type was given the designation "A-8." [...]

Das “A8”-Projekt erforderte also eine grundlegende neue Systemkonfiguration, die analytisch eingehend untersucht wurde (Hellebrand, 1942). Meissner (1941) diskutierte 16 verschiedene Konfigurationen einer “A8”-Rakete, um einen optimalen Ausgleich der verschiedenen Parametergrößen der Rakete zu bestimmen. Bei diesen Entwürfen sollte die aerodynamische Form der “A4”-Rakete möglichst erhalten bleiben.

Die Grundlage der “A8”-Konfiguration bildet ein neues Triebwerk von 30 to (294 kN) Schub. Werner Thiel hatte die Entwicklung eines solchen Triebwerks bereits 1941 begonnen (Thiel, 1941). Die Treibstoffbasis für den 30-to-Motor ist die Kombination von Gasöl mit *Salbei*. Das Gasöl kann gegen ein 50-prozentiges Gemisch von Benzol und Benzin ausgetauscht werden. Dieser Motor ist eine Hochdrucktype mit einem Brennkammerdruck von 40 atü (41 Bar). Mit dem 30-to-Triebwerk wird eine Brennschlußgeschwindigkeit von über 2,000 m/sek bei der Machzahl 6,8 erreicht. Bei diesen hohen Machzahlen wird die Körperlage der Rakete instabil, d.h. der Luftangriffspunkt aller Luftkräfte auf die Rakete rückt vor deren Schwerpunkt. Eine gewisse Verbesserung der Stabilität wird durch Verlängerung der Zelle auf L = 13.5 Kaliber erreicht.[7] [...]

Die “A8”-Rakete wäre ein fortschrittliches, wegweisendes Projekt gewesen. Sie blieb nur ein “Papierprojekt”.

Tabelle XI.2 Dimensionen des “A8” Modells

Länge: 13.5 Kaliber
Kaliber: 1.651 mm
Leergewicht: 22,8 to/224 kN
Brennschluß-Machzahl: 6,8

The “A-8” project thus required a fundamentally new system configuration, which was analyzed in detail (Hellebrand, 1942). Meissner (1941) discussed 16 different configurations of an “A-8” rocket in order to determine an optimal balance of the various parameters of the rocket. In these designs, the aerodynamic shape of the “A-4” rocket was to be retained as far as possible.

The basis of the “A-8” configuration was a new engine with a thrust of 30 tons (294 kN). Werner Thiel had already begun the development of such an engine in 1941 (Thiel, 1941). The fuel basis for the 30-ton engine is a combination of gas oil and *Salbei*. The gas oil can be replaced with a 50 percent mixture of benzene and gasoline. This engine is a high-pressure type with a combustion chamber pressure of 40 atmospheres (41 bars). With the 30-ton engine, an engine cutoff velocity of over 2,000 m/sec, Mach number of 6.8, is achieved. At these high Mach numbers, the rocket becomes aerodynamically unstable, i.e. the center of pressure of all aerodynamic forces on the rocket moves in front of its center of gravity. A certain improvement in stability is achieved by lengthening the airframe to L = 13.5 diameters.[7] [...]

The “A-8” missile would have been an advanced, pioneering project. It remained only a “paper project.”

Table XI.2 Dimensions of the “A-8” model

Length: 13.5 diameters
Diameter: 1.651 m
Weight without payload: 22.8 tons/224 kN
Engine cutoff Mach number: 6.8

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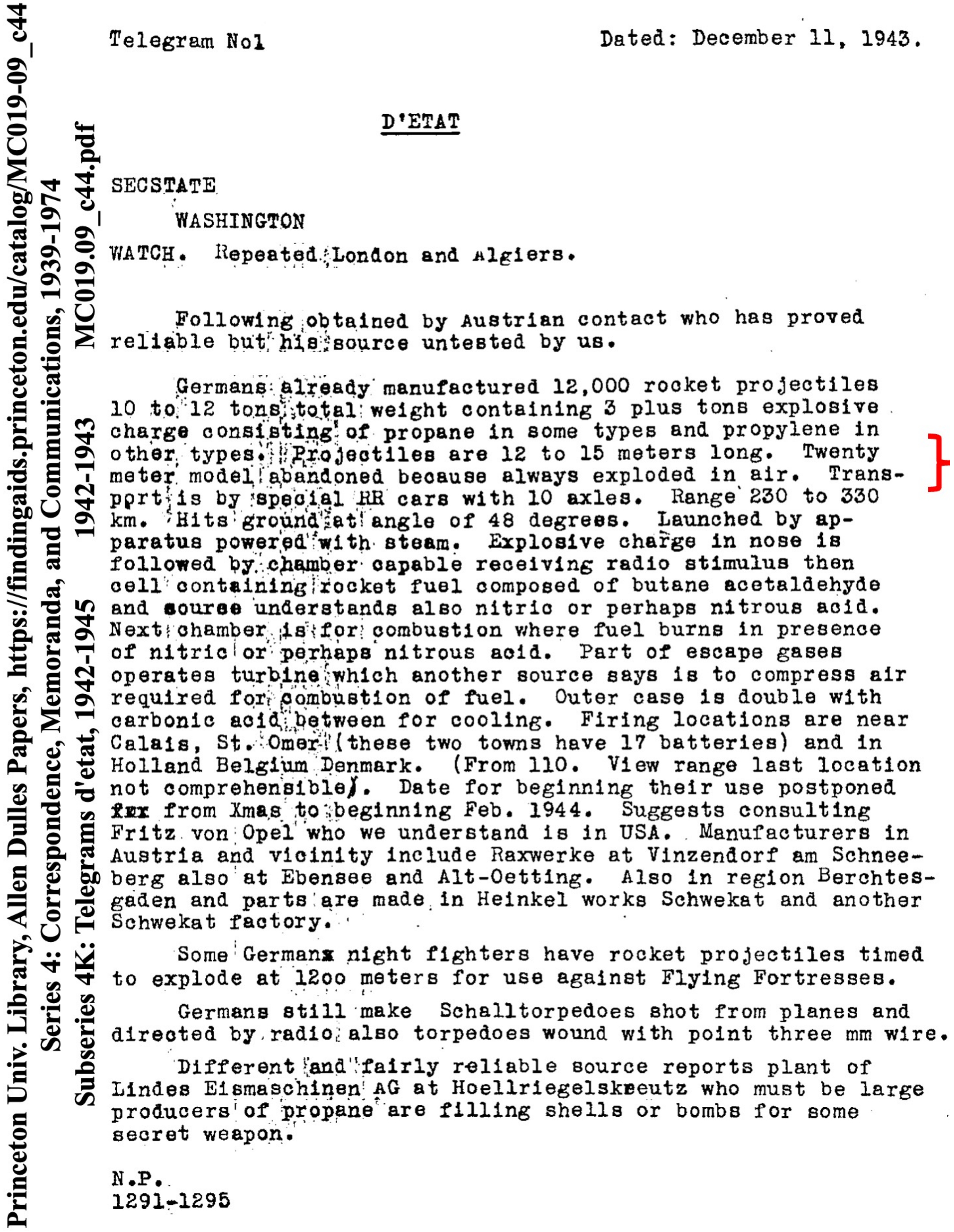
[7] “A4”-Rakete: L=8.5 Kaliber

[7] “A-4” rocket: L=8.5 diameters



Princeton Univ. Library, Allen Dulles Papers, https://findingaids.princeton.edu/catalog/MC019-09_c44
Series 4: Correspondence, Memoranda, and Communications, 1939-1974
Subseries 4K: Telegrams d'etat, 1942-1945 1942-1943 MC019.09_c44.pdf

Telegram No1 Dated: December 11, 1943.

D'ETAT

SECSTATE
WASHINGTON

WATCH. Repeated London and Algiers.

Following obtained by Austrian contact who has proved reliable but his source untested by us.

Germans already manufactured 12,000 rocket projectiles 10 to 12 tons total weight containing 3 plus tons explosive charge consisting of propane in some types and propylene in other types. Projectiles are 12 to 15 meters long. Twenty meter model abandoned because always exploded in air. Transport is by special RR cars with 10 axles. Range 230 to 330 km. Hits ground at angle of 48 degrees. Launched by apparatus powered with steam. Explosive charge in nose is followed by chamber capable receiving radio stimulus then cell containing rocket fuel composed of butane acetaldehyde and **source** understands also nitric or perhaps nitrous acid. Next chamber is for combustion where fuel burns in presence of nitric or perhaps nitrous acid. Part of escape gases operates turbine which another source says is to compress air required for combustion of fuel. Outer case is double with carbonic acid between for cooling. Firing locations are near Calais, St. Omer (these two towns have 17 batteries) and in Holland Belgium Denmark. (From 110. View range last location not comprehensible). Date for beginning their use postponed ~~fxx~~ from Xmas to beginning Feb. 1944. Suggests consulting Fritz von Opel who we understand is in USA. Manufacturers in Austria and vicinity include Raxwerke at Vinzendorf am Schneeberg also at Ebensee and Alt-Oetting. Also in region Berchtesgaden and parts are made in Heinkel works Schwekat and another Schwekat factory.

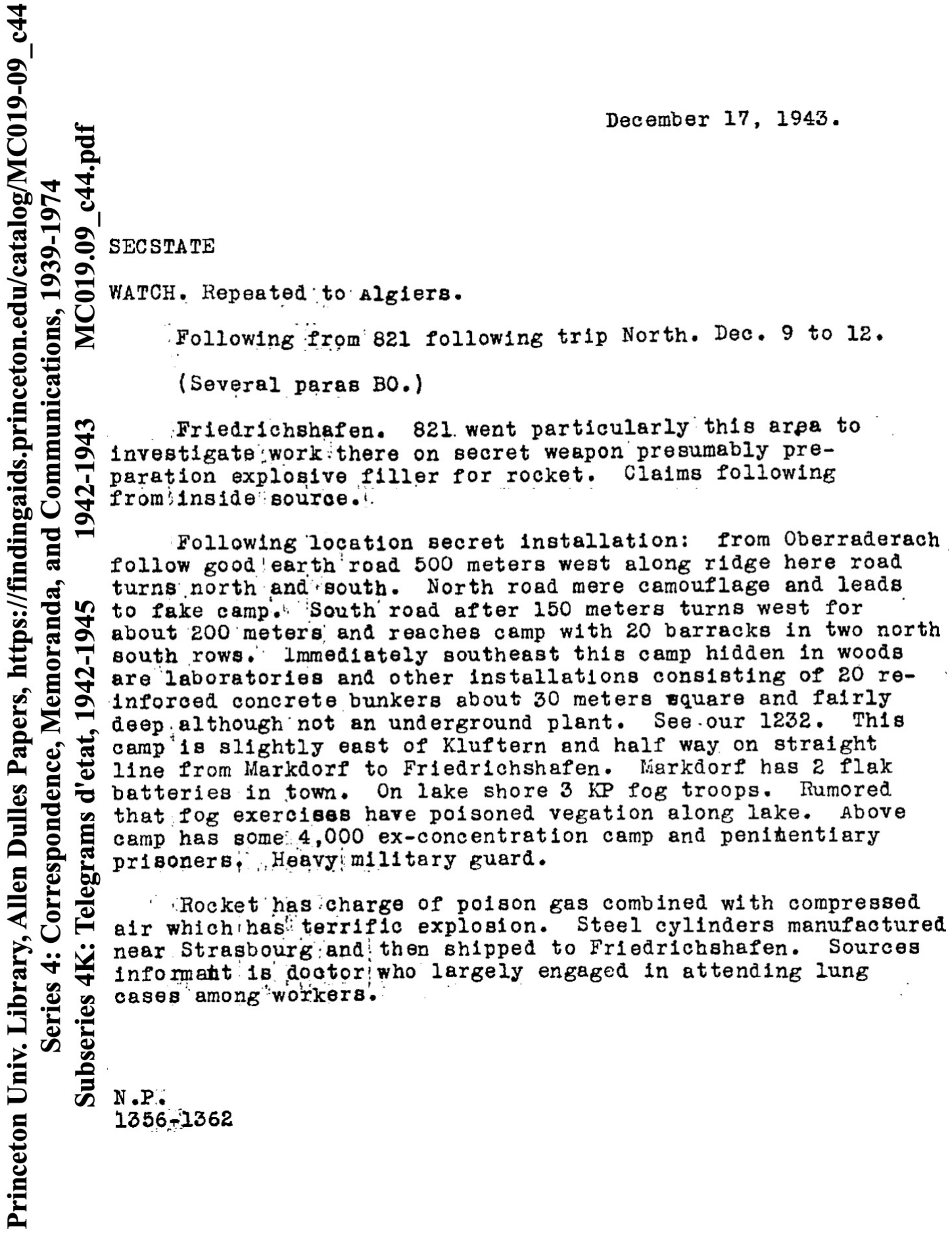
Some Germanx night fighters have rocket projectiles timed to explode at 1200 meters for use against Flying Fortresses.

Germans still make Schalltorpedoes shot from planes and directed by radio also torpedoes wound with point three mm wire.

Different and fairly reliable source reports plant of Lindes Eismaschinen AG at Hoellriegelskreutz who must be large producers of propane are filling shells or bombs for some secret weapon.

N.P.
1291-1295

Figure E.71: Allen Dulles. 11 December 1943. [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44]. As of that date, 20-meter-long rockets had been built and launched but still had unresolved issues (compare with p. 5572).



Princeton Univ. Library, Allen Dulles Papers, https://findingaids.princeton.edu/catalog/MC019-09_c44
Series 4: Correspondence, Memoranda, and Communications, 1939-1974
Subseries 4K: Telegrams d'etat, 1942-1945 1942-1943 MC019.09_c44.pdf

December 17, 1943.

SECSTATE

WATCH. Repeated to Algiers.

Following from 821 following trip North. Dec. 9 to 12.

(Several paras BO.)

Friedrichshafen. 821 went particularly this area to investigate work there on secret weapon presumably preparation explosive filler for rocket. Claims following from inside source.

Following location secret installation: from Oberraderach follow good earth road 500 meters west along ridge here road turns north and south. North road mere camouflage and leads to fake camp. South road after 150 meters turns west for about 200 meters and reaches camp with 20 barracks in two north south rows. Immediately southeast this camp hidden in woods are laboratories and other installations consisting of 20 reinforced concrete bunkers about 30 meters square and fairly deep although not an underground plant. See our 1232. This camp is slightly east of Kluftern and half way on straight line from Markdorf to Friedrichshafen. Markdorf has 2 flak batteries in town. On lake shore 3 KP fog troops. Rumored that fog exercises have poisoned vegation along lake. Above camp has some 4,000 ex-concentration camp and penitentiary prisoners. Heavy military guard.

Rocket has charge of poison gas combined with compressed air which has terrific explosion. Steel cylinders manufactured near Strasbourg and then shipped to Friedrichshafen. Sources informant is doctor who largely engaged in attending lung cases among workers.

N.P.
1356-1362

Figure E.72: Allen Dulles. 17 December 1943. [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44]. There appear to have been several plants in the Friedrichshafen area producing weapons of mass destruction as well as long-range rockets to deliver them.

Allen Dulles. 6 December 1943. [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44].

From 493 source. German technicians working in large underground development back of Fischbach on Bodensee. Entrance at Manzell and main establishment near Kluftern. Believed to have something to do with secret air weapon.

[The sites named above are in the Friedrichshafen area. For more on OSS agent "493," see p. 4176.]

R. R. Thun. 5th Army POW Cage (Air), Target Notes A/5. 4 November 1944. [AFHRA A5417 electronic p. 969–970]

5. Under-ground Factory in FRIEDRICHSHAFEN: In Jan/43 P/W visited the site of a large new under-ground factory being built by Dornier at FRIEDRICHSHAFEN. Factory lies between the lake and the road to IMMENSTAAD, on the NW edge of FRIEDRICHSHAFEN. It is covered by a storage yard for wood and other bulk materials, and there is a R.R. spur leading into the underground part. P/W could give no information as to the size of the underground unit, other than to say that it was about the same size as the large Mercedes Factory in STUTTGART. He heard from friends that V-2 was being made there, and that three R.R. cars were necessary to haul away a single V-2 bomb. P/W considered himself an Italian, having been born in BOLZANO, and was obviously trying to give reliable information.

[See document photos on pp. 5328–5329. See also p. 5392, although there the answers to postwar questioning may have been less than complete and accurate.

Wartime German railroad cars were most commonly around 8–10 meters long. A standard A-4 (V-2) rocket was 14 meters long with all parts from the nosecone to the fins attached. Thus a standard A-4 could have been carried by a single railroad car of somewhat greater than average length (or by a single car of average length, if partially disassembled), or at most by two average-length railroad cars with plenty of room to spare.

If the rockets produced by this underground factory at Friedrichshafen required three average-length railroad cars, the rockets could have been up to 24–30 meters long. (Or the rockets could have been even longer if the railroad cars were longer than average, or if the rockets were partially disassembled.) Thus this description does not sound at all like a standard A-4 rocket. Note some observers used "V-2" in a generic sense to refer to any large German rockets, not just the A-4.

What type of rocket was being produced in this underground factory? The most likely possibilities were an 18-meter-long extended A-4 (without wings) or A-9 (with wings), a 21-meter-long extended A-4 or A-9, a 20- to 26-meter-long A-10, or a ∼30+ meter-long A-9/A-10.

Whatever these unusually large rockets were, they were not at the design stage or the prototype stage. Possibly as early as 1943 and definitely no later than mid-1944, they were being mass-produced.

Where are all the wartime German and postwar Allied reports on this underground rocket factory?

Could an industrial archaeological excavation be conducted at the site of this factory now?]

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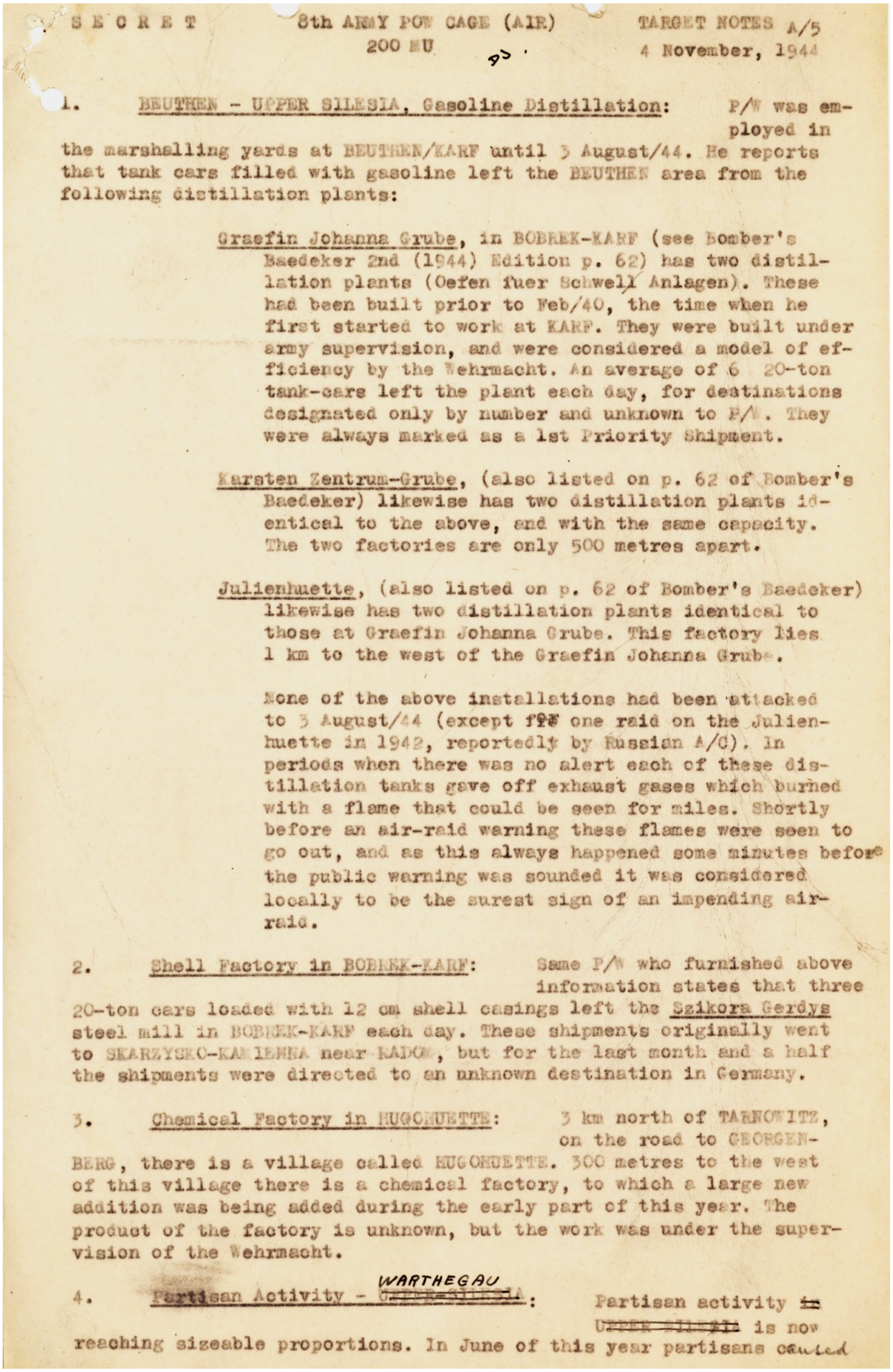
AFHRA folder 512.619C-15A 1943-1945



SECRET | 8th ARMY POW CAGE (AIR) 200 MU | TARGET NOTES A/5 4 November, 1944

93

1. **BEUTHEN - UPPER SILESIA, Gasoline Distillation:** P/W was employed in the marshalling yards at BEUTHEN/KARF until 3 August/44. He reports that tank cars filled with gasoline left the BEUTHEN area from the following distillation plants:

Graefin Johanna Grube, in BOBREK-KARF (see Bomber's Baedeker 2nd (1944) Edition p. 62) has two distillation plants (Oefen fuer Schwel Anlagen). These had been built prior to Feb/40, the time when he first started to work at KARF. They were built under army supervision, and were considered a model of efficiency by the Wehrmacht. An average of 6 20-ton tank-cars left the plant each day, for destinations designated only by number and unknown to P/W. They were always marked as a 1st Priority Shipment.

Karsten Zentrum-Grube, (also listed on p. 62 of Bomber's Baedeker) likewise has two distillation plants identical to the above, and with the same capacity. The two factories are only 500 metres apart.

Julienhuette, (also listed on p. 62 of Bomber's Baedeker) likewise has two distillation plants identical to those at Graefin Johanna Grube. This factory lies 1 km to the west of the Graefin Johanna Grube.

None of the above installations had been attacked to 3 August/44 (except for one raid on the Julienhuette in 1942, reportedly by Russian A/C). In periods when there was no alert each of these distillation tanks gave off exhaust gases which burned with a flame that could be seen for miles. Shortly before an air-raid warning these flames were seen to go out, and as this always happened some minutes before the public warning was sounded it was considered locally to be the surest sign of an impending air-raid.

2. **Shell Factory in BOBREK-KARF:** Same P/W who furnished above information states that three 20-ton cars loaded with 12 cm shell casings left the Szikora Gerdys steel mill in BOBREK-KARF each day. These shipments originally went to SKARZYSKO-KAMIENNA near RADOM, but for the last month and a half the shipments were directed to an unknown destination in Germany.

3. **Chemical Factory in HUGOHUETTE:** 3 km north of TARNOWITZ, on the road to GEORGENBERG, there is a village called HUGOHUETTE. 300 metres to the west of this village there is a chemical factory, to which a large new addition was being added during the early part of this year. The product of the factory is unknown, but the work was under the supervision of the Wehrmacht.

4. **Partisan Activity - ~~UPPER SILESIA~~ WARTHEGAU:** Partisan activity ~~in UPPER SILESIA~~ is now reaching sizeable proportions. In June of this year partisans caused

Figure E.73: A report of rockets larger than the standard A-4 (V-2) being mass-produced at an underground factory in Friedrichshafen. R. R. Thun. 5th Army POW Cage (Air), Target Notes A/5. 4 November 1944 [AFHRA folder 512.619C-15A 1943–1945; AFHRA A5417 electronic pp. 969–970].

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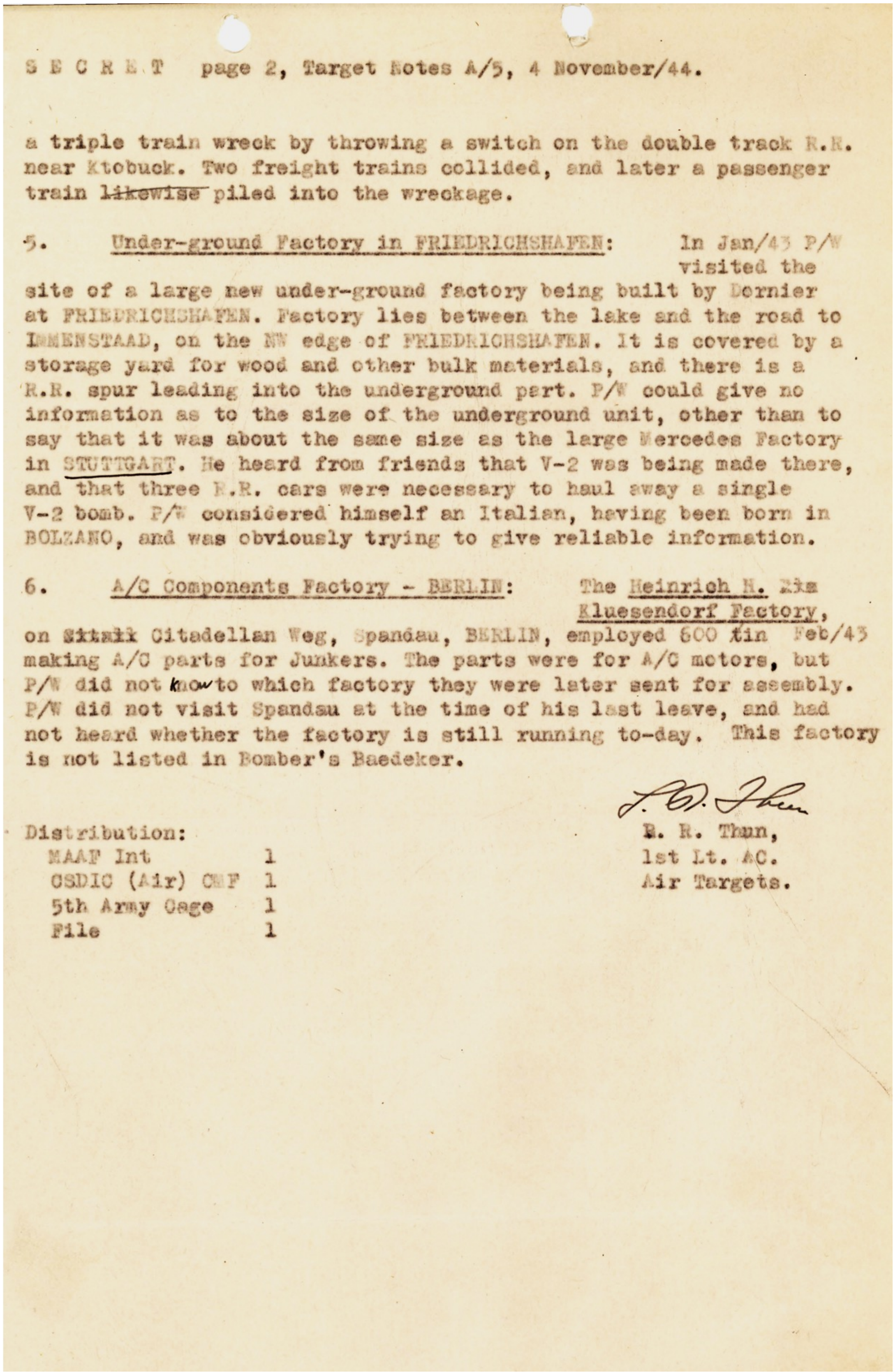
AFHRA folder 512.619C-15A 1943-1945



SECRET page 2, Target Notes A/5, 4 November/44.

a triple train wreck by throwing a switch on the double track R.R. near Ktobuck. Two freight trains collided, and later a passenger train ~~likewise~~ piled into the wreckage.

5. Under-ground Factory in FRIEDRICHSHAFEN: In Jan/43 P/W visited the site of a large new under-ground factory being built by Dornier at FRIEDRICHSHAFEN. Factory lies between the lake and the road to IMMENSTAAD, on the NW edge of FRIEDRICHSHAFEN. It is covered by a storage yard for wood and other bulk materials, and there is a R.R. spur leading into the underground part. P/W could give no information as to the size of the underground unit, other than to say that it was about the same size as the large Mercedes Factory in STUTTGART. He heard from friends that V-2 was being made there, and that three R.R. cars were necessary to haul away a single V-2 bomb. P/W considered himself an Italian, having been born in BOLZANO, and was obviously trying to give reliable information.

6. A/C Components Factory - BERLIN: The Heinrich H. Kluesendorf Factory, on Citadellan Weg, Spandau, BERLIN, employed 600 in Feb/43 making A/C parts for Junkers. The parts were for A/C motors, but P/W did not know to which factory they were later sent for assembly. P/W did not visit Spandau at the time of his last leave, and had not heard whether the factory is still running to-day. This factory is not listed in Bomber's Baedeker.

R. R. Thun,
1st Lt. AC.
Air Targets.

Distribution:

MAAF Int	1
CSDIC (Air) CMF	1
5th Army Cage	1
File	1

Figure E.74: A report of rockets larger than the standard A-4 (V-2) being mass-produced at an underground factory in Friedrichshafen. R. R. Thun. 5th Army POW Cage (Air), Target Notes A/5. 4 November 1944 [AFHRA folder 512.619C-15A 1943–1945; AFHRA A5417 electronic pp. 969–970].

A.D.I. (K) Report No. 113A/1945. Suspected 'V' Weapon Factories—Germany and Poland. [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL]

UNDERGROUND WORKS OBER RADERACH.
(September 1944).

2. A co-operative German P/W, who lived in the Friedrichshafen area until September 1944, said there was an underground factory between two hills to the North West of Ober Raderach village rather less than four miles North North West of Friedrichshafen at 47^o 42' 18" N., 9^o 26' 25" E. This pinpoint is very near that of a site described in a report from Italy dated 24th November 1944 reference MFIU/HQ/CSDIC/12.

3. It was locally rumoured that the Ober Raderach works was closely connected with the Zeppelin works at Friedrichshafen and that "25 ton objects" presumed to be 'V' weapons, were being produced. During the winter of 1943/1944 loud noises similar to those made by a power unit under test emanated from the plant but in about March 1944 there was a loud explosion; thereafter things quietened down more than somewhat.

4. P/W had no idea of how many workers might be employed but said they were all either P/W or German troops undergoing detention and they were never allowed outside the factory precincts.

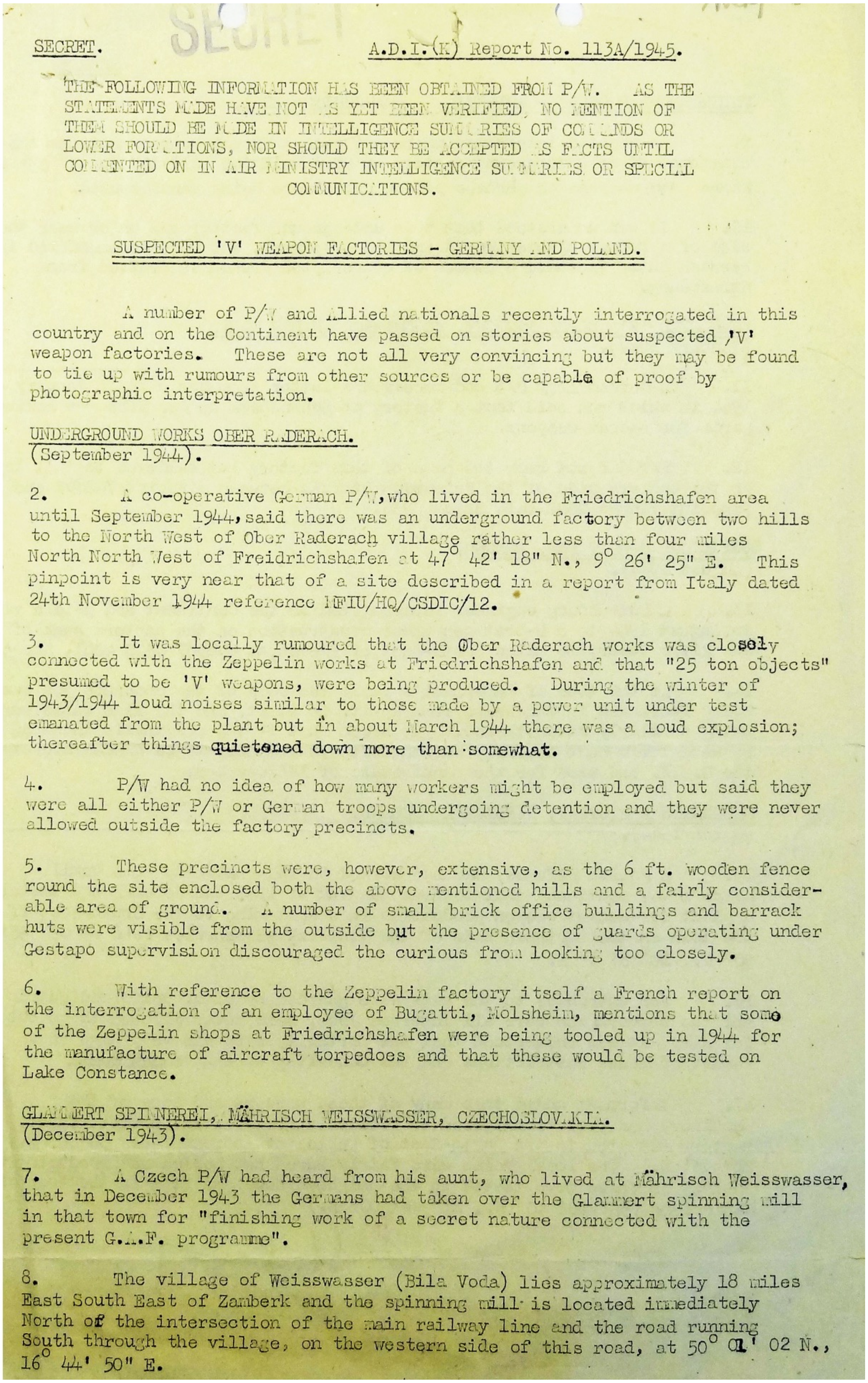
5. These precincts were, however, extensive, as the 6 ft. wooden fence round the site enclosed both the above mentioned hills and a fairly considerable area of ground. A number of small brick office buildings and barrack huts were visible from the outside but the presence of guards operating under Gestapo supervision discouraged the curious from looking too closely.

[See document photo on p. 5331.

This is another report of rockets larger than the standard A-4 (V-2) being mass-produced at an underground factory in Friedrichshafen.]

DECLASSIFIED
Authority NND 917017

NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL



SECRET. SECRET A.D.I.(K) Report No. 113A/1945.

THE FOLLOWING INFORMATION HAS BEEN OBTAINED FROM P/W. AS THE STATEMENTS MADE HAVE NOT AS YET BEEN VERIFIED, NO MENTION OF THEM SHOULD BE MADE IN INTELLIGENCE SUMMARIES OF COMMANDS OR LOWER FORMATIONS, NOR SHOULD THEY BE ACCEPTED AS FACTS UNTIL COMMENTED ON IN AIR MINISTRY INTELLIGENCE SUMMARIES OR SPECIAL COMMUNICATIONS.

SUSPECTED 'V' WEAPON FACTORIES - GERMANY AND POLAND.

A number of P/W and Allied nationals recently interrogated in this country and on the Continent have passed on stories about suspected 'V' weapon factories. These are not all very convincing but they may be found to tie up with rumours from other sources or be capable of proof by photographic interpretation.

UNDERGROUND WORKS OBER RADERACH.
(September 1944).

2. A co-operative German P/W, who lived in the Friedrichshafen area until September 1944, said there was an underground factory between two hills to the North West of Ober Raderach village rather less than four miles North North West of Freidrichshafen at 47° 42' 18" N., 9° 26' 25" E. This pinpoint is very near that of a site described in a report from Italy dated 24th November 1944 reference MFIU/HQ/CSDIC/12.

3. It was locally rumoured that the Ober Raderach works was closely connected with the Zeppelin works at Friedrichshafen and that "25 ton objects" presumed to be 'V' weapons, were being produced. During the winter of 1943/1944 loud noises similar to those made by a power unit under test emanated from the plant but in about March 1944 there was a loud explosion; thereafter things quietened down more than somewhat.

4. P/W had no idea of how many workers might be employed but said they were all either P/W or German troops undergoing detention and they were never allowed outside the factory precincts.

5. These precincts were, however, extensive, as the 6 ft. wooden fence round the site enclosed both the above mentioned hills and a fairly considerable area of ground. A number of small brick office buildings and barrack huts were visible from the outside but the presence of guards operating under Gestapo supervision discouraged the curious from looking too closely.

6. With reference to the Zeppelin factory itself a French report on the interrogation of an employee of Bugatti, Molsheim, mentions that some of the Zeppelin shops at Friedrichshafen were being tooled up in 1944 for the manufacture of aircraft torpedoes and that these would be tested on Lake Constance.

GLAMMERT SPINNEREI, MÄHRISCH WEISSWASSER, CZECHOSLOVAKIA.
(December 1943).

7. A Czech P/W had heard from his aunt, who lived at Mährisch Weisswasser, that in December 1943 the Germans had taken over the Glammert spinning mill in that town for "finishing work of a secret nature connected with the present G.A.F. programme".

8. The village of Weisswasser (Bila Voda) lies approximately 18 miles East South East of Zamberk and the spinning mill is located immediately North of the intersection of the main railway line and the road running South through the village, on the western side of this road, at 50° 01' 02 N., 16° 44' 50" E.

Figure E.75: Another report of rockets larger than the standard A-4 (V-2) being mass-produced at an underground factory in Friedrichshafen. A.D.I. (K) Report No. 113A/1945. Suspected 'V' Weapon Factories—Germany and Poland [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Report T.I. 3339 (SD-2621pt/947), Flying Bombs and Rockets. December 1944. [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL]

V-2, V-26, V-32.

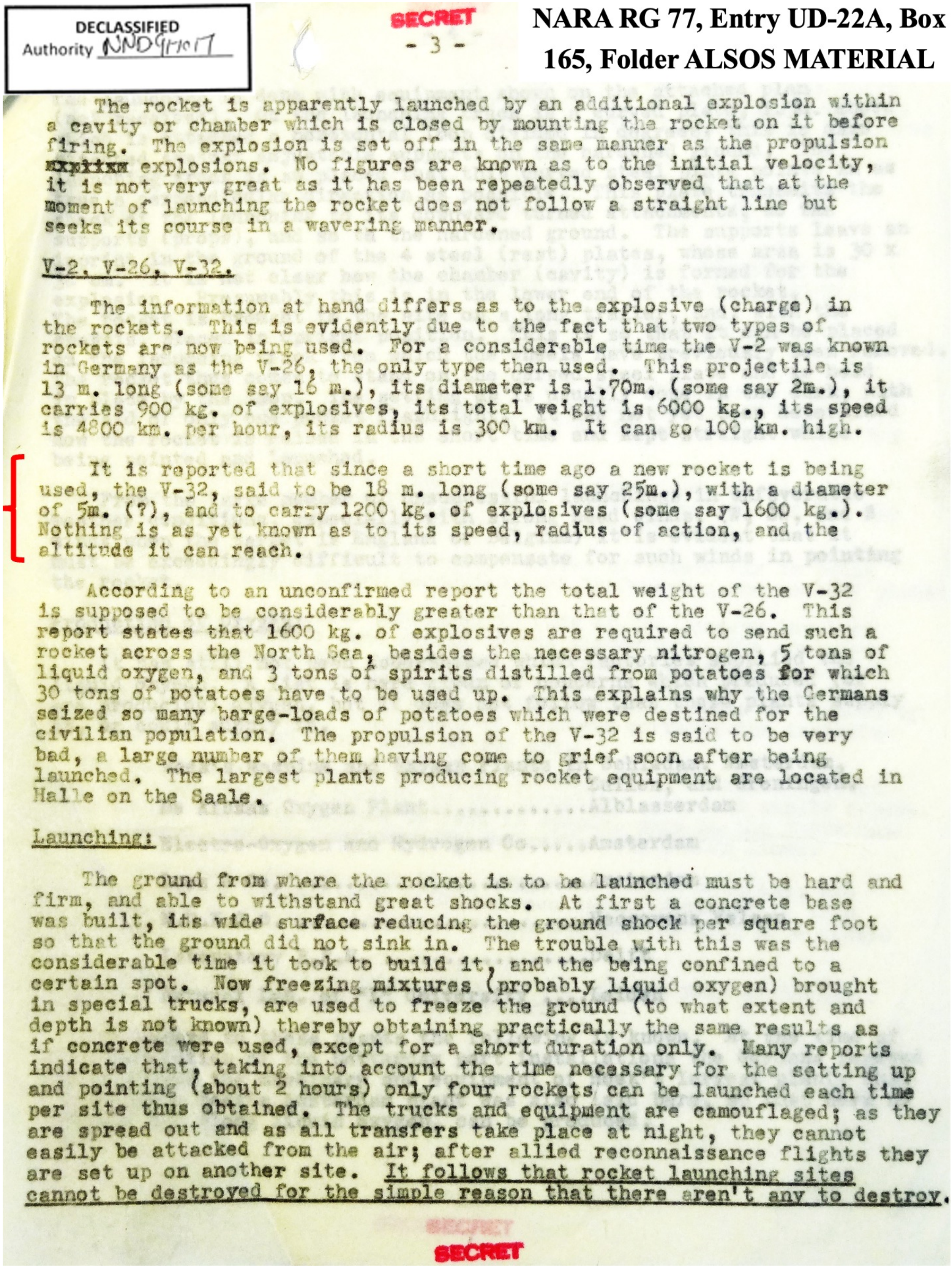
The information at hand differs as to the explosive (charge) in the rockets. This is evidently due to the fact that two types of rockets are now being used. For a considerable time the V-2 was known in Germany as the V-26, the only type then used. This projectile is 13 m. long (some say 16 m.), its diameter is 1.70 m. (some say 2 m.), it carries 900 kg. of explosives, its total weight is 6000 kg., its speed is 4800 km. per hour, its radius [range] is 300 km. It can go 100 km. high.

It is reported that since a short time ago a new rocket is being used, the V-32, said to be 18 m. long (some say 25 m.), with a diameter of 5 m. (?), and to carry 1200 kg. of explosives (some say 1600 kg.). Nothing is as yet known as to its speed, radius [range] of action, and the altitude it can reach.

According to an unconfirmed report the total weight of the V-32 is supposed to be considerably greater than that of the V-26. [...] The propulsion of the V-32 is said to be very bad, a large number of them having come to grief soon after being launched. The largest plants producing rocket equipment are located in Halle on the Saale.

[See document photo on p. 5333.

This is yet another report of rockets larger than the standard A-4 (V-2) being mass-produced.]



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NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL

The rocket is apparently launched by an additional explosion within a cavity or chamber which is closed by mounting the rocket on it before firing. The explosion is set off in the same manner as the propulsion xxpixxm explosions. No figures are known as to the initial velocity, it is not very great as it has been repeatedly observed that at the moment of launching the rocket does not follow a straight line but seeks its course in a wavering manner.

V-2, V-26, V-32.

The information at hand differs as to the explosive (charge) in the rockets. This is evidently due to the fact that two types of rockets are now being used. For a considerable time the V-2 was known in Germany as the V-26, the only type then used. This projectile is 13 m. long (some say 16 m.), its diameter is 1.70m. (some say 2m.), it carries 900 kg. of explosives, its total weight is 6000 kg., its speed is 4800 km. per hour, its radius is 300 km. It can go 100 km. high.

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According to an unconfirmed report the total weight of the V-32 is supposed to be considerably greater than that of the V-26. This report states that 1600 kg. of explosives are required to send such a rocket across the North Sea, besides the necessary nitrogen, 5 tons of liquid oxygen, and 3 tons of spirits distilled from potatoes for which 30 tons of potatoes have to be used up. This explains why the Germans seized so many barge-loads of potatoes which were destined for the civilian population. The propulsion of the V-32 is said to be very bad, a large number of them having come to grief soon after being launched. The largest plants producing rocket equipment are located in Halle on the Saale.

Launching:

The ground from where the rocket is to be launched must be hard and firm, and able to withstand great shocks. At first a concrete base was built, its wide surface reducing the ground shock per square foot so that the ground did not sink in. The trouble with this was the considerable time it took to build it, and the being confined to a certain spot. Now freezing mixtures (probably liquid oxygen) brought in special trucks, are used to freeze the ground (to what extent and depth is not known) thereby obtaining practically the same results as if concrete were used, except for a short duration only. Many reports indicate that, taking into account the time necessary for the setting up and pointing (about 2 hours) only four rockets can be launched each time per site thus obtained. The trucks and equipment are camouflaged; as they are spread out and as all transfers take place at night, they cannot easily be attacked from the air; after allied reconnaissance flights they are set up on another site. It follows that rocket launching sites cannot be destroyed for the simple reason that there aren't any to destroy.

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Figure E.76: Yet another report of rockets larger than the standard A-4 (V-2) being mass-produced. Report T.I. 3339 (SD-2621pt/947), Flying Bombs and Rockets. December 1944 [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Interrogation report of a prisoner of war (PW) who had been employed at Peenemünde as a chemist. MU 500, CSDIC (West), Seventh Army APO 758 US Army, Reference No. 579, Peenemunde Experimental Center (Karlshagen). 14 December 1944. [Published in Georg and Mehner 2004, p. 93; Stevens 2007, p. 237. What is the archival source of this document???]

The V-2 flying bombs are assembled in the EAST Works (see Appendix A) which has about 3,000 engineers and workers. Two types of V-2 have been built: Type A 1 [A-10?], which is about 23 m long and 4.5 m in diameter, and Type A 4, which is about 18 m long and 2.5–3 m in diameter. Only the latter is in mass production. The experimental launching of V-2 used to take place every Saturday afternoon from Mar 43 to Mar 44. At the latter time it was rumored that HITLER had visited the center and had demonstrated his anger at the slow progress of the experiments. From this time on the frequency of the bomb launchings was increased to every other day. When PW left the center in July 44 there were still some launchings which were not successful due to the fact that the bombs were not able to be radio-guided, although they were launched successfully.

[...] PW heard that German technicians intended to launch them to an altitude of 120 km, which would have permitted them to reach NEW YORK. At the height of 15 km the bombs have a range of 500 km. When the bomb drops through the stratosphere to a lower level, it becomes red through friction.

[Various versions of the A-10 design had a length of 20–26 m and a body diameter of approximately 4.15 m (with fins spanning a larger diameter), and were required to achieve enough range to reach New York, so these details are fairly consistent with the prisoner's report.

A-4 had a body diameter of 1.65 m but fins spanning approximately 3.5 m, which may account for the prisoner's description of 2.5–3 m for the diameter. While the standard A-4 length was 14 m, versions of the A-4 (or A-9) with a length of 18 m are reported by a number of sources in addition to this prisoner.

Trajectories in which an A-9 (winged A-4) leveled off at an altitude of 15 km and flew horizontally toward its target, or an A-10-boosted A-9 leveled off at an altitude of 120 km and flew horizontally, were considered in detail alongside better-known trajectories.]

CIOS XXVIII-56. *Rockets and Guided Missiles.* p. 9.

The capacity of the fuel tank was 4,460 litres. Some larger tanks were made for A.4 towards the end of the war, but were never used. (ENG. FINZEL) [...]

Brett Davis. V-2 Plant Survivors Publicize Their Story. *Huntsville Times* 28 February 2000 [http://www.v2rocket.com/start/others/news-archive.html].

"People have now started to realize what happened there," said Alex Baum, who was a member of the French resistance and was captured and sent to the underground V-2 plant. He now lives in California. "We want to make the public more aware," Baum said. [...]

Baum said he remembers von Braun both from Peenemünde and Dora, although he had no contact with him or the other German engineers at the time by orders of the SS. He remembers one day when the top German brass, including Heinrich Himmler, the head of the dreaded SS and the second-ranking official in the Third Reich, visited Peenemünde. Von Braun praised the V-2 to them, Baum said.

"I understand German, too, because I was raised in Alsace-Lorraine (a region of France on the German border)," Baum said. "I could hear von Braun talking about the ultimate weapon that's going to destroy the United States and everything else. We (the prisoners) were not very close, but we could see them." Later, he would see von Braun visit the Mittelwerk, usually in the company of top military officials. "He was very desperate to get this thing going, and he knew exactly what was going on," Baum said.

[Alex Baum remembered that Wernher von Braun eagerly expected the arrival of a new rocket warhead with tremendous destructive power.

Compare Baum's testimony to the incident involving British journalist Gordon Young, who interviewed von Braun and Walter Dornberger at Garmisch in June 1945. They told Young that the V-2 would have soon received a "much more powerful" warhead. Allied censorship forced Young to eliminate any reference to German nuclear weapons at that time, since the U.S. nuclear weapons program was still completely secret. In August 1945, after U.S. nuclear weapons were used on Japan and became publicly known, Young tried to publish a second article reporting what he had learned from von Braun about nuclear-armed rockets. That second article was censored completely; only a brief reference in another article in Young's own newspaper (*Daily Express*) and three short articles in Australian newspapers escaped that second and final censorship (pp. 4679–4681).

Squadron Leader E. J. André Kenny (one of the most important British aerial photo interpreters for Operation Crossbow) confirmed that von Braun "had spoken of atomic energy at Garmisch, in 1945" (p. 5763).

For further evidence of rockets with nuclear warheads, see the summary of the interrogation of engineer Horst Kirfes (p. 4532), as well as the July 1946 *AAF Review* (p. 5038).

For many more references to nuclear-armed rockets that were intended to attack Allied targets during the war, see the list of documents on p. 5821.]

Benjamin Jacobs. 1995. *The Dentist of Auschwitz.* Lexington, Kentucky: University Press of Kentucky. Chapter 16: Dora-Mittelbau [http://nizkor.com/features/dentist/].

"What work are you doing here?" I asked an inmate. [...]

"Have you heard of the German V-rockets? After the Allied bombing destroyed Peenemünde, where they were first built, now we assembled them here, in the Harz mountain caves. At first we worked on the V1, then on the V2, and now," and here he began almost to whisper, "we are beginning to work on the V3."

Colonel Lowell P. Weicker. 1945. Headquarters United States Strategic Air Forces in Europe (REAR), Office of the Director of Intelligence AAF 390, Memorandum to George C. McDonald. 5 January. [Published in Georg and Mehner 2004 p. 203. What is the archival source of this document???]

1. You will recollect that the SHAEF forecast, arrived at after D-day in 1944, placed the capitulation of Germany at the end of December of that year. [...]

3. With the exception of a few modifications and improvements the U.S. Air Forces in this theater are fighting with substantially the same weapons as they used in 1942. [...] This period ended December 31, 1944 with Germany still fighting, but Germany is not fighting with the weapons of 1942. She is leading the world in tested jet propelled airplanes, long range missiles, new type submarines and, in certain classes, better tanks. A large part of her manufacturing facilities have gone underground and she is bending every sinew for the last stand on the Vaterland frontiers.

4. Our Ground Armies, despite superiority in manpower and quantity of equipment, are presently engaged more in defensive than offensive fighting and, unless this state of affairs is quickly changed or the Russians actually drive through to Berlin and victory, we must face the grim expectation of fighting Germany and her new capabilities through greater 1945. [...]

6. CONCLUSION:

a. The war has not terminated in accordance with SHAEF Plans.

b. SHAEF timing has dominated the development of equipment, training progress and establishment of manpower and supply for this theater.

c. The first cycle and period of the war has ended without the capitulation of Germany and with Germany leading in the development of principal new weapons and methods, which will be included in her capabilities during 1945.

7. RECOMMENDATION:

That this Directorate of Intelligence prepare a careful analysis of over-all Germany capabilities for 1945 as they may effect our flying formations and our target systems...

[This is a remarkably frank Allied acknowledgement of the technological superiority of German weapons, even in these final stages of the war.

This request apparently led to the creation of the following 19 January 1945 Commanders Intelligence Digest.]

Headquarters, United States Strategic Air Forces [USSTAF] in Europe, Office of the Director of Intelligence, An Evaluation of German Capabilities in 1945. The Commanders Intelligence Digest. 19 January 1945. [AFHRA folder 519.635 1945 Intelligence Digest; AFHRA A5729 electronic version pp. 255 onward and 561 onward; NARA RG 319, Entry UD-1041, Box 27, Folder 925497]

1. In the following paragraphs are listed the actual or potential weapons which the Germans may use against USSTAF operations in 1945. For the most part they include the so-called V weapons. No consideration is given to those for which there is lacking evidence of possible use for some time to come. [...]

2. V-2:

[...] The V-2, or rocket projectile, with a warhead of approximately one ton, and a current range of 225 miles, is being fired at London at the rate of 180/250 per month, and against Continental ports at the rate of approximately 300 per month.

[...] Larger rockets (68 feet in length as against 45 feet) are known to exist, and may appear in small quantities during the year. They would have a considerably larger warhead. [...]

4. “PHOO” BOMBS: Occasionally reports by pilots and the testimony of prisoners of war and escapees describe this weapon as a radio-controlled, jet-propelled, still-nosed, short-range, high performance ramming weapon, for use against bombing formations. Its speed is estimated at 525 mph and it is estimated to have an endurance of 25 minutes. These bombs are launched from local airfields, and are radio-controlled, either from the ground, or possibly by aircraft. [...]

5. MAGNETIC WAVE: The best information available is from very secret and reliable sources, and forces the conclusion that this weapon exists as a possibility. It is designed to cause failure of various electrical apparatus in aircraft. [...]

7. ATOMIC BOMB: Close check of every report, and close surveillance of the area in which tests are alleged to have taken place lead to the conclusion that such bombs are not a likelihood in 1945.

[See document photos on pp. 5338–5340.

Point 1 above suggests that there is significant evidence for those weapons that are then listed.

Point 2 definitively states that rockets 50% longer than the V-2 (21 m vs. 14 m), and with a warhead “considerably larger” than one ton, are “known to exist.” Are those A-10 boosters, stretched A-4 rockets, or something else?

Point 4 suggests that the mysterious “foo” or “phoo” fighters reported late in the war were a real German anti-aircraft weapon that has never been fully described in publicly available documents; see for example Chester 2007.

Point 5 shows that an electromagnetic pulse directed energy weapon was reported by “very secret and reliable sources.”

Point 7 suggests U.S. knowledge of multiple alleged German atomic bomb tests prior to January 1945, in a particular area that was under close Allied surveillance. This likely means the Baltic coast, including the October 1944 Rügen test.]

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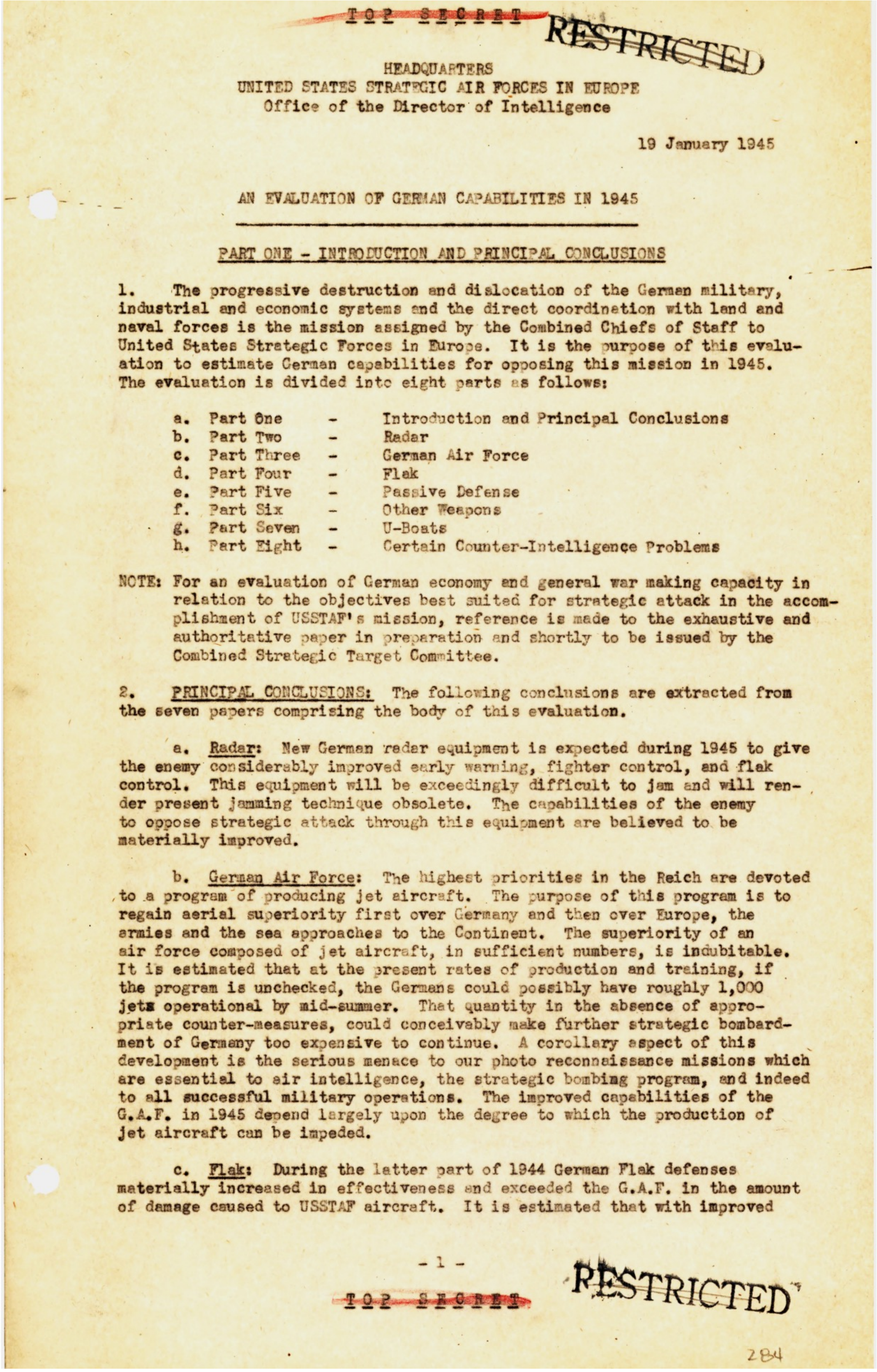

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HEADQUARTERS
UNITED STATES STRATEGIC AIR FORCES IN EUROPE
Office of the Director of Intelligence

19 January 1945

AN EVALUATION OF GERMAN CAPABILITIES IN 1945

PART ONE - INTRODUCTION AND PRINCIPAL CONCLUSIONS

1. The progressive destruction and dislocation of the German military, industrial and economic systems and the direct coordination with land and naval forces is the mission assigned by the Combined Chiefs of Staff to United States Strategic Forces in Europe. It is the purpose of this evaluation to estimate German capabilities for opposing this mission in 1945. The evaluation is divided into eight parts as follows:

a. Part One - Introduction and Principal Conclusions
b. Part Two - Radar
c. Part Three - German Air Force
d. Part Four - Flak
e. Part Five - Passive Defense
f. Part Six - Other Weapons
g. Part Seven - U-Boats
h. Part Eight - Certain Counter-Intelligence Problems

NOTE: For an evaluation of German economy and general war making capacity in relation to the objectives best suited for strategic attack in the accomplishment of USSTAF's mission, reference is made to the exhaustive and authoritative paper in preparation and shortly to be issued by the Combined Strategic Target Committee.

2. PRINCIPAL CONCLUSIONS: The following conclusions are extracted from the seven papers comprising the body of this evaluation.

a. Radar: New German radar equipment is expected during 1945 to give the enemy considerably improved early warning, fighter control, and flak control. This equipment will be exceedingly difficult to jam and will render present jamming technique obsolete. The capabilities of the enemy to oppose strategic attack through this equipment are believed to be materially improved.

b. German Air Force: The highest priorities in the Reich are devoted to a program of producing jet aircraft. The purpose of this program is to regain aerial superiority first over Germany and then over Europe, the armies and the sea approaches to the Continent. The superiority of an air force composed of jet aircraft, in sufficient numbers, is indubitable. It is estimated that at the present rates of production and training, if the program is unchecked, the Germans could possibly have roughly 1,000 jets operational by mid-summer. That quantity in the absence of appropriate counter-measures, could conceivably make further strategic bombardment of Germany too expensive to continue. A corollary aspect of this development is the serious menace to our photo reconnaissance missions which are essential to air intelligence, the strategic bombing program, and indeed to all successful military operations. The improved capabilities of the G.A.F. in 1945 depend largely upon the degree to which the production of jet aircraft can be impeded.

c. Flak: During the latter part of 1944 German Flak defenses materially increased in effectiveness and exceeded the G.A.F. in the amount of damage caused to USSTAF aircraft. It is estimated that with improved

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AFHRA folder 519.635 1945
Intelligence Digest

Figure E.77: Headquarters, United States Strategic Air Forces [USSTAF] in Europe, Office of the Director of Intelligence, An Evaluation of German Capabilities in 1945. The Commanders Intelligence Digest. 19 January 1945. [AFHRA folder 519.635 1945 Intelligence Digest; AFHRA A5729 electronic version pp. 255 onward and 561 onward; NARA RG 319, Entry UD-1041, Box 27, Folder 925497].

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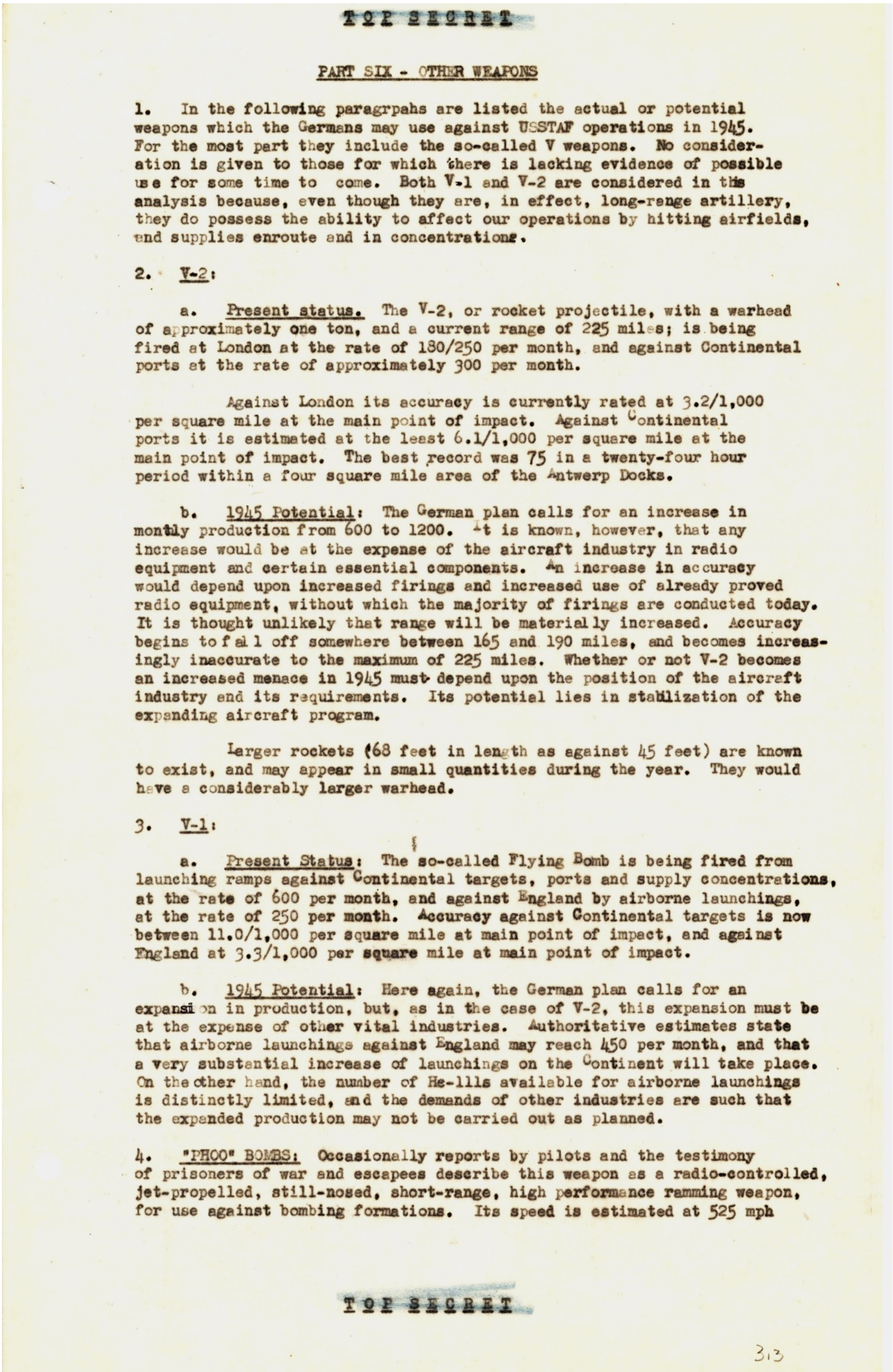
Intelligence Digest



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PART SIX - OTHER WEAPONS

1. In the following paragrpahs are listed the actual or potential weapons which the Germans may use against USSTAF operations in 1945. For the most part they include the so-called V weapons. No consideration is given to those for which there is lacking evidence of possible use for some time to come. Both V-1 and V-2 are considered in this analysis because, even though they are, in effect, long-range artillery, they do possess the ability to affect our operations by hitting airfields, and supplies enroute and in concentrations.

2. V-2:

a. Present status. The V-2, or rocket projectile, with a warhead of approximately one ton, and a current range of 225 miles; is being fired at London at the rate of 180/250 per month, and against Continental ports at the rate of approximately 300 per month.

Against London its accuracy is currently rated at 3.2/1,000 per square mile at the main point of impact. Against Continental ports it is estimated at the least 6.1/1,000 per square mile at the main point of impact. The best record was 75 in a twenty-four hour period within a four square mile area of the Antwerp Docks.

b. 1945 Potential: The German plan calls for an increase in monthly production from 600 to 1200. It is known, however, that any increase would be at the expense of the aircraft industry in radio equipment and certain essential components. An increase in accuracy would depend upon increased firings and increased use of already proved radio equipment, without which the majority of firings are conducted today. It is thought unlikely that range will be materially increased. Accuracy begins to fall off somewhere between 165 and 190 miles, and becomes increasingly inaccurate to the maximum of 225 miles. Whether or not V-2 becomes an increased menace in 1945 must depend upon the position of the aircraft industry and its requirements. Its potential lies in stablization of the expanding aircraft program.

Larger rockets (68 feet in length as against 45 feet) are known to exist, and may appear in small quantities during the year. They would have a considerably larger warhead.

3. V-1:

a. Present Status: The so-called Flying Bomb is being fired from launching ramps against Continental targets, ports and supply concentrations, at the rate of 600 per month, and against England by airborne launchings, at the rate of 250 per month. Accuracy against Continental targets is now between 11.0/1,000 per square mile at main point of impact, and against England at 3.3/1,000 per square mile at main point of impact.

b. 1945 Potential: Here again, the German plan calls for an expansion in production, but, as in the case of V-2, this expansion must be at the expense of other vital industries. Authoritative estimates state that airborne launchings against England may reach 450 per month, and that a very substantial increase of launchings on the Continent will take place. On the other hand, the number of He-111s available for airborne launchings is distinctly limited, and the demands of other industries are such that the expanded production may not be carried out as planned.

4. "PHOO" BOMBS: Occasionally reports by pilots and the testimony of prisoners of war and escapees describe this weapon as a radio-controlled, jet-propelled, still-nosed, short-range, high performance ramming weapon, for use against bombing formations. Its speed is estimated at 525 mph

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Figure E.78: Headquarters, United States Strategic Air Forces [USSTAF] in Europe, Office of the Director of Intelligence, An Evaluation of German Capabilities in 1945. The Commanders Intelligence Digest. 19 January 1945. [AFHRA folder 519.635 1945 Intelligence Digest; AFHRA A5729 electronic version pp. 255 onward and 561 onward; NARA RG 319, Entry UD-1041, Box 27, Folder 925497].

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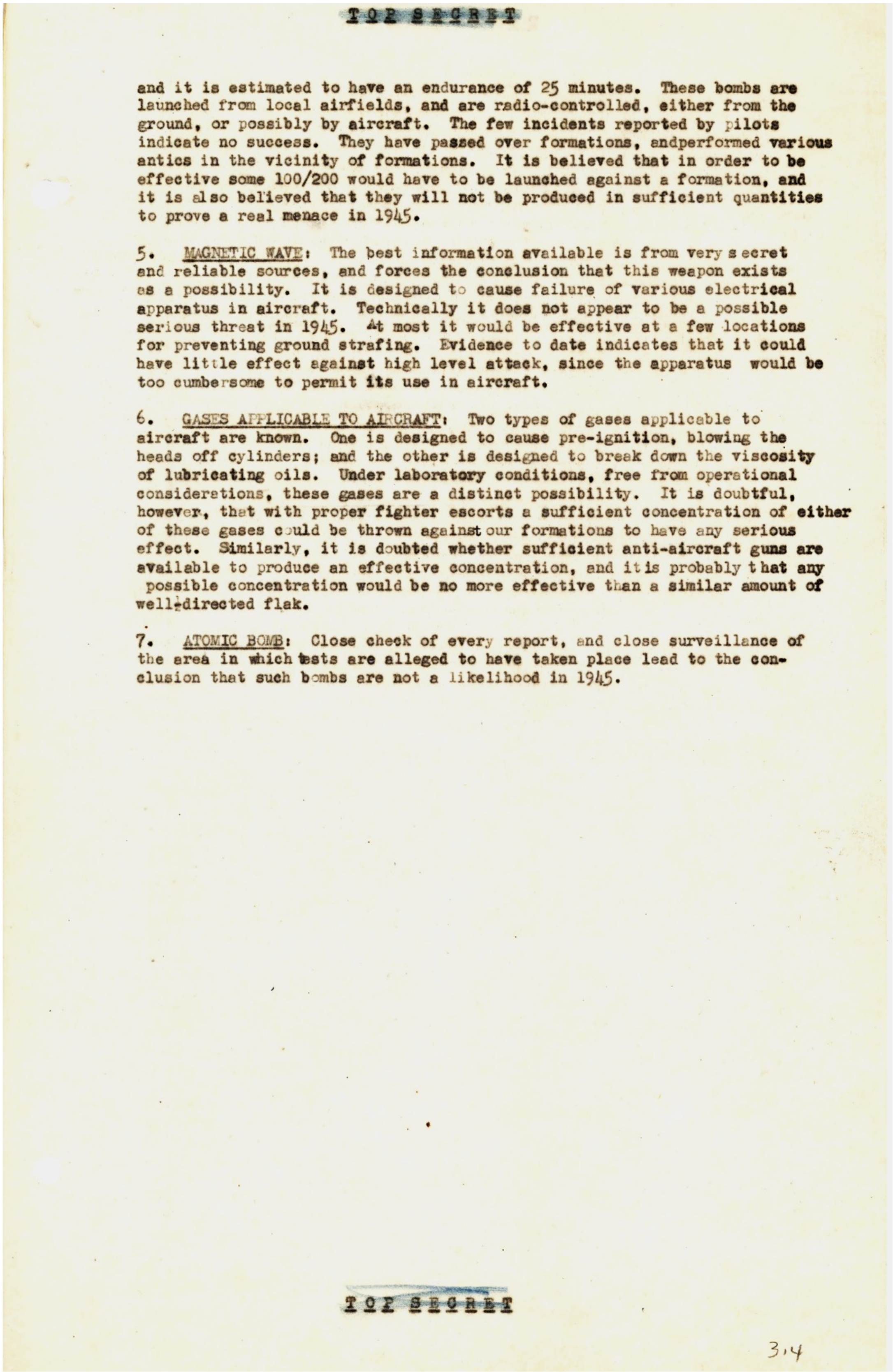
Intelligence Digest



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and it is estimated to have an endurance of 25 minutes. These bombs are launched from local airfields, and are radio-controlled, either from the ground, or possibly by aircraft. The few incidents reported by pilots indicate no success. They have passed over formations, andperformed various antics in the vicinity of formations. It is believed that in order to be effective some 100/200 would have to be launched against a formation, and it is also believed that they will not be produced in sufficient quantities to prove a real menace in 1945.

5. MAGNETIC WAVE: The best information available is from very secret and reliable sources, and forces the conclusion that this weapon exists as a possibility. It is designed to cause failure of various electrical apparatus in aircraft. Technically it does not appear to be a possible serious threat in 1945. At most it would be effective at a few locations for preventing ground strafing. Evidence to date indicates that it could have little effect against high level attack, since the apparatus would be too cumbersome to permit its use in aircraft.

6. GASES APPLICABLE TO AIRCRAFT: Two types of gases applicable to aircraft are known. One is designed to cause pre-ignition, blowing the heads off cylinders; and the other is designed to break down the viscosity of lubricating oils. Under laboratory conditions, free from operational considerations, these gases are a distinct possibility. It is doubtful, however, that with proper fighter escorts a sufficient concentration of either of these gases could be thrown against our formations to have any serious effect. Similarly, it is doubted whether sufficient anti-aircraft guns are available to produce an effective concentration, and it is probably that any possible concentration would be no more effective than a similar amount of well-directed flak.

7. ATOMIC BOMB: Close check of every report, and close surveillance of the area in which tests are alleged to have taken place lead to the conclusion that such bombs are not a likelihood in 1945.

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Figure E.79: Headquarters, United States Strategic Air Forces [USSTAF] in Europe, Office of the Director of Intelligence, An Evaluation of German Capabilities in 1945. The Commanders Intelligence Digest. 19 January 1945. [AFHRA folder 519.635 1945 Intelligence Digest; AFHRA A5729 electronic version pp. 255 onward and 561 onward; NARA RG 319, Entry UD-1041, Box 27, Folder 925497].

Says New V-Bomb Now Ready to Cross Atlantic. *Ottawa Citizen* 26 January 1945 p. 17.

STOCKHOLM, Jan. 25—(Reuters)—V-4—new superflying bomb which the Germans claim can hit New York and other points on the eastern North American coast—now is in production and ready for launching across the Atlantic, a German engineer who was one of the principal inventors of V-weapons told correspondents today.

Until a few days ago he was head of an experimental station for V-bombs in Jutland but escaped to Sweden. He first posed as a Danish refugee but after questioning by Swedish authorities disclosed his real identity.

The German was then interned but as his knowledge was useful to the Swedish general staff, they are granting him special conditions and are keeping his name secret.

The V-4 is faster and more accurate than the V-2—and V-3 which is only an improved version of V-2—the engineer said.

It weighs about 15 tons, travels at 1.8 miles a second and attains an altitude of more than 120 miles.

It reaches this height in just over two minutes after being fired at an angle of 75 degrees.

Its great altitude and speed give it increased accuracy and range. At 360 kilometers altitude, the atmosphere is thinnest, so there is practically no friction to impede flight and thus reduce range.

Further, an object of this weight and travelling with this speed cannot easily be diverted from its course by forces such as wind pressure, when climbing or falling.

The great disadvantage of V-4, the engineer said, is that it is difficult to produce in quantity.

The Germans could therefore only send a limited number of bombs against Halifax, New York or such cities.

The Germans will probably reserve it for European targets until their final defeat, when sheer spite may cause them to attack North American cities, he said.

[Also reported in:

Threat of V-bombs for New York Told by Nazi ‘Refugee’ in Sweden. *Montreal Gazette* 26 January 1945 p. 10. https://news.google.com/newspapers?id=VXotAAAAIBAJ&sjid=vpgFAAAAIBAJ&pg=4256,4045572&hl=en

“V-4 to Attack New York”: German Engineer’s Story. *Manchester Guardian* 26 January 1945 p. 5.

Swedes Guard Inventor of All V-Weapons. *Lowell Sun* (Massachusetts) 26 January 1945 p. 1.]

PW Intelligence Bulletin No 1/47. 13 March 1945. [NARA RG 165, Entry NM84-79, Box 1915]

18. V-Weapon against USA

An acquaintance told PW (28 Jan) that the laboratory in SWINEMÜNDE where he worked, experimented with a new rocket missile, resembling V-2, 30 m long 4–5 m diameter. Experiments conducted with 1/25 of the explosive charge produced devastating results. It was intended to use the projectiles in nuisance bombings of the USA.

19. Atom Smasher

PW heard from friends that atom-smashing experiments (conducted somewhere NW of BERLIN) were successful and would result in the perfecting of an atom-disintegrating weapon by May 45.

(Source: San Uffz Theodor GÖRGES) 4 San Bereitschaft Hermann GÖRING Fallsch Corps captured 1 Mar)

[See document photo on p. 2622.

"A new rocket missile, resembling V-2, 30 m long 4–5 m diameter" for "bombings of the USA" sounds like a remarkably good description of the A-9/A-10 (p. 5271). According to this account it was not merely a paper design, but rather it had already progressed to the point of being "experimented with" as of January 1945, and it was intended to be launched from Europe to the United States as part of the war effort within the near future.

Note that the intercontinental rocket was being assembled and tested in Swinemünde (now Świnoujście, Poland), around 50 km from Peenemünde. That would be close enough to Peenemünde to allow for easy transport of materials and personnel, yet far enough away to potentially avoid the close scrutiny of Allied aerial reconnaissance of Peenemünde.

According to this report, the payload for this intercontinental rocket appears to have been a nuclear weapon. "Experiments conducted with" only "1/25 of the explosive charge produced" effects described as "devastating," which could hardly be said of 1/25 of the conventional explosive payload that had been used on rockets up to that point. Moreover, the report specifically referred to an "atom-disintegrating weapon."

This report indicated that the nuclear weapon had already been successfully tested. "Experiments" had already been "conducted" that "produced devastating results." (If the description meant 1/25 of the explosive yield, then plausible numbers are perhaps ∼1 kiloton for the tested version and ∼25 kilotons for the deployed version. "Atom-smashing experiments... were successful" and mass-produced versions for deployment would be ready by May 1945 if the war continued.]

Gordon Gaskill. March 1945. Can Super-Rockets Hit America? *The American Magazine.* pp. 25–108.

I have talked to the leading V-2 authority for the United States Strategic Air Forces in Europe, an officer of high rank and solid reputation who knows all the Allies know about V-2. And we know a surprising amount.

Because of his secret work I am not permitted to reveal his name. But he has given me new and exclusive information which points to only one conclusion: This great rocket is unquestionably the most revolutionary weapon of our time. [...]

This authority, from facts at his command, has calculated for me approximately what kind of rocket might hit New York. Leaving Germany, it would weigh 63 tons, mostly fuel. Its war head would be 7 tons of high explosive. The journey from Germany to New York—about 4,000 miles—would only take 25 minutes. The "motor" would run but 8 minutes of this time. The rocket would climb almost vertically as high as 300 miles above the earth before leveling off sharply, and its maximum speed would be over 9,000 miles per hour, with an added time saving from the earth's rotation.

"I am using New York merely as an example," he said. "The Germans could just as easily fire at Detroit or Chicago or San Francisco, although the error will naturally be greater if they aim farther west."

It still sounded a little Buck Rogers to me and I must have shown it, for he smiled and said, "I know. Only a few months ago a lot of people in Britain were joking about the 'fantastic' rumors of V-1 and V-2. I've helped dig some of those same people out of the rubble. . . . No, I'm afraid such a rocket is really practical. In fact, it's even more practical than the one they're using now against Britain. The curious thing about rockets is that the bigger you build them, the more efficient and satisfactory and inexpensive they become."

I asked him why the Germans hadn't yet used such a rocket, if it was so simple. In answer he pulled out a newspaper clipping, reporting a speech on December 1 by the Nazi Labor Chief, Speer. In an address to the German War Production Board, Speer promised that "V-3" would be ready for firing at America very soon.

[The anonymous expert was likely U.S. Army Air Forces Colonel Donald Putt.

The 7-ton payload is consistent with several other reports of a German intercontinental rocket with a payload of 6 tons (pp. 4338 and 4350–4363). Perhaps 7 tons was an estimate, or perhaps it included 6 tons for the explosive and 1 ton for guidance and/or pilots.

Even 6 or 7 tons of conventional explosive would hardly have justified the enormous amounts of funding and effort required for Germany to develop, build, and launch such a rocket. However, there is evidence that a 6-ton hydrogen bomb was in the late stages of development (p. 4280), and that would have been a far more logical payload.]

Cläre Werner. 16 May 1962 SED Arnstadt transcript. Jonastalverein Archive, Arnstadt. For a discussion of the background and reliability of this document, see p. 4551.

Am 16. März 1945 war ein weiteres Ereignis. Auch hier gab es gegen 21 Uhr Fliegeralarm für unser Gebiet. Hans war dazu wieder mit einigen Freunden auf dem großen Turm, auch wir konnten mit hoch. Diesmal hatten die Leute Ferngläser mit, und es wurde nicht in Richtung des Übungsplatzes gesehen, sondern in Richtung Ichtershausen. Dort wurde es gegen 23 Uhr sehr hell, es war aber nicht so wie die beiden ersten Male davor, sondern es stieg etwas gegen den Himmel mit einem großen Feuerschweif, es ging immer höher, aber es entfernte sich von uns in Richtung Norden. Die Leute fielen sich in die Arme, wir haben es, hurra, wir sind die Größten, wir sind unbesiegbar usw. Die ca. 15 Leute feierten bis zum Morgen. Hans verbot uns wieder alles Gesehene und sagte nur: Wir waren bei einer weiteren Sache dabei, die in der Welt einmalig ist und in jedem Geschichtsbuch stehen wird.

On 16 March 1945, there was a further event. Again, at 21:00 there were air raid warnings for our area. Hans was to return with some friends to the large tower, also we could go up with them. This time the people had binoculars, and watched not in the direction of the training area, rather in the direction of Ichtershausen. There at 23:00 it became very bright, but not like the first two times before, rather it rose somewhat against the sky with a large fire exhaust, higher and higher, but it moved away from us in the direction of the north. The people fell into each other's arms, [saying] we have it, hurray, we are the biggest, we are invincible, etc. The approximately 15 people celebrated until the morning. Hans forbade us again about everything we had seen and only said: We were present at a further event that is unique in the world and will be in every world history book.

[If the rocket was launched at 11:00 p.m., there would have been relatively few witnesses observing the sky at that hour. If air raid warnings were issued to everyone in the area before the launch, there would have been even fewer witnesses.]

Werner Kasper. 16 May 1962 SED Arnstadt transcript. Jonastalverein Archive, Arnstadt. For a discussion of the background and reliability of this document, see p. 4551.

Auf dem Gelände der Polte Rudisleben gab es ebenfalls eine Versuchsanlage und einen Nachbau für Raketenabschüsse, so wie in Peenemünde. Auch dafür mußten wir vershiedene Tanks aus verschiedenem Stahl errichten, die im Gelände jeweils zu Sechsergruppen gebracht wurden. Auch hier waren Sauerstoff, Stickstoff, verschiedene Treibstoffe und auch verschiedene Gase als Füllungen in den Tanks bzw. Behältern in der Größe von 1000 bis 20 000 Liter.

On the grounds of Polte Rudisleben there was also an experimental station and duplicate equipment for rocket firing, as in Peenemünde. We also had to build different tanks from different steel, which were brought there in groups of six. Here too were oxygen, nitrogen, different fuels and also different gases for filling the tanks in size from 1000 to 20,000 liters.

Es wurden verschiedene Abschüsse in Rudisleben durchgeführt. Höhepunkt war der 16. März 1945 in der Nacht gegen 11 Uhr. So einen Feuerschein bei einem Abschuß habe ich nie wieder gesehen. Wir hatten Bereitschaft und waren vor dem Bunker 4 nahe am Eingang, wo wir auch all unsere Werkzeuge hatten. Einige Wochen zuvor hatten wir viel zu tun, vor allem mußten wir eine Menge von Treibstofftanks errichten. Es lagerten ca. 100 Tonnen Treibstoff im Gelände. Von Nordhausen wurden immer nachts Teile gebracht, und Fachleute von Peenemünde und Berlin waren ständig da. Die Wachmannschaft wurde durch SS ersetzt, nur in unserem Bereich war noch die normale Wachmannschaft.

Am 13. März war eine Kupferleitung verstopft, und ich mußte mit einem Kupferschmied ins Objekt. Wir wurden in einem geschlossenen LKW mit SS-Leuten hingefahren. Was wir dort sahen, war einmalig: Diese Aggregate und dieses riesige Ding. Es muß über 30 m hoch gewesen sein und über 4 m im Durchmesser. Unten waren große Flügel und oben kleine Flügel. Darum waren ein großer Holzverschlag und eine Krananlage.

Uns wurde sofort die Arbeit gegeben, und es war für uns nicht einfach, die Kupferleitung in Gang zu bringen. Nach unserer Arbeit wurden wir nicht wieder zu unserem Bunker, sondern in ein Stollensystem im Bereich des Steigers nach Erfurt gebracht. Dieses war so groß, daß darin LKWs fahren konnten. Von einigen hohen SS-Leuten wurden wir belehrt und mußten einige Unterschriften geben, daß wir nichts gesehen haben; falls wir etwas sagen oder erzählen würden, würden wir sofort von der SS erschossen.

Daher nehme ich an, daß am 16. März dieses riesige Ding in die Luft ging, Flugrichtung Norden. Es war einmalig.

Various firings were conducted in Rudisleben. The high point was 16 March 1945 at 11:00 at night. Such a fire light with a firing I have never seen again. We were on duty and were in front of Bunker 4 near the entrance, where we had all our work equipment. A few weeks earlier, we had a lot to do, above all, we had to build a lot of fuel tanks. It took approximately 100 tons of fuel there. Parts were always brought from Nordhausen at night, and officials from Peenemünde and Berlin were there constantly. The security guards was replaced by SS guards, only in our area were there still the normal guards.

On March 13, a copper line was clogged and I had to go with a coppersmith into the base. We were driven there in a closed truck with SS men. What we saw there was unique: These Aggregates [rockets] and this huge thing. It must have been over 30 m high and over 4 m in diameter. Below were large fins and above were small fins. [Two-stage design.] Around it was a large wooden scaffold and a crane system.

We were put to work immediately, and it was not easy for us to fix the copper line. After our work, we were not brought back to our bunker, but rather went to a system of tunnels in the area of Steiger [forest], near Erfurt. These [tunnels] were so large that trucks could drive inside them. We were instructed by some high SS men and had to give some signatures that we had seen nothing; if we were to say or tell something, we would immediately be shot by the SS.

Therefore I take it that on 16 March this huge thing went in the air, flying in the direction of the north. It was unique.

Albin Kummer. 16 May 1962 SED Arnstadt transcript. Jonastalverein Archive, Arnstadt. For a discussion of the background and reliability of this document, see p. 4551.

Das größte Flugobjekt wurde am 16. März 1945 in der Nacht abgeschossen. Dieses Flugobjekt wurde als Wunderwaffe bezeichnet. Es war über 30 m hoch und hatte unten einen Durchmesser von über 4 m. Zum Betanken dieser Waffe wurden zwei Tage benötigt.

Es war einmalig, wie das große Ding gegen den Nachthimmel ging. Die großen Herren von SS und Forschungsrat feierten bis zum Mittag am anderen Tag. Es war wohl ein großer Erfolg der Wissenschaft und der Forschung. Ein zweites Flugobjekt wurde vorbereitet, doch dann waren einige ganz hohe Tiere im Objekt, ich glaube sogar, daß Speer dabei war. Doch dann war auf einmal alles ruhig, das Objekt wurde sogar abgebaut.

The biggest flying object was fired off on 16 March 1945 in the night. This flying object was called a wonder weapon. It was over 30 m high and had a diameter of over 4 m at the bottom. To fuel up this weapon required two days.

It was amazing how the large thing flew against the night sky. The big men from the SS and Research Council celebrated until noon the next day. It was probably a great success of science and research. A second flying object was prepared, but then some very big shots were in the base, I believe even that Speer was there. But then everything was suddenly quiet, the base was even disassembled.

[The given height and base diameter appear to match the description of an A-9/A-10 two-stage rocket.

The statement that it took two days to fuel the rocket (probably with liquid oxygen for oxidizer and either ethanol or fuel oil for fuel in both stages) makes sense from a technical standpoint and seems to support the credibility of Albin Kummer's account.

Kummer's report is highly consistent not only with other accounts within the 1962 SED Arnstadt transcripts, but also with outside statements such as those by Otto Skorzeny (p. 5352) and Werner Grothmann (p. 5355–5359).]

Alfred Gründler. 22 July 1962 SED Arnstadt transcript. Jonastalverein Archive, Arnstadt. For a discussion of the background and reliability of this document, see p. 4551.

[...] Am 1. Juli 1938 wurde die Produktion der Siemens & Halske AG Berlin in Arnstadt aufgenommen. Ab. 1. September 1938 war hier gleichzeitig das Wernerwerk und das Siemens-Schuckert-Werk untergebracht. [...]

Sie beschäftigten sich mit der Entwicklung von Zielsuchgeräten, welche in Flugzeugen und Raketen eingebaut werden konnten. Das erste Gerät war so um die 20 Kilogramm schwer, dann waren sie nur noch zwölf Kilogramm schwer. Bei den ersten Versuchen im November 1944 gab es in Luisental, Neustadt-Glewe, einige Unfälle, aber dann waren die in Ordnung. Im März 1945 (den Tag kann ich nicht mehr sagen) wurde eine A-4 und dann sogar eine A-9/A-10 von der Polte in Rudisleben abgeschossen. Die große Rakete war so gut, sie ging im Norden Norwegens mit einer Abweichung von nur sechs Metern ins Ziel.

[...] On July 1, 1938, Siemens & Halske AG Berlin started production in Arnstadt. From September 1, 1938, the Wernerwerk and the Siemens-Schuckert-Werk were located here at the same time. [...]

They dealt with the development of guidance systems, which could be installed in aircraft and rockets. The first device was about 20 kilograms heavy, then they were only twelve kilograms heavy. In the first tests in November 1944 in Luisental, Neustadt-Glewe, there were some accidents, but then they were fine. In March 1945 (I can no longer say which day) an A-4 and then even an A-9/A-10 were fired off from Polte in Rudisleben. The large rocket was so good, it went to northern Norway with a deviation of only six meters from the target.

[Gründler said that during the war he worked on advanced guidance systems for very long-range rockets at a Siemens facility in Arnstadt, which had begun operation in 1938. He described rocket work there and at Rudisleben, just north of Arnstadt.

U.S. intelligence documents from 1944 and 1946 confirmed that indeed there was a Siemens plant just north of Arnstadt that produced sophisticated guidance systems for very long-range rockets (see pp. 2938–2962, 5348, 5557), and even that the Siemens plant began operation in 1938.

Northern Norway would have been the most logical target for a long-range rocket test. The distance from Arnstadt to the northern coast of Norway is roughly 2200 km or 1400 miles, and northern Norway was sparsely settled. Germany occupied and tightly controlled all of Norway until the end of the war, had military airfields from southern to northern Norway, and also had submarines operating off the coast of Norway. Germany likely had long-range rocket control and tracking stations in Norway.

At an October 1945 press conference, U.S. Army Air Forces General Henry Arnold announced that German rockets “can now travel” 2000–3000 miles and “hit a target on the button” (p. 5454). That public statement suggests that Germany successfully conducted such a test before the end of the war, and that Arnold had obtained evidence detailing that test.]

[Bombing Target] No. 1341, Arnstadt, GL 2618. [AFHRA 25177 electronic version pp. 7–10]

Report No. SKB 45
Report from Switzerland
Information date: early July
Report date: 12 July, 44
Dissemination date: 14 July, 44

It is reported from an entirely reliable source that the direction apparatus for V-2 is manufactured by Siemens at Arnstadt in Thüringen. 45 kms west of Orlamünde (see our SKB43 of 8 July). Approximately every 10th V-1 has a short wave transmitter to control its flight. Siemens still manufactures precision instruments for a/c at Gera.

Date 26 August 1944

TARGET INFORMATION SHEET

[...] (i) The TARGET is the INSTRUMENT WORKS of SIEMENS & HALSKE A.G., at ARNSTADT in Thuringia. It stands in open country, at a point one mile N. by W. of ARNSTADT. [...] The target is adjacent to a sparsely built-up area.

(ii) The construction of this plant is reported to have started in 1938, when both A.E.G. and the SIEMENS & HALSKE A.G., were stated to have erected workshops in the area for the manufacture of precision instruments. It is possible that both plants are included within the target outline. The target is now reported to specialise on the construction of precision instruments more particularly control apparatus for flying bombs and possibly for other secret weapons. The plant is reported to employ nearly 5,000 workers, and is rated at priority 1.

(iii) The total target area (see Illustration 3(m) 18/2) is about 1,000 yards long and 600 yards wide; its major axis running S.W.–N.E. [...] The chief distinguishing feature is the deeply sunk main structure (1), [...] which may be either the foundation for a building still to be completed, or a roof of a possible underground factory. The large spoil heaps (3) together with buildings (4), (5), and (6) alone stand out within the general target outline. [...]

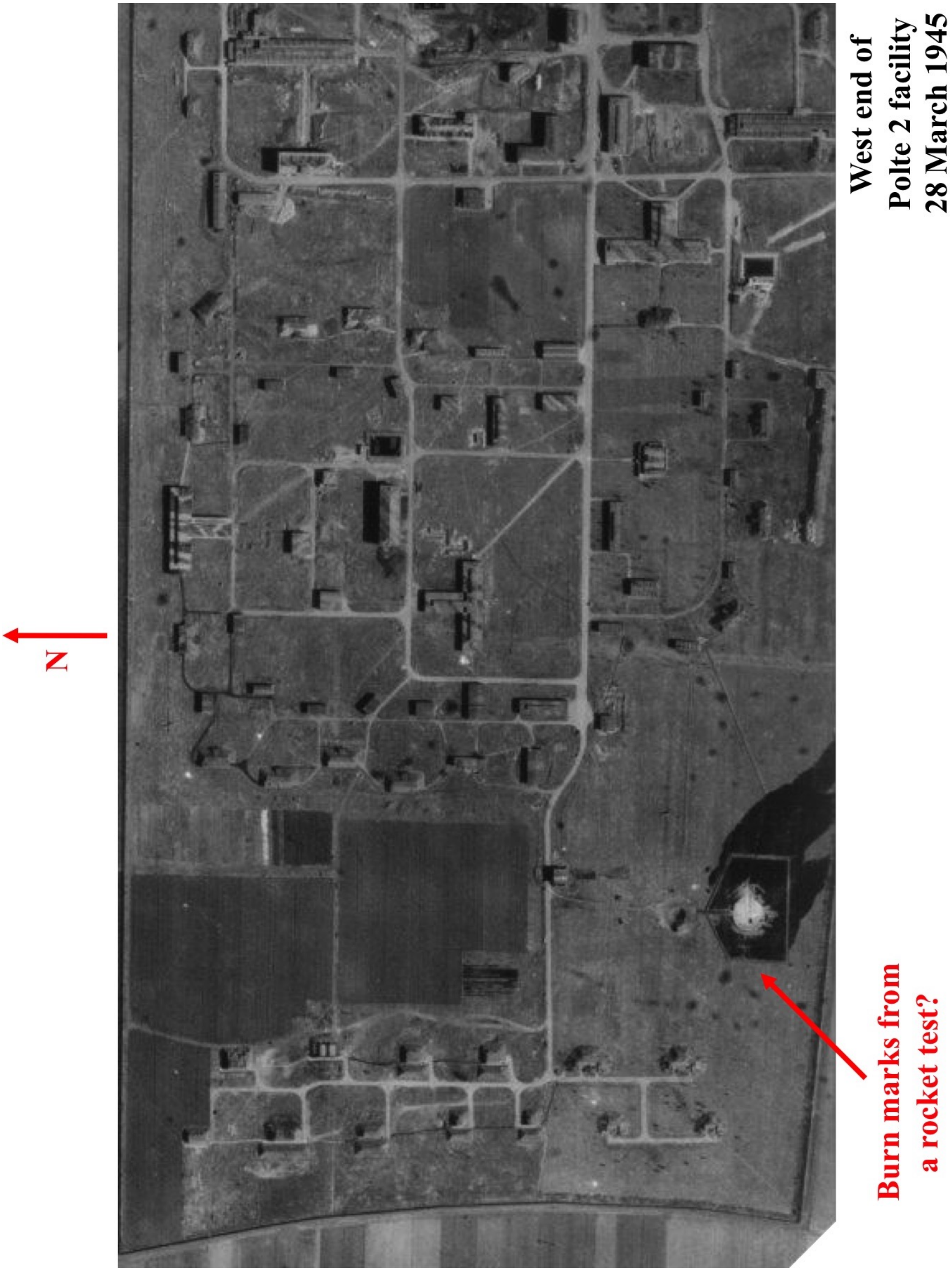

West end of
Polte 2 facility
28 March 1945
N
Burn marks from
a rocket test?

Figure E.80: 28 March 1945 U.S. aerial surveillance photograph of the west end of the Munitionsfabrik Polte 2, Rudisleben, Thuringia, showing what may have been burn marks from a recent rocket test (perhaps the 16 March launch?).

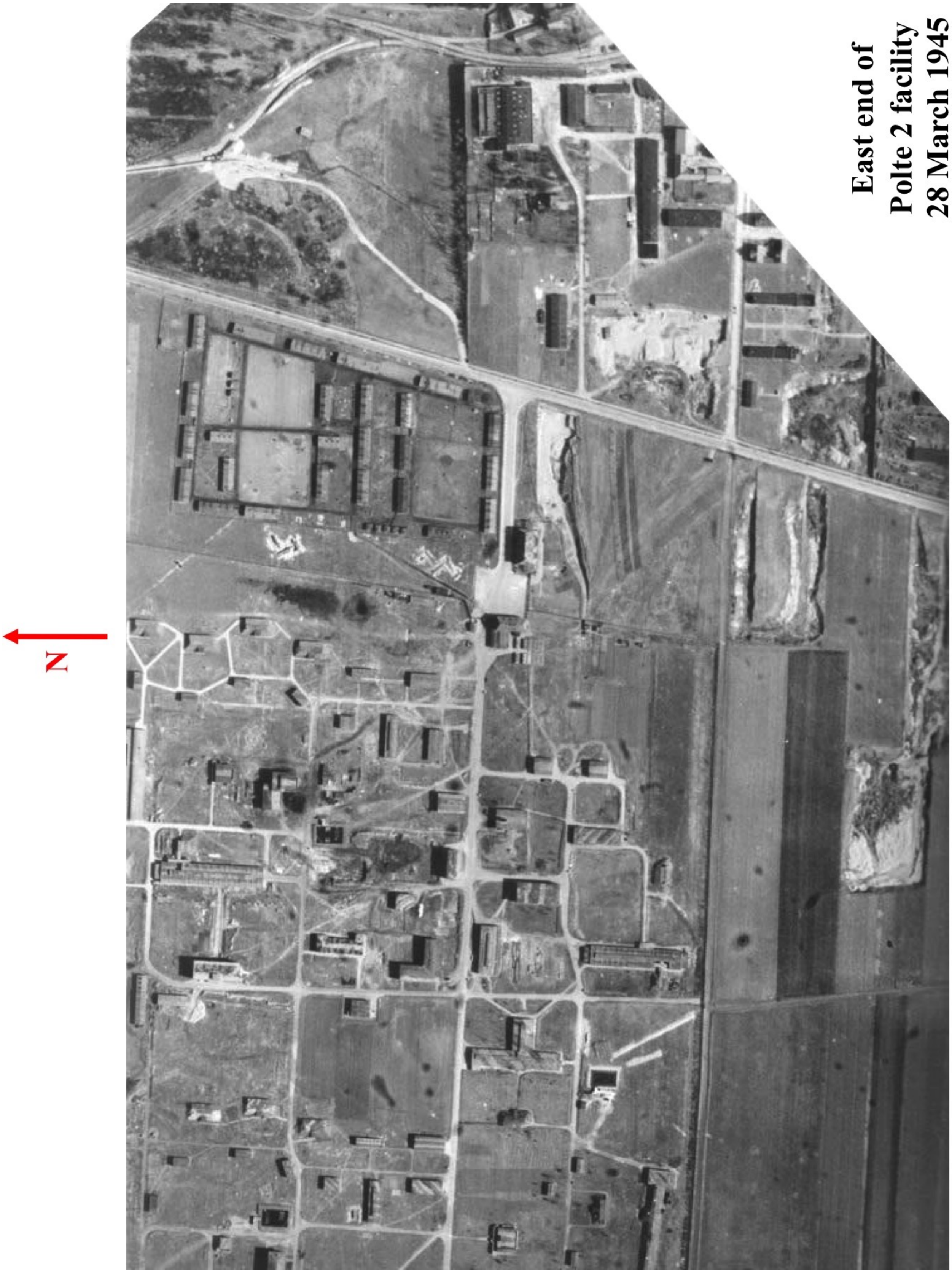
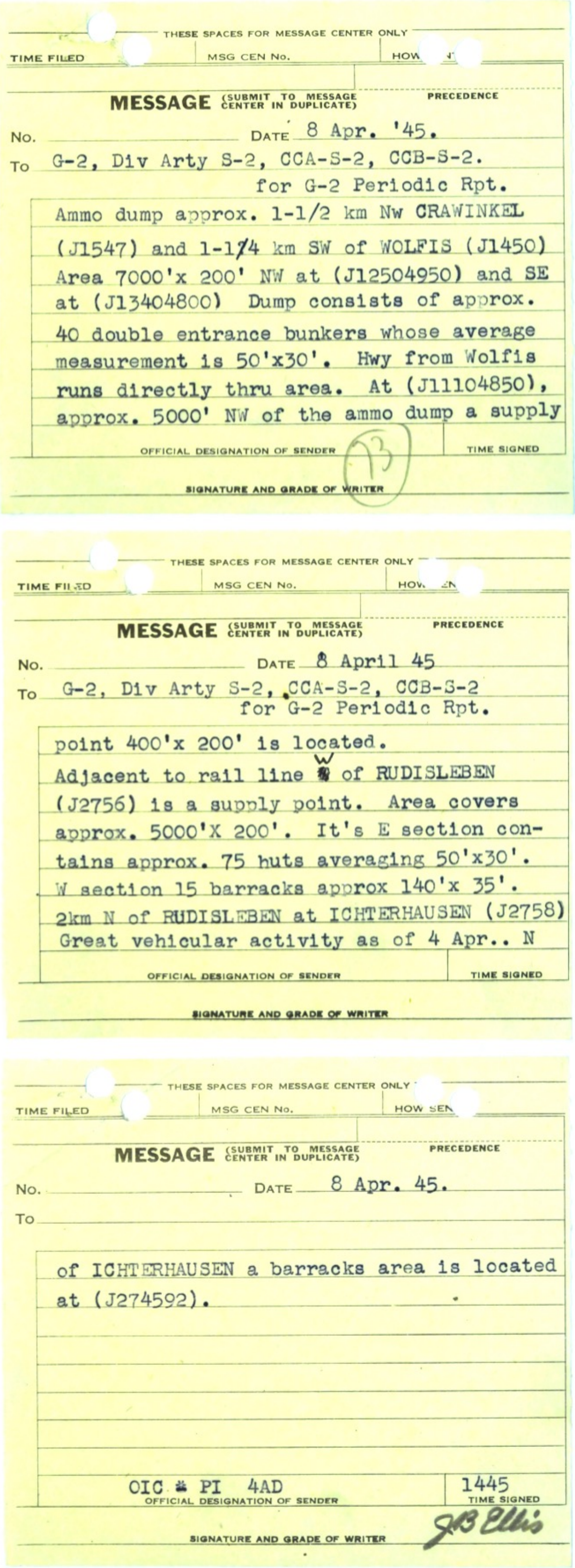

East end of
Polte 2 facility
28 March 1945
N

Figure E.81: 28 March 1945 U.S. aerial surveillance photograph of the east end of the Munitionsfabrik Polte 2, Rudisleben, Thuringia.

DECLASSIFIED
Authority NND 735017

NARA RG 407, Entry NM3-427, Box 12365, Folder 604-2.3 (1688-4) G-2 Jrnl File 4th Armd Div. 7–8 Apr 45



THESE SPACES FOR MESSAGE CENTER ONLY
TIME FILED | MSG CEN No. | HOW SENT

MESSAGE (SUBMIT TO MESSAGE CENTER IN DUPLICATE) PRECEDENCE

No. DATE 8 Apr. '45.
To G-2, Div Arty S-2, CCA-S-2, CCB-S-2.
for G-2 Periodic Rpt.

Ammo dump approx. 1-1/2 km Nw CRAWINKEL (J1547) and 1-1/4 km SW of WOLFIS (J1450) Area 7000'x 200' NW at (J12504950) and SE at (J13404800) Dump consists of approx. 40 double entrance bunkers whose average measurement is 50'x30'. Hwy from Wolfis runs directly thru area. At (J11104850), approx. 5000' NW of the ammo dump a supply

OFFICIAL DESIGNATION OF SENDER 73 TIME SIGNED
SIGNATURE AND GRADE OF WRITER

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MESSAGE (SUBMIT TO MESSAGE CENTER IN DUPLICATE) PRECEDENCE

No. DATE 8 April 45
To G-2, Div Arty S-2, CCA-S-2, CCB-S-2
for G-2 Periodic Rpt.

point 400'x 200' is located.
Adjacent to rail line W of RUDISLEBEN (J2756) is a supply point. Area covers approx. 5000'X 200'. It's E section contains approx. 75 huts averaging 50'x30'. W section 15 barracks approx 140'x 35'. 2km N of RUDISLEBEN at ICHTERHAUSEN (J2758) Great vehicular activity as of 4 Apr.. N

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SIGNATURE AND GRADE OF WRITER

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MESSAGE (SUBMIT TO MESSAGE CENTER IN DUPLICATE) PRECEDENCE

No. DATE 8 Apr. 45.
To

of ICHTERHAUSEN a barracks area is located at (J274592).

OIC * PI 4AD 1445
OFFICIAL DESIGNATION OF SENDER TIME SIGNED
SIGNATURE AND GRADE OF WRITER J B Ellis

Figure E.82: U.S. Army G-2 intelligence messages from 8 April 1945 describing a large installation at Rudisleben and Ichterhausen [NARA RG 407, Entry NM3-427, Box 12365, Folder 604-2.3 (1688-4) G-2 Jrnl File 4th Armd Div. 7–8 Apr 45]. What exactly did U.S. forces discover there? Where are their reports?

SS-Obersturmbannführer Otto Skorzeny. [Skorzeny 1995, pp. 161, 169]

In October 1944, after the Budapest operation, I flew once again to Führer Headquarters in East Prussia. Preparations were just being made for the Ardennes offensive and Hitler wanted to give me his instructions for Operation Greif.

[...] He assured me that the German Army would triumph in the end in spite of treason and mistakes. This offensive would be successful. Apart from that, "new, truly revolutionary weapons would take the enemy completely by surprise."

There was much talk about German "secret weapons" at this time, and Dr. Goebbels' propaganda did its best to nourish these rumors. [...] However most talk was about another, terrible weapon that was supposed to be based on artificially produced radioactivity.

[...] Included in the V-weapons program was the construction of a rocket capable of bombarding New York or Moscow. This rocket was practically finished at the end of March 1945 and could have gone into series production beginning in July.

[...] I could go on and list a whole series of other new weapons which were designed and built by us during the war.

Henry Picker. 2009. *Hitlers Tischgespräche im Führerhauptquartier.* 2nd ed. Berlin: Propyläen-Taschenbuch bei Ullstein.

[See pp. 4635–4639 for excerpts from this source regarding the development of both fission bombs and intercontinental rockets to carry them.

Henry Picker (German, 1912–1988) was a lawyer whom Hitler invited to attend and take notes on many of his mealtime meetings and conversations. After the war, Picker published those notes, along with his own postwar commentary, as *Hitlers Tischgespräche*, or *Hitler's Table Talk*. Many former officials of the Third Reich vouched for the accuracy of Picker's recollections and comments. Picker stated that:

- A fission bomb was successfully developed and was designed to be delivered by a rocket such as the A-9.
- The A-9 rocket was intended to strike targets in the United States. To achieve that sort of range, the A-9 would have had to be launched on top of a larger A-10 first stage. Thus whenever Picker mentioned the A-9, he was apparently referring to the complete A-9/A-10 intercontinental rocket.
- Prototypes of the A-9/A-10 rocket were completed and ready for launch before the war ended.
- Mass-production of the A-9/A-10 was planned and facilities were built, but those operations were interrupted by the end of the war.
- Hitler considered it vital for the German military to hold geographical areas that were closely associated with the nuclear weapons and intercontinental rocket programs until those weapons could be used. Those areas included Silesia, Bohemia, Thuringia, and the Berlin area.]

U.S. astronaut Gordon Cooper. 2000. [Cooper and Henderson 2000, pp. 148–155]

Wernher [von Braun] was brilliant, as one would expect, but I also found him to be a marvelous conversationalist, raconteur, and genial host... On many occasions, I sat at the bar in his home all night long talking space until the sun came shining in the windows... He regaled me with tales of his life in Germany, before and during the war... Then there was Joaquin "Jack" Keutner [actually spelled Joachim Kuettner], with whom I worked in the early days of Mercury on the Redstone rocket program. Jack had some hair-raising flying stories to tell.

At war's end, a manned V-2 was sitting on the pad at Peenemünde, all tested out, fueled up, and ready to go. It would have been launched on a low-energy easterly orbit, Jack explained. The plan: to drop a warhead on New York City. That 1945 manned rocket flight—sixteen years before the first U.S. manned rocket flight—came within a week or so of being launched.

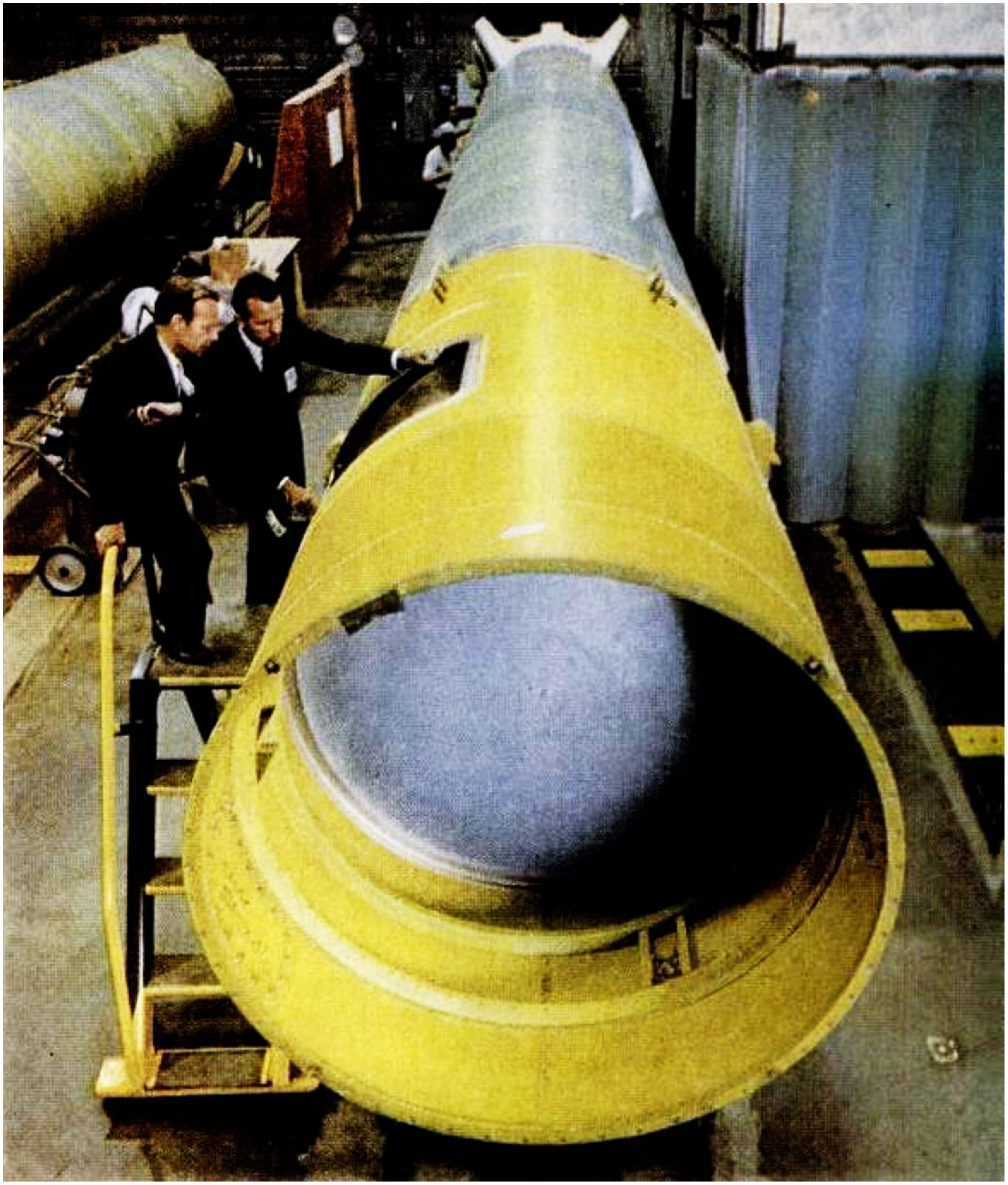
Werner confided to me that the Germans were testing more than rockets at Peenemünde. "Some of the craft we were developing," he said, "were far ahead of anything the rest of the world had or knew about." "You mean jets?" I asked, thinking of the Luftwaffe's Me 262, the world's first jet fighter. He smiled a scientist's knowing smile. "You could almost not refer to them as planes. We flew several craft that were totally different. Very advanced principles were involved."

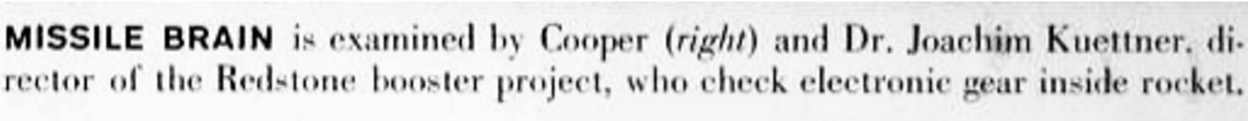
According to Jack, who flew some of these advanced craft, they included saucer-shaped vehicles with double intakes and counter-rotating fans and disks and some with advanced propulsion systems. Jack said they had flown successfully. None of these craft surfaced after the war. Wernher and Jack were unclear about whether any of them had survived the war's last hectic days.

[Cooper had a reputation for telling apparently unsubstantiated UFO stories. At a minimum, Cooper's account of this German rocket project requires some correction: the rocket would likely have been moved from its original development location at Peenemünde to a different launch site by spring 1945, would have been a V-2 variant (A-4b or A-9) on an A-10 booster, and would have been fired westward, and the saucer story invites suspicion.

However, the claim that a manned rocket targeting New York was nearly ready for launch agrees with many independent sources (e.g., pp. 5352, 5355–5359, 5365–5403, 5444–5450), and Kuettner and von Braun are plausible sources for Cooper's information.

Dr. Joachim Kuettner was selected by Wernher von Braun as the project manager for Mercury-Redstone, the first U.S. manned suborbital flights. His previous qualifications were succinctly stated as being a test pilot for high-altitude gliders in Germany during the war. Was he directly involved in a manned suborbital A-9 project?]





MISSILE BRAIN is examined by Cooper (*right*) and Dr. Joachim Kuettner, director of the Redstone booster project, who check electronic gear inside rocket.

Figure E.83: Gordon Cooper and Joachim Kuettner examining a Redstone booster in 1960 [Gordon Cooper 1960].

Heinrich Himmler's chief adjutant Werner Grothmann on advanced rockets [Krotzky 2002]. For a discussion of the background and reliability of this source, see pp. 3396–3397.

[S. 9] Dabei fand ich es doch amüsant, dass ausgerechnet unser bestes Stück, die Riesenrakete, die nach Amerika fliegen sollte, gerade in einer Anlage gebaut wurde, die überhaupt nicht groß war. Na ja, das waren ja auch erst mal die Prototypen für die Flugversuche. Der Serienbau wäre dann näher am Truppenübungsplatz vorgesehen gewesen, wo es eine gute Möglichkeit gab, die enormen Dinger bis zur Flugklar-Meldung in einer Bodensenke zu tarnen. So hätte man die Rakete in einer sehr großen Anlage gebaut, in die eigentlich auch die Produktion einer der Atombombenserien hineinkommen sollte. Das wäre zwar auf zwei unterschiedlichen Geschossen geschehen, aber man hätte dann für beide Teile einen gemeinsamen Weg gehabt. Warum Gerlach sich da quergelegt hatte, ist mir bis heute nicht klar. Es kann sein, dass Himmler mit seiner Einschätzung richtig lag, Gerlach hätte doch zu große Nähe zu uns gemieden, weil er seine eigenen Pläne verfolgen würde. Denn das war ja klar: Die Raketenproduktion, gerade für die Amerika-Rakete, war unsere eigene Sache, die hätten wir auch nicht mehr aus der Hand gegeben. Das war alles unter unserer Kontrolle. Wenn jetzt eine der beiden durchkonstruierten Atombombensorten im selben Komplex hergestellt und zusammengebaut wird, konnten wir den Schutz der Anlage viel effizienter gewährleisten.

[p. 9] I found it amusing, however, that our best piece, the giant rocket, which was to fly to America, had just been built in a plant that was not big at all. Well, those were the prototypes for the flight tests. The mass production would then be closer to the military training base [Ohrdruf], where there was a good possibility to camouflage the enormous things in a depression up to the launch. So the rocket would have been built in a very large plant, which was also supposed to produce one [kind] of the nuclear bombs. This would have happened on two different floors, but then there would have been a common path for both components. Why Gerlach was involved there, is still not clear to me today. It may be that Himmler was correct in his estimation that Gerlach would have avoided too much proximity to us because he would pursue his own plans. Because that was clear: the rocket production, especially for the America rocket, was our own thing, we would not have given it away. It was all under our control. If now one of the two kinds of atomic bombs was built and assembled in the same complex, we would have been able to ensure the protection of the system much more efficiently.

[S. 11] Gerlach ist aber erst dann zu Bormann gefahren, nachdem wir den ersten gelungenen Start unser Grossrakete oder der grossen Rakete für die Entfernung von Thüringen bis London, das war auch eine Neuentwicklung, mitbekommen haben. Das war am 16. März. Das werde ich nie vergessen, da riefen Leute bei Himmlers Stab an, von denen hatte ich noch nie gehört und taten so, als hätten wir jetzt den Krieg gewonnen.

[p. 11] Gerlach did not go to Bormann until we got the first successful launch of our big rocket or the big rocket for the distance from Thuringia to London, which was also a new development. That was on March 16th. I will never forget that, when Himmler's staff got phone calls from people, whom I had never heard of before and who acted as if we had now won the war.

[S. 10] Zur Bezeichnung V 4 kam man wegen den gedanklichen Nähe zur A 4, also der V 2. Das war die echte Langstreckenrakete für Amerika. Dabei hätte es von Thüringen aus nur bis an die Ostküste gereicht, aber dort lagen ja die für uns wichtigen Städte. V 4 hatte man gewählt, weil es ja im Grunde eine Weiterentwicklung der V2 war, wenn auch mit zwei Stufen und mehr als der doppelten Höhe, aber nicht mit höherer Nutzlast. Der erste scharfe Schüß war eigentlich mit voller Ladung für Oktober 45 vorgesehen. Nach dem Test der Versuchsatombombe im März 45 und als man sehen könnte, dass die front nirgegendwo mehr hielt, hatten Hitzköpfe von der politschen Seite einen Angriff mit dem Prototyp und einer eilig zusammengebauten Uranbombe gefordert. Das war aber niemand von uns und ist auch ganz kalt abserviert worden, wie ich vorhin sagte. Außerdem wäre es ein lächerliches Unternehmen geworden, weil das Material nicht gereicht hätte und auch die Rakete noch nie getestet worden war.

[p. 10] One arrived at the designation V 4 because of the mental proximity to the A 4, or the V 2. This was the real long-range rocket for America. From Thuringia it would have reached only the east coast, but there lay the cities that were important to us. V 4 had been chosen because it was basically a further development of the V2, albeit with two stages and more than double the height, but not with a higher payload. The first attack with full cargo was actually scheduled for October 45. After the test of the test bomb in March 45 and when one could see that the front was no longer held anywhere, hotheads from the political side had demanded an attack with the prototype [America rocket] and a hastily assembled uranium bomb. But that was none of us, and it was quite opposed, as I said before. In addition, it would have been a ridiculous attempt because there was not enough [fissionable] material and the rocket had never been tested.

[S. 18] Im Februar oder Anfang März war intern noch mal die Losung bekräftigt worden, den ersten Angriff auf Amerika noch im Oktober durchzuführen. Bei der Beratung dazu lagen Papiere vor, die Skorzeny für die Raketentechniker zusammengeschrieben hatte, also er hatte das sicher nicht selbst geschrieben, sondern jemand von seinen Leuten, und es sind auch Erklärungen von den Wissenschaftlern besprochen worden. Es sah so aus, dass wir das hinbekommen würden. Die große Rakete war ja schon längere Zeit im Bau und die sie gesehen hatten, also die Teile dafür, waren doch beeindruckt. Wir waren jedenfalls von der technischen Vorbereitung für die Waffe un den Träger her überzeugt, dass es dann klappen wird. Früher wäre es keinesfalls gegangen. Ich kenne einiges von der Löiteratur, die dazu so überzogene Angaben macht. Die Autoren übersehen nur, dass man einen umfassenden Angriff auf Städte in Amerika nur mit strategischen Waffen führen kann, nicht mit taktischen. Dann musste auch die Technik sicher funktionieren. Stellen sie sich vor, man wirft das ‘Ei’ über New York ab und es zündet nicht! Am Ende liefern es die Amerikaner vier Wochen später bei einem selbst ab. Eine Schwierigkeit bestand ja auch darin, das Gesamtgewicht für die große Bombe zu reduzieren. Es war wohl von den Ingenieuren immer wieder verlangt worden, den Durchmesser und das Gewicht zu reduzieren, wobei ich glaube, dass sich das auf einen ganz bestimmten Bombentyp bezog, denn da hörte und sah ich später schließlich etwas, wo ganz klar war, dass bei dem Ding der Durchmesser wahrscheinlich nicht das Problem gewesen sein konnte. Jedenfalls ging es um den Platzbedarf und die Unterbringungsmöglichkeiten in der Raketenspitze und natürlich auch um die Nutzlast. Das war ja ein wichtiger Faktor, weil der die Reichweite beeinflusste. Übrigens war das auch ein Thema für die Luftfahrt-Ingenieure bei Messerschmitt und Heinkel.

[p. 18] In February or early March, the goal of the first attack on America in October was reaffirmed internally. In the consultation there were papers that Skorzeny had put together for the rocket technicians, or he certainly had not written them himself, rather someone from his people, and explanations were also discussed by the scientists. It looked like we could do it. The large rocket had already been under construction for a long time, and those who saw it, or the parts for it, were impressed. We were certainly convinced of the technical preparation for the weapon and the carrier, that it would then work. In any case, we were convinced of the technical preparations for the weapon and the launch vehicle, that they would work out. It could not have happened sooner. I know some of the literature, which makes it such exaggerated claims. The authors just overlook the fact that a comprehensive attack on cities in America can only be done with strategic weapons, not with tactical ones. Then also the technology had to work safely. Imagine if you throw the ‘egg’ over New York and it does not detonate! In the end, the Americans would deliver it four weeks later on their own. One difficulty was also to reduce the total weight for the large bomb. It had been asked by the engineers again and again to reduce the diameter and the weight, which I believe involved a certain type of bomb, because when I finally heard and saw something, it was quite clear that the diameter of the thing probably could not have been the problem. In any case, it was about the space requirements and the accommodation possibilities in the rocket nose and of course also the payload [mass]. This was an important factor, because it affected the range. By the way, this was also a topic for the aviation engineers at Messerschmitt and Heinkel.

[S. 33] Den Russen fiel dann mehr in die Hände als wir hofften. Zum Beispiel der Prototyp einer künftigen Rakete, zu der allerdings die Amerikaner zuvor die Konstruktionsunterlagen erbeutet hatten.

[p. 33] The Russians found more [in Thuringia] than we hoped. For example, the prototype of a future rocket for which, however, the Americans had previously captured the design documents.

[S. 48] Wir konnten da nichts erreichen bis auf den dringenden Wunsch Himmlers, wir brauchten schnellstens eine Rakete, die bis Amerika fliegen kann. Die Leute dort waren aber sehr zurückhaltend. Was uns überraschte, war dann allerdings folgendes. Ich glaube, es war von Ploetz, der hatte wohl persönlich Beziehungen zu jemandem aus der Peenemünder Gruppe und Kammler darüber informiert, dass nach seiner Kenntnis die Planungen für eine Rakete mit übergroßer Reichweite eigentlich fertig sind und dass man mit etwas gutem Willen schnellstens damit beginnen könnten, die in die Realität umzusetzen. Kammler hat sich das angehört und dann nach Rücksprache mit Himmler vorgeschlagen, das Konzept von unseren eigenen Raketenleute noch mal durchrechnen zu lassen. Die haben dann nach einiger Zeit gemeldet, dass man in Peenemünde ganz solide gearbeitet hat und daß diese Rakete theoretisch alles erfüllen würde, was sie sollte. Ich glaube, damals war die Rede von gut 4000 km Flugweg und eine Tonne Fracht. Das weiß ich aber nicht mehr so genau, weil es noch ein Parallelprojekt gab, für andere Werte vorgesehen waren.

[p. 48] We could not achieve anything except the urgent wish of Himmler. As soon as possible, we needed a rocket that could fly to America. The people there were very cautious. What surprised us was the following. I think it was von Ploetz, who had been personally in contact with someone from the Peenemünde Group, and informed Kammler that, to his knowledge, the plans for a rocket with a very long range were actually finished and that with a little good effort, they could begin as soon as possible to translate that into reality. Kammler listened to this and then, after consultation with Himmler, suggested that the design of our own rocket people be calculated again. They then reported after some time that they had worked very hard in Peenemünde and that this rocket would theoretically fulfill everything it should. I think at that time there was talk of a good 4000 km of range and a ton of payload. But I do not remember that exactly because there was a parallel project that was intended for other values.

[S. 48] Ich meine, wir hatten wirklich gute Leute in unseren eigenen Projekten, und die hatten wieder recht gute Kontakte nach Peenemünde, aber die konnten auch nur das bestätigen, was Kammler aus Peenemünde hörte: Entweder steuert jemand die Rakete ins Ziel, oder die muß vollautomatisch gehen. Himmler war skeptisch, ob ein Pilot bei der Geschwindigkeit überhaupt reagieren kann. Ich meine, die Rakete sollte ja mit etlichen Tausend Kilometern fliegen. Dann gab es auch gar keine Fernsteuerung, die auf die Entfernung wirklich sicher funktionierte. Da hatte Himmler schon früher mal mit Ohnesorge darüber gesprochen und ich glaube, der hat dazu auch was arbeiten lassen. Was sich da ergeben hat, weiß ich aber nicht. Nur an eines kann ich mich noch erinnern, nämlich unsere Raketenleute hatten ja eine kleine Abteilung von, heute müsste sagen Elektronikern, die haben zur völligen Überraschung von uns und auch von Ohnesorge im Winter 44 eine Sende- und Empfangsanlage entwickelt, die man nicht mehr stören konnte, weil sie selbständig dauernd die Funkfrequenz änderte. Außerdem war die ganz klein, richtig winzig. Die hatte nur ungefähr ein kg, der Empfänger meine ich. Wie die das geschafft haben, diese Technik zu verkleinem, ist mir unbekannt. Himmler aber Befehl gegeben, Ohnesorge den Prototyp zu zeigen. Ob das geschehen ist, kann ich nicht sagen. Ich weiß auch nicht, ob der Sender überhaupt auf die Reichweite bis Amerika ausgelegt war. Nach Krieg hörten wir dann, die Amerikaner hätten den Transistor erfunden. Das hat wohl einige von unseren Leuten sehr aufgeregt, weil der doch von uns stammte. Ein Bekannter sagte mir dazu, bei uns hätte der Transistor "Sperrschicht-Halbleiter" geheißen. Der war von einem Professor an einer technischen Hochschule erfunden worden. Es kann sein das war Aachen.

[p. 48] I mean, we had really good people in our own projects, and they had good contacts again to Peenemünde, but they could only confirm what Kammler heard from Peenemünde: Either someone pilots the rocket into the target, or it must be fully automatic. Himmler was skeptical whether a pilot could react at all at that speed. I mean, the rocket was supposed to fly several thousand kilometers. Then there was no remote control at all, which really worked safely at that distance. Himmler had already talked to Ohnesorge about this and I think he had something worked out. But I don't know what came of it. I can only remember one thing, namely that our rocket people had a small department of, today I would have to say electronic engineers, who, to the complete surprise of us and also of Ohnesorge, developed a transmitting and receiving system in the winter of 44, which could no longer be jammed, because it constantly changed the radio frequency on its own. It was also very small, really tiny. It weighed only about one kilogram, the receiver I mean. How they managed to miniaturize this technology is unknown to me. But Himmler gave orders to show the prototype to Ohnesorge. Whether this was done, I cannot say. I also don't know if the transmitter was even designed to reach America. After the war, we heard that the Americans had invented the transistor. That must have upset some of our people very much, because it came from us. An acquaintance told me that in our country the transistor was called a "junction semiconductor." It had been invented by a professor at a technical university. It may have been Aachen.

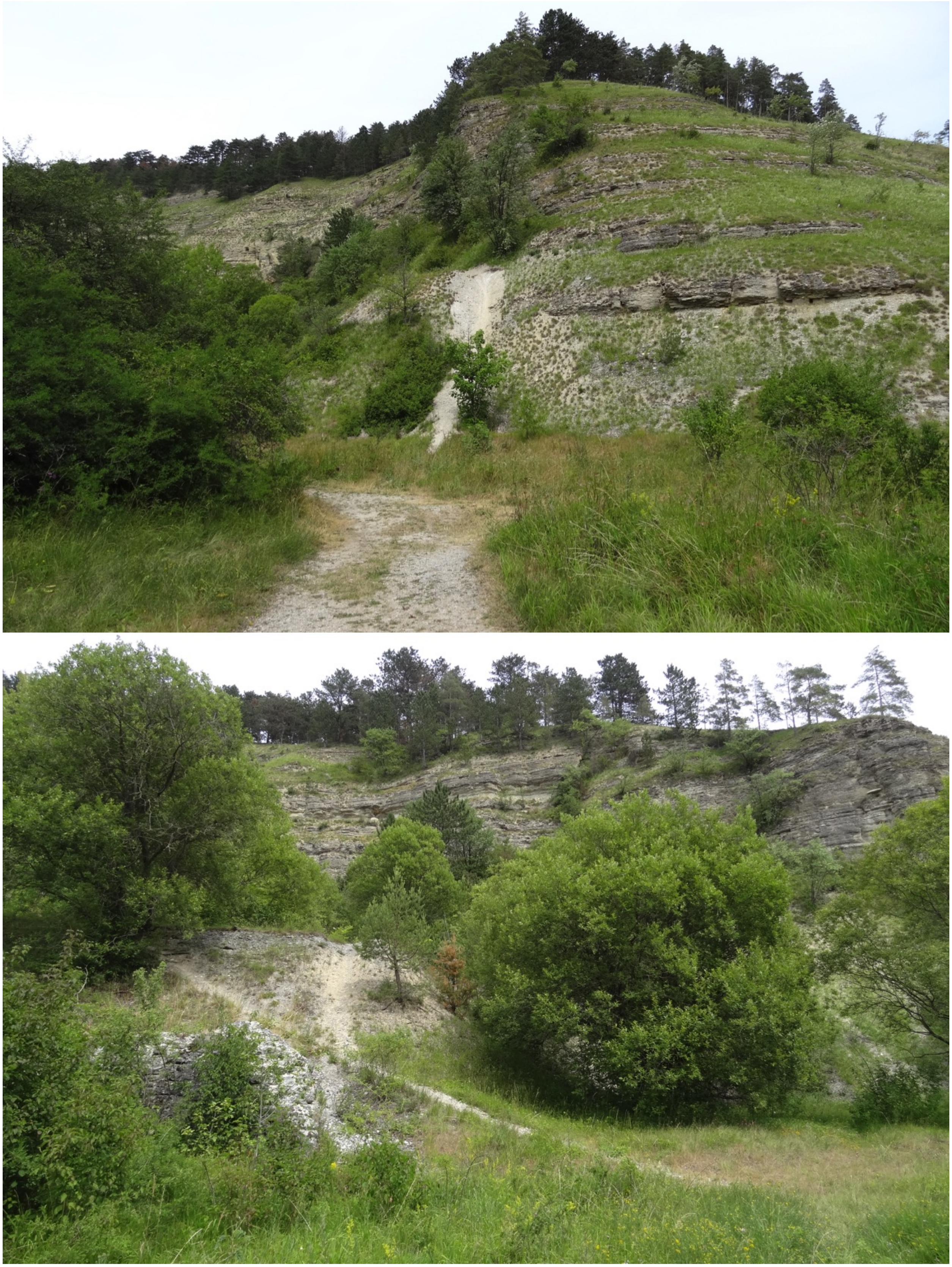


Figure E.84: Location of the former Jonastal tunnel complex (just north of Gossel).

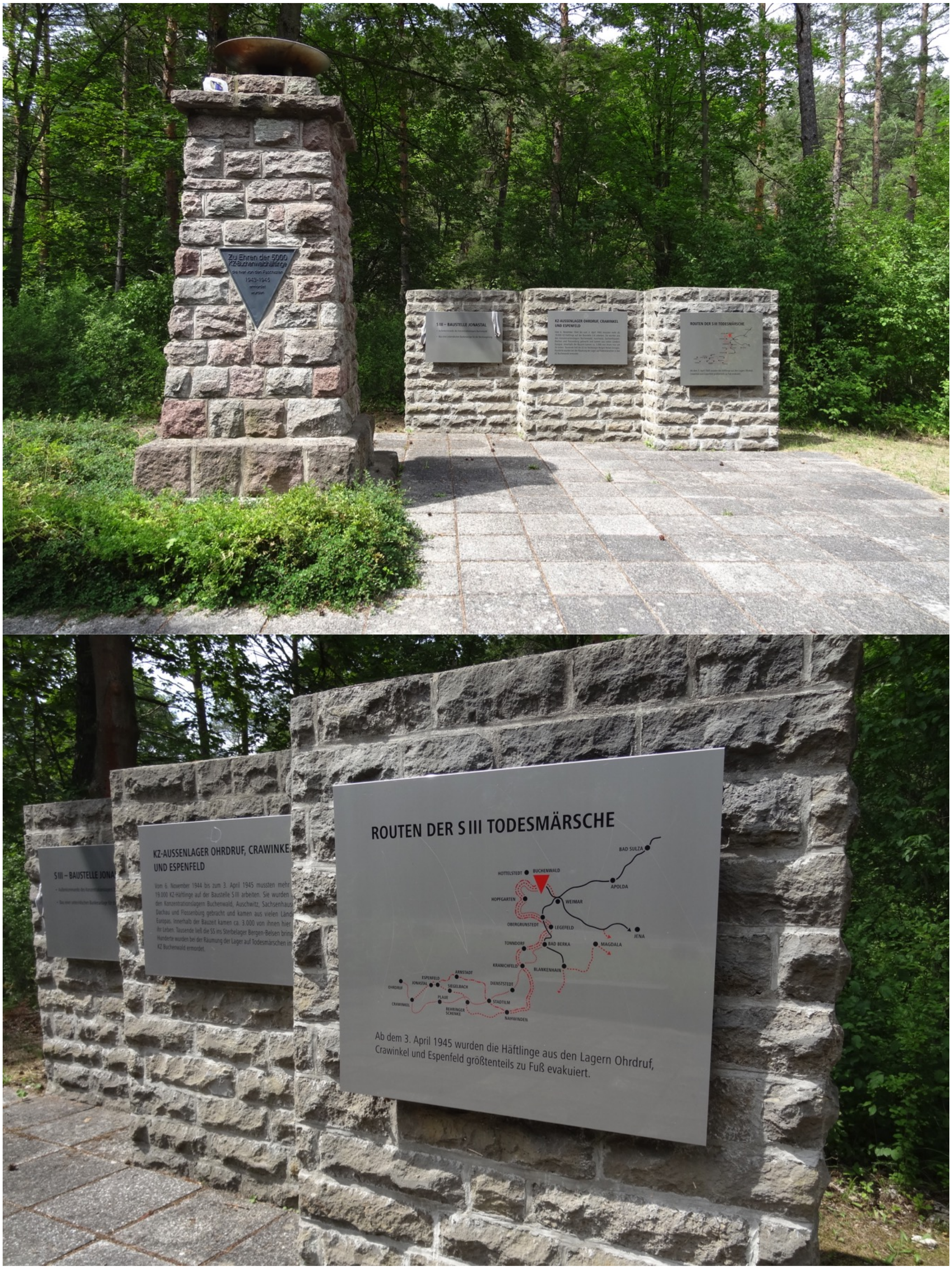

Zu Ehren der 5000
KZ-Buchenwaldhäftlinge
die hier von den Faschisten
1943-1945
ermordet
wurden
S III – BAUSTELLE JONASTAL
KZ-AUSSENLAGER OHRDRUF, CRAWINKE
UND ESPENFELD
Vom 6. November 1944 bis zum 3. April 1945 mussten mehr
19.000 KZ-Häftlinge auf der Baustelle S III arbeiten. Sie wurden
den Konzentrationslagern Buchenwald, Auschwitz, Sachsenhaus
Dachau und Flossenbürg gebracht und kamen aus vielen Lände
Europas. Innerhalb der Bauzeit kamen ca. 3.000 von ihnen hier
ihr Leben. Tausende ließ die SS ins Sterbelager Bergen-Belsen bring
Hunderte wurden bei der Räumung der Lager auf Todesmärschen in
KZ Buchenwald ermordet.
ROUTEN DER S III TODESMÄRSCHE
BAD SULZA
HOTTELSTEDT
BUCHENWALD
APOLDA
HOPFGARTEN
WEIMAR
OBERGRUNSTEDT
LEGEFELD
JENA
TONNDORF
BAD BERKA
MAGDALA
KRANICHFELD
BLANKENHAIN
ARNSTADT
ESPENFELD
JONASTAL
OHRDRUF
SIEGELBACH
DIENSTSTEDT
PLAUE
CRAWINKEL
STADTILM
BEHRINGER SCHENKE
NAHWINDEN
Ab dem 3. April 1945 wurden die Häftlinge aus den Lagern Ohrdruf, Crawinkel und Espenfeld größtenteils zu Fuß evakuiert.

Figure E.85: A memorial for the prisoners who worked at the Jonastal tunnel complex.

File 2508 Memmingen. German Secret Weapons. Undated but probably early 1945. [AFHRA 25193 electronic version p. 579]

The largest flying bomb factory is the DORNIER WERKE at MEMMINGEN on railway KEMPTEN-MEMMINGEN-ULM. V.1 to V.4 types are made here.

[Note that the above information is given casually and without further explanation, as if the U.S. officials writing and reading the report all knew what the V-3 and V-4 were. In addition to the noted railway connection, Memmingen had a large airfield. There were also large Dornier factories 60 km away in Friedrichshafen.]

OSS cable from "Zenda" in Bordeaux to "Climax" in Paris, 21 April 1945 [NARA RG 226, Entry A1-211, Box 8, WN 23251–23273, Folder 116].

[...] We are attempting to locate German secret weapons expert recently flown into Royan to set up something believed to be known as V-4. Lacking technical knowledge we await your instructions.

[Various new weapons were vying for the title of "V-4," and it is not clear which one this was.

Royan on the French coast was held by German forces until April 1945, 10 months after the invasion of Normandy. It has never been explained why German forces were so determined to hold on to that one location long after the rest of France had been liberated. Was there a long-range rocket or other advanced weapon in Royan?

What exactly did Allied forces discover after the fall of Royan? Where are the reports now?]

G-2 Journal of U.S. Headquarters of 4th Armored Division, APO 254. From 041600B to 051600B April 45 (5 April 1945), Gotha J0965 Germany. [NARA RG 407, Entry NM3-427, Box 12345, Folder 604-2.2 (L688...2) G-2 Journal 4th Armored Div.]

64 Russian PW states 50,000 Germans rptd in underground factory mfg jet propelled planes at KAHLA J7152 as of 2 wks ago/not bombed as yet/at JENA J7066 much AA and barrage balloons/ROTHENSTEIN J7257. (Copy Sent VIII Corps 051130B).

65 Polish Civ rptd formed conc camp of 6000 was located at CRAWINKEL J1547 where they were used to dig tunnel for underground factory to manufacture V-1 rockets (no rockets have been made there to date)/GOSSEL J1949 camou[flaged] completed factory no pers allowed near this place which is located about 2 mi N of GOSSEL/on 3 Apr was manufacturing V-1s and experimenting with V-3s.

G-2 Periodic Report No. 177. 7 April 1945. [NARA RG 407, Entry NM3-427, Box 12342, Folder 604-2.1 G-2 Periodic Reports 4th Armored Div 1 Jan–18 May 45]

Murdercamp, vic[inity] OHRDRUF: A PW, NCO, rpts that a Concentration Camp of political prisoners, existed in the vic of OHRDRUF. According to stories told him by members of the guards, several thousand persons were killed during this winter at the camp. The PW himself happened onto an open mass grave some weeks ago, and he states that he saw nude bodies laying in lakes of blood. The PW further rpts that many, or perhaps all, of the bodies were exhumed lately and burned in the woods, vic J 115565. On 28 Mar 45, PW believes, several hundred of the political prisoners were still alive. He further states that guards in part belonged to the SS Das REICH and in part to SS LEIB-STANDARTE Adolf Hitler.

[...] The entire area btwn OHRDRUF–SCHWABHAUSEN–WOLFIS–WECHMAR (J 1156) was a tk troop drill and maneuver ground. PW was told by an ordnance man stationed at OHRDRUF that from here a new secret wpn will shortly rise (wird steigen). It is believed that the entire area should be very thoroughly examined for new material. If any of the above mentioned political prisoners can be found alive, interesting evidence should also be forthcoming. (Source: 89 Inf Div Per Rpt No. 27). [...]

Annex No 1 [...] One of the most ridiculous actions of the supreme command (Nazi regime) is the insistence upon the fighting in the far flung areas such as in the BALTIC States, in ITALY, and also the maintenance of troops in NORWAY and DENMARK. It is deemed a disgusting order to see these forces ill placed with the advances of our troops over the RHINE barrier.

G-2 Journal 80th Infantry Division, 1905 09 Apr 45, Gotha, Page No 1068. [NARA RG 407, Entry NM3-427, Box 10127, Folder 380-2.2, G-2 Jnl—80th Inf. Div. Apr 45. G-2 Journal]

Fr 318: RJ at (127489) entrance to underground plant. French workers going from RJ to WOLFIS (1450) were escorted by armed guards, not allowed to look right or left. 300 meters N of STUTZHAUS (105470) is entrance to 105 plant, working last week. Area at (135495) considered to be very important production area. Rpt from 318th MG O.

[These Modified British System coordinates in the Nord de Guerre Grid all correspond to locations approximately 1–4 km southwest of the town of Wölfis, very close to the small city of Ohrdruf in Thuringia.

The belief that “a new secret weapon will shortly rise” from this area could be a reference to advanced rockets and/or nuclear weapons, and there is evidence that both were being developed and tested in this area.

U.S. Colonel Robert S. Allen visited this area in April 1945 and described underground installations that were numerous, massive, and highly sophisticated (p. 4569).

See the map in Fig. E.86 for the areas still held by the German military at the end of the war, as mentioned in the above report. These areas were fiercely defended and likely held secret weapons that Germany still hoped to deploy, such as long-range rockets, long-range jets, and nuclear weapons.]

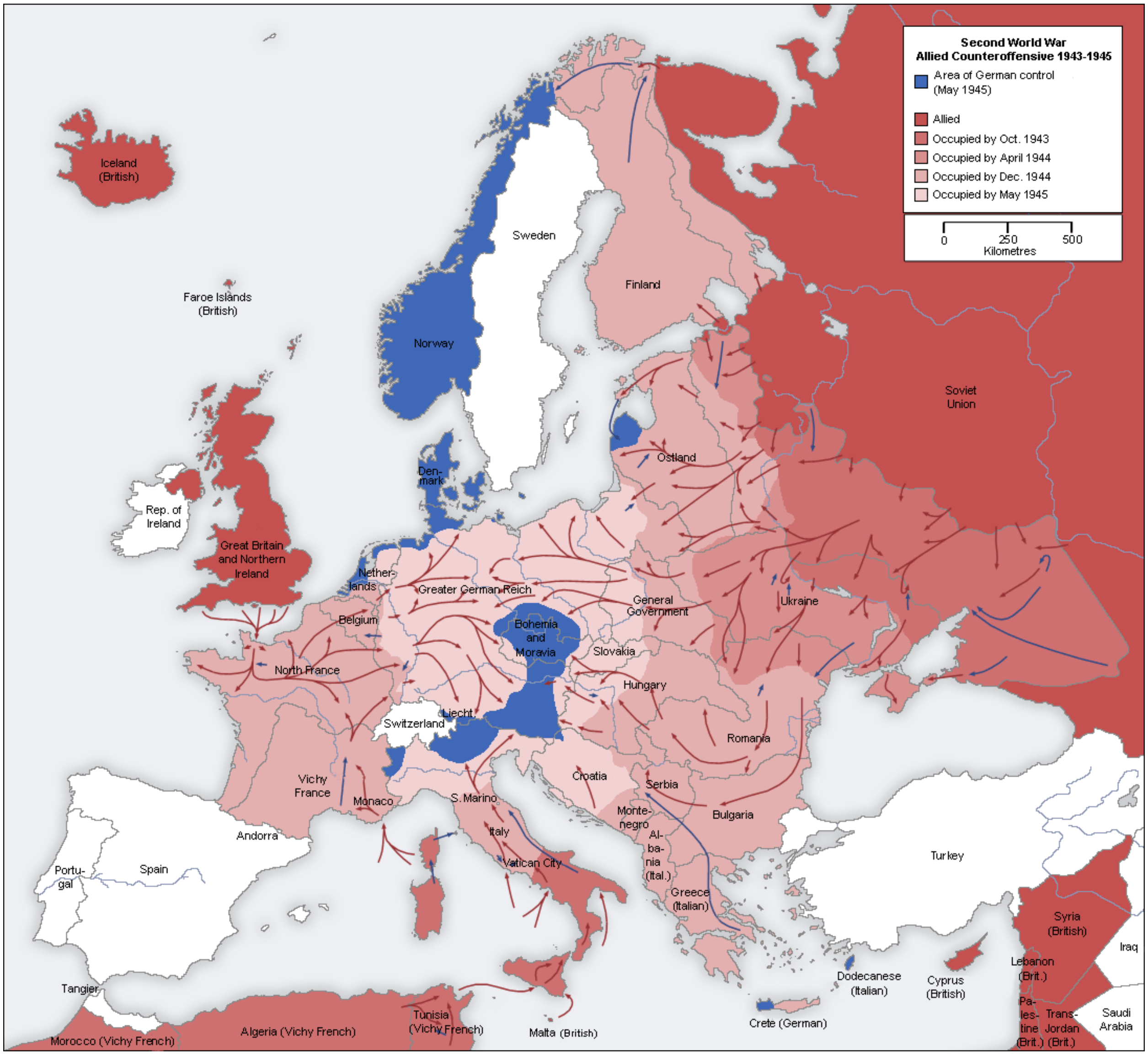

Second World War
Allied Counteroffensive 1943-1945
Area of German control (May 1945)
Allied
Occupied by Oct. 1943
Occupied by April 1944
Occupied by Dec. 1944
Occupied by May 1945
0
250
500
Kilometres
Iceland (British)
Faroe Islands (British)
Norway
Sweden
Finland
Soviet Union
Ostland
Den-mark
Rep. of Ireland
Great Britain and Northern Ireland
Nether-lands
Belgium
Greater German Reich
General Government
Ukraine
Bohemia and Moravia
Slovakia
Hungary
North France
Liecht.
Switzerland
Vichy France
Monaco
Andorra
S. Marino
Croatia
Serbia
Romania
Monte-negro
Al-ba-nia (Ital.)
Bulgaria
Italy
Vatican City
Greece (Italian)
Turkey
Spain
Portu-gal
Tangier
Morocco (Vichy French)
Algeria (Vichy French)
Tunisia (Vichy French)
Malta (British)
Crete (German)
Dodecanese (Italian)
Cyprus (British)
Syria (British)
Lebanon (Brit.)
Iraq
Pa-les-tine (Brit.)
Trans-Jordan (Brit.)
Saudi Arabia

Figure E.86: Map of German-controlled territory at the end of the war.

U.S. Army 89th Infantry Division. G-2 Msg File. 8 April 1945. [NARA RG 407, Entry NM3-427, Box 11005, Folder 389-2.2 G-2 Jrnl File—89th Inf Div. 8–9 Apr 45]

info—

7 DP—report location of installation making V-4

R-6-sheet — ~~869541~~ 869451 in hillside and elevation of hill 315—entrance S side of hill.

Between 20 and 30,000 DP's—Gadget holds 2 men—send finished product to Weimar for complete assembly—

U.S. Army 89th Infantry Division. G-2 Message Summary. 8 April 1945. [NARA RG 407, Entry NM3-427, Box 11005, Folder 389-2.2 G-2 Jrnl File—89th Inf Div. 8–9 Apr 45]

8 April 45

From 353:

Displaced persons report underground factory in hill 315 at J869451. Entrance on south side of hill. Factory employs some twenty to thirty thousand Russians, Poles, French, etc. They are making the V-4, which is a two man rocket of some sort. Partial assembly at this factory and weapon then is sent to WEIMAR J5271. During the time the source of this information worked at this factory, approx one week ago, there had been no bombing.

More information later after a complete interrogation.

Tuxedo 2
0900

[Please see photos of the G-2 messages from 8 April 1945 on pp. 5368–5373.]

[At NARA RG 407, Entry NM3-427, Boxes 11005 and 12365, I found many versions of this U.S. Army message, including copies from the 89th Infantry Division unit that actually originated the message, a copy from another unit that apparently received the report by radio, and copies echoing up and down the chain of command. The details are the same in all of them, except what is apparently the first message (Fig. E.87) says "Gadget holds 2 men," which clarifies that this was a rocket large enough to hold two men, not a rocket small enough to be set up and launched by two men. Unfortunately I could find no further details, and no follow-up reports—no "complete interrogation" of the displaced persons as promised, and no reports of Americans visiting the V-4 factory themselves.

The J869451 coordinates are the same in all of the messages (except the coordinates 869541 that were initially written down and then crossed out and replaced in the first message). That appears to be Modified British System coordinates for the Nord de Guerre Zone, as confirmed by the J5271 coordinate for Weimar. Using the website tool http://www.echodelta.net/mbs/eng-translator.php, Modified British System coordinate wJ869451 in the Nord de Guerre Grid corresponds to a location just south of Dreitzsch, and approximately 3 km east of Neustadt an der Orla. The only other clue is that the entrance was on the "south side" of "hill 315," referring to the elevation of the location.

It is interesting that the V-4 factory coordinates are given with 100-meter precision (J869451), much more precise than even the Weimar coordinates (J5271, with only 1-km precision). That seems to show a remarkable confidence in the location, most likely either from maps that the escaped prisoners brought with them, or from the escaped prisoners pointing to their former home on maps that the U.S. Army had.

Figure E.88 shows adjacent sheets R-6 (above) and S-6 (below) of the GSGS 4416 map used by the U.S. Army, covering the relevant part of Thuringia. In what was apparently the original report (Fig. E.87), the coordinates for the two-man rocket factory were first given as 869541 (above), then as 869451 (below), 9 km due south of the first location. There is no "hill 315" near either location, and neither of these specific locations seems like a very promising site for a massive underground factory.

However, this general location does seem plausible, since there were a number of other known German research and development facilities above or below ground near that area, including for example:

- A factory for making large rockets at Pössneck, 13 km from Neustadt an der Orla, which may or may not have been the same rocket factory mentioned here (p. 5375).
- Factories in Neustadt an der Orla that just happened to have world-class expertise at making nickel membrane filters for gaseous diffusion uranium enrichment (p. 3633).
- The massive Kahla REIMAHG underground jet factory approximately 15 km to the west (pp. 5214–5217).

- Several other factories in or near Neustadt an der Orla.[2]

Could the V-4 site be located somewhere in that area? We have two approximate alleged locations, the approximate hill elevation, the fact that the main entrance was on the south side of the hill, and the presumed fact that that entrance would likely have been adjacent to a railroad track that existed at that time in order to bring large amount of supplies in and to ship partially completed V-4s to Weimar.

At NARA I also photographed as many other relevant Army documents as I could, for several days before and after this report. When this report was filed on 8 April 1945, the U.S. Army units involved were well to the west of these coordinates. Based on the Army's location, and the fact that the message says "Displaced persons report...," the J869451 location appears to have been given to the U.S. Army by French/Polish/Russian prisoners who escaped from there and fled toward the Americans. It is possible that the prisoners did not give exactly the right location, or that due to language differences the Army misunderstood the location, or that someone wrote down the coordinate numbers incorrectly or in the wrong order. Then those same coordinates got repeated in all the messages. Perhaps the rocket factory was not around Neustadt an der Orla, but rather in some entirely different region.

In these NARA files, I could not find any further reports about the V-4 factory. If the U.S. Army wrote a report, it might still be classified and not in the publicly available files. Or perhaps some other American team actually went into the factory and wrote a report—Alsos, CIOS, Theodore von Kármán's team, etc. Or maybe the Germans emptied out the factory and/or collapsed the entrances before the Americans arrived.

Perhaps the entrances were collapsed with V-4s still inside, just waiting for modern historians to rediscover them. Proof that Germany was building and even mass-producing manned spacecraft 20 years ahead of their time (even if they were never launched) would be incredible.

The two-man design also appears to demonstrate that Germany was really serious about delivering some sort of weapon of mass destruction over a long range. Electronic guidance systems were not yet reliable or accurate enough, so a pilot was necessary. With typical German thoroughness, the designers planned for two pilots instead of one, in case one pilot lost consciousness or changed his mind about going through with the mission after launch. I do not see why the Germans would have gone to such engineering extremes if the payload were not a weapon of mass destruction, or if the target were not at a longer range than the existing V-2 could reach accurately with an automated guidance system.

For what appears to be an early public report of the two-man rocket, see p. 5321.

For diagrams of the two-man rocket from an engineer who apparently worked on it, see pp. 5384–5388.]

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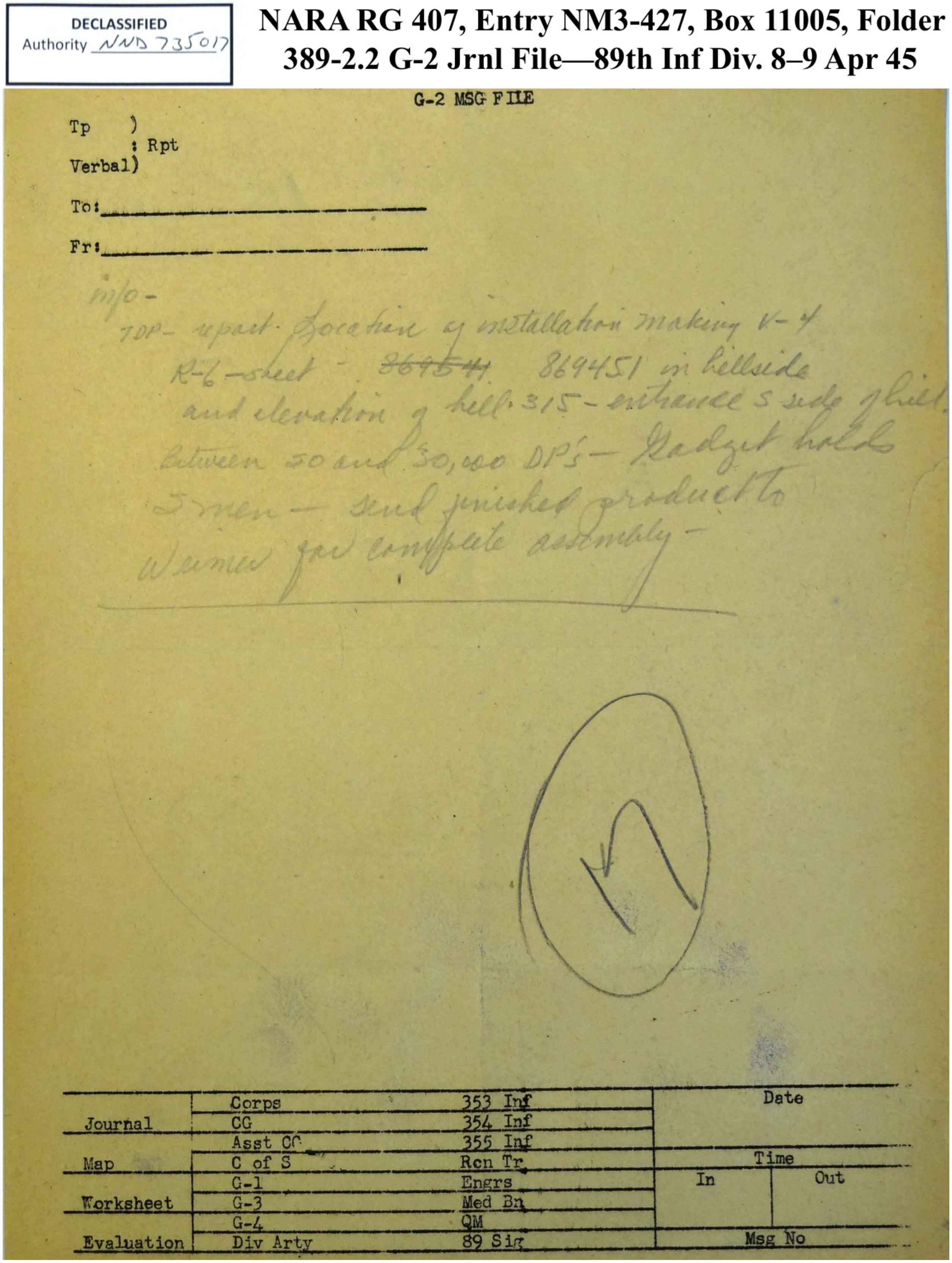
[2] Rainer Karlsch. 2009. Wunderwaffen für den "Endsieg"? Die geheimen Arbeiten des Forschungsinstituts für Physik und dessen Verlagerung nach Neustadt an der Orla (1944–1945). *Zeitschrift für Thüringische Geschichte.* 63:259–276.

009. Geheime Forschungsstätte Harrasmühle 1943–45. https://www.heimatfreunde-neustadt-orla.de/neustadt-umgebung/item/009-erinnerung-an-die-gesandten-zum-20ten.html



DECLASSIFIED
Authority NND 735017

NARA RG 407, Entry NM3-427, Box 11005, Folder 389-2.2 G-2 Jrnl File—89th Inf Div. 8–9 Apr 45

G-2 MSG FILE

Tp)
: Rpt
Verbal)

To:

Fr:

info -
TDP - report · Location of installation making V-4
R-6 - sheet - ~~869541~~ 869451 in hillside
and elevation of hill · 315 - entrance S side of hill.
between 20 and 30,000 DP's - Gadget holds
2 men - send finished product to
Weimar for complete assembly -

	Corps	353 Inf	Date	
Journal	CG	354 Inf		
	Asst CG	355 Inf		
Map	C of S	Rcn Tr	Time	
	G-1	Engrs	In	Out
Worksheet	G-3	Med Bn		
	G-4	QM		
Evaluation	Div Arty	89 Sig	Msg No	

Figure E.87: U.S. Army G-2 intelligence reports from 8 April 1945 describing a large underground factory in the vicinity of Neustadt an der Orla that had been using 20,000–30,000 French and other foreign workers for assembly line production of the "V4... two man rocket." [NARA RG 407, Entry NM3-427, Box 11005, Folder 389-2.2 G-2 Jrnl File—89th Inf Div. 8–9 Apr 45]

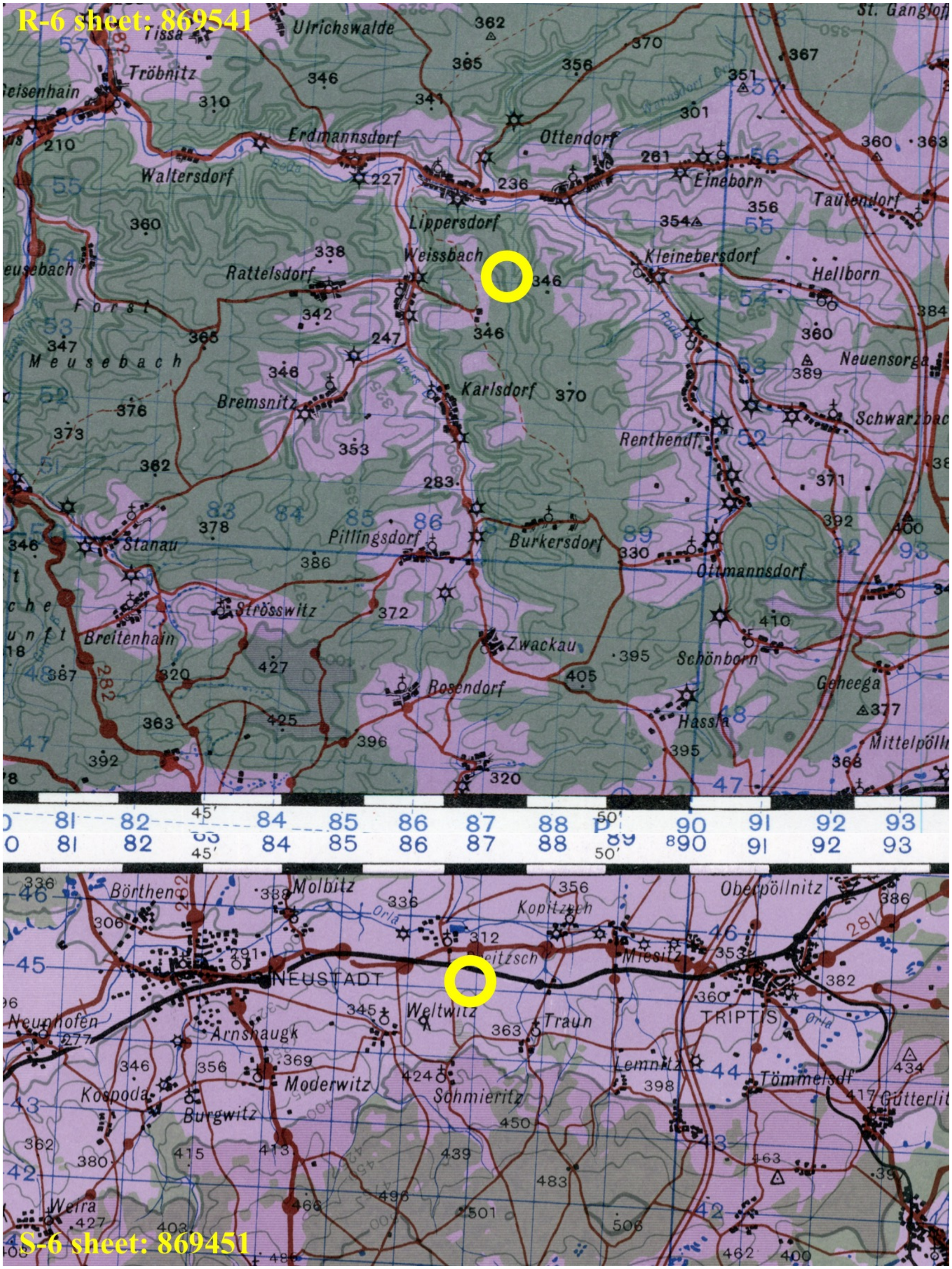
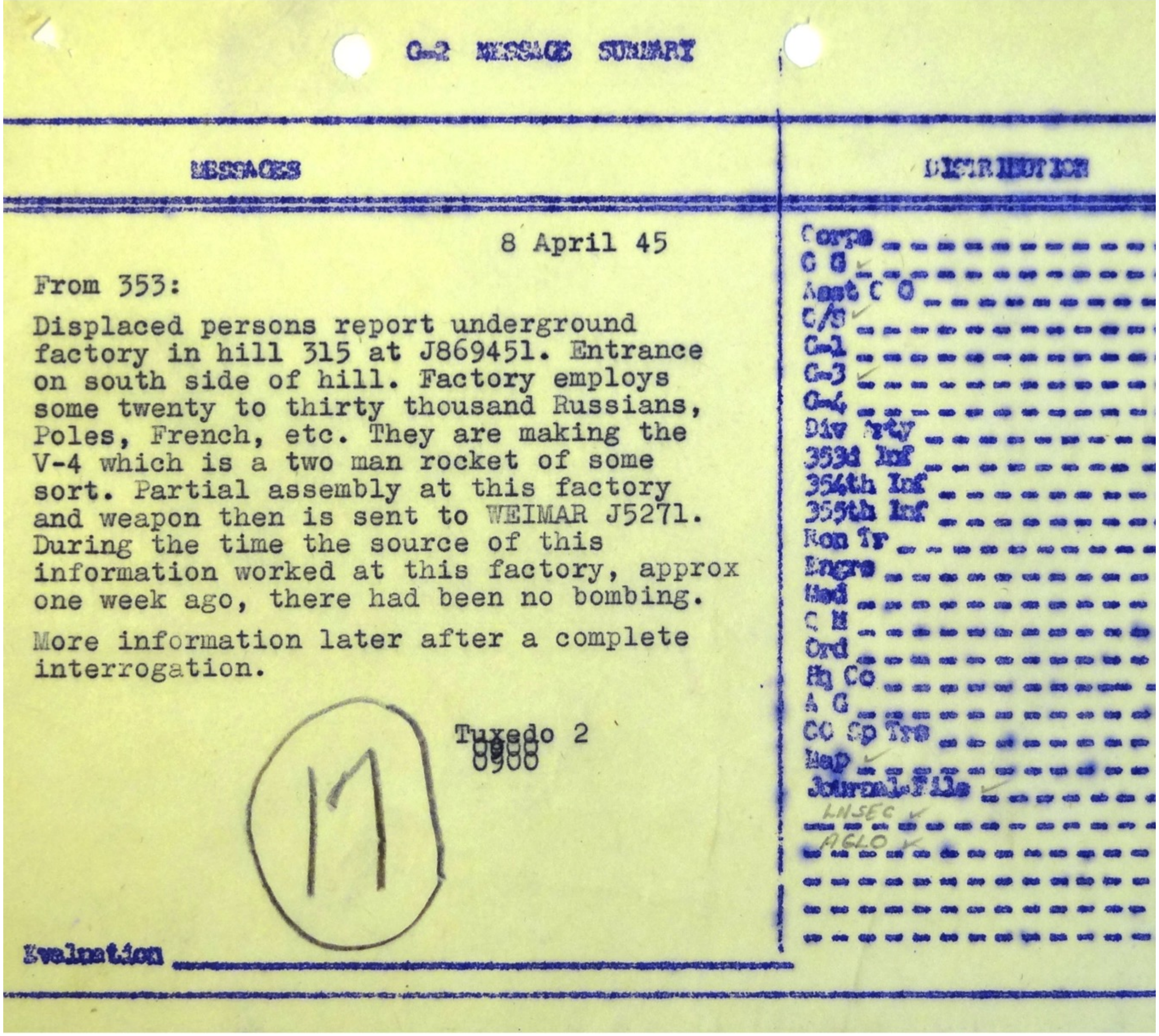

R-6 sheet: 869541
Ulrichswalde
Tissa
Tröbnitz
Erdmannsdorf
Ottendorf
Eineborn
Waltersdorf
Tautendorf
Lippersdorf
Weissbach
Kleinebersdorf
Hellborn
Rattelsdorf
Forst
Meusebach
Neuensorga
Bremsnitz
Karlsdorf
Schwarzbach
Renthendf.
Stanau
Pillingsdorf
Burkersdorf
Ottmannsdorf
Strösswitz
Breitenhain
Zwackau
Schönborn
Rosendorf
Geheega
Hassla
Mittelpöllnitz
Börthen
Molbitz
Kopitzsch
Oberpöllnitz
NEUSTADT
Weltwitz
Traun
TRIPTIS
Neunhofen
Arnshaugk
Moderwitz
Lemnitz
Tömmelsdf
Kospoda
Burgwitz
Schmieritz
Gütterlitz
Weira
Orla
S-6 sheet: 869451

Figure E.88: Adjacent sheets R-6 (above) and S-6 (below) of the GSGS 4416 map used by the U.S. Army. The coordinates for the two-man rocket factory were first given as 869541 (above), then as 869451 (below), 9 km due south of the first location. There is no "hill 315" near either location, and neither location seems like a very promising site for a massive underground factory.

DECLASSIFIED
Authority NND 735017

NARA RG 407, Entry NM3-427, Box 11005, Folder 389-2.2 G-2 Jrnl File—89th Inf Div. 8–9 Apr 45



G-2 MESSAGE SUMMARY

MESSAGES

8 April 45

From 353:

Displaced persons report underground factory in hill 315 at J869451. Entrance on south side of hill. Factory employs some twenty to thirty thousand Russians, Poles, French, etc. They are making the V-4 which is a two man rocket of some sort. Partial assembly at this factory and weapon then is sent to WEIMAR J5271. During the time the source of this information worked at this factory, approx one week ago, there had been no bombing.

More information later after a complete interrogation.

Tuxedo 2
0900

17

Evaluation

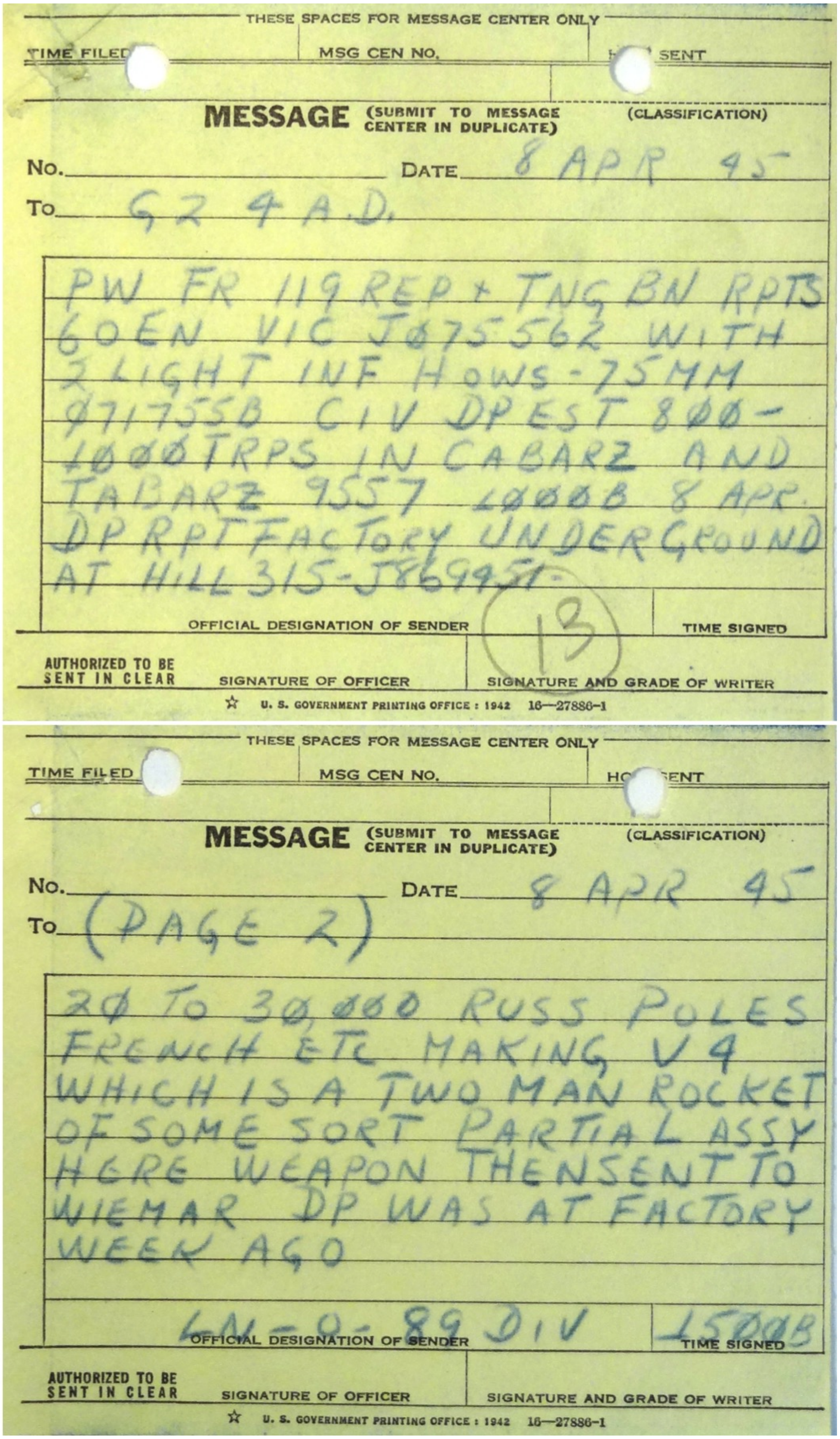
DISTRIBUTION

- Corps
- C G ✓
- Asst C G
- C/S ✓
- G-1
- G-3 ✓
- G-4
- Div Arty
- 353d Inf
- 354th Inf
- 355th Inf
- Rcn Tr
- Engrs
- Med
- Q M
- Ord
- Hq Co
- A G
- CO Sp Trs
- Map ✓
- Journal File ✓
- LNSEC ✓
- AGLO ✓

Figure E.89: U.S. Army G-2 intelligence reports from 8 April 1945 describing a large underground factory in the vicinity of Neustadt an der Orla that had been using 20,000–30,000 French and other foreign workers for assembly line production of the “V4... two man rocket.” [NARA RG 407, Entry NM3-427, Box 11005, Folder 389-2.2 G-2 Jrnl File—89th Inf Div. 8–9 Apr 45]

DECLASSIFIED
Authority NND 735017

NARA RG 407, Entry NM3-427, Box 12365, Folder 604-2.3 (1688-4) G-2 Jrnl File 4th Armd Div. 7–8 Apr 45



THESE SPACES FOR MESSAGE CENTER ONLY

TIME FILED | MSG CEN NO. | HOW SENT

MESSAGE (SUBMIT TO MESSAGE CENTER IN DUPLICATE) (CLASSIFICATION)

No.
DATE 8 APR 45
To G2 4 A.D.

PW FR 119 REP + TNG BN RPTS
60 EN VIC J075562 WITH
2 LIGHT INF HOWS - 75MM
071755B CIV DP EST 800-
1000 TRPS IN CABARZ AND
TABARZ 9557 1000B 8 APR.
DP RPT FACTORY UNDERGROUND
AT HILL 315 - J869451.

OFFICIAL DESIGNATION OF SENDER
TIME SIGNED

13

AUTHORIZED TO BE SENT IN CLEAR
SIGNATURE OF OFFICER
SIGNATURE AND GRADE OF WRITER

☆ U. S. GOVERNMENT PRINTING OFFICE : 1942 16—27886-1

THESE SPACES FOR MESSAGE CENTER ONLY

TIME FILED | MSG CEN NO. | HOW SENT

MESSAGE (SUBMIT TO MESSAGE CENTER IN DUPLICATE) (CLASSIFICATION)

No.
DATE 8 APR 45
To (PAGE 2)

20 TO 30,000 RUSS POLES
FRENCH ETC MAKING V4
WHICH IS A TWO MAN ROCKET
OF SOME SORT PARTIAL ASSY
HERE WEAPON THEN SENT TO
WIEMAR DP WAS AT FACTORY
WEEK AGO

LN - 0 - 89 DIV
OFFICIAL DESIGNATION OF SENDER
1500B
TIME SIGNED

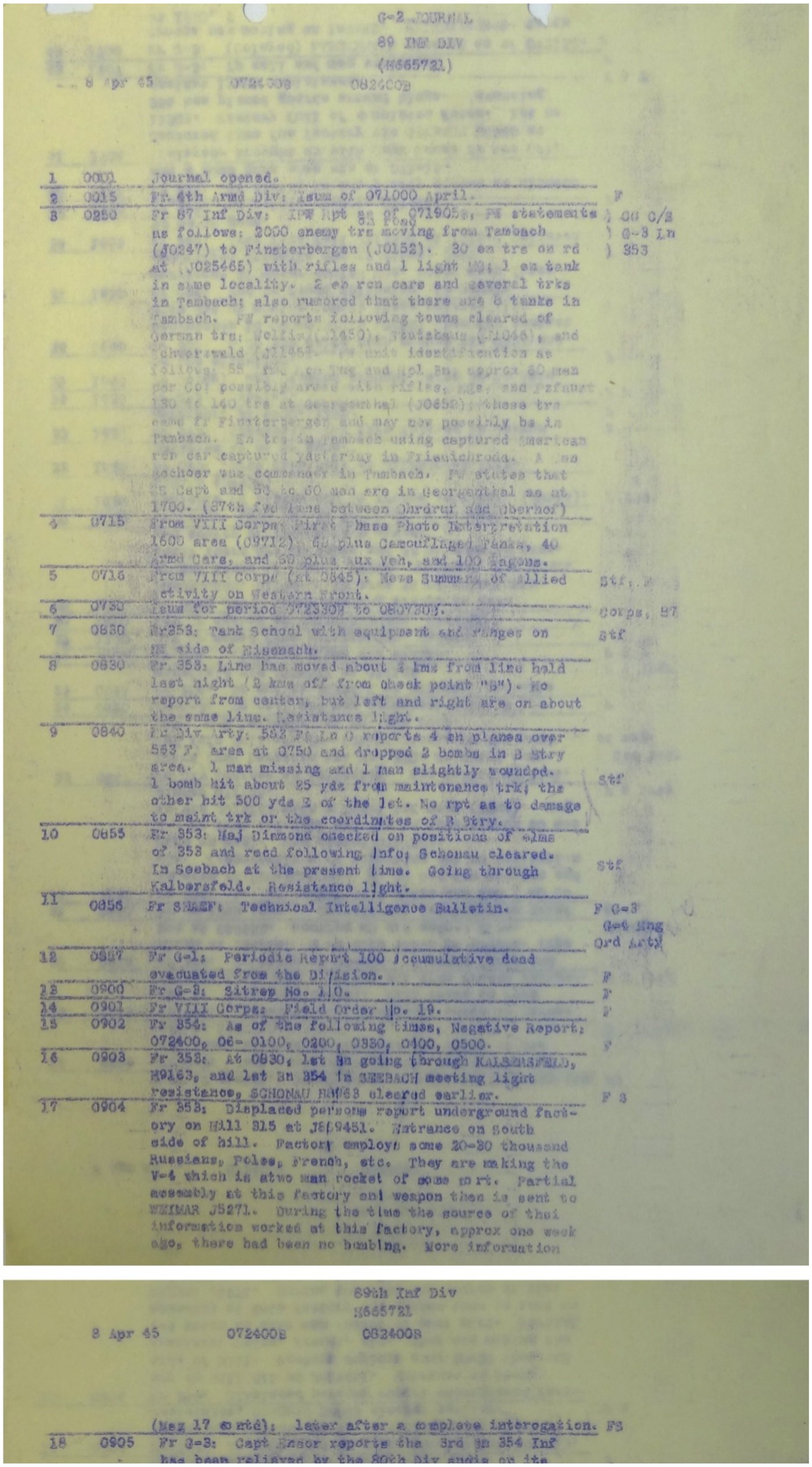
AUTHORIZED TO BE SENT IN CLEAR
SIGNATURE OF OFFICER
SIGNATURE AND GRADE OF WRITER

☆ U. S. GOVERNMENT PRINTING OFFICE : 1942 16—27886-1

Figure E.90: U.S. Army G-2 intelligence reports from 8 April 1945 describing a large underground factory in the vicinity of Neustadt an der Orla that had been using 20,000–30,000 French and other foreign workers for assembly line production of the "V4... two man rocket." [NARA RG 407, Entry NM3-427, Box 12365, Folder 604-2.3 (1688-4) G-2 Jrnl File 4th Armd Div. 7–8 Apr 45]

DECLASSIFIED
Authority NND 735017

NARA RG 407, Entry NM3-427, Box 11005, Folder 389-2.2 G-2 Jrnl File—89th Inf Div. 8–9 Apr 45



G-2 JOURNAL
89 INF DIV
(H665721)

8 Apr 45 072400B 082400B

1	0001	Journal opened.	
2	0015	Fr 4th Armd Div: Isum of 071000 April.	F
3	0250	Fr 87 Inf Div: IPW Rpt as of 071905B, PW statements as follows: 2000 enemy trs moving from Tambach (J0247) to Finsterbergen (J0152). 30 en trs on rd at (J025465) with rifles and 1 light MG; 1 en tank in same locality. 2 en rcn cars and several trks in Tambach; also rumored that there are 6 tanks in Tambach. PW reports following towns cleared of German trs: Wolfis (J1450), Stutzhaus (J1046), and Schwarzwald (J1145). PW unit identification as follows: SS [illegible] Tng and Repl Bn, approx 60 men per Co; possibly armed with rifles, MGs, and Pzfaust 130 to 140 trs at Georgenthal (J0652); these trs came fr Finsterbergen and may now possibly be in Tambach. En trs in Tambach using captured American rcn car captured yesterday in Friedrichroda. A [illegible] Schoer was commander in Tambach. PW states that SS Capt and 50 to 60 men are in Georgenthal as at 1700. (87th fwd lines between Ohrdruf and Oberhof)	) CG C/S) G-3 Ln) 353
4	0715	From VIII Corps: First Phase Photo Interpretation 1600 area (09712): 60 plus Camouflaged Tanks, 40 Armd Cars, and 50 plus Aux Veh, and 100 Wagons.	
5	0716	From VIII Corps (at 0645): News Summary of Allied activity on Western Front.	Stf, [illegible]
6	0730	Isum for period 072330B to 080730B.	Corps, 87
7	0830	Fr353: Tank School with equipment and ranges on NE side of Eisenach.	Stf
8	0830	Fr 353: Line has moved about 2 kms from line held last night (2 kms off from check point "B"). No report from center, but left and right are on about the same line. Resistance light.	
9	0840	Fr Div Arty: 563 FA Ln O reports 4 en planes over 563 FA area at 0750 and dropped 2 bombs in B Btry area. 1 man missing and 1 man slightly wounded. 1 bomb hit about 25 yds from maintenance trk; the other hit 500 yds E of the 1st. No rpt as to damage to maint trk or the coordinates of B Btry.	Stf
10	0855	Fr 353: Maj Dismone checked on positions of elms of 353 and recd following info; Schonau cleared. In Seebach at the present time. Going through Kalbersfeld. Resistance light.	Stf
11	0856	Fr SHAEF: Technical Intelligence Bulletin.	F G-3 G-4 Eng Ord Arty
12	0857	Fr G-1: Periodic Report 100 (cumulative dead evacuated from the Division.	F
13	0900	Fr G-3: Sitrep No. 110.	F
14	0901	Fr VIII Corps: Field Order No. 19.	F
15	0902	Fr 354: As of the following times, Negative Report: 072400, 06- 0100, 0200, 0330, 0400, 0500.	F
16	0903	Fr 353: At 0830, 1st Bn going through KALBERSFELD, H9163, and 1st Bn 354 in SEEBACH meeting light resistance, SCHONAU H8963 cleared earlier.	F 3
17	0904	Fr 353: Displaced persons report underground factory on Hill 315 at J5[illegible]9451. Entrance on South side of hill. Factory employs some 20-30 thousand Russians, Poles, French, etc. They are making the V-4 which is atwo man rocket of some sort. Partial assembly at this factory and weapon then is sent to WEIMAR J5271. During the time the source of thei information worked at this factory, approx one week ago, there had been no bombing. More information	

89th Inf Div
H665721

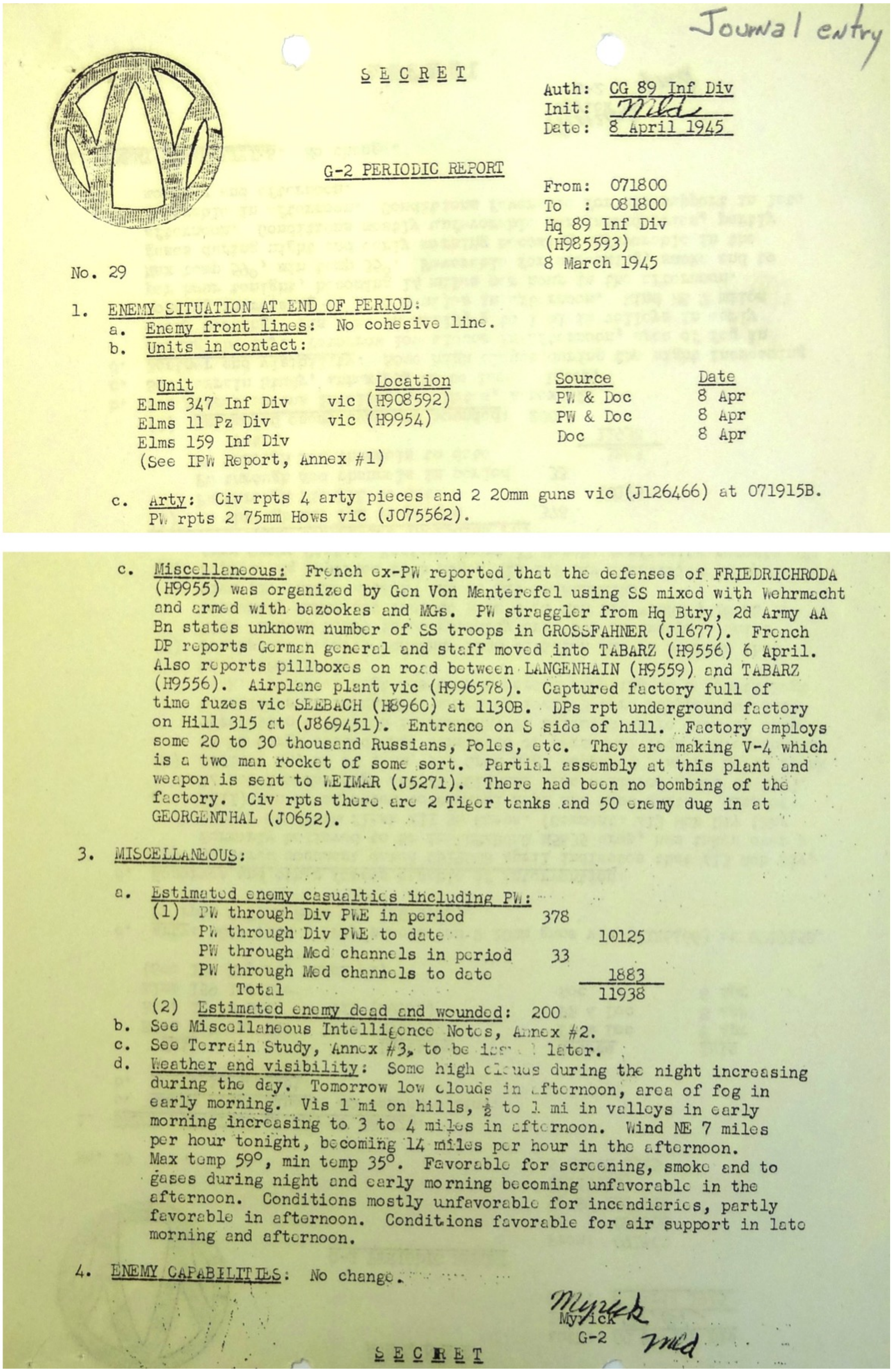
8 Apr 45 072400B 082400B

		(Msg 17 contd): later after a complete interogation.	FS
18	0905	Fr G-3: Capt Ensor reports the 3rd Bn 354 Inf has been relieved by the 80th Div and is on its	

Figure E.91: U.S. Army G-2 intelligence reports from 8 April 1945 describing a large underground factory in the vicinity of Neustadt an der Orla that had been using 20,000–30,000 French and other foreign workers for assembly line production of the "V4... two man rocket." [NARA RG 407, Entry NM3-427, Box 11005, Folder 389-2.2 G-2 Jrnl File—89th Inf Div. 8–9 Apr 45]

DECLASSIFIED
Authority NND 735017

NARA RG 407, Entry NM3-427, Box 11005, Folder 389-2.2 G-2 Jrnl File—89th Inf Div. 8–9 Apr 45



Journal entry

SECRET

Auth: CG 89 Inf Div
Init: Mld
Date: 8 April 1945

G-2 PERIODIC REPORT

From: 071800
To : 081800
Hq 89 Inf Div
(H985593)
8 March 1945

No. 29

1. ENEMY SITUATION AT END OF PERIOD:
   a. Enemy front lines: No cohesive line.
   b. Units in contact:

Unit	Location	Source	Date
Elms 347 Inf Div	vic (H908592)	PW & Doc	8 Apr
Elms 11 Pz Div	vic (H9954)	PW & Doc	8 Apr
Elms 159 Inf Div		Doc	8 Apr

(See IPW Report, Annex #1)

c. Arty: Civ rpts 4 arty pieces and 2 20mm guns vic (J126466) at 071915B. PW rpts 2 75mm Hows vic (J075562).

c. Miscellaneous: French ex-PW reported that the defenses of FRIEDRICHRODA (H9955) was organized by Gen Von Manterofel using SS mixed with Wehrmacht and armed with bazookas and MGs. PW straggler from Hq Btry, 2d Army AA Bn states unknown number of SS troops in GROSSFAHNER (J1677). French DP reports German general and staff moved into TABARZ (H9556) 6 April. Also reports pillboxes on road between LANGENHAIN (H9559) and TABARZ (H9556). Airplane plant vic (H996578). Captured factory full of time fuzes vic SEEBACH (H8960) at 1130B. DPs rpt underground factory on Hill 315 at (J869451). Entrance on S side of hill. Factory employs some 20 to 30 thousand Russians, Poles, etc. They are making V-4 which is a two man rocket of some sort. Partial assembly at this plant and weapon is sent to WEIMAR (J5271). There had been no bombing of the factory. Civ rpts there are 2 Tiger tanks and 50 enemy dug in at GEORGENTHAL (J0652).

3. MISCELLANEOUS:
   a. Estimated enemy casualties including PW:
      (1)

PW through Div PWE in period	378	
PW through Div PWE to date		10125
PW through Med channels in period	33	
PW through Med channels to date		1883
Total		11938

      (2) Estimated enemy dead and wounded: 200
   b. See Miscellaneous Intelligence Notes, Annex #2.
   c. See Terrain Study, Annex #3, to be issued later.
   d. Weather and visibility: Some high clouds during the night increasing during the day. Tomorrow low clouds in afternoon, area of fog in early morning. Vis 1 mi on hills, ½ to 1 mi in valleys in early morning increasing to 3 to 4 miles in afternoon. Wind NE 7 miles per hour tonight, becoming 14 miles per hour in the afternoon. Max temp 59°, min temp 35°. Favorable for screening, smoke and to gases during night and early morning becoming unfavorable in the afternoon. Conditions mostly unfavorable for incendiaries, partly favorable in afternoon. Conditions favorable for air support in late morning and afternoon.

4. ENEMY CAPABILITIES: No change.

Myrick
Myrick
G-2
Mld

SECRET

Figure E.92: U.S. Army G-2 intelligence reports from 8 April 1945 describing a large underground factory in the vicinity of Neustadt an der Orla that had been using 20,000–30,000 French and other foreign workers for assembly line production of the “V4... two man rocket.” [NARA RG 407, Entry NM3-427, Box 11005, Folder 389-2.2 G-2 Jrnl File—89th Inf Div. 8–9 Apr 45]

A. W. Detweiler. V-2 Factory at Pössneck. 19 June 45 [AFHRA folder 519.650-1 Oct 1944–Dec 1945 Exploitation—Enemy Equipment; AFHRA A5729 frame 1573].

1. Following information phoned by Col. T. Ames, Asst. A-2, Air Staff Shaef:

a. The CIO (Group Capt. Humphrey) of 2nd TAF has been advised that the V-2 factory at Pössneck (J-73) has not been examined. Since this is in the Russian area, it is suggested by Group Capt. Humphrey that any action taken must be immediate.

b. Col. Hall, G-2 of the 30th Division, is reported to be familiar with this installation.

c. The above information furnished to 2nd TAF by a Major Darling.

d. It has been requested that Group Capt. Humphrey be advised of any action taken on the above.

[See document photo on p. 5375.

Pössneck and the rest of Thuringia were transferred from occupying U.S. forces to occupying Soviet forces on 1 July 1945, which prompted the urgency of this 19 June 45 memo.

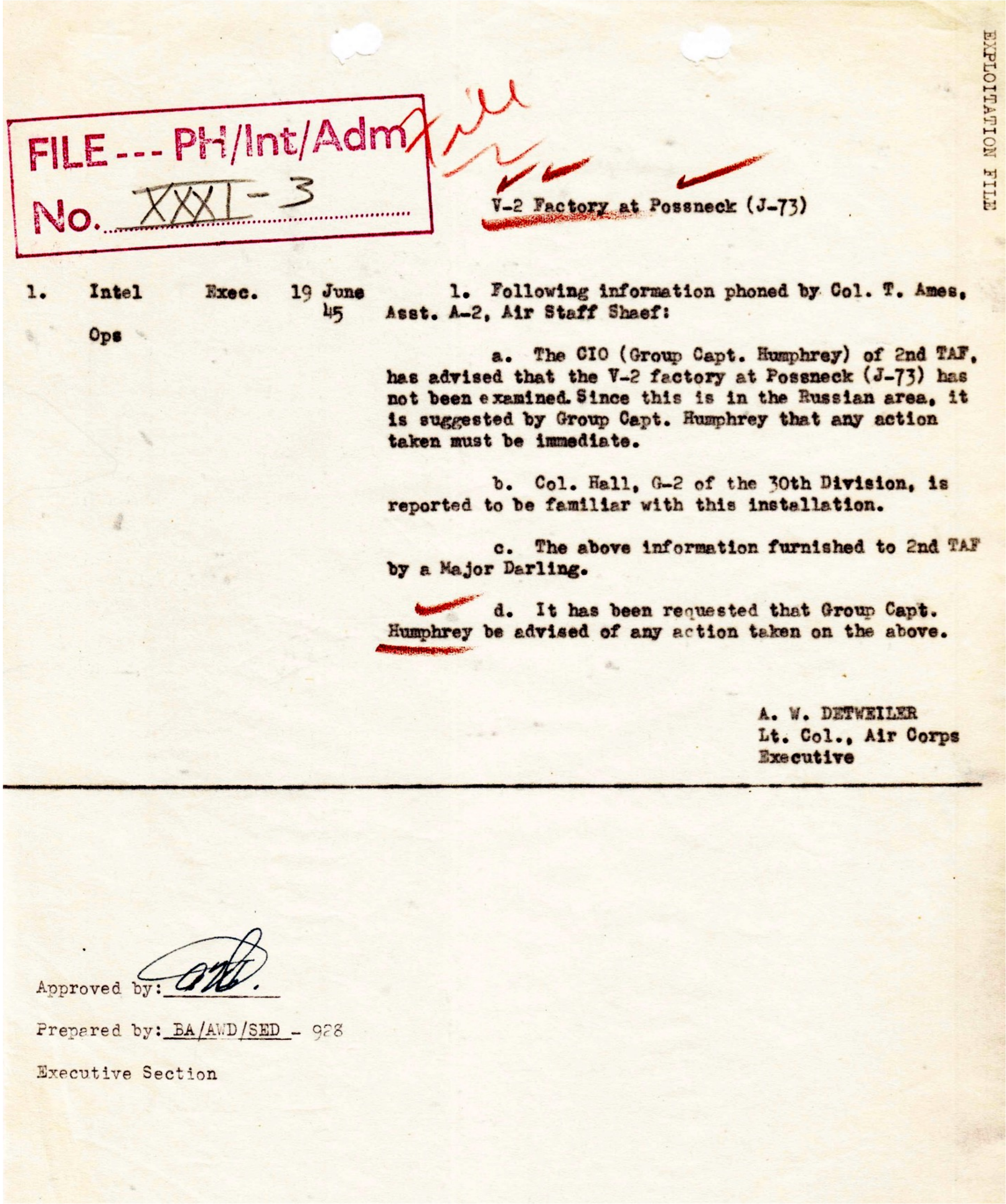
This document proves that there was a rocket factory at Pössneck, which was only 13 km from Neustadt an der Orla, yet both are very far from Nordhausen and would not have been confused with the underground rocket factory there. The U.S. military used "V-2" in the generic sense to refer to large German rockets, so the Pössneck factory could have been manufacturing V-2/A-4 rockets or something else. Was the Pössneck factory the same as the "two-man rocket" factory? Perhaps the "Pössneck" factory was not actually in Pössneck, but was merely nearby, and the U.S. military referred to the nearest town of significant size, Pössneck. Or maybe the escaped prisoners were slightly off in their description of the location of the two-man rocket factory. Even if the Pössneck factory mentioned in the above document was a different facility, its existence demonstrates that that area contained underground rocket factories, making the reports of the two-man rocket factory highly plausible.

For examples of nuclear work that was conducted in this same area and same time, see:

> Rainer Karlsch. 2009. Wunderwaffen für den "Endsieg"? Die geheimen Arbeiten des Forschungsinstituts für Physik und dessen Verlagerung nach Neustadt an der Orla (1944–1945). *Zeitschrift für Thüringische Geschichte.* 63:259–276.
>
> 009. Geheime Forschungsstätte Harrasmühle 1943–45. [https://www.heimatfreunde-neustadt-orla.de/neustadt-umgebung/item/009-erinnerung-an-die-gesandten-zum-20ten.html]

What reports on the Pössneck facility or other scientific facilities in this area were produced by Colonel Hall, Colonel Ames, Lt. Colonel Detweiler, Major Darling, Captain Humphrey, or others? Can those reports be located and (if necessary) declassified?]

AFHRA folder 519.650-1 Oct 1944 – Dec 1945
Exploitation—Enemy Equipment



EXPLOITATION FILE

FILE --- PH/Int/Adm
No. XXXI-3

File

V-2 Factory at Possneck (J-73)

1. Intel Exec. 19 June 45

Ops

1. Following information phoned by Col. T. Ames, Asst. A-2, Air Staff Shaef:

a. The CIO (Group Capt. Humphrey) of 2nd TAF, has advised that the V-2 factory at Possneck (J-73) has not been examined. Since this is in the Russian area, it is suggested by Group Capt. Humphrey that any action taken must be immediate.

b. Col. Hall, G-2 of the 30th Division, is reported to be familiar with this installation.

c. The above information furnished to 2nd TAF by a Major Darling.

d. It has been requested that Group Capt. Humphrey be advised of any action taken on the above.

A. W. DETWEILER
Lt. Col., Air Corps
Executive

Approved by:

Prepared by: BA/AWD/SED - 928

Executive Section

Figure E.93: This 19 June 45 U.S. intelligence memo proves that there was a factory making large rockets at or near Pössneck, 13 km from Neustadt an der Orla [AFHRA folder 519.650-1 Oct 1944–Dec 1945 Exploitation—Enemy Equipment; AFHRA A5729 frame 1573].

Hitler had a V-4 to raid London. *Daily Mail.* 18 April 1945 p. 4.

PARIS, Tuesday.

Hitler had another secret weapon—the V4—which he intended to rain on London, according to the Paris newspaper *Paris-Presse.*

But this last coup was prevented by the lightning Allied advance. A secret underground factory near Erfurt was captured and the secrets of the new weapon discovered.

The newspaper, from interviews with French deportees liberated from the factory, gives this picture of the new "V" weapon:

"Imagine a V2 which, instead of being blind and inaccurate, surpasses the accuracy of the most perfect artillery; a projectile 15 to 20 yards long, controlled by wireless from the ground, and travelling at a speed of some 3,750 miles an hour."

The subterranean factory, built in rock, was several storeys in height, with a network of tunnels and covering an area of about ten square miles.—*Reuter.*

[Tuesday was 17 April, so this *Daily Mail* story appears to have been written by someone in Paris with inside knowledge of the reporting before the *Paris-Presse* edition actually appeared in print on 18 April.]

Raymond Henry. Nous Font des Révélations sur le V-4: Dernier Rêve de Hitler. *Paris-Presse* No. 135, 18 April 1945 p. 1.

Libérés plus tôt que les Allemands ne pouvaient s'y attendre par l'avance americaine, des deportes français affectés à la fabrication des armes secrètes	Liberated earlier than the Germans could have expected by the American advance, French deportees assigned to the manufacture of secret weapons
nous font des révélations sur le V-4 dernier rêve de Hitler	we make revelations about the V-4 last dream of Hitler
Ces déportés qui n'avaient pas vu le jour depuis des mois, travaillaient au secret dans une usine souterraine s'étendant sur 24 km^2	These deportees, who had not seen daylight for months, worked secretly in an underground factory spread over 24 km^2
Hitler avait fait un rêve: le dernier. Il rêvait de gagner la guerre, grâce à une novelle arme secrète, le V-4. Ce rêve ne se réalisa pas. Les nazis n'en emporteront même pas le secret dans leur tombe. Car ils avaient eu l'imprudence d'affecter par représailles, aux usines où l'on expérimentait et fabriquait le V-4, des déportés français qui permettent aujourd'hui aux Alliés de percer le mystère de l'ultime arme secrète sur laquelle le III^{e} Reich fondait ses ultimes espoirs.	Hitler had a dream: the last. He dreamed of winning the war, thanks to a new secret weapon, the V-4. This dream did not come true. The Nazis will not even take the secret to their graves. For they had been imprudent enough to assign, by reprisals, to the factories where the V-4 was experimented with and manufactured, French deportees who now allow the Allies to pierce the mystery of the ultimate secret weapon on which the Third Reich founded its ultimate hopes.
Ces Français, qui ont travaillé pendant plusieurs mois sous terre, sans revoir la lumière du jour, ont pu fournir sur le V-4, ses perspectives et son emploi, des précisions que "Paris-presse" est le premier à publier.	These Frenchmen, who worked for several months underground, without seeing the light of day, were able to provide details on the V-4, its prospects and its use, which "Paris-press" is the first to publish.

[If this is the same massive underground V-4 rocket factory populated by French and other foreign workers and reported by Allied forces on pp. 5368–5373, its location was given there. Using the website tool http://www.echodelta.net/mbs/eng-translator.php, Modified British System coordinate [w]J869451 in the Nord de Guerre Grid corresponds to a location 1 km southeast of Dreitzsch, just east of Neustadt an der Orla. Thus the massive underground rocket factory described was not Nordhausen. It was approximately 110 km away from Nordhausen, and the description indicates it was much larger than Nordhausen.]

Nous connaissions les V-1 et les V-2. Nous connaissions même, par oui-dire, les V-3, qui devaient être une édition améliorée et agrandié des V-2.

Nous savions aussi que les Allemands se proposaient d'expédier une véritable pluie de ces projectiles sur Londres. Mais nul n'avait encore entendu parler des V-4, l'arme qui devait donner la victoire définitive à Hitler.

Cette arme était sur le point de sortir. Les usines où l'on procédait à la fabrication et aux essais viennent d'être conquises par les troupes alliées, au cours de leur foudroyante avance, et les secrets qu'elles ont révélés sont encore inédits.

C'étaient, dans la région d'Erfurt et pas très loin de ce sinistre camp de Buchenwald libéré, lui aussi, par l'offensive alliée, d'immenses, de prodigieuses usines souterraines enfouies les unes à côté des autres, étagées les unes au-dessus des autres, reliées par un labyrinthe de canalisations et de tunnels, et s'étendant sur une superficie de 24 kilomètres carrés. En bref, une gigantesque cité creusée dans le roc et où se succédaient interminablement, à la lumière de puissants globes électriques, ateliers, magasias, laboratoires et casemates.

Deux chemins de fer à voie étroite approvisionnaient ce royaume souterrain, deux chemins de fer si artistement camouflés que jamais l'aviation alliée ne les avait découverts.

We knew the V-1s and the V-2s. We even knew, by the way, the V-3s, which were to be an improved and enlarged version of the V-2s.

We also knew that the Germans intended to hasten a veritable rain of these projectiles on London. But no one had heard of the V-4, the weapon that was to give Hitler the final victory.

This weapon was about to be released. The factories in which it had been manufactured and tested have just been conquered by the allied troops during their tremendous advance, and the secrets they had revealed have not yet been published.

There were, in the region of Erfurt and not very far from the sinister camp of Buchenwald that was also liberated by the allied offensive, immense, prodigious underground factories buried one beside the others, levels ones above others, connected by a labyrinth of pipes and tunnels, and extending over an area of 24 square kilometers. In short, a gigantic city hollowed out of the rock with an interminable succession, lit by powerful electric globes, of workshops, storerooms, laboratories, and fortifications.

Two narrow-gauge railroads supplied this underground kingdom, two railways so artistically camouflaged that the allied aviation never discovered them.

[This article states that it was already known that V-3 (or at least one weapon system vying for that title) was an "improved and enlarged version of the V-2." This probably means that the standard V-2 length of 14 m was enlarged to 18 or 21 m long as reported elsewhere, accommodating more propellant and hence improving the rocket's range and/or payload capacity.]

Un projectile géant d’une précision absolue

C’est là, dans le mystère, que les meilleurs techniciens d’Allemagne, soumis à un étroit contrôle, préparaient le V-4. Le V-4? Imaginez un V-2, mais un V-2 qui, au lieu d’être aveugle et imprécis, aurait au contraire surpassé en précision les canons les plus perfectionnés; un projectile immense, long de 15 ou 20 mètres, propulsé par fusée, comme le V-2, mais pouvant, à la différence de celui-ci, être dirigé de terre par ondes hertziennes et capable, pendant tout le temps de sa course parcourue à une vitesse de 6.000 km à l’heure, d’indiquer sa position à la centrale de tir, grâce à des dispositifs gyroscopiques couplés avec un poste émetteur de T.S.F.; un engin enfin qui n’aurait peut-être pas pu changer le sort de la guerre, mai qui aurait certainement prolongé les hostilités en causant de nouveaux et incalculables ravages, et en provoquant pour les Alliés de graves difficultés supplémentaires.

Mais le danger est conjuré. Le V-4 git désormais, sans force et sans vertu, dans l’ombre de ces cavernes d’où les nazis aux abois n’ont pas eu le temps de le faire surgir. Quelques mois seulement, quelques semaines peut-être, paraît-il, nous séparaient encore du moment où ces monstres nouveaux se seraient abattus sur nous.

A giant projectile of absolute precision

It was there, in the mystery, that the best technicians of Germany, subject to a strict control, were preparing the V-4. The V-4? Imagine a V-2, but a V-2 which, instead of being blind and imprecise, would on the contrary surpass in precision the most perfect canons; an immense projectile, 15 or 20 meters long, propelled by rocket, like the V-2, but capable, unlike the latter, of being guided by Hertzian waves and capable, throughout all the time of its course traveling at a speed of 6,000 km per hour, of indicating its position to the launch station, thanks to gyroscopic devices coupled with a radio transmitter; a device which might not have been able to change the outcome of the war, but which would certainly have prolonged hostilities by causing new and incalculable havoc, and provoking serious difficulties for the Allies.

But danger is avoided. The V-4 lies henceforth, without force and without virtue, in the shadow of these caverns where the stymied Nazis did not have time to make it appear. Only a few months, perhaps a few weeks, it seems, still separated us from the moment when these new monsters would have fallen upon us.

[The V-4 weapon described above was a V-2 or A-4 rocket whose length had been increased from the usual 14 meters to “15 to 20 meters,” in order to carry more propellant and improve the rocket’s range and/or payload capacity. This V-4 was also described as having a much more precise guidance system (combining onboard inertial gyroscopes and external radio signals), which would have been especially important to achieve good targeting accuracy at ranges greater than that of the standard V-2 and/or for highly valuable payloads such as a nuclear bomb.

See also pp. 2938–2962.

If U.S. forces overran a factory that had been producing improved V-3 and V-4 rockets as described here, where is all the documentation for what was actually found and removed by the United States? Can that information be located in archives? Were prototypes of the rockets and the improved guidance systems brought back to the United States? If that material is still classified, can it be located and declassified now?]

Albert Ducrocq. 1947. *Les Armes Secrètes Allemandes.* Paris: Berger-Levrault. pp. 160–161.

On avait longtemps douté de l'efficacité militaire de la A-9: dépenser 100 tonnes de combustible et perdre une machinerie compliquée pour aller jeter seulement une tonne d'explosif sur le territoire américain, voilà qui semblait payer bien cher le plaisir d'ennuyer l'adversaire! Remarquons tout d'abord, à ce sujet, que le prix de revient n'est guère plus élevé que dans le cas d'un bombardement par V-2, puisque la fusée-mère A-10 est récupérable, et d'autre part, ce qui coûte cher (du moins en heures de travail englouties) ce n'est pas tant l'alcohol ou l'eau oxygénée que la machinerie des V-2 ou A-9; dans l'un et l'autre cas on en faisait le sacrafice à l'avance. [...]

Et puis il y a bien pire: dans l'esprit d'Hitler, la A-9 était aussi destinée, le cas échéant, à transporter des bombes atomiques sur le territoire américain. [...] Se rend-on compte des répercussions matérielles et morales du lancer d'une seule bombe atomique sur New-York par exemple! Il nous est pratiquement impossible de les mesurer.

D'ailleurs, outre le bombardement par A-9, les Allemands voulaient entreprendre le bombardement direct des côtes américaines au moyen de V-2 lancées par des sous-marins. C'était leur deuxième arme nouvelle contre l'Amérique. Elle devait entrer en action en même temps que la A-9, c'est-à-dire au début de l'été 1945...

There had long been doubts about the military effectiveness of the A-9: spending 100 tons of fuel and wasting complicated machinery to throw just one ton of explosive on American territory seemed like a high price to pay for the pleasure of annoying your adversary! First of all, it is worth noting that the actual cost is not much higher than in the case of a V-2 attack, since the A-10 first stage is recoverable, and second, what is expensive (at least in terms of man-hours) is not so much the alcohol or liquid oxygen as the V-2 or A-9 machinery; in both cases, the cost was decided in advance. [...]

And there is worse: in Hitler's mind, the A-9 was also intended, if need be, to transport atomic bombs onto American territory. [...] Do you realize the material and moral repercussions of dropping a single atomic bomb on New York, for example? It is virtually impossible to measure them.

What is more, in addition to A-9 bombing, the Germans wanted to undertake direct bombing of the American coastline using submarine-launched V-2s. This was their second new weapon against America. It was to come into action at the same time as the A-9, i.e. in early summer 1945...

[Albert Ducrocq (1921–2001) was a French scientist and science writer who was involved in the French investigations of German science and German scientists near the end of the war and after the war. He would have had considerable knowledge about German scientific plans and capabilities from his own investigations and also from former French (or other) workers that he had talked to.

His claims that German atomic bombs and delivery vehicles for them were ready or nearly ready by the end of the war agree with statements by many other independent sources.

According to Ducrocq, Germany had planned to launch a simultaneous attack on many Allied targets using its atomic bombs and different delivery vehicles for them. For independent confirmation, see pp. 4549–4550, 4587, 4621, 4627–4665, 4679–4681, 4766, 5038, 5454–5466.

For more information from Ducrocq, see pp. 5218, 5658–5659, 5666.]

Walter Dornberger. 1958. *V-2: The Nazi Rocket Weapon.* New York: Viking. pp. 138–140, 152, 236–237.

[pp. 138–140:] It was easy enough to see that the range of one-stage rockets, which had to go on carrying the useless deadweight of the empty tanks and heavy motors after the 'all-burnt', would never be appreciably increased. If we were going to add to the rocket's deadweight, already reduced to a minimum, any considerable load for long distances, even a change of propellants would be of very little use to us. The only exception would be a combination of hydrogen and oxygen with a theoretical exhaust velocity of over 10,000 feet per second. But this was for the time being out of the question because of the difficulty of handling liquid hydrogen. Nor would a bigger rocket help much. [...]

With an improved, lighter A4 type of one-stage rocket with relatively bigger tanks we might be able to achieve a range of 250 to 300 miles—but mainly at the expense of the warhead, that is, the payload.

We had to break new ground. Why need the rocket strike the ground at a speed of nearly 2,000 m.p.h.? If we gave it wings and took advantage of their lift, changing the trajectory to a glide after a suitable time interval, we could use the energy hitherto expended in making great holes in the ground to increase range.

Calculations showed that with such a structure we might achieve a range of 350 miles, which would be double that of the A4. [...]

Thus the A9 came into being.

Hundreds of calculations were made to plot the trajectory that would give the greatest range. Finally the missile was planned to reach, at a height of about 12 miles, a maximum speed of 2,800 m.p.h., and then go into a shallow curving glide with a peak of nearly 18 miles. On arrival over the target, at a height of about 3 miles, it was planned to fall perpendicularly, like the Fi 103 (V1).

It was only a step from the pilotless A9, with fully automatic guidance, to the piloted A9. This extremely fast aircraft, with a wing area of only about 145 square feet, had no military significance. Special landing flaps enabled it to land, after traveling about 400 miles in 17 minutes, at a speed of only 100 m.p.h.

This development of the A9, however, did not satisfy our ambitions. We wanted to cover thousands of miles. Our own private and exclusive sphere of activity began only beyond the extreme limit of the range of the heaviest aircraft.

Only by abandoning the one-stage for the multiple-stage rocket, that is, by dropping the dead weight when it had served its purpose and thereby improving the mass-ratio of the rocket, could we hope for these almost incredible range increases.

This was the origin of the A9/10 project. The object here was to cause the motors of the second stage (the A9) to begin firing only when the missile had reached a high speed by means of its first stage, which acted as a booster.

Catapulting was an alternative method of imparting a high starting speed to the A9. On the basis of calculations and experience with V1 launching sites, a long, inclined catapult had been designed capable of giving the A9 a launching speed of 800 m.p.h. This would have been sufficient for the fully fueled rocket to fly on smoothly, after leaving its launching ramp.

A better plan, however, and one which greatly improved range, was to construct the A10, weighing 87 tons and with a total propellant capacity of 62 tons, as the first stage of the combined A9/A10. The A9 was placed on top of the A10. The latter had a thrust of 200 tons for 50 to 60 seconds and gave the rocket a speed of 2,700 m.p.h. After exhaustion of the first stage the A9 would be ignited and lift out of the A10. The A9 was to tilt fairly sharply soon afterwards and reach a peak altitude of 35 miles. Then the long supersonic glide was to begin. Meanwhile the A10, equipped with brake-flaps and parachute, could be recovered for further use after drifting down on to water.

The A9, beginning to operate at a great height, would acquire an additional velocity of about 3,600 m.p.h., resulting in a maximal velocity of about 6,300 m.p.h. at the moment its motor cut off. A distance of 2,500 miles could therefore be covered in about 35 minutes. Like the single-stage A4 this two-stage rocket was to take off vertically and obviate the need for elaborate launching installations.

Countless trajectories were calculated by our outstanding expert in flight and ballistics, Dr. Steuding, and all of the factors involved, such as the earth's curvature and rotation, were taken into consideration. Guidance systems were investigated and development of the missile began.

For some months work on this project, which had been fully occupying large sections of our establishment, had ceased. I had forbidden further work on the plan in our practical branches, because of the urgency of the A4. Only the Projects Group was permitted to carry on.

During our frequent visits to this department we had repeatedly and thoroughly discussed these plans, due for practical development at an early date, as well as the optimal trajectory of the rocket. We had foreseen and planned for its use in time of peace. Very fast stratospheric rocket-aircraft, travelling at high supersonic speed, had reached design stage. They would be able to cross from Europe to America in 40 minutes.

Once we reached this stage the horses fairly bolted with us. With our big rocket motors and stage-rockets we could build space-ships which would circle the earth like artificial moons at a height of 300 miles and a speed of 18,000 m.p.h. Space stations and glass spheres containing the embalmed bodies of pioneers of rocket development and space travel could be sent round the Earth on endless journeys. Even an expedition to the moon was a popular topic.

We dreamed, too, of atomic energy, which would at last give us the necessary drive for flight into the infinity of pace, to the very stars. [...]

[p. 152:] I could not have been asleep long before I woke with a start.

Sssst—bang!

So Stölzel was doing his experimental firing after all.

Sssst—bang! Sssst—bang!

The window-panes rattled. Yet I had told Stölzel to set the time fuses so as not to disturb the peaceful slumbers of Peenemünde. [...] And I had given him permission to fire only 5 of the 15 rounds available. [...]

Something wrong there. That couldn't be Captain Stölzel, who had asked my permission that evening to carry out test firing during the night with his anti-dive-bomber tank weapon. It was not the 100 lb. high explosive charge of the 10-inch solid-propellant rocket which had awakened me from my first deep slumber and set the windows of my room rattling. [...]

Peenemünde was being raided! [...]

[pp. 236–237:] The demand from increased range made it necessary to start work again without delay on the winged A4, which had been lying fallow since spring 1943. We had named the winged A4 missile the A9. Ever since the beginning of the war we had seen that we could not tackle the A9 at Peenemünde as well as the A4 with any hope of its becoming operational before the end. The problems would have made far too many demands on our depleted staff. Some research had, however, been done in the wind tunnel since the spring of 1940 to determine the proper form of the supersonic wings and tail unit of the A9. The findings were now hastily dug out again and a schedule of tests drawn up.

On 8th January, 1945, the first A9 was launched. The control failed about 100 feet above the firing table. A few days later we were unable to launch a new projectile because the alcohol tank had developed a leak. At last, on the 24th, we had our first success. The rocket, climbing vertically, reached a peak height of nearly 50 miles at a maximum speed of 2,700 m.p.h. This purely rocket-powered aircraft, with a wing area of 145.32 square feet, broke the sound barrier without trouble. It flew with stability and steered automatically at both sub- and supersonic speeds. On the descending part of the trajectory, soon after the rocket levelled out at the upper limit of the atmosphere and began to glide, a wing broke. On the whole the result was eminently satisfactory and more than fulfilled our expectations.

Thus our theories on this design had been borne out as well. It was possible to cause rocket aircraft to fly at many times the speed of sound, and they could certainly be landed by means of braking and landing flaps. We were well on the way to solving a problem which, together with high-altitude research, was the first I had set myself to tackle after the war: the landing after a flight into airless space. We had taken a long stride forward in developing the first intermediate stage preceding the space-ship. Rocket aircraft could cover long distances in the upper stratosphere, at heights of 12–16 miles, at incredible speed and land in safety. If only we could succeed in maintaining full rocket thrust just long enough to ensure that we reached this height at very high supersonic speed, flying horizontally and in the right direction, and then either went into a glide or could switch in a low-thrust cruising motor using very little propellant, why, then we should be able to bridge thousands of miles by strictly economic means. Such were the ideas that occupied our minds in 1944. If we could realize them in practice we might hope to enrich international traffic, a few years after the war, with newer and bigger models. This revolutionary form of transport could never be rivalled for speed and range by normal propeller or jet-driven aircraft.

Basically the problem had already ceased to be a problem. It was only a question of working out the technicalities and devoting enough time to development. But the evacuation of Peenemünde put a stop to all further experiment.

[Dr.-Ing. Hermann Steuding was the main group leader for evaluation in the control and flight technology department BSM / A I (StF) in Peenemünde.]

[The raid was the Operation Hydra bombing attack on Peenemünde by the British Royal Air Force during the night of 17–18 August 1943.]

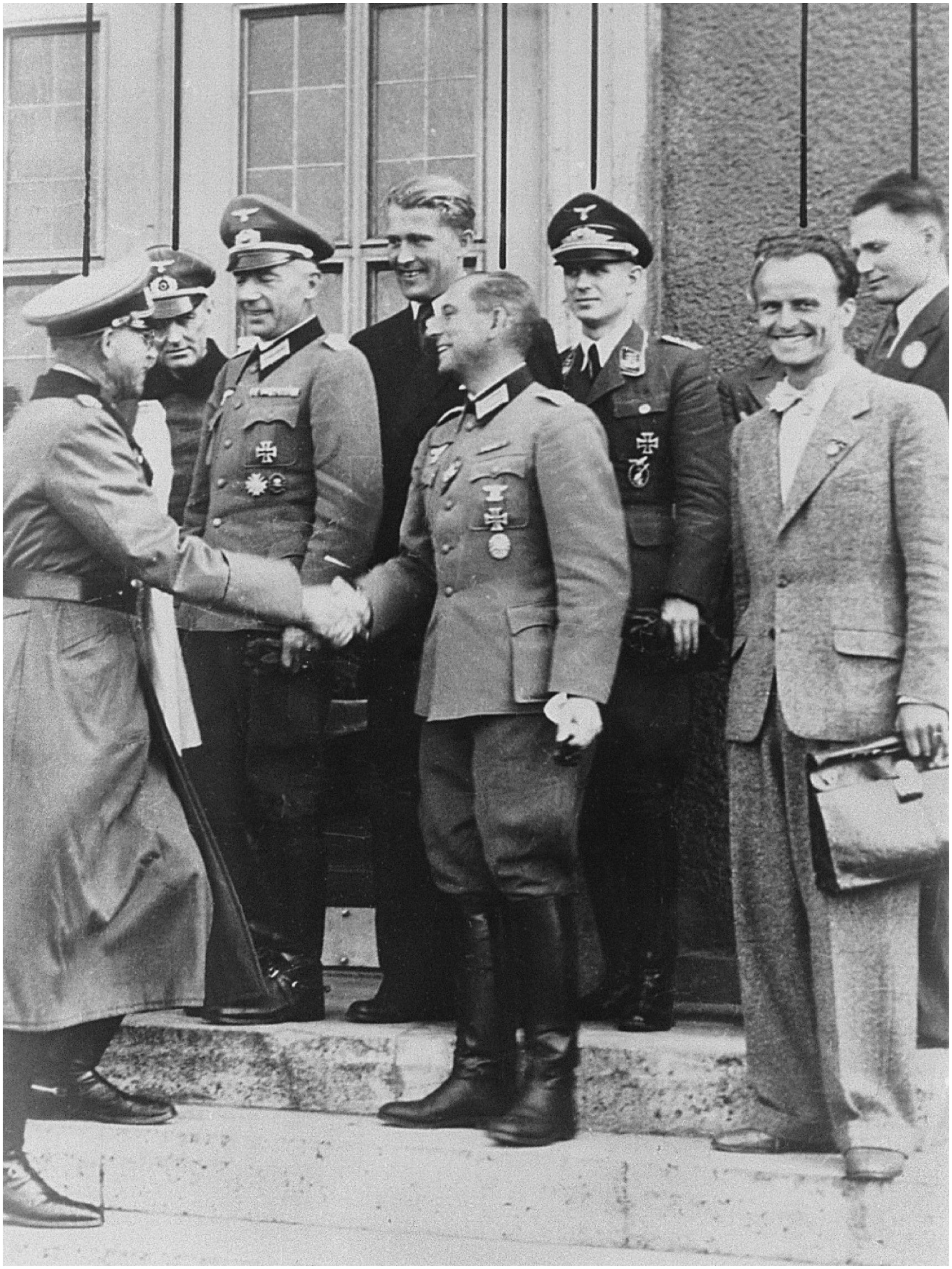
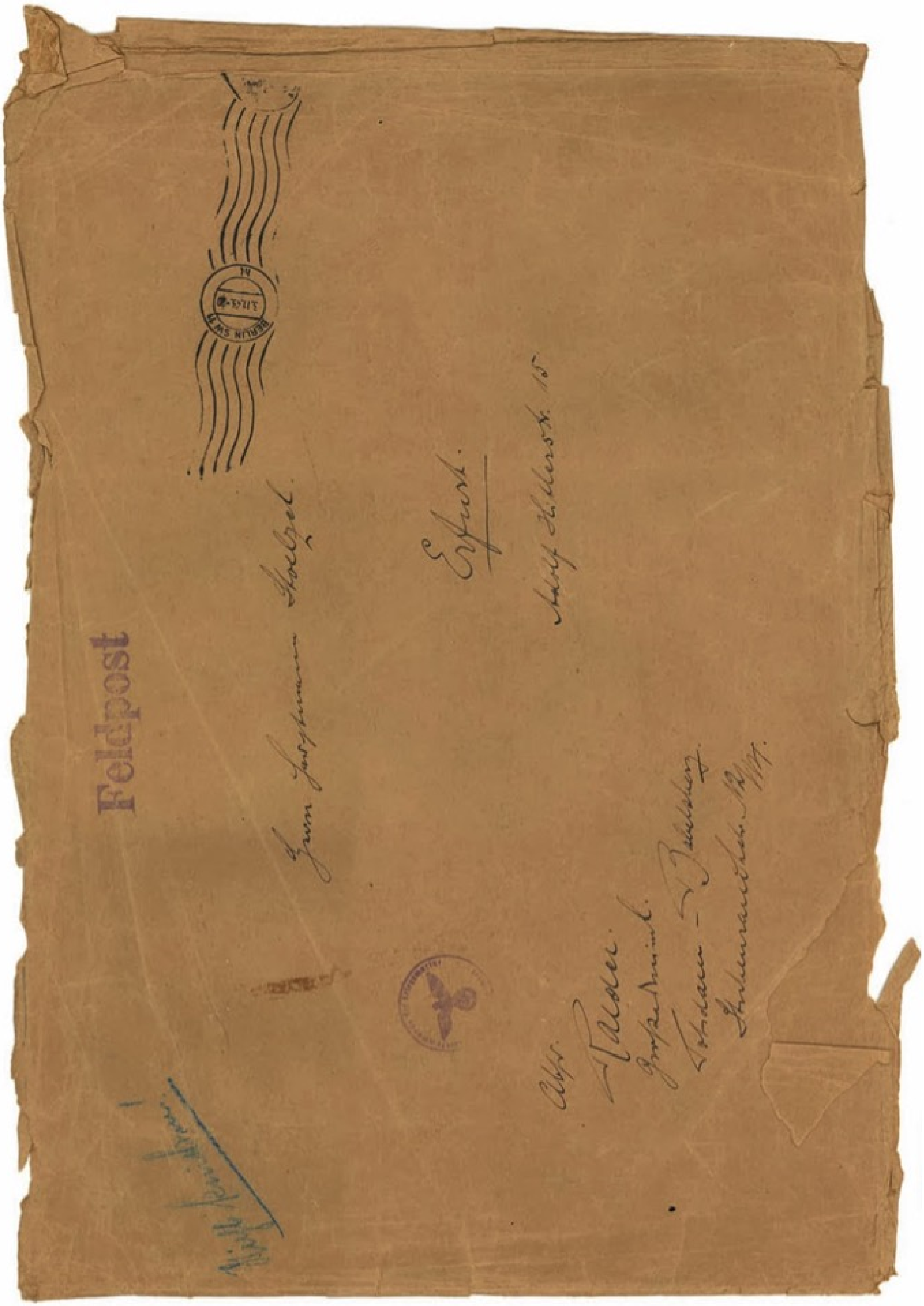


Figure E.94: Recognition for the first successful flight of the A-4/V-2 rocket on 3 October 1942, including Dr. Wernher von Braun (darkest civilian suit), Captain Heinz Stoelzel (young man in dark uniform standing to the right of von Braun as seen from our perspective), and General Walter Dornberger (in front of von Braun, wearing a hat).



Feldpost

Nicht knicken!

BERLIN SW 11 3.11.43 14

Herrn Hauptmann Stoelzel.

Erfurt.

Adolf Hitlerstr. 15

Abs.
Raeder.
Großadmiral.
Potsdam - Babelsberg.
Sternwartestr. 12/14.

Figure E.95: Envelope addressed to Heinz Stoelzel at Erfurt and postmarked 3 November 1943, suggesting that he may have been engaged in rocket development programs near Erfurt by then.

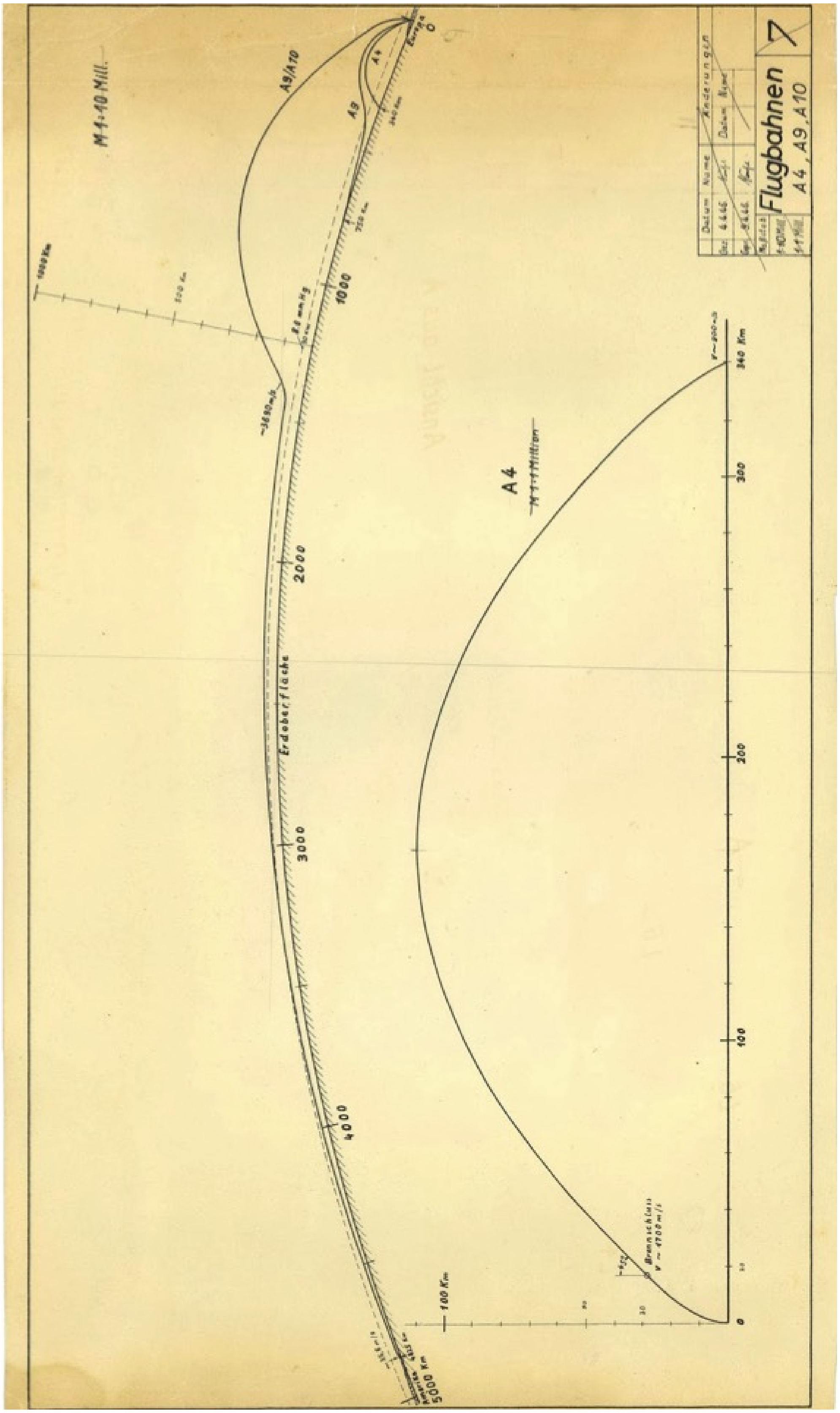

Flugbahnen
A4, A9, A10
7
Datum
Name
Änderungen
M 1:10 Mill.
A9/A10
A9
A4
1000 Km
500 Km
1000
2000
3000
4000
5000 Km
Erdoberfläche
A4
M 1:1 Million
340 Km
300
200
100
0
100 Km
Brennschluss
v ~ 1700 m/s

Figure E.96: Planned A9/A10 trajectory hand-copied in 1945 by Heinz Stoelzel.

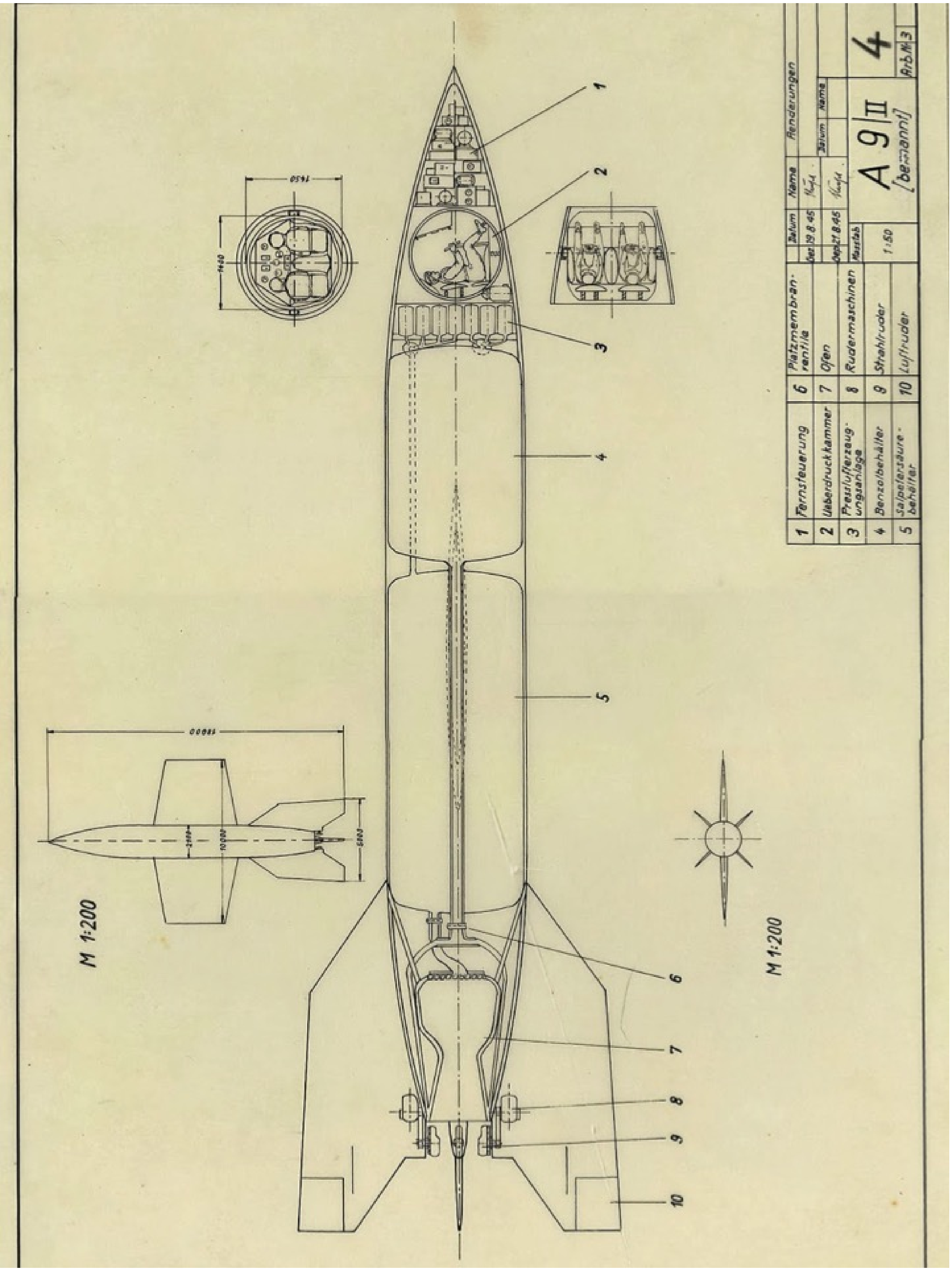

1 Fernsteuerung
2 Überdruckkammer
3 Pressluftererzeugungsanlage
4 Benzolbehälter
5 Salpetersäurebehälter
6 Plattenmembranventile
7 Ofen
8 Rudermaschinen
9 Strahlruder
10 Luftruder
Datum
Name
Gez. 19.8.45
Gepr. 27.8.45
Massstab
1:50
Aenderungen
Datum
Name
A 9/II
[bemannt]
4
Arb.Nr. 3
M 1:200
M 1:200
1450
1400
18000
2500
10000
5000
1
2
3
4
5
6
7
8
9
10

Figure E.97: Design for A-9 upper stage with a two-man crew to be launched into space, hand-copied in 1945 by Heinz Stoelzel. The vast majority of Stoelzel's papers were destroyed after his death, including the A-10 lower stage design if it was in his possession.

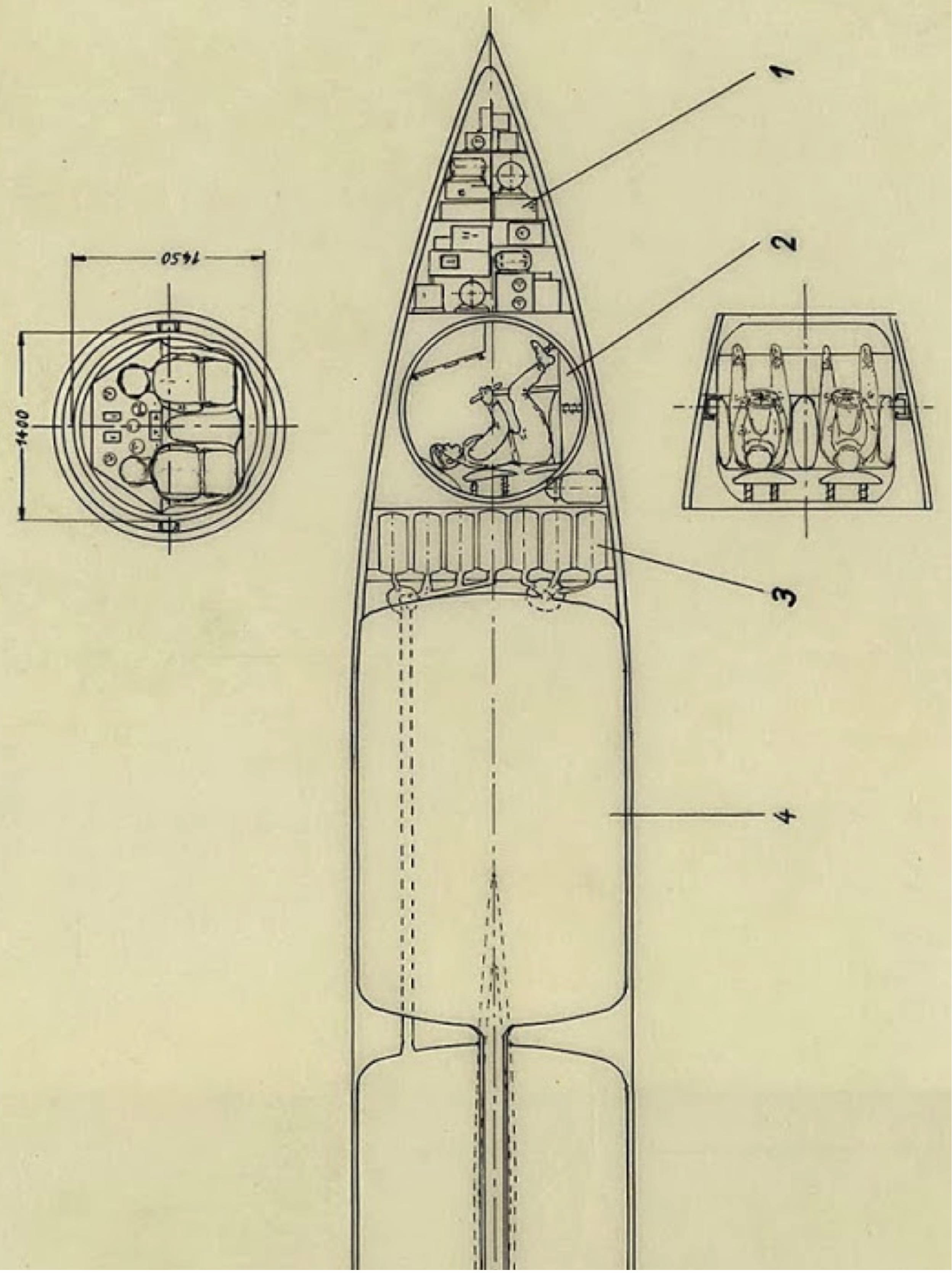


Figure E.98: Detail from Heinz Stoelzel's drawing of the A-9 upper stage showing the two-man crew.

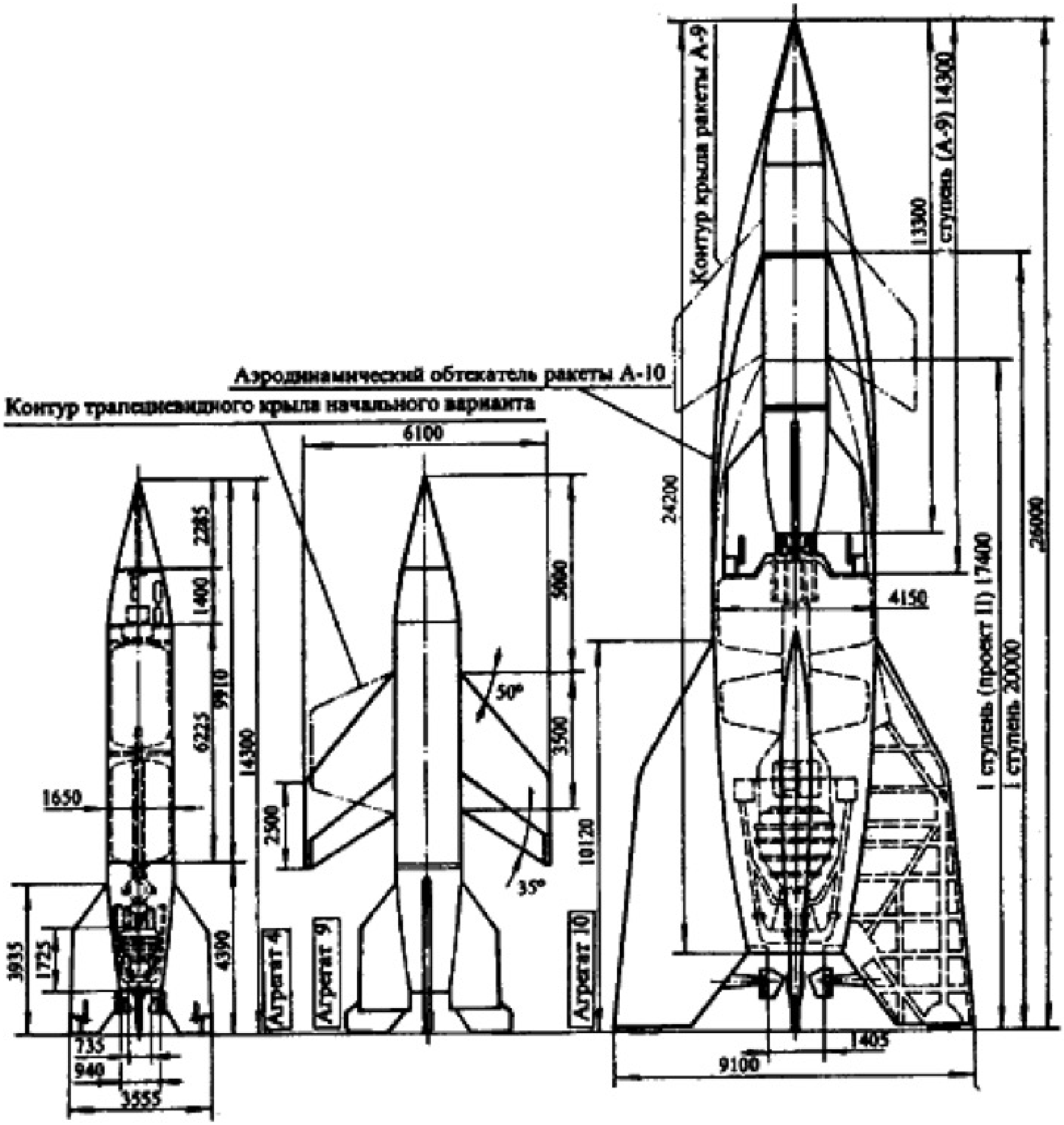

Контур крыла ракеты А-9
ступень (А-9) 14300
13300
Аэродинамический обтекатель ракеты А-10
Контур трапециевидного крыла начального варианта
6100
2285
1400
9910
6225
14300
1650
3935
1725
4390
735
940
3555
Агрегат 4
Агрегат 9
5060
50°
3500
2500
35°
10120
Агрегат 10
24200
4150
I ступень (проект II) 17400
I ступень 20000
26000
1405
9100

Figure E.99: Russian description of German plans and/or equipment captured in 1945, showing complete intercontinental missile with A-9 upper stage on A-10 lower stage [http://epizodsspace.airbase.ru/bibl/k-r/1998/5/fau2.html].

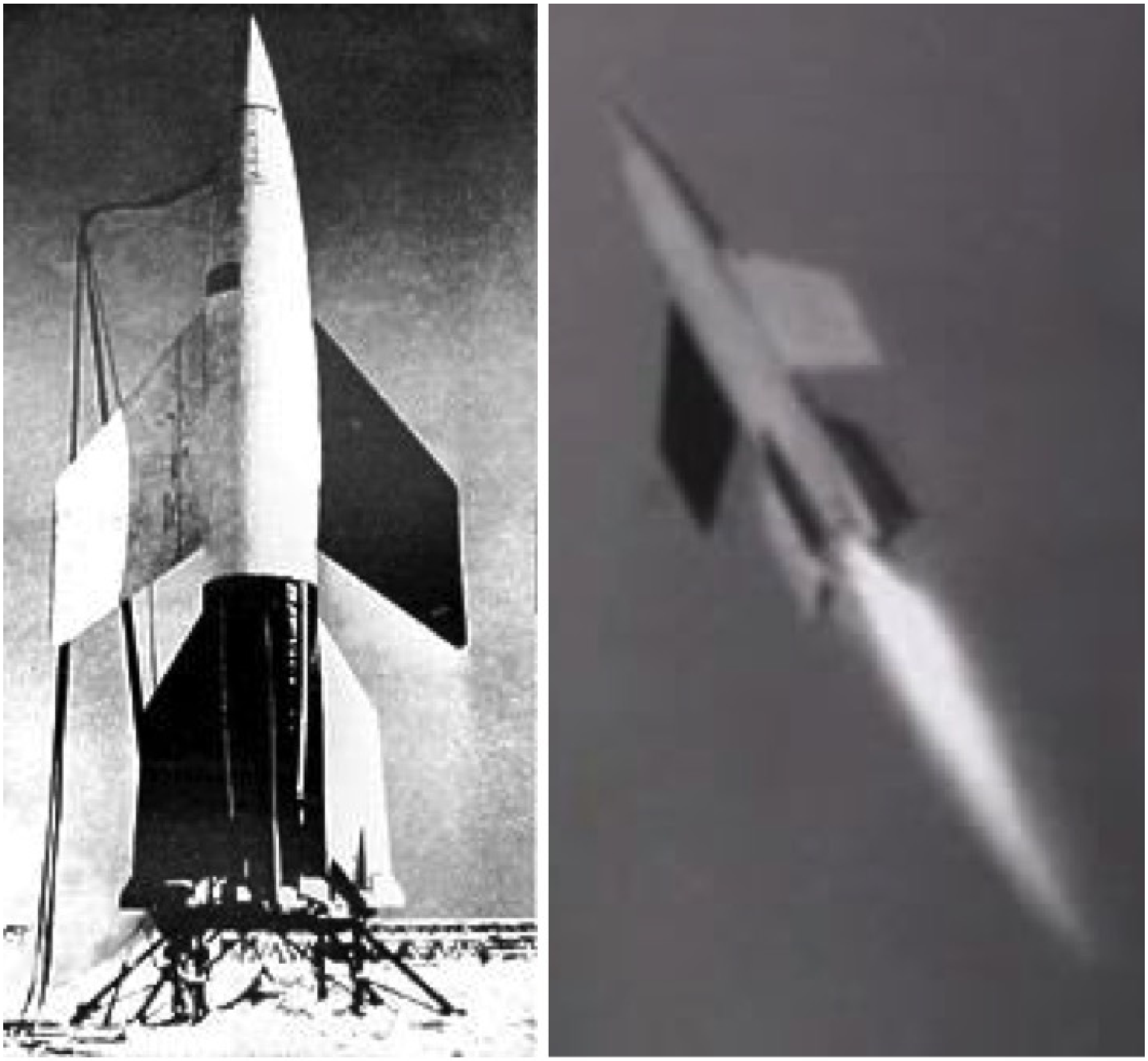


Figure E.100: Test launch of A-9 (A-4b) upper stage (24 January 1945).

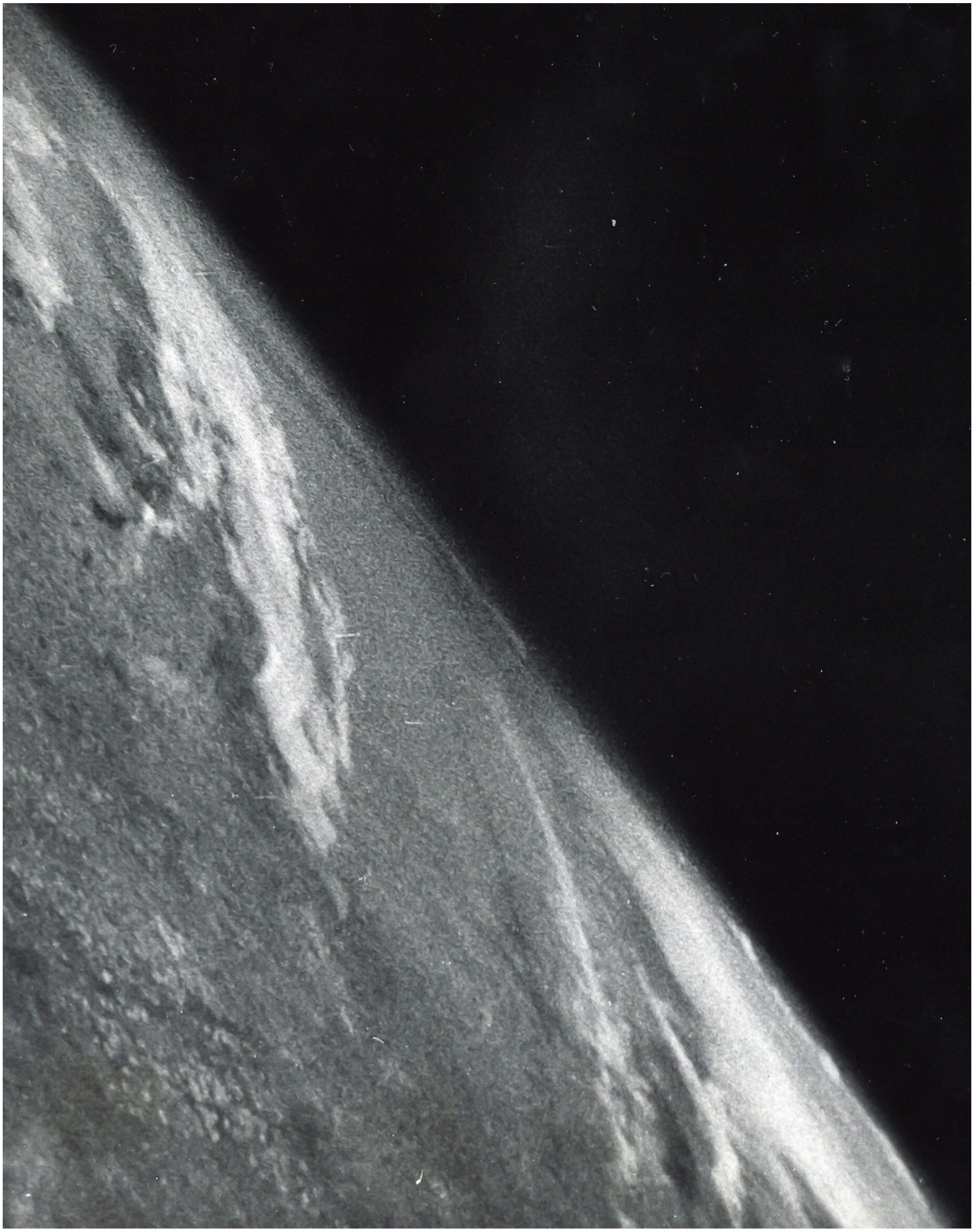


Figure E.101: Photograph of Earth from space, taken using a German A-4 rocket captured and tested by the United States (White Sands Missile Range, 24 October 1946).

CIOS ER 38. *Luftschiffbau Zeppelin—Dir. Eckener.* 25 May 1945. [See also p. 5327.]

[...] DIR. KURT ECKENER was interviewed and gave information:- Luftschiffbau Zeppelin made only the A and B tanks for the A-4, eastings thereto and part of the outer case. The threefold tube casting caused trouble owing to leaks developing.

The tanks were developed by L. Z. who also helped other firms to go into production. One of the main of these firms was Schindler of Kennelbach, Austria, Nr. Bragenz where tanks can probably be found now. DR. VON BRAUN was the Peenemünde representative with whom this firm carried out the development; he gave them an order for tanks of the same diameter but about 20 cm. longer than normal, and about ten of these were made. Some of these should also be available at Kennelbach. In full production 200 pr. of tanks were produced, and 350 bodies. At first they were despatched assembled (but later not) to Mittleberg (werk?) in Harz.

Leichtmetall-Regensburg, Meldewerke-Slesian, Marcus-Berlin also made tanks. The only special tool involved was a welder used on the tanks which is available at the works. All the documents were removed by the French. Herr Zalewski-Neurenborn could give more detail on the tanks and construction. Venturis, Eckener said, were made by Linke-Hoffmann.

The only development of A4 of which Eckener had heard was one of the same size with lateral wings [A-9 or A-4b] which was to have a range of 10,000 Km. and a ht. [maximum altitude] of 60 Km [on an A-10]. One of these had been constructed at Peenemünde. It is possible that this might have been flown by a pilot. One of Eckener's test pilots was exceedingly keen to fly an A4 and had asked him to approach von Braun to suggest this. One of his test pilots had been killed previously flying a V-1. [...]

ZALEWSKI, when interviewed, gave information:-
L. Z. produced only the middle part of the rocket i.e. the tanks and surrounding body. Components to the rear (mainly of ferrous composition) were produced by Linke-Hoffmann of Breslau. Turbines were produced by Walther-Kiel who also with Siemens produced electrical apparatus. [...]

He named ten firms engaged on production of tanks. They were:-

(1) L. Z.—Friedrichshafen.

(2) Austria—Vienna.

(3) Bertram Müller—Weidenein.

(4) Wezel—Uhingen, Nr. Stuttgart.

(5) Marcus—Berlin.

(6) Melder—Freistadt i/e S.

(7) Metallbad—Halberstadt.

(8) Gebrüder Hermann—Köln.

(9) Mittelwerke—Halle.

(10) Schindler—Kennelbach, an associated firm.

Swiss Turning a Deaf Ear to Stories of Nazi Infiltration. *The Swiss Observer* (Journal of the Federation of Swiss Societies in the U.K.) 31 January 1947. [https://doi.org/10.5169/seals-686905]

Reprinted from "New York Herald Tribune."

[...] There has been a great outcry in Switzerland also over the immigration of Captain Heinz Stoelzel, once liaison officer between the army and the German scientists who were working in research laboratories at Peenemünde where the V-2 rockets were developed. Stoelzel is known to be an unrepentant German, and proud of his nation, however he may feel about Nazism. When he arrived in the country last summer he was invited to lecture before the Swiss Federal Institute of Technology.

In his lecture he asserted that Germany was well on its way to perfecting the atomic bomb and then aroused some popular wrath by crying: "Thank God, the Allies did not seriously damage Peenemünde. German research will always continue, and in years to come will make important contributions to science, just as in years gone by." [...]

Cables from the files of Leslie Groves. [NARA RG 77, Entry UD-22A, Box 160, Folder In & Out July 16, 1946–Jan. 1947]

From: Bern Switzerland sgd Harrison

To: State Department

Nr: A 433 23 September 1946

Reference is made to the Legation's confidential airgram No. A-423 to the Department of September 11, 1946, copy of which was sent to Berlin, with respect to the German military internee, Heinz Stoelzel, presumed to be identical with the German national of the same name who delivered a lecture at the Swiss Federal Technical Institute at Zurich on V-2 bomb production as reported in the Legation's restricted airgram A-385 of August 19, copy of which was forwarded to Berlin.

As a result of investigations conducted by Mr. Leonard L. Bacon of the American Consulate General, Zurich, it has now been definitively ascertained that the Legation's presumption as to the identity of Heinz Stoelzel is correct. The Consulate General reports that it has interviewed Mr. Pierre Schwaar, the author of the Die Nation article quoted in the Legation's A-385 and that Mr. Schwaar, who attended Stoelzel's lecture, states that it was conducted under the auspices of the Swiss Federal Technical Institute's School of Aerodynamics. Stoelzel was introduced by Dr. J. Ackeret, Head of the School, with the preface that Stoelzel "was a German scientist with practical experience in his speciality of rocket projectiles". The Consulate General conveys Schwaar's impression that Stoelzel treated the subject in a superficial and "popular" manner; that most of his information appeared to come chiefly from American popular magazines; and that Stoelzel endeavored to give the impression that whereas the atom bomb was all very well as a military weapon, the Germans had developed a principle of application of energy which had immediate peacetime uses.

The Consulate General further reports that it has succeeded in obtaining the following highly confidential information from the office of the Zurich Cantonal Fremdpolizei:

"According to the police file, Stoelzel was born on February 2, 1916, in Germany; birthplace and residence unknown. He was a captain in the Wehrmacht and assigned to the rocket-bomb plant at Peenemünde, at an unknown date he came into Switzerland as a deserter and was interned. In March 1946 he was reclassified as a refugee after examination by the Bundespolizei in pursuance of the general policy of transferring military internees from Army control to police supervision. He was then granted a "Studiumbewilligung" or study permit at the Swiss Federal Technical Institute as an expert on rocket projectiles and took up residence in Zurich at 25 Rosslistrasse. The Kantonal Fremdenpolizei received in August of this year from the Police Division of the Federal Justice and Police Department at Bern a letter stating that Stoelzel was to be repatriated to Germany 'immediately'. This has not yet occurred. The Fremdenpolizei had a copy of Stoelzel's lecture and apparently took an interest in his point of view.

The Legation proposes, through the medium of the American representative on the Joint Allied-Swiss Commission established under the Washington Accord, to present Stoelzel's name as a candidate for repatriation by the Swiss Government. In the event that the Swiss Government agrees to this suggestion, the Legation will, if possible, notify promptly the appropriate authorities in Germany in order that a carefully kept supervision of him there may be effected.

With respect to Stoelzel's associates, Lt. Kunick and Capt. Riedl, referred to in the SSU, Bern, report quoted in the Legation's A-423, the Military Attaché has made available to the Counselor of Legation for Economic Affairs copies of reports prepared by his office on April 4 and April 17, 1946. These reports indicate that Riedl vanished from the internment camp at Weesen and presently is living with his American wife at Ascona. Kunick, although nominally still interned at Weesen, makes frequent trips to Zurich where he is seeking employment.

The Legation will continue to report such additional information with respect to these 3 cases as may come to hand.

[...] INFO: AAF, ASW, CAD, P&O, R&D, Gen Groves, [...]

From: Bern Switzerland sgd Harrison

To: Secretary of State

Nr: A 468 16 October 1946

Reference is made to the Legation's secret airgram No. A-433 of September 23, 1946 to the Department, copy of which was forwarded to Berlin, with respect to the German military internee Heinz Stoelzel.

In accordance with the proposal outlined in the reference airgram, the American member of the Joint Allied Swiss Commission has inquired on behalf of all Allied members the position of the Swiss Government with respect to the freedom accorded Stoelzel and other German military internees and the likelihood of his and their repatriation. This request was made at the October 3 meeting of the said Commission. No response thus far has been made by the Swiss member.

The Department will have noted the allusion in the reference airgram to Professor J. Ackeret, Head of the Swiss Federal Institute's School of Aerodynamics, who introduced Stoelzel at the latter's lecture at Zurich on June 28, 1946. The Consulate General at Zurich has indicated its intention to make further inquiries with respect to Professor Ackeret. The Legation has noted that Professor Ackeret's name is No. one on the list of "Suggested Repatriations from Switzerland" dated August 19, 1946, prepared by the Department's Division of Economic Security Controls, recently transmitted to this Legation. Such a listing would suggest that the Department regards Professor Ackeret as a German national. The Legation's information, however, indicates that he is a Swiss national. In this connection, the Legation quotes herewith the following report submitted to the Counselor of Legation for Economic Affairs under date of October 14, 1946 by local office of SSU:

"According to our information Ackeret is a Swiss national but very pro-German and was pro-Nazi. He is the co-inventor of the experimental Ackeret-Keller internal combustion turbine. In conjunction with Keller who is completely under his influence, Ackeret was trying to form a Swiss cooperative research group to work on jet propulsion aircraft. It is believed that this is being done with an eye to future cooperation with Germany because other projects of more immediate profit were being shelved in favor of a scheme which will, at best, not be profitable for years."

"The above information is dated May 1945."

The comments of the Consulate General at Zurich with respect to Professor Ackeret will be transmitted to the Department upon receipt.

[...] INFO: AAF, ASW, CAD, P&O, R&D, Gen Groves [...]

[The *Swiss Observer* and *New York Herald Tribune* reported that Heinz Stoelzel "asserted that Germany was well on its way to perfecting the atomic bomb." What information did Stoelzel have about the German atomic bomb? Did his knowledge come from the fact that he was developing intercontinental rockets to carry such a bomb?

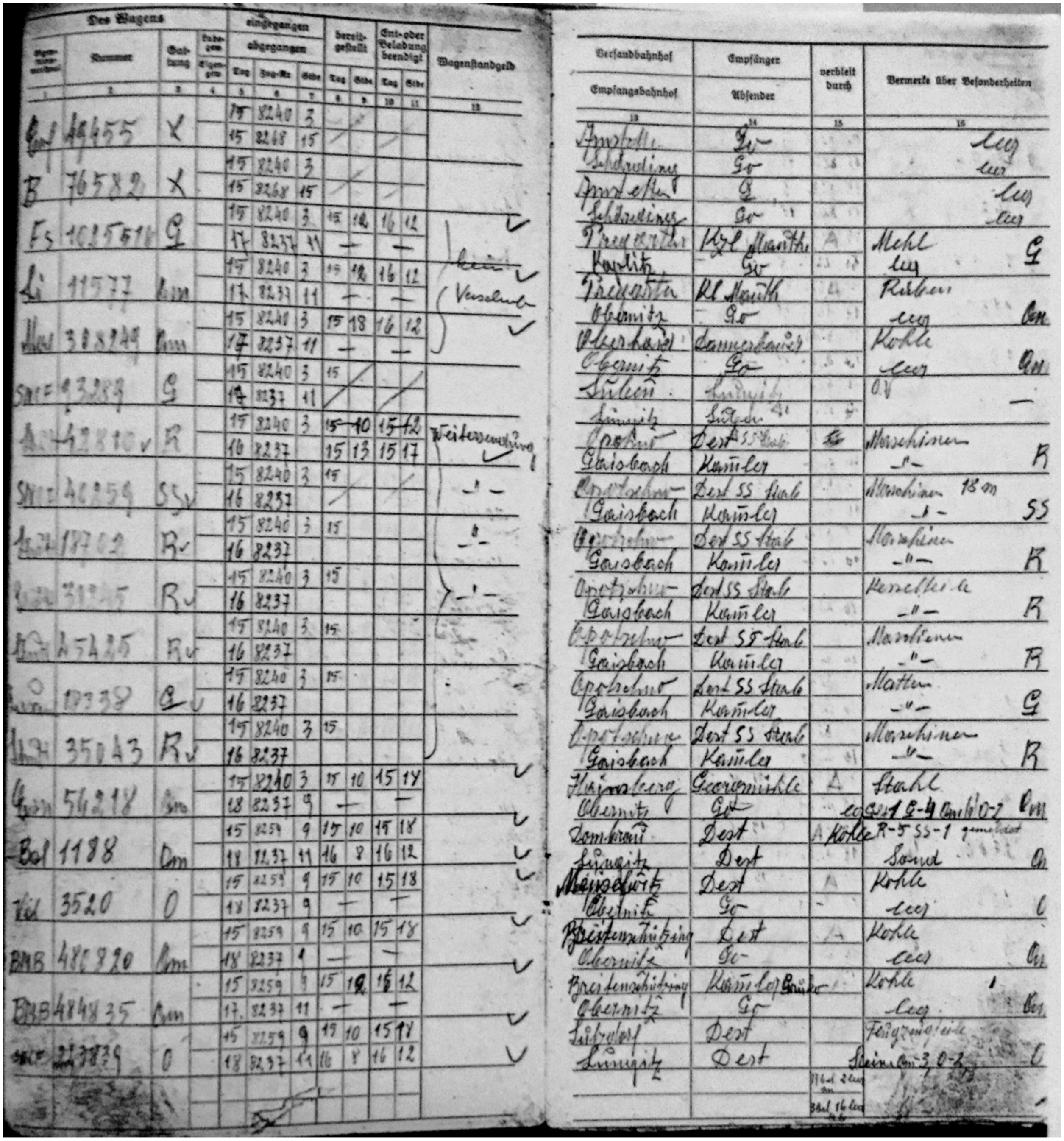
Why was this information on Stoelzel sent directly to the attention of Leslie Groves, where it remains in his files at the U.S. National Archives and Records Administration? Does this incident suggest that Groves knew that there had actually been a German atomic bomb project, and was taking action behind the scenes to ensure that no one (even a lone refugee in Switzerland) spoke out about it?

Essentially all of the other scientists who had been involved in wartime German programs to develop and deliver weapons of mass destruction were employed by and under the tight control of various Allied governments, either in those Allied countries or in Allied-occupied zones of Germany and Austria. Among the knowledgeable alumni of those wartime German programs, Heinz Stoelzel was virtually alone in being free of Allied employment, free of living in an Allied country or an Allied-occupied country, and free to publicly reveal the true facts about how far those wartime programs had progressed. Thus Groves and other high-ranking Allied officials who were aware of the wartime German programs would have viewed Stoelzel as a unique threat.

Note the line in the 23 September 1946 cable: "in order that a carefully kept supervision of him there may be effected." After this incident, Stoelzel did indeed return to Germany, where he apparently kept a very low profile for the rest of his life. His silence from then on may have been enforced by government minders and censors, or it may have been self-imposed to avoid the likely unpleasant consequences.

A corollary to this discussion is that all of the German and Austrian scientists working for Allied countries (or under Allied scrutiny in Germany and Austria) would have been censored by the same sort of "carefully kept supervision" of their public statements for the rest of their lives. Thus it is no surprise that they made so few comments (only the occasional slips) for the rest of their lives about how far the wartime German programs had progressed.

The statements of U.S. officials in these documents do not seem to reflect favorably on them when viewed by a modern reader. Jakob Ackeret (1898–1981) was a Swiss citizen, born in Zurich, and a famous professor of aerodynamics who had been teaching at the university in Zurich since 1931. Despite those facts, U.S. officials claimed that he was a German citizen and made him priority number one on their list of people that the United States was ordering Switzerland to deport to Germany, from whence presumably the United States itself would seize him (and his research). It seems as if the most damning evidence that U.S. officials could cite against Professor Ackeret was that he passed up "other projects of more immediate profit" because he was more interested in working on a much more innovative research "scheme which will, at best, not be profitable for years." Apparently the U.S. officials could not even imagine why someone might prefer to pursue long-term innovative research over short-term non-innovative commercial profit, and were convinced that must mean that Ackeret was part of an evil conspiracy. How common was this mindset?]



A train shipment of "18 m machines" and accessories was apparently personally forwarded by Hans Kammler in St. Georgen an der Gusen, Austria on 15–16 March 1945

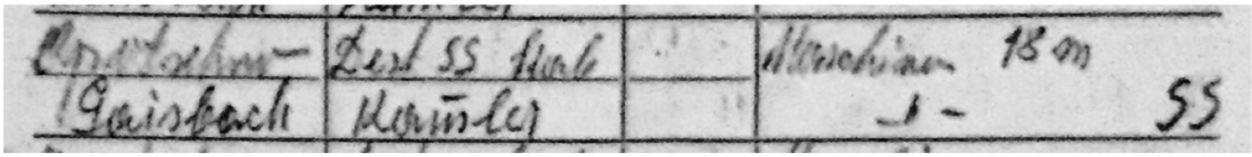


Figure E.102: A shipment of "18 m machines" and accessories was sent by train to the SS staff leadership at DEST (St. Georgen an der Gusen) on 16 March 1945, and apparently personally forwarded by Hans Kammler from there to Gaisbach, Austria on 16 March 1945, as indicated by a logbook of train shipments [Collection Rudolf A. Haunschmied, from St. Georgen an der Gusen train station]. Could these high-priority 18-meter-long machines have been advanced rockets?

Charles R. Christensen. 2002. *A History of the Development of Technical Intelligence in the Air Force, 1917-1945: Operation Lusty.* Edwin Mellan Press. p. 189

Dr. A. Pohlhausen from the Peenemunde Group assisted Northrop Aircraft Company with guidance system for their missile development program. Pohlhausen had worked out the mathematical formula for the motion of a gyroscope under high G-forces. His work was being used to develop a guidance system for the transoceanic A-10 surface-to-surface missile when the war ended.

[See also pp. 2938–2962.

Dr. A. Pohlhausen appears to be Dr. Karl Pohlhausen. For biographical information that is remarkably silent on his wartime work, apart from confirming that his first postwar work was on guidance systems, see: https://www.annualreviews.org/doi/pdf/10.1146/annurev.fl.16.010184.000245

Christensen also cited AFHRA documents [Christensen 2002, pp. 198–199]:

Colonel H. M. McCoy to Commanding General, AAF, Subject: "Effect of Possibly Reduced Funds for Project PAPERCLIP." Letter with Exhibits "A"–"H" dated 12 June 1947 in Air Materiel Command (AMC) History Office. "History of AAF Participation in Project PAPERCLIP, vols. I and II" May 1945–August 1948, dated August 1948, Air Force Materiel Command History Office (AFMC/HO), Boxes 340 and 341, Loose Files attached to reports.

Christensen notes: "McCoy's June 1947 letter with annexes is a full accounting of the support provided to the Air Force from German scientists. Annex 'B,' which is 29 pages long, provides a detailed summary of support given to jet, guided missile, materials, electronics, and aeromedical research by scientific specialists."]

Winston Churchill. 13 May 1945. BBC London.
[https://www.ibiblio.org/pha/policy/1945/1945-05-13a.html]

There was one final danger from which the collapse of Germany has saved us. In London and the south eastern counties we have suffered for a year from various forms of flying-bombs—perhaps you have heard about this—and rockets, and our Air Force and our ack-ack batteries have done wonders against them. In particular the Air Force turned on in good time on what then seemed very slight and doubtful evidence, hampered and vastly delayed all German preparations. But it was only when our Armies cleaned up the coast and overran all the points of discharge, and when the Americans captured vast stores of rockets of all kinds near Leipzig, which only the other day added to the information we had, and when all the preparations being made on the coasts of France and Holland could be examined in detail, in scientific detail, that we knew how grave had been the peril, not only from rockets and flying-bombs but from multiple long range artillery which was being prepared against London. Only just in time did the Allied armies blast the viper in his nest. Otherwise the autumn of 1944, to say nothing of 1945, might well have seen London as shattered as Berlin.

For the same period the Germans had prepared a new U-boat fleet and novel tactics which, though we should have eventually destroyed them, might well have carried anti-U-boat warfare back to the high peak days of 1942. Therefore we must rejoice and give thanks, not only for our preservation when we were all alone, but for our timely deliverance from new suffering, new perils not easily to be measured.

Ernst Krause. Interviewed by David DeVorkin. 10 August 1982.
[https://www.aip.org/history-programs/niels-bohr-library/oral-histories/28022]

DeVorkin: Okay. We're talking about a period that already brings us up into '44 and '45, and I don't want to leave the war years certainly without talking about your second tour to Europe and your interrogation of German scientists. Is this an appropriate time to find out, (a), how you got into it, and (b), what transpired?

Krause: All right. It's a good point in time, yes. What had happened toward the end of the war, and we're now in something like early 1945, spring [...] We went to Garmish Partenkirchen. In fact, we were in Paris, at which point I was joined by a Navy Intelligence officer from ONI, and he and I drove a jeep from Paris to Munich. I was part of the R. Porter group which had been constituted by the Army. Porter was from General Electric and had been working on some Army programs. [...]

In any case, when we went to interview the German technical people in Garmish, the incident that is of interest here is the fact that the intelligence officer said, "Now, don't you technical fellows start talking. We have to soften these people up first. We have experience in this, and let us get them softened up first and then they'll start talking. They won't want to talk initially." We agreed. Our first interview was with three of the Germans, two of whom were technical people. As soon as these three Germans sat down and we sat down at the table, the Germans began talking and talking and talking about what they had developed, what further advances they had on the drawing board, what they could do with the V-2 to improve it, to expand it, to extend its range, to improve its guidance accuracy—all of these things they had worked out in great detail, and they wanted to tell us about it.

DeVorkin: They were not speaking through a translator? You knew German well enough?

Krause: I knew German well enough. We did have a translator present. I understood German well enough so that I didn't really need the translation. In any case, the discussion went on and on. Pretty soon they pointed out that they had on the drawing boards the complete analysis and design for a V-2 which would extend its range to 3000 miles, which I think they called the V-2 A or B.

DeVorkin: The Wasserfall?

Krause: The Wasserfall was one of the German missiles, but as I recall, was not one of the V-2 long range variants. They stated that one of the V-2 design variants included small wings to provide aerodynamic glide on re-entry which would extend its range to 3000 or more miles. With this design it would be possible to set up a launch site somewhere in the state of Washington, and bomb Tokyo.

DeVorkin: That, I didn't know.

Krause: They argued that if only the Americans would now get behind us, and take them, the group, to the U.S., they could set this up in so many days, (they'd worked it all out), and they'd bomb Tokyo.

[Although Krause's memory of details is fuzzy after nearly 40 years, his description of the 3000-mile rocket agrees well with archival documents: a V-2 variant with wings, a longer range, and the letters "A" and "B" in the name (A-4b); the 3000-mile range (if used on an A-10 first stage, which was frequently assumed without being explicitly stated in documents); German experts who believed that goal was very close to being achieved; Allied officials who wanted to use as much German technology as possible against Japan in the time between V-E Day and V-J Day; etc.

One key point from this interview is that the German experts proposed to set up a 3000-mile-range rocket "in so many days" so that the United States could quickly bomb Tokyo. That demonstrates that such long-range rockets were already at a highly advanced stage of development (contradicting Krause's claim elsewhere that they were only "on the drawing board").

Another key point is that both the Germans and the Allies involved in Krause's circa May 1945 discussion would have known that the only way it would be even remotely attractive to build and launch a long-range rocket at Tokyo is if the rocket had a nuclear payload. (U.S. planes were already dropping lots of conventional bombs on Japan—why deliver one more the hard way?) The Allied officials in that discussion likely did not know that the United States would soon have its first fission bombs, and they certainly would not have told the Germans. These German engineers would not have known about the Manhattan Project from any other sources. So if the German engineers and the Allied representatives they were talking to were thinking about a nuclear weapon available for near-term use against Tokyo, they would have been thinking about a German nuclear weapon, and one already specifically designed to mount on a rocket.]

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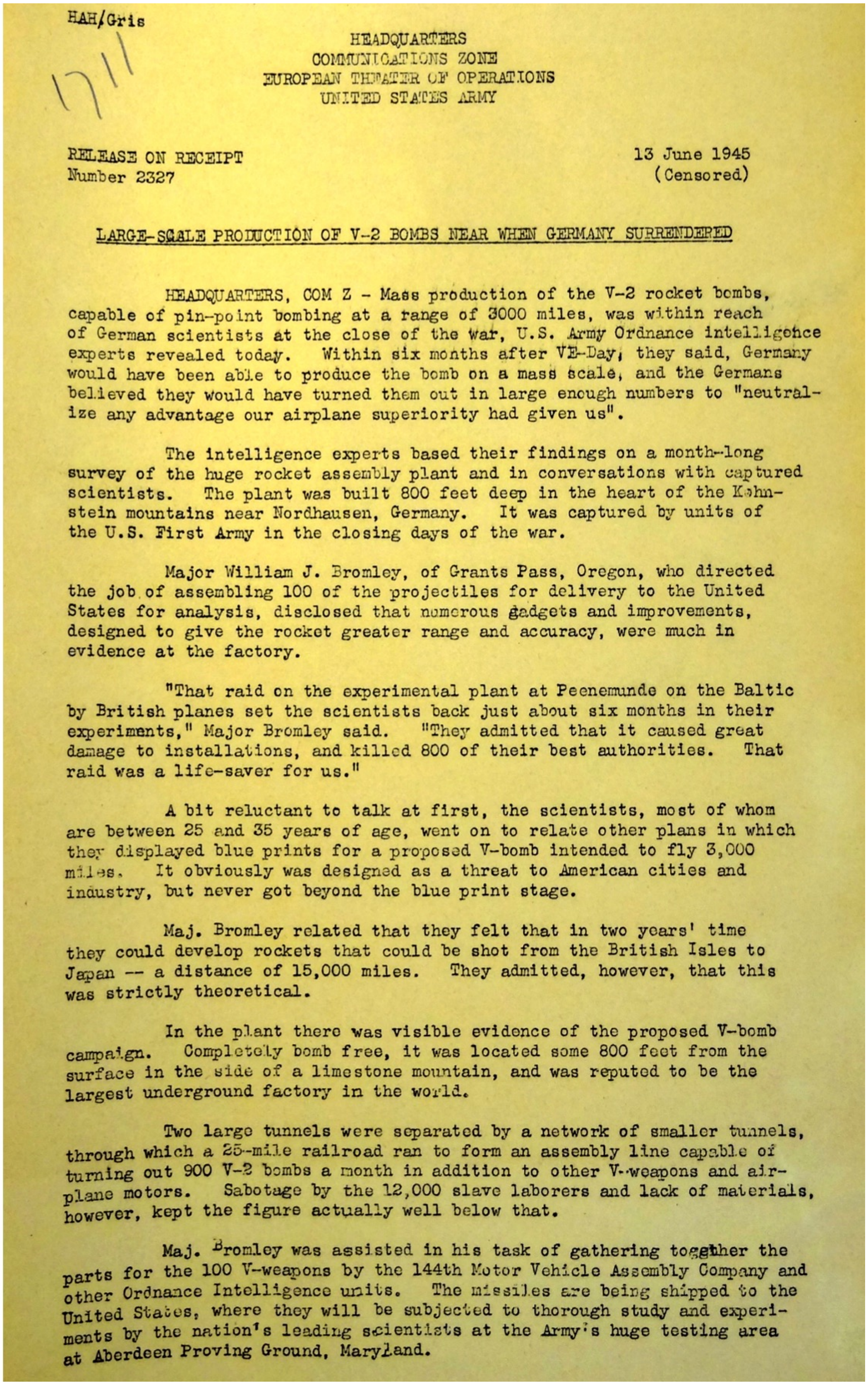

HAH/Gris

1711

HEADQUARTERS
COMMUNICATIONS ZONE
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY

RELEASE ON RECEIPT
Number 2327

13 June 1945
(Censored)

LARGE-SCALE PRODUCTION OF V-2 BOMBS NEAR WHEN GERMANY SURRENDERED

HEADQUARTERS, COM Z - Mass production of the V-2 rocket bombs, capable of pin-point bombing at a range of 3000 miles, was within reach of German scientists at the close of the war, U.S. Army Ordnance intelligence experts revealed today. Within six months after VE-Day, they said, Germany would have been able to produce the bomb on a mass scale, and the Germans believed they would have turned them out in large enough numbers to "neutralize any advantage our airplane superiority had given us".

The intelligence experts based their findings on a month-long survey of the huge rocket assembly plant and in conversations with captured scientists. The plant was built 800 feet deep in the heart of the Kohnstein mountains near Nordhausen, Germany. It was captured by units of the U.S. First Army in the closing days of the war.

Major William J. Bromley, of Grants Pass, Oregon, who directed the job of assembling 100 of the projectiles for delivery to the United States for analysis, disclosed that numerous gadgets and improvements, designed to give the rocket greater range and accuracy, were much in evidence at the factory.

"That raid on the experimental plant at Peenemunde on the Baltic by British planes set the scientists back just about six months in their experiments," Major Bromley said. "They admitted that it caused great damage to installations, and killed 800 of their best authorities. That raid was a life-saver for us."

A bit reluctant to talk at first, the scientists, most of whom are between 25 and 35 years of age, went on to relate other plans in which they displayed blue prints for a proposed V-bomb intended to fly 3,000 miles. It obviously was designed as a threat to American cities and industry, but never got beyond the blue print stage.

Maj. Bromley related that they felt that in two years' time they could develop rockets that could be shot from the British Isles to Japan -- a distance of 15,000 miles. They admitted, however, that this was strictly theoretical.

In the plant there was visible evidence of the proposed V-bomb campaign. Completely bomb free, it was located some 800 feet from the surface in the side of a limestone mountain, and was reputed to be the largest underground factory in the world.

Two large tunnels were separated by a network of smaller tunnels, through which a 25-mile railroad ran to form an assembly line capable of turning out 900 V-2 bombs a month in addition to other V-weapons and airplane motors. Sabotage by the 12,000 slave laborers and lack of materials, however, kept the figure actually well below that.

Maj. Bromley was assisted in his task of gathering together the parts for the 100 V-weapons by the 144th Motor Vehicle Assembly Company and other Ordnance Intelligence units. The missiles are being shipped to the United States, where they will be subjected to thorough study and experiments by the nation's leading scientists at the Army's huge testing area at Aberdeen Proving Ground, Maryland.

NARA RG 331, Entry 83D, Box 33, Folder
S.H.A.E.F. Releases (2 folders)/ 1 June 20 June 45

Figure E.103: U.S. Army, 13 June 1945 press release [NARA RG 331, Entry 83D, Box 33, Folder S.H.A.E.F. Releases (2 folders)/ 1 June 20 June 45].

U.S. Army, 13 June 1945 press release [NARA RG 331, Entry 83D, Box 33, Folder S.H.A.E.F. Releases (2 folders)/ 1 June 20 June 45] [See document photo on p. 5401.]

HAH/Gris

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Gladwin Hill. New York Escaped V-2 Rockets By a 6-Month Margin, Army Says. ***New York Times.*** **14 June 1945 pp. 1, 5.**

PARIS, June 13—The Germans had planned to bomb the United States with V-2 rocket projectiles like those that crashed into London and might have succeeded by November, United States Army Ordnance experts reported today.

German scientists reached the blueprint stage in producing a 3,000-mile bomb that they believed would be accurate enough in destruction to offset our advantage in air power, which was a crucial factor in the Allied victory.

The six-month margin of safety represented by the time between V-E Day and November was provided by the RAF attack on the Germans' experimental plant at Peenemuende on the Baltic two years ago. The Germans said it killed 800 of their leading experts and set their work back six months.

This was the Allies' third escape from big Nazi schemes of destruction which the conquest of the Germans has disclosed.

The Germans had a system of V-1 bases in northwestern Europe that would have demolished London if it had not been disrupted by American bombing. They also had expected within a few months to perfect a bomber capable of attacking New York from Europe.

Purely on the basis of theoretical work, the Germans figured that in two years they could produce a rocket bomb that would go from the British Isles to Japan—15,000 miles—Maj. William Bromley reported.

The Germans' plans were learned during a five-month investigation of an amazing rocket assembly plant 800 feet underground in the Kohnstein Mountains near Nordhausen, Germany, which had 12,000 slave workers, many of them from the odious Nordhausen concentration camp. Sabotage by them, along with a shortage of materials, was credited with keeping production far below the capacity of 900 V-2's monthly, in addition to some V-1's and airplane engines.

The plant, burrowed out of limestone, was composed of two large tunnels connected by a network of smaller ones, with a twenty-five-mile railroad running through them.

The German scientists who described their work were mostly only 25 to 35 years old. One hundred of the V-2's have been assembled and are being shipped to the United States. They will be studied at the Army's Aberdeen Proving Grounds.

[For other newspaper articles based on the same 13 June 1945 press release by the U.S. Army, see:

> V2s with Range of 3,000 Miles: Would Have Been Ready by VE-Day. *Daily Mail* 14 June 1945 p. 1.
>
> "V2" with Range of 3,000 Miles If War Had Gone On. *Manchester Guardian* 14 June 1945 p. 5.
>
> V-2s, to Reach America, Were Nearly Ready. *Daily Worker* (London) 14 June 1945 p. 4.
>
> 6 Months, Foe Might Have "Veed" Toronto. *Toronto Daily Star* 14 June 1945 p. 2.

Construction of standard A-4 or V-2 rockets with a maximum range of approximately 350 km (approximately 200 miles) was ordered in 1939 and pursued with large amounts of funding and personnel for several years before mass-produced A-4 rockets could finally be used militarily starting on 8 September 1944.

This report (based on detailed on-site inspections of German rocket programs) and numerous other Allied and German sources in this appendix (e.g., pp. 5206–5208, 5337–5341, 5352, 5355–5359, 5365, 5398, 5429, 5441–5444, 5452–5455, 5465–5466, 5472, 5479–5490, and 5532) made it clear that mass-produced (not even just prototype) intercontinental rockets with a range roughly 15 times greater than that of the standard A-4 would have been ready by early November 1945, or even sooner without Allied bombing.

Publicly released postwar Allied reports and published history books also claimed that such intercontinental rockets never progressed beyond the paper design phase [e.g., Neufeld 1995, p. 283]. Given that it took over five years from the paper design of the A-4 to the first military use of mass-produced A-4 rockets, well-informed Allied inspectors and German officials could not possibly have expected a far more advanced rocket with 15 times greater range to make the leap from paper design to mass-produced deployed weapon in just six months.

The most plausible explanation for the apparent paradox is that Allied inspectors discovered well advanced hardware development, testing, and/or production programs for intercontinental rockets, but were censored from publicly revealing knowledge of anything more than paper designs.

Indeed, the press release on p. 5402 explicitly indicated that it was censored. Somewhere there must have been (and hopefully there still remains) an original, uncensored version of that press release. What information would it reveal about the mass production of 3000-mile rockets that U.S. Army inspectors reported were months away from striking the United States?

The following pages also give excerpts from some of the published inspectors' reports, which barely mentioned paper designs of advanced rockets and scrupulously avoided any mention of corresponding actual hardware. Those were likely also censored.

Where are the uncensored, full reports by these inspectors? Can they be located and declassified now?]

CIOS XXXII-125. *German Guided Missile Research.* 1945. pp. 5–7. [See pp. 5406–5417.]

A-Series of Missiles.

The complete A-series of weapons had 16 models designated A-0 through A-15. They are all associated with developments up to the V-2 or developments of improvements of the V-2 as it is known to have been used.

[Gives brief descriptions of A0 through A8 missiles]

A9 – Was the result of work on the A6, A7 and A8, and was a V-2 with wings so that instead of following a normal Hyperbolic trajectory, it would glide to earth after reaching a maximum height from the rocket propellant. Its range was increased to about 600-km or about 375 miles. Thus, the projectile could be launched well inside Germany, itself, and still reach England.

A10 – Was an experimental model of an additional thrust unit which was to be fastened to either the A4 (V-2) or the A-9 to give an additional range. It was to carry its own fuel, and when the fuel was completely burned the unit was released, at the same time starting the normal thrust unit in the A4 (V-2) or A9.

["Experimental model" sounds as if it had actually been constructed and tested.]

A-11, A12, A13 & A14 – Were development models of the A9-A10 series attempt—to produce a long range rocket projectile for attacks on the North American continent. The range strived for in these and the A15 model was 3500 miles.

A15 – Was to have been a 3500 mile range projectile using the A9 and A10 developments. This project probably never progressed beyond the drawing board stage.

[Since this comment is made about A15 but not the others, does that suggest that some or all of A10 through A14 had "progressed beyond the drawing board stage"?]

B. V-Series of Missiles.

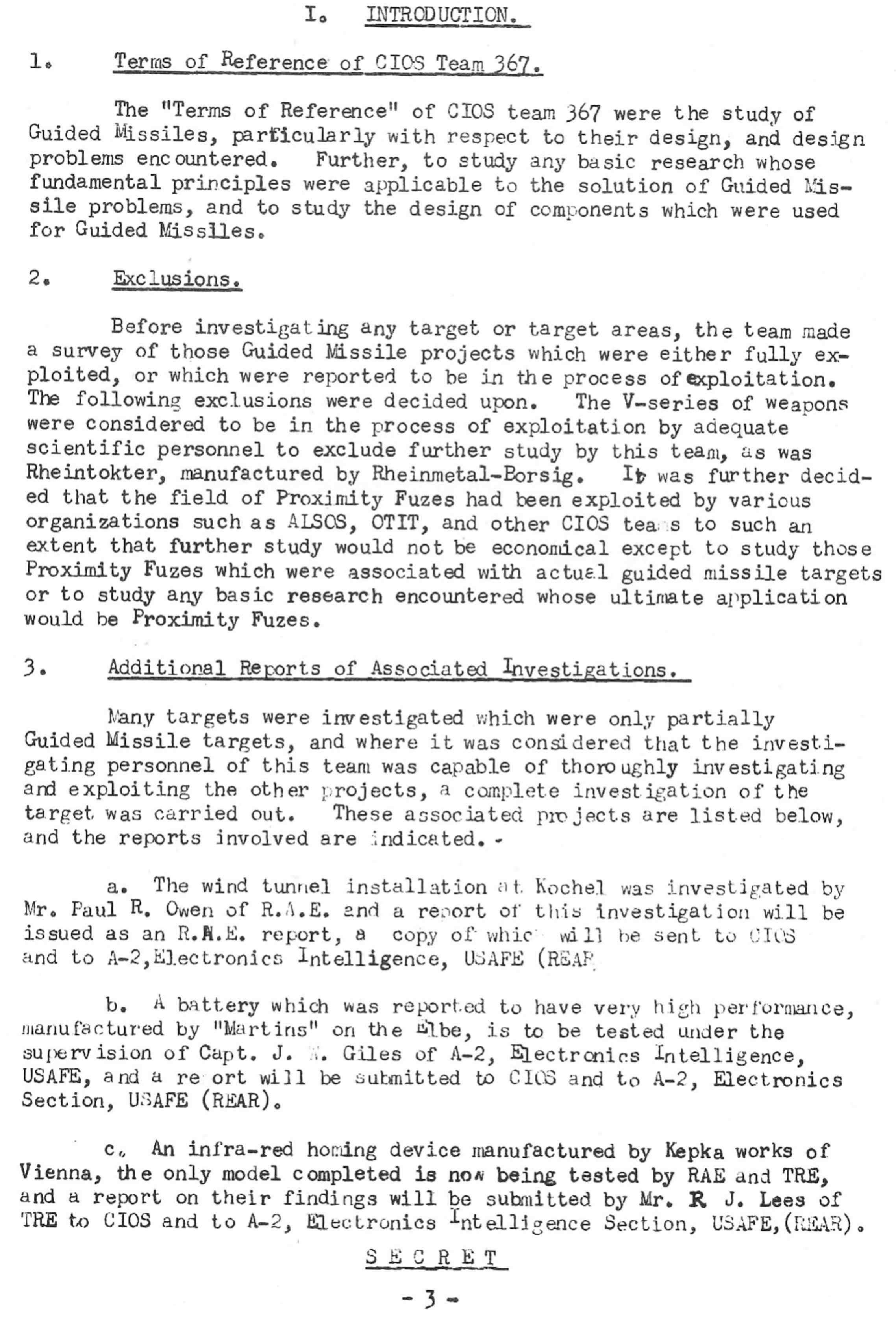
The V-series of missiles, four known types, two being used by the end of the war in Europe, have been covered by large numbers of technical investigation teams whose reports are available; therefore it was decided that CIOS Team 367 would not make a complete Technical Investigation of them. [...]

V1 – Was a jet propelled ground-to-ground missile which was aerodynamically stabilized. [...]

V2 – Was a rocket-propeled ground-to-ground missile which was not aerodynamically stabilized. [...] At the time CIOS team 367 was at Nordhausen, there were evacuation teams moving complete V2 units back to England (and the U.S.) for study, and firing trials; therefore, very little detailed study was made of the equipment. [...]

V3 – Was a larger version of the V1 with an incendiary warhead instead of the HE as normally used. Very little information is available concerning V3 control systems.

[Although a fourth V missile was mentioned above, it is not given even a brief description here. Was that information censored?]



I. INTRODUCTION.

1. Terms of Reference of CIOS Team 367.

The "Terms of Reference" of CIOS team 367 were the study of Guided Missiles, particularly with respect to their design, and design problems encountered. Further, to study any basic research whose fundamental principles were applicable to the solution of Guided Missile problems, and to study the design of components which were used for Guided Missiles.

2. Exclusions.

Before investigating any target or target areas, the team made a survey of those Guided Missile projects which were either fully exploited, or which were reported to be in the process of exploitation. The following exclusions were decided upon. The V-series of weapons were considered to be in the process of exploitation by adequate scientific personnel to exclude further study by this team, as was Rheintokter, manufactured by Rheinmetal-Borsig. It was further decided that the field of Proximity Fuzes had been exploited by various organizations such as ALSOS, OTIT, and other CIOS teams to such an extent that further study would not be economical except to study those Proximity Fuzes which were associated with actual guided missile targets or to study any basic research encountered whose ultimate application would be Proximity Fuzes.

3. Additional Reports of Associated Investigations.

Many targets were investigated which were only partially Guided Missile targets, and where it was considered that the investigating personnel of this team was capable of thoroughly investigating and exploiting the other projects, a complete investigation of the target was carried out. These associated projects are listed below, and the reports involved are indicated. -

a. The wind tunnel installation at Kochel was investigated by Mr. Paul R. Owen of R.A.E. and a report of this investigation will be issued as an R.A.E. report, a copy of which will be sent to CIOS and to A-2, Electronics Intelligence, USAFE (REAR

b. A battery which was reported to have very high performance, manufactured by "Martins" on the Elbe, is to be tested under the supervision of Capt. J. W. Giles of A-2, Electronics Intelligence, USAFE, and a report will be submitted to CIOS and to A-2, Electronics Section, USAFE (REAR).

c. An infra-red homing device manufactured by Kepka works of Vienna, the only model completed is now being tested by RAE and TRE, and a report on their findings will be submitted by Mr. R J. Lees of TRE to CIOS and to A-2, Electronics Intelligence Section, USAFE, (REAR).

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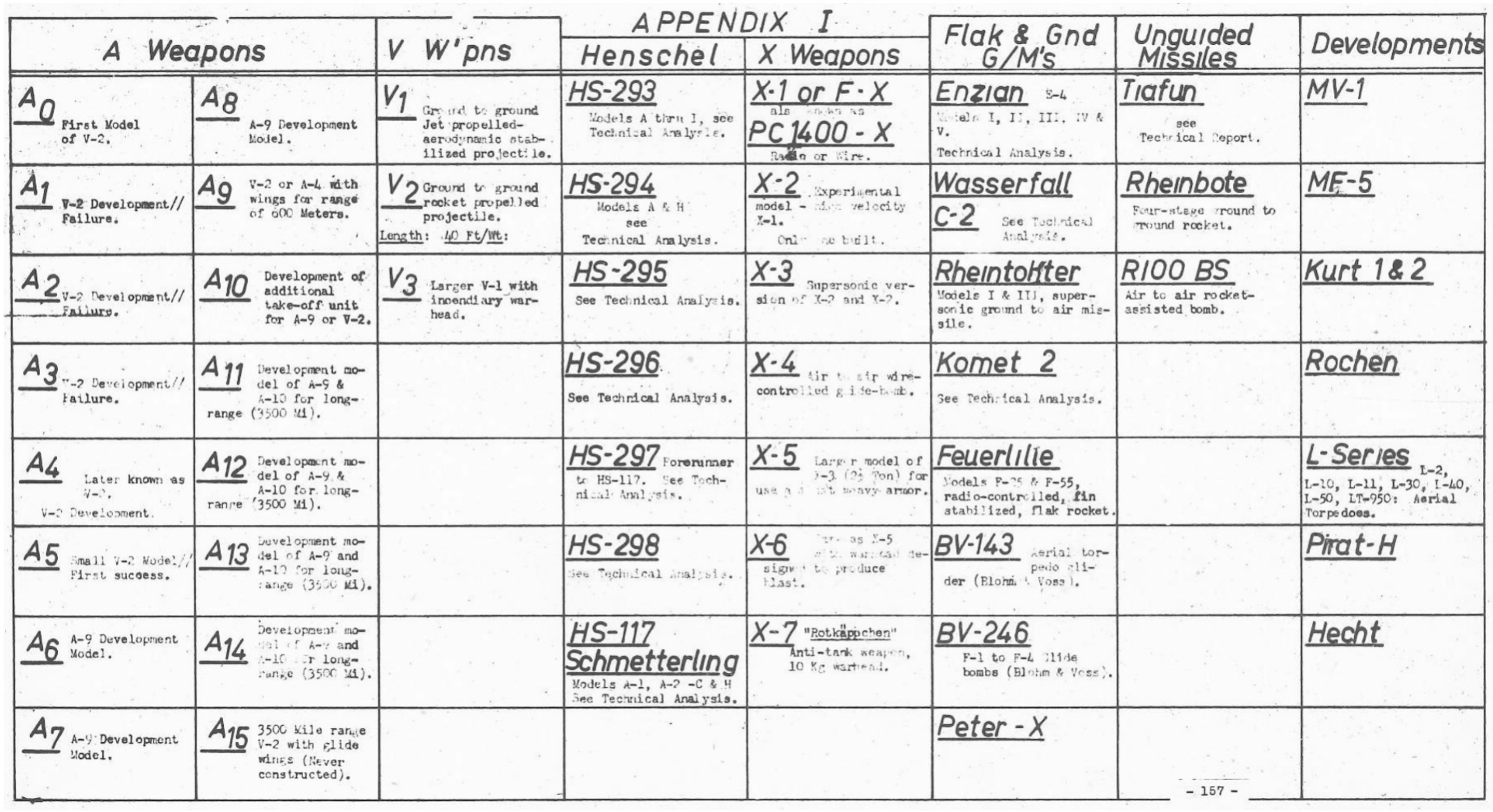
Figure E.104: CIOS XXXII-125, *German Guided Missile Research.*



APPENDIX I

A Weapons		V W'pns	Henschel	X Weapons	Flak & Gnd G/M's	Unguided Missiles	Developments
A0 First Model of V-2.	**A8** A-9 Development Model.	**V1** Ground to ground Jet propelled-aerodynamic stabilized projectile.	**HS-293** Models A thru I, see Technical Analysis.	**X-1 or F-X** also known as **PC 1400 - X** Radio or Wire.	**Enzian** E-4 Models I, II, III, IV & V. Technical Analysis.	**Tiafun** see Technical Report.	**MV-1**
A1 V-2 Development// Failure.	**A9** V-2 or A-4 with wings for range of 600 Meters.	**V2** Ground to ground rocket propelled projectile. Length: 40 Ft/Wt:	**HS-294** Models A & H see Technical Analysis.	**X-2** Experimental model - high velocity X-1. Only one built.	**Wasserfall** **C-2** See Technical Analysis.	**Rheinbote** Four-stage ground to ground rocket.	**MF-5**
A2 V-2 Development// Failure.	**A10** Development of additional take-off unit for A-9 or V-2.	**V3** Larger V-1 with incendiary warhead.	**HS-295** See Technical Analysis.	**X-3** Supersonic version of X-2 and X-2.	**Rheintochter** Models I & III, supersonic ground to air missile.	**R100 BS** Air to air rocket-assisted bomb.	**Kurt 1 & 2**
A3 V-2 Development// Failure.	**A11** Development model of A-9 & A-10 for long-range (3500 Mi).		**HS-296** See Technical Analysis.	**X-4** Air to air wire-controlled glide-bomb.	**Komet 2** See Technical Analysis.		**Rochen**
A4 Later known as V-2. V-2 Development.	**A12** Development model of A-9 & A-10 for long-range (3500 Mi).		**HS-297** Forerunner to HS-117. See Technical Analysis.	**X-5** Larger model of X-3 (2½ Ton) for use against heavy armor.	**Feuerlilie** Models F-25 & F-55, radio-controlled, fin stabilized, flak rocket.		**L-Series** L-2, L-10, L-11, L-30, L-40, L-50, LT-950: Aerial Torpedoes.
A5 Small V-2 Model// First success.	**A13** Development model of A-9 and A-10 for long-range (3500 Mi).		**HS-298** See Technical Analysis.	**X-6** Same as X-5 with warhead designed to produce blast.	**BV-143** Aerial torpedo glider (Blohm & Voss).		**Pirat-H**
A6 A-9 Development Model.	**A14** Development model of A-9 and A-10 for long-range (3500 Mi).		**HS-117 Schmetterling** Models A-1, A-2 -C & H See Technical Analysis.	**X-7** "Rotkäppchen" Anti-tank weapon, 10 Kg warhead.	**BV-246** F-1 to F-4 Glide bombs (Blohm & Voss).		**Hecht**
A7 A-9 Development Model.	**A15** 3500 Mile range V-2 with glide wings (Never constructed).				**Peter - X**		

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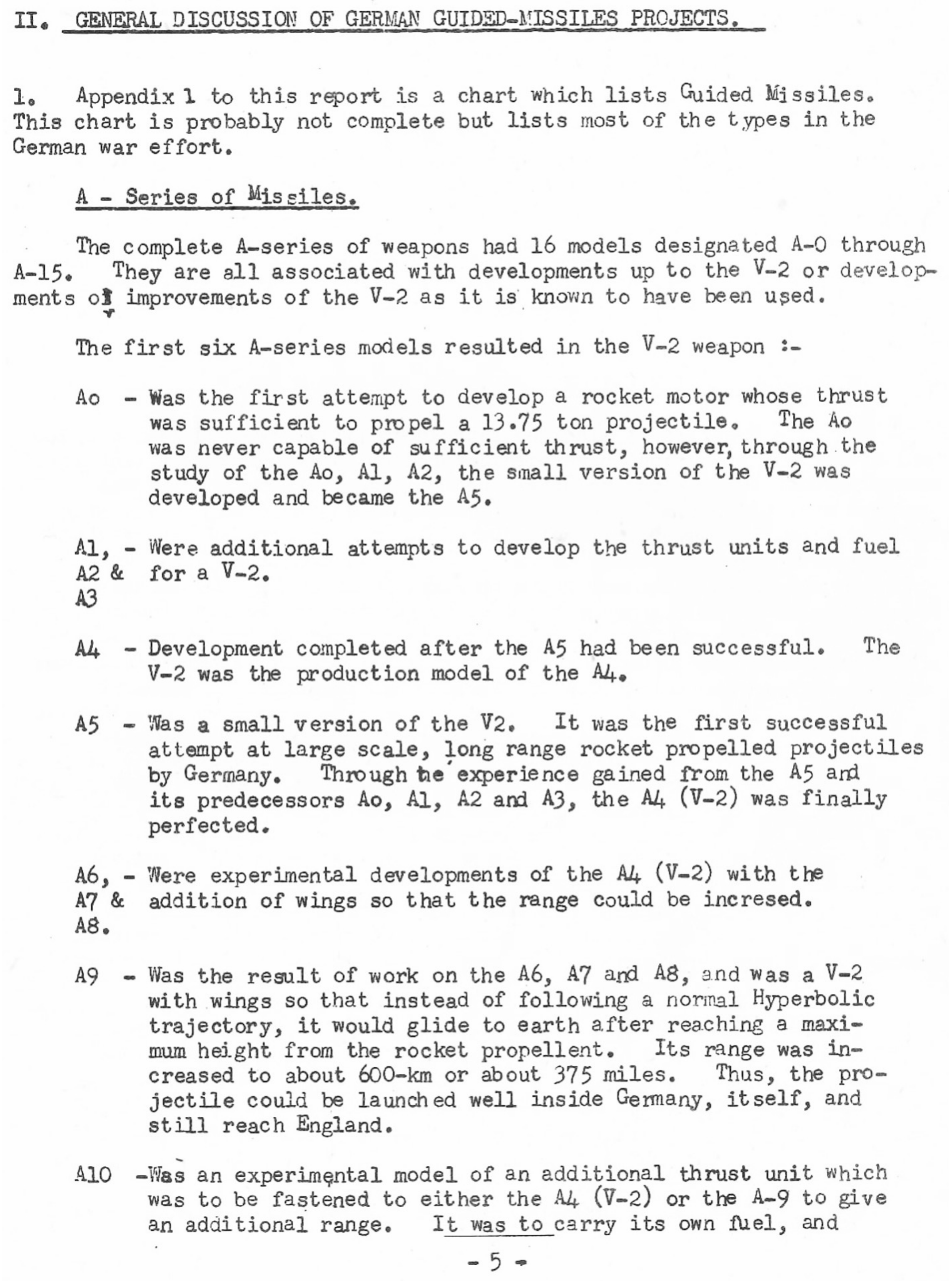
Figure E.105: CIOS XXXII-125, *German Guided Missile Research.*



II. GENERAL DISCUSSION OF GERMAN GUIDED-MISSILES PROJECTS.

1. Appendix 1 to this report is a chart which lists Guided Missiles. This chart is probably not complete but lists most of the types in the German war effort.

A - Series of Missiles.

The complete A-series of weapons had 16 models designated A-0 through A-15. They are all associated with developments up to the V-2 or developments of improvements of the V-2 as it is known to have been used.

The first six A-series models resulted in the V-2 weapon :-

Ao - Was the first attempt to develop a rocket motor whose thrust was sufficient to propel a 13.75 ton projectile. The Ao was never capable of sufficient thrust, however, through the study of the Ao, A1, A2, the small version of the V-2 was developed and became the A5.

A1, A2 & A3 - Were additional attempts to develop the thrust units and fuel for a V-2.

A4 - Development completed after the A5 had been successful. The V-2 was the production model of the A4.

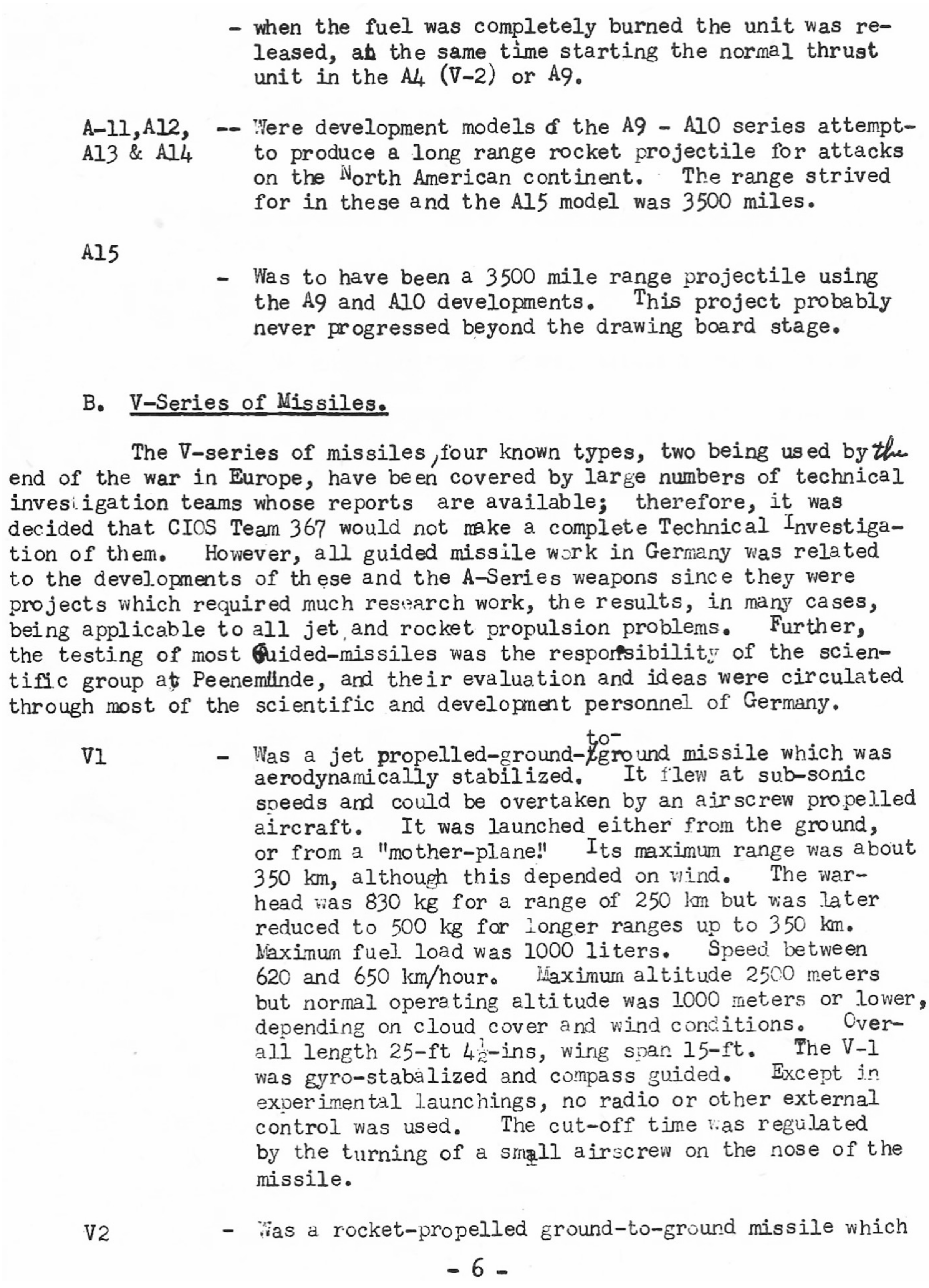
A5 - Was a small version of the V2. It was the first successful attempt at large scale, long range rocket propelled projectiles by Germany. Through the experience gained from the A5 and its predecessors Ao, A1, A2 and A3, the A4 (V-2) was finally perfected.

A6, A7 & A8. - Were experimental developments of the A4 (V-2) with the addition of wings so that the range could be incresed.

A9 - Was the result of work on the A6, A7 and A8, and was a V-2 with wings so that instead of following a normal Hyperbolic trajectory, it would glide to earth after reaching a maximum height from the rocket propellent. Its range was increased to about 600-km or about 375 miles. Thus, the projectile could be launched well inside Germany, itself, and still reach England.

A10 -Was an experimental model of an additional thrust unit which was to be fastened to either the A4 (V-2) or the A-9 to give an additional range. It was to carry its own fuel, and

Figure E.106: CIOS XXXII-125, *German Guided Missile Research.*



- when the fuel was completely burned the unit was released, at the same time starting the normal thrust unit in the A4 (V-2) or A9.

A-11, A12, A13 & A14 -- Were development models of the A9 - A10 series attempt to produce a long range rocket projectile for attacks on the North American continent. The range strived for in these and the A15 model was 3500 miles.

A15 - Was to have been a 3500 mile range projectile using the A9 and A10 developments. This project probably never progressed beyond the drawing board stage.

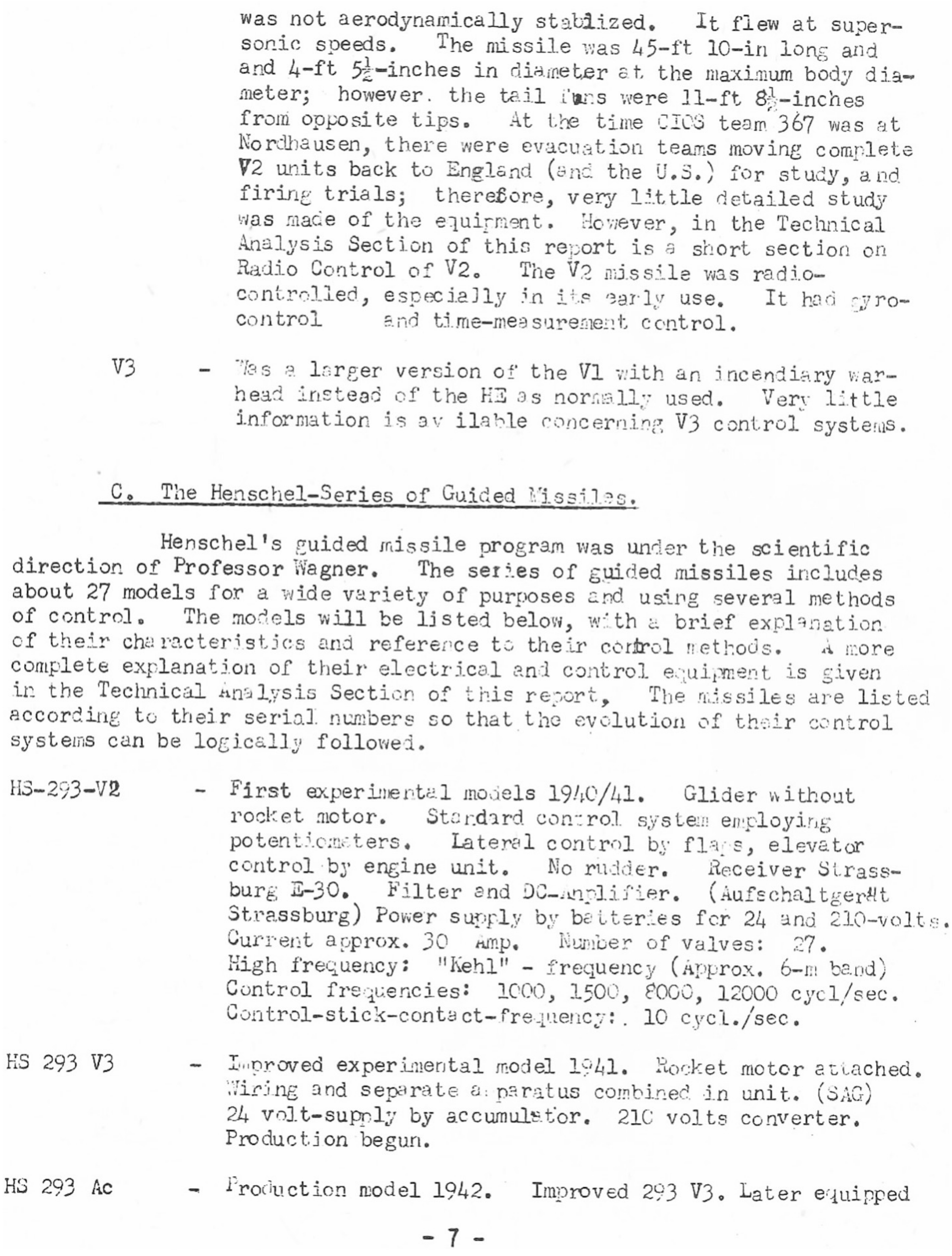
B. V-Series of Missiles.

The V-series of missiles, four known types, two being used by the end of the war in Europe, have been covered by large numbers of technical investigation teams whose reports are available; therefore, it was decided that CIOS Team 367 would not make a complete Technical Investigation of them. However, all guided missile work in Germany was related to the developments of these and the A-Series weapons since they were projects which required much research work, the results, in many cases, being applicable to all jet and rocket propulsion problems. Further, the testing of most Guided-missiles was the responsibility of the scientific group at Peenemünde, and their evaluation and ideas were circulated through most of the scientific and development personnel of Germany.

V1 - Was a jet propelled-ground-to-ground missile which was aerodynamically stabilized. It flew at sub-sonic speeds and could be overtaken by an airscrew propelled aircraft. It was launched either from the ground, or from a "mother-plane." Its maximum range was about 350 km, although this depended on wind. The warhead was 830 kg for a range of 250 km but was later reduced to 500 kg for longer ranges up to 350 km. Maximum fuel load was 1000 liters. Speed between 620 and 650 km/hour. Maximum altitude 2500 meters but normal operating altitude was 1000 meters or lower, depending on cloud cover and wind conditions. Overall length 25-ft $4\frac{1}{2}$-ins, wing span 15-ft. The V-1 was gyro-stabalized and compass guided. Except in experimental launchings, no radio or other external control was used. The cut-off time was regulated by the turning of a small airscrew on the nose of the missile.

V2 - Was a rocket-propelled ground-to-ground missile which

Figure E.107: CIOS XXXII-125, *German Guided Missile Research.*



was not aerodynamically stablized. It flew at supersonic speeds. The missile was 45-ft 10-in long and and 4-ft $5\frac{1}{2}$-inches in diameter at the maximum body diameter; however. the tail fins were 11-ft $8\frac{1}{2}$-inches from opposite tips. At the time CIOS team 367 was at Nordhausen, there were evacuation teams moving complete V2 units back to England (and the U.S.) for study, and firing trials; therefore, very little detailed study was made of the equipment. However, in the Technical Analysis Section of this report is a short section on Radio Control of V2. The V2 missile was radio-controlled, especially in its early use. It had gyro-control and time-measurement control.

V3 - Was a larger version of the V1 with an incendiary warhead instead of the HE as normally used. Very little information is available concerning V3 control systems.

C. The Henschel-Series of Guided Missiles.

Henschel's guided missile program was under the scientific direction of Professor Wagner. The series of guided missiles includes about 27 models for a wide variety of purposes and using several methods of control. The models will be listed below, with a brief explanation of their characteristics and reference to their control methods. A more complete explanation of their electrical and control equipment is given in the Technical Analysis Section of this report. The missiles are listed according to their serial numbers so that the evolution of their control systems can be logically followed.

HS-293-V2 - First experimental models 1940/41. Glider without rocket motor. Standard control system employing potentiometers. Lateral control by flaps, elevator control by engine unit. No rudder. Receiver Strassburg E-30. Filter and DC-Amplifier. (Aufschaltgerät Strassburg) Power supply by batteries for 24 and 210-volts. Current approx. 30 Amp. Number of valves: 27. High frequency: "Kehl" - frequency (Approx. 6-m band) Control frequencies: 1000, 1500, 8000, 12000 cycl/sec. Control-stick-contact-frequency: 10 cycl./sec.

HS 293 V3 - Improved experimental model 1941. Rocket motor attached. Wiring and separate apparatus combined in unit. (SAG) 24 volt-supply by accumulator. 210 volts converter. Production begun.

HS 293 Ac - Production model 1942. Improved 293 V3. Later equipped

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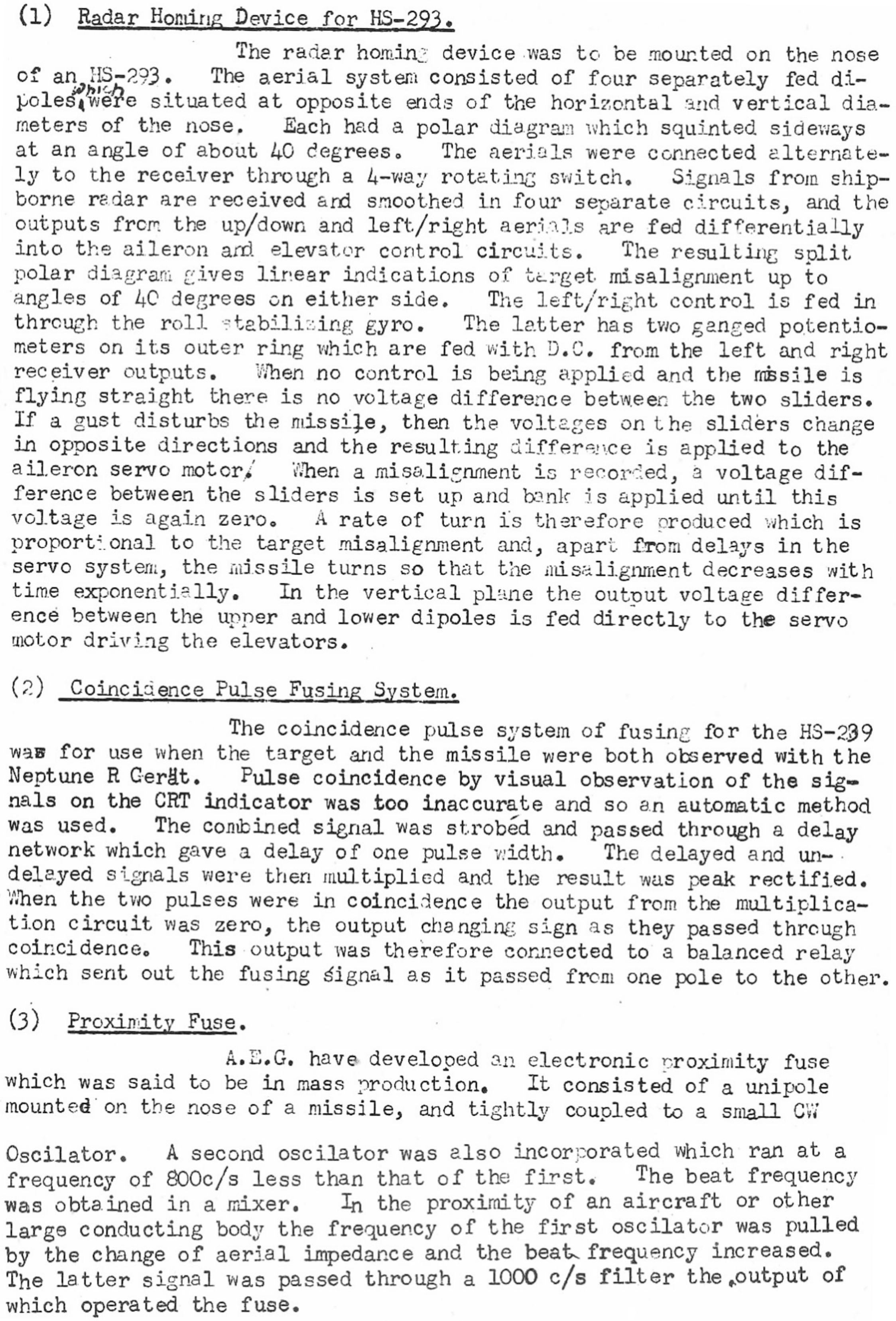
Figure E.108: CIOS XXXII-125, *German Guided Missile Research.*



(1) Radar Homing Device for HS-293.

The radar homing device was to be mounted on the nose of an HS-293. The aerial system consisted of four separately fed dipoles, which were situated at opposite ends of the horizontal and vertical diameters of the nose. Each had a polar diagram which squinted sideways at an angle of about 40 degrees. The aerials were connected alternately to the receiver through a 4-way rotating switch. Signals from shipborne radar are received and smoothed in four separate circuits, and the outputs from the up/down and left/right aerials are fed differentially into the aileron and elevator control circuits. The resulting split polar diagram gives linear indications of target misalignment up to angles of 40 degrees on either side. The left/right control is fed in through the roll stabilising gyro. The latter has two ganged potentiometers on its outer ring which are fed with D.C. from the left and right receiver outputs. When no control is being applied and the missile is flying straight there is no voltage difference between the two sliders. If a gust disturbs the missile, then the voltages on the sliders change in opposite directions and the resulting difference is applied to the aileron servo motor. When a misalignment is recorded, a voltage difference between the sliders is set up and bank is applied until this voltage is again zero. A rate of turn is therefore produced which is proportional to the target misalignment and, apart from delays in the servo system, the missile turns so that the misalignment decreases with time exponentially. In the vertical plane the output voltage difference between the upper and lower dipoles is fed directly to the servo motor driving the elevators.

(2) Coincidence Pulse Fusing System.

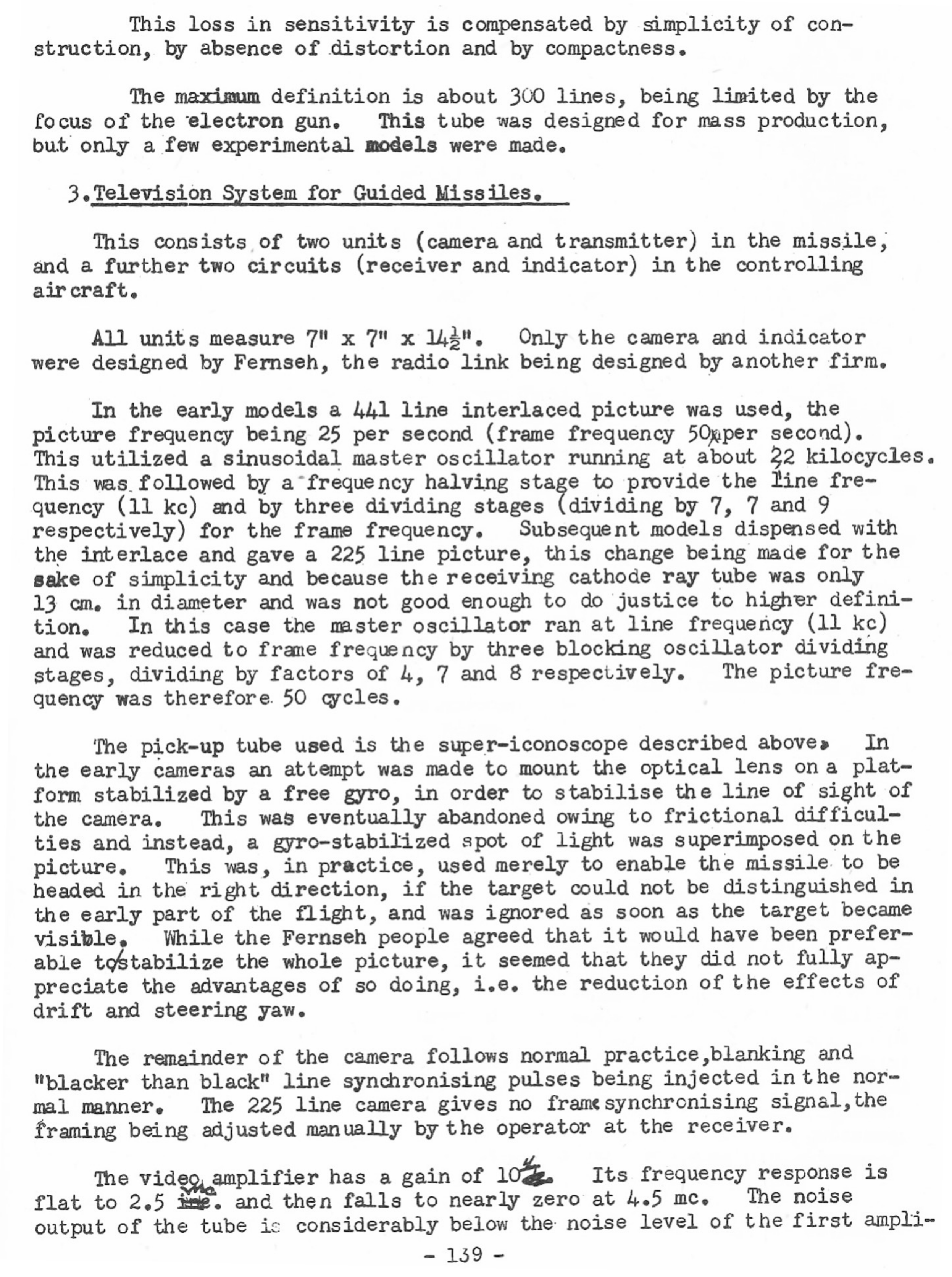
The coincidence pulse system of fusing for the HS-239 was for use when the target and the missile were both observed with the Neptune R Gerät. Pulse coincidence by visual observation of the signals on the CRT indicator was too inaccurate and so an automatic method was used. The combined signal was strobed and passed through a delay network which gave a delay of one pulse width. The delayed and undelayed signals were then multiplied and the result was peak rectified. When the two pulses were in coincidence the output from the multiplication circuit was zero, the output changing sign as they passed through coincidence. This output was therefore connected to a balanced relay which sent out the fusing signal as it passed from one pole to the other.

(3) Proximity Fuse.

A.E.G. have developed an electronic proximity fuse which was said to be in mass production. It consisted of a unipole mounted on the nose of a missile, and tightly coupled to a small CW

Oscilator. A second oscilator was also incorporated which ran at a frequency of 800c/s less than that of the first. The beat frequency was obtained in a mixer. In the proximity of an aircraft or other large conducting body the frequency of the first oscilator was pulled by the change of aerial impedance and the beat frequency increased. The latter signal was passed through a 1000 c/s filter the output of which operated the fuse.

Figure E.109: CIOS XXXII-125, *German Guided Missile Research.*



This loss in sensitivity is compensated by simplicity of construction, by absence of distortion and by compactness.

The maximum definition is about 300 lines, being limited by the focus of the electron gun. This tube was designed for mass production, but only a few experimental models were made.

3. Television System for Guided Missiles.

This consists of two units (camera and transmitter) in the missile, and a further two circuits (receiver and indicator) in the controlling aircraft.

All units measure 7" x 7" x 14½". Only the camera and indicator were designed by Fernseh, the radio link being designed by another firm.

In the early models a 441 line interlaced picture was used, the picture frequency being 25 per second (frame frequency 50 per second). This utilized a sinusoidal master oscillator running at about 22 kilocycles. This was followed by a frequency halving stage to provide the line frequency (11 kc) and by three dividing stages (dividing by 7, 7 and 9 respectively) for the frame frequency. Subsequent models dispensed with the interlace and gave a 225 line picture, this change being made for the sake of simplicity and because the receiving cathode ray tube was only 13 cm. in diameter and was not good enough to do justice to higher definition. In this case the master oscillator ran at line frequency (11 kc) and was reduced to frame frequency by three blocking oscillator dividing stages, dividing by factors of 4, 7 and 8 respectively. The picture frequency was therefore 50 cycles.

The pick-up tube used is the super-iconoscope described above. In the early cameras an attempt was made to mount the optical lens on a platform stabilized by a free gyro, in order to stabilise the line of sight of the camera. This was eventually abandoned owing to frictional difficulties and instead, a gyro-stabilized spot of light was superimposed on the picture. This was, in practice, used merely to enable the missile to be headed in the right direction, if the target could not be distinguished in the early part of the flight, and was ignored as soon as the target became visible. While the Fernseh people agreed that it would have been preferable to stabilize the whole picture, it seemed that they did not fully appreciate the advantages of so doing, i.e. the reduction of the effects of drift and steering yaw.

The remainder of the camera follows normal practice, blanking and "blacker than black" line synchronising pulses being injected in the normal manner. The 225 line camera gives no frame synchronising signal, the framing being adjusted manually by the operator at the receiver.

The video amplifier has a gain of 10^4. Its frequency response is flat to 2.5 ~~kc~~ mc. and then falls to nearly zero at 4.5 mc. The noise output of the tube is considerably below the noise level of the first ampli-

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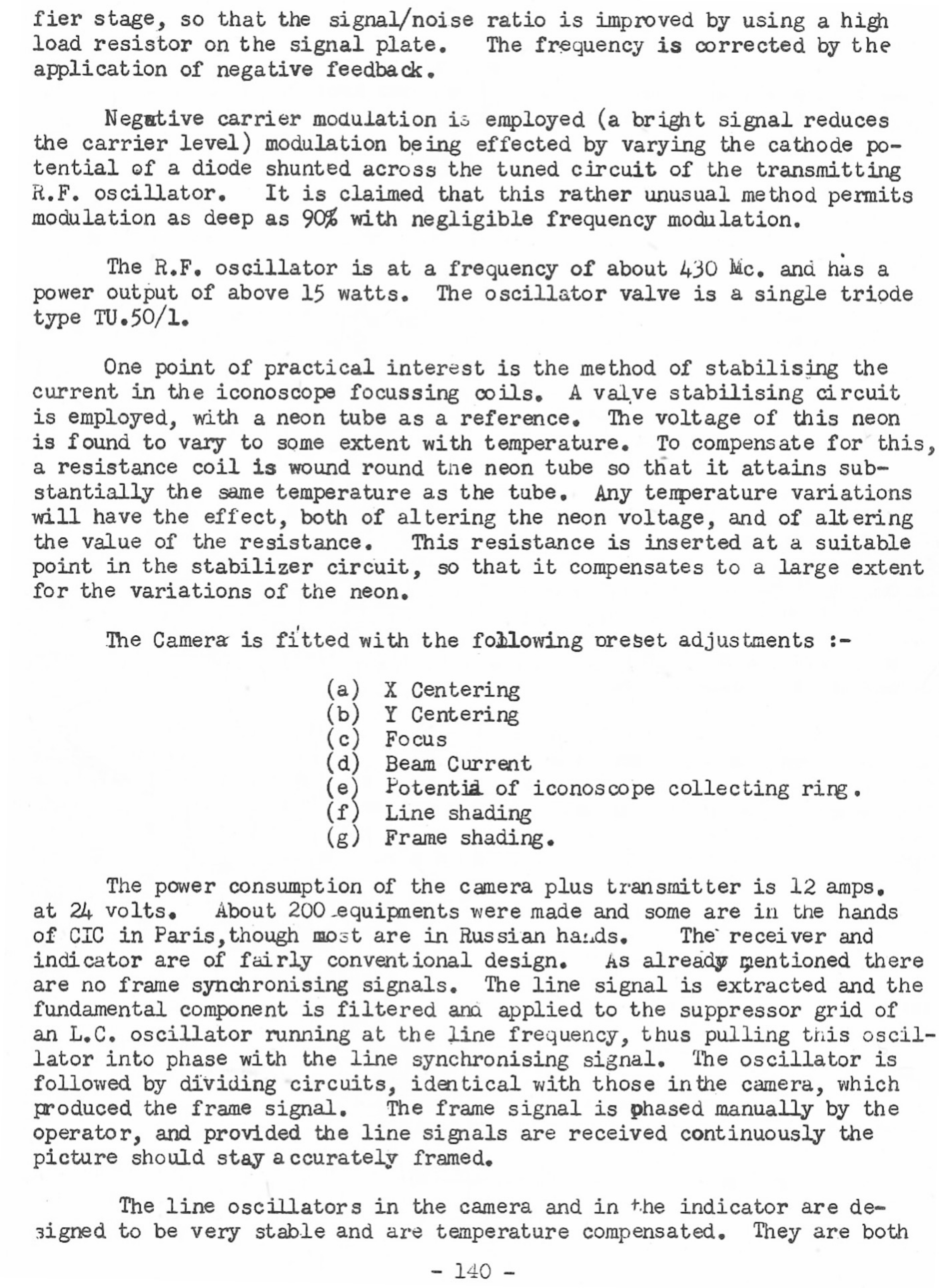
Figure E.110: CIOS XXXII-125, *German Guided Missile Research*.



fier stage, so that the signal/noise ratio is improved by using a high load resistor on the signal plate. The frequency is corrected by the application of negative feedback.

Negative carrier modulation is employed (a bright signal reduces the carrier level) modulation being effected by varying the cathode potential of a diode shunted across the tuned circuit of the transmitting R.F. oscillator. It is claimed that this rather unusual method permits modulation as deep as 90% with negligible frequency modulation.

The R.F. oscillator is at a frequency of about 430 Mc. and has a power output of above 15 watts. The oscillator valve is a single triode type TU.50/1.

One point of practical interest is the method of stabilising the current in the iconoscope focussing coils. A valve stabilising circuit is employed, with a neon tube as a reference. The voltage of this neon is found to vary to some extent with temperature. To compensate for this, a resistance coil is wound round the neon tube so that it attains substantially the same temperature as the tube. Any temperature variations will have the effect, both of altering the neon voltage, and of altering the value of the resistance. This resistance is inserted at a suitable point in the stabilizer circuit, so that it compensates to a large extent for the variations of the neon.

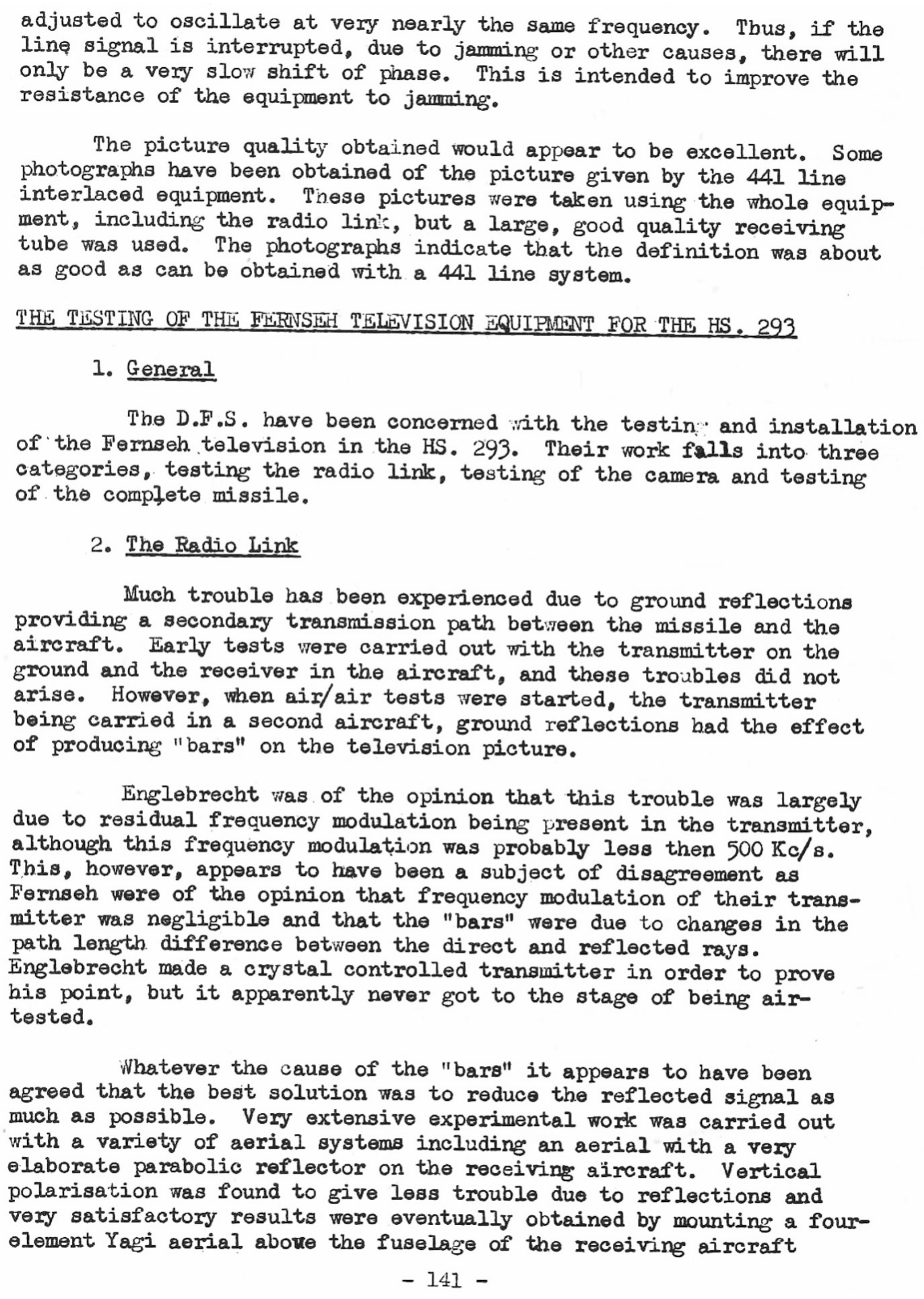
The Camera is fitted with the following preset adjustments :-

(a) X Centering
(b) Y Centering
(c) Focus
(d) Beam Current
(e) Potential of iconoscope collecting ring.
(f) Line shading
(g) Frame shading.

The power consumption of the camera plus transmitter is 12 amps. at 24 volts. About 200 equipments were made and some are in the hands of CIC in Paris, though most are in Russian hands. The receiver and indicator are of fairly conventional design. As already mentioned there are no frame synchronising signals. The line signal is extracted and the fundamental component is filtered and applied to the suppressor grid of an L.C. oscillator running at the line frequency, thus pulling this oscillator into phase with the line synchronising signal. The oscillator is followed by dividing circuits, identical with those in the camera, which produced the frame signal. The frame signal is phased manually by the operator, and provided the line signals are received continuously the picture should stay accurately framed.

The line oscillators in the camera and in the indicator are designed to be very stable and are temperature compensated. They are both

Figure E.111: CIOS XXXII-125, *German Guided Missile Research.*



adjusted to oscillate at very nearly the same frequency. Thus, if the line signal is interrupted, due to jamming or other causes, there will only be a very slow shift of phase. This is intended to improve the resistance of the equipment to jamming.

The picture quality obtained would appear to be excellent. Some photographs have been obtained of the picture given by the 441 line interlaced equipment. These pictures were taken using the whole equipment, including the radio link, but a large, good quality receiving tube was used. The photographs indicate that the definition was about as good as can be obtained with a 441 line system.

THE TESTING OF THE FERNSEH TELEVISION EQUIPMENT FOR THE HS. 293

1. General

The D.F.S. have been concerned with the testing and installation of the Fernseh television in the HS. 293. Their work falls into three categories, testing the radio link, testing of the camera and testing of the complete missile.

2. The Radio Link

Much trouble has been experienced due to ground reflections providing a secondary transmission path between the missile and the aircraft. Early tests were carried out with the transmitter on the ground and the receiver in the aircraft, and these troubles did not arise. However, when air/air tests were started, the transmitter being carried in a second aircraft, ground reflections had the effect of producing "bars" on the television picture.

Englebrecht was of the opinion that this trouble was largely due to residual frequency modulation being present in the transmitter, although this frequency modulation was probably less then 500 Kc/s. This, however, appears to have been a subject of disagreement as Fernseh were of the opinion that frequency modulation of their transmitter was negligible and that the "bars" were due to changes in the path length difference between the direct and reflected rays. Englebrecht made a crystal controlled transmitter in order to prove his point, but it apparently never got to the stage of being air-tested.

Whatever the cause of the "bars" it appears to have been agreed that the best solution was to reduce the reflected signal as much as possible. Very extensive experimental work was carried out with a variety of aerial systems including an aerial with a very elaborate parabolic reflector on the receiving aircraft. Vertical polarisation was found to give less trouble due to reflections and very satisfactory results were eventually obtained by mounting a four-element Yagi aerial abowe the fuselage of the receiving aircraft

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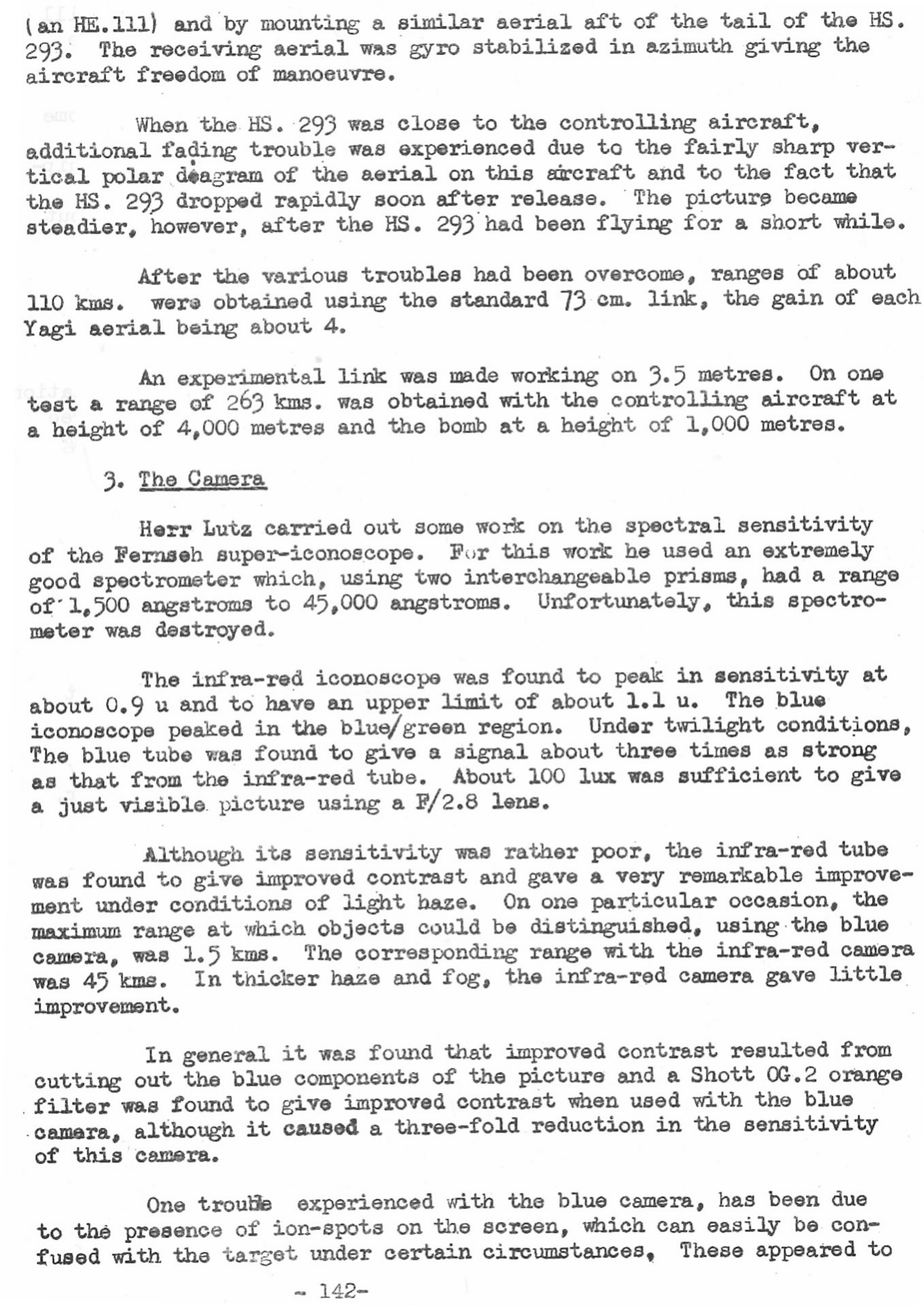
Figure E.112: CIOS XXXII-125, *German Guided Missile Research.*



(an HE.111) and by mounting a similar aerial aft of the tail of the HS. 293. The receiving aerial was gyro stabilized in azimuth giving the aircraft freedom of manoeuvre.

When the HS. 293 was close to the controlling aircraft, additional fading trouble was experienced due to the fairly sharp vertical polar diagram of the aerial on this aircraft and to the fact that the HS. 293 dropped rapidly soon after release. The picture became steadier, however, after the HS. 293 had been flying for a short while.

After the various troubles had been overcome, ranges of about 110 kms. were obtained using the standard 73 cm. link, the gain of each Yagi aerial being about 4.

An experimental link was made working on 3.5 metres. On one test a range of 263 kms. was obtained with the controlling aircraft at a height of 4,000 metres and the bomb at a height of 1,000 metres.

3. The Camera

Herr Lutz carried out some work on the spectral sensitivity of the Fernseh super-iconoscope. For this work he used an extremely good spectrometer which, using two interchangeable prisms, had a range of 1,500 angstroms to 45,000 angstroms. Unfortunately, this spectrometer was destroyed.

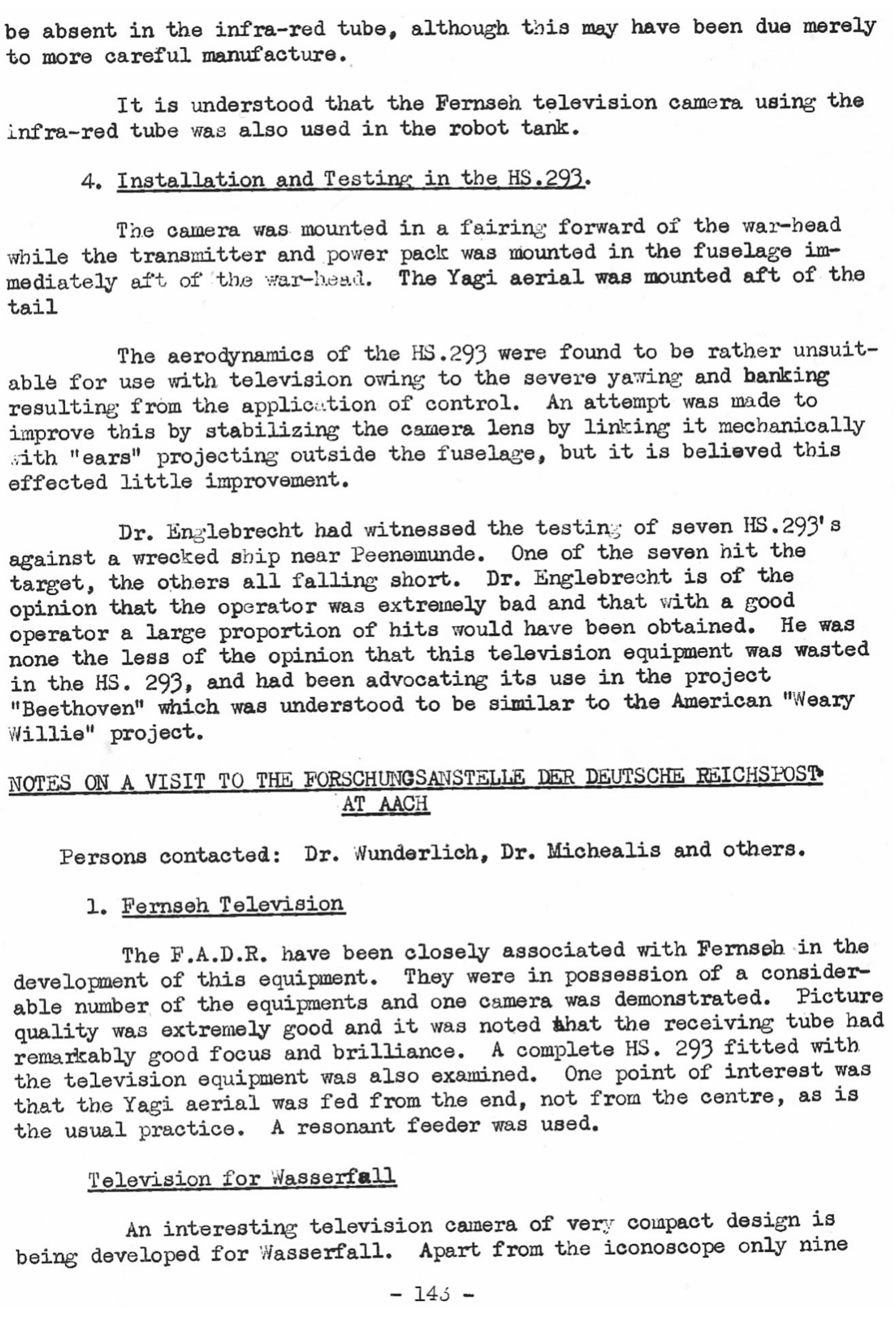
The infra-red iconoscope was found to peak in sensitivity at about 0.9 u and to have an upper limit of about 1.1 u. The blue iconoscope peaked in the blue/green region. Under twilight conditions, The blue tube was found to give a signal about three times as strong as that from the infra-red tube. About 100 lux was sufficient to give a just visible picture using a F/2.8 lens.

Although its sensitivity was rather poor, the infra-red tube was found to give improved contrast and gave a very remarkable improvement under conditions of light haze. On one particular occasion, the maximum range at which objects could be distinguished, using the blue camera, was 1.5 kms. The corresponding range with the infra-red camera was 45 kms. In thicker haze and fog, the infra-red camera gave little improvement.

In general it was found that improved contrast resulted from cutting out the blue components of the picture and a Shott OG.2 orange filter was found to give improved contrast when used with the blue camera, although it caused a three-fold reduction in the sensitivity of this camera.

One trouble experienced with the blue camera, has been due to the presence of ion-spots on the screen, which can easily be confused with the target under certain circumstances, These appeared to

Figure E.113: CIOS XXXII-125, *German Guided Missile Research.*



be absent in the infra-red tube, although this may have been due merely to more careful manufacture.

It is understood that the Fernseh television camera using the infra-red tube was also used in the robot tank.

4. Installation and Testing in the HS.293.

The camera was mounted in a fairing forward of the war-head while the transmitter and power pack was mounted in the fuselage immediately aft of the war-head. The Yagi aerial was mounted aft of the tail

The aerodynamics of the HS.293 were found to be rather unsuitable for use with television owing to the severe yawing and banking resulting from the application of control. An attempt was made to improve this by stabilizing the camera lens by linking it mechanically with "ears" projecting outside the fuselage, but it is believed this effected little improvement.

Dr. Englebrecht had witnessed the testing of seven HS.293's against a wrecked ship near Peenemunde. One of the seven hit the target, the others all falling short. Dr. Englebrecht is of the opinion that the operator was extremely bad and that with a good operator a large proportion of hits would have been obtained. He was none the less of the opinion that this television equipment was wasted in the HS. 293, and had been advocating its use in the project "Beethoven" which was understood to be similar to the American "Weary Willie" project.

NOTES ON A VISIT TO THE FORSCHUNGSANSTELLE DER DEUTSCHE REICHSPOST AT AACH

Persons contacted: Dr. Wunderlich, Dr. Michealis and others.

1. Fernseh Television

The F.A.D.R. have been closely associated with Fernseh in the development of this equipment. They were in possession of a considerable number of the equipments and one camera was demonstrated. Picture quality was extremely good and it was noted that the receiving tube had remarkably good focus and brilliance. A complete HS. 293 fitted with the television equipment was also examined. One point of interest was that the Yagi aerial was fed from the end, not from the centre, as is the usual practice. A resonant feeder was used.

Television for Wasserfall

An interesting television camera of very compact design is being developed for Wasserfall. Apart from the iconoscope only nine

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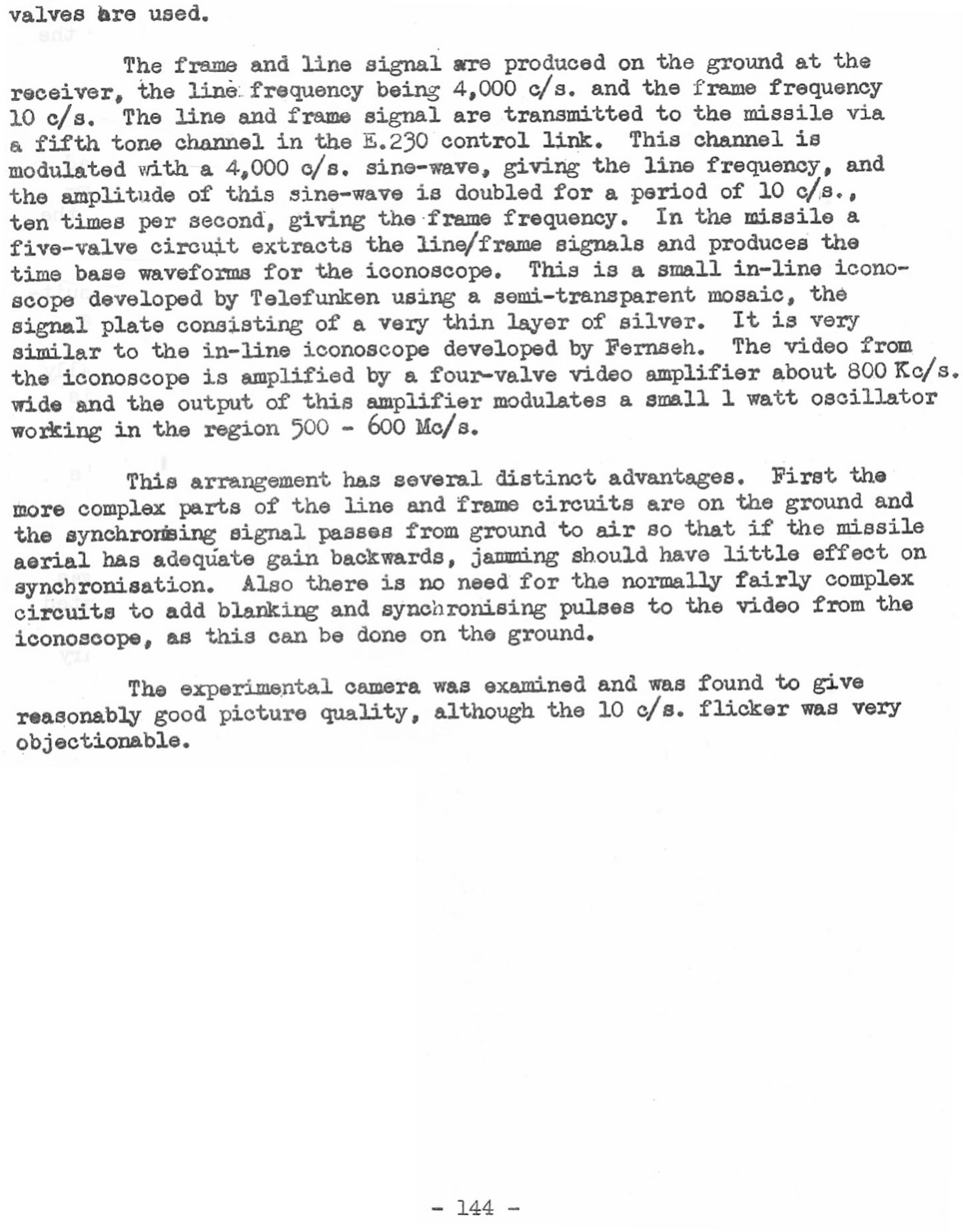
Figure E.114: CIOS XXXII-125, *German Guided Missile Research.*



valves are used.

The frame and line signal are produced on the ground at the receiver, the line frequency being 4,000 c/s. and the frame frequency 10 c/s. The line and frame signal are transmitted to the missile via a fifth tone channel in the E.230 control link. This channel is modulated with a 4,000 c/s. sine-wave, giving the line frequency, and the amplitude of this sine-wave is doubled for a period of 10 c/s., ten times per second, giving the frame frequency. In the missile a five-valve circuit extracts the line/frame signals and produces the time base waveforms for the iconoscope. This is a small in-line iconoscope developed by Telefunken using a semi-transparent mosaic, the signal plate consisting of a very thin layer of silver. It is very similar to the in-line iconoscope developed by Fernseh. The video from the iconoscope is amplified by a four-valve video amplifier about 800 Kc/s. wide and the output of this amplifier modulates a small 1 watt oscillator working in the region 500 - 600 Mc/s.

This arrangement has several distinct advantages. First the more complex parts of the line and frame circuits are on the ground and the synchronising signal passes from ground to air so that if the missile aerial has adequate gain backwards, jamming should have little effect on synchronisation. Also there is no need for the normally fairly complex circuits to add blanking and synchronising pulses to the video from the iconoscope, as this can be done on the ground.

The experimental camera was examined and was found to give reasonably good picture quality, although the 10 c/s. flicker was very objectionable.

Figure E.115: CIOS XXXII-125, *German Guided Missile Research.*

[Note the quality, quantity, and variety of revolutionary new rockets and missiles listed in the table from CIOS XXXII-125 (p. 5407).

The table says that A15 was "never constructed" but does not make that statement about A10 through A14. Were some or all of those partially or fully constructed? The text of the report uses similar wording that suggests there may have been significant progress on rockets up to A14 (p. 5405).

For more information on both proximity fuses and anti-radar missiles (p. 5411), see Section 6.8.8.

For more information on miniaturized television cameras/transmitters and receivers/picture tubes (pp. 5412–5417), see Section 6.3.9).

For more information on robots with which the miniaturized television cameras could be used (p. 5416), see Section 6.7.4.]

CIOS XXVIII-45. *Investigation of Group 2 Targets in Nordhausen Area.* 1945.

[The mention on p. 12 of this report that Walther Riedel was located in Thuringia and brought to Nordhausen has made some authors wonder if Riedel may have still been at a Thuringian rocket installation other than Nordhausen.

The facts are much more unfortunate. Riedel was "found in a jail in Saalfeld, where U.S. soldiers had knocked out his teeth while questioning him about his alleged development of a 'bacteria bomb'" [Neufeld 2007, p. 206 and note 17 on p. 505 for Neufeld's sources]. Walther Riedel was a noted rocket engine designer, not a bacteriologist. The documented facts of this incident raise questions about both the intelligence and the morality of the U.S. forces operating at this place and time that do not appear to have been addressed in history books.

Of course, that information does nothing to settle questions about whether Riedel may have visited Thuringian rocket installations other than Nordhausen anytime prior to that time.]

Wolfgang Hirschfeld and Geoffrey Brooks. 1996. *Hirschfeld: The Story of a U-Boat NCO 1940-1946.* Annapolis, Maryland: Naval Institute Press. pp. 212–213.

Not long after, the stern lookouts reported the approach of a destroyer on the port quarter. This was the USS *Sutton*, which gave us orders by lamp to head for the Gulf of Maine and ignore all further communications from Halifax. [...]

Dr Schlicke had quietly joined me on the bridge and tossed a few rolls of microfilm into the sea. We watched them slowly sink. 'And there goes the rocket that could fly the Atlantic,' he told me.

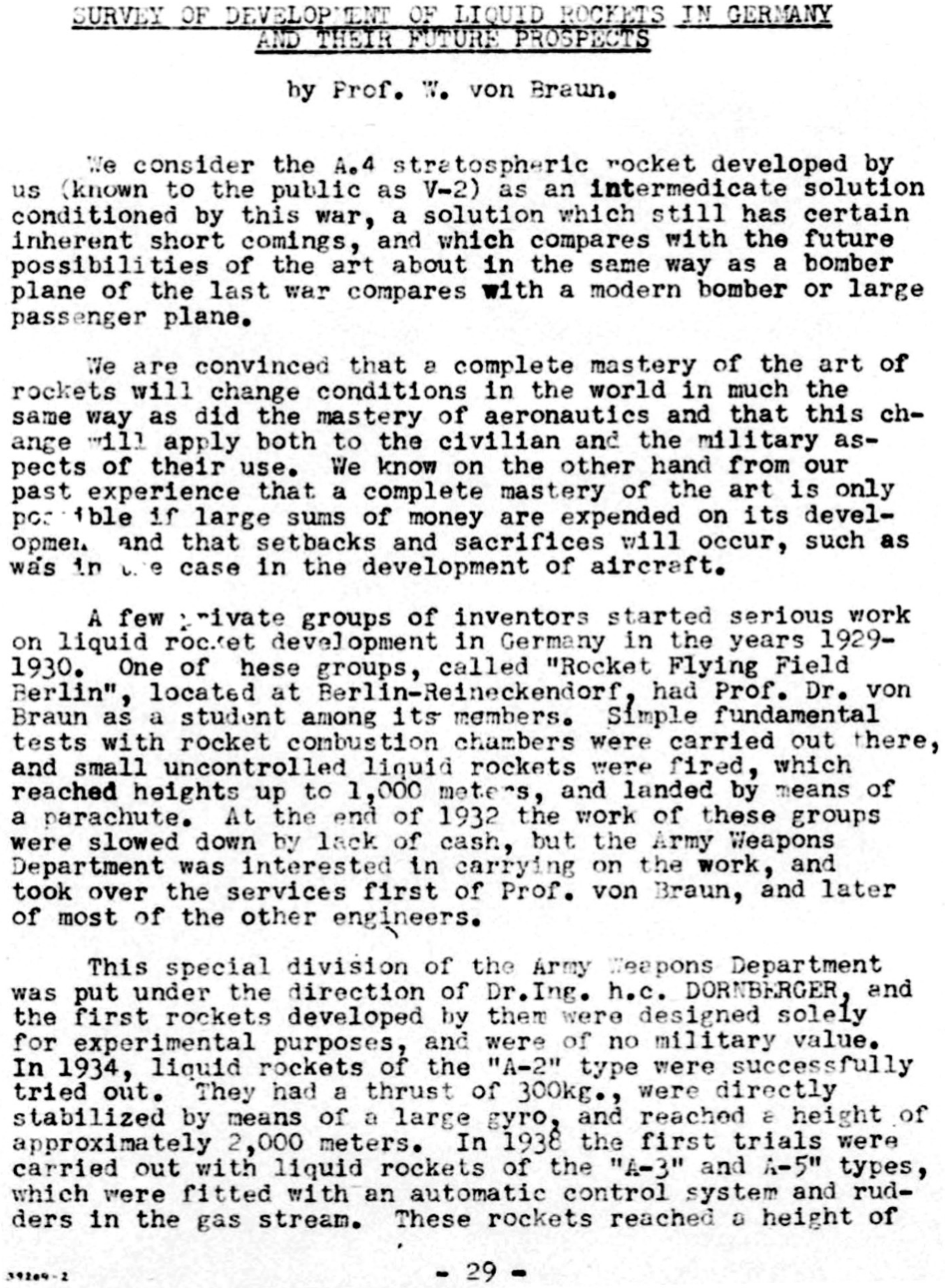
Unit History, 28th Air Disarmament Squadron (Prov), August 1945 [AFHRA A0708 frames 0758–0764]

C.I.C. Activity

One day this month a German civilian, a Herr Hering, presented himself at our installation gate and expressed a desire to speak with the Commanding Officer. He intimated that he had information of great value. The interview was granted and the German civilian was taken to Higher Headquarters after the C.O. was satisfied that the man was not "playing possum". As a result of this episode our country has been greatly enriched with pictures, blue prints and plans of Germany's dreaded jet and rocket bombs. To the German they are know as the Vergeltungs Waffe. To the American they are the V-1, V-2, V-3, and V-4. The majority of this squadron were subjected to incessant bombing by the V-1 and V-2 and are quite familiar with the horror and damage they create.

CIOS XXVIII-56. *Rockets and Guided Missiles.* 1945.

[One section of this report is an English translation of a short summary of rocket development written by Wernher von Braun. It provides useful information, although one must bear in mind that it would have been in von Braun's best personal interests to self-censor some details, and also that it would have been standard U.S. government procedure to further censor his account in making the English translation. See pp. 5420–5428.]



SURVEY OF DEVELOPMENT OF LIQUID ROCKETS IN GERMANY AND THEIR FUTURE PROSPECTS

by Prof. W. von Braun.

We consider the A.4 stratospheric rocket developed by us (known to the public as V-2) as an intermedicate solution conditioned by this war, a solution which still has certain inherent short comings, and which compares with the future possibilities of the art about in the same way as a bomber plane of the last war compares with a modern bomber or large passenger plane.

We are convinced that a complete mastery of the art of rockets will change conditions in the world in much the same way as did the mastery of aeronautics and that this change will apply both to the civilian and the military aspects of their use. We know on the other hand from our past experience that a complete mastery of the art is only possible if large sums of money are expended on its development and that setbacks and sacrifices will occur, such as was in the case in the development of aircraft.

A few private groups of inventors started serious work on liquid rocket development in Germany in the years 1929-1930. One of these groups, called "Rocket Flying Field Berlin", located at Berlin-Reineckendorf, had Prof. Dr. von Braun as a student among its members. Simple fundamental tests with rocket combustion chambers were carried out there, and small uncontrolled liquid rockets were fired, which reached heights up to 1,000 meters, and landed by means of a parachute. At the end of 1932 the work of these groups were slowed down by lack of cash, but the Army Weapons Department was interested in carrying on the work, and took over the services first of Prof. von Braun, and later of most of the other engineers.

This special division of the Army Weapons Department was put under the direction of Dr.Ing. h.c. DORNBERGER, and the first rockets developed by them were designed solely for experimental purposes, and were of no military value. In 1934, liquid rockets of the "A-2" type were successfully tried out. They had a thrust of 300kg., were directly stabilized by means of a large gyro, and reached a height of approximately 2,000 meters. In 1938 the first trials were carried out with liquid rockets of the "A-3" and A-5" types, which were fitted with an automatic control system and rudders in the gas stream. These rockets reached a height of

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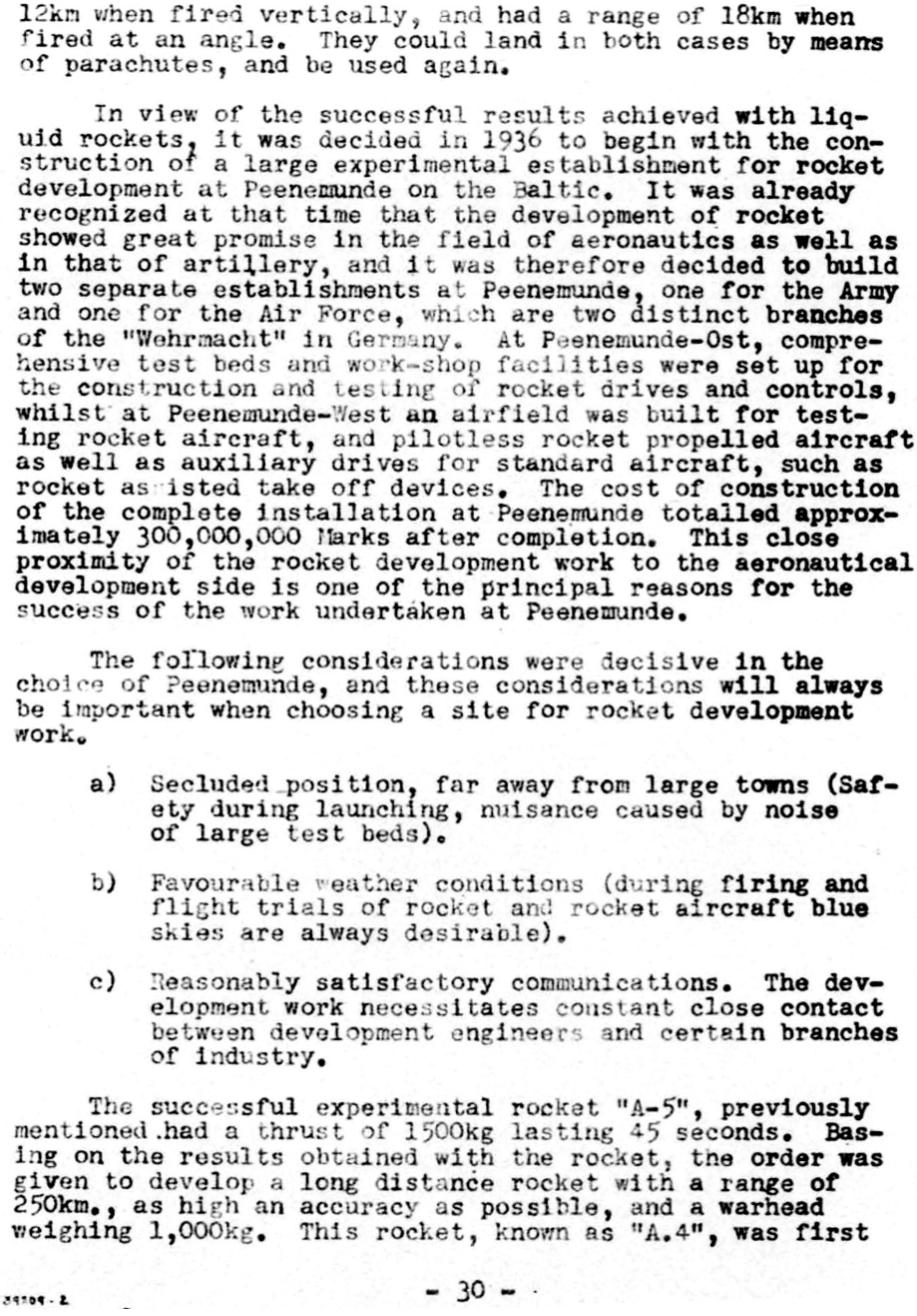
Figure E.116: CIOS XXVIII-56. *Rockets and Guided Missiles.*



12km when fired vertically, and had a range of 18km when fired at an angle. They could land in both cases by means of parachutes, and be used again.

In view of the successful results achieved with liquid rockets, it was decided in 1936 to begin with the construction of a large experimental establishment for rocket development at Peenemunde on the Baltic. It was already recognized at that time that the development of rocket showed great promise in the field of aeronautics as well as in that of artillery, and it was therefore decided to build two separate establishments at Peenemunde, one for the Army and one for the Air Force, which are two distinct branches of the "Wehrmacht" in Germany. At Peenemunde-Ost, comprehensive test beds and work-shop facilities were set up for the construction and testing of rocket drives and controls, whilst at Peenemunde-West an airfield was built for testing rocket aircraft, and pilotless rocket propelled aircraft, as well as auxiliary drives for standard aircraft, such as rocket assisted take off devices. The cost of construction of the complete installation at Peenemunde totalled approximately 300,000,000 Marks after completion. This close proximity of the rocket development work to the aeronautical development side is one of the principal reasons for the success of the work undertaken at Peenemunde.

The following considerations were decisive in the choice of Peenemunde, and these considerations will always be important when choosing a site for rocket development work.

a) Secluded position, far away from large towns (Safety during launching, nuisance caused by noise of large test beds).

b) Favourable weather conditions (during firing and flight trials of rocket and rocket aircraft blue skies are always desirable).

c) Reasonably satisfactory communications. The development work necessitates constant close contact between development engineers and certain branches of industry.

The successful experimental rocket "A-5", previously mentioned had a thrust of 1500kg lasting 45 seconds. Basing on the results obtained with the rocket, the order was given to develop a long distance rocket with a range of 250km., as high an accuracy as possible, and a warhead weighing 1,000kg. This rocket, known as "A.4", was first

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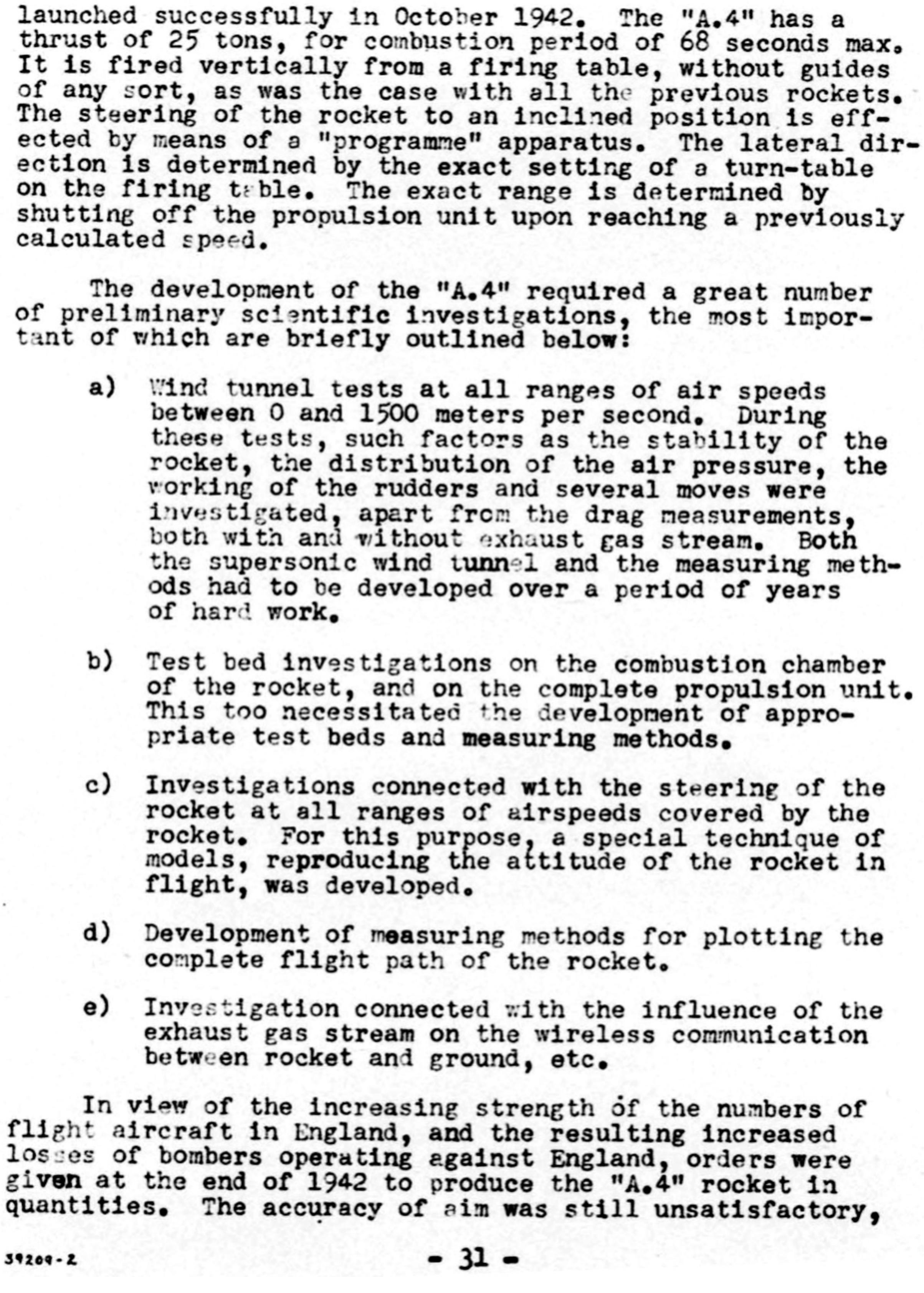
Figure E.117: CIOS XXVIII-56. *Rockets and Guided Missiles.*



launched successfully in October 1942. The "A.4" has a thrust of 25 tons, for combustion period of 68 seconds max. It is fired vertically from a firing table, without guides of any sort, as was the case with all the previous rockets. The steering of the rocket to an inclined position is effected by means of a "programme" apparatus. The lateral direction is determined by the exact setting of a turn-table on the firing table. The exact range is determined by shutting off the propulsion unit upon reaching a previously calculated speed.

The development of the "A.4" required a great number of preliminary scientific investigations, the most important of which are briefly outlined below:

a) Wind tunnel tests at all ranges of air speeds between 0 and 1500 meters per second. During these tests, such factors as the stability of the rocket, the distribution of the air pressure, the working of the rudders and several moves were investigated, apart from the drag measurements, both with and without exhaust gas stream. Both the supersonic wind tunnel and the measuring methods had to be developed over a period of years of hard work.

b) Test bed investigations on the combustion chamber of the rocket, and on the complete propulsion unit. This too necessitated the development of appropriate test beds and measuring methods.

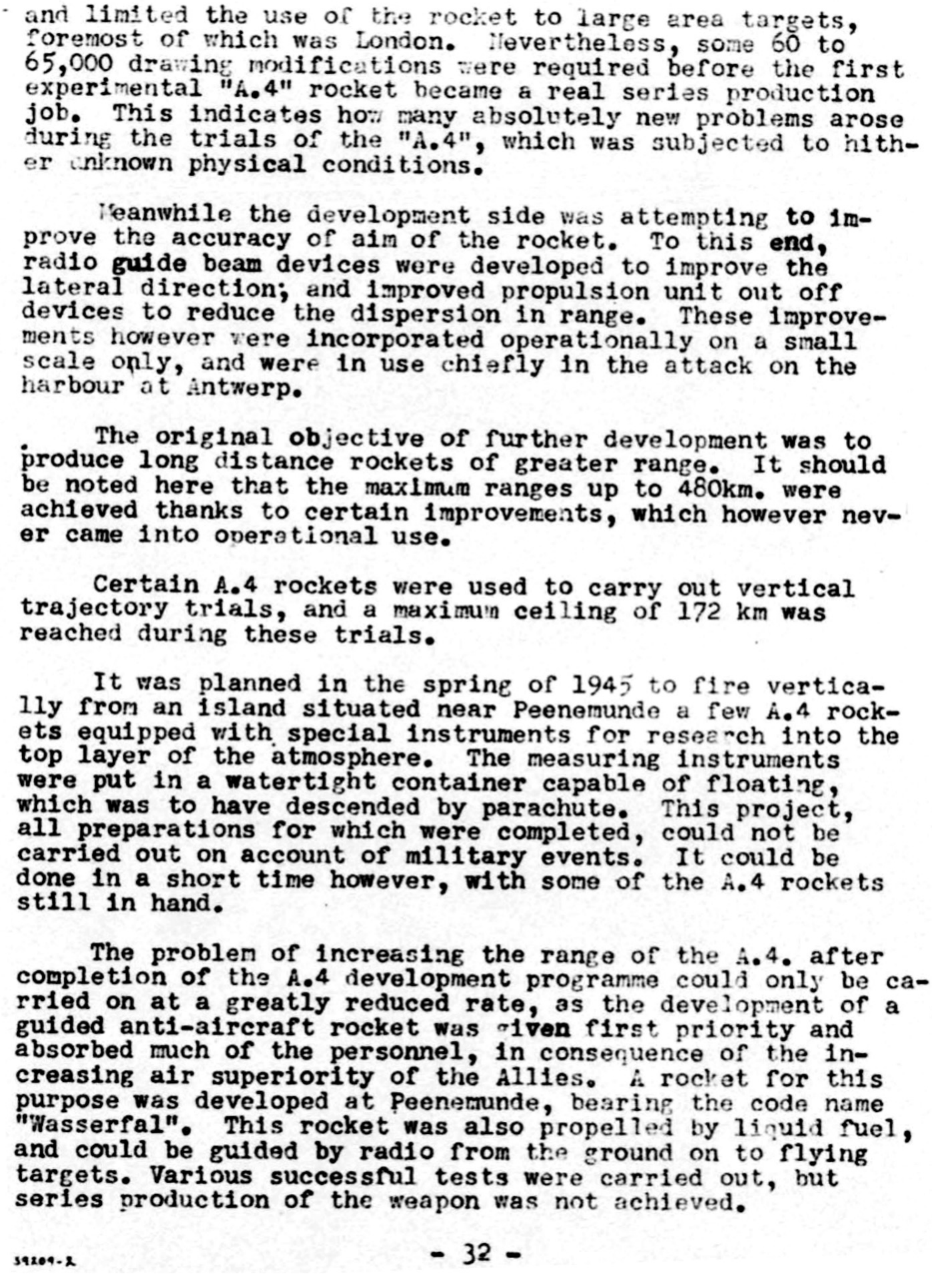
c) Investigations connected with the steering of the rocket at all ranges of airspeeds covered by the rocket. For this purpose, a special technique of models, reproducing the attitude of the rocket in flight, was developed.

d) Development of measuring methods for plotting the complete flight path of the rocket.

e) Investigation connected with the influence of the exhaust gas stream on the wireless communication between rocket and ground, etc.

In view of the increasing strength of the numbers of flight aircraft in England, and the resulting increased losses of bombers operating against England, orders were given at the end of 1942 to produce the "A.4" rocket in quantities. The accuracy of aim was still unsatisfactory,

Figure E.118: CIOS XXVIII-56. *Rockets and Guided Missiles.*



and limited the use of the rocket to large area targets, foremost of which was London. Nevertheless, some 60 to 65,000 drawing modifications were required before the first experimental "A.4" rocket became a real series production job. This indicates how many absolutely new problems arose during the trials of the "A.4", which was subjected to hither unknown physical conditions.

Meanwhile the development side was attempting to improve the accuracy of aim of the rocket. To this end, radio guide beam devices were developed to improve the lateral direction; and improved propulsion unit out off devices to reduce the dispersion in range. These improvements however were incorporated operationally on a small scale only, and were in use chiefly in the attack on the harbour at Antwerp.

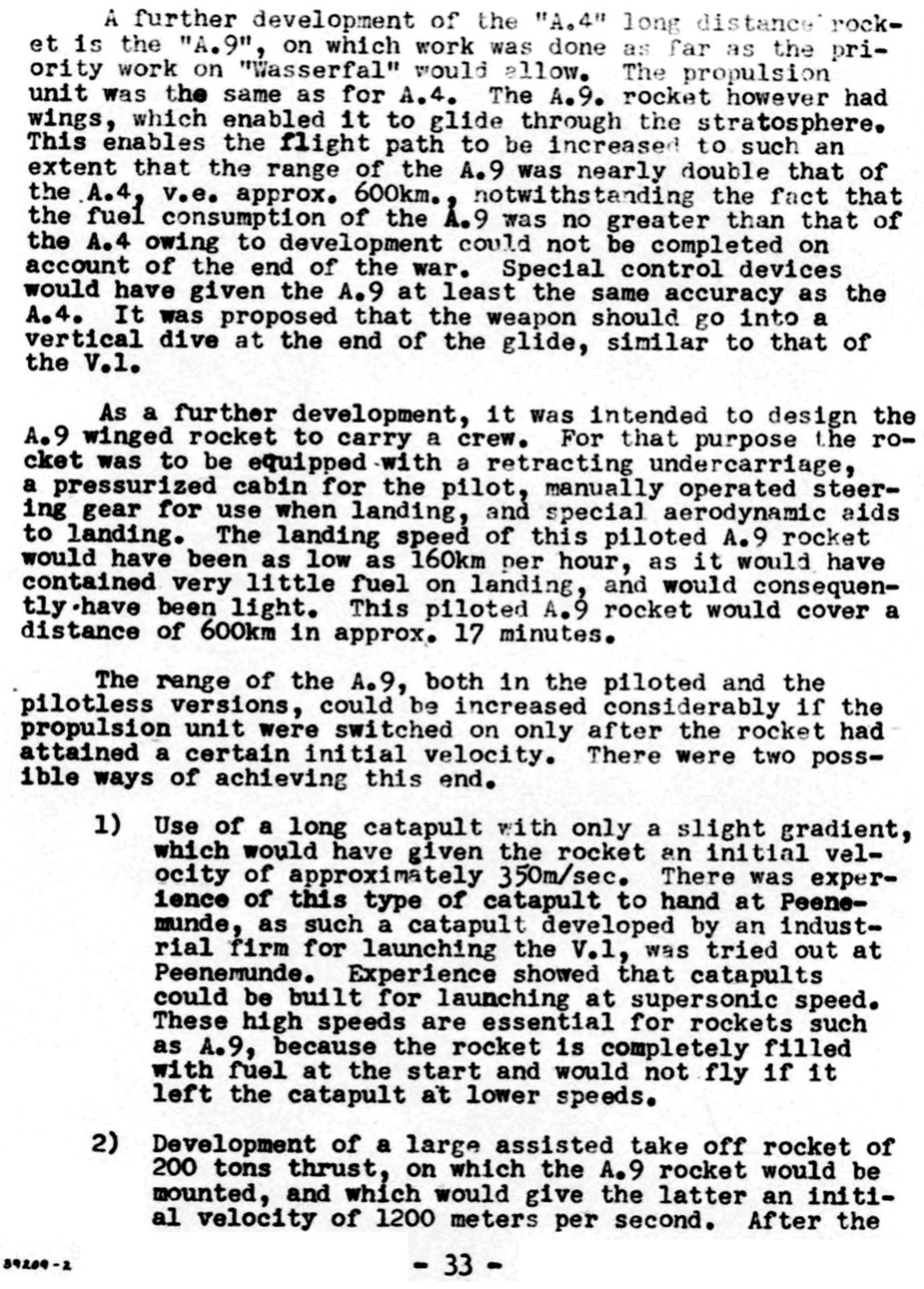
The original objective of further development was to produce long distance rockets of greater range. It should be noted here that the maximum ranges up to 480km. were achieved thanks to certain improvements, which however never came into operational use.

Certain A.4 rockets were used to carry out vertical trajectory trials, and a maximum ceiling of 172 km was reached during these trials.

It was planned in the spring of 1945 to fire vertically from an island situated near Peenemunde a few A.4 rockets equipped with special instruments for research into the top layer of the atmosphere. The measuring instruments were put in a watertight container capable of floating, which was to have descended by parachute. This project, all preparations for which were completed, could not be carried out on account of military events. It could be done in a short time however, with some of the A.4 rockets still in hand.

The problem of increasing the range of the A.4. after completion of the A.4 development programme could only be carried on at a greatly reduced rate, as the development of a guided anti-aircraft rocket was given first priority and absorbed much of the personnel, in consequence of the increasing air superiority of the Allies. A rocket for this purpose was developed at Peenemunde, bearing the code name "Wasserfal". This rocket was also propelled by liquid fuel, and could be guided by radio from the ground on to flying targets. Various successful tests were carried out, but series production of the weapon was not achieved.

Figure E.119: CIOS XXVIII-56. *Rockets and Guided Missiles.*



A further development of the "A.4" long distance rocket is the "A.9", on which work was done as far as the priority work on "Wasserfal" would allow. The propulsion unit was the same as for A.4. The A.9. rocket however had wings, which enabled it to glide through the stratosphere. This enables the flight path to be increased to such an extent that the range of the A.9 was nearly double that of the A.4, v.e. approx. 600km., notwithstanding the fact that the fuel consumption of the A.9 was no greater than that of the A.4 owing to development could not be completed on account of the end of the war. Special control devices would have given the A.9 at least the same accuracy as the A.4. It was proposed that the weapon should go into a vertical dive at the end of the glide, similar to that of the V.1.

As a further development, it was intended to design the A.9 winged rocket to carry a crew. For that purpose the rocket was to be equipped with a retracting undercarriage, a pressurized cabin for the pilot, manually operated steering gear for use when landing, and special aerodynamic aids to landing. The landing speed of this piloted A.9 rocket would have been as low as 160km per hour, as it would have contained very little fuel on landing, and would consequently have been light. This piloted A.9 rocket would cover a distance of 600km in approx. 17 minutes.

The range of the A.9, both in the piloted and the pilotless versions, could be increased considerably if the propulsion unit were switched on only after the rocket had attained a certain initial velocity. There were two possible ways of achieving this end.

1) Use of a long catapult with only a slight gradient, which would have given the rocket an initial velocity of approximately 350m/sec. There was experience of this type of catapult to hand at Peenemunde, as such a catapult developed by an industrial firm for launching the V.1, was tried out at Peenemunde. Experience showed that catapults could be built for launching at supersonic speed. These high speeds are essential for rockets such as A.9, because the rocket is completely filled with fuel at the start and would not fly if it left the catapult at lower speeds.

2) Development of a large assisted take off rocket of 200 tons thrust, on which the A.9 rocket would be mounted, and which would give the latter an initial velocity of 1200 meters per second. After the

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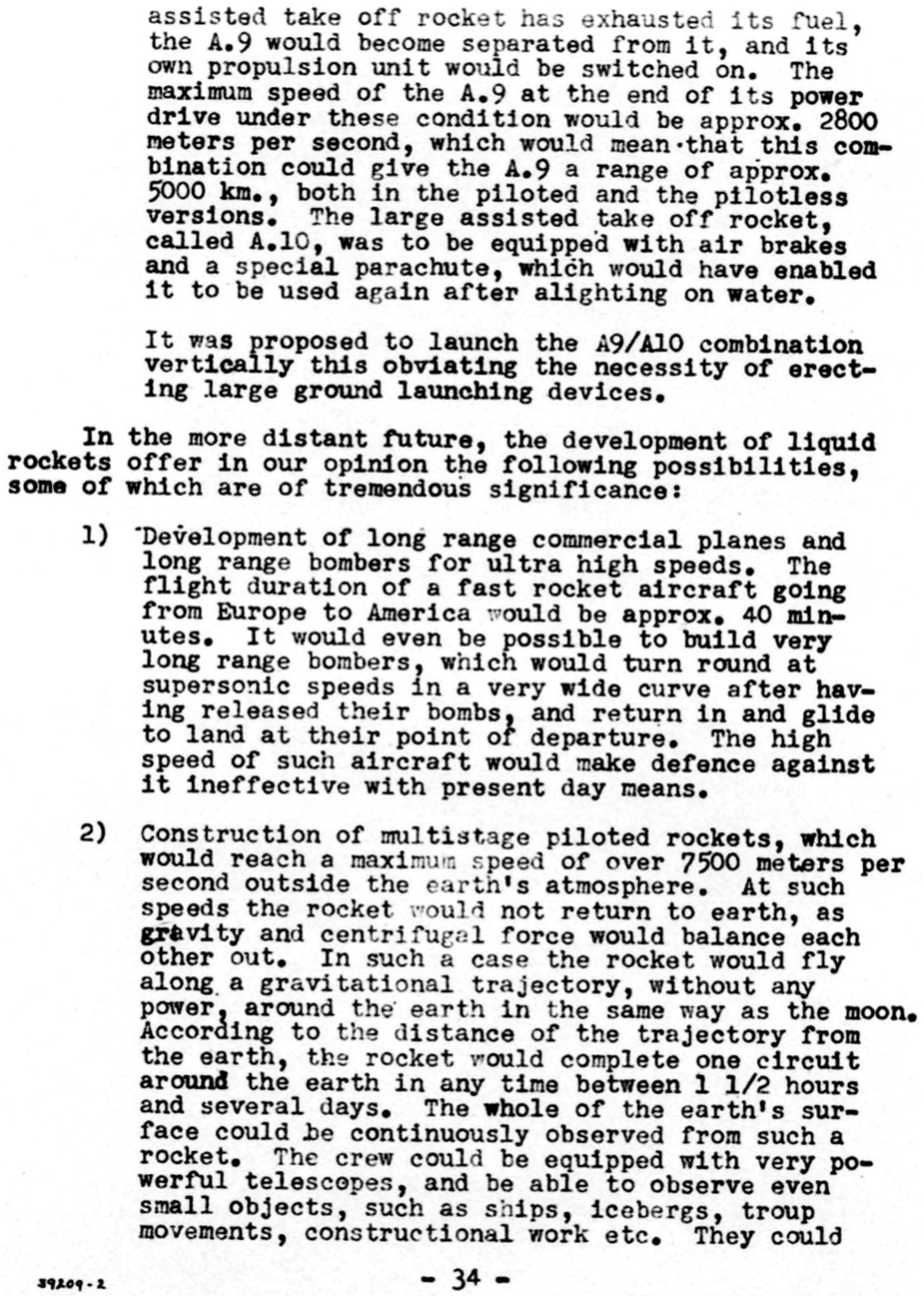
Figure E.120: CIOS XXVIII-56. *Rockets and Guided Missiles.*



assisted take off rocket has exhausted its fuel, the A.9 would become separated from it, and its own propulsion unit would be switched on. The maximum speed of the A.9 at the end of its power drive under these condition would be approx. 2800 meters per second, which would mean that this combination could give the A.9 a range of approx. 5000 km., both in the piloted and the pilotless versions. The large assisted take off rocket, called A.10, was to be equipped with air brakes and a special parachute, which would have enabled it to be used again after alighting on water.

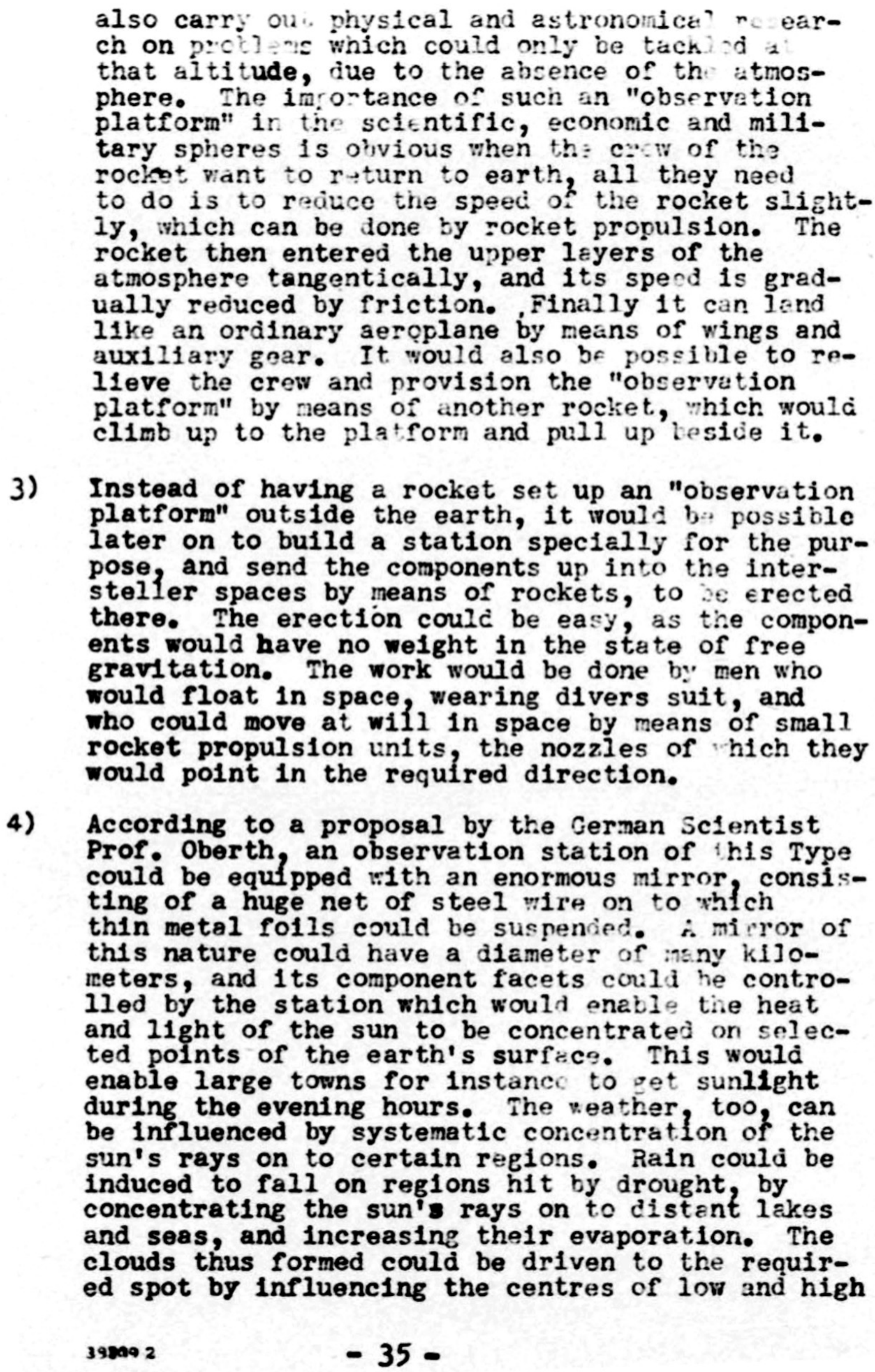
It was proposed to launch the A9/A10 combination vertically this obviating the necessity of erecting large ground launching devices.

In the more distant future, the development of liquid rockets offer in our opinion the following possibilities, some of which are of tremendous significance:

1) Development of long range commercial planes and long range bombers for ultra high speeds. The flight duration of a fast rocket aircraft going from Europe to America would be approx. 40 minutes. It would even be possible to build very long range bombers, which would turn round at supersonic speeds in a very wide curve after having released their bombs, and return in and glide to land at their point of departure. The high speed of such aircraft would make defence against it ineffective with present day means.

2) Construction of multistage piloted rockets, which would reach a maximum speed of over 7500 meters per second outside the earth's atmosphere. At such speeds the rocket would not return to earth, as gravity and centrifugal force would balance each other out. In such a case the rocket would fly along a gravitational trajectory, without any power, around the earth in the same way as the moon. According to the distance of the trajectory from the earth, the rocket would complete one circuit around the earth in any time between 1 1/2 hours and several days. The whole of the earth's surface could be continuously observed from such a rocket. The crew could be equipped with very powerful telescopes, and be able to observe even small objects, such as ships, icebergs, troup movements, constructional work etc. They could

Figure E.121: CIOS XXVIII-56. *Rockets and Guided Missiles.*



also carry out physical and astronomical research on problems which could only be tackled at that altitude, due to the absence of the atmosphere. The importance of such an "observation platform" in the scientific, economic and military spheres is obvious when the crew of the rocket want to return to earth, all they need to do is to reduce the speed of the rocket slightly, which can be done by rocket propulsion. The rocket then entered the upper layers of the atmosphere tangentically, and its speed is gradually reduced by friction. Finally it can land like an ordinary aeroplane by means of wings and auxiliary gear. It would also be possible to relieve the crew and provision the "observation platform" by means of another rocket, which would climb up to the platform and pull up beside it.

3) Instead of having a rocket set up an "observation platform" outside the earth, it would be possible later on to build a station specially for the purpose, and send the components up into the intersteller spaces by means of rockets, to be erected there. The erection could be easy, as the components would have no weight in the state of free gravitation. The work would be done by men who would float in space, wearing divers suit, and who could move at will in space by means of small rocket propulsion units, the nozzles of which they would point in the required direction.

4) According to a proposal by the German Scientist Prof. Oberth, an observation station of this Type could be equipped with an enormous mirror, consisting of a huge net of steel wire on to which thin metal foils could be suspended. A mirror of this nature could have a diameter of many kilometers, and its component facets could be controlled by the station which would enable the heat and light of the sun to be concentrated on selected points of the earth's surface. This would enable large towns for instance to get sunlight during the evening hours. The weather, too, can be influenced by systematic concentration of the sun's rays on to certain regions. Rain could be induced to fall on regions hit by drought, by concentrating the sun's rays on to distant lakes and seas, and increasing their evaporation. The clouds thus formed could be driven to the required spot by influencing the centres of low and high

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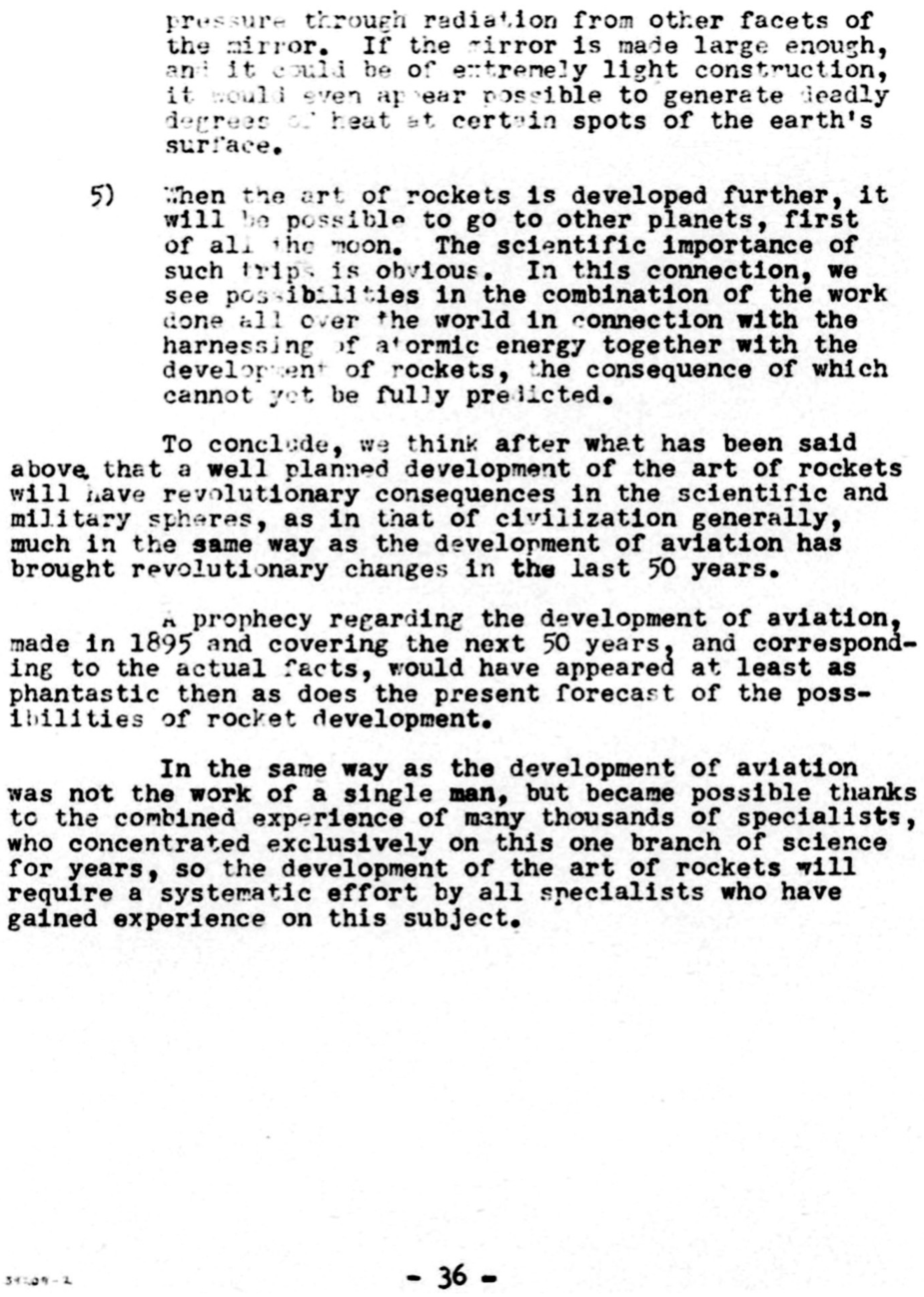
Figure E.122: CIOS XXVIII-56. *Rockets and Guided Missiles.*



pressure through radiation from other facets of the mirror. If the mirror is made large enough, and it could be of extremely light construction, it would even appear possible to generate deadly degrees of heat at certain spots of the earth's surface.

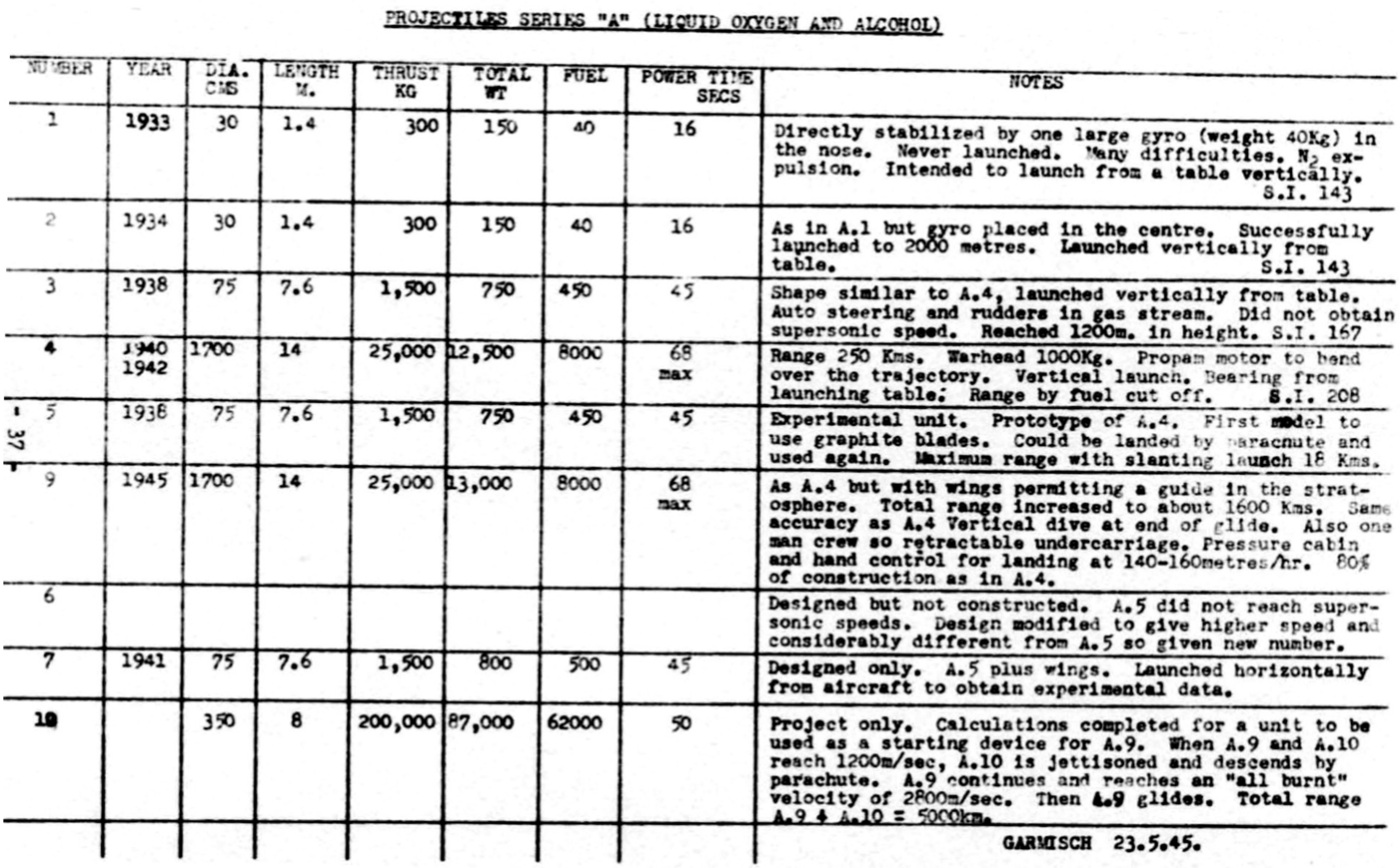
5) When the art of rockets is developed further, it will be possible to go to other planets, first of all the moon. The scientific importance of such trips is obvious. In this connection, we see possibilities in the combination of the work done all over the world in connection with the harnessing of atomic energy together with the development of rockets, the consequence of which cannot yet be fully predicted.

To conclude, we think after what has been said above, that a well planned development of the art of rockets will have revolutionary consequences in the scientific and military spheres, as in that of civilization generally, much in the same way as the development of aviation has brought revolutionary changes in the last 50 years.

A prophecy regarding the development of aviation, made in 1895 and covering the next 50 years, and corresponding to the actual facts, would have appeared at least as phantastic then as does the present forecast of the possibilities of rocket development.

In the same way as the development of aviation was not the work of a single man, but became possible thanks to the combined experience of many thousands of specialists, who concentrated exclusively on this one branch of science for years, so the development of the art of rockets will require a systematic effort by all specialists who have gained experience on this subject.

Figure E.123: CIOS XXVIII-56. *Rockets and Guided Missiles.*



PROJECTILES SERIES "A" (LIQUID OXYGEN AND ALCOHOL)

NUMBER	YEAR	DIA. CMS	LENGTH M.	THRUST KG	TOTAL WT	FUEL	POWER TIME SECS	NOTES
1	1933	30	1.4	300	150	40	16	Directly stabilized by one large gyro (weight 40Kg) in the nose. Never launched. Many difficulties. N_2 expulsion. Intended to launch from a table vertically. S.I. 143
2	1934	30	1.4	300	150	40	16	As in A.1 but gyro placed in the centre. Successfully launched to 2000 metres. Launched vertically from table. S.I. 143
3	1938	75	7.6	1,500	750	450	45	Shape similar to A.4, launched vertically from table. Auto steering and rudders in gas stream. Did not obtain supersonic speed. Reached 1200m. in height. S.I. 167
4	1940 1942	1700	14	25,000	12,500	8000	68 max	Range 250 Kms. Warhead 1000Kg. Propam motor to bend over the trajectory. Vertical launch. Bearing from launching table. Range by fuel cut off. S.I. 208
5	1938	75	7.6	1,500	750	450	45	Experimental unit. Prototype of A.4. First model to use graphite blades. Could be landed by parachute and used again. Maximum range with slanting launch 18 Kms.
9	1945	1700	14	25,000	13,000	8000	68 max	As A.4 but with wings permitting a guide in the stratosphere. Total range increased to about 1600 Kms. Same accuracy as A.4 Vertical dive at end of glide. Also one man crew so retractable undercarriage. Pressure cabin and hand control for landing at 140-160metres/hr. 80% of construction as in A.4.
6								Designed but not constructed. A.5 did not reach supersonic speeds. Design modified to give higher speed and considerably different from A.5 so given new number.
7	1941	75	7.6	1,500	800	500	45	Designed only. A.5 plus wings. Launched horizontally from aircraft to obtain experimental data.
10		350	8	200,000	87,000	62000	50	Project only. Calculations completed for a unit to be used as a starting device for A.9. When A.9 and A.10 reach 1200m/sec, A.10 is jettisoned and descends by parachute. A.9 continues and reaches an "all burnt" velocity of 2800m/sec. Then A.9 glides. Total range A.9 + A.10 = 5000km.

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Figure E.124: CIOS XXVIII-56. *Rockets and Guided Missiles.*

NavTechMisEu 237-45. *Survey of German Activities in the Field of Guided Missiles.* August 1945. [NARA RG 38, Entry P5, Box 38]

[...] It must be borne in mind that the magnitude of the Germans' basic research program was tremendous and that it was equally thorough for all types of controlled missiles. Once they realized the defensive potentialities of various types of this new weapon, a program was inaugurated, which if given six more months uninterrupted time, might well have resulted in the achievement of what had become a basic policy: to drive bombers from the sky at altitudes below fifty thousand feet. [...]

The FX and Hs missiles were predicated on the assumption that the Luftwaffe would maintain air supremacy and while this condition existed they were used to good advantage. Contrary to popular idea, that the Allies succeeded in effectively jamming the radio control used in these missiles consequently arresting their use, the contributing evidence from enemy operational and developmental personnel is definitely negative. [...]

With the increase in Allied air power, Axis interest began to focus on the development of controlled anti-aircraft missiles. This interest grew rapidly and a highly competitive development program for AA missiles expanded with the steady increase of Allied aerial might until at one time in 1943 there were under development in Germany 48 different anti-aircraft missiles. [...] 12 were to be carried through to full development for operational use. [...]

The V-1 was the first long range missile operationally used as a self-controlled, non-piloted guided or controlled weapon. It is estimated that over 20,000 of these were used against the Allies. [...]

During this same period, the development of the A series, i.e., V-2 missiles, for supersonic speed ranges was carried on in spite of continual handicaps caused by Allied bombings. A large modern well-equipped missile development and testing center was established at Peenemünde on the Baltic Sea. This station which cost 300 million gold marks for the initial installation was started in 1936 and was reported in operation in 1937. [...] After the expenditure of a tremendous amount of money and energy on this project, the A-4 missile went into operational use in 1944. It is estimated that 3000–5000 of these missiles were built.

To increase range, the A-4b was made by the simple addition of wings to the A-4. This approximately doubled the A-4's range. With the ultimate operational range in sight for the A-4b, design work was immediately started on more radical weapons. There is little of humorous nature in the statements so often heard that the Germans intended to bombard New York from launching sites in Europe, as two missiles, the A-9 and A-10, were under development for use against the U.S. in the early months of 1946. This contemplated use was scientifically possible and undoubtedly would have been realized had time permitted.

The German guided missile program during the last stages of the war provided for development of every conceivable basic type, one classification of which follows:

(a) Surface launched to air targets.

(b) Air launched to air targets.

(c) Air launched to surface targets.

(d) Surface launched to surface targets.

(e) Underwater launched to underwater targets.

(f) Underwater launched to surface targets.

(g) Underwater launched to air targets.

Every known type of remote control, self-seeking or homing device, and proximity fuse was being developed or exploited for use in guided missiles. This included radio control, wire control, radar, continuous wave radio, acoustics, infra red, light beams, magnetics, etc. It was in this field, however, that the missile program was suffering the most serious difficulties.

All types of jet [rocket] propulsion were being incorporated into the power plants of the missiles which were being built to fly at speeds both subsonic and supersonic.

Work on the science of controlled missiles was being carried out in every area visited in Allied occupied territory, from the border of Denmark to Switzerland and from the coast of France to the Russian zone of occupation. It is a known fact that some work was being done in Denmark, Norway and Poland, and it is estimated that 50% of the total German effort in this field was in what is now Russian-occupied territory, to which investigators have not had access. The results of the enemy's guided missile work are evident on the targets in England, Belgium, and Holland.

It is estimated that one-third of the energy directed to aerodynamic research in Germany was devoted to the problems of guided missiles. The research laboratories at Braunschweig, Goettingen, Darmstadt, Ainring, etc., were involved in major projects and the above establishments have capacities exceeding anything previously dreamed of in America. There exists in Germany numerous wind tunnels with a Mach number of 4, i.e., four times the speed of sound. One tunnel with a Mach number of 10 was under construction. Some degree of guided missiles research was being carried out in all of the above tunnels.

It has been gratifying to find a few isolated items relating to the field of guided missiles in which the German product was inferior to similar accomplished in America. However, this is subject to being misconstrued if used to magnify our virtues or exonerate our failures by so-called experts who have "surveyed the field" in a few weeks, returned to America and announced they are disappointed to find the Germans have nothing to offer. Such a statement is evidence of the individual's refusal to accept the obvious fact, inexcusable if made in innocent though stupid sincerity, and criminal if made for ulterior motives.

From observation of the enemy's work, it is concluded that:

(a) If given a relatively short period of time, Germany would have succeeded in bringing into the war an effective counter measure against aerial bombers. She would have produced infinitely superior assault weapons through intensive exploitation of the science of guided missiles.

(b) From the standpoint of future warfare, the work of the Peenemünde and associated groups without question ranked among the most important being done in Germany on any subject. Although the apparent results of this organization have been extensively covered by investigators, determination of the group's ultimate goal remains an assumption based on the trend of their developments. Undoubtedly they expected to produce weapons from the A series with which they could accurately hit any area on the face of the earth. It is equally obvious that with the V-2 they were not only working out in advance the aerodynamic and control problems of such weapons, but that in the present weapon they had a proven vehicle ready to receive whatever radically new explosive and propulsive substance they expected to become available. It is inconceivable that the V-2 was considered by the German scientists to be an end in itself, nor that with all its complexities, it was developed at the cost of billions of dollars and manufactured in great quantity with highest priority merely to deposit 750 kilograms of ordinary explosive on British territory.

With the relaxation to a practical degree of the impenetrable screen that has surrounded the investigation of German atomic disintegration research, some of the hitherto inexplicables of their guided missile program are now subject to an analysis from which reasonable answers can be derived. It is now obvious that Germans realized and have accepted for years the fact that a controlled missile is the natural vehicle with which to transport atomic explosive. At last, the reasoning behind the design specifications which provided for very small warheads and the invariable orders to terminate missile projects upon completion of development are no longer mysteries or absurdities. [...]

[NavTechMisEu 237-45 is over 450 pages long, with concise yet informative sections on most German rockets and missiles that were developed or under development. What is quoted above and shown on pp. 5432–5437 is just the introduction.

Further Allied investigations appear to have confirmed the conclusions of NavTechMisEu 237-45. In fact, the introduction of NavTechMisEu 237-45 was deemed worthy of being repeated almost verbatim in:

H. H. Smith, N. W. Dickson, V. P. Kovac, and E. H. Bennett. 10 January 1946. German Developments in the Guided Missile Field. Project 2874. [NARA RG 319, Entry NM3-82, Box 2879, Folder Project 2784]]

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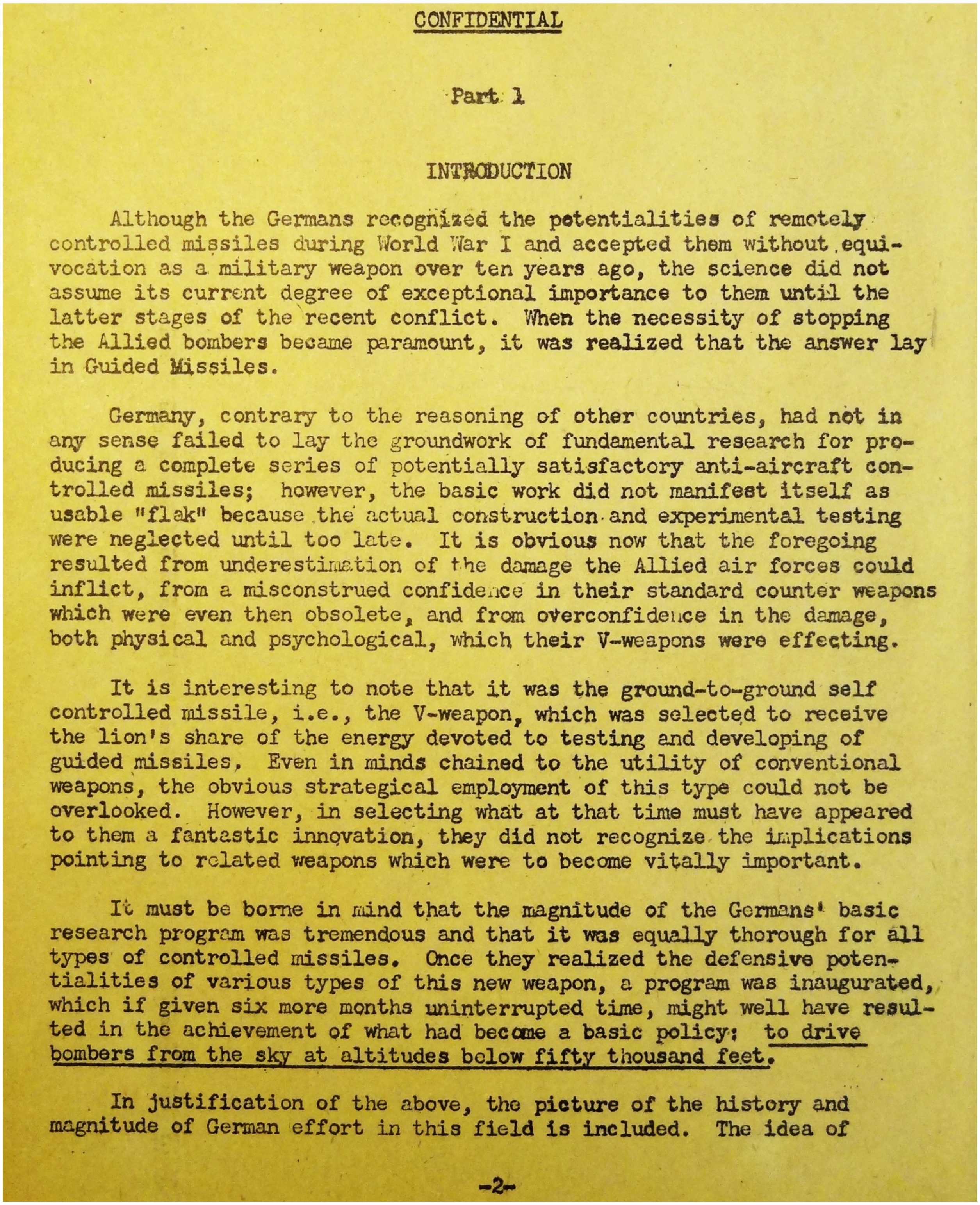
NavTechMisEu 237-45. Survey of German Activities in the Field of Guided Missiles. August 1945. NARA RG 38, Entry P5, Box 38.



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Part 1

INTRODUCTION

Although the Germans recognized the potentialities of remotely controlled missiles during World War I and accepted them without equivocation as a military weapon over ten years ago, the science did not assume its current degree of exceptional importance to them until the latter stages of the recent conflict. When the necessity of stopping the Allied bombers became paramount, it was realized that the answer lay in Guided Missiles.

Germany, contrary to the reasoning of other countries, had not in any sense failed to lay the groundwork of fundamental research for producing a complete series of potentially satisfactory anti-aircraft controlled missiles; however, the basic work did not manifest itself as usable "flak" because the actual construction and experimental testing were neglected until too late. It is obvious now that the foregoing resulted from underestimation of the damage the Allied air forces could inflict, from a misconstrued confidence in their standard counter weapons which were even then obsolete, and from overconfidence in the damage, both physical and psychological, which their V-weapons were effecting.

It is interesting to note that it was the ground-to-ground self controlled missile, i.e., the V-weapon, which was selected to receive the lion's share of the energy devoted to testing and developing of guided missiles. Even in minds chained to the utility of conventional weapons, the obvious strategical employment of this type could not be overlooked. However, in selecting what at that time must have appeared to them a fantastic innovation, they did not recognize the implications pointing to related weapons which were to become vitally important.

It must be borne in mind that the magnitude of the Germans' basic research program was tremendous and that it was equally thorough for all types of controlled missiles. Once they realized the defensive potentialities of various types of this new weapon, a program was inaugurated, which if given six more months uninterrupted time, might well have resulted in the achievement of what had become a basic policy: to drive bombers from the sky at altitudes below fifty thousand feet.

In justification of the above, the picture of the history and magnitude of German effort in this field is included. The idea of

Figure E.125: NavTechMisEu 237-45. *Survey of German Activities in the Field of Guided Missiles.* August 1945. [NARA RG 38, Entry P5, Box 38]

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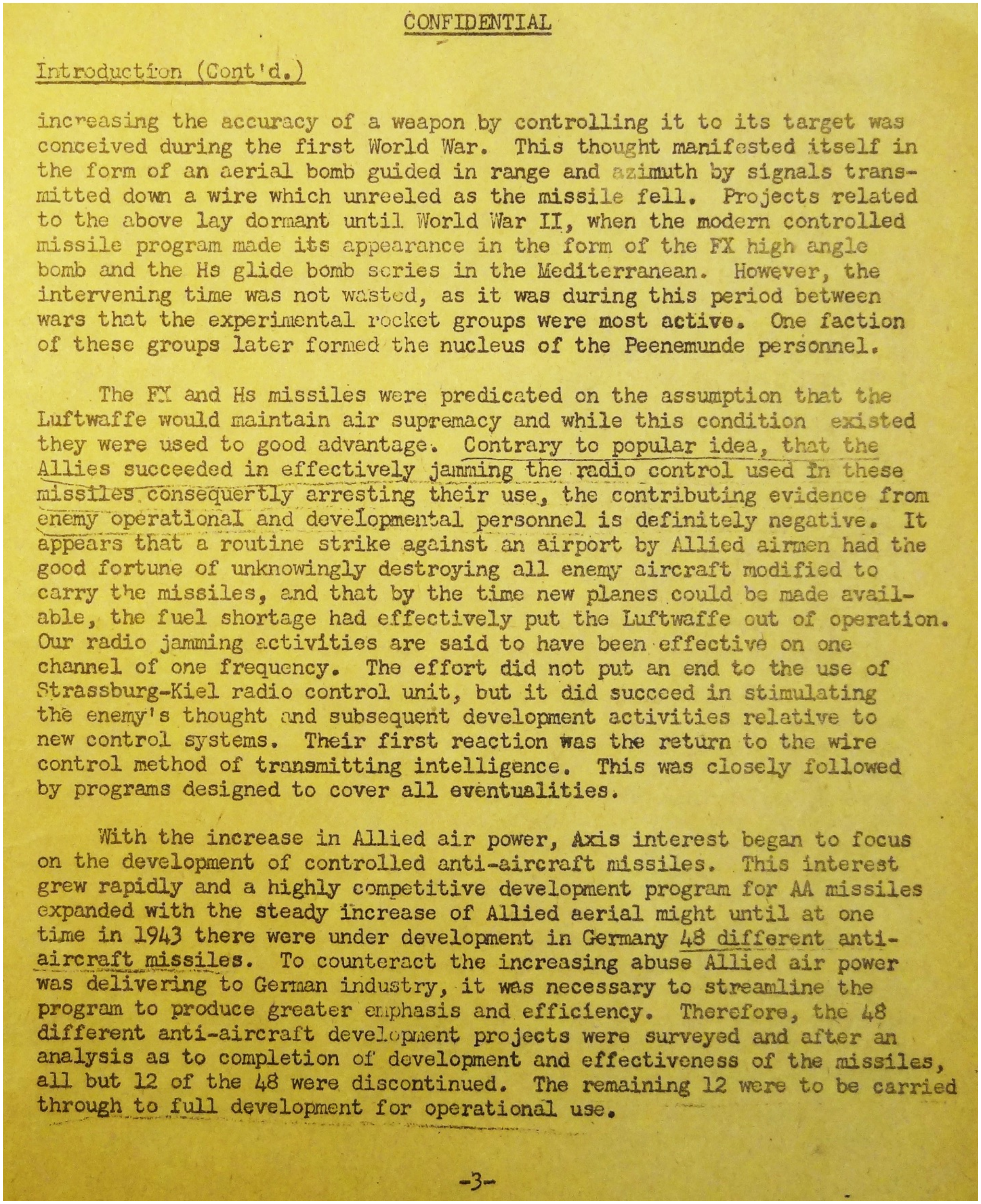

CONFIDENTIAL

Introduction (Cont'd.)

increasing the accuracy of a weapon by controlling it to its target was conceived during the first World War. This thought manifested itself in the form of an aerial bomb guided in range and azimuth by signals transmitted down a wire which unreeled as the missile fell. Projects related to the above lay dormant until World War II, when the modern controlled missile program made its appearance in the form of the FX high angle bomb and the Hs glide bomb series in the Mediterranean. However, the intervening time was not wasted, as it was during this period between wars that the experimental rocket groups were most active. One faction of these groups later formed the nucleus of the Peenemunde personnel.

The FX and Hs missiles were predicated on the assumption that the Luftwaffe would maintain air supremacy and while this condition existed they were used to good advantage. Contrary to popular idea, that the Allies succeeded in effectively jamming the radio control used in these missiles consequently arresting their use, the contributing evidence from enemy operational and developmental personnel is definitely negative. It appears that a routine strike against an airport by Allied airmen had the good fortune of unknowingly destroying all enemy aircraft modified to carry the missiles, and that by the time new planes could be made available, the fuel shortage had effectively put the Luftwaffe out of operation. Our radio jamming activities are said to have been effective on one channel of one frequency. The effort did not put an end to the use of Strassburg-Kiel radio control unit, but it did succeed in stimulating the enemy's thought and subsequent development activities relative to new control systems. Their first reaction was the return to the wire control method of transmitting intelligence. This was closely followed by programs designed to cover all eventualities.

With the increase in Allied air power, Axis interest began to focus on the development of controlled anti-aircraft missiles. This interest grew rapidly and a highly competitive development program for AA missiles expanded with the steady increase of Allied aerial might until at one time in 1943 there were under development in Germany 48 different anti-aircraft missiles. To counteract the increasing abuse Allied air power was delivering to German industry, it was necessary to streamline the program to produce greater emphasis and efficiency. Therefore, the 48 different anti-aircraft development projects were surveyed and after an analysis as to completion of development and effectiveness of the missiles, all but 12 of the 48 were discontinued. The remaining 12 were to be carried through to full development for operational use.

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Figure E.126: NavTechMisEu 237-45. *Survey of German Activities in the Field of Guided Missiles.* August 1945. [NARA RG 38, Entry P5, Box 38]

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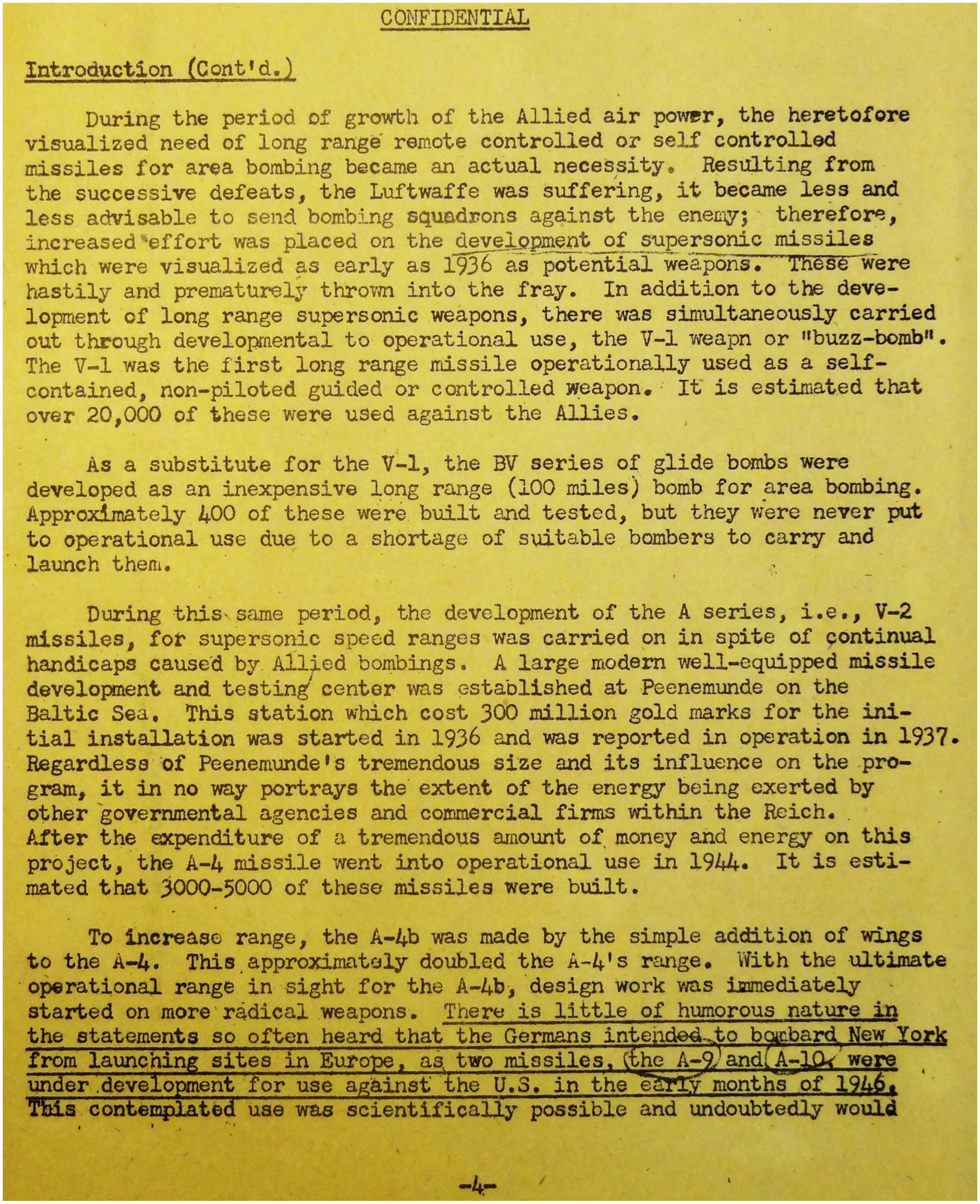

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Introduction (Cont'd.)

During the period of growth of the Allied air power, the heretofore visualized need of long range remote controlled or self controlled missiles for area bombing became an actual necessity. Resulting from the successive defeats, the Luftwaffe was suffering, it became less and less advisable to send bombing squadrons against the enemy; therefore, increased effort was placed on the development of supersonic missiles which were visualized as early as 1936 as potential weapons. These were hastily and prematurely thrown into the fray. In addition to the development of long range supersonic weapons, there was simultaneously carried out through developmental to operational use, the V-1 weapn or "buzz-bomb". The V-1 was the first long range missile operationally used as a self-contained, non-piloted guided or controlled weapon. It is estimated that over 20,000 of these were used against the Allies.

As a substitute for the V-1, the BV series of glide bombs were developed as an inexpensive long range (100 miles) bomb for area bombing. Approximately 400 of these were built and tested, but they were never put to operational use due to a shortage of suitable bombers to carry and launch them.

During this same period, the development of the A series, i.e., V-2 missiles, for supersonic speed ranges was carried on in spite of continual handicaps caused by Allied bombings. A large modern well-equipped missile development and testing center was established at Peenemunde on the Baltic Sea. This station which cost 300 million gold marks for the initial installation was started in 1936 and was reported in operation in 1937. Regardless of Peenemunde's tremendous size and its influence on the program, it in no way portrays the extent of the energy being exerted by other governmental agencies and commercial firms within the Reich. After the expenditure of a tremendous amount of money and energy on this project, the A-4 missile went into operational use in 1944. It is estimated that 3000-5000 of these missiles were built.

To increase range, the A-4b was made by the simple addition of wings to the A-4. This approximately doubled the A-4's range. With the ultimate operational range in sight for the A-4b, design work was immediately started on more radical weapons. There is little of humorous nature in the statements so often heard that the Germans intended to bombard New York from launching sites in Europe, as two missiles, (the A-9) and (A-10, were under development for use against the U.S. in the early months of 1946. This contemplated use was scientifically possible and undoubtedly would

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Figure E.127: NavTechMisEu 237-45. *Survey of German Activities in the Field of Guided Missiles.* August 1945. [NARA RG 38, Entry P5, Box 38]

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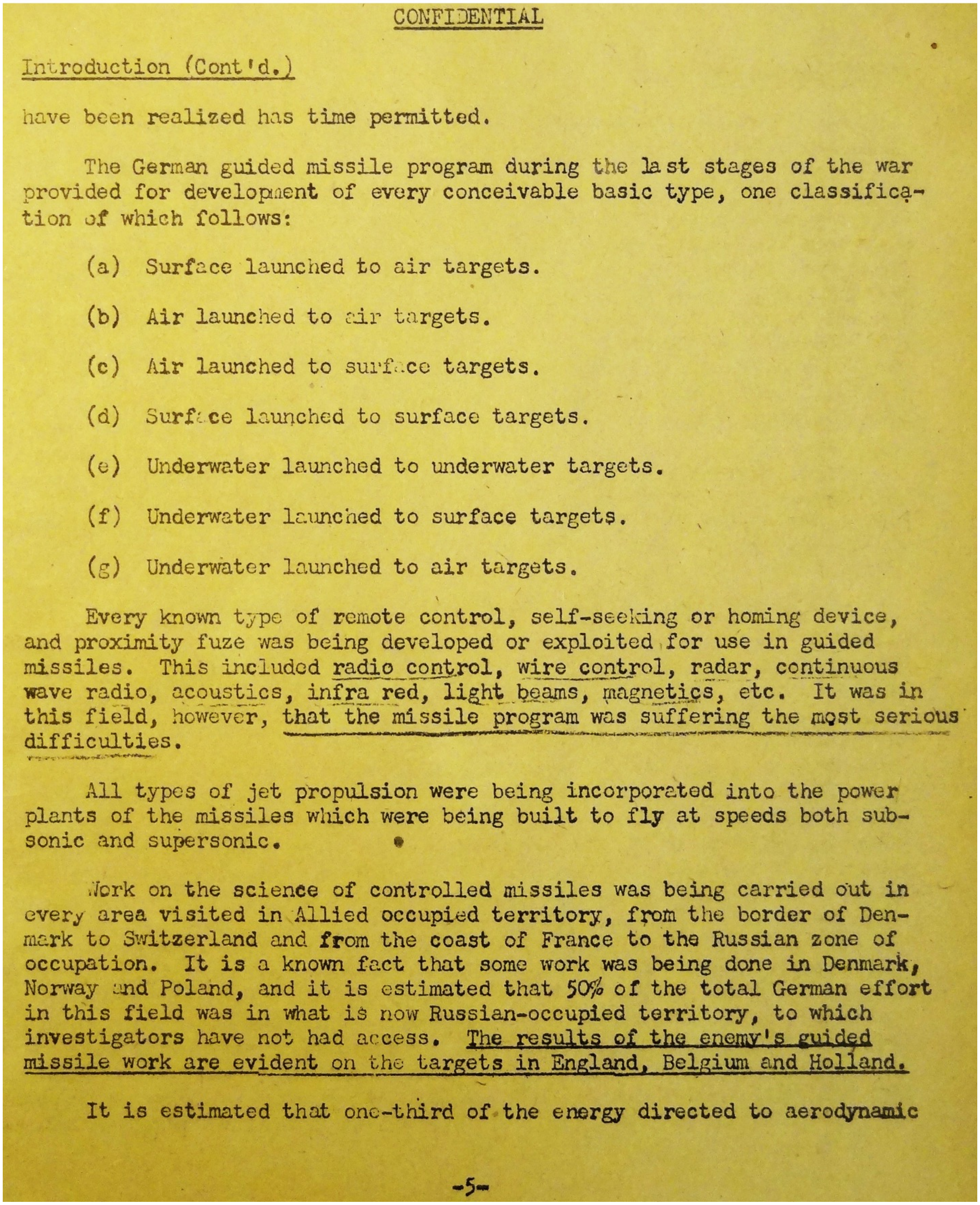

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Introduction (Cont'd.)

have been realized has time permitted.

The German guided missile program during the last stages of the war provided for development of every conceivable basic type, one classification of which follows:

(a) Surface launched to air targets.

(b) Air launched to air targets.

(c) Air launched to surface targets.

(d) Surface launched to surface targets.

(e) Underwater launched to underwater targets.

(f) Underwater launched to surface targets.

(g) Underwater launched to air targets.

Every known type of remote control, self-seeking or homing device, and proximity fuze was being developed or exploited for use in guided missiles. This included radio control, wire control, radar, continuous wave radio, acoustics, infra red, light beams, magnetics, etc. It was in this field, however, that the missile program was suffering the most serious difficulties.

All types of jet propulsion were being incorporated into the power plants of the missiles which were being built to fly at speeds both subsonic and supersonic.

Work on the science of controlled missiles was being carried out in every area visited in Allied occupied territory, from the border of Denmark to Switzerland and from the coast of France to the Russian zone of occupation. It is a known fact that some work was being done in Denmark, Norway and Poland, and it is estimated that 50% of the total German effort in this field was in what is now Russian-occupied territory, to which investigators have not had access. The results of the enemy's guided missile work are evident on the targets in England, Belgium and Holland.

It is estimated that one-third of the energy directed to aerodynamic

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Figure E.128: NavTechMisEu 237-45. *Survey of German Activities in the Field of Guided Missiles.* August 1945. [NARA RG 38, Entry P5, Box 38]

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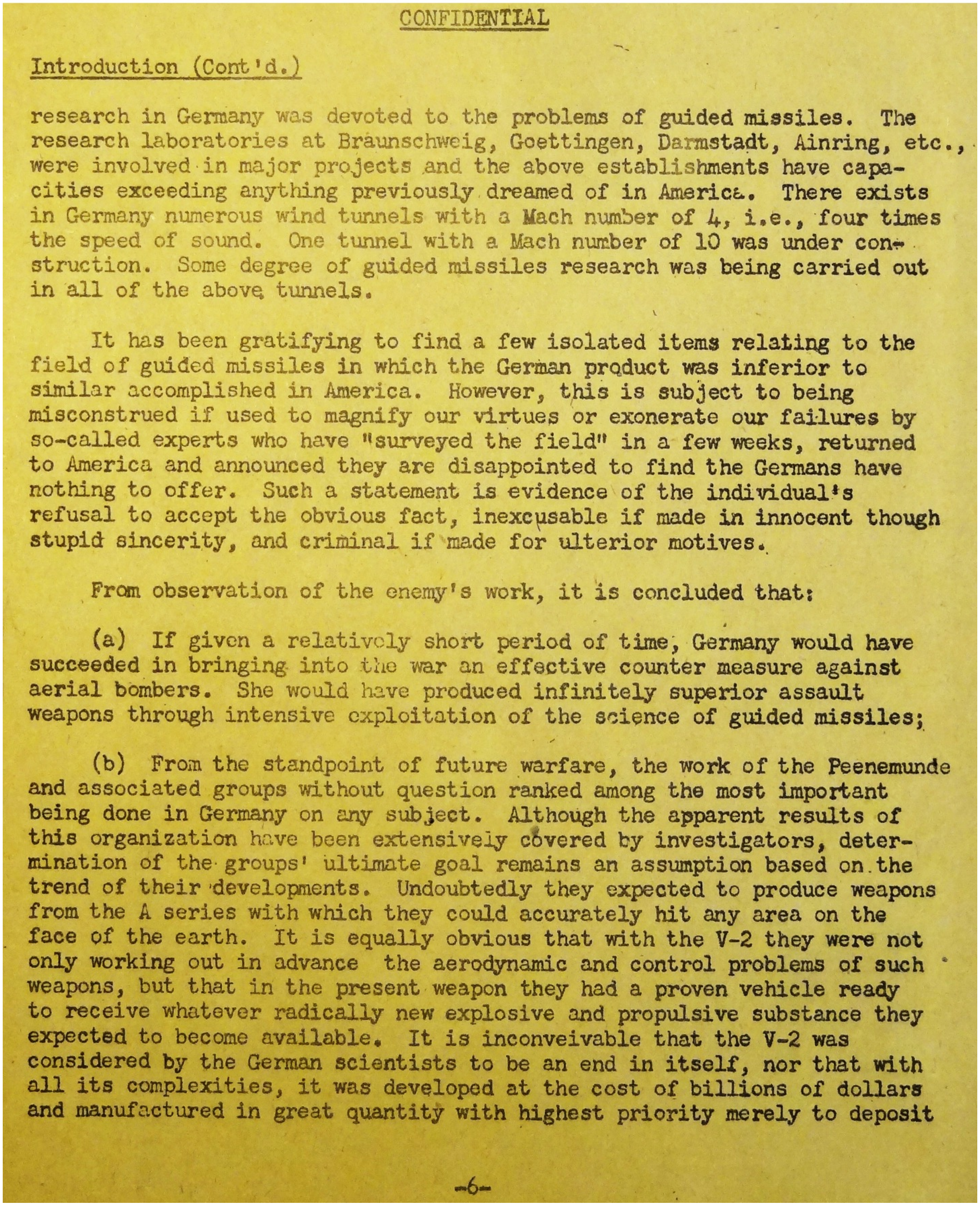

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Introduction (Cont'd.)

research in Germany was devoted to the problems of guided missiles. The research laboratories at Braunschweig, Goettingen, Darmstadt, Ainring, etc., were involved in major projects and the above establishments have capacities exceeding anything previously dreamed of in America. There exists in Germany numerous wind tunnels with a Mach number of 4, i.e., four times the speed of sound. One tunnel with a Mach number of 10 was under construction. Some degree of guided missiles research was being carried out in all of the above tunnels.

It has been gratifying to find a few isolated items relating to the field of guided missiles in which the German product was inferior to similar accomplished in America. However, this is subject to being misconstrued if used to magnify our virtues or exonerate our failures by so-called experts who have "surveyed the field" in a few weeks, returned to America and announced they are disappointed to find the Germans have nothing to offer. Such a statement is evidence of the individual's refusal to accept the obvious fact, inexcusable if made in innocent though stupid sincerity, and criminal if made for ulterior motives.

From observation of the enemy's work, it is concluded that:

(a) If given a relatively short period of time, Germany would have succeeded in bringing into the war an effective counter measure against aerial bombers. She would have produced infinitely superior assault weapons through intensive exploitation of the science of guided missiles;

(b) From the standpoint of future warfare, the work of the Peenemunde and associated groups without question ranked among the most important being done in Germany on any subject. Although the apparent results of this organization have been extensively covered by investigators, determination of the groups' ultimate goal remains an assumption based on the trend of their developments. Undoubtedly they expected to produce weapons from the A series with which they could accurately hit any area on the face of the earth. It is equally obvious that with the V-2 they were not only working out in advance the aerodynamic and control problems of such weapons, but that in the present weapon they had a proven vehicle ready to receive whatever radically new explosive and propulsive substance they expected to become available. It is inconveivable that the V-2 was considered by the German scientists to be an end in itself, nor that with all its complexities, it was developed at the cost of billions of dollars and manufactured in great quantity with highest priority merely to deposit

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Figure E.129: NavTechMisEu 237-45. *Survey of German Activities in the Field of Guided Missiles.* August 1945. [NARA RG 38, Entry P5, Box 38]

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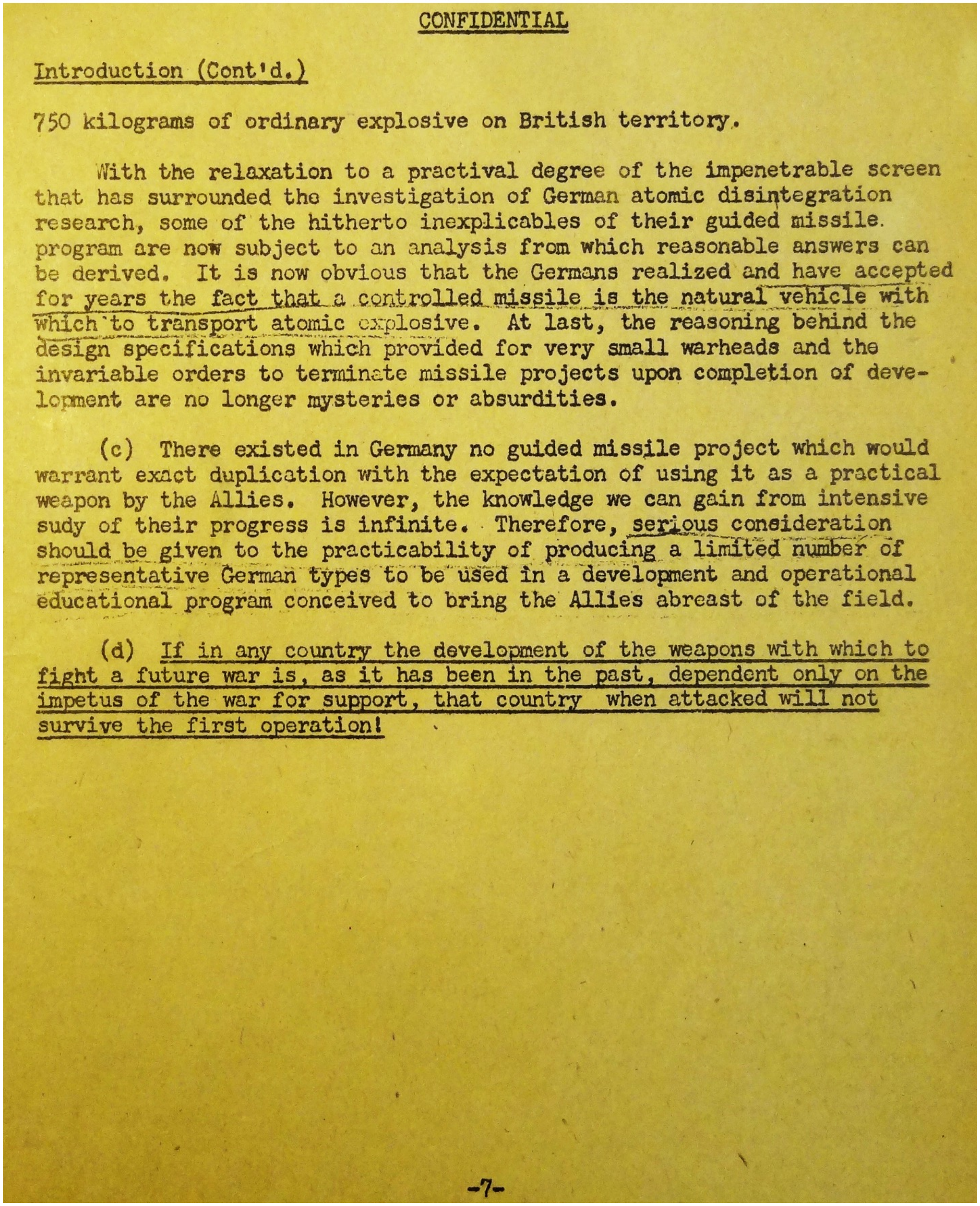

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Introduction (Cont'd.)

750 kilograms of ordinary explosive on British territory.

With the relaxation to a practival degree of the impenetrable screen that has surrounded the investigation of German atomic disintegration research, some of the hitherto inexplicables of their guided missile program are now subject to an analysis from which reasonable answers can be derived. It is now obvious that the Germans realized and have accepted for years the fact that a controlled missile is the natural vehicle with which to transport atomic explosive. At last, the reasoning behind the design specifications which provided for very small warheads and the invariable orders to terminate missile projects upon completion of development are no longer mysteries or absurdities.

(c) There existed in Germany no guided missile project which would warrant exact duplication with the expectation of using it as a practical weapon by the Allies. However, the knowledge we can gain from intensive sudy of their progress is infinite. Therefore, serious consideration should be given to the practicability of producing a limited number of representative German types to be used in a development and operational educational program conceived to bring the Allies abreast of the field.

(d) If in any country the development of the weapons with which to fight a future war is, as it has been in the past, dependent only on the impetus of the war for support, that country when attacked will not survive the first operation!

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Figure E.130: NavTechMisEu 237-45. *Survey of German Activities in the Field of Guided Missiles.* August 1945. [NARA RG 38, Entry P5, Box 38]

Theodore von Kármán. *Where We Stand.* 22 August 1945 [von Kármán 1945].

The present war started on both sides with "conventional" weapons and equipment; "conventional" because their principles of action, design, and performance were fundamentally known to the enemy. During the war both sides produced equipment and weapons of astonishing effects which will certainly change the whole picture of future aerial warfare.

This report is concerned with the main fields in which significant advances have been made and tries to show "where we stand" with some indications as to "where we shall go."

For future planning of research and development, the following new aspects of aerial warfare have to be considered as fundamental realities:

1. that aircraft—manned or pilotless—will move with speeds far beyond the velocity of sound;

2. that due to improvements in aerodynamics, propulsion and electronic control, unmanned devices will transport means of destruction to targets at distances up to several thousand miles;

3. that small amounts of explosive materials will cause destruction over areas of several square miles;

4. that defense against present-day aircraft will be perfected by target seeking missiles;

5. that only aircraft or missiles moving at extreme speeds will be able to penetrate enemy territory protected by such defenses;

6. that a perfect communication system between fighter command and each individual aircraft will be established;

7. that location and observation of targets, take-off, navigation and landing of aircraft, and communication will be independent of visibility and weather;

8. that fully equipped airborne task forces will be enabled to strike at far distant points and will be supplied by air. [...]

German Development of Guided Missiles and Pilotless Aircraft [...]

Dr. von Braun, leader of the Peenemünde group which developed the V-2, was a student of Professor Hermann Oberth, a well-known inventor and writer in the field of rockets, who had published books on interplanetary rocket travel. A group of Oberth's students became interested in rockets and organized an amateur rocket group. All were well-trained scientists. In 1935, Dr. von Braun was employed by the German War Department and sent to Peenemünde. In 1941, von Braun brought Oberth there as head of the Patent Section. By 1941, Peenemünde was an active test station. The Me-163 was brought there in September, 1941 and in October, 1941 flew at a speed of 1,003 km hr (about 623 mph). In October, 1941, the first supersonic wind-tunnel tests were made on a projectile at a Mach number of 4.4. After the bombing of Peenemünde in August, 1943, the activities were decentralized. The wind-tunnel group went to Kochel, where it was in operation in January, 1944. The first use of the V-2 was on 8 September 1944. [...]

The German military agencies, research institutions, and industrial designers devoted a large effort to guided missiles and considered them very promising weapons. In August, 1944, there were some 25 projects for homing devices under developments. The major research laboratories of the air and ground forces made many wind-tunnel and flight tests, some at high supersonic speeds, and made many theoretical studies of problems related to guided missiles and pilotless aircraft (Fig. 6).

Looking over the great variety of projects one finds that the V-2 rocket was the most outstanding technical achievement and that the Peenemünde group of scientists, working for the ground forces, was the most capable missile research group in Germany. It is important for us to note that one element in their success was the fact that they had under a single leadership in one organization, experts in aerodynamics, structural design, electronics, servomechanisms, gyros and control devices, and propulsion; in fact, every group required for the development of a complete missile. The letters and papers in the files of industrial groups, like Messerschmitt, show rapid progress in the field of vehicle and propulsion, the fields in which the firm itself had qualified people, but delay after delay on controls and electronic devices which had to be secured elsewhere. The Luftwaffe research laboratories made little progress in the actual development of specific weapons, largely because of the absence of electronics experts and their lack of facilities for the construction of experimental missiles.

In addition to the German view that the final guided missile would be completely automatic in operation, the possibilities of long-range strategic bombing were fully understood. There is no question but that the diversion of the efforts of the Peenemünde scientists in 1943 to the development of an antiaircraft guided rocket delayed the introduction of the winged V-2 rocket (A-9) and its successor, the transoceanic rocket (A-9 plus A-10). Drawings and computations had been completed for the A-10, a rocket weighing 85 T with a thrust of 200 T to be used as a launching rocket for the A-9, accelerating it to a speed of 3,600 ft/sec. The motor of the A-9 would accelerate it further to a speed of 8,600 ft./sec, giving it a range of about 3,000 miles. Some consideration was given to the design of one version of the A-9 carrying a pilot. The Scientific Advisory Group agrees that the German results of wind-tunnel tests, ballistic computation, and experience with the V-2 justify the conclusion that a transoceanic rocket can be developed.

The principal German advantage in the field of guided missiles was the lead in time in the development of rockets, which were considered to have serious military applications as early as 1935. Much effort was put into this field and as a result the supporting industrial developments were ready as a foundation for missile designers. They could buy rocket motors and rocket fuels from commercial sources. In this respect they lead us. The V-2 development was successful not so much because of striking scientific developments as because of an early start, military support, and a boldness of execution. In the electronic field, radar in particular, we are definitely one or two years in the lead, although we have not put as much effort in the experimental determination of the limits of application of acoustic and infrared devices. [...]

However, beyond that the implications of the accomplishments of the German Peenemünde group and of the recent development of the atomic bomb by United States and British scientists, future methods of aerial warfare call for a reconsideration of all present plans. A part, if not all, of the functions of the manned strategic bomber in destroying the key industries, the communication and transportation systems, and military installations at ranges of from 1,000 to 10,000 miles will be taken over by the pilotless aircraft of extreme velocity. The use of supersonic speeds greatly reduces errors due to wind drift and other atmospheric conditions and the tremendous zone of damage of the atomic bomb diminishes the required precision. Hence, the difficult control problem is made easier.

For the future long-range strategic bomber, the Scientific Advisory Group foresees two types of pilotless aircraft, both with wings, one with a high trajectory reaching far into the outer atmosphere, and the other designed for level flight at high altitudes. The first one can be considered as a further development of the V-2 rocket. In fact, this was planned by the German scientists. By using two or more step-rockets for the acceleration, a very high speed is imparted to a missile, perhaps as high as 17,000 mph or more, to give ranges of several thousand miles. In this case, the wings are required mainly for control purposes, but they also serve to extend the glide path in the lower atmosphere. The German scientists have suggested a second type of trajectory requiring less initial energy, in which the wings are caused to curve the path of the missile when it returns to the region of increasing air density so that it rebounds to great heights. After a number of rebounds the winged missile settles down to a steady glide. Such a trajectory would seem difficult to control accurately (Fig. 8).

The second future strategic bomber is a supersonic pilotless aircraft, flying at altitudes of from 20,000 to say, 60,000 ft. It appears to us now that the speed will be about twice the speed of sound and that the aircraft will be powered by a turbojet motor. An intermediate step might be a pilotless aircraft traveling at high subsonic speeds with a Mach number of about 0.9 about 600 mph at 40,000 ft (Fig. 9). [...]

Leadership in the development of these new weapons of the future can be assured only by uniting experts in aero-dynamics, structural design, electronics, servo-mechanisms, gyros, control devices, propulsion, and warhead under one leadership, and providing them with facilities for laboratory and model shop production in their specialties and with facilities for field tests. Such a center must be adequately supported by the highest ranking military and civilian leadership and must be adequately financed, including the support of related work on special aspects of various problems at other laboratories and the support of special industrial developments. It seems to us that this is the lesson to be learned from the activities of the German Peenemünde group. [...]

Problems of Organization

The following problems relating to the long range research and development program of the Air Forces deserve consideration:

1. Scientific Planning: It is necessary that the Commanding General of the Air Forces and the Air Staff be advised continuously on the progress of scientific research and development in view of the potentialities of new discoveries and improvements in aerial warfare. A permanent Scientific Advisory Group, consisting of qualified officers and eminent civilian scientific consultants, should be available to the Commanding General, reporting directly to him on novel developments and advising him on the planning of scientific research. The scientific material collected by the organizations for military intelligence (G-2 and A-2) should be made available to this group for evaluation. Correspondingly, the scientific branch of G-2 and A-2 should be greatly strengthened by qualified personnel and facilities.

2. Research and Development within the Air Forces: It is necessary to organize a broad training program for officers in scientific and engineering fields, not merely to impart information on scientific and technical matters but to accustom them to working in cooperation with scientific institutions and scientists. [...]

3. Securing the Interest and Collaboration of Scientific Institutions and Individual Scientists: The Air Force should have access to the best qualified scientific talent and the best equipped laboratories of the nation for collaboration on their problems.

Experimental investigations desired by the scientific leaders the Air Forces to be carried out in any laboratory should be obtained by direct contract for the services desired.

Forrestal Urges Arms Inventions. ***New York Times*** **29 August 1945 p. 10.**

At the time of her defeat Germany had almost perfected a submarine that could stay under water virtually indefinitely and a "spider" torpedo that could be guided by a thin wire attached to its firing point, Secretary of the Navy James Forrestal revealed today. Germany was also far ahead of the Allies in many phases of experimentation with speeds faster than sound, he said.

He also disclosed that Germany was feeding technical information to Japan "to keep us as busy as possible in the Pacific." Thus, although he did not mention atomic-bomb experiments, it is possible that Germany either forwarded or tried to forward to Japan whatever information she could develop on the splitting of the atom, since Germany was competing with the United States in this field.

Predicting that, "if, unhappily, there should be another war, it would be fought with fantastically new weapons," Mr. Forrestal urged that the United States stay awake in the field of military research, even to the extent of creating actual models of new weapons.

Germans "Six Months Too Late"

"In general," he declared, "it may be said that the Germans were about six months too late in the development and mass production of new weapons. If in the future some maniac has delusions of world empire, he will start where the Germans left off. For our own defense and for the future peace of the world, it behooves us to continue research in military subjects so that no such maniac can ever feel that he has monopolized an advanced weapon which will put the world in general and the United States in particular at his mercy."

"For that reason I again urge the necessity of a substantial and alert post-war research program in military fields—and this research should be carried through to the actual production of pilot models"

Mr. Forrestal reported that the Germans had used submarines to transmit technical information to Japan, sometimes sending technicians to help the Japanese.

Foe's Submarines Better

He disclosed that, on his inspection trip to Europe between July 26 and Aug. 7, he had investigated the work of the Naval Technical Mission, composed of naval and civilian experts who had followed in the tracks of the invasion and occupation armies gathering useful German technical knowledge. He indicated that Germany had developed a submarine superior in many respects to ours despite previous statements made during the war by some of our naval officers who insisted that our submarines were the finest.

Mr. Forrestal said that present-day submarines might properly be described as submersibles—vessels that can submerge but must spend most of their time on the surface. The Germans, however, were developing a "true submarine" that "would almost never operate on the surface of the sea," and they had achieved "considerable success." [...]

"This submarine, known as Model 21, was capable of traveling under water at eighteen knots. That speed is markedly faster than any previously known craft had attained under the sea and was four knots faster than the Model 21 itself could do on the surface. It could not sustain this very high speed for much over an hour, but the Germans had in advanced states of development new propulsion methods which would have permitted even higher under-water speeds for much longer periods." [...]

Mr. Forrestal said that the Germans had had in development "at least two or three rockets which represented advances over what we call V-2." [...]

German experimentation with supersonic speed was carefully studied, he continued. To perfect the V-2, which had a speed far faster than sounds, and other weapons, the Germans had developed wind tunnels "far in advance of any we have in this country." In these tunnels, the Germans reproduced conditions existing at supersonic speed and tested devices to travel under such extreme conditions.

Nazi Secrets Given Japan to Use on U.S. *Washington Post.* 29 August 1945 p. 3.

The Germans were within six months of mass production of new weapons of great destruction when VE-Day closed their laboratories and shut off their production lines, Naval Secretary Forrestal disclosed yesterday.

His description of specific Nazi projects—new submarines, torpedoes, rockets, fuel—indicates that it was a scientists' race almost to the end.

Forrestal did not mention the Germans' atomic bomb work, but indicated they had a substantial lead over American scientists in many other fields. [...]

Gave Japs Information

Germany, Forrestal said, gave her technical information to Japan to keep us busy in the Pacific. He revealed that some German technicians said they had made the round trip to Japan by submarine.

This explained one reason for our Navy's concern over Japan's still-powerful sub fleet in the closing months of the war. It is known the Germans also passed on their electronics secrets.

The larger German subs could make the trip to Japan without refueling.

The naval secretary based his report on a trip to Europe, during which he observed the work of the Naval Technical Mission. These experts also discovered that the enemy had:

1. "The Spider," a torpedo always connected to its firing point by a thin wire spun out behind it. Through impulses sent over the wire, the missile could be made to change its course or depth, "even make it jump out of the water like a porpoise." This was intended for shore defense and, as far as is known, never was adapted to ships or submarines.

Were Developing Better Rockets

2. In the development stage at least two or three rockets better than the V2, which were to be mass-produced in large underground factories.

3. Devices [gas turbine engines] to control and use steam in some cases at double the pressure and temperature our high-pressure, high-temperature propulsion machinery can handle.

4. Developed a method for using hydrogen peroxide as a fuel, "with what looked like surprisingly good results" for the powering of naval units. Its first known use was in launching V-1 rockets and the auxiliary pumps for the V-2s.

5. Wind-tunnels "far in advance of any we have in this country" to promote basic research in supersonic speeds. In them they could simulate supersonic speed conditions and thus experiment on devices which go faster than sound.

[...] The resulting U-boat, labeled the Model 21, was able to make 18 knots submerged, or four knots better than it could on the surface.

The 18 knots couldn't be sustained, but the Germans were rushing development of new methods permitting even faster speeds for longer periods.

Germany was building nothing but Model 21s at the end of the war. The timetable called for 360 a year and they were to be assembled in 24 days each in huge reinforced concrete shelters between Bremen and Bremerhaven.

[Forrestal stated that "at least two or three rockets" more advanced than the V-2 were "in the development stage" "to be mass-produced in large underground factories," which seems to imply that they were not merely paper designs. He also seemed to include those rockets in the category he was discussing of potential war-winning weapons that were within six months of readiness, which again seems to indicate that they had already progressed well beyond paper designs. Was he implying that by the end of the war, Germany had in fact "monopolized an advanced weapon which will put the world in general and the United States in particular at his mercy"?

Forrestal gave a number of other examples of how much more advanced German technology was compared to American technology in many fields. Even the journalists writing these articles noticed that he carefully avoided saying anything about Germany's atomic bomb work, probably due to tight censorship on that topic.]

R. P. Linstead and T. J. Betts. 15 September 1945. ***The Intelligence Exploitation of Germany. Report of Combined Intelligence Objectives Subcommittee.*** **G-2 Division, SHAEF. Ch. 4, pp. 37, 47–51. [AFHRA A5186 electronic version pp. 904–1026]**

Certain items have been omitted because of security considerations. [...]

The exploitation of intelligence concerning German directed missiles and rocket development was one of the primary objectives of CIOS. In the initial phases of the Committee's work, considerable information was obtained from captured launching sites, propellant storage facilities and actual specimens of early V-weapons. However, it was not until the entire Peenemünde staff, together with most of their files and much of their equipment, were seized at dispersal points in southern Germany that the full story of German V-weapon research and development became available. The resultant intelligence has proven to be one of the most significant and important discoveries in the European Theater.

German authorities responsible for this work have expressed the opinion that the V-1 and V-2 were crude and elementary weapons. They have compared the present state of directed missile design with the technical status of the aircraft industry on the eve of World War I. These same authorities confidently predict that a continuation of present research in this field for another decade would change the strategical and tactical concepts of modern war.

[p. 49 of the document is missing on the microfilm roll. Can that page be located in a surviving hardcopy, or is that page still classified?]

United States and British specialists have obtained complete information covering all German directed missiles from the pioneer model "A sub-o", which employed oxygen and alcohol fuel in attaining a range of 18 miles, to the latest model of the A-9 which was capable of a 3400 mile per hour speed and a range of 2400 miles. The A-9 was an improved development of the V-2 or A-4, and was equipped with wings thereby enabling it to level off at a height of 70,000 feet. One model of this missile was equipped with a Lorin tube which provided propulsion at the peak of the trajectory, the missile was expected to result in a maximum range of 2400 miles. Other variations of this model were capable of attaining altitudes 60 miles above the earth's surface and speeds in excess of 7300 feet per second. Improved radio controls were developed to supercede the "integrating accelerometer" used in early V-weapons. Some measure of the accuracy which could be achieved with these controls is evidenced by the fact that the radio controlled models were capable of an accuracy of plus-or-minus 150 feet in contrast to a plus-or-minus 50 mile error inherent in the V-2.

German scientists engaged in directed missiles envisaged important commercial applications of the long range missile. Experiments had already been conducted on piloted models. Missiles capable of trans-Atlantic crossings in approximately 40 minutes were found on design boards and scale models were undergoing wind tunnel tests. Amazing performances were considered practical because of the lessened atmospheric resistance and gravitational pull in stratospheric regions.

The Germans particularly concentrated on controlled rockets and missiles for anti-aircraft defense. One of the most promising of the AA missiles under development was the "Wasserfall". This was a ground-to-air guided missile capable of a 2200 mile per hour speed. The "Wasserfall" was equipped with a homing device which would enable it to pick up and track a target airplane at a range of one mile. The acoustic fuse provided was designed to detonate the explosive charge within a radius of 20 meters from the target.

The “Enzian” was another type of controlled missile designed for ground-to-air or air-to-air anti-aircraft defense. This weapon was equipped with a homing device and was capable of a 900 mile per hour speed. Other German anti-aircraft missiles included the Taifun and the X-4. The Taifun was a comparatively simple and inexpensive aimed rocket capable of high speed and a 60,000 foot altitude. The X-4 was designed for air-to-air operations and wire control in order to prevent jamming or effective counter-measures.

One of the most important results of Allied investigations of German directed missile development was the vast amount of data obtained concerning aero-dynamic research in the range of supersonic speeds. This information is expected to provide invaluable assistance to research in the United States and United Kingdom.

Of particular significance were the statements, made by German experts in the rocket and controlled missile field, that much of the priority accorded their work by the German High Command was in anticipation of the use of atomic explosives. These authorities stated that KWI had repeatedly assured Hitler that an atomic explosive would be available for use within a comparatively short time. During the last months of work by the Peenemünde staff, V-weapons were designed with much smaller war-heads. Quite possibly this trend was in anticipation of the successful development of a German atomic explosive.

[See document photos on pp. 5446–5447.

This report was written by the CIOS chairs, U.S. General Thomas Jeffries Betts, Deputy G-2 of SHAEF (pp. 3287, 5028–5029), and U.K. Ministry of Supply chief advisor and F.R.S. Professor Reginald Patrick Linstead. Based on specific discoveries by their CIOS investigators, these high-ranking officials reported that:

- “The latest model of the A-9 ... was capable of a 3400 mile per hour speed and a range of 2400 miles.” That statement sounds like a description of completed hardware, not a mere drawing board design. The report also mentioned an A-9 equipped with a ramjet (Lorin) engine. From this and other reports, it sounds as if there were multiple versions of the A-9. What specific hardware and information were discovered that are not discussed in the presently unclassified reports? Can any reports that are still classified be located and released? Much more research is needed to elucidate the wartime versions and actual progress on the A-9.

- With regard to advanced versions of “the long range missile,” “experiments had already been conducted on piloted models.” Were they referring to the two-man V-4 rocket or something else? For “experiments” with “piloted models,” was the rocket launched with or without pilot(s)? If the former, did the pilot(s) survive? Did German or Austrian pilots accomplish in 1944–1945 what Alan Shepard did in 1961? If so, their names should be in the history books.

- Hitler, the German High Command, and the leading experts in the rocket programs had been “repeatedly assured ... that an atomic explosive would be available for use within a comparatively short time.” Thus the CIOS chairs contradicted the public statements of the Alsos Mission and confirmed that there was indeed a German program to develop an atomic bomb, and that it was far more than a paper design program—its hardware had passed through sufficient development, production, and testing by the end of the war that it was ready or nearly ready to be used in combat.]

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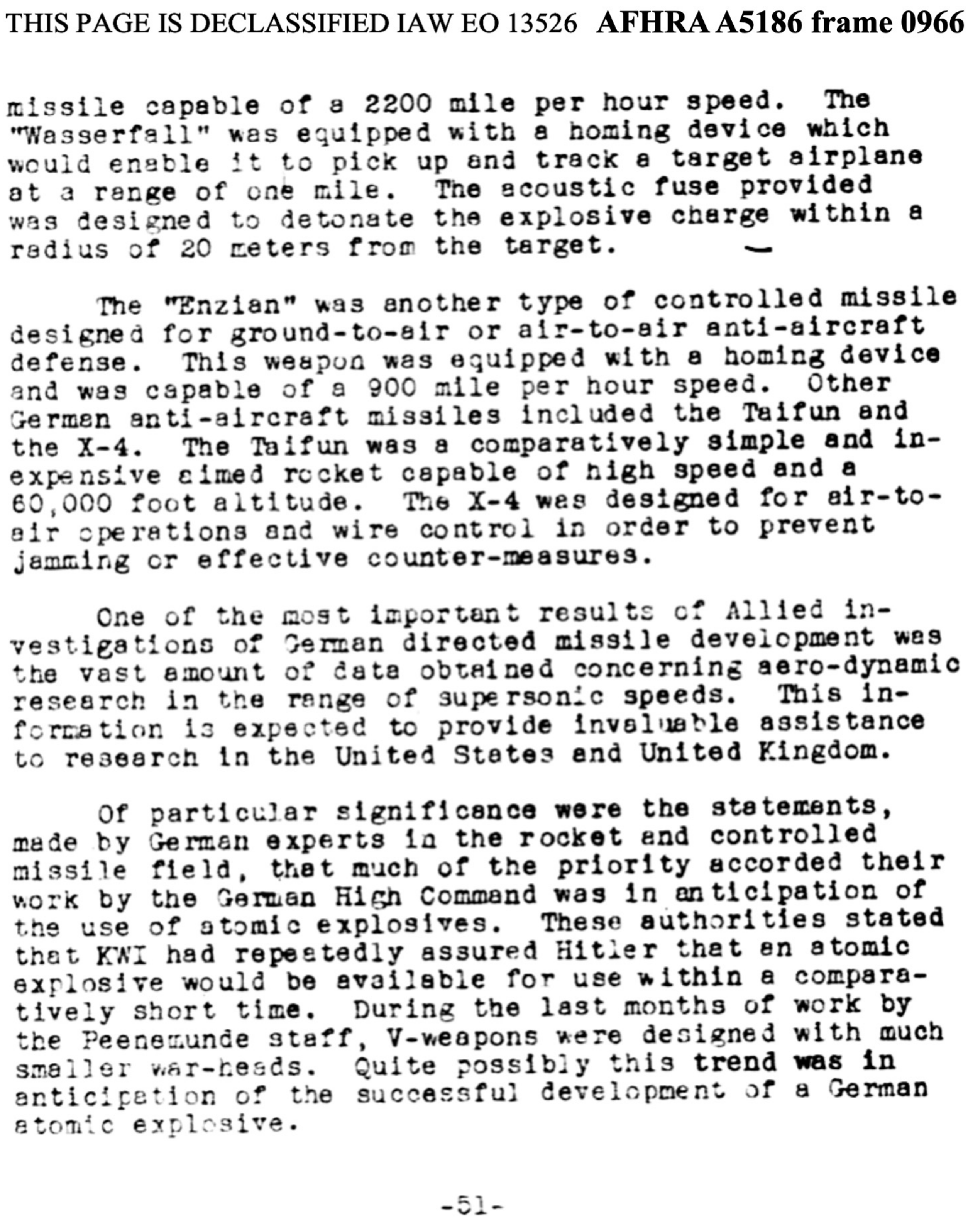
Figure E.131: R. P. Linstead and T. J. Betts. 15 September 1945. *The Intelligence Exploitation of Germany. Report of Combined Intelligence Objectives Subcommittee.* G-2 Division, SHAEF. Ch. 4 [AFHRA A5186 frame 0965].



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-51-

Figure E.132: R. P. Linstead and T. J. Betts. 15 September 1945. *The Intelligence Exploitation of Germany. Report of Combined Intelligence Objectives Subcommittee.* G-2 Division, SHAEF. Ch. 4 [AFHRA A5186 frame 0966].

W. G. A. Perring. 1946. A Critical Review of German Long-Range Rocket Development. *Journal of the American Rocket Society.* 65:1–17. Reprinted from a paper read before the Royal Aeronautical Society, London, 1 November 1945.

Serious rocket development was started in Germany in the years 1929–1930 by a few groups of private inventors. This work attracted the attention of the Army Weapons Group in 1933, and in 1937–1938 a special research and development station was set up at Peenemunde at the cost of 300 million marks, and the work was transferred from Berlin to this new station at about that time.

Peenemunde concentrated mainly on bi-fuel rockets, employing liquid oxygen as the source of oxygen for the combustion of the fuel. Work was started on a range of rockets which they designated Al to A10, only one of which, namely, A4 or as we know it V2, ever being used operationally. [...]

Apart from these main rocket developments, there were many other developments going on all over Germany; in some of these solid fuels were used, and in others nitric acid was the oxygen carrier, and Diesel oil or alcohol the other fuel. [...]

The highest velocity reached is at all burnt, the rocket is then traveling at 5000 ft. per sec. and it is interesting to note that at this velocity the rocket motor is developing well over 600,000 horsepower. The stagnation temperature corresponding to a velocity of 5000 ft. per sec. is about 1400^oK, and in view of this it might be expected that the skin temperatures of the rocket during flight would tend to be high and approach the stagnation value.

To check this point a careful examination of the rocket skin was undertaken, and both from an examination of the condition of the paint, and a metallurgical examination of the skin material, it was concluded that the skin temperatures had not exceeded about 900^oK. This figure agrees very closely with measurements that the Germans were able to make on an actual rocket in flight. In their tests the Germans inserted small discs of various metals of known melting point into the skin of the rocket and connected these into electrical circuits. As each disc melted, a signal was transmitted by telemetering to a ground station. It was found that the skin temperatures nowhere exceed 920^oK, conduction and radiation losses therefore must have kept the skin temperature down well below the stagnation temperature. [...]

A10 was a still more ambitious rocket, in the project stage only; it was to weigh about 85 tons, and was intended to carry the A9 rocket into the stratosphere, and then be jettisoned, A9 and A10, therefore, were separate stages of a two-stage rocket.

Table II gives the specific impulse of a number of fuels, calculated on the basis of working conditions corresponding to the venturi characteristics of the A4 rocket.

Most practical values of the S_I [specific impulse] lies between 180–240, but it will be seen from the table that by using hydrogen and oxygen the value could be pushed up to well over 300 while still retaining a moderate combustion temperature, and some still further improvement in this S_I would be possible at the expense of the working temperatures and pressures.

[...] Starting with the A4 rocket, we have assumed that the warhead is removed, and replaced by a pressure cabin and pilot, and in addition, the rocket is fitted with wings; the wing area being arranged to provide for a landing wing loading of 35 lb. per sq. ft.

Three cases will be touched on briefly. In the first, the A4 rocket with wings is assumed to be fired vertically, and controlled in the same manner as a normal A4 rocket until it reaches the top of its trajectory, when the pilot takes over and glides the rocket to the ground along its optimum glide path.

In the other two cases, the A4 rocket with wings, has been assumed to be taken up by means of a booster rocket rather on the lines of the German A10 project mentioned earlier in the lecture. In this way the rocket reaches a height of 80,000 feet before being released at a speed of 3000 m.p.h. (these conditions corresponding to the height and speed reached by the A4 rocket with wings at all burnt, when it is fired vertically upwards in the normal way). From this point onwards the rocket with its full fuel continues the flight, and in the first of these boosted cases it has been assumed that the rocket venturi is redesigned, and now provides a thrust corresponding to level flight at 1640 m.p.h., at 80,000 feet, while in the other the redesigned venturi provides a thrust which enables the rocket to continue the climb. The results of these calculations are compared with the trajectory of the normal A4 rocket without wings.

The first striking thing about the results is the effect that the addition of wings has on range. The range of 180 miles of the normal A4 rocket without wings has now been raised to 350 miles.

Still more striking however is the effect of the booster on the general performance. Ranges of 1500 to 3000 miles now appear to be possible, and the advantage of continuing the climb at the end of the booster stage is also very marked. It is interesting to note that with a rocket boosted in this way it would be possible to complete the journey from London to New York in well under the hour.

The first of the two cases of the rocket with wings presents no problem that is outside of the experience already gained by the Germans during their work on the A4 rocket, the third case however does raise many new problems. It contemplates for example flight at over 8000 m.p.h., this means a stagnation temperature of nearly 7000^oK, so that even though radiation may play an important part in keeping, the temperature down, the pilot would nevertheless find himself enclosed in a body the skin of which, to say the least of it, was uncomfortably hot. Over a large part of the flight too, the rocket would be moving on a free trajectory, since the wings cannot provide sufficient lifting force to control the motion. Over this part of the trajectory the pilot would be subject to zero g, and it would not be until the rocket returned, to a point about 28 miles above the earth's surface that the pilot could begin to assume control of his machine.

The booster contemplated in connection with these schemes would of course be very large; it would certainly weigh about 100 tons, and the Germans in planning their schemes had hoped that the booster after being jettisoned, would be recoverable. [...]

I should like in conclusion to say how much I am indebted to the many workers in this field who took part in the A4 rocket investigations, on whose work I have drawn quite freely in preparing the present lecture.

[W. G. A. Perring, Deputy Director of Research and Development at the Royal Aircraft Establishment (RAE) in Farnborough, studied intelligence reports and recovered pieces from wartime German rocket tests in order to accurately inform the British government of the design and capabilities of V-2 rockets before they were launched against Allied targets.

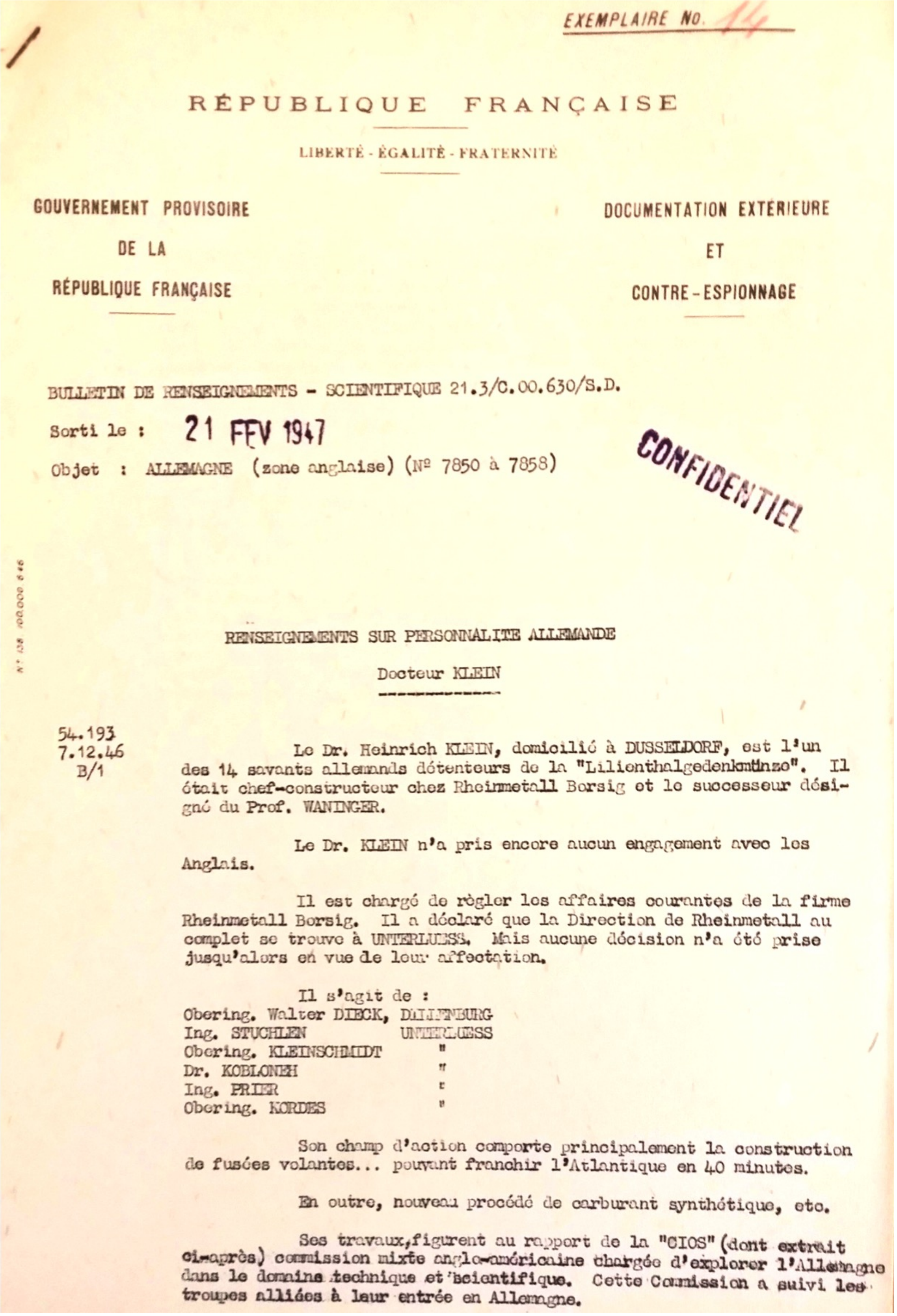
Perring's report here is "drawn quite freely" from detailed postwar investigations of later, more advanced German rocket research and development, and it reports presumed German work on:

- "Rocket developments... going on all over Germany," not just at Peenemünde.
- Development of solid propellant rockets.
- Development of storable and hypergolic liquid rocket propellants, such as inhibited fuming nitric acid oxidizer and Diesel fuel.
- Work on liquid hydrogen and liquid oxygen rocket propellants to obtain specific impulse values "well over 300 while still retaining a moderate combustion temperature." Compared to the alcohol and liquid oxygen propellant in the standard A-4, that would increase a rocket's exhaust velocity by well over 50% and double or triple the rocket's range.
- Both well-known trajectories in which rockets follow a parabolic arc before reentering the atmosphere, and also less well-known trajectories in which the rockets level off at some fixed altitude and continue powered flight horizontally toward their target, as described by the German prisoner of war on p. 5334.
- A reusable A-10 booster stage, which suggests that it was never planned or necessary to build many of them.
- Construction of a modified A-4 (A-9) rocket having a pressure cabin and pilot.
- Experimental measurements of and work to deal with heat transfer to rockets during reentry into the earth's atmosphere.]

MR. W. G. A. PERRING, WITH HIS REMARKABLY ACCURATE RECONSTRUCTION OF A V-2 ROCKET, BASED ON FRAGMENTS FOUND IN SWEDEN BEFORE THE ATTACKS BEGAN.

Mr. W. G. A. Perring was concerned with research work on the German V-2 rocket, and was able to make a remarkably accurate reconstruction of this weapon and assess its potentialities from some two tons of fragments found after one of these weapons had exploded over Sweden before the attacks on Britain were made. He is seen holding his diagrammatic model.

Figure E.133: W. G. A. Perring, Deputy Director of Research and Development at the Royal Aircraft Establishment (RAE) in Farnborough, studied wartime and postwar information on advanced German rocket programs.



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RENSEIGNEMENTS SUR PERSONNALITE ALLEMANDE

Docteur KLEIN

54.193
7.12.46
B/1

Le Dr. Heinrich KLEIN, domicilié à DUSSELDORF, est l'un des 14 savants allemands détenteurs de la "Lilienthalgedenkmünze". Il était chef-constructeur chez Rheinmetall Borsig et le successeur désigné du Prof. WANINGER.

Le Dr. KLEIN n'a pris encore aucun engagement avec les Anglais.

Il est chargé de règler les affaires courantes de la firme Rheinmetall Borsig. Il a déclaré que la Direction de Rheinmetall au complet se trouve à UNTERLUESS. Mais aucune décision n'a été prise jusqu'alors en vue de leur affectation.

Il s'agit de :

Obering. Walter DIECK,	DILLENBURG
Ing. STUCHLEN	UNTERLUESS
Obering. KLEINSCHMIDT	"
Dr. KOBLONEH	"
Ing. PRIER	"
Obering. KORDES	"

Son champ d'action comporte principalement la construction de fusées volantes... pouvant franchir l'Atlantique en 40 minutes.

En outre, nouveau procédé de carburant synthétique, etc.

Ses travaux, figurent au rapport de la "CIOS" (dont extrait ci-après) commission mixte anglo-américaine chargée d'explorer l'Allemagne dans le domaine technique et scientifique. Cette Commission a suivi les troupes alliées à leur entrée en Allemagne.

Figure E.134: 21 February 1947 French background investigation on Heinrich Klein: "His field of experience mainly involves the construction of flying rockets... capable of crossing the Atlantic in 40 minutes." [Archives of the French Army Ministry of Defense, courtesy of Norberto Lahuerta].

WAAF Tells of Aid in Saving New York. *New York Times*, 6 October 1945, p. 18.

British Woman, Now Assigned to U.S., Shows How Her Unit Upset V-Bombing Plans

Standing high over the skyline of New York, the city her military intelligence is credited with helping to save from German rocket-bombing, Flight Officer Constance Babington-Smith of the British Women's Auxiliary Air Force explained yesterday how she did it, at a press conference sponsored by the British Information Services on the sixty-fifth floor of 30 Rockefeller Plaza.

For all her mastery of the intelligence officer's technique in interpreting air reconnaissance photographs for secret information pertaining to enemy aircraft operations, it became apparent during the interview that Flight Officer Babington-Smith's sky-blue eyes, ready imagination and leaping logic were the real clues to her success in the war work that she "really loved." [...]

Miss Smith used only a stereoscope and a measuring magnifier, but she maintained that "one's eyes are the most important—not instruments." Her mission was to detect, from aerial reconnaissance photographs, new developments of German aircraft and aircraft factories, and thus to provide the Allied raiders with vital bombing targets and other intelligence.

In May, 1943, Miss Smith became the first Allied person to detect the enemy's new "vengeance weapon," the V-1, or robot plane, as it was being developed by Germany at an experimental center in Peenemünde, on the Baltic. In a reconnaissance photograph of this place, she interpreted a small, curving black shadow as a ramp; and a tiny, T-shaped, white blot above it as an airplane, the V-1.

On the basis of her discovery Allied air raiders bombed Peenemünde, killing 800 German scientific experts and thereby, by Germany's own admission, retarded the enemy's aeronautical development work by six months so that Germany's elaborate plans for rocket-bombing the United States could not be completed in time.

[In this remarkable article, the U.K.'s most celebrated wartime aerial reconnaissance photo interpreter, the British Information Services, and the *New York Times* all stated clearly and unequivocally that Germany was within only months of attacking New York with rockets when the war ended, and that the New York rockets would have been ready six months sooner if not for Allied bombing of relevant sites in Europe. This information also strongly suggests that the German atomic bomb was ready or almost ready at the end of the war, since a conventional explosive warhead would not do much damage or justify all the costs and resources required to develop a rocket that could reach New York.

If the German atomic bomb and the New York rocket were within months of completion at the end of the war, they could not have been merely at the stage of paper designs when the war ended. German, British, and U.S. experts were all keenly aware that it required years of intensive work both for atomic bombs and for long-range rockets to progress from paper designs to deployable final products.

For more information on Constance Babington-Smith, see:

https://www.theguardian.com/news/2000/aug/12/guardianobituaries]

U.S. Army Air Forces General Henry H. Arnold. 9 January 1945 address to Scientific Advisory Group. Quoted in Thomas A. Sturm. 1967. *The USAF Scientific Advisory Board: Its First Twenty Years 1944–1964.* Washington, D.C.: U.S. Government Printing Office. p. 2

I don't think we dare muddle through the next twenty years the way we have... the last twenty years. I have worked with von Kármán the last twenty years, and I was sometimes scared by the knowledge he had that we weren't using. ... I don't want ever again to have the United States caught the way we were this time.

Arnold Urges Single Defense Department. *Washington Post.* 20 October 1945 pp. 1–2.

AAF Head Asks Co-Equal Status for Air Arm as Best Peace Insurance.

Gen. Henry H. Arnold yesterday warned Congress the next war will come through the air and asked co-equal status for air power in a unified defense system as "the best insurance of peace."

The graying Chief of Army Air Forces backed the War Department's call for one strong department of national defense with statistics charting the "terrifying possibilities" of new air weapons. [...]

Flanked by a group of veteran Air Corps officers, the Army Air Forces commander told how the German V-2 bombs alone, perfected with wings, radar and electronic devices, can now travel over 3000 miles and at 2000 miles hit a target "on the button." [...]

He said there can no longer be defense against the missiles themselves—blows at the source of them must be the goal. [...]

Discussing the atom bomb, the German V-2, jet, bomber and cargo plane developments, Arnold stressed the "extraordinary versatility" of the new air weapons and glimpsed future "more radical" uses. [...]

Arnold said one German jet plane was capable of knocking down 17 American Flying Fortresses. Had Germany concentrated on its jet fighters, he said it would have been "far more difficult to get into Germany."

[How did General Arnold know that German rockets "can now travel" 2000–3000 miles and "hit a target on the button"? That public statement suggests that Germany successfully conducted such a test before the end of the war, and that Arnold had obtained evidence detailing that test. For another document that appears to describe such a test, see Alfred Gründler's testimony on p. 5347.]

Arnold Advocates Co-Equal Air Force. *New York Times* 20 October 1945 p. 3.

He Calls This Vital to U.S. as Only Fliers Could Hit Quickly at Atomic Bomb Source

Creation of a single national defense organization, in which the air arm will have coequal strength and influence with the Army and Navy, is essential if this country is to be prepared against future aggression, Gen. Henry H. Arnold, commander of the Army Air Forces, told the Senate Military Affairs Committee today. [...]

Pleading for unification, which would give the nation's air arm the same position it won with difficulty during the war, General Arnold said:

"It is apparent from any school room globe that war can come through the air to the very heart of this country. It can come with weapons of types now in our possession, and without any land or naval action.

Speed Declared Essential

"Such developments as the atomic bomb, the V-2 and the whole range of radio-directed and homing missiles accentuate the security problems of the air. Responsibility for a rapid and powerful offensive against the source will rest on the air force."

3,000-Mile V-2 Near, Says Arnold. *New York Times* 20 October 1945 p. 3.

General Arnold said that a future war might start with air attacks launched from bases 3,000 miles away, pointing out that the United States even now could blanket most of Asia and Europe and a large part of Africa from bases within this country.

The German V-2 rocket now has a range of 250 miles, he said, but by attaching wings and electronic guiding devices it can easily travel 3,000 miles or more. Such a development, he said, "is just in the offing."

He also said that if Germany had concentrated on the jet-propelled fighter it used toward the end of the war, the Allies would have had a much harder time destroying the Luftwaffe.

"According to our information," he said, "one German pilot in one German jet plane could knock down seventeen to twenty of our Flying Fortresses."

Henry H. Arnold. 12 November 1945. *Third Report of the Commanding General of the Army Air Forces to the Secretary of War.* Baltimore, Maryland: Schneidereith & Sons.

[pp. 8, 10:] The ME-262 jet plane, Germany's greatest hope, and, we must state frankly, the greatest threat to continued bomber operations, was then in production. Under no circumstances, Hitler declared, would the ME-262 be used as anything but a bomber. [...]

Hitler persisted in this amazing decision from April until October, a period which saw the Invasion and the sweep across France. As a bomber, the ME-262 did nothing. The ME-262s which our airmen fought during that period were a few Galland had secured, despite Hitler's edict, for an "Experimental Unit." In October, when Hitler relented, only a handful were released to the fighter arm, and it was 1945 before the bomber idea was finally discarded.

[p. 30:] Very important work remains to be done. [...] One is the making of a large-scale photographic map of the conquered country, something sorely needed and partially obtained only with great difficulty during the war—a bird's eye view of Germany, just in case. Another is the job of disarming the Luftwaffe—not only pullings its fangs but plucking its brains.

Air disarmament includes seeking out and impounding Luftwaffe documents, locating its technicians, scientists and experimental specialists for interrogation, and securing the records of their work and experiments. There is materiel of vital interest for testing and development at Wright Field. Strange devices are being ferreted out, crated, and shipped for study—from blind landing equipment to infra-red meteorological instruments and range finders, from radar apparatus to crew chief stands, from jet engines to bomb sights, flak guns to airborne cannon, compasses and cameras to medical documents and automatic pilots.

Whatever the Germans had of worth, we shall have. Whatever they hoped to develop, we shall know about. We want to make sure it is not being worked on under the guise of a peacetime product. Winning this war was a hard job. Air power intends to do its share toward keeping the peace.

[pp. 66–68:] At lower right is the X-4, a wire controlled, rocket-propelled gyro-stabilized missile, to be launched from parent plane against bombers. X-4 was almost ready for use. [...] Potency of X-4 (right) was tremendously increased by proximity fuse.

[...] We must look at the future of aerial warfare in the light of the following considerations:

1. Aircraft, piloted or pilotless, will move at speeds far beyond the velocity of sound, well over 700 miles per hour.

2. Improvements in aerodynamics, propulsion, and electronic control will enable unmanned devices to transport means of destruction to targets at distances up to many thousands of miles. However, until such time as guided missiles are so developed that there is no further need for manned aircraft, research in the field of "conventional" aircraft of improved design must be vigorously pursued.

3. Small amounts of explosive materials, as in atomic bombs, will cause destruction of many square

miles.

4. Defense against present day aircraft may be perfected by target-seeking missiles.

5. Only aircraft or missiles moving at extreme speeds will be able to penetrate enemy territory protected by such defenses.

6. A communications system between control center and each individual aircraft will be established.

7. Location and observation of targets, take-off, navigation and landing of aircraft, and communications will be independent of visibility or weather.

8. Fully equipped airborne task forces will be able to strike at far distant points and will be totally supplied by air.

[...] Further, the great unit cost of the atomic bomb means that as nearly as possible every one must be delivered to its intended target. This can be done in one of several ways, all of which involve air power. For example, the following evolution may be suggested:

a. Today, our Army Air Forces are the recognized masters of strategic bombing. Until others can match the present efficiency of our own antiaircraft defenses, we can run a large air operation for the sole purpose of delivering one or two atomic bombs. Our experience in the war suggests that the percentage of failures in an operation of this kind would be low.

b. When improved antiaircraft defenses make this impracticable, we should be ready with a weapon of the general type of the German V-2 rocket, having greatly improved range and precision, and launched from great distances. V-2 is ideally suited to deliver atomic explosives, because effective defense against it would prove extremely difficult.

c. If defenses which can cope even with such a 3,000-mile-per-hour projectile are developed, we must be ready to launch such projectiles nearer the target, to give them a shorter time of flight and make them harder to detect and destroy. We must be ready to launch them from unexpected directions. This can be done from true space ships, capable of operating outside the earth's atmosphere. The design of such a ship is all but practicable today; research will unquestionably bring it into being within the foreseeable future.

[...] Complete dispersal of our cities and moving vital industries underground on a sufficiently large scale would be overwhelmingly expensive. [...]

Although there now appear to be insurmountable difficulties in an active defense against future atomic projectiles similar to the German V-2 but armed with atomic explosives, this condition should only intensify our efforts to discover an effective means of defense. [...]

Jet propulsion is in its infancy despite the fact that this war has evolved six distinct methods of utilizing atmospheric oxygen for propulsion, such as (1) *motorjet*—or reciprocating engine plus ducted fan, (2) *turboprop*—a gas turbine plus propeller, (3) *turbofan*—a gas turbine plus ducted fan, (4) *turbojet*—a gas turbine plus jet, (5) *ramjet*—a continuous jet with compression by aerodynamic ram, and (6) *pulsojet*—or intermittent jet. These new and strange sounding words will be familiar ones in our speech in the near future, and right now they carry more meaning for Americans than any other six words I know.

[Arnold's statements in the above report, especially those regarding the use of long-range rockets or spacecraft to deliver atomic bombs, were widely reported in newspapers. As just one example, see:

Space Ships Flying A-Bomb Rockets Visioned by Arnold. *Los Angeles Times* 12 November 1945 p. 1.

For an example of the press reporting this idea in detail, see p. 5460.]

Traitor Suspect Holds Secret Key of Nazis' V-Ten. *Toronto Daily Star* 12 November 1945 p. 28.

Stockholm, Nov 12—(AP)—The newspaper Aftonbladet today quoted an unnamed British lieutenant as saying that the Swedish engineer, Nils Werner Larsson, on trial for delivering military secrets to both Germany and the Allies, held the key to construction of the whole series of Nazi vengeance weapons from V-1 to V-10.

The V-10 was the weapon which the Germans expected to hurl across the Atlantic in 35 minutes to bombard North America. It was in blueprint stage when Germany surrendered.

The newspaper said plans for the V-10 reached the United States seven weeks ago and formed the basis for Gen. Henry H. Arnold's reference to "space ships" in his report yesterday to the U.S. secretary of war.

In the report, Gen. Arnold envisaged space ships travelling 3,000 miles an hour "operating outside the earth's atmosphere."

Larsson is charged specifically with offering German military secrets to Allied military representatives in Sweden and of delivering an improved Swedish machine pistol to the Germans, presumably to create confidence in him.

The newspaper quoted the lieutenant, who recently visited Sweden from Hamburg, as saying that Larsson had great technical knowledge and had worked in the German experimental laboratories in Peenemuende in 1943, where V weapons were developed.

Larsson left Sweden in 1943 for Germany and assisted German discoverers and builders of the V weapons, the newspaper said. After the German collapse, Larsson was said to have had freedom of movement in Germany. The British officer was reported to have met Larsson in an officers' barracks in Hamburg a few weeks ago.

Larsson was arrested by the Swedes at the border, apparently while en route home from Germany.

Swede Arrested as Double Agent. *New York Times* 13 November 1945 p. 5

Accused of Selling Arms Data to Germans and Allies—Tells of V-10 Space Ship

STOCKHOLM, Sweden, Nov. 12—A Swedish engineer, Nils Werner Larsson, who is said to possess the secrets of all Germany's V-weapons, is in jail here accused of having sold designs for secret Swedish weapons to both the Germans and the Allies during the war and of desertion from the Swedish Army.

The Aftonbladet quoted a British officer who said that Larsson had the key to all German V-weapons from V-1 to V-10, which was intended for wiping out American cities. Its designs are now in Washington and are probably what Gen. H. H. Arnold referred to in yesterday's sensational report on space ships.

Larsson made contact with the British Secret Service in the summer of 1943 and agreed to work for the Allies in Germany. He gained the Germans' confidence by selling their agents designs for a new Swedish submachine gun and an anti-tank gun after first having given them to the Allies. The Germans trusted him and in October he went to Germany. The Germans, realizing his great gifts as a constructor, immediately sent him to Peenemuende to work on V-bombs.

He worked for the Allies too and was permitted to move freely in Germany after her collapse. A British officer met him in Hamburg, where Larsson told about his work in Peenemuende. Larsson seemed to be extremely persona grata with the British authorities in Germany and was permitted to go to Norway, whence he returned here.

Larsson said today that all other variations of V-weapons were vastly surpassed by the V-10, which, according to German plans, was to cross the Atlantic in thirty-five minutes and devastate American industries and cities. Later it was to be developed into an "absolute stratosphere ship" with which it should be possible to cruise around in space under human control.

[Versions of this story were also published in other newspapers; see for example:

Swedes Reveal V-10 Weapon as Nazi "Space Ship." *Chicago Tribune* 13 November 1945 p. 2 [http://archives.chicagotribune.com/1945/11/13/page/2/article/swedes-reveal-v-10-weapon-as-nazi-space-ship]

U.S. Has V-10 Plans, Says Swedish Paper. *Los Angeles Times* 13 November 1945 p. 7.

"V-10" seems to have meant the A-9/A-10, which would have been capable of everything described here: carrying pilots, traveling through space from Germany to the United States, and "devastating American cities" (especially if Germany had an atomic bomb the rocket could carry, as discussed in Appendix D). The A-10 was part of Wernher von Braun's series of Aggregat rockets from A-1 through A-10. Since the V-1 (unrelated cruise missile) and V-2 (renamed A-4 rocket) were such well-known names, someone involved in reporting this German work probably tried to apply V-labels to all of the Aggregat rocket numbers. In 1949, General Henry Arnold confirmed that the V-10 was indeed the A-10, and that physical rockets were being built, not just designed (p. 5466).

Nils Werner Larsson led a very exciting life. For more information on him as well as some of the other German rocket information he provided, see p. 5670.]

The 36-Hour War: Arnold Report Hints at the Catastrophe of the Next Great Conflict. *Life*. 15 November 1945. 19:21:27. [See document photos on pp. 5461–5464.] [https://books.google.com/books?id=6UsEAAAAMBAJ&pg=PA27&dq=Life+36+Hour+War&hl=en&sa=X&ved=0ahUKEwjVgMfcr9fiAhVFh-AKHe36D0QQ6AEIKDAA#v=onepage&q=Life%2036%20Hour%20War&f=false https://blog.nuclearsecrecy.com/2013/04/05/the-36-hour-war-life-magazine-1945/]

The start of another war, said General Arnold, might come with shattering speed: "With present equipment an enemy air power can, without warning, pass over all formerly visualized barriers and can deliver devastating blows at our population centers and our industrial, economic or governmental heart even before surface forces can be deployed."

[Not even U.S. bombers could "pass over all formerly visualized barriers" at that time, since fighters, anti-aircraft guns, and anti-aircraft rockets were still potential barriers for them. Was General Arnold admitting that German intercontinental rockets, which could indeed pass over all barriers, were "present equipment" and had been fully developed by the end of the war?

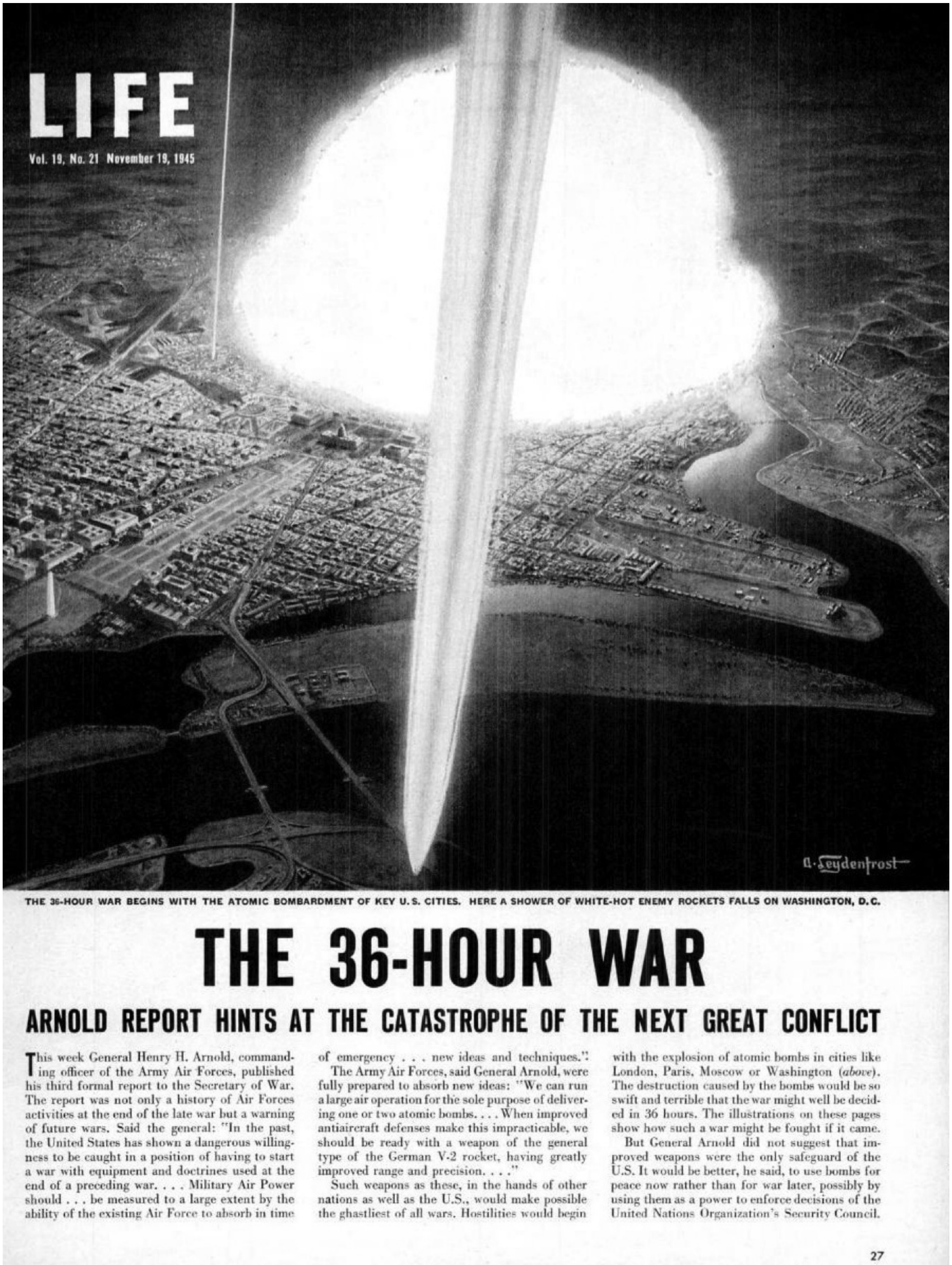
Based directly on information from General Arnold, this *Life* article presented illustrations of a number of very German-like rockets arcing over the Atlantic and delivering nuclear bombs to major U.S. cities, including a full-page illustration of a nuclear explosion in Washington, D.C., and another full-page illustration of the rubble of New York City after a nuclear explosion. Some of the illustrations are shown on the following pages. Was this General Arnold's idea of "present equipment" based on what his investigators found in Germany and Austria at the end of the war? What exactly did they find?

A two-page illustration in the article also depicted a massive underground military complex with areas for manufacturing and storing nuclear weapons and rockets, launching nuclear-armed rockets, providing living quarters for all the workers in the underground complex, and supplying power for the complex. The article portrays such a complex as something that the United States might build, but in 1945, the United States did not have such underground complexes, plans to build them, or intercontinental rockets with which to equip them. However, Germany had spent several years during the war developing just such underground complexes. How far did Germany actually get in making these sorts of underground nuclear weapons production/intercontinental rocket production/launching complexes operational? What did General Arnold know from his investigators?

One of the main engineers in charge of designing and build German underground complexes during the war, Karl Fiebinger, worked in the United States for many years after the war as a "consultant" on secretive government projects (pp. 4986–4991, 4993). His accomplishments in the United States included designing underground missile silos for intercontinental ballistic missiles, which may shed light on the nature and extent of his wartime work for Germany [Freund and Perz 1987, p. 44]. Another person who apparently did similar work for both wartime Germany and the postwar United States was Hans Brand (German, 1879–1959). Thus this arm of the long-standing postwar "nuclear triad," nuclear-armed intercontinental ballistic missiles based in underground silos, appears to have been directly derived from German-speaking creators and their creations.

For a similar but later article, see:

Robert S. Richardson. Rocket Blitz from the Moon. *Collier's Weekly* 23 October 1948, pp. 24–25, 44-46. http://www.zarthani.net/docs/rocket_blitz_from_the_moon-colliers.pdf]


A. Leydenfrost

LIFE
Vol. 19, No. 21 November 19, 1945

THE 36-HOUR WAR BEGINS WITH THE ATOMIC BOMBARDMENT OF KEY U.S. CITIES. HERE A SHOWER OF WHITE-HOT ENEMY ROCKETS FALLS ON WASHINGTON, D.C.

THE 36-HOUR WAR

ARNOLD REPORT HINTS AT THE CATASTROPHE OF THE NEXT GREAT CONFLICT

This week General Henry H. Arnold, commanding officer of the Army Air Forces, published his third formal report to the Secretary of War. The report was not only a history of Air Forces activities at the end of the late war but a warning of future wars. Said the general: "In the past, the United States has shown a dangerous willingness to be caught in a position of having to start a war with equipment and doctrines used at the end of a preceding war. . . . Military Air Power should . . . be measured to a large extent by the ability of the existing Air Force to absorb in time of emergency . . . new ideas and techniques."

The Army Air Forces, said General Arnold, were fully prepared to absorb new ideas: "We can run a large air operation for the sole purpose of delivering one or two atomic bombs. . . . When improved antiaircraft defenses make this impracticable, we should be ready with a weapon of the general type of the German V-2 rocket, having greatly improved range and precision. . . ."

Such weapons as these, in the hands of other nations as well as the U.S., would make possible the ghastliest of all wars. Hostilities would begin with the explosion of atomic bombs in cities like London, Paris, Moscow or Washington (*above*). The destruction caused by the bombs would be so swift and terrible that the war might well be decided in 36 hours. The illustrations on these pages show how such a war might be fought if it came.

But General Arnold did not suggest that improved weapons were the only safeguard of the U.S. It would be better, he said, to use bombs for peace now rather than for war later, possibly by using them as a power to enforce decisions of the United Nations Organization's Security Council.

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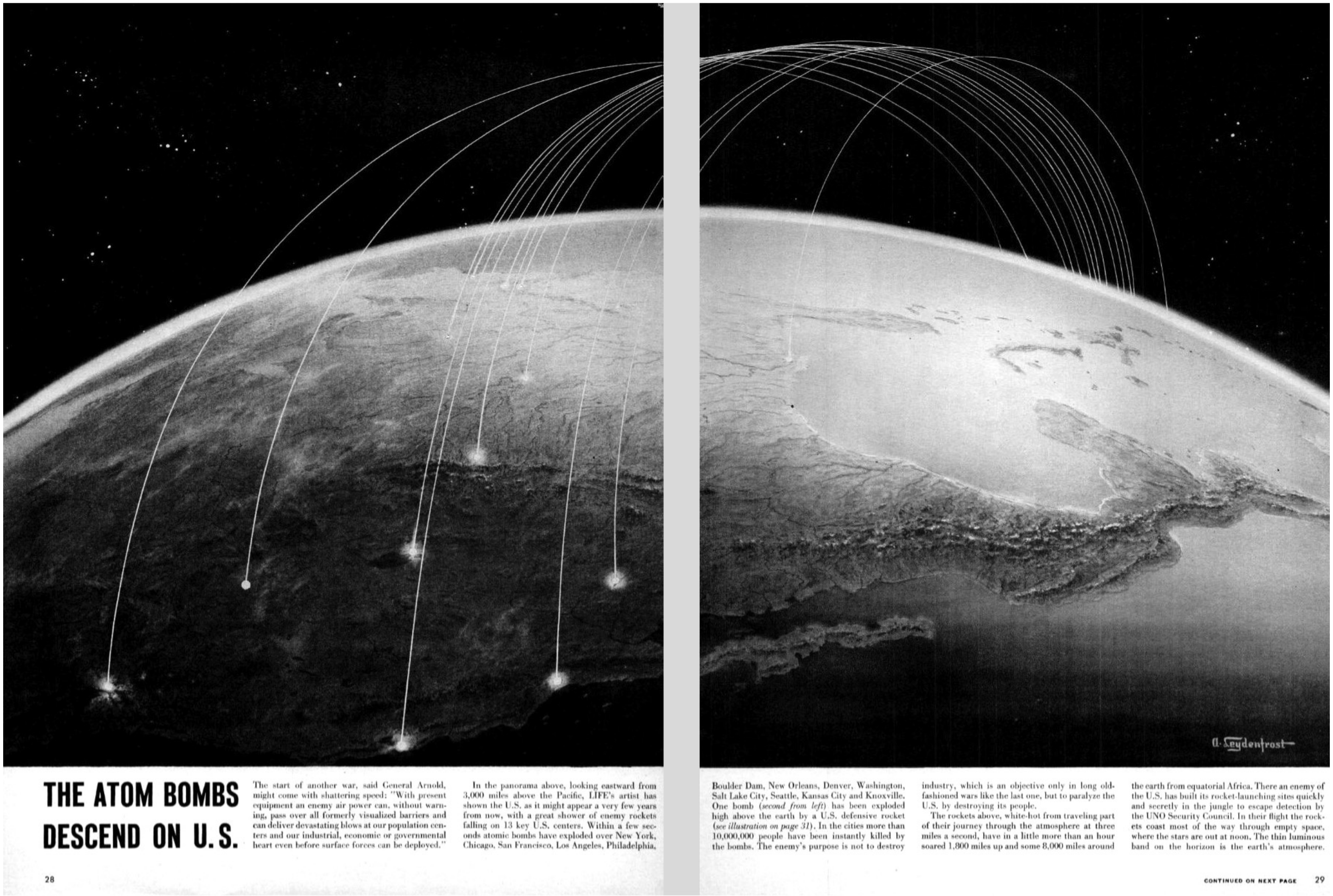
Figure E.135: Illustration from The 36-Hour War.


A. Leydenfrost

THE ATOM BOMBS DESCEND ON U.S.

The start of another war, said General Arnold, might come with shattering speed: "With present equipment an enemy air power can, without warning, pass over all formerly visualized barriers and can deliver devastating blows at our population centers and our industrial, economic or governmental heart even before surface forces can be deployed."

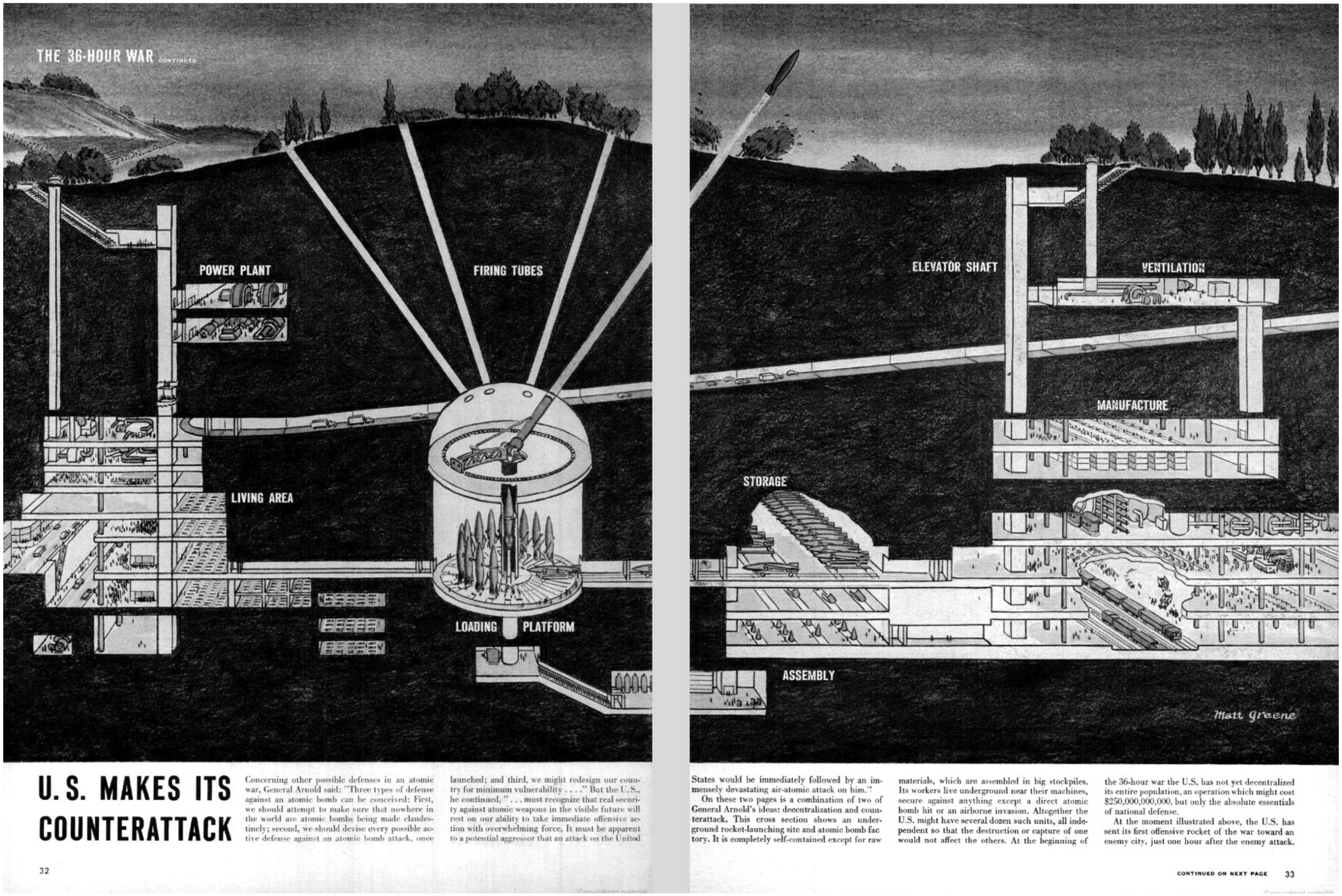
In the panorama above, looking eastward from 3,000 miles above the Pacific, LIFE's artist has shown the U.S. as it might appear a very few years from now, with a great shower of enemy rockets falling on 13 key U.S. centers. Within a few seconds atomic bombs have exploded over New York, Chicago, San Francisco, Los Angeles, Philadelphia, Boulder Dam, New Orleans, Denver, Washington, Salt Lake City, Seattle, Kansas City and Knoxville. One bomb (*second from left*) has been exploded high above the earth by a U.S. defensive rocket (*see illustration on page 31*). In the cities more than 10,000,000 people have been instantly killed by the bombs. The enemy's purpose is not to destroy industry, which is an objective only in long old-fashioned wars like the last one, but to paralyze the U.S. by destroying its people.

The rockets above, white-hot from traveling part of their journey through the atmosphere at three miles a second, have in a little more than an hour soared 1,800 miles up and some 8,000 miles around the earth from equatorial Africa. There an enemy of the U.S. has built its rocket-launching sites quickly and secretly in the jungle to escape detection by the UNO Security Council. In their flight the rockets coast most of the way through empty space, where the stars are out at noon. The thin luminous band on the horizon is the earth's atmosphere.

28

CONTINUED ON NEXT PAGE 29

Figure E.136: Illustration from The 36-Hour War.



U. S. MAKES ITS COUNTERATTACK

Concerning other possible defenses in an atomic war, General Arnold said: "Three types of defense against an atomic bomb can be conceived: First, we should attempt to make sure that nowhere in the world are atomic bombs being made clandestinely; second, we should devise every possible active defense against an atomic bomb attack, once launched; and third, we might redesign our country for minimum vulnerability . . . ." But the U.S., he continued, " . . . must recognize that real security against atomic weapons in the visible future will rest on our ability to take immediate offensive action with overwhelming force. It must be apparent to a potential aggressor that an attack on the United States would be immediately followed by an immensely devastating air-atomic attack on him."

On these two pages is a combination of two of General Arnold's ideas: decentralization and counterattack. This cross section shows an underground rocket-launching site and atomic bomb fac tory. It is completely self-contained except for raw materials, which are assembled in big stockpiles. Its workers live underground near their machines, secure against anything except a direct atomic bomb hit or an airborne invasion. Altogether the U.S. might have several dozen such units, all independent so that the destruction or capture of one would not affect the others. At the beginning of the 36-hour war the U.S. has not yet decentralized its entire population, an operation which might cost $250,000,000,000, but only the absolute essentials of national defense.

At the moment illustrated above, the U.S. has sent its first offensive rocket of the war toward an enemy city, just one hour after the enemy attack.

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Figure E.137: Illustration from The 36-Hour War.

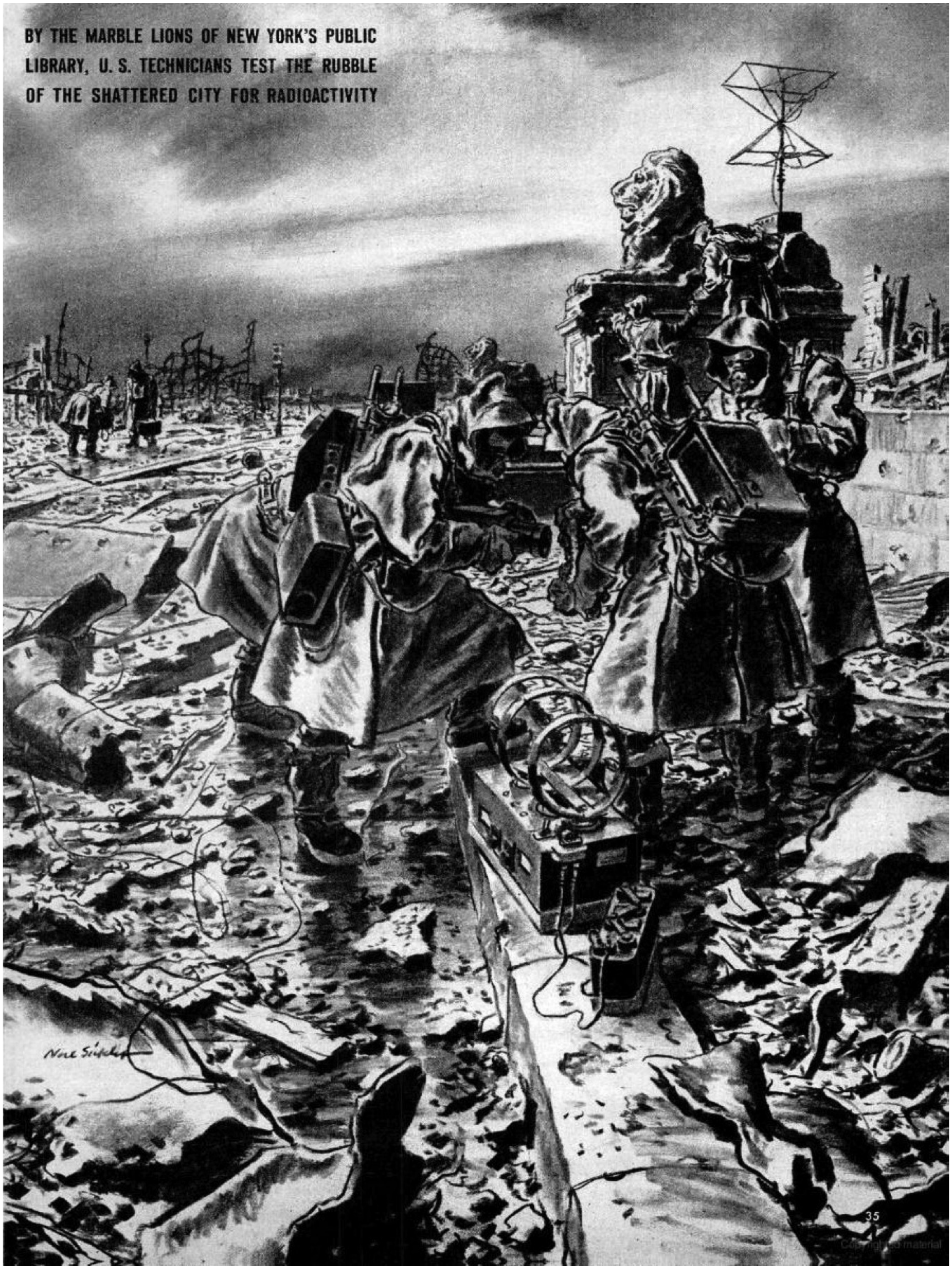
BY THE MARBLE LIONS OF NEW YORK'S PUBLIC LIBRARY, U. S. TECHNICIANS TEST THE RUBBLE OF THE SHATTERED CITY FOR RADIOACTIVITY
35

Figure E.138: Illustration from The 36-Hour War.

Carl A. Spaatz. Air Power in the Atomic Age. *Collier's* 8 December 1945 pp. 11–12, 83–84.

[...] At the top of its arc the V-2 traveled at an altitude of 60 or 70 miles and reached a maximum speed of about 3,500 miles an hour—approximately a mile a second. It was a bifuel rocket utilizing liquid oxygen and a hydrocarbon like alcohol or hydrogen peroxide.

Three improvements would make a similar rocket almost a perfect weapon: more range, increased explosive power, greater accuracy. The Germans were readying a transatlantic model when the war ended. Our atomic development supplies the explosive. There is no visible barrier to solution of the accuracy problem. [...]

[General Spaatz was the commander of the U.S. Strategic Air Forces in Europe during World War II and would have had a detailed knowledge of all relevant intelligence, both during and after the war. Seven months after the end of the war in Europe, Spaatz wrote that he knew the Germans had been **readying** a transatlantic rocket (presumably the A-9/A-10). Thus such rockets were far more than a blueprint design–they were actually being prepared for use against the United States. How exactly did Spaatz know that? Henry Arnold made a very similar statement in 1949 (p. 5466). Where are the U.S. reports on this topic located now? Where are any captured German documents and hardware?]

Balanced Forces Urged by Arnold. *New York Times* 9 December 1945 p. 31.

General, at Pennsylvania Dinner, Calls for Close Watch on Potential Enemies

General of the Army Henry H. Arnold, commanding general of the Army Air Forces, advocating a policy of "offensive readiness," said last night that this country needed an intelligence service that would keep us informed of the intentions and scientific developments of possible enemies. He also called for the maintenance of "balanced armed forces" to insure peace. [...]

Forecasting the further development and perfection of super-bombers—for which no military target will seem too distant—General Arnold pictured radar-directed V-2 weapons equipped with atomic bombs, and said the damage would be "a far too terrible thing to contemplate." While there are no certain means to stop such weapons, once launched, he added, our aids and destructive equipment can make their use more difficult.

Scientific Research Stressed

"One necessity to meet the future is an intelligence service that will always keep us informed of the possible intentions and the scientific developments of possible enemies," he continued. "We must use our most brilliant scientists to develop better weapons more quickly and more effectively. We must take advantage of the bases we now have to be closer to an enemy's vital points with our weapons than he is to ours. We must use the most modern weapons of all kinds so that we can beat any potential opponent to the draw. Our hope lies, then, in a policy of offensive readiness to perpetuate peace—to provide for national security."

The general pointed out that this does not mean we should ever become an aggressor nation. He emphasized it was a plan of insuring peace, since "there will be little or no time for recovery after the first blow is struck by the attacking nation" in any future war. [...]

Henry H. Arnold. 1946. Air Force in the Atomic Age: Future of the Ballistic Rocket [Masters and Way 2007].

[...] The Twentieth Air Force, using atomic bombs, could in one day's raid destroy more of Japan's industry than was actually done in the entire B-29 campaign. [...] A similar fate would have enveloped England had the Germans obtained atomic explosives for their V weapons.

We have now flown a B-29 nonstop for a distance of over 8,000 miles. Ranges of 10,000 miles for one-way trips with newer types of aircraft appear to be a possibility of the near future. [...]

Looking only a little farther to the future, we must consider developments of the V-2 rocket. By designing a rocket consisting mostly of fuel, a speed of 3,400 miles per hour and a range of 200 miles was obtained in operations against England. This rocket weighed 14 tons and delivered only 1 ton of explosive. The Germans had under design a longer range rocket, using a pick-a-back principle. A large rocket was to carry a smaller one up to a speed of 2,500 miles per hour. At this point the smaller one was to take off on its own, attaining a speed of 5,800 miles per hour, which would carry it 500 miles. The combined rocket would weigh 100 tons and deliver 1 ton of explosive. Designs incorporating winged rocket predicted an increase of range to 300 miles for V-2 by finishing the trajectory in a glide and an increase to 3,000 miles for rockets of the 100-ton class. This phenomenal increase in range was based on a trajectory in which the rocket would bounce out of the lower atmosphere into the stratosphere in a succession of jumps (like a stone skipping on water) and end up in a glide. Extensions of these techniques to rockets of more than two stages permit increasing the range indefinitely with a progressive decrease in percent of payload. However, the achievement of range alone is of little strategic value unless it leads to effective and economical destruction of specific targets. [...]

Very long-range rockets were not a serious threat before the atomic bomb because of the high ratio of the weight—and consequently the cost—of the vehicle compared to the explosive load. Even a two-stage rocket would barely break even economically—the cost of destroying a square mile by this means being comparable with, if not larger than, the damage done to the enemy. With an atomic warhead, however, the cost of the carrier is not excessive and even the expense of the most elaborate guiding and control equipment would not make the total product inefficient, for the destructive effect would exceed the total cost by a large factor.

Henry H. Arnold. 1949. *Global Mission.* New York: Harper. pp. 497.

Fortunately, judging from the mere 1100 that finally fell on England, chiefly London, the long-range V-2 rockets did not get into production until January, 1944. The planned output of 900 a month was not achieved, 50 to 300 being the number produced monthly until August. Between September, 1944, and March, 1945, the production rate was 700 a month. [...] A large bombproof launching site was under construction in France as early as May, 1943, however, and another in August, at about the same time the V-1 launching sites were begun. The V-10 (A-10), a very large rocket intended especially for New York, was being built.

[General Arnold would have had detailed classified knowledge of any wartime German development of intercontinental jet bombers, intercontinental rockets, and nuclear weapons. He stated unambiguously that the A-10 New York rocket was being built, and he confirmed that it was the same rocket as what had been called the V-10.]

Statement of Dr. Vannevar Bush to the U.S. Senate. 3 December 1945. *Hearings Before the Special Committee on Atomic Energy, United States Senate, Seventy-Ninth Congress, First Session, Pursuant to S. Res. 179, a Resolution Creating a Special Committee to Investigate Problems Relating to the Development, Use, and Control of Atomic Energy, Part 1, November 27, 28, 29 and 30, 1945. December 3, 1945.* Washington, D.C.: U.S. Government Printing Office, 1945, pp. 179–180. [Bush 1945]

Dr. BUSH. [...] Let me say this: There has been a great deal said about a 3,000-mile high-angle rocket. In my opinion, such a thing is impossible today and will be impossible for many years. [...]

They have been talking about a 3,000-mile high-angle rocket, shot from one continent to another, carrying an atomic bomb and so directed as to be a precise weapon which would land exactly on a certain target, such as a city.

I say, technically, I don't think anybody in the world knows how to do such a thing, and I feel confident that it will not be done for a very long period of time to come. [...]

The CHAIRMAN. Well, Dr. Bush, I read in this week's Collier's magazine an article by General Carl Spaatz of the Air Forces. I would like to have you read that article.

Dr. BUSH. That would not worry me in the slightest degree. I have just been criticizing the report of General Arnold of the Army Air Forces.

The CHAIRMAN. I wish that you would, sometime later on, comment on that article.

Senator TYDINGS. What does it say, Mr. Chairman?

The CHAIRMAN. What it says, Senator, is that the Germans, the year preceding the end of the war, were designing a rocket, and were pretty well along on it, that could carry from that continent to this continent and that would contain a warhead. They did not, of course, at that time have in mind an atomic warhead. That is my understanding of the article, at least.

Of course, I do not quality General Spaatz as an engineer, but he has written this article in Collier's.

Dr. BUSH. If you were talking about 400 miles or 500 miles, I would say by all means. That is what the Germans did with their V-2. I would say yes, even with 2,500 miles.

But 3,000 miles? That is not just a little step beyond, it is a vastly different thing, gentlemen. I think we can leave that out of our thinking. I wish the American public would leave that out of their thinking.

[Vannevar Bush, a doctor of engineering and vice president of MIT, created and ran the umbrella organization for all U.S. government-funded research and development during World War II (including the Manhattan Project), and developed the blueprint for postwar U.S. research programs (p. 2200). He had a deep personal knowledge of science and engineering, had access to the best scientists in the United States, and presumably had access to even the most highly classified information about what the United States had learned regarding German research and development programs.

Not only had Germany been developing long-range rockets during the war, but even as Bush gave this testimony to the U.S. Senate in December 1945, German-speaking scientists were hard at work in the United States, Soviet Union, and other countries to develop more rockets based on those wartime designs.

Because Vannevar Bush was so well informed and his other scientific statements were so accurate, it is striking that his statement about the feasibility of intercontinental rockets was so incorrect. He even ignored the evidence from U.S. Army Air Forces generals that was directly cited in this Senate hearing, insisting not only that intercontinental rockets were not feasible at the present time, but that they would not be feasible within the foreseeable future, and that no one in the world knew how to develop them.

Bush even went so far as to publicly state that it was entirely possible to increase the range of German rockets from the initial ∼190-mile range of the V-2 all the way to 2,500 miles (a 1200% increase), yet completely impossible to increase it just a little more from 2,500 miles to 3,000 miles (a further 20% increase). Such a statement seems scientifically ludicrous.

Was this a rare and extreme error by Bush, or was he intimately aware of the details of the German work—especially German work on 3,000-mile rockets capable of reaching the United States (e.g., pp. 5208, 5402, 5821)—and trying to cover it up in public? If he was trying to cover it up, what did he actually know? In retrospect, one gets the impression that whatever Bush had discovered about wartime German progress on intercontinental rockets (and/or atomic bombs they could carry) must have been sufficiently shocking for him to deny the topic so completely, despite so much evidence to the contrary.

The chairman of the Senate committee added that the Germans "did not, of course, at that time have in mind an atomic warhead." Yet that view was directly contradicted by the chairs of CIOS, U.S. General Thomas Jeffries Betts, Deputy G-2 of SHAEF, and U.K. Ministry of Supply chief advisor and F.R.S. Professor Reginald Patrick Linstead, in their written report (p. 5445). It was also contradicted by a great deal of other evidence that was known at that time to high-ranking U.S. officials (Appendix D and p. 5821).

Are any wartime and postwar papers by Vannevar Bush (and his chief deputies such as James B. Conant) still classified? If so, can they be declassified and searched for wartime or postwar intelligence on German programs to develop weapons of mass destruction and various means of delivering them to Allied targets?]

McNarney Predicts 10,000-Mile Missile. *New York Times.* 4 December 1948 p. 6.

Tell Industrialists Here That Tactics, Weapons of Last War Are Obsolete

Gen. Joseph T. McNarney, Commanding General of the Air Materiel Command at Wright Field, warned yesterday that while America must not consider itself prepared for push-button warfare, it "can no longer afford to fight a war of the future with the strategy, tactics and the conventional weapons of the last." [...]

In a graphic word picture of current developments in the field of rockets, jet propulsion and supersonic flight which he admitted was "fairly well fenced in by security restrictions," the general envisioned a missile with a 10,000-mile range that he held to be representative of future push-button warfare.

Guidance Critical Problem

The critical problem in the development of such a weapon, he declared, is guidance. As ranges increase, he added, the accuracy of radio and radar guidance schemes decreases. The optimum guidance system would be one that is self-contained within the missle and is non-jammable by the enemy, he said. [...]

The general pointed out that such a weapon is one of four types of guided missiles that military and scientific leaders feel will be successfully developed. Surface-to-surface missiles, he said, may be available in three years on America's shorter-range subsonic weapons, but he refused to predict the decade in which the nation will "cross the threshold of true push-button warfare."

Attack Possible "At This Hour"

In his review of the development of another one of the four guided missiles—the air-to-air missile—General McNarney said such a weapon would be effective in the event of an enemy bombing attack on a major American city. Such an attack, he warned, is possible "at this very hour when we consider the long-distance feats already accomplished by our own B-29 Superfortresses, which are even now being relegated to the realm of obsolescence."

The air-to-air missile, he explained, would be launched from interceptor aircraft and would proceed under rocket power at supersonic speeds, guided by a radar homing device at the enemy aircraft. Its development as an operational missile, he said, would take only a relatively short period of time. A surface-to-air missile, also moving at supersonic speeds after being fired from defensive ground sites, he added, "should be available for operational use within the next few years."

The general said that the development of air-to-surface guided missiles, or large bombs of the 12,000-pound, 22,000-pound and 43,000-pound class, designed to strike a specific enemy with high accuracy, is possible in the immediate future, with the 12,000-pound bomb being available within the next year. [...]

[Wright Field was home to vast quantities of documents and equipment captured in Germany, as well as many of the German aerospace engineers who came to the United States. This report may reflect wartime German accomplishments, and in any event shows how deeply indebted postwar U.S. programs were to German creations and creators.]

Germans Had Jet 'Planes 5 Times Faster Than Sound.' *The Ottawa Journal.* 18 January 1946 p. 9. [**https://www.newspapers.com/newspage/50100865/**].

A jet aircraft designed to travel at five times the speed of sound and a rocket motor 10 times larger than those used on V-2s at the end of the war were just two of many German developments in aeronautics viewed by Canadian-scientists during a recent tour of the battered Reich. The experts, five members of the National Research Council Staff, spent four months poking around former German research stations, airfields and underground factories. At a symposium of the Council's Science Association they reported their conclusion that many advances in German aeronautics failed to reach the production stage, only because of Hitler's "intuition and interference" and a lack of co-ordination of various projects by the Nazi air ministry. The experts were W. F. Campbell, wind tunnel expert; R. D. Hiscocks, supervisor of the airframes laboratory; M. S. Kuhring, chief of the engine laboratories; J. L. Orr, in charge of de-icing research, and D. G. Samaras, another engine expert. Mr. Samaras reported the Germans had made "considerable headway" in trans-Atlantic rockets and actually were making preparations for space travel. A lack of materials, skilled labor and proper organisation slowed this project. In rockets and jet propulsion, the Nazis had "10 times our technical facilities" and in rocket research were "miles ahead of us." Research now was extensive in Britain and the United States in this field and it was time similar work was started in Canada. Mr. Hiscocks described several advanced types of jet and propeller-driven aircraft with most of the later models featuring "sweep back" wings.

The most advanced was a fantastic jet affair resembling a paper dart, called the [Lippisch] DM-1. It was a modified glider designed to reach speeds five times faster than sound and operate at an altitude of up to 22 miles. "It was completed just in time for the United States Army to take delivery," he said. Another type in the 600 mile-an-hour bracket resembled a boomerang with a jet engine mounted in the centre. It had a 50-foot wing span and could remain in the air for three to four hours "high for a jet." Another novel feature was a "pilot ejector seat," which broke an air vice-marshall's back when he ventured to test it. Some Messerschmidt 262's had rocket boosters enabling them to climb 30,000 feet in two minutes. A late model Heinkel 162 had a climbing rate of 4,200 feet a minute and sufficient were produced to take "quite a toll of our bombers." Still another type was a tailless rocket job, "the first in the world." It had a speed of 600 miles-an-hour and climbed 30,000 feet in 2 1/2 minutes. The German scientists "knew about as much about air foils as we did," but went farther in designing wings that sweep back sharply from the nose of the aircraft. Such designs give as much as a 60-mile-an-hour boost to speeds, but lack control at lower speeds.

"Hitler's visions disrupted the whole aircraft production program," Mr. Hiscocks said. Once the German leader ordered a plane designed as an interceptor to be converted into a bomber. Mr. Hiscocks said the Germans never produced an outstanding bomber. In general the failure of Germany to win control of the air was "a tactical error by the high command and not the fault of the designers." The world's first jet plane had been flown at Rostock in 1938, about a year ahead of the first Italian effort and three years ahead of Britain.

[Five Canadian aerospace experts reported that while visiting a German research station, they viewed "a rocket motor 10 times larger than those used on V-2s." The most important parameter of a rocket motor is its thrust; if that is the measure of comparison intended here, the standard V-2 motor had a thrust of 27 tons at sea-level atmospheric pressure, so that would mean the Canadians saw a rocket motor with a thrust of roughly 270 tons. Both the A-10 booster and the Silbervogel space plane were designed to use engines with a 200-ton thrust. Thus the reported engine could have been built specifically for either one of those vehicles, and would demonstrate that those projects had progressed well beyond the paper design phase. Alternatively, the reported engine could have been for some other large rocket project that has been even less well characterized in the published literature.

If the reported motor was "10 times larger" in mass, a standard V-2 motor had a mass of approximately 930 kg, so the observed motor would have had a mass of roughly 9300 kg. The best documented design for an A-10 motor used six standard V-2 motors that all fed into a larger nozzle. The A-10 engine mass does not seem to be reported in the published literature but would have included the mass of the six standard motors plus almost as much for the large nozzle, or roughly 10 times the mass of one standard V-2 motor. Likewise the exact Silbervogel engine mass is difficult to find, but a reasonable estimate is that it was roughly half of the 10,000 kg empty mass of the Silbervogel, or roughly 5000 kg.

Conceivably the reported motor might have been "10 times larger" than a standard V-2 motor in length, width, combustion chamber volume, nozzle area, or some other parameter.

In any event, the report by the Canadian aerospace experts demonstrates that some very large rocket project had progressed well beyond the drawing board: A-10, Silbervogel, or some other rocket similarly sized for intercontinental trajectories.

Can the detailed scientific reports of these Canadian experts be located?

Similar versions of this news story were also reported in:

Calgary Herald. 19 January 1946 p. 10. https://news.google.com/newspapers?nid=Hx6RvaqUy9IC&dat=19460119&printsec=frontpage&hl=en

Courier-Mail (Brisbane, Australia). 19 January 1946 p. 1. https://trove.nla.gov.au/newspaper/article/50289068?browse=ndp%3Abrowse%20%2Ftitle%2FC%2Ftitle%2F12%2F1946%2F01%2F19%2Fpage%2F2011541%2Farticle%20%2F50289068]

Donald L. Putt. 1946b. German Developments in the Field of Guided Missiles. ***Society of Automotive Engineering (SAE) Journal (Transactions)*** **54:8:404-411.**

[...] After watching the V-1 and V-2 firing trials at Blizna and Cracow, Poland, in April, 1944, Hitler is reported to have stated that German secret weapons were not the product of dreamers and that England and the whole world would soon feel their effect. It wasn't until allied technicians examined German developments in this field that we fully realized the tremendous achievements of German scientists, and how near they were to achieving the boasts of their leader.

The Germans were preparing rocket surprises for the whole world in general and England in particular, which would have, it is believed, changed the course of the war if the invasion had been postponed for so short a time as six months. Many of Germany's research laboratories and several large commercial firms concentrated on this field of endeavor. This tremendous effort resulted in 138 guided missiles and assorted devices, including their modifications. These were of types wholly unknown to laymen in the United States. At the outbreak of the war some of these were strictly "out of this world"—to use a current phrase. In addition, German scientists had developed other equipment of a type we had considered impracticable, such as the ram jet.

The stupendous effort in basic research expended by the Germans in the guided missile field was designed to cover the complete field of potentialities for such weapons. The losses incurred in Germany by heavy bomber raids can in no way be charged to lack of preliminary research on missiles. Weapons of this category were divided into the following classifications:

A. Ground to air.

B. Air to air.

C. Air to ground.

D. Ground to ground.

E. Underwater to underwater.

F. Underwater to ground.

G. Underwater to air.

Moreover, every known type of remote control and fusing means was exploited. These included radio control, wire control, radar, continuous wave, acoustics, infrared, light beams, and magnetics.

Likewise, all methods of employing jet propulsion for subsonic and supersonic speeds were exploited.

In all, it was estimated that one-third of the aerodynamics research in Germany was devoted to problems of guided missiles. Wind tunnels of undreamed-of speeds were under construction. A Mach number of 10 was not too great for the Germans to comprehend and strive for.

In the matter of aerodynamics and propulsion, the Germans were sufficiently advanced to handle any program desired. In the field of control they appear to have waited too long to make the necessary tests to indicate the proper directions for detail development; also, the fact that the Germans were late in being able to arrive at the answers required to utilize nuclear energy in the warheads made the German missile program more one of nuisance and worry over what might come than one of actual military damage.

Some of the classes of German missiles based on intended use are:

A. The Beethoven [...] was an air-to-ground missile. This composite aircraft consisted of an Me-109 fighter mounted on top of a Ju-88 bomber. The pilot rode in the cockpit of the Me-109, where he manipulated the controls of both craft. The nose of the Ju-88 was modified to contain an explosive. Upon reaching the target area the Ju-88 was released from the Me-109 in a dive which aimed it at the objective. This weapon was not used by the Germans to any extent; however, upon the termination of hostilities it was found that great quantities had been built up for an all-out assault at a later date.

B. The Enzian [...] was a ground-to-air missile. This small-winged flak rocket, named after the flower gentian, was controlled in flight by radio, and was intended for use against heavy-bomber formations. Its plywood fuselage was 17 ft in length and carried 990 lb of explosive. Four auxiliary starting rockets were mounted outside the fuselage, and after 5 sec of flight were jettisoned. Plans were being made to modify the Enzian so that it could attain supersonic speeds, but because of the advances of the U.S. Army only a few successful test firings were made.

C. The Wasserfall was a ground-to-air missile. A 26-ft flak rocket, the Wasserfall, meaning waterfall, is very similar in design to the V-2 rocket launched against Britain. At first it was visibly controlled by radio from the ground, but later methods employed radar tracking to guide it to the objective. Due to persistent allied bombing only 30 test launchings were made.

D. The X-4 was an air-to-air missile. It was a small rocket bomb, named Ruhrstahl or steel of the Ruhr, just under 6 ft in length, and designed to be launched from fighter aircraft. The rocket was controlled from the parent aircraft through two 4-mile lengths of wire. This fine wire was paid out from tapered bobbins enclosed in fairings at the extremities of two of the wings. Detonation occurred by means of a proximity fuse.

E. The Fitz X [...] was an air-to-ground missile. This German bomb was released from aircraft flying at a minimum altitude of 22,000 ft. It was gyrostabilized and visibly guided into the target by radio. The Fritz X was ready for operational use in January, 1943, and was first employed successfully against our shipping and assault forces at Salerno. The warhead on this bomb was armor-piercing and carried a charge of 2530 lb of standard explosive.

F. The Hs-298 [...] was an air-to-air missile. It was about 4 ft in length and could be controlled either by radio or wire. It was originally intended for use against sea targets, but early in 1945 it was being produced for air-to-air fighting in a factory in the underground railway in Berlin. A total of only 300 was built because the X-4 or Ruhrstahl bomb had become available.

G. The Hs-117 [...] was a ground-to-air missile. It was named Schmetterling or butterfly, and was a rocket-propelled, radio-controlled missile to be launched from the ground against bomber formations. It accelerated to a speed of 560 mph, and was steadied in flight by a pendulum device. The take-off rocket burned out and were jettisoned; the main propulsion unit then drove the missile until it was detonated by a proximity fuse. Large-scale production began January, 1945, in an underground factory in Nordhausen.

H. The Rheintochter [...] was a ground-to-air missile. It was a rocket-propelled anti-aircraft weapon and was controlled in flight by radio. It traveled at a speed of 1100 mph and carried an explosive charge of 330 lb, equipped with a proximity fuse, to a ceiling of 48,000 ft. The starting rocket, attached to the base, was blown off after combustion was completed. Development did not go beyond the test firing stage, but experiments were still being conducted as late as February, 1945. The code name Rheintochter means daughter of the Rhine.

I. The FZG-76 [...] was a ground-to-ground missile. It was launched either from the ground or from an aircraft. Ground launching as practiced by the Germans utilized a long run in which the working substance was the steam resulting from the catalytic action of calcium permanganate on a concentrated solution of hydrogen peroxide. The length of the gun and ramp varied from 140 to 170 ft at different sites. It carried 1870 lb of explosive, the range was 120 to 160 miles, and the circular probable error about five miles at a range of 130 miles when ground launched. The error was five times as great for air launching. The overall weight was about 5000 lb. The missile flew at an approximately constant altitude of about 2000 ft at speed varying for individual missiles from 288 to 425 mph.

Numerous techniques for controlling the missiles were evolved, only one or two of which proved satisfactory. Conventional radar units, with special coding mechanisms were used. In one instance a beam-riding system was attempted, but the disastrous test results caused an immediate cessation of the project. It appears that the missile was supposed to follow a beam of energy emanating from a radar unit and aimed at the target, in this case an airplane; however, the missile would usually reverse its direction and ride the beam down to the radar unit, with quite obvious results. As a result, it was decided to augment the control system by adding homing or seeking devices of various sorts. These included systems sensitive to heat or sound. Some of the homing devices incorporated a miniature radar unit.

The German developments being discussed here are generally grouped under the loose term “guided missiles”; however, that isn’t correct, inasmuch as some of the missiles are not guided and some of the developments are not missiles. I have already discussed another widely employed classification based upon the location of the launching device and the target; for example: air-launched-to-ground targets. The classification I shall employ is based upon the type of propulsion unit.

There are six general types of direct-reaction engines.

1. The first example is the reciprocating engine with the exhaust jet.

2. The second example is the gas turbine.

3. The third example is the turbo jet.

4. The fourth example is the reed, intermittent-combustion engine. This is better known as the "buzz bomb" engine. The reed engine is similar to the ram jet engine, with the exception that it is equipped with a grill at the forward end.

5. The fifth example is the ram jet, also known as the athodyd or the Lorin engine, after the inventor. This device consists primarily of a curved, barrel-like tube into which fuel and air are introduced.

6. The sixth and last example is the pure rocket. This is subdivided into the dry fuel and liquid fuel subtypes. In either case, we have simply a combustion chamber in which the fuel burns. In the case of the dry fuel rockets, the fuel is also stored there. A great many of the German guided missiles were equipped with this type of propulsion equipment.

This discussion concerns itself with the latter three listed propulsion systems. For the purpose of simplicity, we will now consider the various engines and their applications, commencing with the reed engine and the ram jet. We have but one example of each of these, whereas we have some 30 examples of the rocket type. [...]

The next type of engine we will consider is the ram jet.

Only quite recently, now that air-speed values are approaching the velocity of sound, has it been practicable to envisage the use of the Lorin nozzle for propulsion. In the fall of 1944, while development in this country was largely limited to discussion as to whether such a powerplant would operate at all, the Germans had developed, built, and flight-tested a unit designed to produce a gross thrust of 4400 lb at 500 mph. (See Fig. 9). This development was accomplished by Walter of Kiel, Dr. Saenger of the DFS (Institute for Study of Soaring Flight), and by engineer Pabst of the Focke-Wulf plant at Bad Eilsen. [...]

A particularly effective employment of the Lorin tube is that of a jet propeller with a rotating wing. [...] Here characteristics and performance are very high; particularly in the range obtained at high altitudes. This is due to the fact that in rotating-wing aircraft the rotors can always be run at suitably high speeds. A rocket attachment can be provided to enable safe landing if the propellers are cut off. Take-offs and landings in these aircraft occur vertically, and only a small flying strip is required. [...]

The most highly publicized missile of the Germans was the V-2, or as the Germans themselves knew it, the A-4.

There were 10 variations of this weapon. [...] Three were prototypes. Four were improved models. One was a launching device intended to increase the already great range to 5000 km. Interestingly enough, one of the improved models was to be equipped with wings, wheels, a pressurized cabin, and to carry a pilot. [...]

The "A" series was considered to be an intermediate step to the practical use of guided weapons. The inherent shortcomings of this type of weapon were partly conditioned by the war, but the future will disclose improvement occurring more rapidly than was thought possible prior to the war.

It is interesting to note that this missile was extremely expensive, each requiring 20,000 man-hr for construction; however, since the Germans launched 3165 A-4's operationally, it is clearly indicated that the place of the large rocket weapon is firmly established in modern warfare. It has been pointed out that the small size of the warhead—1 ton—would hardly seem to have made the cost of the weapon worth while. In this connection it must be pointed out that it was probably the intention of the Germans that the weapon would eventually carry some sort of atomic device, in which case the warhead would have had the requisite specifications. [...]

In conclusion may I state that the Germans in the guided missile field were 10 years in advance of similar American development.

It will be noted that the Germans very largely explored the entire field of rocket-powered equipment. Their program was just beginning to become stabilized with the production of those units which were adaptable to mass production and operational use.

Very fortunately, they were never able to obtain full use of their developments. We are all familiar with the immense rocket-launching establishment on the coast of France which was to be used in destroying London.

It is now the responsibility of the American industrial machine to begin where the Germans stopped and to provide ourselves with the equipment necessary to maintaining our leadership in the scientific world.

American industry and the War Department must cooperate in exploiting this field, in which there appear to be unlimited possibilities for new and better devices and equipment, not alone in the province of weapons of war, but also in the applications to a fuller and more satisfactory civilization. [...]

[Note the similarities between Putt's presentation and the earlier reports on pp. 5429 and E.2 with which he was probably intimately involved. Putt was the U.S. Army Air Forces Colonel (later General) in charge of rounding up most of the German aerospace engineers in Europe at the end of the war, and funding them to continue their work in the United States for many years after the war. From that very well-informed position, he stated in this 7 March 1946 presentation to the Society of Automotive Engineers that among other things:

- German engineers had developed "the complete field of potentialities" of all possible types of missiles, "every known type" of electronic guidance and sensors, and jets and aerodynamics ranging from subsonic through supersonic speeds to Mach 10, or 10 times the speed of sound.
- Based on his studies of this field, the Germans were fully ten years ahead of the United States.
- There were many different types of long-range rockets. Putt's brief description of "10 variations of this weapon" could be taken to mean the well-known series from A-1 to A-10, or it might have reflected other variations that Putt had seen during his investigations of German rocket programs.

- Germany was within six months of employing rockets with much greater range than the A-4 (V-2) that would have "changed the course of the war," which would suggest that such rockets had already progressed well beyond the paper design stage.

- He believed that the Germans intended to put nuclear weapons on their rockets, which would suggest that there had been a long-running and determined nuclear weapons program operating in parallel with the German rocket program.

Interestingly, some of these statements vanished without explanation from later versions of this speech, such as the 27 June 1946 version written at Wright Field, possibly due to censorship. Censorship may also explain why he publicly stated much less than he presumably knew about the A-9/A-10 intercontinental rocket or other long-range rockets that were on the verge of changing "the course of the war." See these two related documents:

> Donald L. Putt. 1946. German Developments in the Field of Guided Missiles: An Address Before the SAE in New York, 7 March 1946. Summary Report. Report No. F-SU-1122-ND. 27 June 1946. Headquarters, Air Materiel Command, Wright Field, Dayton, Ohio. Library of Congress, Washington, DC. Call number MLCM 95/01648 (T) FT-MEADE.
>
> Donald L. Putt. 1946. World's Cities Threatened by Nazi Supersonic Bomber. *Society of Automotive Engineering (SAE) Journal* 54:7:9.

Many details from Putt's March 1946 presentation were repeated, often almost verbatim, by journalists' articles in various publications later from summer 1946 through 1947. See for example:

> Charlotte Knight. German Rocketeers: German Rockets and Guided Missiles Almost Won the War for the Nazis. *AAF Review* July 1946. 29:6:24–26, 48. (See p. 5038.)
>
> Nazis Worked on Plane to Bomb U.S. *Hartford Courant* 15 July 1946, p. 1.
>
> Hitler Planned Supersonic Bomber to Hit New York. *Los Angeles Times* 15 July 1946, p. 2.
>
> List of Terror Weapons of Nazis Revealed by AAF. *Plattsburgh Press-Republican* (Plattsburgh, New York) 15 July 1946, p. 1.
>
> Nazi Scientists Worked on 136 Secret Weapons. *Times Record* (Troy, New York) 15 July 1946, p. 3.
>
> Transatlantic Roller Coaster Designed to Bomb U.S.A. *Popular Science* October 1947. https://neverwasmag.com/2018/09/wonder-weapons-of-the-third-reich/transatlantic-roller-coaster-designed-to-bomb-usa/]

Senator Elbert D. Thomas. April 1946. Sitting Ducks in Our Air Forces. *The American Magazine.* pp. 26–124.

We won the air war against the Germans with muscle, not mind. We smothered them with the sheer weight of our planes. Their air weapons were ahead of ours at the start of the war, and far ahead at its end. Had our invasion of Europe been delayed six months, we might have lost the war, due to our inferiority in the air.

For years our Air Forces have given the American public a false sense of security by untruthful boasting. Before the war, we were told that American air power was best. It wasn't. . . . During the war, we were told that it was both best and biggest. It wasn't best; it was just biggest; it was muscle not mind. . . . We'd better learn the truth. For in the next war—God forbid!—boasting won't count, and there will be no time to build mere muscle into victory, as we did this time. Mind, not muscle, will win, and in days or hours instead of years.

Our combat airmen, the fighter pilots and bomber crews, fought magnificently with the weapons given them. But they weren't the best weapons, as they should have been. Our Air Forces high command clung stupidly and stubbornly to the ideas and weapons of yesterday, while the Germans developed and put into combat those of today and tomorrow.

After V-E Day, Allied civilian scientists and engineers visited Germany and inspected the laboratories, experimental stations, and factories which served the Luftwaffe. Their findings show not only the superiority of new German weapons, but the details of Germany's long-range research and development, a program marked by vision and eagerness to try new ideas. By contrast, the findings reveal our Air Forces' appalling lack of vision and stubborn allergy to new ideas, which were concealed from the American public. [...]

They [Germans] were first in combat with pressurized cabins, essential to high-altitude flight; with pilot-ejection, a mechanical bailout vital to high speeds and altitudes; with special high-altitude parachutes; with unified engine-control, needed by fighter pilots; with plane-to-plane rockets; with a true aircraft gun, a cannon ten times as destructive as our comparable cannon. [...]

The real shock comes when we view the Germans' unconventional developments, their really new ideas and weapons. They had most of them in combat. We had a few in partial development, none in combat. While we were being told what our new weapons were *going* to do, the new German weapons were *doing* it. [...]

This was the Messerschmitt-262 jet-propelled fighter, which first appeared in combat in the summer of 1944. Making 525 miles per hour, it was much faster than our Mustangs, Thunderbolts and Lightnings. At sea level it was *more than 150 m.p.h. faster.* [...]

Another German jet plane, the Heinkel-162 *Volksjaeger* (People's Fighter) had about the same performance. Still another, in development, was the *Triebfluegel Flugzeug* (powerwing aircraft) which had 3 wings radiating from the fuselage, like the fins on a bomb. Each wing-tip carried a jet engine. Launched vertically and shot to high altitude by rockets, its 3 jets would make it extremely fast in combat.

The Germans had jet bombers, too. The Arado-234 was made in 2 models, with speeds of 470 and 546 m.p.h. The Junkers-287, in flight test when the war ended, had more than twice the power of our B-29 Superfortress, could carry as many bombs to London as a B-17 could carry to Berlin, and made 537 m.p.h. There was to be a Junkers flying wing, with 4 jet engines and a speed of 620 m.p.h.

Even their jet bombers were *faster than our fighters*, making interception difficult and pursuit impossible. Our tactical commanders never understood why German jets, fighters, and bombers didn't raid southern England. They had the range and would have found hundreds of airfields crammed with our planes. With their great speed, they would have suffered little from antiaircraft fire. Our fighters couldn't have coped with them. Such raids would have been utterly devastating.

German rocket fighters, in combat during the last six months of the war, were even faster than the jets. One model of the Messerschmitt-163 made 550, another 590, m.p.h.

The Bachem *Natter* (Viper), in development, was launched vertically to get upstairs fast and attack bombers with rockets, and by ramming after its pilot was ejected. Though test-flown, its maximum speed was still estimated, but at more than 600 m.p.h. [...]

The V-1 made 360 m.p.h. at 3,000 feet altitude or less. Our fighters had to dive from higher altitude to catch it. [...] In terms of time and bomb-tonnage, the V-1's were much more destructive than Allied bomber raids on Germany. And much cheaper. [...]

The V-2 was still more spectacular—a rocket 45 feet long, 5 feet in diameter, weighing 12 tons, and carrying a ton of high explosive. [...] It was 6 times as fast as the German jet and rocket planes, traveling about 3,600 m.p.h. Far from catching it, our fighter pilots couldn't even see it. [...]

About a dozen new V-weapons were on drawing boards, in laboratories, and nearing production. One would carry troops in a pressurized cabin. Another would be launched from a submarine 300 feet below the surface. A third would cross the Atlantic in 14 minutes, arching to 500 miles' altitude and flying at 16,000 m.p.h. It was intended for morale-shattering mass raids on New York. It wasn't impractical. The Germans' prediction that they would do it in a year or so was no idle boast.

Had our invasion been delayed six months, the Germans could have regained air superiority, not only in Europe, but over the Channel and southern England. We could have continued night raids, but our daylight raids would have been suicidal. They could have raided England both night and day. Our planes couldn't have stopped them. Striking at airfields, troop-concentration areas, ports, and shipping—decimating our armies and destroying their equipment—they could have made an invasion of Europe almost impossible. Their better planes could have destroyed ours on the ground, as ours did theirs when muscle outweighed mind.

Between raids by their planes there would have been thunderous barrages of V-weapons. They planned to launch 1,000 V-1's a day. Rockets more deadly than the V-2 would have reached north to all important cities in England. We couldn't have prevented it.

England would have been pounded to rubble. Even if the Germans didn't invade, and they might have, a stalemate and negotiated peace would have been our best prospect, and total defeat not at all unlikely. We had a narrow escape, as it was. After our ground forces conquered the Continental coast just before V-E day, I visited a V-weapon factory. I could not help but utter to myself, and I've repeated it often, "We are just in time." That was no flight of poetic oratory; it was the stark and awful truth. And the threatened defeat which it so clearly implied *would have been due directly to our backwardness in the science of aviation.*

With more appetite for publicity than respect for the truth, our Air Forces brought us to World War II believing that we were the world's leading military air power. Press-agent activities produced such magazine articles as *Our Own War Birds Are Best*, in 1939. They weren't; they were inferior in speed, altitude, firepower, armor, and other respects. Commenting on this in 1942, a Congressional report said, "All this, despite the fact that Congressional Committees were frequently told our war planes of that period (1939) were better than those of other nations."

There was no secrecy about the Germans' superiority. They described and illustrated their planes in books and magazines, discussed them on the air and invited foreign pilots, including ours, to inspect and fly them.

Yet during the war hundreds of press agents, advertising men, and others more or less skilled at deceiving the public were hastily commissioned as Air Forces public-relations officers. Combat results, especially in bombing operations, were grossly exaggerated. Scores of enemy strong points were "wiped out" on Monday and "obliterated" on Tuesday, only to offer the bloodiest resistance to our ground forces on Wednesday.

On the home front, newspapers were deluged with misleading handouts. Magazine writers were given similarly misleading information about planes and equipment. Thousands of radio programs went on the air from hundreds of stations, with similar disdain for the truth. [...]

During and immediately after the war the new German weapons—jet and rocket planes, V-1's and V-2's—were ignored or belittled as "weapons of desperation," "fantastic," or "on the lunatic fringe," though anyone who thought so was clearly on the lunatic fringe, himself. Once the weapons were in our hands, the fashion changed. Recent articles discussed them seriously as weapons in our own air arsenal, but their German origin has never been denied. [...]

The Germans produced the weapons of today and tomorrow, while we improved those of World War I.

The defense usually offered by the Air Forces when charged with lack of progress is that they "weren't given enough money." That is largely nonsense. [...] The millions spent on most of these minor improvements, or failures, with propeller-driven planes would have produced jet planes. It was vision, not money, that was lacking. [...]

A change in leadership is not the solution of the problem. The truth is that our Air Forces suffer the ailments common to all military self-perpetuating organizations—ruling cliques, caste, politics, petty bureaucracy, fixed regulations, the purely arbitrary authority of rank and seniority, promotion for these reasons more often than for genuine ability. All these factors encourage acceptance of the past and discourage vision for the future.

[As previously noted, standard A-4 or V-2 rockets required over five years of massive effort to progress from paper designs to deployed weapons, carried one ton of conventional explosives, and could not reach England from areas still under German military control near the end of the war.

Based both on Senator Thomas's on-site inspections of German rocket programs and on his knowledge of detailed reports from scientific inspectors, he stated that Germany was within six months of deploying mass-produced versions of much more advanced rockets that were "more deadly than the V-2" (apparently meaning with payloads that were much more destructive than conventional explosives) and would have enough range to reach all of the United Kingdom from central Europe (with a much longer range than the V-2).

He also mentioned at least three other advanced types of rockets that (1) "would carry troops in a pressurized cabin," (2) "would be launched from a submarine 300 feet below the surface," and (3) "would cross the Atlantic in 14 minutes."

Senator Thomas and the other inspectors could not possibly have expected those more advanced rockets to make the leap from paper design to mass-produced deployed weapon in just six months; most likely the inspectors discovered well advanced hardware development, testing, and/or production programs for the rockets.

Senator Thomas's description of the 1940s U.S. research system seems to still be quite applicable to the modern research system.]

U.S. Army Ordnance Department. 1946. ***History of Ordnance Technical Intelligence in World War II, Part 1: History, Orders & Circulars, Publicity.*** **[https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1059&context=dodmilintel]**

During the war, American Ordnance was tested in deadly combat against the greatest array of enemies to oppose us in all history. They were armed with weapons which were the products of years of planning and building and the best that their mobilized scientific talent could devise. Nor did they stand still—for they realized that they were in a desperate competition wherein other things being equal, the nation which led in the design and production of the most deadly weapons would win. The most obvious example of the truth of this is the atomic bomb. However, this cannot be considered the only example that has appeared in this war which has seriously affected its outcome as there have been many other cases—like that of proximity fuzes and radar.

In connection with the subject of proximity fuzes, the Germans had expended a vast amount of energy on the research and development of fuzes which would detonate ammunition without coming in physical contact with the target. We were far ahead of them on actually getting a proximity fuze into production and into active use during the war, they were very effective, particularly in antiaircraft use. However, at the time the war ended, the German research and development had progressed to such an extent that they had designs almost ready for production and had thoroughly investigated many of the possible types of proximity fuzes; e.g. acoustic, radio, photo-electric and electro-static types.

This same situation occurred in many other fields of ordnance where the Germans were advancing very rapidly at the end of the war, and had the war lasted much longer, some of the new designs may have had an effect on prolonging the war. This possibly is most evident in connection with guided missiles.

Probably because of their lack of aircraft there was a tremendous incentive to develop some kind of a weapon to combat our devastating bombings. A number of rocket propelled missiles which could be guided from the ground and which would detonate by the use of a proximity fuze when coming within the danger area of one of our airplanes were developed to the production stage and one guided missile was actually in production at the end of the war. Our understanding of the way one was to have operated was by means of radar screen which could track both the target and the missile. The operator would have the necessary controls required to direct the missile and by watching the radar screen could take the necessary steps to bring the missile as close as possible to the airplane, at which time the proximity fuze would function and the airplane would disappear.

Quite a number of types of the well-known V-2 rocket had been worked on by the Germans and the research progress was laid out in such a manner that it would appear that very long range rockets might have been used some time in the near future had the war continued and nothing else interfered with their efforts. It is frightful to consider the possibility of a guided missile with an atomic bomb as a warhead, but there is little doubt that the Germans were actively considering the possibilities of such a weapon.

[The U.S. Army Ordnance Department closely investigated advanced German weapons both during and after the war. The Ordnance investigators were actually reprimanded by General Leslie Groves for publicly revealing how advanced the Germans were. See pp. 4186–4187, 5747–5753.]

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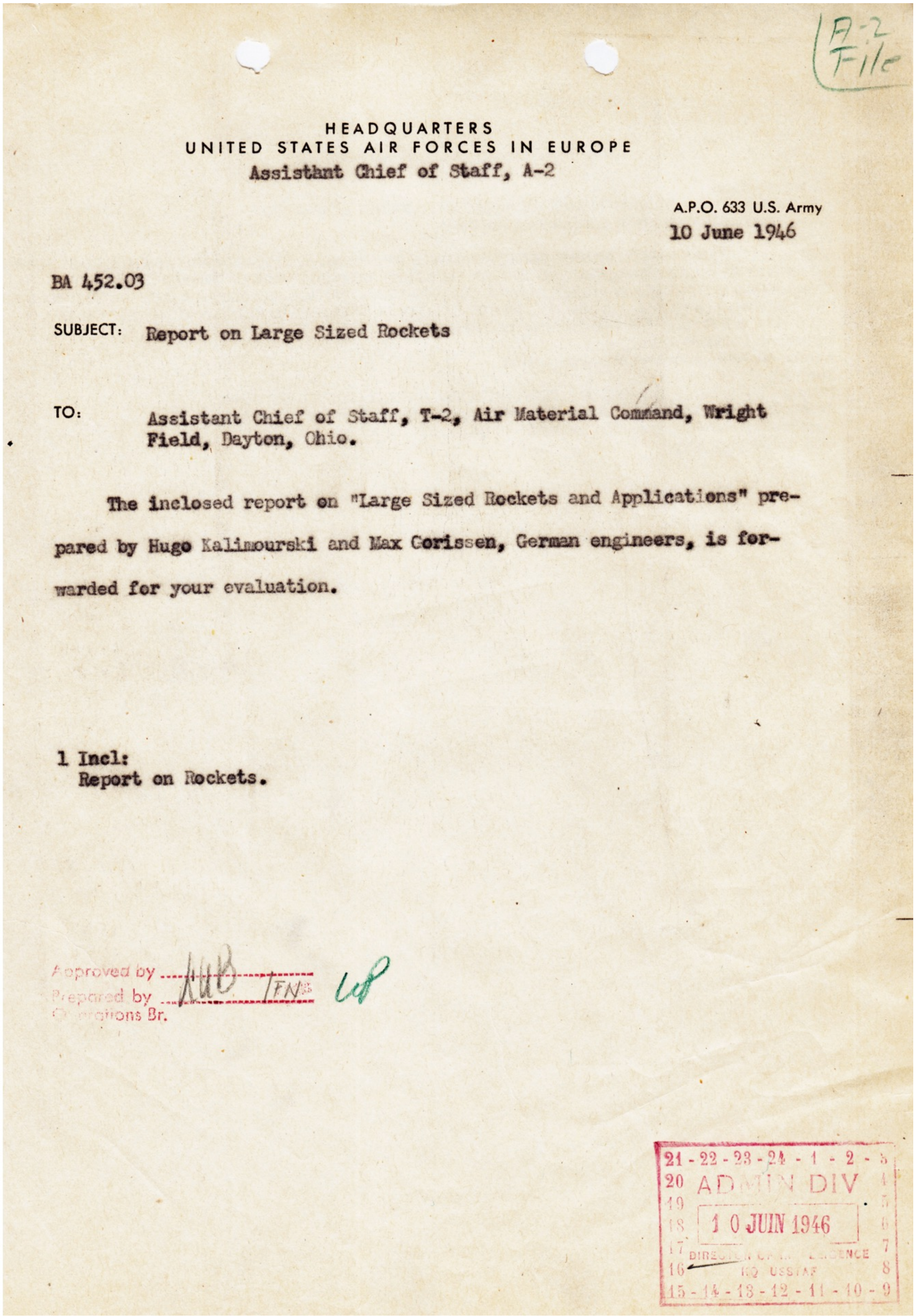
AFHRA folder 570.650 May-Aug 1946



A-2 File

HEADQUARTERS
UNITED STATES AIR FORCES IN EUROPE
Assistant Chief of Staff, A-2

A.P.O. 633 U.S. Army
10 June 1946

BA 452.03

SUBJECT: Report on Large Sized Rockets

TO: Assistant Chief of Staff, T-2, Air Material Command, Wright Field, Dayton, Ohio.

The inclosed report on "Large Sized Rockets and Applications" prepared by Hugo Kalimourski and Max Gorissen, German engineers, is forwarded for your evaluation.

1 Incl:
Report on Rockets.

Approved by ... LWB
Prepared by ... TFN
Operations Br.

21 - 22 - 23 - 24 - 1 - 2 - 3
ADMIN DIV
10 JUIN 1946
DIRECTOR OF INTELLIGENCE
HQ USSTAF
15 - 14 - 13 - 12 - 11 - 10 - 9

Figure E.139: Report on Large Sized Rockets. 10 June 1946 [AFHRA folder 570.650 May–Aug 1946; AFHRA C5098 electronic version p. 523].

Report on Large Sized Rockets. 10 June 1946. [AFHRA folder 570.650 May–Aug 1946; AFHRA C5098 electronic version p. 523]

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[See document photo on p. 5483. This AFHRA file folder and the corresponding microfilm reel only include this cover letter, not the actual report. Can this report be located in archives at AFHRA, NARA, Wright Patterson Air Force Base, or elsewhere?

What exactly did Hugo Kalinourski and Max Gorissen work on during the war? What did they do for the United States after the war? Was this a report of their own work, or a report or translation they wrote based on the work of other German engineers?]

Card catalog entry for *History of German Trans-Atlantic Rocket A-10.* 4 March 1947. [NARA RG 319, Records of the Army Staff, Entry A1-84E, Box 124. BID 8600.0711 Nuclear Physics (Atomic Energy)—Uses—Rockets]

[The photographs from a U.S. Army card catalog of intelligence documents on p. 5485 show that the U.S. government once possessed a complete history of the A-9/A-10 trans-Atlantic rocket, written two years after the war's end, but that this history was either destroyed or not transferred to NARA with the other files; no copies of this report have ever been located. If the A-9/A-10 never entered active development during the war, why would the U.S. government have commissioned a detailed history of its development in 1947, and why would the government have later ordered that history to be suppressed? Does the fact that the Army Assistant Chief of Staff for Intelligence specifically filed this report under "Nuclear Physics (Atomic Energy)—Uses" indicate that the A-9/A-10 had a nuclear warhead? CIG, listed as the source of the report, was the Central Intelligence Group, a U.S. intelligence agency that existed during 1946–1947 as an intermediate step between the wartime Office of Strategic Services (OSS) and the modern Central Intelligence Agency (CIA). [https://irp.fas.org/cia/ciahist.htm]]

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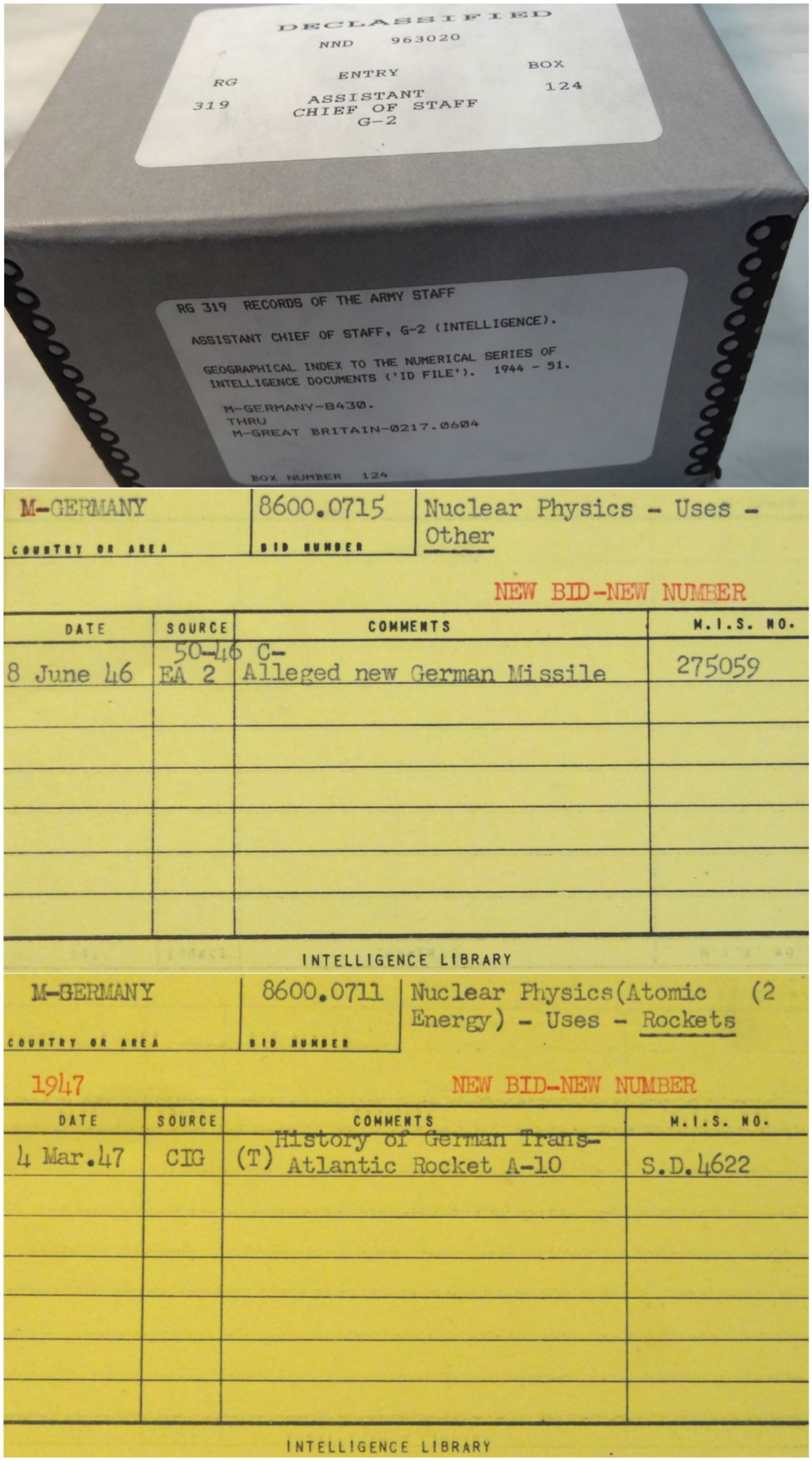

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4 Mar. 47	CIG	(T) History of German Trans-Atlantic Rocket A-10	S.D. 4622

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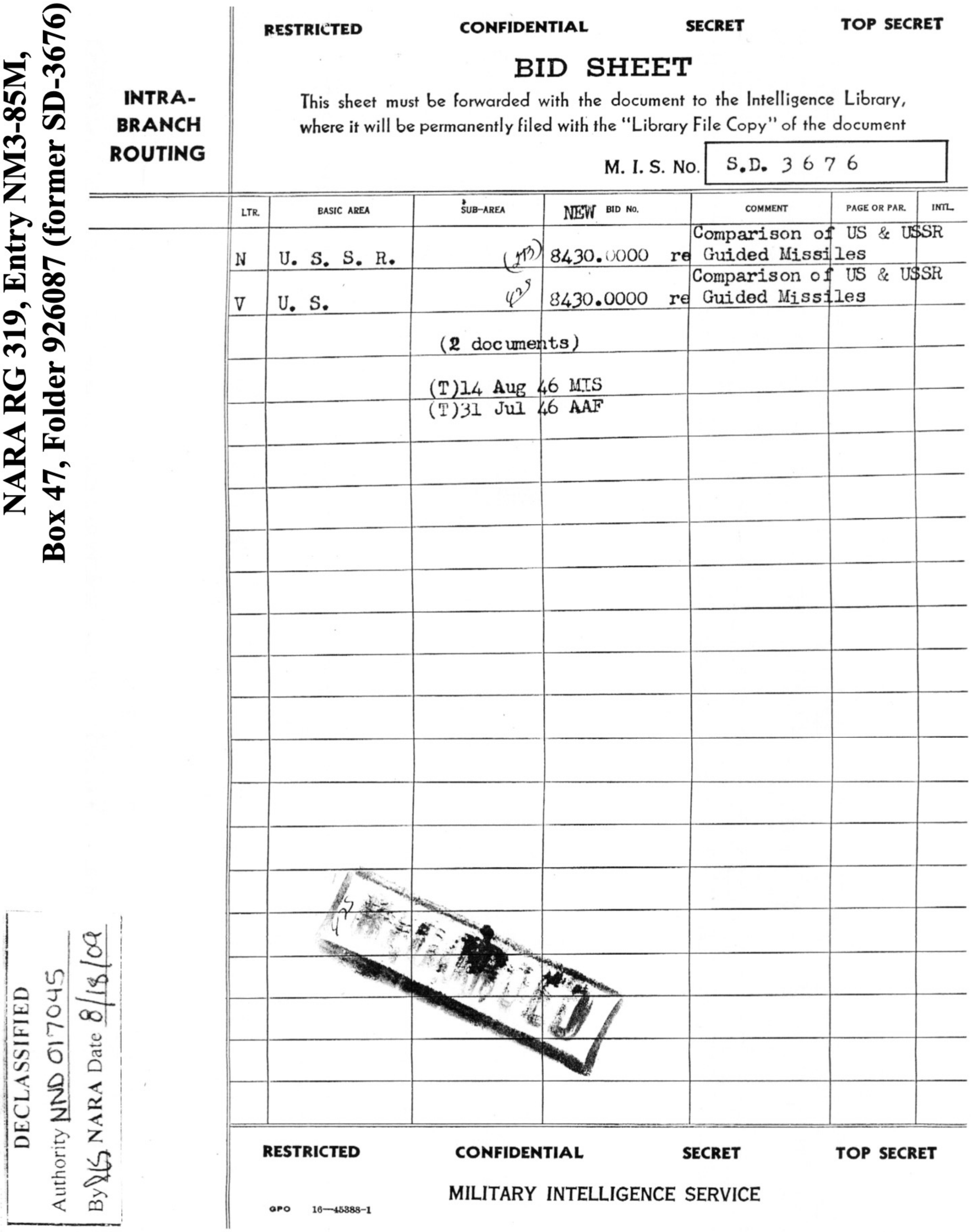
Figure E.140: Card catalog entry for *History of German Trans-Atlantic Rocket A-10*. 4 March 1947. [NARA RG 319, Records of the Army Staff, Entry A1-84E, Box 124. BID 8600.0711 Nuclear Physics (Atomic Energy)—Uses—Rockets]



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V	U. S.	429	8430.0000 re	Comparison of US & USSR Guided Missiles		
		(2 documents)				
		(T)14 Aug 46 MIS (T)31 Jul 46 AAF				

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Figure E.141: Summer 1946 reports on planned U.S. and Soviet guided missiles are still classified and withheld from the public 75+ years later, even though actual postwar Allied missiles have been sitting in museums around the world for many decades. Are these reports kept classified because they describe advanced German missiles from a year earlier from which the postwar Allied missiles were directly derived? [NARA RG 319, Entry NM3-85M, Box 47, Folder 926087 (former SD-3676)]

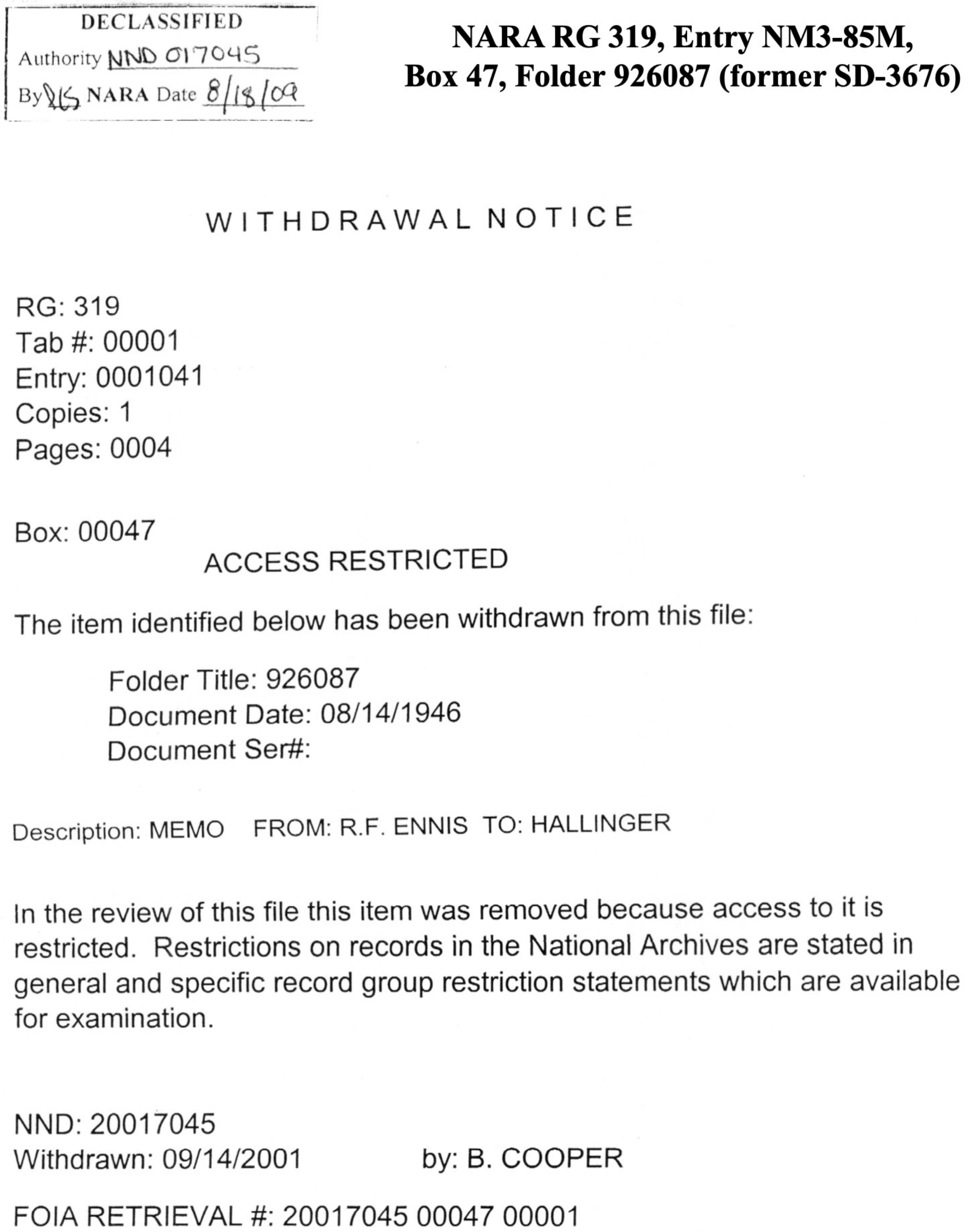

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Figure E.142: Summer 1946 reports on planned U.S. and Soviet guided missiles are still classified and withheld from the public 75+ years later, even though actual postwar Allied missiles have been sitting in museums around the world for many decades. Are these reports kept classified because they describe advanced German missiles from a year earlier from which the postwar Allied missiles were directly derived? [NARA RG 319, Entry NM3-85M, Box 47, Folder 926087 (former SD-3676)]

Charles J. V. Murphy. The State of the Armed Forces. *Life.* 2 Sept. 1946, pp. 96–108. https://books.google.com/books?id=OEIEAAAAMBAJ&pg=PA96&source=gbs_toc_r&cad=2#v=onepage&q&f=false

Yet, as matters stand now, the most important question mark in the U.S. military equation is not the conflicting rate of development of the supersonic airplane and its counter. It is whether the big, long-range supersonic rocket, such as the German V-2, will develop to a point where it will supplant the strategic bomber.

The V-2 now being tested in the New Mexico desert is, by bombsight standards, an inaccurate and unreliable weapon. On a 200-mile range it is seldom accurate within six miles. It consumes about nine tons of alcohol and oxygen to deliver a ton of explosives. But it would be a dull man indeed who considered these shortcomings decisive. As a mechanical proposition, the rocket offers the most effective way to deliver the atomic bomb. Its plunging descent at ultrasonic speed (maximum: 4,400 feet per second) makes the problem of radar tracking and interception as agonizingly difficult as coping with the atomic explosion itself. In fact, even now the 1945 model of the German V-2 with a non-atomic warhead and a 350-mile range (unfortunately none of the samples fell into our hands) has been conceded by the British Imperial Staff as rendering the British Isles indefensible. [...]

Not insignificantly the common language in the assembly sheds at White Sands is German. The fact of our dependence upon German scientists in this epochal development in the art of war explains in large measure the unprecedented preoccupation of our military planners with pure research. For in many fields of research—guided missiles (of which they invented 138 types), supersonic flight and submarine warfare—the Germans were far ahead of us. The real reparations prize of the war was not German machinery but German brains and research records.

Under the Potsdam partitioning of Germany, the Russians ended up with all the guided-missile proving grounds and most of the factories, the principal supersonic research centers (with wind tunnels far in advance of our own) as well as the underground mass-production and V-2 plant at Nordhausen. Equally precious were masses of official records, of which the some 400 tons plucked out by a handful of American intelligence officers represent but an inadequate sampling. Chance delivered into our hands the two leading V-2 research men, but the rank and file of German technicians in nearly all branches of the war sciences—nuclear physics, jet propulsion, supersonics and so on—were left in the Russian zone. The Russians have not only put them to work, but they have begun to coax across the Elbe scientists and other technicians from the American and British zone. Top-flight men are being offered the equivalent of $35,000 a year, with assurance of freedom of research and of person.

The possibility that these wandering talents, embodying billions of dollars worth of research knowledge, may drift into Russia worries U.S. strategists far more than the stripping of German machinery. An American general observes, “These German scientists are the new mercenaries.” [...]

And they give point to the observation of Rear Admiral Luis de Florez, the Navy’s assistant director of research: “If we had only been smart enough to grab Germany’s top 1,000 scientists and technicians and cart them off to a kind of scientific St. Helena, Europe would have remained disarmed for a generation.”

[Charles J. V. Murphy (U.S., 1904–1987) had a long career as a journalist specializing in intelligence and defense for *Time*, *Life*, and other publications. He also served as a colonel in the Air Force Reserve after WWII and handled public relations and speechwriting for many Air Force and NATO officials. Thus he was incredibly well connected and extremely knowledgeable regarding military technologies. For more information on Murphy, see:

https://www.washingtonpost.com/archive/local/1987/12/31/author-and-journalist-charles-murphy-dies/0c630636-8b51-4715-971d-3c64a75d5b99/

In this *Life* article, Murphy clearly stated the usual 200 mile (∼320 km) range of a standard A-4 (V-2) rocket. Then he stated that there were multiple copies of an improved “1945 model” of the rocket with a 350 mile (∼560 km) range that existed at the end of the war but were not seized by U.S. forces. From other information in the article, it sounds as if they were seized by Soviet forces. While 350 miles is much longer than the range of a standard 14-meter-long A-4 (or its postwar Soviet copy, R-1 or SS-1), it is a perfect match for the range of an upgraded 18-meter-long A-4 like the postwar Soviet R-2 or SS-2. Thus the information in this article suggests that upgraded 18-meter A-4 rockets had already been mass-produced by Germany during the war, were taken by Soviet forces at the end of the war, and were copied as the Soviet R-2 or SS-2.

A number of independent sources also indicated that upgraded 18-meter-long A-4 rockets were produced in Germany during the war (p. 5794).

Where are the German documents on these improved rockets? Note that Murphy specifically mentioned “400 tons” of captured German documents that were especially relevant.

Where are the Allied reports on the advanced rockets, or postwar interrogations of Germans who had worked on the advanced rockets?

Where are the documents in which the British Imperial Staff “conceded” these existing German rockets “as rendering the British Isles indefensible?”

Admiral Luis de Florez headed research programs in the U.S. Navy during and after WWII, and in the CIA after the war. From that highly informed position, he voiced his opinion that the top 1,000 scientists in the world who were capable of creating revolutionary military technologies were all German.

The rest of the article, supported by Murphy’s highly placed sources in the U.S. military and intelligence communities, confirms that German-speaking scientists and their technologies were far ahead of those that had been home grown within the United States up to that point.]

Charles Lester Walker. October 1946. Secrets by the Thousands. *Harper's Magazine* 193:329-336.

But of highest significance for the future were the Nazi secrets in aviation and in various types of missiles.

"The V2 rocket, which bombed London," an Army Air Forces publication reports, "was just a toy compared to what the Germans had up their sleeve."

When the war ended, we now know, they had 138 types of guided missiles in various stages of production or development, using every known kind of remote control and fuse: radio, radar, wire, continuous wave, acoustics, infra-red, light beams, and magnetics, to name some; and for power, all methods of jet propulsion for either subsonic or supersonic speeds. Jet propulsion had even been applied to helicopter flight. The fuel was piped to combustion chambers at the rotor blade tips, where it exploded, whirling the blades around like a lawn sprinkler or pinwheel. As for rocket propulsion, their A-4 rocket, which was just getting into large scale production when the war ended, was forty-six feet long, weighed over 24,000 pounds, and traveled 230 miles. It rose sixty miles above the earth and had a maximum speed of 3,735 miles an hour – three times that of the earth's rotation at the equator. The secret of its supersonic speed, we know today, lay in its rocket motor which used liquid oxygen and alcohol for fuel. It was either radio controlled or self-guided to its target by gyroscopic means. Since its speed was supersonic, it could not be heard before it struck.

Another German rocket which was coming along was the A-9. This was bigger still—29,000 pounds—and had wings which gave it a flying range of 3,000 miles. It was manufactured at the famous Peenemünde army experiment station and achieved the unbelievable speed of 5,870 miles an hour.

A long range rocket-motored bomber which, the war documents indicate, was never completed merely because of the war's quick ending, would have been capable of flight from Germany to New York in forty minutes. Pilot-guided from a pressurized cabin, it would have flown at an altitude of 154 miles. Launching was to be by catapult at 500 miles an hour, and the ship would rise to its maximum altitude in as short a time as four minutes. There, fuel exhausted, it would glide through the outer atmosphere, bearing down on its target. With one hundred bombers of this type the Germans hoped to destroy any city on earth in a few days operations.

Little wonder, then, that today Army Air Forces experts declare publicly that in rocket power and guided missiles the Nazis were ahead of us by at least ten years.

The Germans even had devices ready which would take care of pilots forced to leave supersonic planes in flight. Normally a pilot who stuck his head out at such speeds would have it shorn off. His parachute on opening would burst in space. To prevent these calamitous happenings an ejector seat had been invented which flung the pilot clear instantaneously. His chute was already burst, that is, made of latticed ribbons which checked his fall only after the down-drag of his weight began to close its holes.

A Nazi variation of the guided air missile was a torpedo for underwater work which went unerringly to its mark, drawn by the propeller sound of the victim ship from as far away as ten miles. This missile swam thirty feet below the water, at forty miles an hour, and left no wake. When directly under its target, it exploded.

All such revelations naturally raise the question: was Germany so far advanced in air, rocket, and missile research that, given a little more time, she might have won the war? Her war secrets, as now disclosed, would seem to indicate that possibility. And the Deputy Commanding General of Army Air Forces Intelligence, Air Technical Service Command [Donald L. Putt], has told the Society of Aeronautical Engineers within the past few months:

The Germans were preparing rocket surprises for the whole world in general and England in particular which would have, it is believed, changed the course of the war if the invasion had been postponed for so short a time as half a year.

[What Army Air Forces publication reported: "The V2 rocket, which bombed London, was just a toy compared to what the Germans had up their sleeve"???

The German news magazine *Der Spiegel* published a translated and heavily censored version of Charles Walker's 1946 article [Charles Walker 1946], and even that only came after an extraordinary five-year publishing delay [Der Spiegel 1951-06-05] Among the many details from Walker's article that were deleted by *Der Spiegel* were the precision guidance systems for the A-4 rocket, any mention of the A-9 or A-9/A-10 rockets, the fact that the Silbervogel was intended to be piloted, and the public declaration by U.S. Army Air Force experts that Germany was at least ten years more advanced than the United States in these areas. *Der Spiegel* also censored Donald Putt's quote, "The Germans were preparing rocket surprises for the whole world in general and England in particular which would have, it is believed, changed the course of the war if the invasion had been postponed for so short a time as half a year."]

Colonel George Bryant Woods. 1946. *The Aircraft Manufacturing Industry: Present and Future Prospects.* New York: White, Weld & Co. Frontispiece and p. 32.

[See pp. 5072–5073 for this extraordinary 1946 statement by a U.S. Army Air Forces intelligence expert on "Germany's Plans for the 'A-9' with Atomic Bomb."]

Senator Harry F. Byrd. 1948. Hitler's Experts Work for Us. *The American Magazine* (March) 145:24–25, 136–138.

[...] Who are these Germans—Zobel, Lippisch, Hermann, von Braun, Heinrich, Doblhoff, Goethert, Eckert, and the rest? Air Force authorities tell us that they are the scientists who put Germany years ahead of everyone in aeronautical science. They put some of their astounding new air weapons into combat before the war ended. Their jet and rocket fighters slashed through our bomber formations almost unmolested by our slower propeller-driven fighters. Their guided missiles, almost invisibly fast, were conceived to track down planes in flight and explode automatically when near them. Their jet V-1 and rocket V-2 did great damage in England and Europe; we had developed little defense against either the former or the latter. Almost ready was a V-2 of much greater range, for more widespread destruction. As the war ended, I personally saw the progress they had made on the super V-2 type, rocket-powered, which they thought might blast New York across 3,000 miles of Atlantic Ocean.

They started research on supersonics (speeds faster than that of sound) years before we did. Air Force officers concede that they were so far along that uncharted road that findings we captured made radical changes necessary in our supersonic plans, as applied to both planes and guided missiles.

"It will probably cost $100,000,000 to achieve practical supersonic flight" (with a piloted plane), wrote Lt. Gen. Nathan F. Twining, former Wright Field commander, in THE AMERICAN MAGAZINE for August, 1946. There is no estimate on what it would have cost without benefit of the earlier German research.

General Putt states: "Our Washington people say that in guided-missile development alone the Germans we've brought to American will save us 10 years and $750,000,000, and that seems reasonable to me. I'm sure that the total saving will amount to billions of dollars, but the actual figure must be anyone's guess today."

It may be said that German scientists, including those now working for us, were revolutionizing the entire character of air warfare. They were making nearly all the conventional air weapons of World War II obsolete. Jet and rocket propulsion is now virtually a requirement for all combat planes except the longest-range bombers. Guided missiles of fantastic speeds, altitudes, ranges, and destructive force—atomic or high-explosive—are in the making.

These German scientists are showing us how their tricks were done. They are helping us to catch up in our research the easy way. They are carrying on for us the research projects they were forced to interrupt in Germany. They are helping to ensure our aeronautical superiority. [...]

In Germany in the summer of 1945, Maj. Gen. Hugh J. Knerr, now Air Inspector, sent a memorandum to Lt. Gen. Carl A. Spaatz, who then commanded the AAF in Europe. "Occupation of German scientific and industrial establishments," he wrote, "has revealed the fact that we have been alarmingly backward in many fields of research."

General Putt, then a colonel, was in Germany leading the Air Force Intelligence teams which took over the research laboratories, experimental stations, and production plants. "I visited a great many of them," he said, "and talked with the German specialists who manned them. Their research progress in jet and rocket propulsion, aerodynamics, thermodynamics, supersonics, and other fields was clearly far ahead of anything of the kind we had done." [...]

The Air Force Intelligence teams harvested 1,200 tons of German scientific records, screened out the most important 150 tons, and shipped them to Wright Field for translation and evaluation. "But the records weren't enough," said General Putt. "The real need—and it's still greater today—was to put the Germans to work again at their research projects, but now for us. That's what started the procession of German specialists to America." [...]

Col. W. R. Clingerman, chief of the group which administers the Germans' affairs at Wright Field, explains, "They were paid the regular civil-service $6 per diem for detached service. From that they paid 25 to 35 cents for ordinary army mess, per meal, plus 50 to 75 cents a day for janitor or orderly service. They spent about a day's pay each week on packages of lard, coffee, cigarettes, dried eggs, candy, and such things, which they sent to their families in Germany. They also paid for all their clothes, laundry, tobacco, transportation, entertainment, magazines, books, and incidentals.

"Theoretically, they were paid salaries, but they never saw the money. [...] All of it went to their families or dependents, who weren't allowed to leave Germany. Most their families lived in an army housing area at Landshut, Bavaria, where they were guaranteed food, fuel, light, and some other things at fair prices." [Thus the scientists had to spend the "salaries" they were given to pay the U.S. military for keeping themselves and their families in custody.] [...]

When they first arrived they were hungry, and correspondingly meek. Once fed, their native German arrogance reasserted itself. Under the Nazis they had been pampered with special housing, rations, and privileges. Now there were desk-pounding complaints about their surveillance, contracts, housing, delays in getting mail—and even pay—possible loss of assets in Germany, and the security and welfare of families still there. [...]

They complained, and with truth, that they were given no constructive work. For months they wrote routine reports, or twiddled their thumbs, until their made-in-Germany records were translated and evaluated and they were interviewed, by Air Force and industrial engineers, to extract usable information about their past scientific and technical accomplishments. But in this their native German vanity proved valuable. [...]

It was succeeded by a formal contract, renewable yearly for a maximum of five years. [...] But in nearly all its provisions—as to duration, pay, hours, administration, patents, housing, subsistence, surveillance, mail, termination, return to Germany, and even burial—the U.S. Government is judge, jury, and jailer. [...]

"The Germans' salaries," said General Putt, "range from $2,200 to $8,000 per year, and average about $5,500. To establish them, we submitted standard applications, giving detailed qualifications, to Air Force civilian personnel authorities. In all cases salaries were set *one grade lower* than would be paid to Americans with the same qualifications. [...]

Among the first to arrive, in September, 1945, was Dr. Theodor Zobel, wind-tunnel expert of Germany biggest research institute, at Brunswick near Berlin. [...]

Evaluating Dr. Zobel's work, Wright Field's Dr. Wattendorf said, "It has saved us about five years of extremely expensive research time. In fact, five years would fairly measure the research savings of each of the top-flight German scientists working for us."

Also at Wright Field is Dr. Bernhard Goethert. He, too, specialized in high-speed airflow research, especially as applied to wing shapes. His findings influenced the design of the V-1 and the fastest German jet and rocket fighters. Their swept-back wings are believed by many aerodynamic authorities to be best for supersonic flight. [...]

The aerodynamic work on the devastating V-2 was done largely by Dr. Rudolf Hermann who, like Dr. von Braun, was at Peenemünde. He designed a 7,000-m.p.h. wind tunnel, for testing guided-missile models, and was supervising its construction in the Bavarian Alps when the war ended. He brought with him to Wright Field his own staff of 7 expert laboratory assistants, together with much unpublished data on his most important supersonic experiments. The Air Force has plans for his super-supersonic wind tunnel in the great air-research center which the Air Force wants to establish.

Meanwhile, Dr. Hermann is contributing his scientific talents to our guided-missile program. For the Nazis, he designed a 3,000-mile missile. For us, he might produce one with a range of 4,000 to 5,000 miles.

Even faster than the German jet fighters was the rocket-powered ME-163, which got into combat late in the war. Its designer was Dr. Alexander Lippisch, known for his glider experiments before the war. He did research work on supersonics and ballistics, notably on the V-2, and was a leading authority on the flying wing. He was one of the group of German specialists who were making preliminary plans for a “space base”—to be used for refueling rocket ships—which would revolve around the earth as a satellite at a distance of about 4,000 miles. That idea probably sounds fantastic, but the Air Force has listed it as a future project.

The Germans flew their first jet plane in 1939. We didn’t start developing ours until 1942. Fuels, combustion processes, and cooling play very important roles in jet engines. Dr. Ernst Eckert, a thermodynamicist, was in charge of such research at the Brunswick institute. Despite Germany’s lack of critical heat-resistant alloys, thought to be vital in jet turbines, Dr. Eckert produced substitutes which got their jet planes into combat. He is now working in the Wright Field power plant laboratory, continuing his thermodynamic research for the improvement of our jet engines, especially the supersimple ram-jet types.

During the war we were led to believe that our Norden bombsight was infinitely superior to all other bombsights, but the Germans are said to have had bombsights as good as ours in some respects, and superior in others. Joseph Shugt played an important part in their development. He is now experimenting with new bombsights in the Wright Field armament laboratory, where about 10 other German specialists are also working on research in ballistics, dynamics, and automatic instruments of various kinds.

Dr. Helmut Heinrich and Gerhard Aichinger, M.S., conducting research at Stuttgart, developed the “ribbon” type of parachute for very high speeds and altitudes. Even our propeller-driven planes had reached speeds so high that bailouts with our conventional chutes were often fatal. With their “ribbon” chutes, German pilots could bail out safely at greater speeds and higher altitudes. This chute also made it possible to recover the instrument-bearing sections of experimental guided missiles such as the V-2, something we had not done. Both Dr. Heinrich and Mr. Aichinger are now continuing their research for the Air Force, experimenting with rescue devices for extremely high speeds and altitudes.

The Germans were advanced also at the start of the war in the field of aero-medicine. They studied the physiological effects of oxygen-deficiency and low air pressures at very high altitudes, and the “blackout” results of the terrific accelerations encountered in very high speeds. In the latter research they were among the first to use a “human” centrifuge—which actually spins the flier’s body at high acceleration.

Much of this research was carried on at the Berlin Aero-Medical Institute by Dr. Otto Gauer. Now conducting further research in these fields at Wright Field’s aero-medical laboratory, Dr. Gauer is assisted by nearly a score of other German specialists, most of whom did similar research work at the Heidelberg Aero-Medical Institute. [...]

We have in our employ—or custody, if you prefer—German scientists and specialists whose work has been outstanding. They know every foot of that arduous research road, because they were the first to explore and travel it. In doing so they displayed great scientific imagination and technical competence. In my opinion, we are entitled to exploit these talents to our best possible advantage.

[Harry Byrd was a U.S. senator from Virginia 1933–1965. By 1948, he had already been in the Senate for 15 years, was a member of the Senate Armed Services Committee, and was a very well-known and powerful senator.

He wrote that after the war, he had personally seen rockets that were much more advanced than the V-2 and were ready or nearly ready by the end of the war. That agreed well with other sources quoted in this section. Byrd also wrote that at least some of the German scientists who had worked on those rockets were brought to the United States, where they were extensively interrogated and wrote reports. Where are all of those interrogation transcripts, reports, original documents, and inspection details on the rockets that Byrd saw in person? Can those be located and declassified?

Byrd’s article agreed with a number of other descriptions that German-speaking scientists were at least 10 years ahead of the United States in many fields, and that the transfer of German and Austrian innovators and innovations to the United States was worth many billions of 1940s dollars.

With regard to the general topic of producing revolutionary innovators and innovations, one should compare this U.S. senator’s description of:

- How these revolutionary innovators were treated in the German-speaking world vs. how the same innovators were treated in the United States.
- How much support was provided for developing revolutionary innovations in the German-speaking world, vs. how the United States was consciously spending as little money as possible just to transfer existing innovators and innovations from the German-speaking world to the United States.

As openly described by this high-ranking senator, from its national establishment in the 1940s, the U.S. research system was based on exploitation (e.g., “the total saving will amount to billions of dollars” vs. “Theoretically, they were paid salaries, but they never saw the money”), avoidance of challenging intellectual work (“These German scientists are showing us how their tricks were done. They are helping us to catch up in our research the easy way.”), and prejudice (“Once fed, their native German arrogance reasserted itself” and “their native German vanity proved valuable”). It would be difficult for a research system founded on such cornerstones to go on to produce as many new revolutionary innovators and new revolutionary innovations all of its own as a system that is more supportive of people and ideas. 75+ years later, it appears that has indeed proved to be the case (Section 11.3).]

Nazis Were Working On 100-Ton Rocket. ***The Courier-Mail*** **(Brisbane, Australia). 5 December 1946 p. 1.** [**https://trove.nla.gov.au/newspaper/article/49363386**]

NEW YORK, December 4.—When the war ended the Nazis were building a 100-ton rocket with which to strike at the United States.

This has been revealed by the brilliant German scientist, Wernher von Braun, who invented the V2 rocket.

Von Braun is now in the United States working with American experts on rocket experiments.

The super-rocket, he said, was on the drawing-board when Germany was over-run. It would have carried an explosive charge of six tons, and would have been capable of travelling thousands of miles.

He claimed that the V2 rocket failed in only about 5 per cent of its tests in Germany.

Von Braun and his associates from Germany are being kept at work under the utmost secrecy by the Army as they help to train American ordnance men, industrialists, and scientists from leading American universities in the secrets of rocket bombs.

U.S. Gain

An estimate that German and Austrian scientists had saved the United States more than £235 million in basic research in rockets alone was disclosed by the War Department in announcing that 730 additional experts were to be brought to the United States.

Former enemy brain-power, the department said, had advanced American research in several fields by from two to 10 years.

Already 270 former enemy scientists are at work in the United States. They include the former chief designer for the Messerschmitt aircraft works and the technical director of the Nazis' Peenemunde rocket proving ground. They came to the United States voluntarily.

The scientists are being paid on contract, the maximum being £975 annually, plus 37/ daily expense allowance. This is considerably less than the salaries paid to American civil service workers doing comparable work.

The work of the foreign scientists covers the fields of electronics, supersonics, guided missiles, jet propulsion, and fuels.

["100-ton rocket" was a name sometimes used by the Peenemünde engineers for the A-9/A-10.

Usually the expected payload of the A-9/A-10 is given as 1 ton. That could be stretched to 2 tons without much trouble. But why is the payload given here as 6 tons? Was this a different version of the A-9/A-10, or a different rocket entirely?

Why did the payload need to be 6 tons? Did that include two pilots, guidance systems, bomb, etc.? Was it an attempt to fit 6 tons of conventional explosive on the rocket to better justify the expense? Was it a 6-ton fission bomb or hydrogen bomb?]

Nazi Scientists Work On U.S. Rocket Experiment. *Newcastle Morning Herald and Miners' Advocate* (New South Wales, Australia). 5 December 1946 p. 3. [https://trove.nla.gov.au/newspaper/article/133178482]

NEW YORK, Dec. 4.—Before the war ended the Nazis were building a 100-ton rocket to strike the United States. This was revealed by the brilliant German scientist Wernher von Braun, who invented the V2 rocket, and who is now in the United States.

Von Braun is at present working with American experts on rocket experiments.

He said the Nazis' super-rocket was on the drawing board when Germany was overrun. It would have carried an explosive charge of six tons and be capable of travelling thousands of miles.

Von Braun claimed the V2 failed in only about five per cent of its tests in Germany.

Von Braun and his associates from Germany are being kept at work under the utmost secrecy by the army as they help to train American ordnance men, and industrialists and scientists from leading American Universities in the secrets of rocket bombs.

Saved U.S. Millions

A statement issued by the War Department in Washington said it was estimated that German and Austrian scientists had saved the United States more than 750 million dollars (£A234 1/2 millions) in basic research in rockets alone.

The department announced that about 730 additional experts would be brought to the United States.

The statement said that former enemy brainpower had advanced American research in several fields two to ten years. The number of experts put to work since September 1945 had grown to 270, and the total would be increased to about 1000 as soon as transportation arrangements were completed.

The scientists and technicians include the former Chief Designer for the Messerschmitt Aircraft Works and the Technical Director of the Nazis' Peenemunde rocket-proving ground. They came to the United States voluntarily.

Nazis Planned Rocket to Hit U.S. *New York Times.* 4 December 1946.

Wernher von Braun, 34-year-old German scientist who invented the deadly V-2 supersonic rocket, revealed today that before the war ended the Nazis were building a 100-ton rocket to strike at the United States.

Von Braun told reporters that the 100-ton rocket was on the drawing board when the Allies overran Europe. He said it would have carried a "pay-load" of six tons and would have traveled thousands of miles to strike the United States.

Frank H. Winter. George Sutton, the (Other) Father of American Rocketry. *Smithsonian*, 16 November 2020. https://www.smithsonianmag.com/air-space-magazine/george-sutton-other-father-american-rocketry-180976306/

Born Georg Paul Erich Schulhof in Vienna, Sutton was compelled to leave Austria for the United States in June 1938, just three months after the Anschluss. Traveling alone, the 17-year-old was listed as a student on ship passenger lists. After settling in Los Angeles with the family of his uncle, he later anglicized his name to George Paul Sutton and applied to become a U.S. citizen. Although he originally intended to follow family tradition and become a medical doctor, his interests soon took a different direction. After obtaining an associate of arts degree in Mechanical Engineering from Los Angeles City College in 1940, he went on to earn a master's degree in the same field from Caltech in 1943.

Following his graduation that spring, he joined the Aerojet Engineering Corporation (now Aerojet Rocketdyne), which had just opened its doors in Pasadena a year earlier as the second liquid-propellant rocket company in the United States. During this formative period of the American rocket industry, the main focus was not missiles but JATOs—Jet-Assisted-Take-Off units—to shorten the take-off distances for heavily loaded aircraft.

Sutton's first jobs at Aerojet involved rocketry, however, under the guidance of Theodore von Kármán, the company's first president. Sutton became a test engineer on a nitric acid/aniline thrust chamber, then worked on Aerojet's unique, double-chambered rocket engine intended to power the ill-fated Northrop XP-79 Flying-Wing interceptor, which was canceled after one fatal test flight.

He stayed at Aerojet until 1946, then joined North American Aviation as a research engineer to continue his work in rocketry. The U.S. Army Air Forces had recently invited aviation companies to bid on preliminary designs for guided missiles, and NAA's proposal for a 100- to 500-mile range missile called Navaho (for North American Vehicle [using] Alcohol [and] Hydrogen Peroxide and [Liquid] Oxygen) was accepted.

Although North American had no experience in rocketry, it did have highly competent engineers and planners, and the company established a new Aerophysics Laboratory to take on the challenge. Along with his experience working with liquid-fuel rocket motors at Aerojet, Sutton's native German was especially prized, as the Navaho team intensely studied blueprints and hardware from captured V-2 rockets. Sutton was one of the first U.S. rocket engineers sent to Fort Bliss, Texas, to interrogate Wernher von Braun, the former technical director of the V-2 program who had surrendered to the Americans at the close of the war. Besides interviewing other Germans on von Braun's team, he was among the engineers who completely dismantled a V-2 engine or two to see how they worked and how they were made. These engines, as one later historian of Rocketdyne put it, "were torn down and dissected in fine detail."

Under Phase 2 of the Navaho project, NAA began constructing replicas of the V-2 engine under Sutton's supervision, one of which is in the collection of the National Air and Space Museum. These weren't precise copies—the Americans used English rather than metric measurements, along with American screw threads, O-rings and other parts. The captured V-2 engines had come to the United States minus their turbopumps, so American-manufactured aluminum pumps were substituted for the original German steel pumps.

George P. Sutton. 2006. *History of Liquid Propellant Rocket Engines.* Reston, Virginia: American Institute of Aeronautics and Astronautics.

[p. 269:] It is an ironic twist of history that Goddard's pioneering work in LPREs [Liquid Propellant Rocket Engines] and sounding rocket vehicles had relatively little impact on U.S. LPRE development. The large U.S. LPREs, which were developed later by General Electric, Rocketdyne, and Aerojet, were designed and produced without the benefit of the work done by Goddard. [...] At that time (1947–1951) my fellow designers and I had not even heard of Goddard or any of his know-how[....] Instead, Rocketdyne received a lot of help and data from the Germans and their V-2 LPRE information, which was very useful.

[pp. 752–753:] In January 1945, when it was obvious that Germany was losing the war, the personnel at Peenemünde were ordered to evacuate the facility, and Wernher von Braun and his team left the facility, but took many documents and drawings with them. The majority of the key technical personnel surrendered to the American military, were transported to the United States, and eventually joined NASA, where they worked on launching U.S. satellites and on the Saturn Apollo project. During the 1946 [to] 1971 period, the author had repeated meetings with von Braun and about 15 of the Germans who came with him from Peenemünde. These interchanges were in connection with the Rocketdyne development of the large LPREs for the NASA Saturn/Apollo SLVs [Space Launch Vehicles], which were then designed by this team. A lot of information about German LPRE efforts came from this elite German team, and the data were very useful in the U.S. LPRE efforts. Several members of the former Peenemünde team joined various U.S. aerospace companies. For example, Walter Riedel, Dieter Huzel, and Kurt Rothe joined Rocketdyne; Rudi Beichel went to Aerojet[3]; Krafft Ehricke went to Convair[4]; and Walter Dornberger and a few others went to Bell Aircraft.[5] Other German rocket experts went to the Soviet Union, France, and Britain.

It is worth repeating that the V-2 LPRE was an outstanding historic achievement. Its thrust was ten times larger than any other engine at or before that time. The engine incorporated novel features that were copied, adapted, or modified by many subsequent large rocket engines. All the other nations in the LPRE business studied the V-2 engine and two (Soviet Union and the United States) built copies to learn the fabrication process.

[pp. 406–413:] Rocketdyne developed more large LPREs than any other company (except for USSR's Energomash). The first effort was to *copy, build, and flow test three American copies of the German V-2 rocket engine.* Your author was responsible for the effort of copying the thrust chamber of the V-2. [...]

The first indigenous large engine development effort was a pump-fed LPRE of 75,000 lb thrust, which soon became known as the engine for the Army's Redstone ballistic missile. The missile was built by Chrysler, but some of the vehicle's engineering was done by the Germans, formerly of Peenemünde under the leadership of Wernher von Braun.[6] The Rocketdyne-developed Redstone engine is shown in [p. 5500....] Some people consider it to be an upgraded V-2 engine because it used the same propellants (liquid oxygen and 75% ethyl alcohol) and had some similar features.

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[3] Other German-speaking experts such as Karl Klager also went to Aerojet, and Aerojet was founded and run by Theodore von Kármán and Fritz Zwicky.

[4] Other German-speaking experts such as Hans Rudolf Friedrich and Walter Schwidetzky also went to Convair.

[5] Other German-speaking experts such as Heinz E. Mueller also went to Bell.
A number of other German-speaking experts such as Konrad Dannenberg, Hans Hueter, and Hans Lindenberg (died 1946) were also important for rocket engine design in the United States.

[6] See pp. 5354, 5502.

Like the V-2 engine, it had a heavy steel sheet, double-walled regenerative cooling jacket with supplementary film cooling, the turbopump had an aluminum turbine between the aluminum fuel and the oxidizer pumps, and jet vanes were used for thrust vector control during powered flight.

[...] The Redstone engine thrust and chamber pressure were higher, namely, 78,000 lpf vs 56,000 lbf and 317 vs 220 psia. [...]

The first static test of the complete Redstone engine took place in late 1950, and the first flight was in August 1953. It was part of the first U.S. ballistic missile to become operational, and the missiles were also deployed overseas in June 1958. This engine propelled a Redstone missile on 31 July 1958 at Johnston Island in the Pacific; it was carrying a live nuclear warhead to its first high-altitude detonation (at altitude of 47.7 miles). This engine also launched the first U.S. satellite (Explorer on 31 January 1958). [...] The modified Redstone missile also launched two U.S. astronauts in their Mercury capsule on their first suborbital space flights in 1961.

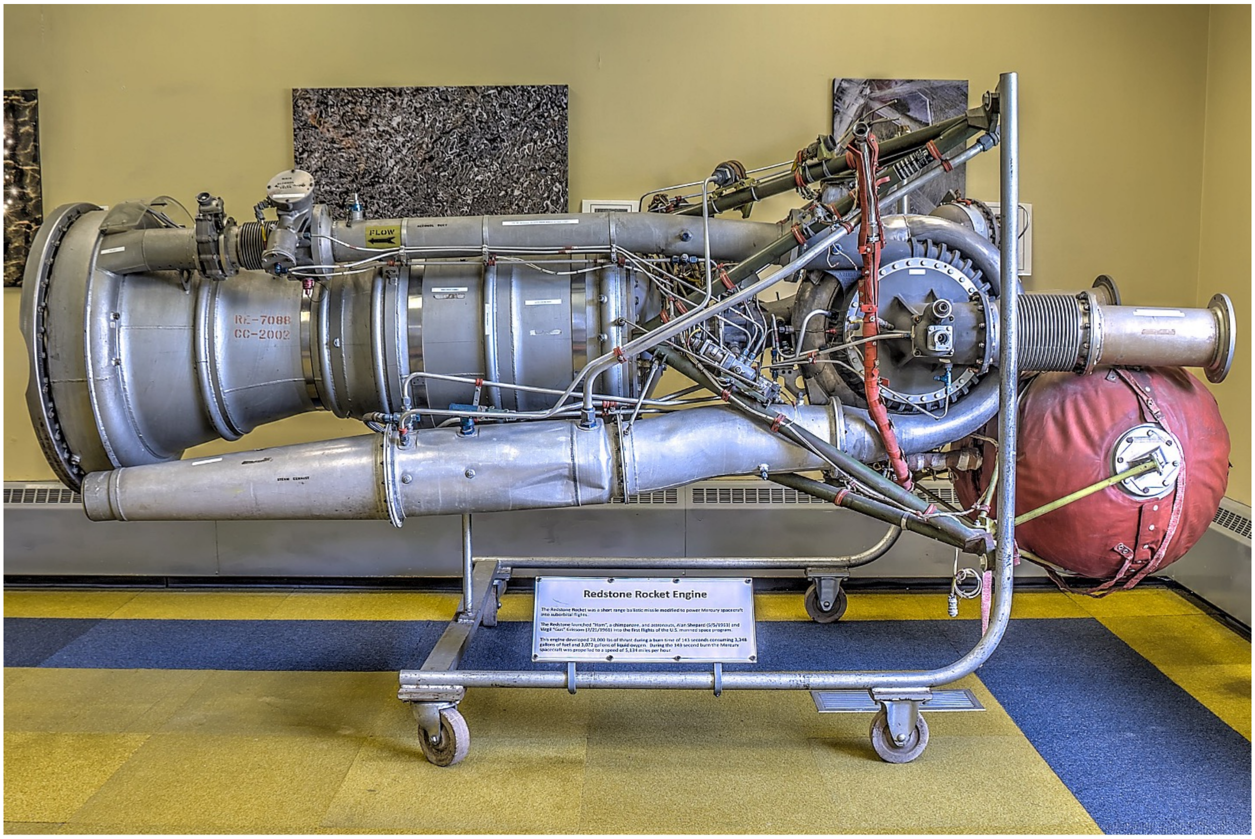


Figure E.143: The Redstone rocket engine (first flown in 1953) was directly derived from the earlier A-4 (V-2) engine and was designed by German-speaking experts including Georg Schulhof/George Sutton, Wernher von Braun, Konrad Dannenberg, Hans Hueter, Dieter Huzel, Hans Lindenberg (propellant injectors, before his death), Walter Riedel, Kurt Rothe, and others. German experts working independently in other countries after the war also produced remarkably similar rocket engine designs, demonstrating that they were using the same German design principles and likely even the same advanced wartime engine designs; see for example pp. 1880, 1884–1885. For wartime production of engines with advanced propellant injectors, see pp. 5284–5285. For another example of North American Aviation (home of Rocketdyne) using German engineers, German documents, German information, and German hardware, see p. 1768.

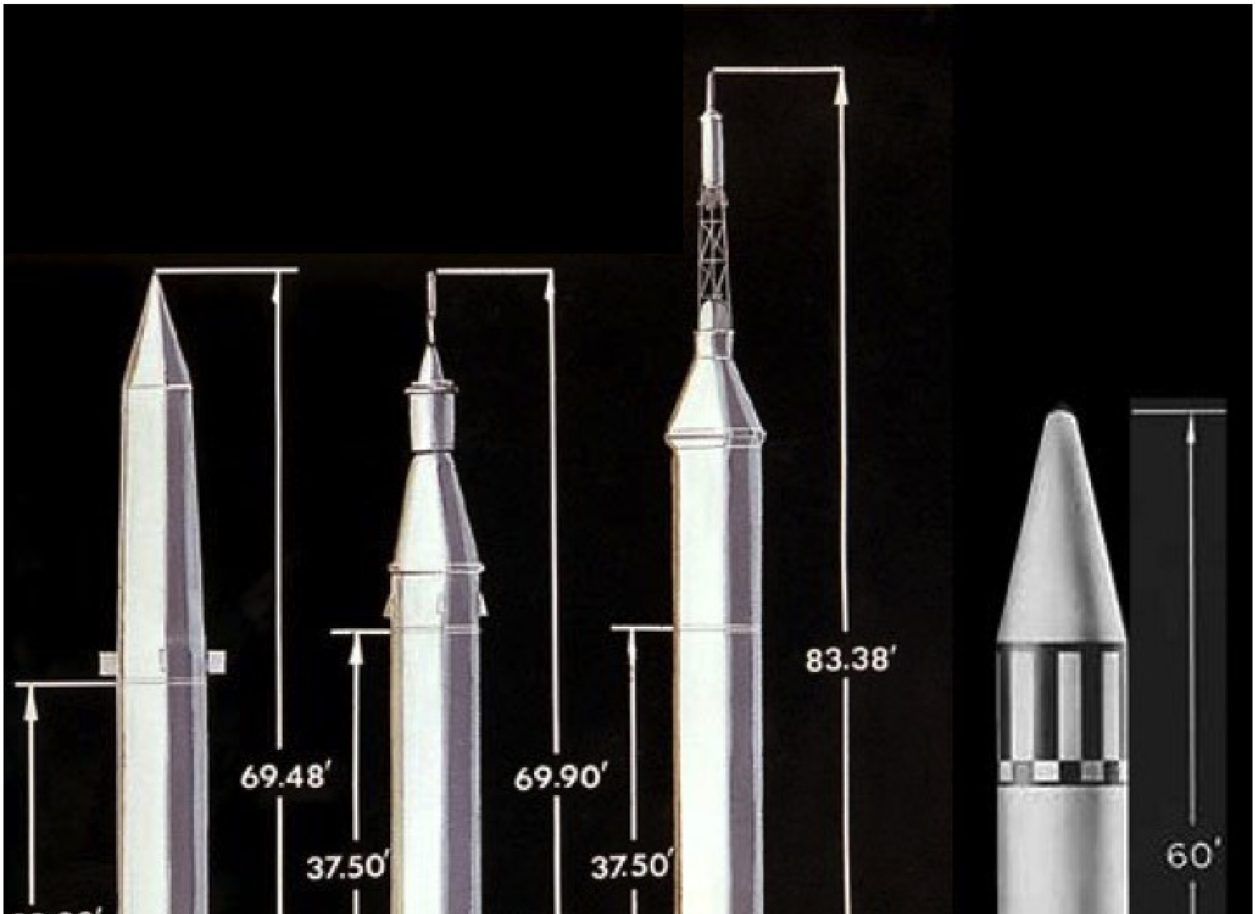
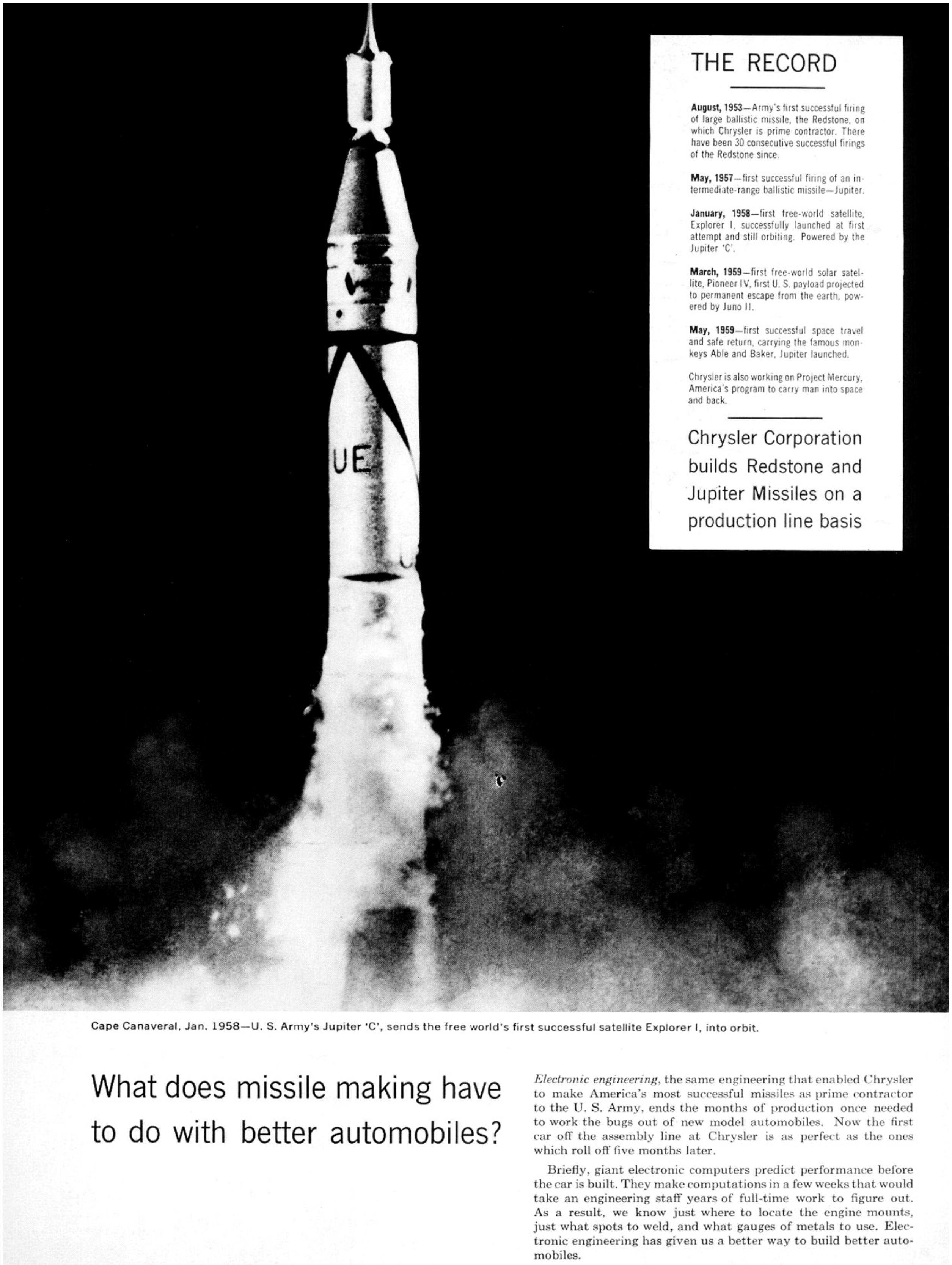

69.48′
32.08′
9.27′
REDSTONE
69.90′
37.50′
JUPITER C
83.38′
37.50′
MERCURY R
60′
JUPITER IRBM
PGM-11
Redstone
In service
1958-1964
Jupiter C/
Juno 1
Launched
1956-1959
Mercury
Redstone
Launched
1960-1961
Jupiter/
Juno II
In service
1958-1963

Figure E.144: Examples of early U.S. rockets derived directly from German creators and creations.



THE RECORD

August, 1953—Army's first successful firing of large ballistic missile, the Redstone, on which Chrysler is prime contractor. There have been 30 consecutive successful firings of the Redstone since.

May, 1957—first successful firing of an intermediate-range ballistic missile—Jupiter.

January, 1958—first free-world satellite, Explorer I, successfully launched at first attempt and still orbiting. Powered by the Jupiter 'C'.

March, 1959—first free-world solar satellite, Pioneer IV, first U. S. payload projected to permanent escape from the earth, powered by Juno II.

May, 1959—first successful space travel and safe return, carrying the famous monkeys Able and Baker, Jupiter launched.

Chrysler is also working on Project Mercury, America's program to carry man into space and back.

Chrysler Corporation builds Redstone and Jupiter Missiles on a production line basis

Cape Canaveral, Jan. 1958—U. S. Army's Jupiter 'C', sends the free world's first successful satellite Explorer I, into orbit.

What does missile making have to do with better automobiles?

Electronic engineering, the same engineering that enabled Chrysler to make America's most successful missiles as prime contractor to the U. S. Army, ends the months of production once needed to work the bugs out of new model automobiles. Now the first car off the assembly line at Chrysler is as perfect as the ones which roll off five months later.

Briefly, giant electronic computers predict performance before the car is built. They make computations in a few weeks that would take an engineering staff years of full-time work to figure out. As a result, we know just where to locate the engine mounts, just what spots to weld, and what gauges of metals to use. Electronic engineering has given us a better way to build better automobiles.

Figure E.145: The Chrysler automotive company worked closely with German-speaking creators to mass-produce the Redstone/Jupiter rockets and the first stage of the Saturn I/IB [*Life*, 5 October 1959, p. 30]. Chrysler produced no rockets before then, produced no other rockets during that time, and has never produced rockets since then. The rocket designs and details came from the German creators. See also pp. 5354, 5499.

Military Intelligence Division W.D.G.S., Military Attaché Report Czechoslovakia. Subject: Russian Demand for German Scientific Secrets. I.G. No. 0404.0700. Prague. Report No. R-32. 20 September 1945. [NARA RG 319, Entry NM3-85M, Box 19, Folder 925253]

Source and degree of reliability:
Czech General Staff Liaison Officer — A-3
Czech Counter Intelligence Officer — A-3

1. Cables No. 18, of 15 September 1945, 2nd subject, and No. 20, of 18 September 1945, are hereby confirmed.

2. A great many American technical intelligence teams have arrived in PRAHA from time to time since the Liberation on various missions, some of them to interview Czech scientists or German scientists living in Czechoslovakia, in regard to the research and development of German secret weapons. It was natural to assume that the Russians would have similar interests.

3. The following has been learned from a Czech Counter Intelligence Officer: When Czechoslovakia was liberated, all secrets pertaining to weapons, discoveries, research and experiments regarding new weapons or new agents of warfare were declared State Secrets, details of which were not to be be made available to anyone outside the Czechoslovak Government.

However, a Russian Technical Mission very soon appeared in PRAHA demanding details of a new German rocket in the experimental stage, referred to variously as V-3 and VA-4, experiments on which had been undertaken in the Protectorate. General BOCEK issued orders to show this mission "something that looked like something but which meant nothing".

Early in June a second Mission, more heavily backed by the Russian authorities, arrived, and General BOCEK under pressure directed that some parts of the rocket be given it, but since the manufacture was on the "mosaic" basis, this was less important.

A third Technical Mission arrive direct from MOSCOW in July, heavily backed up by the Russian Embassy and the Russian Military Mission, and General BOCEK was forced to furnish more parts and to give this Mission access to certain plans and drawings and to allow it to interview some German scientists who were in Czechoslovakia protective custody; however, the Czechs succeeded in withholding the main secrets.

Shortly after this, an American Technical Intelligence Team arrived in PRAHA on a similar mission; among other things they wanted to interview a Dr. H. FRANK, German scientist in Czechoslovak custody, who was held at TEREZIENSTADT. The Czechs were apparently very willing to produce him, but when the time came, it was found that he was no longer there, having been spirited away to PANKRAC Prison in PRAHA. I then personally made representations to the General Staff on the basis that Czechoslovakia and the United States were allied in the war against Japan, and more or less peremptorily demanded full cooperation, which was then given, and the Mission interviewed Dr. FRANK.

Note by M/A: I have since accidentally learned that much information was withheld from our Mission which left PRAHA with the conviction that little could be learned here.

After the departure of the American Technical Intelligence Team the Russians showed great indignation and put pressure to bear on General BOCEK who ordered the court-martial of those Czech officers who had assisted the American team. After considerable noise the thing died down, and General BOCEK passed out the word that nothing would be done, but that Czech officers must be extremely careful in their dealings with the Americans, due to the Russian attitude.

A fourth and final Russian Technical Mission arrived from MOSCOW on 31 August; this mission obviously had the highest backing and was able to put maximum pressure on the Czechs, with the result that General BOCEK issued orders over his signature, which my informant has personally seen, to the effect that anything and everything was to be given the Russian Mission, including parts and plans, and that they were to have free access to all scientists.

4. The Russian Scientific Mission has made offers to both German and Czech scientists of an outright payment of 10 million Czech Crowns ($100,000.00), a fine house in MOSCOW, special food and automobiles if they were willing to go there and work for the Russians; one scientist has disappeared with his wife during the night, taking along his personal belongings which were seen being loaded on a Russian Army truck. A member of this Mission has twice offered my source 10 million Czech Crowns if he would "work with me." Source feels that if German secrets are given to the Russians, they should be given to us as well, and is willing to make any scientist available for interview by American technical intelligence representatives.

5. It was stated by my General Staff source that in the meeting of Foreign Ministers in LONDON, Russia, China and France made unsuccessful demands on the United States and Great Britain for the secrets of the atomic bomb; the following day one battalion of Russian Infantry and certain technical troops occupied the uranium mine and factory in JACHIMOV (St. JOACHIMSTHAL), the only place in Central Europe where uranium is produced, this in spite of the fact that occupation of this area was not provided for in the Russo-Czech agreement. The Russians immediately demanded that the Czechs treble their output. The British Ministry Attache a few days later received an anonymous note giving no details but stating that the Russians had occupied the JACHIMOV mine.

Comment by M/A: It is obvious that the Russians are anxious to secure all possible details of German experiments on secret weapons. Why they should occupy an insignificant uranium mine like the one at JACHIMOV when they have great uranium deposits in their own country is not known, except that it may be to forestall any independent Czech research along these lines.

It is felt that the Counter Intelligence Officer's willingness to cooperate with this office may be inspired by certain high Czech officers who fear the one-sided cooperation with the Red Army and favor a better balance. Personally I am inclined to think that General BOCEK himself may be behind this move, as he has always been extremely frank and friendly with me, and I have known him for a long time.

AAGE WOLDIKE
Lt. Col GSC
Military Attaché

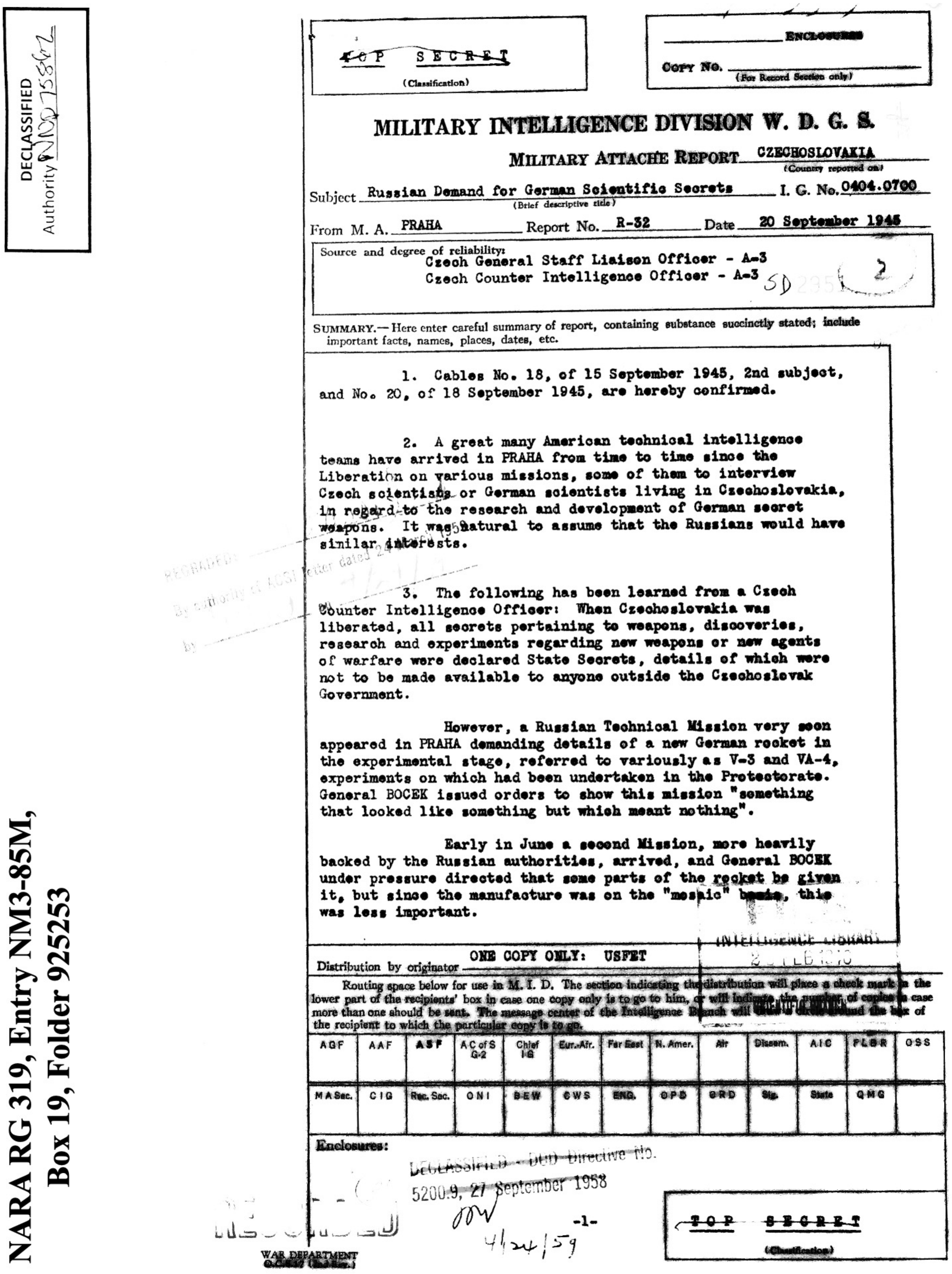
[See document photos on pp. 5506–5507.

To aid in visualizing the locations mentioned in this document and the following several documents, see p. 2098.

A new German rocket had reached the experimental stage in Czechoslovakia during the war, and was so advanced that the postwar Czechoslovakian government wanted to keep the rocket for itself instead of turning it over to the Soviets. It may or may not have been the same as V-3 or V-4 rockets mentioned by other sources. Writing VA-4 instead of V-4 might simply be a typo, or it might indicate that the new rocket was somehow related to the previous A-4 or V-2 rocket.

This report demonstrates how deeply indebted postwar Soviet programs were to German scientists, technologies, prototypes, and supplies. It also illustrates how little U.S. and U.K. inspectors were allowed to learn about wartime German work that occurred in areas that were subsequently occupied by the Soviet Union.

For more information on Helmar Frank, see pp. 1050–1072, 2756–2757, 3983, 5513, and 5549.]



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~~TOP SECRET~~
(Classification)

ENCLOSURES
COPY NO. ____ (For Record Section only)

MILITARY INTELLIGENCE DIVISION W. D. G. S.

MILITARY ATTACHE REPORT CZECHOSLOVAKIA (Country reported on)

Subject Russian Demand for German Scientific Secrets (Brief descriptive title) I. G. No. 0404.0700

From M. A. PRAHA Report No. R-32 Date 20 September 1945

Source and degree of reliability:
Czech General Staff Liaison Officer - A-3
Czech Counter Intelligence Officer - A-3 SD 2

SUMMARY.—Here enter careful summary of report, containing substance succinctly stated; include important facts, names, places, dates, etc.

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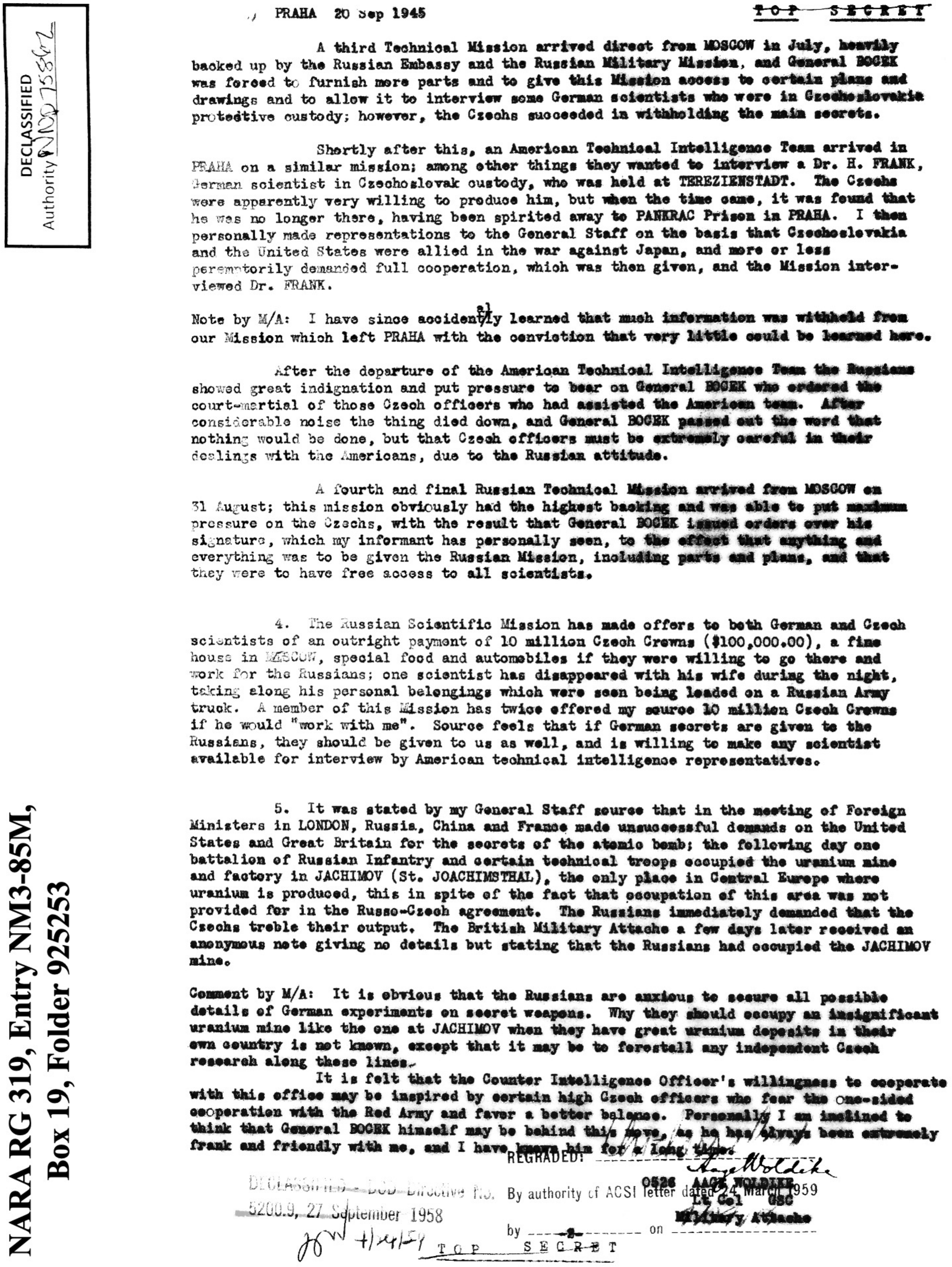
4/24/59

-1-

~~TOP SECRET~~
(Classification)

WAR DEPARTMENT
G.C.S.37 (2nd Rev.)

Figure E.146: Military Intelligence Division W.D.G.S., Military Attaché Report Czechoslovakia. Subject: Russian Demand for German Scientific Secrets. I.G. No. 0404.0700. Prague. Report No. R-32. 20 September 1945. [NARA RG 319, Entry NM3-85M, Box 19, Folder 925253]



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PRAHA 20 Sep 1945 ~~TOP SECRET~~

A third Technical Mission arrived direct from MOSCOW in July, heavily backed up by the Russian Embassy and the Russian Military Mission, and General BOCEK was forced to furnish more parts and to give this Mission access to certain plans and drawings and to allow it to interview some German scientists who were in Czechoslovakia protective custody; however, the Czechs succeeded in withholding the main secrets.

Shortly after this, an American Technical Intelligence Team arrived in PRAHA on a similar mission; among other things they wanted to interview a Dr. H. FRANK, German scientist in Czechoslovak custody, who was held at TEREZIENSTADT. The Czechs were apparently very willing to produce him, but when the time came, it was found that he was no longer there, having been spirited away to PANKRAC Prison in PRAHA. I then personally made representations to the General Staff on the basis that Czechoslovakia and the United States were allied in the war against Japan, and more or less peremptorily demanded full cooperation, which was then given, and the Mission interviewed Dr. FRANK.

Note by M/A: I have since accidentally learned that much information was withheld from our Mission which left PRAHA with the conviction that very little could be learned here.

After the departure of the American Technical Intelligence Team the Russians showed great indignation and put pressure to bear on General BOCEK who ordered the court-martial of those Czech officers who had assisted the American team. After considerable noise the thing died down, and General BOCEK passed out the word that nothing would be done, but that Czech officers must be extremely careful in their dealings with the Americans, due to the Russian attitude.

A fourth and final Russian Technical Mission arrived from MOSCOW on 31 August; this mission obviously had the highest backing and was able to put maximum pressure on the Czechs, with the result that General BOCEK issued orders over his signature, which my informant has personally seen, to the effect that anything and everything was to be given the Russian Mission, including parts and plans, and that they were to have free access to all scientists.

4. The Russian Scientific Mission has made offers to both German and Czech scientists of an outright payment of 10 million Czech Crowns ($100,000.00), a fine house in MOSCOW, special food and automobiles if they were willing to go there and work for the Russians; one scientist has disappeared with his wife during the night, taking along his personal belongings which were seen being loaded on a Russian Army truck. A member of this Mission has twice offered my source 10 million Czech Crowns if he would "work with me". Source feels that if German secrets are given to the Russians, they should be given to us as well, and is willing to make any scientist available for interview by American technical intelligence representatives.

5. It was stated by my General Staff source that in the meeting of Foreign Ministers in LONDON, Russia, China and France made unsuccessful demands on the United States and Great Britain for the secrets of the atomic bomb; the following day one battalion of Russian Infantry and certain technical troops occupied the uranium mine and factory in JACHIMOV (St. JOACHIMSTHAL), the only place in Central Europe where uranium is produced, this in spite of the fact that occupation of this area was not provided for in the Russo-Czech agreement. The Russians immediately demanded that the Czechs treble their output. The British Military Attache a few days later received an anonymous note giving no details but stating that the Russians had occupied the JACHIMOV mine.

Comment by M/A: It is obvious that the Russians are anxious to secure all possible details of German experiments on secret weapons. Why they should occupy an insignificant uranium mine like the one at JACHIMOV when they have great uranium deposits in their own country is not known, except that it may be to forestall any independent Czech research along these lines.

It is felt that the Counter Intelligence Officer's willingness to cooperate with this office may be inspired by certain high Czech officers who fear the one-sided cooperation with the Red Army and favor a better balance. Personally I am inclined to think that General BOCEK himself may be behind this move, as he has always been extremely frank and friendly with me, and I have known him for a long time.

Aage Woldike
0526 AAGE WOLDIKE
Lt Col GSC
Military Attache

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NARA RG 319, Entry NM3-85M, Box 19, Folder 925253

Figure E.147: Military Intelligence Division W.D.G.S., Military Attaché Report Czechoslovakia. Subject: Russian Demand for German Scientific Secrets. I.G. No. 0404.0700. Prague. Report No. R-32. 20 September 1945. [NARA RG 319, Entry NM3-85M, Box 19, Folder 925253]

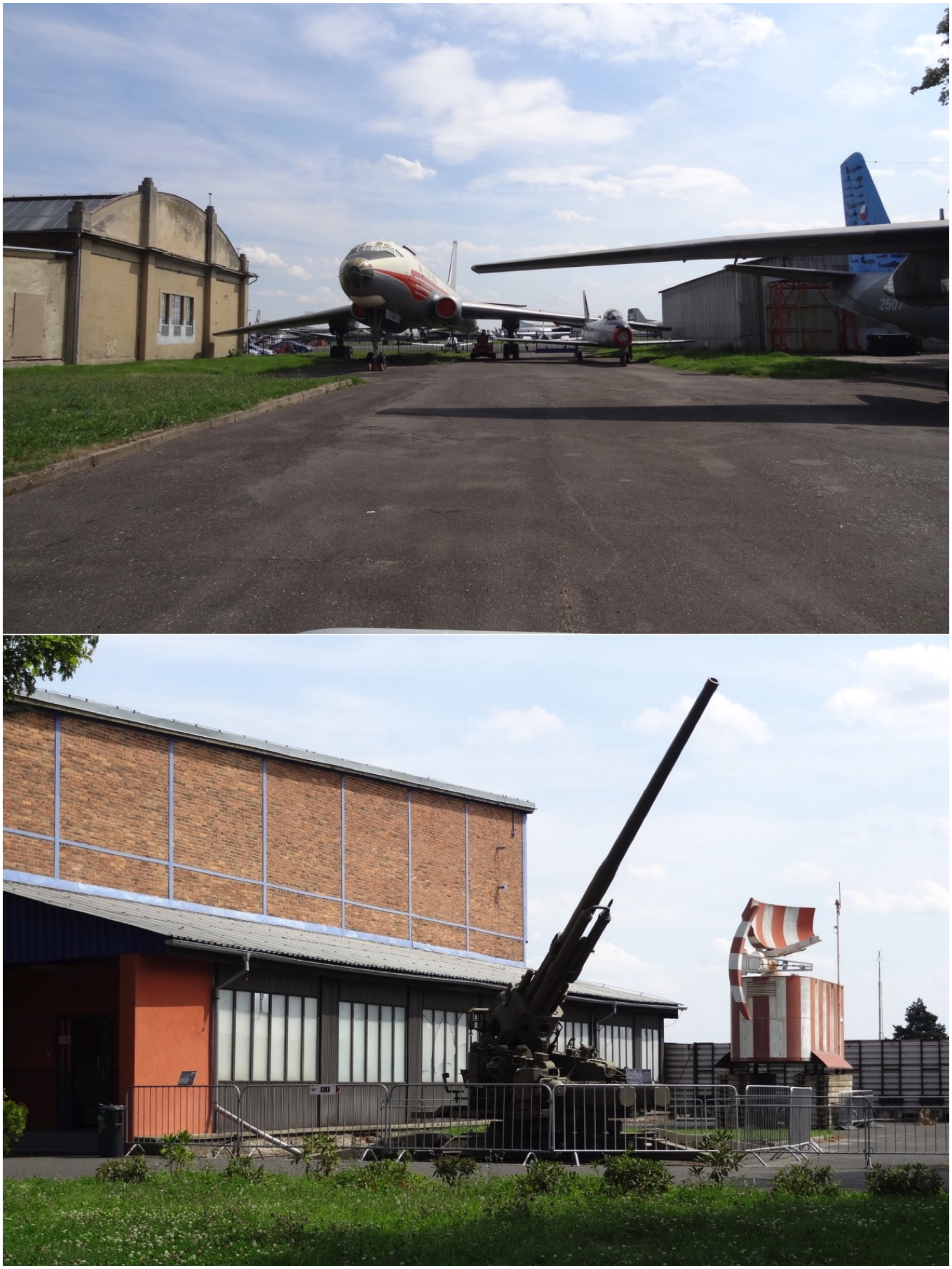

Figure E.148: Kbely airfield near Prague is now a museum.

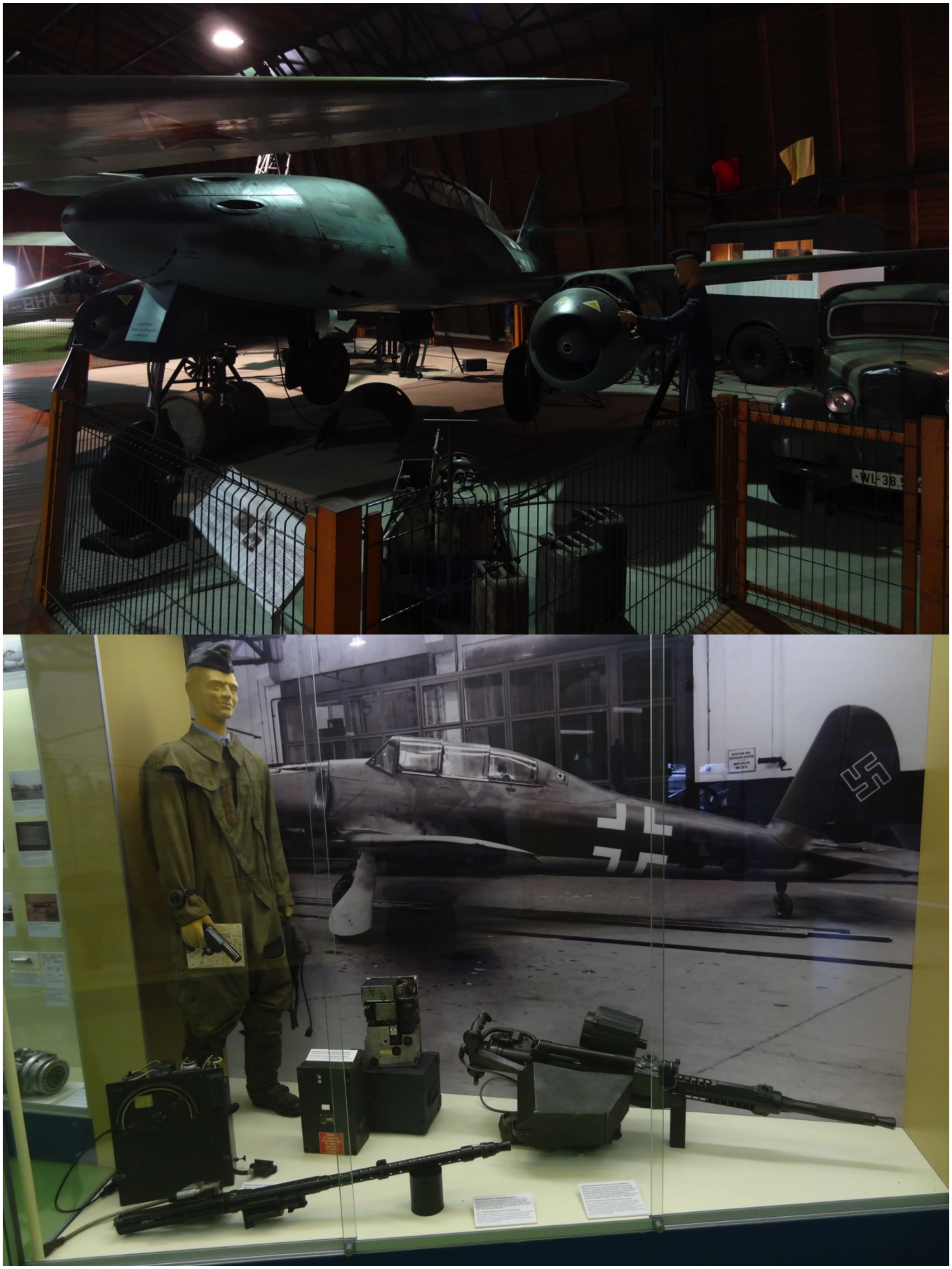

Figure E.149: Kbely airfield near Prague is now a museum.

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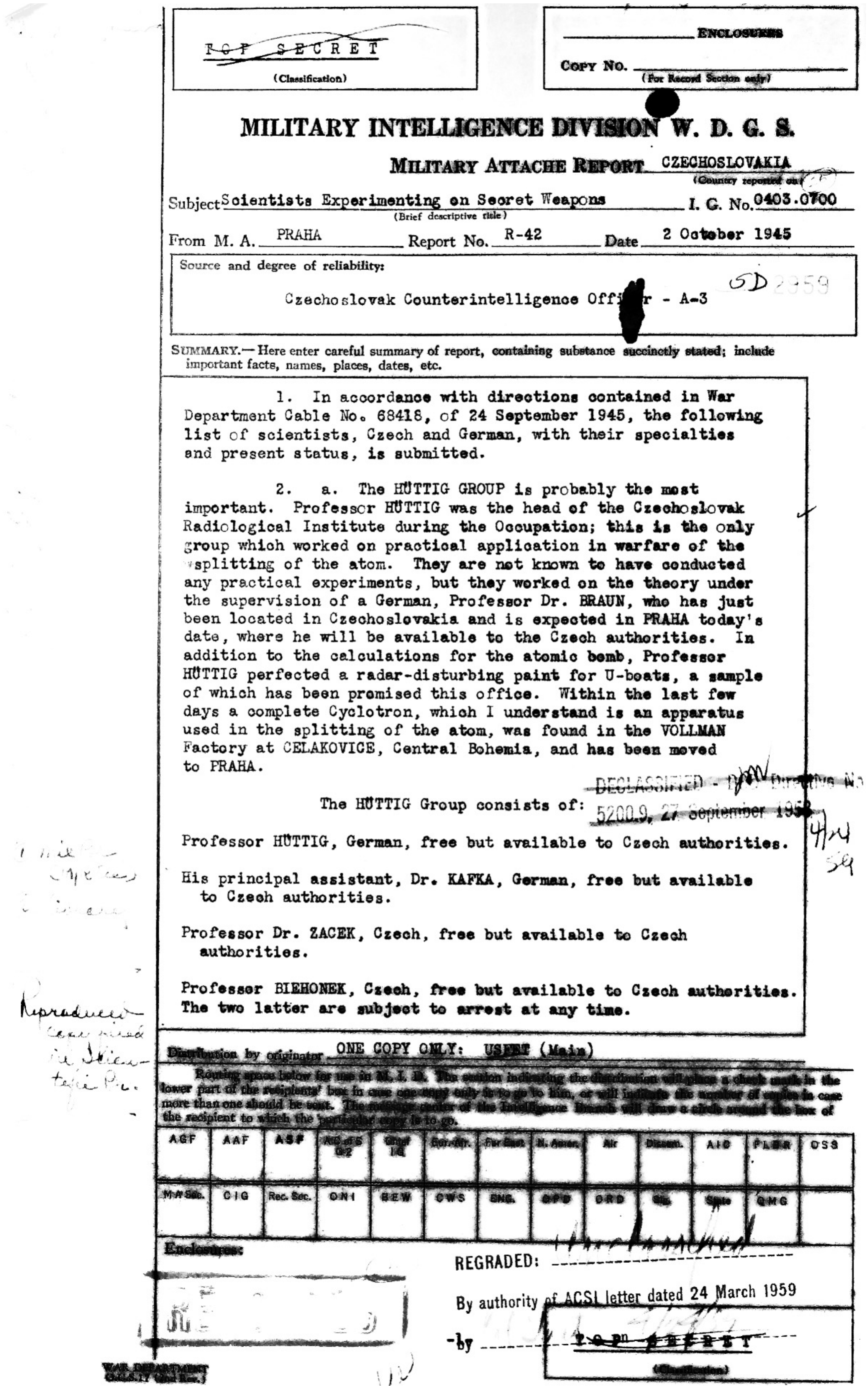

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Enclosures
Copy No.
(For Record Section only)

MILITARY INTELLIGENCE DIVISION W. D. G. S.

Military Attache Report CZECHOSLOVAKIA
(Country reported on)

Subject Scientists Experimenting on Secret Weapons (Brief descriptive title) I. G. No. 0403.0700

From M. A. PRAHA Report No. R-42 Date 2 October 1945

Source and degree of reliability:

Czechoslovak Counterintelligence Offi[illegible]r - A-3 SD 2959

Summary.—Here enter careful summary of report, containing substance succinctly stated; include important facts, names, places, dates, etc.

1. In accordance with directions contained in War Department Cable No. 68418, of 24 September 1945, the following list of scientists, Czech and German, with their specialties and present status, is submitted.

2. a. The HÜTTIG GROUP is probably the most important. Professor HÜTTIG was the head of the Czechoslovak Radiological Institute during the Occupation; this is the only group which worked on practical application in warfare of the splitting of the atom. They are not known to have conducted any practical experiments, but they worked on the theory under the supervision of a German, Professor Dr. BRAUN, who has just been located in Czechoslovakia and is expected in PRAHA today's date, where he will be available to the Czech authorities. In addition to the calculations for the atomic bomb, Professor HÜTTIG perfected a radar-disturbing paint for U-boats, a sample of which has been promised this office. Within the last few days a complete Cyclotron, which I understand is an apparatus used in the splitting of the atom, was found in the VOLLMAN Factory at CELAKOVICE, Central Bohemia, and has been moved to PRAHA.

~~DECLASSIFIED - DOD Directive No 5200.9, 27 September 195~~ 4/14 59

The HÜTTIG Group consists of:

Professor HÜTTIG, German, free but available to Czech authorities.

His principal assistant, Dr. KAFKA, German, free but available to Czech authorities.

Professor Dr. ZACEK, Czech, free but available to Czech authorities.

Professor BIEHONEK, Czech, free but available to Czech authorities. The two latter are subject to arrest at any time.

Reproduced [illegible] [illegible] Scientific Br.

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WAR DEPARTMENT
G.S.17 (2nd Rev.)

NARA RG 319, Entry NM3-85M,
Box 19, Folder 925253

Figure E.150: Military Intelligence Division W.D.G.S., Military Attaché Report Czechoslovakia. Subject: Scientists Experimenting on Secret Weapons. I.G. No. 0403.0700. Prague. Report No. R-42. 2 October 1945. [NARA RG 319, Entry NM3-85M, Box 19, Folder 925253]

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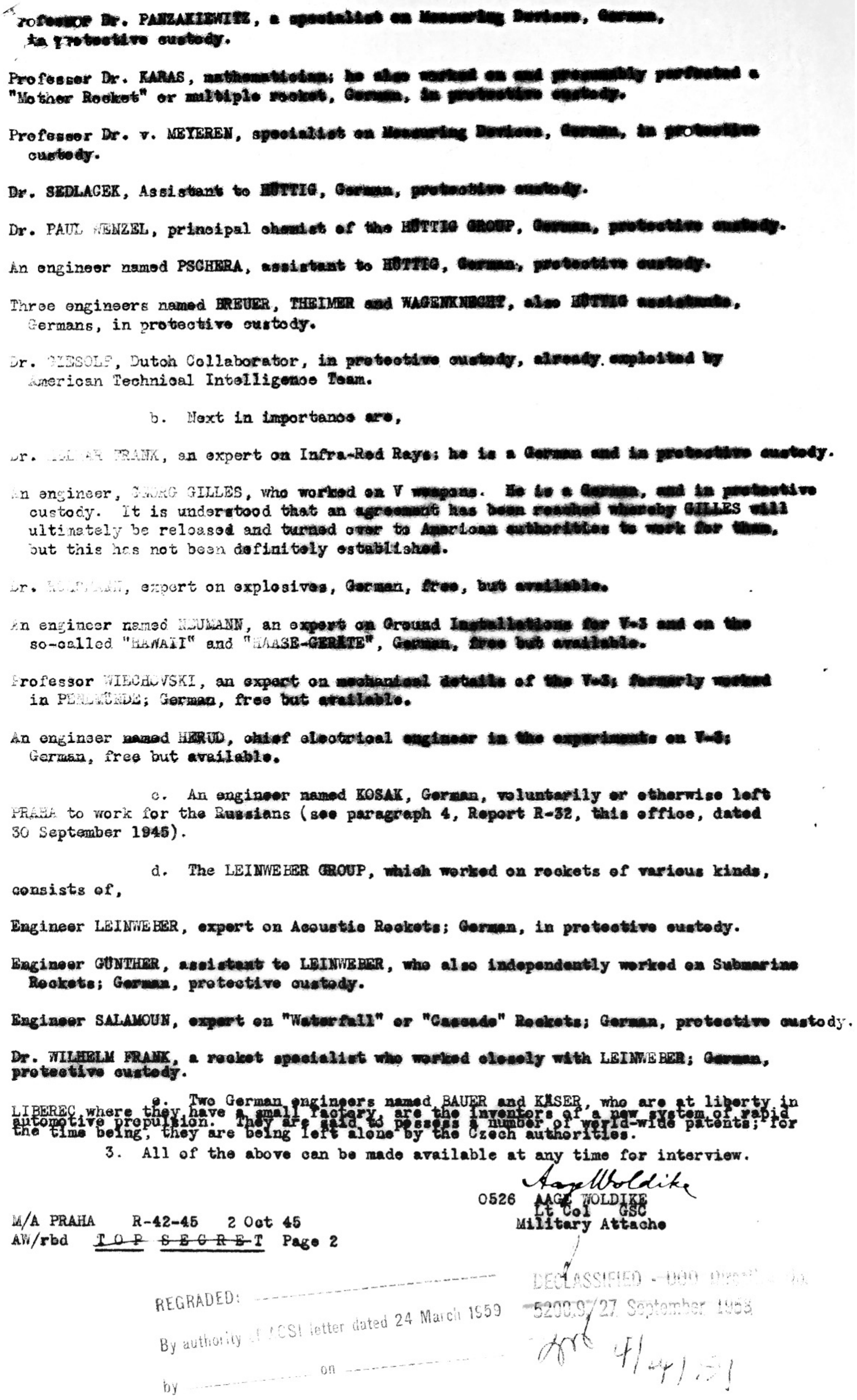
Authority NND 758[illegible]



Professor Dr. PANZAKIEWITZ, a specialist on Measuring Devices, German, in protective custody.

Professer Dr. KARAS, mathematician; he also worked on and presumably perfected a "Mother Rocket" or multiple rocket, German, in protective custody.

Professer Dr. v. MEYEREN, specialist on Measuring Devices, German, in protective custody.

Dr. SEDLACEK, Assistant to HÜTTIG, German, protective custody.

Dr. PAUL WENZEL, principal chemist of the HÜTTIG GROUP, German, protective custody.

An engineer named PSCHERA, assistant to HÜTTIG, German, protective custody.

Three engineers named BREUER, THEIMER and WAGENKNECHT, also HÜTTIG assistants, Germans, in protective custody.

Dr. GIESOLF, Dutch Collaborator, in protective custody, already exploited by American Technical Intelligence Team.

b. Next in importance are,

Dr. [illegible] FRANK, an expert on Infra-Red Rays; he is a German and in protective custody.

An engineer, GEORG GILLES, who worked on V weapons. He is a German, and in protective custody. It is understood that an agreement has been reached whereby GILLES will ultimately be released and turned over to American authorities to work for them, but this has not been definitely established.

Dr. [illegible], expert on explosives, German, free, but available.

An engineer named NEUMANN, an expert on Ground Installations for V-3 and on the so-called "HAWAII" and "HAASE-GERÄTE", German, free but available.

Professor WIECHOVSKI, an expert on mechanical details of the V-3; formerly worked in PEENEMÜNDE; German, free but available.

An engineer named HERUD, chief electrical engineer in the experiments on V-3; German, free but available.

c. An engineer named KOSAK, German, voluntarily or otherwise left PRAHA to work for the Russians (see paragraph 4, Report R-32, this office, dated 30 September 1945).

d. The LEINWEBER GROUP, which worked on rockets of various kinds, consists of,

Engineer LEINWEBER, expert on Acoustic Rockets; German, in protective custody.

Engineer GÜNTHER, assistant to LEINWEBER, who also independently worked on Submarine Rockets; German, protective custody.

Engineer SALAMOUN, expert on "Waterfall" or "Cascade" Rockets; German, protective custody.

Dr. WILHELM FRANK, a rocket specialist who worked closely with LEINWEBER; German, protective custody.

e. Two German engineers named BAUER and KÄSER, who are at liberty in LIBEREC where they have a small factory, are the inventors of a new system of rapid automotive propulsion. They are said to possess a number of world-wide patents; for the time being, they are being left alone by the Czech authorities.

3. All of the above can be made available at any time for interview.

Aage Woldike
0526 AAGE WOLDIKE
Lt Col GSC
Military Attache

M/A PRAHA R-42-45 2 Oct 45
AW/rbd ~~TOP SECRET~~ Page 2

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5200.9/27 September 1958
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NARA RG 319, Entry NM3-85M, Box 19, Folder 925253

Figure E.151: Military Intelligence Division W.D.G.S., Military Attaché Report Czechoslovakia. Subject: Scientists Experimenting on Secret Weapons. I.G. No. 0403.0700. Prague. Report No. R-42. 2 October 1945. [NARA RG 319, Entry NM3-85M, Box 19, Folder 925253]

Military Intelligence Division W.D.G.S., Military Attaché Report Czechoslovakia. Subject: Scientists Experimenting on Secret Weapons. I.G. No. 0403.0700. Prague. Report No. R-42. 2 October 1945. [NARA RG 319, Entry NM3-85M, Box 19, Folder 925253] [See document photos on pp. 5510–5511.]

Source and degree of reliability: Czechoslovak Counter Intelligence Officer — A-3

1. In accordance with directions contained in War Department Cable No. 68418, of 24 September 1945, the following list of scientists, Czech and German, with their specialties and present status, is submitted.

2. a. the HÜTTIG GROUP is probably the most important. Professor HÜTTIG was the head of the Czechoslovak Radiological Institute during the Occupation; this is the only group which worked on practical application in warfare of the splitting of the atom. They are not known to have conducted any practical experiments, but they worked on the theory under the supervision of a German, Professor Dr. BRAUN [Who was this? What organization was he from?], who has just been located in Czechoslovakia and is expected in PRAHA today's date, where he will be available to Czech authorities. In addition to the calculations for the atomic bomb, Professor HÜTTIG perfected a radar-disturbing paint for U-boats, a sample of which has been promised this office. Within the last few days a complete Cyclotron, which I understand is an apparatus used in the splitting of the atom, was found in the VOLMAN Factory at CELAKOVICE, Central Bohemia, and has been moved to PRAHA.

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His principal assistant, Dr. [Heinrich Eduard] KAFKA, German, free but available to Czech authorities.

Professor Dr. ZACEK, Czech, free but available to Czech authorities.

Professor BIEHONEK, Czech, free but available to Czech authorities.
The two latter are subject to arrest at any time.

Professor Dr. PANZAKIEWITZ, a specialist on Measuring Devices, German, in protective custody.

Professor Dr. [Karl] KARAS, mathematician; he also worked on and presumably perfected a "Mother Rocket" or multiple rocket, German, in protective custody.

Professor Dr. v. MEYEREN, specialist on Measuring Devices, German, in protective custody.

Dr. SEDLACEK, Assistant to HÜTTIG, German, protective custody.

Dr. PAUL WENZEL, principal chemist of the HÜTTIG GROUP, German, protective custody.

An engineer named PSCHERA, assistant to HÜTTIG, German, protective custody.

Three engineers named BREUER, THEIMER and WAGENKNECHT, also HÜTTIG assistants, Germans, in protective custody.

Dr. GIESOLF, Dutch Collaborator, in protective custody, already exploited by American Technical Intelligence Team.

b. Next in importance are,

Dr. HELMAR FRANK, an expert on Infra-Red Rays; he is a German and in protective custody.

An engineer, GEORG GILLES, who worked on V weapons. He is a German, and in protective custody. It is understood that an agreement has been reached whereby GILLES will ultimately be released and turned over to American authorities to work for them, but this has not been definitively established.

Dr. ROHSMANN, expert on explosives, German, free, but available.

An engineer named NEUMANN, an expert on Ground Installation for V-3 and on the so-called “HAWAII” and “HAASE-GERÄTE”, German, free but available.

Professor [Witold] WIECHOWSKI, an expert on mechanical details of the V-3; formerly worked in PEENE-MÜNDE; German, free but available.

c. An engineer named KOSAK, German, voluntarily or otherwise left PRAHA to work for the Russians (see paragraph 4, Report R-32, this office, dated 30 September 1945).

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Engineer SALAMOUN, expert on “Waterfall” or “Cascade” [Wasserfall surface-to-air] Rockets; German, protective custody.

e. Two German engineers named BAUER and KÄSER, who are at liberty in LIBEREC where they have a small factory, are the inventors of a new system of rapid automotive propulsion. They are said to possess a number of world-widepatents; for the time being, they are being left alone by the Czech authorities.

3. All of the above can be made available at any time for interview.

AAGE WOLDIKE
Lt. Col GSC
Military Attaché

[This report stated that the Hüttig group was working on theoretical calculations for the atomic bomb, under the supervision of a "Professor Dr. Braun" who may have helped to coordinate their work with a larger German nuclear weapons program.

The Alsos Mission found reports from some members of the Hüttig group in the files of Walther Gerlach, the German Plenipotentiary for Nuclear Physics during the final stages of the war.

Note that the report mentioned a cyclotron that was produced in wartime Czechoslovakia; this cyclotron is also mentioned in subsequent documents.

Some of the engineers who worked on the "V-3" rocket are specifically identified here.

For more information on Helmar Frank, see pp. 1050–1072, 2756–2757, 3983, 5503, and 5549.

For more information on some of the other named scientists, see
https://dspace.cuni.cz/bitstream/handle/20.500.11956/47183/140006538.pdf.]

The Puzzle of Podmokly. *Time.* 12 November 1945.

Had the atomic armaments race begun? In Moscow a writer for The New Times declared that reactionary forces in the U.S. were bent on "blackmailing humanity" by trying to keep the atomic bomb a U.S. property.

From western Czechoslovakia, where the Elbe river bursts through the Sudeten mountains into the flat meadow lands bordering Germany, came a different story.

Nestled in the mountains six miles from Podmokly was a vast underground factory, the Weser Works. In the first three months of liberation the Weser Works were quiet, deserted. Now they hummed with hidden activity. Czech and Russian security police kept close watch on the difficult mountain approaches.

The underground factory was a product of the war. When the Germans came to Podmokly (which they called Bodenbach) they seized the Krizik Works, Czechoslovakia's largest producer of copper wire, the area was rich in coal and hydroelectric power, and had excellent communication facilities. Later they imported French, Belgian and Russian laborers, and set them to work expanding the Krizik plants. Laboratories were built, buildings enlarged, new units erected. One of the new units was put underground, and was supersecret. It was known simply as "the Weser."

The Losing Race.

In time the first secret of the Weser became apparent. Its parent plant was producing V-weapons. But it also manufactured cyclotrons for atomic experimentation. As the Allies bombed German laboratories, the Weser shipped new cyclotrons to secret destinations in the Reich where Hitler's scientists were running a losing race with history. At least three cyclotrons were shipped in the last year and a half of war.

The retreating Germans left the Weser grounds littered with the fuselages, fins and working parts of V-bombs. In iron safes were plans for Vergeltungswaffe-4, said to be a giant, radio-controlled rocket capable of being fired from Prague to the Americas. The Germans also left parts of cyclotrons and other equipment for research in nuclear physics.

For a time the Russians showed no particular interest in the underground factory. Strangers wandered in & out at will. But the explosions over Hiroshima and Nagasaki brought a quick change. The security police moved in, and Germans who had worked in the factory were rounded up, put back to work. Former officials of the Krizik Works were kept out. In northern Bohemia the Russians took over the Jachymov mine, famed for its uranium deposits.

If the Weser's cyclotrons were what interested the Russians, Moscow was still in the experimental stage of atomic development. The U.S. had entered the production stage in 1943.

[The Weser and Krizik Works near Podmokly was a very large German weapons research, development, and production complex during the war. It was reportedly involved in nuclear weapons work, advanced rockets, and other revolutionary innovations.

U.S. intelligence reports explained that the Bohemian V-4 rocket had both an increased range and an improved payload compared to the much better known A-4 (V-2) rocket (p. 5544), and that it was actually "completed," not just a paper design (p. 5516).

Why did Weser/Krizik produce at least three cyclotrons (or maybe more) during the war?

Can all of the records from the Weser/Krizik complex be located in Russia and released?]

V. L. Rychly. Report No. 2655: Report on Visit to Czechoslovakia. 11 February 1946. [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700]

A. Between 3 January and 22 January, arrangements were made with the Czech'k General Staff to visit a number of plants that had been working for the German Navy during the war. Contact was made with this Staff through the British and U.S. Military Attachés who introduced me to Gen. BOCEK. The Czech authorities granted the permission but informed me that I would have to be escorted throughout by the Czech Secret Police (O.B.Z.). The plants visited were the following:

1. C.S.R. ZBROJOVKA at BRNO (Moravia) [formerly Waffenwerke-Brünn]. This firm has in all some eight plants in a radius of 70 Klms of BRNO. [...] Also removed [by the Russian Tech Control Commission] were all documents, drawings and a number of leading technicians.

2. PRVNI PRNENSKA STROJIRNA, BRNO (Moravia). [...] From this plant all documents were removed by the Russians, but no further work was carried out under their supervision.

3. BATA, ZLIN (Moravia). [...] Rubber for experimental [anti-sonar and/or anti-radar stealth] coverings of U-boat hulls. [...]

4. ZIKMUND-CHEMA at LUTIN (Moravia). [...] All documents and valuable machinery were removed by the Russians who, however, evacuated none of the technicians and scientists.

5. STEIN and SPOL at BRNO (Moravia). [...] Everything of interest was removed by the Russians.

6. SCHMIDDING at PODMOKLY (Bohemia). [...] By October 1945 the Russians stopped production, removed the completed torpedoes and other weapons, duplicates of all documents and number of German engineers to Russia.

7. WESERWERKE at DECIN (Teschen) (Bohemia). A lot of inaccurate reports have been circulated about the work carried on in the vast underground workshops of this plant. It has been reported that cyclotrons were manufactured and that in laboratories work was being carried out on atom smashing in conjunction with uranium isotope 235.

In actual fact the following work was carried out: production of V-1 and V-2. 55mm rockets. Schlange. Wespe. 30mm pneumatic cannon. Remote control rockets.

This plant was very strictly guarded until 1 December 1945, and it is thought that German technicians were still employed there up to that date. The plant has now been evacuated.

8. A.E.G. at BEDRICHOV (Bohemia). Manufactured F.B. Zielsuchgeraet. Pfau. Amsel. Ida 105 mine, accoustic, induction and reacting to change in water pressure. V-1 and V-2 fuses. The completed V-4. Lichtspiegelanlage.

The German scientists Pfister and Bakes, with whom I had the opportunity to speak, and some 22 other German scientists are still working on the development of the above under Czech supervision for the Russians. The program on which this firm is still engaged is much more extensive than that listed above. Pfister tried to pass me a copy of the complete program of work, but this was seized from my hand by one of the O.B.Z. officials present.

The O.B.Z. official promised that I should obtain a copy of this program in Prague. On arrival there General Bocek gave orders for it to be surrendered to me, but this got to the ears of Colonel Reicin, the right hand man of General Svoboda, who forbade the authorities to let me have a copy.

Both Pfister and Bakes seemed most keen to be of assistance to us.

9. VOLMAN at CELAKOVICE (Bohemia). Manufactured 3 cyclotrons that were removed to Russia. No work was proceeding in the factory.

10. CESKO-MORAVSKA. KOLBEN-DANEK at SLANY and PRAGUE (Bohemia). [...] This plant was bombed out entirely and as far as is known the Russians removed nothing. [...]

11. HAVEILKA PRAGUE (Bohemia). Manufactured bridge superstructures and conning towers for U-boat types XXI, XXIII, and XXVI W. [...]

The chief engineer of the firm carried out a tirade against the management of the works in my presence and was there and then removed by the O.B.Z.

12. ASKANIA PRAGUE (Bohemia). Works in Prague were bombed out. No permission was granted to see the other Askania works which were reported to me by a friendly major of the Czech General Staff as being inaccessible to Czechs and under Russian control.

B. Further information was obtained about a number of firms by unofficial visits and by enquiries in the right quarter.

1. Jet Propulsion laboratory at Turnov (Bohemia). This was cleaned out by the Russians in October or November 1945, and the scientists including Germans were removed by the Russians.

2. Radium production plant at Jachymov (Bohemia). The following information about this plant was given by a secretary in the Ministry of Mines in Prague who will produce a detailed report of work going on in this mine. Since 1863 uranium ore has been mined here and utilized for the manufacture of radium. Pre-war production of radium amounted to about 2 grams per year. When the Germans moved in, they destroyed the whole factory. At this time, the entire stock of radium amounted to 20 grams. The Germans put mining on a high priority and only mining was done throughout the 6 years occupation. The ore was delivered by special planes to Germany and Austria.

Before the Russians entered Czechoslovakia they made arrangements with the Allies to alter their western boundary for the purpose of including the Jachymov mine which they considered of such importance. On arrival, they put a strong guard around the mine. It has been reported that they removed the ore by night in trucks, but this is unconfirmed. Since then the Russians have officially left and the mine is under Czech administration though almost certainly under Russian control. The production at present is 1 gram of radium from 10,000 kgms of ore. Engineer Koblitz has been commissioned to put the radium processing plant into production and has been or will be sent to England or the U.S. to study our method of production. It is not yet certain whether the output will go to the Czechoslovak State for medical purposes or will be exported to Russia.

3. POLDINA-HUT at VITKOVICE (Moravia). [...] The Russians have taken over the whole plant.

4. SIEMENS at CESKE BUDEJOVIC (Bohemia). Two factories were seen from the outside in this town. There was a strong guard outside. Work is going on in altogether 17 Siemens factories and according to a Czech staff officer, it is under Russian supervision because only specially authorized Czechs are allowed there.

5. STALIN WORKS at DUCHCOV (Bohemia). [...] The plant is at present guarded by 400 of the Czech militia.

C. General Report on State of Czech Factories.

All factories formerly engaged on war production and many others besides have been nationalized and are under the control of the so-called National Administrator, who in every case is a Communist and has been installed under Russian influence. In almost all cases, these administrators have proved themselves incapable of running a factory with the result that there has been trouble in the form of protests among the employees. In some cases these administrators have already been removed and replaced by more competent Communists.

[...] None of the Russian Naptha promised in exchange for Czech coal and textile products has been delivered.

D. OBZ [...]

History: OBZ is the secret Service of Czechoslovakia. It was formed... on the instigation of the Red Army. [...]

The whole organization is based on the lines of the NKVD. [...]

The Russians are by no means dependent on the OBZ for secret service activities inside Czechoslovakia. They have their own excellent independent agents who in fact guide the activities of OBZ. [...]

[See document photos on pp. 5520–5527.

Vladimir "Val" Rychly was born in the U.S. in 1909 to parents who were immigrants from Czechoslovakia. He grew up speaking Czech, knew ten other languages, and had a celebrated career in U.S. Naval Intelligence. See: Marvin B. Durning. 2007. *World Turned Upside Down: U.S. Naval Intelligence and the Early Cold War Struggle for Germany.* Washington, D.C.: Potomac Books.

Rychly's report demonstrates how little postwar U.S. inspectors were able to learn of wartime German work in Czechoslovakia. This rare visit, by a lone Navy lieutenant, came after many other U.S. inspectors were denied or sent away empty-handed. Rychly's report does not even mention some of the major known wartime German research and development locations in Czechoslovakia such as Skoda in Pilsen. Of the locations that Rychly does list, most he was not allowed to visit, or everything had been removed from them by the time he visited. Where Rychly was allowed to visit a site that was still active, he was closely escorted by the OBZ Czechoslovakian secret service and denied access to any information they did not want him to have.

Virtually all documentation, prototypes, laboratories, and scientists connected to wartime German work in Czechoslovakia were removed to the Soviet Union. Presumably that information is still buried in Russian archives if it can be found and released.

Is there any relevant surviving information about wartime German work in Czech archives that was not removed or destroyed by the Soviets or their Czech allies?

What other information about wartime German work in Czechoslovakia do the U.S. and U.K. have from intelligence reports or from individuals who escaped to the west? What else can be found in U.S. and U.K. archives?

Rychly's report does not necessarily negate other reports about the Weser/Krizik complex being involved with work related to nuclear weapons and advanced rockets. Since the plant was cleaned out by the time Rychly visited, his only official information about Weser was apparently whatever his OBZ escorts wanted him to hear. As shown in item 8 of Rychly's report (A.E.G. at BEDRICHOV), actual work at these locations was much more extensive than admitted, and details of that work were blocked by the OBZ and other Czech officials.

From several available documents, "Pfau" seems to have been a general name for certain types of automated guidance systems for missiles and torpedoes [see for example pp. 5544, 5554; Trenkle 1987, pp. 121, 123].

Rychly stated that the V-4 rocket was actually "completed," so it was far more than a paper design. The fact that Rychly could mention the V-4 without further explanation suggests that the high-ranking U.S. military officials to whom he was reporting were already well aware of the existence and details of the V-4 rocket. Indeed, according to other U.S. military officials (p. 5544), this V-4 had both an increased range and an improved payload compared to the much better known A-4 (V-2) rocket.

Volman was a large engineering design and manufacturing company founded and run in Čelákovice by Josef Volman (Austrian/Czech, 1883–1943). Why were the Germans mass-producing cyclotrons at Volman? They reportedly shipped at least three to other German programs during the war, and had at least three left over that were claimed by the Soviet Union after the war. Were cyclotrons being mass-produced at Volman (and elsewhere) and then being used somewhere for electronuclear breeding?

Note that advanced U-boats were being produced, and in the mountains of central Europe.

Advanced jet propulsion work was being done there too.

This report is strong evidence that from 1939 to 1945, Germans used uranium ore from Jachymov (and perhaps other sources as well) for a secret, high-priority purpose that was not radium extraction:

- The Germans put uranium ore mining at Jachymov on a high priority no later than 1939 and continued until 1945.
- 10,000 kg of uranium ore yields 1 gram of radium, so if the Germans were primarily interested in the radium, extracting the radium at or near Jachymov would reduce how much material needed to be transported by a factor of 10,000,000, and also avoid contaminating Germany with all the waste byproducts of the extraction. Instead, the Germans destroyed the radium-extraction factory at Jachymov in 1939, never replaced it, and transported away all the ore.
- Uranium ore is very heavy, yet instead of using trains or trucks, the Germans used "special planes" to carry away the ore, again indicating a very high priority as well as a sense of urgency. It is also much harder to trace where planes go than where trains go, so this arrangement conferred a much higher level of security too.
- Officially Germany only had one uranium ore processing facility, Auer near Berlin, but the "special planes" also delivered uranium ore to Austria. What facility or facilities in Austria were processing uranium ore? Of the ore delivered to Germany, did any go to facilities other than Auer? Did ore only go to Germany and Austria, or could there have been deliveries to processing facilities elsewhere, such as Poland?
- The extreme level of Russian interest in Jachymov may indicate that the Russians knew how the Germans had been using the ore from Jachymov.]

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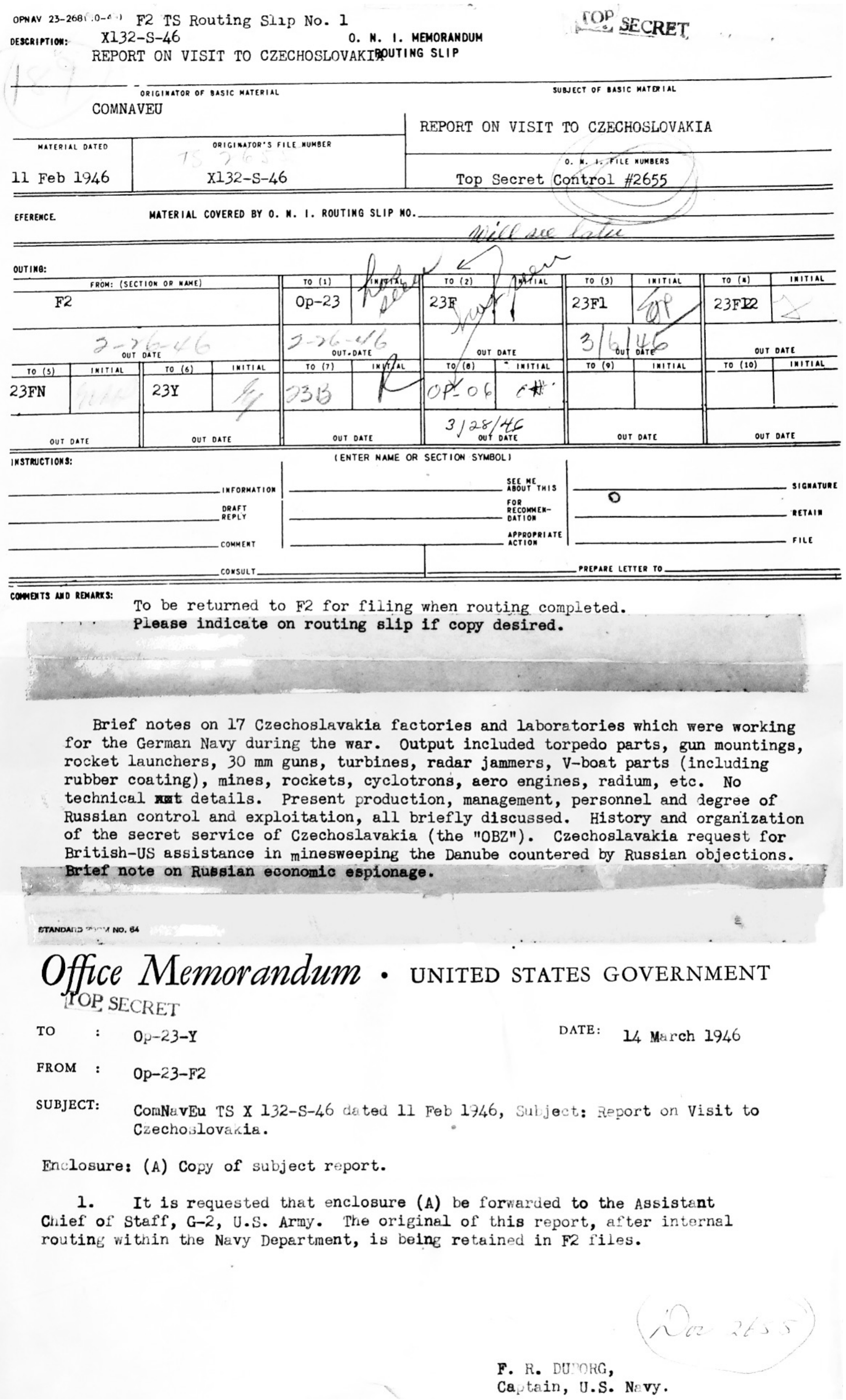

OPNAV 23-268(10-44) F2 TS Routing Slip No. 1

TOP SECRET

DESCRIPTION: X132-S-46
REPORT ON VISIT TO CZECHOSLOVAKIA

O. N. I. MEMORANDUM
ROUTING SLIP

ORIGINATOR OF BASIC MATERIAL COMNAVEU	SUBJECT OF BASIC MATERIAL REPORT ON VISIT TO CZECHOSLOVAKIA

MATERIAL DATED 11 Feb 1946	ORIGINATOR'S FILE NUMBER TS 2655 X132-S-46	O. N. I. FILE NUMBERS Top Secret Control #2655

EFERENCE. MATERIAL COVERED BY O. N. I. ROUTING SLIP NO.

Will see later

OUTING:

FROM: (SECTION OR NAME)	TO (1)	INITIAL	TO (2)	INITIAL	TO (3)	INITIAL	TO (4)	INITIAL
F2	Op-23		23F		23F1		23F12	
OUT DATE 2-26-46	OUT DATE 2-26-46		OUT DATE		OUT DATE 3/6/46		OUT DATE	

TO (5)	INITIAL	TO (6)	INITIAL	TO (7)	INITIAL	TO (8)	INITIAL	TO (9)	INITIAL	TO (10)	INITIAL
23FN		23Y		23B		OP-06					
OUT DATE		OUT DATE		OUT DATE		OUT DATE 3/28/46		OUT DATE		OUT DATE	

INSTRUCTIONS: (ENTER NAME OR SECTION SYMBOL)

INFORMATION
DRAFT REPLY
COMMENT
CONSULT
SEE ME ABOUT THIS
FOR RECOMMENDATION
APPROPRIATE ACTION
SIGNATURE
RETAIN
FILE
PREPARE LETTER TO

COMMENTS AND REMARKS: To be returned to F2 for filing when routing completed.
Please indicate on routing slip if copy desired.

Brief notes on 17 Czechoslavakia factories and laboratories which were working for the German Navy during the war. Output included torpedo parts, gun mountings, rocket launchers, 30 mm guns, turbines, radar jammers, V-boat parts (including rubber coating), mines, rockets, cyclotrons, aero engines, radium, etc. No technical details. Present production, management, personnel and degree of Russian control and exploitation, all briefly discussed. History and organization of the secret service of Czechoslavakia (the "OBZ"). Czechoslavakia request for British-US assistance in minesweeping the Danube countered by Russian objections. **Brief note on Russian economic espionage.**

STANDARD FORM NO. 64

Office Memorandum • UNITED STATES GOVERNMENT

TOP SECRET

TO : Op-23-Y

DATE: 14 March 1946

FROM : Op-23-F2

SUBJECT: ComNavEu TS X 132-S-46 dated 11 Feb 1946, Subject: Report on Visit to Czechoslovakia.

Enclosure: (A) Copy of subject report.

1. It is requested that enclosure (A) be forwarded to the Assistant Chief of Staff, G-2, U.S. Army. The original of this report, after internal routing within the Navy Department, is being retained in F2 files.

Doc 2655

F. R. DUBORG,
Captain, U.S. Navy.

NARA RG 38, Entry 98C,
Box 9, Folder TSC # 2601-2700

Figure E.152: V. L. Rychly. Report No. 2655: Report on Visit to Czechoslovakia. 11 February 1946. [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700]

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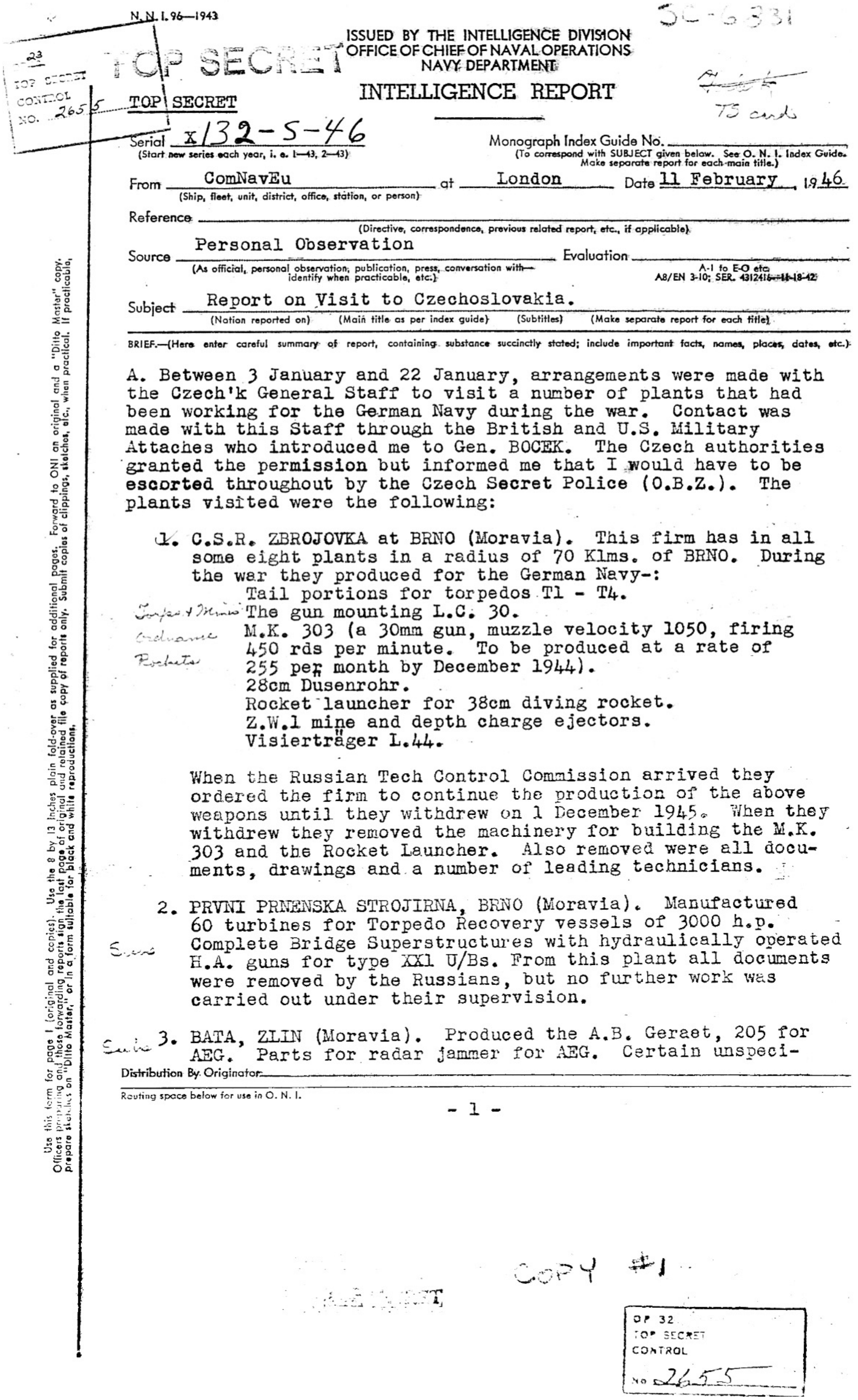

N.N.I. 96—1943

SC-6331

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23
NO. 2655

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ISSUED BY THE INTELLIGENCE DIVISION
OFFICE OF CHIEF OF NAVAL OPERATIONS
NAVY DEPARTMENT

INTELLIGENCE REPORT

TS card

TOP SECRET

Serial x132-5-46
(Start new series each year, i. e. 1—43, 2—43)

Monograph Index Guide No.
(To correspond with SUBJECT given below. See O. N. I. Index Guide. Make separate report for each main title.)

From ComNavEu at London Date 11 February, 1946
(Ship, fleet, unit, district, office, station, or person)

Reference
(Directive, correspondence, previous related report, etc., if applicable)

Source Personal Observation Evaluation
(As official, personal observation, publication, press, conversation with—identify when practicable, etc.)
A-1 to E-O etc.
A8/EN 3-10; SER. 4312416—11-18-42

Subject Report on Visit to Czechoslovakia.
(Nation reported on) (Main title as per index guide) (Subtitles) (Make separate report for each title)

BRIEF.—(Here enter careful summary of report, containing substance succinctly stated; include important facts, names, places, dates, etc.)

A. Between 3 January and 22 January, arrangements were made with the Czech'k General Staff to visit a number of plants that had been working for the German Navy during the war. Contact was made with this Staff through the British and U.S. Military Attaches who introduced me to Gen. BOCEK. The Czech authorities granted the permission but informed me that I would have to be escorted throughout by the Czech Secret Police (O.B.Z.). The plants visited were the following:

1. C.S.R. ZBROJOVKA at BRNO (Moravia). This firm has in all some eight plants in a radius of 70 Klms. of BRNO. During the war they produced for the German Navy-:
   Tail portions for torpedos T1 - T4.
   Torps + Mines The gun mounting L.C. 30.
   Ordnance M.K. 303 (a 30mm gun, muzzle velocity 1050, firing 450 rds per minute. To be produced at a rate of
   Rockets 255 per month by December 1944).
   28cm Dusenrohr.
   Rocket launcher for 38cm diving rocket.
   Z.W.1 mine and depth charge ejectors.
   Visierträger L.44.

   When the Russian Tech Control Commission arrived they ordered the firm to continue the production of the above weapons until they withdrew on 1 December 1945. When they withdrew they removed the machinery for building the M.K. 303 and the Rocket Launcher. Also removed were all documents, drawings and a number of leading technicians.

2. PRVNI PRNENSKA STROJIRNA, BRNO (Moravia). Manufactured 60 turbines for Torpedo Recovery vessels of 3000 h.p. Complete Bridge Superstructures with hydraulically operated H.A. guns for type XXI U/Bs. From this plant all documents were removed by the Russians, but no further work was carried out under their supervision.

   Subs

3. BATA, ZLIN (Moravia). Produced the A.B. Geraet, 205 for AEG. Parts for radar jammer for AEG. Certain unspeci-

   Subs

Distribution By Originator

Routing space below for use in O. N. I.

- 1 -

COPY #1

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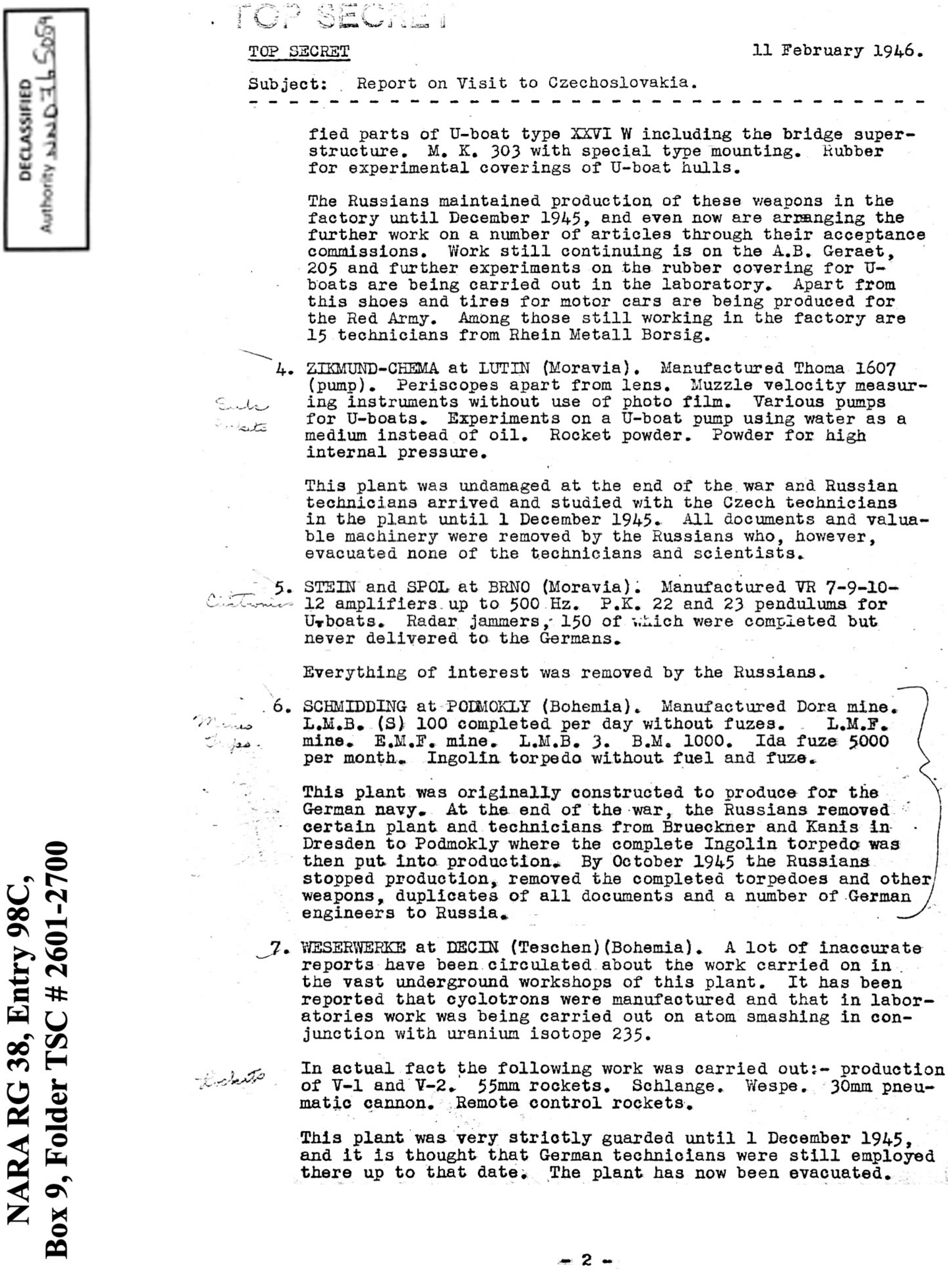
OP 32
TOP SECRET
CONTROL
No 2655

Use this form for page 1 (original and copies). Use the 8 by 13 inches plain fold-over as supplied for additional pages. Forward to ONI an original and a "Ditto Master" copy. Officers preparing and those forwarding reports sign the last page of original and retained file copy of reports only. Submit copies of clippings, sketches, etc., when practical. If practicable, prepare sketches on "Ditto Master," or in a form suitable for black and white reproductions.

NARA RG 38, Entry 98C,
Box 9, Folder TSC # 2601-2700

Figure E.153: V. L. Rychly. Report No. 2655: Report on Visit to Czechoslovakia. 11 February 1946. [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700]



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TOP SECRET 11 February 1946.

Subject: Report on Visit to Czechoslovakia.

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fied parts of U-boat type XXVI W including the bridge superstructure. M. K. 303 with special type mounting. Rubber for experimental coverings of U-boat hulls.

The Russians maintained production of these weapons in the factory until December 1945, and even now are arranging the further work on a number of articles through their acceptance commissions. Work still continuing is on the A.B. Geraet, 205 and further experiments on the rubber covering for U-boats are being carried out in the laboratory. Apart from this shoes and tires for motor cars are being produced for the Red Army. Among those still working in the factory are 15 technicians from Rhein Metall Borsig.

Subs
Rockets

4. ZIKMUND-CHEMA at LUTIN (Moravia). Manufactured Thoma 1607 (pump). Periscopes apart from lens. Muzzle velocity measuring instruments without use of photo film. Various pumps for U-boats. Experiments on a U-boat pump using water as a medium instead of oil. Rocket powder. Powder for high internal pressure.

This plant was undamaged at the end of the war and Russian technicians arrived and studied with the Czech technicians in the plant until 1 December 1945. All documents and valuable machinery were removed by the Russians who, however, evacuated none of the technicians and scientists.

Electronics

5. STEIN and SPOL at BRNO (Moravia). Manufactured VR 7-9-10-12 amplifiers up to 500 Hz. P.K. 22 and 23 pendulums for U-boats. Radar jammers, 150 of which were completed but never delivered to the Germans.

Everything of interest was removed by the Russians.

Mines
Torps.

6. SCHMIDDING at PODMOKLY (Bohemia). Manufactured Dora mine. L.M.B. (S) 100 completed per day without fuzes. L.M.F. mine. E.M.F. mine. L.M.B. 3. B.M. 1000. Ida fuze 5000 per month. Ingolin torpedo without fuel and fuze.

This plant was originally constructed to produce for the German navy. At the end of the war, the Russians removed certain plant and technicians from Brueckner and Kanis in Dresden to Podmokly where the complete Ingolin torpedo was then put into production. By October 1945 the Russians stopped production, removed the completed torpedoes and other weapons, duplicates of all documents and a number of German engineers to Russia.

7. WESERWERKE at DECIN (Teschen)(Bohemia). A lot of inaccurate reports have been circulated about the work carried on in the vast underground workshops of this plant. It has been reported that cyclotrons were manufactured and that in laboratories work was being carried out on atom smashing in conjunction with uranium isotope 235.

Rockets

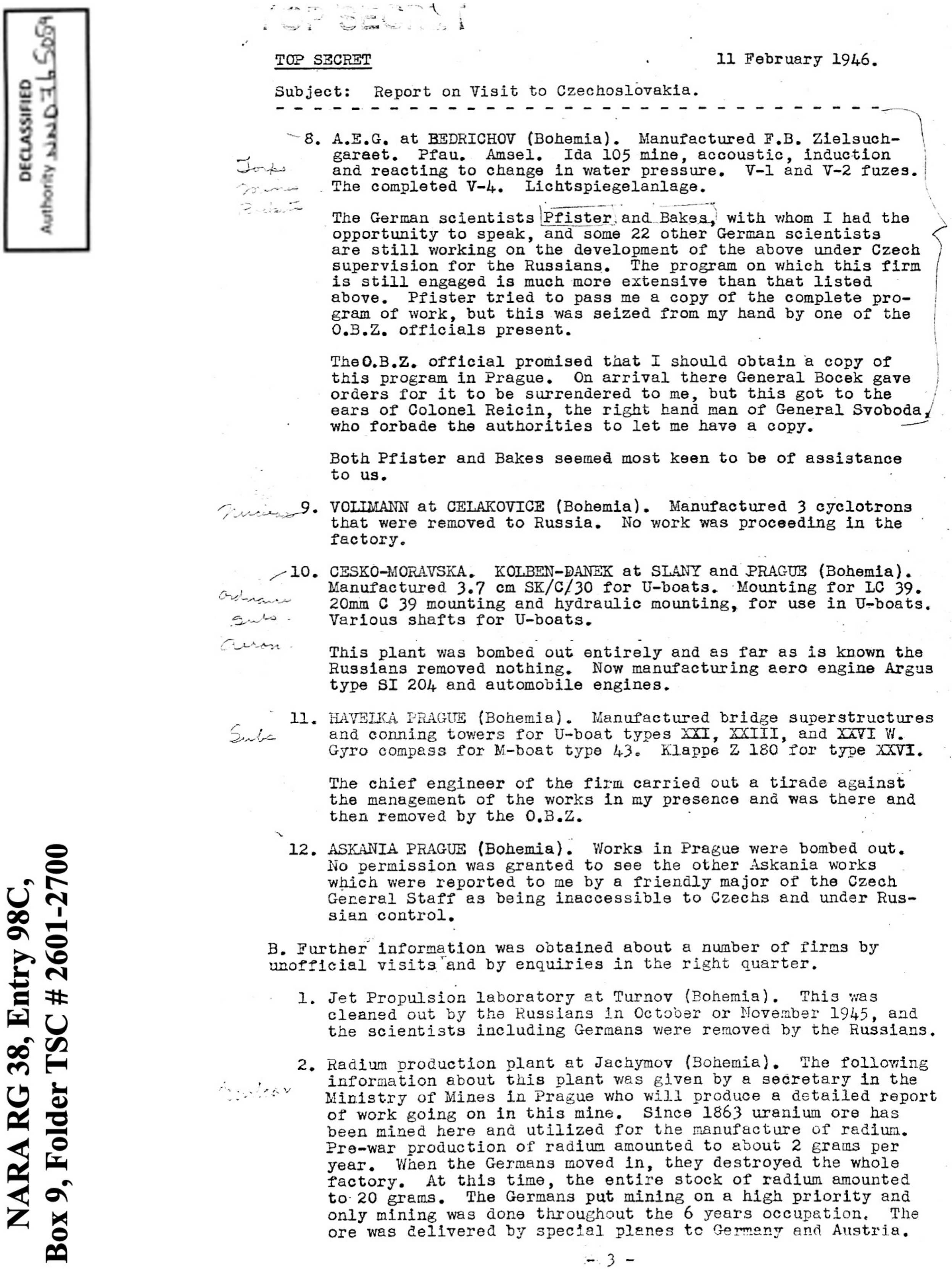
In actual fact the following work was carried out:- production of V-1 and V-2. 55mm rockets. Schlange. Wespe. 30mm pneumatic cannon. Remote control rockets.

This plant was very strictly guarded until 1 December 1945, and it is thought that German technicians were still employed there up to that date. The plant has now been evacuated.

- 2 -

NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601-2700

Figure E.154: V. L. Rychly. Report No. 2655: Report on Visit to Czechoslovakia. 11 February 1946. [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700]



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Torps
Mines
Radar

8. A.E.G. at BEDRICHOV (Bohemia). Manufactured F.B. Zielsuchgeraet. Pfau. Amsel. Ida 105 mine, accoustic, induction and reacting to change in water pressure. V-1 and V-2 fuzes. The completed V-4. Lichtspiegelanlage.

The German scientists Pfister and Bakes, with whom I had the opportunity to speak, and some 22 other German scientists are still working on the development of the above under Czech supervision for the Russians. The program on which this firm is still engaged is much more extensive than that listed above. Pfister tried to pass me a copy of the complete program of work, but this was seized from my hand by one of the O.B.Z. officials present.

The O.B.Z. official promised that I should obtain a copy of this program in Prague. On arrival there General Bocek gave orders for it to be surrendered to me, but this got to the ears of Colonel Reicin, the right hand man of General Svoboda, who forbade the authorities to let me have a copy.

Both Pfister and Bakes seemed most keen to be of assistance to us.

Nuclear

9. VOLLMANN at CELAKOVICE (Bohemia). Manufactured 3 cyclotrons that were removed to Russia. No work was proceeding in the factory.

Ordnance
Subs
Aeron

10. CESKO-MORAVSKA. KOLBEN-DANEK at SLANY and PRAGUE (Bohemia). Manufactured 3.7 cm SK/C/30 for U-boats. Mounting for LC 39. 20mm C 39 mounting and hydraulic mounting, for use in U-boats. Various shafts for U-boats.

This plant was bombed out entirely and as far as is known the Russians removed nothing. Now manufacturing aero engine Argus type SI 204 and automobile engines.

Subs

11. HAVELKA PRAGUE (Bohemia). Manufactured bridge superstructures and conning towers for U-boat types XXI, XXIII, and XXVI W. Gyro compass for M-boat type 43. Klappe Z 180 for type XXVI.

The chief engineer of the firm carried out a tirade against the management of the works in my presence and was there and then removed by the O.B.Z.

12. ASKANIA PRAGUE (Bohemia). Works in Prague were bombed out. No permission was granted to see the other Askania works which were reported to me by a friendly major of the Czech General Staff as being inaccessible to Czechs and under Russian control.

B. Further information was obtained about a number of firms by unofficial visits and by enquiries in the right quarter.

1. Jet Propulsion laboratory at Turnov (Bohemia). This was cleaned out by the Russians in October or November 1945, and the scientists including Germans were removed by the Russians.

Nuclear

2. Radium production plant at Jachymov (Bohemia). The following information about this plant was given by a secretary in the Ministry of Mines in Prague who will produce a detailed report of work going on in this mine. Since 1863 uranium ore has been mined here and utilized for the manufacture of radium. Pre-war production of radium amounted to about 2 grams per year. When the Germans moved in, they destroyed the whole factory. At this time, the entire stock of radium amounted to 20 grams. The Germans put mining on a high priority and only mining was done throughout the 6 years occupation. The ore was delivered by special planes to Germany and Austria.

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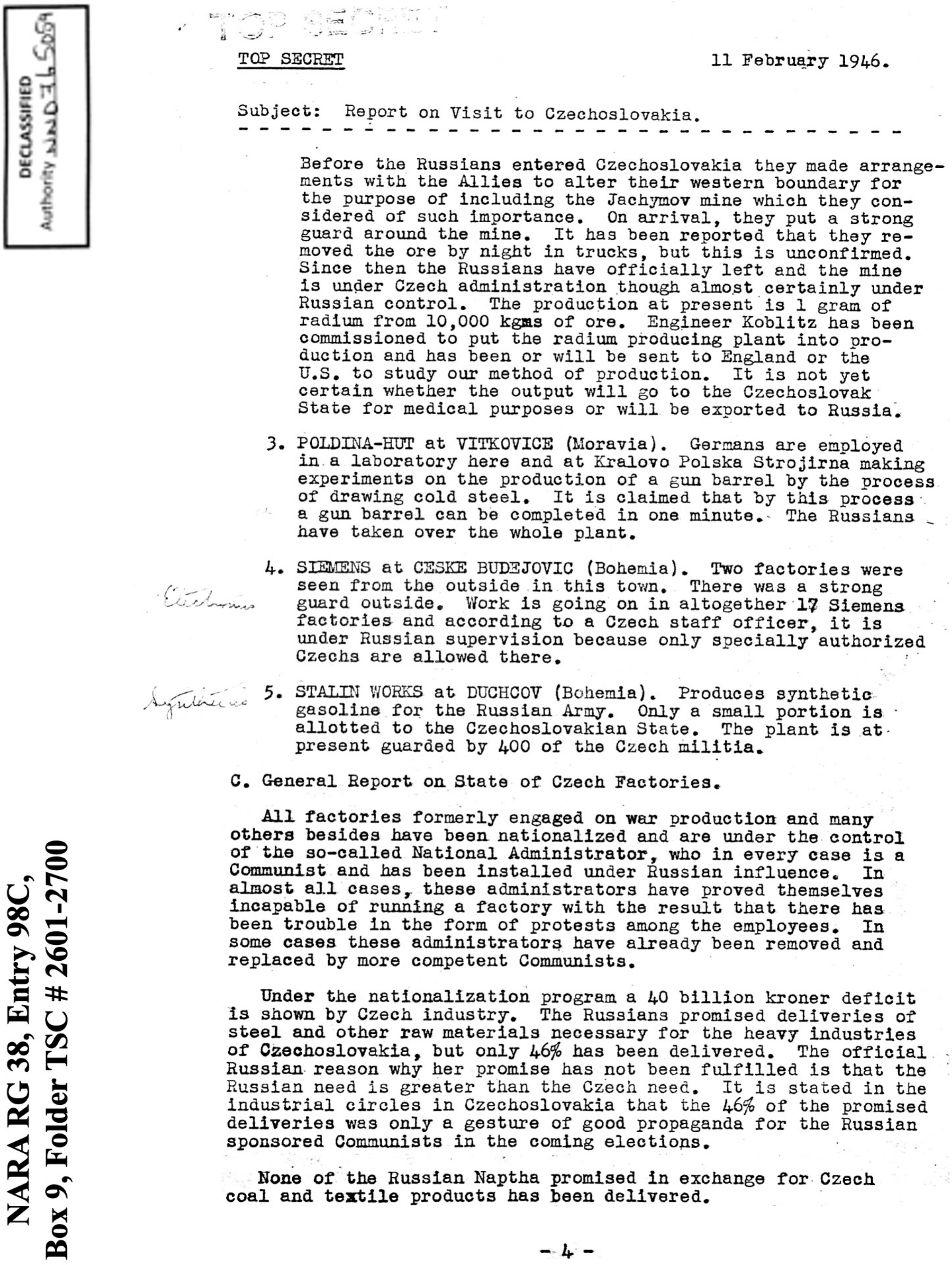
NARA RG 38, Entry 98C,
Box 9, Folder TSC # 2601-2700

Figure E.155: V. L. Rychly. Report No. 2655: Report on Visit to Czechoslovakia. 11 February 1946. [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700]



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Subject: Report on Visit to Czechoslovakia.

Before the Russians entered Czechoslovakia they made arrangements with the Allies to alter their western boundary for the purpose of including the Jachymov mine which they considered of such importance. On arrival, they put a strong guard around the mine. It has been reported that they removed the ore by night in trucks, but this is unconfirmed. Since then the Russians have officially left and the mine is under Czech administration though almost certainly under Russian control. The production at present is 1 gram of radium from 10,000 kgms of ore. Engineer Koblitz has been commissioned to put the radium producing plant into production and has been or will be sent to England or the U.S. to study our method of production. It is not yet certain whether the output will go to the Czechoslovak State for medical purposes or will be exported to Russia.

3. POLDINA-HUT at VITKOVICE (Moravia). Germans are employed in a laboratory here and at Kralovo Polska Strojirna making experiments on the production of a gun barrel by the process of drawing cold steel. It is claimed that by this process a gun barrel can be completed in one minute. The Russians have taken over the whole plant.

Electronics

4. SIEMENS at CESKE BUDEJOVIC (Bohemia). Two factories were seen from the outside in this town. There was a strong guard outside. Work is going on in altogether 17 Siemens factories and according to a Czech staff officer, it is under Russian supervision because only specially authorized Czechs are allowed there.

Synthetics

5. STALIN WORKS at DUCHCOV (Bohemia). Produces synthetic gasoline for the Russian Army. Only a small portion is allotted to the Czechoslovakian State. The plant is at present guarded by 400 of the Czech militia.

C. General Report on State of Czech Factories.

All factories formerly engaged on war production and many others besides have been nationalized and are under the control of the so-called National Administrator, who in every case is a Communist and has been installed under Russian influence. In almost all cases, these administrators have proved themselves incapable of running a factory with the result that there has been trouble in the form of protests among the employees. In some cases these administrators have already been removed and replaced by more competent Communists.

Under the nationalization program a 40 billion kroner deficit is shown by Czech industry. The Russians promised deliveries of steel and other raw materials necessary for the heavy industries of Czechoslovakia, but only 46% has been delivered. The official Russian reason why her promise has not been fulfilled is that the Russian need is greater than the Czech need. It is stated in the industrial circles in Czechoslovakia that the 46% of the promised deliveries was only a gesture of good propaganda for the Russian sponsored Communists in the coming elections.

None of the Russian Naptha promised in exchange for Czech coal and textile products has been delivered.

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NARA RG 38, Entry 98C,
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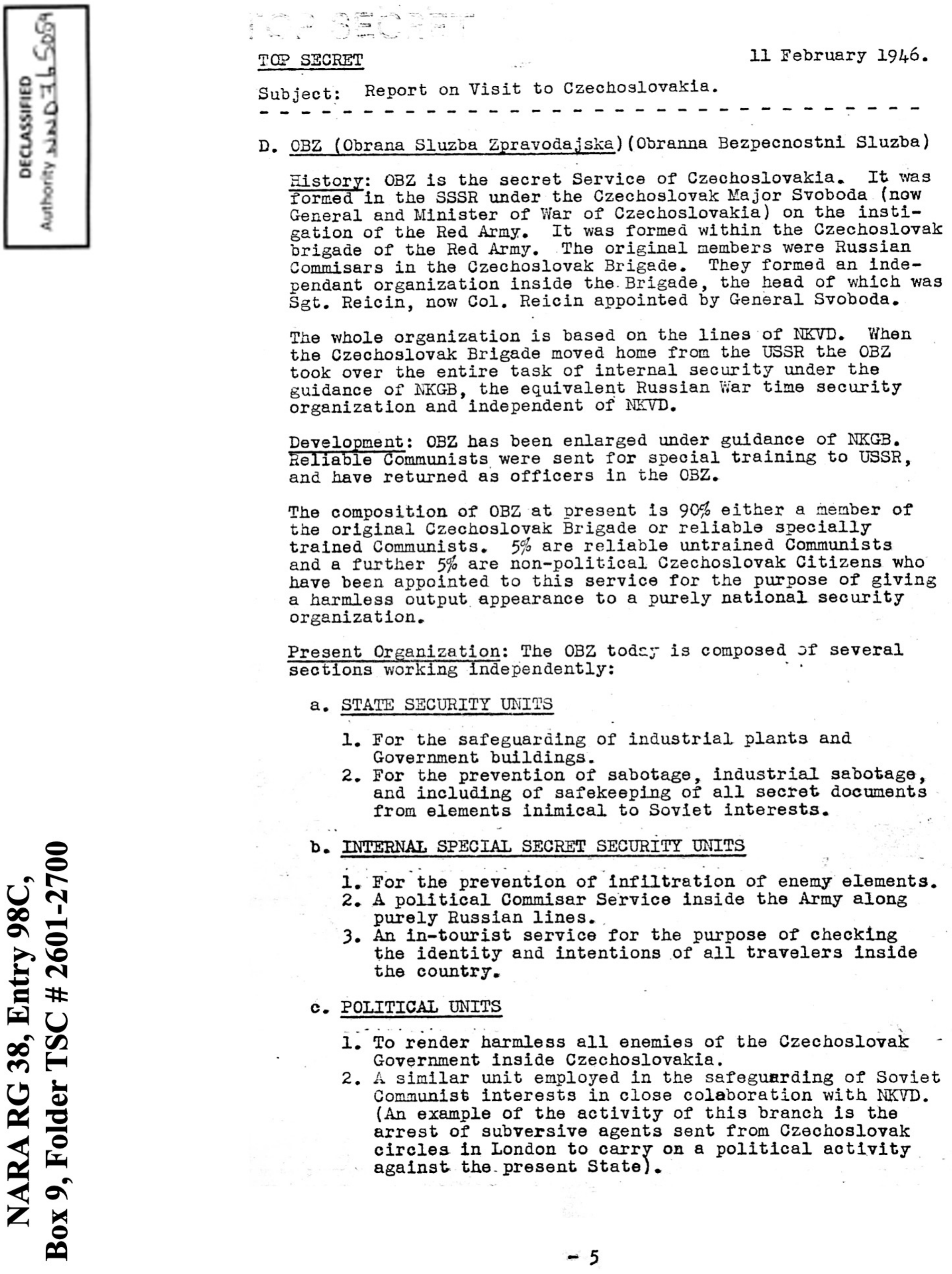
Figure E.156: V. L. Rychly. Report No. 2655: Report on Visit to Czechoslovakia. 11 February 1946. [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700]



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Subject: Report on Visit to Czechoslovakia.

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D. OBZ (Obrana Sluzba Zpravodajska)(Obranna Bezpecnostni Sluzba)

History: OBZ is the secret Service of Czechoslovakia. It was formed in the SSSR under the Czechoslovak Major Svoboda (now General and Minister of War of Czechoslovakia) on the instigation of the Red Army. It was formed within the Czechoslovak brigade of the Red Army. The original members were Russian Commisars in the Czechoslovak Brigade. They formed an independant organization inside the Brigade, the head of which was Sgt. Reicin, now Col. Reicin appointed by General Svoboda.

The whole organization is based on the lines of NKVD. When the Czechoslovak Brigade moved home from the USSR the OBZ took over the entire task of internal security under the guidance of NKGB, the equivalent Russian War time security organization and independent of NKVD.

Development: OBZ has been enlarged under guidance of NKGB. Reliable Communists were sent for special training to USSR, and have returned as officers in the OBZ.

The composition of OBZ at present is 90% either a member of the original Czechoslovak Brigade or reliable specially trained Communists. 5% are reliable untrained Communists and a further 5% are non-political Czechoslovak Citizens who have been appointed to this service for the purpose of giving a harmless output appearance to a purely national security organization.

Present Organization: The OBZ today is composed of several sections working independently:

a. STATE SECURITY UNITS

1. For the safeguarding of industrial plants and Government buildings.
2. For the prevention of sabotage, industrial sabotage, and including of safekeeping of all secret documents from elements inimical to Soviet interests.

b. INTERNAL SPECIAL SECRET SECURITY UNITS

1. For the prevention of infiltration of enemy elements.
2. A political Commisar Service inside the Army along purely Russian lines.
3. An in-tourist service for the purpose of checking the identity and intentions of all travelers inside the country.

c. POLITICAL UNITS

1. To render harmless all enemies of the Czechoslovak Government inside Czechoslovakia.
2. A similar unit employed in the safeguarding of Soviet Communist interests in close colaboration with NKVD. (An example of the activity of this branch is the arrest of subversive agents sent from Czechoslovak circles in London to carry on a political activity against the present State).

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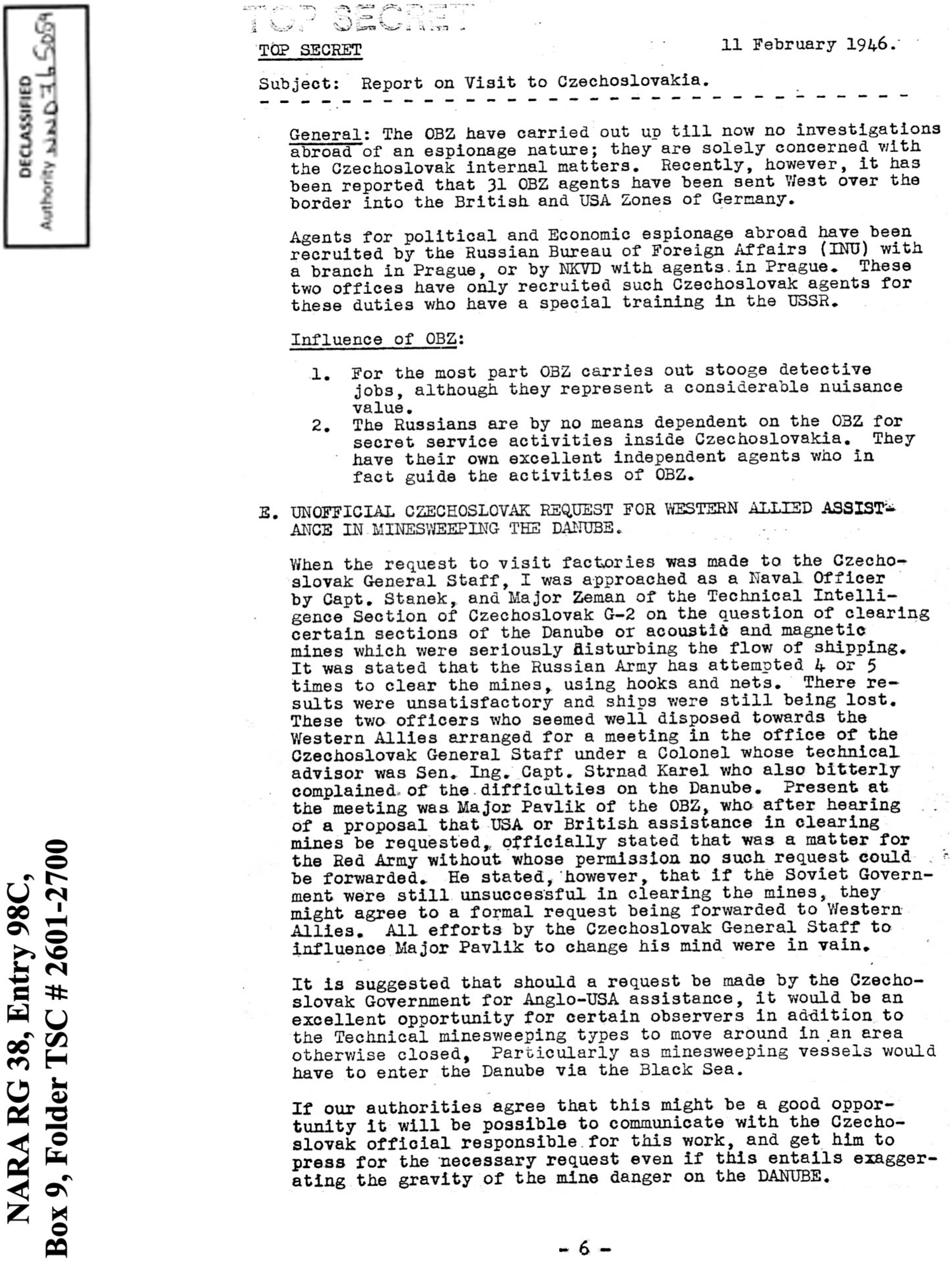
Box 9, Folder TSC # 2601-2700

Figure E.157: V. L. Rychly. Report No. 2655: Report on Visit to Czechoslovakia. 11 February 1946. [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700]



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Subject: Report on Visit to Czechoslovakia.

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General: The OBZ have carried out up till now no investigations abroad of an espionage nature; they are solely concerned with the Czechoslovak internal matters. Recently, however, it has been reported that 31 OBZ agents have been sent West over the border into the British and USA Zones of Germany.

Agents for political and Economic espionage abroad have been recruited by the Russian Bureau of Foreign Affairs (INU) with a branch in Prague, or by NKVD with agents in Prague. These two offices have only recruited such Czechoslovak agents for these duties who have a special training in the USSR.

Influence of OBZ:

1. For the most part OBZ carries out stooge detective jobs, although they represent a considerable nuisance value.
2. The Russians are by no means dependent on the OBZ for secret service activities inside Czechoslovakia. They have their own excellent independent agents who in fact guide the activities of OBZ.

E. UNOFFICIAL CZECHOSLOVAK REQUEST FOR WESTERN ALLIED ASSISTANCE IN MINESWEEPING THE DANUBE.

When the request to visit factories was made to the Czechoslovak General Staff, I was approached as a Naval Officer by Capt. Stanek, and Major Zeman of the Technical Intelligence Section of Czechoslovak G-2 on the question of clearing certain sections of the Danube or acoustic and magnetic mines which were seriously disturbing the flow of shipping. It was stated that the Russian Army has attempted 4 or 5 times to clear the mines, using hooks and nets. There results were unsatisfactory and ships were still being lost. These two officers who seemed well disposed towards the Western Allies arranged for a meeting in the office of the Czechoslovak General Staff under a Colonel whose technical advisor was Sen. Ing. Capt. Strnad Karel who also bitterly complained of the difficulties on the Danube. Present at the meeting was Major Pavlik of the OBZ, who after hearing of a proposal that USA or British assistance in clearing mines be requested, officially stated that was a matter for the Red Army without whose permission no such request could be forwarded. He stated, however, that if the Soviet Government were still unsuccessful in clearing the mines, they might agree to a formal request being forwarded to Western Allies. All efforts by the Czechoslovak General Staff to influence Major Pavlik to change his mind were in vain.

It is suggested that should a request be made by the Czechoslovak Government for Anglo-USA assistance, it would be an excellent opportunity for certain observers in addition to the Technical minesweeping types to move around in an area otherwise closed, Particularly as minesweeping vessels would have to enter the Danube via the Black Sea.

If our authorities agree that this might be a good opportunity it will be possible to communicate with the Czechoslovak official responsible for this work, and get him to press for the necessary request even if this entails exaggerating the gravity of the mine danger on the DANUBE.

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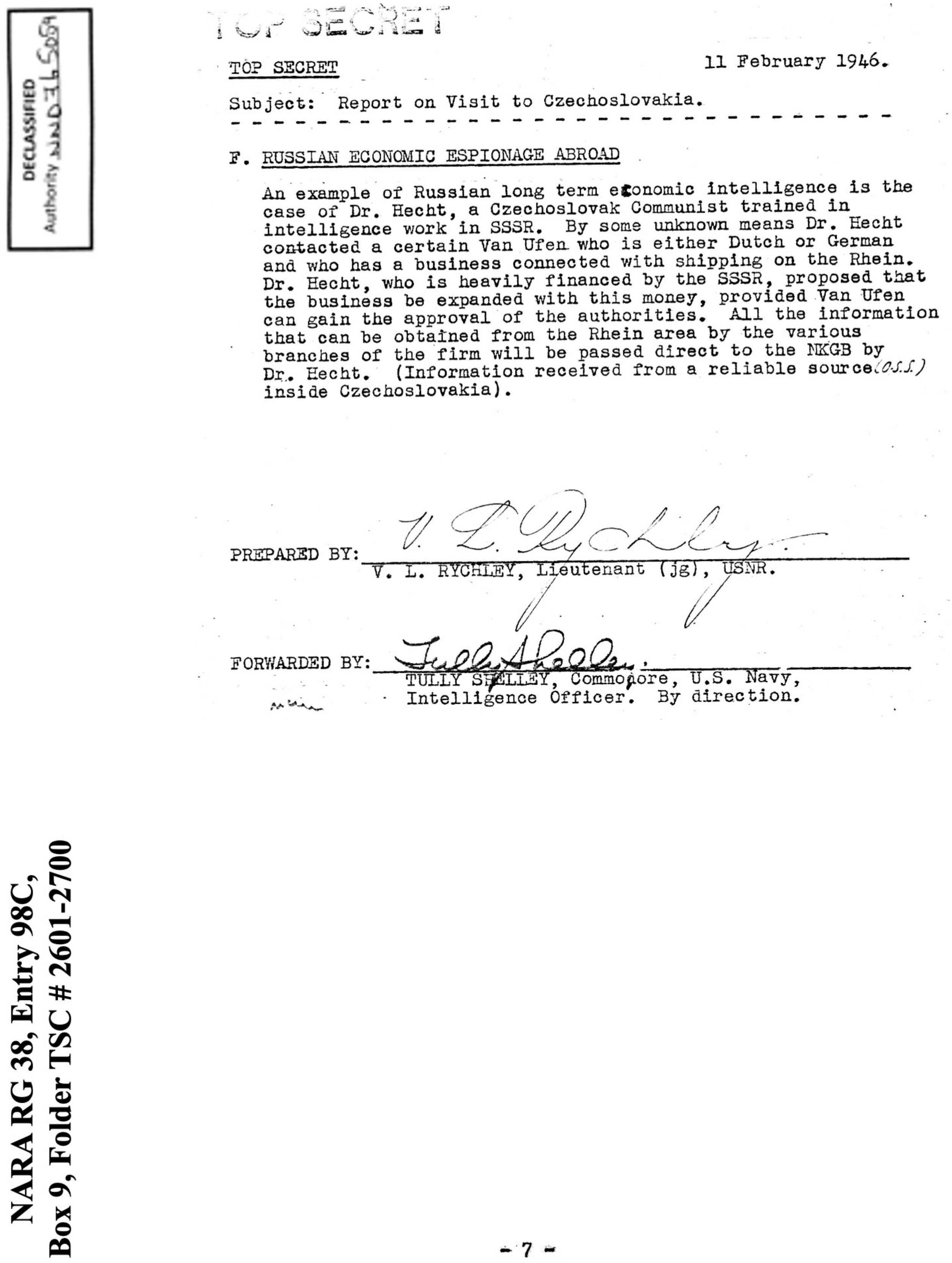
NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601-2700

Figure E.158: V. L. Rychly. Report No. 2655: Report on Visit to Czechoslovakia. 11 February 1946. [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700]



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Subject: Report on Visit to Czechoslovakia.

F. RUSSIAN ECONOMIC ESPIONAGE ABROAD

An example of Russian long term economic intelligence is the case of Dr. Hecht, a Czechoslovak Communist trained in intelligence work in SSSR. By some unknown means Dr. Hecht contacted a certain Van Ufen who is either Dutch or German and who has a business connected with shipping on the Rhein. Dr. Hecht, who is heavily financed by the SSSR, proposed that the business be expanded with this money, provided Van Ufen can gain the approval of the authorities. All the information that can be obtained from the Rhein area by the various branches of the firm will be passed direct to the NKGB by Dr. Hecht. (Information received from a reliable source (O.S.S.) inside Czechoslovakia).

PREPARED BY: V. L. Rychley
V. L. RYCHLEY, Lieutenant (jg), USNR.

FORWARDED BY: Tully Shelley
TULLY SHELLEY, Commodore, U.S. Navy,
Intelligence Officer. By direction.

- 7 -

NARA RG 38, Entry 98C,
Box 9, Folder TSC # 2601-2700

Figure E.159: V. L. Rychly. Report No. 2655: Report on Visit to Czechoslovakia. 11 February 1946. [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700]

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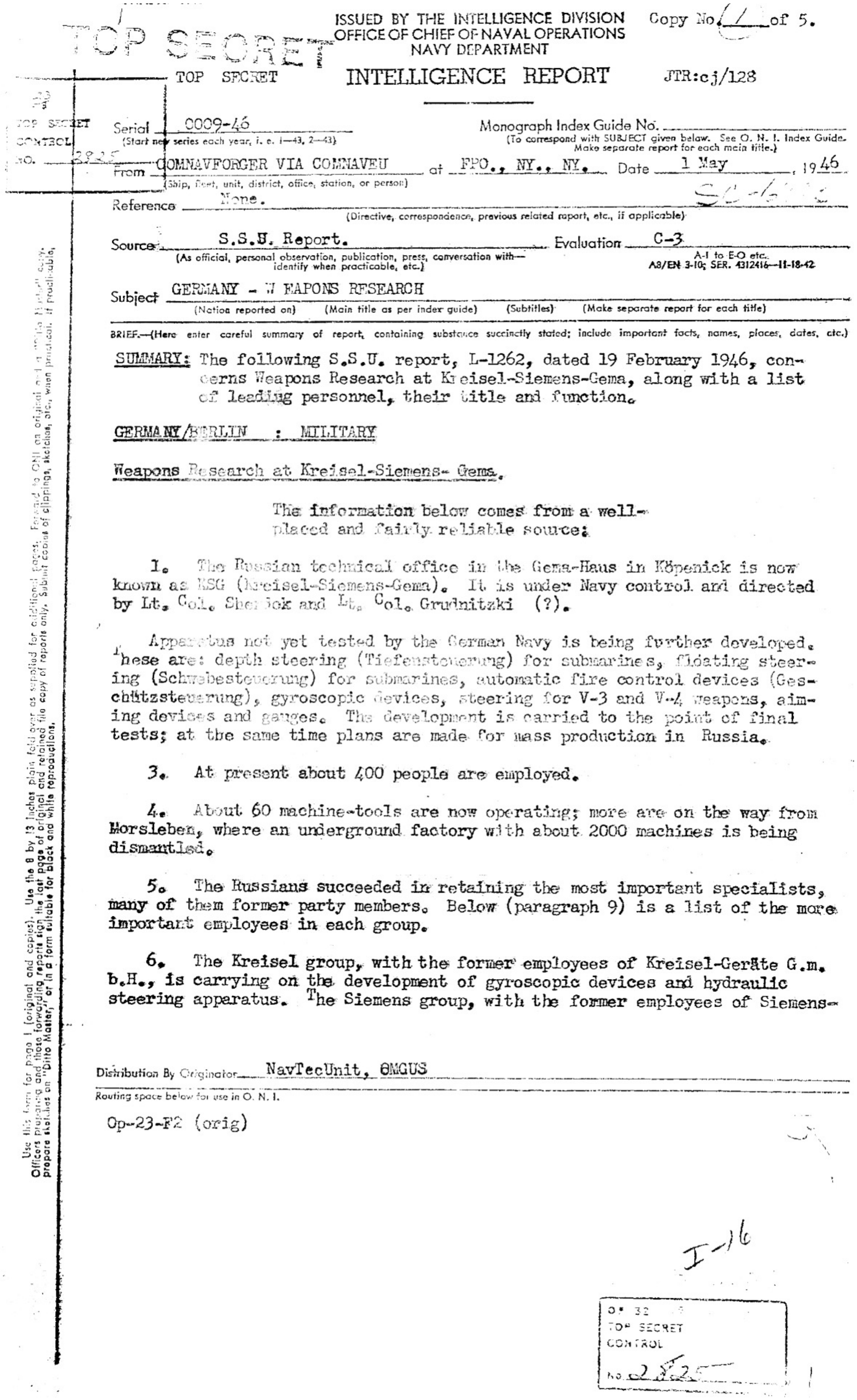
Authority NND 765069

NARA RG 38, Entry 98C,
Box 10, Folder TSC # 2801-2900



TOP SECRET

ISSUED BY THE INTELLIGENCE DIVISION
OFFICE OF CHIEF OF NAVAL OPERATIONS
NAVY DEPARTMENT

Copy No. 1 of 5.

TOP SECRET

INTELLIGENCE REPORT

JTR:cj/128

TOP SECRET
CONTROL
NO. 2825

Serial 0009-46
(Start new series each year, i. e. 1—43, 2—43)

Monograph Index Guide No. ______
(To correspond with SUBJECT given below. See O. N. I. Index Guide. Make separate report for each main title.)

From COMNAVFORGER VIA COMNAVEU at FPO., NY., NY. Date 1 May, 1946
(Ship, fleet, unit, district, office, station, or person)

Reference None.
(Directive, correspondence, previous related report, etc., if applicable)

Source S.S.U. Report. Evaluation C-3
(As official, personal observation, publication, press, conversation with—identify when practicable, etc.)
A-1 to E-O etc.
A8/EN 3-10; SER. 4312416—11-18-42

Subject GERMANY - WEAPONS RESEARCH
(Nation reported on) (Main title as per index guide) (Subtitles) (Make separate report for each title)

BRIEF.—(Here enter careful summary of report, containing substance succinctly stated; include important facts, names, places, dates, etc.)

SUMMARY: The following S.S.U. report, L-1262, dated 19 February 1946, concerns Weapons Research at Kreisel-Siemens-Gema, along with a list of leading personnel, their title and function.

GERMANY/BERLIN : MILITARY

Weapons Research at Kreisel-Siemens- Gems.

The information below comes from a well-placed and fairly reliable source:

1. The Russian technical office in the Gema-Haus in Köpenick is now known as KSG (Kreisel-Siemens-Gema). It is under Navy control and directed by Lt. Col. Sherbok and Lt. Col. Grudnitzki (?).

Apparatus not yet tested by the German Navy is being further developed. These are: depth steering (Tiefensteuerung) for submarines, floating steering (Schwebesteuerung) for submarines, automatic fire control devices (Geschützsteuerung), gyroscopic devices, steering for V-3 and V-4 weapons, aiming devices and gauges. The development is carried to the point of final tests; at the same time plans are made for mass production in Russia.

3. At present about 400 people are employed.

4. About 60 machine-tools are now operating; more are on the way from Morsleben, where an underground factory with about 2000 machines is being dismantled.

5. The Russians succeeded in retaining the most important specialists, many of them former party members. Below (paragraph 9) is a list of the more important employees in each group.

6. The Kreisel group, with the former employees of Kreisel-Geräte G.m.b.H., is carrying on the development of gyroscopic devices and hydraulic steering apparatus. The Siemens group, with the former employees of Siemens-

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Routing space below for use in O. N. I.

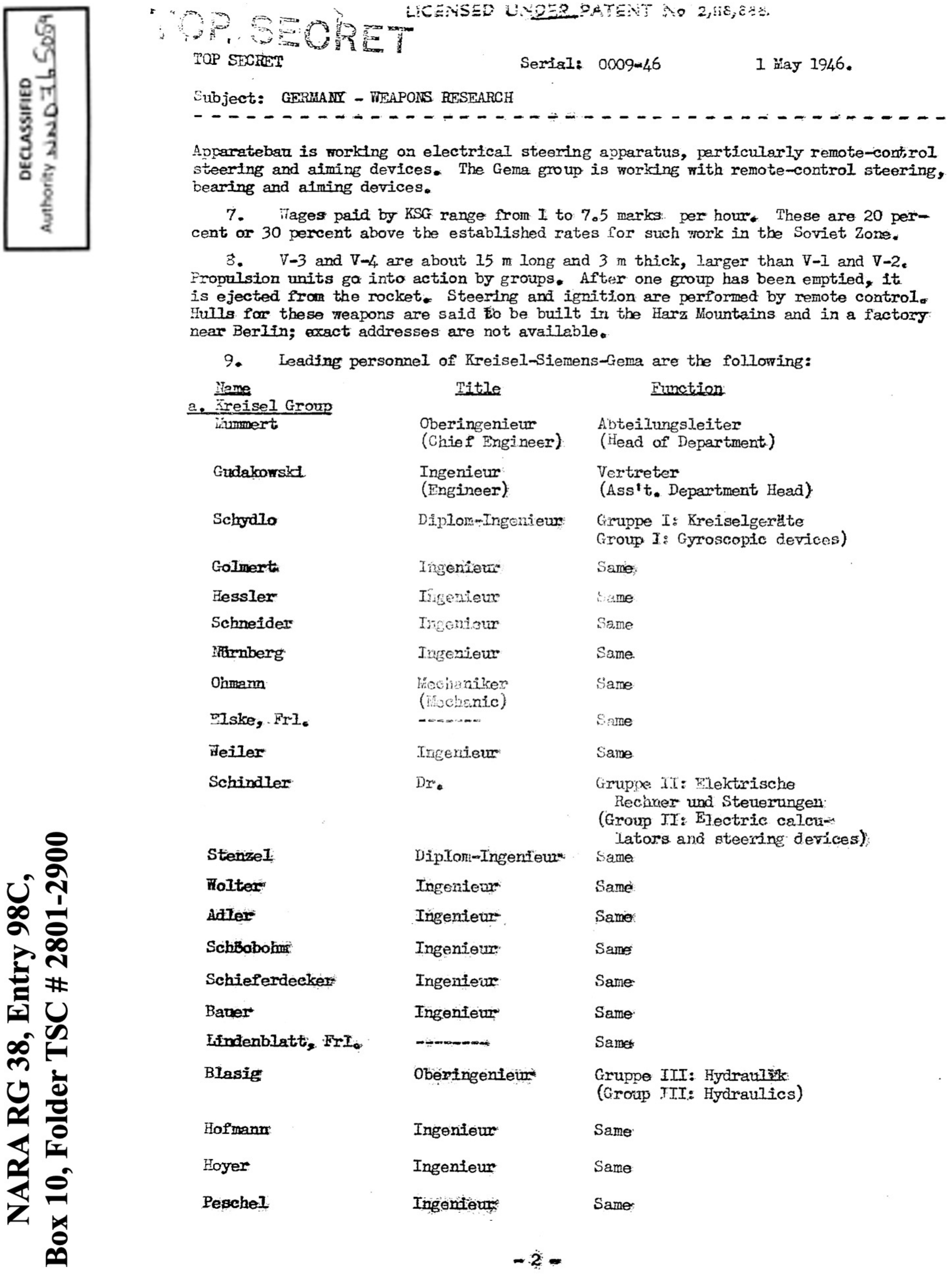
Op-23-F2 (orig)

I-16

TOP SECRET
CONTROL
No. 2825

Use this form for page 1 (original and copies). Use the 8 by 13 inches plain fold over as supplied for additional pages. Forward to ONI an original and a "Ditto Master" copy. Officers preparing and those forwarding reports sign the last page of original and retained file copy of reports only. Submit copies of clippings, sketches, etc., when practical. If practicable, prepare sketches on "Ditto Master," or in a form suitable for black and white reproductions.

Figure E.160: Serial 0009-46. Intelligence Division, Office of Chief of Naval Operations. Subject: Germany–Weapons Research. 1 May 1946. [NARA RG 38, Entry 98C, Box 10, Folder TSC # 2801–2900]



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TOP SECRET

LICENSED UNDER PATENT No 2,118,888.

TOP SECRET Serial: 0009-46 1 May 1946.

Subject: GERMANY - WEAPONS RESEARCH

Apparatebau is working on electrical steering apparatus, particularly remote-control steering and aiming devices. The Gema group is working with remote-control steering, bearing and aiming devices.

7. Wages paid by KSG range from 1 to 7.5 marks per hour. These are 20 percent or 30 percent above the established rates for such work in the Soviet Zone.

8. V-3 and V-4 are about 15 m long and 3 m thick, larger than V-1 and V-2. Propulsion units go into action by groups. After one group has been emptied, it is ejected from the rocket. Steering and ignition are performed by remote control. Hulls for these weapons are said to be built in the Harz Mountains and in a factory near Berlin; exact addresses are not available.

9. Leading personnel of Kreisel-Siemens-Gema are the following:

Name	Title	Function
a. Kreisel Group		
Mummert	Oberingenieur (Chief Engineer)	Abteilungsleiter (Head of Department)
Gudakowski	Ingenieur (Engineer)	Vertreter (Ass't. Department Head)
Schydlo	Diplom-Ingenieur	Gruppe I: Kreiselgeräte Group I: Gyroscopic devices)
Golmert	Ingenieur	Same
Hessler	Ingenieur	Same
Schneider	Ingenieur	Same
Nürnberg	Ingenieur	Same
Ohmann	Mechaniker (Mechanic)	Same
Elske, Frl.	--------	Same
Weiler	Ingenieur	Same
Schindler	Dr.	Gruppe II: Elektrische Rechner und Steuerungen (Group II: Electric calculators and steering devices)
Stenzel	Diplom-Ingenieur	Same
Wolter	Ingenieur	Same
Adler	Ingenieur	Same
Schöbohm	Ingenieur	Same
Schieferdecker	Ingenieur	Same
Bauer	Ingenieur	Same
Lindenblatt, Frl.	---------	Same
Blasig	Oberingenieur	Gruppe III: Hydraulik (Group III: Hydraulics)
Hofmann	Ingenieur	Same
Hoyer	Ingenieur	Same
Peschel	Ingenieur	Same

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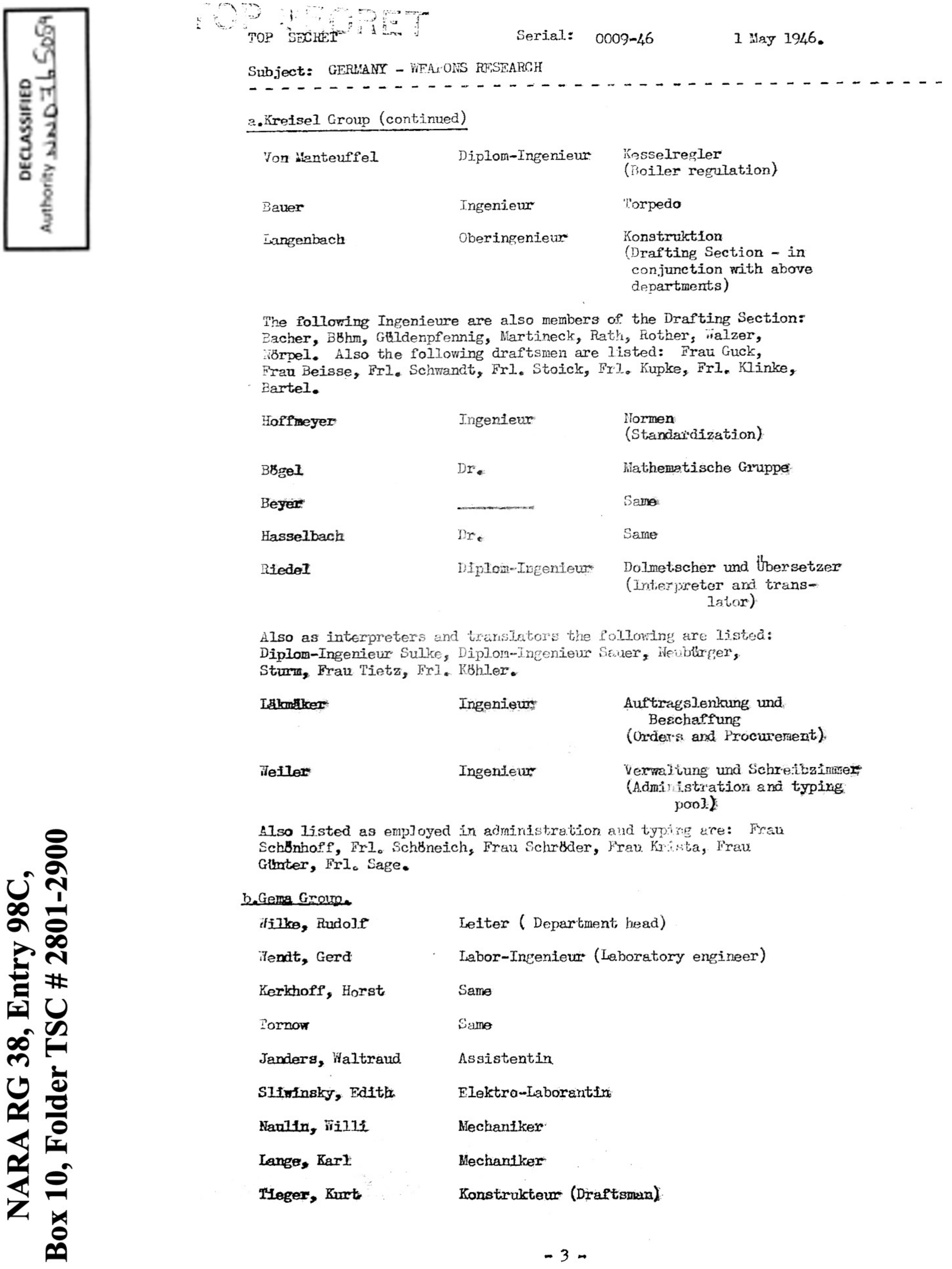
NARA RG 38, Entry 98C,
Box 10, Folder TSC # 2801-2900

Figure E.161: Serial 0009-46. Intelligence Division, Office of Chief of Naval Operations. Subject: Germany–Weapons Research. 1 May 1946. [NARA RG 38, Entry 98C, Box 10, Folder TSC # 2801–2900]



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Authority NND 765069

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TOP SECRET Serial: 0009-46 1 May 1946.

Subject: GERMANY - WEAPONS RESEARCH

- -

a.Kreisel Group (continued)

Von Manteuffel	Diplom-Ingenieur	Kesselregler (Boiler regulation)
Bauer	Ingenieur	Torpedo
Langenbach	Oberingenieur	Konstruktion (Drafting Section - in conjunction with above departments)

The following Ingenieure are also members of the Drafting Section: Bacher, Böhm, Güldenpfennig, Martineck, Rath, Rother, Walzer, Nörpel. Also the following draftsmen are listed: Frau Guck, Frau Beisse, Frl. Schwandt, Frl. Stoick, Frl. Kupke, Frl. Klinke, Bartel.

Hoffmeyer	Ingenieur	Normen (Standardization)
Bögel	Dr.	Mathematische Gruppe
Beyer	________	Same
Hasselbach	Dr.	Same
Riedel	Diplom-Ingenieur	Dolmetscher und Übersetzer (Interpreter and translator)

Also as interpreters and translators the following are listed: Diplom-Ingenieur Sulke, Diplom-Ingenieur Sauer, Neubürger, Sturm, Frau Tietz, Frl. Köhler.

Läkmäker	Ingenieur	Auftragslenkung und Beschaffung (Orders and Procurement)
Weiler	Ingenieur	Verwaltung und Schreibzimmer (Administration and typing pool)

Also listed as employed in administration and typing are: Frau Schönhoff, Frl. Schöneich, Frau Schröder, Frau Krista, Frau Günter, Frl. Sage.

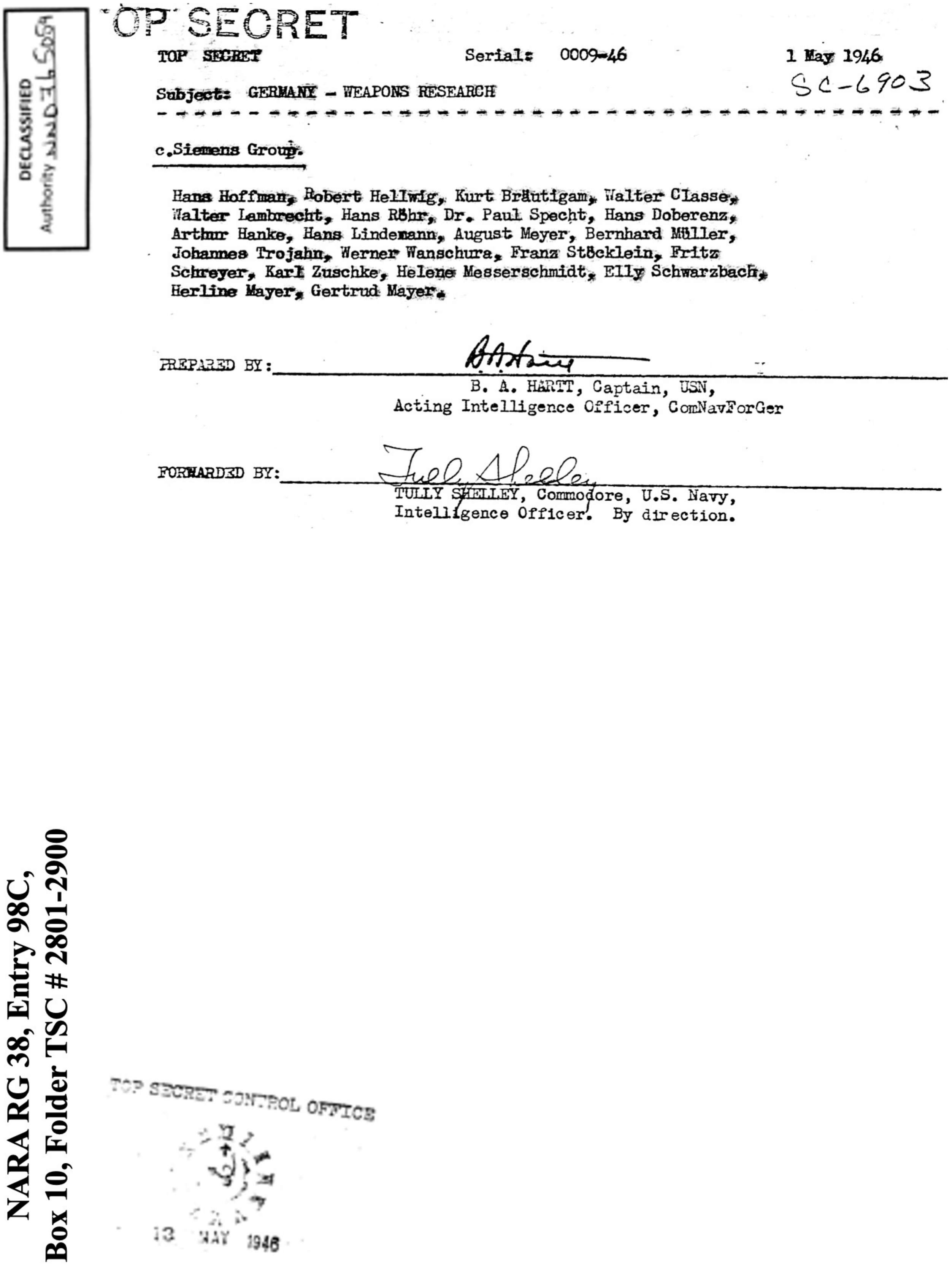
b.Gema Group.

Wilke, Rudolf	Leiter (Department head)
Wendt, Gerd	Labor-Ingenieur (Laboratory engineer)
Kerkhoff, Horst	Same
Tornow	Same
Janders, Waltraud	Assistentin
Sliwinsky, Edith	Elektro-Laborantin
Naulin, Willi	Mechaniker
Lange, Karl	Mechaniker
Tieger, Kurt	Konstrukteur (Draftsman)

- 3 -

NARA RG 38, Entry 98C, Box 10, Folder TSC # 2801-2900

Figure E.162: Serial 0009-46. Intelligence Division, Office of Chief of Naval Operations. Subject: Germany–Weapons Research. 1 May 1946. [NARA RG 38, Entry 98C, Box 10, Folder TSC # 2801–2900]



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Authority NND 765059

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TOP SECRET Serial: 0009-46 1 May 1946

SC-6903

Subject: GERMANY - WEAPONS RESEARCH

c. Siemens Group.

Hans Hoffman, Robert Hellwig, Kurt Bräutigam, Walter Classe, Walter Lambrecht, Hans Röhr, Dr. Paul Specht, Hans Doberenz, Arthur Hanke, Hans Lindemann, August Meyer, Bernhard Müller, Johannes Trojahn, Werner Wanschura, Franz Stöcklein, Fritz Schreyer, Karl Zuschke, Helene Messerschmidt, Elly Schwarzbach, Herline Mayer, Gertrud Mayer.

PREPARED BY:

B. A. HARTT, Captain, USN,
Acting Intelligence Officer, ComNavForGer

FORWARDED BY: Tully Shelley

TULLY SHELLEY, Commodore, U.S. Navy,
Intelligence Officer. By direction.

TOP SECRET CONTROL OFFICE

13 MAY 1946

NARA RG 38, Entry 98C,
Box 10, Folder TSC # 2801-2900

Figure E.163: Serial 0009-46. Intelligence Division, Office of Chief of Naval Operations. Subject: Germany–Weapons Research. 1 May 1946. [NARA RG 38, Entry 98C, Box 10, Folder TSC # 2801–2900]

Serial 0009-46. Intelligence Division, Office of Chief of Naval Operations. Subject: Germany–Weapons Research. 1 May 1946. [NARA RG 38, Entry 98C, Box 10, Folder TSC # 2801–2900]

SUMMARY: The following S.S.U. report, L-1262, dated 19 February 1946, concerns Weapons Research at Kreisel-Siemens-Gema, along with a list of leading personnel, their title and function.

GERMANY/BERLIN : MILITARY

Weapons Research at Kreisel-Siemens-Gema.

The information below comes from a well-placed and fairly reliable source:

1. The Russian technical office in the Gema-Haus in Köpenick [a suburb of Berlin] is now known as KSG (Kreisel-Siemens-Gema). It is under Navy control and directed by Lt. Col. Sherdok and Lt. Col. Grudnitzki (?).

[2.] Apparatus not yet tested for the Germany Navy is being further developed. These are: depth steering (Tiefensteurung) for submarines, floating steering (Schwebesteurung) for submarines, automatic fire control devices (Geschützsteurung), gyroscopic devices, steering for V-3 and V-4 weapons, aiming devices and gauges. The development is carried to the point of final tests; at the same time plans are made for mass production in Russia.

[...] 3. At present about 400 people are employed.

4. About 60 machine-tools are now operating; more are on the way from Morsleben, where an underground factory with about 2000 machines is being dismantled.

5. The Russians succeeded in retaining the most important specialists, many of them former party members. Below (paragraph 9) is a list of the more important employees in each group.

6. The Kreisel group, with the former employees of Kreisel-Geräte G.m.b.H., is carrying on the development of gyroscopic devices and hydraulic steering apparatus. The Siemens group, with the former employees of Siemens-Apparatebau is working on electrical steering apparatus, particularly remote-control steering and aiming devices. The Gema group is working with remote-control steering, bearing and aiming devices.

7. Wages paid by KSG [...]

8. V-3 and V-4 are about 15 m long and 3 m thick, larger than V-1 and V-2. Propulsion units go into action by groups. After one group has been emptied, it is ejected from the rocket. Steering and ignition are performed by remote control. Hulls for these weapons are said to be built in the Harz Mountains and in a factory near Berlin; exact addresses are not available.

9. Leading personnel of Kreisel-Siemens-Gema are the following:

[three pages of names, qualifications, and job descriptions]

[See document photos on pp. 5528–5531.

What exactly was at Morsleben, Saxony-Anhalt? "An underground factory with about 2000 machines" sounds like a very large facility. See also pp. 3433–3437, 3456–3416, 3708, 4922.

Anything being produced and reported by 19 February 1946 would almost certainly not be new technology, but rather simply restarted production of wartime German technology.

Many different projects, with various real names, had been vying for the titles of V-3 and V-4, which would have simply ben the third and fourth projects publicly announced after the V-1 cruise missile and V-2 or A-4 rocket. Thus the V-3 and V-4 rockets mentioned here may or may not be the same as V-3 or V-4 weapons mentioned in other sources.

Note that different components of these V-3 and V-4 rockets were being produced by different surviving wartime German factories: guidance, steering, or other systems at Kopenick, and hulls in the Harz Mountains (Nordhausen, Bleicherode, Gotha, or elsewhere?) and Berlin area (where?).

The V-3 and V-4 rockets described here do not match known or even modified versions of previously documented wartime German rockets. The V-2/A-4 was 1.65 m in diameter ("thick") and single-stage, unlike what is described here. The combined A-9/A-10 was multi-stage but approximately 26 m in total length for both stages, and 4.15 m thick for the lower A-10 stage. It is possible that information given in this report is simply a garbled description of A-4 or A-9/A-10 rockets or modified versions of them. However, given the level of detail in the rest of this report (lengthy lists of names and job duties of personnel working on the projects), it seems much more likely that this description is reasonably accurate, and that the V-3 and V-4 were novel rocket types that have not been previously documented.

If the information provided here is fairly accurate, one plausible interpretation is that it describes a relatively standard A-4 surrounded by strap-on booster rockets that assist with the launch but drop off once their propellant has been consumed. That approach would significantly increase the range and/or payload compared to an ordinary A-4 rocket, and it would be technologically relatively straightforward to implement. A 1.65-m-diameter A-4 with $\sim$ 0.68-meter-diameter booster rockets on opposite sides (or clustered all around it) would be $\sim$3 m "thick" with "propulsion units that go into action by groups" and then are "ejected from the rocket." Is there direct evidence for the development or existence of suitable strap-on solid- or liquid-propellant booster rockets?

Could the described rocket have been a wartime German project that was copied/modified after the war as the Soviet G-2 project (pp. 5560–5562)? Among other configurations, two or more A-4 rockets could have been strapped to the side of a central A-4 to serve as boosters.

As yet another possibility, there are several reasons to believe the described V-3 and V-4 rockets might have been intended to be submarine-launched ballistic missiles:

1. These V-3 and V-4 rockets are included in a list of projects for the German Navy, and alongside numerous projects for submarines.

2. It is known that Germany was actively pursuing submarine-launched versions of the V-1 and

V-2/A-4 that could be launched near the coast of the United States; see for example pp. 5618–5627 and 5628–5660.

3. It is known that German work on submarine-launched missiles was being conducted in the mountains in central Europe and not just on the seacoast; see for example pp. 5640–5645.

4. An A-4 launched from a submarine just off the U.S. coast could travel inland by a maximum range of approximately 350 km with a 1-ton payload, or approximately 280 km with a 2-ton payload (p. 5797). Alternatively, the submarine could keep its distance from coastal defenses and still launch missiles at targets on the coast up to those maximum ranges. (J. Edgar Hoover reported on German plans that "submarines would proceed to within 100 or 200 miles of the United States and then fire these rockets," p. 5626.) However, those ranges would not be satisfactory for targets that were too far from the coast—cities such as Chicago, or manufacturing plants throughout the interior United States. Increasing the amount of propellant and/or using multiple stages would greatly increase the range.

5. In response to attacks by the Allies, Germany rapidly moved its essential wartime manufacturing to less accessible areas (deeper into Europe and/or underground). Thus Germany would likely have expected that if it began to attack coastal targets in the United States, the United States would rapidly move essential industry further inland, and much U.S. industry was already far inland. German war planners would presumably have wanted to have correspondingly longer-range weapons available as soon as possible.

6. Other than the massive A-10 booster stage, other large wartime German rockets (A-4, A-9, and any extended-length versions of them) and postwar Russian rockets directly based on German technology (SS-1/R-1, G-1 design, SS-2/R-2, SS-3/R-5M, etc.) all had a standard diameter of 1.65 m, and varied in length between 14 m and 21 m. Increasing the amount of propellant and hence the payload and/or range could be readily accomplished by simply increasing the length from the starting length of 14 m for the A-4. In contrast, increasing the diameter from 1.65 m to 3 m would:

a. Require large modifications to equipment for producing cylindrical propellant tanks, dome-shaped tank ends, and ring-shaped structural supports for the rocket body.

b. Require major changes to rocket manufacturing areas (often underground tunnels), rocket-transporting trucks or train cars, storage areas, and launch sites.

c. Increase aerodynamic drag losses, which to a first approximation are proportional to the cross-sectional area of the rocket, by a factor of $(3/1.65)^2 \approx 3.3$.

7. The most compelling reason one could think of that would have made German engineers produce rockets that were not much longer than an A-4 but were much wider, despite these serious disadvantages, would be that

a. The rocket needed to carry more propellant than an A-4, in order to have an increased range and/or increased payload, AND

b. The rocket needed to be very compact in order to fit within a submarine or submarine-towed container, so it could only increase in diameter and not length.

8. A 12 October 1947 intelligence report from Russia reported that a team of German specialists was supervising the construction in Russia of "rockets are similar to the German 'V' type but larger in size. This rocket in the shape of a cigar is 16 m long and 2.5 to 3 m in diameter." (See p. 5566.) Those dimensions described in that 12 October 1947 report are very similar to the rocket dimensions described in this 1 May 1946 report.

9. After the war, German engineers in the United States produced the PGM-19 Jupiter (p. 5501) as a candidate submarine-launched ballistic missile (although it was ultimately deployed on land and not in submarines). Jupiter had a diameter of 2.67 m and length of 18 m, not too dissimilar from the dimensions described for the V-3 and V-4. It had a range of 2400 km with a 1-ton payload.]

S.D. 4840/MIS-926047. Headquarters European Command, Office of the Deputy Director of Intelligence. Possible use of Czechoslovak made arms in the Soviet Army and the present status in the Czechoslovak armament industry. Annex A. June 1946 [NARA RG 319, Entry NM3-85M, Box 44, Folder 926047].

It is known that the following plants are producers of scientific warfare weapons: A.E.G. Plant—located at BEDRICHOV; Poldina Hut—VITKOVICE; Siemens Plant—CESKE BUDEJEVIC; and the Askania Works. The A.E.G. Plant produces weapons of a military and secret nature, under the guidance of German scientists. Access is barred to all persons of allied nationality. V-3 and V-4 models presumed to be still there, including all data. Poldina Hut is now producing semi-finished steel and iron products; Siemens—proximity fuses, homing torpedoes, and similar delicate equipment; Askania—fine instruments and laboratory equipment. [...]

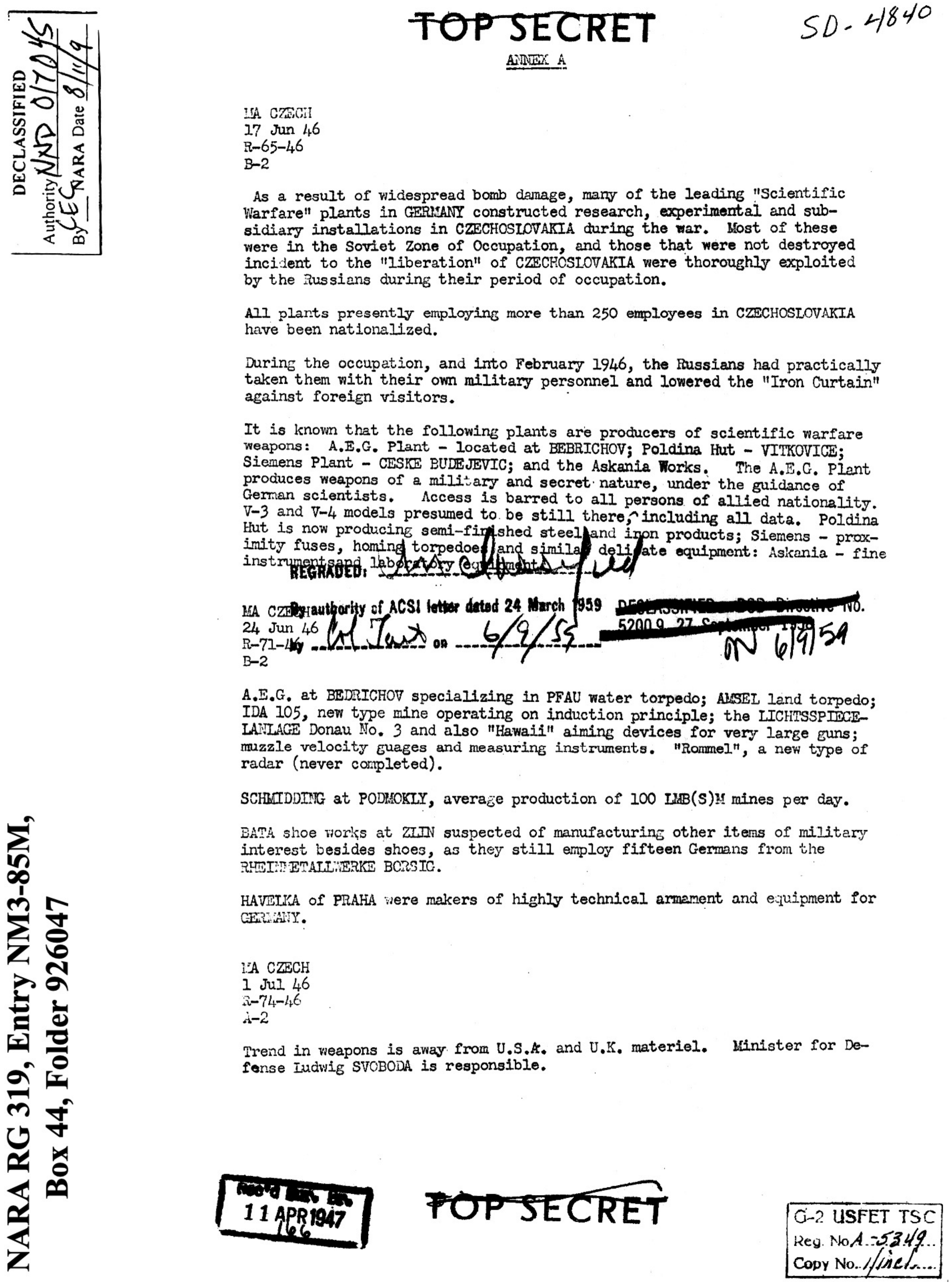
A.E.G. at BEDRICHOV specializing in PFAU water torpedo; AMSEL land torpedo; IDA 105, new type mine operating on induction principle; the LICHTSPIEGELANLAGE Donau No. 3 and also "Hawaii" aiming devices for very large guns; muzzle velocity gauges and measuring instruments. "Rommel", a new type of radar (never completed).

SCHMIDDING at PODMOKLY, average production of 100 LMB(S)M mines per day.

BATA shoe works at ZLIN suspected of manufacturing other items of military interest besides shoes, as they still employ fifteen Germans from the RHEINMETALLWERKE BORSIG.

HAVELKA of PRAHA were makers of highly technical armament and equipment for GERMANY.

[See document photo on p. 5536.]



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SD-4840

ANNEX A

MA CZECH
17 Jun 46
R-65-46
B-2

As a result of widespread bomb damage, many of the leading "Scientific Warfare" plants in GERMANY constructed research, experimental and subsidiary installations in CZECHOSLOVAKIA during the war. Most of these were in the Soviet Zone of Occupation, and those that were not destroyed incident to the "liberation" of CZECHOSLOVAKIA were thoroughly exploited by the Russians during their period of occupation.

All plants presently employing more than 250 employees in CZECHOSLOVAKIA have been nationalized.

During the occupation, and into February 1946, the Russians had practically taken them with their own military personnel and lowered the "Iron Curtain" against foreign visitors.

It is known that the following plants are producers of scientific warfare weapons: A.E.G. Plant - located at BEBRICHOV; Poldina Hut - VITKOVICE; Siemens Plant - CESKE BUDEJEVIC; and the Askania Works. The A.E.G. Plant produces weapons of a military and secret nature, under the guidance of German scientists. Access is barred to all persons of allied nationality. V-3 and V-4 models presumed to be still there, including all data. Poldina Hut is now producing semi-finished steel and iron products; Siemens - proximity fuses, homing torpedoes and similar delicate equipment: Askania - fine instruments and laboratory equipment.

REGRADED: Unclassified
By authority of ACSI letter dated 24 March 1959
by Col Test on 6/9/59

~~DECLASSIFIED DOD Directive NO. 5200.9, 27 September 1958~~
DN 6/9/59

MA CZECH
24 Jun 46
R-71-46
B-2

A.E.G. at BEDRICHOV specializing in PFAU water torpedo; AMSEL land torpedo; IDA 105, new type mine operating on induction principle; the LICHTSSPIEGELANLAGE Donau No. 3 and also "Hawaii" aiming devices for very large guns; muzzle velocity guages and measuring instruments. "Rommel", a new type of radar (never completed).

SCHMIDDING at PODMOKLY, average production of 100 LMB(S)M mines per day.

BATA shoe works at ZLIN suspected of manufacturing other items of military interest besides shoes, as they still employ fifteen Germans from the RHEINMETALLWERKE BORSIG.

HAVELKA of PRAHA were makers of highly technical armament and equipment for GERMANY.

MA CZECH
1 Jul 46
R-74-46
A-2

Trend in weapons is away from U.S.A. and U.K. materiel. Minister for Defense Ludwig SVOBODA is responsible.

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11 APR 1947
166

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NARA RG 319, Entry NM3-85M,
Box 44, Folder 926047

Figure E.164: S.D. 4840/MIS-926047. Headquarters European Command, Office of the Deputy Director of Intelligence. Possible use of Czechoslovak made arms in the Soviet Army and the present status in the Czechoslovak armament industry. Annex A. June 1946 [NARA RG 319, Entry NM3-85M, Box 44, Folder 926047].

Headquarters Berlin District, United States Army, Office of the AC of S, G-2. 31 October 1946. Special Memorandum No 18. [**NARA RG 319, Entry A1-134A, Box 17, Folder XEI69886 Russian Deportation of German Scientists & Technicians**]

Current deportations of German personnel to Russia came as a complete surprise to officer personnel in Karlshorst and to at least some key figures in Potsdam. [...]

Current Soviet deportation and dismantling activities concerning mostly armament factories and plants, include: [...]

3. Dismantling of Schwarzenberg Wasserstoff and Sauerstoff Werke (Hydrogen and Oxygen works).

4. Reported as completely destroyed were Bleicherode V-2 works and “Program A9” Raketenjaeger plants.

[This report covers wartime German plants that were removed by the Soviets.

One of those plants was the “Program A9 Raketenjaeger” or rocket-fighter plant. Program A9 rocket seems like a clear reference to the A-9 rocket, and fighter or Jaeger denotes a manned flying vehicle. This seems to be further evidence that wartime German plants were mass-producing manned A-9 rockets.

Wartime German hydrogen and oxygen production plants are mentioned in conjunction with the report of V-2 and A-9 rocket programs. Liquid oxygen was widely used an the oxidizer in V-2 (and possibly A-9) rockets. Relatively low-performance fuels such as alcohol and petroleum derivatives were used in rockets. Officially liquid hydrogen, a fuel that was much higher performance but needed to be kept so cold that it was difficult to handle, was not. Yet this report seems to suggest that liquid hydrogen was indeed produced and used by the German rocket programs. That interpretation is supported by other claims that liquid hydrogen was used; see for example p. 5311, 5448, 5381, and p. 5764.

Schwarzenberg is only $\sim$ 20 km from the Jachymov uranium mine. Is that simply a coincidence or were nuclear, aerospace, and other top-priority programs concentrated in that geographical area?]

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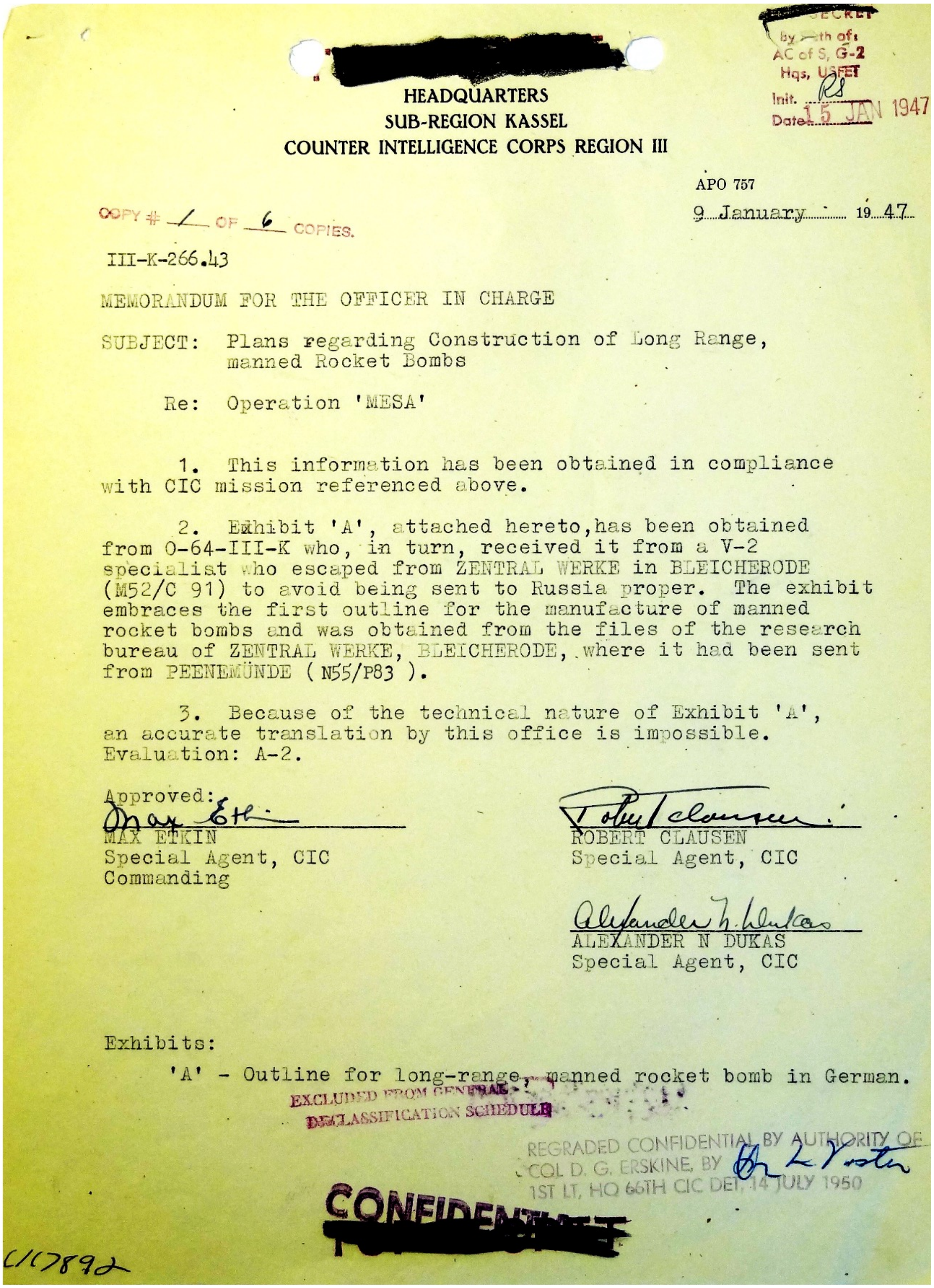
NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Soviet Guided Missiles, Rockets and V-Weapons Research, Development and Production Vol. 1, Fldr. 2 of 3



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by [illegible]th of:
AC of S, G-2
Hqs, USFET
Init. RS
Date 15 JAN 1947

HEADQUARTERS
SUB-REGION KASSEL
COUNTER INTELLIGENCE CORPS REGION III

APO 757
9 January 1947

COPY # 1 OF 6 COPIES.

III-K-266.43

MEMORANDUM FOR THE OFFICER IN CHARGE

SUBJECT: Plans regarding Construction of Long Range, manned Rocket Bombs

Re: Operation 'MESA'

1. This information has been obtained in compliance with CIC mission referenced above.

2. Exhibit 'A', attached hereto, has been obtained from 0-64-III-K who, in turn, received it from a V-2 specialist who escaped from ZENTRAL WERKE in BLEICHERODE (M52/C 91) to avoid being sent to Russia proper. The exhibit embraces the first outline for the manufacture of manned rocket bombs and was obtained from the files of the research bureau of ZENTRAL WERKE, BLEICHERODE, where it had been sent from PEENEMÜNDE (N55/P83).

3. Because of the technical nature of Exhibit 'A', an accurate translation by this office is impossible. Evaluation: A-2.

Approved:
Max Etkin
MAX ETKIN
Special Agent, CIC
Commanding

Robert Clausen
ROBERT CLAUSEN
Special Agent, CIC

Alexander N. Dukas
ALEXANDER N DUKAS
Special Agent, CIC

Exhibits:

'A' - Outline for long-range, manned rocket bomb in German.

EXCLUDED FROM GENERAL
DECLASSIFICATION SCHEDULE

REGRADED CONFIDENTIAL BY AUTHORITY OF
COL D. G. ERSKINE, BY
1ST LT, HQ 66TH CIC DET, 14 JULY 1950

CONFIDENTIAL

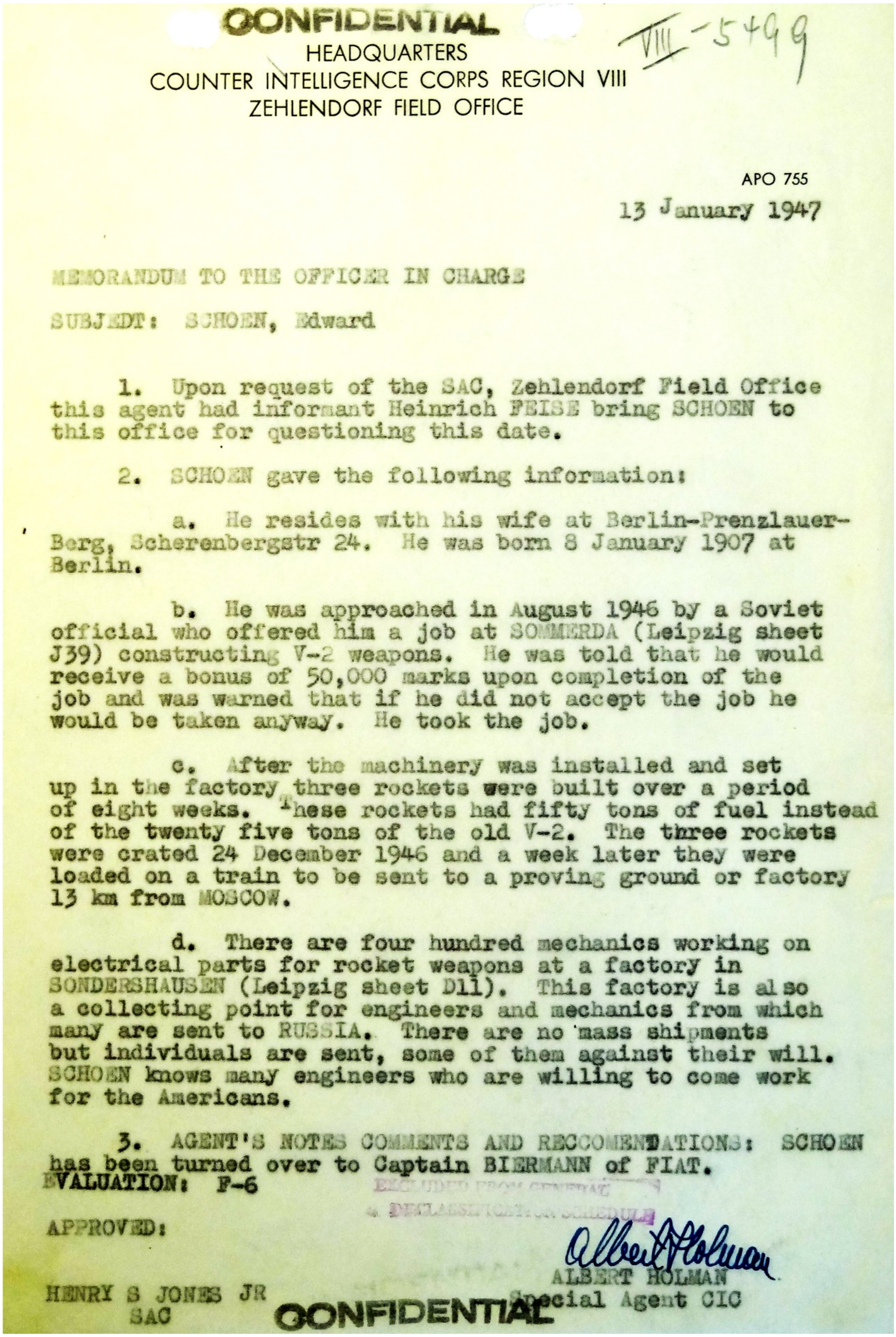
[redacted]

C/C7892

Figure E.165: Robert Clausen and Alexander N. Dukas. 9 January 1947. SUBJECT: Plans regarding Construction of Long Range, manned Rocket Bombs [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Soviet Guided Missiles, Rockets and V-Weapons Research, Development and Production Vol. 1, Fldr. 2 of 3]. "Exhibit 'A', attached hereto... embraces the first outline for the manufacture of manned rocket bombs and was obtained from the files of the research bureau of ZENTRAL WERKE, BLEICHERODE, where it had been sent from PEENEMÜNDE..." [Exhibit A is missing from the NARA file.]

DECLASSIFIED
Authority NND 007016

NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Soviet Guided Missiles, Rockets and V-Weapons Research, Development and Production Vol. 1, Fldr. 2 of 3



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HEADQUARTERS
COUNTER INTELLIGENCE CORPS REGION VIII
ZEHLENDORF FIELD OFFICE

VIII-5499

APO 755
13 January 1947

MEMORANDUM TO THE OFFICER IN CHARGE

SUBJECT: SCHOEN, Edward

1. Upon request of the SAC, Zehlendorf Field Office this agent had informant Heinrich FEISE bring SCHOEN to this office for questioning this date.

2. SCHOEN gave the following information:

a. He resides with his wife at Berlin-Prenzlauer-Berg, Scherenbergstr 24. He was born 8 January 1907 at Berlin.

b. He was approached in August 1946 by a Soviet official who offered him a job at SOMMERDA (Leipzig sheet J39) constructing V-2 weapons. He was told that he would receive a bonus of 50,000 marks upon completion of the job and was warned that if he did not accept the job he would be taken anyway. He took the job.

c. After the machinery was installed and set up in the factory three rockets were built over a period of eight weeks. These rockets had fifty tons of fuel instead of the twenty five tons of the old V-2. The three rockets were crated 24 December 1946 and a week later they were loaded on a train to be sent to a proving ground or factory 13 km from MOSCOW.

d. There are four hundred mechanics working on electrical parts for rocket weapons at a factory in SONDERSHAUSEN (Leipzig sheet D11). This factory is also a collecting point for engineers and mechanics from which many are sent to RUSSIA. There are no mass shipments but individuals are sent, some of them against their will. SCHOEN knows many engineers who are willing to come work for the Americans.

3. AGENT'S NOTES COMMENTS AND RECCOMENDATIONS: SCHOEN has been turned over to Captain BIERMANN of FIAT.
EVALUATION: F-6

EXCLUDED FROM GENERAL
& DECLASSIFICATION SCHEDULE

APPROVED:

Albert Holman
ALBERT HOLMAN
Special Agent CIC

HENRY S JONES JR
SAC

CONFIDENTIAL

Figure E.166: Albert Holman. 13 January 1947. SUBJECT: SCHOEN, Edward [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Soviet Guided Missiles, Rockets and V-Weapons Research, Development and Production Vol. 1, Fldr. 2 of 3]. "...Three rockets were built over a period of eight weeks. These rockets had fifty tons of fuel [probably thrust, a translation error] instead of the twenty five tons of the old V-2. The three rockets were crated 24 December 1946..."

V. L. Rychly. Intelligence Report 324366. 13 November 1946. Subject: Former German Factories Located in Czechoslovakia. [NARA RG 319, Entry NM3-85A, Box 2126, Folder 324361 THRU 324370]

Following information on former German factories located in Czechoslovakia was obtained during an unconducted automobile trip to northern Bohemia (formerly Sudentenland) during the days of 9 and 10 November 1946.

1. AEG FACTORY, BEDRICHOV

Prior to German occupation of Czechoslovakia this plant was engaged in the production of fine table linen. During the first raids on Berlin a section of AEG research department was moved into this factory. Some of Germany's finest apparatus was concentrated in the spacious factory, and a large cement basin was built for testing aerial and naval torpedoes. The German Scientists and Technicians were engaged in the development of the following:

- a. Aerial and Naval Torpedoes
- b. Guided Torpedoes
- c. Guided missiles
  - (1) Ground to ground
  - (2) Ground to air
- d. Supersonic missiles

During an inspection of this plant made in November 1945, the German Scientists continued with their work under Soviet supervision.

Present Status

During the first days of November 1945, the entire plant was evacuated from Bedrichov. The testing basin was destroyed. All scientific apparatus was removed and consolidated in the AEG plant in Podmokly, Czechoslovakia, Ustecka ulice 20, under the supervision of the Czechoslovak Ministry of National Defense.

2. AEG FACTORIES in BENESOV

As the factory in Bedrichov, so the largest milling factories in Benesov were requisitioned by the Germans during the period of occupation in Czechoslovakia. A conducted inspection of both plants in November 1945, revealed that research in Benesov was conducted on a lesser scale. However, both factories in Benesov remained under Soviet supervision till December 1945, when they were partially evacuated by the Soviets.

Present Status

During the first days in November 1945, the remaining research facilities were removed under the order of Czechoslovak Ministry of National Defense and moved to the AEG plant located in Liberea, Czechoslovakia.

3. W. SCHMIDDING, POMOKLY

Originally built by the German Kriegmarine, this plant was engaged during the days of war in the development and production of sea, rive and land mines. The W. SCHMIDDING research department completed for the German Luftwaffe,

a. The solid fuel-rocket drive

b. Gasoline burning-power

and conducted successful tests on the Ingolin torpedoes for the Kriegmarine.

Present status

Now completely nationalized and under the supervision of Krizik and Spol (Krizik Corporation—Specialists in Radio, Radar, etc. equipment), this plant located on Ustecka Ulice 30, is engaged in the production of cast aluminum household products [...] The plant was reconverted to peace production. However, the research department remained intact. No contact could be made with the German Nationals employed in this department to obtain complete details.

4. COMMENT

The liquidation of the AEG Factory in Bedrichov and the AEG factories in Benesov, together with the consolidation of all scientific apparatus in Podmokly and Liberec, is the first indication that the Czechoslovak Government is interested in setting up a large organization to conduct research and development of weapons. The Ministry of National Defense in Czechoslovakia is determined to take the advantage of the advanced wartime German work in this field. [...]

[This report by Rychly confirms some of the observations from his earlier report. Note that the wartime German facilities in Czechoslovakia were equipped with “Germany’s finest apparatus,” filled with German scientists, and working on a wide range of high-priority research programs. This was a very important area, and virtually all of its wartime information, products, facilities, and personnel were removed by the Soviet Union without much opportunity for U.S. and U.K. inspectors to ever learn about them.]

Egmont F. Koenig. MIS-326058. Report No. E-174-46. Office of the Military Attaché, American Embassy Prague. 20 November 1946. Subject: Czechoslovak Research Center. [NARA RG 319, Entry NM3-85A, Box 2138, Folder 326051 to 326060]

[...] Approximately 400 German technicians have been retained by the Czechoslovak army, and are being employed on work involving research on guided missiles and rockets.

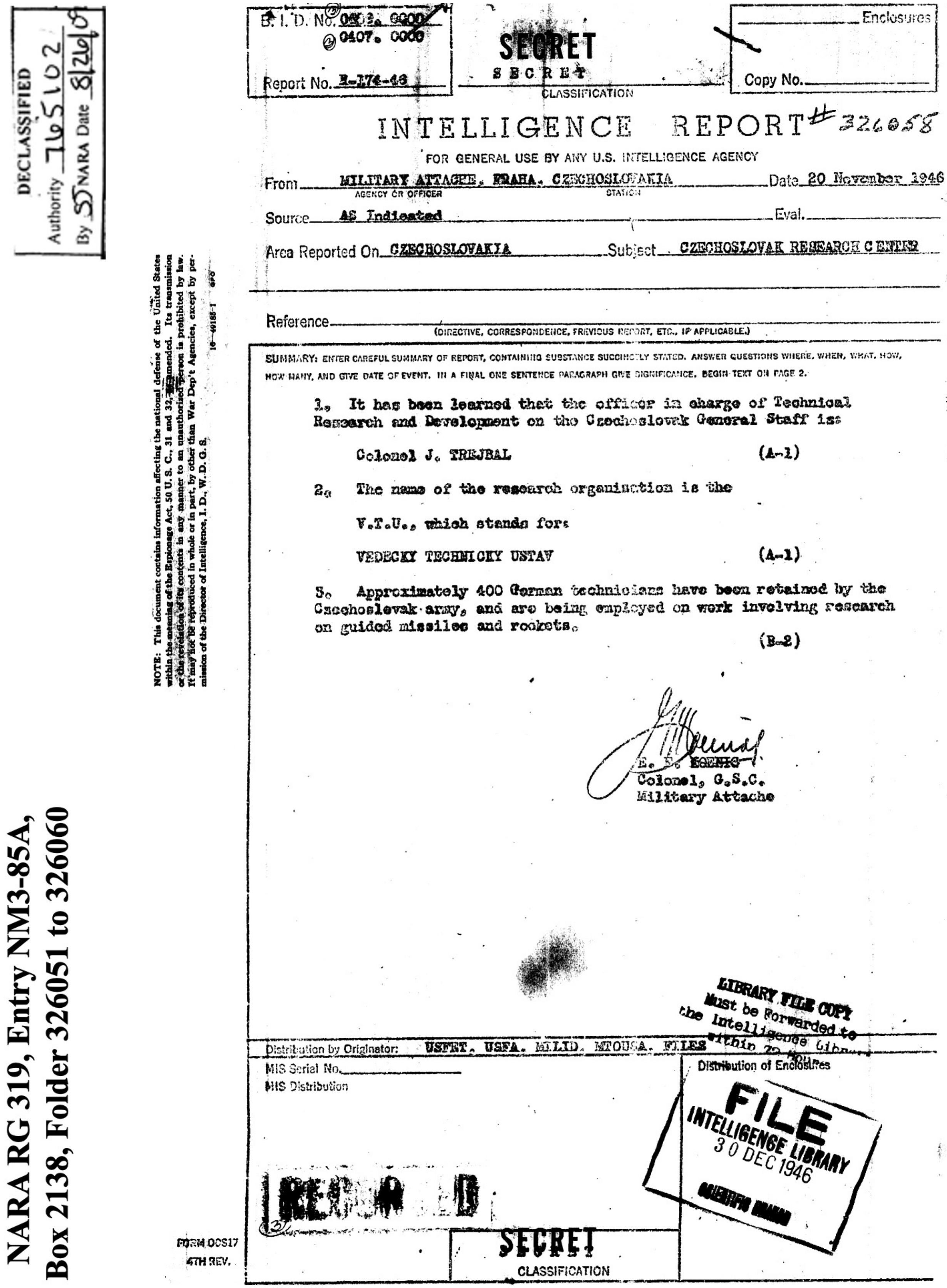
[See document photo on p. 5542. Brigadier General Egmont F. Koenig (1892–1974) was the U.S. military attaché in Czechoslovakia from January 1946 to May 1947. He had a distinguished military career, and his reports of leftover wartime advanced German technology in postwar Czechoslovakia should be taken very seriously. For more information, see:

https://generals.dk/general/Koenig/Egmont_Francis/USA.html

https://valor.militarytimes.com/hero/107290

https://discovery.nationalarchives.gov.uk/details/r/D7403682

https://es.findagrave.com/memorial/22512315/egmont-francis-koenig]



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Authority 765102
By SS NARA Date 8/26/09

B. I. D. No. ~~0803. 0000~~
② 0407. 0000
Report No. E-174-46

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INTELLIGENCE REPORT #326058

FOR GENERAL USE BY ANY U.S. INTELLIGENCE AGENCY

From MILITARY ATTACHE, PRAHA, CZECHOSLOVAKIA (AGENCY OR OFFICER / STATION) Date 20 November 1946

Source AS Indicated Eval.

Area Reported On CZECHOSLOVAKIA Subject CZECHOSLOVAK RESEARCH CENTER

Reference (DIRECTIVE, CORRESPONDENCE, PREVIOUS REPORT, ETC., IF APPLICABLE.)

SUMMARY: ENTER CAREFUL SUMMARY OF REPORT, CONTAINING SUBSTANCE SUCCINCTLY STATED. ANSWER QUESTIONS WHERE, WHEN, WHAT, HOW, HOW MANY, AND GIVE DATE OF EVENT. IN A FINAL ONE SENTENCE PARAGRAPH GIVE SIGNIFICANCE. BEGIN TEXT ON PAGE 2.

1. It has been learned that the officer in charge of Technical Research and Development on the Czechoslovak General Staff is:

Colonel J. TREJBAL (A-1)

2. The name of the research organization is the

V.T.U., which stands for:

VEDECKY TECHNICKY USTAV (A-1)

3. Approximately 400 German technicians have been retained by the Czechoslovak army, and are being employed on work involving research on guided missiles and rockets.

(B-2)

E. F. KOENIG
Colonel, G.S.C.
Military Attache

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NARA RG 319, Entry NM3-85A, Box 2138, Folder 326051 to 326060

Figure E.167: Egmont F. Koenig. MIS-326058. Report No. E-174-46. Office of the Military Attaché, American Embassy Prague. 20 November 1946. Subject: Czechoslovak Research Center. [NARA RG 319, Entry NM3-85A, Box 2138, Folder 326051 to 326060]

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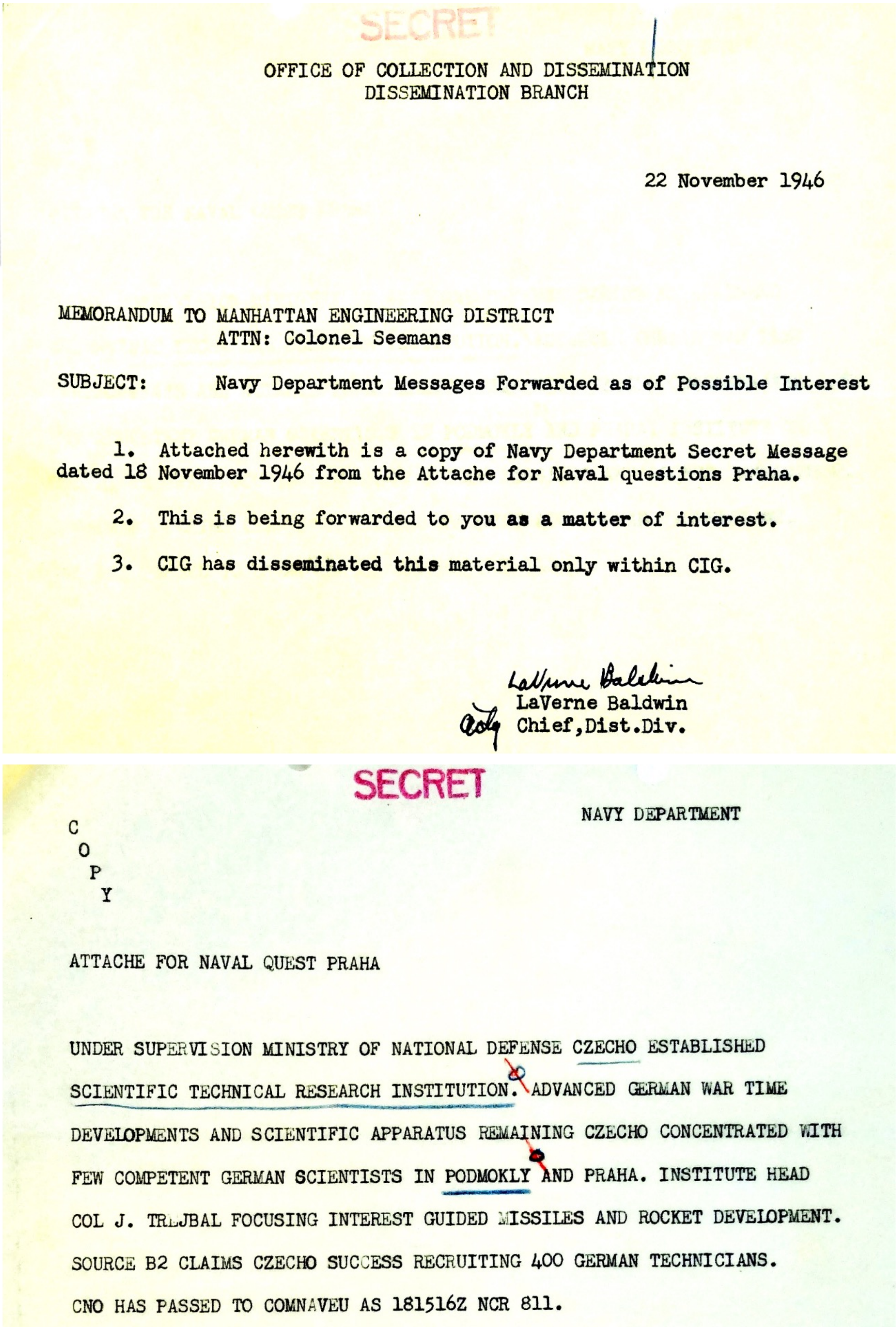
Authority NND 947017

NARA RG 77, Entry UD-22A, Box 175, Folder World



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OFFICE OF COLLECTION AND DISSEMINATION
DISSEMINATION BRANCH

22 November 1946

MEMORANDUM TO MANHATTAN ENGINEERING DISTRICT
ATTN: Colonel Seemans

SUBJECT: Navy Department Messages Forwarded as of Possible Interest

1. Attached herewith is a copy of Navy Department Secret Message dated 18 November 1946 from the Attache for Naval questions Praha.

2. This is being forwarded to you as a matter of interest.

3. CIG has disseminated this material only within CIG.

LaVerne Baldwin
acty LaVerne Baldwin
Chief, Dist. Div.

SECRET

NAVY DEPARTMENT

C
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P
Y

ATTACHE FOR NAVAL QUEST PRAHA

UNDER SUPERVISION MINISTRY OF NATIONAL DEFENSE CZECHO ESTABLISHED SCIENTIFIC TECHNICAL RESEARCH INSTITUTION. ADVANCED GERMAN WAR TIME DEVELOPMENTS AND SCIENTIFIC APPARATUS REMAINING CZECHO CONCENTRATED WITH FEW COMPETENT GERMAN SCIENTISTS IN PODMOKLY AND PRAHA. INSTITUTE HEAD COL J. TREJBAL FOCUSING INTEREST GUIDED MISSILES AND ROCKET DEVELOPMENT. SOURCE B2 CLAIMS CZECHO SUCCESS RECRUITING 400 GERMAN TECHNICIANS. CNO HAS PASSED TO COMNAVEU AS 181516Z NCR 811.

Figure E.168: Top: LaVerne Baldwin to L. E. Seemans, 22 November 1946. Bottom: U.S. Naval Attaché Prague. 18 November 1946 [NARA RG 77, Entry UD-22A, Box 175, Folder World].

Egmont F. Koenig. Dispatch No. A-161-46. Office of the Military Attaché, American Embassy Prague. 20 November 1946. Subject: German V-Weapons in Czechoslovakia. [NARA RG 319, Entry NM3-85A, Box 2144, Folder 326851 THRU 326860]

Subject: German V-Weapons in Czechoslovakia.

1. It has been determined with a fair degree of reliability (B-2) that the "V-4" weapon removed by the Russians from Bedrichov was the nose of a surface to surface guided missile, referred to as the "Pfau-2".

2. This nose had a new and more powerful charge, and missile itself was reported to have considerably increased range over the A-4. (B-3)

3. There are two reports as to the type of head delivered to the Russians:

a. That it was a homing device directed at radio stations or along radio beams. (C-3)

b. That it was a "Kommandogeraet", recording altitude, velocity, and other data of the missile. (C-3)

4. Attention is invited to our report No. R-164-46, dated 13 November 1946, Subject: Former German Factories located in Czechoslovakia [see p. 5540], which informs you of the complete dismantling of the research installations at Bedrichov [AEG factory at Bedrichov/Friedrichsthal/Benesov nad Ploucnici], and their move—in toto—to the new Czechoslovak army research center at Podmokly. (A-1)

5. It has also become known that under the "Two-Year Plan", the army has requested a total of eighteen billion Korunas for research and development. Eleven billion kcs for 1947 and seven billion kcs for 1948. (B-2). For a small country like this, such sums are astronomically profligate.

[All research in Czechoslovakia was ultimately turned over to the Soviet Union, although the postwar Czechoslovakian government initially tried to operate independently. If that government was willing to invest an "astronomically profligate" amount of their money in research and development at former German installations during the very lean years immediately after the war, they must have been extremely impressed by the wartime German technologies that remained at those installations. What exactly were those, and where is the documentation for them now?

From several available documents, "Pfau" seems to have been a general name for certain types of automated guidance systems for missiles and torpedoes [see for example p. 5554; Trenkle 1987, pp. 121, 123]. The "Pfau-2" mentioned here was apparently the guidance system of a very large missile, the V-4, which was described in this document as having greater capabilities than the A-4 (V-2). How advanced and how accurate was the guidance system?

How much payload could the V-4 missile carry? Was the "new and more powerful charge" a conventional explosive or something else?

What was the "considerably increased range over the A-4"? How large was the V-4 missile, in order to have had both an improved payload and an increased range?

For Rychly's statement that this V-4 had actually been completed, see p. 5516.]

V. L. Rychly. Intelligence Report 339171. 9 December 1946. Subject: Czechoslovakia—Scientific and Technical Institution—Re-establishment of. [NARA NARA RG 77, Entry UD-22A, Box 175, Folder World; and RG 319, Entry NM3-85A, Box 2229, Folder 339171 to 339180].

SUMMARY

The Czechoslovak Ministry of National Defence decided to re-establish its pre-war Scientific and Technical Institution (V.T.U.—Vedecky Technicky Ustav) after the Soviet refusal to share their latest military developments with the Czechoslovak Army. According to Czechoslovak members of the V.T.U. in the Czechoslovak General Staff at Praha, Czechoslovakia will base its research on the latest German military developments that remained in Czechoslovakia after German occupation and the U.S.S.R. liberation.

1. The U.S.S.R. was cognizant of the fact that the Germans dispersed many of their important research installations in Czechoslovakia in order to prevent their destruction by the allied bombers or to remove them from territories in danger of being captured by the allied forces. Colonel J. Zeman member of the Scientific and Technical Institution (V.T.U.–Vedecky Technicky Ustav) in Praha claims that the Soviets in Czechoslovakia followed a carefully prepared plan for the exploitation of German research sections, and thus gained a clear insight into the military research conducted by the Germans in Czechoslovakia at the end of the war. Surprisingly enough, the German factories and research sections were not heavily damaged by allied bombings or destroyed by the Czechoslovak and foreign slave labor in their enthusiasm over liberation.

2. The Czechoslovaks, totally disorganized after their liberation, were not allowed to enter the German military establishments taken over by the Soviets. For this reason, the Czechoslovak General Staff was ignorant of the value of research apparatus that was left in Czechoslovakia by the fleeing Germans. They could not determine the physical conditions or the military value of the various German-owned or German-controlled research facilities. The Czechoslovak as well as the United States and British exploitation teams were unable to enter or examine most of the equipment the Germans left in Czechoslovakia. Thus U.S.S.R. was in a preferential position to obtain sufficient information on developments by the Germans, including in many cases models or actual weapons.

3. The Czechoslovak General Staff assumed, according to Major F. Vokoun from the V.T.U., of the Czechoslovak General Staff, that the technological knowledge possessed by the Germans would be made available to the Czechs by the Soviet Technical Commission. However, as all attempts failed to obtain such information from the Red Army, the Czechs with the help of their technical personnel made every effort to rescue everything that was not tagged and sent to Russia. Many German institutions that were not labelled by the Soviets as war-booty fell into the hands of the Czechoslovaks. In other cases, German nationals co-operated with the Czechs in hopes of better treatment.

4. As the Scientific and Technical Institution (V.T.U.) started to function again, two research sections were fully equipped and ready to continue with the research on the developments made by the Germans. One such section of the V.T.U. is located in the rear of the Czechoslovak General Staff Building in Praha, the other in Podmokly (Northern Bohemia). Staff Captain F. E. Zeman

of the V.T.U. in Praha revealed that the proposed plan in the military field for the next two years (1947–1948) is the continuance of research on the latest German developments in the following fields:

(1) Electronics:
  (a) Proximity fuzes
  (b) Acoustic proximity fuzes
  (c) Infra-red devices
  (d) Infra-red proximity fuzes

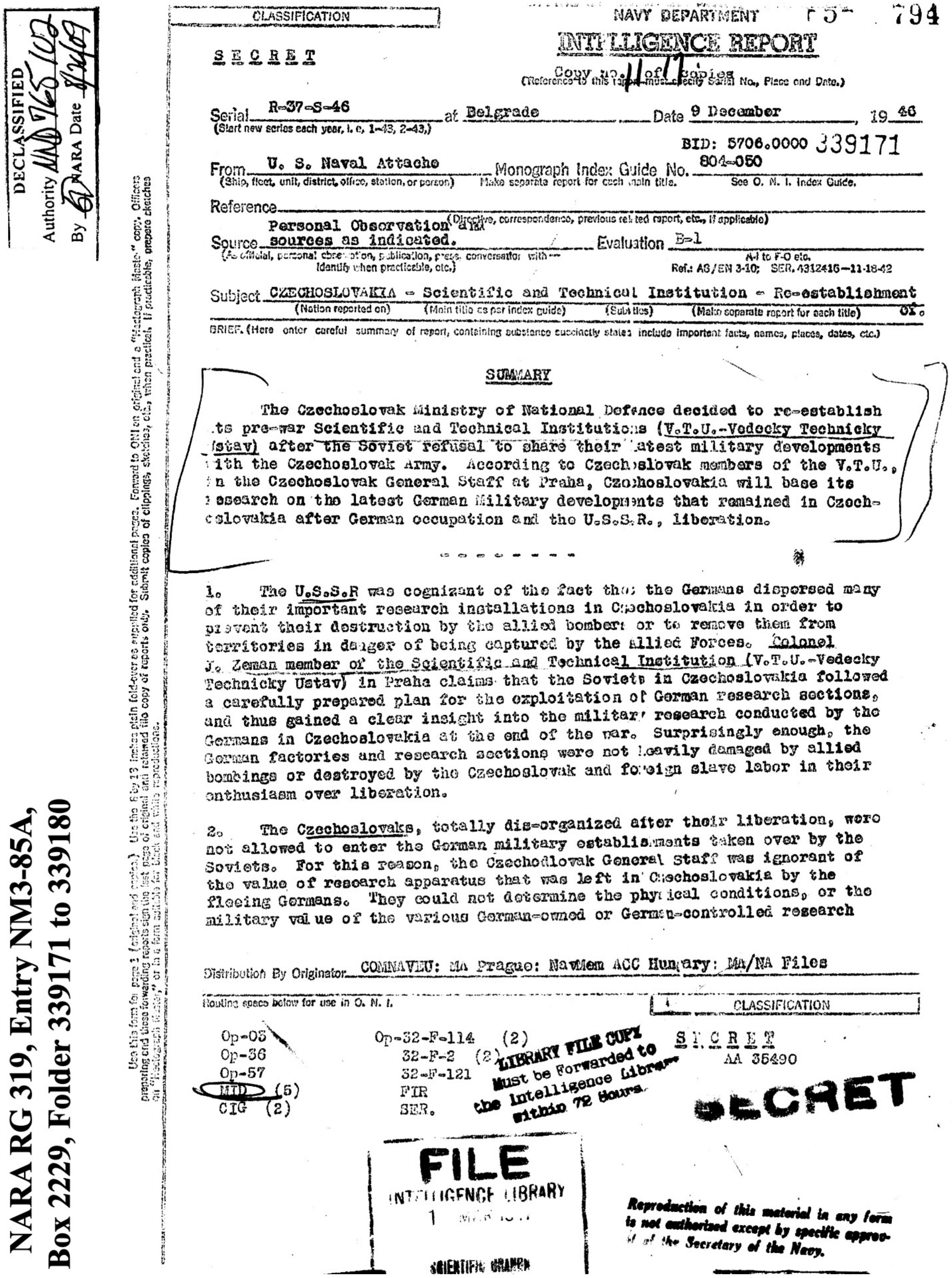
(2) Guided missiles

(3) Rockets:
  (a) With solid fuel drive
  (b) With liquid fuel drive

(4) Hypervelocity guns:
  To be developed:
    Heavy calibers at Skoda
    Light calibers at Zbrojovka, Brno

5. Included in the Czechoslovak estimates for the two years 1947–1948 is the immense sum of 18,000,000,000 Czechoslovak crowns, designated as the Secret Fund set aside for the Ministry of National Defence. Just how much of the secret fund will be allocated to military research could not be reasonably determined, but it is generally assumed that the Scientific and Technical Institution will receive a fairly large appropriation.

[See document photos on pp. 5547–5548.]



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Box 2229, Folder 339171 to 339180

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INTELLIGENCE REPORT

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Serial R-37-S-46 at Belgrade Date 9 December, 19 46
(Start new series each year, i. e, 1-43, 2-43,)

BID: 5706.0000 339171

From U. S. Naval Attache Monograph Index Guide No. 804-050
(Ship, fleet, unit, district, office, station, or person) Make separate report for each main title. See O. N. I. Index Guide.

Reference
(Directive, correspondence, previous related report, etc., if applicable)

Source Personal Observation and sources as indicated. Evaluation B-1
(As official, personal observation, publication, press, conversation with — identify when practicable, etc.) A-1 to F-O etc. Ref.: AS/EN 3-10; SER. 4312416—11-18-42

Subject CZECHOSLOVAKIA - Scientific and Technical Institution - Re-establishment of.
(Nation reported on) (Main title as per index guide) (Subtitles) (Make separate report for each title)

BRIEF. (Here enter careful summary of report, containing substance succinctly stated include important facts, names, places, dates, etc.)

SUMMARY

The Czechoslovak Ministry of National Defence decided to re-establish ts pre-war Scientific and Technical Institutions (V.T.U.-Vedecky Technicky stav) after the Soviet refusal to share their latest military developments ith the Czechoslovak Army. According to Czechoslovak members of the V.T.U., n the Czechoslovak General Staff at Praha, Czechoslovakia will base its esearch on the latest German Military developments that remained in Czechoslovakia after German occupation and the U.S.S.R., liberation.

- - - - - - - -

1. The U.S.S.R was cognizant of the fact that the Germans dispersed many of their important research installations in Czechoslovakia in order to prevent their destruction by the allied bombers or to remove them from territories in danger of being captured by the Allied Forces. Colonel J. Zeman member of the Scientific and Technical Institution (V.T.U.-Vedecky Technicky Ustav) in Praha claims that the Soviets in Czechoslovakia followed a carefully prepared plan for the exploitation of German research sections, and thus gained a clear insight into the military research conducted by the Germans in Czechoslovakia at the end of the war. Surprisingly enough, the German factories and research sections were not heavily damaged by allied bombings or destroyed by the Czechoslovak and foreign slave labor in their enthusiasm over liberation.

2. The Czechoslovaks, totally dis-organized after their liberation, were not allowed to enter the German military establishments taken over by the Soviets. For this reason, the Czechoslovak General Staff was ignorant of the value of research apparatus that was left in Czechoslovakia by the fleeing Germans. They could not determine the physical conditions, or the military value of the various German-owned or German-controlled research

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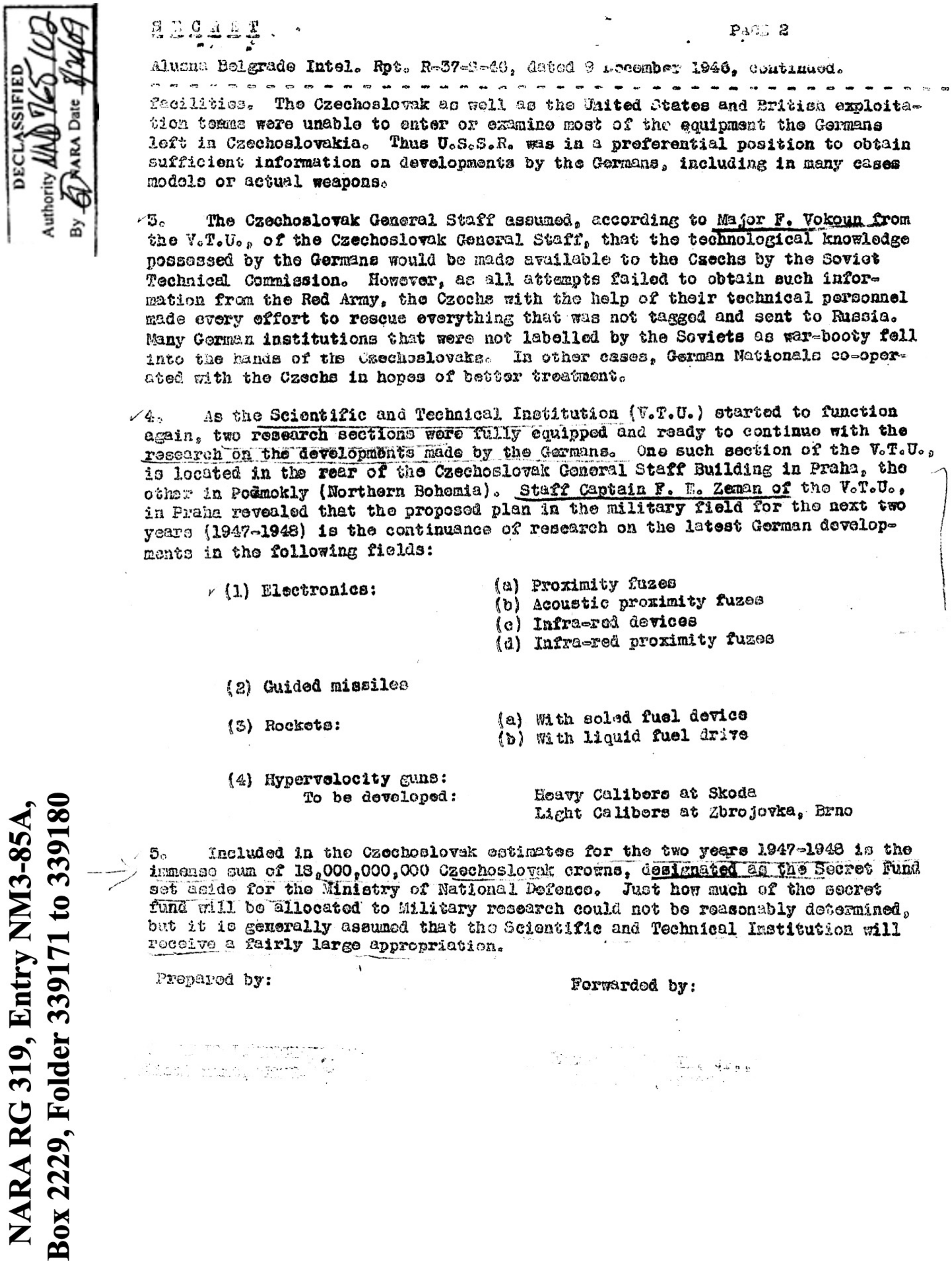
Figure E.169: V. L. Rychly. Intelligence Report 339171. 9 December 1946. Subject: Czechoslovakia—Scientific and Technical Institution—Re-establishment of. [NARA NARA RG 77, Entry UD-22A, Box 175, Folder World; and RG 319, Entry NM3-85A, Box 2229, Folder 339171 to 339180].



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Alusna Belgrade Intel. Rpt. R-37-S-46, dated 9 December 1946, continued.

facilities. The Czechoslovak as well as the United States and British exploitation teams were unable to enter or examine most of the equipment the Germans left in Czechoslovakia. Thus U.S.S.R. was in a preferential position to obtain sufficient information on developments by the Germans, including in many cases models or actual weapons.

3. The Czechoslovak General Staff assumed, according to Major F. Vokoun from the V.T.U., of the Czechoslovak General Staff, that the technological knowledge possessed by the Germans would be made available to the Czechs by the Soviet Technical Commission. However, as all attempts failed to obtain such information from the Red Army, the Czechs with the help of their technical personnel made every effort to rescue everything that was not tagged and sent to Russia. Many German institutions that were not labelled by the Soviets as war-booty fell into the hands of the Czechoslovaks. In other cases, German Nationals co-operated with the Czechs in hopes of better treatment.

4. As the Scientific and Technical Institution (V.T.U.) started to function again, two research sections were fully equipped and ready to continue with the research on the developments made by the Germans. One such section of the V.T.U., is located in the rear of the Czechoslovak General Staff Building in Praha, the other in Podmokly (Northern Bohemia). Staff Captain F. E. Zeman of the V.T.U., in Praha revealed that the proposed plan in the military field for the next two years (1947-1948) is the continuance of research on the latest German developments in the following fields:

(1) Electronics:	(a) Proximity fuzes (b) Acoustic proximity fuzes (c) Infra-red devices (d) Infra-red proximity fuzes
(2) Guided missiles	
(3) Rockets:	(a) With soled fuel device (b) With liquid fuel drive
(4) Hypervelocity guns: To be developed:	Heavy Calibers at Skoda Light Calibers at Zbrojovka, Brno

5. Included in the Czechoslovak estimates for the two years 1947-1948 is the immense sum of 18,000,000,000 Czechoslovak crowns, designated as the Secret Fund set aside for the Ministry of National Defence. Just how much of the secret fund will be allocated to Military research could not be reasonably determined, but it is generally assumed that the Scientific and Technical Institution will receive a fairly large appropriation.

Prepared by: Forwarded by:

NARA RG 319, Entry NM3-85A,
Box 2229, Folder 339171 to 339180

Figure E.170: V. L. Rychly. Intelligence Report 339171. 9 December 1946. Subject: Czechoslovakia—Scientific and Technical Institution—Re-establishment of. [NARA NARA RG 77, Entry UD-22A, Box 175, Folder World; and RG 319, Entry NM3-85A, Box 2229, Folder 339171 to 339180].

MIS 467726. 25 May 1948. Location SKODA Underground Factory [NARA RG 319, Entry NM3-85A, Box 3025. Folder 467721 thru 467730].

A friendly Czech source reported that efforts are being made by several SKODA engineers to reopen the underground factory at HABERSDORF (HABENDORF N51-F65) near PODMOKLY. The plant was built by the Germans and was closed after the war. SKODA intends to manufacture Bofors guns and other light anti-aircraft guns there if it is reopened.

MIS 495076. 7 September 1948. Czech Technical Military Institute (VTU) [NARA RG 319, Entry NM3-85A, Box 3201, Folder 495071 thru 495080].

Summary

The Military Technical Institute, the VTU (Vejensky Technicky Ustav), consists of armament, artillery, ammunitions, infantry weapons, optical, electrotechnical, machinery, chemical and related departments.

The Institute conducts experiments with new equipment and weapons, especially those which are assigned for use by the armed forces. Because of the lack of materials which can be obtained only in the western countries, considerable time is spent experimenting with the material left by the Germans. Both German and Russian armament and arms are tested and compared, but so far, no standardization of equipment has been established.

The Technical Institute has been greatly affected by the coup d'etat. The installing of Communists in key positions has greatly decreased the efficiency of the Institute. [...]

REPORT

The Military Technical Institute (VTU—Vejensky Technicky Ustav)

A. Organization

[...]

2nd (High-voltage electrotechnics) Section

[...]

FRANK, [Helmar] Dr. civilian, graduate engineer (Communist) (German national)

B. Locations

1. Most of the sections of the institute are located in the VTU Building in PRAGUE/Dejvice, Ulice Tatranakeho pluku. Outside PRAGUE are sections which were attached to the VTU in 1945 and sections which were established in places where the Germans had left material, as in the case of the following sections:

a. 1st Section of II. Department is located at KBELY near PRAGUE. Before the war, the Telegraph Ordnance and Stores (military) were located on the same premises. The Germans later converted it into a branch of the "Ostmarkwerke". In 1945 the Section was divided into two parts:

(1) Military (VTU, II/1.) which did research and development

(2) Production.

This separation took a large plot of land and the greater part of the buildings from the army.

b. Television Section of II. Department is located in TANVALD where the Russians concentrated the material left in the country by the Germans.

c. 6th Section of I. Department is located in PODMOKLY, where the German Army constructed the "Schmidding" factory which made parts for jet weapons, such as the V-1 and V-2. In 1945, remnants of electrotechnical material, pertaining mostly to the remote control of rockets and similar weapons, were gathered from different regions in Northern Bohemia and concentrated in the school in PODMOKLY. There was no documentation for this material. After the war, five German technicians remained in PODMOKLY and are now working for the VTU.

The electrotechnical group was transferred from PODMOKLY to PRAGUE in the autumn of 1947 and was established in the so-called "JENERA LKA" in the SARECKE UDOLI. [...]

C. Working Method of the VTU

[...] After the [German] equipment was collected, Czech experts had to study it in order to become up to date with the scientific developments made during the war. These difficulties have been practically overcome and the institute is now beginning to work more systematically. However, there is still a very serious shortage of experts. [...] The situation is especially difficult because the Czech electrotechnical industry is unable to produce valves, klystrons and magnetrons, all of which must be bought abroad. As a result, the VTU spends considerable time developing German material to meet the existing requirements.

D. The Work of Individual Departments

[...] b. II. Department—Electric Engineering

(1) Several sets of German radar equipment were sent to the Institute. After assembling them, the Institute found enough parts to construct three permanent radar stations, one radar train and one anti-aircraft battery train.

The installation of the stations and adjustment of trains have been carried out by the Skoda works. The Military Technical Institute retains control of the equipment.

(2) The wireless receiving and transmitting set "SKRIVANEK" is the only wireless apparatus worth mentioning. The "SKRIVANEK" was constructed for gliders. The range is about 100 km.

(3) The German production of teleprints, ciphering and coding machines is being exploited and developed. This task has been assigned to the Elplys firm in PODMOKLY.

(4) Telephone stations and centrals with multi-channel connections are being established. These are also of German manufacture.

(5) Television parts left behind by the Russians have been improved and a camera, transmitter and receiver (with 625 lines) have been constructed. This set was exhibited in the international radio exhibition (MEVRO). The Sokol festival was broadcast as a test. Almost all the parts of this equipment were manufactured in the Military Technical Institute, including the Braun tubes.

(6) Some German inventions on infra-red lights have been deposited at the Praha University and are being worked on. The work proceeds slowly because of the manpower shortage. Visibility achieved is about 200 meters. [...]

d. IV. Department—Chemical

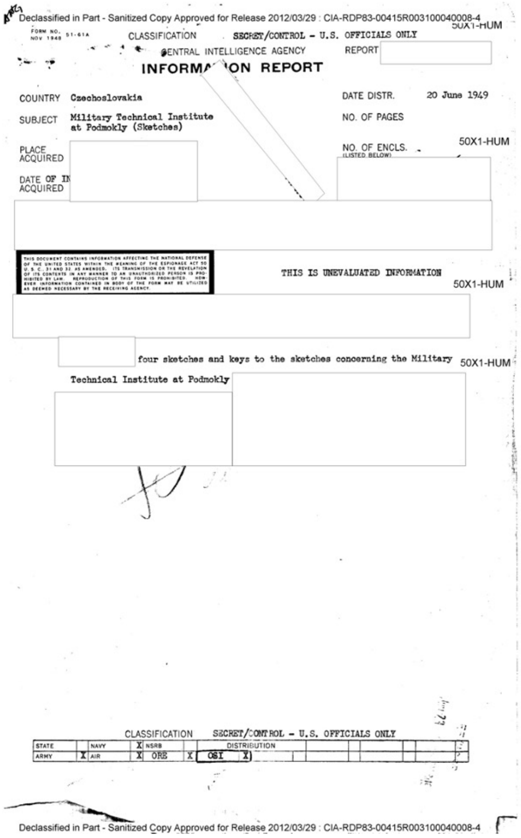
[...] (2) A cheaper fuel based on some artificial substances (bakelite) is being considered for rockets. The tests have not shown much progress.

(3) Atomic science is not handled by the Institute. The JACHYMOV uranium deposits are under Soviet control and are watched by the Red Army. Only activity is liaison with the Ministry of Health on radium research.

MIS 544782. 29 March 1949. Radar Factory Near JABLONEC Reported [NARA RG 319, Entry NM3-85A, Box 3518, Folder 544781 thru 544790].

The source reported information gathered from an underground organization to the effect that there is an electrotechnical factory within three or four kilometers of JABLONEC which has produced several radar sets. (B-2) The source reported that a GERMAN specialist, name unknown, was directing the organization, and that this GERMAN was recently taken to the SOVIET UNION. In addition, SOVIET authorities removed all radar sets from the factory except six. (B-6) The source also reported several active radar sets at RUDOHORI Mountain near FALKNOV. (B-3) The source confirmed the presence of an active radar set on PRAHA Mountain. The set was described as being of GERMAN origin. (B-2)

COMMENT: This office is unable to locate RUDOHORI. A British source reported the radar set on PRAHA Mountain is of the Jadgschloss type. Although the VTU electrotechnical installation at TANVALD is 9 kilometers east of JABLONEC, it is probable that TANVALD was the subject location.



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FORM NO. 51-61A
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CENTRAL INTELLIGENCE AGENCY

INFORMATION REPORT

REPORT [redacted]

COUNTRY Czechoslovakia

SUBJECT Military Technical Institute at Podmokly (Sketches)

PLACE ACQUIRED [redacted]

DATE OF IN ACQUIRED

DATE DISTR. 20 June 1949

NO. OF PAGES

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[redacted]

[redacted] four sketches and keys to the sketches concerning the Military Technical Institute at Podmokly [redacted]

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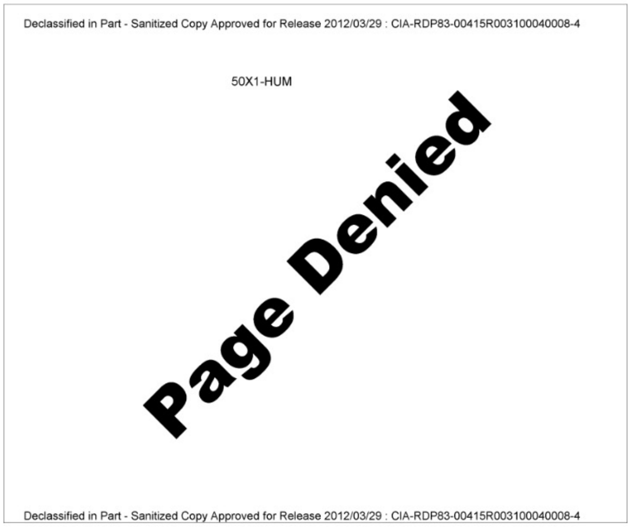

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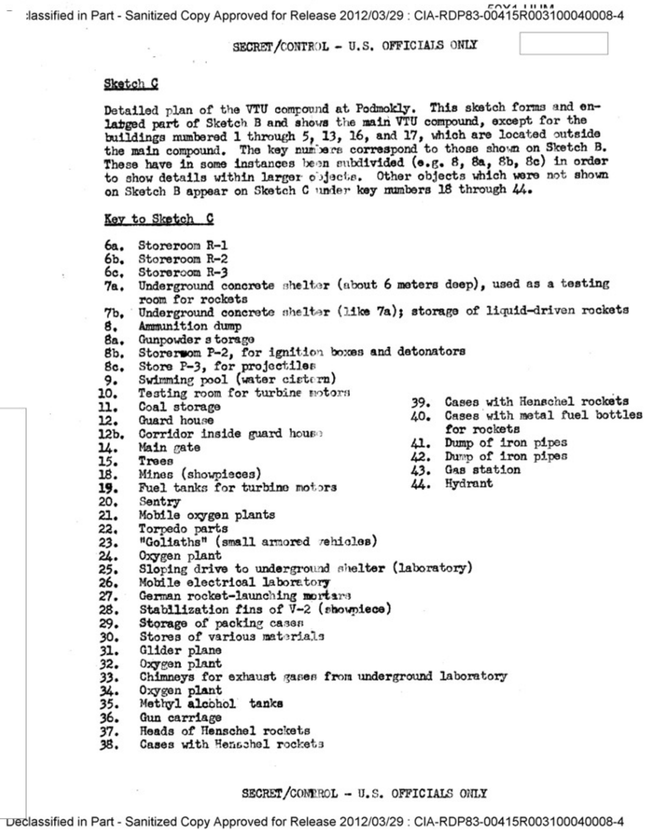

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Sketch C

Detailed plan of the VTU compound at Podmokly. This sketch forms and enlarged part of Sketch B and shows the main VTU compound, except for the buildings numbered 1 through 5, 13, 16, and 17, which are located outside the main compound. The key numbers correspond to those shown on Sketch B. These have in some instances been subdivided (e.g. 8, 8a, 8b, 8c) in order to show details within larger objects. Other objects which were not shown on Sketch B appear on Sketch C under key numbers 18 through 44.

Key to Sketch C

6a. Storeroom R-1
6b. Storeroom R-2
6c. Storeroom R-3
7a. Underground concrete shelter (about 6 meters deep), used as a testing room for rockets
7b. Underground concrete shelter (like 7a); storage of liquid-driven rockets
8. Ammunition dump
8a. Gunpowder storage
8b. Storeroom P-2, for ignition boxes and detonators
8c. Store P-3, for projectiles
9. Swimming pool (water cistern)
10. Testing room for turbine motors
11. Coal storage
12. Guard house
12b. Corridor inside guard house
14. Main gate
15. Trees
18. Mines (showpieces)
19. Fuel tanks for turbine motors
20. Sentry
21. Mobile oxygen plants
22. Torpedo parts
23. "Goliaths" (small armored vehicles)
24. Oxygen plant
25. Sloping drive to underground shelter (laboratory)
26. Mobile electrical laboratory
27. German rocket-launching mortars
28. Stabilization fins of V-2 (showpiece)
29. Storage of packing cases
30. Stores of various materials
31. Glider plane
32. Oxygen plant
33. Chimneys for exhaust gases from underground laboratory
34. Oxygen plant
35. Methyl alcohol tanks
36. Gun carriage
37. Heads of Henschel rockets
38. Cases with Henschel rockets
39. Cases with Henschel rockets
40. Cases with metal fuel bottles for rockets
41. Dump of iron pipes
42. Dump of iron pipes
43. Gas station
44. Hydrant

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Figure E.171: Pages from a 20 June 1949 CIA report on the Soviet use of German technologies at Podmokly [https://www.cia.gov/readingroom/document/cia-rdp83-00415r003100040008-4]. Why does this report remain heavily redacted even today?

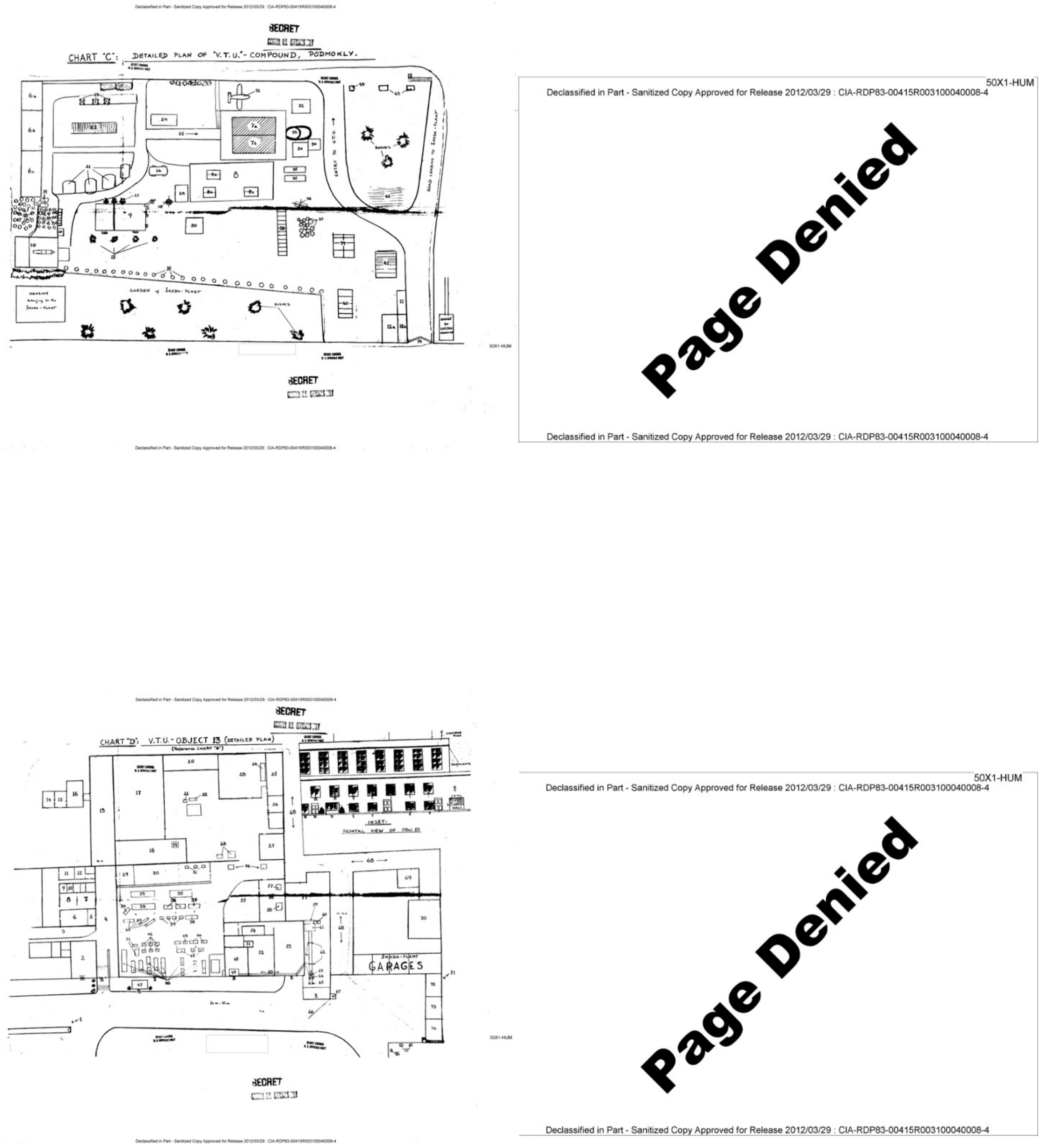
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CHART "C": DETAILED PLAN OF "V.T.U."- COMPOUND, PODMOKLY.

ENTRY TO V.T.U.
ROAD LEADING TO ŠKODA - PLANT
BUSHES
GARDEN of ŠKODA - PLANT
MANSION belonging to the ŠKODA - PLANT

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CHART "D": V.T.U. - OBJECT 13 (DETAILED PLAN)
(Reference CHART "A")

INSET:
FRONTAL VIEW OF OBJ. 13
ŠKODA - PLANT
GARAGES

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Figure E.172: Pages from a 20 June 1949 CIA report on the Soviet use of German technologies at Podmokly [https://www.cia.gov/readingroom/document/cia-rdp83-00415r003100040008-4]. Why does this report remain heavily redacted even today?

Central Intelligence Agency Information Report 25X1A. German Radar and Electronic Equipment Seized and Developed by the Russians. 1 November 1949. [https://www.cia.gov/readingroom/document/cia-rdp82-00457r003600120008-5]

1. AEG Plant at 35–38 Drontheimerstrasse, BERLIN-N 20. [...]

e. Remote Control Mechanisms for Searchlights, Aircraft Armament and Radar Sets; Command Guidance Equipment for V-Missiles

In quantity production in BERLIN, further developed in BENSEN [BENESOV NAD PLOUCNICI].

f. Remote Control "BRIGG" Type Receiving Set

Presumably for bombs and V-missiles; wave length about 25 cm, modulated with audio frequencies, developed by the Telefunken Firm. The licensed construction of these sets was prepared in BENSEN late in 1944. Incomplete sets and records were secured by the Soviets in BENSEN. [...]

k. "S-30" Designated "PFAU"

An automatic pilot for the "LTF-5b" aircraft-launched torpedo; developed in BENSEN. About 300 sets were manufactured by the end of the war. [...]

Source is not fully informed on the nature of the technical records secured by the Soviets in the BERLIN AEG Plant.

2. AEG Branch Plant in BENSEN, County of TETSCHEN-BODENBACH, Czechoslovakia

In order to be safe from air attacks, a section of the BERLIN "AEG Fabrik Drontheimerstrasse" was transferred to BENSEN in July 1943 and installed in the BENSEN and FRIEDRICHSTHAL near BENSEN textile plants operated by the ALTAUSCH Firm. [...]

The plant had about 1,000 employees including foreigners (Frenchmen, Belgians, Dutchmen, Russians). Czechs were not employed in technical departments; in other departments there were only two or three of them. Plant manager was Dr. Ing. WERNER, a German.

After the German surrender the plant was declared Czech state property. The plant was not damaged during the war. [...]

Soviets, and later Czech engineer commissions appeared at the plant from June through August 1945 to familiarize themselves with the war production formerly conducted at the BENSEN Plant. The Soviets seized all original blueprints and prototypes produced or developed there. The Czechs removed everything that the Soviets had left.

The following engineers were employed by the Czechs:

(1) Graduate Engineer Rolf PACKES [BAKES—see p. 5516] (for mine ignition mechanisms)

(2) Graduate Engineer Karl PFISTER (for remote control mechanisms)

(3) Graduate Engineer MENDEL (for the "PFAU" Set)

(4) Graduate Engineer WITT

(5) Graduate Engineer Vitaly GROSSE (for mine ignition sets)

(6) Engineer KIRSCH

(7) Engineer FROEHLING (for remote control sets)

(8) Engineer STOLL

These engineers first worked in BENSEN, in the BODENBACH plant of the Czech "VTU" Institute since late 1945, and since 1947 in the PRAGUE "VTU" Plant. [...]

The developmental work of the AEG was continued by the BODENBACH Military-Technical Institute (VTU). Since no Czechs were employed in AEG plants during the war, the further development and reconstruction of the sets was possible only with the help of German technical personnel.

The report confirms the previously reported activities in the field of radar techniques, of remote control devices, electro-acoustics and proximity fuses. [...]

The "Schmidding" Firm (W. Schmidding, Copper and Aluminum Force, Manufacture of Apparatus and Machines in KOELN-MANNFELD) operated a branch plant for rocket power plants in BODENBACH. Remote-controlled bombs and propelling charges of powder for AA rockets were developed here, and parts for V-2 missiles and torpedoes were manufactured in this plant. The turbo-jet power plant of type 003 was manufactured there at the end of the war. This confirms a previous report.

[During World War II, the main AEG factory in Berlin produced state-of-the art guidance systems for missiles and torpedoes. In July 1943, in order to escape from Allied bombing, parts of the AEG factory in Berlin were evacuated to repurposed previously existing factory buildings in the two villages of Bensen (also known as Beneschau or Benesov nad Ploucnici) and Bedrichov/Friedrichsthal in northern Bohemia. For the rest of the war, they operated there, along with a previously existing AEG factory in the industrial village of Bodenbach (Podmokly). See pp. 5540–5541.

(That entire region of Bohemia was densely filled with electronics factories, such as another AEG plant in Reichenberg/Liberec, many Siemens factories in Budweis/Ceske Budejovice, the electronics SS trust Getewent at multiple locations, etc.)

One of the most important weapons produced in this area during the war was the V-4 missile. It was described as being considerably larger than the V-2 and possessing a more sophisticated guidance system, designated PFAU-II. The factory in Bedrichov/Friedrichsthal assembled the complete V-4 or at least its nose, integrating all the guidance components of the PFAU-II system produced together with the other two AEG factories in Bensen and Podmokly. Bedrichov is where the Soviets found a complete nose of the V-4, including its guidance system. See pp. 5516, 5544.

This background information helps to explain why even in 1949, the CIA was still interested in these former Bohemian German electronics plants, especially with regard to how they could provide advanced weapons technologies for the Soviet military.]

Former Branch Plant of the Schmidding Firm in Bodenbach-Podmokly and Schmiedeberg. 10 May 1950.

[https://www.cia.gov/readingroom/document/cia-rdp82-00457r004800590008-4]

1. Main Plant:

a. Schmidding Plant in Koeln-Niehl. This firm is an old copper forge, formerly in Koeln-Raderberg. During the German rearmament the plant was transferred to Koeln-Niehl and branch plants were set up in Hannover, Bodenbach (N 51/F 56) and Schmiedeberg (N 51/K 83). [...] Managing director of the Bodenbach branch plant was a Herr Mohr whose present whereabouts are not known.

b. A recoil projectile, allegedly with the type designation Rheingold, was under development. [Redacted sentences.] Propulsion unit: Binary [liquid fuel + oxidizer] rocket. The development engineer of this projectile was unknown. It was, however, developed under the control of the chief engineer Dr. Kleiner who went to Argentina. This projectile has not been fully developed. However it was in the testing state and was displayed, after the German surrender, together with other products in the firm's show room.

c. Other weapons produced by the firm:

An AA rocket with an estimated length of 700 mm and a diameter of 200 mm. No details available. Twenty thousand powder-propelled rockets of a type similar to the "SG-41", serving as an assistance for take-offs and braking used by jet fighters, were also manufactured. Another Jato, the "SG-2", a binary liquid rocket, was fully developed by Schmidding and produced in one series. [Redacted sentences.]

d. Work for Peenemünde:

Only the building under license of combustion chambers for the V-2 was planned. A model combustion chamber with nozzles was available and was on display in the showroom after 1945. [...]

Headquarters Berlin Command, Office of Military Goverment for Germany (US). 11 December 1946. Special Intelligence Memorandum No. 48. Subject: V-2 Production in SovZone. Source: Extremely Reliable. D-138175. [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Soviet Guided Missiles, Rockets and V-Weapons Research, Development and Production Vol. 1, Fldr. 2 of 3. See pp. 2960–2961.]

BLEICHERODE in the Harz mountains is still doing fine in the production of V-2 rockets. It was reported from this office that dismantling was going on, but it was stopped as of 1 December. The general procedure for dismantling of installations very dear to the Soviet heart is the following as illustrated best by BLEICHERODE.

As soon as Soviet troops took over the V-2 plants, they did everything in their power to get it reorganized and re-equipped. As soon as this was done, they started production. When they saw that the finished product was satisfactory, they began to dismantle the plant for the first time. The dismantling was not carried through completely, but was halted as soon as about half was taken. Together with the machinery some personnel was taken out, to be shipped to the USSR in order to set up the machinery which was confiscated and complete it with more later.

In the meantime the plant in BLEICHERODE was being rebuilt under supervision of German and Soviet engineers. Once rebuilt, production was started all over again and as soon as satisfactory results were achieved, the dismantling was continued. In this way, Soviet authorities enrich their own country by building up some priceless industries and on the other hand they see to it that the original plant in Germany is reconstructed and re-equipped after each time. Thus, they would be able theoretically to continue an uninterrupted flow of industries from Germany to the Soviet Union.

This procedure is known to have been applied to all V-weapon plants in BLEICHERODE, NORDHAUSEN, GOTHA and BERLIN. In BLEICHERODE the installations were dismantled for the fourth time; in NORDHAUSEN for the sixth time; in Berlin only once; conditions in GOTHA are unknown. [...]

All radio and remote control equipment is manufactured on subcontract by the former SIEMENS Plant in ARNSTADT (Thuringia) while all other parts are manufactured directly in BLEICHERODE. The radio equipment will enable the rocket to send back to base 24 different signals within three seconds, mainly about altitude, airspeed, groundspeed, steering reaction and television view of the objective. [...]

[The above text was also retyped verbatim as: A. H. Graubart. 21 December 1946. Subject: GERMANY/RUSSIA Industry and Industrial Resources. [NARA RG 38, Entry 98C, Box 12, Folder TSC # 3301–3400]

The above document demonstrates that there were many leftover wartime German facilities capable of producing complete rockets or parts for rockets, not just the known Nordhausen plant. Also, the Soviets employed what was apparently a wartime facility in Arnstadt that produced remarkably advanced rocket guidance systems.

Also note that the postwar Russian rocket program is completely indebted to German engineers, technologies, and even factories. Even in the years after the war, the Germans were essentially providing all the expertise, labor, and materials to produce several fully functional copies of each of their wartime factories and then ship those to the Soviet Union, while the Soviet Union ultimately reaped the financial rewards, military power, and technological recognition extracted from those German creators and creations.

Note that the Soviet Union not only shipped hundreds of existing German factories and laboratories to the Soviet Union, but it forced Germans to repeatedly rebuild those facilities and then ship them again. That multiplied both the number of factories and laboratories shipped to the Soviet Union, and also the postwar burden on German science and industry, by several fold.]

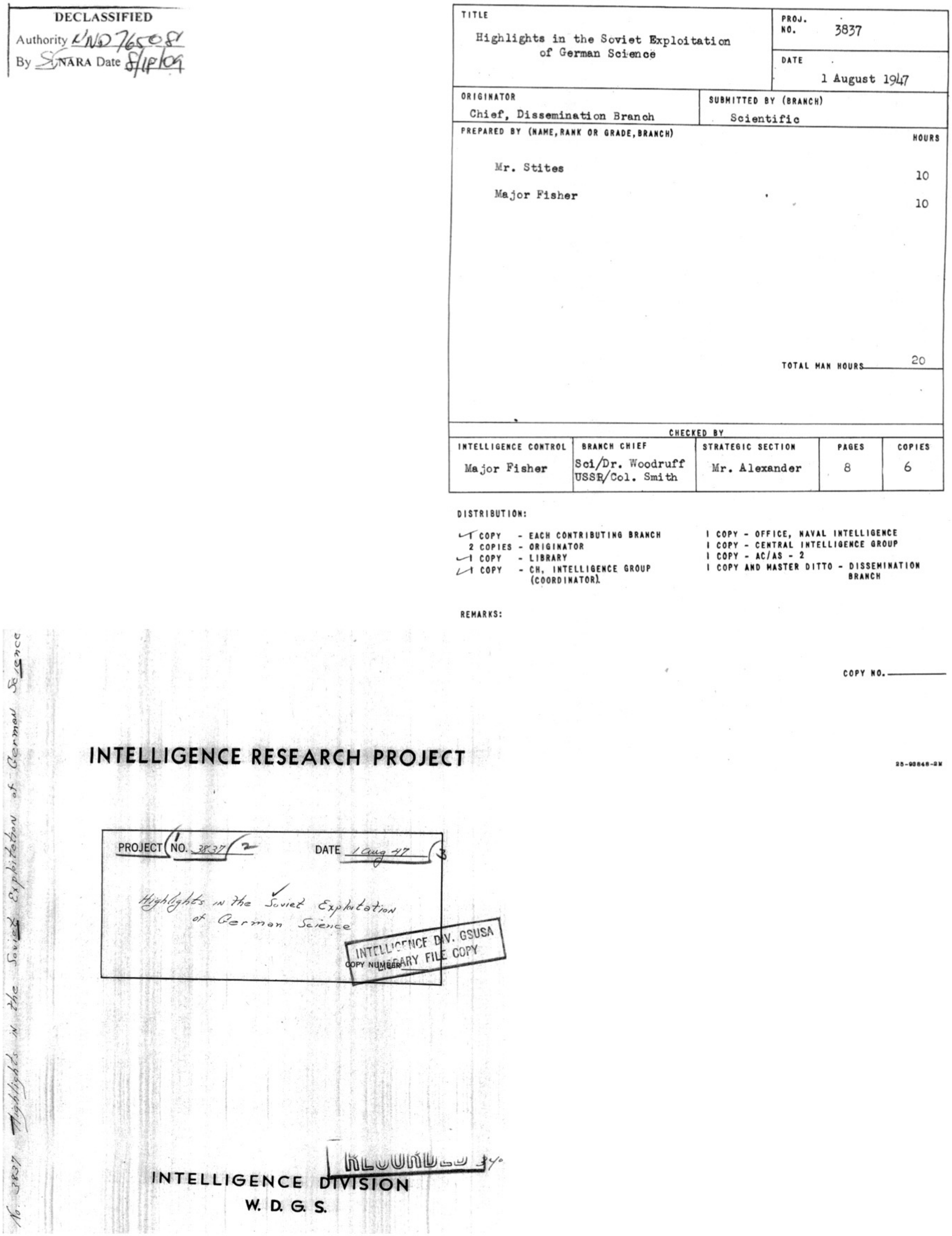

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Figure E.173: In August 1947, the U.S. War Department General Staff (WDGS) Intelligence Division wrote a report summarizing what they had learned about "Soviet Exploitation of German Science." Even after so many decades, that report remains classified and unavailable to the public. Why? What information is in the report? [NARA RG 319, Entry NM3-82, Box 2899, Folder Project 3837]

Subject: Guided Missiles—USSR. Reference No. 478-13. SD-5820. 7 August 1947 [NARA RG 319, Entry NM3-85M, Box 170, Folder 929657.]

[p. 1:] A limited amount of information has been received about the location of G.M. [Guided Missile] research centres in the U.S.S.R. The most interesting feature was a report which stated that the old Inst. RABE, removed from the NORDHAUSEN area of the Soviet Zone had been split into seven distinct groups. This report is the work of one man, but since the information is, piece by piece being confirmed, the data is passed on with confidence. [...]

[p. 4:] When further questioned, this subject said that he believed Guided Missiles were being produced in the U.S.S.R. He spoke of a huge underground factory at ARNSWALDE in the Polish Zone, which, he said, is intact, and production is in full swing. He spoke of the very heavy guards on the place, that the only railway line in the vicinity terminates at the factory, and that he has seen large railway flat wagons leaving covered with tarpaulins. [...]

[pp. 7–8:] As Director General GROETTRUP controlled all the details of production. Among the special projects under his control were the re-construction of the A-4, G-2 and A-9, the possibility of using steel rockets for stratosphere flight, developments for the calculation of course (both electrical and optical), and airframe developments. He registered the formula for KRAFTSTOFF GRUEN with the Russians and took an active interest in all aspects of the work connected with modifications to the G-2. [...]

[p. 14:] Any list of German scientists would seem to be incomplete without mention of Professors HERTZ, STEENBECK and MANFRED von ARDENNE. Hertz won the Nobel Prize in 1926, and the other two can be rated almost as highly. Mention of these men has not been made before because we believe that they are engaged on Nuclear Physics. They are all believed to be at SUCHUM KALE on the Black Sea Coast. [...]

[This is a 14-page report, not counting its cover sheets, so only a small amount is quoted here. Most of the report is devoted to providing the names, research tasks, and believed locations of German rocket engineers who were working on ballistic missiles and rockets in the Soviet Union and/or East Germany after the war. The large numbers of German engineers who are named and their listed tasks demonstrate how utterly dependent the postwar Soviet missile and rocket programs were on German-speaking designers, craftsmen, and experts.

This document also lists some wartime German rocket projects that were re-constructed after the war by German engineers working for the Soviet Union. Of those listed projects, the A-4/V-2 is well known. However, the inclusion of the A-9 in this list may suggest that production and testing of the A-9 progressed much further during the war than has generally been acknowledged. Most intriguingly, the inclusion of the “G-2” in the list (using the designation by which it would have been known to the report’s source, who was quite familiar with Soviet-sponsored, German-designed rocket projects in 1947) suggests that the postwar Soviet G-2 rocket project (pp. 5561–5562) was directly based on wartime German work. Can other documentation of that wartime German work be found? How far did work on the original German G-2 progress during the war? Presumably it would not have been called the “G-2” in wartime Germany, but would have had some other designation. Was the original German G-2 the same as the V-3/V-4 mentioned in Czech and other documents (pp. 5516, 5532, 5535, 5544), or was it another rocket entirely?

The above report appears to be the only known mention of a huge, highly secret, underground factory in Arnswalde (now Choszczno, Poland) that was built and operated by Germany during the war, and restarted by the Soviet Union after the war. The factory seems to have produced something that was quite large and quite secret. This document implies that it was rockets (possibly more advanced than the A-4/V-2 based on the level of secrecy and security). Can other archival documents related to that underground factory be located? Could industrial archaeology be conducted at that site now to shed more light on what it produced?]

Mark Wade. 2019. G-2 [http://www.astronautix.com/g/g-2.html].

The G-2 design objective was to create the first IRBM—to deliver a 1000 kg payload over a 2500 km range. The missile would use three V-2 derived engines with a total thrust of 100 metric tons. A variety of alternate configurations (R-12A through R-12K) were considered by the German team in Russia. These included parallel and consecutive staging, gimbaled motors, and other innovations. The R-12K was particularly interesting because it represented a concept later used on the US Atlas missile—jettisoning of the two outboard engines at altitude to significantly improve range. [...]

More than ten G-2/R-12 variants were studied in detail to determine the optimum technical solution. All used a common bulkhead between the aft fuel and forward liquid oxygen tank. Two major aerodynamic forms were considered—conical, which was aerodynamic stable regardless of the stage velocity and vehicle center of gravity, and cylindrical stages with fins. The variants studied were as follows:

- G-1 cluster - two G-1's as the first stage flanking a single G-1 as the second stage. Lift-off mass 50 metric tons, lift-off thrust 100 metric tons, total span 6 m, length 15 m.
- R-12A dual sequential stage. Conical form, with 3 G-1 engines in the first stage and a single G-1 engine in the second stage. Length 25.3 m, diameter at the base 4.0 m.
- R-12B short-range V-2 replacement based on second stage of R-12A. 2.4 m base diameter, 16.0 m long.
- R-12C dual stage. A variation of the R-12A with a larger-diameter upper stage. 19.2 m long.
- R-12E dual stage. Cylindrical first stage with aerodynamic stabilizing fins
- R-12G single stage design with conical form
- R-12H single stage with cylindrical form and aerodynamic stabilizing fins
- R-12K with jettisonable booster engines.

The optimum technical solution seemed to be the R-12G single-stage conical design. In comparing the G-2 with Korolev's R-2, the state commission favored the Groettrup design. But the Russian designers convinced the government that the G-2 required innovations beyond the immediate capability of Soviet technology. Korolev's R-2, a modest upgrade of the V-2, was selected for production instead.

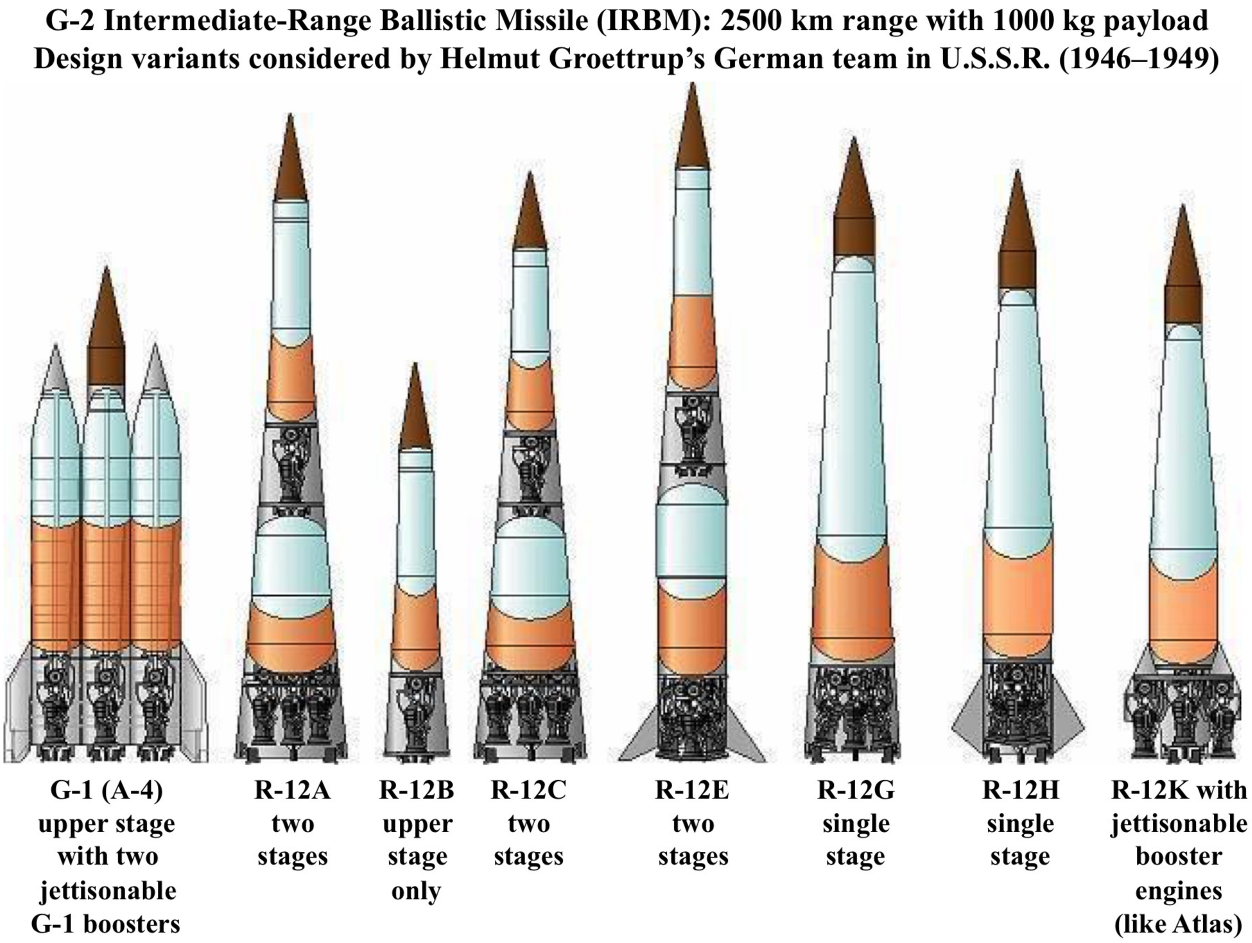

G-2 Intermediate-Range Ballistic Missile (IRBM): 2500 km range with 1000 kg payload
Design variants considered by Helmut Groettrup's German team in U.S.S.R. (1946–1949)
G-1 (A-4) upper stage with two jettisonable G-1 boosters
R-12A two stages
R-12B upper stage only
R-12C two stages
R-12E two stages
R-12G single stage
R-12H single stage
R-12K with jettisonable booster engines (like Atlas)

Figure E.174: Some major design variants of the G-2 Intermediate-Range Ballistic Missile (IRBM) that were considered by Helmut Groettrup's team of German engineers in the Soviet Union during the period 1946–1949 [http://www.astronautix.com/g/g-2.html]. Was this project directly based on wartime German work (p. 5560)?

[After the war, German engineers in the United States produced the PGM-19 Jupiter, a rocket with many similarities to the G-2 designs (p. 5501). Jupiter had a diameter of 2.67 m and length of 18 m. It had a range of 2400 km with a 1000 kg payload. Were the Jupiter and G-2 designs unrelated, or the product of postwar spying leading to information transfer between the U.S. and Soviet design teams, or were the U.S.- and Soviet-based German designers using the same wartime German project as their starting point for these postwar rockets?]

Charles P. Bixel. 9 December 1946. Subject: Report No. 45. [NARA RG 319, Entry NM3-85M, Box 40. Folder 925907].

[...] 6. SOVIET RESEARCH IN ROCKET AND ATOMIC WEAPONS

a. Two CZECH Army officers recently returned from a special aeronautical course were enthusiastic about what they saw while attending the school. The officers stated that the USSR is presently engaged in the construction of what they described as the largest rockets in the world. (Evidently the USSR's propaganda campaign has taken effect.) The plants engaged in the construction of these rockets are located in the URALS and are sufficiently dispersed to safeguard them in the event of concentrated bombing attacks. To insure the secrecy of the rocket project, each plant is engaged in the manufacture of only one part. Work on a rocket which these officers described as twice the size of a German V-2 is being conducted with assistance of German scientists. One assembled rocket was seen at CHELYABINSK. The rocket is approximately 4 meters in diameter and approximately 40–45 meters in length. The war-head of the rocket is conically shaped. It differs from the German V-2 in that its tail fins have a much larger surface and are movable. The weapon is of all metal construction and is motivated by a rocket propellant. Since no visible attachment was apparent on the rocket the officers surmised that the engine was built into the fuselage and the rocket vapors, flames, and gases created by the motor were evacuated through the tail section of the rocket. The officers were told at the school that by May 1947 the USSR will have radio or radar controlled rockets capable of extended flights up to 4000 miles.

b. The following dissertation on the intentions and capabilities of the USSR was obtained from a Czechoslovakian official holding a high position in the Czech Government. The source had recently returned from a trip to the USSR. Evaluation is B-3.

The USSR's industrial strength, along with the industrial capabilities of her Satellites, is at present being concentrated in a gigantic armament effort centered around the development of long range rockets with atomic war-heads. This is the major reason why the rebuilding of the devastated areas of the USSR has advanced so slowly and also the reason why the major Ukrainian and Polish armament industries are being put into operation again. The Czechoslovakian official has heard many comments to the effect that the USSR will have the atomic bomb developed not later than June 1947. He knew of no industries or scientific laboratories engaged in atomic research, but claimed high hopes are attached to this new weapon. The Soviets believe that in the event of war between the Western Powers and the so-called Eastern Bloc they will be capable of firing their rockets from Eastern-most Siberia against all of Southern Asia, Australia, and even the Western part of the United States. Alaska will be within easy range of weapons employed at present. The British Islands and the Eastern half of the United States will be reached by rockets from Central Europe.

[...]

(d) MERSEBURG (D-91)

On 3 November 1946 an unknown number of research workers of the LEUNA plant left for the USSR. It could not be determined if they left voluntarily. (USCon F-6)

(e) HALLE (D-92)

200 German families were evacuated to the USSR. Most of the men involved are said to be boilermakers. (USCon F-6)

(f) LEIPZIG (E-21)

The Director of the G. E. Reinhardt factory as well as his three chief technicians have apparently departed for the USSR. (USCon F-6)

(g) MAGDEBURG (Y-60)

On 28 October 1946 one hundred and thirty expert technicians and engineers of the KRUPP munitions factory and the railroad repair shops left MAGDEBURG presumably for the USSR. They were accompanied by their families. According to source all 130 received contracts for five years employment in the USSR. Whether these were signed voluntarily or whether coercion was resorted to could not be determined. (USCon B-2)

[...]

(2) ARNSTADT (J-25)

The "Polte Works" which at one time employed 22,000 people in the production of munitions was dismantled beginning in October 1945. The work was completed in May 1946. (USCon F-6) Source probably referred to "Meta Metallwerk" factory as the Polte Werke of ARNSTADT (J-25) because the Meta Werk, which is reported to have made anti-tank shells during the war, was believed to be associated with the larger Polte arms work of MAGDEBURG. (Y-60).

(3) GREPPIN (E-14)

Dismantling operations on the munitions plant, which once employed 30,000 people, have been proceeding since May 1946. Shipping stickers on crates indicate the machinery is being sent to KIEV. (USCon C-3) [...]

[There is evidence that during the war, the Polte II plant and other facilities around Arnstadt were producing components for large rockets such as those described in this report; see pp. 5344–5351.

There is also evidence that several of the other locations mentioned in this report were doing nuclear-related work during the war (pp. 3670–3677, 4027–4030).

This report is further evidence for how large German industry was during the war, and how greatly dependent postwar Soviet technical development was on all the German experts, information, materials, hardware, and factories that were seized by the Soviet Union at the end of the war.

Many captured German factories and workers were relocated to Chelyabinsk and other places in or near the Ural Mountains in Russia.

Soviet rockets seen only a year after the war were almost certainly based on wartime German designs, and probably had even been built by German industry before the war ended. Most of those were captured or rebuilt A-4 (V-2) rockets, renamed R-1 by the Soviets.

This report from two knowledgeable witnesses described a rocket far larger than the standard 14-meter-long A-4. The two witnesses said the novel rocket was either twice the size of a standard A-4 (thus approximately 28 meters long) or three times the size of an A-4 (40–45 meters). Perhaps those were the sizes of two different large rockets the witnesses saw; if they were the two witnesses' different estimates of the same rocket, they at least indicate that it was much too large to be an A-4.

The smaller estimate, approximately 28 meters, is too large for even a stretched A-4 such as the 18-meter R-2 and the 21-meter R-5 (p. 5574). However, it is an excellent match for the two-stage A-9/A-10 (p. 5271).

The larger estimate, 40–45 meters, is much too large even for an A-9/A-10. Out of the publicly known wartime German rocket designs, this length best matches that of a three-stage A-9/A-10/A-11. There is other evidence that Soviet investigators knew of wartime German work on that project (p. 5570).

The 4000-mile range and the diameter up to 4 meters are also far too large for even an extended A-4. These are two additional pieces of evidence that this rocket was a two-stage A-9/A-10, a three-stage A-9/A-10/A-11, or something similar [perhaps the Bohemian V-3/V-4 (pp. 5516, 5532, 5535, 5544), and/or a rocket related to the G-series (p. 5562)].

The conically shaped warhead sounds quite different than the shape of a conventional inseparable A-4 warhead. It suggests a warhead that was separable for reentry over the target, and likely nuclear given the size and cost of such a rocket.

Thus this report is further evidence that very large rockets designed for intercontinental ranges and likely nuclear payloads were built during the war and captured by the Soviet Union (and possibly other countries as well) after the war.]

Subject: Construction of Radio-guided Rockets at NOVOSIBIRSK. D-152490, CW138175. 12 October 1947. A.I.B. [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Soviet Guided Missiles, Rockets and V-Weapons Research, Development and Production Vol. 1, Fldr. 1 of 3].

Special Report (translated from Russian)

Subject: Construction of Radio-guided Rockets at NOVOSIBIRSK

1. New radio-guided rockets are being constructed in factory “BOLSHEVIK” at NOVOSIBIRSK. These rockets are similar to the German “V” type but larger in size. This rocket in the shape of a cigar is 16 m long and 2.5 to 3 m in diameter. [...]

2. It is not known how many rockets are being constructed but according to unconfirmed reports only 5 or 6 rockets are constructed for tests and experiments.

3. In charge of the construction is ANSHUKOV an engineer sent from MOSCOW. He is obviously a military officer and he often wears military uniform though without rank insignia. Approx. 10 German specialists arrived from MOSCOW with ANSHUKOV. [...]

[The fact that this larger rocket appeared relatively soon after the war, and as a direct product of German specialists, suggests that it may have been directly based on captured wartime technology, not new designs.

Note that the diameter was much larger than the 1.65 m diameter of the A-4 and closely related rockets.

Based on these dimensions, were these rockets R-12B upper stages (or other design variants) from Helmut Groettrup’s G-2 program?

Alternatively, were these rockets copies of the wartime Bohemian V-3 or V-4 (pp. 5516, 5532, 5535, 5544)?

Or was the Bohemian V-3/V-4 the original wartime German version of the G-2?]

New Soviet Weapons. 10 November 1950 [based on intelligence from 1943–1948]. https://www.cia.gov/readingroom/document/cia-rdp80-00809a000600360061-4

The following is a report of the experiences of a German scientist, Dr H. Tellman, who was taken prisoner by the Russians in 1943 and who worked for them as a scientist until he escaped by airplane. Dr Tellmann now lives in Argentina. [...]

My friend, Professor D. took me along on an inspection trip to Tomsk where the Russians has built an experimental station for V-2 rockets. I met an old acquaintance from Germany, Engineer P., who was in charge of the technical work of the entire installation. At first, the only experiments performed were the same kind which I knew from my work in Germany, but later, during my stay, new designs with much higher power were developed. Work was also carried out in the field of radio guidance of rockets. I saw the launching of several giant rockets whose dimensions considerably exceeded those of the V-2. The measuring devices recorded ceiling altitudes of 210 kilometers in these flights. A new rocket is still in the development stage. It weighs 40 tons and is expected to reach an altitude of more than 400 kilometers. I was also interested in the design of a multistage rocket, whose first stage was to be powered by nuclear energy. [...]

The experimental rockets in the development stage today are nearly powerful enough to fly from the earth to the moon and to leave the earth's gravitational field.

A second trip took me to Kalinin. A large rocket-aircraft-testing station has been built there. The rocket aircraft developed there are based on the design of the German V-1. Essentially, they are nothing but manned rockets. The wings are small and sweptback. The cockpit is hermetically sealed and holds a two-man crew. The Soviets have also succeeded in obtaining the services of most of the important German rocket experts, who have attained very high speeds with their rocket aircraft; in one case, an aircraft equipped with three rocket engines reached a speed of nearly 2,000 kilometers per hour.

During one test flight which I witnessed, the material did not withstand the terrific strain, and the aircraft crashed, killing the German pilot. These aircraft are started from catapults. Fuel consists of a hydrocarbon compound and nitric acid. One of the German test pilots succeeded in reaching an altitude of 25,000 meters with one of these aircraft. The immense power of the engines was demonstrated to me when a rocket aircraft turned over during take-off and exploded. The explosion made a crater of 15 meters in diameter and 3 meters in depth, and the aircraft was torn into tiny fragments. These rocket aircraft are still in the experimental stage. However, the USSR has many types of jet aircraft which are already in service. They were designed and built in a plant near Voronezh by former members of the Messerschmitt firm. [...]

A few days after my return to Moscow, I was taken to Peenemuende. The installation is operating full blast, and the region between Usedom and Greifswald is one single armed camp. There is no trace left of the demolitions carried out in 1945. Over 150 German scientists are working around the clock developing rocket projectiles and rocket-propelled fighter aircraft. I was able to determine that the Russians had obtained all German data for all the versions of the V-2 rocket. Special attention was given to the A-8 version of this rocket, which can fire 6,000 kilometer across the Atlantic with a flight time of 42 minutes.

The tests with guided rockets at Peenemuende made a great impression on me. Rockets were launched from sites in the Leningrad-Kronshtadt area. They landed with almost dead accuracy on the island of Pol. The rockets are launched to an altitude of 12,000 meters, and the propulsion unit of the rocket is cut in at than altitude by radio signal. The rockets then fly in a straight line, controlled by radio and radar signals from picket boats in the Baltic, until a measuring station stops them over the island of Pol and breaks off the flight there. The rockets come down nearly vertically and land near the target. The tests were repeated several times, and the results, in regard to accuracy, were always equally good. I am convinced now that the sensational reports once heard in Germany about rockets over the Baltic were not just imagination, but that rockets from Leningrad sometimes flew as far as Swinemuende, and that some of them supposedly got lost and flew to Sweden.

My work at Peenemuende consisted mostly in trying to persuade the German scientists there to go to work for the War Academy in Moscow. In 1945, the Russians shanghaied the scientists, but stopped this practice in 1948, since they found out that they could not obtain good work from scientists who were in the USSR under duress. During my conversations with my colleagues there I found that the research results obtained at Peenemuende should be a matter of great concern to other countries. The accuracy attained with rockets over the comparatively short range of 1,100 kilometers between Leningrad and Usedom was also attained over a 2,500-kilometer range. These tests were conducted between the Kronshtadt-Leningrad area and the great rocket-testing site at Omsk in Siberia. On the basis of these tests, it could easily be possible for the Russian using rockets launched from the interior of the USSR, to reach any target in Europe or in the US with great accuracy.

I had not given up my plans for escape. I could not bear working under constant political pressure, and I wanted to spare my family from moving to USSR and did not want to expose them to an uncertain fate there.

I was helped by a coincidence. In July 1948 I was at Kharkov, where I had to inspect equipment in the huge power plant. There I met a German engineer named Wintersdorff, a former pilot, who had been shanghaied by the Russians during a visit to Soviet Zone Germany in 1946, and who was plotting an escape by air to Athens where he had a brother-in-law. By luck, a high official of the Ministry of War whom I met at Kharkov invited me to fly back to Moscow with him in his private plane, and agreed to take Wintersdorff, my "assistant" along. During the flight, with the aid of a revolver which Wintersdorff had obtained, we overpowered the official, the pilot, and the radio operator, put parachutes on them, and threw them from the plane. With Wintersdorff at the controls, we flew to Athens, from where I reached Germany.

[Dr. H. Tellmann said he personally witnessed (and in other cases heard of through reliable sources) the testing of several rockets significantly larger and more sophisticated than the A-4/V-2/R-1 in the Soviet Union during the period 1945–1948. The first Soviet-built rocket larger than the A-4/V-2/R-1 was the R-2 or SS-2, which did not fly until October 1950 [Uhl 2001, p. 189]. Thus the advanced rockets that Tellmann described appear to have been captured wartime German rockets.

The A-8 was a modified A-4. For it to travel 6,000 km assumes or implies the existence of the A-10 as a booster stage. Such a long range also indicates that the A-8 would have been equipped with wings like the A-4b or A-9 for a long gliding reentry to the target.]

Boris Chertok. 2005–2012. *Rockets and People.* 4 vols. Washington, DC: U.S. Government Printing Office.
[https://www.nasa.gov/connect/ebooks/rockets_people_vol1_detail.html]

[Vol. 1, p. 242:] The inspection of Peenemünde in May and June 1945 showed that the actual scope of work on rocket technology in Germany was far superior to what we had imagined. We Soviet specialists needed to investigate the entire volume of work that had been done in Germany in the field of rocket technology. But it was just as important to obtain information on the history of these developments and the methods used by German scientists and engineers to solve many difficult problems, such as those involved with the development of long-range guided ballistic missiles.

Before 1945, neither we, the Americans, nor the Brits had been able to develop liquid-propellant rocket engines with a thrust greater than 1.5 metric tons. Those that had been developed were not very reliable, had not gone into series production, and were not used to develop any new type of weapon. By that time, however, the Germans had successfully developed and mastered a liquid-propellant rocket engine with a thrust of up to 27 metric tons—more than eighteen times greater! What is more, they had produced these engines in large-scale series production by the thousands! And the automatic guidance system! It was one thing to fundamentally and theoretically show that for the given level of technology it was possible to control a missile's flight and consequently the engine mode in flight at a range of 300 kilometers; it was a quite another thing to put this into practice and bring the entire system up to a level suitable for acceptance as an operational armament!

[Vol. 1, p. 245:] From 1937 through 1940, the Germans invested more than 550 million Reichsmarks into the construction of the Peenemünde center, an enormous sum for that time. All of Germany's leading electrical and radio engineering firms provided the center with special testing equipment and the latest measurement instruments. Despite our anti-fascist views, we had to credit the directors of the operations, first and foremost Dornberger and von Braun, for the energy and confidence with which they acted.

As a matter of fact, it wasn't just the enthusiasm and organizational capabilities of the Peenemünde directors. They understood perfectly well that the enthusiasm and brilliant capabilities of lone scientists were far from sufficient. What was needed was a clear conception of the scale of operations needed to achieve set objectives, and the determination to create the strongest state-supported scientific-technical, production, and military-testing infrastructure possible. All of this was conceived prior to the war, then refined and implemented during the hostilities under the conditions of Hitler's totalitarian regime, which spared no expense to develop the proposed secret weapon of mass destruction. There was no need to account for the project before parliamentarians. To a significant degree, this contributed to the success of the new endeavor.

On 22 June 1941, Germany attacked the Soviet Union. While certain of a rapid victory on the eastern front, Hitler was troubled by Britain's tenacity. On 20 August 1941, at his "Wolf 's Den" headquarters in East Prussia, he received Colonel Doctor Dornberger, Doctor von Braun, and the lead specialist for the development of missile guidance systems, Doctor Steinhoff. There was no need for the new missile weaponry for the Blitzkrieg against the East, since the Germans would be in Leningrad within a month and Moscow no later than October. Why then such attention to missile specialists? Dornberger and von Braun familiarized Hitler with the current status of their work on the A-4 missile, which had a range of up to 300 kilometers. They also discussed the potential for new missiles that would have intercontinental ranges. As a result of this meeting, Hitler gave the programs at Peenemünde the highest priority.

In autumn 1941, roused by this support from the highest level, the work force at Peenemünde began to speed up the design process for two-stage and perhaps even three-stage A-9, A-10, and A-11 systems. But the basis was to have been the A-4 design.

[Vol. 1, pp. 246–247:] In 1943, there were more than 15,000 dedicated personnel working at Peenemünde. New firing rigs made it possible to conduct firing tests on engines with thrusts from 100 kilograms to 100 metric tons. Peenemünde aerodynamics specialists prided themselves on having the largest wind tunnel in Europe, created over a period of just eighteen months; the largest factory for the production of liquid oxygen; and spacious and excellently equipped design halls. Launching areas for rockets and launch control bunkers were provided during the earliest days of construction on Usedom Island. Correspondingly, the entire path of possible launches along a line running north-to-northeast was equipped with monitoring and observation facilities.

[Vol. 1, p. 254:] In the 1970s, the United States devoted intense attention to developing mobile railroad launchers for the Midgetman missile and, before that, the Minuteman.The USSR also developed intercontinental missile launch variants using railroad rolling stock. But mobile railroad launchers as protection against air attacks had been developed by the Germans as early as 1944 in Peenemünde. The A-4 missile was to have been launched from a simple rack mounted on a railroad flatcar. The mobile launcher consisted of alcohol and liquid oxygen tanks, launch equipment, and the equipment needed to perform pre-launch checks. However, the Germans did not succeed in bringing the mobile launchers to the point of combat-readiness. All of the actual launches were conducted from launch “tables” at fixed positions. The missiles were transported there and set up using a special erector, the so-called *Meillerwagen*.

[Vol. 1, p. 266:] In Peenemünde, there was serious work underway on another large cruise missile. By December 1944, the territory of Germany had been invaded by the Red Army from the east and the Allies from the west. The defeat of the Nazis was inevitable. Nevertheless, the stubborn specialists in Peenemünde launched an A-9 cruise missile under the designation A-4b on 27 December. The launch was unsuccessful. From our vantage point today, the failure can be easily explained—it was simply unavoidable, the knowledge and experience to realize this design did not exist. They started this work with the particular courage that comes with ignorance. The time for the realization of such designs had not yet come, especially since it was already too late to be working on them in Peenemünde. One had only to glance at a map of the military situation.

[Vol. 1, p. 268–269:] Work on the A-9, the winged version of a long-range missile, continued in spite of the catastrophic situation on the Eastern and Western Fronts. On 24 January 1945, a successful launch of the A-4b finally took place. This was the first launch of an experimental long-range missile with wings. [...]

On 14 February 1945, the last A-4 missile was launched from Peenemünde. The Eastern Front of Hitler’s Reich was collapsing. After their decorations were conferred, the Peenemünde directors received no more orders and began to prepare for evacuation on their own initiative. All of the equipment and documentation was packed into cases marked “EW.” The accompanying documents noted that this was the property of an *elektrotechnisches werk* (electrical factory). Convoys of automobiles and special trains carrying specialists, archives, and equipment, headed by Dornberger and von Braun, left Usedom Island on 17 February 1945. They evacuated to the areas of Nordhausen, Bleicherode, Sonderhausen, Lehesten, Witzenhausen, Worbis, and Bad Sachsa. The primary archives with the results of thirteen years of research and work were hidden in the tunnels of Mittelwerk and nearby potassium mines.The main group of Peenemünde directors was sent to the Bavarian Alps. On 4 May, the troops of the Second Byelorussian Army Group entered the area of Peenemünde. On 2 May 1945, the Peenemünde directors went out toward the Americans and surrendered willingly. On the blindingly sunny day of 2 May 1945, when my comrades and I were jubilantly signing our names on the still-smoldering Reichstag walls, the Americans captured some of the most valuable spoils of the war: more than four hundred of the main scientific-technical employees of Peenemünde; documentation and reports; more than one hundred missiles ready to be shipped to the front that had been stored at Mittelwerk and on spur tracks; and combat launchers, along with the military personnel who were trained to operate the missiles!

The next stage in the history of rocket technology had begun. It could rightly be called the Soviet-American stage. German specialists participated in the work of this stage in the USSR and in the United States.

[Vol. 1, pp. 278–279, at the Dora camp:] We began with a Soviet officer who introduced himself as “Shmargun, former prisoner of war, liberated from the camp by the Americans.” [...]

“Now I can show you around the camp. I know some Germans who worked at the factory and didn’t leave. They have agreed to help in investigating everything that was going on there. I can be in contact with ‘that side.’ There were a lot of good guys among the American officers. There are also a lot of Russian girls in town.They were domestic workers and worked on farms.They know the language well, and can serve as interpreters until they are repatriated. I know places where the SS hid the most secret V-2 equipment that the Americans didn’t find. We prisoners knew a lot.”

[...] Shmargun led us to a distant wooden barracks hut, where in a dark corner, after throwing aside a pile of rags, he jubilantly revealed a large spherical object wrapped in blankets. We dragged it out, placed it on a nearby cot, and unwrapped the many layers of blankets. I was stupefied—it was a gyro-stabilized platform of the type that I had seen for the first time in Berlin at the Kreiselgeräte factory. At that time,“civilian” Colonel Viktor Kuznetsov, who was also seeing the instrument the first time, explained its layout to me. How had a gyro-stabilized platform, which still hadn’t become a standard V-2 instrument, ended up in this death camp prisoners’ hut? Shmargun could not give me a clear explanation. According to what he had heard from others, when the camp guards fled, some Germans who were neither guards nor Mittelwerk personnel brought a beautiful case to the barracks, covered it with rags, and quickly fled. By the time that the Americans arrived, the surviving prisoners had discovered the case and opened it; one of them said that it was very secret. They decided to put it away until the Russians arrived. They used the case to pack up various things that they had begun to acquire after liberation, and when they found out that Shmargun was staying to wait for the Russians, they revealed the secret to him and packed everything up in dirty blankets so that the Americans would be less suspicious.

As we could see, the operation went brilliantly. Now Isayev and I were responsible for this priceless windfall. We wrapped it back up in the blankets, since no other container was available, transported it to the division headquarters, and asked them to store it there until we could take it to Moscow. Approximately six months later there was a struggle over the possession of this gyro platform that led to the first rift in the relationship between Viktor Kuznetsov and Nikolay Pilyugin, the friends that I made shortly after the instrument’s discovery.

[Vol. 2, pp. 188–189:] The Germans who developed the guidance system for the A4, and after them our specialists who developed the R-1 and R-2 guidance systems, viewed them as controllable objects possessing the properties of a “solid body,” meaning that when exposed to loads, the missile hull would not deform at all. Such an assumption proved inapplicable for the R-5 missile, which was more than 20 meters long with hull diameter of 1.65 meters, like the R-1. The missile hull bent under the effect of loads from the control fins. The flexural elastic modes of the hull were transferred to the gyroscope bases. The gyroscopes responded naturally to these modes and sent commands to the guidance system, causing the control fins to shift. The loop closed and entered an unexpected self-oscillation mode.

In a joint effort, the OKB-1 and NII-885 dynamics specialists developed measures to limit the effect that this newly discovered phenomenon had on guidance. At one of the meetings that we had on this problem, I reminded Pilyugin about our materials resistance course at the institute. They had taught us that we could use a structure within the limits of its allowable elastic deformation. His comeback was, “We’ll rock the missile with the control fins so much that your Mr. Rough will have to reinforce it with steel longerons.” We introduced various filters into the system, but at NII-885 they continued to bad-mouth the “protection against Mr. Rough.”

Another new curse for the guidance specialists was the effect caused by filling the missile with liquid. The control fins’ vibrations not only bent the missile hull, but also disturbed the liquid oxygen and kerosene in the tanks. The fluctuations of the liquid surface caused additional perturbances. We needed to develop ways to counteract the effect of the filled tanks.

The effect of flexural vibrations and fueled tanks on stability proved very hazardous. The frequency of these vibrations fell within the guidance system’s frequency band. Cooperative research was set up at OKB-1, NII-885, in the scientific departments of NII-88, and the military’s NII-4 to study the new phenomena. Khitrik was in charge of this work at NII-885; Vetrov, Degtyarenko, and Gladkiy headed the project at OKB-1. At NII-4 Georgiy Narimanov made a special study of the effect of the liquid in the missile’s tanks.

Through their combined efforts they developed a guidance theory allowing for the new phenomena. During 1955–56, guidance equipment was developed that was supposed to ensure stabilization over the entire dynamic structure. During this period the R-7 missile was designed, applying the experience derived from the R-5. To this day, missile and guidance system designers have to consider liquidity and elasticity as integrated factors from the very initial design stage.

[Vol. 2, p. 272:] Based on our own many years of experience, as well as that of the Germans, we knew that no orders and entreaties would guarantee the reliability of all the electrical equipment, the onboard cable network, and control instruments, since any single failure such as a broken wire, loss of contact in a plug and socket connector, or random short circuit would cause a missile to crash. Furthermore, the single-stage R-5 was a statically unstable flying vehicle. Unlike the R-1 and R-2, it had no stabilizers. Only after a thorough analysis and study of the behavior of this long missile in flight did we begin to understand the hazard of disregarding the elastic vibrations of the entire structure and the effect of liquid-fueled tanks. The guidance system also needed to have a significantly greater margin of resistance and controllability in terms of its dynamic characteristics than its predecessors.

[Figure E.175 presents the first three major types of Soviet ballistic missiles (see also p. 5797):

- The SS-1 or R-1 Scunner was basically just an A-4/V-2 rocket (14 meters long) that was manufactured by Germans under Soviet control and used 1950–1953.

- The SS-2 or R-2 Sibling was a longer, upgraded A-4 (18 meters long) that was in service 1953–1956. Not only was it produced by German engineers, but it appears to have been copied from 18-meter extended A-4 rockets that were secretly developed and tested in Germany during the war (p. 5794).

- The SS-3 or R-5M Shyster, also shown in Fig. 9.180, was an even longer upgraded A-4 (21 meters long) that was in service 1956–1967. It was again created by German engineers, also apparently based on wartime work (p. 5794). In fact, with its 1200 km range, capable of delivering a nuclear warhead to anywhere in the United Kingdom from dedicated launch sites near Peenemünde, the SS-3 appears to have been the very embodiment of wartime German plans (p. 5575).

Later Soviet rockets, including those still used by Russia today, were also the product of German-speaking engineers working in the Soviet Union (pp. 1879–1881).]

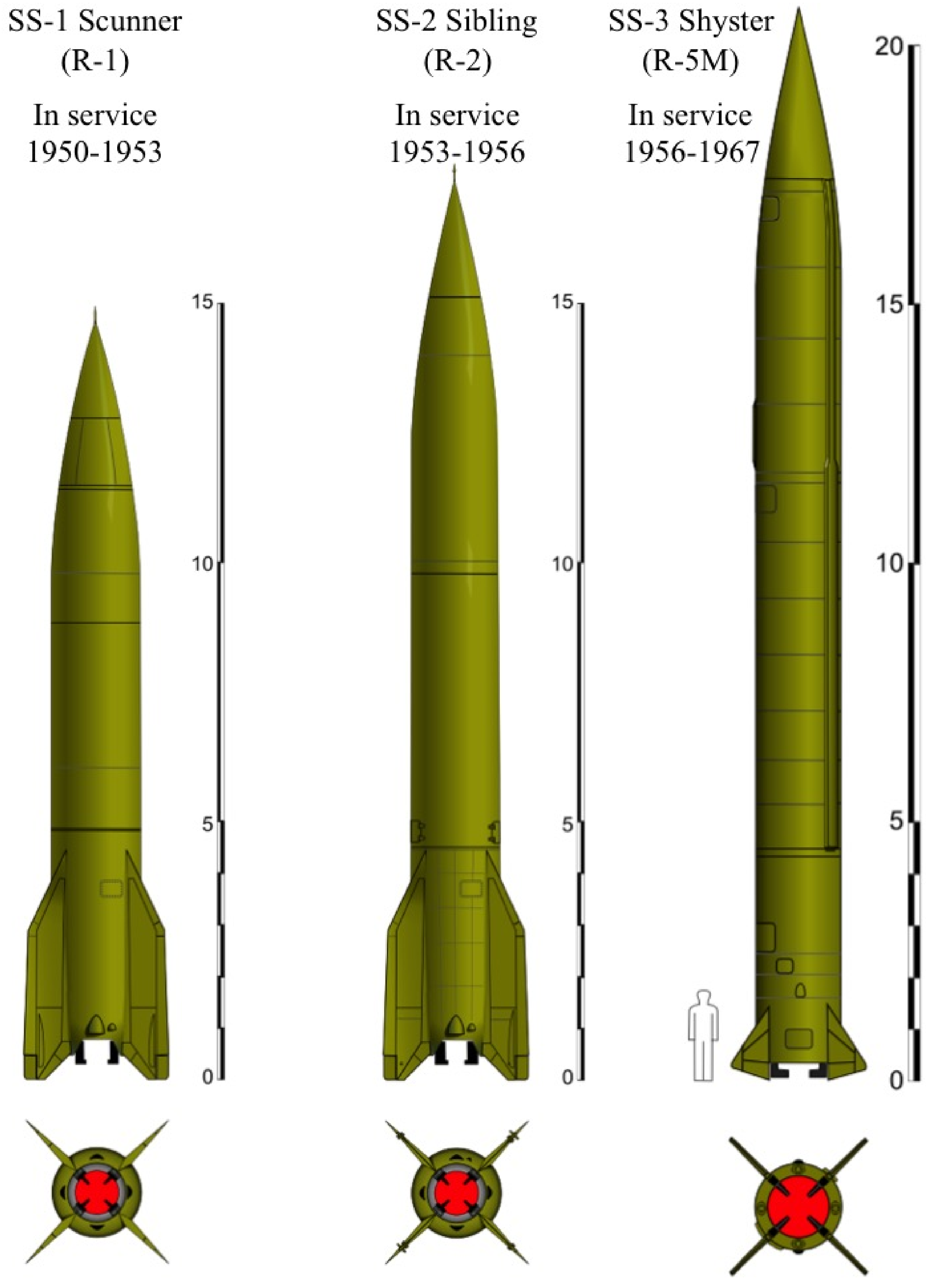

SS-1 Scunner
(R-1)
In service
1950-1953
SS-2 Sibling
(R-2)
In service
1953-1956
SS-3 Shyster
(R-5M)
In service
1956-1967
20
15
10
5
0
15
10
5
0
15
10
5
0

Figure E.175: Examples of early Soviet rockets derived directly from German creators and creations.

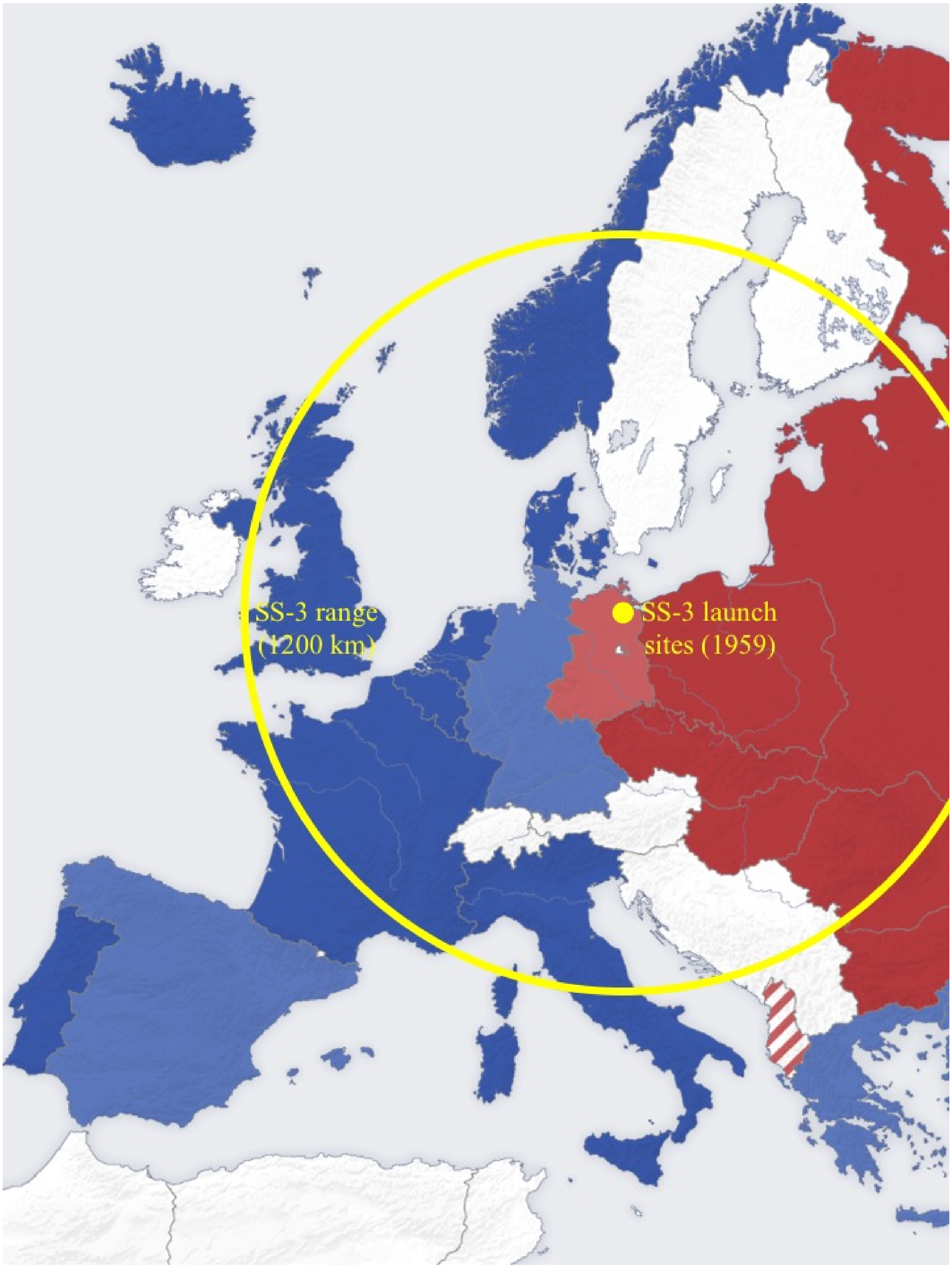

SS-3 range
(1200 km)
SS-3 launch
sites (1959)

Figure E.176: Because the first Soviet nuclear missiles, SS-3 (1959), were based heavily on German work, they may help illuminate wartime German goals for range from similar launch areas.

Niklas Reinke. 2007. ***The History of German Space Policy: Ideas, Influences, and Interdependence 1923–2002.*** **Paris: Beauchesne. pp. 36–37:**

Together with thirty or so leading scientists, propulsion expert Walter Riedel (1902–1968) arrived in Britain, where there had been practically no experiments with liquid-propellant rockets before 1945. Since the British lacked the financial resources for a large-scale rocket programme, the scientists from Peenemünde were unable to develop their work to the full. They are nevertheless credited with work on BLUE STREAK, the military rocket that was to serve as the first stage of the European launcher programme in the 1960s, and on BLACK ARROW, a more powerful rocket that placed the first British satellite, PROSPERO, in polar orbit on 28 October 1971.

Unlike the British, the French already had some experience in the field of [rocket] propulsion. After the war, in conjunction with seventy former members of the Peenemünde team, mostly [rocket] propulsion experts, they developed a small liquid-propellant rocket, VERONIQUE, at their new ballistics and aerodynamics research facility, the Laboratoire de recherches balistiques et aérodynamiques (LRBA) in Vernon. From 1954, VERONIQUE was also used very successfully in a series of German tests. While most of the German experts left France after 1956, the remaining few were involved in the construction of the propulsion unit for the DIAMANT launcher, whose first stage was derived from the V2, and of ARIANE. Another 50 or so experts headed by the German propulsion specialist Sänger worked for the French aviation ministry on the development of rocket- and jet-propelled aircraft.

Most of the Peenemünde technicians were transferred to the Soviet Union[...] While the Americans were able to draw the most important specialists to their side, the production plant at Nordhausen, which was almost intact, remained in the Soviet occupation zone. The old Mittelwerk plant was soon put back into operation, and by the end of 1945 the Soviets had already tested their first V2. In the night of 21 to 22 October 1946 the Red Army deported at least 3,500 German specialized personnel and their families to the USSR in 92 trains. The plant itself had been dismantled by the spring of 1948, and most of it was later blown up.

Charlie Hall. 2019a. ***British Exploitation of German Science and Technology.*** **New York: Routledge. p. 232:**

In the defence sphere, the areas which benefitted most were aeronautics and guided projectile development, many of the German experts in which had been recruited through Operation Surgeon. German expertise contributed to the design of the English Electric Lightning supersonic jet fighter, the Black Knight missile, and, much later, Concorde—all of which remain peaks of post-war British technological production. It really is little wonder that, in August 1948, the Defence Research Policy Committee reported that ‘many of our German scientists are settling down and becoming of real value to our long term research programmes’. This assessment was certainly borne out by the facts—Blue Steel, the principal British nuclear missile between 1963 and 1968, was based on earlier German designs, while Concorde did not come into service until 1976. One of the main reasons why the monetary value of German contributions is so incalculable is because there is no way of knowing how long it would have taken, nor how much it would have cost, for Britain to achieve these developments without German involvement.

Vincent Nouzille and Olivier Huwart. 1999. Comment la France a recruté des savants de Hitler. *L'Express* no. 2498 (20 May), p. 122. https://www.lexpress.fr/informations/comment-la-france-a-recrute-des-savants-de-hitler_633743.html

[Just as they did in the United States, United Kingdom, and Soviet Union, German-speaking scientists, materials, and information had an enormous impact on postwar programs in France. Investigative journalists Vincent Nouzille and Olivier Huwart researched unclassified French government records and described the recruitment and ultimate technological impact of over 1000 German and Austrian scientists and engineers in France after the war, especially with regard to missiles and other aerospace technologies.]

"Regardez comme c'est beau!" De la fenêtre d'un salon campagnard qui surplombe les boucles de la Seine, en aval de Vernon, un petit homme de 86 ans, à l'allure fière et au regard pétillant, montre une immense volute de fumée blanche qui s'élève dans le ciel pâle, au-dessus de la ligne boisée des crêtes. "Ils font encore un essai pour Ariane 5", murmure le vieillard, avant de se rasseoir devant une grande table de chêne, au côté de son épouse, pour feuilleter un classeur de documents jaunis par le temps. "J'ai bien connu tout cela, j'ai bien connu tout cela...", répète-t-il, d'une voix nostalgique mâtinée d'un fort accent germanique. L'homme s'appelle Otto Kraehe. Il est allemand. Pas n'importe quel Allemand.

"Look how beautiful it is!" From the window of a country lounge overlooking the loops of the Seine below Vernon, an 86-year-old man with a proud look and sparkling eyes shows a huge scroll of white smoke rising into the pale sky above the wooded line of the ridges. "They are still testing for Ariane 5," whispered the old man, before sitting down in front of a large oak table next to his wife to leaf through a binder of documents yellowed by time. "I have known all this, I have known all this...," he repeats, in a nostalgic voice with a strong Germanic accent. The man's name is Otto Kraehe. He is German. Not just any German.

Entre 1935 et 1945, cet ingénieur berlinois a participé, sur la base secrète de Peenemünde, en mer Baltique, aux recherches de Wernher von Braun, le concepteur des fusées V2, ces fusées que Hitler lâcha en masse sur Londres et Anvers à la fin de la guerre. Fait prisonnier en 1945 par les Américains, von Braun, scientifique opportuniste et officier SS, devint aux Etats-Unis le père des programmes spatiaux de la Nasa de l'ère Kennedy. "Il rêvait depuis toujours d'envoyer une fusée sur la Lune. Il a réussi", ironise Kraehe. 120 anciens de Peenemünde ont suivi leur patron outre-Atlantique. Plus de 200 ont été embarqués de force par les Soviétiques. D'autres sont restés en Europe. Comme Kraehe. "Von Braun m'avait promis qu'il me ferait venir dès que possible", raconte à L'Express le retraité vernonnais. "Mais, en 1945, j'étais au chômage. Je savais que nous ne pourrions plus mener nos recherches en Allemagne. J'ai appris que la France cherchait des ingénieurs pour reconstituer des V 2. Les conditions étaient bonnes. Alors, j'ai signé un contrat avec le ministère de l'Armement. J'ai commencé à Puteaux, puis j'ai rejoint une soixantaine d'Allemands au Laboratoire de recherches balistiques et aérodynamiques [LRBA], créé à Vernon en mai 1946. Au début, les gens du coin se demandaient ce que nous bricolions dans nos baraques cachées dans la forêt. Nos tests de fusées faisaient un bruit monstre et dégageaient d'épaisses fumées. Et puis tout le monde s'est habitué à notre présence. J'ai été le premier à me marier avec une jeune femme de la région, en 1950. Je suis reparti en Allemagne en 1958, avant de revenir en France en 1963 et de m'installer ici pour ma retraite. Mes collègues restés au LRBA ont mis au point la fusée Véronique et le moteur Viking des fusées Ariane."

Between 1935 and 1945, this Berlin engineer participated, on the secret base of Peenemünde in the Baltic Sea, in the research of Wernher von Braun, the designer of the V2 rockets, those rockets that Hitler dropped en masse on London and Antwerp at the end of the war. Taken prisoner in 1945 by the Americans, von Braun, an opportunist scientist and SS officer, became the father of NASA's space programs in the United States during the Kennedy era. "He had always dreamed of sending a rocket to the moon. He succeeded," Kraehe says ironically. 120 Peenemünde alumni followed their boss across the Atlantic. More than 200 were forcibly taken by the Soviets. Others stayed in Europe. Like Kraehe. "Von Braun promised me that he would bring me as soon as possible," says the retired Vernoner to L'Express. "But in 1945, I was unemployed. I knew we would no longer be able to conduct our research in Germany. I learned that France was looking for engineers to reconstitute V2s. The conditions were good. So I signed a contract with the Ministry of Armament. I started in Puteaux, then joined about sixty Germans at the Laboratory for Ballistic and Aerodynamic Research [LRBA], created in Vernon in May 1946. At first, locals wondered what we were doing in our huts hidden in the forest. Our rocket tests made a monster noise and emitted thick fumes. And then everyone got used to our presence. I was the first to marry a young woman from the region in 1950. I went back to Germany in 1958, before returning to France in 1963 and settling here for my retirement. My colleagues at the LRBA developed the Véronique rocket and the Viking engine for the Ariane rockets."

Un témoignage précieux. Otto Kraehe est, avec Helmut Habermann [...], l'un des rares survivants allemands présents en France de cette épopée. Leur collègue Heinz Bringer, le père du moteur Viking, est décédé près de Vernon le 2 janvier dernier, à l'âge de 90 ans. Leur aventure a longtemps été tenue secrète. Et pour cause: les contrats de travail signés avec le ministère de l'Armement leur interdisaient de parler à quiconque de leurs travaux. Ils risquaient la peine capitale! "Certains croient encore que la France est partie de zéro dans la conquête spatiale. Ce fut longtemps la thèse officielle. Mais c'est faux", raconte Roland Hautefeuille, un passionné d'histoire, dont les travaux sur les V 2 font autorité.

En vérité, sans l'apport de ces Allemands de Peenemünde, le LRBA et la Société européenne de propulsion (créée en 1971 à Vernon pour les moteurs d'Ariane) n'auraient jamais remporté tant de succès. Il n'y aurait pas eu, dès novembre 1965, de roulement de tambour gaullien sur la "troisième puissance spatiale du monde" après l'envol de la fusée Diamant au-dessus du pas de tir d'Hammaguir, où s'activaient quelques-uns de ces experts. Pas de décollage du lanceur européen Ariane de la base de Kourou, en 1979. Pas de fumée blanche sur les rives de la Seine... [...]

A precious testimony. Otto Kraehe is, with Helmut Habermann [...], one of the few German survivors present in France from this epic. Their colleague Heinz Bringer, the father of the Viking engine, died near Vernon on January 2, at the age of 90. Their adventure has long been kept secret. And for good reason: the employment contracts signed with the Ministry of Armament prohibited them from talking to anyone about their work. They were facing capital punishment! "Some still believe that France started from scratch in the space conquest. This was for a long time the official thesis. But that's not true," says Roland Hautefeuille, a history buff, whose work on V2 is authoritative.

In fact, without the contribution of these Germans from Peenemünde, the LRBA and the European Propulsion Company (created in 1971 in Vernon for Ariane engines) would never have been so successful. As early as November 1965, there was no Gaulish drum roll on the "third largest space power in the world" after the Diamant rocket took off over the Hammaguir firing point, where some of these experts were active. No take-off of the European Ariane launcher from the Kourou base in 1979. No white smoke on the banks of the Seine.... [...]

Ces remarques ne sont pas infondées. L'installation dans l'Hexagone des savants d'outre-Rhin ne va pas de soi. Comme l'accord interallié d'avril 1946 interdit toute activité militaire en Allemagne, les grosses équipes, rassemblées d'abord dans la zone française d'occupation, doivent déménager. Une vingtaine d'Allemands, dirigés par Eugen Sänger - un savant hitlérien qui rêvait de fusées rebondissant sur la stratosphère pour bombarder les Etats-Unis! - rejoignent l'arsenal aéronautique de Puteaux en juillet 1946. Ils cohabitent avec l'équipe des "engins spéciaux" d'Emile Stauff, le futur père des missiles tactiques français. Certains s'ignorent: "J'étais assis en face d'un Allemand", racontera l'ingénieur Malaval. "Après m'avoir dit bonjour, il s'asseyait et ne me disait plus un mot. A midi, la moitié de [son paquet de] gris était fumée et la moitié du papier vierge, remplie de calculs. Mais je n'ai jamais rien compris à ce qu'il faisait." Tous ne sont pas aussi renfermés. "C'était des gens urbains et agréables", confiera Emile Stauff. "Ils nous ont été extrêmement utiles." Sans copier les armes allemandes, l'arsenal s'en inspire pour concocter des missiles air-air ou le missile antichar SS 10, qui se vendra à 30 000 exemplaires dans le monde. C'est à partir de ces succès que l'Aerospatiale développera plus tard ses Exocet, Milan, Hot, Roland. Notamment en coopération avec l'Allemagne! Nostalgique et aigri, Eugen Sänger retournera, quant à lui, à Stuttgart en 1954, avant de mettre ses connaissances au service de l'Egyptien Nasser, avec d'autres experts nazis des missiles, dont Wolgang Piltz, ancien de Peenemünde passé par le LRBA de Vernon.

These remarks are not unfounded. The installation in France of scientists from across the Rhine is not self-evident. As the Allied Agreement of April 1946 prohibited all military activity in Germany, the large teams, first gathered in the French occupation zone, had to move. About twenty Germans, led by Eugen Sänger–a Hitlerian scientist who dreamed of rockets bouncing off the stratosphere to bomb the United States!—joined the aeronautical arsenal of Puteaux in July 1946. They cohabit with the "special devices" team of Emile Stauff, the future father of French tactical missiles. Some people ignore each other: "I was sitting in front of a German," said engineer Malaval. "After he said hello, he sat down and didn't say a word to me. At noon, half of [his pack of] grey was smoked and half of the blank paper, filled with calculations. But I never understood anything about what he was doing." Not all of them are so withdrawn. "They were urbane and pleasant people," said Emile Stauff. "They have been extremely helpful." Without copying German weapons, the arsenal was inspired by them to design air-to-air missiles or the SS 10 anti-tank missile, which sold 30,000 units worldwide. It is from these successes that Aerospatiale would later develop its Exocet, Milan, Hot, Roland. Especially in cooperation with Germany! Nostalgic and bitter, Eugen Sänger returned to Stuttgart in 1954, before putting his knowledge at the service of the Egyptian Nasser, along with other Nazi missile experts, including Wolgang Piltz, a former Peenemünde veteran who passed through the LRBA in Vernon.

La plupart des ingénieurs des V 2 recrutés par la France ont, en effet, émigré de la région d'Emmendingen à la petite cité de l'Eure à partir de mars 1947. Une ancienne usine Brandt, isolée dans la forêt, a été aménagée. La colonie allemande vit à deux pas, dans ce qu'ils appellent le Buschdorf, le village de brousse. "En général, l'accueil de la population a été correct, racontera Heinz Bringer au journal de l'Eure Le Démocrate, en 1990. Mais il y avait, à Vernonnet, une bande de jeunes gens hostiles. Une fois, un de mes collègues a été agressé pendant le bal du 14-Juillet."

Ce climat de défiance se dissipe au fil des mois. "Nous nous sommes vite intégrés et la coopération est devenue fructueuse avec les ingénieurs français qui nous ont rejoints", se souvient Helmut Habermann. Après l'abandon en 1948 des coûteuses recherches sur les V 2, le noyau allemand du LRBA—réduit à une trentaine d'ingénieurs—planche sur la fusée-sonde Véronique, le missile sol-air Parca, le radar Aquitaine, le lanceur Diamant. Puis Heinz Bringer, intégré avec une équipe "propulsion" à la SEP en 1971, mettra au point les moteurs Viking qui équiperont les fusées Ariane. Naturalisé sous le nom d'Henri Bringer, ce dernier recevra des "récompenses forfaitaires" au titre de ses inventions, qui demeurent propriété de l'Etat français.

En 1978, le ministère de la Défense lui octroiera notamment un bonus de 56 000 F pour sa "turbo-pompe". Modeste cadeau à l'un des pères d'Ariane! "Je suis heureux d'avoir travaillé pour la France et la recherche spatiale jusqu'à ma retraite, en 1982", explique Helmut Habermann, devenu à la SEP le précurseur des paliers magnétiques.

Most of the V2 engineers recruited by France emigrated from the Emmendingen region to the small town of Eure in March 1947. A former Brandt factory, isolated in the forest, has been built. The German colony lives a stone's throw away, in what they call the Buschdorf, the bush village. "In general, the reception of the population has been correct," Heinz Bringer told the Eure newspaper Le Démocrate in 1990. "But there was a gang of hostile young people in Vernonnet. One time, one of my colleagues was attacked during the ball on July 14th."

This climate of mistrust dissipated over the months. "We quickly integrated and the cooperation became fruitful with the French engineers who joined us," recalls Helmut Habermann. After the abandonment in 1948 of costly research on V2s, the German nucleus of the LRBA—reduced to about thirty engineers—was working on the Véronique sounding rocket, the Parca ground-to-air missile, the Aquitaine radar and the Diamant launcher. Then Heinz Bringer, integrated with a "propulsion" team at SEP in 1971, developed the Viking engines that will power Ariane rockets. Naturalized under the name Henri Bringer, the latter will receive "fixed rewards" for his inventions, which remain the property of the French State.

In 1978, the Ministry of Defence granted him a bonus of 56,000 francs for his "turbo-pump." A modest gift to one of Ariane's fathers! "I am happy to have worked for France and space research until I retired in 1982," says Helmut Habermann, who became the creator of magnetic bearings at SEP.

Mark Wade. 2019. http://www.astronautix.com/s/superv-2.html

French intermediate range ballistic missile. Developed version of German A9 studied by the German team in France in 1946-1948. Cancelled as too ambitious, but led to the Veronique of the 1950's, the Diamant of the 1960's, and the Ariane space booster of 1979–2003.

AKA: Project 4212.
Status: Cancelled 1947.
Payload: 1,000 kg (2,200 lb).
Thrust: 392.00 kN (88,125 lbf).
Gross mass: 20,000 kg (44,000 lb).
Height: 14.50 m (47.50 ft).
Diameter: 1.65 m (5.41 ft).
Span: 3.60 m (11.80 ft).
Location: Vernon.

Jürgen Michels. 1997. *Peenemünde und seine Erben in Ost und West: Entwicklung und Weg deutscher Geheimwaffen.* Bonn: Bernard & Graefe. pp. 277–278.

Projekt 4212 / "Super V 2"

Bereits ab 1946 leistete Heinz Bringer in Riegel Vorarbeit für ein Projekt, das das LRBA zu einer Boden-Boden-Rakete ausbaute. Äußere Form und Maße sollten dem Aggregat 4 entsprechen, aber mit einem stärkeren Triebwerk von 40 t Schub. Drei grundlegende Ausführungen untersuchte man mit folgenden Parametern:

Project 4212 / "Super V-2"

As early as 1946, Heinz Bringer worked in Riegel on the preparatory work for a project which the LRBA developed into a ground-to-ground rocket. The external shape and dimensions were to correspond to those of Aggregate-4, but with a more powerful engine of 40 ton thrust. Three basic designs were investigated with the following parameters:

Type	Payload in kg	Range in km	Propellant delivery	Propellant type
R1	1000	1500	Gas generator	Nitric acid Kerosene
R2	1000	1400	Turbopump	Oxygen Kerosene
R2S	1000	1800	Turbopump	Nitric acid Kerosene
R2S	500	2250	Turbopump	Nitric acid Kerosene

Eine vierte Ausführung wurde später noch hinzugefügt. Es handelt sich um eine semi-ballistische Version mit der Bezeichnung R2M, die zwei Starthilfsraketen besaß und eine Tonne Sprengstoff auf 3600 km bringen sollte. Das Studium am Projekt 4212 erbrachte keine Ausführung eines flugfähigen Gerätes. Aufgrund des geringen Interesses, das die offiziellen französischen Stellen anfänglich an den Tag legten, führte es zur Aufgabe des Projektes im Jahre 1948. Jedoch die theoretischen Studien und die Herstellung von Prototypen und deren Baugruppen wurden in ihrer Gesamtheit durchgeführt. So wurde einige Tage vor Neujahr 1947 der Gasgenerator für den 40 t-Motor auf den Versuchsstation erfolgreich getestet. Im Rahmen dieser Studien wurde erkannt, daß Salpetersäure als Brennstoff Vorteile hinsichtlich der Lagerung, des Transports, der Bedienbarkeit und seines Antriebsvermögens bietet. Während dieser Entwicklungsetappe wurden erste unfangreiche Investitionen des LRBA hinsichtlich der Prüfstände getätigt.

A fourth version was added later. It was a semi-ballistic version called R2M, which had two booster rockets and was supposed to carry a ton of explosives 3600 km. The study at the project 4212 did not yield any execution of an airworthy device. Due to the lack of interest initially shown by the official French authorities, it led to the abandonment of the project in 1948. However, the theoretical studies and the production of prototypes and their assemblies were carried out in their entirety. A few days before New Year's Day 1947, the gas generator for the 40 ton engine was successfully tested on the test stand. During these studies it was recognized that nitric acid as a propellant offers advantages in terms of storage, transport, operability and propulsion. During this development stage, the LRBA made the first major investments in the test benches.

[To what extent was Karl-Heinz Bringer's 1946 Super V-2 design based on wartime German designs or even wartime hardware? Note that the first version of the Super V-2 had many similarities to Heinz Stoelzel's 1945 design (p. 5387): nitric acid for the oxidizer, a long-chain hydrocarbon for the fuel, larger amounts of propellant than in the standard V-2, and pressurized gas for the propellant feed (highly unusual, at least for the publicly known German rockets, which generally used turbopumps!).]

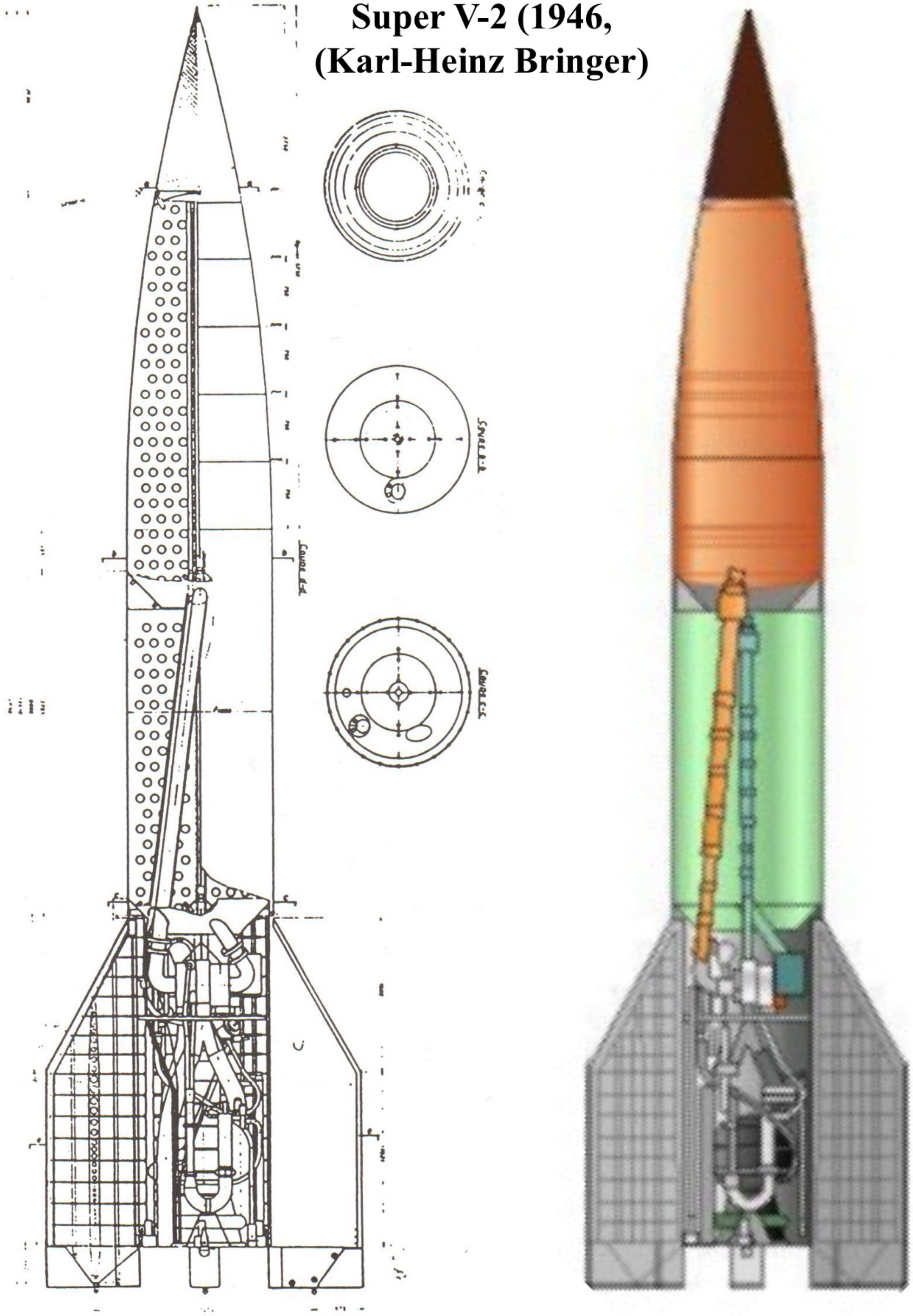

Super V-2 (1946,
(Karl-Heinz Bringer)

Figure E.177: Karl-Heinz Bringer's 1946 design for the French "Super V-2." [Left: Archives of the French Army Ministry of Defense, in Jürgen Michels 1997, p. 278. Right: http://www.astronautix.com/s/superv-2.html].

Jürgen Scheffran. 1991. Die heimliche Raketenmacht: Deutsche Beiträge zur Entwicklung und Ausbreitung der Raketentechnik. ***Wissenschaft & Frieden.***
https://wissenschaft-und-frieden.de/dossier/die-heimliche-raketenmacht/
[One should read all of this long article; I have only quoted a few parts here. See also pp. 4611–4624.]

Die OTRAG

Öffentliches Aufsehen erregte in den siebziger und Anfang der achtziger Jahren der Versuch der in der Bundesrepublik ansässigen Privatfirma Orbital Transport- und Raketen-AG (OTRAG), das Know-how der Peenemünder Raketenspezialisten für die Entwicklung von Raketen großer Reichweite zu nutzen. Die Authorisierung durch einen anderen souveränen Staat war notwendig, da die Bundesrepublik durch die WEU-Bestimmungen eingeschränkt war und nach dem Weltraumvertrag von 1967 die Nutzung durch Privatfirmen ausgeschlossen ist. Offizielles Ziel von OTRAG war die Entwicklung und Vermarktung von Raketen für den billigen Zugang in die kommerziell wichtige geostationäre Umlaufbahn.

Dies sollte mit einer modularen Trägerrakete erfolgen, die von dem deutschen Raketeningenieur Lutz Kayser entwickelt wurde. Kayser, gleichzeitig Gründer und Geschäftsführer der OTRAG seit 1974, hatte bereits als Jugendlicher Kontakt zu den Peenemünder Raketenbauern. Er trat 1954 der GfW in Stuttgart bei und studierte bei Wolfgang Pilz, Eugen Sänger und Armin Dadieu. Dadieu war im Dritten Reich für die Uran-Lagerstättenforschung in der Steiermark verantwortlich, arbeitete später für die OTRAG sowie als Gutachter der Bundesregierung in Sachen OTRAG und gehörte den Ausschüssen für Transportsysteme des Appollo-Nachfolgeprogramms und für die Trägerrakete EUROPA-III an. Kurt H. Debus, ehemals Leiter der Peenemünder V2-Raketenversuche und bis 1975 Leiter des US-Raumfahrtzentrums Cap Canaveral, war seit 1975 Aufsichtsratsvorsitzender der OTRAG. Der ehemalige V2-Triebwerksspezialist in Peenemünde und spätere Leiter der Chrysler Space Division der NASA, Richard Gombertz, wurde Technischer Leiter der OTRAG. [...]

OTRAG

In the 1970s and early 1980s, the attempt by the private company Orbital Transport- und Raketen-AG (OTRAG), based in the Federal Republic of Germany, to use the expertise of the Peenemünde rocket specialists for the development of long-range rockets caused a public stir. Authorization by another sovereign state was necessary, as the Federal Republic of Germany was restricted by WEU regulations and the 1967 Outer Space Treaty precludes use by private companies. OTRAG's official aim was to develop and market rockets for cheap access to the commercially important geostationary orbit.

This was to be achieved with a modular launch vehicle developed by the German rocket engineer Lutz Kayser. Kayser, founder and managing director of OTRAG since 1974, had already been in contact with the Peenemünde rocket builders as a teenager. He joined the GfW in Stuttgart in 1954 and studied under Wolfgang Pilz, Eugen Sänger and Armin Dadieu. Dadieu was responsible for uranium deposit research in Styria during the Third Reich, later worked for OTRAG and as an expert for the German government on OTRAG issues and was a member of the committees for transport systems for the Appollo successor program and for the EUROPA-III launch vehicle. Kurt H. Debus, former head of the Peenemünde V2 rocket tests and head of the US space center Cap Canaveral until 1975, had been Chairman of the Supervisory Board of OTRAG since 1975. The former V2 engine specialist in Peenemünde and later head of NASA's Chrysler Space Division, Richard Gombertz, became Technical Director of OTRAG. [...]

Ägypten

Ägypten hatte bereits in den sechziger Jahren unter Führung von Gamal Abdel Nasser internationales Aufsehen mit einem Raketenprogramm erregt, an dem maßgeblich deutsche Wissenschafter und Ingenieure beteiligt waren.75 Schon nach dem Rückschlag der Vereinigten Arabischen Armeen im Palästina-Krieg 1948-1949 war das Bedürfnis nach verbesserten Waffen aufgekommen (wie im Deutschland der frühen dreißiger Jahre). 1951 wurde ein kleines Team unter Leitung des deutschen Rüstungsexperten Wilhelm Voss beauftragt, eine kleinkalibrige Rakete zu entwickeln und eine moderne Rüstungsindustrie aufzubauen. 1953 wurde das Programm in die Erforschung von Flüssigkeitsantrieben unter Leitung des deutschen Raketen-Ingenieurs Rolf Engel umgewandelt, wegen finanzieller Probleme jedoch 1956 gestrichen.

Nassers Peenemünde

Da sich Ende der fünfziger Jahre einige deutsche Raketenexperten unterbeschäftigt fühlten, ergriff Nasser die Gelegenheit, sie für seine Zwecke zu erwerben. Nach dem Start einer israelischen Höhenforschungsrakete im Juli 1961 wurde die Entwicklung beschleunigt. Da die NASA eine entsprechende Unterstützung Ägyptens abgelehnt hatte, wurde Eugen Sänger beauftragt, Veteranen aus Peenemünde zu rekrutieren. Unter den etwa zehn Wissenschaftlern befanden sich der Triebwerksspezialist Wolfgang Pilz, der schon in den frühen fünfziger Jahren in Kairo und danach in Frankreich an Raketenprogrammen gearbeitet hatte, sowie die Steuerungsexperten Paul Jens-Görcke und Hans Kleinwächter, der ein Elektronikuntenehmen in Bayern besaß (Frank (1967)). Zu diesem Zweck gründeten Sänger, Pilz und Görcke 1960 die Internationale Raketen (INTRA) Handelsgesellschaft mbH, die u.a. von Messerschmidt, Bölkow und Heinkel hergestellte Raketenteile nach Ägypten exportierte. Beteiligt waren die Schweizer Firma Patvag, die Oerlikon-Tochter Contraves und die spanische Messerschmidt-Niederlassung MECO (Geissler (1978)).

Egypt

Egypt had already attracted international attention in the 1960s under the leadership of Gamal Abdel Nasser with a missile program in which German scientists and engineers were heavily involved.75 The need for improved weapons had already arisen after the setback of the United Arab Armies in the 1948-1949 Palestine War (as in Germany in the early 1930s). In 1951, a small team led by the German armaments expert Wilhelm Voss was commissioned to develop a small-caliber missile and establish a modern armaments industry. In 1953, the program was transformed into research into liquid propulsion under the direction of German rocket engineer Rolf Engel, but was cancelled in 1956 due to financial problems.

Nasser's Peenemünde

As some German rocket experts felt underemployed at the end of the 1950s, Nasser seized the opportunity to acquire them for his own purposes. After the launch of an Israeli sounding rocket in July 1961, development was accelerated. As NASA had refused Egyptian support, Eugen Sänger was commissioned to recruit veterans from Peenemünde. The ten or so scientists included engine specialist Wolfgang Pilz, who had already worked on rocket programs in Cairo in the early 1950s and then in France, as well as control experts Paul Jens-Görcke and Hans Kleinwächter, who owned an electronics company in Bavaria (Frank (1967)). To this end, Sänger, Pilz and Görcke founded Internationale Raketen (INTRA) Handelsgesellschaft mbH in 1960, which exported rocket parts manufactured by Messerschmidt, Bölkow and Heinkel, among others, to Egypt. The Swiss company Patvag, the Oerlikon subsidiary Contraves and the Spanish Messerschmidt subsidiary MECO were also involved (Geissler (1978)).

Etwa 250 Techniker aus der Bundesrepublik, Spanien, Österreich und der Schweiz wurden für den Aufbau der Raketenproduktion in der Militärfabrik 333 bei Heliopolis südlich von Kairo benötigt, insgesamt waren dort zeitweise bis zu 4000 Menschen beschäftigt. Allein Sänger und drei seiner Kollegen sollen pro Jahr den für damalige Verhältnisse erklecklichen Risikozuschlag von 450.000 Dollar pro Jahr erhalten haben.76

Nasser mußte für sein Raketenprogramm enorme Summen aufbringen und erhielt als Gegenleistung schon 1962 die ersten Raketen, die er stolz auf einer Parade im Juli des Jahres präsentieren konnte: die etwa 350 km weit reichende AL ZAFIR und die rund 600 km weit reichende AL-KAHIR. Die AL ZAFIR war mehr als 5 m lang und trug einen 500 kg schweren konventionellen, hochexplosiven Gefechtskopf. Die AL-KAHIR war 12 m lang und konnte einen 750 kg Gefechtskopf transportieren. Beide hatten nur eine Stufe und wurden von Kerosin und Salpetersäure angetrieben. Ein Jahr später konnte Nasser einen weiteren Raketentyp vorführen, die zweistufige AL-ARED, die zwei Tonnen Sprengstoff mehr als 1000 km weit tragen sollte und angeblich sogar 1 Tonne in eine niedrige Umlaufbahn. Eine noch größere Rakete war geplant, die dreistufige AL-NEGMA, die die beiden Stufen der AL-ARED verwenden sollte und für die dritte Stufe Ergebnisse der ELDO-Forschungen.

Die technischen Probleme waren allerdings enorm, besonders mit Lenkung und Flugkontrolle, so daß in der Anfangsphase des Fluges die Rakete über Draht gesteuert werden mußte. Daneben geriet das Raketenprojekt auch unter politischen Beschuß, v.a. durch die israelische Regierung, die mit diplomatischen Mitteln und unter Anwendung von Gewalt (Entführung, Bombenanschläge) gegen die Mitglieder des Raketenteams versuchte, das Programm zu beenden. Der Vorwurf der israelischen Außenministerin Golda Meir, Ägypten entwickle Massenvernichtungswaffen für seine Raketen, ließ die deutsche Bundesregierung unter Ludwig Erhard im Dezember 1963 den Rückzug der Raketenexperten einleiten, unter Inkaufnahme des diplomatischen Bruchs mit Ägypten. Eugen Sänger und Armin Dadieu hatten sich auf Bonner Druck bereits vorher verabschiedet.

Around 250 technicians from Germany, Spain, Austria and Switzerland were needed to set up rocket production in military factory 333 near Heliopolis, south of Cairo, and at times up to 4,000 people were employed there. Sänger and three of his colleagues alone are said to have received a risk premium of 450,000 dollars per year, which was considerable by the standards of the time.76

Nasser had to raise enormous sums of money for his rocket program and in return received the first rockets as early as 1962, which he was able to proudly present at a parade in July of that year: the AL ZAFIR with a range of around 350 km and the AL-KAHIR with a range of around 600 km. The AL ZAFIR was more than 5 m long and carried a 500 kg conventional, high-explosive warhead. The AL-KAHIR was 12 m long and could carry a 750 kg warhead. Both had only one stage and were powered by kerosene and nitric acid. A year later, Nasser was able to demonstrate another type of missile, the two-stage AL-ARED, which was to carry two tons of explosives more than 1000 km and allegedly even 1 ton into a low orbit. An even larger rocket was planned, the three-stage AL-NEGMA, which was to use the two stages of the AL-ARED and the results of ELDO research for the third stage.

However, the technical problems were enormous, especially with guidance and flight control, so that in the initial phase of the flight the missile had to be controlled by wire. The missile project also came under political fire, especially from the Israeli government, which tried to end the program by diplomatic means and by using violence (kidnapping, bomb attacks) against the members of the missile team. The accusation by Israeli Foreign Minister Golda Meir that Egypt was developing weapons of mass destruction for its missiles prompted the German government under Ludwig Erhard to initiate the withdrawal of the missile experts in December 1963, at the cost of a diplomatic rupture with Egypt. Eugen Sänger and Armin Dadieu had already left under pressure from Bonn.

E.3 Space Planes and Space Shuttles

[In addition to the winged A-9 rocket, an even larger winged manned space vehicle capable of reaching New York was the Silbervogel (Silver Bird) prototype space shuttle designed by Dr. Eugen Sänger and Dr. Irene Bredt (who later married). A rocket-powered catapult sled on a 3 km long earthbound track would essentially serve as the first stage, and the rocket-powered Silbervogel would effectively be the second stage. The Silbervogel is relatively well known in the published literature [e.g., Griehl 2005 Vol. 2 and Myhra 2002], which tends to describe it as purely a paper design project that never found political and financial support for actual development and testing. For example, aerospace historian Manfred Griehl stated: "Since creation of such a dreadful project was pure fantasy in the 1940s, theoretical research work was halted and Professor Sänger himself was reassigned..." [Griehl 2005 Vol. 2 p. 329].

In contrast, several pieces of evidence suggest that major parts of the Silbervogel system were actually built and even tested; evidence also demonstrates the extensive influence of German-speaking scientists on the development of postwar space planes and space shuttles:

- Eugen Sänger and Irene Bredt completed and submitted a 900-page proposal giving details of the Silbervogel design and development program to the German government in 1941 [Myhra 2002].

- Wind tunnel models of Silbervogel are known to have been constructed and tested (p. 5595).

- At least one photograph exists of a full-sized Silbervogel engine that had been constructed for testing no later than 1944 (p. 5596).

- In January 1946, five Canadian aerospace experts reported that while visiting a German research station, they viewed "a rocket motor 10 times larger than those used on V-2s." That description could match either the Silbervogel motor or the A-10 booster rocket motor (p. 5470).

- Detailed orbital calculations were performed in 1944 to find the best trajectory for the Sänger-Bredt vehicle to reach New York (pp. 5597–5599).

- An article published in the 30 October 1944 *Daily Mail* reported that the Germans in occupied France had been constructing a "huge ramp" that was "intended as a launching place for flying bombs, which... would wreck New York." The size of the ramp, the reference to flying bombs, and the claimed target of New York seem consistent with the Silbervogel launch catapult (p. 5600).

- U.S. Army Air Forces Colonel Donald Putt, in charge of overseeing all German rocket scientists and related equipment and information rounded up at the end of the war, reported in March 1946: "Test model was made that carried one man and had landing gear, although it is not known if this model ever flew; it is known, however, that test runs were made on its engine."

Thus according to an authority with arguably the best access to the available information, the Silbervogel engine was constructed and tested, a Silbervogel vehicle complete with cockpit and landing gear was constructed, its engine was operational, and postwar U.S. officials were left wondering if flight tests of the Silbervogel may have even been conducted (p. 5601). What German witnesses and documents was this information based on? What became of the prototype Silbervogel vehicle—was it destroyed by the Germans, removed by the Americans, or removed by the Soviets?

- A lengthy and detailed October 1946 article in *Harper's Magazine* stated that the Silbervogel system "was never completed merely because of the war's quick ending" (p. 5490).

- A 1957 U.S. Air Force report stated: "The boost-glide concept was... partially tested by the Germans in the early 1940's" (p. 5603).

- Wernher von Braun and other German-speaking engineers published detailed descriptions and illustrations of a space plane in 1952 in *Collier's* magazine, in order to try to excite U.S. public interest and government funding for such a project [*Collier's* 1952-03-22].

- In 1946, Walter Dornberger began work on the Bell Aerospace GAM-63 RASCAL air-launched cruise missile, a large liquid propellant rocket with wings designed for long-range horizontal flight (p. 1854). In 1952, Dornberger led the Bell Aerospace team that proposed the Bomi (Bomber Missile) space plane, which was heavily based on the wartime Silbervogel designs—see p. 1932. In 1954, Dornberger's team designed the X-15 rocket plane, which had many similarities to the wartime manned A-9 designs [Käsmann 2013, p. 105]. After the Bomi proposal was rejected, Dornberger was instrumental in recycling the Bomi and Silbervogel designs to create the X-20 Dyna-Soar space plane; a prototype was built but the program was cancelled in 1963 [Robert Godwin 2003].

- Hans Multhopp (German, 1913–1972) designed the Martin Marietta X-24 lifting body, which first flew in 1969 [R. Dale Reed 1997, pp. 129–130, 136]; see pp. 1933 and 5612.

- In 1965, Walter Dornberger named the newest U.S. space plane program the "Space Shuttle" [Dornberger 1965a, 1965b].

- The U.S. Space Shuttle (Fig. 9.225) incorporated design features, experience, and personnel from the earlier A-9, Silbervogel, Bomi, Dyna-Soar, and X-24 space plane programs [Winter 1990, pp. 42–44, 113–122]; see pp. 5608 and 5610.

- Adolf Busemann (German, 1901–1986) suggested ceramic tiles for thermal insulation on the Space Shuttle, and also contributed his detailed knowledge of hypersonic aerodynamics and heating for the design and reentry [NYT 1986-11-05]; see p. 5611.

- Krafft Ehricke (German, 1917–1984) was deeply involved in space plane projects from Bomi to the Space Shuttle [Freeman 2008].

- The Space Shuttle Main Engines (SSMEs) were directly derived from engine designs with especially high combustion chamber pressures that were developed during and after the war (such as the MBB P111 engine and the Rocketdyne HG-3 engine) by Klaus von Riedel, Karl Stöckel, Hans Georg Paul, Dieter Huzel, and other German-speaking engineers (see pp. 5613–5617).

- The Space Shuttle Solid Rocket Boosters (SRBs) were based on enormous German-speaking contributions to solid propellant rockets (see Sections 9.8 and E.4).

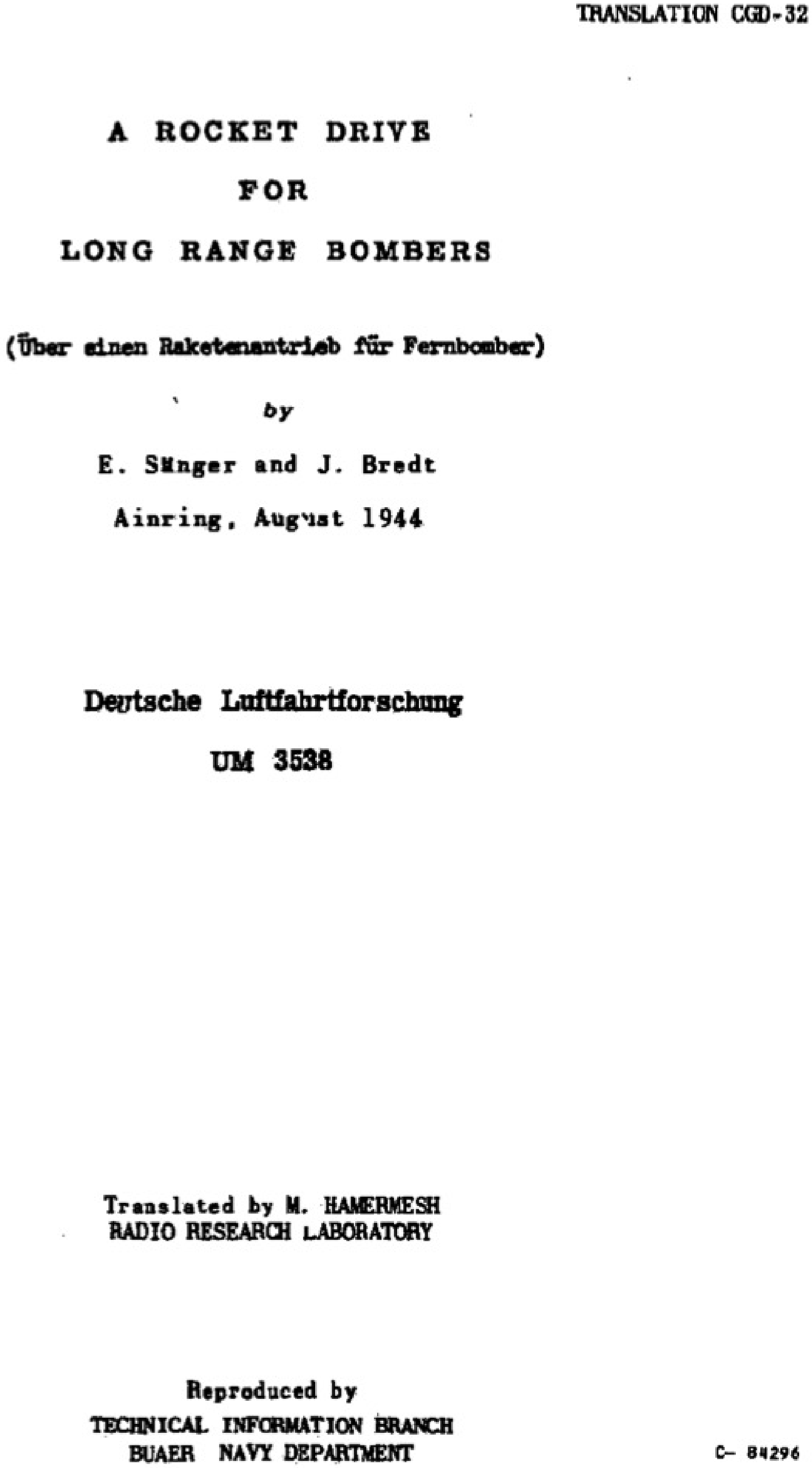
Thus the Silbervogel and the manned winged A-9, as well as the German-speaking scientists who worked on them, led directly to postwar space plane programs such as the X-20 Dyna-Soar, the U.S. Space Shuttle (first launched in 1981, Fig. 9.225), the Soviet Buran (first launched in 1988, Fig. 9.227), and other space planes such as Dream Chaser (Fig. 9.228) [Chertok 2005–2012, Vol. 1, pp. 262–265; Winter 1990, pp. 42–44, 113–122].

Much more archival research on the wartime and postwar development of space planes by German-speaking scientists is necessary.]

Eugen Sänger and Irene Bredt. 1944. *Über einen Raketenantrieb für Fernbomber.* UM 3538. Ainring: Deutsche Luftfahrtforschung. English translation 1952. *A Rocket Drive for Long Range Bombers.* CGD-32, C-84296. Technical Information Branch, Buaer Navy Department. pp. 148, 152.

As an example of area attack with single propulsion and full turn, we use the attack on New York at a range of 6500 km. For c=4000 m/sec, the bomb load is 6 tons, and the detailed attack runs as follows: the motor starts to work 36 seconds after the take-off at 12 km. distance from the take-off point, and consumes the total fuel supply of 84 tons in the next 336 sec. At the end of the climb process, the aircraft reaches a velocity of 6370 m/sec, an altitude of 91 km, a distance of 736 km. from the point of take-off, and a weight of 16 tons. Using only its store of potential and kinetic energy, the bomber flies on to the point of bomb release, 5550 km. from the take-off point, and 950 km. in front of the target. At this point, which is reached 1150 sec. after take-off, the velocity has decreased to 6000 m/sec, and the stationary altitude to 50 km. After the bomb release the weight is 10 tons. Then the aircraft goes into a turn and in 330 sec. goes through a turn-spiral 1000 km. in diameter until it has reached the direction for the return flight to the home base. During turning, the altitude is greatly decreased in order to develop the aerodynamic forces necessary for the turn. At the end of the turn path, the velocity is still 3700 m/sec. and the corresponding stationary altitude is 38 km. The supersonic glide-path in the direction of the home base goes over 5450 km. in 2600 sec. and ends 100 km. before the home base at an altitude of 20 km. and velocity 300 m/sec. Subsonic glide and landing are completed in customary fashion. The whole flight lasts 4755 sec.

Figure E.178: Dr. Irene Bredt and Dr. Eugen Sänger (circa 1945).



TRANSLATION CGD-32

A ROCKET DRIVE
FOR
LONG RANGE BOMBERS

(Über einen Raketenantrieb für Fernbomber)

by

E. Sänger and J. Bredt

Ainring, August 1944

Deutsche Luftfahrtforschung

UM 3538

Translated by M. HAMERMESH
RADIO RESEARCH LABORATORY

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TECHNICAL INFORMATION BRANCH
BUAER NAVY DEPARTMENT

C– 84296

Figure E.179: English translation of Eugen Sänger and Irene Bredt. 1944. *Über einen Raketenantrieb für Fernbomber.* UM 3538. Ainring: Deutsche Luftfahrtforschung [Saenger and Bredt 1944, English translation].

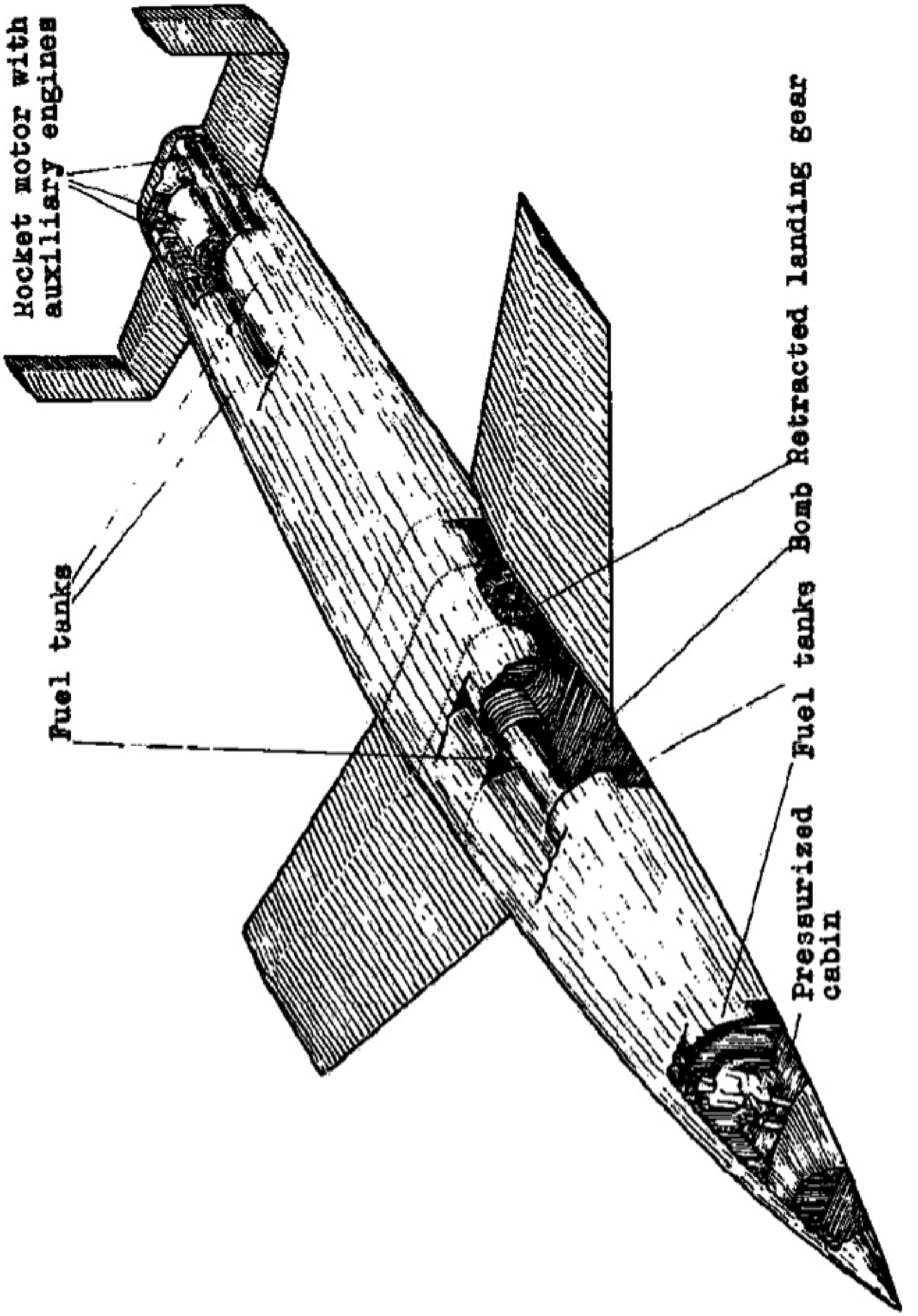

Rocket motor with auxiliary engines
Fuel tanks
Retracted landing gear
Bomb
Fuel tanks
Pressurized cabin

Figure 33; Total view of 10 ton Rocker Bomber

Figure E.180: Silbervogel space plane: design of the vehicle [Saenger and Bredt 1944, English translation].

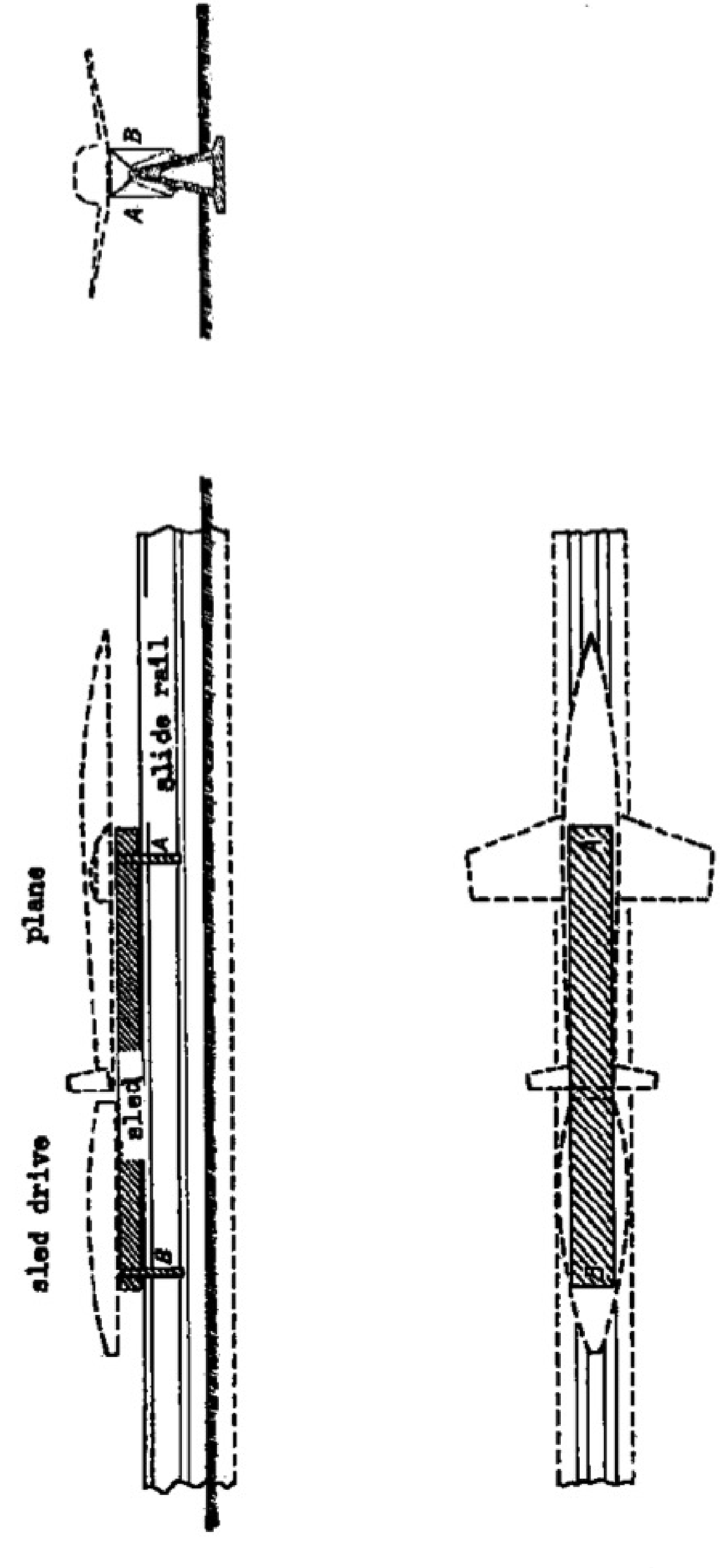

A
B
plane
sled drive
sled
slide rail
A
B

Figure E.181: Silbervogel space plane: design of the booster sled and track [Saenger and Bredt 1944, English translation].

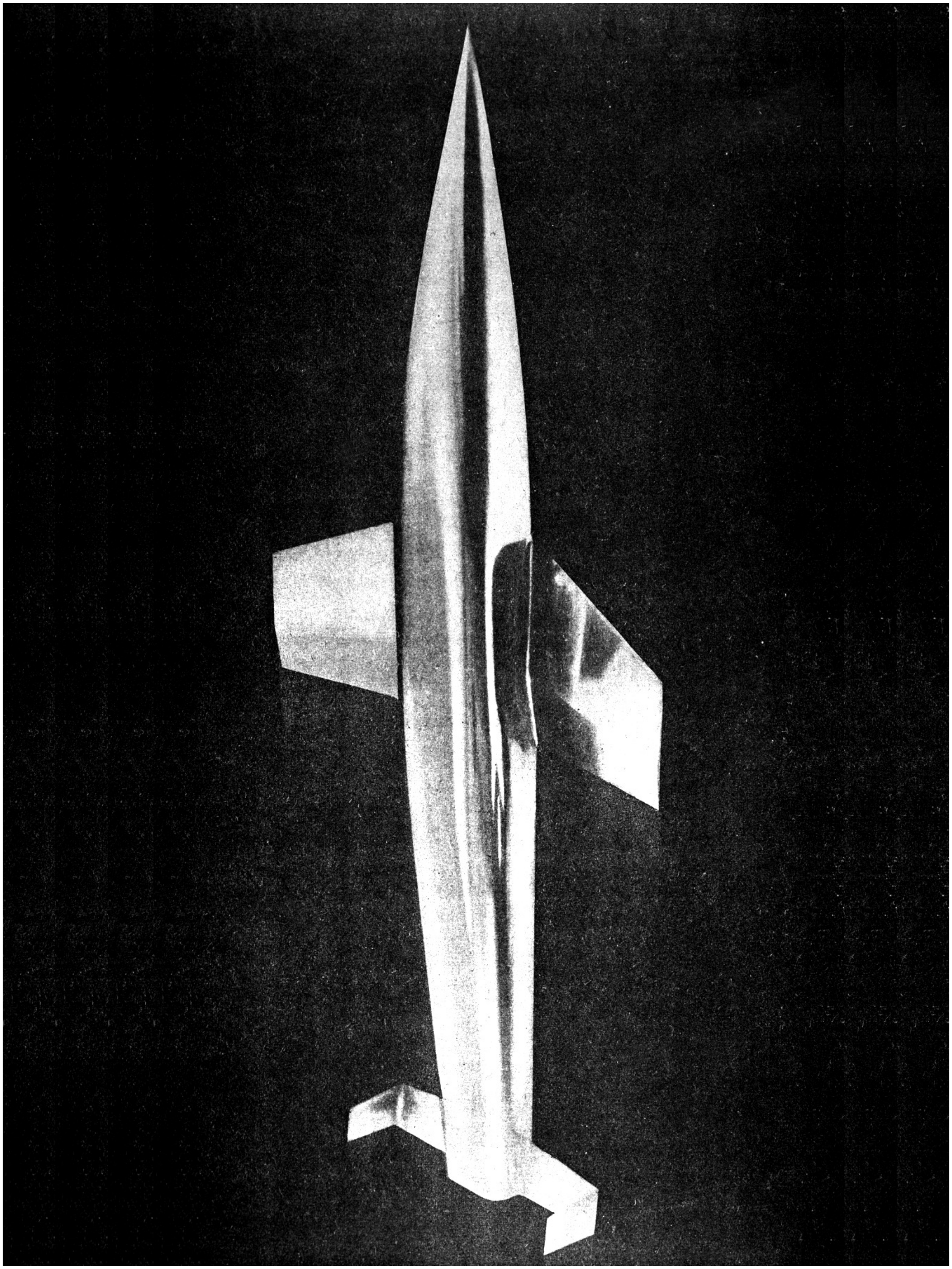


Figure E.182: Silbervogel space plane: wind tunnel model [Deutsches Museum Archive, photo 30394].

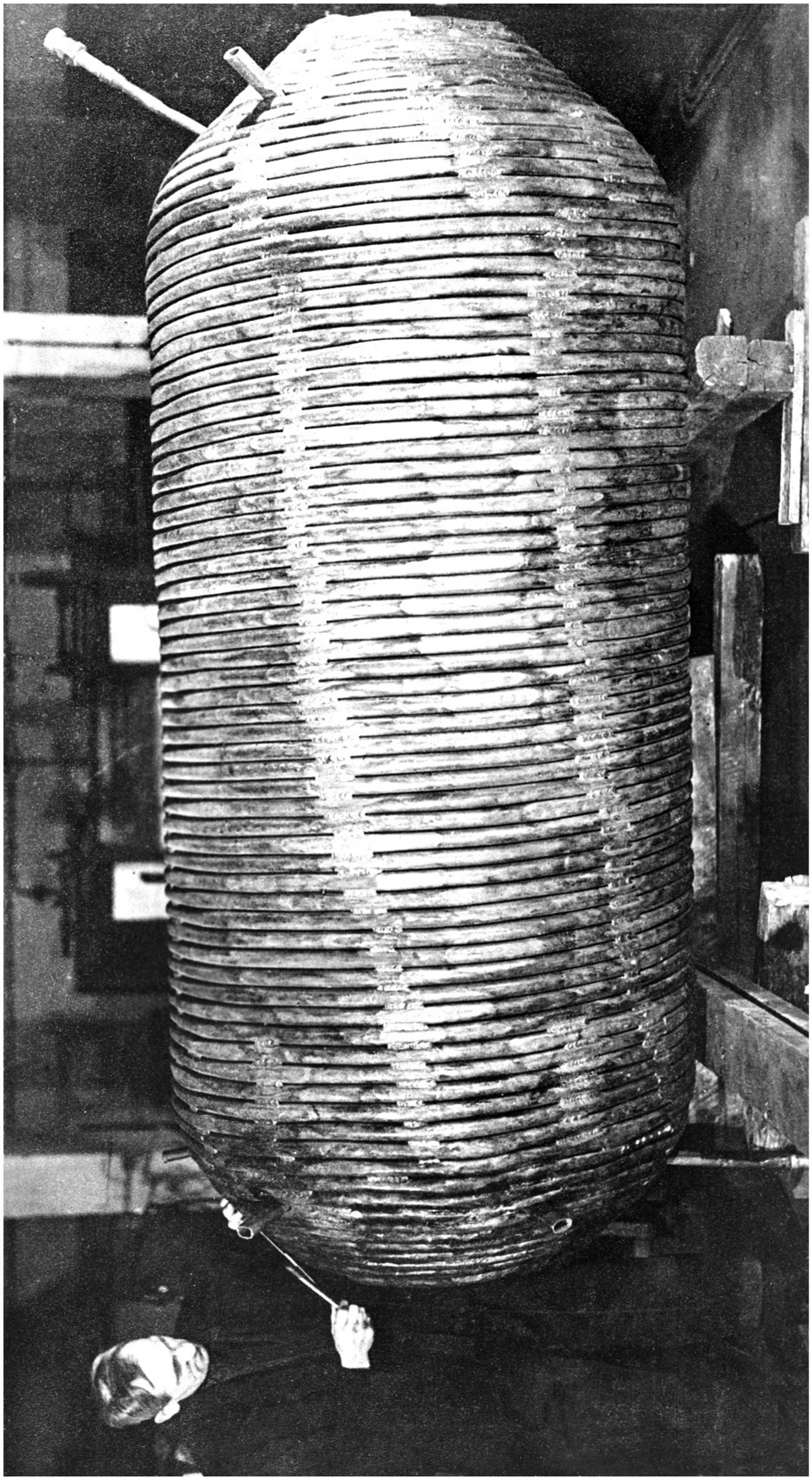


Figure E.183: Silbervogel space plane: construction of prototype 100-ton rocket engine in 1941 [Deutsches Museum Archive, photo 30391].

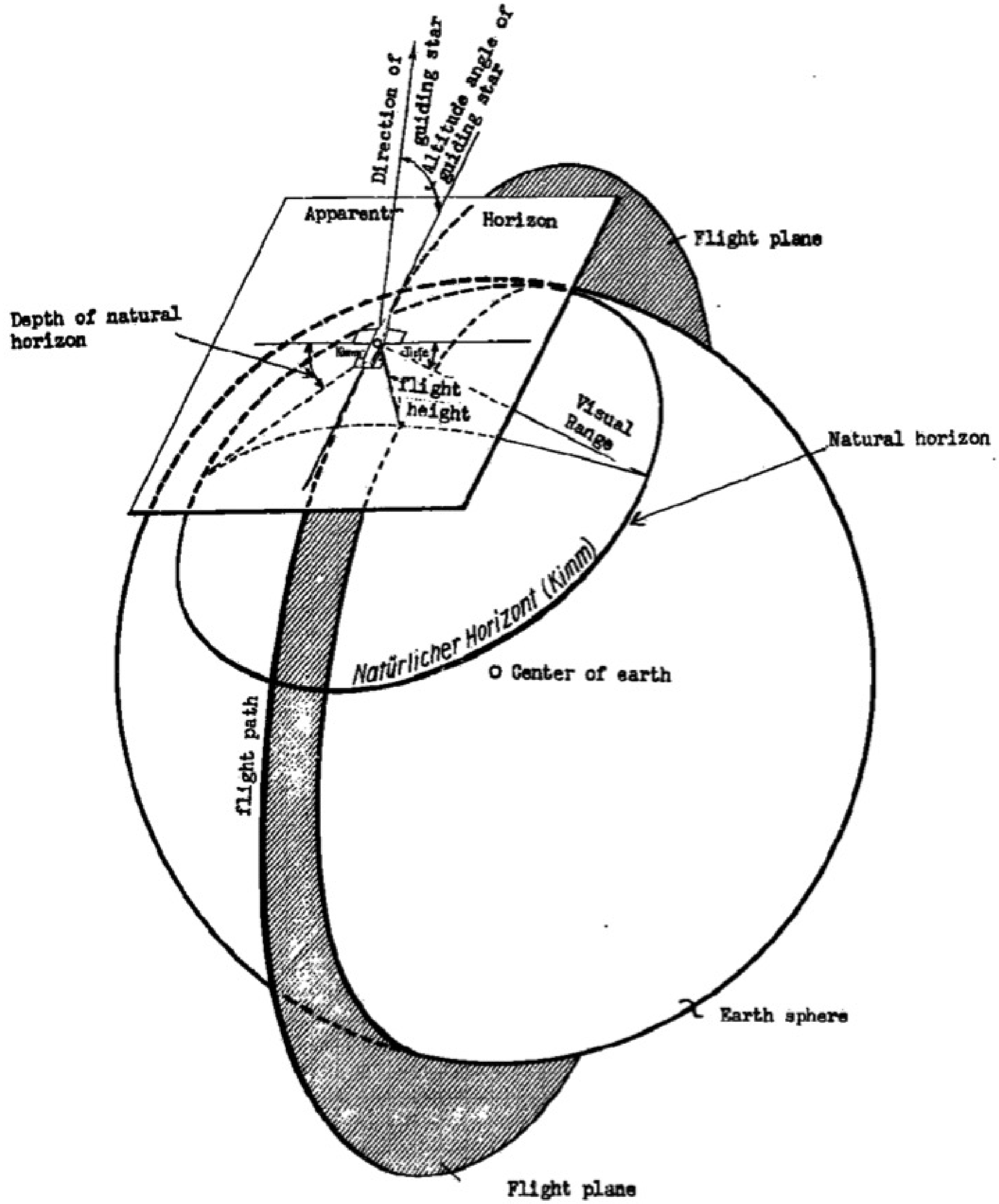
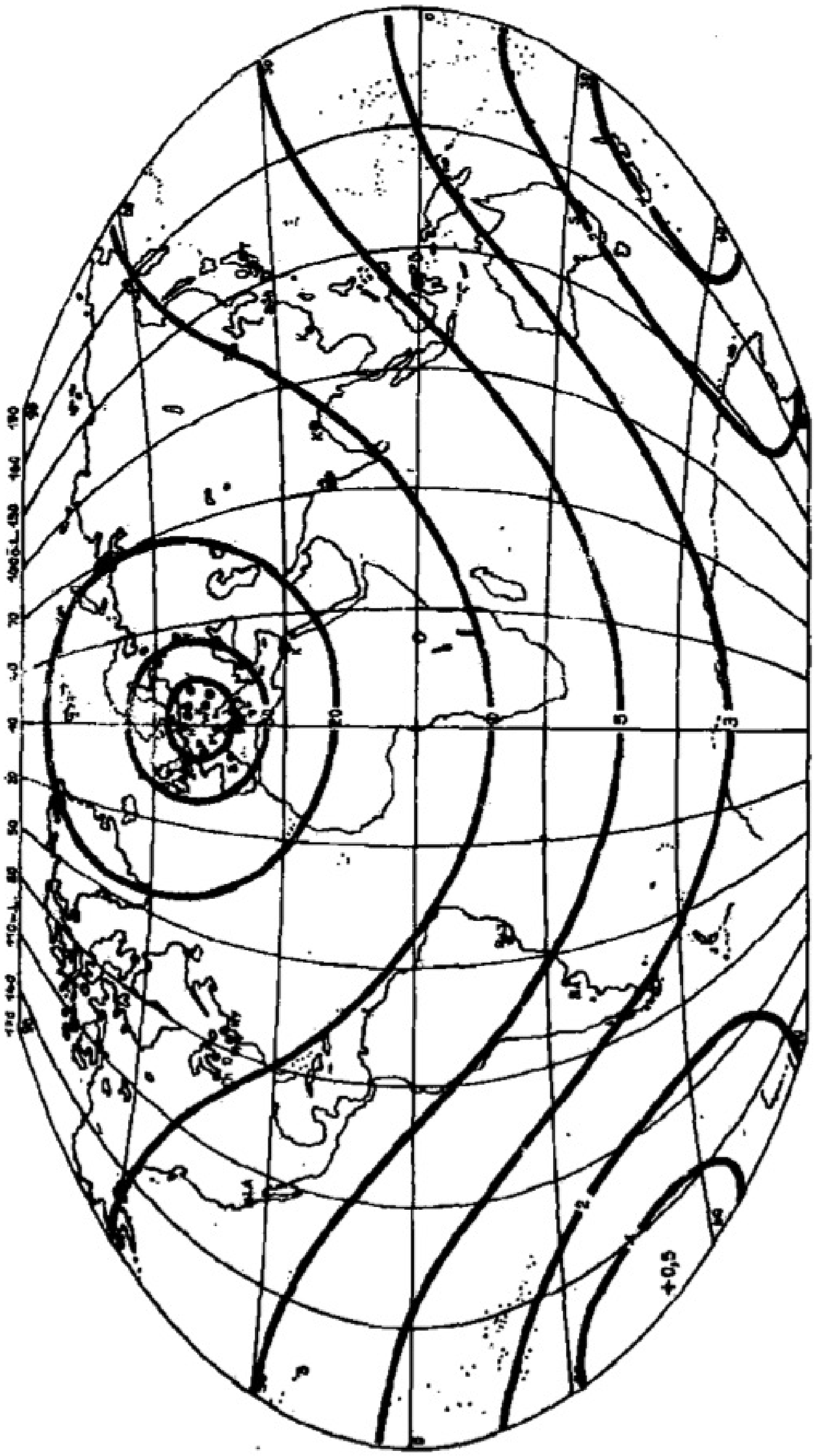

Direction of guiding star
Altitude angle of guiding star
Apparent Horizon
Flight plane
Depth of natural horizon
Tiefe
flight height
Visual Range
Natural horizon
Natürlicher Horizont (Kimm)
Center of earth
flight path
Earth sphere
Flight plane

Figure E.184: Silbervogel space plane: calculated orbital trajectory of the vehicle [Saenger and Bredt 1944, English translation].



● Cities of more than one million

× Home base

+ Antipodal base point

Fig. 97: Bomb load of a Rocket Bomber in tons, that is percent of the initial weight, in the case of point attack with a single acceleration and sacrifice of the bomber and with exhaust velocity c = 3000 m/sec.

Figure E.185: Silbervogel space plane: global targets within range of vehicle [Saenger and Bredt 1944, English translation].

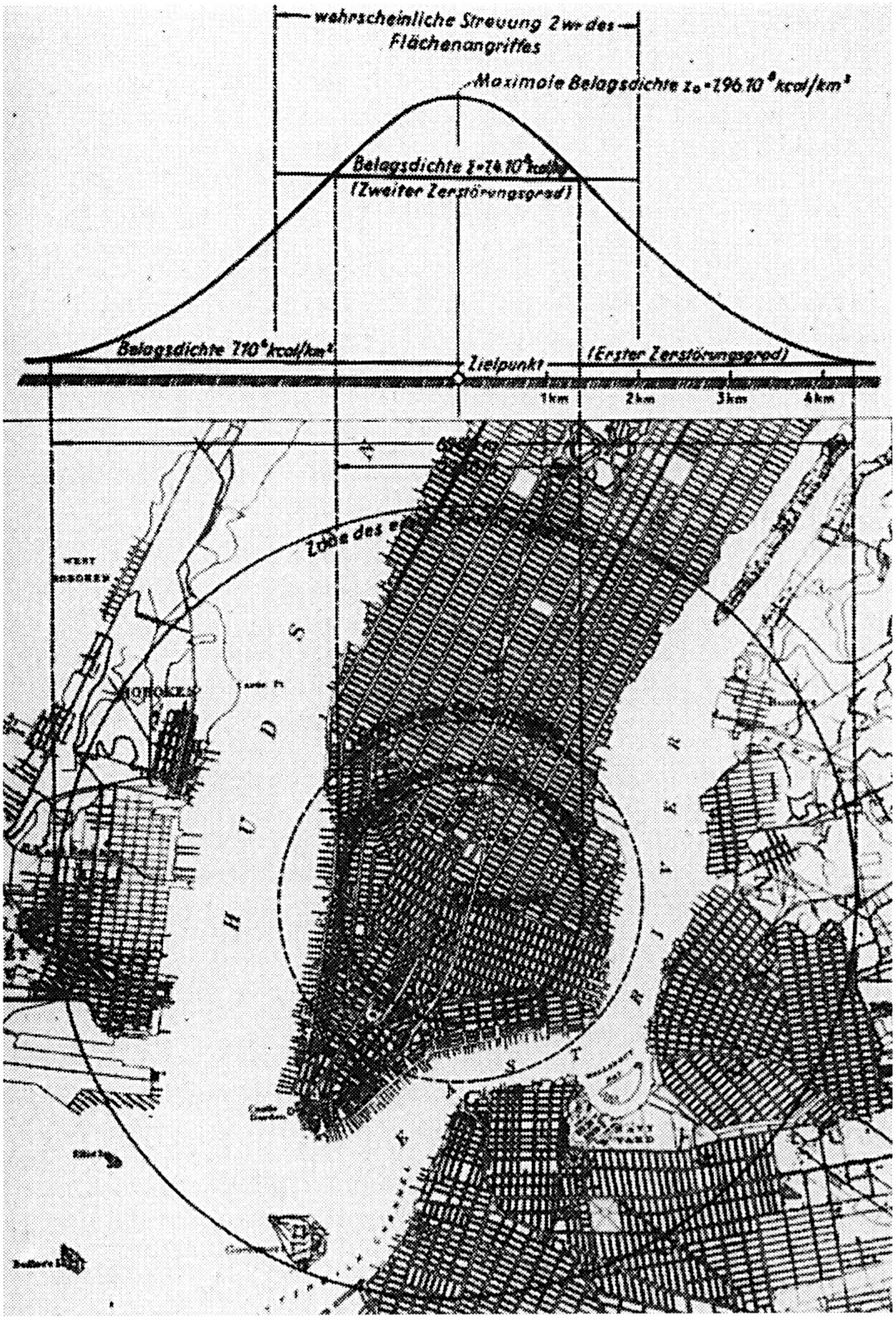

wahrscheinliche Streuung 2w des Flächenangriffes
Maximale Belagsdichte z₀ = 1,96.10⁸ kcal/km²
Belagsdichte z = 7,4.10⁷ kcal/km²
(Zweiter Zerstörungsgrad)
Belagsdichte 7.10⁶ kcal/km²
Zielpunkt
(Erster Zerstörungsgrad)
1km
2km
3km
4km
Zone des e
WEST HOBOKEN
HOBOKEN
HUDSON
RIVER
NAVY YARD

Figure E.186: Silbervogel space plane: projected bomb impact on New York [Deutsches Museum Archive, photo CD56143]. Also published in: Map Showing N.Y. City As Target For German Rocket [NYT 1946-04-02 p. 12.]

G. Ward Price, Fly-bombs Were Meant for U.S.: Huge Ramp Found. *Daily Mail.* 30 October 1944.

Immense concrete works on top of a hill in Artois, near Saint Omer, were intended as a launching place for flying bombs, which, the Germans boasted, would wreck New York.

Thousands of workmen were employed in tunnelling and building a cylindrical cupola on top of the hill, 250ft. in diameter.

Lorries, and even trains, could drive right into the heart of the hill.

German engineers told local French people that when the vast machinery was installed and ready to fire, the district would have to be evacuated for six miles around.

Frequent attacks by the R.A.F. kept on delaying work until the Allied advance from Normandy obliged all the enemy engaged on it to pack up hurriedly.

Footnote.—A German U-boat commander recently told naval cadets at Esjberg, Denmark, that Germany was preparing a new secret weapon for use against America. He said that U-boat crews would play a decisive part in the use of the weapon.

[This sounds like a launching sled track for Silbervogel, or possibly a slightly smaller launching track for the winged A-9 rocket.

The six-mile radius suggests that it would have been carrying a weapon of mass destruction. A 6-mile or 10-km blast radius would correspond to a ∼1.6 megaton bomb, which would suggest a hydrogen bomb and not a simple fission bomb.

Also see article on p. 5011 mentioning development of a catapult-launched atomic bomb delivery system in Norway. Could that have been a rocket-powered sled track for a Silbervogel or winged A-9?

Donald L. Putt. 1946. German Developments in the Field of Guided Missiles. *Society of Automotive Engineering (SAE) Journal (Transactions)* 54:8:404–411. [Putt 1946b]

One of the Germans' most fascinating projects was their long-range bomber. (See Fig. 14.) This was a liquid fuel supersonic pilot-controlled aircraft intended to fly from Germany to New York in 40 min at an altitude of approximately 154 miles. The motor was to weigh 2 1/2 tons and to deliver a thrust of 100 tons. This bomber was never finished, but it is believed that time was the only obstacle against its completion.

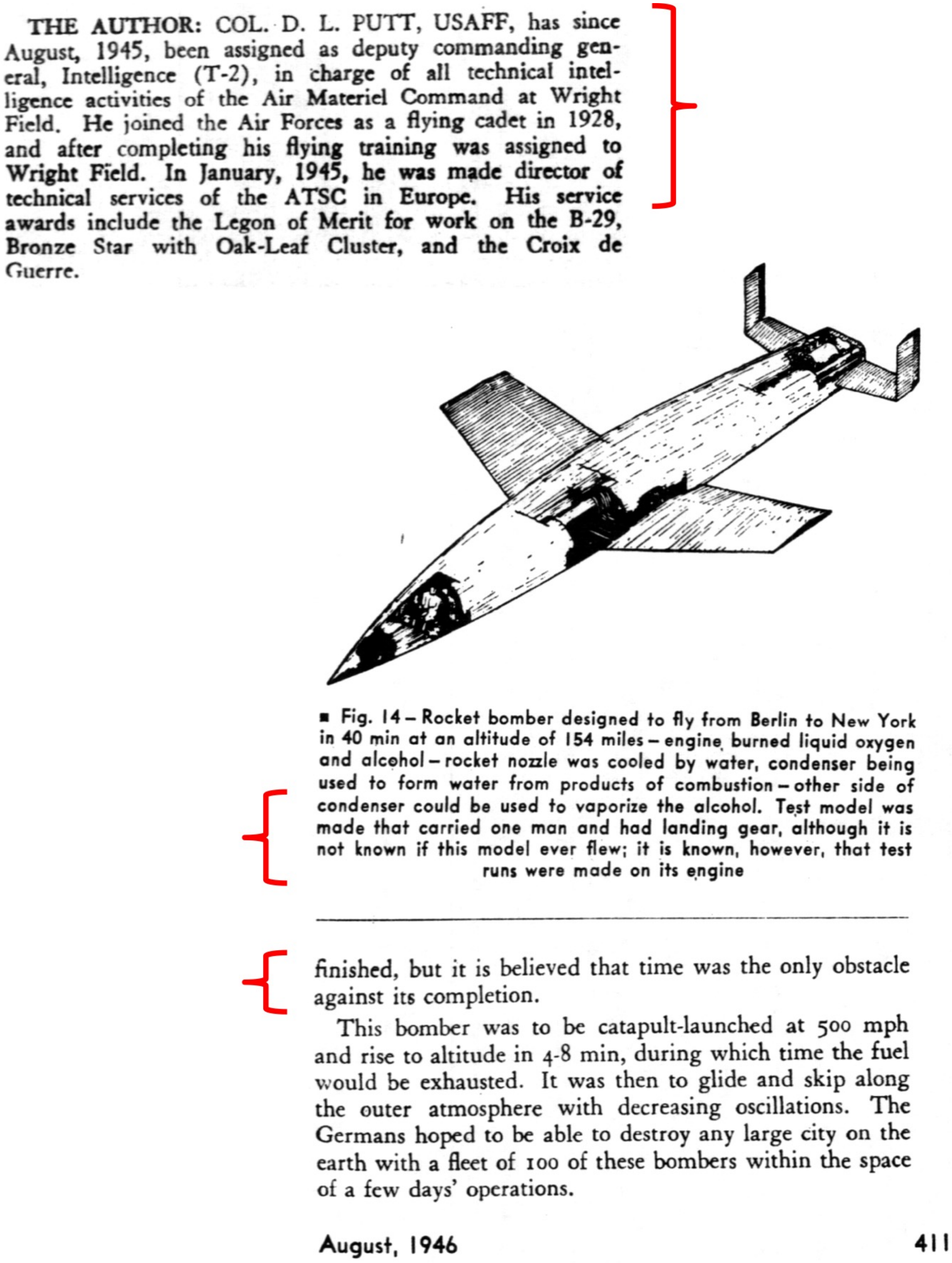
This bomber was to be catapult-launched at 500 mph and rise to altitude in 4–8 min, during which time the fuel would be exhausted. It was then to glide and skip along the outer atmosphere with decreasing oscillations. The Germans hoped to be able to destroy any large city on the earth with a fleet of 100 of these bombers within the space of a few days' operations.

Fig. 14—Rocket bomber designed to fly from Berlin to New York in 40 min at an altitude of 154 miles—engine burned liquid oxygen and alcohol—rocket nozzle was cooled by water, condenser being used to form water from products of combustion—other side of condenser could be used to vaporize the alcohol. Test model was made that carried one man and had landing gear, although it is not known if this model ever flew; it is known, however, that test runs were made on its engine

[Donald Putt was the U.S. Army Air Forces Colonel (later General) in charge of rounding up most of the German aerospace engineers in Europe at the end of the war, and funding them to continue their work in the United States for many years after the war. From that very well-informed position, he stated in this 7 March 1946 presentation to the Society of Automotive Engineers that the Silbervogel space plane was actually built, complete with cockpit, landing gear, and a functioning engine, and that it was possible that it was even test-flown.

Interestingly, his statement that the Silbervogel was actually built and might have been test flown (as well as some of his other statements about German rocket developments) vanished without explanation from later versions of this speech, such as the 27 June 1946 version written at Wright Field, possibly due to censorship:

- Donald L. Putt. 1946. German Developments in the Field of Guided Missiles: An Address Before the SAE in New York, 7 March 1946. Summary Report. Report No. F-SU-1122-ND. 27 June 1946. Headquarters, Air Materiel Command, Wright Field, Dayton, Ohio. Library of Congress, Washington, DC. Call number MLCM 95/01648 (T) FT-MEADE.
- Donald L. Putt. 1946. World's Cities Threatened by Nazi Supersonic Bomber. *Society of Automotive Engineering (SAE) Journal* 54:7:9.]



THE AUTHOR: COL. D. L. PUTT, USAFF, has since August, 1945, been assigned as deputy commanding general, Intelligence (T-2), in charge of all technical intelligence activities of the Air Materiel Command at Wright Field. He joined the Air Forces as a flying cadet in 1928, and after completing his flying training was assigned to Wright Field. In January, 1945, he was made director of technical services of the ATSC in Europe. His service awards include the Legon of Merit for work on the B-29, Bronze Star with Oak-Leaf Cluster, and the Croix de Guerre.

■ **Fig. 14 – Rocket bomber designed to fly from Berlin to New York in 40 min at an altitude of 154 miles – engine burned liquid oxygen and alcohol – rocket nozzle was cooled by water, condenser being used to form water from products of combustion – other side of condenser could be used to vaporize the alcohol. Test model was made that carried one man and had landing gear, although it is not known if this model ever flew; it is known, however, that test runs were made on its engine**

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This bomber was to be catapult-launched at 500 mph and rise to altitude in 4-8 min, during which time the fuel would be exhausted. It was then to glide and skip along the outer atmosphere with decreasing oscillations. The Germans hoped to be able to destroy any large city on the earth with a fleet of 100 of these bombers within the space of a few days' operations.

August, 1946 **411**

Figure E.187: Donald Putt, who was in charge of collecting all technical intelligence from Europe for the U.S. Army Air Forces, published a written statement confirming that a manned Silbervogel complete with landing gear and a working engine was actually built during the war [Donald L. Putt. 1946. German Developments in the Field of Guided Missiles. *Society of Automotive Engineering (SAE) Journal (Transactions)* 54:8:404–411].

U.S. Air Force Air Research and Development Command. 1957. *Weapon Sys 464L Abbreviated Development Plan.* [Reproduced in Robert Godwin 2003, pp. 38–51]

[...] Briefly, this concept is characterized by a manned, winged vehicle, rocket-boosted to hypersonic speeds and altitudes above 100,000 feet, whereupon the vehicles operates in an unpowered gliding mode, trading kinetic and potential energy for ranges on the order of 5,000 nautical miles to 22,000 nautical miles depending upon the mission and time period.

The hypersonic boost-glide concept offers a major technological breakthrough in performance and mission capability which should be exploited in future reconnaissance and bombardment aircraft weapon systems. [...]

The boost-glide concept is not new. In the early Forties, Dr. Sänger, German rocket scientist, proposed a skip-glide vehicle to bomb New York from a launch site in Germany. Serious consideration was given this proposal by the Germans. A program known to the Germans as the A9/A10 development was designed to use a winged V-2 rocket as the second stage of a two-stage system. This vehicle was under development and test by the Germans when the war ended. At the close of the war Dr. Walter Dornberger, ex-German general and head of the Peenemunde Rocket Research Institute in Germany went to work for Bell Aircraft Corporation in this country. It is not surprising then that Bell approached the USAF in 1952 with an unsolicited proposal for a Manned, Hypersonic Boost-Glide Bomber/Reconnaissance Weapon System. Rand conducted investigations of this concept in 1948 and NACA published work on the subject in 1954. Since 1954, the ARDC has sponsored a considerable amount of work in the boost-glide field. The following table summarizes this effort. [Programs BOMI, Brass Bell, ROBO, HYWARDS, and now Dyna-Soar.]

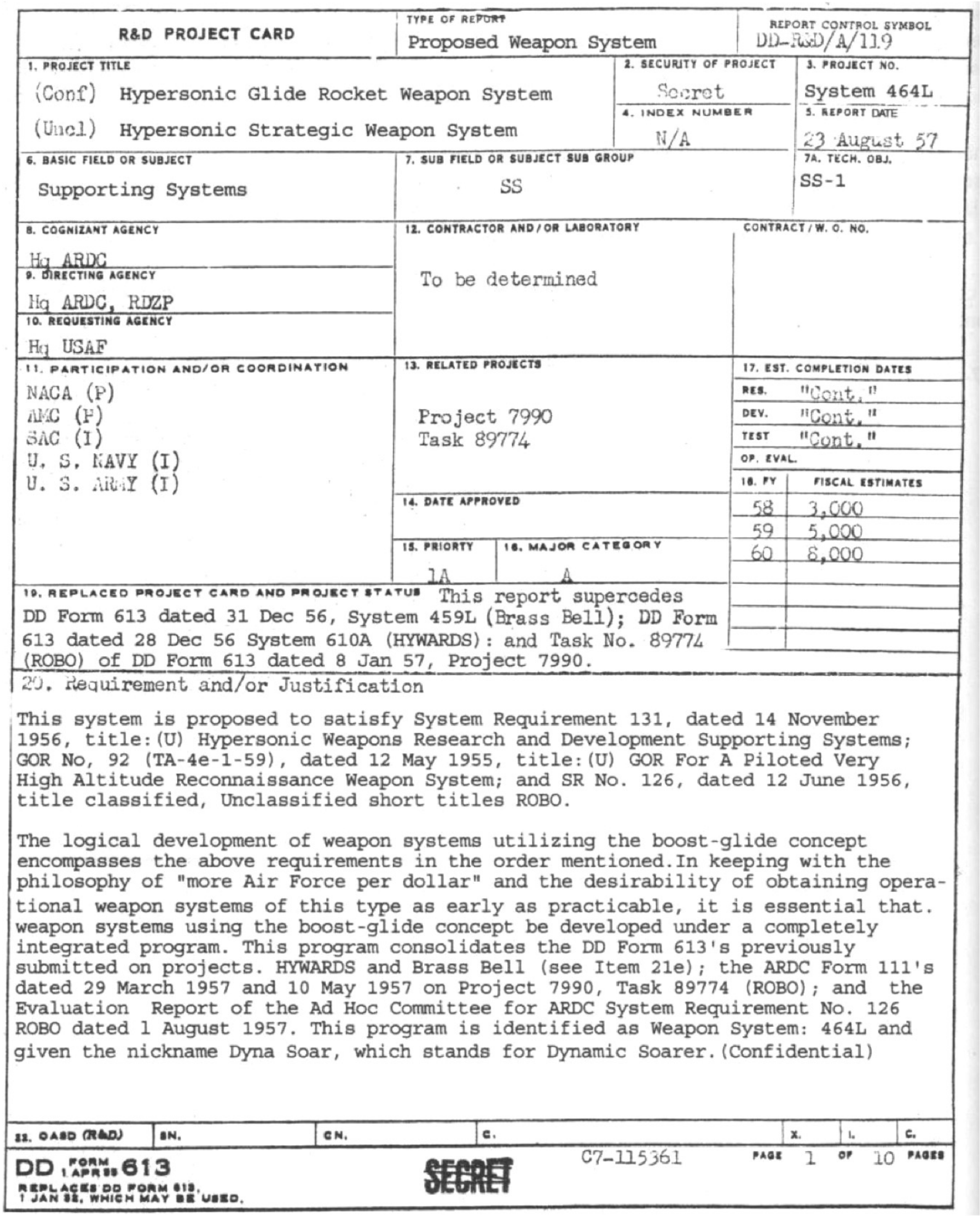
[However far the development of Silbervogel actually got during the war, it led to many German-speaking engineers to develop additional space planes after the war.

After the war this approach was also championed by Walter Dornberger and other German-speaking scientists, ultimately leading to several vehicles: the U.S. X-20 Dyna-Soar that was built but not flown, the U.S. Space Shuttle, the Soviet Buran, and assorted other space planes that have been designed and in some cases flown.

Wernher von Braun and other German-speaking engineers published detailed descriptions and illustrations of a space plane in 1952 in *Collier's* magazine, in order to try to excite U.S. public interest and government funding for such a project [*Collier's* 1952-03-22].

In 1946, Walter Dornberger began work on the Bell Aerospace GAM-63 RASCAL air-launched cruise missile, a large liquid propellant rocket with wings designed for long-range horizontal flight (p. 1854). In 1952, Dornberger led the Bell Aerospace team that proposed the Bomi (Bomber Missile) space plane, which was heavily based on the wartime Silbervogel designs—see p. 1932. In 1954, Dornberger's team designed the X-15 rocket plane, which had many similarities to the wartime manned A-9 designs [Käsmann 2013, p. 105]. After the Bomi proposal was rejected, Dornberger was instrumental in recycling the Bomi and Silbervogel designs to create the X-20 Dyna-Soar space plane; a prototype was built but the program was cancelled in 1963 [Robert Godwin 2003].

Ultimately the work of these and other German-speaking engineers led to several space planes that were actually launched, including the U.S. Space Shuttle and the Soviet Buran.]



R&D PROJECT CARD

TYPE OF REPORT: Proposed Weapon System

REPORT CONTROL SYMBOL: DD-R&D/A/119

1. PROJECT TITLE: (Conf) Hypersonic Glide Rocket Weapon System
(Uncl) Hypersonic Strategic Weapon System

2. SECURITY OF PROJECT: Secret

3. PROJECT NO.: System 464L

4. INDEX NUMBER: N/A

5. REPORT DATE: 23 August 57

6. BASIC FIELD OR SUBJECT: Supporting Systems

7. SUB FIELD OR SUBJECT SUB GROUP: SS

7A. TECH. OBJ.: SS-1

8. COGNIZANT AGENCY: Hq ARDC

9. DIRECTING AGENCY: Hq ARDC, RDZP

10. REQUESTING AGENCY: Hq USAF

12. CONTRACTOR AND/OR LABORATORY: To be determined

CONTRACT/W. O. NO.:

11. PARTICIPATION AND/OR COORDINATION:
NACA (P)
AMC (P)
SAC (I)
U. S. NAVY (I)
U. S. ARMY (I)

13. RELATED PROJECTS:
Project 7990
Task 89774

14. DATE APPROVED:

15. PRIORITY: 1A

16. MAJOR CATEGORY: A

17. EST. COMPLETION DATES

RES.	"Cont."
DEV.	"Cont."
TEST	"Cont."
OP. EVAL.	

18. FY	FISCAL ESTIMATES
58	3,000
59	5,000
60	8,000

19. REPLACED PROJECT CARD AND PROJECT STATUS: This report supercedes DD Form 613 dated 31 Dec 56, System 459L (Brass Bell); DD Form 613 dated 28 Dec 56 System 610A (HYWARDS): and Task No. 89774 (ROBO) of DD Form 613 dated 8 Jan 57, Project 7990.

20. Requirement and/or Justification

This system is proposed to satisfy System Requirement 131, dated 14 November 1956, title: (U) Hypersonic Weapons Research and Development Supporting Systems; GOR No, 92 (TA-4e-1-59), dated 12 May 1955, title: (U) GOR For A Piloted Very High Altitude Reconnaissance Weapon System; and SR No. 126, dated 12 June 1956, title classified, Unclassified short titles ROBO.

The logical development of weapon systems utilizing the boost-glide concept encompasses the above requirements in the order mentioned. In keeping with the philosophy of "more Air Force per dollar" and the desirability of obtaining operational weapon systems of this type as early as practicable, it is essential that. weapon systems using the boost-glide concept be developed under a completely integrated program. This program consolidates the DD Form 613's previously submitted on projects. HYWARDS and Brass Bell (see Item 21e); the ARDC Form 111's dated 29 March 1957 and 10 May 1957 on Project 7990, Task 89774 (ROBO); and the Evaluation Report of the Ad Hoc Committee for ARDC System Requirement No. 126 ROBO dated 1 August 1957. This program is identified as Weapon System: 464L and given the nickname Dyna Soar, which stands for Dynamic Soarer. (Confidential)

22. OASD (R&D)	SN.	CN.	C.	X.	L.	C.

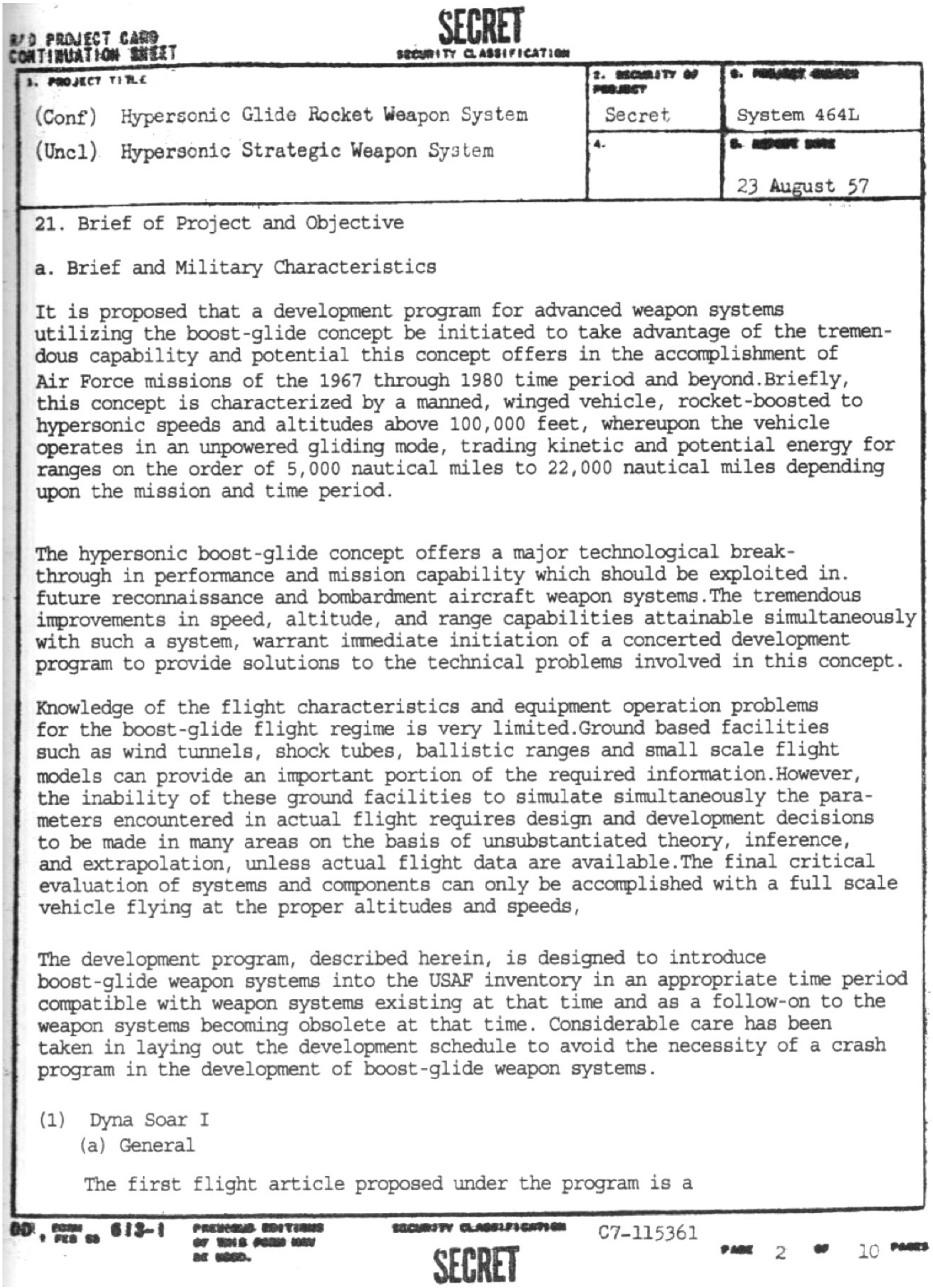
DD FORM 1 APR 55 613
REPLACES DD FORM 613, 1 JAN 52, WHICH MAY BE USED.

SECRET

C7-115361

PAGE 1 OF 10 PAGES

Figure E.188: U.S. Air Force Air Research and Development Command. 1957. *Weapon Sys 464L Abbreviated Development Plan.* [Robert Godwin 2003, pp. 38–51].



R/D PROJECT CARD
CONTINUATION SHEET

SECRET
SECURITY CLASSIFICATION

1. PROJECT TITLE (Conf) Hypersonic Glide Rocket Weapon System (Uncl) Hypersonic Strategic Weapon System	2. SECURITY OF PROJECT Secret	3. PROJECT NUMBER System 464L
	4.	5. REPORT DATE 23 August 57

21. Brief of Project and Objective

a. Brief and Military Characteristics

It is proposed that a development program for advanced weapon systems utilizing the boost-glide concept be initiated to take advantage of the tremendous capability and potential this concept offers in the accomplishment of Air Force missions of the 1967 through 1980 time period and beyond.Briefly, this concept is characterized by a manned, winged vehicle, rocket-boosted to hypersonic speeds and altitudes above 100,000 feet, whereupon the vehicle operates in an unpowered gliding mode, trading kinetic and potential energy for ranges on the order of 5,000 nautical miles to 22,000 nautical miles depending upon the mission and time period.

The hypersonic boost-glide concept offers a major technological breakthrough in performance and mission capability which should be exploited in. future reconnaissance and bombardment aircraft weapon systems.The tremendous improvements in speed, altitude, and range capabilities attainable simultaneously with such a system, warrant immediate initiation of a concerted development program to provide solutions to the technical problems involved in this concept.

Knowledge of the flight characteristics and equipment operation problems for the boost-glide flight regime is very limited.Ground based facilities such as wind tunnels, shock tubes, ballistic ranges and small scale flight models can provide an important portion of the required information.However, the inability of these ground facilities to simulate simultaneously the parameters encountered in actual flight requires design and development decisions to be made in many areas on the basis of unsubstantiated theory, inference, and extrapolation, unless actual flight data are available.The final critical evaluation of systems and components can only be accomplished with a full scale vehicle flying at the proper altitudes and speeds,

The development program, described herein, is designed to introduce boost-glide weapon systems into the USAF inventory in an appropriate time period compatible with weapon systems existing at that time and as a follow-on to the weapon systems becoming obsolete at that time. Considerable care has been taken in laying out the development schedule to avoid the necessity of a crash program in the development of boost-glide weapon systems.

(1) Dyna Soar I
(a) General

The first flight article proposed under the program is a

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SECURITY CLASSIFICATION
SECRET

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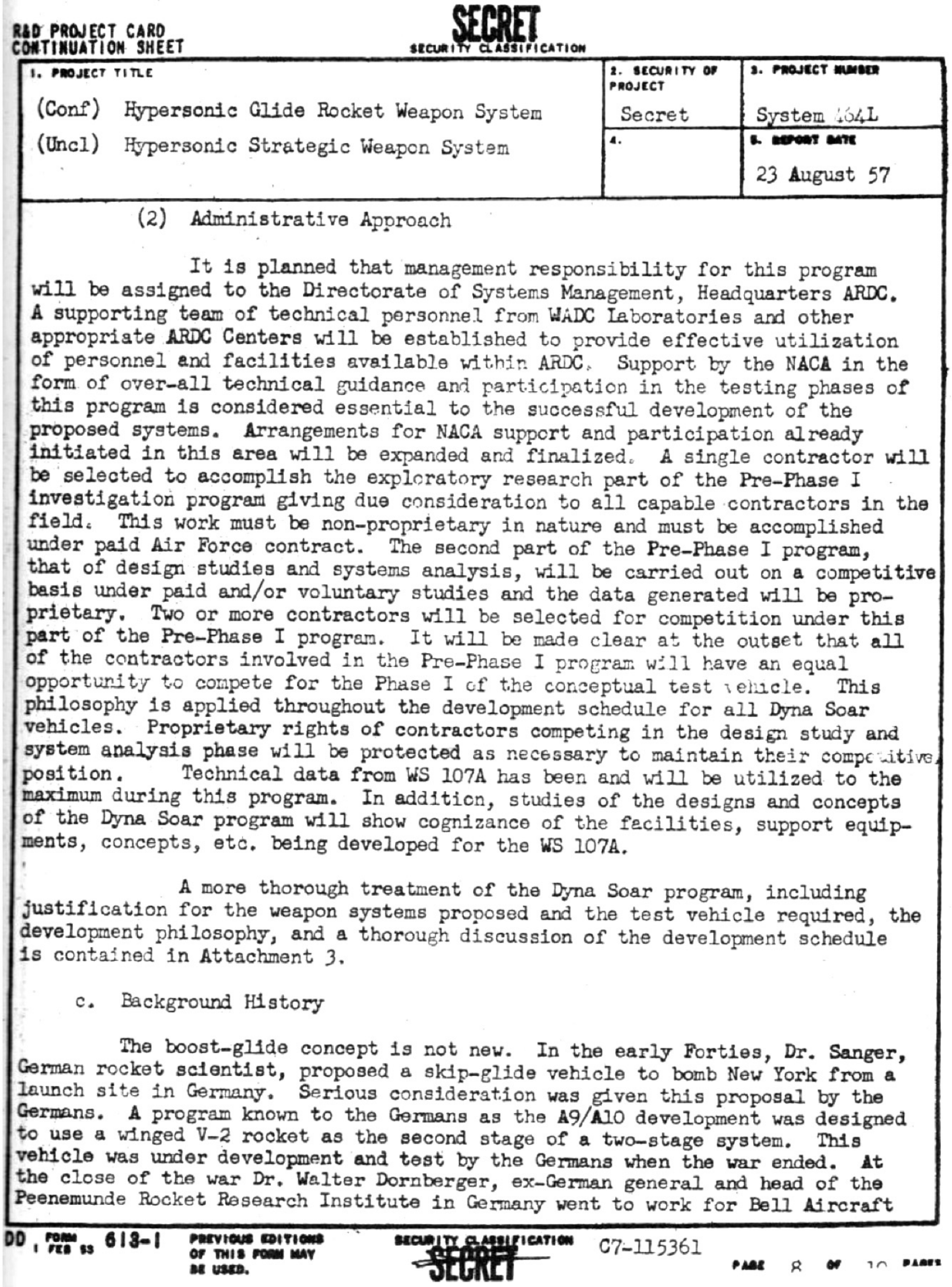
Figure E.189: U.S. Air Force Air Research and Development Command. 1957. *Weapon Sys 464L Abbreviated Development Plan.* [Robert Godwin 2003, pp. 38–51].



R&D PROJECT CARD
CONTINUATION SHEET

SECRET
SECURITY CLASSIFICATION

1. PROJECT TITLE (Conf) Hypersonic Glide Rocket Weapon System (Uncl) Hypersonic Strategic Weapon System	2. SECURITY OF PROJECT Secret	3. PROJECT NUMBER System 464L
	4.	5. REPORT DATE 23 August 57

(2) Administrative Approach

It is planned that management responsibility for this program will be assigned to the Directorate of Systems Management, Headquarters ARDC. A supporting team of technical personnel from WADC Laboratories and other appropriate ARDC Centers will be established to provide effective utilization of personnel and facilities available within ARDC. Support by the NACA in the form of over-all technical guidance and participation in the testing phases of this program is considered essential to the successful development of the proposed systems. Arrangements for NACA support and participation already initiated in this area will be expanded and finalized. A single contractor will be selected to accomplish the exploratory research part of the Pre-Phase I investigation program giving due consideration to all capable contractors in the field. This work must be non-proprietary in nature and must be accomplished under paid Air Force contract. The second part of the Pre-Phase I program, that of design studies and systems analysis, will be carried out on a competitive basis under paid and/or voluntary studies and the data generated will be proprietary. Two or more contractors will be selected for competition under this part of the Pre-Phase I program. It will be made clear at the outset that all of the contractors involved in the Pre-Phase I program will have an equal opportunity to compete for the Phase I of the conceptual test vehicle. This philosophy is applied throughout the development schedule for all Dyna Soar vehicles. Proprietary rights of contractors competing in the design study and system analysis phase will be protected as necessary to maintain their competitive position. Technical data from WS 107A has been and will be utilized to the maximum during this program. In addition, studies of the designs and concepts of the Dyna Soar program will show cognizance of the facilities, support equipments, concepts, etc. being developed for the WS 107A.

A more thorough treatment of the Dyna Soar program, including justification for the weapon systems proposed and the test vehicle required, the development philosophy, and a thorough discussion of the development schedule is contained in Attachment 3.

c. Background History

The boost-glide concept is not new. In the early Forties, Dr. Sanger, German rocket scientist, proposed a skip-glide vehicle to bomb New York from a launch site in Germany. Serious consideration was given this proposal by the Germans. A program known to the Germans as the A9/A10 development was designed to use a winged V-2 rocket as the second stage of a two-stage system. This vehicle was under development and test by the Germans when the war ended. At the close of the war Dr. Walter Dornberger, ex-German general and head of the Peenemunde Rocket Research Institute in Germany went to work for Bell Aircraft

DD FORM 1 FEB 53 613-1 PREVIOUS EDITIONS OF THIS FORM MAY BE USED.

SECURITY CLASSIFICATION SECRET

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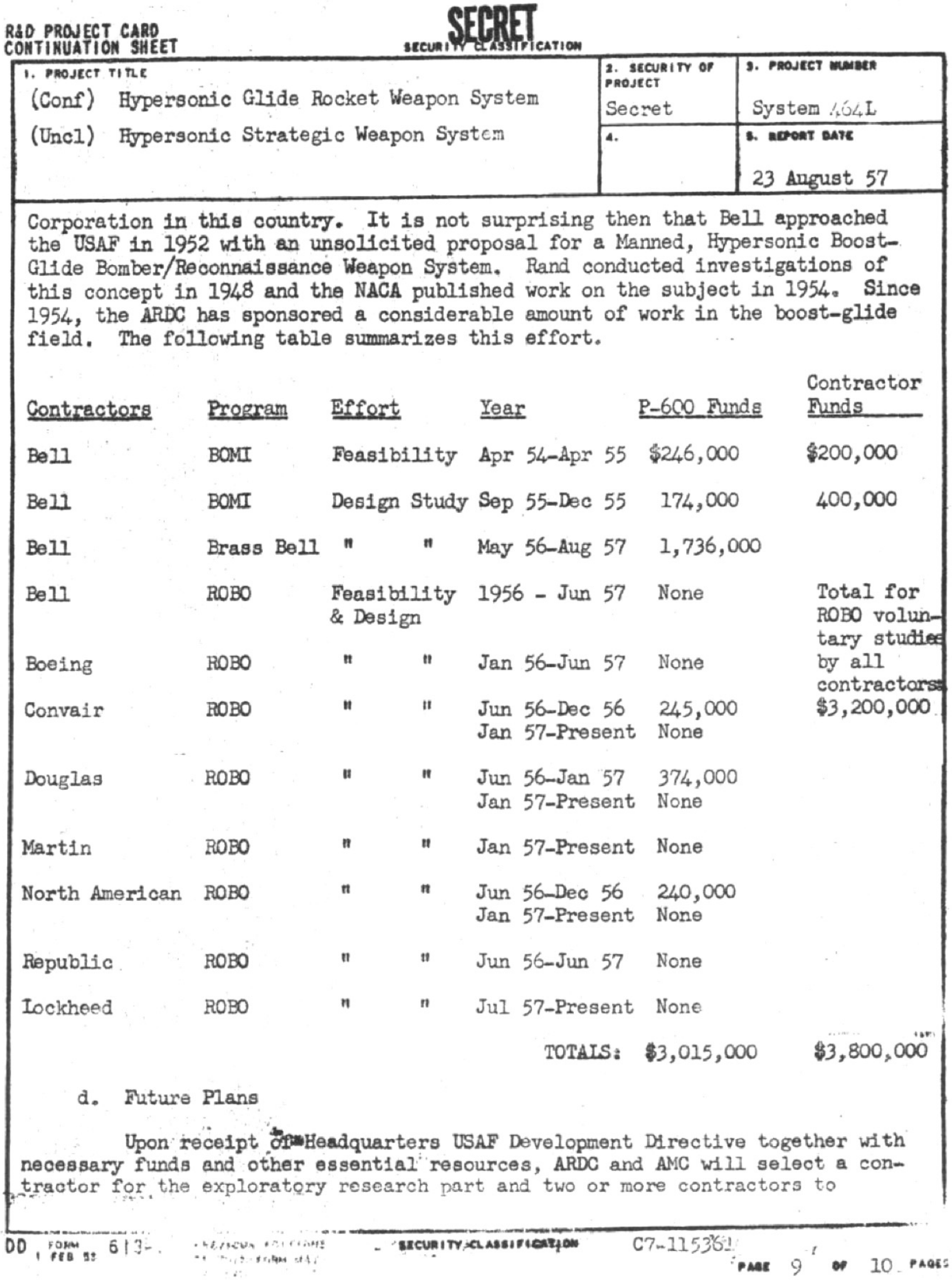
Figure E.190: U.S. Air Force Air Research and Development Command. 1957. *Weapon Sys 464L Abbreviated Development Plan.* [Robert Godwin 2003, pp. 38–51].



R&D PROJECT CARD
CONTINUATION SHEET

SECRET
SECURITY CLASSIFICATION

1. PROJECT TITLE
(Conf) Hypersonic Glide Rocket Weapon System
(Uncl) Hypersonic Strategic Weapon System

2. SECURITY OF PROJECT
Secret

3. PROJECT NUMBER
System 464L

4.

5. REPORT DATE
23 August 57

Corporation in this country. It is not surprising then that Bell approached the USAF in 1952 with an unsolicited proposal for a Manned, Hypersonic Boost-Glide Bomber/Reconnaissance Weapon System. Rand conducted investigations of this concept in 1948 and the NACA published work on the subject in 1954. Since 1954, the ARDC has sponsored a considerable amount of work in the boost-glide field. The following table summarizes this effort.

Contractors	Program	Effort	Year	P-600 Funds	Contractor Funds
Bell	BOMI	Feasibility	Apr 54-Apr 55	$246,000	$200,000
Bell	BOMI	Design Study	Sep 55-Dec 55	174,000	400,000
Bell	Brass Bell	" "	May 56-Aug 57	1,736,000	
Bell	ROBO	Feasibility & Design	1956 - Jun 57	None	Total for ROBO voluntary studies by all contractors $3,200,000
Boeing	ROBO	" "	Jan 56-Jun 57	None	
Convair	ROBO	" "	Jun 56-Dec 56 Jan 57-Present	245,000 None	
Douglas	ROBO	" "	Jun 56-Jan 57 Jan 57-Present	374,000 None	
Martin	ROBO	" "	Jan 57-Present	None	
North American	ROBO	" "	Jun 56-Dec 56 Jan 57-Present	240,000 None	
Republic	ROBO	" "	Jun 56-Jun 57	None	
Lockheed	ROBO	" "	Jul 57-Present	None	
			TOTALS:	$3,015,000	$3,800,000

d. Future Plans

Upon receipt of Headquarters USAF Development Directive together with necessary funds and other essential resources, ARDC and AMC will select a contractor for the exploratory research part and two or more contractors to

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SECURITY CLASSIFICATION

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Figure E.191: U.S. Air Force Air Research and Development Command. 1957. *Weapon Sys 464L Abbreviated Development Plan.* [Robert Godwin 2003, pp. 38–51].

Boris Chertok. 2005–2012. *Rockets and People.* 4 vols. Washington, DC: U.S. Government Printing Office.
[**https://www.nasa.gov/connect/ebooks/rockets_people_vol1_detail.html**]

[Vol. 1, pp. 262–265:] The collective panel of experts that was set up there on the spot determined that this document was the design for a rocket-powered bomber. [...]

As far as I was able to understand later, this was not the design of theA-9/A-10 missile, which was designed for a range of 800 kilometers. The report discussed the ranges required to strike New York. From today's standpoint, we can say that the layout of the vehicle described in the report—found in the woodpile in Peenemünde in May 1945—anticipated the structure of the American Space Shuttle and our Energiya-Buran system. [...]

The report had been issued in Germany in 1944. Its authors were the Austrian rocket engine researcher E. Sänger, who was already well known before the war, and I. Bredt, who was unknown to us and was later identified as Irene Bredt, a gas aerodynamics specialist.

Eugen Sänger was known for his book *Raketen-flugtechnik* (The Technology of Rockets and Aviation), which he published in 1933. It had been translated and published in the Soviet Union. Back when he was a 25-year-old engineer, Sänger was captivated by the problems of rocket technology. He was one of the first serious researchers of gas dynamic and thermodynamic processes in rocket engines.

You can imagine how Bolkhovitinov and other NII-1 specialists felt as they leafed through the top-secret report, one of 100 printed copies. Judging by the distribution list, it had been sent to the leaders of the *Wehrmacht* main command, the ministry of aviation, to all institutes and organizations working in military aviation, and to all German specialists and leaders who were involved in rocket technology, including General Dornberger in the army department of armaments, who also served as chief of the Peenemünde center.

The title of the report was "Über einen Raketenantrieb für Fernbomber" (On a Rocket Engine for a Long-Range Bomber). This paper analyzed in great detail the technical capabilities for creating a manned winged rocket weighing many tons. The authors convincingly showed by constructing nomograms and graphics that with the proposed liquid-propellant rocket engine with a thrust of 100 metric tons it was possible to fly at altitudes of 50–300 kilometers at speeds of 20,000–30,000 kilometers/hour, with a flight range of 20,000–40,000 kilometers. The physical and chemical processes of high-pressure and high-temperature propellant combustion were studied in great detail, along with the energetic properties of propellants, including emulsions of light metals in hydrocarbons. The work proposed a closed, direct-flow, steam power plant both as a cooling system for the combustion chamber and as a means to activate the turbopump assembly.

The problems of aerodynamics for an aircraft with a speed ten to twenty times greater than the speed of sound were new for our aerodynamics specialists.The report went on to describe the launch, takeoff, and landing dynamics. In an apparent attempt to interest the military, the report included a highly detailed examination of bombing issues, considering the enormous speed of a bomb dropped from such an aircraft before it approached the target.

It is interesting that Sänger had already shown by the early 1940s that launching space aircraft without auxiliary means was unacceptable. He proposed launching space aircraft using a catapult with a horizontal track that would enable the aircraft to reach a speed greater than the speed of sound. [...]

The total takeoff weight of the bomber was 100 metric tons, of which 10 metric tons was the weight of the bombs.The landing weight was assumed to be 10 metric tons. If the flight range were reduced, the weight of the bombs could be increased to 30 metric tons.They proposed that the subsequent work to implement the design of the rocket-propelled bomber be divided into twelve stages, in which the bulk of the time would be devoted to firing rig optimization of the engine, rig testing of the interaction of the engine and aircraft, launcher testing, and finally, all phases of flight tests.

In 1945, the work of Sänger and Bredt was translated, and in 1946 it was published under the title "Survey of Captured Technology" by the Military Publishing House of the USSR Armed Forces Ministry, under the editorship of Major General of the Aviation Engineer Service V. F. Bolkhovitinov; a large number of copies were printed.

Being in Germany at the time, Isayev and I had no idea that this report had caused quite a stir after its delivery to NII-1 in May 1945.We could only imagine the feelings experienced by our patron, who was considered a dreamer in higher aviation circles, but who was respected for his enthusiasm in the face of extremely bold proposals, a quality that was very unusual for a chief designer.Together with the engine specialists from RNII, we had only obtained a reliable liquid-propellant rocket engine with a thrust of 1.5 metric tons in 1943. Isayev dreamed of bringing the engine up to a thrust of 2–3 metric tons in a year or two. But then, in 1944, a V-2 engine with a thrust of almost 30 metric tons was recovered in Poland. Added to this now was Sänger's report, which outlined the design for an aircraft with engine thrust of 100 metric tons!

When Bolkhovitinov's deputy, MAI professor Genrikh Naumovich Abramovich, flew into Berlin from Moscow in June, he was already familiar with Sänger's work. Being a very erudite theoretician, he said that such an abundance of gas-kinetic, aerodynamic, and gas-plasma problems required a profound scientific analysis. He believed it would take ten years—God willing—before it came down to the business of designers."It's easier to make rockets than that airplane."

Yes, that proposal was at least twenty-five years ahead of its time. The first space aircraft in the form of the Space Shuttle flew in 1981. But it launched vertically as the second stage of a rocket. To this day there is no authentic aerospace vehicle with a horizontal launch.

Frank Winter, U.S. National Air and Space Museum Curator [Winter 1990, pp. 42–44, 113–119, 122]

The Space Shuttle concept also originated in the 1920s and 1930s. [...]

Eugen Sänger of Austria, who held a doctorate in aeronautical engineering from Vienna's Technische Hochschule, focused on the rocket-propelled stratospheric plane. [...]

From the start [1920s], Sänger favored the reusable rocket plane over "ballistic" systems[...]

After the war, as leader of the newly formed International Astronautical Federation, Sänger became a tireless advocate of the spaceplane. He died in 1964, before he could see his Silver Bird take flight, greatly modified in the form of the Space Shuttle. [...]

Two early postwar designs based on his work, as well as on the winged V-2s, were by von Braun and Dornberger. Von Braun's idea, the more famous, was introduced in the March 22, 1952, issue of *Collier's* magazine as part of a marvelously illustrated series on manned spaceflight. [...]

At about the same time von Braun was drafting these concepts (1951–1955), Walter Dornberger and Krafft Ehricke were working at Bell Aircraft on the highly classified Bomi (Bomber-Missile) study for the Air Force. [...T]he Bomi owed much to the Antipodal Bomber. [...]

Meanwhile, the Air Force was developing three projects similar to the Bomi. [...] In October 1957 the three were consolidated into the Air Force's X-20, known as the Dyna-Soar (Dynamic Soaring) vehicle, so called because it combined ballistic missile lift with the soaring and precise flight control of an airplane. For the same reasons, it was also called a boost-glider. In its brief, controversial carrier, the Dyna-Soar nearly became the very first Space Shuttle. [...]

The PRIME project (Precision Recovery Including Maneuvering Entry) was the second phase of START. Three PRIME vehicles, flown between 1966 and 1967 and boosted into space by Atlas launchers, were likewise small unmanned gliders but were true lifting bodies. [...]

The X-24B made especially valuable contributions toward the Shuttle, not only by gathering data on aerodynamics and handling but also by test-flying components later incorporated in the Shuttle's orbiter (the manned spaceplane which orbits the Earth). In addition, the X-24B showed that a spaceplane did not need any cumbersome auxiliary turbojet or other powerplant to land, as some designs of the time required. [...]

The years 1969 to 1972 thus represented an intense period of evolution, during which the Shuttle design was refined on the basis of many proposals. [...]

One remarkable feature of the Shuttle is its reusable thermal protection system. This consists of four types of insulation, which are used on various parts of the ship according to the heat protection required. The most critical areas are the underside and the leading edges of the wings and body, which reach a searing 1,200–2,300 degrees Fahrenheit during reentry. Here are glued 30,922 individually contoured tiles made of silicon carbide and carbon cloth.

[High-temperature ceramics for the Space Shuttle trace back to wartime German work on high-temperature ceramic components for turbojet engines.

Suitable shapes for hypersonic reentry and the suggestion to use ceramic tiles both came from Adolf Busemann at Langley–see the obituary for Adolf Busemann below.

In 1965, Walter Dornberger named the newest U.S. space plane program the "Space Shuttle" [Dornberger 1965a, 1965b].

Krafft Ehricke (German, 1917–1984) was deeply involved in space plane projects from Bomi to the Space Shuttle [Freeman 2008].

The X-24 lifting body design came from Hans Multhopp [R. Dale Reed 1997, pp. 129–130, 136]; see pp. 1933 and 5612.

The Space Shuttle Main Engines (SSMEs) were directly derived from engine designs with especially high combustion chamber pressures that were developed during and after the war (such as the MBB P111 engine and the Rocketdyne HG-3 engine) by Klaus von Riedel, Karl Stöckel, Hans Georg Paul, Dieter Huzel, and other German-speaking engineers (see pp. 5613–5617).

The Space Shuttle Solid Rocket Boosters (SRBs) were based on enormous German-speaking contributions to solid propellant rockets (see Sections 9.8 and E.4).]

Adolf Busemann, 85, Dead; Designer of the Swept Wing [NYT 1986-11-05]

Adolf Busemann, whose design of the swept wing for aircraft helped make supersonic flight possible, died Monday at the Fraiser Meadows Manor Health Care Center here. He was 85 years old.

Mr. Busemann, a native of Luebeck, Germany, presented his discovery at the Volta Congress in Rome in 1935. After World War II, he carried on his research in the United States.

The swept-wing design was used in American F-86 and Soviet MIG-15 jet fighters in the Korean War.

He had held a professorship in aerospace engineering at the University of Colorado since 1963. Research in wind tunnels led him to advise the National Aeronautics and Space Administration on the use of ceramic tiles, which could withstand high temperatures better than aluminum, on the space shuttle.

R. Dale Reed, retired NASA engineer who worked on the lifting body reentry tests that paved the way for the U.S. Space Shuttle [R. Dale Reed 1997, pp. 129–130, 136].

A high-volume lifting body, the SV-5 was the brain child of Hans Multhopp, an aerodynamicist at the Martin Aircraft Company. The SV-5 quickly became the centerpiece of a new Air Force program known as START (Spacecraft Technology and Advanced Reentry Tests). Established in January 1964, START consisted of dual programs—the unpiloted PRIME (Precision Recovery Including Maneuvering Entry) and the piloted PILOT (Piloted Lowspeed Tests).

In early 1964, I visited the Martin Aircraft Company to gather information on the SV-5 and possibly gain some support from Martin and the Air Force in convincing NASA management to fund a supersonic lifting-body flight-test program. I met Hans Multhopp, introduced to me as Martin's chief scientist and the designer of the SV-5. A soft-spoken man with a heavy German accent, Multhopp seemed to be highly respected and admired by others in Martin engineering. After a conversation with him about the SV-5, I could understand why he was so highly respected, for his knowledge of aerodynamics and aircraft design was impressive.

A former aeronautical engineer, Multhopp had worked during World War II for the Focke-Wulf Flugzeugbau in Bremen, Germany, first as head of the aerodynamics department and then as chief of the advanced design bureau. One of his projects at Focke-Wulf was designing, in conjunction with Kurt Tank, the Ta-183. Information on the Ta-183 design obtained by the Russians at the end of World War II greatly influenced the design of the Russian MIG-15 jet fighter. The Pulqui-II, a derivation of the Ta-183 design flown in Argentina after World War II, had been built by former Focke-Wulf employees who had fled to Argentina.

Whisked out of Germany at the end of World War II, Multhopp went to work for the British at Farnborough. There, he designed the swept-wing British Lightning fighter, using calculation techniques he had developed. After four years, however, the British found his arrogance intolerable and he was sacked. He then became the chief scientist for the company that eventually became the giant American aviation and space contractor, Martin Marietta.

Multhopp was able to convince Martin management as well as the Air Force that the SV-5 shape was superior to NASA's M2-F3 and HL-10 shapes on the basis of six features. First, the SV-5 was a maneuverable lifting body with no essential surface components that would be destroyed on reentry from orbit. Second, the vehicle had a hypersonic lift-to-drag ratio of 1.2 or better, permitting a lateral range of 1,000 miles. This feature would enable a recall to any preselected site at least once a day as well as emergency recall to a suitable location from every orbit.

Third, the low-speed aerodynamics of the SV-5 were suitable for making a tangential landing without resort to automatic controls. Fourth, volumetric efficiency was as high as possible, the shape giving as much volume forward as possible for center-of-gravity control. The resulting configuration gave more room up front for the pilot and equipment. The center-of-gravity could then be positioned sufficiently forward to provide adequate vehicle control without resorting to an unstable vehicle with a negative static margin. Fifth, positive camber was included in the body, allowing trimmed lift conditions at lower angles of attack as well as a high subsonic lift-to-drag ratio of about 4.0. Sixth, in regards to pilot visibility, the SV-5 cockpit canopy design was superior to that of the M2-F3 and the HL-10.

My first meeting with Hans Multhopp at Martin in early 1964 also turned out to be my last. After that visit, he seemed simply to disappear from public view. Later, when the X-24A was being flown at Edwards Air Force Base as the final stage of the PILOT portion of the SV-5 program, I was surprised to learn that my Air Force colleagues at Edwards had never even heard of Hans Multhopp. At that time, there was still considerable resentment in this country about using German engineers in American aerospace projects. Consequently, it became the usual practice to keep German engineers at low profile. However, this was not always true. A good example of an exception to this practice was Wernher von Braun, who rose to high rank in NASA in full public view and made a significant contribution to our space program. [...]

By combining much larger fuel tanks with a lighter-weight structure in the X-24A, Hans Multhopp and the other Martin designers theoretically achieved the potential for the X-24A to attain much higher speed and altitude than either the M2-F3 or the HL-10.

Dan Sharp. 2016. *Luftwaffe Secret Bombers of the Third Reich.* Horncastle, U.K.: Mortons. pp. 127–129.

KARL STÖCKEL ROCKETS AND RAMMERS

Another DVL employee who dreamed up unusual concepts with advanced features was Karl Stöckel. During 1944, when the effects of Allied bombing were becoming increasingly significant for Germany, he began thinking of specialised aircraft that might be able to tackle the incoming enemy bombers. It was noted in Luftwaffe: Secret Jets of the Third Reich that what was frequently referred to as the Blohm & Voss MGRP 'Manually Guided Rocket Projectile' might well be one of a series of 'rammer', ramjet and rocket concepts drafted by Stöckel—and this can now be conclusively verified.

A drawing showing a 'Manuell gesteuertes Raketenprojektil' has been discovered, signed by Stöckel and dated August 23, 1944. It shows a large missile, similar in size to a V2, with a very small parasite aircraft attached at its base—barely large enough for one man. The missile would weight five tonnes, the aircraft 0.5 tonnes and the remaining 4.5 tonnes of the combination's all-up weight would be rocket fuel. A diagram and notes on the same sheet indicate how the MGRP was intended to operate. [...]

After the war, Stöckel seems to have gone on to work for Bölkow, designing and patenting a series of rocket engine chambers during the 1950s and 1960s.

[Karl Stöckel began his career by designing rocket planes that would be carried aloft by riding piggyback on the side of a larger rocket booster, essentially a miniature version of what the U.S. Space Shuttle was when it finally launched nearly four decades later.

To power such vehicles, Stöckel spent most of the rest of his career designing and building ever more sophisticated rocket engines capable of operating with especially high combustion chamber pressures (in order to maximize the thrust-to-weight ratio of the engines). The best known of Stöckel's own engines was the Bölkow/MBB P111, which caught the eye of other German engineers at Rocketdyne and NASA and directly led first to the Rocketdyne HG-3 engine and ultimately to the Space Shuttle Main Engines (SSMEs).]

Karl Stoeckel. 1985. History of Development of Staged Combustion Rocket Engine in Germany. [https://www.researchgate.net/publication/293622179_History_of_Development_of_Staged_Combustion_Rocket_Engine_in_Germany]

The development history of the staged combustion engine begins with preliminary studies for interceptors at DVL Berlin during the war, continues with the first test runs using small LOX-regeneratively cooled copper combustion chambers at Boelkow KG in Stuttgart in 1957 and culminates in the 50 kN-LOX/Kerosine staged combustion engine P 111 at MBB in Ottobrunn in 1965. This particular high pressure engine was the first of its kind in the history of rocketry and influenced the development of the space shuttle main engine (SSME) with the H 13 combustion chamber. Subsequent development work continued until 1975 at MBB with the planned 200 kN-LH_2/LO_2 high pressure stage engine H 20 for ELDO III, the combustion tests up to a pressure of 200 bar with the N_2O_4/UDMH-copper chamber M 1 in Ottobrunn and finally the development and manufacture of the LH_2/LO_2 combustion chamber HM 7 for the third stage of Ariane. Past work shows that continued development of high-pressure engine for future applications still has potential.

Christophe Rothmund, Helmut Hopmann, and Erich Kirner. 1992. The early days of LOX/LH2 engines at SEP and MBB. IAF, 43rd International Astronautical Congress, Washington, D.C. Aug. 28–Sept. 5, 1992. [https://www.researchgate.net/publication/234528704_The_early_days_of_LOXLH2_engines_at_SEP_and_MBB]

The development of cryogenic LOX and LH2 rocket engines is reviewed for two European manufacturers. Of note are: (1) the HM4 early turbopump LOX/LH2 engine; (2) the P111 engine with a staged combustion cycle and oxygen-rich preburner; (3) a thrust-chamber program; and (4) the development of LOX-cooled bearings, dynamic LOX seals, and LOX inducers. Launchers were developed by these manufacturers that incorporated LOX and H2O technologies, and the Europa is emphasized. These developments led to collaboration on the Ariane series of Vulcain rocket motors which relied heavily on the technologies established for the HM7 engine. The correction of ignition delays and bearing instabilities in these engines led to a class of rocket engines with a wide range of applications.

Frank-E. Rietz. 2006. EADS Expertise on the Space Shuttle: An Idea Catches On. *Planet AeroSpace* 2006:2:76–78.

Which is where EADS technology comes into play, for the space shuttle main engines work on a principle that originated south of Munich. The design of these innovative engines was conceived 50 years ago—in 1956—at Bölkow GmbH, a predecessor of EADS.

The historical roots of this engine design actually go back even further, to an original idea dating from 1942. Karl Stöckel, an aeronautical engineering graduate who later worked for Bölkow, devoted his research to ultra-high velocity aircraft and possible means of propelling them. He was particularly interested in the concept of combined rocket and turbojet propulsion. Stöckel believed it was crucial to raise the pressure in the combustion chamber to a point where it would meet flightworthiness requirements in terms of compact architecture, low weight and low fuel consumption. The pressure in standard combustion chambers could not be raised above the level of 15 bars, which is why conventional rocket engines work on what is known as the bypass flow principle. This means that the gas generator with the turbine driving the fuel pumps is installed parallel to the thrust chamber. Inevitably, this technique results in loss of momentum and a significant drop in efficiency. The new concept involved 'staged combustion', with combustion taking place in two successive stages. In the first stage of this arrangement, a certain amount of the fuel is burnt up at high pressure in a pre-burner to generate the gas that drives the turbines for the fuel pumps. In the second stage, the gas is mixed with fuel and burns up completely in the combustion chamber. At the same time, a means of cooling the combustion chamber was discovered: the liquid oxygen flowing round the combustion chamber through an arrangement of channels, cooling the chamber and being itself heated in readiness for the combustion process.

Practical testing of this type of engine began on 1 September 1956. The following year, the German ministry of defence awarded Bölkow a contract to develop the full-flow engine. Development of the P111 test engine began in 1958 as soon as the company had relocated from Stuttgart to Ottobrunn. In the months and years that followed, the Bölkow engineers learned important lessons on the structure and function of high-pressure engines. They conducted research into ignition and combustion processes, cooling requirements and heat transfer ratios and paved the way for copper combustion chambers with axial cooling channels. This made it possible to increase chamber pressure to 100 bars. In 1963, only five years after the start of development, the full-flow engine underwent its first test run. And finally, the innovative rocket engine was presented to experts at the 1966 Hanover air show.

NASA began to take an interest in the full-flow engine during its preliminary studies for the space shuttle. Working in conjunction with the U.S. company Rocketdyne, specialists at Ottobrunn developed an engine based on the full-flow principle. During their test runs they achieved a chamber pressure of 282 bars—a world record even today. NASA decided to adopt full-flow engine technology for the shuttle, and this in turn brought licence fees for the German company. Ever since the first flight of Columbia 25 years ago, the technology from Ottobrunn has proved its worth in the entire shuttle fleet.

Roland Kindermann, Steffen Beyer, Peter Bichler, Wolfgang Keinath, Torsten Sebald. Advanced Production Technologies for Thrust Chambers of Liquid Rocket Engines. AAAF Paper 16_96_P, 6th International Symposium for Space Propulsion.

The forebear of today's rocket combustion chamber was tested in Berlin under the leadership of Klaus von Riedel. This was the first time that new, good heat-conducting materials such as aluminum and copper, were used for a thin-walled combustion-chamber liner instead of the steel that was commonly used at the time. Technologies for forced cooling under high pressure were also being used, as was fuel injection through jets. The years to follow saw ever-increasing requirements for higher pressures combined with efforts to arrive at a compact construction, low weight and minimized fuel consumption. There was therefore a move towards main flow engines with the aim of achieving the desired cooling for an increase in power. Development of the P111 (Figure 1) commenced at Astrium, the space subsidiary of EADS (European Aeronautic Defense and Space Company) and ushered in a 40-year tradition of liquid engines.

Processes such as cool-channel milling, waxing the channels and electronickeling were used in the manufacture of the support liner. A successful test was carried out in 1963 using a LOX/kerosene fuel mixture, achieving a thrust of 49 kN at a pressure of 85 bar. The first engine powered by LH2/LOX, the RL10, was successfully produced in the USA over the same period. At the close of the 1960s, the experience thus obtained led to a transatlantic joint venture between Astrium and Rocketdyne. A heat test performed during the course of this cooperation produced a world record that is still in place today: chamber pressure of 282 bar. The construction and operation of the P111 was patented by MBB. It later formed the basis for developing the high-energy SSME by NASA. The 1970s saw the commencement of the long period of technological cooperation between France and Germany. The two countries were working on the joint development of their own cryogenic engines. The HM7 engine for the Ariane 4 was the first LOX/LH2 to be developed outside the USA. The fast expanding market for satellites placed increasingly large demands on launcher payloads and it was essential to develop Ariane 5. Requirements of 100 bar or more for chamber pressures and exceptional heat flux entailed a new combustion chamber material with the relevant physical and mechanical properties.

Successful development of the Narloy-Z copper-based alloy for the combustion chamber of the Space Shuttle Main Engine (SSME) constituted the foundation stone for the development and introduction of the European variant CuAgZr as the combustion chamber material used in the Vulcain engine powering Ariane 5. The principle of construction based on HM7 production technology was transferred to the low-energy upper stage rocket of Ariane 5, the Aestus engine. The corrosion fuel combination used with Aestus (MMH/N2O4) and the low thermal load involved selecting an austenitic chromium-nickel steel (1.4546) for the combustion chamber.

Mike Wright. 1995. MSFC Propulsion Center of Excellence is Built on Solid Foundation [https://web.archive.org/web/20150427090253/http://history.msfc.nasa.gov/saturn_apollo/propulsion_center.html].

Space Shuttle Main Engine

The last Saturn F-1's that NASA employed helped lift Skylab into orbit in 1973. By then, NASA engineers were already deep into the design for the space shuttle main engine, a concept that broke with the past, according to shuttle historian Dennis R. Jenkins. The challenge, Jenkins said, was "not to build a larger, more powerful engine, but to build a small, compact engine that could be throttled during ascent to provide some measure of control over the maximum dynamic pressure and speed of the vehicle." MSFC engineers who have traced the technology projects leading to the development of the space shuttle main engine have pointed to an "aggressive technology program in high-pressure tubomachinery initiated in the 1960's." They point out that much of the work was done by Pratt & Whitney under MSFC's sponsorship, with outgrowth known in-house as the concept for the HG-3, a 350,000-pound-thrust engine named after Hans G. Paul, the long-time chief of the Propulsion Division. In essence, the HG-3 concept eventually became the space shuttle main engine. [...]

Mark Wade. 2019. HG-3. [http://www.astronautix.com/h/hg-3.html].

HG-3.

Rocketdyne LOx/LH2 rocket engine. Study 1967. High-performance high-pressure chamber engine developed from J-2. Considered for upgrades to Saturn V launch vehicle upper stages. Technology led to Space Shuttle Main Engines. [...]

E.4 Submarine-Launched and Solid Propellant Rockets

[This section concerns submarine-launched missiles that were developed or were under development during the war, including submarine-launched versions of small rockets, V-1, V-2, and other missiles, as well as the postwar influence of such projects and German-speaking scientific experts. This section also presents numerous sources about the wartime and postwar development of solid propellant rockets. Not all submarine-launched missiles used solid propellant, and not all solid propellant rockets were designed to be launched from submarines, but the two histories are so deeply intertwined (because solid propellant is especially desirable for submarine-launched rockets) that they are presented here in the same section.

Official histories claim that the major innovations underlying modern solid propellant rockets and submarine-launched ballistic missiles (SLBMs) were invented primarily in the United States, and primarily after World War II. For example, Vaclav Smil, a prolific science historian at the University of Manitoba, wrote [Smil 2006, p. 84]:

> In 1942 John W. Parsons, an explosives expert at California Institute of Technology, formulated the first castable composite solid propellant by combining asphalt (fuel and binder) with potassium perchlorate (an oxidizer).
>
> Key improvements in the preparation of these propellants were made during the late 1940s and the early 1950s. In 1945 Caltech's Charles Bartley and his coworkers replaced asphalt with Thiokol (synthetic rubber). This polysulfide polymer was synthesized for the first time in 1926 by Joseph C. Patrick, and the eponymous corporation was formed in 1928. In 1947 Thiokol Corporation began the systematic, and still continuing (now as Morton-Thiokol), development of solid propellant rockets. The second key innovation was the replacement of potassium perchlorate by ammonium perchlorate (AP) as an oxidizer. Another critical discovery was made at the Atlantic Research Corporation by Keith Rumbel and Charles B. Henderson, who found that adding large amounts of aluminum (Al) greatly increased the specific impulse of composite propellants: they used 21% Al, 59% AP, and 20% plasticized polyvinyl chloride (PVC).
>
> Solid propellants, configured inside the casings mostly in five- to twelve-pointed stars, were used in America's first SLBMs (*Polaris* in 1960, with AP/Al/polyurethane propellant) and ICBMs.

However, evidence demonstrates that these innovations were imported from earlier German-speaking scientists and engineers:

- During the war, German-speaking scientists developed and demonstrated solid propellant rockets that used ammonium perchlorate oxidizer (pp. 5684, 5690).

- The same German-speaking scientists also developed and demonstrated solid propellant rockets that used polybutadiene "buna" synthetic rubber in the propellant to act as both fuel and binder (pp. 5684, 5690).

- The same German-speaking scientists also added plasticizers to enable the propellant to be molded into any desired shape, to adhere tightly to metal walls, and not to be prone to crumbling or brittleness (pp. 5684, 5690).

- During the war, German-speaking scientists added powdered aluminum to rocket propellants and closely related solid explosives in order to improve performance (pp. 5692–5695).

- During the war, German-speaking scientists used a wide variety of grain designs for the geometrical shape of the combustion surface inside the propellant to give the desired variation of thrust with time (pp. 5668–5669, 5690, 5695).

- The Rochen ammonium perchlorate/polybutadiene short-range missile was first fired in 1944 (p. 1911).

- The Rheintochter two-stage solid-propellant surface-to-air missile was first launched in 1943 (p. 1912).

- The Rheinbote four-stage solid-propellant long-range rocket was first launched in 1943 (p. 1913).

- The V-101, an ammonium perchlorate/polybutadiene propelled, 140-ton, 30-meter-tall, long-range ballistic missile, was under development when the war ended 1914).

- Submarine-launched small ballistic rockets were successfully demonstrated during the war (pp. 5628–5645).

- Submarine-launched V-1 cruise missiles were developed, tested, and possibly even deployed (pp. 5618–5627).

- Methods of firing large ballistic missiles from deeply submerged submarines were perfected by the end of the war (p. 5747).

- Towed submarine carriers for A-4 or V-2 rockets were designed and possibly developed during the war (pp. 5628–5660).

- Rockets with dimensions suitable for submarine launch were developed by wartime laboratories under contract with the German navy (p. 5532).

- An August 1945 U.S. report stated that the Germans had developed a wide variety of guided missiles including “underwater launched to air,” “surface,” and “underwater targets” (p. 5429).

- German-speaking scientists were directly involved in developing Jupiter, a postwar U.S. ballistic missile designed to be launched from submarines (but ultimately only deployed on land; see p. 5501).

- German-speaking scientists were deeply involved in the development of the U.S. Polaris, Pershing, and Minuteman solid propellant ballistic missiles in ways that have never been fully disclosed to the public (pp. 5700–5736).

The wartime and postwar German technologies and the associated scientists were directly responsible for the development of large solid propellant rockets for modern ballistic missiles, strap-on rocket boosters, and some satellite launch vehicles.

The German-derived technologies and scientists led directly to the postwar development of submarine-launched nuclear missiles, the third component of the nuclear triad. (Thus the entire modern nuclear triad was a wartime German creation.) The wartime programs included both submarine-launched ballistic missiles—direct ancestors of postwar SLBMs such as Polaris, Poseidon, and Trident—and submarine-launched V-1 cruise missiles—direct ancestors of modern versions such as the U.S. Tomahawk and Russian Kalibr.]

Neal Stanford. Must Be Last War. *Wilmington Star* (North Carolina), 31 October 1944, p. 4. [**https://chroniclingamerica.loc.gov/lccn/sn78002169/1944-10-31/ed-1/seq-4**]

Five times, one day, this week, Washington correspondents lived through buzz-bomb raids. Vicariously, to be sure, and the raids were only nine minutes each.

But that was more than enough for most. It was more than enough to persuade all that in these robot bombs, these rocket bombs, rumors of atomic bombs, the world had something which, if not controlled, would destroy it. Truly the world has a bear by the tail and can't let go. Its only choice is to tame it.

Buzz-bombs have such tremendous destructive potentialities that despite Britain's suffering from this menace that has killed over 5,000, injured 16,000 more, destroyed 23,000 homes, churches, hospitals, stores, schools in London, and damaged 1,000,000 more, we have only begun to feel its power of devastation.

That lesson was shouted from every foot of the film—with appropriate sound effects—that the British Information Service showed, for the first time either in Britain or the United States, to the Washington press corps. We saw these bombs hurtling through Britain's skies, morning, noon, and night. We heard them zooming overhead as rescue crews dug out hapless victims of V-1. We watched them in fascination plummet to earth and explode in a blast of smoke. And we gloried in Britain's defenses, ack-ack gun crews, Spitfires, barrage balloons that caught over half of the 8,000 mechanical buzzards in flight. But thousands out-sped defenses. We realized only too well why buzz-bombs were not a peculiarly British problem—why they were our problem as well.

This nine-minute capsule of buzz-bomb terror, it is expected, will shortly be shown widespread over the United States. Its purpose is to educate, to awaken, to arouse—not to entertain or cause fear. For while 50,000,000 Britons know that the buzz-bomb, the rocket bomb, the automatic bomb have made this war civilization's last hope, there is no similar assurance that 135,000 Americans are irrevocably committed to working to make this the last war. It may be their aim, but is it their determination?

The V-1, or buzz-bomb, is still hitting England from time to time. Capture of the Calais coast has not ended the danger. Launching platforms with shortened German lines can still speed robots over England. Planes also can launch these robots, and have. So for Britain, the Battle of the Robomb is still not over.

Theoretically, America is not immune from the possibility of robot bombings. German U-boats still prowl up and down the Atlantic coast. If a plane can be launched from a submarine, why not robot bombs? They might have to be modified versions, since submarines aren't long enough for serving as launching platforms for the present buzz-bomb. They could certainly not come over any American seacoast area one a minute as they have over London. They might be able to launch two or three or four.

But they would only be vengeance shots involving all the inaccuracies of such bombings. The whole thing, to use a favorite word of President Roosevelt, is very "iffy." If the Nazis have adapted buzz-bombs to U-boat use, and if they are persuaded even the weakest token bombing of America would have psychological benefits, they might spend valuable manpower and resources that way. But the chances seem slight. Some authoritative sources here believe it impossible.

There is no doubt, though, that Germany is experimenting with new types of rocket bombs of larger and deadlier variety. A Stockholm report that the Nazis have some super-rocket bomb is common gossip here. Sometimes it's a 40-foot robot with "atomic explosive features." Other times it's a 40-ton projectile that can, theoretically at least, be hurled 3,000 miles. It is rumored to be as large as a Sherman tank and the destructive possibilities of having a tank full of high explosives crash in your backyard after a 3,000-mile rocket ride through space is best left to your imagination. If V-2 comes up to certain rumors, it is possible that some day one or two might come hurtling across the Atlantic. Of course, they might fall 500 to 1,000 miles off their objective.

As an Army Air Forces officer commented, "Most things are possible technically, of course, but there do seem to be immense technical difficulties involved." Germany, he explained, was no doubt working to develop rocket bombs with atomic explosive features. They'd be foolish if they didn't, he added.

These buzz-bombs or rocket bombs are the best argument that has come out of this war why, from purely selfish reasons, this country, any country, must consecrate itself to preventing another world war.—Christian Science Monitor.

Clayton Bissell and Hewlett Thebaud to the Joint Chiefs of Staff. 9 December 1944. Subject: Agreed Joint Evaluation of the Possible Existence of the V-3 Rocket and Probability of Attack against the U.S. [Franklin Delano Roosevelt Library, Hyde Park, New York. Map Room Files, Box 164, Folder Naval Aides. Files: A/16—General Correspondence]

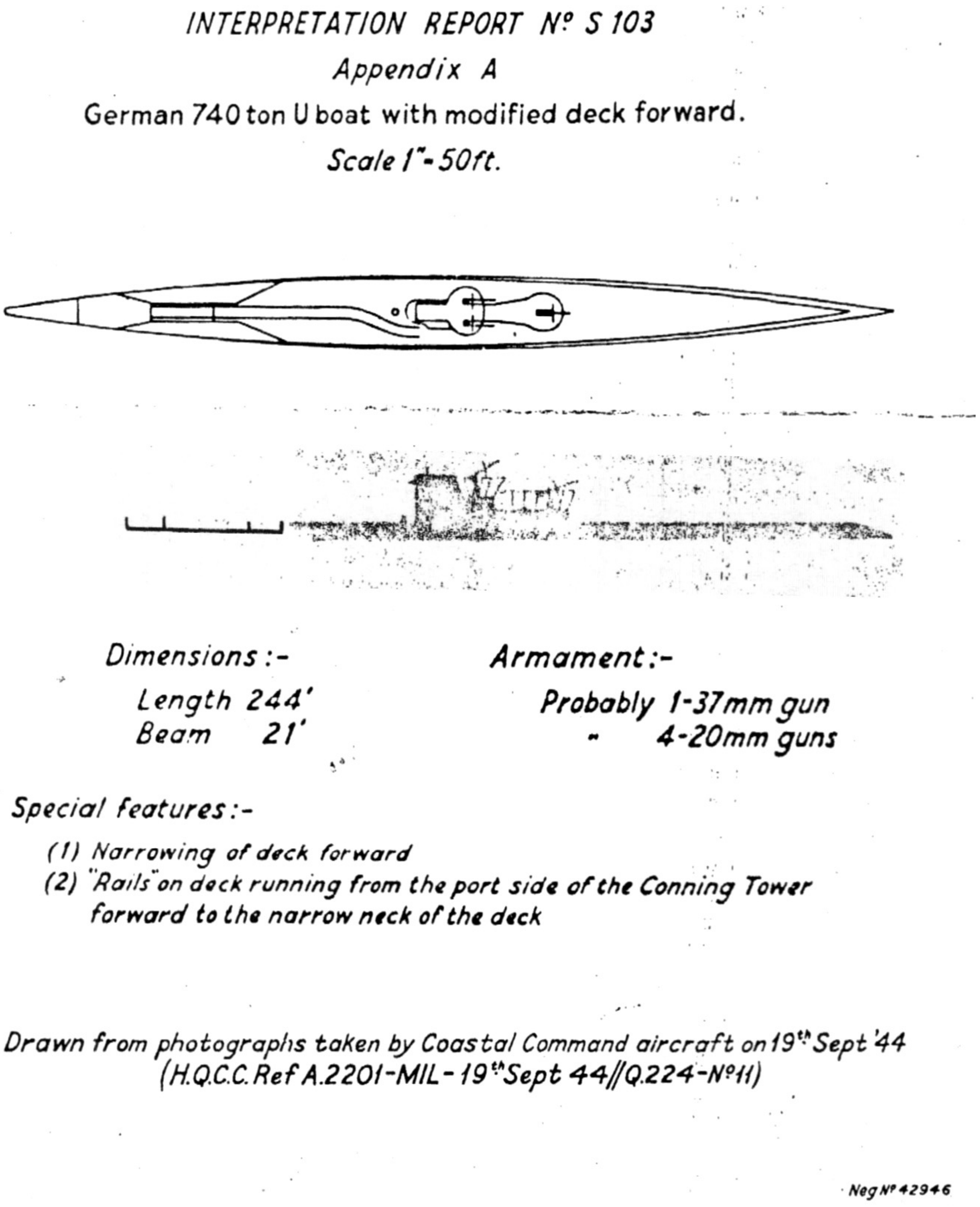
1. The cable from Lieutenant Commander Earle, Naval Attaché, Turkey is probably propaganda and represents a plant by the Germans. There is no reliable information available of German development of a long range rocket other than the V-2.

2. The V-3 may possibly be a rocket of smaller dimensions than the V-2 with a shorter range. It would be possible to launch such a missile from specially designed or modified submarines. Attached is a sketch of a German submarine based in a southern Norwegian port showing a pair of rails extending from conning tower to the bow and terminating at a flat, rectangular surface. The purpose of this is unknown.

3. German attack from Europe of United States cities by long range rockets is deemed impossible now. Small rocket or flying bomb attacks from specially constructed submarines are considered possible. Any such action would be made with propaganda effect rather than material damage as the primary objective.

[The sketch mentioned in this document is on p. 5623. The sketch was based on photographs taken on 19 September 1944.]

FDR Library, Map Room Files, Box 164, Folder Naval Aides. Files: A/16—General Correspondence



INTERPRETATION REPORT Nº S 103

Appendix A

German 740 ton U boat with modified deck forward.

Scale 1"-50ft.

Dimensions :-

Length 244'
Beam 21'

Armament :-

Probably 1-37mm gun
" 4-20mm guns

Special features :-

(1) Narrowing of deck forward
(2) "Rails" on deck running from the port side of the Conning Tower forward to the narrow neck of the deck

Drawn from photographs taken by Coastal Command aircraft on 19th Sept '44
(H.Q.C.C. Ref A.2201-MIL-19th Sept 44//Q.224-Nº11)

Neg Nº 42946

Figure E.192: Allied drawing of a German submarine that was apparently modified to launch V-1 cruise missiles, based on photographs taken on 19 September 1944 [FDR Library, Map Room Files, Box 164, Folder Naval Aides. Files: A/16—General Correspondence].

Dwight Eisenhower to AGWAR. 1 November 1944. Outgoing Cable. [TNA WO 219/298; Henshall 2000, p. 165]

Following passed for what it is worth.

Special Force report quoting Danish source states U-boat will be leaving European waters shortly to launch V-1s against NEW YORK.

Date of report 30 October.

Clayton Bissell to Stockholm Military Attaché. 3 November 1944. Outgoing Cable WAR 56799. [Franklin Delano Roosevelt Library, Hyde Park, New York. Map Room Files, Box 49, Folder Rocket Bombs 1944]

Have been advised through OSS that Tykander their representative in Stockholm has received reliable information that German U boats are equipped with bomb launching platforms. Investigate and keep us fully informed.

Dwight Eisenhower to SFHQ, London. 7 November 1944. Outgoing Cable 8-65824. [TNA WO 219/298; Georg and Mehner 2004, p. 209.]

War Department G-2 have requested further evidence and any other confirmation of Special Force report of 30 October quoting Danish source who stated U boat would be leaving European waters shortly to launch V 13 [sic: V-1s] against NEW YORK. Most grateful your assistance including re evaluation source and report if possible.

Dwight Eisenhower to AGWAR. 13 November 1944. Outgoing Cable S-66672. [TNA WO 219/298; Henshall 2000, p. 164]

Special Force Headquarters reports same source reported 7 November that he believed 4 U-Boats were to be used in operation against NEW YORK operating from BERGEN but course and rate unknown. Special Force Headquarters grades source as (usually reliable) but comments that no other confirmation to possibility of such action received from BERGEN or elsewhere.

U-Boat Aimed V-Bomb Here, Army Paper Says. *New York Times.* 15 May 1945 p. 10.

A German submarine tried to V-bomb New York last election day, presumably with a jet-propelled or rocket-propelled weapon, the Army newspaper Stars and Stripes reported tonight, quoting "sources considered reliable."

It was reported that the bomb was launched from the deck of a U-boat lying off the coast and that it fell short or was knocked down by fighter planes patrolling as a screen against any such projectiles. The Stars and Stripes said that "operators" at Mitchel Field were quoted as having said that it was determined that the bomb fell into the sea.

The paper recalled that last Nov. 8, the day after the Presidential election, the Army and Navy in a joint statement said that a V-bomb attack on the United States was entirely possible.

A Navy spokesman in Washington said that the report of the submarine attack was without foundation, The United Press reported.

An official of the bomb squad of New York's Police Department said last night that the squad had no knowledge of an attempted bombing of New York last Nov. 7 by the Germans.

"Undoubtedly, if a robot bomb had been launched at New York from a U-boat, as reported, and had neared its objective, we would have been informed," the spokesman said.

[The original version of this story appeared as: U-Boat Aimed V-Bomb at New York, *Stars and Stripes*, 14 May 1945. Considering that the report came from the U.S. Army's own newspaper and sources that they considered reliable, the subsequent denials by the U.S. Navy spokesman and New York bomb squad do not seem very convincing.

If the incident actually occurred, can it be clarified if the weapon was a sub-launched V-1 cruise missile or something else? If the weapon fell into the sea, was it ever located?

Was the warhead a conventional explosive, or a chemical, biological, or nuclear weapon? A V-1 strike on a U.S. city with only a conventional warhead would have done relatively little damage and would have had no strategic military value. For evidence of modified V-1 missiles that could have delivered weapons of mass destruction, see pp. 1841 and 4896–4897, as well as Henshall 2000, pp. 129–130.

U.S. fears of a submarine-launched missile strike on East Coast cities continued in spring 1945. From April to the end of the war in Europe, the U.S. Navy conducted Operation Teardrop to intercept a number of German submarines approaching the United States. Were any of those submarines armed with something more than has been acknowledged in the official history books? All relevant archival files need to be located and declassified.]

S. McClintic, Headquarters U.S. Strategic Air Forces in Europe, Office of the Director of Intelligence, to George C. McDonald. 6 January 1945. Big Ben (Rockets). [AFHRA A5734 electronic version pp. 1093]

[...] Again we receive reports of ships being constructed for the launching of flying bombs, this one a 6000 ton boat at Hamburg, and another report that the shipyards, DEUTSCHE WERFT BETRIEB FINKENWERDER are putting ramps on the decks. [...]

J. Edgar Hoover to Harry Hopkins. 8 January 1945. [Franklin Delano Roosevelt Library, Hyde Park, New York. Official File 10b. Box 20. Folder OF 10-b, Justice Department, FBI Reports 1944–45. 2597–2618]

During the interrogation of William Curtis Colepaugh, the enemy agent who was landed by German submarine off the coast of Frenchman's Bay, Maine, on the night of November 29, 1944, several interesting features have arisen concerning his submarine trip to the United States. [...]

Upon arrival at Kristianson, Norway, on the U-1230 he learned that the U-1231 and the U-1233, both submarines of the same type as the U-1230, had just completed some sort of test at Kristianson, Norway.

Colepaugh has said that members of the crew of the U-1230 indicated in conversation that they had observed at one of the submarine ports near Danzig some members of other submarine crews practicing in groups with equipment of a rocket or gun type on the deck and these crew members presumed this equipment would be used against the United States. He said the crew members he talked with were pretty definite about this stating that the submarines would proceed to within 100 or 200 miles of the United States and then fire these rockets. Colepaugh pointed out, however, that the crew members on the U-1230 had no knowledge of the use of this rocket and based their presumption only on what they had observed at the submarine port near Danzig.

Robot Bomb Attacks Here Held 'Probable' by Admiral. *New York Times*, 9 January 1945, pp. 1, 6.

AN EAST COAST PORT, Jan. 8—A strategically futile attack on New York or Washington by robot bombs within thirty to sixty days was described today as not only "possible but probable" by Admiral Jonas H. Ingram, new Commander in Chief of the Atlantic Fleet, whose command stretches from the Arctic to the Falkland Islands. [...]

"And we know very definitely that there are three ways in which he might get robot bombs within range of either city. He might sneak a half dozen submarines off the coast. He might launch robots from the long-range planes we know he has. Or he might sneak a surface ship, disguised as a neutral, within range." [...]

[See also: Officials Silent on Robot Threat/London Paper Predicts Attack. *New York Times*, 10 January 1945, p. 7.]

H. H. Smith, N. W. Dickson, V. P. Kovac, and E. H. Bennett. German Developments in the Guided Missile Field. 10 January 1946. Project 2874. [NARA RG 319, Entry NM3-82, Box 2879, Folder Project 2784]

Two further developments of the V-1 program were an attempt to launch the missile from a ramp on the deck of a submarine and a project for a piloted V-1. In the first case a ramp was constructed though never used; it is believed that this was intended for attacks against coastal towns and defenses on the Eastern seaboard of the U.S.A. In the second instance, several models were constructed though, as far as is known, none were ever used. It was intended that the pilot should fly the missile to within a short range of the target, set the controls and then jump out.

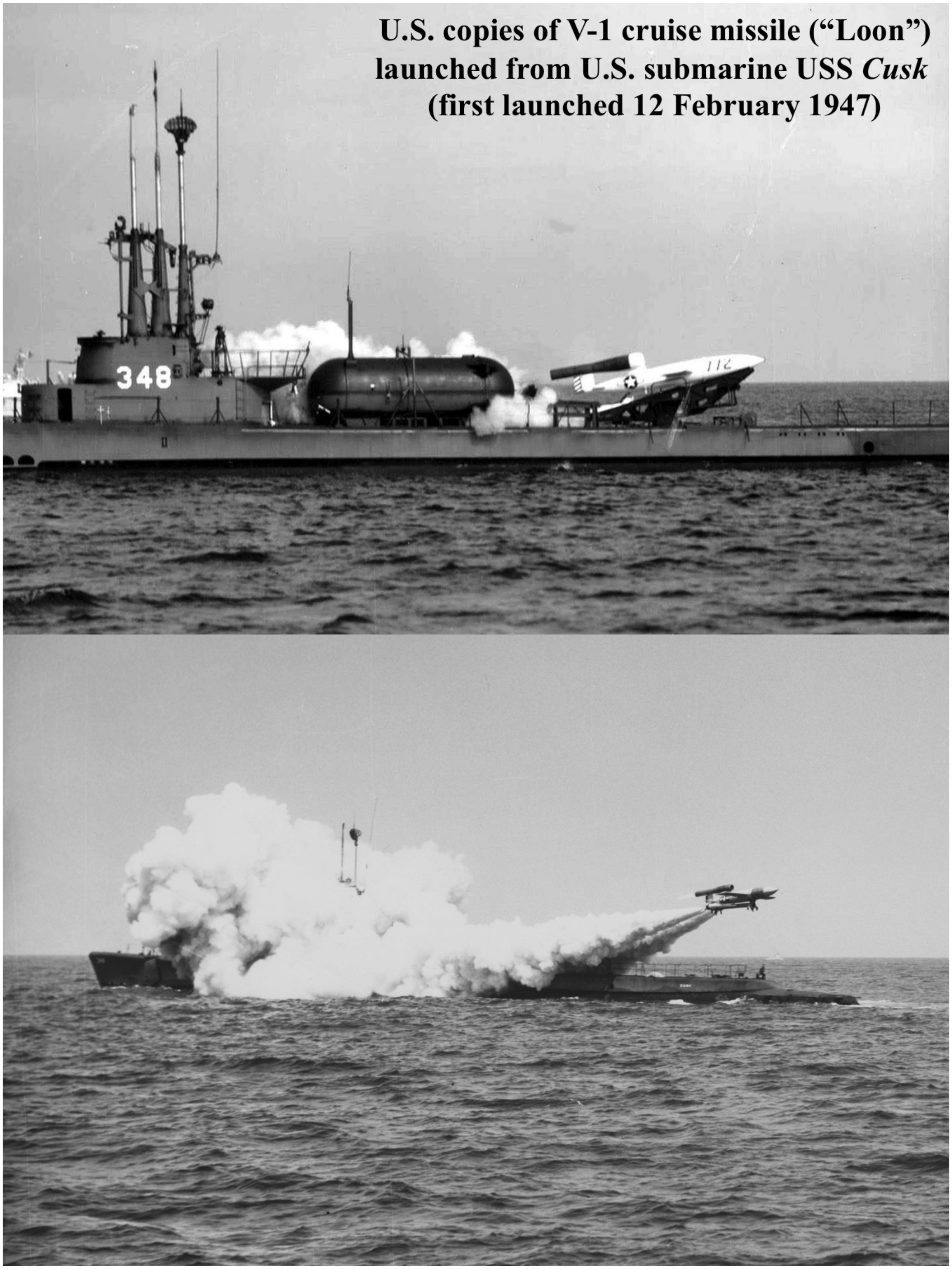

U.S. copies of V-1 cruise missile ("Loon")
launched from U.S. submarine USS *Cusk*
(first launched 12 February 1947)
348
112

Figure E.193: Loon, a U.S. copy of the V-1 cruise missile, was launched from the USS *Cusk* submarine, based on wartime German developments and implemented by German-speaking scientists at Point Mugu Naval Air Missile Test Center.

Walter Dornberger. 1958. *V-2: The Nazi Rocket Weapon.* New York: Viking. pp. 231–237.

In the autumn of 1943 Lafferenz, of the German Labour Front, paid me a visit and told me that he had proved by practical experiment that, contrary to predictions by the Navy, a submarine could take in tow as many as three cigar-shaped, submersible containers 100 feet long. He urged us to examine the possibility of launching our A4 from these floats. It it could be done we should be able to bombard big military objectives overseas across hundreds of miles of water.

The problem interested us. In the summer of 1942 we had already experimented near the Greifswald Oie with launching solid-propellant rockets from a submarine. It had been Steinhoff's idea at the time. He had noticed the heavy projectiles developed by my department, the solid rockets for the *Nebelwerfer*[1] detachments. His brother was a submarine commander and had a long voyage to make very shortly. We were talking about it and suddenly had an idea. Rockets worked under water; how would it be if we could accommodate 20 or 30 of them, with a charge of inflammable oil or high explosive and ready for launching, aboard a submarine? The submarine could then submerge, approach to within 2 miles of the shore and discharge the rockets under water against oil tank installations on the coast. The petrol and oil tanks would certainly be set on fire by the oil which would ignite on impact.

[1] The *Nebelwerfer* was a weapon roughly equivalent to a trench mortar, in which rocket-propelled shells (originally intended to lay smoke-screens, etc.) were fired from a multi-barrelled launcher.

At Swinemünde improvised launching frames were erected on the deck of the submarine by workmen from Peenemünde and a few days later several salvos were launched from a depth of 30–50 feet. Nothing whatever could be felt of the launchings in the submerged submarine. The trajectory was capital, in fact dispersion was reduced and range slightly increased by the improved initial motion of the missiles through the water. A staggering sight it was when those 20 heavy solid rockets suddenly rose, with a rush and roar, from the calm waters of the Baltic. This improvisation could have been put to immediate and successful use against the enemy, but the Naval Weapons Department, the competent authority for all naval weapon development, would not approve it, though it had served its purpose perfectly. The Navy itself insisted on doing the designing. Months, a whole year went by. [...]

Peenemünde made a thorough study of the problem set by Lafferenz. A submarine could tow three floats weighing about 500 tons for 30 days at an average speed of 12 knots. Their submerging and surfacing could be controlled from the submarine. An A4 and the necessary quantities of propellants could be accommodated without difficulty.

On arrival at the launching point the floats could be partially flooded so that they stood upright in the water. The top hatch could then be opened and the A4, erect upon its gyro-stabilized platform, after being fueled, prepared for launching and laterally adjusted, could be discharged.

We did not expect any construction difficulties that could not be overcome, but work on the subject had been temporarily suspended because of the A4 troubles. Now, at the end of 1944, it was resumed. By the middle of December a full memorandum was being prepared on the preliminary experiments, and we were getting to work on the first draft designs. The evacuation of Peenemünde put paid once for all to a not unpromising project.

[Dornberger mentioned several wartime projects that are illustrated on the following pages:

- In May 1942, there was a series of successful tests to launch small Nebelwerfer rockets from a submerged submarine (U-511). Those tests were documented in a June 1942 report [Bundesarchiv Militärarchiv Freiburg RH 8/369]. See pp. 5631–5639.

- Based on those successful initial tests, during 1942–1945, the German Navy sponsored the development of a whole series of increasingly sophisticated short-range rockets that could be launched from a submerged submarine. Those rockets were successfully demonstrated at Toplitz See, Austria. The rockets and testing equipment were all destroyed at the end of the war as American forces approached. After the war, though, U.S. Navy investigators interrogated several of the engineers who were involved in the project and wrote a report about their work [NavTecMisEu 500-45]. See pp. 5640–5645.

- Also based on the 1942 tests and the proposal by Lafferenz, engineers from Peenemünde began working on the "Prüfstand XII" project to transport and launch A-4 (V-2) rockets from specially designed underwater cargo containers that could be towed by submarines. For examples from a large collection of 1944 design drawings [Bundesarchiv Militärarchiv Freiburg RH 8/4067K], see pp. 5646–5654. Although in Dornberger's postwar public statements he said that nothing ever came of the project, it is unclear how far the project may have actually progressed. There were reports that at least one Prüfstand XII unit may have been constructed and tested before the end of the war.

- As described in earlier documents (pp. 5618–5627), there were also wartime programs to launch modified V-1 cruise missiles from German submarines.

These and other wartime German projects were continued in other countries after the war, with the aid of German-speaking scientists and captured German hardware and plans:

- Beginning in February 1947, Loon missiles, U.S. copies of German V-1 cruise missiles [Quigg 2014], were launched from the USS *Cusk* submarine, based on wartime German developments and implemented by German-speaking scientists at Point Mugu Naval Air Missile Test Center. See p. 5627.

- As part of Operation Sandy, the U.S. Navy launched an A-4 (V-2) rocket from the deck of the USS Midway on 6 September 1947, demonstrating that an A-4 rocket could indeed be transported and launched at sea (p. 5661).

- German-speaking scientists and technologies were used to develop a series of more advanced U.S. cruise missiles beginning in the late 1940s (pp. 1850–1854).

- Wernher von Braun's team was directly involved in developing Jupiter, a liquid propellant ballistic missile designed to be launched from submarines (but ultimately only deployed on land; see p. 1897).

- German-speaking scientists were deeply involved in the development of U.S. solid propellant submarine-launched ballistic missiles (SLBMs) in ways that have never been fully disclosed to the public (pp. 1902–1904 and 5700–5736).

- In 1962, Robert Truax at Aerojet proposed to greatly scale up the "Prüfstand XII" approach to create the Sea Dragon, a sea-launched rocket that would have been larger than even a Saturn V (p. 5655).

- The Soviet Union also investigated versions of the "Prüfstand XII" approach as part of its postwar Golem program to develop SLBMs.[7]

- The first deployed Soviet SLBM, the R-11FM Zemlya (SS-1B SCUD-A), was directly based on the German Wasserfall (first launched in 1944). Like the Wasserfall, it used storable liquid propellants. The R-11FM was first launched from a submarine on 16 September 1955. See pp. 1898–1899.

- Later generations of Soviet SLBMs, such as the R-13 (SS-N-4, first launched in 1959) and R-21 (SS-N-5, first launched in 1962) were scaled up from the R-11FM and again were directly based on German-developed technologies and propellants (p. 1900).

- German-speaking scientists and technologies likely also had a great impact on the postwar submarine-launched missile programs of other countries (e.g., p. 5660).]

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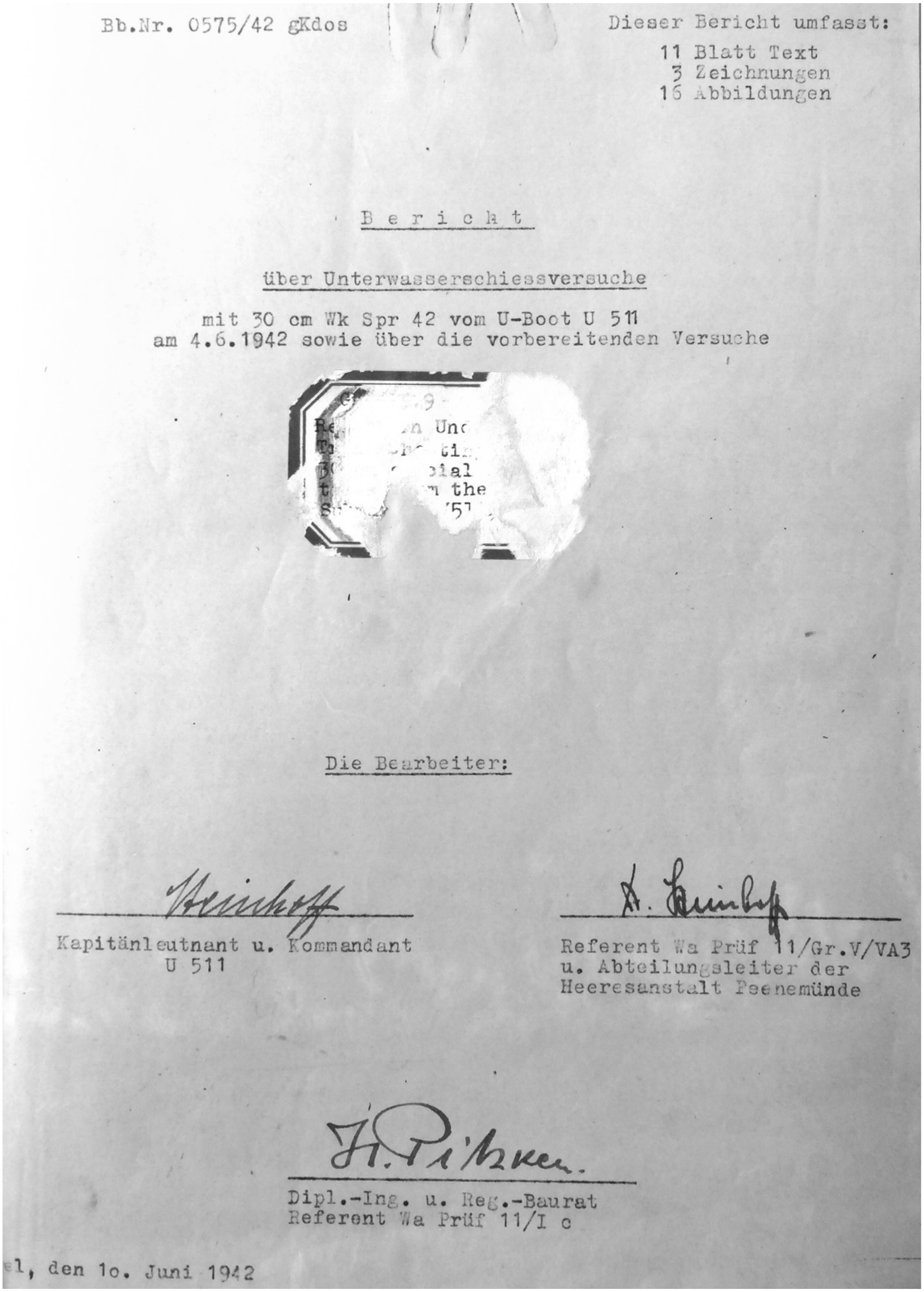
[7] https://www.globalsecurity.org/wmd/world/russia/golem.htm



Bb.Nr. 0575/42 gKdos

Dieser Bericht umfasst:
11 Blatt Text
3 Zeichnungen
16 Abbildungen

Bericht

über Unterwasserschiessversuche

mit 30 cm Wk Spr 42 vom U-Boot U 511
am 4.6.1942 sowie über die vorbereitenden Versuche

Re[illegible]n Und
T[illegible]ting
30[illegible]cial
t[illegible]n the
S[illegible]51

Die Bearbeiter:

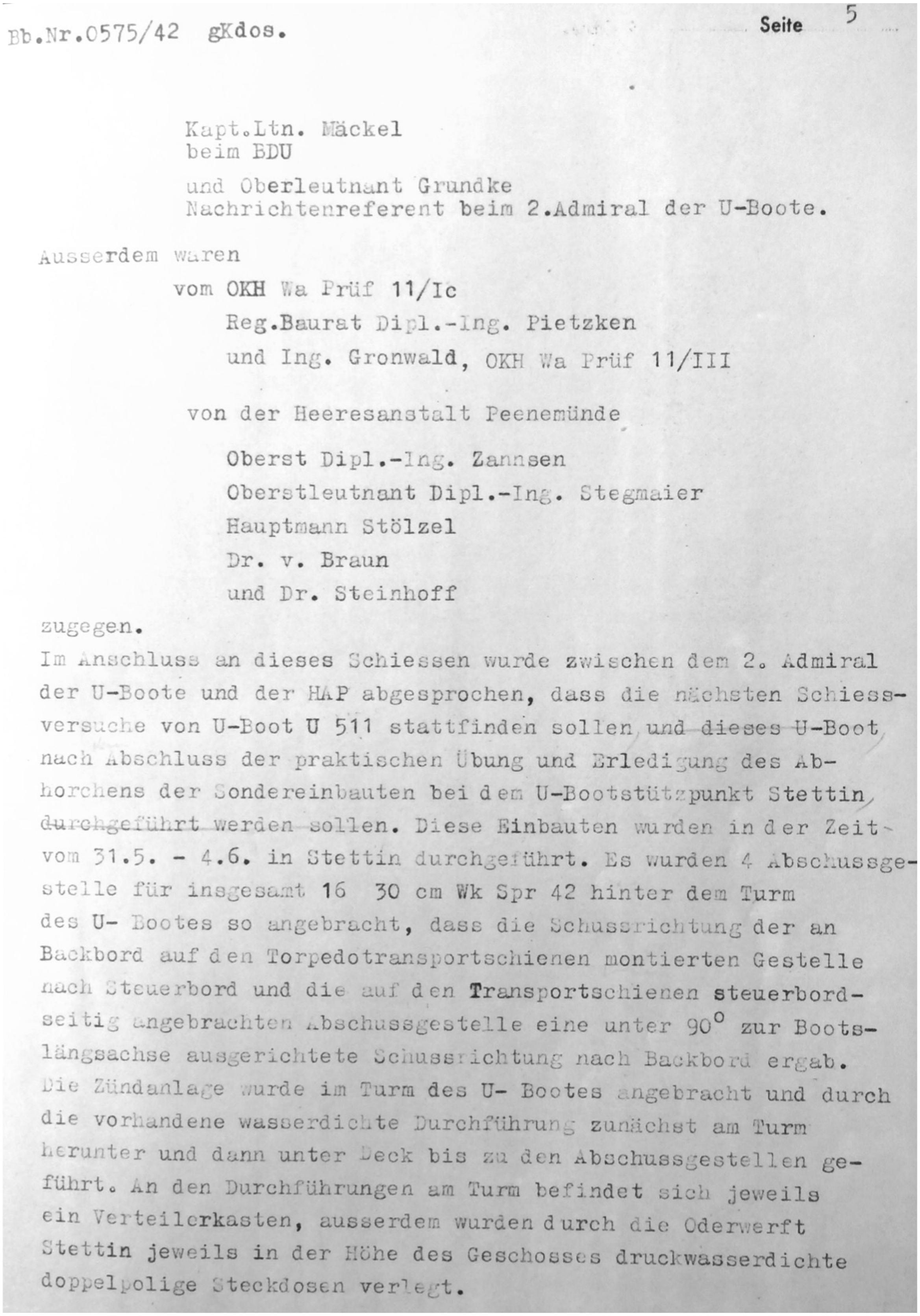
Steinhoff
Kapitänleutnant u. Kommandant
U 511

Referent Wa Prüf 11/Gr.V/VA3
u. Abteilungsleiter der
Heeresanstalt Peenemünde

Dipl.-Ing. u. Reg.-Baurat
Referent Wa Prüf 11/I c

el, den 1o. Juni 1942

Figure E.194: Selected pages from a June 1942 report describing a series of successful tests to launch small rockets from a submerged submarine [Bundesarchiv Militärarchiv Freiburg RH 8/369].



Bb.Nr.0575/42 gKdos. Seite 5

Kapt.Ltn. Mäckel
beim BDU

und Oberleutnant Grundke
Nachrichtenreferent beim 2.Admiral der U-Boote.

Ausserdem waren
vom OKH Wa Prüf 11/Ic
Reg.Baurat Dipl.-Ing. Pietzken
und Ing. Gronwald, OKH Wa Prüf 11/III

von der Heeresanstalt Peenemünde

Oberst Dipl.-Ing. Zannsen
Oberstleutnant Dipl.-Ing. Stegmaier
Hauptmann Stölzel
Dr. v. Braun
und Dr. Steinhoff

zugegen.

Im Anschluss an dieses Schiessen wurde zwischen dem 2. Admiral der U-Boote und der HAP abgesprochen, dass die nächsten Schiessversuche von U-Boot U 511 stattfinden sollen, ~~und dieses U-Boot~~ nach Abschluss der praktischen Übung und Erledigung des Abhorchens der Sondereinbauten bei dem U-Bootstützpunkt Stettin, ~~durchgeführt werden sollen~~. Diese Einbauten wurden in der Zeit vom 31.5. - 4.6. in Stettin durchgeführt. Es wurden 4 Abschussgestelle für insgesamt 16 30 cm Wk Spr 42 hinter dem Turm des U- Bootes so angebracht, dass die Schussrichtung der an Backbord auf den Torpedotransportschienen montierten Gestelle nach Steuerbord und die auf den Transportschienen steuerbordseitig angebrachten Abschussgestelle eine unter 90° zur Bootslängsachse ausgerichtete Schussrichtung nach Backbord ergab. Die Zündanlage wurde im Turm des U- Bootes angebracht und durch die vorhandene wasserdichte Durchführung zunächst am Turm herunter und dann unter Deck bis zu den Abschussgestellen geführt. An den Durchführungen am Turm befindet sich jeweils ein Verteilerkasten, ausserdem wurden durch die Oderwerft Stettin jeweils in der Höhe des Geschosses druckwasserdichte doppelpolige Steckdosen verlegt.

Figure E.195: Selected pages from a June 1942 report describing a series of successful tests to launch small rockets from a submerged submarine [Bundesarchiv Militärarchiv Freiburg RH 8/369].

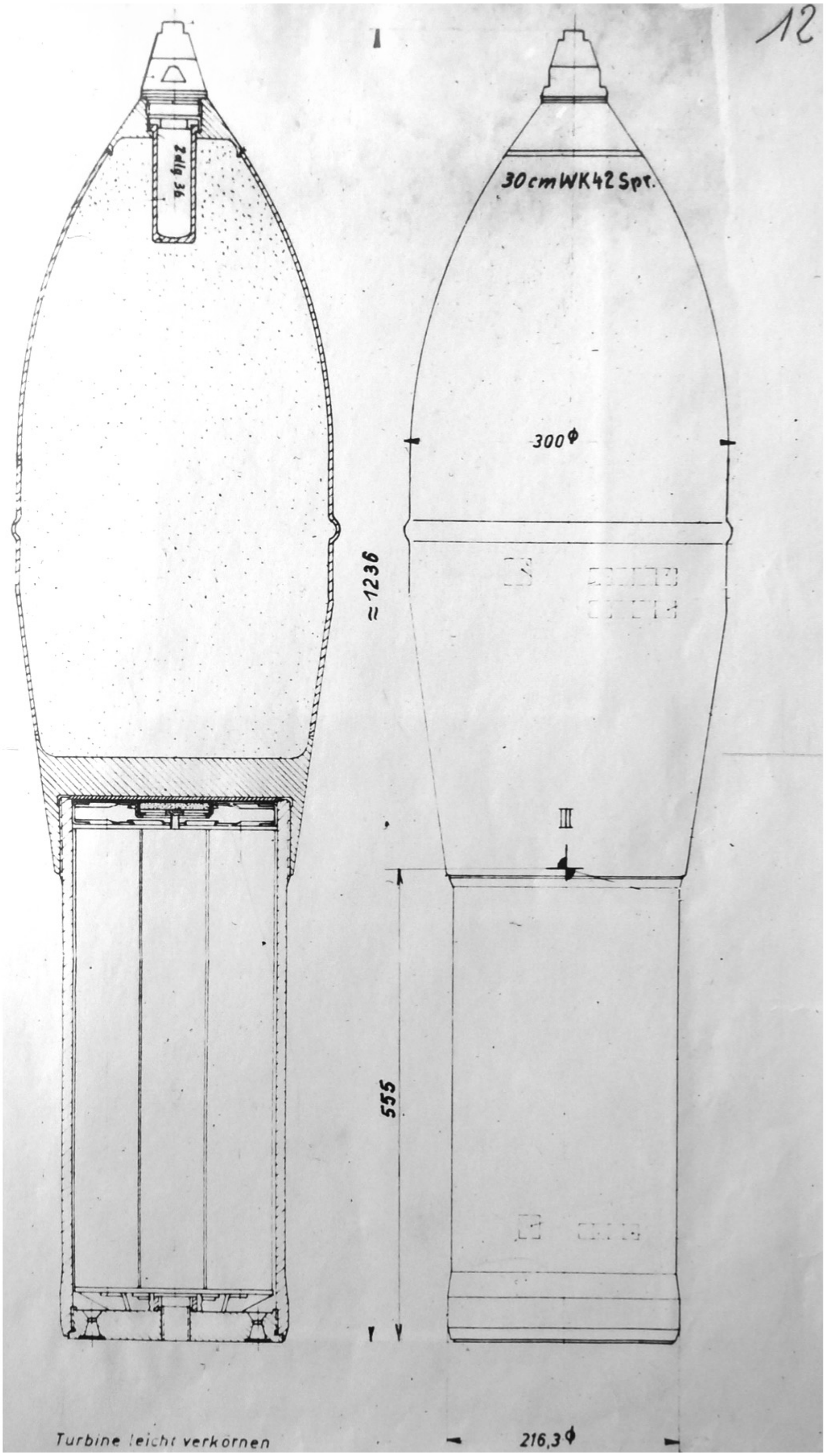

12
Zdlg 36
30cmWK42Spr.
300φ
≈1236
III
555
Turbine leicht verkornen
216,3φ

Figure E.196: Selected pages from a June 1942 report describing a series of successful tests to launch small rockets from a submerged submarine [Bundesarchiv Militärarchiv Freiburg RH 8/369].

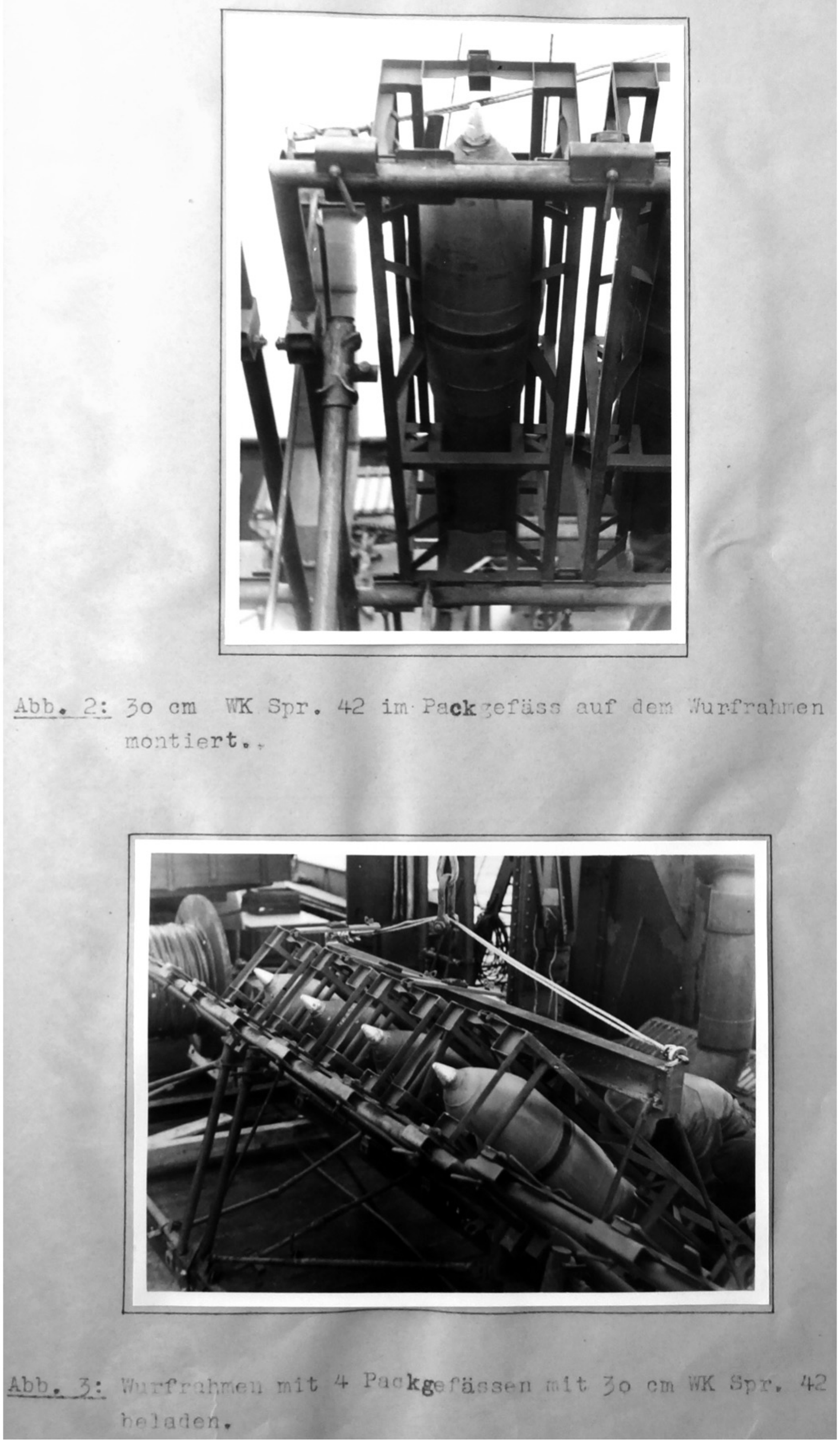


Abb. 2: 3o cm WK Spr. 42 im Packgefäss auf dem Wurfrahmen montiert.

Abb. 3: Wurfrahmen mit 4 Packgefässen mit 3o cm WK Spr. 42 beladen.

Figure E.197: Selected pages from a June 1942 report describing a series of successful tests to launch small rockets from a submerged submarine [Bundesarchiv Militärarchiv Freiburg RH 8/369].

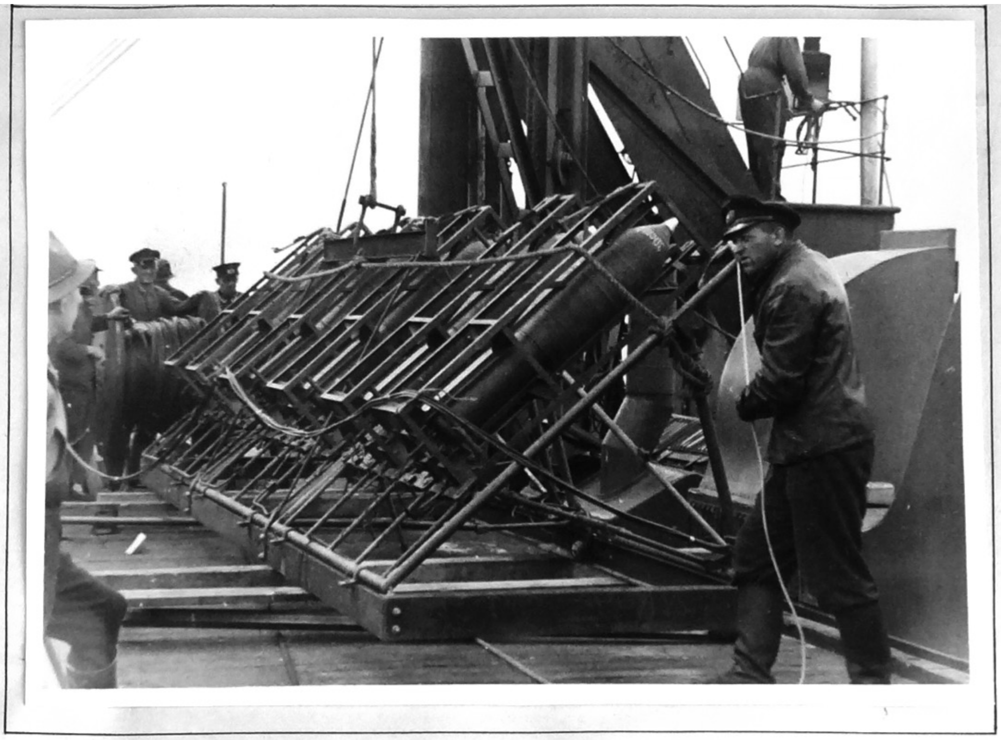


Abb. 4

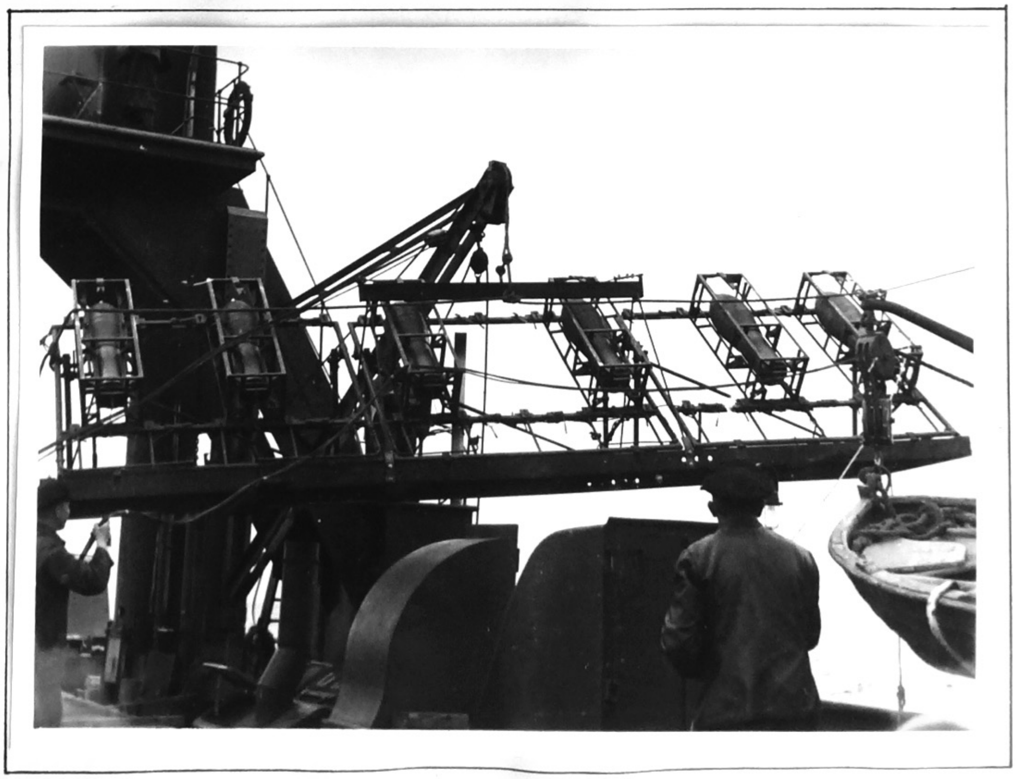


Abb. 5

Figure E.198: Selected pages from a June 1942 report describing a series of successful tests to launch small rockets from a submerged submarine [Bundesarchiv Militärarchiv Freiburg RH 8/369].

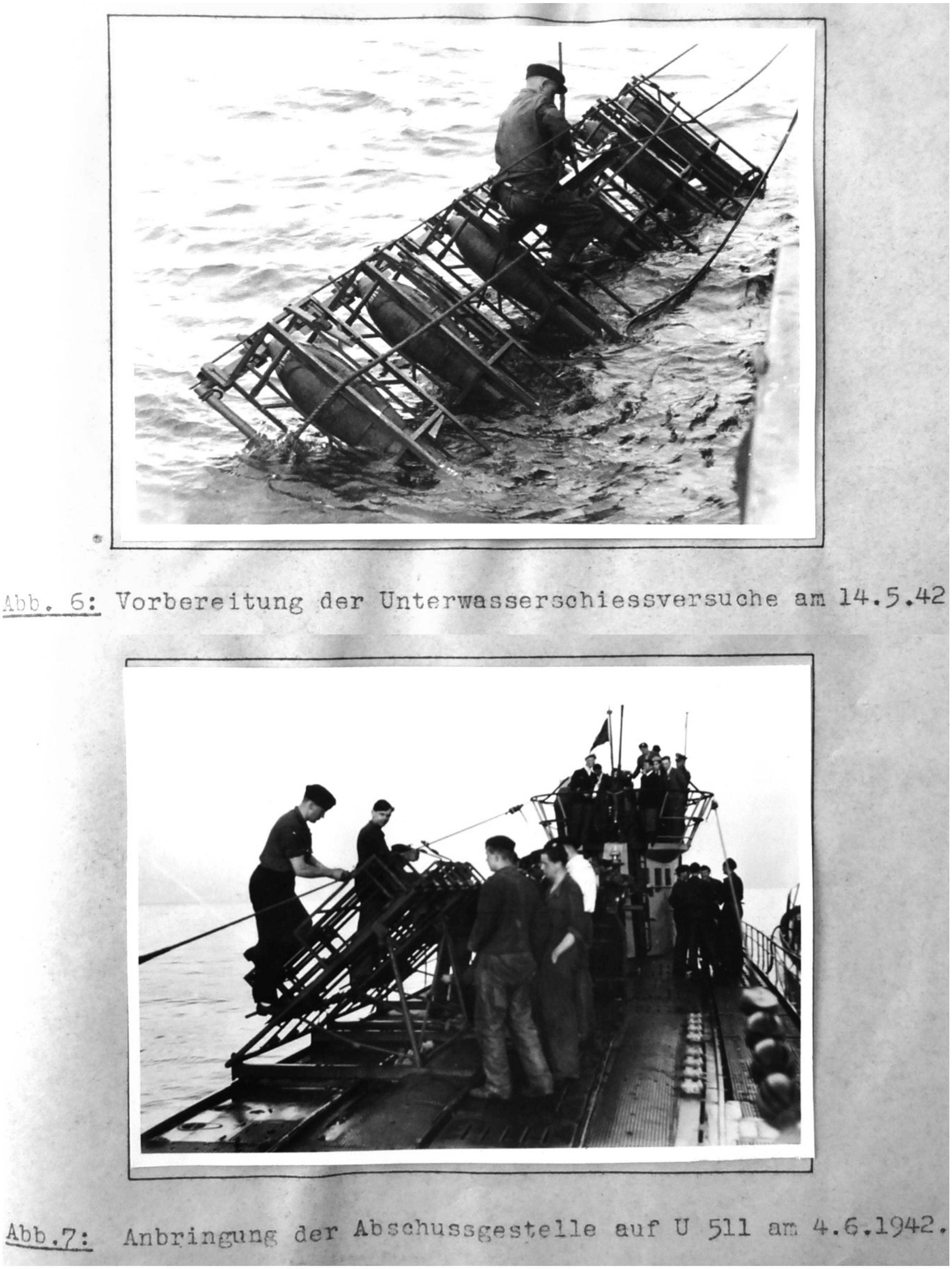
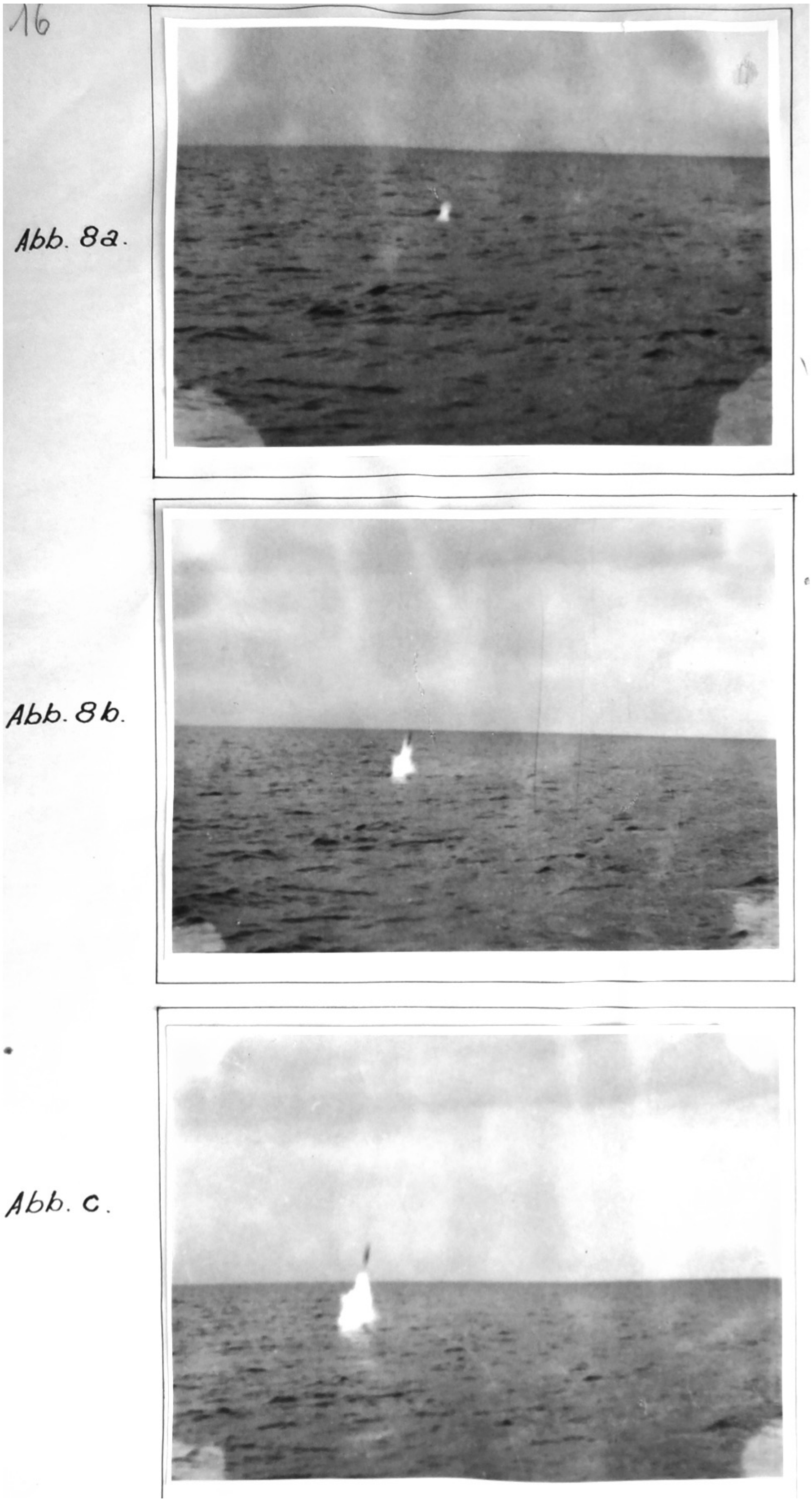


Abb. 6: Vorbereitung der Unterwasserschiessversuche am 14.5.42

Abb.7: Anbringung der Abschussgestelle auf U 511 am 4.6.1942.

Figure E.199: Selected pages from a June 1942 report describing a series of successful tests to launch small rockets from a submerged submarine [Bundesarchiv Militärarchiv Freiburg RH 8/369].



16

Abb. 8a.

Abb. 8b.

Abb. c.

Figure E.200: Selected pages from a June 1942 report describing a series of successful tests to launch small rockets from a submerged submarine [Bundesarchiv Militärarchiv Freiburg RH 8/369].

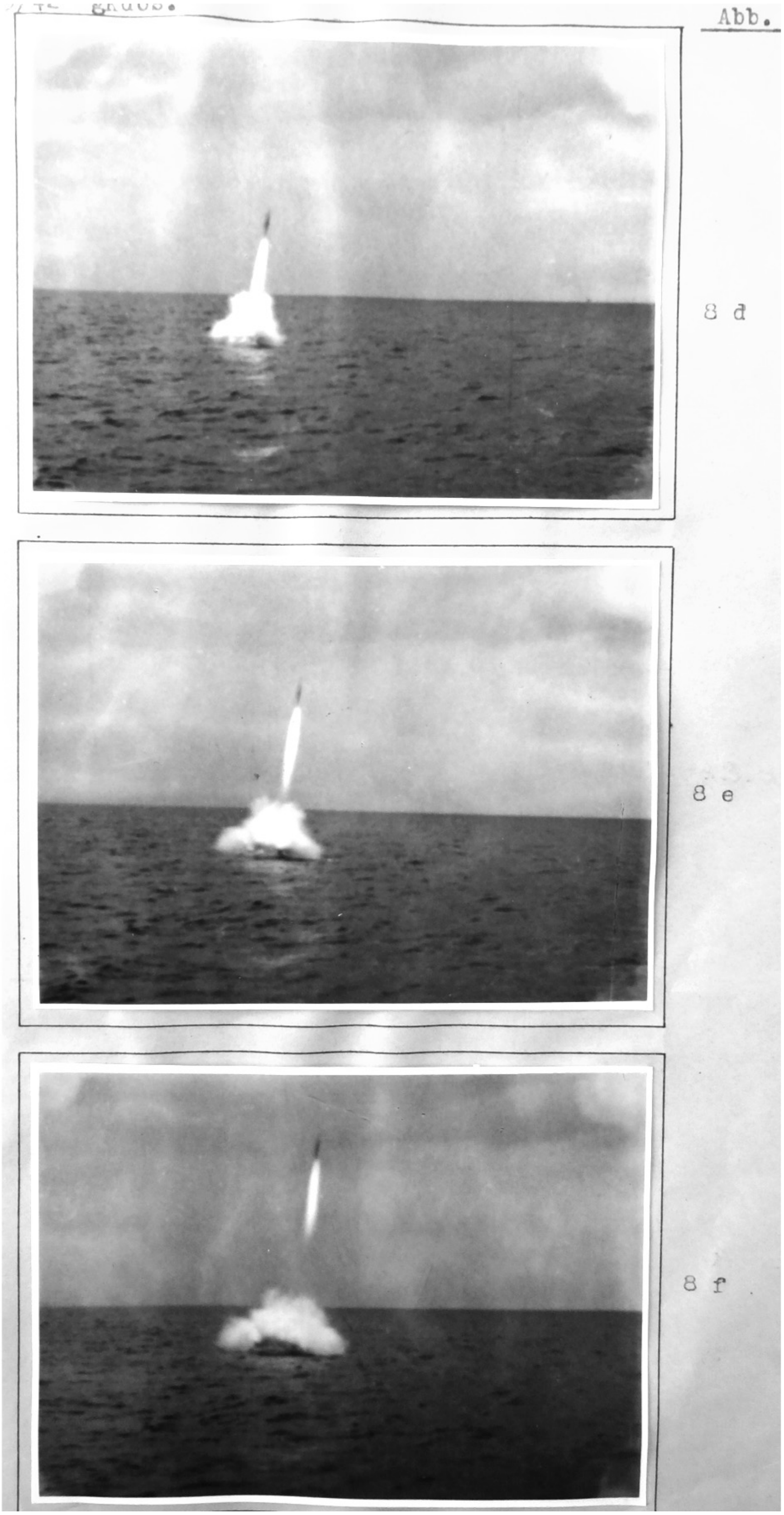


Abb.

8 d

8 e

8 f

Figure E.201: Selected pages from a June 1942 report describing a series of successful tests to launch small rockets from a submerged submarine [Bundesarchiv Militärarchiv Freiburg RH 8/369].

Abb. 8g.

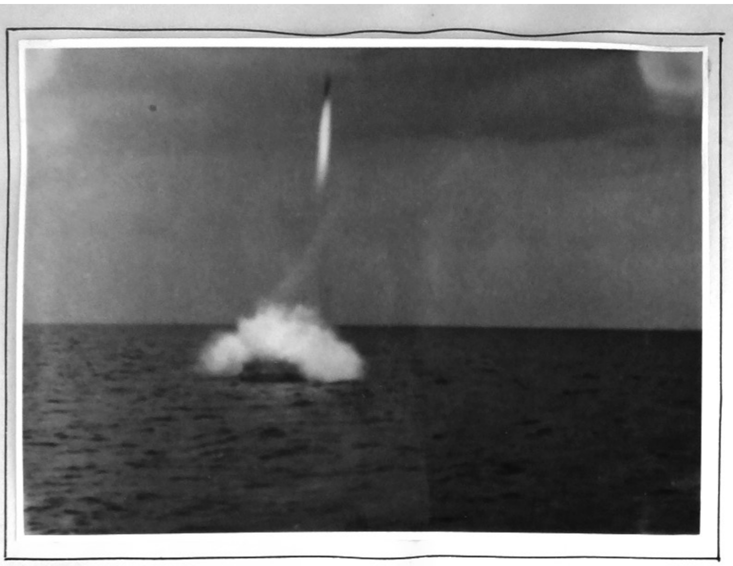


Abb. 8h.

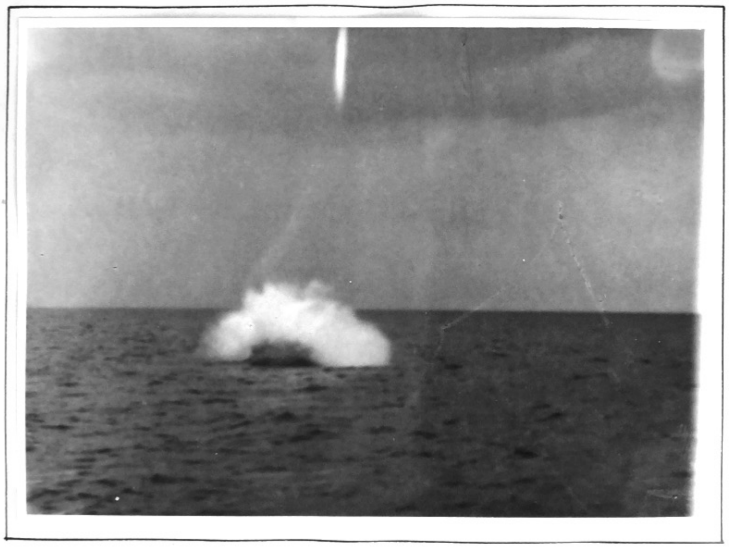


Abb. 8i.

Figure E.202: Selected pages from a June 1942 report describing a series of successful tests to launch small rockets from a submerged submarine [Bundesarchiv Militärarchiv Freiburg RH 8/369].

DECLASSIFIED
Authority NND 57481

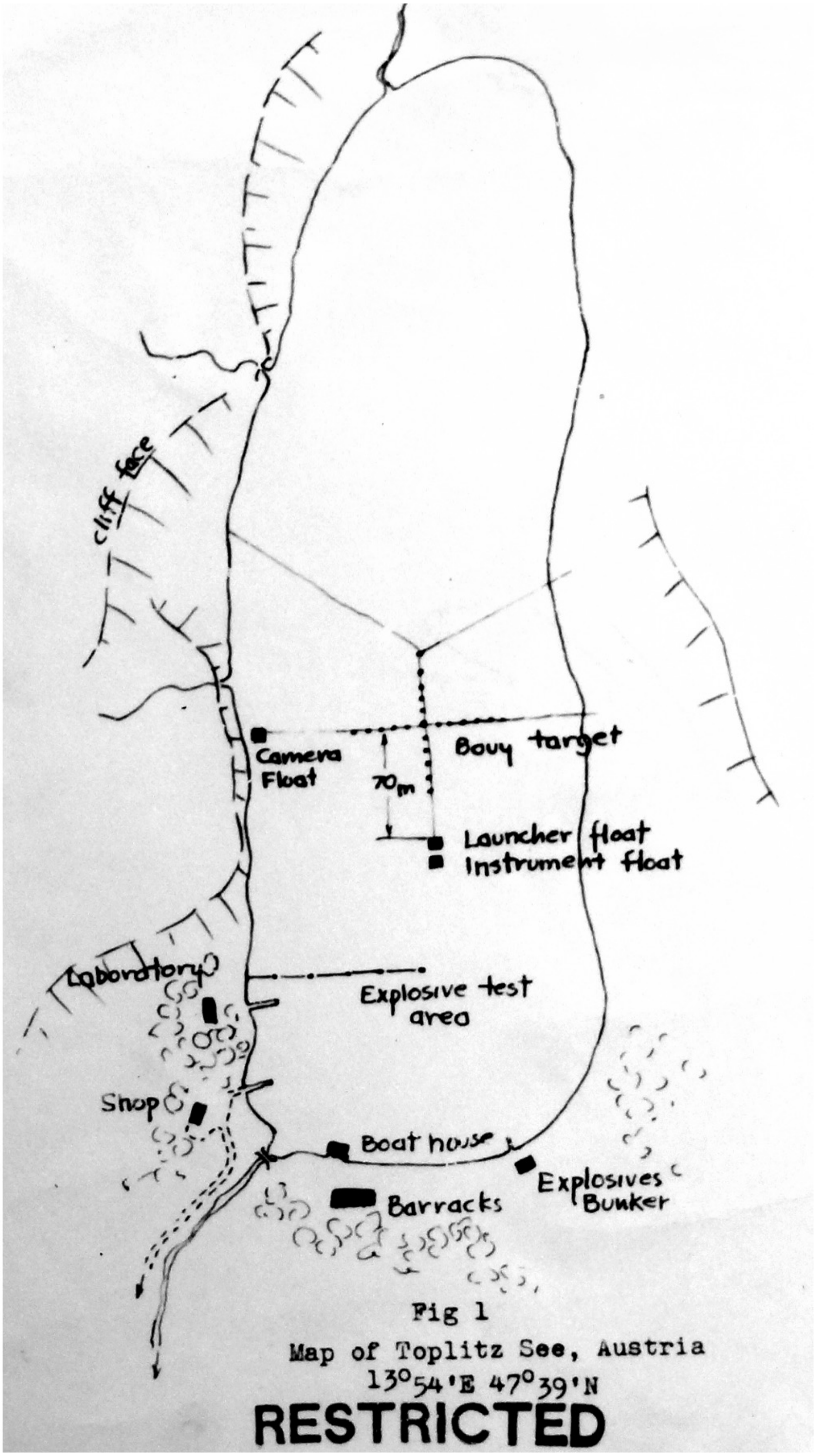
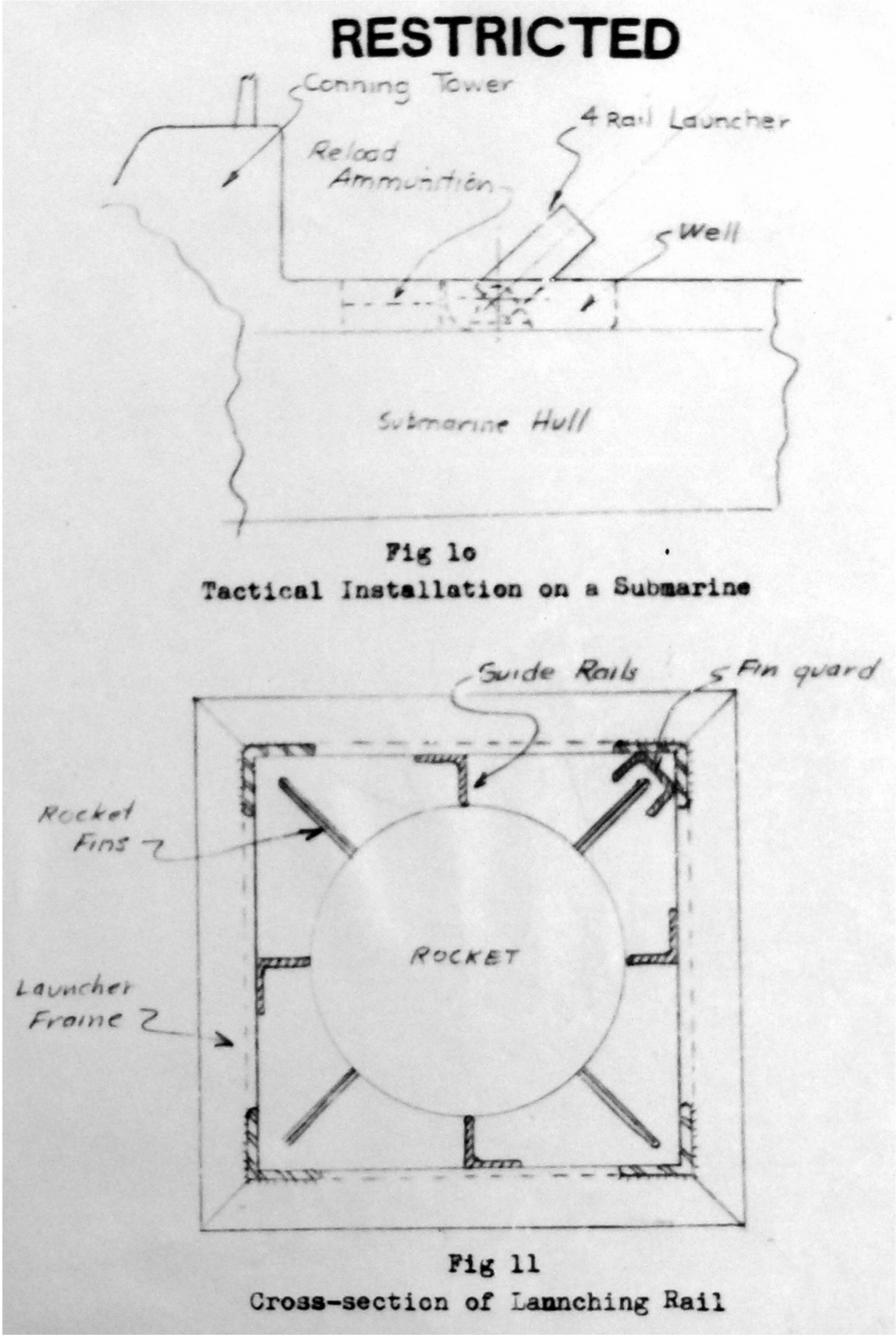

cliff face
Camera Float
70m
Bouy target
Launcher float
Instrument float
Laboratory
Explosive test area
Shop
Boat house
Barracks
Explosives Bunker

Fig 1
Map of Toplitz See, Austria
$13^{0}54$'E $47^{0}39$'N

RESTRICTED

Figure E.203: Drawings from a postwar report on a long series of increasingly sophisticated submarine-launched rockets that were developed 1942–1945 and successfully demonstrated at Toplitz See, Austria [NavTecMisEu 500-45].


RESTRICTED

Conning Tower
4 Rail Launcher
Reload Ammunition
Well
Submarine Hull

Fig 10
Tactical Installation on a Submarine

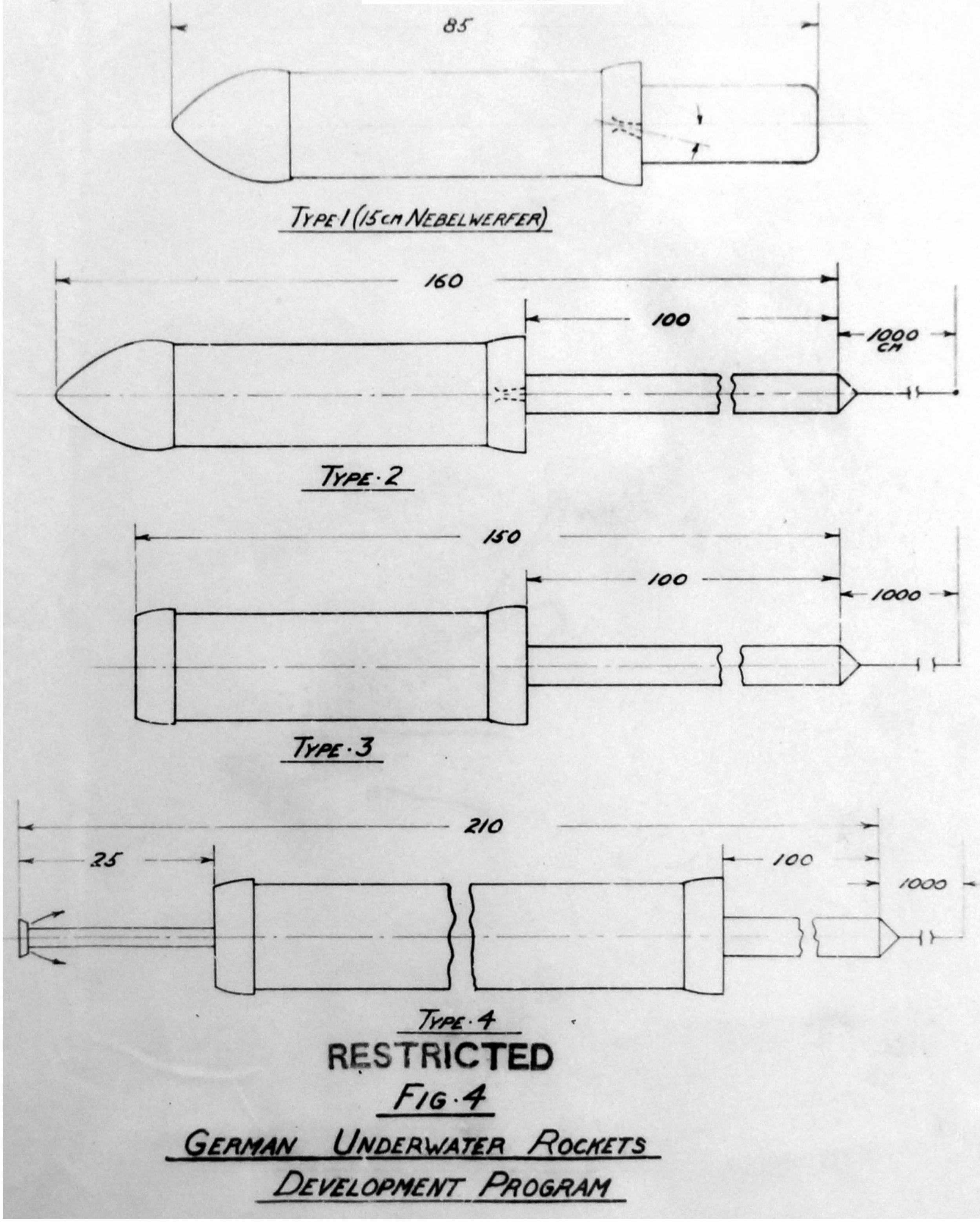
Guide Rails
Fin guard
Rocket Fins
ROCKET
Launcher Frame

Fig 11
Cross-section of Launching Rail

DECLASSIFIED
Authority NW 54481

Figure E.204: Drawings from a postwar report on a long series of increasingly sophisticated submarine-launched rockets that were developed 1942–1945 and successfully demonstrated at Toplitz See, Austria [NavTecMisEu 500-45].

DECLASSIFIED
Authority NW 54481


85
TYPE·1 (15 CM NEBELWERFER)
160
100
1000 CM
TYPE·2
150
100
1000
TYPE·3
210
25
100
1000
TYPE·4

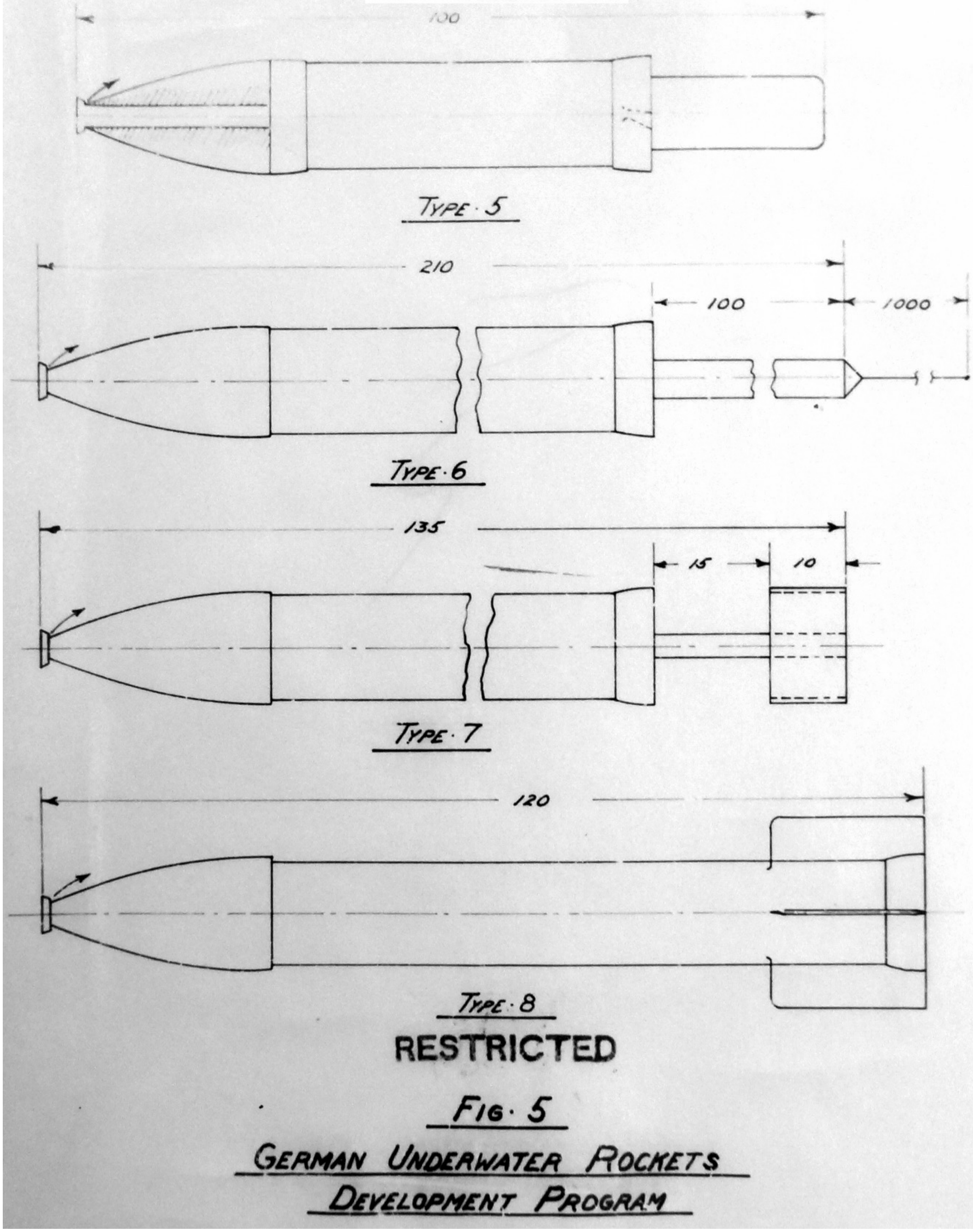
RESTRICTED

FIG·4

GERMAN UNDERWATER ROCKETS
DEVELOPMENT PROGRAM

Figure E.205: Drawings from a postwar report on a long series of increasingly sophisticated submarine-launched rockets that were developed 1942–1945 and successfully demonstrated at Toplitz See, Austria [NavTecMisEu 500-45].

DECLASSIFIED
Authority NW 54481

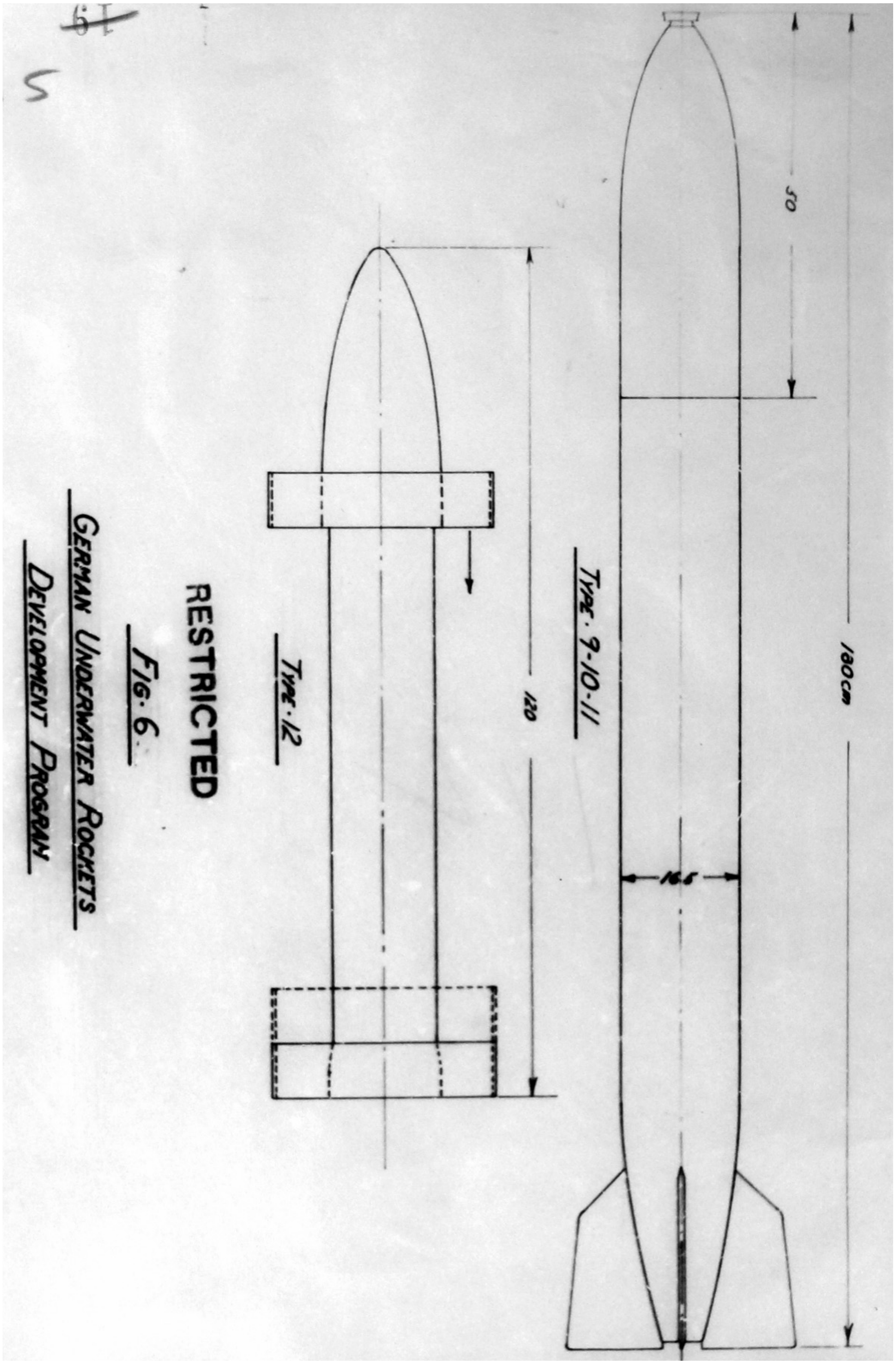

100
TYPE · 5
210
100
1000
TYPE · 6
135
15
10
TYPE · 7
120
TYPE · 8

RESTRICTED

FIG · 5

GERMAN UNDERWATER ROCKETS
DEVELOPMENT PROGRAM

Figure E.206: Drawings from a postwar report on a long series of increasingly sophisticated submarine-launched rockets that were developed 1942–1945 and successfully demonstrated at Toplitz See, Austria [NavTecMisEu 500-45].


~~61~~
5
RESTRICTED
GERMAN UNDERWATER ROCKETS
DEVELOPMENT PROGRAM
FIG. 6.
TYPE. 12
TYPE. 9-10-11
50
120
180cm
16.5

DECLASSIFIED
Authority NW 54481

Figure E.207: Drawings from a postwar report on a long series of increasingly sophisticated submarine-launched rockets that were developed 1942–1945 and successfully demonstrated at Toplitz See, Austria [NavTecMisEu 500-45].

DECLASSIFIED
Authority NW 54481

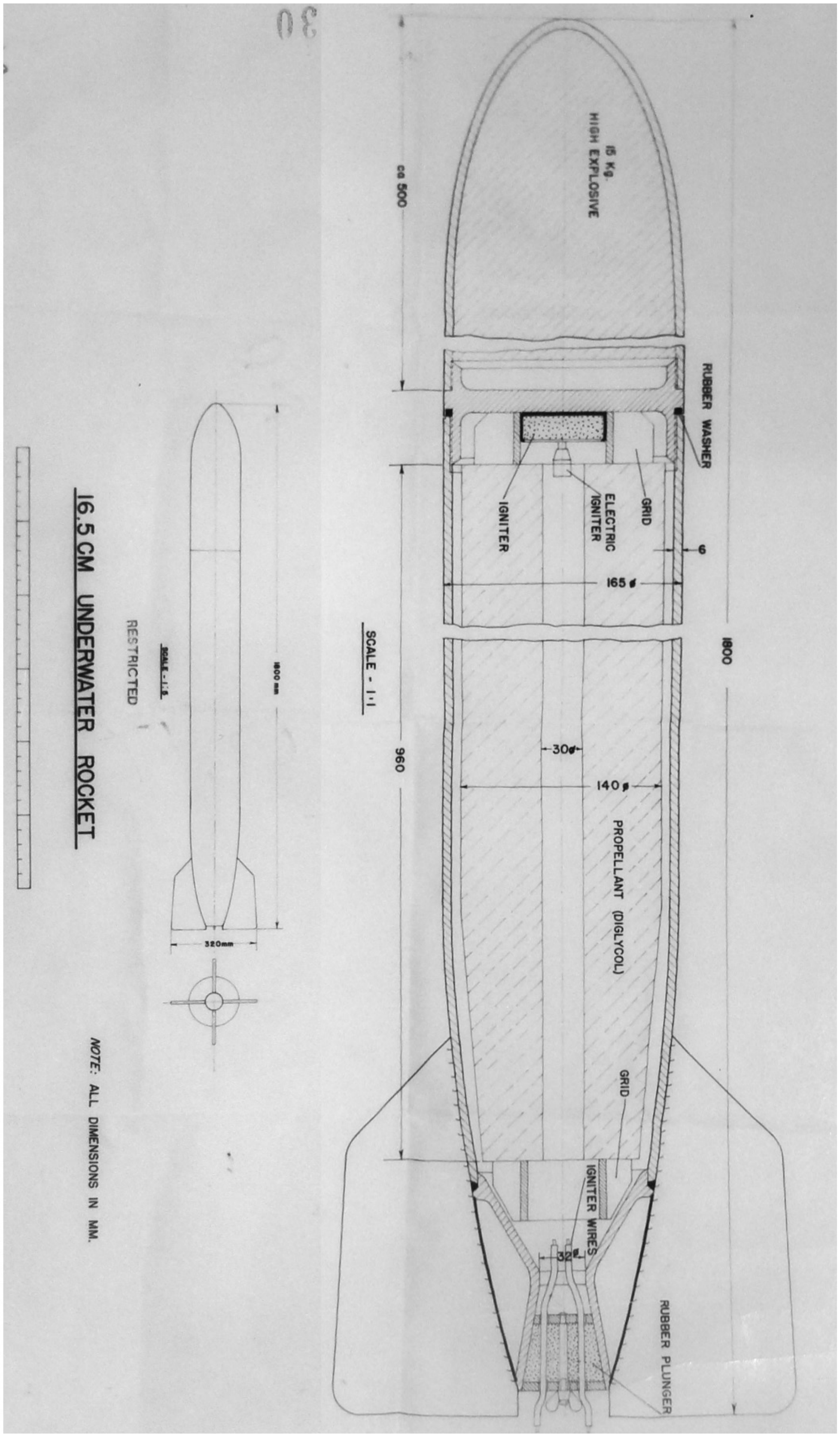

30
15 Kg.
HIGH EXPLOSIVE
ca 500
RUBBER WASHER
GRID
ELECTRIC IGNITER
IGNITER
6
165 ø
1800
SCALE - 1:1
960
30ø
140 ø
PROPELLANT (DIGLYCOL)
GRID
IGNITER WIRES
32ø
RUBBER PLUNGER
16.5 CM UNDERWATER ROCKET
RESTRICTED
SCALE - 1:5
1800 mm
320mm
NOTE: ALL DIMENSIONS IN MM.

Figure E.208: Drawings from a postwar report on a long series of increasingly sophisticated submarine-launched rockets that were developed 1942–1945 and successfully demonstrated at Toplitz See, Austria [NavTecMisEu 500-45].

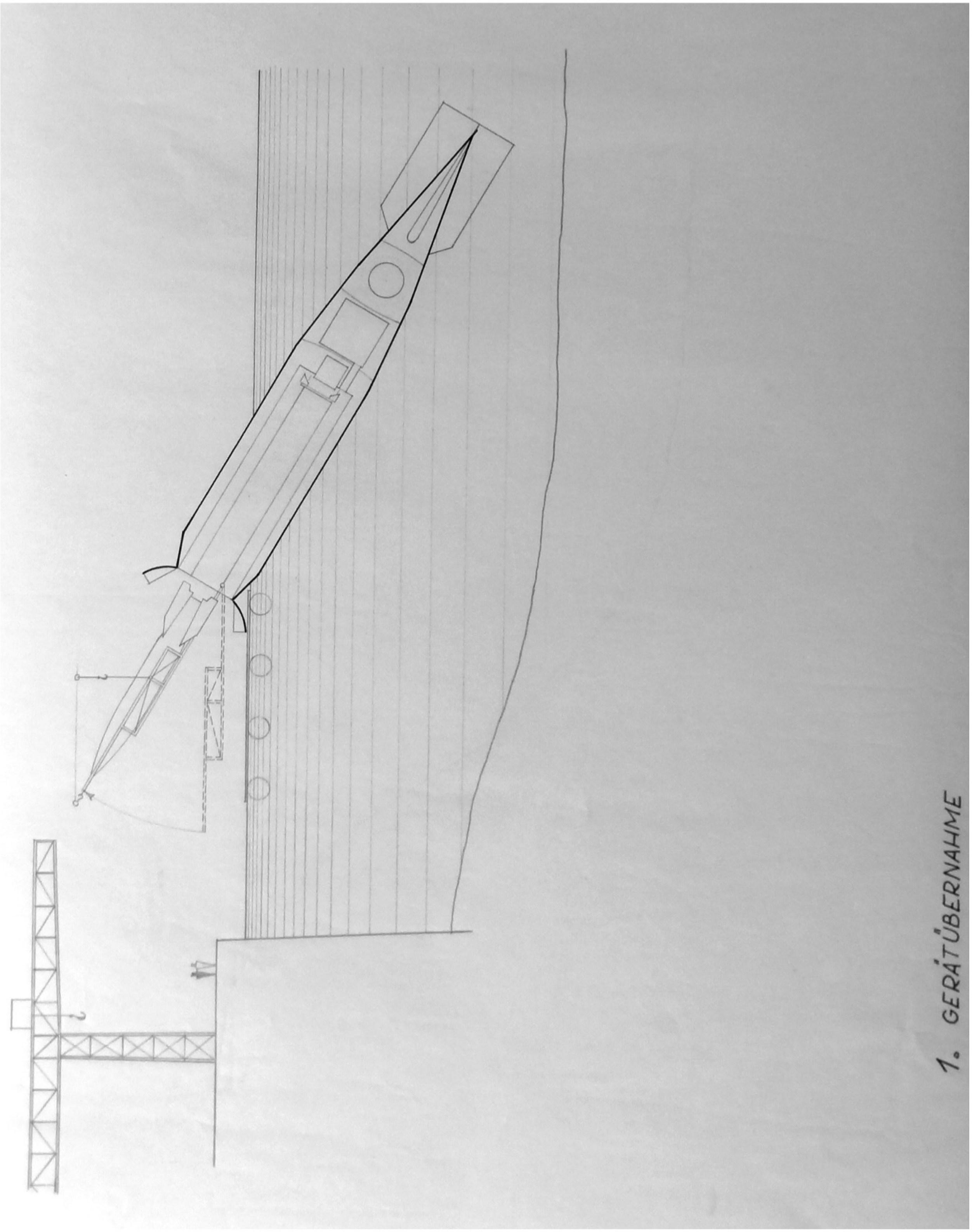


Figure E.209: 1944 drawings from the "Prüfstand XII" project to transport and launch A-4 (V-2) rockets from specially designed underwater cargo containers that could be towed by submarines [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

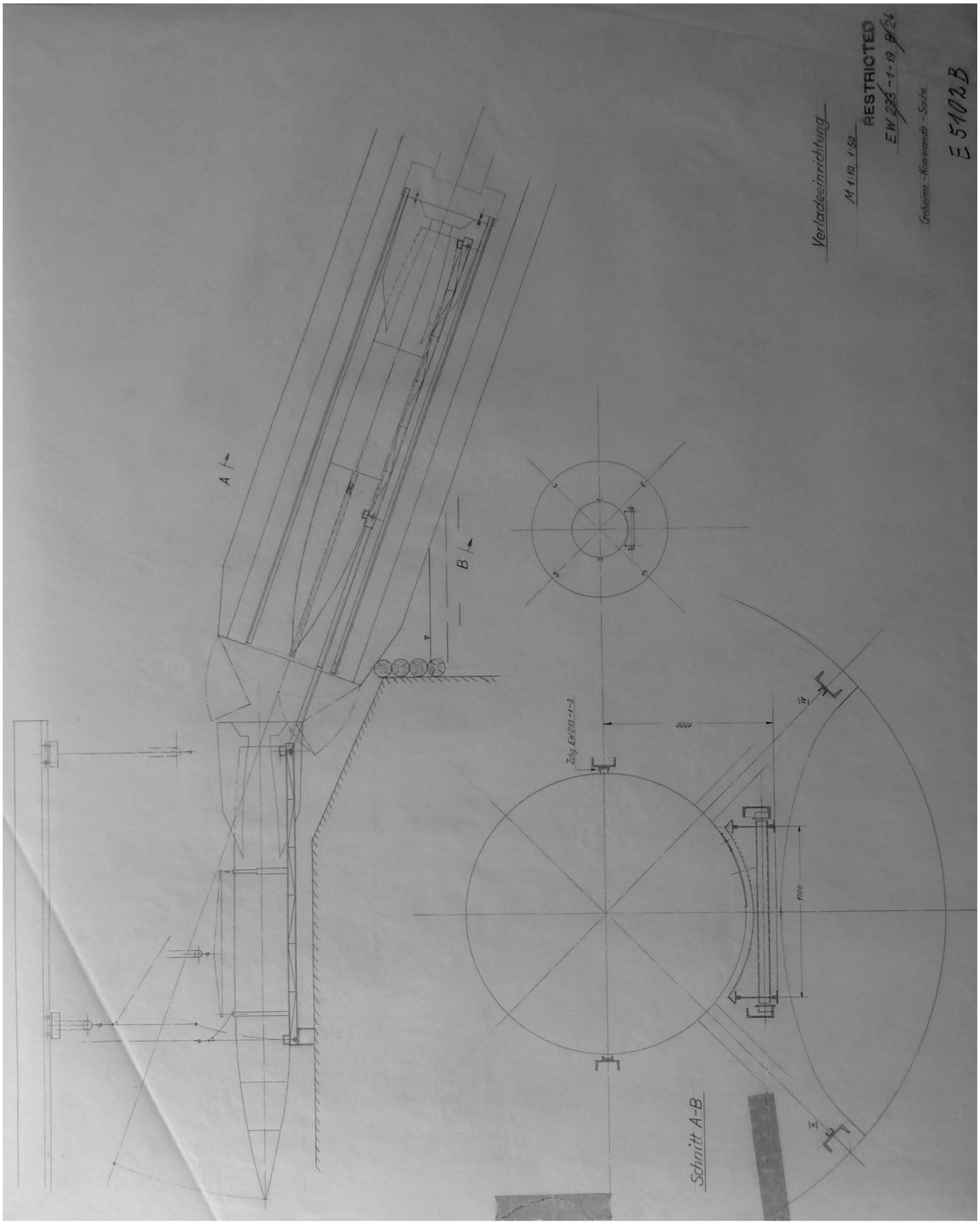

Verladeeinrichtung
M 1:10 1:50
RESTRICTED
EW 233-1-19 Bl.24
Geheime-Kommando-Sache
E 5102 B
A
B
1000
1000
Zchg. EW 233-1-3
Schnitt A-B

Figure E.210: 1944 drawings from the "Prüfstand XII" project to transport and launch A-4 (V-2) rockets from specially designed underwater cargo containers that could be towed by submarines [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

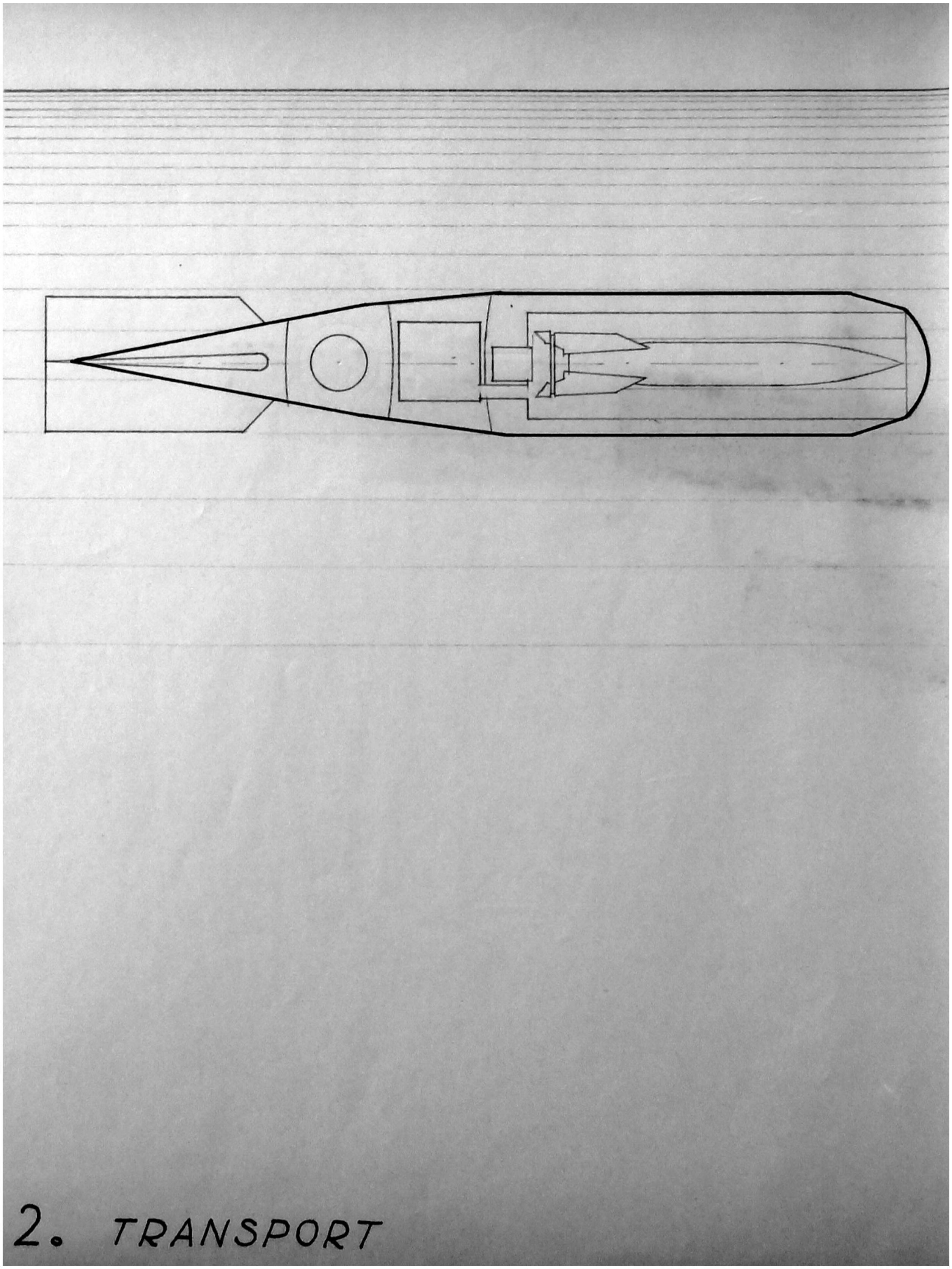


Figure E.211: 1944 drawings from the "Prüfstand XII" project to transport and launch A-4 (V-2) rockets from specially designed underwater cargo containers that could be towed by submarines [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

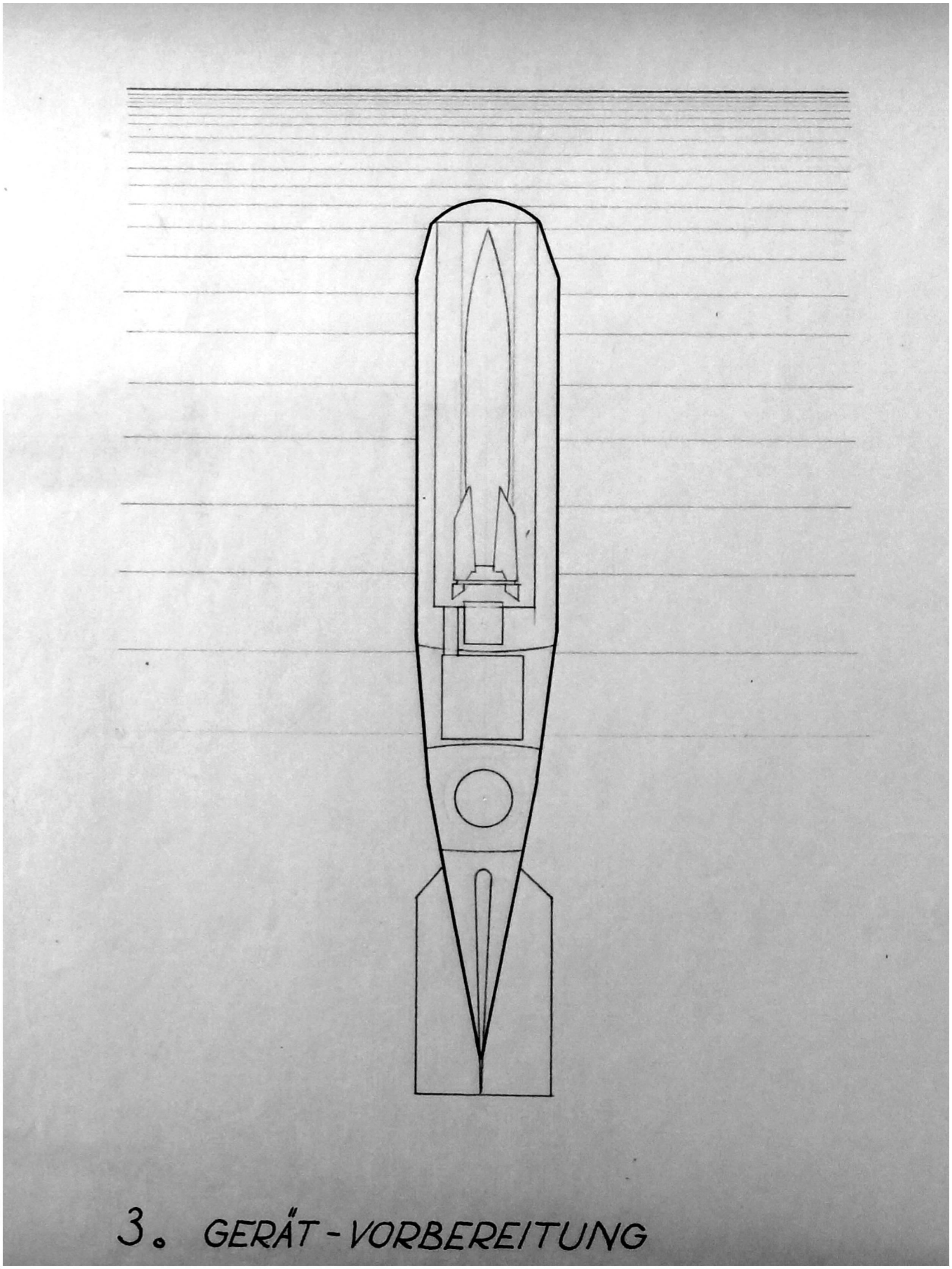


Figure E.212: 1944 drawings from the “Prüfstand XII” project to transport and launch A-4 (V-2) rockets from specially designed underwater cargo containers that could be towed by submarines [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

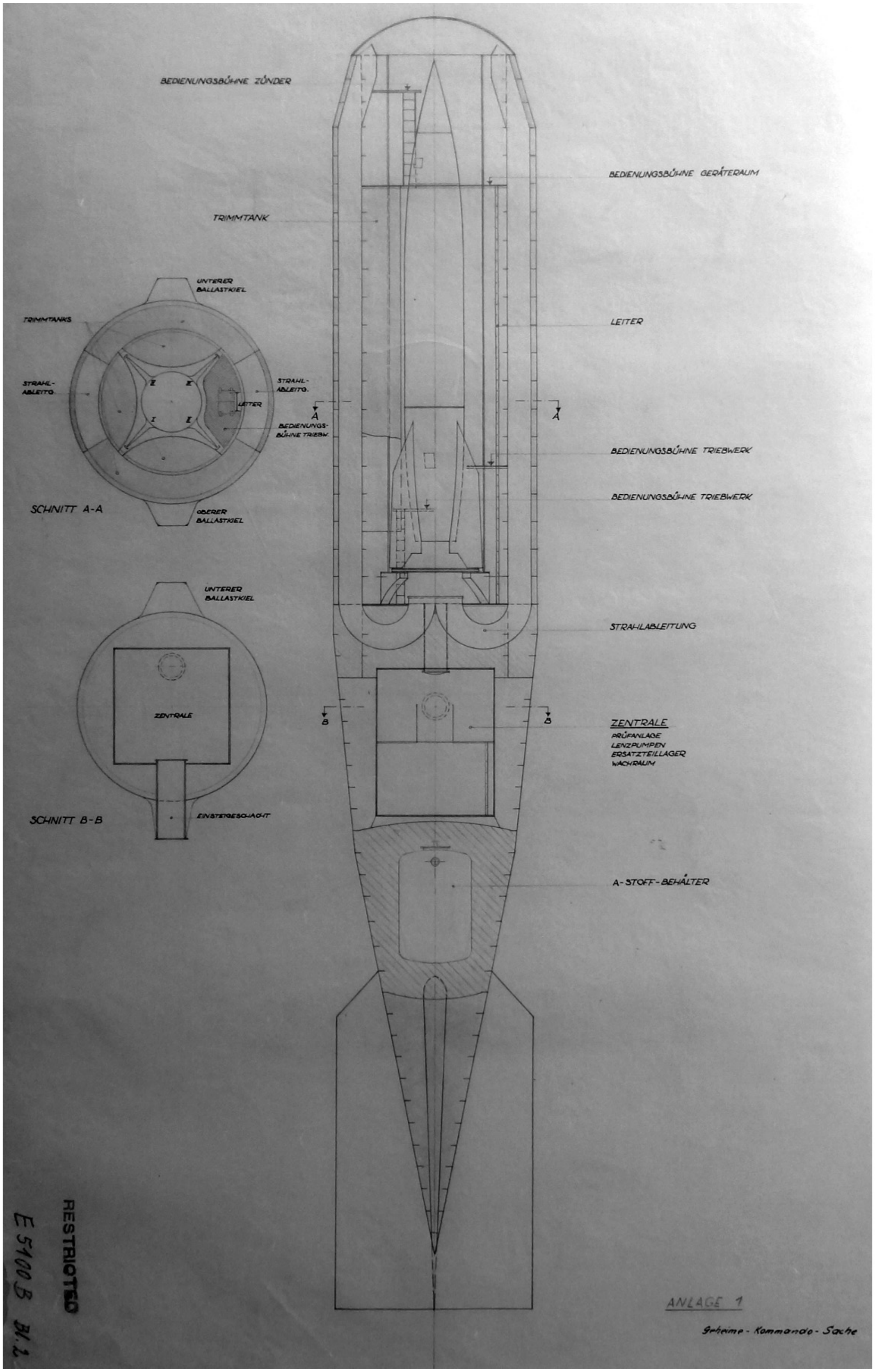

BEDIENUNGSBÜHNE ZÜNDER
BEDIENUNGSBÜHNE GERÄTERAUM
TRIMMTANK
LEITER
A
A
UNTERER BALLASTKIEL
TRIMMTANKS
STRAHL-ABLEITG.
STRAHL-ABLEITG.
LEITER
BEDIENUNGS-BÜHNE TRIEBW.
SCHNITT A-A
OBERER BALLASTKIEL
BEDIENUNGSBÜHNE TRIEBWERK
BEDIENUNGSBÜHNE TRIEBWERK
STRAHLABLEITUNG
UNTERER BALLASTKIEL
ZENTRALE
SCHNITT B-B
EINSTEIGESCHACHT
B
B
ZENTRALE
PRÜFANLAGE
LENZPUMPEN
ERSATZTEILLAGER
WACHRAUM
A-STOFF-BEHÄLTER
RESTRICTED
E 5100 B Bl.2
ANLAGE 1
Geheime - Kommando - Sache

Figure E.213: 1944 drawings from the “Prüfstand XII” project to transport and launch A-4 (V-2) rockets from specially designed underwater cargo containers that could be towed by submarines [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

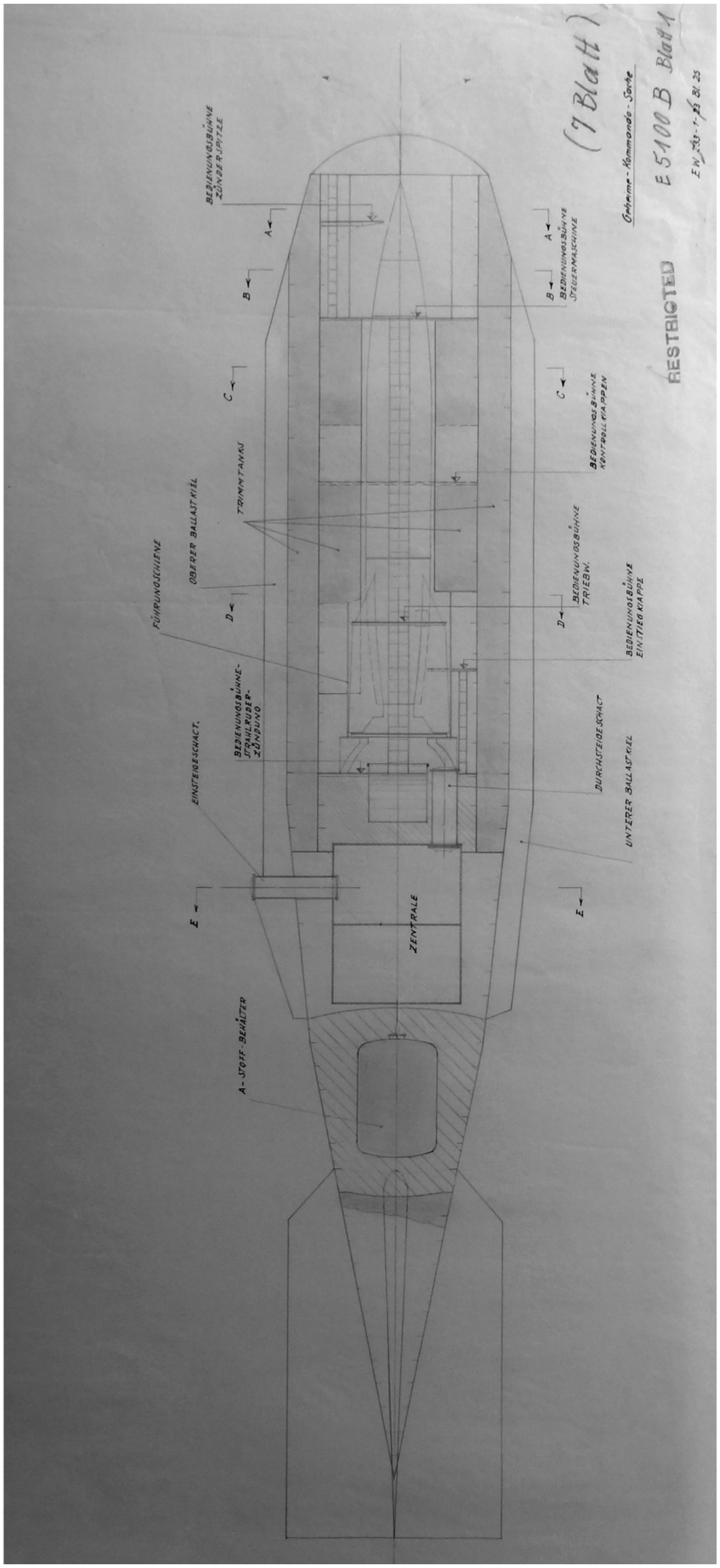

(7 Blatt)
Geheime - Kommando - Sache
E 5100 B Blatt 1
EW 733-1-23 Bl. 25
RESTRICTED
BEDIENUNGSBÜHNE ZÜNDERSPITZE
A
B
C
D
E
BEDIENUNGSBÜHNE STEUERMASCHINE
BEDIENUNGSBÜHNE KONTROLLKIAPPEN
TRIMMTANKS
OBERER BALLASTKIEL
FÜHRUNGSCHIENE
BEDIENUNGSBÜHNE TRIEBW.
BEDIENUNGSBÜHNE EINSTIEGKIAPPE
BEDIENUNGSBÜHNE-STRAHLRUDER-ZÜNDUNG.
EINSTEIGESCHACT.
DURCHSTEIGESCHACT
UNTERER BALLASTKIEL
ZENTRALE
A-STOFF-BEHÄLTER

Figure E.214: 1944 drawings from the “Prüfstand XII” project to transport and launch A-4 (V-2) rockets from specially designed underwater cargo containers that could be towed by submarines [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

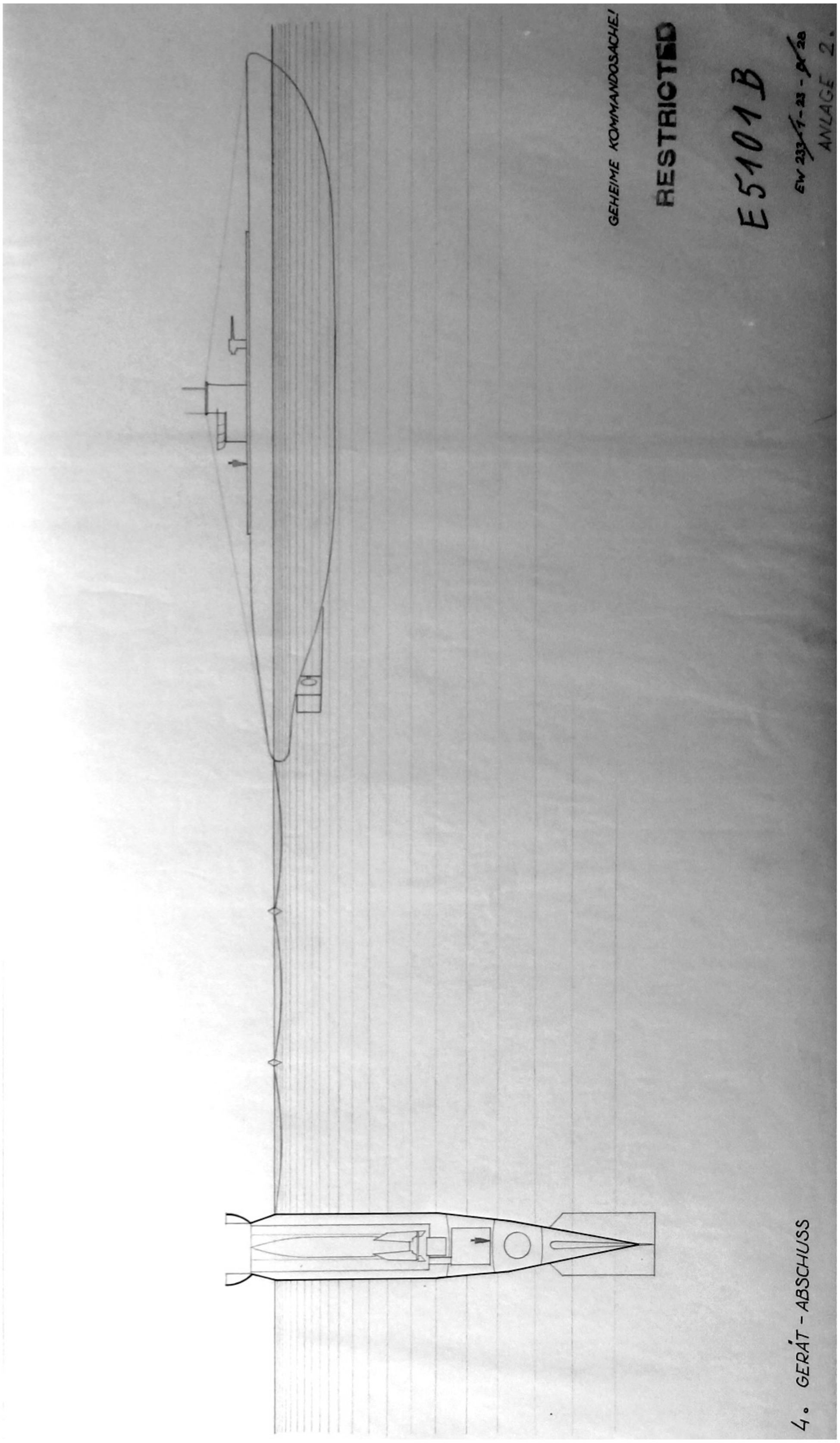

GEHEIME KOMMANDOSACHE!
RESTRICTED
E 5101 B
EW 233/1-23 - 8/28
ANLAGE 2.
4. GERÄT - ABSCHUSS

Figure E.215: 1944 drawings from the “Prüfstand XII” project to transport and launch A-4 (V-2) rockets from specially designed underwater cargo containers that could be towed by submarines [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

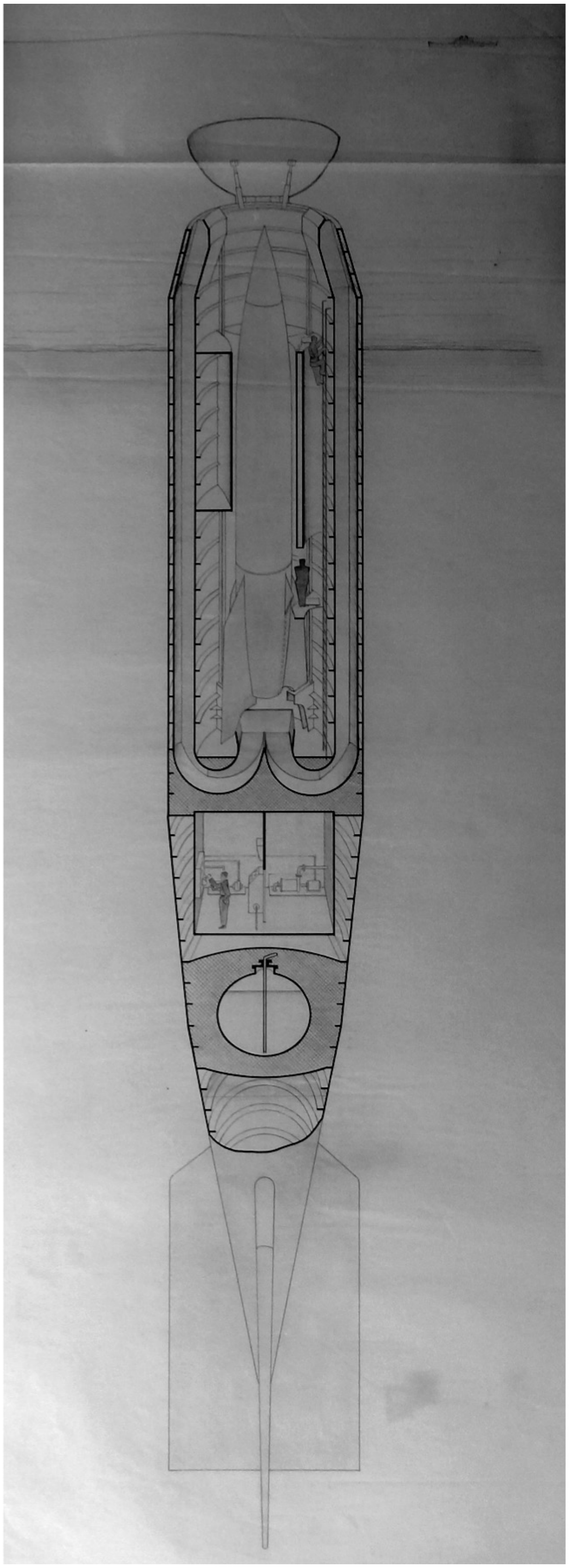


Figure E.216: 1944 drawings from the "Prüfstand XII" project to transport and launch A-4 (V-2) rockets from specially designed underwater cargo containers that could be towed by submarines [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

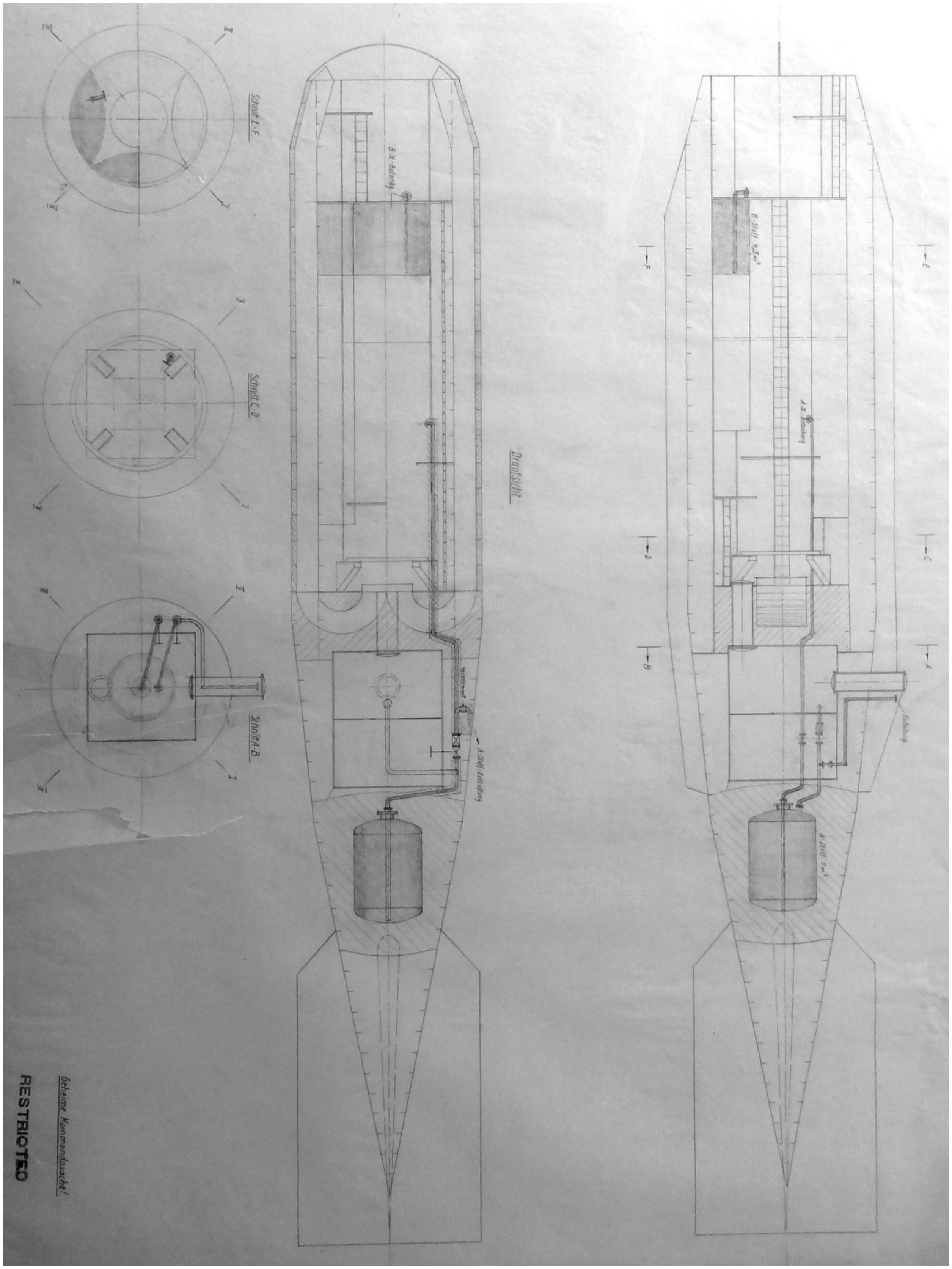

Schnitt E-F
Schnitt C-D
Schnitt A-B
Draufsicht
B-St.-Betankg
A-Stoff-Entlüftung
B-Stoff 4,5 m³
A-St.-Belüftung
Füllung
A-Stoff 9 m³
E
F
C
D
A
B
I
II
III
IV
Geheime Kommandosache!
RESTRICTED

Figure E.217: 1944 drawings from the “Prüfstand XII” project to transport and launch A-4 (V-2) rockets from specially designed underwater cargo containers that could be towed by submarines [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

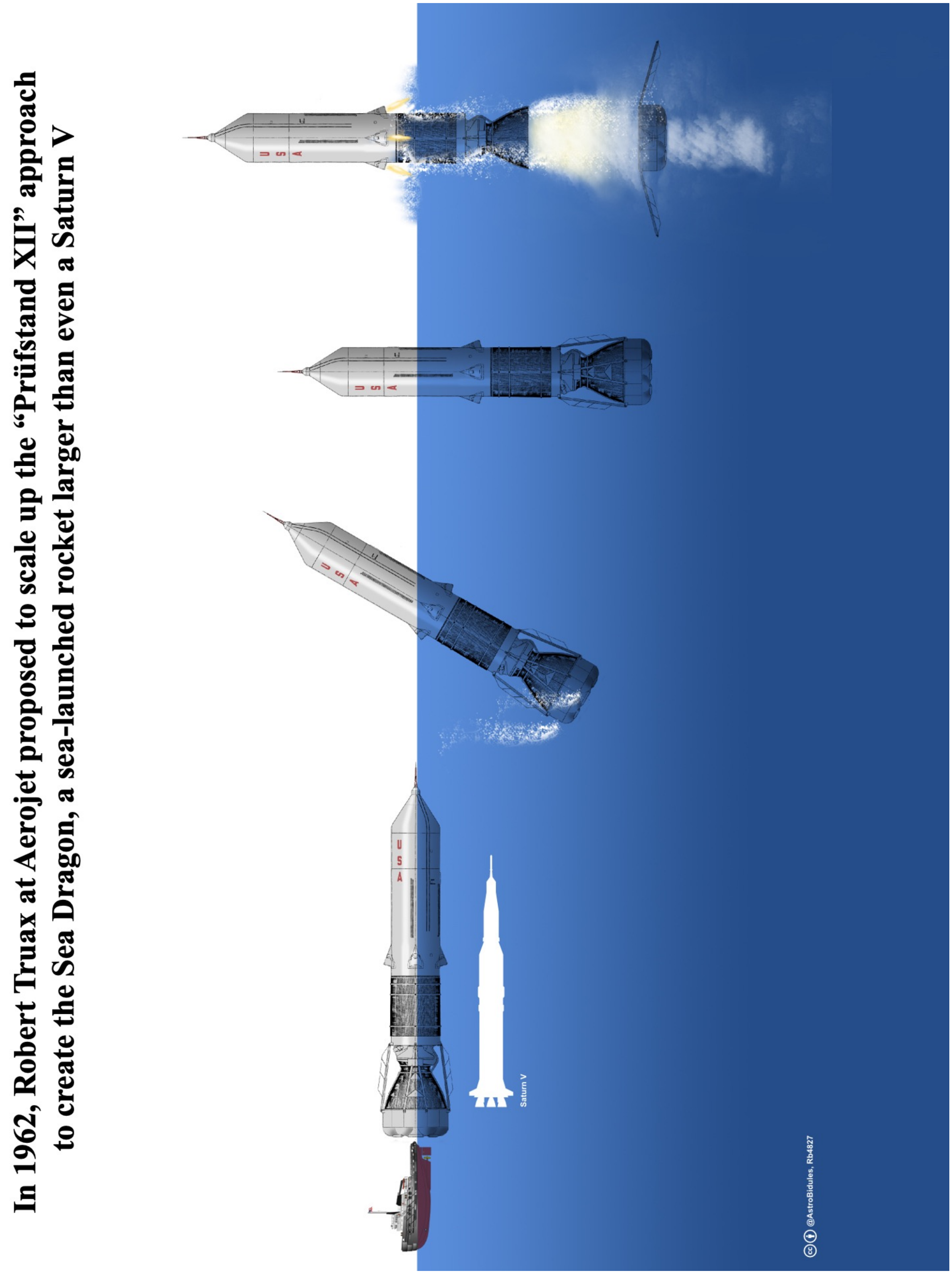

In 1962, Robert Truax at Aerojet proposed to scale up the "Prüfstand XII" approach
to create the Sea Dragon, a sea-launched rocket larger than even a Saturn V
USA
USA
USA
USA
Saturn V
@AstroBidules, Rb4827

Figure E.218: In 1962, Robert Truax at Aerojet proposed to greatly scale up the "Prüfstand XII" approach to create the Sea Dragon, a sea-launched rocket that would have been larger than even a Saturn V.

Fritz Hahn. 1998. *Waffen und Geheimwaffen des deutschen Heeres 1933-1945.* 3rd ed. Bonn: Bernard & Graefe. p. 172

Das System konnte natürlich nicht für die große A 4-Fernrakete angewendet werden. Aber auch für einen derartigen, zum Beschuß der amerikanischen Küste geplanten Einsatz fand man eine Lösung. U-Boote sollten die Rakete in einem 500 t großen Behälter von 32 170 mm Länge und 5500 mm Durchmesser in die Nähe der gegnerischen Küste schleppen. Dort wollte man das Heck dieses Behälters so weit fluten, daß er, nun senkrecht stehend, etwa 5 m aus dem Wasser herausstand. Mit den im Behälter vorhandenen Treibstoffen wollte man dann die Rakete auftanken. Kreiselstabilisiert hätte das sicherlich eine ausreichende Platform für den vom U-Boot durch Funk ausgelösten Abschuß ergeben. Ein Problem wäre der Verlust an Sauerstoff durch die Verdunstung geworden, denn das U-Boot wäre bei 12 sm etwa 30 Tage unterwegs gewesen.

Der Unterwasserschlepp wurde mit U 1063 erprobt und zeigte kaum Probleme. Für den Einsatz waren die Elektro-Boote vom Typ XXI vorgesehen. Die ersten Besprechungen zur Lösung der technischen Fragen führte Dr. Dickmann von der mit dem Bau beauftragten *Stettiner Vulkan-Werft* am 9. Dezember 1944—die drei begonnen Muster sind aber nicht mehr fertig geworden.

Of course, this system [small sub-launched rockets] could not be used for the large A-4 long-range rocket. But a solution was also found for such an operation planned for the American coast. Submarines were to tow the rocket in a 500 ton container of 32.17 m length and 5.5 m diameter near the enemy coast. There they wanted to flood the stern of this container so far that it, then standing vertically, protruded about 5 m out of the water. They wanted to fuel the rocket with the propellant contained in tanks. Stabilized by gyroscopes, this would surely have provided a sufficient platform for the launch controlled by radio from the submarine. A problem would have been the loss of oxygen by the evaporation, because the submarine would have required 12 sm or about 30 days for the voyage.

The underwater towing was tested with U-1063 and showed hardly any problems. The electric boats of type XXI were intended for use. The first discussions for the solution of the technical questions were held by Dr. Dickmann of the *Stettiner Vulkan-Werft* on 9 December 1944—the three started samples were not finished anymore.

[Fritz Hahn did not cite sources for the information in his books, but he was very closely connected to people who were involved in advanced military projects.

It is true that cryogenic liquid oxygen, the usual oxidizer for A-4 rockets, would have been difficult to keep from evaporating during a long sea voyage. However, wartime Germany developed storable, noncryogenic oxidizers such as nitrogen tetroxide (N_2O_4) and inhibited red fuming nitric acid (IRFNA) that could have been used instead of liquid oxygen in an A-4 rocket.]

Deutsches U-Boot-Museum. U 511 and Missiles: U 511, U 1063 and plans for U-boats armed with seabased missiles. [**https://dubm.de/u-511-and-missiles/?lang=en**]

Also, the vision, born after the US entered the war, to fire at the US an advanced multiple stage version of the V-2 (the project A-9/A-10 with ranges of more than 5,000 km) gained some momentum following a proposal brought forward by a director of the "Deutsch Arbeitsfront" (= German Labor Front, a sort of national socialistic controlled trade union), Otto Lafferenz. After a visit of the facilities at Peenemünde and a meeting with the Military Commander, Major General Walter Dornberger, in the Autumn of 1943, he proposed to develop floating containers to accommodate V-2s and to tow them by U-boats before the US Eastern coast, to fire at New York and other area targets utilizing on their range up to 300 km. This arms project now called "Lafferenz-Project" (somewhat irritating, various authors in historic writing use other project names such as "Schwimmweste" = "Life Vest", "Apparat F", or "Prüfstand XII" = "Test Stand XII") was consequently developed further, and as a first step a floating container was invented able to transport and launch, to be towed by U-boats. The end status of the concept envisaged an operation, where up to three containers were towed simultaneously by U-boats across the Atlantic Ocean, to be erected in some distance before the coasts into a vertical firing position by partial flooding—and to launch the V-2s.

For that the Weapons Test Command No. 10 at Stetting developed a container with a length of about 32 meters, a diameter of about 5.5 meters and a displacement of some 300 tons, to be constructed at the Vulcan shipyard at Stettin. At the turn of 1944 to 1945 successful towing trials were actually executed using the type VII C/41 U-boat U 1063, which went through its basic and combat readiness training with the 5th U-boat (Training) Flotilla at Stetting at that time, after it had been commissioned on 08 July 1944 at the end of its construction by the Germania shipyard at Kiel. Following its training period until the end of February 1945 the U-boats came frontal unit as of 01 May 1945 at Bergen, Norway.

[Most books say that the Prüfstand XII project was only a paper design that was briefly considered and never progressed further. However, from the above and similar reports, it sounds as if at least one Prüfstand XII unit may have actually been constructed and tested. It is unclear how far the project may have actually progressed by the end of the war].

Joseph Mark Scalia. 2000. ***Germany's Last Mission to Japan: The Failed Voyage of U-234.*** **Annapolis, Maryland: Naval Institute Press. p. 84.**

American naval intelligence officials were determined to press Kessler for as much information as possible on the state of Germany's U-boat capability. While the Wehrmacht and the Luftwaffe had been virtually destroyed by the time of Germany's capitulation, Dönitz's submarine corps, rejuvenated by the potential of the revolutionary electric U-boats, remained a considerable threat. As a result, the export of German submarine technology to Japan constituted an immediate threat to the U.S. Navy. A major area of concern was Germany's alleged development of submarine ballistic-missile technology. Reports of the submerged launching of missiles prompted the ONI to question Kessler regarding the rumor of U-boats, stationed in Norway, that were able to launch a V-2 rocket while submerged.

Albert Ducrocq. 1947. *Les Armes Secrètes Allemandes.* Paris: Berger-Levrault. pp. 161–163.

D'ailleurs, outre le bombardement par A-9, les Allemands voulaient entreprendre le bombardement direct des côtes américaines au moyen de V-2 lancées par des sous-marins. C'était leur deuxième arme nouvelle contre l'Amérique. Elle devait entrer en action en même temps que la A-9, c'est-à-dire au début de l'été 1945...

Les V-2 amphibies

L'idée d'utiliser les sous-marins pour transporter des V-2 remonte à 1942. Au moment où la fabrication industrielle des V-2 était entreprise, l'entourage d'Hitler avait porté beaucoup d'attention au projet de V-2 amphibies que venait d'élaborer l'équipe de von Braun. Mais les travaux d'aménagement pratiques furent longs et fastidieux et ne purent être menés à bonne fin qu'en 1944, date à laquelle le premier sous-marin capable de lancer des V-2 fut effectivement construit. [...]

Il apparait que les mises au point devaient être complètement terminées au moment de l'effondrement allemand de mail 1945 et que les Allemands s'apprêtaient à continuer les essais sur l'Amérique elle-même. Quelle aurait été la zone menacée? Il semble que la portée de la V-2 amphibie, du moins dans l'état où les recherches expérimentales du lac Toplitz ont laissé la question, était très nettement inférieure à celle de la V-2 ordinaire, de l'ordre de 150 à 200 kilomètres seulement. Inutile d'ajouter que c'eût quand même été largement suffisant pour le bombardement des port américains: Boston, New-York, Philadelphie, Baltimore, Charleston, etc. Évidemment plus la profondeur à laquelle opéraient les sous-marins était grande, plus la portée était réduite. Nous avons vu que les derniers sous-marins allemands pouvaient voguer à 300 mètres de profondeur; il ne semble toutefois pas qu'un lancer de V-2 amphibies ait pu être envisagé à partir d'une telle profondeur.

What is more, in addition to A-9 bombing, the Germans wanted to undertake direct bombing of the American coastline using submarine-launched V-2s. This was their second new weapon against America. It was to come into action at the same time as the A-9, i.e. in early summer 1945...

Amphibious V-2s

The idea of using submarines to transport V-2s dates back to 1942. At the same time as industrial production of the V-2s was being undertaken, Hitler's entourage had paid close attention to the amphibious V-2 project that von Braun's team had just drawn up. But the practical development work was long and tedious, and was not completed until 1944, when the first submarine capable of launching V-2s was actually built. [...]

It transpires that the tests were to be completed by the time of the German collapse in 1945, and that the Germans were preparing to continue the tests on America itself. What area would have been threatened? It seems that the range of the amphibious V-2, at least in the state left by the experimental research at Lake Toplitz, was considerably less than that of the ordinary V-2, of the order of only 150 to 200 kilometers. Needless to say, this would still have been more than sufficient for bombing American ports such as Boston, New York, Philadelphia, Baltimore, and Charleston. Obviously, the greater the depth at which the submarines operated, the shorter their range. We have seen that the latest German submarines could operate at a depth of 300 meters; however, it doesn't seem that an amphibious V-2 launch could have been envisaged from such a depth.

Quoi qu'il en soit, la menace eût été extrêmement sérieuse pour la côte américaine puisque, d'une part, une fois la V-2 lancée, il a jusqu'ici été impossible de se défendre contre elle, et que, d'autre part, la détection et la lutte contre les nouveaux sous-marins allemands n'eût pas été une petite affaire, indépendamment de l'auto-guidage de la V-2 par détection de rayons infra-rouges ou autres. [...]

C'est vraisemblablement à partir du mois de juin 1945 que l'Allemagne pensait attaquer le territoire américain. Notons-le: alors que la mise en action d'autres armes secrètes, comme les bombes volantes et les nouveaux avions-fusées, était littéralement imminente, cette menace contre les États-Unis doit être située à six semaines ou deux mois après la date qui marqua l'effondrement du Reich. On nous permettra de la trouver pratiquement tout aussi dangereuse, d'autant plus que les V-2 amphibies, elles aussi, auraient très bien pu transporter des bombes atomiques.

In any case, the threat would have been extremely serious for the American coast, since, on the one hand, once the V-2 had been launched, it has so far been impossible to defend against it, and, on the other hand, detecting and combating the new German submarines would have been no small matter, independently of the V-2's self-guidance by infra-red ray detection or other means. [...]

Germany was probably thinking of attacking American territory beginning in June 1945. It should be noted that while the use of other secret weapons, such as flying bombs and new rocket planes, was literally imminent, this threat to the United States must be located six weeks or two months after the date of the collapse of the Reich. We are allowed to consider it almost as dangerous, especially since the amphibious V-2s, too, could very well have carried atomic bombs.

[Albert Ducrocq (1921–2001) was a French scientist and science writer who was involved in the French investigations of German science and German scientists near the end of the war and after the war. He would have had enormous insight into German scientific plans and capabilities.

Based on his personal experience and his sources, Ducrocq stated that Germany possessed atomic bombs and planned to deliver them via submarine-launched missiles and other means, with a massive, nearly simultaneous attack on many Allied targets to be carried out within a matter of weeks if the war in Europe had not ended when it did. For independent confirmation, see pp. 4549–4550, 4587, 4621, 4627–4665, 4679–4681, 4766, 5038, 5454–5466.

For more information from Ducrocq, see pp. 5218, 5380, 5666.]

Raketen aus dem Ozean: Roboterhände helfen starten: Neue U-Boot-Kampfmittel. *Abendpost* (Frankfurt) 14 April 1950 p. 2.

In der für die Zivilluftschifffahrt gesperrten Morecambe-Bucht an der Westküste Englands arbeiten englische und deutsche Fachleute an der Entwicklung der Waffen des zukünftigen Seekrieges. Ihr Ziel: schnelle, weitreichende, fast unbegrenzt tauchfähige U-Kreuzer, die zur Abwehr feindlicher U-Boote, vor allem aber als Abschluß-Basen für ferngelenkte Raketen eingesetzt werden können.

Was es für die Techniker schon eine schwierige Aufgabe, auf den fischförmigen schmalen Rumpf eines U-Bootes die breite Plattform für den Abschuß einer V 2 zu montieren, so schien es zunächst fast unmöglich, das Problem des Abschusses von Raketen unter Wasser zu lösen. Deutsche Pläne, die nach der Kapitulation von englischen Truppen gefunden wurden, gaben der britischen Admiralität die entscheidenden Anregungen für die nun in der Morecambe-Bucht erprobten Geschosse.

Die neuen Raketen werden in zwei Phasen abgeschossen. Wie ein Torpedo gelangt das riesige Geschoß von der Plattform des beliebig tief getauchten U-Bootes mit Hilfe von Preßluft an die Wasseroberfläche. Hier geschieht das Wunder: im Augenblick des Auftauchens treten von Präzisions-Uhrwerken angetriebene Roboterhände in Tätigkeit. Sie bauen aus einem Gitterwerk von Leichtmetallplatten, die aus dem Schwanzteil der Rakete herausgeschleudert werden, eine Art schwimmende Abschußbasis. Auf die Sekunde genau mit der Fertigstellung der Plattform beginnen die Rückstoßkammern der Rakete zu arbeiten. Mit einem feurigen Schweif steigt der unheimliche, wassergeborene Komet in die Höhe. Zugleich mit der Rakete wird eine Tele-Boje mit kompletter Radareinrichtung an die Oberfläche geschickt, die nun als Zwischenstation die Richtungsbefehle des getauchten U-Bootes an die Rakete weitergibt. [...]

In Morecambe Bay on the west coast of England, which is closed to civil aviation, English and German experts are working on the development of weapons for the future naval war. Their goal: fast, long-range, almost unlimited submersible U-cruisers, which can be used to defend against enemy submarines, but above all as bases for remote-controlled missiles.

What was already a difficult task for the technicians to mount the wide platform for launching a V-2 on the fish-shaped narrow hull of a submarine, at first it seemed almost impossible to solve the problem of launching rockets under water. German plans, which were found after the surrender of English troops, gave the British admiralty the decisive suggestions for the projectiles now tested in Morecambe Bay.

The new missiles will be launched in two phases. Like a torpedo, the huge projectile is launched from the platform of the submarine submerged to any depth with the aid of compressed air to the surface of the water. This is where the miracle happens: at the moment of emergence, robotic hands driven by precision clockworks start working. They build a kind of floating launch base from a lattice of light metal plates which are ejected from the tail of the rocket. The recoil chambers of the rocket start to work exactly to the second when the platform is completed. With a fiery tail, the eerie, water-born comet rises. At the same time as the rocket, a tele-buoy with complete radar equipment is sent to the surface, which now transmits the directional commands of the submerged submarine to the rocket as an intermediate station. [...]

[This article describes a wartime alternative to the Prüfstand XII approach, and also serves as an example of how German plans and German-speaking scientists played critical roles in other countries' postwar programs to develop submarine-launched missiles.]

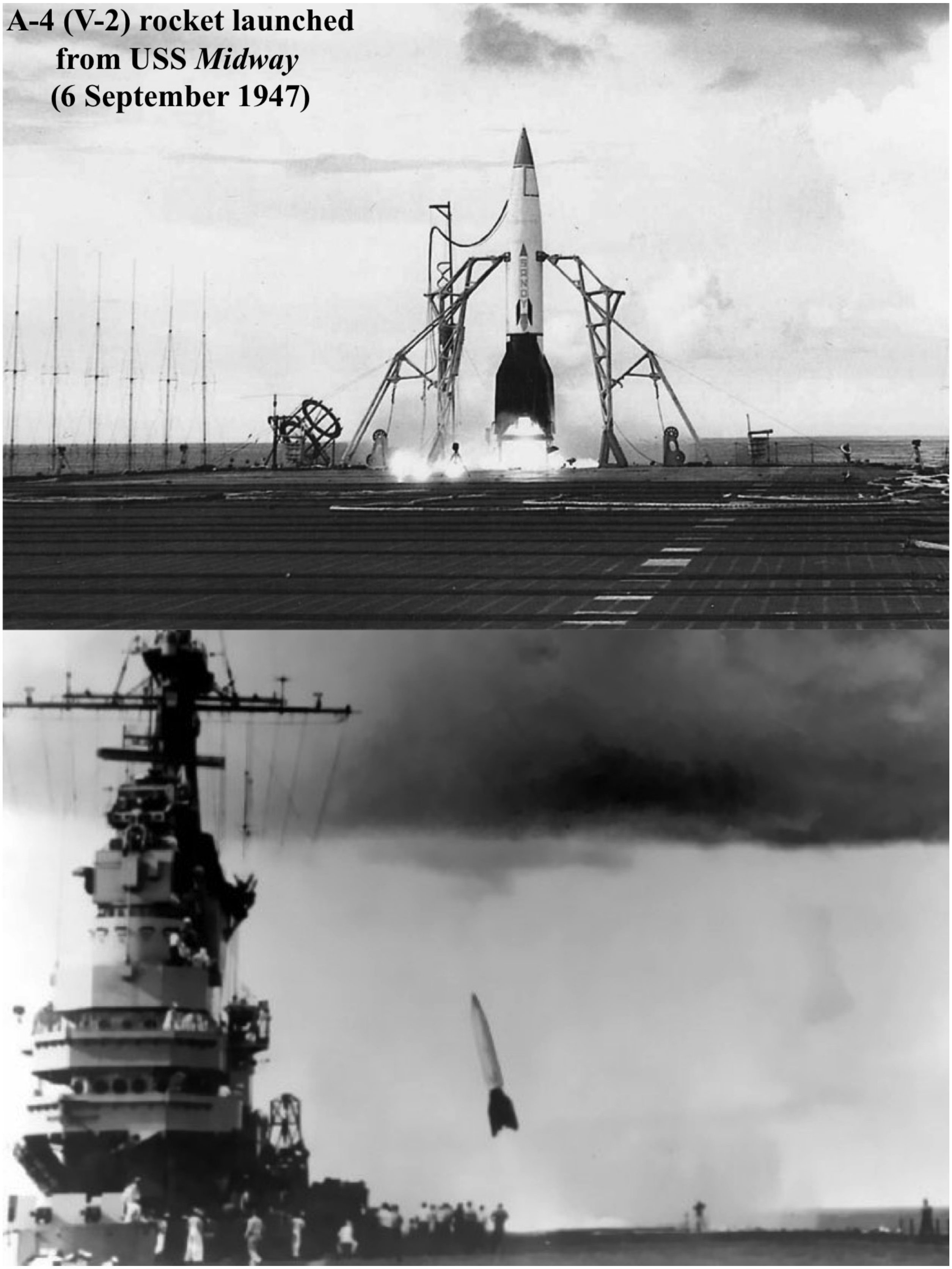

A-4 (V-2) rocket launched
from USS *Midway*
(6 September 1947)

Figure E.219: As part of Operation Sandy, the U.S. Navy launched an A-4 (V-2) rocket from the deck of the USS Midway on 6 September 1947 [http://www.cv41.org/photos/gallery/main.php?g2_itemId=17451].

[Although solid propellant rockets have lower exhaust velocities than liquid propellant rockets, they can generally be stored for years without degradation. Therefore, they are primarily used for military rockets and "off-the-shelf" boosters that can be strapped to the side of the first stage of a spacecraft launch vehicle. For submarine-launched rockets, where it is necessary to be able to store the rockets stably and safely for years and yet fire them on very short notice, solid propellants are highly preferable to liquid propellants.

In a solid propellant rocket, the propellant burns along its exposed surfaces, releasing hot exhaust gases through the nozzle unless the thrust termination port is opened (see p. 1905). Different solid propellant grain designs have different cross-sectional patterns of exposed surfaces such that the exposed surface area and hence the thrust changes in some desired way (increasing, remaining constant, or decreasing) as the rocket burns.

During World War II, a number of nearly forgotten German-speaking chemists and engineers (such as those shown on pp. 1906–1910), successfully developed and demonstrated advanced solid propellant rockets, including for example:

- The Rochen ammonium perchlorate/polybutadiene short-range missile, first fired in 1944 (p. 1911).
- The Rheintochter two-stage surface-to-air missile, first launched in 1943 (pp. 1912 and 5663).
- The Rheinbote four-stage long-range rocket, first launched in 1943 (pp. 1913 and 5663).
- The V-101, an ammonium perchlorate/polybutadiene propelled, 140-ton, 30-meter-tall, long-range ballistic missile that was under development when the war ended (p. 1914).

Key German innovations of that solid propellant rocket technology included:

1. Ammonium perchlorate oxidizer [BIOS 31; BIOS 571].
2. Polybutadiene "buna" synthetic rubber in the propellant to act as both fuel and binder [BIOS 31; BIOS 571].
3. Plasticizers to enable the propellant to be molded into any desired shape, to adhere tightly to metal walls, and not to be prone to crumbling or brittleness [BIOS 31; BIOS 571].
4. Powdered aluminum as a fuel additive to improve performance [BIOS 27; BIOS 31; BIOS 100; BIOS 477; BIOS 1261; FIAT 1035; HEC 2434; HEC 2485; HEC 2487; NavTecMisEu 327-45].
5. Various grain designs for the combustion surface inside the propellant to give the desired variation of thrust with time [Benecke and Quick 1957, pp. 253–255; Klein 1977; BIOS 31; BIOS 1110; NavTecMisEu 327-45].

This wartime German technology became the basis for large postwar solid propellant rockets, including satellite launch vehicles such as the U.S. Scout; strap-on solid rocket boosters such as those used with the U.S. Space Shuttle, Titan, and Delta rockets; submarine-launched ballistic missiles such as the U.S. Polaris, Poseidon, and Trident; and solid propellant land-based ballistic missiles such as the U.S. Minuteman and MX.]

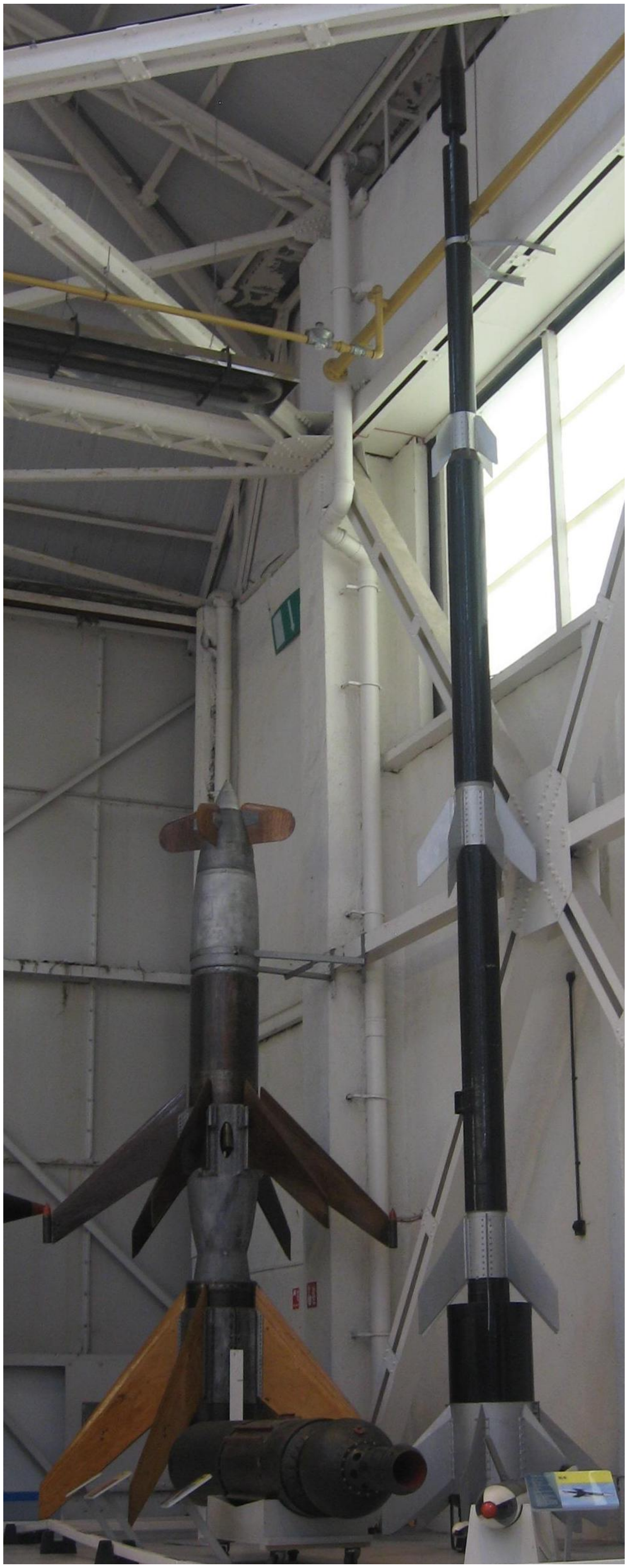


Figure E.220: Rheintochter R1 two-stage solid propellant rocket (left), partial Rheintochter R3 strap-on solid propellant booster (horizontal, center), and Rheinbote four-stage solid propellant rocket (right).

Nazis Use ‘AA’ Rockets in Italy. *New York Times*, 16 January 1945, p. 12.

ROME, Jan. 15 (Reuter)—The Germans are using anti-aircraft rockets for the first time in northern Italy, it was reported today. Havoc pilots of the Mediterranean Allied Air Force said on returning to bases that two volleys of twenty-five rockets each were fired at them when they were attacking enemy motor transport and communications in the Genoa area.

Carl Spaatz. 19 June 1945. [AFHRA A5729 frame 1570]

GEORGE C. McDONALD
Brigadier General, USA
Asst. Chief of Staff A-2

19 June 1945

COMMANDING OFFICER, 2ND TAF (RAF)

FOR WING COMMANDER WHEELER. INFORMATION HERE THAT RHEINTOCHTER HAS SEVEN EACH NEW TYPE ROCKETS. ANTI AIRCRAFT ROCKETS SUPPOSED TO USE PROXIMITY FUZE. SIGNAL ALLSTONT [?] AND LOCATION FOR AIR LIFT BY OUR AIRCRAFT.

SPAATZ

NavTecMisEu 373-45. ***German War Research vs Air Superiority.***

In the Me 262 the Germans had years of development behind both the turbo-jet engine and the high speed airplane. The latter was achieved through their supersonic wind tunnel research. Their experience with this airplane was rapidly leading them toward the supersonic airplane speed we hope to achieve in the future. In our own development, the advent of our jet engines has created a situation in which we do not have airplane designs capable of efficiently utilizing the high speeds they make possible.

Guided missels were not in the original research and development program of 1933. They did not receive important consideration until after the German research reorganization. However, the strong foundation of basic research and development laid for other aeronautical purposes was immediately available. The magnitude of this work was such as to provide the rapid expansion and development of some two hundred different designs and studies of guided missels. One of the best developed at war's end was a ground-to-air rocket projected by a ground director into the rear of its target. There, an infra red homing device picked up the heat from the engines and directed it into the rear of its target. It was claimed that 70 four-engine bombers were brought down with 75 of these guided missels.

Various naval devices were being used in their accelerated science to expedite aeronautical developments. In Hamburg the high speed towing basin was being used for the underwater towing of airplane components to determine their air load carrying capacity at very high air speeds. A complete airplane, the Heinkel He 162 was towed underwater in the experiment. In Goettingen, a water tunnel was being used to determine airfoil cavitation, translatable into air cavitation at high speeds.

Completely synthesized aircraft engine oils and other lubricants were in use. Precise control had been developed for each individual hydrocarbon molecule. Thus, there was achieved in war reality, a dream of our organic chemists for many years.

[By 1945, German-speaking scientists and engineers had been developing approximately 200 different types of missiles, many of which were actually fielded, ranging from the A-4 (V-2) to heat-seeking anti-aircraft missiles that were successfully demonstrated according to this report.

The Allied investigators did not even know how to spell the word "missile."

But the Allied investigators were very excited to take the German-developed missiles and other technologies.]

Albert Ducrocq. 1947. *Les Armes Secrètes Allemandes.* Paris: Berger-Levrault. pp. 96–98.

La Rheintochter était la R-1; la R-2 ne fut jamais construite industriellement, et an mai 1945, les usines allemandes auraient sorti la R-3.

Ces bombes volantes, série “R”, étaient toutes destinées à la lutte contre l’aviation alliée et elles devaient littéralement révolutionner la D. C. A. [Défense Contre Avions] [...]

Quant à la fusée auxiliaire pour le départ, elle possédait sa propre voilure cruciforme, les quatre ailes étant reliées par un système de haubans. A l’extrémité, se trouvaient cinq réacteurs. En général, cette fusée auxiliaire était abandonnée au bout de 2 kilomètres de vol et alors la R-1 prenait presque instantanément une vitesse de l’ordre de 1.500 kilomètres/heure. C’était donc bien un appareil supersonique!

La précision, déjà bonne dans la R-1, s’annonçait excellente avec les R-3, car les Allemands mettaient au point leur fameux dispositif de radar interconnecté. Il s’agissait en somme d’une carte du ciel, en l’occurrence l’écran d’un oscillographe, où apparaissait la zone balayée par l’aviation anglo-américaine; on y voyait la trajectoire des avions alliés, et la trajectoire des bombes R lancées sur eux; les servants de R-1 et de R-3 auraient ainsi pu suivre le chemin de leur engin, et, au fur et à mesure, corriger les trajectoires par radio-guidage en regardant sur le *Reichshimmel* les déplacements relatifs des avions et des bombes, cette opération, bien entendu, s’effectuant à plusieurs mètres sous terre dans un confortable abri.

C’est en se penchant sur ces réalisations que l’on peut seulement comprendre l’immense espoir de gagner la guerre qui, jusqu’à la dernière seconde, put animer certains Allemands...

The Rheintochter was the R-1; the R-2 was never built industrially, and by May 1945, German factories would have produced the R-3.

These flying bombs, the “R” series, were all intended for use against Allied aircraft, and were literally to revolutionize anti-aircraft defenses. [...].

As for the auxiliary rocket for departure, it had its own cruciform canopy, with the four wings connected by a system of stays. At the end were five jet engines. This auxiliary rocket was usually abandoned after 2 kilometers of flight, at which point the R-1 reached speeds of around 1,500 km/h almost instantaneously. A supersonic aircraft indeed!

Accuracy, already good in the R-1, was to become excellent with the R-3, as the Germans developed their famous interconnected radar system. This was basically a map of the sky, in this case the screen of an oscillograph, showing the area swept by Anglo-American aircraft; it showed the trajectory of Allied planes, and the trajectory of the R-rockets fired at them; R-1 and R-3 servicemen could thus follow the path of their vehicles, and, as they went along, correct trajectories by radio guidance, watching the relative movements of the planes and rockets on the *Reichshimmel*, this operation, of course, being carried out several meters underground in a comfortable shelter.

It is only by looking at these achievements that one can understand the immense hope of winning the war that, right up to the last second, could animate certain Germans...

[For more information from Ducrocq, see pp. 5218, 5380, 5658–5659.]

John Christopher. 2013. *The Race for Hitler's X-Planes: Britain's 1945 Mission to Capture Secret Luftwaffe Technology.* The Mill, Gloucestershire: History Press. pp. 131–132, 136–137.

Rheintochter, named after Richard Wagner's Rhine Maidens, was a multi-stage solid-fuel surface-to-air missile developed by Rheinmetall-Borsig for the German Army. [...] It was 20ft 8in (6.3m) long overall including the booster stage, and the body had a diameter of 1ft 9.25in (54cm). [...]

After eighty-two test launches, further development of the *Rheintochter* R-I, and the proposed operational version R-II, was abandoned in December 1944 because it was only attaining the same altitude as the other missile systems. A third version of the *Rheintochter*, the R-III, was to have been a far sleeker affair with a liquid-propellant rocket motor for the main stage, and it did away with the second stage in favour of solid-fuelled boosters mounted to the side of the missile. Only six test firings were made. [...]

Rheinbote ('Rhine messenger') was developed by the Rheinmetall-Borsig company in 1943. Strictly speaking this slender four-stage rocket cannot be classified as a smart bomb as it was aimed solely by the positioning of the launcher and possessed no internal or external guidance systems. Apart from the V-2 (A4) this was the only other long-range ballistic missile to enter service during the Second World War. [...]

In appearance *Rheinbote* was a slender spike 37ft (11.4m) long, with stabilising fins at the rear and three sets of smaller fins arranged at the end of each of the four stages. The rockets were fuelled by diglycol-dinitrate solid-fuel propellant and in tests achieved a blistering Mach 5.5, or 4,224mph (6,800km/h), the fastest speed of any missile at the time. *Rheinbote* was transported and launched from a modified V-2 (A4) rocket trailer which had an elevating launch gantry. The missile was aimed by orientating the trailer itself and elevating the gantry, although the accuracy of this method of aiming is highly questionable.

In tests the *Rheinbote* carried an 88lb (40kg) warhead, only 6.5 per cent of the missile's total mass, up to 48 miles (78km) into the atmosphere to a range of up to 135 miles (220km), but for shorter ranges some of the stages could be removed. Over 200 were produced and they were used in the bombardment of Antwerp from November 1944 into early 1945. After the war ended the Soviets helped themselves to the designs at Rheinmetall-Borsig's Berlin-Marienfelde headquarters, but in general the *Rheinbote* was considered to be lacking accuracy, thanks partly to the effect of the stage separations, and lacking punch as the payload was too small and the almost vertical high-speed delivery tended to bury it deep into the ground.

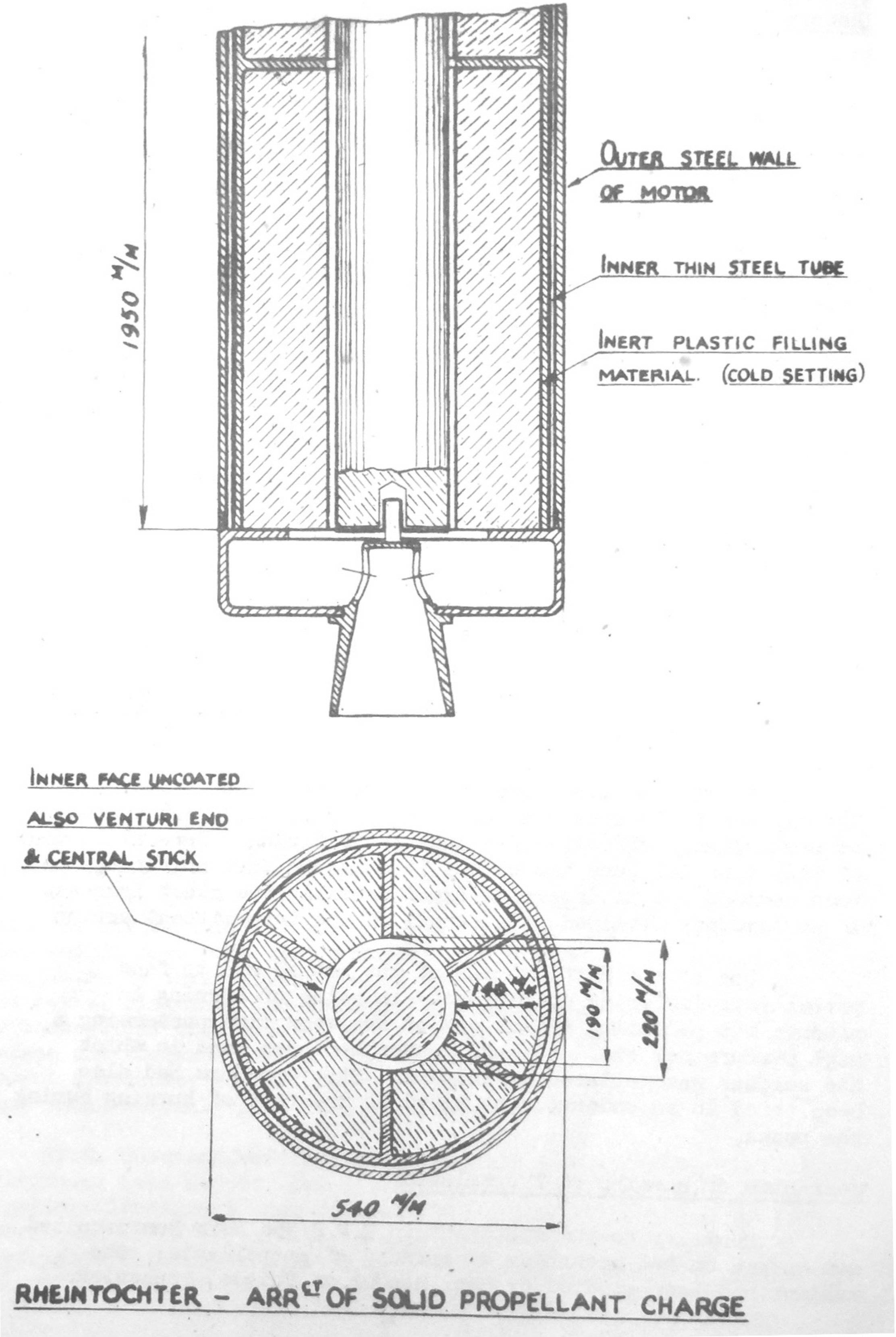
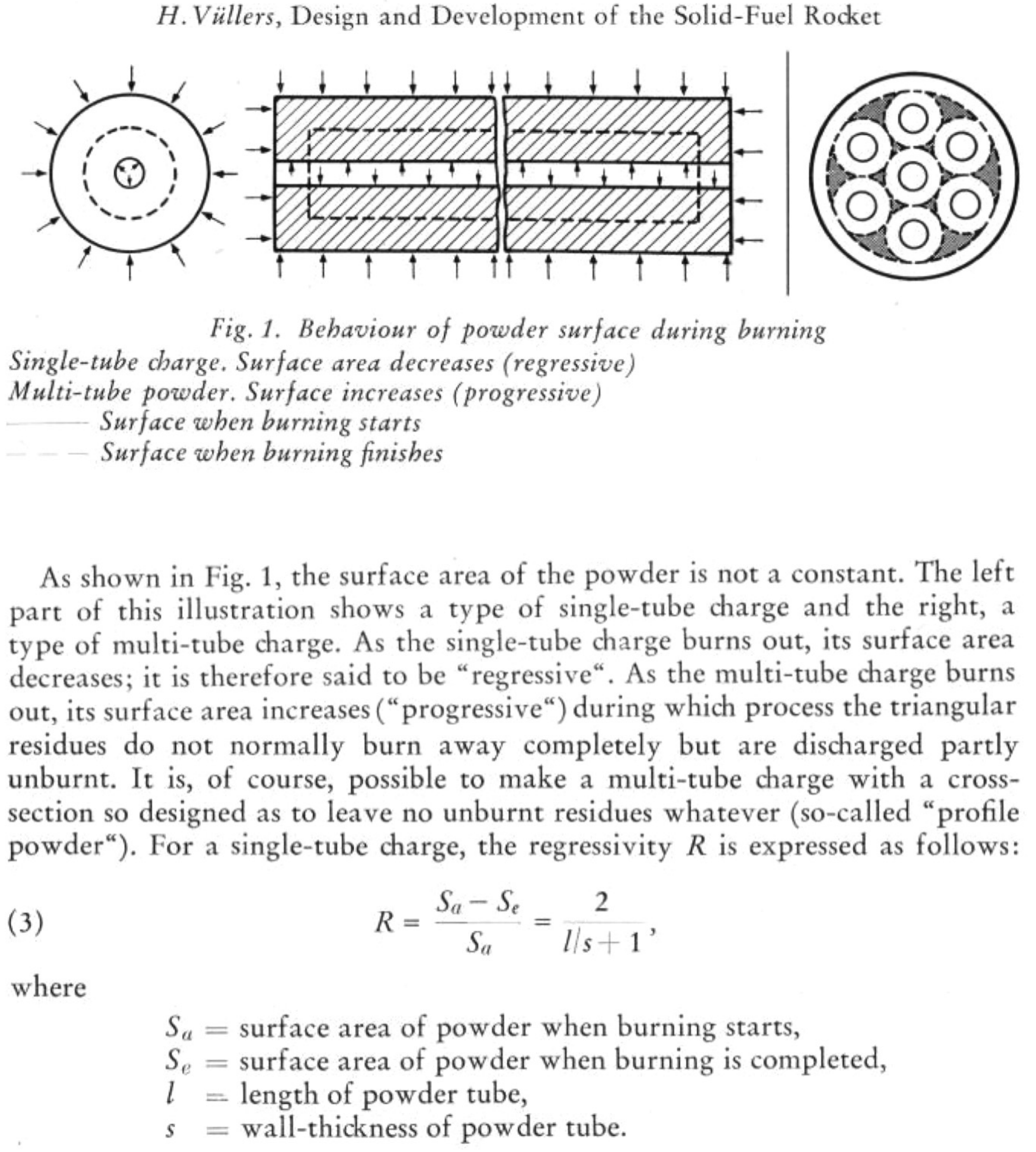

OUTER STEEL WALL
OF MOTOR
INNER THIN STEEL TUBE
INERT PLASTIC FILLING
MATERIAL. (COLD SETTING)
1950 M/M
INNER FACE UNCOATED
ALSO VENTURI END
& CENTRAL STICK
140 M/M
190 M/M
220 M/M
540 M/M
RHEINTOCHTER – ARR^CT OF SOLID PROPELLANT CHARGE

Figure E.221: Rod-and-tube grain design for constant thrust in the large Rheintochter solid propellant rocket engine [BIOS 1110, p. 10].



H. Vüllers, Design and Development of the Solid-Fuel Rocket

Fig. 1. Behaviour of powder surface during burning
Single-tube charge. Surface area decreases (regressive)
Multi-tube powder. Surface increases (progressive)
——— *Surface when burning starts*
– – – *Surface when burning finishes*

As shown in Fig. 1, the surface area of the powder is not a constant. The left part of this illustration shows a type of single-tube charge and the right, a type of multi-tube charge. As the single-tube charge burns out, its surface area decreases; it is therefore said to be "regressive". As the multi-tube charge burns out, its surface area increases ("progressive") during which process the triangular residues do not normally burn away completely but are discharged partly unburnt. It is, of course, possible to make a multi-tube charge with a cross-section so designed as to leave no unburnt residues whatever (so-called "profile powder"). For a single-tube charge, the regressivity R is expressed as follows:

$$R = \frac{S_a - S_e}{S_a} = \frac{2}{l/s + 1}, \tag{3}$$

where

S_a = surface area of powder when burning starts,
S_e = surface area of powder when burning is completed,
l = length of powder tube,
s = wall-thickness of powder tube.

Figure E.222: Hermann Vüllers's description of wartime practices for designing, calculating, and fabricating various regressive grain designs for steadily decreasing thrust (upper left) and progressive grain designs for steadily increasing thrust (upper right) [Benecke and Quick 1957, pp. 254–255].

[One of the main sources of information on solid propellant rocket development in Germany, Nils Werner Larsson, would be worthy of a complete book in his own right. He was a young engineer working on explosives in Sweden, and then in 1943 he defected to Germany and began working his way through its rocket research centers. In 1945 he provided everything he had learned about the German rocket programs to U.K. and U.S. intelligence, yet was officially condemned as a traitor by the Swedish government. Then he defected to the Soviet Union, worked his way through its rocket research centers, and came back to the West in 1960 with everything he had learned there. Currently there is not enough publicly available information to conclusively judge the true motivation behind Larsson's many moves. The most likely explanation is that he had been recruited by Western intelligence agencies to be an undercover agent first in the wartime German rocket programs, then in the postwar Soviet rocket programs. Alternatively, perhaps he just wanted to keep his life exciting by completely switching sides every few years. I would highly recommend that someone research Larsson's life more thoroughly and then make him the subject of a book and/or film.

In addition to large amounts of information about German solid propellant rockets, Larsson also provided U.K. and U.S. officials with large amounts of information about German liquid propellant rockets, including the intercontinental "V-10" (apparently another designation for the A-9/A-10). See pp. 5458–5459. Some brief reports are presented on the following pages, but where are the detailed Allied technical reports that must have been written about all of the liquid and solid rocket information that Larsson conveyed?]

Report Swedish Deserter Took Army Data to Nazis. *New York Times* 15 October 1943.

An engineer who until recently was in the service of the Swedish Army as an expert on explosives and shells has deserted to Germany with many army secrets, it is feared, according to an announcement here today. It concerns one Nils Werner Larsson, age 25, whose flight was only discovered by his failure to answer a lower court summons on charges of an expense account swindle after he had been discharged from army employment.

It now appears that Larsson fled to Germany some time this summer via Norway. He is now employed at a Berlin office of the Wehrmacht. Prior to his flight Larsson participated in a tour of Sweden's more important fortifications, among them being those at Borden and Karlsborg. His mission on this tour was to check grenade throwers, on which he was considered to be an expert. Prior to this he had also been engaged on many secret and highly confidential missions in connection with Swedish defense.

Nils Werner Larsson. 8 June 1945 interrogation at Augsburg [AFHRA C5094, frames 0874–0890].

[This is a lengthy written account by Larsson that described his personal history from the 1930s to 1945. While it did not provide many technical details of German projects, it did include his claim that in 1943, he was recruited and trained by U.S. and U.K. intelligence to work undercover on German military research programs.]

Engineer Arrested as Swedish Traitor. *Toronto Daily Star* 1 November 1945 p. 20. [http://news.google.com/newspapers?id=29QXAAAAIBAJ&sjid=pSMDAAAAIBAJ&pg=7981,5176166&dq=nils+werner+larsson]

Nils Werner Larsson, a Swedish Engineer, has been arrested by Swedish police at Charlottenburg on his way home from Norway.

It is reported that four years ago he wanted to go to Germany to do intelligence work for Britain. The Germans didn't trust him and he had to find some way to show them that he was apparently a friend of Germany, so he stole drawings of a new Swedish gun.

When the war ended Larsson went over to the British lines.

Ein Mann namens Larsson [A Man Named Larsson]. *Die Zeit* 11 March 1960 p. 4. [https://www.zeit.de/1960/11/Ein-Mann-namens-Larsson]

[...] Jenes andere Beispiel aber, von dem es hier zu erzählen gilt, ist die Geschichte des schwedischen Ingenieurs Nils Werner Larsson. Der Schwede hat mehrere Jahre als westlicher Agent hinter dem Eisernen Vorhang gelebt, ist ins Zentrum der östlichen Raketenforschung vorgedrungen, hat fünf Monate vor dem ersten Sputnik den Start einer roten Großrakete miterlebt und behauptet, er kenne das Geheimnis der atomgetriebenen sowjetischen Super-Rakete. Mit diesem Wissen meldete er sich jüngst wieder im Westen, bei den Dienststellen der US-Army. [...]

[...] But the other example we have to talk about here is the story of the Swedish engineer Nils Werner Larsson. The Swede lived behind the Iron Curtain as a Western agent for several years, penetrated the centre of Eastern missile research, witnessed the launch of a large communist rocket five months before the first Sputnik and claims to know the secret of the nuclear-powered Soviet super-rocket. With this knowledge he recently contacted the US Army again in the West. [...]

[See also:

3 March 1960. Soviet secrets about rockets... were discovered at a press conference in Hamburg by Swedish constructor Nils Werner Larsson. [Includes photo of Larsson in 1960, https://www.alamy.com/mar-03-1960-soviet-secrets-about-rockets-were-discovered-at-a-press-image69364205.html]

Chris Johnstone. 20 June 2015. Czech Episode of Nazi Rocket Science Uncovered by Historian. Czech Radio. [Archival research by Michal Plavec, curator at the National Technical Museum in Prague, https://english.radio.cz/czech-episode-nazi-rocket-science-uncovered-historian-8256618]]

Seventh Army Interrogation Center. 17 May 1945. Notes on Personalities and Establishments Associated with Development of V-Weapons. SAIC/12. [https://www.cia.gov/readingroom/document/cia-rdp83-00415r006200030002-7]

LARSSON, Nils, a Swedish engineer who has worked for two years in Germany on rocket research. He appears to have a well-rounded picture of German rocket production and plans, and although he admits that he is only a "small man in this field", he knows the more important men and where they can be found. [...]

Seventh Army Interrogation Center. 3 June 1945. Notes on German Weapons Developments. SAIC/38. [https://www.scribd.com/document/431240796/File-Datastream http://hydrastg.library.cornell.edu/fedora/objects/nur:01298/datastreams/pdf/content]

I. PREAMBLE

The following information was obtained from Dr Edgar RUPPELT, Dr Alfred NORDT, Dr Ernst KNUST, and Nils LARSSON, all of the PIBRANS, Czechoslovakia, SKODA Works Rocket Experimental Station. While all of them gave a certain amount of information, LARSSON, the head of the group, can be considered the main source.

LARSSON, Nils, is a 27-year-old Swedish engineer whose special field was the development of new weapons, especially in the rocket category. In summer 40 a proposed A/T weapon of his design was accepted by the Swedish military authorities. He attended a military technical school for some time and in winter 42/43 met the Norwegian Military attaché, Lt Col SMITH-KIELLAND, and through him, the American and British Military Attachés in STOCKHOLM. He attempted to leave Sweden to work for the United Nations, he claims, and when this proved impossible due to difficulties in transportation, he got in touch with an American intelligence official, a "Col ANDREWS", and a representative of the British Secret Service, a "Mr GREEN", who instructed him to go to Germany and keep in close touch with the latest developments in rockets and other weapons. Source claims to have obtained definite instructions as to his proposed mission in Germany.

Through a representative of the German Military Attaché, a 1st Lt "MÜLLER-LIEBENAU", source obtained permission to enter Germany as specialist in rocket development.

Source worked at first, starting on 1 Jul 43, for the firm MAGET in BERLIN/TEGEL. In order to avoid troubles with the German Police, his case was cleared by the German authorities through the at the time unimportant SS HPTSTUF (Capt) SKORZENY. Due to SKORZENY's subsequent rise in power and importance, it was possible for source to gain access to the top German agencies involved in the development of new weapons.

After short periods of work in various smaller agencies involved in rocket experiments, source was sent to the VERSUCHS-ANSTALT (Research Center) GROSSENDORF, on the HELA Peninsula, about May 44. Here source had occasion to acquaint himself with the latest developments in the rocket field, as well as to get to know the names of the leading scientists involved in the experiments and research work. From here, source claims, he sent reports through a contact-man in BERLIN as well as through his wife in STOCKHOLM. Furthermore, source made contact with the leading scientists of the Torpedo Research Center GOTENHAFEN (GDYNIA), which was a sub-post of the MARINE REICHSVERSUCHSANSTALT (REICH Naval Experimental Station), KIEL.

In winter 44/45 the GROSSENDORF Center was evacuated to PIBRANS, Czechoslovakia, where, together with the Research Post of the PIBRANS SKODA Plant, it formed a new elaborate Research Center under Eng Rolf ENGEL, former head of the GROSSENDORF Center. In Apr 45, when Germany's collapse was near, this Center was dissolved and the personnel were given permission to leave Czechoslovakia. Source left for Southern Germany, securing on his way important scientific data as well as some secret Police documents applying to the plant.

Source appears to have had occasion to form an overall picture not only of the latest developments in the rocket field, but in the general line of research on other new secret weapons as well. Due to his travels and his access to data in the top German research centers, he knows a remarkable number of names connected with latest German scientific developments. He wants, with the help of American and British influence, [to] re-instate his "good name" in Sweden where, it seems, he is regarded as a traitor because of his departure for Germany. Whatever his reasons, he is cooperative and helpful. He has an excellent memory, and his information is considered reliable.

Rating: B-2 Date of Information: Beg. May 45 Interrogator: M.N.

NOTE: The following report should be regarded as basis for further specialized interrogation. It is believed that sources would be able to furnish detailed technical data on many of the instruments described as well as on the experiments carried out. It should be noted that source LARSSON was Specialist in Charge (SACHBEARBEITER) of some of the developments.

[...]

II. GERMAN AGENCIES SUPERVISING RESEARCH AND DEVELOPMENT OF NEW WEAPONS [...]

ii) TORPEDO VERSUCHSANSTALT (Torpedo Research Center), GOTENHAFEN. KAP Z SEE (Navy Captain) PRALL was the head of the Center. In charge of the development of special torpedos was Dr SCHMIDT, and in charge of development of the "ROCHEN" ("Roe"—see III, A, 5, a, below) was Dipl Ing WONDRAK. [...]

Under the FORSCHUNGSFUEHRUNG source recalls the following departments:

i) RHEINTOCHTERENTWICKLUNG ("RHINE Daughter" Development - see III, A, 5, b, below). The man in charge of these experiments (REFERENT) was Prof Dr ORTHMANN.

ii) R-ENTWICKLUNG (Rocket Development), headed by Maj HARRAS. Specialists in Charge (SACHBEARBEITER) were HPTM (Capt) TILLING and FL STABSING (GAF Maj) HESSE.

iii) PULVERENTWICKLUNG (Powder Development); REFERENT in FoFü for this dept was Dr BUNDE. [...]

f) RUESTUNGSKOMMISSIONEN MIT FUEHRERVOLLMACHT (Armament Commissions with FUEHRER Authority) [...]

iii) PULVERKOMMISSION (Powder Commission), headed by the General Director of DYNAMIT AG Dr Paul MUELLER. Specialist in interior ballistics and powders in this dept was REGIERUNGSBAURAT Dr POEPL, who also was in Wa Prüf 1. HPTM (Capt) Dr HIMMELHEBER, specialist of small assemblies for V-1, was head of the section for research in wood.

iv) SONDERKOMMISSION FUER R-ENTWICKLUNG BEIM RfRuK (Special Commission for Rocket Development in the SPEER Ministry) was headed by FL STABSING (GAF Maj) ZEYSS.

v) SONDERAUSSCHUSS FUER PULVER BEIM RfRuk (Special Section for Powder in SPEER Ministry) was headed by Director Dr WUNDER. [...]

III. GERMAN RESEARCH ON NEW WEAPONS

[...]

1. Projectors [...]

a) M 8 Projector

This projector, research on which was supervised by the SS WAFFENAMT (Ordnance Office) through SS HPTSTUF (Capt) HANNEBERG, was developed in the WAFFENWERKE BRUENN AG and in the GROSSENDORF, Pomerania, Research Center under Ing Rolf ENGEL. The specialists in charge of the research and experiments were Dr KALSCHEUER, Prof Dr BOEDENWADT, and Ing PROKOP. The projector has 48 barrels on a SP chassis. The rockets are 8 cm in diameter, have flight stabilizers and percussion fuzes. The maximum range of the rockets is 7 km. [...]

2. Rocket AA Weapons [...]

a) ORKAN FLA

This weapon, ordered by the OKL, ARBEITSSTAB (Staff) DORNBERGER and supervised by FL STABSING (GAF Maj) ZEYSS, was being developed in the Research Center of the WAFFEN-UNION in PIBRANS, Czechoslovakia. OBLT (1st Lt) FISCHER and Dr TEICHMANN were the specialists in charge of the experiments and research. The projector, consisting of 24 rails on a rotating chassis, was to be used against low-flying planes. The rockets have a cal of 55 mm, percussion fuzes, and flight stabilizers. They attain a distance of 5 km in 3 sec. The powder charge is placed in a single tube 48 x 15 x 1,100 mm and weighs 1.7 kg; the weight of the explosive charge carried by the rocket is 500 g. The experiments on the weapon were concluded, and it was planned to manufacture the first 50,000 rockets for combat employment. [...]

5. Controlled Rocket Weapons

a) ROCHEN ("Roe")

This is a rocket projectile which is controlled by means of impulses transmitted through a wire unwinding during its flight (see F, 2, below). The OKM (Navy High Command) was the agency interested in the development of this weapon, and Director SCHMIDT of the TVA (Torpedo Research Center), GOTESHAFEN was supervising the experiments. The research and experiments were carried out in the TVA GOTESHAFEN and in the GROSSENDORF Research Center under the supervision of KAP Z SEE (Navy Captain) VON PRALL. SACHBEARBEITER (specialists in charge) were Ing WONDRAK and Dr KALSCHEUER. The ROCHEN was to be used against naval and land targets. The projectile is 2 m long and approx 1 m wide. It has both a rocket starting mechanism (the DOV 21 is used for this purpose) and a rocket propelling device. The weight of the projectile before it is fired is 320 kg, of which 100 kg are the "Useful weight". Its flight can be controlled to a distance of 4–7 km, through a polarisation relay. The weight of the powder is 16[0] kg, the combustion time 3 tons-sec. The device was ready for experiments when hostilities ceased.

b) RHEINTOCHTER ("RHINE Daughter") (Source: Dr NORDT)

This is a controlled heavy AA missile, developed by RHEINMETAL-BORSIG, BERLIN/MARIENFELDE, under the management of Dr KLEIN, for the OKL. Supervisor of the project on the part of the OKL was Prof Dr ORTHMANN, and specialist in charge during the experiments and research work was OBERING MUELLER. The shell, containing an explosive charge of approx 100 kg, was to be used against bomber formations. It is controlled by means of an infra-red device, and has an acoustically controlled fuel ignition cut-out. The device consists of two parts, a starting device and a propelling device, each with a thrust of 25–30 tons and a fuel combustion time of approx 2 sec. After the ignition of the propelling device, the empty starting device is automatically dropped. It was planned to substitute the propelling device by a long-burning powder device, with a fuel combustion time of 30 sec, or by using a liquid propellant (SCHMETTERLING and WASSERFALL). Sources state that the steering problems of the "RHINE Daughter" had not been solved, as of beg May 45. Research was carried on up to the last minute.

7. Long Range Rocket Missiles

The V-series weapons are the representatives of this class. Also, future developments for communication purposes can be expected in rockets of this category.

a) V-l.

b) A-4, which was the prototype of V-2.

c) V-2.

d) TL (TURBOLADER)—for jet-propelled planes.

e) V-101.

This weapon, in the planning stages only, was being developed in the PIBRANS Experimental Center by Dr BOEDENWADT, Dr TEICHMANN, Dr KALSCHEUER, and Ing THOMAS. It is a giant rocket of a total weight of 140 tons, of which 100 tons were to be taken up by the fuel. It was to have a length of 30 m and a diameter of 2.8 m. It was to attain a velocity of 2,000 km per hour at an altitude of 200 km. Its maximum range was calculated to be 1,800 km. It was to be fired by a catapult mechanism, also rocket-operated. Source LARSSON claims that he would be able to prepare a complete report, with drawings, of this weapon. [...]

3. Heterogen Powders [...]

b) PER Powder

This powder was developed in the PIBRANS Experimental Station, under Dr TEICHMANN. Its developments were supervised by FL STABSING (GAF Maj) ZEYSS, of the OKL. The powder was synthesized from a plastic material and an inorganic oxygen carrier. Depending on this plastic material, the powder could be molded or poured into shape. The burning proceeds uniformly at atmospheric pressure and up. The linear burning velocity at one atm is 1 mm/sec. The burning velocity increases proportionately to the increase of pressure.

F. MEASURING AND AUXILIARY DEVICES

1. Radar Devices

Sources mention the DARMSTADT Device and Y-Device as the latest developments in this field.

2. Wire Control Device

This is the spinner used in the ROCHEN and wire controlled torpedo. It was developed in the TVA (Torpedo Experimental Station) GOTENHAFEN (GDYNIA) the head of which was KAP Z SEE (Navy Captain) VON PRALL, by Dir SCHMIDT and Dipl Ing WONDRAK, and several series of the device were already manufactured. The missile is controlled through polarization relays over a wire which unrolls during its traveling. The range of the device (and thus of the missile) is said to be from 7 to 12 km.

3. Remote-Control Devices

Generally, the devices send out high frequency signals, modulated light signals, infra-red, or acoustic signals. Sources know of a modulated-light device which was being developed at the PIBRANS Experimental Station by Dr SIMON and Dr TRENKA, under the supervision of OBLT (1st Lt) FISCHER, of OKL/GL FLAK. The device is said to have passed the experimental stage, as of beg May 45.

[This solid propellant mixture was probably dubbed "per powder" because its dominant ingredient was ammonium perchlorate. Was the Zeyss mentioned here the same as Wilhelm Zeyss (p. 1910), who played a role in other solid propellant rocket programs?]

NavTechMisEu 237-45. ***Survey of German Activities in the Field of Guided Missiles.*** **August 1945. [NARA RG 38, Entry P5, Box 38]**

[p. 46:]

SKETCH OF THE MISSILE	SKETCH OF MISSILE NOT AVAILABLE
MISSILE	V-101
CODE NAME	
USED AS	A GROUND TO GROUND MISSILE
1. SPEED RANGE	SUPER SONIC
2. DEVELOPED BY	DR.'s BUEDENWADT, TEICHMANN.
3. MANUFACTURED BY	PIBRANS EXP. CENTER
4. STATUS [...]	NONE [...]
5. METHOD OF LAUNCHING	GROUND MOUNTED CATAPULT
6. AUX. LAUNCHING PROPULSION UNIT [...] (a) TYPE [...]	ROCKETS NOT KNOWN [...]
7. LAUNCHING ATTITUDE	NOT KNOWN
8. LAUNCHING MECHANISM (a) LENGTH OF GUIDE (b) AIMING RANGE	ROCKET PROPELLED CATAPULT NOT KNOWN " "
9. VELOCITY, MAXIMUM (a) LAUCHING (b) END OF PROPULSION BURNING	SUPER SONIC NOT KNOWN 2000 KM./HR.
10. PROPULSION UNIT (a) MAKE [...] (i) THRUST	NOT KNOWN [...] 100 TONS
11. MISSILE DIMENSIONS (a) WEIGHT 1. TOTAL 2. EMPTY 3. WAR HEAD 4. EXPLOSIVE (b) DIMENSIONS 1. LENGTH 2. SPAN 3. DIAMETER	 140 TONS NOT KNOWN " " " " 30 METRES NOT KNOWN 2.8 METRES
12. CONTROL [...]	NOT KNOWN [...]
13. HOMING [...] (d) TYPES PROPOSED [...]	[...] NOT KNOWN [...]
14. FUSES [...]	NOT KNOWN [...]
15. OPERATING RANGE (a) RANGE (b) ALTITUDE	1800 KM. 200 KM.

[p. 190:]

V-101 LONG RANGE ROCKET

A. General

1. Introduction.

(a) The V-101 is a long range rocket missile which was in the planning stages at the Pibrans Rocket Experimental Station, a subsidiary of the SKODA Munitions Work at Pibrans, Czechoslovakia. The only information presently available is from a brief interrogation of Dr. Edgar Ruppelt, Dr. Alfred Nordt, Dr. Ernst Knust and Nils Larsson, in the 7th Army Interrogation Center. (Report Ref. No. SAIC/38 of June 1945).

(b) No drawings or illustrations are available.

(c) As in the case of the Rochen, reference to the V-101 has been made simply as an illustration of the extent of the German effort being utilized in the development of long range rockets and missiles.

B. Details

2. Description.

(a) It is believed that the projected purpose of the weapon was for use in long range area bombing. The type of explosive, fuel, and exact utilization had not been fully determined. The missile was to operate in the stratosphere.

(b) The rocket was to be about 30 meter long; the diameter was estimated to be 2.8 meters. The total weight was to be approximately 140 tons, with the fuel weight of approximately 100 tons.

(c) The speed of the rocket was estimated to be in the vicinity of 2000 km/hr when operating at an altitude of 200 kilometers. The proposed range was to be 1800 kilometers.

(d) The rocket was to be launched from a catapult mechanism.

[In the table of rockets on p. 46 of this report, the numbers from p. 190 of the report are repeated, but the thrust is indicated as 100 tons, and all other details are listed as “not known.” In order to lift off, the rocket’s thrust must be larger than the rocket’s weight, so the actual thrust must have been greater than 140 tons.

This report stated that its only information on the V-101 came from the SAIC/38 interrogation report, which did not indicate the thrust of the rocket. The most likely explanation is that whoever typed the table in this NavTechMisEu 237-45 report misread the reported fuel weight of 100 tons as being a thrust of 100 tons.

A less likely explanation is that whoever typed this table was thinking of a thrust of 200 tons but mistyped it as 100 tons. 200 tons of thrust would give a very plausible thrust-to-weight ratio for a rocket weighing 140 tons when launched.

Note that the name given as “Dr BOEDENWADT” in SAIC/38 has been mangled to “BUEDENWADT” in this NavTechMisEu 237-45 report.]

HEC 5787. Headquarters, U.S. Forces, European Theater, Alsos Mission. 15 September 1945. Subject: Survey of Facilities in Germany for Development of Guided Missiles. [NARA RG 319, Entry NM3-82, Box 1582]

Part V

Development and Fabrication of Complete Missiles

[...] K. Skoda "V-101"

The large munitions work Skoda in Pilsen, Czechoslovakia, operated a rocket experimental station at Pribrans, Czechoslovakia. Here work was being done towards the development of a stratosphere rocket 100' long and weighing 140 tons.

L. "Rochen" ("Roe")

This was a rocket projectile for wire control under development by the Torpedo Research Station Gotenhaven. Tests were conducted there and at a research station Grossendorf. This project was under the cognizance of the Navy High Command.

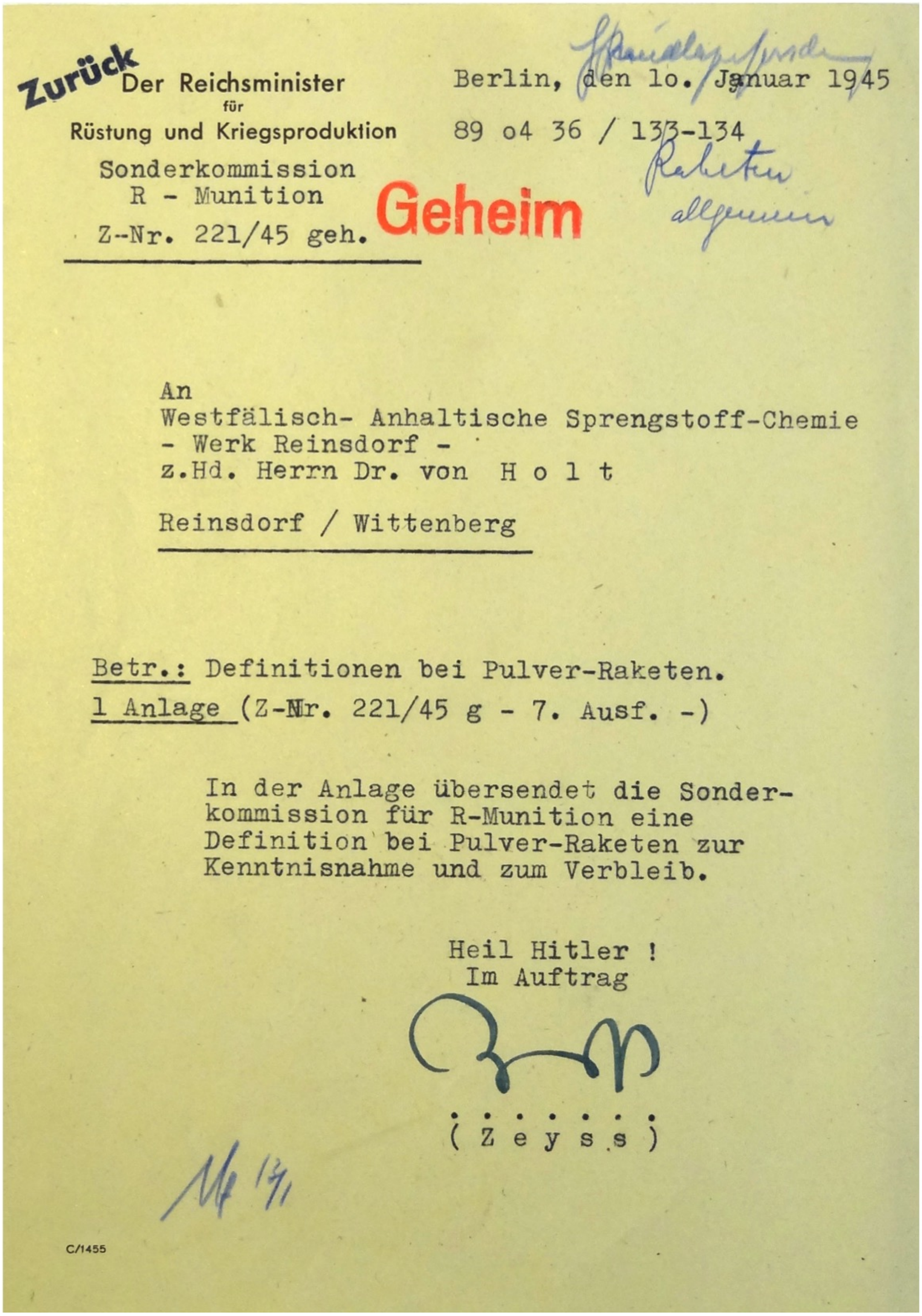
[The Alsos Mission traveled around Europe independently investigating a wide range of scientific innovations and collecting vast numbers of German documents. Was this statement in HEC 5787 based on their own investigations, or was it simply rephrased from the earlier U.S. and U.K. reports?

As an example of at least one relevant German document collected by Alsos, please see the following pages. Was Alsos's statement that "work was being done towards the development of a stratosphere rocket 100' long and weighing 140 tons" based on other documents that they collected? If so, where are those documents now?

From this statement in HEC 5787, the V-101 sounds like more than a paper design study. The Alsos Mission reported the V-101 under the heading of "Development and Fabrication of Complete Missiles," alongside fully built (if not perfected) projects such as the Rochen wire-guided missile and Natter vertical take-off rocket plane, and with the wording that there was "work" toward its "development." It would have been very difficult to fully build such a large rocket, but what development work was actually done?]

DECLASSIFIED
Authority NND 755001

NARA RG 319, Entry NM3-82A,
Box 14, Folder OB-3



Zurück
Der Reichsminister
für
Rüstung und Kriegsproduktion
Sonderkommission
R - Munition
Z-Nr. 221/45 geh.

Geheim

[illegible]
Berlin, den lo. Januar 1945
89 o4 36 / 133-134
Raketen
allgemein

An
Westfälisch- Anhaltische Sprengstoff-Chemie
- Werk Reinsdorf -
z.Hd. Herrn Dr. von Holt

Reinsdorf / Wittenberg

Betr.: Definitionen bei Pulver-Raketen.
1 Anlage (Z-Nr. 221/45 g - 7. Ausf. -)

In der Anlage übersendet die Sonderkommission für R-Munition eine Definition bei Pulver-Raketen zur Kenntnisnahme und zum Verbleib.

Heil Hitler !
Im Auftrag

(Zeyss)

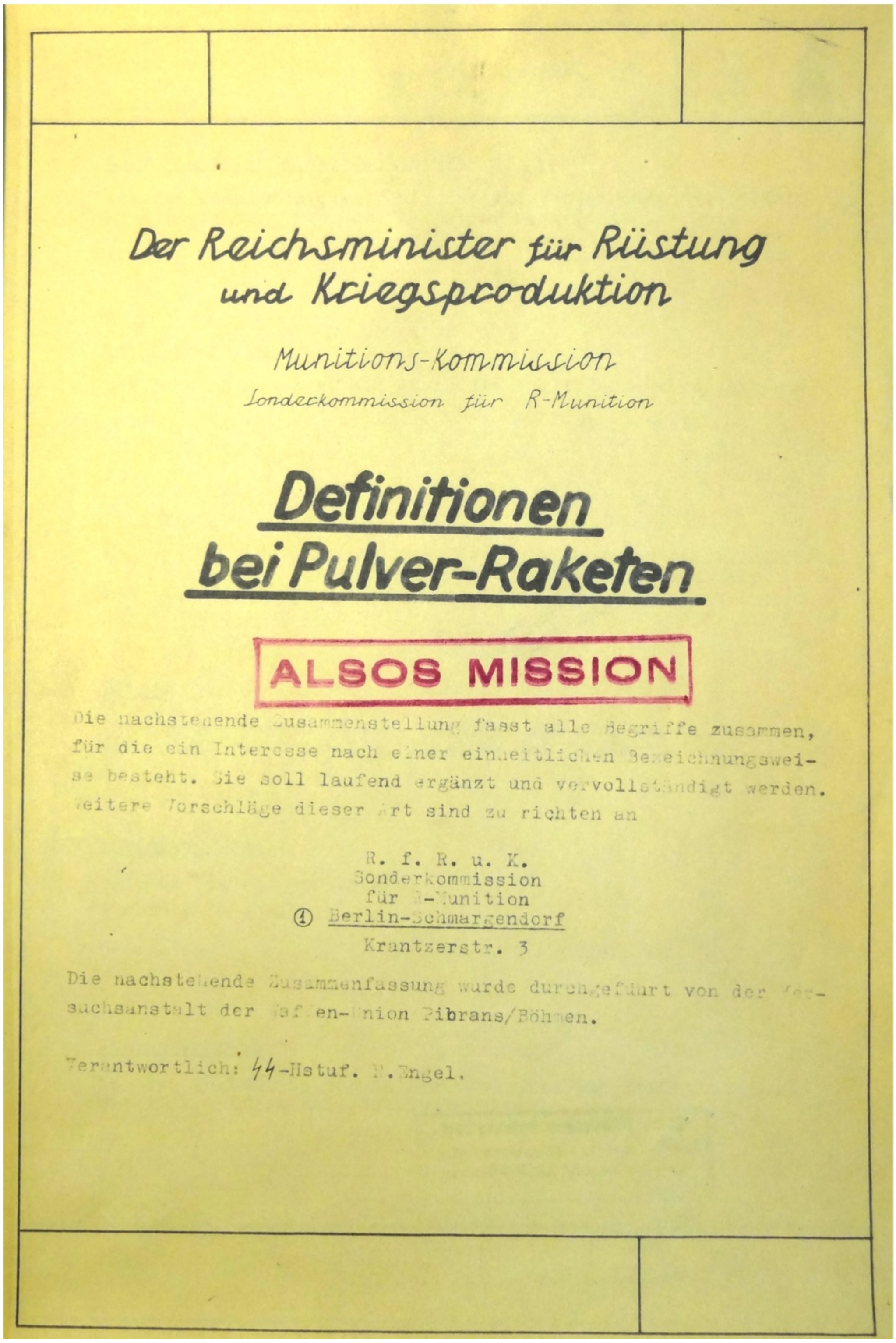
Mf 13/1

C/1455

Figure E.223: Excerpts from a 49-page book from Rolf Engel and Wilhelm Zeyss listing definitions of mathematical variables used for calculating the performance of solid propellant rockets, collected by the U.S. Alsos Mission. [NARA RG 319, Entry NM3-82A, Box 14, Folder OB-3]

DECLASSIFIED
Authority NND 755001

**NARA RG 319, Entry NM3-82A,
Box 14, Folder OB-3**



Der Reichsminister für Rüstung
und Kriegsproduktion

Munitions-Kommission
Sonderkommission für R-Munition

**Definitionen
bei Pulver-Raketen**

ALSOS MISSION

Die nachstehende Zusammenstellung fasst alle Begriffe zusammen, für die ein Interesse nach einer einheitlichen Bezeichnungsweise besteht. Sie soll laufend ergänzt und vervollständigt werden. Weitere Vorschläge dieser Art sind zu richten an

R. f. R. u. K.
Sonderkommission
für R-Munition
① Berlin-Schmargendorf
Krantzerstr. 3

Die nachstehende Zusammenfassung wurde durchgeführt von der Versuchsanstalt der Waffen-Union Pibrans/Böhmen.

Verantwortlich: ϟϟ-Hstuf. R. Engel.

Figure E.224: Excerpts from a 49-page book from Rolf Engel and Wilhelm Zeyss listing definitions of mathematical variables used for calculating the performance of solid propellant rockets, collected by the U.S. Alsos Mission. [NARA RG 319, Entry NM3-82A, Box 14, Folder OB-3]

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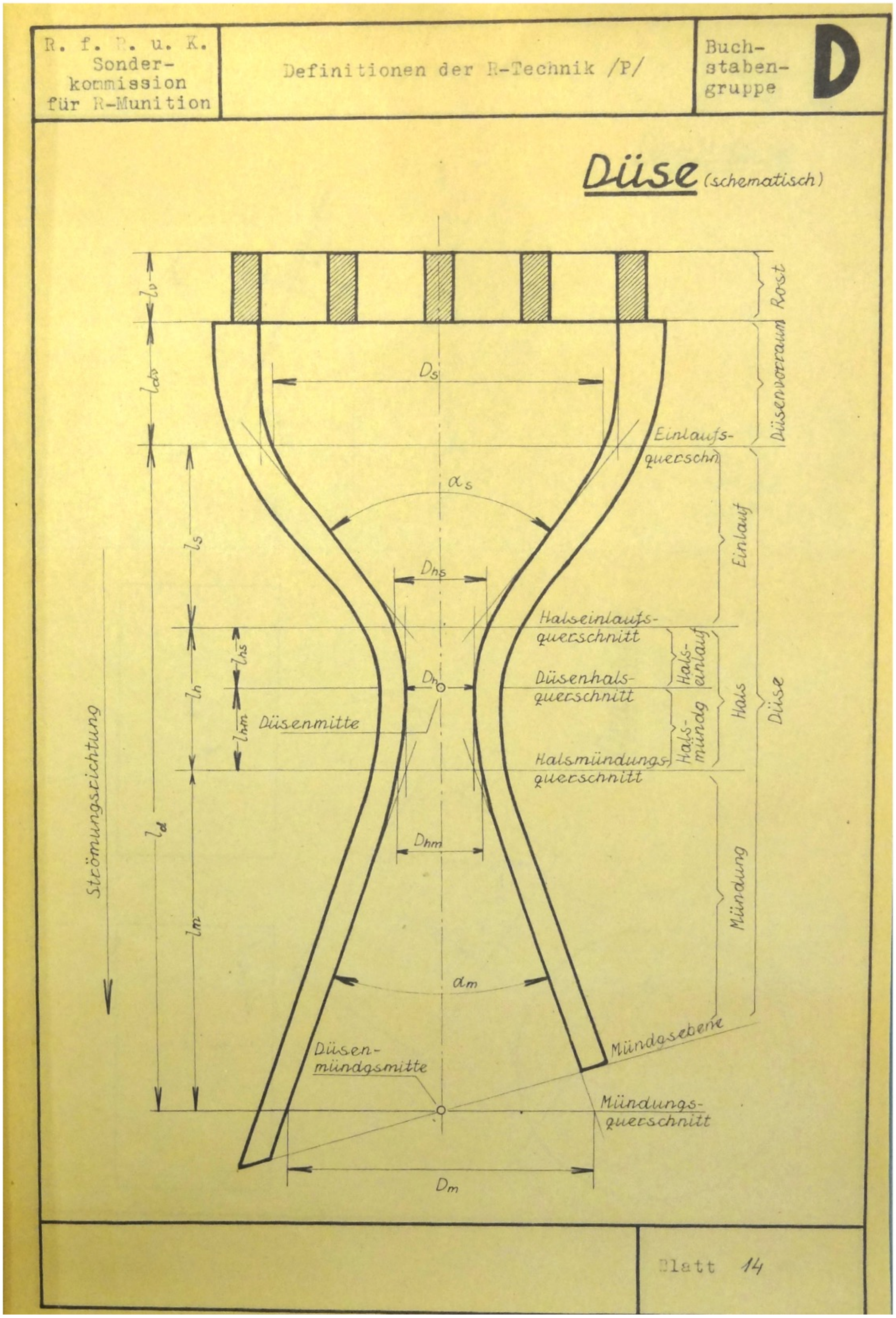


R. f. R. u. K.
Sonder-
kommission
für R-Munition

Definitionen der R-Technik /P/

Buch-
staben-
gruppe
D

Düse (schematisch)

Blatt 14

l_r
l_{dv}
l_s
l_h
l_{hs}
l_{hm}
l_d
l_m
D_s
α_s
D_{hs}
D_h
D_{hm}
α_m
D_m
Rost
Düsenvorraum
Einlaufs-
querschn.
Einlauf
Halseinlaufs-
querschnitt
Hals-
einlauf
Düsenhals-
querschnitt
Hals
Düse
Düsenmitte
Hals-
mündg
Halsmündungs-
querschnitt
Mündung
Strömungsrichtung
Mündgsebene
Düsen-
mündgsmitte
Mündungs-
querschnitt

Figure E.225: Excerpts from a 49-page book from Rolf Engel and Wilhelm Zeyss listing definitions of mathematical variables used for calculating the performance of solid propellant rockets, collected by the U.S. Alsos Mission. [NARA RG 319, Entry NM3-82A, Box 14, Folder OB-3]

Fritz Hahn. 1998. *Waffen und Geheimwaffen des deutschen Heeres 1933-1945.* 3rd ed. Bonn: Bernard & Graefe. Vol. 2, pp. 180, 182.

V 101

Unter dieser Bezeichnung hatten 1944 Dr. Büdewald und Dr. Teichmann im *Zweigwerk Pibrans* der Firma *Skoda* mit der Entwicklung einer großen Feststoff-Rakete begonnen.

Bei 30,000 mm Länge und 2800 mm Durchmesser sollte diese dreistufige Rakete 140 t wiegen. Das Pulvertriebwerk der ersten Stufe war für einen Schub von 100 t ausgelegt, die rechnerische Flugbahn zeigte bei einer Reichweite von 1800 km eine Gipfelhöhe von 200 km. Der Entwurf war nur in groben Zügen festgelegt, über Einzelheiten existieren keine Unterlagen mehr. Dieses Projekt wäre, wie andere auch am Treibmittel, dem immer knapper werdenden Pulver gescheitert.

V 101

Under this designation Dr. Büdewald and Dr. Teichmann started the development of a large solid propellant rocket in the Pibrans branch of the Skoda company in 1944.

At 30 m in length and 2.8 m in diameter, this three-stage rocket was supposed to weigh 140 tons. The powder [solid propellant] engine of the first stage was designed for a thrust of 100 tons; the calculated trajectory showed a peak altitude of 200 km with a range of 1800 km. The design was only laid out in general outline; documents about details no longer exist. This project, like others on the propellant, failed because of the increasingly scarce powder.

[Almost all of Fritz Hahn's information appears to have come from the NavTechMisEu 237-45 report, including the erroneous thrust of 100 tons.

Dr. "Bödenwadt" (from SAIC/38) or "Büdenwadt" (from NavTechMisEu 237-45) has been further altered to "Büdewald." The scientist's actual name was Uwe Bödewadt (German, 1911–2003).

The only major new technical detail added by Hahn is that the rocket had three stages. That does not appear to be stated anywhere in the available U.S. or U.K. reports. Was that simply a guess by Hahn, or did sources with knowledge of the project give that additional information to Hahn? For the projected performance characteristics of the V-101, it seems probable that it would have had 2–4 stages, so three stages is highly plausible.]

BIOS 571. ***German Rocket Propellants (Interrogation of Mr. N. W. Larsson).***

I. Introduction

Mr. N. W. Larsson is an engineer with great faculties of memorising technical data. He is a Swedish subject, talks German fluently, and claims that he went to Germany as an allied spy, working for the British Secret Service.

Mr. Larsson has been employed in German Armament Research from May 1943 to V.E. day. He first spent some months at the Rheinmetall-Borsig factories where he worked on the "Gehrlich" recoilless gun.

He was then transferred to Peenemünde, where he assisted in the development of various rocket weapons.

In December 1944 he went with the Peenemünde staff to a research station of the Skoda Works at Pibrans, Czechoslovakia, when he carried on his work until the cessation of hostilities.

During the interrogation Mr. Larsson gave some information upon the German 'alternative' rocket propellants Per-pulver and Giessling-pulver, as well as some indication upon the technique employed in making "cigarette-burning" charges.

II. Per-pulver

Mr. Larsson worked with the applications of this propellant to various rocket weapons, at the Skoda Works Rocket Research Station at Pibrans, Czechoslovakia, for about 6 months. Here he met the inventor of Per-pulver, Dr. Teichmann, and his two collaborators, Dr. Knust and Dr. Nord.

Per-pulver is also called Nider-druck-pulver, Super-pulver and Dauerbrand.

Composition:

Ammonium perchlorate	25–40%
Buna S3	25%
Vinapas	50–35%
Stabiliser	3–5%

Later interrogations of Dr. Teichmann, however, show that these figures are not exact. The composition contains about 80% of ammonium perchlorate.

Ingredients:

Buna S3. It appears that this synthetic rubber corresponds to Buna SG. Delivered in sheets, vulcanised, 2–3 mm. thick, the sheets being in rolls of about 100 Kg. weight.

The sheets were disintegrated in special machines, down to dimensions of the order of 3–5 mm. (The synthetic rubber industry was later asked to deliver the rubber in a more favourable state, such as an intermediate product consisting of small grains).

Vinapas. Produced by Wacker Chemie, Burghausen near Salzburg. This is a synthetic plastic, which also appears under other commercial names. It is used as a binder, conferring to the propellant a consistency somewhat like a plastic. The yellow colour of the propellant is due to the Vinapas. It is used as small flakes or a fine powder.

Ammonium perchlorate. It is added as fine crystals (particle size roughly as ordinary table salt). Also other perchlorates have been used, such as sodium perchlorate.

Preparation of the propellant.

The ingredients are mixed at room temperature (plus 15^{o}C) in a usual rotating incorporator. The mixture is then rolled on a roller-mill of the usual type employed for Digl. pulver.

The initial temperature is 60^{o}C, which is increased during milling to 90–95^{o}C. The milling time is dependent on the consistency of the dough, which in turn varies with the proportions of the constituents. The time appears to be 25–30 mins. for a batch of 25 Kg.

Mr. Larsson's notes do not make quite clear at which state of the process the perchlorate is introduced. On one occasion he said that it was added on the rolls, when a sheet was formed, and this appears to be most likely, as this procedure would be the safest.

The resulting dough is extruded or molded. The extrusion press is worked very much in the same way as for Digl. pulver. The extrusion pressure is, of course, dependent of the temperature.

The molding is, however, the most important method of preparing propellant charges, as it makes possible the production of charges of almost any size and shape. The propellant is molded at 110–120^{o}C, in jacketed moulds preferably warmed to a somewhat lower temperature. This temperature is maintained for 5–10 min. to allow air bubbles to mount and assemble in the upper part of the mould. The jacket is then cooled rapidly with cold water. After solidification of the propellant the mould is taken to pieces. 4–6 inches is cut off the top of the charge, to take away any air bubbles that may be included owing to the more rapid cooling of the surface of the charge during molding. The surface is then polished.

Ballistic properties.

The rate of burning exponent is "somewhat lower than 1". The propellant burns regularly under low pressure. It appears that the highest specific impulse was obtained when the propellant is burning at 25 atm. (350 p.s.i.) The flame temperature also gives a maximum at this pressure (1600^o–1800^{o}C.).

The rate of burning at 25 atm. is claimed to be 25 mm/sec. Striction ratio K=50–80.

There is danger of detonation when the pressure rises to 1100 atm. at which pressure the rate of burning is 1000 mm/sec. The pressure limit for which detonation occurs is increased by introducing more Vinapas in the propellant.

Physical properties.

Consistency somewhat like a plastic.
d- 1.85 to 1.90
Colour yellow to brown.
Smooth, hard surface.
Can be worked with cutting tools.

Applications.

Per-pulver was used in the A.T.O. unit of "Rochen", where it was burning at a pressure of 25 atm. with a rate of burning of 25 mm./sec.

"Rochen" is a heavy rocket missile, guided by wires. It was intended for use from light vehicles and MTBs against shipping and ground targets.
Weight about 300 Kg., 150 Kg. of explosives.
Guided by the "Spinner" system.

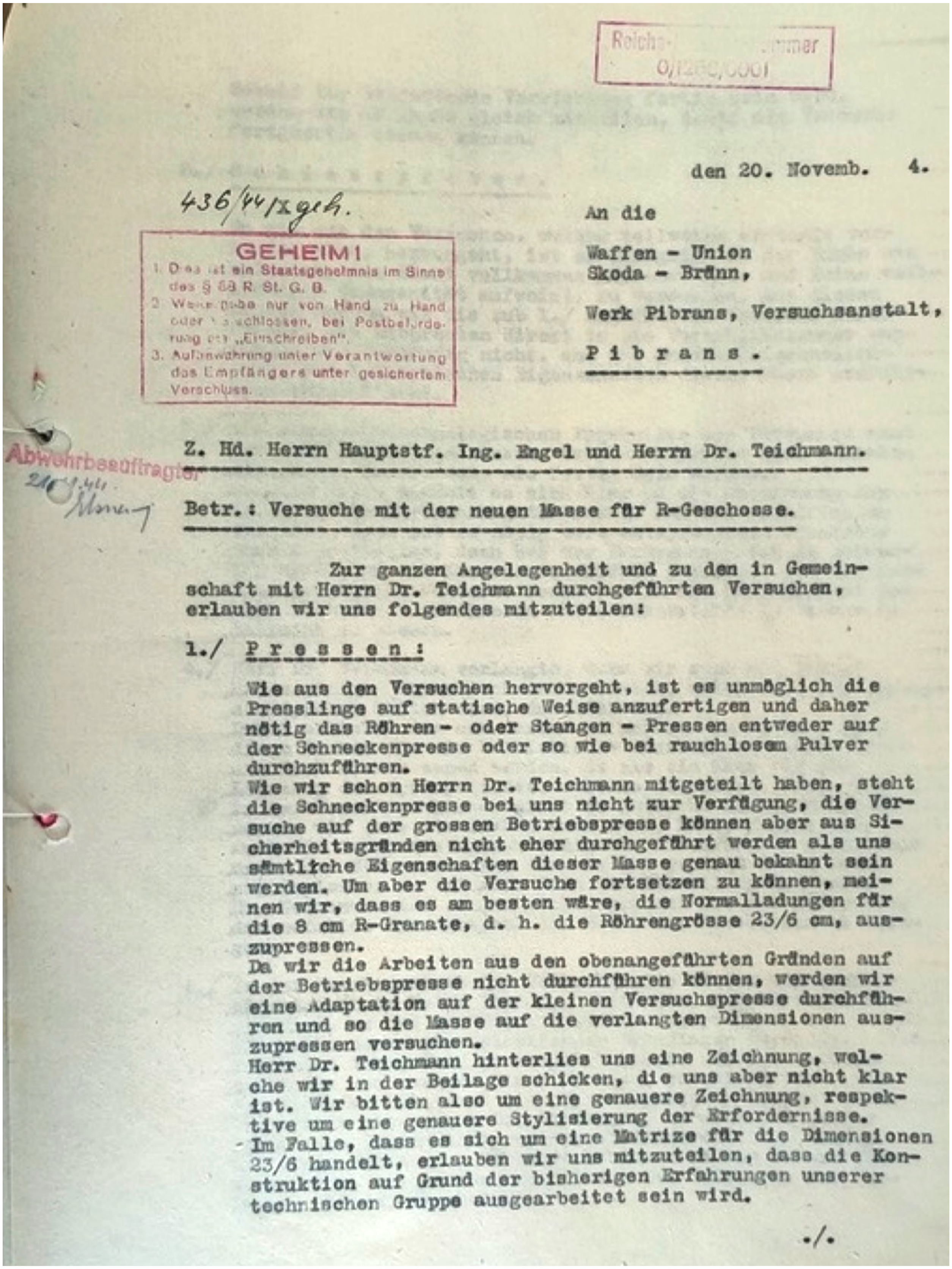
[This solid propellant mixture was probably dubbed Per-pulver or "per powder" because its dominant ingredient was ammonium perchlorate. It is mentioned in several of the documents in this section, and this appears to have been the origin and first use of truly modern solid propellant rocket propellant.

Where are the "later interrogations of Dr. Teichmann" that gave complete details about the solid rocket propellant, as mentioned in this report? An early interrogation of Teichmann appeared in the following report, BIOS 31, but in that early interrogation Teichmann was unwilling to reveal many of the details of his work on solid rocket propellant. Somewhere there must be much more detailed written reports on later interrogations of Teichmann, or even wartime or postwar reports written by Teichmann or others from his research group. Can those reports be located in archives?]

Hermann Teichmann. 7 June 1945. Survey of research work of Dr. Teichmann group [AFHRA C5094, frames 0770–0772]

[After the war, Hermann Teichmann and several other members of his solid propellant rocket group were interned at Camp Föhrenwald-Wolfratshausen in Bavaria by U.S. forces. They wrote this three-page letter to the American military occupying government in Munich offering their services to work for the United States. Without going into technical details, they explained that they had made important new inventions and discoveries with regard to solid rocket propellants.

While they were never hired by the United States or United Kingdom, they were apparently interrogated extensively by U.S. and U.K. scientific investigators. After they were released, they went to work in France.]



Reichs-[illegible]mmer
0/1256/0001

den 20. Novemb. 4.

436/44/IX geh.

GEHEIM!

1. Dies ist ein Staatsgeheimnis im Sinne des § 88 R. St. G. B.
2. Weitergabe nur von Hand zu Hand oder verschlossen, bei Postbeförderung als „Einschreiben".
3. Aufbewahrung unter Verantwortung des Empfängers unter gesichertem Verschluss.

An die
Waffen - Union
Skoda - Brünn,
Werk Pibrans, Versuchsanstalt,
Pibrans.

Abwehrbeauftragter
21.11.44

Z. Hd. Herrn Hauptstf. Ing. Engel und Herrn Dr. Teichmann.

Betr.: Versuche mit der neuen Masse für R-Geschosse.

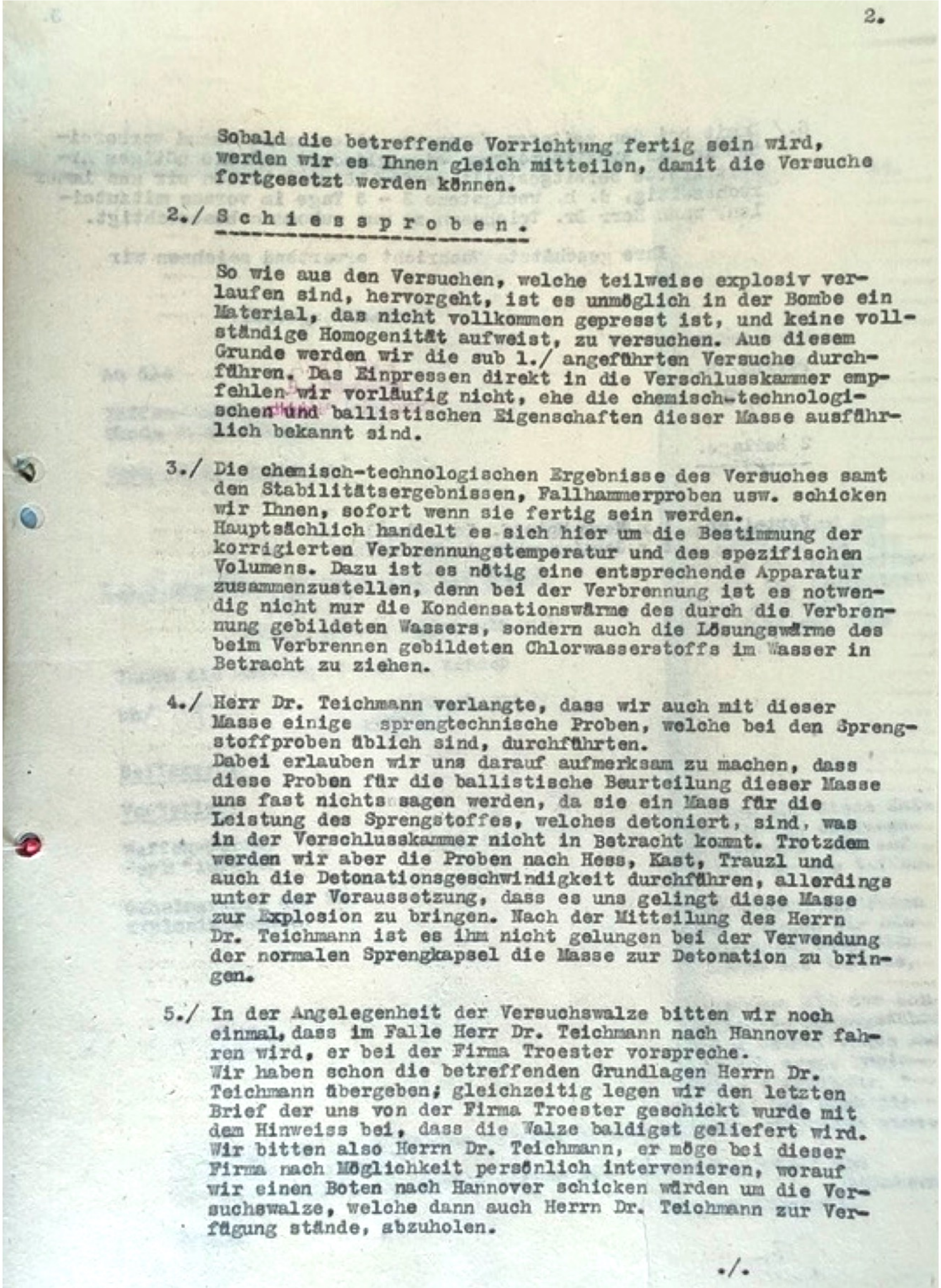
Zur ganzen Angelegenheit und zu den in Gemeinschaft mit Herrn Dr. Teichmann durchgeführten Versuchen, erlauben wir uns folgendes mitzuteilen:

1./ Pressen:

Wie aus den Versuchen hervorgeht, ist es unmöglich die Presslinge auf statische Weise anzufertigen und daher nötig das Röhren- oder Stangen - Pressen entweder auf der Schneckenpresse oder so wie bei rauchlosem Pulver durchzuführen.
Wie wir schon Herrn Dr. Teichmann mitgeteilt haben, steht die Schneckenpresse bei uns nicht zur Verfügung, die Versuche auf der grossen Betriebspresse können aber aus Sicherheitsgründen nicht eher durchgeführt werden als uns sämtliche Eigenschaften dieser Masse genau bekannt sein werden. Um aber die Versuche fortsetzen zu können, meinen wir, dass es am besten wäre, die Normalladungen für die 8 cm R-Granate, d. h. die Röhrengrösse 23/6 cm, auszupressen.
Da wir die Arbeiten aus den obenangeführten Gründen auf der Betriebspresse nicht durchführen können, werden wir eine Adaptation auf der kleinen Versuchspresse durchführen und so die Masse auf die verlangten Dimensionen auszupressen versuchen.
Herr Dr. Teichmann hinterlies uns eine Zeichnung, welche wir in der Beilage schicken, die uns aber nicht klar ist. Wir bitten also um eine genauere Zeichnung, respektive um eine genauere Stylisierung der Erfordernisse.
Im Falle, dass es sich um eine Matrize für die Dimensionen 23/6 handelt, erlauben wir uns mitzuteilen, dass die Konstruktion auf Grund der bisherigen Erfahrungen unserer technischen Gruppe ausgearbeitet sein wird.

./.

Figure E.226: 20 November 1944 letter demonstrating the involvement of Hermann Teichmann and Rolf Engel in tests of a solid rocket propellant that produced hydrochloric acid in the exhaust (a key characteristic of Per-pulver, due its ammonium perchlorate—see p. 5691).



2.

Sobald die betreffende Vorrichtung fertig sein wird, werden wir es Ihnen gleich mitteilen, damit die Versuche fortgesetzt werden können.

2./ Schiessproben.

So wie aus den Versuchen, welche teilweise explosiv verlaufen sind, hervorgeht, ist es unmöglich in der Bombe ein Material, das nicht vollkommen gepresst ist, und keine vollständige Homogenität aufweist, zu versuchen. Aus diesem Grunde werden wir die sub 1./ angeführten Versuche durchführen. Das Einpressen direkt in die Verschlusskammer empfehlen wir vorläufig nicht, ehe die chemisch-technologischen und ballistischen Eigenschaften dieser Masse ausführlich bekannt sind.

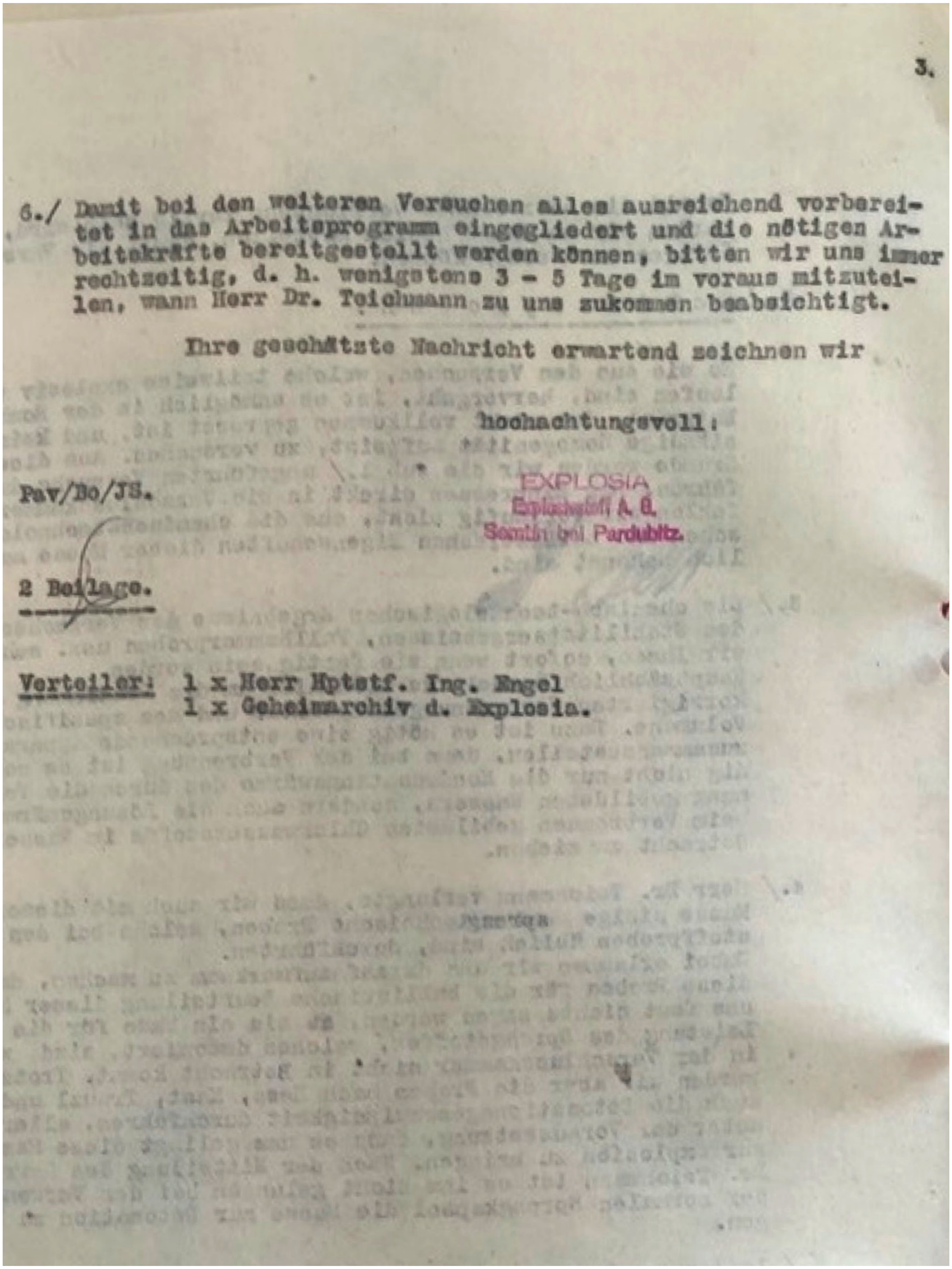
3./ Die chemisch-technologischen Ergebnisse des Versuches samt den Stabilitätsergebnissen, Fallhammerproben usw. schicken wir Ihnen, sofort wenn sie fertig sein werden.
Hauptsächlich handelt es sich hier um die Bestimmung der korrigierten Verbrennungstemperatur und des spezifischen Volumens. Dazu ist es nötig eine entsprechende Apparatur zusammenzustellen, denn bei der Verbrennung ist es notwendig nicht nur die Kondensationswärme des durch die Verbrennung gebildeten Wassers, sondern auch die Lösungswärme des beim Verbrennen gebildeten Chlorwasserstoffs im Wasser in Betracht zu ziehen.

4./ Herr Dr. Teichmann verlangte, dass wir auch mit dieser Masse einige sprengtechnische Proben, welche bei den Sprengstoffproben üblich sind, durchführten.
Dabei erlauben wir uns darauf aufmerksam zu machen, dass diese Proben für die ballistische Beurteilung dieser Masse uns fast nichts sagen werden, da sie ein Mass für die Leistung des Sprengstoffes, welches detoniert, sind, was in der Verschlusskammer nicht in Betracht kommt. Trotzdem werden wir aber die Proben nach Hess, Kast, Trauzl und auch die Detonationsgeschwindigkeit durchführen, allerdings unter der Voraussetzung, dass es uns gelingt diese Masse zur Explosion zu bringen. Nach der Mitteilung des Herrn Dr. Teichmann ist es ihm nicht gelungen bei der Verwendung der normalen Sprengkapsel die Masse zur Detonation zu bringen.

5./ In der Angelegenheit der Versuchswalze bitten wir noch einmal, dass im Falle Herr Dr. Teichmann nach Hannover fahren wird, er bei der Firma Troester vorspreche.
Wir haben schon die betreffenden Grundlagen Herrn Dr. Teichmann übergeben; gleichzeitig legen wir den letzten Brief der uns von der Firma Troester geschickt wurde mit dem Hinweiss bei, dass die Walze baldigst geliefert wird. Wir bitten also Herrn Dr. Teichmann, er möge bei dieser Firma nach Möglichkeit persönlich intervenieren, worauf wir einen Boten nach Hannover schicken würden um die Versuchswalze, welche dann auch Herrn Dr. Teichmann zur Verfügung stände, abzuholen.

./.

Figure E.227: 20 November 1944 letter demonstrating the involvement of Hermann Teichmann and Rolf Engel in tests of a solid rocket propellant that produced hydrochloric acid in the exhaust (a key characteristic of Per-pulver, due its ammonium perchlorate—see p. 5691).



3.

6./ Damit bei den weiteren Versuchen alles ausreichend vorbereitet in das Arbeitsprogramm eingegliedert und die nötigen Arbeitskräfte bereitgestellt werden können, bitten wir uns immer rechtzeitig, d. h. wenigstens 3 - 5 Tage im voraus mitzuteilen, wann Herr Dr. Teichmann zu uns zukommen beabsichtigt.

Ihre geschätzte Nachricht erwartend zeichnen wir

hochachtungsvoll:

EXPLOSIA
Explosivstoff A. G.
Semtin bei Pardubitz.

Pav/Bo/JS.

2 Beilage.

Verteiler: 1 x Herr Hptstf. Ing. Engel
1 x Geheimarchiv d. Explosia.

Figure E.228: 20 November 1944 letter demonstrating the involvement of Hermann Teichmann and Rolf Engel in tests of a solid rocket propellant that produced hydrochloric acid in the exhaust (a key characteristic of Per-pulver, due its ammonium perchlorate—see p. 5691).

BIOS 31. ***Rocket Developments in South Germany and Austria.***

[pp. 8–11:]

Target	Dr. Hermann Teichmann.	(E)
Location	Lager Föhrenwald (D.P. camp) Wolfratshausen. M.48 WY. 778 (U.S. zone)	
Nature of Target	Research chemist.	
Date visited	2.8.45.	

Dr. Teichmann graduated at Hanover in 1937 and then worked as an assistant to Prof. Jost at Hanover and at Leipzig.

He worked for various organisations including the German Air Ministry in Berlin and Strassbourg, leaving the latter city in August 1944 to continue work in the explosives (H.E.) factory at Wolfratshausen. There he was in charge of a group developing solid propellants for rockets. He is still in touch with other members of his group and is desirous of continuing his work.

He was to a large extent co-operative, but frankly admitted that he did not intend to reveal all the results of his work to everybody who questioned him, without some assurances regarding his future.

From 1937 until quite recently he was engaged on an academic study of gaseous combustion. [...]

He stressed the importance of the gaseous reactions as the factor controlling the rate of burning of solid propellants, and claimed to have based his design of a propellant on the results of his study of gaseous combustion.

According to his theories, any solid propellant, the burning of which involves a "liquid" layer between the solid unburnt propellant and the gaseous phase, will not burn reliably at low pressures, because the rate of the slowest reaction in the gaseous phase is slower than the rate of thermal decomposition of the solid. The result is "chuffing" and incomplete combustion. At higher pressures the gaseous reaction rate is enormously increased, whereas the rate of thermal decomposition is practically unaffected. The gaseous reactions, therefore, take control and burning proceeds smoothly and continuously.

He said that in Germany there was a complete mathematical theory of the burning of solid propellants in rockets, based on the reactions occurring in the gaseous phase.

He discoursed on the properties of propellants consisting of ammonium perchlorate bound with various plastic materials, either thermoplastic or heat irreversible materials. These, he claimed, gave no "liquid" layer on thermal composition.

A few small samples, which he possessed, were examined. They had not the appearance of colloidal propellants, but rather that of a consolidated material. Although they were hard, they were not brittle as would be expected, on striking with a hammer.

In replies to questions Dr. Teichmann claimed the following properties for these propellants.

A. Burning Characteristics

1. Stable burning at pressures from 20 to 700 atms.
2. Rate of burning could be varied over a wide range, by altering the composition, and could be made many times greater than that of normal colloidal propellants, even at low pressures.
3. Erosion effect was small at low pressures.
4. Smokeless.
5. Almost flashless, since combustion was practically complete, the products being N_2, H_2O, CO_2, HCl and a little CO.
6. Calorimetric value about 1000 cals./grm.
7. Performance index, 250.
8. Ignition presented no difficulties, owing to the reliability of burning at low pressures.
9. No erosion of the venturi had been observed after firing. It was his practice to use venturis of comparatively large throat diameter.

B. Physical Properties

1. Mechanical properties could be varied over a wide range from soft thermo plastic materials to hard infusible solids, depending, presumably, on the nature of the binder. (Teichmann would not say what plastics were used as binders).
2. S.G. about 1.8.

C. Charge Design

1. The thermoplastic propellants could be extruded at 120^{o}C. and used as sticks, or the more plastic varieties could be pressed into star centred charges adhering to the walls of the tube.
2. The rigid types could be cast and hardened either by warming or in the cold. He claimed good adhesion to steel even for these, and preferred the cast, cold hardening materials for large charges and the extruded thermoplastic varieties for small charges.

D. Storage and Safety

1. No deterioration either chemically or physically on long storage. Gassing did not occur below 180^{o}C.
2. Spontaneous ignition temperature, 270^{o}C.
3. Could be detonated by powerful initiation.

Dr. Teichmann said that development had not proceeded beyond the stage of static firings in vented vessels. His idea was to burn the propellant at lower pressures (300 lb./sq. in.) and thus increase the performance of the rocket by saving weight on the metallic components.

This team was not impressed by the mechanical properties of the samples of propellant examined, and doubted Teichmann's claim of good, permanent adhesion to steel. He appears, however, to have done a considerable amount of fundamental work on gaseous combustion, but this team was not sufficiently well acquainted with this field to be able to assess its value. [...]

[p. 30:]

Work on liquid fuel rockets had been confined principally to fundamental research, rather than to specific projects, although some routine work connected with development had been done. Dr. Sänger had not worked with solid propellants.

The object of the research was to increase the efflux velocity of the gases. Two methods had been investigated using the hydrocarbon/liquid oxygen system.

1. Increasing the heat content of the products of combustion (H_2O and CO_2) of the fuel by the dispersion in the fuel of certain light elements, e.g. Be, B, Li, Mg or Al.
2. The use of liquid ozone mixed with liquid oxygen.

[...] Sedimentation of dispersions of the aluminium in the hydrocarbon fuel (diesel oil) presented some difficulty, which was finally solved by stabilisation with oppanol (a hydrocarbon polymer). Sedimentation was then very slight after standing for one month.

The hydrocarbon/aluminium fuel gave rise to a large amount of white smoke from the rocket motor, as would be expected.

[Polybutadiene synthetic rubber was invented by German scientists in 1929–1930 (see pp. 656–657). Teichmann appears to have been working in this field of rocket propulsion since 1937.

This report also stated that aluminum powder was being used to increase the performance of large liquid propellant rockets, and even that highly novel chemical methods had been developed and demonstrated in order to keep the aluminum powder suspended in the liquid propellant for over a month during storage. While this report does not specifically mention the use of aluminum powder in large solid propellant rockets, it seems likely that that was done as well. For examples of other reports on the use of aluminum powder to improve the performance of small solid propellant rockets or closely related solid explosives in wartime Germany, please see the following reports.]

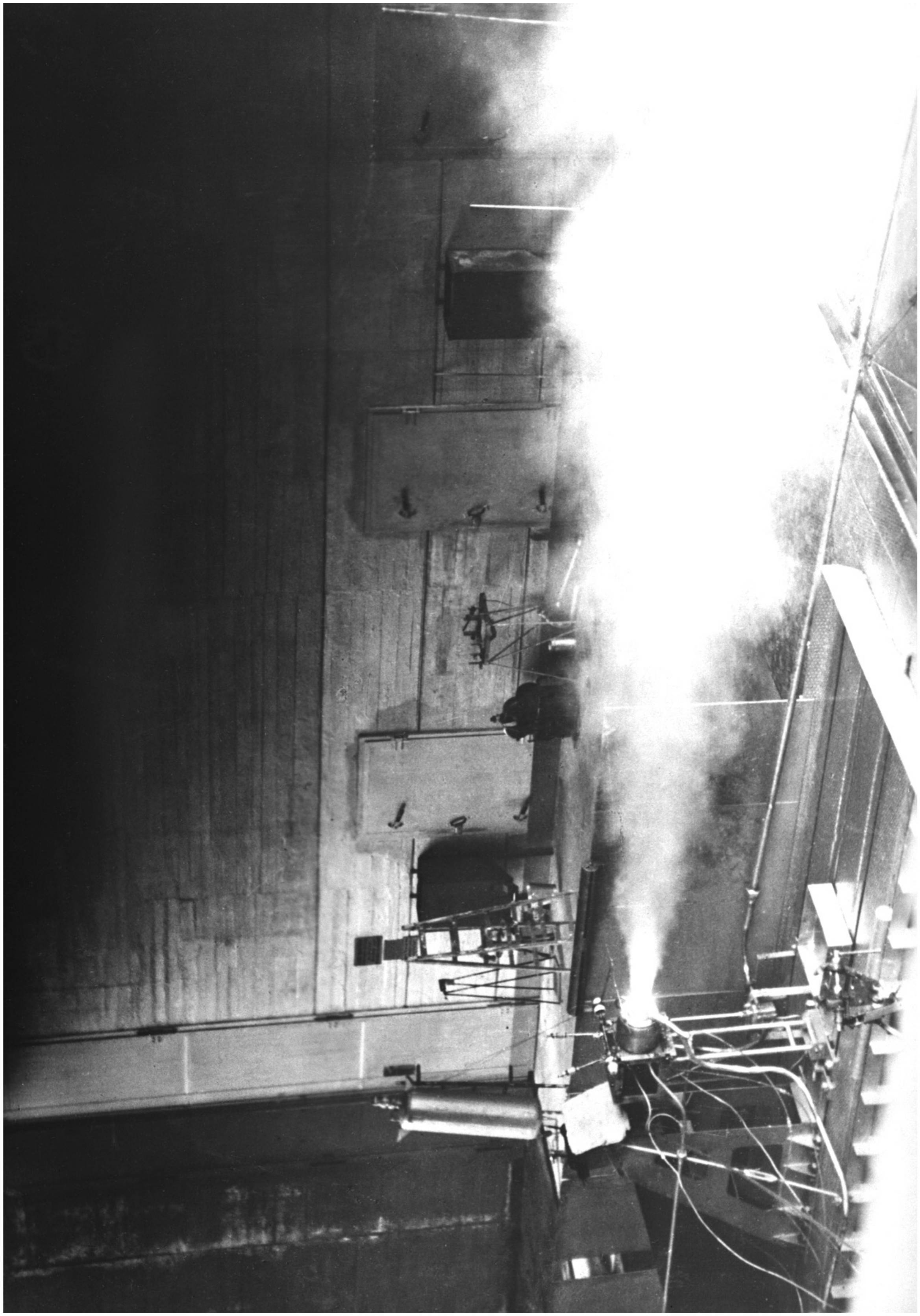


Figure E.229: 1941 test firing of one of Eugen Sänger's rocket engines using aluminum powder in the propellant mixture [Deutsches Museum Archive, photo 30389]

BIOS 27. ***Modern High Explosive Developments at Deutsche Waffen und Munitions Fabriken, A.G., Schlutup near Lübeck.***

The factory normally received its explosives already mixed in the form of lumps but Dr. Weidle had carried out a certain amount of research in order to determine the optimum proportions of the various ingredients. He found that 20 per cent aluminium mixed with 80 per cent of the hexogen/wax mixture gave the best blast effect in small light cased munitions. [...] Aluminium in flake form was used in the early days of development but had been abandoned in favour of granulated owing to difficulties in handling the former. [...] The size of the granulated aluminium used was stated to be all through a 0.15 mm aperture sieve. [...]

Production of the mixture was said to be carried out in the following way. The T.N.T. was melted in a steam kettle, dry hexogen added with stirring and finally the aluminium. 50 litre kettles were used and the mixture stirred by a conventional propeller stirrer.

(iii) and (iv) were used as poured fillings for hollow charge ammunition[...]

BIOS 1261. ***Visit to German High Explosive and Filling Factories.*** **pp. 9–10.**

The W.A.S.A.G., Allendorf, Kreis Marburg, Hesse was visited on 16.10.45. [...]

Dr. Walther Naumann, formerly a director of the factory, was available for interrogation and demonstration of sections of the plant required. [...]

When preparing hexanite/aluminium the T.N.T. was first melted and run into a jacketed stainless steel mixer. The aluminium was added next and the hexanitrodiphenylamine last. Similarly when preparing trialen 105 or 106 the T.N.T. was charged first, the aluminium next and then the hexogen. [...]

Dr. Naumann stated that larger mixing units than the type seen had been installed more recently, these having a capacity of 1000 Kg. as compared with the 400 Kg. units of the original plant.

With regard to the aluminium powder it was stated that two types were used viz. Pyro-schliff and Griess. The first of these was prepared by grinding and the second was a fine blown aluminium. Pyro-schliff was very dusty but was less inclined to sedimentation than the coarser blown powder. All the aluminium was specified to pass a sieve of 6400 meshes per sq. cm., approximately 200-mesh. A chemical specification was in existence but not available for inspection. The management were conscious of the risk of ignition of airborne fine aluminium powder through electrical agency and had in fact experienced two ignitions attributable to this cause. Owing to the provision of a simple drenching apparatus fitted to the mixing unit there were no serious consequences to these ignitions. The aluminium was fed to the pan through a stainless steel funnel attached to the pan-cover and fitted with a wide skirt which directed the aluminium against the wall of the pan, the object being to remove as much as possible of any accumulated static charge on the powder.

BIOS 100. *Development of Panzerfaust.* pp. 10–11.

Langweiler appeared to attach more importance to the flame effect behind the target than the remaining power of the jet itself. The enhancing of this flame effect was in his opinion the most likely method of increasing the efficiency of hollow charges. This effect could be increased very greatly by incorporating into the H.E. charge up to 30% of powdered aluminium. This proportion could be used without impairing performance. Had it not been for the great shortage of aluminium in Germany this type of filling would have been used in Panzerfaust.

NavTecMisEu 327-45. *Solid Rocket Propellant. Translation of a Report by Dipl. Ing. Hans Grosse.* p. 14. [NARA RG 38, Entry P5, Box 46]

In general black powder was used as an auxiliary charge. Black powder causes a relatively slight ignition delay, however, is sensitive to moisture and as far as transportation is concerned, and increases the creation of smoke. In cold temperatures, furthermore, it does not always give a sufficiently intensive ignition, especially in the case of long charges. Therefore, besides black powder, boosters were also used. These consist of mixtures of a composition similar to that of flash light powder for photographic purposes, i.e., light metal dust, Al., Mg., together with salts giving off oxygen, such as potassium nitrate, barium nitrate, etc. These mixtures are firmly pressed in capsules of aluminum, lately also of cardboard. They produce, especially at low temperatures, a very hot flame and thus avoid ignition failure in this temperature range. At high temperature they do not effect such a great increase in gas pressure as does a black powder auxiliary charge of an equally strong ignition effect, because they develop relatively little gas.

HEC 2434. German patent D70226. Use of black powder for rocket propulsion, containing metal sulfides and/or metal alloys which give off oxygen on heating.

HEC 2485. Propellant for rockets which discharges vapours of metals or their salts.

HEC 2487 = HEC 2468. Powdered metals as ingredients of rocket propellants.

BIOS 477. *German Pyrotechnic Factories* [aluminum powder for pyrotechnic manufacture]

FIAT 1035. *German Developments in High Explosives.*

[See also the 1942 Peenemünde document on p. 5758.]

R. V. Shepherd. BIOS 313. ***Report on Visit to Czechoslovakia by Armament Design Department. 16th November to 9th December, 1945.***

[p. 5:]

[...] All visits and official interviews were arranged in conjunction with the Czech military intelligence and a Czech officer was present on these occasions. [...]

[...] The following persons were interviewed at the Czech War Office:

[...] Dr. W. Voss	[...] Head of Waffen Union
[...] Ing. K. Staller	[...] Deputy to Dr. Voss
Ing. Musel	Managing Director, Zbrojovka
Ing. S̆idlék	Czechomoravian Engineering Works
Dr. Frey	Jawa

[pp. 29–32:]

EXPERIMENTAL STATION AT PRIBRAM

[...] The preliminary work for the formation of the station was started late in 1943 and it was not until the early summer of 1944 that the staff commenced serious work. [...]

There is a fact which should be noted. When the buildings were visited in late November, they were completely stripped and only one engineer and a woman secretary left in charge. In answer to the query as to what had happened to the library, equipment and staff it was stated that the Mining Institute had been removed to Moravaka Ostrava and the scientific staff had returned to Charles University, the technical schools and firms from whom they had come originally. It is remarkable that a move of some magnitude involving a journey from the west side of Bohemia to the Eastern frontier should have been carried out with such completeness within six months of the end of the war in Europe considering the difficulties of road and rail transport during this period.

[...] Staff. The strength of the Institute was 350. This figure includes workmen as well as the higher staff. Skoda and Zbrojovka contributed engineers and designers, whilst the scientific staff was recruited from the Universities and technical schools.

The card index covering the whole of the staff was produced for inspection at Pribram. A cursory examination of the cards revealed a fair percentage of German staff[...]

The following details of some of the personnel were compiled from the card index and other sources. [...]

Engel, Rolf. Born in 1912. Came from the research institute at Grossendorf and arrived at Pribram on 23.7.44 to take charge of a section. A Diploma Engineer and a physicist. Later he took charge of the whole Institute. Stated to be a most able engineer and mathematician. Was Hauptsturmführer in the S.S. Escaped to Germany and was last heard of south of Munich. [...]

Bödewadt. Dr. Born 1911 at Essen. Came from the research institute at Grossendorf and was chief of ballistics. He escaped. [...]

Teichmann, Hermann. Dr. Born 1913. A doctor of engineering who worked on explosives and also did administration. Escaped.

Schmidt, Kurt. Dr. Born 1912. Also an engineer. Worked on chemical research.

Schmidt, Walter. Dr. Head of the Chemical Department and came from the Waffen-Union. Held in prison at Pribram.

Bock, Helmuth. Born 1923. A machine designer in the technical section.

Nordt, Dr. Worked on explosives. Escaped. [...]

Seifert, Hugo. Ing. In charge of the workshops. Imprisoned at Pribram.

Kucera. Leader of Werkschutz. Imprisoned at Pribram.

Larsson. A Swede engaged on the study of rockets.

Votruba, Karel. Dr. Ing. Was chief of the high frequency group. A Czech and now with VTR research.

Simon, Inval. Dr. Czech. Chief of the low frequency group. Now back at Charles University, Prague.

Truha, Zdenek. Dr. Ing. Czech. Chief of the section dealing with long distance control and measuring. Now working in a technical school in Prague.

Broz, Jaroslav, Dr. Czech. Head of the magnetic section. Now with VTR research.

Jahoda, Dr. Czech. Manager of range laboratories at Drahelcice.

Zbozinek, Arnost, Ing. A Skoda man and head of the general design. Now working in the national administration at Klastenec Nad Ohri.

Stelsovsky, Jan. Ing. Czech. Head of the rocket design section. Is now in the Czech Army.

Sternad, Dr. Czech. Born 1912. A Skoda man who worked in the physics section at Pribram. Considered one of the more outstanding technical men.

Kalendovsky, Dr. Czech. Born 1911. Worked as an engineer.

Buresova, Florentine, Ing. (Woman). Born 1922. A German chemical research worker.

Behounek, Dr. Ing. No other information other than that he is under interrogation as as doubtful Czech.

Knust, Dr. Born 1915. A chemist and belonged to the S.S. A German.

Odstracil, Ing. Czech. An engineer and scientist employed by Zbrojovka.

The above particulars are in many cases very sketchy, indeed some are just the bare facts taken from the card index. In others this information has been supplemented. [...]

[p. 42:]

The purpose of the institute was to prepare the documentation for production and to make prototypes of new products included into the manufacturing programme of the company Waffen Union. It was engaged in the study of rockets, especially from the theoretical point of view and therefore preparatory tests were carried out. As an example of the research work we are stating the high frequency transmission for transmitting the shooting elements at a distance of 10 km., stabilization device for shooting from tanks by means of a telescope on a gyroscope, simultaneous aiming and directing of a number of machine-guns, study of directing the rockets by means of infra red rays.

[p. 68:]

Baubin. Was permanent secretary of Skoda. A member of the S.D. [...]

Staller, Karel Ing. Acted as deputy to Voss but worked in the resistance movement and has been cleared of suspicion of collaboration. He has been given a certificate from Czech General Headquarters to this effect. One of the most able engineers in Czechoslovakia. Sent over 120 engineers and designers to Allies, as well as machine tools. [...]

Voss, Wilhelm, Dr. Born 1896. A jurist and accountant. Came from Rostock Mecklenberg and was educated at the Universities of Berlin and Leipzig. Trained as an accountant and worked in an agricultural organisation and the legal branch of an insurance company. Visited England in 1926 and read paper to an international congress of accountants. Joined the Nazi party in 1937. Was appointed in 1938 as General Director of Administration and Commerce in the Hermann Goering Trust in Berlin and in 1939 came to Prague.

Differences with Pleiger caused Goering to form the Skoda Brünn Waffen Union and Voss put in charge. He was dismissed in January 1945 as unsatisfactory. Now in prison in Prague.

[Despite the deep involvement of Hans Kammler and Erich Purucker with these facilities and programs, all mention of them has been carefully omitted from this BIOS report (compare with the information on p. 4914). Likewise all mention of nuclear-related work has been carefully omitted (compare with pp. 3751–3754).]

Tom Bower. 1987. *The Paperclip Conspiracy: The Hunt for the Nazi Scientists.* Boston: Little, Brown. p. 151.

Rolf Engel, an SS officer who during the war had supervised the production of solid-fuel rockets at a Skoda plant in Czechoslovakia, was recruited by French agents while hiding in the American zone, fearing arrest for his wartime activities.

[Rolf Engel, Uwe Bödewadt, and Hermann Teichmann all went to work for France after the war (p. 1883). Information on their postwar contributions is not publicly available, but presumably they were instrumental in developing modern solid propellant missiles and rockets in France, and they may have made important contributions in other areas—such as nuclear weapons—as well.]

Jan Kotůlek. František Čuřík (†June 7, 1944): The First Professor of Mathematics and Descriptive Geometry at Mining University (VŠB).
[http://homel.vsb.cz/~kot31/Veda/23-3mi-s71-76Kotulek.pdf]

[...] Some of his colleagues from VŠB promoted the story that František Čuřík was forced by the Nazis to collaborate in their company Waffen-Union research institute in Příbram (contemporary German name of the town was Pibrans) on the ballistic computations of missiles V-2. He resolutely refused it as treason and, because he could not see any other way out of this situation, he took his own life, cf. [7].

However, the story is probably only partially based on the truth. The holding company Waffen-Union Skoda-Brünn worked in weapon industry within the concern Reichswerke Hermann Göring. The top management was exclusively German, but research divisions were under Czech governance, mathematical research division was led by Miloslav Hampl (1897–1974) and physics division by Professor Václav Dolejšek (1895–1945), who handed his responsibilities to dr. Miloslav Tayerle during 1940. Tayerle should have set up the research institute of Waffen-Union in Příbram. He brought his collaborators from Skoda, hired some researchers from Zbrojovka Brno (Brünn) and counted also with some professors from the closed VŠB in Příbram. Their names are listed in the report about the visit of the Mining University from October 9 1943: Jirkovský, Šebesta, Čechura, Glazunov and Mitinský. František Čuřík, then already pensioned for three years, was not considered. However, in this period, there was also no rocket research.

The situation changed rapidly in August 1944, when SS-Hauptsturmführer Rolf Engel, head of the Versuchsanstalt für Strahltriebwerke in Grossendorf, evacuated his institute from West Prussia to the Protectorate of Bohemia and Moravia and overtook the governance of the research facilities in Příbram. He had already worked intensively in the rocket research for SS and he strictly opposed the German army project of V-2, cf. [6]. When Engel came to Příbram, Čuřík was already dead. But even if Engel had looked for collaborators in the spring 1944, he would not have chosen Čuřík. Ballistics was a key discipline, controlled entirely by the Germans, and Engel had his own mathematicians with expertise in ballistics, namely Dr. Uwe Tim Bödewadt (1911–2003), Dr. Franz Kalscheuer (1913–2002), Niels W. Larsson or H. Teichmann, see [3].

[...]

[3] Kotůlek J.: Angewandte Mathematik in der Rüstungsforschung der Škoda-Werke; mit Akzent auf der Versuchsanstalt der Waffen-Union Škoda-Brünn in Příbram. In: Fothe M., Schmitz M., Skorsetz B., Tobies R. (eds.): *Mathematik und Anwendungen*, Forum 14 (Thillm, Bad Berka, 2014), 50–57.

[...]

[6] Neufeld M.J.: Rolf Engel vs. the German Army: a Nazi career in rocketry and repression, *History and Technology* 13 (1996), 53–72.

[7] Pajer M.: K vývoji a výrobě raketových zbraní v Příbrami v letech druhé světové války, *Podbrdsko* 13 (2006), 155–164.

Robert Taylor 3rd. 16 July 1946. Subject: Assembling Certain German Scientific Personnel for Interrogation. [NARA RG 319, Entry NM3-47B, Box 991, Folder 400. 112 Research/009. 14 May 1945]

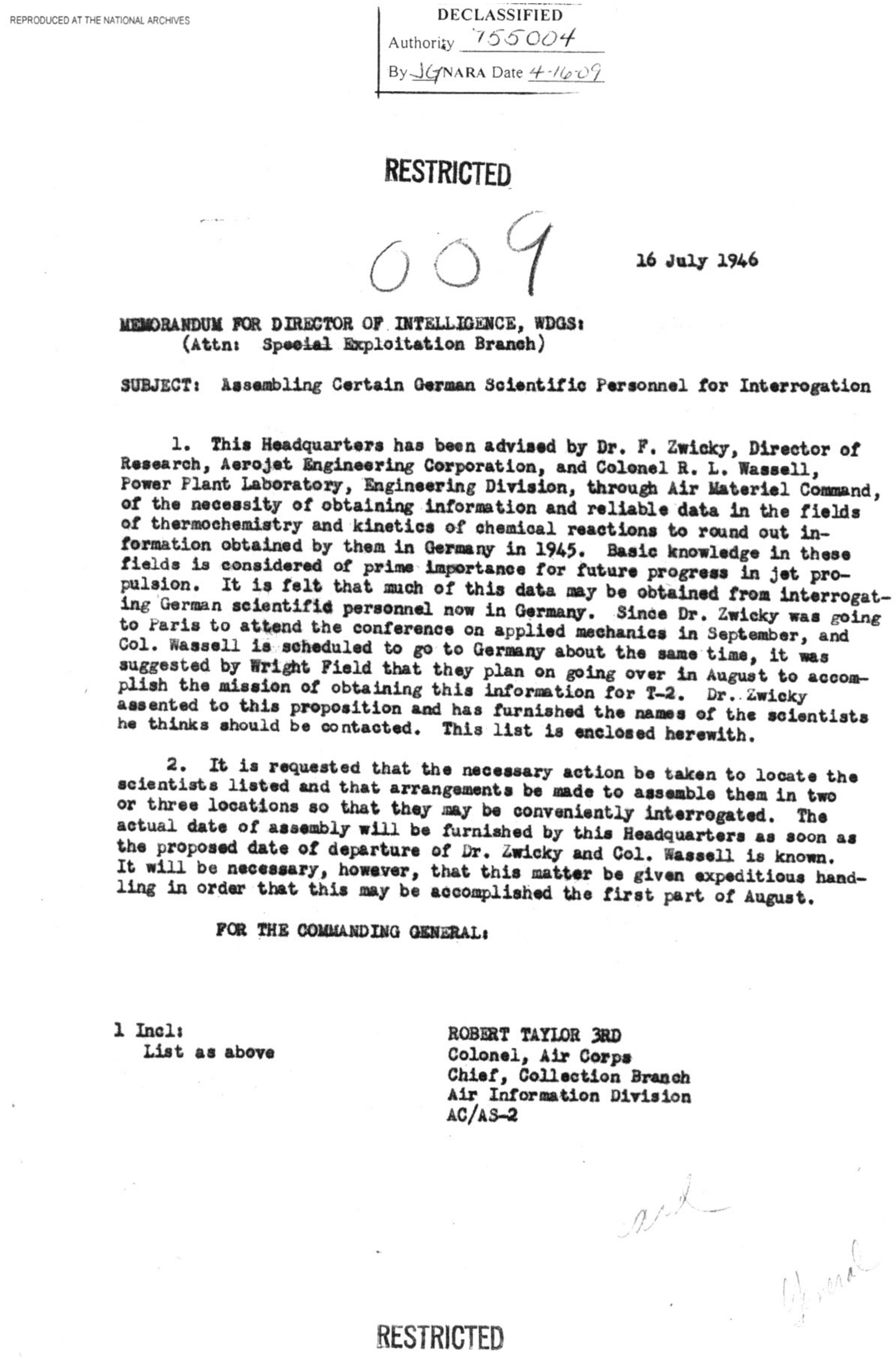
1. This Headquarters has been advised by Dr. F. Zwicky, Director of Research, Aerojet Engineering Corporation, and Colonel R. L. Wassell, Power Plant Laboratory, Engineering Division, through Air Materiel Command, of the necessity of obtaining information and reliable data in the fields of thermochemistry and kinetics of chemical reactions to round out information obtained by them in Germany in 1945. Basic knowledge in these fields is considered of prime importance for future progress in jet propulsion. It is felt that much of this data may be obtained from interrogating German scientific personnel now in Germany. [...]

2. It is requested that the necessary action be taken to locate the scientists listed and that arrangements be made to assemble them in two or three locations so that they may be conveniently interrogated. [...]

PARTIAL LIST OF GERMAN THERMOCHEMISTS HAVING RECENT PUBLICATIONS

NAME	INSTITUTE ASSOCIATED WITH AT TIME OF PUBLICATION	LAST KNOWN ADDRESS
[...]	[...]	[...]
Teichmann, Dr.	He and staff were associated with Prof. Jost. Group has very good ideas about chemical reaction problems important for jet propulsion. Teichmann joined Waffen Union, Skoda, Pibrans in 1944. He and staff was at Camp Föhrenwald, Wolfratshausen, Bavaria in 1945. It is important to find Dr. Teichmann.	Hindenburgstrasse 96A, Berlin-Wilmersdorf

[Please see this complete memo on the following pages.]



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Authority 755004
By JG NARA Date 4-16-09

RESTRICTED

009

16 July 1946

MEMORANDUM FOR DIRECTOR OF INTELLIGENCE, WDGS:
(Attn: Special Exploitation Branch)

SUBJECT: Assembling Certain German Scientific Personnel for Interrogation

1. This Headquarters has been advised by Dr. F. Zwicky, Director of Research, Aerojet Engineering Corporation, and Colonel R. L. Wassell, Power Plant Laboratory, Engineering Division, through Air Materiel Command, of the necessity of obtaining information and reliable data in the fields of thermochemistry and kinetics of chemical reactions to round out information obtained by them in Germany in 1945. Basic knowledge in these fields is considered of prime importance for future progress in jet propulsion. It is felt that much of this data may be obtained from interrogating German scientific personnel now in Germany. Since Dr. Zwicky was going to Paris to attend the conference on applied mechanics in September, and Col. Wassell is scheduled to go to Germany about the same time, it was suggested by Wright Field that they plan on going over in August to accomplish the mission of obtaining this information for T-2. Dr. Zwicky assented to this proposition and has furnished the names of the scientists he thinks should be contacted. This list is enclosed herewith.

2. It is requested that the necessary action be taken to locate the scientists listed and that arrangements be made to assemble them in two or three locations so that they may be conveniently interrogated. The actual date of assembly will be furnished by this Headquarters as soon as the proposed date of departure of Dr. Zwicky and Col. Wassell is known. It will be necessary, however, that this matter be given expeditious handling in order that this may be accomplished the first part of August.

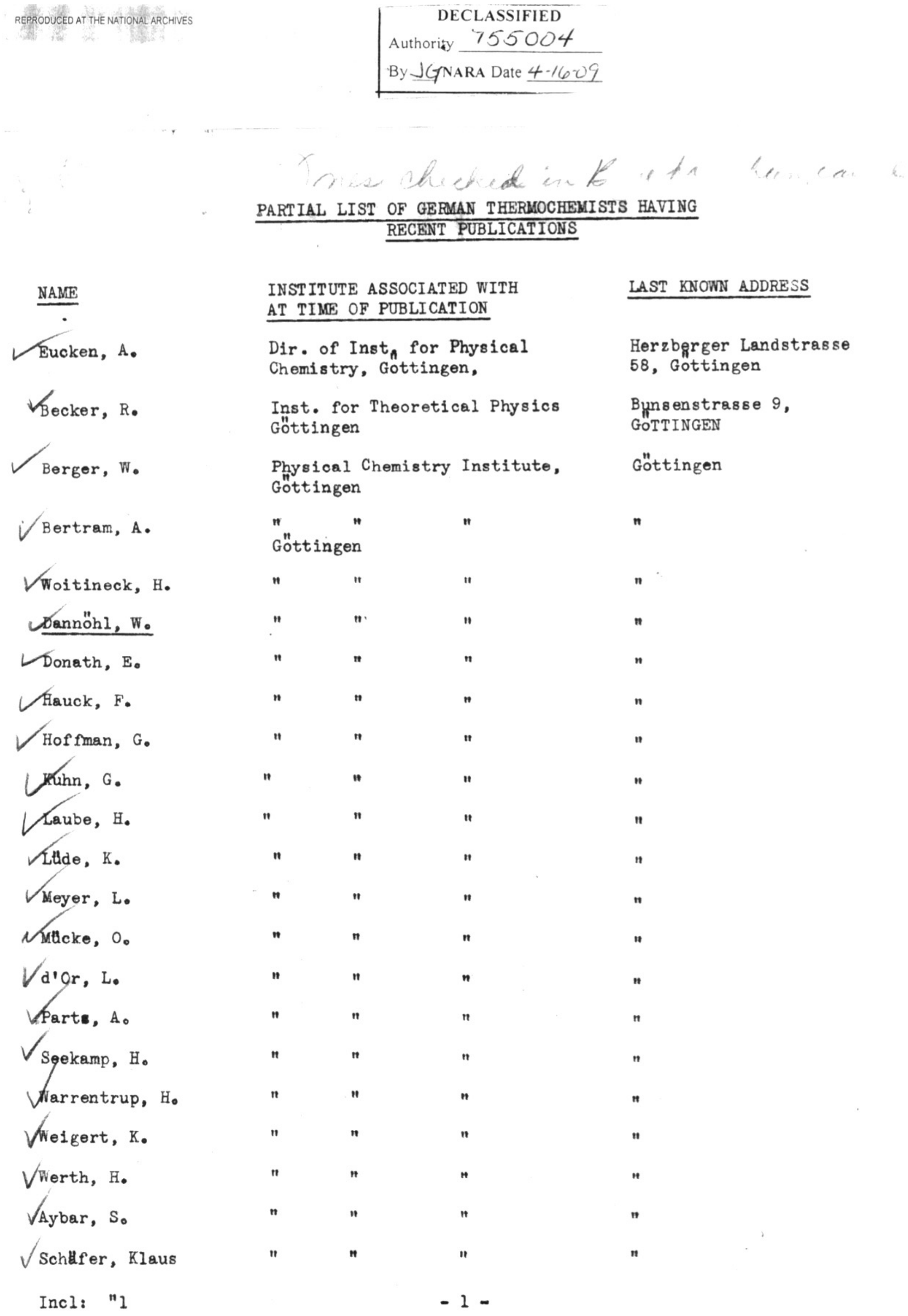
FOR THE COMMANDING GENERAL:

1 Incl:
List as above

ROBERT TAYLOR 3RD
Colonel, Air Corps
Chief, Collection Branch
Air Information Division
AC/AS-2

RESTRICTED

Figure E.230: 16 July 1946 list of German scientists to be interrogated by Fritz Zwicky. [NARA RG 319, Entry NM3-47B, Box 991, Folder 400. 112 Research/009. 14 May 1945]



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Ones checked in B [illegible] [illegible]

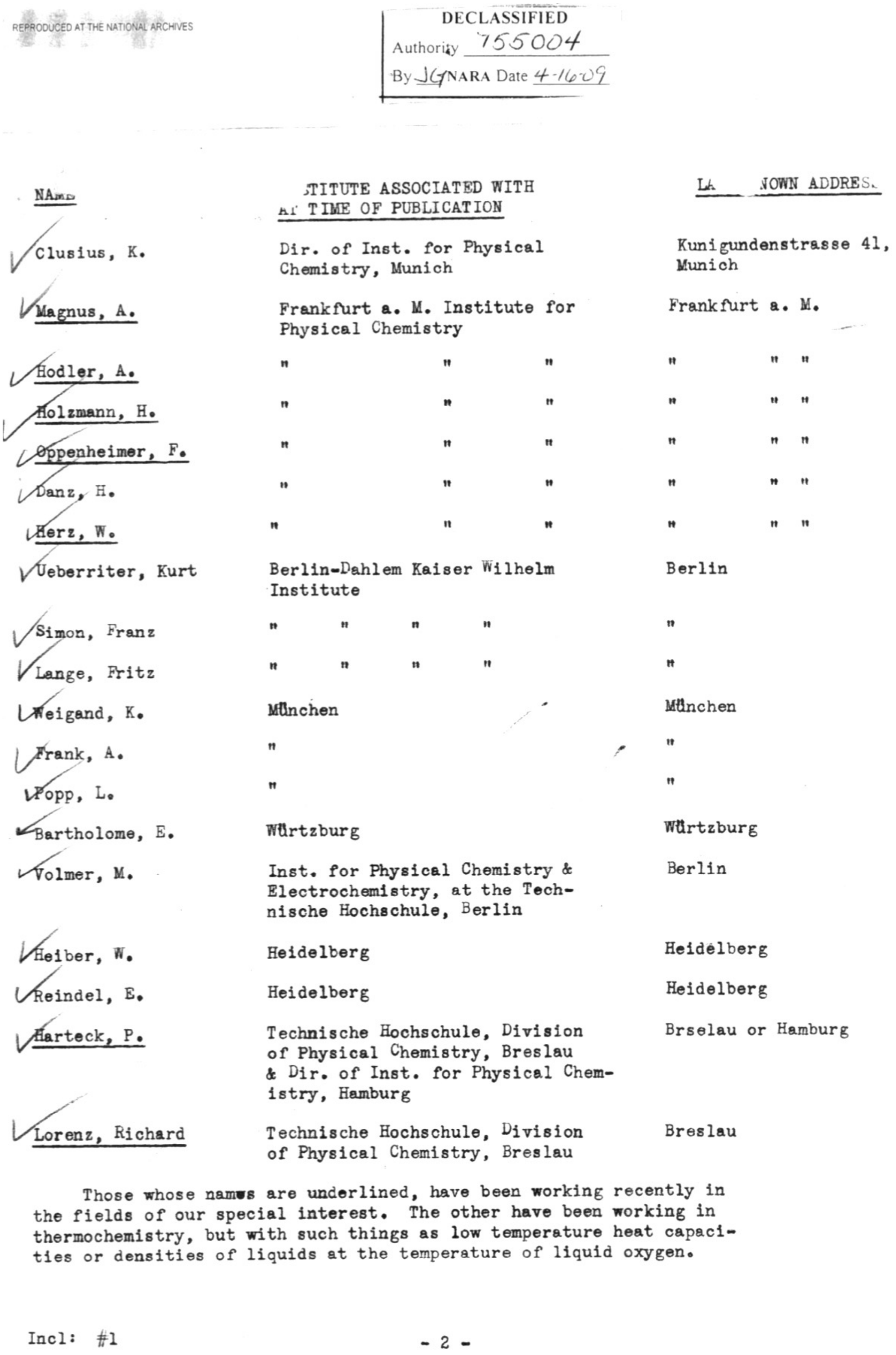
PARTIAL LIST OF GERMAN THERMOCHEMISTS HAVING RECENT PUBLICATIONS

NAME	INSTITUTE ASSOCIATED WITH AT TIME OF PUBLICATION	LAST KNOWN ADDRESS
✓ Eucken, A.	Dir. of Inst. for Physical Chemistry, Gottingen,	Herzberger Landstrasse 58, Gottingen
✓ Becker, R.	Inst. for Theoretical Physics Göttingen	Bunsenstrasse 9, GöTTINGEN
✓ Berger, W.	Physical Chemistry Institute, Göttingen	Göttingen
✓ Bertram, A.	" " " Göttingen	"
✓ Woitineck, H.	" " "	"
✓ Dannöhl, W.	" " "	"
✓ Donath, E.	" " "	"
✓ Hauck, F.	" " "	"
✓ Hoffman, G.	" " "	"
✓ Kuhn, G.	" " "	"
✓ Laube, H.	" " "	"
✓ Lüde, K.	" " "	"
✓ Meyer, L.	" " "	"
✓ Mücke, O.	" " "	"
✓ d'Or, L.	" " "	"
✓ Parts, A.	" " "	"
✓ Seekamp, H.	" " "	"
✓ Warrentrup, H.	" " "	"
✓ Weigert, K.	" " "	"
✓ Werth, H.	" " "	"
✓ Aybar, S.	" " "	"
✓ Schäfer, Klaus	" " "	"

Incl: "1

- 1 -

Figure E.231: 16 July 1946 list of German scientists to be interrogated by Fritz Zwicky. [NARA RG 319, Entry NM3-47B, Box 991, Folder 400. 112 Research/009. 14 May 1945]



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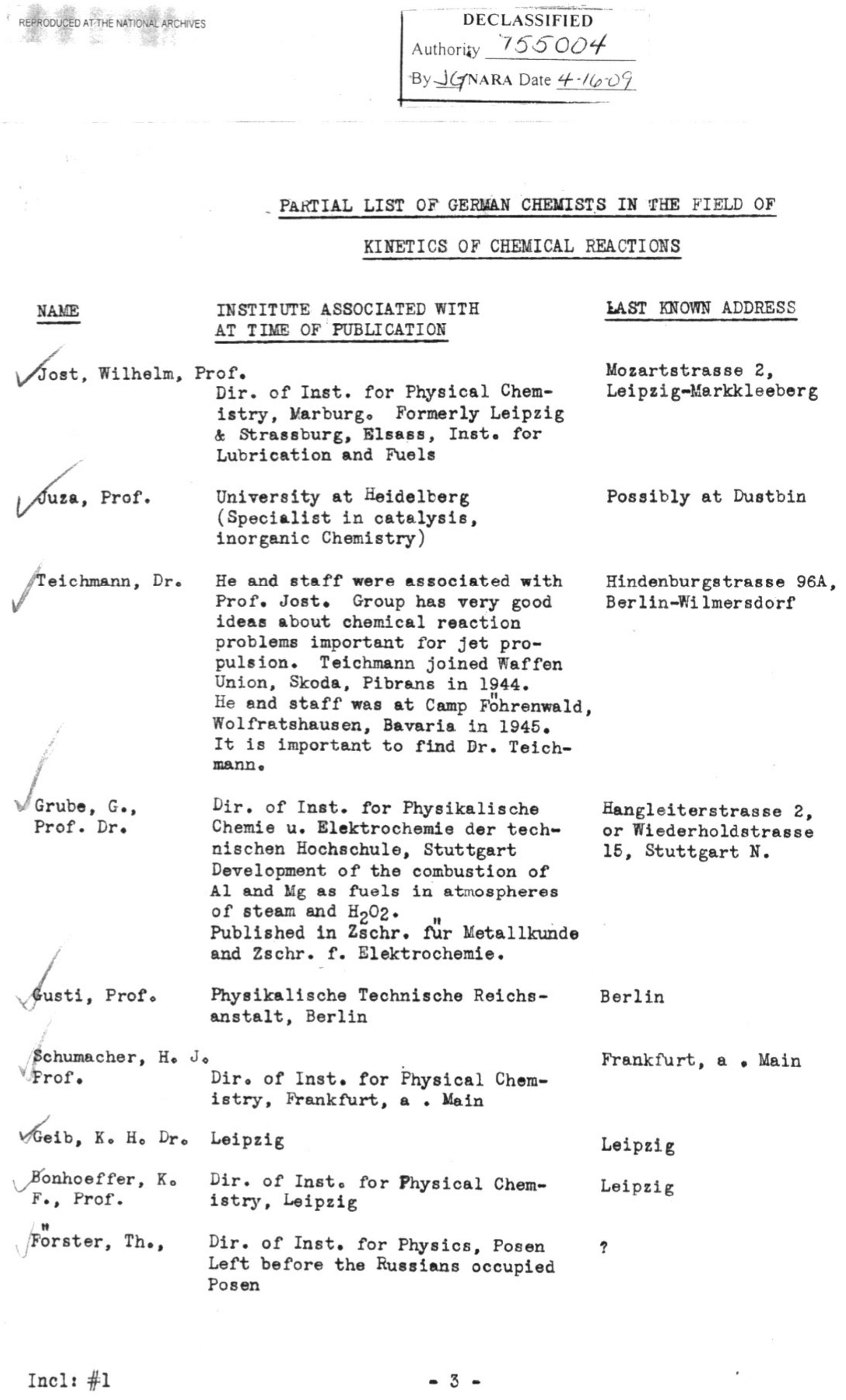
NAME	INSTITUTE ASSOCIATED WITH AT TIME OF PUBLICATION	LAST KNOWN ADDRESS
Clusius, K.	Dir. of Inst. for Physical Chemistry, Munich	Kunigundenstrasse 41, Munich
Magnus, A.	Frankfurt a. M. Institute for Physical Chemistry	Frankfurt a. M.
Hodler, A.	" " "	" " "
Holzmann, H.	" " "	" " "
Oppenheimer, F.	" " "	" " "
Danz, H.	" " "	" " "
Herz, W.	" " "	" " "
Ueberriter, Kurt	Berlin-Dahlem Kaiser Wilhelm Institute	Berlin
Simon, Franz	" " " "	"
Lange, Fritz	" " " "	"
Weigand, K.	München	München
Frank, A.	"	"
Popp, L.	"	"
Bartholome, E.	Würtzburg	Würtzburg
Volmer, M.	Inst. for Physical Chemistry & Electrochemistry, at the Technische Hochschule, Berlin	Berlin
Heiber, W.	Heidelberg	Heidelberg
Reindel, E.	Heidelberg	Heidelberg
Harteck, P.	Technische Hochschule, Division of Physical Chemistry, Breslau & Dir. of Inst. for Physical Chemistry, Hamburg	Brselau or Hamburg
Lorenz, Richard	Technische Hochschule, Division of Physical Chemistry, Breslau	Breslau

Those whose names are underlined, have been working recently in the fields of our special interest. The other have been working in thermochemistry, but with such things as low temperature heat capacities or densities of liquids at the temperature of liquid oxygen.

Incl: #1

- 2 -

Figure E.232: 16 July 1946 list of German scientists to be interrogated by Fritz Zwicky. [NARA RG 319, Entry NM3-47B, Box 991, Folder 400. 112 Research/009. 14 May 1945]



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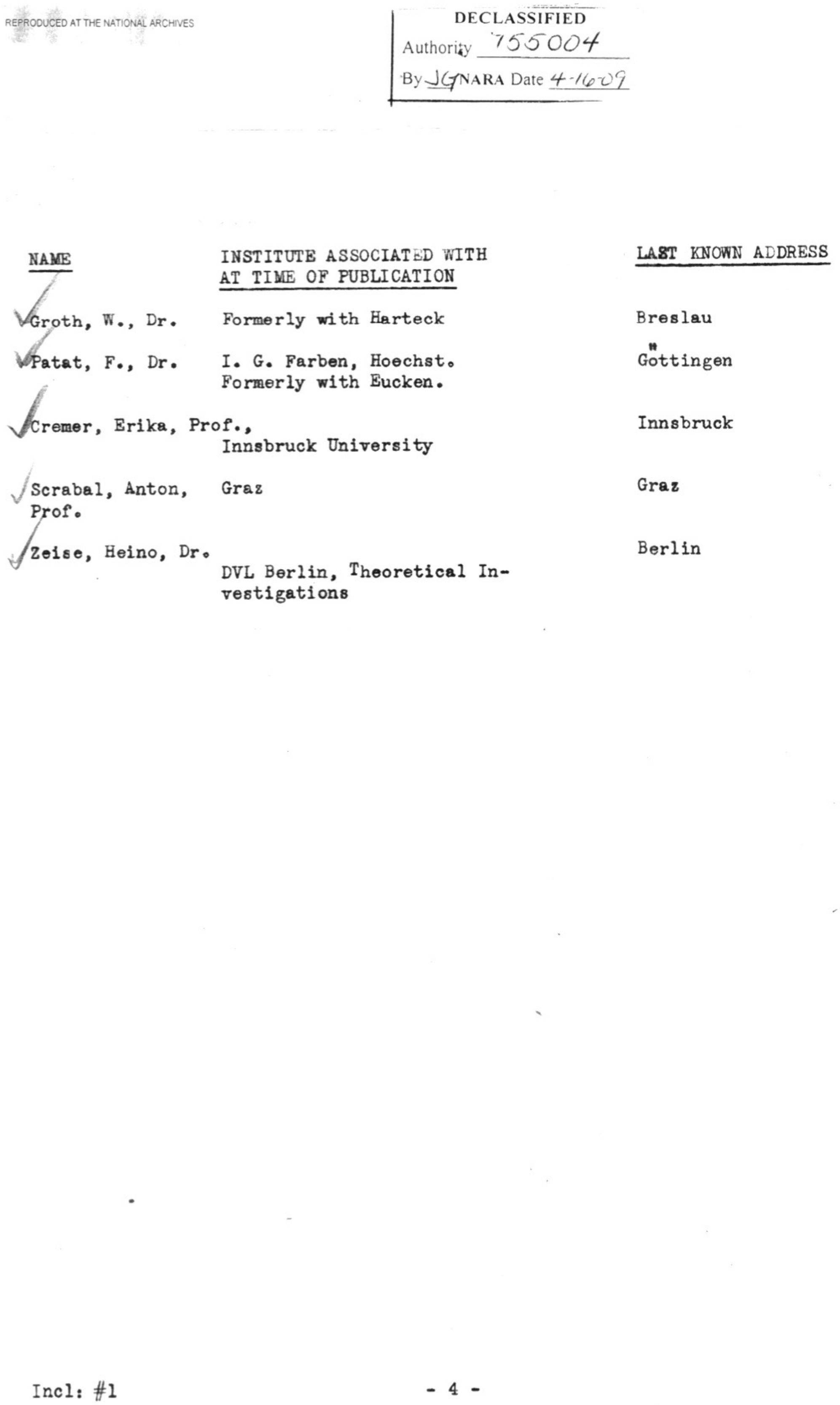
PARTIAL LIST OF GERMAN CHEMISTS IN THE FIELD OF KINETICS OF CHEMICAL REACTIONS

NAME	INSTITUTE ASSOCIATED WITH AT TIME OF PUBLICATION	LAST KNOWN ADDRESS
✓ Jost, Wilhelm, Prof.	Dir. of Inst. for Physical Chemistry, Marburg. Formerly Leipzig & Strassburg, Elsass, Inst. for Lubrication and Fuels	Mozartstrasse 2, Leipzig-Markkleeberg
✓ Juza, Prof.	University at Heidelberg (Specialist in catalysis, inorganic Chemistry)	Possibly at Dustbin
✓ Teichmann, Dr.	He and staff were associated with Prof. Jost. Group has very good ideas about chemical reaction problems important for jet propulsion. Teichmann joined Waffen Union, Skoda, Pibrans in 1944. He and staff was at Camp Föhrenwald, Wolfratshausen, Bavaria in 1945. It is important to find Dr. Teichmann.	Hindenburgstrasse 96A, Berlin-Wilmersdorf
✓ Grube, G., Prof. Dr.	Dir. of Inst. for Physikalische Chemie u. Elektrochemie der technischen Hochschule, Stuttgart Development of the combustion of Al and Mg as fuels in atmospheres of steam and H_2O_2. Published in Zschr. für Metallkunde and Zschr. f. Elektrochemie.	Hangleiterstrasse 2, or Wiederholdstrasse 15, Stuttgart N.
✓ Gusti, Prof.	Physikalische Technische Reichsanstalt, Berlin	Berlin
✓ Schumacher, H. J. Prof.	Dir. of Inst. for Physical Chemistry, Frankfurt, a . Main	Frankfurt, a . Main
✓ Geib, K. H. Dr.	Leipzig	Leipzig
✓ Bonhoeffer, K. F., Prof.	Dir. of Inst. for Physical Chemistry, Leipzig	Leipzig
✓ Förster, Th.,	Dir. of Inst. for Physics, Posen Left before the Russians occupied Posen	?

Incl: #1

- 3 -

Figure E.233: 16 July 1946 list of German scientists to be interrogated by Fritz Zwicky. [NARA RG 319, Entry NM3-47B, Box 991, Folder 400. 112 Research/009. 14 May 1945]



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Authority 755004
By JG NARA Date 4-16-09

NAME	INSTITUTE ASSOCIATED WITH AT TIME OF PUBLICATION	LAST KNOWN ADDRESS
✓Groth, W., Dr.	Formerly with Harteck	Breslau
✓Patat, F., Dr.	I. G. Farben, Hoechst. Formerly with Eucken.	Göttingen
✓Cremer, Erika, Prof.,	Innsbruck University	Innsbruck
✓Scrabal, Anton, Prof.	Graz	Graz
✓Zeise, Heino, Dr.	DVL Berlin, Theoretical Investigations	Berlin

Incl: #1

Figure E.234: 16 July 1946 list of German scientists to be interrogated by Fritz Zwicky. [NARA RG 319, Entry NM3-47B, Box 991, Folder 400. 112 Research/009. 14 May 1945]

[Fritz Zwicky (Swiss, 1898–1974) moved to the United States in 1925, part of the wave of German-speaking scientific immigrants who came before the Third Reich. He recruited additional German-speaking scientific immigrants during and after the Third Reich and directly assisted the U.S. government in transferring as much scientific knowledge as possible out of the German-speaking world. While Zwicky is best remembered as an astrophysicist, he was keenly interested in all forms of aerospace propulsion and greatly aided the United States in that area. He was a professor at Caltech but also a research director/scientific advisor at Aerojet 1943–1961. Zwicky was deeply involved in scientific interrogations after the war in 1945, and this memo shows that in 1946 he was still interrogating large numbers of German-speaking scientists. He made the interrogations listed in this memo on behalf of Aerojet.

Although the memo said the list was aimed at "thermochemistry" or "jet propulsion," the listed scientists (and the interrogations that they were probably subjected to) covered a far broader range of fields. For example, many scientists on this list were primarily nuclear experts—Klaus Clusius, Max Volmer, Paul Harteck, Wilhelm Groth, etc. A few names on the list were underlined, and the memo noted: "Those whose names are underlined, have been working recently in the fields of our special interest." One of the underlined names was Paul Harteck. Was that unnamed "special interest" simply thermochemistry, or some other topic, such as heavy water production or uranium isotope separation? Was this "thermochemistry" memo an umbrella for a much broader and multipurpose series of scientific interrogations by the United States?

This memo demonstrates just how dependent the United States was on German-derived scientific knowledge. It emphasized how much important information was obtained "in Germany in 1945." Then it stated that it was "considered of prime importance for future progress" to obtain even more information, and that "this data may be obtained from interrogating German scientific personnel now in Germany" during 1946. The United States needed to transfer large amounts of scientific information and scientific personnel from the German-speaking world, and even that transfer process itself was directed by U.S. representatives such as Fritz Zwicky and Theodore von Kármán who were themselves German-speaking scientists.

Hermann Teichmann, who invented and demonstrated ammonium perchlorate/polybutadiene solid rocket propellant, was especially singled out on this list. The document gave more information about him than any other scientist on the list, and he was the only scientist for which it was specifically stated, "It is important to find" him. Apparently either Fritz Zwicky had been directly involved in interrogating Teichmann in 1945, or else Zwicky had read detailed reports on those interrogations (such as the other documents quoted in this section). Teichmann eventually ended up working for France. It is unclear from this and other available documents if Zwicky actually did interrogate Teichmann in 1946, but it seems evident that Zwicky and his employer Aerojet were keenly interested in and highly knowledgeable about Teichmann's revolutionary work on solid propellant rockets.

Presumably based on such information, in 1948 Aerojet began producing ammonium perchlorate/polymer propellants, and it even hired German-speaking scientists such as Karl Klager to perfect those propellants, along with the continuing guidance of Zwicky. Please see the following documents for more information.]

Donald L. Putt to Curtis B. LeMay. 23 January 1946. SUBJECT: Research and Development of Solid Fuel Rockets. [AFHRA folder 201-56 Vol. 1 Pt. 2 May 1945–Mar 1947; AFHRA A2055 Frames 1109–1110]

HEADQUARTERS
AIR TECHNICAL SERVICE COMMAND

23 January 1946

SUBJECT: Research and Development of Solid Fuel Rockets

TO: Commanding General
Army Air Forces
Washington 23, D.C.

Attn: Major General Curtis B. LeMay
Deputy Chief of Air Staff for
Research and Development

1. It is understood that your office has recently received a communication setting forth the need for reviving research on solid fuel rockets.

2. For such use as can be made of the information, it is desired to present the following:

a. German aeronautical research establishments and industry have spent years working on subject development. It is believed that the Germans were considerably advanced beyond our own efforts in this field. Most of the documentary information covering this past research is available in the Air Document Division, Wright Field.

b. Every effort should be made to take advantage of this work which has already been done so as to profit from the mistakes made by the Germans and to prevent costly duplication of effort in repeating work already done.

c. There are presently stationed at Wright Field several German scientists who have worked in the rocket field. One scientist in particular has done research work on solid rocket fuels and motors for the past ten years. Another was instrumental in the development of the motor and liquid fuels for the ME-163. Both have plans and ideas for further research which would lead to improved fuels and increased efficiencies of rocket motors. Every effort should be made to provide means and facilities to acquire the projected thinking and plans of these scientists to assist and expedite our own research and development to the greatest possible extent.

d. These scientists are not now and can not be effectively and efficiently utilized at Wright Field, due to the current restrictive regulations governing the exploitation of German scientists, which, in the opinion of this office, have no sound or logical basis. Nearly all of the rocket motor and fuel research work has been done by agencies outside of Wright Field, such as N.A.C.A., California Institute of Technology and Monsanto Chemical Company. The regulations prohibit any contact between German scientists and those institutions, to whom they could be of great benefit. Certainly there can be no sound basis for prohibiting companies having contracts with the Army Air Forces or other Government agencies to interview German scientists at Wright Field to obtain their advice and assistance in furtherance of their Government contracts. This procedure would likewise bolster the morale of the German scientists and eliminate their complaint of having to live in a “scientific desert", which is occasioned by a complete lack of contact with people on the same scientific level.

3. Any assistance which your office might render to obtain a revision of regulations which would permit a full and complete utilization of the German scientists now in the United States would materially aid and benefit our own research and development program, not only in the field of rockets but in those of guided missiles, supersonics, jet engines and jet aircraft.

FOR THE COMMANDING GENERAL,

D. L. Putt
Colonel, Air Corps
Deputy Commanding General
Intelligence (T-2)

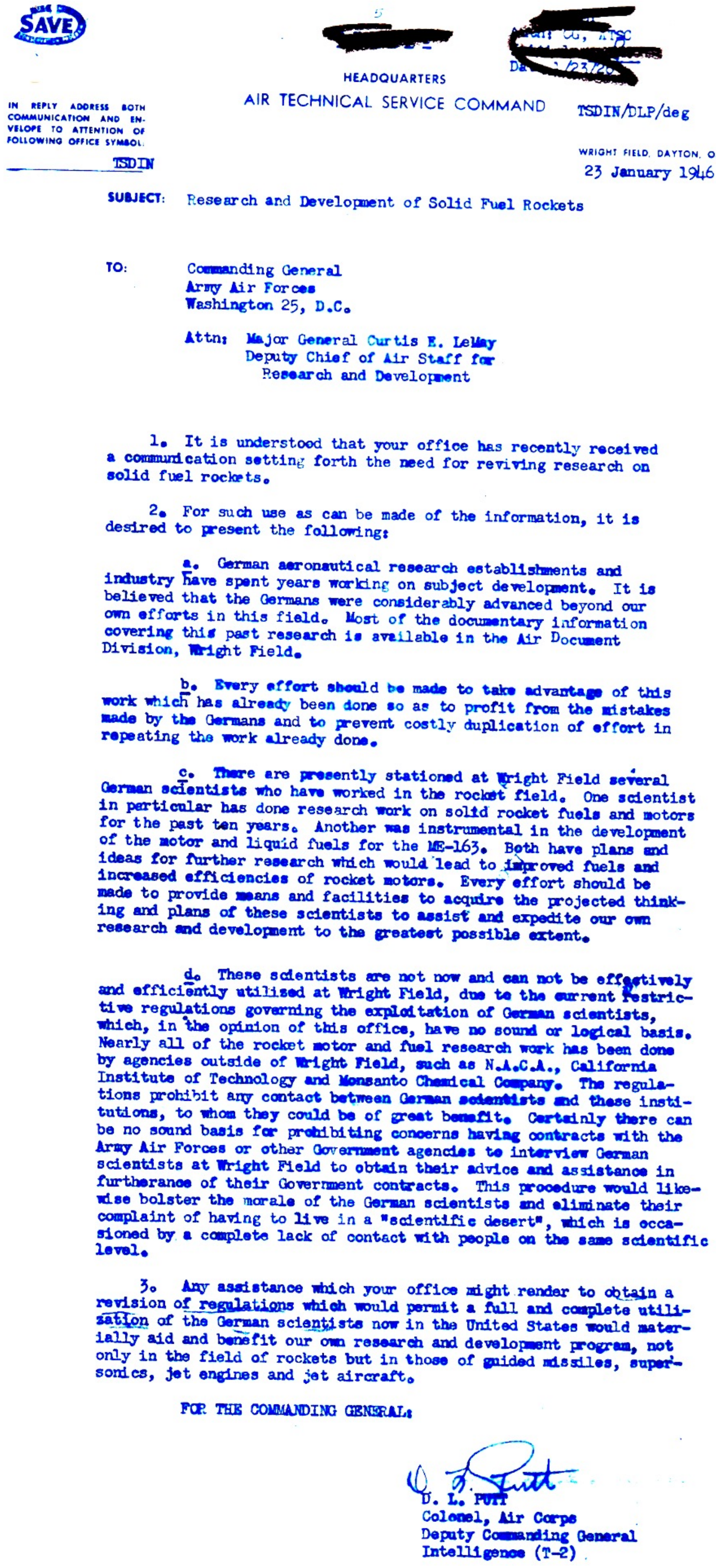
[At this point, by the year after the war, Donald Putt arguably had the best understanding in the world of all the rocket-related accomplishments up to that time both in Germany and in the United States. From that well-informed vantage point, Putt clearly stated that "the Germans were considerably advanced beyond our own efforts" on "solid fuel rockets." To back up that assertion, he explicitly said that he had "documentary information covering this past research" stored at the Wright Field Air Document Division, and that he also had under his direct supervision scientists with up to ten years of previous experience on solid propellant rockets in Germany. From his wartime and postwar jobs, Putt would also have been intimately familiar with other relevant evidence, scientists, and projects throughout Germany and the United States.

At the time of Putt's memo, Wolfgang Noeggerath was at Wright Field [e.g., AFHRA A2055 Frame 1165]. During the war, he had worked on hypergolic liquid propellants for the Me 163 rocket plane and other vehicles [John Clark 1972, pp. 13–17], so he appears to have been the second scientist that Putt referenced. Putt's memo succeeded in getting the German scientists to the U.S. programs that needed them, and Noeggerath became the lead scientist for the first U.S. solid propellant, submarine-launched ballistic missile, Polaris (p. 5722).

The first scientist that Putt referenced, someone who already had a decade of experience developing solid rocket fuels and motors, may have been Gerhard Braun, Rudolf Edse, or another German or Austrian expert who was at Wright Field at that time [e.g., compare p. 1906 and AFHRA A2055 Frame 1165]. Future scholars should delve much further into the wartime and postwar work of these and other German-speaking scientists.

Note that in addition to direct work credited to the German scientists, Putt also specifically mentioned the quiet transfer of their knowledge and ideas to U.S. scientists and organizations. Therefore the actual contributions and true impact of the German-speaking creators were probably far larger than what the preserved documents show.]

AFHRA folder 201-56 Vol. 1 Pt. 2 May 1945--Mar 1947 THIS PAGE DECLASSIFIED IAW EO 13526



[redacted] [redacted]

HEADQUARTERS
AIR TECHNICAL SERVICE COMMAND

IN REPLY ADDRESS BOTH COMMUNICATION AND ENVELOPE TO ATTENTION OF FOLLOWING OFFICE SYMBOL:
TSDIN

TSDIN/DLP/deg

WRIGHT FIELD, DAYTON, OHIO
23 January 1946

SUBJECT: Research and Development of Solid Fuel Rockets

TO: Commanding General
Army Air Forces
Washington 25, D.C.

Attn: Major General Curtis E. LeMay
Deputy Chief of Air Staff for
Research and Development

1. It is understood that your office has recently received a communication setting forth the need for reviving research on solid fuel rockets.

2. For such use as can be made of the information, it is desired to present the following:

a. German aeronautical research establishments and industry have spent years working on subject development. It is believed that the Germans were considerably advanced beyond our own efforts in this field. Most of the documentary information covering this past research is available in the Air Document Division, Wright Field.

b. Every effort should be made to take advantage of this work which has already been done so as to profit from the mistakes made by the Germans and to prevent costly duplication of effort in repeating the work already done.

c. There are presently stationed at Wright Field several German scientists who have worked in the rocket field. One scientist in particular has done research work on solid rocket fuels and motors for the past ten years. Another was instrumental in the development of the motor and liquid fuels for the ME-163. Both have plans and ideas for further research which would lead to improved fuels and increased efficiencies of rocket motors. Every effort should be made to provide means and facilities to acquire the projected thinking and plans of these scientists to assist and expedite our own research and development to the greatest possible extent.

d. These scientists are not now and can not be effectively and efficiently utilized at Wright Field, due to the current restrictive regulations governing the exploitation of German scientists, which, in the opinion of this office, have no sound or logical basis. Nearly all of the rocket motor and fuel research work has been done by agencies outside of Wright Field, such as N.A.C.A., California Institute of Technology and Monsanto Chemical Company. The regulations prohibit any contact between German scientists and these institutions, to whom they could be of great benefit. Certainly there can be no sound basis for prohibiting concerns having contracts with the Army Air Forces or other Government agencies to interview German scientists at Wright Field to obtain their advice and assistance in furtherance of their Government contracts. This procedure would likewise bolster the morale of the German scientists and eliminate their complaint of having to live in a "scientific desert", which is occasioned by a complete lack of contact with people on the same scientific level.

3. Any assistance which your office might render to obtain a revision of regulations which would permit a full and complete utilization of the German scientists now in the United States would materially aid and benefit our own research and development program, not only in the field of rockets but in those of guided missiles, supersonics, jet engines and jet aircraft.

FOR THE COMMANDING GENERAL:

D. L. Putt
D. L. PUTT
Colonel, Air Corps
Deputy Commanding General
Intelligence (T-2)

Figure E.235: Donald L. Putt to Curtis B. LeMay. 23 January 1946. SUBJECT: Research and Development of Solid Fuel Rockets. [AFHRA folder 201-56 Vol. 1 Pt. 2 May 1945–Mar 1947; AFHRA A2055 Frames 1109–1110]

J. D. Hunley. 1999. The History of Solid-Propellant Rocketry: What We Do and Do Not Know. AIAA paper 99-2925. [Hunley 1999; https://doi.org/10.2514/6.1999-2925]

Integral to the stories of the propellants used on large rockets and missiles, smaller tactical missiles, and a host of smaller rockets for a variety of rockets and spacecraft were the various binders, fuels, and oxidizers that went into the propellants. For example, the motors for the Polaris A1 missile designed by Aerojet featured a cast, case-bonded polyether-polyester-polyurethane composition with 15 percent aluminum and ammonium perchlorate. Karl Klager at Aerojet has been credited with being largely responsible for developing both the grain and the propellant for these motors, but the story of their development is evidently quite complex. Klager received the U. S. Navy Distinguished Public Services Award in 1958 for his work on the Polaris missile, but the development of some of the propellant ingredients predates when Klager joined Aerojet in 1950. [...]

Karl Klager, who is credited with the development of HTPB [hydroxyl-terminated polybutadiene], was asked how he came to develop this low-cost, low-viscosity propellant that has become an industry standard. He said only that he started development in 1961 but waited until 1969 to propose the propellant to NASA for the Astrobee D and Astrobee F sounding rockets on which it flew successfully. Perhaps, however, Klager's response regarding how he came to discover unsymmetrical dimethylhydrazine (UDMH) (which is a liquid propellant used on the Bomarc missile, Titan 2 missile, Titan 3 and Titan 4 rockets, and other missiles and rockets) applies equally to HTPB. Klager said that he simply brought his knowledge of the science of chemistry to bear on the need for a propellant. He had earned a Ph.D. in chemistry from the University of Vienna in 1934 and had worked for several chemical firms in Europe from 1931 to 1948 before moving to the United States and starting work for Aerojet in 1950.

[Although aerospace historian J. D. Hunley focused mainly on the work of American engineers in the above paper and in the following book, he could not avoid mentioning the important contributions of Karl Klager (Austrian, 1908–2002) to the development of large solid-propellant rockets in the United States after the war.]

J. D. Hunley. *Preludes to U.S. Space-Launch Vehicle Technology: Goddard Rockets to Minuteman III.* [Hunley 2008a]

[pp. 154–156:]

Meanwhile, the first known castable solid propellant was the composite developed by John Parsons at the Guggenheim Aeronautical Laboratory at Caltech back in 1942 for use in JATO motors. Containing asphalt as a binder and potassium perchlorate as an oxidizer, this propellant—known as GALCIT 53 after the lab's acronym—did not have a particularly impressive performance compared, for example, with the double-base composition called ballistite. But it retained its performance at temperatures down to 40^oF far better than the compressed black powder Parsons had been using in JPL's JATO motors. At lower temperatures, however, GALCIT 53 cracked. It also melted in the tropical sun and was very smoky when burning. This last characteristic limited the takeoff of follow-on aircraft using JATO units on a single runway because the smoke restricted visibility. These shortcomings led researchers at GALCIT and its successor, JPL, to search for an elastic binder with storage limits beyond GALCIT 53's extremes of -9°F and 120°F. In particular, a young engineer named Charles Bartley, who was employed at JPL from June 1944 to August 1951, began examining synthetic rubbers and polymers, eventually hitting upon a liquid polysulfide compound designated LP-2, which worked as as solid-propellant binder. It was made by the Thiokol Chemical Corporation for sealing aircraft tanks and other applications. [...]

Before learning of LP-2, Bartley and his associates at JPL had tried a variety of moldable synthetic rubbers to use as binders and fuels, including Buna-S, Buna-N, and Neoprene. Neoprene worked best, both as a binder and as a fuel, but molding it required high pressures, like the extrusion process used with double-base propellants, which made the production of large propellant grains impractical. [...]

With encouragement from Army Ordnance and the Navy, Bartley—joined by John I. Shafer, a JPL design engineer, and H. Lawrence Thackwell Jr., whose expertise lay in aircraft structures—began in 1947 to develop a small rocket designated Thunderbird, which had a 6-inch diameter. The three researchers used it for testing whether polysulfide propellants could withstand the forces of high acceleration that a large launch vehicle might also encounter. [...]

Combining a polysulfide propellant with the star design and casting it in the case so that a bond formed, the team under Bartley produced the successful Thunderbird rocket that passed its flight tests in 1947–48.

While this rocket was being tested, another significant development for composite propellants was occurring—the replacement of potassium perchlorate by ammonium perchlorate, which offered higher performance and less smoke. [...] Already in 1947, however, JPL had developed a propellant designated JPL118 that used only ammonium perchlorate as an oxidizer together with polysulfide as the binder and couple of curing agents. Although this propellant had yet to be fully investigated in 1947, by mid-1948 it provided a specific impulse of 198 lbf-sec/lbm at sea level using an expansion ratio of 10 for the rocket nozzle. [...]

Aerojet likewise began using ammonium perchlorate in its Aeroplex (polyester polymer) propellants in 1948 in order to increase specific impulse and reduce smoke. Funded by the Navy Bureau of Aeronautics to develop a basic understanding of the production and employment of solid propellants, Aerojet increased the specific impulse of its ammonium perchlorate propellants to 235 lbf-sec/lbm, but its Aeroplex binder was not case bondable, leading the firm to switch in 1954 to a polyurethane propellant that was.

In the interim, Thiokol sought to sell its polymer to Aerojet and another manufacturer of rockets, the Hercules Powder Company, but both rejected Thiokol's product because its 32 percent sulfur content made it a poor fuel. [...]

[p. 295–296:]

It was not ARC's polyvinyl chloride, however, that served as the binder for Polaris. Rather it was a polyurethane developed by Aerojet. This development began under a small Navy nitropolymer program funded by the Office of Naval Research about 1947 to seek high-energy binders for solid propellants. A few Aerojet chemists synthesized a number of high-energy compounds, but the process required levels of heating that went beyond what was safe for potentially explosive compounds. Then one of the chemists, Rodney Fischer, found "an obscure reference in a German patent" suggesting that "iron chelate compounds would catalyze the reaction of alcohols and isocyanates to make urethanes at essentially room temperature." This discovery started the development of polyurethane propellants in many places besides Aerojet.

Meanwhile, in 1949 Dr. Karl Klager, then working for the Office of Naval Research in Pasadena, suggested to Aerojet's parent firm, General Tire, that it begin work on foamed polyurethane, leading to two patents held by Klager with Dick Geckler and R. Parette of Aerojet. In 1950 Klager, who had earned a Ph.D. in chemistry from the University of Vienna in 1934 and had come to this country as part of Project Paperclip, began working for Aerojet. By 1954 he headed the rocket firm's solid-propellant development group. Once the Polaris program began in December 1956, Klager's group decided to reduce the percentage of solid oxidizer as one component of the propellant by including oxidizing capacity in the binder itself, using a nitromonomer as a reagent to produce the polyurethane plus some inert polynitro compounds as plasticizers, or softening agents. [...T]hey came up with successful propellants for both stages of Polaris A1.

These consisted of a cast, case-bonded polyurethane composition including different percentages of ammonium perchlorate and aluminum for stages 1 and 2, both of them featuring an internal-burning six-point star configuration.

[p. 396:]

10. [...] According to Fuhrman, "Polaris to Trident," 12, "Tests at the Naval Ordnance Test Station in 1955, which were confirmed by the Atlantic Research Corporation in 1956, demonstrated a significant increase in specific impulse obtained by the addition of finely divided aluminum to the propellant."

11. [...] For his work in developing both the grain and the propellant, Klager received the Navy's Distinguished Public Service Award in 1958[...]

[p. 319:]

The Minuteman team delivered the first Minuteman I to the Strategic Air Command in October 1962, almost exactly four years after the first development contracts were signed. [...]

The first stage, developed and produced by Thiokol, included a new propellant binder developed by the company's chemists between 1952 and 1954.

[...] Thiokol added 10 percent acrylonitrile to the PBAA, creating polybutadiene-acrylic acid-acrylonitrile (PBAN). The binder and curing agent constituted only 14 percent of the propellant, with ammonium perchlorate (the oxidizer) and aluminum (the major fuel) being the two other main ingredients.

[A] Teflon-coated mandrel created the tapered six-point star that formed the internal-burning cavity. [...]

B. P. Mason and C. M. Roland. 2019. Solid Propellants. *Rubber Chemistry and Technology* 92:1:1–24. [**https://arxiv.org/pdf/1904.01510.pdf**]

[...] V. POLYMERIC BINDERS [...]

C. POLYSULFIDES

In the latter stages of World War II, SRM binder work for JATOs led to the use of a styrene-butadiene rubber, Buna-S, developed by IG Farben in Germany before the war. Although Buna-S performed well over a broad temperature range, dewetting of the motor grain from the case proved an insurmountable problem. Adhesion at the motor's bond line is critical because the debonded surface of the grain will burn prematurely, causing motor failure. [...]

D. PLASTISOLS

[...] Plastisol nitrocellulose (PNC), sometimes called "spheroidal" or "pelletized" nitrocellulose, was developed at ARC and also featured a long pot life, although not as long as PVC's. PNC used NC nitrated at 12.6%, dissolved in nitromethane and ethyl centralite, and emulsified in water. The nitromethane was then leached out and 5–50 micron spheres collected by centrifugation. While used sparingly in SRM, PNC was employed in warheads and gun propellants. The U.S. Navy deemed PNC important enough that it manufactured the material itself at the Naval Propellant Plant in Indian Head, Maryland, starting in 1958. Production ended when accidents forced closure of the facility in the 1990s.

E. POLY(BUTADIENE-ACRYLIC ACID)

In the mid-1950s, butadiene-containing copolymers reappeared with poly(butadiene-acrylic acid; PBAA), a random copolymer developed as a binder by Thiokol at Redstone Arsenal. PBAA had a molecular weight of about 3000 Da, but being made by free radical emulsion polymerization, it was a mixture of various polyfunctional chains, including some nonfunctional, resulting in poor reproducibility. Crosslinking was carried out by ring opening of difunctional epoxides and aziridines by the acrylic acid groups. Although the prepolymer had a sufficiently low viscosity to allow high solids loading, the resulting crosslinked polymer had poor mechanical properties because of the irregular network structure and for this reason was abandoned. However, PBAA was used by Thiokol as the binder for the first stage of the Minuteman I ICBM. [...]

H. HTPB

Hydroxyl-functionalized prepolymers had been combined with multifunctional isocyanates in the early 1950s, even before the introduction of PBAN and CTPB. General Tire & Rubber experimented with urethane crosslinked polyethers and polyesters for propulsion formulations as early as 1947. However, it was Aerojet that had the initial successes with these materials under the leadership of Karl Klager, an Austrian chemist who had worked for IG Farben during the Second World War and was brought to the United States by the U.S. Office of Naval Research under Operation Paperclip in 1949. Klager's polyurethanes were used in both stages of the Polaris A1 and in the second stage of the Minuteman I. These materials were a combination of poly(1,2-propylene oxide) (PPG) and poly(1,4-tetramethylene oxide) (PTMEG), cured with toluene diisocyanate and crosslinked with triethanolamine. Other examples of such binders included poly(ethylene oxide) (PEG), poly(neopentylglycol azelate), and poly(butylene oxide); commonly referred to as B-2000.

These types of binders had excellent stability, mechanical properties, and reliability for their era but nevertheless were passed over in favor of CTPB-based formulations.

So dominant was CTPB throughout the 1960s that although HTPB was first synthesized for use in binders in 1961, it did not see actual use in a rocket motor until 1968, when Aerojet used it in a dual-thrust radial-burning motor grain formulation for the Astrobee D, a NASA-sponsored meteorological sounding rocket. Gradually, HTPB gained widespread use as a replacement binder in older systems employing CTPB, for example, in the Maverick, Stinger, and Sidewinder missiles. After 50 years of use, HTPB remains the standard binder for nearly all U.S.-made SRM. HTPB-based polyurethane binders are relatively inexpensive, have low viscosity prepolymers, and exhibit good mechanical and aging properties. The binary system enables a high solids content, providing one of the highest specific impulses among solid propellants. [...]

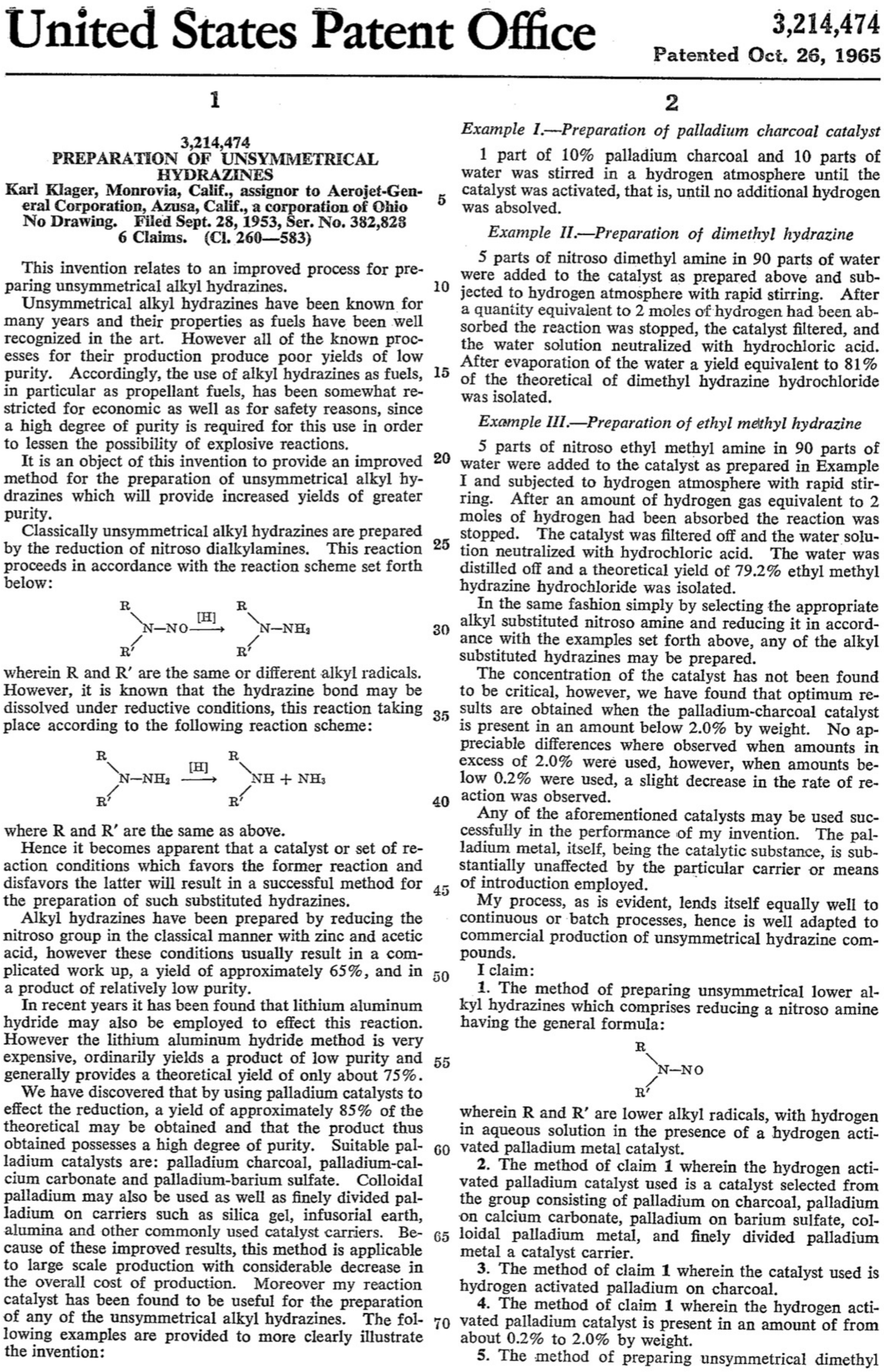
VI. ENERGETIC POLYMERS [...]

A. POLY(GLYCIDYL NITRATE)

In 1953, formulators at the U.S. Naval Ordnance Test Station in China Lake, California, synthesized 800 to 3400 Da poly(glycidyl nitrate; PGN) using stannic chloride as a catalyst[...]

[Karl Klager had a huge number of patents on solid and liquid rocket propellants—see for example Figs. E.236–E.242.

The above article specifically credits some of the contributions of Karl Klager, but likely there were many other contributions from the German-speaking world to postwar solid propellant rockets. After the war, U.S. aerospace laboratories in places such as Redstone Arsenal, China Lake, and Indian Head were filled with German-speaking scientists, German-produced hardware, and German-derived documents and technical information. If many of these solid propellant innovations were not derived from German work, why were they not developed by the United States during World War II, before the German-speaking scientists and information arrived, when the United States had great need for such technologies in the war? It would be useful for future historians to search for specific people, paper trails, and other links connecting wartime German work on solid rocket propellants and postwar U.S. work on such propellants.]



United States Patent Office

3,214,474
Patented Oct. 26, 1965

3,214,474
PREPARATION OF UNSYMMETRICAL HYDRAZINES
Karl Klager, Monrovia, Calif., assignor to Aerojet-General Corporation, Azusa, Calif., a corporation of Ohio
No Drawing. Filed Sept. 28, 1953, Ser. No. 382,828
6 Claims. (Cl. 260—583)

This invention relates to an improved process for preparing unsymmetrical alkyl hydrazines.

Unsymmetrical alkyl hydrazines have been known for many years and their properties as fuels have been well recognized in the art. However all of the known processes for their production produce poor yields of low purity. Accordingly, the use of alkyl hydrazines as fuels, in particular as propellant fuels, has been somewhat restricted for economic as well as for safety reasons, since a high degree of purity is required for this use in order to lessen the possibility of explosive reactions.

It is an object of this invention to provide an improved method for the preparation of unsymmetrical alkyl hydrazines which will provide increased yields of greater purity.

Classically unsymmetrical alkyl hydrazines are prepared by the reduction of nitroso dialkylamines. This reaction proceeds in accordance with the reaction scheme set forth below:

$$\overset{R}{\underset{R'}{>}}N{-}NO \xrightarrow{[H]} \overset{R}{\underset{R'}{>}}N{-}NH_2$$

wherein R and R′ are the same or different alkyl radicals. However, it is known that the hydrazine bond may be dissolved under reductive conditions, this reaction taking place according to the following reaction scheme:

$$\overset{R}{\underset{R'}{>}}N{-}NH_2 \xrightarrow{[H]} \overset{R}{\underset{R'}{>}}NH + NH_3$$

where R and R′ are the same as above.

Hence it becomes apparent that a catalyst or set of reaction conditions which favors the former reaction and disfavors the latter will result in a successful method for the preparation of such substituted hydrazines.

Alkyl hydrazines have been prepared by reducing the nitroso group in the classical manner with zinc and acetic acid, however these conditions usually result in a complicated work up, a yield of approximately 65%, and in a product of relatively low purity.

In recent years it has been found that lithium aluminum hydride may also be employed to effect this reaction. However the lithium aluminum hydride method is very expensive, ordinarily yields a product of low purity and generally provides a theoretical yield of only about 75%.

We have discovered that by using palladium catalysts to effect the reduction, a yield of approximately 85% of the theoretical may be obtained and that the product thus obtained possesses a high degree of purity. Suitable palladium catalysts are: palladium charcoal, palladium-calcium carbonate and palladium-barium sulfate. Colloidal palladium may also be used as well as finely divided palladium on carriers such as silica gel, infusorial earth, alumina and other commonly used catalyst carriers. Because of these improved results, this method is applicable to large scale production with considerable decrease in the overall cost of production. Moreover my reaction catalyst has been found to be useful for the preparation of any of the unsymmetrical alkyl hydrazines. The following examples are provided to more clearly illustrate the invention:

Example I.—Preparation of palladium charcoal catalyst

1 part of 10% palladium charcoal and 10 parts of water was stirred in a hydrogen atmosphere until the catalyst was activated, that is, until no additional hydrogen was absolved.

Example II.—Preparation of dimethyl hydrazine

5 parts of nitroso dimethyl amine in 90 parts of water were added to the catalyst as prepared above and subjected to hydrogen atmosphere with rapid stirring. After a quantity equivalent to 2 moles of hydrogen had been absorbed the reaction was stopped, the catalyst filtered, and the water solution neutralized with hydrochloric acid. After evaporation of the water a yield equivalent to 81% of the theoretical of dimethyl hydrazine hydrochloride was isolated.

Example III.—Preparation of ethyl methyl hydrazine

5 parts of nitroso ethyl methyl amine in 90 parts of water were added to the catalyst as prepared in Example I and subjected to hydrogen atmosphere with rapid stirring. After an amount of hydrogen gas equivalent to 2 moles of hydrogen had been absorbed the reaction was stopped. The catalyst was filtered off and the water solution neutralized with hydrochloric acid. The water was distilled off and a theoretical yield of 79.2% ethyl methyl hydrazine hydrochloride was isolated.

In the same fashion simply by selecting the appropriate alkyl substituted nitroso amine and reducing it in accordance with the examples set forth above, any of the alkyl substituted hydrazines may be prepared.

The concentration of the catalyst has not been found to be critical, however, we have found that optimum results are obtained when the palladium-charcoal catalyst is present in an amount below 2.0% by weight. No appreciable differences where observed when amounts in excess of 2.0% were used, however, when amounts below 0.2% were used, a slight decrease in the rate of reaction was observed.

Any of the aforementioned catalysts may be used successfully in the performance of my invention. The palladium metal, itself, being the catalytic substance, is substantially unaffected by the particular carrier or means of introduction employed.

My process, as is evident, lends itself equally well to continuous or batch processes, hence is well adapted to commercial production of unsymmetrical hydrazine compounds.

I claim:

1. The method of preparing unsymmetrical lower alkyl hydrazines which comprises reducing a nitroso amine having the general formula:

$$\overset{R}{\underset{R'}{>}}N{-}NO$$

wherein R and R′ are lower alkyl radicals, with hydrogen in aqueous solution in the presence of a hydrogen activated palladium metal catalyst.

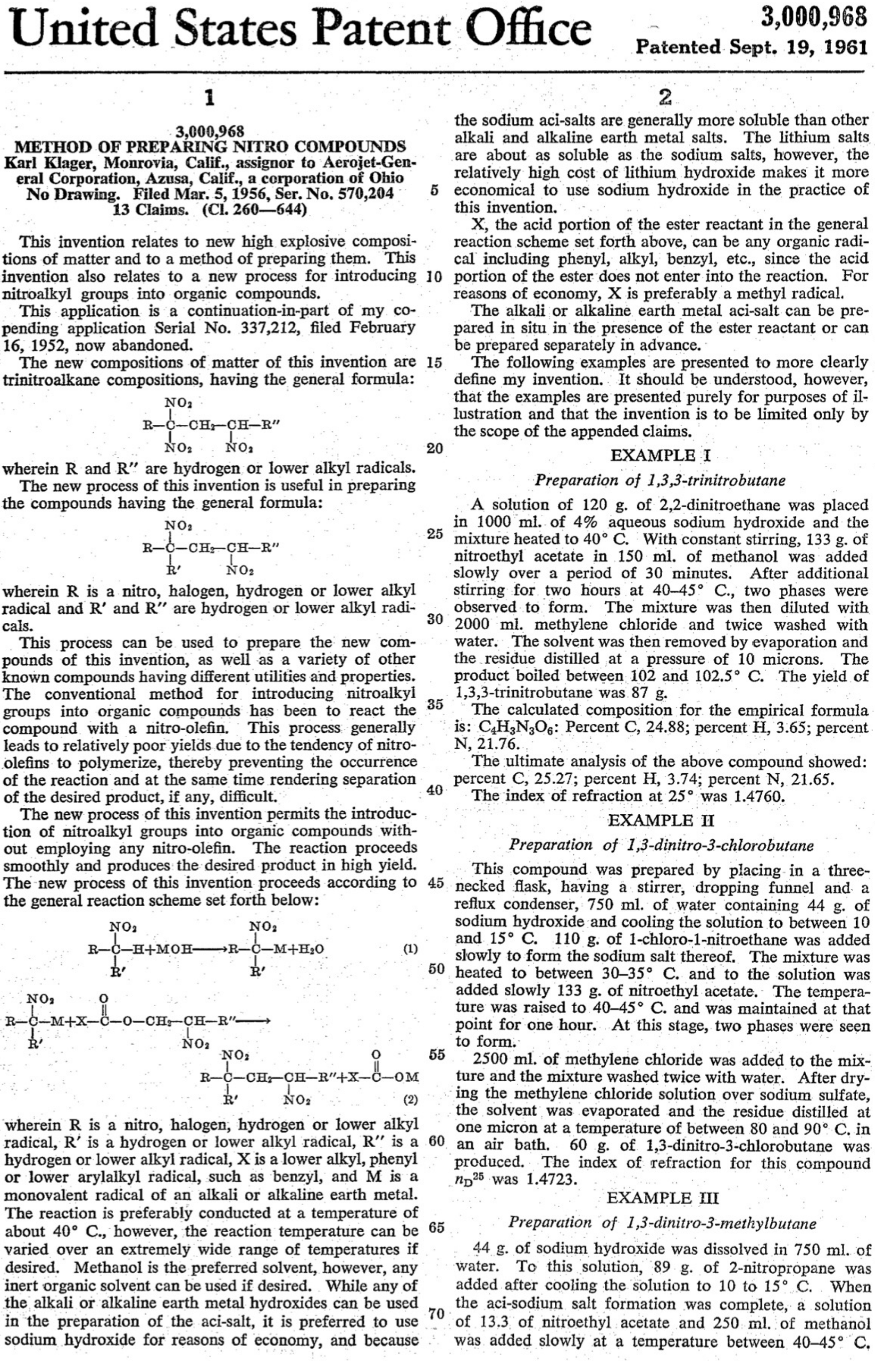
2. The method of claim **1** wherein the hydrogen activated palladium catalyst used is a catalyst selected from the group consisting of palladium on charcoal, palladium on calcium carbonate, palladium on barium sulfate, colloidal palladium metal, and finely divided palladium metal a catalyst carrier.

3. The method of claim **1** wherein the catalyst used is hydrogen activated palladium on charcoal.

4. The method of claim **1** wherein the hydrogen activated palladium catalyst is present in an amount of from about 0.2% to 2.0% by weight.

5. The method of preparing unsymmetrical dimethyl

Figure E.236: An example of Karl Klager's patents on rocket propellant.



United States Patent Office

3,000,968
Patented Sept. 19, 1961

1

3,000,968
METHOD OF PREPARING NITRO COMPOUNDS
Karl Klager, Monrovia, Calif., assignor to Aerojet-General Corporation, Azusa, Calif., a corporation of Ohio
No Drawing. Filed Mar. 5, 1956, Ser. No. 570,204
13 Claims. (Cl. 260—644)

This invention relates to new high explosive compositions of matter and to a method of preparing them. This invention also relates to a new process for introducing nitroalkyl groups into organic compounds.

This application is a continuation-in-part of my copending application Serial No. 337,212, filed February 16, 1952, now abandoned.

The new compositions of matter of this invention are trinitroalkane compositions, having the general formula:

$$R-\underset{NO_2}{\overset{NO_2}{C}}-CH_2-\underset{NO_2}{CH}-R''$$

wherein R and R'' are hydrogen or lower alkyl radicals.

The new process of this invention is useful in preparing the compounds having the general formula:

$$R-\underset{R'}{\overset{NO_2}{C}}-CH_2-\underset{NO_2}{CH}-R''$$

wherein R is a nitro, halogen, hydrogen or lower alkyl radical and R' and R'' are hydrogen or lower alkyl radicals.

This process can be used to prepare the new compounds of this invention, as well as a variety of other known compounds having different utilities and properties. The conventional method for introducing nitroalkyl groups into organic compounds has been to react the compound with a nitro-olefin. This process generally leads to relatively poor yields due to the tendency of nitro-olefins to polymerize, thereby preventing the occurrence of the reaction and at the same time rendering separation of the desired product, if any, difficult.

The new process of this invention permits the introduction of nitroalkyl groups into organic compounds without employing any nitro-olefin. The reaction proceeds smoothly and produces the desired product in high yield. The new process of this invention proceeds according to the general reaction scheme set forth below:

$$R-\underset{R'}{\overset{NO_2}{C}}-H+MOH\longrightarrow R-\underset{R'}{\overset{NO_2}{C}}-M+H_2O \qquad (1)$$

$$R-\underset{R'}{\overset{NO_2}{C}}-M+X-\overset{O}{\overset{\|}{C}}-O-CH_2-\underset{NO_2}{CH}-R''\longrightarrow$$
$$R-\underset{R'}{\overset{NO_2}{C}}-CH_2-\underset{NO_2}{CH}-R''+X-\overset{O}{\overset{\|}{C}}-OM \qquad (2)$$

wherein R is a nitro, halogen, hydrogen or lower alkyl radical, R' is a hydrogen or lower alkyl radical, R'' is a hydrogen or lower alkyl radical, X is a lower alkyl, phenyl or lower arylalkyl radical, such as benzyl, and M is a monovalent radical of an alkali or alkaline earth metal. The reaction is preferably conducted at a temperature of about 40° C., however, the reaction temperature can be varied over an extremely wide range of temperatures if desired. Methanol is the preferred solvent, however, any inert organic solvent can be used if desired. While any of the alkali or alkaline earth metal hydroxides can be used in the preparation of the aci-salt, it is preferred to use sodium hydroxide for reasons of economy, and because

2

the sodium aci-salts are generally more soluble than other alkali and alkaline earth metal salts. The lithium salts are about as soluble as the sodium salts, however, the relatively high cost of lithium hydroxide makes it more economical to use sodium hydroxide in the practice of this invention.

X, the acid portion of the ester reactant in the general reaction scheme set forth above, can be any organic radical including phenyl, alkyl, benzyl, etc., since the acid portion of the ester does not enter into the reaction. For reasons of economy, X is preferably a methyl radical.

The alkali or alkaline earth metal aci-salt can be prepared in situ in the presence of the ester reactant or can be prepared separately in advance.

The following examples are presented to more clearly define my invention. It should be understood, however, that the examples are presented purely for purposes of illustration and that the invention is to be limited only by the scope of the appended claims.

EXAMPLE I

Preparation of 1,3,3-trinitrobutane

A solution of 120 g. of 2,2-dinitroethane was placed in 1000 ml. of 4% aqueous sodium hydroxide and the mixture heated to 40° C. With constant stirring, 133 g. of nitroethyl acetate in 150 ml. of methanol was added slowly over a period of 30 minutes. After additional stirring for two hours at 40–45° C., two phases were observed to form. The mixture was then diluted with 2000 ml. methylene chloride and twice washed with water. The solvent was then removed by evaporation and the residue distilled at a pressure of 10 microns. The product boiled between 102 and 102.5° C. The yield of 1,3,3-trinitrobutane was 87 g.

The calculated composition for the empirical formula is: $C_4H_3N_3O_6$: Percent C, 24.88; percent H, 3.65; percent N, 21.76.

The ultimate analysis of the above compound showed: percent C, 25.27; percent H, 3.74; percent N, 21.65.

The index of refraction at 25° was 1.4760.

EXAMPLE II

Preparation of 1,3-dinitro-3-chlorobutane

This compound was prepared by placing in a three-necked flask, having a stirrer, dropping funnel and a reflux condenser, 750 ml. of water containing 44 g. of sodium hydroxide and cooling the solution to between 10 and 15° C. 110 g. of 1-chloro-1-nitroethane was added slowly to form the sodium salt thereof. The mixture was heated to between 30–35° C. and to the solution was added slowly 133 g. of nitroethyl acetate. The temperature was raised to 40–45° C. and was maintained at that point for one hour. At this stage, two phases were seen to form.

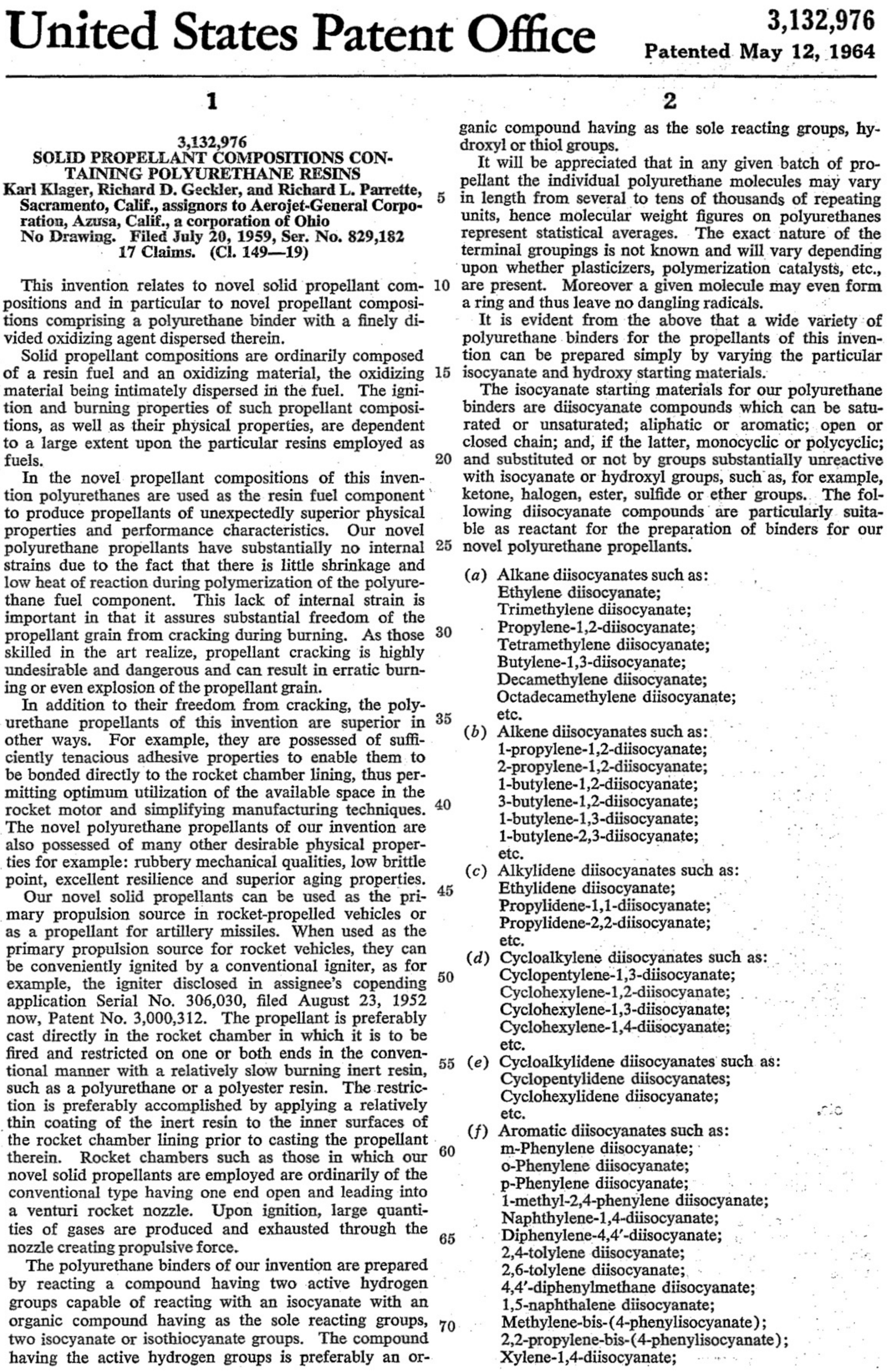
2500 ml. of methylene chloride was added to the mixture and the mixture washed twice with water. After drying the methylene chloride solution over sodium sulfate, the solvent was evaporated and the residue distilled at one micron at a temperature of between 80 and 90° C. in an air bath. 60 g. of 1,3-dinitro-3-chlorobutane was produced. The index of refraction for this compound n_D^{25} was 1.4723.

EXAMPLE III

Preparation of 1,3-dinitro-3-methylbutane

44 g. of sodium hydroxide was dissolved in 750 ml. of water. To this solution, 89 g. of 2-nitropropane was added after cooling the solution to 10 to 15° C. When the aci-sodium salt formation was complete, a solution of 13.3 of nitroethyl acetate and 250 ml. of methanol was added slowly at a temperature between 40–45° C.

Figure E.237: An example of Karl Klager's patents on rocket propellant.



United States Patent Office

3,132,976
Patented May 12, 1964

1

3,132,976
SOLID PROPELLANT COMPOSITIONS CONTAINING POLYURETHANE RESINS
Karl Klager, Richard D. Geckler, and Richard L. Parrette, Sacramento, Calif., assignors to Aerojet-General Corporation, Azusa, Calif., a corporation of Ohio
No Drawing. Filed July 20, 1959, Ser. No. 829,182
17 Claims. (Cl. 149—19)

This invention relates to novel solid propellant compositions and in particular to novel propellant compositions comprising a polyurethane binder with a finely divided oxidizing agent dispersed therein.

Solid propellant compositions are ordinarily composed of a resin fuel and an oxidizing material, the oxidizing material being intimately dispersed in the fuel. The ignition and burning properties of such propellant compositions, as well as their physical properties, are dependent to a large extent upon the particular resins employed as fuels.

In the novel propellant compositions of this invention polyurethanes are used as the resin fuel component to produce propellants of unexpectedly superior physical properties and performance characteristics. Our novel polyurethane propellants have substantially no internal strains due to the fact that there is little shrinkage and low heat of reaction during polymerization of the polyurethane fuel component. This lack of internal strain is important in that it assures substantial freedom of the propellant grain from cracking during burning. As those skilled in the art realize, propellant cracking is highly undesirable and dangerous and can result in erratic burning or even explosion of the propellant grain.

In addition to their freedom from cracking, the polyurethane propellants of this invention are superior in other ways. For example, they are possessed of sufficiently tenacious adhesive properties to enable them to be bonded directly to the rocket chamber lining, thus permitting optimum utilization of the available space in the rocket motor and simplifying manufacturing techniques. The novel polyurethane propellants of our invention are also possessed of many other desirable physical properties for example: rubbery mechanical qualities, low brittle point, excellent resilience and superior aging properties.

Our novel solid propellants can be used as the primary propulsion source in rocket-propelled vehicles or as a propellant for artillery missiles. When used as the primary propulsion source for rocket vehicles, they can be conveniently ignited by a conventional igniter, as for example, the igniter disclosed in assignee's copending application Serial No. 306,030, filed August 23, 1952 now, Patent No. 3,000,312. The propellant is preferably cast directly in the rocket chamber in which it is to be fired and restricted on one or both ends in the conventional manner with a relatively slow burning inert resin, such as a polyurethane or a polyester resin. The restriction is preferably accomplished by applying a relatively thin coating of the inert resin to the inner surfaces of the rocket chamber lining prior to casting the propellant therein. Rocket chambers such as those in which our novel solid propellants are employed are ordinarily of the conventional type having one end open and leading into a venturi rocket nozzle. Upon ignition, large quantities of gases are produced and exhausted through the nozzle creating propulsive force.

The polyurethane binders of our invention are prepared by reacting a compound having two active hydrogen groups capable of reacting with an isocyanate with an organic compound having as the sole reacting groups, two isocyanate or isothiocyanate groups. The compound having the active hydrogen groups is preferably an organic compound having as the sole reacting groups, hydroxyl or thiol groups.

2

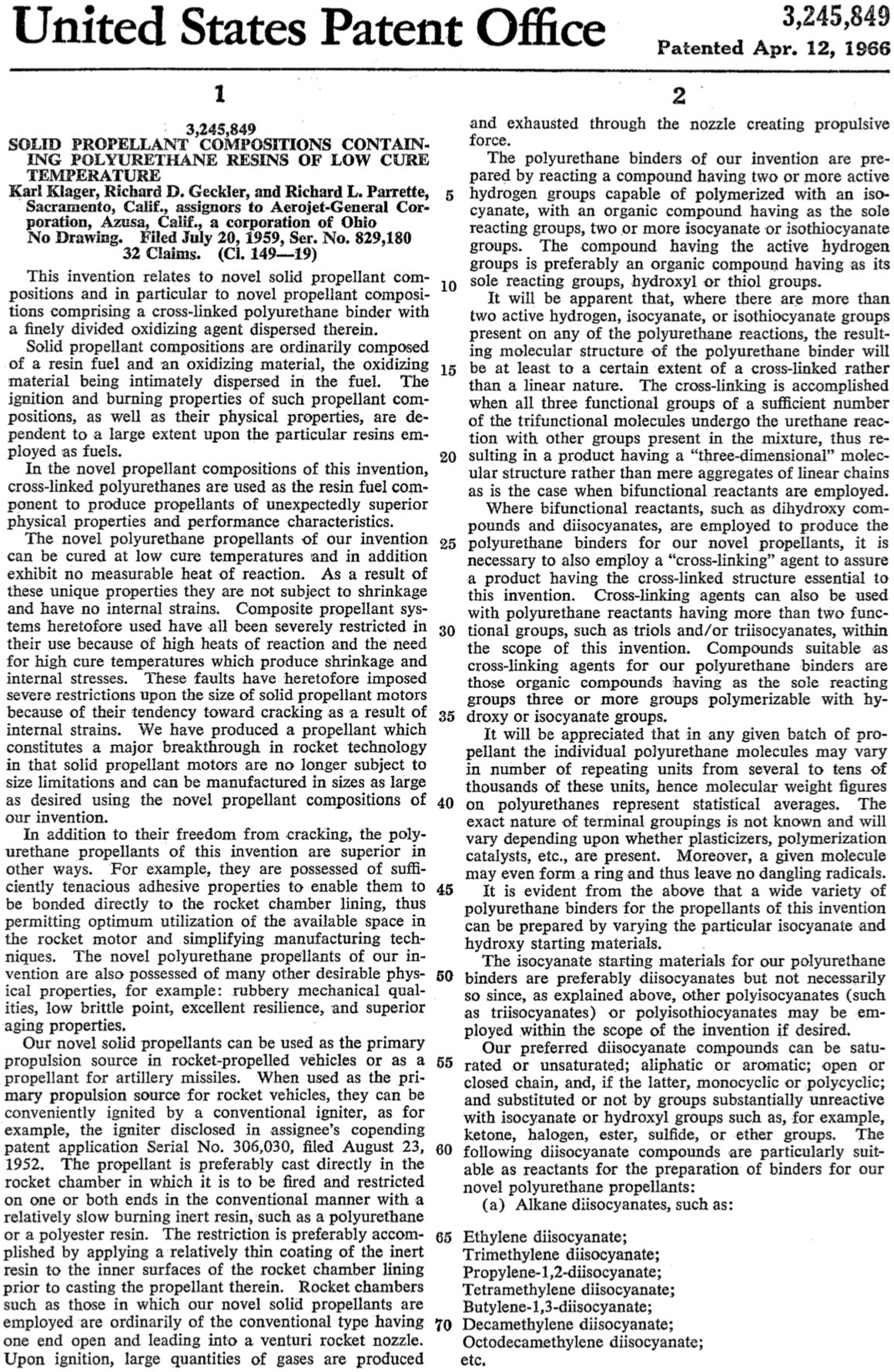
It will be appreciated that in any given batch of propellant the individual polyurethane molecules may vary in length from several to tens of thousands of repeating units, hence molecular weight figures on polyurethanes represent statistical averages. The exact nature of the terminal groupings is not known and will vary depending upon whether plasticizers, polymerization catalysts, etc., are present. Moreover a given molecule may even form a ring and thus leave no dangling radicals.

It is evident from the above that a wide variety of polyurethane binders for the propellants of this invention can be prepared simply by varying the particular isocyanate and hydroxy starting materials.

The isocyanate starting materials for our polyurethane binders are diisocyanate compounds which can be saturated or unsaturated; aliphatic or aromatic; open or closed chain; and, if the latter, monocyclic or polycyclic; and substituted or not by groups substantially unreactive with isocyanate or hydroxyl groups, such as, for example, ketone, halogen, ester, sulfide or ether groups. The following diisocyanate compounds are particularly suitable as reactant for the preparation of binders for our novel polyurethane propellants.

(*a*) Alkane diisocyanates such as:
  Ethylene diisocyanate;
  Trimethylene diisocyanate;
  Propylene-1,2-diisocyanate;
  Tetramethylene diisocyanate;
  Butylene-1,3-diisocyanate;
  Decamethylene diisocyanate;
  Octadecamethylene diisocyanate;
  etc.
(*b*) Alkene diisocyanates such as:
  1-propylene-1,2-diisocyanate;
  2-propylene-1,2-diisocyanate;
  1-butylene-1,2-diisocyanate;
  3-butylene-1,2-diisocyanate;
  1-butylene-1,3-diisocyanate;
  1-butylene-2,3-diisocyanate;
  etc.
(*c*) Alkylidene diisocyanates such as:
  Ethylidene diisocyanate;
  Propylidene-1,1-diisocyanate;
  Propylidene-2,2-diisocyanate;
  etc.
(*d*) Cycloalkylene diisocyanates such as:
  Cyclopentylene-1,3-diisocyanate;
  Cyclohexylene-1,2-diisocyanate;
  Cyclohexylene-1,3-diisocyanate;
  Cyclohexylene-1,4-diisocyanate;
  etc.
(*e*) Cycloalkylidene diisocyanates such as:
  Cyclopentylidene diisocyanates;
  Cyclohexylidene diisocyanate;
  etc.
(*f*) Aromatic diisocyanates such as:
  m-Phenylene diisocyanate;
  o-Phenylene diisocyanate;
  p-Phenylene diisocyanate;
  1-methyl-2,4-phenylene diisocyanate;
  Naphthylene-1,4-diisocyanate;
  Diphenylene-4,4'-diisocyanate;
  2,4-tolylene diisocyanate;
  2,6-tolylene diisocyanate;
  4,4'-diphenylmethane diisocyanate;
  1,5-naphthalene diisocyanate;
  Methylene-bis-(4-phenylisocyanate);
  2,2-propylene-bis-(4-phenylisocyanate);
  Xylene-1,4-diisocyanate;

Figure E.238: An example of Karl Klager's patents on rocket propellant.



United States Patent Office

3,245,849
Patented Apr. 12, 1966

3,245,849

SOLID PROPELLANT COMPOSITIONS CONTAINING POLYURETHANE RESINS OF LOW CURE TEMPERATURE

Karl Klager, Richard D. Geckler, and Richard L. Parrette, Sacramento, Calif., assignors to Aerojet-General Corporation, Azusa, Calif., a corporation of Ohio
No Drawing. Filed July 20, 1959, Ser. No. 829,180
32 Claims. (Cl. 149—19)

This invention relates to novel solid propellant compositions and in particular to novel propellant compositions comprising a cross-linked polyurethane binder with a finely divided oxidizing agent dispersed therein.

Solid propellant compositions are ordinarily composed of a resin fuel and an oxidizing material, the oxidizing material being intimately dispersed in the fuel. The ignition and burning properties of such propellant compositions, as well as their physical properties, are dependent to a large extent upon the particular resins employed as fuels.

In the novel propellant compositions of this invention, cross-linked polyurethanes are used as the resin fuel component to produce propellants of unexpectedly superior physical properties and performance characteristics.

The novel polyurethane propellants of our invention can be cured at low cure temperatures and in addition exhibit no measurable heat of reaction. As a result of these unique properties they are not subject to shrinkage and have no internal strains. Composite propellant systems heretofore used have all been severely restricted in their use because of high heats of reaction and the need for high cure temperatures which produce shrinkage and internal stresses. These faults have heretofore imposed severe restrictions upon the size of solid propellant motors because of their tendency toward cracking as a result of internal strains. We have produced a propellant which constitutes a major breakthrough in rocket technology in that solid propellant motors are no longer subject to size limitations and can be manufactured in sizes as large as desired using the novel propellant compositions of our invention.

In addition to their freedom from cracking, the polyurethane propellants of this invention are superior in other ways. For example, they are possessed of sufficiently tenacious adhesive properties to enable them to be bonded directly to the rocket chamber lining, thus permitting optimum utilization of the available space in the rocket motor and simplifying manufacturing techniques. The novel polyurethane propellants of our invention are also possessed of many other desirable physical properties, for example: rubbery mechanical qualities, low brittle point, excellent resilience, and superior aging properties.

Our novel solid propellants can be used as the primary propulsion source in rocket-propelled vehicles or as a propellant for artillery missiles. When used as the primary propulsion source for rocket vehicles, they can be conveniently ignited by a conventional igniter, as for example, the igniter disclosed in assignee's copending patent application Serial No. 306,030, filed August 23, 1952. The propellant is preferably cast directly in the rocket chamber in which it is to be fired and restricted on one or both ends in the conventional manner with a relatively slow burning inert resin, such as a polyurethane or a polyester resin. The restriction is preferably accomplished by applying a relatively thin coating of the inert resin to the inner surfaces of the rocket chamber lining prior to casting the propellant therein. Rocket chambers such as those in which our novel solid propellants are employed are ordinarily of the conventional type having one end open and leading into a venturi rocket nozzle. Upon ignition, large quantities of gases are produced

and exhausted through the nozzle creating propulsive force.

The polyurethane binders of our invention are prepared by reacting a compound having two or more active hydrogen groups capable of polymerized with an isocyanate, with an organic compound having as the sole reacting groups, two or more isocyanate or isothiocyanate groups. The compound having the active hydrogen groups is preferably an organic compound having as its sole reacting groups, hydroxyl or thiol groups.

It will be apparent that, where there are more than two active hydrogen, isocyanate, or isothiocyanate groups present on any of the polyurethane reactions, the resulting molecular structure of the polyurethane binder will be at least to a certain extent of a cross-linked rather than a linear nature. The cross-linking is accomplished when all three functional groups of a sufficient number of the trifunctional molecules undergo the urethane reaction with other groups present in the mixture, thus resulting in a product having a "three-dimensional" molecular structure rather than mere aggregates of linear chains as is the case when bifunctional reactants are employed.

Where bifunctional reactants, such as dihydroxy compounds and diisocyanates, are employed to produce the polyurethane binders for our novel propellants, it is necessary to also employ a "cross-linking" agent to assure a product having the cross-linked structure essential to this invention. Cross-linking agents can also be used with polyurethane reactants having more than two functional groups, such as triols and/or triisocyanates, within the scope of this invention. Compounds suitable as cross-linking agents for our polyurethane binders are those organic compounds having as the sole reacting groups three or more groups polymerizable with hydroxy or isocyanate groups.

It will be appreciated that in any given batch of propellant the individual polyurethane molecules may vary in number of repeating units from several to tens of thousands of these units, hence molecular weight figures on polyurethanes represent statistical averages. The exact nature of terminal groupings is not known and will vary depending upon whether plasticizers, polymerization catalysts, etc., are present. Moreover, a given molecule may even form a ring and thus leave no dangling radicals.

It is evident from the above that a wide variety of polyurethane binders for the propellants of this invention can be prepared by varying the particular isocyanate and hydroxy starting materials.

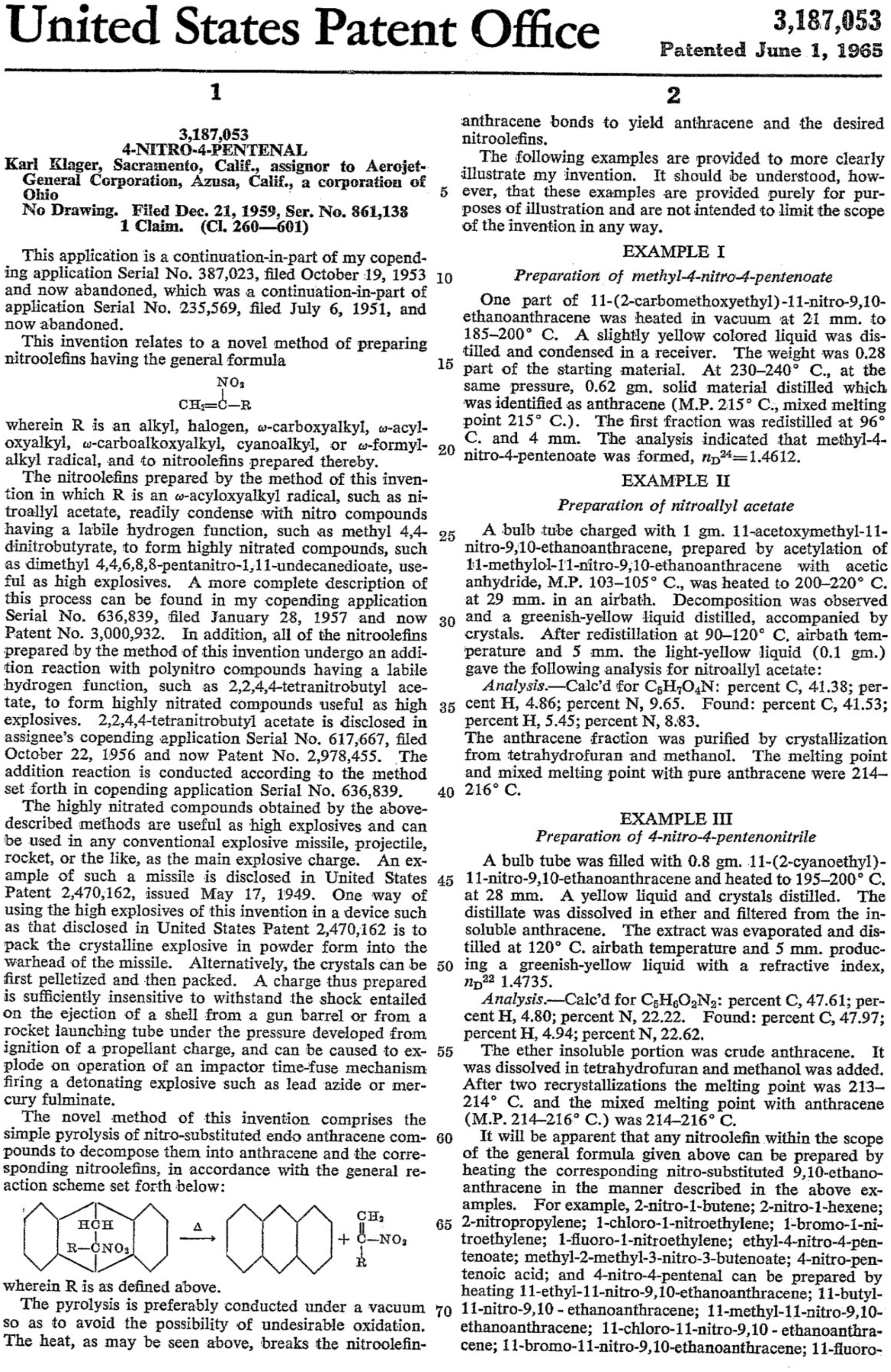
The isocyanate starting materials for our polyurethane binders are preferably diisocyanates but not necessarily so since, as explained above, other polyisocyanates (such as triisocyanates) or polyisothiocyanates may be employed within the scope of the invention if desired.

Our preferred diisocyanate compounds can be saturated or unsaturated; aliphatic or aromatic; open or closed chain, and, if the latter, monocyclic or polycyclic; and substituted or not by groups substantially unreactive with isocyanate or hydroxyl groups such as, for example, ketone, halogen, ester, sulfide, or ether groups. The following diisocyanate compounds are particularly suitable as reactants for the preparation of binders for our novel polyurethane propellants:

(a) Alkane diisocyanates, such as:

Ethylene diisocyanate;
Trimethylene diisocyanate;
Propylene-1,2-diisocyanate;
Tetramethylene diisocyanate;
Butylene-1,3-diisocyanate;
Decamethylene diisocyanate;
Octodecamethylene diisocyanate;
etc.

Figure E.239: An example of Karl Klager's patents on rocket propellant.



United States Patent Office

3,187,053
Patented June 1, 1965

1

3,187,053
4-NITRO-4-PENTENAL
Karl Klager, Sacramento, Calif., assignor to Aerojet-General Corporation, Azusa, Calif., a corporation of Ohio
No Drawing. Filed Dec. 21, 1959, Ser. No. 861,138
1 Claim. (Cl. 260—601)

This application is a continuation-in-part of my copending application Serial No. 387,023, filed October 19, 1953 and now abandoned, which was a continuation-in-part of application Serial No. 235,569, filed July 6, 1951, and now abandoned.

This invention relates to a novel method of preparing nitroolefins having the general formula

$$CH_2{=}\overset{NO_2}{\overset{|}{C}}{-}R$$

wherein R is an alkyl, halogen, ω-carboxyalkyl, ω-acyloxyalkyl, ω-carboalkoxyalkyl, cyanoalkyl, or ω-formylalkyl radical, and to nitroolefins prepared thereby.

The nitroolefins prepared by the method of this invention in which R is an ω-acyloxyalkyl radical, such as nitroallyl acetate, readily condense with nitro compounds having a labile hydrogen function, such as methyl 4,4-dinitrobutyrate, to form highly nitrated compounds, such as dimethyl 4,4,6,8,8-pentanitro-1,11-undecanedioate, useful as high explosives. A more complete description of this process can be found in my copending application Serial No. 636,839, filed January 28, 1957 and now Patent No. 3,000,932. In addition, all of the nitroolefins prepared by the method of this invention undergo an addition reaction with polynitro compounds having a labile hydrogen function, such as 2,2,4,4-tetranitrobutyl acetate, to form highly nitrated compounds useful as high explosives. 2,2,4,4-tetranitrobutyl acetate is disclosed in assignee's copending application Serial No. 617,667, filed October 22, 1956 and now Patent No. 2,978,455. The addition reaction is conducted according to the method set forth in copending application Serial No. 636,839.

The highly nitrated compounds obtained by the above-described methods are useful as high explosives and can be used in any conventional explosive missile, projectile, rocket, or the like, as the main explosive charge. An example of such a missile is disclosed in United States Patent 2,470,162, issued May 17, 1949. One way of using the high explosives of this invention in a device such as that disclosed in United States Patent 2,470,162 is to pack the crystalline explosive in powder form into the warhead of the missile. Alternatively, the crystals can be first pelletized and then packed. A charge thus prepared is sufficiently insensitive to withstand the shock entailed on the ejection of a shell from a gun barrel or from a rocket launching tube under the pressure developed from ignition of a propellant charge, and can be caused to explode on operation of an impactor time-fuse mechanism firing a detonating explosive such as lead azide or mercury fulminate.

The novel method of this invention comprises the simple pyrolysis of nitro-substituted endo anthracene compounds to decompose them into anthracene and the corresponding nitroolefins, in accordance with the general reaction scheme set forth below:

wherein R is as defined above.

The pyrolysis is preferably conducted under a vacuum so as to avoid the possibility of undesirable oxidation. The heat, as may be seen above, breaks the nitroolefin-anthracene bonds to yield anthracene and the desired nitroolefins.

2

The following examples are provided to more clearly illustrate my invention. It should be understood, however, that these examples are provided purely for purposes of illustration and are not intended to limit the scope of the invention in any way.

EXAMPLE I

Preparation of methyl-4-nitro-4-pentenoate

One part of 11-(2-carbomethoxyethyl)-11-nitro-9,10-ethanoanthracene was heated in vacuum at 21 mm. to 185–200° C. A slightly yellow colored liquid was distilled and condensed in a receiver. The weight was 0.28 part of the starting material. At 230–240° C., at the same pressure, 0.62 gm. solid material distilled which was identified as anthracene (M.P. 215° C., mixed melting point 215° C.). The first fraction was redistilled at 96° C. and 4 mm. The analysis indicated that methyl-4-nitro-4-pentenoate was formed, $n_D^{24}=1.4612$.

EXAMPLE II

Preparation of nitroallyl acetate

A bulb tube charged with 1 gm. 11-acetoxymethyl-11-nitro-9,10-ethanoanthracene, prepared by acetylation of 11-methylol-11-nitro-9,10-ethanoanthracene with acetic anhydride, M.P. 103–105° C., was heated to 200–220° C. at 29 mm. in an airbath. Decomposition was observed and a greenish-yellow liquid distilled, accompanied by crystals. After redistillation at 90–120° C. airbath temperature and 5 mm. the light-yellow liquid (0.1 gm.) gave the following analysis for nitroallyl acetate:

Analysis.—Calc'd for $C_5H_7O_4N$: percent C, 41.38; percent H, 4.86; percent N, 9.65. Found: percent C, 41.53; percent H, 5.45; percent N, 8.83.

The anthracene fraction was purified by crystallization from tetrahydrofuran and methanol. The melting point and mixed melting point with pure anthracene were 214–216° C.

EXAMPLE III

Preparation of 4-nitro-4-pentenonitrile

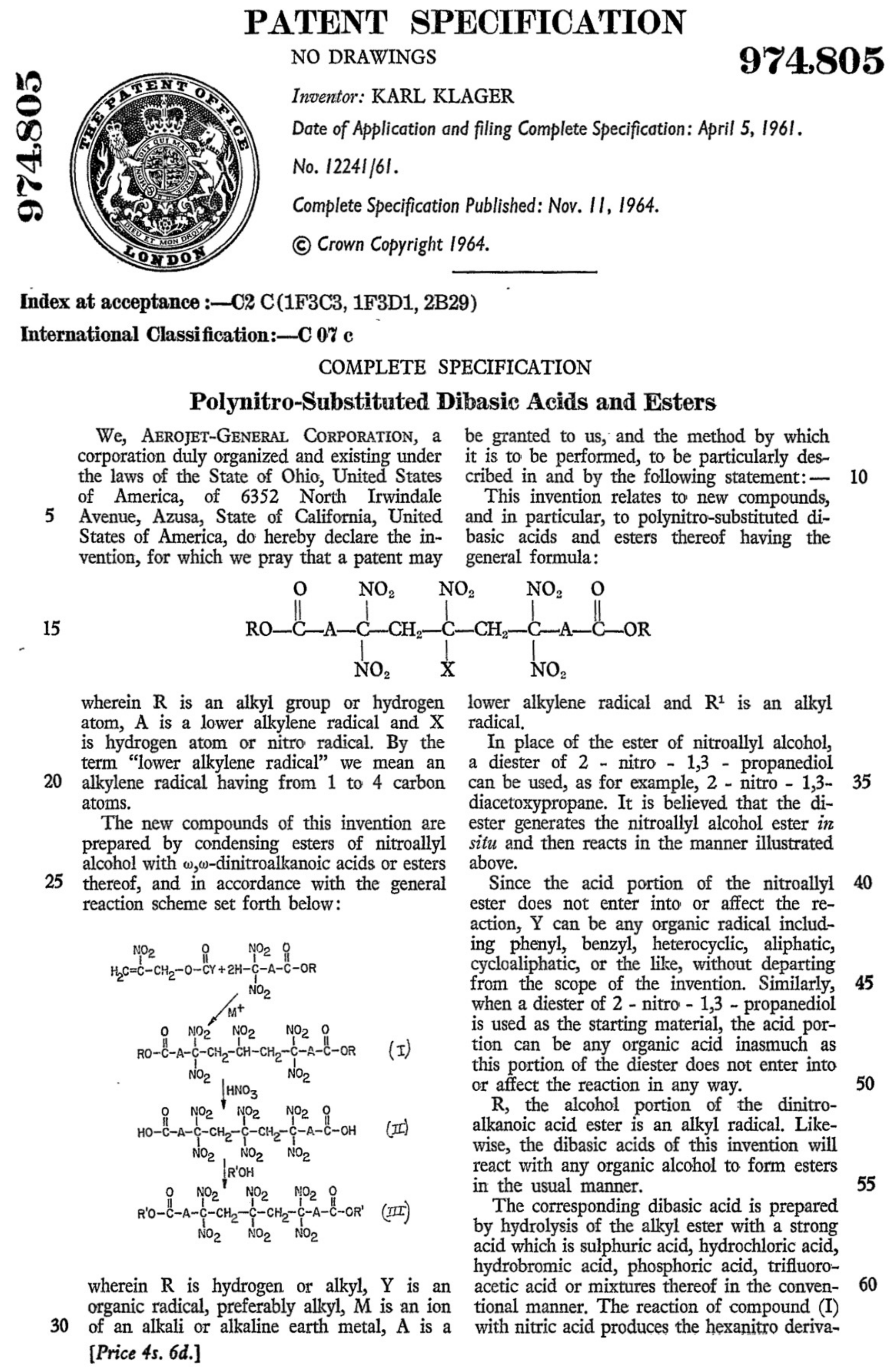
A bulb tube was filled with 0.8 gm. 11-(2-cyanoethyl)-11-nitro-9,10-ethanoanthracene and heated to 195–200° C. at 28 mm. A yellow liquid and crystals distilled. The distillate was dissolved in ether and filtered from the insoluble anthracene. The extract was evaporated and distilled at 120° C. airbath temperature and 5 mm. producing a greenish-yellow liquid with a refractive index, n_D^{22} 1.4735.

Analysis.—Calc'd for $C_5H_6O_2N_2$: percent C, 47.61; percent H, 4.80; percent N, 22.22. Found: percent C, 47.97; percent H, 4.94; percent N, 22.62.

The ether insoluble portion was crude anthracene. It was dissolved in tetrahydrofuran and methanol was added. After two recrystallizations the melting point was 213–214° C. and the mixed melting point with anthracene (M.P. 214–216° C.) was 214–216° C.

It will be apparent that any nitroolefin within the scope of the general formula given above can be prepared by heating the corresponding nitro-substituted 9,10-ethanoanthracene in the manner described in the above examples. For example, 2-nitro-1-butene; 2-nitro-1-hexene; 2-nitropropylene; 1-chloro-1-nitroethylene; 1-bromo-1-nitroethylene; 1-fluoro-1-nitroethylene; ethyl-4-nitro-4-pentenoate; methyl-2-methyl-3-nitro-3-butenoate; 4-nitro-pentenoic acid; and 4-nitro-4-pentenal can be prepared by heating 11-ethyl-11-nitro-9,10-ethanoanthracene; 11-butyl-11-nitro-9,10 - ethanoanthracene; 11-methyl-11-nitro-9,10-ethanoanthracene; 11-chloro-11-nitro-9,10 - ethanoanthracene; 11-bromo-11-nitro-9,10-ethanoanthracene; 11-fluoro-

Figure E.240: An example of Karl Klager's patents on rocket propellant.



PATENT SPECIFICATION

NO DRAWINGS

974,805

974,805

Inventor: KARL KLAGER

Date of Application and filing Complete Specification: April 5, 1961.

No. 12241/61.

Complete Specification Published: Nov. 11, 1964.

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Index at acceptance:—C2 C(1F3C3, 1F3D1, 2B29)

International Classification:—C 07 c

COMPLETE SPECIFICATION

Polynitro-Substituted Dibasic Acids and Esters

We, AEROJET-GENERAL CORPORATION, a corporation duly organized and existing under the laws of the State of Ohio, United States of America, of 6352 North Irwindale Avenue, Azusa, State of California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to new compounds, and in particular, to polynitro-substituted dibasic acids and esters thereof having the general formula:

$$RO-\overset{O}{\overset{\|}{C}}-A-\underset{NO_2}{\overset{NO_2}{C}}-CH_2-\underset{X}{\overset{NO_2}{C}}-CH_2-\underset{NO_2}{\overset{NO_2}{C}}-A-\overset{O}{\overset{\|}{C}}-OR$$

wherein R is an alkyl group or hydrogen atom, A is a lower alkylene radical and X is hydrogen atom or nitro radical. By the term "lower alkylene radical" we mean an alkylene radical having from 1 to 4 carbon atoms.

The new compounds of this invention are prepared by condensing esters of nitroallyl alcohol with ω,ω-dinitroalkanoic acids or esters thereof, and in accordance with the general reaction scheme set forth below:

$$H_2C=\overset{NO_2}{C}-CH_2-O-\overset{O}{\overset{\|}{C}}Y+2H-\underset{NO_2}{\overset{NO_2}{C}}-A-\overset{O}{\overset{\|}{C}}-OR$$

$$\downarrow M^+$$

$$RO-\overset{O}{\overset{\|}{C}}-A-\underset{NO_2}{\overset{NO_2}{C}}-CH_2-\overset{NO_2}{CH}-CH_2-\underset{NO_2}{\overset{NO_2}{C}}-A-\overset{O}{\overset{\|}{C}}-OR \qquad (I)$$

$$\downarrow HNO_3$$

$$HO-\overset{O}{\overset{\|}{C}}-A-\underset{NO_2}{\overset{NO_2}{C}}-CH_2-\underset{NO_2}{\overset{NO_2}{C}}-CH_2-\underset{NO_2}{\overset{NO_2}{C}}-A-\overset{O}{\overset{\|}{C}}-OH \qquad (II)$$

$$\downarrow R'OH$$

$$R'O-\overset{O}{\overset{\|}{C}}-A-\underset{NO_2}{\overset{NO_2}{C}}-CH_2-\underset{NO_2}{\overset{NO_2}{C}}-CH_2-\underset{NO_2}{\overset{NO_2}{C}}-A-\overset{O}{\overset{\|}{C}}-OR' \qquad (III)$$

wherein R is hydrogen or alkyl, Y is an organic radical, preferably alkyl, M is an ion of an alkali or alkaline earth metal, A is a lower alkylene radical and R^1 is an alkyl radical.

In place of the ester of nitroallyl alcohol, a diester of 2 - nitro - 1,3 - propanediol can be used, as for example, 2 - nitro - 1,3-diacetoxypropane. It is believed that the diester generates the nitroallyl alcohol ester *in situ* and then reacts in the manner illustrated above.

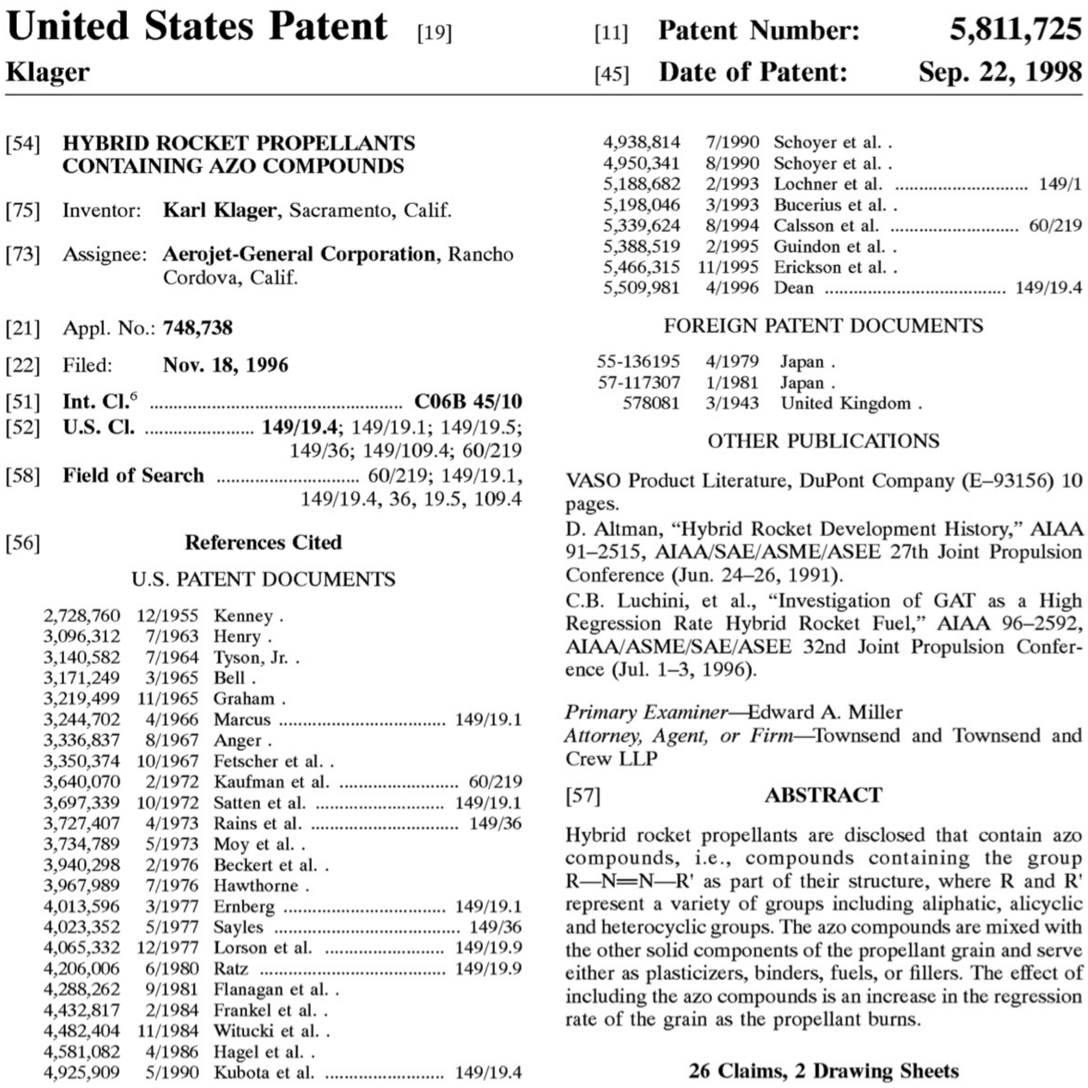
Since the acid portion of the nitroallyl ester does not enter into or affect the reaction, Y can be any organic radical including phenyl, benzyl, heterocyclic, aliphatic, cycloaliphatic, or the like, without departing from the scope of the invention. Similarly, when a diester of 2 - nitro - 1,3 - propanediol is used as the starting material, the acid portion can be any organic acid inasmuch as this portion of the diester does not enter into or affect the reaction in any way.

R, the alcohol portion of the dinitroalkanoic acid ester is an alkyl radical. Likewise, the dibasic acids of this invention will react with any organic alcohol to form esters in the usual manner.

The corresponding dibasic acid is prepared by hydrolysis of the alkyl ester with a strong acid which is sulphuric acid, hydrochloric acid, hydrobromic acid, phosphoric acid, trifluoroacetic acid or mixtures thereof in the conventional manner. The reaction of compound (I) with nitric acid produces the hexanitro deriva-

[*Price 4s. 6d.*]

Figure E.241: An example of Karl Klager's patents on rocket propellant.



United States Patent [19]
Klager

[11] **Patent Number: 5,811,725**
[45] **Date of Patent: Sep. 22, 1998**

[54] **HYBRID ROCKET PROPELLANTS CONTAINING AZO COMPOUNDS**

[75] Inventor: **Karl Klager**, Sacramento, Calif.

[73] Assignee: **Aerojet-General Corporation**, Rancho Cordova, Calif.

[21] Appl. No.: **748,738**

[22] Filed: **Nov. 18, 1996**

[51] **Int. Cl.^{6}** **C06B 45/10**
[52] **U.S. Cl.** **149/19.4**; 149/19.1; 149/19.5; 149/36; 149/109.4; 60/219
[58] **Field of Search** 60/219; 149/19.1, 149/19.4, 36, 19.5, 109.4

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,728,760	12/1955	Kenney .	
3,096,312	7/1963	Henry .	
3,140,582	7/1964	Tyson, Jr. .	
3,171,249	3/1965	Bell .	
3,219,499	11/1965	Graham .	
3,244,702	4/1966	Marcus	149/19.1
3,336,837	8/1967	Anger .	
3,350,374	10/1967	Fetscher et al. .	
3,640,070	2/1972	Kaufman et al.	60/219
3,697,339	10/1972	Satten et al.	149/19.1
3,727,407	4/1973	Rains et al.	149/36
3,734,789	5/1973	Moy et al. .	
3,940,298	2/1976	Beckert et al. .	
3,967,989	7/1976	Hawthorne .	
4,013,596	3/1977	Ernberg	149/19.1
4,023,352	5/1977	Sayles	149/36
4,065,332	12/1977	Lorson et al.	149/19.9
4,206,006	6/1980	Ratz	149/19.9
4,288,262	9/1981	Flanagan et al. .	
4,432,817	2/1984	Frankel et al. .	
4,482,404	11/1984	Witucki et al. .	
4,581,082	4/1986	Hagel et al. .	
4,925,909	5/1990	Kubota et al.	149/19.4
4,938,814	7/1990	Schoyer et al. .	
4,950,341	8/1990	Schoyer et al. .	
5,188,682	2/1993	Lochner et al.	149/1
5,198,046	3/1993	Bucerius et al. .	
5,339,624	8/1994	Calsson et al.	60/219
5,388,519	2/1995	Guindon et al. .	
5,466,315	11/1995	Erickson et al. .	
5,509,981	4/1996	Dean	149/19.4

FOREIGN PATENT DOCUMENTS

55-136195	4/1979	Japan .
57-117307	1/1981	Japan .
578081	3/1943	United Kingdom .

OTHER PUBLICATIONS

VASO Product Literature, DuPont Company (E–93156) 10 pages.

D. Altman, "Hybrid Rocket Development History," AIAA 91–2515, AIAA/SAE/ASME/ASEE 27th Joint Propulsion Conference (Jun. 24–26, 1991).

C.B. Luchini, et al., "Investigation of GAT as a High Regression Rate Hybrid Rocket Fuel," AIAA 96–2592, AIAA/ASME/SAE/ASEE 32nd Joint Propulsion Conference (Jul. 1–3, 1996).

Primary Examiner—Edward A. Miller
Attorney, Agent, or Firm—Townsend and Townsend and Crew LLP

[57] **ABSTRACT**

Hybrid rocket propellants are disclosed that contain azo compounds, i.e., compounds containing the group R—N═N—R' as part of their structure, where R and R' represent a variety of groups including aliphatic, alicyclic and heterocyclic groups. The azo compounds are mixed with the other solid components of the propellant grain and serve either as plasticizers, binders, fuels, or fillers. The effect of including the azo compounds is an increase in the regression rate of the grain as the propellant burns.

26 Claims, 2 Drawing Sheets

Figure E.242: An example of Karl Klager's patents on rocket propellant.

David Beers. 1996. *Blue Sky Dream: A Memoir of America's Fall from Grace.* [Beers 1996, pp. 38–39]

"The most beautiful missiles ever fired," a U.S. Navy Rear Admiral pronounced the nuclear-tipped A1X Polaris, having witnessed its successful submarine test on a summer day in 1960. The fully evolved, deployed Polaris, designed under the guidance of Wernher von Braun's friend and fellow former Nazi, Wolfgang Noeggerath, was capable of traveling 2,400 nautical miles in a few minutes and delivering, from its elusively mobile launchpad, three separate warheads to a single target deep within the Soviet Union—facts no doubt beautiful to a nuclear warfare strategist.

[The journalist David Beers, who grew up surrounded by the research of his father and his father's coworkers at Lockheed, singled out the importance of Wolfgang Noeggerath for the Polaris solid-propellant missile.]

Baltimore Sun 2000-11-29. Werner W. Hohenner, 93, Scientist Who Helped Develop Polaris Missile [https://www.baltimoresun.com/news/bs-xpm-2000-11-29-0011290120-story.html].

[...] From 1947 until 1954, Mr. Hohenner was at the Point Mugu Naval Air Weapon Station in California, working in the Naval Ballistic Program that led to the development of the Polaris missile, the first U.S. submarine-launched ballistic missile.

During the rocket's development, Mr. Hohenner prevailed over Mr. von Braun, who insisted that the rocket be fueled by liquid rather than solid fuel.

"He brought a great knowledge ... in fuel handling, and convinced the Navy that if they followed von Braun's plan to use liquid fuel, which is dangerous, they could plan on losing a sub a year in accidents," said Robert L. Frohmuth, a retired Navy electrical engineer. "It was a breakthrough, and he was the one who got solid fuel missiles started, which are still being used today."

"His greatest achievement was the development of the Polaris," said Mr. Schmitz.

From 1957 until retiring in 1973, Mr. Hohenner was chief scientist at the air arm division at the Westinghouse plant in Linthicum, where he continued his work on weapon systems and ballistic missiles.

[The *Baltimore Sun* reported the death of another German scientist who played an important role in the development of the Polaris missile, which was confirmed in the later *Los Alamos Daily Post* article below.]

***Los Alamos Daily Post.* 2013-04-10. Rosmarie H. Frederickson.**
[https://ladailypost.com/new-living-treasures-of-los-alamos-unveiled/]

Rosmarie H. Frederickson was born in Germany and came to the US at age 12. She is the daughter of scientist Werner W. Hohenner who was able to bring his family to the US after the war, and once here he was able to help develop the Polaris missile. [...]

The Birth and Boyhood of Point Mugu by Captain Grayson Merrill, USN (Ret). 2003.
https://www.usna.com/tributes-and-stories—stories-1934
http://stagone.org/?page_id=28 [Merrill 2003]

Shortly after this I was detailed to witness some V-2 firings at Cuxhaven staged by the British and executed by Germans from Peenemunde. It reinforced, in my mind, the correctness of choosing Point Mugu. After the firings a small group of American observers gathered in a Bremen rathskeller to quaff beer and discuss what we had seen. A rumpled fake Army Colonel named Theodore von Kármán summed up our feelings, “You young fellows must now go home and arrange to put these Germans to work. In the meantime build a test range for the missiles to come.”

Almost 20 years later it can be said that Point Mugu has borne out the committee’s judgments. [...]

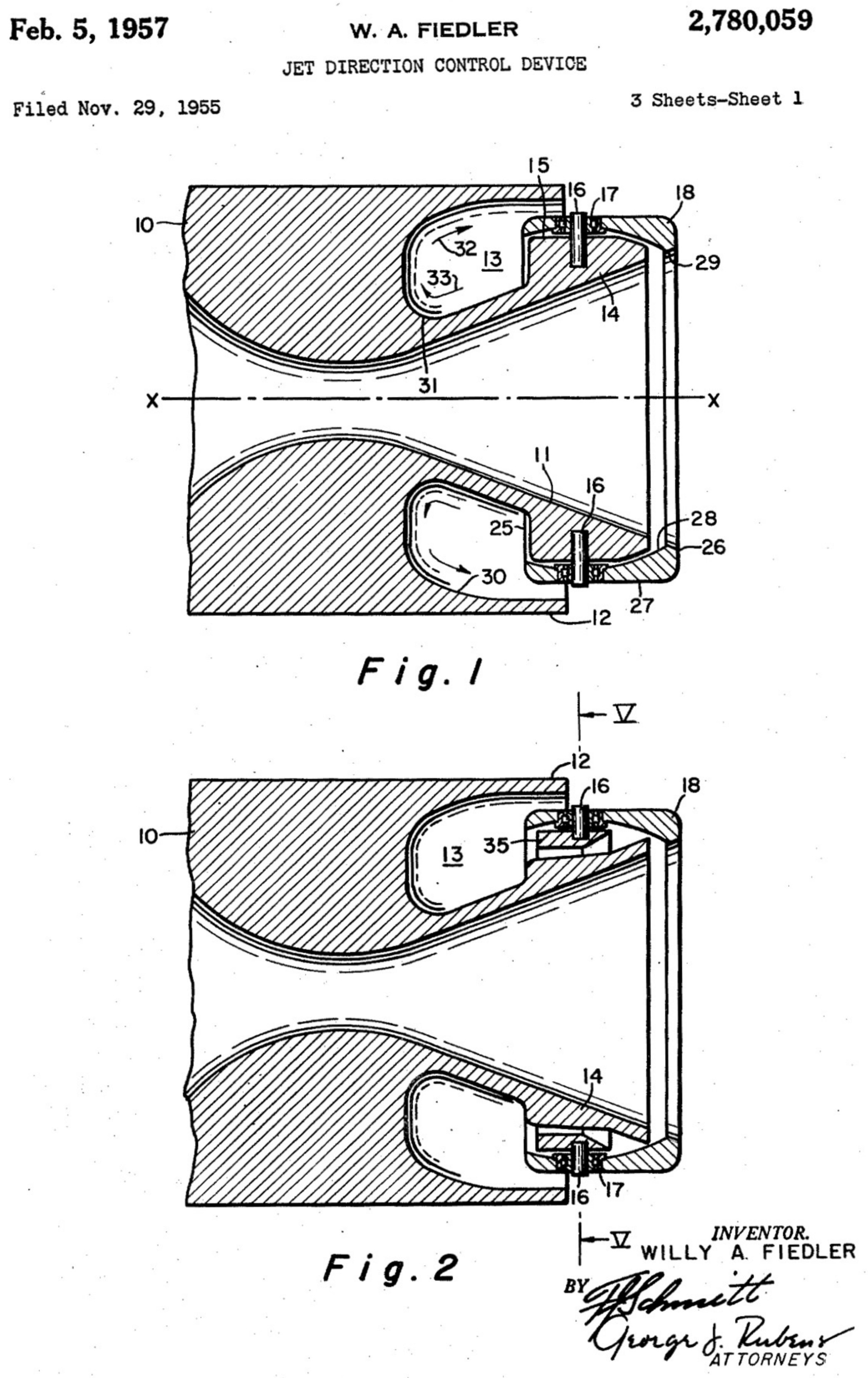
Many of the LOON technical successes are traceable to the “German Scientists” who migrated to Point Mugu. These included Willy Fiedler, Robert Lusser and Otto Schwede. But Dr. Herbert A. Wagner, now deceased, deserves special mention. [...]

I left in 1949 but nevertheless watched with pride as the range expanded in support of such missiles as LARK, SPARROW, REGULUS, RIGEL, POLARIS and TOMAHAWK.

[Grayson Merrill, a retired Navy Captain, also emphasized the central role of German-speaking scientists in the missile programs.

For considerable documentation on Willy Fiedler’s aerospace work in both Germany and the United States, see https://earlyflightera.com/from-fledermaus-to-polaris/]

Figure E.243: Willy Fiedler made many major contributions to the Polaris missile program.



Feb. 5, 1957 W. A. FIEDLER **2,780,059**

JET DIRECTION CONTROL DEVICE

Filed Nov. 29, 1955 3 Sheets-Sheet 1

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Fig. 1
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Fig. 2

INVENTOR.
WILLY A. FIEDLER

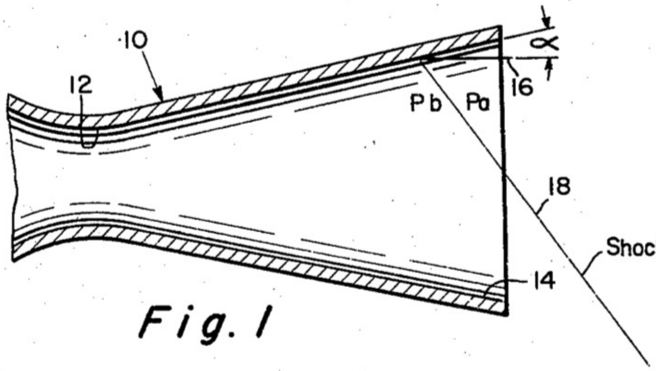
BY Schmitt
George J. Rubens
ATTORNEYS

Figure E.244: An example of Willy Fiedler's patents related to the Polaris missile.

Sept. 15, 1959 W. A. FIEDLER **2,903,851**

JET DEFLECTOR

Filed May 7, 1956 2 Sheets-Sheet 1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Shock wave
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Fig. 1

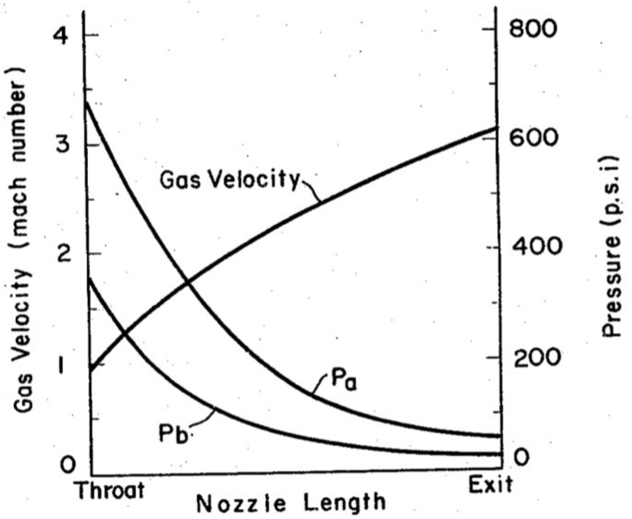

Fig. 2

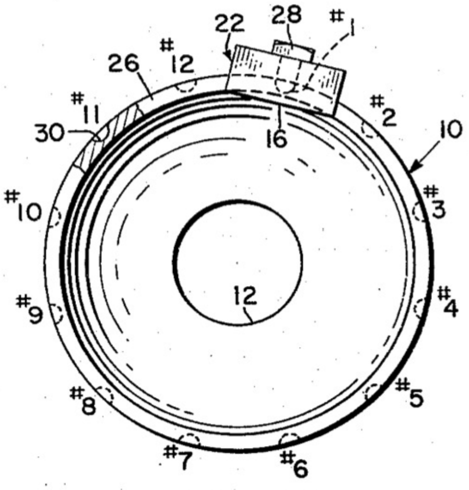
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Fig. 4

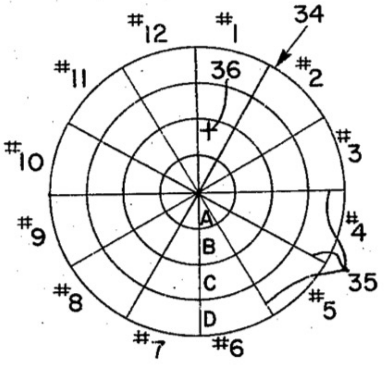
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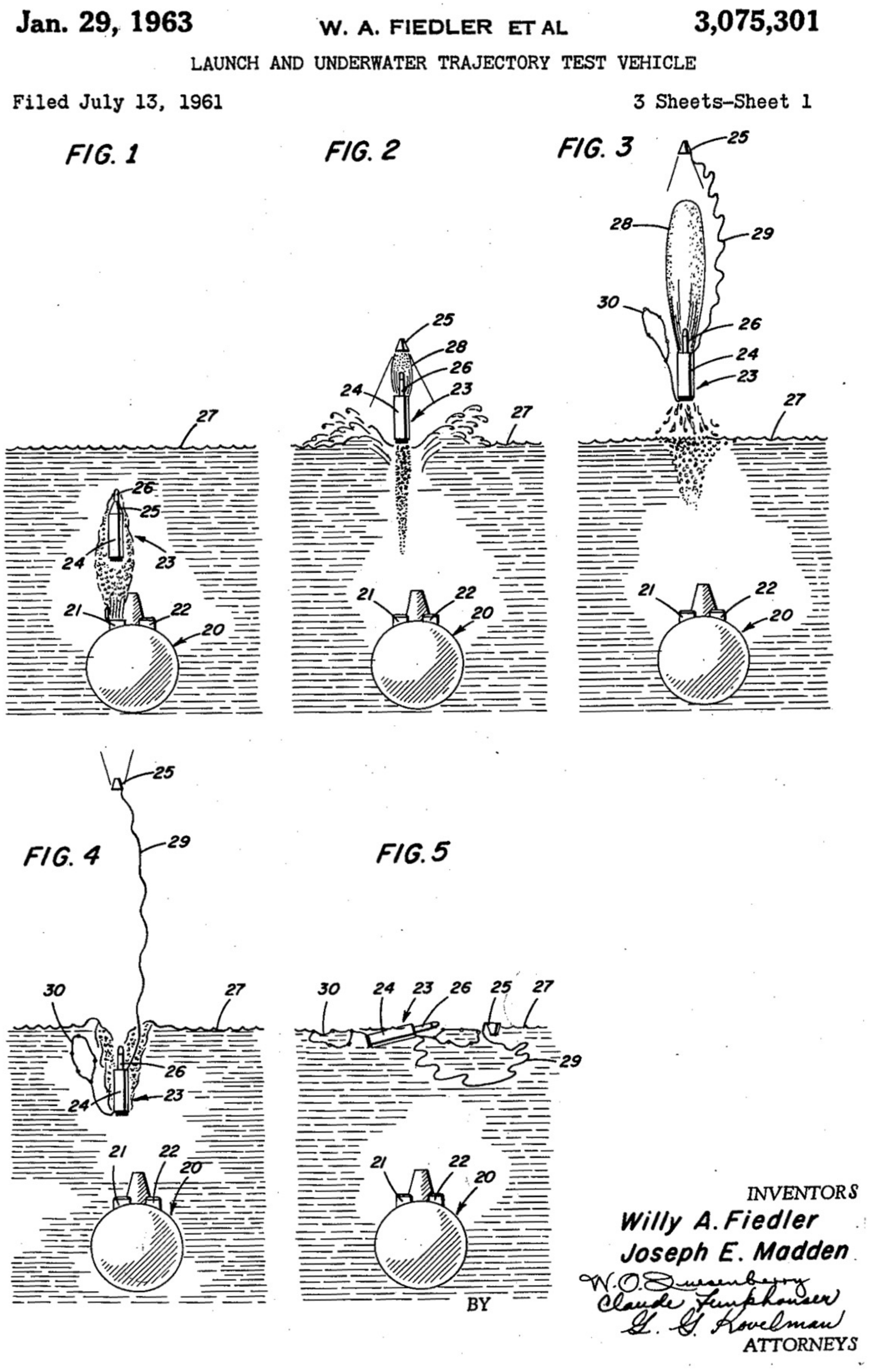
Fig. 7

INVENTOR.
WILLY A. FIEDLER

BY

George J. Rubens
ATTORNEYS

Figure E.245: An example of Willy Fiedler's patents related to the Polaris missile.



Jan. 29, 1963 W. A. FIEDLER ET AL **3,075,301**

LAUNCH AND UNDERWATER TRAJECTORY TEST VEHICLE

Filed July 13, 1961 3 Sheets-Sheet 1

FIG. 1
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FIG. 2
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FIG. 3
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FIG. 4
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FIG. 5
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INVENTORS
Willy A. Fiedler
Joseph E. Madden

BY W. O. Quesenberry
Claude Funkhouser
G. G. Kovelman
ATTORNEYS

Figure E.246: An example of Willy Fiedler's patents related to the Polaris missile.

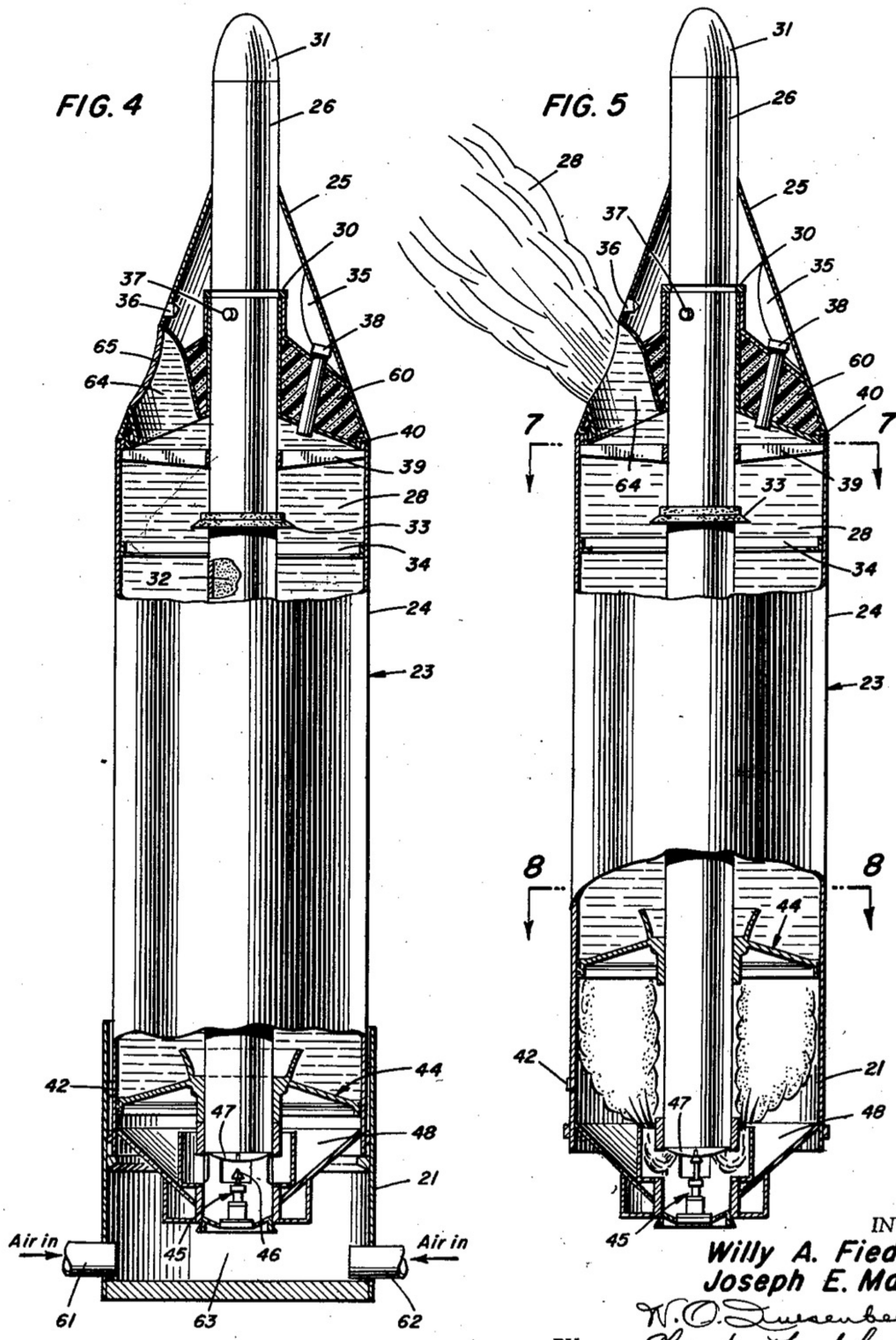
Jan. 29, 1963 **W. A. FIEDLER ET AL** **3,075,302**

UNDERWATER PITCH-OVER LAUNCH TEST VEHICLE

Filed Aug. 17, 1961 3 Sheets-Sheet 2

FIG. 4

FIG. 5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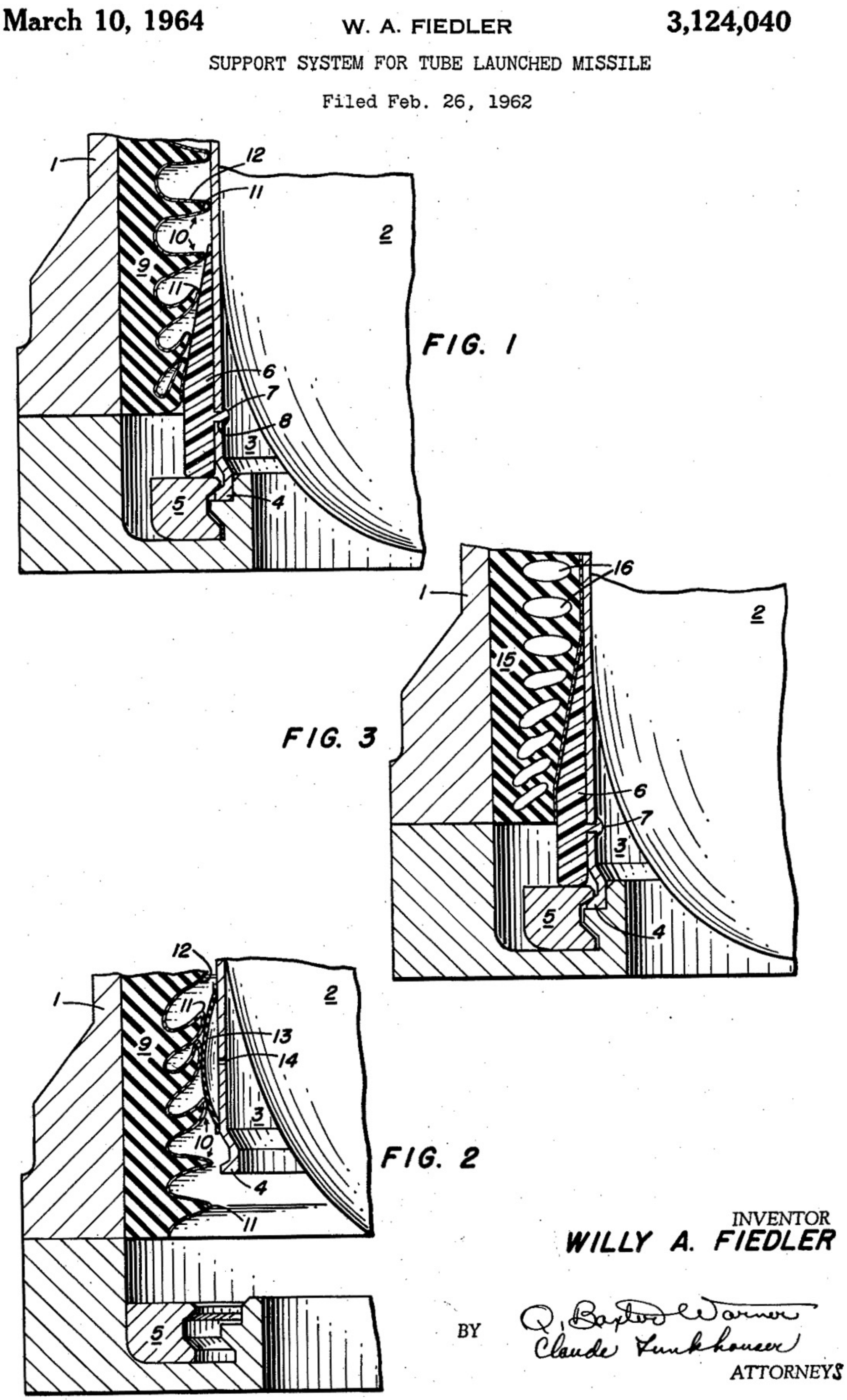
INVENTORS
Willy A. Fiedler
Joseph E. Madden

BY W. O. Quesenberry
Claude Funkhouser
G. J. Kovelman
ATTORNEYS

Figure E.247: An example of Willy Fiedler's patents related to the Polaris missile.



March 10, 1964 W. A. FIEDLER **3,124,040**

SUPPORT SYSTEM FOR TUBE LAUNCHED MISSILE

Filed Feb. 26, 1962

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FIG. 3
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FIG. 2
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INVENTOR
WILLY A. FIEDLER

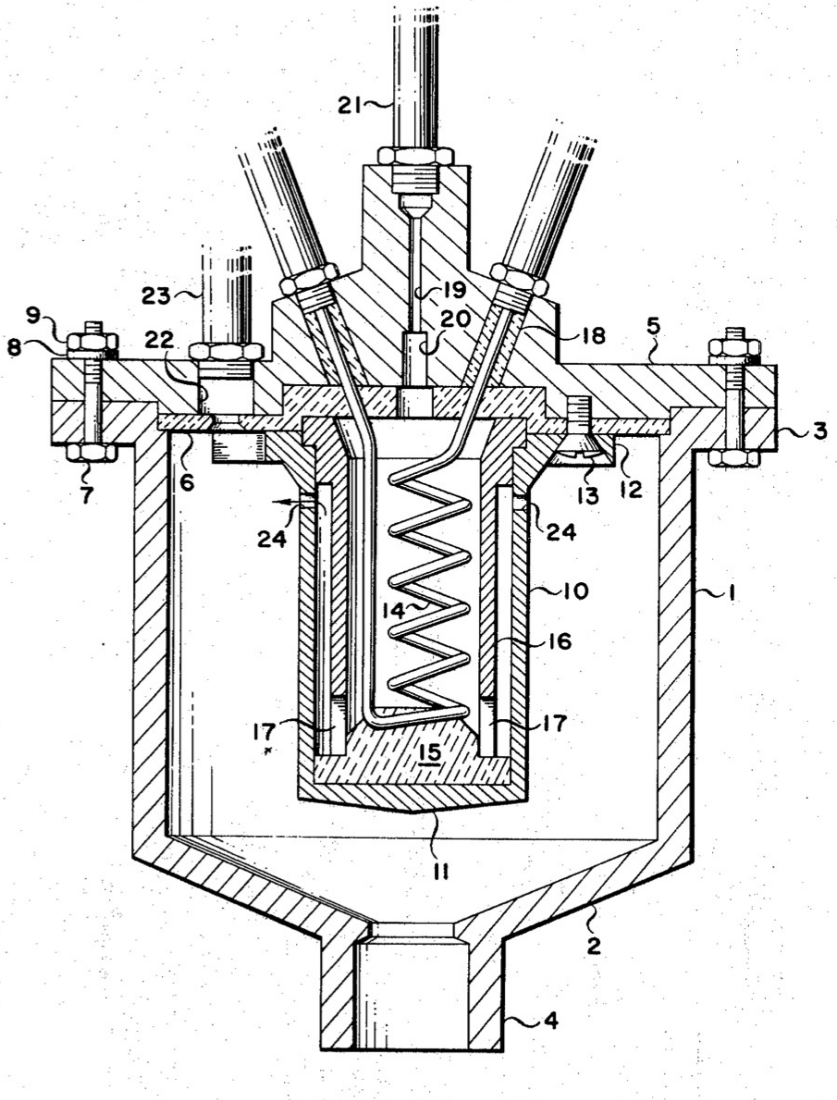
BY Q. Baxter Warner
Claude Funkhouser
ATTORNEYS

Figure E.248: An example of Willy Fiedler's patents related to the Polaris missile.

Oct. 13, 1970 **W. A. FIEDLER ET AL** **3,533,233**

HOT GAS GENERATOR UTILIZING A MONO-PROPELLANT FUEL

Filed Sept. 13, 1967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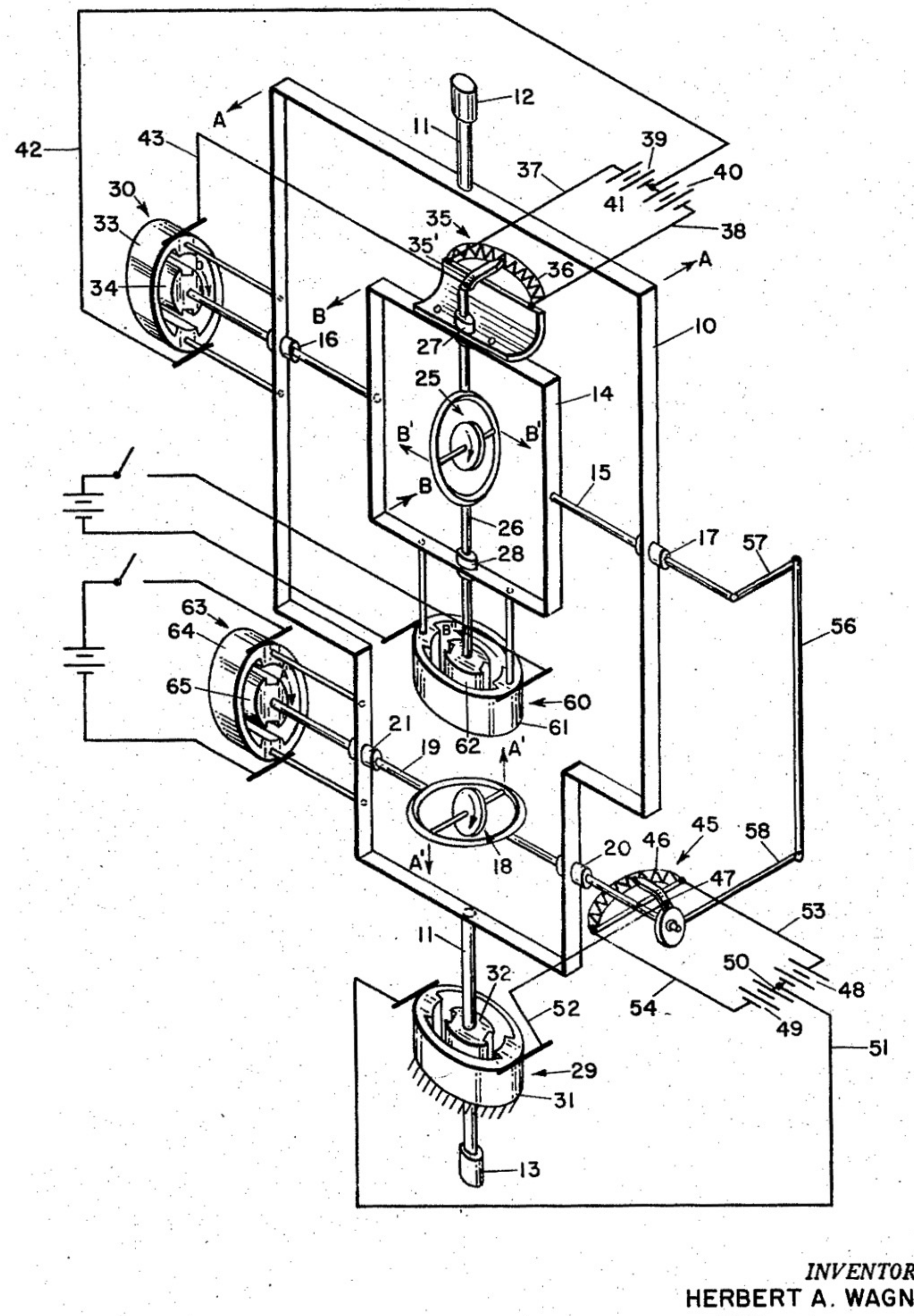
INVENTORS.
WILLY A. FIEDLER
WILLI K. KRETSCHMER
GEORGE A. HONZIK
BY George C. Sullivan
Agent

Figure E.249: An example of Willy Fiedler's patents related to the Polaris missile.

Aug. 6, 1957 H. A. WAGNER **2,801,544**

GYROSCOPICALLY STABILIZED PLATFORM SYSTEM

Filed Jan. 5, 1953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INVENTOR.
HERBERT A. WAGNER
BY
ATTORNEYS

Figure E.250: A patent on missile guidance systems for the U.S. Navy by Herbert Wagner.

Marsha Freeman. 2003. Arthur Rudolph and the Rocket That Took Us to the Moon. 54th International Astronautical Congress of the International Astronautical Federation, the International Academy of Astronautics, and the International Institute of Space Law. IAC-03-IAA.2.1.02 [https://www.scientistsandfriends.com/files/arthur.pdf].

In 1956, the decision was made that the U.S. Army needed a "shoot and scoot" mobile missile, which meant it had to be solid-fueled. This was the Pershing program.

Arthur Rudolph was made the project director, with $500 million for its development. He assembled a team, and took bids. He visited the potential contractors in person, and, knowing the guidance system was critical, chose the Bendix plant in New Jersey for the job. After inspecting their facilities, he noted that it had the best precision machine tools for the job, which were made in Germany! "That was the firm for us!" he decided.

The creed that Arthur Rudolph developed to manage the Pershing rocket was that "nothing could fall through the cracks." Research and development laboratories were expanded for testing vibration, hearing, and other conditions that would face the rocket in flight.

Following the uproar after the Soviet launch of Sputnik in November 1957, the National Aeronautics and Space Administration (NASA) was established. The heart of the new civilian space program would be rockets, and the von Braun team was transferred from the Army—all but Arthur Rudolph. He was considered irreplaceable on the Pershing program.

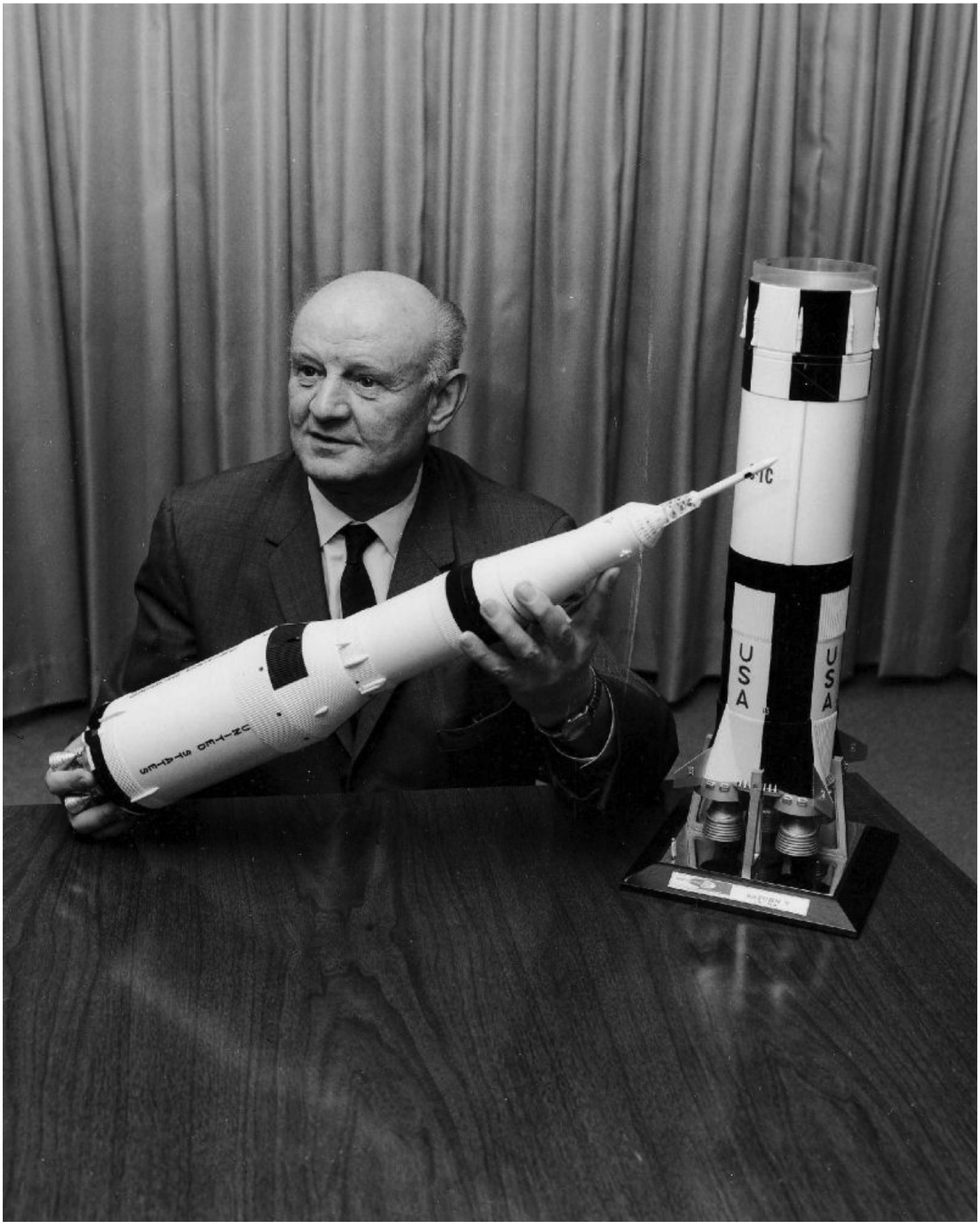
In 1960, Arthur Rudolph, for his management of the Pershing missile program, received the Exceptional Civilian Service award, the highest civilian award in the Army. [...]

In 1962, at a meeting at NASA headquarters in Washington, Arthur Rudolph put forward his list of basic requirements for the Apollo rocket, and a mission plan that was based on his experience managing the Pershing program. In 1963, he was named the program manager for the Saturn V. [...]

Arthur Rudolph's management of the massive Saturn V rocket program involved his personal tracking of all of the aspects of the system. He had a chart in his office showing all of the components, large and small, to be able to immediately see their progress. This made the entire program transparent, and provided an overview of the massive coordination. Every problem was dealt with, in excruciating detail, by the program manager and his staff. [...]

For his management of the Saturn V program, Arthur Rudolph received both the Exceptional Service Medal and the Distinguished Medal from NASA.

His job of developing and producing the rocket to take men to the Moon completed, Arthur Rudolph retired from the space agency, and rocket research, on January 1, 1969.



Arthur Rudolph (1906–1996) managed the development of the Pershing 1 missile and then the Saturn V rocket

Figure E.251: Arthur Rudolph managed the development of the Pershing 1 missile, and then the development of the Saturn V moon rocket.

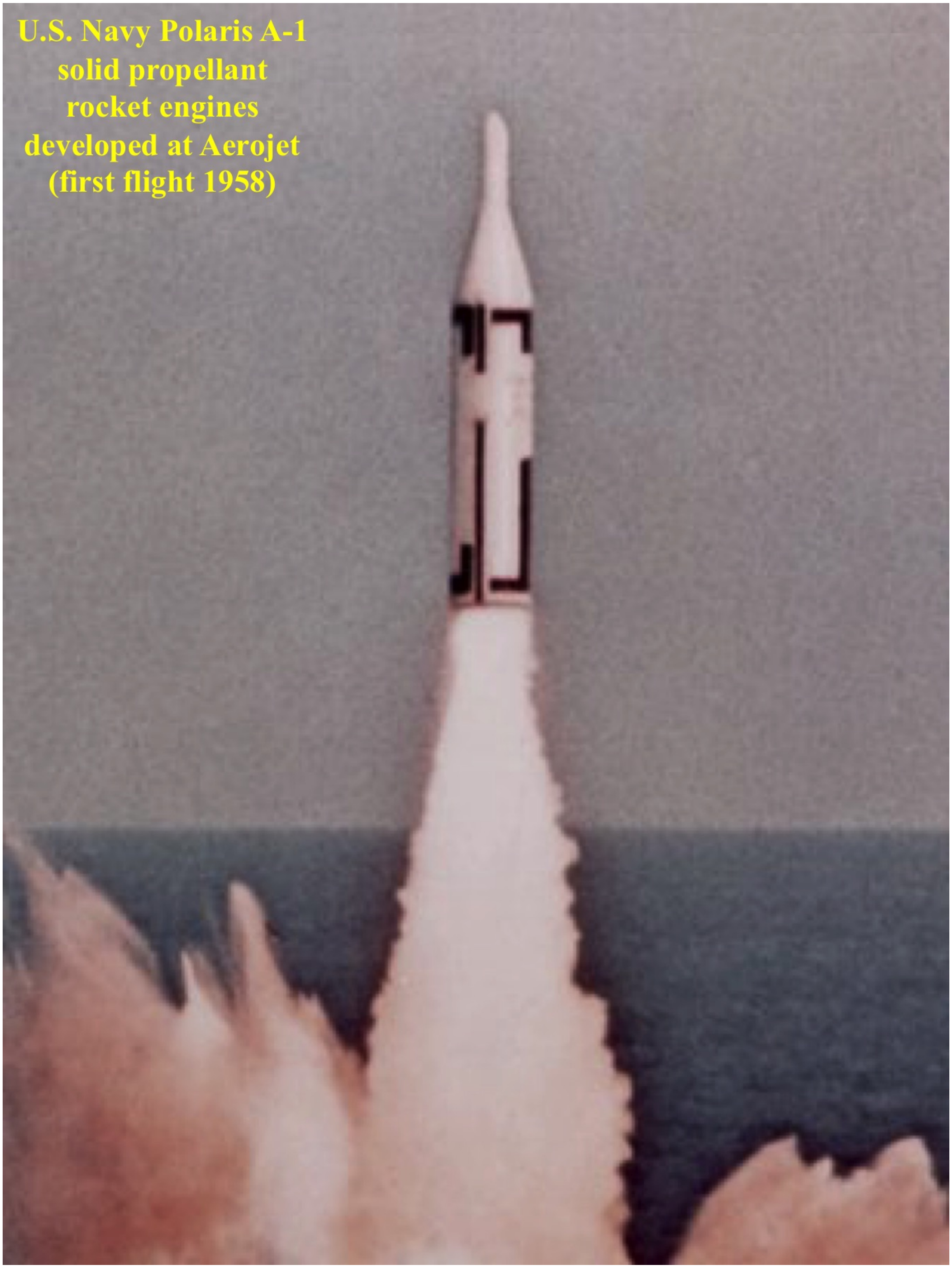

U.S. Navy Polaris A-1
solid propellant
rocket engines
developed at Aerojet
(first flight 1958)

Figure E.252: German-speaking scientists played major roles in the development of postwar large solid propellant rockets such as the Polaris missiles.

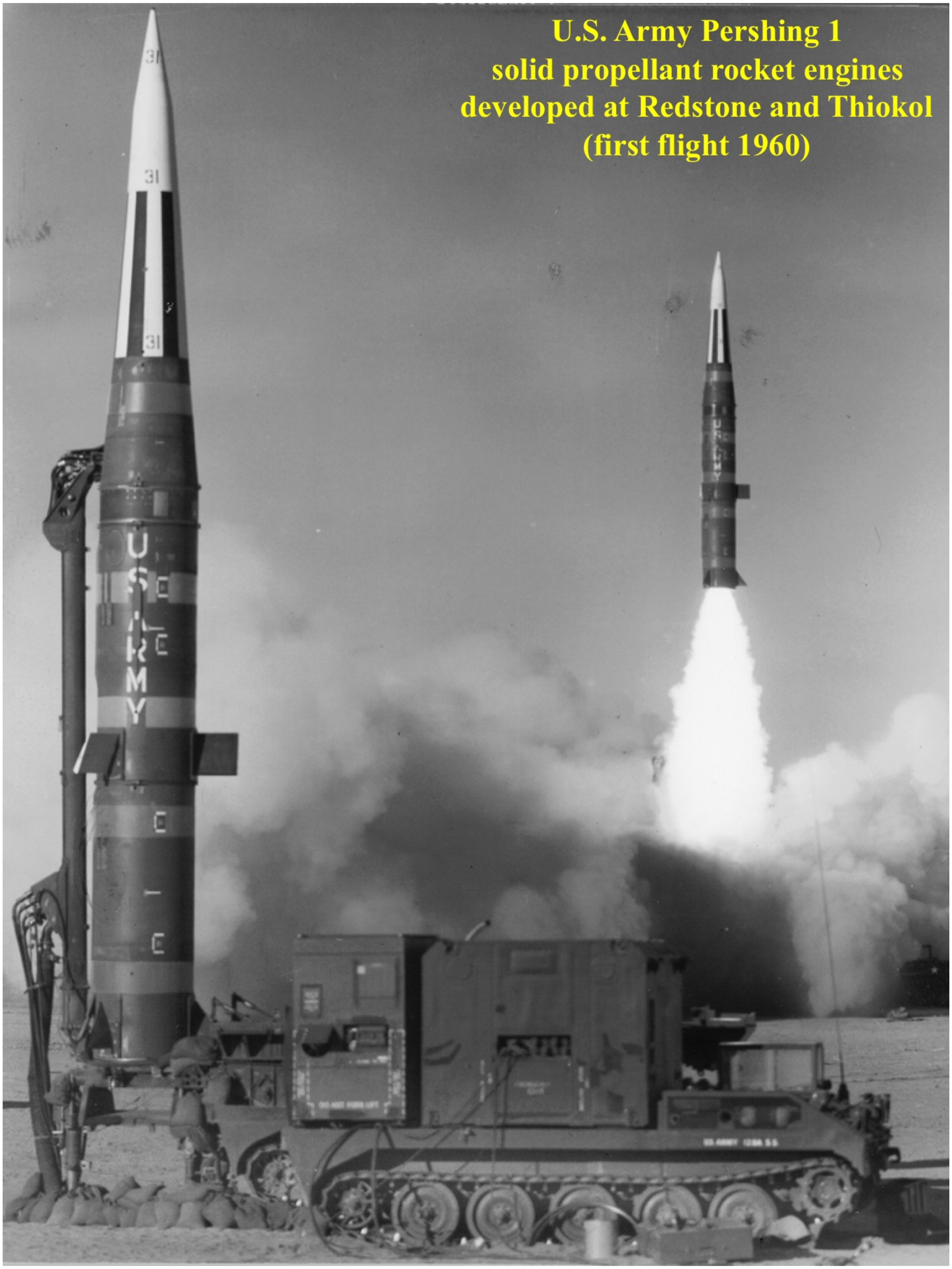

U.S. Army Pershing 1
solid propellant rocket engines
developed at Redstone and Thiokol
(first flight 1960)
U.S. ARMY
31

Figure E.253: German-speaking scientists played major roles in the development of postwar large solid propellant rockets such as the Pershing missiles.

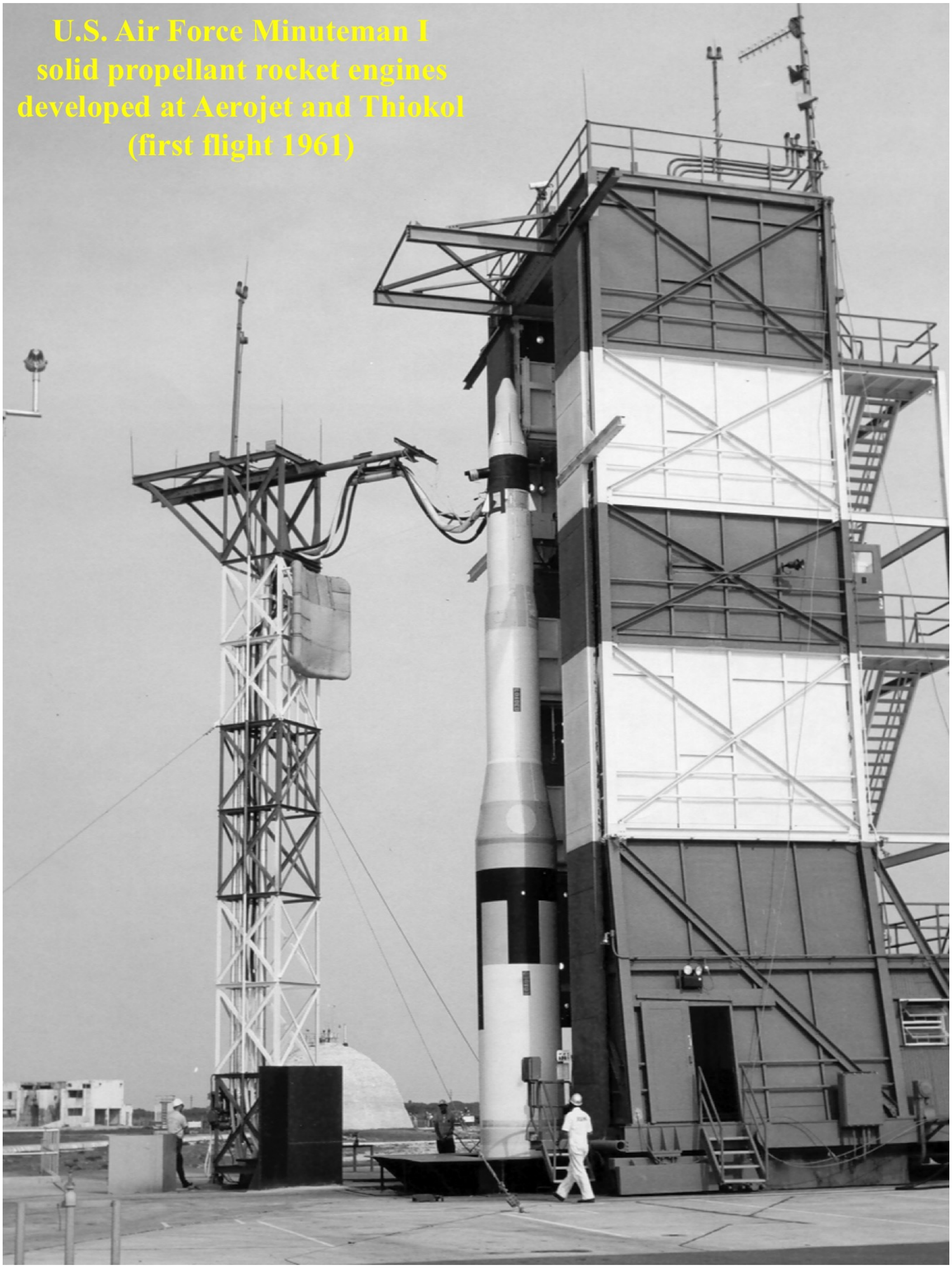

U.S. Air Force Minuteman I
solid propellant rocket engines
developed at Aerojet and Thiokol
(first flight 1961)

Figure E.254: German-speaking scientists played major roles in the development of postwar large solid propellant rockets such as the Minuteman missiles.

E.5 Longer-Term Space Projects

[The prevailing public perception is that technologies for space exploration were developed by the United States and the Soviet Union, beginning with the October 1957 launch of the Soviet Sputnik satellite. However, scientists in interwar and wartime Germany did a great deal of work on technologies for space exploration, and continued to develop those technologies in other countries after World War II:

- Walter Hohmann published a detailed textbook of calculations for spacecraft trajectories and orbits in 1925 [Hohmann 1925]. See pp. 5739–5742.
- In 1928, Hermann Potočnik, under the pen name of "Hermann Noordung," published a book with detailed designs of a large, circular, rotating space station, as shown on pp. 5743–5746 [Noordung 1928].
- Guido von Pirquet and Hermann Oberth separately designed space stations in 1928–1929 [Ley 1928; Oberth 1929]. See Fig. 9.233.
- Plans for a space station were seriously considered by the German government during World War II, especially with regard to potential military applications. See p. 5747.
- There were detailed wartime designs for large three-stage rockets (A-11 through A-15) capable of launching cargo or vehicles into Earth orbit or beyond (p. 5405).
- Scientists at Peenemünde and the Reichspost began programs on fission thermal rocket propulsion no later than 1942 (p. 5757). Creators such as Krafft Ehricke continued those programs in the United States after the war.
- External pulse propulsion by nuclear explosives was first proposed in approximately 1942 by Wernher von Braun. By the end of the war, work in this area had apparently progressed at least as far as creating small test models powered by conventional chemical explosives. After the war, external fission pulse propulsion was explored in the United States by Stanislaw Ulam, another creator from the greater German-speaking world. See p. 5770.
- Electric rocket propulsion systems were first proposed by Hermann Oberth in 1929 (p. 5772). Experimental development of electric propulsion in Germany began no later than 1937 and continued until at least 1944 (p. 5311). Ernst Stuhlinger, Wernher von Braun, and other German-speaking scientists continued to develop and promote electric propulsion after the war (pp. 1958, 5772).
- Eugen Sänger was the first to propose matter-antimatter rockets and to work out their details, including using anti-hydrogen made from positrons and antiprotons, storing the antimatter without letting it come into contact with ordinary matter, and using highly novel types of nozzles to direct the matter-antimatter reaction products out the back of the rocket. See pp. 1956, 1958, and 5773.

These wartime German creators and their creations were directly responsible for the postwar space exploration programs in the United States, Soviet Union, and other countries [e.g., Chertok 2005–2012; Jürgen Michels 1997; Ordway and Sharpe 1979; Uhl 2001].

This section is subdivided into categories of sources that cover:

E.5.1. Orbital spacecraft and space stations.

E.5.2. Fission thermal rocket propulsion.

E.5.3. Fission pulse rocket propulsion.

E.5.4. Electric rocket propulsion.

E.5.5. Antimatter rocket propulsion.]

E.5.1 Orbital Spacecraft and Space Stations

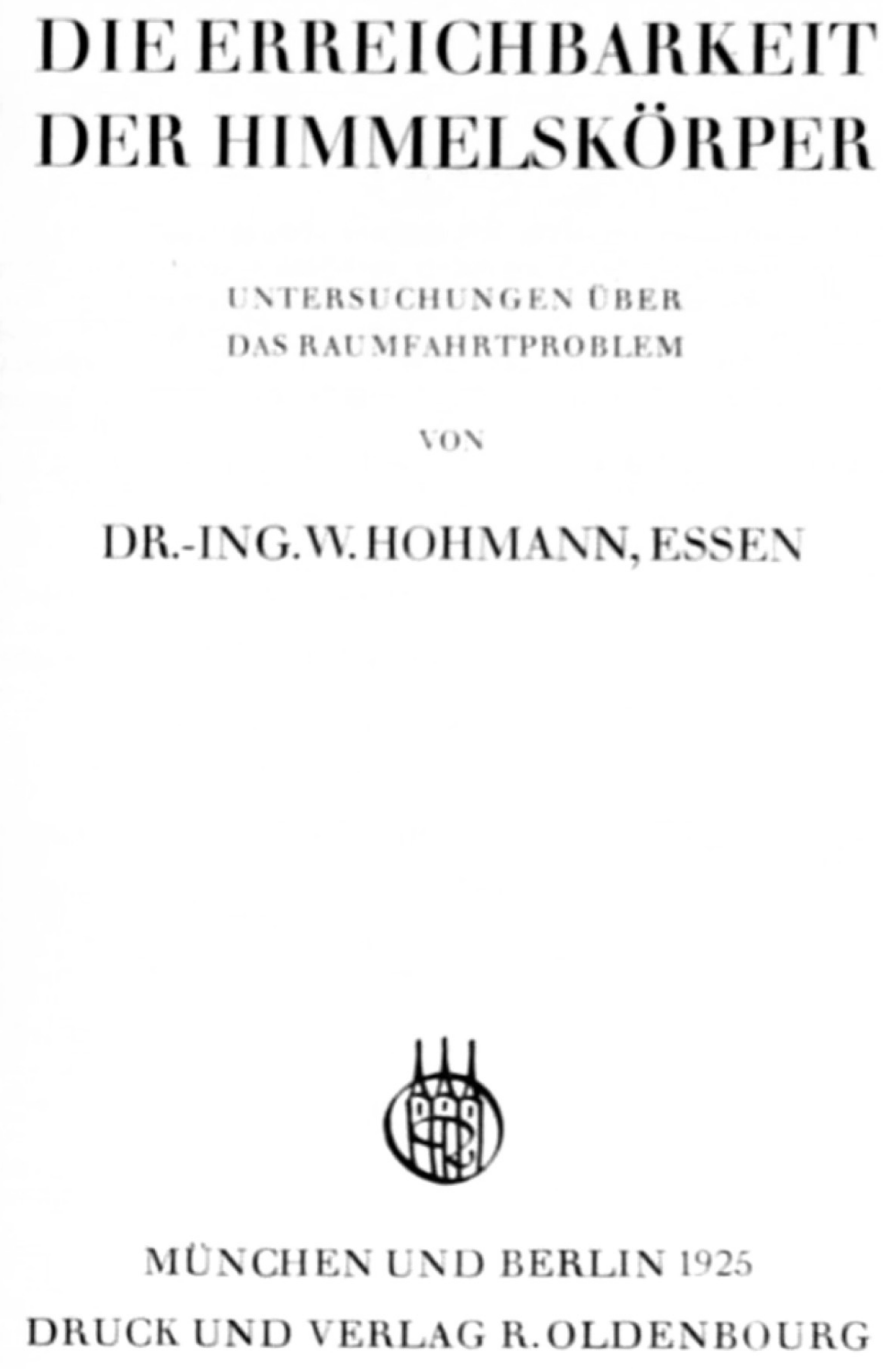
[Walter Hohmann (German, 1880–1945) published a detailed textbook of calculations for spacecraft trajectories and orbits in 1925 [Hohmann 1925]. Figures E.255–E.258 show illustrations from his book for calculations regarding atmospheric reentry, aerobraking, and what are now called Hohmann ellipses—elliptical orbits for transferring from one nearly circular orbit (such as that of a planet) to another (such as that of another planet) with the smallest possible expenditure of energy. The methods that Hohmann proposed and worked out in 1925 have been utilized quite effectively since the 1960s and will continue to be widely used in future space missions.

In 1928, Hermann Potočnik (Austrian/Slovene, 1892–1929), under the pen name of "Hermann Noordung," published a book with detailed designs of a large, circular, rotating space station, as shown in Figs. E.259–E.262 [Noordung 1928]. Potočnik's designs accurately accounted for everything from the solar energy requirements of the space station's power plant to the artificial gravity in its living quarters. His book also incorporated many of Hohmann's proposed methods for interplanetary missions. Unfortunately Potočnik died from tuberculosis (which he had contracted during World War I) when he was only 36; if he had lived he might have helped to realize some of his visions.

Guido von Pirquet (Austrian, 1880–1966) and Hermann Oberth (German, 1894–1989) separately designed space stations in 1928–1929 [Ley 1928; Oberth 1929]. See Fig. 9.233. Oberth pointed out that such a station could for example tend large space-based mirrors to reflect sunlight on the earth. Depending on they were used, such mirrors might improve everything from agriculture to power production to weather, or they might incinerate opposing countries.

Plans for a space station and space mirror were seriously considered by the German government during World War II, especially with regard to potential military applications [NYT 1945-06-29 p. 1, 1945-06-30 p. 3; *Life* 1945-07-23 p. 78; *Time* 1946-09-02 p. 52]. See p. 5747.

There were detailed wartime designs for large three-stage rockets (A-11 through A-15) capable of launching cargo or vehicles into Earth orbit or beyond (see p. 5405). During the war, was any experimental work beyond the drawing board done on any of them—wind tunnel models, rocket engine mock-ups, etc? Considering the evidence for other developments in Appendices A–E, historians should not be too quick to rule out the possibility.]



DIE ERREICHBARKEIT
DER HIMMELSKÖRPER

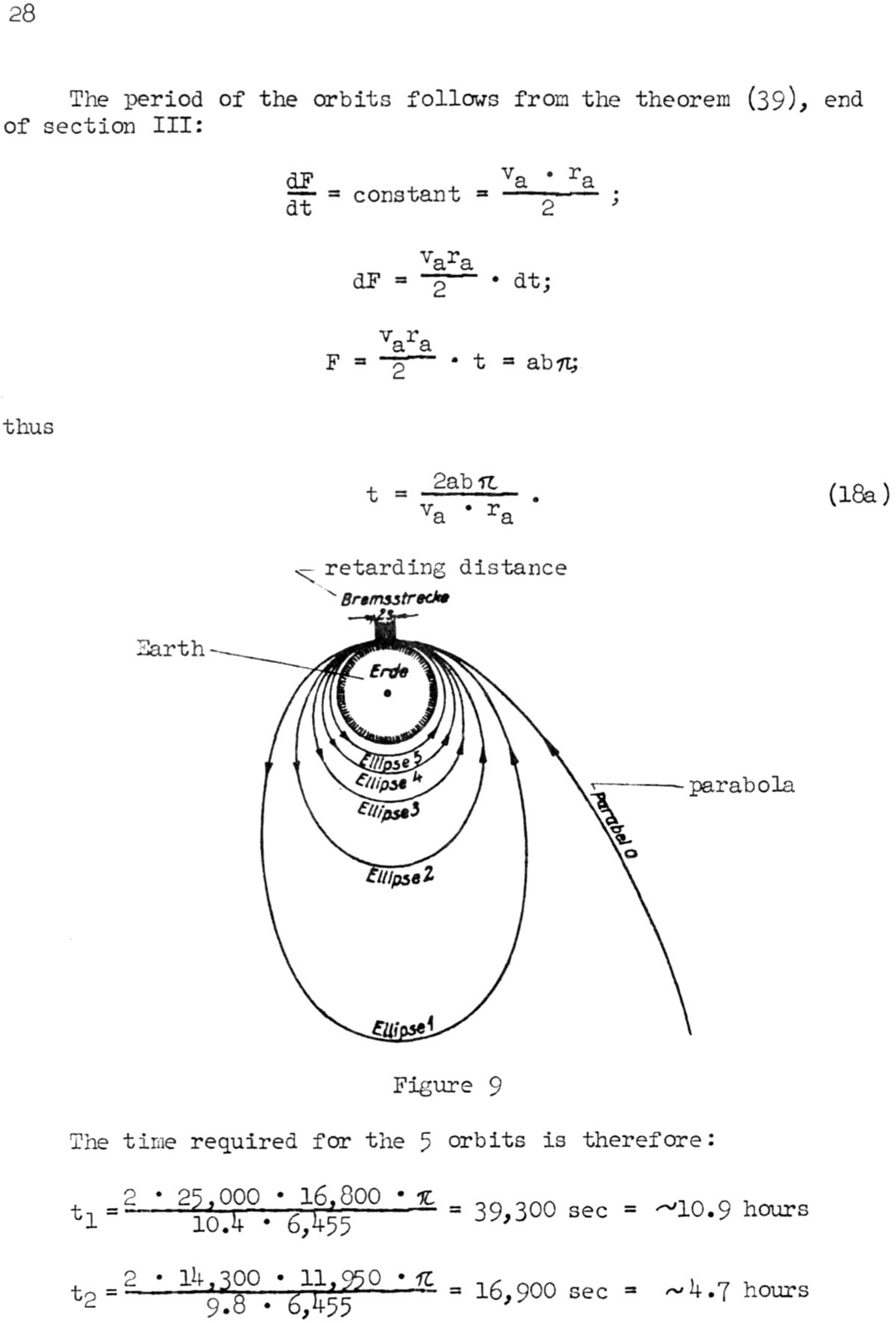
UNTERSUCHUNGEN ÜBER
DAS RAUMFAHRTPROBLEM

VON

DR.-ING. W. HOHMANN, ESSEN

MÜNCHEN UND BERLIN 1925
DRUCK UND VERLAG R. OLDENBOURG

Figure E.255: Walter Hohmann published a detailed textbook of calculations for spacecraft trajectories and orbits in 1925 [Hohmann 1925].



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The period of the orbits follows from the theorem (39), end of section III:

$$\frac{dF}{dt} = \text{constant} = \frac{v_a \cdot r_a}{2};$$

$$dF = \frac{v_a r_a}{2} \cdot dt;$$

$$F = \frac{v_a r_a}{2} \cdot t = ab\pi;$$

thus

$$t = \frac{2ab\pi}{v_a \cdot r_a}. \tag{18a}$$

retarding distance
Bremsstrecke
23
Earth
Erde
Ellipse 5
Ellipse 4
Ellipse 3
Ellipse 2
Ellipse 1
parabola
Parabel 0

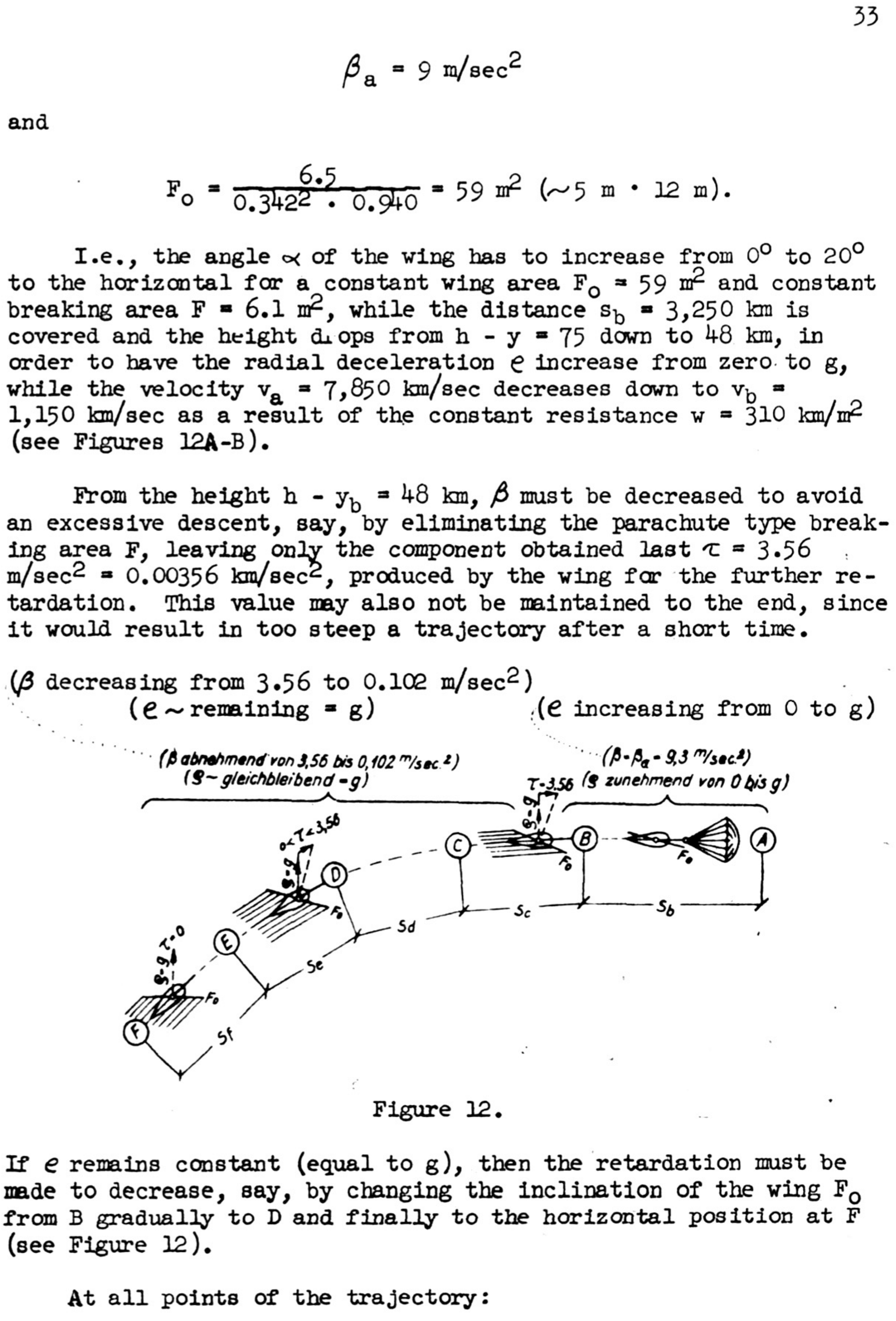
Figure 9

The time required for the 5 orbits is therefore:

$$t_1 = \frac{2 \cdot 25{,}000 \cdot 16{,}800 \cdot \pi}{10.4 \cdot 6{,}455} = 39{,}300 \text{ sec} = \sim 10.9 \text{ hours}$$

$$t_2 = \frac{2 \cdot 14{,}300 \cdot 11{,}950 \cdot \pi}{9.8 \cdot 6{,}455} = 16{,}900 \text{ sec} = \sim 4.7 \text{ hours}$$

Figure E.256: Walter Hohmann proposed and calculated aerobraking maneuvers to slow an interplanetary spacecraft by briefly dipping into the atmosphere of the target planet [Hohmann 1925].



$$\beta_a = 9 \text{ m/sec}^2$$

and

$$F_o = \frac{6.5}{0.342^2 \cdot 0.940} = 59 \text{ m}^2 \ (\sim 5 \text{ m} \cdot 12 \text{ m}).$$

I.e., the angle α of the wing has to increase from 0° to 20° to the horizontal for a constant wing area $F_o = 59 \text{ m}^2$ and constant breaking area $F = 6.1 \text{ m}^2$, while the distance $s_b = 3{,}250$ km is covered and the height drops from h - y = 75 down to 48 km, in order to have the radial deceleration ϱ increase from zero to g, while the velocity $v_a = 7{,}850$ km/sec decreases down to $v_b = 1{,}150$ km/sec as a result of the constant resistance w = 310 km/m² (see Figures 12A-B).

From the height $h - y_b = 48$ km, β must be decreased to avoid an excessive descent, say, by eliminating the parachute type breaking area F, leaving only the component obtained last $\tau = 3.56$ m/sec² = 0.00356 km/sec², produced by the wing for the further retardation. This value may also not be maintained to the end, since it would result in too steep a trajectory after a short time.

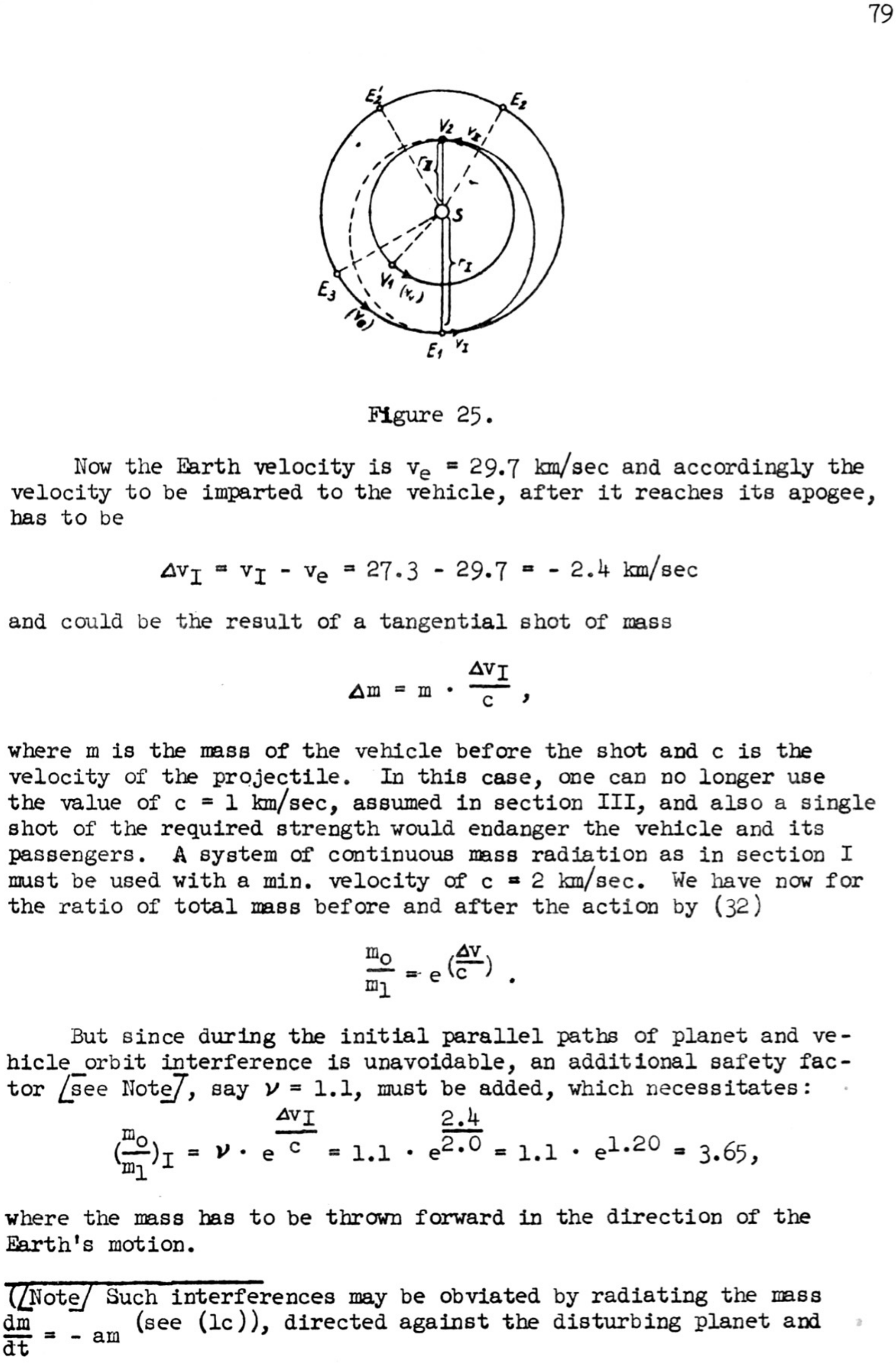
(β decreasing from 3.56 to 0.102 m/sec²)
($\varrho \sim$ remaining = g) (ϱ increasing from 0 to g)

Figure 12.

If ϱ remains constant (equal to g), then the retardation must be made to decrease, say, by changing the inclination of the wing F_o from B gradually to D and finally to the horizontal position at F (see Figure 12).

At all points of the trajectory:

Figure E.257: Walter Hohmann proposed and calculated reentry trajectories to slow a spacecraft returning to Earth without creating excessive g-forces from atmospheric drag [Hohmann 1925].



E_2'
E_2
V_2
v_{II}
r_{II}
S
r_I
$V_1\ (v_1)$
E_3
(v_e)
E_1
v_I

Figure 25.

Now the Earth velocity is $v_e = 29.7$ km/sec and accordingly the velocity to be imparted to the vehicle, after it reaches its apogee, has to be

$$\Delta v_I = v_I - v_e = 27.3 - 29.7 = - 2.4 \text{ km/sec}$$

and could be the result of a tangential shot of mass

$$\Delta m = m \cdot \frac{\Delta v_I}{c} ,$$

where m is the mass of the vehicle before the shot and c is the velocity of the projectile. In this case, one can no longer use the value of $c = 1$ km/sec, assumed in section III, and also a single shot of the required strength would endanger the vehicle and its passengers. A system of continuous mass radiation as in section I must be used with a min. velocity of $c = 2$ km/sec. We have now for the ratio of total mass before and after the action by (32)

$$\frac{m_o}{m_1} = e^{(\frac{\Delta v}{c})} .$$

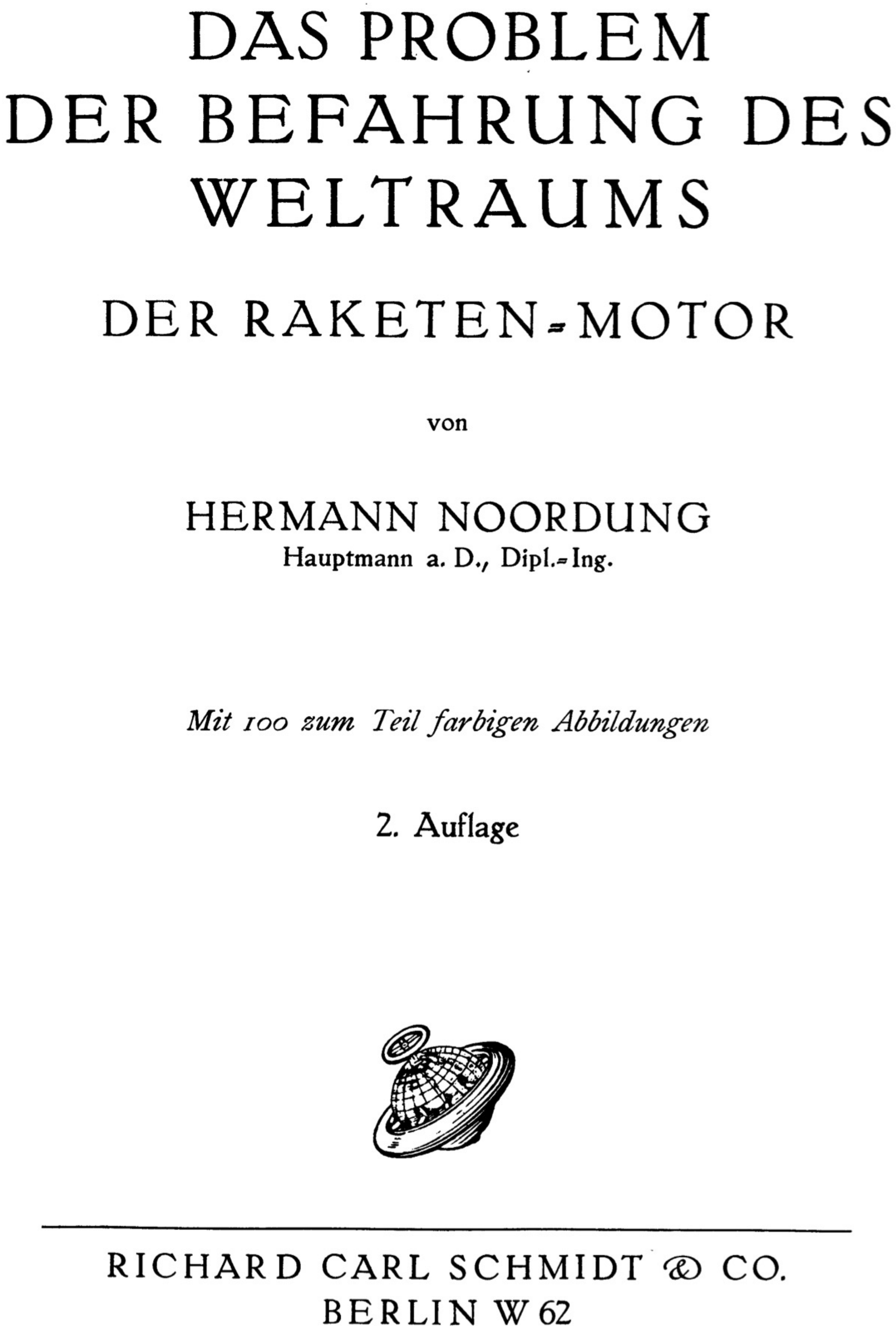
But since during the initial parallel paths of planet and vehicle orbit interference is unavoidable, an additional safety factor [see Note], say $\nu = 1.1$, must be added, which necessitates:

$$(\frac{m_o}{m_1})_I = \nu \cdot e^{\frac{\Delta v_I}{c}} = 1.1 \cdot e^{\frac{2.4}{2.0}} = 1.1 \cdot e^{1.20} = 3.65,$$

where the mass has to be thrown forward in the direction of the Earth's motion.

([Note] Such interferences may be obviated by radiating the mass $\frac{dm}{dt} = - am$ (see (1c)), directed against the disturbing planet and

Figure E.258: Walter Hohmann proposed and calculated what are now called Hohmann ellipses—elliptical orbits for transferring from one nearly circular orbit (such as that of a planet) to another (such as that of another planet) with the smallest possible expenditure of energy [Hohmann 1925].



DAS PROBLEM DER BEFAHRUNG DES WELTRAUMS

DER RAKETEN-MOTOR

von

HERMANN NOORDUNG
Hauptmann a. D., Dipl.-Ing.

Mit 100 zum Teil farbigen Abbildungen

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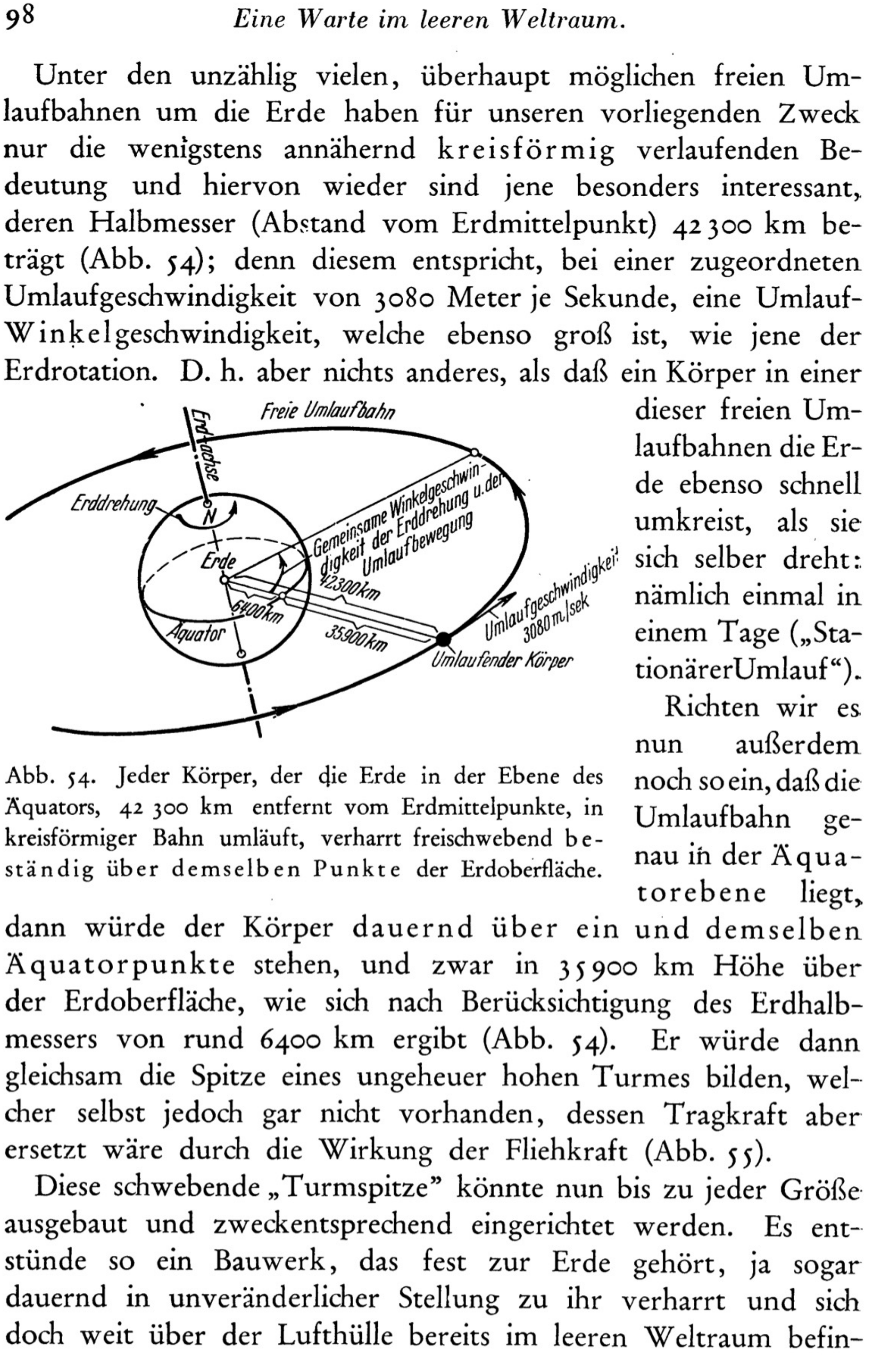
Figure E.259: Hermann Potočnik, under the pen name of “Hermann Noordung,” published a book with detailed designs of a large, circular, rotating space station in 1928 [Noordung 1928].



Unter den unzählig vielen, überhaupt möglichen freien Umlaufbahnen um die Erde haben für unseren vorliegenden Zweck nur die wenigstens annähernd kreisförmig verlaufenden Bedeutung und hiervon wieder sind jene besonders interessant, deren Halbmesser (Abstand vom Erdmittelpunkt) 42 300 km beträgt (Abb. 54); denn diesem entspricht, bei einer zugeordneten Umlaufgeschwindigkeit von 3080 Meter je Sekunde, eine Umlauf-Winkelgeschwindigkeit, welche ebenso groß ist, wie jene der Erdrotation. D. h. aber nichts anderes, als daß ein Körper in einer dieser freien Umlaufbahnen die Erde ebenso schnell umkreist, als sie sich selber dreht: nämlich einmal in einem Tage („StationärerUmlauf“). Richten wir es nun außerdem noch so ein, daß die Umlaufbahn genau in der Äquatorebene liegt, dann würde der Körper dauernd über ein und demselben Äquatorpunkte stehen, und zwar in 35 900 km Höhe über der Erdoberfläche, wie sich nach Berücksichtigung des Erdhalbmessers von rund 6400 km ergibt (Abb. 54). Er würde dann gleichsam die Spitze eines ungeheuer hohen Turmes bilden, welcher selbst jedoch gar nicht vorhanden, dessen Tragkraft aber ersetzt wäre durch die Wirkung der Fliehkraft (Abb. 55).

Freie Umlaufbahn
Erdachse
Erddrehung
N
Erde
Gemeinsame Winkelgeschwindigkeit der Erddrehung u. der Umlaufbewegung
42300 km
6400 km
35900 km
Äquator
Umlaufgeschwindigkeit 3080 m/sek
Umlaufender Körper

Abb. 54. Jeder Körper, der die Erde in der Ebene des Äquators, 42 300 km entfernt vom Erdmittelpunkte, in kreisförmiger Bahn umläuft, verharrt freischwebend beständig über demselben Punkte der Erdoberfläche.

Diese schwebende „Turmspitze“ könnte nun bis zu jeder Größe ausgebaut und zweckentsprechend eingerichtet werden. Es entstünde so ein Bauwerk, das fest zur Erde gehört, ja sogar dauernd in unveränderlicher Stellung zu ihr verharrt und sich doch weit über der Lufthülle bereits im leeren Weltraum befin-

Figure E.260: Hermann Potočnik proposed placing a satellite into geosynchronous orbit, such that the satellite would make one orbit every 24 hours, the same as the Earth’s rotation. Thus the satellite would stay over the same part of the Earth as it orbited [Noordung 1928].

Das Wohnrad. 137

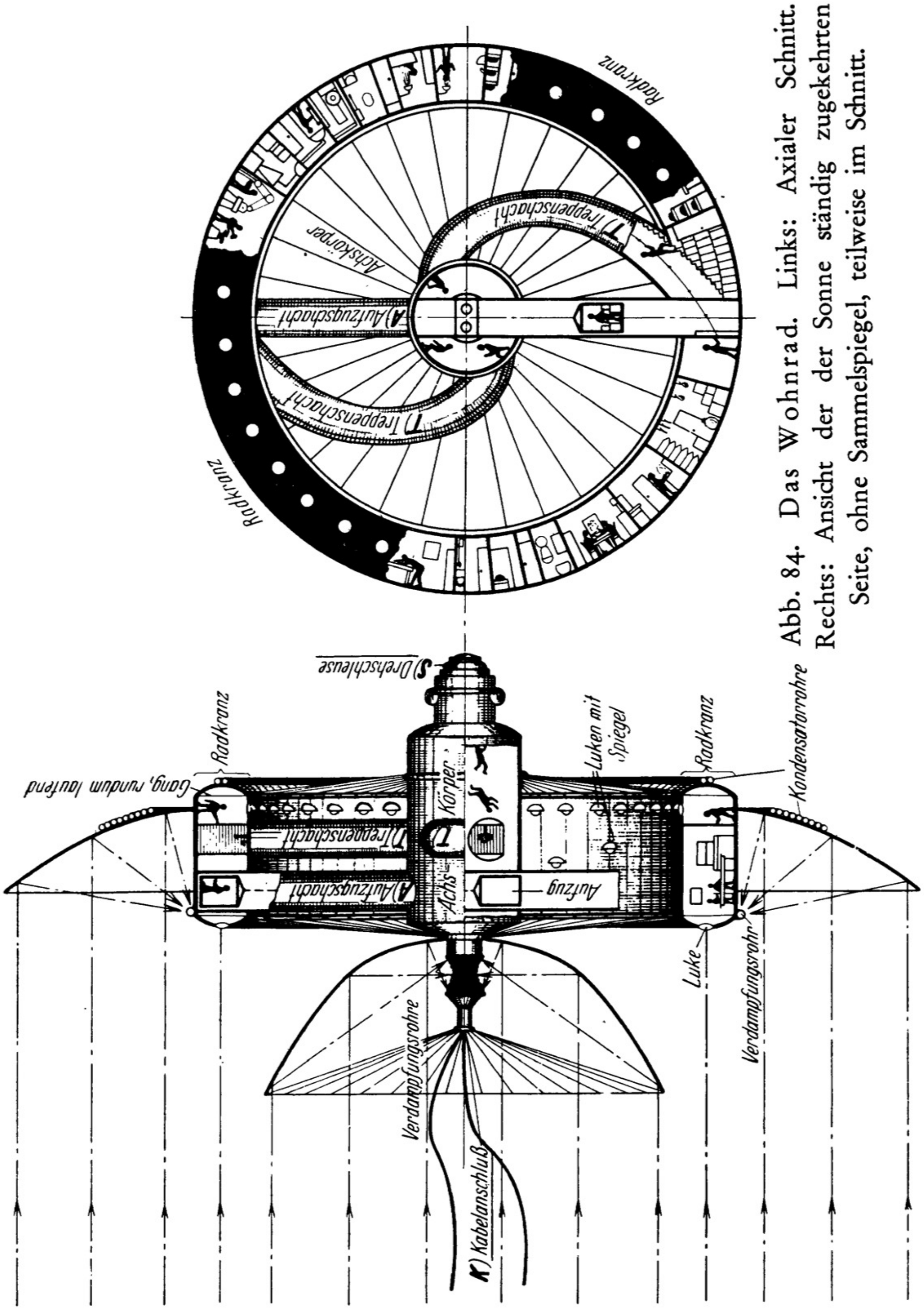
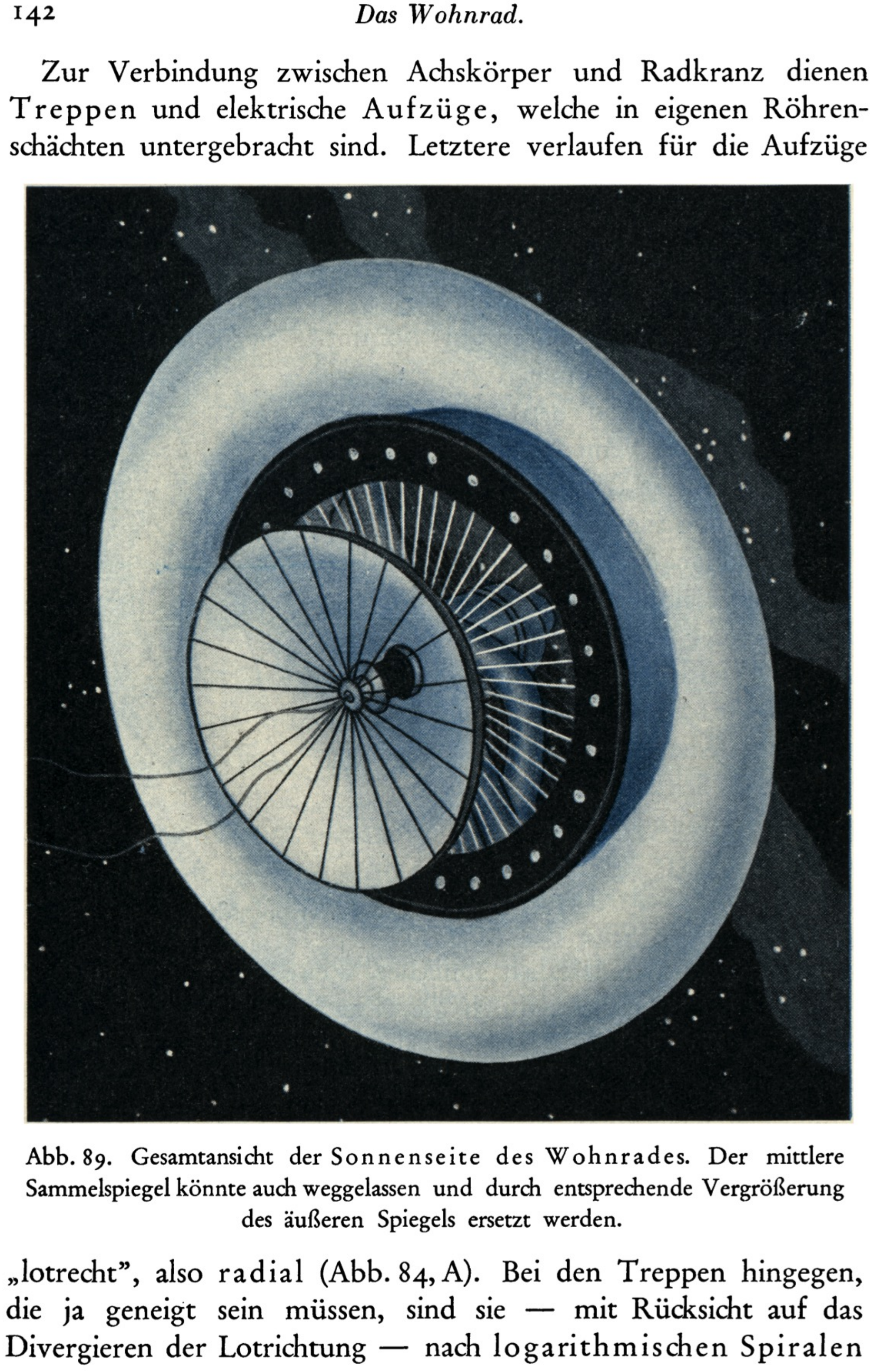

Radkranz
Radkranz
Achskörper
T) Treppenschacht
T) Treppenschacht
A) Aufzugschacht
S) Drehschleuse
Gang, rundum laufend
Radkranz
Radkranz
Luken mit Spiegel
Kondensatorrohre
Körper
Achs
Aufzug
Luke
Verdampfungsrohr
Verdampfungsrohre
K) Kabelanschluß

Abb. 84. Das Wohnrad. Links: Axialer Schnitt.
Rechts: Ansicht der Sonne ständig zugekehrten
Seite, ohne Sammelspiegel, teilweise im Schnitt.

Figure E.261: Hermann Potočnik, under the pen name of “Hermann Noordung,” published a book with detailed designs of a large, circular, rotating space station in 1928 [Noordung 1928].



142 *Das Wohnrad.*

Zur Verbindung zwischen Achskörper und Radkranz dienen Treppen und elektrische Aufzüge, welche in eigenen Röhrenschächten untergebracht sind. Letztere verlaufen für die Aufzüge

Abb. 89. Gesamtansicht der Sonnenseite des Wohnrades. Der mittlere Sammelspiegel könnte auch weggelassen und durch entsprechende Vergrößerung des äußeren Spiegels ersetzt werden.

„lotrecht", also radial (Abb. 84, A). Bei den Treppen hingegen, die ja geneigt sein müssen, sind sie — mit Rücksicht auf das Divergieren der Lotrichtung — nach logarithmischen Spiralen

Figure E.262: Hermann Potočnik, under the pen name of "Hermann Noordung," published a book with detailed designs of a large, circular, rotating space station in 1928 [Noordung 1928].

Gladwin Hill, Nazis' Scientists Planned Sun 'Gun' 5,100 Miles Up. *New York Times.* 29 June 1945 p. 1.

PARIS, June 28—German scientists, a high United States Army ordnance officer disclosed today, were soberly working on a project of contriving a platform 5,100 miles in the air from which, within a matter of fifty or 100 years, it was believed, it might be possible to harness the sun's rays to demolish nations at will and rule the world.

"Fantastic" is the only word that comes to mind for this project. Yet "fantastic," officers here avow on the basis of the caliber of the scientists involved and the cold, sound method of their work, is a classification into which the project definitely cannot be put.

"We were interested," ordnance officers said after exhaustive interrogation of the scientists, "with their practical engineering minds and their distaste for the fantastic." They had even figured the dimensions of a mirror that would be necessary up 5,100 miles to focus the sun's rays for the purpose—three kilometers [1.86 miles] square.

These are some of the scientists who devised so recently the inconceivable buzz-bombs and the V-2 rocket bombs. They are some of the scientists who, it was disclosed today, had virtually perfected, in addition to the previously revealed secret weapons, a method of launching V-2 rocket bombs from submarines 300 feet under water that might have blasted New York as London was blasted.

They are scientists who, on the basis of their amazing rocket work, take it for granted that transatlantic mail rockets are a development of only a few years hence and that forty-minute transatlantic passenger rockets are probable in fifteen to twenty-five years.

It was disclosed further that a number of these scientists—there were about 100 leading rocket researchers and around 1,100 others—are so dedicated to their researches and so aware that there is no hope of pursuing them in Germany during their lifetime that they are putting science ahead of nationality and volunteering to move to the United States and Britain to continue their work. Plans are under official discussion for a center in the United States to exploit their discoveries.

How many of these discoveries have been disclosed to the Japanese is not known, but an intelligence officer at Supreme Allied Headquarters said last week that the Germans had withheld some secrets from them.

The man who made these astonishing revelations and the fullest report yet on German weapons at a press conference today is Lieut. Col. John A. Keck, chief of the Ordnance Service's enemy technical intelligence branch in the European theatre. Colonel Keck is a retired Pittsburgh engineer whose home is in Greensburg, Pa. A World War I veteran, he went to London in April, 1943, when his branch was organized to work with a similar British hush-hush bureau.

Spies Traced Germans' Work

Colonel Keck indicated that there was a regular traffic of Allied spies in and out of Germany, and said that through undercover activities the Allies had been able to keep virtually day-to-day information on the work at the Germans' main rocket-development base at Peenemuende on the Baltic, making possible the famous Royal Air Force bombing attack there during a conclave of scientists, which inflicted hundreds of casualties and is believed to have set rocket development back a fatal six months. [...]

The final contemplated objective was to launch projectile vehicles from the sky platform into interstellar space.

Despite the weird nature of these notions, the scientists were described by the Allied examiners as “men of extremely practical and keen minds,” Colonel Keck said.

Scientists Talkative on Ideas

One hundred and fifty rocket and other scientists were found by the Allied forces soon after the German surrender at a research center in Hillersleben, pondering their projects and waiting to discuss them. British officers have participated in the interrogations, which still are going on. The British War Office automatically receives copies of all American reports in this field, and Colonel Keck said the Russians had interrogated some of the same scientists and that it was intended to share German scientific information with “all the Allied nations.”

The submarine V-2 project was developed in Toplitz Lake, in the Austrian Alps, by Dr. Heinrich Determann and fourteen assistants, who were arrested by the Eightieth Infantry Division after a small boy and an old shoemaker in the lakeside village of Gossl had told the Americans of “big metal fish jumping from the water into the air” and of “undersea boats that shot out fiery comets.”

It transpired that the experimenters have started by shooting Nebelwerfer rocket field guns from a few feet under water and by last January had worked up to shooting from a depth of 300 feet a rocket that, once in the air, traveled like the V-2.

By the time the troops arrived the apparatus had been sunk in the lake and the records destroyed. Dr. Determann remarked: “Who knows? Perhaps German victory likes under Toplitz Lake.” It is hoped the work can be reconstructed.

New Anti-Aircraft Weapon

Another of the secret weapons that Colonel Keck said the Germans had “practically perfected” was a rocket-propelled missle capabe of exploding within ten yards of a plane ten miles in the air.

“It is generally conceded that the Allies urgently need a more effective anti-aircraft weapon, and it is expected that the rocket will replace all other types of anti-aircraft guns,” Colonel Keck said. “The German scientists’ contribution to the rocket field in the last decade was unique and a great engineering accomplishment.”

The speed attained by the V-2’s—which, it had been previously disclosed, the Germans were developing not only to fire across the Atlantic, but also as far as from Britain to Japan—would get them from Europe to the United States in less than an hour, Colonel Beck said, and, in the light of progress up to now, the question of slowing them down at the end of the trip to make them feasible for mail and passengers is a relatively “minor problem.” [...]

[This report describes detailed plans (and in some cases extensive development programs) for:

- Surface-to-air missiles that were "practically perfected" and had range and accuracy far better than anything possessed by the Allies.
- Submarine-launched ballistic missiles (note that much of the development and testing was being performed in the central European mountains, not just on the coast).
- Intercontinental rockets capable of crossing the Atlantic ocean (approximately 5000 km).
- Intercontinental rockets capable of traveling halfway around the Earth (approximately 20,000 km).
- A manned space station.
- Space-based solar energy collectors and directed energy weapons.
- Interplanetary (incorrectly stated as interstellar) space probes.

Versions of this story were also reported in:

Gladwin Hill, Sun Gun Weighed By Germans In 1929. *New York Times.* 30 June 1945 p. 3.

The German Space Mirror: Nazi Men of Science Seriously Planned to Use a Man-Made Satellite as a Weapon for Conquest. *Life.* 23 July 1945 p. 78.

Sun-Ray War. *The Evening Post* (Wellington, New Zealand). 29 June 1945 p. 5.
[https://paperspast.natlib.govt.nz/newspapers/evening-post/1945/06/29]

To Rocket Mail over Atlantic in 40 Minutes. *Toronto Daily Star.* 29 June 1945 p. 1.]

George Millar. Hitler's Crazy Gang Were Not So Crazy. *Daily Express* 29 June 1945 p. 1.

PARIS, Thursday.—Hitler's scientists planned permanent stations 5,100 miles above the earth, to harness the sun's energy.

Allied experts have found this plan to be technically sound, it was stated in Paris tonight by Lieut.-Colonel John A. Keck, the senior U.S. soldier in the job of questioning German scientists.

The value of their work, Colonel Keck says, is staggering, so staggering that it is likely to revolutionise the course of our lives. It shivers the imagination.

And it sprang from the mad energy of Hitler, who demanded "scare and screw-ball weapons."

When the first silver clouds of Flying Fortresses filled the German sky, while the Allied world hailed these planes as the height of modernity, our experts knew that they were already obsolete.

The German "dream of space" began from the horror weapons which attacked London.

To the German scientists V2 was only a toy. They had worked out A10, which had a range of from 1,200 to 1,800 miles, compared with the V2's 162 miles.

And then they worked on an advanced version of A10, a giant rocket with wings.

Colonel Keck added: "If the war had gone on another six months we know that V weapons would probably have been pounding New York."

He went on to the second stage of the V experiments. At 5,100 miles above the earth's surface, where gravity is known to be neutral, the Germans planned to establish within from 50 to 100 years a "space station"—a kind of solid platform in the sky to house a colony of scientists, astronomers and observers.

Rule the world

There they would set up a large reflector or reflectors for concentrating the sun's rays on the earth for power-generating purposes.

The rays would be directed at specific spots on the earth's surface, where the heat energy of generated steam would be converted into electrical energy.

One German scientist said that the first country to install these reflectors in the heavens would be able to rule the world by focusing them to:–

> Turn the oceans to steam;
> Kindle forest fires;
> Wipe out whole cities.

Even more fantastic is the next objective—the forming on those platforms of "space stations" for launching space-ships which would travel, presumably, to other planets.

Colonel Keck added that all this material was at the disposal of the British Government, and that much of it had undoubtedly been handed by the Nazis to the Japanese.

The Russians had been given access to some of the German scientists questioned.

Volney D. Hurd. Nazi Trick Weapons 'Out Of This World.' *Christian Science Monitor* 29 June 1945 p. 1.

PARIS, June 29—Bombing of San Francisco by robot bombs launched in Japan cannot be considered entirely impossible, in the view of German physicists who stated that they would have been ready to shoot improved V-2's over a distance of 3,600 miles if they had been granted another six months' time for their research.

The step-by-step uncovering of German research work of the last five years has caused other surprises, too—none probably greater than the sensation provoked by the disclosure that German physicists gave serious thought even to fantastic plans for construction of a solar power station 5,100 miles above the earth's surface.

American ordnance experts are seriously interested in how far the Japanese have progressed in their rocket research. They find some German natural scientists very sound and think that an extension of the 3,600-mile range can be expected shortly.

Japan Given Data

Col. John A. Keck, chief of the Enemy Technical Intelligence branch, says he now can disclose this with the knowledge that the Japanese have full possession of German information.

Colonel Keck proved to the satisfaction of his office that German physicists would be so useful that plans are under consideration to bring a number of them to the United States and set up an exploitation center where United States armed forces and American industrialists may take advantage of their ability.

German rocket research followed two lines: Flight control and range. By 1938, a model had been developed which went 13 miles into the air and then came down with a parachute, allowing time to check the control instruments. From this grew the first V-2 used against London with a 150-mile range.

By the beginning of this year, the range was extended to 300 miles. A third model, the most recent, had a 1,200-to-1,800-mile range as a step to the 3,600-mile job scheduled to come up in November.

It is on this basis that Colonel Keck said he would very much like to know what Japan has done with the rocket information given it by the Germans.

According to Colonel Keck, the V-2, built on improved lines, weighs 13 tons, carries 2,150 pounds of TNT, and reaches a top speed of 3,600 miles an hour. This is achieved during the first third of the flight, at which time the fuel is exhausted. During the last two thirds of the flight, the bomb is carried by its own momentum through the stratosphere. It falls down to earth with a terminal velocity of 2,400 miles an hour.

There is no known defense against V-2's except to strike at the source from which they are launched.

Another phase of the German rocket research also promised plenty of trouble in the future. A group of researchists, headed by Dr. Heinrich Determann, explored the problems of underwater launching of rockets.

Colonel Keck pointed out that Hitler ordered all German artillery to be converted to rocket types by 1944. Actually the Germans have developed an antiaircraft or rocket flak gun able to range as high as 50,000 feet. Its explosion can be timed to within 10 feet of the objective, it was disclosed.

Other weapons of the rocket-launching variety were described as a 38-centimeter—about 15-inch—projector on a Tiger tank which could fire 760-pound shells and an 11-inch railway gun firing rocket-propelled missiles.

Flak Guns for U-Boats

By working on underwater launching, they developed flak guns for submarines. They had developed such a gun, so that their submarines in the future could have fired at low-flying airplanes without having to surface at all.

By January of this year, Dr. Determann had a rocket gun ready that could fire a rocket the size of a V-2 from 300 feet below the water surface at a predetermined point and angle of departure. It would burst out into the air in a typical V-2 flight.

This meant another answer to attacking the coast of the United States, for even with their short range of 300 miles, V-2's could be carried by submarines to a point 200 or 300 miles off the American coast. If fired from such a depth, chances of the German submarine being detected and caught would be very very slight. Unfortunately, Dr. Determann was able to destroy his blueprints, formulas, and other data and to sink the experimental machinery and equipment in the Toplitz See in Austria before American troops went there.

Technical Vistas Enlarged

Development of the rocket has opened vast vistas of technical marvels, long dreamed of by imaginative physicists all over the world.

One of these vistas, considered a "logical expectation within some 50 to 100 years," is the construction of a "space station," 5,100 miles up in the troposphere, with a 2-mile reflecting mirror capable of generating from the sun all the power needed in an area the size of Germany.

The space station is merely a theoretical projection, following the successful design of long-range load-carrying rockets with accurate controls.

So far, however, the Germans had not solved the problem of getting the "space stations" up there, or of controlling them when they arrived.

The conditions in the stratosphere and troposphere are well known enough to physicists so that factors to be met at great heights can be anticipated. The rocket's efficiency becomes the greater the higher it gets. It is on the basis of their recent achievements that German rocketeers look ahead and see the 5,100-mile altitude achieved in rocket travel within 50 to 100 years.

Of course it will be useful to remember that stories about exploitation of sun power have been a stock-in-trade of German pseudo- and popular-scientific literature. In most of the earlier instances, however, the scientifically valid idea of marshaling and transmitting sun energy by means of giant reflectors was coupled with the plan of building the power station in the Sahara desert.

Factor of Gravity

This 5,100 miles is a key number to the rocket engineers, because that is where the effect of gravity ends. [That idea is scientifically incorrect and does not appear in German reports. It is an American misunderstanding and seems to indicate that the general level of scientific understanding in the United States was quite backward compared to that in the German-speaking world at this time.] That means that all kinds of useful structures can be erected with minimum engineering problems because weight as such would no longer exist at such level. On the other hand, building without relying on the weight factor is bound to raise technical problems of a new kind.

Use of sun energy is a logical evolution of this "progressive" thinking. At this height, a large reflector concentrating the sun rays on a small area on the earth would offer tremendous potentialities. Sun rays massed and directed at a vast boiler area of some coastal country could generate enough steam to produce all the electric power the country could use, state the German natural scientists. And of course the warlike German thought must not be forgotten.

Concentrated sun energy could just as well be turned to destructive aims and used for the scorching and burning down of countries and the first state to develop the necessary devices would become all but invincible.

Moving back to the immediate future in rockets from Europe to America, there will be mail-carrying rockets first, and passenger-carrying rockets soon after, according to researchists. Like the advanced V-2, they would make the trip from Paris to New York in 40 minutes.

Nazis to Focus Rays of Sun for Slaughter. *Pittsburgh Post-Gazette* 29 June 1945 p. 63.

Paris, June 28—(UP)—German scientists at the end of the war were working on the idea of erecting stratospheric platforms 5,000 miles above the earth to be reached by rockets and used to launch attacks on targets on the earth's surface, it was revealed today by Lieutenant Colonel John A. Keck, chief of the work of salvaging enemy equipment.

The plan was known to 100 of Germany's foremost rocket experts, all of whom have been questioned by American and Russian army experts, he said. [...]

Another new German weapon, which was in the advanced stage, was a long-range transatlantic rocket called the A-10 which was designed to bomb the United States and which the scientists asserted would have been perfected in a few more months. [...]

A number of weapons were planned, Keck said. Among them were long-range rockets with a 3,000-mile radius, a 200-ton tank, a 5,000-pound multiple rocket with an anticipated 100-mile range, a transatlantic rocket which was to have been perfected this summer for the bombing of American cities, a "rocket assist" shell device designed to increase by 50 per cent the range of German artillery, and a "water to air" rocket fired from a submerged submarine which was to be used to bomb cities or as anti-aircraft against patrolling planes.

The Station in Space: Sun Power Stations Planned by Germans. *Journal of the American Rocket Society* September 1945, No. 63, pp. 8–9.

Disclosure of German war secrets found buried in mines and in the beds of rivers and lakes reveal that the Germans were contemplating the construction of solar space stations in the next 50 years. The stations, floating some 5,000 miles above the earth, were to function as an observatory, to possess a mirror, two miles in diameter, for focusing the sun's rays on earth steam-producing plants or for reflecting concentrated sunlight against hostile forces, and finally to act as a base for launching spaceships into outer regions.

The reported plans coincide so closely to proposals made on the subject in the late 20's and early 30's by Noordung, Pirquet, Oberth and others that apparently the Germans based their projects on these early theories. The terminal in space idea, which may at present appear visionary, generally takes the form of an elaborate rocket-powered plant of several sections circling the earth like a satellite at an altitude depending on its duties.

Noordung's Design

Captain Hermann Noordung, pen name of the Austrian Captain Potocnik, proposed a space station consisting of three separate units—living quarters, observatory and powerplant—connected by flexible air cables and pipelines to each other and moving in the same orbit. Placed some 22,300 miles above sea level the station was to revolve around the earth each 24 hours.

A large wheel-like structure about 100 feet in diameter, creating artificial gravity by rotating once every eight seconds, would house scientists and crew. This rotary house had rooms for every purpose located around the rim of the wheel and connected to the central airlock by elevators and stairs. All the necessities of life—light, heat, oxygen, water and food—were provided for, with energy from the sun supplying the power requirements of the station.

Captain Noordung intended that the cylindrical spatial observatory would observe weather conditions and other happenings on the earth's surface and report all observations in detail to ground stations. Due to the absence of air and dust and the lack of weight powerful telescopes of any size could be constructed and maintained. Study of the motions, distances, magnitudes and physical constitutions of the heavenly bodies would be undertaken by learned astronomers.

The sun power plant, consisting of a parabolic mirror and engine house, was to function in a manner similar to an ordinary steam turbine system. Liquid nitrogen vaporized by the sun's rays would drive a turbine coupled to an electric dynamo for providing direct current to the different buildings. The fluid on leaving the turbine would circulate to a dark-surfaced cooling unit and be pumped back for reuse.

The Triple Station

Count Guido von Pirquet, a co-founder of an Austrian rocket society, elaborating on the plans of Noordung suggested a three-unit arrangement consisting of an inner station for observations, an outer station for landing and refueling spaceships, and a transit station for contact purposes. The first two stations would travel in circular orbits around the earth while the transit stations circling in an elliptical orbit would approach within a mile of their orbits.

The approximate altitudes from the earth, length of orbits and time required for the stations to revolve around the earth are shown in the table. Speed of the transit station was to be three-quarters of a mile faster than the inner station as it neared the latter's orbit.

	Altitude above sea level (miles)	Length of orbits (miles)	Revolution around earth (minutes)
Inner Station	470	27000	100
Transit Station	470–3100	34000	150
Outer Station	3100	44600	200

Oberth Sun Mirror

Professor Hermann Oberth was much in favor of a station for observations which every four hours circled the earth at a height of 600 miles. He also conceived of a concave sun mirror constructed of small movable facets of metallic sodium mounted on a wire network in a circular frame. Sodium, a silver-white alkaline metallic element having high reflective properties, was considered most favorable for use in the non-corrosive airless regions of space. Adjustment of the facets by electro-magnets or other means would reflect the sun's rays over a large area or concentrate the heat energy into a single beam. Construction details were minutely worked out whereby free wires attached to a rotating spaceship could be made to spread out to form a huge network upon which strips of metallic sodium would be fastened.

Suggestions for shooting the sky station to its destination, towing or propelling it by rocket power were discarded in favor of the accepted idea of transporting the space plant piece by piece by rocket ship and assembling it in space. In the weightlessness of space workmen in space suits were conceded to have no difficulty in assembling heavy sections of the station.

The proposed sun mirror was to be employed beneficially or as a devastating force. Solar energy on being directed to ground turbine stations was to be utilized to generate steam for creating electrical power. Reflected heat would control weather, evaporate useless water and melt ice fields or illuminate large areas of the earth's surface at night.

Means for launching exploring spaceships to other planets and beyond into inter-stellar space was foreseen. Especially favorable was the suggestion of using the station as a refueling depot for spaceships ascending from the earth. The required fuel load from earth to space would be greatly reduced, as only enough fuel would need to be carried to overcome gravity from earth to the starting point for space travel.

History relates that in the siege of Syracuse, 212 B.C., Archimedes, Greek philosopher and inventor, set fire to the sails of the Roman ships by focusing the rays of the sun through newly invented burning glasses. As a weapon the Oberth reflector would also act much like a burning glass. Concentrated rays on earthly targets would turn bodies of water into steam while ships, cities and the implements of war would be burnt and destroyed.

Suggested References

Noordung, Hermann, Das Problem der Befahrung des Weltraums (The Problems of Space Flying). Revised English printing in Science Wonder Stories, 1929.

Oberth, Hermann, Wege zur Raumschifffahrt, 1929.

Ley, Willy, Rockets: The Future of Travel Beyond the Stratosphere, 1944.

[This article demonstrates that the space station and space exploration designs of the 1950s–1960s United States actually originated in the German-speaking world of the 1920s, and were transferred to the United States beginning before the war but especially at the end of World War II.]

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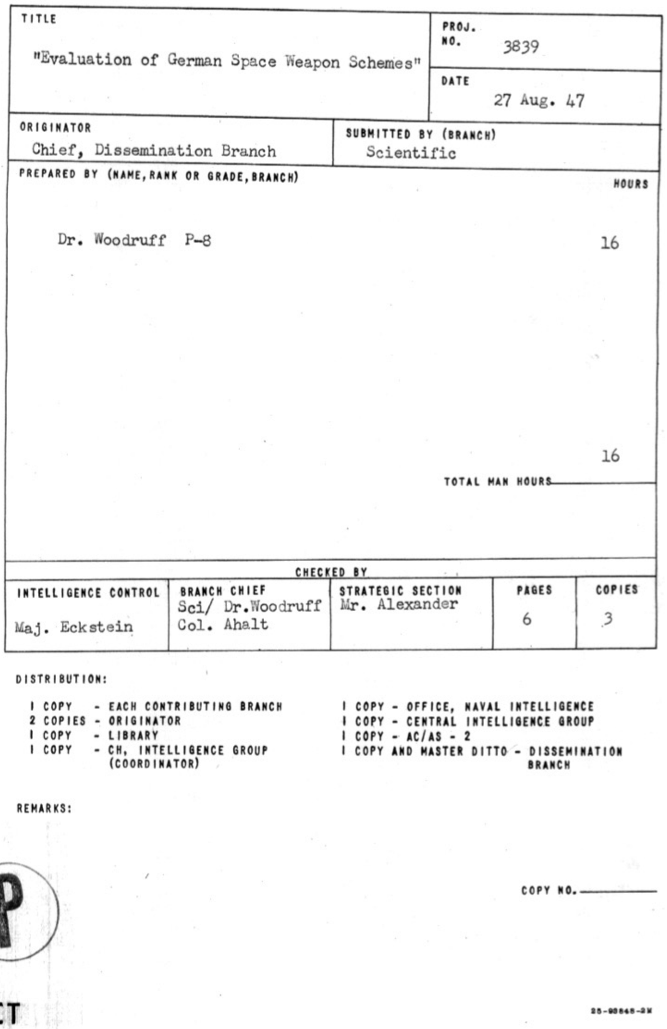

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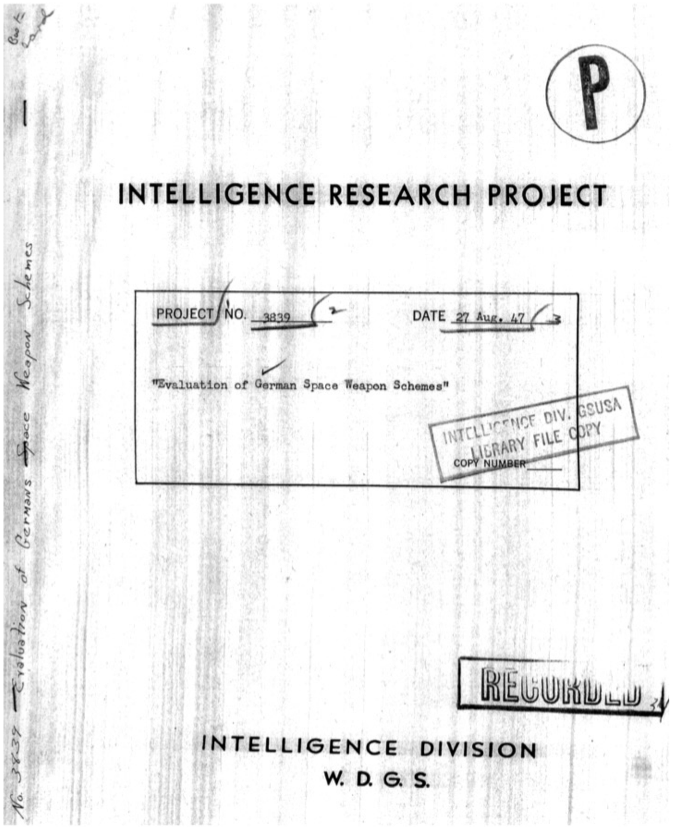

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INTELLIGENCE RESEARCH PROJECT

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No. 3839 — Evaluation of Germans Space Weapon Schemes

Figure E.263: Over two years after World War II ended in Europe, the U.S. War Department General Staff (WDGS) Intelligence Division wrote a report summarizing what they had learned about “German Space Weapon Schemes” that had been developed during the war. Even after so many decades, that report remains classified and unavailable to the public. Why? What information is in the report? [NARA RG 319, Entry NM3-82, Box 2899, Folder Project 3839]

E.5.2 Fission Thermal Rocket Propulsion

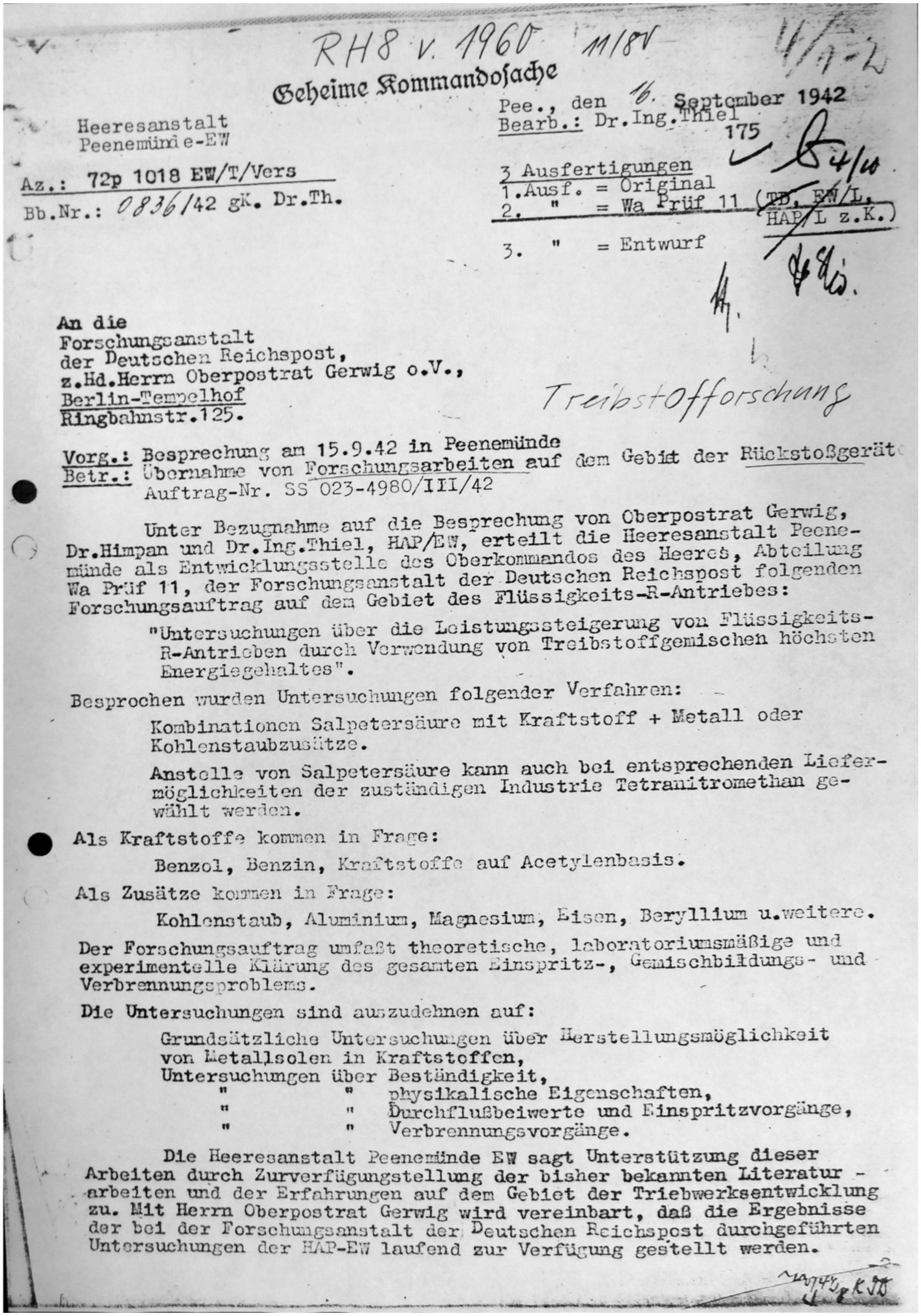
[Whereas most rockets employ chemical reactions, non-chemical (i.e., nuclear) rockets could deliver much higher performance for deep space missions. German-speaking scientists began the development of such advanced rocket propulsion systems during World War II and continued to lead their development after the war.

Fission thermal rockets store energy onboard in the form of a relatively conventional fission reactor, which is powered by suitable fuel such as uranium-233, uranium-235, or plutonium-239. Like chemical rockets, fission thermal rockets also store propellant onboard, yet unlike chemical rockets, fission thermal rockets do not require the propellant to undergo chemical reactions and release energy of its own. The propellant is simply heated by the reactor to achieve very high temperatures and pressures, then expelled out of the rocket nozzle, as shown in the upper part of Fig. 9.240. Minimizing the molecular weight of the expelled propellant maximizes the exhaust velocity, so most proposed fission thermal rockets use hydrogen propellant. The temperature to which the propellant is heated is limited by how hot the fission reactor can become without melting the fission fuel or other reactor components, but that still yields an exhaust velocity roughly twice that of the best chemical rocket engine.]

16 September 1942 memorandum of understanding between Peenemünde and the Reichspost [Peenemünde Archive, AHT0205].

Als zweite Forschungsarbeit auf größere Sicht wird seitens der Heeresanstalt Peenemünde-EW vorgeschlagen:	The second research project proposed by the Heeresanstalt Peenemünde-EW is a larger-scale research project:
“Untersuchung der Möglichkeit der Ausnutzung des Atomzerfalls und Kettenreaktion zum R-Antrieb”.	“Exploring the possibility of exploiting atomic decay and chain reaction for rocket propulsion.”
Die notwendigen Mittel für die Durchführung der Aufträge stellt das Reichspostministerium selbst zur Verfügung.	The Reichspost Ministry itself will provide the necessary funds to carry out the commission.

[This document proves that scientists at Peenemünde and the Reichspost began programs on nuclear rocket propulsion no later than 1942. See Figs. E.264–E.265.]



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Geheime Kommandosache

Heeresanstalt
Peenemünde-EW

Az.: 72p 1018 EW/T/Vers
Bb.Nr.: 0836/42 gK. Dr.Th.

Pee., den 16. September 1942
Bearb.: Dr.Ing.Thiel
175

3 Ausfertigungen
1.Ausf. = Original
2. " = Wa Prüf 11 (TB, EW/L, HAP/L z.K.)
3. " = Entwurf

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An die
Forschungsanstalt
der Deutschen Reichspost,
z.Hd.Herrn Oberpostrat Gerwig o.V.,
Berlin-Tempelhof
Ringbahnstr.125.

Treibstofforschung

Vorg.: Besprechung am 15.9.42 in Peenemünde
Betr.: Übernahme von Forschungsarbeiten auf dem Gebiet der Rückstoßgerät
Auftrag-Nr. SS 023-4980/III/42

Unter Bezugnahme auf die Besprechung von Oberpostrat Gerwig, Dr.Himpan und Dr.Ing.Thiel, HAP/EW, erteilt die Heeresanstalt Peenemünde als Entwicklungsstelle des Oberkommandos des Heeres, Abteilung Wa Prüf 11, der Forschungsanstalt der Deutschen Reichspost folgenden Forschungsauftrag auf dem Gebiet des Flüssigkeits-R-Antriebes:

"Untersuchungen über die Leistungssteigerung von Flüssigkeits-R-Antrieben durch Verwendung von Treibstoffgemischen höchsten Energiegehaltes".

Besprochen wurden Untersuchungen folgender Verfahren:

Kombinationen Salpetersäure mit Kraftstoff + Metall oder Kohlenstaubzusätze.

Anstelle von Salpetersäure kann auch bei entsprechenden Liefermöglichkeiten der zuständigen Industrie Tetranitromethan gewählt werden.

Als Kraftstoffe kommen in Frage:

Benzol, Benzin, Kraftstoffe auf Acetylenbasis.

Als Zusätze kommen in Frage:

Kohlenstaub, Aluminium, Magnesium, Eisen, Beryllium u.weitere.

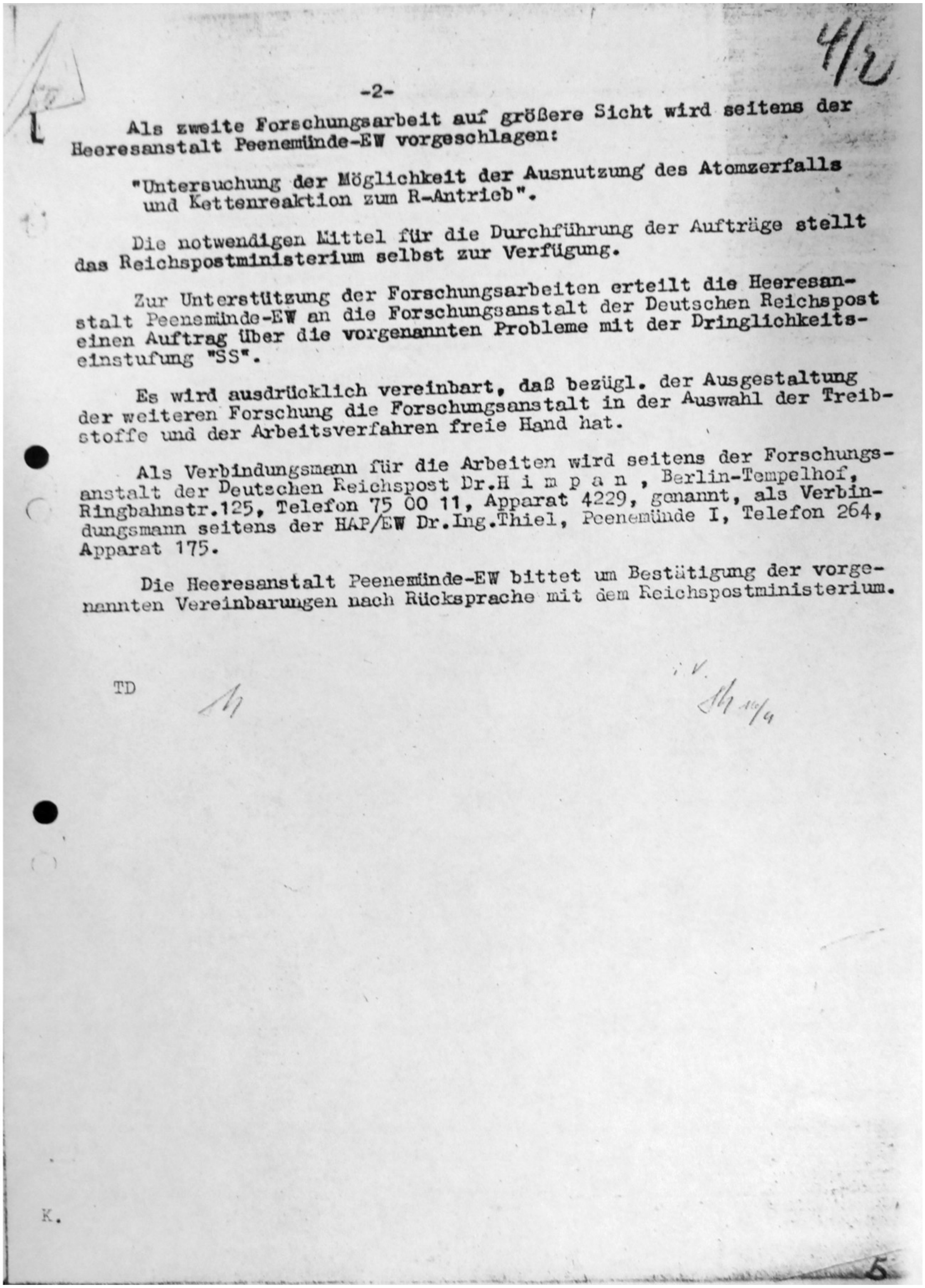
Der Forschungsauftrag umfaßt theoretische, laboratoriumsmäßige und experimentelle Klärung des gesamten Einspritz-, Gemischbildungs- und Verbrennungsproblems.

Die Untersuchungen sind auszudehnen auf:

Grundsätzliche Untersuchungen über Herstellungsmöglichkeit von Metallsolen in Kraftstoffen,
Untersuchungen über Beständigkeit,
" " physikalische Eigenschaften,
" " Durchflußbeiwerte und Einspritzvorgänge,
" " Verbrennungsvorgänge.

Die Heeresanstalt Peenemünde EW sagt Unterstützung dieser Arbeiten durch Zurverfügungstellung der bisher bekannten Literatur-arbeiten und der Erfahrungen auf dem Gebiet der Triebwerksentwicklung zu. Mit Herrn Oberpostrat Gerwig wird vereinbart, daß die Ergebnisse der bei der Forschungsanstalt der Deutschen Reichspost durchgeführten Untersuchungen der HAP-EW laufend zur Verfügung gestellt werden.

Figure E.264: Scientists at Peenemünde and the Reichspost began programs on nuclear rocket propulsion no later than 1942 [Peenemünde Archive, AHT0205].



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Als zweite Forschungsarbeit auf größere Sicht wird seitens der Heeresanstalt Peenemünde-EW vorgeschlagen:

"Untersuchung der Möglichkeit der Ausnutzung des Atomzerfalls und Kettenreaktion zum R-Antrieb".

Die notwendigen Mittel für die Durchführung der Aufträge stellt das Reichspostministerium selbst zur Verfügung.

Zur Unterstützung der Forschungsarbeiten erteilt die Heeresanstalt Peenemünde-EW an die Forschungsanstalt der Deutschen Reichspost einen Auftrag über die vorgenannten Probleme mit der Dringlichkeitseinstufung "SS".

Es wird ausdrücklich vereinbart, daß bezügl. der Ausgestaltung der weiteren Forschung die Forschungsanstalt in der Auswahl der Treibstoffe und der Arbeitsverfahren freie Hand hat.

Als Verbindungsmann für die Arbeiten wird seitens der Forschungsanstalt der Deutschen Reichspost Dr.Himpan, Berlin-Tempelhof, Ringbahnstr.125, Telefon 75 00 11, Apparat 4229, genannt, als Verbindungsmann seitens der HAP/EW Dr.Ing.Thiel, Peenemünde I, Telefon 264, Apparat 175.

Die Heeresanstalt Peenemünde-EW bittet um Bestätigung der vorgenannten Vereinbarungen nach Rücksprache mit dem Reichspostministerium.

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Figure E.265: Scientists at Peenemünde and the Reichspost began programs on nuclear rocket propulsion no later than 1942 [Peenemünde Archive, AHT0205].

Charles A. Masson, Headquarters United States Air Forces in Europe, Assistant Chief of Staff, A-2, to Assistant Chief of Staff, T-2, Headquarters Air Technical Service Command, Wright Field, Ohio. 1 February 1946. Transmittal of German Documents. [AFHRA C5098 frame 0393]

1. Forwarded herewith for evaluation are documents received from three German scientists:

[...] c. KRAFFT EHRICKE (or Müller)—"Discussion of Activity on Rocket Problems." This man apparently has a very extensive background in rocket propulsion. However, his assertions can probably be checked with the German scientists now at Wright Field.

2. It is requested that this headquarters be notified as soon as possible as to the decisions made with regard to these documents and their submitters, [...]

3 Incl: [...]
3. Krafft Ehricke (or Müller)—"Discussion of Activity on Rocket Problems."

H. M. McCoy, Acting Deputy Commanding General Intelligence (T-2), H.Q., AMC, Wright Field, Dayton, Ohio to U.S. Air Forces in Europe, Assistant Chief of Staff, A-2. 14 August 1946. Transmittal of German Documents. [AFHRA C5098 frame 0392]

1. Inclosures 2 and 3 to basic communication are returned with the request that, if possible, additional information be furnished this office on the following subjects:

[...] b. Metals in fuels and designs of atomic rockets and secret reports of Professor Heisenberg referred to in paragraph 2, page 4, inclosure 3.

c. Burning metals or use of uranium 235 for rocket propulsion referred to in paragraph 2, page 3, inclosure 3.

d. Experience on tetranitromethane referred to in paragraph 2, page 6, inclosure 3.

2. If additional data are available on the above subjects, it is requested such data as can be obtained be forwarded to this office for transmittal to the proper laboratory. [...]

2 Incls: [...]
3. Krafft Ehricke (or Müller)—"Discussion of Activity on Rocket Problems."

[Where are the enclosures and secret reports referenced in these two documents? Note that these two documents appear to be directly related to the document shown in Figs. E.264–E.265—in addition to nuclear propulsion there are mentions of tetranitromethane and burning metals.

Why was Krafft Ehricke apparently going by the pseudonym of "Müller"?

Exactly what work did Krafft Ehricke, Werner Heisenberg, and others scientists do on atomic rockets during the war? The United States seems to have interrogated them and also acquired many of their written reports. Where are those interrogation reports and scientific reports now?

How much effect did German-speaking scientists and their information have on postwar programs on atomic rockets in the United States and other countries?]

BIOS 142. *Information Obtained from Targets of Opportunity in the Sonthofen Area.* 1945. p. 8.

(e) High speed fighter aircraft

Ernst said that while he was in Camp Mecklenburg, he found out that there were three new types of high speed fighter aircraft. One of these was the P 1073, made by Messerschmitt with a B.M.W. 003 engine using petrol as fuel; and the second was a similar aircraft using crude oil as a fuel. The third was alleged to be powered with an atomic engine. The fuselage, which was the same as the P 1073, was of wooden construction and was fitted with skid landing gear. The engine was 60 cms. long and 20 cms. in diameter, and produced about 2,000 h.p. This aircraft was supposed to have a speed of 2,000 km./hr. and a ceiling of 18,000 m. The engines were made by the prisoners at Camp Mecklenburg. Only one model was ever in existence, and that was completely destroyed, as was the whole camp, by the S.S. during the Allied advance.

(f) Other work at Camp Mecklenburg

Ernst also stated that work was carried out at this camp on a new liquid air bomb, and liquid air gun (?), while trials on some kind of atomic bomb were made at or near the camp.

[During this postwar interrogation by British investigators, Josef Ernst described several now well-known wartime projects, as well as a mysterious wartime project to construct a supersonic fission-powered aircraft. He also mentioned other nuclear work at the same facility. There were several independent reports of nuclear-related work at that facility, which adds to the credibility of Ernst's story. For more information on the facility, see p. 4180.

See p. 4532 for a similar account of the wartime production of a nuclear-related supersonic jet aircraft by Horst Kirfes, an engineer captured by the Soviet Union after the war.

Was the nuclear device mentioned by Josef Ernst fission fuel for a nuclear-powered jet engine, or could it have been a nuclear weapon that would have been delivered by that aircraft?]

Robert E. Work. 17 April 1946. Preliminary Interrogation Report. Franz Focke. [AFHRA A5183 frames 0091–0092; see also frames 0108–0109]

Focke has been interested in atomic energy for many years. He claims to have worked out theories which involve the use of atomic energy as source power for aircraft engines. Focke is convinced that the unlocking of the energy of atomic kernels [nuclei] for industrial and transportation purposes can be effected. As a result of his extensive research work he applied for and/or obtained the following patents from the German Patent Office. [...]

This office plans to interrogate him regarding his ideas of the utilization of atomic energy in aircraft. [...]

[Can the patents, more detailed interrogation reports, and other information on Franz Focke's work on nuclear aircraft propulsion be located?]

Edmund Tilley. Brief Interrogation Report on Prof. Dr. Wernher von Braun. With additional statements on PROJECT ABSTRACT. FIAT, T-Force, SPEC-A 477/3. 8 July 1947. [TNA FO 1031/128]

1. On 8 March 1947 Dr. von BRAUN was brought to H.Q. USFET for an interrogation by Dr. John H. MARCHANT of BROWN University and by the undersigned. The interrogators were told of von BRAUN's status in the United States where many senior officers, especially in Army Ordnance, hold him in high esteem and consider him invaluable in his work. The interrogation was, therefore, conducted very informally and on cordial terms.

2. Indirectly intelligence had reached interested agencies in the United States that von BRAUN was aware of the existence of caches of PEENEMÜNDE documents and also instruments and that he had not yet revealed these caches to his employers in the United States. It was rumoured that he might use this knowledge as a bargaining point in any future negotiations in the United States. Furthermore, there was the feeling in some circles that he was not reproducing freely all the latest phases of German development in guided missiles, in particular in V-2. [...]

4. Recently Lt. Gen. DORNBERGER stated that von BRAUN and (Lt. Col.) AXTER were both present when he hid a tin, containing the location maps or sketches of hiding places, at OBERJOCH, in May 1945. He repeated this statement several times at OBERJOCH, during a search for the tin, in May 1947. When he discovered that the tin had been removed he recalled that von BRAUN had shown him some location maps in May 1945, a few days after they had surrendered to the American forces. [...]

70. Atomic Energy as Propellant for V-2. The second question about the possibility of using atomic charges in the warhead of V-2 was firmly rejected. "I had nothing to do with atomic energy". In the end he admitted that atomic energy had been considered by him in 1943.

71. "Two years before 1945" (i.e. in 1943) he had had "a private and not very definite contact with the KAISER WILHELM INSTITUT in DAHLEM" (now in the American Sector of BERLIN). In 1943 he talked to Professor Werner HEISENBERG and his fellow-workers, DR. WEIZAECKER, and Manfred von ARDENNE. In 1943 HEISENBERG was preparing a uranium pile with heavy water which had been produced in NORWAY. This work was financed by the German Navy which hoped to have submarine engines driven by atomic piles. The project was abandoned "because the atomic research people lacked the necessary quantities of raw materials". +) and Dr. RAMM

72. Once more he denied that there had been any discussion of atomic, BW or CW charges at BAD SACHSA; he had not even heard rumors of such charges for guided missiles. He stated that he had shown an interest in atomic energy in 1943 only to determine if it could be used for V-2 as well as for submarines, i. e. as a propellant, but not as a charge for the warhead.

73. He has not discussed this subject with anyone in the UNITED STATES. "Nobody has ever asked me about this".

74. GROETTROP and "PROPELLANT GREEN".

List of German V-2 Experts in Russia. Von BRAUN mentioned casually that a few days before this interrogation a German expert who is now working for the Russians had visited him at LANDSHUT and had given him a list of all important Germans employed by the Russians in the field of guided missiles. Von BRAUN promised to send two copies of this list, through secure channels, to G-2 USFET. (From the UNITED STATES he was also going to forward a list of all projects at BAD SACHSA in 1945).

75. GROETTROP: According to other sources GROETTROP is the most important German V-2 expert with the Russians. Von BRAUN said of him: "He is a dangerous man. He copies all sorts of things that are not in his field."

84. Von BRAUN has made several mistakes. He did not inform American experts in the UNITED STATES of some important projects and activities in the field of guided missiles, such as the contemplated use of the ROECHLING Projectile (paras 64–69), the project to use atomic energy as a propellant (paras 70–73) and the various projects, whether good or bad, at BAD SACHSA. Above all, as late as March 1947 he failed to tell the truth about important caches of documents. As far as OBERJOCH or UPPER BAVARIA is concerned the evidence forces us to declare him deliberately untruthful [...]

88. (Note: While these notes were being written S/Ldr. KENNY informed the undersigned that von BRAUN had spoken of atomic energy at GARMISCH, in 1945. It is odd that, in March 1947, he should deny any previous discussion of this important point (Par. 73.)

[For information on Edmund Tilley, see pp. 4894–4895. For more information on Project Abstract, see Mills and Johanson 2019.

In point 88 above, Squadron Leader E. J. André Kenny (one of the most important British aerial photo interpreters for Operation Crossbow [David Irving 1965, see index; McGovern 1964, pp. 13, 268]) said that Wernher von Braun had discussed nuclear-armed rockets at Garmisch in 1945, in contrast to what von Braun was admitting to Tilley in 1947. Kenny had visited Garmisch and other German sites in early May 1945 as part of CIOS Team 183 [O'Mara 1945, pp. 544–547].

This information from Kenny was independently confirmed by British journalist Gordon Young, who interviewed von Braun and Walter Dornberger at Garmisch in June 1945. They told Young that the V-2 would have soon received a "much more powerful" warhead. Allied censorship forced Young to eliminate any reference to German nuclear weapons at that time, since the U.S. nuclear weapons program was still completely secret. In August 1945, after U.S. nuclear weapons were used on Japan and became publicly known, Young tried to publish a second article reporting what he had learned from von Braun about nuclear-armed rockets. That second article was censored completely; only a brief reference in another article in Young's own newspaper (*Daily Express*) and three short articles in Australian newspapers escaped that second and final censorship (pp. 4679–4681).

See also the testimony given by former Nordhausen forced laborer Alex Baum (p. 5335). Baum remembered that von Braun eagerly expected the arrival of a new rocket warhead with tremendous destructive power.

For further evidence of rockets with nuclear warheads, see the summary of the interrogation of engineer Horst Kirfes (p. 4532), as well as the July 1946 *AAF Review* (p. 5038).

For many more references to nuclear-armed rockets that were intended to attack Allied targets during the war, see the list of documents on p. 5821.]

Howard R. Schmidt. 14 November 1962. History of the Nuclear Rocket: Pre-NERVA Development. American Rocket Society conference paper.

[I need to find a copy of this. Pages 2–3 mention wartime German research on nuclear rocket propulsion.]

John Sloop. 1978. *Liquid Hydrogen as a Propulsion Fuel, 1945-1959.* NASA SP-4404. Washington, D.C.: U.S. Government Printing Office. pp. 191–192. [https://www.hq.nasa.gov/pao/History/SP-4404/ch10-3.htm]

The first rocket stage to fly using liquid hydrogen and liquid oxygen as propellants was the Centaur stage on top of an Atlas intercontinental ballistic missile. Centaur was the brainchild of Krafft Ehricke. For nearly three decades, Ehricke had prepared himself for the space age; when it dawned with Sputnik, he was ready. Within a month, he proposed a hydrogen-oxygen stage for use with the Atlas missile. Ehricke was able to move rapidly because previous work on the Atlas missile and the ideas of others about hydrogen-oxygen upper stages had laid the groundwork.

Ehricke became a space enthusiast at the age of eleven when he was captivated by Fritz Lang's "Girl in the Moon," shown in Berlin in 1928. Advanced in mathematics and physics for his age, he appreciated the great technical detail that Hermann Oberth had provided to make the film realistic. Young Krafft became acquainted with Tsiolkovskiy's space rocket using hydrogen-oxygen, which he read about in Scherschevsky's *Die Rakete fuer Fahrt und Flug*. He also tackled Oberth's *Wege zur Raumschifffahrt* in his early teens, but was slowed by the mathematics. Ehricke graduated from the Technical University in Berlin (aeronautical engineering) and took postgraduate courses at the Humboldt University in celestial mechanics and nuclear physics. He was conscripted into the army, served in a Panzer division on the Russian front during World War II, but was recalled and reassigned to rocket development work at Peenemunde in June 1942. There he came under the strong influence of Walter Thiel, in charge of rocket engine development, who was killed in the first British air raid on Peenemunde in October 1943. Peenemunde, under Maj. Gen. Walter Dornberger and Wernher von Braun, his technical director, had a single purpose—the rapid development of specific weapons—and there was no official tolerance of work not directly related to the main goal. In spite of this, Thiel shared Ehricke's desire to look beyond the immediate future to greater possibilities. Thiel himself drew plans for testing rockets larger than any yet dreamed of—on the order of 5–14 meganewtons (1–3 million lb thrust). He wanted to use natural gorges in Bavaria as testing sites. He talked to Ehricke about resuming his own earlier experiments with liquid hydrogen in small rocket thrust chambers. The experiments of Heisenberg and Pohl with a nuclear reactor using heavy water excited Thiel. When he heard that Heisenberg was planning to operate a turbine with steam heated by the heavy water reactor, Thiel urged Ehricke to study the possibilities of using nuclear energy for propulsion. Ehricke considered several working fluids, but both he and Thiel favored hydrogen and believed it was a fuel with a future.[11]

As the war was ending, Ehricke helped move Peenemunde records into Bavaria, to keep them out of Russian hands. He made his way on foot to Berlin where he found his wife and went into hiding until the Western Allies moved in. He was located by the U.S. Army, given a six-month contract, and came to the United States to rejoin the von Braun team as part of the Paperclip operation.*

Ehricke and von Braun recalled another time they had considered hydrogen. In 1947, von Braun asked Ehricke to check a report by Richard B. Canright of the Jet Propulsion Laboratory on the relative importance of exhaust velocity and propellant density for rockets of the V-2 size and larger (pp. 47–48). It had caught von Braun's attention because he and two associates had written a paper the previous year which Canright had cited.[12] Von Braun had found, under the assumptions of fixed tank volume and a relatively heavy structural mass, that propellants with the highest densities and reasonably high exhaust velocities had the greater ranges. Canright, on the other hand, found that for large rockets and his assumptions (which included a variable tank volume and relatively light structural mass), exhaust velocity was decidedly more important than density. Canright's analysis showed hydrogen to be superior to other fuels when using the same oxidizer. Both Ehricke and von Braun, familiar with Oberth's case for using hydrogen-oxygen in upper stages of rockets (appendix A-2), agreed that hydrogen had a good potential for certain applications. Practical experience with liquid hydrogen in rockets at that time, however, was still very small and its handling problems large. The Army, for whom von Braun and Ehricke worked, wanted practical propellants that could be stored and handled safely in the field. This convinced von Braun to stick to well tested and denser propellants, but Ehricke felt less restrained and hydrogen's potential remained prominent in his thinking.

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[11] Interview with Krafft Ehricke, Rockwell International, El Segundo, CA. 26 Apr. 1974.

* Ehricke wanted to work for the Americans, and he hid each time someone knocked on his door, waiting for the right caller. One day his wife answered the door and routinely said, “I don't know where he is.” As she did so, she recognized the insignia of a U. S. Army officer and immediately began screaming, “He's here! He's here!” Interview, 26 Apr. 1974. Paperclip was the project for bringing German rocket experts to the United States.

[12] Ibid.; Wemher von Braun to Monte D. Wright, NASA History Office, 29 Dec. 1975.

[Who was Pohl and what else did he do? Is that Robert Pohl from Göttingen or another Pohl?]

Charles A. Lindbergh. 1970. *The Wartime Journals of Charles A. Lindbergh.* New York: Harcourt Brace Jovanovich. pp. 970–971.

From the Wörthsee we drove to Allach to look for Dr. Neugebauer,[13] head of the Munich research center near Hohenbrunn, which never reached completion. Baeumker said he was one of the best men in Germany to give a comparison of the development and uses of their various types of engines. We found him living with his family in a small frame house not far from the Allach railroad station. He had one more week's work to close the research institute, he said. Then, since he had eleven people to support, including five children, he would apply for work in a locomotive factory.

Neugebauer is primarily interested in the development of a diesel turbine to be connected to a free-piston reciprocating engine, for use in long-range aircraft cruising at speeds of 500 to 550 kilometers per hour. This type of engine would be for the immediate future, Neugebauer thinks. The turbine engine will come later when we learn how to use higher temperatures. The sequence of engines used in aviation in the future will be 1) diesel; 2) turbine with propeller; 3) turbojet, according to Neugebauer. He thinks the Lorin jet [ramjet] will be used for speeds above 1,000 kilometers per hour. He says that a single-cylinder engine for his diesel development was almost finished.

I gave Dr. Neugebauer the rest of the candy I had with me for his children, and we started back to our billets.

[13] Dr. Franz Josef Neugebauer, engineer specializing in thermal systems for aircraft nuclear propulsion. He had been chief of initial development at the Junkers factory at Dessau, 1924–38; technical and plant manager at the Junkers factory in Munich, 1938–43; manager at the Luftfahrtforschungsanstalt in Munich, 1943–45. In 1945 he came to the U.S. and was a consulting engineer at headquarters, Air Materiel Command, Wright Field.

[Neugebauer apparently worked on both nuclear and non-nuclear aircraft propulsion during the war. Lindbergh, in collaboration with his editors, mentioned the nuclear work in a footnote. Lindbergh's personal discussions with Neugebauer seem to have focused on the non-nuclear work for one or more reasons:

1. Lindbergh's own career, knowledge, and interests were centered on long-range non-nuclear aircraft propulsion.
2. Maximizing the range of non-nuclear aircraft engines was a high priority in Germany by the end of the war.
3. Neugebauer did not want to discuss details of classified nuclear work with Lindbergh.
4. Lindbergh deliberately avoided writing down details about classified nuclear work.
5. Any nuclear details that Lindbergh did write down were censored before publication.]

Joyce Milton. 1993. *Loss of Eden: A Biography of Charles and Anne Morrow Lindbergh.* New York: HarperCollins. pp. 415–416.

Charles worked for United Aircraft in Connecticut until May of 1945, and shortly after V-E day, he joined a Naval Technical Mission in Europe as a civilian representative of the corporation. [...]

Joining the Technical Mission in Munich, Lindbergh became part of a team of observers who drove their jeeps into territory where the Wehrmacht, defeated but not yet demobilized, was still in effective control. [...] Lindbergh's group located Professor Willy Messerschmitt, who was living in a barn; Dr. Felix Kracht, the inventor of the rocket glider; Dr. Helmut Schelp, assistant head of development of the jet and rocket propulsion program; Dr. Franz Josef Neugebauer, who was working on a design for a nuclear-propelled aircraft; Dr. August Lichte, a developer of the Junker JU 004 turbojet engine; and Dr. Ulrich Henschke, who was working on artificial limbs capable of being controlled by neurological impulses.

Tom Agoston. 1985. *Blunder! How the U.S. Gave Away Nazi Supersecrets to Russia.* New York: Dodd, Mead. pp. 12-13.

By quirk of fate, the careers of Kammler and Voss overlapped at Skoda, where they jointly set up and operated what was generally regarded by insiders as the Reich's most advanced high-technology military research center. Working as a totally independent undercover operation for the SS, the center was under the special auspices of Hitler and Himmler. [...] In so doing the SS group was to go beyond the first generation of secret weapons.

Its purpose was to pave the way for building nuclear-powered aircraft, working on the application of nuclear energy for propelling missiles and aircraft; laser beams, then still referred to as "death rays"; a variety of homing rockets, and to seek other potential areas for high-technology breakthrough. In modern high-tech jargon, the operation would probably be referred to as an "SS research think tank." Some work on second-generation secret weapons, including the application of nuclear propulsion for aircraft and missiles, was already well advanced.

It was far from a mad Nazi scientist's dream of getting to the end of the nuclear rainbow. The field had been pioneered by Dr. Wernher von Braun, designer of the V-2, in the early 1930s. In addition, it was recently disclosed that one of the first top German engineers cleared for urgent work for the U.S. Air Force in 1945 was Dr. Franz Josef Neugebauer, a specialist in thermal systems for aircraft nuclear propulsion. In 1958 the United States launched Project Orion to probe the applicability of nuclear propulsion for aircraft, employing some Czech scientists. The project was continued until 1965 and then was turned over to the U.S. Air Force, plans for its application for the civilian space programs having been dropped.

The SS research operation at Skoda had been set up without the knowledge of Goering, Speer, or the German research centers. The builders of the V-1 and V-2 were likewise kept out of the picture. The undercover SS research operation fitted in with Himmler's dream that, as the Rheingold of the Nibelung's, if shaped into a ring, would give its possessor mastery of the world, so would the SS team give the Greater Reich mastery of much of the world.

A study of intelligence reports shows that blueprints, drawings, calculations, and other relevant documentation or materials were protected by a triple ring of SS counter-intelligence specialists Himmler had assigned to Pilsen to prevent security leaks and sabotage in the research divisions and the plant in general. The SS team was internally referred to as the Kammler Group. Taking a leaf from the armament ministry name for the special section Kammler headed there to iron out aircraft production bottlenecks, they were called the Kammler stab or Kammler "staff."

[This book by British journalist Tom Agoston was based on extensive postwar interviews with Wilhelm Voss, wartime manager of the Skoda works in German-occupied Czechoslovakia.]

[Franz Josef Neugebauer's 1946 U.S. Army Air Forces report, *Project No. NFE-64: Effect of Power-Plant Weight on Economy of Flight*, appears to be a translation of one of his wartime German reports [Neugebauer 1946]. Although the type of power plant is not specified in this particular report, weight would be one of the most important factors in nuclear versus more conventional propulsion systems. There may have been a classified, unreleased, longer version of the report that included details about the nuclear aspects of the project.

Neugebauer apparently continued his work on nuclear aircraft propulsion in the United States for many years. In 1962, working with both General Electric and the Office of Naval Research, he released an unclassified reference book on hot gases that was probably just one small part of his work on nuclear propulsion [Neugebauer 1962].

Would it be possible to locate and declassify uncensored versions of those or other reports by Neugebauer that do explicitly refer to nuclear propulsion?]

Heinrich Himmler's chief adjutant Werner Grothmann on nuclear rocket propulsion [Krotzky 2002]. For a discussion of the background and reliability of this source, see pp. 3396–3397.

[S. 47] Spätestens als wir in Peenemünde den Finger in die Tür bekamen, ist überlegt worden, ob es nicht möglich wäre, die Atombombe mit einer Rakete zu verschießen. Das war ja erst mal reine Theorie. weil wir doch Vorstellungen von dem Ding hatten, die sich nicht umsetzen ließen. Die Untersuchungen dazu sind aber weiter gelaufen. In Peenemünde selbst ist an der Frage, so weit ich weiß nicht mit großer Begeisterung geforscht worden, obwohl die ja eigene Atomlabors hatten. Ich war ja schließlich selbst drin. Für die war aber eher die Frage wichtig, ob eine Rakete mit Atomantrieb fliegen kann. Warum die daran geforscht haben, hatten Himmler und ich bei unserem ersten gemeinsamen Besuch auch gehört. Die Techniker hatten uns berichtet, dass der Antrieb schon wunderbar funktioniert, das konnte man dann später ja auch sehen. Es war aber so, dass der gesamte Treibstoff in kürzester Zeit verbraucht war und damit konnte man nur über eine kurze Entfernung schießen. Kurz ist eigentlich nicht richtig. Damals waren wir schon begeistert von der Entfernung, die man mit der Rakete hinbekommt. Wenn man jetzt aber weiß ,dass in dem Uran viel mehr Energie steckt als im gleichen Gewicht von dem Treibstoff, den die verwendet haben, also das war Sauerstoff und noch was, dann müsste es doch möglich sein, über weitere Strecken zu fliegen. So ist uns das erklärt worden. Man hat uns aber auch gesagt, die Forschung dazu steckt in den Kinderschuhen, das ist noch ein weiter Weg. Himmler hat dann gesagt, er begrüßt diese Forschung, wichtiger ist aber erst mal, dass man die Rakete so hinbekkommt, dass die überhaupt zuverlässig funktioniert, und das muß schnell gehen.

[p. 47] At last when we [SS] got a finger in the door in Peenemünde, it was considered whether it would be possible to launch the atomic bomb with a rocket. That was pure theory for the time being, because we had ideas about the thing that could not be implemented. However, the investigations continued. In Peenemünde itself, the question, as far as I know, had not been investigated with great enthusiasm, even though they had their own atomic laboratories. I was finally there myself. For them, however, the more important question was whether a rocket can fly with nuclear propulsion. On our first joint visit, Himmler and I heard why they researched that topic. The technicians told us that the propulsion already works wonderfully, we could also see that later. But it was true that all the propellant was consumed within a very short time, and so it could fly only over a short range. Short is actually not right. At that time, we were already excited by the range that the rocket gave. But if you now know that there is much more energy in the uranium than in the same mass of the fuel that they used, which was oxygen and something else, then it should be possible to fly over greater distances. That is how it was explained to us. But we were also told, the research is in its infancy, with still a long way to go. Himmler then said he welcomed this research, but it is more important that the rocket is perfected so that it works reliably, and that must be done quickly.

[Grothmann stated that the rocket research center at Peenemünde had its “own atomic laboratories” and was using those to develop nuclear rocket engines. How far did research on nuclear rocket engines get during the war? Did that work cover fission thermal engines, ion engines, external pulse propulsion, or other methods? How much did that wartime German research influence postwar work on nuclear rocket engines in the United States and other countries?]

E.5.3 Fission Pulse Rocket Propulsion

[In contrast to fission thermal propulsion, fission pulse propulsion employs fission reactions that occur outside of the rocket, and therefore are not constrained by the melting temperatures of the fission fuel or any rocket components. Thus the fission reactions can reach the highest possible temperatures—those of a fission explosion. Small fission bombs could be ejected from the rear of the spacecraft; they would explode near the spacecraft, and some fraction of the blast would be intercepted by a thick ablative "pusher plate," transferring momentum while protecting the rest of the spacecraft (Fig. 9.240 bottom). To smooth out the violent shocks of intermittent explosions into more continuous and more survivable acceleration for the spacecraft, the pusher plate would be connected to the rest of the spacecraft by giant compressible shock absorbers. The heat, radiation, and shock to which the vehicle would be subjected pose formidable constraints on the materials and engineering design, yet the prospect of achieving both very high exhaust velocities and high thrust-to-weight ratios with an available energy source (fission explosives) is attractive.

Most books on the subject say that nuclear pulse propulsion was first proposed after World War II by Stanislaw Ulam (Polish, 1909–1984), who was a creator from the greater German-speaking world [e.g., Dyson 2002, p. 2]. In fact, this approach was first proposed and explored by even earlier German-speaking creators.

External pulse propulsion by conventional chemical explosives was first proposed by Hermann Ganswindt (German, 1856–1934) [Ron Miller 1993, pp. 75–76; Ron Miller 2016, p. 48].

The following sources show that external pulse propulsion by nuclear explosives was first proposed in approximately 1942 by Wernher von Braun. Considering the German military's great wartime interest in and funding for rockets, nuclear weapons, and revolutionary methods of delivering heavy payloads long distances, it seems likely that fission pulse propulsion was seriously considered during the war, although little relevant documentation is currently available. By the end of the war, work in this area had apparently progressed at least as far as creating small test models powered by conventional chemical explosives, which is as far as the work ever progressed in the United States after the war before the U.S. program was cancelled.

Archives and personal collections worldwide should be searched for more information about nuclear pulse propulsion work that was conducted during the war.]

Friedwardt Winterberg. 2010. *The Release of Thermonuclear Energy by Inertial Confinement: Ways Towards Ignition.* Singapore: World Scientific. pp. v, vii.

Dedicated to [...]

Wernher von Braun
who first thought about nuclear rocket propulsion [...]

Having been born in Germany in 1929, I received my PhD in physics under Heisenberg in 1955.

[...] I was invited by the US government under "Operation Paperclip" to come to the United States. In San Diego I met Ted Taylor and Freeman Dyson, who were working on the famous "Orion" nuclear bomb propulsion concept. This concept is generally credited to Ulam, but as I know from conversations I had with Heisenberg, a similar idea was presented to Heisenberg by Wernher von Braun, who had visited Heisenberg in Berlin in or around 1942.

Seventh Army Interrogation Center. 3 June 1945. Notes on German Weapons Developments. SAIC/38. https://www.scribd.com/document/431240796/File-Datastream http://hydrastg.library.cornell.edu/fedora/objects/nur:01298/datastreams/pdf/content

8. "Detonation Rocket Weapons"

Contrary to the normal rockets, where the projectile is propelled forward by the rearward push of the gases during the explosions, the "detonation rockets" move through the utilization of the rearward impulses caused by the detonations themselves. For practical purposes this principle is applicable only at extremely high velocities. The DERA is the only rocket in which this principle was used. Ing LARSSON (source) was the specialist in charge of research on this rocket at the GROSSENDORF Experimental Station, under Ing THOMAS. Source explains that the successive detonation impulses are properly directed by means of a parabolic surface. Normal rocket mechanisms are used to attain a certain minimum velocity, at which time the "detonation" mechanism begins to function.

E.5.4 Electric Rocket Propulsion

[Electric rocket propulsion, or an ion-electron thruster, uses energy (heat, resonant electromagnetic waves, high-energy electrons from an electron gun, or other methods) to ionize initially electrically neutral propellant atoms into positively charged ions and negatively charged electrons, as shown in the upper half of Fig. 9.241. The positively charged ions are accelerated by the voltage difference between two electrically charged grids and ejected from the rear of the spacecraft at some desired velocity. To prevent the spacecraft from accumulating more and more net electric charge (as a result of the lost ions) that would actually draw the ejected ions back to the spacecraft, electrons that have been stripped off the ions must also be ejected, generally by harvesting them from the ionization chamber and firing them from electron guns toward the departing ion exhaust. This method of particle acceleration can produce much higher exhaust velocities than chemical combustion or even fission thermal rockets. However, because charged particle beams have far lower densities than flows of more traditional rocket propellant, their thrust is very low. Thus electric propulsion is best for deep space missions where a low thrust applied over the course of months or even years can yield useful final velocities or changes in the spacecraft's orbit. Although ion-electron thrusters could be powered by solar panels or any other source of electrical energy, it is usually proposed to power them with a fission reactor.

Electric rocket propulsion systems were first proposed by Hermann Oberth in 1929 (see below). Experimental development of electric propulsion in Germany began no later than 1937 and continued until at least 1944 (p. 5311). Ernst Stuhlinger, Wernher von Braun, and other German-speaking scientists continued to develop and promote electric propulsion after the war (p. 1958 and the document below). Currently very few documents on the wartime electric propulsion program are available, but it seems likely that Oberth, Stuhlinger, and von Braun were involved in it as well.]

Ernst Stuhlinger. 1964. *Ion Propulsion for Space Flight.* New York: McGraw-Hill. pp. vii, 2–3.

The present book was written during the years 1958 to 1962. From 1960 to 1961, the author directed the NASA program for the development of arc-jet and ion propulsion systems at the George C. Marshall Space Flight Center in Huntsville, Alabama. [...]

Hermann Oberth [...] contributed probably more to the theoretical foundation of the broad field of rockets and space flight than any other individual. [...] Many of his early thoughts found precipitation in the book "Wege zur Raumschiffahrt" (1929), probably the outstanding classic of rocketry and space travel. One chapter in this book deals with electric propulsion. In a later book, "Man into Space" (1957), the same ideas were taken up again and presented in a similar form. Oberth first described the old classroom experiment where a needlepoint, connected with a source of high voltage, produces an "electric wind," and he then elaborated on methods of generating a flow of electrically charged particles from the thrust engine of a space vehicle. Porous plates, he wrote, will provide a finely dispersed flow of propellant; high voltage applied to the plates will form a spray of charged particles which leaves the vehicle with high velocity. Almost any kind of material, even refuse from the vehicle crew, could be used as propellant. The rate of propellant flow will always be small, but since the exhaust velocity is high, a noticeable thrust will be developed. It is characteristic of electric propulsion engines that they will produce a low thrust over a long period of time; hence, electric systems will find application in space vehicles which are designed to travel to distant targets.

E.5.5 Antimatter Rocket Propulsion

[For equal amounts of matter and antimatter, 100% of the combined propellant mass could be converted to energy, versus $< 1\%$ for nuclear reactions, so antimatter propulsion could yield the maximum performance obtainable from a rocket, with exhaust velocities approaching the speed of light. Eugen Sänger was the first to propose matter-antimatter rockets and to work out their details, including using anti-hydrogen made from positrons and antiprotons, storing the antimatter without letting it come into contact with ordinary matter, and using highly novel types of nozzles to direct the matter-antimatter reaction products out the back of the rocket. Sänger did a great deal of work in this area after the war; it is possible that he did some related theoretical design work during the war as well. See Figs. 9.241 and 9.243.]

Eugen Sänger. 1965. *Space Flight: Countdown for the Future.* New York: McGraw-Hill. pp. 255–258. [This English translation of Sänger's original German book is rather sloppy. I have adjusted a few words to try to improve the accuracy.]

Pure photon rockets represent the final, though today still entirely hypothetical, goal of all rocket systems. It is expected of them that they will transform all of the propellant mass carried aboard the vehicle into energy. The directed exhaust of this energy, at the speed of light of 300,000 km/sec, corresponds to the absolute, lowest limiting value of the specific propellant consumption of rocket engines at 3.3×10^{-5} kg/ton-sec. [...]

An exhaust velocity of all propellants carried aboard which is equal to the speed of light will also permit a similarly close approximation of the flight velocity to the speed of light so that the relativistic effects, particularly the phenomenon of time dilation between launch site and spacecraft, will figure prominently in the flight mechanics involved. [...]

At the time when the idea of the photon rocket was conceived, the existence of positrons as antiparticles of electrons was already known. Soon thereafter followed the discovery of the antiproton as the antiparticle of the proton so that now the combination of a positron and an antiproton to form an antihydrogen atom seems quite feasible. The first building blocks of antimatter became visible at the horizon, of that antimatter which might annihilate spontaneously upon collision with the matter of our ordinary world, thus disintegrating into photons whose energy is equivalent to the rest mass of the matter from which they originated. [...]

At present there is no certainty at all as to whether the annihilation of matter and antimatter is the only method by which matter can be transformed into energy. [...]

The latter process would be more advantageous than the combination of matter and antimatter insofar as obviating the problem of storing large quantities of antimatter, which has to be protected from any contact with ordinary matter. [...]

Meanwhile basic research in pure photon rockets has made considerable progress toward the solution of a related problem, namely that of the generation and collimation of very intensive photon rays.

E.6 Analysis of Advanced Jet Developments

Very simple mathematical models of aircraft performance may be derived from first principles, and then applied to estimate the performance of various types of German aircraft.

The frame of reference is important for analyzing aircraft engines. In the frame of reference of the atmospheric air surrounding the aircraft (motionless if there is no wind, or moving with the wind if the wind speed is nonzero), the surrounding air has zero velocity and the aircraft has a forward velocity v_{aircraft} [Fig. E.266(a)]. The exhaust velocity v_{exh} from the aircraft's engines is measured relative to the aircraft, so in the frame of reference of the surrounding air, the exhaust has a rearward velocity of $v_{\text{exh}} - v_{\text{aircraft}}$. However, it is much easier to analyze aircraft engine performance in the frame of reference of the aircraft, in which the surrounding atmospheric air has a rearward velocity of v_{aircraft}, the aircraft has zero velocity, and the engine exhaust has a rearward velocity of v_{exh} [Fig. E.266(b)].

In either frame of reference, $\dot{m}$ is the mass of air per time flowing through the engine. Aircraft engines are generally powered by burning fuel stored on-board with the air flowing through; the rate at which fuel is added is $\dot{m}_{\text{fuel}}$, which is typically far smaller than the air flow rate $\dot{m}$. In the rest frame of the aircraft [Fig. E.266(b)], the momentum flow rate entering the engine is $\dot{m}v_{\text{aircraft}}$, and that leaving the engine is $(\dot{m} + \dot{m}_{\text{fuel}})v_{\text{exh}} \approx \dot{m}v_{\text{exh}}$.

The thrust force of the engine is the net change in momentum flow rate before and after passing through the engine (creating an equal and opposite momentum change or force on the engine), plus the net difference between the pressure p_{exhaust} pushing on the rear cross-sectional area A_{engine} of the engine and the pressure p_{atm} pushing on the front cross-sectional area A_{engine} of the engine:

$$F_{\text{thrust}} = (\dot{m} + \dot{m}_{\text{fuel}})v_{\text{exh}} - \dot{m}v_{\text{aircraft}} + A_{\text{engine}}(p_{\text{exh}} - p_{\text{atm}}) \tag{E.1}$$

$$\approx (\dot{m} + \dot{m}_{\text{fuel}})v_{\text{exh}} - \dot{m}v_{\text{aircraft}} \tag{E.2}$$

$$\approx \dot{m}(v_{\text{exh}} - v_{\text{aircraft}}) \tag{E.3}$$

Equation (E.3) was further simplified by assuming $\dot{m}_{\text{fuel}} \ll \dot{m}$. Because the exhaust pressure exerts a forward force against nozzle surfaces, it is advantageous to let the exhaust expand within the nozzle until its pressure has finally fallen to the external atmospheric pressure. During that time, the pressure potential energy of the flow is steadily converted into kinetic energy of the increasing exhaust velocity. Since the exhaust velocity gets multiplied by the typically large mass flow rate $\dot{m}$ in Eq. (E.1), that also maximizes the thrust. If the nozzle expands the exhaust until its pressure is below atmospheric pressure, that creates a net drag and reduces the thrust as shown in Eq. (E.1). If the nozzle expands the exhaust until it reaches external ambient pressure, the exhaust is said to fully expanded. Exhaust at higher than external ambient pressure is under expanded, and exhaust at lower than ambient pressure is over expanded. The nozzle shape and size of a given aircraft engine are designed to fully expand the flow until expected operating conditions for that engine, so the pressure term in Eq. (E.1) is generally zero or negligibly small, as assumed in Eqs. (E.2)–(E.3). Aircraft such as supersonic fighter jets that must operate under a variety of conditions use nozzles with moveable surfaces so that the nozzle shape and the degree of exhaust expansion can be tailored for maximum efficiency at the current conditions.

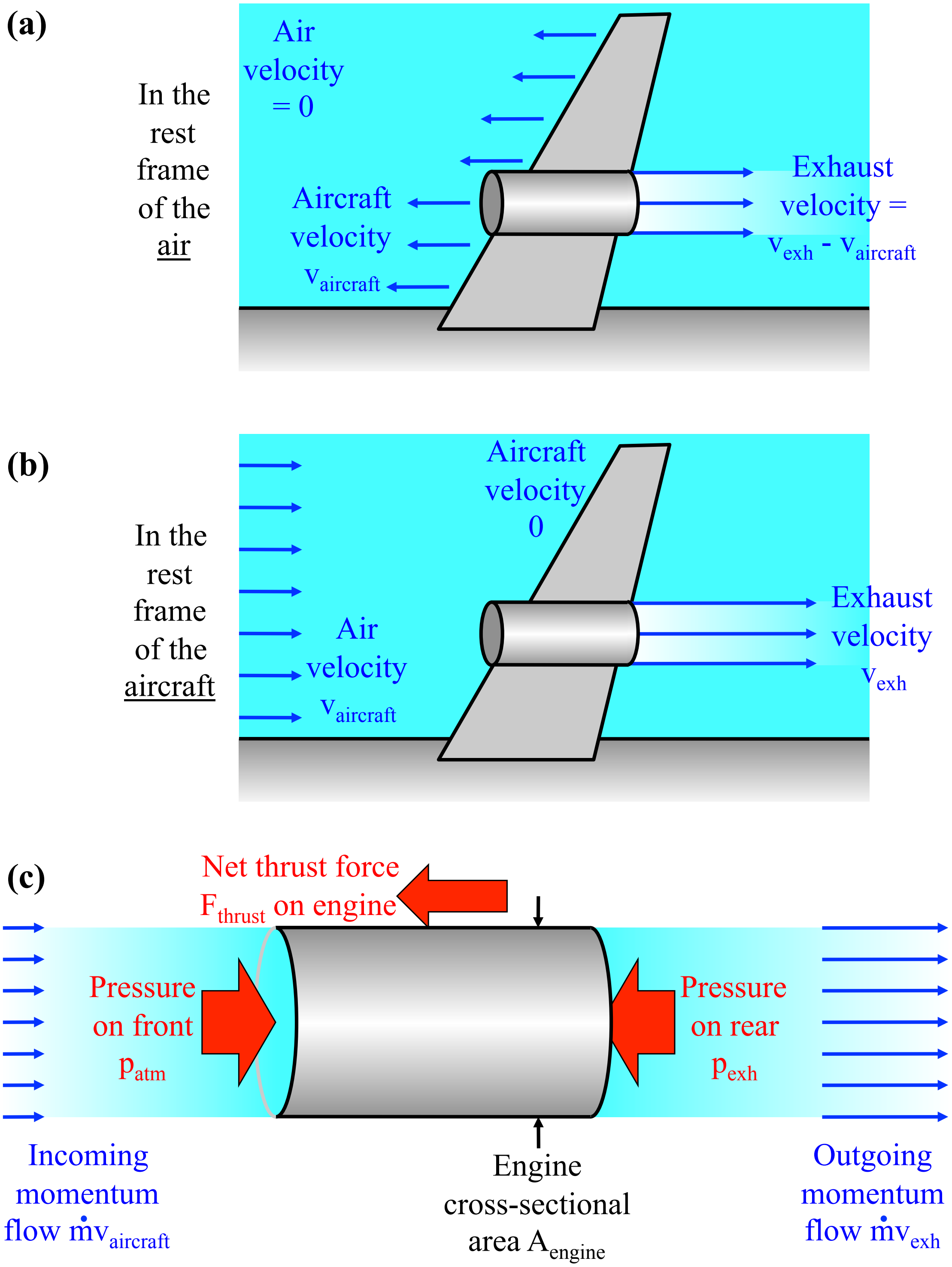
(a)
In the rest frame of the air
Air velocity = 0
Aircraft velocity $v_{aircraft}$
Exhaust velocity = v_{exh} - $v_{aircraft}$
(b)
In the rest frame of the aircraft
Aircraft velocity 0
Air velocity $v_{aircraft}$
Exhaust velocity v_{exh}
(c)
Net thrust force F_{thrust} on engine
Pressure on front p_{atm}
Pressure on rear p_{exh}
Incoming momentum flow $\dot{m}v_{aircraft}$
Engine cross-sectional area A_{engine}
Outgoing momentum flow $\dot{m}v_{exh}$

Figure E.266: Basics of aircraft propulsion. (a) Relative velocities of the atmospheric air, aircraft, and exhaust in the rest frame of the air. (b) Relative velocities of the atmospheric air, aircraft, and exhaust in the rest frame of the aircraft. (c) Factors affecting the thrust of an aircraft engine in the rest frame of the aircraft.

An aircraft propulsion system converts the chemical energy stored in on-board fuel into thermal energy by burning the fuel with oxygen from the surrounding air. As with any other heat engine, an aircraft propulsion system then converts some fraction of that thermal energy into kinetic energy (of the exhaust and/or aircraft), while the rest remains as waste heat energy that is exhausted to the surrounding air. The thermodynamic efficiency η_{thermo} of an aircraft engine is defined as follows and will be less than the Carnot efficiency:

$$\eta_{\text{thermo}} = \frac{\text{Energy converted to kinetic energy of aircraft or exhaust}}{\text{Total heat energy produced by combustion}} \tag{E.4}$$

$$< 1 - \frac{T_{\text{highest temperature in engine}}}{T_{\text{external air}}} \tag{E.5}$$

Since the work or energy put into an object is equal to the product of the applied force and the distance that force moves the object, the power (energy/time) put into an object is equal to the product of the applied force and the object's instantaneous velocity. Therefore in the rest frame of the surrounding air [Fig. E.266(a)], the rate of increase (denoted by an overhead dot) of the kinetic energy of the aircraft is simply the product of the thrust force on the aircraft and the aircraft's instantaneous velocity:

$$(\dot{\text{KE}})_{\text{aircraft}} = F_{\text{thrust}}\, v_{\text{aircraft}} \tag{E.6}$$

$$\approx \dot{m}(v_{\text{exh}} - v_{\text{aircraft}})v_{\text{aircraft}} \tag{E.7}$$

in which Eq. (E.7) used Eq. (E.3) for the thrust.

Likewise, in the rest frame of the surrounding air [Fig. E.266(a)], air has zero velocity before and velocity $v_{\text{exh}} - v_{\text{aircraft}}$ after passing through the engine, so the rate of increase of the kinetic energy of the exhausted air is:

$$(\dot{\text{KE}})_{\text{exh}} = \frac{1}{2}\dot{m}(v_{\text{exh}} - v_{\text{aircraft}})^2 \tag{E.8}$$

The propulsive efficiency η_{prop} is defined as the fraction of the total produced kinetic energy that ends up with the aircraft and not the exhaust:

$$\eta_{\text{prop}} = \frac{(\dot{\text{KE}})_{\text{aircraft}}}{(\dot{\text{KE}})_{\text{aircraft}} + (\dot{\text{KE}})_{\text{exh}}} \tag{E.9}$$

$$= \frac{\dot{m}(v_{\text{exh}} - v_{\text{aircraft}})v_{\text{aircraft}}}{\dot{m}(v_{\text{exh}} - v_{\text{aircraft}})v_{\text{aircraft}} + (1/2)\dot{m}(v_{\text{exh}} - v_{\text{aircraft}})^2} \tag{E.10}$$

$$= \frac{2}{1 + (v_{\text{exh}}/v_{\text{aircraft}})} \tag{E.11}$$

Note from Eq. (E.11) that the propulsive efficiency increases as the exhaust velocity decreases. A propulsive efficiency greater than 1 is nonphysical, since it would require $v_{\mathrm{exh}} < v_{\mathrm{aircraft}}$, or negative thrust due to the aircraft engine actually decelerating air passing through it, creating a net drag on the aircraft. A propulsive efficiency of 1 can be approached by making v_{exh} slightly larger than but as close to v_{aircraft} as possible, although of course in that case the thrust from Eq. (E.3) also goes to zero. For $v_{\mathrm{exh}} \gg v_{\mathrm{aircraft}}$, the thrust from Eq. (E.3) is very high, but the propulsive efficiency from Eq. (E.11) is very low–most of the kinetic energy ends up with the exhaust and not the aircraft. In practice, an aircraft engine's exhaust velocity must always be chosen based on the tradeoffs between the relative importance of high-thrust and high-efficiency operation.

The total efficiency of an aircraft engine is the product of its thermodynamic efficiency in converting heat to kinetic energy, and its propulsive efficiency in converting that kinetic energy to motion of the aircraft instead of the exhaust:

$$\eta_{\mathrm{total}} = \eta_{\mathrm{prop}}\, \eta_{\mathrm{thermo}} \tag{E.12}$$

The specific impulse I_{sp} is the "bounce per ounce" of the fuel, the ratio of thrust produced to fuel consumed:

$$I_{\mathrm{sp}} = \frac{F_{\mathrm{thrust}}}{\dot{m}_{\mathrm{fuel}}\, g} \tag{E.13}$$

in which $g \approx 9.807$ m/sec^2 is the earth's surface gravitational acceleration, multiplied by $\dot{m}_{\mathrm{fuel}}$ so the fuel consumption is considered in terms of weight (force) per time and not mass per time.

Another oft-cited parameter is the thrust specific fuel consumption (TSFC), which is simply the inverse of the specific impulse:

$$\mathrm{TSFC} = \frac{1}{I_{\mathrm{sp}}} = \frac{\dot{m}_{\mathrm{fuel}}\, g}{F_{\mathrm{thrust}}} \tag{E.14}$$

By historical convention, I_{sp} is usually measured in seconds, yet TSFC is usually measured in inverse hours. Occasionally I_{sp} and/or TSFC are defined without the factor of g, resulting in more complicated units, but we won't worry about that here. Higher I_{sp} and lower TSFC both mean better fuel efficiency, with more thrust resulting from less fuel consumed. Typical values for different types of aircraft engines are:

$$\text{Turbojet engine:} \quad I_{\mathrm{sp}} \approx 3600 \text{ sec} \qquad \mathrm{TSFC} \approx 1.0 \text{ hr}^{-1} \tag{E.15}$$

$$\text{Turbofan engine:} \quad I_{\mathrm{sp}} \approx 6000 \text{ sec} \qquad \mathrm{TSFC} \approx 0.6 \text{ hr}^{-1} \tag{E.16}$$

$$\text{Propeller piston engine:} \quad I_{\mathrm{sp}} \approx 6500 \text{ sec} \qquad \mathrm{TSFC} \approx 0.55 \text{ hr}^{-1} \tag{E.17}$$

$$\text{Turboprop engine:} \quad I_{\mathrm{sp}} \approx 12,000 \text{ sec} \qquad \mathrm{TSFC} \approx 0.3 \text{ hr}^{-1} \tag{E.18}$$

One can use the specific impulse (or TSFC) to estimate an aircraft's maximum flying time Δt at cruising conditions, neglecting takeoffs and landings. Due to fuel consumption, the aircraft's weight W changes at a rate $dW/dt = -\dot{m}_{\text{fuel}}\, g$, so the specific impulse from Eq. (E.13) may be rewritten as:

$$I_{\text{sp}} = -\frac{F_{\text{thrust}}}{dW/dt} \tag{E.19}$$

$$dt = -\frac{I_{\text{sp}}}{F_{\text{thrust}}}\, dW = -I_{\text{sp}}\, \frac{L}{D}\, \frac{dW}{W} \tag{E.20}$$

$$= -I_{\text{sp}}\, \frac{C_L}{C_D}\, \frac{dW}{W} \tag{E.21}$$

Equations (E.20) and (E.21) used the facts that for an aircraft at steady cruising conditions, the forward thrust force must balance the rearward aerodynamic drag force D ($F_{\text{thrust}} = D$), the downward weight must balance the upward aerodynamic lift L ($W = L$), and the ratio of the lift and drag forces is simply the ratio of the lift and drag coefficients and can be assumed constant ($L/D = C_L/C_D$). Integrating Eq. (E.21) yields the maximum flying time:

$$\Delta t = I_{\text{sp}}\, \frac{C_L}{C_D}\, \ln\left(\frac{W_{\text{initial}}}{W_{\text{final}}}\right) = I_{\text{sp}}\, \frac{C_L}{C_D}\, \ln\left(\frac{M_{\text{initial}}}{M_{\text{final}}}\right) \tag{E.22}$$

The aircraft's maximum range R is just the product of its cruising speed v_{aircraft} and Δt:

$$R = v_{\text{aircraft}}\, \Delta t \tag{E.23}$$

$$= v_{\text{aircraft}}\, I_{\text{sp}}\, \frac{C_L}{C_D}\, \ln\left(\frac{M_{\text{initial}}}{M_{\text{final}}}\right) \tag{E.24}$$

As a sanity check, Eq. (E.24) can be applied to the U.S. Boeing B-29 bombers that were used to deliver the bombs to Hiroshima and Nagasaki. Using typical values of $v_{\text{aircraft}} \approx 100$ m/sec (Mach 0.33 at an altitude of 9–10 km), $I_{\text{sp}} \approx 6500$ sec for piston-powered propeller engines, $C_L/C_D \approx 16.8$, and $M_{\text{final}}/M_{\text{initial}} \approx 0.62$ (38% of the initial aircraft weight is fuel) yields

$$R \approx (100 \text{ m/sec})\, (6500 \text{ sec})\, (16.8)\, \ln\left(\frac{1}{0.62}\right) \tag{E.25}$$

$$\approx 5220 \text{ km} \approx 3240 \text{ mi} \tag{E.26}$$

Thus despite the simplifying assumptions involved in this method, the calculated range is in excellent agreement with the actual 5230 km (3250 mi) range of the B-29.

Equation (E.24) can also be applied to calculate the maximum theoretical range of various possible categories of German bombers. Like the B-29, such bombers would have had a likely cruising altitude of 9–10 km, where the speed of sound (Mach 1) is approximately 300 m/sec. Piston-powered propeller aircraft might have been designed to cruise at Mach 0.33 $\approx$ 100 m/sec with $I_{\rm sp} \approx 6500$ sec like the B-29. Turboprop aircraft might have been designed to cruise at Mach 0.5 $\approx$ 150 m/sec with $I_{\rm sp} \approx 12,000$ sec. Turbojet and turbofan aircraft might have been designed to cruise at Mach 0.8 $\approx$ 240 m/sec, with $I_{\rm sp} \approx 3600$ sec for turbojets and $I_{\rm sp} \approx 6000$ sec for turbofans. For all categories of aircraft, the largest likely lift-to-drag ratio would have been $C_L/C_D \approx 20$. The mass ratio likely would have been around $M_{\rm final}/M_{\rm initial} \approx 0.6$ (40% of the initial aircraft weight is fuel), although one can also consider the very optimistic case with $M_{\rm final}/M_{\rm initial} \approx 0.5$ (50% of the initial aircraft weight is fuel). Using Eq. (E.24), Tables E.1–E.2 present the results for these cases.

Characteristic	**Piston prop**	**Turbojet**	**Turbofan**	**Turboprop**
Cruising velocity v	100 m/sec	240 m/sec	240 m/sec	150 m/sec
Specific impulse $I_{\rm sp}$	6500 sec	3600 sec	6000 sec	12,000 sec
Lift/drag ratio C_L/C_D	20	20	20	20
Mass ratio $M_{\rm final}/M_{\rm initial}$	0.6	0.6	0.6	0.6
Maximum range R	6600 km	8800 km	15,000 km	18,000 km

Table E.1: Estimated characteristics and corresponding calculated maximum ranges for German bombers with a mass ratio $M_{\rm final}/M_{\rm initial} = 0.6$ using piston propeller, turbojet, turbofan, or turboprop engines.

Characteristic	**Piston prop**	**Turbojet**	**Turbofan**	**Turboprop**
Cruising velocity v	100 m/sec	240 m/sec	240 m/sec	150 m/sec
Specific impulse $I_{\rm sp}$	6500 sec	3600 sec	6000 sec	12,000 sec
Lift/drag ratio C_L/C_D	20	20	20	20
Mass ratio $M_{\rm final}/M_{\rm initial}$	0.5	0.5	0.5	0.5
Maximum range R	9000 km	12,000 km	20,000 km	25,000 km

Table E.2: Estimated characteristics and corresponding calculated maximum ranges for German bombers with a mass ratio $M_{\rm final}/M_{\rm initial} = 0.5$ using piston propeller, turbojet, turbofan, or turboprop engines.

German bombers likely would have been designed to make a round trip so that they and their crews could be reused if they survived the trip. New York seemed to be the preferred U.S. target mentioned by the German military; it was larger and also somewhat closer than Washington D.C.

The German launching point furthest west would have been someplace like Brest on the French coast, although such options were no longer available after the Allied invasion beginning in June 1944. (Intelligence about German plans might explain why the Allied invasion occurred when and where it did.) The distance from Brest to New York is approximately 5,400 km one-way, or 10,800 km round-trip.

A viable launching point up until the end of the war would have been the large German airfields around Oslo, Norway (Section E.1). The distance from Oslo to New York is approximately 6000 km one-way, or 12,000 km round-trip.

From these trans-Atlantic distances and Tables E.1–E.2, piston aircraft (such as the Ju 290) might have been able to make the one-way trip, but they certainly would not have been able to return to their launching point.

From Tables E.1–E.2, bombers powered by turbojets, the most readily available new aircraft engines in Germany, could have comfortably made a one-way trip. However, they would have had to operate at their maximum theoretical limits, with the best possible engine performance, lift/drag ratio, and mass ratio, in order to be able to make a 12,000 km round trip from Oslo to New York. Given realistic factors involved with technologies, missions, and payloads, that level of performance seems unlikely. Moreover, it would have been even more difficult to push that sort of technology to even greater ranges to reach other destinations (e.g., 12,500 km round trip from Oslo to Washington D.C. or 13,000 km round trip to Chicago).

Based on these fundamental considerations, aircraft powered by turbofan or turboprop engines would have been by far the best options for such round-trip missions.

Karl Leist (German, 1901–1960) built and demonstrated the first functional turbofan engine, the Daimler-Benz DB 007, also known as the Zweikreis Turbinen-Luftstrahltriebwerk ZTL 6001 (began development 1939, first run 1 April 1943). See pp. 1746, 5233–5241. At least three DB 007 turbofan engines were produced. The Heinkel company was also developing turbofan engines.

There were several notable turboprop engine development projects, including the Jumo 022 (p. 1748), BMW 028 (p. 1748), and Heinkel He S 021 (a turboprop version of the He S 011, p. 1731).

According to official histories, none of the turbofan or turboprop engines were used on aircraft before the end of the war. However, historians should carefully investigate whether some of the turbofan or turboprop work may have actually progressed further during the war, and how much it influenced postwar work on turbofan and turboprop engines, in view of:

1. The high priority placed on intercontinental jet bombers in the final years of the war.
2. The significantly higher fuel efficiency and hence longer range enabled by turbofan and turboprop engines compared to turbojet engines.
3. The great secrecy with which both wartime German scientists and postwar Allied investigators would have handled jet engine technology that was so advanced and had such strategic implications for intercontinental bombing.

E.7 Analysis of Advanced Rocket Developments

Very simple mathematical models of rocket performance may be derived from first principles, and then applied to estimate the performance of a wide variety of German rockets.

E.7.1 Fundamentals of Rocket Performance

A rocket expels exhaust rearward, accelerating the rocket forward as an equal and opposite reaction by Newton's laws. Ignoring forces such as gravity and aerodynamic drag for the moment, the maximum final velocity of the rocket depends on the mass $m_{\text{propellant}}$ of the propellant that is expelled as exhaust, the mass m_{final} of the empty rocket, and the velocity v_{exh} of the exhaust relative to the rocket. The result will also depend on whether the rocket body is divided into multiple stages that can be jettisoned along the way after the propellant in each stage has been consumed. One can derive a simple result for a single-stage rocket. By treating the rocket and exhaust as one combined system with a total momentum $p = p_{\text{rocket}} + p_{\text{exhaust}}$, and designating the current mass of the rocket and any remaining propellant it contains as m, conservation of total momentum yields:

$$\frac{dp_{\text{rocket}}}{dt} = -\frac{dp_{\text{exhaust}}}{dt} \tag{E.27}$$

$$m\frac{dv}{dt} = -\left(-v_{\text{exh}}\right)\left(-\frac{dm}{dt}\right) \tag{E.28}$$

$$\frac{dv}{dt} = -\frac{v_{\text{exh}}}{m}\frac{dm}{dt} \tag{E.29}$$

$$\int dv = -v_{\text{exh}}\int \frac{dm}{m} \tag{E.30}$$

$$\Delta v = v_{\text{final}} - v_{\text{initial}} = v_{\text{exh}} \ln\left(\frac{m_{\text{initial}}}{m_{\text{final}}}\right) \tag{E.31}$$

in which v_{initial} is the initial velocity of the rocket before consuming its propellant, v_{final} is the final velocity of the rocket after consuming its propellant, $\Delta v = v_{\text{final}} - v_{\text{initial}}$ is the net change in velocity, and $m_{\text{initial}} = m_{\text{final}} + m_{\text{propellant}}$ is the initial mass of the rocket including propellant.

Equation (E.31) may be extended to cover rockets with two or more stages:

$$\Delta v = \left(v_{\text{exh}}\right)_1 \ln\left[\frac{(m_{\text{initial}})_1}{(m_{\text{final}})_1}\right] + \left(v_{\text{exh}}\right)_2 \ln\left[\frac{(m_{\text{initial}})_2}{(m_{\text{final}})_2}\right] + \ldots \tag{E.32}$$

in which $(v_{\text{exh}})_1$ is the exhaust velocity of the rocket engine(s) on stage 1, $(m_{\text{initial}})_1$ is the initial mass of the entire remaining rocket when stage 1 begins its burn, and $(m_{\text{final}})_1$ is the final mass of the entire remaining rocket when stage 1 finishes its burn, and so forth for stage 2 and any higher stages. After one stage has used all of its propellant, it is jettisoned and the next stage takes over. For most rocket stages, $(m_{\text{initial}})_i/(m_{\text{final}})_i \sim 2-4$ and $(\Delta v)_i \sim (v_{\text{exh}})_i$, so the total velocity change is typically $\Delta v \sim \sum_i (v_{\text{exh}})_i$.

From Eqs. (E.27)-(E.28), the exhaust exerts an equal and opposite thrust force F_{thrust} on the rocket, so the thrust, exhaust velocity, propellant mass, and burn time t_{burn} required to consume that propellant are interrelated:

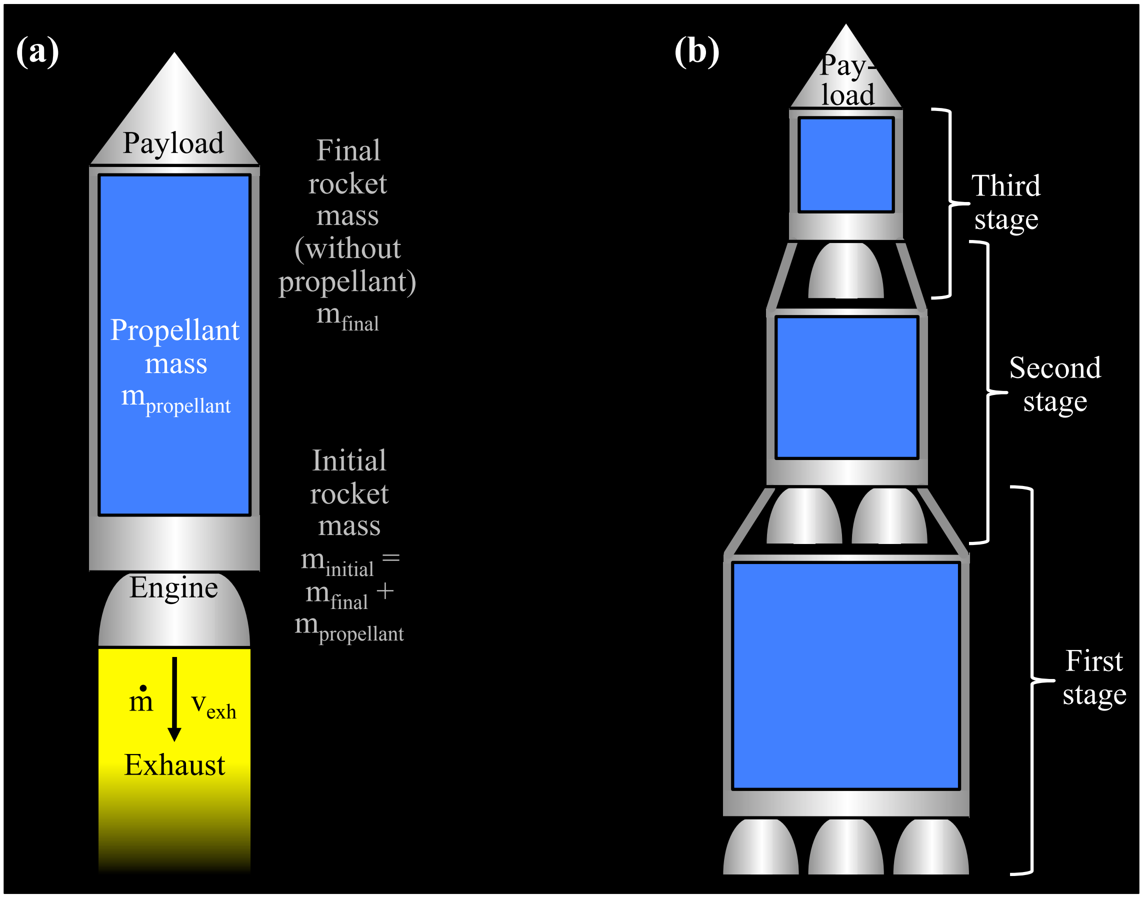
(a)
Payload
Final rocket mass (without propellant) m_final
Propellant mass m_propellant
Initial rocket mass m_initial = m_final + m_propellant
Engine
ṁ
v_exh
Exhaust
(b)
Pay-load
Third stage
Second stage
First stage

Figure E.267: Rockets (a) store propellant onboard and expel it out the back at a rate dm/dt and with an exhaust velocity v_{exh}, and (b) may be divided into multiple stages, such that each can be jettisoned as soon as its propellant has been consumed, reducing the rocket's mass later in flight and improving its overall performance.

$$\begin{aligned} \frac{dp_{\text{exhaust}}}{dt} &= v_{\text{exh}} \frac{dm}{dt}\,, \quad \text{or} \\ F_{\text{thrust}} &= v_{\text{exh}} \frac{m_{\text{propellant}}}{t_{\text{burn}}} \end{aligned} \tag{E.33}$$

The exhaust velocity can be expressed as the product of the earth's standard gravitational acceleration $g \approx 9.807\ \text{m}/\text{sec}^2$ and the specific impulse I_{sp} (measured in units of seconds):

$$v_{\text{exh}} = I_{\text{sp}}\, g \tag{E.34}$$

One could get along just fine by discussing the exhaust velocity and never using its alter-ego, the specific impulse. However, specific impulse became a widespread term of convention among rocket scientists since from Eqs. (E.33) and (E.34), it is basically the "bounce per ounce" of the propellant, the thrust force per propellant flow rate (weight per second):

$$I_{\text{sp}} = \frac{F_{\text{thrust}}}{g\, m_{\text{propellant}}/t_{\text{burn}}} \tag{E.35}$$

Liquid propellant rockets can achieve higher specific impulses/exhaust velocities than solid propellant rockets, but since liquid propellants are often cryogenic or chemically degrade over time, they usually cannot be stored for more than a few days. Therefore, they are primarily used for spacecraft launch vehicles, which can be fueled shortly before launch.

Figure E.268 shows schematic views of a liquid propellant rocket engine. As illustrated in Fig. E.268(a), burning of fuel and oxidizer in the combustion chamber generates hot gas with velocity $v_{\text{chamber}} \approx 0$ (initially nearly motionless in the combustion chamber, at least compared to the very high exhaust velocity coming out of the nozzle), pressure p_{chamber}, and temperature T_{chamber}. The hot gas expands in the nozzle until it has exhaust velocity v_{exh}, pressure p_{exh}, and temperature T_{exh} when it exits. For comparison, the ambient pressure outside the nozzle is p_{ambient}, which may be significant if the rocket is still inside the atmosphere.

Figure E.268(b) shows a schematic view of other components in a liquid propellant rocket engine. Pumps raise the pressure of oxidizer and fuel drawn from the propellant storage tanks to a pressure higher than p_{chamber} so they can be injected into the combustion chamber. Before entering the combustion chamber, fuel passes through coils wrapping the combustion chamber and nozzle, cooling the engine and preheating the fuel. To power the pumps, small amounts of oxidizer and fuel are diverted to burn in a gas generator, producing hot exhaust that powers a gas turbine and thereby the pumps. In some liquid rocket engine designs, the gas generator is powered by a small amount of dedicated solid rocket propellant, rather than diverted liquid propellant. A few combinations of fuels and oxidizers are hypergolic, or ignite on contact with each other, but most are not hypergolic, and require an igniter similar to a spark plug in the ignition chamber (not shown).

Thrust vector control or steering of a liquid propellant rocket engine during its burn may be accomplished in any of several ways. Gimbaling or tilting the entire engine (both the nozzle and the combustion chamber) is commonly used on large modern rockets. It is also possible to tilt just the nozzle if it is connected to the combustion chamber by a flexible yet heat-resistant seal or joint. Older, simpler methods include moving heat-resistant rudders or vanes that protrude into the exhaust stream (the method of choice for the A-4 and related rockets), or injecting fluid into one side of the exhaust to divert the rest of the hot exhaust gas. Those simpler methods are still used on smaller modern rockets. Of course, if there are multiple engines, they can be tilted in different directions to control roll around the long axis of the rocket, as well as pitch and yaw (tilting one way or the other) of the rocket's long axis relative to its flight path.

If a rocket accelerates in bursts instead of continuously, the temporarily increased propellant pressure during a burst of acceleration can be amplified by the pumps, temporarily increase propellant flow to the engine, and thus reinforce the transient bursts of thrust and acceleration. This propellant instability is called pogo, since the rocket seems to vibrate like a toy pogo stick. (Pogo was even shown for the fictionalized depiction of an A-10 rocket engine in the 1965 film *Operation Crossbow.*) To prevent this problem, some rocket engines have pogo accumulators between the propellant tanks and the propellant pumps, such that gas-filled regions of the accumulators allow the liquid propellant to expand when necessary and dampen the pogo vibrations.

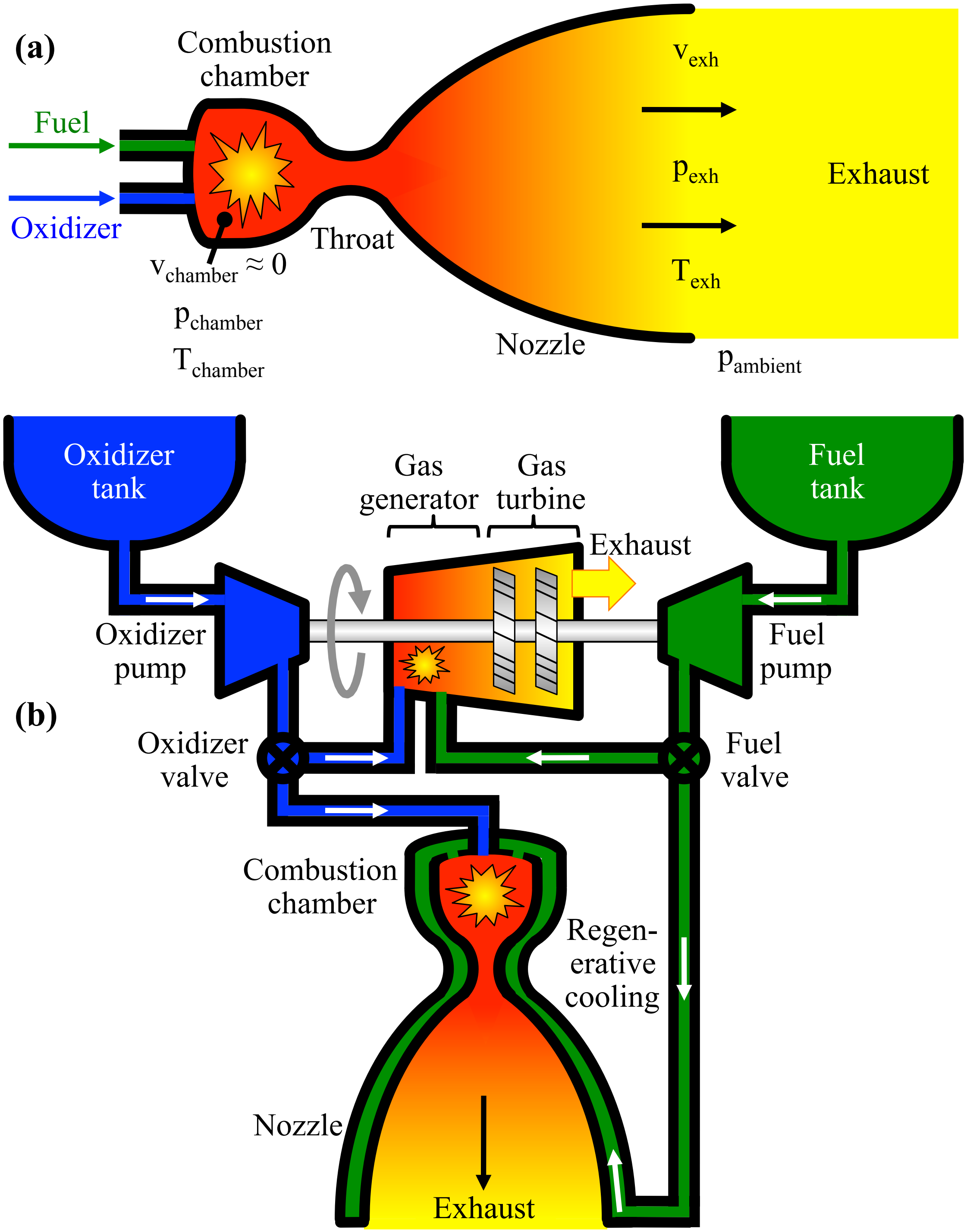
(a)
Combustion chamber
Fuel
Oxidizer
$v_{chamber} \approx 0$
$p_{chamber}$
$T_{chamber}$
Throat
Nozzle
v_{exh}
p_{exh}
T_{exh}
Exhaust
$p_{ambient}$
Oxidizer tank
Gas generator
Gas turbine
Exhaust
Fuel tank
Oxidizer pump
Fuel pump
(b)
Oxidizer valve
Fuel valve
Combustion chamber
Regen-erative cooling
Nozzle
Exhaust

Figure E.268: Liquid propellant rocket design. (a) Burning of fuel and oxidizer in the combustion chamber generates hot gas with velocity $v_{\text{chamber}} \approx 0$, pressure p_{chamber}, and temperature T_{chamber}, which expands in the nozzle until it has exhaust values v_{exh}, p_{exh}, and T_{exh}. (b) Pumps raise the pressure of oxidizer and fuel from the storage tanks and inject it into the combustion chamber. Along the way, fuel detours through coils wrapping the combustion chamber and nozzle, cooling the engine and preheating the fuel. Small amounts of oxidizer and fuel are diverted to burn in a gas generator, producing hot exhaust that powers a gas turbine and thereby the pumps.

Burning of propellant in the combustion chamber produces an exhaust gas of molecules with both a high thermal energy due to the temperature T_{chamber} and also a high potential energy in the form of the pressure p_{chamber}. The rocket nozzle is shaped in such a way to convert as much as possible of that gas's thermal energy and pressure potential energy into directed kinetic energy of the molecules moving straight out of the rear of the nozzle. From basic thermodynamics, molecules with D degrees of freedom (three degrees of freedom for linear motion in three dimensions, plus three more degrees of freedom for rotation around three axes, plus more degrees of freedom if each molecular bond has enough energy to vibrate) will have an initial thermal energy of

$$\text{Thermal energy per mole} \quad = \quad \frac{D}{2} R_0 T_{\text{chamber}} \ , \tag{E.36}$$

in which the universal gas constant is $R_0 \approx 8314$ J/(kg ^{o}K).

Also from basic thermodynamics, the initial pressure potential energy will be

$$\text{Pressure energy per mole} \quad = \quad R_0 T_{\text{chamber}} \ . \tag{E.37}$$

The exhaust gas leaving the nozzle will have a kinetic energy of

$$\text{Kinetic energy per mole} \quad = \quad \frac{1}{2} (\text{M.W.}) v_{\text{exh}}^2 \ , \tag{E.38}$$

in which M.W. is the molecular weight of the exhaust molecules (basically the total number of protons and neutrons in each molecule).

Using Eqs. (E.36)–(E.38), if the rocket engine nozzle converts the initial thermal and pressure energy of the exahust to final kinetic energy with some conversion efficiency ϵ_{nozzle}, one can calculate the exhaust velocity:

$$\text{Kinetic energy per mole} \quad = \quad \text{Efficiency} \times (\text{Thermal energy per mole} \ + \ \text{Pressure energy per mole})$$

$$\begin{aligned}
\frac{1}{2} (\text{M.W.}) v_{\text{exh}}^2 \quad &= \quad \epsilon_{\text{nozzle}} \ \frac{D+2}{2} \ R_0 T_{\text{chamber}} \ , \quad \text{or} \\
v_{\text{exh}} \quad &= \quad \sqrt{\frac{\epsilon_{\text{nozzle}} (D+2) R_0 T_{\text{chamber}}}{\text{M.W.}}} \qquad \text{(E.39)}
\end{aligned}$$

$$I_{\text{sp}} \quad = \quad \frac{v_{\text{exh}}}{g} \quad = \quad \frac{1}{g} \sqrt{\frac{\epsilon_{\text{nozzle}} (D+2) R_0 T_{\text{chamber}}}{\text{M.W.}}} \tag{E.40}$$

Most exhaust products from chemical rockets are triatomic molecules (H_2O, CO_2, etc.) with $D =$ 8 degrees of freedom (linear motion in three dimensions, plus rotation around three axes, plus vibration of two bonds). Using that assumption and the values $R_0 \approx 8314$ J/(kg ^{o}K) and $g \approx 9.807$ m/sec^2, Eqs. (E.39)–(E.40) become

$$v_{\text{exh}} \quad = \quad 288.3 \sqrt{\frac{\epsilon_{\text{nozzle}}\, T_{\text{chamber}} \text{ (in }^o\text{K)}}{\text{M.W.}}} \;\; \frac{\text{meters}}{\text{sec}} \tag{E.41}$$

$$I_{\text{sp}} \quad = \quad 29.40 \sqrt{\frac{\epsilon_{\text{nozzle}}\, T_{\text{chamber}} \text{ (in }^o\text{K)}}{\text{M.W.}}} \;\; \text{sec} \tag{E.42}$$

The nozzle efficiency is $\epsilon_{\text{nozzle}} \approx 1$ for rocket engines designed to operate in the vacuum of space, where the nozzle can be so large that it expands the exhaust gas until its pressure is virtually zero, and all of the exhaust gas's energy has become kinetic energy. For rocket engines designed to operate within the atmosphere (generally launching from the surface, where the atmospheric pressure is greatest), the nozzle can only be large enough to expand the exhaust gas until its pressure reaches the pressure of the outside atmosphere. (If the nozzle expanded the exhaust to a pressure lower than that of the atmosphere, the rocket would lose thrust as a result of the higher atmospheric pressure "dragging" on the outside of the rocket nozzle that had lower exhaust pressure inside.) For sea-level atmospheric pressure, typical values of nozzle efficiency are around $\epsilon_{\text{nozzle}} \approx 0.64$ ($\sqrt{\epsilon_{\text{nozzle}}} \approx 0.8$).

The combustion chamber temperature T_{chamber} is limited not by any chemical properties of the propellants, but rather by the requirement not to damage the engine by overheating. Whereas jet engines (Section E.6) must run for hours without overheating, most rocket engines only need to operate for a few minutes, and their propellant can also circulate outside the combustion chamber and nozzle to cool the engine before the propellant is burned. As a result, rocket engine combustion chambers can operate at higher temperatures than jet engines, typically ranging from $T_{\text{chamber}} \sim 2200^o$K for the standard A-4 engine to $\sim 3500^o$K for most modern rocket engines.

The molecular weight (M.W.) of the exhaust depends on the propellant used. For hydrogen as fuel and oxygen as oxidizer, the reaction product is water (H_2O), with a molecular weight M.W. ≈ 18. To lower the average molecular weight, most hydrogen-oxygen engines burn hydrogen-rich; the excess molecular hydrogen (M.W. ≈ 2) in the exhaust reduces the average exhaust molecular weight to M.W. ≈ 12. Hydrogen/oxygen propellant yields the best performance currently available from chemical propellants, but both the fuel and oxidizer are cryogenic, so they cannot be stored in onboard tanks for long. Hydrogen also has a very low density even when liquified, so it requires a fairly large and massive fuel tank on a rocket. Despite these difficulties, hydrogen/oxygen is the preferred fuel for most stages of most modern launch vehicles.

Liquid oxygen may also be used with storable fuels such as ethanol (CH_3CH_2OH, as in the A-4) or petroleum oil derivatives (typically a mixture of molecules $\sim C_nH_{2n+2}$, where $n \sim 6$–20, as in some proposed German rockets or the first stage of the Saturn V). For a standard A-4 rocket with oxygen as oxidizer and 75% ethanol/25% water as fuel (the water was added both to cool the engine and to lower the average molecular weight of the exhaust), roughly 2/3 of the reaction products are water (M.W. ≈ 18) and roughly 1/3 are carbon dioxide (CO_2, M.W. ≈ 44), yielding an average molecular weight of M.W. ≈ 27. The effective molecular weight could vary slightly, depending on what the exact propellant mix was and how one does the averaging, but M.W. ≈ 27 is a representative number, and small variations in that number are relatively insignificant, since it is in the square root in Eqs. (E.41)–(E.42).

Using these values and Eqs. (E.41), Table E.3 presents the approximate sea-level ($\epsilon_{\text{nozzle}} \approx 0.64$) and vacuum ($\epsilon_{\text{nozzle}} \approx 1$) exhaust velocities for various propellants and combustion temperatures.

Rocket fuel	**Rocket oxidizer**	**Exhaust M.W.**	**Combustion temperature**	**Sea-level exh. velocity**	**Vacuum exh. velocity**
Hydrogen	Oxygen	12	2200^oK	3120 m/sec	3900 m/sec
Hydrogen	Oxygen	12	3500^oK	3940 m/sec	4920 m/sec
Ethanol	Oxygen	27	2200^oK	2080 m/sec	2600 m/sec
Ethanol	Oxygen	27	3500^oK	2630 m/sec	3280 m/sec
Fuel oil	Oxygen	27	2200^oK	2080 m/sec	2600 m/sec
Fuel oil	Oxygen	27	3500^oK	2630 m/sec	3280 m/sec

Table E.3: Approximate exhaust velocities for rocket engines with various propellants, different combustion temperatures, and exhaust nozzles optimized for either sea-level and or vacuum conditions.

The thrust of a rocket engine may be estimated from the physical size of the engine, or vice versa. The combustion chamber pressure p_{chamber} pushes on all the forward inside areas of the chamber, but not on the open throat area A_{throat} in the rear of the chamber, producing an imbalanced pressure-based thrust force of $p_{\text{chamber}}A_{\text{throat}}$. The velocity and mass escaping through the throat produce a momentum-based thrust force of comparable value, doubling the total. Including the nozzle efficiency ϵ_{nozzle}, the total thrust including both pressure and momentum effects is

$$F_{\text{thrust}} \approx 2\,\epsilon_{\text{nozzle}}\,p_{\text{chamber}}\,A_{\text{throat}} \tag{E.43}$$

Like the chamber temperature, the chamber pressure p_{chamber} is limited not by any chemical properties of the propellants, but rather by the stresses that the combustion chamber can endure. Chamber pressures vary from $p_{\text{chamber}} \approx 1.45$ MPa for the standard A-4 engine to $p_{\text{chamber}} \approx 20$ MPa for the Space Shuttle Main Engines. (For reference, sea-level atmospheric pressure is approximately 0.1 MPa.)

Expressing the chamber pressure in MPa and writing the throat area in terms of the throat diameter, $A_{\text{throat}} \approx (\pi/4)D_{\text{throat}}^2$, the thrust from Eq. (E.43) may be rewritten as:

$$F_{\text{thrust}} \ \text{[in Newtons]} \ \approx \ 1.6 \times 10^6 \, \epsilon_{\text{nozzle}} \, D_{\text{throat}}^2 \ \times \ p_{\text{chamber}} \ \text{[in MPa]} \tag{E.44}$$

For the standard A-4 engine with sea-level nozzle efficiency $\epsilon_{\text{nozzle}} \approx 0.64$, throat diameter $D_{\text{throat}} = 0.405$ m, and chamber pressure $p_{\text{chamber}} \approx 1.45$ MPa, Eq. (E.44) predicts a thrust of $F_{\text{thrust}} \approx 2.44 \times 10^5$ N, very close to the stated sea-level A-4 thrust of 2.65×10^5 N.

In order to reduce the exhaust gas pressure from the chamber pressure $p_{\text{chamber}} > 1$ MPa to atmospheric pressure $p_{\text{atm}} \sim 0.1$ MPa for a first-stage engine, the flared nozzle must have an exhaust area that is $A_{\text{exh}}/A_{\text{throat}} \sim$ 4–16 times as large as the throat area, or an exhaust diameter that is $D_{\text{exh}}/D_{\text{throat}} \sim$ 2–4 times as large as the throat diameter (taking the square root of the area ratio). Vacuum-optimized upper-stage engines typically have typical area ratios of $A_{\text{exh}}/A_{\text{throat}} \sim$ 25–100, or diameter ratios of $D_{\text{exh}}/D_{\text{throat}} \sim$ 5–10.

Although solid propellant rockets have lower specific impulses/exhaust velocities than liquid propellant rockets, they can generally be stored for years without degradation. Therefore, they are primarily used for military rockets and “off-the-shelf” boosters that can be strapped to the side of the first stage of a spacecraft launch vehicle. Despite their internal differences (see p. 1905), solid propellant rockets obey the same thrust equations derived above for liquid propellant rockets.

Very complex calculations would be required to analyze the performance of a rocket including factors such as the duration and angle of its rocket engine burn, aerodynamic drag, variations in the gravitational acceleration g, curvature of the earth, and rotation of the earth. However, for suborbital rockets, adequate approximations may be obtained using much simpler methods. As shown in Fig. E.269, major categories of potential flight paths for rockets include: (a) a ballistic trajectory, (b) a glide trajectory, (c) a ballistic trajectory followed by a glide trajectory, and (d) a ballistic trajectory with multiple skips off the upper atmosphere (followed by a glide).

a. Ballistic trajectory

For a crude but simple calculation of a ballistic trajectory (the path of a rocket without aerodynamic lift or wings), one can model the rocket's performance as that of a ballistic projectile which is instantaneously accelerated to a velocity Δv at launch, is fired some initial angle relative to the flat surface of the earth, and follows a parabolic trajectory to its target. Using Eq. (E.31) and assuming a 10% loss for aerodynamic drag and gravitational forces, the effective launch velocity of a ballistic rocket in this model is:

$$\Delta v \quad = \quad 0.9\, v_{\text{exh}} \, \ln\left(\frac{m_{\text{initial}}}{m_{\text{final}}}\right) \tag{E.45}$$

As shown in Fig. E.269(a), such a ballistic projectile achieves the greatest range when it is fired at a 45^o angle from the surface, devoting equal amounts of its velocity to achieving a maximum height and traveling a maximum distance before it falls back to the earth. If the projectile has a mass m and an initial velocity Δv, its total kinetic energy is $m(\Delta v)^2/2$, of which half goes to carry it to a maximum height ΔH and half goes to carry it to a maximum downrange distance Δx when it impacts at time Δt after being launched. Since half the initial kinetic energy is used up to achieve the gravitational potential energy $mg\Delta H$ at maximum height, that height may be found:

$$\frac{1}{2}\left[\frac{1}{2}m(\Delta v)^2\right] \quad = \quad m\, g\, \Delta H \ , \ \text{ or} \tag{E.46}$$

$$\Delta H \quad = \quad \frac{(\Delta v)^2}{4g} \tag{E.47}$$

Half of the total time Δt is spent reaching height ΔH, and half to fall from it back to the ground:

$$\Delta H \quad = \quad \frac{1}{2}\, g \left(\frac{\Delta t_{\text{ballistic}}}{2}\right)^2 \ , \ \text{ or} \tag{E.48}$$

$$\Delta t_{\text{ballistic}} \quad = \quad \sqrt{\frac{8\Delta H}{g}} \tag{E.49}$$

$$\quad = \quad \sqrt{2}\,\frac{\Delta v}{g} \tag{E.50}$$

in which Eq. (E.50) used Eq. (E.47).

An amount $\Delta v/\sqrt{2}$ of the projectile's velocity is directed horizontally, carrying it a distance

$$\Delta x_{\text{ballistic}} \quad = \quad \frac{\Delta v}{\sqrt{2}}\ \Delta t_{\text{ballistic}} \tag{E.51}$$

$$\quad = \quad \frac{(\Delta v)^2}{g} \tag{E.52}$$

in which Eq. (E.52) used Eq. (E.50).

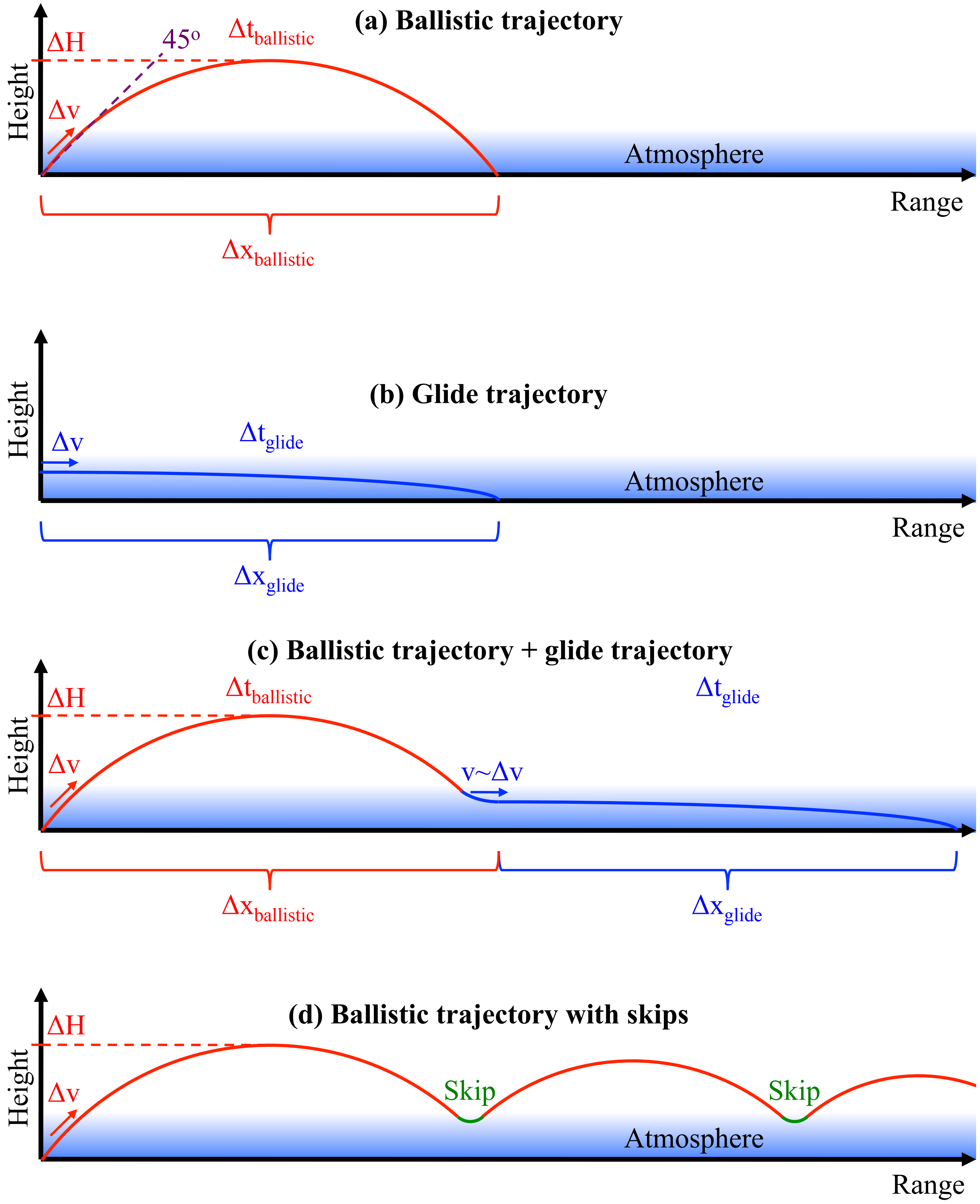
(a) Ballistic trajectory
ΔH
45°
Δt_ballistic
Δv
Height
Atmosphere
Range
Δx_ballistic
(b) Glide trajectory
Height
Δv
Δt_glide
Atmosphere
Range
Δx_glide
(c) Ballistic trajectory + glide trajectory
ΔH
Δt_ballistic
Δt_glide
Height
Δv
v~Δv
Δx_ballistic
Δx_glide
(d) Ballistic trajectory with skips
ΔH
Height
Δv
Skip
Skip
Atmosphere
Range

Figure E.269: Major categories of potential flight paths for rockets include: (a) a ballistic trajectory, (b) a glide trajectory, (c) a ballistic trajectory followed by a glide trajectory, and (d) a ballistic trajectory with multiple skips off the upper atmosphere (followed by a glide).

b. Glide trajectory

In a gliding trajectory as illustrated in Fig. E.269(b), the rocket is boosted to an initial velocity Δv that is horizontal but high enough in the atmosphere that it will not crash before it loses its horizontal velocity. If the rocket has wings, it can use the aerodynamic lift force generated by those wings to maintain a nearly horizontal gliding flight path for as long as possible, until aerodynamic drag has slowed its forward velocity to zero (or in practice, to a low enough velocity that the wings no longer generate enough lift to keep the vehicle aloft).

For the rocket to maintain a horizontal trajectory, the upward lift force L must balance the downward gravitational force mg, in which m is the mass of the rocket and g is the gravitational acceleration:

$$L = mg \tag{E.53}$$

Using Newton's second law, the aerodynamic drag force D in the horizontal direction causes the rocket's forward velocity to decelerate at a rate a (where a is defined to be positive for deceleration):

$$D = ma \tag{E.54}$$

Dividing Eq. (E.54) by Eq. (E.53), one finds:

$$\frac{D}{L} = \frac{a}{g}\,, \quad \text{or}$$

$$a = g\,\frac{D}{L} \tag{E.55}$$

Note that the deceleration is constant and only depends on the rocket's lift-to-drag ratio (D/L). At that uniform deceleration, the time required to decelerate from initial velocity Δv to $v = 0$ is:

$$\begin{aligned} \Delta t_{\text{glide}} &= \frac{\Delta v}{a} \\ &= \frac{\Delta v}{g}\,\frac{L}{D} \end{aligned} \tag{E.56}$$

For uniform deceleration, the average velocity during the glide is $\Delta v/2$, so the range travelled during the glide is:

$$\begin{aligned} \Delta x_{\text{glide}} &= \frac{\Delta v}{2}\,\Delta t_{\text{glide}} \\ &= \frac{1}{2}\,\frac{L}{D}\,\frac{(\Delta v)^2}{g} \end{aligned} \tag{E.57}$$

Dividing Eq. (E.57) by Eq. (E.52), the range of a gliding trajectory compared to the range of a ballistic trajectory with the same initial velocity is:

$$\frac{\Delta x_{\text{glide}}}{\Delta x_{\text{ballistic}}} = \frac{1}{2}\frac{L}{D} \tag{E.58}$$

Thus the gliding range is at least as large as the ballistic range for lift-to-drag ratios of

$$\frac{L}{D} \geq 2 \tag{E.59}$$

For reference, the lift-to-drag ratio of the U.S. space shuttle was $L/D \approx 2.5$, and Silbervogel was designed to have L/D in the range 6.4–7.5 (the ratio varied slightly with the velocity of the vehicle).

c. Ballistic trajectory followed by a glide trajectory

As shown in Fig. E.269(c), greater range may be achieved if a rocket first follows a ballistic trajectory, then follows a glide trajectory. For simplicity, one can assume that the glide begins after the rocket's ballistic trajectory has fallen enough that the rocket has regained virtually all of its initial velocity Δv, yet is still high enough that it can glide nearly horizontally until its forward velocity is gone, without hitting the ground prematurely. With this simplistic but useful assumption, the total range travelled during both the ballistic and glide phases is:

$$\Delta x_{\text{total}} \approx \Delta x_{\text{ballistic}} + \Delta x_{\text{glide}} = \left(1 + \frac{1}{2}\frac{L}{D}\right)\frac{(\Delta v)^2}{g} \tag{E.60}$$

$$\approx \left(1 + \frac{1}{2}\frac{L}{D}\right)\Delta x_{\text{ballistic}} \tag{E.61}$$

If $L/D = 2$, adding a glide to the end of a ballistic trajectory would approximately double the total range, compared to a purely ballistic trajectory. If $L/D = 4$, adding a glide to the end of a ballistic trajectory would approximately triple the total range.

The total time required for both the ballistic and glide phases is:

$$\Delta t_{\text{total}} \approx \Delta t_{\text{ballistic}} + \Delta t_{\text{glide}} = \left(\sqrt{2} + \frac{L}{D}\right)\frac{\Delta v}{g} \tag{E.62}$$

$$\approx \left(1 + \frac{\sqrt{2}}{2}\frac{L}{D}\right)\Delta t_{\text{ballistic}} \tag{E.63}$$

d. Skip trajectory

In a skip trajectory as illustrated in Fig. E.269(d), the rocket follows an initial ballistic trajectory but then instead of gliding back through the atmosphere, it bounces off the upper atmosphere to follow a second ballistic trajectory. If the rocket has wings, it can use those wings to generate enough aerodynamic lift for the skip back out of the atmosphere, instead of a nearly horizontal glide. However, there will also be a corresponding amount of aerodynamic drag during the atmospheric skip, so the rocket will lose some of its velocity and the second ballistic trajectory will not achieve as much altitude or as much range as the first ballistic trajectory. In principle the rocket can execute several skips and several ballistic trajectories, each smaller than the preceding one, before eventually settling into a conventional glide trajectory. The skip trajectory is analogous to skipping a stone off the surface of a pond of water. The equations for the skip trajectory are too complicated to include here, but will be discussed in Section E.7.7. Yet even without equations, one can see that a skip trajectory has the potential to have a total range several times larger than a simple ballistic trajectory, and larger even than a combined ballistic and glide trajectory.

Methods of improving rocket performance

Throughout the war, Germany was strongly motivated to improve the performance of its rockets to increase their range in order to reach more distant targets, and/or to increase their payload capacity in order to deliver larger bombs (conventional explosive, incendiary, fuel-air explosive, fission, radiological, chemical, or biological). Once Allied military forces began advancing into territory previously held by Germany, making potential Allied targets like London and Moscow even further away, this motivation became even stronger.

The A-4 or V-2 rocket was the most successful, most visible, and most widely produced German rocket, and was able to carry a 1-ton payload to a maximum range of approximately 350 km. There were six major ways to improve its performance, which could be done individually or in any combinations:

- Increasing the size of the rocket.
- Increasing the exhaust velocity of the rocket engine.
- Adding a booster stage to the rocket.
- Adding strap-on boosters to the rocket.
- Adding wings to the rocket.
- Decreasing stresses during atmospheric reentry.

Evidence for wartime German progress on each of these approaches will now be analyzed.

E.7.2 Increasing the Size of the Rocket

Length was the most straightforward improvement, since it would have simply involved producing longer cylinders for the fuel and oxidizer tanks, and possibly increasing the propellant flow rate to the engine to produce more thrust to lift the larger rocket mass. Whereas the regular A-4 rocket was approximately 14 meters long, including the fins and nosecone, there is evidence for extended versions of the A-4, especially a ∼18-meter version and a ∼21-meter version. There is also evidence for larger rockets such as the A-10.

For some publicly available sources on the wartime development of rockets larger than the standard A-4, see for example:

Wernher von Braun (pp. 4678, 5496–5497)

U.S. Army in France (p. 5012)

Henry H. Fowler (pp. 5206–5206)

Convair (pp. 5208–5211)

Roy Fedden (pp. 5246–5249)

French launch sites (pp. 5295–5296, 5311)

Franz Peter (pp. 5311–5315)

John A. O'Mara (pp. 5316–5318)

U.S. Army Air Forces General Henry Arnold (pp. 5316, 5319, 5454–5466)

Multiple *New York Times* sources (p. 5321)

Albert Speer (p. 5322)

Gerhard Reisig (pp. 5323–5324)

Allen Dulles (p. 5325)

Prisoner of war from Friedrichshafen (pp. 5327–5329)

Another prisoner of war from Friedrichshafen (pp. 5330–5331)

Allied intelligence (pp. 5332–5333)

Peenemünde chemist (p. 5334)

CIOS Final Report XXVIII-56 (p. 5334)

Forced laborers (p. 5335)

U.S. Army Air Forces General Lowell Weicker (pp. 5337–5340)

German engineer (p. 5341)

German prisoner of war (p. 5342)

Strategic Air Forces in Europe (p. 5343)

Cläre Werner (p. 5344)

Werner Kasper (pp. 5344–5345)

Albin Kummer (p. 5346)

Alfred Gründler (p. 5347)

Otto Skorzeny (p. 5352)

Henry Picker (pp. 4635–4639)

Werner Wächter (pp. 4640–4664)

Gordon Cooper (pp. 5353–5354)

Werner Grothmann (pp. 5355–5359)

Allied intelligence reports (p. 5362)

U.S. Army (pp. 5363–5375)

Former French forced laborers (pp. 5376–5379)

Albert Ducrocq (p. 5380)

Walter Dornberger (pp. 5381–5383)

Heinz Stoelzel (pp. 5384–5396)

Kurt Eckener (p. 5392)

1945 St. Georgen an der Gusen train log book (p. 5397)

Karl Pohlhausen (p. 5398)

Winston Churchill (p. 5398)

Ernst Krause (pp. 5399–5400)

U.S. Army (pp. 5401–5402)

Gladwin Hill (pp. 5403–5404)

CIOS Final Report XXXII-125 (pp. 5405–5418)

NavTechMisEu Final Report 237-45 (p. 5429–5437)

U.S. Navy Secretary James Forrestal (pp. 5441–5443)

CIOS chairs R. P. Linstead and T. J. Betts (pp. 5444–5447)

W. G. A. Perring (pp. 5448–5451)

French Ministry of Defense (p. 5452)

Nils Werner Larsson (pp. 5458–5459)

U.S. Army Air Forces General Carl Spaatz (p. 5465)

U.S. Army Air Forces General Joseph T. McNarney (p. 5469)

Canadian investigators (pp. 5470–5471)

U.S. Army Air Forces Colonel Donald L. Putt (p. 5472)

U.S. Senator Elbert D. Thomas (pp. 5478–5481)

U.S. Army Ordnance Office (p. 5482)

Headquarters, U.S. Air Forces in Europe (pp. 5483–5484)

Central Intelligence Group (pp. 5484–5485)

Charles J. V. Murphy (pp. 5488–5489)

U.S. Army Air Forces (pp. 5490–5491)

U.S. Senator Harry F. Byrd (pp. 5492–5495)

Aage Woldike (pp. 5506–5505)

Time magazine (pp. 5514–5515)

V. L. Rychly (p. 5520–5546)

B. A. Haartt (pp. 5528– 5532)

Egmont F. Koenig (p. 5544)

August 1947 U.S. intelligence report (p. 5560)

Czech officials (pp. 5563–5565)

October 1947 U.S. intelligence report (p. 5566)

H. Tellmann (pp. 5567–5568)

Using German engineers, plans, and technologies after the war, the United States produced the Redstone missile, which was essentially a 21-meter-long A-4 (p. 5501).

Using German engineers, plans, and technologies after the war, France was developing and considering producing the Super V-2 missile, which was essentially an A-4 with enlarged propellant tanks (p. 5584).

Using German engineers, plans, and technologies after the war, the Soviet Union produced the SS-2 (R-2) missile, which was basically an 18-meter-long A-4, and the SS-3 (R-5M) missile, which was essentially a 21-meter-long A-4 (p. 5574).

Boris Chertok mentioned that the 21-m-long SS-3/R-5, but not the 14-m SS-1/R-1 and 18-m SS-2/R-2, suffered from unforeseen guidance problems. The SS-3 was so long that there was appreciable structural bending between the nose of the rocket, where the motion-sensing guidance system was, and the tail of the rocket, where the steering fins were. The guidance system erroneously interpreted small bending motions of the intervening structure as course changes of the entire rocket, and then led the rocket astray. (See pp. 5572–5572.) Because these Soviet rockets were directly based on German technology, it is likely that this same problem would have afflicted a 21-m A-4 but not 14-m or 18-m versions of the A-4. The wartime German program could certainly have overcome this problem just as the postwar Soviet program ultimately did, but it might have been one more cause for critical delays in the German rocket program.

Characteristic	**A-4**	**18 m A-4**	**21 m A-4**	**SS-1**	**SS-2**	**SS-3**	**Super V-2**	**Redstone**
Country	Germany	Germany	Germany	USSR	USSR	USSR	France	US
Operational	1942–45	1945?	1945?	1950–53	1953–56	1956–67	1946 design	1958–64
Diameter (m)	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.77
Length (m)	14	18	21	14	18	21	14.5	21
Body (kg)	4000	4000	4000	4000	5000	4000	3000	4000
Propellant (kg)	9000	16,000	24,000	9000	16,000	24,000	16,000	24,000
Payload (kg)	1000–2000	1000–2000	1000–2000	1000	1000	2000	1000	4000
Total mass (kg)	14,000–15,000	21,000–22,000	29,000–30,000	14,000	22,000	30,000	20,000	32,000
Fuel	Ethanol	Ethanol	Ethanol	Ethanol	Ethanol	Ethanol	Kerosene	Ethanol
Oxidizer	LOX	LOX	LOX	LOX	LOX	LOX	Nitric acid	LOX
v_{exh} **(m/s)**	2000	2000	2000	2000	2000	2300	2630	2300
Thrust (kN)	270	380	400	280	380	490	392	460
Burn time (s)	68	85	120	63	85	112	108	120
Range (km)	300	600	900	300	600	1200	1500	400
Est. velocity Δv **(m/s)**	1850–1650	2600–2300	3200–2900	1850	2300	3300	3800	2900
Est. flight time Δt **(min)**	4.5–4.0	6.2–5.6	7.6–7.0	4.5	5.6	8.0	9.2	6.9
Est. altitude ΔH **(km)**	88–70	170–140	250–210	88	140	280	370	210
Est. range Δx **(km)**	350–280	680–560	1000–860	350	560	1100	1500	840

Table E.4: Approximate values from known German (14-meter regular A-4), German-based Soviet (SS-1, SS-2, and SS-3), German-based French (Super V-2), and German-based U.S. (Redstone) rockets used to extrapolate characteristics of possible German extended A-4 rockets (18-meter and 21-meter versions) [data adapted from Jürgen Michels 1997; Uhl 2001; http://www.astronautix.com]. Extended German rockets may have also used kerosene (or other hydrocarbon fuel) and nitric acid oxidizer like the proposed Super V-2.

From Table E.4, note that the estimated altitude and range agree very well with the A-4 trajectory shown in Heinz Stoelzel's diagram in Fig. E.96.

E.7.3 Increasing the Exhaust Velocity of the Rocket Engine

Another way to improve the overall performance of the rocket would be to increase the exhaust velocity of the engine. This solution was presumably being pursued with better metal alloys and improved regenerative engine cooling systems to allow higher combustion temperatures, and improved fuels (especially liquid hydrogen) to lower the average molecular weight of the exhaust gas, since the range varies like:

$$\begin{aligned} \Delta x &\propto (\Delta v)^2 \propto v_{\rm exh}^2 \\ &\propto \frac{T_{\rm chamber}}{\rm M.W.} \end{aligned} \tag{E.64}$$

Because the range is directly proportional to the engine combustion chamber temperature, using more heat-resistant materials and increasing the temperature from 2200^oK (standard for the A-4) to 3500^oK (typical for modern rockets) would increase the range by a factor of

$$\frac{3500^o\text{K}}{2200^o\text{K}} \approx 1.59 \,, \tag{E.65}$$

or approximately 59%. For example, the maximum range of the A-4 would increase from approximately 350 km to approximately 557 km.

It seems likely that A-4 engines with higher combustion temperatures would have been actively researched and possibly even mass-produced during the war:

a. There was an urgent wartime demand for rockets with longer ranges, especially after D-Day as rockets had to be launched from deeper and deeper into the European continent.

b. German-led engineering teams in postwar Allied countries made simultaneous and similar improvements to A-4 engine technology to raise the combustion temperatures.

c. There were a number of wartime and early postwar documents that mentioned "improved V-2s."

d. Rocket engine testing was so important that a number of testing facilities were built and operated in addition to Peenemünde. If the engine technology was standardized and remained unchanged, those engine testing sites are harder to explain. (Ordinary quality control would have required less extensive testing of some fraction of the mass-produced engines.)

Indeed, there is at least one photograph from a postwar U.S. report showing an advanced A-4 engine that was apparently mass-produced (p. 5285). Much more archival research should be conducted to determine the performance characteristics and production history of that and other advanced wartime rocket engines.

Since the range is inversely proportional to the molecular weight of the exhaust molecules, changing the fuel from ethanol or hydrocarbons to liquid hydrogen would reduce the average molecular weight from M.W. $\approx$ 27 (a mixture of roughly 1/3 CO_2 and roughly 2/3 H_2O) to M.W. = 12 (H_2O with some H_2, if a fuel-rich propellant mix is used) while keeping the combustion chamber temperature the same (2200^{o}K) would increase the range by a factor of

$$\frac{27}{12} \approx 2.25 , \tag{E.66}$$

or approximately 125%. For example, the maximum range of the A-4 would increase from approximately 350 km to approximately 788 km.

Both changing the fuel from ethanol to liquid hydrogen and increasing the combustion chamber temperature from 2200^{o}K to 3500^{o}K would increase the range by a factor of

$$\frac{3500^o\mathrm{K}}{2200^o\mathrm{K}} \, \frac{27}{12} \approx 3.58 , \tag{E.67}$$

or approximately 258%. For example, the maximum range of the A-4 would increase from approximately 350 km to approximately 1250 km.

Although liquid hydrogen is even more cumbersome than liquid oxygen, using it would yield a huge increase in range, whether or not the combustion chamber temperature could be increased. For this reason, there would have been very strong incentive for the German rocket program to pursue liquid hydrogen fuel. In fact, there is some evidence that it did so:

a. A 1944 prisoner of war report stated that German rockets using hydrogen fuel had been successfully tested (p. 5311).

b. A November 1945 conference presentation reporting details of postwar Allied investigations of the German rocket program mentions hydrogen fuel (p. 5448).

c. A 1946 U.S. intelligence report mentions wartime German hydrogen and oxygen production plants in conjunction with the report of V-2 and A-9 rocket programs that were taken over by Soviet forces (p. 5537).

d. Walter Dornberger mentioned wartime interest in liquid hydrogen to increase the performance of the A-4 (p. 5537).

e. Krafft Ehricke mentioned wartime research on liquid hydrogen for rockets (p. 5764).

f. Is there other evidence?

E.7.4 Adding a Booster Stage to the Rocket

Another solution to increase the rocket performance was to use two or more stages, such that the structural mass of each stage could be jettisoned once all of the propellant in that stage had been consumed. This solution is very effective and therefore widely used in modern launch vehicles, but it is also fairly complex as it requires the development and perfection of a larger and entirely new rocket engine and stage to serve as the first-stage booster of a smaller rocket.

In the wartime German rocket program, the best-known example of this approach was the A-9/A-10 two-stage rocket; Table E.5 gives approximate specifications for the A-9 and A-10 stages. The Silbervogel space plane may also be viewed as a two-stage system, in which the rocket-powered catapult booster sled was effectively the first stage and the rocket plane itself was the second stage. Table E.6 gives approximate specifications for that system. Exact values for the A-9/A-10 and Silbervogel specifications vary among different sources in the literature and for different versions of these systems[8], but the approximate values given in these tables are sufficient to estimate the performance of each system.

Characteristic	**Symbol**	**Approximate value**
Payload mass	m_{payload}	2000 kg
A-9 empty mass	m_{A9}	3000 kg
A-9 propellant mass	$m_{\text{A9 propellant}}$	12,000 kg
A-9 total initial mass	$(m_{\text{initial}})_2 = m_{\text{payload}} + m_{\text{A9}} + m_{\text{A9 propellant}}$	17,000 kg
A-9 total final mass	$(m_{\text{final}})_2 = m_{\text{payload}} + m_{\text{A9}}$	5000 kg
A-9 effective exhaust velocity	$(v_{\text{exh}})_2$	2000 m/sec
A-9 burn time	t_2	95 sec
A-9 thrust	$(F_{\text{thrust}})_2$	3×10^5 N
A-10 empty mass	m_{A10}	17,000 kg
A-10 propellant mass	$m_{\text{A10 propellant}}$	52,000 kg
A-9/A-10 total initial mass	$(m_{\text{initial}})_1 = m_{\text{payload}} + m_{\text{A9}} + m_{\text{A9 propellant}} + m_{\text{A10}} + m_{\text{A10 propellant}}$	86,000 kg
A-9/A-10 total final mass	$(m_{\text{final}})_1 = m_{\text{payload}} + m_{\text{A9}} + m_{\text{A9 propellant}} + m_{\text{A10}}$	34,000 kg
A-10 effective exhaust velocity	$(v_{\text{exh}})_1$	2000 m/sec
A-10 burn time	t_1	50 sec
A-10 thrust	$(F_{\text{thrust}})_1$	2×10^6 N

Table E.5: Specifications for estimating performance of A-9/A-10 rocket.

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[8] Fritz Hahn 1998, Vol. 2, pp. 162–170; Hölsken 1994, p. 335; Huzel 1962, pp. 236–237; Ley 1968, pp. 390–392; Jürgen Michels 1997, pp. 35, 71–75; Miranda and Mercado 1996, pp. 65–80; Myhra 2002; Sänger and Bredt 1944; Hartmut Sänger 2006, p. 52.

Characteristic	**Symbol**	**Approximate value**
Payload mass	m_{payload}	2000 kg
Silbervogel empty mass	m_{plane}	10,000 kg
Silbervogel propellant mass	$m_{\text{plane propellant}}$	88,000 kg
Silbervogel total initial mass	$(m_{\text{initial}})_2 = m_{\text{payload}} + m_{\text{plane}} + m_{\text{plane propellant}}$	100,000 kg
Silbervogel total final mass	$(m_{\text{final}})_2 = m_{\text{payload}} + m_{\text{plane}}$	12,000 kg
Silbervogel effective exhaust velocity	$(v_{\text{exh}})_2$	3000 m/sec
Silbervogel burn time	t_2	168 sec
Silbervogel thrust	$(F_{\text{thrust}})_2$	1×10^6 N
Booster sled empty mass	m_{sled}	??
Booster sled propellant mass	$m_{\text{sled propellant}}$	?? kg
Sled + Silbervogel total initial mass	$(m_{\text{initial}})_1 = m_{\text{payload}} + m_{\text{plane}} + m_{\text{plane propellant}} + m_{\text{sled}} + m_{\text{sled propellant}}$	?? kg
Sled + Silbervogel total final mass	$(m_{\text{final}})_1 = m_{\text{payload}} + m_{\text{plane}} + m_{\text{plane propellant}} + m_{\text{sled}}$	?? kg
Booster sled effective exhaust velocity	$(v_{\text{exh}})_1$	2000 m/sec
Booster sled Δv	$(\Delta v)_1$	500 m/sec
Booster sled burn time	t_1	11 sec
Booster sled thrust	$(F_{\text{thrust}})_1$	?? N

Table E.6: Specifications for estimating performance of Silbervogel space plane.

Using the A-9/A-10 rocket specifications from Table E.5 in Eq. (E.32), the A-9/A-10 had a maximum velocity $\Delta v \approx 4300$ m/sec. Assuming $\sim$ 10% loss for aerodynamic drag and gravitational losses, the effective maximum velocity was

$$(\Delta v)_{\mathrm{A9/A10}} \approx 3870 \text{ m/sec} \tag{E.68}$$

Using Eq. (E.68) in Eqs. (E.47), (E.50), and (E.52), the maximum altitude, flight time, and range of the A-9/A-10 rocket during its ballistic trajectory (not counting the subsequent gliding reentry using its wings) were:

$$(\Delta H)_{\mathrm{A9/A10}} \approx 380 \text{ km} \tag{E.69}$$

$$(\Delta t_{\mathrm{ballistic}})_{\mathrm{A9/A10}} \approx 9.3 \text{ min} \tag{E.70}$$

$$(\Delta x_{\mathrm{ballistic}})_{\mathrm{A9/A10}} \approx 1500 \text{ km} \tag{E.71}$$

Note that this maximum altitude and range agree very well with the early (ballistic) part of the A-9/A-10 trajectory shown in Heinz Stoelzel's diagram in Fig. E.96. This does not include the additional range from using the A-9's wings to follow a gliding trajectory after the ballistic trajectory; that effect will be calculated shortly.

Using the Silbervogel space plane/booster sled specifications from Table E.6 in Eq. (E.32), the two-stage Silbervogel system had a maximum velocity $\Delta v \approx 6860$ m/sec. Assuming $\sim$ 10% loss for aerodynamic drag and gravitational losses, the effective maximum velocity was

$$(\Delta v)_{\mathrm{Silbervogel}} \approx 6170 \text{ m/sec} \tag{E.72}$$

Using Eq. (E.72) in Eqs. (E.47), (E.50), and (E.52), the maximum altitude, flight time, and range of the Silbervogel during its ballistic trajectory (not counting the subsequent skip and/or gliding trajectories using its wings) were:

$$(\Delta H)_{\mathrm{Silbervogel}} \approx 970 \text{ km} \tag{E.73}$$

$$(\Delta t_{\mathrm{ballistic}})_{\mathrm{Silbervogel}} \approx 15 \text{ min} \tag{E.74}$$

$$(\Delta x_{\mathrm{ballistic}})_{\mathrm{Silbervogel}} \approx 3900 \text{ km} \tag{E.75}$$

The effect of the Silbervogel's wings will be calculated shortly.

E.7.5 Adding Strap-on Boosters to the Rocket

Strap-on boosters could also improve the performance of rocket such as the A-4, just as they have been used to improve the performance of many modern launch vehicles such as the U.S. Space Shuttle, Titan, and Delta. Do any reports give the empty mass, propellant mass, exhaust velocity, burn time, and thrust of suitable strap-on boosters? If so, one can calculate how much they would improve the performance of an A-4, A-9, or other rocket.

E.7.6 Adding Wings to the Rocket

Wings would enable a rocket to execute a long gliding reentry into the atmosphere instead of a steep ballistic reentry, so that a rocket of the same size would have greatly extended range. This solution was being pursued with the winged A-9 and Silbervogel space plane, but it was more complex due to the large aerodynamic and heating loads on the reentering vehicle and the need for real-time onboard or remote human guidance during the tricky reentry phase to reach the intended target.

From Eq. (E.61), using wings to add a glide trajectory after a ballistic trajectory increases the total range by a factor of $[1+(L/2D)]$. It also increases the total flight time by factor of $[1+(L/\sqrt{2}D)]$.

Assuming a lift-to-drag ratio of $L/D \approx 5$, adding wings to a standard A-4 with a range of 350 km and a flight time of 4.5 min would produce an A-4b (or A-9) with a range and flight time of

$$(\Delta x_{\text{ballistic+glide}})_{\text{A4b}} \approx 1200 \text{ km} \tag{E.76}$$

$$(\Delta t_{\text{ballistic+glide}})_{\text{A4b}} \approx 20 \text{ min} \tag{E.77}$$

For this same lift-to-drag ratio of $L/D \approx 5$, adding wings to an A-9/A-10 with a range of 1500 km and a flight time of 9.3 min would yield a total range and flight time of

$$(\Delta x_{\text{ballistic+glide}})_{\text{A9/A10}} \approx 5300 \text{ km} \tag{E.78}$$

$$(\Delta t_{\text{ballistic+glide}})_{\text{A9/A10}} \approx 42 \text{ min} \tag{E.79}$$

Note that these ranges agree very well with those for the winged A-9 or A-9/A-10 trajectories shown in Heinz Stoelzel's diagram in Fig. E.96.

Assuming a lift-to-drag ratio of $L/D \approx 6.5$ for the Silbervogel, adding a glide (but no skips) would extend its purely ballistic range of 3900 km and flight time of 15 min to a total range and flight time of

$$(\Delta x_{\text{ballistic+glide}})_{\text{Silbervogel}} \approx 17{,}000 \text{ km} \tag{E.80}$$

$$(\Delta t_{\text{ballistic+glide}})_{\text{Silbervogel}} \approx 84 \text{ min} \tag{E.81}$$

Adding skips would extend the Silbervogel's range and flight time even further. The detailed effects of the skips are difficult to calculate precisely but will be addressed in Section E.7.7.

In general, the A-9/A-10 and Silbervogel plane/sled systems had many similarities. Both were two-stage rockets that launched a winged space plane on an intercontinental trajectory involving both ballistic and glide phases. However, Silbervogel was approximately 6 times larger than A-9 (100,000 kg vs. 17,000 kg), and over 50% faster, with a much more advanced trajectory (repeated skips) and more serious reentry stress and heating requirements. Even if experimental work did not get as far on it as the experimental work for the A-9/A-10, the Silbervogel was an incredibly advanced design for its time and the true predecessor of the U.S. Space Shuttle and other space planes. Its planned skip trajectory led to the double-dip reentry trajectory for returning missions from beyond Earth orbit, as will be discussed in Section E.7.7.

E.7.7 Decreasing Stresses During Atmospheric Reentry

Very simple mathematical models of reentry performance may be derived from first principles, and then applied to estimate the reentry deceleration, heating, and range of the A-4, A-9, and Silbervogel and show how they would compare to the reentry performance of modern ballistic missiles and spacecraft.

General considerations

The typical velocity of vehicles reentering the atmosphere from orbit may be found by considering a vehicle of mass m in a circular orbit just above the earth's atmosphere, say at a height $H = 150$ km above the earth's surface. Because H is much smaller than the radius of the earth $R_\oplus \approx 6380$ km, one may simply use $R_\oplus$ for the orbital radius and the surface value $g \approx 9.807$ m/sec^2 for the gravitational acceleration. In a circular orbit at velocity v_o, viewed in a rotating reference frame, the outward centrifugal force $mv_o^2/R_\oplus$ balances the inward gravitational force mg:

$$\frac{mv_o^2}{R_\oplus} = mg \ , \ \text{or} \tag{E.82}$$

$$v_o = \sqrt{gR_\oplus} \approx 7.91 \ \text{km/sec} \approx \text{Mach} \ 23 \tag{E.83}$$

At this speed, each kg of the vehicle has a kinetic energy 1 kg $\cdot \, v_o^2/2 \approx 3.13 \times 10^7$ J that is equivalent to the explosive energy of roughly 7 kg of TNT–the vehicle's energy is equivalent to seven times its mass in high explosives. This enormous kinetic energy must be safely dissipated before the vehicle reaches the earth's surface. A rocket could slow an orbiting vehicle to a stop, but such a decelerating rocket would need to be as large as the one that initially accelerated the vehicle to orbital speed, and then sending the decelerating rocket into orbit would require an unimaginably large initial launch vehicle.

The simplest solution is to use aerodynamic drag in the atmosphere to steadily dissipate a vehicle's kinetic energy before it lands. However, the reentry trajectory must be chosen so that both:

1. Deceleration of the vehicle is not too severe for the instrumentation or the passengers (if there are any). The deceleration must be prolonged over at least a few minutes to limit it to levels that can be tolerated by humans. At the upper limit of human endurance, a $\sim 10g \sim 100$ m/sec^2 deceleration would require 80 seconds to brake an initial velocity of 8000 m/sec, and a more readily tolerated $\sim 3g \sim 30$ m/sec^2 deceleration would require ~ 4.5 minutes.

2. Heating of the vehicle from aerodynamic drag is not too great. The kinetic energy ~ 30 MJ/kg that must be dissipated is 2-4 times larger than the energy required to vaporize most materials. Methods for safely dissipating this much energy without vaporizing the vehicle will now be discussed.

When air flow impacts a reentering vehicle, the kinetic energy density $\rho v^2/2$ of the flow relative to the vehicle is converted to thermal energy density $\rho c_p T$, heating the air to a temperature T far higher than the ambient air temperature. As the temperature rises, air molecules first are excited into higher energy states, then dissociate into individual atoms, and then finally are progressively stripped of their electrons and ionized. While the specific heat capacity at constant pressure c_p is a constant for air at lower temperatures, at higher temperatures c_p is a function of temperature, to account for these various effects. Air is mostly nitrogen, and monatomic nitrogen would have $c_p \approx 717.5$ J/(kg ^{o}K). As the nitrogen atoms are excited and partially ionized, they gain more degrees of freedom (the electrons can be in various energy levels), so c_p increases. The extent of excitation and ionization and hence the value of c_p vary over the temperature range characteristic of reentry, but in general a good value to use for Earth reentry is:

$$c_p \approx 5000 \ \frac{\mathrm{J}}{\mathrm{kg\ ^oK}} \tag{E.84}$$

A vehicle reentering at velocity v heats the flow directly impacting it (converting virtually all of the kinetic energy $\frac{1}{2}mv^2$ to thermal energy mc_pT, where m is the mass of the air) to a stagnation temperature of

$$T \approx \frac{v^2}{2c_p} \approx 10^{-4}\, v^2_{\mathrm{m/sec}} \ \ ^{\mathrm{o}}\mathrm{K} \tag{E.85}$$

For a vehicle with orbital velocity $v \sim 8000$ m/sec, the stagnation temperature is $T \sim 6400^o$K. This is high enough to melt or vaporize virtually all materials, and is even hotter than the surface of the sun, which is approximately 5800^{o}K.

Since the drag force per cross-sectional area of a vehicle is $C_D\rho v^2/2$ and power is the product of force and velocity, the rate at which a reentering vehicle's kinetic energy is converted to heat is $C_D\rho v^3/2$. Using a coefficient of drag $C_D \approx 2$ for a blunt hypersonic vehicle, the heat production rate is

$$q_{\mathrm{total}} \approx \rho\, v^3 \ \frac{\mathrm{W}}{\mathrm{m}^2} \tag{E.86}$$

For a typical high-altitude atmospheric density $\rho \sim 10^{-4}$ kg/m^3 and vehicle velocity $v \sim 8000$ m/sec, the total heat production rate is an incredible $q_{\mathrm{total}} \sim 50$ MW/m^2.

Fortunately, for a well-designed vehicle, only a small fraction of this heat is transferred to the vehicle, and the rest is imparted to the surrounding air. Ideally a reentry vehicle should have blunt instead of sharp leading surfaces, in order to minimize heating of the vehicle. At hypersonic speeds, a streamlined vehicle creates a weaker shock wave and heats the air less, but the vehicle absorbs much more of the heat that is generated, since the shock and boundary layers are so close to the vehicle, especially where the shock wave is attached at the vehicle's nose. (For such a streamlined design, reentry would first melt the nose, and then proceed to destroy the rest of the vehicle.) In contrast, a very blunt vehicle creates a stronger shock wave and heats the air more, but the vehicle absorbs much less of the heat that is generated, since the shock wave is detached from the vehicle, and the intervening boundary layer serves to insulate the vehicle from most of the heat. Thus modern reentry capsules have broad, flattened heat shields facing the oncoming flow, and modern space-shuttle-type reentry vehicles have blunt noses and rounded leading wing edges and also reenter at a high angle of attack with the flat underside facing the oncoming flow.

At the velocities that will be considered in this section, convection is the dominant mode of heat transfer, although at higher velocities, radiative heat transfer would also need to be considered. The heat transferred from a medium at temperature T_∞ through a boundary layer of thickness δ and thermal conductivity κ to a vehicle of surface temperature T_s and radius R is

$$q_{\mathrm{vehicle}} \approx \frac{\kappa(T_\infty - T_s)}{\delta(R)} \tag{E.87}$$

The laminar boundary layer thickness for a vehicle of size R is $\delta \sim R/\sqrt{\mathrm{Re}_R}$, where Re_R is the Reynolds number, so the heat transfer is

$$q_{\text{vehicle}} \;\sim\; \sqrt{\mathrm{Re}_R}\,\frac{\kappa(T_\infty - T_s)}{R} \tag{E.88}$$

Empirical measurements yield the best numerical factor for heat transfer to a sphere:

$$q_{\text{vehicle}} \;\approx\; 2\,\sqrt{\mathrm{Re}_R}\,\frac{\kappa(T_\infty - T_s)}{R} \tag{E.89}$$

Assuming that the air temperature just beyond the boundary layer is the stagnation temperature $T_\infty = v^2/(2c_p)$, that the stagnation temperature is much higher than the vehicle temperature ($T_\infty \gg T_s$), and that the Reynolds number is $\mathrm{Re}_R = \rho v R/\mu$, Eq. (E.89) becomes

$$q_{\text{vehicle}} \;\approx\; \frac{\kappa/c_p}{\sqrt{\mu}}\sqrt{\frac{\rho}{R}}\,v^{2.5} \;\approx\; \sqrt{\mu}\,\sqrt{\frac{\rho}{R}}\,v^{2.5} \tag{E.90}$$

in which Eq. (E.90) used the relation $\mu \approx \kappa/c_p$ from the Prandtl number for air, $\mathrm{Pr} = c_p\mu/\kappa \approx 1$.

The viscosity of air varies with temperature according to Sutherland's law. Assuming $\mu_0 \approx 1.72 \times 10^{-5}$ Pa·sec and $T_0 \approx 273^o$K, neglecting S in comparison to the temperatures, and using Eq. (E.85), the viscosity may be expressed as:

$$\mu \;\approx\; 1.0 \times 10^{-6}\,\sqrt{T_{^oK}}\;\frac{\text{kg}}{\text{m sec}} \;\approx\; 1.0 \times 10^{-8}\,v_{\text{m/sec}}\;\frac{\text{kg}}{\text{m sec}} \tag{E.91}$$

Combining Eqs. (E.90) and (E.91), the heat transfer becomes

$$q_{\text{vehicle}} \;\approx\; 1 \times 10^{-4}\sqrt{\frac{\rho}{R}}\,v^3\;\frac{\text{W}}{\text{m}^2} \tag{E.92}$$

Of course, a reentering vehicle is generally not spherical, and the precise local and total heat transfer rates will depend on the specific shape of the vehicle. However, Eq. (E.92) is extremely useful for obtaining initial estimates of reentry heat transfer before doing more detailed calculations.

Taking the ratios of Eqs. (E.92) and (E.86), the fraction of the heat transferred to the vehicle is

$$\frac{q_{\text{vehicle}}}{q_{\text{total}}} \;\approx\; 10^{-4}\,\frac{1}{\sqrt{\rho R}} \tag{E.93}$$

For ballpark values of high-altitude atmospheric density $\rho \sim 10^{-4}$ kg/m^3 and reentry capsule size $R \sim 1$ m, the ratio is $q_{\text{vehicle}}/q_{\text{total}} \sim 10^{-2}$. Thus only $\sim 1\%$ of the produced heat is imparted to the vehicle, but that is still a very considerable ~ 0.5 MW/m^2. Likewise, the boundary layer insulates the vehicle from the $\sim 6000^o$K stagnation temperature of the airflow, although heat transfer across the boundary layer can still heat the leading surfaces of the vehicle to 1000–2000^{o}K.

To protect the vehicle, these leading surfaces are covered by a heat shield. The underside of the U.S. Space Shuttle was covered with low-density tiles made of silica fibers (the tiles had a net density only $\sim 6\%$ that of solid silica, the remainder of the volume being empty space to minimize thermal conductivity) covered with black borosilicate paint, and the shuttle's nose and leading wing edges had tiles of carbon-carbon composite (graphite fibers for strength embedded in amorphous carbon for lower thermal conductivity than carbon lattices) better able to withstand the higher temperatures in those locations. Because these tiles were very good thermal radiators and insulators, they reradiated most of the heat they acquired back to the airflow, and conducted very little of the heat to the rest of the shuttle. Most other reentry vehicles are single-use and employ ablative heat shields that are gradually vaporized during reentry in order to remove the thermal energy they have absorbed before it can be conducted to the rest of the vehicle. For example, each U.S. Apollo command module used a fiberglass heat shield that was initially $\sim 25\%$ silica fibers and $\sim 75\%$ epoxy resin; after reentry most of the silica fibers remained, but the epoxy resin had been charred until only carbon remained from its initial composition.

Since the power dissipated by atmospheric deceleration is $\sim \rho v^3$, to limit deceleration and heating to tolerable levels, it is important to choose reentry trajectories that remain as high as possible (to minimize ρ) while the velocity v is still very large. Reentry trajectories suitable for different types of missions are shown in Fig. E.270: (a) ballistic reentry, (b) lifting reentry, (c) skip reentry, and (d) double-dip reentry.

The atmospheric density decays exponentially with increasing altitude, starting from the sea level value $\rho_o \approx 1.225$ kg/m^3. Physically, higher air weighs on lower air, making it more dense, and all of that weighs even more on air below that, making the density vary exponentially:

$$\rho = \rho_o \, e^{-H/H_o} \tag{E.94}$$

$$\text{where } H_o \equiv \frac{RT}{g} \approx 29.3 \, T_{^o\mathrm{K}} \text{ m} \qquad \text{Atmospheric scale height} \tag{E.95}$$

The stratosphere is the most important layer of the atmosphere for reentry. For the temperature $T \approx 220$ ^{o}K typical of the stratosphere, the scale height is $H_o \approx 6.5$ km.

A vehicle of cross-sectional area A experiences aerodynamic drag D and lift L forces:

$$D = \frac{1}{2} C_D A \rho v^2 \tag{E.96}$$

$$L = \frac{1}{2} C_L A \rho v^2 \tag{E.97}$$

where the drag and lift coefficients C_D and C_L are assumed to be constant for simplicity.

Although centrifugal force is considered (in a rotating frame of reference that effectively follows the vehicle around the earth), curvature of the Earth with respect to the flight path is generally neglected in the following calculations.

To convert the equations of motion into an easily solvable form, reentry calculations commonly change the independent variable in differential equations by taking the ratio of derivatives, as will be shown.

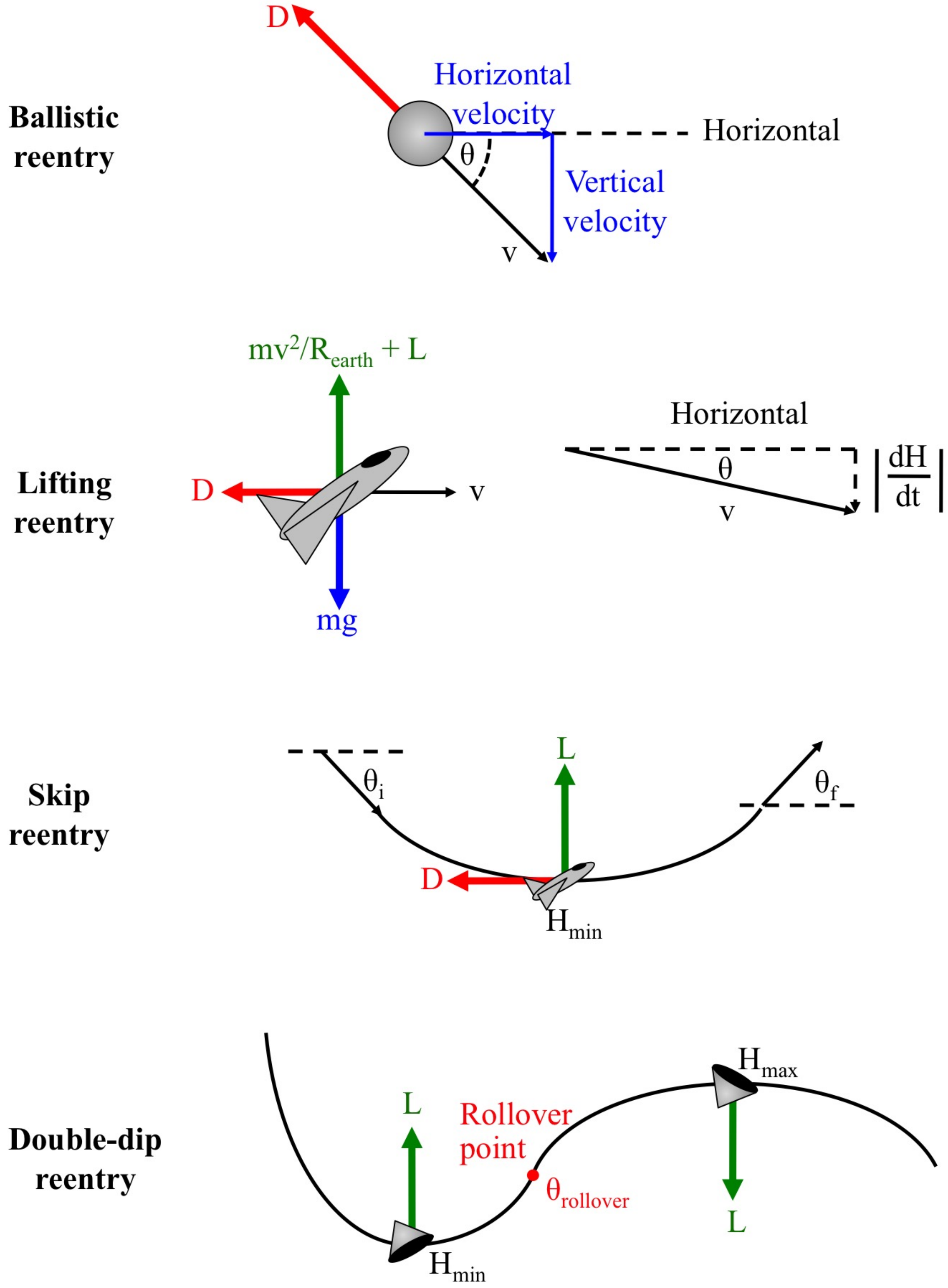
Ballistic reentry
D
Horizontal velocity
Horizontal
θ
Vertical velocity
v
Lifting reentry
$mv^2/R_{earth} + L$
D
v
mg
Horizontal
θ
v
$\left|\frac{dH}{dt}\right|$
Skip reentry
θ_i
L
θ_f
D
H_{min}
Double-dip reentry
H_{max}
L
Rollover point
$\theta_{rollover}$
L
H_{min}

Figure E.270: Atmospheric reentry approaches include ballistic reentry, lifting-body reentry, skip reentry, and double-dip reentry.

A. Ballistic reentry

In a ballistic reentry (Fig. E.270), the vehicle cannot generate aerodynamic lift; this applies to many warheads and the Vostok and Mercury space capsules. The effective gravitational acceleration, the difference between the downward gravitational acceleration and the upward centrifugal acceleration, is between 0 and 1 g. (0 g would be a circular orbit with the gravitational and centrifugal forces balanced, and 1 g would be falling with no forward velocity.) As will be shown, the vehicle deceleration due to aerodynamic drag is far larger than this, so gravity and centrifugal force may be neglected. The vehicle's initial velocity v_i is typically of the order of v_o from Eq. (E.83). The pitch angle θ between the trajectory and the local horizontal is defined to be negative when downward; for simplicity it is assumed to be constant. Using Eq. (E.96), Newton's second law for the acceleration a along the trajectory is

$$a \;=\; \frac{dv}{dt} \;=\; -\,\frac{1}{2m}\,C_D A\rho v^2 \tag{E.98}$$

Taking the ratio of $d\rho/dH = -\rho/H_o$ [using Eq. (E.94)] and $dH/dt = -v\,|\sin\theta|$, one finds:

$$\frac{d\rho}{dt} \;=\; \frac{d\rho}{dH}\,\frac{dH}{dt} \;=\; \frac{\rho v}{H_o}\;|\sin\theta| \tag{E.99}$$

Equation (E.99) may be used to rewrite Eq. (E.98), changing the independent variable from t to ρ:

$$\frac{dv}{d\rho} \;=\; \frac{dv/dt}{d\rho/dt} \;=\; -\,\frac{C_D A H_o}{2m\,|\sin\theta|}\;v \tag{E.100}$$

Equation (E.100) is simply an equation for exponential decay, so its solution is

$$v \;=\; v_i\,\exp\left(-\,\frac{C_D A H_o}{2m\,|\sin\theta|}\;\rho\right) \tag{E.101}$$

$$\;=\; v_i\,\exp\left(-\,\frac{C_D A H_o \rho_o}{2m\,|\sin\theta|}\;e^{-H/H_o}\right) \tag{E.102}$$

Inserting Eq. (E.101) into Eq. (E.98) yields the acceleration as a function of the local density:

$$a \;=\; -\,\frac{C_D A\rho v_i^2}{2m}\,\exp\left(-\,\frac{C_D A H_o \rho}{m\,|\sin\theta|}\right) \tag{E.103}$$

Setting $d/d\rho$ of Eq. (E.103) equal to zero, one finds the density at which maximum deceleration occurs:

$$\frac{da}{d\rho} \;=\; -\,\frac{C_D A v_i^2}{2m}\,\exp\left(-\,\frac{C_D A H_o \rho}{m\,|\sin\theta|}\right)\left(1\;-\;\frac{C_D A H_o \rho}{m\,|\sin\theta|}\right) \;=\; 0$$

$$\Longrightarrow\;\; \rho_{\text{max decel}} \;=\; \frac{m\,|\sin\theta|}{C_D A H_o} \tag{E.104}$$

Inserting Eq. (E.104) into (E.101) and (E.94) gives the velocity and altitude for the maximum deceleration:

$$v_{\text{max decel}} \;=\; e^{-1/2}\, v_i \;\approx\; 0.607\, v_i \tag{E.105}$$

$$H_{\text{max decel}} \;=\; H_o \ln\left(\frac{\rho_o}{\rho_{\text{max decel}}}\right) \;=\; H_o \ln\left(\frac{C_D A H_o \rho_o}{m\,|\sin\theta|}\right) \tag{E.106}$$

Note that for an object with a sufficiently large mass and small cross section for drag ($m/A \to \infty$), atmospheric drag does not slow an object much, and Eq. (E.106) predicts that maximum deceleration would not occur until a theoretical negative altitude, whereas of course the solid ground (not included in the equation) intervenes to cause maximum deceleration at $H = 0$. The reentry and impact of a large, dense meteorite would be a good example.

Plugging Eq. (E.104) into Eq. (E.103) gives the maximum deceleration:

$$\begin{aligned} |a|_{\text{max decel}} \;&=\; \frac{v_i^2\,|\sin\theta|}{2H_o e} \;=\; \frac{R_\oplus}{2H_o e}\;|\sin\theta|\left(\frac{v_i}{v_o}\right)^2\;\text{g} \\ &\approx\; 180\;|\sin\theta|\left(\frac{v_i}{v_o}\right)^2\;\text{g} \end{aligned} \tag{E.107}$$

From Eq. (E.107), the maximum deceleration is independent of the vehicle drag coefficient. For a given reentry angle, vehicles with different values of C_D experience the same maximum deceleration, though higher-drag vehicles experience it at a higher altitude, according to Eq. (E.106).

The deceleration can be over 100 g for $v_i \sim v_o$ and large reentry angles θ. This justifies the original assumption that the effective gravitational acceleration could be neglected. If the reentry angle could be made arbitrarily small, Eq. (E.107) shows that the deceleration would approach zero. Unfortunately, even in a ballistic reentry into the atmosphere from a circular orbit with $v_i = v_o$, the decelerating vehicle will begin to lose altitude as its decreasing upward centrifugal acceleration fails to balance the downward gravitational acceleration, so there is a minimum achievable value of θ and hence a minimum achievable value for the peak deceleration. At the point of maximum deceleration, this difference between the gravitational and centrifugal forces produces a net downward effective gravitational acceleration of

$$|g_{\text{effective}}|_{\text{max decel}} \;=\; g \;-\; \frac{(v_o/\sqrt{e})^2}{R_\oplus} \;=\; \frac{e-1}{e}\,g \tag{E.108}$$

Assuming that θ is small, the vehicle's horizontal velocity at the point of maximum deceleration is approximately

$$\frac{v_o}{\sqrt{e}} \;=\; v_o - |a|_{\text{avg}}\,\Delta t \tag{E.109}$$

$$\Longrightarrow\; \Delta t \;=\; \frac{v_o}{|a|_{\text{avg}}}\,\frac{\sqrt{e}-1}{\sqrt{e}}\;, \tag{E.110}$$

in which Δt is the time between the beginning of reentry and the point of maximum deceleration, and $|a|_{\text{avg}}$ is the average deceleration during that time.

Similarly, for small θ the downward vertical velocity at the point of maximum deceleration is approximately

$$\frac{v_o}{\sqrt{e}}\,\theta \;=\; |g_{\text{effective}}|_{\text{avg}}\;\Delta t \tag{E.111}$$

$$\Longrightarrow\;\theta \;=\; (\sqrt{e}-1)\,\frac{|g_{\text{effective}}|_{\text{avg}}}{|a|_{\text{avg}}} \tag{E.112}$$

$$\approx\; (\sqrt{e}-1)\,\frac{|g_{\text{effective}}|_{\text{max decel}}}{|a|_{\text{max decel}}}\;, \tag{E.113}$$

which may be used to find the minimum achievable ballistic reentry angle.

Inserting Eqs. (E.115) and (E.107) into Eq. (E.113) and solving for θ yields

$$\theta \;=\; \left[\frac{(\sqrt{e}-1)(e-1)}{180e}\right]^{1/2} \;\approx\; 0.0477\text{ radians}\quad(\text{or }\;2.73^{o}) \tag{E.114}$$

$$|a|_{\text{max decel}} \;=\; 180\theta\text{ g} \;\approx\; 8.6\text{ g} \tag{E.115}$$

The Soviet Vostok and U.S. Mercury capsules executed a shallow-angle ballistic reentry and hence experienced $\sim 8-9$ g of deceleration, at the upper limit of what their pilots could tolerate. Reducing $|a|_{\text{max}}$ below this value requires aerodynamic lift, so that the spacecraft can remain longer at very high altitudes, where the air is less dense and the aerodynamic drag less severe.

For a Vostok or Mercury reentry with typical values $H_o \approx 6500$ m, $C_D \approx 2$, $A \sim 3$ m^2, $\rho_o \approx 1.225$ kg/m^3, $m \sim 2000$ kg, and $\theta \approx 0.0477$, Eqs. (E.104) and (E.106) indicate that maximum deceleration for a capsule reentering from circular orbit occurs at an atmospheric density $\rho_{\text{max decel}} \approx 2\times10^{-3}$ kg/m^3 and an altitude $H_{\text{max decel}} \approx 40$ km.

Inserting Eq. (E.101) into Eq. (E.92), the heat transfer rate to the vehicle during ballistic reentry is

$$q_{\text{vehicle}} \;\approx\; 1\times10^{-4}\,v_i^3\sqrt{\frac{\rho}{R}}\;\exp\left(-\,\frac{3C_DAH_o}{2m\,|\sin\theta|}\,\rho\right)\;\frac{\text{W}}{\text{m}^2} \tag{E.116}$$

Using Eq. (E.116) and setting $dq_{\text{vehicle}}/d\rho = 0$, one finds that the maximum heat transfer occurs when the atmospheric pressure is

$$\rho_{\text{max heat}} \;=\; \frac{m\,|\sin\theta|}{3C_DAH_o} \;=\; \frac{1}{3}\,\rho_{\text{max decel}}\;, \tag{E.117}$$

or $\rho_{\text{max heat}} \sim 7\times10^{-4}$ kg/m^3 for the Vostok/Mercury case.

Inserting Eq. (E.117) into Eq. (E.116) gives the maximum heat transfer:

$$q_{\text{vehicle, max}} \quad \approx \quad 1 \times 10^{-4}\, v_i^3 \sqrt{\frac{m\,|\sin\theta|}{3eC_D A H_o R}}\ \frac{\text{W}}{\text{m}^2} \tag{E.118}$$

For a Vostok or Mercury capsule with $v_i = v_o \approx 8000$ m/sec, $m \sim 2000$ kg, $\theta \sim 0.0477$, $C_D \approx 2$, $A \sim 3$ m^2, $H_o \approx 6500$ m, and $R \sim 1$ m, the maximum heat transfer is $q_{\text{vehicle, max}} \sim 1$ MW/m^2. As predicted by Eqs. (E.86) and (E.93), this is indeed only a small fraction of the total generated heat, although it is still a large number and required a very good ablative heat shield.

On the other hand, a reentering A-4 (or a warhead or capsule separated from an A-4, if that were done) would have a much lower initial velocity than the Vostok and Mercury capsules, since it would not be coming from orbit. From Table E.4, a typical value for the A-4 would have been more like $v_i \approx 1750$ m/sec, or around 0.22 of orbital velocity (8000 m/sec). Assuming for simplicity that all other parameters were roughly the same, Eq. (E.118) shows that the maximum heat transfer to the A-4 would have been roughly $(1750/8000)^3 \approx 0.01$ times as large as that for reentering orbital capsules, or $q_{\text{vehicle, max}} \sim 10$ kW/m^2, a much more manageable number. Of course, that is the peak heat transfer on a reentry trajectory designed to be as shallow as possible in order to minimize the deceleration and heating. An A-4 on a steeper reentry trajectory would experience greater heating.

Inserting Eq. (E.117) into Eq. (E.101) and (E.94) gives the velocity and altitude for the maximum heating:

$$v_{\text{max heat}} \quad = \quad e^{-1/6}\, v_i \ \approx\ 0.846\, v_i \tag{E.119}$$

$$H_{\text{max heat}} \quad = \quad H_o \ln\left(\frac{\rho_o}{\rho_{\text{max heat}}}\right) \ = \ H_o \ln\left(\frac{3C_D A H_o \rho_o}{m\,|\sin\theta|}\right) \tag{E.120}$$

$$= \quad H_o \ln\left(\frac{3C_D A H_o \rho_o}{m\,|\sin\theta|}\right) + H_o \ln 3 \ \approx\ H_{\text{max decel}} + 1.10 H_o \tag{E.121}$$

Thus the point of maximum heating occurs earlier during reentry than the point of maximum deceleration, or when the vehicle is approximately 1.1 $H_o \approx 7$ km higher.

B. Lifting-body reentry

Lifting reentry (Fig. E.270) covers the case in which the vehicle generates aerodynamic lift as well as drag. For simplicity, the ratio of the lift and drag forces from Eqs. (E.97) and (E.96), $L/D = C_L/C_D$, is assumed to remain constant during the reentry, and the initial velocity is assumed to be the orbital velocity v_o from Eq. (E.83). Because very small angles minimize the deceleration (as shown for ballistic reentry) and the vehicle now has lift to help support it, one can assume that the trajectory is essentially horizontal.

Neglecting vertical acceleration, the downward gravitational and upward centrifugal and lift forces must balance:

$$mg = \frac{mv^2}{R_\oplus} + L \tag{E.122}$$

Using Eq. (E.97) for L in Eq. (E.122) and solving for the velocity v yields:

$$mg = \frac{mv^2}{R_\oplus} + \frac{1}{2} C_L A \rho v^2 \tag{E.123}$$

$$\Longrightarrow v = \frac{v_o}{\sqrt{1 + \frac{R_\oplus C_L A \rho}{2m}}} = \frac{v_o}{\sqrt{1 + \frac{R_\oplus C_L A \rho_o}{2m}\, e^{-H/H_o}}} \tag{E.124}$$

$$\approx \sqrt{\frac{2mg}{C_L A \rho_o}}\, e^{H/2H_o} \tag{E.125}$$

The approximation in the last step is valid once the velocity is low enough that the centrifugal force is much smaller than the lift.

Equation (E.122) may be turned around into a form that will be useful in a moment:

$$\frac{1}{m} = \frac{g}{L}\left[1 - \left(\frac{v}{v_o}\right)^2\right] \tag{E.126}$$

Newton's second law along the trajectory is:

$$\frac{dv}{dt} = -\frac{D}{m} \tag{E.127}$$

Substituting Eq. (E.126) into Eq. (E.127), one finds the acceleration:

$$\frac{dv}{dt} = -g\,\frac{D}{L}\left[1 - \left(\frac{v}{v_o}\right)^2\right] \tag{E.128}$$

Thus the magnitude of the deceleration increases as the velocity v decreases, asymptotically approaching gD/L:

$$|a|_{\text{max decel}} \;=\; \frac{D}{L}\;\;\text{g} \tag{E.129}$$

The Gemini, Apollo, and Soyuz capsules had a lift-to-drag ratio $L/D \approx 0.5$, giving a maximum deceleration ~ 2 g, much better than the earlier Mercury and Vostok. The U.S. Space Shuttle's lift-to-drag ratio was $L/D \approx 2.5$, so its peak deceleration was even more gentle, ~ 0.4 g. A-9 would have had $L/D \approx 5$, or a ~ 0.2 g peak deceleration. Silbervogel would have had $L/D \approx 6.5$, or a ~ 0.15 g peak deceleration during the gliding portion of its terminal trajectory. (Silbervogel would have experienced brief periods of greater acceleration during its skips off the atmosphere before that; see p. 5818.)

The reentry trajectory of a lifting body actually deviates from the horizontal by a small negative (downward) angle θ, which may be found from the relation:

$$\sin\theta \;=\; \frac{1}{v}\,\frac{dH}{dt} \;=\; \frac{1}{v}\,\frac{dv/dt}{dv/dH} \tag{E.130}$$

Taking the derivative d/dH of both sides of Eq. (E.125) produces

$$\frac{dv}{dH} \;=\; \frac{Lv}{2mgH_o} \tag{E.131}$$

Inserting Eqs. (E.127) and (E.131) into Eq. (E.130), one finds:

$$\sin\theta \;=\; 2\,\frac{D}{L}\,\frac{H_o g}{v^2} \tag{E.132}$$

Equation (E.132) shows that the magnitude of θ increases (the vehicle drops more rapidly) as the velocity v decreases, since there is less centrifugal force and lift to keep the vehicle aloft.

θ is small enough that the approximation $\sin\theta \approx \theta$ is valid. Using a mid-reentry value of the velocity, $v \sim v_o/2$, yields an estimate of θ during reentry:

$$\theta \;\sim\; 8\,\frac{D}{L}\,\frac{H_o}{R_\oplus} \;\approx\; \frac{D}{L}\,0.5\,^o\,, \tag{E.133}$$

validating the initial assumption of nearly horizontal flight.

The ground range Δx travelled during reentry may be estimated from θ and the altitude drop during that time, say $\Delta H \sim 2H_o$:

$$\Delta x \;\;\sim\;\; \frac{\Delta H}{\sin\theta} \;\sim\; \frac{2H_o}{\theta} \;\sim\; \frac{1}{4}\,\frac{L}{D}\,R_\oplus \tag{E.134}$$

Since the U.S. Space Shuttle had $L/D \approx 2.5$, Eq. (E.134) shows that it could travel ~ 4000 km during reentry. Thus the reentry began very far from the actual landing site. Because the shuttle had no fuel to maneuver during landing, it arrived at the landing site with excess altitude to ensure that it would not fall short of the runway. If the extra altitude was not needed for contingencies, the shuttle banked back and forth to burn off the extra altitude before approaching the runway.

Inserting Eqs. (E.94) and (E.124) into Eq. (E.92), the heat transfer to a lifting reentry vehicle is

$$q_{\text{vehicle}} \approx 1 \times 10^{-4} \sqrt{\frac{\rho_o}{R}}\, v_o^3\, e^{-H/2H_o} \left(1 + \frac{R_\oplus C_L A \rho_o}{2m}\, e^{-H/H_o}\right)^{-3/2} \frac{\text{W}}{\text{m}^2} \qquad \text{(E.135)}$$

Setting $dq_{\text{vehicle}}/dH = 0$ and solving for H yields the altitude where peak heat transfer occurs:

$$H_{\text{max heat}} = H_o \ln\left(\frac{R_\oplus C_L A \rho_o}{m}\right) \qquad \text{(E.136)}$$

Inserting Eq. (E.136) into Eq. (E.135), the maximum heat transfer to a lifting reentry vehicle is

$$q_{\text{vehicle, max}} \approx 5 \times 10^{-5}\, v_o^3 \sqrt{\frac{\rho_o m}{R R_\oplus C_L A \rho_o}} \quad \frac{\text{W}}{\text{m}^2} \qquad \text{(E.137)}$$

As a good number to keep in mind for comparison, sunlight warms an absorbing surface with a heat transfer rate of approximately 1.4 kW/m^2 above the Earth's atmosphere (or somewhat less on Earth's surface, after the atmosphere has filtered out some of the solar radiation).

For a Space Shuttle reentry with typical values $H_0 \approx 6500$ m, $R_\oplus \approx 6.38 \times 10^6$ m, $C_L \approx 2$, $A \sim 400$ m^2, $\rho_o \approx 1.225$ kg/m^3, and $m = 1{\times}10^5$ kg, Eq. (E.136) indicates that maximum heat transfer occurs at an altitude $H_{\text{max heat}} \sim 70$ km, or an atmospheric pressure $\rho_{\text{max heat}} = m/(R_\oplus C_L A) \sim 2 \times 10^{-5}$ kg/m^3. Also using the representative values $R \sim 20$ m and $v_o \approx 8000$ m/sec, the maximum heat transfer is $q_{\text{vehicle, max}} \sim 25$ kW/m^2, or ∼40x lower than the ballistic case. Note that the large lift means the decelerating vehicle can stay much higher in the atmosphere much longer than a ballistic vehicle with no lift, changing the point of maximum heating to a much higher altitude, much lower atmospheric density, and much lower peak heat transfer. In fact, the heat transfer is sufficiently low that silica tiles were sufficient to insulate the vehicle and re-radiate the heat to the surrounding atmosphere, whereas higher heat transfer values would require single-use ablative heat shields.

Neglecting relatively insignificant changes in the other parameters in Eq. (E.137), the main difference between the U.S. Space Shuttle and the older German spacecraft that were under development was velocity. The Space Shuttle had to reenter from an orbital velocity $v \approx 8000$ m/sec. The German vehicles did not have to reach orbit and would have had lower velocities. Because the velocity is cubed in Eq. (E.137), their heat transfer rates were much lower.

For the A-9 by itself (launched without the A-10 booster stage), the maximum velocity would have been $v \approx 1750$ m/sec (based on the A-4 from Table E.4), so the maximum heat transfer during reentry would have been $q_{\text{vehicle, max}} \sim 0.26$ kW/m^2, much smaller even than solar heating. Thus reentry heating would not have been a problem at all, at least with a properly chosen trajectory.

For the A-9 launched from the A-10 booster stage, the maximum velocity would have been higher, $v \approx 3870$ m/sec from Eq. (E.68). The maximum reentry heat transfer would have been $q_{\text{vehicle, max}} \sim 2.8$ kW/m^2, only about twice as much as solar heating, and roughly nine times smaller than the heating experienced by the U.S. Space Shuttle. Again, reentry heating would not have been a problem with a properly chosen trajectory.

For Silbervogel, the maximum velocity would have been even higher, $v \approx 6170$ m/sec from Eq. (E.72). The maximum reentry heat transfer would have been $q_{\text{vehicle, max}} \sim 11$ kW/m^2, still less than half the heating experienced by the U.S. Space Shuttle. Silbervogel also would have experienced this heating for a shorter period of time than the Space Shuttle, since it would not have been coming all the way from orbital velocity. Suitable metal alloys might have withstood and re-radiated the heat during Silbervogel's reentry while insulation protected the interior, or ablative coatings could have been added to the exterior. The greatest problem with Silbervogel's design is that heating would have been concentrated at the sharp leading edges of the vehicle, as opposed to the rounded leading edges of the Space Shuttle. However, because realistically the Silbervogel would not have been reused if launched during wartime, whereas the Space Shuttle was designed to be reused for many flights, this level of heating could have been acceptable.

Thus from this simple theoretical analysis, it appears that there are no fundamental reasons why an A-9, A-9/A-10, or Silbervogel could not have survived reentry.

C. Skip reentry

If desired, a vehicle can skip off the upper atmosphere like a fast-moving flat rock skipping off the surface of a pond, and this is called a skip reentry (Figs. E.269 and E.270). This was the main idea of Silbervogel, which would have used rocket power to achieve a suborbital flight and then would have repeatedly skipped off the atmosphere to travel most of the way around the Earth before reentering for a final time and landing. One skip with initial velocity v_i will be considered here to illustrate the basic principle.

Gravity and centrifugal force are negligible relative to the strong aerodynamic forces involved in skipping off the atmosphere. Newton's second law parallel and perpendicular to the trajectory is

$$m\,\frac{dv}{dt} = -D \tag{E.138}$$

$$mv\,\frac{d\theta}{dt} = L \tag{E.139}$$

Taking the ratio of Eqs. (E.138) and (E.139) gives the variation of velocity with vehicle pitch angle,

$$\frac{dv}{d\theta} = \frac{dv/dt}{d\theta/dt} = -\frac{D}{L}\,v \tag{E.140}$$

Equation (E.140) describes exponential decay due to drag during the skip, so its solution is

$$v = v_i \exp\left[-\frac{D}{L}(\theta - \theta_i)\right] , \tag{E.141}$$

in which θ_i is the initial pitch angle for atmospheric entry. If the vehicle does not lose much of its velocity during the skip, its pitch angle θ_f leaving the atmosphere is approximately the mirror image of the angle entering the atmosphere, $\theta_f = -\theta_i$, like a light ray reflecting off a surface. Using these angles in Eq. (E.141) yields

$$v_f = v_i \exp\left(-2\theta_i \frac{D}{L}\right) \tag{E.142}$$

Newton's second law perpendicular to the trajectory in Eqs. (E.138) and (E.139) indicates that

$$\frac{d\theta}{dt} = \frac{C_L A \rho v}{2m} \tag{E.143}$$

An equation for the altitude may be found by taking the ratio of $dH/dt = v \sin\theta$ and Eq. (E.143):

$$\begin{aligned} \frac{dH}{d\theta} &= \frac{dH/dt}{d\theta/dt} = \frac{2m\sin\theta}{C_L A\rho} \\ &= \frac{2m\sin\theta}{C_L A\rho_o e^{-H/H_o}} \end{aligned} \tag{E.144}$$

Separating variables in Eq. (E.144) and integrating gives the minimum altitude during the skip:

$$\begin{aligned} \frac{C_L A\rho_o}{2m}\int_{\infty}^{H_{\min}} dH\, e^{-H/H_o} &= \int_{\theta_i}^{0} d\theta\, \sin\theta \\ \Longrightarrow\quad H_{\min} &= H_o \ln\left[\frac{C_L A\rho_o H_o}{2m(1-\cos\theta_i)}\right] \end{aligned} \tag{E.145}$$

Pilots are generally happier if $H_{\min}$ is greater than 0, which means that the argument of the logarithm in Eq. (E.145) must be greater than 1. For small values of θ_i, the approximation $\cos\theta_i \approx 1 - \theta_i^2/2$ may be used, and the positive altitude requirement reduces to:

$$\theta_i^2 < \frac{C_L A\rho_o H_o}{m} \tag{E.146}$$

Thus skipping requires a small entry angle θ_i and/or large coefficient of lift C_L.

Using Eq. (E.145), the atmospheric density at the minimum altitude is

$$\rho_{\text{at min}} = \rho_o\, e^{-H_{\min}/H_o} = \frac{2m(1-\cos\theta_i)}{C_L A H_o} \tag{E.147}$$

The maximum acceleration is lateral due to the lift and occurs at the minimum altitude:

$$
\begin{aligned}
|a|_{\max} &= \frac{L_{\text{atmin}}}{m} = \frac{C_L A \rho_{\text{at min}} v_{\text{at min}}^2}{2m} \\
&= \frac{v_i^2}{H_o}\,(1-\cos\theta_i)\exp\left(-2\theta_i\,\frac{D}{L}\right) \\
&\approx 490\left(\frac{v_i}{v_o}\right)^2 \theta_i^2 \exp\left(-2\theta_i\,\frac{D}{L}\right)\ \text{g} \qquad \text{(E.148)}
\end{aligned}
$$

Using $v_i \sim v_o$ and $\theta_i = 5^o \approx 0.087$ rad and neglecting the exponential factor yields $|a|_{\max} \approx 3.7$ g.

The ground range Δx traversed while the angle changes by $\Delta\theta$ may be estimated from Eq. (E.143):

$$
\Delta\theta \sim \frac{C_L A \rho}{2m}\, v\,\Delta t \sim \frac{C_L A \rho}{2m}\,\Delta x \qquad \text{(E.149)}
$$

Using Eq. (E.149) with $\Delta\theta = 2\theta_i$, the ground range covered during the entire skip maneuver is

$$
(\Delta x)_{\text{skip}} \sim \frac{2m}{C_L A \rho_{\text{atmin}}}\,2\theta_i = \frac{2\theta_i}{1-\cos\theta_i}\,H_o \approx \frac{26\ \text{km}}{\theta_i}\,, \qquad \text{(E.150)}
$$

which is ~ 300 km for $\theta_i = 5^o \approx 0.087$ rad. The range travelled above the atmosphere between each skip would be much larger than that (Fig. E.269).

In addition to suborbital bombers, skip reentries are extremely useful for aerobraking, or slowing an interplanetary spacecraft into orbit when it arrives at its target planet. By plotting the spacecraft's trajectory so that its perigee slightly dips into the planet's upper atmosphere, one can cause the spacecraft to lose enough velocity to lower its apogee from infinity (escape velocity) to some finite value for an orbit around the planet. If the velocity loss on one skip is not too great, just the trajectory of the spacecraft tangentially grazing the curved atmosphere of the planet is enough to cause the spacecraft to "pull up" from the skip, even if the vehicle is not capable of lift. In practice, though, it is better to employ lift as in the skip example calculated above, since it affords much more control over the aerobraking process to deal with fluctuations in atmospheric density. If necessary to minimize the forces and heating the spacecraft experiences during each skip, several successive passes through a planet's atmosphere with a small skip each time can be used to aerobrake from very large initial velocities.

D. Double-dip reentry

Skip reentries are also useful as part of a more complicated maneuver called a double-dip reentry (Fig. E.270), which is used by spacecraft returning to the Earth from deep space, such as in the Apollo missions to the moon.

E.8 Conclusions

This final section gives a brief overview of some possible combinations of payloads and delivery vehicles, as well as broader conclusions based on information in this and the other appendices.

While rocket pioneers such as Hermann Oberth and Wernher von Braun always wanted to use rockets to carry scientific instruments or astronauts to explore space, and jet pioneers such as Hans von Ohain hoped to utilize faster aircraft to improve transportation networks, wartime priorities and wartime funding compelled the creators of new aerospace vehicles to consider methods of using those vehicles to deliver destructive payloads to military targets.

E.8.1 Payloads

Military payloads that were used or planned may be divided into several categories:

- Conventional explosives. These were extensively used with the V-1 cruise missile, A-4 or V-2 liquid propellant ballistic missile, Rheinbote solid propellant ballistic missile, and a wide variety of aircraft. Yet the enormous expense of developing such vehicles, and the great difficulty of successfully sending many of them to distant Allied targets, strongly suggest that conventional explosives were not the primary intended payload, but only an interim measure while other payloads were being perfected or debated.

- Fuel-air explosives. Although fuel-air explosives also use conventional explosives, they disperse those in the air before igniting them, then combust them with oxygen from the air, so the resulting blast affects a much larger area than a conventional bomb with the same amount of explosive would. Beginning in the 1930s, large teams of German-speaking scientists developed and demonstrated fuel-air explosives. By the end of the war, fuel-air explosive bombs weighing up to several tons each had been mass-produced and stockpiled (pp. 538–557). Such fuel-air explosives could have been intended for delivery by aircraft or by large missiles.

- Biological weapons. According to official histories, Germany's wartime work on biological weapons was only defensive (developing methods to protect against biological weapons) instead of offensive (developing biological weapons and methods to disseminate them). Yet as shown by the examples in Section A.3, many credible wartime and early postwar documents from archives mentioned offensive development of biological weapons, and even mass production and packaging of such weapons into deployable bombs. Since so many other relevant documents were either destroyed or remain buried in classified archives, the details of the German biological weapons program are even more mysterious than those of the German nuclear weapons program. Nonetheless, if biological weapons were indeed produced, they could have been intended for delivery by a wide range of aircraft, missiles, or other methods.

- Chemical weapons. The nerve agents tabun and sarin were mass-produced and packaged into bombs in wartime Germany (Section 3.5). Soman was produced and tested on an experimental scale, and could potentially have been packaged into bombs before the end of the war. The even more deadly V-series nerve agents were invented, synthesized, and tested during the war (Section A.4); it is possible that they were produced on a large scale. Germany also produced a number of chemical weapons other than nerve agents, ranging from highly corrosive chemicals to endothermic reactions reported to cause freezing conditions. Any of those chemical weapons could potentially have been delivered by aircraft, missiles, or other means.

- Nuclear weapons, including fission bombs (Section D.8), fusion bombs (H-bombs, Section D.9), and radiological weapons (radioactive "dirty" bombs, p. 5171). There is considerable evidence that fission bombs were successfully tested during the war (Sections D.10, D.11, and D.12), and that a hydrogen bomb was nearing completion when the war ended (Section D.9). Given the enormous amount of resources that would have been invested in developing nuclear weapons, and Germany's desperate state late in the war, there must have been concrete plans and methods for delivering such weapons to Allied targets, including targets in the United States. In the usual German fashion, several different delivery methods, including aircraft and large missiles, were probably developed in parallel.

E.8.2 Delivery Vehicles

There is significant evidence that Germany was developing the following specific methods to deliver weapons of mass destruction (especially nuclear weapons) to Allied targets such as New York and Washington, D.C.:

1. There is documentary evidence for intercontinental bomber aircraft, and for nuclear weapons designed to be dropped by such aircraft (often dropped with a parachute, indicating that the expected blast was so large that the aircraft needed more time to escape to a safe distance after dropping the bomb). See for example:

Erwin Respondek (p. 4194)

Werner Grothmann (pp. 4272 and 4436)

Edmund Tilley (p. 4350)

Stars and Stripes, *Washington Post*, and other major newspapers (p. 5197)

Werner Wächter (pp. 4640–4664)

Hermann Goering (p. 5200)

Alexander P. de Seversky (p. 5202)

Chicago Daily Tribune (p. 5202)

Allen Dulles (p. 5203)

German prisoner of war (p. 5206)

Henry H. Fowler (pp. 5206–5206)

Convair (p. 5208)

Albert Ducrocq (p. 5218)

Roy Fedden (p. 5246)

New York Times (p. 5403)

Other postwar Allied discoveries of intercontinental jet bombers intended to attack the United States (Section E.1)

2. There is documentary evidence that V-1 cruise missiles were modified to attack the United States with a payload sufficiently destructive to justify the mission. There were several different versions of the V-1 that could be ground-launched, submarine-launched, or air-launched from a large aircraft, and that were either unmanned or manned. See for example:

Allied discoveries of piloted and air-launched V-1 missiles (p. 1841)

Interrogation of Edmund Sorg regarding nuclear-armed V-1 missiles (pp. 4896–4897)

Hans Kammler's 23 April 1945 telegram ordering the destruction of special V-1s near Berlin to prevent them from being captured by Russian forces (p. 4897)

Allied intelligence reports on submarine-launched V-1 missiles intended to attack the United States (pp. 5618–5627)

3. There is a great deal of evidence that the A-4 (V-2), A-9/A-10, Silbervogel, or other rockets were intended and even fully built to carry nuclear weapons. (Such rockets were primarily ground-launched, although the A-4 or smaller rockets could be submarine-launched.) See for example:

Hermann Zumpe (p. 4359)
Wernher von Braun (pp. 4361–4362)
Eugen Sänger and Irene Bredt (p. 4363)
G. Ward Price (p. 4365)
Defense Minister Rodolfo Graziani (p. 4366)
Air Intelligence Report (p. 4368)
OSS, October 1944 (p. 4402)
Luigi Romersa (p. 4432)
Felix Kersten (p. 4470)
Wilhelm Wulff (p. 4471)
General Ivan Ilyichev (p. 4486)
Igor Kurchatov (4496)
Horst Kirfes (p. 4532)
German film captured by Soviets (p. 4533)
Swiss intelligence report (p. 4590)
Hans Ulrich Rudel (p. 4591)
Italian ambassador Anfuso in Berlin (p. 4600)
OSS, November 1944 (p. 4605)
J. Edgar Hoover (p. 4605)
Theodor Soucek (p. 4617)
German officials in Spain (pp. 4629–4631)
Erwin Giesing (p. 4634)
Henry Picker (pp. 4635–4639)
Werner Wächter (pp. 4640–4664)
General Gerhard Franz (p. 4674)
Gordon Young (pp. 4679–4681)
Walter Dornberger (p. 4684)
George Earle and FDR (pp. 4701–4703)
Dutch intelligence (pp. 4832–4853)
French intelligence (pp. 4854–4855)
Postwar French hiring (p. 4857)
Major Edmund Tilley (pp. 4902–4903)
Heinrich Klein (p. 4913)
Wilhelm Voss (pp. 4914–4934)
Los Angeles Times (p. 5012)
U.K. House of Lords (pp. 5014–5016)
Gerald Klein (p. 5020)
U.S. News (p. 5022)
Office of War Information (pp. 5023–5027)
R. P. Linstead and T. J. Betts (p. 5030)
General George Marshall (pp. 5031–5032)
General William Richardson (pp. 5035–5036)
AAF Review (p. 5038)
Colonel George Woods (pp. 5072–5073)
Roy Fedden (p. 5246)
Multiple *New York Times* sources (p. 5321)
Albert Speer (p. 5322)
Peenemünde chemist (p. 5334)
Alex Baum (p. 5335)
Peenemünde engineer (p. 5341)
German prisoner of war (p. 5342)
U.S. Strategic Air Forces in Europe (p. 5343)
Otto Skorzeny (p. 5352)
Gordon Cooper (p. 5353)
Werner Grothmann (pp. 5355–5359)
Albert Ducrocq (p. 5380)
Heinz Stoelzel (pp. 5393–5396)
U.S. intelligence analysts (pp. 5431, 5437)
Nils Werner Larsson (p. 5459)
General Henry Arnold (pp. 5454–5466)
General Donald Putt (pp. 5472–5476)
Senator Elbert D. Thomas (p. 5479)
U.S. Army Ordnance (p. 5482)
Charles J. V. Murphy (pp. 5488–5489)
Senator Harry Byrd (pp. 5492–5495)
New York Times, etc. (pp. 5496–5497)
Time magazine (p. 5514–5515)
General Egmont F. Koenig (p. 5544)
Soviet SS-3 program (pp. 5573–5575)
Squadron Leader E. J. André Kenny (p. 5763)

E.8.3 Forgotten History

History is a series of factual events that actually occurred. Something either really happened, or really did not. An event either happened one way, or it happened another way. Afterward, different sources may make contradictory claims about what happened, or all references to a particular historical event may be silenced or erased. As a result, it may not be possible to know exactly what happened at certain places and times in the past, yet that does not change the fact that concrete events and actions did in fact occur.

Conventional history almost uniformly paints a particular picture of advanced weapons technology during and after World War II. According to conventional history, Germany experimented with nerve agents but never considered using them for fear of Allied chemical weapons. According to conventional history, Germany never produced nuclear weapons, biological weapons, or fuel-air bombs. According to conventional history, Germany never built intercontinental jet bombers, V-1 cruise missiles capable of striking the United States, or any rockets with larger sizes or longer ranges than the A-4 (V-2). According to conventional history, the V-1 and V-2 programs were foolish and counterproductive for Germany. According to conventional history, the steady march toward Allied victory was simply a matter of time, drawn out only by an irrational German stubbornness to admit the inevitable defeat. According to conventional history, the United States and United Kingdom demonstrated technological superiority over Germany by inventing radar, building and exploding the first fission bombs, and winning World War II. According to conventional history, the United States further proved its own inherent technological superiority after the war by inventing the hydrogen bomb, jet fighters, stealth technology, smart bombs, transistors, computers, lasers, plastics, the contraceptive pill, and biotechnology, as well as by winning the Space Race and the Cold War.

That conventional history, taught nearly worldwide and learned by heart for 75+ years, appears to be a fictional canvas that was painted by a combination of people who knew it was false and others who hoped it was true. That fictional canvas is punctured and torn by large numbers of highly placed Allied and German sources quoted in this book, by more that could be cited, and by others that remain yet to be discovered in archives. Behind that tattered canvas lies the true history of wartime and postwar advanced technologies.

Documents record that German-speaking scientists invented and successfully demonstrated jet fighters, radar, stealth technology, smart bombs, transistors, computers, plastics, the contraceptive pill, and biotechnology, and were developing lasers when the war ended. Documents record that all of those creations and countless others were transferred to the United States, which later claimed credit for them. Documents record that German-controlled territory was filled with an interconnected infrastructure of hundreds of high-tech research and manufacturing sites from Norway to Strassburg (Strasbourg) to Budapest to Königsberg (Kaliningrad), many of them in huge, fully furnished underground installations, some of them even equipped with video conferencing systems and computers. Documents record that wartime Germany successfully developed fuel-air bombs, chemical weapons up to advanced V-series nerve agents, biological weapons, and fission bombs, and that it was close to finishing a hydrogen bomb when the war ended. Documents record that wartime Germany built at least 40 intercontinental jet bombers, several different types of rockets larger than the A-4, and at least two different types of piloted space planes. Documents record that weapons of mass destruction were integrated with delivery vehicles corresponding to all elements of the modern nuclear triad—ground-launched intercontinental missiles, submarine-launched missiles, and intercontinental jet bombers—for missions to Allied targets, including U.S. cities.

Then the Allies won.

What happened, what really happened? The conventional historical explanation that those advanced German technologies never existed is simply untenable in the face of so much evidence. Perhaps the weapons of mass destruction or their delivery vehicles were not quite ready before the end of the war, slowed by Allied attacks, sabotage, or mismanagement by senior German officials. Maybe the weapons and vehicles were ready, but their numbers and their probability of success were too small for it to be strategically useful to employ them late in the war. It could be that the novel threat of mutual assured destruction (MAD, by primitive but effective chemical weapons from the Allied side, and by nuclear, biological, and advanced chemical weapons from the German side) constrained both sides to fight the war to its end using only conventional weapons. Perhaps during the war, the Allies secretly contacted key German officials, such as Hans Kammler, and made it far more personally rewarding for those officials to turn over German advanced weapons technologies to the Allies than to employ them against the Allies. Or maybe some combination of those factors is the true explanation.

There are countless questions that still need to be answered, vast amounts of evidence that still must be sought in classified archives and industrial archaeological excavations. What is certain is that the real history of wartime and postwar technology does not resemble the fictions that have been repeated in history books, documentaries, and films for 75+ years. The real history, the full story, was far more dramatic than that.

And it deserves to be told.

Bibliography

Jeder, der den ganzen Verlauf der wissenschaftlichen Entwickelung kennt, wird natürlich viel freier und richtiger über die Bedeutung einer gegenwärtigen wissenschaftlichen Bewegung denken als derjenige, welcher, in seinem Urtheil auf das von ihm selbst durchlebte Zeitelement beschränkt, nur die augenblickliche Bewegungsrichtung wahrnimmt.

They that know the entire history of the development of science, will, as a matter of course, judge more freely and more correctly of the significance of any present scientific movement than they, who limited in their views to the age in which their own lives have been spent, contemplate merely the momentary trend that the course of intellectual events takes at the present moment.

Ernst Mach. 1897. *Die Mechanik in ihrer Entwickelung: Historisch-kritisch dargestellt.*
3rd ed. Leipzig: F. A. Brockhaus. Introduction. English translation by Thomas J. McCormack.

The Bibliography is organized into a number of broad categories, instead of being one long list with everything mixed together. Please see the following page for an overview of the organization of the Bibliography. Hopefully any difficulties in guessing in which category a citation will be found are greatly outweighed by the convenience to those who are interested in easily perusing all sources on a given topic.

Newspaper articles, series of government reports, and archival references are given in separate lists later in the Bibliography.

Last names with von or vom retain that prefix, but are alphabetized as if it were not there.

Names, dates, and abbreviations used to cite each reference in the book are indicated in bold red font. Dates for newspapers are given as year-month-day, as in 1945-04-30.

I hope that this Bibliography, including its topical sections and especially its sections of report titles and archival locations, will serve as a useful roadmap for other researchers to investigate some of these topics more deeply and to make additional historical discoveries in the future.

Bibliography Section	Page
Scientific Innovation in the Modern World	5827
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AAAS1 (American Academy of Arts & Sciences). **2014**. *Restoring the Foundation: The Vital Role of Research in Preserving the American Dream.* Cambridge, Massachusetts: American Academy of Arts & Sciences. https://www.amacad.org/content/Research/researchproject.aspx?d=1276

AAAS2 (American Association for the Advancement of Science). **2018**. R&D Budget and Policy Program. https://www.aaas.org/program/rd-budget-and-policy-program

Aitkenhead, Decca. **2013**. Peter Higgs: I Wouldn't Be Productive Enough for Today's Academic System. *The Guardian* (6 December 2013). https://www.theguardian.com/science/2013/dec/06/peter-higgs-boson-academic-system

Alberts, Bruce, Marc W. Kirschner, Shirley Tilghman, and Harold Varmus. **2014**. Rescuing US Biomedical Research from Its Systemic Flaws. *Proceedings of the National Academy of Sciences of the U.S.A.* 111:16:5773–5777.

Alvarez, Robert. **2014**. Y-12: Poster Child for a Dysfunctional Nuclear Weapons Complex. *Bulletin of the Atomic Scientists* (4 August 2014). https://thebulletin.org/2014/08/y-12-poster-child-for-a-dysfunctional-nuclear-weapons-complex/

Andersen, Kurt. **2020**. *Evil Geniuses: The Unmaking of America: A Recent History.* New York: Random House.

Andreessen, Marc. **2020**. It's Time to Build. https://future.a16z.com/its-time-to-build/

Arora, Ashish, Sharon Belenzon, and Andrea Patacconi. **2015**. *Killing the Golden Goose? The Decline of Science in Corporate R&D. NBER Working Paper No. 20902.* Cambridge, Massachusetts: National Bureau of Economic Research. https://www.nber.org/papers/w20902

Arora, Ashish, Sharon Belenzon, Andrea Patacconi, and Jungkyu Suh. **2019**. Why the U.S. Innovation Ecosystem Is Slowing Down. *Harvard Business Review.* 26 November.
https://hbr.org/2019/11/why-the-u-s-innovation-ecosystem-is-slowing-down

Armstrong, J. S. **1997**. Peer Review for Journals: Evidence on Quality Control, Fairness, and Innovation. *Science and Engineering Ethics* 3:63-84.

Atkinson, Robert D. **2014a**. *Understanding the U.S. National Innovation System.* Information Technology & Innovation Foundation. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3079822
https://itif.org/publications/2020/11/02/understanding-us-national-innovation-system-2020/

Atkinson, Robert D. **2014b**. The Decline of America's National Innovation System. Information Technology & Innovation Foundation. https://itif.org/publications/2014/07/16/decline-america's-national-innovation-system/

Azoulay, Pierre, Joshua S. Graff Zivin and Manso Gustavo. **2011**. Incentives and Creativity: Evidence from the Academic Life Sciences. *RAND Journal of Economics* 42:3:527–554.

Baumberg, Jeremy J. **2018**. *The Secret Life of Science: How It Really Works and Why It Matters.* Princeton: Princeton University Press.

Begley, Sharon. **2009**. Why Academia Slows the Search for Cures. *Newsweek* (15 June 2009).
https://www.newsweek.com/why-academia-slows-search-cures-80505

Begley, C. Glenn, and Lee M. **Ellis**. **2012**. Raise Standards for Preclinical Cancer Research. *Nature* 483:531–533. https://doi.org/10.1038/483531a

Belluz, Julia, Brad Plumer, and Brian Resnick. **2016a**. The 7 Biggest Problems Facing Science, According to 270 Scientists. *Vox* (14 July 2016). https://www.vox.com/2016/7/14/12016710/science-challeges-research-funding-peer-review-process

Belluz, Julia, Brad Plumer, and Brian Resnick. **2016b**. We Asked Hundreds of Scientists What They'd Change About Science. Here Are 33 of Our Favorite Responses. *Vox* (14 July 2016). https://www.vox.com/2016/7/14/12120746/science-challenges-fixes

Bhattacharya, Jay, and Mikko **Packalen**. **2020**. Stagnation and Scientific Incentives. NBER Working Paper Series 26752. https://www.nber.org/papers/w26752

Bloom, Nicholas, Charles I. Jones, John Van Reenen, and Michael Webb. **2020**. Are Ideas Getting Harder to Find? *American Economic Review* 110:4:1104–1144. https://doi.org/10.1257/aer.20180338 https://web.stanford.edu/∼chadj/IdeaPF.pdf

Blumenstyk, Goldie. **2014**. *American Higher Education in Crisis?: What Everyone Needs to Know*. Oxford: Oxford University Press.

Boudreau, Kevin J., Eva C. Guinan, Karim R. Lakhani, and Christoph Riedl. **2016**. Looking Across and Looking Beyond the Knowledge Frontier: Intellectual Distance, Novelty, and Resource Allocation in Science. *Management Science* 62:10:2765–2783. https://doi.org/10.1287/mnsc.2015.2285

Braben, Donald W. 1994. *To Be a Scientist: The Spirit of Adventure in Science and Technology*. Oxford: Oxford University Press.

Braben, Donald W. 2004. *Pioneering Research: A Risk Worth Taking*. Hoboken, New Jersey: Wiley.

Braben, Donald W. 2008. *Scientific Freedom: The Elixir of Civilization*. Hoboken, New Jersey: Wiley.

Braben, Donald W. 2014. *Promoting the Planck Club: How Defiant Youth, Irreverent Researchers and Liberated Universities Can Foster Prosperity Indefinitely*. Hoboken, New Jersey: Wiley.

Brenner, Sydney. **2014**. Frederick Sanger (1918–2013). *Science* 343:6168:262.

Brezis, E. S. **2007**. Focal Randomization: An Optional Mechanism for the Evaluation of R&D Projects. *Science and Public Policy* 34:691-698.

Brodwin, Erin. 8 September **2019**. MIT's Media Lab Has an Ambitious Project That Purports to Revolutionize Agriculture. Insiders Say It's Mostly Smoke and Mirrors. *Business Insider* https://www.businessinsider.in/mits-media-lab-has-an-ambitious-project-that-purports-to-revolutionize-agriculture-insiders-say-its-mostly-smoke-and-mirrors-/articleshow/71030483.cms

Buxton, Bill. **2008**. The Price of Forgoing Basic Research. *Bloomberg Businessweek* (17 December 2008). https://www.bloomberg.com/news/articles/2008-12-17/the-price-of-forgoing-basic-researchbusinessweek-business-news-stock-market-and-financial-advice

Carey, Kevin. **2015**. *The End of College: Creating the Future of Learning and the University of*

Everywhere. Riverhead Books.

Carr, Edward. **2009**. The Last Days of the Polymath. *1843 Magazine* (Autumn). https://www.economist.com/1843/2009/10/01/the-last-days-of-the-polymath

Carr, Nicholas. **2012**. Why Our Innovators Traffic in Trifles. *Wall Street Journal* 6 July. https://www.wsj.com/articles/SB10001424052702304141204577508820786062502 and see also https://www.roughtype.com/?p=1800

Carr, Nicholas. **2015**. Does innovation arc toward decadence? *Rough Type* 20 January. https://www.roughtype.com/?p=5452

Carroll, Archie B., Kenneth J. Lipartito, James E. Post, Patricia H. Werhane, and Kenneth E. Goodpaster. **2012**. *Corporate Responsibility: The American Experience.* Cambridge, UK: Cambridge University Press.

Cauwels, Peter, and Didier **Sornette**. **2020**. Are 'Flow of Ideas' and 'Research Productivity' in Secular Decline? Swiss Finance Institute Research Paper 20-90. http://dx.doi.org/10.2139/ssrn.3716939 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3716939

Charlton, Bruce G. **2009**. Why Are Modern Scientists So Dull? How Science Selects for Perseverance and Sociability at the Expense of Intelligence and Creativity. *Medical Hypotheses* 72:237–243.

Charlton, Bruce G. **2012**. *Not Even Trying: The Corruption of Real Science.* Buckingham, U.K.: University of Buckingham Press.

Childress, Herb. **2019**. *The Adjunct Underclass: How America's Colleges Betrayed Their Faculty, Their Students, and Their Mission.* Chicago: University of Chicago Press.

Chu, Johan S. G., and James A. **Evans**. **2021**. Slowed Canonical Progress in Large Fields of Science. *Proceedings of the National Academy of Sciences* 118:41:e2021636118. https://doi.org/10.1073/pnas.2021636118

Collins, Jim. **2003**. The 10 Greatest CEOs Of All Time: What These Extraordinary Leaders Can Teach Today's Troubled Executives. *Fortune Magazine* 21 July. https://www.jimcollins.com/article_topics/articles/10-greatest.html

Collison, Patrick, and Michael **Nielsen**. **2018**. Science Is Getting Less Bang for Its Buck. *The Atlantic* November 16. https://www.theatlantic.com/science/archive/2018/11/diminishing-returns-science/575665/

Collison, Patrick, and Tyler **Cowen**. **2019**. Humanity Needs to Get Better at Knowing How to Get Better. *The Atlantic* July 30. https://www.theatlantic.com/science/archive/2019/07/we-need-new-science-progress/594946/

Cowen, Tyler. **2011**. *The Great Stagnation.* New York: Dutton.

Cowen, Tyler, and Ben **Southwood**. **2019**. Is the Rate of Scientific Progress Slowing Down? GMU Working Paper in Economics No. 21-13. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3822691

Dahlgreen, Will. 7 October **2016**. Why Are Nobel Prize Winners Getting Older? *BBC News.* https://www.bbc.com/news/science-environment-37578899

Denning, Steve. **2013**. The Surprising Reasons Why America Lost Its Ability to Compete. *Forbes* (March 10, 2013). https://www.forbes.com/sites/stevedenning/2013/03/10/the-surprising-reasons-why-america-lost-its-ability-to-compete/

Denning, Steve. **2014**. Why IBM Is in Decline. *Forbes* (30 May 2014). https://www.forbes.com/sites/stevedenning/2014/05/30/why-ibm-is-in-decline/

Douthat, Ross. **2020**. *The Decadent Society: How We Became the Victims of Our Own Success.* New York: Avid Reader Press.

Dutton, Edward, and Bruce G. **Charlton**. **2016**. *The Genius Famine: Why We Need Geniuses, Why They Are Dying Out, Why We Must Rescue Them.* Buckingham, U.K.: University of Buckingham Press.

Dyer, Davis. **1998**. *TRW: Pioneering Technology + Innovation Since 1900.* Boston: Harvard Business School Press.

Dzeng, Elizabeth. **2014**. How Academia and Publishing are Destroying Scientific Innovation: A Conversation with Sydney Brenner. *The King's Review* (24 February 2014). https://elizabethdzeng.com/tag/post-doc/ https://www.kingsreview.co.uk/interviews/how-academia-and-publishing-are-destroying-scientific-innovation-a-conversation-with-sydney-brenner

Economist. *The Economist.* **2010**. Doctoral Degrees: The Disposable Academic: Why Doing a PhD is Often a Waste of Time. (16 December 2010). https://www.economist.com/christmas-specials/2010/12/16/the-disposable-academic

Errington, Timothy M., Alexandria Denis, Nicole Perfito, Elizabeth Iorns, and Brian A. Nosek. **2021a**. Reproducibility in Cancer Biology: Challenges for Assessing Replicability in Preclinical Cancer Biology. *eLife* 10:e67995.

Errington, Timothy M., Maya Mathur, Courtney K. Soderberg, Alexandria Denis, Nicole Perfito, Elizabeth Iorns, and Brian A. Nosek. **2021b**. Investigating the Replicability of Preclinical Cancer Biology. *eLife* 10:e71601.

Estrin, Judy. **2008**. *Closing the Innovation Gap.* New York: McGraw-Hill.

Farrow, Ronan. 6 September **2019**. How An Élite University Research Center Concealed Its Relationship with Jeffrey Epstein. *The New Yorker.* https://www.newyorker.com/news/news-desk/how-an-elite-university-research-center-concealed-its-relationship-with-jeffrey-epstein

Feighery, Linda. **2013**. Opinion: Academic Waste: From Funding to Publishing, Academic Research Needlessly Burns Through Time and Money. *The Scientist* 17 October. https://www.the-scientist.com/opinion/opinion-academic-waste-38547

Foote, Caleb, and Robert D. **Atkinson**. **2019**. Federal Support for R&D Continues Its Ignominious Slide. Information Technology & Innovation Foundation. 12 August. https://itif.org/publications/2019/08/12/federal-support-rd-continues-its-ignominious-slide/

Foroohar, Rana. **2017**. *Makers and Takers: How Wall Street Destroyed Main Street.* New York: Crown Business.

Fox, Justin. **2012**. When Will This Low-Innovation Internet Era End? *Wired*, 27 April 2012. https://www.wired.com/2012/04/opinion-fox-net-innovation/

Frey, B. S. **2003**. Publishing as Prostitution? Choosing Between One's Own Ideas and Academic Success. *Public Choice* 116:205-2023.

GAO (U.S. Government Accountability Office). **2016**. *Federal Agencies Need to Address Aging Legacy Systems. Report GAO-16-696T*. Washington, DC. https://www.gao.gov/products/gao-16-696t

Garner, Mandy. **2006**. I'm a postdoc—get me out. *Times Higher Education* (17 November 2006). https://www.timeshighereducation.com/features/im-a-postdoc-get-me-out/206810.article

Gee, Alastair. **2017**. Facing Poverty, Academics Turn to Sex Work and Sleeping in Cars. *The Guardian* 28 September. https://www.theguardian.com/us-news/2017/sep/28/adjunct-professors-homeless-sex-work-academia-poverty

Gillies, Donald. **2008**. *How Should Research Be Organised?*. London: College Publications.

Gladwell, Malcolm. **2008**. *Outliers: The Story of Success*. New York: Little, Brown and Company.

Godlee, F., C. R. Gale, and C. N. Martyn. **1998**. The Effect on the Quality of Peer Review of Blinding Reviewers and Asking Them to Sign Their Reports: A Randomised Controlled Trial. *Journal of the American Medical Association* 280:237-240.

Gordon, Robert J. **2000**. Does the "New Economy" Measure Up to the Great Inventions of the Past? NBER Working Paper Series 7833. https://www.nber.org/papers/w7833

Gordon, Robert J. **2012**. Is US Economic Growth Over? Faltering Innovation Confronts the Six Headwinds. NBER Working Paper Series 18315. https://www.nber.org/papers/w18315

Gordon, Robert J. **2016**. *The Rise and Fall of American Growth: The U.S. Standard of Living Since the Civil War*. Princeton: Princeton University Press.

Gref, Lynn G. **2010**. *The Rise and Fall of American Technology*. New York: Algora Publishing.

Gruber, Jonathan, and Simon **Johnson**. **2019**. *Jump-Starting America: How Breakthrough Science Can Revive Economic Growth and the American Dream*. New York: PublicAffairs.

Hage, Jerald, and J. Rogers **Hollingsworth**. **2000**. A Strategy for the Analysis of Idea Innovation Networks and Institutions. *Organization Studies* 21:5: 971–1004.

Hanlon, Michael. **2014**. The Golden Quarter: Some of Our Greatest Cultural and Technological Achievements Took Place Between 1945 and 1971. Why Has Progress Stalled? *Aeon* 3 December 2014. https://aeon.co/essays/has-progress-in-science-and-technology-come-to-a-halt

Harris, Richard, and Robert **Benincasa**. **2014**. U.S. Science Suffering From Booms And Busts In Funding. *Morning Edition* 9 September 2014. https://www.npr.org/sections/health-shots/2014/09/09/340716091/u-s-science-suffering-from-booms-and-busts-in-funding

Hollingsworth, J. Rogers. **2000**. Doing Institutional Analysis: Implications for the Study of Innovations. *Review of International Political Economy* 7:4:595–644.

Horgan, John. **2015**. *The End of Science: Facing the Limits of Knowledge in the Twilight of the Scientific Age*. Revised ed. New York: Basic Books.

Horrobin, D. F. **1990**. The Philosophical Basis of Peer Review and the Suppression of Innovation. *Journal of the American Medical Association* 263:1438-1441.

Hsueh, Brian. **2015**. At TEDMED 2015: Thinking About "Breaking Through" the Valley of Death in Science. SCOPE (23 November 2015). https://scopeblog.stanford.edu/2015/11/23/at-tedmed-2015-thinking-about-breaking-through-the-valley-of-death-in-science/

Huebner, Jonathan. **2005**. A Possible Declining Trend for Worldwide Innovation. *Technological Forecasting & Social Change* 72:980–986.
https://doi.org/10.1016/j.techfore.2005.01.003

Hyde, Lewis. **2019**. *The Gift.* 3rd ed. New York: Vintage Books.

Ietto-Gillies, G. **2008**. A XXI-Century Alternative to XX-Century Peer Review. *Real-World Economics Review* 45:10-22.

Ioannidis, John P. A. **2011**. Fund People Not Projects. *Nature* 477:529–531.

Ip, Greg. **2016**. The Economy's Hidden Problem: We're Out of Big Ideas. *Wall Street Journal* 20 December. https://www.wsj.com/articles/the-economys-hidden-problem-were-out-of-big-ideas-1481042066

Isaacson, Walter. **2019**. How America Risks Losing Its Innovation Edge. *Time.* 3 January.
https://time.com/longform/america-innovation/

Junod, Pascal. **2013**. An Aspiring Scientist's Frustration with Modern-Day Academia: A Resignation (9 September 2013).
https://www.sott.net/article/266422-An-aspiring-scientists-frustration-with-modern-day-academia-A-Resignation

Kendzior, Sarah. **2015**. *The View from Flyover Country: Dispatches from the Forgotten America.* New York: Flatiron Books.

Kennefick, D. **2009**. Einstein Versus the Physical Review. *Physics Today* 58:43.

King, Kenneth. **2011**. *Germs Gone Wild: How the Unchecked Development of Domestic Bio-Defense Threatens America.* Pegasus.

Kramer, David. **2016**. What Went Wrong with the Los Alamos Contract? *Physics Today* 69:3:22.
http://dx.doi.org/10.1063/PT.3.3103

Kuhn, Thomas S. **2012**. *The Structure of Scientific Revolutions.* 4th ed. Chicago: University of Chicago Press.

Kwoh, Leslie. **2012**. You Call That Innovation? *Wall Street Journal* (May 23, 2012).
https://www.wsj.com/articles/SB10001424052702304791704577418250902309914

LaFeber, Walter. **1997**. *The Clash: U.S.-Japanese Relations Throughout History.* New York: W. W. Norton.

Laitinen, Herbert A. **1970**. Reverberations from the Mansfield Amendment. *Analytical Chemistry* 42:7:689.

Landes, David S., Joel Mokyr, and William J. Baumol. **2010**. *The Invention of Enterprise: En-*

trepreneurship from Ancient Mesopotamia to Modern Times. Princeton: Princeton University Press.

Lin, Thomas. **2014**. At 90, Freeman Dyson Ponders His Next Challenge. *Wired* (31 March 2014). https://www.wired.com/2014/03/quanta-freeman-dyson-qa/

López-Corredoira, Martin. **2013**. *The Twilight of the Scientific Age.* Boca Raton, Florida: Brown-Walker Press.

Lucibella, Michael, and Alaina G. **Levine**. **2010**. It's a Bumpy Ride to Private Management for Los Alamos, Livermore. *APS News* 19:6:1,6.
https://www.aps.org/publications/apsnews/201006/losalamos.cfm

Lyons, Dan. **2016**. *Disrupted: My Misadventure in the Start-Up Bubble.* New York: Hachette.

Lyons, Dan. **2018**. *Lab Rats: How Silicon Valley Made Work Miserable for the Rest of Us.* New York: Hachette.

Maddox, John. **1995**. Is the Principia Publishable Now? *Nature* 376:6539:385.

Mahoney, M. **1997**. Publication Prejudices: an Experimental Study of Confirmatory Bias in the Peer Review System. *Cognitive Therapy and Research* 1:161-175.

Malone, Patrick. **2017**. A Near-Disaster at a Federal Nuclear Weapons Laboratory Takes a Hidden Toll on America's Arsenal. Center for Public Integrity. 18 June. https://apps.publicintegrity.org/nuclear-negligence/near-disaster/

Mandel, Michael. **2009**. The Failed Promise of Innovation in the US. *Bloomberg Businessweek* (3 June 2009). https://www.bloomberg.com/news/articles/2009-06-03/the-failed-promise-of-innovation-in-the-u-dot-s

Mann, A. **2011**. NASA Human Space-Flight Programme Lost in Translation. *Nature* 472:16-17.

Matthews, Chris. **2015**. The Death of American Research and Development. *Fortune* (21 December 2015). https://fortune.com/2015/12/21/death-american-research-and-development/

McCurdy, Howard E. **1993**. *Inside NASA: High Technology and Organizational Change in the U.S. Space Program.* Baltimore: Johns Hopkins University Press.

Merton, R. K. **1968**. The Matthew Effect in Science. *Science* 159:3810:56-63.

Millis, Marc G., and Eric W. **Davis**, eds. **2009**. *Frontiers of Propulsion Science.* Reston, Virginia: American Institute of Aeronautics and Astronautics. [See especially Ch. 22, Prioritizing Pioneering Research.]

MIT (Massachusetts Institute of Technology). **2015**. *The Future Postponed: Why Declining Investment in Basic Research Threatens a U.S. Innovation Deficit.* Cambridge, Massachusetts: MIT. https://www.aau.edu/node/8651

Mittra, Indraneel. **2009**. Why Is Modern Medicine Stuck in a Rut? *Perspectives in Biology and Medicine* 52:500-517.

Mooney, Chris. **2006**. *The Republican War on Science.* 2nd ed. New York: Basic Books.

Mooney, Chris, and Sheril **Kirshenbaum**. **2010**. *Unscientific America: How Scientific Illiteracy*

Threatens Our Future. 2nd ed. New York: Basic Books.

Mokyr, Joel. **1990**. *The Lever of Riches: Technological Creativity and Economic Progress.* Oxford: Oxford University Press.

NAS (U.S. National Academy of Sciences). **2007**. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future.* Washington, DC: National Academies Press. https://nap.nationalacademies.org/catalog/11463/rising-above-the-gathering-storm-energizing-and-employing-america-for

NAS (U.S. National Academy of Sciences). **2010**. *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5.* Washington, DC: National Academies Press. https://nap.nationalacademies.org/catalog/12999/rising-above-the-gathering-storm-revisited-rapidly-approaching-category-5

NSF. (U.S. National Science Foundation). **2006**. Time to Degree of U.S. Research Doctorate Recipients. [Average age for receiving a Ph.D. from modern academia is 33.3] https://wayback.archive-it.org/5902/20150628155648/http://www.nsf.gov/statistics/infbrief/nsf06312/nsf06312.pdf

NSF (U.S. National Science Foundation). **2018**. National Center for Science and Engineering Statistics. https://ncses.nsf.gov

Nelson, R. R., ed. **1993**. *National Innovation Systems: A Comparative Analysis.* Oxford: Oxford University Press.

Nesbit, Jeff. **2016**. NASA Won't Get Us to Mars. *U.S. News & World Report* (20 May, 2016). https://www.usnews.com/news/articles/2016-05-20/nasa-will-never-take-us-to-mars-at-the-rate-we-are-going

Odenwald, Sten. **1995**. My First Post-Doc... The Naval Research Laboratory. http://www.astronomycafe.net/guide/w3s7.html

OECD (Organisation for Economic Cooperation and Development). **2018**. Science and Technology. https://www.oecd-ilibrary.org/science-and-technology

O'Neill, Robert. **2012**. Pharmaceutical Mergers and the Decline of Innovation. *Impact* Winter. https://www.hks.harvard.edu/news-events/publications/impact-newsletter/archives/winter-2012/pharmaceutical-mergers-and-the-decline-of-innovation

O'Shaughnessy, Lynn. **2012**. 12 Reasons Not to Get a PhD. *CBS News* (10 July 2012). https://www.cbsnews.com/news/12-reasons-not-to-get-a-phd/ [Average age for receiving a Ph.D. from the modern academic system is 33.3]

OTA (Office of Technology Assessment). **1991**. *Federally Funded Research: Decisions for a Decade.* Washington, D.C.: U.S. Government Printing Office. https://www.princeton.edu/~ota/disk1/1991/9121/912104.PDF

Otto, Shawn Lawrence. **2016**. *The War on Science: Who's Waging It, Why It Matters, What We Can Do About It.* Minneapolis: Milkweed.

Park, Michael, Erin Leahey, and Russell J. Funk. **2023**. Papers and Patents Are Becoming Less Disruptive Over Time. *Nature* 613:138–144.

Pearlstein, Steven. **2018**. *Can American Capitalism Survive? Why Greed Is Not Good, Opportunity Is Not Equal, and Fairness Won't Make Us Poor.* New York: St. Martin's Press.

Peters, D. P., and S. J. **Ceci**. **1982**. Peer Review Practices of Psychological Journals: the Fate of Published Articles, Submitted Again. *Behavioural and Brain Sciences* 5:187-195.

Price, Carter C., and Kathryn A. **Edwards**. **2020**. Trends in Income From 1975 to 2018. Santa Monica, California: RAND Corporation. www.rand.org/pubs/working_papers/WRA516-1.html

Price, Derek J. de Solla. **1986**. *Little Science, Big Science and Beyond.* New York: Columbia University Press.

Racker, E. **1989**. A View of Misconduct in Science. *Nature* 339:91-93.

Ramo, Simon. **1980a**. *America's Technology Slip.* New York: John Wiley & Sons, 1980.

Ramo, Simon. **1980b**. *The Management of Innovative Technological Corporations.* New York: John Wiley & Sons.

Ramo, Simon. **1983**. *What's Wrong with Our Technological Society—and How to Fix It.* New York: McGraw-Hill.

Ramo, Simon. **1988**. *The Business of Science: Winning and Losing in the High-Tech Age.* New York: Hill & Wang.

Ramo, Simon. **2005**. *Meetings, Meetings, and More Meetings: Getting Things Done When People Are Involved.* New York: Taylor Trade Publishing.

Ritchie, Stuart. **2020**. *Science Fictions: How Fraud, Bias, Negligence, and Hype Undermine the Search for Truth.* New York: Metropolitan Books.

Rosenbloom, Richard S., and William J. **Spencer**, eds. **1996**. *Engines of Innovation: U.S. Industrial Research at the End of an Era.* Boston: Harvard Business Review Press.

Rothwell, P. M., and C. N. **Martyn**. **2000**. Reproducibility of Peer Review in Clinical Neuroscience: Is Agreement Between Reviewers Any Greater Than Would Be Expected by Chance Alone? *Brain* 123:1964-1969.

Saez, Emmanuel, and Gabriel **Zucman**. **2016**. Wealth Inequality in the United States Since 1913: Evidence from Capitalized Income Tax Data. *Quarterly Journal of Economics* 131:2:519–578. https://doi.org/10.1093/qje/qjw004

Sandal, Massimo. **2011a**. Goodbye Academia, I Get a Life. blog.devicerandom (18 February 2011). http://blog.devicerandom.org/2011/02/18/getting-a-life/

Sandal, Massimo. **2011b**. Goodbye Academia: The Aftermath. blog.devicerandom (22 February 2011). http://blog.devicerandom.org/2011/02/22/goodbye-aftermath/

Sandal, Massimo. **2016**. Abolish the PhD. blog.devicerandom (16 May 2016). http://blog.devicerandom.org/2016/05/16/abolish-the-phd/

Sarewitz, Daniel. **2016**. Saving Science. *New Atlantis* (Spring/Summer 2016). https://www.thenewatlantis.com/publications/saving-science

Schneider, Leonid. 22 July **2016**. The Infectious Self-Plagiarism of Radiologist Hedvig Hricak. *For Better Science.* https://forbetterscience.com/2016/07/22/the-infectious-self-plagiarism-of-radiologist-hedvig-hricak/

Schneider, Leonid. 1 March **2017**. DFG Decision: Antonia Joussen Innocent Victim of Co-authors' Data Manipulations. *For Better Science.* https://forbetterscience.com/2017/03/01/dfg-decision-antonia-joussen-innocent-victim-of-co-authors-data-manipulations/

Schneider, Leonid. 24 January **2020**. The Full-Service Paper Mill and Its Chinese Customers. *For Better Science.* https://forbetterscience.com/2020/01/24/the-full-service-paper-mill-and-its-chinese-customers/

Scott, Debra Leigh. 12 August **2012**. How The American University Was Killed, in Five Easy Steps. https://junctrebellion.wordpress.com/2012/08/12/how-the-american-university-was-killed-in-five-easy-steps/ [See also many of her other related essays at that website.]

Scranton, Philip. **2006**. Technology, Science, and American Innovation. *Business History* 48:3:311–331.

Serling, Robert J. **1992**. *Legend & Legacy: The Story of Boeing and Its People.* New York: St. Martin's Press.

Shavinina, Larisa V, ed. **2003**. *International Handbook on Innovation.* Oxford: Elsevier. [pp. 1018–1043: Hariolf Grupp, Ićiar Dominguez-Lacasa, and Monika Friedrich-Nishio. The National German Innovation System: Its Development in Different Governmental and Territorial Structures.]

Shavinina, Larisa V, ed. **2013**. *The Routledge International Handbook of Innovation Education.* New York: Routledge.

Sisk, Richard. **2015**. GAO Discovers More Problems at Military Labs Beyond Anthrax Fiasco. *Military.com* (29 June 2015). https://www.military.com/daily-news/2015/06/29/gao-discovers-more-problems-military-labs-beyond-anthrax-fiasco.html

Slywotzky, Adrian. **2009**. Where Have You Gone, Bell Labs? *Bloomberg Business Week* (27 August 2009). https://www.bloomberg.com/news/articles/2009-08-27/where-have-you-gone-bell-labs

Smaldino, Paul E., and Richard **McElreath**. **2016**. The Natural Selection of Bad Science. *Royal Society Open Science* 3:160384.

Smith, Noah. **2020**. Interview: Patrick Collison, Co-Founder and CEO of Stripe. https://www.noahpinion.blog/p/interview-patrick-collison-co-founder

Snow, C. P. **1961**. The Moral Un-Neutrality of Science. *Science* 133:255–262. 27 January.

Steelman, John R. **1947**. *Science and Public Policy: A Program for the Nation.* Vol. 1. Washington, D.C.: U.S. Government Printing Office.

Steinbock, Dan. **2015**. The Decline of US Military Innovation. *Project Syndicate* (January 27, 2015). https://www.project-syndicate.org/commentary/us-military-technology-budget-cuts-by-dan-steinbock-2015-01

Stephenson, Neal. **2011**. Innovation Starvation. *World Policy Journal* 28:3:11–16. https://read.dukeupress.edu/world-policy-journal/article-abstract/28/3/11/84887/Innovation-Starvation https://www.wired.com/2011/10/stephenson-innovation-starvation/

Szent-Györgyi, Albert. **1972**. Dionysians and Apollonians. *Science* 176:4038:966. https://www.science.org/doi/10.1126/science.176.4038.966.a

Tarver, Mark. **2007**. Why I am Not a Professor OR the Decline and Fall of the British University. https://marktarver.com/professor.html

Taschner, R. **2007**. Erosion von Wissenschaft. *Erwägen-Wissen-Ethik* 18:1:58-59.

Terkel, Amanda. **2011**. America's 'Brain Drain': Best And Brightest College Grads Head For Wall Street. *Huffington Post* (15 November 2011). https://www.huffpost.com/entry/brain-drain-college-grads-wall-street_n_1069424

Thiel, Peter. **2011**. The End of the Future. *National Review* (3 October 2011). https://www.nationalreview.com/2011/10/end-future-peter-thiel/

Thiel, Peter, et al. **2016**. What Happened to the Future? https://foundersfund.com/2017/01/manifesto/

Thiel, Peter. **2023**. The Diversity Myth. *The New Criterion* 41:10:4. https://newcriterion.com/issues/2023/6/the-diversity-myth

Thompson, Derek. 1 December **2021**. America Is Running on Fumes. *The Atlantic.* https://www.theatlantic.com/ideas/archive/2021/12/america-innovation-film-science-business/620858/

Trento, Joseph J., and Susan B. **Trento**. **1987**. *Prescription for Disaster: From the Glory of Apollo to the Betrayal of the Shuttle.* New York: Random House.

Trigaux, Robert. **2015**. Talk of town when it arrived, Draper Lab sounds retreat from Tampa Bay. *Tampa Bay Times* (20 April 2015). https://www.tampabay.com/news/business/economicdevelopment/talk-of-town-when-it-arrived-draper-lab-sounds-retreat-from-tampa-bay/2226316/

Vijg, Jan. **2011**. *The American Technological Challenge: Stagnation and Decline in the 21st Century.* New York: Algora Publishing.

Vithlani, Hema. **1997**. *An Empirical Study of the UK Innovation System Prepared by the Department of Trade and Industry.* https://www.oecd.org/science/inno/2380078.pdf

Vollrath, Dietrich E. **2020**. When Did Productivity Growth Slow Down? *Growth Economics Blog.* https://growthecon.com/feed/2020/12/07/BLS-TFP.html

Wagner, Tony. **2012**. *Creating Innovators: The Making of Young People Who Will Change the World.* New York: Scribner.

Warner, John. **2020**. *Sustainable. Resilient. Free.: The Future of Public Higher Education.* Cleveland, Ohio: Belt Publishing.

Young, Alison. **2015a**. CDC to Review Oversight of Bioterror Labs After USA Today Investigation. *USA Today* (21 July 2015). https://www.usatoday.com/story/news/2015/07/21/cdc-review-oversight-bioterror-labs-after-usa-today-investigation/30458589/

Young, Alison. **2015b**. Secret Sanctions Revealed Against University Hosting $1.25 Billion Biolab. *USA Today* (4 August 2015). https://www.usatoday.com/story/news/nation/2015/08/04/secret-sanctions-revealed-against-university-hosting-125-billion-biolab/31075709/

Ziman, John. **1995**. *Of One Mind: The Collectivization of Science*. Woodbury, New York: American Institute of Physics.

The Historical German-Speaking World and Scientific Innovation

ACLS (American Council of Learned Societies). **2000**. *Concise Dictionary of Scientific Biography.* 2nd ed. New York: Scribner.

Adenauer, Konrad. **1966**. *Memoirs 1945–53* Chicago: Henry Regnery.

Albach, Horst, ed. **1993**. *Culture and Technical Innovation: A Cross-Cultural Analysis and Policy Recommendations.* Berlin: Walter de Gruyter.

Alexander, Bevin. **2000**. *How Hitler Could Have Won World War II: The Fatal Errors That Led to Nazi Defeat.* New York: Crown.

Arnold, Matthew. **1882**. *Higher Schools and Universities in Germany.* 2nd ed. London: Macmillan.

Asbury, Jonathan. **2014**. *Imperial War Museums London: Guidebook.* London: Imperial War Museums.

Ash, Mitchell G., ed. **1997**. *German Universities Past and Future: Crisis or Renewal?*. Providence: Berghahn.

Ash, Mitchell G., and Jan **Surman**, eds. **2012**. *The Nationalization of Scientific Knowledge in the Habsburg Empire, 1848-1918.* New York: Palgrave Macmillan.

Bald, Albrecht, and Jörg **Skriebeleit**. **2003**. *Das Außenlager Bayreuth des KZ Flossenbürg: Wieland Wagner und Bodo Lafferentz im "Institut für physikalische Forschung."* Bayreuth: C. und C. Rabenstein.

Baranowski, Frank. **2013**. *Rüstungsproduktion in der Mitte Deutschlands 1929-1945.* Bad Langensalza: Rockstuhl.

Barrowclough, David. **2016**. *Digging for Hitler: The Nazi Archaeologists Search for an Aryan Past.* Fonthill Media.

Basov, A. **1976**. *Landgangen på Bornholm: Baggrunden for landgangen set med sovjetrussiske øjne.* Copenhagen: Antikvariat Richard Levin.

Baumgart, Peter, ed. **1980**. *Bildungspolitik in Preussen zur Zeit des Kaiserreichs.* Stuttgart: Klett-Cotta.

Beardsley, Monroe C., ed. **1960**. *The European Philosophers from Descartes to Nietzsche.* New York: Random House.

Beckh, Joachim. **2005**. *Blitz & Anker: Informationstechnik—Geschichte, Hintergründe.* 2 vols. Norderstedt: Books on Demand.

Beier, A. **1902**. *Die höheren Schulen in Preußen und ihre Lehrer.* Halle: Buchhandlung des Waisenhauses.

Beierl, Florian W. **2011**. *History of the Eagle's Nest: A Complete Account of Adolf Hitler's Alleged "Mountain Fortress."* 7th English ed. Berchtesgaden: Anton Plenk.

Beloff, Max, ed. **1960**. *On the Track of Tyranny: Essays Presented by the Wiener Library to Leonard G. Montefiore, on the Occasion of His Seventieth Birthday.* Vallentine.

Ben-David, Joseph. **1984**. *The Scientist's Role in Society: A Comparative Study.* 2nd ed. Chicago: University of Chicago Press.

Ben-David, Joseph. **1992**. *Centers of Learning: Britain, France, Germany, United States.* London: Routledge.

Berghahn, Volker R. **2005**. *Imperial Germany, 1871–1918: Economy, Society, Culture, and Politics.* 2nd ed. New York: Berghahn Books.

van Berkel, Klaas, Albert van Helden, and Lodewijk Palm, eds. **1998**. *A History of Science in the Netherlands: Survey, Themes and Reference.* Leiden: Brill.

Beyerchen, Alan D. **1977**. *Scientists Under Hitler: Politics and the Physics Community in the Third Reich.* New Haven, Connecticut: Yale University Press.

von Bismarck, Otto. **1942**. *Gedanken und Erinnerungen: Reden und Briefe.* Berlin: Safari.

Black, Edwin. **2012a**. *IBM and the Holocaust: The Strategic Alliance Between Nazi Germany and America's Most Powerful Corporation.* 2nd ed. Washington, D.C.: Dialog Press.

Black, Edwin. **2012b**. *War Against the Weak: Eugenics and America's Campaign to Create a Master Race.* 2nd ed. Washington, D.C.: Dialog Press.

Black, Edwin. **2017**. *Nazi Nexus: America's Corporate Connections to Hitler's Holocaust.* Washington, D.C.: Dialog Press.

Boelcke, Willi A., ed. **1969**. *Deutschlands Rüstung im Zweiten Weltkrieg. Hitlers Konferenzen mit Albert Speer 1942–1945.* Frankfurt am Main: Akademische Verlagsanstalt Athenaion.

Bogdanovich, Peter. **1967**. *Fritz Lang in America.* New York: Praeger.

Bornholm. **1976**. *Bornholmske Samlinger.* II: Vol. 9. Rønne: Colbergs Eftf. Bogtrykkeri.

Borsche, Tilman. **1990**. *Wilhelm von Humboldt.* Munich: Beck.

Bouchal, Robert, and Johannes **Sachslehner**. **2013**. *Unterirdisches Österreich: Vergessene Stollen, Geheime Projekte.* Vienna: Styria Premium.

Bower, Tom. **1997**. *Nazi Gold: The Full Story of the Fifty-Year Swiss-Nazi Conspiracy to Steal Billions from Europe's Jews and Holocaust Survivors.* New York: HarperCollins.

Breuer, William B. **2000**. *Secret Weapons of World War II.* Hoboken, New Jersey: Wiley.

vom Brocke, Bernhard, ed. **1991a**. *Wissenschaftsgeschichte und Wissenschaftspolitik im Industriezeitalter: Das "System Althoff" in historischer Perspektive.* Hildesheim: Lax.

vom Brocke, Bernard. **1991b**. Friedrich Althoff: A Great Figure in Higher Education Policy in Germany. *Minerva* (September 1991) 29:3:269-293.

vom Brocke, Bernhard, and Hubert **Laitko**, eds. **1996**. *Die Kaiser-Wilhelm-/Max-Planck-Gesellschaft und ihre Institute: Studien zu ihrer Geschichte: Das Harnack-Prinzip.* Berlin: De Gruyter. [Weiss, Burghard. Harnack-Prinzip und Wissenschaftswandel: Die Einführung kernphysikalischer Großgeräte (Beschleuniger) an den Instituten der Kaiser-Wilhelm-Gesellschaft.]

Broda, Engelbert. **1979**. Warum war es in Österreich um die Naturwissenschaft so schlecht bestellt? *Wiener Geschichtsblätter* 34:3:89–107.

Brown, John Franklin. **1911**. *The Training of Teachers for Secondary Schools in Germany and the United States.* New York: Macmillan.

vom Bruch, Rüdiger. **2005**. *Bürgerlichkeit, Staat und Kultur im Deutschen Kaiserreich.* Stuttgart: Franz Steiner.

vom Bruch, Rüdiger, Uta Gerhardt, and Aleksandra Pawliczek, eds. **2006**. *Kontinuitäten und Diskontinuitäten in der Wissenschaftsgeschichte des 20. Jahrhunderts.* Stuttgart: Franz Steiner.

vom Bruch, Rüdiger, and Brigitte **Kaderas**, eds. **2002**. *Wissenschaften und Wissenschaftspolitik: Bestandsaufnahmen zu Formationen, Brüchen und Kontinuitäten im Deutschland des 20. Jahrhunderts.* Stuttgart: Franz Steiner.

vom Bruch, Rüdiger, and Rainer A. **Müller**, eds. **1990**. *Formen ausserstaatlicher Wissenschaftsförderung im 19. und 20. Jahrhundert: Deutschland im europäischen Vergleich.* Stuttgart: Franz Steiner. [pp. 211-225: Walter Höflechner. Zur nichtstaatlichen Wissenschaftsförderung in Österreich in der Zeit von 1848 bis 1938 am Beispiel der Akademie der Wissenschaften in Wien.]

vom Bruch, Rüdiger, and Rainer A. **Müller**, eds. **2000**. *Kaiserreich und Erster Weltkrieg, 1871–1918.* Stuttgart: Franz Steiner.

Bruford, W. H. **1975**. *The German Tradition of Self-Cultivation: 'Bildung' from Humboldt to Thomas Mann.* Cambridge, UK: Cambridge University Press.

Brunzel, Ulrich. **2013**. *Hitlers Geheimobjekte in Thüringen.* 16th ed. Meiningen: Heinrich-Jung-Verlagsgesellschaft.

Buchheim, Gisela und Rolf **Sonnemann**, ed. **1990**. *Geschichte der Technikwissenschaften.* Leipzig: Edition Leipzig.

Bunch, Bryan, and Alexander **Hellemans**, eds. **2004**. *The History of Science and Technology.* New York: Houghton Mifflin.

Bryson, Bill. **2003**. *A Short History of Nearly Everything.* New York: Broadway Books. [innovations come from outsiders to fields]

Cahan, David. **1989**. *An Institute for an Empire: The Physikalisch-Technische Reichsanstalt, 1871–1918.* Cambridge, UK: Cambridge University Press.

Cardwell, Donald. **1995**. *The Norton History of Technology.* New York: W.W. Norton.

Caron, François, Paul Erker, and Wolfram Fischer, eds. **1995**. *Innovations in the European Economy Between the Wars.* Berlin: De Gruyter. [pp. 163–173: Gottfried Plumpe. Innovation and the Structure of the IG Farben. pp. 277–319: John Cantwell, The Evolution of European Industrial Technology in the Interwar Period]

Carson, Cathryn, Alexei Kojovnikov, and Helmuth Trischler, eds. **2011**. *Weimar Culture and Quantum Mechanics: Selected Papers by Paul Forman and Contemporary Perspectives on the Forman Thesis.* London: Imperial College Press.

Challoner, Jack, ed. **2009**. *1001 Inventions That Changed the World.* Barron's.

Chandler, Alfred, Jr. **1990**. *Scale and Scope: The Dynamics of Industrial Capitalism.* Cambridge, Massachusetts: Harvard University Press. [pp. 393–395]

Cook, Nick. **2001**. *The Hunt for Zero Point: One Man's Journey to Discover the Biggest Secret Since the Invention of the Atom Bomb.* London: Century.

Cornwell, John. **2003**. *Hitler's Scientists: Science, War, and the Devil's Pact.* New York: Viking. German translation: 2004. *Forschen für den Führer: Deutsche Naturwissenschaftler und der Zweite Weltkrieg.* Bergisch Gladbach: Gustav Lübbe.

Delattre, Lucas. **2005**. *Betraying Hitler. The Story of Fritz Kolbe, the Most Important Spy of the Second World War.* London: Atlantis Books.

Deutsches Museum. **2004**. *Meisterwerke aus dem Deutschen Museum.* 6 vols. Munich: Deutsches Museum.

Dinçkal, Noyan, Christof Dipper, and Detlev Mares, eds. **2010**. *Selbstmobilisierung der Wissenschaft: Technische Hochschulen im "Dritten Reich."* Darmstadt: Wissenschaftlichen Buchgesellschaft.

DK. **2009**. *World War II.* New York: DK.

Dupuy, Trevor Nevitt. **1977**. *A Genius For War: The German Army and General Staff, 1807–1945.* Englewood Cliffs, New Jersey: Prentice-Hall.

EB. *Encyclopaedia Britannica.* **1911**. 11th ed. Chicago: Encyclopaedia Britannica. https://archive.org/details/EncyclopaediaBritannica1911HQDJVU

EB. *Encyclopaedia Britannica.* **2010**. 15th ed. Chicago: Encyclopaedia Britannica.

Eberle, Henrik, and Matthias **Uhl**, eds. **2005**. *The Hitler Book: The Secret Dossier Prepared for Stalin.* London: John Murray.

Eisenschitz, Bernard, and Paolo **Bertetto**. **1994**. *Fritz Lang.* Valencia: Filmoteca generalitat.

Eisner, Lotte H. **1977**. *Fritz Lang.* Oxford: Oxford University Press.

Faensen, Hubert. **1997**. *Geheimnisträger Hakeburg. Beispiel eines Funktionswandels: Herrensitz, Ministerresidenz, Forschungsanstalt, SED-Parteischule.* Potsdam: Brandenburgische Landeszentrale für politische Bildung.

Faensen, Hubert. **2001**. *Hightech für Hitler: Die Hakeburg—Vom Forschungszentrum zur Kaderschmiede.* Berlin: Chrisoph Links.

Fäth, Harald. **1999**. *Geheime Kommandosache—S III Jonastal und die Siegeswaffenproduktion: Weitere Spurensuche nach Thüringens Manhattan Project.* Suhl: CTT-Verlag.

Fäth, Harald. **2000**. *1945—Thüringens Manhattan Project: Auf Spurensuche nach der verlorenen*

V-Waffen-Fabrik in Deutschlands Untergrund. Schleusingen: AMUN-Verlag.

Feldenkirchen, Wilfried. **1987**. Big Business in Interwar Germany: Organizational Innovation at Vereinigte Stahlwerke, IG Farben, and Siemens. *Business History Review* 61:3:417–451.

Findlen, Paula, ed. **2004**. *Athanasius Kircher: The Last Man Who Knew Everything.* New York: Routledge.

Fischer, Wolfram, ed. **2000**. *Die Preußische Akademie der Wissenschaften zu Berlin 1914-1945.* Berlin: Akademie. [pp. 237–277: Peter Nötzholdt. Strategien der deutschen Wissenschaftsakademien gegen Bedeutungsverlust und Funktionsverarmung.]

Fisher, Peter S. 1991. *Fantasy and Politics: Visions of the Future in the Weimar Republic.* Madison, Wisconsin: University of Wisconsin Press.

FitzGerald, Michael. **2019**. *Hitler's Secret Weapons of Mass Destruction: The Nazi Plan for Final Victory.* London: Arcturus.

Focken, Christel. **2008**. *FHQ "Führerhauptquartiere" Riese.* Aachen: Helios.

Ford, Brian J. 2011. *Secret Weapons: Technology, Science & the Race to Win World War II.* Oxford: Osprey, 2011.

Ford, Roger. **2013**. *Germany's Secret Weapons of World War II.* New York: Chartwell Books.

Forman, Paul. **1971**. Weimar culture, causality, and quantum theory: adaptation by German physicists and mathematicians to a hostile environment. *Historical Studies in the Physical Sciences* Vol. 3, pp 1-115. [Forman thesis]

Forman, Paul. **1984**. Kausalität, Anschaullichkeit, and Individualität, or How Cultural Values Prescribed the Character and Lessons Ascribed to Quantum Mechanics. In Nico Stehr and Volker Meja (eds.), *Society and Knowledge.* Transaction Books, 1984, pp. 333-347. [Forman thesis]

Forman, Paul. **1987**. Behind quantum electronics: National security as basis for physical research in the United States, 1940-1960. *Historical Studies in the Physical and Biological Sciences* Vol. 18, Pt. 1, pp. 149-229. [Forman thesis]

Forman, Paul. **2007**. The Primacy of Science in Modernity, of Technology in Postmodernity, and of Ideology in the History of Technology. *History and Technology* Vol. 23, No. 1/2, pp. 1-152, March/June 2007. [Forman thesis]

Forman, Paul, and José M. Sánchez-Ron, eds. **1996**. *National Military Establishments and the Advancement of Science and Technology: Studies in the 20th Century History.* Dordrecht: Kluwer.

Fullbrook, Mary. **2004**. *A Concise History of Germany.* 2nd ed. Cambridge, UK: Cambridge University Press.

Gaarskjaer, Jesper. **2012**. *Bornholm Besat: Det glemte hjørne af Danmark under Anden Verdenskrig.* Copenhagen: Gyldendal.

Gardner, Howard. **2011**. *Creating Minds.* 2nd ed. New York: Basic Books.

Gerwin, Robert, ed. **1989**. *Wie die Zukunkft Wurzeln schlug.* Berlin: Springer.

Gillispie, Charles C., ed. **1970–1990**. *Dictionary of Scientific Biography.* 18 vols. New York: Scribner.

Gleichmann, Markus, and Ronny **Dörfer**. **2011**. *Geheimnisvolles Thüringen: Militär- und Rüstungsobjekte des Dritten Reiches.* 2nd ed. Meiningen: Heinrich-Jung-Verlagsgesellschaft.

Glum, Friedrich. **1964**. *Zwischen Wissenschaft, Wirtschaft und Politik: Erlebtes und Erdachtes in vier Reichen.* Bonn: Bouvier.

Godwin, Joscelyn. **2009**. *Athanasius Kircher's Theatre of the World: The Life and Work of the Last Man to Search for Universal Knowledge.* Rochester, Vermont: Inner Traditions.

Goñi, Uki. **2002**. *The Real Odessa: How Perón Brought the Nazi War Criminals to Argentina.* London: Granta.

Gööck, Roland. **2000**. *Erfindungen der Menschheit.* 8 vols. Blaufelden: Sigloch.

Goodrick-Clarke, Nicholas. **1992**. *The Occult Roots of Nazism: Secret Aryan Cults and Their Influence on Nazi Ideology.* New York: New York University Press.

Goodstein, Judith R. **1991**. *Millikan's School: A History of the California Institute of Technology.* New York: W. W. Norton.

Greenfield, Liah, ed. **2012**. *The Ideals of Joseph Ben-David: The Scientist's Role and Centers of Learning Revisited.* New Brunswick, New Jersey: Transaction Publishers.

Gribbin, John. **2002**. *The Scientists: A History of Science Told Through the Lives of Its Greatest Inventors.* New York: Random House.

Grupp, Hariolf, Ićiar Dominguez-Lacasa, and Monika Friedrich-Nishio. **2002**. *Das deutsche Innovationssystem seit der Reichsgründung: Indikatoren einer nationalen Wissenschafts- und Technikgeschichte in unterschiedlichen Regierungs- und Gebietsstrukturen.* Heidelberg: Physica.

Grupp, Hariolf, Ićiar Dominguez-Lacasa, and Monika Friedrich-Nishio. **2005**. The National German Innovation System–Its Development in Different Governmental and Territorial Structures. In: Kurt Dopfer (ed.), *Economics, Evolution and the State: The Governance of Complexity* (Cheltenham, UK: Edward Elgar Publishing, 2005, pp. 239-273).

Grupp, Hariolf, Ićiar Dominguez-Lacasa, Monika Friedrich-Nishio, and A. Jungmittag. **2005**. Innovation and Growth in Germany Over the Past 150 Years. In: Uwe Cantner (ed.), *Entrepreneurship, the New Economy and Public Policy: Schumpeterian Perspectives* (Berlin: Springer, 2005, pp. 267-287).

Gruss, Peter, Reinhard Rürup, and Susanne Kiewitz. **2010**. *Denkorte: Max-Planck-Gesellschaft und Kaiser-Wilhelm-Gesellschaft. Brüche und Kontinuitäten 1911–2011.* Dresden: Sandstein Kommunikation.

Hachtmann, Rüdiger. **2008**. Wissenschaftsgeschichte in der ersten Hälfte des 20. Jahrhunderts. *Archiv für Sozialgeschichte* 48:539–606.

Hahn, Fritz. **1986a**. *Deutsche Waffen und Geheimwaffen 1939-45 I Flugzeugbewaffnungen.* Bonn: Bernard & Graefe.

Hahn, Fritz. **1986b**. *Deutsche Waffen und Geheimwaffen 1933-45 II Luftwaffe—Marine.* Bonn: Bernard & Graefe.

Hahn, Fritz. **1998**. *Waffen und Geheimwaffen des deutschen Heeres 1933-1945.* 3rd ed. Bonn: Bernard & Graefe.

Hale, Christopher. **2006**. *Himmler's Crusade: The Nazi Expedition to Find the Origins of the Aryan Race.* Edison, New Jersey: Castle Books.

Hammerstein, Notker. **1999**. *Die Deutsche Forschungsgemeinschaft in der Weimarer Republik und im Dritten Reich: Wissenschaftspolitik in Republik und Diktatur.* Munich: C. H. Beck.

Hargittai, Balazs, Magdolna Hargittai, and István Hargittai. **2014**. *Great Minds: Reflections of 111 Top Scientists.* Oxford: Oxford University Press.

Hargittai, István. **2000–2006**. *Candid Science.* 6 vols. London: Imperial College Press.

Hargittai, István. **2002**. *The Road to Stockholm: Nobel Prizes, Science, and Scientists.* Oxford: Oxford University Press.

Hargittai, István. **2011**. *Drive and Curiosity: What Fuels the Passion for Science.* Amherst, New York: Prometheus.

Hargittai, István. **2016**. Michael Polanyi—Pupils and Crossroads—On the 125th Anniversary of His Birth. *Structural Chemistry* 27:1327–1344.

Harrison, Mark, ed. **1998**. *The Economics of World War II: Six Great Powers in International Comparison.* Cambridge, U.K.: Cambridge University Press.

von Hassell, Agostino, Sigrid MacRae, and Simone Ameskamp. **2006**. *Alliance of Enemies: The Untold Story of the Secret American and German Collaboration to End World War II.* New York: Thomas Dunne.

Haunschmied, Rudolf A, Jan-Ruth Mills, and Siegi Witzany-Durda. **2007**. *St. Georgen—Gusen—Mauthausen. Concentration Camp Mauthausen Reconsidered.* Norderstedt: Books on Demand.

Hawes, James. **2019**. *The Shortest History of Germany: From Julius Caesar to Angela Merkel—A Retelling for Our Times.* New York: The Experiment.

Heckl, Wolfgang M., ed. **2010.** *Technology in a Changing World: The Collections of the Deutsches Museum.* Munich: Deutsches Museum.

Heckl, Wolfgang M., ed. **2011.** *Deutsches Museum: A Guide to the Exhibitions.* Munich: Deutsches Museum.

Heim, Susanne, Carola Sachse, and Mark Walker, eds. **2009**. *The Kaiser Wilhelm Society under National Socialism.* Cambridge, UK: Cambridge University Press.

Heintz, Bettina, and Bernhard **Nievergelt**, eds. **1998**. *Wissenschafts- und Technikforschung in der Schweiz: Sondierungen einer neuen Disziplin.* Zurich: Seismo. [pp. 195–211: David Gugerli. "Translationen" der elektrischen Übertragung: Ein Beitrag zur Revision der Geschichte technischer Innovationen.]

Henco, Guido-Gordon. **2004**. *Die phantastischen Erfindungen im Dritten Reich. Zivile und militä-*

rische Innovation. Wölfersheim: Podzun-Pallas.

Herber, Klaus. **2011**. *Inferno Jonastal: Hitlers letzte Zuflucht in Thüringen.* 3rd ed. Ilmenau: Rhino.

Herf, Jeffrey. **2009**. *Nazi Propaganda for the Arab World.* New Haven, Connecticut: Yale University Press. [p. 231]

Herrlitz, Hans-Georg, Wulf Hopf, Hartmut Titze, and Ernst Cloer. **2009**. *Deutsche Schulgeschichte von 1800 bis zur Gegenwart.* 5th ed. Landsberg: Juventa.

Herrmann, Ulrich G., and Detlef K. **Müller**. **2003**. *Datenhandbuch zur deutschen Bildungsgeschichte. Band II/2: Regionale Differenzierung und gesamtstaatliche Systembildung. Preußen und seine Provinzen—Deutsches Reich und seine Staaten 1800–1945.* Göttingen: Vandenhoeck & Ruprecht.

Heßler, Martina. **2012**. *Kulturgeschichte der Technik.* Frankfurt am Main: Campus.

Hof, Hagen and Ulrich **Wengenroth**, eds. **2010**. *Innovationsforschung. Ansätze, Methoden, Grenzen und Perspektiven.* 2nd ed. Hamburg: LIT.

Hogg, Ian V. **1999**. *German Secret Weapons of the Second World War: The Missiles, Rockets, Weapons and New Technology of the Third Reich.* London: Greenhill Books.

Impey, Andrew, Mark Steer, and Hayley Birch, eds. **2008**. *Defining Moments in Science.* Cassell.

Irving, David. **1974**. *The Rise and Fall of the Luftwaffe: The Life of Field Marshal Erhard Milch.* New York: Little, Brown.

Irving, David. **1989**. *Göring: A Biography.* New York: William Morrow.

Jammer, Max. **1966**. *The Conceptual Development of Quantum Mechanics.* [Forman thesis]

Jankowsky, Heinz. **2000**. *Österreichs große Erfinder: Ihr Leben, ihre Arbeiten, ihre Schicksale.* Graz: Styria.

Janssen, Gregor. **1968**. *Das Ministerium Speer: Deutschlands Rüstung im Krieg.* Berlin: Ullstein.

Jenkins, Stephen, ed. **1981**. *Fritz Lang: The Image & the Look.* London: British Film Institute.

Jensen, Thomas E. **1996**. *Bornholmske Samlinger.* III: Vol. 9. Rønne: Colbergs Eftf. Bogtrykkeri.

Jensen, Thomas E. **2001**. *Bornholm i Krig 1940–1946.* 2nd ed. Rønne: Bornholms Museum.

Jessen, Ralph, and Jakob **Vogel**, eds. **2002**. *Wissenschaft und Nation in der europäischen Geschichte.* Frankfurt am Main: Campus. [pp. 285–309: Gabriele Metzler. Nationalismus und Internationalismus in der Physik des 20. Jahrhunderts: Das deutsche Beispiel.]

Jones, Michael. **2015**. *After Hitler: The Last Days of the Second World War in Europe.* London: John Murray. [BW]

Kater, Michael H. **2006**. *Das "Ahnenerbe" der SS 1935-1945: Ein Beitrag zur Kulturpolitik des Dritten Reiches.* 4th ed., Munich: Oldenbourg.

Kaule, Martin. **2009**. *Ostseeküste 1933–1945: Der historische Reiseführer.* Berlin: Christoph Links.

Keynes, John Maynard. **2019**. *The Economic Consequences of the Peace.* London: Palgrave Macmillan.

Kirchhoff, Jochen. **2007**. *Wissenschaftsförderung und forschungspolitische Prioritäten der Notgemeinschaft der deutschen Wissenschaft 1920–1932.* Ph.D. thesis. University of Munich.

Kitchen, Martin. **1996**. *The Cambridge Illustrated History of Germany.* Cambridge, U.K.: Cambridge University Press.

Kitchen, Martin. **2015**. *Speer: Hitler's Architect.* New Haven, Connecticut: Yale University Press.

Klee, Ernst. **2016**. *Das Personenlexikon zum Dritten Reich: Wer war was vor und nach 1945.* Hamburg: Nikol.

Köberl, Markus. **1993**. *Der Toplitzsee.* 2nd ed. Vienna: OBV.

Koertge, Noretta, ed. **2007**. *New Dictionary of Scientific Biography.* New York: Scribner.

Kofod, Helmer. **1964**. *Bornholmske Samlinger.* Vol. 1. Rønne: Colbergs Eftf. Bogtrykkeri.

Kohler, Robert E. **1991**. *Partners in Science: Foundations and Natural Scientists, 1900–1945.* Chicago: University Of Chicago Press.

Kohlrausch, Martin, and Helmuth **Trischler**. **2014**. *Building Europe on Expertise: Innovators, Organizers, Networkers.* New York: Palgrave Macmillan.

König, Wolfgang, ed. **2000**. *Propyläen Technikgeschichte.* Berlin: Propyläen.

König, Wolfgang. **2009**. *Technikgeschichte: Eine Einführung in ihre Konzepte und Forschungsergebnisse.* Stuttgart: Franz Steiner.

König, Wolfgang, and Helmuth **Schneider**, eds. **2007**. *Die technikhistorische Forschung in Deutschland von 1800 bis zur Gegenwart.* Kassel: Kassel University Press.

Kopleck, Maik. **2013**. *Past Finder Berlin 1933–1945.* 3rd ed. Berlin: Christoph Links.

Kraft, P., and P. **Kroes**. **1984**. Adaptation of Scientific Knowledge to an Intellectual Environment. Paul Forman's "Weimar Culture, Causality, and Quantum Theory, 1918–1927": Analysis and Review. *Centaurus* Jan. 1984, Vol. 27 Issue 1, pp. 76-99. [Forman thesis]

Krüger, Dennis. **2011**. *Das okkulte 3. Reich: SS-Forschungsprojekte zwischen Germanenkunde, Okkultwissenschaften & Geheimwaffentechnologie.* Bottrop: Forsite.

Krüger, Dennis. **2016**. *Wunderwaffen & Geheimprojekte: Fortschrittliche Waffentechnologie & rätselhafte Militärforschung im 3. Reich.* Gilching: Druffel & Vowinckel.

Ksiaż Castle. **2009**. *The Ksiaż Castle—A Tourist Guide.* Wrocław: Wydawnictwo ZET.

Kuhn, F. **1992**. *Ergebnisse der Luftbildauswertung für den Deponiestandort Eulenberg bei Arnstadt/Thüringen. Teil I: Auswertung und Interpretation historischer Luftbilder.* Berlin: Bundesanstalt für Geowissenschaften und Rohstoffe.

Kure, Børge. **1981**. *En ø i krig.* Rønne: Bornholmerens Forlag.

Kurlander, Eric. **2017**. *Hitler's Monsters: A Supernatural History of the Third Reich.* New Haven, Connecticut: Yale University Press.

Lange, Gerhard, and Klaus **Knödel**. **2003**. *Erkundungspraxis: Fallbeispiele Schöneiche-Mittenwalde, Eulenberg/Arnstadt und Rabenstein/Chemnitz.* Berlin: Springer.

Longerich, Peter. **2012**. *Heinrich Himmler.* Oxford: University of Oxford Press. [p. 735]

Ludwig, Karl-Heinz. **1974**. *Technik und Ingenieure im Dritten Reich.* Düsseldorf: Droste.

Lundgreen, Peter, ed. **1985**. *Wissenschaft im Dritten Reich.* Frankfurt am Main: Suhrkamp.

Lundgreen, Peter, and André **Grelon**, eds. **1994**. *Ingenieure in Deutschland 1770–1990.* Frankfurt am Main: Campus.

Lusar, Rudolf. **1956**. *Die deutschen Waffen und Geheimwaffen des 2. Weltkrieges und ihre Weiterentwicklung.* 1st ed., Munich: J. F. Lehmanns.

Lusar, Rudolf. **1971**. *Die deutschen Waffen und Geheimwaffen des 2. Weltkrieges und ihre Weiterentwicklung.* 6th ed., Munich: J. F. Lehmanns.

Maas, Ad, and Hans **Hooijmaijers**, eds. **2009**. *Scientific Research in World War II: What Scientists Did in the War.* London: Routledge. [Falk Müller. The Birth of a Modern Instrument and Its Development during World War II: Electron Microscopy in Germany from the 1930s to 1945. Ch. 8.]

Macrakis, Kristie. **1993**. *Surviving the Swastika: Scientific Research in Nazi Germany.* Oxford: Oxford University Press.

Maier, Helmut, ed. **2002**. *Rüstungsforschung im Nationalsozialismus: Organisation, Mobilisierung und Entgrenzung der Technikwissenschaften.* Göttingen: Wallstein.

Mann, Golo. **1968**. *The History of Germany Since 1789.* New York: Frederick A. Praeger.

Marsch, Ulrich. **1994b**. *Notgemeinschaft der Deutschen Wissenschaft: Gründung und frühe Geschichte 1920-1925.* Frankfurt am Main: Lang.

Marsch, Ulrich. **2000**. *Zwischen Wissenschaft und Wirtschaft. Industrieforschung in Deutschland und Großbritannien, 1880–1936.* Paderborn: Schöningh.

Matis, Herbert, Juliane Mikoletzky, and Wolfgang Reiter, eds. **2014**. *Wirtschaft, Technik und das Militär 1914–1918: Österreich-Ungarn im Ersten Weltkrieg: Austria: Forschung und Wissenschaft Geschichte.* Münster: LIT.

Mayer, Milton. **2017**. *They Thought They Were Free: The Germans, 1933–45.* Chicago: University of Chicago Press.

Mayntz, Renate, Friedhelm Neidhardt, Peter Weingart, and Ulrich Wengenroth, eds. **2008**. *Wissensproduktion und Wissenstransfer. Wissen im Spannungsfeld von Wissenschaft, Politik und Öffentlichkeit.* Bielefeld: transcript.

McFarland, Stephen L. **1997**. *Battles Not Fought: The Creation of an Independent Air Force.* https://www.usafa.edu/app/uploads/Harmon40.pdf

McGilligan, Patrick. **1997**. *Fritz Lang: The Nature of the Beast.* London: Faber and Faber.

McNab, Chris. **2009**. *The SS 1923–1945.* London: Amber.

McNab, Chris. **2011**. *Hitler's Masterplan 1933–1945.* London: Amber.

Mercatante, Steven D. **2012**. *Why Germany Nearly Won: A New History of the Second World War in Europe.* Santa Barbara, California: Praeger.

Meyer, August. **1999**. *Hitlers Holding: Die Reichswerke "Hermann Göring."* 2nd ed. Munich: Europa.

Mitchell, B. R., ed. **1975**. *European Historical Statistics, 1750–1970.* London: Palgrave Macmillan.

Müller-Benedict, Volker, Jörg Janssen, and Tobias Sander. **2008**. *Datenhandbuch zur deutschen Bildungsgeschichte Band VI: Akademische Karrieren in Preußen und Deutschland 1850–1940.* Göttingen: Vandenhoeck & Ruprecht.

NDB. *Neue Deutsche Biographie.* **1953–2020**. Historischen Kommission bei der Bayerischen Akademie der Wissenschaften. Berlin: Duncker & Humblot.

Norris, Christopher. **2000**. *Quantum Theory and the Flight from Realism: Philosophical Responses to Quantum Mechanics.* p. 79. [Forman thesis]

Nowak, Jan. **1982**. *Courier from Warsaw.* Detroit, Michigan: Wayne State University Press. [pp. 62–63]

Østre Landsdelskommando. **1985**. *Bornholms Militaere Domiciler.* Ringsted.

Ottomeyer, Hans, and Hans-Jörg **Czech**. **2009**. *Deutsche Geschichte in Bildern und Zeugnissen.* Berlin: Deutsches Historisches Museum.

Overy, Richard J. **1990**. *The Origins of the Second World War.* 4th ed. New York: Routledge.

Overy, Richard J. **1994**. *War and Economy in the Third Reich.* Oxford: Clarendon Press.

Overy, Richard J. **2006**. *Why the Allies Won.* 2nd ed. New York: W. W. Norton.

Overy, Richard J. **2013**. *The Bombing War: Europe 1939–1945.* London: Allen Lane.

Parker, Danny S. **2014**. *Hitler's Warrior: The Life and Wars of SS Colonel Jochen Peiper.* Boston: Da Capo.

Paturi, Felix R. **1998**. *Harenberg Schlüsseldaten Entdeckungen und Erfindungen.* Dortmund: Harenberg Lexikon.

Paulsen, Friedrich. **1906**. *The German Universities and University Study.* London: Longmans.

Paulsen, Friedrich. **1908**. *German Education, Past and Present.* London: T. F. Unwin.

Perz, Bertrand. **2014**. *Das Projekt "Quarz": Der Bau einer unterirdischen Fabrik durch Häftlinge des KZ Melk für die Steyr-Daimler-Puch AG 1944–1945.* Innsbruck: Studienverlag.

Pfetsch, Frank R. **1985**. *Datenhandbuch zur Wissenschaftsentwicklung.* 2nd ed. Cologne: Zentrum für historische Sozialforschung.

Pichler, Rupert, ed. **2003**. *Innovationsmuster in der österreichischen Wirtschaftsgeschichte: Wirt-*

schaftliche Entwicklung, Unternehmen, Politik und Innovationsverhalten im 19. und 20. Jahrhundert. Innsbruck: Studien.

Pieken, Gorch, and Matthias **Rogg**. **2012**. *Militärhistorisches Museum: Exhibition Guide.* Dresden: Sandstein.

Porter, David. **2010**. *World War II Data Book: Hitler's Secret Weapons 1933-1945.* London: Amber Books.

Porter, Roy, ed. **1994**. *The Biographical Dictionary of Scientists.* 2nd ed. Oxford: Oxford University Press.

Pringle, Heather. **2006**. *The Master Plan: Himmler's Scholars and the Holocaust.* New York: Hachette.

Pyenson, Lewis, and Susan **Sheets-Pyenson**. **1999**. *Servants of Nature: A History of Scientific Institutions, Enterprises, and Sensibilities.* New York: W.W. Norton.

Radkau, Joachim. **1989**. *Technik in Deutschland.* Frankfurt: Suhrkamp.

Radkau, Joachim. **2016**. *Technik in Deutschland: Vom 18. Jahrhundert bis heute.* 2nd. Frankfurt am Main: Campus.

Radkau, Joachim. **2017**. *Geschichte der Zukunft: Prognosen, Visionen, Irrungen in Deutschland von 1945 bis heute.* 2nd ed. Carl Hanser.

Rawson, Andrew. **2010**. *The Third Reich 1919–1939: The Nazis' Rise to Power.* Stroud, Gloucestershire: Spellmount.

Rdułtowski, Bartosz. **2012a**. *The Postwar Secrets of the Owl Mountains.* Krakow: Technol.

Rdułtowski, Bartosz. **2012b**. *The Hunt for Wunderwaffe.* Krakow: Technol.

Reitzenstein, Julien. **2014**. *Himmlers Forscher: Wehrwissenschaft und Medizinverbrechen im "Ahnenerbe" der SS.* Paderborn: Ferdinand Schöningh.

Renneberg, Monika, and Mark **Walker**, eds. **1993**. *Science, Technology, and National Socialism.* Cambridge, UK: Cambridge University Press.

Resch, Andreas, und Reinhold **Hofer**. **2010**. *Österreichische Innovationsgeschichte seit dem späten 19. Jahrhundert: Indikatoren des Innovationssystems und Muster des Innovationsverhaltens.* Innsbruck: Studien.

Ringer, Fritz K. **1969**. *The Decline of the German Mandarins: The German Academic Community, 1890–1933.* Cambridge, Massachusetts: Harvard University Press.

Ritter, Gerhard A. **1992**. *Großforschung und Staat in Deutschland: Ein historischer überblick.* Munich: C. H. Beck.

Röhrs, Hermann. **1995**. *The Classical German Concept of the University and its Influence on Higher Education in the United States.* Frankfurt: Peter Lang.

Różycki, Sebastian, Marek Michalski, and Edward Kopówka. **2017**. *Obóz Pracy Treblinka I: metodyka integracji danych wieloźródłowych.* [*Labor Camp Treblinka I.*] Treblinka: Treblinka Museum.

Russell, J. E. **1899**. *German High Schools.* New York: Longmans.

Sachse, Arnold. **1928**. *Friedrich Althoff und sein Werk.* Berlin: E. S. Mittler.

Schain, Martin A. **2001**. *The Marshall Plan: Fifty Years After.* New York: Palgrave MacMillan.

Schalenberg, Marc and Peter Thomas **Walther**, eds. **2004**. *"... immer im Forschen bleiben": Rüdiger vom Bruch zum 60. Geburtstag.* Stuttgart: Franz Steiner. [pp. 157–177: Sören Flachowsky and Peter Nötzoldt. Von der Notgemeinschaft der deutschen Wissenschaft zur Deutschen Forschungsgemeinschaft.]

Schambach, Klaus-Peter. **2011**. *Tatort Jonastal: Ermordet für das Führerhauptquartier in Thüringen im Außenkommando S III des KL Buchenwald.* 2nd ed. Meiningen: Heinrich-Jung-Verlagsgesellschaft.

Schilling, Willy. **2010**. *Thüringen 1933–1945: Der historische Reiseführer.* Berlin: Christoph Links.

Schmidt, Gert Dieter. **2014**. *Verborgenen Schätzen auf der Spur: Die unendlich Suche nach dem Bernsteinzimmer.* Meiningen: Heinrich Jung.

Schmidt, Jörg. **1993**. *Der Untergrund der Altlast "Eulenberg" bei Arnstadt—ein tektonisches Modell und Beiträge zur Umweltgeologie.* Thesis. Freiberg: Bergakademie Freiberg.

Schrader, Wilhelm. **1893**. *Erziehungs- und Unterrichtslehre für Gymnasien und Realschulen.* 5th ed. Berlin: Hempel.

Schwinges, Rainer Christoph, ed. **2007**. *Examen, Titel, Promotionen: Akademisches und staatliches Qualifikationswesen vom 13. bis zum 21. Jahrhundert.* Basel: Schwabe.

Seckelmann, Margrit. **2006**. *Industrialisierung, Internationalisierung und Patentrecht im Deutschen Reich, 1871–1914.* Frankfurt am Main: Vittorio Klostermann.

Seidler, Franz W., and Dieter **Zeigert**. **2006**. *Hitler's Secret Headquarters: The Führer's Wartime Bases from the Invasion of France to the Berlin Bunker.* London: Greenhill Books.

Senn, Peter R. **1993**. Where is Althoff? Looking for Friedrich Althoff in English Language Sources. *Journal of Economic Studies* 20:4/5. https://doi.org/10.1108/EUM0000000000179

Shirer, William L. **1941**. *Berlin Diary: The Journal of a Foreign Correspondent, 1934–1941.* New York: Alfred A. Knopf.

Shirer, William L. **1947**. *End of a Berlin Diary 1944–1947.* New York: Alfred A. Knopf.

Shirer, William L. **1960**. *The Rise and Fall of the Third Reich: A History of Nazi Germany.* New York: Simon and Schuster.

Shirer, William L. **1984**. *The Nightmare Years: 1930–1940.* Boston: Little, Brown.

Sikora, Miroslaw. (Helmut Maier, ed.) **2014**. *Die Waffenschmiede des "Dritten Reiches": Die deutsche Rüstungsindustrie in Oberschlesien während des Zweiten Weltkrieges.* Göttingen: Wallstein.

Simon, Leslie E. **1947a**. *German Scientific Establishments.* Mapleton House.

Simon, Leslie E. **1947b**. *German Research in World War II: An Analysis of the Conduct of Research.* New York.

Simon, Leslie E. **1971**. *Secret Weapons of the Third Reich: German Research in World War II.* 2nd ed. New York: Wiley.

Simonton, Dean Keith. **1984**. *Genius, Creativity, and Leadership: Historiometric Inquiries.* Cambridge, Massachusetts: Harvard University Press.

Simonton, Dean Keith. **1994**. *Greatness: Who Makes History and Why.* New York: Guilford Press.

Simonton, Dean Keith. **1999**. *Origins of Genius: Darwinian Perspectives on Creativity.* Oxford, U.K.: Oxford University Press.

Simonton, Dean Keith. **2004**. *Creativity in Science: Chance, Logic, Genius, and Zeitgeist.* Cambridge, U.K.: Cambridge University Press.

Simonton, Dean Keith. **2009**. *Scientific Genius: A Psychology of Science.* Cambridge, U.K.: Cambridge University Press.

Sørensen, Egon, Ole Andersen, and Niels Chr. Pihl. **2003**. *Tyske og russiske aktiviteter på Bornholm under 2. Verdenskrig.* Rønne: Bornholms Tidendes Forlag.

Stevens, Henry. **2007**. *Hitler's Suppressed and Still-Secret Weapons, Science and Technology.* Kempton, Illinois: Adventures Unlimited Press.

Stone, David. **2011**. *Twilight of the Gods: The Decline and Fall of the German General Staff in World War II.* London: Conway.

Stratton, Julius A., and Loretta H. **Mannix**. **2005**. *Mind and Hand: The Birth of MIT.* Cambridge, Massachusetts: MIT Press.

Surman, Jan Jakub. **2012**. *Habsburg Universities 1848–1918: Biography of a Space.* Ph.D. thesis. Vienna: University of Vienna.

Sutton, Antony C. **1976**. *Wall Street and the Rise of Hitler.* Seal Beach, California: '76 Press.

Szöllösi-Janze, Margit, ed. **2001**. *Science in the Third Reich.* Oxford: Berg. [pp. 111–138: Luitgard Marschall. Consequences of the Politics of Autarky: The Case of Biotechnology.]

Szöllösi-Janze, Margit, and Helmuth **Trischler**, eds. **1990**. *Großforschung in Deutschland.* Frankfurt am Main: Campus.

Tanaka, Masahiro. **2005**. *The Cross-cultural Transfer of Educational Concepts and Practices: A Comparative Study.* Oxford: Symposium Books.

Taylor, Blaine. **2010**. *Hitler's Engineers: Fritz Todt and Albert Speer: Master Builders of the Third Reich.* Philadelphia: Casemate.

Technisches Museum Wien. **2011**. *Museum Guide.* Vienna: Technisches Museum Wien.

Teichmann, Jürgen, Wolfgang Schreier, and Michael Segre. **2008**. *Experimente, die Geschichte machten.* 2nd ed. Munich: Deutsches Museum.

Thelin, John R. **2019**. *A History of American Higher Education.* 3rd ed. Baltimore, Maryland: Johns Hopkins University Press.

Thom, Ilka, and Kirsten **Weining**, eds. **2010**. *Mittendrin: Eine Universität macht Geschichte.* Berlin: Akademie.

Thomson, David. **1962**. *Europe Since Napoleon.* 2nd ed. New York: Alfred A. Knopf.

Titze, Hartmut. **1987**. *Datenhandbuch zur deutschen Bildungsgeschichte. Band I/1: Das Hochschulstudium in Preussen und Deutschland 1820–1944.* Göttingen: Vandenhoeck & Ruprecht.

Titze, Hartmut. **1990**. *Der Akademiker-Zyklus: Historische Untersuchungen über die Wiederkehr von überfüllung und Mangel in akademischen Karrieren.* Göttingen: Vandenhoeck & Ruprecht.

Titze, Hartmut, Hans-Georg Herrlitz, Volker Müller-Benedict, and Axel Nath. **1995**. *Datenhandbuch zur deutschen Bildungsgeschichte. Band I/2: Wachstum und Differenzierung der deutschen Universitäten 1830–1945.* Göttingen: Vandenhoeck & Ruprecht.

Trischler, Helmuth, and Mark **Walker**, eds. **2010**. *Physics and Politics: Research and Research Support in Twentieth Century Germany in International Perspective.* Stuttgart: Franz Steiner.

Turra, Axel. **1998**. *Heeresversuchsstelle Hillersleben: Fleissiges Lieschen, Dora, Karl und Andere Schwere Geschütze in der Erprobung 1935–1945.* Wölfersheim: Podzun-Pallas.

Uhl, Matthias, Martin Holler, Jean-Luc Leleu, Dieter Pohl, and Thomas Pruschwitz, eds. **2020**. *Die Organisation des Terrors: Der Dienstkalender Heinrich Himmlers 1943–1945.* Munich: Piper.

Universitätsarchiv der TU Wien, ed. **1997**. *K. K. Polytechnisches Institut: Technische Hochschule: Technische Universität Wien.* Vienna: Herold.

Urlich-Kornacka, Małgorzata. **2015**. *Lower Silesia: Ten Exquisite Excursions.* Wrocław: Via Nova.

Van Der Vat, Dan. **1997**. *The Good Nazi: The Life and Lies of Albert Speer.* Boston: Houghton Mifflin.

Vereeck, Lode. **2001**. *Das deutsche Wissenschaftswunder: eine ökonomische Analyse des Systems Althoff.* Berlin: Duncker & Humblot.

Vierhaus, Rudolf, and Bernhard **vom Brocke**. **1990**. *Forschung im Spannungsfeld von Politik und Gesellschaft—Geschichte und Struktur der Kaiser-Wilhelm-/Max-Planck-Gesellschaft.* Stuttgart: Deutsche Verlags-Anstalt.

Vogt, Annette. **2008**. *Wissenschaftlerinnen in Kaiser-Wilhelm-Instituten. A–Z.* 2nd ed. Berlin: Archiv der Max-Planck-Gesellschaft.

Wachsmann, Nikolaus. **2015**. *Kl: A History of the Nazi Concentration Camps.* New York: Farrar, Straus and Giroux.

Walker, Mark, Karin Orth, Ulrich Herbert, and Rüdiger vom Bruch, eds. **2013**. *The German Research Foundation 1920–1970: Funding Poised Between Science and Politics.* Stuttgart: Franz Steiner.

Wallace, Max. **2004**. *The American Axis: Henry Ford, Charles Lindbergh, and the Rise of the*

Third Reich. New York: St. Martin's Griffin.

Watson, Peter. **2010**. *The German Genius.* New York: HarperCollins.

Weinberg, Gerhard L. **2005**. *A World at Arms: A Global History of World War II.* 2nd ed. Cambridge, UK: Cambridge University Press.

Weitensfelder, Hubert. **2009**. *Die großen Erfinder.* Wiesbaden: Marix.

Weitensfelder, Hubert. **2013**. *Technikgeschichte: Eine Annäherung.* Vienna: New Academic Press.

Wels, Susan. **1999**. *Stanford: Portrait of a University.* Stanford: Stanford University Press.

Wengenroth, Ulrich, ed. **1993**. *Technische Universität München. Annäherungen an ihre Geschichte.* Munich: TUM.

Wengenroth, Ulrich. **1997**. Germany: Competition abroad—cooperation at home, 1870–1990. In Alfred D. Chandler, Franco Amatori, and Takashi Hikino, eds. 1997. *Big Business and the Wealth of Nations.* Cambridge, UK: Cambridge University Press. pp. 139–175.

Wengenroth, Ulrich. **2009**. *Enterprise and Technology. The German and British Steel Industries 1865-1895.* 2nd ed. Cambridge: Cambridge University Press.

Whitman, James Q. **2018**. *Hitler's American Model: The United States and the Making of Nazi Race Law.* 2nd ed. Princeton, New Jersey: Princeton University Press.

Wichert, Hans Walter, ed. **1999**. *Decknamenverzeichnis deutscher unterirdischer Bauten des zweiten Weltkrieges.* 2nd ed. Marsberg: Druck.

Wilcox, Robert K. **2008**. *Target: Patton: The Plot to Assassinate General George S. Patton.* 2nd ed. Washington, D.C.: Regnery.

Williamson, Gordon. **2006**. *The SS: Hitler's Instrument of Terror.* 2nd ed. London: Amber.

Willmott, H. P. **2003**. *World War I.* New York: DK.

Witkowski, Igor. **2010**. *Die Wahrheit über die Wunderwaffe: Geheime Waffentechnologie im Dritten Reich, Teil 1.* 2nd ed. Immenstadt: Mosquito.

Witkowski, Igor. **2012**. *Die Wahrheit über die Wunderwaffe: Geheime Waffentechnologie im Dritten Reich, Teil 2.* 2nd ed. Immenstadt: Mosquito.

Witkowski, Igor. **2011**. *Die Wahrheit über die Wunderwaffe: Geheime Waffentechnologie im Dritten Reich, Teil 3.* Immenstadt: Mosquito.

Witkowski, Igor. **2013**. *The Truth About the Wunderwaffe.* 2nd ed. New York: RVP Press.

Yenne, William. **2003**. *Secret Weapons of World War II: The Techno-Military Breakthroughs that Changed History.* New York: Berkley Books.

Zeigert, Dieter. **2003**. *Hitlers letztes Refugium? Das Projekt eines Führerhauptquartiers in Thüringen 1944/45.* Herbert Utz.

Zischka, Anton. **1966**. *War Es Ein Wunder? Zwei Jahrzehnte deutschen Wiederaufstiegs.* Hamburg: Mosaik.

Zweig, S. **1964**. *The World of Yesterday.* Lincoln, Nebraska: University of Nebraska Press.

Technology Transfer Out of the German-Speaking World and the Development of the Modern Research World

Agoston, Tom. **1985**. *Blunder! How the U.S. Gave Away Nazi Supersecrets to Russia.* New York: Dodd, Mead. Translated into German as Tom Agoston. 1993. *Teufel oder Technokrat? Hitlers graue Eminenz.* Herford: E. S. Mittler.

Albrecht, Ulrich, Andreas Heinemann-Grüder, and Arend Wellman. **1992**. *Die Spezialisten: Deutsche Naturwissenschaftler und Techniker in der Sowjetunion nach 1945.* Berlin: Dietz.

Allen, Robert S. **1947**. *Lucky Forward: The History of Patton's Third U.S. Army.* New York: Vanguard.

Ambrose, Stephen E. **1983**. *Eisenhower: Soldier, General of the Army, President-Elect, 1890–1952.* New York: Simon & Schuster.

Ambrose, Stephen E. **1984**. *Eisenhower: The President.* New York: Simon & Schuster.

Armbruster, Thomas. **2008**. *Rückerstattung der Nazi-Beute: Die Suche, Bergung und Restitution von Kulturgütern durch die westlichen Alliierten nach dem Zweiten Weltkrieg.* Berlin: De Gruyter.

Ash, Mitchell, and Alfons **Söllner**, eds. **1996**. *Forced Migration and Scientific Change: Emigré German-Speaking Scientists and Scholars after 1933.* Cambridge, UK: Cambridge University Press.

Augustine, Dolores L. **2007**. *Red Prometheus: Engineering and Dictatorship in East Germany, 1945–1990.* Cambridge, Massachusetts: MIT Press.

Azoulay, Pierre, Erica Fuchs, Anna P. Goldstein, and Michael Kearney. **2019**. Funding Breakthrough Research: Promises and Challenges of the "ARPA Model." *Innovation Policy and the Economy* 19:69–96. https://mitsloan.mit.edu/shared/ods/documents?PublicationDocumentID=5173 Also NBER Working Paper 24674: https://www.nber.org/papers/w24674

Bar-Zohar, Michel. **1967**. *The Hunt for the German Scientists.* New York: Hawthorn.

Baxter 3rd, James Phineas. **1946**. *Scientists Against Time.* New York: Little, Brown.

BBC. 14 July **2023**. The Barbie Movie Gives a Nod to the Doll's Creator Ruth Handler. https://www.bbc.com/culture/article/20230714-barbie-creator-ruth-handler-on-the-real-life-inspiration-for-the-doll

Bernbaum, John A. **1970**. The Captured German Records: A Bibliographical Survey. *The Historian* (August) 32:564-575.

Beschloss, Michael. **2002**. *The Conquerors: Roosevelt, Truman, and the Destruction of Hitler's Germany 1941-1945.* New York: Simon & Schuster.

Bishop, Jr., Joseph W. **1955**. The 'Contractual Agreements' with the Federal Republic of Germany. *The American Journal of International Law* (April) 49:125-147.

Blanpied, William A. **1998**. Inventing US Science Policy. *Physics Today* 51:2:34–40.

Boghardt, Thomas. **2022**. *Covert Legions: U.S. Army Intelligence in Germany, 1944–1949.* U.S.

Army.

Bower, Tom. **1987**. *The Paperclip Conspiracy: The Hunt for the Nazi Scientists.* Boston: Little, Brown.

Brinley, Sheridan. **2010**. The Mad Scientists' Club. http://www.madscientistsclub.com/MSC/Home.html

Bud, Robert, and Philip **Gummett**, eds. **1999**. *Cold War, Hot Science: Applied Research in Britain's Defence Laboratories 1945–1990.* Amsterdam: Harwood Academic.

Buranyi, Stephen. 27 June **2017**. Is the Staggeringly Profitable Business of Scientific Publishing Bad for Science? *Guardian.* https://www.theguardian.com/science/2017/jun/27/profitable-business-scientific-publishing-bad-for-science

Burchard, John. **1948**. *Q.E.D.: M.I.T. in World War II.* New York: Wiley.

Burns, James MacGregor. **1956**. *Roosevelt: The Lion and the Fox 1882–1940.* New York: Harcourt, Brace.

Burns, James MacGregor. **1970**. *Roosevelt: The Soldier Of Freedom 1940–1945.* New York: Harcourt, Brace.

Bush, Vannevar. **1945**. *Hearings Before the Special Committee on Atomic Energy, United States Senate, Seventy-Ninth Congress, First Session, Pursuant to S. Res. 179, a Resolution Creating a Special Committee to Investigate Problems Relating to the Development, Use, and Control of Atomic Energy, Part 1, November 27, 28, 29 and 30, 1945. December 3, 1945.* Washington, D.C.: U.S. Government Printing Office, 1945. [pp. 179–180]

Bush, Vannevar. **1946**. *Endless Horizons.* Washington, DC: Public Affairs Press.

Bush, Vannevar. **1949**. *Modern Arms and Free Men.* New York: Simon & Schuster.

Bush, Vannevar. **1960**. *Science—the Endless Frontier.* Washington: National Science Foundation.

Bush, Vannevar. **1967**. *Science Is Not Enough.* New York: Morrow.

Bush, Vannevar. **1970**. *Pieces of the Action.* New York: Morrow.

Buyer, Harriet, and Edna **Jensen**. **1948**. *Study No. 214: History of AAF Participation in Project Paperclip, May 1945-March 1947. Vol. 1.* Historical Office, Air Materiel Command, Wright-Patterson Air Force Base (August 1948). On microfilm AFHRA A2055.

Byrd, Harry F. **1948**. Hitler's Experts Work for Us. *The American Magazine* (March) 145:24–25, 136–138.

Casey, William. **1988**. *The Secret War Against Hitler.* Washington, DC: Regnery Gateway.

Churchill, Winston S. **1948**. *The Gathering Storm.* Boston: Houghton Mifflin.

Churchill, Winston S. **1949**. *Their Finest Hour.* Boston: Houghton Mifflin.

Churchill, Winston S. **1950a**. *The Grand Alliance.* Boston: Houghton Mifflin.

Churchill, Winston S. **1950b**. *The Hinge of Fate.* Boston: Houghton Mifflin.

Churchill, Winston S. **1951**. *Closing the Ring.* Boston: Houghton Mifflin.

Churchill, Winston S. **1953**. *Triumph and Tragedy.* Boston: Houghton Mifflin.

Clayton, William L. **1945**. *Security Against Renewed German Aggression. Statement by William L. Clayton, Assistant Secretary of State, Before the Subcommittee on War Mobilization, Senate Committee on Military Affairs, June 25, 1945.* Washington, D.C.: U.S. Government Printing Office. pp. 34–37. [Library of Congress HC 286.4.C5]

Clute, John, David Langford, Peter Nicholls, and Graham Sleight, eds. **2017**. *The Encyclopedia of Science Fiction.* London: Gollancz. https://sf-encyclopedia.com/entry/heinlein_robert_a https://sf-encyclopedia.com/entry/del_rey_lester https://sf-encyclopedia.com/entry/ley_willy

Coben, Stanley. **1963**. *A. Mitchell Palmer: Politician.* New York: Columbia University Press.

Cochran, Gregory, Jason Hardy, and Henry Harpending. **2006**. Natural History of Ashkenazi Intelligence. *Journal of Biosocial Science* 38:5:659–693.

Cocroft, Wayne D. **2010**. *Fort Halstead, Dunton Green, Sevenoaks, Kent: A Brief Assessment of the Role of Fort Halstead in Britain's Early Rocket Programmes and the Atomic Bomb Project.* Report 49/2010. Portsmouth, UK: English Heritage.
https://historicengland.org.uk/research/results/reports/49-2010

Conant, James B. **1970**. *My Several Lives: Memoirs of a Social Inventor.* New York: Harper & Row.

Conant, Jennet. **2002**. *Tuxedo Park: A Wall Street Tycoon and the Secret Palace of Science That Changed the Course of World War II.* New York: Simon & Schuster.

Conant, Jennet. **2017**. *Man of the Hour: James B. Conant, Warrior Scientist.* New York: Simon & Schuster.

Cooper, John Milton, Jr. **2009**. *Woodrow Wilson: A Biography.* New York: Alfred A. Knopf.

Cooper, Jonathan K. **2007**. The Complete Tom Swift Jr. Home Page.
http://www.tomswift.info/homepage/index.html

Crim, Brian E. **2018**. *Our Germans: Project Paperclip and the National Security State.* Baltimore, Maryland: Johns Hopkins University Press.

Dallek, Robert. **1991**. *Lone Star Rising: Lyndon Johnson and His Times 1908–1960.* Oxford: Oxford University Press.

Dallek, Robert. **1998**. *Flawed Giant: Lyndon Johnson and His Times 1961–1973.* Oxford: Oxford University Press.

Danhof, Clarence H. **1970**. Transferring Technology by Transferring People. *Monthly Labor Review* (May) 93:62-63.

Defrance, Corine. **2001**. La mission du CNRS en Allemagne (1945–1950): Entre exploitation et contrôle du potentiel scientifique allemand. *La revue pour l'histoire du CNRS* no. 5.
https://journals.openedition.org/histoire-cnrs/3372

Döbert, Frank. **2015**. Standortbestimmungen und Fluchtpunkte: Über das Wirken von Hans

Kammler in den letzten Kriegswochen 1945 und Erklärungsansätze über seinen Verbleib. *Betrifft Widerstand* 119:4–21.
https://memorial-ebensee.at/content/stories/Medien/Zeitschriftenarchiv/pdf_bw119.pdf

Döbert, Frank, and Rainer **Karlsch**. **2019**. Hans Kammler, Hitler's Last Hope, in American Hands. Woodrow Wilson International Center for Scholars, Cold War International History Project, Working Paper 91.
https://www.wilsoncenter.org/publication/hans-kammler-hitlers-last-hope-american-hands

DOC (U.S. Department of Commerce). **1947**. *Classified List of OTS Printed Reports.* Washington, D.C.: Office of Technical Services Reports Division. October 1947.

DOW (U.S. Department of War). **1945a**. *Handbook on German Military Forces.* TM-E 30-451. https://www.ibiblio.org/hyperwar/Germany/HB/

DOW (U.S. Department of War). **1945b**. Outstanding German Scientists Being Brought to U.S. Bureau of Public Relations, Press Branch (1 October).
http://www.v2rocket.com/start/chapters/paperclip.gif

DOW (U.S. Department of War). **1946**. United States Gains Technical Aid from German-Austrian Scientists. Press Release (4 December). Air Force Historical Research Agency (Maxwell Air Force Base, Alabama).

Downey, William G. **1950**. Captured Enemy Property: Booty of War and Seized Enemy Property. *The American Journal of International Law* (July) 44:488-504.

Eckert, Astrid M. **2012**. *The Struggle for the Files: The Western Allies and the Return of German Archives after the Second World War.* Cambridge, UK: Cambridge University Press.

Edelstein, Julius C. **1948**. Science as Reparations. *Physics Today* (December) 1:6-14.

Edgerton, David. **2006**. *Warfare State: Britain, 1920–1970.* Cambridge, U.K.: Cambridge University Press.

Efron, Noah J. **2006**. *Judaism and Science: A Historical Introduction.* Westport, Connecticut: Greenwood.

Efron, Noah J. 21 October **2013**. The Real Reason Why Jews Win So Many Nobel Prizes. Haaretz. https://www.haaretz.com/opinion/2013-10-21/ty-article/.premium/the-real-reason-jews-win-so-many-nobels/0000017f-f5f9-d460-afff-ffffa0c20000

Efron, Noah J. **2014**. *A Chosen Calling: Jews in Science in the Twentieth Century.* Baltimore, Maryland: Johns Hopkins University Press.

Faragher, Warren F. **1948**. Collecting German Industrial Information. *Chemical and Engineering News* (27 December) 26:3816-3820.

Ferguson, R. Brian. **2007**. How Jews Became Smart: Anti-"Natural History of Ashkenazi Intelligence." https://www.semanticscholar.org/paper/How-Jews-Became-Smart-%3A-Anti-%22-Natural-History-of-%22-Ferguson-Antoniello/1eedb19bcf7c059a4b10a9ed8c58027d9ed22bae?p2df

Fichter, George S. **1970a**. *Exploring Biology.* Chicago: Sears Golden Library.

Fichter, George S. **1970b**. *Exploring with the Microscope.* Chicago: Sears Golden Library.

Finkbeiner, Ann. **2006**. *The Jasons: The Secret History of Science's Postwar Elite.* New York: Viking.

Francis, Rohin. 22 October **2020**. The Biggest Scandal in Science. *MedPage Today.* https://www.medpagetoday.com/publichealthpolicy/generalprofessionalissues/89261

Fraser, Gordon. **2012**. *The Quantum Exodus: Jewish Fugitives, the Atomic Bomb, and the Holocaust.* Oxford: Oxford University Press.

Georg, Friedrich. **2012**. *"Unternehmen Patentenraub" 1945: Die Geheimgeschichte des größten Technologieraubs aller Zeiten.* 6th ed. Tübingen: Grabert.

Gerstl, Ronald. **2014**. *The Superachievers.* North Charleston, South Carolina: CreateSpace.

Gilbert, A. C., and Marshall **McClintock**. **1954**. *The Man Who Lives in Paradise.* New York: Rinehart & Company.

Gimbel, John. **1986**. U.S. Policy and German Scientists: The Early Cold War. *Political Science Quarterly* 101:3:433-451.

Gimbel, John. **1990a**. *Science, Technology, and Reparations: Exploitation and Plunder in Postwar Germany.* Stanford: Stanford University Press.

Gimbel, John. **1990b**. Project Paperclip: German Scientists, American Policy, and the Cold War. *Diplomatic History* 14:3:343–366.

Gimbel, John. **1990c**. German Scientists, United States Denazification Policy, and the "Paperclip Conspiracy". *International History Review* 12:441–85.

Glatt, Carl. **1994**. Reparations and the Transfer of Scientific and Industrial Technology from Germany: A Case Study of the Roots of British Industrial Policy and of Aspects of British Occupation Policy in Germany between Post-World War II Reconstruction and the Korean War, 1943–1951. Ph.D. thesis. Florence: European University Institute.

Glenn, Bess. **1962**. Private Records Seized by the United States in Wartime—Their Legal Status. *American Archivist* (October) 25:399-405.

Goudsmit, Samuel A. **1947**. German Scientists in Army Employment. *Bulletin of the Atomic Scientists* (February) 3:64ff.

Graham, Loren. **1993**. *Science in Russia and the Soviet Union: A Short History.* Cambridge, UK: Cambridge University Press.

Green, John C. **1946**. Scientific Information from Enemy Sources and Government Sponsored Research. *Chemical and Engineering News* (10 July) 24:1795-1799.

Green, John C. **1947a**. Last Call for Germany. *Federal Science Progress* (February) 1:1:24-25.

Green, John C. **1947b**. Technology Imports from Germany: New World-Trade Opportunities. *Foreign Commerce Weekly* (3 May) 27:3-5ff.

Greenewalt, Crawford. **1959**. *The Uncommon Man: The Individual in the Organization.* New

York: McGraw-Hill.

Grometstein, Alan A., ed. **2011**. *MIT Lincoln Laboratory: Technology in Support of National Security.* Cambridge, Massachusetts: MIT Press.

Gross, Daniel A. 28 July **2014**. The U.S. Confiscated Half a Billion Dollars in Private Property During WWI: America's Home Front Was the Site of Internment, Deportation, and Vast Property Seizure. *Smithsonian.* https://www.smithsonianmag.com/history/us-confiscated-half-billion-dollars-private-property-during-wwi-180952144/

Gross, Daniel A. Spring **2015**. Chemical Warfare: From the European Battlefield to the American Laboratory. *Distillations.* 1:1:16–23. https://www.sciencehistory.org/stories/magazine/chemical-warfare-from-the-european-battlefield-to-the-american-laboratory/

Haertel, T. G. **1947**. Three Months in Germany: A Factual Account in Fiction Form of the Investigation of German Industrial 'Know-How.' *Federal Science Progress* (April) 1:7.

Hall, Charlie. **2019a**. *British Exploitation of German Science and Technology.* New York: Routledge.

Hargest, William J. **1946**. German Industry Is Taking a Beating. *American Machinist* (14 February) 90:113-121.

Hargittai, Balazs, and **István Hargittai**. **2015**. *Wisdom of the Martians of Science: In Their Own Words with Commentaries.* Singapore: World Scientific.

Hargittai, István. **2006**. *Martians of Science: Five Physicists Who Changed the Twentieth Century.* Oxford: Oxford University Press.

Hathaway, Ian. 4 December **2017**. Almost Half of Fortune 500 Companies Were Founded by American Immigrants or Their Children. Brookings Institution. https://www.brookings.edu/articles/almost-half-of-fortune-500-companies-were-founded-by-american-immigrants-or-their-children/

Henke, Klaus-Dietmar. **2015**. *Die amerikanische Besetzung Deutschlands.* 2nd ed. Berlin: De Gruyter. pp. 754–758. https://books.google.com/books?id=J73yCQAAQBAJ

Herrnstein, Richard J., and Charles **Murray**. **1996**. *The Bell Curve: Intelligence and Class Structure in American Life.* 2nd ed. New York: Free Press.

Hounshell, David A., and John K. **Smith**, Jr. **1988**. *Science and Corporate Strategy: Du Pont R&D, 1902-1980.* Cambridge, UK: Cambridge University Press.

Howard, Michael. **2010**. *Otherwise Occupied: Letters Home from the Ruins of Nazi Germany.* London: Old Street Publishing.

Hullinger, Edwin War. **1945**. World's Greatest Treasure Hunt. *Nation's Business* (October) 33:21-22ff.

Hunt, Linda. **1985**. U.S. Coverup of Nazi Scientists. *Bulletin of the Atomic Scientists* (April) 41:4:16-24.

Hunt, Linda. **1991**. *Secret Agenda.* New York: St. Martin's Press.

Hunt, Morton M. **1949**. The Nazis Who Live Next Door. *The Nation* (16 July 1949) 56-58 and

(23 July) 82-84.

Isaacson, Walter, and Evan **Thomas**. **1986**. *The Wise Men: Six Friends and the World They Made.* New York: Simon & Schuster.

Jacobsen, Annie. **2014**. *Operation Paperclip: The Secret Intelligence Program that Brought Nazi Scientists to America.* New York: Little, Brown.

Jacobsen, Annie. **2015**. *The Pentagon's Brain: An Uncensored History of DARPA, America's Top Secret Military Research Agency.* Boston: Little, Brown.

Jardini, David. **2013**. *Thinking Through the Cold War: RAND, National Security and Domestic Policy, 1945–1975.* Amazon ebook.

Jensen, Edna. **1948**. *Study No. 215: History of AAF Participation in Project Paperclip, September 1946-April 1948. Vol. 2.* Historical Office, Air Materiel Command, Wright-Patterson Air Force Base (November 1948). Microfilm A 2055, Air Force Historical Research Agency (Maxwell Air Force Base, Alabama).

Jitterbuzz. **2017**. My Experience with Gilbert Science Sets. http://www.jitterbuzz.com/scikits.html

Johnson, Stephen B. **2002**. *The United States Air Force and the Culture of Innovation, 1945–1965.* Washington, D. C.: Air Force History and Museums Program. https://media.defense.gov/2010/May/26/2001330260/-1/-1/0/AFD-100526-019.pdf

Jones, Evan. **2002**. The Employment of German Scientists in Australia after World War II. Prometheus: Critical Studies in Innovation 20:4:305–321.

Jordan, George Racey, and Richard L. **Stokes**. **1952**. *From Major Jordan's Diaries: The Inside Story of Soviet Lend-Lease—from Washington to Great Falls to Moscow.* New York: Harcourt, Brace. [cited in Richard Rhodes, Dark Sun] German translation: G. R. Jordan. 1960. *Sowjets siegen durch Spione. Roosevelt hat der Sowjetunion die Atombombe ausgeliefert.* Göttingen: K.W. Schütz.

Josephs, Ray. February **1946**. The World's Greatest Treasure Hunt. *The American Magazine* pp. 44–96.

Jösten, Joachim. **1947**. This Brain for Hire. *The Nation* (11 January) 164:36-38.

Judt, Matthias, and Burghard **Ciesla**, eds. **1996**. *Technology Transfer out of Germany after 1945.* New York: Routledge.

Judt, Tony. **2005**. *Postwar: A History of Europe Since 1945.* New York: Penguin Press.

Kaplan, Fred. **1991**. *The Wizards of Armageddon.* 2nd ed. Stanford: Stanford University Press.

Kent, John L. **1948**. Manufacturing Advances in Wartime Germany: Machines and Processes Which Were Developed in Competition with Allied Engineering Brains Are Now Available to U.S. Industry. *Scientific American* (April) 178:161-164.

Keyes, Donald B. **1945**. Technical Investigation in Germany in World War II. *Chemical Industries* (December) 57:1053.

Kirkpatrick, Sidney D. **1945**. Through Germany in a Jeep. *Chemical and Metallurgical Engineer-*

ing (June) 52:94-96.

Koerner, Steven T. **2004**. Technology Transfer from Germany to Canada after 1945: A Study in Failure? *Comparative Technology Transfer and Society* 2:1: 99–124.

Krige, John. **2006**. *American Hegemony and the Postwar Reconstruction of Science in Europe.* Cambridge, Massachusetts: MIT Press.

Krige, John. **2010**. Building the Arsenal of Knowledge. *Centaurus* 52:4:280–296.

Kurowski, Franz. **1982**. *Alliierte Jagd auf deutsche Wissenschaftler: Das Unternehmen Paperclip.* Munich: Kristall bei Langen Müller.

Lasby, Clarence G. **1971**. *Project Paperclip: German Scientists and the Cold War.* New York: Atheneum.

Lebrecht, Norman. **2019**. *Genius & Anxiety: How Jews Changed the World, 1847–1947.* New York: Scribner.

Leff, Laurel. **2019**. *Well Worth Saving: American Universities' Life-and-Death Decisions on Refugees from Nazi Europe.* New Haven, Connecticut: Yale University Press.

Lehmann, Walter. **2006**. *Die Bundesrepublik und Franco-Spanien in den 50er Jahren: NS-Vergangenheit als Bürde?* Munich: Oldenbourg.

LeMay, Curtis E. June **1946**. The AAF's War of Research. *Flying* 38:17–19.

Lichtblau, Erich. **2014**. *The Nazis Next Door: How America Became a Safe Haven for Hitler's Men.* Boston: Houghton Mifflin Harcourt.

Lindbergh, Charles A. **1970**. *The Wartime Journals of Charles A. Lindbergh.* New York: Harcourt Brace Jovanovich.

Littell, Robert. **1958**. The Kremlin Picks a German Brain. *Reader's Digest* (August pp. 97-101).

Ludmann-Obier, Marie-France. **1986**. Un aspect de la chasse aux cerveaux: les transferts de techniciens allemands en France: 1945–1949. *Relations Internationals* 46:195–208.

Ludmann-Obier, Marie-France. **1988**. Le contrôle de la recherche scientifique en zone française d'Occupation en Allemagne, 1945–1949. *Revue d'Allemagne* 4:404.

Ludmann-Obier, Marie-France. **1989**. *Die Kontrolle der chemischen Industrie in der französischen Besatzungszone 1945–1949.* Mainz: Hase & Koehler.

Maddrell, Paul. **2006**. *Spying on Science: Western Intelligence in Divided Germany 1945–1961.* Oxford: Oxford University Press.

Margolian, Howard. **2000**. *Unauthorized Entry: The Truth about Nazi War Criminals in Canada, 1946–1956.* Toronto: University of Toronto Press.

Marx, George. **2001**. *The Voice of the Martians: Hungarian Scientists who Shaped the 20th Century in the West.* 2nd ed. Budapest: Akadémiai Kiadó.

McCullough, David. **1992**. *Truman.* New York: Simon & Schuster.

Medawar, Jean, and David Pyke. **2000**. *Hitler's Gift: The True Story of the Scientists Expelled by the Nazi Regime.* New York: Arcade.

Michalski, Marek, Rainer Karlsch, and Andreas Sulzer. **2019**. Wunderwaffe: Prisoner of War: Hans Kammler w rękach Amerykanów. *Odkrywca* No. 7 p. 12.

Mick, Christoph. **2000**. *Forschen für Stalin: Deutsche Fachleute in der sowjetischen Rüstungsindustrie 1945–1958.* Munich: Oldenbourg.

Milton, Joyce. **1993**. *Loss of Eden: A Biography of Charles and Anne Morrow Lindbergh.* New York: HarperCollins.

Murphy, Walter J. **1945**. The Job Is Still Unfinished: Some Thoughts on the Collection and Dissemination of Technical and Scientific Information from Occupied Countries. *Chemical and Engineering News* (10 September) 23:1528-1531.

Murray, Charles. **2003**. *Human Accomplishment: The Pursuit of Excellence in the Arts and Science, 800 B. C. to 1950.* New York: HarperCollins.

Murray, Charles. April **2007**. Jewish Genius. *Commentary.*
https://www.commentary.org/articles/charles-murray/jewish-genius/

Murray, Charles. **2020**. *Human Diversity: The Biology of Gender, Race, and Class.* New York: Hachette.

Nachmansohn, David. **1979**. *German-Jewish Pioneers in Science 1900-1933.* New York: Springer.

Nagan, Seymour. **1947**. Top Secret: Nazis at Work. *New Republic* (11 August) 117:24-26.

Naimark, Norman M. **1995**. *The Russians in Germany: A History of the Soviet Zone of Occupation, 1945-1949.* Cambridge, Massachusetts: Belknap Press.

Neitzel, Sönke. **2007**. *Tapping Hitler's Generals: Transcripts of Secret Conversations, 1942–45.* South Yorkshire, U.K.: Frontline Books.

Neitzel, Sonke, and Harald **Welzer**. **2012**. *Soldaten: On Fighting, Killing, and Dying: The Secret WW II Transcripts of German POWs.* Oxford, U.K.: Signal. [pp. 224–233]

Nouzille, Vincent, and Olivier **Huwart**. **1999**. Comment la France a recruté des savants de Hitler. *L'Express* no. 2498 (20 May), p. 122. https://www.lexpress.fr/informations/comment-la-france-a-recrute-des-savants-de-hitler_633743.html

NSF. **1946**. *National Science Foundation: Report from the Committee on Military Affairs, United States Senate, Pursuant to S. 1850.* Washington, DC: U.S. Government Printing Office. [p. 6: WWII US accomplishments based on German ideas]

Open Library. **2010**. James Duncan Lawrence.
https://openlibrary.org/authors/OL956419A/James_Duncan_Lawrence

O'Reagan, Douglas Michael. **2014**. *Science, Technology, and Know-How: Exploitation of German Science and the Challenges of Technology Transfer in the Postwar World.* Ph.D. thesis. University of California, Berkeley.

O'Reagan, Douglas Michael. **2019**. *Taking Nazi Technology: Allied Exploitation of German Sci-*

ence after the Second World War. Baltimore, Maryland: Johns Hopkins University Press.

Paneth, F. A. **1948**. Scientific Research in the British Zone of Germany. *Nature* (7 February) 161:191-192.

Parker, Bertha M., and Alice F. **Martin**. **1970a**. *Exploring Chemistry Volume I.* Chicago: Sears Golden Library.

Parker, Bertha M., and Alice F. **Martin**. **1970b**. *Exploring Chemistry Volume II.* Chicago: Sears Golden Library.

Parker, Bertha M., and Alice F. **Martin**. **1970c**. *Exploring Geology.* Chicago: Sears Golden Library.

Pinker, Steven. **2006**. Groups and Genes. *New Republic* 26 June. https://newrepublic.com/article/77727/groups-and-genes

Preston, John. **2021**. *Fall: The Mysterious Life and Death of Robert Maxwell, Britain's Most Notorious Media Baron.* New York: Harper.

Rauch, Basil, ed. **1957**. *Franklin D. Roosevelt: Selected Speeches, Messages, Press Conferences, and Letters.* New York: Rinehart.

Regis, Ed. **1987**. *Who Got Einstein's Office? Eccentricity and Genius at the Institute for Advanced Study.* Reading, Massachusetts: Addison-Wesley.

Reuter, Dean, Colm Lowery, and Keith Chester. **2019**. *The Hidden Nazi: The Untold Story of America's Deal with the Devil.* Washington, DC: Regnery.

Richelson, Jeffrey T. **2001**. *The Wizards of Langley: Inside the CIA's Directorate of Science and Technology.* Cambridge, Massachusetts: Perseus.

Sargeant, Howland H., and James E. **Markham**. **1945**. *Hearings on Science Legislation (S. 1297 and Related Bills). Hearings Before a Subcommittee of the Committee on Military Affairs, United States Senate, Seventy-Ninth Congress, First Session. Part 2.* Washington, D.C.: U.S. Government Printing Office. pp. 675–676, 692–695.

Sarkowski, Heinz. **2001**. The Growth and Decline of German Scientific Publishing 1850–1945. In: E.H. Fredriksson, ed. 2001. *A Century of Science Publishing.* IOS Press.

Sayer, Ian, and Douglas **Botting**. **1989**. *America's Secret Army: The Untold Story of the Counter Intelligence Corps.* London: Grafton Books.

Scatchard, George. **1948**. The Policy for Controlling German Scientific Work. *Chemical Engineering* (January) 55:260-262.

Schlesinger, Arthur, Jr. **1965**. *A Thousand Days: John F. Kennedy in the White House.* Boston: Houghton Mifflin.

Schrage, Michael. **1990**. Remembering the Great Vannevar Bush. *Los Angeles Times* 1990-05-24. https://www.latimes.com/archives/la-xpm-1990-05-24-fi-444-story.html

Shearman, Jennifer. **2008**. *The MITRE Corporation: Fifty Years of Service in the Public Interest.* Bedford, Massachusetts: The MITRE Corporation.

Siddiqi, Asif. **2009**. Germans in Russia: Cold War, Technology Transfer, and National Identity. *Osiris* 24:120–43.

Simpson, Christopher. **1988**. *Blowback: The First Full Account of America's Recruitment of Nazis, and Its Disastrous Effect on Our Domestic and Foreign Policy.* New York: Weidenfeld & Nicolson.

Smil, Vaclav. **2005**. *Creating the Twentieth Century: Technical Innovations of 1867-1914 and Their Lasting Impact.* Oxford: Oxford University Press.

Smil, Vaclav. **2006**. *Transforming the Twentieth Century: Technical Innovations and Their Consequences.* Oxford: Oxford University Press.

Sokolov, V. L. **1955**. *Soviet Use of German Science and Technology, 1945-1946.* New York.

Sommerich, Otto C. **1955**. Treatment by the United States of World War I and II Enemy-Owned Patents and Copyrights. *The American Journal of Comparative Law* 4:587-600.

Stanley, Ruth. **1999**. *Rüstungsmodernisierung durch Wissenschaftsmigration? Deutsche Rüstungsfachleute in Argentinien und Brasilien 1947–1963.* Frankfurt am Main: Vervuet.

Sutton, Antony C. **1973**. *Western Technology and Soviet Economic Development 1945 to 1965.* Stanford, California: Hoover Institution Press.

Teyssier, Arnaud, and Roland **Hautefeuille**. **1989**. Recherche scientifique et politique militaire en France (1945–1958). *Revue Historique des Armées* 175:111–22.

Thompson, Lawrence S. **1947**. The Bibliography of Scientific and Industrial Reports. *The Journal of Documentation* (June) 3:3-8.

Trichet, Pierre. **2009**. Paperclip, French Style. AIAA 2009-962. 47th AIAA Aerospace Sciences Meeting. https://arc.aiaa.org/doi/abs/10.2514/6.2009-962

Tyler, John. **2003**. *The Chemcraft Story: The Legacy of Harold Porter.* Haworth, New Jersey: St. Johann Press.

Van der Vleuten, Erik. **2008**. Toward a Transnational History of Technology: Meanings, Promises, Pitfalls. *Technology and Culture* 49:974–94.

Walker, Charles Lester. **1946**. Secrets by the Thousands. *Harper's Magazine* (October 1946) 193:329-336.

Warnecke, Dieter. **1995**. *Barbie im Wandel der Jahrzehnte.* Munich: Heyne.

Watson, Bruce. **2002**. *The Man Who Changed How Boys and Toys Were Made.* New York: Viking.

Weinberger, Sharon. **2017**. *The Imagineers of War: The Untold Story of DARPA, the Pentagon Agency That Changed the World.* New York: Knopf.

Whelihan, Peter J. **1949**. German Genius Pays a Debt. *Nation's Business* (May) 37:76-80.

Wiener, Norbert. **1993**. *Invention: The Care and Feeding of Ideas.* Cambridge, Massachusetts: MIT Press.

Wiesner, Jerome B. **1979**. *Vannevar Bush 1890–1974.* Washington, D.C.: National Academies Press. http://www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/bush-vannevar.pdf

Zachary, G. Pascal. **1997a**. *Endless Frontier: Vannevar Bush, Engineer of the American Century.* New York: Free Press, 1997.

Zachary, G. Pascal. **1997b**. The Godfather. *Wired* (November 1997). https://www.wired.com/1997/11/es-bush/

Zachary, G. Pascal, ed. **2022**. *The Essential Writings of Vannevar Bush.* New York: Columbia University Press.

Zeller, Marc. **2009**. *Intellektuelle Reparationen und westdeutscher Wiederaufstieg: Die Chemische Industrie 1945–1955.* Ph.D. thesis. Justus-Liebig-Universität Gießen. http://geb.uni-giessen.de/geb/volltexte/2009/7145/pdf/ZellerMarc_2009_06_24.pdf

Zilg, Gerard Colby. **1984**. *Du Pont Dynasty: Behind the Nylon Curtain.* Secaucus, New Jersey: Lyle Stuart.

Historical Innovations in Biology and Medicine

Abernethy, John Leo. **1967**. Franz Hofmeister: The Impact of His Life and Research on Chemistry. *Journal of Chemical Education* 44:3:177. https://doi.org/10.1021/ed044p177

Allen, Arthur. **2014**. *The Fantastic Laboratory of Dr. Weigl: How Two Brave Scientists Battled Typhus and Sabotaged the Nazis.* New York: W. W. Norton.

von Ardenne, Manfred, and Gottfried **Pyl**. **1940**. Versuche zur Abbildung des Maul- und Klauenseuche-Virus mit dem Universal-Elektronenmikroskop. *Die Naturwissenschaften* 33:531–532.

Aronowitz, Jesse N. **2012**. Whitmore, Henschke, and Hilaris: The Reorientation of Prostate Brachytherapy (1970–1987). *Brachytherapy* 11:2:157–162. https://doi.org/10.1016/j.brachy.2011.03.003

Barenblatt, Daniel. **2004**. *A Plague Upon Humanity: The Secret Genocide of Axis Japan's Germ Warfare Operation.* New York: HarperCollins.

Barlow, C. and P. **Barlow**. **1971**. *Robert Koch.* Geneva: Heron Books.

Bateson, W. **1909**. *Mendel's Principles of Heredity.* Cambridge, UK: Cambridge University Press.

Benninga, H. **1990**. *A History of Lactic Acid Making: A Chapter in the History of Biotechnology.* Dordrecht: Kluwer.

Bielka, Heinz. **2002**. *Geschichte der Medizinisch-Biologischen Institute Berlin-Buch.* 2nd ed. Berlin: Springer.

Bliss, Michael. **2007**. *The Discovery of Insulin: Twenty-fifth Anniversary Edition.* Chicago: University Of Chicago Press.

Blome, Kurt. **1941**. *Arzt im Kampf: Erlebnisse und Gedanken.* Leipzig: Johann Ambrosius Barth.

Boettcher, Wolfgang, Frank Merkle, and Heinz-Hermann Weitkemper. **2003**. History of Extracorporeal Circulation: The Conceptional and Developmental Period. *Journal of the American Society* *of Extra-Corporeal Technology* 35:172–183.

Bopp, Martin. **1996**. The Origin of Developmental Physiology of Plants in Germany. *International Journal of Developmental Biology* 40:1:89–92.

Brandis, Henning. **1957**. Die Anwendung von Phagen in der bakteriologischen Diagnostik mit besonderer Berücksichtigung der Typisierung von Typhus- und Paratyphus B-Bakterien sowie Staphylokokken. *Ergebnisse der Mikrobiologie, Immunitätsforschung und experimentellen Therapie* p. 96.

Brandt, Christina. **2004**. *Metapher und Experiment: Von der Virusforschung zum genetischen Code.* Göttingen: Wallstein.

Brinkman, R., L. D. Eerland, L. A. G. Hissink, and J. J. M. Vegter. **1945**. Hydrolyzed Casein (Capain) as a Plasma Substitute. *Journal of Laboratory and Clinical Medicine* 30:1034–1036.

Brock, Thomas D. 1999. *Robert Koch: A Life in Medicine and Bacteriology.* 2nd ed. Washington, DC: ASM Press.

Bud, Robert. **2006**. *Penicillin: Triumph and Tragedy.* Oxford: Oxford University Press.

Burch, Mary R., and Duane **Pickel**. **1990**. A Toast to Most: Konrad Most, a 1910 Pioneer in Animal Training. *Journal of Applied Behavior Analysis* 23:2:263–264. https://pubmed.ncbi.nlm.nih.gov/16795731/

Butenandt, Adolf. **1931**. Über die chemische Untersuchung der Sexualhormone. *Zeitschrift für angewandte Chemie* (14 November 1931) 44:46:905–916.

Campbell, Mark, and Viktor **Harsch**. **2013**. *Hubertus Strughold: Life and Work in the Fields of Space Medicine.* Neubrandenburg: Rethra.

Campbell, Mark R., and Victor **Harsch**. **2019**. Dr. Hans Guido Mutke and the Dive of his Me-262: First to Break the Sound Barrier? *Aerospace Medicine and Human Performance* 90:2:144–146.

Campbell, Mark R., Stanley R. Mohler, Viktor A. Harsch, and Denise Baisden. **2007**. Hubertus Strughold: the "Father of Space Medicine". *Aviation, Space, and Environmental Medicine* 78:7:716–719.

Carroll, Michael Christopher. **2004**. *Lab 257: The Disturbing Story of the Government's Secret Plum Island Germ Laboratory.* New York: HarperCollins.

Carus, W. Seth. **2001**. *Bioterrorism and Biocrimes: The Illicit Use of Biological Agents Since 1900.* Revised ed. Washington, D.C.: National Defense University. https://wmdcenter.ndu.edu/Portals/97/Documents/Publications/Articles/Bioterrorism-and-Biocrimes.pdf

Clark, Ronald W. **1985**. *The Life of Ernst Chain: Penicillin and Beyond.* New York: St. Martin's Press.

Corcos, Alain F., and Floyd V. **Monaghan**. **1993**. *Gregor Mendel's Experiments on Plant Hybrids: A Guided Study.* New Brunswick, New Jersey: Rutgers University Press.

Deichmann, Ute. **1996**. *Biologists Under Hitler.* Cambridge, Massachusetts: Harvard University Press.

Dobell, Clifford, ed. **1960**. *Antony van Leeuwenhoek and His "Little Animals": Being Some Account of the Father of Protozoology & Bacteriology and His Multifarious Discoveries in These Disciplines.* New York: Harcourt, Brace and Company.

Domagk, Gerhard. **1935**. Ein Beitrag zur Chemotherapie der bakteriellen Infektionen. *Deutsche Medizinische Wochenschrift* 61:7:250-253.

Dominguez-Lacasa, Ićiar. **2005**. *Exploring Technological Change in the German Pharmaceutical Industry: A History-Friendly Model of Technological Change and Technology Adoption in a Science-Based Industry.* Ph.D. thesis. Universität Fridericiana zu Karlsruhe.

Dostál, Ondřej, Michaela Jarkovska, and Daniela Vránová. **2016**. *Gregor Johann Mendel.* Brno: Masaryk University.

Drews, Gerhart. **2010**. *Mikrobiologie: Die Entdeckung der unsichtbaren Welt.* Berlin: Springer.

Eberle, Henrik. **2015**. *"Ein wertvolles Instrument": Die Universität Greifswald im Nationalsozialismus.* Vienna: Böhlau.

Eckart, Wolfgang U., ed. **2000**. *100 Years of Organized Cancer Research—100 Jahre organisierte Krebsforschung.* Stuttgart: Georg Thieme.

Edelson, Edward. **1999**. *Mendel and the Roots of Genetics.* Oxford: Oxford University Press.

Eder, Josef Maria, and Leopold **Freund**. **1922**. Ein neues Schutzmittel gegen Lichtschäden. *Wiener klinische Wochenschrift* 35:681–684.

Egelhaaf, Albrecht. **1996**. Alfred Kühn, His Work and His Contribution to Molecular Biology. *International Journal of Developmental Biology* 40:1:69–75.

Fäßler, Peter E. **1996**. Hans Spemann (1869–1941) and the Freiburg School of Embryology. *International Journal of Developmental Biology* 40:1:49–57.

Fast, Andreas, and Barbara **Riebe**. **2011**. *Archivbilder Forschungsinsel Riems: Fotos aus dem Alltag ihrer Bewohner.* Erfurt: Sutton.

Finger, Stanley. **1994**. *Origins of Neuroscience: A History of Explorations into Brain Function.* Oxford: Oxford University Press.

Fischer, Ernst Peter. **1988**. *Das Atom der Biologen: Max Delbrück und der Ursprung der Molekulargenetik.* Munich: Piper.

Friedrich-Freksa, Hans. **1940**. Bei der Chromosomenkonjugation wirksame Kräfte und ihre Bedeutung für die identische Verdopplung von Nucleoproteinen. *Die Naturwissenschaften* 28:24:376–379.

Furman, Bess. **1962**. *Progress in Prosthetics.* Washington, D.C.: U.S. Government Printing Office. pp. 105–109. http://www.oandplibrary.org/assets/pdf/ProgressInProsthetics.pdf

Gamow, George. **1940**. *Mr. Tompkins in Wonderland.* Cambridge, UK: Cambridge University Press.

Gamow, George. **1945**. *Mr. Tompkins Explores the Atom.* Cambridge, UK: Cambridge University Press.

Gamow, George. **1953**. *Mr. Tompkins Learns the Facts of Life.* Cambridge, UK: Cambridge University Press.

Gamow, George. **1967**. *Mr. Tompkins Inside Himself: Adventures in the New Biology.* New York: Viking.

Gamow, George. **1970**. *My World Line: An Informal Autobiography.* New York: Viking.

Gausemeier, Bernd. **2005**. *Natürliche Ordnungen und politische Allianzen: Biologische und biochemische Forschung an Kaiser-Wilhelm-Instituten 1933–1945.* Göttingen: Wallstein.

Gausemeier, Bernd, Staffan Müller-Wille, and Edmund Ramsden. **2015**. *Human Heredity in the Twentieth Century.* London: Routledge.

Gedeon, Andras. **2006**. *Science and Technology in Medicine: An Illustrated Account Based on Ninety-Nine Landmark Publications from Five Centuries.* New York: Springer.

Geissler, Erhard. **1998a**. *Hitler und die Biowaffen.* Münster: LIT.

Geissler, Erhard. **1998b**. *Biologische Waffen—Nicht in Hitlers Arsenalen: Biologische und Toxin-Kampfmittel in Deutschland von 1915 bis 1945.* Münster: LIT.

Geissler, Erhard, and John Ellis **van Courtland Moon**. **1999**. *Biological and Toxin Weapons: Research, Development and Use from the Middle Ages to 1945.* Oxford: Oxford University Press.

Gelderblom, Hans R., and Detlev H. **Krüger**. **2014**. Helmut Ruska (1908–1973): His Role in the Evolution of Electron Microscopy in the Life Sciences, and Especially Virology. *Advances in Imaging and Electron Physics* 182:1–94.

Gentile, Massimo, and Hans R. **Gelderblom**. **2014**. Electron Microscopy in Rapid Viral Diagnosis: An Update. *New Microbiologica* 37:403–422.

Gerber, Klaus. **1966**. *Bibliographie der Arbeiten aus dem Robert Koch-Institut 1891–1965.* Stuttgart: Gustav Fischer.

Gilbert, Scott F., and Michael J. F. **Barresi**. **2016**. *Developmental Biology.* 11th ed. Sunderland, Massachusetts: Sinauer.

Gold, Hal. **1997**. *Unit 731 Testimony.* Tokyo: Tuttle.

Goschler, Constantin. **2009**. *Rudolf Virchow: Mediziner—Anthropologe—Politiker.* 2nd ed. Vienna: Böhlau.

Gradmann, Christoph. **2009**. *Laboratory Disease: Robert Koch's Medical Bacteriology.* Baltimore, Maryland: Johns Hopkins University Press. Original German edition: 2005. *Krankheit im Labor: Robert Koch und die medizinische Bakteriologie.* Göttingen: Wallstein.

Gradmann, Christoph, and Jonathan **Simon**. **2010**. *Evaluating and Standardizing Therapeutic Agents, 1890–1950.* New York: Palgrave Macmillan.

Grossbach, Ulrich. **1996**. Genes and Development: An Early Chapter in German Developmental Biology. *International Journal of Developmental Biology* 40:1:83–87.

Grossbach, Ulrich. **2009**. Seventy-Five Years of Developmental Genetics: Ernst Caspari's Early

Experiments on Insect Eye Pigmentation, Performed in an Academic Environment of Political Suppression. *Genetics* 181: 1175–1182.

Grow, Malcolm C. **1946**. Hydraulic Leg. *AAF Review* July 1946, p. 8.

Grundmann, Ekkehard. **2004**. *Gerhard Domagk: The First Man to Triumph over Infectious Diseases.* Münster: LIT.

Haagen, Eugen. **1941**. *Viruskrankheiten des Menschen.* Dresden: Theodor Steinkopff.

Hager, Thomas. **2006**. *The Demon Under the Microscope: From Battlefield Hospitals to Nazi Labs, One Doctor's Heroic Search for the World's First Miracle Drug.* New York: Harmony Books.

Hammer, Friedrich. **1891**. *Über den Einfluss des Lichtes auf die Haut.* Stuttgart: Ferdinand Enke.

Hansen, Friedrich. **1993**. *Biologische Kriegsführung im Dritten Reich.* Frankfurt am Main: Campus.

Harris, Henry. **1999**. *The Birth of the Cell.* 2nd ed. New Haven, Connecticut: Yale University Press.

Harris, Sheldon H. **2002**. *Factories of Death: Japanese Biological Warfare, 1932–1945, and the American Cover-up.* 2nd ed. Abingdon, U.K.: Routledge.

Harsch, Viktor. **2000a**. Aerospace Medicine in Germany: From the Very Beginnings. *Aviation, Space, and Environmental Medicine* 71:4:447–450.

Harsch, Viktor. **2000b**. German Acceleration Research from the Very Beginning. *Aviation, Space, and Environmental Medicine* 71:8:854–856.

Harsch, Viktor. **2004**. Ludolph Brauer, German Aeromedical Pioneer. *Aviation, Space, and Environmental Medicine* 75:8:705–707.

Harsch, Viktor. **2006a**. Aeromedical Evacuation in the "Luftwaffe" from its Origins until 1945. *Aviation, Space, and Environmental Medicine* 77:1:73–76.

Harsch, Viktor. **2006b**. Centrifuge "Therapy" for Psychiatric Patients in Germany in the Early 1800s. *Aviation, Space, and Environmental Medicine* 77:2:157–160.

Harsch, Viktor. **2007a**. Theodor Benzinger, German Pioneer in High Altitude Physiology Research and Altitude Protection. *Aviation, Space, and Environmental Medicine* 78:9:906–908.

Harsch, Viktor. **2007b**. Otto von Gericke (1602–1686) and His Pioneering Vacuum Experiments. *Aviation, Space, and Environmental Medicine* 78:11:1075–1077.

Harsch, Viktor. **2015**. Hermann von Schrötter (1870-1928): Inventor of the Sealed Cabin. *Aerospace Medicine and Human Performance* 86:6:581.

Harsch, Viktor. **2017**. Early Ejection Seats in Germany. *Aerospace Medicine and Human Performance* 88:8:801.

Harsch, Viktor. **2018**. Use of the Fieseler "Stork" in World War II Aeromedical Evacuation. *Aerospace Medicine and Human Performance* 89:6:576–577.

Harsch, Viktor. **2019**. Heinz von Diringshofen: Aeromedical Pioneer. *Aerospace Medicine and Human Performance* 90:5:501–503.

Harsch, Viktor, and Juergen **Kriebel**. **2006**. Albrecht Ludwig Berblinger—Inventor of the Spring Prosthesis and Hang-glider (1811). *Aviation, Space, and Environmental Medicine* 77:10:1087–1090.

Harsch, Viktor, Benny Bardrum, and Petra Illig. **2008**. Lilienthal's Fatal Glider Crash in 1896: Evidence Regarding the Cause of Death. *Aviation, Space, and Environmental Medicine* 79:10:993–994.

Harwood, Jonathan. **1987**. National Styles in Science: Genetics in Germany and the United States between the World Wars. *Isis* 78:3:390–414.

Harwood, Jonathan. **1993**. *Styles of Scientific Thought: The German Genetics Community 1900–1933.* Chicago: University of Chicago Press.

Hausser, Karl Wilhelm, and Wilhelm **Vahle**. **1922**. Die Abhängigkeit des Lichterythems un der Pigmentbildung von der Schwingungszahl (Wellenlänge) der erreyenden Strahiung. *Strahlentherapie* 13:41–71.

Haustein, Knut-Olaf. **2004**. Fritz Lickint (1898–1960)—Ein Leben als Aufklärer über die Gefahren des Tabaks. *Suchtmed* 6:3:249–255.

Henig, Robin Marantz. **2000**. *The Monk in the Garden: The Lost and Found Genius of Gregor Mendel, the Father of Genetics.* Boston: Houghton Mifflin Harcourt.

Hinz-Wessels, Annette. **2008**. *Das Robert Koch-Institut im Nationalsozialismus.* Berlin: Kulturverlag Kadmos.

Hinz-Wessels, Annette, and Jens **Thiel**. **2010**. *The Friedrich-Loeffler-Institut 1910–2010: 100 Years of Research for Animal Health.* be.bra wissenschaft.

Holmes, Frederick L. **1993**. *Hans Krebs.* 2 vols. Oxford: Oxford University Press.

Horzinek, Marian C. **1997**. The Birth of Virology. *Antonie van Leeuwenhoek* 71:15–20.

Höxtermann, Ekkehard, and Ulrich **Sucker**. **1989**. *Otto Warburg.* Leipzig: Teubner.

Hulverscheidt, Marion, and Anja **Laukötter**, eds. **2009**. *Infektion und Institution: Zur Wissenschaftsgeschichte des Robert Koch-Instituts im Nationalsozialismus.* Göttingen: Wallstein.

Hüntelmann, Axel C. **2008**. *Hygiene im Namen des Staates: Das Reichsgesundheitsamt 1876–1933.* Göttingen: Wallstein.

Hüntelmann, Axel C. **2011**. *Paul Ehrlich: Leben, Forschung, Ökonomien, Netzwerke.* Wallstein.

Hupfauer, Max. **1972**. Milchgeräte. *Bayerisches Landwirtschaftliches Jahrbuch* 49:1: 105–124. https://mediatum.ub.tum.de/1554376

Hüsselmann, H. **1952**. Speicherungserscheinungen beim Menschen nach Periston. *Klinische Wochenschrift* 30:801–808.

Jahn, Ilse. **2004**. *Geschichte der Biologie.* 3rd ed. Hamburg: Nikol.

Jeffreys, Diarmuid. **2004**. *Aspirin: The Remarkable Story of a Wonder Drug.* New York: Bloomsbury.

Jones, Mary Ellen. **1953**. Albrecht Kossel, a Biographical Sketch. *Yale Journal of Biology and Medicine* 26:9:80–97.

Junker, Thomas. **2004**. *Geschichte der Biologie: Die Wissenschaft vom Leben.* Munich: C. H. Beck.

Kaplan, Donald R., and Todd J. **Cooke**. **1996**. The Genius of Wilhelm Hofmeister: The Origin of Causal-Analytical Research in Plant Development. *American Journal of Botany* 83:12:1647–1660.

Karlson, Peter. **1990**. *Adolf Butenandt: Biochemiker, Hormonforscher, Wissenschaftspolitiker.* Stuttgart: Wissenschaftliche Verlagsgesellschaft.

Kater, Michael H. **1989**. *Doctors Under Hitler.* Chapel Hill, North Carolina: University of North Carolina Press.

Keremidis, Haralampas. **2013**. Historical Perspective on Agroterrorism: Lessons Learned from 1945 to 2012. *Biosecurity and Bioterrorism* 11:S17.

Klee, Ernst. **2001**. *Deutsche Medizin im Dritten Reich: Karrieren vor und nach 1945.* 2nd ed. Frankfurt am Main: S. Fischer.

Knippers, Rolf. **2017**. *Eine kurze Geschichte der Genetik.* 2nd ed. Berlin: Springer.

Koesling, Volker, and Florian **Schülke**, eds. **2010**. *Pillen und Pipetten: Facetten einer Schlüsselindustrie.* Leipzig: Koehler & Amelang.

Kohler, Robert E. **1994**. *Lords of the Fly: Drosophila Genetics and the Experimental Life.* Chicago: University Of Chicago Press.

Kohler, Robert E. **2002**. *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology.* Chicago: University Of Chicago Press.

Kohler, Robert E. **2006**. *All Creatures: Naturalists, Collectors, and Biodiversity, 1850–1950.* Princeton: Princeton University Press.

Kohler, Robert E. **2008**. *From Medical Chemistry to Biochemistry: The Making of a Biomedical Discipline.* Cambridge, UK: Cambridge University Press.

Krebs, Hans. **1981**. *Reminiscences and Reflections.* Oxford: Oxford University Press.

Krüger, D. H., P. Schneck, and H. R. Gelderblom. **2000**. Helmut Ruska and the Visualisation of Viruses. *The Lancet* 355:1713–1717.

Lagerkvist, Ulf. **1998**. *DNA Pioneers and Their Legacy.* New Haven, Connecticut: Yale University Press.

Lagerkvist, Ulf. **2003**. *Pioneers of Microbiology and the Nobel Prize.* Singapore: World Scientific.

Lagerkvist, Ulf. **2005**. *The Enigma Of Ferment: From The Philosopher's Stone To The First Biochemical Nobel Prize.* Singapore: World Scientific.

Lax, Eric. **2004**. *The Mold in Dr. Florey's Coat: The Story of the Penicillin Miracle.* New York: Henry Holt.

Leitenberg, Milton, and Raymond A. **Zilinskas**. **2012**. *The Soviet Biological Weapons Program: A History.* Cambridge, Massachusetts: Harvard University Press.

Linton, Otha. **2006**. Ulrich Henschke. *Journal of the American College of Radiology* 3:8:639. https://doi.org/10.1016/j.jacr.2006.03.016

Loeffler, Friedrich, und Paul **Frosch**. **1897**. Summarischer Bericht über die Ergebnisse der Untersuchungen der Kommission zur Erforschung der Maul- und Klauenseuche bei dem Institut für Infektionskrankheiten in Berlin. *Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten, Abt. I* 22:257–259.

Loeffler, Friedrich, und Paul **Frosch**. **1898**. Berichte der Kommission zur Erforschung der Maul- und Klauenseuche bei dem Institut für Infektionskrankheiten in Berlin. *Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten, Abt. I* 23:371–391.

Loeffler, Friedrich. **1919**. Filtrierbare Virusarten. In: Ernst Friedberger and Richard Pfeiffer, eds. *Lehrbuch der Mikrobiologie (mit besonderer Berücksichtigung der Seuchenlehre).* Vol. 2. Jena: Gustav Fischer. pp. 1091–1155.

Magner, Lois N. **2002**. *A History of the Life Sciences.* 3rd ed., New York: Dekker.

Marks, Lara V. **2010**. *Sexual Chemistry: A History of the Contraceptive Pill.* New Haven, Connecticut: Yale University Press.

Mawer, Simon. **2006**. *Gregor Mendel: Planting the Seeds of Genetics.* New York: Abrams.

Mayr, Ernst. **1984**. *Die Entwicklung der biologischen Gedankenwelt: Vielfalt, Evolution und Vererbung.* Berlin: Springer.

Meienhofer, Johannes, Eugen Schnabel, Hellmut Bremer, Otto Brinkhoff, Rudolf Zabel, Werner Sroka, Henning Klostermeyer, Dietrich Brandenburg, Toru Okuda, and Helmut Zahn. **1963**. Synthese der Insulinketten und ihre Kombination zu insulinaktiven Präparaten. *Zeitschrift für Naturforschung B* 18:12:1120–1121.

Mellinghoff, Klaus Helmut. **1971**. *Georg Ludwig Zuelzers Beitrag zur Insulinforschung.* Düsseldorfer Arbeiten zur Geschichte der Medizin, Band 36. Düsseldorf: Triltsch.

Mellinghoff, Klaus Helmut. **1972**. Georg Ludwig Zuelzers Beitrag zur Pankreasextraktforschung. *Die Medizinische Welt* 23:16:622–626.

Mettenleiter, Thomas C., ed. **2005**. *Friedrich-Loeffler-Institut Federal Research Institute for Animal Health, Isle of Riems: A Short History of Virus Research on the Isle of Riems.* Riems: Friedrich-Loeffler-Institut.

Mettenleiter, Thomas C. **2017**. The First "Virus Hunters." *Advances in Virus Research* 99:1–16.

Miller, Douglas, ed. **1988**. *Goethe: Scientific Studies.* Princeton, New Jersey: Princeton University Press.

Morange, Michel. **2020**. *The Black Box of Biology: A History of the Molecular Revolution.* Cambridge, Massachusetts: Harvard University Press.

Morange, Michel. **2021**. *A History of Biology.* Princeton, New Jersey: Princeton University Press.

Moritz, Karl B., and Helmut W. **Sauer**. **1996**. Boveri's Contributions to Developmental Biology–A Challenge for Today. *International Journal of Developmental Biology* 40:1:27–47.

Müller, Irmgard. **1996**. The Impact of the Zoological Station in Naples on Developmental Physiology. *International Journal of Developmental Biology* 40:1:103–111.

Müller-Wille, Staffan, and Christina **Brandt**, eds. **2016**. *Heredity Explored: Between Public Domain and Experimental Science, 1850–1930.* Cambridge, Massachusetts: MIT Press.

Müller-Wille, Staffan, and Hans-Jörg **Rheinberger**, **2012**. *A Cultural History of Heredity.* Chicago: University Of Chicago Press.

Murphy, Eugene. **1989**. Hans Adolph Mauch 1906–1984. *Memorial Tributes: Volume 3*, pp. 258–264. National Academy of Engineering. https://www.nae.edu/189294/HANS-ADOLPH-MAUCH-19061984

Müssemeier. **1957**. Die Entwicklung der Tierseuchenbekämpfung in Deutschland und ihre zukünftige Gestaltung. *Monatshefte für Veterinärmedizin* 12:273–281.

Ohler, Norman. **2017**. *Blitzed: Drugs in the Third Reich.* Boston: Houghton Mifflin Harcourt.

Olby, Robert. **1994**. *The Path to the Double Helix: The Discovery of DNA.* Mineola, New York: Dover.

Oudshoorn, Nelly. **1991**. *The Making of the Hormonal Body: A Contextual History of the Study of Sex Hormones 1923–1940.* Enschede: Alfa.

Pasternak, Luise, ed. **2004**. *Wissenschaftler im biomedizinischen Forschungszentrum: Berlin-Buch 1930–2004.* Frankfurt: Peter Lang.

Perutz, Max. **1989**. *Is Science Necessary? Essays on Science and Scientists.* New York: E. P. Dutton.

Perutz, Max. **1998**. *I Wish I'd Made You Angry Earlier: Essays on Science, Scientists, and Humanity.* Plainview, New York: Cold Spring Harbor Laboratory Press.

Pfankuch, Edgar, and Helmut **Ruska**. **1947**. Versuche über Länge und Sedimentationskonstante der Tabakmosaik-Virusmoleküle vor und nach ihrer Beschallung. *Zeitschrift für Naturforschung* 2b:358–360.

Plett, Peter C. **2006**. *Peter Plett (1766–1823): Lehrer in der Probstei und Entdecker der Kuhpockenimpfung.* Konstanz: Druckerei Hergeröder.

Posner, Gerald L., and John **Ware**. **2000**. *Mengele: The Complete Story.* New York: Cooper Square Press.

Possehl, Ingunn. **1989**. *Modern aus Tradition: Geschichte der chemischpharmazeutischen Fabrik E. Merck Darmstadt.* Darmstadt: E. Merck.

Pou, Sovitj, Rolf W. Winter, Aaron Nilsen, Jane Xu Kelly, Yuexin Li, J. Stone Doggett, Erin

W. Riscoe, Keith W. Wegmann, David J. Hinrichs, and Michael K. Riscoe. **2012**. Sontochin as a Guide to the Development of Drugs against Chloroquine-Resistant Malaria. *Antimicrobial Agents and Chemotherapy* 56:7:3475–3480.

Pregl, Fritz. **1917**. *Die Quantitative Organische Mikroanalyse.* Berlin: Julius Springer.

Proctor, Robert N. **1999**. *The Nazi War on Cancer.* Princeton: Princeton University Press.

Ratmoko, Christina. **2010**. *Damit die Chemie stimmt: Die Anfänge der industriellen Herstellung von weiblichen und männlichen Sexualhormonen 1914–1938.* Zurich: Chronos. https://www.research-collection.ethz.ch/handle/20.500.11850/81326

Raviña, Enrique, and Hugo **Kubinyi**. **2011**. *The Evolution of Drug Discovery: From Traditional Medicines to Modern Drugs.* Weinheim: Wiley-VCH.

Regis, Ed. **1999**. *The Biology of Doom: The History of America's Secret Germ Warfare Project.* New York: Henry Holt.

Reinhardt, Klaus. **2013**. The Entomological Institute of the Waffen-SS: Evidence for Offensive Biological Warfare Research in the Third Reich. *Endeavour* (December 2013) 37:4:220–227.

Richards, Robert J. **2004**. *The Romantic Conception of Life: Science and Philosophy in the Age of Goethe.* Chicago: University Of Chicago Press.

Richards, Robert J. **2009**. *The Tragic Sense of Life: Ernst Haeckel and the Struggle over Evolutionary Thought.* Chicago: University Of Chicago Press.

Riebe, Barbara, and Diedrich **Möhlmann**. **2012**. *Die Forschungsinsel Riems: Neue Einblicke in die Vergangenheit.* Erfurt: Sutton.

Roth, R. R. **1983**. The Foundation of Bionics. *Perspectives in Biology and Medicine* 26:2:229–242. https://muse.jhu.edu/article/403622/pdf

Rott, Rudolf. **1999**. Friedrich Loeffler und Paul Frosch: die Begrunder der animalen Virologie. *Naturwissenschaftliche Rundschau* 52:183–186.

Rott, Rudolf and Stuart **Siddell**. **1998**. One Hundred Years of Animal Virology. *Journal of General Virology* 79:2871–2874.

Ruska, Helmut, Bodo von Borries, and Ernst Ruska. **1939**. Die Bedeutung der Übermikroskopie für die Virusforschung. *Archiv für die gesamte Virusforschung* 1:155–169.

Ruska, Helmut, and Kurt **Poppe**. **1947**. Morphologische Beziehungen zwischen filtrierbaren Mikroorganismen und großen Virusarten. *Zeitschrift für Naturforschung* 2b:35–36.

Sander, Klaus. **1996**. On the Causation of Animal Morphogenesis: Concepts of German-Speaking Authors from Theodor Schwann (1839) to Richard Goldschmidt (1927). *International Journal of Developmental Biology* 40:1:7–20.

Schardinger, Fritz. **1905**. Bacillus macerans, ein Aceton bildender Rottebacillus. *Zentralblatt für Bakteriologie, Parasiten- kunde, Infektionskrankheiten und Hygiene* 2:14:772–781.

Schieder, Wolfgang, and Achim **Trunk**, eds. **2004**. *Adolf Butenandt und die Kaiser-Wilhelm-Gesellschaft: Wissenschaft, Industrie und Politik im "Dritten Reich".* Göttingen: Wallstein. [pp.

198–246: Jean-Paul Gaudillière. Biochemie und Industrie: Der "Arbeitskreis Butenandt-Schering" in Nationalsozialismus.]

Schlegel, Hans Günter. **2004**. *Geschichte der Mikrobiologie.* 2nd ed. Deutsche Akademie der Naturforscher Leopoldina.

Schnalke, Thomas, and Isabel **Atzl**, eds. **2010**. *Dem Leben auf der Spur im Berliner Medizinhistorischen Museum der Charité.* Munich: Prestel.

Schneider, Wolfgang. **1972**. *Geschichte der pharmazeutischen Chemie.* Weinheim: Verlag Chemie.

Schoen, Horst. **1949**. Organveränderungen beim Säugling nach Zufuhr von Periston. *Klinische Wochenschrift* (July 1949) 27:463–468.

Schramm, Gerhard. **1941**. Über die enzymatische Abspaltung der Nucleinsäure aus dem Tabakmosaikvirus. *Bericht der deutschen chemischen Gesellshaft* 74:532–536.

Schramm, Gerhard. **1943**. Über die Spaltung des Tabakmosaikvirus in niedermolekulare Proteine und die Rückbildung hochmolekularen Proteins aus den Spaltstücken. *Die Naturwissenschaften* 31:7–8:94–96.

Schramm, Gerhard, and Heinz **Dannenberg**. **1944**. Über die Ultraviolettabsorption des Tabakmosaikvirus. *Bericht der deutschen chemischen Gesellshaft* 77:53–60.

Schramm, Gerhard, and Hans **Müller**. **1940**. Zur Chemie des Tabakmosaikvirus: Über die Einwirkung von Keten und Phenylisocyanat auf das Virusprotein. *Zeitschrift für physiologische Chemie* 266:43–55.

Schramm, Gerhard, and Hans **Müller**. **1942**. Über die Bedeutung der Aminogruppen für die Vererbungsfähigkeit des Tabakmosaikvirus. *Zeitschrift für physiologische Chemie* 274:267–275.

Schramm, Gerhard, and L. **Rebensburg**. **1942**. Zur vergleichenden Charakterisierung einiger Mutanten des Tabakmosaikvirus. *Die Naturwissenschaften* 30:48–51.

von Schwerin, Alexander. **2004**. *Experimentalisierung des Menschen: Der Genetiker Hans Nachtsheim und die vergleichende Erbpathologie, 1920–1945.* Göttingen: Wallstein.

von Schwerin, Alexander, Heiko Stoff, and Bettina Wahrig, eds. **2013**. *Biologics, A History of Agents Made From Living Organisms in the Twentieth Century.* London: Pickering & Chatto.

Segrè, Gino. **2011**. *Ordinary Geniuses: Max Delbrück, George Gamow, and the Origins of Genomics and Big Bang Cosmology.* New York: Viking.

Semmelweis, Ignaz. **1981**. *The Etiology, the Concept and the Prophylaxis of Childbed Fever.* Birmingham, Alabama: Classics of Medicine Library.

Shama, Gilbert. **2003**. Pilzkrieg: The German Wartime Quest for Penicillin. *Microbiology Today* 30:3:120–123.

Shama, Gilbert, and Jonathan **Reinarz**. **2002**. Allied Intelligence Reports on Wartime German Penicillin Research and Production. *Historical Studies in the Physical and Biological Sciences* 32:2:347-367.

Simmons, John Galbraith. **2002**. *Doctors & Discoveries: Lives that Created Today's Medicine:*

From Hippocrates to the Present. Boston: Houghton Mifflin Harcourt. [Ernst Ruska (1906-1988). Inventing the Electron Microscope. pp. 270-274.]

Sloan, Phillip R., and Brandon **Fogel**, eds. **2011**. *Creating a Physical Biology: The Three-Man Paper and Early Molecular Biology.* Chicago: University of Chicago Press.

Smith, Roger. **1997**. *The Norton History of the Human Sciences.* New York: W.W. Norton.

Sneader, Walter. **2005**. *Drug Discovery: A History.* New York: Wiley.

Spitz, Vivien. **2005**. *Doctors from Hell: The Horrific Account of Nazi Experiments on Humans.* Boulder: Sentient.

Stichnothe-Botschafter, Karin. **2013**. *The Behring Route Marburg: An Accompanying Brochure.* Marburg: Magistrat der Universitätsstadt Marburg.

Stoff, Heiko. **2012**. *Wirkstoffe: Eine Wissenschaftsgeschichte der Hormone, Vitamine und Enzyme, 1920–1970.* Stuttgart: Franz Steiner.

Strughold, Hubertus, ed. **1950**. *German Aviation Medicine, World War II.* 2 vols. Washington, D.C.: U.S. Government Printing Office.

Stubbe, Hans. **1965**. *Kurze Geschichte der Genetik bis zur Wiederentdeckung der Vererbungsregeln Gregor Mendels.* 2nd ed. Jena: Gustav Fischer.

Taschwer, Klaus, Johannes Feichtinger, Stefan Sienell, and Heidemarie Uhl, eds. **2016**. *Experimental Biology in the Vienna Prater: On the History of the Institute for Experimental Biology 1902 to 1945.* Vienna: Austrian Academy of Sciences.

Timoféeff-Ressovsky, N. W., K. G. Zimmer, and M. Delbrück. **1935**. Über die Natur der Genmutation und der Genstruktur. Nachrichten von der Gesellschaft der Wissenschaften zu Göttingen: Mathematische-Physikalische Klasse, Fachgruppe VI, Biologie 1:13:189-245.

Tokyo War Crimes Trial. **1950**. *Prozessmaterialien in der Strafsache gegen ehemalige angehörige der japanischen Armee wegen Vorbereitung und Anwendung der Bakterienwaffe.* Moscow: Verlag für Fremdsprachige Literatur.

Urbach, Frederick. **2001**. The Historical Aspects of Sunscreens. *Journal of Photochemistry and Photobiology B: Biology* 64:2–3:99–104.

U.S. Army. **1956**. *Technical Manual No. 3-216: Military Biology and Biological Warfare Agents.* Washington, DC: Department of the Army.

U.S. Army Air Forces *Report from Heidelberg: The Story of the Army Air Forces Aero Medical Center in Germany 1945–1947.* 28 February 1947.
https://collections.nlm.nih.gov/catalog/nlm:nlmuid-14130150R-bk

Verg, Erik, Gottfried Plumpe, and Heinz Schultheis. **1988**. *Milestones: The Bayer Story 1863–1988.* Leverkusen: Bayer.

Virchow, Rudolph. **1860**. *Cellular Pathology.* London: John Churchill.

Wagner, Gustav, and Andrea **Mauerberger**. **2012**. *Krebsforschung in Deutschland. Vorgeschichte und Geschichte des Deutschen Krebsforschungszentrums.* Berlin: Springer.

Weatherall, M. **1991**. *In Search of a Cure: A History of Pharmaceutical Discovery.* Oxford: Oxford University Press.

Weinberg, Wilhelm. **1908**. Über den Nachweis der Vererbung beim Menschen. *Jahreshefte des Vereins für vaterländische Naturkunde in Württemberg* 64:369–382.

Weiss, Robin A. **2005**. Robert Koch: The Grandfather of Cloning? *Cell* 123:539–542.

Widmark, Erik Johan. **1889**. Über den Einfluss des Lichtes auf die Haut. *Hygiea* 3:264–330.

Williams, Gareth. **2019**. *Unravelling the Double Helix: the Lost Heroes of DNA.* London: Weidenfeld & Nicolson.

Wirtz, Jean. **1998**. A Reappraisal of the Contribution of Friedrich Loeffler to the Development of the Modern Concept of Virus. *Archives of Virology* 143:2261–2263.

Zimmer, Heinz-Gerd. **2003**. The Heart-Lung Machine was Invented Twice—the First Time by Max von Frey. *Clinical Cardiology* 26:443–445.

Historical Innovations in Chemistry and Materials Science

Abelshauser, Werner, Wolfgang von Hippel, Jeffrey Allan Johnson, and Raymond G. Stokes. **2004**. *German Industry and Global Enterprise: BASF: The History of a Company.* Cambridge, UK: Cambridge University Press.

Adenstedt, Heinrich K. O. **1948**. German Methods in Developing Turbine-Wheel Blades for the Jumo-004. [Air Technical Intelligence] *ATI Technical Data Digest* 13:6:7–13. https://books.google.com/books?id=F8JGAQAAMAAJ&pg=RA5-PA7#v=onepage&q&f=false

Albarelli, H. P., Jr. **2009**. *A Terrible Mistake: The Murder of Frank Olson and the CIA's Secret Cold War Experiments.* Walterville, Oregon: Trine Day.

Baird, W. **1955**. Synthetic Detergents. *Progress in the Chemistry of Fats and other Lipids.* 3:95–151.

Barrera, Pilar. **1994**. The Evolution of Corporate Technological Capabilities: Du Pont and IG Farben in Comparative Perspective. *Zeitschrift für Unternehmensgeschichte* 39:1:31–45.

Becker, Peter W. **1981**. The Role of Synthetic Fuel in World War II Germany: Implications for Today? *Air University Review* (July-August) 32:45–53.

Beer, John Joseph. **1958**. Coal Tar Dye Manufacture and the Origins of the Modern Industrial Research Laboratory. *Isis* 49:123–131.

Behrens, Helmut. **1998**. *Wissenschaft in turbulenter Zeit: Erinnerungen eines Chemikers an die Technische Hochschule München 1933-1953.* Munich: Munich University.

Berghahn, Volker R., ed. **1996**. *Quest for Economic Empire: European Strategies of German Big Business in the Twentieth Century.* Providence, Rhode Island: Berghahn Books.

Bobleter, Ortwin. **1997**. In memoriam em. Univ.-Prof. Dr. phil. Dr. rer. nat. H.c. Erika Cremer. (1900–1996): 96 Jahre eines Forscherlebens. *Berichte des Naturwissenschaftlich-medizinischen Vereins in Innsbruck* 84:397–406. https://www.zobodat.at/pdf/BERI_84_0397-0406.pdf

Borkin, Joseph. **1978**. *The Crime and Punishment of I. G. Farben: The Unholy Alliance Between Hitler and the Great Chemical Combine.* New York: Free Press. German translation: 1979. *Die unheilige Allianz der I.G. Farben: Eine Interessengemeinschaft im Dritten Reich.* Frankfurt am Main: Campus.

Braun, Dietrich. **2017**. *Kleine Geschichte der Kunststoffe.* 2nd ed. Munich: Carl Hanser.

Brock, William H. **1993**. *The Norton History of Chemistry.* New York: W.W. Norton.

Brooks, G. T. **1974**. *Chlorinated Insecticides. Volume I: Technology and Application.* Boca Raton, Florida: CRC Press.

Brown, George Ingham. **1998**. *The Big Bang: A History of Explosives.* Stroud, Gloucestershire, UK: Sutton.

Bruce, Duncan W., Kurt Heyns, and Volkmar Vill. **1997**. Vorlander's Wheel. *Liquid Crystals* 23:6:813–819.

Bugge, Günther, ed. **1955**. *Das Buch der großen Chemiker.* 2 vols. Weinheim: Verlag Chemie.

Carson, Rachel. **1962**. *Silent Spring.* Boston: Houghton Mifflin.

Clarke, W. Tresper. **1946**. How German Chocolate Ration was Made for Wehrmacht. *Food Industries* (November 1946) 18:87-90.

Coffey, Patrick. **2008**. *Cathedrals of Science: The Personalities and Rivalries That Made Modern Chemistry.* Oxford, Oxford University Press.

Collin, Gerd. **2009**. *Geschichte der Steinkohlenteerchemie am Beispiel der Rütgerswerke.* Hamburg: Urban.

Conant, Jennet. **2020**. *The Great Secret: The Classified World War II Disaster that Launched the War on Cancer.* New York: W.W. Norton.

Deichmann, Ute. **2001**. *Flüchten, Mitmachen, Vergessen: Chemiker und Biochemiker in der NS-Zeit.* Weinheim: Wiley-VCH.

Deutsch, Priscilla A. **1946**. What Do We Want from Germany? *Food Industries* (June 1946) 18:81-82.

DOD (U.S. Department of Defense). **1953**. *German Explosive Ordnance (Bombs, Fuzes, Rockets, Land Mines, Grenades, and Igniters).* TM 9-1985-2. Washington, D.C.: U.S. Government Printing Office. https://archive.org/details/TM919852GermanExplosiveOrdnance1953

Drummer, Heike, and Jutta **Zwilling**. **2007**. *Von der Grünenburg zum Campus Westend: Die Geschichte des IG Farben-Hauses.* Frankfurt: Präsidium der Johann Wolfgang Goethe-Universität.

Dunmur, David, and Tim **Sluckin**. **2011**. *Soap, Science, and Flat-Screen TVs: A History of Liquid Crystals.* Oxford: Oxford University Press.

Engels, Siegfried, Rüdiger Stolz, Wolfgang Göbel, Franz Nawrocki, and Alois Nowak. **1989**. *ABC Geschichte der Chemie.* Leipzig: VEB Deutscher Verlag für Grundstoffindustrie.

Ettre, Leslie Stephen. **2001**. The Predawn of Paper Chromatography. *Chromatographia* 54:5–

6:409–414.

Farber, Eduard, ed. **1961**. *Great Chemists.* New York: Interscience.

Feichtinger, Johannes. **2017**. Die Wiener Schule der Hochpolymerforschung in England und Amerika Emigration, Wissenschaftswandel und Innovation. Unpublished manuscript.

Field, Simon Quellen. **2017**. *Boom! The Chemistry and History of Explosives.* Chicago: Chicago Review Press.

Flueckiger, Barbara. **2020**. Timeline of Historical Film Colors. https://filmcolors.org

Friedrich, Bretislav, Dieter Hoffmann, Jürgen Renn, Florian Schmaltz, and Martin Wolf (eds.). **2017**. *One Hundred Years of Chemical Warfare: Research, Deployment, Consequences.* Berlin: Springer. https://link.springer.com/content/pdf/10.1007/978-3-319-51664-6.pdf

Gellermann, Günther W. **1986**. *Der Krieg, der nicht stattfand: Möglichkeiten, Überlegungen und Entscheidungen der deutschen Obersten Führung zur Verwendung chemischer Kampfstoffe im Zweiten Weltkrieg.* Bonn: Bernard & Graefe.

Gemmill, Arthur V. **1946**. Continuous Butter Making Successful in Wartime Germany. *Food Industries* (June 1946) 18:75-77ff.

Gill, Manfred, and Heinz **Mustroph**. **2014**. Agfa und die Anfänge der Fotografie: Vom Blutlaugensalz zur größten europäischen Filmfabrik: Teil 1 von 3. *Chemie in unserer Zeit.* 48:424-438.

Gill, Manfred, and Heinz **Mustroph**. **2015a**. Zum praktikablen Farbfilm: Auf dem Weg zum Gipfel. Teil 2 von 3. *Chemie in unserer Zeit.* 49:124–136.

Gill, Manfred, and Heinz **Mustroph**. **2015b**. Wiederaufbau und schleichender Niedergang: Filmfabrik Wolfen. Teil 3 von 3. *Chemie in unserer Zeit.* 49:182–194.

Goppelsröder, Friedrich. **1861**. Ueber ein Verfahren, die Farbstoffe in ihren Gemischen zu erkennen. *Verhandlungen der Naturforschenden Gesellschaft zu Basel* 3:2:268–275.

Goppelsröder, Friedrich. **1901**. *Capillaranalyse beruhend auf Capillaritäts- und Adsorptionserscheinungen.* Basel: Emil Birkhäuser.

Gritz, Egbert. **2013**. *Mersol: Entwicklung und Einsatz von Ersatzwaschrohstoffen aus Kohle 1936–1945.* Stuttgart: Franz Steiner.

Gritz, Egbert. **2014**. “Mersol”—ein Waschmittel aus Kohle. *Mitteilungen, Gesellschaft Deutscher Chemiker/Fachgruppe Geschichte der Chemie* (Frankfurt/Main) 24:165–180. www.gdch.de/fileadmin/downloads/Netzwerk_und_Strukturen/Fachgruppen/Geschichte_der_Chemie/Mitteilungen_Band_24/2014-24-09.pdf

Gröhler, Olaf. **1989**. *Der Lautlose Tod: Einsatz und Entwicklung deutscher Giftgase von 1914 bis 1945.* Hamburg: Rowohlt Taschenbuch.

Guillemin, Jeanne. **2005**. *Biological Weapons: From the Invention of State-Sponsored Programs to Contemporary Bioterrorism.* New York: Columbia University Press.

Haber, Ludwig F. **1958**. *The Chemical Industry during the Nineteenth Century: A Study of the Economic Aspect of Applied Chemistry in Europe and North America.* Oxford: Clarendon Press.

Haber, Ludwig F. **1971**. *The Chemical Industry 1900-1930: International Growth and Technological Change.* Oxford: Clarendon Press.

Hager, Thomas. **2008**. *The Alchemy of Air: A Jewish Genius, a Doomed Tycoon, and the Scientific Discovery That Fed the World but Fueled the Rise of Hitler.* New York: Three Rivers Press.

von Haken, Kurd. German patent DE680483, Fliegerbombe für Kohlenstaubexplosionen [Airborne Bombs for Coal Dust Explosions]. Filed 6 April **1933**.

Harris, Robert, and Jeremy **Paxman**. **2002**. *A Higher Form of Killing: The Secret History of Chemical and Biological Warfare.* 2nd ed. New York: Random House.

Hasche, R. Leonard. **1945**. Acetylene Chemistry. *Chemical and Engineering News* (25 October 1945) 23:1840-1845.

Hayes, Peter. **2001**. *Industry and Ideology: I.G. Farben in the Nazi Era.* 2nd ed. Cambridge, UK: Cambridge University Press.

Heppenstall, C. W., Jr. **1946**. Forging Practice in Wartime Germany. *Iron Age* (1 August 1946) 158:55-57.

Hofmann, Hein. **2008**. *Geheimobjekt "Seewerk": Vom Geheimobjekt des Dritten Reiches zum wichtigsten Geheimobjekt des Warschauer Vertrages.* 2nd ed. Meiningen: Heinrich Jung.

Homburg, Ernst. **1992**. The Emergence of Research Laboratories in the Dyestuffs Industry, 1870-1900. *British Journal for the History of Science* 25:91–111.

Housley, Kathleen L. **2007**. *Black Sand: The History of Titanium.* Hartford, Connecticut: Metal Management Aerospace. pp. 28–29. https://vdoc.pub/documents/housley-black-sand-the-history-of-titanium-7ksc3nudpbt0

Hunter, Ralph M. **1945**. German Chlorine: A Report on Production Methods. *Chemical and Metallurgical Engineering* (October 1945) 52:104–106ff.

Ihde, Aaron J. **1984**. *The Development of Modern Chemistry.* New York: Dover.

Jantzen, Eilhard. **1996a**. The Origins of Synthetic Lubricants: The Work of Hermann Zorn in Germany. Part 1: Basic Studies of Lubricants and the Polymerisation of Olefins. *Journal of Synthetic Lubrication* 12:4:283–301.

Jantzen, Eilhard. **1996b**. The Origins of Synthetic Lubricants: The Work of Hermann Zorn in Germany. Part 2: Esters and Additives for Synthetic Lubricants. *Journal of Synthetic Lubrication* 13:2:113–128.

Jeffreys, Diarmuid. **2008**. *Hell's Cartel: IG Farben and the Making of Hitler's War Machine.* New York: Bloomsbury. German translation: 2011. *Weltkonzern und Kriegskartell: Das zerstörerische Werk der IG Farben.* Munich: Karl Blessing.

Jindra, Zdeněk. **2012**. *Der Bahnbrecher des Stahl- und Eisenbahnzeitalters: Die Firma Fried. Krupp/Essen von der Gründung der Gussstahlfabrik bis zur Entwicklung zum "Nationalwerk" und weltbekannten Kanonenlieferanten (1811 bis Anfang der 90er Jahre des 19. Jahrhunderts).* Stuttgart: Franz Steiner.

Johnson, Jeffrey Allan. **1990**. *The Kaiser's Chemists: Science and Modernization in Imperial Germany.* Chapel Hill, North Carolina: University of North Carolina Press.

Kahlert, Heinrich. **2002**. *Chemiker unter Hitler.* Aachen: Bernardus.

Karlsch, Rainer. Großvaters Vakuumbombe [Grandfather of the Vacuum Bomb]. *Frankfurter Allgemeine Zeitung* 23 September **2007** p. 70. Expanded, unabridged version of the article translated by Laura G. McGee.

Karlsch, Rainer. *Leuna: 100 Jahre Chemie.* Wettin: Janos Stekovics.

Kastens, M. L., L. L. Hirst, and R. G. Dressler. **1952**. An American Fischer-Tropsch Plant. *Industrial and Engineering Chemistry* (March 1952) 44:450–466.

Kaszeta, Dan. **2020**. *Toxic: A History of Nerve Agents, from Nazi Germany to Putin's Russia.* London: C. Hurst.

Katzir, Shaul. **2009**. Hermann Aron's Electricity Meters: Physics and Invention in Late Nineteenth-Century Germany. *Historical Studies in the Natural Sciences* 39:4:444–481.

Katzir, Shaul. **2013**. Scientific Practice for Technology: Hermann Aron's Development of the Storage Battery. *History of Science* 51:4:481–500.

Kelker, Hans. **1973**. History of Liquid Crystals. *Molecular Crystals and Liquid Crystals Incorporating Nonlinear Optics.* 21:1–48.

Kelker, Hans. **1988**. Survey of the Early History of Liquid Crystals. *Molecular Crystals and Liquid Crystals Incorporating Nonlinear Optics.* 165:1:1–43.

Kelker, Hans, and B. **Scheurle**. **1969**. A Liquid-Crystalline (Nematic) Phase with a Particularly Low Solidification Point. *Angewandte Chemie International Edition* 8:11:884–885.

Kennedy, Donald R. **1990**. *History of the Shaped Charge Effect: The First 100 Years.* https://apps.dtic.mil/dtic/tr/fulltext/u2/a220095.pdf

Kertesz, Z. I. **1946**. Germans Using Improved Methods to Preserve Fruit Juices. *Food Industries* (1946) 18:496–498, 632–634.

Kline, Gordon M. **1946**. German Manufacture of Polyvinyl Ethers. *Chemical Industries* (December 1946) 59:1018–1020.

Kracke, Art. **2010**. Superalloys, the Most Successful Alloy System of Modern Times—Past, Present and Future. 7th International Symposium on Superalloy-718 and Derivatives. TMS (The Minerals, Metals & Materials Society).
https://www.tms.org//superalloys/10.7449/2010/Superalloys_2010_13_50.pdf

Krammer, Arnold. **1978**. Fueling the Third Reich. *Technology and Culture* (July 1978) 19:394–422.

Krammer, Arnold. **1981**. Technology Transfer as War Booty: The U.S. Technical Oil Mission to Europe, 1945. *Technology and Culture* (January 1981) 22:1:68–103.

Lampe, David. **1977**. Ersatz Gasoline: Forgotten Archives Yielding Secret of How German Army Ran a War on Fuel from Low-Grade Coal. *Science Digest* (October 1977) 82:65–67.

Lehmann, Otto. **1889**. Über fliessende Krystalle. *Zeitschrift für Physikalische Chemie* 4:462–472.

Lehmann, Otto. **1904**. *Flüssige Krystalle.* Leipzig.

Lehmann, Otto. **1911**. *Die neue Welt der Flüssigen Krystalle und deren Bedeutung für Physik, Chemie, Technik und Biologie.* Leipzig.

Lesch, John E., ed. **2000**. *The German Chemical Industry in the Twentieth Century.* London: Kluwer.

Lewis, Julian. **2002**. *Changing Direction: British Military Planning for Post-war Strategic Defence, 1942–47.* 2nd ed. London: Taylor & Francis.

Lindemann, Mechthild. **2016**. Deutsche Wissenschaftler als Erfinder von "Agent Orange"? Eine Spurensuche. *Vierteljahrshefte für Zeitgeschichte* 64:1:69–98. https://www.ifz-muenchen.de/heftarchiv/2016_1.pdf

Lindner, Stephan H. **2008**. *Inside IG Farben: Hoechst During the Third Reich.* Cambridge, UK: Cambridge University Press.

Maier, Helmut. **2007**. *Forschung als Waffe: Rüstungsforschung in der Kaiser-Wilhelm-Gesellschaft und das Kaiser-Wilhelm-Institut für Metallforschung 1900–1945/48.* 2 vols. Göttingen: Wallstein.

Maier, Helmut. **2015**. *Chemiker im "Dritten Reich": Die Deutsche Chemische Gesellschaft und der Verein Deutscher Chemiker im NS-Herrschaftsapparat.* Weinheim: Wiley.

Mark, Herman. **1993**. *From Small Organic Molecules to Large: A Century of Progress.* Washington, D.C.: American Chemical Society.

Marsch, Ulrich. **1994a.** Strategies for Success: Research Organization in German Chemical Companies and IG Farben until 1936. *History and Technology* 12:23–77.

Meyer-Thurow, Georg. **1982**. The Industrialization of Invention: A Case Study from the German Chemical Industry. *Isis* 73:363–381.

Miller, Albert E. **1945**. The Story of the Technical Oil Mission. *American Petroleum Institute Proceedings* 25:3:15-23.

Mitov, Michel. **2014**. Liquid-Crystal Science from 1888 to 1922: Building a Revolution. *ChemPhysChem* 15:1245–1250.

Mohr, Karl Friedrich. **1837**. Ansichten über die Natur der Wärme. *Annalen der Pharmacie* 24:141–147.

Möller, Horst, Gregor Schöllgen, Tim Geiger, Matthias Peter, and Mechthild Lindemann, eds. **2014**. *Akten zur Auswärtigen Politik der Bundesrepublik Deutschland 1983.* Oldenbourg: De Gruyter. https://books.google.com/books?id=sYXpBQAAQBAJ

Morris, Peter J. T. **2005**. *Polymer Pioneers: A Popular History of the Science and Technology of Large Molecules.* Philadelphia: Chemical Heritage Foundation.

Mrazek, James E. **1970**. *The Fall of Eben Emael.* Washington, D.C.: Robert B. Luce.

Neufeldt, Sieghard. **2003**. *Chronologie Chemie: Entdecker und Entdeckungen.* 3rd ed. Weinheim:

Wiley-VCH.

Office of the Chief of Chemical Corps, Headquarters European Command. **1947**. *The History of Captured Enemy Toxic Munitions in the American Zone European Theatre May 1945 to June 1947.*

Partington, J. R. **1935**. *Origins and Development of Applied Chemistry.* London: Longman.

Partington, J. R. **1957**. *A Short History of Chemistry.* New York: Macmillan.

Partington, J. R. **1964**. *A History of Chemistry.* 4 vols. New York: Macmillan.

Peppas, Nicholas A., ed. **2013**. *One Hundred Years of Chemical Engineering.* Alphen aan den Rijn: Kluwer.

Pfingsten, Otto. **2003**. *Dr. Gerhard Schrader: Der Erfinder des Schädlingsbekämpfungsmittels E 605.* Wendeburg: Uwe Krebs.

Phillips, Albert J. **1946**. Non-Ferrous Metallurgy in Wartime Germany. *Engineering and Mining Journal* (June 1946) 147:90-93.

Plumpe, Gottfried. **1990**. *Die I. G. Farbenindustrie AG. Wirtschaft, Technik und Politik 1904–1945.* Berlin: Duncker & Humblot.

Priesner, Claus. **2014**. Ein synthetisches Kaffeearoma: Von Coffarom zu Nescafé. *Chemie in unserer Zeit.* 48:22–35.

Priesner, Claus. **2016**. Die Kaffeefälscher. *Kultur & Technik* 40:3:52–57.

Reinitzer, Friedrich. **1888**. Beiträge zur Kenntniss des Cholesterins. *Monatshefte für Chemie* 9:1:421–441.

Rosner, Robert W. **2004**. *Chemie in Österreich 1740–1914. Lehre—Forschung—Industrie.* Vienna: Böhlau.

Runge, Friedlieb Ferdinand. **1850**. *Farbenchemie: Musterbilder für Freunde des Schönen und zum Gebrauch für Zeichner, Maler, Verzierer und Zeugdrucker, dargestellt durch chemische Wechselwirkung.* Berlin: E. S. Mittler.

Sandermann, Wilhelm. **1984**. Dioxin: Die Entdeckungsgeschichte des 2,3,7,8-Tetrachlordibenzo-p-dioxins (TCDD, Dioxin, Sevesogift). *Naturwissenschaftliche Rundschau* 37:5:173–178. https://www.anstageslicht.de/fileadmin/user_upload/Geschichten/Ein_junger_Staatsanwalt_gegen_die_Grosschemie/Dioxin.pdf

Sasuly, Richard. **1947**. *IG Farben.* New York: Boni & Gaer.

Scerri, Eric R. **2006**. *The Periodic Table: Its Story and Its Significance.* Oxford: Oxford University Press.

Schahinian, David. 16 October **2018**. Ferdinand Münz: Der Chemie-Pionier, den die Welt vergaß. *Frankfurter Neue Presse.* https://www.fnp.de/frankfurt/ferdinand-muenz-chemie-pionier-welt-vergass-10357498.html

Schönbein, Christian. **1839**. On the Voltaic Polarization of Certain Solid and Fluid Substances.

London and Edinburgh Philosophical Magazine and Journal of Science 14:1:43–45.

Schönbein, Christian. **1861**. Ueber einige durch die Haarröhrchenanziehung des Papiers hervorgebrachten Trennungswirkungen. *Verhandlungen der Naturforschenden Gesellschaft zu Basel* 3:2:249–255.

Schroeder, W. C. **1945**. Investigation by the U.S. Government Technical Oil Mission. *American Petroleum Institute Proceedings* 25:3:24-29.

Schwedt, Georg. **2013**. *Plastisch, elastisch, fantastisch: Ohne Kunststoffe geht es nicht.* Weinheim: Wiley-VCH.

Schwenk, Ernst F. **2000**. *Sternstunden der frühen Chemie: von Johann Rudolph Glauber bis Justus von Liebig.* 2nd ed. Munich: C. H. Beck.

Serafini, Anthony. **1989**. *Linus Pauling: A Man and His Science.* New York: Paragon House.

Seymour, Raymond B., ed. **2013**. *Pioneers in Polymer Science (Chemists and Chemistry).* Alphen aan den Rijn: Kluwer.

Sheldon, Ruth. **1945**. The Hunt for Nazi Oil Secrets. *The Saturday Evening Post* (6 October 1945) 218:27+.

Simcoe, Charles R., and Frances **Richards**. **2018**. *The History of Metals in America.* Materials Park, Ohio: ASM International.

Sinsteden, Josef. **1854**. Versuche über den Grad der Continuität und die Stärke des Stroms eines grössern magneto-elektrischen Rotations—Apparats und über die eigenthümliche Wirkung der Eisendrahtbündel in den Inductionsrollen dieser Apparate. *Annalen der Physik und Chemie* 92:1:1–21.

Sluckin, Tim, David Dunmur, and Horst Stegemeyer. **2004**. *Crystals That Flow—Classic Papers from the History of Liquid Crystals.* London: Taylor & Francis.

Sorge, Petra. 14 November **2017**. Years Before Vietnam, the Chemical Industry Knew About Dioxins. *Independent Science News.* https://www.independentsciencenews.org/news/years-before-vietnam-the-chemical-industry-knew-about-dioxins/

Soukup, Rudolf Werner. **2007**. *Chemie in Österreich: Bergbau, Alchemie und frühe Chemie. Von den Anfängen bis zum Ende des 18. Jahrhunderts.* Vienna: Böhlau.

Spitz, Peter H. **1965**. How to Evaluate Licensed Processes. *Chemical Engineering* (20 December 1965) 72:91-98.

Stegemeyer, Horst. **1994**. Horst Sackmann, 1921–1993. *Liquid Crystals Today* 4:1–2.

Stokes, Raymond. **1988**. *Divide and Prosper: The Heirs of I.G. Farben Under Allied Authority, 1945-1951.* Berkeley, California: University of California Press.

Stoltzenberg, Dietrich. **1994**. *Fritz Haber: Chemiker, Nobelpreisträger, Deutscher, Jude.* Weinheim: VCH.

Stoltzenberg, Dietrich. **2005**. *Fritz Haber: Chemist, Nobel Laureate, German, Jew.* Philadelphia: Chemical Heritage Foundation.

Stranges, Anthony N. **1984**. Synthetic Petroleum from High-Pressure Coal Hydrogenation. In: John Parascandola and James C. Whorton, eds. 1984. *Chemistry and Modern Society.* Washington, D.C.: American Chemical Society.

Strom, E. Thomas, and Seth C. **Rasmussen**. **2012**. *100+ Years of Plastics: Leo Baekeland and Beyond.* Washington, DC: American Chemical Society.

Szöllösi-Janze, Margit. **2015**. *Fritz Haber 1868-1934: Eine Biographie.* Munich: C. H. Beck.

Teltschik, Walter. **1992**. *Geschichte der deutschen Grosschemie: Entwicklung und Einfluss in Staat und Gesellschaft.* Weinheim: Wiley-VCH.

Travis, Anthony S., Harm G. Schröter, Ernst Homburg, and Peter J. T. Morris, eds. **1998**. *Determinants in the Evolution of the European Chemical Industry, 1900–1939. New Technologies, Political Frameworks, Markets and Companies.* Berlin: Springer. [pp. 67-88: Carsten Reinhardt. Basic Research in Industry: Two Case Studies at I.G. Farbenindustrie AG in the 1920's and 1930's.]

Tucker, Jonathan B. **2006**. *War of Nerves: Chemical Warfare from World War I to Al-Qaeda.* New York: Pantheon. Complete text online at https://archive.org/details/B-001-000-016

Tuttle, William M., Jr. **1981**. The Birth of an Industry: The Synthetic Rubber 'Mess' in World War II. *Technology and Culture* (January 1981) 22:35-67.

Ungewitter, Claus. **1938**. *Chemie in Deutschland.* Berlin: Junker & Dünnhaupt Verlag.

Vaupel, Elisabeth. **2010**. Hermann Staudinger und der Kunstpfeffer: Ersatzgewürze. *Chemie in unserer Zeit.* 44:396–412.

Vaupel, Elisabeth. **2011**. Ersatzgewürze (1916–1948): Der Chemie-Nobelpreisträger Hermann Staudinger und der Kunstpfeffer. *Technikgeschichte* 78:2:91–122.

Vieter, Richard H. K. **1980**. The Synthetic Liquid Fuels Program: Energy Politics in the Truman Era. *Business History Review* 54:1-34.

Wagner, Bernd C. **2000**. *IG Auschwitz: Zwangsarbeit und Vernichtung von Häftlingen des Lagers Monowitz 1941–1945.* Munich: K. G. Saur.

Walters, William P., and Jonas A. **Zukas**. **1989**. *Fundamentals of Shaped Charges.* New York: Wiley.

Warde, John M. **1946**. Status Report on the German Ceramic, Glass, and Refractories Industries in the U.S. Zone of Occupation. *American Ceramic Society Bulletin* (15 September 1946) 25:321-32.

Weeks, Mary Elvira, and Henry M. **Leicester**. **1968**. *Discovery of the Elements.* 7th ed. Washington, DC: American Chemical Society.

Welsch, Fritz. **1981**. *Geschichte der chemischen Industrie.* Berlin: Deutscher Verlag der Wissenschaft.

Werner, Helmut. **2017**. *Geschichte der anorganischen Chemie: Die Entwicklung einer Wissenschaft in Deutschland von Döbereiner bis heute.* Weinheim: Wiley-VCH.

Weygand, Conrad. **1943**. Daniel Vorländer. 11.6.1867–8.6.1941. *Berichte der Deutschen Chemischen Gesellschaft* 76:6:A41–A58.

Winnacker, Karl. **1972**. *Challenging Years: My Life in Chemistry.* London: Sidgwick & Jackson.

Yahraes, Herbert. **1949**. The Arrival of Acetylene. *Scientific American* (January 1949) 180:16-21.

Zecha, Wolfgang. **2000**. *"Unter die Masken!" Giftgas auf den Kriegsschauplätzen Österreich-Ungarns im Ersten Weltkrieg.* Vienna: ÖBV&hpt.

Zhu, Xiaolong, Chunhua T. Hu, Jingxiang Yang, Leo A. Joyce, Mengdi Qiu, Michael D. Ward, and Bart Kahr. **2019**. Manipulating Solid Forms of Contact Insecticides for Infectious Disease Prevention. *Journal of the American Chemical Society.* 141:42:16858–16864.

Historical Innovations in Earth Science

von Boguslawski, Heinrich Georg, and Otto **Krümmel**. **1884–1887**. *Handbuch der Ozeanographie.* 2 vols. Stuttgart: J. Engelhorn.
https://archive.org/details/handbuchderozean01bogu/page/n3/mode/2up

Bowler, Peter J. **1993**. *The Norton History of the Environmental Sciences.* New York: W.W. Norton.

Brückner, Eduard, and Albrecht **Penck**. **1909**. *Die Alpen im Eiszeitalter.* Leipzig: Tauchnitz.

Buchroithner, Manfred F., and René **Pfahlbusch**. **2016**. Geodetic Grids in Authoritative Maps—New Findings about the Origin of the UTM Grid. *Cartography and Geographic Information Science.* https://doi.org/10.1080/15230406.2015.1128851

Chambers, Paul. **2002**. *Bones of Contention: The Fossil that Shook Science.* London: John Murray.

Chladni, Ernst. **1794**. *Über den Ursprung der von Pallas gefundenen und anderer ihr ähnlicher Eisenmassen und über einige damit in Verbindung stehende Naturerscheinungen.* Riga, Latvia: Johann Friedrich Hartknoch. https://digital.slub-dresden.de/werkansicht/dlf/79533/5

Colbert, Edwin H. **1984**. *The Great Dinosaur Hunters and Their Discoveries.* New York: Dover.

Galle, Johann Gottfried, and Diedrich **Wattenberg**. **1963**. *Johann Gottfried Galle, 1812-1910: Leben und Wirken eines deutschen Astronomen.* Leipzig: Johann Ambrosius Barth.

Geiger, Rudolf. **1950**. *The Climate Near the Ground.* 2nd ed. Cambridge, Massachusetts: Harvard University Press.

Greene, Mott T. **2015**. *Alfred Wegener: Science, Exploration, and the Theory of Continental Drift.* Baltimore, Maryland: Johns Hopkins Press.

von Hann, Julius. **1887**. *Atlas der Meteorologie.* Gotha: Justus Perthes.

von Hann, Julius, and Reinhard **Süring**. **1926**. *Lehrbuch der Meteorologie.* Leipzig: Tauchnitz.

Haurwitz, Bernhard. **1941**. *Dynamic Meteorology.* New York: McGraw-Hill.
https://archive.org/details/dynamicmeteorolo031899mbp/page/n5/mode/2up

Hesse, Richard. **1924**. *Tiergeographie auf kologischer Grundlage.* Jena: Gustav Fischer.

Hesse, Richard. **1937**. *Ecological Animal Geography.* New York: John Wiley.

Hoskin, Michael. **2011**. *Discoverers of the Universe: William and Caroline Herschel.* Princeton, New Jersey: Princeton University Press.

Javanović-Kruspel, Stefanie, ed. **2015**. *Natural History Museum Vienna: A Guide to the Collections.* 2nd ed. Vienna: Naturhistorisches Museum Wien.

Köppen, Wladimir. **1955**. *Ein Gelehrtenleben.* Wissenschaftliche Verlagsgesellschaft.

Lemonick, Michael. **2008**. *The Georgian Star: How William and Caroline Herschel Revolutionized Our Understanding of the Cosmos.* New York: W. W. Norton.

Lüdecke, Cornelia. **2015**. *Deutsche in der Antarktis: Expeditionen und Forschungen vom Kaiserreich bis heute.* Berlin: Christoph Links.

Mohs, Friedrich. **1825**. *Treatise on Minerology.* 3 vols. London: Hurst, Robinson.

North, John. **1995**. *The Norton History of Astronomy and Cosmology.* New York: W.W. Norton.

Nothdurft, William, and Josh **Smith**. **2002**. *The Lost Dinosaurs of Egypt.* New York: Random House.

Probst, Ernst. **2015**. *Der rätselhafte Spinosaurus: Leben und Werk des Forschers Ernst Stromer von Reichenbach.* Munich: GRIN.

Rubin, Harry. **1995**. *Walter M. Elsasser 1904–1991.* Washington, D.C.: National Academies Press. https://www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/elsasser-walter.pdf

Sagan, Carl. **1980**. *Cosmos.* New York: Random House.

Schön, Heinz. **2004**. *Mythos Neu-Schwabenland: Für Hitler am Südpol: Die deutsche Antarktisexpedition 1938/39.* Selent: Bonus.

Schwarzschild, Martin. **1958**. *Structure and Evolution of the Stars.* Princeton, New Jersey: Princeton University Press.

Spiess, Fritz. **1985**. *The Meteor Expedition: Scientific Results of the German Atlantic Expedition, 1925–1927.* New Delhi: Amerind Publishing.

Wegener, Alfred. **1966**. *The Origin of Continents and Oceans.* New York: Dover.

Wellnhofer, Peter. **2008**. *Archaeopteryx: Der Urvogel von Solnhofen.* Munich: Friedrich Pfeil.

Wulf, Andrea. **2015**. *The Invention of Nature: Alexander von Humboldt's New World.* New York: Knopf.

Historical Innovations in Physics and Mathematics

Andriesse, C. D. **2005**. *Huygens: The Man behind the Principle.* Cambridge, U.K.: Cambridge University Press.

Antognazza, Maria Rosa. **2009**. *Leibniz: An Intellectual Biography.* Cambridge, U.K.: Cambridge University Press.

Auer von Welsbach, Carl. **1910**. Mitteilungen der Radium-Kommission der kaiserl. Akademie der Wissenschaften. VI. Über die chemische Untersuchung der Actinium enthaltenden Rückstände der Radiumgewinning (I. Teil). *Monatshefte für Chemie* 31:10:1159.

Bitbol, Michael. **2012**. *Schrödinger's Philosophy of Quantum Mechanics.* Berlin: Springer.

Blum, Alexander S., and Dean **Rickles**. **2018**. *Quantum Gravity in the First Half of the Twentieth Century: A Sourcebook.* Berlin: Edition Open Access.
https://pure.mpg.de/pubman/faces/ViewItemOverviewPage.jsp?itemId=item_2629877

Boltzmann, Ludwig. **1964**. *Lectures on Gas Theory.* Berkeley: University of California Press.

Bothe, Walther, and Herbert **Becker**. **1930**. Künstliche Erregung von Kern-γ-Strahlen. *Zeitschrift für Physik* 66:289–306. https://doi.org/10.1007/BF01390908

Brown, Brandon R. **2015**. *Planck: Driven by Vision, Broken by War.* Oxford: Oxford University Press.

Brown, Laurie M., and Lillian **Hoddeson**. **1983**. *The Birth of Particle Physics.* Cambridge, UK: Cambridge University Press.

Brown, Laurie M., Abraham Pais, and Brian Pippard. **1995**. *Twentieth Century Physics.* 3 vols. Bristol: Institute of Physics and New York: American Institute of Physics.

Cahan, David. **2018**. *Helmholtz: A Life in Science.* Chicago: University of Chicago Press.

Calinger, Ronald S. **2015**. *Leonhard Euler: Mathematical Genius in the Enlightenment.* Princeton, New Jersey: Princeton University Press.

Čapek, Karel. **1923**. *R.U.R. (Rossum's Universal Robots).* English translation by Paul Selver. New York: Doubleday, Page & Co.

Cheney, Margaret. **1981**. *Tesla: Man Out of Time.* Englewood Cliffs, New Jersey: Prentice-Hall.

Cheney, Margaret, and Robert **Uth**. **1999**. *Tesla: Master of Lightning.* New York: Barnes & Noble.

Dunnington, Guy Waldo. **1955**. *Carl Friedrich Gauss: Titan of Science.* New York: Exposition Press. [Reprinted in 2003 by Mathematical Association of America, Washington, DC.]

Eckert, Michael. **2013**. *Arnold Sommerfeld: Science Life and Turbulent Times 1868–1951.* Berlin: Springer.

Einstein, Albert. **1954**. *Ideas and Opinions.* New York: Bonanza.

Einstein, Albert. **1956**. *The Meaning of Relativity.* 5th ed. Princeton, New Jersey: Princeton University Press.

Farmelo, Graham. **2009**. *The Strangest Man: The Hidden Life of Paul Dirac, Quantum Genius.* London: Faber and Faber.

Forstner, Christian, and Mark **Walker**, eds. **2020**. *Biographies in the History of Physics: Actors, Objects, Institutions.* Berlin: Springer.

Gamow, George. **1966**. *Thirty Years That Shook Physics: The Story of Quantum Theory.* New York: Doubleday.

Grattan-Guinness, Ivor. **1998**. *The Norton History of the Mathematical Sciences.* New York: W.W. Norton.

Greenspan, Nancy Thorndike. **2005**. *The End of the Certain World: The Life and Science of Max Born: The Nobel Physicist Who Ignited the Quantum Revolution.* New York: Basic Books.

Greiner, Walter, and Joachim **Reinhardt**. **1994**. *Quantum Electrodynamics.* 2nd. ed. Berlin: Springer.

Hoffmann, Dieter and Mark **Walker**, eds. **2007**. *Physiker zwischen Autonomie und Anpassung.* Weinheim: Wiley. English translation: 2012. *The German Physical Society in the Third Reich: Physicists Between Autonomy and Accommodation.* Cambridge: Cambridge University Press.

Isaacson, Walter. **2007**. *Einstein: His Life and Universe.* New York: Simon & Schuster.

Johnson, John, Jr. 2019. *Zwicky: The Outcast Genius Who Unmasked the Universe.* Cambridge, Massachusetts: Harvard University Press.

Jones, Sheilla. **2008**. *The Quantum Ten: A Story of Passion, Tragedy, and Science.* Oxford: Oxford University Press.

Jungnickel, Christa, and Russell **McCormmach**. **1986**. *Intellectual Mastery of Nature.* 2 vols. Chicago: University of Chicago Press.

Jungnickel, Christa, and Russell **McCormmach**. **2017**. *The Second Physicist.* Berlin: Springer.

Kragh, Helge. **2002**. *Quantum Generations: A History of Physics in the Twentieth Century.* [Ch. 10. Forman thesis]

Kragh, Helge and Robert W. **Smith**. **2003**. Who Discovered the Expanding Universe? *History of Science* 41:2:141–162.
https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.879.9956&rep=rep1&type=pdf

Levenson, Thomas. **2003**. *Einstein in Berlin.* New York: Bantam Books.

Mendelssohn, Kurt. **1973**. *The World of Walther Nernst: The Rise & Fall of German Science 1864–1941.* Pittsburgh: University of Pittsburgh Press.

von Meÿenn, Karl. **1997**. *Die großen Physiker.* 2 vols. Munich: C. H. Beck.

Middleton, Eric William. **1989**. *Higher Dimensional Theories in Physics, Following the Kaluza Model of Unification.* Thesis. Durham University. http://etheses.dur.ac.uk/6315/

Moore, Walter. **1989**. *Schrödinger: Life and Thought.* Cambridge, UK: Cambridge University Press.

Müller, Ingo. **2007**. *A History of Thermodynamics: The Doctrine of Energy and Entropy.* Berlin: Springer.

O'Connor, John J., and Edmund F. **Robertson**. **2020**. MacTutor History of Mathematics Archive. University of St. Andrews, Scotland. https://mathshistory.st-andrews.ac.uk/Countries/

Pais, Abraham. **1982**. *'Subtle Is the Lord…': The Science and the Life of Albert Einstein.* Oxford: Oxford University Press.

Planck, Max. **1950**. *Scientific Autobiography and Other Papers.* London: Williams & Norgate.

Richeson, David S. **2008**. *Euler's Gem: The Polyhedron Formula and the Birth of Topology.* Princeton: Princeton University Press.

Schrödinger, Erwin. **1995**. *The Interpretation of Quantum Mechanics: Dublin Seminars (1949–1955) and Other Unpublished Essays.* Oxford, U.K.: OxBow.

Schweber, Silvan S. **1994**. *QED and the Men Who Made It.* Princeton, New Jersey: Princeton University Press.

Segal, Sanford L. **2003**. *Mathematicians under the Nazis.* Princeton, New Jersey: Princeton University Press.

Seitter, Waltraut C. and Hilmar W. **Duerbeck**. **1999**. Carl Wilhelm Wirtz—Pioneer in Cosmic Dimensions. In: Daniel Egret and Andre Heck, eds. *Harmonizing Cosmic Distance Scales in a Post-Hipparcos Era*, ASP Conference Series, vol. 167, p. 237–242.
https://adsabs.harvard.edu/full/1999ASPC..167..237S

Steinhauser, Georg, Gerd Löffler, and Roland Adunka. **2013**. The possible discovery of neutron activation in 1910. *Journal of Radioanalytical and Nuclear Chemistry* 296:157–163.

Stern, Fritz. **1999**. *Einstein's German World.* Princeton, New Jersey: Princeton University Press.

Stöckli, Alfred, and Roland **Müller**. **2008**. *Fritz Zwicky, Astrophysiker: Genie mit Ecken und Kanten.* Zurich: Neue Zürcher Zeitung.

Tesla, Nikola. **1893**. *The Inventions, Researches and Writings of Nikola Tesla.* Reprinted 2014. New York: Barnes & Noble.

Tesla, Nikola. **1904**. *Experiments with Alternate Currents of High Potential and High Frequency.* New York: McGraw.

Tesla, Nikola. **1919**. *My Inventions.* Reprinted 1982. Williston, Vermont: Hart Brothers.

Tesla, Nikola. **1940**. *Nikola Tesla's Teleforce & Telegeodynamics Proposals.* Reprinted 1998. Leland I. Anderson, ed. Breckenridge, Colorado: Twenty First Century Books.

Thorne, Kip. **1994**. *Black Holes and Time Warps: Einstein's Outrageous Legacy.* New York: Norton.

van den Bergh, Sidney. **2011**. Discovery of the Expansion of the Universe. *Journal of the Royal Astronomical Society of Canada* 105:5:197.
https://ui.adsabs.harvard.edu/abs/2011JRASC.105..197V/abstract
https://arxiv.org/pdf/1108.0709.pdf

Weber, Robert L. **1988**. *Pioneers of Science: Nobel Prize Winners in Physics.* 2nd ed. Bristol: Adam Hilger.

Wirtz, Carl Wilhelm. **1918**. Über die Bewegungen der Nebelflecke. Vierte Mitteilung. *Astronomische Nachrichten* 206:4933:109–116. https://articles.adsabs.harvard.edu/full/1918AN....206..109W

Wirtz, Carl Wilhelm. **1922a**. Einiges zur Statistik der Radialbewegungen von Spiralnebeln und Kugelsternhaufen. *Astronomische Nachrichten* 215:5153:349–354.

https://articles.adsabs.harvard.edu/full/1922AN....215..349W

Wirtz, Carl Wilhelm. **1922b**. Notiz zur Radialbewegung der Spiralnebel. *Astronomische Nachrichten* 215:5184:451–452. https://adsabs.harvard.edu/full/1922AN....216..451W

Wirtz, Carl Wilhelm. **1924**. De Sitters Kosmologie und die Radialbewegungen der Spiralnebel. *Astronomische Nachrichten* 222:5306:21–26. https://adsabs.harvard.edu/full/1924AN....222...21W

Wirtz, Carl Wilhelm. **1936**. Ein literarischer Hinweis zur Radialbewegung der Spiralnebel. *Zeitschrift für Astrophysik* 11:261. https://articles.adsabs.harvard.edu/full/1936ZA.....11..261W

Zwicky, Fritz. **1969**. *Discovery, Invention, Research Through the Morphological Approach.* New York: Macmillan.

Historical Innovations in Electrical and Electromagnetic Engineering

Albert, Hinnerk. **2014**. Über den Magnetisierungsvorgang des Tonbandes. ResearchGate. www.researchgate.net/publication/262484231_Uber_den_Magnetisierungsvorgang_des_Tonbandes

Albrecht, Helmuth. **2019**. *Laserforschung in Deutschland 1960–1970: Eine vergleichende Studie zur Frühgeschichte von Laserforschung und Lasertechnik in der Bundesrepublik Deutschland und der Deutschen Demokratischen Republik.* Diepholz: GNT-Verlag.

Arns, Robert G. **1998**. The Other Transistor: Early History of the Metal-Oxide Semiconductor Field-Effect Transistor. *Engineering Science and Education Journal* 7:5:233–240.

Auerbach, Felix. **1918**. *Ernst Abbe 1840–1905: Sein Leben, sein Wirken, seine Persönlichkeit.* Leipzig: Akademische Verlagsgesellschaft.

Auerbach, Felix. **1925**. *Das Zeisswerk & die Carl-Zeiss Stiftung in Jena.* 5th ed. Leipzig: Akademische Verlagsgesellschaft.

Bähr, Johannes. **2016**. *Werner von Siemens 1816–1892: Eine Biographie.* Munich: C. H. Beck.

Bamford, James. **2002**. *Body of Secrets: Anatomy of the Ultra-Secret National Security Agency.* New York: Anchor Books. [pp. 8–18]

Banneitz, F., ed. **1927**. *Taschenbuch der drahtlosen Telegraphie und Telephonie.* Berlin: Springer.

Bassett, Ross Knox. **2002**. *To the Digital Age: Research Labs, Start-Up Companies, and the Rise of MOS Technology.* Baltimore, Maryland: Johns Hopkins University Press.

Bauer, Arthur O. **2006**. Some Aspects of German Airborne Radar Technology, 1942 to 1945. DEHS Autumn Symposium, Shrivenham. www.cdvandt.org/German%20airborne%20radar%20def.pdf

Berlin. **1936**. *Das Fernsehen in Deutschland: XI. Olympische Spiele Berlin 1936.*

Bernstein, Jeremy. **1984**. *Three Degrees Above Zero: Bell Labs in the Information Age.* New York: Charles Scribner's Sons.

Bertolotti, Mario. **2015**. *Masers and Lasers: An Historical Approach.* 2nd ed. Boca Raton, Florida: CRC Press.

Blanchard, Yves, Gaspare Galati, and Piet van Genderen. **2013**. The Cavity Magnetron: Not

Just a British Invention. *IEEE Antennas and Propagation Magazine* 55:5:244–254. https://ed-thelen.org/EarlyMagnetron-r-.pdf

Bloch, Felix. **1929**. Über die Quantenmechanik der Elektronen in Kristallgittern. *Zeitschrift für Physik* 52:555–600.

von Borries, Bodo, and Ernst **Ruska**. **1940a**. Neue Wege der Mikroskopie. *Der Vierjahresplan.* 4:504–507.

von Borries, Bodo, and Ernst **Ruska**. **1940b**. Die Technik des Siemens-Übermikroskops. *Siemens Zeitschrift* 20:217–227.

von Borries, Bodo, and **Ernst Ruska**. **1940c**. Hochleistungsoszillographen mit abgeschmolzener Braunscher Röhre. *Archiv für Elektrotechnik* 34:106–114.

von Borries, Bodo, and Ernst **Ruska**. **1944**. Neue Beiträge zur Entwicklungsgeschichte der Elektronenmikroskopie und der Übermikroskopie. *Physikalische Zeitschrift* 45:314–326.

Broad, William J. **1985**. *Star Warriors: A Penetrating Look into the Lives of the Young Scientists Behind Our Space Age Weaponry.* New York: Simon & Schuster.

Broad, William J. **1992**. *Teller's War: The Top-Secret Story Behind the Star Wars Deception.* New York: Simon & Schuster.

Bromberg, Joan Lisa. **1991**. *The Laser in America 1950-1970.* Cambridge, Massachusetts: MIT Press.

Brown, Louis. **2017**. *Technical and Military Imperatives: A Radar History of World War II.* Boca Raton, Florida: CRC Press.

Buckley, Oliver E. **1952**. *Frank Baldwin Jewett 1879–1949.* Washington, D.C.: National Academies Press. www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/jewett-frank.pdf

Bukowski, Helmut. **2007**. *Radarkrieg und Nachtluftverteidigung über Berlin 1939 bis 1945.* Zweibrücken: VDM Nickel.

Ceruzzi, Paul E. **1998**. *A History of Modern Computing.* Cambridge, Massachusetts: MIT Press.

Clark, Gregory C. **2014**. *Deflating British Radar Myths of World War II.* CreateSpace.

Conot, Robert. **1979**. *Thomas A. Edison: A Streak of Luck.* New York: Seaview Books.

Contrada, Norma. **1995**. Golem and Robot: A Search for Connections. *Journal of the Fantastic in the Arts* 7:2/3:244–254. https://www.jstor.org/stable/43308245

Crawford, Bret E. **1991**. The Invention of the Transistor. M.S. thesis. Burlington, Vermont: University of Vermont. https://scholarworks.uvm.edu/graddis/1469/

Daumas, Maurice. **1989**. *Scientific Instruments of the 17th & 18th Centuries and Their Makers.* London: Portman.

Debye, Peter. **1912**. Zur Theorie der spezifischen Wärmen. *Annalen der Physik* 344:14:789–839

Debye, Peter. and Arnold **Sommerfeld**. **1913**. Theorie des lichtelektrischen Effektes vom Standpunkt des Wirkungsquantums. *Annalen der Physik* 346:10:873–930.

Drude, Paul. **1900**. Zur Elektronentheorie der Metalle. *Annalen der Physik* 306:3:566–613.

Eckert, Michael, and Helmut **Schubert**. **1990**. *Crystals, Electrons, Transistors: From Scholar's Study to Industrial Research.* College Park, Maryland: American Institute of Physics.

Eisler, Paul. **1989**. *My Life with the Printed Circuit.* Bethlehem, Pennsylvania: Lehigh University Press.

Evans, Ronald. **2015**. *Greenglow & the Search for Gravity Control.* Leicester, U.K.: Troubador.

Everett, H. R. **2015**. *Unmanned Systems of World Wars I and II.* Cambridge, Massachusetts: MIT Press.

Fisher, David E., and Marshall Jon **Fisher**. **1996**. *Tube: The Invention of Television.* Washington, D.C.: Counterpoint.

Fort Monmouth Historical Office. **2008**. *A History of Army Communications and Electronics at Fort Monmouth, New Jersey 1917–2007.* Washington, D.C.: U.S. Government Printing Office. https://archive.org/details/historyofarmycom00fort

Frank, Manfred. **2003**. Leiterplatten—die System-plattform der Zukunft. *productonic* 2003:11:2–5.
https://www.all-electronics.de/wp-content/uploads/migrated/article-pdf/92733/b05b06e0df8.pdf

Füßl, Wilhelm, ed. **2010**. *100 Jahre Konrad Zuse: Einblicke in den Nachlass.* Munich: Deutsches Museum.

Gehrts, August. **1940**. 5 Jahre Fernsehdienst der Deutschen Reichspost. *Europäischer Fernsprechdienst* 55:145–146.

Gerber-Stroh, Amy. **2012**. *My Grandfather Was A Nazi Scientist: Opa, von Braun and Operation Paperclip.* Flatcoatfilms.

Gernsback, Hugo. **1909**. Television and the Telephot. *Modern Electrics* 2:9:403–416.
https://babel.hathitrust.org/cgi/pt?id=mdp.39015067294952&view=1up&seq=5 and
https://www.jstor.org/stable/10.5749/j.ctt1jktpxr.13 [Ernst Ruhmer]

Gertner, Jon. **2012**. *The Idea Factory: Bell Labs and the Great Age of American Innovation.* New York: Penguin Press.

Gillmor, C. Stewart. **2004**. *Fred Terman at Stanford: Building a Discipline, a University, and Silicon Valley.* Stanford: Stanford University Press.

Gjudjenow, Karin, and Hans **Meinl**, eds. **2013**. *Treasury of Optics: The Collections of the Optisches Museum Jena.* Jena: Optisches Museum Jena.

Göbel, Gerhart. **1953**. Das Fernsehen in Deutschland bis zum Jahre 1945. *Archiv für Post- und Fernmeldewesen* 5:259–393.

Goebel, Gregory V. **2018**. *The Wizard War: WW2 & The Origins of Radar.*
http://vc.airvectors.net/ttwiz.html

Goerth, Joachim. **2010**. Early Magnetron Development Especially in Germany. *IEEE International Conference on the Origins and Evolution of the Cavity Magnetron* pp. 17–22. https://ieeexplore.ieee.org/document/5565571

Goldstine, Herman H. **1993**. *The Computer from Pascal to von Neumann.* Princeton: Princeton University Press.

Greenstein, Jesse L. **1997**. *Lee Alvin DuBridge September 21, 1901–January 23, 1994.* Washington, D.C.: National Academies Press.

Guerlac, Henry E. **1987**. *Radar in World War II.* 2 vols. American Institute of Physics.

Habann, Erich. **1924**. Eine neue Generatorröhre. *Zeitschrift für Hochfrequenztechnik* 24:115–20, 135–41.

Habann, Erich. **1929**. *Die neuere Entwicklung der Hochfrequenztelephonie und telegraphie auf Leitungen.* Braunschweig: Vieweg & Sohn.

Handel, Kai Christian. **1999**. Anfänge der Halbleiterforschung und -entwicklung: Dargestellt an den Biographien von vier deutschen Halbleiterpionieren. Aachen: Rheinisch-Westfälische Technische Hochschule Aachen. http://publications.rwth-aachen.de/record/94503/files/Handel_Kai.pdf

Hansen, James L., ed. **1974**. *The Billings Microscope Collection.* 2nd ed. Washington, D.C.: Armed Forces Institute of Pathology.

Hawkes, Nigel. **1981**. *Early Scientific Instruments.* New York: Abbeville Press.

Hawkes, Peter W. **2013**. *The Beginnings of Electron Microscopy.* Cambridge, Massachusetts: Academic Press.

Hecht, **Jeff**. **1985**. *Beam Weapons.* 2nd ed. New York: Plenum Press.

Hecht, Jeff. **2010**. *Beam: The Race to Make the Laser.* Oxford: Oxford University Press.

Helfert, Martin, Petra Mazuran, and Christoph M. Wintersteiger. **2007**. *Gustav Tauschek und seine Maschinen.* Linz: Rudolf Trauner.

Hepcke, Gerhard. **2012**. *The Radar War 1930–1945.* Translated by Hannah Liebmann. https://www.radarworld.org/radarwar.pdf

Herschel, William. **1800**. Experiments on the Refrangibility of the Invisible Rays of the Sun. *Philosophical Transactions of the Royal Society of London* 90:284–292. https://royalsocietypublishing.org/doi/pdf/10.1098/rstl.1800.0015

Hickethier, Knut. **1998**. *Geschichte des deutschen Fernsehens.* Stuttgart: Metzler.

Hicks, Jesse. **2012**. 'The Idea Factory': How Bell Labs Invented the Future. *The Verge* (21 March 2012). https://www.theverge.com/2012/3/21/2887206/jon-gertner-idea-factory-bell-labs-great-american-age-innovation-book-review

Hilsch, Rudolf. **1939**. Elektronenleitung in Kristallen. *Die Naturwissenschaften* 27:489–492.

Hilsch, Rudolf, and Robert **Pohl**. **1938**. Steuerung von Elektronenströmen mit einem Dreielektrodenkristall und ein Modell einer Sperrschicht. *Zeitschrift für Physik* 111:399–408.

Hinsley, F. H. **1979**. *British Intelligence in the Second World War.* 6 vols. London: H. M. Stationery Office.

Hoddeson, Lillian, Ernst Braun, Jürgen Teichmann, and Spencer Weart, eds. **1992**. *Out of the Crystal Maze: Chapters from The History of Solid State Physics.* Oxford: Oxford University Press.

Hoddeson, Lillian, and Vicki **Daitch**. **2002**. *True Genius: The Life and Science on John Bardeen.* Washington, DC: Joseph Henry Press.

Hodges, Andrew. **1983**. *Alan Turing: The Enigma.* New York: Simon and Schuster.

Hollmann, Martin. **2012**. *History of Radio Flight Navigation Systems.* https://www.radarworld.org/flightnav.pdf

Horeis, Heinz, and Michael **Liebig**. **1985**. *Strahlenwaffen: Militärstrategie im Umbruch.* Munich: Verlag für Wehrwissenschaften.

Isaacson, Walter. **2011**. *Steve Jobs.* New York: Simon & Schuster.

Isaacson, Walter. **2014**. *The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution.* New York: Simon & Schuster.

Jaugitz, Marcus. **2001**. *Funklenkpanzer: A History of German Army Remote- and Radio-Controlled Armor Units.* Winnipeg, Manitoba: J. J. Fedorowicz.

Josephson, Matthew. **1959**. *Edison: A Biography.* New York: McGraw Hill.

Kahn, David. **1998**. *Seizing the Enigma: The Race to Break the German U-Boat Codes 1939–1943.* 2nd ed. New York: Barnes & Noble.

Katzir, Shaul. **2006**. *The Beginnings of Piezoelectricity.* Berlin: Springer.

Katzir, Shaul. **2018**. The Shaping of Interwar Physics by Technology: The Case of Piezoelectricity. *Science in Context* 31:3:321–350.

Kelly, Mervin J. **1950**. The Bell Telephone Laboratories—An Example of an Institute of Creative Technology. *Proceedings of the Royal Society of London A. Mathematical and Physical Sciences* 203:287–301.

Kloft, Michael. **2000**. *Fernsehen unterm Hakenkreuz/Deutscher Fernseh-Rundfunk.* Spiegel TV. https://www.youtube.com/watch?v=VLDcA51lKqA

Knoll, Max, and Ernst **Ruska**. **1932a**. Beitrag zur geometrischen Elektronenoptik. *Annalen der Physik* 12:607–661.

Knoll, Max, and Ernst **Ruska**. **1932b**. Das Elektronenmikroskop. *Zeitschrift für Physik* 78:318–339.

Kompfner, Rudolf. **1964**. *The Invention of the Traveling Wave Tube.* San Francisco: San Francisco Press.

Kompfner, Rudolf. **1976**. The Invention of Traveling Wave Tubes. *IEEE Transactions on Electron Devices* 23:7:730–738. https://ieeexplore.ieee.org/document/1478491

König, Wolfgang. **1996**. Science-Based Industry or Industry-Based Science? Electrical Engineering in Germany Before World War I. *Technology and Culture* 37:70–101.

Korey, Michael. **2007**. *The Geometry of Power: Mathematical Instruments and Princely Mechanical Devices from around 1600.* Munich: Deutscher Kunstverlag.

von Kroge, Harry. **1998**. *GEMA-Berlin: Geburtsstätte der deutschen aktiven Wasserschall- und Funkortungstechnik.* Hamburg: Lühmanndruck.

Lécuyer, Christophe. **2007**. *Making Silicon Valley: Innovation and the Growth of High Tech, 1930–1970.* Cambridge, Massachusetts: MIT Press.

Lemmerich, Jost. **1987**. *Zur Geschichte der Entwicklung des Lasers.* Berlin: DAVID.

Lewis, Harold W., Robert E. LeLevier, Arnold Nordsieck, Andrew M. Sessler, Kenneth M. Watson, and Steven Weinberg. **1968**. *Study S-307: Project Seesaw.* Arlington, Virginia: Institute for Defense Analyses/JASON.

Lewis, Damien. **2020**. *Churchill's Shadow Raiders: The Race to Develop Radar, World War II's Invisible Secret Weapon.* New York: Citadel.

Lickfeld, Karl G. **1979**. *Elektronenmikroskopie.* UTB.

Lojek, Bo. **2007**. *History of Semiconductor Engineering.* Berlin: Springer.

Lowen, Rebecca S. **1997**. *Creating the Cold War University: The Transformation of Stanford.* Berkeley, California: University of California Press.

Luxbacher, Günther. **2003**. *Massenproduktion im globalen Kartell: Glühlampen, Radioröhren und die Rationalisierung der Elektroindustrie bis 1945.* Berlin: Verlag für Geschichte der Naturwissenschaften und der Technik.

Lyndon, Roger C. **1947**. The Zuse Computer. *Mathematics of Computation* 2:355–359. https://doi.org/10.1090/S0025-5718-1947-0022444-9

Macrae, Norman. **1992**. *John von Neumann: The Scientific Genius Who Pioneered the Modern Computer, Game Theory, Nuclear Deterrence, and Much More.* New York: Pantheon.

Mergl, L. **1998**. Magnetron—Its Origin and the Contribution of August Žáček to its Development. *DVT dejiny ved a techniky* XXXI. Prague: Society for the History of Sciences and Technology.

Mertz, Pierre. **1946**. Communications in Germany. *Bell Laboratories Record* (July 1946) 24:271–274.

Metzler, Florian. **2020**. The Transistor, an Emerging Invention: Bell Labs as a Systems Integrator Rather Than a 'House of Magic.' https://ssrn.com/abstract=3678081

Metzler, Florian. **2023**. Radical Technological Innovations and How to Promote Them. https://ssrn.com/abstract=4521978

Mills, John FitzMaurice. **1983**. *Encyclopedia of Antique Scientific Instruments.* New York: Facts on File.

Mons, Wilhelm, Horst Zuse, and Roland Vollmar. **2005**. *Konrad Zuse.* Berlin: Ernst Freiberger-

Stiftung.

Müller, Werner. **1998**. *Ground Radar Systems of the Luftwaffe 1939–1945.* Atglen, Pennsylvania: Schiffer.

Nagel, Günter. **2006**. Pionier der Funktechnik. *Brandenburger Blätter.* 15 December 2006 p. 9.

Nature. **1936**. Public Television in Germany. *Nature* 137:391. https://doi.org/10.1038/137391a0

Nix, Foster C. 27 June **1975**. Interview of Foster Cary Nix by Lillian Hoddeson. American Institute of Physics, Niels Bohr Library and Archives. https://www.aip.org/history-programs/niels-bohr-library/oral-histories/4798

Noll, A. Michael, and Michael **Geselowitz**. **2011**. *Bell Labs Memoirs: Voices of Innovation.* IEEE History Center.

Nowottnick, Mathias. **2014**. *Konstruktion und Fertigung elektronischer Baugruppen.* Rostock: Universität Rostock. www.uni-rostock.de/storages/uni-rostock/UniHome/Weiterbildung/KOSMOS/E-Technik/Material_Ergebnisse_E-Technik/Einfuehrung_Konstruktion_elektronischer_Baugruppen.pdf See also: https://industry-press.com/happy-birthday-111-jahre-leiterplattentechnologie/

Parrish, Thomas. **1985**. *The Ultra Americans: The U.S. Role in Breaking the Nazi Codes.* New York: Stein & Day.

PBS (Public Broadcasting Service). **2000**. Tesla: Master of Lightning: Life and Legacy: The Missing Papers. http://www.pbs.org/tesla/ll/ll_mispapers.html

Peierls, Rudolf. **1932**. Elektronentheorie der Metalle. *Ergebnisse der exakten Naturwissenschaften* 11:264–322.

Petri, R. J. **1896**. *Das Mikroskop: Von seinen Anfängen bis zur jetzigen Vervollkommnung für alle Freunde dieses Instruments.* Berlin: Richard Schoetz.

Pierce, John R. **1975**. *Mervin Joe Kelly 1894–1971.* Washington, D.C.: National Academies Press. www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/kelly-mervin.pdf

Pierce, John R. **1983**. Rudolph Kompfner 1909–1977. Washington, D.C.: National Academies Press. www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/kompfner-rudolph.pdf

Pierce, John R. **1991**. My Work with Vacuum Tubes at Bell Laboratories. *Vintage Electrics* Vol. 3, No. 1. Southwest Museum of Engineering, Communications and Computation. www.smecc.org/john_r__pierce____electron_tubes.htm

Plaßmeyer, Peter, ed. **2007**. *Die Luftpumpe am Himmel: Wissenschaft in Sachsen zur Zeit Augusts des Starken und Augusts III.* Dresden: Sandstein.

Power, R. A. **1946**. The German Magnetophone. *Wireless World* (June 1946) 52:195–198.

Pritchard, David. **1989**. *The Radar War: Germany's Pioneering Achievement 1904–1945.* Patrick Stephens.

Qing, Lin. **1995**. *Zur Frühgeschichte des Elektronenmikroskops.* Diepholz: GNT.

Ranger, Richard H. **1947**. Magnetic Tape Recorder for Movies and Radio. *Electronics* (October

1947) 20:99-103.

Reuvers, Paul, and Marc **Simons**. **2020**. Crypto Museum. https://www.cryptomuseum.com

Rhoads, Christopher. **2005**. AT&T Inventions Fueled Tech Boom, And Its Own Fall. *Wall Street Journal* (2 February 2005). https://www.wsj.com/articles/SB110729925236542968

Ringer, Walter, and Heinrich **Welker**. **1948**. Leitfähigkeit und Hall-Effekt von Germanium. *Zeitschrift für Naturforschung A* 3:20–29.

Riordan, Michael. **2005**. How Europe Missed the Transistor. *IEEE Spectrum* 42:52–57.

Riordan, Michael, and Lillian **Hoddeson**. **1997**. *Crystal Fire: The Birth of the Information Age.* New York: W. H. Norton.

Rohde, Hans-Christian. **2007**. *Die Göbel-Legende: Der Kampf um die Erfindung der Glühlampe.* Springe: Zu Klampen.

Rojas, Raúl. **2023**. *Konrad Zuse's Early Computers: The Quest for the Computer in Germany.* Berlin: Springer.

Ruska, Ernst. **1930**. *Untersuchung elektrostatischer Sammelvorrichtungen als Ersatz der magnetischen Konzentrierspulen beim Kathodenstrahloszillographen.* Diplomarbeit Technische Hochschule Berlin, Lehrstuhl für Hochspannungstechnik. 23 December 1930.

Ruska, Ernst. **1933a**. Die elektronenoptische Abbildung elektronenbestrahlter Oberflächen. *Zeitschrift für Physik* 83:492–497.

Ruska, Ernst. **1933b**. Zur Fokussierbarkeit von Kathodenstrahlbündeln großer Ausgangsquerschnitte. *Zeitschrift für Physik* 83:684–697.

Ruska, Ernst. **1940a**. Über neuere Ergebnisse bei der Sichtbarmachung und Abbildung kleinster Gegenstände. *Natur und Volk* 70:209–217.

Ruska, Ernst. **1940b**. Aufnahme von Elektronenbeugungsdiagrammen im Übermikroskop. *Wiss. Veröff. Siemens Werkstoff-Sonderheft* 372–379.

Ruska, Ernst. **1952a**. Über den Aufbau einer elektronenoptischen Bank für Versuche und Demonstrationen. *Zeitschrift wiss. Mikroskopie* 60:317–328.

Ruska, Ernst. **1952b**. Prinzip und Grenzen der elektronenmikroskopischen Abbildung. *Acta Physica Austria* VI:91–92.

Ruska, Ernst. **1952c**. Untersuchungen über regelbare magnetostatische Elektronenlinsen. *Zeitschrift für wissenschaftliche Mikroskopie* 61:152–171.

Ruska, Ernst. **1952d**. Über die Technik der Elektronenmikroskopie und das neue Siemens-Übermikroskop für 100 kV. *Siemens-Zeitschrift* 26:6–15.

Ruska, Ernst. **1954**. Experiments with adjustable magnetostatic electron lenses. *Electron Physics* No. 44, U.S. Dept. of Commerce, National Bureau of Standards, Circular 527 pp. 389–410.

Ruska, Ernst. **1979**. *Die frühe Entwicklung der Elektronenlinsen und der Elektronenmikroskopie.* Halle: Deutsche Akademie der Naturforscher Leopoldina.

Ruthven, John, and Peter **Bardehle**. **2009**. *From Hunter to Hunted: U-480, the First Stealth U-boat in History.* National Geographic Channel.

Sarkar, Tapan K., Robert J. Mailloux, Arthur A. Oliner, Magdalena Salazar-Palma, and Dipak L. Sengupta. **2006**. *History of Wireless.* New York: Wiley-IEEE Press.

Saxena, Arjun N. **2009**. *Invention of Integrated Circuits: Untold Important Facts.* Singapore: World Scientific.

Schaeffer, Heinz. **1952**. *U-Boat 977.* New York: W. W. Norton.

Schiebold, Ernst. **1944**. Über die Möglichkeit biologischer Wirkungen kurzwelliger Röntgen-bsw. Gammastrahlen von Röntgenröhren besonderer Bauart auf größere Entfernungen (Forschungszentrum Karlsruhe Technik und Umwelt, 6 May).

Schnitger, Herbert, and Dieter **Weber**. **1949**. Untersuchungen über selbsterregte Schwingungen in der Wanderfeldröhre. *Frequenz* 3:7:189–195. https://doi.org/10.1515/FREQ.1949.3.7.189

Schottky, Walter. **1938**. Halbleitertheorie der Sperrschicht. *Naturwissenschaften* 26:843.

Schottky, Walter. **1939**. Zur Halbleitertheorie der Sperrschicht- und Spitzengleichrichter. *Zeitschrift für Physik* 113:367–414.

Shockley, William, and Gerald L. **Pearson**. **1948**. Modulation of Conductance of Thin Films of Semi-Conductors by Surface Charges. *Physical Review* 74:2:232. https://doi.org/10.1103/PhysRev.74.232

von Siemens, Werner. **1895**. *Lebenserinnerungen von Werner von Siemens.* 4th ed. Berlin: Julius Springer.

Smith, Scott S. **2016**. Thomas Watson Jr. Powered IBM to the Top of the Tech World. *Investor's Business Daily.* 28 May. https://www.investors.com/news/management/leaders-and-success/thomas-watson-jr-powered-ibm-to-the-top-of-the-tech-world/

Sommerfeld, Arnold. **1927**. Zur Elektronentheorie der Metalle. *Naturwissenschaften* 15:825–832.

Stephenson, Bruce, Marvin Bolt, and Anna Felicity Friedman. **2000**. *The Universe Unveiled: Instruments and Images Through History.* Chicago: Adler Planetarium.

Strauss, Rudolf. **1998**. *SMT Soldering Handbook.* 2nd ed. Oxford, U.K.: Newnes.

Sullivan, A. H., Jr. **1949**. German Electronics in World War II. *Electrical Engineering* (May) 68:403–409.

Swords, Seán S. **1986**. *Technical History of the Beginnings of Radar.* London: Peter Peregrinus.

Sze, S M. **1991**. *Semiconductor Devices: Pioneering Papers.* Singapore: World Scientific.

Tall, Joel. **1958**. *Techniques of Magnetic Recording.* New York: Macmillan.

Taylor, Nick. **2000**. *Laser: The Inventor, the Nobel Laureate, and the Thirty-Year Patent War.* New York: Simon & Schuster.

Teichmann, Jürgen. **1988**. *Zur Geschichte der Festkörperphysik: Farbzentrenforschung um 1940.*

Stuttgart: Franz Steiner.

Thurnauer, Hans. **1946**. Electrical Insulators. *Ceramic Industry* (June 1946) 46:55-56.

Tomayko, James E. **1985**. Helmut Hoelzer's Fully Electronic Analog Computer. *Annals of the History of Computing* 7:3:227–240.

Townes, Charles H. **1999**. *How the Laser Happened: Adventures of a Scientist.* Oxford: Oxford University Press.

Trenkle, Fritz. **1987**. *Die deutschen Funklenkverfahren bis 1945.* 2nd ed. Ulm: Hüthig.

Turner, Gerard L'Estrange. **1981**. *Collecting Microscopes.* New York: Mayflower Books.

Turner, Gerard L'Estrange. **1989**. *The Great Age of the Microscope.* New York: Adam Hilger.

Turner, Gerard L'Estrange. **1998**. *Scientific Instruments 1500–1900: An Introduction.* Berkeley: University of California Press.

Van Delft, Dirk. **2014**. 100 Years of Philips Research. *Europhysics News* 45:2:27–31. [Gilles Holst] http://dx.doi.org/10.1051/epn/2014204

Van Dormael, Armand. **2004**. The "French" Transistor. *Proceedings of the 2004 IEEE Conference on the History of Electronics.* https://ethw.org/w/images/e/e6/VanDormael.pdf

Van Dormael, Armand. **2009**. Biographies: Herbert F. Mataré. *IEEE Annals of the History of Computing* 31:3:68–73. https://ieeexplore.ieee.org/document/5223988

Van Dormael, Armand. **2012**. *The Silicon Revolution.* CreateSpace.

Villard, O. G., Jr. **1998**. *Frederick Emmons Terman, June 7, 1900–December 19, 1982.* Washington, D.C.: National Academies Press. https://www.nap.edu/read/6201/chapter/18

Warnow-Blewett, Joan, and Jürgen **Teichmann**. **1992**. *Guide to Sources for History of Solid State Physics.* College Park, Maryland: American Institute of Physics.

Watson, Raymond C., Jr. **2009**. *Radar Origins Worldwide: History of Its Evolution in 13 Nations Through World War II.* Bloomington, Indiana: Trafford.

Watson, Thomas J., Jr. **1963**. *Business and Its Beliefs: The Ideas that Helped Build IBM.* New York: McGraw-Hill.

Watson, Thomas J., Jr. **2000**. *Father, Son & Co.: My Life at IBM and Beyond.* New York: Bantam.

von Weiher, Siegfrid, ed. **1983**. *Männer der Funktechnik: 70 Lebenswerke deutscher Pioniere von Funk, Rundfunk und Fernsehen.* Berlin: VDE.

Werner, Herbert A. **1969**. *Iron Coffins: A Personal Account of the German U-Boat Battles of World War II.* New York: Holt, Rinehart & Winston.

Wessel, Horst A., ed. **2002**. *Das elektrische Jahrhundert: Entwicklung und Wirkungen der Elektrizität im 20. Jahrhundert.* Essen: Klartext.

West, Nigel. **1999**. *Venona: The Greatest Secret of the Cold War.* New York: HarperCollins.

Wiedemann, Gustav and Rudolph **Franz**. **1853**. Ueber die Wärme-Leitungsfähigkeit der Metalle. *Annalen der Physik und Chemie* 89:8:497–531.

Wimmer, Wolfgang. **2017**. Carl Zeiss, Ernst Abbe, and Advances in the Light Microscope. *Microscopy Today* 25:4:50–57. https://doi.org/10.1017/S155192951700058X

Wolff, Michael F. **1983**. Among the Giants: Mervin J. Kelly: Manager and Motivator. *IEEE Spectrum* 20:71–75. https://ieeexplore.ieee.org/document/6370063

Woo, Joseph S. K. **2006**. A Short History of the Development of Ultrasound in Obstetrics and Gynecology. https://www.ob-ultrasound.net/history1.html

Žáček, August. **1924**. Nová metoda k vytvorení netlumenych oscilací. *Časopis pro pěstování matematiky a fysiky* 53:378–380.

Žáček, August. **1936**. Magnetron Generators. *Slaboproudy obzor* 1:1:6–9 and 1:2:22–26.

Zahl, Harold A. **1968**. *Electrons Away or Tales of a Government Scientist.* New York: Vantage.

Zuse, Konrad. **1993**. *The Computer—My Life.* Berlin: Springer.

Historical Innovations in Mechanical Engineering

Archer, Sarah. 8 May **2019**. The Frankfurt Kitchen Changed How We Cook—and Live. Citylab. https://www.bloomberg.com/news/articles/2019-05-08/the-frankfurt-kitchen-changed-how-we-cook-and-live

Baines, Anthony. **1991**. *Woodwind Instruments and Their History.* Mineola, New York: Dover.

Baines, Anthony. **1993**. *Brass Instruments: Their History and Development.* Mineola, New York: Dover.

Bauer, Arthur O., Ralph Erskine, and Klaus Herold. **1997**. *Funkpeilung als alliierte Waffe gegen deutsche U-Boote 1939-1945: Wie Schwächen und Versäumnisse bei der Funkführung der U-Boote zum Ausgang der Schlacht im Atlantik beigetragen haben.* Diemen: Bauer. https://aobauer.home.xs4all.nl/Goliath.pdf

Bishop, Chris. **2014**. *The Illustrated Encyclopedia of Weapons of World War II: A Comprehensive Guide to Weapons Systems, Including Tanks, Small Arms, Warplanes, Artillery, Ships and Submarines.* London: Amber.

Bishop, Chris, and David **Ross**. **2016**. *Submarines: World War I to the Present.* London: Amber.

Breyer, Siegfried. **1999**. *German U-Boat Type XXI.* Atglen, Pennsylvania: Schiffer.

Broelmann, Jobst. **2012**. *Das Unterseeboot: Auftauchende Technologien.* Munich: Deutsches Museum.

Bull, Stephen. **2004**. *Encyclopedia of Military Technology and Innovation.* Westport, Connecticut: Greenwood Press.

Burstyn, Gunther. **1912**. Das Motorgeschütz. *Streffleurs Militärische Zeitschrift* 53:1:303–308. https://hdl.handle.net/2027/umn.31951002807783k

Cowie, J. S. **1949**. *Mines, Minelayers and Minelaying.* Oxford: Oxford University Press.

Cummins, Lyle. **2002**. *Internal Fire: The Internal Combustion Engine 1673–1900.* 3rd ed., Carnot Press.

DK. **2014**. *Firearms: An Illustrated History.* New York: DK.

Ebeling, Hermann. **1985**. *Der Freiherr von Drais: Das tragische Leben des "verrückten Barons": Ein Erfinderschicksal im Biedermeier.* Karlsruhe: G. Braun.

Echle, Willi. **1979**. *Theodor Bergmann 1850–1931: Leben und Wirken eines Gaggenauer Industriepioniers.* 2nd ed. Gaggenau: Torzewski.

Eisenstein, Elizabeth. **2005**. *The Printing Revolution in Early Modern Europe.* 2nd ed. Cambridge, U.K.: Cambridge University Press.

Engelmann, Joachim, and Horst **Scheibert**. **1974**. *Deutsche Artillerie 1934–1945: Eine Dokumentation in Text, Skizzen und Bildern: Ausrüstung, Gliederung, Ausbildung, Führung, Einsatz.* Limburg: C. A. Starke.

Febvre, Lucien, and Henri-Jean **Martin**. **2010**. *The Coming of the Book: The Impact of Printing 1450–1800.* 3rd ed. New York: Verso.

Feldhaus, Franz Maria. **1914**. *Die Technik: Ein Lexikon der Vorzeit, der geschichtlichen Zeit und der Naturvölker.* Leipzig: Engelmann.

Füssel, Stephan. **2004**. *Gutenberg und seine Wirkung.* 2nd ed. Frankfurt am Main: Insel.

Gander, Terry, and Peter **Chamberlain**. **1979**. *Weapons of the Third Reich: An Encyclopedic Survey of All Small Arms, Artillery, and Special Weapons of the German Land Forces, 1939–1945.* Garden City, New York: Doubleday.

Geoghegan, John J. **2013**. *Operation Storm: Japan's Top Secret Submarines and Its Plan to Change the Course of World War II.* New York: Broadway Books.

Germanisches Nationalmuseum. **1985**. *Leben und Arbeiten im Industriezeitalter.* Stuttgart: Konrad Theiss Verlag.

Götz, Hans Dieter. **1990**. *German Military Rifles and Machine Pistols 1871–1945.* Atglen, Pennsylvania: Schiffer.

Graf, Michael, and Wolff **Metternich**. **1986**. *Edmund Rumpler: Konstrukteur und Erfinder.* Munich: Neue Kunst Verlag.

Grünewald, Martin, and Willy Harold **Williamson**. **2013**. *Carl Benz: Ein Leben für das Automobil.* Kehl am Rhein: Sadifa-Media.

Halkasch, Hans-Jürgen. **1993**. *Biografisches Lexikon des Druck- und Verlagswesens: Lebensdaten und Leistungen.* Itzehoe: Verlag Beruf und Schule. [König and Bauer]

Hartmann, Gregory K., and Scott C. **Truver**. **1991**. *Weapons that Wait: Mine Warfare in the U.S. Navy.* 2nd ed. Annapolis, Maryland: Naval Institute Press.

Hellbeck, Robert. **2008**. *Friedrich Soennecken. Sein Leben und sein Werk.* Bonn: Verlag Interna.

Herzog, Bodo. **1996**. *Deutsche U-Boote 1906–1966.* Bonn: Karl Müller.

Hogg, Ian V. **1997**. *German Artillery of World War Two.* London: Greenhill Books.

Hogg, Ian V. **2001**. *German Handguns: The Complete Book of the Pistols and Revolvers of Germany, 1869 to the Present.* London: Greenhill Books.

Hubbard, Ernst. **1887**. *Die Verwerthung der Holzabfälle.* Vienna: Hartleben.

Hussey, G. F., Jr. **1946**. *German Underwater Ordnance Mines.* Ordnance Pamphlet (OP) 1673A. U.S. Navy Bureau of Ordnance. stephentaylorhistorian.files.wordpress.com/2020/09/op-1673a-german-underwater-ordnance.pdf

Hutchinson, Robert. **2001**. *Jane's Submarines: War Beneath the Waves: From 1776 to the Present Day.* New York: HarperCollins.

Jäger, Herbert. **2001**. *German Artillery of World War One.* Ramsbury, Marlborough, U.K.: Crowood Press.

Jean, Sheryl. **2004**. Ernst Eckert, 99, Aeronautics Pioneer. *Pioneer Press* and TwinCities.com. 11 July 2004. https://web.archive.org/web/20040809091924/http://www.me.umn.edu/divisions/tht/symp2004/EckertPioPressObit.pdf

Jolie, E. W. **1978**. *A Brief History of U.S. Navy Torpedo Development.* NUSC Technical Document 5436. U.S. Naval Underwater Systems Center. http://large.stanford.edu/courses/2015/ph241/hernandez2/docs/TorpDevel-Usn-JolieNusc1978.pdf

Kapr, Albert. **1996**. *Johann Gutenberg: The Man and his Invention.* 3rd ed. Abingdon, U.K.: Routledge.

Karlsch, Rainer, Christian Kleinschmidt, Jorg Lesczenski, Anne Sudrow. **2019**. *Playing the Game: The History of Adidas.* Munich: Prestel.

Kasischke, Friedrich. **1999**. *Friedrich Koenig: Erfinder der Druckmaschine und Vollender der Gutenbergschen Druckkunst.* Würzburg: König & Bauer.

Klawitter, Gerd. **1998**. *100 Jahre Funktechnik in Deutschland: Funksendestellen rund um Berlin.* Berlin: Wiss.- und Technik-Verlag. [pp. 113–128 Goliath ELF transmitter for worldwide submarine communication]

Köberl, Markus. **1990**. *Der Toplitzsee: Wo Geschichte und Sage zusammentreffen.* OBV. [sub-launched missiles]

Köhl, Fritz. **1988**. *Vom Original zum Modell: Uboottyp XXI.* Bonn: Bernard & Graefe.

Krzysztalowicz, Marek. **2012**. *Type VII: Germany's Most Successful U-Boats.* Annapolis, Maryland: Naval Institute Press.

Lassnig, Ewald. **1993**. *Peter Mitterhofer 1822–1893: Ein Pionier der Schreibmaschine.* Bozen, Italy: Athesia Tappeiner Verlag.

Lessing, Hans-Erhard. **2003**. *Automobilität: Karl Drais und die unglaublichen Anfänge.* Leipzig: Maxime.

Lessing, Hans-Erhard. **2010**. *Karl Drais: Zwei Räder statt vier Hufe.* Karlsruhe: G. Braun.

Ludvigsen, Karl. **2015**. *Professor Porsche's Wars: The Secret Life of Legendary Engineer Ferdinand Porsche Who Armed Two Belligerents Through Four Decades.* Barnsley, UK: Pen & Sword.

Madsen, Chris. **1998**. *The Royal Navy and German Naval Disarmament 1942–1947.* London: Frank Cass.

Michels, Ulrich. **2008**. *dtv-Atlas Musik: Systematischer Teil. Musikgeschichte von den Anfängen bis zur Gegenwart.*Munich: dtv.

Möller, Eberhard. **2000**. *Marine Geheimprojekte: Hellmuth Walter und seine Entwicklungen.* Stuttgart: Motorbuch.

Ortner, M. Christian. **2007**. *Die österreichisch-ungarische Artillerie von 1867 bis 1918: Technik, Organisation und Kampfverfahren.* Vienna: Verlag Militaria. Also published in English as: *The Austro-Hungarian Artillery from 1867 to 1918: Technology, Organization, and Tactics.*

Peters, Dorothea. **2007**. Die Welt im Raster: Georg Meisenbach und der lange Weg zur gedruckten Photographie. In: Alexander Gall, ed. 2007. *Konstruieren, Kommunizieren, Präsentieren. Bilder von Wissenschaft und Technik.* Göttingen: Wallstein. pp. 181–244.

Peters, Rolf-Herbert. **2007**. *Die Puma-Story.* Munich: Hanser.

Polmar, Norman, and Kenneth J. **Moore**. **2004**. *Cold War Submarines: The Design and Construction of U.S. and Soviet Submarines.* Washington: Brassey's.

Popplow, Markus. **2011**. *Felix Wankel: Mehr als ein Erfinderleben.* Erfurt: Sutton Verlag.

Raidt, Erik. **2014**. *Gottlieb Daimler und Robert Bosch: Von hier aus wird ein Stern aufgehen.* Stuttgart: Theiss.

Rauck, Max J. B., Gerd Volke, and Felix R. Paturi. **1979**. *Mit dem Rad durch zwei Jahrhunderte: Das Fahrrad und seine Geschichte.* 2nd ed. Aarau: AT Verlag.

Rauck, Michael. **1983**. *Karl Freiherr Drais von Sauerbronn: Erfinder und Unternehmer (1785–1851).* Stuttgart: Franz Steiner.

Rössler, Eberhard. **1987**. *Geschichte des deutschen U-Bootbaus.* 2 vols. Koblenz: Bernard & Graefe. Translated into English as: Eberhard Rössler. 2002. *The U-Boat: The Evolution and Technical History of German Submarines.* Cassell.

Rössler, Eberhard. **1998**. *Vom Original zum Modell: Die großen Walter-Uboote Typ XVII und Typ XXVI.* Bonn: Bernard & Graefe.

Rössler, Eberhard. **2005**. *Die Torpedos der deutschen U-Boote.* Hamburg: Mittler.

Rössler, Eberhard. **2010**. *Die schnellen Unterseeboote von Hellmuth Walter.* Bonn: Bernard & Graefe.

Rössler, Eberhard. **2016**. *U-Boot Schnorchel: Entwicklung und Einsatz 1943–1945.* Martenshagen: M & M Sundhaus.

Rößler, Max. **1982**. *Friedrich Koenig. Der Erfinder der Schnellpresse.* Würzburg: Echter.

Romanych, Marc and Martin **Rupp**. **2013**. *42cm "Big Bertha" and German Siege Artillery of World War I.* London: Osprey Publishing.

Roth, Karl Heinz, and Michael **Schmid**. **1987**. *Die Daimler-Benz AG 1916–1948. Schlüsseldokumente zur Konzerngeschichte.* Nördlingen: Delphi Politik, Verlegt bei Greno.

Sachs, Curt. **1940**. *The History of Musical Instruments.* Mineola, New York: Dover.

Sakaida, Henry, Gary Nila, and Koji Takaki. **2006**. *I-400: Japan's Secret Aircraft-Carrying Strike Submarine: Objective Panama Canal.* Friar Gate Farm, Essex: Hikoki Publications.

von Salvisberg, Paul. **1980**. *Der Radfahrsport in Bild und Wort.* Hildesheim: Georg Olms.

Sauer, Walter, ed. **2016**. *Max Himmelheber—Drei Facetten eines Lebens: Philosoph—Erfinder—Pfadfinder.* Baunach: Spurbuchverlag.

Schlesinger, Carl, ed. **1989**. *The Biography of Ottmar Mergenthaler: Inventor of the Linotype.* New Castle, Delaware: Oak Knoll Books.

Schmidt-Bachem, Heinz. **2011**. *Aus Papier. Eine Kultur- und Wirtschaftsgeschichte der Papierverarbeitenden Industrie.* Berlin: De Gruyter Saur.

Schulze-Wegener, Guntram. **1997**. *Die deutsche Kriegsmarine-Rüstung 1942-45.* Herford: Mittler.

Senich, Peter R. **1982**. *The German Sniper 1914–1945.* Boulder, Colorado: Paladin Press.

Senich, Peter R. **1987**. *The German Assault Rifle 1935–1945.* Boulder, Colorado: Paladin Press.

Taube, Gerhard. **1979**. *Eisenbahngeschütz DORA. Das größte Geschütz aller Zeiten.* Stuttgart: Motorbuch.

Taube, Gerhard. **1981**. *Die schwersten Steilfeuer-Geschütze 1914–1945: Geheimwaffen "Dicke Berta" und "Karl".* Stuttgart: Motorbuch.

Technisches Museum Wien. **2005**. *Schreiben wie gedruckt: Peter Mitterhofers Schreibmaschinen 1864–1869.* Vienna: Technisches Museum Wien.

Technisches Museum Wien. **2006**. *Marcus-Wagen: Original und Replika.* Vienna: Technisches Museum Wien.

Völker, Renate. **2013**. *Gottlieb Daimler: Ein bewegtes Leben.* 2nd ed. Tübingen: Silberburg.

Waize, Alfred. **2003**. *Peter Mitterhofer und seine fünf Schreibmaschinenmodelle in neuer Sicht. Die wechselvolle Geschichte des Tiroler Zimmermanns Peter Mitterhofer aus Partschins von 1864 bis 1869.* 2nd ed. Erfurt: Desotron.

Weingroff, Richard F. **2003**. The Man Who Changed America, Part I. *Public Roads* Vol. 66, No. 5, March/April. https://www.fhwa.dot.gov/publications/publicroads/03mar/05.cfm

Weir, Gary E. **1993**. *Forged in War: The Naval-Industrial Complex and American Submarine Construction, 1940–1961.* Washington, D.C.: U.S. Government Printing Office.

Wendlandt, Wilhelm. 1913. *Die deutsche Industrie (1888–1913).* Berlin. [Philipp Moritz Fischer pp. X40–X41]

Wetzel, Eckard. **1999**. *U 2540: Das U-Boot beim Deutschen Schiffahrtsmuseum in Bremerhaven.* 4th ed. Erlangen: Karl Müller.

Wictor, Thomas. **2007**. *German Flamethrower Pioneers of World War I.* Atglen, Pennsylvania: Schiffer.

Wilkinson, Philip. **2014**. *The History of Music in Fifty Instruments.* Richmond Hill, Ontario: Firefly.

Wise, James E., Jr. **2005**. *U-505: The Final Journey.* Annapolis, Maryland: Naval Institute Press.

Wolf, Hans-Jürgen. **1974**. *Geschichte der Druckpressen.* Frankfurt am Main: Interprint. [Koenig and Bauer]

Wollert, Günter, Reiner Lidschun, and Wilfried Kopenhagen. **2008**. *Illustrierte Enzyklopädie der Infanteriewaffen aus aller Welt.* Königswinter: Siegler.

Zaloga, Steven J., and Peter **Dennis**. **2016**. *Railway Guns of World War II.* Oxford, U.K.: Osprey Publishing.

Historical Innovations in Nuclear Science and Engineering

ACS (American Chemical Society). **2021**. Confirming the Pedigree of Uranium Cubes from Nazi Germany's Failed Nuclear Program. www.acs.org/content/acs/en/pressroom/newsreleases/2021/august/confirming-the-pedigree-of-uranium-cubes-from-nazi-germanys-failed-nuclear-program.html

Adams, A. **1993**. The Origin and Early Development of the Belgian Radium Industry. *Environment International* 19:491–501.

Albrecht, Ulrich, Ulrike Beisiegel, Reiner Braun, and Werner Buckel, eds. **1997**. *Der Griff nach dem atomaren Feuer.* 2nd ed. Franfurt am Main: Peter Lang.

Allen, Thomas B., and Norman **Polmar**. **2007**. *Rickover: Father of the Nuclear Navy.* Washington, D.C.: Potomac Books.

Alvarez, Luis W. **1987**. *Alvarez: Adventures of a Physicist.* New York: Basic Books. [p. 137]

von Ardenne, Manfred. **1990.** *Die Erinnerungen.* 10th ed. Munich: Herbig.

von Ardenne, Manfred. **1997**. *Ich bin ihnen begegnet: Wegweiser der Wissenschaft, Pioniere der Technik, Köpfe der Politik.* 2nd ed. Düsseldorf: Droste.

Arnold, Lorna. **2007**. *Windscale 1957: Anatomy of a Nuclear Accident.* 3rd ed. New York: Palgrave Macmillan.

Atkinson, Robert, and Fritz **Houtermans**. **1929a**. Zur Frage der Aufbaumöglichkeiten der Elemente in Sternen. *Zeitschrift für Physik* 54:9/10:656-665.

Atkinson, Robert, and Fritz **Houtermans**. **1929b**. Quantenmechanik der alpha-Strahlung. *Zeitschrift für Physik* 58:478–496.

Bagge, Erich, and Kurt **Diebner**. **1961**. Verfahren zur Verwertung der Fusionsenergie von Deuterium und Tritium mit Hilfe konvergenter, periodischer Verdichtungsstöße. Patent application DE 1414759 (20 March 1961).

Bagge, Erich, Kurt Diebner, and Kenneth Jay. **1957**. *Von der Uranspaltung bis Calder Hall.* Hamburg: Rowohlt.

Baggott, Jim. **2010**. *The First War of Physics: The Secret History of the Atom Bomb, 1939–1949.* New York: Pegasus Books.

Barashenkov, V. S., A. Polanski, and A. N. Sosnin. **1987**. Application of Low-Energy Accelerators in Electronuclear Systems. *Kerntechnik* 63:197–198.

Barber, W. C., and W. D. **George**. **1959**. Neutron Yields from Targets Bombarded by Electrons. *Physical Review* 116:1551–1559.

Barkleit, Gerhard. **2008**. *Manfred von Ardenne: Selbstverwirklichung im Jahrhundert der Diktaturen.* 2nd ed. Berlin: Duncker & Humblot.

Bartmann, Erwin. **2013**. *Für Volk und Führer: The Memoir of a Veteran of the 1st SS Panzer Division Leibstandarte SS Adolf Hitler.* Solihull, UK: Helion.

Barwich, Heinz, und Elfi **Barwich**. **1970**. *Das rote Atom: Als deutscher Forscher in der UdSSR.* Frankfurt am Main: Fischer.

Bascomb, Neal. **2016**. *The Winter Fortress: The Epic Mission to Sabotage Hitler's Atomic Bomb.* New York: Houghton Mifflin Harcourt.

Batvinis, Raymond J. **2014**. *Hoover's Secret War Against Axis Spies: FBI Counterespionage During World War II.* Lawrence, Kansas: University of Kansas Press.

Beams, Jesse, and F. **Haynes**. **1936**. The Separation of Isotopes by Centrifuging. *Physical Review* 50:5:491–492.

Beck, Johann. Undated. *Vom Schwanenkeller zum Atomkellermuseum.* Haigerloch: ST Elser.

Beck, Lorenz Friedrich, and Hubert **Laitko**, eds. **2008**. *Dahlemer Archivgespräche.* Vol. 13. Berlin: Archiv der Max-Planck-Gesellschaft.

Bekker, Bjarne. **2013**. *Flying Enterprise & Kurt Carlsen.* Svendborg, Denmark: Bekker. p. 141. http://flying-enterprise.øavisen.dk

Benedict, Manson, Thomas H. Pigford, and Hans Wolfgang Levi. **1981**. *Nuclear Chemical Engineering.* 2nd ed. Boston: McGraw Hill.

Bergier, Jacques. **1956**. *Secret Weapons—Secret Agents.* London: Hurst & Blackett. German edition: 1972. *Wissenschaftsspione + Geheimwaffen.* Munich: BLV.

Bergier, Jacques. **1977**. *Je Ne Suis Pas Une Legende.* Paris: Retz.

Bernstein, Jeremy. **2001**. *Hitler's Uranium Club: The Secret Recordings at Farm Hall.* 2nd ed. New York: Springer-Verlag.

Bernstein, Jeremy. **2007**. *Plutonium: A History of the World's Most Dangerous Element.* Ithaca, New York: Cornell University Press.

Bethe, Hans A. **1991**. *The Road from Los Alamos.* New York: Simon & Schuster.

Bethe, Hans A. **1997**. *Selected Works of Hans A. Bethe: With Commentary.* World Scientific.

Beyer, Robert T., ed. **1949**. *Foundations of Nuclear Physics.* New York: Dover.

Bird, Kai, and Martin J. **Sherwin**. **2005**. *American Prometheus: The Triumph and Tragedy of J. Robert Oppenheimer.* New York: Random House.

Blackett, P. M. S. **1949**. *Military and Political Consequences of Atomic Energy.* London: Turnstile Press.

Blatt, John M., and Victor F. **Weisskopf**. **1952**. *Theoretical Nuclear Physics.* New York: Wiley.

Blumberg, Stanley A., and Louis G. **Panos**. **1990**. *Edward Teller: Giant of the Golden Age of Physics.* New York: Scribners.

Boch, Rudolf, and Rainer **Karlsch**, eds. **2011**. *Uranbergbau im Kalten Krieg: Die Wismut im sowjetischen Atomkomplex.* 2 vols. Berlin: Christoph Links.

Bradley, David. **1948**. *No Place to Hide.* Boston: Little, Brown.

Braunbeck, Joseph. **1996**. *Der strahlende Doppeladler: Nukleares aus Österreich-Ungarn.* Graz: Leykam.

Brooks, Geoffrey. **1992**. *Hitler's Nuclear Weapons.* London: Leo Cooper.

Brooks, Geoffrey. **2002**. *Hitler's Terror Weapons.* London: Leo Cooper.

Brown, Colin. **2016.** *Operation BIG. The Race to Stop Hitler's A-Bomb.* Gloucestershire: Amberley Publishing.

Brown, Gerald E., and Chang-Hwan **Lee**, eds. **2006**. *Hans Bethe And His Physics.* World Scientific.

Brüchmann, Peter. **2009**. *Top Secret: Amerikas verschwiegener Triumph: Die Erbeutung der deutschen Atomwaffen 1945.* Rottenburg: Kopp.

Brüchmann, Peter. **2011**. *Der große Bluff: Keine Atombomben im Juli/August 1945.* Tübingen: Grabert.

Brunner, Maximilian. **2017**. *Armin Dadieu: Versuch der Biographie eines Nationalsozialisten.* Thesis, University of Graz.
https://unipub.uni-graz.at/obvugrhs/download/pdf/1703351

Bryden, John. **2014**. *Fighting to Lose: How the German Secret Intelligence Service Helped the Allies Win the Second World War.* Toronto: Dundurn.

Bühl, Alfons. **1972**. *Atomwaffen.* 3rd ed. Bonn: Osang-Verlag.

Bussard, Robert W., and R. D. **DeLauer**. **1958**. *Nuclear Rocket Propulsion.* New York: McGraw-Hill.

Bussard, Robert W., and R. D. **DeLauer**. **1965**. *Fundamentals of Nuclear Flight.* New York: McGraw-Hill.

Cabella, Gian Gaetano. **1948**. *Testamento politico di Mussolini.* Rome: Tosi. benitomussoliniblog.altervista.org/wp-content/uploads/2017/04/TESTAMENTO_POLITICO_MUSSOLINI.pdf

Carlisle, Rodney P., ed. **2005**. *Encyclopedia of Intelligence and Counterintelligence.* New York: M.E. Sharpe. [p. xxi]

Cassidy, David C. **1992**. *Uncertainty: The Life and Science of Werner Heisenberg.* New York: W. H. Freeman.

Cassidy, David C. **2009**. *Beyond Uncertainty: Heisenberg, Quantum Physics, and The Bomb.* New York: Bellevue Literary Press.

Chichester, David L. **2009**. *Production and Applications of Neutrons Using Particle Accelerators.* INL/EXT-09-17312. Idaho Falls: Idaho National Laboratory. https://inldigitallibrary.inl.gov/sites/sti/sti/6302373.pdf

Coats, Callum. **1996**. *Living Energies: Viktor Schauberger's Brilliant Work with Natural Energy Explained.* Bath: Gateway Books.

Conant, Jennet. **2005**. *109 East Palace: Robert Oppenheimer and the Secret City of Los Alamos.* New York: Simon & Schuster.

Coster-Mullen, John. **2012**. *Atom Bombs: The Top Secret Inside Story of Little Boy and Fat Man.* Self-published.

Craven, Wesley Frank, and James Lea **Cate**, eds. **1951**. *The Army Air Forces in World War II. Volume Three: Europe: Argument to V-E Day: January 1944 to May 1945.* Chicago: University of Chicago Press. https://media.defense.gov/2010/Nov/05/2001329888/-1/-1/0/AFD-101105-007.pdf

Cronin, James W., ed. **2004**. *Fermi Remembered.* Chicago: University of Chicago Press.

Curie, Eve. **1938**. *Madame Curie: A Biography.* New York: Doubleday.

Curtis, Charles P. **1955**. *The Oppenheimer Case: The Trial of a Security System.* New York: Simon and Schuster.

Dahl, Per F. **1999**. *Heavy Water and the Wartime Race for Nuclear Energy.* Philadelphia: Institute of Physics.

Dahn, Ryan. **2022a**. The Farm Hall Transcripts: The Smoking Gun That Wasn't. *Berichte zur Wissenschaftsgeschichte* 45:1–2:202–218. https://doi.org/10.1002/bewi.202100033

Dahn, Ryan. 19 May **2022b**. The Elusive Truth of Farm Hall. *Physics Today.* https://physicstoday.scitation.org/do/10.1063/PT.6.4.20220519a/full/

Davis, Nuel Pharr. **1968**. *Lawrence & Oppenheimer.* New York: Simon & Schuster.

Dawidoff, Nicholas. **1994**. *The Catcher Was a Spy: The Mysterious Life of Moe Berg.* New York: Pantheon Books.

Del Borgo, Vania. **2006**. *In Missione per Mussolini.* 110-minute film. Rome: Instituto Luce.

Dewar, James A. **2004**. *To the End of the Solar System: The Story of the Nuclear Rocket.* Lexington, Kentucky: University Press of Kentucky.

Diebner, Kurt. **1955**. Der deutsche Forscheranteil. *Die Zeit* (18 August 1955).

Diebner, Kurt (alias Werner Tautorus). **1956**. Die deutschen Geheimarbeiten zur Kernenergieverwertung während des zweiten Weldkrieges 1939–1945. *Atomkernenergie* 1:368–370 and 423–425.

Diebner, Kurt. **1957**. UK Patent 84L387: Thermonuclear Reactions (20 November 1957).

Diebner, Kurt. **1962**. Fusionsprozesse mit Hilfe konvergenter Stosswellen—einige ältere und neuere Versuche und überlegungen. *Kerntechnik* 4:3:89–93.

Diebner, Kurt, and Friedwardt **Winterberg**. **1956**. German patent application D 23685: Verfahren zur Zündung thermonuklearer Reaktionen mittels konvergenter Detonationsverdichtungssöße (28 August 1956).

Dippel, John V. H. **1992**. *Two Against Hitler: Stealing the Nazis' Best-Kept Secrets.* New York: Praeger.

DOE (U.S. Department of Energy). **1996**. *Plutonium: The First 50 Years: United States Plutonium Production, Acquisition, and Utilization from 1944 through 1994.* Washington, DC: Department of Energy. Ch. 9. https://sgp.fas.org/othergov/doe/pu50yc.html

Dyson, George. **2002**. *Project Orion: The True Story of the Atomic Spaceship.* New York: Henry Holt.

Ehrenberg, Wolfgang. **1958a**. *Probleme und Möglichkeiten der Atomkernfusion* (Garmisch-Patenkirchen 1958). [p. 17 wartime fusion research by Richter]

Ehrenberg, Wolfgang. **1958b**. Die Argentinischen Kernfusionsversuche in neuem Licht. *Atompraxis* (April 1958) 4 Jg., p. 139. [fusion research by Richter]

Eilers, Gernot. **2007**. Abschätzungen zur Starke der Explosion bein Ohrdruf. In: Rainer Karlsch and Heiko Petermann, eds. 2007. *Für und Wider "Hitlers Bombe".* Münster: Waxmann.

Eilers, Gernot. **2015**. Überlegungen zu den Aussagen des GRU-Berichts vom 23.3.1945. Unpublished manuscript.

Eisenhower, Dwight D. **1948**. *Crusade in Europe.* New York: Doubleday.

Elsner, Gine, and Karl-Heinz **Karbe**. **1999**. *Von Jáchymov nach Haigerloch.* Hamburg: Vsa.

Ermel, Adrian. **2010**. *Nachbarschaft zwischen Übung und Ernstfall. Der Truppenübungsplatz Ohrdruf und die Region Gotha—Arnstadt—Jonastal.* Bad Langensalza: Rockstuhl.

Farrell, Joseph P. **2004**. *Reich of the Black Sun: Nazi Secret Weapons & the Cold War Allied Legend.* Kempton, Illinois: Adventures Unlimited Press.

Fechter, Egidius. **2006**. *The Atomkeller-Museum at Haigerloch.* Haigerloch: ST Elser.

Fechter, Egidius. **2013**. *Humbug in der Höhlenforschungsstelle: Zum Atomkeller-Museum Haigerloch.* Haigerloch: ST Elser.

Felton, Mark. **2005**. *Yanagi: The Secret Underwater Trade between Germany & Japan 1942–1945.*

Barnsley, UK: Pen & Sword.

Fengler, Silke. **2014**. *Kerne, Kooperation und Konkurrenz. Kernforschung in Österreich im internationalen Kontext (1900-1950).* Vienna: Böhlau.

Fengler, Silke, and Carola **Sachse**, eds. **2012**. *Kernforschung in Österreich.* Vienna: Böhlau.

Fermi, Enrico. **1950**. *Nuclear Physics.* 2nd ed. Chicago: University of Chicago Press.

Fermi, Laura. **1987**. *Atoms in the Family: My Life with Enrico Fermi.* American Institute of Physics.

Fischer, Helmut J. **1984–1985**. *Erinnerungen.* 2 vols. Ingolstadt.

Fischer, Helmut J. **1987**. *Hitler und die Atombombe: Bericht eines Zeitzeugen.* Asendorf: MUT.

Fischer, Helmut J. **1988**. *Hitlers Apparat: Namen, Ämter, Kompetenzen: Eine Strukturanalyse des 3. Reiches.* Kiel: Arndt.

Fischer, Klaus. **1993**. *Changing Landscapes of Nuclear Physics: A Scientometric Study on the Social and Cognitive Position of German-Speaking Emigrants Within the Nuclear Physics Community 1921–1947.* Berlin: Springer.

Fisher, Joseph. **2017**. *Die Himmel waren vermauert/The Heavens Were Walled In.* Vienna: New Academic Press.

Ford, Kenneth W. **2015**. *Building the H Bomb: A Personal History.* World Scientific Publishing.

Frank, Charles, ed. **1993**. *Operation Epsilon: The Farm Hall Transcripts.* Berkeley: University of California Press.

Freund, Florian, and Bertrand **Perz**. **1987**. *Das KZ in der Serbenhalle: Zur Kriegsindustrie in Wiener Neustadt.* Vienna: Verlag für Gesellschaftskritik.

Freund, Leopold. **1903**. *Grundriß der gesamten Radiotherapie für praktische Ärzte.* Berlin: Urban & Schwarzenberg.

Frisch, Otto R. **1939**. Physical Evidence for the Division of Heavy Nuclei under Neutron Bombardment. *Nature.* 143:3616:276.

Frisch, Otto R. **1991**. *What Little I Remember.* Cambridge, UK: Cambridge University Press.

Gamow, George. **1932**. *Der Bau des Atomkerns und die Radioaktivität.* Leipzig: Hirzel.

Gamow, George, and Fritz **Houtermans**. **1928**. Quantenmechik der radioaktive Kerns. *Zeitschrift für Physik* 52:496-509.

Gantz, Kenneth F., ed. **1960**. *Nuclear Flight: The United States Air Force Programs for Atomic Jets, Missiles, and Rockets.* New York: Duell, Sloan and Pearce.

Gensicke, Klaus. **2011**. *The Mufti of Jerusalem and the Nazis: The Berlin Years.* Vallentine Mitchell.

Glaser, Alexander. **2008**. Characteristics of the Gas Centrifuge for Uranium Enrichment and Their Relevance for Nuclear Weapon Proliferation. *Science and Global Security* 16:1–25.

Glasstone, Samuel. **1958**. *Sourcebook on Atomic Energy.* 2nd ed. New York: Van Nostrand.

Glasstone, Samuel, and Philip J. **Dolan**, eds. **1977**. *The Effects of Nuclear Weapons.* Washington, DC: U.S. Government Printing Office.

Glasstone, Samuel, and Alexander **Sesonske**. **1981**. *Nuclear Reactor Engineering.* 3rd ed. New York: Van Nostrand Reinhold. .

Gollmann, Sabine Elisabeth. **1994**. *Die Radium- und Uranabteilung der Treibacher Chemischen Werke: Unter Berücksichtigung des deutschen Atombombenprojektes während des Zweiten Weltkrieges.* Ph.D. thesis. Graz: University of Graz.

Goncharov, G. A. **1996a**. American and Soviet H-Bomb Development Programmes: Historical Background. *Physics–Uspekhi* 39:10:1033–1044. https://www.globalsecurity.org/wmd/library/report/1996/goncharov-h-bomb.pdf

Goncharov, G. A. **1996b**. Thermonuclear Milestones. *Physics Today* 49:11:44–61.

Goncharov, G. A., and Lev D. **Riabev**. **2001**. The Development of the First Soviet Atomic Bomb. *Physics-Uspekhi* 44:1:71–93.

Goudsmit, Samuel A. **1945**. Testimony in *Hearings Before the Special Committee on Atomic Energy, United States Senate, Seventy-Ninth Congress, First Session, Pursuant to S. Res. 179, a Resolution Creating a Special Committee to Investigate Problems Relating to the Development, Use, and Control of Atomic Energy, Part 2, December 5, 6, 10, and 12, 1945.* Washington, D.C.: U.S. Government Printing Office, 1946, pp. 253–265.

Goudsmit, Samuel A. **1947**. *Alsos.* New York: Henry Schuman. [A highly condensed version was published as Nazis' Atomic Secrets, *Life*, 20 October 1947, pp. 123–134.]

Groves, Leslie R. **1962**. *Now It Can Be Told: The Story of the Manhattan Project.* New York: Harper.

Grunden, Walter E. **2005**. *Secret Weapons & World War II: Japan in the Shadow of Big Science.* Lawrence, Kansas: University Press of Kansas.

Gsponer, André, and Jean-Pierre **Hurni**. **2009**. *The Physical Principles of Thermonuclear Explosives, Inertial Confinement Fusion, and the Quest for Fourth Generation Nuclear Weapons.* Geneva: Independent Scientific Research Institute. http://isri.ch/wiki/_media/publications:ag-09-01.pdf

Guderley, Gottfried. **1942**. Starke kugelige und zylindrische Verdichtungsstösse in der Nähe des Kugelmittelpunktes bzw. der Zylinderachse. *Luftfahrtforschung* 19:302-312. Translated into English as *Nonstationary Gas Flow in Thin Pipes of Variable Cross Section* (NACA Technical Memorandum 1196, December 1948).

Guerrazzi, Amedeo Osti, ed. **2020**. *Le udienze di Mussolini durante la Repubblica Sociale Italiana, 1943–1945.* 2nd ed. Heidelberg: Heidelberg University. heiup.uni-heidelberg.de/catalog/book/522

Gutzeit, Andreas. **2001**. *U-234: Hitler's Last U-Boat.* Film. Washington, D.C.: Story House Productions.

Haber, Heinz. **1956**. *Our Friend the Atom.* New York: Golden Press.

Hahn, Otto, and Fritz **Strassmann**. **1939**. Über den Nachweis und das Verhalten der bei der Bestrahlung des Urans mittels Neutronen entstehenden Erdalkalimetalle. *Naturwissenschaften* 27:11–15.

Hahn, Otto. **1968**. *Mein Leben.* Frankfurt am Main: Bruckmann. English translation: 1970. *My Life.* London: MacDonald.

Hahn, Paul-Jürgen. **2003**. *Das Richter Experiment.* http://www.p-j-hahn.de/richter.html

Hair, Denny G. **2018a**. *Secrets Hidden.* Houston: Third Army Publishing.

Hair, Denny G. **2018b**. *The Images Uncovered: The Story of Patton and His Army Hidden in Print for 75 Years.* 2nd ed. Houston: Third Army Publishing.

Halbrook, Steven P. **2006**. Operation Sunrise: America's OSS, Swiss Intelligence, and the German Surrender 1945. In Marino Viganò and Dominic M. Pedrazzini, eds. 2006. *Atti del Convegno Internazionale.* Lugano. pp. 103-30. https://www.stephenhalbrook.com/law_review_articles/sunrise.pdf

Hansen, Chuck. **1988**. *U.S. Nuclear Weapons.* New York: Orion.

Hansen, Chuck. **2007**. *Swords of Armageddon.* 2nd ed. http://www.uscoldwar.com.

Hargittai, István. **2010**. *Judging Edward Teller: A Closer Look at One of the Most Influential Scientists of the Twentieth Century.* Amherst, New York: Prometheus Books.

Hargittai, István. **2013**. *Buried Glory: Portraits of Soviet Scientists.* Oxford: Oxford University Press.

von Hassell, Ulrich. **2011**. *The Ulrich von Hassell Diaries, 1938–1944: The Story of the Forces Against Hitler Inside Germany.* London: Frontline.

Hauk, Rolf-Günter. **2015**. *Kernspaltung und Gaslaterne: Die Verwendung von Thorium im Dritten Reich.* Hamburg: Tredition.

Hauk, Rolf-Günter, and Christel **Focken**. **2017**. *Atombombe—Made in Germany.* Königswinter: Mathias Lempertz.

Haukelid, Knut. **1989**. *Skis Against the Atom: The Exciting, First Hand Account of Heroism and Daring Sabotage During the Nazi Occupation of Norway.* 2nd ed. Minot, North Dakota: North American Heritage Press.

Haupt, Heinz Dieter. **2022**. *Deutschlands Weg zur Bombe: Chimäre oder Realität? Vom Dritten Reich bis zur Bundesrepublik.* Munich: Literareon.

Hawkins, David, Edith C. Truslow, and Ralph Carlisle Smith. **1983**. *Project Y: The Los Alamos Story.* American Institute of Physics.

Hayes, Peter. **2004**. *From Cooperation to Complicity: Degussa in the Third Reich.* Cambridge, UK: Cambridge University Press. Translated into German as Peter Hayes. 2004. *Von der Zusammenarbeit zur Mittäterschaft: Die Degussa im Dritten Reich.* Munich.

Hays, Robert. **2013**. *Patton's Oracle: Gen. Oscar Koch, as I Knew Him.* Savoy, Illinois: Herndon Sugarman.

Heilbron, J. L., and Robert W. **Seidel**. **1989**. *Lawrence and His Laboratory: A History of the Lawrence Berkeley Laboratory, Volume I.* Berkeley: University of California Press. http://ark.cdlib.org/ark:/13030/ft5s200764/

Heinemann-Gruder, Andreas. **1992**. *Die Sowjetische Atombombe.* Münster: Westfälisches Dampfboot.

Heisenberg, Werner. **1953**. *Nuclear Physics.* New York: Philosophical Library.

Heisenberg, Werner. **1971**. *Physics and Beyond: Encounters and Conversations.* New York: Harper & Row.

Helmbold, Bernd. **2016**. *Forschungstechnologien und Wissenschaftspolitik in der Biografie des Physikers Max Steenbeck (1904–1981).* Ph.D. thesis. Friedrich-Schiller-Universität Jena. https://www.ruhr-uni-bochum.de/imperia/md/content/tug/dgm/diss_helmbold_bernd_-_forschungstechnologien_und_wissenschaftspolitik_bei_max_steenbeck__thulb.pdf

Helmreich, Jonathan E. **1986**. *Gathering Rare Ores: The Diplomacy of Uranium Acquisition, 1943–1954.* Princeton, New Jersey: Princeton University Press.

Henshall, Philip. **1998**. *Vengeance: Hitler's Nuclear Weapon: Fact or Fiction?* Phoenix Mill, UK: Sutton.

Henshall, Philip. **2000**. *The Nuclear Axis: Germany, Japan and the Atom Bomb Race 1939-1945.* Phoenix Mill, UK: Sutton.

Henshall, Philip. **2002**. *Hitler's V-Weapons Sites.* Phoenix Mill, UK: Sutton.

Hentschel, Klaus, and Ann M. **Hentschel**. **1996**. *Physics and National Socialism: An Anthology of Primary Sources.* Basel: Birkhäuser.

Herken, Gregg. **2002**. *Brotherhood of the Bomb: The Tangled Lives and Loyalties of Robert Oppenheimer, Ernest Lawrence, and Edward Teller.* New York: Henry Holt.

Hiebert, Miriam E. **2023**. *The Uranium Club: Unearthing Lost Relics of the Nazi Nuclear Program.* Chicago: Chicago Review Press.

Hillgruber, Andreas, ed. **1970**. *Staatsmänner und Diplomaten bei Hitler: Vertrauliche Aufzeichnungen über Unterredungen mit Vertretern des Auslandes 1942-1944.* Vol. 2. Frankfurt am Main.

Hirschfeld, Wolfgang. **1991**. *Feindfahrten: Das Logbuch eines U-Bootfunkers.* Klagenfurt: Kaiser.

Hirschfeld, Wolfgang, and Geoffrey **Brooks**. **1996**. *Hirschfeld: The Story of a U-Boat NCO 1940-1946.* Annapolis, Maryland: Naval Institute Press.

Hoddeson, Lillian, Paul W. Henriksen, Roger A. Meade, and Catherine Westfall. **1993**. *Critical Assembly: A Technical History of Los Alamos During the Oppenheimer Years, 1943-1945.* Cambridge, UK: Cambridge University Press.

Hoffmann, Dieter, ed. **2023**. *Operation Epsilon: Die Farm-Hall-Protokolle erstmals vollständig, ergänzt um zeitgenössische Briefe und weitere Dokumente der 1945 in England internierten deutschen Atomforscher.* Diepholz: GNT.

Høibråten, Steinar. **2020**. Tritium Production. Norwegian Defence Research Establishment (FFI)

Report 20/01388. https://publications.ffi.no/nb/item/asset/dspace:6780/20-01388.pdf

Holloway, David. **1994**. *Stalin & the Bomb: The Soviet Union & Atomic Energy 1939-1956.* New Haven, Connecticut: Yale University Press.

Hooper, John. **2005**. Author fuels row over Hitler's bomb. *The Guardian* (30 September 2005). https://www.theguardian.com/world/2005/sep/30/books.italy

Hoover, J. Edgar. **1944**. 16 November letter. Franklin Delano Roosevelt Library, Hyde Park, New York. Small Collections, Atomic Bomb File, Box 1, Folder 3. [German double agent inquiries on atomic bomb]

Houghton, Vince. **2019**. *The Nuclear Spies: America's Atomic Intelligence Operation against Hitler and Stalin.* Ithaca, New York: Cornell University Press.

Houtermans, Fritz. **1953**. Application de la méthode du RaD à la mesure de l'âge chimique d'un minerai d'uranium. *Acta Geochim. Cosmochim.* 4:21–35.

Houtermans, Fritz. **1953**. Determination of the Age of the Earth from the Isotopic Composition of Meteoritic Lead. *Nuovo Cimento* 10:1623–1633.

Houtermans, Fritz, and I. Bartz. **1943**. Kernphotoeffekt im Beryllium. *Physik. Zeitschrift* 44:167-176.

Houtermans, Fritz, and V. Fomine. **1936**. Neutron Absorption of Boron and Cadmium at Low Temperature. *Nature* 137:505.

Houtermans, Fritz, and V. Fomine. **1936**. Absorption of Thermal Neutrons in Silver at Low Temperature. *Nature* 138:326.

Houtermans, Fritz, and J. H. Jensen. **1947**. Thermische Dissoziation des Vakuums. *Zeitschrift für Naturforschung* 2a:146–148.

Houtermans, Fritz, and Pascual Jordan. **1946**. Annahme der zeitlichen Veränderlichkeit des beta-Zerfalls und der Möglichkeit ihrer experimentelle Prüfung. *Zeitschrift für Naturforschung* 1:125-130.

Houtermans, Fritz, et al. **1954**. Isotopen-zusammensetzung und Radioactivität von rezentem Vesuvblei. *Helvet. Physica Acta* 27:175.

Houtermans, Fritz, et al. **1955**. Preliminary Note on Age Determinations of Magnetic Rocks by Means of Radioactivity. *Geol. Mijnbouw.* 17:217–223.

Hydrick, Carter Plymton. **1998**. *Critical Mass: The Real Story of the Birth of the Atomic Bomb and the Nuclear Age.* 1st ed. https://www.scribd.com/document/209775841/Hydrick-Carter-P-Critical-Mass-The-Real-Story-of-the-Birth-of-the-Atomic-Bomb

Hydrick, Carter Plymton. **2016**. *Critical Mass: How Nazi Germany Surrendered Enriched Uranium for the United States' Atomic Bomb.* 3rd ed. Walterville, Oregon: Trine Day.

Ilyichev, Ivan. **1944**. Intelligence report to General Antonov and Joseph Stalin (15 November 1944) Archive of the President of the Russian Federation, 93-81 (45) 37. Quoted in Karlsch 2005 p. 220, Karlsch and Petermann 2007 p. 22.

Ilyichev, Ivan. **1945**. Intelligence report to General Antonov and Joseph Stalin (23 March 1945)

Archive of the President of the Russian Federation, 93-81 (45) 37. Quoted in Karlsch 2005 pp. 220-221, Karlsch and Petermann 2007 pp. 25-26.

Irving, David. **1967**. *The Virus House.* London: William Kimber.

Irving, David. **2002**. *Hitler's War and the War Path.* London: Focal Point. [p. 789]

Jackson, Robert. **1946**. Cross-examination of Albert Speer (June 21, 1946).
http://avalon.law.yale.edu/imt/06-21-46.asp
http://law2.umkc.edu/faculty/projects/ftrials/nuremberg/speer.html

Jasiński, Janusz. **1994**. *Historia Królewca: szkice z XIII-XX stulecia.* Książnica Polska.

Jetter, Ulrich. **1950**. Die sogenannte Superbombe. *Physikalische Blätter* 6:199–205.

Jetter, Ulrich. **1952**. *Atomwaffen: Anwendung, Wirkungsweise, Schutzmaßnahmen.* Mosbach: Physik-Verlag.

Jetter, Ulrich. **1954**. Die Zeitgenossen der Wasserstoffbombe. *Physikalische Blätter* 10:596–600.

Johnson, Karen E. **2004**. From Natural History to the Nuclear Shell Model: Chemical Thinking in the Work of Mayer, Haxel, Jensen, and Suess. *Physics in Perspective* 6:3:295–309.

Jones, Vincent C. **1985**. *Manhattan: The Army and the Atomic Bomb.* Washington, DC: Center of Military History, United States Army. https://history.army.mil/html/books/011/11-10/CMH_Pub_11-10.pdf

Jungk, Robert. **1958**. *Brighter than a Thousand Suns: A Personal History of the Atomic Scientists.* New York: Harcourt Brace. Original German edition: 1956. *Heller als tausend Sonnen: Das Schicksal der Atomforscher.* Lizenzausgabe des Deutschen Bücherbundes.

Karlsch, Rainer. **2005**. *Hitlers Bombe.* Munich: Deutsche Verlags-Anstalt.

Karlsch, Rainer. **2006**. Die "Thüringer Protokolle": Über den Wert oder Unwert von Zeitzeugenaussagen. https://www.scribd.com/doc/87075616/GERMANY-NW-RainerKarlsch-Thuringer-Protokole-Zeitzeugen-32p-De

Karlsch, Rainer. Der große Bluff [The Big Bluff]. *Der Freitag* 24 August **2007**. Expanded English translation with references provided by Karlsch. https://www.freitag.de/autoren/der-freitag/der-grosse-bluff

Karlsch, Rainer. **2009**. Wunderwaffen für den "Endsieg"? die geheimen Arbeiten des Forschungsinstituts für Physik und dessen Verlagerung nach Neustadt an der Orla (1944–1945). *Zeitschrift für Thüringische Geschichte.* 63:259–276.

Karlsch, Rainer. **2010**. "Ich grüße Dich, Atomreaktor." *Frankfurter Allgemeine Zeitung.* 3 October 2010 pp. 65, 67.

Karlsch, Rainer. **2011**. *Uran für Moskau: Die Wismut—Eine populäre Geschichte.* 4th ed. Berlin: Christoph Links.

Karlsch, Rainer. **2013**. Die Abteilung Atomphysik der PTR in Ronneburg und das deutsche Uranprojekt. *PTB-Mitteilungen* 123:1:73–81.

Karlsch, Rainer. **2014**. Ein inszenierter Selbstmord: Überlebte Hitlers "letzter Hoffnungsträger", SS-Obergruppenführer Hans Kammler, den Krieg?, *Zeitschrift für Geschichtswissenschaft* 62:6:485–505.

Karlsch, Rainer, and Jochen **Laufer**, eds. **2002**. *Sowjetische Demontagen in Deutschland 1944–1949.* Berlin: Duncker & Humblot.

Karlsch, Rainer, and Heiko **Petermann**, eds. **2007**. *Für und Wider "Hitlers Bombe".* Münster: Waxmann.

Karlsch, Rainer, and Mark **Walker**. **2005**. New Light on Hitler's Bomb. *Physics World* (June 2005) pp. 15-18.

Karlsch, Rainer, and Zbynek **Zeman**. **2016**. *Urangeheimnisse: Das Erzgebirge im Brennpunkt der Weltpolitik 1933-1960.* 2nd ed. Berlin: Edition Berolina.

Kean, Sam. **2019**. *The Bastard Brigade: The True Story of the Renegade Scientists and Spies Who Sabotaged the Nazi Atomic Bomb.* New York: Little, Brown.

Kelly, Cynthia C., ed. **2007**. *The Manhattan Project: The Birth of the Atomic Bomb in the Words of Its Creators, Eyewitnesses, and Historians.* New York: Black Dog & Leventhal.

Kemp, R. Scott. **2005**. Nuclear Proliferation with Particle Accelerators. *Science and Global Security* 13:183–207. http://scienceandglobalsecurity.org/archive/sgs13kemp.pdf

Kemp, R. Scott. **2009**. Gas Centrifuge Theory and Development: A Review of U.S. Programs. *Science and Global Security* 17:1–19. https://scienceandglobalsecurity.org/archive/sgs17kemp.pdf

Kemp, R. Scott. **2012**. The End of Manhattan: How the Gas Centrifuge Changed the Quest for Nuclear Weapons. *Technology and Culture* 53:2:272–305.

Kemp, R. Scott. **2017**. Opening a Proliferation Pandora's Box: The Spread of the Soviet-Type Gas Centrifuge. *Nonproliferation Review* 24:1–2:1–27.

Kersten, Felix (edited by Herma Briffault). **1947**. *The Memoirs of Doctor Felix Kersten.* Garden City, New York: Doubleday.

Kersten, Felix. **1957**. *The Kersten Memoirs 1940–1945.* New York: Macmillan.

Kinzer, Stephen. **2013**. *The Brothers: John Foster Dulles, Allen Dulles, and Their Secret World War.* New York: Times Books.

Kleint, Christian, and Gerald **Wiemers**, eds. **1993**. *Werner Heisenberg in Leipzig 1927–1942.* Weinheim: Wiley-VCH.

Klinkenberg, Wim. **1971**. *De ultracentrifuge, 1937–1970: Hitlers bom voor Strauss?* Amsterdam: Van Gennep.

Knappe, Siegfried, and Ted **Brusaw**. **1992**. *Soldat: Reflections of a German Soldier 1936–1949.* New York: Orion.

Koch, Oscar W., with Robert G. **Hays**. 1999. *G-2: Intelligence for Patton.* Atglen, Pennsylvania: Schiffer.

Kogelnik, H. Dieter. **1997**. Inauguration of Radiotherapy as a New Scientific Speciality by Leopold Freund 100 Years Ago. *Radiotherapy & Oncology* 42:3:P203–211.

Kojevnikov, Alexei B. **2004**. *Stalin's Great Science: The Times and Adventures of Soviet Physicists.* London: Imperial College Press.

Kollert, Roland. **2000**. *Atomtechnik als Instrument westdeutscher Nachkriegs-Außenpolitik.* Berlin: Vereinigung Deutscher Wissenschaftler. https://docplayer.org/6556108-Vdw-materialien11-vereinigung-deutscher-wissenschaftler-2000-roland-kollert-atomtechnik-als-instrument-westdeutscher-nachkriegs-aussenpolitik.html

Kozyrev, Alexander S. **2005**. *Gas-Dynamic Thermonuclear Fusion.* Moscow: Sarov. [April 1947 Soviet designs based on earlier German work?]

Kramish, Arnold. **1986**. *The Griffin: The Greatest Untold Espionage Story of World War II.* Boston: Houghton Mifflin.

Krehl, Peter O. K. **2009**. *History of Shock Waves, Explosions and Impact: A Chronological and Biographical Reference.* Berlin: Springer.

Krotzky, Wolf. **2002**. *Die Grothmann-Protokolle.* Jonastalverein Archive, Arnstadt. [Interviews with Werner Grothmann.]

Kruglov, Arkadii. **2002**. *The History of the Soviet Atomic Industry.* London: Taylor & Francis.

Kruse, Kevin. **2015**. Leadership Lessons From Admiral Rickover. *Forbes* 6 January. https://www.forbes.com/sites/kevinkruse/2015/01/06/leadership-lessons-from-admiral-rickover/

Kuhn, Heinrich Gerhard. **1965**. James Franck 1882–1964. *Biographical Memoirs of Fellows of the Royal Society* 11:52–74. https://royalsocietypublishing.org/doi/pdf/10.1098/rsbm.1965.0004

Kurowski, Franz. **1985**. Von der bedingungslosen Kapitulation bis zur Mondorfer Erklärung vom 6. Juni 1945. In *Kongress Protokoll 1985: Jalta und Potsdam überwinden,* Bassum: Gesellschaft für Freie Publizistik (GFP). [p. 22, Donald L. Putt: "Only a few more weeks and, in the V-2 armed with nuclear weapons, the Germans would have had the decisive weapon"]

L'Annunziata, Michael F. **2016**. *Radioactivity: Introduction and History, from the Quantum to Quarks.* 2nd ed. Amsterdam: Elsevier.

Lanouette, William, with Bela **Silard**. **1992**. *Genius in the Shadows: A Biography of Leo Szilard, The Man Behind the Bomb.* New York: Charles Scribner's Sons.

Leahy, William D. **1944a**. 9 December memorandum for the President. Franklin Delano Roosevelt Library, Hyde Park, New York. Map Room Files, Box 20. Folder: Warm Springs, Dec. 9-18, 1944. [possibility of V-3 stratospheric bomb attack on U.S.]

Leahy, William D. **1944b**. War Department Report 14630 (9 December). Memos for FDR and JCS. Franklin Delano Roosevelt Library, Hyde Park, New York. Map Room Files, Box 164, Folder: Naval Aides, Files: AI 16—General Correspondence. [nuclear-armed V-3]

Lemmerich, Jost. **2011**. *Science and Conscience: The Life of James Franck.* Stanford, California: Stanford University Press.

Little, Robert D. **1963**. *Nuclear Propulsion for Manned Aircraft: The End of the Program 1959-1961.* K 168.01-11, AFD-110322-045. United States Air Force Historical Division Liaison Office. https://media.defense.gov/2011/Mar/22/2001330198/-1/-1/0/AFD-110322-045.pdf

Livdahl, Philip V. **1981**. The Livermore MTA Project and Its Influence on Modern Linacs. *Proceedings of the 1981 Linear Accelerator Conference.* Santa Fe, New Mexico. https://accelconf.web.cern.ch/accelconf/l81/papers/a101.pdf

Mader, Julius. **1965**. *Der Banditenschatz.* Deutscher Militärverlag. [pp. 229-233 atomic research by DEGUSSA]

Magill, J., and P. **Peerani**. **1999**. (Non-) Proliferation Aspects of Accelerator Driven Systems. *J. Phys. IV France* 9:Pr7:167–181. jp4.journaldephysique.org/articles/jp4/abs/1999/07/jp4199909PR711/jp4199909PR711.html

Mahaffey, James. **2014**. *Atomic Accidents: A History of Nuclear Meltdowns and Disasters: From the Ozark Mountains to Fukushima.* New York: Pegasus.

Mareš, Jaroslav V. **2020**. *Štěchovický poklad—konec legend.* Prague: Universum.

Mareš, Jaroslav V. **2021**. *Nacistické poklady a StB.* Prague: Universum.

Mareš, Jaroslav V. **2022**. *Atomový protektorát.* Prague: Universum.

Marshall, George C. **1996**. *Biennial Reports of the Chief of Staff of the United States Army to the Secretary of War: 1 July 1939 – 30 June 1945.* Washington, D.C.: U.S. Government Printing Office. pp. 132, 210. https://history.army.mil/html/books/070/70-57/CMH_Pub_70-57.pdf

Mayer, Maria Goeppert, and J. Hans D. **Jensen**. **1955**. *Elementary Theory of Nuclear Shell Structure.* New York: Wiley.

Mayer, Edgar, and Thomas **Mehner**. **2001**. *Das Geheimnis der deutschen Atombombe: Gewannen Hitlers Wissenschaftler den nuklearen Wettlauf doch?* Rottenburg: Kopp.

Mayer, Edgar, and Thomas **Mehner**. **2002**. *Die Atombombe und das Dritte Reich: Das Geheimnis des Dreiecks Arnstadt-Wechmar-Ohrdruf.* Rottenburg: Kopp.

Mayer, Edgar, and Thomas **Mehner**. **2004a**. *Hitler und die "Bombe": Welche Stand erreichte die deutsche Atomforschung und Geheimwaffenentwicklung wirklich?* Rottenburg: Kopp.

Mayer, Edgar, and Thomas **Mehner**. **2004b**. *Geheime Reichssache: Thüringen und die deutsche Atombombe.* Rottenburg: Kopp.

Mayer, Edgar, and Thomas **Mehner**. **2009**. *Die Angst der Amerikaner vor der deutschen Atombombe: Neue Informationen und Dokumente zum größten Geheimnis des Dritten Reiches.* 2nd ed. Rottenburg: Kopp.

Mayer, Edgar, and Thomas **Mehner**. **2010**. *Die Lügen der Alliierten und die deutschen Wunderwaffen: Das Dritte Reich, die Atombombe und der 6. August 1945.* Rottenburg: Kopp.

Mayer, Edgar, and Thomas **Mehner**. **2016**. *Und sie hatten sie doch! Spektakuläre neue Indizien bestätigen: Hitler verfügte über die Atombombe.* Rottenburg: Kopp.

Mayer, Edgar, and Thomas **Mehner**. **2019**. *Zeitbombe Jonastal: Das Dritte Reich und die Nuk-*

learwaffe. Gefahren im Boden. Das gelöste Energieproblem. Rottenburg: Kopp.

McRae, Kenneth D. **2014**. *Nuclear Dawn: F. E. Simon & the Race for Atomic Weapons in World War II.* Oxford: Oxford University Press.

Mehner, Thomas. **2004**. *Geheimnisse in Thüringens Untergrund: Die ungehobenen "Altlasten" des Dritten Reiches.* 3rd ed. Meiningen: Heinrich Jung.

Meitner, Lise, and Otto R. **Frisch**. **1939**. Disintegration of Uranium by Neutrons: A New Type of Nuclear Reaction. *Nature.* 143:3615:239.

Mellini Ponce De Leon, Ubaldo Alberto. **1950**. *Guerra diplomatica a Salò.* Cappelli.

Mineev, Vladimir, and Alexander **Funtikov**. **2007**. Physikalische Analysen zur Energiefreisetzung bei den deutschen Atomtests von 1945. In: Rainer Karlsch and Heiko Petermann, eds. 2007. *Für und Wider "Hitlers Bombe"*. Münster: Waxmann.

Misch, Rochus. **2014**. *Hitler's Last Witness: The Memoirs of Hitler's Bodyguard.* Barnsley, U.K.: Frontline Books.

Moczarski, Kazimierz. **1981**. *Conversations with an Executioner: An Incredible 255-Day-Long Interview with the Man Who Destroyed the Warsaw Ghetto.* Englewood Cliffs, New Jersey: Prentice-Hall. [p. 214]

Mödder, Ulrich and Uwe **Busch**, eds. **2008**. *Die Augen des Professors: Wilhelm Conrad Röntgen: Eine Kurzbiographie.* Berlin: Vergangenheitsverlag.

Nagel, Günter. **2002**. Rätsel Forschungsstelle Lebus. *Brandenburger Blätter* (16 August 2002, p. 7). [Richter 1942 fusion research]

Nagel, Günter. **2003**. *Atomversuche in Deutschland.* 2nd ed. Meiningen: Heinrich Jung.

Nagel, Günter. **2011**. *Himmlers Waffenforscher: Physiker, Chemiker, Mathematiker und Techniker im Dienste der SS.* Aachen: Helios.

Nagel, Günter. **2012a**. *Wissenschaft für den Krieg: Die geheimen Arbeiten der Abteilung Forschung des Heereswaffenamtes.* Stuttgart: Franz Steiner.

Nagel, Günter. **2016**. *Das geheime deutsche Uranprojekt 1939-1945: Beute der Alliierten.* Meiningen: Heinrich Jung.

Nash, Matthew. **2013**. *16 Photographs at Ohrdruf.* Film. 454 Productions.

Naujoks, Arthur, and Lee **Nelson**. **2002**. *The Last Great Secret of the Third Reich.* Springville, Utah: Cedar Fort.

Neugebauer, Franz J. **1946**. *Project No. NFE-64: Effect of Power-Plant Weight on Economy of Flight.* Headquarters Air Material Command, Wright Field, Dayton, Ohio. Air Force Historical Research Agency (Maxwell Air Force Base, Alabama).

Neugebauer, Franz J. **1962**. *Collection of Heat-Transfer Properties of Gases at Moderate Pressures, and Rules for Rapid Estimation of Missing Data.* Schenectady, New York: General Electric, on behalf of Office of Naval Research.

Nichols, Kenneth D. **1987**. *The Road to Trinity.* New York: William Morrow.

Noddack, Ida. **1934**. Über das Element 93. *Angewandte Chemie.* 47:37:653–655.

Norris, Robert S. **2002**. *Racing for the Bomb: General Leslie R. Groves, the Manhattan Project's Indispensable Man.* South Royalton, Vermont: Steerforth Press.

Nowak, Karl. **1960**. *Neue Physik* 2:3:90. [fusion]

Nowak, Karl. **1960** or 1961??? *Neue Physik* 2:4:154. [fusion]

Nowak, Karl. **1963**. *Neue Physik* 3:3:67. [fusion]

Nowak, Karl. **1964**. Rückschau über 20 Jahre. *Neue Physik* 4:1:?. [fusion]

Oleynikov, Pavel V. **2000**. German Scientists in the Soviet Atomic Project. *Nonproliferation Review* 7:2:1–30.

Oliver, Dave. **2014**. *Against the Tide: Rickover's Leadership Principles and the Rise of the Nuclear Navy.* Annapolis, Maryland: Naval Institute Press.

Olsen, Lasse Spang, and Emil **Oigaard**. **2002**. The Mystery of Flying Enterprise. Copenhagen: Offshore Film Production. www.idfa.nl/en/film/4d5ab20b-f3ce-4238-a0e0-42d1119403c4/the-mystery-of-flying-enterprise/docs-for-sale www.youtube.com/watch?v=DzCOYlMcOiA

Oppenheimer, Erwin K. **2023**. *I'm Afraid!* North Haven, Connecticut: Ezra Company. [This is an English translation of a 1955 French book, *J'ai Peur!* It claims to be an inside account of the German and U.S. nuclear weapons programs by "Erwin Oppenheimer," a scientist who was allegedly involved in both, and it has sometimes been cited as a serious source. Actually the entire book appears to be a work of fiction intended as a cautionary political tale by French journalist Well Allot/François Brigneau and Romanian journalist Gheorghe Barbul. The book's central scientist did not exist under that or any other name, and the book's descriptions of people, events, and scientific details are wildly inaccurate.]

Oppenheimer, J. Robert. **1984**. *Uncommon Sense.* Boston: Birkhäuser.

OTA (U.S. Office of Technology Assessment). **1977**. *Nuclear Proliferation and Safeguards.* NTIS Report PB-275843.
Appendix Volume II, Part One: https://www.princeton.edu/∼ota/disk3/1977/9586.html
Appendix Volume II, Part Two: https://www.princeton.edu/∼ota/disk3/1977/9587.html

Pancheri, Giulia. **2022**. *Bruno Touschek's Extraordinary Journey: From Death Rays to Antimatter.* Berlin: Springer.

Pash, Boris T. **1969**. *The Alsos Mission.* New York: Award House.

Pauwels, Louis, and Jacques **Bergier**. **1964**. *The Morning of the Magicians.* New York: Stein & Day.

Pellas, William J. **2020**. *The Japanese Bomb, By Way of Germany?* Bellevue, Washington: Amazon.

Persico, Joseph E. **2001**. *Roosevelt's Secret War: FDR and World War II Espionage.* New York: Random House.

Petermann, Heiko. **2000**. Wärterin der Wachsenburg erlebte drei merkwürdige Explosionen zum Kriegsende. *Freies Wort* (16 August 2000).

Petermann, Heiko. **2005**. *Hitlers Bombe.* Unreleased film.

Petersen, Neal H., ed. **2008**. *From Hitler's Doorstep: The Wartime Intelligence Reports of Allen Dulles, 1942–1945.* University Park, Pennsylvania: Penn State University Press.

Picker, Henry. **2009**. *Hitlers Tischgespräche im Führerhauptquartier.* 2nd ed. Berlin: Propyläen-Taschenbuch bei Ullstein.

Pondrom, Lee G. **2018**. *The Soviet Atomic Project: How the Soviet Union Obtained the Atomic Bomb.* Singapore: World Scientific.

Popp, Manfred. **2016**. Misinterpreted Documents and Ignored Physical Facts: The History of 'Hitler's Atomic Bomb' needs to be corrected. *Berichte zur Wissenschaftsgeschichte* 39:3:265–282. https://doi.org/10.1002/bewi.201601794

Popp, Manfred. **2021**. Why Hitler Did Not Have Atomic Bombs. *Journal of Nuclear Engineering* 2:1:9–27. https://doi.org/10.3390/jne2010002

Porezag, Karsten. **1996**. *Geheime Kommandosache.* Wetzlar: Wetzlardruck. [Wilhelm Haus. 1947. Letter from the Wetzlar Court Prison to the Chairman of the 1st Criminal Chamber of the District Court in Limburg on 20 June 1947. Hessian Hauptstaatsarchiv Wiesbaden, section 463, number 920, pp. 109–112. Quoted on p. 46.]

Post, Walter. **2004**. Kurt Diebner: Vater der deutschen Atombombe. *Deutsche Geschichte* (May 2004) 73:5:37.

Powers, Thomas. **1993**. *Heisenberg's War: The Secret History of the German Bomb.* New York: Alfred A. Knopf.

Preisler, Jerome, and Kenneth **Sewell**. **2013**. *Code Name Caesar: The Secret Hunt for U-Boat 864 During World War II.* New York: Berkley Caliber.

Preuss, Johannes, and Frank **Eitelberg**. **2003**. *Heeres-Munitionsanstalt Lübbecke: Vorgeschichte der Stadt Espelkamp.* Mainz: Geographisches Institut der Johannes Gutenberg-Universität.

Radkau, Joachim, and Lothar **Hahn**. **2013**. *Aufstieg und Fall der deutschen Atomwirtschaft.* Munich: oekom.

Reed, Bruce Cameron. **2015a**. *The Physics of the Manhattan Project.* 3rd ed. Berlin: Springer.

Reed, Bruce Cameron. **2015b**. Kilowatts to Kilotons: Wartime Electricity Use at Oak Ridge. *History of Physics Newsletter* 12:6:5–6.
https://engage.aps.org/fhpp/resources/newsletters/newsletter-archive/spring-2015

Reed, Bruce Cameron. **2019**. *The History and Science of the Manhattan Project.* 2nd ed. Berlin: Springer.

Reeves, Richard. **2008**. *A Force of Nature: The Frontier Genius of Ernest Rutherford.* New York: W. W. Norton.

Remdt, Gerhardt, and Gunter **Wermusch**. **2006**. *Rätsel Jonastal.* 2nd ed. Meiningen: Heinrich-

Jung-Verlagsgesellschaft.

Reuth, Ralf Georg, ed. **2000**. *Joseph Goebbels Tagebücher 1924-1945.* 5 vols. Munich: Piper.

Rhodes, Richard. **1986**. *The Making of the Atomic Bomb.* New York: Simon and Schuster.

Rhodes, Richard. **1995**. *Dark Sun: The Making of the Hydrogen Bomb.* New York: Simon and Schuster.

Riabev, L. D., ed. **1998**. *Atomnii Projekt SSR 1938–1945* [The Soviet Atomic Project]. Vol. I Part 1. Moscow.

Riabev, L. D., ed. **2002a**. *Atomnii Projekt SSR 1938–1945* [The Soviet Atomic Project]. Vol. I Part 2. Moscow.

Riabev, L. D., ed. **2002b**. *Atomnii Projekt SSR 1945–1954* [The Soviet Atomic Project]. Vol. II Part 1. Moscow.

Riabev, L. D., ed. **2002c**. *Atomnii Projekt SSR 1945–1954* [The Soviet Atomic Project]. Vol. II Part 2. Moscow.

Riabev, L. D., ed. **2002d**. *Atomnii Projekt SSR 1945–1954* [The Soviet Atomic Project]. Vol. II Part 3. Moscow.

Riabev, L. D., ed. **2006a**. *Atomnii Projekt SSR 1945–1954* [The Soviet Atomic Project]. Vol. II Part 4. Moscow.

Riabev, L. D., ed. **2006b**. *Atomnii Projekt SSR 1945–1954* [The Soviet Atomic Project]. Vol. II Part 5. Moscow.

Riabev, L. D., ed. **2006c**. *Atomnii Projekt SSR 1945–1954* [The Soviet Atomic Project]. Vol. II Part 6. Moscow.

Richardson, Cordell. [Pseudonym for David Gattiker.] **1977**. *Uranium Trail East.* London: Bachman & Turner.

Richelson, Jeffrey T. **2006**. *Spying on the Bomb: American Nuclear Intelligence from Nazi Germany to Iran and North Korea.* New York: W. W. Norton.

Richter, Ronald. **1991**. *Memoirs.* Private collection of Ing. Paul-Jürgen Hahn.

Rider, Dwight R. **2012**. *Hog Wild—1945: One B-29, One Soviet Conspiracy.* http://www.mansell.com/Resources/the_file_bin.html

Rider, Dwight R. **2016**. *Burn Before Reading: The Japanese Atomic Bomb Program, the Battles of the Chosin Reservoir, and the Cave at Koto-ri. The Cell.* http://www.mansell.com/Resources/the_file_bin.html

Rider, Dwight R., Eric Hehl, and Wes Injerd. **2017**. *The "Kuroda Papers:" Translation and Commentary.* http://www.mansell.com/Resources/the_file_bin.html

Rider, Dwight R. **2018**. *Japan's Biological and Chemical Weapons Programs; War Crimes and Atrocities: Who's Who, What's What and Where's Where—1928–1945.* http://www.mansell.com/Resources/the_file_bin.html

Rider, Dwight R. **2020**. *The Japanese Wartime Atomic Energy and Weapons Research Program—Seishin (Chongjin), Northern Korea. 1938–1984.* http://www.mansell.com/Resources/the_file_bin.html

Rider, Dwight R., and Eric **DeLaBarre**. **2014**. *Tsetusuo Wakabayashi, Revealed.* www.academia.edu/42335016/Tsetusuo_Wakabayashi_Revealed

Rider, Dwight R., and Eric **Hehl**. **2020a**. *A Dark Valley. North Korea's Sinanju Munitions Plant: A Not-So Clandestine Uranium Enrichment Facility.* http://www.mansell.com/Resources/the_file_bin.html

Rider, Dwight R., and Eric **Hehl**. **2020b**. *Railway of Infinite Regret: Uranium on the Thai-Burma Railway. 1943–1945.* http://www.mansell.com/Resources/the_file_bin.html

Rider, Todd H. **1995**. *Fundamental Limitations on Plasma Fusion Systems Not in Thermodynamic Equilibrium.* Ph.D. thesis. Cambridge, Massachusetts: MIT.

Rider, Todd H. **1997**. Fundamental Limitations on Plasma Fusion Systems Not in Thermodynamic Equilibrium. *Physics of Plasmas* 4:1039–1046.

Riehl, Nikolaus, and Frederick **Seitz**. **1993**. *Stalin's Captive: Nikolaus Riehl and the Soviet Race for the Bomb.* Washington, D.C.: American Chemical Society.

Riendeau, Christine D., David L. Moses, and Arne P. Olson. **1999**. Proliferation Potential of Accelerator-Driven Systems: Feasibility Calculations. Report K/NSP-778. Oak Ridge, Tennessee: Oak Ridge National Laboratory. https://digital.library.unt.edu/ark:/67531/metadc620806/m2/1/high_res_d/12464.pdf

Rife, Patricia. **1999**. *Lise Meitner and the Dawn of the Nuclear Age.* Boston: Birkhäuser.

Ritter, R. J., ed. July **2013**. Inside the Mushroom Cloud. *Newsletter for America's Atomic Veterans.* pp. 3–10. National Association of Atomic Veterans. https://www.naav.com/assets/2013_07_NAAV_Newsletter.pdf

Rockwell, Theodore. **1995**. *The Rickover Effect: The Inside Story of How Adm. Hyman Rickover Built the Nuclear Navy.* New York: Wiley.

Romersa, Luigi. **1955a**. Le armi segrete di Hitler [Hitler's Secret Weapons]. *Civilta Delle Macchine.* May-June.

Romersa, Luigi. **1955b**. J'ai Vu Exploser La Bombe Atomique de Hitler! *Paris-Presse L'Intransigeant.* 19 November, p. 14.

Romersa, Luigi. **1984**. Las "Armas Secretas" de Hitler, algo más que fantasía. *Defensa* August–September, No. 76–77.

Romersa, Luigi. **2005**. *Le Armi Segrete di Hitler.* Milan: Mursia.

Rose, Paul Lawrence. **1998**. *Heisenberg and the Nazi Atomic Bomb Project: A Study in German Culture.* Berkeley, California: University of California Press.

Rubin, Barry, and Wolfgang G. **Schwanitz**. **2014**. *Nazis, Islamists, and the Making of the Modern Middle East.* New Haven, Connecticut: Yale University Press.

Rudel, Hans Ulrich. **1958**. *Stuka Pilot.* New York: Ballantine Books.

Sadovsky, A. S. **2011a**. Heavy Water. History of One Priority. Part 1. https://web.archive.org/web/20141111234744/http://www.sci-journal.ru/articles/2011/030e.pdf

Sadovsky, A. S. **2011b**. Heavy Water. History of One Priority. Part 2. https://www.academia.edu/39286335/Heavy_water_History_of_one_priority_Part_2_031e

Sadovsky, A. S., and Barbara **Pietsch**. **2015**. Heavy Water. History of One Priority. Part 3. *SWorld Journal* J11505. https://sworld.com.ua/e-journal/j11505.pdf

Sanchez, Rene, David Loaiza, Robert Kimpland, David Hayes, Charlene Cappiello, and Mark Chadwick. **2008**. Criticality of a ^{237}Np Sphere. *Nuclear Science and Engineering* 158:1:1–14. https://doi.org/10.13182/NSE08-A2734

Scalia, Joseph Mark. **2000**. *Germany's Last Mission to Japan: The Failed Voyage of U-234.* Annapolis, Maryland: Naval Institute Press. German translation: 2005. *In geheimer Mission nach Japan: U 234.* Ullstein: Taschenbuch.

Schaaf, Michael. **2001**. *Heisenberg, Hitler und die Bombe: Gespräche mit Zeitzeugen.* Berlin: Diepholz.

Schauka, Frank. **2015**. Historiker: Nazis zündeten 1945 zwei Atombomben in Thüringen. *Thüringer Allgemeine* 1 August.

Scheich, Elvira. **2004**. *Von "Forschergewissen" und "Friedensfrauen". Das politische Gedächtnis der westdeutschen Nachkriegsgesellschaft und die Wissenschaft von der Physik. Historische Voraussetzungen und politische Bedeutungen als konstitutive Elemente eines soziologischen Wissenschaftsverständnisses.* Berlin: Freie Universität Berlin. https://refubium.fu-berlin.de/handle/fub188/20653

von Schirach, Richard. **2015**. *Night of the Physicists: Operation Epsilon: Heisenberg, Hahn, Weizsäcker and the German Bomb.* London: Haus.

Schmidt, Howard R. 1962. History of the Nuclear Rocket: Pre-NERVA Development (American Rocket Society conference paper, 14 November 1962, pp. 2-3).

Schmidt, Marten. **2008**. *Rügens geheime Landzunge: Die Verschlusssache Bug.* 3rd ed. Berlin: Christoph Links.

Schmitzberger, Markus. **2004**. *Was die US Army in der Alpenfestung wirklich suchte: Eine Theorie zum Decknamen der Anlage "Quarz" in Roggendorf bei Melk.* Rottenburg: Kopp.

Schumann, Erich. **1949**. *Die Wahrheit über die deutschen Arbeiten und Vorschläge zum Atomenergie-Problem (1939–45).* Unpublished manuscript. Erich Schumann estate.

Schumann, Erich, and Walter **Trinks**. **1952a**. German patent 977825: Vorrichtung, um ein Material zur Einleitung von mechanischen, thermischen oder nuklearen Prozessen auf extrem hohe Drücke und Temperaturen zu bringen. Filed 13 August 1952 and issued 8 April 1971.

Schumann, Erich, and Walter **Trinks**. **1952b**. German patent 977863: Vorrichtung zur Behandlung von Material mit hohen Drücken und Temperaturen. Filed 13 August 1952 and issued 25 November 1971.

Schwanitz, Wolfgang G. **2009**. Review of Karlsch, Rainer; Petermann, Heiko, Für und Wider "Hitlers Bombe": Studien zur Atomforschung in Deutschland. *H-Soz-u-Kult, H-Net Reviews.* February. [https://www.h-net.org/reviews/showrev.php?id=24129]

Schwartz, David N. **2017**. *The Last Man Who Knew Everything: The Life and Times of Enrico Fermi, Father of the Nuclear Age.* New York: Basic Books.

von Schwarzenbeck, Gerulf. **2010**. *Verschwörung Jonastal: Sensationelle neue Erkenntnisse zu Ereignissen und zur Lage unterirdischer Objekte im AWO-Gebiet sowie zur Technologie der deutschen Atombombe.* 3rd ed. Rottenburg: Kopp.

Schweber, Silvan S. **2012**. *Nuclear Forces: The Making of the Physicist Hans Bethe.* Cambridge, Massachusetts: Harvard University Press.

SED Arnstadt. **1962a**. Befragung von Cläre Werner, Heinz Wachsmut, Albin Kummer, Werner Kasper. 16 May 1962 transcript. Jonastalverein Archive, Arnstadt.

SED Arnstadt. **1962b**. Befragung von Alfred Gründler. 22 July 1962 transcript. Jonastalverein Archive, Arnstadt. [March 1945 A9/A10 launch]

Segrè, Emilio. **1970**. *Enrico Fermi Physicist.* Chicago: University of Chicago Press.

Sellwood, Arthur V. **1956**. *Dynamite for Hire.* London: Werner Laurie.

Serber, Robert. **1992**. *The Los Alamos Primer: The First Lectures on How to Build an Atomic Bomb.* Berkeley, California: University of California Press.

Shampo, Marc A., Robert A. Kyle, and David P. Steensma. **2011**. Hans Geiger—German Physicist and the Geiger Counter. *Mayo Clinic Proceedings* 86:12:e54.

Shaviv, Giora. **2012**. The nuclear shell model, the cosmic abundances and why we do not know how the heavy elements were synthesized. Mem. S.A.It. Vol. 83, 859–873. http://sait.oat.ts.astro.it/MSAIt830212/PDF/2012MmSAI..83..859S.pdf

Shurkin, Joel N. **2017**. *True Genius: The Life and Work of Richard Garwin, the Most Influential Scientist You've Never Heard of.* Amherst, New York: Prometheus Books.

Sime, Ruth Lewin. **1996**. *Lise Meitner: A Life in Physics.* Berkeley, California: University of California Press.

Sloop, John. **1978**. *Liquid Hydrogen as a Propulsion Fuel, 1945-1959.* NASA SP-4404. Washington, D.C.: U.S. Government Printing Office. [p. 192 German nuclear rocket research]

Smyth, Henry DeWolf. **1945**. *Atomic Energy for Military Purposes.* Princeton: Princeton University Press.

Sørheim, Aashild. **2020**. *Obsessed by a Dream: The Physicist Rolf Widerøe—a Giant in the History of Accelerators.* Berlin: Springer.

Soucek, Theodor. **2001**. *Mein Richter, mein Henker.* Malmö, Sweden: Bright Rainbow.

Spampanato, Bruno. **1974**. *Contromemoriale.* Rome: Centro Editoriale Nazionale.

Spangenburg, Ray, and Diane K. **Moser**. **1995**. *Niels Bohr: Gentle Genius of Denmark.* New York: Facts on File.

Speer, Albert. **1970**. *Inside the Third Reich.* New York: Macmillan.

Speer, Albert. **1981**. *Infiltration: How Heinrich Himmler Schemed to Build an SS Industrial Empire.* New York: Macmillan.

Stange, Thomas. **2000**. *Institut X: Die Anfange der Kern- und Hochenergiephysik in der DDR.* Stuttgart.

Steenbeck, Max. **1980**. *Impulse und Wirkungen.* 3rd ed. Berlin: Verlag der Nation.

Stumpf, Hans-Friedrich. **1995**. *Kernenergieforschung in Celle 1944/45: Die geheimen Arbeiten zur Uranisotopentrennung im Seidenwerk Spinnhütte.* Stadtarchiv.

Sublette, Carey. **2019**. *The Nuclear Weapon Archive: A Guide to Nuclear Weapons.* nuclearweaponarchive.org

Suckert, Hans-Ulrich, and Jürgen **Zboron**. **2017**. *1938—Geheime Reichssache: Der Weg zur deutschen Atombombe.* 2nd ed. Weltbuch.

Suckley, Margaret. **1944**. Papers, Journal Group E, 06/30/1944-12/29/1944, Journal Entry 1-253 (9 December). Franklin Delano Roosevelt Library, Hyde Park, New York. [possibility of V-3 stratospheric bomb attack on U.S.]

Sulzer, Andreas, and Stefan **Brauburger**. **2014**. *Hitlers Geheimwaffenchef: Auf den Spuren von Hans Kammler.* Film. Pro Omnia Film and Zweites Deutsches Fernsehen (ZDF).

Sulzer, Andreas, and Stefan **Brauburger**. **2015**. *Die Suche nach Hitlers Atombombe.* Film. Pro Omnia Film and Zweites Deutsches Fernsehen (ZDF).

Sulzer, Andreas, and Stefan **Brauburger**. **2019a**. *Hitlers Geheimwaffenchef: Die zwei Leben Hans Kammlers.* Film. Pro Omnia Film and Zweites Deutsches Fernsehen (ZDF).

Sulzer, Andreas, and Stefan **Brauburger**. **2019b**. *Die geheimste Unterwelt der SS.* Film. Pro Omnia Film and Zweites Deutsches Fernsehen (ZDF).

Sulzer, Andreas, and Stefan **Brauburger**. **2019c**. *Geheime Unterwelten der SS: Wunderwaffen und Verstecke.* Film. Pro Omnia Film and Zweites Deutsches Fernsehen (ZDF).

Sulzer, Andreas, and Stefan **Brauburger**. **2019d**. *Geheime Unterwelten der SS: Das Geheimnis von Stechovice.* Film. Pro Omnia Film and Zweites Deutsches Fernsehen (ZDF).

Sutton, Robert K. 2021. *Nazis on the Potomac: The Top-Secret Intelligence Operation That Helped Win World War II.* Philadelphia: Casemate.

Szanton, Andrew, ed. **1992**. *The Recollections of Eugene P. Wigner.* New York: Plenum Press.

Teller, Edward. **1979**. *Energy from Heaven and Earth.* San Francisco: W. H. Freeman.

Teller, Edward. **1987**. *Better a Shield Than a Sword: Perspectives on Defense & Technology.* New York: Macmillan.

Teller, Edward, with Judith Shoolery. **2001**. *Memoirs: A Twentieth-Century Journey in Science and Politics.* Cambridge, Massachusetts: Perseus.

Teller, Edward, Wilson K. Talley, Gary H. Higgins, and Gerald W. Johnson. **1968**. *The Constructive Uses of Nuclear Explosives.* New York: McGraw-Hill.

Thirring, Hans. **1946**. *Die Geschichte der Atombombe.* Vienna: Neues Österreich.

Thirring, Hans. **1955**. Thermonuclear Power Reactors—Are They Feasible? *Nucleonics* (November 1955) 13:11:65. [1942 fusion research by Richter]

Trevethan, Sidney. **1999**. *The Controversial Cargo of U-234.* Unpublished manuscript.

Trevethan, Sidney. **2017**. *Early Atomic History: A Timeline 1937–1957.* Anchorage, Alaska: Library North.

Trevor-Roper, Hugh, ed. **1978**. *The Diaries of Joseph Goebbels: Final Entries 1945.* New York: G. P. Putnam's Sons.

Trinks, Walter. **1943**. *Über ein Verfahren zur Erzeugung höchster Drucke und Temperaturen.* Unpublished manuscript.

Trinks, Walter. **1958a**. Über das Wesen der Detonation und die Wirkungsweise von Hohlsprengladungen. *Soldat und Technik* 11.

Trinks, Walter. **1958b**. 10 Millionen Atm durch Molekülzertrümmerung. *Soldat und Technik* 12:604.

Ueberschär, Gerd D. **1999**. *Die Deutsche Reichspost 1933–1945: Eine politische Verwaltungsgeschichte.* 2 vols. Berlin: Nicolai.

Uhl, Matthias. **2024**. *GRU: Die unbekannte Geschichte des sowjetisch-russischen Militärgeheimdienstes von 1918 bis heute.* Darmstadt: Wissenschaftliche Buchgesellschaft.

Ulam, Stan M. **1991**. *Adventures of a Mathematician.* Berkeley: University of California Press.

Umar, Abd al-Karim. **1999**. *Muzakkirat al-Hagg Muhammad Amin al-Husaini* [*The Memoirs of al-Hagg Muhammad Amin al-Husaini*]. Damascus. pp. 127, 162ff. Also: Abd al-Karim Umar. *Guerilla-Fidaiyun-Kommandos.* Damascus. p. 145. https://www.h-net.org/reviews/showrev.php?id=24129 https://www.worldpoliticsreview.com/articles/2082/amin-al-husaini-and-the-holocaust-what-did-the-grand-mufti-know

Van Atta, C. M. **1977**. *A Brief History of the MTA Project.* UCRL-79151. Livermore, California: Lawrence Livermore National Laboratory.
https://inis.iaea.org/collection/NCLCollectionStore/_Public/08/322/8322162.pdf

Van Calmthout, Martijn. **2018**. *Sam Goudsmit and the Hunt for Hitler's Atom Bomb.* Amherst, New York: Prometheus Books.

Verga, Maurizio. **2023**. *Flying Saucers from Naziland: The Real Story of the Nazi UFOs.* Vol. 1. Maurizio Verga/Amazon.com. [Most of this book points out problems with postwar claims about German "flying saucers." However, one unrelated chapter in the book (skeptically) discusses the wartime German nuclear program, and it very helpfully cites many obscure but relevant newspaper articles from that time.]

Wagemans, Cyriel. **1991**. *The Nuclear Fission Process.* Boca Raton, Florida: CRC Press.

Walker, Mark. **1989**. *German National Socialism and the Quest for Nuclear Power, 1939–1949.* Cambridge, UK: Cambridge University Press.

Walker, Mark. **1995**. *Nazi Science: Myth, Truth, and the German Atomic Bomb.* New York: Plenum.

Walker, Mark. **2020**. A Biography of the German Atomic Bomb. In: Forstner C., Walker M., eds., *Biographies in the History of Physics.* Berlin: Springer. https://doi.org/10.1007/978-3-030-48509-2_10

Walker, Mark. **2024a**. The Historiography of "Hitler's Atomic Bomb." *Physics in Perspective* 26:18–41. https://doi.org/10.1007/s00016-024-00309-6

Walker, Mark. **2024b**. *Hitler's Atomic Bomb: History, Legend, and the Twin Legacies of Auschwitz and Hiroshima.* Cambridge, UK: Cambridge University Press.

Waloschek, Pedro. **2004**. *Todesstrahlen als Lebensretter: Tatsachenberichte aus dem Dritten Reich.* 2nd ed. Norderstedt: Books on Demand.

Waloschek, Pedro. **2007**. *Rolf Wideröe 1902–1996: A Pioneer of Particle Accelerators and Radiation Therapy.* 2nd ed. Books on Demand.

Waloschek, Pedro. **2012**. *Death-Rays as Life-Savers in the Third Reich.* Draft English translation of *Todesstrahlen als Lebensretter.* www-library.desy.de/preparch/books/death-rays.pdf

Ward, Geoffrey C., ed. **1995**. *Closest Companion: The Unknown Story of the Intimate Friendship Between Franklin Roosevelt and Margaret Suckley.* Boston: Houghton Mifflin. [9 December 1944 Margaret Suckley diary entry on pp. 357–358]

Watson, Peter. **2018**. *Fallout: Conspiracy, Cover-Up, and the Deceitful Case for the Atom Bomb.* New York: PublicAffairs.

Weart, Spencer R. **1979**. *Scientists in Power.* Cambridge, Massachusetts: Harvard University Press.

Weart, Spencer R., and **Gertrud Weiss Szilard**, eds. **1978**. *Leo Szilard: His Version of the Facts: Selected Recollections and Correspondence.* Cambridge, Massachusetts: MIT Press.

Weinberg, Alvin M., and Eugene P. **Wigner**. **1958**. *The Physical Theory of Neutron Chain Reactors.* Chicago: University of Chicago Press.

Weingand, Hans-Peter. **1995**. *Die Technische Hochschule Graz im Dritten Reich.* Graz: T. U. Graz. pp. 60–61. https://diglib.tugraz.at/die-technische-hochschule-graz-im-dritten-reich-1995

Weiss, Burghard. **1996**. *'Forschungsstelle D': Der Schweizer Ingenieur Walter Dällenbach (1892-1990), die AEG und die Entwicklung kernphysikalischer Großgeräte im nationalsozialistischen Deutschland.* Berlin: Verlag für Wissenschafts- und Regionalgeschichte Engel.

Weiss, Hermann F. 2006. *Buschvorwerk im Riesengebirge: Eine Gemeinde in Niederschlesien von den Kriegsjahren bis zur Vertreibung.* Herbolzheim: Centaurus.

Weisskopf, Victor F. **1972**. *Physics in the Twentieth Century.* Cambridge, Massachusetts: MIT Press.

Weisskopf, Victor F. **1989**. *The Privilege of Being a Physicist.* New York: W. H. Freeman.

von Weizsäcker, Carl Friedrich. **1941**. Energieerzeugung aus dem Uranisotop der Masse 238 und anderen schweren Elementen (Herstellung und Verwendung des Elements 94) (6 June 1941).

Wellerstein, Alex, and Edward **Geist**. **2017**. The Secret of the Soviet Hydrogen Bomb. *Physics Today* 70:4:40.

West, Nigel. **2004**. *Mortal Crimes: The Greatest Theft in History: The Soviet Penetration of the Manhattan Project.* 2nd ed. New York: Enigma.

Wigner, Eugene P. **1967**. *Symmetries and Reflections.* Bloomington, Indiana: Indiana University Press.

Wilcox, Robert K. **2019**. *Japan's Secret War: How Japan's Race to Build its Own Atomic Bomb Provided the Groundwork for North Korea's Nuclear Program.* 3rd ed. New York: Permuted Press.

Williams, Susan. **2016**. *Spies in the Congo: America's Atomic Mission in World War II.* New York: PublicAffairs.

Winterberg, Friedwardt. **1981**. *The Physical Principles of Thermonuclear Explosive Devices.* New York: Fusion Energy Foundation.

Winterberg, Friedwardt. **2010**. *The Release of Thermonuclear Energy by Inertial Confinement: Ways Towards Ignition.* Singapore: World Scientific.

Witte, Peter, and Stephens **Tyas**. **2014**. *Himmler's Diary 1945: A calendar of events leading to suicide.* Stroud, UK: Fonthill Media.

Woods, George Bryant. **1946**. *The Aircraft Manufacturing Industry: Present and Future Prospects.* New York: White, Weld & Co.

Wulff, Wilhelm. **1973**. *Zodiac and Swastika: How Astrology Guided Hitler's Germany.* New York: Coward, McCann & Geoghegan.

Yad Vashem Archive M.9/339. Tagung der deutschen Wissenschaftler/Bavarian document. Ca. 1945. https://portal.ehri-project.eu/units/il-002798-m_9-339#desc-eng

Yudin, Yury A. Undated. *Manuscript on the History of the Soviet Nuclear Weapons and Nuclear Infrastructure.* ISTC Project # 1763p. Moscow: Ministry of Atomic Energy.
www.partnershipforglobalsecurity-archive.org/Documents/history-manuscript_eng.pdf

Zachariae, Georg. **1948**. *Mussolini si confessa.* Milan: Garzanti. Reprinted in 2004 by Milan: BUR.

Zeman, Zbynek, and Rainer **Karlsch**. **2008**. *Uranium Matters: Central European Uranium in International Politics 1900-1960.* Budapest: Central European University Press.

Ziegert, Albrecht. **2011**. Gab es Sprengkörpertests im März 1945 bei Ohrdruf? https://www.db-thueringen.de/receive/dbt_mods_00019340

Zippe, Gernot. **2008**. *Rasende Ofenrohre in stürmischen Zeiten: Ein Erfinderschicksal aus der Geschichte der Uranisotopentrennung im heissen und im kalten Krieg des 20. Jahrhunderts.* Vienna: Ekkehard Kubasta.

Historical Innovations in Aerospace Engineering

Amtmann, Hans H. **1988**. *The Vanishing Paperclips: America's Aerospace Secret: A Personal Account.* Boylston, Massachusetts: Monogram Aviation Publications.

Anderson, John D. **1997**. *A History of Aerodynamics.* Cambridge, UK: Cambridge University Press.

Arnold, Henry H. **1945**. *Third Report of the Commanding General of the Army Air Forces to the Secretary of War.* Baltimore, Maryland: Schneidereith & Sons.

Arnold, Henry H. **1949**. *Global Mission.* New York: Harper.

Aumann, Philipp. **2015**. *Rüstung auf dem Prüfstand: Kummersdorf, Peenemünde und die totale Mobilmachung.* Berlin: Christoph Links.

Aumann, Philipp, and Thomas **Köhler**. **2018**. *Vernichtender Fortschritt: Serienfertigung und Kriegseinsatz der Peenemünder "Vergeltungswaffen."* Berlin: Christoph Links.

Barber, Murray. **2017**. *V2: The A4 Rocket from Peenemünde to Redstone.* Manchester, UK: Crecy.

Bauduin, Philippe. **2014**. *Hitler's Spyplane over Normandy 1944: The World's First Jet.* Barnsley, UK: Pen & Sword.

Baumann, Ansbert. **2007.** Die Gründung des Institut Saint-Louis. In Ulrich Pfeil, ed. *Deutsch–französische Kultur- und Wissenschaftsbeziehungen im 20. Jahrhundert: Ein institutionsgeschichtlicher Ansatz.* Munich: Oldenbourg.

Baumann, Ansbert. **2008**. "Was die wissenschaftlichen Ergebnisse betrifft, so is es völlig unerheblich wo wir arbeiten": Les balisticiens allemands au service de la France après 1945. *Cahiers du Centre d'Études d'Histoire de la Défense* 33:445–58.

Beasley, Norman. **1963**. The Capture of the German Rocket Secrets Military Intelligence: Its Heroes and Legends. *American Legion Magazine* October.

Beauvais, Heinrich, Karl Kössler, Max Mayer, and Christoph Regel. **2002**. *German Secret Flight Test Centres to 1945: Johannisthal, Lipetsk, Rechlin, Travemünde, Tarnewitz, Peenemünde-West.* Hinckley, UK: Midland. Original German edition: 1998. *Die Deutsche Luftfahrt: Flugerprobungsstellen bis 1945.* Bonn: Bernard & Graefe.

Becklake, John. **1994**. Secrets of the Reich's Rocket Man. *New Scientist* 17 December.
https://www.newscientist.com/article/mg14419564-500-secrets-of-the-reichs-rocket-man/

Beers, David. **1996**. *Blue Sky Dream: A Memoir of America's Fall from Grace.* New York: Doubleday.

Belew, Leland F., ed. **1977**. *Skylab: Our First Space Station.* NASA SP-400. Washington, D.C.: U.S. Government Printing Office. https://history.nasa.gov/SP-400/contents.htm

Benecke, Theodore, and A. W. **Quick**, eds. **1957**. *History of German Guided Missiles Development.* North Atlantic Treaty Organization.

Benson, Charles D., and William D. **Compton**. **1983**. *Living and Working in Space: A History of Skylab.* NASA SP-4208. Washington, D.C.: U.S. Government Printing Office.

https://history.nasa.gov/SP-4208/contents.htm

Bilstein, Roger E. **1980**. *Stages to Saturn: A Technological History of the Apollo/Saturn Launch Vehicles.* NASA SP-4206. Washington, D.C.: U.S. Government Printing Office.
https://history.nasa.gov/SP-4206/contents.htm

Bizony, Piers. **2006**. *The Man Who Ran the Moon: James E. Webb, NASA, and the Secret History of Project Apollo.* New York: Thunder's Mouth Press.

Blank, Ralf. **1997**. Energie für die "Vergeltung": Die Akkumulatoren Fabrik AG Hagen und das deutsche Raketenprogramm 1942–1945. *Beitrags im Hagener Jahrbuch* 3:141–151.

Bode, Volkhard, and Gerhard **Kaiser**. **2013**. *Raketenspuren: Waffenschmiede und Militärstandort Peenemünde.* 8th ed. Berlin: Christoph Links. Earlier edition translated into English as: Volkhard Bode and Gerhard Kaiser. 2008. *Building Hitler's Missiles: Traces of History in Peenemünde.* 8th ed. Berlin: Christoph Links.

Bohr, Edmund. **2013**. *Verlorene Wunderwaffen: Die Erbeutung deutscher Flug- und Raketentechnik 1945 und ihre Weiterentwicklung durch die USA und UdSSR.* Aachen: Helios.

Boog, Horst. **1982**. *Die deutsche Luftwaffenführung 1935-1945: Führungsprobleme, Spitzengliederung, Generalstabsausbildung.* Stuttgart: DVA.

Bowen, Lee. **1960**. *The Threshold of Space: The Air Force in the National Space Program, 1945–1959.* K 168.01-6, AFD-110321-032. United States Air Force Historical Division Liaison Office.
http://www.afhso.af.mil/shared/media/document/AFD-110321-032.pdf

Bowen, Lee. **1964**. *An Air Force History of Space Activities, 1945–1959.* SHO-C-64/50, AFD-110321-031. United States Air Force Historical Division Liaison Office.
http://www.afhso.af.mil/shared/media/document/AFD-110321-031.pdf

Boyne, Walter J. June **2007**. Project Paperclip. *Air Force Magazine* pp. 70–74.

von Braun, Wernher, Kenneth W. Gatland, Harry E. Ross, and A. V. Cleaver. **1958**. *Project Satellite.* New York: British Book Centre.

von Braun, Wernher, Frederick I. Ordway III, and Dave Dooling. **1985**. *Space Travel: A History.* New York: Harper & Row.

von Braun, Wernher. **1991**. *The Mars Project.* Chicago: University of Illinois Press.

Brinchman, Susan. **2015**. *Gustave Whitehead: First in Flight.* Apex.

Brinkley, Douglas. **2019**. *American Moonshot: John F. Kennedy and the Great Space Race.* New York: HarperCollins.

Brinkworth, Brian. **2014**. *Secrets of a German POW: The Revelations of Hauptmann Herbert Cleff.* Barnsley, UK: Pen & Sword.

Brix, Wolfgang. **2022**. *Jet: Die Geschichte des Strahlantriebs.* Norderstedt: Books on Demand.

Brooks, W. T. 1972. *Solid Propellant Grain Design and Internal Ballistics.* NASA SP-8076.

Brown, John. **2016**. *Gustave Whitehead and the Wright Brothers: Who Flew First?* CreateSpace.

Budraß, Lutz. **1998**. *Flugzeugindustrie und Luftrüstung in Deutschland 1918–1945.* Düsseldorf: Droste.

Butler, Phil. **1994**. *War Prizes: An Illustrated Survey of German, Italian and Japanese Aircraft Brought to Allied Countries During and After the Second World War.* Hinckley, UK: Midland.

Butler, Phil. **2007**. *War Prizes: The Album: A Pictorial Compendium of Axis Aircraft Operated by the Allies During and After the Second World War.* Hinckley, UK: Midland.

Campion, Frank. 4 February **1952**. But Why Are We Losing Air Supremacy over Korea? *Life.* p. 67. https://books.google.com/books?id=fVQEAAAAMBAJ&pg=PA67#v=onepage&q&f=false

Carpenter, David M. **2003**. *NX-2 ANP 1951–1961: Convair Nuclear Propulsion Jet: GE X211/J87 Nuclear Powered Jet Engine.* Jet Pioneers of America. https://leehite.org/anp/documents/NX-2_ANP_1951-1961_Convair_Nuclear_Propulsion_Jet.pdf

Carter, Jimmy. **1977**. *Public Papers of the Presidents of the United States: Jimmy Carter. January 20 to June 24, 1977.* Washington, D.C.: U.S. Government Printing Office. [p. 1125 Wernher von Braun]

Chant, Chris. **1999**. *German Warplanes of World War II.* London: Amber Books.

Chapman, John L. **1960**. *Atlas: The Story of a Missile.* New York: Harper.

Chertok, Boris. **2005–2012**. *Rockets and People.* 4 vols. Washington, DC: U.S. Government Printing Office. https://www.nasa.gov/connect/ebooks/rockets_people_vol1_detail.html

Chester, Keith. **2007**. *Strange Company: Military Encounters with UFOs in WWII.* San Antonio, Texas: Anomalist.

Christensen, Charles R. **2002**. *A History of the Development of Technical Intelligence in the Air Force, 1917-1945: Operation Lusty.* Edwin Mellan Press.

Christopher, John. **2013**. *The Race for Hitler's X-Planes: Britain's 1945 Mission to Capture Secret Luftwaffe Technology.* The Mill, Gloucestershire: History Press.

Ciesla, Burghard. **1997**. Die Transferfalle: Zum DDR-Flugzeugbau in den fünfziger Jahren. In Dieter Hoffmann and Kristie Macrakis, eds. *Naturwissenschaft und Technik in der DDR.* Berlin: Akademie.

Ciesla, Burghard, and Helmuth **Trischler**. **2003**. Legitimation Through Use: Rocket and Aeronautic Research in the Third Reich and the USA. In Mark Walker, ed. *Science and Ideology: A Comparative History.* London: Routledge.

Clark, John D. **1972**. *Ignition! An Informal History of Liquid Rocket Propellants.* New Brunswick, New Jersey: Rutgers University Press.

Coats, Steve, and Jean Christophe **Carbonel**. **2002**. *Helicopters of the Third Reich.* Hersham, Surrey: Classic Publications.

Cole, Lance. **2012**. *Secrets of the Spitfire: The Story of Beverley Shenstone, the Man Who Perfected the Elliptical Wing.* Barnsley, South Yorkshire: Pen & Sword.

Cole, Lance. **2015**. *Secret Wings of World War II: Nazi Technology and the Allied Arms Race.*

Barnsley, South Yorkshire: Pen & Sword.

Conner, Margaret. **2001**. *Hans von Ohain: Elegance in Flight.* Reston, Virginia: American Institute of Aeronautics and Astronautics.

Constant, Edward. **1980**. *The Origins of the Turbojet Revolution.* Baltimore, Maryland: Johns Hopkins University Press.

Convair (Consolidated Vultee Aircraft Corporation). **1945**. ...By the Skin of Our Teeth. *Life* (27 August) 19:9:2–3. https://books.google.com/books?id=e0gEAAAAMBAJ&pg=PA2

Cooke, Charles, and Douglas J. **Ingells**. **1945**. Sky Monsters We Found in Germany. *Science Digest* (November) 18:23–26.

Cooper, Gordon. 3 October **1960**. First Rocket We Will Ride. *Life*, pp. 78–84. books.google.com /books?id=ykQEAAAAMBAJ&pg=PA78v=onepage&q&f=false#v=onepage&q&f=false

Cooper, Gordon, with Bruce **Henderson**. **2000**. *Leap of Faith: An Astronaut's Journey into the Unknown.* New York: HarperCollins.

Crouch, Tom D. **2002**. *A Dream of Wings: Americans and the Airplane, 1875–1905.* New York: W. W. Norton.

Crouch, Tom. **2013**. The Flight Claims of Gustave Whitehead. Smithsonian National Air and Space Museum. 6 April 2013. airandspace.si.edu/stories/editorial/flight-claims-gustave-whitehead

Dabrowski, Hans-Peter. **1991**. *The Horten Flying Wing in World War II: The History & Development of the Ho 229.* Atglen, Pennsylvania: Schiffer.

Dabrowski, Hans-Peter. **1993**. *Lippisch P13a & Experimental DM-1.* Atglen, Pennsylvania: Schiffer.

Danelek, J. Allan, and Chuck **Davis**. **2011**. *Phantoms of the Skies: The Lost History of Aviation from Antiquity to the Wright Brothers.* Adventures Unlimited Press.

Daso, Dik Alan. **2002**. Operation LUSTY: The US Army Air Forces' Exploitation of the Luftwaffe's Secret Aeronautical Technology, 1944–45. *Aerospace Power Journal* (Spring 2002) 16:1:28-40.

Dee, Richard. **2007**. *The Man Who Discovered Flight: George Cayley and the First Airplane.* Toronto: McClelland & Stewart.

De Seversky, Alexander. **1952**. We Have No Air Power. *The Freeman.* 16 June, pp. 601–604. https://fee.org/media/16536/1952-6b.pdf

DeVorkin, David H. **1992**. *Science with a Vengeance.* New York: Springer.

deZeng IV, Henry L. **2014**. Luftwaffe Airfields 1935–45 Norway. http://www.ww2.dk/Airfields%20-%20Norway.pdf

Dick, Steven J., ed. **2008**. *Remembering the Space Age.* NASA SP-2008-4703. Washington, D.C.: NASA.

Diedrich, Hans-Peter. **1999**. *Die deutschen Strahlflugzeuge bis 1945.* Oberhaching: Aviatic Verlag.

Donovan, James. **2019**. *Shoot for the Moon: The Space Race and the Extraordinary Voyage of Apollo 11.* New York: Little, Brown.

Dornberger, Walter. **1958**. *V-2: The Nazi Rocket Weapon.* New York: Viking. [pp. 143, 252 nuclear rocket propulsion]

Dornberger, Walter. **1965a**. Space Shuttle for the Future: The Aerospaceplane. *Rendezvous* 4:1:2–5.

Dornberger, Walter. **1965b**. The Recoverable, Reusable Space Shuttle. *Astronautics & Aeronautics* November, pp. 88–94.

Dornberger, Walter. **1994**. *Peenemünde: Die Geschichte der V-Waffen.* 5th ed. Frankfurt am Main: Ullstein.

Dorr, Robert F. **2013**. *Fighting Hitler's Jets: The Extraordinary Story of the American Airmen Who Beat the Luftwaffe and Defeated Nazi Germany.* Minneapolis, Minnesota: Zenith Press.

Dressel, Joachim, and Manfred **Griehl**. **1995**. *Die deutschen Raketenflugzeuge 1935-45.* Stuttgart: Motorbuch.

Ducrocq, Albert. **1947**. *Les Armes Secrètes Allemandes.* Paris: Berger-Levrault.

Duffy, James P. **2012**. *Target: America: Hitler's Plan to Attack the United States.* Guilford, Connecticut: Lyons Press.

Dungan, T. **2020**. V2ROCKET.COM A-4/V-2 Resource Site. http://www.v2rocket.com

Dunkan, T. D. **2005**. *V2: A Combat History of the First Ballistic Missile.* Yardley, Pennsylvania: Westholm.

Ebert, Hans J., Johann B. Kaiser, and Klaus Peters. **1999**. *Willy Messerschmitt: Pioneer of Aviation Design.* Atglen, Pennsylvania: Schiffer.

Eckert, Michael. **2017**. *Ludwig Prandt—Strömungsforscher und Wissenschaftsmanager: Ein unverstellter Blick auf sein Leben.* Berlin: Springer.

Ehricke, Krafft. **1960**. *Space Flight. I. Environment and Celestial Mechanics.* Princeton, New Jersey: Van Nostrand.

Eisfeld, Rainer: **2000**. *Mondsüchtig: Wernher von Braun und die Geburt der Raumfahrt aus dem Geist der Barbarei.* Reinbeck bei Hamburg: Rowohlt Taschenbuch.

Engel, Rolf. **1948**. *Beiträge zur Geschichte der Deutschen Raketentechnik.* Unpublished manuscript, estate of Rolf Engel.

Engel, Rolf. **1979**. *Moskau militarisiert dem Weltraum.* Landshut: Verlag politisches Archiv.

Engelmann, Joachim. **2006a**. *Geheime Waffenschmiede Peenemünde: V2, Wasserfall, Schmetterling.* Eggolsheim: Dörfler.

Engelmann, Joachim. **2006b**. *Raketen, die den Krieg entscheiden sollten: Taifun, Natter, Kirschkern (V1), Rheinbote (V4), Föhn (V3) u.a.* Eggolsheim: Dörfler.

Epp, J. Andreas. **2005**. *Die Realität der Flugscheiben.* 2nd ed. Peiting: Michaels.

Erfurth, Helmut. **2006**. *Vom Original zum Modell: Messerschmitt Me 262.* Bonn: Bernard & Graefe.

Erichsen, Johannes, and Bernhard M. **Hoppe**, eds. **2011**. *Peenemünde: Mythos und Geschichte der Rakete 1923–1989.* 2nd ed., Berlin: Nicolai.

Faber, Peter. **2015**. *Aufbruch in den Weltraum: Die geheime Geschichte der deutschen V2-Rakete.* 2nd ed. Gilching: Druffel & Vowinckel.

Filchner, Gerhard, and Bettina **Gundler**. **2005**. *Deutsches Museum: Flugwerft Schleissheim Air and Space Museum.* Munich: Deutsches Museum.

Fleischer, Wolfgang. **2006**. *Heeresversuchsstelle Kummersdorf: Maus, Tiger, Panther, Luchs, Raketen und andere Waffen der Wehrmacht bei der Erprobung.* Eggolsheim: Dörfler. English translation: 1997. *The Wehrmacht Weapons Testing Ground at Kummersdorf.* Atglen, Pennsylvania: Schiffer.

Fleischer, Wolfgang. **2007**. *Heeresversuchsstelle Kummersdorf: Augenzeugenberichte, Fotografien, Akten 1874-1945.* Eggolsheim: Dörfler.

Ford, Brian. **1969**. *German Secret Weapons: A Blue Print for Mars.* New York: Ballantine Books.

Forsyth, Robert, and Eddie J. **Creek**. **2007**. *Messerschmitt Me 264 Amerikabomber: The Luftwaffe's Lost Transatlantic Bomber.* Hersham, Surrey: Classic Publications.

Franklin, Thomas. **1987**. *An American in Exile: The Story of Arthur Rudolph.* Huntsville, Alabama: Christopher Kaylor.

Franz, Anselm. **1985**. *From Jets to Tanks: My Contribution to the Turbine Age.* Stratford, Connecticut: Avco Lycoming.

Freeman, Marsha. **1993**. *How We Got to the Moon: The Story of the German Space Pioneers.* Washington, D.C.: 21st Century Science Associates.

Freeman, Marsha. **2008**. *Krafft Ehricke's Extraterrestrial Imperative.* Burlington, Ontario: Apogee Books.

Galison, Peter, and Alex **Roland**, eds. **2000**. *Atmospheric Flight in the Twentieth Century.* Alphen aan den Rijn: Kluwer. https://vdoc.pub/documents/atmospheric-flight-in-the-twentieth-century-7o4lo0covue0

Garliński, Józef. **1978**. *Hitler's Last Weapons: The Underground War Against the V-1 and V-2.* New York: Times Books.

Gaskill, Gordon. March **1945**. Can Super-Rockets Hit America? *The American Magazine* pp. 25–108.

Geiger, Clarence J. **1963**. *History of the X-20A Dyna Soar, Volume I (Narrative)*, AFSC Historical Publications Series 63-50-I, Document ID ASD-TR-63-50-I. Wright Patterson Air Force Base, Ohio: Aeronautical Systems Division Information Office.
https://www.dtic.mil/dtic/tr/fulltext/u2/a951933.pdf

General Electric. **1979**. *Seven Decades of Progress: A Heritage of Aircraft Turbine Technology.* Fallbrook, California: Aero Publishers.

Georg, Friedrich. **2008**. *Mit dem Balkenkreuz zum Mond.* Rottenburg: Kopp.

Georg, Friedrich. **2009**. *Hitlers letzter Trumpf.* 2 vols. Tübingen: Grabert. Earlier edition translated into English as Friedrich Georg. 2003–2009. *Hitler's Miracle Weapons.* 3 vols. Solihull, UK: Helion.

Georg, Friedrich, and Thomas **Mehner**. **2004**. *Atomziel New York.* Rottenburg: Kopp.

von Gersdorff, Kyrill, Helmut Schubert, and Kurt Grasmann. **2004**. *Die deutsche Luftfahrt: Flugmotoren und Strahltriebwerke.* 4th ed. Bonn: Bernard & Graefe.

Giffard, Hermione. **2011**. *The Development and Production of Turbojet Aero-Engines in Britain, Germany and the United States, 1936–1945.* Ph.D. thesis. London: Imperial College.

Gildenhaar, Dietrich. **2013a**. *Geheime Kommandosache "Peenemünde-West".* 2nd ed. Ilmenau: RhinoVerlag.

Gildenhaar, Dietrich, and Sven **Gildenhaar**. **2013b**. *Geheime Kommandosache "Peenemünde-Ost".* Ilmenau: RhinoVerlag.

Gleichmann, Markus. **2013**. *Reimahg-Werk "Lachs".* Meiningen: Heinrich-Jung-Verlagsgesellschaft.

Gleichmann, Markus, and Karl-Heinz **Bock**. **2009**. *Düsenjäger über dem Walpersberg: Die Geschichte des unterirdischen Flugzeugwerkes "REIMAHG" bei Kahla/Thüringen.* 2nd ed. Meiningen: Heinrich-Jung-Verlagsgesellschaft.

Godwin, Robert, ed. **2001**. *Rocket and Space Corporation Energia: The Legacy of S. P. Korolev.* Burlington, Ontario, Canada: Apogee Books.

Godwin, Robert. **2003**. *Dyna-Soar: Hypersonic Strategic Weapons System.* Apogee. [A9/A10 under development and test pp. 38-51]

Gooden, Brett. **2006**. *Project Natter: The Last of the Wonder Weapons.* Hershan, UK: Ian Allen.

Gorn, Michael H. **1992**. *The Universal Man: Theodore von Kármán's Life in Aeronautics.* Washington: Smithsonian Institution.

Gorn, Michael H., ed. **1994**. *Prophecy Fulfilled: "Toward New Horizons" and Its Legacy.* Air Force History and Museums Program.

Griehl, Manfred. **1990**. *Arado Ar 234.* Atglen, Pennsylvania: Schiffer.

Griehl, Manfred. **2003**. *Das große Buch der Flak: Deutsche Luftverteidigung 1912–1945.* Wölferscheim: Podzun-Pallas.

Griehl, Manfred. **2004**. *Luftwaffe Over America: The Secret Plans to Bomb the United States in World War II.* London: Greenhill Books.

Griehl, Manfred. **2005**. *Jet Planes of the Third Reich: The Secret Projects.* 2 vols. Boylston, Massachusetts: Monogram.

Griehl, Manfred. **2015**. *Luftwaffe X-Planes: German Experimental Aircraft of World War II.* London: Greenhill Books.

Gropp, Dorit. **1999**. *Aussenkommando Laura und Vorwerk Mitte Lehesten: Testbetrieb für V2-Triebwerke.* Bad Münstereifel: Westkreuz.

Gunston, Bill. **2006a**. *The Development of Jet and Turbine Aero Engines.* 4th ed. Sparkford, Somerset, UK: Haynes.

Gunston, Bill. **2006b**. *World Encyclopedia of Aero Engines.* 5th ed. Phoenix Mill, Gloucestershire, UK: Sutton.

Hall, R. Cargill, ed. **2014**. *Essays on the History of Rocketry and Astronautics: Proceedings of the Third Through the Sixth History Symposia of the International Academy of Astronautics.* 2 vols. NASA Conference Publication 2014. Washington, DC: NASA.

Hall, Charlie. **2019**. 'The Other End of a Trajectory': Operation Backfire and the German Origins of Britain's Ballistic Missile Programme. *International History Review* 42:6:1118–1136. https://doi.org/10.1080/07075332.2019.1690026

Hall, Charlie. 21 November **2022**. The V-2 Rocket: Changing the Trajectory of Warfare. The Drive. https://www.thedrive.com/the-war-zone/the-v-2-rocket-changing-the-trajectory-of-warfare

Hallion, Richard. **1979**. Lippisch, Gluhareff, and Jones: The Emergence of the Delta Planform and the Origins of the Sweptwing in the United States. *Aerospace Historian* 26:1:1–10.

Hanle, Paul A. **1982**. *Bringing Aerodynamics to America.* Cambridge, Massachusetts: MIT Press.

Harford, James. **1997**. *Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon.* New York: Wiley.

Heinkel, Ernst (edited by Jürgen Thorwald). **1956**. *Stormy Life: Memoirs of a Pioneer of the Air Age.* New York: E. P. Dutton.

Heinzerling, Werner, and Helmuth **Trischler**, eds. **1991**. *Otto Lilienthal: Flugpionier, Ingenieur, Unternehmer.* Munich: Bertelsmann Lexikon.

Hellmold, Wilhelm. **1999**. *Die V-1: Eine Dokumentation.* Esslingen: Bechtle.

Henze, Bernd, and Gunther **Hebestreit**. **2008**. *Raketen aus Bleicherode: Raketenbau und Entwicklung in Bleicherode am Südharz 1943–1948.* 2nd ed. Bleicherode: H & H Verlag.

Heppenheimer, T.A. **1997**. *Countdown: A History of Space Flight.* New York: John Wiley.

Herwig, Dieter, and Heinz **Rode**. **2000**. *Luftwaffe Secret Projects: Strategic Bombers 1935-1945.* 2nd ed. Hinckley, UK: Midland.

Herwig, Dieter, and Heinz **Rode**. **2003**. *Luftwaffe Secret Projects: Ground Attack & Special Purpose Aircraft.* Hinckley, UK: Midland.

Hill, Philip, and Carl **Peterson**. **1991**. *Mechanics and Thermodynamics of Propulsion.* 2nd ed. Englewood Cliffs, New Jersey: Prentice-Hall.

Hirschel, Ernst Heinrich, Horst Prem, and Gero Madelung. **2004**. *Aeronautical Research in Ger-*

many: From Lilienthal until Today. Berlin: Springer.

Historisch-Technische Museum Peenemünde. **2015**. *Das Historisch-Technische Museum Peenemünde: Museumsführer Durch Freigelände Ausstellungen Denkmallandschaft.* Peenemünde: Historisch-Technische Museum Peenemünde.

Historisch-Technische Museum Peenemünde, ed. **2016**. *Wunder mit Kalkül: Die Peenemünder Fernwaffenprojekte als Teil des deutschen Rüstungssystems.* Berlin: Christoph Links.

Hohmann, Walter. **1925**. *Die Erreichbarkeit der Himmelskörper.* Munich: R. Oldenbourg. English translation: *The Attainability of Heavenly Bodies.* NASA Technical Translation F-44, 1960. https://archive.org/details/nasa_techdoc_19980230631

Hölsken, Dieter. **1994**. *V-Missiles of the Third Reich: The V-1 and V-2.* Monogram. Original German edition: 1984. *Die V-Waffen. Entstehung—Propaganda—Kriegseinsatz.* Stuttgart: Deutsche Verlagsanstalt.

Holzer, Hans. **2010**. *Aviation: A Guide to the Aeronautics Collection.* Munich: Deutsches Museum.

Hopmann, Helmut. **1999**. *Schubkraft für die Raumfahrt: Entwicklung der Raketenantriebe in Deutschland.* Lemwerder: Stedinger.

Horeis, Heinz, ed. **1992**. *Rolf Engel: Raketenbauer der ersten Stunde.* Munich: Lehrstuhl für Raumfahrttechnik, Techniche Universität München.

Horten, Reimar and Peter F. **Selliger**. **2012**. *Nurflügel: Die Geschichte der Horten-Flugzeuge 1933–1960.* 7th ed. Graz: H. Weishaupt.

Hunley, J. D. **1999**. The History of Solid-Propellant Rocketry: What We Do and Do Not Know. AIAA paper 99-2925. https://www.nasa.gov/centers/dryden/pdf/88635main_H-2330.pdf

Hunley, J. D. **2007**. *The Development of Propulsion Technology for U.S. Space-Launch Vehicles, 1926–1991.* College Station, Texas: Texas A&M University Press.

Hunley, J. D. **2008a**. *Preludes to U.S. Space-Launch Vehicle Technology: Goddard Rockets to Minuteman III.* Gainesville, Florida: University of Florida Press.

Hunley, J. D. **2008b**. *U.S. Space-Launch Vehicle Technology: Viking to Space Shuttle.* Gainesville, Florida: University of Florida Press.

Huwart, Olivier. **2004**. *Du V2 à Véronique: La Naissance des Fusées Françaises.* Nantes: Marines éditions.

Huzel, Dieter K. **1962**. *Peenemünde to Canaveral.* Englewood Cliffs, New Jersey: Prentice Hall.

Huzel, Dieter K., and David H. **Huang**. **1992**. *Modern Engineering for Design of Liquid Propellant Rocket Engines.* Reston, Virginia: American Institute of Aeronautics and Astronautics.

Hyland, Gary, and Anton **Gill**. **1998**. *Last Talons of the Eagle: Secret Nazi Technology Which Could Have Changed the Course of World War II.* London: Headline.

Irving, Clive. **2014**. *Jumbo: The Making of the Boeing 747.* Edditt.

Irving, David. **1965**. *The Mare's Nest.* Boston: Little, Brown.

Jacobsen, Annie. **2011**. *Area 51: An Uncensored History of America's Top Secret Military Base.* Boston: Little, Brown.

Jackson, Sophie. **2014**. *Hitler's Heroine: Hanna Reitsch.* Gloustershire, UK: History Press.

Jakobs, Fred, Robert Kröschel, and Christian Pierer. **2009**. *BMW Aero Engines: Milestones in Aviation from the Beginnings to the Present.* Munich: BMW.

Johnsen, Frederick A. **2014**. *Captured Eagles: Secrets of the Luftwaffe.* Oxford: Osprey.

Johnson, Clarence "Kelly" with Maggie **Smith**. **1989**. *Kelly: More Than My Share of It All.* Washington, D.C.: Smithsonian Books.

Johnson, Kenneth F. **2005**. *The Need for Speed. Hypersonic Aircraft and the Transformation of the Long Range Power.* Masters thesis. Maxwell Air Force Base: Air University.

Johnson, Stephen B. **2002.** *The Secret of Apollo: Systems Management in American and European Space Programs.* Baltimore, Maryland: Johns Hopkins University Press.

Johnston, David, transl. **1996**. *Flettner Fl 282.* Atglen, Pennsylvania: Schiffer.

Jones, R. V. **1978**. *Most Secret War: British Scientific Intelligence 1939-1945.* London: Hamish Hamilton.

Jorgensen, Michael. **2009**. *Hitler's Stealth Fighter.* Zweites Deutsches Fernsehen (ZDF) and National Geographic Channel.

von Kármán, Theodore. **1945**. *Where We Stand: First Report to General of the Army H. H. Arnold on Long Range Research Problems of the AIR FORCES with a Review of German Plans and Developments.* 22 August 1945. Reprinted in Dik A. Daso. 1997. *Architects of American Air Supremacy: Gen. Hap Arnold and Dr. Theodore von Kármán.* Maxwell Air Force Base, Alabama: Air University Press. https://www.airuniversity.af.edu/Portals/10/AUPress/Books/B_0044_DASO_ARCHITECTS_AIR_SUPREMACY.pdf

von Kármán, Theodore. **1967**. *The Wind and Beyond.* Boston: Little, Brown.

Käsmann, Ferdinand C. W. **2013**. *Weltrekordflugzeuge: Die schnellsten Flugzeuge von 1906 bis heute.* 2nd ed. Kolpingring: Aviatic Verlag. [p. 105 Dornberger and X-15]

Kay, Antony L. **2002**. *German Jet Engine and Gas Turbine Development 1930–1945.* Shrewsbury, UK: Airlife.

Kerrebrock, Jack L. **1992**. *Aircraft Engines and Gas Turbines.* 2nd ed. Cambridge, Massachusetts: MIT Press.

King, Benjamin, and Timothy **Kutta**. **1998**. *Impact: The History of Germany's V-Weapons in World War II.* Sarpedon.

Klee, Ernst, and Otto **Merk**. **1963**. *Damals in Peenemünde: Ein Dokumentarbericht.* Oldenburg: Gerhard Stalling.

Klein, Heinrich. **1977**. *Vom Geschoß zum Feuerpfeil: Der große Umbruch der Waffentechnik in Deutschland 1900–1970: Eine Dokumentation.* Stuttgart: Motorbuch.

Knight, Charlotte. **1946**. German Rocketeers: German Rockets and Guided Missiles Almost Won the War for the Nazis. *AAF Review* (July) 29:6:24-26, 48.

Kober, Franz. **1990**. *The World's First Jet Bombers: Arado Ar 234, Junkers Ju 287.* Atglen, Pennsylvania: Schiffer.

Koelle, Heinz Hermann. **1961**. *Handbook of Astronautical Engineering.* New York: McGraw-Hill.

Kurowski, Franz. **2001**. *Raketenpionier Arthur Rudolph: Geehrt—verfemt—rehabilitiert.* Vowinckel.

Lambright, W. Henry. **1995**. *Powering Apollo: James E. Webb of NASA*. Baltimore, Maryland: Johns Hopkins University Press.

Lauer, Christopher. **2021**. *Raketenentwicklung am Heereswaffenamt zwischen 1930 und 1937 unter besonderer Berücksichtigung der Rolle Wernher von Brauns.* Thesis. Technische Universität Berlin. http://christopherlauer.de/2022/01/13/masterarbeit-raketenentwicklung-am-heereswaffenamt-zwischen-1930-und-1937-unter-besonderer-beruecksichtigung-der-rolle-wernher-von-brauns/

Launius, Roger D., and Dennis R. **Jenkins**, eds. **2002**. *To Reach the High Frontier: A History of U.S. Launch Vehicles.* Lexington, Kentucky: University Press of Kentucky.

Lehman, Milton. **1988**. *Robert Goddard: Pioneer of Space Research.* New York: Da Capo.

Leishman, J. Gordon. **2006**. *Principles of Helicopter Aerodynamics.* 2nd ed. Cambridge, UK: Cambridge University Press.

Leist, Karl, and Hans Georg **Wiening**. **1963**. *Enzyklopädische Abhandlung über ausgeführte Strahltriebwerke.* Berlin: Springer.

Le Maner, Yves, and André **Sellier**. **2001**. *Bilder aus Dora: Zwangsarbeit im Raketentunnel 1943-1945.* Berlin: Westkreuz.

Ley, Willy, ed. **1928**. *Die Möglichkeit der Weltraumfahrt: Allgemeinverständliche Beiträge zum Raumschifffahrtsproblem.* Leipzig: Hachmeister & Thal.

Ley, Willy. **1968**. *Rockets, Missiles, and Men in Space.* New York: Viking.

Leyes, Richard A., II, and William A. **Fleming**. **1999**. *The History of North American Small Gas Turbine Aircraft Engines.* Reston, Virginia: American Institute of Aeronautics and Astronautics.

Lichtfuss, Hanns-Jürgen, and Helmut **Schubert**. **2014**. *75 Jahre Turbostrahlflug: Der Beginn eines neuen Zeitalters der Luftfahrt.* Augsburg: 63rd Deutscher Luft- und Raumfahrtkongress. https://www.dglr.de/publikationen/2017/340021.pdf

Logsdon, John M. **2010**. *John F. Kennedy and the Race to the Moon.* New York: Palgrave Macmillan.

Logsdon, John M. **2015**. *After Apollo? Richard Nixon and the American Space Program.* New York: Palgrave Macmillan.

Logsdon, John M. **2019**. *Ronald Reagan and the Space Frontier.* New York: Palgrave Macmillan.

Lommel, Horst. **2000**. *Das bemannte Geschoss Ba 349 "Natter": Die Technikgeschichte.* Zweibrücken: VDM.

Lommel, Horst. **2002**. *Vom Höhenaufklärer bis zum Raumgleiter, Geheimprojekte der DFS 1935–45.* Stuttgart: Motorbuch.

Lommel, Horst. **2005**. *Luftfahrt History 2: Fieseler Fi-103.* Reichenberg: Lautec.

Longden, Sean. **2009**. *T-Force: The Race for Nazi War Secrets, 1945.* London: Constable & Robinson Ltd.

Lukasiewicz, Julius. **1986**. Canada's Encounter with High-Speed Aeronautics. *Technology and Culture* 27:2:223–261.

Mack, Pamela E. **1998**. *From Engineering Science to Big Science.* NASA SP-4219. Washington, DC: NASA. https://history.nasa.gov/SP-4219/Contents.html

Mackowski, Maura Phillips. **2006**. *Testing the Limits: Aviation Medicine and the Origins of Manned Space Flight.* College Station, Texas: Texas A&M University Press.

Mader, Julius. **1963**. *Geheimnis von Huntsville.* Deutscher Militärverlag.

Margry, Karel, ed. **1998**. *After the Battle: Nordhausen.* London: Battle of Britain International.

Margry, Karel, ed. **2001**. *After the Battle: The V3 and V4.* London: Battle of Britain International.

Mark, Hans. **1987**. *The Space Station: A Personal Journey.* Durham, North Carolina: Duke University Press.

Masters, David. **1982**. *German Jet Genesis.* London: Jane's.

Masters, Dexter, and Katherine **Way**, eds. **2007**. *One World or None.* New York: New Press. [Henry H. Arnold and others.]

McCurdy, Howard E. **2011**. *Space and the American Imagination.* 2nd ed. Baltimore, Maryland: Johns Hopkins University Press.

McDougall, Walter A. **1997**. *The Heavens and the Earth: A Political History of the Space Age.* 2nd ed. Baltimore, Maryland: Johns Hopkins University Press.

McGovern, James. **1964**. *Crossbow and Overcast.* New York: Morrow.

McNab, Chris. **2014**. *The Luftwaffe 1933–45: Hitler's Eagles.* New York: Chartwell.

McWhorter, Diane. **2001**. *Carry Me Home: Birmingham, Alabama: The Climactic Battle of the Civil Rights Revolution.* New York: Simon & Schuster. [Winner of 2002 Pulitzer Prize for General Non-Fiction.]

McWhorter, Diane. **Forthcoming**. [Two-volume biography of Wernher von Braun.] New York: Riverhead/Penguin Random House.

Meier, Hans-Ulrich. **2010**. *German Development of the Swept Wing: 1935-1945.* Reston, Virginia: American Institute of Aeronautics and Astronautics.

Merrill, Grayson. **2003**. The Birth and Boyhood of Point Mugu by Captain Grayson Merrill, USN (Ret). http://stagone.org/?page_id=28

Michels, Jürgen. **1997**. *Peenemünde und seine Erben in Ost und West: Entwicklung und Weg deutscher Geheimwaffen.* Bonn: Bernard & Graefe.

Mieczkowski, Yanek. **2013**. *Eisenhower's Sputnik Moment: The Race for Space and World Prestige.* Ithaca, New York: Cornell University Press.

Miller, Jay. **2001**. *The X-Planes: X-1 to X-45.* 3rd ed. Hinckley, UK: Midland.

Miller, Ron. **1993**. *The Dream Machines: A Pictorial History of the Spaceship in Art, Science and Literature.* Malabar, Florida: Krieger.

Miller, Ron. **2016**. *Spaceships: An Illustrated History of the Real and the Imagined.* Washington, D.C.: Smithsonian Books.

Mills, James. **2020**. The Transfer and Exploitation of German Air-to-Air Rocket and Guided Missile Technology by the Western Allies after World War II. *International Journal for the History of Engineering & Technology* 90:1:75–108. https://doi.org/10.1080/17581206.2020.1797446

Mills, James. **2022**. *The Origins of Surface-to-Air Guided Missile Technology: German Flak Rockets and the Onset of the Cold War.* Havertown, Pennsylvania: Casemate.

Mills, James, and Graeme **Johanson**. **2019**. Project Abstract: An Anglo-American Intelligence Operation in 1947 to Recover Guided Weapon Technical Documentation Buried in Germany. *Intelligence and National Security* 34:1:129–148. https://doi.org/10.1080/02684527.2018.1524055

Miranda, Justo. **2015**. *The Ultimate Flying Wings of the Luftwaffe.* Croydon, UK: Fonthill.

Miranda, Justo, and P. **Mercado**. **1996**. *Secret Wonder Weapons of the Third Reich: German Missiles 1934-1945.* Atglen, Pennsylvania: Schiffer.

Müller, Klaus W., and Willy **Schilling**. **2005**. *Deckname LACHS: Die Geschichte der unterirdischen Fertigung der Me 262 im Walpersberg bei Kahla 1944/45.* 5th ed. Meiningen: Heinrich-Jung-Verlagsgesellschaft.

Murray, Charles, and Catherine Bly **Cox**. **1989**. *Apollo: The Race to the Moon.* New York: Simon & Schuster.

Myhra, David. **1998a**. *Secret Aircraft Designs of the Third Reich.* Atglen, Pennsylvania: Schiffer.

Myhra, David. **1998b**. *The Horten Brothers and their All-Wing Aircraft.* Atglen, Pennsylvania: Schiffer.

Myhra, David. **2000a**. *Arado Ar 234C.* Atglen, Pennsylvania: Schiffer.

Myhra, David. **2000b**. *DFS 228.* Atglen, Pennsylvania: Schiffer.

Myhra, David. **2001**. *Fieseler Fi 103R.* Atglen, Pennsylvania: Schiffer.

Myhra, David. **2002**. *Sänger: Germany's Orbital Rocket Bomber in World War II.* Atglen, Pennsylvania: Schiffer.

Myhra, David. **2003**. *Dragonfly: The Luftwaffe's Experimental Triebflügeljäger Project.* Atglen, Pennsylvania: Schiffer.

Nagel, Günter. **2012b**. Wissenschaftler und Erfinder—ein jüdischer Offizier im Heeresdienst. *Märkischen Oderzeitung* 16 March 2012.

Nagel, Günter. **2012c**. Die Raketenväter von Kummersdorf. Die "R-Frage": Wernher von Braun konnte auf wichtige Forschungsergebnisse anderer Wissenschaftler zurückgreifen. *Märkische Allgemeine Zeitung*, Zossen edition, 26 October 2012, p. 15.

Nagel, Günter. **2012d** Raketenversuche in Ludwigsfelde. *Märkischen Oderzeitung.*

Nagel, Günter. **2013a**. Was war Vers. Saalow? *Märkischen Allgemeinen Zeitung.* Teltow-Fläming edition. 24 May 2013.

Nagel, Günter. **2013b**. Ein Gelehrter des Preußischen Militärversuchsamtes in Kummersdorf. *Märkischen Allgemeinen Zeitung.* Teltow-Fläming edition. 19 July 2013.

Nagel, Günter. **2015**. Zu den deutschen Forschungen während der NS-Zeit auf dem Gebiet Feststoff-Raketen.

Nagel, Günter. **2016b**. Dipl.-Ing. Graf Helmut von Zborowski (21.08.1905–16.11.1969)—Ein Triebwerks- und Raketenbauer paktiert mit der SS. *Tagungsband Raumfahrtmuseum Oberth.*

Nebel, Rudolf. **1972**. *Die Narren von Tegel: Ein Pionier der Raumfahrt erzählt.* Düsseldorf: Droste.

Neufeld, Jacob. **2004**. General Bernard A. Schriever: Technological Visionary. *High Frontier* Fall pp. 16–19. https://apps.dtic.mil/dtic/tr/fulltext/u2/a593643.pdf

Neufeld, Michael J. **1995**. *The Rocket and the Reich: Peenemünde and the Coming of the Ballistic Missile Era.* New York: Free Press.

Neufeld, Michael J. **2002**. Wernher von Braun, the SS and Concentration Camp Labor: Questions of Moral, Political and Criminal Responsibility. *German Studies Review* 25:1:57–78.

Neufeld, Michael J. **2003**. Wernher von Braun and Concentration Camp Labor: An Exchange. *German Studies Review* 26:1:122–26.

Neufeld, Michael J. **2004**. Overcast, Paperclip, Osoaviakhim: Looting and the Transfer of German Military Technology. In Detlef Junker, ed. *The United States and Germany in the Era of the Cold War, 1945–2000.* Vol. 1. Cambridge, U.K.: Cambridge University Press. pp. 197–203.

Neufeld, Michael J. **2007**. *Von Braun: Dreamer of Space, Engineer of War.* New York, Alfred A. Knopf.

Neufeld, Michael J. **2012**. The Nazi Aerospace Exodus: Towards a Global, Transnational History. *History and Technology* 28:49–67.

Newkirk, Roland W., Ivan D. Ertel, and Courtney G. Brooks. **1977**. *Skylab: A Chronology.* NASA SP-4011. Washington, D.C.: U.S. Government Printing Office. https://history.nasa.gov/SP-4011/contents.htm

Newton, J. L. January **1946**. *German Aircraft: New and Projected Types.* A.I.2(G) Report No. 2383. Imperial War Museum Archive, Duxford, UK.

Noordung, Hermann. **1928**. *Das Problem der Befahrung des Weltraums: Der Raketen-Motor.* Berlin: Richard Carl Schmidt. http://bhaak.net/buchscans/noordung.html English translation: *The*

Problem of Space Travel: The Rocket Motor. NASA SP-4026. https://history.nasa.gov/SP-4026.pdf

Nordeen, Lon O., and David **Nicolle**. **1996**. *Phoenix over the Nile: A History of Egyptian Air Power, 1932–1994.* Washington, DC: Smithsonian Institution Press.

Nowarra, Heinz J. **1988**. *Die deutsche Luftrüstung 1933–1945.* 4 vols. Koblenz: Bernard & Graefe.

Nowarra, Heinz J. **1990**. *German Helicopters 1928–1945.* Atglen, Pennsylvania: Schiffer.

Oberg, James E. **1981**. *Red Star in Orbit: The Inside Story of Soviet Failures and Triumphs in Space.* New York: Random House.

Oberth, Hermann. **1929**. *Wege zur Raumfschifffahrt.* Munich: Oldenbourg. English translation: *Ways to Spaceflight.* NASA Technical Translation F-622.
https://archive.org/details/nasa_techdoc_19720008133

Oberth, Hermann (Hans Barth, ed.). **1984**. *Briefwechsel.* 2 vols. Bucharest: Kriterion.

O'Dwyer, William J. **1978**. *History by Contract.* Leutershausen: Fritz Majer & Sohn.

O'Mara, John A., ed. **1945**. *The Story of Peenemünde/Peenemünde East: Through the Eyes of 500 Detained at Garmisch.* Washington, D.C.: Smithsonian Libraries.
https://archive.org/details/Peenemundeeastt00OMar/page/n5/mode/2up
See also: https://www.historyofinformation.com/detail.php?id=3534

Ordway III, Frederick I., and Mitchell **Sharpe**. **1979**. *The Rocket Team.* New York: Thomas Y. Crowell.

Pace, Steve. **2016**. *The Projects of Skunk Works.* Minneapolis: Voyageur Press.

Pallud, Jean Paul. **2011**. *First Manned Rocket Launch.* Essex: Hobbs Cross House.

Pavelec, Sterling Michael. **2007**. *The Jet Race And The Second World War.* Santa Barbara, California: Praeger.

Perring, W. G. A. **1946**. A Critical Review of German Long-Range Rocket Development. *Journal of the American Rocket Society.* 65:1–17.

Phelan, Dominic, ed. **2013**. *Cold War Space Sleuths: The Untold Secrets of the Soviet Space Program.* New York: Springer.

Pöhlmann, Markus, Christian Bauermeister, and Evelyn Sommerer. **2014**. *Die Heeresversuchsstelle Kummersdorf: Schießplatz—Geheimer Ort—Denkmal.* Kummersdorf: Förderverein Historisch-Technisches Museum Versuchsstelle Kummersdorf.

Polte, Hans-Joachim. **1995**. *Militärgeschichtlicher Reiseführer Peenemünde.* Berlin: E. S. Mittler. [A9/A10]

Portree, David S. F. 19 March **2012**. After EMPIRE: Using Apollo Hardware to Explore Venus and Mars (1965). *Wired.* https://www.wired.com/2012/03/apollotovenusandmars/

Powell-Willhite, Irene E., ed. **2007**. *The Voice of Dr. Wernher von Braun.* Burlington, Ontario: Apogee Books.

Priewe, Gerd D., ed. **1987**. *Peenemünder berichten über Peenemünde.* Unpublished manuscript. Peenemünde archive.

Przybilski, Olaf H. **1999**. Die Deutschen und die Raketentriebwerksentwicklung in der UdSSR. *Luft- und Raumfahrt* 2:30–33, 3:28–33, and 4:33–41.

Przybilski, Olaf H. **2002a**. The Germans and the Development of Rocket Engines in the USSR. *Journal of the British Interplanetary Society* 55:404–427.

Przybilski, Olaf. **2002b**. *Streng geheim! Das Geheimnis der deutschen Raketen und raketengetriebenen Fluggeräte.* Wölfersheim: Podzun-Pallas.

Przybilski, Olaf. **2014**. *Raketentriebwerke aus dem deutschen Heereswaffenamt: Vermischungsstrategien bei der Injektorentwicklung in Kummersdorf.* Books on Demand.

Pulla, Ralf. **2006**. *Raketentechnik in Deutschland: Ein Netzwerk aus Militär, Industrie und Hochschulen 1930 bis 1945.* Frankfurt am Main: Peter Lang.

Putt, Donald L. **1946a**. German Developments in the Field of Guided Missiles. *Society of Automotive Engineering (SAE) Transactions* 54:8:410-411.

Putt, Donald L. **1946b**. German Developments in the Field of Guided Missiles: An Address Before the SAE in New York, 7 March 1946. Air Materiel Command. Library of Congress, Washington, DC. Call number MLCM 95/01648 (T) FT-MEADE.

Quigg, Gary Francis. **2014**. *JB-2: America's First Cruise Missile.* Thesis. Indiana University. http://dx.doi.org/10.7912/C2/234

Randolph, Stella. **1966**. *The Story of Gustave Whitehead: Before the Wrights Flew.* New York: G.P. Putnam's Sons.

Ranson, Stephen, and Hans-Hermann **Cammann**. **2003**. *Me-163: Rocket Interceptor.* 2 vols. Hersham, Surrey: Classic Publications.

Ransted, Chris. **2013**. *Disarming Hitler's V Weapons.* Barnsley, UK: Pen & Sword.

Reed, R. Dale. **1997**. *Wingless Flight: The Lifting Body Story.* NASA SP-4220. Washington, DC: NASA.

Reichl, Eugen. **2016**. *Interkontinental Raketen.* Stuttgart: Motorbuch.

Reinke, Niklas. **2007**. *The History of German Space Policy: Ideas, Influences, and Interdependence 1923–2002.* Paris: Beauchesne.

Reisig, Gerhard. **1997**. *Raketenforschung in Deutschland: Wie die Menschen das all eroberten.* Münster: Edition Lenser.

Rendall, Graeme. **2021**. *UFOs Before Roswell: European Foo-Fighters 1940–1945.* Reiver Country Books.

Reuter, Claus. **2000**. *The V2, and the Russian and American Rocket Program.* 2nd ed. New York: S.R. Research & Publishing.

Rich, Ben R., and Leo **Janos**. **1994**. *Skunk Works.* Boston: Little, Brown.

Rich, Ben R. **1995**. *Clarence Leonard (Kelly) Johnson 1910–1990.* Washington, D.C.: National Academies Press.
www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/johnson-clarence.pdf

Romersa, Luigi. **2011**. *Von Braun Racconta.* Milan: Mursia.

Rose, Bill. **2011**. *Flying Saucer Technology.* Manchester, UK: Crecy.

Rose, Bill and Tony **Buttler**. **2007**. *Secret Projects: Flying Saucer Aircraft.* Hinckley, UK: Midland.

Rosenberg, Max. **1960**. *Plans and Policies for the Ballistic Missile Initial Operational Capability Program.* SHO-S-60/75, AFD-110321-028. United States Air Force Historical Division Liaison Office. http://www.afhso.af.mil/shared/media/document/AFD-110321-028.pdf

Rosenberg, Max. **1962**. *The Air Force in Space 1959-1960.* K 168.01-7, AFD-110318-006. United States Air Force Historical Division Liaison Office. [p. 46: "Robo, Brassbell, Bomi, and Hywards, finally culminating in Project Dyna-Soar"]
http://www.afhso.af.mil/shared/media/document/AFD-110318-006.pdf

Rosenberg, Max. **1964**. *The Air Force and the National Guided Missile Program 1944-1950.* SHO-C-64/38, AFD-110321-029. United States Air Force Historical Division Liaison Office.
http://www.afhso.af.mil/shared/media/document/AFD-110321-029.pdf

Rotta, Julius C. **1990**. *Die Aerodynamische Versuchsanstalt Göttingen—ein Werk Ludwig Prandtls: Eine Dokumentation ihrer Geschichte 1907–1925.* Göttingen: Vandenhoeck & Ruprecht.

Ruland, Bernd. **1969**. *Wernher von Braun: Mein Leben für die Raumfahrt.* Offenburg: Burda.

Sambaluk, Nicholas Michael. **2015**. *The Other Space Race: Eisenhower and the Quest for Aerospace Security.* Annapolis, Maryland: Naval Institute Press.

Samuel, Wolfgang W. E. **2004**. *American Raiders: The Race to Capture the Luftwaffe's Secrets.* Jackson, Mississippi: University Press of Mississippi.

Samuel, Wolfgang W. E. **2010**. *Watson's Whizzers: Operation Lusty and the Race for Nazi Aviation Technology.* Atglen, Pennsylvania: Schiffer.

Sänger, Eugen. **1965**. *Space Flight: Countdown for the Future.* New York: McGraw-Hill.

Sänger, Eugen, and Irene **Bredt**. **1944**. *Über einen Raketenantrieb für Fernbomber.* UM 3538. Ainring: Deutsche Luftfahrtforschung. English translation 1952. *A Rocket Drive for Long Range Bombers.* CGD-32, C-84296. Technical Information Branch, Buaer Navy Department.

Sänger, Hartmut E. **2006**. *Ein Leben für die Raumfahrt: Erinnerungen an Prof. Dr.-Ing. Eugen A. Sänger.* Lemwerder: Stedinger.

Schick, Walter, and Ingolf **Meyer**. **1997**. *Luftwaffe Secret Projects: Fighters 1939-1945.* Hinckley, UK: Midland.

Schlenoff, Daniel C. **2014**. Scientific American Debunks Claim Gustave Whitehead Was "First in Flight". *Scientific American* 8 July 2014. https://www.scientificamerican.com/article/scientific-american-debunks-claim-gustave-whitehead-was-first-in-flight/

Scortia, Thomas N., and Howard G. **Cutforth**. **1971**. *Solid Propellant Selection and Characterization.* NASA SP-8064.

Scranton, Philip. **2009**. Constraints as Sources of Radical Innovation? Insights from Jet Propulsion Development. *Management & Organizational History* 4:4:385–399.

Scranton, Philip. **2011**. Mastering Failure: Technological and Organisational Challenges in British and American Military Jet Propulsion, 1943–57. *Business History* 53:4:479–504.

Sellier, André. **2003**. *A History of the Dora Camp.* Chicago: Ivan R. Dee.

Sharp, Dan. **2016**. *Luftwaffe Secret Bombers of the Third Reich.* Horncastle, U.K.: Mortons.

Shayler, David J., Robert Godwin, and Gary Kitmacher. **2018**. *Outpost in Orbit: A Pictorial & Verbal History of the Space Station.* Burlington, Ontario: Apogee Books.

Sheehan, Neil. **2009**. *A Fiery Peace in a Cold War: Bernard Schriever and the Ultimate Weapon.* New York: Random House.

Shepelev, Andrei, and Huib **Ottens**. **2015**. *Horten Ho 229 Spirit of Thuringia: The Horten All-Wing Jet Fighter.* Manchester, UK: Crecy.

Siddiqi, Asif A. **2000**. *Challenge to Apollo: The Soviet Union and the Space Race, 1945-1974.* NASA SP-2000-4408. Washington, D.C.: U.S. Government Printing Office.

Siddiqi, Asif. **2010**. *The Red Rocket's Glare: Spaceflight and the Soviet Imagination, 1857–1957.* Cambridge, U.K.: Cambridge University Press.

Simons, Graham M. **2016**. *Operation LUSTY: The Race for Hitler's Secret Technology.* Barnsley, UK: Pen & Sword.

Skorzeny, Otto. **1993**. *Meine Kommandounternehmen: Krieg ohne Fronten.* Munich: Universitas. Translated into English as Otto Skorzeny. 1995. *My Commando Operations: The Memoirs of Hitler's Most Daring Commando.* Atglen, Pennsylvania: Schiffer.

Smith, J. Richard, and Eddie J. **Creek**. **1982**. *Jet Planes of the Third Reich.* Boylston, Massachusetts: Monogram.

Smith, J. Richard, and Eddie J. **Creek**. **1992**. *Arado 234 Blitz.* Boylston, Massachusetts: Monogram.

Smith, J. Richard, and Eddie J. **Creek**. **2001**. *Me-262.* 4 vols. Hersham, Surrey: Classic Publications.

Smith, J. Richard, and Antony **Kay**. **2002**. *German Aircraft of the Second World War.* 2nd ed. Annapolis, Maryland: Naval Institute Press.

Sobolew, Dimitri Alexejewitsch. **2000.** *Deutsche Spuren in der Sowjetischen Luftfahrtgeschichte.* Hamburg: Mittler.

Späte, Wolfgang. **1983**. *Der Streng Geheime Vogel Me 163.* Eggolsheim: Dörfler Zeitgeschichte.

Stanley, Roy M., II. **2010**. *V Weapons Hunt.* Barnsley, UK: Pen & Sword.

Stoelzel, Heinz. **1945**. Manned A9 and other rocket-related plans. http://www.printsandprinciples.com/p/object.html

Stoelzel, Heinz. **1965**. Walter Dornberger: General und Raketeningenieur. *Soldat und Technik* 10:575–577.

Stuhlinger, Ernst. **1964**. *Ion Propulsion for Space Flight.* New York: McGraw-Hill.

Stuhlinger, Ernst, and Frederick I. **Ordway** III. **1994a**. *Wernher von Braun: Crusader for Space: A Biographical Memoir.* Malabar, Florida: Krieger.

Stuhlinger, Ernst, and Frederick I. **Ordway** III. **1994b**. *Wernher von Braun: Crusader for Space: An Illustrated Memoir.* Malabar, Florida: Krieger.

Sturm, Thomas A. **1967**. *The USAF Scientific Advisory Board: Its First Twenty Years 1944–1964.* Washington, D.C.: U.S. Government Printing Office.

Stüwe, Botho. **1999**. *Peenemünde West—die Erprobungsstelle der Luftwaffe für geheime Fernlenkwaffen und deren Entwicklungsgeschichte.* Esslingen: Bechtle.

Stüwe, Botho. **2014**. *Vom Tretantrieb zur Brennstoffzelle.* Petershausen: Aero.

Stüwe, Botho. **2015**. *Peenemünde West: Die Erprobungsstelle der Luftwaffe für Geheimwaffen.* Petershausen: Aero Buch.

Sutter, Joe, and Jay **Spenser**. **2006**. *747: Creating the World's First Jumbo Jet and Other Adventures from a Life in Aviation.* Washington, DC: Smithsonian.

Sutton, George P. **1992**. *Rocket Propulsion Elements.* 6th ed. New York: Wiley.

Sutton, George P. **2006**. *History of Liquid Propellant Rocket Engines.* Reston, Virginia: American Institute of Aeronautics and Astronautics.

Swenson, Loyd S., Jr., James M. Grimwood, and Charles C. Alexander. **1989**. *This New Ocean: A History of Project Mercury.* NASA SP-4201. Washington, D.C.: U.S. Government Printing Office. [aerospace medicine]

Thomas, Elbert D. April **1946**. Sitting Ducks in Our Air Forces. *The American Magazine* pp. 26–124.

Tirpak, John A. **2018**. Skunk Works at 75. *Air Force Magazine* 2018-07-26. https://www.airforcemag.com/article/skunk-works-at-75/

Trischler, Helmuth. **1992a**. *Luft- und Raumfahrtforschung in Deutschland 1900–1970: Politische Geschichte einer Wissenschaft.* Frankfurt am Main: Campus.

Trischler, Helmuth. **1992b**. *Dokumente zur Geschichte der Luft- und Raumfahrtforschung in Deutschland 1900-1970.* Cologne: DLR-Mitteilungen.

Trischler, Helmuth, and Kai-Uwe **Schrogl**, eds. **2007**. *Ein Jahrhundert im Flug: Luft- und Raumfahrtforschung in Deutschland 1907-2007.* Frankfurt am Main: Campus.

Twigge, Stephen Robert. **1993**. *The Early Development of Guided Weapons in the United Kingdom, 1940–1960.* Chur, Switzerland: Harwood Academic.

Uhl, Matthias. **2001**. *Stalins V-2: Der Technologietransfer der deutschen Fernlenkwaffentechnik in die UdSSR und der Aufbau der sowjetischen Raketenindustrie 1945 bis 1959.* Bonn: Bernard & Graefe.

U.S. Senate 1945-06-26. *Elimination of German Resources for War. Hearings Before a Subcommittee of the Committee on Military Affairs, United States Senate, Seventy-Ninth Congress, First Session, Pursuant to S. Res. 107 (78th Congress) and S. Res. 46 (79th Congress) Authorizing a Study of War Mobilization Problems. Part 3: Testimony of Foreign Economic Administration and Materials on German Penetration of European Industry* (Washington, DC: U.S. Government Printing Office, 26 June 1945) p. 162. [East coast rocket and jet attacks had been near.]

Vajda, Ferenc A., and Peter **Dancey**. **1998**. *German Aircraft Industry & Production 1933–45.* Ramsbury, UK: Airlife Publishing.

Vann, Frank. **1993**. *Willy Messerschmitt: First Full Biography of an Aeronautical Genius.* Somerset, U.K.: Patrick Stephens.

Van Nimmen, Jane, Leonard C. Bruno, Robert L. Rosholt, and Linda Neuman Ezell. **1988**. *NASA Historical Data Book. Volume I: NASA Resources 1958-1968. Volume II: Programs and Projects 1958-1968. Volume III: Programs and Projects 1969-1978.* NASA SP-4012. Washington, D.C.: U.S. Government Printing Office.

Vesco, Renato. **1971**. *Intercept—But Don't Shoot.* New York: Grove Press.

Vesco, Renato. **1973**. *Operazione Plenilunio.* 2nd ed. Milan: Mursia.

Villain, Jacques. **1997**. France and the Peenemünde Legacy. In Phillipe Jung, ed. *History of Rocketry and Astronautics: Proceedings of Twenty-Sixth History Symposium of the International Academy of Astronautics.* San Diego: Univelt.

Vogel-Prandtl, Johanna. **2014**. *Ludwig Prandtl: A Personal Biography Drawn from Memories and Correspondence.* Göttingen: Universitätsverlag Göttingen.
http://library.oapen.org/handle/20.500.12657/31848

Wade, Mark. **2020**. *Encyclopedia Astronautica.* http://www.astronautix.com

Wagner, Jens-Christian, ed. **2011**. *Mittelbau-Dora Concentration Camp 1943–1945: Companion Volume to the Permanent Exhibition at Mittelbau-Dora Concentration Camp Memorial.* Göttingen: Wallstein.

Wagner, Jens-Christian. **2015**. *Produktion des Todes: Das KZ-Mittelbau-Dora.* Göttingen: Wallstein.

Wagner, Ray. **2000**. *Mustang Designer: Edgar Schmued and the P-51.* Washington, DC: Smithsonian Institution Press.

Wagner, Wolfgang. **1998.** *Kurt Tank: Focke Wulf's Designer and Test Pilot.* Atglen, Pennsylvania: Schiffer.

Walker, James, Lewis Bernstein, and Sharon Watkins Lang. **2003**. *Seize the High Ground.* U.S. Army. https://www.smdc.army.mil/ABOUT/History/

Wegener, Peter P. **1996**. *The Peenemünde Wind Tunnels: A Memoir.* New Haven, Connecticut:

Yale University Press.

Wheeler, Keith. **1965**. Building the XB-70. *Life* 15 January, pp. 74–83.

Winter, Frank H. **1983**. *Prelude to the Space Age: The Rocket Societies: 1924–1940.* Washington, DC: Smithsonian Institution Press.

Winter, Frank H. **1990**. *Rockets into Space.* Cambridge, Massachusetts: Harvard University Press.

Winter, Frank H. 17 September **2019**. Hermann Koelle, the Most Important German Rocket Scientist You've Probably Never Heard Of. *Air & Space.* http://www.airspacemag.com/daily-planet/hermann-koelle-most-important-german-rocket-scientist-youve-probably-never-heard-180973159/

Winter, Frank H. 16 November **2020**. George Sutton, the (Other) Father of American Rocketry. *Smithsonian.* https://www.smithsonianmag.com/air-space-magazine/george-sutton-other-father-american-rocketry-180976306/

Winter, Robert. **2011**. *Das Werk III: Hitlers geheime Raketenwerkstatt.* Taucha: Tauchaer.

Winterstein, William E. **2005**. *Secrets of the Space Age: An American Gift to Humanity.* Bandon, Oregon: Robert E. Reed Publishers.

Wulforst, Harry. **1990**. *The Rocketmakers: The Dreamers Who Made Space Flight a Reality.* New York: Orion.

Yenne, Bill. **2014**. *Area 51 Black Jets: A History of the Aircraft Developed at Groom Lake, America's Secret Aviation Base.* Minneapolis: Zenith.

Yenne, Bill. **2018**. *The Complete History of U.S. Cruise Missiles.* Forest Lake, Minnesota: Specialty Press.

Zaloga, Steven J. **2002**. *The Kremlin's Nuclear Sword: The Rise and Fall of Russia's Strategic Nuclear Forces, 1945–2000.* Washington, DC: Smithsonian Institution Press.

Zaloga, Steven J., and Jim **Laurier**. **2019**. *German Guided Missiles of World War II: Fritz-X to Wasserfall and X4.* Oxford, U.K.: Osprey.

New York Times (NYT)

NYT 1943-08-19 p. 11. German Air General Killed.

NYT 1943-08-21 p. 3. Death of 2 Generals Announced in Berlin. [Luftwaffe General Wolfgang von Chamier-Glisczinski was apparently in charge of coordination between the rocket and nuclear programs. He seems to have been killed in the August 1943 Allied bombing of Peenemünde, although he was "officially" reported to have been killed in an unrelated plane crash in Croatia that month.]

NYT 1944-09-30 p. 3. Americans Get Hint of New German Bomb. [V-3 blast area of 2 miles]

NYT 1944-10-22 p. E5. Germans Are Still Striving to Perfect New V Weapons.

NYT 1944-12-03. V-3 Ready to Hit New York This Month, German Says.

NYT 1944-12-05. Rockets in Reich Defense: U.S. Bomber Crews See 'Lots' of Them, Also Nazi

Jet Planes.

NYT 1944-12-14. La Guardia's Advice Draws Nazi Irony.

NYT 1945-01-16 p. 12. Nazis Use 'AA' Rockets in Italy.

NYT 1945-01-18 p. B9. Enemy Patents: U.S. Publishes List of 8,000 Seized from Germans.

NYT 1945-02-02 p. 1. Allies Will Strip German Economy.

NYT 1945-02-24 p. 1. Posen Capitulates—Arnswalde Gives Up.

NYT 1945-02-25 p. 21. Posen In Ruins.

NYT 1945-04-18 p. 6. Picture: Zeiss Plant in Ruins.

NYT 1945-04-19 p. 5. Big Rubber Factory Near Leipzig Seized.

NYT 1945-05-15. U-Boat Aimed V-Bomb Here, Army Paper Says.

NYT 1945-05-23 p. 4. Picture: Dornberger & Von Braun Captured.

NYT 1945-05-23 p. 21. Teagle Bares [Synthetic Gasoline] Deal with the Germans.

NYT 1945-06-03 p. 11. Swedish 'Pro-Nazi' Duped Foe 3 Years: 'Blacklisted' by U.S., He Sent Allies Latest Secret Data on Synthetic Gasoline Plants.

NYT 1945-06-06 p. 11. To Keep German Patents.

NYT 1945-06-06 p. 7. British Instrument Makers Demand Ban on German Rivals as a Preventative of War.

NYT 1945-06-08. New York Bomber Built in Germany.

NYT 1945-06-16 p. 15. German Synthetic Rubber Data Brought Back To U.S. By Experts.

NYT 1945-06-17 p. 6. Reich's Industry Seen on Upgrade—Despite War Damage.

NYT 1945-06-20 p. 12. Technical Secrets Of Reich Uncovered.

NYT 1945-06-27. Disarmed Germany Urged by Crowley: Bombed and Defeated Country Has Power to Rebuild War Machine, Says FEA Chief. [East coast rocket and jet attacks had been near.]

NYT 1945-06-27 p. 8. All Reich's Radium In Americans' Hands.

NYT 1945-06-29 p. 1. Gladwin Hill, Nazis' Scientists Planned Sun 'Gun' 5,100 Miles Up.

NYT 1945-06-30 p. 3. Gladwin Hill, Sun Gun Weighed By Germans In 1929.

NYT 1945-06-30 p. 3. U.S. Navy To Use German Weapons.

NYT 1945-07-01 p. E5. Germany's Economic Power Broken for Years to Come–People of the Reich Do Not Realize Their Real Position in the World.

NYT 1945-07-01 Magazine p. 8. 'Occupy Germany For Fifty Years' By Leopold Schwartzschild.

NYT 1945-07-02 p. 1. President Orders Oil Plant Seizure.

NYT 1945-07-03 p. 15. Report Mercury Valued At $5,000,000 Found On Nazi Submarine At Portsmouth, N. H.

NYT 1945-07-06 p. 1. U.S. Seizes Farben Plants to Bar Reich Arms Output [24 Plants].

NYT 1945-07-07 pp. 1, 3. Use of [German] Armament Seized in Europe Ask in Pacific.

NYT 1945-07-07 p. 5. Disposal of German War Material Poses Severe Problem for Allies.

NYT 1945-07-08 p. 4. Russia Said to Strip U.S. [Claimed] Plants in Reich.

NYT 1945-07-10 p. 4. Reich War Power Declared Strong [By Sen. H. M. Kilgore Report].

NYT 1945-07-15 p. E7. Aloofness of Scientists Condemned.

NYT 1945-07-17 p. 2. Berlin's Factories Stripped by Soviet.

NYT 1945-07-26 p. 6. 2,000 Reich Planes Found By British.

NYT 1945-07-29 p. 18. U.S. Gets Secrets Of Reich Industry.

NYT 1945-08-03 p. 1. Germany Stripped Of Industry By Big 3.

NYT 1945-08-05 p. 6. Soviet Said to Get Its Yalta Demand [half of movable Reich property].

NYT 1945-08-08 p. 15. German Industry Grew under Raids–Coal a Major Problem.

NYT 1945-08-09. Hitler Bluff Reported. [Luftwaffe General Wolfgang von Chamier-Glisczinski was apparently in charge of coordination between the rocket and nuclear programs. He seems to have been killed in the August 1943 Allied bombing of Peenemünde, although he was "officially" reported to have been killed in an unrelated plane crash in Croatia that month.]

NYT 1945-08-09. All Foreign Sabotage of Atomic Bomb Foiled.

NYT 1945-08-10 p. 5. Secret War Nipped Reich Cosmic Bomb. [Norway heavy water raid]

NYT 1945-08-24 p. 8. German War Scientists Will Work For Our Forces.

NYT 1945-08-27 p. 10. 17-Minute Oversea Rocket Plane Among Germany's War Secrets.

NYT 1945-08-28 p. 15. Industry Will Get Enemies' Secrets.

NYT 1945-09-18 p. 4. Interrogation Camps Hold 225 High Nazis. ["Dust Bin"]

NYT 1945-09-21 p. 5. Synthetic Blood Plasma Developed by Germany.

NYT 1945-09-25 p. 10. Industrial Plots of Germans Bared.

NYT 1945-09-26 p. 8. U.S. Allies to Get 5 Plants In Reich.

NYT 1945-09-30 p. 25. U.S. Will Transfer 11 More Reich Plants.

NYT 1945-09-30 p. 16. Reich Technicians Brought To Boston.

NYT 1945-10-02 p. 2. Germans Will Aid U.S. In War Research.

NYT 1945-10-04 pp. 1, 14. Truman to Seize Oil Plants Today.

NYT 1945-10-05 p. 2. Russia Would Take Big Plants in Reich.

NYT 1945-10-06 p. 18. WAAF Tells of Aid in Saving New York.

NYT 1945-10-09 p. 5. Reich Device Mines Coal without Drilling or Blasting.

NYT 1945-10-10 p. S1. Text of the Report of General Marshall.

NYT 1945-10-11 p. 4. Opel's Equipment Sought by Russians.

NYT 1945-10-11 p. 6. 75% of Industries in Reich Survived.

NYT 1945-10-13 p. 3. Allies Confiscate 300 Farben Plants.

NYT 1945-10-15 p. 4. Russians Believed Near Atom Secret. [Bornholm]

NYT 1945-10-21 p. 1. Smash I. G. Farben Empire, Eisenhower Advises Allies.

NYT 1945-10-27 p. 4. U.S. Set to Blast Reich Arms Plant.

NYT 1945-10-27 p. 4. Bearings Plants Dismantled.

NYT 1945-10-31 p. 6. Russia Confident on Bomb. [Bornholm]

NYT 1945-11-04 p. 31. German Arms Plant Destroyed.

NYT 1945-11-08 p. 8. Will Give Nazi Fuel Data.

NYT 1945-11-14 p. 11. 90 German Scientists Coming.

NYT 1945-11-17 pp. 1, 6. 88 German Scientists Reach Here.

NYT 1945-11-18 p. 20. Reich Experts Identified.

NYT 1945-11-20 p. 5. 5 More Arms Plants Doomed in Germany.

NYT 1945-11-22 p. 16a. Ten U-Boats for Russia to be Yielded in Ulster.

NYT 1945-11-22 p. 16b. Russian Seizures in Austria Aired.

NYT 1945-11-22 p. 17. U.S. Plans To Sell German Machines.

NYT 1945-11-26 p. 23. Ickes Pushes Test Of Synthetic Fuel [German Process].

NYT 1945-11-28 pp. 33, 36. Calls Gr-S Rubber Synthetic Leader.

NYT 1945-12-02 p. E9. German Synthetic Fuel.

NYT 1945-12-07 p. 4. 25 More Scientists Here From Germany.

NYT 1945-12-11 p. 4. 26 German Plants Divided By Allies.

NYT 1945-12-13 p. 8. Army Cartel Expert Sees Farben Threat.

NYT 1945-12-23 p. 7. 26 German Plants Ready For Delivery.

NYT 1945-12-30 p. 5. U.S. Said To Pamper Nazi Industrialists.

NYT 1946-01-02 p. 26. Synthetic Rubber to Ease Shortage.

NYT 1946-01-02 p. 32. 3 of 725 Research Scientists for Farben Retained.

NYT 1946-01-06 p. 20. Factories on Sale in Germany Listed.

NYT 1946-01-09 p. 15. Americans Prepare Reparations Plan.

NYT 1946-01-09 p. 14. 28 Aircraft Plants to Be Razed.

NYT 1946-01-10 p. 17. Allies Set Limit on German Steel.

NYT 1946-01-10 p. 20. Hahn, Atom-Splitter, Was Held in Britain.

NYT 1946-01-17 p. 14. 21 Farben Plants Wiped Out By U.S.

NYT 1946-01-17 p. 42. Asks Rubber Plan Before Plants Go.

NYT 1946-01-24 p. 26. Norwegian Skiers Played Big Role in Resistance against the Nazis.

NYT 1946-01-25 p. 4. German Guns to Be Tested.

NYT 1946-01-27 p. 11. Germans Ship Synthetic Rubber. [to Russia]

NYT 1946-01-29 p. 1. Russians Operating Czech Uranium Mine.

NYT 1946-01-29 p. 5. Austrians to Build Radios–for Others.

NYT 1946-02-11 p. 30. Big German Guns Arrive.

NYT 1946-02-15 p. 6. 130 German Scientists Are At Work In U.S. On Experiments For The Army And Navy.

NYT 1946-02-15 p. 6. U.S. Seen ‘Fumbling’ Its Job in Germany–Germany Seen as Vacuum.

NYT 1946-02-18 p. 3. U.S. Urged To Free Nazi Scientists Barred From Working By Politics.

NYT 1946-02-18 p. 8. German Fuel Patents Available.

NYT 1946-02-24 p. 29. Czechs to Regain Papers Army Took.

NYT 1946-02-25 p. 2. Bohemian Raids Gambled Lives to Recover German Documents.

NYT 1946-02-28 p. 2. Secret Arms Maker Seized in Germany.

NYT 1946-03-01 p. 1. Army To Use V-2 Bombs To Test Radar As Atom-Rocket Defense.

NYT 1946-03-03 p. 23. Russian Denies Interview—Mukden General Says He Did Not Tell of Looting Factories.

NYT 1946-03-08 p. 2. Austrians See Drain by Soviet on Output. [Russians taking all synthetic rubber]

NYT 1946-03-08 p. 5. Infa-Red Ray Gave German Sniper Edge.

NYT 1946-03-09 p. 6. Germans [Scientists] To Aid British.

NYT 1946-03-11 p. 30. German Data On Dyes Are Available Here.

NYT 1946-03-14 p. 44. German Patents To Aid U.S. Plants.

NYT 1946-03-21 p. 9. All-Out Nazi Effort Is Placed in Mid-1944.

NYT 1946-03-24 p. 18. Russians To Strip 600 German Mills.

NYT 1946-03-29 p. 10. German Industry Gets Allies' Bill.

NYT 1946-04-02 p. 12. Map Showing N.Y. City As Target For German Rocket.

NYT 1946-04-09 p. 38. Du Pont Planning For Vast Growth.

NYT 1946-04-12 p. 11. German Rocket in White Sands N. M.

NYT 1946-04-17 p. 13. Germany Moving Out Factory Equipment.

NYT 1946-04-20 p. 6. American Plants in Germany in Use.

NYT 1946-04-22 p. 6. V-2 Rockets To Test Upper Atmosphere.

NYT 1946-04-24 p. 14. U.S. To Get 4,209,000 Tons of Germany's Shipping.

NYT 1946-04-30 p. 1. German Research for War Banned by Control Council.

NYT 1946-05-07 p. 3. The V-2 Ready For Launching At White Sands.

NYT 1946-05-08 p. 34. Germany's Research On Color Film Told.

NYT 1946-05-13 p. 4. Washington Gives Plans Of German Helicopters.

NYT 1946-05-22 p. 4. Russians Said To Use German War Experts.

NYT 1946-06-19 p. 13. Nazi [Captured Poison Gas] Bombs Fell 40 In Alabama.

NYT 1946-06-23 p. 3. Our Army Drains A Deadly German Gas Bomb.

NYT 1946-06-29 p. 11. German V-2 Sets The Altitude Record At U.S. Army, Navy Test.

NYT 1946-07-05 p. 4. Russians Increase German Industry-Reparations in Kind.

NYT 1946-07-06 p. 12. New Tube Expands Radio Possibilities.

NYT 1946-07-11 p. 5. Russia for Seizing 200 German Firms.

NYT 1946-07-25 p. 6. Allies Will Share 11 German Plants.

NYT 1946-08-02 p. 1. Soviet 'Take' From 4 Losers Now Set At $3,000,000,000.

NYT 1946-08-03 p. 7. Russians Charge Looting of Reparations from Plants in U.S. Zone of Germany.

NYT 1946-08-07 p. 11. Reparations Wait on German Unity.

NYT 1946-08-09 p. 8. 100,000 German Patents Available.

NYT 1946-08-26 p. 7. 200 German Firms Seized By Soviet.

NYT 1946-08-27 p. 12. Transfers Of Plants From American Zone To Russia Ahead Of Schedule.

NYT 1946-09-10 p. 16. Russians Take 90% Of Zeiss Output.

NYT 1946-10-09 p. 22. German Plant Ask as U.S. Reparations.

NYT 1946-10-10 p. 5. 14 Countries Score Reparations Lag—Germans Urge Revision.

NYT 1946-10-19 p. 25. General Aniline and Film Wants Assurances for the Future.

NYT 1946-10-20 p. 30. 658 German Plants Listed For Payment.

NYT 1946-10-24 p. 14. Seizure Of 3,000 [Germans] Laid To Russians—Human Reparations.

NYT 1946-10-27 p. 32. Germans Report More Removals—310 Plants In Thuringia Removed And Sent To Russia.

NYT 1946-10-29 p. 10. Germans Strike Against Removals.

NYT 1946-11-01 p. 16. Germans Going To Britain–Ten Technicians Sign Voluntary Contracts For Work.

NYT 1946-11-02 p. 5. German Secrets Codified–Studied By FIAT, Field Intelligence Agency Technical.

NYT 1946-11-04 p. 15. Soviet Said To Enlist Physicians In Berlin.

NYT 1946-11-13 p. 5. Army To Tell Its Use Of German Scientists.

NYT 1946-11-14 p. 17. German Machines in U.S. Zone Freed.

NYT 1946-11-14 p. 18. Clay Sees End Soon To Occupation Costs [General Hildring Says 60-80% of Dismantling of German Industry Complete].

NYT 1946-11-28 p. 11. Germans [Scientists] To Go To Canada.

NYT 1946-11-28 p. 16. Uranium Field In Poland.

NYT 1946-12-04. Nazis Planned Rocket to Hit U.S.

NYT 1946-12-04 p. 36. Nazi Scientists Aid Army On Research.

NYT 1946-12-06 p. 1. 10 Soviet Trusts Drain Germany, U.S. Occupation Sources Report.

NYT 1946-12-06 p. 17. Hahn Says Soviet Lags In Cyclotrons–Hints At 'Kidnapping' Of German Scientists.

NYT 1946-12-10 p. 11. Reparation Plan Enters 2 D Phase–U.S. Sends Soviet Equipment from Two German Plants.

NYT 1946-12-14 p. 4. U.S. Policy Limits German Recovery.

NYT 1946-12-17 p. 18. 3,000,000 Axis POW on Siberian Projects.

NYT 1946-12-21 p. 4. Former German Officers Reported Sent To Russia.

NYT 1946-12-28 p. 7. Soviet Seen Ready To Shift Workers–Technicians Are Needed In The

East.

NYT 1946-12-28 p. 6. German Progress in Paying Own Way.

NYT 1946-12-30 p. 21. Citizenship Opposed For Nazi Scientists.

NYT 1946-12-31 p. 24. Synthetic Rubber 73% of the 1946 Total.

NYT 1947-01-04 p. 6. Nazis Sent To U.S. As Technicians.

NYT 1947-02-12 p. 10. Nazi U-Boat Ideas Aid [U.S.] Navy.

NYT 1947-02-16 p. 3. U.S. Said To Seize German Patents.

NYT 1947-02-23 pp. SM33–35. George H. Copeland. Nazi Science Secrets: A Technological Treasure Hunt in Conquered Germany Enriches U.S. Research and Business.

NYT 1947-02-24 p. 1. Soviet Said To 'Buy' [German] Atom Men.

NYT 1947-02-24 p. 26. Synthetic Rubber Held Vital To U.S.

NYT 1947-03-01 p. 5. German Atom Expert Kept from Argentina.

NYT 1947-03-02 p. 17. Reich Kin Join [German] Scientists [in Texas].

NYT 1947-05-17 p. 2. German Scientists' Help Said To Save Us 10 Years.

NYT 1947-05-18 p. 42. 'Get Tough' Policy In Germany Begins.

NYT 1947-05-18 p. 45. Nazi Rocket Base In Complete Ruin: Russians Open Up Peenemuende for First Time.

NYT 1947-05-19 pp. 1, 11. Scientists See U.S. Vulnerable To Germ Warfare.

NYT 1947-05-25 p. 42. Synthetic Blood Plasma: 'Periston,' Used By Germans In War, Chemists Are Told.

NYT 1947-05-26 p. 35. German Secrets Net U.S. $1,500,000: 400,000 Copies of Documents Already Sold to Industry—Russia Good Customer. [6000 U.S. industry experts sent to Germany in search of files, patents, and factories]

NYT 1947-06-22 p. E7. New Peenemuende Rises On Rio Grande's Banks.

NYT 1947-07-13 Magazine p. 8. A German Plant Dismantled By The Russians.

NYT 1947-08-24 p. 15. Reich Scientists Here [Ohio] Hate Russia.

NYT 1947-10-02 p. 8. Clay Will Force Plant Removals. [threatens to stop flow of food to Germans]

NYT 1947-10-17 p. 8. 682 [More] German Plants To Be Dismantled.

NYT 1947-10-24 p. 17. Industrialists Got Nazi War Secrets.

NYT 1947-10-31 p. 15. France To Recruit German Labor.

NYT 1947-11-30 p. 14. Sound Waves Kill in Tests by Army.

NYT 1947-12-04 p. 34. U.S. Urged To Start Synthetic Oil Plan.

NYT 1947-12-06 p. 6. Germany Will Lose Her Buna Factories.

NYT 1947-12-17 p. 15. German Dismantling Is Eased By The West.

NYT 1947-12-23 p. 5. 28 More Plants In Germany Allotted [to Allies].

NYT 1948-01-07 p. 15. German Charges Allies Loot West [Germany].

NYT 1948-01-09 p. 17. Germans Warned on Food Supplies. [if Germany blocks dismantling of plants]

NYT 1948-01-13 p. 35. Standard To Push Synthetic Oil.

NYT 1948-01-20 p. 2. Protests Removal of German Plants.

NYT 1948-02-01 p. 25. Russia Keeps Prisoners. [a million POWs for labor]

NYT 1948-02-09 p. 1. Marshall Opposes End to Dismantling of German Plants.

NYT 1948-03-26 p. 14. Allies Order Bosch to Drop 20 Branches.

NYT 1948-04-03 p. 27. V-2 Weather Rocket Fired into Upper Sky.

NYT 1948-04-15 p. 17. Heinkel a ‘Nominal’ Nazi.

NYT 1948-05-26 p. 3. U.S. Asserts Russians Kidnap Germans To Mine Uranium Ore.

NYT 1948-06-02 p. 10. Soviet Dismantles 19 Plants in Zone.

NYT 1948-06-11 p. 5. Farben Attorney Condemns Allies.

NYT 1948-07-18 p. 9. U.S., Britain Clash on German Steel.

NYT 1948-07-25 p. 1. Farben Liquidation Mapped; New Concerns Are Planned–U.S. and British Officials.

NYT 1948-08-27 p. 3. Baden Chiefs Quit Over Dismantling.

NYT 1948-09-01 p. 1. U.S. Is Reviewing [German] Reparations Policy.

NYT 1948-09-04 p. 19. All German Scrap Is Now Allocated.

NYT 1948-09-05 p. 19. Germans Protest [Plant Dismantling] Restitution Plans.

NYT 1948-09-09 p. 10. Britain Cling To Dismantling [Of German Factories To Be Rebuilt In Britain]; Opposes Change In [U.N.] German Policy.

NYT 1948-09-18 p. 21. Germany Shipping Scrap Metal Here.

NYT 1948-10-15 p. 39. German Scrap Due to Arrive Oct. 25.

NYT 1948-10-16 p. 4. Reparations Study Sped By Hoffmann.

NYT 1948-10-17 p. 3. Reparations Lag in East Germany.

NYT 1948-10-17 p. 16. Russians Enraged by ‘Slave’ Charges—‘It’s a Lie,’ Delegate Shouts.

NYT 1948-10-21 p. 7. Briton in Germany over Dismantling.

NYT 1948-10-22 p. 2. Germans [Scientists] Going To Britain.

NYT 1948-10-28 p. 10. French Dismantling 38 [German] Plants.

NYT 1948-10-29 p. 22. Swiss Scientist Who Developed DDT Spray Wins The 1948 Nobel Prize.

NYT 1948-11-07 p. 13. Austrians Attack Russian Seizures [of Austrians].

NYT 1948-11-21 p. 10. Dismantling Feared by French.

NYT 1948-11-26 p. 9. Drydock Is Blown Up.

NYT 1948-11-28 p. 10. Soviets Hold Up Reparations Debt.

NYT 1948-11-28 p. 12. Allied Suggestion Provokes German Ire.

NYT 1948-11-28 p. 12. Russians Reduce German Current.

NYT 1948-11-28 p. 13. French Ruhr View Backed In Britain.

NYT 1948-12-04 p. 3. Nazi Plane-Maker [Dornier] Freed.

NYT 1948-12-04 p. 6. Macnarney Predicts 10,000 Mile Missile.

NYT 1948-12-05 p. 9. Dismantling Halt by U.S. Protested.

NYT 1948-12-06 p. 3. Germans Boycott British over Plant Dismantling.

NYT 1948-12-07 p. 9. Allies Weigh Rift on German Plants.

NYT 1948-12-08 p. 6. Dismantling Accord For Germany Closer.

NYT 1948-12-08 p. 12. British Blow Up Ranges.

NYT 1948-12-28 p. 10a. Nazis Spurned Idea of Atomic Bomb: Dr. Heisenberg Says Germans Were Far Advanced But Lacked Hitler Support.

NYT 1948-12-28 p. 10b. Russia Uses 30,000 Women as Slave Labor in Uranium Mines, Escaped German Says.

NYT 1948-12-29 p. 8. Plan for Ruhr Control Authority Is Bitterly Assailed by Germans.

NYT 1948-12-31 p. 5. German Protests on Ruhr Rejected.

NYT 1949-05-22 p. 4. Nazis Had Television Eye to Guide Missile’s Path.

NYT 1951-02-08 p. 35. U.S. Stockpile Urged in Plasma Substitute.

NYT 1951-05-20 p. E9. ‘Extender’ to Eke Out Blood Supply: Widely Used During the War Tests Being Made Here.

NYT 1958-10-09 p. 73. Plant That Built Nautilus Wheel Ready for Other Big Propellers.

NYT 1961-11-19 p. 81. New Device Tried in Breast Cancer.

NYT 1962-07-25 p. 29. Breast Cancer Work Is Cited at Parley.

NYT 1968-04-11 p. 26. Rise in Cancer Cures Shown in Iodine Use.

NYT 1978-02-12 p. 1. James B. Conant Is Dead at 84; Harvard President for 20 Years. https://www.nytimes.com/1978/02/12/archives/james-b-conant-is-dead-at-84-harvard-president-for-20-years-from.html

NYT 1980-07-01 p. 31. Dr. Ulrich K. Henschke, Noted for Cancer Work [obituary].

NYT 1986-11-05. Adolf Busemann, 85, Dead; Designer of the Swept Wing.

NYT 1995-12-31 p. A22. William J. Broad. Captured Cargo, Captivating Mystery. [Manhattan Project security chief: uranium sent to Oak Ridge]

NYT 2004-03-23. William J. Broad. Slender and Elegant, It Fuels the Bomb. [German production of uranium gas centrifuges in the postwar Soviet nuclear program] https://www.nytimes.com/2004/03/23/science/slender-and-elegant-it-fuels-the-bomb.html

NYT 2008-09-01 p. C4. Claire Cain Miller. Another Voice [Judy Estrin] Warns of an Innovation Slowdown. https://www.nytimes.com/2008/09/01/technology/01estrin.html

NYT 2011-01-23 p. A1. Gardiner Harris. Federal Research Center Will Help Develop Medicines. https://www.nytimes.com/2011/01/23/health/policy/23drug.html

NYT 2011-05-02. David Bornstein. Helping New Drugs Out of Research's 'Valley of Death'. https://archive.nytimes.com/opinionator.blogs.nytimes.com/2011/05/02/helping-new-drugs-out-of-academias-valley-of-death/

NYT 2011-09-11 p. A23. John Upton. Employee Lawsuit Exacerbates Issues at Livermore Lab. https://www.nytimes.com/2011/09/11/us/11bclivermore.html

NYT 2015-04-18 p. A15. Kristin Hussey. First in Flight? Connecticut Stakes a Claim. https://www.nytimes.com/2015/04/18/nyregion/where-was-modern-flight-invented-connecticut-believes-it-holds-the-answer.html

NYT 2015-05-20 p. B1. Eduardo Porter. American Innovation Lies on Weak Foundation. https://www.nytimes.com/2015/05/20/business/economy/american-innovation-rests-on-weak-foundation.html

NYT 2016-06-30 p. A25. Patricia Cohen. Simon Ramo Dies at 103; Helped Develop ICBMs in the Cold War. https://www.nytimes.com/2016/06/30/business/simon-ramo-dies-at-103-helped-develop-icbms-in-the-cold-war.html

NYT 2021-04-02. No Federal Taxes for Dozens of Big, Profitable Companies. https://www.nytimes.com/2021/04/02/business/economy/zero-corporate-tax.html

NYT 2023-06-15 p. A1.. Despite War, Paying Russia For Uranium. https://www.nytimes.com/2023/06/14/climate/enriched-uranium-nuclear-russia-ohio.html

Miscellaneous Periodicals

***Aero Digest* 1946-01**. Luftwaffe Data at Wright Field. 52:99.

***Air World* 1946-01**. Swan Song of the Luftwaffe.

Archiv. Issues 1–13, 1966–1968. International Society of German Aviation Historians. [Article authors such as Antony Kay, Richard Smith, Eddie Creek, and others later expanded some of these articles into published books cited in the aerospace section of this Bibliography, but other articles were never never elaborated upon elsewhere.]

***The Argus* 1944-09-18 p. 1**. German "Death Ray" Weapon Wrecked. Melbourne, Australia.

***Army News* 1945-06-21 p. 4**. V2 Rocket Inventor Tells Story of Bomb. Darwin, Australia.

***Army News* 1945-08-16 p. 3**. Nazis Planned Atomic Rocket. Darwin, Australia.

Baltimore Sun 2000-11-29. Werner W. Hohenner, 93, scientist who helped develop Polaris missile. https://www.baltimoresun.com/news/bs-xpm-2000-11-29-0011290120-story.html

***Boston Globe* 1993-07-27** p. A1. David Arnold. The Uranium Vanishes: A Mystery of World War II.

***Boston Globe* 1945-05-19**. [U-234]

***Boston Globe* 1945-05-20**. [U-234]

***Business Week* 1946-05-18 pp. 19–20**. Scientific Cleanup.

***The Calgary Herald* 1946-01-19 p. 10**. Germans 'Miles Ahead' in Rocket Research. https://news.google.com/newspapers?nid=Hx6RvaqUy9IC&dat=19460119&printsec=frontpage&hl=en

***Chemical and Engineering News* 1956-12-17**. Brainpower from Abroad. 34:6188.

***Chemical and Metallurgical Engineering* 1945-08**. American Technical Men Investigate Germany's Industrial War Developments. 52:147-148.

***Chemical and Metallurgical Engineering* 1946-02**. German Fibers. 53:162-163.

***Chemical Week* 1953-06-27**. There for the Digging. 72:26.

***Chemistry and Industry* 1947-09-27 587–589**. Technical Investigations in Germany: Some Observations by a Recent Investigator.

***Chicago Daily Tribune* 1945-04-13** p. 9. German 'Flying Wing' Factory Found by Yanks.

***Chicago Daily Tribune* 1945-06-27**. Laurence Burd, Crowley Urges Long Term Curb on German Arms. [East coast rocket and jet attacks had been near.]

***Chicago Daily Tribune* 1945-06-29 p. 4**. Planned N.Y. Bombing. [40 new 7000-mile-range Heinkel bombers at giant airfield near Oslo]

***Chicago Daily Tribune* 1945-08-08**. Reveal Allies Destroyed Nazi Atom Factory.

***Chicago Daily Tribune* 1945-08-09**. Charles Chamberlain, Reveal Allied Capture of Nazi Atom Factory.

***Chicago Daily Tribune* 1945-08-10**. Bare Nazi Spy Plot to Get U.S. Atom Bomb Data: Orders to Agents Told of Foe's Progress.

***Chicago Daily Tribune* 1946-01-26**. Nazis' A-Bomb 90 Days Late, Says Goering.

***Chicago Daily Tribune* 1946-12-04 p. 18**. Ex-Nazi Experts Work on Secret Weapons in U.S.: Army Tells How German Scientists Aid America.

***Chicago Daily Tribune* 1949-05-20 p. 2**. Seize 2 More Germans with Uranium; Army Hunts Nazi Hoard.

***Collier's* 1952-03-22.** Man Will Conquer Space Soon. [Many articles by Wernher von Braun et al.]

***The Courier Mail* 1945-08-09 p. 2**. Nazis Planned to Link Atomic Bomb with V-2's. Brisbane, Australia.

***The Courier-Mail* 1946-01-19 p. 1**. Germans Had Fastest "Jet." Brisbane, Australia.

***The Daily Express* 1945-08-09**. RAF Killed Atom Chief. [Luftwaffe General Wolfgang von Chamier-Glisczinski was apparently in charge of coordination between the rocket and nuclear programs. He seems to have been killed in the August 1943 Allied bombing of Peenemünde, although he was "officially" reported to have been killed in an unrelated plane crash in Croatia that month.]

***The Daily Illini* 1940-05-14 p. 1**. Report Death Ray Is Nazi 'Secret'.

***Daily Mail* 1944-10-11 p. 1**. Walter Farr, Berlin Is 'Silent' 60 Hours: Still No Phones.

***Daily Mail* 1944-10-30**. G. Ward Price, Fly-Bombs Were Meant for U.S.: Huge Ramp Found.

***Daily Mail* 1945-01-12**. U-Boat into V-Boat: New Menace to America.

***Daily Mail* 1945-04-18**. [V-4 article].

***Daily Mail* 1945-05-05 p. 1**. U. S. Coast Has a V-Scare: Huge Flash and Bang.

***Daily Mail* 1945-06-14** p. 1. V2s with Range of 3,000 Miles: Would Have Been Ready by VE-Day.

***Daily Mail* 1945-08-09**. In That Swoop on Peenemunde a German Atom Ace Died. [Luftwaffe General Wolfgang von Chamier-Glisczinski was apparently in charge of coordination between the rocket and nuclear programs. He seems to have been killed in the August 1943 Allied bombing of Peenemünde, although he was "officially" reported to have been killed in an unrelated plane crash in Croatia that month.]

***Daily Mail* 1945-10-10**. Next Time: America Might Be Annihilated.

***Daily Telegraph* 1945-08-09**. RAF Killed Nazi Atom Scientist. [Luftwaffe General Wolfgang von Chamier-Glisczinski was apparently in charge of coordination between the rocket and nuclear programs. He seems to have been killed in the August 1943 Allied bombing of Peenemünde, although he was "officially" reported to have been killed in an unrelated plane crash in Croatia that month.]

***Daily Telegraph* 1945-10-01, 02, 05, 09 p. 4** of each issue. Roy Fedden. German Plans to Revolutionise Air Warfare.

***Daily Telegraph* 1969-09-02 p. 13**. Lone Bomber Raid on New York Planned by Hitler.

***Daily Telegraph and Morning Post* 1945-08-11**. Nazis' Atom Bomb Plans: Britain Ready a Year Ago.

***Dayton Daily News* 1946-12-04**. Herbert Shaw. Wright Field Reveals 'Operation Paperclip.'

***Deutsches Technikmuseum Berlin* 2010**. Issue 2.

***Deutsches Technikmuseum Berlin* 2013**. Issue 1.

***Eighth Army News* 1945-08-28**. Nazis Had 10,000 mph Atom Plane—In Theory.

***Electronics* 1946-05**. Capacitators without Foil. 19:303-305.

***Electronics* 1946-07**. German Industrial Techniques. 19:200-207.

***Evening Standard* 1945-08-07**. Germans Timed Atom Bomb for October. [planned 6-mile blast radius, Wilhelm Groth sent to Britain]

***Frankfurter Allgemeine Sonntagszeitung* 2002-10-27 pp. 10-11**. Andreas Oberholz. Raketen in Thüringen: Neue Hinweise auf eine unbekannte Nazi-Waffenschmiede.

Geschichts- und Technologiegesellschaft Großraum Jonastal e.V. *Geheimnis Jonastal.* 2002 (issue 1) – 2024 (issue 24). https://gtgj.de

***Handelsblatt* 1947-07**. Deutsche Technik als Auftrieb: Stärkste Nutzung deutscher Verfahren in den USA. 17:7.

Intelligence Bulletin. U.S. War Department. [April 1946 pp. 2, 18: Guided Missiles: The Weapon of the Future.]

Intelligence Review. U.S. War Department.

***Iron Age* 1945-08-16**. German Design Improvisation Described by Timken Metallurgist. 156:109.

***Life* 1946-12-09**. Nazi Brains Help U.S.: German Scientists Are Revealed as Army Researchers. 21:49-50.

***Life* 1945-07-23 p. 78**. The German Space Mirror: Nazi Men of Science Seriously Planned to Use a Man-Made Satellite as a Weapon for Conquest.

***Life* 1945-11-15**. The 36-Hour War: Arnold Report Hints at the Catastrophe of the Next Great Conflict. 19:21:27.

***Life* 1946-12-02**. Sixty-five Miles Up: Camera Rides Experimental V-2 Rocket to Photograph Earth's Surface from Altitude Never Reached by Man.

***Los Angeles Times* 1945-07-20 p. 5**. William H. Stoneman. Atomic Bomb Discovery of Germans Told.

***Los Angeles Times* 1945-06-29**. Plan to Bomb New York Told. [40 new 7000-mile-range Heinkel bombers at giant airfield near Oslo]

***Los Angeles Times* 1947-07-11** p. 1. Nazi Weapon Experts Now Aiding Navy.

***The Mercury* 1945-08-09 p. 2**. Hitler's Physicists Hoped to Blast British Cities with Atomic Bombs. Hobart, Tasmania, Australia.

***Modern Industry* 1946-06-15**. German Industrial Know-How at 5 & 10 Prices. 11:150-162.

***News Chronicle* 1945-10-15 p. 1**. Russia Will Have Secret Soon. London. [Bornholm]

***News Chronicle* 1946-02-21 p. 2**. Ian Bevin. Germany Disgorges Her Rich Secrets. London.

***Newsweek* 1945-07-09 p. 52**. The Hydra.

***Newsweek* 1946-12-09 p. 64**. Secrets from Hitler.

***New York Herald Tribune* 1945-08-08**. John O'Reilly. Germany Close to Solving Atom as War Ended.

***Office of Naval Intelligence Review* 1949-02**. Paperclip, Part I.

***The Ottawa Journal* 1946-01-18 p. 9**. Germans Had Jet 'Planes 5 Times Faster Than Sound.' https://www.newspapers.com/newspage/50100865/

***Parade* 1953-01-11**. Our Navy's 100-Mile Stinger. [US copy of sub-launched V-1]

***Paris Presse* 1945-04-18 p. 1**. Raymond Henry. Nous Font des Révélations sur le V-4: Dernier Rêve de Hitler.

***Popular Science* 1947-10**. Transatlantic Roller Coaster Designed to Bomb U.S.A.

Press and Sun-Bulletin (Binghamton, New York), **1946-09-19** p. 1. Ambitious Experiment: Brain-Controlled Artificial Leg was Goal of Nazi Scientists.

***The Review of Scientific Instruments* 1946-12**. Progress in Science in Germany, 1939–1946. 17:564-567.

***Ruhr-Nachtrichten* 1987-01-24**. Deutsches Zirkonium war für erstes Atom-U-Boot der Welt bestimmt: Taucher bargen geheime Fracht des See-Helden Kapitän Carlsen. [German Zirconium Was Destined for the World's First Nuclear Submarine: Divers Rescued Secret Cargo of Sea-Hero Captain Carlsen.] Dortmund.

***The San Bernadino County Sun* 1940-05-14**. Nazis Using Death Ray, Rome Reports.

***Science Illustrated* 1947-02**. Science Has No Nationality. 2:13.

***Science News Letter* 1945-12-22**. German Magnetic Tape Machine Brought to the United States. 48:399.

***Science News Letter* 1946-12-14**. Noted German Scientists Work for Uncle Sam. 50:373.

Scientific Intelligence Review. U.S. War Department. [28 February 1946, 2:33-35: Russian Developments in Field of Guided Missiles.]

***Der Spiegel* 1951-06-05**. Die Grösste Kriegsbeute Deutschlands Patente. https://www.spiegel.de/politik/die-groesste-kriegsbeute-deutschlands-patente-a-479a3b9f-0002-0001-0000-000029194050 [This is a translated and highly abridged version of Charles Walker 1946.]

Der Spiegel **1963-07-24 p. 58**. Schweiz/Todesstrahlen: Schnee geschmolzen.

Der Spiegel **1967-06-19 pp. 80–95**. David Irving. “So groß wie eine Ananas...”

Der Spiegel **1996-01-08**. Heiße Ladung: Steckte deutsches Uran in der Hiroschima-Bombe? Ein früherer US-Geheimdienstler halt das für wahrscheinlich.

Spokane Daily Chronicle **1948-03-16 p. 6**. Rich Uranium Ore on Danish Island Russia Evacuated.

Stars and Stripes **1945-05-14**. [U-Boat Aimed V-Bomb at New York].

St. Joseph Gazette (St. Joseph, Missouri) **1946-09-19** p. 7. Germans Tried to Develop Controlled Artificial Leg. https://news.google.com/newspapers?id=zypaAAAAIBAJ&sjid=HkwNAAAAIBAJ&hl=es&pg=1168%2C1131947

Sydney Morning Herald **1946-04-20 p. 2**. Atomic Energy May Be Behind Bornholm Mystery.

Time **1944-11-27 p. 88**. V-3. [German atomic bomb using spherical implosion—Neumann crusher]

Time **1946-09-02 p. 52**. Extra-Atmospheric War.

The Times **1945-05-15**. Clearing of Bornholm: Germans Who Refused to Surrender. London.

The Times **1945-05-18**. Danes Seek Restoration of Communications. London. [Bornholm]

The Times **1945-08-27**. [17-Minute Oversea Rocket Plane, etc.] London.

The Times **1945-08-28**. Enemy’s Secret Weapons: Mr. Truman on Release of Information. London.

Union and Tribune-Sun **1944-07-26**. Hitler O.K.’s N.Y. City Attack with Robots, Says Madrid. San Diego.

Walpersberg Geschichts- und Forschungsjournal. 2015–2016.

Washington Post **1945-06-29**. Were Ready to Bomb N.Y. [40 new 7000-mile-range Heinkel bombers at giant airfield near Oslo]

Washington Post **1945-10-20 pp. 1–2**. Arnold Urges Single Defense Department. [V-3]

British Intelligence Objectives Subcommittee Evaluation Reports (BIOS ER)

BIOS ER 1 through at least **BIOS ER 576** [NARA RG 319, Entry NM3-82, Boxes 377–378]

British Intelligence Objectives Subcommittee (BIOS) Final Reports

BIOS 1. *Heraklith Plant of Deutsche Magnesit A.G. at Ferndorf, Austria.*

BIOS 2. *German Photoconducting Cells for the Detection of Infra-Red Radiation.*

BIOS 3. *Zimmerit (Anti-Magnetic Plaster for AFVs).*

BIOS 4. *Visits to Targets Connected with the German Plywood Industry.*

BIOS 5. *Report on Visit to the Zellstoffe Fabrik A. G. Near Regensburg: Production of Yeast.*

BIOS 6. *Report on Visit to Munich Technical High School. Dr. Siegfried Windisch on Food Yeast.*

BIOS 7. *The Saccharification of Wood by the Bergius Process at Süddeutschen Holzversuchserung Werke A.G. Regensburg.*

BIOS 8. *Manufacture and Application of Specialized Magnetic Materials Generally.*

BIOS 9. *Interrogation of German Air Ministry (OKL) Technical Personnel Luftwaffe Lager, Near Kiel.*

BIOS 10. *German Plastic Developments, Homogenholzwerke "Holig" G.m.B.H. Baiersbronn, m. Freudenstadt Schwarzwald.*

BIOS 11.

BIOS 12.

BIOS 13. *German Montan-Wax Industry.*

BIOS 14. *High Speed Schlieren Camera for Observation of Flame Travel.*

BIOS 15.

BIOS 16. *Interference Method Studying Air Flow in Turbine.*

BIOS 17. *Statistics: Interrogation of Dr. Rolf Wagenführ Statistical Section of the Planungsamt, Speer Armaments Ministry.*

BIOS 18. *Interview with Dr. K. Freudenberg, Director of Institut für die Chemie des Holzes, Universität, Heidelberg.*

BIOS 19. *Lurgi Gesellschaft für Warmetechnik, m.b.H., Lurgi Gesellschaft für Chemie und Hütterwesen m.b.H., Lurgi Apparatebau G.m.b.H.*

BIOS 20. *Lurgi Gesellschaft für Warmetechnik, Frankfurt.*

BIOS 21.

BIOS 22.

BIOS 23. *High Temperature Ceramics in South Germany.*

BIOS 24. *Peenemunde West.*

BIOS 25. *Copper Smelting and Refining, Particularly from Alloy Scrap and Residues at Zinnwerke Wilhelmsberg Gmb.H Hamburg.*

BIOS 26. *Copper Smelting and Refining, Together with Related Metallurgical Activities at Nord Deutsche Affinerie, Hamburg.*

BIOS 27. *Modern High Explosive Developments at Deutsche Waffen und Munitions Fabriken, A.G., Schlutup near Lübeck.* [RDX, aluminum]

BIOS 28. *The Voith-Schneider Propellor.*

BIOS 29. *German Directed Missiles: Brief Notes on Kochel, Otterbrunn and L.F.A. Volkenrode.*

BIOS 30. *Telefunken Metal/Ceramic Radio Valves.*

BIOS 31. *Rocket Developments in South Germany and Austria.*

BIOS 32. *Albumen and Egg Substitute Industries.* [Serum albumen]

BIOS 33.

BIOS 34. *Interrogation of Dipl. Ing. Ernest Kniepkamp (A F Vs.).*

BIOS 35. *Report on Visit to Daimler-Benz A.G. at Stuttgart—Untertürkheim.*

BIOS 36. *Magnetic Materials and Beryllium.*

BIOS 37. *German Aircraft Industry, Dornier-Werke, Friedrichshafen Area.*

BIOS 38. *Visit to Germany—Electric Power.*

BIOS 39. *Concealed Oil Targets in the Brilion-Bredelar Area.*

BIOS 40. *Optical Activities at Steinheil u. Söhne München.* [AR coatings and optical crystals.]

BIOS 41. [CW]

BIOS 42. *German Oil Storage Blending and Filling Installations. Reports on W.I.F.O. Oil Storage Depots Located at Eickeloh, Ruthen and Nienberg. With Particular Reference to Drum and Can Filling.*

BIOS 43. *Skoda Works, Pilsen, Czecho-Slovakia.*

BIOS 44. With appendices. [CW]

BIOS 45. *J. M. Voith, Maschinen Fabriken (Pulp and Paper Machinery Dept.), Heidenheim.*

BIOS 46. *Feldmuhle Papier und Zellstoff Werke A.G., Reisholz Works, Düsseldorf, Reisholz, Westphalia.*

BIOS 47. *Handliche Papierfabrik, Schöngau Works, Schöngau, Bavaria.*

BIOS 48.

BIOS 49. *Aschaffenburger Zellstoff A.G., Aschaffenburg Mill, Aschaffenburg, Hessen.*

BIOS 50. *Weissenstein Papierfabrik A.G., Pforzheim-Dillweissenstein, Wurtemberg.*

BIOS 51. *Zellstofffabrik Waldhof, Kelheim Mill, Kelheim, Bavaria.*

BIOS 52. *Zellstofffabrik Waldhof, Mannheim Mill, Mannheim, Waldhof.*

BIOS 53. *Feldmuhle Papierfabrik, Hillegossen.*

BIOS 54. *Institut für Cellulose Chemie, Darmstadt.*

BIOS 55. *Papier Fabrik-Kabel Hagen.*

BIOS 56.

BIOS 57. *Scientific Background of the German Chocolate Industry.*

BIOS 58. *Pulping of Beechwood with Nitric Acid at Wolfen Near Leipzig.*

BIOS 59. *Paper Binder Twine.*

BIOS 60. *Robert Bosch G.m.b.H., Stuttgart, and Sundry Dispersal Sites.*

BIOS 61. *Weapons Section of the LFA, Volkenrode, with Notes on Photographic Methods Used in German Ballistics.*

BIOS 62.

BIOS 63.

BIOS 64. *Dental Industry.*

BIOS 65. *Philips Valvo Works, Hamburg; Hammerwerke (Valve Works), Minden; C.H. Müller AG (X-Ray Tube Factory) Hamburg.*

BIOS 66. *Dornier Structural Strength Test Equipment and Methods.*

BIOS 67. *German Airborne Gun and R.P. Sights.*

BIOS 68. *Bosch Sparking Plug Factories.*

BIOS 69.

BIOS 70. *Harburger Gummiwaren-Fabrik Phoenix at Hamburg/Harburg 1.*

BIOS 71. *Chemische Physikalische Versuchsanstalt at Danisch Niendorf.*

BIOS 72. *Vereinigte Flussspatgruben G.m.b.H. at Stulln (United Fluorspar Mines).*

BIOS 73. *Laboratorium für Elektronen und Ionenlehre at Schwarzenfeld.* [Dielectrics research]

BIOS 74.

BIOS 75. *The Production of Acetaldehyd, Acetic Acid, Acetic Anhydride and Acetone fro Acetylene at the Bunawerke, Schkopau.*

BIOS 76. *Pulp & Paper Industry in the Leipzig Area.*

BIOS 77. *German Stereoscopic Rangefinder. Em 4m R.40 Entferungsmesser 4m. Raumbild 40.*

BIOS 78. *Some Aspects of German Powder Metallurgy.*

BIOS 79. *Applied Mathematical Research in Germany, with Particular Reference to Naval Applications.*

BIOS 80. *German Industrial Jewel Bearing Production.*

BIOS 81.

BIOS 82. *Inspection of Hydrogenation and Fischer-Tropsch Plants in Western Germany During September, 1945.*

BIOS 83. *Kaiser Wilhelm Institut für Arbeitsphysiologie (Physiology of Exercise and Application to Industry, Particularly Mining.* [Human performance enhancement]

BIOS 84. *The Production of Bi-metallic Strip in Germany.*

BIOS 85. *Some Developments in Dairying in Germany.* [Albumen]

BIOS 86. *Oils and Fats Industry.*

BIOS 87.

BIOS 88. *Lehr Spinnerei (Model Spinning Mill) Denkendorf.*

BIOS 89.

BIOS 90. [Albumen]

BIOS 91.

BIOS 92. *Production of Acrylonitrile at Leverkusen Plant of I. G. Farbenindustrie.*

BIOS 93. *German Leather Goods and Ancillary Industry.*

BIOS 94. *Kalie-Chemie Rhenania Phosphat Werke, Brunsbüttelkoog.*

BIOS 95.

BIOS 96.

BIOS 97. *Interrogation of German Technicians Engaged on the Design of Turretry and Gun Mountings for Armoured Fighting Vehicles.*

BIOS 98. *Report on German Development of Gas Turbines for Armoured Fighting Vehicles.*

BIOS 99. *Development of German Panzerfaust and Other Hollow Charge Weapons.*

BIOS 100. *Development of Panzerfaust.*

BIOS 101. *German Large Fatigue Testing Machines.*

BIOS 102. *German Electric Detonators, Caps and Fuzeheads.*

BIOS 103. *"Komet"—Installation. A Proposed German Long Range Radio Navigational Aid.*

BIOS 104.

BIOS 105. *Interrogation of Dr. Heinrich Langweiler.*

BIOS 106. *Textile Finishing Machinery for Cotton & Rayon Piece Goods.*

BIOS 107. *Production of a Phosphate Fertiliser by Sintering of Phosphate Rock with Sodium Sulphate and Lignite.*

BIOS 108.

BIOS 109. *Report on German Steel Foundries.*

BIOS 110. *Drägerwerk Factories at Lübeck, Hamburg and Uetersen.* [Protective clothing, respiration filters, sensors, etc. for chemical warfare]

BIOS 111. *Production of Flour and Bread in Germany.*

BIOS 112. *Interim Report of Freon-12 at I. G. Works, Hoechst.*

BIOS 113.

BIOS 114.

BIOS 115. *Report on the Interrogation of Dr. Kurt Stenge.*

BIOS 116. *Pharmaceuticals: Research and Manufacture at I.G. Farbenindustrie.* With supplement. [very large and detailed report]

BIOS 117. *Electrical Dynamometer.*

BIOS 118. *Munich Technical High School. Interrogation of Dr. E. H. Kadmer and Dr. K. Schnauffer.*

BIOS 119. *Deutsche Versuchsanstalt für Luftfahrt (D.V.L.) Institut für Betriebstoff Forschung.*

BIOS 120. *Wirtschaftliche Forschungsgesellschaft m.b.H. Hitzacker Depot.*

BIOS 121. *Wirtschaftliche Forschungsgesellschaft m.b.H. (WIFO), Heiligenstadt Installation.*

BIOS 122. *Wirtschaftliche Forschungsgesellschaft m.b.H. Interrogation of Herr Helmut Plote of the Construction Department.*

BIOS 123. *RATO and Walther propulsion.*

BIOS 124.

BIOS 125. *Ernst Beuttler Werke, Dinglingen, Near Lahr.*

BIOS 126.

BIOS 127. *The Aluminum Fabricating Plant of Aluminium Wals-on Persbedrljvon N. V., Utrecht, Holland.*

BIOS 128.

BIOS 129. *Some Phases of German Electrical Utility Practice.* [Electricity in Berlin]

BIOS 130. [CW]

BIOS 131. *German Spring Making Industry.*

BIOS 132. *Production and Further Investigation of Wesch Anti-Radar Material.*

BIOS 133. *Visit to Brunswick Region to Study German Developments in Mechanics of Materials Applied to Armaments.*

BIOS 134.

BIOS 135.

BIOS 136. *Investigation of Koepe Winding Practice in the Ruhr District of Germany and the Limburg District of Holland.*

BIOS 137. *Cyclopolyolefines (Paper by Dr. J. W. Reppe, I.G. Farben Research Chemist).* With Appendix.

BIOS 138. [CW]

BIOS 139.

BIOS 140. *The Work Done During the War by the Static Unit of the D.V.L.*

BIOS 141.

BIOS 142. *Information Obtained from Targets of Opportunity in the Sonthofen Area.* [Zuse, atomic aircraft, fuel-air explosives, Josef Ernst, von Ardenne, Zippermayr, etc.]

BIOS 143. *German Porous Ceramic Industry.*

BIOS 144. *Wrought Light Alloy Plants in North-West Germany.*

BIOS 145. *Technical High School, Munich.*

BIOS 146. *Air and Oil Filtration in Germany.*

BIOS 147. *Reciprocating Aero Engines (Daimler Benz).*

BIOS 148. *German Betatrons.*

BIOS 149. *Report on Visit to H. Maihak A.G., Hamburg.*

BIOS 150. *Some Aspects of the German Leather Industry.*

BIOS 151. *German Aluminum and Magnesium Melting and Rolling Practices.*

BIOS 152. *Developments in Protective Clothing in Germany.*

BIOS 153. *Miscellaneous German Radio and Communication Targets.*

BIOS 154. *Turntable for German Railway Gun. 28 cm. K 5 (E).*

BIOS 155. [Synthetic fibres]

BIOS 156. *Vereinigte Glanzstoff G.m.b.h. 14–16 Auerschule Strasse, Elberfeld, Wuppertal.*

BIOS 157.

BIOS 158. *Production of Beryllia and Beryllium at Degussa Plants.*

BIOS 159. *Report on Visit to Aerodynamische Versuchsanstalt Göttingen.* [Canadian team]

BIOS 160. *Luftforschungsanstalt Hermann Göring Volkenrode, Brunswick.* [Canadian team]

BIOS 161. *Interview with Dr. Barchfeld, Chemist at Dynamit A.G. at Troisdorf.*

BIOS 162.

BIOS 163. *Some German Aircraft Armament Projects with Particular Reference to Fire Control Developments.*

BIOS 164. *German Oil Seal Manufacturers.*

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BIOS 169. [Lofer—missing at IWM]

BIOS 170. *Visits to American and French Zones. Aircraft and Aircraft Engines.*

BIOS 171. *Catalytic Hydrogenation of Acetylene to Ethylene, Dr. Alexander Wacker Ges. für Elektrochemische Industrie, Burghausen.*

BIOS 172. *Continental Gummiwerke—"Excelsior" Factory, Limmer, Hanover.* [Rubberized clothing for CW protection]

BIOS 173. *Gummiwaren Fabrik Pheonix, Harburg/Hamburg.*

BIOS 174. *Hanauer Gummischuh Fabrik A.G., Hanau am Main.*

BIOS 175. *Dräger Werke, Lübeck and Hamburg.* [CW protective clothing]

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BIOS 178. *Textile Testing in Germany.*

BIOS 179. *German Cable Industry.*

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BIOS 182. *German Coast Artillery Equipment Employed in the Defence of the West Coast of Denmark.*

BIOS 183. *Report on Investigation of the Design and Operation of High Voltage Networks in Central Germany.*

BIOS 184. *German Camera Industry.*

BIOS 185. *The Cellulose Plastics Industry in Germany.*

BIOS 186. *Dehydrated Potatoes and Vegetables.*

BIOS 187. [CW]

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BIOS 192. *Supersonic Wind Tunnels and Static Testing of V2.*

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BIOS 195. *Interrogation of Personnel of Elektro-Mekanische Werke.* [Rockets]

BIOS 196. *German Rayon Industry.*

BIOS 197. *Reichsinstitut für Erdolforschung, Technische Hochschule, Hannover.*

BIOS 198.

BIOS 199. *"Ten Years of Oxygen-Gasification at Leuna" by Oberingenieur Sabel.*

BIOS 200. *Organisation of Deutsche Versuchsanstalt für Luftfahrt (D.V.L.).*

BIOS 201. *Visit to C.H.F. Müller AG Röntgenstr. 24 Bahrenfeld, Hamburg.*

BIOS 202.

BIOS 203. *The Non-destructive Testing of Materials and X-Ray Protection Methods.*

BIOS 204. *Hochfrequenz Forschungsinstitut of Dr. Plendl, Thumersbach, Austria.*

BIOS 205. *The K.W.I. für Eisen Forschung Düsseldorf.* [X-ray stress measurement]

BIOS 206.

BIOS 207. *The Magnetophon of A.E.G. 150 Hohenzollern Damm. Berlin/Grunewald.* [short and grumpy]

BIOS 208. *Acoustics Laboratories of the Physikalische Technische Reichsanstalt Göttingen.*

BIOS 209.

BIOS 210. [Submarine anti-sonar coating]

BIOS 211. *Infra-red Research, Dr. A. Becker, 36 Blumenthal Strasse, Heidelberg.*

BIOS 212. *Ultra-sonic Research and Development in X-Ray Equipment. Siemens-Reiniger Werke, AG Erlangen.* [6 MeV betatron]

BIOS 213. *Siemens-Halske Werke, Erlangen.*

BIOS 214. *Non-destructive Testing of Materials, Siemens-Werner Werk "M", Berlin/Siemenstadt.* [ultrasonic sonograms of objects]

BIOS 215. *Interview with Prof. Dr. Rudolf Hase, Bismark Strasse, Gehrden.* [IR bolometer]

BIOS 216. *Report on Visits to (1) the Technical High School, Darmstadt, (2) C. F. Boehringer und Söhne, Mannheim—Waldhof, (3) Dr. Freudenberg, Heidelberg University, (4) Dr. Wolman, Wood Preservation Specialist, Bad Kessingen, (5) Imbert Gas Producer Plant, Cologne.*

BIOS 217.

BIOS 218. *Investigation of Planetaria.*

BIOS 219. *Work on Synthesis and Production of Drugs 3065 (2:2*^{1}*-Dihydroxy-5:5*^{1}*-Dibrome Benzil) and 3214 (2:2*^{1}*-Dihydroxy-3:3*^{1}*-5:5*^{1}*-Tetrachlor Benzil).*

BIOS 220. *Citric acid from fermentation process.*

BIOS 221. *Propeller Development at V.D.M., Frankfurt am Main.*

BIOS 222.

BIOS 223. *Visit to Austro-American Magnesite Co., Radenthein, Austria.*

BIOS 224. *German Underwater Ballistics.*

BIOS 225. *German Gear Cutting Plant, Gear Manufacturing Technique and Design Development.*

BIOS 226. *Metallised Paper Capacitors.*

BIOS 227. *Manufacture of Harmonicas (Mouth Organs) and Accordions.*

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BIOS 229. *Wrought Light Alloy Plants in Southern Germany.* [Aluminum]

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BIOS 232. *Production of Tantalum at the Works of Siemens and Halske.*

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BIOS 235.

BIOS 236. *Developments in Pure and Applied Microbiology (American, British and French Zones) During World War II.* [lots of biotech]

BIOS 237. *Housing Research of the Institut f”ur Technische Physik, Technische Hochschule Stuttgart.*

BIOS 238. *Visit to Mahle Kom. Ges. Pragstrasse 26, Stuttgart, Bad Cannstadt.*

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BIOS 240. *Synthetic Tanning Agents and Leather Auxiliary Products of the I. G. Farbenindustrie.*

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BIOS 242. *Lurgi Apparatebau G.m.b.H. Electro Filter Section.*

BIOS 243.

BIOS 244. *I.G. Hoechst and Ludwigshafen, Manufacture of Sulphuric Acid, I.G. Converter Design and Vanadium Catalyst.*

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BIOS 247. *German Chemical Plant with Particular Reference to Centrifuges.*

BIOS 248. *The Radio Valve and Lamp Industry in Vienna.*

BIOS 249. *Rockets and Guided Missiles.*

BIOS 250. *German Research into Increasing Range and Performance of Flame Throwers.*

BIOS 251. *German Landing Gear, Design and Testing.*

BIOS 252. *I. G. Photopapier Fabrik (AGFA), Leverkusen, Near Cologne.*

BIOS 253. *Production of Silumin Alloys, Horrem.*

BIOS 254. *German Aircraft Industry.*

BIOS 255. *Gas Turbine and Reciprocating Engine Activities.* [piezo sensors, etc.]

BIOS 256. *Phosphoric Acid and Sodium Phosphates in Germany.* [Synthetic citric acid]

BIOS 257. *Metallgesellschaft A.G., Frankfurt, Chemicals for Phosphating Iron and Steel.*

BIOS 258. *Carbon Electrodes, I.G. Farben, Griesheim.*

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BIOS 260.

BIOS 261. *Hydrofluoric Acid Vereinigte Flusspathgruben G.m.b.H. Stulln.*

BIOS 262. *German Photographic Film Base Industry.*

BIOS 263. *Part I. I.G. Farben Industrie-Oppau Works, Ludwigshafen (Report on Nickel and Iron Powder Plants. Part II. Nord Deutsche Affinerie, Hamburg (Report on the Treatment of Nickel-Copper Ores and Residues).*

BIOS 264. *German Brass and Copper Wire Industry.*

BIOS 265. *The German Bichromate and Chrome Compound Industry.*

BIOS 266. *New Technical Applications of Acetylene.* With Appendix. [Periston]

BIOS 267.

BIOS 268. *German Test Equipment for Materials and Vehicle Components.*

BIOS 269. *A Survey of Some Aspects of German Development on Power Plants and Air Compressors Suitable for A.F.V.*

BIOS 270. *Investigations in Germany by Tank Armament Research, Ministry of Supply.*

BIOS 271.

BIOS 272. *Some Aspects of German Work on High Temperature Materials.* [High temp jet materials + SiC]

BIOS 273. *Symposium of Interrogations and Reports on German Methods of Statistical Reporting.*

BIOS 274. *Technical Developments in German Margarine Industry.* With Addendum.

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BIOS 276. *Telefunken Gesellschaft für Drahtlose Telegraphie m.b.h., Berlin; Special Materials for Radio Valves.*

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BIOS 278. *Preliminary Survey of the German Hydraulic Industry.*

BIOS 279. *German Technique in the Production of Light Alloys.*

BIOS 280. *Interrogation of Professor Alexander von Philippovich. Petroleum Technologist.*

BIOS 281. *German Circular Lace Braiding Machine Building Industry.*

BIOS 282. *German Casein Plastics Industry.*

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BIOS 284. *German Production of Guns, Gun Mountings and Carriages and Small Arms.*

BIOS 285. *Structural Work at Focke-Wulf, Bad Eilson.*

BIOS 286. *Krupps, Essen and Incorporating Information on Luftfahrtgerätewerke, Hakenfeld Berlin and Activities by Dudenhausen at Rietberg.*

BIOS 287. *Barytes and Pyrite in North-West Germany.*

BIOS 288. *Aluminium Hydrate and Alumina Production in German Factories.*

BIOS 289. *Report on German Textile Machinery Firms.*

BIOS 290. *The Viscose Continuous and Rayon Staple Fibre Plants of the British, American and French Occupation Zones of Germany.*

BIOS 291. *Visit to Deutsche Eisenwerke and Deutsche Rohrenwerke, at Mulheim.*

BIOS 292. *German Aircraft Development as Applicable to Civil Transport.*

BIOS 293. *Methods of Shock Wave Measurement in German Armament Research Establishment.*

BIOS 294. *Hydrogen Peroxide Works of Otto Schickert & Co., at Bad Lauterberg and Rhumspringe.* [Silicon detectors]

BIOS 295. *German S.A.A. Factories.*

BIOS 296. *German Non-Ferrous (Copper-Base) Foundry Industry.*

BIOS 297. *Norddeutsche Seekabelwerke Nordenhaus.*

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BIOS 300. *Investigation of the Developments in the German Automobile Industry During the War Period.*

BIOS 301. *German Piston and Piston Ring Industry.*

BIOS 302. *Investigation of Henk Heinrichs' Claim in Connection with the Refining of Aluminium Alloy Scrap.*

BIOS 303. *Production of Luminous Compounds at the Works of Auer Gesellschaft A.G.*

BIOS 304.

BIOS 305. [Insulin]

BIOS 306. *The Manufacture of Caffeine and Theophyline in the U.S. and French Zones.*

BIOS 307. *German Secondary Batteries (with Special Reference to Those Used by Army Signals).* [Alkaline batteries]

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BIOS 310. *Flexible Pipes, Flexible Fuel Tanks and Self-Sealing Fuel Tank Coverings for Aircraft.*

BIOS 311. *Production of Aluminium Sulphate Giulini.*

BIOS 312. *German Papermaking Industry.*

BIOS 313. *Report on Visit to Czechoslovakia by Armament Design Department.* [mentions many significant people and places but gives no significant scientific details]

BIOS 314. *The German Electricity Supply System.*

BIOS 315. *Berliner Lübecker Maschinen Fabrik, Lübeck.*

BIOS 316. *German Light Alloy Foundry Industry.*

BIOS 317. *German Glass Manufacture as Applied to Illumination with Particular Reference to Aviation Lighting.*

BIOS 318. [Oxygen breathing apparatus + suits Draeger]

BIOS 319. *Production of Beryllium "Degussa".*

BIOS 320. *German Aero Engine Industry.*

BIOS 321. *Steel Propellor Blade Development at V.D.M., Hamburg.*

BIOS 322. *Rheinmetal Borsig A.G. Düsseldorf.* [brief report on guns, not missiles]

BIOS 323. *Waggonfabrik A.G. (Ringfeder G.m.b.H.), Uerdingen.*

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BIOS 327. *Dandy Roll Making Industry.*

BIOS 328. *Antimony Smelting Industry.*

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BIOS 330. *Wirtschaftliche Forschungsgesellschaft m.b.H. (WIFO) Eickeloh Installation. Investigation of the Installation and Interrogation of the Personnel.*

BIOS 331. *Amalia Benzole Refinery, Harpener Bergwerksverein, Bochum.*

BIOS 332. *Chemische Fabrik Weyl A.G., Sandhoferstr. 96–106, Mannheim—Waldhof.*

BIOS 333. *Winkler Generators for Manufacture of Water Gas, Etc.*

BIOS 334. *Developments of Geophysical Prospecting in Germany During the War.*

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BIOS 336. *Investigation of Steam Generating Plants and Boiler Practice in Central Germany.*

BIOS 337. *German Graphitising Furnances at Meitingen (Siemens Plania).*

BIOS 338. *German Carbon Electrode Manufacture at Griesheim (I.G.F.).*

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BIOS 341. *German Chemical Plant Manufacture.*

BIOS 342. *The German Wartime Electricity Supply: Conditions, Development, Trends.*

BIOS 343. *German Diesel Engine Industry.*

BIOS 344.

BIOS 345. *A German Thermometer for Use in the Range 400°–1200°C.* [thermometer using gallium instead of mercury]

BIOS 346. *The German Ball and Roller Bearing Industry.*

BIOS 347.

BIOS 348. *German Plywood, Improved Wood, Shuttle Block and Joinery Industries.*

BIOS 349. *German General Rubber Goods Industry.*

BIOS 350. *The Synthesis of Intermediates for Polyamides on an Acetylene Basis (Translation of a Report by Dr. W. Reppe, Ludwigshafen).* [Use of acetylene to synthesize dicarboxylic acids, amino acids, diamines, and polyhydric alcohols]

BIOS 351. *Preparation of Adipic Acid from Tetrahydrofuran and Carbon Monoxide.*

BIOS 352. *Cyclopolyolefines. Miscellaneous Report Compiled from Interviews with Dr. Reppe, Dr. Schlichting and Dr. Kröper (I.G. Farben, Ludwigshafen).*

BIOS 353. *Preparation of 5-Diethylaminopentanol-2 by the Reppe Process.*

BIOS 354. *Polvinyl Pyrrolidones. Translation of a Report by Dr. Fikentscher and Dr. Herrle, Ludwigshafen, with an Addendum on Periston (Synthetic Blood Serum).*

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BIOS 356. *Characterisation of Butadiene Catalysts by X-Ray and Chemical Analysis.*

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BIOS 358. *Acrylic Esters, Synthesis from Acetylene and Nickel Carbonyl.*

BIOS 359.

BIOS 360. *Notes on Manufacture of Ethylene Oxide by I.G. Farben.*

BIOS 361. *Non-Metallic Materials for Aircraft: Visits to Research Establishments in Germany.* [engine oils, coolants, paints, etc.]

BIOS 362. *German Primary Battery Industry.*

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BIOS 364. *Kalle and Co., Aktiengesellschaft, Wiesbaden, Biebrich.* [Enzymes]

BIOS 365. *German Aircraft Paints.* [Heat reflecting paints]

BIOS 366. *German Textile Dyeing, Drying and Finishing Engineers.*

BIOS 367. *Manufacture of 1:4 Butinediel at I. G. Ludwigshafen, Including Manufacture of 1:4 Butanediel and Tetrahydrofuran, Precautions in Handling Acetylene, and Semitechnical Precautions of 1:4 Butenediel.* [Synthetic rubber]

BIOS 368. *Manufacture of Adipic Dinitrile and Hexamethylene Diamine.*

BIOS 369. *Manufacture of Hydrazine Hydrate.*

BIOS 370. *Manufacture of Acetaldehyde.*

BIOS 371. *Regeneration of Nickel Carbonyl (from Aqueous Solutions).*

BIOS 372. *German Tin Smelting and Allied Industries.*

BIOS 373. *I.G. Farbenindustry AG Ludwigshafen (Fuels and Lubricants).*

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BIOS 375. [Aluminum]

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BIOS 384. *German Battery Electric Vehicles and the German Storage Battery Industry.*

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BIOS 389. *Production of Alcohol and Yeast from Waste Sulphite Liquor by the Zellstofffabrik Waldhof Company.*

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BIOS 395. *German Fluorescent Lamp Industry and Phosphor Chemical Manufacture.*

BIOS 396. *Report on Visit to Germany and Austria to Investigate Alloys for Use at High Temperature.*

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BIOS 400. *The Cerium Industry in German Territory including Reports on Radium and Mesothorium.*

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BIOS 407. *D.R.P. Broadcasting Studios, München.*

BIOS 408. *Contact Rectifier for Heavy Currents, by Siemens Schuckert—Berlin.*

BIOS 409. *D.C. Cup Type Motors by Siemens Schuckert Zaehlerwerk, Nürnberg.*

BIOS 410. *Some Electrical Factories in Berlin—British Zone.*

BIOS 411. *Miscellaneous Electrical Factories in the British and American Zones.* [Condensers of metallized paper, durac batteries]

BIOS 412. *The Ott Differential Analyser.*

BIOS 413. *Primary Cells by Prof. A. Schmid.*

BIOS 414. *Prof. Dr. Ing. Humburg, Technische Hochschule—Hannover.*

BIOS 415. *P.J. Kipp en Zonen.*

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BIOS 417. *M.A.N. Track Testing Equipment.*

BIOS 418. *Textile Auxiliary Products—Manufacture, I.G. Farbenindustrie, Hoechst.*

BIOS 419. *I.G. Waxes: Manufacture at Gershofen and Oppau.*

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BIOS 421. *Textile Auxiliary Products: Manufacture by I.G. Farbenindustrie, Ludwigshafen.*

BIOS 422.

BIOS 423. *Deutsche Gold und Silber Scheide Anstalt (Degussa)—Frankfurt.* With Appendix. [Dental quick hardener]

BIOS 424. *Chemische Fabrik Dr. Jacob—Bad Kreuznach. Manufacture of Carbon Bi-sulphide, Thiourea and Ammonium Thiocyanate.*

BIOS 425. *A.G. für Chemische Industrie, Gelsenkirchenschalke (a Controlled Subsidiary of the I.G.). Manufacture of Carbon Bi-sulphide.*

BIOS 426. *German Organic Chemical Industry.*

BIOS 427. *Investigation of German Engravers of Rollers and Plates as Used by Wall Paper, Leather and Leather Cloth Industries.*

BIOS 428. *German Rayon and Staple Fibre Industry and Allied Engineering Industry.*

BIOS 429. *German Electroplating Industry.* [Electroplating on aluminum]

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BIOS 431. *German Watch and Clock Industry.*

BIOS 432. *German Pyrotechnic Dyestuffs and Synthetic Consolidating Materials to Obviate the Pressing of Pyrotechnic Compositions.*

BIOS 433. *Investigation of German Plastics Plants: Part IV. Additional Information on Thermosetting Resins and Processing of Polystyrene.*

BIOS 434. *Sunlicht A.G., Mannheim.*

BIOS 435. *Ozalid Light-Sensitive Materials, Kalle & Co., Wiesbaden—Biebrich (I.G. Farbenindustrie A.G.).* [Ozalid chemical-coated paper for dry photocopying]

BIOS 436. *Enzyme Products and "Acrisin" Finishing Agents for Textiles: Rohm and Haas G.m.b.H., Darmstadt.* [Enzymes for washing]

BIOS 437. *Production of Cast Iron Porcelain Enamelled Baths in Germany.*

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BIOS 441. *The Platinum Metals Industry in Germany.* [Rhodium mirrors]

BIOS 442. *Performance of Pfauter Hobbing Machine Employing "Giant" Hobs.*

BIOS 443. *Some Notes on German Hollow Turbine Blade Manufacture.*

BIOS 444. *Compressed Air Turbine Developed by the Karlsruhe Technical High School.*

BIOS 445. *Investigation of German Plastics Plants Part III. Processing of Polyvinyl Chloride.*

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BIOS 449. *German Medical Targets.* [Pharmaceuticals, hormones, antibiotics, cancer research, DDT]

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BIOS 463. *Miscellaneous Technical Information on the Development of Pyrotechnics.*

BIOS 464. *German Pest Control Industry, Pflanzenschutz—Stahler, Erbach—Rheingau.* [Fungicides]

BIOS 465. *High Temperature Refractories and Ceramics.*

BIOS 466. *German Parachute Design and Manufacture.*

BIOS 467. *German Secondary Battery Industry.* [Alkaline batteries]

BIOS 468. *The Manufacture of Synthetic Crystals in the Plant of I.G. Farbenindustrie Oppau—Ludwigshafen.* [halite crystals]

BIOS 469. *Slotted Tube Catapult Operated by T and Z Stoff for Launching the Flying Bomb (Preliminary Survey).*

BIOS 470. *Specialized Ceramic Materials with Particular Reference to Ceramic Gas Turbine Blades.* [High-temp ceramics]

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BIOS 472. *German Lead, Copying and Coloured Pencil Manufacture, and Allied Industries.*

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BIOS 477. *German Pyrotechnic Factories.* [Aluminum powder for pyrotechnic manufacture]

BIOS 478. *Textile Auxiliary Products: Development of Mersol and Hostapon Processes by I.G.*

Farbenindustrie, Höchst.

BIOS 479. *Some Aspects of the German Peat Industry.*

BIOS 480. *German Spectacle Frame Industry.*

BIOS 481.

BIOS 482. *German Reclaimed Rubber Industry.*

BIOS 483. *Report on Investigation of Research in Animal Diseases in Germany and Austria 1939–1945.* [relatively mundane work, nothing on Riems]

BIOS 484. *The German Printing Industry.* [Photocopying, color printing, and photography]

BIOS 485. *German Filtration Industry.* [Electron microscopes]

BIOS 486. *The Manufacture of Line Telecommunications Equipment in Germany.*

BIOS 487. *German Wheel Manufacture.*

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BIOS 489. *Chemische Fabrik Joh. A. Benckiser, G.m.b.H. Ladenburg Works. Manufacture of Calcium Citrate.*

BIOS 490. *Primary Battery Development by the Chemische-Physikalische Versuchsanstalt, Danisch Nienhof.*

BIOS 491. *Some German Pulse Communication and F.M. Systems.*

BIOS 492. *Explosives Work and Associated Photographic Technique.* [measurement techniques according to some of Hubert Schardin's staff]

BIOS 493. *Certain Aspects of the German Fishing Industry.* [flash freezing and antioxidants for fish preservation]

BIOS 494. *Research and Development of Life Saving Equipment Medical Aspects of Shipwreck.* [Human expts]

BIOS 495. *Copper and Copper Base Alloy Tube Manufacture in Germany.*

BIOS 496. *Extraction of Copper and Other Metals from Pyrites Cinder.*

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BIOS 500. *The Ljunqström Turbines in Germany.*

BIOS 501. *Rugged Valves and Mechanical Tests for Valves and Components.* [fuzes for rockets]

BIOS 502. *Plant Breeding.*

BIOS 503. *Materials and Aerodynamics Research Institutes, Sonthofen, Bavaria.*

BIOS 504. *Visit to Metallgesellschaft A.G., Frankfurt a.M.*

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BIOS 506. *German Skate Industry.*

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BIOS 508. *Fried. Krupp, Germaniawerft, Kiel: Water Brake Dynamometers.*

BIOS 509. *Voith-Schneider Propellor.* [Visit to J. M. Voith Works at Heidenheim]

BIOS 510. *Samples of Petroleum Products Collected from the Hamburg, Hannover, Bremen and Kiel Area.*

BIOS 511. *Ruhr-Chemie A.G. Sterkrade Holten. Interrogation of Dr. O. Roelin.*

BIOS 512. *Schlafhorst Chemische Werke G.m.b.H., Hamburg, Germany: Lubricants.*

BIOS 513. *Notes on the Organisation of the German Petroleum Industry During the War.*

BIOS 514. *German Textile Industry.*

BIOS 515. *Report on the Interrogation of Dr. Erich Scholz, an Expert on Electric and Percussion Caps, Formerly Employed by D.W.M. (Grötzingen).*

BIOS 516. *Petrological Microscopes (Germany).* [polarizing microscopes]

BIOS 517. *Brass Hardware and Fittings.*

BIOS 518. *Textile Auxiliary Products of I.G. Farbenindustrie: Application, Testing and Miscellaneous Information.* [Fire proofing of fabrics]

BIOS 519.

BIOS 520. *German Experimental Work on the Attack of Reinforced Concrete by Explosives and Projectiles and Inspection of the Möhne and Eder Dams, September, 1945.*

BIOS 521. *Lurgi High Pressure Gasification.*

BIOS 522. *I.G. Farbenindustrie A.G., Höchst. The De-Ashing of Coal by Combined Jig Washing, Froth-Flotation, and Extraction with Caustic Soda.*

BIOS 523. *Carl Alexander Mine, Baesweiler Near Alsdorf. The De-Ashing of Coal by Froth Flotation and Acid Extraction and the Ruhrwerks Coal Cleaning Process.*

BIOS 524. *Deutsche Gasolin A.G., Hamburg, Germany: Lubricants.*

BIOS 525. *Staatlisches Material Prüfungsamt, Unter den Eichen 86–87, Berlin-Dahlem.*

BIOS 526. *Development and Manufacture of Alberich.* [Submarine sonar absorbing coating]

BIOS 527. *Iron, Steel and Non-Ferrous Metal Works Plant and Machinery.*

BIOS 528. *Report on Dams and Hydro-electric Schemes in South West Germany.*

BIOS 529. *Investigation of Targets Connected with the German Plywood Industry.*

BIOS 530. *Photosurfaces, a Report on German Developments of Photocells, Electron Multipliers, Television Pick-Up Tubes.* [Electron multipliers, photocells, guided projectiles, TV valve]

BIOS 531.

BIOS 532. [Magnetic analyzer for oxygen in air, IR spectroscopy of gases]

BIOS 533. *Electric Furnace Design. Manufacture and Application in Germany.*

BIOS 534. *The Organisation of the German Chemical Industry and Its Development for War Purposes.*

BIOS 535. *German Edgewise Pressure Gauge Manufactured by Dreyer, Rosenkranz and Droop.*

BIOS 536. *Tallöl: Its Processing and Utilization in Germany.*

BIOS 537. *Investigation of Production Control and Organisation in German Factories.*

BIOS 538. *Report on German Patent Records.*

BIOS 539. *German Incendiary Bomb Manufacture and Development: German Explosive, Propellant and Cellulose Derivative Manufacture.*

BIOS 540. *German Types of Heating and Coolers for Marine and Land Applications.*

BIOS 541. *Some German Methods of Grading and Surface Coating of Abrasives.*

BIOS 542. *Interrogation of Certain German Personalities Connected with Chemical Warfare.*

BIOS 543. *The German Cycle and Cycle Components Industry.*

BIOS 544. *Interrogation of Generalmajeur Holzhauer.* [tank development]

BIOS 545. *Seifenfabrik Rose, Frankfurt-Osthafen.*

BIOS 546. *Melliand Textilberichte, Heidelberg.*

BIOS 547. *"Tylose" Cellulose Derivatives, Kalle & Co. A.G., Wiesbaden-Biebrich.*

BIOS 548. *German Camera Manufacture, Plant and Equipment.* [Camera lenses and shutters]

BIOS 549. *Calculating Machines: Plant and Equipment.*

BIOS 550. *Investigation of Beryllium Production in Germany and Italy Including Production and Uses of Oxides and Alloys.*

BIOS 551. *German Wireless Communication: Mainly with Reference to Cm, Dm, and Pulse Technique.* [Klystrons]

BIOS 552. *Report on the Investigation on the Production of Synthetic Crystals in Germany and Copenhagen.* [IR and UV crystals, piezoelectrics]

BIOS 553.

BIOS 554. *Ampules and Vial Making Machines, Improvements and Developments in Germany.*

BIOS 555. *German Naval Distilling Equipment.*

BIOS 556.

BIOS 557. *Visits to Radio Targets in Germany.* [Batteries]

BIOS 558. *Boule Manufacture, Wiede's Carbidwerk—Bavaria.*

BIOS 559. *German Flying Boat Research and Development.*

BIOS 560.

BIOS 561. *The Manufacture of Sodium Sulphide at I.G. Farben Fabrik, Wolfen.*

BIOS 562. *The German Phosphorus Industry at Bitterfeld & Piesteritz.*

BIOS 563. *The German Radio Component Industry.* [condensers, amplifiers, photo-electric cells, rectifiers, novel batteries, etc.]

BIOS 564. *Industrial Electronic Measuring Equipment.* [X-ray dosimeter]

BIOS 565. *German Chain Industry.*

BIOS 566. *A Visit to Germany to Investigate Wartime Advances in Certain Branches of Applied Physiology. (Revised)* [aviation medicine experiments; immersion of "dogs" (probably actually humans) in cold water and then revival, etc.]

BIOS 567. *Resistors and Fixed Capacitors Produced in Germany.*

BIOS 568. *Printing Process Used by the Wehrmacht.*

BIOS 569. *German Glass or Enamelled Lined Equipment on Mild Steel and Cast Iron for Chemical–Food–Drink and Allied Industries.*

BIOS 570. *Development of Hollow-Charge Work by Rheinmetall Borsig, Berlin.* [interview with Dr. Hermann]

BIOS 571. *German Rocket Propellants (Interrogation of Mr. N. W. Larsson).* [Solid rocket propellant with butadiene and ammonium perchlorate]

BIOS 572. *Investigation into Manufacture and Use of Carbon Blacks and Lamp Blacks in Germany.*

BIOS 573.

BIOS 574. *A Survey of the German Cotton, Rayon and Silk Industries.*

BIOS 575. [Autobahn]

BIOS 576. *German Limeburning Industry.*

BIOS 577. *German Car Industry, Special Servicing Equipment for Cars.*

BIOS 578.

BIOS 579. *The Z.F. Electro-Magnetic Transmission with a Special Application for the Panther*

Tank.

BIOS 580. *Reports on Tests of the Wagner Boiler Company with a Model Boiler.*

BIOS 581. *Hot Rolled Strip Mills.*

BIOS 582.

BIOS 583. [Teleprinter]

BIOS 584. *Investigation of the German Oil Engine Industry: Design, Research and Production.*

BIOS 585.

BIOS 586. *Ernst Schliemann's Oelwerke und Export-Cerecin-Fabrik, Hamburg—Germany.*

BIOS 587. *German Naval Mining Relays and Moulded Powder Permanent Magnets.*

BIOS 588.

BIOS 589. *German Light Alloy Die Casting Industry—Machine Tools for Die Sinking.*

BIOS 590.

BIOS 591. *Large Scale Production of Oxygen and Atmospheric Gases.* [focuses mainly on Linde process, mainly on Leuna]

BIOS 592.

BIOS 593. *Dynamit A.G. Schlebusch.*

BIOS 594. *The Production and Application in Germany of High Silicon Acid Resisting Iron.*

BIOS 595. *Sintered Iron and Steel Components.*

BIOS 596. *Gesellschaft für Teerverwertung, Varziner-Strasse, Duisburg-Meiderich, Ruhr.* [tar distillation]

BIOS 597. *Interrogation of Dr. C. H. N. Bensmann, October 10th, 1945.* [oil]

BIOS 598. *Oelwerke Julius Schindler G.m.b.H., Hamburg—Germany.*

BIOS 599.

BIOS 600. *German Heavy Electrical Industry: Motors and Power Transformers.*

BIOS 601. *German Mattress and Furnishing Spring Making Industry.*

BIOS 602. *German Plywood Industry: Interrogation of Dr. Doffine.* With Appendix.

BIOS 603. *The Investigation in Germany of Technical Developments in Prefabricated Housing.*

BIOS 604. *The Shellac Industry in Germany.*

BIOS 605. *Some Marine Applications of Light Alloys in Germany.*

BIOS 606. *The Design of German Telephone Subscribers' Apparatus.* [Crystal telephone amplifiers,

audiometer, telecommunications]

BIOS 607. *German Wire Rope Industry.*

BIOS 608. *The Manufacture of Electrical Measuring Instruments in Germany.* [Selenium rectifiers]

BIOS 609. *Non-destructive Testing of Materials.* [ultrasound imaging]

BIOS 610.

BIOS 611. *Utilisation of Washery Refuse as Boiler Fuel in Ruhr Coal Mines.*

BIOS 612. *Klein Schanglin and Becker A.G.: Hydraulic Couplings and Torque Converters.*

BIOS 613. *Cordage Industry.*

BIOS 614. *Welding Design & Fabrication of German Tank Hulls & Turrets.*

BIOS 615. *The Continuous Tar Distillation Still at Gesellschaft für Teerverwertung.*

BIOS 616. *Inspection of Krupp-Lurgi Plants for the Carbonisation of Coal at Low Temperatures.*

BIOS 617. *Top Stripping Equipment Used in Open Caste Coal Working.*

BIOS 618. *German Bright Steel Bar Industry.*

BIOS 619. *Developments in the German Steel Tube Industry.* With two Addenda.

BIOS 620. *The German Motor-Cycle Industry.*

BIOS 621. *The Manufacture of Wofatit Base-Exchange Resins.* [anion exchange resins for purification]

BIOS 622. *Investigation of Cold-Cathode Tubes Made by Siemens Reiniger Werke, Rudolstadt: Part II—Production Details.*

BIOS 623. *Lurgi Gesellschaft für Warmetechnik, Frankfurt-am-Main.* [Bacteriological process for phenol removal]

BIOS 624. *German Jute Industry.*

BIOS 625. *German Wire Rod Rolling Industry.*

BIOS 626. *Drying, Briquetting and Low-Temperature Carbonisation of Brown Coal in Lurgi-Spülgas Retorts.*

BIOS 627. *The Worsted Spinning Industry in the British and U.S. Zones of Germany.* [glass fibers]

BIOS 628.

BIOS 629. *Investigation of Synthetic Resins Used in the German Surface Coating Industry.* [polyurethane and other synthetic polymer coatings]

BIOS 630. *German Dental Industry.*

BIOS 631. *Netting Industry.*

BIOS 632. *German Gauge and Tool Industry.*

BIOS 633. *Manufacture of Oxalic Acid at I.G. Farbenindustrie, Bitterfeld.*

BIOS 634. *The Processing of Rayon Staple Fibre on Cotton Spinning Machinery in Germany.*

BIOS 635. *Mineralölwerke Albrecht: Lubricants.*

BIOS 636. *Mineralölwerke F. Harmsen, Kiel—Germany: Lubricants.*

BIOS 637. *Olex Deutsche Benzin und Petroleum Gesellschaft: Fuels and Distribution.*

BIOS 638. *Deutsche Erdöl A.G., Hamburg—Germany: Crude Oil and Products.*

BIOS 639. *Deurag-Nerag Gewerkschaft, Deutsche Erdöl Raffinerie und Neue Erdöl Raffinerie: Fuels and Lubricants.*

BIOS 640. *German Precision Chain Industry (British and American Zones Only).*

BIOS 641. *The German Machine Tool Industry.* [electronic control of machine tools—not much information beyond the fact that it existed in wartime Germany]

BIOS 642. *Performance of Pfauter Hobbing Machine Employing "Giant" Hobs.*

BIOS 643. *German Anodising Practice.*

BIOS 644. *Detonator Factory, D.A.G., Troisdorf.*

BIOS 645. *German Woodbending Industry.*

BIOS 646. *German Paper Machine Wire Industry.*

BIOS 647. *Research and Development of Snow-Moving and Snow Crossing Vehicles in Germany.*

BIOS 648. *Ordnance Muzzle Brakes.*

BIOS 649.

BIOS 650. *Armament Production and Design.*

BIOS 651. *German Docks and Harbours.*

BIOS 652. *German Furnishing Fabric Industry.*

BIOS 653.

BIOS 654. *Lead-Zinc-Copper Mining in the Harz and Lead-Zinc Mining in the Ruhr Coalfield.* [many tons of zinc, lead, and copper]

BIOS 655. *Manufacture of Brushes in Germany.*

BIOS 656.

BIOS 657. *German Laboratory Porcelain Industry.*

BIOS 658. *German Photographic Industry.*

BIOS 659. *Interview with Dr. Stocklin, Formerly of the Leverkusen Laboratories of A.G. Farbenindustrie A.G.* [Buna]

BIOS 660. *Rütgerswerke A.G. Rauxel.*

BIOS 661. *Manufacture of Vulcanisation Accelerators and Antioxidants.*

BIOS 662. *Manufacture of Phenylbetanaphthylamine at I.G. Farbenindustrie, Ludwigshafen.*

BIOS 663.

BIOS 664. *I.G. Farbenindustrie Leverkusen.* [Salicylic acid]

BIOS 665. *C. F. Boehringer & Sohne, Sandhoferstr., Mannheim-Waldhof. Manufacture of Vanillin Coumarin Anisaldehyde.*

BIOS 666. *I.G. Farbenindustrie Uerdingen. Manufacture of Phthalic Anhydride, Benzoic Acid, Etc.*

BIOS 667. *I.G. Farbenindustrie Mainkur.* [Thiamine S and thiamine T chemical manufacture]

BIOS 668. *"Eumuco" Shell Forging Press Usage.*

BIOS 669. *Interview with Dr. Roelig, Formerly of the Leverkusen Laboratories of I.G. Farbenindustrie A.G.* [Hysteresis machine]

BIOS 670. *German Methods of Manufacture of Copper Tuyeres for Blast Furnaces.*

BIOS 671.

BIOS 672. *Production of Nitrous-Oxide GMI.*

BIOS 673. *Production of Krypton-Xenon Mixture.*

BIOS 674. *The German Electrically Welded Steel Tube Industry.*

BIOS 675. *The Production of Thorium and Uranium in Germany.*

BIOS 676. *German Metallurgical Laboratories for Ferrous Metals with Special Reference to the K. W. Institute for Iron Research.* [KWI measuring boron in steel]

BIOS 677. *German Clock and Watch Dial Production.*

BIOS 678. *Manufacture of Cement and Sulphuric Acid from Anhydrite, I.G. Farbenfabrik Wolfen.*

BIOS 679. *I.G. Farben Works at Bitterfeld. Manufacture of Potassium Dichromate and Chromic Oxide.*

BIOS 680. *Manufacture of Caustic Soda, Chlorine and HCl, I.G. Farbenfabrik Wolfen.*

BIOS 681. *German Cold Rolled Strip Industry.*

BIOS 682. *German Transformer Industry.*

BIOS 683. *Hydrogen Peroxide—Production by Electrolysis of 35 Per Cent. Solutions. Deutsche Gold und Silber Anstalt.*

BIOS 684. *Production of Molybdenum & Tungsten for Radio Valves & Electric Lamps, Metallwerke Plansee, Reutte, Tyrol.* [Advanced lamp bulbs, radio valves]

BIOS 685. *German Ingot Moulds for the Casting of Steel Ingots.*

BIOS 686.

BIOS 687. *The Design of German Line Telecommunications Transmission Systems.* [Amplifiers, condensers, valves]

BIOS 688. *Interview with Dr. Stocklin & Dr. Roelig, Formerly of the Leverkusen Laboratories of I.G. Farbenindustrie A.G.* [Buna interrogation]

BIOS 689. *Interrogation of Dr. Casper, Dr. Eisenmann, Dr. Mersch, Dr. Stocklin.* [several different polymers]

BIOS 690. *Prevention of Atmospheric Pollution by Noxious or Offensive Gases, Fumes or Dusts.*

BIOS 691. *Some Aspects of Microbiological Research in Germany.* [Lots of microbiology]

BIOS 692. *German Watch-Jewel Industry.*

BIOS 693. *The Investigation of the Light Alloy Forging Industry in Germany.*

BIOS 694. *Magnesium Pressure Die Casting, Mahlewerk, Fellbach, Stuttgart.*

BIOS 695. *The Design and Operation of German Telephone Exchange Equipment.* [Automatic telephone exchange]

BIOS 696. *The Manufacture of Phosphate Esters at Bitterfeld.*

BIOS 697. *Fire Protection of Oil Installations in Germany.* [protein-based firefighting foams and dispersal methods]

BIOS 698. *Survey of the German Heavy Textile Proofing Industry.* [Fireproofing of fabrics]

BIOS 699. *Methods of Production in Germany of General Heavy Forgings and Railway Axles, Tyres & Wheels.*

BIOS 700. *The German Centrifugal Castings Industry with Special Reference to the Production of Cast Iron Pipe, Cylinder Liners and Piston Rings.*

BIOS 701. *The German Asbestos Textile, Jointing and Friction Lining Industries.*

BIOS 702. *Interview with Dr. Roelig of the I. G. Rubber Service Laboratories, Leverkusen.* [Synthetic rubber]

BIOS 703. *German Methods of Excavating and Briquetting Brown Coal.*

BIOS 704. *Mechanical Foam Liquid and Equipment.* [Fire fighting foam]

BIOS 705. *Mechanical Stokers for Shell Type Boilers.*

BIOS 706. *Metal Powders (Sintered).*

BIOS 707. *Investigation of Research Technique and Testing Equipment in Germany with Reference*

to Problems in the Automobile Engineering Industry.

BIOS 708. *German Alkaline Accumulator Industry.* [Alkaline batteries]

BIOS 709.

BIOS 710. *Manufacture of Biolase (Starch-Hydrolysing Enzyme) at Kalle & Co. (I. G. Farben A. G.) Wiesbaden, Biebrich.*

BIOS 711. *Interrogation of Dr. Hans-Albrecht Kind of Böhme Fettchemie and Henkel & Cie, Düsseldorf.*

BIOS 712. *German Artists' Colour Manufacturers.*

BIOS 713. *Notes on Items of Chemical Plant at Works of: I.G. Farbenindustrie, Knapsack; Dr. Alexander Wacker, Burghausen; Anorgana, Gendorf; I.G. Farbenindustrie Hoechst.* [no CW information]

BIOS 714. *The Development of New Insecticides and Chemical Warfare Agents.* [original edition; revised edition only covers insecticides and is less than half as long!]

BIOS 715. *The Microanalytical Methods Employed in the Analytical Laboratories of I.G. Farben, Elberfeld-Wuppertal, Germany.*

BIOS 716. *German Steel Foundries.*

BIOS 717. *The German Permanent Magnet Industry.*

BIOS 718. *Milling of Barley and Oats in Germany.*

BIOS 719. *Interview with Professor Otto Bayer, Formerly Member of the Directorate and Head of the Scientific Laboratories of the I.G. Farbenindustrie, Leverkusen.* [isocyanates–superglue!]

BIOS 720. *Metallurgical Research and Testing Laboratories in the Stuttgart Area.* [KWI Physics, sonde for testing materials]

BIOS 721.

BIOS 722. *Lurgi Gesellschaft für Wärmetechnik Frankfurt. High Pressure Gasification of Brown Coal.*

BIOS 723.

BIOS 724. *Electronic Principles as Applied in Germany to the Testing of Materials.* [Piezo-electric, electronic materials testing]

BIOS 725. *German Research on Rectifiers and Semi-Conductors.*

BIOS 726. *Television Development at Fernseh.*

BIOS 727. *Manufacture of Anti-Fouling Paints in Germany and Related Matters.* [Anti-IR and anti-radar coatings]

BIOS 728. *A Survey of Certain German Manufacturers of Grain Handling, Cleaning and Milling Machinery.*

BIOS 729.

BIOS 730.

BIOS 731. *Manufacture of Carbon Tetrachloride at I.G. Farben, Bitterfeld.*

BIOS 732. *Lüneburger Wachswerke A.G., Lüneburg—Germany. Waxes.*

BIOS 733. *Brewing and Malting Machinery. Seitz Filter Media.*

BIOS 734. *German Brown Coal Industry.*

BIOS 735.

BIOS 736. *Chemical Laboratory Instrumentation in Germany.* [Mass spectrographs, micro-photometer, etc.]

BIOS 737. *The Investigation of Cast Iron Roll Manufacture in Germany, with Notes on the Usage in Rolling Mill Plants.*

BIOS 738. *Bast Fibre Textile Machinery in Germany.*

BIOS 739. *Maleic Anhydride by Oxidation of Crotonaldehyde at I.G. Ludwigshafen.*

BIOS 740. *C. F. Boehringer und Soehne, Mannheim-Waldhof. Commercial Organic Solvent Production.*

BIOS 741. *Zellstoffabrik A. G., Mannheim.*

BIOS 742. *Preparation and Polymerisation of Vinyl Ethers and Preparation of Acetaldehyde from Methyl Vinyl Ether at I.G. Farbenindustrie, Ludwigshafen.*

BIOS 743. *Manufacture of Cyclohexanol, Cyclohexanone, Cycloketone Resins at I.G. Ludwigshafen.*

BIOS 744. *Manufacture of Vinyl Acetate Polymers and Derivatives at I.G. Hoechst.*

BIOS 745. *Manufacture of Monomeric Vinyl Acetate at I.G. Hoechst.*

BIOS 746. *Vinyl Carbazole and Vinyl Pyrollidone at I.G. Ludwigshafen.*

BIOS 747. *Acetylene by the ARC. Also the Oxosynthesis at Ruhrchemie, Holten.*

BIOS 748. *Manufacture of Fatty Acids by Oxidation of Paraffins, Hydrogenation of the Fatty Acids at I.G. Ludwigshafen-Oppau.* [synthetic fatty acids made from synthetic paraffins made from acetylene, primarily used for making soap]

BIOS 749. *Pilot Plant at I.G. Höchst on the Manufacture of Diketene from Acetic Acid.*

BIOS 750. *Manufacture of Monomeric Styrene at I.G. Ludwigshafen.*

BIOS 751. *Pilot Plant Manufacture of Vinylacetylene at I.G. Hoechst.*

BIOS 752.

BIOS 753. *Manufacture of Phthalic Anhydride and Phthalates at I.G. Ludwigshafen.*

BIOS 754. *Hydrocyanic Acid, I.G. Oppau and Ludwigshafen.*

BIOS 755. *Manufacture of Butanol, Methoxybutanol, Butyraldehyde, Glycerogen at I.G. Hoechst.*

BIOS 756. *Polymeric Processes at I.G. Ludwigshafen.* [several different types of polymers]

BIOS 757. *Manufacture of Ethylene Cyanhydrin at I.G. Ludwigshafen.*

BIOS 758.

BIOS 759. *Pilot Plant for Manufacture of Acrylonitrile at I.G. Oppau.* [Synthetic rubber]

BIOS 760. *German War-Time Development in Fluid Turbulence with Particular Reference to the Lower Atmosphere and the Meteorology of Chemical Warfare.*

BIOS 761. *German Bursting Coloured Smoke Shell. Interrogation of Dipl. Ing. C. von Watzdorf and Dr. W. Sauermilch.*

BIOS 762.

BIOS 763. *Identification of Dyestuffs in I.G.*

BIOS 764. *Production of Aluminium Compounds in Germany.*

BIOS 765. *German Locomotive Experience with Pulvarised Fuels and Lump Brown Coal.*

BIOS 766. *The Manufacture of Pharmaceuticals and Fine Chemicals in the U.S. and French Zones of Germany.* [lots! 3065, etc.]

BIOS 767. *Accumulator Manufacture in Germany.*

BIOS 768. *The German Automobile Industry.*

BIOS 769. *German Manufacture of Sewing Machines, Garment Making Machines, Cloth Cutting Machines, Sewing Machine Needles.* [gives lists of documents and machines to be “evacuated” from Germany for “research” purposes]

BIOS 770. *Further Developments in Dairying in Germany.* [Milk pasteurization by UV]

BIOS 771. *Specification and Testing of Oils, Fuels and Lubricants in Germany.* [Rocket fuels p. 30]

BIOS 772. *Manufacture of Diazo Chemicals, Kalle & Co., Wiesbaden/Biebrich.* [Photocopiers]

BIOS 773. *Manufacture of Photographic Developing Substances at I.G. Farbenfabrik, Wolfen.*

BIOS 774. *German Mine Parachutes and Barometric Fuzes.*

BIOS 775. *Investigation into Steel Shaving Machines in the French Zone of Germany.*

BIOS 776. *Manufacture of Ethylene Oxide, Ethylene Glycols and Ethylene Chloride at I.G. Farbenfabrik, Wolfen.*

BIOS 777.

BIOS 778. *German Manufacture of Wires and Strips for Electrical Heating.*

BIOS 779. [Nickel-chrome alloys for pyrometers.]

BIOS 780. *The Manufacture of Cigarettes, Cigars and Pipe Tobacco in Germany.*

BIOS 781. *Some German Synthetic-Resin. Moulding Plants and Processes.*

BIOS 782. *Interrogation of Professor Ferdinand Flury and Dr. Wolfgang Wirth on the Toxicology of Chemical Warfare Agents.*

BIOS 783. *Manufactures at HIAG, Mainz-Mombach. Particularly Acetone Cyanhydrin, Acrolein and Acetonitrile.*

BIOS 784. *Interrogation of Dr. Gross, Prof. Flury and Dr. Wirth on Industrial Hygiene and Toxicology.* [cancer research]

BIOS 785. *The German Mica Industry.* [Synthetic mica]

BIOS 786. *Investigation of Methods of Development and Evaluation of New Plastic Products in Certain German Establishments.* [Plastics research labs]

BIOS 787. *Report on German Engineers' Tool Industry.*

BIOS 788. *The German Vitreous Enamel Industry.* With Appendix.

BIOS 789. *Special Steels. Notes on Practice at Krupp A.G., Essen, and Deutsche Edelstahlwerke A.G., Krefeld.*

BIOS 790. *Armour Plate. Notes of Gas Carburising Process Carried Out at Krupp A.G., Essen.*

BIOS 791. *Dynamic Properties of Rubber. Interrogation of Dr. H. Roelig.*

BIOS 792. *Properties and Testing of Rubber. Interrogation of Dr. P. Stöcklin at Beltane Schools S.W.19.*

BIOS 793.

BIOS 794. *Investigation of the Scrap Position in Germany.*

BIOS 795.

BIOS 796. *Coated, Gummed and Fancy Paper and Board Mills.*

BIOS 797. *The German Metal Rectifier Industry.* [Selenium rectifiers]

BIOS 798. *The German Ferro-Alloy Industry.*

BIOS 799.

BIOS 800. *Chemistry of Polymerisation as Applied to the Preparation of Buna Synthetic Rubbers. Interview with Dr. Becker.*

BIOS 801. *German Photo-Engraving Industry. Collodion Emulsion Cross-Line Screens.*

BIOS 802. *Bomb, Rocket & Guided Missile Control Gear Targets in Berlin.*

BIOS 803. *Production of Tantalum in Germany.*

BIOS 804.

BIOS 805. *Aspects of the Synthetic Fatty Acid and Synthetic Fat Industries in Germany.* [Synthetic fats for both soap and cooking fat]

BIOS 806. *Investigation of the Methods Used by a Few Selected Firms of German Ball and Roller Bearing Manufacturers.*

BIOS 807.

BIOS 808.

BIOS 809.

BIOS 810. *German Wool Textile and Mantle Plush Manufacture.*

BIOS 811. *Tetrachloroethane, Vinyl Chloride and Polyvinyl Chloride at Dr. Alexander Wacker. Gesellschaft für Electrochemische Industrie Burghausen, Germany.*

BIOS 812.

BIOS 813. *Zinc Works at Porto Marghera, Italy (Montecatini-Montevecchio, Soc. Italiana del Piombo e dello Zinco).*

BIOS 814. *A Survey of the German Pile Fabric Industry.*

BIOS 815. *Manufacture of Hydrazine Hydrate, I.G. Farben A.G., Leverkusen, Germany.*

BIOS 816. *Gewerkschaft Rheinpreussen Utfort/Mörs. Tar Distillation.*

BIOS 817. *Krupp-Lurgi Low-Temperature Carbonisation Plant at Krupp Treibstoffwerke, Wanne-Eickel.*

BIOS 818. *Foundries. Notes on German Iron and Steel Foundries Including Centrifugal Casting.*

BIOS 819. *Blast Furnaces. Notes on German Practice.*

BIOS 820. *Tungsten Carbide. Notes on Krupp Widia Plants.*

BIOS 821.

BIOS 822. *Shipbuilding. Notes on Visits to Blohm und Voss, Deutsche Werft, Germania Werft and Deschimag.*

BIOS 823. *Steel Wire. Notes on German Wire Drawing and Steel Rope Manufacture.*

BIOS 824. *Rolling Mills. Notes on German Practice.*

BIOS 825. *Steelmaking. Notes on German Practice.*

BIOS 826. *Investigation of German Researches on Fine Structure of Metals with Especial Reference to X-Ray Diffraction Techniques.* [Magnetically focusing X-ray tubes and X-ray diffraction analysis of metals]

BIOS 827. *German Filling Factories.*

BIOS 828.

BIOS 829. *German Agricultural Engineering Industry.*

BIOS 830.

BIOS 831. *Heat Treatment of Refractory Materials.*

BIOS 832.

BIOS 833. *Investigation of German Commercial Explosives Industry.*

BIOS 834. *Kohlenwertstoff Verbände A.G. Bochum. Benzole & Tar Products Distribution.*

BIOS 835.

BIOS 836. *German Light Metal Industry (Fancy Goods).*

BIOS 837. *Design, Construction and Production of High Speed Centrifuges.*

BIOS 838. *Investigation of Certain German Paper and Board Mills with Particular Reference to the Production of Leatherboard, Carton and Shoe Board and Coated Papers.*

BIOS 839. *Report on Investigation of Methods of Gaseous Metal Treatment.*

BIOS 840.

BIOS 841. *Synthetic Rubber Developing and Testing at the I.G. Central Rubber Laboratory, Leverkusen.*

BIOS 842.

BIOS 843. *Manufacture of Ethyl Acetate from Acetaldehyde at I.G. Farbenindustrie, Hoechst.*

BIOS 844.

BIOS 845. *Constructional Details of Chlorine Plant at Hoechst and Gendorf.*

BIOS 846. *German Chlorine Plants in the American, French and British Zones. Part I. Chlorine Production.*

BIOS 847. *German Chlorine Plants in the American, French and British Zones. Part II. Liquid Chlorine, Including Distribution of Gaseous Chlorine.*

BIOS 848. *German Chlorine Plants in the American, French and British Zones. Part III. Synthetic HCl.*

BIOS 849. *German Chlorine Plants in the American, French and British Zones. Part IV. Sodium Hypochlorite.*

BIOS 850. *German Chlorine Plants in the American, French and British Zones. Part V. Evaporation and Finishing of Diaphragm Cell Caustic Soda Liquor.*

BIOS 851. *I.G. Höchst. Chlorinated Methane Derivatives.*

BIOS 852. *I.G. Leverkusen. Hydrofluoric Acid.*

BIOS 853. *I.G. Leverkusen. Azobenzene.*

BIOS 854. *Deutsche Gold und Silber Scheideanstant, Rheinfelden. Sodium Peroxide, Sodium Percarbonate and Sodium Perborate.*

BIOS 855. *Manufacture of Salt Cake, Sodium Sulphide and Sulphigran by I.G. at Leverkusen.*

BIOS 856.

BIOS 857.

BIOS 858. *Investigation of the German Regenerated Cellulose Film Industry.*

BIOS 859.

BIOS 860.

BIOS 861. *The Stratton Mission to Germany July 1945 on Hides, Skins, Leather, Footwear, Leather Substitutes and Ancillary Machinery.* [Naturin]

BIOS 862.

BIOS 863. *Production of Liquid Sulphur Dioxide at I.G. Farben Fabrik, Wolfen.*

BIOS 864. *German Precision Instrument Potentiometers and Resolver Elements Used in Computer and Remote Control Applications.*

BIOS 865. *German Quartz Clocks and Frequency Standards.*

BIOS 866. *High Frequency Heating.* [Microwave heating for food, delousing, glue drying, and many other applications]

BIOS 867. *Television Development and Application in Germany.*

BIOS 868. *Public Address Industry, Hearing Aids, and Acoustics in Germany.*

BIOS 869. *Ferromagnetic Materials for Radar Absorption.*

BIOS 870. *Physics of the Solid State.*

BIOS 871. *Work of Professor Hüttig on Ferromagnetic Substances for Use in Radar Camouflage.*

BIOS 872.

BIOS 873. *By-Product Ammonia Recovery.*

BIOS 874. *Computing and Testing Methods in the German Optical Industry.* [Gastroscopes]

BIOS 875. *Phthalic Anhydride Plant at I.G. Farbenindustrie A.G., Uerdingen, Germany.*

BIOS 876. *Coke Oven Gas Separation by Linde. I.G. Oppau.*

BIOS 877. *Oxidation of Hydrocarbons to Ethylene and of Methane to Acetylene, with Conversion of Acetylene to Acetone. I.G. Oppau.*

BIOS 878. *The Activities of the Commission for Boiler Protection and Feed Water Treatment (KKS) for the Chief Commanding Officer of the Admiralty.*

BIOS 879. *Manufacture of Wool Felt, Fur Felt and Velour Hoods, Hats and Capelines in Germany.*

BIOS 880. *Sodium Hydrosulphite, Rongalit and Liquid Sulphur Dioxide Manufacture at I.G. Ludwigshafen. Interrogation of Herr Johannsen at Beltane School, Wimbledon.*

BIOS 881.

BIOS 882.

BIOS 883. *Notes on Casting and Fabrication of Lead and Production of Bahnmetall.*

BIOS 884. *Ball Bearings. Notes on Production of Ball Tubing at Deutsche Edelstahlwerke A.G., Krefeld, and Production of Ball Races at Kugelfischer A.G., Schweinfurt.*

BIOS 885. *Report on a Visit to Rheinmetall-Borsig, Unterluss, on 5th and 6th September, 1945 (Additional to B.I.O.S. Final Report No. 97).* [guns, no missiles]

BIOS 886. *Manufacture of Hydrogen Peroxide.*

BIOS 887. *Spray Drying, Fatty Acid Distillation, Sodium Perborate at Henkel & Cie, Düsseldorf, Germany.*

BIOS 888. *Gun Boring.*

BIOS 889. *Manufacture of Nitric Acid, Ammonium Nitrate and Fertilizers at Bitterfeld, Wolfen and Piesteritz.*

BIOS 890. *German Methods of Forging and Machining H.E. and A.P. Shell.*

BIOS 891. *Ophthalmic Optical Industry in Germany (British & U.S. Zones).* [AR eyeglass lenses]

BIOS 892.

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[several synthetic rubbers and plastics]

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BIOS 1320. *Preparation of Biological Products at Selected Targets in Germany.* [Lots of vaccines, hormones extracted from organs, serums, etc.]

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BIOS 1336. *The Klingelnberg System of Hobbing Spiral Bevel Gears.*

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BIOS 1338. *Developments in Magnesium Production and Fabrication.* [Beryllium, zirconium at Degussa; also fluorine and carbon at I.G. Farben.]

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BIOS 1370. *Viscose Manufacture with Special Reference to the Accelerated Ageing of Alkali-Cellulose. Interrogations of Dr. Lakatos.*

BIOS 1371. *The German Toy Industry.* [p. 76 Steiff]

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BIOS 1404. *Additional Pharmaceutical and Fine Chemical Targets.* [Lots of pharmaceuticals, including caffeine and opioid synthesis]

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BIOS 1433. *I.G. Farbenindustrie, A.G. The Manufacture of Triphenylmethane Dyestuffs at Hoechst, Ludwigshafen and Leverkusen.* [Methylene blue, neutral red, and many others]

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BIOS 1480. *The Manufacture, Formulation and Application of the Major Pest Control Products in the British, U.S. & French Zones of Germany.* [Lots of pesticides]

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BIOS 1630.

BIOS 1631. *Lurgi Apparatebau and Lurgi Chemie Frankfurt a.M. Design of Sulphuric Acid Plants.*

BIOS 1632. *I.G. Ludwigshafen and Höchst. Notes on the Manufacture of Sulphuric Acid and of Vanadium Catalyst.*

BIOS 1633. *Manufacture of Sulphuric Acid. I.G. Farbenindustrie, Leverkusen. Bei Koln.*

BIOS 1634. *Manufacture of Sulphuric Acid. Fabrik Schlebusch der Dynamit A.G. Vormals Alfred Nobel & Co. Leverkusen-Schlebusch.*

BIOS 1635. *Manufacture of Sulphuric Acid. The Nievenheim and Busbach-Münsterbusch Factories of Stollberger Zink A.G. für Bergbau und Hüttenbetrieb.*

BIOS 1636. *Manufacture of Sulphuric Acid. Berzelius Metallhütten G.m.b.H. Duisburg-Wanheim.*

BIOS 1637. *Manufacture of Sulphuric Acid. Henkel & Cie G.m.b.H. Düsseldorf-Holthausen.*

BIOS 1638. *Manufacture of Sulphuric Acid.*

BIOS 1639. *Manufacture of Sulphuric Acid. A.G. des Altenbergs für Bergbau und Zinkhütten-Betrieb, Essen-Bergeborbeck.*

BIOS 1640. *Unterharzer Berg und Hüttenwerke G.m.b.H. Goslar, Schieferweg 7/8.*

BIOS 1641. *Manufacture of Sulphuric Acid. Norddeutsche Affinerie-Hamburg.*

BIOS 1642. *Manufacture of Sulphuric Acid. Chemische Düngerfabrik Rendsburg.*

BIOS 1643. *Manufacture of Sulphuric Acid. Die Dynamit A.G. Vormals A. Nobel & Co., Krümmel Geesthacht.*

BIOS 1644. *Manufacture of Sulphuric Acid. Chemische Fabrik Wesseling A.G. Wesseling bei Köln.*

BIOS 1645. *Manufacture of Sulphuric Acid. Die Gaswerke Frankfurt a.M.*

BIOS 1646. *Miscellaneous Information on Fuels, Detergents and Lubricants.* [Explosion limits of hydrocarbon oxygen mixtures, lots of information on many synthetic detergents]

BIOS 1647. *German Spoon and Fork Industry.*

BIOS 1648. *Manufacture of Air Compressors and Pneumatic Tools and Appliances in Germany.*

BIOS 1649. *The German Surveying and Associated Industry.*

BIOS 1650. *Manufacture of Crotonaldehyde and Maleic Acid at I.G. Farbenindustrie A.G. Hoechst and Ludwigshafen.*

BIOS 1651. *Solvents and Plasticizers in Germany. Plasticizers Section.*

BIOS 1652. *Solvents and Plasticizers in Germany. Solvents Section.*

BIOS 1653. *German Oil Burning Devices Industry.*

BIOS 1654.

BIOS 1655. *Investigation of Red Lead Factories in Germany.*

BIOS 1656. *Extrusion of Light Alloys at I.G. Farbenindustrie, Bitterfeld. Interrogation of Herr K. F. Brauninger.*

BIOS 1657. *German Motor Control Gear.*

BIOS 1658. *Interrogation of Erwin Weise. Research and Development of Semi-Conducting Materials. Practical Applications for Ultra-Sensitive Temperature Measuring Equipment and Automatic Control and Stabilizing Problems.*

BIOS 1659. *German Measuring Instruments and Machines Used in Precision Engineering.*

BIOS 1660. *A General Survey of the German Non-Ferrous Industry.* [aluminum, beryllium]

BIOS 1661. *German Organic Pigments and Lake Dyestuffs.*

BIOS 1662. *Methyl Chloride Production at I.G. Farben. Hoechst.*

BIOS 1663. *The Use in Germany of Water-Proofing and Other Additions to Mortar & Concrete.*

BIOS 1664. *German Fibrous and Scientific Glass Industry.*

BIOS 1665. *Investigation of Dry Generator for Acetylene Type "Schammlos".*

BIOS 1666. *Technical Report on Skip & Cage Equipment for Main Shafts as Manufactured & Employed in the Ruhr Coalfield.*

BIOS 1667. *Some Notes on Open Hearth Furnace Design and Operation.*

BIOS 1668. *Manufacture of Nitrocellulose and Research Developments in Nitrocellulose Manufacture in Germany.*

BIOS 1669. *The Use of Dismulgans for Breaking Crude and Naval Fuel Oil Emulsions.*

BIOS 1670. *The Production of Ship Armour in Italy.*

BIOS 1671. *Electron Microscopy in Germany.*

BIOS 1672. *Thermal Measuring Instruments. Thermostats and Associated Apparatus.* [optical pyrometers and wide variety of other sensors]

BIOS 1673. *German Hardened and Tempered Steel Strip Industry.* [Safety razors]

BIOS 1674.

BIOS 1675.

BIOS 1676.

BIOS 1677. *German Textile Tube and Bobbin Manufacture.*

BIOS 1678. *The Rolling of Broad Flanged Beams in Germany.*

BIOS 1679. *Ultrasonic Material Testing and Other Applications.* [ultrasonic equipment production, applications, and research at 20 different labs–very long report including many papers from labs]

BIOS 1680. *The German Coking Industry.*

BIOS 1681. *German Rawhide Picker Industry (for Textile Weaving Looms).*

BIOS 1682. *The Manufacture of Hydrazine Hydrate in Germany.*

BIOS 1683. *German Limestone Quarries. The Processing of Limestone in Mechanised Quarries to Obtain a Clean Product for Limeburning and Chemicals.*

BIOS 1684.

BIOS 1685.

BIOS 1686.

BIOS 1687.

BIOS 1688. *Radiological Activities in Germany.* [including brief mentions of Schumann, Schall, Hubert, etc.]

BIOS 1689. *German Fine Balance Industry.*

BIOS 1690.

BIOS 1691. *Bonding of Rubber to Metal.*

BIOS 1692. *Mercury Arc Rectifier Practice in Germany.*

BIOS 1693. *German Chain Link Fencing and Wire Netting Industry.*

BIOS 1694. *Widia Tungsten Carbide.*

BIOS 1695. *Operational and Administration Report on a Visit to German Filling Factories.*

BIOS 1696. *German Magnetic Separator Applications, Particularly the Concentration of Minerals Feebly Magnetic.*

BIOS 1697. *Synthetic Oil Production in Germany. Interrogation of Dr. Bütefisch.*

BIOS 1698. *German Domestic Solid Fuel Appliances.*

BIOS 1699. *Bonding of Rubber to Aluminium and Aluminium Alloys, and Bonding of Rubber to Metal by Means of Desmodur R. Interrogation of Dr. Asbrandt.* [polyisocyanate superglue]

BIOS 1700. *The Manufacture of Glycerophosphates and Hypophosphites in Germany.*

BIOS 1701. *Pharmaceuticals—Tabletting, Ampouling and Packing in Selected German Factories.*

BIOS 1702. *The Manufacture of Carbon Bisulphide in Germany with Notes on Sulphur Recovery and Thio-Urea.*

BIOS 1703. *Manufacture of Aluminium at I.G. Farben Factory, Bitterfeld.*

BIOS 1704.

BIOS 1705. *The German Ceramic Industry.*

BIOS 1706. *Polymerisation of Ethylene in Germany: With Special Reference to High Pressure Design and Techniques.*

BIOS 1707.

BIOS 1708. *Production of Butane-1:2:4-Triol at I.G. Ludwigshafen.*

BIOS 1709. *German Laminating Plastic and Sleeving Industry.*

BIOS 1710.

BIOS 1711. *German Tungsten Carbide Wire, Bar, and Tube, Drawing Dies (With Brief Reference to Other Cemented Carbide Products).*

BIOS 1712. *Medium Pressure Synthesis with Iron Fixed-Bed Catalysts, and Operation of the Fischer Tropsch Synthesis in the Liquid Phase. Interrogation of Dr. H. Kölbel.*

BIOS 1713. *The Manufacture of Isovaleric Acid and Bromisovalerylurea in the French Zone of Germany.*

BIOS 1714. *Electrical Aspects of Buna. With Some Notes on Other Dielectrics.* 2 vols.

BIOS 1715. *Synthetic Resin Emulsions and Cellulose Lacquers. Interrogation of Dr. A. Kraus.*

BIOS 1716. *The German Electrical Indicating Instrument Industry. Its Technique & Materials.*

BIOS 1717. *Report on German Work Relevant to the Interaction Between Tyres, Vehicles and*

Road Surfaces.

BIOS 1718.

BIOS 1719.

BIOS 1720. *Dicyandiamide Production.*

BIOS 1721. *The Use of Prestressed Concrete in Germany.*

BIOS 1722. *Additional Information Concerning the Fischer-Tropsch Process and Its Products.*

BIOS 1723.

BIOS 1724. *German Papermaking Industry with Particular Reference to Paper Mills Using Rags as Raw Material and Producing Filter Papers, Blottings and Fine Papers.*

BIOS 1725. *Synthetic Aromatics, Perfumes, Isolates and Their Derivatives.*

BIOS 1726.

BIOS 1727. *The Manufacture of Tungsten Carbide and Its Application to the Coal Mining Industry.*

BIOS 1728. *Thermal Measuring Instruments.*

BIOS 1729. *Cellular Rubber & Plastics.*

BIOS 1730. *Industrial Electrical Research in Germany.* [6 MeV betatrons, 15 MeV betatron, Erwin Weise, etc.]

BIOS 1731.

BIOS 1732.

BIOS 1733. *Interrogation of Dr. Hampel on His Design for a Suspended Centrifugal Collector for Rayon Spinning.*

BIOS 1734. *German Stationery Industry.*

BIOS 1735. *German Optical Machine Tools.*

BIOS 1736. *Interrogation of Dr. Engelhardt, Research Chemist of I.G. Farbenindustrie, on the Production of Synthetic Waxes, Nibren and Clophen (Chlorinated Naphthalene & Chlorinated Diphenyl).*

BIOS 1737. *Continuous Chlorination of Benzene Process at I.G. Farbenindustrie, Bitterfeld and Wolfen, for Manufacture of Paradichlor Benzene as Primary Product. Interrogation of Dr. Richard Klar.*

BIOS 1738.

BIOS 1739. *German Welding Gauges.*

BIOS 1740. *Cellulose-Acetate, Cellulose Tripropionate and Cellulose Acetetate-Butyrate. Interrogation of Drs. Röhm, Ziegler, Schneg, of I.G. Dormagen.*

BIOS 1741.

BIOS 1742. *Sodium Perborate and Hydrogen Peroxide at Falkenau, Czechoslovakia. Interrogation of Herr Walter Neumann.*

BIOS 1743. *The German Superphosphate Industry.*

BIOS 1744. *The Pilot Plant Production at Völklingen, Saar, and the Proposed Manufacture at Mannheim/Rheinau of Röchling Phosphate, a Basic Phosphatic Fertilizer.*

BIOS 1745. *German Artillery Equipment. Stranded Wire Springs. Spiral (Clock Type) Springs.*

BIOS 1746. *German Development of Modulator Valves for Radar Applications.*

BIOS 1747. *German Drawing Instrument Industry. Design of Tools and Assembly Fixtures.*

BIOS 1748. *German Development of Steam-Driven Road Vehicles and Railcars.*

BIOS 1749. *German Synthetic Detergents. Interrogation of Dr. W. E. Lange of Bohme Fettchemie and Henkel & Cie, Düsseldorf and Chemnitz.*

BIOS 1750. *Arc Welding Equipment and Electrodes and Welding Applications in Germany.*

BIOS 1751. *German Research on Semi-Conductors, Metal Rectifiers, Detectors and Photocells.*

BIOS 1752.

BIOS 1753. *Ore Dressing and Cement Machinery in Germany.*

BIOS 1754. *Melamine Production: Mainkur.*

BIOS 1755. *Investigation into the Development of German Grand Prix Racing Cars Between 1934 and 1939 (Including a Description of the Mercedes World's Land Speed Record Contender).*

BIOS 1756. *Light Alloys in Western Germany, with Particular Reference to Rolling of Magnesium Alloys, and Rolling Mills.*

BIOS 1757. *Manufacture of Super-Purity Aluminium at the Vereinigte Aluminium Werke, Erftwerk, Grevenbroich.*

BIOS 1758.

BIOS 1759. *Montan & I.G. Waxes.*

BIOS 1760. *Brown Coal Briquetting Practice in Germany. Part I. Preparation of the Coal for Briquetting. Part II. Briquette Conveying, De-Dusting and Firing. Part III. Official Regulations of the Brown Coal Industry and Detailed Operating Experience.* 3 vols.

BIOS 1761.

BIOS 1762. *German Electro-Technical Ceramics.*

BIOS 1763.

BIOS 1764. *Manufacture of Polystyrene III.*

BIOS 1765. *German Fire Services.*

BIOS 1766. *Manufacture of Barium Compounds. Interrogation of Dr. Ing. Alfred Nobis.*

BIOS 1767.

BIOS 1768. *Trilon and Praecutan.*

BIOS 1769.

BIOS 1770. *High Strength Aluminium-Zinc-Magnesium Alloy Development in Germany.*

BIOS 1771. *Fuses, Electric Protection. Fine-Sensitive and Surge-Resisting types, Below 5 Amperes, Produced in Germany.*

BIOS 1772. *Some Engineering Aspects of the Edeleanu Process.*

BIOS 1773. *German Progress in Products and Processes for Cellulosic Textiles.*

BIOS 1774. *The Manufacture of Papaverine in the French and American Zones of Germany.*

BIOS 1775.

BIOS 1776. *Yeast and Citric Acid Production from Sugar Beet Molasses in Germany.*

BIOS 1777. *Research and Development of Impulsive Ducts in Germany.* [V-1 engine]

BIOS 1778. *Some Notes on I.G. Detergents.*

BIOS 1779. *Manufacture of Perbunan.* [Buna]

BIOS 1780. *Some Aspects of the German Glass Industry in 1946.*

BIOS 1781. *Production of Monomeric Styrene at Chemische Werke, Huls.*

BIOS 1782. *Further Aspects of the Manufacture of Egg and Albumen Substitutes.* [milk casein converted into egg albumen substitute]

BIOS 1783. *German Practice in the Production and Utilisation of High Boiling Coal Tar Chemicals.*

BIOS 1784. *Benson Boilers in Germany for Naval and Mercantile Marine Use.*

BIOS 1785. *Some Notes on Electro-Precipitation in Germany.*

BIOS 1786.

BIOS 1787. *Manufacture of Diphenyl at I.G. Farbenindustrie, A.G., Leverkusen.*

BIOS 1788. *Manufacture of Formaldehyde at I.G. Farbenindustrie, A.G., Leverkusen.*

BIOS 1789.

BIOS 1790. *Aluminium Chloride and Alkali-Chlorine Plants. Interrogation of Dr. Max Gruber.*

BIOS 1791. *Eddy Current Instruments for Use in the Field of Non-Destructive Testing.*

BIOS 1792. *German Laboratory Porcelain Industry.*

BIOS 1793. *Plasticisers for Polyvinyl Chloride.*

BIOS 1794. *Synthetic Resins for Surface Coatings.*

BIOS 1795. *Synthetic Resin Adhesives—Heinkel & Co.*

BIOS 1796.

BIOS 1797. *Centrifugal Casting in Germany with Particular Reference to the Production of Non-Ferrous Tubes.*

BIOS 1798. *Investigation of Horizon Mining and Area Planning as Practised in the Ruhr Coalfield, Germany.*

BIOS 1799. *The Science of Work. German Work-Study and Occupational Psychology. Conference at Hahnenklee, December 1946.*

BIOS 1800. *Industrial Gas Installations.*

BIOS 1801.

BIOS 1802.

BIOS 1803. *Investigation of German Rubber and Plastics Machinery.*

BIOS 1804.

BIOS 1805. *Investigation Concerning Rubber and Plastic Lining.*

BIOS 1806. *Pressure Dyeing.*

BIOS 1807. *Some Notes on the Production of the Prontor II Shutter.*

BIOS 1808.

BIOS 1809. *Report on the 0 to 2 Metre Zeiss Measuring Machine for External and Internal Measurement.*

BIOS 1810.

BIOS 1811. *Synthesis of Acrylates by Reaction of Acetylene, Carbon Monoxide and Alcohols.*

BIOS 1812. *Notes on Non-Destructive Testing by Means of Eddy Currents (Prufautomat) and Ultrasonics.*

BIOS 1813. *I.G. Products for the Leather Industry.*

BIOS 1814. *German Metal Degreasing Practice.*

BIOS 1815. *Low Temperature Gas Separation.* [liquid oxygen production]

BIOS 1816. *The "Sodingen" Process for the Recovery of Ethylene from Coke Oven Gas.*

BIOS 1817. *German Peat Industry.*

BIOS 1818. *Accelerated Light Fading Equipment in I.G.*

BIOS 1819.

BIOS 1820. *Heating, Ventilating and District Heating in Germany.*

BIOS 1821. *The Manufacture of Forged and Hardened Steel Rolls in Germany and Austria.*

BIOS 1822. *Steelworks and Other Industrial Buildings (Structural) in Germany.*

BIOS 1823. *German Carbon Industry and Hydraulic Press Manufacture.*

BIOS 1824.

BIOS 1825. *German Practice and Operation of Producer Gas Driven Vehicles and Vehicles Operating on Compressed Gas.*

BIOS 1826. *German Power Press Industry.*

BIOS 1827. *Safety Fuse Manufacture in Germany.*

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BIOS 1829. *The Manufacture of Borax, Boric Acid and Sodium Perborate in the Western Zones of Germany.*

BIOS 1830. *The Krupp-Herglotz Ring-Roll Press.*

BIOS 1831. *The Wax Industry in Germany.*

BIOS 1832. *German Tyre and Belting Plants.*

BIOS 1833. *400 kV Transmission Lines with Special Reference to Multiple Conductor Lines (Bündelleitungen).*

BIOS 1834. *Production and Use of Getter Materials in German Radio Valves, Thermionic Devices Generally, and Electric Lamps.*

BIOS 1835. *Investigation of Power Loading Developments in Germany.*

BIOS 1836.

BIOS 1837.

BIOS 1838. *German High Pressure Hydrogen Oxygen Electrolyser Development.*

BIOS 1839. *Welding of Plastics in Germany.*

BIOS 1840.

BIOS 1841. *The Manufacture of Synthetic Phenol at Dr. F. Raschig G.m.b.H. Ludwigshafen.*

BIOS 1842.

BIOS 1843.

BIOS 1844. *Some Aspects of German Soldering, Brazing and Welding Methods.*

BIOS 1845.

BIOS 1846. *The Manufacture in Germany of Building Materials from Wood-Waste.*

BIOS 1847. *High Tension Direct Current Transmission Experiments in Germany.*

BIOS 1848. *Butt Welding Methods Employed in Pipe Erection and Fabrication in Germany.*

BIOS 1849. *Welding Research and Development in Germany.*

BIOS 1850. *Iron and Steel Works in Germany.*

BIOS 1851. *Steam Utilisation in Germany.*

BIOS 1852.

BIOS 1853. *Interrogation of Dr. Reiner Chelius of Fried. Krupp, A.G., Essen, on 16th March, 1948, with the Analysis of Synthetic Carbide Materials and Components Used in Their Manufacture.*

BIOS 1854. *German Resistance Welding Equipment and Developments.*

BIOS 1855.

BIOS 1856. *Information Obtained During an Interrogation of Dr. Federn (Carl Schenck G.m.b.H.) on Matters Connected with Vibration and Shock.*

BIOS 1857.

BIOS 1858.

BIOS 1859. *Manufacture of Cellulose Triacetate, Yarn and Film. Interrogation of Dr. Gerhard Hinz (Schering A.G. Berlin) at Spedan Towers, Hampstead.*

BIOS 1860.

BIOS 1861. *Light Alloy Foundries in Germany.*

BIOS 1862. *The German Flycatcher Making Industry Part II.*

BIOS 1863.

BIOS 1864.

BIOS 1865.

BIOS 1866.

BIOS 1867. *An Investigation into the Steel Bridge and Constructional Engineering Industry of Germany.*

BIOS 1868.

BIOS 1869. *Manufacture of Synthetic Phenol by the Chlorination Route at I.G. Farben Industrie, A.G., Leverkusen.*

BIOS 1870.

BIOS 1871.

BIOS 1872.

BIOS 1873.

BIOS 1874. *Steam Drying of Coal.*

Report series/number??? J. A. J. Bennett. January 1945. *Notes on a BIOS Mission to Germany and Austria to Investigate German Flettner Helicopter Fl 282 'Kolibri' Developments.*

Report series/number??? Bartram Kelley and Hugh J. Mulvey. CIOS Target No. 25/488. 17 August 1947. [helicopters]

British Intelligence Objectives Subcommittee Miscellaneous (BIOS Misc) Reports

BIOS Misc 1. [Plastics and foamed plastics]

BIOS Misc 2.

BIOS Misc 3.

BIOS Misc 4. [Toxicology]

BIOS Misc 5.

BIOS Misc 6.

BIOS Misc 7.

BIOS Misc 8.

BIOS Misc 9.

BIOS Misc 10.

BIOS Misc 11. [Detergents]

BIOS Misc 12.

BIOS Misc 13. [Detergents]

BIOS Misc 14.

BIOS Misc 15.

BIOS Misc 16.

BIOS Misc 17.

BIOS Misc 18.

BIOS Misc 19 Vol. 1 and Vol. 2. *A Survey of German Wartime Food Processing, Packaging, and Allocation.* [Vacuum freeze drying and synthetic butter]

BIOS Misc 20.

BIOS Misc 21. [Biosyn synthetic protein.]

BIOS Misc 22.

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BIOS Misc 35.

BIOS Misc 36. [Insecticide]

BIOS Misc 37.

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BIOS Misc 57. [Magnetic amplifiers]

BIOS Misc 58.

BIOS Misc 59. [Hydrodynamics]

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BIOS Misc 66. *German Infra Red Driving and Fire Control Equipment.*

BIOS Misc 67.

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BIOS Misc 72. *The Manufacture of Aviation Gasoline in Germany.*

BIOS Misc 73.

BIOS Misc 74.

BIOS Misc 75.

BIOS Misc 76.

BIOS Misc 77. *European Electron Induction Accelerators.*

BIOS Misc 78.

BIOS Misc 79.

BIOS Misc 80.

BIOS Misc 81.

BIOS Misc 82.

BIOS Misc 83. *Advantages and Disadvantages of Frequency and Phase Modulation in the Light of the Special Requirements Demanded by Aviation, as Well as its Application to Wireless Navigation (Report Prepared by Ministry of Supply).*

BIOS Misc 84.

BIOS Misc 85.

BIOS Misc 86.

BIOS Misc 87.

BIOS Misc 88.

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BIOS Misc 90.

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BIOS Misc 100.

BIOS Misc 101. *Dutch Report on German Manufacture of Scales on Metal, Glass and Celluloid.*

BIOS Misc 102. *Dutch Report on Transmitting Tube Targets in Germany.*

BIOS Misc 103.

BIOS Misc 104.

BIOS Misc 105.

BIOS Misc 106.

BIOS Misc 107.

BIOS Misc 108.

BIOS Misc 109.

BIOS Misc 110. *Dutch Report on Manufacture of Radio Components in the American Zone of Germany.*

British Intelligence Objectives Subcommittee (BIOS) Overall Reports

BIOS Overall 1. *Petroleum and Synthetic Oil.*

BIOS Overall 2. *Shipbuilding and Industry.*

BIOS Overall 3. *Timber and Industry.*

BIOS Overall 4. *Glass and Industry.*

BIOS Overall 5. *German Motor Roads.*

BIOS Overall 6. *Agricultural Aspects.*

BIOS Overall 7. *Rubber.*

BIOS Overall 8. *Rotating Wing Aircraft in Germany During the Period 1939–1945.*

BIOS Overall 9. *Wool Industry.*

BIOS Overall 10. *Diamond Tools.*

BIOS Overall 11. *Electric Power Engines.*

BIOS Overall 12. *Gas Turbine Development.*

BIOS Overall 13. *Cotton Silk Rayon.*

BIOS Overall 14. *Food Manufacturing.*

BIOS Overall 15. *Ferrous Metal Industry.*

BIOS Overall 16. *Railways.*

BIOS Overall 17. *Jute.*

BIOS Overall 18. *Fire Fighting.*

BIOS Overall 19. *Photographic Industry.*

BIOS Overall 20. *Powder Metallurgy.*

BIOS Overall 21. *Motor Industry.*

BIOS Overall 22. *Paint Industry.*

BIOS Overall 23. *Nonferrous Metal Industry.*

BIOS Overall 24. *Pharmaceutical Industry.*

BIOS Overall 25. *Coal Tar and Benzole.*

BIOS Overall 26. *Abrasives, Their Use and Manufacture.*

BIOS Overall 27. *Leather Manufacturing.*

BIOS Overall 28. *Fine Ceramics.*

BIOS Overall 29. *Telecommunications.*

BIOS Overall 30. *Acetylene Chemistry.*

BIOS Overall 31. *Packaging.*

BIOS Overall 32. *Pest Control.*

BIOS Overall 33. *The German Rayon Industry.*

BIOS Overall 34. *German Plastics.*

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BIOS Overall 50.

Combined Intelligence Objectives Subcommittee Evaluation Reports (CIOS ER)

CIOS ER 1. *Professor R. Kuhn at the KWI, Heidelberg.* [synthetic antibiotic 3065]

CIOS ER 2. *Preliminary Reports on Aeronautical Activities at Darmstadt.*

CIOS ER 3. *Oil Team Report on I.G. Farbenindustrie—Heidelberg.*

CIOS ER 4. *I.G. Farbenindustrie at Höchst.*

CIOS ER 5. *Project for Location of Ships by Ionisation Measurements.*

CIOS ER 6. *German Controlled Missiles.*

CIOS ER 7. *Oil Targets in the Ruhr and Hannover Areas.*

CIOS ER 8. *Brief Description of Operation of X-4 Missiles.*

CIOS ER 9. *Information on a Material Possibly Used for or in Jet Propulsion.*

CIOS ER 10. *K.W.I. für Medizinische Forschung, Heidelberg.* [synthetic antibiotic 3065]

CIOS ER 11. *Information on a New Group of Toxic War Gases.*

CIOS ER 12. *I.G. Production of Synthetic Fatty Acids.*

CIOS ER 13. *Heinkel Hirth at Stuttgart.*

CIOS ER 14. *Ammoniawerk Merseburg G.m.b.H. Plant of I.G. Farbenindustrie A.G. at Leuna.*

CIOS ER 15. *I.G. Plastics Activity.*

CIOS ER 16. *I.G. Farbenindustrie A.G. Ludwigshafen-Oppau. Fuels and Lubricants Testing and Development.*

CIOS ER 17. *Dr. Müller Conradi of I.G. Farbenindustrie.*

CIOS ER 18. *Interrogation of Mr. Waldeman Bergner and Mr. Schumacher.*

CIOS ER 19. *Statistics of German Production, Consumption and Stocks of Liquid Fuels, Rubber and Strategic Chemicals.*

CIOS ER 20. *Planning Board of Reich Research Council.*

CIOS ER 21. *Elektrochemisches Werke München A.G.*

CIOS ER 22. *Work in the Heidelberg Area.*

CIOS ER 23. *Robert Bosch G.m.b.H.*

CIOS ER 24. *Friedrich Krupp, Essen.*

CIOS ER 25. *Rheinmetall-Borsig A.G.*

CIOS ER 26. *Information on Poison Gas Manufacture in Germany.*

CIOS ER 27. *Report on I.G. Farbenindustrie Aktiengesellschaft.*

CIOS ER 28. *Report on Metallgesellschaft and Lurgi Gesellschaft für Warmetechnik G.m.b.H.*

CIOS ER 29. *Visit to Krupps Experimental Range, Meppen.*

CIOS ER 30. *Report on Giessling Pulver "Cast" Rocket Propellant at Wolff & Co., Bomlitz.*

CIOS ER 31. *I.G. Farbenindustrie at Höchst.*

CIOS ER 32. *The Records of the Fedwirtschaftsamt of the O.K.W.*

CIOS ER 33. *Interview with Dr. Klebert, Dr. Redies and Dr. Knonradi: Synthetic Rubber, Chemical Warfare.*

CIOS ER 34. *Assessment Report, Degaussing Laboratory, Physikalische Institut, University of Tübingen.*

CIOS ER 35. *I.G. Farbenindustrie at Frankfurt.*

CIOS ER 36. *Investigation of Ruhr Synthetic Oil Plants.*

CIOS ER 37. *I.G. Farbenindustrie at Bitterfeld.*

CIOS ER 38. *Luftschiffbau Zeppelin—Dir. Eckener.*

CIOS ER 39. *Lechfeld Airfield.*

CIOS ER 40. *Sonderausschuss A-4.*

CIOS ER 41. *Dr. Butefisch, a Director of I.G. Farbenindustrie and a Member of Its Executive Technical Committee and an Expert on Coal Hydrogenation.*

CIOS ER 42. *Professor Waninger, Chief of Research, Rheinmetall-Borsig.*

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CIOS XXV-51. *The Schacht Marie Salt Mine, Beendorf (Dispersal of Siemens, Berlin).* [autopilot]

CIOS XXV-52. *Production and Uses of Calcium Carbide in Germany.*

CIOS XXV-53. *German Aircraft Industry Bremen-Hamburg Area.*

CIOS XXV-54. *Pharmaceuticals at I.G. Farbenindustrie Plant Elberfeld.* [antibiotics, antimalarials, periston, steroid hormones]

CIOS XXVI-1. *Proximity Fuze Development, Rheinmetall-Borsig AG, Mülhausen.*

CIOS XXVI-2.

CIOS XXVI-3. *Seefliegerhorst Wesermünde (Evacuation from Erprobungsstelle der Luftwaffe, Karlshagen).* [missiles and smart bombs]

CIOS XXVI-4. *M. W. M. Mannheim, Daimler Benz, Rothenbach Brown Boveri Co., Mannheim.*

CIOS XXVI-5. *Wirtschaftliche Forschungs G.m.b.H., Stassfurt and Bad Berka.*

CIOS XXVI-6. *Focke Wulf Designing Offices and General Management, Bad Eilsen.*

CIOS XXVI-7. *Focke Wulf Photo Reproduction Department, Bad Eilsen.*

CIOS XXVI-8. *Focke Wulf Structural Research Laboratory, Detmold.*

CIOS XXVI-9. *C.H. Boehringer und Sohn, Ingleheim am Rhein.* [Pharmaceuticals]

CIOS XXVI-10. *Heeresmunitionsanstalt St. Georgen, Bavaria, Germany.*

CIOS XXVI-11. *I.G. Farbenindustrie AG Höchst am Main.* [wide range of products]

CIOS XXVI-12. *Reich Ministry of Armaments and War Production. (Part I—Organization).*

CIOS XXVI-13. *Reich Ministry of Armaments and War Production. (Part II—Summary of Technical Information).* [sonic weapons, Speer on atomic weapons research]

CIOS XXVI-14. *Reich Ministry of Armaments and War Production. (Part III—Summary of Economics and General Information).*

CIOS XXVI-15. *Deutsches Gummi-Regenierwerke Wilhelm Galombeck and Co, Hamburg.*

CIOS XXVI-16. *NY Hamburger Gummiwaren-Compagnie, Harburg.*

CIOS XXVI-17. *Gummiwarenfabrik Phoenix AG, Harburg.*

CIOS XXVI-18. *Rheinische Gummi Celluloid AG, Mannheim.*

CIOS XXVI-19. *Harburger Gummiwarenfabrik Phoenix AG Harburg.* [rubber, etc.]

CIOS XXVI-20. *Franz Clouth Rheinische Gummiwarenfabrik Nippes, Cologne.* [rubber]

CIOS XXVI-21. *Continental Gummiwerke, Hanover.*

CIOS XXVI-22. *Light Steel Building Products.*

CIOS XXVI-23. *Medical, Dental and Veterinary Education and Practice in Germany as Reflected by the Universities of Leipzig, Jena, Halle and Erlangen.*

CIOS XXVI-24. *The Schornsteinfeger Project.* [anti-radar]

CIOS XXVI-25. *Pulverised Magnesium.*

CIOS XXVI-26. *Voigtlander Und Sohn AG, Braunschweig-Gliesmarode.*

CIOS XXVI-27. *Research and Development of Engines at Hermann Goering Institute, Volkenrode.*

CIOS XXVI-28. *Research and Development on Gas Turbines at Hermann Goering Institute, Volkenrode.*

CIOS XXVI-29. *Research and Development on Gas Turbines at Junkers Motoren Werke, Dessau.*

CIOS XXVI-30. *Gas Turbine Development by B. M. W.*

CIOS XXVI-31. *Technische Akademie der Luftwaffe, Eckertal.*

CIOS XXVI-32. *August Thyssen Hutte AG, Hamborn.*

CIOS XXVI-33. *Werke Koholyte, Luelsdorf.*

CIOS XXVI-34. *Aschaffenburger Zellstoffwere AG*

CIOS XXVI-35. *Electro Schmelzewerke AG, Kempton, Allgau, Bavaria.*

CIOS XXVI-36. *Kaiser Wilhelm Institut für Arbeitsphysiologie at Bad Ems and at Dietz a.d. Lahn.*

CIOS XXVI-37. *The Treatment of Shock from Prolonged Exposure to Cold, Especially in Water.*

CIOS XXVI-38. *German Submarine Construction at Bremen and Kiel.*

CIOS XXVI-39. *German Destroyers at Bremen and Kiel.*

CIOS XXVI-40. *Daimler Benz Plant at Wendlingen.*

CIOS XXVI-41. *The Manufacture of Krupp Cemented Armor.*

CIOS XXVI-42. *The Manufacture of Armor Piercing Projectiles for the German Navy.*

CIOS XXVI-43. *The Manufacture of Armor Plate by Hoerder Huttenverein, Dortmund.*

CIOS XXVI-44. *Messerschmitt Bombproof Assembly Plant, Landsberg.*

CIOS XXVI-45. *German Submarine Pens in France.*

CIOS XXVI-46. *Sterephon Sound Recording System Developed by Dr. Carl-Heinz Becker.*

CIOS XXVI-47. *Gebr. Ciulini G.m.b.H., Ludwigshafen.*

CIOS XXVI-48. *Dr. F. Raschig G.m.b.H., Chemische Fabrik, Ludwigshafen.*

CIOS XXVI-49. *Heeresgasschutzschule I, Celle.* [chemical warfare]

CIOS XXVI-50. *Production of Synthetic Fatty Acids and Edible Fats—Deutsche Fettsaurewerke, Witten.*

CIOS XXVI-51. *Plant of Chemische Werke, Huls.*

CIOS XXVI-52. *Manufacture of Fabrication of Polyvinyl Chloride (PCU and PC) at I.G. Farbenindustrie Bitterfeld.*

CIOS XXVI-53. *Manufacture of Caprolactam at I.G. Farbenindustrie Leunawerke, Merseburg.*

CIOS XXVI-54. *I.G. Farbenindustrie AG, für Stickstoff-Duenger Knapsack.*

CIOS XXVI-55. *Chemische Werke Albert, Biebrick.*

CIOS XXVI-56. *Research in Aviation Medicine for the German Air Force.*

CIOS XXVI-57. *German Development of Homing Devices.*

CIOS XXVI-58. *The Status of Synthetic Training in Germany.*

CIOS XXVI-59. *German Anti-Fouling Compositions.*

CIOS XXVI-60. *Light Metal Production and Development for Aircraft I.G. Farbenindustrie, Bitterfeld.*

CIOS XXVI-61. *Film Production and Methods, Agfa Film Fabrik Plant, Wolfen.*

CIOS XXVI-62. *The German Chlorine Industry with Particular Emphasis on I.G. Farbenindustrie AG and the War Influence.*

CIOS XXVI-63. *Rohm and Haas, Darmstadt.* [Enzymatic pharmaceutical production]

CIOS XXVI-64. *Manufacture of Hydrocyanic Acid, I.G. Farbenindustrie, Oppau.*

CIOS XXVI-65. *Findings on German Proximity Fuze Developments in 21 Army Group Area.*

CIOS XXVI-66. *Klein Schanglin and Becker AG, Hydraulic Couplings and Torque Converters.*

CIOS XXVI-67. *German Ordnance Research and Developments.*

CIOS XXVI-68. *Wirtschaftliche Forschungs G.m.b.H. (WIFO). Fuel Blending Station, Eferbachtel.*

CIOS XXVI-69. *Steel Forging Industry of Germany.*

CIOS XXVI-70. *Rottweil AG* [Explosives R&D]

CIOS XXVI-71. *Seigfried Junghans Schorndorf.*

CIOS XXVI-72. *Maschinen für Massenverpackung G.m.b.H., Schultrup.*

CIOS XXVI-73. *Insecticides, Insect Repellents, Rodenticides and Fungicides of I. G. Farbenindustrie A. G., Elberfeld and Leverkusen, Germany.*

CIOS XXVI-74. *The Manufacture of German Steel Cartridge Case, Part I.*

CIOS XXVI-75. *Production of Cellulose Acetate, I. G. Farbenindustrie, Dormagen/Cologne.*

CIOS XXVI-76. *Manufacture of Polyisobutylene—I. G. Farbenindustrie, Oppau.*

CIOS XXVI-77. *Rotary Air Compressors Built by Demag AG, Duisburg.*

CIOS XXVI-78. *French Oil Shale Industry.*

CIOS XXVI-79. *I. G. Farbenindustrie, Meinkur-Hoechst.*

CIOS XXVI-80. *Steinkohlen-Bergwerk Rheinpreussen, Moers-Meerbeck.*

CIOS XXVI-81. *Neuropsychiatric Organizations in the German Air Force.*

CIOS XXVI-82. *German Production Methods for High Test Peroxide.*

CIOS XXVI-83. *Bayerische Motor Werke (BMW).*

CIOS XXVI-84. *Mahle KG (Piston Plant).*

CIOS XXVI-85. *The Luftwaffe Signal School, Köthen.*

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CIOS XXVI-87. *Dachs Lubricating Oil Plant, Porta, Germany.*

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CIOS XXVII-2. *The German Surgical Instrument Industry in the Tuttlingen Area.*

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CIOS XXVII-5. *German Clock and Watch Industry.*

CIOS XXVII-6. *Manufacture of Styrene and Polystyrene, I.G. Farbenindustrie, Schkopau.*

CIOS XXVII-7. *Vereinigte Lichtmetalle Werke, Hanover.*

CIOS XXVII-8. *Teuto Metall Werke, Osnabruck.*

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CIOS XXVII-10. *Hanomag, Hanover.*

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CIOS XXVII-12. *Westfalische Draftindustrie, Hamm.*

CIOS XXVII-13. *Research and Development in Hydraulic Couplings (Fluid Power Transmissions), J.M. Voith, Heidenheim/Brenz.*

CIOS XXVII-14. *I.G. Farbenindustrie, Mainkur/Hoechst.* [Penicillin]

CIOS XXVII-15. *Manufacture of Acetaldehyde, I.G. Farbenindustrie, Schkopau.*

CIOS XXVII-16. *Fabrication of Plastics, I.G. Farbenindustrie Wolfen.*

CIOS XXVII-17. *I.G. Farbenindustrie Plant, Hoechst/Main.*

CIOS XXVII-18. *The Oxo Plant, Ruhrchemie Oberhausen-Holden.*

CIOS XXVII-19. *Steel Metallurgy at Messerchmitt, Oberammergau and Garmisch-Partenkirchen.*

CIOS XXVII-20. *Prof. Dr. Ing. Emil Sorensen, Maschinenfabrik Augsberg-Nurnberg AG, Augsberg.* [Ceramic gas turbine blades]

CIOS XXVII-21. *Research Activity at Deutsche Versuchsanstalt für Luftfahrt, Garmisch.*

CIOS XXVII-22. *Gas Turbine and Wind Tunnel Activity, Brown Boverie CIE, Heidelberg.*

CIOS XXVII-23. *Optical Grinding and Centering Equipment Used by Carl Zeiss, Jena.*

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CIOS XXVII-25. *Waggonfabrik Verdingen AG, Krefeld-Verdingen.*

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CIOS XXVII-27. *Recoilless Guns Development of Rheinmetall-Borsig.*

CIOS XXVII-28. *Research Institute for Materials of the D.V.L., Sonthofen.* [High-temperature alloys for jets]

CIOS XXVII-29. *Metallurgical High Lights in the Recent Manufacture of Rolled Steel Plates and Sheets in Germany.*

CIOS XXVII-30. *Repair of Damage to Armor Structures.*

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CIOS XXVII-32. *A Series of Interviews with Members of German Medical Schools, Research Institutes and Hospitals.*

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CIOS XXVII-34. *War Gas Production and Miscellaneous Chemical Warfare Information, Anorgana G.m.b.H., Gendorf.*

CIOS XXVII-35. *Rheinmetall-Borsig AG Werk, Unterlüss.*

CIOS XXVII-36. *Manufacture of Steel Case Small Arms Ammunition, Dynamit AG, Stadelin and Nurnberg.*

CIOS XXVII-37. *Fuzing System of German A4 Rocket (V-2).*

CIOS XXVII-38. *Manufacture of Initiating Explosives and Their Handling for Use in Cap Detonator Loadings at Fabrik Wolfratshausen Chemischer Erzeugnisse and Dynamit AG, Stadeln.*

CIOS XXVII-39. *I.G. Farbenindustrie, Uerdigen.* [Plastics patents]

CIOS XXVII-40. *Deutsche Edelstahlwerke AG, Hochfrequenz-Tregelstahl G.m.b.H., Bochum.*

CIOS XXVII-41. *Tovarna Na Nabojky A Kovove Zbozi (Patronen Hulsen Und Metallwaren Fabrik), Rokycany, Czechoslovakia.*

CIOS XXVII-42. *Bochumer Verein AG, ABT Stahlwerke, Bochum.*

CIOS XXVII-43. *Manufacture of Glass Fabric Impregnated Fibre Used as a Substitute for Mica Insulation Between Commutator Segments in Motors and Generators.*

CIOS XXVII-44. *Manufacture of Metalized Paper Fixed Capacitor Units by the Robert Bosch Co., Stuttgart.* [Metallized paper capacitors]

CIOS XXVII-45. *Suddeutsche Apparate-Fabrik.*

CIOS XXVII-46. *Design of Radar Test Equipment, Siemens Halske Plant, Munich.*

CIOS XXVII-47. *Interrogation of Dr. Stiele von Heydenkampf, President of the Panzer Kommission.*

CIOS XXVII-48. *Chemische Werke Albert and Other Pharmaceutical Targets, Weisbaden.* [Neuroscience]

CIOS XXVII-49. *Thermocolour Paints, I.G. Farbenindustrie, Oppau.* [Heat sensitive paints]

CIOS XXVII-50. *Manufacture of Hydroquinone, I.G. Farbenindustrie, Wolfen.*

CIOS XXVII-51. *Manufacture of Vinyl Chloride and Polyvinyl Chloride, I.G. Farbenindustrie, Schkopau.*

CIOS XXVII-52. *Proposed T-44 Class German Destroyers.*

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CIOS XXVII-58. *The Wilhelm Schmidding Werke, Koln.*

CIOS XXVII-59. *Underground German Liquid Oxygen Plant, Wittring.*

CIOS XXVII-60. *The Wesseling Synthetic Fuel Plant.*

CIOS XXVII-61. *Drägerwerk, Lübeck Germany.* [Oxygen breathing apparatus, CO2 measuring instruments]

CIOS XXVII-62. *German Safety Fuze and Dynamo Exploders.*

CIOS XXVII-63. *Rocket Fuel and Explosive Mixtures Containing Peroxides.*

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CIOS XXVII-66. *Description of the Construction and Performance of the Anti-Aircraft Rocket "Enzian E4."*

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CIOS XXVII-68. *Fischer-Tropsch Unit at Leipzig Gas Works.*

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CIOS XXVII-70. *Gutehoffnungshutte AG, Sterkrade.*

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CIOS XXVII-72. *Manufacture of Solventless Type Smokeless Powder and Nipolit, Kraiburg Works, Deutsche Spreng-Chemie G.m.b.H.*

CIOS XXVII-73. *The Manufacture of Nitrocellulose, Deutsche Sprengstoffe, Aschau and Ebenhausen.*

CIOS XXVII-74. *The Proving Ground, Hillersleben, Germany.*

CIOS XXVII-75. *Electrical Induction Face, Hardening of Thick Armour Plate.*

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CIOS XXVII-77. *The Neustadt Wire and kabel Werke, Neustadt Bei Cobarg.*

CIOS XXVII-78. *German Cast Armor.*

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CIOS XXVII-80. *I.G. Farbenindustrie AG, Uerdingen.* [Selenium Rectifiers]

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CIOS XXVII-82. *Fischer Tropsch and Allied Processes.*

CIOS XXVII-83. *AG für Stickstoffduenger Knapsack.*

CIOS XXVII-84. *I.G. Farbenindustrie AG, Ludwigshafen and Oppau Wehrmacht Items.* [Dyes fluorescent in UV]

CIOS XXVII-85. *Miscellaneous Chemicals, I.G. Farbenindustrie AG, Ludwigshafen and Oppau.*

CIOS XXVII-86. *Research Activities at Göttingen on Aerodynamics of Projectiles, Missiles and Ramjets.* [transonic/supersonic airfoil shapes]

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CIOS XXVII-93. *Wirtschaftliche Forschungs G.m.b.H., Fuel Blending Station, Heiligenstadt.*

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CIOS XXVII-96. *Oberfeldarzt Professor Hugo Spatz, The Department of Brain Research, Kaiser Wilhelm Institute.*

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CIOS XXVIII-2. *Artillery Experimental Range, Hillersleben.*

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CIOS XXVIII-17. *German High Speed Aircraft Developments.*

CIOS XXVIII-18. *The Universal Fauth System Extraction Process.*

CIOS XXVIII-18, Item 22. *Gesellschaft Zur Verwertung Fauthscher G.m.b.H., Wiesbaden.*

CIOS XXVIII-19. *Food Chemistry Institute, Franfurt-a-Main.*

CIOS XXVIII-20. *Radio Sonde Transmitters, Wurt Radio G.m.b.H.—Stuttgart and Neuhausen.* [Meteorology R&D]

CIOS XXVIII-21. *German Submarine Rotary Wing Kite.*

CIOS XXVIII-22. *Dornier Werke G.m.b.H., Friedrichshafen.*

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CIOS XXVIII-24. *Institut für Bauforschung und Material Prufungen des Bauwesens, Stuttgart.*

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CIOS XXVIII-41. *Institut für Physikalische Forschung, Neu Drossenfeld.* [TV homing device]

CIOS XXVIII-42. *Wood Sugar Yeast Manufacture, I.G. Farbenindustrie, AG, Wolfen.*

CIOS XXVIII-43. *The German "Fasteners" Industry.*

CIOS XXVIII-44. *Kienzle Apparate G.m.b.H., Villingen/Schwarzwald.*

CIOS XXVIII-45. *Group 2 Targets in Nordhausen Area.* [p. 12 Walter Riedel located in Thuringia

and brought to Nordhausen]

CIOS XXVIII-46. *Automotive Targets in 12th Army Group Area.*

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CIOS XXVIII-59. *Aviation Medicine, General Medicine, Veterinary Medicine, and Chemical Warfare.*

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CIOS XXIX-5. *Dessauer Werke für Zucker und Chemische Industrie AG*

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CIOS XXIX-13. *Miscellaneous Interviews on Medical Practice and Research in Germany.* [Pharmaceuticals]

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CIOS XXIX-37. *Deutsches Waffen und Munitions-fabriken AG Schlutup-Lubeck.*

CIOS XXIX-38. *Gesellschaft für Gerätebau, near Garmisch-Partenkirchen.*

CIOS XXIX-39. *German Facilities for the Production of Centrifugally Cast Gun Tubes.*

CIOS XXIX-40. *Lubricants Manufactured and Used by Zeiss in Jena.*

CIOS XXIX-41. *Production of Optical Glass in Germany and France. CIOS Target Nos. 9/1, 9/36 & 9/80. Physical and Optical Instruments and Devices.*

CIOS XXIX-42. *The Production of Binoculars by Zeiss. CIOS Target No. 9/1. Physical and Optical Instruments and Devices.*

CIOS XXIX-43. *Pots Used in Melting Optical Glass at Schott and Genossen.*

CIOS XXIX-44. *Welding of German Armored Vehicles.*

CIOS XXIX-45. *Luftfahrtforschungsanstalt, Hermann Goring Braunschweig.* [liq/sol rockets]

CIOS XXIX-46. *Armament Design and Development at the Skoda Works, Pilsen, Czechoslovakia.*

CIOS XXIX-47. *Cyclotron Investigation Heidelberg.*

CIOS XXIX-48. *Ceramic Developments of Dr. Rother, Lutz and Co., Lauf/Pegnitz.*

CIOS XXIX-49. *Development of Propulsive Ducts at the D.F.S., Ainring.*

CIOS XXIX-50. *Pharmaceutical Targets in Germany.*

CIOS XXIX-51. *Thyssen'sche Gas und Wasserwerke G.m.b.H., Duisberg-Hamborn, Krupp Treipstoffwerk, Wanne-Eickel.*

CIOS XXIX-52. *German Optical Production. CIOS Target Nos. 9/1, 9/14, 9/36, 9/121, 9/124, 9/130, 9/139, 9/199, 9/388. Optical and Physical Instruments and Devices.*

CIOS XXIX-53. *Low Tension Ignition.*

CIOS XXIX-54. *Ignition by Means of an Injection of Ignition Oil.*

CIOS XXIX-55. *Restricted Summary of German Controlled Missiles.*

CIOS XXIX-56. *Suspension Unit for Tanks Type E 50/75.*

CIOS XXIX-57. *Development of Submerged Wading for Tanks.*

CIOS XXIX-58. *German Tank Design Trends.*

CIOS XXIX-59. *Equipment for Producing Divided Circles at the Zeiss Plant.*

CIOS XXIX-60. *The Production of Fused Quartz of Optical Quality by Herseus. CIOS Target No. 9/389. Physical and Optical Instruments and Devices.*

CIOS XXIX-61. *Klockner Werke AG, Hagen-Haspe.*

CIOS XXIX-62. *Investigation of German Plastics Plants.*

CIOS XXIX-63. *Rocket Developments and Projects at BMW.*

CIOS XXX-1. *Ingolene (Hydrogen Peroxide) Cycle for Submarines.*

CIOS XXX-2. *Synthesis of Acetone.*

CIOS XXX-3. *German Infra-Red Equipment in the Kiel Area.*

CIOS XXX-4. *The Preparation of Formamide as an Intermediate for Acrylonitril Production and Acrylonitril from Acetylene.*

CIOS XXX-5. *Synthetic Lubricating Oils.*

CIOS XXX-6. *Preparation of "Alkazid" M and Dik.*

CIOS XXX-7. *A New Lightweight German Automatic Pilot (Model K 23).*

CIOS XXX-8. *Metallwerke Plansee Reutte, Tyrol.*

CIOS XXX-9. *Survey of Operations of Group V Automotive Caft in 6th Army Group.*

CIOS XXX-10. *I.G. Farbenindustrie, Hoechst.* [Emulsifier research]

CIOS XXX-11. *Gas-Proofing of Tanks.*

CIOS XXX-12. *Schaumkohle and Dr. Heinrich Schmitt-Werke K.G.*

CIOS XXX-13. *A. G. Sachsische Werke Bohlen.*

CIOS XXX-14. *Visit to Thüringen Small Arms Industry.*

CIOS XXX-15. *Agfa Film Factory, Wolfen.*

CIOS XXX-16. *German Marine Paints.*

CIOS XXX-17. *I.G. Farben, Agfa Subsidiary, Wolfen.* [AGFA Color]

CIOS XXX-18. *Oil Recovery From Wurttemberg Shale.*

CIOS XXX-19. *Chemical Warfare, I.G. Farbenindustrie AG, Frankfurt/Main.*

CIOS XXX-20. *Viscose Staple Fibre, Sachische Zellwolle AG, Plauen.*

CIOS XXX-21. *Continuous Viscose Making, Thuringische Zellwolle AG, Schwarza.*

CIOS XXX-22. *Manufacture of Spinnerettes, Eilfeld AG, Grobzig.*

CIOS XXX-23. *Continuous Viscose making, IG Farben AG, Wolfen.*

CIOS XXX-24. *Machinery for Winning and Loading of Bituminous Coal Underground.*

CIOS XXX-25. *The Brieden Pneumatic Packing Machine, Karl Brieden and Co, Bochum.*

CIOS XXX-26. *Operation of Compressed Air Shearing Machines.*

CIOS XXX-27. *Mining Method for a Five Foot Seam Pitch 60 Degrees.*

CIOS XXX-28. *Operation of the Coal-Planer.*

CIOS XXX-29. *Mining Method for a Five Foot Seam Pitch 25 Degrees to 50 Degrees, Mine Fritz, Hoesch AG, Essen.*

CIOS XXX-30. *Operation of Pneumatic Packing Machine and Scraper Loader with Planer.*

CIOS XXX-31. *German Marine Diesel Engine Practice.*

CIOS XXX-32. *Investigations of the Latest Ship Designs and Operating Experiences with the Technical Personnel of the Hamburg-American Steamship Line, Hamburg.*

CIOS XXX-33. *Interview with Mr. Eric Schneider, Technical Director, North German Lloyd Line.* [Marine engine developments]

CIOS XXX-34. *Technical Assistance on Synthetic Oils Rendered the Japanese by the I.G. Farbenindustrie AG*

CIOS XXX-35. *The Carl Bosch Laboratory of Berlin.* [IR telescopes]

CIOS XXX-36. *Physikalisch-Technische Reichsanstalt.*

CIOS XXX-37. *Lubecker Flenderwerke AG, Lübeck.*

CIOS XXX-38. *Hamburg Model Basin.*

CIOS XXX-39. *Manufacture of Widia Bits for Chain Coal-Cutting Machines.*

CIOS XXX-40. *Present Status of Coal Shearing Machine Design.*

CIOS XXX-41. *Activities of the Westfalische Berggewerkschaftskasse During Wartime.*

CIOS XXX-42. *Design of German Coal-Planer.*

CIOS XXX-43. *Design of Mine-Diesel Locomotive.*

CIOS XXX-44. *Visit to the Ludwigshaven Mannheim Area.*

CIOS XXX-45. *Aero Engine Accessories.*

CIOS XXX-46. *Wind Tunnels in the Munich Area.*

CIOS XXX-47. *Siemens Zahler Fabrik, Nurnberg Area.*

CIOS XXX-48. *Bayerische Motorenwerke AG, Munich—Oberwissenfeld.*

CIOS XXX-49. *Messerschmitt Company's Design and Development Department, Oberammergau.*

CIOS XXX-50. *German Medical Schools.*

CIOS XXX-51. *Wrought Copper Alloy Industry of Southern Germany.*

CIOS XXX-52. *Rheinmetall Borsig, Sommerda.*

CIOS XXX-53. *German Development of the Primary Battery.*

CIOS XXX-54. *Submarine Cables.*

CIOS XXX-55. *Ferro-Alloy Production, Badische Wolframerz G.m.b.H., Sollingen.*

CIOS XXX-56. *"Schmeltz" Cement.*

CIOS XXX-57. *Radio Telemetering Receiver Selector Developed at the Technische Hochschule Darmstadt.*

CIOS XXX-58. *A Communication System for Small Submarines.*

CIOS XXX-59. *Manufacturing Process for Fabrication of Turbine Blades Used in 109-003 BMW Jet Propulsion Engine.*

CIOS XXX-60. *Trim and Drainage Systems on German Submarines, Volkenrode.*

CIOS XXX-61. *Living Conditions and Accommodations Aboard German Submarines.*

CIOS XXX-62. *Observations on Shaped Charge Development in Germany.*

CIOS XXX-63. *Styroflex, a Plastic Produced by Norddeutsche Seekabelwerke.*

CIOS XXX-64. *Messerschmitt Aircraft Design Development.*

CIOS XXX-65. *Automatic Parachute Opening Device.*

CIOS XXX-66. *Information on Ceramic and Water-Cooled Turbine Blading for Gas Turbines.*

CIOS XXX-67. *Synthetic Coatings for Gasoline Tanks.*

CIOS XXX-68. *Damage Control in the German Navy.*

CIOS XXX-69. *Aerological Work, Friedrich Krupp, Schiessplatz Meppen.* [meteorology]

CIOS XXX-70. *The Preparation of Tetrahydrofuran Polymers as a Synthetic Lubricant for Metals.*

CIOS XXX-71. *Special Mission on Captured German Scientific Establishment, Braunschweig: Artillery and Weapons, Rockets and Rocket Fuels, Guided Missiles, Aircraft Instruments and Equipment.* [Leslie M. Simon]

CIOS XXX-72. *Aluminum and Magnesium Fabrication, Leipziger Leichtmetall Werk-Rackwitz, Rackwitz.*

CIOS XXX-73. *Aluminum Fabrication, Osnabrucker Kupfer and Drahtwerk, Osnabruck.*

CIOS XXX-74. *Training of Free Gunners in the German Air Force.*

CIOS XXX-75. *Structural Flight Test Equipment Developed or Used by the Peenemünde Group.*

CIOS XXX-76. *German Naval Closed Cycle Diesel Development for Submerged Propulsion.*

CIOS XXX-77. *Deliveries of Material and Data to Japan by the Rheinmetall-Borsig AG Divisions at Unterluss and Sommerda.*

CIOS XXX-78. *Summary of German Developments in Meteorology During the War.*

CIOS XXX-79. *German Turbine Driven Pump Combinations.*

CIOS XXX-80. *Bavarian Motor Works: A Production Survey.* [BMW jets]

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CIOS XXX-82. *The Braunschweiger and Dickerhoff Systems of Concrete Reinforcement.*

CIOS XXX-83. *The Arc Process for Acetylene Production.*

CIOS XXX-84. *Iron Ore Beneficiation Plants of the Hermann Goring Works, Salzgitter.*

CIOS XXX-85. *A Survey of the German Can Industry During the Second World War.*

CIOS XXX-86. *Versuchsstation Fur Konserven Industrie Braunschweig.*

CIOS XXX-87. *T. H. Lampe Konserven Fabrik, Braunschweig.*

CIOS XXX-88. *Maggi G.m.b.H., Singen.*

CIOS XXX-89. *Woodsaccarification by the Scholler Process, Dessauer Zucker Raffinerie.*

CIOS XXX-90. *Mauxion, Saalfeld.*

CIOS XXX-91. *Pahl and Doescher Gebruder.*

CIOS XXX-92. *Gebruder Schubert Grossbackerei, Halle/Saale.*

CIOS XXX-93. *Fried Krupp AG, Blankenburg.*

CIOS XXX-94. *Administration, Plastics, Production Tooling, Spare Parts and Servicing in German Aircraft Industry.*

CIOS XXX-95. *German Dental Industry.* [comprehensive]

CIOS XXX-96. *Otto Bertram, Hamburg.*

CIOS XXX-97. *Felsche Chocolate Works, Leipzig.*

CIOS XXX-98. *Most Schokoladenfabrik, Halle/Saale.*

CIOS XXX-99. *Deutsche AG für Nestle Erzeugniss, Kiel, Mitchewerke Angeln Kappeln.*

CIOS XXX-100. *Konservenfabrik Gifhorn, Gifhorn.*

CIOS XXX-101. *Bevollmaechtigter fuer Hochfrequenzforschung.* [anti-radar]

CIOS XXX-102. *Scholven Hydrogenation Plant.*

CIOS XXX-103. *I.G. Farbenindustrie AG Works, Ludwigshaven and Oppau.* [Synthetic fats]

CIOS XXX-104. *Botrop-Welheim Hydrogenation Plant.*

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CIOS XXX-106. *The German SKR and Portable Steel Bridge.*

CIOS XXX-107. *Natter Interceptor Project.*

CIOS XXX-108. *German Infra-Red Devices and Associated Investigations.*

CIOS XXX-109. *Hydrogen Peroxide Storage Practices in Three German Plants.*

CIOS XXX-110. *Operation of the Type XVII 2500 HP Hydrogen Peroxide Turbine Propulsion Plant for Submarines.*

CIOS XXX-111. *Geier Torpedo Control.*

CIOS XXX-112. *Fuzing System of German FZG 76 Flying Bomb (V-1).*

CIOS XXX-113. *Electronic Equipment Aboard German Naval Units.*

CIOS XXX-114. *Acoustic Torpedo Pistol P1-Kiel.*

CIOS XXX-115. *Rocket Power Plants Designed and Constructed by Walter Werke, Kiel.*

CIOS XXX-116. *Steam Turbine Technology in Germany.*

CIOS XXX-117. *Development and Production of Tungsten Carbide Cores for Armour Piercing Shot by Friedrich Krupp AG*

CIOS XXX-118. *Radio and Radar Research Establishments of the German Service Ministries.* [Peenemünde, Lofer, etc.]

CIOS XXX-119. *Airplane Fire Control System "Oberon."* [air-to-air missiles]

CIOS XXXI-1. *Establishments of the Forschungsanstalt der Deutschen Reichspost.*

CIOS XXXI-2. *Research Work Undertaken by the German Universities and Technical High Schools for the Bevollmaechtigter fuer Hochfrequenztechnik; Independent Research on Associated Subjects.* [semiconductors, superconductivity, Gerlach, Erwin Weise transistor idea, World-Review of the Manufacture of Semi-Conductors, "the S.S. placed high importance on obtaining Neutron generators."]

CIOS XXXI-3. *German High Speed Airplanes and Design Development.*

CIOS XXXI-4. *Cobaltine Alni-steel Magnets, Robert Bosch Dispersal Plant at Engingen, Germany.*

CIOS XXXI-5. *Doblhoff Jet-Propelled Helicopter.*

CIOS XXXI-6. *The VDM Propeller Works, Frankfurt/Main and Hasselborn.*

CIOS XXXI-7. *German Aircraft Industry and Luftwaffe Service Organizations.*

CIOS XXXI-8. *Plastics and Wooden Parts in German Aircraft.*

CIOS XXXI-9. *Robert Bosch G.m.b.H. Stuttgart.* [electrical equipment]

CIOS XXXI-10. *Weser Flugzeugbau.*

CIOS XXXI-11. *Flettner Helicopter FL 282 Kolibri.*

CIOS XXXI-12. *Artillery Design and Development Performed by Rheinmetall-Borsig AG*

CIOS XXXI-13. *Ramjet and Rocket Work, Heerte.*

CIOS XXXI-14. *Binoculars for Night Seeing.*

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CIOS XXXI-16. *E Merck, Darmstadt Works, Ludwigshafen and Oppau.*

CIOS XXXI-17. *Dutch Scientific Institutions in Utrecht and Amsterdam.* [Penicillin]

CIOS XXXI-18. *Interrogation of Dr Waninger.*

CIOS XXXI-19. *German Electric Time Fuzes, Rheinmetall-Borsig AG, Breslau.*

CIOS XXXI-20. *Refining of Cobalt, Nickel, Zinc and Cadmium.*

CIOS XXXI-21. *Organic Protective Coatings.*

CIOS XXXI-22. *Refractories in Turbine Blades.*

CIOS XXXI-23. *Metallgesellschaft-Lurgi, Frankfurt Am Main.*

CIOS XXXI-24. *Fuel Research and Technology at Rheinisch-Westfalisches, Kohlen-Syndikat, Essen.*

CIOS XXXI-25. *Fuel Research and Technology, Bergbau-Verein, Essen-Heisingen.*

CIOS XXXI-26. *German Tool and Special Steel Industry.*

CIOS XXXI-27. *Coal Extraction Plant of Ruhrol G.m.b.H..*

CIOS XXXI-28. *Fuel Technology and the Reichsvereinigung, Kohle.*

CIOS XXXI-29. *Fuel Research Activities, The AG Der Kohlenwertsoff-Verbande, Bochum.*

CIOS XXXI-30. *Krupp-Lurgi Low-Temperature Carbonization Plant, Wanne-Eickel.*

CIOS XXXI-31. *Coal and Coke Research, H Koppers G.m.b.H., Essen.*

CIOS XXXI-32. *Solo Feinfrost G.m.b.H., Hamburg.*

CIOS XXXI-33. *Elmshorn Genossenschoft Meierei, Elmshorn.*

CIOS XXXI-34. *Bergedorfer Eisenwerke, Bergedorf.*

CIOS XXXI-35. *Interview with Dr Stoeckicht on Gear Design.*

CIOS XXXI-36. *Junkers Aircraft and Engines Facilities.* [10,000 g accelerometer, Jumo engine]

CIOS XXXI-37. *Institutes of the Bevollmaechtigter für Hochfrequenz-Forschung.* [Fuses for missiles, R&D]

CIOS XXXI-38. *The I.T.T., Siemens and Robert Bosch Organizations.* [Missile TV, autopilot]

CIOS XXXI-39. *Messerschmitt Engineering and Research Facilities, Oberammergau and Aeronautical Research Institute of Vienna.* [Lippisch, etc.]

CIOS XXXI-40. *Berlin Lubecker Maschinenfabrik (BLM).*

CIOS XXXI-41. *The Design of German Aircraft Hydraulic Systems, Fuel Systems and Fuel System Components and Accessories.*

CIOS XXXI-42. *High Quality Steel Castings, Ruhrstahl AG, Annen.*

CIOS XXXI-43. *Tube-Making Plants, Mannesmann Rohrenwerke.*

CIOS XXXI-44. *Heat-Resisting and Corroision-Resisting Alloy Steels, F. Krupp AG, Essen.*

CIOS XXXI-45. *Manufacture of High Tensile Bolts, Bauer and Schaurte.*

CIOS XXXI-46. *Special Alloy Steel Manufacture and Centifrugal Casting of Alloy Tubes and Gun Barrels.*

CIOS XXXI-47. *Research Laboratory Deutsche Edelstahlwerke AG, Krefeld.*

CIOS XXXI-48. *Open-Hearth Steel Making Practice at Guss-Stahlfabrikation.*

CIOS XXXI-49. *Examination of Dr. Ing. W. Osenberg.* [Appendix V covers nuclear]

CIOS XXXI-50. *German Cold Cathode Tubes, Siemens Reiniger Werke, Rudolfstadt.* [Siemens cold cathode tubes]

CIOS XXXI-51. *Luftfahrtforschungsanstalt, Volkenrode.* [Buseman, Guderley, etc.]

CIOS XXXI-52. *Telefunken G.m.b.H.* [Organization of Telefunken Radar, Signals Communications, Optical Devices]

CIOS XXXI-53. *Langbein-Pfanhauser Werke AG, Leipzig.*

CIOS XXXI-54. *Hugo Schneider AG, Steel Cartridge Cases, Leipzig.*

CIOS XXXI-55. *Mansfeldscher Kupperschieferbergbau AG, Eisleben.*

CIOS XXXI-56. *George Von Giesche's Erben, Magdeburg.*

CIOS XXXI-57. *Hugo Schneider AG, Messingwerke Aluminum Werke, Leipzig.*

CIOS XXXI-58. *Compilation of German Fuels and Lubricants Specifications.*

CIOS XXXI-59. *Gesellschaft für Geratebau.* [railgun]

CIOS XXXI-60. *The German BLC 50 Photoflash Bomb.*

CIOS XXXI-61. *Disc Valve Engine, Junkers Torpedo Engine, Model Jumo KM8.*

CIOS XXXI-62.

CIOS XXXI-63. *Development of Weapons by Rheinmetall-Borsig.*

CIOS XXXI-64. *Electric Igniter Manufacture by Dynamit AG Troisdorf.*

CIOS XXXI-65. *Polte-Werke, Magdeburg.*

CIOS XXXI-66. *Aircraft Gas Turbine Engine Developments at Junkers, Dessau and Associated Factories.* [Jumo 004]

CIOS XXXI-67. *German Clock and Watch Industries.*

CIOS XXXI-68. *Duneberg Factory of DAG.*

CIOS XXXI-69. *Spare Parts and Provisioning in the G.A.F. Additional information.*

CIOS XXXI-70.

CIOS XXXI-71. *Interrogation of Helmut Gröttrup Dipl.-Ing. Elektromechische Werke.*

CIOS XXXI-72.

CIOS XXXI-73. *Vereingte Leichtmetall Werke G.m.b.H., Hannover Linden.*

CIOS XXXI-74. *Research Institute for World Forestry and Silviculture.*

CIOS XXXI-75. *Huls Chemical Works-IG Farben, Huls.*

CIOS XXXI-76. *The Leverkusen Works of IG Farben, Braunschweig.*

CIOS XXXI-77. *The Fabrication of Plastic Container Used for Storage of Hydrogen Peroxide on German Submarines.*

CIOS XXXI-78. *Internal Combustion Engines.*

CIOS XXXI-79. *The Manufacture of Synthetic Butter.*

CIOS XXXI-80. *A German Supersonic Method of Testing Aircraft Bearings.*

CIOS XXXI-81. *The Manufacture and Physical Properties of Iporka.*

CIOS XXXI-82. *German Fifty-Two Centimeter Mamouth Press for the Extrusion of Rocket Propellant.*

CIOS XXXI-83???. *German Research Institutes.* [radar CM, speech systems, calculating machines, etc.]

CIOS XXXI-83???. *Report to Secretariat Concerning Physikalisch-Technische Reichsanstalt.*

CIOS XXXI-84. *German and Danish Industries.* [electronics, optics, anti-radar, smart bombs, railgun]

CIOS XXXI-85. *Edeleanu G.m.b.H., Altenburg.*

CIOS XXXI-86. *Chemical Warfare Installations in the Munsterlager Area.* [very long and very detailed, including personnel and molecular structures]

CIOS XXXII-1. *Photometric Procedures Used in Research and Production of German Pyrotechnic*

Ammunition.

CIOS XXXII-2. *Tank Development at Machinenfabrik Augsburg and Nurnberg.*

CIOS XXXII-3. *Deutsche Erdöl AG Mineralölwerke Rositz.*

CIOS XXXII-4. *IG Farben, Leverkusen.* [CW protective clothing]

CIOS XXXII-5. *Pharmahologisches Institut Der Friederisch-Wilhelms Universitat, Berlin.*

CIOS XXXII-6. *German CW Charging Station and CW Dump at Espelkamp.*

CIOS XXXII-7. *Production of Vesicant Agents at Ammendorf.*

CIOS XXXII-8. *Hexogen Manufacture at Fabrik Bobingen Der G.m.b.H., Zur Verwertung Chemischer Erzevgnisse.*

CIOS XXXII-9. *The Chemical Compositions of German Pyrotechnic Colored Signal Items.*

CIOS XXXII-10. *German Illuminating Flares.*

CIOS XXXII-11. *Interrogation of Dr Haberland.* [IG Farben chemical products]

CIOS XXXII-12. *C. F. Boehringer and Soehne G.m.b.H., Mannheim-Waldhof.*

CIOS XXXII-13. *Production of Smoke, Incendiary and Chemical Warfare Weapons.*

CIOS XXXII-14. *Deutsche Erdol AG, Regis.*

CIOS XXXII-15. *Kukuck I Plant, Niedersachswerfen.*

CIOS XXXII-16. *Stuttgart Technische Hochschule Forschungs Institut Fur Kraftfahrwesen Und Fahrzeug Motoren.* [Diesel engine developments]

CIOS XXXII-17. *Underground Factories in Central Germany.*

CIOS XXXII-18. *FW Fechner and Co, Hamburg/Wandsbeck.*

CIOS XXXII-19. *Fritz Muller Pressenfabrik, Esslingen.*

CIOS XXXII-20. *German Tracer Compositions.*

CIOS XXXII-21. *Aluminum from Clay.*

CIOS XXXII-22. *Optical Glass Manufacturing at Schott & Gen, Jena.*

CIOS XXXII-23. *Production of Cellulose Acetate Flake.*

CIOS XXXII-24. *The German Commercial Air Transport Industry and Related Aeronautical Activities and Developments.* [Aviation medicine]

CIOS XXXII-25. *German and French Radiators and Oil Coolers for Aeronautical and Automotive Purposes.*

CIOS XXXII-26. *Plastics in German Aircraft Tooling.*

CIOS XXXII-27. *German Pyrotechnics.*

CIOS XXXII-28. *Hak Hanseatisches Kettenwerke G.m.b.H., Hamburg.*

CIOS XXXII-29. *DWM and MFM at Lubeck-Schlutup.*

CIOS XXXII-30. *Development of Tank Design Skoda Works, Pilsen.*

CIOS XXXII-31. *Axial Flow Compressor Development at the Stuttgart Research Institute.*

CIOS XXXII-32. *Laboratory for the Study of Tracked Vehicles MAN Factory, Nuremberg.*

CIOS XXXII-33.

CIOS XXXII-34. *Stabilized Optical Sight for German Tank Guns.*

CIOS XXXII-35. *Development of New Series German Tanks up to End of March, 1945.*

CIOS XXXII-36. *Methods Used in Calculations of Tanks Transmissions.*

CIOS XXXII-37. *Messerschmitt Aircraft Design.*

CIOS XXXII-38. *Explosives Summary of Capacity and Production in Germany.* [Explosives R&D]

CIOS XXXII-39. *Landing Gear of ME 262 Airplane.*

CIOS XXXII-40. *Aeronautics Versuchsanstalt, Goettingen.* [Aircraft research]

CIOS XXXII-41. *Messerschmitt Advanced Fighter Design.*

CIOS XXXII-42. *Walter Submarine Machinery.*

CIOS XXXII-43. *The Deutsche Seewarte Aerological Station.* [Meteorology R&D]

CIOS XXXII-44. *Aircraft Engines Additional and Temporary Supercharge by the use of Nitrous Oxide N2O in the Air.*

CIOS XXXII-45. *Gas Turbine Developments.*

CIOS XXXII-46. *Interrogation of Dipl. Ing. Helmut Schelp.* [jets]

CIOS XXXII-47. *Medical and Pharmaceutical Targets in Northern Germany and Holland.* [Lots of medical research]

CIOS XXXII-48. *Hans A Keune, Hamburg.*

CIOS XXXII-49. *Wilster Gennossenschoft Meierei, Wilster.*

CIOS XXXII-50. *Anderson and Co, Hamburg-Altona.*

CIOS XXXII-51. *Holsteinische Konserven Fabrik Gerlingsweig, Elmshorn.*

CIOS XXXII-52. *Gas Utilities in Germany.*

CIOS XXXII-53. *Variable Displacement Hydraulic Transmissions for Power Tracking.*

CIOS XXXII-54. *Remote Control System for Bomber Gun Turrets.*

CIOS XXXII-55. *Recovery of Metals from Scrapped Airplanes.*

CIOS XXXII-56. *Pyrotechnic Anti-Pathfinder Devices.*

CIOS XXXII-57. *Gun Fire Control Equipment.*

CIOS XXXII-58. *The Chemical Conpositions of German Pyrotechnic Smoke Signals.*

CIOS XXXII-59. *Aluminum and Magnesium Production and Fabrication.*

CIOS XXXII-60. *Combination Air-Oil-Cooled Engine Development for 3-Ton Opel-Blitz Truck.*

CIOS XXXII-61. *History of General Automotive Development at the Stuttgart Research Institute.* [Automotive developments]

CIOS XXXII-62. *Maybach HL234 Tank Engine.*

CIOS XXXII-63. *Variable Speed Hydraulic Drive for Remote Control of 5.5 cm Flak 58.*

CIOS XXXII-64, Item 2. *Chrome Plating of Barrels.*

CIOS XXXII-64, Item 22. *Manufacture of Hydrocyanic Acid, I.G. Farben, Oppau.*

CIOS XXXII-65. *German Aeronautical Research of Naval Interest.*

CIOS XXXII-66. *Deutsche Forschungsanstalt Für Segelflug Ainring.*

CIOS XXXII-67.

CIOS XXXII-68. *The Manufacture and Application of Lubricants in Germany.*

CIOS XXXII-69. *Otto Acoustic Proximity Pistol for Torpedoes.* [sonar]

CIOS XXXII-70. *Dust Fuse for German SD10 Bomb.*

CIOS XXXII-71. *German 8.6 Centimetre Rockets.*

CIOS XXXII-72. *Standard German Projectile Fuses.*

CIOS XXXII-73. *The Development of German Optical Mine Firing Mechanisms.*

CIOS XXXII-74. *Wosthoff Torsional Vibration Amplitude Indicator.*

CIOS XXXII-75. *German Rocket Power Plants.* [liquid and solid rocket engines]

CIOS XXXII-76. *A Sonic Altimeter for Aircraft.*

CIOS XXXII-77. *The Production of Intense Audio Sounds by an Intermittent Flame.* [acoustic weapon]

CIOS XXXII-78. *The Passive Acoustic Proximity Device "Kranich."*

CIOS XXXII-79. *Passive Acoustic Proximity Fuses for Use Against Bomber Formations.*

CIOS XXXII-80. *Acoustic Steering Control for the X-4 Missile-Dogge.*

CIOS XXXII-81. *The Manufacture of Hard Rubber Parts for Storage Batteries.*

CIOS XXXII-82. *German Acoustic Ground Proximity Fuse.*

CIOS XXXII-83. *Acceleration Tolerances of the Human Body.*

CIOS XXXII-84. *German High Speed Aerodynamic and Guided Missile Research.* [Supersonic flow instruments]

CIOS XXXII-85. *Aerodynamische Versuchsanstalt and The Kaiser Wilhelm Institute Fur Stromungsforschung Gottingen.*

CIOS XXXII-86. *The Manufacture of Propellants, Nitrocellulose and D.G.N.*

CIOS XXXII-87. *Interrogation of Prof. Scherzer of the BHF.*

CIOS XXXII-88. *Stassfurter Rundfunk Stassfurt.* [Remote control for guiding bombs]

CIOS XXXII-89. *Luftfahrtforschungsanstalt, Braunschweig.* [Jet engine research]

CIOS XXXII-90. *Wintershall AG, Lutzkendorf.*

CIOS XXXII-91. *Lurgi Gesellschaft Fur Warmetechnik, Frankfurt-am-Main.*

CIOS XXXII-92. *Brabag I Plant, Bohlen.*

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Note: There are several cases in which one FIAT report was given two different numbers. There are an inexplicably large number of cases in which two different, unrelated FIAT reports were assigned the same number. If fact, there may well be additional FIAT final reports that are not listed here but that have the same number as a different report that is listed. It is unclear if the numerical mayhem was due to administrative carelessness by FIAT, or if there were intended to be two different series of FIAT final reports, or if more mundane reports with a given number were used as an unclassified placeholder to help conceal the existence of then-classified reports with the same number.

FIAT 1. *Investigation of Machine Tool Practice of M.A.N. at Augsburg, Germany.*

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FIAT 3. *Investigation of Machine Tools of Adam Opel at Russelsheim, Germany.*

FIAT 4. *German Infrared Targets in South Germany and Austria.*

FIAT 4. *Investigation of Measuring Instruments, Gages and Cutting Tools.*

FIAT 5. *Interrogation of General Gerhard Rose, Vice-President of the Robert Koch Institute,*

Berlin, and Chief Consultant in Tropical Medicine to the German Air Force.

FIAT 6. *Viscose Making at Suddeutsche Zellwolle A.G. Kelheim.*

FIAT 7. *Rayon Tow (Spinnband) and Staple in the Worsted Spinning Industry. Augsburger Kammgarm Spinnerei, Augsburg.*

FIAT 8. *Investigation of Textiles, I.G. Farbenindustrie Bobingen.*

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FIAT 10. *Continuous Process for Spinning Viscose Yarn at Zellwolle Lenzing Aktiengesellschaft Lenzing, Oberdonau, Austria.*

FIAT 11. *German Military Water Supply Equipment.*

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FIAT 19. *Viscose Staple Fiber (Spinning) at Lonziger Zellwolle Fabrik, A.G. Lenzing, Ost.*

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FIAT 23. *Viscose Rayon Staple Manufacture at Shia Viscosa Cesana Maderno (Milano).*

FIAT 24. *“Animalized” Viscose and Acetate Staple at I.G. Farbenindustrie, A.G., Bobbingen, Höchst and München.*

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FIAT 26. *Raw Materials Used in German Iron and Steel Industry.*

FIAT 26. *Manufacture of Viscose Yarn, Staple Fibre and Artificial Horsehair at Spinstoff Fabrik Berlin-Zehlendorf.*

FIAT 27. *“Cottonin” or Cottonized Flax, 3rd Army Intelligence Center Freising.*

FIAT 28. *Making of Acetic Anhydride by Pyrolysis of Acetic Acid at C.S. Boehringer & Sohne,*

Mannheim-Waldorf.

FIAT 29. *Manufacture of Acetic Anhydride at Consortium für Elektrochemie, Hollriegelskreuth.*

FIAT 30. *Polyvinyl Chloride Manufacture—Vinol HH at Alexander Wacker, Burghausen.*

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FIAT 32. *Acetic Anhydride, Cellulose Acetate Production and Weak Acid Recovery at I.G. Farben Dormagen.*

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FIAT Review of German Science 1939–1946

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Joint Intelligence Objectives Agency (JIOA) Final Reports

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NavTecMisEu LR 36-45. *German Bomb Carrier.*

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NavTecMisEu LR 48-45. *Eibia G.m.b.H., Investigation of.*

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NavTecMisEu LR 50-45. *Seat Belt and Harness and Membranlunge—Forwarding of.*

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NavTecMisEu LR 64-45. *Seasonal Variations and Psychological Causes of Flight Accidents by Wiedermann—Forwarding of.*

NavTecMisEu LR 65-45. *Sintered Iron Rotating Bands.*

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NavTecMisEu LR 72-45. *Union Rheinische Braunkohlen Kraftstoff AG. Partially Completed Underground Oil Refinery Located in Cement Quarry of Westfalische Kalkwerke Near Deiling Hofen (south of Menden).*

NavTecMisEu LR 73-45. *German Aircraft Engines and LTA Data.*

NavTecMisEu LR 74-45. *High Velocity Measurements on a Model of the Messerschmitt Me-163 Tailless Airplane with Untwisted Wings.*

NavTecMisEu LR 75-45. *Weather Observations from German Submarines, Information Concerning.*

NavTecMisEu LR 76-45. *A.D.I. (K) Secret Report Number 284/1945 on German Aircraft Cannon- 5.5cm. MK 112.*

NavTecMisEu LR 77-45. *Lead Sulphide Semi-Conductor Infra-red Cells for Homing Rockets.*

NavTecMisEu LR 78-45. *German Pi-Berlin Acoustic Torpedo Pistol.*

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NavTecMisEu LR 82-45. *Demonstration of a German Saboteur Swimmer (CNO Project Op-30-3E).*

NavTecMisEu LR 83-45. *Minesweeping German Navy, Investigation of a Ship Fitted to Stream and SSG Sweep.*

NavTecMisEu LR 84-45. *Pi 52A and Pi 52B Magnetic Torpedo Exploders.*

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NavTecMisEu LR 90-45. *Variable Area Exhaust Nozzles for Jet Engines, Test Data, Operating Curves, and Performance Data of.*

NavTecMisEu LR 91-45. *Perpetual Jack and Concrete Testing Machine.*

NavTecMisEu LR 92-45. *Jet Propulsion Reports—Forwarding of.*

NavTecMisEu LR 93-45. *Filters and High Refractive Index Class.*

NavTecMisEu LR 94-45. *Information Made Available to the Japanese Regarding German, British and U.S. Sweep Gear.*

NavTecMisEu LR 95-45. *Construction Equipment.*

NavTecMisEu LR 96-45. *Electronic Research, German. Interrogation of Prof. Dr. Scherger, Radar Research Director of the German Central Establishment for High Frequency Research.*

NavTecMisEu LR 97-45. *Great Torpedo Engine.*

NavTecMisEu LR 98-45. *Torpedo Pistols Pi 30, Pi 30M, and Pi 45.*

NavTecMisEu LR 99-45. *Babcock and Wilcox "Schlagermuhle" for Pulverizing Coal; the HS-Muhle for Pulverizing, Drying, Separating and Conveying Coal.*

NavTecMisEu LR 100-45. *Aerological Work at the Friedrick Krupp Shiessplatz in Meppen, Germany.*

NavTecMisEu LR 101-45. *"Influence Fuse" found at Unterluss.*

NavTecMisEu LR 102-45. *Induction Hardening Unit.*

NavTecMisEu LR 103-45. *Supersonic Plane.*

NavTecMisEu LR 104-45. *Aviation Medicine Research Library, Forwarding Duplicate Copies of.*

NavTecMisEu LR 105-45. *Torpedo Gyroscopes, LUT II and Specht.*

NavTecMisEu LR 106-45. *Transmittal of Drawings of Hydrogen Peroxide Production through 2-Ethyl Anthraquinone.*

NavTecMisEu LR 107-45. *Aerological Developments at the Deutsche Seewarte.*

NavTecMisEu LR 108-45. *Rust Preventive Coating for Steel and Miscellaneous Paints and Varnish.*

NavTecMisEu LR 109-45. *Anti-Aircraft Computer.*

NavTecMisEu LR 110-45. *Computing Sight for 3.7 cm. A.A. Guns.*

NavTecMisEu LR 111-45. *Torpedo Data Computer.*

NavTecMisEu LR 112-45. *German Equipment—Information on.*

NavTecMisEu LR 113-45. *The German Schnorchel.*

NavTecMisEu LR 114-45. *Rhinemetall Borsig, Sommerda Plant, Experimental Gun Development.*

NavTecMisEu LR 115-45. *Optics—German.*

NavTecMisEu LR 116-45. *Propellants.*

NavTecMisEu LR 117-45. *Evacuated Document "Bericht über Steuerungen," Summary of Contents of.*

NavTecMisEu LR 118-45. *Igloo type Magazines, Ventilation of.*

NavTecMisEu LR 119-45. *Lubricant Additive for Decreasing the Time for Gasoline Engine Break-in Periods.*

NavTecMisEu LR 120-45. *Report "Wassereinschlag und Unterwasserbahn des BT-1000" by the Graf Zepplin Research Laboratory, Stuttgart-Ruit, October 1942.*

NavTecMisEu LR 121-45. *Special Type Integrator for Computers.*

NavTecMisEu LR 122-45. *Acetylene Determination and Removal in Oxygen Plants.*

NavTecMisEu LR 123-45. *The Preparation of Tetrahydrofuran Polymers as a Synthetic Lubricant for Metals.*

NavTecMisEu LR 124-45. *Submarine Oxygen Plant Development.*

NavTecMisEu LR 125-45. *The Henschel HS-297 "Schmetterling" (Butterfly) Missile.*

NavTecMisEu LR 126-45. *Guided Missile Priority Ratings Obtained from a Letter from Reichsminister for Armament and War Production, Dated 9 March 1945.*

NavTecMisEu LR 127-45. *Gyro Controlled Anti-Aircraft Gun Sight.*

NavTecMisEu LR 128-45. *Synthetic Rubber Polymerization and Drying—Report on.*

NavTecMisEu LR 129-45. *Guided Missiles—Report on Controlled Explosive Boat, TASSO.*

NavTecMisEu LR 130-45. *German 40.6 cm Naval Gun. Notes on the Relation Between Careful Arrangement of the Propellant and Uniformity of Muzzle Velocity.*

NavTecMisEu LR 131-45. *Tables on Special Diesel Fuel Cuts—Forwarding of.*

NavTecMisEu LR 132-45. *Raising and Repairing of Structural Steel Bridge over the Weichsel River at Thorn, Poland.*

NavTecMisEu LR 133-45. *Control Organizations of German Naval Torpedo Production.*

NavTecMisEu LR 134-45. *Title: German Four Wheel Drive Car, Body Suspension of.*

NavTecMisEu LR 135-45. *Designations for German Mine Cases and German Influence Mine Units; System to be Used.*

NavTecMisEu LR 136-45. *Items of General Information Concerning the Hull Design of German Surface Vessels.*

NavTecMisEu LR 137-45. *Lurgi Mahltrochknug Process (Pulvo-Drying).*

NavTecMisEu LR 138-45. *Breech Ring Design, German Methods of Computing Breech Ring Stresses.*

NavTecMisEu LR 139-45. *List of Reports on Airframe Design and Testing—Transmittal of.*

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NavTecMisEu LR 147-45. *Supersonic Artificial Radar Target.*

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NavTecMisEu 495-45. *The German Aviation Exposure Foam Suit.*

NavTecMisEu 496-45. *Hydraulic Couplings for Marine Main Drives.*

NavTecMisEu 497-45. *A Review of the Infrared Work of the Electrical Testing an Experimental Office of the German Railways, “Elversa” (Elektro Technischos Versuchsamt Der Reichsbahn).*

NavTecMisEu 498-45. *Trends and Developments in German Fire Fighting Equipment During*

the War.

NavTecMisEu 499-45. *Water Entry and Underwater Trajectory Tests of the Bomb-Torpedo BT-1000.*

NavTecMisEu 500-45. *German Underwater Rockets.*

NavTecMisEu 501-45. *Comments on the German Aeronautical Research Program.*

NavTecMisEu 502-45. *Aerodynamic and Power Plant Research and Facilities at Luftfahrt Forschungsanstalt (LFA) Braunschweig and Aerodynamische Versuchs Anstalt (AVA) Goettingen.*

NavTecMisEu 503-45. *Gun Design and Interior Ballistics.*

NavTecMisEu 504-45. *The HFG Electromagnetic Mine Sweeping Gear.*

NavTecMisEu 505-45. *Marine Railways in Germany.*

NavTecMisEu 506-45. *Harbor and Graving Dock Construction Kriegsmarine, Wilhelmshaven, Germany.*

NavTecMisEu 507-45. *German Degaussing Station at Waalhaven, Holland.*

NavTecMisEu 508-45. *Demag Pneumatic Pile Driver.*

NavTecMisEu 509-45. *Steam Turbine Power Plant For Long Range Aircraft.*

NavTecMisEu 510-45. *Initiating Explosives, Lead Azide, Lead Styphnate and Tetracene.*

NavTecMisEu 511-45. *German Midget Submarines.*

NavTecMisEu 512-45. *Structural Welding Practices in Germany.*

NavTecMisEu 513-45. *Hexanitrodiphenylamine Manufacture in Germany.*

NavTecMisEu 514-45. *V-1 and V-2 Launching Sites and Handling Equipment.*

NavTecMisEu 515-45. *German Construction Equipment.*

NavTecMisEu 516-45. *Schmidt-Meissner Continuous Nitrators for Liquid Explosive Manufacture.*

NavTecMisEu 517-45. *The German Schnorchel.*

NavTecMisEu 518-45. *German Progress in the Development of Heat Iconoscopes (Infrared Image Tubes Sensitive To Wavelengths Longer than 2 Microns).*

NavTecMisEu 519-45. *The Properties of Klieforth Infrared Transparent Glasses.*

NavTecMisEu 520-45. *The Nachtfee (Night Fairy) System for Ground Control of Fighters.*

NavTecMisEu 521-45. *German Proposals for Improvement of Geier Torpedo Controls.*

NavTecMisEu 522-45. *Lippisch Proposed Design of Long-Range Anti-Aircraft Shell with Lorin Dynamic Pressure Rocket Propulsion.*

NavTecMisEu 523-45. *Trends in Design of German Medium Caliber Aircraft Guns.*

NavTecMisEu 524-45. *Report on Dornier Pursuit Plane Development Program.*

NavTecMisEu 525-45. *Full Scale Ship Trials in Germany.*

NavTecMisEu 526-45. *Projected Battleships of German Navy, Consisting of Two Types Known as "O" and "H," and Some Projected Types Known as "H" 41, "H" 42, "H" 43, and "H" 44.*

NavTecMisEu 527-45. *German Naval Hospitals.*

NavTecMisEu 528-45. *German Recorder for Plotting the Way of Torpedoes.*

NavTecMisEu 529-45. *The Low-Frequency Aspects of the "Marine Kurier" High Speed Radio Telegraph System.*

NavTecMisEu 530-45. *Sonar in the German Navy.*

NavTecMisEu 531-45.

NavTecMisEu 532-45. *Ellira Welding and Automatic Welding in Germany.*

NavTecMisEu 533-45. *German Navy Moored Minesweeping.*

NavTecMisEu 534-45. *Cavitation Tunnels in Foreign Model Basins and Research Institutions.*

NavTecMisEu 535-45. *Research and Facilities of Foreign Model Basins and Related Establishments.*

NavTecMisEu 536-45. *Research on Super-Conductivity at University of Erlangen, from an Interview with Prof. R. Hilsch.*

NavTecMisEu 537-45. *High Speed Research at AVA Goettingen.*

NavTecMisEu 538-45. *Aerodynamic Considerations of the Lorin Propulsion Power Plant.*

NavTecMisEu 539-45. *German Work on Atmospheric Electricity with Special Applications to Meteorology and Radio Systems.*

NavTecMisEu 540-45. *Long Range Aircraft Power Plant Developments.*

NavTecMisEu 541-45. *Engine Laboratory Techniques.*

NavTecMisEu 542-45. *Submarine Propulsion Plant Utilizing Ingolin Boiler.*

NavTecMisEu 543-45. *Facilities, Instrumentation, and Methods of the Hamburgische Schiffbau Versuchsanstalt.*

NavTecMisEu 544-45. *Blauschrift: A German Dark-Trace Cathode Ray Tube with Method of Erasure and Illumination.*

NavTecMisEu 545-45. *Manufacture and Design of Propellers in Germany.*

NavTecMisEu 546-45. *Information on the Aerodynamic Design of Axial Flow Compressors in Germany.*

NavTecMisEu 547-45. *Underwater Explosion Research in Germany.*

NavTecMisEu 548-45. *The Use of Coal Dust as an Explosive in Unconfined Areas.*

NavTecMisEu 549-45. *Radar and Countermeasures Developments of the Gema Company of Berlin, the Gesellschaft für Electroakustische und Mechanische Apparäte.*

NavTecMisEu 550-45. *History of German Jet Engine Developments.*

NavTecMisEu 551-45. *German Ram Jet Developments.*

NavTecMisEu 552-45. *German Sperrbrechers.*

NavTecMisEu 553-45. *Silver Solder for High Temperature Service.*

NavTecMisEu 554-45. *German Practice in Industrial and Military Radiography.*

NavTecMisEu 555-45.

NavTecMisEu 556-45. *Methane Cracking by Partial Combustion with Oxygen or Air in Germany.*

NavTecMisEu 557-45. *Scientific Developments of Interest for the Detection of Radiation by Superconductors.*

American Institute of Physics Niels Bohr Library & Archives (AIP)

AIP Goudsmit. Samuel A. Goudsmit Papers, 1921–1979.
https://repository.aip.org/islandora/object/nbla%3AAR2000-0092

Archiv der Max-Planck-Gesellschaft (AMPG)

AMPG 2019. Übersichten zum deutschen Uranprojekt Kernenergieforschung in Deutschland von 1939 bis 1945. https://www.archiv-berlin.mpg.de/79110/

AMPG 34/29. 2 July 1941. Karl Wirtz an das Oberkommando des Heeres (Befehlshaber des Ersatzheeres). Betrifft: Patentschrift 662 036 [Brasch and Lange]; Anmeldung Dr. G. Stetter. pp. 328–329.

AMPG 54. 1915–1918. Peter Debye. Thermodynamik. Abteilung I, Repositur 34.

AMPG 99a. 1945. Russian interrogations of German nuclear scientists. Abteilung I, Repositur 34.

AMPG 99b. 1945. Russian interrogations of German nuclear scientists. Abteilung I, Repositur 34.

AMPG 100. 1945–1946. Correspondence on nuclear research. Abteilung I, Repositur 34.

AMPG 4311. 1940–1943. Correspondence on nuclear research. Abteilung I, Repositur 34.

AMPG 4312. 1942–1944. Correspondence on nuclear research. Abteilung I, Repositur 34.

AMPG 4314. 1942–1944. Correspondence on nuclear research. Abteilung I, Repositur 34.

AMPG 4315. 1940–1944. Correspondence on nuclear research. Abteilung I, Repositur 34.

AMPG 4316. 1940–1943. Correspondence on nuclear research. Abteilung I, Repositur 34.

AMPG 7311. 1939–1941. U-235. Abteilung I, Repositur 34.

AMPG 7312. 1940. U-238. Abteilung I, Repositur 34.

AMPG 7313. 1941–1945. Brinq. Abteilung I, Repositur 34.

AMPG 7314. 1940–1941. Pu. Abteilung I, Repositur 34.

AMPG 7315. 1942–1945. Die Erfahrungen. Abteilung I, Repositur 34.

Bundesarchiv Militärarchiv, Freiburg

N822/1–17. Nachlass. Schumann, Erich.

RH8/369. [June 1942 report on submarine-launched Nebelwerfer rocket trials]

RH8/1276. [December 1944 report on Prüfstand XII]

RH8/4067K. [Original 1944 design drawings for Prüfstand XII]

RH8/4079K. [Original design drawings of A-4b or A-9 rocket]

RH8/4080K. [Original design drawings of A-4b or A-9 rocket]

RH8/4167K. [Original design drawing of A-10 rocket]

RH8/4213K. [Original drawings of flight trajectories of A-9 and A-9/A-10 rockets]

RH8/4406K. [Original design drawings of A-4b or A-9 rocket]

RH8/5817. [G-series and related nuclear reports]

RH8/5818. [G-series and related nuclear reports]

RH8/5819. [G-series and related nuclear reports]

RH8/5820. [G-series and related nuclear reports]

RL39/910. [Report on 1942 flight tests with Sänger-Bredt ramjet mounted on top of Dornier Do 217 aircraft]

Deutsches Museum Archive, Munich

ARCH 20/11. Carl Wagner. 10 May 1941. *Bericht über die thermodynamische Durchrechnung des Zustandes von Feuerungsgasen XI. (Vergleich verschiedener Sauerstoffträger).*

ARCH 50/10. A. Thiel and A. Walther. 8 April 1943. *10. Bericht um Gleiter. Einfluß des Brennschluß-Bahnwinkels* v_B *auf die Flugweite des A 9 mit Salbeiantrieb.*

ARCH 57/23. 23 October 1944. *Über die Möglichkeit der Schußweitensteigerung des Gerätes "F."*

ARCH 62/11. Klagge. 23 May 1941. *Zweistufen-Aggregat 25/4 to und 25/6 to.*

ARCH 62/16. Klagge and Richober? 23 September 1943. *Zweistufenaggregate mit flüssigen Treibstoffen.*

ARCH 66/56. Anonymous. Undated. *Über das Prandtl-Busemannsche Verfahren zur zeichner-*

ischen Verfolgung ebener Ueberschallströmungen, seine Verwendung für den Entwurf von Windkanalüsen und die hierbei anzubringenden Korrekturen.

ARCH 68/9. 9 November 1940. *Bericht 8/40: Berechnung der Hauttemperatur für Gleiter A 4.*

ARCH 68/11. 15 March 1941. *Bericht: 1/41 TA/Proj. Aerodynamische Unterlagen für Gleiter A 4 V 12/c.*

ARCH 68/17. 8 September 1941. *Bericht 7/41: Konstruktionsentwurf und Dimensionierung des Gleiters A 4 V 12/c.*

ARCH 68/19. Vettin Graupe. 3 December 1941. *Bericht Proj. 9/41: Zwei Flugbahnen des A9 (Gleiter A4 V12/c) mit verschiedenen Nutzlasten.*

ARCH 68/20. 17 November 1941. *Bericht 10/41: Erwärmung der Nutzlastspitze des Gleiters A 4 während des Fluges.*

ARCH 68/21. Vettin Graupe. 20 October 1941. *Bericht 11/41: Die Flugbahn eines Zweistufengleiters.*

ARCH 68/22. Hermann Oberth. 7 January 1942. *Über die beste Teilung von Stufenaggregaten.*

ARCH 68/25. 16 June 1942. *Erwärmung der Haut und der Nutzlastspitze verschiedener Entwürfe A8 und A9 während des Fluges.*

ARCH 68/58. Stümke. 7 October 1944. *Zwei Flugbahnen des Gleiters A 4 b mit berichtigten Betriebsdaten. (Beitrag zur Frage der zweckmässigsten Flugart).*

ARCH 81/11. Thiel and Heller. 14 October 1941. *Beurteilung von Stickstofftetroxyd als Sauerstoffträger.*

ARCH 87/146. 30 November 1942. *Sachgruppe A/b = Flugbahnberechnungen. Bericht Nr. 146: Umlenkung mit Hawaii für A 4.*

ARCH 88/1. Steuding. 28 May 1940. *A/a betr.: Allgemeine Flugbahnberechnungen. Bericht 1: Ein Beitrag zur äusseren Ballistik der R-Geschosse auf dem drehenden Erdsphäroid.*

ARCH 94/14. 5 Juli 1941. *Arbeitsbericht der Abt. TA/Proj. für den Monat Juni 1941.*

ARCH 94/15. 5 August 1941. *Monatsbericht der Abteilung TA/Proj. für den Monat Juli 1941.*

ARCH 94/16. 6 September 1941. *Monatsbericht der Abteilung TA/Proj. für den Monat August 1941.*

ARCH 94/17. 6 Oktober 1941. *Monatsbericht der Abteilung TA/Proj. für den Monat September 1941.*

ARCH 94/18. 6 November 1941. *Monatsbericht der Abteilung TA/Proj. für den Monat Oktober 1941.*

ARCH 94/19. 6 December 1941. *Monatsbericht der Abteilung T/Proj. für den Monat November 1941.*

ARCH 94/20+21. 4 February 1942. *Monatsbericht der Abteilung T/Proj. für die Monate Dezem-*

ber 1941 und Januar 1942.

ARCH 94/22. 10 March 1942. *Monatsbericht der Abteilung T/Proj. für den Monat Februar 1942.*

ARCH 94/23. 15 April 1942. *Monatsbericht der Abteilung T/Proj. für den Monat März 1942.*

ARCH 110/25. Büchner. 20 April 1944. *Berechnung thermodynamischer Daten von Feuergasen 1: Treibstoffkombination: Benzin oder Gasöl + Salpetersäure.*

ARCH 110/27. Schabert. 10 May 1944. *Laborsonderbericht 12: Verbrennung von Kohlenwasserstoffen mit Sauerstoffträgern. 1 Teilbericht: Verbrennungsgeschwindigkeit von Benzin.*

ARCH 115/3. Steuding. 29 November 1939. *Fesselung des. Agg. IV und X (100 t) im Standversuch. Aerodynamische Führung der Agg. in Höhen über 50 bis 100 km.*

Digipeer. http://www.digipeer.de

FA 002/811. Undated. Fotografien des Versuchsaufbaus zur Ultrazentrifuge I. Hellige, Freiburg. http://digital.deutsches-museum.de/item/FA-002-811/

G-1. Erbacher. Undated. [*Chemistry of Protactinium and Isotopes.*]

G-2. Herbert Hoyer. Undated. [*Effect of the Catalytic Effectiveness of a Few Contact Catalysts on the Isotope Exchange Between Water Vapor and* H_2 *Gas.*]

G-3. Erich Wietig. Undated. [*The Testing of the Permeability of Filters with the Help of Radioactive Indicators.*]

G-4. W. Wiebe. Undated. [*The Cyclotron as a Method of Accelerating Light Ions. A Survey of the Literature and Report on the Construction of a Cyclotron at the University of Bonn.*]

G-5. Siegfried Flügge. 1939. [*Can the Energy Content of Atomic Nuclei Be Used Technically?*]

G-6. Siegfried Flügge. 1939. [*Calculation of Fraction of Neutrons Which Undergo Resonance Absorption in a Uranium Hydrogen Mixture.*]

G-7. Paul O. Müller. 1939. [*Effective Cross Section for U Fission.*]

G-8. Nikolaus Riehl. 1940. [*Analysis of Uranium Oxide from a Belgian Source.*]

G-9. Erich Bagge. 1940. [*The Destruction of Deuterons by Fast Neutrons.*]

G-10. Walther Bothe. 1940. [*Method of Measuring Diffusion of Neutrons.*]

G-11. Walther Bothe. 1940. [*Quantitative Analysis of Three Samples of Preparation No. 38 (*U_3O_8*).*]

G-12. Walther Bothe. 7 June 1940. *Die Diffusionsläge für thermische Neutronen in Kohle.* [*Diffusion Length of Thermal Neutrons in Carbon.*]

G-13. Walther Bothe. 28 June 1940. *Die Abmessungen endlicher Uranmaschinen.* [*Survey of Finite Piles.*]

G-14. Walther Bothe. 17 July 1941. *Die Abmessungen von Maschinen mit rücksteuendem Mantel.* [*Evaluation of Pile with Reflector.*]

G-15. Walther Bothe. 1940. [*Rules of Indicator Measurements.*]

G-16. Walther Bothe. 1940. [*Rigorous Treatment of Diffusion in an Absorbing Medium.*]

G-17. Walther Bothe and Wolfgang Gentner. 9 May 1940. *Die Energie der Spaltungsneutronen aus Uran.* [*The Energy of Fission Neutrons from Uranium.*]

G-18. Klaus Clusius. January–April 1940. [*Report on the Separation Experiments on Metallic Ions with the Help of Nernst Partition Law.*]

G-19. Klaus Clusius and M. Maierhauser. May–June 1940. [*Report II. Part 1. On the Separation Experiments on Metallic Ions with the Help of Nernst Partition Law. Part 2. Construction of a Separation Column.*]

G-20. Klaus Clusius, Gerhard Dickel, and M. Maierhauser. August–December 1940. [*Report III. A. Results of Operation of Separation Column Described in Report II. B. Preliminary Experiments on the Choice of a U Salt for the Separation Experiments. C. Supplement to Report II on the Separation Experiments of Metal Ions Applying the Nernst Partition Law.*]

G-21. Erica Cremer and Karl Wirtz. 21 June 1940. *Untersuchungen des Schwerwassergehaltes einiger technischer Elektrolyseure in Deutschland.* [*The Heavy Water Content of Several Commercial Electrolytic Cells in Germany.*]

G-22. Robert Döpel, Klara Döpel, and Werner Heisenberg. 5 December 1940. *Bestimmung der Diffusionslänge thermischer Neutronen in Präparat 38.* [*Determination of the Diffusion Length of Thermal Neutrons in Preparation 38 (U_3O_8).*]

G-23. Robert Döpel, Klara Döpel, and Werner Heisenberg. 7 August 1940. *Bestimmung der Diffusionslänge thermischer Neutronen in schwerem Wasser.* [*Bestimmung der Diffusionslänge thermischer Neutronen in Präparat 38.* [*Determination of the Diffusion Length of Thermal Neutrons in Heavy Water.*]

G-24. Gottfried von Droste. 1940. [*Report on an Experiment with Two Tons of Sodium Uranate.*]

G-25. Arnold Flammersfeld, Peter Jensen, and Wolfgang Gentner. 1940. [*The Energy Spectrum Developed by Uranium Fission.*]

G-26. Arnold Flammersfeld, Peter Jensen, and Wolfgang Gentner. 1940. [*The Distribution Ratio and Energy Spectrum in U Fission.*]

G-27. Rudolf Fleischmann. 1940. [*A Possible Process for Isotope Separation of Uranium.*]

G-28. Rudolf Fleischmann. 13 December 1940. *Über einige Konstanten und Eigenschaften von UF_6.* [*Some Constants and Properties of UF_6.*] Deutsches Museum number FA 002/0515. http://digital.deutsches-museum.de/item/FA-002-515/

G-29. Siegfried Flügge. 1940. [*Calculation of the Fraction of Neutrons Which Undergo Resonance Absorption in a Uranium-Hydrogen Mixture, Part II.*]

G-30. Siegfried Flügge. 1940. [*Calculation of the Fraction of Neutrons Which Undergo Resonance Absorption in a Uranium-Hydrogen Mixture, Part III.*]

G-31. Erwin Fünfer. 1940. [*Intermediate Report on the Back Scattering of C Group Neutrons in*

Iron.]

G-32. Wilhelm Groth and Paul Harteck. 12 May 1940. *Korrosionsversuche an zwei eingesandten Metallegierungen (Stahllegierung und Leichtmetallegierung) mit Uranhexafluorid.* [*Corrosion Experiments on Two Alloys (Steel and Light Metal Alloys) with Uranium Hexafluoride.*] Deutsches Museum number FA 002/511. http://digital.deutsches-museum.de/item/FA-002-511/

G-33. Wilhelm Groth and Paul Harteck. 1940. *Stand der Arbeiten zur Trennung der Isotope* ^{235}U *und* ^{238}U. [*Status of Work on Separating* ^{235}U *und* ^{238}U.] Deutsches Museum number FA 002/0490. http://digital.deutsches-museum.de/item/FA-002-490/

G-34. Otto Hahn(?). 1940. [*Report on the Work of the Kaiser Wilhelm Institute on the Chemistry of Preparation 38* (U_3O_8).]

G-35. Wilhelm Hanle. 1940. [*Investigation of Cadmium Content of Carbon.*]

G-36. Paul Harteck, Johannes Jensen, Friedrich Knauer, and Hans Süß. 19 August 1940. *Über die Bremsung, die Diffusion und den Einfang von Neutronen in fester Kohlensäure und über ihren Einfang in Uran.* [*The Slowing Down, Diffusion, and Capture of Neutrons in Solid* CO_2*, and Their Capture in Uranium.*]

G-37. Otto Haxel and H. Volz. 1940. [*The Absorption of Neutrons in Aqueous Solutions.*]

G-38. Otto Haxel and H. Volz. 1940. [*Absorption Cross Section for Slow Neutrons. Method 1. Dependence on Concentration.*]

G-39. Werner Heisenberg. 6 December 1939. *Die Möglichkeit der technischer Energiegewinnung aus der Uranspaltung.* [*The Possibility of Technical (Useful) Energy Production from Uranium Fission.*]

G-40. Werner Heisenberg. 29 February 1940. *Bericht über die Möglichkeit technischer Energiegewinnung aus der Uranspaltung (II).* [*Report on the Possibility of Technical (Useful) Energy Production from Uranium Fission.*]

G-41. Karl-Heinz Höcker. 16 June 1940. *Die Abhängigkeit des Energiegewinnes in der Uranmaschine von der Dichte des Urans und der Dichte der Bremssubstanz.* [*Dependence of the Energy Output of the Uranium Pile on the Density of the Uranium and the Density of the Moderator.*]

G-42. Karl-Heinz Höcker. 20 April 1940. *Berechnung der Energieerzeugung in der Uranmaschine. II. Kohle als Bremssubstanz.* [*Calculation of Energy Production in the Uranium Pile. II. Carbon as Moderator.*]

G-43. Karl-Heinz Höcker. 3 June 1940. *Berechnung der Energieerzeugung in der Uranmaschine. IV. Wasser.* [*Calculation of Energy Production in the Uranium Pile IV. Water as Moderator.*]

G-44. Willibald Jentschke and Friedrich Prankl. 1940. [*Energies and Masses of Uranium Fission Products.*]

G-45. Willibald Jentschke, Friedrich Prankl, and F. Hernegger. 1940. [*Proof of the Nuclear Fission of Ionium under Neutron Irradiation.*]

G-46. Georg Joos. 29 March 1940. [*The Production of Extremely Pure Carbon.*]

G-47. Fritz Kirchner and H. Twick. 1940. [*Energy Distribution of Uranium Fission Neutrons.*]

G-48. Josef Mattauch. 1940. [*The Number of Neutrons Occurring in the Fission of* U^{235} *and* U^{238}*.*]

G-49. Paul O. Müller. Undated. *Die Energiegewinnung aus dem Uranspaltungsprozeß durch schnelle Neutronen.* [*Energy Production by the Fast Neutron Fission of Uranium.*] Deutsches Museum number FA 002/0463.

G-50. Paul O. Müller. 1940. [*A Requirement for the Utilization of Uranium as an Explosive.*]

G-51. Paul O. Müller. 1940. [*Neutron Absorption in Spherical Shells of Uranium.*]

G-52. Paul O. Müller. 1940. [*The Temperature Coefficient of the Uranium Pile.*]

G-53. Paul O. Müller. 1940. [*Calculation of Energy Production of Uranium Pile. III.* D_2O *as Moderator.*]

G-54. Wolfgang Riezler. 1940. [*Absorption of C Neutrons in Rare Earths.*]

G-55. Josef Schintlmeister and Friedrich Hernegger. June 1940. *Über ein bisher unbekanntes alphastrahlendes chemisches Element.* [*Concerning a Heretofore Unknown Alpha Emitting Chemical Element.*] Deutsches Museum number FA 002/0486. https://digital.deutsches-museum.de/item/FA-002-486/

G-56. Ernst Stuhlinger. 1940. [*The Determination of Absorption Cross Sections for Slow Neutrons.*]

G-57. Carl Friedrich von Weizsäcker. 1940. [*The Production of Neutrons in Heavy Water by the Process D(n,2n)H.*]

G-58. Carl Friedrich von Weizsäcker. 1940. [*The Disintegration of Deuterons.*]

G-59. Carl Friedrich von Weizsäcker. 17 July 1940. *Eine Moglichkeit der Energiegewinnung aus* ^{238}U*.* [*The Possibility of Obtaining Energy from* U^{238}*.*] Deutsches Museum number FA 002/0501. http://digital.deutsches-museum.de/item/FA-002-501/

G-60. Carl-Friedrich von Weizsäcker, Paul Müller, and Karl-Heinz Höcker. 26 February 1940. *Berechnung der Energieerzeugung in der Uranmaschine.* [*Calculation of the Energy Production in the Uranium Pile.*]

G-61. Karl Wirtz. 19 January 1940. *Bericht II. Eine 10-stufige Elektrolyseuranlage zur Gewinnung von schwerem Wasser.* [*Report II. A Ten Stage Electrolysis Plant for Producing Heavy Water.*]

G-62. Karl Wirtz. 1940. [*Heavy Water Production.*]

G-63. Karl Wirtz. 1940. [*Heavy Water Production.*]

G-64. 1941. [*Solubilities and Properties of Uranium Salts.*]

G-65 = **G-11**.

G-66. Walther Bothe. 28 March 1941. *Einige Eigenschaften des U und der Bremsstoffe. Zusammenfassender Bericht über die Arbeiten.* [*A Few Properties of Uranium and Moderators.*]

G-67. Walther Bothe and Arnold Flammersfeld. 20 January 1941. *Die Wirkungsquerschnitte von 38 für thermische Neutronen aus Diffusionsmessungen.* [*The Effective Cross Section of Preparation 38 (U_3O_8) for Thermal Neutrons from Diffusion Measurements.*]

G-68. Walther Bothe and Arnold Flammersfeld. 8 March 1940. *Resonanzeinfang an einer Uranoberfläche.* [*The Resonance Capture in a Uranium Surface.*]

G-69. Walther Bothe and Arnold Flammersfeld. 26 May 1941. *Messungen an einem Gemisch von 38-Oxyd und -Wasser; der Vermehrungsfaktor und der Resonanzeinfang.* [*Measurement of the Multiplication Factor X and the Resonance Absorption Factor W for a Mixture of 38-Oxide (U_3O_8); the Diffusion Length in 38-Metal.*]

G-70. Walther Bothe and Arnold Flammersfeld. 11 July 1941. *Die Neutronenvermehrung bei schnellen und langsamen Neutronen in 38 und die Diffusionslänge in 38 Metall und Wasser.* [*Neutron Increase for Fast and Slow Neutrons in 38 (U_3O_8) and the Diffusion Length in 38-Metal and Water.*]

G-71. Walther Bothe and Peter Jensen. 20 January 1941. *Die Absorption thermischer Neutronen in Elektrographit.* [*The Absorption of Thermal Neutrons in Electrographite.*]

G-72. Walther Bothe and Peter Jensen. 12 May 1941. *Resonanzeinfang an einer Uranoberfläche.* [*Resonance Capture in a Uranium Oxide Surface.*]

G-73. Klaus Clusius, M. Maierhauser, and Gerhard Dickel. 1941. [*Report for the Year 1940–41 on the Experiments for the Development of an Extraction Process for Isotope Separation.*]

G-74. Walther Bothe and Arnold Flammersfeld. 28 April 1941. *Versuche mit einer Schichtenanordnung von Wasser und Präparat 38.* [*Experiments with a Layer Arrangement of Water and Preparation 38 (U_3O_8).*]

G-75. Robert Döpel, Klara Döpel, and Werner Heisenberg. 28 October 1941. *Versuche mit Schichtenanordnungen von D_2O und 38.* [*Experiments with a Layer Arrangement of D_2O and Preparation 38 (U_3O_8).*]

G-76. Gottfried von Droste. 1941. [*The Absorption Cross Section of Boron and Lithium for Thermal Neutrons.*]

G-77. Gottfried von Droste. 1941. [*Increase in Neutron Density in Preparation 38 (U_3O_8).*]

G-78. Gottfried von Droste. 1941. [*The Fission Process in Preparation 38 (U_3O_8).*]

G-79. Erich Fischer. 1941. [*Determination of the Absorption Cross Section of Uranium for Slow Neutrons.*]

G-80. Rudolf Fleischmann. 1941. [*The Capture Cross Sections of Aluminum for Thermal Neutrons.*]

G-81. Walther Bothe and Erwin Fünfer. 10 October 1941. *Absorption thermischer Neutronen und die Vermehrung schneller Neutronen in Beryllium.* [*The Absorption of Thermal Neutrons and the Increase of Fast Neutrons in Beryllium.*]

G-82. Wilhelm Groth. 1941. [*Status of Work on Building an Ultracentrifuge.*]

G-83. Wilhelm Groth and Hans Suess. 1941. [*Status of Work on Isotope Separation of Preparation 38 (U_3O_8) at the Institute of Physical Chemistry, University of Hamburg. Separation Column Experiment and Construction of Ultracentrifuge. Analysis of Tests.*]

G-84. Otto Hahn, Siegfried Flügge, and Gottfried von Droste. 1941. [*Work Done at the Kaiser*

Wilhelm Institute for Chemistry. (A). Report on Chemical Work. (B) On Physical Work, Especially Investigation of Resonance Process. (C) The Fission Process of Preparation 38 (U_3O_8).]

G-85. Wilhelm Hanle. 1941. [*The Determination of Boron and Cadmium in Carbon.*]

G-86. Paul Harteck. December 1941. *Die Produktion von schwerem Wasser.* [*The Production of Heavy Water.*]

G-87. Paul Harteck. 1941. [*Report on Status of Work and Proposals for Future Work.*]

G-88. Paul Harteck. December 1941. *Die Trennung der Uranisotope.* [*The Separation of Uranium Isotopes.*]

G-89. Paul Harteck and Johannes Hans Jensen. 18 February 1941. *Der Thermodiffusionseffekt im Zusammenspiel mit der Konvektion durch mechanisch bewegte Wände und Vergleich mit der Thermosiphonwirkung.* [*Thermo Diffusion Effects in Interaction with Convection by Mechanically Moved Walls and Comparison with Thermo-Siphon Effect.*]

G-90. Paul Harteck and Johannes Hans Jensen. 1941. [*The Energy Requirements in the Enrichment of U^{235} Isotope.*]

G-91. Otto Haxel, Ernst Stuhlinger, and H. Volz. 1941. [*.The Absorption and Slowing Down of Neutrons in Beryllium Oxide.*]

G-92. Werner Heisenberg. 1941. *Über die Möglichkeit der Energieerzeugung mit Hilfe des Isotops 238.* [*The Possibility of Producing Energy from the Isotope 238.*]

G-93. Werner Heisenberg. May 1941. *Bericht über Versuche mit Schichtenanordnungen von Präparat 38 und Paraffin am Kaiser Wilhelm Institut für Physik in Berlin-Dahlem.* [*Report on Experiments with Layers of Preparation 38 (U_3O_8) and Paraffin at the Kaiser Wilhelm Institute for Physics at Berlin-Dahlem.*]

G-94 = **G-267** (also part of G-318). Fritz G. Houtermans. August 1941. *Zur Frage der Auslösung von Kern-Kettenreaktionen.* [*The Question of Starting a Nuclear Chain Reactor.*] Deutsches Museum number FA 002/0744. http://digital.deutsches-museum.de/item/FA-002-744/

G-95. Johannes Hans Jensen. 1941. *Über die Ultrazentrifugenmethode zur Trennung der Uranisotopen.* [*The Ultracentrifuge Method for Separating Uranium Isotopes.*] Deutsches Museum number FA 002/0531. https://digital.deutsches-museum.de/item/FA-002-531/

G-96 = **G-97**. Johannes Hans Jensen. 1941. [*Theoretical Considerations on the Exchange Reaction in the Presence of Colloidal Catalysts.*]

G-98. Peter Jensen. 1941. [*A Further Determination of the Absorption Cross Section of 38 (U_3O_8) for Thermal Neutrons.*]

G-99. Willibald Jentschke. 1941. [*Energies and Masses of Uranium Fission Fragments by Irradiation with Fast (Ra + Be) Neutrons.*]

G-100. Willibald Jentschke and Karl Lintner. 1941. [*The Range Distribution of Heavy Fission Products from U by Irradiation with Slow Neutrons.*]

G-101. Fritz Kirchner. 1941. [*Remarks Concerning the Estimation of the Number of Fission Neu-*

trons Per Absorbing Neutron.]

G-102. Horst Korsching. 5 September 1941. *Trennung von schwerem und leichtem Benzol durch Thermo-Diffusion in flüssiger Phase.* [*Separation of Heavy and Light Benzene by Thermal Diffusion in the Liquid Phase.*]

G-103. Horst Korsching. 1941. [*On the Production of Metallic Uranium by Electrolysis.*]

G-104. Josef Kremer. 1941. [*Neutron Absorption Measurements by Means of Artificially Radioactive Indicators.*]

G-105. Linde Ice Machine Company. 1941. [*Process for Producing Heavy Hydrogen and/or Heavy Water.*] Deutsches Museum number FA 002/0788. https://digital.deutsches-museum.de/item/FA-002-788/

G-106. Karl Lintner. October 1941. [*Determination of the Water Content of Uranium Oxide.*]

G-107. H. Martin and K. H. Eldau. 1941. [*Appendix to Report of 15 July 1941 on the Construction of an Ultracentrifuge to Separate Isotopes. The Stability of Some Metals to* UF_6 *Vapor at Room Temperature and at* $50^{\circ}C$.]

G-108. H. Martin and K. H. Eldau. 9 December 1940. [*The Question of Stability of Uranium Pentachloride.*]

G-109. Wolfgang Riezler. 1941. [*The Absorption Cross Section of Metallic Uranium for Slow Neutrons.*]

G-110. Kurt Sauerwein. 1941. [*Investigation of the Resonance Capture of Neutrons by Uranium.*]

G-111. Josef Schintlmeister. 1941. *Die Stellung des Elementes mit Alphastrahlen von 1,8 cm Reichweite im periodischen System.* [*The Placing in the Periodic Table of the Element with Alpha Rays of 1.8 cm Range.*] Deutsches Museum number FA 002/0554. https://digital.deutsches-museum.de/item/FA-002-554/

G-112. Josef Schintlmeister and Friedrich Hernegger. May 1941. *Weitere chemische Untersuchungen an dem Element mit Alphastrahlen von 1,8 cm Reichweite.* [*Further Chemical Investigation of an Element with Alpha Rays of 1.8 cm Range.*] Deutsches Museum number FA 002/0552. https://digital.deutsches-museum.de/item/FA-002-552/

G-113. Kurt Starke. 1941. [*Enrichment of Artificially Radioactive Uranium Isotope* ${}_{92}U^{239}$ *and Its Daughter* 93^{239} *(Element 93).*]

G-114. Ernst Stuhlinger. 1941. [*The Determination of the Capture Cross Section of Nitrogen and Chlorine for Thermal Neutrons.*]

G-115. Hans Suess. 1941. [*The Exchange Reaction* H_2O *(Vapor)* H_2 *on a Nickel Catalyst and the Situation of the Exchange Equilibrium.*]

G-116. H. Volz. 1941. [*The Absorption of Uranium in the Resonance Region.*]

G-117. H. Volz. 1941. [*The Velocity Distribution of Neutrons in a Mixture of Heavy Water and Uranium.*]

G-118. H. Volz and Otto Haxel. 1941. [*The Absorption of Neutrons in Uranium.*]

G-119. L. Waldmann. 1941. [*Production of Heavy Hydrogen by Electrolysis.*]

G-120. L. Waldmann. 1941. [*The Effect of Thermal Decomposition of the Gas on the Separating Factor in the Separating Tube.*]

G-121. Carl-Friedrich von Weizsäcker. 1941. [*The Temperature Effect of the Layer Type Pile.*]

G-122. Carl-Friedrich von Weizsäcker. 1941. [*Comments on the Calculation of Layer Arrangements.*]

G-123. W. Wiebe. Undated. [*Investigation of the Construction of a Cyclotron.*]

G-124. Erich Bagge. 1942. [*The Possibility of Enrichment of the Light Uranium Isotope with a "Velocity Selector."*] Deutsches Museum number FA 002/735.
http://digital.deutsches-museum.de/item/FA-002-735/

G-125. Friedrich Berkei, W. Borrmann, Werner Czulius, Kurt Diebner, Georg Hartwig, Karl-Heinz Höcker, Walter Herrmann, Heinz Pose, and Ernst Rexer. 1942. *Bericht über einen Würfelversuch mit Uranoxyd und Paraffin.* [*Report on a Cube Experiment with Uranium Oxide and Paraffin at the Army Weapons Experimental Station, Gottow.*]

G-126. Fritz Bopp, Erich Fischer, Werner Heisenberg, Carl-Friedrich von Weizsäcker, and Karl Wirtz. 1942. [*Preliminary Report on the Results with a Layer Sphere of 38-Metal and Paraffin.*]

G-127. Fritz Bopp, Erich Fischer, Werner Heisenberg, Carl-Friedrich von Weizsäcker, and Karl Wirtz. March 1942. *Untersuchungen mit neuen Schichtenanordnungen aus U-metall und Paraffin.* [*Tests with a New Layer Arrangement of U-Metal and Paraffin.*]

G-128. Walther Bothe. 7 December 1941. *Maschinen mit Ausnutzung der Spaltung durch schnelle Neutronen.* [*Piles for the Utilization of Fission by Fast Neutrons.*]

G-129. Walther Bothe. 1942. [*Comments on the Leipzig D_2O Experiment.*]

G-130. Walther Bothe. 1942. [*The Velocity Distribution of Neutrons in a Slowing Down Medium.*]

G-131. Walther Bothe. 1942. [*The Increase of Fast Neutrons in Uranium and Some Other Work from K.W.I. Heidelberg.*]

G-132. Klaus Clusius, Gernhard Dickel, and L. Waldmann. 1942. [*Effect on the Performance of Wire Separator Tubes by the Centering and Insertion of Discs.*]

G-133. Klaus Clusius and M. Maierhauser. 1942. [*The Further Development of the Process for Isotope Separation by Means of the Nernst Partition Law.*]

G-134. Klaus Clusius and Kurt Starke. 1942. [*The Production of Heavy Water. Extraction and Rectification of H_2-HD-D_2 Mixtures.*]

G-135. Robert Döpel. 9 July 1942. *Bericht über Unfälle beim Umgang mit Uranmetall.* [*Report on Two Accidents Occurring with Uranium Metal.*]

G-136. Robert Döpel, Klara Döpel, and Werner Heisenberg. July 1942. *Der experimentelle Nachweis der effektiven Neutronenvermehrung in einem Kugel-Schichten-System aus D_2O und Uran-Metall.* [*The Experimental Demonstration of Neutron Multiplication in a Spherical System of Uranium Metal Plates and Heavy Water.*]

G-137. Robert Döpel, Klara Döpel, and Werner Heisenberg. 1942. [*The Neutron Increase in 38 Metal by Fast Neutrons.*]

G-138. Elbel. 1942. [*Graphical Representation of Water Enriching Experiments.*]

G-139. Heinz Ewald. 1942. *Eine neue Methode zur magnetischen Isotopentrennung.* [*A New Method of Magnetic Isotope Separation.*] Deutsches Museum number FA 002/0613.

G-140. Siegfried Flügge. 27 January 1942. *Zur spontane Spaltung von Uran und seinen Nachbarelementen.* [*The Spontaneous Fission of Uranium and Its Neighboring Elements.*]

G-141 (also part of G-318). Siegried Flügge. 1942. *Zur Theorie der Resonanzabsorption.* [*Theory of Resonance Absorption. Calculation of the Fraction of Neutrons Which Undergo Resonance Absorption in a Uranium-Hydrogen Mixture, Part IV.*] Deutsches Museum number FA 002/0744.

G-142 (also part of G-318). Siegried Flügge. 1942. *Kann man eine Uranmaschine mit schnellen Neutronen betreiben?* [*Can the Uranium Pile Work with Fast Neutrons?*] Deutsches Museum number FA 002/0744.

G-143. Siegried Flügge and Kurt Sauerwein. 1942. [*Investigation of the Resonance Capture of Neutrons by Uranium, Part II.*]

G-144. W. Fritz and E. Justl. 1942. [*Report on the Performance of the Uranium Pile.*]

G-145. Wilhelm Groth. 1942. [*Report on Conference with Professor Svedberg and Dr. Pedersen of the Institute of Physical Chemistry at the University of Upsala (Sweden).*]

G-146. Wilhelm Groth. 1942. *Trennung der Uranisotope nach dem Ultrazentrifugenverfahren. I. Anreicherung der Xenonisotope in einer einstufigen Ultrazentrifuge.* [*Separation of Uranium Isotopes by the Ultracentrifuge. I. Enrichment of the Xenon Isotope in a Single Stage Ultracentrifuge.*]

G-147. Wilhelm Groth. 1942. *Die Trennung der Uranisotope nach dem Trennrohr- und dem Ultrazentrifugenverfahren.* [*Separation of the Uranium Isotopes by the Separation Tube and the Ultracentrifuge.*] Deutsches Museum number FA 002/0610.

G-148. Wilhelm Groth and Hans Suess. 1942. [*Status of Work on Separation of Isotopes of Preparation 38.*]

G-149. Wilhelm Groth and A. Suhr. 1942. *Trennung der Uranisotope nach dem Ultrazentrifugenverfahren. II. Anreichung der Uranisotope U_{234} and U_{235} in einer einstufigen Ultrazentrifuge.* [*Separation of Uranium Isotopes by the Ultracentrifuge. II. Enrichment of Uranium Isotopes U_{234} and U_{235} in a Single Stage Ultracentrifuge.*] Deutsches Museum number FA 002/0621.

G-150. Otto Hahn. 1942. [*The Fission of the Uranium Nucleus.*]

G-151. Otto Hahn and Fritz Strassmann. 27 February 1942. *Zur Folge nach der Entstehung des 2,3 Tage-Isotops des Elements 93 aus Uran.* [*The Origin of 2.3 Day Isotope of Element 93 from Uranium.*]

G-152. Otto Hahn, Fritz Strassmann, and H. Götte. 27 February 1942. [*Experimental Work on the Separation of Uranium Fission Products.*]

G-153. Wilhelm Hanle. 1942. [*Spectroscopic Analysis of Carbon, Aluminum, and Beryllium.*]

G-154. 26 February 1942. Paul Harteck. *Die Gewinnung von schwerem Wasser.* [*The Production of Heavy Water.*] Deutsches Museum number FA 002/0591.

G-155. Paul Harteck. 1942. [*Viewpoints on the Construction of the Clusius Linde Exchange Plant.*]

G-156. Paul Harteck. 1942. *Die Trennung von Isotopen unter besonderer Berücksichtigung der Isotopen des Urans.* [*The Separation of Isotopes with Special Reference to the Isotopes of Uranium.*] Deutsches Museum number FA 002/0518.

G-157. Paul Harteck and Wilhelm Groth (Institut für Phys. Chemie, Hamburg); Erich Noack and Walter Kwasnik (I.G. Farben Leverkusen). 11 June 1942. *Herstellung von Uranhexafluorid im Halbtechnischen Masstab. Untersuchung der Legierungsfahigkeit von Metallischem Uran.* [*Production of Uranium Hexafluoride on a Semi-Commercial Scale. Investigation of Alloying Properties of Metallic Uranium.*] Deutsches Museum number FA 002/0730. http://digital.deutsches-museum.de/item/FA-002-730/

G-158. Paul Harteck and Johannes Hans Jensen. February 1943. *Berechnung des Trenneffektes und der Ausbeute verschiedener Zentrifugenanordnungen zur Erhöhung des Wirkungsgrades einer einzelnen Zentrifuge.* [*Calculation of the Separation Effect and the Yield of Various Arrangements of Centrifuges in Order to Improve the Efficiency of a Single Centrifuge.*] Deutsches Museum number FA 002/0592.

G-159. Paul Harteck, Johannes Hans Jensen, and Albert Suhr. *Über den Zusammenhang zwischen Ausbeute und Trennschärfe bei der Niederdruckkolonne.* [*Relationship Between the Yield and Separating Ability of a Low Pressure Column.*]

G-160. Paul Harteck and Hans Suess. 1942. [*The Production of Heavy Water.*]

G-161. Werner Heisenberg. 31 July 1942. *Bemerkungen zu dem geplanten halbtechnischen Versuch mit 1,5 To* D_2O *und 3 To 38-Metall.* [*Notes on the Planned Semi-Technical Experiment with 1.5 Tons* D_2O *and 3 Tons U.*]

G-162. Werner Heisenberg, Fritz Bopp, Erich Fischer, Carl-Friedrich von Weizsäcker, and Karl Wirtz. 30 October 1942. *Messungen an Schichtenanordnungen aus 38-Metall und Paraffin.* [*Measurements on Layer Arrangements of 38 Metal and Paraffin.*]

G-163. Friedrich Hernegger and Berta Karlik. 1942. [*Tests of Metallic Uranium for Rare Earths.*]

G-164. Karl-Heinz Höcker. 26 November 1942. *Auswertung des Würfelversuchs mit Uranoxyd und Paraffin in der Versuchsstelle Gottow des Heereswaffenamts.* [*Evaluation of the Cube Experiment with Uranium Oxide and Paraffin at the Army Weapons Experimental Station Gottow.*]

G-165. H. Hoyer. 1942. [*Deuterium Scrubbing from Hydrogen Gas Using Platinum Hydrosol.*]

G-166. Erwin Fünfer. 1942. [*Increase and Absorption of Fast Neutrons in Carbon, Water, and Heavy Water.*]

G-167. Erwin Fünfer and Walther Bothe. 1942. [*Further Measurements on the Neutron Increase in Uranium by Fast Neutrons.*]

G-168. Johannes Hans Jensen. 1942. [*Method to Increase Deuterium Production at Norsk Hydro by Using Exchange Ovens.*]

G-169. Peter Jensen. 1942. [*Slowing Down Path of Neutrons in Carbon, Water, and Heavy Water.*]

G-170. Peter Jensen. 1942. [*Slowing Down Measurements II.*]

G-171. Willibald Jentschke, F. Koch, and G. Protiwinsky. 1942. [*The Dependence of the Effective Cross Section on the Neutron Energy in the Fission of* U^{238}*; the Spontaneous Fission of Uranium.*]

G-172. Alfred Klemm. 1942. [*Enrichment of the Light Isotope of Copper.*]

G-173. Friedrich Knauer. 1942. [*The Measurement of Resonance Absorption of Neutrons in Uranium.*]

G-174. Horst Korsching. 25 February 1942. *Zur Frage des Isotopeneffekts bei Thermodiffusion in flüssiger Phase.* [*The Isotope Effect in Thermal Diffusion in Liquid Phase.*]

G-175. Hans Martin. 1942. [*Spontaneous Gas Convection on Conducting Walls in a High Centrifugal Field.*]

G-176. Werner Maurer and Heinz Pose. 1942. [*Neutron Emission of the Uranium Nucleus as a Result of Its Spontaneous Fission.*]

G-177. Heinz Pose. 1942. [*The Spontaneous Fission of the Uranium Nucleus.*]

G-178. Undated. [*The Determination of the Emanating Power of Uranium Compounds Having a High Specific Surface and the Dependence of this Power on the Relative Humidity.*]

G-179. W. Ramm. 1942. [*Measurement of the Capture Cross Sections for Slow Neutrons.*]

G-180. W. Ramm. 1942. [*Capture of Thermal Neutrons and Diffusion Length in Uranium at Various Temperatures.*]

G-181. Wolfgang Riezler. 1942. [*Peculiar Behavior of the Effective Cross Section of Uranium for Thermal Neutrons.*]

G-182. Wolfgang Riezler and W. Stupp. 1942. [*Effect of Layer Thickness on the Measurement of Effective Cross Sections for Thermal Neutrons.*]

G-183. Kurt Sauerwein. 1942. [*Incomplete Summary of Work on Nuclear Fission.*] Deutsches Museum number FA 002/0537.

G-184. Kurt Sauerwein. 1942. [*Self Absorption.*]

G-185. Kurt Sauerwein and Siegfried Flügge. 28 January 1942. *Untersuchungen I und II über den Resonanzeinfang von Neutronen beim Uran.* [*Investigation of the Resonance Capture of Neutrons by Uranium.*]

G-186. Josef Schintlmeister. 1942. *Die Aussichten für eine Energieerzeugung durch Kernspaltung des 1,8 cm Alphastrahlers.* [*Prospects for Energy Production by the Fission of the 1.8 cm Alpha Radiator.*] Deutsches Museum number FA 002/0607.

G-187. W. Schmitz and W. Wiebe. 1942. [*Technical Experiences in the Construction of the Bonn Cyclotron.*]

G-188. Paul Harteck, Hans Suess, Konsul Schoepke, N. Stephansen, and Jomar Brun. 27 May

1942. [*Minutes of the Meeting at Norsk Hydro.*]

G-189. Kurt Starke and Klaus Clusius. 1942. [*Theory of Fractional Distillation of* H_2*-HD-*D_2 *Mixtures.*]

G-190. Georg Stetter. 1942. [*Fast Neutrons in Uranium.*]

G-191. Georg Stetter and Karl Lintner. 1942. [*Fast Neutrons in Uranium (I): The Increase by Fission Process and the Decrease by Inelastic Scattering.*]

G-192. Georg Stetter and Karl Lintner. September 1942. *Schnelle Neutronen in Uran (II.): Genaue Bestimmung des unelastischen Streuquerschnittes und der Neutronenzahl bei "schneller" Spaltung.* [*Fast Neutrons in Uranium (II): Exact Determination of Inelastic Scattering Cross Section and Number of Neutrons by Fast Fission.*] Deutsches Museum number FA 002/0622.

G-193. Georg Stetter and Karl Lintner. 1942. *Schnelle Neutronen in Uran (III.): Streuversuche.* [*Fast Neutrons in Uranium (III): Scattering Experiments.*] Deutsches Museum number FA 002/0623.

G-194. Hans Suess. 1942. [*Production of Deuterium by Exchange at Two Different Temperatures.*]

G-195. Hans Suess. 1942. [*Report on Visit to Vemork from Decmber 12 to December 15, 1942.*]

G-196. Wilhelm Walcher. 1942. [*Report on the Status of Mass Spectroscope Work at Kiel. The Effect of Space Charge on Focussing Properties of Magnetic Sector Fields.*]

G-197. Carl-Friedrich von Weizsäcker. 1942. [*Improved Theory of Resonance Absorption in the Pile.*]

G-198. Karl Wirtz. 26–28 February 1942. *Die elektrolytische Schwerwassergewinnung in Norwegen.* [*The Electrolytic Production of Heavy Water in Norway.*]

G-199. Karl Wirtz. 1942. [*Investigation of Water Samples from the Water Gas Process for Deuterium Content.*]

G-200. Karl Wirtz. 1942. [*Determination of Specific Gravity and Concentration of Heavy Water.*]

G-201. Karl Wirtz. 1942. [*Report on Visit to Rjukan from November 13 to 15, 1942.*]

G-202. Erich Bagge. 1943. [*The Enrichment of the Light Silver Isotope by Means of the "Velocity Selector."*] Deutsches Museum number FA 002/650. http://digital.deutsches-museum.de/item/FA-002-650/

G-203. W. Borchardt, W. Ramm, and Karl Wirtz. 1943. [*Corrosion in the Uranium Pile and Its Prevention.*]

G-204. Walther Bothe. 29 June 1943. *Über Stahlenschutzwäne.* [*Radiation Shielding Walls.*]

G-205. Walther Bothe. 5 May 1943. *Die Forschungsmittel der Kernphysik.* [*The Research Tools of Nuclear Physics.*]

G-206. Walther Bothe and Erwin Fünfer. 6 December 1943. *Schichtenversuche mit Variation der U- und* D_2O*-Dicken.* [*Layer Experiments with Variation in the Thickness of U and* D_2O*.*]

G-207. Klaus Clusius. 1943. [*Separation of Isotopes.*]

G-208. Klaus Clusius and L. Schachinger. 1943. [*Preliminary Determination of the Atomic Heat of Uranium Between 20°K and Room Temperature.*]

G-209. Walter Dällenbach. 1943. [*Patent Application and General Correspondence with the German Patent Office on a Particle Accelerator.*]

G-210. Kurt Diebner, Werner Czulius, Walter Herrmann, Georg Hartwig, Friedrich Berkei and E. Kamin. 1943. *Über die Neutronenvermehrung einer Anordnung aus Uranwürfeln und schwerem Wasser (G III).* [*Report on Neutron Multiplication of an Arrangement of Uranium Cubes and Heavy Water (Gottow III).*]

G-211. Kurt Diebner, Georg Hartwig, Walter Herrmann, H. Westmeyer, Werner Czulius, Friedrich Berkei, and Karl-Heinz Höcker. April 1943. *Vorläufige Mitteilung über einen Versuch mit Uranwüfeln und schwerem Eis als Bremssubstanz.* [*Progress Report on Experiments with Uranium Cubes and Heavy Ice as Moderator.*]

G-212. Kurt Diebner, Georg Hartwig, Walter Herrmann, H. Westmeyer, Werner Czulius, Friedrich Berkei, and Karl-Heinz Höcker. July 1943. *Bericht über einen Versuch mit Würfeln aus Uran-Metall und schwerem Eis.* [*Report on an Experiment with U Metal Cubes and Heavy Ice.*]

G-213. Abraham Esau. 1943. [*Production of Luminous Paints without the Use of Radium.*]

G-214. Abraham Esau. 1943. [*Introduction to Meeting on Nuclear Physics.*]

G-215. Wilhelm Groth, Paul Harteck, and Albert Suhr. 1943. *Trennung der Uranisotope nach dem Ultrazentrifugenverfahren. III. Anreicherung der Xenon- und der Uranisotope nach dem Schaukelverfahren.* [*Separation of Uranium Isotopes by the Ultracentrifuge. III. Enrichment of Xenon and Uranium Isotopes by the Cascade Method.*] Deutsches Museum number FA 002/0635.

G-216. Otto Hahn. 1943. [*Artificial Transmutation and Fission of Uranium.*]

G-217. Werner Heisenberg. 6 May 1943. *Die Energiegewinnung aus der Atomkernspaltung.* [*Energy from Nuclear Fission.*]

G-218. Karl-Heinz Höcker. 25 January 1943. *Über die Anordnung von Ruan und Streusubstanz in der U-Machine.* [*Concerning the Arrangement of Uranium and Moderator in the U Pile.*]

G-219. Karl-Heinz Höcker. 1943. [*Theoretical Evaluation of the Gottow Experiment.*]

G-220. Karl-Heinz Höcker. 1943. [*Theoretical Evaluation of Dahlem Large Scale Experiment.*]

G-221. Karl-Heinz Höcker. 1943. *Zure Auswertung der Grossversuche.* [*Theoretical Evaluation of Large Scale Experiments.*]

G-222. Karl-Heinz Höcker. 23 June 1943. *Über die Abmessungen von Uran und schwerem Wasser in einer Kugelstrukturmaschine.* [*The Dimensioning of a Uranium-Heavy-Water Spherical Pile.*]

G-223. Karl-Heinz Höcker. November 1943. *Vergleich der bei L-VI bestimmten Neutronendichte mit der Theorie.* [*Comparison of the Neutron Density in the Leipzig Experiment L IV with Theory.*]

G-224. Herbert Hoyer. 1943. [*Effectiveness of the Contact Catalyst Used in the High Concentration Plant for Heavy Water at Leuna.*]

G-225. Herbert Hoyer. 1943. [*Experiments on Deuterium Extraction with Palladium Hydrosol.*]

G-226. Johannes Hans Jensen. 1943. [*Some Calculations on the Production of Deuterium by Electrolysis in Norway.*]

G-227. Willibald Jentschke and Karl Lintner. 1943. *Schnelle Neutronen in Uran V. (Absorption von Photoneutronen).* [*Fast Neutrons in Uranium (Part V).*] Deutsches Museum number FA 002/0637.

G-228. Friedrich Knauer. 1943. [*The Measurement of Resonance Absorption of Neutrons in Uranium, Part II.*]

G-229. Horst Korsching. 1943. [*Status of Measurements on 19 May 1943.*]

G-230. J. Kramer and H. Lesche. 1943. [*Physical Properties and Corrosion Protection of Uranium.*]

G-231. K. Krebs. 1943. [*The Significance of Heavy Atoms for the Slowing Down of Neutrons.*]

G-232. H. Lange and K. Fink. 1943. [*The Possibility of Saving Material in Building Cyclotron Magnets.*]

G-233. Detlof Lyons. 1943. [*The Velocity and Spatial Distribution of Fast Neutrons in Paraffin.*]

G-234. H. Martin. 1943. [*Chamber Centrifuge with Axial Temperature Gradient.*]

G-235. Orlicek. 1943. [*The Enrichment of Deuterium by Utilizing the Equilibrium* $H_2O + HDS \leftrightarrow HDO + H_2S$.]

G-236. Orlicek. 1943. [*Illustrations for G-235.*]

G-237. Orlicek. 1943. [*Cost Estimate for a Plant for the Enrichment of 5 Tons Per Year of Product SH 200 to 10% by the Harteck-Suess Method.*]

G-238. Paschke. [*Production of Graphite-Free Uranium Carbide.*]

G-239. Hans Suess. 1943. [*The Distribution Equilibrium of Deuterium Between Water and Hydrogen.*]

G-240. Heinz Pose and Ernst Rexer. 12 October 1943. *Versuche mit verschiedenen geometrischen Anordnungen von Uranoxyd und Paraffin.* [*Experiments with Different Geometrical Arrangements of Uranium Oxide and Paraffin.*]

G-241. Carl Ramsauer. 2 April 1943. *Über Leistung und Organisation der angelsächsischen Physik: Mit Ausblicken für die deutsche Physik.* [*On the Performance and Organization of Anglo-Saxon Physics with an Outlook for German Physics.*]

G-242. Günter Rehmann. 1943. [*On the Absorption of D Group Neutrons.*]

G-243. Hans Suess. 1943. [*The Equilibrium* $H_2 + HDO \leftrightarrow HD + H_2O$ *and the Further Exchange Equilibrium in the System by* H_2, D_2, *and* H_2O.]

G-244. Hans Suess. 1943. [*Experiments with Contact 6545.*]

G-245. Friedrich Berkei, Werner Czulius, Kurt Diebner, Georg Hartwig, and Walter Herrmann. 1943. [*Report on a Cube Experiment with Uranium Oxide and Paraffin at the Army Ordnance Office, Gottow.*]

G-246. Karl G. Zimmer. 1943. [*The Possibilities of Harm from Radiation and Protective Measures

Necessary When Working with Uranium Compounds.]

G-247 (also part of G-318). Otto Baier. 1944. *Bericht über die konstruktiven Arbeiten an Vakuumkammer und Lecherkreis für das Zyklotron des APS der RPF.* [*Report on the Design of the Vacuum Tank and Oscillator for the Cyclotron of the Physics Section of the German Post Office Department Research Institution.*] Deutsches Museum number FA 002/0744.

G-248 = **G-333**. Konrad Beyerle. 12 December 1944. *Die Gaszentrifugen-Anlage GZA 451 für den Reichsforschungsrat.* [*The Gas Centrifuge Setup GZA 451 for the German Federal Research Board.*] Deutsches Museum number FA 002/0808. (Same as FA 002/0809.)

G-249. Fritz Bopp and Erich Fischer. *Einfluss des Rückstrumantels auf die Neutronenausbeute des U-Brenners.* [*Effect of the Reflector on the Neutron Yield of the U Pile.*]

G-250. H. Danzer. March 1944. [*Theoretical Considerations on Neutron Shielding Walls.*]

G-251. Robert Döpel and Klara Döpel. 1944. [*Temperature Dependence of Total Cross Sections of Uranium Bombarded by Slow Neutrons.*]

G-252. Robert Döpel and O. Ritter. 1944. [*Thermal Expansion of U238.*]

G-253. V. Faltings. 18 September 1944. [*Short Note on a Preliminary Water Electrolysis Experiment with Alternating Current.*]

G-254 (also part of G-318). Siegried Flügge. 1944. *Das Geschwindigkeitsspektrum der aus einer Paraffinoberfläche austretenden langsamen Neutronen.* [*Emission Spectra of Slow Neutrons from Paraffin.*] Deutsches Museum number FA 002/0744.

G-255 (also part of G-318). Siegried Flügge. 1944. *Betrachtungen zur Theorie des Rheotrons.* [*Observations Concerning the Theory of the Rheotron.*] Deutsches Museum number FA 002/0744.

G-256. 1944. *Über den Aufbau eines Massenspektrographen bei der Forschungsanstalt der Deutschen Reichspost.* [*Mass Spectrograph Construction Planned by the German Post Office Department Research Institution.*] Deutsches Museum number FA 002/0667.

G-257. Füchtbauer. 1944. [*A Speech on Atom Physics and Nuclear Fission.*]

G-258. Undated. [*Chemistry of Radioactive Atoms.*]

G-259. Otto Hahn and Fritz Strassmann. 1944. [*The Chemical Separation of Elements and Atomic Species Produced by Uranium Fission (General Part).*]

G-260. Otto Hahn and Fritz Strassmann. 1944. [*Chemical Separation of Uranium Fission Products. Halogens, Rare Gases, Earth Metals and Alkaline Earth Metals.*]

G-261. 1944. [*Deuterium Production by the Clusius-Linde Process in Combination with the Hydrogen Regenerator Designed by Harteck and Suess.*] Deutsches Museum number FA 002/0681. https://digital.deutsches-museum.de/item/FA-002-681/ [Linde]

G-262. Paul Harteck. 1944. [*Status of Deuterium Production.*]

G-263. K. O. Habel. 1944. [*Thickness Measurements of Corrosion Protection Coatings on Special Metals.*]

G-264. Werner Heisenberg. 1944. [*Nuclear Physics.*]

G-265. B. Hess. 2 March 1944. [*Neutron Dosimeter.*]

G-266. J. Hiby. Undated. [*The Exchange of Deuterium.*]

G-267 = **G-94** revised edition.

G-268. [*Compilation of Material on Heavy Water Production by Staff Members of the I. G. Farben Aktiengesellschaft Patent Office.*]

G-269. Willibald Jentschke and K. Kaindl. 1944. [*Preliminary Communication on the Dependence of Resonance Absorption at Different Temperatures.*]

G-270. Fritz Kirchner. 1944. [*The Construction of a New Physics Building for the University of Cologne.*]

G-271. Fritz Kirchner. 1944. [*Neutron Scattering by Strongly Absorbing Materials.*]

G-272. Richard Kuhn. October 1944. [*Experiments on Preparation and Application of Artificial Radioisotopes.*]

G-273. Karl Lintner. 1943. [*Fast Neutrons in Uranium Oxide IV. Inelastic Scattering and Absorption in Uranium Oxide.*]

G-274 = **G-275**. Lwowski. 1944. [*Experiments with the Special Metal (U) at Leverkusen.*]

G-276 (also part of G-318). Detlof Lyons. 1944. *Über die Theorie der Isotopentrennung mit Hilfe der Ultrazentrifuge mit Thermokonvektion.* [*Theory of Isotope Separation by Ultracentrifuges with Thermal Convection.*] Deutsches Museum number FA 002/0744.

G-277. Heinz Maier-Leibnitz. 1944. [*Measurement of Gamma Radiation with Counting Tubes.*]

G-278. H. Neuert. 6 May 1944. [*A Method for Counting of Impulses at High Radiation Levels.*]

G-279. Otto Peter. 1944. [*Neutron Photography.*]

G-280. I. R. Rajewsky. 1944. [*The Question of Radiation Shielding.*]

G-281. Boris Rajewsky. 1944. [*On the Effect of Radioactivity Introduced into the Organism.*]

G-282 (also part of G-318). H. Salow. 1944. *Der Hochfrequenzschwingungskreis für ein Zyklotron.* [*The High Frequency Circuit for a Cyclotron.*] Deutsches Museum number FA 002/0744.

G-283. Schäfer. 12 February 1944. [*Isotopes as Indicators for Analytical Methods.*]

G-284. Erich Schiebold. 6 May 1944. [*On the Possibility of Biological Effects of Shortwave X Rays or Gamma Rays, Using Specially Constructed X-Ray Tubes, at Long Distances. Lecture Given at the Meeting of the Kuratorium of the German Air Force Research Institute Grossostheim.*] Deutsches Museum number FA 002/0683.

G-285. Josef Schintlmeister. 30 September 1944. *Vorläufiger Bericht über ein neues elektromagnetisches Schnellzählwerk.* [*A New High-Speed Electromagnetic Counter.*] Deutsches Museum number FA 002/0689. Also: *Elektromagnetisches Schnellzählwerk.* [*High-Speed Electromagnetic Counter.*] Deutsches Museum number FA 002/0728.

G-286. W. Schmitz and A. Weckesser. 1944. [*Investigations of High Frequency Currents for Construction of a Large Cyclotron.*]

G-287. L. Senzky. 1944. [*Counting Device for Indicator Measurements.*]

G-288. Hans Suess. 1944. [*Combustion of Oxyhydrogen Gas for a High Concentration Setup.*]

G-289. Hans Suess. 1944. [*The Equilibrium HDO + H_2S rightarrow H_2O + HDS. Supplement to the Report of January 26, 1944.*]

G-290. Hans Suess. 1944. [*The Equilibrium HDO + H_2S rightarrow H_2O + HDS. Calculations of Temperature Dependence of the Equilibrium Constant Using H. Geib's Measurement and Comparison of These with the Results of Grafe, Clusius, and Kruis.*]

G-291. Wilhelm Walcher. 12 October 1944. [*Report on Investigations of Ion Sources for High Power Installations.*]

G-292. W. Wiebe. 1944. [*Consideration for Construction of a 80 Million Volt Cyclotron.*]

G-293. Günter Wirths. 1944. [*Effect of Uranium Surface Structure on Corrosion by Water, and Corrosion Protection of Uranium by Lacquer Coatings.*]

G-294. Karl Wirtz. 1944. [*Peculiarities in the Molecular Volume and Other Properties of Light and Heavy Water.*]

G-295. Karl Wirtz. 1944. [*Slowing Down Length of Ra + Be Neutrons in Heavy Water.*]

G-296. Karl Wirtz. 8 August 1944. *Einrichtung der Elektrolyse zur Aufbearbeitung von schwerem Wasser.* [*Electrolysis Setup for Production of Heavy Water.*]

G-297. Karl G. Zimmer. 1944. *Bericht über die Untersuchungen der relativen Wirksamkeit von Röntgenstrahlen und schnellen Neutronen bezügl. der Erzeugung von Chromosomenmutationen.* [*Investigations of the Relative Effects of X Radiation and Fast Neutrons on Production of Chromosome Mutations.*]

G-298. Karl G. Zimmer and Otto Peter. 1944. [*Radiobiological Investigations with Fast Neutrons.*]

G-299. Erich Bagge. 1945. [*An Extension of Modern Mechanics Brought on by Developments in Nuclear Physics.*]

G-300. Fritz Bopp, Walther Bothe, Erich Fischer, Erwin Fünfer, Werner Heisenberg, O. Ritter, and Karl Wirtz. 3 January 1945. *Bericht über einen Versuch mit 1.5 To D_2O und U und 40 cm Kohlerückstreumantel (B7).* [*Report on an Experiment with 1.5 Tons of D_2O and U und 40 cm Carbon Reflector.*]

G-301. Walther Bothe. 1945. [*Some Simple Relations in Neutron Multiplication Experiments.*]

G-302. Walther Gerlach. 1945. [*Gerlach's Summary of Nuclear Reports.*]

G-303. Walter Herrmann, Georg Hartwig, Heinz Rackwitz, Walter Trinks, and H. Schaub. 1944. *Versuche über die Einleitung von Kernreaktionen durch die Wirkung explodierender Stoffe.* [*Experiments on Initiation of Nuclear Reactions by Explosives.*] Deutsches Museum number FA 002/0721. https://digital.deutsches-museum.de/item/FA-002-721/

G-304. H. Schüler and L. Reinbeck. 1945. [*On the Possibility of D_2O Enrichment by a Separation Effect Recently Observed on Al Surfaces.*]

G-305. Hans Suess. 1945. [*Measurements of Difference in Vapor Pressure of NH_3 and ND_3.*]

G-306. Karl Wirt. 1945. [*Slowing Down of Neutrons in Carbon.*]

G-307. Erwin Fünfer. 1942. [*Multiplication and Absorption of Fast Neutrons in Beryllium.*]

G-308 (includes **G-89**, **G-121**, **G-126**, **G-128**, **G-129**, **G-140**, **G-143**, **G-176**, **G-185**). January 1942. [*Utilization of Nuclear Energy. Reports on Secret Research Investigations.*]

G-309 (includes **G-81**, **G-95**, **G-115**, **G-116**, **G-117**, **G-130**, **G-172**, **G-191**, **G-200**). February 1942. [*Utilization of Nuclear Energy. Reports on Secret Research Investigations. (II).*]

G-310 (includes **G-124**, **G-127**, **G-131**, **G-132**, **G-133**, **G-134**, **G-137**, **G-147**, **G-151**, **G-159**, **G-169**, **G-171**, **G-174**, **G-177**, **G-179**, **G-182**, **G-186**, **G-187**, **G-190**, **G-194**, **G-196**, **G-197**, **G-198**, **G-307**, **G-373**). February 1942. [*Utilization of Nuclear Energy. Reports on Secret Research Investigations. (III).*]

G-311 (includes **G-135**, **G-139**, **G-146**, **G-148**, **G-149**, **G-153**, **G-161**, **G-163**, **G-167**, **G-168**, **G-170**, **G-173**, **G-175**, **G-181**, **G-189**). October 1942. [*Utilization of Nuclear Energy. Reports on Secret Research Investigations. (IV).*]

G-312 (includes **G-158**, **G-162**, **G-180**, **G-192**, **G-193**, **G-199**, **G-218**, **G-225**, **G-231**, **G-245**). February 1943. [*Utilization of Nuclear Energy. Reports on Secret Research Investigations. (V).*]

G-313 (includes **G-203**, **G-230**, **G-252**, **G-293**). Walther Gerlach, ed. 1944. [*Nuclear Physics Research Reports (I).*]

G-314 (includes **G-144**, **G-206**, **G-222**, **G-227**, **G-228**, **G-240**, **G-249**, **G-273**). Walther Gerlach, ed. 1944. [*Nuclear Physics Research Reports (II).*]

G-315 (includes **G-204**, **G-246**, **G-250**, **G-280**). Walther Gerlach, ed. 1944. [*Nuclear Physics Research Reports (III).*]

G-316 (includes **G-202**, **G-224**, **G-234**). Walther Gerlach, ed. 1944. [*Nuclear Physics Research Reports (IV).*]

G-317 (includes **G-208**, **G-251**, **G-267**, **G-269**). Walther Gerlach, ed. 1944. [*Nuclear Physics Research Reports (V).*]

G-318 (includes **G-94**, **G-141**, **G-142**, **G-247**, **G-254**, **G-255**, **G-276**, **G-282**). Walther Gerlach, ed. 1944. [*Special Publication.*]

G-319. Hugo Neuert. 1945. [*A Method of Direct Current Measurement of Tube Counter Pulses.*]

G-320. Hugo Neuert. 1945. [*After-Effects in Self-Quenching Tube Counters with Photosensitive Cathodes.*]

G-321. Hugo Neuert. 1945. [*Disintegration of the Long-Life Radioactive Isotope of Tantalum.*]

G-322. [No report???]

G-323 (includes **G-205**, **G-207**, **G-213**, **G-214**, **G-216**, **G-217**). Abraham Esau, ed. 1943. [*Problems of Nuclear Physics. Publications of the German Academy of Aeronautics.*]

G-324. Walter Völkel. 9 November 1945. *Herstellung von Uran bei der Degussa.* [*Production of Uranium by the Degussa Corporation.*] Deutsches Museum number FA 002/0715. https://digital.deutsches-museum.de/item/FA-002-715/

G-325. Kurt Sauerwein. 1945. [*On a New Method of Neutron Capture.*]

G-326. [No report???]

G-327. [No report???]

G-328. Hans Martin. 1945. [*The Effect of Uranium Hexafluoride Vapor on Fluorides, Particularly Sodium Fluoride.*]

G-329. W. Hauser. Undated. [*Thermal Neutron Irradiation of* Cl^{35} *with Emission of Protons.*]

G-330. Konrad Beyerle, Wilhelm Groth, Paul Harteck, et al. 1944–1945. [*Correspondence, Cost Estimates, and Technical Data Concerning the Construction of the Ultracentrifuge by the Anschütz Company.*] Deutsches Museum number FA 002/0805. https://digital.deutsches-museum.de/item/FA-002-805/

G-331. Konrad Beyerle, Wilhelm Groth, Paul Harteck, et al. 1941–1944. [*Technical Letters Concerning the Ultracentrifuge, Taken from Dr. Groth's File.*] Deutsches Museum number FA 002/0792. http://digital.deutsches-museum.de/item/FA-002-792/

G-332. Undated. [*Folder Containing Blueprints for Construction of an Ultracentrifuge.*]

G-333 = **G-248**. Konrad Beyerle. 12 December 1944. *Die Gaszentrifugen-Anlage GZA 451 für den Reichsforschungsrat.* [*The Gas Centrifuge Setup GZA 451 for the German Federal Research Board.*] Deutsches Museum number FA 002/0808. https://digital.deutsches-museum.de/item/FA-002-808/ (Same as FA 002/0809. https://digital.deutsches-museum.de/item/FA-002-809/)

G-334. Undated. [*Folder Containing Blueprints for Construction of an Ultracentrifuge.*] Deutsches Museum number FA 002/0793. https://digital.deutsches-museum.de/item/FA-002-793/

G-335. Undated. [*Folder Containing Drawings, Blueprints and Photographs of the Ultracentrifuge.*]

G-336. Undated. [*Folder Containing Blueprints for Construction of an Ultracentrifuge.*]

G-337. Jomar Brun and Hans Suess. 1942. [*Report on the First Research and Operating Results Obtained with the Research Apparatus Set Up for Testing of "Step 6."*]

G-338. [*Report on H Ion Exchange Experiments Conducted in Vemork, Using a Research Setup from Hamburg.*]

G-339. Jomar Brun and Hans Suess. 1942. [*Second Report on H Ion Exchange in Vemork: Experiments with I.G. Farben, Leuna, Catalysts.*]

G-340. Jomar Brun. 1941. [*Considerations on the Use of Professor Harteck's and Dr. Wirtz's Method of* D_2 *Regeneration (Extraction) in the Heavy Water Setup in Vemork.*]

G-341. Paul Harteck. Undated. [*Technical Papers and Correspondence on Heavy Water Production,*

Volumes 1–6.]

G-342. [No report???]

G-343. Undated. *Translations and Abstracts of German Correspondence of General Interest to Medical Scientists.*

> Deutsches Museum number FA 002/0097.
>
> Deutsches Museum number FA 002/0099.
>
> Deutsches Museum number FA 002/0343.
>
> Letter from Maurer to Rudolf Fleischmann. 12 January 1943. Letter from Maurer to Rudolf Fleischmann. 5 March 1943. Letter from Rudolf Fleischmann to Kirchner. 18 August 1943. Letter from Major Calvert to Samuel Goudsmit. 8 December 1944. Deutsches Museum number FA 002/0362.
>
> Letter from Rudolf Fleischmann to Maurer. 10 February 1943. Deutsches Museum number FA 002/0384.
>
> Letter from Rudolf Fleishmann to Georg Stetter. 12 June 1942. Letter from Rudolf Fleishmann to Dr. Th. Schuchardt Firm, Goerlitz. 14 December 1943. Deutsches Museum number FA 002/0401.

G-344. Jesse W. Beams. 9 April 1946. *Report on the Use of the Centrifuge Method for the Concentration of* U^{235} *by the Germans.* Deutsches Museum number FA 002/0769. https://digital.deutsches-museum.de/item/FA-002-769/

G-345. Georg Stetter et al. 1945. *Bericht über das II. Physikalische Institut der Wiener Universität.* [*Report on the II. Physics Institute of the Vienna University.*] 1945. Deutsches Museum number FA 002/0712. https://digital.deutsches-museum.de/item/FA-002-712/

G-346. Rudolf Fleischmann. 1940–1941. [*Notebook Containing Gaseous Diffusion Data and Results of Meetings on Nuclear Physics.*] Deutsches Museum number FA 002/0772. http://digital.deutsches-museum.de/item/FA-002-772/

G-347. [*Employees of the Institute for Physical Chemistry, Hamburg.*]

G-348. Shinichiro Tomonaga. 1941. [*Meson Scattering by a Nuclear Particle.*]

G-349. 12 November 1944. [*Application of Radioactive and Stable Isotopes in Biochemistry.*]

G-350. Rudolf Fleischmann. 1941. [*Most Favorable Construction of a Separation Tube Installation for Continuous Operation.*]

G-351. Rudolf Fleischmann. 1940. [*A Possible Procedure for Separation of U Isotopes.*]

G-352. Berta Karlik. 1944. [*Alpha Emission from Ra, Th, and Ac.*]

G-353. Rudolf Fleischmann. Undated. [*Application of Radioactive and Stable Isotopes.*]

G-354. [*Volumes 1–3.*]

G-355. [*A Diary Noting Events Concerning Progress in the Heavy Water Production Program.*]

G-356. 1945. [*Nuclear Physics Research.*]

G-357. Karl-Heinz Höcker. Undated. [*What Is Nuclear Physics?*]

G-358. Werner Heisenberg. 1942–1943. [*Theory of Elementary Particles.*]

G-359. Carl-Friedrich von Weizsäcker. 1939. [*A Treatise on Neutrons 1939.*]

G-360. Georg Stetter et al. 1945. [*Report on the II. Physics Institute of the University of Vienna.*]

G-361. Thullis Vellat, Walter Biberschick, and E. Fues. 1945. [*Report on the II. Physics Institute of the University of Vienna.*]

G-362. Carl-Friedrich von Weizsäcker. 1944. [*Introductory Lecture on Isotopes.*]

G-363 = Translation of **G-307**.

G-364 (includes **G-278**, **G-279**, **G-286**, **G-287**, **G-292**). Walther Gerlach, ed. 1944. [*Research Reports.*]

G-365 (includes **G-265**, **G-272**, **G-297**). Walther Gerlach, ed. 1944. [*Research Reports.*]

G-366. Siegfried Flügge. 1943. [*New Investigations on the Problem of the Uranium Pile.*]

G-367. Wolfgang Ferrant. 1945. [*Proposal for a New Method of Releasing Nuclear Energy by a Beam of Heavy Particles.*] German original: Deutsches Museum number FA 002/0764.
https://digital.deutsches-museum.de/item/FA-002-764/
English translation: Deutsches Museum number FA 002/0700.
https://digital.deutsches-museum.de/item/FA-002-700/

G-368 = Translation of **G-274**.

G-369. M. Paschke. 1943. [*Production of a Uranium Carbide Free from Graphite.*]

G-370. [No report???]

G-371. Alvin M. Weinberg and Lothar W. Nordheim. 8 November 1945. *Memorandum on the State of Knowledge in Nuclear Science Reached by the Germans in 1945.* Deutsches Museum number FA 002/0765. https://digital.deutsches-museum.de/item/FA-002-765/

G-372. Feodor Schiskow. [*The Mechanisms of Heavy Air and Atom Bomb Explosions as Explained by Investigations on the Structure of the Channel Wall of an Impulse Discharge by the Schlieren Method (High-Voltage Conomatography).*]

G-373. Robert Döpel, Klara Döpel, and Werner Heisenberg. March 1942. *Die Neutronenvermehrung in einem D_2O-38-Metallschichtensystem.* [*Neutron Multiplication in D_2O-38 Metal (Metallic Uranium) Layer System.*]

G-374. 1944–1945. [*Miscellaneous German Correspondence on Biological Effects of Radiation.*]

G-375. Richard Herzog. 1943. [*Report on the Status of the Work Towards Construction of a Large New Mass Spectrometer.*]

G-376. H. Wetzlawek. 1943. [*Treatise on Technical Nuclear Physics.*]

G-377. [No report???]

G-378. Georg Stetter. 1939. *Technische Energiegewinnung mit Hilfe von Kernreaktionen.* [*Energy Production by Nuclear Reactions.*] Deutsches Museum number FA 002/0762.
https://digital.deutsches-museum.de/item/FA-002-762/

G-379. [*Diagram of a Cooling System for the RFR Machine (Reactor).*]

G-380. Georg Stetter and K. Kaindl. Undated. *Schnelle Neutronen in Uran (VI): Der (n,2n)-Prozeß in Blei und die Deutung der Vermehrung schneller Neuronen in Uran.* [*Fast Neutrons in Uranium (VI): The (n,2n) Reaction in Lead and the Calculation of Fast Neutron Multiplication in Uranium.*] Deutsches Museum number FA 002/0661.
https://digital.deutsches-museum.de/item/FA-002-661/

G-381. Friedrich Prankl. 1945. [*Absorption and Multiplication of Fast Neutrons.*]

G-382. 1944. [*Electrodynamometer with Oscillograph Indicator.*]

G-383. Paul Harteck and Johannes Hans Jensen. 1941. [*Reaction Velocity of Colloid Catalysts.*]

G-384. Rudolf Fleischmann. Undated. [*Nuclear Physics and Prospects for Its Practical Application.*]

G-385. Schmidt. 1945. [*Description of Construction of the Dewar-Beaker for the RFR Reactor.*]

G-386. K. Fink. 1944. [*Radiometric Determination of Smallest Amounts of Al in Steel.*]

G-387. Siemens & Halske Corporation. 1941–1942. [*Cost Estimates for the 1000 kV Neutron Generator for the University of Vienna.*]

G-388. Franz Gundlach. Undated. [*Determination of Absorption Cross Sections for Thermal Neutrons (Summary).*]

G-389. Rudolf Fleischmann. 1944. [*Analytical Determination of Potassium by Its Radioactivity.*]

G-390. [No report???]

G-391. Paul Harteck. Undated. [*Use of Normal or Heavy Water in Chain Reacting Systems.*]

G-392. Paul Harteck. 1941. [*State of Work Progress in the Institute for Physical Chemistry, Hamburg.*]

G-393. [*Blueprints, Photos, and Three Drawings on Heavy Water Production Installations.*]

G-394. [*Neutron Generator Strasbourg.*]

GD-639.2.8 FE. 1741. Heeresversuchsanstalt Peenemünde. 1944. *Permanent Launching Sites, Projekt Z Salamander.*

NL 080/232-04. Walther Gerlach. *Dienstkalender 1943–1944.*

NL 080/232-05. Walther Gerlach. *Dienstkalender 1945–1947.*

NL 080/270-66. Walther Gerlach. *Notizbuch 1943/44.*

NL 080/270-67. Walther Gerlach. *Notizbuch 1944.*

TID-3030. Lore R. David and I. A. Warheit. 6 June 1952. *German Reports on Atomic Energy: A Bibliography of Unclassified Literature.* Deutsches Museum number FA 002/0972.
https://digital.deutsches-museum.de/item/FA-002-972/

Peenemünde Archive

AHT0205. 16 September 1942. Mitteilung der Heeresversuchsanstalt an die Forschungsanstalt der Deutschen Reichspost in Berlin betr. Übernahme von Untersuchungen auf den Gebieten der Treibstoffforschung und des Atomzerfalls zur Leistungssteigerung von Flüssigkeits-Raketenantrieben. [Copy in light gray folder.]

APR. Dornberger FT-Proj. [Yellowish-orange folder still without signature.]

ARK0041. [Copies of design drawings of whole A-4 and A-5 rockets and of individual components in light gray folder.]

AZZ. Kurt Dierks. 7 March 1986. Peenemünde—Wie ich das Ende überlebte. [Still without signature.]

B/715/10. Gerd D. Priewe. 11 May 1987. *Peenemünder berichten über Peenemünde.* [Manuscript in green 2-ring binder.]

E/99/12. A-9/A-10 Typenübersichten / Typenblätter. [Hanging file folder.]

E/100. Technik, andere Typen. [Hanging file folder.]

EA/18. Technik, andere Typen, C2-Wasserfall. [Hanging file folder.]

The National Archives (TNA), Kew, UK

AB: Atomic Energy Authority papers

TNA AB 1/ 110 [Investigation of Nuclear Physics Developments in Germany], 285 [Monazite Sands], 355 [German Activities], 356 [Reports on German Literature and Correspondence], 363 [Czechoslovakia], 507 [Uranium Intelligence], 518 [Contracts—General], 608 [Use of Radio-active Fission Products as Military Weapon]

ADM: Admiralty papers

TNA ADM 178/ 392 [Take-over of German Naval War Factories]

TNA ADM 202/ 308 [30 Assault Unit]

TNA ADM 223/ 349 [30 Assault Unit], 500 [30 Assault Unit], 501 [30 Assault Unit], 674–675

AIR: Air Ministry papers

TNA AIR 2/ 8415–8416 [V weapons]

TNA AIR 14/ 2505, 2642, 2753, 2953, 3722–3756, 3808–3809 [V weapons]

TNA AIR 19/ 434 [British Bombing Research Mission]

TNA AIR 20/ 1661, 1667, 1695, 1715 [Future of German Scientists], 1722 [Exercise Post Mortem], 2629, 2644, 3398, 3428, 3440, 4039, 4132, 4262–4263, 4818 [British Bombing Survey Unit], 5865–5950, 6253, 7699, 8124, 8138, 8158, 8199, 8217, 8773, 8972 [V weapons]

TNA AIR 34/ 80, 109–134, 232, 241, 429, 624–625, 695, 718, 750, 838–851 [V weapons]

TNA AIR 37/ 370, 429, 832, 899, 1015, 1270–1431 [V weapons]

TNA AIR 40/ 98, 158, 540, 579, 604, 655–674, 888, 1011, 1036–1039, 1084, 1178 [ADIK Periodical Progress Reports], 1219, 1283, 1457, 1678, 1718, 1762–1779 [Joint Crossbow Working Committee], 1824, 2114, 2161, 2332–2333, 2517–2572, 2665, 2832 [V weapons]

TNA AIR 51/ 351 [V weapons]

AVIA: Ministry of Aviation papers

TNA AVIA 7/ 2133–2134 [V weapons]

TNA AVIA 9/ 83 [Roy Fedden's Mission to Germany]

TNA AVIA 10/ 70 [Alsos Mission]

TNA AVIA 12/ 82 [Operation Surgeon], 191 [Reparations from Germany]

TNA AVIA 15/ 2209 [Personnel: Scientific and Technical Staff]

TNA AVIA 22/ 940 [German Reparations: Canadian Requirements]

TNA AVIA 40/ [V weapons, including blueprints of an added central payload compartment, ring, and/or "Korsett" for modified A-4 rockets; see for example AVIA 40/717]

TNA AVIA 54/ 1294 [Employment of Germans in UK under DCOS Scheme], 1295 [Employment of Germans in UK under DCOS Scheme], 1403 [Employment of German Scientists and Technicians], 1404 [Halstead Exploiting Centre], 1826 [Long-Term Employment of German Scientists]

BT: Board of Trade papers

TNA BT 211/ 23 [Lists of BIOS, CIOS, FIAT and JIOA reports], 62 [Operation Bottleneck], 116 [Reparations assessment teams], 117 [Disposal of BIOS equipment], 541 [Meeting papers]

CAB: Cabinet Office papers

TNA CAB 21/ 1421 [Scientific intelligence]

TNA CAB 69/ 7 [Technology transfer from Germany]

TNA CAB 79/ 37, 68 [Technology transfer from Germany]

TNA CAB 81/ 24, 47, 92–93, 133–134 [Technology transfer from Germany]

TNA CAB 82/ 3, 6, 8 [Technology transfer from Germany]

TNA CAB 121/ 429 [Technology transfer from Germany]

TNA CAB 122/ 342–363 [Technology transfer from Germany]

TNA CAB 124/ 544, 1924–1928 [Control of science in postwar Germany]

TNA CAB 126/ 333. Folder: German Tube Alloy Activities. 1945.

TNA CAB 131/ 1, 5 [Technology transfer from Germany]

TNA CAB 158/ 2 [Technology transfer from Germany]

TNA CAB 176/ 8 [Technology transfer from Germany]

DEFE: Ministry of Defence papers

TNA DEFE 2/ 1107 [30 Assault Unit]

TNA DEFE 10/ 66 [Inter-Departmental Committee on German Scientists]

FO: Foreign Office papers

TNA FO 371/ 71038 [Unterluss]

TNA FO 800/ 565 [German nuclear scientists]

TNA FO 935/ 1, 25, 140 [Technology targets in Germany]

TNA FO 936/ 39 [FIAT]

TNA FO 942/ 8, 27, 79, 425–426 [Reparations]

TNA FO 943/ 42 [Reparations]

TNA FO 1010/ 20 [Reparations]

TNA FO 1012/ 420–421 [Reparations]

TNA FO 1013/ 373 [German scientists in U.K.]

TNA FO 1031/ 1–86 [Technology transfer from Germany], 138 [Russian recruitment of German scientists]

TNA FO 1032/ 35 [Disarmament], 164–179 [Technology transfer from Germany], 247 [BW], 297–302 [German scientists in U.K.], 470–475 [CIOS], 1231A–1231B [Operation Matchbox], 1459–1470A [FIAT], 2555 [Denazification]

TNA FO 1036/ 13 [Reparations]

TNA FO 1039/ 671–672 [Scientific and Technical Intelligence Branch]

TNA FO 1049/ 1008 [Biological warfare]

TNA FO 1050/ 67 [Scientific and Technical Intelligence Branch], 1419–1421 [CIOS]

TNA FO 1062/ 114 [Operation Surgeon], 149, 396 [Technology transfer from Germany]

TNA FO 1065/ 12 [FIAT and T Force]

HW: GCHQ papers

TNA HW 8/ 104 [History of 30 Commando]

LAB: Ministry of Labour papers

TNA LAB 8/ 1198 [Darwin Panel], 1450 [General policy and correspondence]

PREM: Office of the Prime Minister papers

TNA PREM 3/ 21/3 [British Bombing Research Mission]

TNA PREM 8/ 373 [Interrogation of German Scientists in United Kingdom]

T: Treasury papers

TNA T 294/ 15 [Assembly reports 1951 and 1961]

WO: War Office papers

TNA WO 33/ 2554–2559 [V weapons]

TNA WO 106/ 2817–2824 [V weapons]

TNA WO 109/ 1103 [V weapons]

TNA WO 188/ 1799 [CIOS and BIOS reports], 1800 [CIOS and BIOS reports]

TNA WO 193/ 432 [Combined Intelligence Priorities Committee]

TNA WO 199/ 889–891, 1104, 1610 [V weapons]

TNA WO 204/ 5950, 6748, 12455 [Marine Einsatz Kommando 80], 12911 [Abwehrkommandos]

TNA WO 208/ 2174 [Porton group], 2183 [Tabun and Sarin], 3143, 3974 [Interrogation of Dr K Blome], 4178 [wartime Allied contacts with von Braun], 4277–4280 [Bacteriological Targets], 4334, 4969 [ASHCAN]

TNA WO 219/ 1630A [T Force Planning], 1668 [30 Advanced Unit], 1669 [Collection of economic intelligence], 1986 [FIAT T Force], 1987 [FIAT T Force], 2165 [Operation Backfire], 3365, 4929, 4937 [V weapons]

Air Force Historical Research Agency (AFHRA), Maxwell Air Force Base, Alabama

[Virtually all documents are on microfilm reels, or electronic copies of microfilm reels.]

AFHRA A0417.

AFHRA A0548. [34th Squadron at Gusen.]

AFHRA A0572. [Frame 1974 Linz.]

AFHRA A0599.

AFHRA A0708. [Received V1 through V4 plans.]

AFHRA A1007. [Many CIOS Evaluation Reports.]

AFHRA A1008. [Many CIOS Evaluation Reports.]

AFHRA A1035. [1945–1947 intelligence, including some information related to wartime German work.]

AFHRA A1036. [1947–1948 intelligence, including some information related to wartime German work.]

AFHRA A1071.

AFHRA A1157.

AFHRA A1166.

AFHRA A1258. [Schmidding rocket documents.]

AFHRA A1259. [Many wartime Allied reports on German secret weapons.]

AFHRA A1260. [Many wartime Allied reports on German secret weapons.]

AFHRA A1261. [Many wartime Allied reports on German secret weapons.]

AFHRA A1262. [Many wartime Allied reports on German secret weapons.]

AFHRA A1263. [Many wartime Allied reports on German secret weapons.]

AFHRA A1264. [Many wartime Allied reports on German secret weapons.]

AFHRA A1265.

AFHRA A1317. [Escaped prisoner of war reports.]

AFHRA A1871.

AFHRA A2055. [*History of AAF Participation in Project Paperclip.*]

AFHRA A2056. [*History of AAF Participation in Project Paperclip.*]

AFHRA A2092B. [Postwar reports on aerospace work.]

AFHRA A2624.

AFHRA A3197.

AFHRA A3214.

AFHRA A4200.

AFHRA A5065. [Mauthausen]

AFHRA A5066. [pp. 266– secret weapons]

AFHRA A5067. [Report on SS medical research.]

AFHRA A5069. [Long report on I.G. Farben.]

AFHRA A5070. [CIOS-related reports.]

AFHRA A5071.

AFHRA A5109. [Captured jets and rockets.]

AFHRA A5127. [Crossbow target intelligence fall 1944–spring 1945.]

AFHRA A5128. [Frame 562 On-site report and photos from large rocket launching sites on French coast. Frame 677 V3 and V4 rockets. Frame 690 1944 rumor of V2 to V5.]

AFHRA A5183. [Interrogations of German and Austrian scientists.]

AFHRA A5184. [Frame 0690 scientists from Russian zone; other lists of scientists.]

AFHRA A5185. [Wartime Allied reports on German secret weapons.]

AFHRA A5186. [Wartime Allied reports on German secret weapons; postwar CIOS final reports.]

AFHRA A5187. [CIOS final reports.]

AFHRA A5188. [CIOS final reports.]

AFHRA A5189. [CIOS Evaluation Reports.]

AFHRA A5190. [CIOS documents.]

AFHRA A5191. [CIOS documents.]

AFHRA A5199. [CIOS documents.]

AFHRA A5200. [CIOS documents.]

AFHRA A5286. [Frames 0156-165 Auschwitz. Frames 0391-0402 Kummersdorf.]

AFHRA A5399. [Frame 1474 list of Peenemünde scientists targeted for capture, including von Braun.]

AFHRA A5413. [Wartime intelligence from Germans held as prisoners of war.]

AFHRA A5414. [Wartime intelligence from Germans held as prisoners of war.]

AFHRA A5415. [Wartime intelligence from Germans held as prisoners of war.]

AFHRA A5416. [Wartime intelligence from Germans held as prisoners of war.]

AFHRA A5417. [Wartime intelligence from Germans held as prisoners of war.]

AFHRA A5459. [Heavy water memo says Allies want information but do not have it.]

AFHRA A5465. [Locations of “oil” plants including Austria.]

AFHRA A5466. [Locations of German aircraft factories, including Posen.]

AFHRA A5467. [BIOS final reports.]

AFHRA A5496.

AFHRA A5498.

AFHRA A5689A. [Scientific exploitation in Austria.]

AFHRA A5721. [pp. 1865-1945 Focke-Wulf Triebflugel and FW 183 jet, He-Hirth jet engine]

AFHRA A5722. [Postwar scientific exploitation targets in Czechoslovakia, Austria, Germany.]

AFHRA A5723. [Air Intelligence Summary 1944–1945.]

AFHRA A5724. [Air Intelligence Summary 1944–1945.]

AFHRA A5726. [Interrogations of captured German officers and scientists.]

AFHRA A5727. [Files on various aspects of Luftwaffe organization.]

AFHRA A5729. [Lots of wartime and postwar intelligence on secret weapons. pp. 255 and 561: An Evaluation of German Capabilities in 1945.]

AFHRA A5730. [Long, detailed lists of captured German technologies.]

AFHRA A5730A. [Long, detailed lists of captured German technologies.]

AFHRA A5731. [Long, detailed lists of captured German technologies.]

AFHRA A5732. [Long, detailed lists of captured German technologies.]

AFHRA A5733. [Long, detailed lists of captured German technologies.]

AFHRA A5734. [Long, detailed lists of captured German technologies; Peenemünde.]

AFHRA A5735. [Some documents on captured German technologies.]

AFHRA A5924. [Frames 999–1110 bombing of Oranienburg and Gusen on 15 March 1945.]

AFHRA A6091. [Frames 961– Lots of PW reports of underground factories, etc.]

AFHRA A6494. [Frames 1332–1812 Auschwitz bombings.]

AFHRA A6539. [Frames 127–136 Auschwitz aerial photos.]

AFHRA A6544. [Frames 1139-1239 Aerial photos of Melk, Gusen, etc.]

AFHRA A7123.

AFHRA A7737.

AFHRA A7739.

AFHRA A7741.

AFHRA A7744.

AFHRA B0082. [Frame 1325: Linz occupation, but only mundane details of daily life.]

AFHRA B0187. [U.S. photo booklet of Ohrdruf and other concentration camps, written in German for Germans.]

AFHRA B0240.

AFHRA B0498. [Frames 1033-1045 bombing Pilsen, Linz, etc.]

AFHRA B0673.

AFHRA B0678.

AFHRA B0679.

AFHRA B0680.

AFHRA B0852.

AFHRA B1728. [*Intelligence Review*.]

AFHRA B1729. [*Intelligence Review*.]

AFHRA B1730. [*Intelligence Review*.]

AFHRA B1731. [Intelligence documents.]

AFHRA B1734. [Frames 0997– *Scientific Intelligence Review* 1946.]

AFHRA B1735. [Intelligence Bulletins.]

AFHRA B1736. [Intelligence Bulletins.]

AFHRA B1756. [Lots of intelligence reports, including V2; frame 0774 calculated V2 ranges with heavier payloads; frame 0794 Allied prediction of 2-stage rocket with uranium bomb produced underground.]

AFHRA B1759. [Frame 607 Lise “Keltner.”]

AFHRA B1760.

AFHRA B1761.

AFHRA B1763. [Frame 432 Ahnenerbe; implosion diagnostics–lots of important people; etc.]

AFHRA B1764.

AFHRA B1806. [Frame 895 V-weapons history; Kammler.]

AFHRA B1901.

AFHRA B1974. [Doenitz on German Navy history in 1946; frame 1900 overview of German aircraft.]

AFHRA B1975. [Frame 1326 Lectures by Heinz Schlicke!!! Frame 1695 IR homing.]

AFHRA B1976. [Frame 0305 Sonar in the German Navy. Frame 700 DFS? 346 supersonic aircraft. Frame 737 rockets according to Dornberger interrogation.]

AFHRA B5017. [Frames 299-483 Arnstadt, Ohrdruf, etc. bombing information.]

AFHRA B5287. [Frames 1676-1724 bombing photos including Ohrdruf, Arnstadt.]

AFHRA B5350. [Frames 797-930 bombing reports of relevant areas but not much information.]

AFHRA B5736.

AFHRA B5737. [p. 340 Second Zinsser report.]

AFHRA B5965. [Frame 0895 TAL Report 5/44 Röntgenblitzaufnahmen detonierdener H-Körper mit kegelförmigem Hohlraum–Zimmer, Thomer]

AFHRA C5087A. [Interrogations of Luftwaffe high command.]

AFHRA C5088. [*German Armaments and Munitions.*]

AFHRA C5089. [FIAT-related documents.]

AFHRA C5090. [FIAT-related documents.]

AFHRA C5091.

AFHRA C5092. [FIAT-related documents; postwar intelligence.]

AFHRA C5093. [Lots of interrogations of Peenemünde personnel.]

AFHRA C5094. [Lots of interrogations of detained German and Austrian scientists/engineers. Frame 1546 First report on Rudolph Zinsser.]

AFHRA C5095. [Frame 0021 Justice Jackson received information from George McDonald, CIOS, and OSS.]

AFHRA C5096. [FIAT-related documents; postwar intelligence.]

AFHRA C5097. [FIAT-related documents; postwar intelligence.]

AFHRA C5098. [Frame 0886 Hans Kammler available for interrogation in November 1945.]

AFHRA C5099. [FIAT-related documents; postwar intelligence.]

AFHRA C5099A. [Aviation medicine.]

AFHRA C5100. [Aviation medicine.]

AFHRA C5107.

AFHRA 15390. [Frame 557 Paperclip history and accomplishments.]

AFHRA 25011. [Lots of intelligence reports, especially file 188.]

AFHRA 25082. [No. 18 V weapons part 1: Auschwitz/Silesia as major area, Zipf, V-5.]

AFHRA 25141.

AFHRA 25172. [Target 1192 Floridsdorf.]

AFHRA 25177. [Target 1341 Arnstadt: Siemens & Halske V-2 guidance plant. Target 1391 Redl Zipf thorium, beryllium.]

AFHRA 25181. [Auschwitz.]

AFHRA 25189. [Frames 1181–1184 Arnstadt target file.]

AFHRA 25190. [Other target files.]

AFHRA 25191. [Other target files; V-weapons file 2171 just one card.]

AFHRA 25192. [Other target files.]

AFHRA 25193. [File 2508 Memmingen: "The largest flying bomb factory is the DORNIER WERKE at MEMMINGEN on railway KEMPTEN-MEMMINGEN-ULM. V.1 to V.4 types are made there."]

AFHRA 25194. [Frames 28-43 St. Georgen/Gusen target file.]

AFHRA 25216. [Underground locations producing secret weapons.]

AFHRA 25220. [No. 4476 onward Jockey Committee–jet factories to bomb.]

AFHRA 25227. [Doc. 92 Bomb factory prisoners die rapidly with burns and yellow skin.]

AFHRA 25239. [Aerial photos of Austria.]

AFHRA 25245.

AFHRA 34628. [U.S. postwar aircraft nuclear propulsion projects.]

AFHRA 36713.

AFHRA 39812. [Frame 1145 Japanese atomic bomb research.]

AFHRA 40051.

AFHRA 40505. [Goering. 1943 bombing of targets in Austria.]

AFHRA 43811. [Allied intelligence on German secret weapons. Preparing the American Public for a V-3 Attack. German Long-Range Missiles]

AFHRA 43826. [Long interviews with Donald Putt–few pages on Germans, mentions wartime research on lasers.]

U.S. National Archives and Records Administration (NARA), College Park, Maryland

RG 38: Records of the Office of the Chief of Naval Operations

NARA RG 38, Entry P-5, Boxes 1–64. [Alsos and Naval Technical Mission in Europe reports.]

NARA RG 38, Entry UD-16, Boxes 1–8. [Lists of documents and cargo from U-234.]

NARA RG 38, Entry UD-38, Box 13. [Interrogations of U-234 crew and passengers.]

NARA RG 38, Entry 72, Box 15. Naval Technical Mission in Europe, Serials and Enclosures 312 to 198, Serial 338. [examples of equipment transported to US, including submarine, 39 aircraft, V-1 and V-2 missiles, etc.]

NARA RG 38, Entry 98C, Boxes 1–17. Intelligence Division [Formerly] Top Secret Reports of Naval Attachés 1944–1947. [Some wartime and many postwar intelligence reports on advanced nuclear and rocket research programs that were conducted during the Third Reich.]

RG 40: General Records of the Department of Commerce

NARA RG 40, Entry UD-70, Boxes 1-25. Office of Technical Services, Records of John Weber.

NARA RG 40, Entry UD-71, Boxes 1-28. Office of Technical Services, Industrial Research and Development Division Project Files.

NARA RG 40, Entry UD-72, Boxes 29-35. Office of Technical Services, Industrial Research and Development Division Contract Files.

NARA RG 40, Entry UD-73, Boxes 36-38. Office of Technical Services, Industrial Research and Development Division Reports.

NARA RG 40, Entry UD-74, Boxes 39-67. Office of Technical Services, Industrial Research and Development Division Subject Files.

NARA RG 40, Entry UD-75, Boxes 1-71. Office of Technical Services, Policy and Program Files of the Technical Industrial Intelligence Division. [Extremely enlightening office files from some of the key U.S. officials behind the technology transfer from Germany and Austria to the United States.]

NARA RG 40, Entry UD-76, Boxes 1-10. Office of Technical Services, Records of Interdepartmental Committees.

NARA RG 40, Entry UD-77, Boxes 1-11. Office of Technical Services, Records Accumulated by the Publications Board.

NARA RG 40, Entry UD-78, Boxes 1-6. Office of Technical Services, *FIAT Review of German Science*.

RG 59: Department of State Central Files

NARA RG 59. Conant, James B. 1956. Memorandum to Secretary of State (13 July), State Department “Operation Paperclip” microfiche, Civil Reference Branch.

NARA RG 59, Entry A1-3008A, Box 489. Joliot-Curie.

RG 65: Records of the Federal Bureau of Investigation

NARA RG 65, Entry A1-136AB, Box 35. Karl Fiebinger.

RG 72: Records of the Bureau of Aeronautics

NARA RG 72, Entry ??, Boxes ??. German aerodynamics information in U.S. Navy files.

RG 77: Records of the Office of the Chief of Engineers [Manhattan Engineer District]

NARA RG 77, Entry UD-22A (General Records), Boxes 160–177. Manhattan Engineer District Foreign Intelligence Section. [Virtually all of these boxes and most of their folders contain information related to the German nuclear program, even if the box/folder titles do not sound relevant.]

NARA RG 77, Microfilm M1108. Harrison-Bundy Files Relating to the Development of the Atomic Bomb, 1942–1946. [Available online at https://downloads.paperlessarchives.com]

NARA RG 77, Microfilm M1109. Correspondence ("Top Secret") of the Manhattan Engineer District, 1942–1946.

RG 80: General Records of the Department of the Navy, 1798–1947

NARA RG 80, Entry UD-17, Boxes 1–57. U.S. Navy top secret files.

RG 84: Records of Foreign Service Posts of the Department of State

NARA RG 84, Entry UD-2467, Box 3. German Atomic Energy Files.

RG 153: Records of the Office of the Judge Advocate General

NARA RG 153, Entry A1-144, Box 91 (August Eigruber–Mauthausen/Auschwitz) and Box 95 (Gusen).

RG 165: Records of the War Department General and Special Staffs

NARA RG 165, Entry NM84-79 (Security Classified Intelligence Reference Publication Files, 1940-45), Boxes 161–164 (Alsos personnel photo album and other records), Boxes 577–585 (CIOS Evaluation Reports and other records), and Boxes 899–900 (FIAT Evaluation Reports and other records).

NARA RG 165, Entry NM84-187, Boxes 137–140. Alsos.

NARA RG 165, Entry NM84-489, Boxes 170–177. Crossbow, biological warfare, etc.

NARA RG 165, Entry UD-27, Box 6. Walther Schieber.

NARA RG 165, Entry 179 (records of interrogations of German-speaking detainees at Fort Hunt)

RG 208: Records of the Office of War Information

NARA RG 208, Entry 198, Box 1042. Press release Franklin-2994, NB-3297. Technical Industrial Intelligence Committee. 25 August 1945. Germany's Inner War Secrets, 26 August 1945. [significant German atomic progress]

NARA RG 208, Entry NC148-358, Box 109. Germany–Secret weapons.

RG 216: Records of the Office of Censorship

NARA RG 216.

RG 218: Records of the U.S. Joint Chiefs of Staff

NARA RG 218, Entry UD-1 (Central Decimal File 1942-45), Box 95 (File CCS 471.9, Sec. 5. Ernest W. Gruhn to Secretary, JIC. JIOA Memorandum attached to Draft press release, 11 March 1946) and Box 475 (Folder: CCS 471.9... (5-1- 45)... Sec. 3. Joint Intelligence Committee. Exploitation of German Scientists and Technicians. 5 January 1946. J.I.C. 317/10.)

NARA RG 218, Entry UD-93, Boxes 1–4. Biological warfare, missiles, exploitation of German scientists, etc.

RG 226: Records of the Office of Strategic Services 1940–1946

NARA RG 226, Entry UD-90, Boxes 1–10 (OSS Washington Radio and Cables). See especially Box 6, Folder 64 SUNRISE [Allen Dulles, Cable IN 9061, 1 April 1945] and Box 7, Folder 86 BERN–IN OUT 1944–1945 [Cable IN 9470, 5 April 1945].

NARA RG 226, Entry UD-125, Box 6, Folder 78. [Intelligence reports from Frederick Loofbourow and "Dr. Berg."]

NARA RG 226, Entry A1-134, Box 216 (Toledo In/Out Folders 1359–1360) and Box 219 (Azusa In/Out Folders 1370–1371).

NARA RG 226, Entry UD-165A, Box 15. [Underground installations.]

NARA RG 226, Entry UD-190 (Field Station Files), Box 551, Folder 170 (JIC 317: Exploitation of German and Austrian scientists in science and technology in the U.S.); Box 552, Folder 173 (JIC 317: Interim procedures for the coordinated exploitation of German specialists in science and technology in the US, December 1945) and Folder 174 (Basic direction re: JIOA); OSS Washington Director's Office Files (Microfilm Publication M1642) (Check series index under "German scientists").

NARA RG 226, Entry A1-210, Box 447, Folder WN16162–16171. Erwin Respondek. 6 November 1945. Übersicht des Standes der wissenschaftlichen Arbeiten in Deutschland zur Atom-Bombe, Berlin.

NARA RG 226, Entry A1-211 (Sources and Methods Files—Previously Withdrawn Material), Box 8, Folder 116. Incoming Cable Form, 21 April 1945. [V-4.]

NARA RG 226, Entry A1-212, Box 3 (Folder WN 20796), Box 5 (Folder WN 20939), and Box 7 (Folder WN 24481). [German atomic work.]

NARA RG 226, Entry A1-214, Box 2, Folder: WN 21090-21105. [A. J. Saxon.]

NARA RG 226, Entry A1-215, Box 6, Folder: WN 26150-26164. [List of 75 German nuclear scientists.]

RG 227: Records of the Office of Scientific Research and Development

NARA RG 227, Microfilm M1392. Bush-Conant File Relating to the Development of the Atomic Bomb, 1940–1945. [Available online at https://downloads.paperlessarchives.com]

RG 238: National Archives Collection of World War II War Crimes Records

NARA RG 238, Entry P-66, Box 39. Mauthausen/Gusen staffs.

NARA RG 238, Entry NM70-160, Box 30, Folder FIAT—Misc.—Reports—No. 1–10. Office of Military Government for Germany (US). Field Information Agency, Technical. DI 254-82 (FIAT) EP. 24 June 1946. Personality List No 2. Also Box 42, Walther Schieber.

NARA RG 238, M1019 Roll 80. War Crimes Records, Interrogation Summaries 4476 (1 December 1947) and 4453 (16 December 1947). [Secret weapon expected soon in Feb. 1945.]

NARA RG 238, M1270 Roll 24. Interrogation Records Prepared for War Crimes Proceedings at Nuernberg, 1945–1947.

RG 242: National Archives Collection of Captured German Records

NARA RG 242, Entry P-33, Box 17. [Walther Schieber.]

NARA RG 242, Entry UD-282AU1, Box 20. [Underground factories.]

NARA RG 242, Entry UD-282AY, Box 55. [Underground installations.]

NARA RG 242, Microfilm Series T-83. [Financial records.]

NARA RG 242, Microfilm Series T-321. [Underground and other records.]

NARA RG 242, Microfilm Series T-976. [SS economic records.]

NARA RG 242, Microfiche Series ??. German reports on atomic energy.

RG 243: Strategic Bombing Survey

NARA RG 243, Entry 27 I-10, Box 46 (Ebensee), Box 59 (Gaisbach, Wartberg), Box 107 (Mauthausen), Box 134 (Redl-Zipf), Box 171 (Zipf).

RG 260: Records of U.S. Occupation Headquarters, World War II

NARA RG 260, Entry A1-170, Boxes 1–15. FIAT Administrative Records, 1945–1947.

NARA RG 260, Entry A1-171, Boxes 16–21. FIAT Daily Journals, 1945–1947.

NARA RG 260, Entry A1-172, Boxes 22–23. FIAT Index Card File, 1946–1947.

NARA RG 260, Entry A1-173, Boxes 24–44. FIAT General Records, 1945–1947.

NARA RG 260, Entry A1-174, Boxes 45–46. FIAT Document Evaluation Forms, 1946.

NARA RG 260, Entry A1-175, Boxes 566–575. FIAT Administrative, Program, and Publications Files.

NARA RG 260, Entry A1-224, Box 101. [Reichspost.]

NARA RG 260, Entry A1-455, Box 649. [Messerschmitt Oberammengau.]

NARA RG 260, Entry A1-1573, Boxes 506–508. [Records Relating to German Scientists.]

NARA RG 260, Entry ??, Box 20-3/5. OMGUS (U.S. Office of Military Government for Germany) Historical Office. History of Field Information Agency, Technical (FIAT). Period 8 May 1945–30 June 1946. Period 1 July 1946–30 June 1947. [4994 FIAT investigators visited Germany during that 12-month period]

NARA RG 260, Microfilm Roll 0084. Records of the German External Assets Branch of the U.S. Allied Commission for Austria Section, 1945–1950.

RG 263: Records of the Central Intelligence Agency

NARA RG 263, Entry ZZ-16. CIA Name Files First Release.

NARA RG 263, Entry ZZ-18. CIA Name Files Second Release.

RG 298: Records of the Office of Naval Research

NARA RG 298, Entry UD-1, Boxes 66–67.

RG 319: Records of the Army Staff

NARA RG 319, Entry A1-84E, Box 124. [BID 8600.0711 Nuclear Physics (Atomic Energy)—Uses—Rockets. History of German Trans-Atlantic Rocket A-10. 4 March 1947.]

NARA RG 319, Entry A1-134A (Records of the Investigative Records Repository [IRR], Impersonal File).

NARA RG 319, Entry A1-134B (Records of the Investigative Records Repository [IRR], Personal Name File).

NARA RG 319, Entry NM3-47B, Box 991, Folder Implementation, General Policy & History.

NARA RG 319, Entry NM3-58, Box 7. Folders 1. TO: CZECHOSLOVAKIA 9-16-45–12-31-45 and 1. FR: CZECHOSLOVAKIA... (MISC) 9-3-45–12-31-45.

NARA RG 319, Entry NM3-82 (Publication Files), especially Boxes 375–426 [BIOS Evaluation Reports and Final Reports], Boxes 668–695 [CIOS Final Reports], Boxes 1264–1283 [FIAT Final Reports], Boxes 1545–1547 and 1622 [Guided Missiles], Boxes 1550–1621 [Halstead Exploitation Centre (HEC) Reports], Boxes 1674–1684 [German documents collected by Alsos Mission], Boxes 2151–2153 [JIOA], Box 2879 [Project 2784].

NARA RG 319, Entry NM3-82A, Boxes 1–19. [German documents collected by Alsos Mission.]

NARA RG 319, Entry NM3-85A (Army Intelligence Document File), especially Box 2126 (Folder 324361–324370), Box 2144 (Folder 326851–326860), Box 2534 (Folder 390731–390740).

NARA RG 319, Entry NM3-85M, Box 19. Folders 925253 and 925256. [Czechoslovakia.]

NARA RG 319, Entry UD-57, Boxes 76–81. [Wernher von Braun.]

NARA RG 319, Entry UD-151. [Counter Intelligence Corps.]

NARA RG 319, Entry UD-1080. [Counter Intelligence Corps.]

NARA RG 319, Entry UD-1041, Box 27, Folder 925497. [The Commanders Intelligence Digest. 19 January 1945.]

NARA RG 319, Entry ZZ-5 (Records of the Investigative Records Repository [IRR], Selected Personal Name Files).

NARA RG 319, Entry ZZ-6 (Records of the Investigative Records Repository [IRR], Selected Impersonal Files).

RG 326: Records of the Atomic Energy Commission

NARA RG 326.

RG 330: Records of the Office of the Secretary of Defense

NARA RG 330, Entry A1-1A, Boxes 1–43. General Correspondence of the Joint Intelligence Objective Agency (JIOA). 1946–1952.

Archival location??? Objective List of German and Austrian Scientists. (1,600 “Scientists”). 2 January 1947. https://www.smecc.org/heinz_muller/german_and_austrian_scientists_interrogated.pdf

NARA RG 330, Entry A1-1B, Boxes 1–186. JIOA Foreign Scientist Case Files. Index of names and boxes available online: https://www.archives.gov/files/iwg/declassified-records/rg-330-defense-secretary/foreign-scientist-case-files.pdf

NARA RG 330, Entry A1-1C, Boxes 1–3. Defense Scientist Immigration Program (DEFSIP) Administrative Records.

RG 331: Records of Allied Operational and Occupation Headquarters, World War II

NARA RG 331, Entry UD-13D. [CIOS reports.]

NARA RG 331, Entry NM8-18, Boxes 142–144. Subject File, 1944–45 (Re: Target Lists And Reports Of Target Teams, 1944–45). [FIAT records.]

NARA RG 331, Entry 83D, Box 33. Folder Com. Z. Releases: 1 May to 30 June 1945. John A. Keck. 28 June 1945 press release.

RG 341: Records of Headquarters United States Air Force (Air Staff)

NARA RG 341, Entry NM15-44 (Historical Branch Subject File), Box 152. Historical Studies Re: Project Paperclip.

RG 374: Records of the Defense Threat Reduction Agency

NARA RG 374, Microfilm A1218. Manhattan District History. [Available online at https://ia803409.us.archive.org/14/items/ManhattanDistrictHistory/]

RG 407: Records of the Adjutant General's Office, 1917–

NARA RG 407, Entry NM3-427 (WW II Operations Reports, 1941–48), especially Box 10127 (80th Infantry Division G-2, April 1945), Boxes 11005–11006 (89th Infantry Division G-2, April 1945), Boxes 12341–12345 (4th Armored Division, 1945), Boxes 12364–12366 (4th Armored Division G-2, April 1945), and Box 14465 (102nd Infantry Division G-2, 1945).

RG 457: Records of the National Security Agency

NARA RG 457, Entry A1-9004, Japanese Army Attaché Messages Translations, SRA 14,200 thru 15,000. SRA 14628–14632.

RG 498: Records of Headquarters, European Theater of Operations, U.S. Army

NARA RG 498, Entry UD-639, Boxes 4116–4117. FIAT Intelligence Reports, 1946.

NARA RG 498, Entry UD-640, Box 4117, FIAT [Background and] History, 1944–1946.

NARA RG 498, Roll MP63-9_0137 (Series Historical Reports and Monographs—Miscellaneous Reports), File 604k, Ordnance Section, ETO Monographs, Ordnance Technical Services, Section VI, pp. 156–181. [Report of John A. Keck after inspecting Hillersleben facility.]

GOUDS: Samuel A. Goudsmit Papers, 1943–1967

NARA RG GOUDS, Entry UD-7420, Boxes 1–9.

LRG: Leslie R. Groves Papers, 1941–1970

NARA RG LRG.

U.S. National Archives and Records Administration at Boston (NARA Boston), Waltham, Massachusetts

NARA Boston RG 181. 1st Naval District. Office of the Assistant Chief of Staff for Operations. Formerly Security Classified General Correspondence 1944–1945. Box 26. Relevant documents in three folders: Surrender of German Submarines (1 of 2); Enemy Submarines, Surrender of; U-Boats, Surrender of.

Figure Credits

Wo ein Begeisterter steht, ist der Gipfel der Welt.	Where an enthusiast is standing is the summit of the world.

Joseph von Eichendorff. 1815.
Ahnung und Gegenwart [*Idea and Present*]
Book II, Chapter 15.

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Fig. 1.3: U.S. government, public domain [https://www.nsf.gov/statistics/2018/nsb20181/figures];
World Intellectual Property Organization [https://www.wipo.int/edocs/pubdocs/en/wipo_pub_941_2019.pdf].

Fig. 1.4: Courtesy of: Nicholas Bloom [Bloom et al. 2020; Jonathan Huebner Huebner 2005; Jan Vijg Vijg 2011].

Fig. 1.5: Courtesy of Michael Park and Russell Funk [Park et al. 2023].

Fig. 1.6: U.S. Library of Congress, public domain.

Fig. 1.7: Todd Rider.

Fig. 2.1: commons.wikimedia.org and public domain.

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Fig. 2.9: commons.wikimedia.org and public domain.

Fig. 2.10: commons.wikimedia.org and public domain.

Fig. 2.11: commons.wikimedia.org and public domain.

Fig. 2.12: [Weinberg 1908].

Fig. 2.13: commons.wikimedia.org and public domain.

Fig. 2.14: commons.wikimedia.org and public domain.

Fig. 2.15: Top: commons.wikimedia.org, public domain, and Archiv der Max-Planck-Gesellschaft (Berlin-Dahlem).
Bottom: [Timoféeff-Ressovsky, Zimmer, and Delbrück 1935].

Fig. 2.16: commons.wikimedia.org; Friedrich-Freksa 1940.

Fig. 2.17: commons.wikimedia.org; Schramm and Rebensburg 1942; Schramm 1943.

Fig. 2.18: commons.wikimedia.org and public domain.

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Fig. 2.26: public domain [Haustein 2004].

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Fig. 2.32: commons.wikimedia.org and public domain.

Fig. 2.33: [Widmark 1889; Hammer 1891] and public domain.

Fig. 2.34: omni.ie and public domain.

Fig. 2.35: https://www.pizbuin.com/en/our-heritage and Archiv der Max-Planck-Gesellschaft (Berlin-Dahlem).

Fig. 2.36: Todd Rider.

Fig. 2.37 Top: Todd Rider. Bottom: commons.wikimedia.org.

Fig. 2.38: commons.wikimedia.org and public domain.

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Fig. 2.45 Top: Todd Rider. Bottom: commons.wikimedia.org and public domain.

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Fig. 2.51: commons.wikimedia.org.

Fig. 2.52: [Pregl 1917].

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Fig. 2.69: *Bulletin de la Société Chimique de France* 9:728–730 (1893); European Patent Office, Swiss patent CH 90,955, public domain.

Fig. 2.70: public domain.

Fig. 2.71: Todd Rider [FIAT 195; BIOS 1776].

Fig. 2.72: Todd Rider [BIOS 236; FIAT 910].

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Fig. 2.83: Friedrich Loeffler Institute, commons.wikimedia.org, and public domain.

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Fig. 2.100 Top: Todd Rider. Bottom: commons.wikimedia.org and public domain.

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Fig. 2.164: Todd Rider.

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Fig. 2.174: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

Fig. 2.175: commons.wikimedia.org and public domain.

Fig. 2.176: *Journal of Laboratory and Clinical Medicine* (1945) 30:1034–1036.

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Fig. 2.191: https://www.muvs.org and commons.wikimedia.org.

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Fig. 2.207: U.S. government, commons.wikimedia.org, and public domain.

Fig. 2.208: U.S. government, commons.wikimedia.org, and public domain.

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Fig. 3.55: European Patent Office, commons.wikimedia.org, and public domain.

Fig. 3.56: Todd Rider [FIAT 885; BIOS 449].

Fig. 3.57: commons.wikimedia.org and public domain.

Fig. 3.58: U.S. Patent and Trademark Office, commons.wikimedia.org, and public domain.

Fig. 3.59: European Patent Office and public domain.

Fig. 3.60: Todd Rider [BIOS 805].

Fig. 3.61: Todd Rider [BIOS 236; BIOS 691].

Fig. 3.62: Todd Rider [BIOS 236; BIOS 1417; BIOS 1481; BIOS 1513].

Fig. 3.63: commons.wikimedia.org and public domain.

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Fig. 3.75: Norberto Lahuerta [NARA RG 319, Entry NM3-82, Box 2899, Folder Project 3826].

Fig. 3.76: European Patent Office.

Fig. 3.77: Norberto Lahuerta [Bundesarchiv, Berlin-Lichterfelde, R 26/III, Aktenbestand Nr. 52].

Fig. 3.78: Manuel Lukas [AFHRA A5183 frame 0351].

Fig. 3.79: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Fig. 3.80: Norberto Lahuerta [NARA RG 319, Entry NM3-85A, Box 1007, Folder 157361 THRU 157370].

Fig. 3.81: Norberto Lahuerta [NARA RG 319, Entry NM3-85A, Box 1007, Folder 157361 THRU 157370].

Fig. 3.82: Norberto Lahuerta [NARA RG 319, Entry NM3-85A, Box 1007, Folder 157361 THRU 157370].

Fig. 3.83: Norberto Lahuerta [NARA RG 319, Entry NM3-85A, Box 1007, Folder 157361 THRU 157370].

Fig. 3.84: George Cully [PW Intelligence Bulletin No 1/49, AFHRA folder 506.61951 Nos. 1/47–1/56 13 Mar–9 Apr 1945, IRIS 207526].

Fig. 3.85: George Cully [PW Intelligence Bulletin No 1/49, AFHRA folder 506.61951 Nos. 1/47–1/56 13 Mar–9 Apr 1945, IRIS 207526].

Fig. 3.86: David N. R. Bleecker [NARA RG 165, Entry NM84-79, Box 1916, PW Intelligence Bulletin 2/32, 30 January 1945].

Fig. 3.87: David N. R. Bleecker [NARA RG 165, Entry NM84-79, Box 1916, PW Intelligence Bulletin 2/32, 30 January 1945].

Fig. 3.88: Todd Rider [BIOS 142].

Fig. 3.89: Norberto Lahuerta [NARA RG 331, Entry UD-18A, Box 157,
Folder 319.1-2 Reports—Evacuation of Targets & Target Addresses].

Fig. 3.90: Norberto Lahuerta [NARA RG 331, Entry UD-18A, Box 157,
Folder 319.1-2 Reports—Evacuation of Targets & Target Addresses].

Fig. 3.91: European Patent Office, public domain.

Fig. 3.92: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 3.93: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 3.94: commons.wikimedia.org, public domain, and Günter Nagel.

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Fig. 3.111: David N. R. Bleecker [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3347, Book 8, SC 231579].

Fig. 3.112: Todd Rider [BIOS 714].

Fig. 3.113: European Patent Office, public domain.

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Fig. 3.117: commons.wikimedia.org and public domain.

Fig. 3.118: commons.wikimedia.org and public domain.

Fig. 3.119: commons.wikimedia.org and public domain.

Fig. 3.120: commons.wikimedia.org and public domain.

Fig. 3.121: commons.wikimedia.org and public domain.

Fig. 3.122: commons.wikimedia.org and public domain.

Fig. 3.123: commons.wikimedia.org and public domain.

Fig. 3.124: [Schönbein 1839].

Fig. 3.125: [Sinsteden 1854].

Fig. 3.126: U.S. Patent and Trademark Office, public domain.

Fig. 3.127: European Patent Office, public domain.

Fig. 3.128: BIOS 362; BIOS 467; FIAT 800.

Fig. 3.129: U.S. Patent and Trademark Office, public domain.

Fig. 3.130: European Patent Office and U.S. Patent and Trademark Office, public domain.

Fig. 3.131: commons.wikimedia.org and public domain.

Fig. 3.132: commons.wikimedia.org and public domain.

Fig. 3.133: commons.wikimedia.org and public domain.

Fig. 3.134: commons.wikimedia.org and public domain.

Fig. 3.135: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain.

Fig. 3.136: commons.wikimedia.org and public domain.

Fig. 3.137: commons.wikimedia.org and public domain.

Fig. 3.138: European Patent Office and public domain.

Fig. 3.139: commons.wikimedia.org and public domain.

Fig. 3.140: U.S. Patent and Trademark Office, public domain.

Fig. 3.141: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain.

Fig. 3.142: Todd Rider [FIAT 678].

Fig. 3.143: Todd Rider [FIAT 678].

Fig. 3.144: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

Fig. 3.145: commons.wikimedia.org and public domain.

Fig. 3.146: commons.wikimedia.org and public domain.

Fig. 3.147: commons.wikimedia.org and public domain.

Fig. 3.148: commons.wikimedia.org and public domain.

Fig. 3.149: commons.wikimedia.org and public domain.

Fig. 3.150: commons.wikimedia.org and public domain.

Fig. 3.151: commons.wikimedia.org and public domain.

Fig. 3.152: commons.wikimedia.org and public domain.

Fig. 3.153: commons.wikimedia.org and public domain.

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Fig. 3.159: commons.wikimedia.org and public domain.

Fig. 3.160: commons.wikimedia.org and public domain.

Fig. 3.161: commons.wikimedia.org and public domain.

Fig. 3.162: commons.wikimedia.org and public domain.

Fig. 3.163: commons.wikimedia.org and public domain.

Fig. 3.164: velcro.com, commons.wikimedia.org, and U.S. Patent and Trademark Office.

Fig. 3.165: Todd Rider [NARA RG 40, Entry UD-75, Box 61, Folder Booster Letters].

Fig. 3.166: commons.wikimedia.org and public domain.

Fig. 3.167: commons.wikimedia.org and public domain.

Fig. 3.168: commons.wikimedia.org and public domain.

Fig. 3.169: commons.wikimedia.org and public domain.

Fig. 3.170: commons.wikimedia.org and public domain.

Fig. 3.171: commons.wikimedia.org and public domain.

Fig. 3.172: [CIOS XXXI-22, FIAT 617].

Fig. 3.173: commons.wikimedia.org and public domain.

Fig. 3.174: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain.

Fig. 3.175: Todd Rider [BIOS 563] and public domain.

Fig. 3.176: Todd Rider [AFHRA A5729 electronic pp. 1650–1651].

Fig. 3.177: Todd Rider [BIOS 1340].

Fig. 3.178: U.S. government, public domain [Adenstedt 1948].

Fig. 3.179: U.S. government, public domain [Adenstedt 1948].

Fig. 3.180: commons.wikimedia.org and public domain.

Fig. 3.181: commons.wikimedia.org and public domain.

Fig. 3.182: https://www.heraeus.com, commons.wikimedia.org, and public domain.

Fig. 3.183: https://www.heraeus.com, commons.wikimedia.org, and public domain.

Fig. 3.184: commons.wikimedia.org and public domain.

Fig. 3.185: commons.wikimedia.org and public domain.

Fig. 3.186: commons.wikimedia.org and public domain.

Fig. 3.187: [BIOS 1179; BIOS 1770; CIOS XXVI-60; CIOS XXIX-3].

Fig. 3.188: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases].

Fig. 3.189: [Runge1850] and commons.wikimedia.org, public domain.

Fig. 3.190: [Schönbein 1861; Goppelsröder 1861] and commons.wikimedia.org, public domain.

Fig. 3.191: [Goppelsröder 1901].

Fig. 3.192: [Goppelsröder 1901].

Fig. 3.193: [Goppelsröder 1901].

Fig. 3.194: commons.wikimedia.org and public domain.

Fig. 3.195: commons.wikimedia.org and European Patent Office, public domain.

Fig. 3.196: commons.wikimedia.org and public domain.

Fig. 3.197: commons.wikimedia.org and public domain.

Fig. 3.198: U.S. Patent and Trademark Office and public domain.

Fig. 3.199: U.S. Patent and Trademark Office and public domain.

Fig. 3.200: commons.wikimedia.org, U.S. Patent and Trademark Office, and European Patent Office, public domain.

Fig. 3.201: U.S. Patent and Trademark Office and public domain.

Fig. 3.202: European Patent Office and public domain.

Fig. 3.203: [BIOS 518].

Fig. 3.204: [BIOS 518].

Fig. 3.205: [BIOS 518].

Fig. 4.1: commons.wikimedia.org and public domain.

Fig. 4.2: commons.wikimedia.org and public domain.

Fig. 4.3: commons.wikimedia.org and public domain.

Fig. 4.4: commons.wikimedia.org and public domain.

Fig. 4.5: commons.wikimedia.org and public domain.

Fig. 4.6: commons.wikimedia.org and public domain.

Fig. 4.7: commons.wikimedia.org and public domain.

Fig. 4.8: commons.wikimedia.org and public domain.

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Fig. 4.19: commons.wikimedia.org and public domain.

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Fig. 4.35: commons.wikimedia.org and public domain.

Fig. 4.36: commons.wikimedia.org and public domain.

Fig. 4.37: commons.wikimedia.org and public domain.

Fig. 4.38: commons.wikimedia.org and U.S. government, public domain.

Fig. 4.39: commons.wikimedia.org and public domain.

Fig. 4.40: commons.wikimedia.org and public domain.

Fig. 4.41: commons.wikimedia.org and public domain.

Fig. 4.42: commons.wikimedia.org and public domain.

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Fig. 4.44: commons.wikimedia.org and public domain.

Fig. 4.45: commons.wikimedia.org and public domain.

Fig. 4.46: commons.wikimedia.org and public domain.

Fig. 4.47: commons.wikimedia.org and public domain.

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Fig. 4.58: commons.wikimedia.org and public domain.

Fig. 4.59: commons.wikimedia.org and public domain.

Fig. 4.60: commons.wikimedia.org and public domain.

Fig. 4.61: commons.wikimedia.org and public domain.

Fig. 5.1: commons.wikimedia.org and public domain.

Fig. 5.2: commons.wikimedia.org and public domain.

Fig. 5.3: commons.wikimedia.org and public domain.

Fig. 5.4: commons.wikimedia.org and public domain.

Fig. 5.5: commons.wikimedia.org and public domain.

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Fig. 5.9: commons.wikimedia.org and public domain.

Fig. 5.10: commons.wikimedia.org and public domain.

Fig. 5.11: commons.wikimedia.org and public domain.

Fig. 5.12: commons.wikimedia.org and public domain.

Fig. 5.13: commons.wikimedia.org and public domain.

Fig. 5.14: commons.wikimedia.org and public domain.

Fig. 5.15: commons.wikimedia.org and public domain.

Fig. 5.16: commons.wikimedia.org and public domain.

Fig. 5.17: commons.wikimedia.org and public domain.

Fig. 5.18: Todd Rider.

Fig. 5.19: commons.wikimedia.org and public domain.

Fig. 5.20: commons.wikimedia.org and public domain.

Fig. 5.21: commons.wikimedia.org and public domain.

Fig. 5.22: commons.wikimedia.org and public domain.

Fig. 5.23: commons.wikimedia.org and public domain.

Fig. 5.24: Todd Rider.

Fig. 5.25: commons.wikimedia.org and public domain.

Fig. 5.26: commons.wikimedia.org and public domain.

Fig. 5.27: commons.wikimedia.org and public domain.

Fig. 5.28: commons.wikimedia.org and public domain.

Fig. 5.29: commons.wikimedia.org and public domain.

Fig. 5.30: commons.wikimedia.org and public domain.

Fig. 5.31: commons.wikimedia.org and public domain.

Fig. 5.32: Todd Rider.

Fig. 5.33: [Wirtz 1918, 1922a, 1922b, 1924]

Fig. 5.34: Todd Rider.

Fig. 5.35: commons.wikimedia.org and public domain.

Fig. 5.36: commons.wikimedia.org and public domain.

Fig. 5.37: commons.wikimedia.org and public domain.

Fig. 5.38: commons.wikimedia.org and public domain.

Fig. 5.39: commons.wikimedia.org, public domain, and Archiv der Max-Planck-Gesellschaft (Berlin-Dahlem).

Fig. 5.40: Todd Rider.

Fig. 5.41: Todd Rider.

Fig. 5.42: commons.wikimedia.org and public domain.

Fig. 5.43: commons.wikimedia.org and public domain.

Fig. 5.44: commons.wikimedia.org and public domain.

Fig. 5.45: commons.wikimedia.org and public domain.

Fig. 5.46: commons.wikimedia.org and public domain.

Fig. 5.47: commons.wikimedia.org and public domain.

Fig. 5.48: commons.wikimedia.org and public domain.

Fig. 5.49: Todd Rider.

Fig. 5.50: commons.wikimedia.org and public domain.

Fig. 5.51: commons.wikimedia.org and public domain.

Fig. 5.52: commons.wikimedia.org and public domain.

Fig. 5.53: commons.wikimedia.org and public domain.

Fig. 5.54: commons.wikimedia.org and public domain.

Fig. 5.55: commons.wikimedia.org and public domain.

Fig. 5.56: commons.wikimedia.org and public domain.

Fig. 5.57: Todd Rider.

Fig. 6.1: commons.wikimedia.org and public domain.

Fig. 6.2: commons.wikimedia.org and public domain.

Fig. 6.3: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain.

Fig. 6.4: commons.wikimedia.org and public domain.

Fig. 6.5: commons.wikimedia.org and public domain.

Fig. 6.6: commons.wikimedia.org and European Patent Office, public domain.

Fig. 6.7: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain.

Fig. 6.8: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain.

Fig. 6.9: commons.wikimedia.org and public domain.

Fig. 6.10: commons.wikimedia.org and public domain.

Fig. 6.11: commons.wikimedia.org and public domain.

Fig. 6.12: https://www.lamptech.co.uk, U.S. Patent and Trademark Office, and European Patent Office, public domain.

Fig. 6.13: https://www.lamptech.co.uk and U.S. Patent and Trademark Office, public domain.

Fig. 6.14: commons.wikimedia.org, U.S. Patent and Trademark Office, and http://edison.rutgers.edu/digital/search?query=John+Kruesi&query_type=keyword&submit_search=Search

Fig. 6.15: commons.wikimedia.org and public domain.

Fig. 6.16: commons.wikimedia.org and public domain.

Fig. 6.17: commons.wikimedia.org and public domain.

Fig. 6.18: commons.wikimedia.org and public domain.

Fig. 6.19: commons.wikimedia.org and public domain.

Fig. 6.20: Philips Eindhoven photo archive, European Patent Office, and commons.wikimedia.org, public domain.

Fig. 6.21: commons.wikimedia.org and U.S. National Magnet Laboratory [https://nationalmaglab.org/magnet-academy/history-of-electricity-magnetism/museum/gauss-weber-telegraph-1833/], public domain.

Fig. 6.22: commons.wikimedia.org, siemens.com, and public domain.

Fig. 6.23: commons.wikimedia.org and Deutsches Museum, public domain.

Fig. 6.24: commons.wikimedia.org and public domain.

Fig. 6.25: commons.wikimedia.org and public domain.

Fig. 6.26: commons.wikimedia.org and public domain.

Fig. 6.27: commons.wikimedia.org and public domain.

Fig. 6.28: commons.wikimedia.org and public domain.

Fig. 6.29: commons.wikimedia.org and European Patent Office, public domain.

Fig. 6.30: commons.wikimedia.org and public domain.

Fig. 6.31: commons.wikimedia.org and public domain.

Fig. 6.32: Verkehrsmuseum Nürnberg and commons.wikimedia.org, public domain.

Fig. 6.33: commons.wikimedia.org and public domain.

Fig. 6.34: commons.wikimedia.org and public domain.

Fig. 6.35: commons.wikimedia.org and public domain.

Fig. 6.36: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder Replies to Letters of April 29, 1947].

Fig. 6.37: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

Fig. 6.38: commons.wikimedia.org and public domain.

Fig. 6.39: Gernsback 1909 and commons.wikimedia.org, public domain.

Fig. 6.40: commons.wikimedia.org and public domain.

Fig. 6.41: Todd Rider and public domain.

Fig. 6.42: commons.wikimedia.org and public domain.

Fig. 6.43: commons.wikimedia.org and public domain.

Fig. 6.44: commons.wikimedia.org and public domain.

Fig. 6.45: commons.wikimedia.org and public domain [archival video in Kloft 2000].

Fig. 6.46: Norberto Lahuerta and Todd Rider.

Fig. 6.47: Norberto Lahuerta and Todd Rider.

Fig. 6.48: Norberto Lahuerta.

Fig. 6.49: commons.wikimedia.org and public domain.

Fig. 6.50: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain.

Fig. 6.51: public domain.

Fig. 6.52: *Look*, 11 August 1964, p. 9.

Fig. 6.53: commons.wikimedia.org and public domain.

Fig. 6.54: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

Fig. 6.55: https://www.welte-mignon.de and commons.wikimedia.org.

Fig. 6.56: www.dutchaudioclassics.nl/awards-for-philips-compact-disc-scientist-piet-kramer-gijs-bouwhuis-klaas-compaan and commons.wikimedia.org.

Fig. 6.57: www.mp3-history.com/en/the_mp3_team.html and commons.wikimedia.org.

Fig. 6.58: commons.wikimedia.org and public domain; *Verhandlungen der Deutschen Physikalischen Gesellschaft* (1916) 18:13–14:318–323; *Mitteilungen der Physikalischen Gesellschaft Zürich* (1916) 18:47–62.

Fig. 6.59: commons.wikimedia.org and public domain; *Zeitschrift für Physik* (1923) 20:1:145–152.

Fig. 6.60: commons.wikimedia.org and public domain; *Zeitschrift für Physik* (1930) 65:3–4:167–188; *Zeitschrift für Physikalische Chemie* (1928) 139:1:375–385.

Fig. 6.61: Todd Rider [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

Fig. 6.62: commons.wikimedia.org and public domain.

Fig. 6.63: commons.wikimedia.org and public domain.

Fig. 6.64: Todd Rider.

Fig. 6.65: Wiedemann and Franz 1853; Debye and Sommerfeld 1913; Debye 1912; Drude 1900.

Fig. 6.66: commons.wikimedia.org and public domain.

Fig. 6.67: commons.wikimedia.org and public domain.

Fig. 6.68: commons.wikimedia.org and public domain.

Fig. 6.69: commons.wikimedia.org and public domain.

Fig. 6.70: commons.wikimedia.org and public domain.

Fig. 6.71: commons.wikimedia.org and public domain.

Fig. 6.72: commons.wikimedia.org and public domain.

Fig. 6.73: U.S. Patent and Trademark Office, public domain.

Fig. 6.74: U.S. Patent and Trademark Office, public domain.

Fig. 6.75: commons.wikimedia.org and European Patent Office, public domain.

Fig. 6.76: European Patent Office, public domain.

Fig. 6.77: U.S. Patent and Trademark Office, public domain.

Fig. 6.78: Philips Eindhoven photo archive and U.S. Patent and Trademark Office, public domain.

Fig. 6.79: [Hilsch and Pohl 1938].

Fig. 6.80: commons.wikimedia.org, public domain.

Fig. 6.81: Günter Nagel.

Fig. 6.82: European Patent Office, public domain.

Fig. 6.83: commons.wikimedia.org, Zeitschrift für Physik 118:9–10:539–592 (1942), and NARA RG 40, Entry UD-75, Box 24, Folder Selenium Rectifier Machinery.

Fig. 6.84: European Patent Office, public domain.

Fig. 6.85: European Patent Office, public domain.

Fig. 6.86: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain.

Fig. 6.87: CIOS XXXI-2.

Fig. 6.88: BIOS 1658.

Fig. 6.89: commons.wikimedia.org and European Patent Office, public domain.

Fig. 6.90: European Patent Office, public domain.

Fig. 6.91: CIOS ER 350, commons.wikimedia.org, and European Patent Office, public domain.

Fig. 6.92: U.S. Patent and Trademark Office, public domain.

Fig. 6.93: commons.wikimedia.org and public domain.

Fig. 6.94: Todd Rider.

Fig. 6.95: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain. NARA RG 40, Entry UD-75, Box 28, Folder Edwin Y. Webb, Jr. 1945 memo from Harry Dauber.

Fig. 6.96: U.S. Patent and Trademark Office, public domain.

Fig. 6.97: Todd Rider [NARA RG 40, Entry UD-75, Box 23, Folder Advisory Panel I Agenda].

Fig. 6.98: Todd Rider [NARA RG 40, Entry UD-75, Boxes 24 and 58].

Fig. 6.99: BIOS 30, BIOS 276, FIAT 272, FIAT 294.

Fig. 6.100: BIOS 725, BIOS 1751, BIOS 30, BIOS 276.

Fig. 6.101: commons.wikimedia.org and public domain.

Fig. 6.102: commons.wikimedia.org and European Patent Office, public domain.

Fig. 6.103: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain.

Fig. 6.104: U.S. Patent and Trademark Office, public domain.

Fig. 6.105: CIOS XXVII-44.

Fig. 6.106: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

Fig. 6.107: European Patent Office, public domain.

Fig. 6.108: https://www.fed.de/fileadmin/user_upload/Roentgentest__eine_zerstoerungsfreie_Analysemethode.pdf

Fig. 6.109: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain.

Fig. 6.110: Todd Rider [NARA RG 40, Entry UD-75, Box 25, Folder Odarenko, Dr. T. M., undated press release (probably late 1946)].

Fig. 6.111: European Patent Office and U.S. Patent and Trademark Office, public domain.

Fig. 6.112: European Patent Office, public domain.

Fig. 6.113: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain.

Fig. 6.114: U.S. Patent and Trademark Office, public domain.

Fig. 6.115: commons.wikimedia.org and European Patent Office, public domain.

Fig. 6.116: U.S. Patent and Trademark Office, public domain.

Fig. 6.117: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain.

Fig. 6.118: U.S. Patent and Trademark Office, public domain.

Fig. 6.119: commons.wikimedia.org and European Patent Office, public domain.

Fig. 6.120: commons.wikimedia.org and *Zeitschrift für Physik* 18:1:199–206 (1923).

Fig. 6.121: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain.

Fig. 6.122: U.S. Patent and Trademark Office, public domain.

Fig. 6.123: commons.wikimedia.org and *IEEE Journal of Quantum Electronics* 23:6:659–673 (1987)

Fig. 6.124: U.S. Patent and Trademark Office, public domain.

Fig. 6.125: commons.wikimedia.org and U.S. Patent and Trademark Office, public domain.

Fig. 6.126: commons.wikimedia.org and public domain.

Fig. 6.127: commons.wikimedia.org and public domain.

Fig. 6.128: commons.wikimedia.org and public domain.

Fig. 6.129: G-345, courtesy of Deutsches Museum Archive, FA 002/0712; English translation in FIAT 63.

Fig. 6.130: G-345, courtesy of Deutsches Museum Archive, FA 002/0712; English translation in FIAT 63.

Fig. 6.131: commons.wikimedia.org and public domain.

Fig. 6.132: commons.wikimedia.org and public domain.

Fig. 6.133: commons.wikimedia.org and public domain.

Fig. 6.134: commons.wikimedia.org and public domain.

Fig. 6.135: [BIOS 724; BIOS 1316; CIOS XXV-13; FIAT 641].

Fig. 6.136: [BIOS 255].

Fig. 6.137: [FIAT 575].

Fig. 6.138: commons.wikimedia.org and public domain.

Fig. 6.139: [BIOS Misc 66].

Fig. 6.140: U.S. government, public domain.

Fig. 6.141: BIOS Misc 66 and U.S. government, public domain.

Fig. 6.142: U.S. government, public domain.

Fig. 6.143: [BIOS Misc 66].

Fig. 6.144: Top [BIOS Misc 66]. Bottom [U.S. government photo, reprinted in *Popular Mechanics*, August 1950, p. 256]. See also: CIOS XXXI-14.

Fig. 6.145: public domain.

Fig. 6.146: U.S. government, public domain.

Fig. 6.147: commons.wikimedia.org, Benecke and Quick 1957, and U.S. government, public domain.

Fig. 6.148: [Benecke and Quick 1957].

Fig. 6.149:

Fig. 6.150:

Fig. 6.151: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

Fig. 6.152: [BIOS 2; BIOS Misc 66].

Fig. 6.153: *Dayton Daily News*, 8 December 1946, p. 55 and U.S. government, public domain.

Fig. 6.154: U.S. government, public domain, and Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder Webb].

Fig. 6.155: U.S. government and U.S. Patent and Trademark Office, public domain.

Fig. 6.156: commons.wikimedia.org and U.S. government, public domain.

Fig. 6.157: U.S. Patent and Trademark Office, public domain.

Fig. 6.158: commons.wikimedia.org and public domain.

Fig. 6.159: commons.wikimedia.org and public domain.

Fig. 6.160: commons.wikimedia.org and public domain.

Fig. 6.161: U.S. Patent and Trademark Office, commons.wikimedia.org, and public domain.

Fig. 6.162: Technisches Museum Wien; U.S. Patent and Trademark Office, public domain.

Fig. 6.163: U.S. Patent and Trademark Office, commons.wikimedia.org, and public domain.

Fig. 6.164: commons.wikimedia.org and public domain.

Fig. 6.165: European Patent Office, public domain.

Fig. 6.166: Todd Rider.

Fig. 6.167: Todd Rider.

Fig. 6.168: [Zuse 1993].

Fig. 6.169: Todd Rider.

Fig. 6.170: Historisch-Technisches Museum Peenemünde Archive.

Fig. 6.171: commons.wikimedia.org and public domain.

Fig. 6.172: European Patent Office and U.S. Patent and Trademark Office, public domain.

Fig. 6.173: commons.wikimedia.org and public domain.

Fig. 6.174: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

Fig. 6.175: U.S. government, commons.wikimedia.org, and public domain.

Fig. 6.176: U.S. government, commons.wikimedia.org, and public domain.

Fig. 6.177: U.S. Patent and Trademark Office, commons.wikimedia.org, and public domain.

Fig. 6.178: commons.wikimedia.org and Todd Rider collection.

Fig. 6.179: commons.wikimedia.org and public domain.

Fig. 6.180: commons.wikimedia.org and public domain.

Fig. 6.181: commons.wikimedia.org and public domain.

Fig. 6.182: https://www.cryptomuseum.com/crypto/bombe, commons.wikimedia.org, and public domain.

Fig. 6.183: commons.wikimedia.org and public domain.

Fig. 6.184: commons.wikimedia.org and public domain.

Fig. 6.185: commons.wikimedia.org and public domain.

Fig. 6.186: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

Fig. 6.187: [Faensen 2001].

Fig. 6.188: U.S. government and public domain.

Fig. 6.189: commons.wikimedia.org and public domain.

Fig. 6.190: commons.wikimedia.org and public domain.

Fig. 6.191: commons.wikimedia.org and public domain.

Fig. 6.192: U.S. Patent and Trademark Office, commons.wikimedia.org, and public domain.

Fig. 6.193: commons.wikimedia.org, European Patent Office, and public domain.

Fig. 6.194: U.S. government, commons.wikimedia.org, and public domain.

Fig. 6.195: commons.wikimedia.org and public domain.

Fig. 6.196: commons.wikimedia.org and Deutsches Museum Archive, courtesy of Diane McWhorter.

Fig. 6.197: Deutsches Museum Archive, courtesy of Diane McWhorter.

Fig. 6.198: Deutsches Museum Archive.

Fig. 6.199: Deutsches Museum Archive.

Fig. 6.200: European Patent Office, public domain.

Fig. 6.201: European Patent Office, public domain.

Fig. 6.202: commons.wikimedia.org and public domain.

Fig. 6.203: commons.wikimedia.org and public domain.

Fig. 6.204: U.S. Patent and Trademark Office and public domain.

Fig. 6.205: U.S. Patent and Trademark Office and public domain.

Fig. 6.206: commons.wikimedia.org and public domain.

Fig. 6.207: commons.wikimedia.org and public domain.

Fig. 6.208: commons.wikimedia.org and public domain.

Fig. 6.209: U.S. Patent and Trademark Office and public domain.

Fig. 6.210: courtesy of Norberto Lahuerta.

Fig. 6.211: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Evacuation of German Equipment].

Fig. 6.212: commons.wikimedia.org and public domain.

Fig. 6.213: commons.wikimedia.org and public domain.

Fig. 6.214: commons.wikimedia.org and public domain.

Fig. 6.215: Todd Rider [BIOS 866].

Fig. 6.216: European Patent Office, public domain.

Fig. 6.217: Todd Rider [NavTecMisEu 530-45].

Fig. 6.218: Todd Rider [NavTecMisEu 530-45].

Fig. 6.219: Todd Rider [NavTecMisEu 530-45].

Fig. 6.220: Todd Rider [NavTecMisEu 530-45].

Fig. 6.221: commons.wikimedia.org and public domain.

Fig. 6.222: Woo 2006 and public domain.

Fig. 6.223: Todd Rider [BIOS 609; BIOS 1679].

Fig. 6.224: Todd Rider [CIOS XXXII-77], commons.wikimedia.org, and public domain.

Fig. 6.225: U.S. government and public domain.

Fig. 6.226: commons.wikimedia.org and public domain.

Fig. 6.227: commons.wikimedia.org and public domain.

Fig. 6.228: commons.wikimedia.org and public domain.

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Fig. 6.236: commons.wikimedia.org and public domain.

Fig. 6.237: commons.wikimedia.org and public domain.

Fig. 6.238: commons.wikimedia.org and Caltech.

Fig. 6.239: commons.wikimedia.org and public domain.

Fig. 6.240: U.S. Patent and Trademark Office and European Patent Office, public domain.

Fig. 6.241: U.S. government, public domain.

Fig. 6.242: commons.wikimedia.org and European Patent Office, public domain.

Fig. 6.243: European Patent Office, public domain.

Fig. 6.244: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder Budget].

Fig. 6.245: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

Fig. 6.246: Todd Rider.

Fig. 6.247: commons.wikimedia.org and public domain.

Fig. 6.248: commons.wikimedia.org and public domain.

Fig. 6.249: commons.wikimedia.org and public domain.

Fig. 6.250: commons.wikimedia.org and public domain.

Fig. 6.251: commons.wikimedia.org and public domain.

Fig. 6.252: commons.wikimedia.org and public domain.

Fig. 7.1: commons.wikimedia.org and public domain.

Fig. 7.2: commons.wikimedia.org and public domain.

Fig. 7.3: commons.wikimedia.org, public domain, Technisches Museum Wien.

Fig. 7.4: https://oztypewriter.blogspot.com/2011/09/on-this-day-in-typewriter-history-cxxii.html, Smithsonian Institution, and U.S. Patent and Trademark Office, public domain.

Fig. 7.5: commons.wikimedia.org and public domain.

Fig. 7.6: commons.wikimedia.org and public domain.

Fig. 7.7: commons.wikimedia.org and public domain.

Fig. 7.8: commons.wikimedia.org and public domain.

Fig. 7.9: commons.wikimedia.org and public domain.

Fig. 7.10: commons.wikimedia.org and public domain.

Fig. 7.11: commons.wikimedia.org, public domain, Technisches Museum Wien.

Fig. 7.12: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases].

Fig. 7.13: commons.wikimedia.org and public domain.

Fig. 7.14: commons.wikimedia.org and public domain.

Fig. 7.15: commons.wikimedia.org and public domain.

Fig. 7.16: commons.wikimedia.org and public domain.

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Fig. 7.22: commons.wikimedia.org and public domain.

Fig. 7.23: commons.wikimedia.org and public domain.

Fig. 7.24:

Fig. 7.25: commons.wikimedia.org and public domain.

Fig. 7.26: U.S. Patent and Trademark Office, public domain.

Fig. 7.27: U.S. Patent and Trademark Office, public domain.

Fig. 7.28: commons.wikimedia.org, U.S. Patent and Trademark Office, public domain.

Fig. 7.29: commons.wikimedia.org and public domain.

Fig. 7.30: commons.wikimedia.org and public domain.

Fig. 7.31: commons.wikimedia.org and public domain.

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Fig. 7.39: commons.wikimedia.org and public domain.

Fig. 7.40: commons.wikimedia.org and public domain.

Fig. 7.41: commons.wikimedia.org and public domain.

Fig. 7.42: commons.wikimedia.org and public domain.

Fig. 7.43: https://www.press.bmwgroup.com/global/photo/detail/P90094341/ernst-henne-land-speed-records-1937-12/2012 and commons.wikimedia.org, public domain.

Fig. 7.44: commons.wikimedia.org and public domain.

Fig. 7.45: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases].

Fig. 7.46: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases].

Fig. 7.47: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases].

Fig. 7.48: European Patent Office, public domain.

Fig. 7.49: European Patent Office and https://www.roru.de/airbag/gasgenerator.htm.

Fig. 7.50: commons.wikimedia.org, European Patent Office, public domain.

Fig. 7.51: commons.wikimedia.org and public domain.

Fig. 7.52: commons.wikimedia.org and public domain.

Fig. 7.53: commons.wikimedia.org and public domain.

Fig. 7.54: European Patent Office, public domain.

Fig. 7.55: Burstyn 1912.

Fig. 7.56: commons.wikimedia.org and public domain.

Fig. 7.57: commons.wikimedia.org and public domain.

Fig. 7.58: commons.wikimedia.org and public domain.

Fig. 7.59: U.S. Patent and Trademark Office, commons.wikimedia.org, public domain.

Fig. 7.60: U.S. government, public domain.

Fig. 7.61: European Patent Office, commons.wikimedia.org, public domain.

Fig. 7.62: U.S. Patent and Trademark Office, commons.wikimedia.org, public domain.

Fig. 7.63: Todd Rider.

Fig. 7.64: commons.wikimedia.org and public domain.

Fig. 7.65: Top: commons.wikimedia.org and public domain. Bottom: Todd Rider.

Fig. 7.66: commons.wikimedia.org and public domain.

Fig. 7.67: commons.wikimedia.org and public domain.

Fig. 7.68: commons.wikimedia.org and public domain.

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Fig. 7.73: commons.wikimedia.org and public domain.

Fig. 7.74: commons.wikimedia.org and public domain.

Fig. 7.75: commons.wikimedia.org and public domain.

Fig. 7.76: European Patent Office, commons.wikimedia.org, public domain.

Fig. 7.77: commons.wikimedia.org, U.S. government, public domain.

Fig. 7.78: commons.wikimedia.org and public domain.

Fig. 7.79: commons.wikimedia.org and public domain.

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Fig. 7.90: commons.wikimedia.org and public domain.

Fig. 7.91: commons.wikimedia.org and public domain.

Fig. 7.92: commons.wikimedia.org and public domain.

Fig. 7.93: Top: William Schneck. Bottom: commons.wikimedia.org and public domain.

Fig. 7.94: commons.wikimedia.org and public domain.

Fig. 7.95: commons.wikimedia.org and public domain.

Fig. 7.96: commons.wikimedia.org and public domain.

Fig. 7.97: David N. R. Bleecker [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment,

German, Box 3344, Book 5, SC 205713, SC 205714].

Fig. 7.98: commons.wikimedia.org and public domain.

Fig. 7.99: commons.wikimedia.org and public domain.

Fig. 7.100: commons.wikimedia.org and public domain.

Fig. 7.101: commons.wikimedia.org and public domain.

Fig. 7.102: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28]; U.S. government and public domain.

Fig. 7.103: commons.wikimedia.org and public domain.

Fig. 7.104: commons.wikimedia.org and public domain.

Fig. 7.105: commons.wikimedia.org and public domain.

Fig. 7.106: commons.wikimedia.org and public domain.

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Fig. 7.108: commons.wikimedia.org and public domain.

Fig. 7.109: commons.wikimedia.org and public domain.

Fig. 7.110: commons.wikimedia.org and public domain.

Fig. 7.111 Top: commons.wikimedia.org and public domain. Bottom: Todd Rider.

Fig. 7.112: commons.wikimedia.org and public domain.

Fig. 7.113: Todd Rider.

Fig. 7.114: Todd Rider.

Fig. 7.115: Todd Rider.

Fig. 7.116: Todd Rider.

Fig. 7.117: Todd Rider.

Fig. 7.118: Todd Rider.

Fig. 7.119: *Pittsburgh Press*, 21 November 1946, p. 9; http://www.navsource.org/archives/08/08358.htm and U.S. government, public domain.

Fig. 7.120: commons.wikimedia.org and public domain.

Fig. 7.121: [NYT 1958-10-09 p. 73].

Fig. 7.122: https://www.cia.gov/readingroom/document/cia-rdp80-00809a000600360061-4.

Fig. 7.123: commons.wikimedia.org and public domain.

Fig. 7.124: commons.wikimedia.org and public domain.

Fig. 7.125: commons.wikimedia.org and public domain.

Fig. 7.126: commons.wikimedia.org and public domain.

Fig. 7.127: commons.wikimedia.org and public domain.

Fig. 7.128 Top: commons.wikimedia.org and public domain. Bottom: Lori Rider.

Fig. 7.129: Public domain.

Fig. 7.130: Public domain.

Fig. 7.131: Public domain.

Fig. 7.132: commons.wikimedia.org and public domain.

Fig. 7.133: commons.wikimedia.org and public domain.

Fig. 7.134: commons.wikimedia.org and public domain.

Fig. 7.135: commons.wikimedia.org and public domain.

Fig. 7.136: commons.wikimedia.org and public domain.

Fig. 7.137: commons.wikimedia.org and public domain.

Fig. 7.138: Technisches Museum Wien, commons.wikimedia.org, and public domain.

Fig. 7.139: commons.wikimedia.org and public domain.

Fig. 7.140 Top: commons.wikimedia.org and public domain. Bottom: Todd Rider.

Fig. 7.141: commons.wikimedia.org and public domain.

Fig. 7.142: commons.wikimedia.org and public domain.

Fig. 7.143: https://www.deutsches-museum.de/bibliothek/unsere-schaetze/technikgeschichte/schaeffer-waschmaschine and commons.wikimedia.org, public domain.

Fig. 7.144: commons.wikimedia.org and public domain.

Fig. 7.145: commons.wikimedia.org and public domain.

Fig. 7.146: commons.wikimedia.org and public domain.

Fig. 8.1: commons.wikimedia.org and public domain.

Fig. 8.2: commons.wikimedia.org and public domain.

Fig. 8.3: [Leopold Freund 1903].

Fig. 8.4: commons.wikimedia.org and public domain.

Fig. 8.5: Archiv der Österreichischen Akademie der Wissenschaften, Bildarchiv.

Fig. 8.6: commons.wikimedia.org and public domain.

Fig. 8.7: commons.wikimedia.org and public domain.

Fig. 8.8: commons.wikimedia.org and public domain.

Fig. 8.9: commons.wikimedia.org and public domain.

Fig. 8.10: *Archiv für Elektrotechnik* (1928) 21:4:387–406; NARA RG 319 Entry NM3-82A, Box 6, Folder ALSOS G-20; U.S. Patent and Trademark Office, U.S. patent 2,572,551; public domain.

Fig. 8.11: commons.wikimedia.org and European Patent Office, German patent DE 698,867, public domain.

Fig. 8.12: commons.wikimedia.org and public domain.

Fig. 8.13: commons.wikimedia.org and public domain.

Fig. 8.14: commons.wikimedia.org and public domain.

Fig. 8.15: *Zeitschrift für Physik* (1927) 42:9–10:741–758; *Zeitschrift für Physik* (1935) 96:7–8:431–458; Mayer and Jensen 1955; Blatt and Weisskopf 1952.

Fig. 8.16: Todd Rider.

Fig. 8.17: Todd Rider.

Fig. 8.18: commons.wikimedia.org and public domain.

Fig. 8.19: Todd Rider.

Fig. 8.20: commons.wikimedia.org and public domain.

Fig. 8.21: commons.wikimedia.org and public domain.

Fig. 8.22: commons.wikimedia.org and public domain.

Fig. 8.23: commons.wikimedia.org and public domain.

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Fig. 8.28: commons.wikimedia.org and public domain.

Fig. 8.29: commons.wikimedia.org and public domain.

Fig. 8.30: commons.wikimedia.org and public domain.

Fig. 8.31: Todd Rider.

Fig. 8.32: European Patent Office; Rainer Karlsch, Heiko Petermann, and Matthias Uhl.

Fig. 8.33: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.34: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.35: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.36: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.37: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.38: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.39: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.40: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.41: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.42: commons.wikimedia.org, public domain, Archiv der Max-Planck-Gesellschaft (Berlin-Dahlem), and Günter Nagel.

Fig. 8.43: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.44: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.45: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.46: commons.wikimedia.org, public domain, Günter Nagel, and Archiv der Österreichischen Akademie der Wissenschaften, Bildarchiv.

Fig. 8.47: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.48: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.49: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.50: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.51: commons.wikimedia.org, public domain, and Norberto Lahuerta.

Fig. 8.52: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.53: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.54: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 8.55: commons.wikimedia.org, public domain, Archiv der Max-Planck-Gesellschaft (Berlin-Dahlem), and Günter Nagel.

Fig. 8.56: commons.wikimedia.org and public domain.

Fig. 8.57: commons.wikimedia.org and public domain.

Fig. 9.1: commons.wikimedia.org and public domain.

Fig. 9.2: commons.wikimedia.org and public domain.

Fig. 9.3: commons.wikimedia.org and public domain.

Fig. 9.4: commons.wikimedia.org and public domain.

Fig. 9.5: commons.wikimedia.org and public domain.

Fig. 9.6: commons.wikimedia.org and public domain.

Fig. 9.7: commons.wikimedia.org and public domain.

Fig. 9.8: commons.wikimedia.org and public domain.

Fig. 9.9: commons.wikimedia.org and public domain.

Fig. 9.10: *Bridgeport Sunday Herald*, 18 August 1901, p. 5
[see this and many other examples of 1901 newspaper articles at gustavewhitehead.info].

Fig. 9.11: 1948 contract between the Wright estate and the Smithsonian Institution, public domain
[see http://historybycontract.org for this and additional related documents and information].

Fig. 9.12: 1948 contract between the Wright estate and the Smithsonian Institution, public domain
[see http://historybycontract.org for this and additional related documents and information].

Fig. 9.13: commons.wikimedia.org and Todd Rider.

Fig. 9.14: commons.wikimedia.org, archive.org, and Todd Rider.

Fig. 9.15: commons.wikimedia.org and public domain.

Fig. 9.16: commons.wikimedia.org and public domain.

Fig. 9.17: public domain [http://www.histaviation.com/AVA.html].

Fig. 9.18: commons.wikimedia.org and public domain.

Fig. 9.19: U.S. government, public domain.

Fig. 9.20: commons.wikimedia.org and public domain.

Fig. 9.21: U.S. government, public domain.

Fig. 9.22: David N. R. Bleecker [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3344, Book 5, SC 209555].

Fig. 9.23: commons.wikimedia.org and public domain.

Fig. 9.24: Historisch-Technisches Museum Peenemünde Archive, commons.wikimedia.org, and public domain.

Fig. 9.25: commons.wikimedia.org and public domain.

Fig. 9.26: *Dayton Daily News*, 8 December 1946, p. 55 and U.S. government, public domain.

Fig. 9.27: commons.wikimedia.org and public domain.

Fig. 9.28: commons.wikimedia.org and public domain.

Fig. 9.29: commons.wikimedia.org and public domain.

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Fig. 9.38: commons.wikimedia.org and public domain.

Fig. 9.39: commons.wikimedia.org and public domain.

Fig. 9.40: commons.wikimedia.org and public domain.

Fig. 9.41: Todd Rider.

Fig. 9.42 Top: commons.wikimedia.org and public domain. Bottom: Todd Rider.

Fig. 9.43: commons.wikimedia.org and public domain.

Fig. 9.44: U.S. government and public domain.

Fig. 9.45 Top: commons.wikimedia.org and public domain. Bottom: Todd Rider.

Fig. 9.46: Norberto Lahuerta [NARA RG 319, Entry NM3-82, Box 1568, HEC 842].

Fig. 9.47: Norberto Lahuerta [NARA RG 319, Entry NM3-82, Box 1568, HEC 842].

Fig. 9.48: hoernerfluiddynamics.com.

Fig. 9.49: commons.wikimedia.org and public domain.

Fig. 9.50: commons.wikimedia.org and public domain.

Fig. 9.51: Todd Rider.

Fig. 9.52: Todd Rider.

Fig. 9.53: Todd Rider.

Fig. 9.54: European Patent Office, U.S. Patent and Trademark Office, and commons.wikimedia.org, public domain.

Fig. 9.55: U.S. Patent and Trademark Office, public domain.

Fig. 9.56: European Patent Office, public domain.

Fig. 9.57: commons.wikimedia.org, public domain.

Fig. 9.58: U.S. Patent and Trademark Office and European Patent Office, public domain.

Fig. 9.59: European Patent Office, U.S. Patent and Trademark Office, and commons.wikimedia.org, public domain.

Fig. 9.60: European Patent Office and U.S. Patent and Trademark Office, public domain.

Fig. 9.61: European Patent Office and commons.wikimedia.org, public domain.

Fig. 9.62: European Patent Office, public domain.

Fig. 9.63: European Patent Office, public domain.

Fig. 9.64: European Patent Office and commons.wikimedia.org, public domain.

Fig. 9.65: commons.wikimedia.org and public domain.

Fig. 9.66: commons.wikimedia.org and public domain.

Fig. 9.67: commons.wikimedia.org and public domain.

Fig. 9.68: commons.wikimedia.org and public domain.

Fig. 9.69: commons.wikimedia.org and public domain.

Fig. 9.70: commons.wikimedia.org and public domain.

Fig. 9.71: commons.wikimedia.org and public domain.

Fig. 9.72: European Patent Office, public domain.

Fig. 9.73: European Patent Office, public domain.

Fig. 9.74: European Patent Office, public domain.

Fig. 9.75: European Patent Office, public domain.

Fig. 9.76: commons.wikimedia.org and public domain.

Fig. 9.77: U.S. government, public domain.

Fig. 9.78: U.S. Patent and Trademark Office, public domain.

Fig. 9.79: European Patent Office and U.S. Patent and Trademark Office, public domain.

Fig. 9.80: European Patent Office and U.S. Patent and Trademark Office, public domain.

Fig. 9.81: commons.wikimedia.org and public domain.

Fig. 9.82: U.S. government, public domain.

Fig. 9.83: commons.wikimedia.org and public domain.

Fig. 9.84: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.85: commons.wikimedia.org and public domain.

Fig. 9.86: U.S. government; *Cincinnati Enquirer*, 15 June 1997, p. 32.

Fig. 9.87: U.S. government and commons.wikimedia.org, public domain.

Fig. 9.88: U.S. government and commons.wikimedia.org, public domain.

Fig. 9.89: U.S. government, public domain.

Fig. 9.90: U.S. government, public domain.

Fig. 9.91: [Carpenter 2003].

Fig. 9.92: European Patent Office and U.S. Patent and Trademark Office, public domain.

Fig. 9.93: U.S. Patent and Trademark Office, public domain.

Fig. 9.94: U.S. Patent and Trademark Office, public domain.

Fig. 9.95: U.S. Patent and Trademark Office and commons.wikimedia.org, public domain.

Fig. 9.96: U.S. Patent and Trademark Office and commons.wikimedia.org, public domain.

Fig. 9.97: U.S. Patent and Trademark Office, public domain.

Fig. 9.98: General Electric and U.S. government, public domain. Fleet Ballistic Missile, Kings Bay https://books.google.com/books?id=Ex86AQAAMAAJ&pg=SA9-PA241&lpg=SA9-PA241&dq=%22walter+brisken%22+engines&source=bl&ots=cG4CgxXj-x&sig=ACfU3U0ZTV-nr0aORDptfUMHY7GrX3YvFA&hl=en&sa=X&ved=2ahUKEwjN2evWiLD5AhXOxoUKHRtsBAcQ6AF6BAgXEAM#v=onepage&q&f=false

Fig. 9.99: Todd Rider [AFHRA A2055 Frame 1257].

Fig. 9.100: commons.wikimedia.org and public domain.

Fig. 9.101: commons.wikimedia.org and public domain.

Fig. 9.102: commons.wikimedia.org and public domain.

Fig. 9.103: commons.wikimedia.org and public domain.

Fig. 9.104: commons.wikimedia.org and public domain.

Fig. 9.105: commons.wikimedia.org and public domain.

Fig. 9.106: Top: commons.wikimedia.org and public domain. Bottom: Lori Rider.

Fig. 9.107: commons.wikimedia.org and public domain.

Fig. 9.108: commons.wikimedia.org and public domain.

Fig. 9.109: commons.wikimedia.org and public domain.

Fig. 9.110: commons.wikimedia.org and public domain.

Fig. 9.111:

Fig. 9.112: [BIOS 466; FIAT 465].

Fig. 9.113: [BIOS 466].

Fig. 9.114: [BIOS 466].

Fig. 9.115: Courtesy of Deutsches Museum Archive, photo 39529.

Fig. 9.116: *Dayton Daily News*, 8 December 1946, p. 55 and U.S. government, public domain.

Fig. 9.117: commons.wikimedia.org and public domain.

Fig. 9.118: European Patent Office, public domain.

Fig. 9.119: European Patent Office, public domain.

Fig. 9.120: European Patent Office, public domain.

Fig. 9.121: commons.wikimedia.org and public domain.

Fig. 9.122: Todd Rider.

Fig. 9.123: commons.wikimedia.org and public domain.

Fig. 9.124: commons.wikimedia.org and public domain.

Fig. 9.125: commons.wikimedia.org and public domain.

Fig. 9.126: commons.wikimedia.org and public domain.

Fig. 9.127: commons.wikimedia.org and public domain.

Fig. 9.128: commons.wikimedia.org and public domain.

Fig. 9.129: commons.wikimedia.org and public domain.

Fig. 9.130: commons.wikimedia.org and public domain.

Fig. 9.131: commons.wikimedia.org and public domain.

Fig. 9.132: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.133: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.134: U.S. government and public domain.

Fig. 9.135: U.S. government and public domain.

Fig. 9.136: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.137: Todd Rider.

Fig. 9.138: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.139: U.S. government and public domain.

Fig. 9.140: U.S. government and public domain.

Fig. 9.141: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.142: Ron Barrett, University of Kansas, and Martin UAV.

Fig. 9.143: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.144: U.S. government and public domain.

Fig. 9.145: U.S. government and public domain.

Fig. 9.146: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.147: commons.wikimedia.org and public domain.

Fig. 9.148: Todd Rider [BIOS Overall 8] and public domain.

Fig. 9.149: Todd Rider [BIOS Overall 8] and public domain.

Fig. 9.150: Todd Rider [FIAT 604].

Fig. 9.151: commons.wikimedia.org and public domain.

Fig. 9.152: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.153: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.154: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.155: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.156: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.157: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.158: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.159: David N. R. Bleecker [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3347, Book 8, SC 231474].

Fig. 9.160: U.S. government and public domain.

Fig. 9.161: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.162: *Los Angeles Times* and *Oxnard Press-Courier*.

Fig. 9.163: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.164: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.165: commons.wikimedia.org and public domain.

Fig. 9.166: Todd Rider.

Fig. 9.167: commons.wikimedia.org and public domain.

Fig. 9.168 Left: commons.wikimedia.org and public domain. Right: Todd Rider.

Fig. 9.169: commons.wikimedia.org and public domain.

Fig. 9.170: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.171: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.172: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.173: Todd Rider collection.

Fig. 9.174: commons.wikimedia.org, public domain.

Fig. 9.175: commons.wikimedia.org, public domain.

Fig. 9.176: commons.wikimedia.org, public domain.

Fig. 9.177: U.S. government (via heroicrelics.org), commons.wikimedia.org, and public domain.

Fig. 9.178: public domain.

Fig. 9.179: commons.wikimedia.org and public domain.

Fig. 9.180: commons.wikimedia.org and public domain.

Fig. 9.181: Mark Wade [www.astronautix.com/g/g-5.html].

Fig. 9.182: [Przybilski 2002a].

Fig. 9.183: commons.wikimedia.org and public domain.

Fig. 9.184: commons.wikimedia.org, public domain.

Fig. 9.185: U.S. Patent and Trademark Office, public domain.

Fig. 9.186: public domain.

Fig. 9.187: commons.wikimedia.org, public domain.

Fig. 9.188: commons.wikimedia.org, public domain.

Fig. 9.189: commons.wikimedia.org, public domain.

Fig. 9.190: commons.wikimedia.org, public domain.

Fig. 9.191: [Bundesarchiv Militärarchiv Freiburg RH 8/369].

Fig. 9.192: [NavTecMisEu 500-45].

Fig. 9.193: [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

Fig. 9.194: U.S. government and public domain [http://www.cv41.org/photos/gallery3/index.php/op/opsandy].

Fig. 9.195: U.S. government and public domain [http://www.usscusk.com/1953.htm].

Fig. 9.196: U.S. government, public domain; Lori Rider.

Fig. 9.197: commons.wikimedia.org, public domain.

Fig. 9.198: Courtesy of Norberto Lahuerta.

Fig. 9.199: commons.wikimedia.org, public domain.

Fig. 9.200: Todd Rider.

Fig. 9.201: U.S. government, commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 9.202: U.S. government, commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 9.203: U.S. government, commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 9.204: U.S. government, commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 9.205: U.S. government, commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 9.206: public domain.

Fig. 9.207: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.208: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.209 Top: BIOS 571. Bottom: HEC 5787.

Fig. 9.210: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.211: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.212: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.213: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.214: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.215: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.216: *Dayton Daily News*, 8 December 1946, p. 55 and U.S. government, public domain.

Fig. 9.217: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.218: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.219: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.220: Todd Rider.

Fig. 9.221: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.222: U.S. government and public domain.

Fig. 9.223: U.S. government, commons.wikimedia.org, Peenemünde Archive, and public domain.

Fig. 9.224: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.225: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.226: Washington Dulles International Airport, public domain.

Fig. 9.227: commons.wikimedia.org and public domain.

Fig. 9.228: commons.wikimedia.org and public domain.

Fig. 9.229: commons.wikimedia.org and public domain [Hohmann 1925].

Fig. 9.230: [Hohmann 1925].

Fig. 9.231: commons.wikimedia.org and public domain.

Fig. 9.232: commons.wikimedia.org and public domain [Noordung 1928].

Fig. 9.233: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.234: Todd Rider collection.

Fig. 9.235: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.236: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.237: U.S. government, public domain [Belew 1977].

Fig. 9.238: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.239: U.S. government, commons.wikimedia.org, and public domain.

Fig. 9.240: Todd Rider.

Fig. 9.241: Todd Rider.

Fig. 9.242 Top: Peenemünde Archive, AHT0205. Bottom: U.S. government and public domain.

Fig. 9.243: Todd Rider collection.

Fig. 10.1: commons.wikimedia.org and public domain.

Fig. 10.2: commons.wikimedia.org and public domain.

Fig. 10.3: commons.wikimedia.org and public domain.

Fig. 10.4: commons.wikimedia.org and public domain.

Fig. 10.5: Todd Rider.

Fig. 10.6: Todd Rider.

Fig. 10.7: Todd Rider [Bundesarchiv Militärarchiv Freiburg N822/6].

Fig. 10.8: commons.wikimedia.org and public domain.

Fig. 10.9: commons.wikimedia.org and public domain.

Fig. 10.10: commons.wikimedia.org and public domain.

Fig. 10.11: commons.wikimedia.org and public domain.

Fig. 10.12: commons.wikimedia.org, public domain, and Günter Nagel.

Fig. 10.13: Todd Rider.

Fig. 10.14: commons.wikimedia.org and public domain.

Fig. 10.15: Todd Rider.

Fig. 10.16: Todd Rider.

Fig. 11.1: U.S. government, public domain [Gross 2014].

Fig. 11.2: commons.wikimedia.org and public domain.

Fig. 11.3: Todd Rider [AFHRA A2055 Frame 1062].

Fig. 11.4: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

Fig. 11.5: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

Fig. 11.6: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

Fig. 11.7: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

Fig. 11.8: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

Fig. 11.9: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

Fig. 11.10: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

Fig. 11.11: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

Fig. 11.12: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

Fig. 11.13: U.S. government, public domain.

Fig. 11.14: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Fig. 11.15: commons.wikimedia.org, public domain.

Fig. 11.16: public domain.

Fig. 11.17: commons.wikimedia.org, public domain.

Fig. 11.18: David N. R. Bleecker [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3344, Book 5, SC 203875, SC 203876].

Fig. 11.19: David N. R. Bleecker [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3354, Book 15, SC 282453, SC 282456].

Fig. 11.20: Todd Rider, adapted from commons.wikimedia.org.

Fig. 11.21: Todd Rider, adapted from commons.wikimedia.org.

Fig. 11.22: Todd Rider, adapted from commons.wikimedia.org.

Fig. 11.23: Todd Rider, adapted from commons.wikimedia.org.

Fig. 11.24: https://books.google.com/books?id=U9Q9TS-FtSgC

Fig. 11.25: https://books.google.com/books?id=U9Q9TS-FtSgC

Fig. 11.26: https://books.google.com/books?id=U9Q9TS-FtSgC

Fig. 11.27: BIOS 342.

Fig. 11.28: BIOS 342.

Fig. 11.29: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.21 Germ. Res. Gen.].

Fig. 11.30: Todd Rider [NARA RG 40, Entry UD-75, Box 12, Folder Technical Inquiries - H -, Technical Industrial Intelligence Division to R. P. Isaacs, 21 April 1947].

Fig. 11.31: Todd Rider [NARA RG 40, Entry UD-75, Box 12, Folder Technical Inquiries - H -, Technical Industrial Intelligence Division to R. P. Isaacs, 21 April 1947].

Fig. 11.32: *Dayton Daily News*, 8 December 1946, p. 55 and U.S. government, public domain.

Fig. 11.33: Todd Rider.

Fig. 11.34: Todd Rider.

Fig. 11.35: Todd Rider [NARA RG 40, Entry UD-75, Box 62, Report German Documents Conference].

Fig. 11.36: Todd Rider [NARA RG 40, Entry UD-75, Box 62, Report German Documents Conference].

Fig. 11.37: commons.wikimedia.org and public domain.

Fig. 11.38: [Cocroft 2010].

Fig. 11.39: Todd Rider [HEC files at Imperial War Museum, Duxford].

Fig. 11.40: [Cocroft 2010].

Fig. 11.41: Todd Rider [AFHRA A5186 electronic p. 907].

Fig. 11.42: Todd Rider [NARA RG 330, Entry A1-1A, Box 4, Folder 383.7 Policy–1946].

Fig. 11.43: Todd Rider [NARA RG 330, Entry A1-1A, Box 4, Folder 383.7 Policy–1946].

Fig. 11.44: Todd Rider [NARA RG 330, Entry A1-1A, Box 4, Folder 383.7 Policy–1946].

Fig. 11.45: Todd Rider [NARA RG 330, Entry A1-1A, Box 4, Folder 383.7 Policy–1946].

Fig. 11.46: Todd Rider [NARA RG 330, Entry A1-1A, Box 4, Folder 383.7 Policy–1946].

Fig. 11.47: Todd Rider [NARA RG 330, Entry A1-1A, Box 4, Folder 383.7 Policy–1946].

Fig. 11.48: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

Fig. 11.49: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

Fig. 11.50: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Inter-Office Memoranda: To and From Robert Reiss].

Fig. 11.51: Todd Rider [AFHRA A2056 electronic p. 405].

Fig. 11.52: Todd Rider [AFHRA A2056 electronic p. 406].

Fig. 11.53: Todd Rider [AFHRA A2055 Frame 1265].

Fig. 11.54: Todd Rider [AFHRA A2055 Frame 1177].

Fig. 11.55: Todd Rider [AFHRA A2055 Frame 1178].

Fig. 11.56: Todd Rider [AFHRA A2055 electronic p. 747].

Fig. 11.57: Todd Rider [AFHRA K2838 (15390) electronic p. 887].

Fig. 11.58: Todd Rider [AFHRA K2838 (15390) electronic p. 894].

Fig. 11.59: commons.wikimedia.org and public domain.

Fig. 11.60: U.S. government, public domain [Steelman 1947].

Fig. 11.61: https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd

Fig. 11.62: https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd
https://saylordotorg.github.io/text_introduction-to-economic-analysis/s05-05-government.html#mcafee-ch04_s05_f10

Fig. 11.63: https://www.nsf.gov/statistics/2018/nsb20181/figures

Fig. 11.64: https://www.nsf.gov/statistics/2018/nsb20181/figures

Fig. 11.65: commons.wikimedia.org and public domain.

Fig. 11.66: commons.wikimedia.org and public domain.

Fig. 11.67: commons.wikimedia.org and public domain.

Fig. 11.68: commons.wikimedia.org and public domain.

Fig. 11.69: commons.wikimedia.org and public domain.

Fig. 11.70: commons.wikimedia.org and public domain.

Fig. 11.71: commons.wikimedia.org and public domain.

Fig. 11.72: Todd Rider.

Fig. 11.73: commons.wikimedia.org and public domain.

Fig. 11.74: Todd Rider.

Fig. 11.75: commons.wikimedia.org and public domain.

Fig. 11.76: Todd Rider [redrawn based on Carr 2015].

Fig. 12.1: Todd Rider.

Fig. A.1: *Bulletin de la Société Chimique de France* 9:728–730 (1893).

Fig. A.2: *Bulletin de la Société Chimique de France* 9:728–730 (1893).

Fig. A.3: *Bulletin de la Société Chimique de France* 9:728–730 (1893).

Fig. A.4: European Patent Office, Swiss patent CH 90,955, public domain.

Fig. A.5: [Pregl 1917].

Fig. A.6: [Pregl 1917].

Fig. A.7: [Pregl 1917].

Fig. A.8: [Pregl 1917].

Fig. A.9: [Pregl 1917].

Fig. A.10: Todd Rider [BIOS 236].

Fig. A.11: Todd Rider [BIOS 236].

Fig. A.12: Todd Rider [BIOS 236].

Fig. A.13: Todd Rider [BIOS 236].

Fig. A.14: Todd Rider [BIOS 236].

Fig. A.15: Todd Rider [BIOS 236].

Fig. A.16: Todd Rider [BIOS 236].

Fig. A.17: Todd Rider [BIOS 236].

Fig. A.18: Todd Rider [BIOS 236].

Fig. A.19: Todd Rider [BIOS 236].

Fig. A.20: Todd Rider [BIOS 236].

Fig. A.21: Todd Rider [BIOS 266 Appendix].

Fig. A.22: Todd Rider [BIOS 266 Appendix].

Fig. A.23: Todd Rider [BIOS 266 Appendix].

Fig. A.24: Todd Rider [BIOS 354].

Fig. A.25: Todd Rider [BIOS 354].

Fig. A.26: Todd Rider [BIOS 354].

Fig. A.27: Todd Rider [BIOS 354].

Fig. A.28: Todd Rider [BIOS 354].

Fig. A.29: Todd Rider [BIOS 354].

Fig. A.30: Todd Rider [BIOS 354].

Fig. A.31: Todd Rider [BIOS 354].

Fig. A.32: Todd Rider.

Fig. A.33: Todd Rider [BIOS 449].

Fig. A.34: Todd Rider [BIOS 449].

Fig. A.35: Todd Rider [BIOS 449].

Fig. A.36: Todd Rider [BIOS 449].

Fig. A.37: Todd Rider [BIOS 691].

Fig. A.38: Todd Rider [BIOS 691].

Fig. A.39: Todd Rider [BIOS 691].

Fig. A.40: Todd Rider [BIOS 766].

Fig. A.41: Todd Rider [BIOS 770].

Fig. A.42: Todd Rider [BIOS 770].

Fig. A.43: European Patent Office, German patent DE 894,956, public domain.

Fig. A.44: European Patent Office, German patent DE 877,100, public domain.

Fig. A.45: European Patent Office, German patent DE 877,100, public domain.

Fig. A.46: European Patent Office, German patent DE 885,954, public domain.

Fig. A.47: Todd Rider [BIOS 784].

Fig. A.48: Todd Rider [BIOS 784].

Fig. A.49: Todd Rider [BIOS 784].

Fig. A.50: Todd Rider [BIOS 1253].

Fig. A.51: European Patent Office, German patent DE 740,593, public domain.

Fig. A.52: European Patent Office, German patent DE 740,593, public domain.

Fig. A.53: European Patent Office, German patent DE 740,593, public domain.

Fig. A.54: European Patent Office, German patent DE 740,593, public domain.

Fig. A.55: European Patent Office, German patent DE 731,494, public domain.

Fig. A.56: European Patent Office, German patent DE 731,494, public domain.

Fig. A.57: European Patent Office, German patent DE 731,494, public domain.

Fig. A.58: European Patent Office, German patent DE 731,494, public domain.

Fig. A.59: Todd Rider [BIOS 1481].

Fig. A.60: Todd Rider [BIOS 1481].

Fig. A.61: Todd Rider [BIOS 1481].

Fig. A.62: https://mediatum.ub.tum.de/1554376

Fig. A.63: Todd Rider [BIOS 1487].

Fig. A.64: Todd Rider [BIOS 1513].

Fig. A.65: Todd Rider [BIOS 1776].

Fig. A.66: Todd Rider [BIOS 1776].

Fig. A.67: Todd Rider [BIOS 1776].

Fig. A.68: Todd Rider [CIOS ER 1].

Fig. A.69: Todd Rider [CIOS ER 10].

Fig. A.70: Todd Rider [CIOS ER 10].

Fig. A.71: Todd Rider [CIOS ER 10].

Fig. A.72: Todd Rider [CIOS ER 10].

Fig. A.73: Todd Rider [CIOS ER 10].

Fig. A.74: Stephen Walton [CIOS XXIV-16].

Fig. A.75: Stephen Walton [CIOS XXV-54].

Fig. A.76: Stephen Walton [CIOS XXV-54].

Fig. A.77: Stephen Walton [CIOS XXV-54].

Fig. A.78: Stephen Walton [CIOS XXV-54].

Fig. A.79: Stephen Walton [CIOS XXV-54].

Fig. A.80: Stephen Walton [CIOS XXV-54].

Fig. A.81: Stephen Walton [CIOS XXV-54].

Fig. A.82: Stephen Walton [CIOS XXV-54].

Fig. A.83: Stephen Walton [CIOS XXV-54].

Fig. A.84: Stephen Walton [CIOS XXV-54].

Fig. A.85: Stephen Walton [CIOS XXV-54].

Fig. A.86: Stephen Walton [CIOS XXV-54].

Fig. A.87: Stephen Walton [CIOS XXV-54].

Fig. A.88: Stephen Walton [CIOS XXV-54].

Fig. A.89: Stephen Walton [CIOS XXV-54].

Fig. A.90: Stephen Walton [CIOS XXV-54].

Fig. A.91: Stephen Walton [FIAT 371].

Fig. A.92: Stephen Walton [FIAT 371].

Fig. A.93: Stephen Walton [FIAT 371].

Fig. A.94: Stephen Walton [FIAT 371].

Fig. A.95: Stephen Walton [FIAT 371].

Fig. A.96: Stephen Walton [FIAT 371].

Fig. A.97: Stephen Walton [FIAT 371].

Fig. A.98: Stephen Walton [FIAT 371].

Fig. A.99: European Patent Office, public domain.

Fig. A.100: European Patent Office, public domain.

Fig. A.101: European Patent Office, public domain.

Fig. A.102: European Patent Office, public domain.

Fig. A.103: European Patent Office, public domain.

Fig. A.104: European Patent Office, public domain.

Fig. A.105: Todd Rider [FIAT 871].

Fig. A.106: Todd Rider [FIAT 910].

Fig. A.107: Todd Rider [FIAT 910].

Fig. A.108: Todd Rider [FIAT 910].

Fig. A.109: Stephen Walton [FIAT 964].

Fig. A.110: Stephen Walton [FIAT 964].

Fig. A.111: Stephen Walton [FIAT 964].

Fig. A.112: Stephen Walton [FIAT 964].

Fig. A.113: Stephen Walton [FIAT 964].

Fig. A.114: Stephen Walton [FIAT 964].

Fig. A.115: Stephen Walton [FIAT 964].

Fig. A.116: Stephen Walton [FIAT 996].

Fig. A.117: Stephen Walton [FIAT 996].

Fig. A.118: Stephen Walton [FIAT 996].

Fig. A.119: Stephen Walton [FIAT 996].

Fig. A.120: Stephen Walton [FIAT 996].

Fig. A.121: Stephen Walton [FIAT 996].

Fig. A.122: Stephen Walton [FIAT 996].

Fig. A.123: Stephen Walton [FIAT 996].

Fig. A.124: Stephen Walton [FIAT 996].

Fig. A.125: Stephen Walton [FIAT 1014].

Fig. A.126: Stephen Walton [FIAT 1014].

Fig. A.127: Stephen Walton [FIAT 1059].

Fig. A.128: Stephen Walton [FIAT 1059].

Fig. A.129: Stephen Walton [FIAT 1059].

Fig. A.130: Stephen Walton [FIAT 1059].

Fig. A.131: Stephen Walton [FIAT 1059].

Fig. A.132: Stephen Walton [FIAT 1059 Supplement].

Fig. A.133: Stephen Walton [FIAT 1059 Supplement].

Fig. A.134: Stephen Walton [FIAT 1059 Supplement].

Fig. A.135: Stephen Walton [FIAT 1059 Supplement].

Fig. A.136: Stephen Walton [FIAT 1059 Supplement].

Fig. A.137: Stephen Walton [FIAT 1059 Supplement].

Fig. A.138: U.S. Patent and Trademark Office, U.S. patent 2,480,856, public domain.

Fig. A.139: U.S. Patent and Trademark Office, U.S. patent 2,489,291, public domain.

Fig. A.140: U.S. Patent and Trademark Office, U.S. patent 2,561,370, public domain.

Fig. A.141: U.S. Patent and Trademark Office, U.S. patent 2,490,806, public domain.

Fig. A.142: *Report from Heidelberg: The Story of the Army Air Forces Aero Medical Center in Germany 1945–1947.* 28 February 1947 [https://collections.nlm.nih.gov/ext/dw/14130150R/PDF/14130150R.pdf].

Fig. A.143: *Report from Heidelberg: The Story of the Army Air Forces Aero Medical Center in Germany 1945–1947.* 28 February 1947 [https://collections.nlm.nih.gov/ext/dw/14130150R/PDF/14130150R.pdf].

Fig. A.144: Todd Rider [AFHRA A2055 Frames 1214-1216].

Fig. A.145: Todd Rider [AFHRA A2055 Frame 1283].

Fig. A.146: Todd Rider [AFHRA A2055 Frame 1286].

Fig. A.147: Malcolm C. Grow. Hydraulic Leg. *AAF Review* July 1946, p. 8. In *Report from Heidelberg: The Story of the Army Air Forces Aero Medical Center in Germany 1945–1947.* 28 February 1947 [https://collections.nlm.nih.gov/ext/dw/14130150R/PDF/14130150R.pdf].

Fig. A.148: Ad Hoc Committee on Fluid-Controlled Legs. 1960. *Final Summary Report: Henschke-Mauch "Hydraulik" System, Model B (Swing-Phase Control) for Above-Knee Prostheses.* Washington, D.C.: National Research Council. Bess Furman. 1962. *Progress in Prosthetics.* Washington, D.C.: U.S. Government Printing Office

[www.oandplibrary.org/assets/pdf/ProgressInProsthetics.pdf].

Fig. A.149: U.S. Patent and Trademark Office, U.S. patent 2,590,101, public domain.

Fig. A.150: U.S. Patent and Trademark Office, U.S. patent 2,590,101, public domain.

Fig. A.151: U.S. Patent and Trademark Office, U.S. patent 2,590,101, public domain.

Fig. A.152: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44].

Fig. A.153: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44].

Fig. A.154: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44].

Fig. A.155: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

Fig. A.156: Todd Rider [AFHRA 43811 electronic p. 1075].

Fig. A.157: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

Fig. A.158: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

Fig. A.159: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

Fig. A.160: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

Fig. A.161: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

Fig. A.162: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

Fig. A.163: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

Fig. A.164: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

Fig. A.165: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

Fig. A.166: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].

Fig. A.167: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].

Fig. A.168: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].

Fig. A.169: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].

Fig. A.170: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].

Fig. A.171: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].

Fig. A.172: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].

Fig. A.173: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].

Fig. A.174: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].

Fig. A.175: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].

Fig. A.176: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1944 May-July 15, MC019.09_c46.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c46].

Fig. A.177: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

Fig. A.178: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

Fig. A.179: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

Fig. A.180: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

Fig. A.181: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

Fig. A.182: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

Fig. A.183: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1359 IN TOLEDO].

Fig. A.184: Todd Rider [NARA RG 226, Entry A1-134, Box 216, Folder 1360 OUT TOLEDO].

Fig. A.185: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. A.186: Todd Rider [NARA RG 165, Entry NM84-187, Box 137, Folder BW 55].

Fig. A.187: Todd Rider [NARA RG 165, Entry NM84-187, Box 137, Folder BW 55].

Fig. A.188: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. A.189: Todd Rider [NARA RG 38, Entry P5, Box 8, Folder ALSOS Intelligence Report B-C-H-H/305].

Fig. A.190: Todd Rider [NARA RG 38, Entry P5, Box 8, Folder ALSOS Intelligence Report B-C-H-H/305].

Fig. A.191: Todd Rider [NARA RG 38, Entry P5, Box 8, Folder ALSOS Intelligence Report B-C-H-H/305].

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Fig. A.200: Todd Rider [NARA RG 319, Entry NM3-82A, Box 4, Folder DCL-1].

Fig. A.201: Todd Rider [NARA RG 38, Entry P5, Box 8, Folder ALSOS Intelligence Report B-C-H-H/305].

Fig. A.202: Todd Rider [NARA RG 319, Entry NM3-82A, Box 4, Folder DCL-1].

Fig. A.203: Todd Rider [NARA RG 319, Entry NM3-82A, Box 4, Folder Biological Warfare/BW # 25].

Fig. A.204: Todd Rider [NARA RG 319, Entry NM3-82A, Box 4, Folder Data/DCC-2].

Fig. A.205: Todd Rider.

Fig. A.206: Todd Rider [NARA RG 38, Entry P5, Box 8, Folder ALSOS Intelligence Report B-C-H-H/305].

Fig. A.207: Todd Rider [NARA RG 319, Entry NM3-82A, Box 4, Folder DCL-1].

Fig. A.208: Todd Rider.

Fig. A.209: Todd Rider [NARA RG 319, Entry A1-84E, Box 124].

Fig. A.210: Todd Rider [NARA RG 319, Entry A1-84E, Box 124].

Fig. A.211: European Patent Office, public domain.

Fig. A.212: European Patent Office, public domain.

Fig. A.213: European Patent Office, public domain.

Fig. A.214: European Patent Office, public domain.

Fig. A.215: Todd Rider [BIOS 714].

Fig. A.216: Todd Rider [BIOS 714].

Fig. A.217: Todd Rider [BIOS 714].

Fig. A.218: Todd Rider [BIOS 714].

Fig. A.219: Todd Rider [BIOS 714].

Fig. A.220: Todd Rider [BIOS 714].

Fig. A.221: Todd Rider [BIOS 714].

Fig. A.222: Todd Rider [BIOS 714].

Fig. A.223: Todd Rider [BIOS 714].

Fig. A.224: Todd Rider [BIOS 714].

Fig. A.225: Todd Rider [BIOS 714].

Fig. A.226: Todd Rider [BIOS 714].

Fig. A.227: Todd Rider [BIOS 714].

Fig. A.228: Todd Rider [BIOS 714].

Fig. A.229: Todd Rider [BIOS 714].

Fig. A.230: Todd Rider [BIOS 714].

Fig. A.231: Todd Rider [BIOS 714].

Fig. A.232: Todd Rider [BIOS 714].

Fig. A.233: Todd Rider [BIOS 714].

Fig. A.234: Todd Rider [BIOS 714].

Fig. A.235: Todd Rider [BIOS 714].

Fig. A.236: Todd Rider [BIOS 714].

Fig. A.237: Todd Rider [BIOS 714].

Fig. A.238: Todd Rider [BIOS 714].

Fig. A.239: Manuel Lukas [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44].

Fig. A.240: David N. R. Bleecker [NARA RG 165, Entry NM84-79, Box 1915, PW Intelligence Bulletin 1/47, 13 March 1945].

Fig. A.241: David N. R. Bleecker [NARA RG 165, Entry NM84-79, Box 1915, PW Intelligence Bulletin 1/47, 13 March 1945].

Fig. A.242: David N. R. Bleecker [NARA RG 165, Entry NM84-79, Box 1915, PW Intelligence Bulletin 1/47, 13 March 1945].

Fig. A.243: David N. R. Bleecker [NARA RG 165, Entry NM84-79, Box 1915, PW Intelligence Bulletin 1/47, 13 March 1945].

Fig. A.244: David N. R. Bleecker [NARA RG 165, Entry NM84-79, Box 1915, PW Intelligence Bulletin 1/47, 13 March 1945].

Fig. A.245: David N. R. Bleecker [NARA RG 165, Entry NM84-79, Box 1915, PW Intelligence Bulletin 1/47, 13 March 1945].

Fig. A.246: David N. R. Bleecker [NARA RG 165, Entry NM84-79, Box 1915, PW Intelligence Bulletin 1/47, 13 March 1945].

Fig. A.247: David N. R. Bleecker [NARA RG 165, Entry NM84-79, Box 1915, PW Intelligence Bulletin 1/47, 13 March 1945].

Fig. A.248: George Cully [PW Intelligence Bulletin 2/45, 14 March 1945, AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533].

Fig. A.249: George Cully [PW Intelligence Bulletin 2/45, 14 March 1945, AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533].

Fig. A.250: George Cully [PW Intelligence Bulletin 2/45, 14 March 1945, AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533].

Fig. A.251: George Cully [PW Intelligence Bulletin 2/45, 14 March 1945, AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533].

Fig. A.252: George Cully [PW Intelligence Bulletin 2/45, 14 March 1945, AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533].

Fig. A.253: George Cully [PW Intelligence Bulletin 2/45, 14 March 1945, AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533].

Fig. A.254: George Cully [PW Intelligence Bulletin 2/45, 14 March 1945, AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533].

Fig. A.255: George Cully [PW Intelligence Bulletin 2/45, 14 March 1945, AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533].

Fig. A.256: Gellermann 1986, p. 245.

Fig. A.257: Top: commons.wikimedia.org.
Bottom: *December 1943: Hell Over Bari* [https://www.youtube.com/watch?v=XGJQpmFJYyI]

Fig. A.258: NARA, https://www.nhd.org/sites/default/files/The%20Bari%20Incident%20-%20Lesson%20Plan.pdf

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Fig. B.2: U.S. Patent and Trademark Office, U.S. patent 1,745,175, public domain.

Fig. B.3: U.S. Patent and Trademark Office, U.S. patent 1,745,175, public domain.

Fig. B.4: U.S. Patent and Trademark Office, U.S. patent 1,745,175, public domain.

Fig. B.5: U.S. Patent and Trademark Office, U.S. patent 1,745,175, public domain.

Fig. B.6: U.S. Patent and Trademark Office, U.S. patent 1,900,018, public domain.

Fig. B.7: U.S. Patent and Trademark Office, U.S. patent 1,900,018, public domain.

Fig. B.8: U.S. Patent and Trademark Office, U.S. patent 1,900,018, public domain.

Fig. B.9: U.S. Patent and Trademark Office, U.S. patent 1,900,018, public domain.

Fig. B.10: U.S. Patent and Trademark Office, U.S. patent 1,900,018, public domain.

Fig. B.11: U.S. Patent and Trademark Office, U.S. patent 1,900,018, public domain.

Fig. B.12: U.S. Patent and Trademark Office, U.S. patent 1,900,018, public domain.

Fig. B.13: U.S. Patent and Trademark Office, U.S. patent 1,900,018, public domain.

Fig. B.14: U.S. Patent and Trademark Office, U.S. patent 1,900,018, public domain.

Fig. B.15: U.S. Patent and Trademark Office, U.S. patent 1,900,018, public domain.

Fig. B.16: U.S. Patent and Trademark Office, U.S. patent 1,877,140, public domain.

Fig. B.17: U.S. Patent and Trademark Office, U.S. patent 1,877,140, public domain.

Fig. B.18: U.S. Patent and Trademark Office, U.S. patent 1,877,140, public domain.

Fig. B.19: U.S. Patent and Trademark Office, U.S. patent 1,877,140, public domain.

Fig. B.20: U.S. Patent and Trademark Office, U.S. patent 1,877,140, public domain.

Fig. B.21: U.S. Patent and Trademark Office, U.S. patent 1,877,140, public domain.

Fig. B.22: U.S. Patent and Trademark Office, U.S. patent 1,877,140, public domain.

Fig. B.23: European Patent Office, Swiss patent CH184,396, public domain.

Fig. B.24: European Patent Office, Swiss patent CH184,396, public domain.

Fig. B.25: European Patent Office, Swiss patent CH184,396, public domain.

Fig. B.26: European Patent Office, U.K. patent GB439,457, public domain.

Fig. B.27: European Patent Office, U.K. patent GB439,457, public domain.

Fig. B.28: European Patent Office, U.K. patent GB439,457, public domain.

Fig. B.29: European Patent Office, U.K. patent GB439,457, public domain.

Fig. B.30: U.S. Patent and Trademark Office, U.S. patent 2,173,904, public domain.

Fig. B.31: U.S. Patent and Trademark Office, U.S. patent 2,173,904, public domain.

Fig. B.32: U.S. Patent and Trademark Office, U.S. patent 2,173,904, public domain.

Fig. B.33: *Zeitschrift für Physik* (1938) 111:399–408.

Fig. B.34: *Zeitschrift für Physik* (1938) 111:399–408.

Fig. B.35: *Die Naturwissenschaften* (1939) 27:489–492.

Fig. B.36: European Patent Office, German patent 971,775, public domain.

Fig. B.37: European Patent Office, German patent 971,775, public domain.

Fig. B.38: European Patent Office, German patent 971,775, public domain.

Fig. B.39: European Patent Office, German patent 971,775, public domain.

Fig. B.40: Günter Nagel.

Fig. B.41: *Zeitschrift für Physik* (1942) 118:539–592.

Fig. B.42: European Patent Office, German patent 841,174, public domain.

Fig. B.43: European Patent Office, German patent 841,174, public domain.

Fig. B.44: European Patent Office, German patent 841,174, public domain.

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Fig. B.47: European Patent Office, German patent 841,174, public domain.

Fig. B.48: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Selenium Rectifier Machinery].

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Fig. B.54: European Patent Office, German patent 980,084, public domain.

Fig. B.55: European Patent Office, German patent 980,084, public domain.

Fig. B.56: U.S. Patent and Trademark Office, U.S. patent 2,673,948, public domain.

Fig. B.57: U.S. Patent and Trademark Office, U.S. patent 2,673,948, public domain.

Fig. B.58: U.S. Patent and Trademark Office, U.S. patent 2,673,948, public domain.

Fig. B.59: U.S. Patent and Trademark Office, U.S. patent 2,673,948, public domain.

Fig. B.60: Todd Rider [CIOS XXXI-2].

Fig. B.61: Todd Rider [CIOS XXXI-2].

Fig. B.62: Todd Rider [CIOS XXXI-2].

Fig. B.63: Todd Rider [BIOS 1658].

Fig. B.64: Todd Rider [BIOS 1658].

Fig. B.65: Todd Rider [BIOS 1658].

Fig. B.66: Todd Rider [BIOS 1658].

Fig. B.67: Todd Rider [BIOS 1658].

Fig. B.68: European Patent Office, German patent 721,677, public domain.

Fig. B.69: European Patent Office, German patent 721,677, public domain.

Fig. B.70: European Patent Office, German patent 721,677, public domain.

Fig. B.71: European Patent Office, German patent 721,677, public domain.

Fig. B.72: U.S. Patent and Trademark Office, U.S. patent 2,648,805, public domain.

Fig. B.73: U.S. Patent and Trademark Office, U.S. patent 2,648,805, public domain.

Fig. B.74: U.S. Patent and Trademark Office, U.S. patent 2,648,805, public domain.

Fig. B.75: U.S. Patent and Trademark Office, U.S. patent 2,648,805, public domain.

Fig. B.76: U.S. Patent and Trademark Office, U.S. patent 2,648,805, public domain.

Fig. B.77: U.S. Patent and Trademark Office, U.S. patent 2,648,805, public domain.

Fig. B.78: U.S. Patent and Trademark Office, U.S. patent 2,648,805, public domain.

Fig. B.79: U.S. Patent and Trademark Office, U.S. patent 2,648,805, public domain.

Fig. B.80: U.S. Patent and Trademark Office, U.S. patent 2,648,805, public domain.

Fig. B.81: U.S. Patent and Trademark Office, U.S. patent 2,648,805, public domain.

Fig. B.82: Todd Rider [CIOS ER 350].

Fig. B.83: Todd Rider [CIOS ER 350].

Fig. B.84: U.S. Patent and Trademark Office, U.S. patent 2,701,216, public domain.

Fig. B.85: U.S. Patent and Trademark Office, U.S. patent 2,701,216, public domain.

Fig. B.86: U.S. Patent and Trademark Office, U.S. patent 2,701,216, public domain.

Fig. B.87: U.S. Patent and Trademark Office, U.S. patent 2,701,216, public domain.

Fig. B.88: U.S. Patent and Trademark Office, U.S. patent 2,876,400, public domain.

Fig. B.89: U.S. Patent and Trademark Office, U.S. patent 2,876,400, public domain.

Fig. B.90: U.S. Patent and Trademark Office, U.S. patent 2,876,400, public domain.

Fig. B.91: U.S. Patent and Trademark Office, U.S. patent 2,773,224, public domain.

Fig. B.92: U.S. Patent and Trademark Office, U.S. patent 2,773,224, public domain.

Fig. B.93: U.S. Patent and Trademark Office, U.S. patent 2,773,224, public domain.

Fig. B.94: European Patent Office, U.K. patent 15,077, public domain.

Fig. B.95: European Patent Office, U.K. patent 15,077, public domain.

Fig. B.96: European Patent Office, U.K. patent 15,077, public domain.

Fig. B.97: European Patent Office, U.K. patent 15,077, public domain.

Fig. B.98: European Patent Office, U.K. patent 15,077, public domain.

Fig. B.99: European Patent Office, U.K. patent 15,077, public domain.

Fig. B.100: European Patent Office, U.K. patent 4681, public domain.

Fig. B.101: European Patent Office, U.K. patent 4681, public domain.

Fig. B.102: European Patent Office, U.K. patent 4681, public domain.

Fig. B.103: European Patent Office, U.K. patent 4681, public domain.

Fig. B.104: European Patent Office, U.K. patent 4681, public domain.

Fig. B.105: European Patent Office, U.K. patent 4681, public domain.

Fig. B.106: https://www.fed.de/fileadmin/user_upload/Roentgentest__eine_zerstoerungsfreie_Analysemethode.pdf

Fig. B.107: Eisler 1989 and public domain.

Fig. B.108: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.109: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.110: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.111: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.112: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.113: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.114: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.115: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.116: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.117: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.118: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.119: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.120: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.121: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.122: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.123: U.S. Patent and Trademark Office, U.S. patent 2,441,960, public domain.

Fig. B.124: Todd Rider [NARA RG 40, Entry UD-75, Box 25, Folder Odarenko, Dr. T. M., undated press release (probably late 1946)].

Fig. B.125: Todd Rider [NARA RG 40, Entry UD-75, Box 25, Folder Odarenko, Dr. T. M., undated press release (probably late 1946)].

Fig. B.126: Todd Rider [NARA RG 40, Entry UD-75, Box 25, Folder Odarenko, Dr. T. M., undated press release (probably late 1946)].

Fig. B.127: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.128: Strauss 1998.

Fig. B.129: U.S. Patent and Trademark Office, U.S. patent 3,056,370, public domain.

Fig. B.130: U.S. Patent and Trademark Office, U.S. patent 3,056,370, public domain.

Fig. B.131: U.S. Patent and Trademark Office, U.S. patent 3,056,370, public domain.

Fig. B.132: U.S. Patent and Trademark Office, U.S. patent 3,056,370, public domain.

Fig. B.133: European Patent Office, U.K. patent 715,055, public domain.

Fig. B.134: European Patent Office, U.K. patent 715,055, public domain.

Fig. B.135: Todd Rider [Peenemünde Archive, Folder ARK 41].

Fig. B.136: Courtesy of Deutsches Museum Archive, photo 10890.

Fig. B.137: European Patent Office, German patent DE 833,366, public domain.

Fig. B.138: European Patent Office, German patent DE 833,366, public domain.

Fig. B.139: Todd Rider [NARA RG 40, Entry UD-75, Box 28, Folder Edwin Y. Webb, Jr.].

Fig. B.140: U.S. Patent and Trademark Office, U.S. patent 2,993,998, public domain.

Fig. B.141: U.S. Patent and Trademark Office, U.S. patent 2,993,998, public domain.

Fig. B.142: U.S. Patent and Trademark Office, U.S. patent 2,993,998, public domain.

Fig. B.143: U.S. Patent and Trademark Office, U.S. patent 2,993,998, public domain.

Fig. B.144: U.S. Patent and Trademark Office, U.S. patent 2,993,998, public domain.

Fig. B.145: U.S. Patent and Trademark Office, U.S. patent 2,779,877, public domain.

Fig. B.146: U.S. Patent and Trademark Office, U.S. patent 2,779,877, public domain.

Fig. B.147: U.S. Patent and Trademark Office, U.S. patent 2,779,877, public domain.

Fig. B.148: U.S. Patent and Trademark Office, U.S. patent 2,779,877, public domain.

Fig. B.149: U.S. Patent and Trademark Office, U.S. patent 3,029,366, public domain.

Fig. B.150: U.S. Patent and Trademark Office, U.S. patent 3,029,366, public domain.

Fig. B.151: U.S. Patent and Trademark Office, U.S. patent 3,029,366, public domain.

Fig. B.152: U.S. Patent and Trademark Office, U.S. patent 3,029,366, public domain.

Fig. B.153: U.S. Patent and Trademark Office, U.S. patent 3,029,366, public domain.

Fig. B.154: European Patent Office, German patent 1,414,089, public domain.

Fig. B.155: European Patent Office, German patent 1,414,089, public domain.

Fig. B.156: European Patent Office, German patent 1,414,089, public domain.

Fig. B.157: U.S. Patent and Trademark Office, U.S. patent 3,467,896, public domain.

Fig. B.158: U.S. Patent and Trademark Office, U.S. patent 3,467,896, public domain.

Fig. B.159: U.S. Patent and Trademark Office, U.S. patent 3,467,896, public domain.

Fig. B.160: U.S. Patent and Trademark Office, U.S. patent 3,467,896, public domain.

Fig. B.161: U.S. Patent and Trademark Office, U.S. patent 3,467,896, public domain.

Fig. B.162: U.S. Patent and Trademark Office, U.S. patent 3,467,896, public domain.

Fig. B.163: U.S. Patent and Trademark Office, U.S. patent 3,467,896, public domain.

Fig. B.164: U.S. Patent and Trademark Office, U.S. patent 3,467,896, public domain.

Fig. B.165: U.S. Patent and Trademark Office, U.S. patent 3,467,896, public domain.

Fig. B.166: U.S. Patent and Trademark Office, U.S. patent 3,467,896, public domain.

Fig. B.167: U.S. Patent and Trademark Office, U.S. patent 3,025,589, public domain.

Fig. B.168: U.S. Patent and Trademark Office, U.S. patent 3,025,589, public domain.

Fig. B.169: U.S. Patent and Trademark Office, U.S. patent 3,025,589, public domain.

Fig. B.170: U.S. Patent and Trademark Office, U.S. patent 3,025,589, public domain.

Fig. B.171: U.S. Patent and Trademark Office, U.S. patent 3,025,589, public domain.

Fig. B.172: U.S. Patent and Trademark Office, U.S. patent 3,025,589, public domain.

Fig. B.173: U.S. Patent and Trademark Office, U.S. patent 3,064,167, public domain.

Fig. B.174: U.S. Patent and Trademark Office, U.S. patent 3,064,167, public domain.

Fig. B.175: U.S. Patent and Trademark Office, U.S. patent 3,064,167, public domain.

Fig. B.176: U.S. Patent and Trademark Office, U.S. patent 3,064,167, public domain.

Fig. B.177: U.S. Patent and Trademark Office, U.S. patent 3,064,167, public domain.

Fig. B.178: U.S. Patent and Trademark Office, U.S. patent 3,108,914, public domain.

Fig. B.179: U.S. Patent and Trademark Office, U.S. patent 3,108,914, public domain.

Fig. B.180: U.S. Patent and Trademark Office, U.S. patent 3,108,914, public domain.

Fig. B.181: U.S. Patent and Trademark Office, U.S. patent 3,108,914, public domain.

Fig. B.182: U.S. Patent and Trademark Office, U.S. patent 3,108,914, public domain.

Fig. B.183: U.S. Patent and Trademark Office, U.S. patent 3,411,199, public domain.

Fig. B.184: U.S. Patent and Trademark Office, U.S. patent 3,411,199, public domain.

Fig. B.185: U.S. Patent and Trademark Office, U.S. patent 3,411,199, public domain.

Fig. B.186: U.S. Patent and Trademark Office, U.S. patent 3,411,199, public domain.

Fig. B.187: U.S. Patent and Trademark Office, U.S. patent 3,411,199, public domain.

Fig. B.188: U.S. Patent and Trademark Office, U.S. patent 3,411,199, public domain.

Fig. B.189: U.S. Patent and Trademark Office, U.S. patent 3,411,199, public domain.

Fig. B.190: U.S. Patent and Trademark Office, U.S. patent 3,411,199, public domain.

Fig. B.191: U.S. Patent and Trademark Office, U.S. patent 3,411,199, public domain.

Fig. B.192: U.S. Patent and Trademark Office, U.S. patent 3,556,966, public domain.

Fig. B.193: U.S. Patent and Trademark Office, U.S. patent 3,556,966, public domain.

Fig. B.194: U.S. Patent and Trademark Office, U.S. patent 3,556,966, public domain.

Fig. B.195: U.S. Patent and Trademark Office, U.S. patent 3,556,966, public domain.

Fig. B.196: U.S. Patent and Trademark Office, U.S. patent 3,556,966, public domain.

Fig. B.197: U.S. Patent and Trademark Office, U.S. patent 3,556,966, public domain.

Fig. B.198: U.S. Patent and Trademark Office, U.S. patent 3,641,316, public domain.

Fig. B.199: U.S. Patent and Trademark Office, U.S. patent 3,641,316, public domain.

Fig. B.200: U.S. Patent and Trademark Office, U.S. patent 3,641,316, public domain.

Fig. B.201: U.S. Patent and Trademark Office, U.S. patent 3,641,316, public domain.

Fig. B.202: U.S. Patent and Trademark Office, U.S. patent 3,641,316, public domain.

Fig. B.203: U.S. Patent and Trademark Office, U.S. patent 3,641,316, public domain.

Fig. B.204: U.S. Patent and Trademark Office, U.S. patent 3,641,316, public domain.

Fig. B.205: U.S. Patent and Trademark Office, U.S. patent 3,641,316, public domain.

Fig. B.206: U.S. Patent and Trademark Office, U.S. patent 3,641,316, public domain.

Fig. B.207: U.S. Patent and Trademark Office, U.S. patent 3,641,316, public domain.

Fig. B.208: U.S. Patent and Trademark Office, U.S. patent 3,641,316, public domain.

Fig. B.209: *Zeitschrift für Physik* (1923) 18:1:199–206.

Fig. B.210: U.S. Patent and Trademark Office, U.S. patent 2,254,957, public domain.

Fig. B.211: U.S. Patent and Trademark Office, U.S. patent 2,254,957, public domain.

Fig. B.212: U.S. Patent and Trademark Office, U.S. patent 2,254,957, public domain.

Fig. B.213: U.S. Patent and Trademark Office, U.S. patent 2,254,957, public domain.

Fig. B.214: U.S. Patent and Trademark Office, U.S. patent 2,254,957, public domain.

Fig. B.215: U.S. Patent and Trademark Office, U.S. patent 2,776,367, public domain.

Fig. B.216: U.S. Patent and Trademark Office, U.S. patent 2,776,367, public domain.

Fig. B.217: U.S. Patent and Trademark Office, U.S. patent 2,776,367, public domain.

Fig. B.218: U.S. Patent and Trademark Office, U.S. patent 2,776,367, public domain.

Fig. B.219: U.S. Patent and Trademark Office, U.S. patent 2,776,367, public domain.

Fig. B.220: U.S. Patent and Trademark Office, U.S. patent 2,776,367, public domain.

Fig. B.221: U.S. Patent and Trademark Office, U.S. patent 2,776,367, public domain.

Fig. B.222: U.S. Patent and Trademark Office, U.S. patent 2,776,367, public domain.

Fig. B.223: U.S. Patent and Trademark Office, U.S. patent 2,894,145, public domain.

Fig. B.224: U.S. Patent and Trademark Office, U.S. patent 2,894,145, public domain.

Fig. B.225: U.S. Patent and Trademark Office, U.S. patent 2,894,145, public domain.

Fig. B.226: U.S. Patent and Trademark Office, U.S. patent 2,894,145, public domain.

Fig. B.227: U.S. Patent and Trademark Office, U.S. patent 2,894,145, public domain.

Fig. B.228: U.S. Patent and Trademark Office, U.S. patent 2,894,145, public domain.

Fig. B.229: U.S. Patent and Trademark Office, U.S. patent 2,894,145, public domain.

Fig. B.230: U.S. Patent and Trademark Office, U.S. patent 2,894,145, public domain.

Fig. B.231: *IEEE Journal of Quantum Electronics* (1987) 23:6:659–673.

Fig. B.232: U.S. Patent and Trademark Office, U.S. patent 3,121,203, public domain.

Fig. B.233: U.S. Patent and Trademark Office, U.S. patent 3,121,203, public domain.

Fig. B.234: U.S. Patent and Trademark Office, U.S. patent 3,121,203, public domain.

Fig. B.235: U.S. Patent and Trademark Office, U.S. patent 3,121,203, public domain.

Fig. B.236: U.S. Patent and Trademark Office, U.S. patent 3,121,203, public domain.

Fig. B.237: U.S. Patent and Trademark Office, U.S. patent 3,309,553, public domain.

Fig. B.238: U.S. Patent and Trademark Office, U.S. patent 3,309,553, public domain.

Fig. B.239: U.S. Patent and Trademark Office, U.S. patent 3,309,553, public domain.

Fig. B.240: U.S. Patent and Trademark Office, U.S. patent 3,309,553, public domain.

Fig. B.241: U.S. Patent and Trademark Office, U.S. patent 3,309,553, public domain.

Fig. B.242: U.S. Patent and Trademark Office, U.S. patent 3,309,553, public domain.

Fig. B.243: Todd Rider [NARA RG 40, Entry UD-75, Box 23, Folder Communications Subcommittee Agenda].

Fig. B.244: Todd Rider [NARA RG 40, Entry UD-75, Box 23, Folder Communications Subcommittee Agenda].

Fig. B.245: Todd Rider [NARA RG 40, Entry UD-75, Box 23, Folder Communications Subcommittee Agenda].

Fig. B.246: Todd Rider [NARA RG 40, Entry UD-75, Box 23, Folder Advisory Panel I Agenda].

Fig. B.247: Todd Rider [NARA RG 40, Entry UD-75, Box 23, Folder Advisory Panel I Agenda].

Fig. B.248: Todd Rider [NARA RG 40, Entry UD-75, Box 23, Folder Advisory Panel II Agenda].

Fig. B.249: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. B.250: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. B.251: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. B.252: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. B.253: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. B.254: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. B.255: Norberto Lahuerta [NARA RG 407, Entry NM3-427, Box 14465, Folder G-2 Journal—102nd Inf Div Jun–Jul 45].

Fig. B.256: Norberto Lahuerta [NARA RG 238, Entry NM70-160, Box 30, Folder FIAT—Misc.—Reports—No. 1–10].

Fig. B.257: Norberto Lahuerta [NARA RG 238, Entry NM70-160, Box 30, Folder FIAT—Misc.—Reports—No. 1–10].

Fig. B.258: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Evacuation of German Equipment].

Fig. B.259: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Evacuation of German Equipment].

Fig. B.260: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Evacuation of German Equipment].

Fig. B.261: [NYT 1946-07-06].

Fig. B.262: [Schnitger and Weber 1949].

Fig. B.263: Norberto Lahuerta [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Vol. 1, Fldr. 3 of 3].

Fig. B.264: Norberto Lahuerta [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Vol. 1, Fldr. 3 of 3].

Fig. B.265: Norberto Lahuerta [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Vol. 1, Fldr. 2 of 3].

Fig. B.266: Norberto Lahuerta [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Vol. 1, Fldr. 2 of 3].

Fig. B.267: Norberto Lahuerta [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Vol. 1, Fldr. 2 of 3].

Fig. B.268: Norberto Lahuerta [https://www.cia.gov/readingroom/document/cia-rdp82-00457r001900550002-3].

Fig. B.269: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.270: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.271: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.272: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.273: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.274: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.275: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

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Fig. B.278: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

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Fig. B.280: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.281: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.282: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.283: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.284: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.285: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Evacuation of German Equipment].

Fig. B.286: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.287: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.288: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.289: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.290: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

Fig. B.291: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Record of Captured Elec. Equipment].

Fig. B.292: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Record of Captured Elec. Equipment].

Fig. B.293: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Record of Captured Elec. Equipment].

Fig. B.294: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.295: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder Administration Personnel TIID].

Fig. B.296: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder Administration Personnel TIID].

Fig. B.297: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder TIID Discards].

Fig. B.298: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder Webb].

Fig. B.299: FIAT 54.

Fig. B.300: FIAT 54.

Fig. B.301: FIAT 54.

Fig. B.302: BIOS 725.

Fig. B.303: BIOS 725.

Fig. B.304: BIOS 725.

Fig. B.305: BIOS 725.

Fig. B.306: BIOS 725.

Fig. B.307: BIOS 725.

Fig. B.308: BIOS 725.

Fig. B.309: BIOS 725.

Fig. B.310: BIOS 1751.

Fig. B.311: BIOS 1751.

Fig. B.312: BIOS 1751.

Fig. B.313: BIOS 1751.

Fig. B.314: BIOS 1751.

Fig. B.315: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.316: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.317: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder Replies to Letters of April 29, 1947].

Fig. B.318: Todd Rider [NARA RG 40, Entry UD-75, Box 24, Folder Bell System].

Fig. B.319: Todd Rider [NARA RG 40, Entry UD-75, Box 58, Folder Webb].

Fig. C.1: Todd Rider.

Fig. C.2: Todd Rider.

Fig. C.3: *Archiv für Elektrotechnik* (1928) 21:4:387–406.

Fig. C.4: U.S. Patent and Trademark Office, U.S. patent 2,572,551, public domain.

Fig. C.5: U.S. Patent and Trademark Office, U.S. patent 2,572,551, public domain.

Fig. C.6: U.S. Patent and Trademark Office, U.S. patent 2,572,551, public domain.

Fig. C.7: U.S. Patent and Trademark Office, U.S. patent 2,572,551, public domain.

Fig. C.8: U.S. Patent and Trademark Office, U.S. patent 2,698,384, public domain.

Fig. C.9: U.S. Patent and Trademark Office, U.S. patent 2,698,384, public domain.

Fig. C.10: U.S. Patent and Trademark Office, U.S. patent 2,698,384, public domain.

Fig. C.11: U.S. Patent and Trademark Office, U.S. patent 2,510,448, public domain.

Fig. C.12: U.S. Patent and Trademark Office, U.S. patent 2,631,234, public domain.

Fig. C.13: U.S. Patent and Trademark Office, U.S. patent 2,550,212, public domain.

Fig. C.14: European Patent Office, German patent DE 698,867, public domain.

Fig. C.15: European Patent Office, German patent DE 698,867, public domain.

Fig. C.16: European Patent Office, German patent DE 698,867, public domain.

Fig. C.17: European Patent Office, German patent DE 698,867, public domain.

Fig. C.18: European Patent Office, German patent DE 698,867, public domain.

Fig. C.19: European Patent Office, German patent DE 698,867, public domain.

Fig. C.20: European Patent Office, German patent DE 698,867, public domain.

Fig. C.21: European Patent Office, German patent DE 698,867, public domain.

Fig. C.22: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)].

Fig. C.23: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)].

Fig. C.24: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)].

Fig. C.25: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)].

Fig. C.26: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)].

Fig. C.27: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)].

Fig. C.28: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)].

Fig. C.29: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)].

Fig. C.30: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)].

Fig. C.31: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)].

Fig. C.32: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)].

Fig. C.33: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (July–October 1944)].

Fig. C.34: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. C.35: David N. R. Bleecker [NARA RG 165, Entry NM84-79, Box 1916, PW Intelligence Bulletin 2/32, 30 January 1945].

Fig. C.36: David N. R. Bleecker [NARA RG 165, Entry NM84-79, Box 1916, PW Intelligence Bulletin 2/32, 30 January 1945].

Fig. C.37: George Cully [AFHRA folder 519.6501-2 1945].

Fig. C.38: George Cully [AFHRA folder 519.6501-2 1945].

Fig. C.39: George Cully [AFHRA folder 519.6501-2 1945].

Fig. C.40: George Cully [AFHRA folder 519.6501-2 1945].

Fig. C.41: George Cully [AFHRA folder 519.6501-2 1945].

Fig. C.42: Manuel Lukas [NARA RG 242, Copies of Research Materials on the Role of the German Air Force in World War II, Microfilm 15, Frames 305–310. https://catalog.archives.gov/id/316278533?objectPage=465].

Fig. C.43: Manuel Lukas [NARA RG 242, Copies of Research Materials on the Role of the German Air Force in World War II, Microfilm 15, Frames 305–310. https://catalog.archives.gov/id/316278533?objectPage=465].

Fig. C.44: Manuel Lukas [NARA RG 242, Copies of Research Materials on the Role of the German Air Force in World War II, Microfilm 15, Frames 305–310. https://catalog.archives.gov/id/316278533?objectPage=465].

Fig. C.45: Manuel Lukas [NARA RG 242, Copies of Research Materials on the Role of the German Air Force in World War II, Microfilm 15, Frames 305–310. https://catalog.archives.gov/id/316278533?objectPage=465].

Fig. C.46: Manuel Lukas [NARA RG 242, Copies of Research Materials on the Role of the German Air Force in World War II, Microfilm 15, Frames 305–310. https://catalog.archives.gov/id/316278533?objectPage=465].

Fig. C.47: Manuel Lukas [NARA RG 242, Copies of Research Materials on the Role of the German Air Force in World War II, Microfilm 15, Frames 305–310. https://catalog.archives.gov/id/316278533?objectPage=465].

Fig. C.48: Todd Rider [NARA RG 319 Entry NM3-82A, Box 6, Folder ALSOS G-20].

Fig. C.49: Todd Rider [NARA RG 319 Entry NM3-82A, Box 6, Folder ALSOS G-20].

Fig. C.50: Todd Rider [NARA RG 319 Entry NM3-82A, Box 6, Folder ALSOS G-20].

Fig. C.51: Todd Rider [NARA RG 319 Entry NM3-82A, Box 6, Folder ALSOS G-20].

Fig. C.52: Todd Rider [NARA RG 319 Entry NM3-82A, Box 6, Folder ALSOS G-20].

Fig. C.53: Todd Rider [BIOS 1730].

Fig. C.54: Todd Rider [BIOS 1730].

Fig. C.55: Todd Rider [BIOS 1730].

Fig. C.56: U.S. government, commons.wikimedia.org, and public domain.

Fig. C.57: Rudolf Kollath and Gerhard Schumann. 1947. Untersuchungen an einem 15-MV-Betatron.
Zeitschrift für Naturforschung 2a:634–642 [http://zfn.mpdl.mpg.de/data/Reihe_A/2/ZNA-1947-2a-0634.pdf].

Fig. C.58: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Fig. C.59: U.S. government and public domain.

Fig. C.60: *Verhandlungen der Deutschen Physikalischen Gesellschaft* (1916) 18:13–14:318–323.

Fig. C.61: *Mitteilungen der Physikalischen Gesellschaft Zürich* (1916) 18:47–62.

Fig. C.62: *Zeitschrift für Physik* (1923) 20:1:145–152.

Fig. C.63: *Handbuch der Physik* (1926) 23:641–775].

Fig. C.64: *Zeitschrift für Physik* (1928) 48:1–2:15–25.

Fig. C.65: *Zeitschrift für Physik* (1928) 48:1–2:26–50.

Fig. C.66: *Zeitschrift für Physik* (1928) 48:1–2:51–61.

Fig. C.67: *Zeitschrift für Physik* (1928) 48:3–4:192–204.

Fig. C.68: *Zeitschrift für Physik* (1930) 65:3–4:167–188.

Fig. C.69: *Zeitschrift für Physik* (1930) 65:3–4:189–206.

Fig. C.70: *Zeitschrift für Physikalische Chemie* (1928) 139:1:375–385.

Fig. C.71: *Zeitschrift für Physik* (1930) 63:9–10:616–633.

Fig. C.72: *Zeitschrift für Physik* (1930) 63:9–10:634–639.

Fig. C.73: *Zeitschrift für Physik* (1932) 79:1–2:42–61.

Fig. C.74: *Zeitschrift für Physik* (1933) 83:3–4:234–246.

Fig. C.75: *Zeitschrift für Physik* (1933) 85:5–6:366–372.

Fig. C.76: U.S. Patent and Trademark Office, public domain.

Fig. C.77: U.S. Patent and Trademark Office, public domain.

Fig. C.78: U.S. Patent and Trademark Office, public domain.

Fig. C.79: European Patent Office, German patent DE 735,435, public domain.

Fig. C.80: European Patent Office, German patent DE 735,435, public domain.

Fig. C.81: European Patent Office, German patent DE 735,435, public domain.

Fig. C.82: European Patent Office, German patent DE 735,435, public domain.

Fig. C.83: Todd Rider [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

Fig. C.84: Todd Rider [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

Fig. C.85: Todd Rider [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

Fig. C.86: Todd Rider [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

Fig. C.87: Todd Rider [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

Fig. C.88: Todd Rider [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

Fig. C.89: Todd Rider [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

Fig. C.90: Todd Rider [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

Fig. C.91: Todd Rider [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

Fig. C.92: Todd Rider [NARA RG 319, Entry NM3-82A, Box 6, Folder G3].

Fig. C.93: public domain.

Fig. C.94: public domain.

Fig. C.95: public domain.

Fig. C.96: Todd Rider.

Fig. C.97: public domain.

Fig. C.98: European Patent Office, German patent DE2308071, public domain.

Fig. C.99: European Patent Office, German patent DE2308071, public domain.

Fig. C.100: European Patent Office, German patent DE2308071, public domain.

Fig. C.101: European Patent Office, German patent DE2308071, public domain.

Fig. C.102: European Patent Office, German patent DE2308071, public domain.

Fig. C.103: European Patent Office, German patent DE2308071, public domain.

Fig. C.104: European Patent Office, German patent DE2308071, public domain.

Fig. C.105: European Patent Office, German patent DE2308071, public domain.

Fig. C.106: Todd Rider [BIOS 1504].

Fig. C.107: Todd Rider [BIOS 1504].

Fig. C.108: Todd Rider [BIOS 1504].

Fig. C.109: Todd Rider [BIOS 1504].

Fig. C.110: Todd Rider [BIOS 609].

Fig. C.111: Todd Rider [BIOS 1679].

Fig. C.112: Todd Rider [BIOS 1679].

Fig. C.113: Todd Rider [CIOS XXXII-77].

Fig. C.114: Todd Rider [CIOS XXXII-77].

Fig. C.115: Todd Rider [CIOS XXXII-77].

Fig. C.116: Todd Rider [CIOS XXXII-77].

Fig. C.117: Todd Rider [CIOS XXXII-77].

Fig. C.118: U.S. government, commons.wikimedia.org, and public domain.

Fig. C.119: U.S. Patent and Trademark Office, U.S. patent 782,312, public domain.

Fig. C.120: U.S. Patent and Trademark Office, U.S. patent 782,312, public domain.

Fig. C.121: U.S. Patent and Trademark Office, U.S. patent 782,312, public domain.

Fig. C.122: U.S. Patent and Trademark Office, U.S. patent 782,312, public domain.

Fig. C.123: U.S. Patent and Trademark Office, U.S. patent 782,312, public domain.

Fig. C.124: U.S. Patent and Trademark Office, U.S. patent 782,312, public domain.

Fig. C.125: U.S. Patent and Trademark Office, U.S. patent 782,312, public domain.

Fig. C.126: U.S. Patent and Trademark Office, U.S. patent 782,312, public domain.

Fig. C.127: European Patent Office, German patent DE643316, public domain.

Fig. C.128: European Patent Office, German patent DE643316, public domain.

Fig. C.129: European Patent Office, German patent DE643316, public domain.

Fig. C.130: European Patent Office, German patent DE643316, public domain.

Fig. C.131: European Patent Office, German patent DE643316, public domain.

Fig. C.132: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.133: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.134: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.135: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.136: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.137: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.138: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.139: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.140: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.141: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.142: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.143: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.144: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.145: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.146: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.147: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.148: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.149: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.150: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.151: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.152: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.153: Todd Rider [NARA RG 319, Entry NME-82A, Box 15, Folders OB-27 and OB-28].

Fig. C.154: English translation of French intelligence reports from February 1944 [Witkowski 2010, pp. 129–131, and 2013, pp. 93–94].

Fig. C.155: English translation of French intelligence reports from February 1944 [Witkowski 2010, pp. 129–131, and 2013, pp. 93–94].

Fig. C.156: English translation of French intelligence reports from February 1944 [Witkowski 2010, pp. 129–131, and 2013, pp. 93–94].

Fig. C.157 U.S. government and public domain.

Fig. D.1: Todd Rider [NARA RG 226, Entry A1-134, Box 219, Folder 1371: OUT AZUSA Nov. '43 Sept. '45].

Fig. D.2: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)].

Fig. D.3: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)].

Fig. D.4: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)].

Fig. D.5: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)].

Fig. D.6: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)].

Fig. D.7: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)].

Fig. D.8: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.9: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.10: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.11: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.12: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder APR–Dec. '45].

Fig. D.13: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)].

Fig. D.14: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.15: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.16: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.17: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.18: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.19: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA—(1943–June 1946)].

Fig. D.20: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.].

Fig. D.21: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.].

Fig. D.22: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-2 GERMANY: Research—Res. Inst. & other Facilities (May 45–Dec 46)].

Fig. D.23: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.24: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder British–U.S. Relations on Atomic Energy Intelligence (War Period) to 8 Oct 1945].

Fig. D.25: Todd Rider [NARA RG GOUDS, Entry UD-7420, Box 6, Folder Rosbaud].

Fig. D.26: Norberto Lahuerta [Goudsmit 1945].

Fig. D.27: Norberto Lahuerta [Goudsmit 1945].

Fig. D.28: Norberto Lahuerta [Goudsmit 1945].

Fig. D.29: Norberto Lahuerta [Goudsmit 1945].

Fig. D.30: Norberto Lahuerta [Goudsmit 1945].

Fig. D.31: Norberto Lahuerta [Goudsmit 1945].

Fig. D.32: Todd Rider [NARA RG GOUDS, Entry UD-7420, Box 6, Folder Alsos Mission].

Fig. D.33: Todd Rider [NARA RG GOUDS, Entry UD-7420, Box 6, Folder Alsos Mission].

Fig. D.34: Todd Rider [NARA RG GOUDS, Entry UD-7420, Box 6, Folder Alsos Mission].

Fig. D.35: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA—(1943–June 1946), Henry Lowenhaupt to Major Mattina, 11 May 1946].

Fig. D.36: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.37: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.38: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.39: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.40: Todd Rider [NARA RG GOUDS, Entry UD-7420, Box 5, Folder "ALSOS" Clearance of Book].

Fig. D.41: [Pash 1969, frontispiece].

Fig. D.42: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 202.3-2 LONDON OFFICE: Combined Oper Ger Group].

Fig. D.43: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder 205.3 Cables Outgoing, Secret and Under January 1946 thru December 1946].

Fig. D.44: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Fig. D.45: David N. R. Bleecker [NARA RG GOUDS, Entry UD-7420, Box 5, Folder Postwar Reconstruction of German Science and Academia].

Fig. D.46: David N. R. Bleecker [NARA RG GOUDS, Entry UD-7420, Box 5, Folder Postwar Reconstruction of German Science and Academia].

Fig. D.47: Otto Hahn and Fritz Strassmann. January 1939. Über den Nachweis und das Verhalten der bei der Bestrahlung des Urans mittels Neutronen entstehenden Erdalkalimetalle. *Die Naturwissenschaften* 27:11–15.

Fig. D.48: Todd Rider [NARA RG GOUDS, Entry UD-7420, Box 6, Folder ALSOS—Reports and Operations].

Fig. D.49: Siegfried Flügge. Kann der Energieinhalt der Atomkerne technisch nutzbar gemacht werden? *Die Naturwissenschaften* 27:402–410. 9 June 1939. [https://digital.deutsches-museum.de/item/FA-002-746

Fig. D.50: Siegfried Flügge. Kann der Energieinhalt der Atomkerne technisch nutzbar gemacht werden? *Die Naturwissenschaften* 27:402–410. 9 June 1939. [https://digital.deutsches-museum.de/item/FA-002-746

Fig. D.51: Siegfried Flügge. Kann der Energieinhalt der Atomkerne technisch nutzbar gemacht werden? *Die Naturwissenschaften* 27:402–410. 9 June 1939. [https://digital.deutsches-museum.de/item/FA-002-746

Fig. D.52: European Patent Office, Austrian patent AT219170, public domain.

Fig. D.53: European Patent Office, Austrian patent AT219170, public domain.

Fig. D.54: Todd Rider [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].

Fig. D.55: Bundesarchiv Lichterfelde, NS 19-2012.

Fig. D.56: Todd Rider [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].

Fig. D.57: Todd Rider [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].

Fig. D.58: Todd Rider [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].

Fig. D.59: Todd Rider [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].

Fig. D.60: Todd Rider [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].

Fig. D.61: Todd Rider [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].

Fig. D.62: Todd Rider [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].

Fig. D.63: Todd Rider [NARA RG 319, Entry NM3-82A, Box 5, Folder Documents from which ALSOS reports were made].

Fig. D.64: Manuel Lukas [NARA RG 242, Records of the Reich Leader of the Schutzstaffel (SS) and Chief of the German Police, Microfilm 183, NAID 273992206 (https://catalog.archives.gov/id/273992206)].

Fig. D.65: NARA RG 238, Microfilm M1270, Interrogation Records Prepared for War Crimes Proceedings at Nuernberg, Roll 24.

Fig. D.66: NARA RG 238, Microfilm M1270, Interrogation Records Prepared for War Crimes Proceedings at Nuernberg, Roll 24.

Fig. D.67: NARA RG 238, Microfilm M1270, Interrogation Records Prepared for War Crimes Proceedings at Nuernberg, Roll 24.

Fig. D.68: NARA RG 238, Microfilm M1270, Interrogation Records Prepared for War Crimes Proceedings at Nuernberg, Roll

24.

Fig. D.69: NARA RG 238, Microfilm M1270, Interrogation Records Prepared for War Crimes Proceedings at Nuernberg, Roll 24.

Fig. D.70: commons.wikimedia.org and public domain.

Fig. D.71: [Krotzky 2002, p. 31, Jonastalverein Archive, Arnstadt].

Fig. D.72: [Krotzky 2002, p. 32, Jonastalverein Archive, Arnstadt].

Fig. D.73: Todd Rider.

Fig. D.74: Todd Rider.

Fig. D.75: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.76: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.77: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.78: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.79: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.80: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.81: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.82: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

Fig. D.83: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

Fig. D.84: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

Fig. D.85: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

Fig. D.86: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret January 1946 thru December 1946].

Fig. D.87: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

Fig. D.88: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

Fig. D.89: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

Fig. D.90: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

Fig. D.91: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

Fig. D.92: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Fig. D.93: David N. R. Bleecker [NARA RG GOUDS, Entry UD-7420, Box 6, Folder Alsos Reports and Operations 5/21].

Fig. D.94: David N. R. Bleecker [NARA RG GOUDS, Entry UD-7420, Box 3, Folder "Historian's Office Inventory Control Job Goudsmit Box 4 Folder 6"].

Fig. D.95: Todd Rider [CIOS ER 343, AFHRA A1008 frames 0794–0797].

Fig. D.96: Todd Rider [CIOS ER 343, AFHRA A1008 frames 0794–0797].

Fig. D.97: Todd Rider [CIOS ER 343, AFHRA A1008 frames 0794–0797].

Fig. D.98: Todd Rider [NARA RG 77, Entry UD-22A, Box 174, Folder 10.70 Austria Misc].

Fig. D.99: Todd Rider [https://www.cia.gov/readingroom/document/cia-rdp83-00415r003900020006-0].

Fig. D.100: Todd Rider [https://www.cia.gov/readingroom/document/cia-rdp83-00415r003900020006-0].

Fig. D.101: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.102: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.103: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Fig. D.104: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45].

Fig. D.105: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Fig. D.106: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Fig. D.107: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

Fig. D.108: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

Fig. D.109: Todd Rider [NARA RG 77, Entry UD-22A, Box 173, Folder 57.70. Poland Misc].

Fig. D.110: Google Earth, courtesy of Gernot Eilers.

Fig. D.111: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45—Dec. '45].

Fig. D.112: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.42.B Germ Captured Materials Uran].

Fig. D.113: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Fig. D.114: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.42.B Germ Captured Materials Uran].

Fig. D.115: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Fig. D.116: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Fig. D.117: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Fig. D.118: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Fig. D.119: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder 205.4 Cables Outgoing, Top Secret].

Fig. D.120: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.42.B Germ Captured Materials Uran].

Fig. D.121: Deutsches Museum Archive [G-32].

Fig. D.122: Deutsches Museum Archive [G-33].

Fig. D.123: Deutsches Museum Archive [G-33].

Fig. D.124: Deutsches Museum Archive [G-33].

Fig. D.125: Deutsches Museum Archive [G-28].

Fig. D.126: Deutsches Museum Archive [G-28].

Fig. D.127: Deutsches Museum Archive [G-28].

Fig. D.128: Deutsches Museum Archive [G-28].

Fig. D.129: Deutsches Museum Archive [G-157].

Fig. D.130: Deutsches Museum Archive [G-157].

Fig. D.131: Manuel Lukas [AFHRA A5183 frames 0346, 0609].

Fig. D.132: George Cully [PW Intelligence Bulletin No 1/34, 5 February 1945, pp. 9–11, AFHRA folder 506.61951 Nos. 1/19–1/35 26 Dec 1944–7 Feb 1945, IRIS 207524].

Fig. D.133: George Cully [PW Intelligence Bulletin No 1/34, 5 February 1945, pp. 9–11, AFHRA folder 506.61951 Nos. 1/19–1/35 26 Dec 1944–7 Feb 1945, IRIS 207524].

Fig. D.134: Georg Bredig. 1895. Ueber den Einfluss der Zentrifugalkraft auf chemische Systeme. *Zeitschrift für Physikalische Chemie A* 17:459. https://doi.org/10.1515/zpch-1895-1726

Fig. D.135: Georg Bredig and Fritz Haber. 1904. Prinzipien der Gasscheidung durch Zentrifugalkraft. *Zeitschrift für Angewandte Chemie* 17:452. https://doi.org/10.1002/ange.19040171503

Fig. D.136: Helmuth Hausen and R. Schlatterer. 1939. Aussichten der Zerlegung von Gasgemischen durch Zentrifugieren. *Z. VDI Beiheft Verfahrenstechnik* 1939:1:15–21.

Fig. D.137: Helmuth Hausen. 1942. Zerlegung von Gasgemischen in einer Zentrifuge mit Gegenstromwirkung. *Z. VDI Beiheft Verfahrenstechnik* 1942:4:93–102.

Fig. D.138: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.139: European Patent Office, German Patent DE 833,487, public domain.

Fig. D.140: European Patent Office, German Patent DE 833,487, public domain.

Fig. D.141: European Patent Office, German Patent DE 872,936, public domain.

Fig. D.142: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.24-1 GERMANY: Research–Res. Inst. & other Facilities (1943–Apr. 1945)].

Fig. D.143: European Patent Office, German Patent DE 906,094, public domain.

Fig. D.144: European Patent Office, German Patent DE 906,094, public domain.

Fig. D.145: European Patent Office, German Patent DE 906,094, public domain.

Fig. D.146: European Patent Office, German Patent DE 906,094, public domain.

Fig. D.147: *Zeitschrift für Physikalische Chemie A* (1941) 189:219–316.

Fig. D.148: *Zeitschrift für Physikalische Chemie A* (1941) 189:317–326.

Fig. D.149: Todd Rider [NARA RG 226, Entry A1-134, Box 219, Folder IN AZUSA Nov. '43 Sept. '45].

Fig. D.150: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int.

(July–Oct. 44)].

Fig. D.151: Deutsches Museum Archive [G-331].

Fig. D.152: Deutsches Museum Archive [G-331].

Fig. D.153: European Patent Office, public domain.

Fig. D.154: European Patent Office, public domain.

Fig. D.155: European Patent Office, public domain.

Fig. D.156: European Patent Office, public domain.

Fig. D.157: Deutsches Museum Archive FA 002/811. http://digital.deutsches-museum.de/item/FA-002-811/

Fig. D.158: Deutsches Museum Archive FA 002/811. http://digital.deutsches-museum.de/item/FA-002-811/

Fig. D.159: Deutsches Museum Archive FA 002/811. http://digital.deutsches-museum.de/item/FA-002-811/

Fig. D.160: Deutsches Museum Archive FA 002/811. http://digital.deutsches-museum.de/item/FA-002-811/

Fig. D.161: Deutsches Museum Archive FA 002/811. http://digital.deutsches-museum.de/item/FA-002-811/

Fig. D.162: Deutsches Museum Archive FA 002/811. http://digital.deutsches-museum.de/item/FA-002-811/

Fig. D.163: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA—(1943–June 1946), CIOS ER 318].

Fig. D.164: NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb, https://downloads.paperlessarchives.com, pp. 6084–6089.

Fig. D.165: NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb, https://downloads.paperlessarchives.com, pp. 6084–6089.

Fig. D.166: NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb, https://downloads.paperlessarchives.com, pp. 6084–6089.

Fig. D.167: Todd Rider [NARA RG GOUDS, Entry UD-7420, Box 8, Folder Haycock/Brown/Tape AEC].

Fig. D.168: Todd Rider [NARA RG GOUDS, Entry UD-7420, Box 8, Folder Haycock/Brown/Tape AEC].

Fig. D.169: Todd Rider [BIOS 1487].

Fig. D.170: Todd Rider [BIOS 1487].

Fig. D.171: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA—(1943–June 1946)].

Fig. D.172: [G-139].

Fig. D.173: [G-139].

Fig. D.174: [G-139].

Fig. D.175: [G-139].

Fig. D.176: [G-139].

Fig. D.177: [G-139].

Fig. D.178: [G-139].

Fig. D.179: [G-139].

Fig. D.180: Rainer Karlsch.

Fig. D.181: Rainer Karlsch.

Fig. D.182: Rainer Karlsch.

Fig. D.183: Rainer Karlsch.

Fig. D.184: Rainer Karlsch.

Fig. D.185: Rainer Karlsch.

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Fig. D.197: Rainer Karlsch.

Fig. D.198: Rainer Karlsch.

Fig. D.199: Rainer Karlsch.

Fig. D.200: Rainer Karlsch.

Fig. D.201: Rainer Karlsch.

Fig. D.202: Todd Rider and Annette Gowin.

Fig. D.203: Todd Rider [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].

Fig. D.204: Todd Rider [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].

Fig. D.205: Todd Rider [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].

Fig. D.206: Todd Rider [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].

Fig. D.207: Todd Rider [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].

Fig. D.208: Todd Rider [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].

Fig. D.209: Todd Rider [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].

Fig. D.210: Todd Rider [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].

Fig. D.211: Todd Rider [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].

Fig. D.212: Todd Rider [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 80–10].

Fig. D.213: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)].

Fig. D.214: Frank Döbert [TNA FO 1031/59].

Fig. D.215: Frank Döbert [TNA FO 1031/59].

Fig. D.216: Frank Döbert [TNA FO 1031/59].

Fig. D.217: Frank Döbert [TNA FO 1031/59].

Fig. D.218: Frank Döbert [TNA FO 1031/59].

Fig. D.219: Frank Döbert [TNA FO 1031/59].

Fig. D.220: U.S. Patent and Trademark Office, U.S. patent 1,486,521, public domain.

Fig. D.221: U.S. Patent and Trademark Office, U.S. patent 1,486,521, public domain.

Fig. D.222: U.S. Patent and Trademark Office, U.S. patent 1,486,521, public domain.

Fig. D.223: U.S. Patent and Trademark Office, U.S. patent 1,498,097, public domain.

Fig. D.224: U.S. Patent and Trademark Office, U.S. patent 1,498,097, public domain.

Fig. D.225: European Patent Office, Austrian Patent AT 107,571, public domain.

Fig. D.226: European Patent Office, Austrian Patent AT 107,571, public domain.

Fig. D.227: European Patent Office, Austrian Patent AT 107,571, public domain.

Fig. D.228: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.229: U.S. government [https://s3.documentcloud.org/documents/22799707/reed-manufacture-at-the-metallweberei-neustadtorla-vvb-tewa.pdf].

Fig. D.230: U.S. government [https://archive.org/details/CIA-RDP83-00415R011000030025-8].

Fig. D.231: U.S. government [https://www.cia.gov/readingroom/docs/CIA-RDP83-00415R011000030026-7.pdf].

Fig. D.232: U.S. government [https://www.cia.gov/readingroom/docs/CIA-RDP83-00415R012000160002-8.pdf].

Fig. D.233: Deutsches Museum Archive [G-346].

Fig. D.234: commons.wikimedia.org and public domain.

Fig. D.235: European Patent Office, French Patent FR 881,316, public domain.

Fig. D.236: European Patent Office, French Patent FR 881,316, public domain.

Fig. D.237: European Patent Office, French Patent FR 881,316, public domain.

Fig. D.238: European Patent Office, French Patent FR 881,316, public domain.

Fig. D.239: European Patent Office, French Patent FR 881,316, public domain.

Fig. D.240: European Patent Office, French Patent FR 881,316, public domain.

Fig. D.241: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45].

Fig. D.242: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.243: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.244: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.245: Deutsches Museum Archive [G-124].

Fig. D.246: Deutsches Museum Archive [G-124; G-202].

Fig. D.247: Deutsches Museum Archive FA 002/782. https://digital.deutsches-museum.de/item/FA-002-782/

Fig. D.248: Deutsches Museum Archive FA 002/782. https://digital.deutsches-museum.de/item/FA-002-782/

Fig. D.249: Deutsches Museum Archive FA 002/782. https://digital.deutsches-museum.de/item/FA-002-782/

Fig. D.250: Deutsches Museum Archive FA 002/782. https://digital.deutsches-museum.de/item/FA-002-782/

Fig. D.251: Todd Rider [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 100–103].

Fig. D.252: Todd Rider [FIAT Rev: *Nuclear Physics and Cosmic Rays* Vol. II, pp. 100–103].

Fig. D.253: European Patent Office, German patent DE1058024, public domain.

Fig. D.254: European Patent Office, German patent DE1058024, public domain.

Fig. D.255: Todd Rider [NARA RG GOUDS, Entry UD-7420, Box 8, Folder Haycock/Brown/Tape AEC].

Fig. D.256: Todd Rider.

Fig. D.257: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.258: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.259: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, unlabeled gray folder].

Fig. D.260: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

Fig. D.261: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

Fig. D.262: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)].

Fig. D.263: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)].

Fig. D.264: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.265: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.266: George Cully [AFHRA folder 512.619C-15A 1943–1945].

Fig. D.267: George Cully [AFHRA folder 512.619C-15A 1943–1945].

Fig. D.268: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.269: FF4936 Research on Secret Weapons (January 1945) [NARA RG 226, Entry ??, Box 361, Folder ??. Published in https://www.hsozkult.de/publicationreview/id/reb-7382].

Fig. D.270: George Cully [AFHRA folder 506.619B 1945–47].

Fig. D.271: George Cully [AFHRA folder 506.619B 1945–47].

Fig. D.272: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

Fig. D.273: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int.

(July–October 1944)].

Fig. D.274: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

Fig. D.275: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

Fig. D.276: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

Fig. D.277: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

Fig. D.278: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

Fig. D.279: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.280: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)].

Fig. D.281: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11 Tech-Countermeasures + RW 1943–1944].

Fig. D.282: Todd Rider NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.283: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.284: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.285: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

Fig. D.286: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

Fig. D.287: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

Fig. D.288: Todd Rider [AFHRA 25177 p. 932].

Fig. D.289: commons.wikimedia.org and public domain.

Fig. D.290: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

Fig. D.291: George Cully [AFHRA Mediterranean Allied Air Forces Reel 189, No. 1391 Zipf GN 5061].

Fig. D.292: George Cully [AFHRA Mediterranean Allied Air Forces Reel 189, No. 1391 Zipf GN 5061].

Fig. D.293: George Cully [AFHRA Mediterranean Allied Air Forces Reel 189, No. 1391 Zipf GN 5061].

Fig. D.294: George Cully [AFHRA Mediterranean Allied Air Forces Reel 189, No. 1391 Zipf GN 5061].

Fig. D.295: George Cully [AFHRA Mediterranean Allied Air Forces Reel 189, No. 1391 Zipf GN 5061].

Fig. D.296: George Cully [AFHRA Mediterranean Allied Air Forces Reel 189, No. 1391 Zipf GN 5061].

Fig. D.297: George Cully [AFHRA Mediterranean Allied Air Forces Reel 189, No. 1391 Zipf GN 5061].

Fig. D.298: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

Fig. D.299: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–October 1944)].

Fig. D.300: Todd Rider [NARA RG 226, Entry A1-134, Box 219, Folder IN AZUSA Nov. '43 Sept. '45].

Fig. D.301: Todd Rider [NARA RG 226, Entry A1-134, Box 219, Folder IN AZUSA Nov. '43 Sept. '45].

Fig. D.302: Todd Rider [NARA RG 226, Entry A1-134, Box 219, Folder IN AZUSA Nov. '43 Sept. '45].

Fig. D.303: Jaroslav Mareš [SOkA Příbram, Elektrifikace—1944, AM Příbram—S, inv. č. 1001].

Fig. D.304: Jaroslav Mareš [SOkA Příbram, Elektrifikace—1944, AM Příbram—S, inv. č. 1001].

Fig. D.305: Jaroslav Mareš [Národní archiv, Ústřední výbor KSČ, Klement Gottwald, sv. 81, aj. 1031, courtesy of Jaroslav Mareš].

Fig. D.306: AFHRA, courtesy of Gunther Hebestreit.

Fig. D.307: Jaroslav Mareš.

Fig. D.308: Jaroslav Mareš.

Fig. D.309: Jaroslav Mareš.

Fig. D.310: commons.wikimedia.org and public domain.

Fig. D.311: Jaroslav Mareš.

Fig. D.312: U.S. government, public domain [www.archives.gov/publications/prologue/2007/winter/stechovice.html].

Fig. D.313: U.S. government, public domain [www.archives.gov/publications/prologue/2007/winter/stechovice.html].

Fig. D.314: U.S. government, public domain [www.archives.gov/publications/prologue/2007/winter/stechovice.html].

Fig. D.315: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

Fig. D.316: Jaroslav Mareš [Archiv Bezpečnostních Složek. H-544 Akce Úkryty].

Fig. D.317: Jaroslav Mareš [Archiv Kanceláře Prezidenta Republiky. https://www.prazskyhradarchiv.cz/file/edee/archivalie_mesice/2016/1602.pdf].

Fig. D.318: Jaroslav Mareš [Archiv Bezpečnostních Složek. File 304_81_5].

Fig. D.319: Jaroslav Mareš [Archiv Bezpečnostních Složek. File 304_81_5].

Fig. D.320: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder 205.4 Cables Outgoing, Top Secret].

Fig. D.321: Jaroslav Mareš [Pohraniční útvary SNB 1946–1947].

Fig. D.322: Adam Kretschmer [Czech National Archive].

Fig. D.323: Adam Kretschmer [Czech National Archive].

Fig. D.324: Adam Kretschmer [Czech National Archive].

Fig. D.325: Adam Kretschmer [Czech National Archive].

Fig. D.326: Adam Kretschmer [Czech National Archive].

Fig. D.327: Adam Kretschmer [Czech National Archive].

Fig. D.328: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.329: George Cully [AFHRA folder 512.619C-6C 1944–1945].

Fig. D.330: George Cully [AFHRA folder 512.619C-6C 1944–1945].

Fig. D.331: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.332: George Cully [AFHRA folder 122.25 Jan–May 1948].

Fig. D.333: Ida Noddack. 1934. Über das Element 93. *Angewandte Chemie.* 47:37:653–655.

Fig. D.334: Manuel Lukas [Bundesarchiv Berlin-Lichterfelde R 43-II/342 https://invenio.bundesarchiv.de/invenio/direktlink/9bd5f753-48a5-439d-aef7-6341624b1221/].

Fig. D.335: Manuel Lukas [Bundesarchiv Berlin-Lichterfelde R 43-II/342 https://invenio.bundesarchiv.de/invenio/direktlink/9bd5f753-48a5-439d-aef7-6341624b1221/].

Fig. D.336: Deutsches Museum Archive [G-55].

Fig. D.337: Deutsches Museum Archive [G-59].

Fig. D.338: Deutsches Museum Archive [G-59].

Fig. D.339: Deutsches Museum Archive [G-59].

Fig. D.340: Deutsches Museum Archive [G-59].

Fig. D.341: Deutsches Museum Archive [G-59].

Fig. D.342: Deutsches Museum Archive [G-59].

Fig. D.343: Todd Rider [AMPG 7314, KWIP 7, Folder 4 Pu].

Fig. D.344: Todd Rider [AMPG 7314, KWIP 7, Folder 4 Pu].

Fig. D.345: Todd Rider [AMPG 7314, KWIP 7, Folder 4 Pu].

Fig. D.346: Todd Rider [AMPG 7314, KWIP 7, Folder 4 Pu].

Fig. D.347: Todd Rider [AMPG 7314, KWIP 7, Folder 4 Pu].

Fig. D.348: Todd Rider [AMPG 7314, KWIP 7, Folder 4 Pu].

Fig. D.349: Deutsches Museum Archive [G-94].

Fig. D.350: Deutsches Museum Archive [G-94].

Fig. D.351: Deutsches Museum Archive [G-94].

Fig. D.352: Deutsches Museum Archive [G-94].

Fig. D.353: Deutsches Museum Archive [G-94].

Fig. D.354: Deutsches Museum Archive [G-94].

Fig. D.355: Deutsches Museum Archive [G-94].

Fig. D.356: Deutsches Museum Archive [G-94].

Fig. D.357: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.].

Fig. D.358: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.].

Fig. D.359: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Fig. D.360: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Fig. D.361: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Fig. D.362: David N. R. Bleecker [NARA RG GOUDS, Entry UD-7420, Box 3, Folder "Historian's Office Inventory Control Job Goudsmit Box 4 Folder 6"].

Fig. D.363: Todd Rider [NARA RG 77, Entry UD-22A, Box 173, Folder 60.22-1 RUSSIA: Research—TA (43–Jun 46)].

Fig. D.364: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Fig. D.365: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Fig. D.366: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.367: Todd Rider.

Fig. D.368: Deutsches Museum Archive [G-371].

Fig. D.369: Deutsches Museum Archive [G-371].

Fig. D.370: Deutsches Museum Archive [G-371].

Fig. D.371: Todd Rider.

Fig. D.372: U.S. government, public domain.

Fig. D.373: Todd Rider.

Fig. D.374: Todd Rider.

Fig. D.375: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)].

Fig. D.376: Günter Nagel.

Fig. D.377: Günter Nagel.

Fig. D.378: Todd Rider [Bundesarchiv Militärarchiv Freiburg N 822/13].

Fig. D.379: Todd Rider.

Fig. D.380: Todd Rider.

Fig. D.381: Todd Rider.

Fig. D.382: Todd Rider.

Fig. D.383: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.384: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Fig. D.385: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Fig. D.386: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Fig. D.387: George Cully [PW Intelligence Bulletin 2/50, 1 April 1945, AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533].

Fig. D.388: George Cully [PW Intelligence Bulletin 2/50, 1 April 1945, AFHRA folder 506.61952 Nos. 2/41–2/50 6 Mar–1 Apr 1945, IRIS 207533].

Fig. D.389: Top: Bayerische Staatsbibliothek, courtesy of Andreas Sulzer.
Bottom: U.S. government, commons.wikimedia.org, and public domain.

Fig. D.390: Bayerische Staatsbibliothek, courtesy of Andreas Sulzer.

Fig. D.391: Bayerische Staatsbibliothek, courtesy of Andreas Sulzer.

Fig. D.392: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

Fig. D.393: Collection Rudolf A. Haunschmied, from St. Georgen an der Gusen train station.

Fig. D.394: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45].

Fig. D.395: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45].

Fig. D.396: AFHRA, courtesy of Rudolf Haunschmied.

Fig. D.397: AFHRA, courtesy of Gunther Hebestreit.

Fig. D.398: AFHRA Report U 57 on St. Georgen, courtesy of Rudolf Haunschmied

Fig. D.399: AFHRA Report U 57 on St. Georgen, courtesy of Rudolf Haunschmied

Fig. D.400: AFHRA, courtesy of Gunther Hebestreit.

Fig. D.401: AFHRA, courtesy of Gunther Hebestreit.

Fig. D.402: https://thebulletin.org/2021/08/rebranding-chernobyl/ and
https://www.oxfordmail.co.uk/news/14780388.decommissioning-harwell-nuclear-site-mired-controversy-high-court-ruling/

Fig. D.403: https://www.energy.gov/em/articles/crews-begin-pre-demolition-work-lawrence-livermore-national-laboratory-reactor

Fig. D.404: AFHRA, courtesy of Gunther Hebestreit.

Fig. D.405: AFHRA, courtesy of Gunther Hebestreit.

Fig. D.406: Rudolf Haunschmied and Todd Rider.

Fig. D.407: Sammlung Franz Jakob, courtesy of Andreas Sulzer.

Fig. D.408: Sammlung Franz Jakob, courtesy of Andreas Sulzer.

Fig. D.409: Sammlung Franz Jakob, courtesy of Andreas Sulzer.

Fig. D.410: Sammlung Franz Jakob, courtesy of Andreas Sulzer.

Fig. D.411: Sammlung Franz Jakob, courtesy of Andreas Sulzer.

Fig. D.412: Sammlung Franz Jakob, courtesy of Andreas Sulzer.

Fig. D.413: Sammlung Franz Jakob, courtesy of Andreas Sulzer.

Fig. D.414: George Cully [AFHRA folder 570.6501A 1945–1946].

Fig. D.415: George Cully [AFHRA folder 570.6501A 1945–1946].

Fig. D.416: George Cully [AFHRA folder 570.6501A 1945–1946].

Fig. D.417: Todd Rider.

Fig. D.418: Top: commons.wikimedia.org. Bottom: Rudolf Haunschmied.

Fig. D.419: Rudolf Haunschmied.

Fig. D.420: Rudolf Haunschmied.

Fig. D.421: Archives of the French Army Ministry of Defense, courtesy of Andreas Sulzer.

Fig. D.422: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.423: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.424: George Cully [AFHRA folder 170.2279C-1 NO DATE].

Fig. D.425: George Cully [AFHRA folder 170.2279C-1 NO DATE].

Fig. D.426: George Cully [AFHRA folder 170.2279C-1 NO DATE].

Fig. D.427: George Cully [AFHRA folder 170.2279C-1 7 SEP 1945].

Fig. D.428: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.429: NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb, https://downloads.paperlessarchives.com, p. 6148.

Fig. D.430: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)].

Fig. D.431: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.432: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA (1943–June 1946)].

Fig. D.433: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA (1943–June 1946)].

Fig. D.434: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA (1943–June 1946)].

Fig. D.435: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Fig. D.436: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Fig. D.437: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder In & Out Jan 46–July 15, '46].

Fig. D.438: Todd Rider [NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel].

Fig. D.439: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA (1943–June 1946)].

Fig. D.440: CIOS XXVIII-31.

Fig. D.441: CIOS XXVIII-31.

Fig. D.442: CIOS XXVIII-31.

Fig. D.443: CIOS XXVIII-31.

Fig. D.444: CIOS XXVIII-31.

Fig. D.445: CIOS XXVIII-31.

Fig. D.446: CIOS XXVIII-31.

Fig. D.447: CIOS XXVIII-31.

Fig. D.448: CIOS XXVIII-31.

Fig. D.449: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret January 1946 thru December 1946].

Fig. D.450: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.7002 GERMANY—ALSOS MISSION ∗ Administrative Matters (1940–1945)].

Fig. D.451: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder Apr 45–Dec. '45].

Fig. D.452: David N. R. Bleecker [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3345, Book 6, SC 221938].

Fig. D.453: David N. R. Bleecker [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3345, Book 6, SC 222100].

Fig. D.454: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.455: Todd Rider [NARA RG 77, Entry UD-22A, Box 173, Folder 50.20. Netherlands: Research].

Fig. D.456: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45].

Fig. D.457: Manuel Lukas [NARA RG 319, Entry A1-134B, Box ??, Folder XE065437 Focke, Franz].

Fig. D.458: Manuel Lukas [NARA RG 319, Entry A1-134B, Box ??, Folder XE065437 Focke, Franz].

Fig. D.459: Todd Rider [NARA NARA RG 77, Entry UD-22A, Box 175, Folder World].

Fig. D.460: Todd Rider [NARA NARA RG 77, Entry UD-22A, Box 175, Folder World].

Fig. D.461: Norberto Lahuerta [NARA RG 218, Entry UD-1, Box 475, Folder CCS 471.9... (5-1-45)... Sec. 3].

Fig. D.462: Norberto Lahuerta [NARA RG 218, Entry UD-1, Box 475, Folder CCS 471.9... (5-1-45)... Sec. 3].

Fig. D.463: Norberto Lahuerta [NARA RG 218, Entry UD-1, Box 475, Folder CCS 471.9... (5-1-45)... Sec. 3].

Fig. D.464: Norberto Lahuerta [NARA RG 218, Entry UD-1, Box 475, Folder CCS 471.9... (5-1-45)... Sec. 3].

Fig. D.465: Jaroslav Mareš [Vojenský historický archiv, Vědecký technický ústav 1945–1946, kart. 1].

Fig. D.466: Jaroslav Mareš [Vojenský historický archiv, Vědecký technický ústav 1945–1946, kart. 1].

Fig. D.467: Jaroslav Mareš [Vojenský historický archiv, Vědecký technický ústav 1945–1946, kart. 1].

Fig. D.468: Jaroslav Mareš [Vojenský historický archiv, Vědecký technický ústav 1945–1946, kart. 1].

Fig. D.469: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret January 1946 thru December 1946].

Fig. D.470: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 68.91. US: Russian Int in US].

Fig. D.471: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 68.91. US: Russian Int in US].

Fig. D.472: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 68.91. US: Russian Int in US].

Fig. D.473: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 68.91. US: Russian Int in US].

Fig. D.474: Todd Rider [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3101–3200].

Fig. D.475: Todd Rider [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3101–3200].

Fig. D.476: Todd Rider [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3101–3200].

Fig. D.477: Todd Rider [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3101–3200].

Fig. D.478: Todd Rider [NARA RG 38, Entry 98C, Box 12, Folder TSC # 3401–3500].

Fig. D.479: George Cully [AFHRA folder 122.25 Mar–July 1947].

Fig. D.480: Todd Rider.

Fig. D.481: Lori Rider.

Fig. D.482: Lori Rider.

Fig. D.483: Lori Rider.

Fig. D.484: Lori Rider.

Fig. D.485: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.486: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45].

Fig. D.487: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.42.B Germ Mat Res Captured Materials Heavy Water].

Fig. D.488: commons.wikimedia.org and public domain.

Fig. D.489: commons.wikimedia.org and public domain.

Fig. D.490: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)].

Fig. D.491: commons.wikimedia.org and public domain.

Fig. D.492: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.9132-1 Germ: Russ Int in Germ. Ind TA Leuna Werke].

Fig. D.493: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.9132-1 Germ: Russ Int in Germ. Ind TA Leuna Werke].

Fig. D.494: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.9132-1 Germ: Russ Int in Germ. Ind TA Leuna Werke].

Fig. D.495: David N. R. Bleecker [NARA RG GOUDS, Entry UD-7420, Box 3, Folder "Historian's Office Inventory Control Job Goudsmit Box 4 Folder 4"].

Fig. D.496: commons.wikimedia.org and public domain.

Fig. D.497: Norberto Lahuerta [NARA RG 319, Entry NM3-85M, Box 51, Folders 926136–926139].

Fig. D.498: Norberto Lahuerta [NARA RG 319, Entry NM3-85M, Box 51, Folders 926136–926139].

Fig. D.499: Todd Rider [NARA RG 319, Entry A1-84E, Box 124].

Fig. D.500: commons.wikimedia.org and public domain.

Fig. D.501: Lori Rider.

Fig. D.502: Todd Rider.

Fig. D.503: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.504: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)].

Fig. D.505: commons.wikimedia.org.

Fig. D.506: Silke Fengler.

Fig. D.507: Silke Fengler.

Fig. D.508: U.S. government, public domain.

Fig. D.509: P. J. Eisenbauer.

Fig. D.510: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)].

Fig. D.511: Todd Rider [NARA RG 77, Entry UD-22A, Box 175, Folder World].

Fig. D.512: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)].

Fig. D.513: David N. R. Bleecker [NARA RG GOUDS, Entry UD-7420, Box 6, Folder ALSOS—Reports and Operations].

Fig. D.514: Todd Rider [NARA RG GOUDS, Entry UD-7420, Box 6, Folder ALSOS—Reports and Operations].

Fig. D.515: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1 GERMANY—Research—TA—(1943–June 1946)].

Fig. D.516: Todd Rider [FIAT 295].

Fig. D.517: Todd Rider [FIAT 750].

Fig. D.518: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Fig. D.519: Todd Rider [BIOS 158].

Fig. D.520: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Fig. D.521: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Australia].

Fig. D.522: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.523: Deutsches Museum Archive [G-35].

Fig. D.524: Deutsches Museum Archive [G-85].

Fig. D.525: Deutsches Museum Archive [G-153].

Fig. D.526: Deutsches Museum Archive [G-153].

Fig. D.527: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Ind. TA].

Fig. D.528: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Ind. TA].

Fig. D.529: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Ind. TA].

Fig. D.530: Todd Rider [FIAT 397].

Fig. D.531: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944), Philip Morrison to Samuel K. Allison, 20 December 1943, Report on Enemy Physics Literature: Survey Report P].

Fig. D.532: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)].

Fig. D.533: Todd Rider [BIOS 1595].

Fig. D.534: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.535: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.536: Todd Rider [BIOS 675].

Fig. D.537: Todd Rider [BIOS 675].

Fig. D.538: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Ind. TA].

Fig. D.539: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32 Germ. Ind. TA].

Fig. D.540: Todd Rider [FIAT 750].

Fig. D.541: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-1 GERMANY: Personnel (Mar 43–Dec 44)]

Fig. D.542: Norberto Lahuerta and commons.wikimedia.org.

Fig. D.543: Todd Rider [BIOS 1159].

Fig. D.544: Todd Rider [BIOS 1009 and BIOS 1615].

Fig. D.545: *Zeitschrift für Physik* 104:442–447 (1937).

Fig. D.546: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Fig. D.547: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Fig. D.548: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Fig. D.549: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Fig. D.550: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Fig. D.551: Stephen Walton [Halstead Exploitation Centre Report 10722, English translation].

Fig. D.552: Stephen Walton [Halstead Exploitation Centre Report 10722, English translation].

Fig. D.553: Stephen Walton [Halstead Exploitation Centre Report 10722, English translation].

Fig. D.554: U.S. government, public domain.

Fig. D.555: U.S. government, public domain.

Fig. D.556: Todd Rider [NARA RG 226, Entry 125, Box 6, Folder 78].

Fig. D.557: Todd Rider [NARA RG 226, Entry 125, Box 6, Folder 78].

Fig. D.558: Todd Rider [NARA RG 226, Entry 125, Box 6, Folder 78].

Fig. D.559: Todd Rider [NARA RG 226, Entry 125, Box 6, Folder 78].

Fig. D.560: commons.wikimedia.org.

Fig. D.561: David N. R. Bleecker [NARA RG GOUDS, Entry UD-7420, Box 3, Folder “Historian’s Office Inventory Control Job Goudsmit Box 4 Folder 6”].

Fig. D.562: Todd Rider.

Fig. D.563: Manuel Lukas [NARA RG 319, Entry A1-134B, Box ??, Folder XE170590 Schumann, Erich].

Fig. D.564 Todd Rider [NARA RG 226, Entry A1-210, Box 447, Folder WN 16162–16171].

Fig. D.565 Todd Rider [NARA RG 226, Entry A1-210, Box 447, Folder WN 16162–16171].

Fig. D.566 Todd Rider [NARA RG 226, Entry A1-210, Box 447, Folder WN 16162–16171].

Fig. D.567 Todd Rider [NARA RG 226, Entry A1-210, Box 447, Folder WN 16162–16171].

Fig. D.568: Todd Rider [Bundesarchiv Militärarchiv Freiburg N822/17].

Fig. D.569: Todd Rider [Bundesarchiv Militärarchiv Freiburg N822/17].

Fig. D.570: Todd Rider [Bundesarchiv Militärarchiv Freiburg N822/17].

Fig. D.571: Günter Nagel [Archiv der Max-Planck-Gesellschaft, I. Abteilung, Rep. 34, Nr. 105].

Fig. D.572: Günter Nagel [Archiv der Max-Planck-Gesellschaft, I. Abteilung, Rep. 34, Nr. 105].

Fig. D.573: Günter Nagel [Archiv der Max-Planck-Gesellschaft, I. Abteilung, Rep. 34, Nr. 105].

Fig. D.574: Stephen Walton [Halstead Exploitation Centre Report 2590, English translation].

Fig. D.575: Stephen Walton [Halstead Exploitation Centre Report 2590, English translation].

Fig. D.576: Stephen Walton [Halstead Exploitation Centre Report 2590, English translation].

Fig. D.577: Stephen Walton [Halstead Exploitation Centre Report 2590, English translation].

Fig. D.578: Stephen Walton [Halstead Exploitation Centre Report 2590, English translation].

Fig. D.579: Stephen Walton [Halstead Exploitation Centre Report 2590, English translation].

Fig. D.580: Stephen Walton [Halstead Exploitation Centre Report 5919, English translation].

Fig. D.581: Stephen Walton [Halstead Exploitation Centre Report 5919, English translation].

Fig. D.582: Deutsches Museum Archive FA 002/0721 [https://digital.deutsches-museum.de/item/FA-002-721/].

Fig. D.583: Deutsches Museum Archive FA 002/0721 [https://digital.deutsches-museum.de/item/FA-002-721/].

Fig. D.584: Deutsches Museum Archive FA 002/0721 [https://digital.deutsches-museum.de/item/FA-002-721/].

Fig. D.585: Rainer Karlsch.

Fig. D.586: Rainer Karlsch.

Fig. D.587: Rainer Karlsch.

Fig. D.588: Rainer Karlsch [AMPG, Abt. III, Rep. 83, Nr. 286].

Fig. D.589: European Patent Office, German patent DE977825, public domain.

Fig. D.590: European Patent Office, German patent DE977825, public domain.

Fig. D.591: European Patent Office, German patent DE977825, public domain.

Fig. D.592: European Patent Office, German patent DE977825, public domain.

Fig. D.593: European Patent Office, German patent DE977825, public domain.

Fig. D.594: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret].

Fig. D.595: Manuel Lukas [NARA RG 319, Entry A1-134B, Box ??, Folder XE098301 Trinks, Walter].

Fig. D.596: Manuel Lukas [NARA RG 319, Entry A1-134B, Box ??, Folder XE098301 Trinks, Walter].

Fig. D.597: European Patent Office, U.K. Patent 841,387, public domain.

Fig. D.598: [Diebner 1962].

Fig. D.599: [Diebner 1962].

Fig. D.600: Todd Rider [redrawn from Diebner 1962].

Fig. D.601: Lori Rider.

Fig. D.602: David N. R. Bleecker [NARA RG 165, Entry NM84-79, Box 1915, PW Intelligence Bulletin 1/47, 13 March 1945].

Fig. D.603: Todd Rider [NARA RG 165, Entry NM84-187, Box 137, Folder BW 55].

Fig. D.604: European Patent Office, German Patent DE 662036, public domain.

Fig. D.605: European Patent Office, German Patent DE 662036, public domain.

Fig. D.606: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.607: European Patent Office, U.K. Patent GB 508,233, public domain.

Fig. D.608: U.S. Patent and Trademark Office, U.S. patent 2,251,190, public domain.

Fig. D.609: U.S. Patent and Trademark Office, U.S. patent 2,251,190, public domain.

Fig. D.610: U.S. Patent and Trademark Office, U.S. patent 2,288,717, public domain.

Fig. D.611: U.S. Patent and Trademark Office, U.S. patent 2,288,717, public domain.

Fig. D.612: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

Fig. D.613: Deutsches Museum Archive FA 002/700 [https://digital.deutsches-museum.de/item/FA-002-700/].

Fig. D.614: Deutsches Museum Archive FA 002/700 [https://digital.deutsches-museum.de/item/FA-002-700/].

Fig. D.615: Deutsches Museum Archive FA 002/700 [https://digital.deutsches-museum.de/item/FA-002-700/].

Fig. D.616: Deutsches Museum Archive FA 002/700 [https://digital.deutsches-museum.de/item/FA-002-700/].

Fig. D.617: Deutsches Museum Archive FA 002/700 [https://digital.deutsches-museum.de/item/FA-002-700/].

Fig. D.618: George Cully [CIOS XXXI-2 p. 74].

Fig. D.619: George Cully [CIOS X-13 Appendix B].

Fig. D.620: George Cully [CIOS ER 63, AFHRA folder 506.6202 Nr. 1–99 20 Apr–13 Jun 1945, IRIS 207658].

Fig. D.621: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder 32.32. Germ. Ind. TA].

Fig. D.622: Manuel Lukas [Technical Oil Mission Microfilm 119 (BM-6—Ludwigshaven), Folder LU III-2. https://www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOC_TOM-119.htm].

Fig. D.623: Manuel Lukas [Technical Oil Mission Microfilm 119 (BM-6—Ludwigshaven), Folder LU III-2. https://www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOC_TOM-119.htm].

Fig. D.624: Manuel Lukas [Technical Oil Mission Microfilm 119 (BM-6—Ludwigshaven), Folder LU III-2. https://www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOC_TOM-119.htm].

Fig. D.625: Manuel Lukas [Technical Oil Mission Microfilm 119 (BM-6—Ludwigshaven), Folder LU III-2. https://www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOC_TOM-119.htm].

Fig. D.626: Manuel Lukas [Technical Oil Mission Microfilm 119 (BM-6—Ludwigshaven), Folder LU III-2. https://www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOC_TOM-119.htm].

Fig. D.627: Manuel Lukas [Technical Oil Mission Microfilm 119 (BM-6—Ludwigshaven), Folder LU III-2. https://www.fischer-tropsch.org/Tom%20Reels/Linked/TOM%20119%20Partial/TOC_TOM-119.htm].

Fig. D.628: G-378. Georg Stetter. Technische Energiegewinnung mit Hilfe von Kernreaktionen. FA 002/0762. Deutsches Museum Archive, Munich. https://digital.deutsches-museum.de/item/FA-002-762/

Fig. D.629: G-378. Georg Stetter. Technische Energiegewinnung mit Hilfe von Kernreaktionen. FA 002/0762. Deutsches Museum Archive, Munich. https://digital.deutsches-museum.de/item/FA-002-762/

Fig. D.630: Todd Rider [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3001–3100. NARA RG 319, Entry A1-134A, Box 31, Folder 02/006 430.].

Fig. D.631: Todd Rider [NARA RG 319, Entry A1-134B, Box 749, Folder 23 Nov 95 Georg Stetter XA001081. NARA RG 330, Entry A1-1B, Box 103, Folder Lintner, Karl.].

Fig. D.632: Rainer Karlsch.

Fig. D.633: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Fig. D.634: *Zeitschrift für Naturforschung.* 2a:245–249 (1947).
[https://doi.org/10.17617/3.GRUJYR].

Fig. D.635: Todd Rider collection.

Fig. D.636: Frank Döbert [TNA FO 1031/57].

Fig. D.637: Frank Döbert [TNA FO 1031/57].

Fig. D.638: Frank Döbert [TNA FO 1031/112].

Fig. D.639: Frank Döbert [TNA FO 1031/112].

Fig. D.640: Frank Döbert [TNA FO 1031/112].

Fig. D.641: Frank Döbert [TNA FO 1031/112].

Fig. D.642: Todd Rider [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3001–3100]

Fig. D.643: Todd Rider [NARA RG 38, Entry 98C, Box 11, Folder TSC # 3001–3100]

Fig. D.644: Top: [Diebner 1962]. Bottom: [Winterberg 1981].

Fig. D.645: [Winterberg 1981].

Fig. D.646: Courtesy of Deutsches Museum Archive, NL 080/270-66, final page.

Fig. D.647: Todd Rider [NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.].

Fig. D.648: Todd Rider [NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.].

Fig. D.649: Todd Rider [NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.].

Fig. D.650: Todd Rider [NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.].

Fig. D.651: Todd Rider [NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.].

Fig. D.652: Todd Rider [NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.].

Fig. D.653: Todd Rider [NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.].

Fig. D.654: Todd Rider [NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.].

Fig. D.655: Todd Rider [NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.].

Fig. D.656: Todd Rider [NARA RG 330, Entry A1-1B, Box 134, Folder Richter, Ronald W. Dr.].

Fig. D.657: Todd Rider [AFHRA A1260 frame 0951].

Fig. D.658: Todd Rider [AFHRA A5729 frame 1148].

Fig. D.659: commons.wikimedia.org and Norberto Lahuerta.

Fig. D.660: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

Fig. D.661: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.662: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

Fig. D.663: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-2 GERMANY: US Wartime Positive Int. (July–Oct. 44)].

Fig. D.664: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Fig. D.665: George Cully [AFHRA folder 570.620-1 17 July 1945].

Fig. D.666: George Cully [AFHRA folder 570.620-1 17 July 1945].

Fig. D.667: Todd Rider [AFHRA folder 533.619-5 1945].

Fig. D.668: Todd Rider [AFHRA folder 533.619-5 1945].

Fig. D.669: Todd Rider [AFHRA folder 533.619-5 1945].

Fig. D.670: Todd Rider [AFHRA folder 533.619-5 1945].

Fig. D.671: Todd Rider [AFHRA folder 533.619-5 1945].

Fig. D.672: Todd Rider [AFHRA folder 533.619-5 1945].

Fig. D.673: Todd Rider [NARA RG 330, Entry A1-1B, Box 35, Folder Edse, Rudolf] and https://www.geni.com/people/Rudolf-Zinsser/6000000016349874663.

Fig. D.674: Todd Rider [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700].

Fig. D.675: Todd Rider [NARA RG 330, Entry A1-1B, Box 35, Folder Edse, Rudolf].

Fig. D.676: Todd Rider [NARA RG 330, Entry A1-1B, Box 35, Folder Edse, Rudolf].

Fig. D.677: U.S. government and public domain.

Fig. D.678: U.S. government, public domain, courtesy of Marek Michalski.

Fig. D.679: George Cully [AFHRA folder 506.61952 Nos. 2/25–2/31 9–25 Jan 1945, IRIS 207531].

Fig. D.680: George Cully [AFHRA folder 506.61952 Nos. 2/25–2/31 9–25 Jan 1945, IRIS 207531].

Fig. D.681: George Cully [AFHRA folder 506.61952 Nos. 2/25–2/31 9–25 Jan 1945, IRIS 207531].

Fig. D.682: George Cully [AFHRA folder 506.61952 Nos. 2/25–2/31 9–25 Jan 1945, IRIS 207531].

Fig. D.683: George Cully [AFHRA folder 506.61952 Nos. 2/25–2/31 9–25 Jan 1945, IRIS 207531].

Fig. D.684: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.685: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.686: Norberto Lahuerta [NARA RG 319, Entry 85A, Box 2534, Folder 390731–390740].

Fig. D.687: Todd Rider [NARA RG 77, Entry UD-22A, Box 173, Folder 57.70 Poland Misc].

Fig. D.688: commons.wikimedia.org and public domain.

Fig. D.689: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.690: commons.wikimedia.org and public domain.

Fig. D.691: Lori Rider [US Holocaust Memorial Museum, RG-15.169M (1998.A.0247) microfilm reel 8].

Fig. D.692: Lori Rider [US Holocaust Memorial Museum, RG-15.169M (1998.A.0247) microfilm reel 8].

Fig. D.693: Lori Rider [US Holocaust Memorial Museum, RG-15.169M (1998.A.0247) microfilm reel 8].

Fig. D.694: Lori Rider [US Holocaust Memorial Museum, RG-15.169M (1998.A.0247) microfilm reel 8].

Fig. D.695: Lori Rider [US Holocaust Memorial Museum, RG-15.169M (1998.A.0247) microfilm reel 8].

Fig. D.696: Lori Rider [US Holocaust Memorial Museum, RG-15.169M (1998.A.0247) microfilm reel 8].

Fig. D.697: Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 37, courtesy of Rainer Karlsch.

Fig. D.698: Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 37, courtesy of Rainer Karlsch.

Fig. D.699: Courtesy of Deutsches Museum Archive, photo CD74787.

Fig. D.700: Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 37, courtesy of Rainer Karlsch.

Fig. D.701: Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 37, courtesy of Rainer Karlsch.

Fig. D.702: Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 37, courtesy of Rainer Karlsch.

Fig. D.703: Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 37, courtesy of Rainer Karlsch.

Fig. D.704: Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 24–25, courtesy of Rainer Karlsch and Heiko Petermann.

Fig. D.705: Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 24–25, courtesy of Rainer Karlsch and Heiko Petermann.

Fig. D.706: Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 24–25, courtesy of Rainer Karlsch and Heiko Petermann.

Fig. D.707: Archive of the President of the Russian Federation, Fund 93, Division 81 (45), List 24–25, courtesy of Rainer Karlsch and Heiko Petermann.

Fig. D.708: commons.wikimedia.org and public domain.

Fig. D.709: commons.wikimedia.org.

Fig. D.710: Lori Rider.

Fig. D.711: commons.wikimedia.org.

Fig. D.712: Todd Rider.

Fig. D.713: commons.wikimedia.org.

Fig. D.714: Todd Rider.

Fig. D.715: commons.wikimedia.org.

Fig. D.716: commons.wikimedia.org and public domain.

Fig. D.717: commons.wikimedia.org.

Fig. D.718: Archive of the President of the Russian Federation, Fund 93, Division 77 (45), List 4–11 [Riabev 2006c, pp. 60–64].

Fig. D.719: Archive of the President of the Russian Federation, Fund 93, Division 77 (45), List 4–11 [Riabev 2006c, pp. 60–64].

Fig. D.720: Archive of the President of the Russian Federation, Fund 93, Division 77 (45), List 4–11 [Riabev 2006c, pp. 60–64].

Fig. D.721: Archive of the President of the Russian Federation, Fund 93, Division 77 (45), List 4–11 [Riabev 2006c, pp. 60–64].

Fig. D.722: Todd Rider [NARA RG 77, Entry UD-22A, Box 174, Folder 10.70 Austria Misc].

Fig. D.723: Archive of the President of the Russian Federation, courtesy of Rainer Karlsch.

Fig. D.724: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder 205.2 Cables Incoming, Top Secret January 1946 thru December 1946].

Fig. D.725: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder In & Out July 16, 1946–Jan. 1947].

Fig. D.726: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder 205.3 Cables Outgoing, Secret and Under January 1946 thru December 1946].

Fig. D.727: U.S. government, public domain, via Gunther Hebestreit.

Fig. D.728: U.S. government, public domain, via Gunther Hebestreit.

Fig. D.729: U.S. government, public domain, via Gunther Hebestreit.

Fig. D.730: U.S. government, public domain, via Gunther Hebestreit.

Fig. D.731: U.S. government, public domain, via Gunther Hebestreit.

Fig. D.732: Todd Rider.

Fig. D.733: Todd Rider.

Fig. D.734: Todd Rider.

Fig. D.735: Heiko Petermann.

Fig. D.736: Lori Rider.

Fig. D.737: [Ziegert 2011].

Fig. D.738: U.S. Holocaust Memorial Museum, public domain.

Fig. D.739: Lori Rider.

Fig. D.740: Todd Rider collection.

Fig. D.741: Todd Rider.

Fig. D.742: U.S. government, commons.wikimedia.org, and public domain.

Fig. D.743: commons.wikimedia.org.

Fig. D.744: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.745: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.746: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.747: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.748: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.749: Todd Rider [AFHRA A1261 electronic version pp. 31 (top) and 27 (bottom)].

Fig. D.750: commons.wikimedia.org.

Fig. D.751: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.752: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.753: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.754: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)].

Fig. D.755: Todd Rider [NARA RG 77, Entry UD-22A, Box 166, Folder 32.22-1—GERMANY—Research—TA—(1943–June 1946)].

Fig. D.756: [Weingand 1995, pp. 60–61; https://diglib.tugraz.at/die-technische-hochschule-graz-im-dritten-reich-1995].

Fig. D.757: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.758: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.759: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.760: https://www.cia.gov/readingroom/docs/OSS%20-%20SSU%20-%20CIG%20EARLY%20CIA%20DOCUMENTS%20%20%20VOL.%205_0008.pdf

Fig. D.761: https://www.cia.gov/readingroom/docs/OSS%20-%20SSU%20-%20CIG%20EARLY%20CIA%20DOCUMENTS%20%20%20VOL.%205_0008.pdf

Fig. D.762: commons.wikimedia.org.

Fig. D.763: Matthias Uhl [FSB Archive, Moscow].

Fig. D.764: Matthias Uhl [FSB Archive, Moscow].

Fig. D.765: Matthias Uhl [FSB Archive, Moscow].

Fig. D.766: Matthias Uhl [FSB Archive, Moscow].

Fig. D.767: Matthias Uhl [FSB Archive, Moscow].

Fig. D.768: Matthias Uhl [FSB Archive, Moscow].

Fig. D.769: Matthias Uhl [FSB Archive, Moscow].

Fig. D.770: Matthias Uhl [FSB Archive, Moscow].

Fig. D.771: Matthias Uhl [FSB Archive, Moscow].

Fig. D.772: Matthias Uhl [FSB Archive, Moscow].

Fig. D.773: Matthias Uhl [FSB Archive, Moscow].

Fig. D.774: Matthias Uhl [FSB Archive, Moscow].

Fig. D.775: Matthias Uhl [FSB Archive, Moscow].

Fig. D.776: Matthias Uhl [FSB Archive, Moscow].

Fig. D.777: Matthias Uhl [FSB Archive, Moscow].

Fig. D.778: Matthias Uhl [FSB Archive, Moscow].

Fig. D.779: Todd Rider [NARA RG 226, Entry UD-90, Box 6, Folder 64 SUNRISE].

Fig. D.780: Todd Rider [NARA RG 226, Entry UD-90, Box 6, Folder 64 SUNRISE].

Fig. D.781: George Cully [AFHRA folder 512.619C-6C 1944–1945].

Fig. D.782: George Cully [AFHRA folder 512.619C-6C 1944–1945].

Fig. D.783: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946); Box 174, Folder 10.70 Austria Misc].

Fig. D.784: George Cully [C.S.D.I.C. (U.K.) G.R.G.G. 341, AFHRA folder 512.619C-5F 1945, IRIS 212009].

Fig. D.785: George Cully [C.S.D.I.C. (U.K.) G.R.G.G. 341, AFHRA folder 512.619C-5F 1945, IRIS 212009].

Fig. D.786: George Cully [C.S.D.I.C. (U.K.) G.R.G.G. 341, AFHRA folder 512.619C-5F 1945, IRIS 212009].

Fig. D.787: George Cully [C.S.D.I.C. (U.K.) G.R.G.G. 341, AFHRA folder 512.619C-5F 1945, IRIS 212009].

Fig. D.788: NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb, https://downloads.paperlessarchives.com, pp. 11,357–11,361.

Fig. D.789: NARA RG 227, Microfilm M1392, Bush-Conant File Relating to the Development of the Atomic Bomb, https://downloads.paperlessarchives.com, pp. 11,357–11,361.

Fig. D.790: Norberto Lahuerta [Franklin Delano Roosevelt Library, Hyde Park, New York, Margaret Suckley Papers, Journal Group E, 06/30/1944-12/29/1944, Journal Entry 1-253, 9 December 1944].

Fig. D.791: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.792: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.793: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.794: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.795: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.796: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.797: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.798: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.799: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.800: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.801: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.802: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

Fig. D.803: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

Fig. D.804: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

Fig. D.805: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

Fig. D.806: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

Fig. D.807: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

Fig. D.808: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

Fig. D.809: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

Fig. D.810: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-1 GERMANY: US Wartime Positive Int. (July 42–June 44)].

Fig. D.811: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.812: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

Fig. D.813: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.814: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.815: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.816: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.817: Todd Rider [NARA RG 77, Entry UD-22A, Box 170, Folder 32.60-1 GERMANY: Summary Reports (1944)].

Fig. D.818: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.819: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

Fig. D.820: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

Fig. D.821: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

Fig. D.822: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 203.11—Tech. Countermeasures + RW—1943–1944].

Fig. D.823: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.824: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.825: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.826: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.827: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.828: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.829: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.830: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.831: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.832: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.833: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.834: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.835: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.836: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.837: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.838: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.839: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 Germany: Summary Reports (1945–1946)].

Fig. D.840: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

Fig. D.841: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

Fig. D.842: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

Fig. D.843: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

Fig. D.844: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

Fig. D.845: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

Fig. D.846: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

Fig. D.847: Todd Rider [NARA RG GOUDS, Entry UD-7420].

Fig. D.848: Todd Rider [NARA RG GOUDS, Entry UD-7420].

Fig. D.849: Todd Rider [NARA RG GOUDS, Entry UD-7420].

Fig. D.850: Todd Rider [NARA RG GOUDS, Entry UD-7420].

Fig. D.851: Todd Rider [NARA RG GOUDS, Entry UD-7420].

Fig. D.852: Todd Rider [NARA RG GOUDS, Entry UD-7420].

Fig. D.853: Todd Rider [NARA RG GOUDS, Entry UD-7420].

Fig. D.854: Todd Rider [NARA RG GOUDS, Entry UD-7420].

Fig. D.855: Todd Rider [FIAT 63].

Fig. D.856: Todd Rider [FIAT 63].

Fig. D.857: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Fig. D.858: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Fig. D.859: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Fig. D.860: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Fig. D.861: Todd Rider [NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel].

Fig. D.862: Todd Rider [NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel].

Fig. D.863: Todd Rider [NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel].

Fig. D.864: Todd Rider [NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel].

Fig. D.865: Todd Rider [NARA RG 319, Entry A1-134B, Box 749, Folder 23 Nov 95 Georg Stetter XA001081].

Fig. D.866: Todd Rider [NARA RG 319, Entry A1-134B, Box 749, Folder 23 Nov 95 Georg Stetter XA001081].

Fig. D.867: Todd Rider [NARA RG 319, Entry A1-134B, Box 749, Folder 23 Nov 95 Georg Stetter XA001081].

Fig. D.868: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.].

Fig. D.869: Norberto Lahuerta [TNA FO 800/565, Henry Maitland Wilson to John Anderson, 26 October 1945].

Fig. D.870: Norberto Lahuerta [TNA FO 800/565, Henry Maitland Wilson to John Anderson, 26 October 1945].

Fig. D.871: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.].

Fig. D.872: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.873: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.874: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.875: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.876: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.877: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.878: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.879: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.880: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.881: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.882: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.883: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.884: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.885: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.886: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.887: Todd Rider [NARA RG 77, Entry UD-22A].

Fig. D.888: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

Fig. D.889: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.3-1 LONDON OFFICE: Combined Intell Rpts.].

Fig. D.890: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder Foreign Intelligence Unit Index].

Fig. D.891: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder Foreign Intelligence Unit Index].

Fig. D.892: Todd Rider [Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945–1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010].

Fig. D.893: Todd Rider [Nationaal Archief (Den Haag), Ministerie van Justitie Bureaus Kabinet en Juridische Zaken van de Afdeling Politie (1932-) 1945–1952 (-1968), Blok J36, Toegang 2.09.107, Inv. nr. 931].

Fig. D.894: Todd Rider [Nationaal Archief (Den Haag), Ministerie van Justitie Bureaus Kabinet en Juridische Zaken van de Afdeling Politie (1932-) 1945–1952 (-1968), Blok J36, Toegang 2.09.107, Inv. nr. 931].

Fig. D.895: Todd Rider [Nationaal Archief (Den Haag), Ministerie van Justitie Bureaus Kabinet en Juridische Zaken van de Afdeling Politie (1932-) 1945–1952 (-1968), Blok J36, Toegang 2.09.107, Inv. nr. 931].

Fig. D.896: Todd Rider [Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945–1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010].

Fig. D.897: Todd Rider [Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945–1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010].

Fig. D.898: Todd Rider [Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945–1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010].

Fig. D.899: Todd Rider [Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945–1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010].

Fig. D.900: Todd Rider [Nationaal Archief (Den Haag), Ministerie van Buitenlandse Zaken 1945–1954, Blok Z36, Toegang 2.05.117, Inv. nr. 25010; Archief van het Ministerie van Buitenlandse Zaken (Londens Archief) (1936) 1940–1945 (1958), Blok Z27018, Toegang 2.05.80, Inv. nr. 5666].

Fig. D.901: Todd Rider [NARA RG 77, Entry UD-22A, Box 169, Folder British Liason].

Fig. D.902: Todd Rider [NARA RG GOUDS, Entry UD-7420, Box 3].

Fig. D.903: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. D.904: Archives of the French Army Ministry of Defense, courtesy of Norberto Lahuerta.

Fig. D.905: U.S. government, public domain.

Fig. D.906: Todd Rider [NARA RG 38, Entry UD-38, Box 13, Folder U-234 and RG 330, Entry A1-1B, Box 145, Folder Schlicke, Heinz].

Fig. D.907: Todd Rider [NARA Boston RG 181].

Fig. D.908: Todd Rider [NARA Boston RG 181].

Fig. D.909: Todd Rider [NARA Boston RG 181].

Fig. D.910: Todd Rider [NARA Boston RG 181].

Fig. D.911: Todd Rider [NARA Boston RG 181].

Fig. D.912: Todd Rider [NARA Boston RG 181].

Fig. D.913: Todd Rider [NARA Boston RG 181].

Fig. D.914: Todd Rider [NARA RG 38, Entry UD-16, Box 4, Folder Manifest of U-234].

Fig. D.915: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.916: David N. R. Bleecker [NARA RG GOUDS, Entry UD-7420, Box 3, Folder "Historian's Office Inventory Control Job Goudsmit Box 4 Folder 6"].

Fig. D.917: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.918: Frank Döbert [TNA FO 1031/57].

Fig. D.919: Frank Döbert [TNA FO 1031/57].

Fig. D.920: Manuel Lukas [NARA RG 242, Records of the Reich Leader of the Schutzstaffel (SS) and Chief of the German Police, Microfilm 183, NAID 273992206 (https://catalog.archives.gov/id/273992206)].

Fig. D.921: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder Apr 45—Dec. '45].

Fig. D.922: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Fig. D.923: Norberto Lahuerta [NARA RG 238, Entry NM70-160, Box 26, Folder: Hq—FIFTEENTH USA Reports—TIC-PIR / Interr. Kaltenbrunner].

Fig. D.924: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 196, Folder XE061504 Fiebinger, Karl].

Fig. D.925: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 196, Folder XE061504 Fiebinger, Karl].

Fig. D.926: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 196, Folder XE061504 Fiebinger, Karl].

Fig. D.927: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].

Fig. D.928: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].

Fig. D.929: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].

Fig. D.930: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].

Fig. D.931: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].

Fig. D.932: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].

Fig. D.933: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].

Fig. D.934: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].

Fig. D.935: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].

Fig. D.936: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].

Fig. D.937: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].

Fig. D.938: Manuel Lukas [NARA RG 319, Entry A1-134B, Box 831, Folder XE065651 Voss, Wilhelm].

Fig. D.939: Courtesy of Rainer Karlsch; published in Reuter et al. 2019, p. 168.

Fig. D.940: Manuel Lukas [https://digital.library.cornell.edu/catalog/nur01453].

Fig. D.941: Manuel Lukas [https://digital.library.cornell.edu/catalog/nur01453].

Fig. D.942: George Cully [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

Fig. D.943: George Cully [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

Fig. D.944: George Cully [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

Fig. D.945: George Cully [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

Fig. D.946: George Cully [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

Fig. D.947: George Cully [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

Fig. D.948: George Cully [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

Fig. D.949: George Cully [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

Fig. D.950: George Cully [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

Fig. D.951: George Cully [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

Fig. D.952: George Cully [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

Fig. D.953: George Cully [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

Fig. D.954: George Cully [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

Fig. D.955: George Cully [AFHRA folder 570.605 1944–46, Misc. Documents G-2 Miscellaneous Data].

Fig. D.956: Todd Rider [NARA RG 77, Entry UD-22A, Box 174, Folder 10.10. Austria Personnel].

Fig. D.957: Tom Kunkle [NARA RG 260, DN1929, Roll 0126, pp. 26 ff.].

Fig. D.958: Tom Kunkle [NARA RG 260, DN1929, Roll 0126, pp. 26 ff.].

Fig. D.959: Todd Rider [AFHRA folder 570.6501A 1945–46, Special Projects—Current].

Fig. D.960: Tammy Horton [AFHRA C5098 frames 0886–0890].

Fig. D.961: Tammy Horton [AFHRA 00043922 SQ-BOMB-34-HI 1–31 July 1945].

Fig. D.962: Tammy Horton [AFHRA 00043922 SQ-BOMB-34-HI 1–31 July 1945].

Fig. D.963: Tammy Horton [AFHRA 00043922 SQ-BOMB-34-HI 1–31 July 1945].

Fig. D.964: Rudolf Haunschmied.

Fig. D.965: U.S. Holocaust Memorial Museum, public domain.

Fig. D.966: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45].

Fig. D.967: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45].

Fig. D.968: commons.wikimedia.org and public domain.

Fig. D.969: U.S. Holocaust Memorial Museum, public domain.

Fig. D.970: Todd Rider.

Fig. D.971: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder APR 45–Dec. '45].

Fig. D.972: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

Fig. D.973: Todd Rider [NARA RG 38, Entry 98C, Box 12, Folder TSC # 3301–3400. Vladimir L. Rychly, 5 December 1946].

Fig. D.974: Todd Rider [NARA RG 38, Entry 98C, Box 12, Folder TSC # 3301–3400. Vladimir L. Rychly, 5 December 1946].

Fig. D.975: Todd Rider [NARA RG 38, Entry 98C, Box 12, Folder TSC # 3301–3400. Vladimir L. Rychly, 5 December 1946].

Fig. D.976: PB 123064. *Underground Installations: Foreign Installations* [Library of Congress].

Fig. D.977: PB 123064. *Underground Installations: Foreign Installations* [Library of Congress].

Fig. D.978: PB 123064. *Underground Installations: Foreign Installations* [Library of Congress].

Fig. D.979: PB 123064. *Underground Installations: Foreign Installations* [Library of Congress].

Fig. D.980: PB 123064. *Underground Installations: Foreign Installations* [Library of Congress].

Fig. D.981: PB 123064. *Underground Installations: Foreign Installations* [Library of Congress].

Fig. D.982: Todd Rider [NARA RG 330, Entry A1-1B].

Fig. D.983: Todd Rider [NARA RG 330, Entry A1-1B, Box 66].

Fig. D.984: Manuel Lukas [NARA RG 319, Entry A1-134B, Box ??, Folder XE301420 Haxel, Otto].

Fig. D.985: Todd Rider [NARA RG 330, Entry A1-1B, Box 43, Folder Flügge, Siegfried].

Fig. D.986: Todd Rider [NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge].

Fig. D.987: Todd Rider [NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge].

Fig. D.988: Todd Rider [NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge].

Fig. D.989: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 202.3-2 LONDON OFFICE: Combined Oper Ger Group].

Fig. D.990: Todd Rider [NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge].

Fig. D.991: Todd Rider [NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge].

Fig. D.992: Todd Rider [NARA RG 319, Entry A1-134B, Box 202, Folder XE196681 Siegfried Fluegge].

Fig. D.993: David N. R. Bleecker [NARA RG GOUDS, Entry UD-7420, Box 3, Folder "Historian's Office Inventory Control Job Goudsmit Box 4 Folder 4"].

Fig. D.994: Todd Rider [AFHRA A2055 Frames 1173, 1362].

Fig. D.995: Frank Döbert [AFHRA C5094 frames 0957–0958].

Fig. D.996: Norberto Lahuerta [NARA RG 40, Entry 75, Box 62].

Fig. D.997: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.998: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.7003-3 GERMANY: US Wartime Positive Int. (Nov. 44–June 45)].

Fig. D.999: Todd Rider [NARA RG 226, Entry A1-134, Box 219, Folder 1371: OUT AZUSA Nov. '43 Sept. '45].

Fig. D.1000: Todd Rider [NARA RG 77, Entry UD-22A, Box 168, Folder 202.2 LONDON OFFICE: Combined Intell Disc.].

Fig. D.1001: Todd Rider [NARA RG 77, Entry UD-22A, Box 160, Folder Apr 45–Dec. '45].

Fig. D.1002: [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Fig. D.1003: [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Fig. D.1004: [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Fig. D.1005: [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Fig. D.1006: [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Fig. D.1007: [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Fig. D.1008: [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Fig. D.1009: [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Fig. D.1010: [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Fig. D.1011: [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Fig. D.1012: [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Fig. D.1013: [Princeton University Library, Special Collections, Moe Berg Papers (C1413), Box 20, Folder 3—Loose Notes: Central Intelligence Agency].

Fig. D.1014: Todd Rider [NARA RG 77, Entry UD-22A, Box 163, Folder Czechoslovakia].

Fig. D.1015: Todd Rider [NARA RG 40, Entry UD-75, Box 3, Folder Press Releases].

Fig. D.1016: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Fig. D.1017: Todd Rider [NARA RG 77, Entry UD-22A, Box 167, Folder 32.12-2 GERMANY: Personnel (Jan 45–Dec 45)].

Fig. D.1018: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.1019: Todd Rider [NARA RG 77, Entry UD-22A, Box 171, Folder 32.60-2 GERMANY: Summary Reports (1945–1946)].

Fig. D.1020: Woods 1946.

Fig. D.1021: Todd Rider [NARA RG 319, Entry A1-84E, Box 124].

Fig. D.1022: Todd Rider [NARA RG 319, Entry A1-84E, Box 124].

Fig. D.1023: Todd Rider.

Fig. D.1024: Todd Rider.

Fig. D.1025: Todd Rider.

Fig. D.1026: Todd Rider.

Fig. D.1027: Todd Rider.

Fig. D.1028: Todd Rider.

Fig. D.1029: Todd Rider.

Fig. D.1030: Todd Rider.

Fig. D.1031: Manhattan District History. Book I, Volume 12, Part 1, p. 12.5.
https://ia803409.us.archive.org/14/items/ManhattanDistrictHistory/MDH-B1V12P01-General-CEW_Central_Facilities.pdf

Fig. D.1032: Manhattan District History. Book I, Volume 12, Part 2, Appendix C-7.
https://ia803409.us.archive.org/14/items/ManhattanDistrictHistory/MDH-B1V12P02-General-CEW_Central_Facilities_Appendices_A-C.pdf

Fig. D.1033: Todd Rider.

Fig. D.1034: Todd Rider.

Fig. D.1035: Todd Rider.

Fig. D.1036: U.S. government, commons.wikimedia.org, and public domain.

Fig. D.1037: https://commons.wikimedia.org/wiki/File:Fat_Man_Internal_Components.png

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Fig. E.3: commons.wikimedia.org and public domain.

Fig. E.4: commons.wikimedia.org and public domain.

Fig. E.5: commons.wikimedia.org and public domain.

Fig. E.6: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44].

Fig. E.7: George Cully [PW Intelligence Bulletin No 1/34, 5 February 1945, AFHRA folder 506.61951 Nos. 1/19–1/35 26 Dec 1944–7 Feb 1945, IRIS 207524].

Fig. E.8: *Life*, 27 August 1945.

Fig. E.9: *Life*, 27 August 1945.

Fig. E.10: U.S. Army, public domain.

Fig. E.11: U.S. Army, public domain.

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Fig. E.13: commons.wikimedia.org.

Fig. E.14: Frank Döbert.

Fig. E.15: Frank Döbert.

Fig. E.16: commons.wikimedia.org.

Fig. E.17: Todd Rider [Newton 1946].

Fig. E.18: Todd Rider [Newton 1946].

Fig. E.19: commons.wikimedia.org and public domain.

Fig. E.20: FOIA: Operation Harass and the Horton [sic: Horten] Brothers. Control Number: FP-10-027542. Activity Number: FA-10-4911. Initial Reception Date: 7/13/2010. Requested by: Jacobsen, Annie. pp. 202–205 and 318–325. [documents.theblackvault.com/documents/foia/4402F-12Greenewald_Redacted.pdf]

Fig. E.21: FOIA: Operation Harass and the Horton [sic: Horten] Brothers. Control Number: FP-10-027542. Activity Number: FA-10-4911. Initial Reception Date: 7/13/2010. Requested by: Jacobsen, Annie. pp. 202–205 and 318–325. [documents.theblackvault.com/documents/foia/4402F-12Greenewald_Redacted.pdf]

Fig. E.22: FOIA: Operation Harass and the Horton [sic: Horten] Brothers. Control Number: FP-10-027542. Activity Number: FA-10-4911. Initial Reception Date: 7/13/2010. Requested by: Jacobsen, Annie. pp. 202–205 and 318–325. [documents.theblackvault.com/documents/foia/4402F-12Greenewald_Redacted.pdf]

Fig. E.23: FOIA: Operation Harass and the Horton [sic: Horten] Brothers. Control Number: FP-10-027542. Activity Number: FA-10-4911. Initial Reception Date: 7/13/2010. Requested by: Jacobsen, Annie. pp. 202–205 and 318–325. [documents.theblackvault.com/documents/foia/4402F-12Greenewald_Redacted.pdf]

Fig. E.24: David N. R. Bleecker [NARA Still Pictures, RG 111 SCA—Records of the Chief Signal Officer. Prints: U.S. Army Signal Corps Photographs of Military Activity During WW II and the Korean Conflict, 1941–1954. Captured German Equipment, German, Box 3353, Book 15, SC 314829].

Fig. E.25: Courtesy of Deutsches Museum Archive, photo 9664.

Fig. E.26: Courtesy of Deutsches Museum Archive, photo 32307.

Fig. E.27: Historisch-Technisches Museum Versuchsstelle Kummersdorf.

Fig. E.28: Todd Rider.

Fig. E.29: Todd Rider.

Fig. E.30: Todd Rider.

Fig. E.31: commons.wikimedia.org and public domain.

Fig. E.32: Historisch-Technisches Museum Peenemünde, commons.wikimedia.org, and public domain.

Fig. E.33: Todd Rider.

Fig. E.34: Todd Rider.

Fig. E.35: Todd Rider.

Fig. E.36: Public domain.

Fig. E.37: commons.wikimedia.org.

Fig. E.38: [Przybilski 2002a].

Fig. E.39: U.S. government, public domain [heroicrelics.org/info/v-2/a-4-combustion-chamber.html].

Fig. E.40: Michael Haupt [TNA AVIA 40/717]. See also Henshall 2000, p. 123.

Fig. E.41: Todd Rider.

Fig. E.42: Todd Rider.

Fig. E.43: U.S. government, public domain.

Fig. E.44: U.S. government, public domain.

Fig. E.45: U.S. government, public domain.

Fig. E.46: Todd Rider.

Fig. E.47: Todd Rider.

Fig. E.48: Todd Rider.

Fig. E.49: U.S. government, public domain.

Fig. E.50: commons.wikimedia.org.

Fig. E.51: Frank Döbert [Zeitgeschichte Museum Ebensee, copy of original in Deutsches Museum Archive].

Fig. E.52: U.S. government, public domain.

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Fig. E.54: George Cully [PW Intelligence Bulletin No 1/57. AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527].

Fig. E.55: George Cully [PW Intelligence Bulletin No 1/57. AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527].

Fig. E.56: George Cully [PW Intelligence Bulletin No 1/57. AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527].

Fig. E.57: George Cully [PW Intelligence Bulletin No 1/57. AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527].

Fig. E.58: George Cully [PW Intelligence Bulletin No 1/57. AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527].

Fig. E.59: George Cully [PW Intelligence Bulletin No 1/57. AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527].

Fig. E.60: George Cully [PW Intelligence Bulletin No 1/57. AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527].

Fig. E.61: George Cully [PW Intelligence Bulletin No 1/57. AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527].

Fig. E.62: George Cully [PW Intelligence Bulletin No 1/57. AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527].

Fig. E.63: George Cully [PW Intelligence Bulletin No 1/57. AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527].

Fig. E.64: George Cully [PW Intelligence Bulletin No 1/57. AFHRA folder 506.61951 # 1/57 12 April 1945, IRIS 207527].

Fig. E.65: Courtesy of Deutsches Museum Archive, photo CD61663.

Fig. E.66: U.S. government, public domain.

Fig. E.67: Todd Rider [NARA RG 38, Entry 98C, Box 3, Folder TSC #1001–1100].

Fig. E.68: George Cully [AFHRA folder 519.6522-4].

Fig. E.69: George Cully [AFHRA folder 519.6522-4].

Fig. E.70 Top: Norberto Lahuerta. Bottom: Lori Rider.

Fig. E.71: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44].

Fig. E.72: Todd Rider [Princeton University Library, Allen Dulles Papers, Series 4, Subseries 4K: Telegrams d'etat, 1942–1945, 1942–1943, MC019.09_c44.pdf, https://findingaids.princeton.edu/catalog/MC019-09_c44].

Fig. E.73: George Cully [AFHRA folder 512.619C-15A 1943–1945].

Fig. E.74: George Cully [AFHRA folder 512.619C-15A 1943–1945].

Fig. E.75: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. E.76: Todd Rider [NARA RG 77, Entry UD-22A, Box 165, Folder ALSOS MATERIAL].

Fig. E.77: George Cully [AFHRA folder 519.635 1945 Intelligence Digest].

Fig. E.78: George Cully [AFHRA folder 519.635 1945 Intelligence Digest].

Fig. E.79: George Cully [AFHRA folder 519.635 1945 Intelligence Digest].

Fig. E.80: U.S. government, public domain, courtesy of Friedrich Georg.

Fig. E.81: U.S. government, public domain, courtesy of Friedrich Georg.

Fig. E.82: Todd Rider [NARA RG 407, Entry NM3-427, Box 12365, Folder 604-2.3 (1688-4) G-2 Jrnl File 4th Armd Div. 7–8 Apr 45].

Fig. E.83: [Gordon Cooper 1960].

Fig. E.84: Todd Rider.

Fig. E.85: Todd Rider.

Fig. E.86: commons.wikimedia.org/

Fig. E.87: Todd Rider [NARA RG 407, Entry NM3-427, Box 11005, Folder 389-2.2 G-2 Jrnl File—89th Inf Div. 8–9 Apr 45].

Fig. E.88: U.S. government, public domain, courtesy of Dietmar Staude and Tobias Keidel.

Fig. E.89: Todd Rider [NARA RG 407, Entry NM3-427, Box 11005, Folder 389-2.2 G-2 Jrnl File—89th Inf Div. 8–9 Apr 45].

Fig. E.90: Todd Rider [NARA RG 407, Entry NM3-427, Box 12365, Folder 604-2.3 (1688-4) G-2 Jrnl File 4th Armd Div. 7–8 Apr 45].

Fig. E.91: Todd Rider [NARA RG 407, Entry NM3-427, Box 11005, Folder 389-2.2 G-2 Jrnl File—89th Inf Div. 8–9 Apr 45].

Fig. E.92: Todd Rider [NARA RG 407, Entry NM3-427, Box 11005, Folder 389-2.2 G-2 Jrnl File—89th Inf Div. 8–9 Apr 45].

Fig. E.93: George Cully [AFHRA folder 519.650-1 Oct 1944–Dec 1945 Exploitation—Enemy Equipment].

Fig. E.94: NASA, public domain.

Fig. E.95: Gordon James Brown and the family of Heinz Stoelzel.

Fig. E.96: Gordon James Brown and the family of Heinz Stoelzel.

Fig. E.97: Gordon James Brown and the family of Heinz Stoelzel.

Fig. E.98: Gordon James Brown and the family of Heinz Stoelzel.

Fig. E.99: http://epizodsspace.airbase.ru/bibl/k-r/1998/5/fau2.html.

Fig. E.100: U.S. government, public domain.

Fig. E.101: U.S. government, public domain.

Fig. E.102: Collection Rudolf A. Haunschmied, from St. Georgen an der Gusen train station.

Fig. E.103: Todd Rider [NARA RG 331, Entry 83D, Box 33, Folder S.H.A.E.F. Releases (2 folders)/ 1 June 20 June 45].

Fig. E.104: Stephen Walton [CIOS XXXII-125].

Fig. E.105: Stephen Walton [CIOS XXXII-125].

Fig. E.106: Stephen Walton [CIOS XXXII-125].

Fig. E.107: Stephen Walton [CIOS XXXII-125].

Fig. E.108: Stephen Walton [CIOS XXXII-125].

Fig. E.109: Stephen Walton [CIOS XXXII-125].

Fig. E.110: Stephen Walton [CIOS XXXII-125].

Fig. E.111: Stephen Walton [CIOS XXXII-125].

Fig. E.112: Stephen Walton [CIOS XXXII-125].

Fig. E.113: Stephen Walton [CIOS XXXII-125].

Fig. E.114: Stephen Walton [CIOS XXXII-125].

Fig. E.115: Stephen Walton [CIOS XXXII-125].

Fig. E.116: Todd Rider [CIOS XXVIII-56].

Fig. E.117: Todd Rider [CIOS XXVIII-56].

Fig. E.118: Todd Rider [CIOS XXVIII-56].

Fig. E.119: Todd Rider [CIOS XXVIII-56].

Fig. E.120: Todd Rider [CIOS XXVIII-56].

Fig. E.121: Todd Rider [CIOS XXVIII-56].

Fig. E.122: Todd Rider [CIOS XXVIII-56].

Fig. E.123: Todd Rider [CIOS XXVIII-56].

Fig. E.124: Todd Rider [CIOS XXVIII-56].

Fig. E.125: Todd Rider [NavTechMisEu 237-45, NARA RG 38, Entry P5, Box 38].

Fig. E.126: Todd Rider [NavTechMisEu 237-45, NARA RG 38, Entry P5, Box 38].

Fig. E.127: Todd Rider [NavTechMisEu 237-45, NARA RG 38, Entry P5, Box 38].

Fig. E.128: Todd Rider [NavTechMisEu 237-45, NARA RG 38, Entry P5, Box 38].

Fig. E.129: Todd Rider [NavTechMisEu 237-45, NARA RG 38, Entry P5, Box 38].

Fig. E.130: Todd Rider [NavTechMisEu 237-45, NARA RG 38, Entry P5, Box 38].

Fig. E.131: Todd Rider [AFHRA A5186 frame 0965].

Fig. E.132: Todd Rider [AFHRA A5186 frame 0966].

Fig. E.133: https://www.gracesguide.co.uk/images/6/6d/ImILN12071946_003.jpg.

Fig. E.134: Archives of the French Army Ministry of Defense, courtesy of Norberto Lahuerta.

Fig. E.135: *Life*, 15 November 1945.

Fig. E.136: *Life*, 15 November 1945.

Fig. E.137: *Life*, 15 November 1945.

Fig. E.138: *Life*, 15 November 1945.

Fig. E.139: George Cully [AFHRA folder 570.650 May–Aug 1946].

Fig. E.140: Todd Rider [NARA RG 319, Records of the Army Staff, Entry A1-84E, Box 124. BID 8600.0711 Nuclear Physics (Atomic Energy)—Uses—Rockets].

Fig. E.141: Norberto Lahuerta [NARA RG 319, Entry NM3-85M, Box 47, Folder 926087 (former SD-3676)].

Fig. E.142: Norberto Lahuerta [NARA RG 319, Entry NM3-85M, Box 47, Folder 926087 (former SD-3676)].

Fig. E.143: commons.wikimedia.org.

Fig. E.144: commons.wikimedia.org.

Fig. E.145: *Life*, 5 October 1959, p. 30.
https://books.google.com/books?id=rkwEAAAAMBAJ&pg=PA30#v=onepage&q&f=false

Fig. E.146: Todd Rider [NARA RG 319, Entry NM3-85M, Box 19, Folder 925253].

Fig. E.147: Todd Rider [NARA RG 319, Entry NM3-85M, Box 19, Folder 925253].

Fig. E.148: Todd Rider.

Fig. E.149: Todd Rider.

Fig. E.150: Todd Rider [NARA RG 319, Entry NM3-85M, Box 19, Folder 925253].

Fig. E.151: Todd Rider [NARA RG 319, Entry NM3-85M, Box 19, Folder 925253].

Fig. E.152: Todd Rider [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700].

Fig. E.153: Todd Rider [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700].

Fig. E.154: Todd Rider [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700].

Fig. E.155: Todd Rider [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700].

Fig. E.156: Todd Rider [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700].

Fig. E.157: Todd Rider [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700].

Fig. E.158: Todd Rider [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700].

Fig. E.159: Todd Rider [NARA RG 38, Entry 98C, Box 9, Folder TSC # 2601–2700].

Fig. E.160: Todd Rider [NARA RG 38, Entry 98C, Box 10, Folder TSC # 2801–2900].

Fig. E.161: Todd Rider [NARA RG 38, Entry 98C, Box 10, Folder TSC # 2801–2900].

Fig. E.162: Todd Rider [NARA RG 38, Entry 98C, Box 10, Folder TSC # 2801–2900].

Fig. E.163: Todd Rider [NARA RG 38, Entry 98C, Box 10, Folder TSC # 2801–2900].

Fig. E.164: Norberto Lahuerta [NARA RG 319, Entry NM3-85M, Box 44, Folder 926047].

Fig. E.165: Todd Rider [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Soviet Guided Missiles, Rockets and V-Weapons Research, Development and Production Vol. 1, Fldr. 2 of 3].

Fig. E.166: Todd Rider [NARA RG 319, Entry A1-134A, Box 29, Folder ZA 019293 Soviet Guided Missiles, Rockets and V-Weapons Research, Development and Production Vol. 1, Fldr. 2 of 3].

Fig. E.167: Norberto Lahuerta [NARA RG 319, Entry NM3-85A, Box 2138, Folder 326051 to 326060].

Fig. E.168: Todd Rider [NARA RG 77, Entry UD-22A, Box 175, Folder World].

Fig. E.169: Norberto Lahuerta [NARA NARA RG 77, Entry UD-22A, Box 175, Folder World; and RG 319, Entry NM3-85A, Box 2229, Folder 339171 to 339180].

Fig. E.170: Norberto Lahuerta [NARA NARA RG 77, Entry UD-22A, Box 175, Folder World; and RG 319, Entry NM3-85A, Box 2229, Folder 339171 to 339180].

Fig. E.171: https://www.cia.gov/readingroom/document/cia-rdp83-00415r003100040008-4

Fig. E.172: https://www.cia.gov/readingroom/document/cia-rdp83-00415r003100040008-4

Fig. E.173: Norberto Lahuerta [NARA RG 319, Entry NM3-82, Box 2899, Folder Project 3837].

Fig. E.174: http://www.astronautix.com/g/g-2.html.

Fig. E.175: Adapted from https://commons.wikimedia.org/wiki/User:H_A_A.

Fig. E.176: Adapted from https://commons.wikimedia.org/wiki/File:Cold_war_europe_military_alliances_map.png.

Fig. E.177: Left: Archives of the French Army Ministry of Defense, in Jürgen Michels 1997, p. 278.
Right: http://www.astronautix.com/s/superv-2.html.

Fig. E.178: http://www.luft46.com/misc/sanger.html.

Fig. E.179: U.S. government, public domain [Saenger and Bredt 1944, English translation].

Fig. E.180: U.S. government, public domain [Saenger and Bredt 1944, English translation].

Fig. E.181: U.S. government, public domain [Saenger and Bredt 1944, English translation].

Fig. E.182: Courtesy of Deutsches Museum Archive, photo 30394.

Fig. E.183: Courtesy of Deutsches Museum Archive, photo 30391.

Fig. E.184: U.S. government, public domain [Saenger and Bredt 1944, English translation].

Fig. E.185: U.S. government, public domain [Saenger and Bredt 1944, English translation].

Fig. E.186: Courtesy of Deutsches Museum Archive, photo CD56143.

Fig. E.187: Norberto Lahuerta.

Fig. E.188: U.S. government, public domain [Robert Godwin 2003, pp. 38–51].

Fig. E.189: U.S. government, public domain [Robert Godwin 2003, pp. 38–51].

Fig. E.190: U.S. government, public domain [Robert Godwin 2003, pp. 38–51].

Fig. E.191: U.S. government, public domain [Robert Godwin 2003, pp. 38–51].

Fig. E.192: Norberto Lahuerta [Franklin Delano Roosevelt Library, Map Room Files, Box 164, Folder Naval Aides. Files: A/16—General Correspondence].

Fig. E.193: U.S. government, public domain.

Fig. E.194: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/369].

Fig. E.195: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/369].

Fig. E.196: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/369].

Fig. E.197: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/369].

Fig. E.198: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/369].

Fig. E.199: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/369].

Fig. E.200: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/369].

Fig. E.201: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/369].

Fig. E.202: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/369].

Fig. E.203: Todd Rider [NavTecMisEu 500-45].

Fig. E.204: Todd Rider [NavTecMisEu 500-45].

Fig. E.205: Todd Rider [NavTecMisEu 500-45].

Fig. E.206: Todd Rider [NavTecMisEu 500-45].

Fig. E.207: Todd Rider [NavTecMisEu 500-45].

Fig. E.208: Todd Rider [NavTecMisEu 500-45].

Fig. E.209: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

Fig. E.210: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

Fig. E.211: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

Fig. E.212: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

Fig. E.213: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

Fig. E.214: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

Fig. E.215: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

Fig. E.216: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

Fig. E.217: Todd Rider [Bundesarchiv Militärarchiv Freiburg RH 8/4067K].

Fig. E.218: commons.wikimedia.org.

Fig. E.219: U.S. government, public domain [http://www.cv41.org/photos/gallery3/index.php/op/opsandy].

Fig. E.220: commons.wikimedia.org.

Fig. E.221: Todd Rider [BIOS 1110, p. 10].

Fig. E.222: [Benecke and Quick 1957, pp. 254–255].

Fig. E.223: Todd Rider [NARA RG 319, Entry NM3-82 A, Box 14, Folder OB-3].

Fig. E.224: Todd Rider [NARA RG 319, Entry NM3-82 A, Box 14, Folder OB-3].

Fig. E.225: Todd Rider [NARA RG 319, Entry NM3-82 A, Box 14, Folder OB-3].

Fig. E.226: Czech National Archive (Prague), courtesy of Andreas Sulzer.

Fig. E.227: Czech National Archive (Prague), courtesy of Andreas Sulzer.

Fig. E.228: Czech National Archive (Prague), courtesy of Andreas Sulzer.

Fig. E.229: Courtesy of Deutsches Museum Archive, photo 30389.

Fig. E.230: Norberto Lahuerta [NARA RG 319, Entry NM3-47B, Box 991, Folder 400. 112 Research/009. 14 May 1945].

Fig. E.231: Norberto Lahuerta [NARA RG 319, Entry NM3-47B, Box 991, Folder 400. 112 Research/009. 14 May 1945].

Fig. E.232: Norberto Lahuerta [NARA RG 319, Entry NM3-47B, Box 991, Folder 400. 112 Research/009. 14 May 1945].

Fig. E.233: Norberto Lahuerta [NARA RG 319, Entry NM3-47B, Box 991, Folder 400. 112 Research/009. 14 May 1945].

Fig. E.234: Norberto Lahuerta [NARA RG 319, Entry NM3-47B, Box 991, Folder 400. 112 Research/009. 14 May 1945].

Fig. E.235: George Cully [AFHRA folder 201-56 Vol. 1 Pt. 2 May 1945–Mar 1947].

Fig. E.236: U.S. Patent and Trademark Office, public domain.

Fig. E.237: U.S. Patent and Trademark Office, public domain.

Fig. E.238: U.S. Patent and Trademark Office, public domain.

Fig. E.239: U.S. Patent and Trademark Office, public domain.

Fig. E.240: U.S. Patent and Trademark Office, public domain.

Fig. E.241: U.S. Patent and Trademark Office, public domain.

Fig. E.242: U.S. Patent and Trademark Office, public domain.

Fig. E.243: U.S. government, public domain.

Fig. E.244: U.S. Patent and Trademark Office, public domain.

Fig. E.245: U.S. Patent and Trademark Office, public domain.

Fig. E.246: U.S. Patent and Trademark Office, public domain.

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Fig. E.249: U.S. Patent and Trademark Office, public domain.

Fig. E.250: U.S. Patent and Trademark Office, public domain.

Fig. E.251: U.S. government, public domain.

Fig. E.252: U.S. government, public domain.

Fig. E.253: U.S. government, public domain.

Fig. E.254: U.S. government, public domain.

Fig. E.255: [Hohmann 1925].

Fig. E.256: [Hohmann 1925].

Fig. E.257: [Hohmann 1925].

Fig. E.258: [Hohmann 1925].

Fig. E.259: [Noordung 1928].

Fig. E.260: [Noordung 1928].

Fig. E.261: [Noordung 1928].

Fig. E.262: [Noordung 1928].

Fig. E.263: Norberto Lahuerta [NARA RG 319, Entry NM3-82, Box 2899, Folder Project 3839].

Fig. E.264: Todd Rider [Peenemünde Archive, AHT0205].

Fig. E.265: Todd Rider [Peenemünde Archive, AHT0205].

Fig. E.266: Todd Rider.

Fig. E.267: Todd Rider.

Fig. E.268: Todd Rider.

Fig. E.269: Todd Rider.

Fig. E.270: Todd Rider.

p. 6315: Lori Rider.

About the Author

> About 1670, religious persecution caused [his father] to uproot his home and seek refuge at Frankenstein, and here Johann Konrad was born at the castle on 10 August 1673... With his flair for disputation he soon established a reputation for brilliance, which in its turn brought adulation from fellow-students and from tutors...
>
> About 1700, Dippel became interested in the oil obtained by the destructive distillation of animal parts... The oil came to be associated with the name of Dippel through his claim that in it he had discovered a universal medicine: a large part of his M.D. thesis (*Vitae animalis morbus et medicina suae vindicata origini*, 1711) is devoted to establishing this claim...
>
> Johann Konrad ceased to hope for either university or Church appointments, and removed himself to Berlin to follow an alchemical career... Further evidence about Dippel's relationships with other chemical workers emerges from the story of Prussian blue...
>
> The remainder of the old philosopher's life was lived out in comparative obscurity... As a guest of the Duke of Wittgenstein-Gützow, he was provided with a laboratory at Wittgenstein Castle... A last flamboyant gesture of fantasy in the face of reality was his prediction, a few months before his death, that he would live until 1808.
>
> E. E. Aynsley and W. A. Campbell. 1962. Johann Konrad Dippel, 1673–1734.
> *Medical History* Vol. 6, No. 3, pp. 281–286.

Through reading about scientists such as Nikola Tesla, Albert Einstein, John von Neumann, Wernher von Braun, and Edward Teller, Todd Rider was inspired from an early age to pursue a career in scientific innovation, ultimately winning the Grand Prize at the 1986 International Science and Engineering Fair and filing his first patent application at age 17. He studied at MIT and Harvard 1986–1995, covering electrical engineering, nuclear engineering, mechanical and aerospace engineering, physics, biomedicine, chemistry, applied mathematics, and other areas, and received his Ph.D. in 1995. He headed the DNA sequencing program at the startup biotechnology company Aeiveos 1995–1996, became Senior Staff Scientist at MIT Lincoln Laboratory 1997–2013, and served as senior Laboratory Technical Staff at Draper Laboratory 2013–2015. In 2015 he founded the RIDER (Revolutionary Innovation, Discovery, Education, and Research) Institute.

During his career, Dr. Rider has invented a much more efficient rocket staging system and worked on antimatter rocket engine approaches; developed and tested methods of coherently combining multiple laser beams into a more powerful laser beam; discovered fundamental limitations on controlled fusion reactors; invented and demonstrated the CANARY rapid pathogen identifier; invented and developed the DRACO and PANACEA broad-spectrum antiviral therapeutics; and conducted research in various other areas. He has also worked to improve kindergarten through twelfth grade (K–12) science education, creating and running the MIT Science on Saturday program, writing educational guides for *Science News* magazine, judging state and national science fairs and competitions, and conducting presentations and hands-on lab activities on a wide range of science topics in K–12 classrooms in over 100 schools. Dr. Rider and his projects have been featured in *Science*, *Nature Biotechnology*, *Time*, *Scientific American*, *Technology Review*, *National Geographic*, *Der Spiegel*, the *New York Times*, *NBC Nightly News*, BBC, ZDF, Discovery Channel, and numerous other outlets. An inveterate acronym engineer, he has dubbed the work summarized in this book High-Yield Directed Research Approaches.

Zusammenfassung

Umwälzende wissenschaftliche Neuerungen scheint die Welt nicht länger in demselben Tempo wie früher hervorzubringen (was ganz offenkundig wird, wenn man das heutige Forschungspersonal oder die bereitgestellten Fördergelder nach revolutionären Innovationen bemisst). Statt sich an die grundsätzliche Lösung dieses systemischen Problems zu wagen, kann man genausogut untersuchen, was für Bedingungen zu anderen Zeiten und andernorts den Erfolg von Innovatoren begünstigten (Kapitel 1).

Erfindungen und Entdeckungen wurden überall und zu jeder Zeit gemacht—die größte Häufung an umwälzenden Neuerungen jedoch ist mit Wissenschaftlern und Ingenieuren verbunden, die im 19. und frühen 20. Jahrhundert in der vornehmlich deutschsprachigen Forschungslandschaft Mitteleuropas ausgebildet wurden. Durch den Ersten und Zweiten Weltkrieg, den Kalten Krieg, durch Sprachbarrieren und infolge kultureller Stereotypen verblaßte die Geschichte dieser Innovatoren und ihrer Neuerungen, so dass die moderne Welt kaum noch Einzelheiten kennt und wenig willens zu sein scheint, die Forschungsbedingungen, die einst zu so zahlreichen revolutionären Errungenschaften führten, nachzuahmen.

Die Ziele dieses Buches bestehen somit darin

- Aufklärung über die wichtigsten Schöpfer im deutschsprachigen Raum und deren Werke in verschiedenen Bereichen der Natur- und Ingenieurwissenschaften zu leisten (Kapitel 2–9),
- die systemischen Faktoren zu ermitteln, die in diesem Raum so zahlreiche revolutionäre Innovationen hervorbrachten (Kapitel 10),
- erfolgreiche, aber auch fehlgeschlagene Anläufe einer Übertragung des Wissens und der systemischen Faktoren auf andere Forschungslandschaften zu bewerten (Kapitel 11),
- Methoden vorzuschlagen, mithilfe derer heutige Regierungen, Organisationen und/oder Einzelpersonen dem Erfolg des früheren deutschsprachigen Forschungsraums besser nacheifern können (Kapitel 12).

Die Archivrecherchen für dieses Buch förderten darüber hinaus zahlreiche Dokumente zutage, die darauf hindeuten, dass die deutschen Forschungsprogramme zur Zeit des Zweiten Weltkrieges in den Bereichen Biotechnik, Mikroelektronik, Technik der Energiewaffen, Kernwaffen sowie Luft- und Raumfahrt viel fortgeschrittener waren als durch die heutige Geschichtsschreibung anerkannt wird, und dass diese Programme nach dem Krieg entsprechende Aktivitäten in anderen Ländern nach sich zogen (Anhänge A–E).

Und so, nachdem ich mir den Scherz erlaubt, dem eine Stelle zu gönnen in diesem durchweg zweideutigen Leben kaum irgend ein Blatt zu ernsthaft seyn kann, gebe ich mit innigem Ernst das Buch hin, in der Zuversicht, daß es früh oder spät Diejenigen erreichen wird, an welche es allein gerichtet seyn kann, und übrigens gelassen darin ergeben, daß auch ihm in vollem Maaße das Schicksal werde, welches in jeder Erkenntniß, also um so mehr in der wichtigsten, allezeit der Wahrheit zu Theil ward, der nur ein kurzes Siegesfest beschieden ist, zwischen den beiden langen Zeiträumen, wo sie als paradox verdammt und als trivial geringgeschätzt wird. Auch pflegt das erstere Schicksal ihren Urheber mitzutreffen.—Aber das Leben ist kurz und die Wahrheit wirkt ferne und lebt lange: sagen wir die Wahrheit.

Arthur Schopenhauer. 1819. *Die Welt als Wille und Vorstellung.* 1. Auflage. Leipzig.

Abstract

The world does not appear to be producing truly revolutionary scientific innovations at the same rate as it once did (certainly if measured in terms of revolutionary innovations per researcher or per amount of funding). Rather than trying to create solutions for this modern systemic problem from scratch, one may study what conditions facilitated the successes of innovators in other times and places (Chapter 1).

Inventions and discoveries have been made throughout the world and throughout history, yet the highest concentration of revolutionary innovations appears to have come from scientists and engineers who were trained in the predominantly German-speaking central European research world in the nineteenth and early twentieth centuries. Unfortunately, the history of those innovators and innovations has been significantly obscured by World Wars I and II, the Cold War, language barriers, and cultural stereotypes, leaving the modern world less aware of the details and less able to fully reproduce the research conditions that led to so many revolutionary achievements.

Therefore the objectives of this book are to:

- Elucidate the major creators and creations produced by that German-speaking world in various fields of science and engineering (Chapters 2–9).
- Determine the systemic factors that promoted so much revolutionary innovation in that particular place and time (Chapter 10).
- Evaluate the previous successes and failures of transferring that scientific knowledge and those systemic methods to other research systems (Chapter 11).
- Propose methods by which modern governments, organizations, and/or individuals could better emulate the success of the earlier German-speaking research world (Chapter 12).

Archival research for this book also yielded many documents that suggest that World War II German programs in biotechnology, microelectronics, directed energy technologies, nuclear weapons, and aerospace technologies progressed much further than has been acknowledged in conventional histories, and that they aided postwar programs in other countries (Appendices A–E).

And now that I have allowed myself the jest to which in this ambiguous life hardly any page can be too serious to grant a place, I part with the book with deep seriousness, in the sure hope that sooner or later it will reach those to whom alone it can be addressed; and for the rest, patiently resigned that the same fate should, in full measure, befall it, that in all ages has, to some extent, befallen all knowledge, and especially the weightiest knowledge of the truth, to which only a brief triumph is allotted between the two long periods in which it is condemned as paradoxical or disparaged as trivial. The former fate is also wont to befall its author.—But life is short, and truth works far and lives long: let us speak the truth.

Arthur Schopenhauer. 1819. *The World as Will and Representation.* 1st ed. Leipzig.